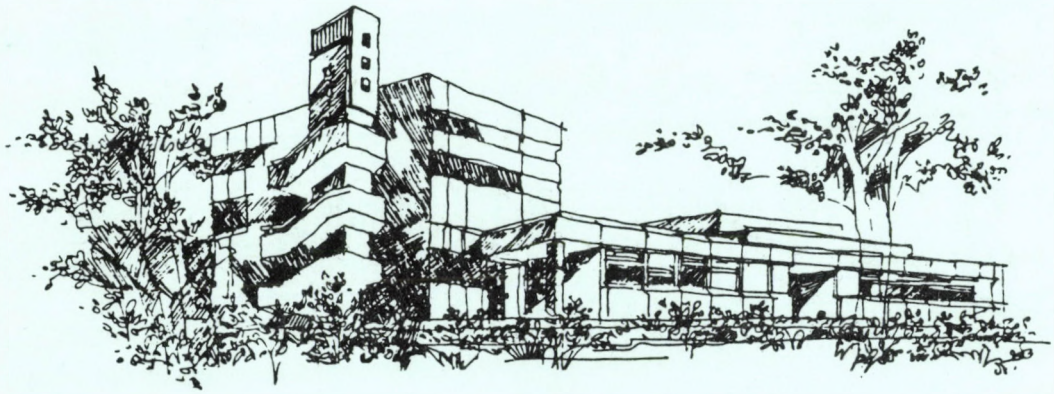
ATOMKI
ANNUAL REPORT
1986



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

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PREFACE

The Annual Report of ATOMKI is being published according to a new concept from now on. In our former Annual Reports only the titles and abstracts of the papers published or submitted were included. Starting with the present issue, beside the list of publications short summaries of works in progress will be presented giving preliminary results on them.

Looking back to the past year 1986, undoubtedly one of the main tasks was to start the intensive utilization of our compact isochronous MGC cyclotron (Ø 103 cm) which was put into operation on November 15, 1985. The utilization was started immediately after the opening ceremony but in the first half of the year there were some break-downs and the beam parameters did not meet the specified values. In the second half of the year, however, the situation improved and now the beam parameters are in the specified range. Presently ten basic and applied research projects are running on the cyclotron. The publication of some results on ion-atom collision measured at this cyclotron is now in preparation. The first results in the analytical applications (the study of wear of ball-bearings, axes, etc.) have also been obtained. The production of ^{67}Ga isotope for medical purposes is in progress and the production of some other short-lived and ultra-short-lived isotopes is in preparation.

ATOMKI has a good record of cooperation with a number of companies in the frame of research-contracts. In the end of October 1986, however, we entered a new phase of this cooperation, when ATOMKI, the L. Kossuth University and some leading companies of the region signed an agreement to establish the Debrecen Science and Technology Park.

Another agreement has also been signed on the basis of which a close collaboration will be realized between ATOMKI and the Physics Departments of the L. Kossuth University establishing the Debrecen Physics Center. The constituents of this Center will maintain their independence in their operations, budgeting etc. but they will have some common establishments as e.g. library, mechanical workshop, etc.

We hope that these new organizations will promote our work to be more successful both in the fundamental research and in the applications.

Debrecen, February 10, 1987

Prof. Dénes Berényi

Director

CONTENTS

EXCITED STATES OF ^{110}In, ^{112}In AND ^{114}In OBSERVED IN (p,nγ) REACTIONS

A. Krasznahorkay, T. Kibédi, J. Timár, T. Fényes, A. Passoja*, R. Julin*, J. Kumpulainen* and V. Paar**

The γ-ray spectra of the ^{110}Cd(p,nγ)^{110}In, ^{112}Cd(p,nγ)^{112}In and ^{114}Cd(p,nγ)^{114}In reactions were measured with Ge(Li) and Ge(HP) spectrometers at different proton energies between 4.8 and 7.0 MeV. The energies and relative intensities of more than 90 transitions (including > 70 new ones) in ^{110}In, 50 transitions in ^{114}In and more than 170 γ-ray transitions in ^{114}In have been determined. The conversion electron spectra of the reactions were measured with a combined magnetic plus Si(Li) spectrometer. Internal-conversion coefficients of about 100 transitions were determined for the first time. Typical γ-ray and conversion electron spectra of the ^{112}Cd(p,nγ)^{112}In reaction as well as well as the deduced internal conversion coefficients of the ^{112}In transitions are shown in figs 1 and 2, respectively. Fig. 3 shows parts of the γγ-coincidence spectra of the ^{110}Cd(p,nγ)^{110}In reaction.

The level schemes of ^{110}In, ^{112}In and ^{114}In [1], γ-ray branching ratios, transition multipolarities, level energy, spin and parity values have been deduced. The energies of several ^{110}In, ^{112}In and ^{114}In [1] proton-neutron multiplet states were calculated on the basis of the parabolic rule derived from the cluster-vibration model. The comparison of experimental and theoretical results provided classification of many multiplet states.

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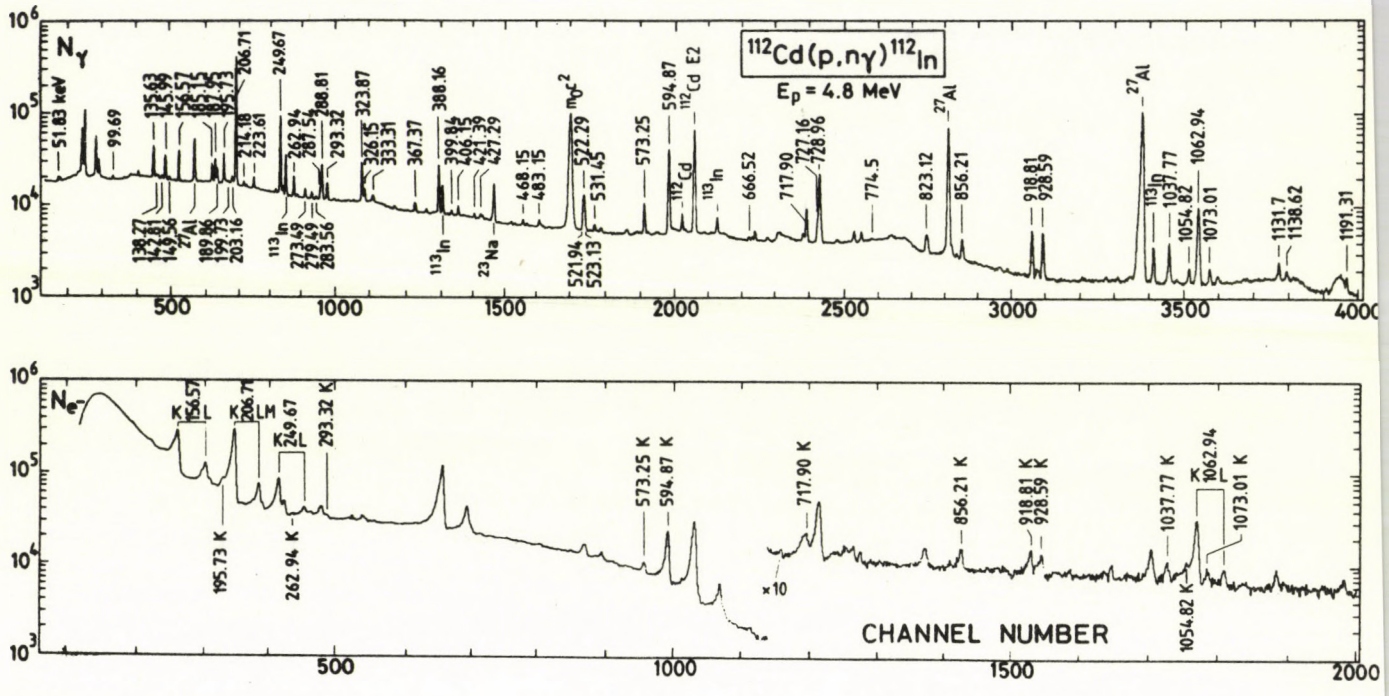

Fig. 1. Typical γ-ray and internal conversion electron spectra of the ^{112}Cd(p,nγ)^{112}In reaction. N_γ and N_{e^-} denote counts in channels. The energies are shown only at ^{112}In lines.

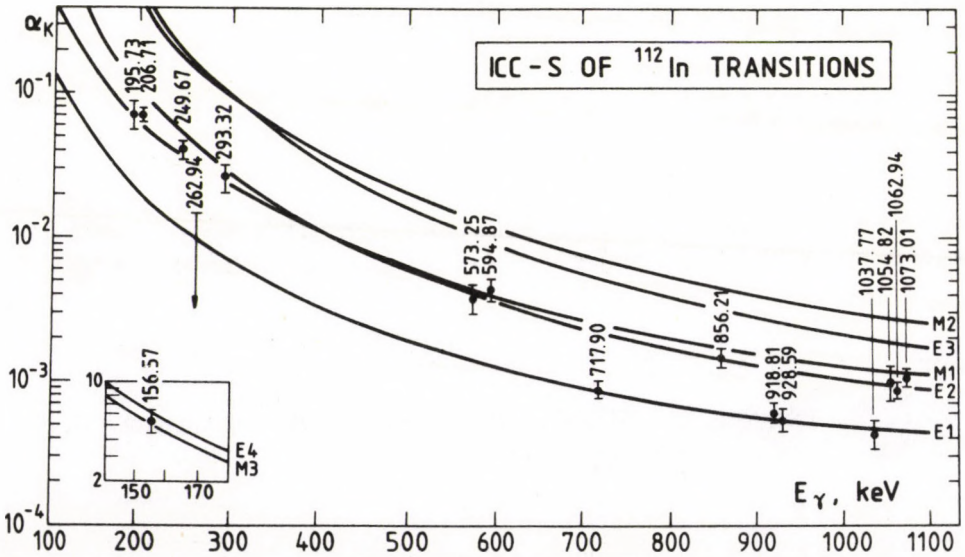

Fig. 2. The experimental α_K internal conversion coefficients of ^{112}In transitions (dots with error bars) as a function of γ-ray energy (E_γ). The curves shown are theoretical results.

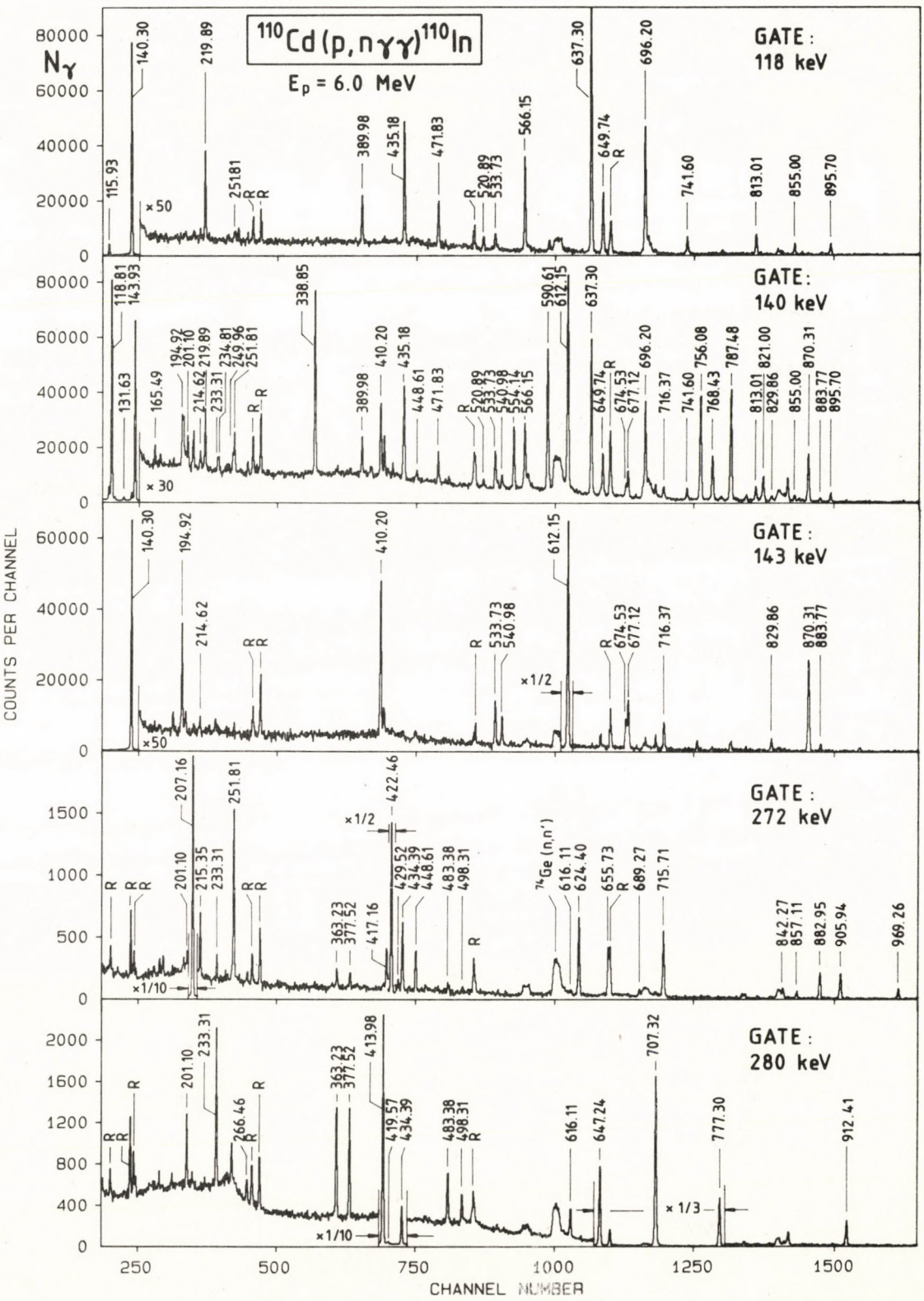

Fig.3. Parts of the γγ-coincidence spectra of the ^{110}Cd(p,nγ)^{110}In reaction.

^{40}Ar LEVELS AT 9 TO 10 MeV STUDIED BY THE REACTION ^{36}S(α,γ)^{40}Ar

M. Józsa, J. Keinonen*, Á.Z. Kiss, E. Koltay, B. Nyakó, E. Somorjai

The properties of ^{40}Ar were known in some details up to 12 MeV except for the energy range of 8.0-10.3 MeV where no experimental data had been available [1]. The ^{36}S(α,γ)^{40}Ar reaction with its Q-value of 6.8 MeV seemed to be a useful tool for studying highly excited states of ^{40}Ar in the above mentioned energy range with the use of bombarding alpha-energies around 3 MeV. The nucleus ^{36}S has a low natural abundance (0.017 %) but the recent availability of highly enriched ^{36}S made it possible for us to observe the ^{36}S(α,γ)^{40}Ar reaction for the first time [2]. Energy and strength of 51 resonances have been determined in the bombarding energy range E_α = 2.3 to

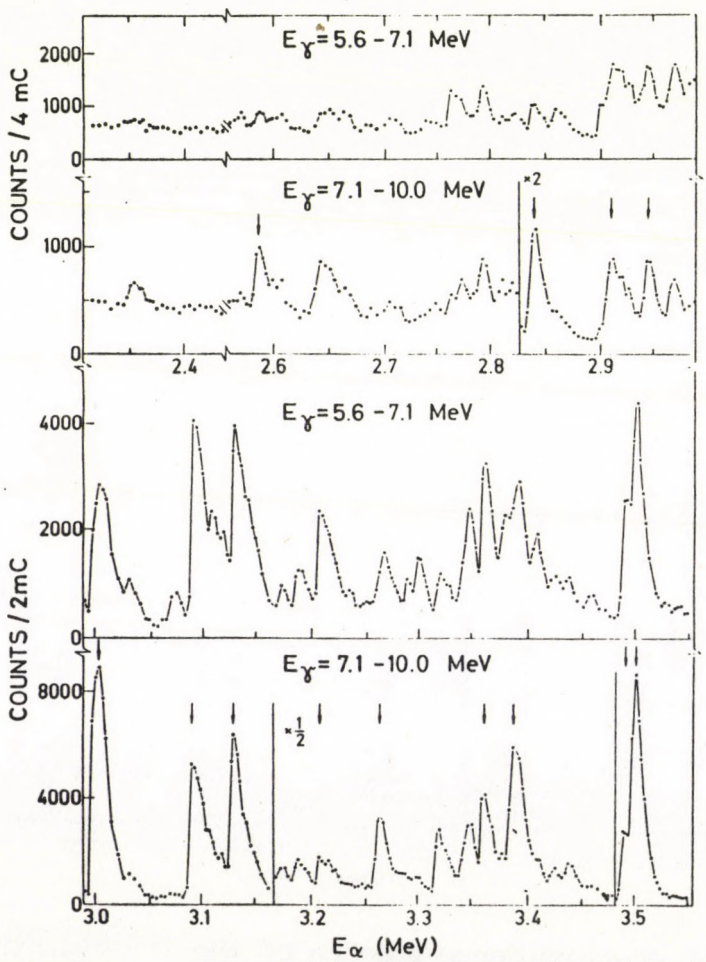

Fig. 1. Gamma-ray yield curve of the ^{36}S(α,γ)^{40}Ar reaction measured at 55° relative to the beam on implanted target.

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3.55 MeV. Fig. 1 shows the measured gamma-ray yield curve [3].

γ-ray angular distribution measurements were performed to determine the spin-parity values of resonance levels. The results together with the decay schemes are given in Table 1.

Table 1

Spin-parity and gamma-ray decay of $^{36}S(\alpha,\gamma)^{40}Ar$ resonances

RESONANCES			Gamma decay (%) to E_{xf} (MeV) in ^{40}Ar									
E_α [a] (keV)	E_{xi} [a] (keV)	J^π	0 0^+	1.46 2^+	2.12 0^+	2.52 2^+	2.89 4^+	3.21 2^+	3.51 $1,2^+$	3.68 3^-	3.92 2^+	Other levels E_{xf} (%)
2584	9126	1^-	100									
2838	9354	1^-	87								7	4.30(6)
2897 2907 }	9407 9416 }	$(1^-,2^+)$	35	11		3			18		14	4.08(19)
2943	9449	1^-	24	35	12	13	(4)	8	8			
3004	9504	1^-	89	6	2						3	
3089 3095 }	9580 9585 }	1^-	41	18	25	11	(5)				5	
3130	9617	1^-	31	46	3	7	(3)	4	2	2	5	
3207 3215 }	9686 9693 }		3	4		54		5	6		6	4.33(8),4.60(14)
3262	9735	1^-	48	11	7	5		11			13	4.60(5)
3360	9824	1^-	17	25	7	17		13	2	9	10	
3387 3391 }	9848 9851 }	1^-	47	25		28	(9)					
3493	9943	1^-	38	25	9	23					5	
3503	9953	1^-	71	12		9					2	4.04(2),4.33(4)

a) Errors are ± 3 keV in most cases.

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SHAPE COEXISTENCE AND DISCRETE-LINE SUPERDEFORMED BAND IN ^{152}Dy

B.M. Nyakó, P.J. Twin[a], A.H. Nelson[a], J. Simpson[a]
M.A. Bentley[b], H.W. Cranmer-Gordon[b], P.D.Forsyth[b]
D. Howe[b], A.R. Mokhtar[b], J.D. Morrison[b]
J.F.Sharpey-Schafer[b] and G. Sletten[c]

After the first observation of superdeformed structures at very high spins in ^{152}Dy [1] through the gamma-energy correlation method our interest has been focussed on the search for any existing link of the superdeformed states to the other high-spin spherical/oblate states. We have progressed in two directions: a) to search for such links using existing data; b) to collect new data with high statistics using detector array TESSA3 consisting of 12 escape-suppressed Ge-detectors and a 50 element bizmuth germanate (BGO) "crystal ball", with improved electronics which enabled us to eliminate the n-induced events from the Ge spectra and to discriminate between prompt events and the delayed events related to the 60 ns 17^+ isomer.

In program a) we have observed a rotational band [2] with an almost constant moment of inertia $\mathcal{J}^{(2)}=58\hbar^2/$MeV. This band is the continuation of the ground state sequence from 0^+ to 18^+ and it extends upto $42\hbar$ (Fig.1.) ($40\hbar$ in TESSA2 data); it is proposed to be a four-quasiparticle configuration with pairs of both $i_{13/2}$ neutrons and $h_{11/2}$ protons aligned, and may be identified as structures with small prolate deformation at $\beta\approx0.15$ and triaxiality of $\gamma\approx15^o$ [3]. The new band coexists with the oblate particle-hole yrast states, although from 18^+ upwards it lies between 0.5-1.5 MeV higher in excitation energy. In spite of this shape-coexistence in the very wide spin range of 8^+-40^+, no observable links between the collective and single particle structures were observed.

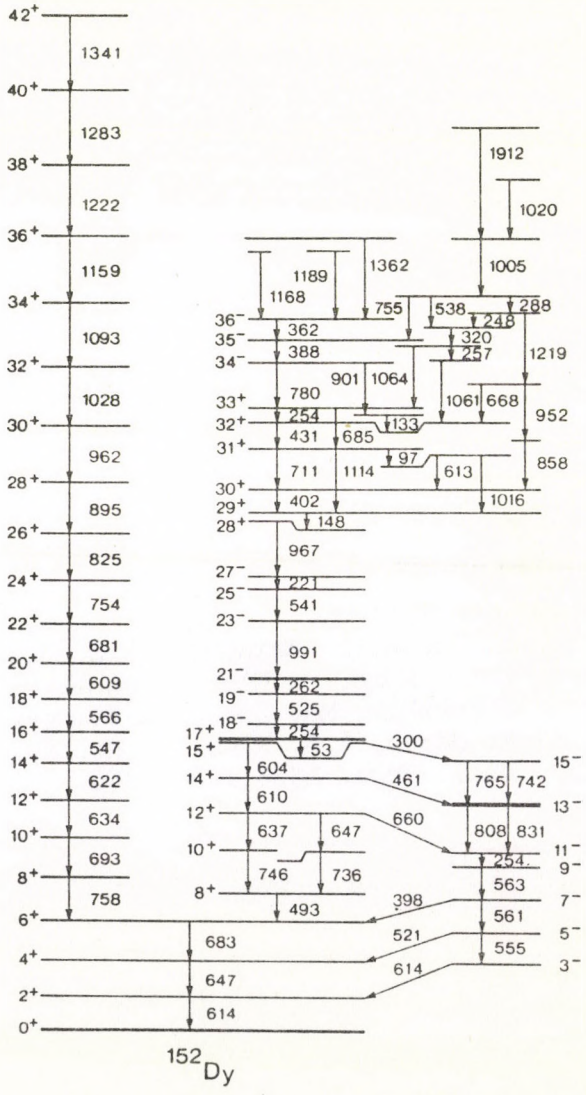

Figure 1. Level scheme of ^{152}Dy: to the left is the low-deformation band; to the right are the yrast oblate states.

