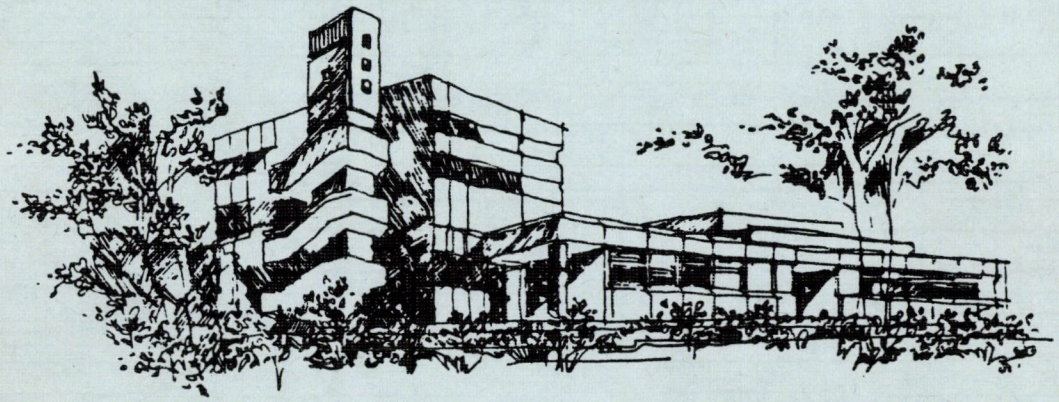
ATOMKI
ANNUAL REPORT
1992



INSTITUTE OF NUCLEAR RESEARCH
OF THE HUNGARIAN ACADEMY OF SCIENCES
DEBRECEN, HUNGARY

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Preface

The year 1992 has brought a fortunate mixture of changes and continuity in the research activity of the institute. Readers looking for the traditional subjects of research will find them in this Annual Report, but I hope that those curious about the news will also be satisfied.

The 81 contributions to this Annual Report, against the background of a steady budget decline, still show a pretty colourful picture. Their distribution among the research fields faithfully represents the activity of the institute. In this Preface I will mention a few of these results mainly to advertise them, and the selection, of course, reflects my personal taste. General information on the institute can be found in the next section.

In previous years results in **general physics** were presented in the section on atomic or nuclear physics. They have grown in number, and to emphasize this, we put them in a separate chapter now. These results show the interest of our atomic and nuclear theorists in fundamental problems, like general aspects of the Coulomb problem and supersymmetric quantum mechanics.

In **nuclear physics** the study of nuclear reactions at low energies has been going on, and our interest has turned towards reactions of astrophysical interest. "In beam" nuclear spectroscopy remains an important branch of our research, and in 1992 new results were produced for the isotopes ^{66,68}Ga, ^{70,72}As and ^{112,118}Sb. The study of giant dipole resonances in conjunction with the neutron skin of heavy nuclei is a new line of research, which exemplifies our successful cooperation. The application and refinement of the cluster model of light nuclei keep busy some of our nuclear theorists, and the description of the neutron halo of ^{6}He is a nice example of continuity and adventure.

In our **atomic collision physics** research the study of the electron capture and electron loss cusps was carried on. The electron cusp observed when neutral projectiles ionize the target has been further investigated to clarify the role of metastable projectile atoms. The classical-trajectory Monte Carlo calculations of ion-atom collisions continued to be a vigorous project. More emphasis was laid on the investigation of two-electron processes, both experimentally and theoretically.

Materials science and analysis is an expanding research field in the institute. We do genuine solid state physics research (e.g. in superconductivity), but all other works on materials science and analysis originate from nuclear and atomic physics. The most obvious examples are the energy loss studies and the applications of PIXE, PIGE and X-ray as well as electron spectroscopy in material analysis.

Environmental research has a long tradition in the institute. The study of the effects of the Chernobyl reactor catastrophe will probably capture the attention of our readers. The radioactivity and trace elements in ground waters, the origin of ground waters and the vulnerability of the Waterworks in Debrecen are issues of local interest. Their significance may still transcend the boundaries of our region if they are considered to be representative of the state of the environment in

this part of the world. The investigation of air pollution and aerosol transfer is believed to be a very important environmental issue, and our PIXE, XRFA and ESCA groups are involved in these studies. Our applications of mass spectroscopy in **earth sciences** are still focussed on geochronology and hydrology.

The institute contributes to the success of **biological and medical research** elsewhere by producing isotopes for medical purposes. The impact of environmental radioactivity and heavy-element pollution on human health presented in the chapter on environmental research could as well be considered to belong to biological and medical research.

Our activity in the **development of methods and instruments** is, of course, connected to our experimental research and is focussed primarily on spectrometers, detectors and data acquisition systems. Our participation in the radiation hardness test of front-end electronics of detector systems is a new adventure. The design and construction of special electron spectrometers is an ongoing activity. The installation of a split-pole magnetic spectrograph transferred from Vrije Universiteit, Amsterdam, with the generous help of many of our colleagues there is expected to start a new line of research here. The installation of a state-of-the-art computer network in the institute in the near future will significantly improve our computing and communicating capabilities.

Our **educational activity** has now been organized by our Joint Physics Department with Lajos Kossuth University. Several diploma works and doctoral theses were completed in 1992. At the end of the year with the physics departments of Lajos Kossuth University we started to work on the program of a new type of PhD training in physics. By now this work has been completed and submitted to the Accreditation Committee. We hope that this PhD program will be approved, and from September, 1993, our students will start their studies in this new framework.

I concluded the Preface of our 1991 Annual Report with our plans for the future. Our hopes expressed then seem now to come true: The National Foundation for Scientific Resesearch (OTKA), the National Commettee for Technological Development (OMFB) and the Soros Foundation have jointly granted a fund for a positron emission tomograph (PET). In January, 1993, we ordered a GE 4096 ^{plus} PET scanner. Experts from General Electric made their first site visit in February 1993, and I hope in the next Annual Report we shall be able to show pictures taken with our new tomograph. The ECR project will also be funded by OTKA, and a newly formed group started work on its development. These new projects will continue in 1993 and we all look forward to seeing the first results.

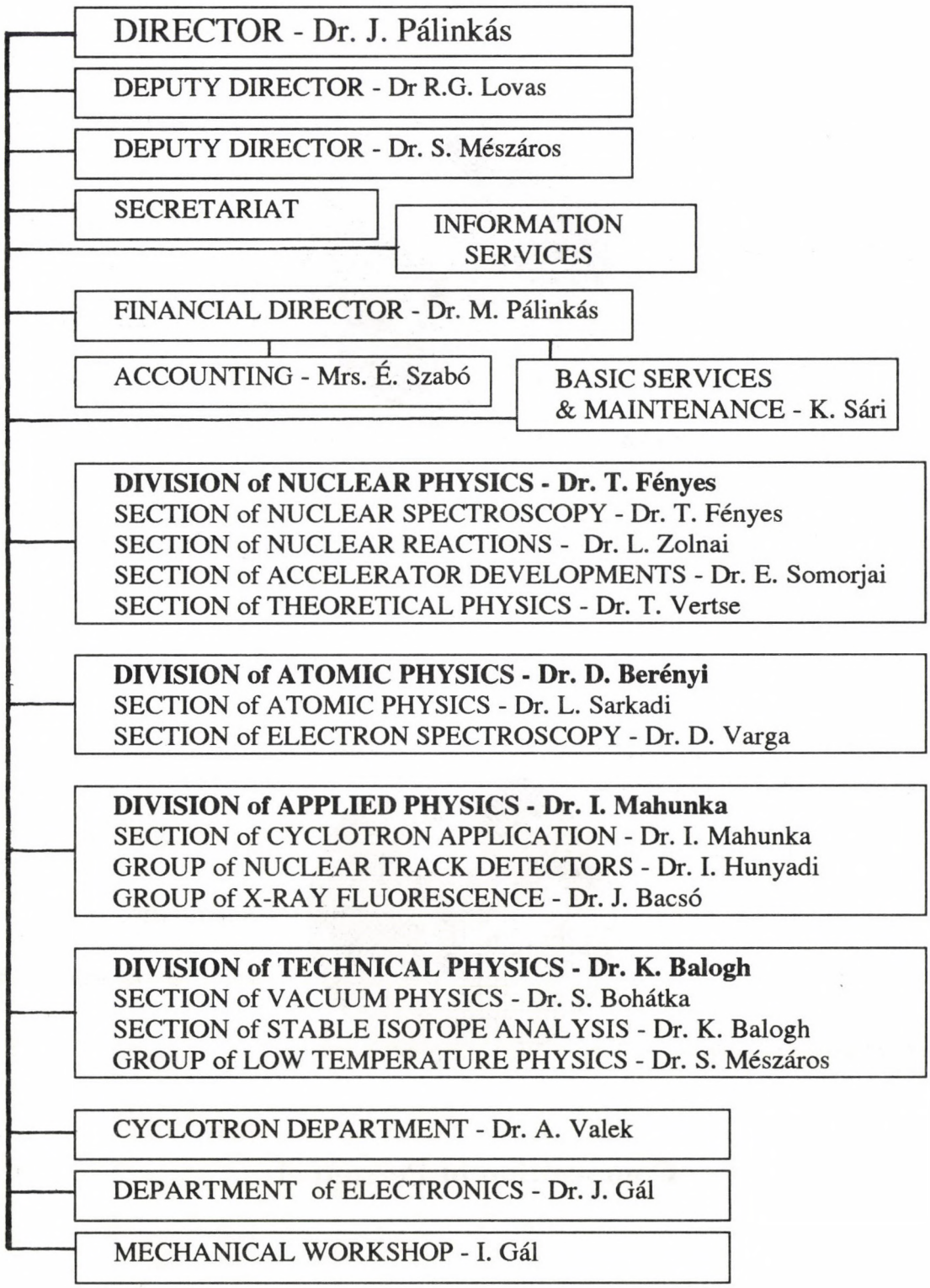
Debrecen, February 18, 1993

Dr. József Pálinkás
Director

The organisation structure of the

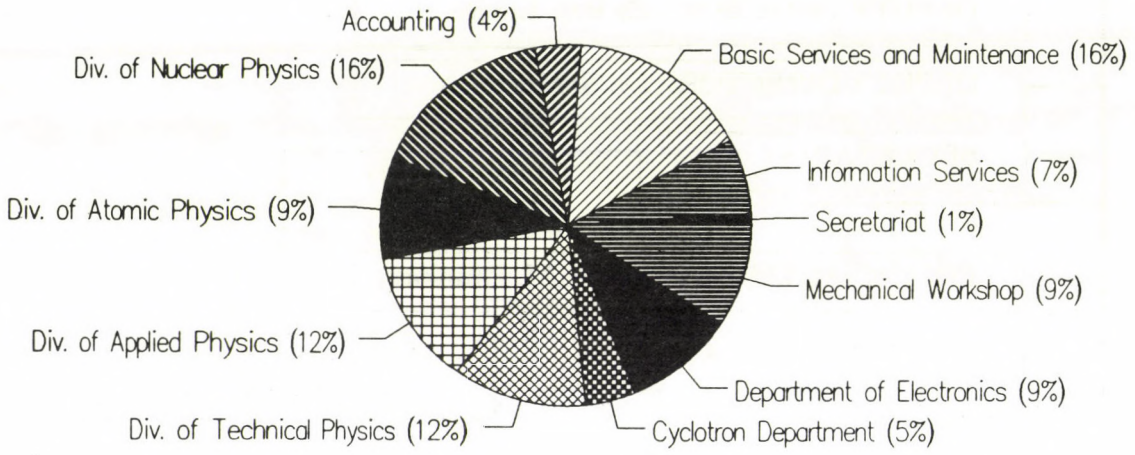
Institute of Nuclear Research

of the Hungarian Academy of Sciences

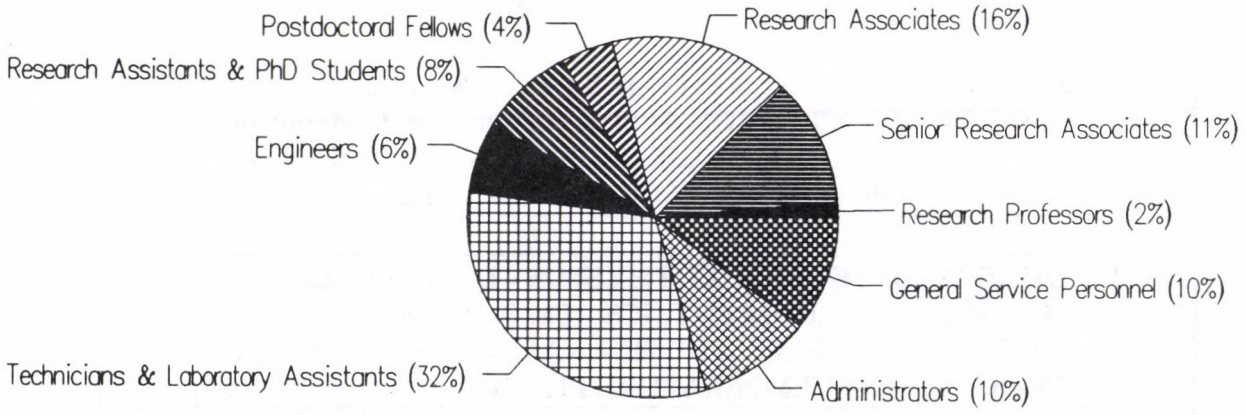


Personnel

The Institute at present employs a total of 244 persons. The affiliation of personnel to unists of organisation and the composition of personnel are given below.



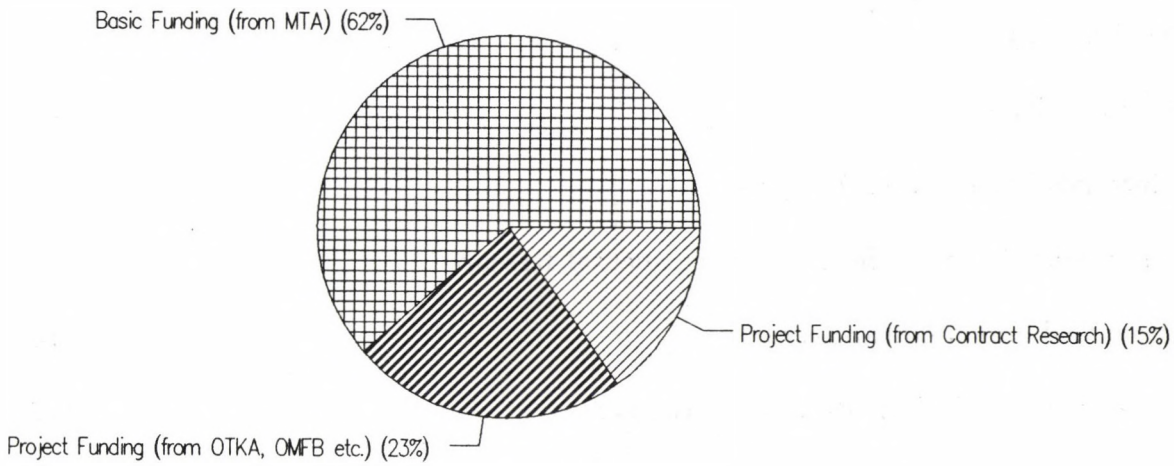
Affiliation of Personnel to Units of Organisation



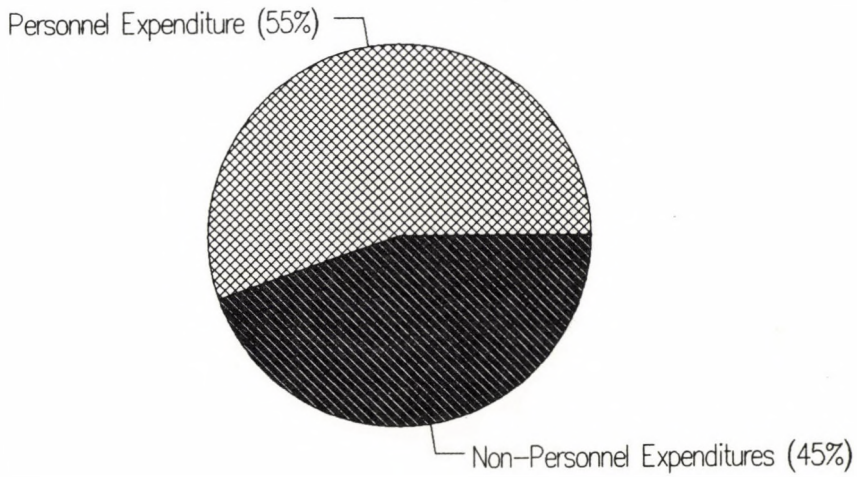
Composition of Personnel

Finance

The total budget of the Institute in 1992 was 159 Million Hungarian Forints. The composition of the budget and the breakdown of expenditure according to different categories are given below.



Composition of the Institute's Budget
MTA: Hungarian Academy of Sciences
OTKA: National Fund for Scientific Research
OMFB: National Committee for Technological Development



Breakdown of Expenditure into Personnel and Non-Personnel Expenditures

CONTENTS

REPORTS:

PUBLICATIONS AND SEMINARS:

GENERAL PHYSICS

States in a potential having time-dependent parameter

L. Végh

We study the solutions of the time-dependent Schrödinger equation

$$i\hbar\frac{\partial\Psi(\boldsymbol{r},t)}{\partial t} = H(\boldsymbol{r},t)\Psi(\boldsymbol{r},t) \tag{1}$$

for a particle moving in a potential which has a parameter or parameters with strong time dependence. Such potentials are for example a box with infinite moving walls[1], the harmonic oscillator with time-dependent oscillator parameter, and so on. The method is useful if the solution of the time-independent Schrödinger equation with the constant value of the potential parameter has an analytic form.

The problem is solved using a coupled channel method. First Eq. (1) is written in integral form as

$$\Psi(\boldsymbol{r},t) = \Psi(\boldsymbol{r},t_0) + \frac{1}{i\hbar}\int_{t_0}^{t} H(\boldsymbol{r},t')\Psi(\boldsymbol{r},t')dt'. \tag{2}$$

Now we introduce the Hamiltonian $H^t(\boldsymbol{r})$ where the potential parameter is equal to that of the potential at the time t. According to this definition $H^t(\boldsymbol{r}) \equiv H(\boldsymbol{r},t)$. The stationary eigenfunctions φ_i^t of $H^t(\boldsymbol{r})$ fulfill the Schrödinger equation

$$H^t(\boldsymbol{r})\varphi_i^t(\boldsymbol{r}) = \varepsilon_i^t\varphi_i^t(\boldsymbol{r}). \tag{3}$$

Now $\Psi(\boldsymbol{r},t)$ at the time t is expanded by the stationary eigenfunctions $\varphi_i^t(\boldsymbol{r})$ where the expansion coefficients $c_i(t)$ are time dependent. Then the integral equation (2) can be rewritten as a system of coupled integral equations for $c_i(t)$

$$\sum_i c_i(t)e-\frac{i}{\hbar}\varepsilon_i^t t\varphi_i^t(\boldsymbol{r}) = e^{-\frac{i}{\hbar}\varepsilon_k^{t_0}t}\varphi_k^{t_0}(\boldsymbol{r}) + \frac{1}{i\hbar}\sum_j\int_{t_0}^{t} dt' c_j(t')\varepsilon_j^{t'}e^{-\frac{i}{\hbar}\varepsilon_j^{t'}t'}\varphi_j^{t'}(\boldsymbol{r}). \tag{4}$$

The initial condition may be $c_i(t_0) = \delta_{ki}$ assuming that at t_0 the particle is in a state with $c_k = 1$. Using the orthogonality of the eigenfunctions taken at the same t and introducing the notations

$$d_i(t) \equiv e^{-\frac{i}{\hbar}\varepsilon_i^t t)}c_i(t), \quad \Gamma_{ij}(t_1,t_2) \equiv \int_{-\infty}^{\infty} d\boldsymbol{r}\varphi_i^{t_1}(\boldsymbol{r})\varphi_j^{t_2}(\boldsymbol{r}),$$

Eq. (6) can be expressed as

$$d_i(t) = d_k(t_0)\Gamma_{ik}(t,t_0) + \frac{1}{i\hbar}\sum_j\int_{t_0}^{t} dt' d_j(t')\varepsilon_j^{t'}\Gamma_{ij}(t,t'). \tag{7}$$

This system of coupled Volterra-type integral equations can easily be solved numerically.

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A generalisation of the Coulomb problem

G. Lévai[a] and B. W. Williams[b]

The past ten years have seen revived interest in exactly solvable potentials of nonrelativistic quantum mechanics, partly as the result of the introduction of supersymmetric quantum mecahnics. Although the general solution of large potential families (the Natanzon [1] and Natanzon confluent [2] potentials) have been given, their practical application is hindered by technical difficulties. Some of the special subclasses, however, may avoid these drawbacks, and at the same time may offer potential shapes different from those of the simplest solvable quantum mechanical problems. Until now only few such cases have been studied in detail [3].

We have described [4] an exactly solvable potential which belongs to the Natanzon confluent class. It depends on four parameters and can be considered the generalised version of the Coulomb problem which it contains as a special case. Its functional form is

$$V(r) = -\frac{CD}{h(r)+\tau} + \frac{C\tau}{2(h(r)+\tau)^3} + \frac{3C\tau^2}{16h(r)(h(r)+\tau)^3} + \frac{Cl(l+1)}{h(r)(h(r)+\tau)},$$

where the $h(r)$ function is determined implicitly by the equation

$$C^{1/2}r = \tau \tanh^{-1}\left(\left(\frac{h(r)}{h(r)+\tau}\right)^{1/2}\right) + (h(r)(h(r)+\tau))^{1/2}.$$

This potential is Coulomb–like for large r–s and has an angular–momentum–dependent repulsive "core" (vanishing in the $\tau = 0$ Coulomb case), which could be interpreted as an effective potential arising from the presence of electrons occupying inner atomic shells. The energy eigenvalues depend on $n+l+1$ only, and therefore exhibit level degeneracies similar to that of the Coulomb problem:

$$E_n = -C\left([(n+l+1)^2 + D\tau]^{1/2} - (n+l+1)\right)^2/\tau^2.$$

[a] Fulbright scholar; present address: Yale University, New Haven, CT, USA
[b] Bucknell University, Lewisburg, PA, USA

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On the relation between supersymmetric quantum mechanics and the potential group method

G. Lévai[a)]

The symmetries characterising a wide range of exactly solvable quantum mechanical potentials can be formulated in a variety of ways.

The potential group method [1] allows simultaneous description of the bound– and scattering states of large potential classes by using the representation theory noncompact groups. The basis for the unitary irreducible representations of the potential group is formed by degenerate eigenstates of potentials of the same kind but of different depth.

Supersymmetric quantum mechanics [2] offers another elegant method of describing isospectral potentials. The degeneracy of the energy levels can be viewed as the consequence of supersymmetry in this case. Adjacent members of infinite series potentials, each having one more bound state than the previous one, can be interpreted as supersymmetric partner potentials.

Since the two methods can be applied to the same classes of solvable potentials, furthermore the ladder operators connecting the degenerate eigenstates have the same structure (i.e. they are linear differential operators) in both cases, the question whether there exists a connection between the two approaches arises naturally.

In order to examine this connection we have studied solvable potentials related to the generalised Laguerre and the Gegenbauer polynomials. Considering a general realisation [3] of the generators of the $SO(2,1) \simeq SU(1,1)$ potential group relevant to this special case, we have studied the procedure of deriving various solvable potentials by means of variable– and similarity transformations of the group generators, and compared their resulting form with the corresponding supersymmetric ladder operators.

[a)] Fulbright scholar; present address: Yale University, New Haven, CT, USA

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Dynamic versus kinematic symmetry breaking in a two–dimensional model of collective motion

J. Cseh

The question is addressed, whether or not the vibrational spectrum of a two–dimensional interacting boson model [1] can be transfomed into the rotational one via quantum deformation of the group structure [2]. It turns out [3], that although the spectrum of the q–deformed model shows one or another of the rotational like features at different values of the deformation parameter, nevertheless, all the requirements of the rotational behaviour can not be obtained simutaneously. This result indicates that the quantum algebraic treatment can not give analytical solution for the eigenvalue problem of the interacting boson models of nuclear and molecular physics in the whole range of the physically relevant breaking of dynamical symmetries.

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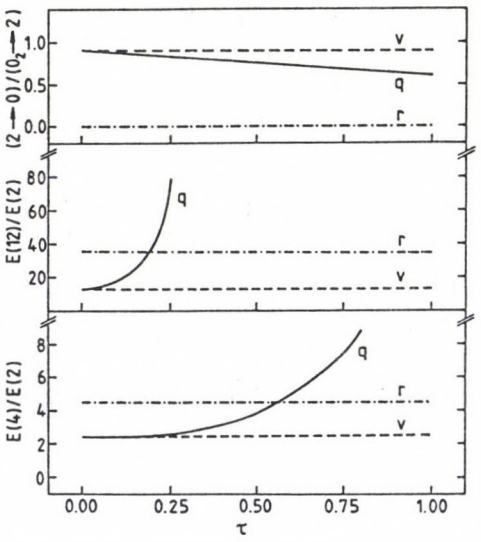

Fig. 1. Characteristic ratios of energies and electric transitions of the two–dimensional algebraic collective models. The values corresponding to the vibrational and rotational limits of the classical Lie algebraic description are denoted by v and r, respectively. The curves labelled with q show the results of the quantum algebraic model, as a function of the real deformation parameter ($q = e^{\tau}$). The lower and middle panels display two energy ratios of the ground state band, while the upper part shows the $B(E2)$ ratios of the interband $0_2^+ \rightarrow 2_1^+$ and intraband $2_1^+ \rightarrow 0_1^+$ electric transitions.

Simulation study of nonlinear dynamics of RF SQUID

S. Mészáros and É. Kirsch

Josephson junctions (JJs) and the systems containing them are excellent examples of nonlinear systems with complex dynamics. The simplest theoretical model of JJ is the resistively shunted junction (RSJ) model which is described by the following equation [1]:

$$C\frac{\Phi_0}{2\pi}\frac{d^2\varphi}{dt^2} + \frac{\Phi_0}{2\pi R}\frac{d\varphi}{dt} + I_c \sin\varphi = I \qquad (1)$$

where C, R, I_c are the junction capacitance, resistance and critical current respectively, Φ_0 is the magnetic flux quantum, φ is the quantum phase difference across the junction and I is the external drive current. The voltage V across the junction is related to the phase difference φ by the relation : $V = \frac{\Phi_0}{2\pi}\frac{d\varphi}{dt}$. Equation (1) can be brought to a reduced form by appropriate scaling. It describes a very complex dynamics, provided that the drive current has the form of $I = I_0 + I_1 \sin\omega t$, i.e. it contains an ac component. One of the most important systems containing JJs is the RF SQUID. This consists of a superconducting ring containing one JJ (single junction superconducting ring, SJSR) coupled to a parallel resonant circuit. Equations describing SJSR and RF SQUID can be easily deduced from (1) by adding the linear equations describing the superconducting ring and the tank circuit. These equations have different solutions for periodic external drive: boundary cycle, period multiplication and chaos. The mapping of the possible solutions can be calculated by numerical methods and compared to experimental observations. The observation of chaotic dynamics in real SQUIDs is technically difficult due to technological reasons. An analogue simulator has been designed and constructed to study complex dynamics of RSJ, SJSR and RF SQUID. The simulator is well suited to obtain results rapidly and demonstrate the behaviour of the systems on a scope screen which is very useful in education. A detailed mapping of the dynamics of SJSR under sinusoidal excitation was performed [3],[4]. Transitions from boundary cycle to chaos through Feingenbaum scenario and intermittency was observed. Strange attractors were taken and their fractal dimensions were calculated. The results were in good agreement with values obtained by numerical simulations (where available) [2]. Transient chaos was observed in SJSR. SQUID characteristics were simulated and compared with those observed for real SQUIDs with reasonable qualitative agreement.

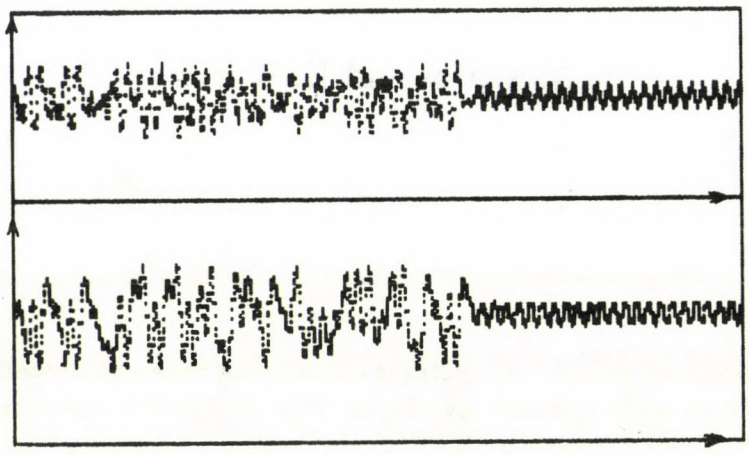

Fig. 1. Time dependence of the quantum phase difference (lower trace) and voltage (upper trace) in SJSR showing transient chaos

Fig. 2. Example of a strange attractor of SJSR

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NUCLEAR PHYSICS

The Effects of Electron Screening and Resonances in (p, α) Reactions on ^{10}B and ^{11}B at Thermal Energies

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The fusion reactions $^{10}B(p,\alpha)^{7}Be$ and $^{11}B(p,\alpha)^{8}Be$ have been studied over the c.m. energy range E=15 to 134 keV using intense proton beams (of the 100 and 400 kV accelerators at the Ruhr-University Bochum) and thick solid targets. In the case of $^{11}B(p,\alpha)^{8}Be$ the low energy data in terms of the astrophysical $S(E)$ factor show (Fig.1.a.) an exponential enhancement (up to a factor of 1.9) due to the effects of electron screening, where the deduced screening potential is larger than expected. In the case of $^{10}B(p,\alpha)^{7}Be$ the low energy data exhibit (Fig.1.b.) an enhancement by more than a factor of 200, which cannot be explained by the effect of electron screening only. The enhancement mostly arises here from the high–energy tail of an expected s–wave resonance at E_R =10 keV. The results offer an improved prospect for this reaction as an advanced fuel in future fusion reactors than previously envisioned.

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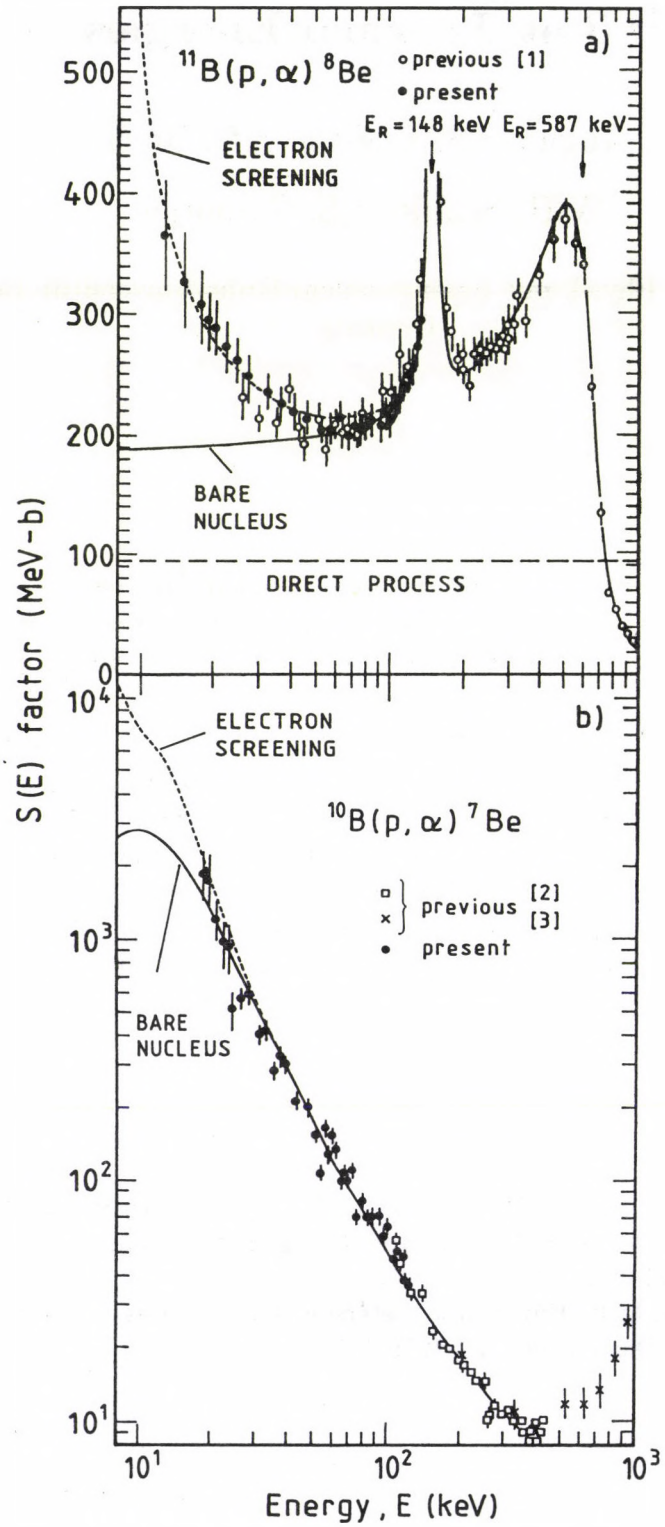

Fig. 1. Absolute $S(E)$ factor for $^{11}B+p$ (a) and $^{10}B+p$ (b). The solid curve represents a fit including 2 resonances, a nonresonant (direct) process, and interference effects (a) and a fit for a resonance at E_R =10 keV (b). The dashed curves represent the enhancement caused by electron screening

Astrophysical p–process: $^{70}Ge(\alpha,\gamma)^{74}Se$

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E. Somorjai, H.P. Trautvetter *,

*Institut für Physik mit Ionenstrahlen, Ruhr–Universität, Bochum, Germany

The role of (α,γ) reactions in the astrophysical p–process is well known, however, no experimental information are available. The study of the inverse (α,γ) reaction could provide experimental data, e.g. for the lightest p–nucleus, ^{74}Se. The expected very low cross section of the reaction $^{70}Ge(\alpha,\gamma)^{74}Se$ makes a basic importance of the choice of the material for target backing and that was the goal of the first experiments. The Ta and Cu backings are the ones which on the one hand, correspond to the requirements of the probably necessary implantation procedure, on the other, are used mostly in (α,γ) experiments. Ge(Li) gamma–spectra have been measured on Ta (electrically heated under vacuum) and Cu plates bombarded by E= 3.5 MeV alpha–beam (with a collected charge of Q=0.18 C). Their comparison showed, that the Cu plate produces less gamma–peaks at the vicinity of gamma–energies expected from the $^{70}Ge(\alpha,\gamma)^{74}Se$ reaction than the Ta plate, however, the total gamma–yield was higher. The gamma–yield from contaminations has been reduced strongly by the electrical heating in the case of Ta however not in Cu because of its extremely good heat conductivity. One of the next tasks is to achieve similar reduction of contaminations for Cu plates, too. Also for background reduction purpose, Ge(Li) gamma–spectra taken for Ta with and without a BGO anti–Compton device were compared. The anti–Compton setup provided a background reduction of a factor of 4, which is very promising, however, the drawback of it is the required larger target–detector distance, which can be disadvantageous in our case (expected low yield from the reaction).

A ^{70}Ge target implanted into Ta backing was also bombarded by E= 3.8 MeV alpha–beam (Q=0.27 C). Close geometry (without BGO) was used. No significant gamma–peak originating from the $^{70}Ge(\alpha,\gamma)^{74}Se$ reaction was seen. Therefore the target was checked by measuring $(p,p'\gamma)$ reaction, PIXE as well as Rutherford–backscattering yields and only a small amount of Ge was found in the backing. The next step is to improve the amount of the implanted material and/or to prepare evaporated ^{70}Ge targets.

Low-energy elastic scattering of alpha particles from ^{34}S, ^{50}Cr, and ^{62}Ni

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P. Manngård †, Z. Máté, S. Szilágyi, and L. Zolnai

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The energy dependence of the phenomenological optical potential at low bombarding energies has roused an increased interest, which is mainly due to observations on the anomalous behaviour of this energy dependence near the Coulomb barrier [1]. The interest in the low energy alpha scattering data appears also from the side of applications.

We have investigated three medium light targets (^{34}S, ^{50}Cr and ^{62}Ni) at energies available at the cyclotrons of Åbo Akademi (Turku, Finland) and Atomki. Angular distributions of elastically scattered alpha particles were measured in the alpha energy range 12.8-20.0 MeV and then analysed with Saxon-Woods potential. The results are in accordance with the global alpha optical model study of England et al. [2] (Fig.1).

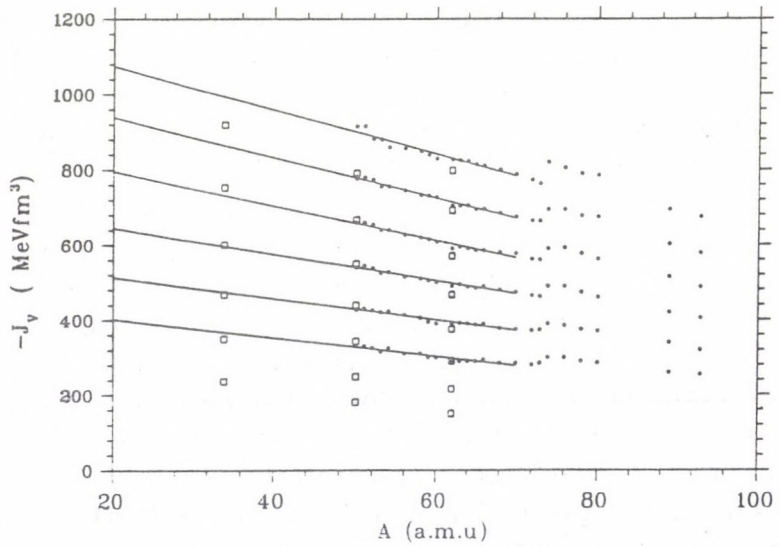

Fig. 1. Comparison of real volume integral values obtained in the present work (squares) with the values from England et al. [2] (full circles).

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New Results on the Resonance States of ^{38}Ar

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We continued our α–capture measurements [1] on implanted ^{34}S targets using the 5 MV VdG accelerator of our institute. We have found 5 new resonances in the E_α=3.4–3.8 MeV region (E_α=3548, 3673, 3688, 3698 and 3732 keV). Resonance strengths and decay schemes for the new resonances have been deduced. The yield curve for the reaction $^{34}S(\alpha,\gamma)^{38}Ar$ is shown in Fig. 1. The new resonances are marked by asterisk. The energy window is E_γ=9.5–11.5 for the solid line and E_γ=7.5–9.5 for the dashed line.

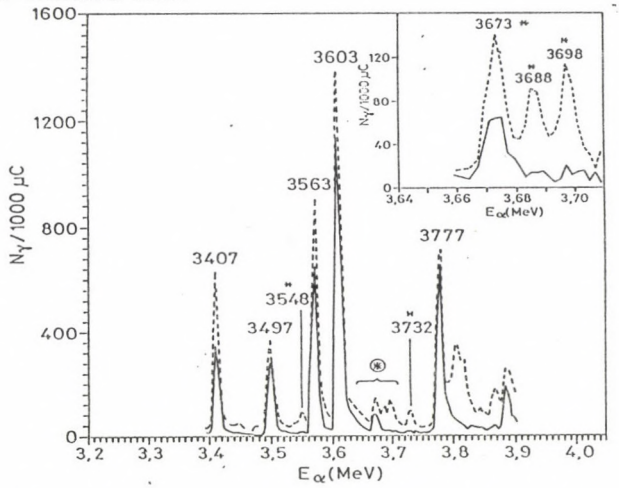

Fig. 1. Yield curve for the reaction $^{34}S(\alpha,\gamma)^{38}Ar$

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Low-energy level scheme of ^{66}Ga nucleus

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We have built a new, more complete level scheme of ^{66}Ga (Fig. 1). The construction was based mainly on the results obtained from our former γ-ray, $\gamma\gamma$-coincidence and internal conversion electron measurements [1]. Spin and parity values have been determined on the basis of measured internal conversion coefficients, Hauser-Feshbach analysis of relative level cross sections (Fig. 2), decay properties of levels, log ft values of β-decay [2] and available γ-ray angular distribution data [3,4].

This work was supported partly by the National Scientific Research Foundation /OTKA/.

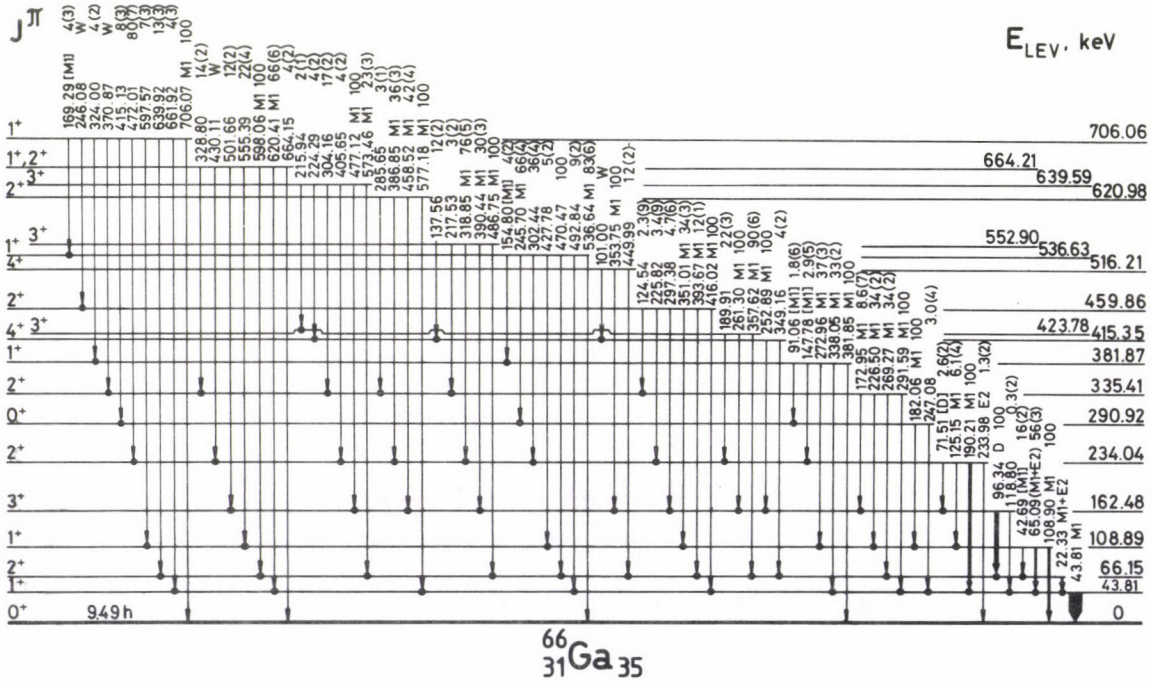

Fig. 1. Low-energy part of the proposed level scheme of ^{66}Ga. The level scheme was obtained from (p,nγ)reaction. Solid circles at the ends of arrows indicate $\gamma\gamma$-coincidence relations. Behind γ-ray energies and multipolarities γ-ray branching ratios are shown. W denotes weak γ line.