In order to establish if this band is involved or not in the decay of the superdeformed states we carried out an experiment with TESSA3, collecting 150 million Ge-Ge-BGO coincidences in the reaction ^{108}Pd (^{48}Ca,4n) ^{152}Dy at 205 MeV bombarding energy. Two gamma-energy correlation matrices were generated, a "prompt" and an "isomer" matrix, from which - by requiring coincidences with known γ-lines - a new discrete-line decay-sequence of 19 transitions were identified (Fig.2). The constant energy separation around 47keV of these lines gave a moment of inertia $\mathcal{J}^{(2)}=(84\pm2)\ \hbar^2$/MeV and this band was interpreted as the lowest energy band of the superdeformed prolate shape. The band however is not related to the low-deformation band, but rather it bypasses the 60 ns 17^+ isomer state by 25%, and feeds the oblate yrast levels between 19^- and 25^- by 75%. It extends in spin from 22$\hbar$ upto 60 $\hbar$, as it was estimated from feeding intensities into the yrast states and from considerations regarding the character of the out-of-band transitions. The 2.2% total gamma-ray intensity accumulated in this band accounts for the whole of the ridge structure observed in the continuum E_γ-E_γ correlations. This first observation of a discrete-line superdeformed band [4] extended the highest spin seen experimentally for a discrete level from 46$\hbar$ to 60$\hbar$. Some unexpected properties of the band raised many open questions to be answered theoretically.

This work was done in Daresbury Laboratory, U.K. with a Visiting Fellowship, the receipt of which from the Science and Engineering Research Council is highly appreciated by B.M.Ny.

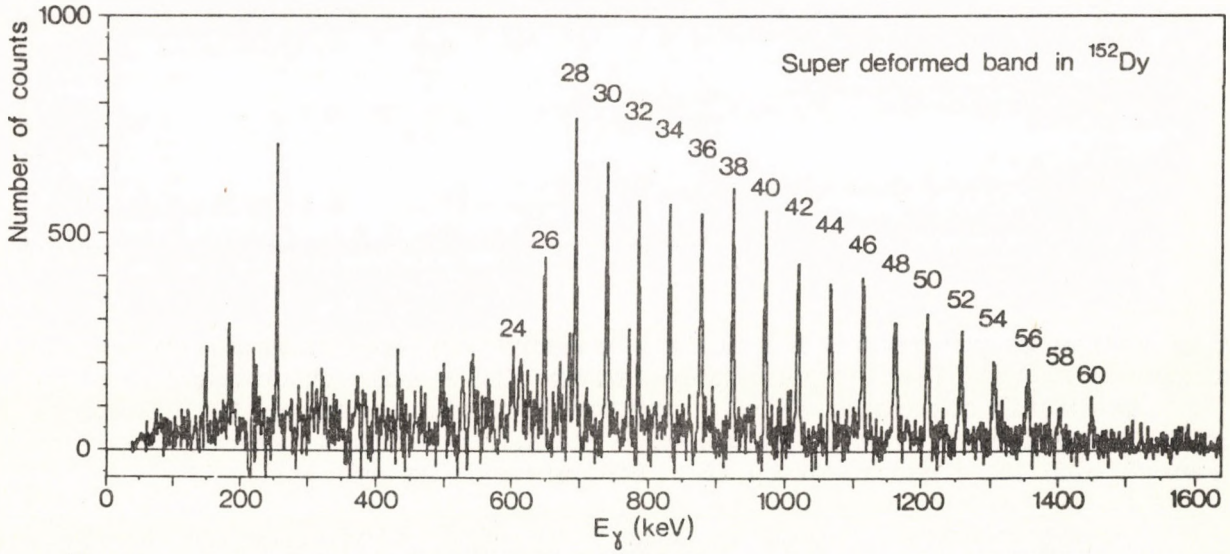

Figure 2. Discrete-line superdeformed band as seen in TESSA3 data

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a) SERC Daresbury Laboratory, Warrington, U.K.
b) Oliver Lodge Laboratory, University of Liverpool, Liverpool, U.K.
c) Niels Bohr Institute, Riso, Roskilde, Denmark

BEAM CHANNELS FOR NUCLEAR SPECTROSCOPY AT THE MGC CYCLOTRON

T. Kibédi, A. Krasznahorkay, Z. Gácsi and S. Nagy

The target room 3, which is separated from the MGC cyclotron vault and target room 1 by concrete walls, is devoted mainly to γ-ray and internal conversion electron spectroscopy. Two beam channels have been built following a 45° switching magnet (Fig. 1).

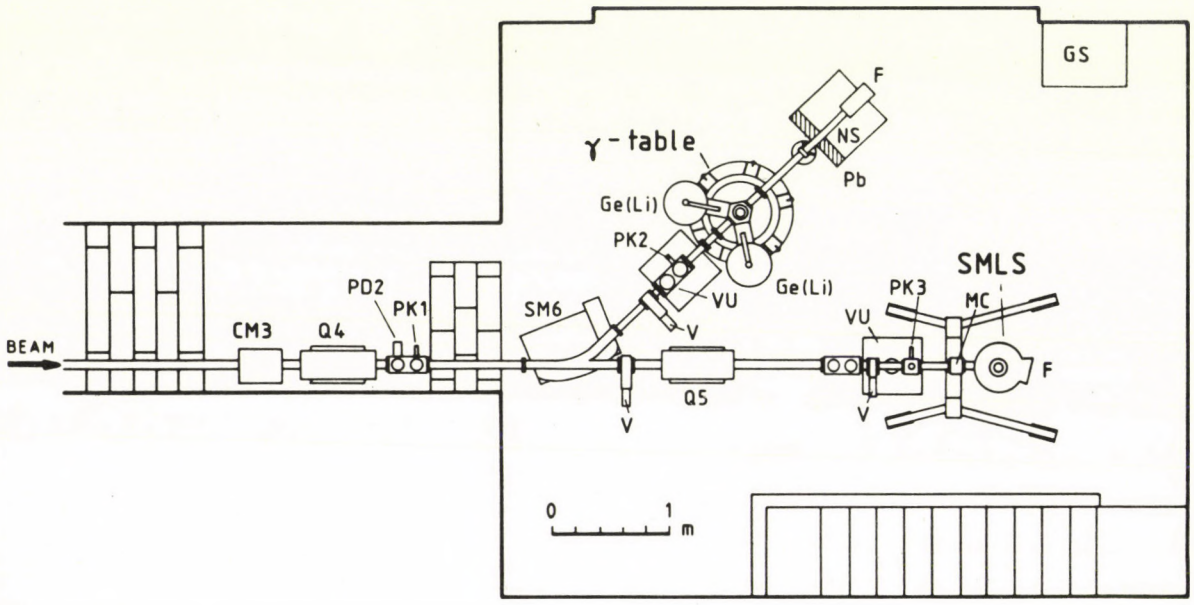

Fig. 1. The target room 3 for nuclear spectroscopy experiments (SM6 - switching magnet; Q4-5 - quadrupole lenses; CM3 - correction magnet; PD2 - pneumatic diphragm; PK1-3 - pneumatic quartz + camera; VU - vacuum unit; V - valve; F - Faraday-cup; MC - movable collimator system; Pb - lead-shield; NS - neutronstop; GS - He-gas handling system).

First channel based on the γ-angular distribution table. The philosophy was to design the beam line in a modular fashion so that flexibility is attained No collimator is used in the room. The flux of the neutrons, produced by the beam on the Faraday-cup and on diaphragms placed before the concrete wall, has been tested by a neutron detector at the positions of the spectrometers and has been found insignificant.

The possible types of experiments performed on the first channel are as follows:

- single γ-spectrum with Ge(Li), LEPS and Compton-suppression* spectrometers,
- γ-excitation function,
- γγ-coincidence,
- γ-angular distribution,
- γ-polarisation*

- lifetime by electronic, Doppler shift attenuation and recoil distance (in a special chamber) [1] methods,
- internal conversion electron spectrum with a mini-orange spectrometer,
- e-γ-coincidence,
- coincidences with charged particles.

Suitable chambers, spectrometers and methods have been developed or the developement is under progress (*).

Second channel. The superconducting magnetic lens plus Si(Li) electron spectrometer (SMLS) [2] is installed on the beam line following the Q5 quadrupole lens.A ∿0.5 m long, electromechanically movable collimator system is used to obtain well positioned beam at the target position. The system consists of a series of diaphragms manufactured of tantalum. Suitably shaped and positioned lead-shields are used to reduce background radiation from the collimator and the Faraday-cup. The beam spot can be observed by a video camera on the wide quartz-plate of the Faraday-cup. In order to measure the correct beam intensity and to reduce the background a tantalum plate can be turned into the beam. The following types of experiments can be performed by the SMLS:

- single internal conversion electron spectra (by two equivalent lenses),
- e^-e^--coincidence (the first lens fixed on the gate, the second sweeped),
- e^-e^+ internal pair spectrum (one lens measures the electrons, the second measures the positrons, using opposite baffle system in the lenses),
- e^--charged particle coincidence.

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NUCLEAR STRUCTURE STUDIES IN THE RARE-EARTH REGION

Zoltán Árvay

In the transitional rare-earth region around the doubly magic nucleus $^{146}_{64}Gd_{82}$ drastic changes occur in particle and collective properties. It is caused by the double shell-closure at Z=64, N=82 and the proximity of the deformed region at N>89. The nuclei of this region lie far off the stability line and so decay by the emission of energetic β^+-radiation with short half-lives.

We have calculated [1] excitation energies for odd-parity states (Fig.1.) and M1,E2 transition probabilities in the ^{149,151}Gd isotopes in the framework of the Interacting Boson-Fermion Model [9] (IBFM). The nuclei ^{148,150}Gd were selected as SU(5) even-even cores and $2f_{7/2}$, $1h_{9/2}$ orbitals were taken for the multi-j description of the odd-A nuclei.

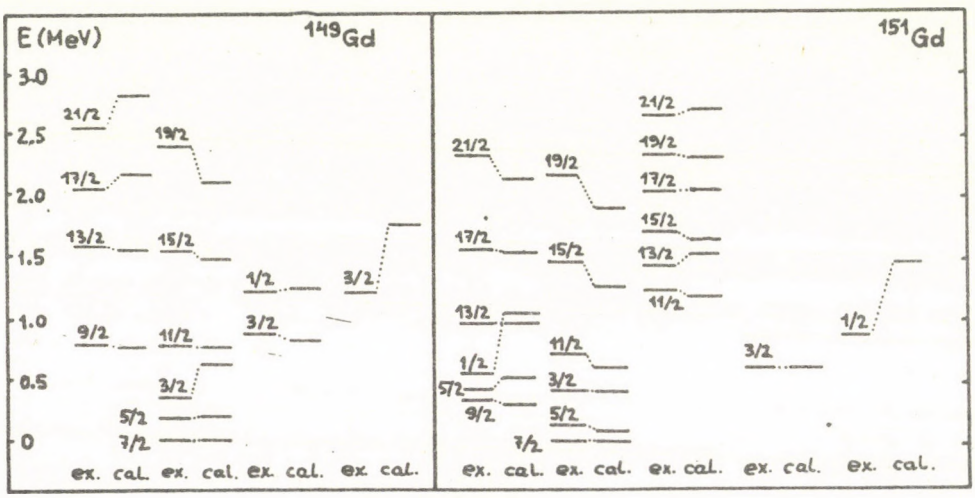

Figure 1. Experimental and calculated energies for odd-parity states in ^{149,151}Gd

The neutron number 89 is the border of the deformed rare-earth region. In the N=89 isotopes ^{151}Sm, ^{153}Gd and ^{155}Dy the one-quasiparticle band-head energies and the rotational bands have been calculated [2] explicitly taking into account the Coriolis-interaction. For the calculation of one-quasiparticle states we used a model with anisotropic Saxon-Woods potential[3]. The structure of rotational states has been described in the framework of a non-adiabatic rotor model [4]. We have reproduced the experimental ground and excited rotational band structures and investigated the role of the Fermi-level and the deformations and also the Coriolis-attenuation, decoupling and mixing effects.

Experimental nuclear structure data are very scarce in the far unstable transitional rare-earth region. The 700 MeV energy proton beam of the Synchro-Cyclotron at JINR produces high yield of neutron deficient nuclei in a target, which is the

ion-source of an on-line mass-separator. An intelligent, multi-parameter nuclear spectroscopy facility ELGA has been built [5] to operate on one of the external radioactive ion-beam lines of the mass-separator (Fig.2.).

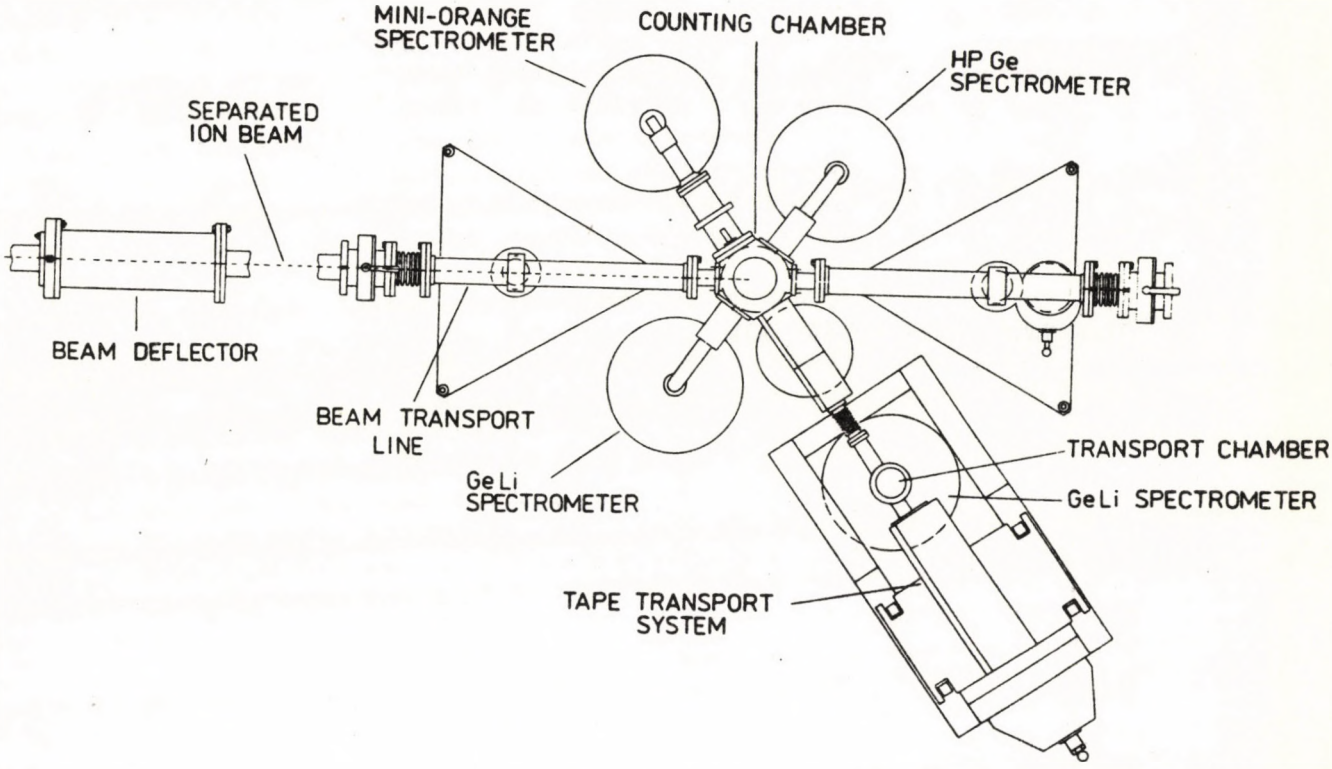

Figure 2. The ELGA spectrometric facility

Radioactive source can be coupled on a tape and transported with the help of a stepping-motor. The HpGe, GeLi and mini-orange spectrometers serve for the detection of the x-ray, gamma and conversion electron radiation of the source. The mini-orange spectrometer very effectively suppresses the β^+ background in the conversion electron measurements. Single and coincidence measurements can be performed to determine the half-lives and excitation schemes of nuclei, life-times and spin-parities of excited states, multipolarities and transition probabilities. A micro-computer based digital electronic system has been constructed for the programmed automatic control of measurement, single and coincidence data acquisition and storage in the memory of an 8K channel analyser and also for express data evaluation [6,7].

For the nucleus ^{153}Gd e^--gamma coincidence measurements have been performed with the high-luminosity ion-free Beta-spectrometer TOR [8]. On the base of the measured ∿400 transitions an excitation scheme of 80 levels, among them 27 new ones, has been constructed [10,11]. Theoretical interpretation was performed in the framework of the quasiparticle + rotor model [2].

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ELASTIC SCATTERING OF ALPHA PARTICLES ON ^{62}Ni

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and

M. Brenner, K.-M. Källman, P.Manngard, A. Sjöberg*

Absolute differential cross-sections for elastic scattering of α-particles on ^{62}Ni have been measured with the beams of the MGC cyclotrons of the Abo Academy and the Institute of Nuclear Research at bombarding energies 12.8, 13.7, 14.56, 16.34 and 18.13 MeV using standard surface barrier detectors. Thin evaporated self-supporting isotopically enriched ^{62}Ni (97.94%) targets were used .

The angular distributions were measured in steps of 4^{o} between 20 and 168^{o} and show the regular diffraction structure. The angular distribution at E_{α}=16.34 MeV is shown in figure 1. In this particular measurement the small solid angle of the detectors enabled to observe the well defined dips in the angular distribution.

The analysis of the data to get the low energy behaviour of the optical potential sets is in progress.

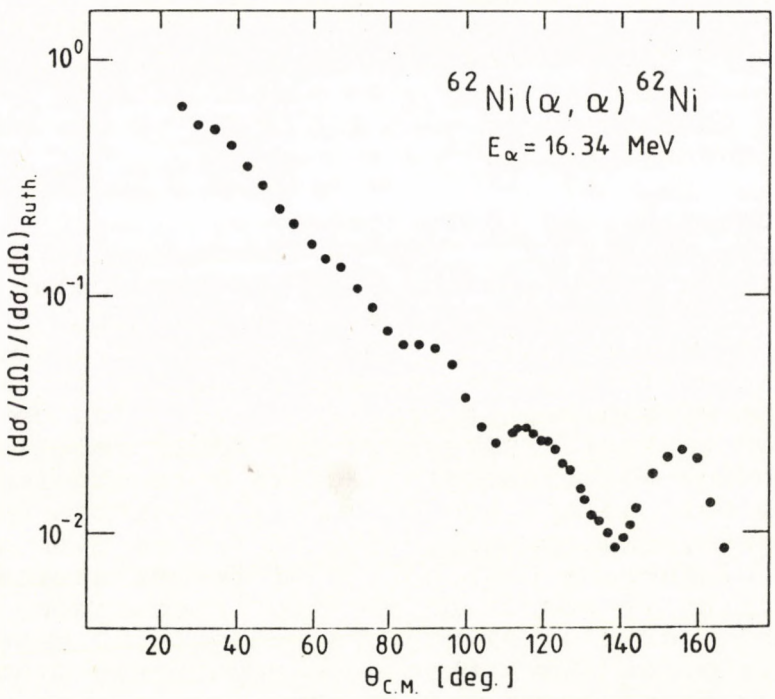

Fig. 1 Measured angular distribution of elastically scattered α-particles by ^{62}Ni at E_{α}=16.34 MeV.

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APPLICATIONS OF THE BREATHING CLUSTER MODEL

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The stability of the free α particle, triton, ^{3}He, ^{12}C, ^{16}O, ^{40}Ca etc. indicates that these structures may play some role as building blocks or clusters in the description of other nuclei as well. Some years ago a comprehensive method was developed by some of us to describe nuclear states as expansions in terms of cluster states [1]. Technical simplicity makes it desirable to include only spherically symmetrical states of the clusters. Therefore, in this model the nucleus is divided into as many clusters as are required by the assumption of the spherical shape. In fact, the cluster states included in addition to the ground states can be regarded as breathing modes built upon the ground states, whence the model is called the breathing cluster model.

Our recent investigations in this field have been focussed on two subjects. One is a conceptual point: to find the relationship between complicated cluster expansions, such as those in the breathing cluster model, to simple cluster pictures. The other is more practical: to test the power of the model by applying it to actual nuclei.

As to the conceptual point, we defined a quantity, the amount of clustering, to characterize a cluster-model component of nuclear states [2]. This is the norm square of the projection of the wave function onto the particular cluster-model subspace. It was pointed out that, although the clusters cannot be localized in space by measurement, the amount of clustering characterizes the cluster formation in close analogy with a quantum mechanical probability. The model dependence of the amounts of various clusterings and their relationship to the corresponding spectroscopic factors were studied via numerical examples for the nucleus ^{6}Li. It was pointed out that, in a relative sense, the spectroscopic factor is also characteristic of the clustering contents of different states of the same nucleus, but it cannot be used for comparisons between different nuclei or clusterings. An analysis by means of the amount of clustering shows that even apparently minute changes on the cluster-model space modify the ground-state wave function of ^{6}Li appreciably. But the extensions of the model space considered do not invalidate the α+d picture since the amount of α+d clustering in terms of consistently modified cluster internal wave functions remains close to unity.

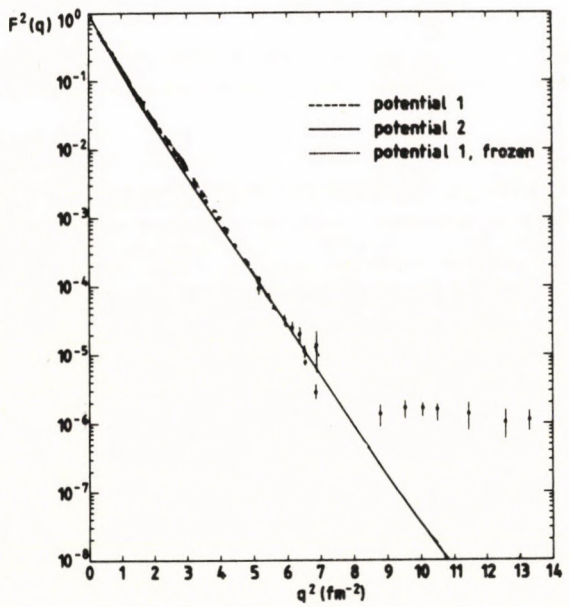
We also examined the question of the measurability of the amount of clustering [3,4]. We found that the conventional spectroscopic factor is more directly related to experiment.

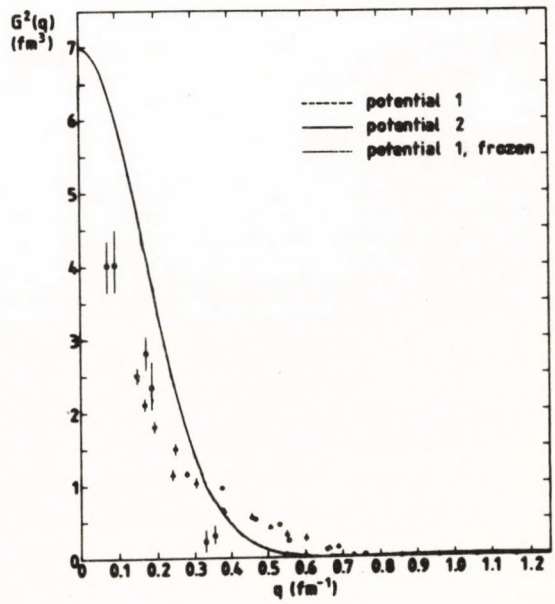
As regards applications, we considered the nuclei with mass number $5 \leq A \leq 8$ [5,6]. These may be concieved to consist of an α cluster and a cluster composed of the rest of the

nucleons. The two clusters may distort each other, so the wave function must contain a combination of several states of the free clusters. In this work we described these nuclei microscopically by including the g.s.'s and breathing excitations of the clusters. One of our effective N-N interactions fitted to reproduce the measured energies and radii of the free clusters and the energy of ^{6}Li or ^{7}Li predicts the two-cluster energies as follows:

Potential	E(^{5}He)	E(^{6}Li)	E*(^{6}Li,L=2)	E(^{7}Li)	E(^{7}Be)	E(^{8}Be)
For ^{6}Li	-26.64	-31.99	3.76	-38.16		-55.79
For ^{7}Li	-26.81	-32.85		-39.24	-37.68	-56.49
Experiment	-26.08	-31.99	3.59	-39.09	-37.46	-56.50

The calculated squared monopole charge form factor $F^2(q)$ and αd fragmentation strength $G^2(q)$, shown below, improve on previous cluster-model calculations. It is argued that even the diffraction dip of $F^2(q)$ and the slope of $G^2(q)$ could be reproduced by explicitly including short-range N-N correlation in the wave function.





We also performed a detailed analysis of the electromagnetic [7] and fragmentation [8] properties of ^{6}Li. These works are to be published in the near future.

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STUDIES BASED ON THE ANALOGY BETWEEN COLLECTIVE p-p AND p-h EXCITATIONS

I. Giant resonances

M.W.Herzog[+], R.J.Liotta[+], O.Civitarese*, L.S.Ferreira[‡], L.J.Sibanda°, T. Vertse

The formal equivalence which exists between the particle-hole and the two-particle excitations in nuclei leads to the concept of a new type of giant resonances. These are the "pairing giant resonances" (PGR) which are high-lying collective states populated strongly in two-particle transfer reactions. A detailed study of the ^{208}Pb + two nucleon system [1] within TDA using surface delta interaction showed that in collective states (ground state and PGR) the two nucleons are strongly clustered in the surface region. The results of zero-range DWBA calculations suggested that in favourable kinematical conditions this

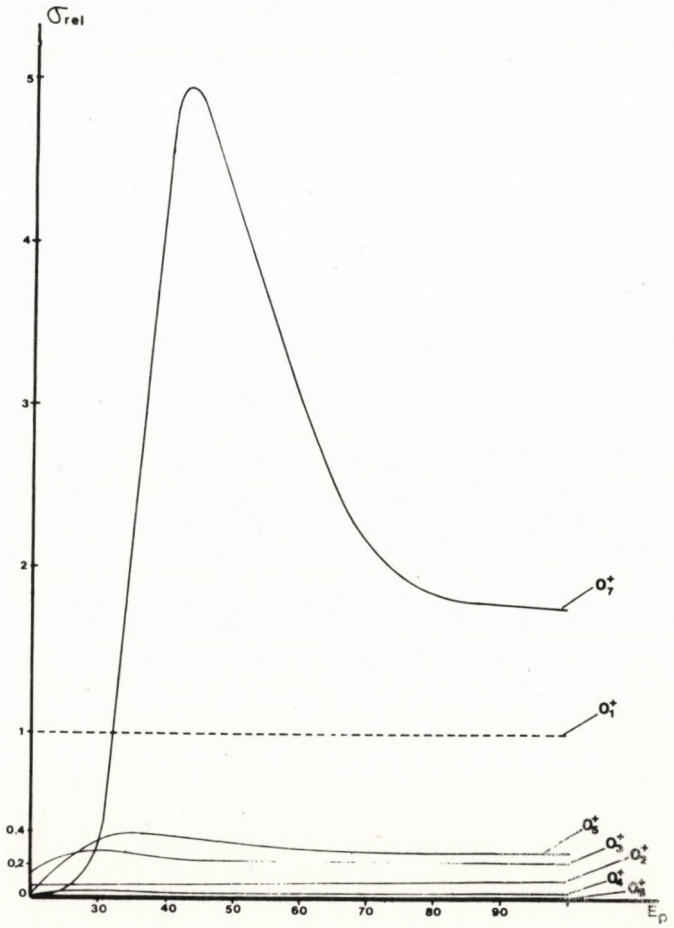

Fig.1. Energy dependence of the relative angle integrated cross sections for ^{208}Pb(p,t)^{206}Pb(0_i^+). The state i=7 is the HPGR.

clusterization might cause enhancement of the cross section of the two-particle transfer leading to the PGR even beyond the value corresponding to the ground state transition [1]. Appearance of "hole pairing giant resonance" (HPGR) has also been suggested by us [2] in the study of the ^{208}Pb - two nucleon system with similar methods. The HPGR could be observed as the seventh 0^+ state in the ^{208}Pb(p,t)^{206}Pb reaction. From the result of the DWBA calculations presented on figure 1. one can observe that the cross section for this transition might reach a value which is five times stronger than that of the ground state transition around 45 MeV proton energy. It is a challange for the experimentalist to observe the giant resonances predicted (both the PGR and the HPGR).

II. Macroscopic formfactors for 2-particle transfer

O. Dragun[§], R.J. Liotta[+], T. Vertse

Another field where the analogy between p-h and two particle (two hole) collective states might be very fruitful is the macroscopic description of the two particle transfer. The vibration in particle number (gauge-space vibration) resembles the shape vibrations used extensively in the description of the collective inelastic scattering. The use of this similarity greatly simplifies the calculation of the formfactor for two-particle transfer and offers an inexpensive way to calculate the transfer cross section both in DWBA and in coupled-channels calculations. In order to check the limits of validity of this approximation we have carried out a series of calculations by using both heavy and light bombarding particles and different values of the bombarding energy [3]. Though the characteristic features of the measured angular distributions have always been reproduced by the calculations, the values of the pairing deformation parameters extracted from the ratio of the measured and the calculated cross sections showed strong dependence on the bombarding energy. This fact warns us not to overstretch the applicability of the simple macroscopic description.

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SUPERSYMMETRY AND QUARK EFFECTS IN NUCLEAR STRUCTURE

Zoltán Árvay

The concept of Supersymmetry [1] is a natural extension of the well known symmetries for systems containing both bosonic and fermionic degrees of freedom. Ordinary symmetries transform bosonic and fermionic variables independently among each other. One can construct so called supertransformations which transform bosonic variables to fermionic ones and vice versa. The associated superalgebra containes both commutators and anti-commutators. The question is to what extent the Nature exhibit Supersymmetry. In this connection a large variety of theories has been formulated from supersymmetric quantum mechanics and field theories to statistical mechanics and applied to particle, nuclear and atomic physics, condensed matter and gravity. To date, experimental evidence has been found only in Nuclear Structure to suggest the presence of Supersymmetry in Nature. In 1980 Iachello [2] has proposed a supersymmetric extension of the Interacting Boson-Fermion Model (IBFM) by embedding the dynamical symmetry group $U^B(6) \times U^F(4)$ into the graded Lie group $U(6/4)$. In the $O(6)$ limit of the model excitation spectra in ^{192}Pt and ^{191}Ir nuclei have been described in good agreement with the experiment.

We first extended the supersymmetric IBFM for the description of superquartets of nuclei in the vibrational $U(5)$ limit [6,9]. The Hamiltonian of the $U(6/2+2)$ Nuclear Supersymmetry Model was expressed in terms of Casimir invariants of groups appearing in the decomposition

$$U^{(B)}(6) \otimes U^{(F_\pi)}(2) \otimes U^{(F_\nu)}(2) \supset U^{(B)}(5) \otimes SU^{(F_\pi)}(2) \otimes SU^{(F_\nu)}(2) \supset$$

$$\supset SO^{(B)}(5) \otimes SU^{(F_{\pi\nu})}(2) \supset SO^{(B)}(3) \otimes SU^{(F_{\pi\nu})}(2) \supset$$

$$\supset Spin^{(BF_{\pi\nu})}(3) \supset Spin^{(BF_{\pi\nu})}(2).$$

Experimental and theoretical level schemes according to the $U(6/2+2)$ supersymmetry are shown in Figure 1. for the $^{102,103}Ru$ and $^{102,103}Rh$ quartet of nuclei belonging to the $[N=7]$ supermultiplet.

We have also predicted states in the ^{100}Tc nucleus [6] which is the odd-odd member of the $^{98,99}Mo$ and $^{99,100}Tc$ superquartet with $[N=7]$. Experimental spectra for ^{100}Tc have been measured [7] previously by the use of a Superconducting Magnet Spectrometer (SMS) constructed in ATOMKI [8].

The bosons and fermions which represent the collective and particle excitations of the nucleus, can be thought, at the microscopic level, as correlated nucleon pairs and single nucleons, respectively. Furthermore, as an important result of the particle physics it became clear that nucleons are constructed from three quarks permanently confined in a volume with radius of order 1 fm. Thus, an atomic nucleus can be considered as a system of fermionic 3-quark and bosonic 6-quark clusters. The

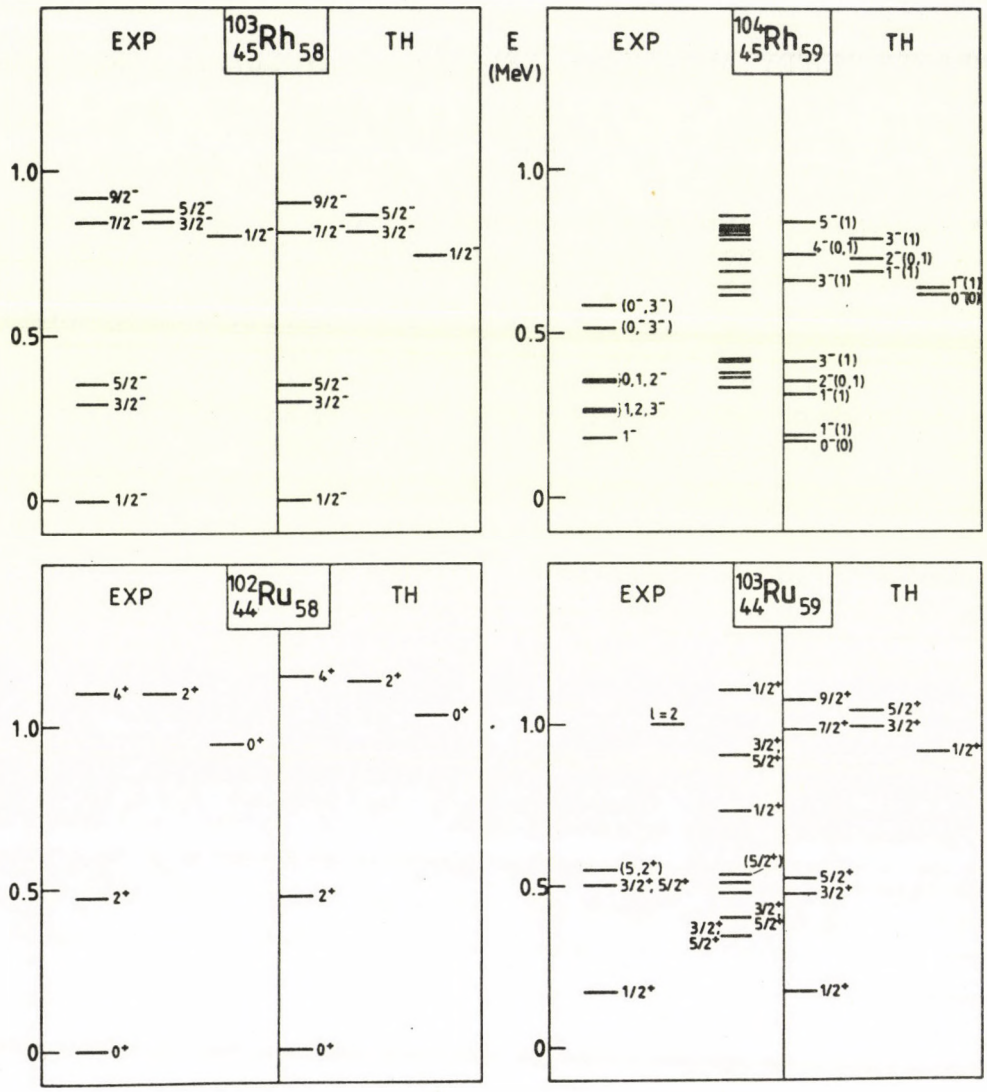

Figure 1. Selected excited states in ^{102,103}Ru and ^{103,104}Rh nuclei

EMC effect [4] discovered in 1983 was the first experimental sign to demonstrate the role of quark constituents of nucleons already in the ground state of the nucleus.

We first presented a hybrid Quark Cluster model [5,10] which takes into account the quark and mesonic degrees of freedom in the description of nuclear structure. In the model, based on the underlying Quantum Chromodynamics [3], two nucleons outside a closed-shell core are considered as a six-quark cluster. The quark-quark interaction potential has the form

$$v_{ij} = -\lambda_i\lambda_j[v(r_{ij}) + \sigma_i\sigma_j u(r_{ij})]$$

where $v(r_{ij})$ is to describe color confinement, $u(r_{ij})$ characterises the one-gluon exchange, σ_i, σ_j are the quark spins and λ_i, λ_j are the generators of the color SU(3) group. The ef-

fective NN potential is defined as the difference between the expectation values of the energy of the six-quark cluster at finite and infinite separation

$$V_{NN} = \langle\Psi_6|\Psi_6\rangle^{-1}\langle\Psi_6|2H_3+\sum_{i=1}^{3}\sum_{j=4}^{6} V_{ij}|\Psi_6\rangle - 2\langle\Psi_3|H_3|\Psi_3\rangle \ .$$

As an application of the Quark Cluster Model the radius of the nucleon described as a three-quark cluster has been calculated to be 0.44 fm [10]. It was determined by the evaluation of a Cohen-Kurath matrix element of the residual interaction. Such type of investigations for a broader state space and range of nuclei offer possibilities to recognise connections between Quantum Chromodynamics and Nuclear Structure.

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ATOMIC PHYSICS

PROJECTILE Z/v DEPENDENCE OF THE MULTIPLE IONIZATION OF THE Ne L-SHELL ACCOMPANYING K-SHELL IONIZATION IN HEAVY-ION-ATOM COLLISIONS

D. Berényi, G. Hock, I. Kádár, S. Ricz, B. Sulik, D. Varga and J. Végh

The range of the high resolution measurements of the K-Auger spectrum of neon obtained from high-energy heavy-ion--atom collisions at the heavy-ion cyclotron of JINR, Dubna [1,2,3] have been extended with the measurement of collisions with lower Z projectiles partly in Dubna (N^{2+}, N^{7+}) and partly at the Debrecen cyclotron (H^{+}, Fig. 1.).

From the first satellite group around 785 eV the ionization and in most cases the vacancy production probabilities as well as the anisotropy parameters have been evaluated. The results are summarized in Table 1 and 2, comparison of the experimental ionization probability values and the corresponding theoretical values calculated according to [4] are shown in Fig. 2. The obtained anisotropy parameter values are shown in Fig. 3. in function of Z/v.

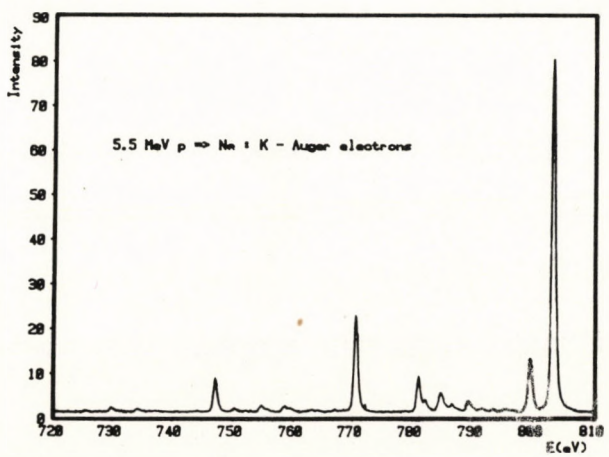

Fig. 1. Energy distribution of K-Auger electrons of Ne from the 5.5 MeV H^{+}-Ne collision.

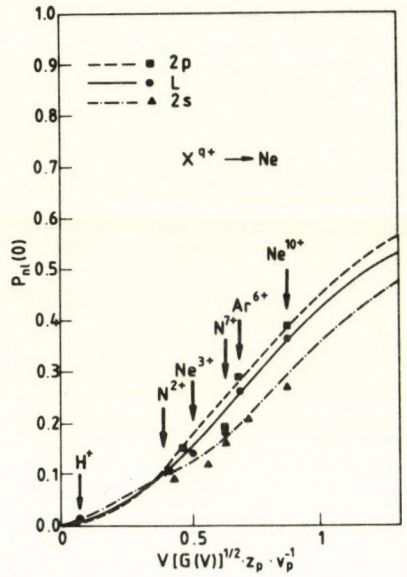

Fig. 2. Experimental and theoretical subshell and total L-shell ionization probabilities per electron

Table 1

The experimental ionization and vacancy production probabilities per electron and their ratios from the collision of the projectiles given below with the Ne atom

	H^+	N^{2+}	N^{3+}	N^{7+}	Ar^{6+}	Ne^{10+}
P_{2s}	0.017(5)	0.08(1)	0.121(5)	0.16(2)	0.23(2)	0.27(2)
P_{2p}	0.020(5)	0.09(1)	0.158(2)	0.19(2)	0.307(9)	0.39(2)
P_L	0.019(5)	0.09(1)	0.149(2)	0.18(2)	0.288(8)	0.36(1)
P_L^{v*}			0.20(2)	0.22(2)	0.35(5)	0.38(7)
P_{2p}/P_{2s}	1.18(7)	1.1(1)	1.31(6)	1.19(3)	1.36(9)	1.44(10)

* from the total/diagram ratio, supposing binomial distribution

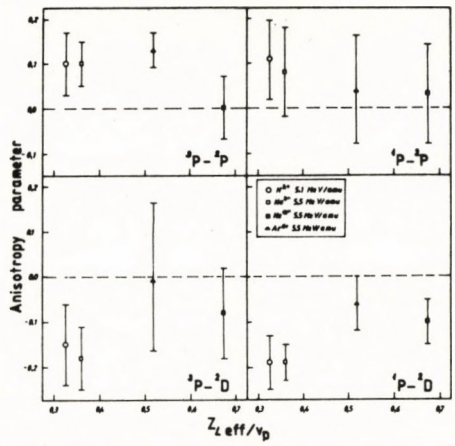

Fig. 3. The experimental anisotropy parameters in function of Z/v

Table 2

Anisotropy parameters of the measured $KL-LL_{2,3}L_{2,3}$ transitions

	N^{2+}	Ne^{3+}	Ne^{10+}	Ar^{6+}
$^3P-^2D$	-0.15(7)	-0.18(7)	0.0(1)	0.0(2)
$^3P-^2P$	0.10(6)	0.10(5)	0.0(1)	0.13(4)
$^1P-^2D$	-0.19(6)	-0.19(4)	-0.10(9)	-0.06(6)
$^1P-^2P$	0.09(9)	0.08(10)	0.02(15)	0.04(10)

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L_3-SUBSHELL ALIGNMENT OF ARGON FOLLOWING CHARGE-CHANGING COLLISIONS WITH PROTONS

L. Sarkadi, J. Pálinkás, A. Kövér, K. Tőkési, L. Gulyás and D. Berényi

The alignment of inner-shell vacancies with $j>1/2$ has been extensively studied for various collision systems. In most of these studies it was supposed that the vacancies were created by direct Coulomb ionization. For light target atoms and for low collision velocities ($v/v_{n\ell}<1$) the electron capture plays an important role in the vacancy production. It has been shown theoretically [1] that these two vacancy production mechanisms lead to considerably different alignments. To the best of our knowledge, however, there is no experimental data on the alignment of inner shell vacancies produced by capture of the inner shell electron into a bound state of the projectile. Such measurements are highly desirable, because on the basis of the obtained experimental results several questions of great theoretical importance could be answered. The primary question: is there any difference at all between the alignments arising from the two vacancy production mechanisms? Furthermore, the experiments would sensitively check the performance of different theoretical approaches of the description of charge-transfer processes. The Oppenheimer-Brinkmann-Kramers (OBK) approximation [1,2], the first Born approximation [2], the semiclassical impulse approximation [3], and the one and a half centered atomic orbital expansion (OHCE) method [4] give significantly different results for the alignment of inner shell vacancies produced by electron capture. Here we mention the resonance-like behaviour of the alignment parameter predicted by the OBK approximation for $v/v_{n\ell}\approx 1$, which is not shown by any other theories. Measurements of the alignment (due to direct ionization and electron capture) of the $2p_{3/2}$ vacancies of magnesium by H^+ and He^+ impact [5] seem to support this special feature of the OBK theory. On the other hand, alignment parameter values obtained for the He-like 2P states of sulphur projectiles excited by passage through a thin carbon foil [6] do not show the OBK resonance. The latter experiment, however, cannot be considered as a very decisive one, because it was based on the assumption that the 2P states of the projectiles were populated mostly by capture of K-shell electrons from the carbon (foil).