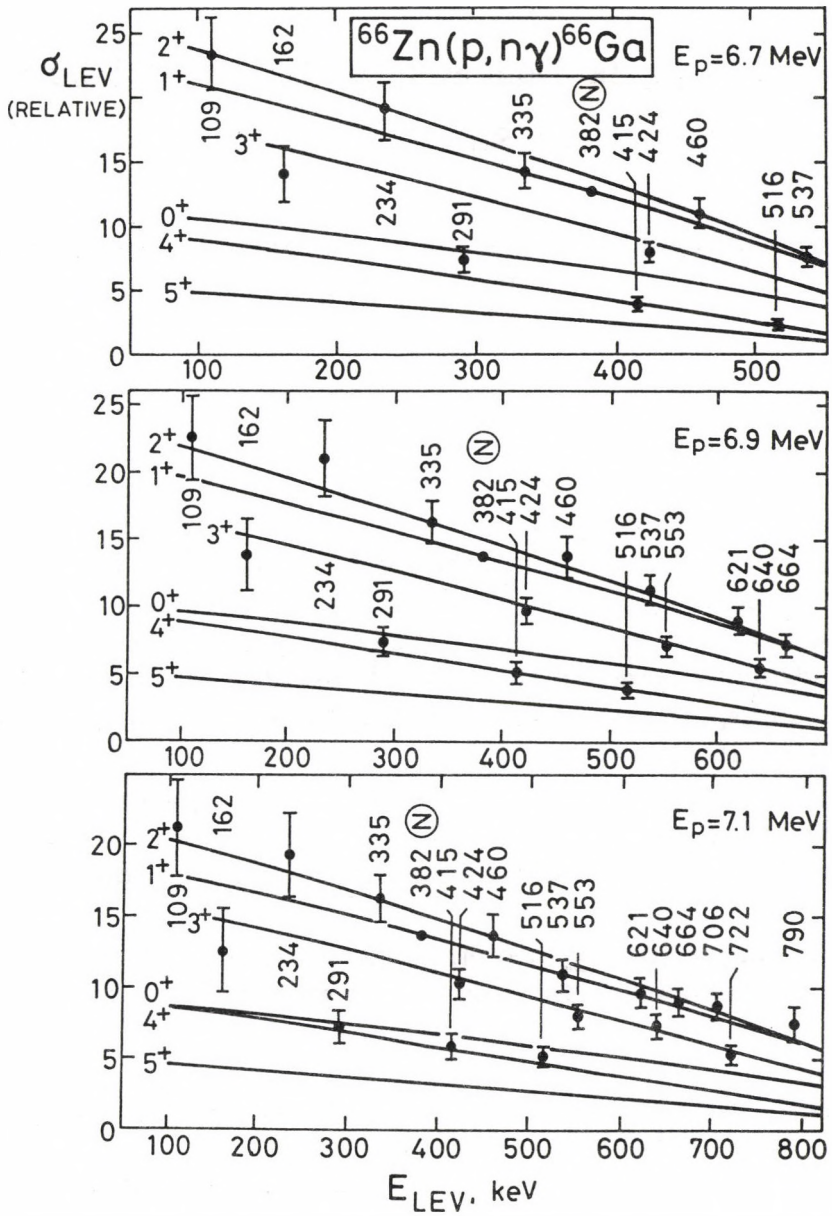

Fig. 2. Experimental (symbols with error bars) and theoretical (curves) relative level cross sections for ^{66}Ga as a function of the level energy. N denotes normalization point.

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Interacting boson-fermion-fermion model description of ^{68}Ga

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In our earlier works we have studied the level scheme of ^{68}Ga with different in-beam γ- and e^--spectroscopic methods through (p,nγ) and (α,nγ) reactions [1,2]. In the present work we have calculated the ^{68}Ga energy spectrum, magnetic dipole and electric quadrupole moments, the reduced transition probabilities, gamma-branching ratios and spectroscopic factors in the framework of *i*nteracting *b*oson-*f*ermion-*f*ermion *m*odel (IBFFM).

The calculations showed that it is possible to give a reasonable, consistent description of the energy spectra and electromagnetic properties of the core ^{66}Zn, single-odd ^{67}Ga, ^{67}Zn, and odd-odd ^{68}Ga nuclei using the same family of IBFFM parameters.

The experimental and IBFFM theoretical energy spectra of ^{68}Ga are compared in Fig. 1. The ^{68}Ga electromagnetic moments are given in Table I.

Table 1. Calculated electric quadrupole and magnetic dipole moments of the low-lying states of ^{68}Ga compared to the available experimental data.

	Q (eb)		$\mu(\mu_N)$	
J^π_{IBFFM}	IBFFM	EXP. [3]	IBFFM	EXP. [3]
1^+_1	0.0082	$\pm 0.0277(14)^{k,st}$	−0.0134	$\pm 0.01175(5)^k$
2^+_1	−0.026		1.03	
1^+_2	−0.025		0.92	
2^+_2	0.036		1.81	
2^-_1	−0.203		−1.96	
4^-_1	−0.392		−0.84	
7^-_1	−0.514	$\pm 0.72(2)^{st}$	0.67	$\pm 0.707(14)$

^{k} signs of μ and Q are different

st Sternheimer or other polarization correction included

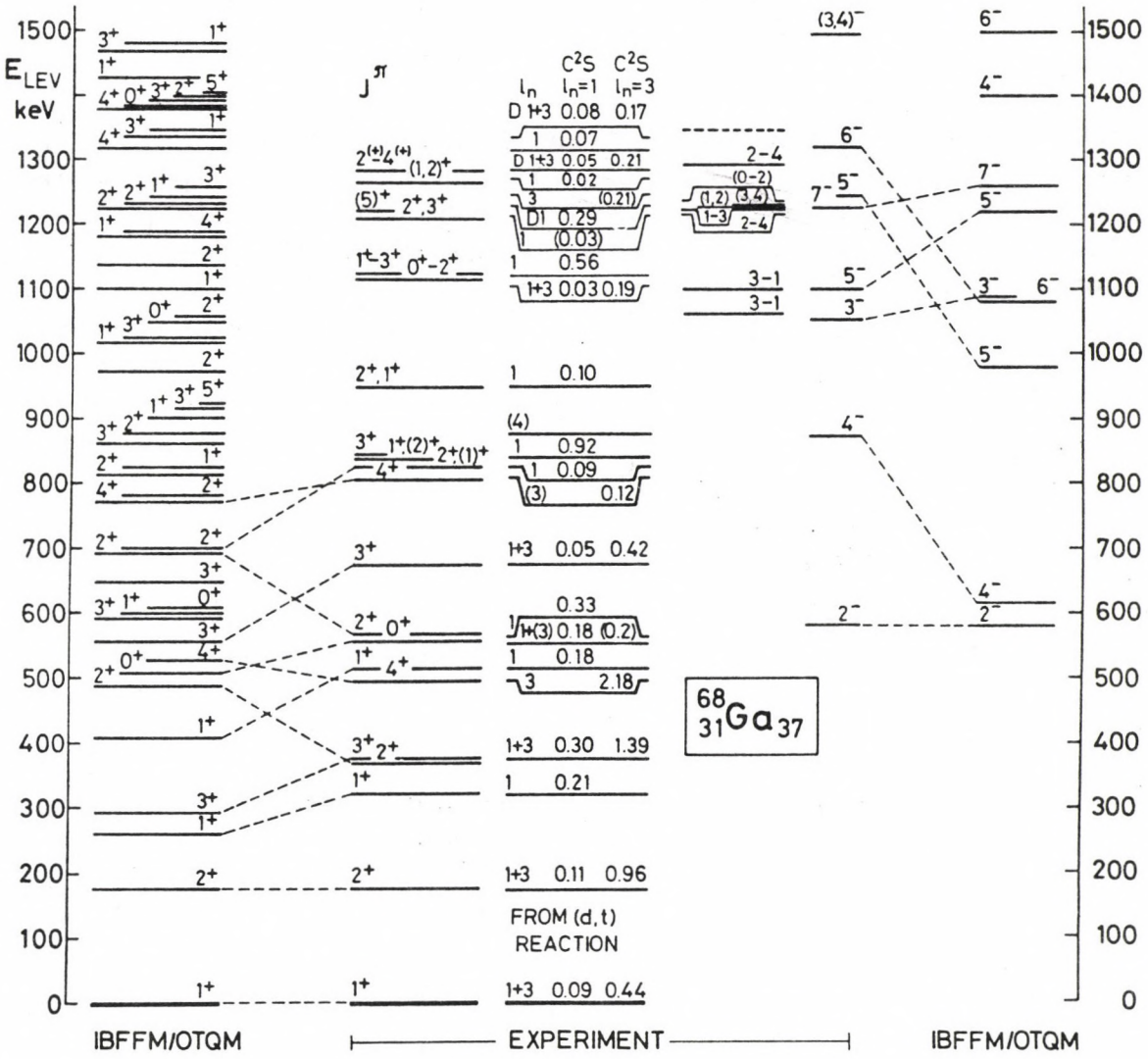

Fig. 1. IBFFM energy spectrum of ^{68}Ga in comparison with available experimental data, separately for positive and negative parity levels.

This work was supported partly by the National Scientific Research Foundation (OTKA).

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Spectroscopic Study of the ^{70}Ge(p,nγ)^{70}As Reaction

Zs. Podolyák, J. Timár and T. X. Quang

γ-ray and internal conversion electron spectra (Fig. 1) of ^{70}As from (p,nγ) reaction were measured with Ge(HP) and Compton-suppressed* Ge(HP) γ-ray, as well as with superconducting magnetic lens plus Si(Li) electron spectrometers. For reliable identification of γ rays we measured the γ-spectra of ^{72}Ge+p, ^{73}Ge+p, ^{74}Ge+p and ^{76}Ge+p reactions, too, using enriched Ge targets. The bombarding proton energies and intensities were between 8.1 - 8.7 MeV and 5 - 100 nA, respectively. The energy resolutions were ~2 keV (at 1332 keV) for the γ-detectors and ~2.7 keV (at 917 keV) for the electron spectrometer. Energies and relative intensities of more than 40 γ transitions of the ^{70}As nucleus have been determined.

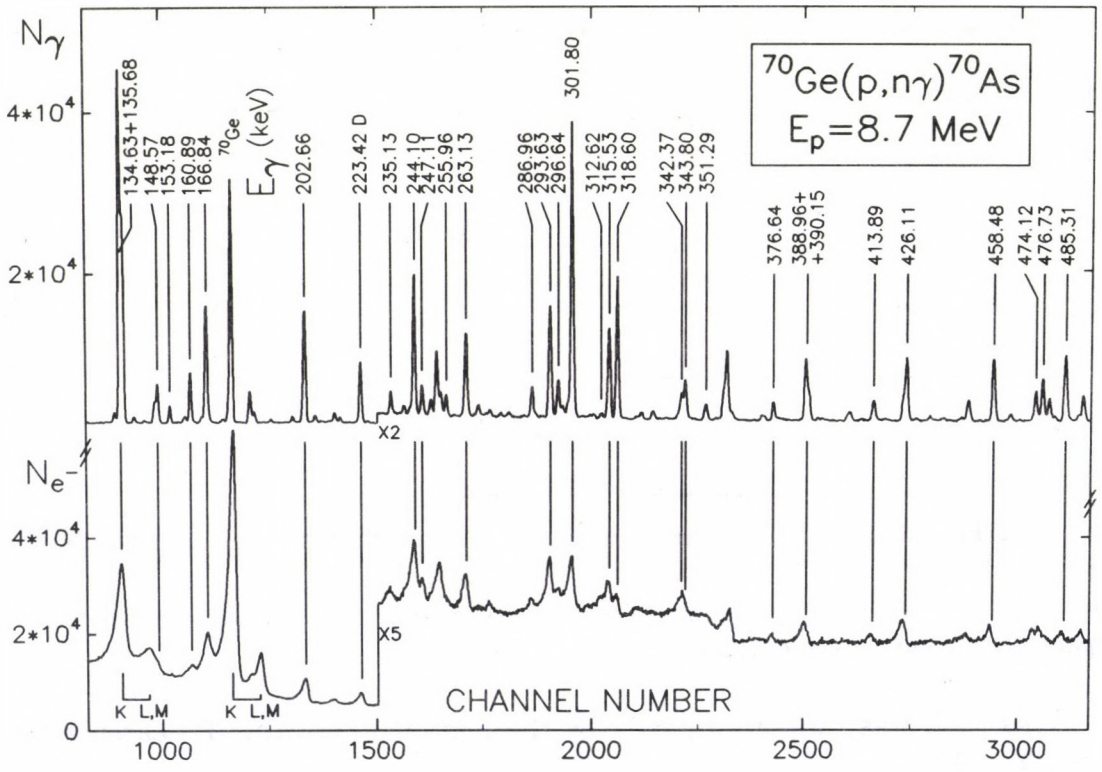

Fig. 1. Typical γ-ray and internal conversion electron spectra from the ^{70}Ge(p,nγ)^{70}As reaction.

Internal conversion coefficients (ICC) of 25 transitions have been deduced (Fig. 2) for the first time, enabling determination of many new γ-ray multipolarities and unambiguous parity assignments for several ^{70}As levels. For the normalization of the experimental ICC-s we have used the theoretical α_K value [1] of the 176 keV

pure E2 [2] ^{70}Ge transition. ICC-s obtained with this normalization are in good agreement with former results on multipolarities of ^{70}Ge and ^{70}As γ transitions.

We are indebted to Dr. T. Fényes for active participation in the research program, as well as to Dr. Z. Gácsi and Dr. A. Krasznahorkay for their valuable help in the experiments.

This work was supported by the National Scientific Research Foundation /OTKA/.

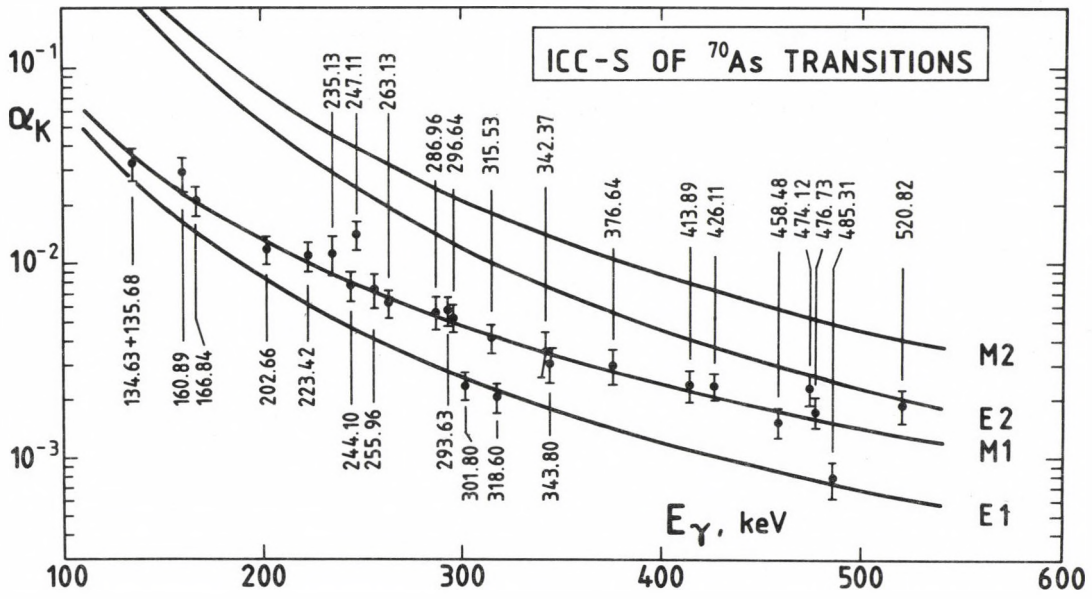

Fig. 2. Experimental (symbols with error bars) and theoretical (curves) internal conversion coefficients of ^{70}As transitions as a function of the γ-ray energy.

* The Compton-suppression shield was borrowed from KVI (Groningen).

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Study of ^{72}Ge(p,nγ)^{72}As Reaction

D. Sohler, A. Algora and Z. Gácsi

As a continuation of the study of ^{72}As [1], γ-ray, internal conversion electron and $\gamma\gamma$-coincidence spectra of the ^{72}Ge(p,nγ)^{72}As reaction were measured with Ge(HP) and superconducting magnetic lens plus Si(Li) electron spectrometers at 5.8 and 6.1 MeV proton energies. Internal conversion coefficients (ICC) of 25 transitions have been determined (Fig.1.), 12 of them were obtained for the first time (for comparison see [2]). Unambiguous parity assigments for the levels below 600 keV were deduced. Approximately 20 million $\gamma\gamma$-coincidence events were recorded on magnetic tapes. Typical $\gamma\gamma$-coincidence gate spectra are shown in Fig.2.

We are indebted to Prof.T.Fényes for his active participation in the research program. This work was supported by the National Scientific Research Foundation (OTKA).

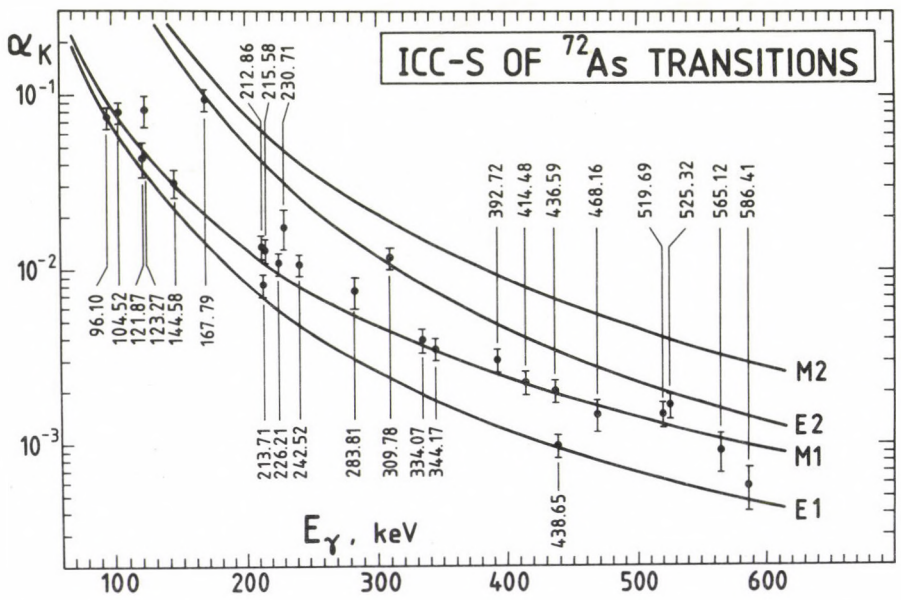

Fig. 1. Experimental internal conversion coefficients of ^{72}As transitions (the curves show theoretical results).

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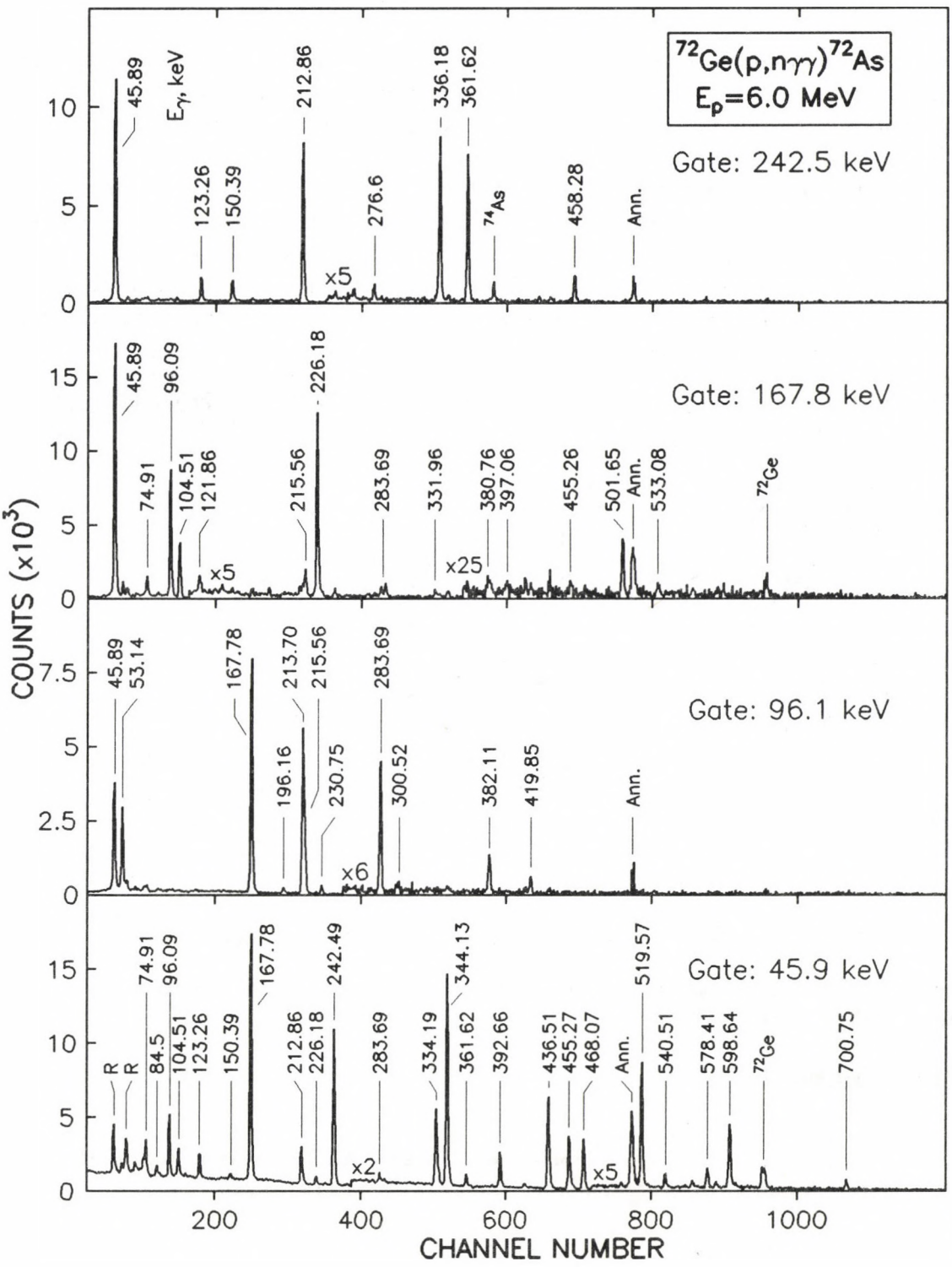

Fig. 2. Typical $\gamma\gamma$-coincidence spectra of ^{72}As. R denotes random coincidences.

Spectroscopic Study of ^{74}As from ^{74}Ge(p,nγ)^{74}As Reaction

A.Algora, D.Sohler and Z.Gácsi

As a continuation of our study of ^{74}As [1], γ-ray, internal conversion electron, and gamma-gamma coincidence spectra were measured with Ge(HP) γ-ray and superconducting magnetic lens plus Si(Li) electron spectrometers between 4.2 and 4.7 MeV proton energies. Internal conversion coefficients of > 15 transitions (Fig.1) have been deduced for the first time resulting in many new γ-ray multipolarities and reliable parity assigments for levels below 650 keV [2]. Furthermore, previously unobserved coincidence relations have been found as illustrated in Fig.2.

The active participation of Prof. T. Fényes in the research program and the support by the National Scientific Research Foundation (OTKA) is acknowledged.

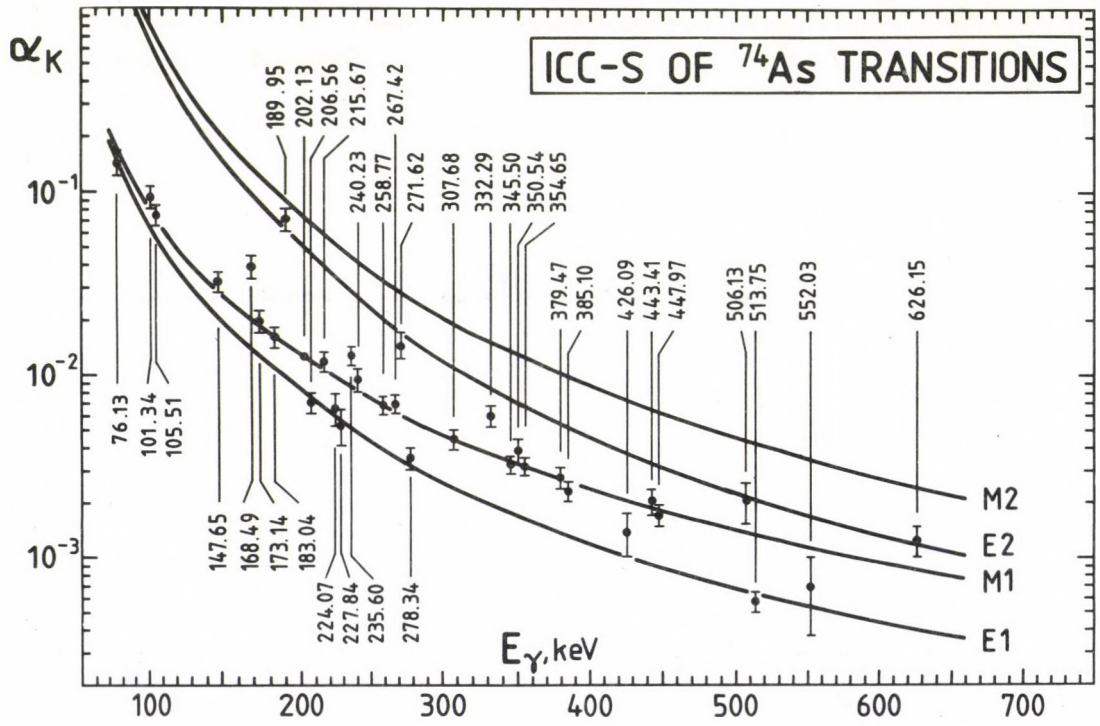

Fig. 1. Experimental internal conversion coefficients of ^{74}As transitions (the curves show theoretical results)

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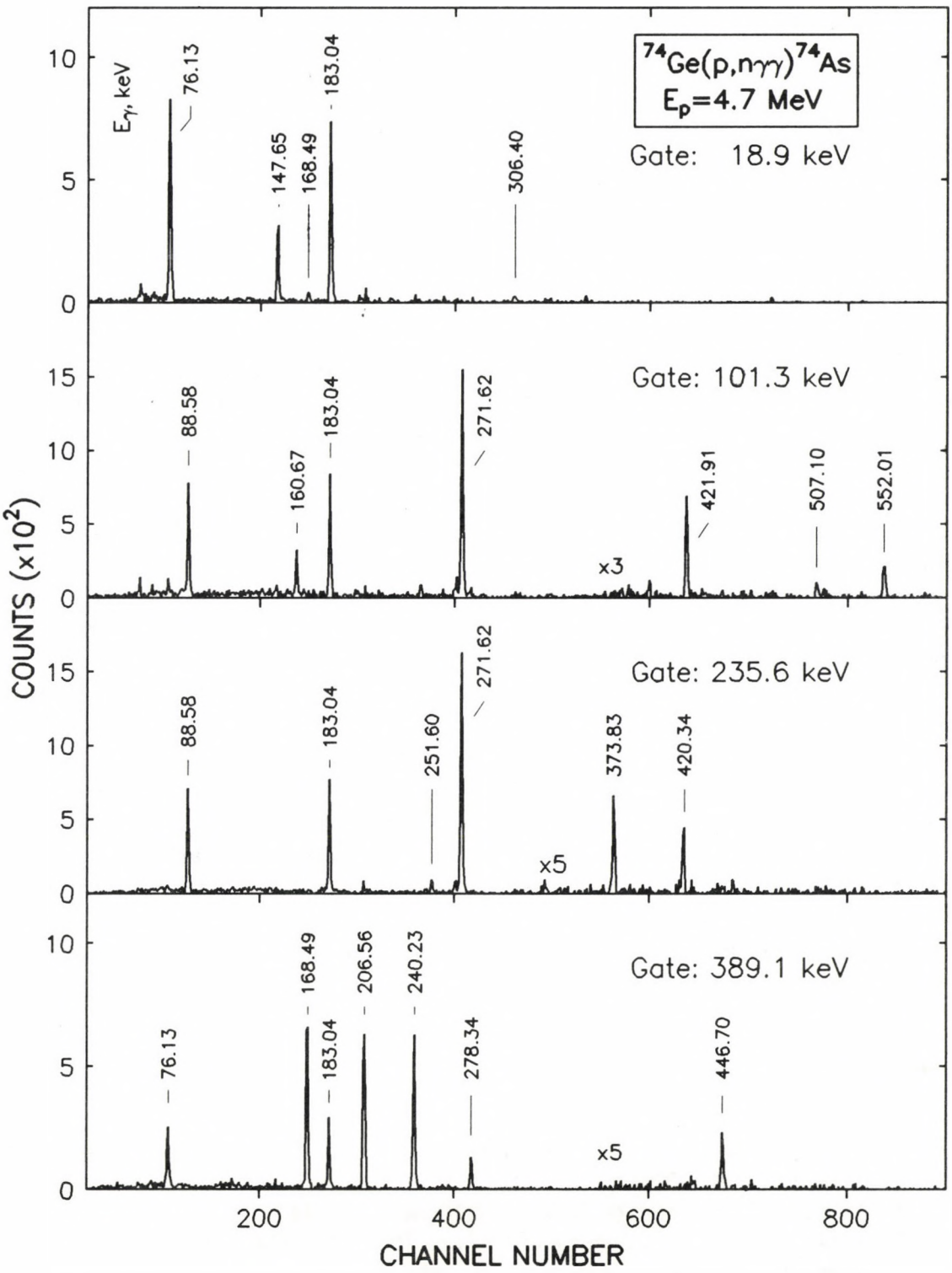

Fig. 2. Typical $\gamma\gamma$ coincidence gate spectra after background subtraction.

Gamma and conversion electron spectroscopic study of the ^{112}Sn(p,nγ)^{112}Sb reaction

J. Gulyás, I. Dankó, J. Kumpulainen † and R. Julin †

†University of Jyväskylä, Department of Physics
SF-40351 Jyväskylä, Finland

As an extension of the study of the light odd-odd Sb nuclei [1-3], γ-ray spectra of the ^{112}Sn(p,n,γ)^{112}Sb reaction were measured at E_p=8.7, 9.1, 9.2, 9.3 and 9.6 MeV proton energies with Ge(HP) detectors. Self-supporting targets, from isotopically enriched (up to 81.6 %) ^{112}Sb, were used in the experiments. For the sake of reliable identification of γ-rays, we studied (p,n) reaction on different tin isotopes, too. Approximately 18 million $\gamma\gamma$-coincidence events were recorded on magnetic tapes at E_p=9.3 MeV and a subsequent gating procedure was used for the analysis of the coincidence spectra. Typical gated $\gamma\gamma$-coincidence spectra are shown in Fig. 1.

About 50 γ-transitions (including 39 new ones, compared to ref. [4]) were assigned to ^{112}Sb. Angular distribution data have been obtained for five gamma-rays at E_p=8.7 MeV.

Internal conversion electron spectra were measured with an intermediate-image-lens electron spectrometer at E_p=9.2 MeV. Preliminary experimental internal conversion coefficients for 13 ^{112}Sb transitions were found.

A more complete level scheme of ^{112}Sb, multipolarities of transitions and gamma-ray branching ratios have been deduced. Determinations of spins and parities of the excited states, based on transition multipolarities and gamma-ray angular distribution data, as well, as Hauser-Feshbach analysis of (p,n) reaction cross sections, are in progress.

This work was supported partly by the National Scientific Research Foundation /OTKA/.

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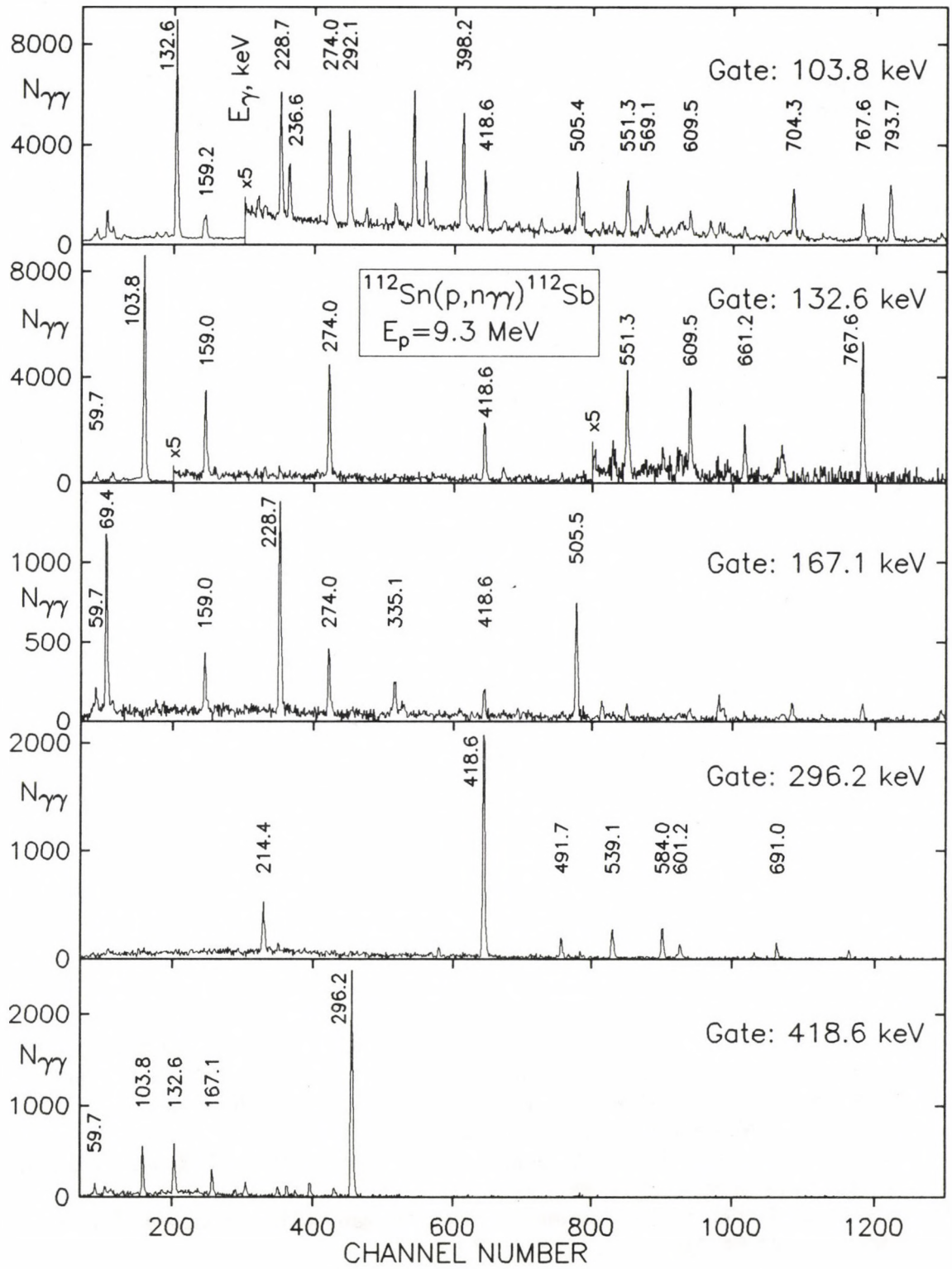

Fig. 1. Selected gamma-gamma coincidence spectra of the ^{112}Sn(p,nγ)^{112}Sb reaction. The background was subtracted.

Intruder states in ^{118}Sb nucleus

J. Gulyás, T. Fényes and M. Fayez F. M. Hassan

It is known that systematic $\Delta J = 1$ bands are built on low- lying $9/2^+$ proton hole (two-particle-one hole) states in ^{113,115,117,119,121,123}Sb nuclei [1]. The $9/2^+$ states are fed by a bandlike cascade of $J \rightarrow J-1$ gamma-ray transitions and with $J \rightarrow J-2$ crossovers. The experimental level energies of the ^{117}Sb $\pi g_{9/2}^{-1}$ intruder band are presented in Fig. 1. Intruder bands of other odd-A Sb nuclei are very similar.

$\Delta J = 1$ collective bands have been observed also in ^{114,116}Sb [2,3] and ^{118,120}Sb [4] nuclei, based on 8^- states. The level spacing properties show strong resemblance with the band observed in odd-A nuclei. In our former work [5] the 8^-, 9^-, 10^- and 11^- members of the band have been observed in ^{118}Sb from (α,nγ) reaction. The results are presented in the right side of Fig. 1, together with the data of Vajda et al. [4] on the 12^- and 13^- states.

In the framework of the interacting boson-fermion and interacting boson-fermion-fermion models we have calculated the energy levels of the intruder bands of ^{117}Sb and ^{118}Sb. In this simple calculations we have supposed that there is a proton hole in the ^{118}Te core, and the configuration mixing with other states have been neglected. In ^{118}Sb the 1186 keV 8^- state of the $\pi g_{9/2}^{-1} \nu h_{11/2}$ multiplet was considered as the head of the band. The obtained results are shown in Fig. 1 (subscripts IBFM and IBFFM). Aside from the low-energy part, where configuration mixing is expected with other 8^-, 9^- and 10^- states, rather good agreement have been observed between experiment and theory. The wave functions of the states contain different phonon components and the dominating configurations contain higher and higher phonon number components with increasing spin.

This work was supported by the National Scientific Research Foundation (OTKA).

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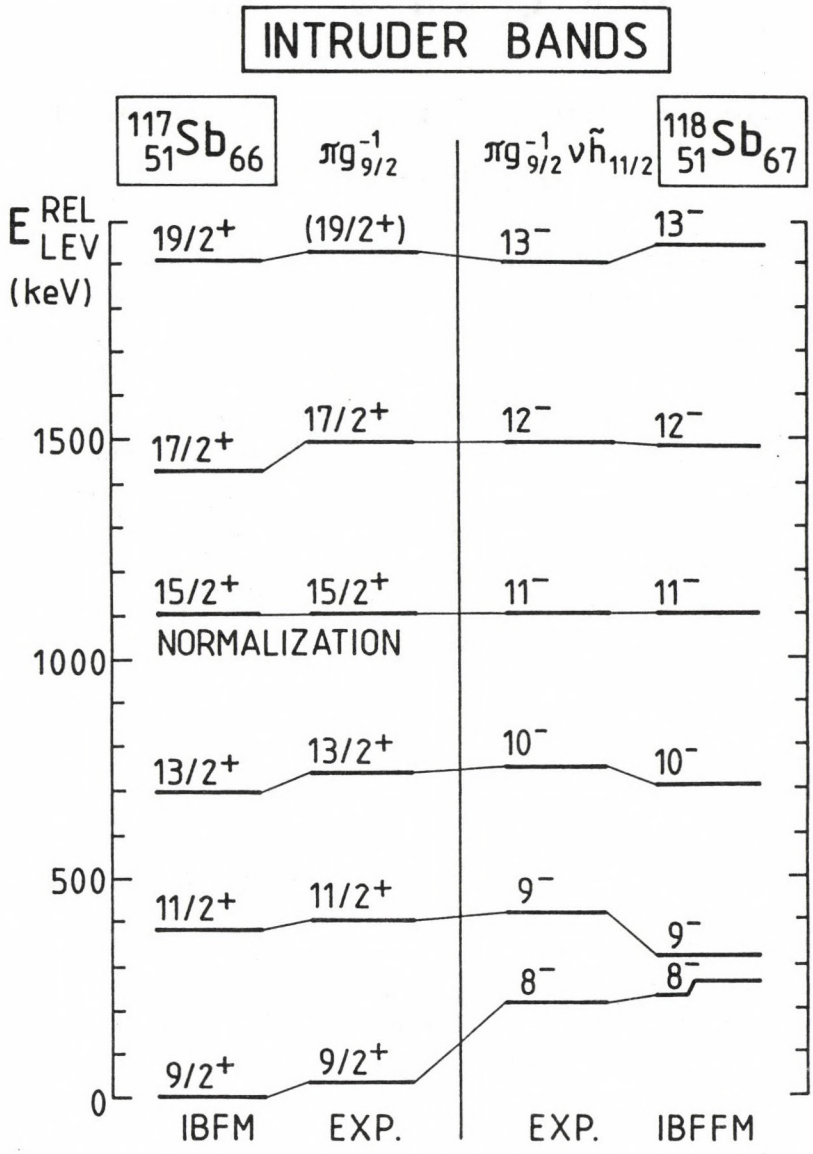

Fig. 1. The experimental and theoretical level energies of the intruder bands in ^{117}Sb and ^{118}Sb.

Interacting boson-fermion-fermion model description of ^{118}Sb

J. Gulyás, T. Fényes, M. Fayez F. M. Hassan and

Zs. Dombrádi

During the last few years we have extensively studied the level scheme of ^{118}Sb from (p,nγ) and (α,nγ) reactions with different in-beam γ- and e^--spectroscopic methods [1,2]. In the present work we have calculated the energy spectra of the low-lying positive and negative parity states of ^{118}Sb, the magnetic dipole and electric quadrupole moments, the E2/M1 mixing and gamma branching ratios in the framework of the *i*nteracting-*b*oson-*f*ermion-*f*ermion *m*odel (IBFFM). The theoretical and experimental energy spectra are compared in Fig. 1. The calculations give resonable description both of the energy spectra and electromagnetic properties of the low-lying states of ^{118}Sb.

A more detailed description of the obtained results is given in [3].

This work was partly supported by the National Scientific Research Foundation (OTKA).

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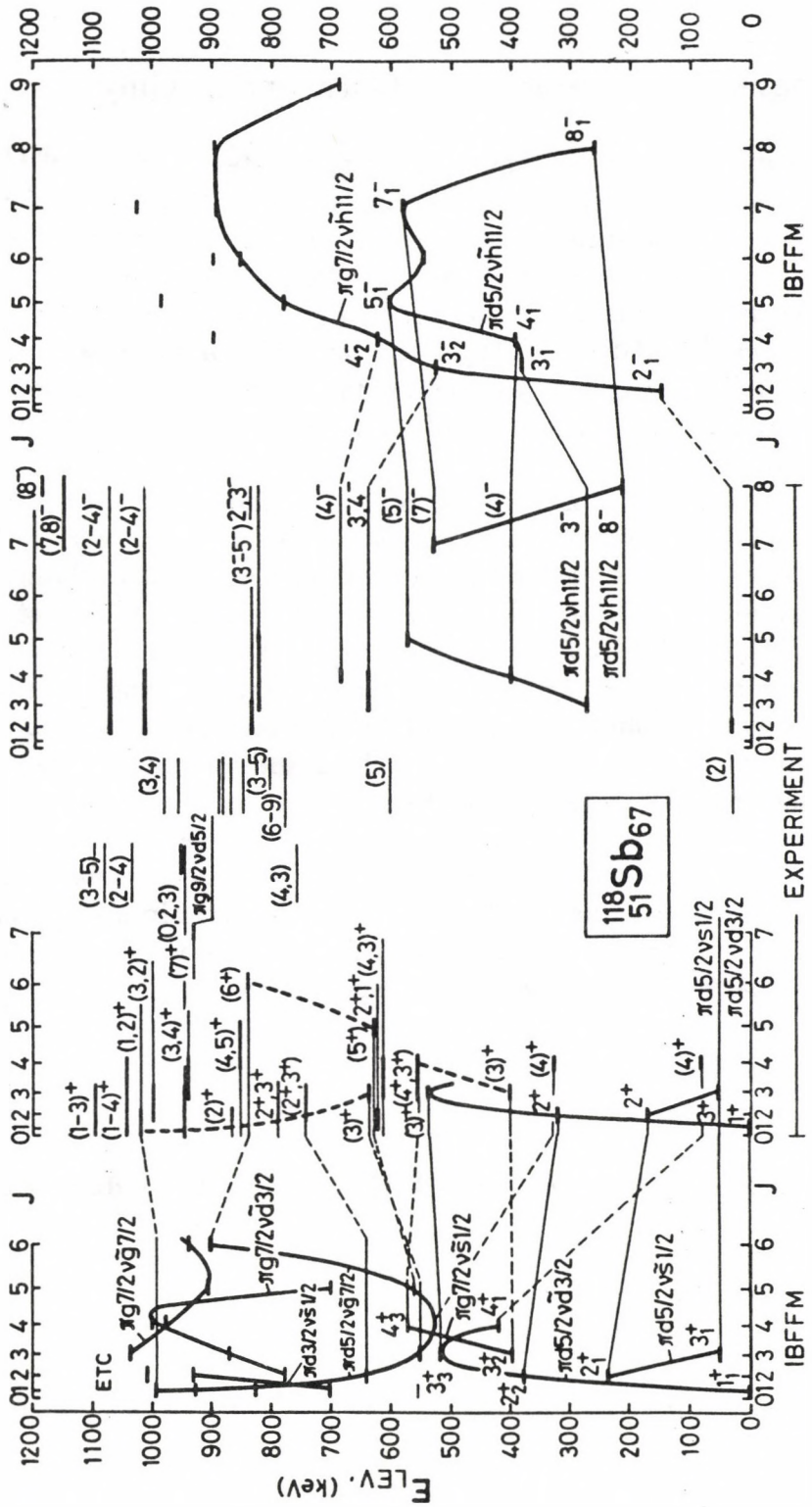

Fig. 1. Experimental and IBFFM theoretical energy spectra of ^{118}Sb, separately for positive and negative parity states. Thick solid lines connect levels, having the same dominating configuration. The abscissa is scaled according to $J(J+1)$, where J is the spin of the state.

Structure of odd-odd Sb nuclei

T. Fényes, Zs. Dombrádi, Z. Gácsi and J. Gulyás

The energy splitting of proton-neutron multiplet states of ^{116,118,120,122,124}Sb was calculated on the basis of the "parabolic rule". About 70 p-n multiplet states have been identified and conclusions have been drawn on the applicability of the parabolic rule, as a simple guideline for experimental investigations.

In the framework of *i*nteracting *b*oson-*f*ermion-*f*ermion / *o*dd-odd *t*runcated *q*uadrupole phonon *m*odel (IBFFM/OTQM) we have calculated the level energies, magnetic dipole and electric quadrupole moments, the reduced transition probabilities, gamma-branching and gamma E2/M1 mixing ratios for ^{116,118,120,122,124}Sb nuclei in a systematic way.