To get direct experimental information on the alignment of the inner shell vacancies created by electron capture, we have started to measure the angular distribution of the $L_{2,3}$-$M^2_{2,3}$ Auger electrons of argon in coincidence with the charge-changed outgoing projectiles.

In these measurements the electrons were analysed by a distorted field double pass cylindrical mirror electron spectrometer (ESA-13) [7] with 0.4 % relative energy resolution. The charge-state selection of the outgoing projectiles was made by

electrostatic deflection between two capacitor plates. The charge-changed projectiles were detected by a surface barrier silicon detector, the charged-unchanged ones were collected in a Faraday cup. The single Auger electron spectrum, and the spectrum of Auger electrons in coincidence with the charged-changed projectiles were recorded simultaneously. The coincidence condition was determined by a standard fast-slow coincidence electronics. The true coincidences were separated from the random ones by recording the time spectrum of the coincidence events. A time resolution of about 20 ns FWHM and true to random ratio of about 4 was achieved.

As an example, the single Auger electron spectrum, the time spectrum and the coincidence Auger spectrum obtained with 1 MeV proton impact on Ar at 170° observation angle are shown in figures 1a-1c.

Preliminary results have been obtained for 0.5 and 1 MeV proton bombardment. The alignment parameter of the L_3 subshell is deduced from the angular distribution of the intensity ratio of the L_3-$M^2_{2,3}$ ($^1S_0$) and L_2-$M^2_{2,3}$ ($^3P_{0,1,2}$) lines. At 1 MeV impact energy the alignment parameter obtained from the angular distribution of the single

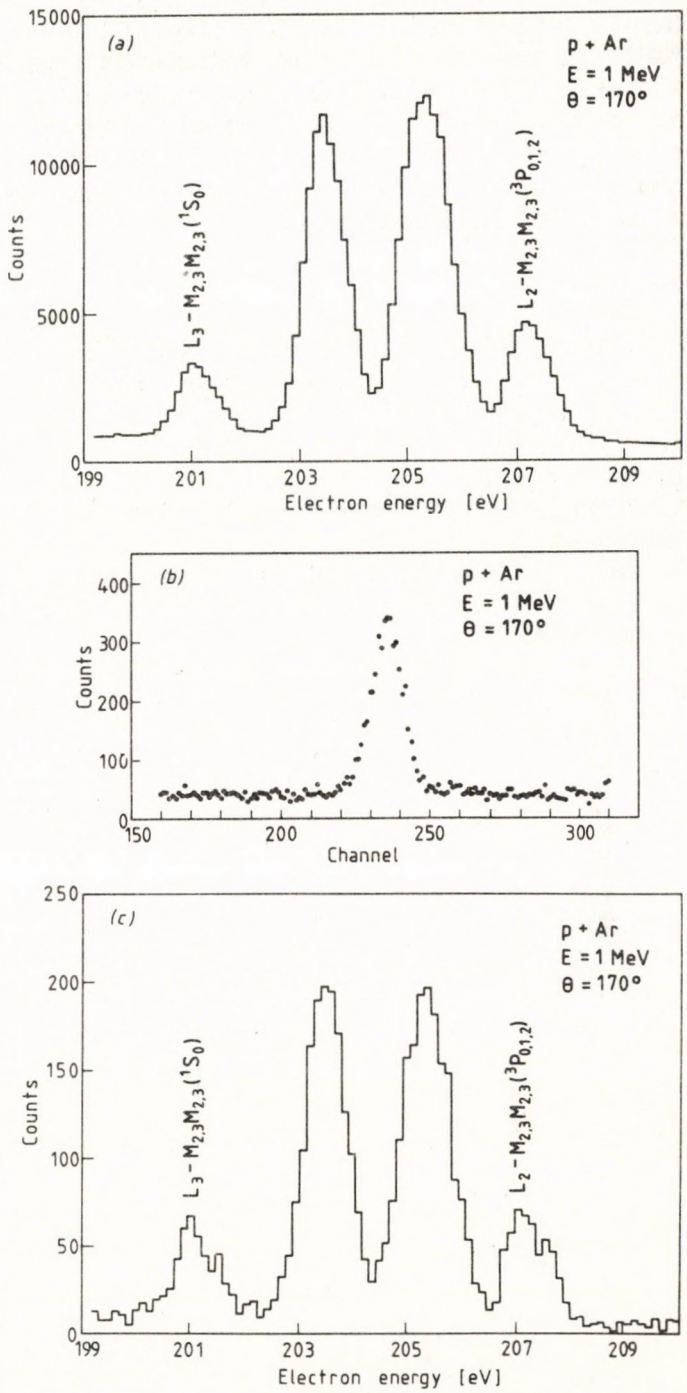

Figure 1. Single electron spectrum (a), time spectrum (b), and coincidence electron spectrum (c) from 1 MeV proton on argon collision. The coincidences are detected between the Auger electrons and the outgoing H⁰projectiles.

(capture + ionization) and that of obtained from the coincidence (capture) Auger electron spectrum differ considerably. The coincidence spectra indicate significant negative alignment. At 0.5 MeV impact energy the alignment parameters obtained with and without the coincidence condition agree within the experimental error and indicate small alignments. This observation is in a strong contradiction with the OBK theory. The detailed evaluation of the data and measurements at different impact energies are in progress.

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THE SHAPE OF THE "CUSP" IN THE SPECTRUM OF ELECTRONS EJECTED INTO FORWARD DIRECTION IN ION-ATOM COLLISIONS

D. Berényi, L. Gulyás, Á. Kövér and Gy. Szabó

There is a very intensive sharp peak (a so called "cusp") in the energy spectrum of electrons ejected into forward directions from ion-atom collisions. The energy of the cusp corresponds to a value of the velocity of the ejected electron which is equal to that of the emergent ion. The origin of the electrons in the cusp can be either the transfer (capture) of a target electron to a low lying projectile continuum state (ECC, Electron Capture to the Continuum), or the excitation of a projectile electron (ELC, Electron Loss to the Continuum) when the projectile carries electron(s).

During the last years a number of experimental and theoretical studies were carried out on this phenomenon investigating the cross section, the position, the width, the shape of the cusp as a function of impact energy, type and charge state of the projectile (see in detailes in ref. [1]). Several years ago, a series expansion and fitting procedure was introduced for better characterization of the experimental cusp shape. This multipole expansion method is independent of any specific theory and of the actual experimental set up.

We investigated the shape of the cusp in He^{++}-He and He^{+}-He collision in the 0.6-1.6 MeV impact energy region by the above mentioned serial expansion method [2]. The optimal number of the necessary coefficients as well as the effect of the range of the fitting around the top of the cusp was examined too.

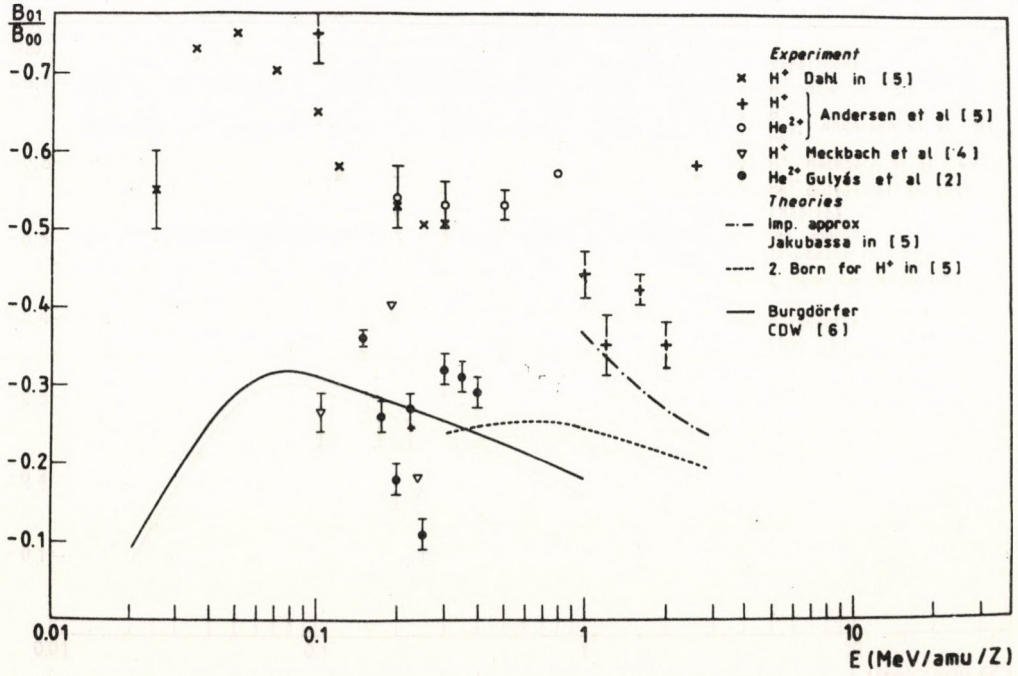

Fig. 1. Comparison of the experimental and theoretical B_{00}/B_{01} parameters determined by different authors

Recently we discussed the energy dependence of the fitting parameters in the series expansion by using our recent results and those which can be found in the literature. The existing theoretical interpretations are also investigated [3].

In the figure the value of the B_{00}/B_{01} parameter for light projectiles can be seen as a function of the impact energy and the projectile charge state. This paremeter characterizes mainly the asymmetric behaviour of the cusp. Our data agree rather well with the data measured by Meckbach et al [4] and with those data which were measured for heavy projectiles but differ from the data of Andersen et al [5]. The detailed analysis of this discrepancy can be found in ref. [3].

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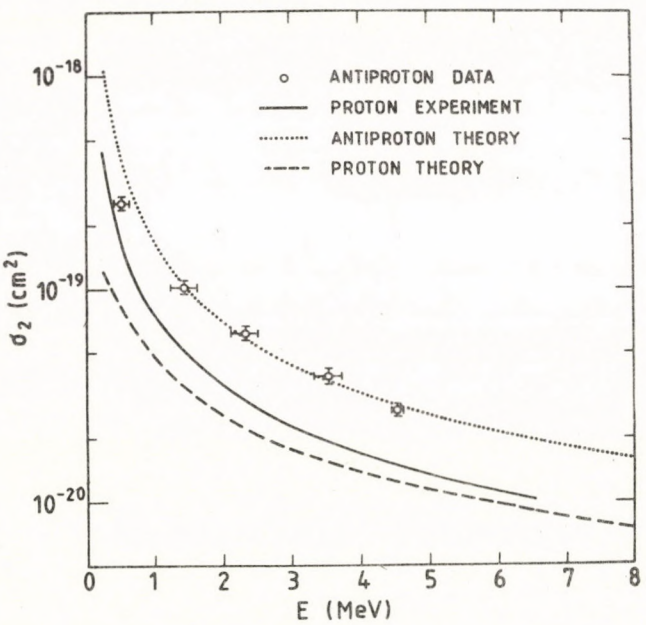
SCATTERING CORRELATION IN DOUBLE IONIZATION OF HELIUM BY FAST ANTIPROTONS AND PROTONS

L. Végh

The difference between the double-ionization cross sections of antiprotons and protons colliding with helium [1] may be explained by the distortion of the two-electron wavefunction during the collision. The distortion is related to the presence of electron-electron correlations and depends on the sign of the projectile charge. Due to their mutual repulsion the two electron favour positions on the opposite sides of the nucleus. The proton attracts the near-side electron stronger than the far-side one, which, due to the electron-electron interaction, moves away from the projectile. For antiprotons, due to the repulsive interaction, the near-side electron moves away and the far-side electron comes nearer to the projectile. Building in this polarization effect into the center-of-charge interaction formulation [2] of the independent-particle model the calculated cross sections [3] are in agreement with the experimental data.



The measured and calculated double-ionization cross-sections for helium target. The experimental curve and data are taken from Andersen et al [1].

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COUPLED-STATES ANALYSIS OF THE HEAVY-ION INDUCED L_3-SUBSHELL ALIGNMENT

László Sarkadi

The L_3-subshell alignment parameter for nitrogen and neon impact ionization of gold has been calculated in the energy range of 0.17-1.5 MeV/amu. The strong distorion of the L shell caused by the relatively low velocity heavy ions has been taken into account by a truncated set of coupled equations including couplings only between the L substates. Compared with the first and second order Born theories considerable improvement has been obtained in the description of the experimental data. As a further refinement of the theory the inclusion of the electronic relativistic effects is necessary.

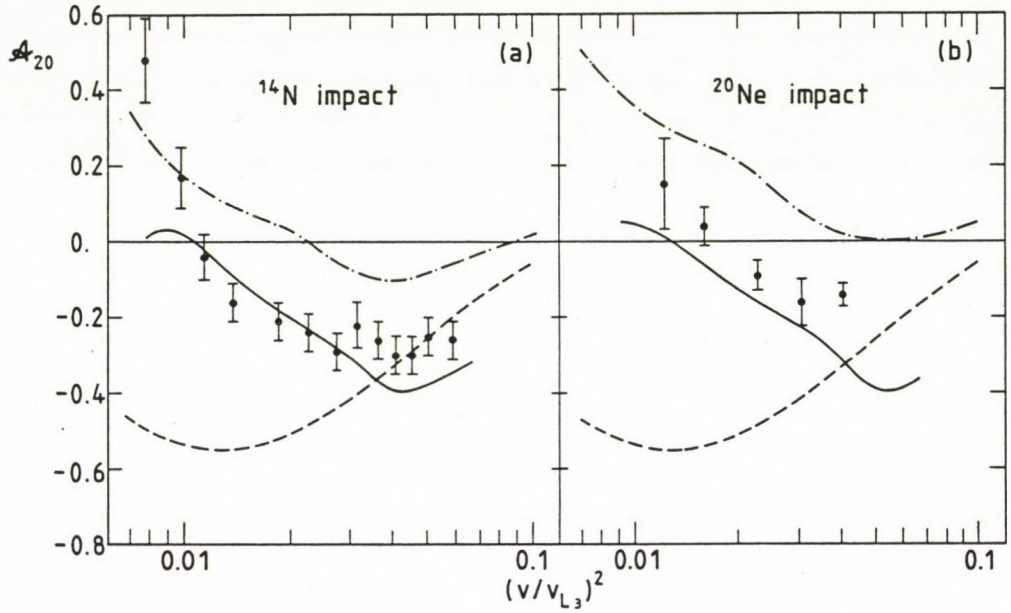

Fig. 1. L_3-subshell alignment of gold induced by (a) nitrogen and (b) by neon ions as a function of the relative collision velocity. Theoretical curves: - - - -, first order Born approximation [1] ; -. -. -. -, second order Born approximation [2] ; ————, the present coupled-states theory. The experimental data are from [3,4] .

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EXPERIMENTAL STUDY OF THE EFFECT OF MULTIPLE IONIZATION ON THE ALIGNMENT OF L_3-SUBSHELL VACANCIES

T. Papp and J. Pálinkás

At the beginning of this decade several research groups addressed the problem of the alignment of L_3-subshell vacancies produced by ion impact ionization [1-2]. In the case of heavy elements (e.g. gold) ionized by light (e.g. p,He^+) ion impact (i.e. when it can be supposed that mainly single ionization occurs in the collision) the alignment of the L_3-subshell vacancies can be obtained from the angular distribution of some L x-ray or LMM Auger lines. The physical quantity obtained directly from the angular distribution measurement is the anisotropy parameter and to convert this into alignment parameter one has to use some atomic parameters (Coster-Kronig and fluorescence yields). When heavy particles (e.g. N, Ne, S) are used to ionize the L-shell [3,4], one (or several) M- or N-shell vacancies may be produced simultaneously. The presence of an M-shell vacancy complicates the matter in several ways:

(i) The single ionization values of the atomic parameters can not be used.

(ii) The L- and M-shell vacancies can couple and several L- or M-satellite lines will appear. The M-shell vacancies can also be aligned and the angular distribution of the L-satellites may reflect both the M- and L-shell alignment.

These problems made it practically impossible to deduce the L_3-subshell alignment parameter from the measured angular distribution of an L-satellite complex. The comparison of the experimental anisotropy parameters with the theoretical predictions could not reach a clear conclusion: One can not be sure whether the experimental analysis supplied meaningless data or the theories did not give fair description of the problem.

To shed some more and new light on these problems, we have designed a new experimental procedure which is outlined here. In the x-ray region absorption edges can provide very good resolution if one finds a material with its K-absorption edge falling between an L-diagram line and its higher energy satellites. This material can be used as an absorber in front of a Si(Li) detector and the intensity of the satellites will be much more (e.g. 98 %) reduced than the intensity of the diagram lines (e.g. 50 %). Running the angular distribution measurements with and without the absorbers, the contribution of the multiply ionized atoms can be separated form the contribution of the singly ionized ones.

The experiment can be realised for the L_ℓ x-ray line of Tl with Cu absorber. If one uses Au target and Zn absorber (or U target and Ba absorber) a further interesting possibility arises. The absorption edge of Zn falls between the L_{α_2} and L_{α_1} lines of Au, so that using a Zn absorber the angular distribution of the L_{α_2} line can be measured and the alignment parameter of the L_3-subshell can be deduced. This gives a

further possibility to determine the alignment even in the case of single ionization.

To perform these experiments a scattering chamber has been constructed, so that three Si(Li) x-ray detectors and a surface barrier particle detector observe thin targets mounted in the centre of the scattering chamber. The absorbers on Al holders can be mounted in front of the Si(Li) detectors. This experimental arrangement is installed on one of the beam lines of the MGC cyclotron of ATOMKI. The first experiments with 6 and 12 MeV He^{2+} particles on Au and Tl targets provided promising results, and the drastic effect of the Zn absorber on the Au L x-ray spectra can be seen on figure 1.

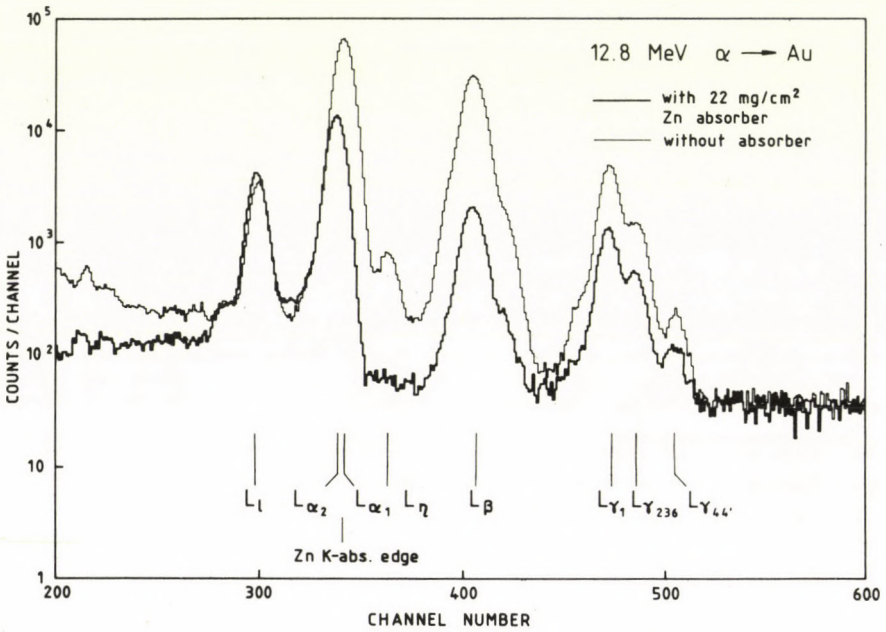

Figure 1. L x-ray spectra of gold induced by 12.8 MeV He^{2+} ion impact recorded with and without a 22 mg/cm^2 Zn absorber

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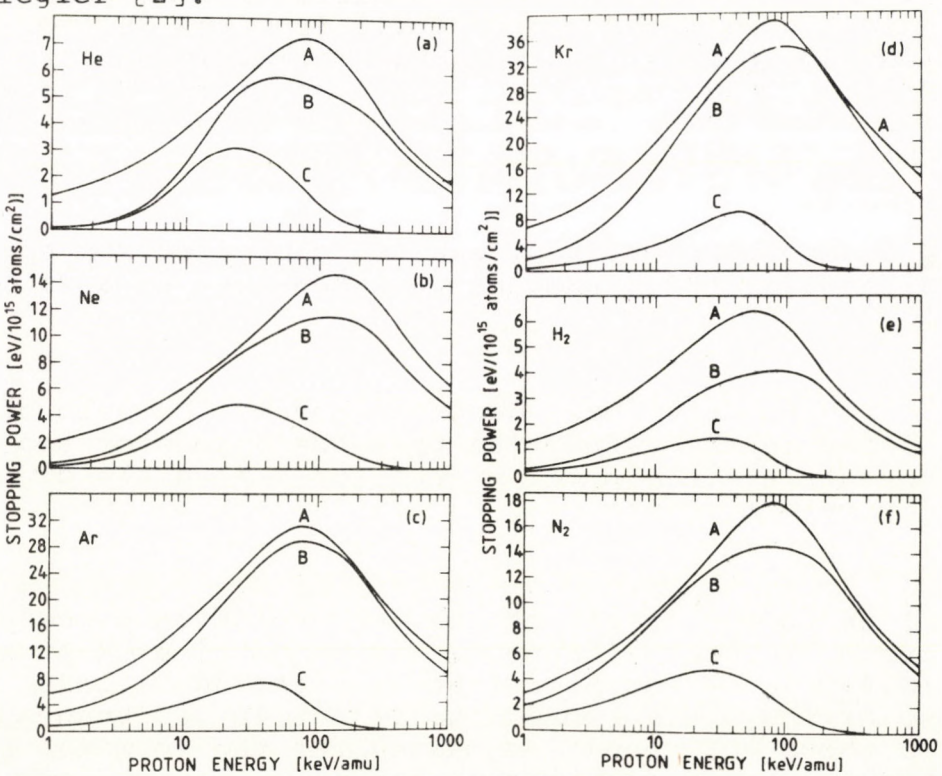
STOPPING POWERS CALCULATED BY EMPIRICAL ELECTRON-EJECTION CROSS SECTIONS

L. Végh

Ionization and charge-changing contributions to the proton stopping power have been calculated in H_2, He, N_2, Ne, Ar and Kr targets over the energy range 1-1000 keV. The model is based on the use of empirical analytic ionization, electron--capture and electron-loss cross-section formulae. The energies E_e of the ejected electrons are determined by the exponential model of Rudd [1] for projectile velocities v lower or equal than the orbital velocities v_o. At velocities $v \geq \sqrt{6} v_o$ E_e is taken to be constant. Except the proton energies less than 10 keV, where the excitation contribution to the stopping power should be remarkable, the calculated stopping powers are in reasonable agreement with the data of Andersen and Ziegler [2].