The energy splitting of proton-neutron multiplets shows a great variety as a function of the spin (J) of the state (Fig. 1, thick lines). The splitting is different for different multiplets, and even for the same multiplet it often changes with changing neutron number. The IBFFM calculations give account both of regular (parabolic or doublet) and irregular (non parabolic) splitting of multiplets (Fig. 1, thin lines). We have analysed the effect of dynamical and exchange core-particle interactions on the energy splitting of multiplets. The theoretical electromagnetic moments, transition probabilities, gamma-branching and mixing ratios are also in a reasonable agreement with the experimental data.

The parameters of the calculations (proton single particle and neutron quasiparticle energies, occupation probabilities, etc.) show a smooth variation for different Sb nuclei, allowing a consistent description of Sb nuclei in a wide region.

The obtained results are published in detail in [1]. This work was supported partly by the National Scientific Research Foundation (OTKA).

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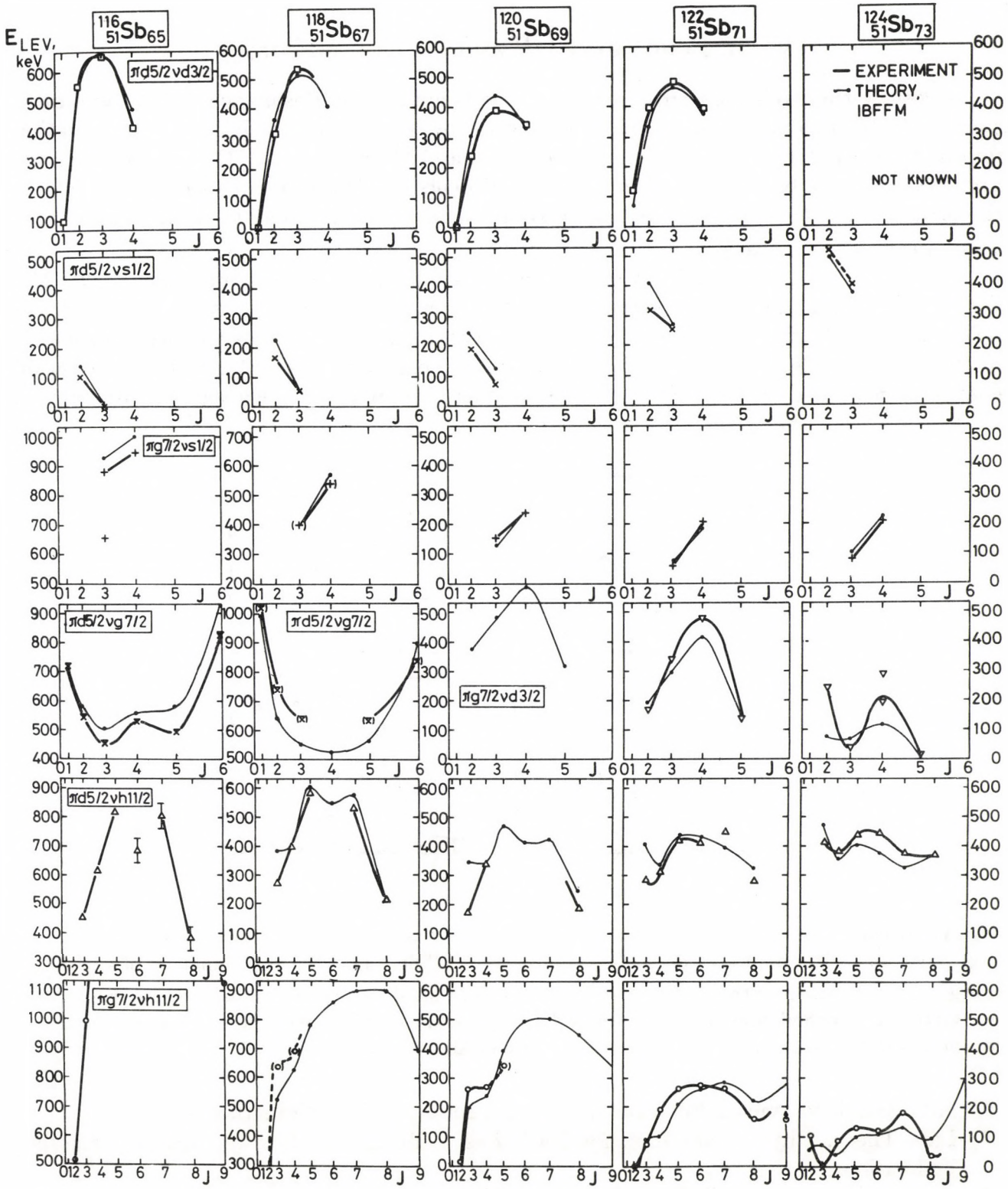

Fig. 1. Systematics of energy splitting of different p-n multiplets of odd-odd Sb nuclei. The abscissa is scaled according to $J(J+1)$, where J is the spin of the state.

γ-decay of the Giant Dipole Resonance to Different Final States in Tin Isotopes

V.Yu. Ponomarev [a,b] and A. Krasznahorkay

Recently the excitation cross section of the Giant Dipole Resonance (GDR) was measured in inelastic α-scattering in coincidence with the γ-decay of the GDR to get information for the neutron skin thickness of the ^{116}Sn, ^{124}Sn and ^{208}Pb nuclei [1]. One interesting phenomenon has also been observed in these experiments. In ^{208}Pb we got GDR decay only to the ground state (γ_0) as we expected, while in tin isotopes the decay to the 2_1^+ state ($\gamma_{2_1^+}$) was almost as itense as γ_0.

The data have been analyzed within the quasiparticle phonon model (QPM) [2]. The decay of the GDR into the 2_1^+ state is explained as a result of mixing of the GDR and the GDR built on the first 2^+ state. The mixing between these two modes has been calculated microscopically. The behavior of the experimental cross sections as a function of excitation energy is described rather well by the calculation (see in Fig. 1.) without introducing an artifical width of the GDR.

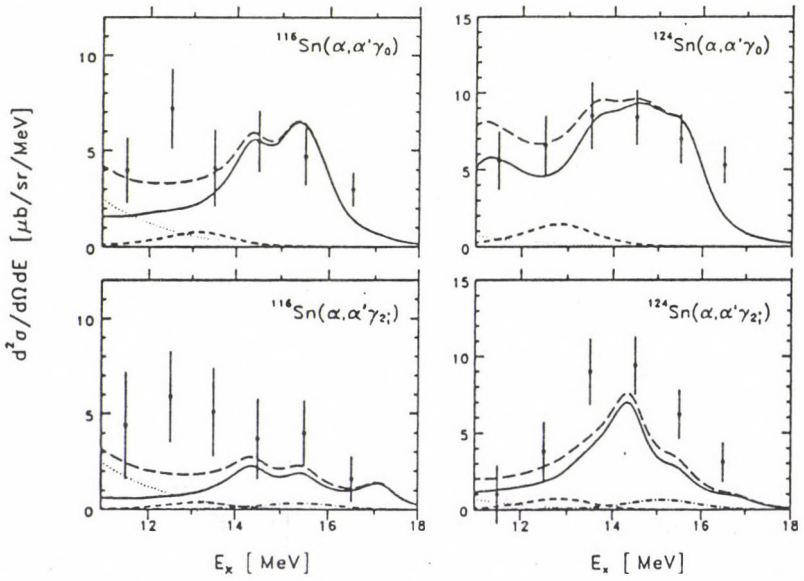

Fig. 1. Measured differential cross section for inelastic α-scattering in coincidence with the γ_0-decay (top part) and with the ($\gamma_{2_1^+}$) decay (bottom part) of ^{116}Sn and ^{124}Sn as a function of excitation energy in comparison with the QPM calculations. The solid line corresponds to the excitation of the GDR, the dashed line the GQR, dott-dashed line the GMR, dotted line contribution of the compound decay and long-dashed line: is the sum of all contributions.

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[b]) Lab. Theor. Phys., Joint Inst. for Nucl. Res. Dubna, P.O. Box 79, Moscow, Russian Federation

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Energy Loss of Light Ions in CR39 Nuclear Track Detector Material

Zs. Fülöp, Á.Z. Kiss, E. Somorjai, I. Hunyadi,

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This year we continued our earlier programme to measure stopping powers of different kind of metallic and composite foils [1], most recently the LR–115 nuclear track detector material [2] for protons and helium ions. The measurements were performed in the transmission geometry in the energy range of protons and alpha particles provided by the Van de Graaff accelerator of the Institute. As part of our cooperation project with the Accelerator Laboratory of the University of Helsinki the extension of the energy loss measurements to ions of higher Z number like oxygen has been started.

The object of the present study is to provide experimental stopping power data for a number of light ions in the nuclear track detector material mentioned above and to compare these data to the predictions of two recent semiempirical models (Ziegler, 1980 [3] and TRIM–91 [4]) for calculating the stopping powers.

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The neutron halo of ^{6}He

A. Csótó, K. Varga and R. G. Lovas

The light nuclei of large neutron or proton excess, such as ^{6}He, ^{8}He, ^{8}Li, ^{8}B, ^{11}Li, have recently become accessible to experiments, which have revealed their halo-like nucleon distributions. The structure of these nuclei must be greatly affected by nucleon exchange and cluster rearrangement effects, which calls for microscopic approaches in their theoretical description. Our dynamical microscopic multiconfiguration multicluster model developed recently [1] is general enough to lend itself to the description of such nuclei.

Our first concern has been to describe ^{6}He in an α+n+n model. Along with many other nuclei of this breed, this nucleus is borromean, which means that removal of any of the three clusters causes the rest to split into two. This underlines the importance of treating the intercluster relative motions as rigorously as in our three-cluster model of the ^{6}Li ground state [2]. In this the α-cluster state is a sum of 0s shell-model states with different size parameters, which allows the α cluster to be distorted by the two neutrons. The intercluster motions contain all partial waves of any significance. The effective nucleon–nucleon interaction contains central, Coulomb, spin–orbit and tensor parts. Except for the tensor part, we now adopted a Minnesota force [3], supplemented with the spin-orbit term of Ref. [4]. Some of the parameters of this force have been fitted to $\alpha + N$ and $N + N$ phase shifts and $N + N$ effective-range parameters. The tensor force parameters have been fitted to the splitting of the p-wave $N - N$ phase shifts. However, in these $N - N$ calculations a single-channel approximation is used, which is not consistent with the use of a tensor force in the description of ^{6}He. That is why we have carried through the ^{6}He calculations both with and without the tensor force. We emphasize that, in contrast to other models used for this system, in our model the two-neutron system is unbound, thus the borromean nature of ^{6}He is reproduced. In respect of ^{6}He, our model is free of parameters.

Up till now we have calculated the two-neutron separation energy and the various rms radii of ^{6}He. The results are shown in the first row of table 1. (In these calculations the tensor force was excluded; its inclusion decreases the separation energies by as little as 0.09 MeV.) As we can see, ^{6}He is underbound by about 0.23 MeV. Until now the best semi-microscopic theoretical estimate was $E_{\rm sep}$=0.5 MeV [5]. The best three-body models [6] give values for the separation energy very similar to ours. To check the effect of the separation energy on the radii, we slightly readjusted one parameter of our force so as to give the correct $E_{\rm sep}$ (row 2 in table 1). The calculated thickness of the neutron halo, $r_n - r_p$, is substantially larger than the experimental value. It is very unlikely that our model is in such a gross error, which indicates that the experimental radii, which were extracted from certain reaction cross sections [7], may not be reliable.

Table 1. Separation energy and matter, proton and neutron rms radii

Parameters	$E_{\rm sep}$ (MeV)	r_m (fm)	r_p (fm)	r_n (fm)
Best for subsystems	0.740	2.440	1.790	2.707
Best for ^{6}He	0.976	2.388	1.761	2.647
Experiment [5,7]	0.976	2.48±0.03	2.21±0.03	2.61±0.03

Table 2. Two-nucleon separation energies in MeV

	^{6}He, 0^+	^{6}Li, 1^+	^{6}Li, 0^+
Present work	0.740	4.911	−0.165
Three-body model [6]	0.138	3.849	−0.187
Experiment	0.976	3.70	0.137

We have performed similar calculations for two states of ^{6}Li, the (1^+) ground state and the (0^+) isobaric analogue of ^{6}He. The results, summarized in table 2, are similar to those of a three-body model [6]. What is neglected in both models is cluster rearrangement. In accord with our earlier finding for ^{6}Li [8], the $t+t$ contribution has proved substantial. In fact, with this contribution, ^{6}He has become overbound by about 0.35 MeV. This can be explained by recalling that the effective force is tailored for a state space that does not include rearrangement channels, and hence is more restrictive than the $\{\alpha+n+n; t+t\}$ state space.

Calculation of other physical quantities (spectroscopic amplitudes, dipole strengths, β-decay branching ratios) as well as the description of some of the other above mentioned nuclei (^{8}Li, ^{8}B) are also in progress.

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Multicluster model of the $^{6-8}$He isotopes

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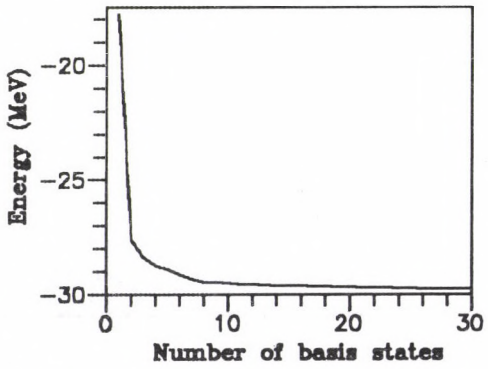
The experimental and theoretical study of light neutron-rich nuclei is one of the most developing areas of nuclear physics. Although considerable effort has been focussed on the understanding of the structure of these nuclei, we believe that our cluster approach is more fundamental and more microscopic than other models.

In our formalism we treat the isotopes ^{6}He=α+n+n, ^{7}He=α+n+n+n and ^{8}He=α+n+n+n+n as 3- 4- and 5-body systems, respectively. We use the conventional cluster model, i.e. the wave function Ψ of the system is an antisymmetrized product of the internal wave function of the alpha particle and the wave functions of the relative motions. The wave function of the relative motion is expanded in terms of Gaussians $\phi_{lm}(\mathbf{r}) = \sum_{i=1}^{N} c_i r^l e^{-\lambda_i r^2} Y_{lm}(\hat{r})$ and we incorporate all the possible arrangements (e.g. $\Psi_{^6He} = \Psi_{\alpha+(n+n)} + \Psi_{(\alpha+n)+n}$) but we limit ourselves to low partial waves l=0,1,2. For these loosely bound systems this approximation seems to be realistic.

To determine the nonlinear parameters λ_i we use the "stochastic variational method" [1]. At the ith step of this procedure the optimal value of $\{\lambda_i\}$ is chosen from n random-number sets by the trial and error method and each step gives a new term to the expansion. This step-by-step optimization is an automatic search for the appropriate parameters and reduces the dimension of the basis considerably. The convergence of energy for the ^{6}He ground state is shown in Figure 1.

We have calculated the spectroscopic amplitude for the removal of two neutrons and found, in agreement with previous semi-microscopic three-body models [2], that the "dineutron" and "cigar-like" configurations play important roles. The spectroscopic factor is around 1.2 . We also determined the transverse momentum distribution of the alpha particle. Similar calculations for ^{7}He and ^{8}He are under way.

Figure 1.



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Local potentials from RGM phase shifts

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Inversion of phenomenological phase shifts and microscopic methods represent two extremes in the description of composite-particle scattering. While in the former the colliding partners are regarded as structureless and their local interaction is sought, in the latter the process is described in terms of the interaction of their constituents. In this work we combine the two approaches to see whether the phenomena observed when the inverse approach is applied to empirical data are borne out by the microscopic model. To this end we use the phase shifts resulting from the microscopic resonating-group model (RGM) as "experimental data" in the inverse approach.

We examine the elastic scattering of nucleons off ^{4}He between zero energy and the t(or h)+d threshold. We use essentially the same RGM as recently in an analysis of the $\frac{3}{2}^+$ resonance above the t+d threshold [1]. In this model the intrinsic states of the fragments are 0s states, in the nucleon–nucleon interaction tensor as well as spin–orbit terms are included, and the coupling to the t(or h)+d channel is taken into account. We adopt the inverse scattering method in the form applied to the nucleon+^{4}He system earlier [2].

We have derived nucleon–^{4}He potentials for the whole energy range as well as for narrow energy regions. We tried to construct potentials for all partial waves and for specific partial waves as well. We have compared results obtained by the use of the full RGM with those in which the channel coupling is switched off.

The results with the full RGM resemble those obtained with the actual experimental phase shifts [2]. In particular, it is possible to find an energy independent potential for each partial wave, but the potentials for multiple partial waves are mostly energy dependent. The potentials for only even and for only odd partial waves behave sensibly, but those which fit all partial waves simultaneously behave erratically, thus showing that the parity dependence is a genuine physical effect. The 'odd' potential has a longer range than the 'even' potential, an effect also found [2] by inverting empirical phase shifts. The channel-coupling effects for even partial-wave potentials are stronger than for the odd wave potentials.

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^{28}Si bands in terms of $^{24}Mg + \alpha$ configuration

J. Cseh

The collective bands of the ^{28}Si nucleus provide an excellent possibility for checking the model space of the semimicroscopic algebraic cluster model [1,2]. The reason is that the band–structure of the low–energy states are established on the basis of primary experimental data, and in addition to many of these bands $SU(3)$ quantum numbers are associated without supposing any cluster structure [3]. Therefore the energy spectrum of the $U(3)$ dynamical symmetry can be expected to approximate well the experimental situation. Furthermore, in this nucleus the *sd* shell is half–filled, thus the Pauli principle plays a cruical role in the cluster model description of the ground–state region.

It turns out [2], that all the known bands are reproduced by the $^{24}Mg + \alpha$ model calculation within the dynamical symmetry approximation (Fig. 1). The $T = 0$ states with known spin–parities and excitation energies not larger than $11.5MeV$ [4], as well as the densities of low–spin states in a highly excited energy region [5] can also be obtained from the same calculation [6].

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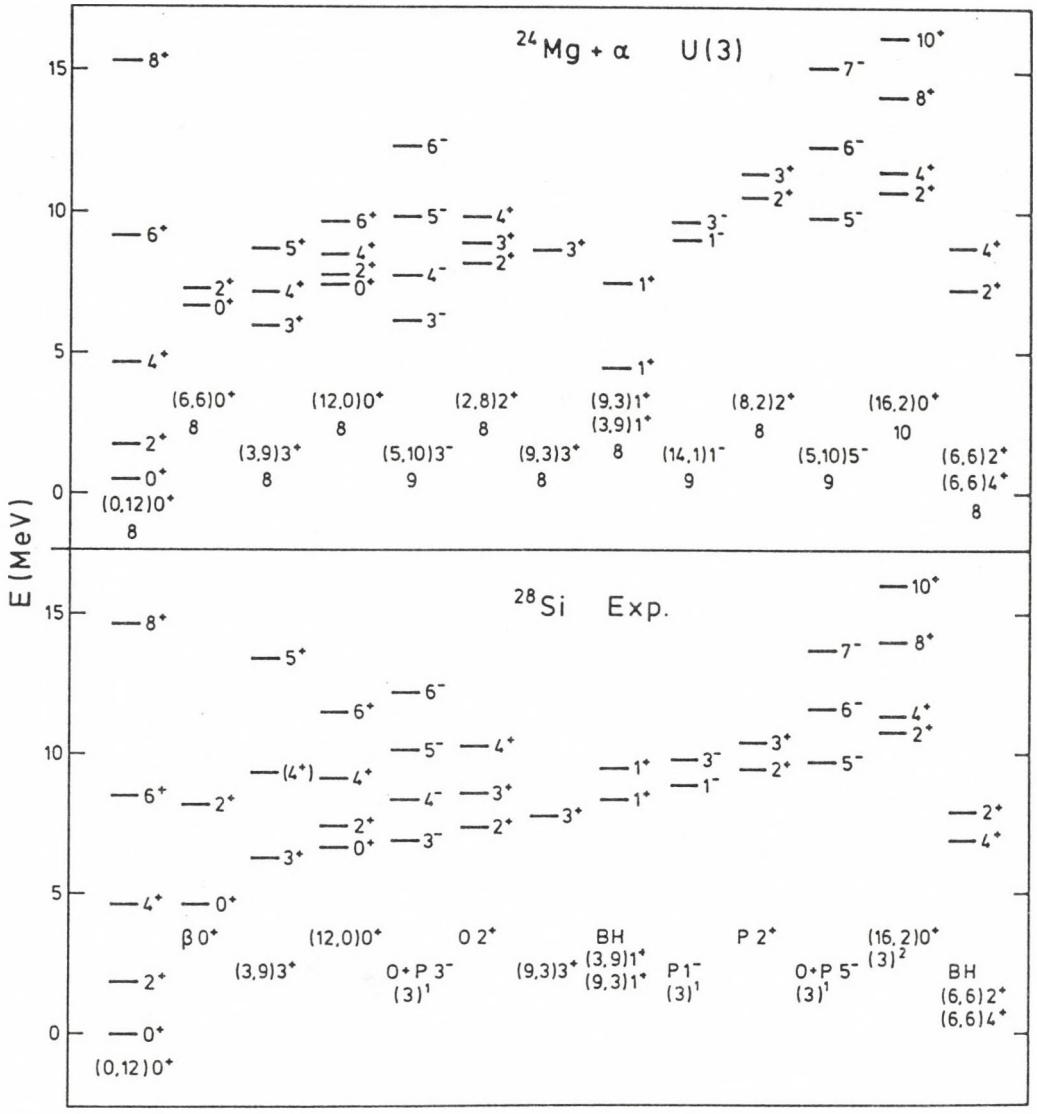

Fig. 1. Band structure of ^{28}Si in comparison with the model spectrum of the $^{24}Mg + \alpha$ system. The bands are labelled by the $(\lambda,\mu)K^{\pi}$ quantum numbers. In the model spectrum the relative motion quantum number n_{π} is given below the $SU(3)$ labels. In the experimental part the excited shell model configurations are also indicated, so e.g. $(3)^1$ means: $(0)^4(1)^{12}(2)^{11}(3)^1$. When no such configuration is shown, it should be understood as $(0)^4(1)^{12}(2)^{12}$. Further notations: β : β–instable, O: oblate ($\lambda < \mu$), P: prolate ($\lambda > \mu$).

A unified tratment of the ground–state region and the molecular resonances in the ^{24}Mg nucleus

J. Cseh, G. Lévai and W. Scheid [a)]

A semimicroscopic algebraic $^{12}C + {}^{12}C$ cluster model is applied to describe the structure of the ^{24}Mg nucleus. The spectrum of the $T = 0$ states is analysed in terms of this configuration with ^{12}C clusters allowed to occupy their 0^+(0.0 MeV), 2^+(4.439 MeV) and 4^+(14.083 MeV) states. About a hundred experimental levels below $E_x \simeq 16$ MeV are assigned to model bands. A large number of observed reduced $E2$ transition probabilities are reproduced reasonably well indicating the approximate realisation of $SU(3)$ dynamical symmetry. The spectrum of molecular resonances is also obtained in relatively good agreement with the experimental data. $E2$ transitions within this region are found to be significantly weaker than what has been predicted by other models.

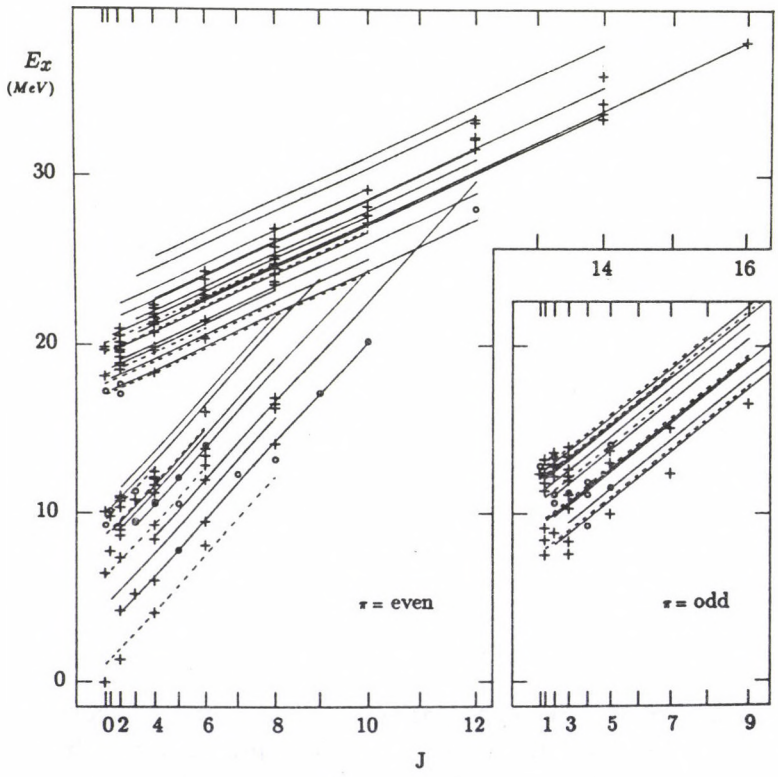

Fig. 1. The positive and negative parity $T = 0$ energy levels of the ^{24}Mg nucleus displayed separately in rotational diagram form. The lines indicate the positions of the calculated model bands. (Dashed lines indicate bands with $K = 0$ which contain only every second possible J value.)

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Band structure of ^{224}Ra in terms of a $^{210}Pb + {}^{14}C$ model

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The low-lying bands of the ^{224}Ra nucleus are calculated in terms of a semimicroscopic algebraic $^{210}Pb + {}^{14}C$ cluster model [1]. The relative motion of the clusters is described by the vibron model, while their internal structures are handled by the shell model. For the light cluster a real shell scheme, and for the heavy one a pseudo shell model in used. The energy spectrum is shown in Fig. 1. One-body transition operators give good agreement with the available $BE(2)$ values, and produce no $E(1)$ transitions.

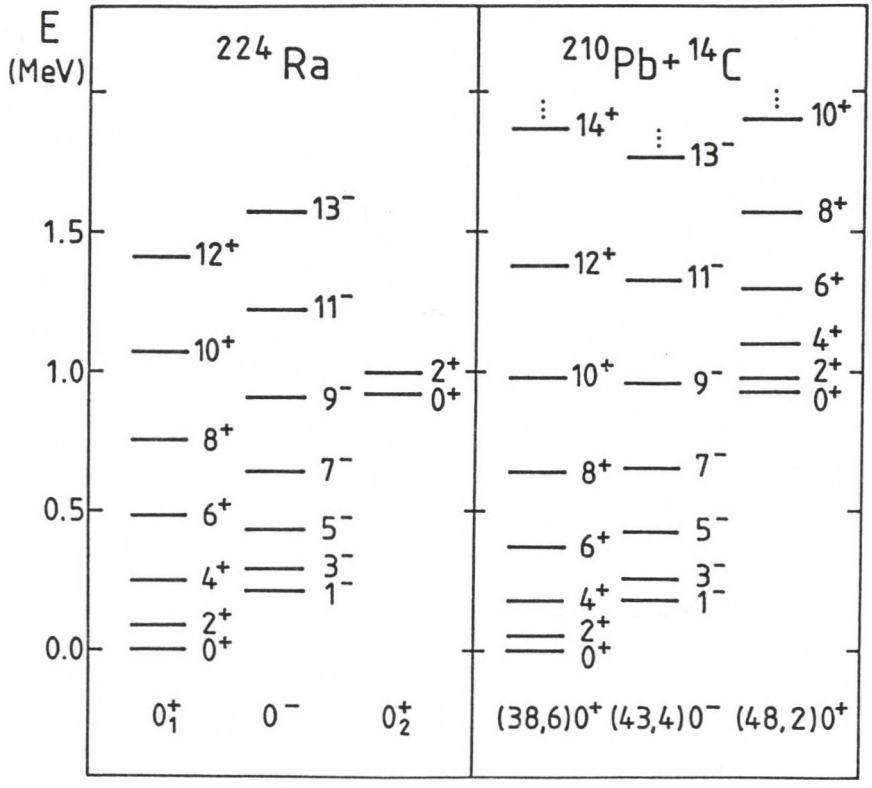

Fig. 1. Low-lying bands in the energy spectrum of ^{224}Ra in comparison with the $^{210}Pb + {}^{14}C$ model calculation. In the right-hand part the bands are characterised by the $(\lambda, \mu)K^{\pi}$ quantum numbers.

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On the binary fission modes of ground–state–like configurations in *sd* shell nuclei

J. Cseh

An interpretation of the fission process of light nuclei was put forward recently [1], based on two essential ingredients: i) a mechanism which excites the nucleus above the fission threshold in such a way that its structure remain similar to that of the ground state band, and ii) the rearrangment of the nucleons from the parent nucleus into the daughter ones, governed by the Pauli blocking effect. Technically this latter requirement was formulated in terms of Harvey's prescription [2]. In order to aid the investigations of this kind we have determined systematically the allowed and forbidden binary fission modes of the ground–state–like configurations in *sd* shell nuclei [3]. Those fragmentations were considered in which all the nuclei are stabil isotopes. Instead of Harvey's prescription we have used a more concise $U(3)$ selection rule, which have a similar physical contant [4]. Illustrative examples are given in Table 1.

Table 1. Allowed and forbidden binary fission modes of ground–state–like configurations in some *sd* shell nuclei according to the $U(3)$ selection rule (for nuclei in the first half of the *sd* shell all the binary fragmentations into stabil isotopes are allowed).

Nucleus	Allowed	Forbidden
^{28}Si		$^{14}N + {}^{14}N$ $^{16}O + {}^{12}C$
^{29}Si	$^{17}O + {}^{12}C$ $^{19}F + {}^{10}B$ $^{20}Ne + {}^{9}Be$ $^{23}Na + {}^{6}Li$	$^{15}N + {}^{14}N$ $^{16}O + {}^{13}C$
^{30}Si	$^{21}Ne + {}^{9}Be$ $^{23}Na + {}^{7}Li$	$^{15}N + {}^{15}N$ $^{17}O + {}^{13}C$ $^{18}O + {}^{12}C$ $^{19}F + {}^{11}B$
^{31}P	$^{19}F + {}^{12}C$ $^{21}Ne + {}^{10}B$ $^{20}Ne + {}^{11}B$ $^{23}Na + {}^{8}Be$ $^{24}Mg + {}^{7}Li$ $^{25}Mg + {}^{6}Li$	$^{16}O + {}^{15}N$ $^{17}O + {}^{14}N$
^{32}S	$^{20}Ne + {}^{12}C$	$^{16}O + {}^{16}O$

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$^{16}O + \alpha$ cluster states in terms of a $U_q(3)$ anharmonic oscillator model

J. Cseh

The dynamical symmetry of $U(3) \supset O(3) \supset O(2)$, as well as its q–deformed version [1] is applied for the description of some $^{16}O + \alpha$ cluster bands in ^{20}Ne. The energy spectrum and the cluster specroscopic factors are calculated, and the question is investigated, whether the q–deformed model gives a better description of the experimental data [2]. As far as the energy spectrum is concerned, the best agreement is obatined with the deformation parameter of $q = e^{0.125}$, but this deformation damages the fit of the spectroscopic factors with zero deformation. Nevertheless, the averall description of the q–deformed model turns out to be slightly better, than that of the classical Lie algebraic model.

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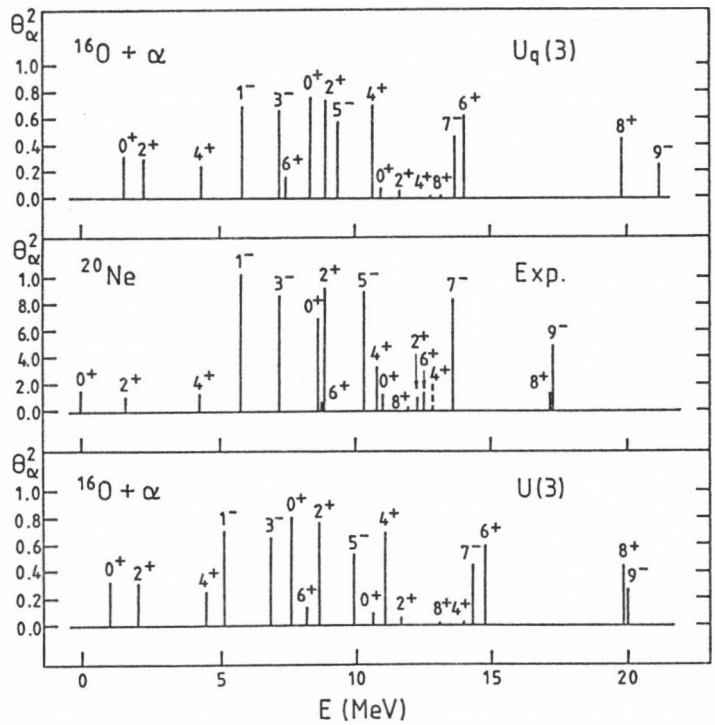

Fig. 1. Experimental energies and alpha–particle spectroscopic factors of the 0^+_1, 0^-, 0^+_4 and 0^+_5 bands of ^{20}Ne (central panel) in comparison with the $^{16}O + \alpha$ cluster model calculations in terms of the undeformed (lower panel) and q–deformed (upper panel) $U(3)$ dynamical symmetry.

Partial decay widths from the giant monopole resonance in ^{208}Pb

E. Maglione [1], R. J. Liotta [2], T. Vertse

Partial widths of the giant monopole resonance in the ^{208}Pb are calculated in the frame of the continuum RPA (CRPA) exactly, i.e. without further approximation and compared to those calculated by other authors as well as the experimental data available [1].

The total Hamiltonian is $H = H_0 + V$. The unperturbed H_0 has Woods-Saxon, spin-orbit and Coulomb potential terms and the residual interaction V is separable and it corresponds to a field $Q_{\lambda\mu}(\boldsymbol{r}\ ) = f_\lambda(r)Y_{\lambda\mu}(\hat{r})$, which is also the external field in the response function. The S-matrix is

$$S_{cc'} = \delta_{cc'}e^{2i\delta_c} - 2i\pi < \chi_{\mathcal{E}}^{c'(-)}|V|\chi_{\mathcal{E}}^{c(+)} > -2i\pi < \chi_{\mathcal{E}}^{c'(-)}|VG^{(+)}(\mathcal{E})V|\chi_{\mathcal{E}}^{c(+)} > \quad (1)$$

where $G^{(+)}$ is the CRPA Green function and the scattering solution of H_0 has the form

$$\chi_{\mathcal{E}}^{c(+)}(\boldsymbol{r}_p, \boldsymbol{r}_h) = e^{i\delta_c}u_\epsilon(\boldsymbol{r}_p)\phi(\boldsymbol{r}_h) \quad (2)$$

where $\phi(\boldsymbol{r}_h)$ is the wave function of a hole, i.e. the daughter nucleus ^{207}Pb, ϵ is the kinetic energy of the escaping particle, i. e. $\mathcal{E} = \epsilon + \epsilon_h$, and $u_\epsilon(\boldsymbol{r}_p)$ is the corresponding scattering wave function. The physical resonances that we are interested in are given by the complex poles of the Green function and therefore we keep only the last term of equation (1). We assume that the S-matrix can be parametrized in the standard form and associate the residues of eq.(1) with the partial decay widths. Performing a partial wave expansion of u_ϵ and using the spectral representation of $G^{(+)}$ the escape width from the resonance n acquires the simple form

$$\Gamma_{n,h} = \frac{\mu}{\hbar^2 k}\frac{\kappa_\lambda^2}{2j_h+1}\mathcal{R}_{n\lambda}$$

$$\times \sum_{lj}\frac{1+(-1)^{l+l_h+\lambda}}{2}(2j+1) < j1/2\lambda 0|j_h 1/2 >^2 \left(\int dr u_{\epsilon lj}(r)f_\lambda(r)\phi_h(r)\right)^2 \quad (3)$$

where $\mathcal{R}_{n\lambda} =< 0|Q_\lambda|n >^2$ is the residue of the response function and h labels the hole state. The energy of the escaping particle is the complex quantity $\epsilon = \omega_n - \epsilon_h$.

The complex poles of the Green function are the same as those in the (correlated) response function R. In our case of a separable interaction R has a simple form

$$R(\mathcal{E}) = R_0(\mathcal{E})/(1 + \kappa_\lambda R_0(\mathcal{E})) \quad (4)$$

where κ_λ is the strength of the interaction and $R_0(\mathcal{E})$ is the uncorrelated particle-hole response function at the complex energy $\mathcal{E}$. Therefore the roots of the denominator in eq.(4) $\mathcal{E} = \omega_n$ can be calculated from the equation

$$R_0(\omega_n) = -1/\kappa_\lambda. \quad (5)$$

We fixed the strength κ by choosing $\omega_0 = (13.6 - i0.17)$ MeV in eq.(5). Then we solved eq. (5) and found that there are three roots (pieces of the giant resonance) which carry most of the EWSR. According to the experiments[2,3] these pieces are located within the range of the giant resonance, which has a total width of 2.4±0.3 MeV. In table 1 the partial decay widths, calculated according to eq. (4), corresponding to each pieces of the giant resonance are also presented. It is interesting to notice that the wider the resonance is the more the sum of the partial decay widths differs from the total escape width (i. e. -2Im(ω_n)).

Hole state	$\lvert\Gamma_{1,ch}\rvert$	$\lvert\Gamma_{2,ch}\rvert$	$\lvert\Gamma_{3,ch}\rvert$	$\bar{\Gamma}_{ch}$
$(1/2)^-$	3	22	14	17
$(13/2)^+$	0	4	6	4
$(5/2)^-$	20	114	69	88
$(3/2)^-$	7	43	27	33
$(7/2)^-$	47	197	104	149
Sum	77	380	220	291
Ratio	0.05	1.12	1.10	

Table 1. Partial contributions to the escape widths, (in keV) corresponding to the three main fragments of the giant monopole resonance located at energies ω_1=(12.579 - i 0.747)MeV, ω_2=(13.600 - i 0.169)MeV and ω_3=(14.086 - i 0.100)MeV. The corresponding percentages P_n of the EWSR are $P_1 = 7\%$, $P_2 = 40\%$ and $P_3 = 23\%$. In the last row is the ratio $\sum_h \Gamma_{n,ch}/(-2Im(\omega_n))$.

Since the three pieces of the giant resonance are not resolved in the experiments, the partial decay width from the giant resonance to a hole state in ^{207}Pb should correspond to a weighted average of the three pieces. We either can neglect interference effects and define $\bar{\Gamma}_{ch} = \sum_{n=1}^{3} W_n |\Gamma_{n,ch}|$ where the weight is defined as $W_n = |\mathcal{R}_{n\lambda}|/(|\mathcal{R}_1| + |\mathcal{R}_2| + |\mathcal{R}_3|)$ or calculate the branching ratios B_{ch} of eq.(6) in which the interference of the overlaping pieces of the giant resonance is taken into account.

Hole state	Experiment		Theory		
	ref. [3]	ref. [2]	ref. [3]	ref. [4]	this work
$(1/2)^-$	140±35	0	5	76	17
$(13/2)^+$		75±35	6	2	4
$(5/2)^-$	70±15	<35	92	410	88
$(3/2)^-$	50±10	75±40	8	156	33
$(7/2)^-$	165±40	<140±30	174	241	149
Sum	425±100	325±105	285	885	291

Table 2. Comparisson of experimental and theoretical partial escape widths (in keV).

In table 2 we compare our results with experimental values[2,3] as well as the other two calculations that we are aware of[3,4]. Our calculated partial decay widths are closer to the experimental values of ref.[2] than those of ref. [3], but substantial differences still exist. There is a rather good agreement between our calculation and that of ref.[3], specially considering the sensitivity of the calculated partial decay widths to changes in the residual interaction and also the approximations performed in ref.[3] which may play some role in the differences between the two calculations. We do not agree with the theoretical results of ref.[4].

Calculation of the branching ratios shows that the interference among the pieces of the giant resonance play an important role. The energy averaged braching ratios are calculated as

$$B_{ch} = -i(\sum_{n,n'} \frac{(\Gamma_{n,ch}\mathcal{R}_n)^{1/2}(\Gamma^*_{n',ch}\mathcal{R}^*_{n'})^{1/2}}{\omega_n - \omega^*_{n'}})/\sum_n |\mathcal{R}_n|. \qquad (6)$$

Our values for the branching ratios in table 3 agree well with that values of ref.[5] where the spreading width is not included.

Decay channel	ref. [5]	B_{ch}
$(1/2)^- + (13/2)^+$	0.14	0.13
$(5/2)^-$	0.38	0.39
$(3/2)^-$	0.30	0.23
$(7/2)^-$	0.17	0.24

Table 3. Branching ratios B_{ch}, eq. (6). The values of ref.[5] correspond to a Skyrme calculation with coupling to the continuum only.

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Resonance State Expansions of the Continuum

P. Lind [1], R. J. Liotta [2], E. Maglione [3], T. Vertse

There are several ways of performing resonant state expansions. They all use some or all of the following states: a) antibound states, b) bound states, c) capturing resonances and d) decaying resonances. The identity (or projection) operator can be written as

$$1 = \eta \sum_n |u_n >< \tilde{u}_n| + \frac{1}{\pi} \int_L |\psi(k) > dk < \psi(k^*)| \tag{1}$$

where u_n and $\psi(k)$ are the resonance and continuum wave functions and L is a contour in the complex k-plane. Neglecting the integral one can express the expansion of a matrix element as

$$< f|g >= \eta \sum_n < f|u_n >< \tilde{u}_n|g > . \tag{2}$$

where f and g are regular functions. If the set $\{n\}$ contains states of the type b and d only, η =1 and the resulting expansion is called "Berggren expansion" (BE), while one refers to the expansion (2) as "Mittag-Leffler expansion" (MLE) if all states of the type $a - d$ are included and $\eta = \frac{1}{2}$. The BE allows for a convenient physical interpretation of the calculated quantities in terms of single-particle states and the MLE is of mathematical nature and it is better in reproducing the correct symmetries moreover it verifies the relation

$$0 = \sum_n < f|u_n > \frac{1}{2k_n} < \tilde{u}_n|f > \tag{3}$$

if the contribution of the continuum integral is neglected. The drawback of the MLE is that the corresponding elements in the set $\{n\}$ do not define a standard complete set. Thus, since the operator (1) is not idempotent it cannot be considered as a unity operator in a shell-model sense (although the basis states are orthogonal). We analyse in detail the convergence properties of the BE and MLE as the number of resonances n is increased. We use single-particle states generated by a local Woods-Saxon potential with spin-orbit and Coulomb interactions corresponding to the case of ^{208}Pb. The convergence of the expansion in eq.(1) is tested by computing the quantity

$$U = \frac{\eta \sum_n < f|u_n >< \tilde{u}_n|f >}{< f|f >}. \tag{4}$$

In table 1 the values of BE and MLE of U and the MLE of eq.(3) are presented. One sees that the expansions (2) and (3) are valid if enough resonances are included and that contributions of unphysical states are substantial. One can prove only for

the MLE that it should converge to the correct value if the central potential is of limited range. The MLE converges better to the correct value than the BE while the BE do not converge exactly to the correct values because the contribution of the integral is not negligible. Nevertheless cancellations in the imaginary part of the BE make the final error much smaller than that of the dominant contributions.

Table 1. Neutron $f_{5/2}$ single-particle states. The energy ϵ_n is in MeV. The values of BE_1 and MLE_1 correspond to the quantity U (eq. (4)) for the BE and MLE, respectively. The values of MLE_0 correspond to eq. (3). The dashed line in the column BE_1 indicates antibound states.

ϵ_n	BE_1	MLE_1	MLE_0
−24.78 +0.00i	0.27 +0.00i	0.14 +0.00i	0.00 −0.13i
−24.78 +0.00i	- - - - - -	0.27 +0.00i	0.00 +0.00i
−8.08 +0.00i	0.78 +0.00i	0.52 +0.00i	0.00 −0.41i
−5.81 +0.00i	- - - - - -	0.64 +0.00i	0.00 −0.18i
−1.52 −1.37i	0.77 +0.01i	0.63 +0.00i	0.00 −0.20i
−1.37 −11.75i	1.20 −0.39i	1.06 +0.00i	0.00 −0.12i
2.70 −2.32i	1.15 −0.53i	1.02 +0.00i	0.00 −0.47i
9.74 −18.97i	1.55 +0.25i	1.41 +0.00i	0.00 +0.38i
22.12 −21.90i	0.62 −0.26i	0.49 +0.00i	0.00 −0.29i
33.34 −26.90i	1.43 −0.05i	1.29 +0.00i	0.00 +0.04i
49.32 −32.06i	0.97 +0.07i	0.84 +0.00i	0.00 +0.03i
66.14 −36.11i	1.21 −0.11i	1.08 +0.00i	0.00 −0.03i
85.09 −40.94i	1.10 +0.03i	0.97 +0.00i	0.00 +0.02i
106.10 −45.28i	1.14 −0.05i	1.01 +0.00i	0.00 −0.01i

We tested the accuracy of using the BE and MLE also in the case of particle-hole excitations. Giant multipole resonances were calculated exactly i.e. using the continuum RPA (CRPA) for ^{208}Pb and with the use of resonant state expansions in calculating the s.p. Green function in the p-h response function. The positions of the poles of the p-h response function given by the CRPA were reproduced with the accuracy of 3-5 decimal digits using the BE and the MLE while the largest deviation from the CRPA results in the corresponding residues was about 15%. One advantage of the expansion methods is that the corresponding codes run at least 30 times faster than the CRPA code.

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ATOMIC PHYSICS

Systematic Study of the ECC Cusp at Impact of Neutral Atoms

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The process of the electron capture into the continuum of the projectile (ECC) is well understood theoretically in the case of charged bombarding particles. The cusp-shaped peak in the spectrum of the forward ejected electrons due to ECC can be explained by means of the diverging normalization constant of the final electronic projectile continuum state at threshold in the field of the long-range Coulomb interaction. As an unexpected result, however, a sharp cusp was observed also at impact of neutral atoms [1], i.e. for fully screened Coulomb potential characterized by short interaction range. In the experiment the ECC process was identified in He^0 (300 keV) on He, Ar collisions by measuring the cusp peak in the electron spectrum in coincidence with the outgoing He^0 atoms. The observation (confirmed recently in another experiment [2]) has initiated several theoretical investigations [3]. To provide a better data basis for comparison with the theories, in the present work we have carried out a systematic experimental study of the process, especially for its dependence on the impact energy. The He^0 – Ar collision system was chosen for this purpose.

The experimental arrangement was similar to that used in our previous investigations [4]. The He^0 beam was produced by neutralization of a He^+ beam obtained from the 1.5 MV Van de Graaff accelerator of ATOMKI. An electrostatic "beam cleaner" was used to deflect the charged component out of the beam. The electrons ejected from a gas jet target were energy analyzed by a double-stage cylindrical mirror electron spectrometer with an energy resolution $\Delta E/E = 0.4\%$ and acceptance angle $\Theta_0 = 1.9°$. The outgoing particles were charge-state analyzed and counted by a fast particle detector. The pulses from the latter detector served as gate signals to the electron spectrum to identify the different reaction channels: the electrons in coincidence with He^0 are produced by ECC; coincidences with He^+ are due to projectile ionization (ELC, electron loss into the continuum); and coincidences with He^{2+} are due to double ionization of the projectile (DELC, double electron loss into the continuum).

Fig.1. shows the contributions ("fractions") of the different reaction channels (ECC, ELC, DELC) to the total cusp yield as functions of the impact energy. The yield of the ECC channel strongly increases with decreasing energy, and it becomes the dominant channel below 100 keV.

We have also determined absolute single differential cross sections (SDCS) for the ECC cusp production by neutral He atoms. We have compared the obtained values to those obtained by He^+ bombardment. The difference between the SDCS

values measured at impact of neutral and charged projectiles is surprisingly small (20-40%), particularly at larger collision energies.

In an other experiment performed at the 2.5 MV Van de Graaff accelerator of the Institut für Kernphysik of the J.W. Goethe Universität (Frankfurt/M) we have investigated the role of those He atoms in the neutral beam which are in excited metastable states [5]. The fraction of such atoms is estimated to range from 25% to 35%. We used the technique of the collisional quenching to reduce the metastable fraction of the beam. At 400 keV impact energy we observed a dramatic decrease of the ECC cusp yield (by a factor of about 3) when the metastable atoms were completely quenched. The results of this experiment are under evaluation.

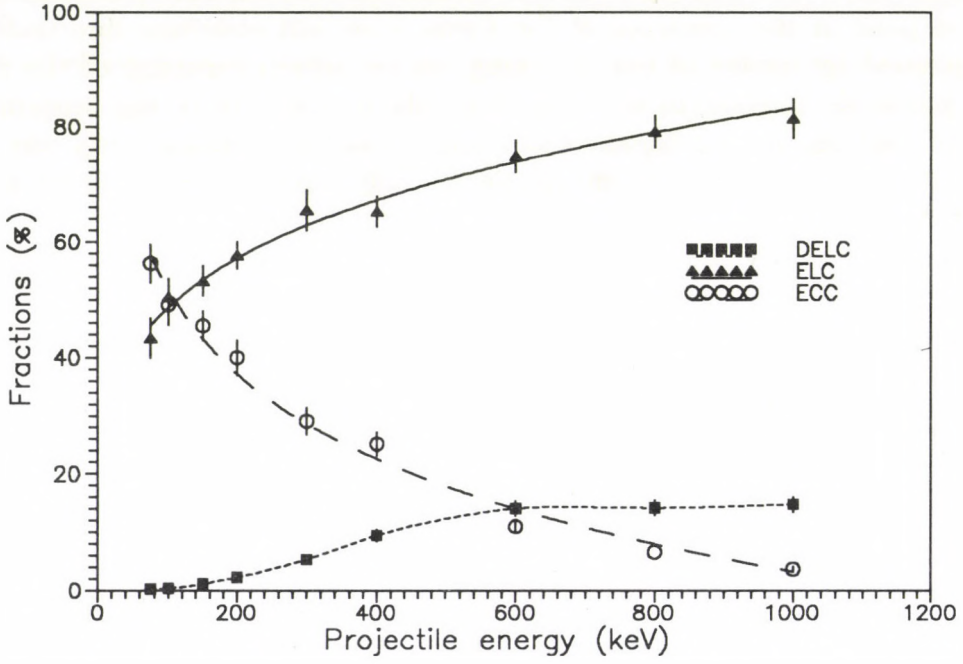

Fig. 1. The contributions of the ECC, ELC and DELC channels to the total cusp production as functions of the impact energy in He^0 on Ar collisions.

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Contribution of Transfer Ionization to Cusp Electron Production in He^+ on Ar Collisions

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In a previous systematic study [1] carried out at the Institute, the role of the different processes contributing to the cusp peak appearing in the spectrum of forward ejected electrons was investigated. For 50-150 keV/amu He^+ – He, Ar collisions it was found that, in addition to the one-electron processes (electron capture to the continuum, ECC and electron loss to the continumm, ELC), a two-electron process contributes significantly to the total cusp production. This process, known as transfer ionization (TI), involves the simultaneous capture of two target electrons by the projectile: one into a bound state and another into a continuum state. TI was observed to increase rapidly with decreasing projectile velocity. In similar work by Tanis et al. [2] using low-energy (5 keV/amu) O^{6+} projectiles on a He target, the two-electron process (TI) was found to dominate the corresponding one-electron process (ECC). This latter finding indicated the presence of strong correlation between the two participating electrons in TI.

The increasing role of TI with decreasing energy for He^+ impact, as well as its dominance for heavy-ion bombardment, have motivated us to extend the previous measurements to lower energies, where evidence for electron correlation was expected also for light-ion impact. We chose the $He^+ \rightarrow Ar$ collision system for this study.

As in ref. [1], the ECC, ELC and TI reaction channels were identified by detecting cusp electrons in coincidence with outgoing charge-state analysed $He^{1+,2+,0}$ (for details of the experimental arrangement, see also the abstract on a similar topic by Sarkadi et al. in this volume). Special care was taken to ensure single-collision conditions (this is particularly important when one measures a two-electron process). From the measurements we have determined the contributions ("fractions") of the different reaction channels as functions of the target pressure and extrapolated them to zero pressure. A strong pressure dependence was found for the TI fraction which could be explained in terms of a double collision process. Specifically, before reaching the target region the He^+ projectile is first neutralized, following which an ECC process takes place in a subsequent collision between the neutral He and a target atom [3] leading to the same outgoing products (He^0 and e^-) as in the TI process.

Fig.1. shows the ECC, ELC and TI fractions as functions of the projectile energy. With decreasing projectile energy the relative contribution of the two-electron TI process increases sharply, and below 45 keV/amu it exceeds the one-electron ELC process. The dominant cusp-production mechanism in the energy range investigated, however, is the one-electron ECC process.

The increasing strength of TI at low impact velocities does not necessarily mean that the role of the electron correlation in the cusp-electron production increases, however. Correlation effects could be unveiled by comparing the experimental data with the results of theoretical calculations based on the independent electron approximation as well as with the predictions of models which include correlation. Unfortunately, no theory exists at present for the simultaneous capture of electrons into bound and continuum states.

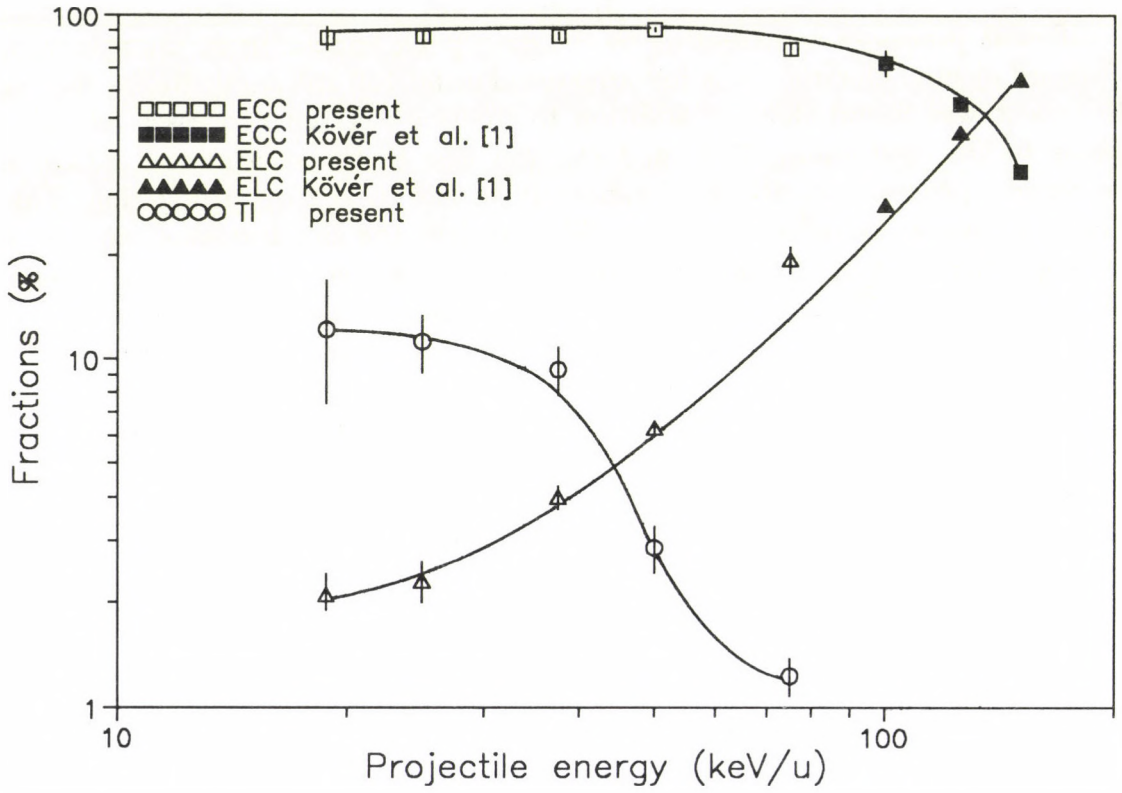

Fig. 1. Energy dependence of the contributions of the different reaction channels to the total cusp-electron production for He^+ impact on Ar. The curves are drawn to guide the eye.

References

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Resonant double-electron capture in He^{2+}+He collision

L. Gulyás and Gy. Szabó

Recently the first Born approximation with correct boundary conditions (B1B) /1/ is satisfactorily used for the description of single electron capture phenomena. It gives values comparable to the ones of higher-order models (CDW , CDW-EIS, etc...) at not too high impact velocities where the Thomas scattering is negligible /2/.

In the present study the total cross-section of the resonant double electron capture in high energy,

$$He^{2+} + He(1s^2) \rightarrow He(1s^2) + He^{2+} \qquad (1)$$

collision has been calculated in the frame of the B1B model. The 'prior' form of the transition amplitude for process (1) in the B1B model is the following:

$$T_{if}^{(-)}(\mathbf{p}) = \iiint d\mathbf{r}_i d\mathbf{r}_{P1} d\mathbf{r}_{P2} e^{i\mathbf{K}_f\mathbf{r}_f} \varphi_f^*(\mathbf{r}_{P1},\mathbf{r}_{P2}) \left[-\frac{Z_P}{r_{P1}} - \frac{Z_P}{r_{P2}} + \frac{2Z_P}{R} \right]$$
$$\times e^{i\mathbf{K}_i\mathbf{r}_i} \varphi_i(\mathbf{r}_{T1},\mathbf{r}_{T2}) E(\mathbf{R}) \qquad (2)$$

where $\mathbf{p}$ is the momentum transferred to the projectile, Z_K (K=P,T) is the charge of the Kth nucleus, $\mathbf{r}_{Kk}$ are the position vectors of the kth electron relative to the nucleus K. The vector of the internuclear axis is denoted by $\mathbf{R}$, further, $\mathbf{r}_i$ ($\mathbf{r}_f$) are the position vectors of the center of mass system Z_T-e_1-e_2 (Z_P-e_1-e_2) relative to Z_P (Z_T), $\mathbf{K}_i$ and $\mathbf{K}_f$ are the initial and final momenta and

$$E(\mathbf{R}) = \exp\left\{ i\frac{Z_P(Z_T-2)}{v} \ln(vR - v\mathbf{R}).. \right. \qquad (3)$$
$$\left. + i\frac{Z_T(Z_P-2)}{v} \ln(vR - v\mathbf{R}) \right\},$$

$\varphi_f(\mathbf{r}_{P1},\mathbf{r}_{P2})$ and $\varphi_i(\mathbf{r}_{T1},\mathbf{r}_{T2})$ are the initial and final electronic ground states, which are described by the configuration-interaction (CI) wave function /3/ in order to avoid the independent approximation. Namely, Eqs. 2.,3. show that the electron-electron repulsion $1/r_{12}$ enters the problem only through the unperturbed initial and final wave functions (static correlation). Uncorrelated bound state wave functions, (a product of K-shell one electronic hydrogen-like orbitals with a variationally determined nuclear charge Z=1.67 and a product of 5-z HF Clementi-Roetti orbitals /4/) were also applied for comparison. The figure gives the comparison of the present calculation with experiments and with other first order theoretical approximations.

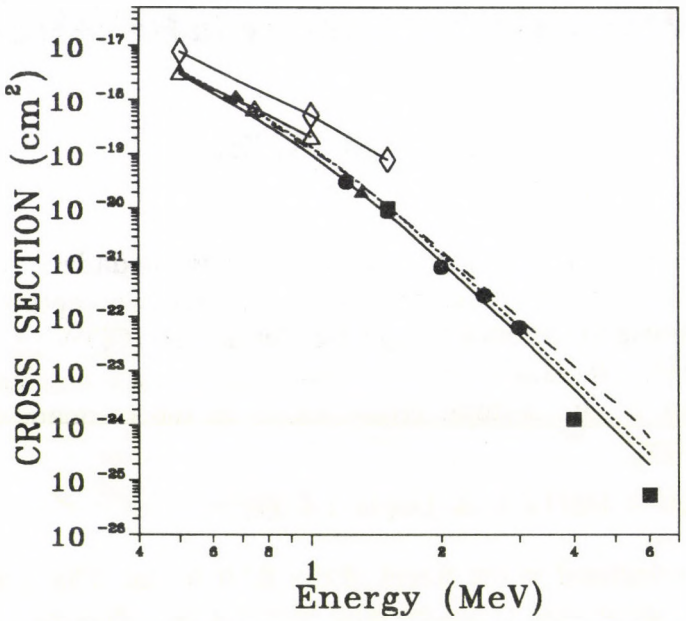

Figure: Total double capture cross sections for He^{2+} - He collision. Theories are for the resonant collisions ($1s^2$-$1s^2$). Present B1B calculation using the: solid line, CI ; dashed line, 5-z HF ; dotted line, hydrogen-like wave functions. Full line+lozenge: first Born approach (Ref. 5) ; full line+triangle: two state atomic approach (Ref. 6). Experiments for capture into all bound states: full circles: Ref. 7 ; full triangles: Ref. 8 ; full squares: Ref.9.

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X-ray production of K-Auger transitions of elements Z=13-26 in solids

L. Kövér, A. Némethy, I. Cserny, D. Varga

Due to the advantage of the high photoionization cross sections exciting near the ionization threshold and to the present developments in instrumentation, applications of the X-ray induced Auger spectroscopy have been gained an increasing attention recently, especially the extension towards the studies of high (E>1.5 keV) energy transitions. The data obtainable in this energy region enhance the possibilities for the chemical identification of surface species considerably and studies of the structures of high energy Auger spectra contribute to the better understanding of dynamical processes in solids, involving deep core and valence levels. Laboratory experiments are useful from the point of view of establishing optimum experimental conditions for the respective synchrotron applications as well.

The advantage of the high near threshold cross section can be amplified by the possibility of using a wider part of a continuous photon energy spectrum for exciting Auger transitions, contrary to the case of producing Auger electrons by narrow characteristic X-ray lines. On the other hand, X-rays with energy higher than the respective ionization threshold, can produce photoelectrons contributing adversely to the background of the excited Auger spectrum. Therefore, avoiding this effect, an optimum photon energy bandwidth can be selected.

In the experiments, the results of which are presented here, we demonstrate the attainable gain in K-Auger production at high energy resolution by using a Mo anode, comparing the respective yields to that obtainable by using an Al anode (conventional in XPS).

The experiments were made by using our new home built electron spectrometer (ESA-31) with a 180°, 250 mm working radius hemispherical analyzer, floatable up to 10 kV, a multielement zoom input lens and a max. 30 kV, 30 mA dual (Al, Mo) anode X-ray source with an Al filter foil of 0.9 μm thickness. The analyser works in the pass energy range 20-500 eV with a resolution of $5*10^{-3}$. In the present measurements the fixed retardation ratio (FRR) working mode was used with a retardation factor of 20.

Fig. 1 summarizes the measured KLL yields using Al and Mo anodes, respectively, with same source parameters (20 kV, 15 mA), as well as the effects of increasing the values of the tube parameters. The results show that the Mo anode, mainly due to the Mo $L_{\alpha,\beta}$ characteristic X-ray lines lying close to the respective ionization thresholds in energy, is especially advantageous for exciting K-Auger transitions of Al, Si and P, ensuring an intensity gain of almost one order of magnitude relatively to that obtainable by Al bremsstrahlung.

The K-Auger yields for the elements with atomic numbers 16-26 are strongly affected by the absorption of the emitted photons in the respective anode material. As it can be expected, an increase of the tube voltage results in the greatest increase in the region of Ti-Fe, where the Auger production is due to the bremsstrahlung part of the X-ray spectra.

Fig. 2 shows the X-ray excited P KLL Auger spectra from a GaP single crystal sample and demonstrates the energy resolution achieved. A factor of over 20 gain in P KLL Auger intensity was obtained exciting by Mo X-rays from a high voltage (25 kV, 20 mA) source, in comparison with the corresponding yield obtained by using Al X-rays from a tube operating with conventional (15 kV, 15 mA) parameters.

The higher efficiency in K-Auger production allows to use higher energy resolution, taking possible to attain better accuracy in determining spectroscopic data.

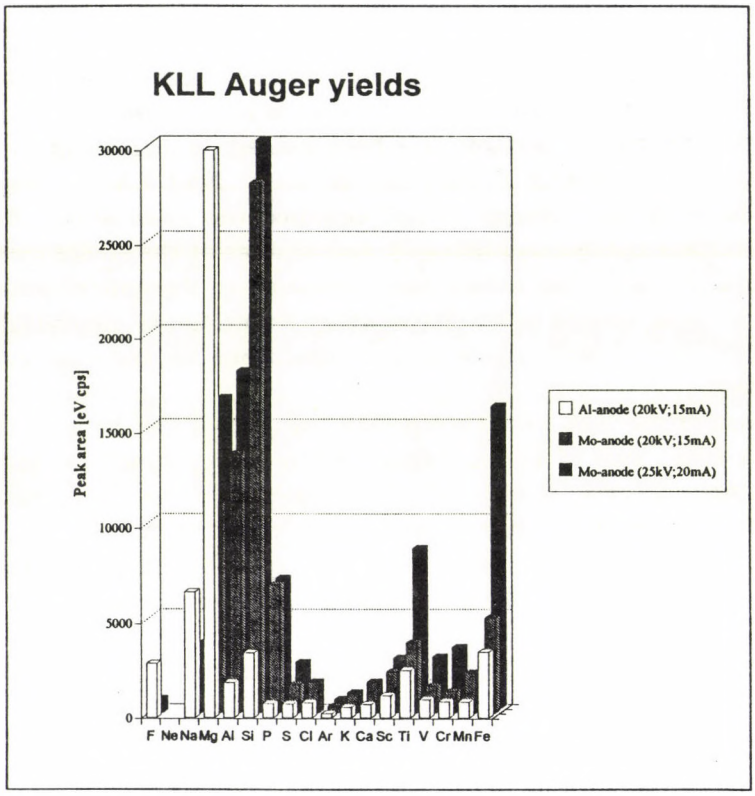

Fig. 1. Measured KLL Auger yields excited by Al and Mo X-rays, respectively.

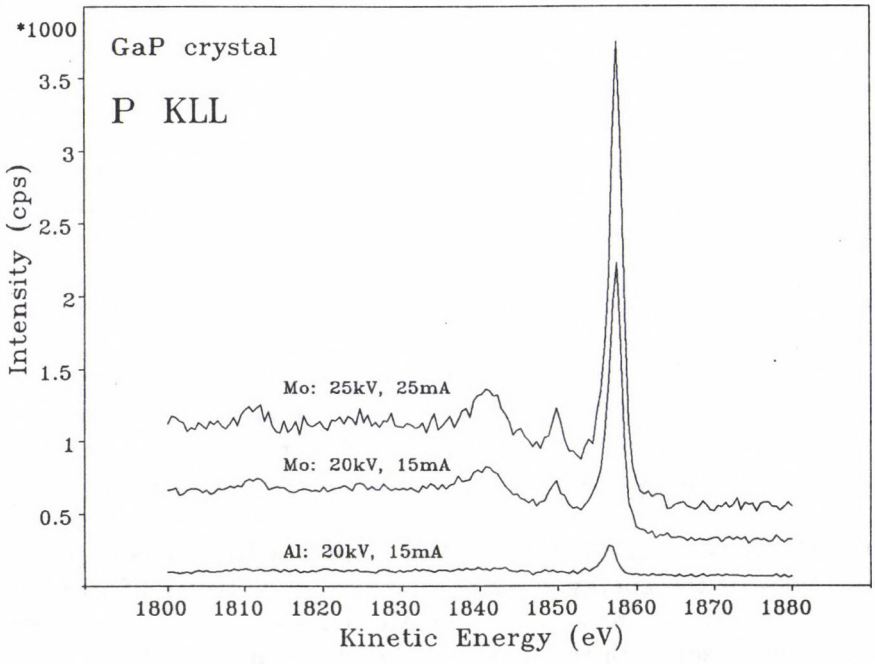

Fig. 2. P KLL Auger spectra excited from a GaP single crystal by Al and Mo X-rays, using different source parameters.

Al $K_{\alpha'}$ satellite polarization measurements in metal and in sapphire (Al_2O_3) using different projectiles

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In the last year we started a series of measurements to determine the degree of polarization of aluminium K_α satellites in metal and in oxides (sapphire) [1]. Similar measurements and related theoretical estimations were performed earlier for the Al metal only [2-8]. A short description of our experimental procedure was given in refs. [1,9]. Here we report the results obtained for 3.2 MeV He^+ ion bombardment.

The spectra were evaluated by the EWA code [10]. The nominal energies of the distinct satellite features like $K_{\alpha'}$, $K_{\alpha 3}$, $K_{\alpha 4}$ [11] were used in the fitting. For both target materials, and for both measuring positions (i. e. parallel and perpendicular relative to the incoming ion beam) the intensities of the satellite features have been determined, relative to the $K_{\alpha 1}$ peak. The degree of polarization was calculated from these relative intensities.

In our spectra there was an instrumental distortion of the peak shapes: we had some unknown-shaped tailing at the high-energy side. In the fitting this tail was approximated by an exponential function, and this increased the error of our data considerably. The obtained polarization values for the $K_{\alpha'}$ line were 0.40 ± 0.15 for the metal and 0.18 ± 0.09 for the oxide.

The results of these measurements [12] are compared in Fig. 1. to the values obtained by others [2-8]. Similar measurements have been performed recently in Berlin at the Humboldt University, with the participation of one of the authors (V. P. P.), where the targets were also Al metal and sapphire, but the bombarding particles were 350 keV protons. The experiments were performed also by a polarimeter of Moscow-design. They have similar result: the degree of polarization of Al $K_{\alpha'}$ satellite line in oxide is about half of that of the metal.

The decrease of polarization for the $K_{\alpha'}$ line in sapphire relative to that in metal can be caused by several mechanisms, which are discussed in our paper [12].

An attempt has been made by modifying the Soller collimator to avoid the peak shape distorsion. A new series of measurements was performed using 1 MeV proton projectiles. The evaluation of the spectra is in progress.

Further experimental investigations are being planned to obtain more accurate polarization values also for other satellite lines and for other compounds. The theoretical explanation for the observed large difference in polarization is yet missing.

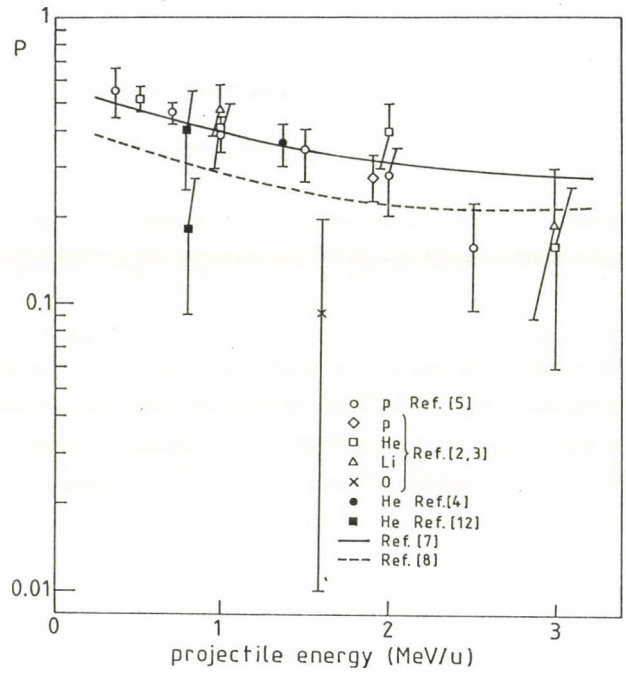

Fig. 1. The P polarization fraction of the line ($K_{\alpha'}+K_{\alpha''}$) of aluminium bombarded by different projectiles.

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Experimental study of two-center electron-electron interaction in energetic atomic collisions

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L. Xiao+, G. Schiwietz+, P. Grande+, R. Köhrbrück+, K. Sommer+ and M. Grether+

In atomic collisions, when both partners carry electrons, the Coulomb-field of the nuclei may be strongly screened. In some cases, inelastic processes can be dominated by the collision of projectile and target electrons, i.e. by dielectronic processes [1].

Both screening effects and dielectronic processes are manifestations of the two-center electron-electron interaction [2]. They were treated first by Bates and Griffing [3,4] for H+H collisions within the framework of the plane wave Born approximation.

Two center electron-electron interactions turned out to be particularly important in projectile spectroscopy, where the examined projectile ion is excited or ionized by a neutral target atom. Recently, it has been demonstrated that dielectronic processes provide a large contribution to the electron loss of the projectile [5].

In the present study, we investigate a collision process where the nuclear contribution is negligible compared to the dielectronic one. According to the theory [2,3], it may occur for projectile excitations belonging to small momentum and energy transfer values, i.e. for far collisions. Then the target nucleus is almost completely screened and the main contribution originates from electron-electron collisions. In our study, different target gases (H_2, He, CH_4, N_2, Ne, Ar) in a gas cell have been bombarded by 80 and 120 MeV Ne^{6+} ions on the beamline of the VICKSI accelerator facility in Hahn-Meitner Institute, Berlin. The electron spectra were analysed in energy by a tandem electron spectrometer at zero degree to the beam direction [6]. The process to be studied was a 2s-nl excitation followed by a Coster-Kronig (C-K) transition:

$$\mathbf{Ne^{6+}\ 1s^2,2s,2p\ (metastable) \longrightarrow\ 1s^2,2p,nl\ (n \geq 7) \longrightarrow\ 1s^2,2s + e^-_{C\text{-}K}}$$

The metastable fraction of the beam is around 35 %. Fig. 1 displays an electron spectrum under zero degree. The C-K peak groups are sitting on the two sides of the electron loss (EL) cusp. Their intensities are proportional to the cross sections of 2s-nl excitations summed over the orbital angular momentum quantum number **l**.

The pressure in the gas cell , i.e. the number-density of the scattering centers was kept constant, and the relative cross sections of different targets could be determined.

According to our calculations [2], one may expect that the 2s - nl cross sections are proportional to the number of electrons per scattering center at large impact energies. Fig. 2 shows that our masured data are in agreement with the above consideration.

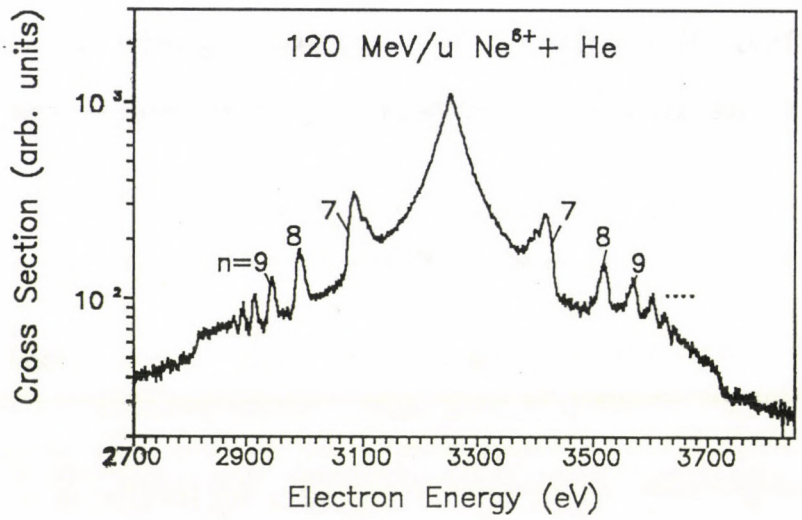

Fig. 1 A zero degree electron spectrum

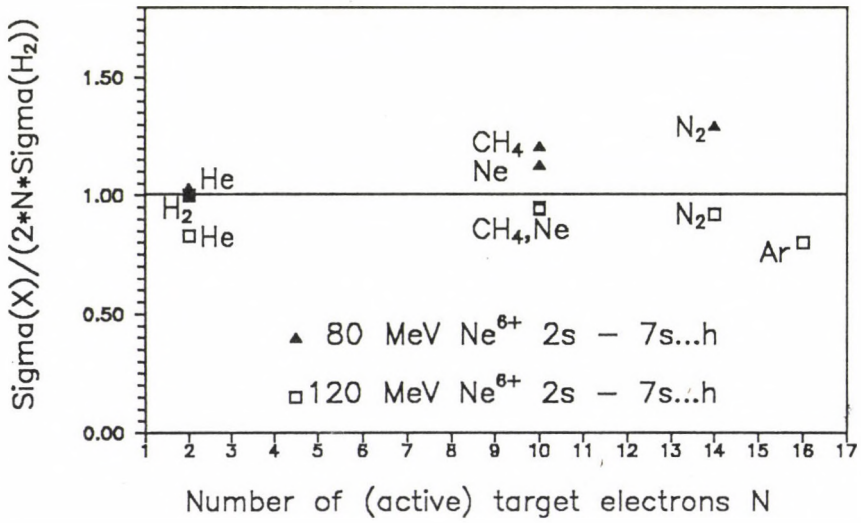

Fig. 2 Coster-Kronig production cross sections normalized to the half of the H_2 cross section and divided by the number of electrons per target centers. Line: theory.

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Alignment of the 1s2p vacancy states of neon doubly ionized by 700-2000 keV proton impact

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We have investigated the angular distribution of different $KL_{2,3}$ - $KLL_{2,3}$ Auger electrons emitted from the decay of 1s2p vacancy states of doubly ionized Ne by 700-2000 keV protons. From the measured anisotropy of the different Auger lines the alignment of the double-vacancy states has been deduced.

The electron spectra were recorded at 13 different angles simultaneously by the ESA-21 triple pass electrostatic electron spectrometer [1]. The Ne beam from an effusion target were crossed by the bombarding proton beam obtained from the 5 MV Van de Graaf accelerator of ATOMKI. The evaluation was carried out by the EWA computer code [2].

Fig. 1 shows the energy dependence of the measured and calculated alignment parameter. It can be seen that the absolute value of the alignment parameter increases as the energy of the projectile decreases, and its sign is negative in the whole energy range. From the results of our SCA calculations (Semi-Classical Approximation) we have shown that the results obtained with Hartree-Slater wave functions differ from the results with hydrogen like wave functions, moreover, the Hartree-Slater results are closer to the experimental data (see Fig. 1). We have found indications that beside the direct Coulomb double ionization we must consider another mechanism of double vacancy production to explain our observations. Taking into account the shake-off process, and calculating an effective alignment we have got a better agreement with our experimental results (see Fig. 1). In this way it becames possible to explain the results of Ricz et al. [3] for high-energy proton collisions, and the results of Albiez et al. [4] for electron bombardment.

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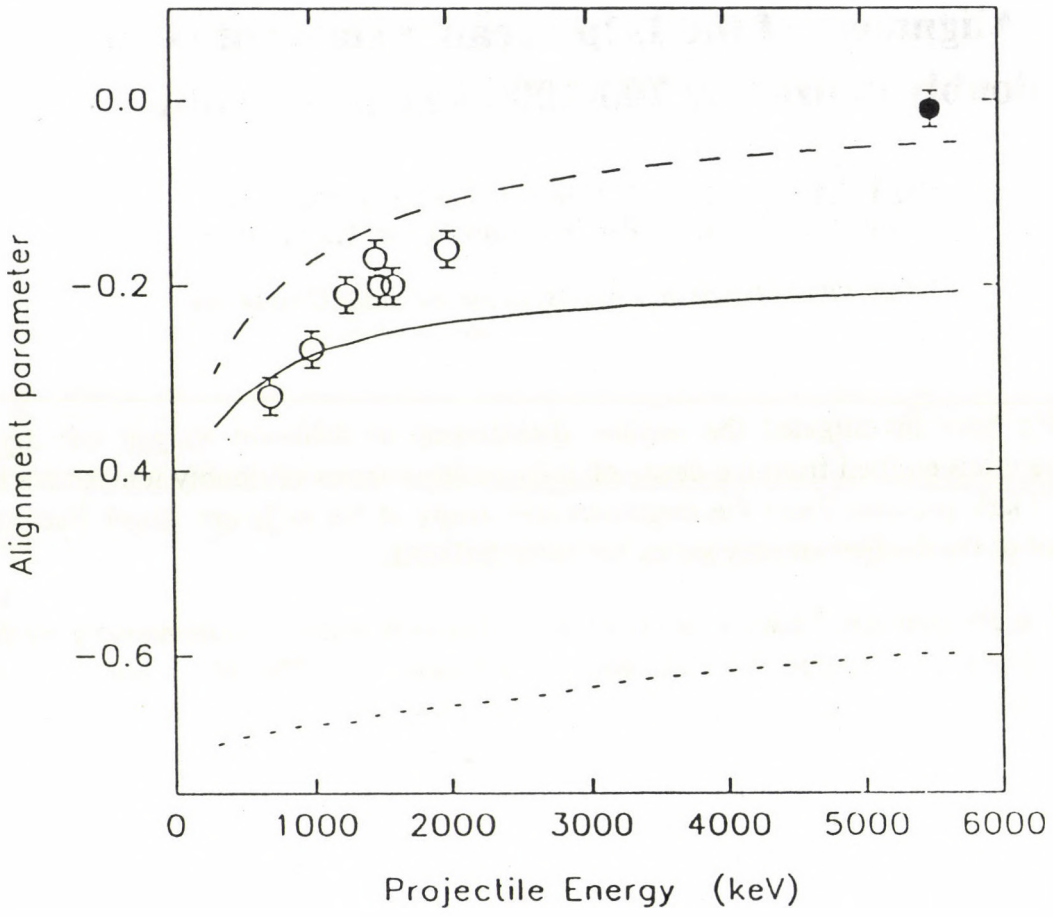

FIG. 1. The projectile energy dependence of the $\mathcal{A}_2$ alignment parameter of the Ne $1s^1 2s^2 2p^5$ states. Dotted line: the results of the calculations within the framework of the straight line semi-classical approximation and independent electron model with hydrogen-like wave functions; Solid line: same calculation as for the dotted line except that Hartree-Slater wave functions were used; Dashed line: the $\mathcal{A}_2$ effective alignment parameter (shake-off corrected) using the Hartree-Slater data for the double ionization of Ne and the 2.38% for shake-off probability of 1s shell of Ne (see Ref. [5]). Open circles: experimental results of the present measurement; Full circles: experimental data of Ref. [3].

Some aspects of PIXE with crystal spectrometer, using different orders of reflection.

I. Török and T. Bondár

In traditional x-ray crystal spectrometry the element concentration is measured by the intensity of most intense x-ray line in the first order reflection. If the atomic number of two elements are very different, they are measured using different analyzer crystals. However closely spaced higher order and lower order reflections can be used to determine element concentration ratios even in such cases in a single scan, using the same analyzer crystal. The method is based on empirical calibration curves giving the peak area ratios as a function of element (or its compound) concentration ratio. If the low intensity higher order peak comes from the major element and the lower order strong reflection peak is originated from a minor element, one can determine efficiently a minor lower Z element in a sample of a major higher Z element. As an example, we have measured small amounts of Mg in the presence of much Ca, using first order Mg K_α and third order Ca K_α lines excited by proton bombardment. Such measurements can be optimized [1-8].

For other element pairs, e. g., in semiconductor industry or in materials science, one can use the method efficiently, because in these industries many small accelerators are already in use. Table 1. lists element combinations for which the method can be used in principle, having proper 2Θ values.

Table 1. is partly taken from the paper [9]. In this paper discussions can be found on the effect of the aging of the analyzer crystal, and on the possible use of heavier bombarding particles. Regarding the crystal aging our method is advantageous, when a single analyzer crystal is used, where the aging is similar for both element's x-ray lines, so less recalibration is needed, if one uses the crystal for long time.

The heavier bombarding particles are not advantageous, because they produce many vacancies also in the outer shells, giving a much wider satellite region in the spectra. The increased satellite spectrum regions of the interesting elements can be overlapped for heavy ions, disturbing the evaluation.

The high resolution PIXE method is available at many accelerators. We began to publish a series of papers on the existing systems and their applications [10]. In the first part of the survey 7 facilities are discussed. Perhaps from discussing as much x-ray crystal spectrometer - accelerator system as possible, a promising direction for the high resolution PIXE research can be drawn.

This work was partly supported by the OTKA grants No. 1184-85, and No. 3011.

Table 1.. Element pairs (and a triad), for which in principle the concentration ratio can be measured by determining the peak area ratio of neighbouring x-ray lines of different orders of reflection.

element									analyzer crystal
No. 1	line	order of refl.	No. 2	line	order of refl.	No. 3	line	order of refl.	
Mg	K_α	1.	Ca	K_α	* 3.				ADP{101}
Si	K_α	1.	V	K_α	3.				ADP{101}
Si	K_α	1.	V	K_α	3.				EDDT
Si	K_α	1.	V	K_α	3.				PET
Si	K_α	1.	V	K_α	3.				quartz{100}
Na	K_α	1.	K	K_α	3.				gypsum
Si	K_α	1.	Cr	K_α	3.				EDDT[1]
P	K_α	1.	Mn	K_α	3.				graphite{002}
Al	K_α	1.	Ti	K_α	3.				quartz{100}[2]
S	K_α	1.	Ti	K_α	2.				NaCl{200}
Cl	K_α	1.	Cu	K_α	3.				NaCl{200}
P	K_β	2.	In	$L_{\alpha 1,2}$	3.				gypsum{020}
Ca	K_α	2.	Cr	K_α	3.				ADP{200}
Co	$K_{\beta 1,3,5}$	2.	Y	K_α	4.				LiF{200}
Sr	$L_{\alpha 1,2}$	1.	Ca	K_α	2.				ADP{200}[3]
Ba	$L_{\beta 1,3,4}$	2.	Ni	K_α	3.	Co	$K_{\beta 1,3}$	3.	NaCl{200}

Remarks: * Proved in practice.
[1] The Si K_β interferes with the Cr $K_{\alpha 3,4}$ lines.
[2] The Al $K_{\alpha 5,6}$ interferes with the Ti $K_{\alpha'}$,$K_{\alpha 3,4}$ lines.
[3] The Ca $K_{\alpha 5,6}$ interferes with the Sr $L_{\beta 1}$ line.

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Screening in semiclassical treatment of energetic atomic collisions

S. Ricz, B. Sulik*, I. Kádár and N. Stolterfoht+*

In atomic collisions, when the exciting partner carries electrons, the Coulomb-field of its nucleus is screened [1]. This effect is particularly important in projectile spectroscopy, where the projectile ion is excited by a neutral target atom.

The screening effect has been described by Bates and Griffing for H^0+H^0 collisions [2] within the framework of the plane wave Born approximation (PWBA). A similar method has been used also in the semiclassical approximation (SCA) [3,4]. However, within these approximations simple solutions can be found only in first order.

In the present study, we determine $\boldsymbol{R}$ dependent matrix elements wich are suitable for higher order calculations within the framework of the time dependent perturbation theory. We utilize the multipole expansion for H-like screening potentials [6]:

$$\frac{e^{-a|\vec{R}-\vec{r}|}}{|\vec{R}-\vec{r}\,|} = \sum_j \frac{(2j+1)}{\sqrt{Rr}}\, I_{j+1/2}(ar_<)\; K_{j+1/2}(ar_>)\; P_j(\hat{R}\,\hat{r}) \qquad (1)$$

and the identity

$$x^n\, e^{-ax} = \frac{d^{n+1}}{d(-a)^{n+1}}\, \frac{e^{-ax}}{x}\,, \qquad (2)$$

where $I_{j+½}$ and $K_{j+½}$ are the modified Bessel functions of fractional order, P_j is the Legendre polynomial of j-th degree, $r_<$ denotes the smaller and $r_>$ the higher component of the $\boldsymbol{R}$ and $\boldsymbol{r}$. For H-like wavefunctions, the radial matrix elements are analytical.

There is usually considered [4] that screening matrix elements at small internuclear distances as well as excitation probabilities at small impact parameters tend to those values wich can be calculated for the bare (unscreened) nucleus. By the present method we have shown that these considerations are not true in many collision systems.

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Semiclassical treatment of collisional dielectronic processes

B. Sulik and N. Stolterfoht+*

In projectile spectroscopy, when one investigate the final state of the projectile, the target electrons may play different roles in the collision process. They may screen the field of the target nucleus, remaining in their initial states during the collision. However, target electrons can change their states via electron-electron interaction with simultaneous transitions on the projectile. This dielectronic process, wich can be treated as electron correlation [1] usually increases the cross section of projectile transitions [2].

The contribution of the screening effect can be calculated within the framework of SCA, but there is no general impact parameter treatment of the dielectronic contribution [3,4]. An approximate solution has been developed in PWBA to take into account all the dielectronic contributions originating from different final states of the target electrons, without performing a summation over all the non-negligible terms [2]. This closure approximation has been justified by both detailed calculations and experiments.

Recently, we have shown that a closure approximation for the dielectronic process can be introduced in SCA, providing equivalent total cross sections to PWBA. The probability of a projectile transition induced by a target electron can be given in the form

$$p_{diel}(b) = \int d\vec{r}\ |\psi_0(\vec{r})|^2\ p(\vec{b}+\vec{r}) - p_{cloud}(b) \qquad (1)$$

where b is the impact parameter, $\Psi_0(\vec{r})$ is the ground state wavefunction of the target, p is the probability of a transition induced by a unit charge, and p_{cloud} is a probability induced by the charge cloud of the electron moving as a whole along a straight line trajectory. The first term in eq. (1) is the probability induced by a unit charge averaged over the impact parameter region determined by the ground state of the target.

Our calculations show that dielectronic processes contribute significantly to the production of $1s^22s\ ^2S$ - $1s2p^2\ ^2D$ transition of energetic Li-like projectiles colliding with noble gas target atoms, in agreement with our Ne^{7+} + inert gas and O^{5+} + He data [5].