Comparison of the experimental stopping power curves A to the calculated contributions [3]. B denotes the sum of ionization and charge-changing contributions, C is the charge-changing contribution determined by the energy loss in the two-step capture-and-loss process.

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CHEMICAL EFFECT ON Tc $3d_{3/2}$ CORE HOLE LIFETIME

L. Kövér, J. Tóth, I. Cserny, M. Fišer*

In the metals Nb-Rh (Z=41-45) the existence of a considerable $M_4M_5N_{4,5}$ Coster-Kronig (CK) broadening of the $3d_{3/2}$ core level was observed previously [1] with the exception of the case of the Tc $3d_{3/2}$ level (not examined). Tc 3d lines are often used for identification of various valent forms of Tc [2,3] therefore the determination of the CK-broadening and its dependence on the Tc chemical state has an importance from the point of view of the accuracy of the chemical analysis of Tc compounds as well.

Photoelectron spectroscopy has been used to investigate 3d core line widths obtained from spectra of Tc metal and TcO_2 samples.

EXPERIMENTAL METHODS

Sample preparation

All samples were performed using a stock of the NH_4TcO_4 in 0.01 M NH_4OH. The samples were prepared by electrodeposition onto mechanically polished copper foils from the NH_4TcO_4 solution (200-300μg Tc^g) in 4 N H_2SO_4 (Tc metal sample) or in 2.5 N NaOH (TcO_2*2H_2O sample). In the case of the Tc metal sample the surface oxide layer was removed by using in situ Ar ion etching (5 keV, 1 mA*min*cm^{-2}).

XPS measurements

Al K_α (nonmonochromatized) excited photoelectron spectra of Tc metal and TcO_2*2H_2O samples were measured at a vacuum level of 10^{-6} Pa.

Data evaluation

The 3d spectra have been deconvoluted by the help of an algorithm based on the assumption that the shapes of two spin-orbit components are the same, except for a possible difference in the lifetime broadening [4].

RESULTS

Fig. 1 shows the result of the deconvolution procedure for a spectrum of Tc metal sample. For Tc metal a CK-broadening of (0.4±0.1) eV has been found for the $3d_{3/2}$ level while in the case of TcO_2 this broadening is not larger than 0.15 eV.

Fig. 2 shows our results obtained for the Tc metal in comparison with the data published in [1].

Using an interpolated value of 7.7 for the $TcM_5N_{4,5}N_{4,5}$ Auger intensity (I) relative to $M_4N_{4,5}N_{4,5}$ (from ref. [1]) and applying the relation [1]:

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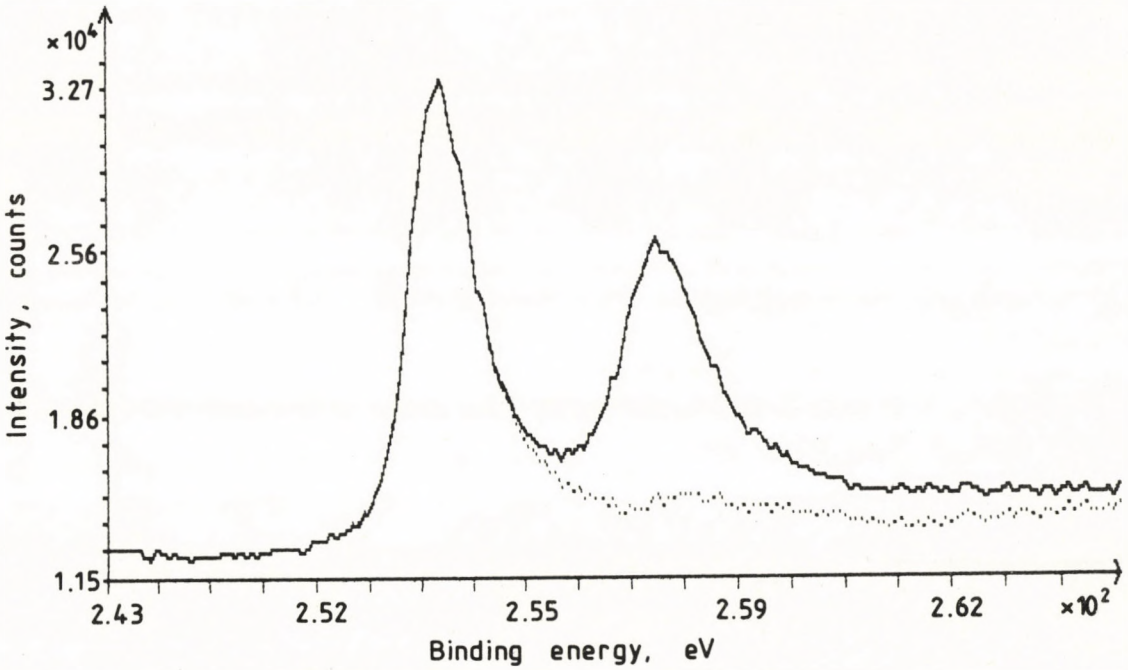

Fig. 1 The deconvolution of the Tc 3d spectrum obtained from the technetium metal sample, CK-broadening = 0.4 eV.

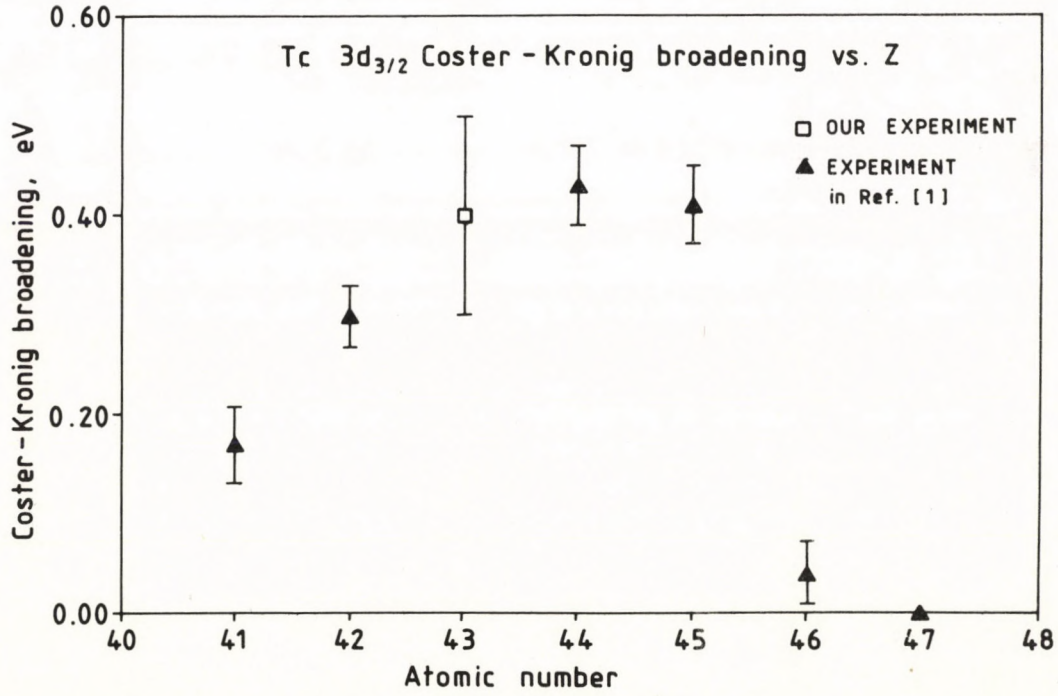

Fig. 2 Experimental Coster-Kronig broadenings for the $3d_{3/2}$ levels

$$\Gamma = \frac{5*\Gamma_{CK}}{2I-3} ,$$

the absolute value of the level width can be estimated for both Tc 3d levels:

$$\Gamma_{est} = 0.16(10).$$

Table 1 contains the measured binding energy values.

Table 1

Binding energy values obtained from the measurements of the Tc metal and TcO_2*2H_2O samples

sample \ level	$3p_{3/2}$	$3p_{1/2}$	$3d_{3/2}$	$3d_{5/2}$	4p	C 1s
Tc metal	427.9	447.6	257.5	253.9	40.5	284.4
TcO_2*2H_2O	429.9	449.3	259.7	256.2		285.2

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ANALYTICAL APPLICATIONS

THE ANALYTICAL APPLICATION OF CHARGED PARTICLE INDUCED X-RAY AND GAMMA-RAY EMISSION (PIXE, PIGE)

I. Borbély-Kiss, M. Józsa, Á.Z. Kiss, E. Koltay, Gy. Szabó and L. Zolnai

Charged particle induced x-ray emission observed with a Si(Li) detector constitutes a powerful multielemental analytical technique of high sensitivity. Since 1970 it is widely used for analytical purposes. The PIXE method is applied in our Institute at the Department of Developments and Applications of Accelerators. The scientific program of the PIXE group is the improvement of PIXE technique in order to obtain better accuracy and precision and the application of this technique in several scientific fields. The method and the chamber used for routine analysis together with the calibration procedure has been described earlier. A description of the different applications is given below.

There is an increasing demand on accurate elemental analysis in present day vegetable growing. PIXE analysis has been performed on leave sample from melon grown in greenhouse and subjected to dose experiments in the application of artificial fertilisers and plant protectives. The samples were collected in the Institute of Vegetable Growing. Absolute concentration data were deduced for elements Br, Ca, Cr, Cu, Fe, K, Mn, Ni, P, Pb, S, Si, Sr, Ti and Zn [1].

Observation on the effect of micronutrients on low birth weight of babies called our attention to the need of completing our data obtained in the PIXE analysis of blood samples from human pregnancies with concentration of light elements like magnesium and sodium. The limitation of the PIXE method in the analysis of elements with atomic number $Z<12$ can be overcome by the combined application of X-ray and Gamma-ray (PIGE) analysis. Based on a systematic determination of thick target yield curves for PIGE processes we performed gamma spectroscopy measurements on blood samples and combined the PIGE and PIXE data to deduce elemental concentrations for the elements observed. K, Cl, S and P appearing both in gamma and X-ray spectra are used for normalising relative concentrations obtained in PIGE measurements to absolute data deduced from the PIXE-spectra [2]. Fig. 1. shows the PIGE spectrum of human erythrocytes at 3.8 MeV proton energy.

Milk powder samples made of monthly collected milk were investigated in period of one year. The concentrations of trace and macro elements (Si, P, Cl, K, Ca, Te, Co, Ni, Cu, Zn, Br, Rb) were determined by PIXE technique. Seasonal variation of the elemental concentrations was also investigated and completed with the study of the electric and dielectric features of the samples [3].

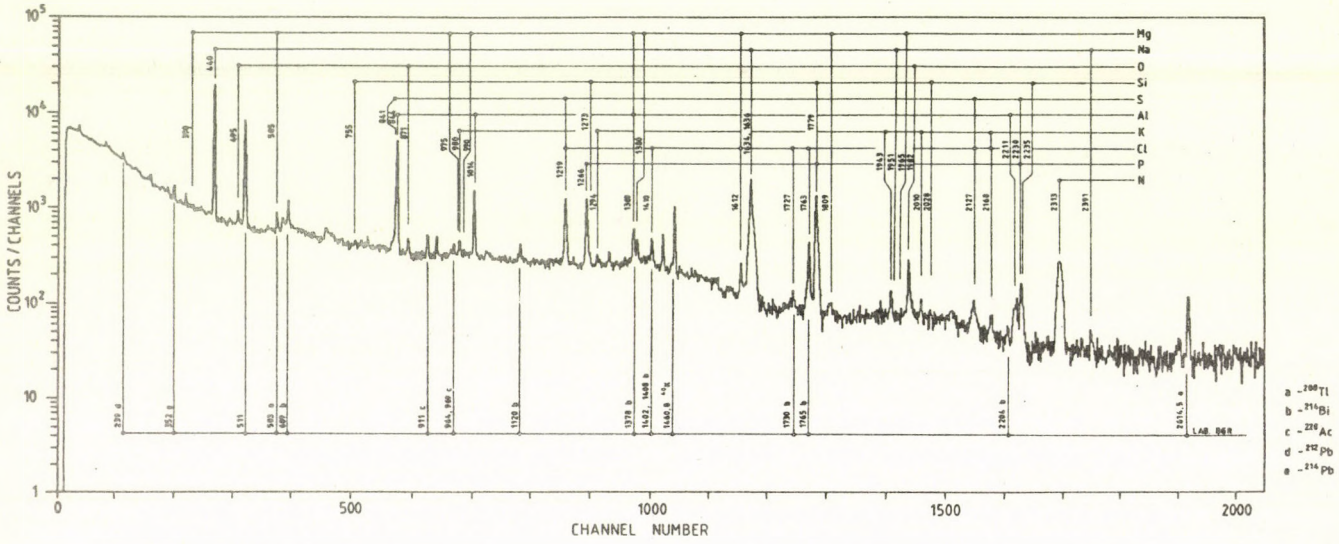

Fig. 1. PIGE spectrum of human erythrocytes at 3.8 MeV proton energy

Samples of atmospheric particles collected during one year at rural sites were analysed up to 20 elements by PIXE. The average concentrations, enrichment factors and size distribution curves were presented and discussed. Concentration ratios for selected trace elements sometimes used as tracers in following long distance transport of air masses were deduced and compared with the data of Rahn. Conclusions were drawn from these regional signatures on the contribution of Eastern European area to the aerosols detected in the artic atmosphere [4].

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APPLICATION OF THE MGC CYCLOTRON IN DEBRECEN FOR PRACTICAL PURPOSES

L. Andó, F. Ditrói, A. Fenyvesi, I. Mahunka, T. Molnár*
F. Szelecsényi, S. Takács, F. Tárkányi

A small compact cyclotron (MGC) has been in operation at the Institute of Nuclear Research (ATOMKI, Debrecen) since November 1985. The cyclotron is used both for fundamental research in atomic and nuclear physics and for applications in the field of medical, industrial and agricultural practice. Several beam-lines (horizontal and vertical) are established for practical applications.

1. Analytical Applications

The modern trends in material analysis demand an increasing use of nuclear analytical methods. The most important methods used in our laboratory are: PIXE, PIGE, CPAA and FNAA. The energy and intensity range of our cyclotron make it especially applicable for CPAA .

The CPAA is a suitable tool for the simultaneous determination of several elements in one sample, with sensitivities of ppm-ppb.

Table I. Matrix materials investigable by 10 MeV proton activation

COOLING TIME	
no cooling	1-15 days
Be C Na Mg Al Si Mn Co Tb Ho Ta Bi	Ca Sc Ni Ag Nb Ba Ce Pr Dy Ir Au Tl

For the above mentioned analytical purposes a special analytical chamber was built. (Fig. 1)

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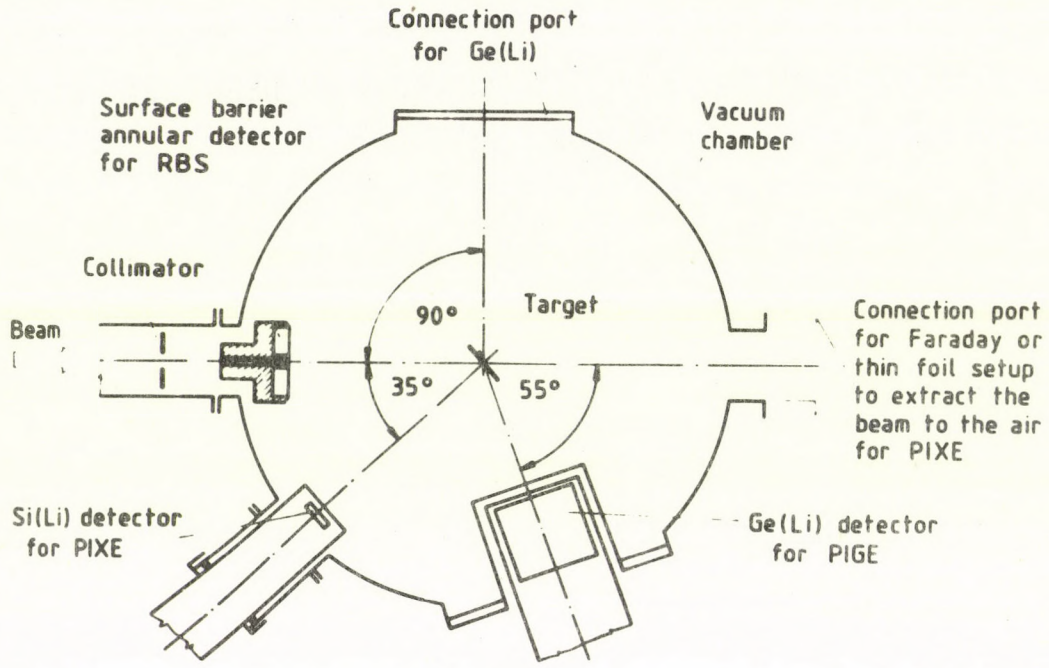

Fig. 1. Schematic diagram of a multi-purpose analytical chamber

Surface loss of different materials caused by mechanical wear, corrosion or erosion can be measured by means of thin layer activation. The investigated surface is irradiated with different charged particle beams, and knowing the distribution of the produced activity, the quantitative measure of the wear can be determined from the change of the sample activity during its wear.

2. Fast Neutron Source

Presently fast neutrons are produced by 18 MeV proton or 10 MeV deuterons incident on a water and He-gas cooled 3 mm thick beryllium target. Heavy-water and deuterium gas targets are under establishment. The target holder is mounted at the end of the beam-line. The room of the remote controlled fast neutron irradiation facility is connected to the Medical Section of the Cyclotron Laboratory.

For the most intense fast neutron sources at the MGC cyclotron the estimated average neutron energies (E_n), thick target yields (Y_n) and absorbed dose rates (D_n) at 5 cm depth in a tissue equivalent phantom at the beam current of 1μA and a distance of 1 m from the targets at zero degree are shown in the table II.

Table II. Main parameters of the neutron sources at the MGC cyclotron

Target	Particle (Energy)	$E_n(0^o)$ (MeV)	$Y_n(0^o)$ $n \cdot sr^{-1} \cdot s^{-1} \cdot \mu A^{-1}$	$D_n(0^o, 1\ m)$ $(mGy \cdot min^{-1} \cdot \mu A^{-1})$
Be	p (18 MeV)	3.7	1.8×10^{10}	3.7
Be	d (10 MeV)	3.9	1.0×10^{10}	2.5
D_2O (heavy water)	d (9 MeV)	6.6	0.4×10^{10}	1.4
D_2 gas	d (10 MeV)	9.1	1.2×10^{10}	4.0

Planned applications

- fast neutron activation analysis for industrial purposes
- in vitro and in vivo activation analysis of biological samples
- dosimetry investigations of mixed n-γ fields
- radiobiological and oncological researches
- mutation induction and stimulation by neutron irradiation in agricultural samples

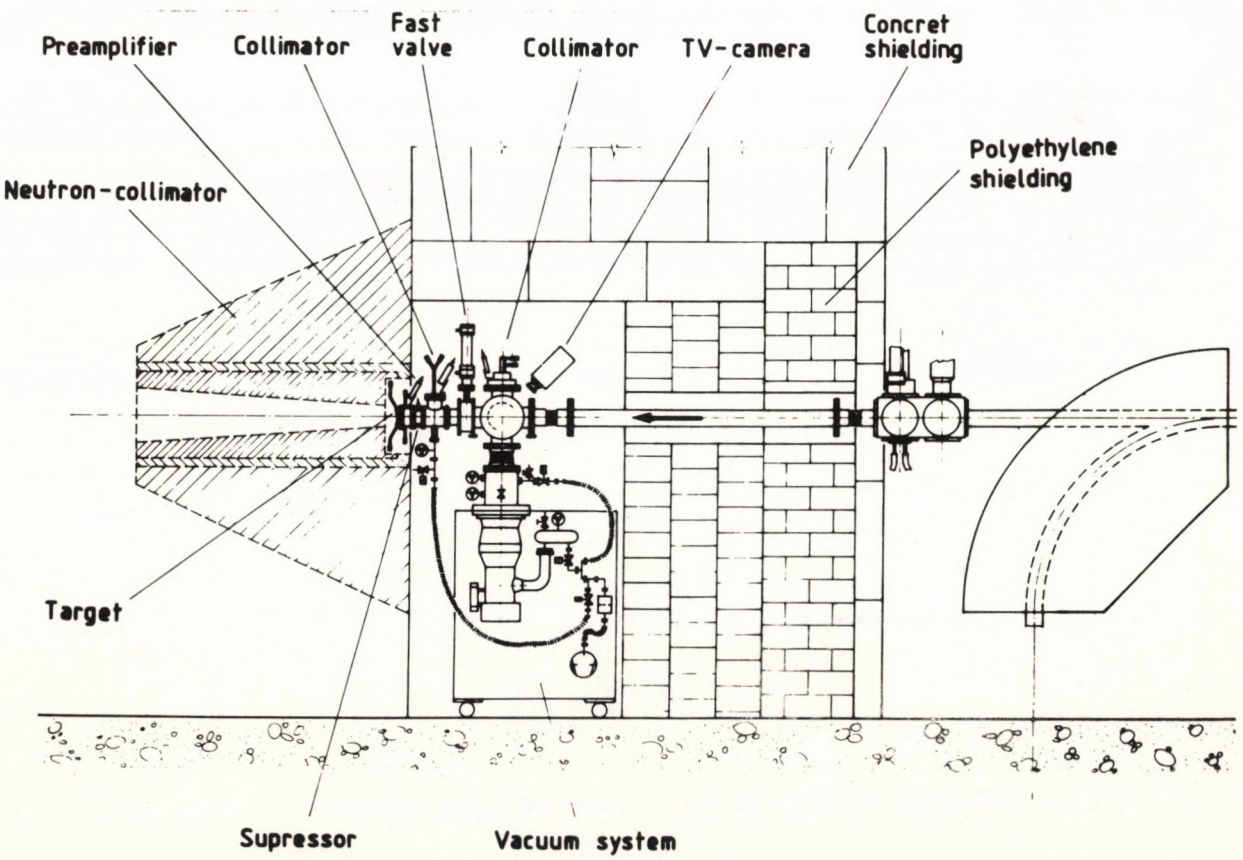

Fig. 2. Horizontal beam line for fast neutron production

3. Radioisotope production

One of the main tasks of our Cyclotron Laboratory is the production of radioisotopes for medical use. The MGC cyclotron is capable of producing the most important radioisotopes used in medical practice.
For isotope production a vertical beam line is established, in the basement of the cyclotron building.
The irradiation system (see fig.3.) is a remote controlled one for different (solid, melted and gaseous) target materials.