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Two-electron processes in ionization of molecular hydrogen

L. Nagy and L. Végh

Cross sections for two-electron processes that occur during collisions of fast charged projectiles with H_2 were recently reported by Edwards et al [1–3].

These processes included double ionization, single ionization plus excitation and double excitation. The production of these dissociative states were analyzed at specified angles of the molecular axis relative to the beam direction.

The events above can be produced by several interactions [1,4]. The double collision mechanism was investigated in our preceeding paper [5]. In the present paper we calculate the differential cross sections relative to the orientation of the molecular axes for double ionization and ionization plus excitation of the $2s\sigma_g$ state considering shake-off or shake-up processes. Our aim is to investigate the importance of the considered interactions (shake-up and shake-off) in two-electron processes in ionization of H_2.

In computing the cross sections we have used the semiclassical approximation, assuming a straight-line trajectory for the projectile. As in paper [5], we have described the ground state of the H_2 with the simple Heitler–London-type wave functions. The final state, in case of the double ionization is a product of two continuum wave functions, and in case of the ionization plus excitation is a product of a continuum wave function centered at the center of the molecule and a two-center molecular wave function of the H_2^+ excited state. The two-center wave functions are expanded into series in terms of the Legendre polynomials with the angle between the position vector of the electron (relative to the center of the molecule) and the molecular axis in their argument.

If the initial state is a product of two single-electron wave functions, in computing the probability amplitudes one can apply the formulas of McGuire [4]. In our case for the double collision the amplitudes has the form

$$a_{DC} = \sum_{l_g L_g} [1 + (-1)^{l_g + L_g}] \langle \phi^f_{\mathbf{k}_1} | U_1(+\infty, -\infty) | c_{l_g} P_{l_g}(\cos\omega_1) \rangle$$

$$\langle \phi^f_{\mathbf{k}_2} | U_2(+\infty, -\infty) | c_{L_g} P_{L_g}(\cos\omega_2) \rangle,$$

where c_l are the coefficients of the Legendre-expansion and U_i are the single-electron evolution operators. Similarly for the shake-off process we obtain:

$$a_{SO} = \sum_{l_g L_g} [1 + (-1)^{l_g + L_g}] \langle \phi^f_{\mathbf{k}_1} | U_1(+\infty, -\infty) | c_{l_g} P_{l_g}(\cos\omega_1) \rangle \langle \phi^f_{\mathbf{k}_2} | c_{L_g} P_{L_g}(\cos\omega_2) \rangle.$$

In case of the shake-up, the situation is more simple, because c_{L_g} is nonzero only for $L_g = 0$, and the total amplitude is a simple product of two single-electron amplitudes. The overlap integral between the ground state and the excited state is nonzero only for the $2s\sigma_g$ state, so there is no shake-up contribution for the

exciting of the $2p\sigma_u$ and $2p\pi_u$ states. Applying the first-order perturbation theory in expressing the evolution operator, one gets the well-known SCA amplitudes. Since in our model there is no interference between te double collision and the shake-off processes, we cannot reproduce the the dependence of the cross sections on the sign of the projectile charge.

For double ionization our results are in good agreement with experimental data except for the dependence on the sign of the projectile charge. The cross sections are not too senstive to the ground state wave function. One can conclude, the double collision and shake-off are dominant processes for the double ionization in the considered energy interval. Shake-off becomes the most important above 500 keV proton energy. As for the angular dependece our results are in better agreement with the data for positively charged projectile.

In case of the ionization and the excitation of the $2s\sigma_g$ state, the calculated cross section are by one order of magnitude lower than the experimental ones. The shake-up and the double collision processes has approximately the same importance, but the results are very sensitive to the ground state wave function. For further investigations one has to use more accurate molecular wave functions, and would take in account other kind of interactions, too.

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CTMC calculations for a positron-hydrogen atom scattering

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Theoretical investigations of the positron-hydrogen atom collisions have been carried out from the ground state of atomic hydrogen in the incident positron energy range 10-500 eV by using the classical Trajectory Monte Carlo (CTMC) method [1,2]. We calculated the total cross sections, the energy and angular differential cross sections of the elastic and inelastic (excitation) scattering, direct and transfer ionization processes. The total cross sections of the charge transfer to the bound state, the n and nl capture processes have been described by using the positronium (ps) formation, and the single differential cross sections of the above processes are shown. The present results are compared with existing theoretical and experimental calculations.

The results of our CTMC calculations for total ionization processes are shown in Fig. 1 where the existing experimental and theoretical results are compared. Calculations in the classical picture gave very close results in the low energy range and higher than 100 eV positron energy. Our CTMC results gave a higher cross section value from 30 eV to 100 eV.

Fig. 2 shows the electron-capture cross sections product, the n levels at different projectile velocities. In all energy ranges the n=1 capture is dominating. From 25 eV bombardment energy the n dependent cross section function is the same. Increasing the projectile energy the cross sections decrease. We got an anomalous behavior under 25 eV positron energy. Decreasing the positron energy the higher n levels capture cross sections decrease dramatically. At this energy range the n=1 capture cross sections are close to each other.

Acknowledgment
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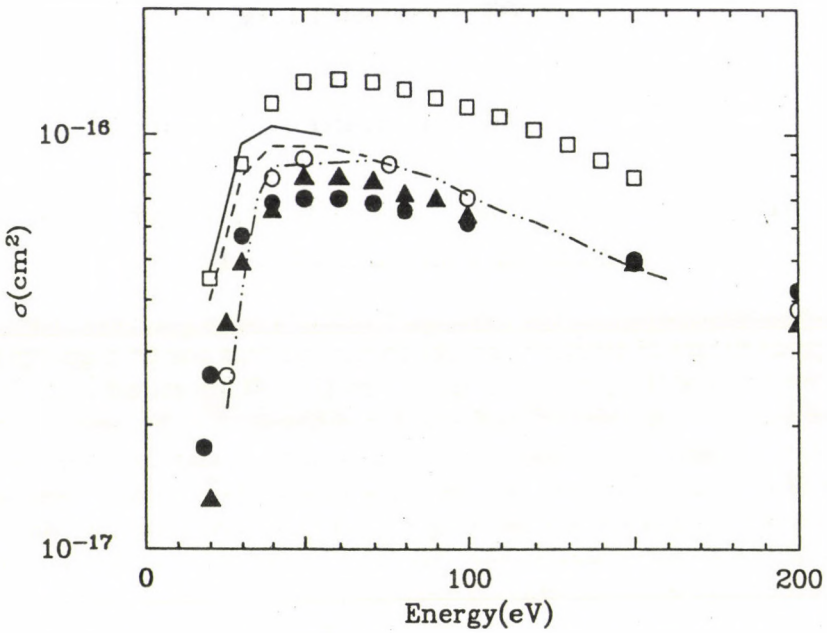

Fig. 1. Positron impact - total ionization cross section of atomic hydrogen. Open circles: present CTMC results, square: Spicher et al (1989) [3], broken curve: Mukherjee et al (1989) [4], dash-double-dot curve: Wetmore and Olson (1986) [5], full curve: Gosh et al (1985) [6], solid-triangle: Abrines and Percival (1966) [7] , solid-circle: Ohsaki et al (1985) [8]

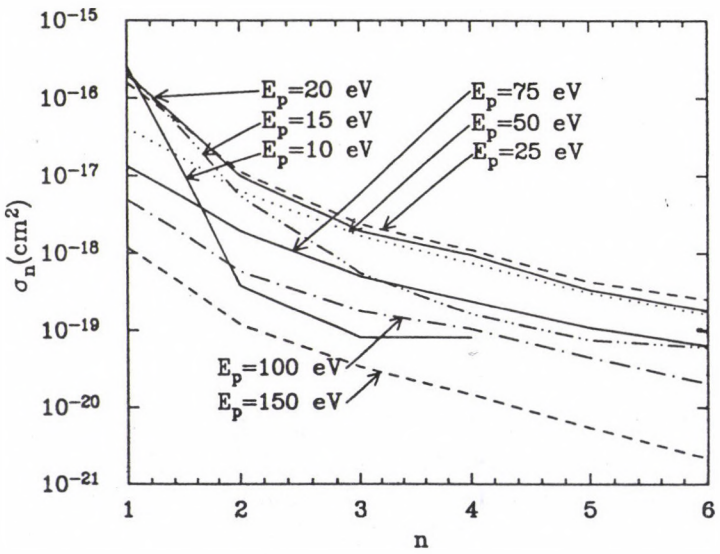

Fig. 2. Electron-capture cross sections product n levels for $e^+ + H^0$ system at various energies.

Double scattering involving correlation in projectile ionization in H + H,He collisions at backward observation angle.

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The effects of electron-electron interactions (scattering correlation) are studied in atomic collisions between structured particles. Recent developments in experiments and theory reveal signatures of correlation effects. We investigate one such signature involving projectile ionization at backward observation angle in collisions of H on H and He targets. The correlation is treated in a multiple scattering sequence. Quantum mechanically the series is truncated to include single scattering of the projectile electron with the target electron, and double scattering in which the projectile electron first scatters at the target electron, followed by another scatterint at the target nucleus. We find that the ionization cross section is dominated by double scattering at large electron emission angles. Work is in progress to identify the corresponding classical two-step process similar to the Thomas capture mechanism, but withut the restriction on the geometric angle.

We show in Fig. 1 as an example the electron loss for a symmetric system 0.5 MeV/u H + H at 130 . The quantal results are obtained by truncating the Born series to include single scattering and double scattering [1]. The classical calculation is performed as a full four-body system in the classical trajectory Monte Carlo method (CTMC) [2,3]. Fig 2 shows the DDCS results of the full 4-body CTMC calculations and the Fig 3. shows the DDCS results of the reduced 4-body CTMC calculations (switching off the interaction between the projectile electron and the target nucleus) at different observation angle. The most striking feature is the overwhelming dominance of double scattering over single scattering. It illustrates that the momentum mismatch is so large that a two-step collision is favored over a single-step one. It also demonstrates that correlation may play an important role in multiple scattering, even though it is negligible when treated in a Single (or direct) step. Considering the small magnitude of cross sections, the classical and quantal results are in reasonable agreement, especially in the shape of the peak. This is not too surprising due to the very classical nature of the process.

Acknowledgment

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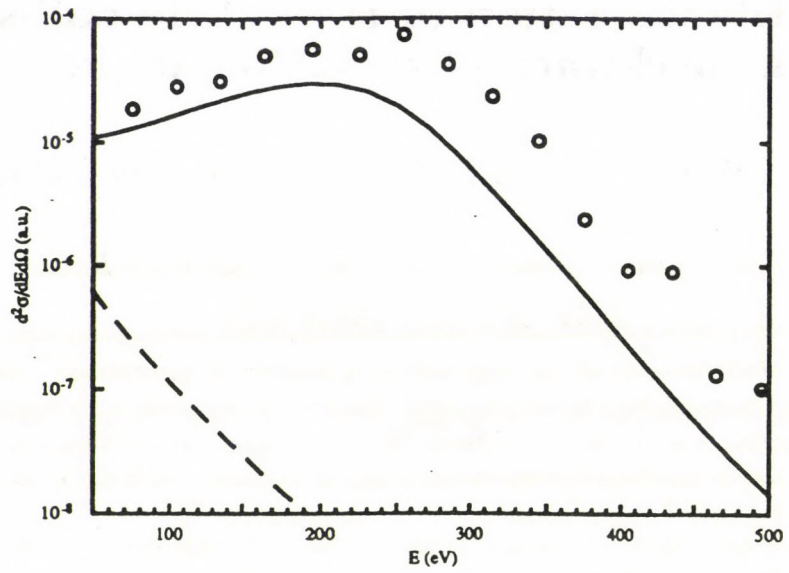

Fig. 1. Doubly differential cross section for electron loss in 0.5 MeV/u H+H at 130 . Solid line - quantal result for single and double scattering, dashed line - quantal result for single scattering only, circles - full 4-body CTMC result.

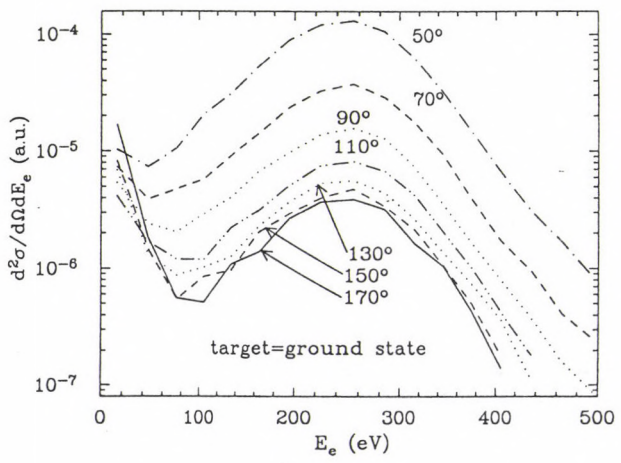

Fig. 2. Present DDCS results of the full 4-body CTMC calculations in 0.5 MeV/u H+H at different observation angle

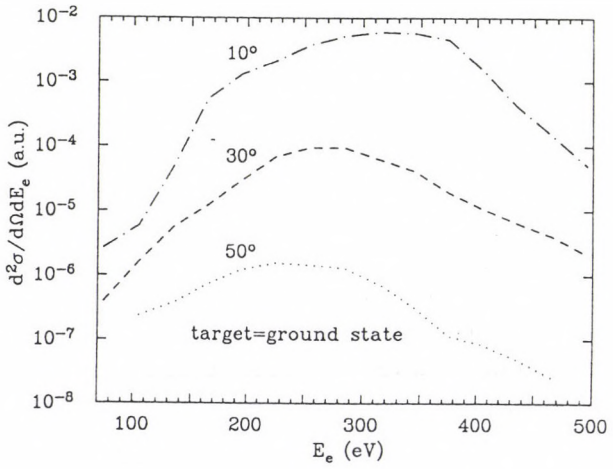

Fig. 3. Present DDCS results of the reduced 4-body CTMC calculations in 0.5 MeV/u H+H at different observation angle

Theoretical investigation of the ECC peak for charged particle with the CTMC method

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Using the Classical Trajectory Monte Carlo Method (CTMC) [1,2,3], we have calculated the energy spectra of the target electrons ejected in $p + H^0$ at an impact energy of 25 keV. We have developed a simple way to determine the ECC peak with charged particles. This study has shown that the electronic spectrum is very sensitive to the energy and solid angle windows used for the evaluation of the calculated data.

All the numerical computations in the present work have been performed on the CRAY Y-MP2E supercomputer in the Institute for Chemical Research, Kyoto University.

The calculated results of the DDCS for the 25-keV protons on hydrogen is shown in Fig. 1. The total number of histories was 2×10^6. The ejected electron spectrum was observed at 0.2°, corresponding to the solid angle window of 0.4 sr, and the energy window was 0.22 eV. It is clear from the figure that the calculated shape of the ECC peak is similar to the shape observed by Dahl [4] and by Gibson and Reid [5] for 100-keV protons on He.

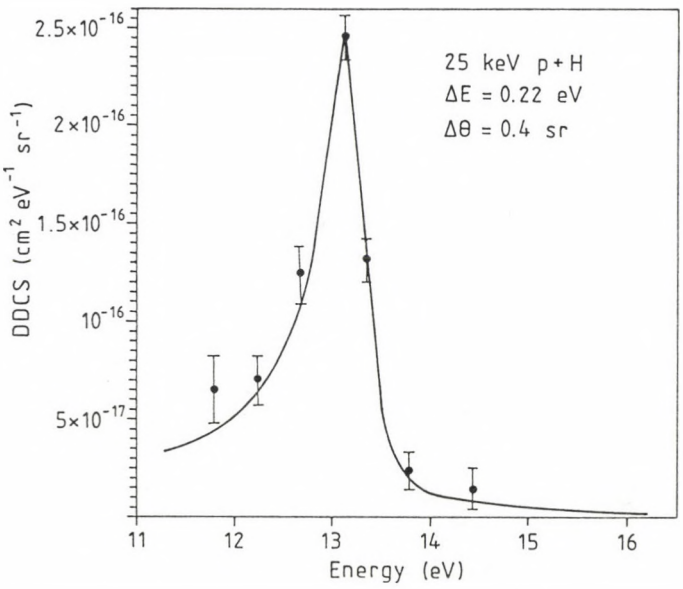

Fig. 1. Calculated shape of the ECC peak in the case of 25 keV $p + H^0$ collisions. The energy window was set to 0.22 eV and the solid angle window 0.4 sr.

Since it is well known that the peak position of the ECC sharply depends on the observed angle and the CTMC method is considered as the "theoretical experiement", we tested the evaluation procedure of the data. We change the energy and solid angle windows, see Table 1, and computed the position of the cusp peak. In the present case of the equivalent electron energy, the cusp peak position should be at $E_e = 13.5eV$.

Table 1. Calculated dependence of peak position on the energy and solid angle windows.

ΔE (eV)	$\Delta\Theta$ (sr)	Peak position (eV)
1.0	1.0	12.5
1.0	0.8	12.8
0.44	0.8	13.0
0.44	0.4	13.2
0.22	0.4	13.4

We have shown that the ECC electrons come only from the transfer ionization process. This fact was a great surprise for us, because we described the transfer ionization process over 40 au. from the collision center. Since the Coulomb force is a long range force, this indicates that the effect of this force cannot be neglected until $10^4 \div 10^5$ au.

We described that the position of the ECC peak strongly depends on the evaluation procedure, ie. if we decrease the solid angle or energy windows, the peak position moves to the exact theoretical value ($E = E_e$).

The present calculation method could reduce the total CPU time about 50%. It is very useful, because this type of calculations requires several billion trajectories.

Acknowledgements

This work was performed under the Japanese-Hungarian Cooperative Research Project.

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MATERIALS SCIENCE AND ANALYSIS

Magnetic flux dynamics in high temperature superconductors

S. Mészáros, K. Vad, G. Halász and N. Hegman

The structure and dynamics of magnetic vortices play a decisive role in macroscopic electrodynamical properties of high temperature superconductors (HTSCs). Critical current density, energy loss, magnetization and high frequency properties of HTSC materials were studied experimentally by measuring the:

- temperature, magnetic field and transport current dependence of voltage in four-probe arrangement
- temperature, magnetic field, excitation amplitude and frequency dependence of complex ac magnetic susceptibility

In order to eliminate heating effects a special pulsed current method combined with He gas stream cooling was used. The temperature ranged from 5 K to 150 K, while the magnetic field from environmental fields to 6 T. In addition to the conventional low frequency (100 Hz – 10 kHz) ac susceptibility measurements, high frequency measurements were performed in the radiofrequency (RF) range, i.e. from 20 MHz to 500 MHz to make the period of excitation comparable to the expected relaxation times of the magnetic flux lattice. To perform RF susceptibility measurements a special computer controlled RF lock-in system was designed and constructed. Studies were carried out on YBaCuO ceramics and single crystals and Bi(Pb)SrCaCuO screen-printed films.

Transport and susceptibility measurements demonstrated the importance of grain boundary weak couplings in magnetic properties of HTSCs. The critical current density, its magnetic field dependence and the irreversibility of this dependence can be explained by taking the Josephson junction network formed at grain boundaries into account [1]. We found that weak couplings are present in YBaCuO single crystals too, as can be seen in Fig 1. The presence of Josephson junctions was demonstrated in screen-printed films by direct observation of macroscopic quantum interference (see Fig 2). The current-voltage characteristics of screen-printed films with different film widths show properties of large size Josephson junctions and of multijunction SQUIDs depending on current density, temperature and magnetic field. The chaotic motion of magnetic flux in the grain boundary junctions of these films was demonstrated as is shown in Fig 2. The most important conclusion is that the understanding of superconductive properties of grain boundaries in HTSCs is one of the key points as far as their description and applications are concerned [2].

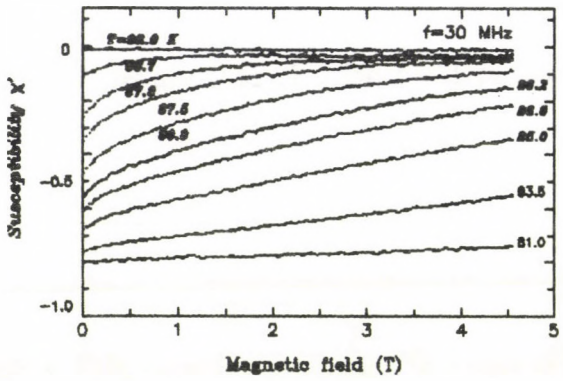

Fig. 1. Static magnetic field dependence of the real part of ac susceptibility of an YBaCuO single crystal at different temperatures. The presence of the dip around zero field and the linear dependence at higher fields is a clear indication of a Josephson network.

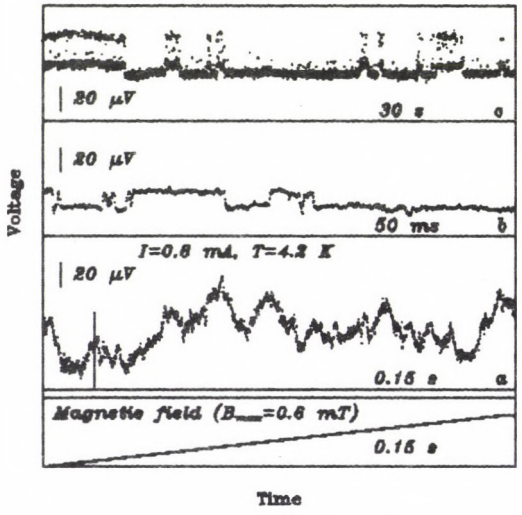

Fig. 2. Quantum interference patterns in a screen printed film: – *a*: output voltage as a function of external field at fixed current – *b* and *c*: output voltage at fixed current and magnetic field – lowermost trace: change of the magnetic field in time

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Effect of Pb impurity of chemicals on the adsorption of phosphonic acids on iron electrodes - an XPS study

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Pb impurity has been observed in an XPS study, investigating the adsorption of a corrosion inhibitor material, 1-hydroxy-ethane 1,1-diphosphonic acid (HEDP) on Fe samples. The experiments revealed, that the Pb impurity originates from one of the applied chemicals. Testing the applied materials (distilled water, sodium perchlorate and HEDP) individually, no visible Pb 4f XPS signal could be detected from the impurity. Mixing these materials together, however, resulted a well detectable signal (Fig. 1), suggesting that a strong enrichment of Pb takes place at the sample surface.

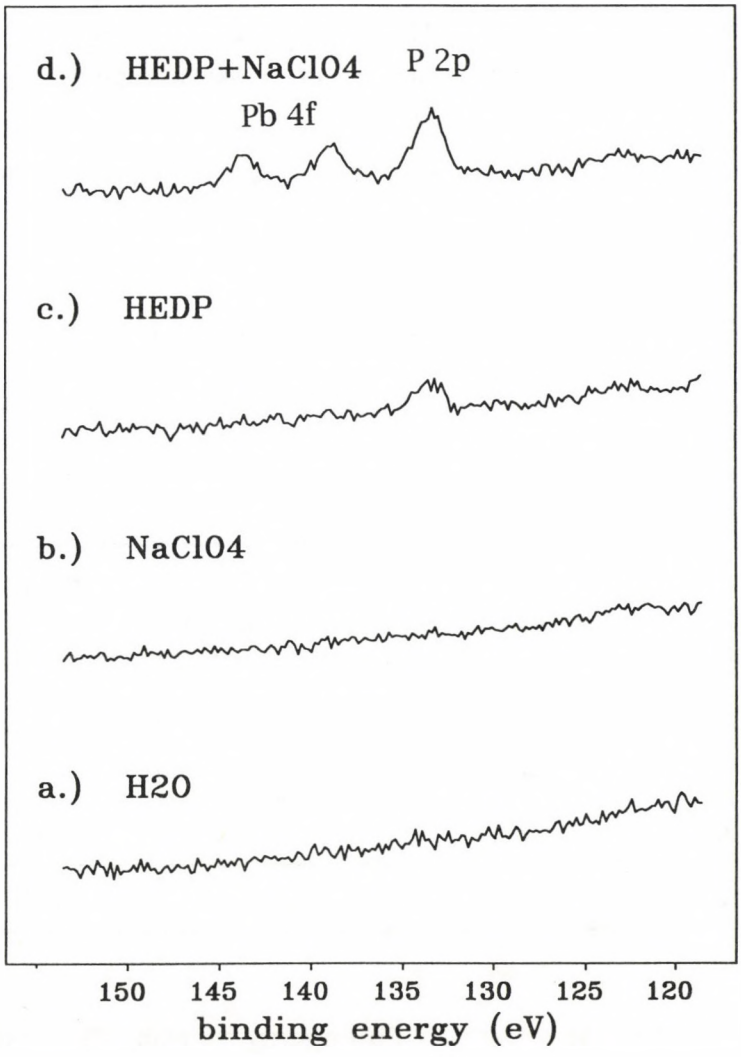

Fig. 1. *Pb 4f XPS spectra from Fe samples which were dipped into one of the solutions* ***a*** *through* ***d*** *respectively:* ***a.*** *distilled water,* ***b.*** *0.5 M $NaClO_4$,* ***c.*** *2.4×10^{-3} M HEDP,* ***d.*** *0.5 M $NaClO_4$ + 2.4×10^{-3} M HEDP.*

Substituting the HEDP with NTA (nitrilo triacetate, another compound that preferably forms metal complexes, especially with Pb) gives similar results, confirming that the Pb impurity originates from the sodium perchlorate (Merck product, *"pro analysi"* quality), and it is enriched on the sample surface during the adsorption procedure by the help of organic molecules.

The amount of the Pb impurity in the solution has been determined by the *"standard addition"* method adding known quantity of $Pb(NO_3)_2$ to the solution used for sample preparation. Analyzing the Al K_α XPS line of the constituents (Pb 4f, P 2p) and measuring the Mo Lα excited P KLL Auger spectra the effects caused by the added Pb standard have been followed.

In the region of 0.2-2 mg/dm^3 Pb addition the Pb 4f XPS signal increased almost linearly with the increasing amount of the standard added. The amount of Pb impurity in the solution has been determined from a linear regression:

$$c_{Pb} = (0.22 \pm 0.07)\ mg/dm^3.$$

This value is below the upper limit (Pb < 0.0005 % which corresponds to 0.35 mg/dm^3) specified by the manufacturer, Merck. The N_P/N_{Pb} atomic concentration ratio in the solution can be determined from the concentration of the constituents ($c_{HEDP}=2.4\times10^{-3}$ M, $c_{Pb}=0.22$ mg/dm^3, atomic weight of Pb=207.19).

The ratio of the atomic concentrations on the sample surface can be determined from the P 2p and Pb 4f XPS line intensities, taking into account the respective photoionization cross sections. Supposing a homogeneous surface layer we get:

$$N_P/N_{Pb}=I_{P\ 2p}\times\sigma_{Pb\ 4f}/I_{Pb\ 4f}\times\sigma_{P\ 2p}.$$

Table 1. *The N_P/N_{Pb} atomic concentration ratios obtained for the solution and for the sample surface, as a function of the amount of Pb standard added. In these calculations a photoionization cross section ratio of $\sigma_{Pb\ 4f}/\sigma_{P\ 2p} = 22.74/1.19$ was used [1].*

Pb addition [mg/dm^3]	N_P/N_{Pb} in the solution	N_P/N_{Pb} on the surface	Enrichment of Pb
0.0	4520	21.2	213
0.2	2367	9.73	243
1.0	815	1.85	440
2.0	448	0.82	546

During the determination of the amount of Pb impurity by using the *"standard addition"* method, the adsorption of HEDP was also followed. In the region of 0.2 - 2 mg/dm^3 Pb addition the phosphor signals decreased rapidly and showed reverse proportionality. Above 2 mg/dm^3 Pb addition the effects are much smaller, near saturation takes place.

The decrease in the adsorption of HEDP has been observed from the opposite side as well: the amount of HEDP remaining in the solution after the adsorption process has been measured by radioisotope tracing method [2]. The results show that 2 mg/dm^3 Pb addition nearly halves the amount of the adsorbed HEDP, in accordance with the results of the XPS measurements.

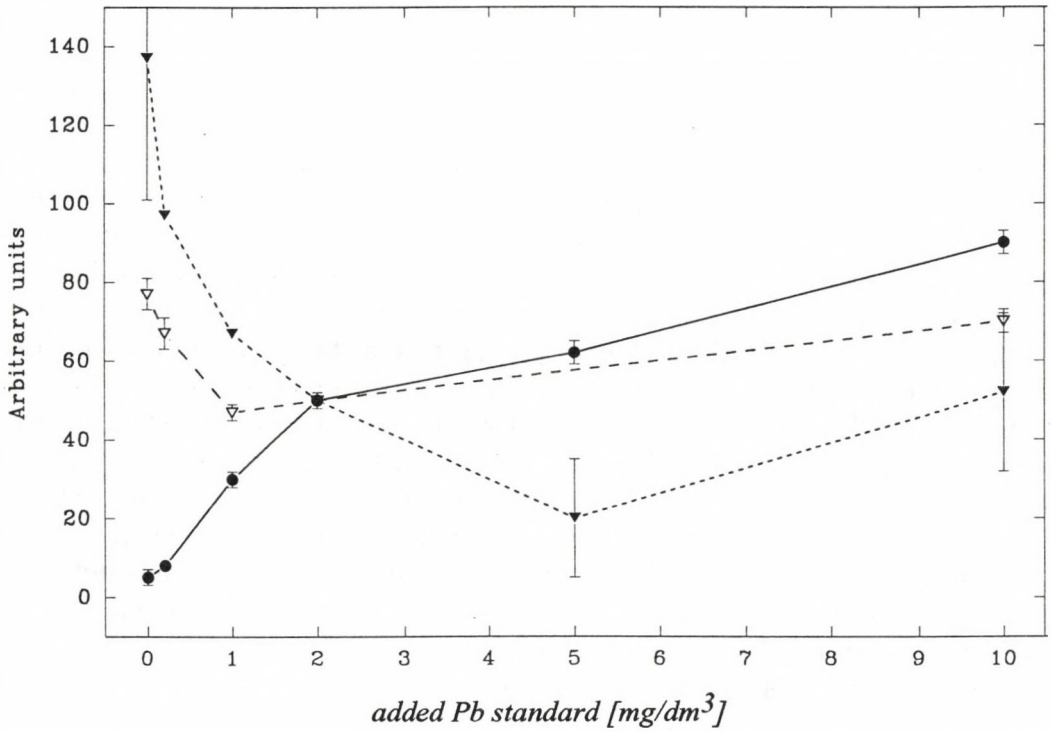

Fig. 2. *Al Kα excited Pb 4f (filled circles) and P 2p (filled triangles) photoelectron line intensities and Mo Lα excited P KL_2L_3 line intensity (hollow triangles) as a function of the amount of Pb standard added.*

The fact, that the intensities of the P 2p and P KLL signals have been found to be strongly influenced by the amount of the added standard, proves, that even a small amount of impurity (which may be contained in chemicals of analytical purity) can produce significant effects in similar adsorption experiments, when an enrichment of impurities can take place by the help of formation of organo-metal complexes.

The authors gratefully acknowledge valuable discussions with D. Varga and F. H. Kármán. This work was supported in part by OTKA under Contract No. 1808.

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Energy loss of protons in ⟨110⟩ Si crystals

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The energy loss of energetic protons in silicon was investigated in near to low index and random directions. Energetic ions traversing a crystal in directions near to low index crystal axes can be steered by the atomic potentials of the crystal in such a way, that they are passing through lower electron densities than the average electron density in the crystal. Such ions have longer range and an inhomogenous lateral distribution after penetrating a depth in the lattice (flux-peaking). Following the path of the individual ions in the crystal one recognizes that they test different electron densities (or stopping powers) on their way up to a given depth. The shape and the parameters of the energy distribution were found to be dependent on the kind and the energy of the bombarding particle and the mode of channeling (axial or planar) and the sample thickness.

To describe the path and the parameters of charged particles penetrating through a crystal, a model based on the different interactions between the ions and the crystal atoms and electrons was developed. This model[1] can be used generally for materials analysis, it was tested on ⟨110⟩ Si.

The motion of the impinging ions within the crystal can be described by Monte-Carlo calculations which give the energy, angle and position of the single ions after each step. Taking into account the thermal vibrations of the crystal constituents, the measurable distribution of the ions, their angles and energies could be determined using an appropriate number of ions. As a working step the distance between two crystal planes was chosen, and so many neighbouring atoms were involved into the calculations, that the contribution of the next not involved atoms must have been less than 0.1% in every single case (for force, stopping, straggling, scattering contributions). The ions were impinged homogeneously distributed within a unit cell (x-y plane, which is perpendicular to the ion beam) and during their motion were always translated back to the same unit cell in case they leave it (translation invariancy).

To control the capability of our model and theory, the simulated energy distributions were compared with experimental data and other calculations. In a first comparison protons of 300 keV impinging on a 705 nm thick Si crystal were used. The random distribution was taken from TRIM92 calculation [1], the ⟨110⟩ channeling spectrum was taken from the literature (see Fig. 1.) [3]. To simulate the spectra the MABIC program was developed, based on the above described theory. To reach better the experimental conditions of an electrostatic energy analyzer, each spectrum, excluding the experimental one was redistributed by

[1] MABIC, Materials Analysis by Ion Channeling

using a Gauss function with 1 keV FWHM (detector resolution). At least 4000 ions were necessary for the simulation to cover appropriately the whole impact parameter range. All spectra were normalised to unit height. Fig. 1. shows a good agreement for both (random and channeling) direction. The random TRIM spectrum is $\approx$ 10 % wider than our result. This can be explained because in TRIM Bohr straggling is used, which is no more valid in this energy range [2]. In MABIC the energy (velocity) and electron density dependent straggling is used, which gives a better result.

The new model which takes into account the main interactions and processes influencing the motion of charged particles in crystal lattice proved to be useful to describe the energy loss (stopping power) an energy distribution of protons, and yields results in good agreements with the experiments and other calculations.

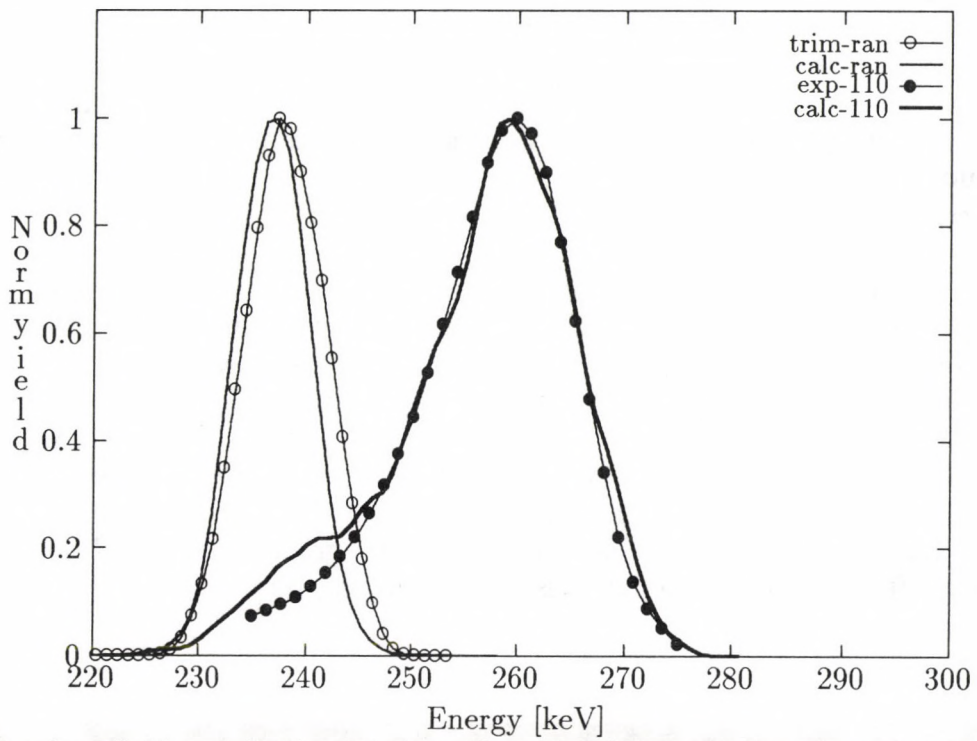

Fig. 1. Random (left) and ⟨110⟩ axial channeling (right) transmission energy spectra of 300 keV protons on a 705 nm silicon crystal. The random spectrum was simulated with TRIM92 (trim-ran) and with MABIC program (calc-ran). The channeling simulation (calc-110) is compared with an experimental spectrum (exp-110)[3].

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Studies of Density Reduction in Stacked Gas Targets

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Penetration of energetic charged particle beams in gas targets has been studied by several author [1]. An increase of the penetration depth of the particles with increasing beam intensities has been observed due to the density reduction in the gas volume where the particles passing through. Using parallel beams of charged particles for measuring cross-sections, excitation functions or thick-target yields for different nuclear reactions in gas targets one must consider that the particles are scattered and the beam diameter gradually expands with increasing depth. Therefore, it is important to check the shape of the beam and density distribution of the gas for nuclear data measurement. It can be used to optimize the shape and the geometrical measures of the target chambers used for radioisotope production, which is especially important when the target is an expensive enriched material.

The charged particles make the target gas atoms glow while passing through. The emitted light gives a possibility to study the beam broadening effect and the asymmetry of the beam in gas targets optically. In present work this optical method was applied to study the behaviour of different beams in stacked gas targets on vertical and on horizontal beam line simultaneously with the so called foil activation technique [2]. Measuring excitation function for a nuclear reaction in gas cells placed behind each other the calculated [3] and the experimentally determined beam shape in the cells are not always not in agreement. The obtained values usually differ remarkably for the last cells of a long stack.

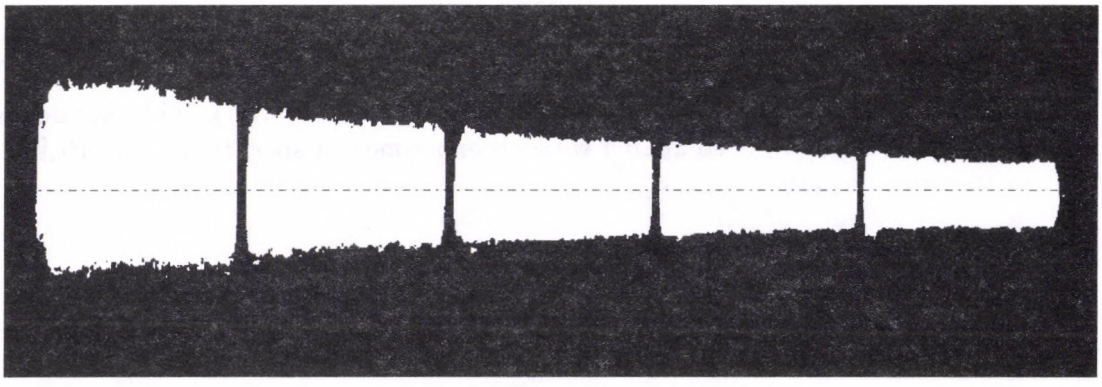

Figure 1. The shape of proton beam through a stacked gas cells.

The main reason, as it can be seen on Fig. 1, is the extreme beam broadening. Multiple scattering of the beam in the window foils of the gas cells and by the target gas, as well as reduction of gas density and heath convection seriously affect the energy loss and the penetration of the beam through the stack.

Investigation of this effect is of importance for production of PET isotopes, therefore, the interaction of high intensity charged particle beams with dense gas targets are under investigation. On the basis of measured data a model is under development.

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Status Report on Nuclear Data Program for Practical Application

F. Tárkányi, S. Takács, F. Szelecsényi, Z. Kovács, L. Vasváry, P. Mikecz

In the last one year period the nuclear data measuring and compilation program has been continued in collaboration with other institutes and with support of different organizations. Papers published in the frame of this program during 1992 are listed under [1-5]. The main activities for the year 1992 are as follow:

Experimental work

Excitation functions of proton induced nuclear reactions on ^{nat}Ti, ^{nat}Cr, ^{nat}Fe, ^{nat}Co, ^{nat}Ni, ^{nat}Mo and ^{nat}W in alloy have been measured. Experiment to determine the excitation function of ^{3}He, α and d induced reactions on natural Ti, Cu and Ni for application of thin layer activation (TLA) technique and monitoring of charged particle beams have been continued in collaboration with Department of Radiopharmaceuticals, Nuclear Research Institute, Rez, Czehoslovakia.

New measurement of excitation function of proton induced nuclear reactions on natural and enriched Kr has been performed in collaboration with the Institute für Nuclearchemie, Forschungszentrum Jülich GmbH, Jülich, FRG.

The effect of density reduction in gas targets has been started for nuclear data measurement in collaboration with Accelerator Laboratory of Åbo Akademi, Turku, Finland.

Establishment of charged particle database for practical applications

With support of Hungarian National Committee for Technical Development and International Atomic Energy Agency establishment of a charged particle database has been started. The database will support different applications isotope production for nuclear medicine, application of TLA technique, charged particle nuclear analytical methods and monitoring charged particle beams. The data files and the necessary programs is planned to be installed into the computer network.

Compilation and evaluation of nuclear reaction cross-sections induced by charged particles

There is a growing need for constant supply of improved nuclear data in compiled and evaluated form and written in internationally agreed EXFOR formats for many different application. In collaboration with IAEA Nuclear Data Group installation of computer codes for EXFOR software (edition, retrieval) and for EXFOR based data evaluation (numerical format, plotting) has been started. Compilation and evaluation of cross sections for common used biomedical isotopes ^{67}Ga and ^{111}In, and for p, d, α and ^{3}He induced monitor reactions on Cu, Ti, Ni and Fe are under development.

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PIXYKLM Computer Package for PIXE Analyses

Gy. Szabó, I. Borbély-Kiss, I. Kuti

Our program package, shortly introduced in [1], has been improved considering the new requirements and our experience given by the application of the previous version. Changes were done for an easier handling and to extend the applicability of the program.

One part of the PIXYKLM the PFIT program, which performs the spectra fitting and concentration calculation, has been modified for decreasing the speed of calculation and has been extended to the next possibilities. It calculates dead time correction using an external pulse generator or NZ-870, NZ-871 and NZ-881 signal processor. It can read and use the data stored in the spectrum file given by the ANAL90 program [2]. If it is necessary, one can use the energy calibration with three parameters. It can handle 50 elements with maximum 40 lines belonging to an element in the range Z=12-83, and so the consideration of M lines is also possible.

The second part of the program package called KLM calculates the effective X-ray production cross section for the concentration calculation. It has been extended to handling M lines as well. At present the most acceptable procedure to determine M ionization cross sections is based on PWBA calculations with Dirac-Hartree-Slater wave functions [3], this table contains cross section data for protons in the 60 KeV - 2 MeV energy range. Because of this table is one of the input file for KLM, it works for M lines only for the above mentioned energy range. The atomic physical constants for the calculation of M X-ray production cross sections are not published for all elements and are known from theoretical calculations only for some elements. The missing values are taken by interpolation.

The concentration calculation by this program package is based on the method using calculated absolute yields. This program calculates the X-ray production cross section in a physically exact way from the models applied for the ionization cross section and treats the contribution of secondary X-ray and pile-up effects in a mathematically exact way.

This PIXYKLM program package among the published similar programs can be considered the most complete and it containes the less approximations. A detailed description and a few examples can be found in reference [4].

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Influence of Compton Scattering on Fluorescent Line Shapes

M.Kis-Varga and J.Végh

The scattering processes play an important role in X-ray fluorescence analysis, especially at higher energies of fluorescent and exciting radiation in thick and light matrices . While the Rayleigh and Compton scattering of exciting radiation, as well as the Rayleigh scattering of the fluorescent radiation do not influence the shape of the characteristic line, the Compton scattering of that radiation appears as a shelf on the low energy side of the photopeak.

To describe this region He et al.[1] used a broad Gaussian. Campbell et al.[2] reported the use of a symmetrical flat shelf ranging from the Compton energy of 180° scattering to the energy of the photopeak. From thick, pure element samples they observed 1-5 % contribution of Compton scattering.

We studied the line shapes by measuring the fluorescent radiation from light matrices of different thickness. Excitations were made: with Am-241 annular source in conventional XRF arrangement; with Am-241 point source by using well collimated beam in 45°/45° geometry; with a low power, changeable anode X-ray tube in 45°/45° geometry; with a 2 kW Siemens FK 60-04 Mo anode tube in a three axis secondary target arrangement, described earlier [3]. The line shape fits were performed with the EWA code [4], by using the same response function as Campbell et al. [2], except the flat shelf: we used an asymmetrical truncated shelf, which better describes the lower slope of Compton shelf due to multiple, large angle scattering (see Fig. 1).

As seen in Fig. 2, the Compton contribution to the photopeak increases with sample thickness and with the energy of fluorescent radiation. For thick sample, at 30 keV the Compton shelf/photopeak area ratio, measured in conventional XRF geometry, exceeds 20 %.

The measured line shapes were compared with the simulated profiles calculated on transport theory basis with the SHAPE code of Fernández and Sumini [5]. The Compton shelf/main Gaussian ratios measured in narrow beam geometry are close to the simulated values for lower atomic number elements (Y and Zr) excited with low energy (<30 keV) radiation, but the Fernández model gives higher ratios for havier elements by using 60 keV energy excitation source. A detailed description of the work is given in [6].

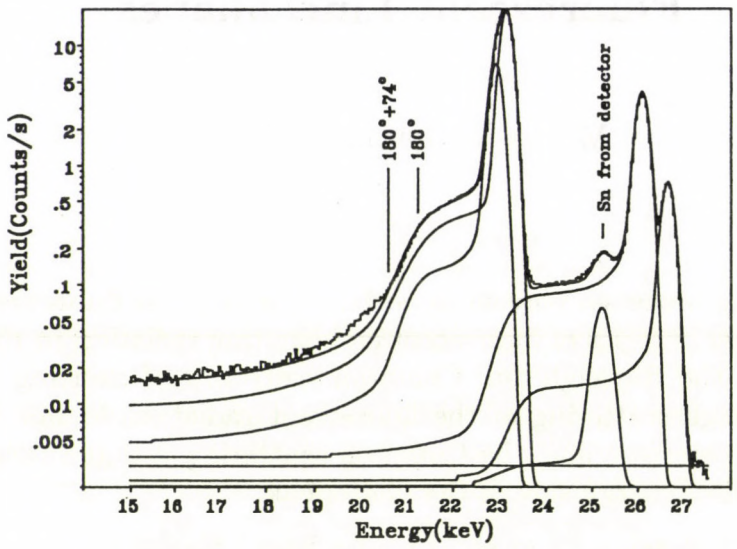

Fig. 1. The least squares fit of CdK-lines measured with annular shaped Am-241 excitation.

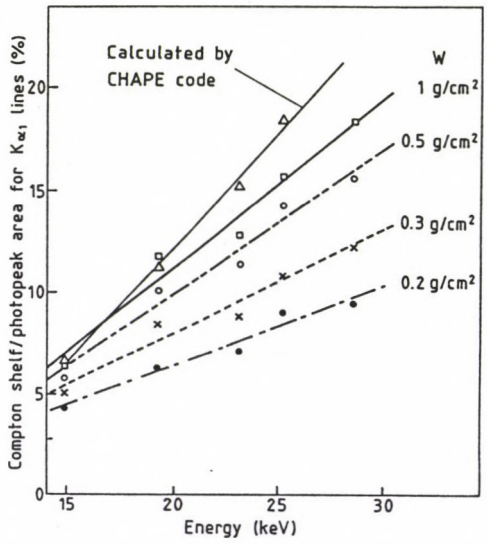

Fig. 2. Compton shelf/photopeak area ratios as a function of characteristic X-ray energy for samples of 0.2, 0.3, 0.5 and 1 g/cm^2. Uppermost curve: theoretical calculation for infinite thickness obtained by SHAPE code [5].

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Escape peak and SiK line intensities in Si(Li) detectors with dead layer

G. Kalinka

Experimental investigations [1-7] on the nature of low energy X-ray spectra taken with Si(Li) detectors have led to the hypothesis of the universal existence of entrance windows, composed of an outer perfectly dead region of thickness x_d, with charge collection efficiency $\eta = 0$, and an inner incomplete charge collection region with thickness x_D and $0 < \eta < 1$, followed by the innermost sensitive detector region of $\eta = 1$.

In order to test the validity of this model, theoretical expressions for escape and SiK line intensities, both being higly sensitive to variations of x_d and x_D, have been derived with the following assumptions:

(i) A collimated beam is incident normal onto the surface of a planar detector, whose lateral dimension and thickness are much larger than $x_d + x_D$.

(ii) An escape event will be generated, if a SiK photon emitted from the sensitive region escapes to the outer dead layer or vacuum, without absorption in the intermediate incomplete charge collection region.

(iii) A SiK event will be recorded, if a SiK photon excited in the outer dead layer reaches the sensitive region.

The expressions under discussion are :

$$I_{ESC} = \frac{1}{2} I_0 \, exp[-\mu_0(x_d + x_D)] J_K \omega_K \Big\{ exp(-\mu_i x_D) \left[1 - \frac{\mu_i}{\mu_0} ln \left(\frac{\mu_i + \mu_0}{\mu_i} \right) \right]$$

$$- \frac{\mu_i}{\mu_0} exp(\mu_0 x_D) \Big[Ei[-(\mu_i + \mu_0)x_D] - exp(-\mu_0 x_D) \, Ei(-\mu_i x_D)$$

$$- exp[-(\mu_i + \mu_0)x_D] \, ln \left(\frac{\mu_i + \mu_0}{\mu_i} \right) \Big] + \mu_i x_D \, Ei(-\mu_i x_D) \Big\} \qquad (1)$$

and

$$I_{SiK} = \frac{1}{2} I_0 J_K \omega_K \Big\{ [exp(-\mu_i x_d) - exp(-\mu_0 x_d)] \, exp(-\mu_i x_D)$$

$$+ \frac{\mu_i}{\mu_0} exp[-\mu_0(x_d + x_D)] \Big[Ei[(\mu_0 - \mu_i)(x_d + x_D)] - Ei[(\mu_0 - \mu_i)x_D]$$

$$- [1 - \mu_0(x_d + x_D)] \, exp[\mu_0(x_d + x_D)] \, Ei[-\mu_i(x_d + x_D)]$$

$$+ (1 - \mu_0 x_D) \, exp(\mu_0 x_D) \, Ei(-\mu_i x_D) \Big] \Big\}, \qquad (2)$$

where I_0 is the intensity of the incident radiation, J_K and ω_K are the jump factor and fluorescence yield for the K-shell, μ_0 and μ_i are the linear attenuation coefficients of silicon for the incoming and SiK radiation respectively, while $Ei(x)$ denotes the exponential integral function.

Since these expressions are valid for arbitrary x_d, x_D values, experiments with Si(Li) detectors having extremely thick entrance windows ($x_d = 0 \div 5\mu$m, $x_D = 0.2 \div 15\mu$m) to enhance the tiny effects hardly observable with normal Si(Li)s have been carried out to check the model and the above formulas at the same time. In two from three cases the results are very convincing [8].

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EARTH AND COSMIC SCIENCES,

ENVIRONMENTAL RESEARCH

Determination of reliable K/Ar ages in case of correlated K and excess Ar concentrations: A case study for the alkalic olivine basalt of Somoška, Slovakian-Hungarian boundary

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On the basis of previous studies (Balogh et al., 1981; Kantor & Wiegerova, 1981; Balogh et al., 1986) 2.5 - 2.0 Ma age was expected for the alkalic olivine basalt of Somoška, Slovakian-Hungarian boundary. Contrary to this expectation, a set of K/Ar measurements performed on different fractions (prepared by magnetic and heavy liquid separation) resulted ages from 7.27 Ma to 4.65 Ma (Tab. 1) and isochron ages show similarly great scatter from 6.02 Ma to 4.31 Ma (Fig. 1); the fit of the points to the straight lines is poor. It has been demonstrated, that linear relation of K and Ar(ex) concentrations may cause erroneously old isochron ages and it is difficult to recognize this bias, since the value of the $^{40}Ar/^{36}Ar$ - $^{40}K/^{36}Ar$ and $^{40}Ar(rad)$ - ^{40}K isochron ages is similar.

On the ground of correlation of K and Ar(atm) concentrations in the fractions of the Somoška basalt, similar relation between the K and Ar(ex) concentrations could not be excluded, thus, the reality of old K/Ar as well as isochron ages remained questionable. The correlation of K and Ar cocentrations is conceivable if both elements are incompatible with the minerals constituting the rock.

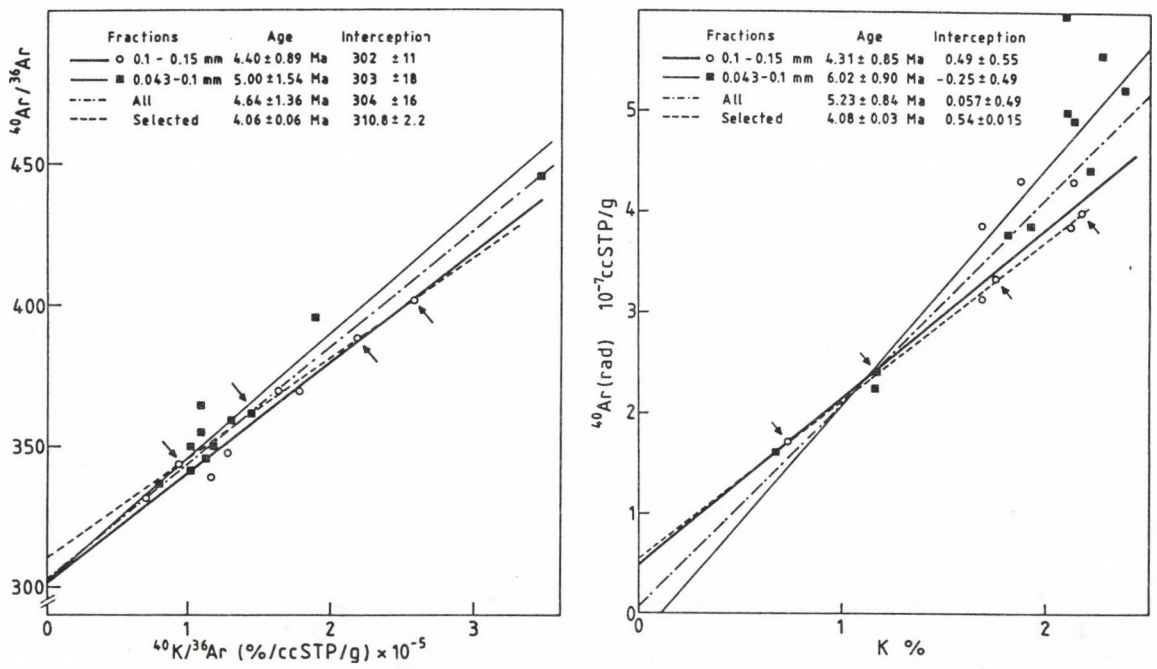

Fig. 1. Isochron diagrams

However, by selecting fractions of similar Ar(atm) concentrations (D_1M_5, D_2M_7, D_2M_1 and D_4M_3 in Table 1 and marked with arrows in Fig. 1) very accurate isochron ages of 4.06 ± 0.06 Ma and 4.08 ± 0.03 Ma were obtained, which are interpreted in terms of the real age of the Somoška basalt. This demonstrates the use of Ar(atm) content in extending the applicability of K/Ar isochron methods and proves that basaltic volcanism in the study area started at least 4.08 - 4.06 Ma ago.

Table 1. K/Ar ages of fractions of the basalt from Somoška.

Fraction	K	$^{40}Ar(rad)$	$\frac{^{40}Ar(rad)}{^{40}Ar(tot)}$	$^{40}Ar(atm)$	$\frac{^{40}Ar}{^{36}Ar}$	$^{40}K/^{36}Ar$	Age
	%	10^{-7} ccSTP/g		10^{-6} ccSTP/g		x10^{-5}	Ma
grain size: 0.1 - 0.15 mm							
D_1 M_7	2.14	4.310	0.00	1.72	369.7	1.64	5.18±0.38
D_1 M_5	2.182	4.001	0.265	1.11	402.0	2.58	4.72±0.28
D_1 M_3	2.132	3.860	0.150	2.19	347.6	1.28	4.65±0.44
D_1 M_1	1.884	4.317	0.110	3.49	332.0	0.71	5.89±0.75
D_2 M_7	1.760	3.345	0.240	1.06	388.8	2.19	4.89±0.31
D_2 M_4	1.689	3.881	0.170	1.90	339.7	1.17	5.80±0.49
D_2 M_2	1.698	3.142	0.20	1.26	369.7	1.78	4.70±0.35
D_2 M_1	0.743	1.723	0.140	1.06	343.6	0.93	5.96±0.60
grain size: 0.043 - 0.1 mm							
W.r.1.	1.819	3.782	0.156	2.05	350.1	1.18	5.35±0.48
W.r.2.	1.932	3.871	0.135	2.48	341.6	1.02	5.15±0.51
D_1 M_3	2.389	5.227	0.178	2.41	359.5	1.30	5.62±0.45
D_1 M_1	2.107	5.959	0.190	2.54	364.8	1.09	7.27±0.56
D_2 M_3	2.223	4.428	0.146	2.59	346.0	1.13	5.12±0.47
D_2 M_2	2.282	5.559	0.168	2.75	355.2	1.09	6.26±0.53
D_2 M_1	2.145	4.942	0.123	3.52	336.9	0.80	5.92±0.67
D_3 M_2	2.109	4.992	0.254	1.47	396.1	1.89	6.08±0.37
D_4 M_3	1.173	2.404	0.184	1.07	362.1	1.45	5.27±0.38
D_4 M_2	1.162	2.251	0.338	0.44	446.4	3.47	4.98±0.20
D_1 M_1	0.678	1.625	0.156	0.88	350.1	1.02	6.16±0.53

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Geochronological studies with the K/Ar method in 1992

K. Balogh, E. Árva-Sós. Z. Pécskay

A short summary of chronologic results published in 1992 will be given below.

In accordance with the expectations, K/Ar data verified that S-Harghita is younger than N-Harghita. On the basis of detailed investigations 2 -3 Ma was established for the duration of volcanic activity of the Kakukk Mts. [1]. The latites of Fruska Gora (N. Serbia) crystallized near the Eocene - Oligocene boundary, i.e. they are more or less coeval with the Paleogene volcanic rocks that are present in Hungary along the Darno-line [2,3]. A summary of chronologic studies performed on Tertiary volcanites in Hungary has been prepared [4]. The presence of Lower Rhyolitic Tuff level in the central part of the Danube - Tisza Interfluve was proved by measuring 19.0 Ma on a biotite from borehole Lajosmizse-1 [5]. Early Oligocene age of 30.9 ± o.9 Ma has been estab-lished for the Perelik volcanic massif (Central Rhodopes, Bulgaria) [6]. Lower Cretaceous age was measured on dikes uncovered by boreholes between the Mecsek and Villányi Mts., SW Hungary. The dikes represent a differentiation series of an alkali basaltic magma, and the K/Ar age is regarded as the time of magmatic activity. The rejuvenating effect of the Austrian orogenic phase (cca 100 Ma) can be observed only on rocks from the tectonic block represented by boreholes Nagykozár-2 and Máriakéménd-3 [7].

Granites were studied from a 450 km^2 area in SW Sinai, Egypt. Hornblende and biotite were dated. The older as-semblages (diorite - tonalite - granodiorite) resulted ages from 653 ± 26 Ma to 567 ± 22 Ma, while from 602 ± 23 Ma to 568 ± 22 Ma ages were obtained for the younger (monzogranite - syenogranite - alkali feldspar granite) assemblages. (Coop.: A. M. Abdel-Karim, Geol. Dept. Fac. Sci., Zagazig Univ., Egypt).

Dating of basaltic rocks from the Cerova Vrchovina hills, Slovakia was continued and an age of about 1.3 Ma was indicated for the termination of basaltic volcanic activity. (Coop.: D. Vass, GUDS, Bratislava, Slovakia).

Ages from 103 Ma to 78 Ma were measured on biotites from the Sopron Mts. These are older than the Rb/Sr and FT ages and unusually large ($^{40}Ar/^{36}Ar$ = 842) enrichment of radiogenic Ar was observed in a fluid inclusion in a hydrothermal quartz. (Coop.: I. Dunkl, Geochem. Res. Lab. Hung. Acad. Sci., Budapest).

The age of hydrothermal mineralization of Nagybörzsöny has been directly determined as 14.6 ± 0.5 Ma by dating hydromuscovite. This shows that hydrothermal mineralization was not separated in time from the volcanic activity. (Coop.: B. Nagy, Hung. Geol. Inst., Budapest).

The K/Ar ages measured in 1992 confirm that the volcanic activity in the Baia Mare zone is partly contem-poraneous with that in the Tokaj, Oas and Vihorlat Mts., and differs from the Calimani - Gurghiu - Harghita zone where it lasted until the Quaternary. (Coop.: O. Edelstein et al., CUART. S. A. Baia Mare, Romania).

Middle Jurassic age was deduced for the ophiolitic rocks of Darno Hill (N Hungary), suggesting their similarity in age with the rock suites of Szarvaskö. On the other hand, the ophiolites of the Bódva Valley are older, but all the ophiolitic series were affected during the Austrian tectonophase. (Coop.: S. Józsa, Dept. Petrogr. Geochem., Eötvös Univ., Budapest).

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Radon monitoring at a geologically active area

J. Hakl and I. Hunyadi

The Northern foreground of Mátra mountain in Hungary was well known for a long time for their hydrocarbon deposits. In the last decades in several places carbon dioxide upflows at the surface were also reported, which intensity was changing both in time and space.

In January 1992, drastically increased CO_2 levels were measured in a few houses of Mátraderecske village, located in the same area, with concentrations often exceeding 2 % vv. in some parts of the houses.

It was found that CO_2 originates from a saturated deep Triassic karst water reservoir, from where it migrates to the surface near the structural faults of the covering strata.

Since the beginning in was clear that ^{222}Rn can be well used as a tracer of underground fluid motions in the areal mapping of this process and possibly can also be found at increased levels in the exposed houses.

Two series of radon measurements were applied using nuclear track detector technique to localise the gas seepage phenomena. A quick search for the active areas was performed using one week long exposure time. The radon concentration profile was measured along three lines of 1 m deep shallow drills, running N-S (one line) and E-W (two lines) and crossing the expected exposed area. Starting at the same time a spatially more extended radon survey was performed in 130 houses of the village with two months exposition time.

The results of both radon surveys revealed a structure with similar character showing the same enhanced regions in Northern and Central part of the village. These regions with enhanced gas upflow were also well identified by other geological and geophysical methods.

The mean radon activity concentration for studied dwellings is 517 Bq/m^3, which value for the 70 houses located in the critical region is 929 Bq/m^3. The highest values exceeded 8000 Bq/m^3 levels. In these houses successful mitigation actions were already completed.

This work was supported in part by the City Hall of Mátraderecske.

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External Exposure of the Population in Summer 1992 in Regions Contaminated by the Chernobyl Reactor Catastrophe

I.Uray

Six years after the Chernobyl catastrophe there are still regions of Ukraine, Bjelorussia and Russia with a considerable level of contamination. This fact is a continuous problem of the officials and of about 15 millions of people living here, respectively. Both sides require the possible exact knowledge about the present situation, of course. Within the scope of a large scale expedition, sponsored by the Federal Republic of Germany, the external exposure of the population was investigated among others. Using precision measuring technics, connections between the contamination level, different social factors and the level of the external exposure were examined.

For the measurements LiF thermoluminescent detectors (TLD-100, Harshaw) and a SOLARO reader have been used. Using the BET method [1] and a special evaluation and correction program FASTGLOW (unpublished) a measuring accuracy of about 10 per cent of a week background exposure has been obtained. By this technics a short (max. 2 weeks) exposition, consequently a quickly rotation of the dosimeters and more reliable exposition circumstances have been arranged. As both the distribution of the contamination and the circle of movement of different persons were very different, a correct value of a "personally characteristic" mean dose rate is measurad. An active and correct cooperation with the population is necessary, but it would be inpossible for a longer measuring period.

In a four month period the dosimetric control of 3600 persons has been carried out. A lot of localities of different characters and contamination levels, (from contamination free ones to a contamination of 4.07MBq/m^2,) in different distances (30-300km) from Chernobyl have been chosen. A questionary enclosed to the dosimeters has solved the collection of the most important social data for the single measurements: place of residence, sex, age, characteristic way of the work (indoor, outdoor or mixed), and the character of the living home (wooden, brick or concret). A mean value of the contamination is known from a lot of Russian measurements for every locality [2]. The correlation between the mean values of the contamination and of the measured dose rate in the case of the small villages with agricultural character is extremly high (the correlation coefficient is 0.996). In the localities with mixed living and working conditions the picture is more complicated. The urban character is in general a restriction factor of the radiation level, but the decrease of the measured dose rate is different for the different social groups. The specific dose rate (the values of the dose rate/contamination in μSvm^2/MBqh units) is 0.1414 for the indoor and 0.2077 for the outdoor groups. This value is 0.2196 in the case of people living in wooden houses and is 0.1278 for those living in brick or concrete buildings, 0.1963 for male and 0.1820 for female. There is an unambiguos minimum for the age-groups between 20-49 years, while

the dose rate measured for children is about 30, and for the old people near 60 per cent higher.

The efficiency of a high scale Russian decontamination action in year 1989 was also investigated. A decrease of the radiation level is measurable at different groups of the inhabitants, but the degree of it is only moderate. On the other hand, in these villages one find a bright dose rate distribution, the effectiveness of the decontamination for different groups of the inhabitants seems to be very different.

Six years after the Chernobyl catastrophe the main problem is the 137-Cs contamination. Because of its long half life and of the slow migration the present stage changes only slowly. The distribution of the activity is very casual, its concentration in a few meter distance may change many orders of magnitude. There are places in a distance of 2-300 kilometers with higher contamination, than that at the border of the 30km zone. In this situation the accurate dosimetric control, the dosis reconstruction and the determination of the collective dose are very difficult, the decontamination is scarcely possible, and the sense of fear of the population is very high.

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An XPS and EPMA study of size fractionated ambient aerosol particles collected in urban and rural areas

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Surface and bulk analytical investigations of ambient aerosol particles were carried out by XPS and EPMA, respectively. The instrumentation used were: the homemade XAES measure system of the ATOMKI [1,2] and the AMRAY 1830I SEM equipped with EDAX EDS which belongs to the KLTE. [XPS: X-ray Photoelectron Spectroscopy; EPMA: Electron Probe Micro-Analysis; XAES: X-ray excited Auger Electron Spectroscopy; SEM: Scanning Electron Microscope; EDS: Energy Dispersive X-ray Spectrometer].

The size fractions of particles sampled were (0.5-1, 1-2, 2-4, 4-8, 8-16, >16 μm) as before [3]. For sampling two types of cascade impactors were used, a Battelle-type (with six stages) developed in the PIXE group of ATOMKI and an OH-611-C type produced by the R&D Inst. of Iron Industry, Budapest.

By the help of the good sensitivity of our new XAES instrumentation XPS spectra of S, N, C were measured on samples collected using 3 hour sampling periods (I, II and III) in the day time (morning peak hours (I), noon hours (II) and afternoon peak hours (III)), respectively in the heavy traffic centre of Debrecen. In all of the periods we pumped about 2 m^3 air through the Battelle impactor at a flow rate of 12 l/m. Using the OH-611-C impactor we measured the mass of 220 $\mu g/m^3$ of the total flying dust (sizes below 15 μm) at a flow rate about 70 m^3/hour in the time period overlapped well with the other 3 ones. The sampling period at the rural sites in the neighbourhood of a coal fired power plant (Visonta near town Gyöngyös in the mountains Mátra, Hungary) was 6 hours long. All of our sampling periods were short enough and set up in the day time not to overlap with the night time, which are important from the point of view of representative sampling [4].

In the experiments a special sampler consisting of a thin PTFE (polytetrafluorethylene) layer on the surface of a graphite backing was used which proved to be optimal from the point of view of both XPS and EDX (Energy Dispersive X-ray Spectroscopy) techniques. First the XPS measurements were carried out on the samples. Then the same samples were coated with a very thin carbon layer (the thickness of a few times 10 nm) to minimize the charging effects. In this way we were able to get good spatial resolution BSE (backscattering electron), SE (secondary electron) and EDX (Energy Dispersive X-ray) images by EPMA.

Preliminary results coming from XPS and EDX on the fine fractions (0.5-1, 1-2 μm) of the particles are given in the next paragraphs.

Assigning the S and N peaks in the XPS spectra, it was found that the S was in the chemical state of SO_4^{2-} and the N was in the NH_x (named after [5]) state in both of the fine fractions. From the XPS peak areas of S and N we obtained the SO_4^{2-}/NH_x photoelectron intensity ratios. At the Debrecen site in the 0.5-1 μm fraction, in all of the 3 hour periods I, II and III this ratio was 0.5, while in the 1-2 μm fraction the respective temporal ratios were 0.1, 0.3 and 0.5, respectively. At the power plant sites N°1 (about 50 m to the plume) and N°2 (about 2.5 km to the plume) the ratios were 0.8 and 0.7 in the 0.5-1 μm fraction, respectively and 0.1 and 0.3 in the 1-2 μm fraction, respectively. These ratios are very different from the ratio of 1.0 can be found in the compound $(NH_4)_2SO_4$ except in the case of plant sites in the 0.5-1 μm fraction.

At the Debrecen sampling site in the 1-2 μm fraction the S/Si atomic concentration ratios in the time periods I, II and III were 0.5, 1.0 and 1.5, respectively from the surface by XPS and 0.3, 0.2 and 0.4, respectively from the bulk by EDX. From the ratios a strong surface enrichment of S and a gradual increase of S content in the surface layers from the morning to the afternoon period can be concluded. In the 0.5-1 μm fraction the Si peaks could not be detected by XPS, the bulk S/Si ratios were 0.9, 0.2 and 1.0 by EDX. The tendencies of the temporal changes of the bulk S/Si ratios were similar in both of the fractions, but the morning and afternoon ratios related to the noon ones were a factor of 3 and 2.5 times higher in the smaller fraction than in the larger one indicating enrichment of S in the bulk in the morning and in the afternoon.

An interesting result is coming from the temporal (the Debrecen site) and spatial (the power plant sites) XPS measurements, too. The XPS peak areas of S in the 0.5-1 μm fraction related to the peak areas of S in the 1-2 μm fraction were 6, 3 and 2 in the time periods I, II and III, respectively. From the spatial measurements these ratios were 5 and 10, at site N°1 and site N°2, respectively. The conclusion is very similar to the conclusion of the review article [6], namely that the continental airborne sulphate is mainly in the smaller size fraction (around 0.5 μm) .

The data interpretation (f.e. images by EPMA) and the comparison of our results with other data (SO_2, NO_2 concentrations, meteorological data) are presently under way.

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Measurement of Pb Concentration in Airborne Particles from Three Different Sites of Debrecen City

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We have been interested in studying the Pb concentrations of atmospheric particulates in Debrecen city for more than two years. The toxicity of lead inhaled is well known and its chronic effects on humans have been extensively studied [1]. Damage to the central nervous system - causing lead encepholopathy and neuropathy - is a marked and common feature, especially in children with their low Pb tolerance. In children, chronic Pb poisoning may result in physical brain damage with permanent sequelae, including behavioral problems, intellectual impairment, and hyperactivity [2]. In our city the motor traffic can be regarded as the main source of lead in airborne particles. The aim of our measurements has been to determine the trends in the variation of Pb level throughout a longer period of time.

Atmospheric aerosol samples were collected weekly at three different locations: "A" Dósa Nádor square (center), "B" Dobozi street (east) and "C" Medical University School (DOTE, north) in Debrecen city from July 1990 to June 1992. On the whole, 204 samples were taken by the National Public Health Center of County Hajdú-Bihar (air pollution monitoring is one of their regular tasks) and put at our disposal for analysis. The atmospheric aerosols were collected on two types of glass fiber filters: Sartorius SM 13400 and Paraplan. The analysis of atmospheric samples were carried out with an automatic measuring and evaluating XRF system based on an ATOMKI-Type SiLi x-ray spectrometer [3], an automatic sample changer equipment [4], and an IBM compatible AT. The resolution of the spectrometer was 165 eV at the MnK_α line. For the excitation of characteristic x-ray lines I-125 (200 MBq activity) ring shaped radioisotope x-ray source was used. Measurement times were 3600s. All the spectra were analyzed by the AXIL program [5] and the "Sensitivity Calculation" procedure was used for the determination of concentration values of Pb.

The average concentration data of lead are summarized in Fig. 1, and Fig. 2, through two years. It can be seen that the lead concentration values are higher in the center of the city than they are in the outskirts "B" and "C". This is quite expectable because location "A" is much more congested with traffic than places "B" and "C". The monthly concentrations of lead averaged for the three sites are plotted in Fig. 2. Studying the variation of Pb concentration as a function of time we can see that there is an abrupt decrease at the beginning of 1991 which could probably be attributed to the 100% increase of the price of the fuel at the end

of 1990. It can also bee seen that the Pb concentrations are somewhat but not significantly higher in the first half of 1991 than in the same period of 1992 (200 $\pm 90 ngPb/m^3$ and $170 \pm 120 ngPb/m^3$ separately). This may be the consequence of the reduction of Pb concentration (from 0.4gPb/l to 0.2 gPb/l) in benzine, supposing that the motor traffic remained the same in the two time interval.

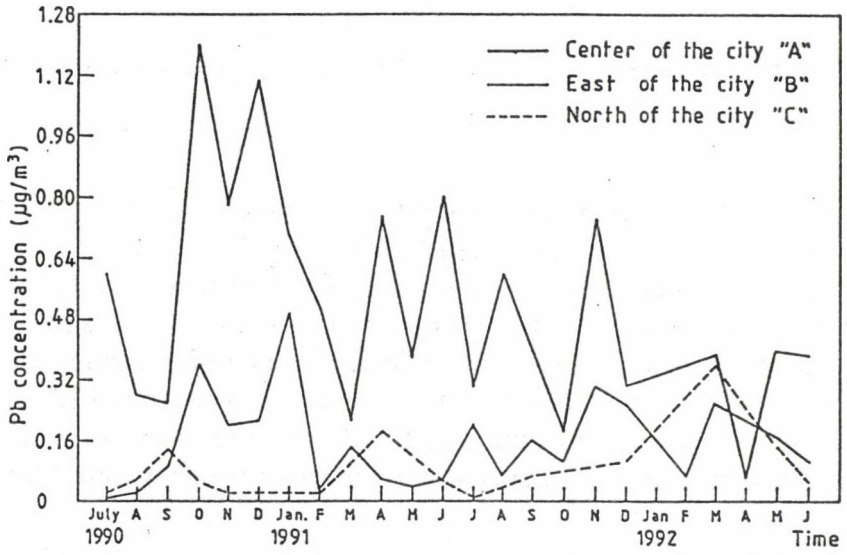

Fig. 1. Monthly average Pb concentrations at the three sampling sites.

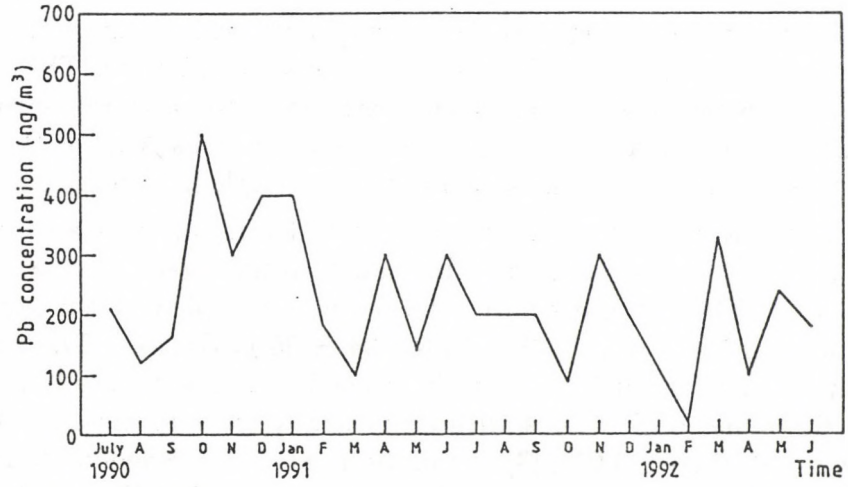

Fig. 2. Average Pb concentration in atmospheric aerosol in Debrecen city.

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Studies On Bromine : Lead Ratios In Car Exhaust Gas

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Br and Pb elements are regarded generally as reliable indicators of human activity, considering particularly car exhaust, which is the major contributor of Pb and Br in fine and coarse airborne particles of the atmosphere [1]. Namely, Pb-ethyl is added to the benzine (in 0.2g /l quantity) to improve its anti-knocking properties and this compound burns into PbBrCl [2]. Therefore, when analyzing airborne particles Br/Pb ratio is used as a tracer for car exhaust gas [2]. The aim of our experiment has been to determine the Br/Pb ratio in fresh car exhaust gas and to investigate the efficiency of a special lead trap filter constructed by a local firm.

Samples were taken directly from car exhaust tube with a simple technique (see Fig. 1) which consisted of a metal cylinder, a holder, a glass tube (water trap), an air volume counter and a vacuum pump with flaw rate of 5 m^3/h. The gas samples were filtrated on ash free filter paper (free from Br and Pb) with and without the lead trap filter. Altogether, 10 independent experiments were carried out at different times using a SKODA car and benzine of 92-type. The analysis of the gas exhaust samples was carried out with an automatic measuring and evaluating XRF system explained in a previous article in this Annual Report. A typical x-ray spectrum representing car exhaust gas sample is shown in Fig. 2.

Br and Pb concentration data measured with and without the lead trap filter are presented in Table 1. It is seen that the lead trap filter reduces the quantity of Pb and Br emitted from the exhaust tube to the atmosphere from 805 $\pm$ 218 to 644 $\pm$ 112 $\mu gPb/m^3$ and from 229 $\pm$ 40 to 194 $\pm$ 35 $\mu gBr/m^3$. The efficiency of this lead trap filter is about 20% . Br/Pb ratios in our results are 0.31 $\pm$ 0.10 with lead trap filter and 0.29 $\pm$ 0.04 without it which are very close to the ones measured in England (0.25 $\pm$ 0.01) [3] and in Mölndal (0.24), Sweden [2]. It is also seen that Br/Pb ratio has a relatively high fluctuation (0.22-0.47 with lead trap filter and 0.26-0.37 without it) and their average is lower than the expectable one (0.386) calculated from the stochiometric ratio of the PbBrCl. Therefore, these results, in accordance with other investigators' data, mean limit in the estimation of Pb content of aerosol particles which can be attributed to car exhaust by using the stochiometrical Br/Pb ratio (0.386) for the separation.

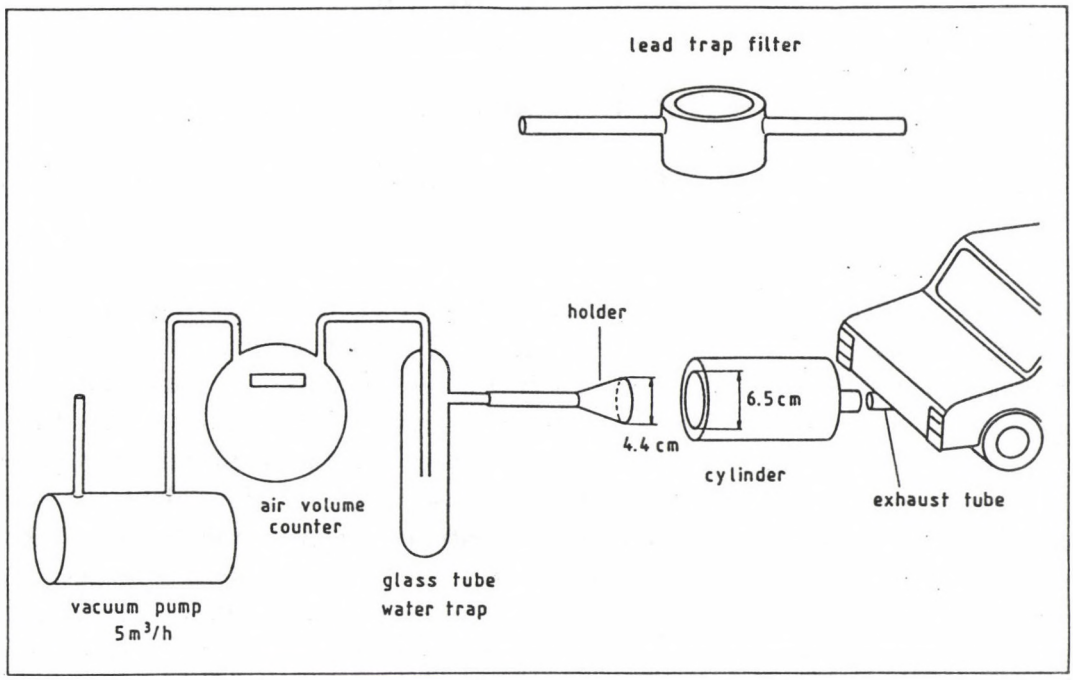

Fig. 1. Experimental set-up for sample collection from the exhaust tube.

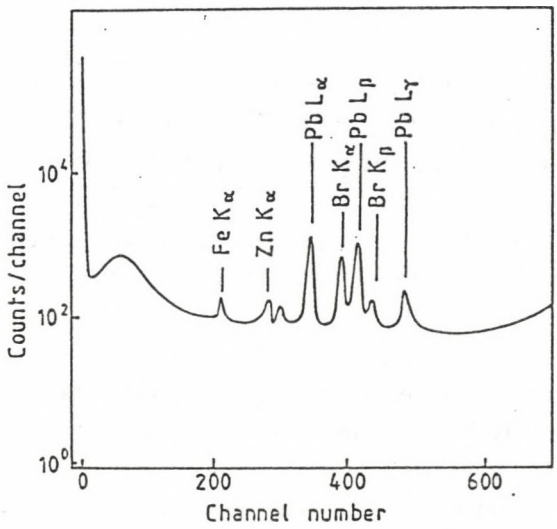

Fig. 2. A typical X-ray spectrum of exhaust gas sample.

	With Lead Trap Filter			Without L.T.Filter		
Results Number	Pb	Br	Br/Pb	Pb	Br	Br/Pb
1	-	-	-	969	264	0.2720
2	-	-	-	837	234	0.2792
3	688	151	0.2197	-	-	-
4	-	-	-	995	263	0.2647
5	691	187	0.2710	-	-	-
6	-	-	-	772	215	0.2779
7	781	219	0.2799	-	-	-
8	-	-	-	451	167	0.3693
9	510	240	0.4704	-	-	-
10	548	175	0.3200	-	-	-
Average ± S.D.	644 ±112	194 ± 35	0.3122 ±0.0954	805 ±218	229 ± 40	0.2926 ±0.0432

Table 1. Br and Pb concentrations in car exhaust gas.

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Application of Glass Fiber Filters in ED XRF Analysis

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A systematical study of the applicability of glass fiber prefilters in energy dispersive x-ray fluorescence analysis (ED XRF) has been carried out. As it was discussed in a previous article of ours in this Annual Report, airborne particles collected on glass fiber prefilters were given to us for XRF analysis. Having some disadvantageous features —too high blank values, unequal penetration of particles into the filter material, etc.— they are rarely used in ED XRF analysis. In order to get reliable analytical results we had to investigate which elements can or can not be analyzed using this filter material. The aerosol samples were collected on two different types of glass fiber prefilters: SARTORIUS SM 134 00 and PARAPLAN (Hungarian product). The diameter of filters was 257mm and the loaded areas were 230mm in diameter. The border part was free from particles and it was selected as a blank material in the analysis, since different sheets produced significantly different characteristic x-ray yields still from the same paper type.

From each of the two different filter types used for the collection of samples one was selected for the study. They were expected to give the lowest characteristic intensities for most of the elements (in order to study the least measurable material) because the sample collection was carried out in the outskirt of Debrecen city where the motor traffic is relatively low. From both of the loaded and clean areas of each kind of filter 5-5 disks were analyzed by ED XRF method. The experimental conditions were the same as discussed in our previous article except that (depending on the characteristic energies of elements, $E \leq 5$KeV or $E > 5$KeV) Fe-55 (26GBq) and I-125 (400MBq) ring shaped radioisotope sources were used for the excitation . The measurement times were 5000s (I-125) and 300s (Fe-55) respectively.

Results are summarized in Table 1. Average values of the five independent measurements of characteristic x-ray peak counts are reported together with their standard deviation. Elements having significantly higher characteristic peak intensities in the sample than in the blank area are regarded as measurable ones. For the determination of significant differences unpaired T-test was used. It is seen, that selecting $p<0.01$ significance level, only the S and Pb elements are measurable from the 24 elements analyzed. The blank glass fiber filter contains almost all of the elements to be measured, such as Si, P, S, Cl, K, Ca, Ti, Ba, Mn, Fe, Co, Ni, Cu, Zn, Br, Rb, Sr, Zr, Mo, which is in good accordance with the literature data [1]. Fortunately, in case of lead, the filters have blank values low enough to measure Pb quantitatively. It has to be mentioned that the blank values, measured for Au and Pb elements, are only an artefact of the SiLi spectrometer itself.

These results show , in accordance with other literature data [2], that besides Pb element, glass fiber prefilters have very limited value in multielemental analysis of airborne samples.

Table 1. Characteristic peak counts of elements measured with Fe-55 (Si–Ba) and I-125 (Mn–Pb) source excitation using two different types of glass fiber prefilters: Sartorius and Paraplan. (*) Denotes significant differences ($p<0.05$).

SARTORIUS

	SAMPLE		BLANK			
Elem.	Mean	± S.D.	Mean	± S.D.	T-stat	p
Si	14392	250	15302	440	-4.0	0.004*
P	161	67	88	89	1.5	0.178
S	427	78	166	30	7.0	0.000*
Cl	514	112	387	29	2.5	0.039*
K	29584	342	30517	1339	-1.5	0.169
Ca	30985	2037	28955	2014	1.6	0.152
Ti	9234	2869	13472	6625	-1.3	0.226
Ba	65069	2854	64004	10133	0.2	0.827
Mn	211	28	198	11	0.9	0.372
Fe	591	160	352	54	3.2	0.013*
Co	39	29	57	22	-1.1	0.304
Ni	110	24	94	36	0.8	0.453
Cu	258	40	260	49	-0.1	0.923
Zn	47279	793	46480	327	2.1	0.071
Se	13	11	-1	13	1.8	0.111
Br	46	20	45	13	0.1	0.927
Rb	798	41	821	55	-0.8	0.463
Sr	2916	85	2859	70	1.1	0.287
Zr	259	30	227	22	2.0	0.085
Mo	39	13	45	25	-0.5	0.649
Cd	-14	21	2	56	-0.6	0.576
Au	73	39	88	31	-0.7	0.526
Hg	3	24	1	14	0.2	0.865
Pb	289	23	138	32	8.6	0.000*

PARAPLAN

	SAMPLE		BLANK			
Elem.	Mean	± S.D.	Mean	± S.D.	T-stat	p
Si	19565	385	20333	225	-3.9	0.005*
P	493	68	511	49	-0.5	0.643
S	1249	77	376	32	23.4	0.000*
Cl	177	33	266	24	-4.9	0.001*
K	11133	192	10734	136	3.8	0.005*
Ca	110905	1249	112860	819	-2.9	0.019*
Ti	641	168	576	128	0.7	0.509
Ba	1531	61	1646	157	-1.5	0.163
Mn	26	25	15	28	0.6	0.557
Fe	431	46	437	32	-0.2	0.829
Co	18	23	7	10	1.0	0.357
Ni	40	12	35	25	0.4	0.681
Cu	62	30	21	10	2.9	0.019*
Zn	1147	49	1074	61	2.1	0.071
Se	10	39	13	11	-0.2	0.872
Br	81	26	31	43	2.2	0.060
Rb	78	33	74	23	0.2	0.814
Sr	233	27	209	23	1.6	0.156
Zr	362	45	344	17	0.8	0.434
Mo	56	20	40	36	0.9	0.397
Cd	3	12	1	38	0.1	0.930
Au	75	20	67	26	0.6	0.562
Hg	17	12	22	19	-0.4	0.691
Pb	236	19	139	28	6.4	0.000*

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PIXE Data Set on Atmospheric Aerosol Evaluated by Wind Sector and Target Transformation Factor Analyses

I. Borbély–Kiss, E. Koltay, Gy. Szabó

In the present work [1] a PIXE data set containing elemental concentrations in nearly 200 aerosol samples collected between March 1988 and December 1989 have been subjected to a twofold analysis. On the one hand a subdivision of the samples into five wind sectors has been made on the basis of calculated 850 hPa air trajectories provided by A. Molnár, L. Bozó, E. Mészáros and J. M. Harris [2]. The variation of some regional signatures with wind sectors has been observed and compared with similar data from earlier publications dealing with aerosol in the Swedish atmosphere and in the Black Sea region. On the other hand total data, i.e. unresolved with respect to wind direction, have been subjected to target transformation factor analysis. The calculations were performed with the computer code FANTASIA.