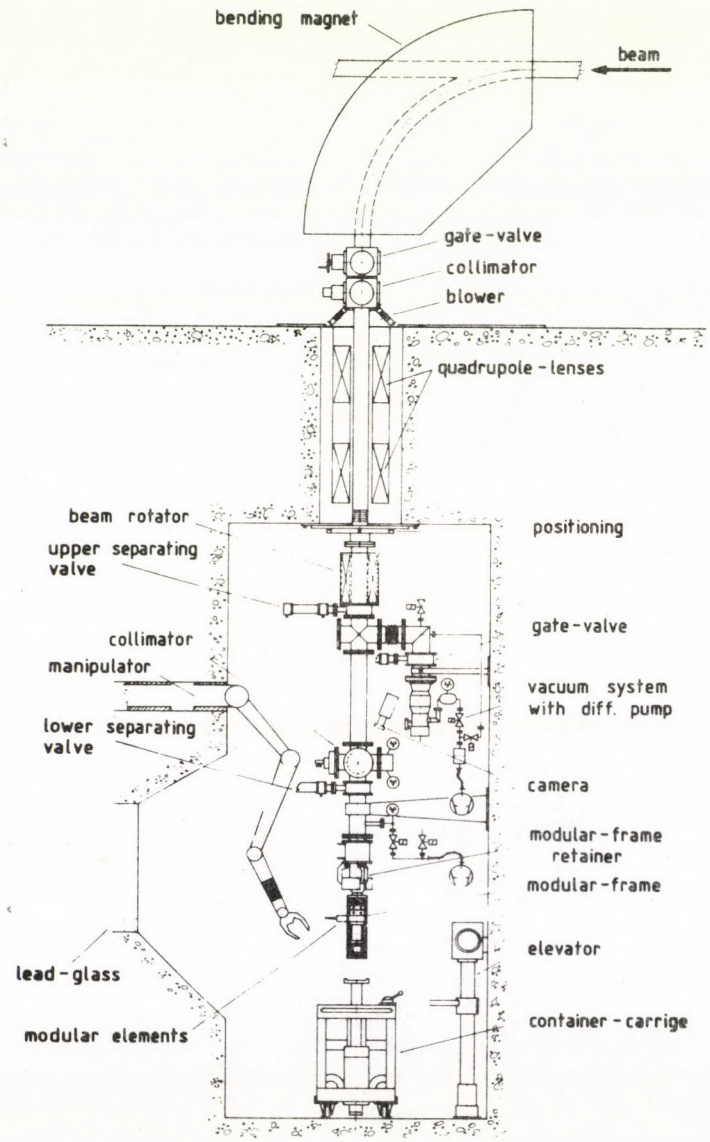

Fig. 3. Vertical beam line for isotope production

Procedures for the production of ^{67}Ga, ^{123}I, ^{201}Tl, ^{81m}Kr and ^{111}In labelled pharmaceuticals are elaborated in cooperation with Hungarian medical institutes. In the second step of our isotope production project the production of short lived PET isotopes (^{11}C, ^{13}N, ^{15}O, ^{18}F) is planned.

Table III. Radioisotopes produced in the first step for medical applications

ISOTOPE	TARGET MATERIAL	REACTION	BOMB. ENERGY (MeV)	YIELD (GBq/C)
^{67}Ga	^{68}Zn(98 %)	$^{68}Zn(p,2n)^{67}Ga$	18	10.3
	^{66}Zn(99 %)	$^{66}Zn(d,n)^{67}Ga$	10	2.1
^{123}I	^{123}Te(73 %)	$^{123}Te(p,n)^{123}I$	15	15.4
^{201}Tl	^{202}Hg(98 %)	$^{202}Hg(p,2n)^{201}Tl$	18	15.4
^{81m}Kr	^{nat}Br	$^{nat}Br(^{3}He,xn)^{81}Rb$	28	13.4
^{111}In	^{111}Cd(95 %)	$^{111}Cd(p,n)^{111}In$	16	5.1

GEOCHRONOLOGICAL STUDIES WITH THE K/Ar METHOD IN THE ATOMKI IN 1986

K. Balogh, E.Árva-Sós, Z. Pécskay

In 1986 geochronological research continued in a wide cooperation with geological institutes and geological departments of universities.

The completed studies comprise the elaboration of morphological development of the Tapolca-basin in the Late Pliocene [1], (common project with the Dept. of Geography, Kossuth Univ., Debrecen), the detailed chronological studies of Miocene volcanic activity in the Tokaj Mts [2] and that of the covered Miocene volcanites in the Great Hungarian Plain [3]. The two latter works were realized in a cooperation with the Dept. of Mineralogy and Geology of Kossuth Univ., Debrecen. With the participation of the Geological Dept. of Eötvös Univ., Budapest and the Geophysical Institute of Univ. of Tokyo, K/Ar and $^{40}Ar/^{39}Ar$ dating has been performed on a biotite sample from the vicinity of the Eocene/Oligocene boundary [4]. The result suggests a datum of about 34-35 Ma for the disputed age of this boundary [4]. The existence of Mesozoic intermediate magmatic activity in North Hungary has been evidenced by dating an andesite body [5]. Samples of basic, intermediate and acid rocks collected by the Hungarian Geological Expedition working in Cuba resulted Cretaceous, mostly Upper Cretaceous ages.

In 1986 continued the study of Mesozoic basic magmatism by dating basaltic rocks from the southern foreground of the Mecsek Mts., and a reconnaissance chronologic study of Miocene-Pliocene basaltic rocks in East Austria started in cooperation with the Dept. of Petrology, Univ. Vienna.

In the frame of a project for the establishment of a universal noble gas laboratory a gas extraction/mass spectrometer system has been constructed; its installation and the elaboration of measuring methods have been in progress in 1986.

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CHANGES IN THE ENVIRONMENTAL RADIOACTIVITY CAUSED BY THE CHERNOBYL ACCIDENT

E. Csongor, T. Kibédi, Á.Z. Kiss, B.M. Nyakó, E. Somorjai, I. Uray

The collection of samples and the measurement of their radioactivity concentration was started on 29 April, 3 days after the Chernobyl accident. The systematic investigations directed mostly into two ways:

Firstly: the measurement of the beta activity of rain water, which was actually a continuation of the regular measurements of the total beta activity of fallout washed out in the precipitation in Debrecen since 1952 [1,2]. These measurements were completed by the identification of the radioisotopes by measuring the gamma spectra of the samples. The first results were published in Nature [3].

Secondly: the measurement of the airborn activity by pumping air through a sampling device containing filter paper and active carbon granulatum. The samples were taken during 12 hours at the beginning and for longer periods a few days later. The sampling was continued for 8 weeks, however the decay of radioactivity was followed for several months by gamma spectra measurements using a large Ge(Li) detector [4].

Upon the request of different authorities, the Biogal Pharmaceutical Works, as well as private persons, several hundred of samples from food (different kinds of meet, milk, vegetables, fruits), pharmaceutical basic material, sand, protective waxen layer from the surface of imported cars etc. were measured, their specific activities determined. As an example the ^{131}I specific activity of packed milk bought in shops in Debrecen is presented in Table 1 correlated with the date of issue.

Table 1

^{131}I activity of cow milk in Bq/l

DATE	IV.30.	V.4.	5	7	8	9	10	12	13	14	15	16	17	19	21	26	30
A:	<10	70	80	140	150	150	280	320	330	340	340	200	180	170	150	90	50
B:							410		470	680	510		230				

A: State Dairy, Debrecen, B: Coop. Dairy "Sárrét"

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DEVELOPMENT OF METHODS AND INSTRUMENTS

THE OPERATION OF THE VAN DE GRAAFF ACCELERATOR IN 1986

L. Bartha, Á.Z. Kiss, E. Koltay, I. Papp, Gy. Szabó

The operation time of the 5 MV Van de Graaff accelerator amounted to 1616 hours this year. This number is somewhat smaller than the average beam time of the preceding years. The decrease is partly due to the fact, that the measuring center of the accelerator laboratory was engaged in continuous gamma spectrum measurements of aerosol and food samples around the Chernobyl reactor accident, for a period of more than two months.

The available machine time was distributed mainly among atomic physics, nuclear physics and analytical studies at the rate of 1/3-1/3 each, as shown in table 1. Only protons and alpha particles were accelerated. Their rate was 70 % and 30 %, respectively.

Aiming at higher stability of beam position at tube exit we replaced the removable electrode plates of the used tube of spiralling inclined field structure by new electrodes defining a straight tube configuration with axial gradient modulation. The test of the new configuration lasted for more than 1000 hours and gave reliable results. Among others, good stability was obtained at beam energies as low as 0.5 MeV. The physical properties of the tube optics are being investigated through the mapping of the bremsstrahlung field by thermoluminescent dose meters.

Due to the needs of recent investigations in ion-atom collision physics to perform experiments at beam energies of a few hundred kiloelectronvolts the model Van de Graaff generator of 1 MV rated voltage has been partly reconstructed and subjected to test runs. Stable working conditions have been reached in the energy range 0.08-1.0 MeV.

Table 1

Field	Hours	%
Nuclear Physics	492	30.4
Analytical Studies	349	21.6
Atomic physics	442	27.4
Accelerator physics	193	11.9
Machine Tests	140	8.7
Total:	1616	100.0

STATUS REPORT ON THE CYCLOTRON LABORATORY

A. Valek and J. Pálinkás

The MGC-20 cyclotron of the Institute was put into operation at the end of the last year, so that 1986 was its first year of operation. In this year the machine was covered with a one year warranty by the the supplier, the D. Yefremov Scientific Research Institute of Electrophysical Apparatus, Leningrad. According to the agreement with the manufacturer, the cyclotron was shut down for two month for modification of some parts of the extraction and RF system and to make the final adjustments to increase the extraction efficiency to 50 %.

The machine was available for research, beam development and training of the operation personel for 31 weeks. During most of its operation it was used in two shifts per day. An extensive beam development work was carried out, during which proton, deuteron, alpha, $^{3}He^{++}$ and $^{3}He^{+}$ particles were accelerated at various energies, and the transport and beam handling features of each of the ten beam lines were tested.

In 1986 ten basic and applied research projects were runing on the cyclotron and their beam time statistics is shown in table 1.

Table 1. Beam-time statistics of the basic and applied research projects on the MGC cyclotron in 1986

Project	Beam time (in hours)	
	Scheduled	Effectively used
Nuclear spectroscopy	307	202
Nuclear reaction studies	132	88
Nuclear life-time studies	33	28
Atomic collisions	201	140
Ion-atom collisions	196	114
Isotope production	288	231
Neutron source	145	66
Analitical applications	205	166
Neutron physics	27	17
Elastic Recoil Detection	0	0
Beam development	137	44
Scheduled maintainance	498	498
Total run-time	2122	1524
Unscheduled maintainance		607

During the year several gests, experts, potential users and collaborators visited the laboratory and the 23rd European Cyclotron Progress meeting was held in this Laboratory in May 15-16, 1986.

LENS OPERATION MODE OF A SUPERCONDUCTING MAGNET PLUS Si(Li) ELECTRON SPECTROMETER

T. Kibédi, Z. Gácsi, A. Krasznahorkay and S. Nagy

The superconducting magnetic spectrometer (SMS) [1] was built in the middle of the 70s, and was used mainly for in-beam internal conversion electron [2] and for internal pair spectroscopy [3].

During the last year a new operation mode, a two loops lens mode (Fig. 1) was designed and tested. This way the spectrometer consists of two equivalent lenses, which transport only a certain part of the emitted electrons from the target (or source) to the detectors, at a given magnetic field. The X- and γ-rays, scattered particles are absorbed by the baffles made of tungsten. A specially formed antipositron baffle system is also used.

The momentum window of the superconducting magnetic lens plus Si(Li) electron spectrometer (SMLS) was tested by a ^{207}Bi source and was numerically calculated (Fig. 2). The aim of the calculations was to obtain an optimal baffle system and to investigate the dependence of the efficiency on the source radius and position. The maximum efficiency of one lens is $\sim$5.6%. The obtained momentum band width is $\sim$20%. The orbits of electrons emitted from the source with different energies and at the $20^{o} \leq \theta \leq 38^{o}$ angles (with respect to the spectrometer axis) were calculated in a homogenic field approximation. The difference between the measured and calculated values of the momentum window (Fig. 2) at higher energy is caused by the 6.5 % inhomogenity of the magnetic field and by the antipositron baffle. The positron suppression of the SMLS was tested by fixing the momentum window on the 1063 K line of the ^{207}Bi source and by changing the

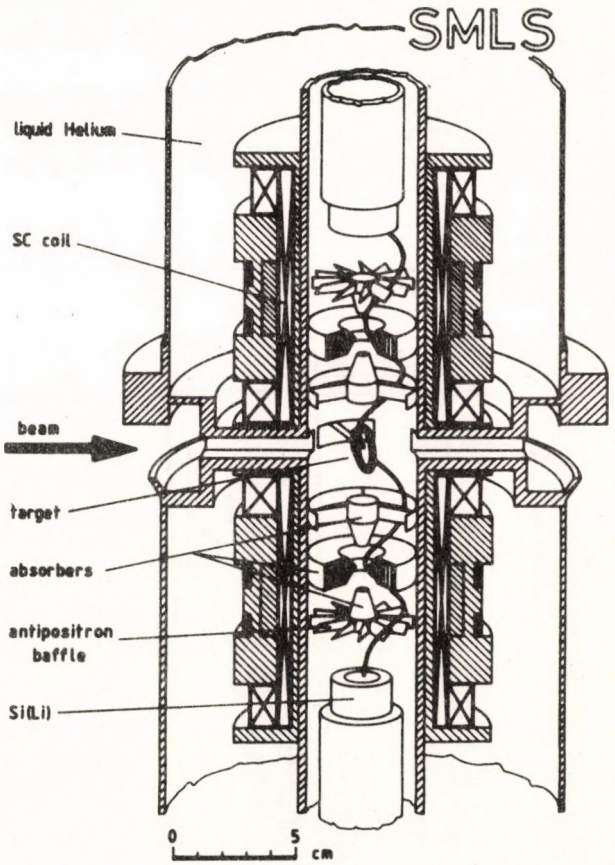

Fig. 1. Schematic view of the central part of the double superconducting magnetic lens plus Si(Li) spectrometer.

polarity of the power supply. The counts recorded in peak were insignificant.

The relative sweeping-mode efficiency curve was measured with ^{152}Eu and ^{207}Bi sources and was well reproduced by numerical integration of the experimental momentum window over the sweeped current interval. For this calculation the experimental momentum window was approximated by a smoothed curve fit to the measured points shown in Fig. 2.

The SMLS was installed on a beam channel of the MGC cyclotron [4]. A new target changing system (with a three axis goniometer) and a new helium gas handling system was also constructed.

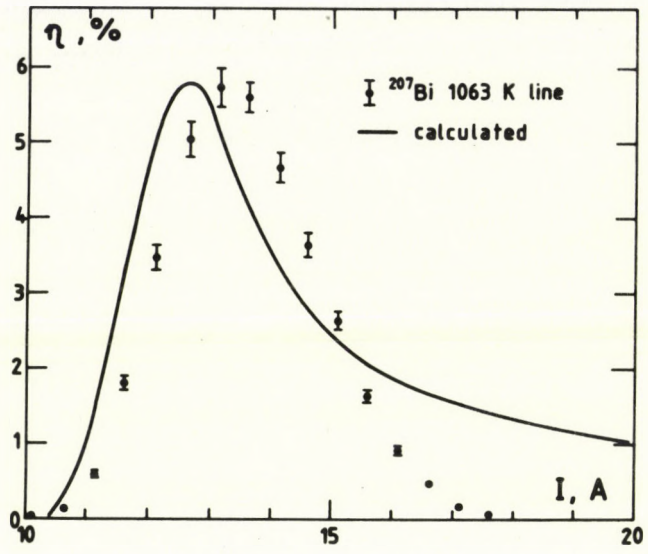

Fig. 2. The detection efficiency as a function of the magnet current.

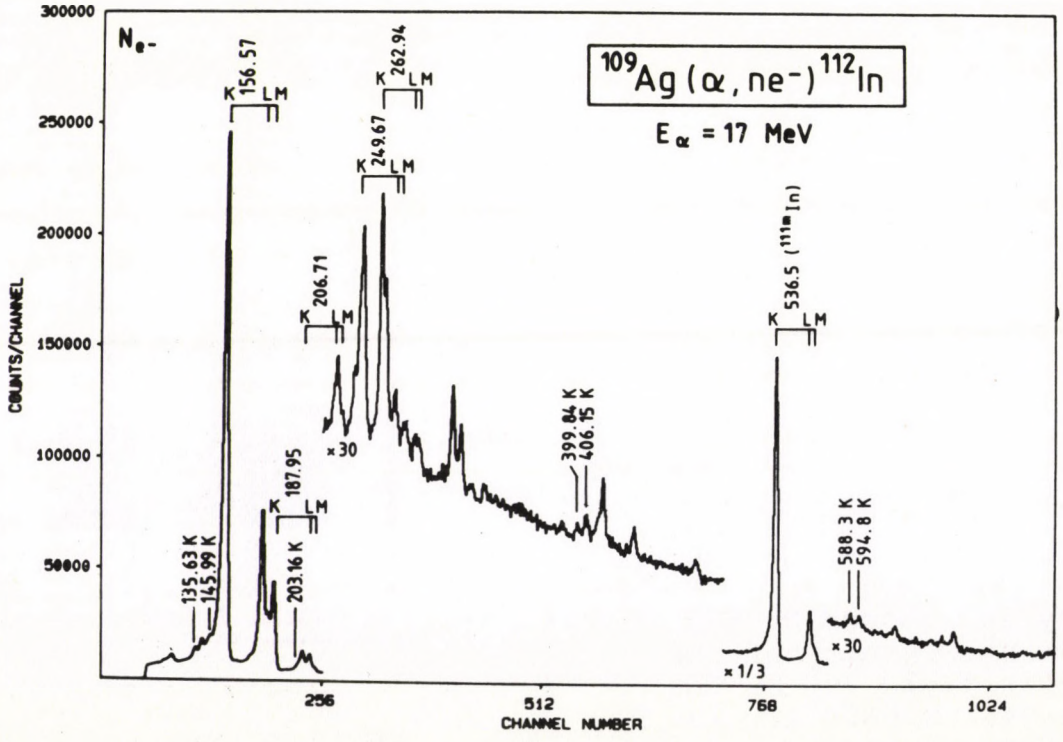

Fig. 3. Conversion electron spectrum measured in the reaction of 17 MeV α-particles on ^{109}Ag. The target tichness was ∿0.5 mg/cm^2. The measuring time was 5 h at beam current of approximately 400 nA.

The first in-beam measurement was performed to investigate the internal conversion electron spectra of the $^{107,109}Ag(\alpha,n)^{110,112}In$ reaction (Fig. 3.). The background was reduced by a low level discriminator sweeped simultaniously with the momentum window.

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STABLE ISOTOPE MASS SPECTROMETER

E. Hertelendi, J. Gál, A. Paál, S. Fekete, M. Györffi, I. Gál, Zs. Kertész and S. Nagy

A high precision stable isotope ratio mass spectrometer has been designed, built and its performance evaluated [1]. The mass spectrometer is provided with two ion sources (H, CNOS sources) and ten separate Faraday cups. Its analysers of 3.7cm (H) and 13.6-15.1 cm (CNOS) radii and 180° deflection angle provide first order focusing for ion beams diverging in the radial plane (see fig. 1.).

Trap regulation of a magnetically and electrostatically focused electron beam is used to achieve stable ion production in the ion sources. Ion currents are amplified with low bias-current solid state amplifiers and integrated with voltage to frequency converters and scalers. Mass setting is performed by varying the ion accelerating voltage.