Our attempt to source region identification is based in the first case on the evaluation of 104 samples devided into five groups according to the wind sectors given by the analysis of air trajectories. Derived Mn*/V* ratios are presented in Fig.1A as the length of the vectors directed along the bisectrices of the wind sector. Our data in sectors 1 and 5 are in accordance with the accepted West-European mean value. The high value in sector 2 indicates high East-European emission. The high value in sector 4 is considered as an effect of South-European sources. In Fig.1B the Zn/V* ratio is represented by the polygon. The effect of South-European sources does not show up in sector 4. In sector 2 a high anthropogenic contribution is well indicated. For the sake of a comparison wind sector diagrams were constructed and presented in Figs.1A-1B from the data by Swietlicki [3] taken with PIXE method at a rural site in Sweden and from those by Hacisalihoglu et al. [4] received from INAA on samples collected over the Black Sea. The Swedish measurements reveal low absolute concentrations and signature values, but diagrams point again towards the middle or eastern part of Europe. The scale of the polygon does not apply to the Black Sea case because the published data allowed only to determine its shape (the mean ratio Mn*/V*=5.8 gives an idea about the magnitudes) from which the same conclusion can be drawn. All three cases give a fairly strong support to the guess that Middle-East Europe plays a non-negligible role in the emission of aerosols with high values of signatures Mn*/V* and Zn/V*.

The results of the target transformation factor analysis are obtained in the form of source profiles, i.e. contribution of the revealed factors in arbitrary units, and as source scores, i.e. contribution of the factors (sources) to the atmospheric aerosol normalized to the measured concentrations. The yearly data as well as their subdivision to summer and winter parts were treated.

The interpretation of the factors in terms of aerosol sources is somewhat arbitrary. The first factor heavily loaded with elements of low enrichment factor, repre-

sents the soil as source. The second factor containing much Pb, S and soil-degraded elements is considered as a mixed source of dust and exhaust particles, typical for motor vehicle traffic. The third factor is interpretable as coal-combustion mixed with oil-burning. The fourth factor highly correlated with Cl and heavily loaded with S may be identified as domestic heating. It is very likely that the fifth factor contains mostly emissions related to industrial metallurgy.

The evaluation of the source scores indicates, as shown in Fig.2, that the five-factor solution exhausts the measured elemental concentrations almost completely. The sums of the calculated scores are generally close to 100 %.

For more reliable information a new larger set of samples is being collected under well-controlled conditions.

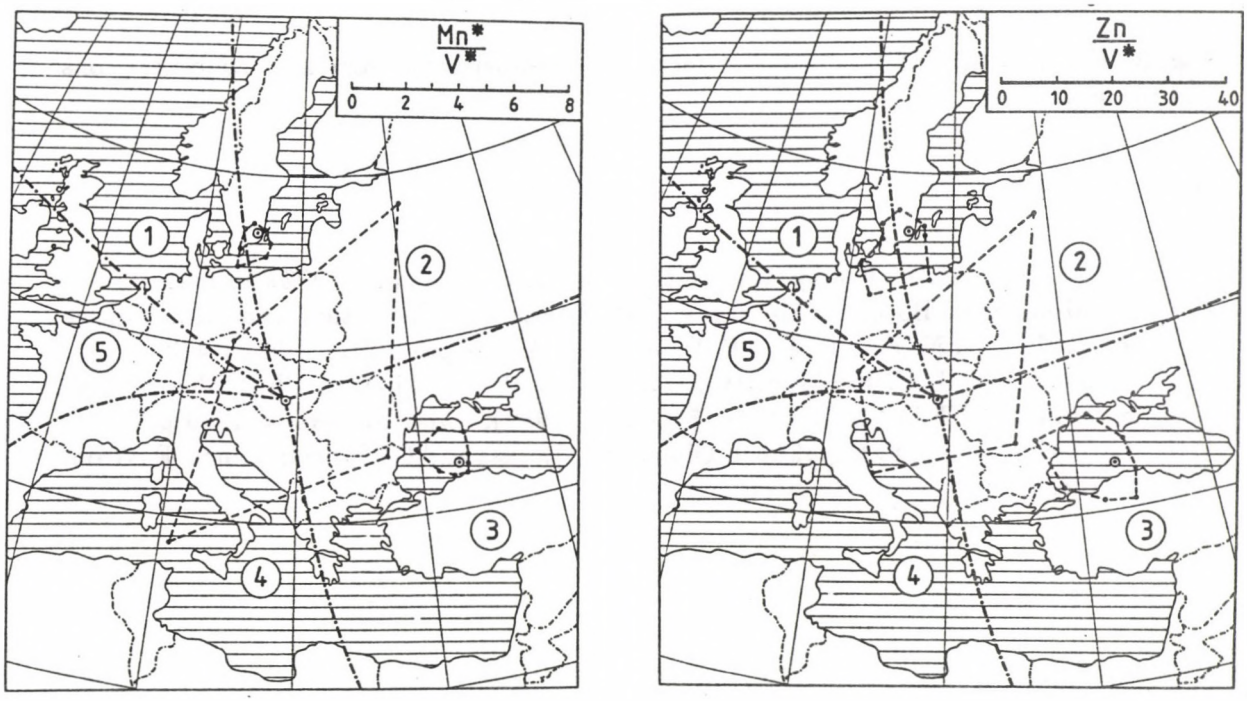

Fig. 1 A and B. Wind sector distribution polygons for regional signatures (data taken from [1,3,4]

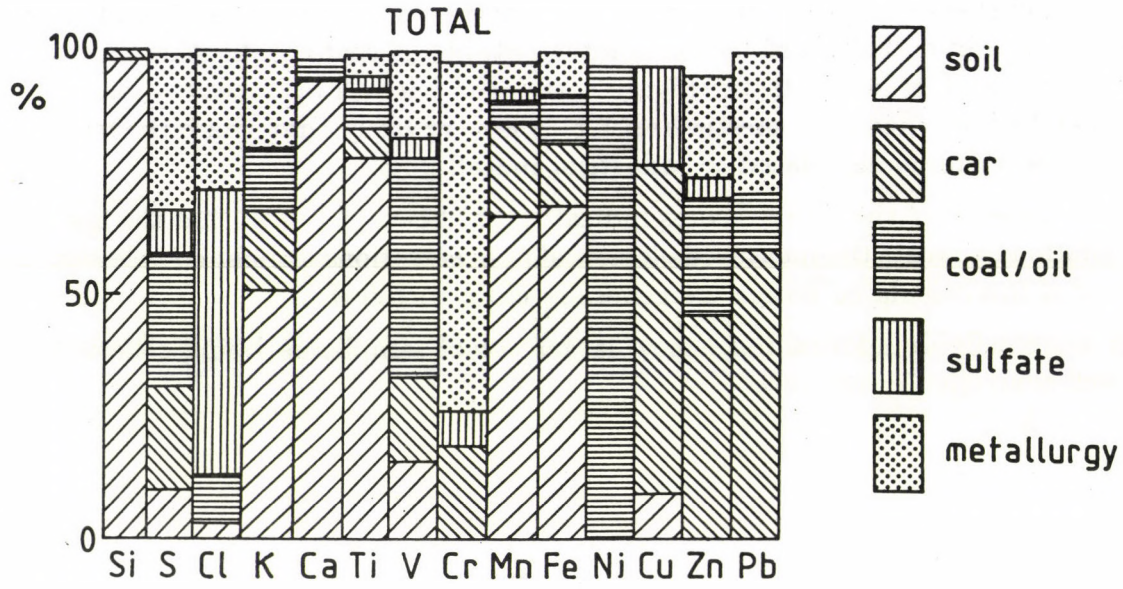

Fig. 2. Contribution of the revealed factors to atmospheric elemental concentrations (source scores)

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Aerosol Sampling and Analysis by PIXE

I. Borbély-Kiss, E. Koltay, Gy. Szabó,

A regular aerosol sampling has been continued in collaboration with Central Institute of Atmospheric Physics.

Further 132 aerosol samples collected in Debrecen (in ATOMKI) has been analysed by PIXE. Elemental concentration of Al, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Br, Ba, Pb has been calculated for each samples.

Yearly and monthly averages of the concentrations for the above mentioned elements has been calculated together with the enrichment factors. On the basis of enrichment factors we could identify the origin of elements (soil or anthropogenic).

The results of this analysis has been presented on the II. Hungarian Aerosol Conference in Debrecen.

ELEMENTAL CONCENTRATIONS in ATMOSPHERIC AEROSOL PARTICLES in ng/m^3

ELE-MENT	BELGIUM [1]	DANMARK [2]			HUNGARY 1991-1992	
	BRUSSELS	COPENHAGEN		ESBJERG	K-PUSZTA	DEBRECEN
	urban	urban	suburban	rural	rural	suburban
Al		853.0	344.0	289.0	294	429
Si	340	1946.0	749.0	650.0	662	1534
P					129	85
S	2220				1429	2673
Cl					24	86
K	192				218	520
Ca	300				345	816
Ti	23	100.0	33.0	32.0	17	52
V		19.0	9.5	10.0	2	9
Cr		5.6	1.8	1.9	7	23
Mn	17	27.0	12.0	11.0	10	16
Fe	780	1466.0	336.0	318.0	256	775
Co					1	16
Ni		8.9	3.6	3.2	2	7
Cu	51	52.7	10.6	4.7	2	13
Zn	113	151.0	49.4	53.1	24	57
As					3	32
Se		0.6	0.6	0.7	1	≤3
Br	125	257.0	22.7	29.2	≤2	22
Ba		62.1	9.5	8.5	≤20	32
Pb	480	909.0	105.0	105.0	19	86

[1] Maenhaut W.,Thiessen L.,Verduyin G.: Nucl. Instr. Meth. B49 (1990) 406
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Gross alpha radioactivity and chemical trace element content of thermal waters

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In a joint research project alpha radioactivity and microelement content of thermal waters originating from different geological layers of the Great Hungarian Plane were analysed by complex nuclear analytical methods. The sampled wells are situated in Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties in Trans Tisza Region (see Fig.1) and in the majority they supply seasonally or permanently operating public baths [1].

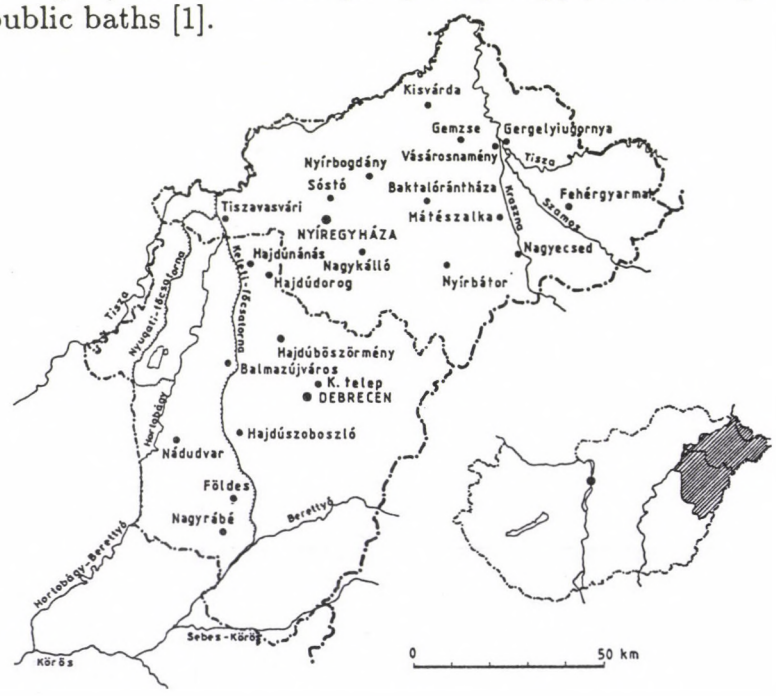

Fig. 1. Geographical location of the thermal wells investigated.

Solid state track detection and energy dispersive x-ray spectrometry were applied for the determination of alpha radioactivity and chemical element concentration, respectively. The same solid tablet of 10 mm in diameter and 1 mm thickness pressed from the dry residue of thermo-evaporated water samples was used for both analysis.

Two pieces of CR-39 type track detector were closely mounted on both sides of the tablets and this sandwich was sealed in a tight radon proof bag during the

time of exposure which was about 100 days. The gross alpha activity concentration of the water sample was deduced from the number of accumulated alpha tracks.

Fe-55 and I-125 sources were used for the x-ray fluorescence analysis, the characteristic lines of the excited elements were measured by a Si(Li) x-ray spectrometer having typically 170 eV energy resolution. The macro and micro element ($Z \geq 14$) concentrations present in the solid tablets were determined by sensitivity calculation method of the QXAS (AXIL) programme. For the determination of trace elements (I, Mo, Fe, Cu, Zn, As, Br, Sr, Hg, Ba) in ppm quantities 16-20 hours measuring time was necessary.

From the first evaluation of the measured data it appeared that the dry mineral residue of half of the samples falls in the range of 1-3 g/l independently of the depth of the aquifer. In the case of water samples originating from 900-1200 m depth the mineral content shows a very wide distribution (1-12 g/l). The measured alpha radioactivity weakly correlates to the dry residue content but the correlation is more evident for Ca and Sr (Fig.2.). As both Ca and Sr are chemically homologue of the radium, this is a strong indication that the gross alpha radioactivity corresponds most probably to Ra-226. Evaluation of the measured data concerning other elements and the geological environment of the thermal wells is in progress.

This work was partly supported by the Hungarian Geological Institute and National Scientific Research Fund, contract No. 3005.

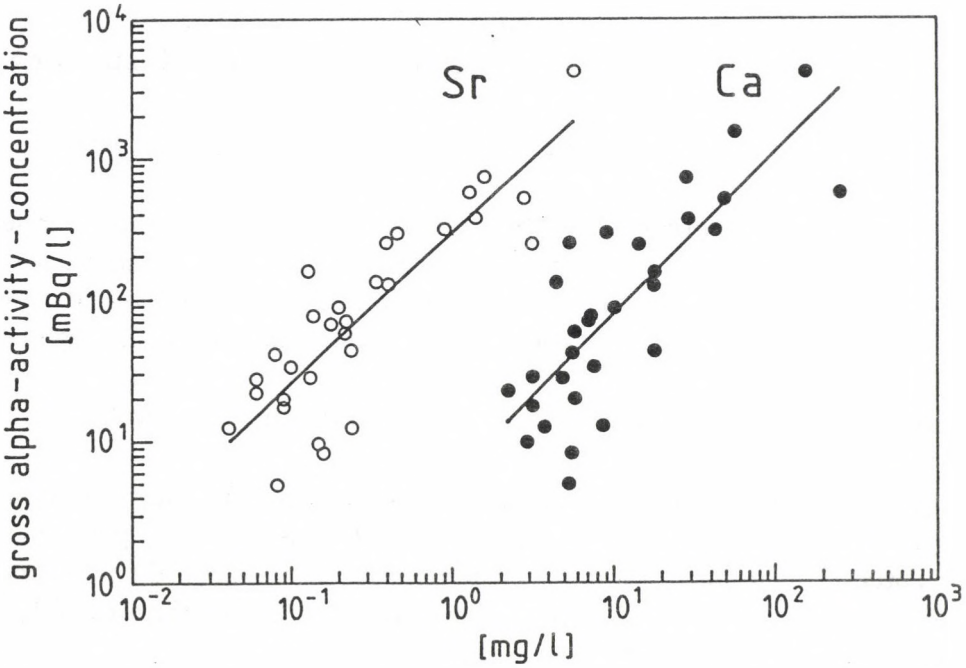

Fig. 2. Correspondence between alpha activity and concentrations of Ra homologues.

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The Origin of Groundwater and Dissolved Ammonium in SE-Hungary by Environmental Isotope Data

J. Deák [1], I.Fórizs [2], É. Deseő [1], E. Hertelendi, M. Veres

The Regional Water Supply of Újkígyós (RWSU), providing 18000 m^3/day of drinking water, was established in 1960's on the alluvial fan of the River Maros, SE-Hungary. The systematic water quality control always resulted high content of NH_4 (average: 2 mg/l) and some chemical components (As, CH_4) exceeding the allowed limit for drinking water.

The stable nitrogen isotope ratio ($\delta^{15}N$) of the ammonium dissolved in the supplied water was measured to determine the origin of the NH_4. There are several potential sources, which could pollute the supplied water by NH_4:

-agricultural activity using artificial fertilizer

-livestock farms

-the waste water of the villages Újkígyós and Szabadkígyós

The natural origin of NH_4 (abyssal or layer) is also possible. The stable nitrogen isotope composition of any nitrogen-bearing material is characteristic for its origin. Based on the literature [1], [2], [3], [4], [5] :

-$\delta^{15}N$ value of the groundwater is about $+7.5‰$ in natural state

-$\delta^{15}N$ value of nitrogen in the shallow groundwater derived from artificial fertilizer is in the range $0 - +2‰$

-$\delta^{15}N$ value of nitrogen derived from livestock farms is in the range $+10 - +20‰$

-the $\delta^{15}N$ value of nitrogen of the shallow groundwater under settlements varies greatly, because that water is a mixture of precipitation and waste water, and both waters may contain nitrogen from different sources (household, livestock, artificial fertilizer, etc.), and the ratio of mixing determines the nitrogen isotope composition.

-the nitrogen isotope composition of surface water matches well with that of the shallow groundwater of this surroundings.

The groundwater of the strata deeper than 80 m is very old. It derives from the precipitation fallen at foreland of mountains 25–30 thousand years ago. This water is protected, therefore we can exclude the surface origin of the ammonium. The mean of $\delta^{15}N$ values is $+5‰$, which confirms the layer origin of NH_4 with a possible contribution of some abyssal NH_2 or N_2.

The groundwater from the main aquifer (18-80 m) is also very old, but probably because of the exploitation, some shallow, uncontaminated groundwater mixed to it. The $\delta^{15}N$ value in the main aquifer is $+7\pm1‰$, which differs from the values measured in the shallow groundwater of areas, where artificial fertilizers have been used ($+1 - +4‰$), and of areas, which are contaminated by waste water of villages or of livestock farms ($+10 - +25‰$).

The tritium content of water from the wells exploiting the 18-80 m depth region is under the detection limit (1 TU) with two exceptions (WS-6 and WS-7), where they are 1.9 TU and 2.8 TU. Hence the 1 TU detection limit corresponds to about 40 year water age, the precipitation fallen during the latest 40 years is not detectable in most of the wells. The agriculture has been using the artificial fertilizers for 30 years only. By this way the dissolved NH_4 could not originate from artificial fertilizers.

In the two wells, where tritium content is detectable, the $\delta^{15}N$ is $+7.8‰$, which is a little bit more positive than in the other wells ($+7‰$) and may indicate a contribution of organic nitrogen of little amount (Fig.1.). This could be demonstrated by systematic tritium and stable nitrogen measurement. In these two wells the electric conductivity is also higher (730 μS/cm) than in the other wells (average 624 μS/cm). In accordance with the stable isotopes, this positive shift can also indicate a contribution of some surface water, where the electric conductivity is more than thousand μS/cm.

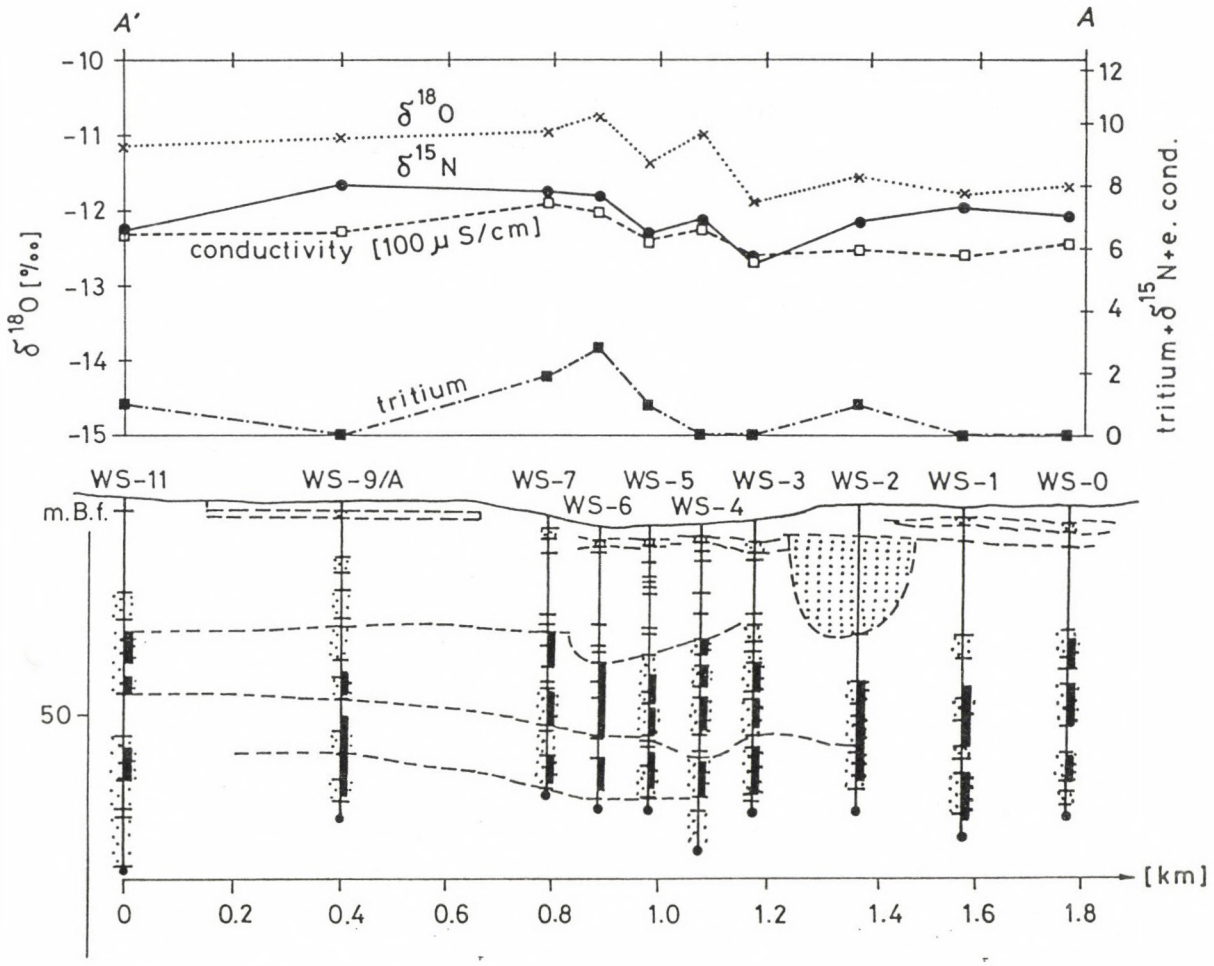

Fig.1. Cross section through the wells of RWSU and some isotopic and chemical composition of the supplied water.

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The vulnerability to pollution of the Debrecen Waterworks

E. Hertelendi, M. Veres, L. Mikó [1], L. Marton [1]

The Debrecen Waterworks has four fields (see Fig.1.) using groundwater from Lover Pleistocene aquifers. It has been generally accepted that the water resources in the Lower Pleistocene aquifers at the depth of $160-180$ m are protected against contaminants being overlain by thick layers of silt and silty clay aquitards of low permeability. However, radiocarbon measurements of groundwaters in the Field II. show that the major aquifer of this field is not protected against pollution from the surface. The radiocarbon ages along the cross section (see Fig.1.) are decreasing in the direction of the main flow. ^{14}C activities of samples from aquifer 3 and taken from wells number 22a, 8 and 30 are 28.15 pmc, 28.10 pmc and 24.13 pmc respectively (code 664, 668 and 663). The computed ages are 7500, 8100 and 8600 years respectively. This may be interpreted as a result of a leakage from aquifer 2 to aquifer 3. Radiocarbon activities in aquifer 2 are 42.3 and 39.58 pmc which result in ages of 3700 and 4200 years (code 667 and 673). The water production in the Field II. started in 1953. Radiocarbon results show that water masses from aquifer 2 moving vertically could have reached aquifer 3 during the last 40 years. Considering this fact carried out hydrodinamical calculations which show that contamination from the surface can reach the major aquifer within 100 years. The situation is even more hazardous in the case of shallower wells drilled in the territory of the Pharmaceutical Factory BIOGAL in Field II. These wells were deepened into the aquifers 1 and 2, where vertical travel times are much shorter than discussed above [1].

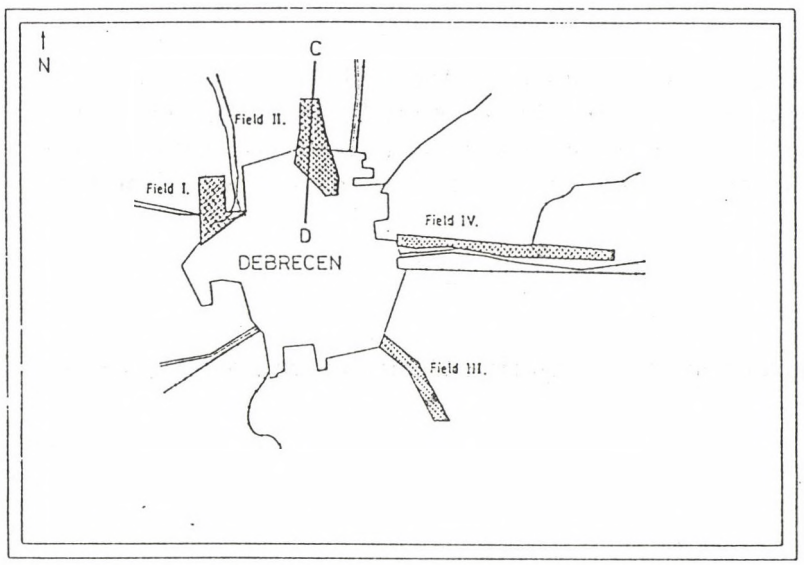

Fig.1. Location of the Debrecen Waterworks with four fields and the position of the C-D section.

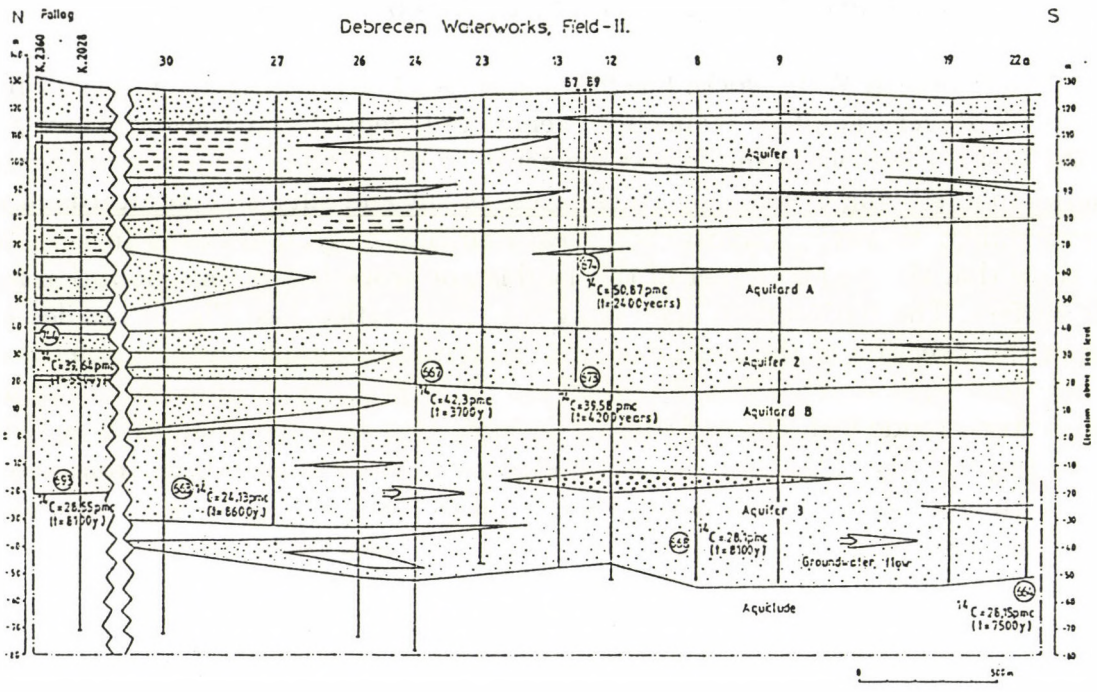

Fig.2. Geological profile (C-D section) set trough Field-II with the location of water production wells.

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[1] Regional Geological Service, Hungarian Geological Survey, Debrecen

BIOLOGICAL

AND

MEDICAL RESEARCH

Production and Radiochemical Separation of ^{45}Ti for Biomedical Studies

I. Mahunka, P. Mikecz, T. Ido*, M. Kawamura*, L. Andó, Z. Kovács
* Tohoku University, Sendai 980, Japan

The role of the trace elements especially of the essential elements is very important from different aspects of human life [1]. The number of the essential elements is growing, because the biological importance of some new trace elements is verified. Nowadays it is uncertain weather titanium is an essential trace element. The titanium has a ^{45}Ti positron emitter radioisotope, which can be produced with small cyclotrons and it has proper nuclear data for the application of nuclear tracer technique in the human PET studies too.

Taking into consideration the importance and producibility of ^{45}Ti we decided to elaborate an improved method for its production and radiochemical separation at our cyclotron laboratory. This work has been performed in cooperation with the Tohoku University (Sendai, Japan), which has already experiences in this field [2].

The ^{45}Ti was produced via the ^{45}Sc(p,n)^{45}Ti reaction. At the irradiation of thin scandium foil (thickness: 250 μm, purity: 99.9%) with 11.5 MeV proton beam the measured yield was (9.3 $\pm$ 0.9)mCi/μAh in good agreement with the results of Ishiwata et. al. [2]. In our later experiments we increased the bombarding energy up to E_p = 14.5 MeV to produce simultaneously the ^{44}Sc via the ^{45}Sc(p,pn)^{44}Sc (Q = -11.3 MeV) reaction. The ^{44}Sc radioisotope was used for the quality control of the radiochemical separation. The measured yield at this energy was (10.0 $\pm$ 1.0)mCi/μAh.

An improved method was also elaborated for the radiochemical separation of ^{45}Ti from the target material. The separation took place on a freshly prepared DOWEX 50 WX 2 ionexchange column (100 - 200 mesh, 1 cm i.d. x 16 cm). The irradiated target (≈500 mg) was dissolved in 6 M HCl and after oxidation it was loaded onto the column. The titanium was then eluted with 6 M HCl, while the scandium was removed with 4 M HCl containing 0.1 M HF. This procedure required less than 2 hours and had a yield of (75 $\pm$ 10) %. The scandium content of the no carrier added ^{45}Ti fraction was lower than 0.1 mg. On the basis of our preliminary results this method is giving a higher purity at the separation, which is controlled by gamma-line measurement of the radioisotopes of titanium and scandium.

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Excitation Function and Thick Target Yields for ^{123}I Production

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The cyclotron-produced ^{123}I is regarded as one of the most suitable radionuclide for SPECT studies. Considering the importance of ^{123}I, different methods have been investigated for its production [1].

In our earlier work [2] a method was elaborated to obtain highly enriched ^{123}Te (95.6%). Using this target material the optimum conditions for production have been investigated and some disagreement was found between the measured and calculated yield values. In these calculations, the cross section data of Scholten et al. [3] were used. To clear the discrepancy, we remeasured the excitation function of ^{123}Te(p,n)^{123}I reaction up to 18 MeV proton energy by using the conventional stacked-foil technique. The measured cross section data in comparison with the data of Sholten et al. [3] are shown in Fig. 1.

To evaluate the most practical and economical ^{123}I production parameters, thick target yields on $^{123}TeO_2$ targets (100 % ^{123}Te enrichement) were calculated at different target thicknesses as a function of the bombarding proton energy. The results are shown in Fig. 2.

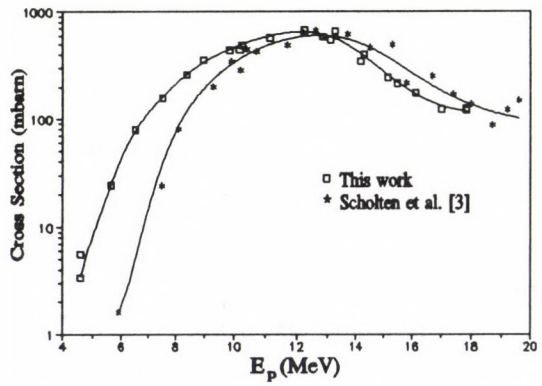

Fig.1.: Excitation functions of ^{123}Te(p,n)^{123}I reaction

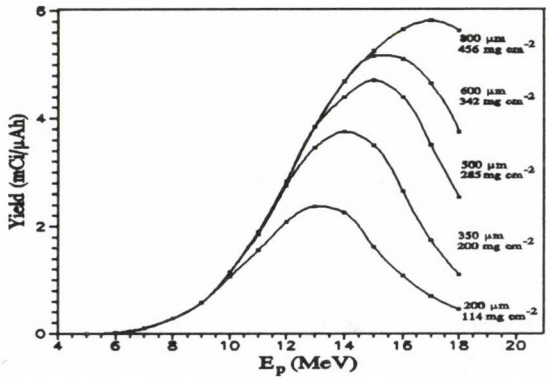

Fig.2.: Yields for ^{123}I production on $^{123}TeO_2$ thick targets

Comparing our cross section data to the results of Scholten et al. [3], there is a good agreement as for the maximum value of the cross section, but our excitation function is shifted to the lower energy direction about 1 MeV (Fig.1.). This shift explains the discrepancy between the measured and calculated yields of ^{123}I, and makes even more favourable the use of direct production method at small cyclotrons.

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DEVELOPMENT OF METHODS

AND

INSTRUMENTS

Gas Injection with Switching Mode Controlled Membrane Valve

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In the experiments on ion–source development the excellent reproducibility of gas–flow is essential. A traditional combination of needle valve and a gas–flow meter as a solution assures very slow regulation, and it requires manual adjustment.

Instead of manual control, we applied a Balzers–made membran valve, and made it operate in switching mode, unlike usual analogous regulation [1]. We have designed two versions. In the first one we influence the gas–flow by the frequency and width of a pulse train. This can be useful in a very wide range. The other case is offered for lower gas–flows, controlling the valve by the width of a single pulse. The fluctuation of gas–flow due to the switching mode operation, is smoothed by a capillary, connected in series with the valve and a dead zone of a Pirani–probe.

The electronic circuits regulating the valve, consist of a single CMOS IC (CD 4093) and a couple of transistors. They are conrolled by TTL–level of SWITCH I. output of a PIRANI VACUUM GAUGE NX–10, made by our institute.

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ATOMKI Közl. vol. 23. 1981. p42

Building the Institute's local Ethernet network

Zs. Dombrádi and G. Székely

The demand for a local area network (LAN) in the Institute has been arisen in the end of the 80-ies. The old PDP-11/40 host computer became obsolete, more and more PC-s were installed, and the users wanted to communicate with their colleagues throughout the world. They wanted also to reach powerful computers and other services, like scientific libraries and databases or high quality printing.

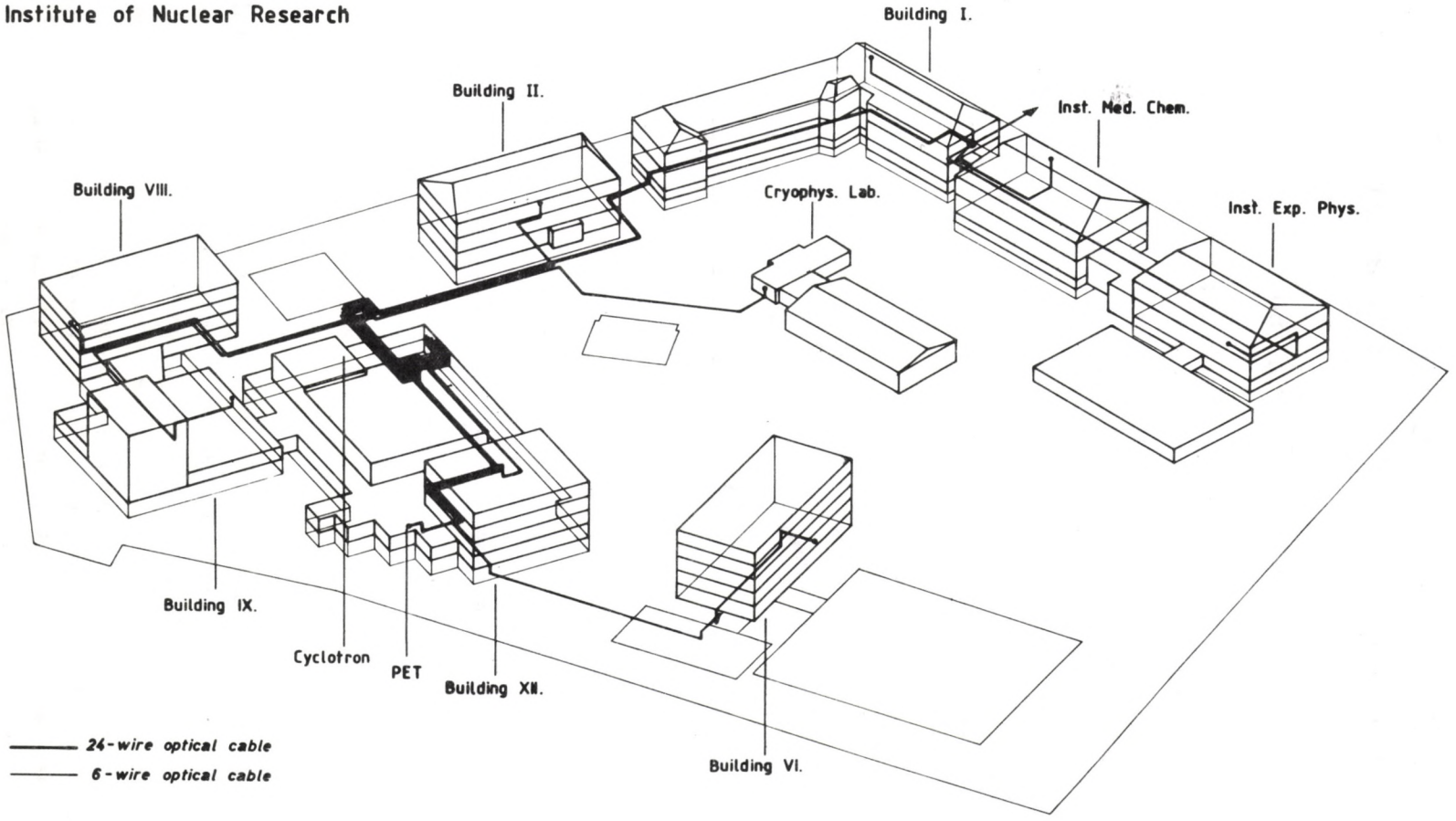
The first historical step happened in the spring of 1991, when a single thin Ethernet segment was installed in building VIII. Later on it was extended with two other segments connected through a 4-port repeater and a separate new segment was installed in building I. To provide funds for the extension of the network we have played an active role in preparing an application and later a bid for a metropolitan area network (MAN), connecting the members of the Universitas of Debrecen, and for building the backbones of LAN-s of the member institutions. Now, after the bidding procedure, we have a rather clear plan for our LAN.

The optical backbone of the Institute will have a star topology, shown in the figure. It will be connected to the mono-mode FDDI ring of the Universitas in room 001 of building I. A *Cisco AGS+* router will be the communication server, placed in the Cyclotron Laboratory. From the Ethernet ports of the router 6-fibres optical cables will run to each building. The sharing of the ports will be solved with *Cabletron* opto-repeaters. At the end of the optical cables generally a *Cabletron* repeater will be placed, which is able to connect the optical cable to several coaxial segments. We plan to use their ports on a one segment per level basis. The network will be manageable down to repeater port level using *SunNet* manager.

The repeaters will be placed in the following rooms: 107/I, 019/II, 001/VIII, 123/IX, 110/VI, 114/XII. Separate optical cables will go to the room 114 of Department of Experimental Physics, to the reading room of Department of Medical Chemistry and to the Cryophysics Laboratory. The last endpoint will contain an opto-transciever instead of repeater, which allows to connect one coaxial segment. Possibility for connecting the positron tomograph (PET) to the network will also be provided. The coaxial cabling will be carried out by the Institute's workers, the optical cabling, the purchase and installation of the network devices will be made by *Optotrans Ltd.* They will help to do a first setup and tuning of our LAN.

A *Sun SPARCserver 10*, to be placed in the Cyclotron Laboratory, will provide network services such as remote login, file transfer, electronic mail in addition to NFS. The basic protocol supported on the backbone will be the TCP/IP. DECNET will be available through the MicroVAX in building VIII. The Novell network in building I will be able to access the server through an IPX-TCP/IP gateway. The international services of Internet will be used through the national IP backbone. Until the realization of the Universitas ring, it will be accessed through our X.25 line. The Internet domain name of the Institute is: **atomki.uni-deb.hu.**

Optical backbone of the
Institute of Nuclear Research



A New Type of Electrostatic Electron Analyzer with Cylindrical Symmetry

I. Rajta, K. Tőkési and D. Varga

The calculated electron optical properties of a new mirror type analyzer with distorted cylindrical field are presented here. The aim of the design of the analyzer was to provide a device to measure the energy distribution of electrons simultaneously at different angles, in the full azimuthal angular range (like the ESA-21 electron spectrometer [1].)

The analyzer consists of two cylindrical symmetric parts, the house of the analyzer and the inner cylinder are at ground potential while the focussing outer cylinders with conical ends are at negative potentials (see the Fig. 1).

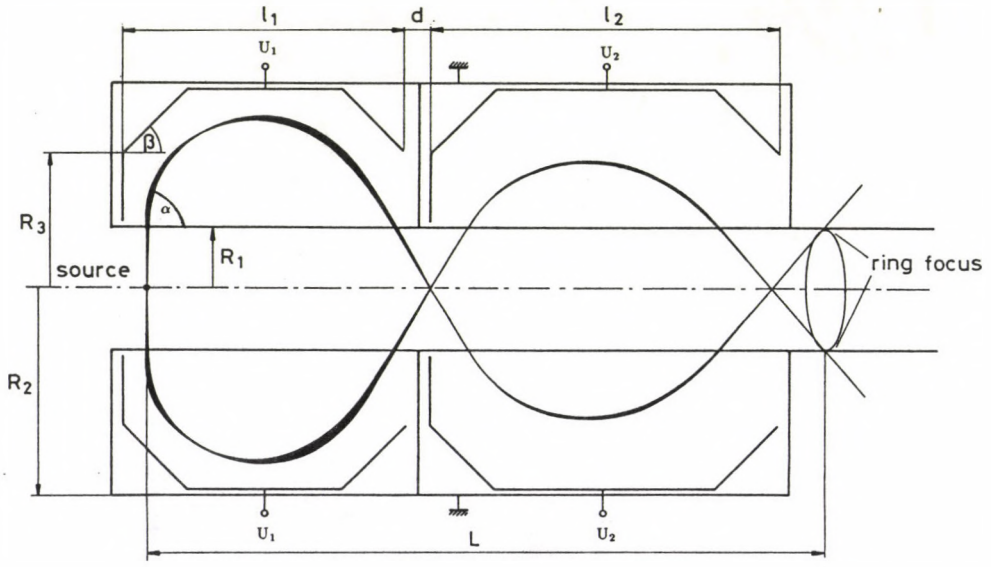


Fig. 1. Schematic cross section of the calculated electrostatic analyzer with several electron trajectories around 90^0 entrance angle

In Fig. 1. L is the distance between the point source and the focal ring. L is dependent on the entrance angle (α) of the electrons with respect to the spectrometer axis (the medium value of α was chosen to be $\alpha_0 = 90^0$). The $L(\alpha)$ curve characterizes the focussing properties. The results of the numerical potential and trajectories calculations are shown in Fig. 2 and Table 1.

Figure 2. shows that the new system has a second order focus near $\alpha_0 = 90^0$ (see the curve with n=0.905, where n is the spectrometer constant, $n = U/E$ with U as the focussing voltage and E as the electron energy).

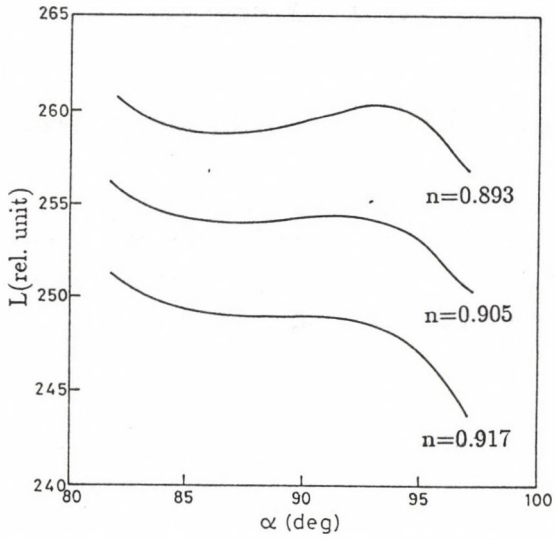


Fig. 2. The focal length (L;point source - ring focus) as a function of the entrance angle of the electron trajectories at different spectrometer constant. $n = U/E$ where U is the focussing voltage and E is the electron energy.

The calculated relative energy dispersion of the new analyzer is considerably higher than that of the several type of analyzers designed previously, as it can be seen from the data in Table 1.

Table 1. Relative energy dispersion of the different type electrostatic spectrometers

Type of the spectrometer	$D_r = \frac{E\Delta L}{L\Delta E}$
Classical CMA[2]	0.914
Distorted field DCMA (ESA-13)[3]	1.202
SM-DCMA (ESA-21)[1]	0.983
present analyzer	1.505

We have managed to design a double pass electron spectrometer with a ring focus, appropriate for measuring energy and angular distribution of the electrons simultaneously. Its dispersion is higher and the mechanical construction is simpler, than in the case of previous designs.

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Installation of a Split-Pole Magnetic Spectrograph in Debrecen

A. Krasznahorkay, S. Török and L. Félegyházi

It is well known that a magnetic spectrograph is a basic tool in cyclotron laboratories. At the end of 1991 Prof. M.N. Harakeh (Vrije Universiteit, Amsterdam, The Netherlands) offered us a Scanditronix Split-Pole magnetic spectrograph as a present. The main characteristics of the spectrograph are the following:

The K value ($E_{MAX} = KZ^2/A$) :	K=80
Maximal solid angle:	$\Delta\Omega$ = 5.4 msr
Used solid angle:	$\Delta\Omega$ = 2 msr
Angle of the focal plane:	45°
Length of the focal plane:	120 cm
Bending radius:	40-90 cm
Energy region:	E_{max}/E_{min} = 4.8
Horizontal magnification:	0.34
Vertical magnification:	1.7-3.3
Dispersion:	10mm/%
Energy resolution:	ΔE/E = 6x10^{-4}

According to the above parameters and the possibilities available at our institute, we have got a green light for the installation of the spectrograph. The cost of dismantling and transportation was covered by the Dutch Ministry of Education with the kind help of Dr. S.Y. van der Werf (K.V.I. Groningen, The Netherlands). The installation in Debrecen was supported by the Hungarian National Science and Research Foundation (OTKA).

The spectrograph arrived at our institute on September 23 1992. The mechanical installation at our cyclotron was finished in November 1992 with an extensive help of Prof. H.P. Blok and L. Mars (Vrije Universiteit, Amsterdam, The Netherlands). A schematic lay-out of the spectrograph and beam channels can be seen in Fig. 1.

The power supply, NMR magnetic field meter, vacuum system, target chamber with the sliding-seel, the Si position sensitive detectors and related electronics were already checked. The first test measurements with the spectrograph will be carried out at the beginning of 1993.

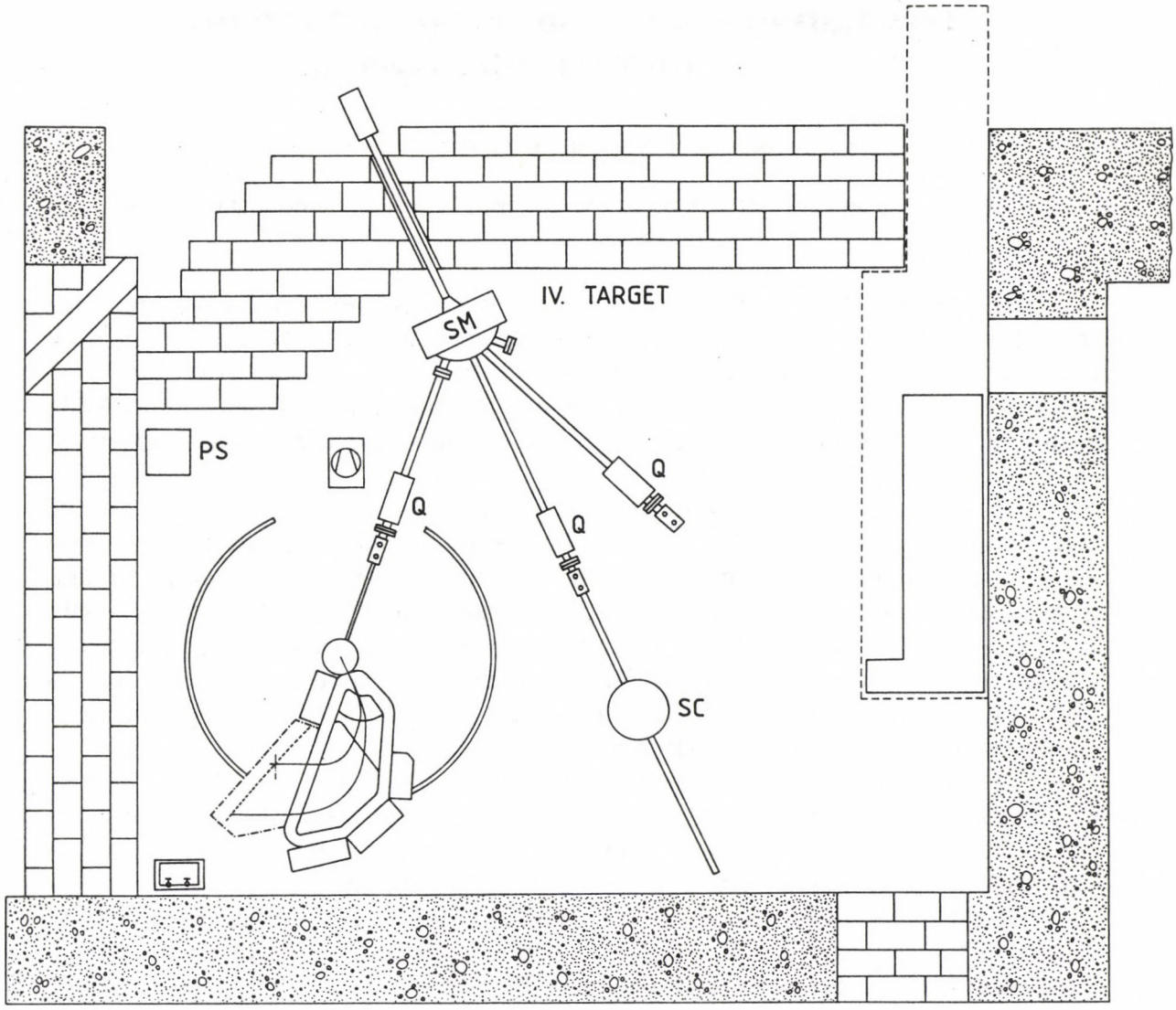

Fig. 1. Schematic layout of the split-pole spectrograph at the 45° analyzed beam line of the 103 cm cyclotron; switching magnet (SM), power supply of the spectrograph (PS), quadrupole doublets (Q), scattering chamber (SC).

Irradiation studies on integrated circuits for the FERMI microsystem

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The FERMI digital Front-End and Readout MIcrosystem for detectors for the future LHC experiments at CERN is under development within the framework of the RD-16 project [1]. The microsystem will be fabricated using the Silicon on Silicon technique with bipolar type process for the analog and 1 μm CMOS technology for the digital part. The system must withstand the radiation expected over its life time.

The neutron flux and gamma dose calculations by Ferrari et al. [2] for the calorimeter region of the LHC detector EAGLE (now ATLAS) show, that the most exposed region is the end cap zone. In these calculations the expected annual gamma dose is 10^3 Gy and the neutron flux is assumed to be 10^{14} n/cm^2*year with an exposure time of 10^7 sec/year. The energy spectrum of the neutrons peaks around 1 MeV. The intense environmental gamma and neutron radiation field as well as the gamma radiation of the neutron activated package itself might result in radiation damage of the FERMI chip.

These processes can be studied using 1.173 MeV and 1.332 MeV photons emitted by a ^{60}Co gamma source and neutrons from a ^{9}Be target bombarded by 18 MeV protons. The neutron spectrum has its maximum intensity around 1 MeV, it is extended up to 18 MeV and the average neutron energy is 3.7 MeV.

CMOS production test circuits (manufactured by AMS, Austria) containing a set of FET transistors with different characteristics and a ring oscillator with a fixed frequency of 28.869 MHz were irradiated at the intense ^{60}Co gamma source and at the p(18 MeV) + ^{9}Be cyclotron neutron source at ATOMKI.

The gamma dose dependence of the frequency of the ring oscillator is shown in fig. 1. Effects of recombination processes at room temperature and at 120 °C after the irradiation are also presented in fig. 1. A test irradiation with 2.4x10^{13} n/cm^2 was also made on 3 pieces of these type of IC's for a period of approximately 3 hours. The oscillator frequency dropped by 5 % at these neutron doses. [3]

The neutron activation of these integrated circuits as well as 6 different packages with their silicone chips (table I) (planned to use for the FERMI IC, obtained from IMM Linköping, Sweden) were also investigated. The found isotopes and their estimated activities after one year (continuous run of 10^7 sec/year) irradiation with 10^{14} n/cm^2 for the 6 different packages and a bare chip of IC5 are shown in table II. As a simple estimation for IC5 , if one assumes that one third of the energy of each decay (with mean energy of 6 MeV) is absorbed in the silicone chip (10 gramms), the contribution from the activation of the IC to the above mentioned yearly environmental gamma dose is about 10 % [4].

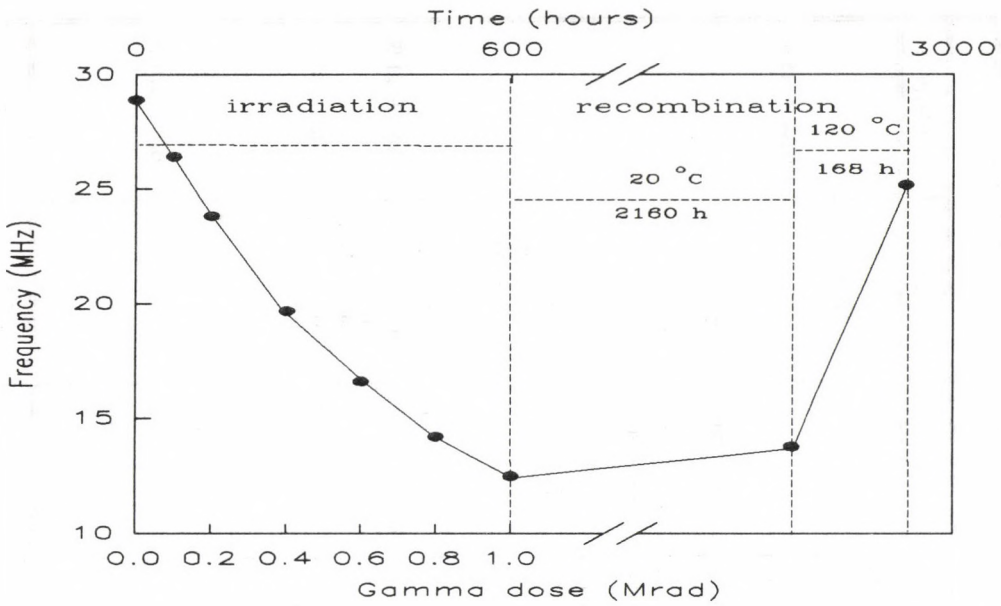

Figure 1 Gamma dose dependence of frequency of the ringoscillator of the CMOS test IC (obtained from AMS, Austria) and post irradiation effects at room temperature and at 120 ^{0}C.

Table I Main characteristic data of the irradiated packages obtained from IMM Linköping (Sweden).

Sample code	Size (mm^2)	No. and type of connections	Main construction materials
IC1	31 x 31	84 connectors	epoxy case Si, Sn, Cu
IC2	31 x 31	84 connectors	epoxy, Au, Si silica gel coatings glass fibre PC board
IC3	31 x 31	84 connectors	epoxy, Au, Si epoxy soft coatings glass fibre PC board
IC2-3	31 x 31	84 connectors	same as IC2 and IC3 without coating glass fibre PC board
IC4	37 x 37	92 pins	polyamid, Kovar, Au, Si, Al
IC5	53 x 53	144 pins	ceramic case, Kovar, Au
CHIP	31 x 31		bare chip of IC5

Table II Found isotopes and their estimated activities after one year (continuous run of 10^7 sec/year) irradiation with 10^{14} neutron/cm^2 for packages obtained from IMM Linköping, Sweden.

Isotope	$T_{1/2}$	Activity (Bq)						
		IC1	IC2	IC3	IC2-3	IC4	IC5	CHIP
^{106m}Ag	8.5 d	151 +-28 %	121 +-31 %	135 +-25 %	125 +-29 %	98 +-21 %	97 +-25 %	
^{110m}Ag	249.9 d	82 +-26 %	69 +-31 %	57 +-31 %	69 +-37 %	53 +-34 %	53 +-30 %	
^{112}Ag	3.14 h		116 +-15 %					
^{28}Al	2.31 m							189444 +-15 %
^{29}Al	6.56 m	1400 +-14 %			289 +-13 %			
^{76}As	1.1 d				4.5 +-60 %			
^{196}Au	6.18 d	32 +-18 %	81 +-14 %	72 +-14 %	66 +-18 %	107 +-20 %	388 +-14 %	
^{196n}Au	9.7 h			3.4 +-55 %	4.2 +-65 %			
^{198}Au	2.697 d	223 +-13 %	798 +-12 %	663 +-11 %	661 +-12 %	962 +-14 %	2926 +-15 %	
^{199}Au	3.15 d	35 +-16 %	9.2 +-33 %		6.6 +-46 %	195 +-26 %		
^{80}Br	17.6 m		5234 +-13 %					
^{82}Br	1.47 d	214 +-23 %	630 +-13 %	529 +-11 %	521 +-18 %	639 +-21 %		
^{57}Co	271.77 d		25 +-41 %	22 +-46 %		122 +-26 %	217 +-26 %	
^{58}Co	70.78 d		465 +-23 %	379 +-17 %	384 +-16 %	2853 +-19 %	3339 +-46 %	
^{60}Co	5.269 y	40 +-37 %	12 +-61 %	14 +-61 %		167 +-24 %	18 +-56 %	
^{62m}Co	13.91 m	26 +-20 %						
^{64}Cu	12.71 h	8570 +-11 %	975 +-14 %	853 +-14 %	815 +-20 %			
^{59}Fe	45.1 d					105 +-21 %	8.7 +-56 %	
^{27}Mg	9.46 m	197 +-11 %	487 +-11 %	295 +-11 %	482 +-12 %	12994 +-11 %	96023 +-12 %	106 +-21 %
^{56}Mn	2.576 h		4 +-60 %	3 +-65 %	3 +-65 %	626 +-13 %	505 +-13 %	
^{99}Mo	2.78 d						544 +-20 %	
^{24}Na	15.06 h	15 +-30 %	218 +-11 %	217 +-11 %	219 +-11 %	5341 +-11 %	40845 +-11 %	16 +-14 %
^{57}Ni	1.5 d		3 +-58 %	4 +-65 %	2.9 +-65 %	9.1 +-40 %	317 +-12 %	
^{65}Ni	2.52 h	176 +-12 %	20 +-25 %	17 +-35 %	20 +-30 %			
^{120m}Sb	5.8 d	38 +-20 %						
^{122}Sb	2.70 d	517 +-18 %						
^{124}Sb	60.2 d	177 +-40 %						
^{48}Sc	1.82 d	5.9 +-45 %	3.5 +-54 %	3.6 +-60 %	2.6 +-70 %			0.8 +-120 %
^{117m}Sn	14 d	72 +-27 %			3.5 +-60 %			
^{123}Sn	129.2 d				125 +-29 %			
^{125}Sn	9.62 d		75 +-27 %		69 +-37 %			
^{187}W	23.9 h						4350 +-15 %	
	Sum:	12 kBq	9.5 kBq	3.5 kBq	4 kBq	25 kBq	150 kBq	190 kBq

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Automated Production of Sterile ^{67}Ga-citrate and Na^{123}I

Z. Kovács, P. Mikecz, Z. Szűcs, I. Dombi

The purpose of this work was to develop automatic computer controlled systems for the production of medium lived radioisotopes and the following preparation of radiopharmaceuticals, for laboratories having small cyclotrons. These methods fulfil the demands of the local medical community in which a regular supply is required in a few GBq/week. Both the ^{67}Ga and ^{123}I are produced by (p,n) reaction from enriched ^{67}Zn and ^{123}Te.

The apparatuses are based on improved procedure of our previously described methods [1]. The ^{67}Ga was separated from the target by cation exchange method, while the ^{123}I by dry distillation. The block diagram of the $^{67}GaCl_3$ intermedier and ^{67}Ga-citrate pharmaceutical production is shown in Fig.1 and the sheme of the apparatus for ^{123}I production is shown in Fig. 2.

The automated systems are equipped with different sensors and detectors which permanently control the correct functions during the whole procedure. All the parameters (radioactivities, flow rates, temperatures, fraction volumes etc.) are stored for later control. New automatic system was also developed for the sterile dispensing of ^{67}Ga-citrate and Na^{123}I, according to the GMP.

These systems are able to handle all similar procedures based on ion exchange and dry distillation methods.

This work was supported by National Technical Development Fund (OMFB No 9197-07-0932).

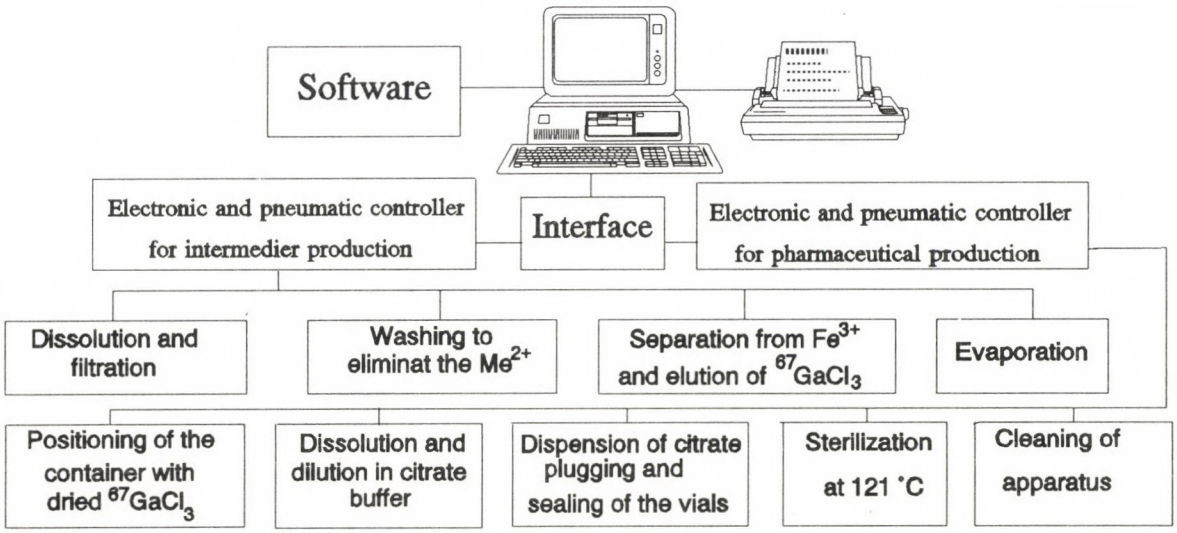

Fig. 1. The block scheme of automated ^{67}Ga-citrate production

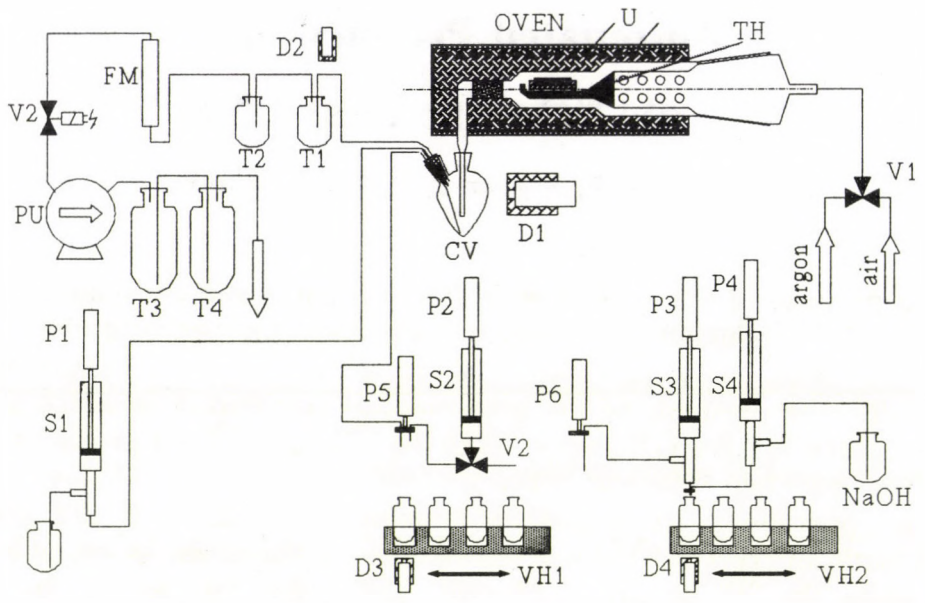

Fig.2. Automated separation of ^{123}I from tellurium dioxide and dispension of the $Na^{123}I$ solution

(legend: V valves; VH vial holders; TH targetholder; U Heating voltage; CV collecting vial; D detectors; S syringes; T iodine traps; FM flowmeter; PU pump; P pneumatic cilinders;)

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Development of multichannel data acquisition system for simultaneous measurement of radiation and analytical data during syntheses of radiopharmaceuticals

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The installation of a Positron Emission Tomograph (PET) in our laboratory in the near future requires elaboration of syntheses of some basic precursors and radiopharmaceuticals.

In this process a multichannel data acquisition system of digital and analogue signals which simultaneously controls the radioactive and inactive compounds at different phases of the synthesis is very informative. It is useful especially in such cases when control of intermediates and products has to be carried out by high performance liquid chromatography (HPLC) or gas chromatography (GC) during the synthesis. The simultaneous monitoring of the radioactivity data from different phases of the process and the analysis data makes the optimization of radiopharmaceutical production easier. The immediate control of the effect of modification of the production parameters give valuable information about the quality of the final product during routine production runs. This, of course, cannot replace the quality control but reports on the run of synthesis which is particularly important at short lived isotopes used in PET investigations.

The arrangement of the measurement is shown in Fig.1.

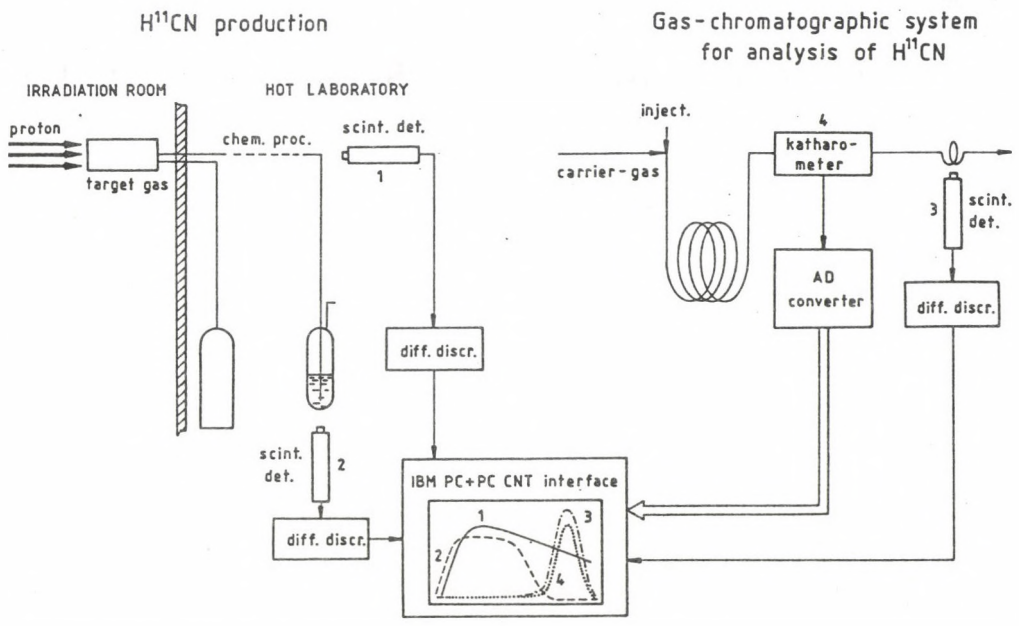

Fig 1. Multichannel data acquisition system

The multichannel data acquisition system,which was developed in ATOMKI for monitoring of the $H^{11}CN$ intermediate production [1] recently, handles four independent channels (one 32 bits counter, two 16 bits counters and one 16 bits digital input). The software acquires data from each channels simultaneously and makes possible the real time appearance of the time depending content of the individual channels as curves on the graphic-screen. The registered data are stored in Nucleus file form at the end of measurement.

The radioactivity of the $^{11}CH_4$ produced, coming up from target through a stainless steel tube of 35 m length and 2,4 mm i.d., is registered by channel 1. Tubes with smaller diameter, which would give smaller dead volume, showed narrow retention peak (at O,9 i.d. approx. 3 min) which makes the conversion worse over the Pt catalyzer.

The trapping of the $H^{11}CN$ is followed by channel 2. It helped to optimize the conversion and absorption circumstances like gas flow rates, temperature, form of the vessel, height of absorber solution etc.

Channel 3. and 4. receive the signals from HPLC or GC. Channel 3. measures the radioactive peaks, while 4. monitors the digitalized analogue signals of inactive compounds coming from ultra-violet or thermal-conductivity detectors through a 10 bits ADC (analogue - digital converter).

In the case of $H^{11}CN$ production up to three gas samples can be taken and analyzed with GC which gives information about the condition of the Pt catalyzer during the conversion. The software makes the start of subsequent analysis possible during the whole run by different markers.

This set up will be extended to measure more channels simultaneously which is required at more complicated syntheses.

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Optimization of the Irradiation Geometry for Nuclear Wear Measurement of Superhard Turning Tools

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Thin Layer Activation (TLA) technique is a useful method in the measurement and monitoring of the wear of superhard turning tools [1,2]. On the basis of our earlier work [3,4,5] it was concluded that the method should be improved to fulfill the following demands emerging in industrial conditions:

- higher accuracy;
- maximal sensitivity should be adjustable to different stages of the wear process;
- measuring interval should be changeable.

To fulfill these demands the possible optimization of the irradiation geometry was investigated. For this purpose we studied the geometrical parameters of the volume of the cutting edge lost due to the wear. We have found, that the wear land is not normal to the main axis of the tool, but it is sloped to the normal surface approximately under 20^{o}. It means, that the boundary of the activated area must be the same, as the wear land at the end of the lifetime of the tool.

The uncertainty of nuclear data and the unknown composition and density of the activated material give considerable error to the wear measurement. It would be preferable to "drop out" these sources of error. This is possible founding an irradiation geometry, where the activity distribution is uniform in the direction of the wear. This condition can be achieved, if the direction of the irradiation is perpendicular to the wear direction.

Due to the considerations described above we irradiated the tools from the top side. The tool to be irradiated was placed behind a mask. In such a way we could expose to the beam only that part of the cutting edge, which will be worn during the turning. This mask allows an adjustment of the interval of wear measurement by changing the size of the part of the tool exposed to the ion beam. (h: height of the part of the cutting edge, not covered by the mask; see Fig.1.) Using this irradiation geometry one can calculate the calibration (wear-activity) curve (see Fig.2.). For this purpose the ratio of the projection of lost volume onto the irradiated surface to the whole irradiated surface must be calculated.

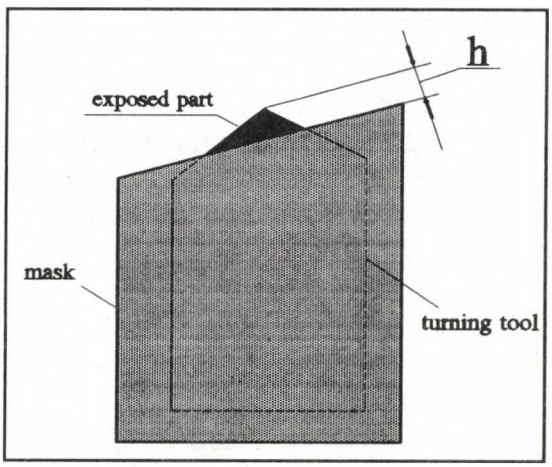

Fig.1.: Position of the tool behind the mask

In Fig.2., some calculated calibration curves for different sizes of irradiated surface (h), and a measured one are shown, with a good agreement between them.

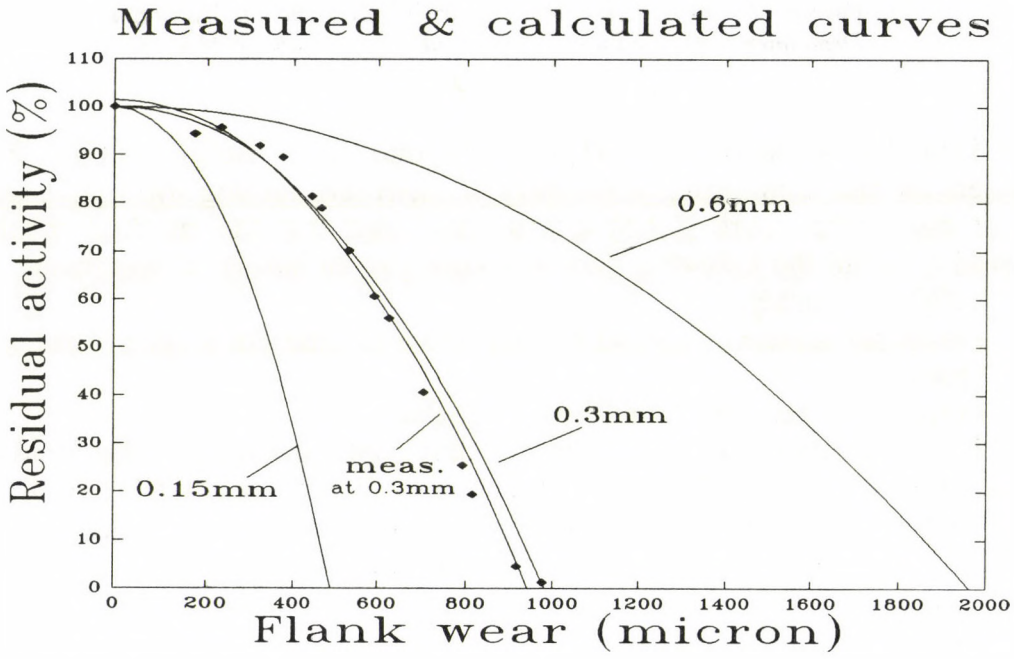

Fig.2.: Measured and calculated calibration curves for tool made of artificial diamond at different h values

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Mass spectrometric monitoring of PAA and POAA in penicillin fermentation

I.Futó, S.Bohátka, M. Simon and J. Szilágyi

Mass spectrometry has gained an increasing role in fermentation monitoring. For the measurement of gases of low molecular weight (M≤64u) a complex system has been used in pilot and large-scale plants [1]. A larger range of components (volatiles and nonvolatiles) in fermentation liquids can be measured if suitable sampling methods are invented and higher mass range is covered by the MS. Such a sampling unit and method were developed for the measurement of phenylacetic (PAA) and phenoxyacetic acids (POAA).

A quadrupole MS of medium mass range (Q300-PC, ATOMKI) was a necessity. The success of the measurement depends critically on the properties of the membrane interfacing the aqueous solution and the QMS. The interface is a sheet silicone rubber membrane (type: Dow Corning Silastic Medical grade) and it is located just next to the closed ion source to avoid undesired desorption of the sample material on the surfaces in vacuum, the phenomenon which is responsible for the attenuation of the signal and the increase of response time (Fig.1). It is possible to monitor dinamic processes by continuously flushing the membrane with fermentation liquid. Heating of the sampling unit and tubes as well as the acidification of the sample are substantial requiremens. Optimal temperature was 55-60 °C, pH=1.

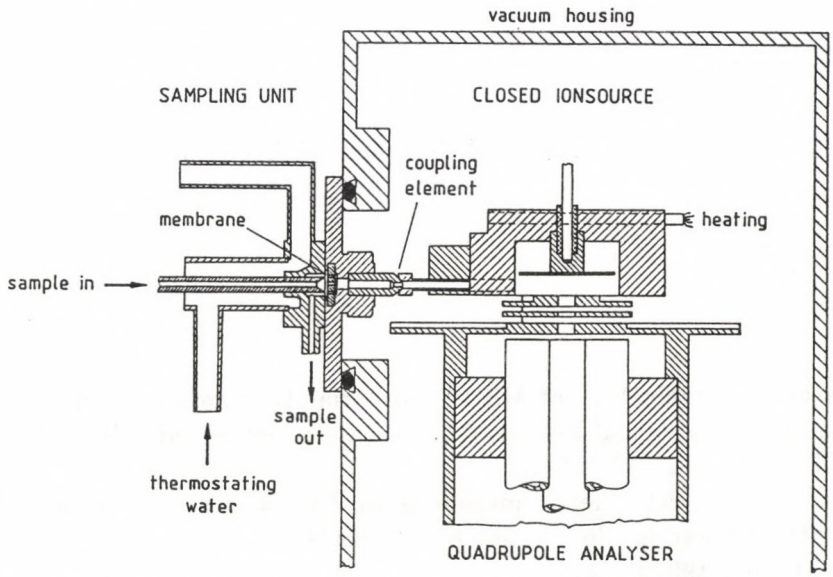

Fig. 1. Sampling unit for the measurement of PAA and POAA.

The Q300 PC response at 136u and 152u (molecular weights of PAA and POAA) were calibrated using standard solutions. In both cases the relationship

in the range of 0.2 - 14 mMol were linear (Fig.2). When unknown samples were analysed, known quantities of PAA and POAA solutions were added to the filtered fermentation broth (pH=1) and the response was also linear. Other components of the fermentation liquid did not disturb the measurement in this range. The detection limits were found to be 0.2 mMol of PAA and 0.7 Mmol of POAA with Faraday cup detector. The response time (depending on the temperature of the sample) was approximately 4 minutes at 60 °C. We checked the results by HPLC and found good correlation between the two methodes [2].

The advantage of this method is that - after filtration - fermentation liquids can be continuously sampled and analysed quantitatively.

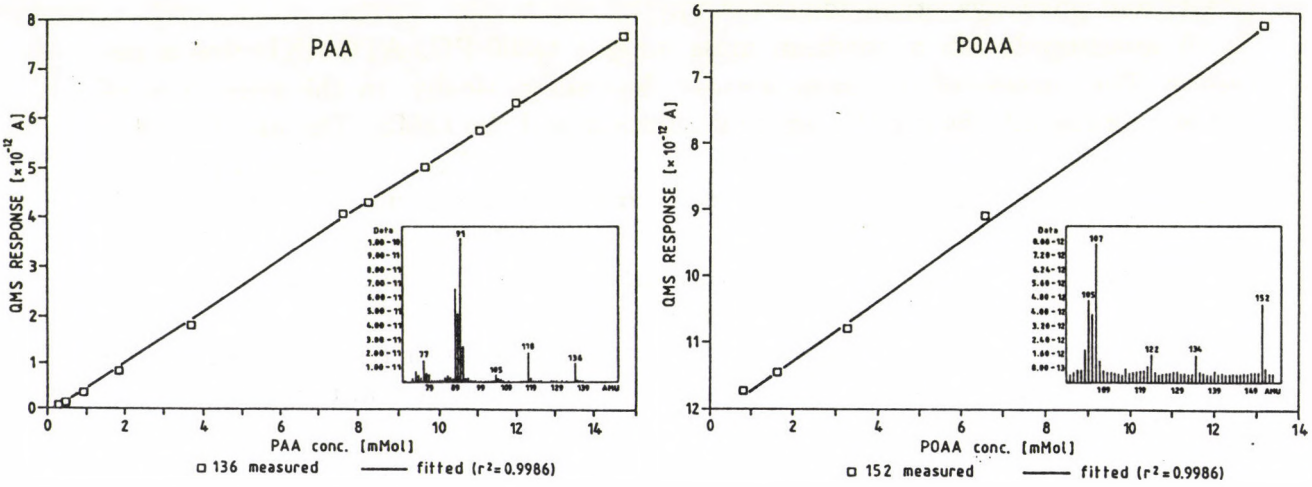

Fig. 2. Calibration curves of PAA and POAA solutions.

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Optimization of Quadrupole Pre-filters

M.Simon, Cs.Trajber, S.Bohátka, and I.Futó

In quadrupole mass spectrometers (QMS) the mass filters can be interfaced to ion sources through RF-only prefilters (PF) to increase sensitivity and reliability. A computer simulation model of QMS has been published recently [1] and it was applied to study optimization of PF-QMS systems. The model is able to calculate the transmission of QMS but it is a rather time consuming process. Instead, we suggest that a simple method should calculate optimal prefilter length.

It was discovered that we can well characterize ion trajectories (and consequently the stability of ions in the PF-QMS field) by the average maximum displacement function of ions (1):

$$D_r(l_{pre}) = \frac{1}{N} \int_0^{r[ape]} \int_0^{r[ape]} \int_0^{2\pi} U_{max}(l_{pre}, \theta) d\theta dx_0 dy_0 \qquad (1)$$

where r[ape] is the radius of the entrance aperture of PF, N is a normalization constant (the maximal value the integer can take), l_{pre} is the PF length, θ is the initial RF phase, U_{max} replaces maximum magnitude of ion position vector (r) or its coordinates (x),(y) [2],[3] (Fig. 1a). Transverse components of ion velocities are neglected.

This function is periodic and the length of period is independent of the mass number if we keep the ion velocity constant . This function is unequivocally connected with the transmission of PF-QMS systems : those ions can pass the mass filter wich have smaller radial displacement than the quadrupole field radius (r_o). It means that the transmission is maximal if D_r has a minimal value and vice versa.

The transmission was calculated at several PF lengths and it was compared with the measured values (Fig.1b). Such comparisons are not known because of the difficulties of the measurement. Schematic drawing of the experimental setup is shown in Fig.2.

This setup was able to realise monoenergetic and parallel ion beams as it had been supposed in calculations. The first condition was satisfied with the energy filter which was a cylindrical condenser of 90^o deflection. Filtering gave 3-fold improvement resulting 10 % spread of the ion energy. The lens was responsible for parallelism of the ion beam. Measurements were completed at an ion energy of 12 eV. The experimental value of PF-QMS transmission was given by the ratio of intensities of ions outcoming from the exit of the analyser (measured with Faraday cup 2) and incoming to the prefilter (measured with the rotatable Faraday cup 1). Fringing fields were not taken into consideration in the model, therefore we used He ions in the measurement. Light ions spend less time in the fringing field and suffer of less influence in the transient field.

Experimental results are in good agreement with the prediction of the proposed method. Measurements confirm that the calculation of D_r function can predict optimal prefilter lengths.

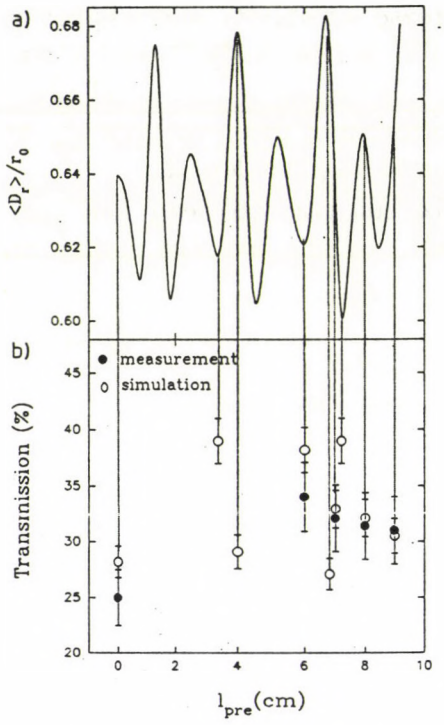

Fig. 1. a/ The average displacement of the ions as a function of the PF - length. b/ Measured and calculated transmission at several PF-lengths.

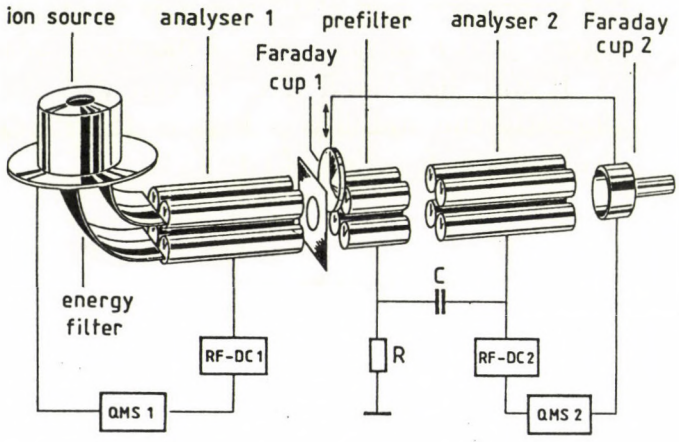

Fig. 2. Schematic drawing of the quadrupole assembly used to measure ion transmission in the PF-QMS system.

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Status Report on the Cyclotron

A. Valek

The planned operation of the cyclotron and the measuring centre were very similar to those of the previous years. The utilization of the machine was concentrated to 9 months; January, July and August were reserved for maintenance. Because of a damage in the power supply of HF final stage, the cyclotron was out of work from the 45th week. The overall working time of the cyclotron was 3743 hours and the break down periods amounted up to 233 hours. The cyclotron was available to users for 2807 hours, the effectively used beam time is summarized in Table 1. In the maintenance period only the regular repairs and test runs were carried out.

Table 1. Effectively used beam time

Projects	Beam time (hours)	%
Nuclear spectroscopy	672	31
Nuclear reactions	497	23
Applications	982	46
Total	2151	100

Activities at the Van de Graaff Accelerator Laboratory

L. Bartha, Á. Z. Kiss, E. Koltay, A. Nagy,

E. Somorjai and Gy. Szabó

During 1992 the beam time of the VdG–1 machine amounted to 1137 hours. The accelerator delivered proton and helium beams according to the needs of electron spectrometry group working in atomic physics, as long as 1007 hours, and it produced carbon beam in 118 hours for applications in surface science. In order to extend the lower part of the usable energy range, and increase the number of available ion species, building up of a low energy injector line with a hollow cathode ion source is in progress. A switching magnet and a second beam transport tube have been developed to govern the beam of the hollow cathode ion source or the accelerated ions of the VdG–1 machine, alternatively.

The 5 MeV Van de Graaff machine was operating for 1484 hours during this period (Table 1).

Field	Hours	%
Atomic physics:	659	44
Nuclear physics:	373	25
Analytical studies:	163	11
Machine tests:	289	20
Total:	1484	100

Table 1. Time distribution among different research activities at VdG–5

In the experiments protons and helium–4 ions were accelerated. A straight acceleration tube of axial gradient modulation using dish–shaped electrodes was used from the beginning of this year. The effect of decoupling sections on secondary electron loading has been investigated with the help of bremsstrahlung measurements by TL detectors.

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January 16
Modification of materials by ion beams
J. Gyulai, Central Research Institute for Physics, Budapest

January 30
The new radiation- and enviromental monitoring system of the institute
T. Lakatos

February 6
Liquid-phase NMR spectroscopy and its applications
L. Szilágyi, Kossuth University, Debrecen

February 13
K-shell ionization at adiabatic ionic collisions
Z. Smit, University of Ljubjana

February 20
Investigation of ion-atom collisions by coincidence technics
T. Vajnai, University of Miskolc

February 27
Present and future of the nuclear power station at Paks
G. Rósa, Nuclear Power Station, Paks
Project for monitoring of corrosion in the primary circle
P. Tilki, T. Pintér, and P. Ormai, Nuclear Power Station, Paks

March 12
Low-energy optical potentials for Sn isotopes
L. Zolnai

March 19
The difference between the proton and neutron density distributions in nuclei
A. Krasznahorkay

March 31
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K. Varga

April 2
The CERN with the eyes of a Hungarian
Gy. Vesztergombi, Institute for Nuclear and Particle Research, Budapest

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April 23
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N. M. Kabachnik, Moscow State University

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M. Kis-Varga

May 14
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D. Szakály, University of Miskolc

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June 4
Systematic radon investigations in geological enviroment
J. Hakl

June 11
Asymptotically correct description of charged systems for two-body final states
Z. Papp

June 18
Ion-optical models of quadrupole mass spectrometers
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June 25
Microscopic description of nuclear structures and reactions for light nuclei
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September 3
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The violation of the quatummechanical superposition principle
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October 8
Applications of isotope analytical methods
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Investigation of super- and hyperdeformed nuclear states by magnetic spectrograph
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Deformation, superdeformation and clustering of light nuclei
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K. Martinás, Eötvös University, Budapest

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E. Sudár

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Positron emmision tomography project for the Debrecen cyclotron
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