A symmetrical dual viscous inlet system has been constructed for measuring the sample and standard gases alternatingly. Pneumatically actuated bakeable gold sealed metal valves exclude cross mixing between sample and standard gases. The instrument, including the inlet system with variable reservoir volumes, is controlled by a microcomputer thus providing automatic and reproducible operation.

The sensitivity of the instrument for nitrogen is better than 4×10^{-4} A/mbar using the ion source adopted for higher masses with an exit slit of 0.2 mm and collector entry slit of 1 mm width.

The collector slits are of 1 mm width for nitrogen, carbon, oxygen, sulfur and 2.5 mm for hydrogen, resulting a working resolution of $M/\Delta M = 120$ (10% valley) and $M/\Delta M=8$ for hydrogen. The slits are wide enough to produce flat topped trapezoidal peaks with the shape of about 10^{-3} top flatness.

The H_3^+ contribution of the hydrogen source depends strongly on the operational pressure. It is in the region of 12 ppm (equivalent to 4 % contribution to minor current at natural level) for the standard operating major current of 8×10^{-9} A. H_3^+ contribution is compensated by the software.

The quality of the mass spectrometer and the inlet system may be characterized by the value of correction factors which should be considered during the data evaluation. The classical error factors coming from instrumental artifacts like peak overlap (AS), leak correction (LC), residual gas and memory contribution (BG), cross mixing of sample and standard at the changeover valve (VC), beam position and amplifier zero stability are summarised in table 1.

It can be seen that the correction factors are of low values and generally no correction is necessary. Memory effect can also be neglected if the samples are clean and dry otherwise longer pumping times should be applied.

The internal reproducibility of the spectrometer defined as the 2 σ values from a single set of ten values taken over a ten minute period is 0.01‰, for N_2 and CO_2 and 0.3‰ for hydrogen using 1 cm^3 sample.

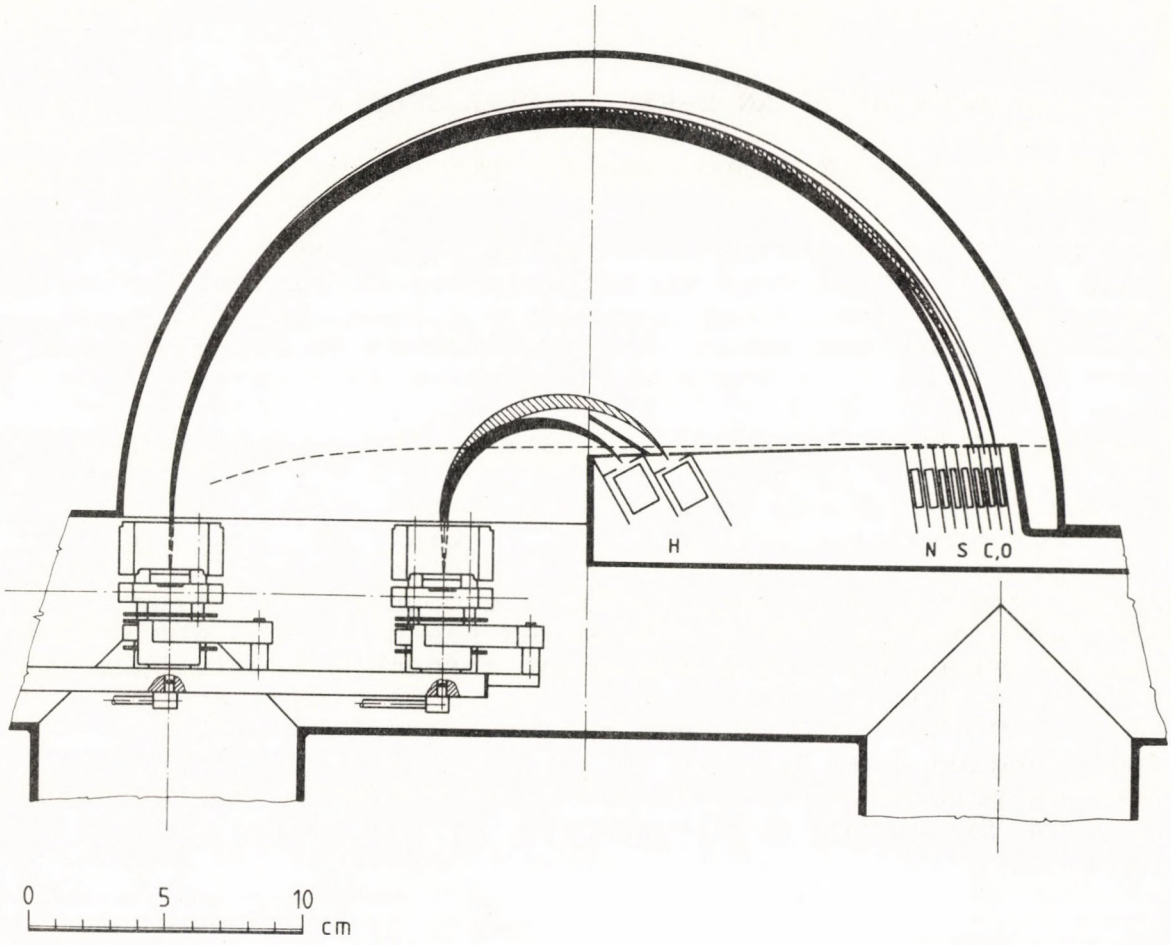

Fig.1. Cross-sectional view of the mass spectrometer flight tube, ion sources and detectors. Broken line shows the first order focal plane for the CNOS ion source.

Table 1

Instrumental correction factors

peak overlap abundance sensitivity correction (AS^{45})	1.00065
leak correction (LC^{45})	<0.01 ‰
background correction (BC^{45})	1.00003
cross mixing correction (VC^{45})	<1.0000001

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DEVELOPMENT OF AN X-RAY CRYSTAL SPECTROMETER

I. Török and B. Tóth

A Soller-type flat crystal X-ray spectrometer has been constructed, which can be used at accelerators for investigation of ion-induced X-rays. First the vacuum chamber and the spectrometer mechanism was built. The arrangement of the mechanism is shown on Figure 1. A 6-position revolver type target holder receives either thick or thin targets. The excitation can be made either by the horizontal ion beam of the accelerator, or - after turning the revolver head by 90 degrees - by a vertical X-ray beam from an X-ray tube mounted on the top of the vacuum chamber. The home made Soller slits, viewing the target at 90 degrees, provide an 0.3 degrees angular divergence. The X-rays reflected from the analyzer crystal are counted by a flow proportional counter. The spectrometer has a rhombic goniometer mechanism, driven by a stepping motor through a precision screw drive. This mechanism permits less then 0.01 degree angular increments. We have 8 different analyzer crystals with 2d spacings ranging from 2.848 A to 26.121 A. For monitoring and calibration purposes an additional Si(Li) detector can be used, which views the target at 135 degrees. An oil diffusion pump maintains ca. 3.10^{-3} Pa (2.10^{-5} torr) pressure in the chamber.

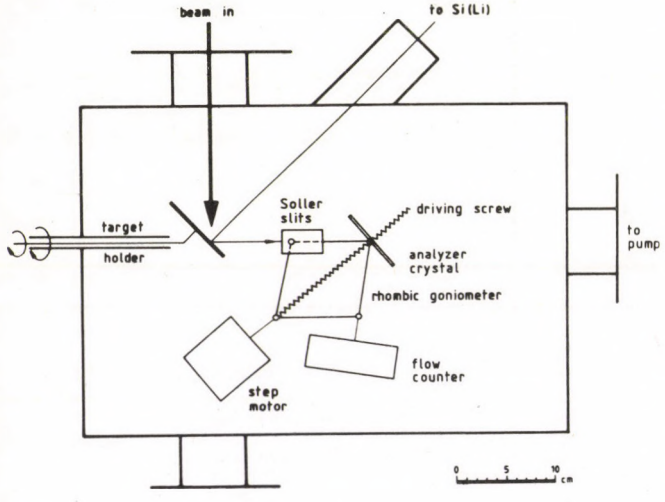

Figure 1.

The spectrometer is controlled by a microcomputer based multichannel analyzer. This flexible instrument can be used either in pulse height analysis (PHA) or in multiscaler mode (MCS). The computer also controls the spectrometer mechanism. Four bits of an I/O port of the microcomputer is used to initiate the step pulses for the motor, to prescribe the direction of movement and for checking the limit-switches defining the allowed angular range of the goniometer.

The spectrum is collected in a memory of four 1K segments. The start position, the step size and the end position can be set from keyboard inputs. The channel advancement is done whenever a preset number of pulses either from an internal dwell time clock or from external source (e. g. from a target current integrator or from the Si(Li) detector) is reached. As the analyzer uses the same input discriminator window in both working mode (PHA and MCS), it is easy to find the proper window for a given X-ray range to be measured. Except the window

setting, which is made by helical potentiometers from the front panel, all the measurement parameter settings are made from the keyboard.

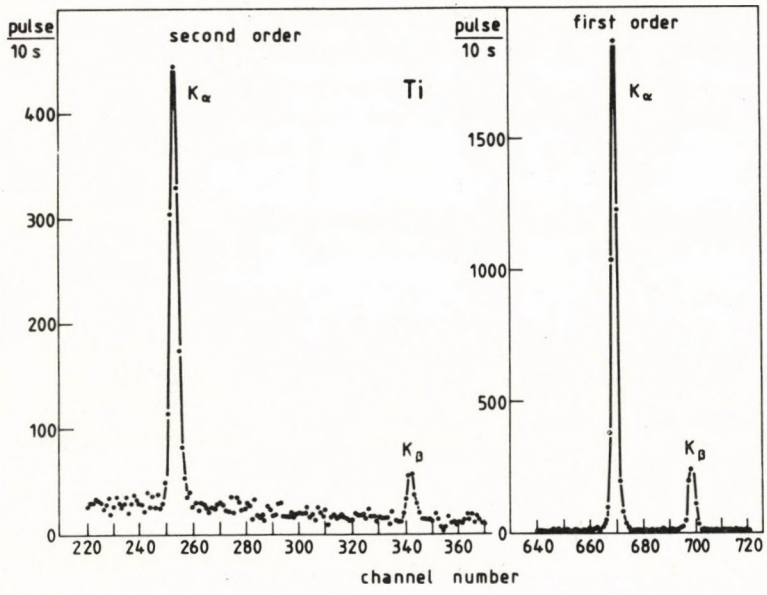

Figure 2.

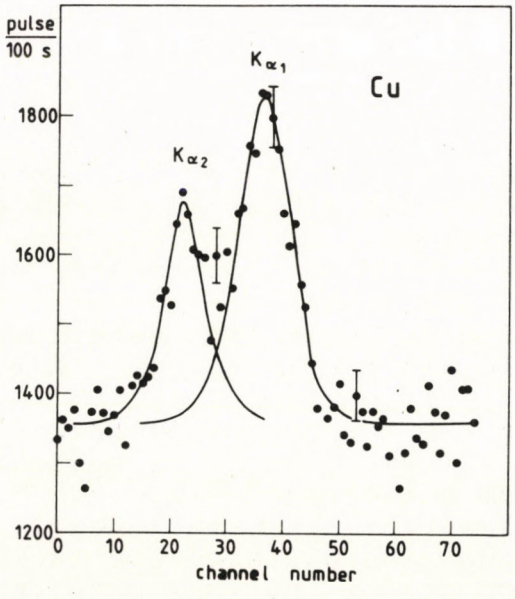

Figure 3.

The spectra can be displayed graphically in 512x256 point resolution. For the storage of spectra and programs 5.25" floppy disks are used. The spectra can be printed out or can be sent on cable to a larger computer for further processing.

A simple analysis of the spectra can be carried out on the microcomputer. The programs on the microcomputer are written in BASIC, except the I/O rutines which are written in assembler.

A number of different test spectra were taken under different conditions. With a series of modification in the spectrometer significant intensity and signal to background ratio improvements were achieved.

Figure 2. displays two portions of a titanium K X-ray spectrum obtained with a quartz analyzer crystal, X-ray excitation and 0.15 degrees/channel angular steps were used. Figure 3. shows a copper K-alpha doublette in fourth order reflexion, taken with quartz analyzer crystal and with 0.05 degrees/ channel increments.

SCIENTIFIC PROGRAM PACKAGE FOR THE PROCESSING OF XPS SPECTRA

I. Cserny

Most commercial spectrometers can be purchased with a dedicated data system, which may be fairly expensive. The availability of cheap microcomputers allows automation of data collection and many digital methods of data analysis to be applied at a substantially reduced cost.

Our XPS spectrometer is controlled by a 8-bit home made microcomputer, while the data analysis is carried out on a 16-bit IBM PC compatible machine. A program package has been developed to perform the collection, transfer, and analysis of spectroscopic data.

The data acquisition software was written in FORTH language and stores spectra on floppy disks in CP/M format. Data files can be transferred to a 16-bit computer (SANYO MBC-555) through a serial line. A communication program (ACCEPT.PAS) was developed for the SANYO computer which receives the transferred data and writes it to disk in MS-DOS format.

Nearly all data systems provide a facility to smooth data. Smoothing is a process that attempts to increase the correlation between points while supressing uncorrelated noise. The three most common methods for smoothing are: moving average, least-squares and Fourier transformation. The last method is probably the best, since it lends itself naturally to identifying and eliminating noise. The reason for this is that noise is usually present at high frequencies, whereas the proper signal is usually at low frequencies.

Fourier transformation produces the frequency spectrum. By eliminating the high-frequency portion of the spectrum and performing an inverse Fourier transformation, the original data can be obtained without much of the noise.

The algorithm developed by Aubanel and Oldham [1] can be effectively implemented on microcomputers: by using the properties of the sine and cosine functions, the number of function value calculations is drastically reduced.

The majority of XPS spectrometers have no monchromator and the ionising radiation includes various higher energy satellite line associated with multiply-ionised Al atoms. The satellite structure can be removed by a simple procedure assuming that the contribution of the satellites is proportional to the primary signal and it is shifted by the corresponding energy value. The necessary parameters of the exciting Al K_α radiation were taken from the paper of Beatham and Orchard [2].

In XPS, the observed width of spectral lines includes several broadening contributions: the line width of the exciting radiation, the response function of the analyser etc. Therefore there is a significant loss of resolution, some of which can be recovered by deconvolution.

Our program uses the so-called ordinate ratio corrections method [3], which is similar to the original Van Cittert's iterative formula, but leads to faster convergence and prevents

negative wing corrections.

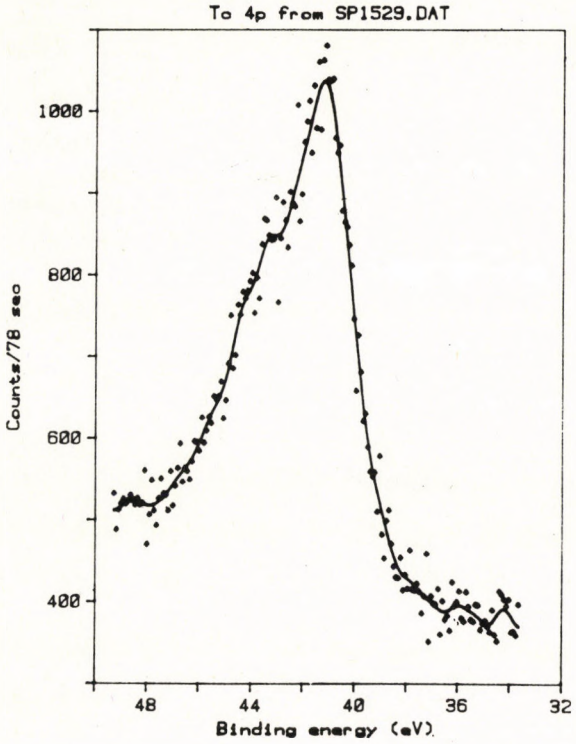

Fig.1. An example of Fourier smoothing

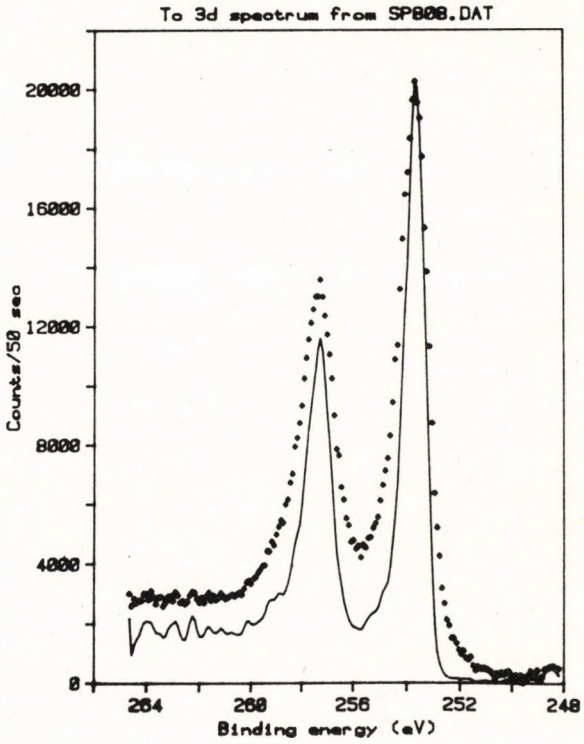

Fig.2. An example of X-ray broadening removal

The main advantages of the iterative method over the Fourier technique are the ease of computation and the fact that noise builds up slowly and linearly.

An accurate knowledge of the broadening contributions is necessary for proper deconvolution. The analyser response function may often be assumed Gaussian and its FWHM may be estimated. The X-ray broadening may be computed separately using published parameters [2].

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MULTI-COUNTER MEASURING SYSTEM FOR ^{14}C DATING

E. Hertelendi, É. Csongor, L. Záborszky, J. Molnár, J. Gál,
K. Juhász, S. Nagy

A multi-counter radiocarbon dating system was developed applying the experiences of the previous one-channel low-level counting facility [1]. The counter system consists of nine electrolytic copper proportional counters of identical diameter with sensitive volumes of 0.4-0.7 dm^3, and filled with methane at high pressure (max. 6 bar). The inner counters are surrounded by an anticoincidence shield consisting of five multiwire proportional flat counters filled with propane.

Both counter systems are located in a lead shield with a wall thickness of 15 cm and 25 cm on the top. A 5 cm lead layer was applied between the anticoincidence and the ^{14}C measuring counters and 5 cm thick boron loaded paraffin layer was used for thermalization and absorption of neutrons produced by cosmic ray particles in the lead (see fig.1.). The low-level counting equipment was settled on the basement of a two story building, 2 m below the surface.

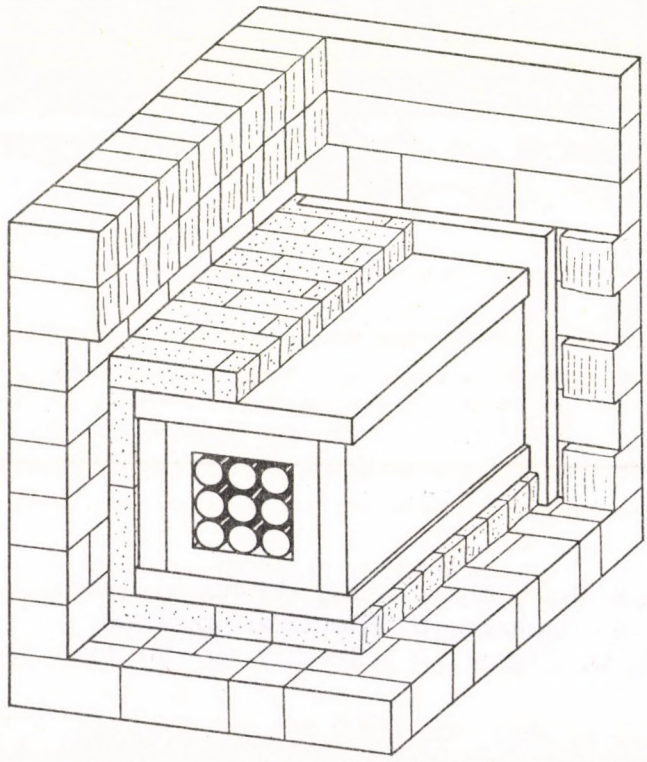

Fig.1. Counter system and shield arrangement

The pulses of the detectors are handled by integrated amplifiers, discriminators and anticoincidence units interfaced to a microprocessor controlled data evaluation unit. Software is written in ASSEMBLER in order to achieve the highest possible counting speed.

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APPLICATIONS OF STATISTICAL METHODS TO TEST XPS MEASUREMENTS

L. Kövér, J. Végh, J. Tóth

Analysis of consistency of spectra measured sequentially in pulse counting mode can be used as a sensitive tool to control the validity of assumptions about either the instrumental performance or the sample conditions. It allows to estimate the level of the instrumental reliability and to identify data statistically incompatible with all others.

Statistical analysis of spectra measured sequentially provides methods to get quantitative criterions for the "goodness" of the measurement (apparatus, i.e. to control the validity of the assumptions connected with the distribution of the measured data and the constancy of the experimental conditions during measurements (reproducibility test). The information obtained helps to improve the instrumental performance and takes possible the estimation of realistic experimental errors.

First it is necessary to check the random nature and the distribution of the data in the same energy channel accumulated in subsequent scans. Computing the empirical mean and standard deviation of the experimental distribution and supposing the same parameters for the distribution expected theoretically, a χ^2 test gives the probability to get higher value for the normalized Chi - square in the case of the next similar set of measurements. This test is sensitive to systematic errors both constant or fluctuating in time, the selection of the intervals of the frequency distribution, however, influences the Chi - square value.

For analysis of the reproducibility of the measurements a method is proposed which comprises the advantages of the known statistical consistency tests and provides a quantitative measure of the compatibility of the spectra under test allowing to estimate the effects of instrumental changes during adjustment or measurements and to identify scans incompatible with all others [1]. This method is based on the normalized distribution of the difference of counts detected in the identical channels of two scans:

$$r_i^{kj} = \frac{y_k - y_j}{(d_k^2 + d_j^2)^{1/2}}$$

where $y_k = y_i + d_k$ and $y_j = y_i + d_j$ are the measured counts in the i-th energy interval (y_i is the empirical mean) an in the k-th and j-th scan, respectively. This random variable follows a normal distribution N(0,1) independently from the structure of the spectra while the distribution of the corresponding empirical average and standard deviation should follow $N(0,n^{-1/2})$ and χ^2 distribution, respectively.

The identification of the incompatibilities can be more unambiguous and convenient presenting the empirical averages and standard deviations (for each pair of spectra) obtained from reproducibility tests in matrix form.

The sensitivity of the methods described mass demonstrated

in the case of comparing a series of AlK_α excited Ag 3d photoelectron spectra. Very sharp changes of the parameters of the normalized count difference distribution occured e.g. as a consequence of setting the discriminator level of detection improperly.

In some cases, small fluctuations in parameters of the reproducibility test could be reduced using different intensity scales (constant peak to background ratio) which pointed to instabilities in the exciting photon flux as a probable origin of these fluctuations. Similar "scaling" methods proved to be useful taking into account a slow decrease of photoelectron intensity during measurements.

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APPLICATION OF QUADRUPOLE MASS SPECTROMETER TO INDUSTRIAL FERMENTATION

S. Bohátka, I. Berecz, G. Langer, J. Szilágyi*

Metabolic products of microorganisms are produced industrially in fermentation plants. Culture media are liquid mixtures (broth) aerated and stirred as necessary. It has vital importance to control the composition of the fermentation broth. Conventionally specific electrodes can be used for the measurement of dissolved O_2, CO_2 and NH_3, but they are sensitive to the frequent heat sterilizations and require replacement and calibration. Other components are determined by chemical assay. In most cases gas components, other than O_2, are measured only in gas phase: in the exhaust gas of the fermentor.

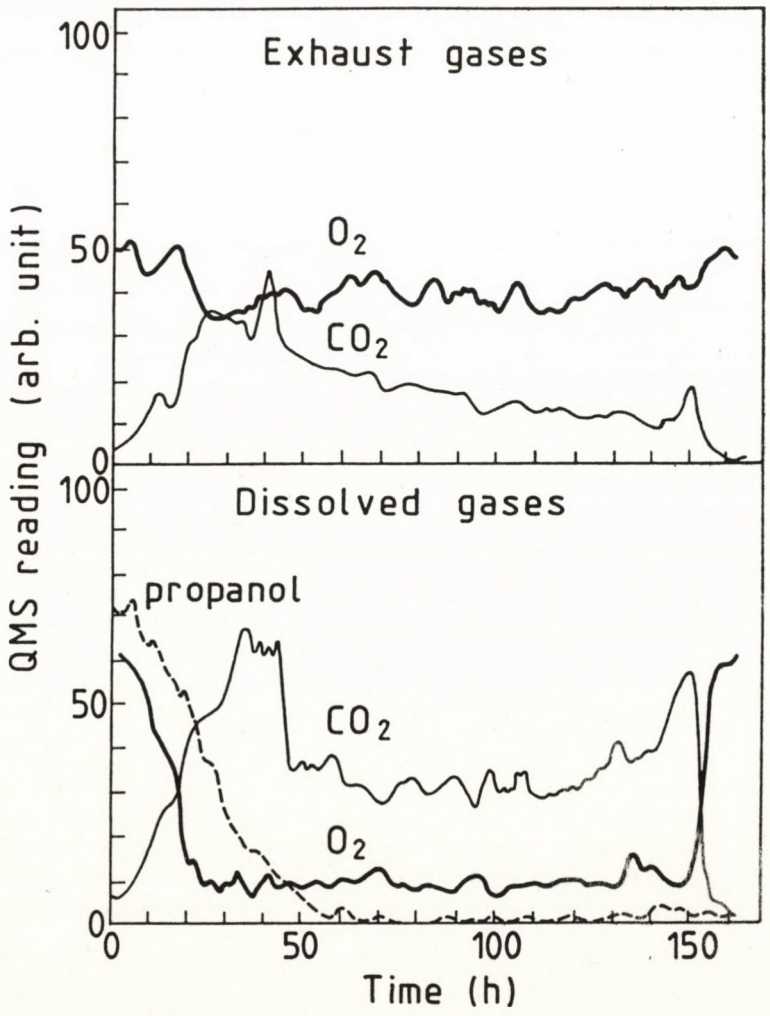

Fig. 1. Components measured on-line by the QMS during an erythromycin fermentation.

A quadrupole mass spectrometer (QMS) analyser system was constructed in ATOMKI [1] and is used in monitoring fermentation processes in BIOGAL. Multi-component analysis can be carried out with the QMS due to its non-specific character (quadrupole type: Q300C, mass range: 1-300 u). Multi-channel quasi-simultaneous measurement in many fermentors is possible using the multi-channel sampling system of the instrument. Both dissolved and free gases are measured. There are four membrane inlets for on-line and off-line sampling in fermentation broth, one inlet for sampling exhaust gases of max. 5 fermenters. A dynamic gas sampler (response time: 50 ms) completes the sampling facilities. The distance between the fermenters and the QMS is about 10 m. The connecting pipeline is heated up to 100 C. The QMS and the sampling system have separate high vacuum systems. The QMS and the sampling system is controlled by a microcomputer (type μPS-500), data are handled by an IBM PC XT compatible computer.

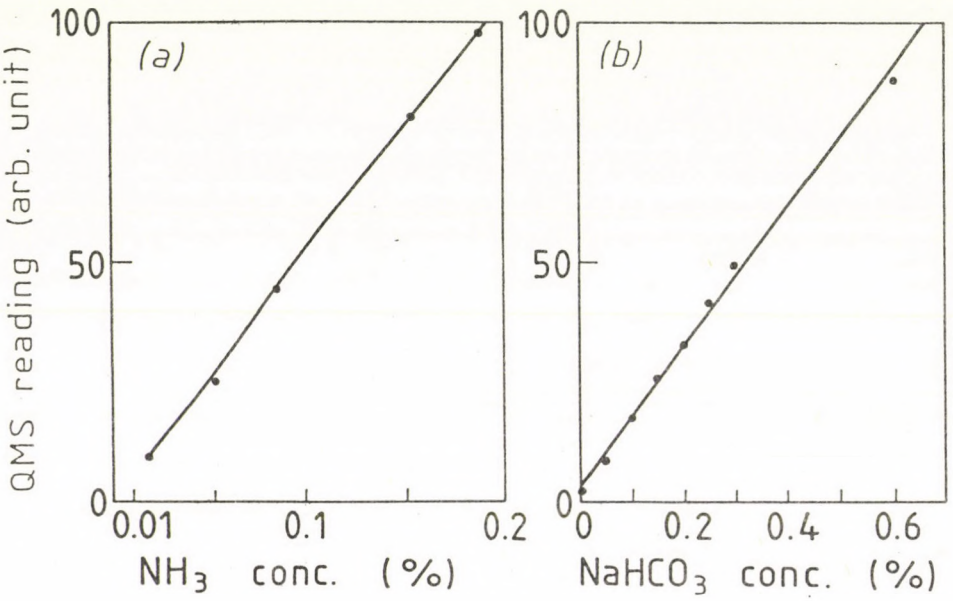

Fig. 2. Calibration curves for NH_3 (a) and $NaHCO_3$ (b) measured off-line.

The QMS analyser system is devoted to industrial application and first it has been used with 1.5 m^3 fermenters in a pilot plant. Membrane inlets need only yearly replacement of the silicon rubber membrane. The system has been tested since 1983. In most cases week-long fermentations are monitored. Dissolved and exhaust O_2, CO_2 and propanol are measured on-line. N_2 is used as internal standard. Progress curves of an erythromycin fermentation are shown in Fig. 1. Off-line analysis of ammonia and (hydro-) carbonates was also elaborated. These non-volatile components can be measured by changing the pH of the liquid sample. Linearity of the QMS output is good in the actual range (Fig. 2). Off-line analysis of CO_2 chemically bound in liquid phase demonstrates,

that the changes of (hydro) carbonate content of the broth have to be taken into account at the calculation of respiratory quotient. Further non-volatile components can be measured off-line when using sophisticated chemical treatment [2]. Components measured in fermentation broth with our QMS system are shown in Table 1.

Table 1. Components measured with QMS in fermentation broth. Detection limits in brackets.

Gases and volatile components, on-line measurements		Non-volatile components, off-line measurements	
H_2	(1 µM)	Increasing the volatility by changing pH and temperature	Producing volatile compounds by chemical conversion
N_2	(1 µM)		
O_2	(1 µM)		
Ar	(1 µM)	HCO_3^-, CO_3^{2-} (0.1 mM)	α-ketaglutaric acid (0.1 mM)
CO_2	(1 µM)	Phenylacetic acid (0.5 mM)	Pyruvic acid (0.1 mM)
Methanol	(1 µM)		
		Phenoxyacetic acid (0.5 mM)	
Ethanol	(1 µM)	NH_3 (10 mM)	
Propanol	(1 µM)		

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*BIOGAL Pharmaceutical Works Debrecen, H 4042, Hungary

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Z. Arvay "Supersymmetry and quark effects in Nuclear Structure", VIII. Meeting of the Hungarian Nuclear Physicists, Debrecen, June 30 - July 3, 1986 (in Hungarian)

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J. Pálinkás, "Basic and applied research projects at the ATOMKI cyclotron", 23rd Cyclotron Progress Meeting, Debrecen, May 15-16, 1986

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J. Pálinkás, "Alignment in ion-atom collisions at high energies", Department Seminar, Zfk, Rossendorf, Sept. 2, 1986

T. Papp "On the alignment of multiple-ionized atoms", Department Seminar, Department of Physics, University of Bergen, Norway, March 17, 1986

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J. Kemmler, C. Biedermann, P. Koschar, M. Burkhard, I.A. Sellin, O. Heil, A. Kövér, P. Focke, K.O. Groeneveld, "Konvoielektronen in Koinzidenz mit Ejektilladungszustanden", DPG - Fruhjahrstagung (Atomphysik) Heidelberg, March 17-21, 1986

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ANALYTICAL APPLICATIONS

I. Borbély-Kiss, M. Józsa, A. Z. Kiss, E. Koltay, Gy. Szabó, "On the combined application of PIXE and PIGE methods for elemental analysis of human blood samples", 10th International Symposium on microchemical techniques, Antwerp, August 25-29, 1986

I. Borbély-Kiss, L. Haszpra, E. Koltay, Gy. Szabó, S. László, A. Mészáros, E. Mészáros, L. Zolnai, "Elemental concentration and regional signatures in atmospheric Aerosols over Hungary", Seminar talk in Institutio de Fisica, Universidad Nacional Autonoma, Mexico, January 6, 1986

M. Pankotai, I. Borbély-Kiss, E. Koltay, Gy. Szabó, "The analitical application of PIXE in vegetable growing", Chemical products in agriculture, Keszthely, July 26, 1986, NEVIKI, Veszprém, p. 254 (in Hungarian)

I. Borbély-Kiss, E. Koltay, Gy. Szabó, L. Zolnai, "Analytical applications of PIXE-method in ATOMKI", Seminar talk Institute of Atomic Energy, Beijing Oct. 4, 1986

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I. Borbély-Kiss, E. Koltay, Gy. Szabó, L. Zolnai, "Different application of the proton induced X-ray emission (PIXE) technique", Seminar talk, Department of Physics, Univ. of Khartoum, Sudan, March 12, 1986

I. Uzonyi, J. Bacsó, "Trace-element analysis of hay and animal bone, kidney and liver with X-ray flourescenece method", Joint Session of the Agricultural, Chemical and Physical Committee of DAB, Debrecen, March 12, 1986 (in Hungarian)

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S. Takács, F. Ditrói, "A rewiev of analytical methods based on cyclotrons", Joint Session of the Agricultural, Chemical and Physical Committee of DAB, Debrecen, March 12, 1986 (in Hungarian)

L. Zolnai, "An introduction to the accelerator based nuclear analytical techniques ", Seminar talk, Department of Physics, University of Khartoum, Sudan, March 9, 1986

L. Zolnai, S. Szilágyi and Z. Máté, "Possibility of FAST analysis on MGC-20 E cyclotron", 23rd European Cyclotron Progress Meeting, Debrecen, May 13-15, 1986

J. Tóth, "Latest Results in the Field of Photoelectron Spectroscopy (XPS)" (in ATOMKI), 8th Meeting of the Hungarian Nuclear Physicists, Debrecen, 30 June - 3 July, 1986 (in Hungarian)

D. Novák, S. Mészáros, K. Vad, K. Botos, "Residual resistivity investigations on high purity gallium", 3rd Seminar on Low Temperature Physics - Cryosem'86, Visegrád, Hungary, May 26-31, 1986. (submitted to Zeitschrift für Metallkunde)

S. Bohátka, J. Szilágyi, G. Langer, "Application of MS to industrial fermentation", Mass Spectrometry in Biotechnological Process Analysis and Control, Graz, Austria, Oct. 23-24, 1986

I. Hunyadi, G. Somogyi, "Determination of nitrogen microdistribution with proton-sensitive track detector via the nuclear reaction 14N(n,p)14C". 8th Meeting of the Hungarian Nuclear Physicists., Debrecen, June 30-July 3, 1986 (in Hungarian)

I. Hunyadi, G. Somogyi, L. András, F. Körösi, "Boron and nitrogen micromapping in plants by nuclear technique", XVth International Symposium on Autoradiography, Mátrafüred, Oct. 19-23, 1986

I. Hunyadi, G. Somogyi, K. Freyer, H. C. Treutler, "Nitrogen mapping with CR-39 track detector", XVth International Symposium on Autoradiography, Mátrafüred, Oct. 19-23, 1986

EARTH SCIENCES AND ENVIRONMENTAL RESEARCH

I. Borbély-Kiss, L. Haszpra, E. Koltay, Gy. Szabó, S. László, A. Mészáros, E. Mészáros, "Elemental concentration and regional signatures in atmospheric Aerosols over Hungary", Environmental Physics- Atmospheric aerosols, Adriatic Research Conference, Trieste I.C.T.P., July 22-25, 1986

K. Balogh, "Noble gas mass spectrometry in earth sciences", 10th Meeting of the Roland Eotvos Physical Society, Debrecen, Aug. 25-28, 1986 (in Hungarian)

Z. Pécskay, "Results of K/Ar studies on the Miocene volcanites of the Zemplen Mountains and on the covered Miocene volcanites of the Trans Tisza Region", Plenary Session of the Hungarian Geographic Society, Debrecen, February 25, 1986

K. Balogh, "Possibilities of K/Ar methods for dating Pliocene and Pleistocene rocks and the results of studies in Hungary", Plenary Session of the Hungarian Geographic Society, Debrecen, February 18, 1986 (in Hungarian)

É. Csongor, "14C ages of charcoal samples from the iron mine and the iron smelting furnace of Kőpháza", Working session of the Committee of Archaeometry and Industrial Archaeology, Budapest, April 25, 1986 (in Hungarian)

É. Csongor, Á. Z. Kiss, B. Nyakó, E. Somorjai and I. Hunyadi, "Alpha-, beta- and gamma radioactivity of Chernobyl Fallout in the precipitation in Debrecen", Scientific meeting on "Radioanalytical Methods in Environmental Monitoring", Tengelic, October 6-8, 1986 (in Hungarian)

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DEVELOPMENT OF METHODS AND INSTRUMENTS

A Valek, "An MGC-20E Cyclotron in ATOMKI", 23rd European Cyclotron Progress Meeting, Debrecen, May 15-16, 1986

A. Valek, "Experiences of test operation of cyclotron MGC", VIIIth Meeting of the Hungarian Nuclear Physicists, Debrecen, June 30-July 3, 1986 (in Hungarian)

Z. Kormány, "Study of heavy ion acceleration in the MGC-20E Cyclotron" 23rd European Cyclotron Progress Meeting, Debrecen, May 15-16, 1986

E. Koltay, " Physics and Technology of Electrostatic Accelerators", Seminar talk in Institutio de Fisica, Universidad Nacional Autonoma, Mexico, January 6, 1986

A. Paál, K. Sepsy, B. Sulik, A. Vass, "Data Acquisition System at the ATOMKI Cyclotron Laboratory", VIIIth Meeting of the Hungarian Nuclear Physicists, Debrecen, June 30-July 3, 1986 (in Hungarian)

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L. Zolnai and S. Szilágyi, "A comparison of storage methods" XVIIIth Masurian Summer School on Nuclear Physics, Mikotajki, Poland, Sept 1-13, 1986

S. Szilágyi and L. Zolnai, "A new coding method for spectra storage" XVIIIth Masurian Summer School on Nuclear Physics, Mikotajki, Poland, Sept 1-13, 1986

I. Cserny, "Processing of XPS Spectra Using Microcomputers, Meeting of the Solid state Chemistry Committee, Visegrád, 28-29 April, 1986 (in Hungarian)

I. Cserny, "Scientific Program Package for the Processing of XPS Spectra", 6th Seminar on Electron Spectroscopy of Socialist Countries, Liblice, Czechoslovakia, 1-5 September 1986, Conference Abstracts p.41.

L. Kövér, J. Végh, J. Tóth, "Application of Statistical Methods to Test XPS Measurements", 4th International Conference on Quantitative Surface Analysis, Teddington (U.K.), 18-20 November 1986

T. Lakatos, "Maximum througput rate signal processeing for high resolution gamma spectrometers based on digital filtening", IAEA Consultants' Meeting on High Count Rate Gamma Spectroscopy, Vienna, Sept. 15-19, 1986

L. Andó, F. Ditrói, A. Fenyvesi, I. Mahunka, T. Molnár, F. Szelecsényi, S. Takács, F. Tárkányi, "Practical Applications at the MGC Cyclotron in Debrecen", 23rd European Cyclotron Progress Meeting, Debrecen, May 15-16, 1986

A. Fenyvesi, I. Mahunka, T. Molnár, F. Tárkányi, "Cyclotron Neutron Sources for Medical Purposes", Meeting of Hungarian Young Oncologists, Debrecen, 2 April, 1986 (in Hungarian)

F. Szelecsényi, L. Andó, I. Mahunka, F. Tárkányi, "Cyclotron Isotopes for Oncological Applications", Meeting of Hungarian Young Oncologists, Debrecen, 2 April, 1986 (in Hungarian)

E. Hertelendi, "Multicounter measuring system for 14C dating", Scientific meeting on "Radioanalitical Methods in Environmental Monitoring", Tengelic, October 6-8, 1986 (in Hungarian)

I. Uray, "Dose independent use of LiF detectors in mixed neutron-gamma radiation fields", 8th International Conference on Solid State Dosimetry,Oxford, UK, August 26-29, 1986

K. Vad, S. Mészáros, G. Halász, "Biomagnetic Measurements with a 3rd order gradiometer", 3rd Seminar on Low Temperature Physics - Cryosem'86, Visegrád, Hungary, May 26-31, 1986

S. Bohátka, I. Berecz, G. Langer, J. Szilágyi, "Biotechnological application of quadrupole masspectrometers" , Spring Conference of the German Physical Society, Frendenstadt, April 7-11, 1986

S. Bohátka, G. Langer, J. Szilágyi, "Mass spetrometric measurements of fermentation gases", 4th Symposium of the Socialist Countries on Biotechnology, Várna, Bulgaria, May 26-30, 1986

I. Berecz, S. Bohátka, Z. Diós, I. Gál, J. Gál, L. Kiss, R. M. Kovács, G. Langer, J. Molnár, A. Paál, K. Sepsy, I. Szabó, G. Székely, "Mass spectrometer analyser system for monitoring fermentation gases", 4th Symposium of the Socialist Countries on Biotechnology, Várna, Bulgaria, May 26-30, 1986

G. Somogyi, "Development of a heavy-ion space-dosimeter based on track detectors and its use in Cosmos Spacecrafts", Plenary Session of the Hungarian Academy of Sciences on "Hungarian Space Research 1981-1985", Budapest, May 28-29, 1986 (in Hungarian)

G. Somogyi, "New results and perspectives in field radon measurements using track techniques", Seminar talk, Josef Stefan Institute, Ljubljana, Yugoslavia, May 16, 1986

G. Somogyi, "Quantitative aspects in autoradiography using nuclear track detectors", Invited paper on the XVth International Symposium on Autoradiography, Mátrafüred, Oct.19-23, 1986

L. Medveczky, M. Nagy, G. Somogyi, "Portable kit for using nuclear track detectors in teaching", XVth International Symposium on Autoradiography, Mátrafüred, Oct.19-23, 1986

J. Szilágyi, S. Bohátka, "Mass spectrometry in fermentation research and technology", Workshop on Biotechnology of Antibiotica, Steroids and Alkaloids of Medicinal Importance, Razgrad, Bulgaria, Sept. 1-5, 1986.

G. Somogyi, "Development of heavy-ion space-dosimeters based on track detectors and their use in Cosmos spacecrafts", Plenary Session of the Hungarian Academy of Sciences on "Hungarian Space Reseach 1980-1985", Budapest, May 28-29, 1986 (in Hungarian)

THESES COMPLETED

Doctor of Physical Science Degree

B. Gyarmati
Separable expansion of the potential and its application in nuclear and atomic physics

Candidate of Physical Science Degree

D. Novák
Application of cryo- and superconduction techniques in nuclear and material studies

A.F.Hafez, (Alexandria University, Egypt)
Study of high-sensitivity nuclear track detectors and their use for measuring environmental alpha-radioactivity (Supervisor: G.Somogyi)

PhD in Physics

I. Uzonyi
Determination of trace element concentration of biological samples by XRF analysis (supervisor: J. Bacsó)

F. Ditrói
Application of Nuclear Methods for Material Analysis (supervisor: I. Mahunka)

P. Mikecz
Production of 111In, 123I, 201Tl Radioisotopes on High-Energy Accelerators (supervisor: I. Mahunka)

Diplom Theses

I. Csige
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S. Kerėkgyártó
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Investigation of the focusing properties of a distorted-field cilindrical-mirror electron spectrometer with numerical model calcualtions (Supervisor: L. Kövėr)

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Neurological Clinic, Medical University, Debrecen

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Varró S.
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Magyar Tudományos Akadémia
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A kiadásért és szerkesztésért felelős
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Készült a Kinizsi Szakszövetkezet nyomdájában

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