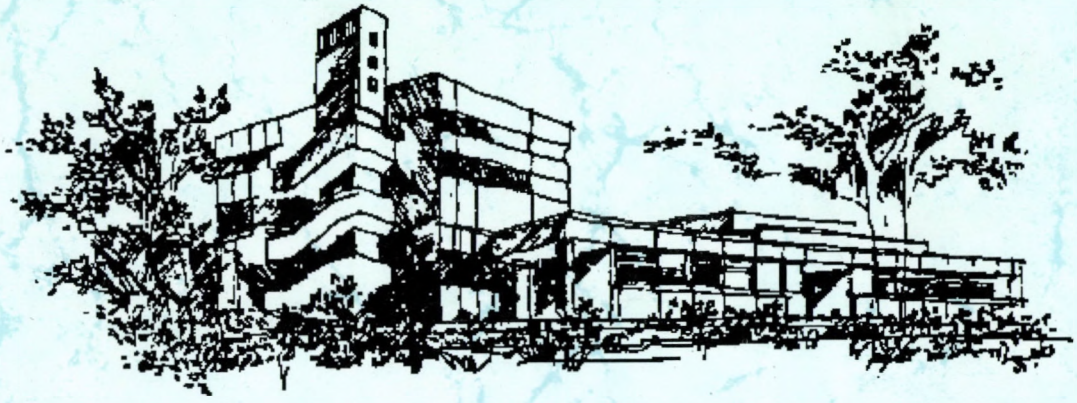
ATOMKI

ANNUAL REPORT 2000



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

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Organizational structure of ATOMKI

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Dr. S. Mészáros

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& MAINTENANCE
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& EARTH SCIENCES
headed by Dr. S. Bohátka

SECTION OF ELECTRONICS
headed by Dr. J. Gál

MECHANICAL WORKSHOP
headed by I. Gál

Data on ATOMKI

At present the Institute employs 199 persons. The affiliation of personnel to units of organization and the composition of personnel are given below.

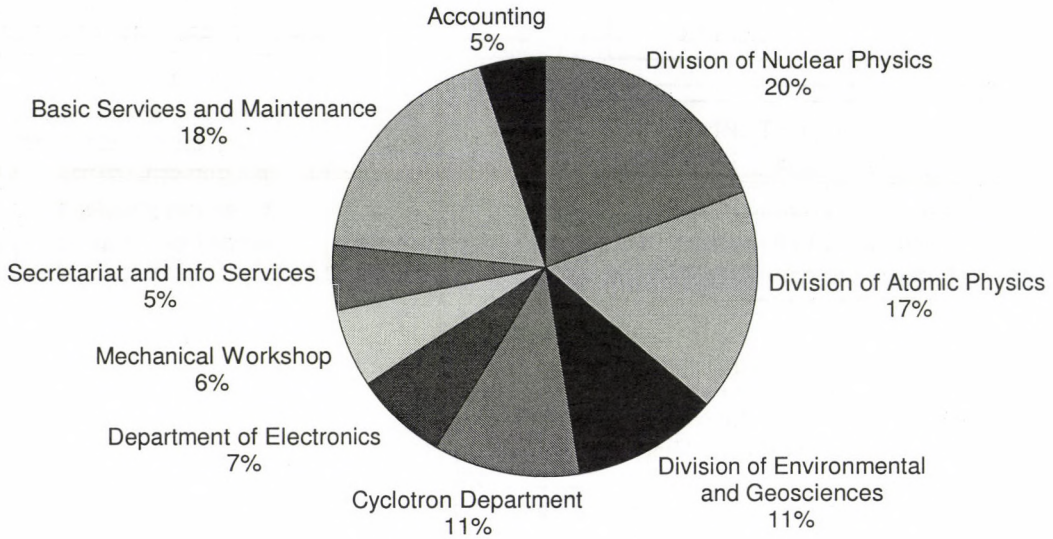

Figure 1: *Affiliation of personnel to units of organization*

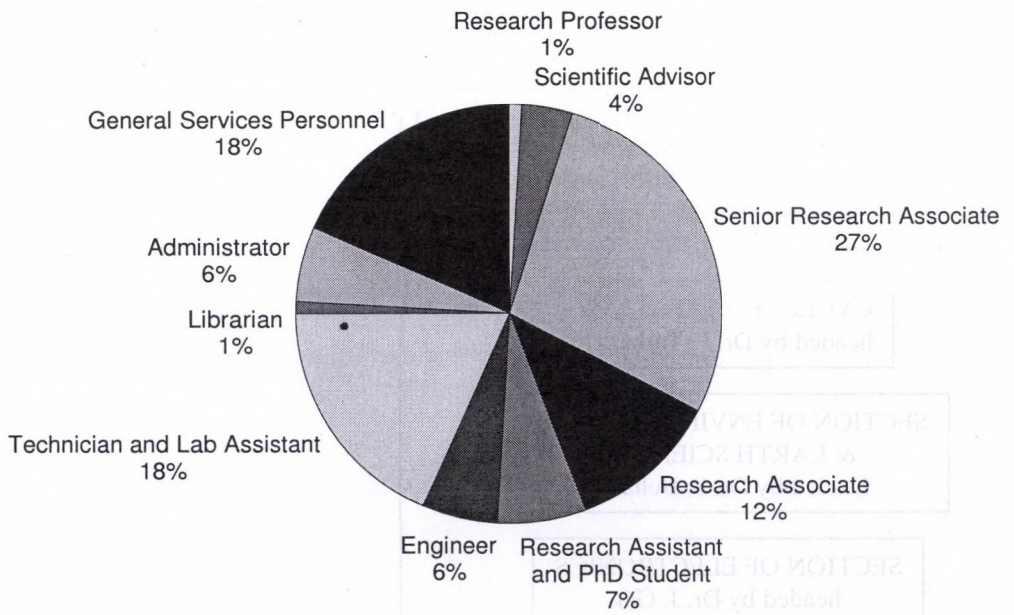

Figure 2: *Composition of personnel*

Finance

The total budget of the Institute for the year 2000 was 866 million Hungarian Forints. The composition of the budget and the share of personnel expenditure within the budget are shown below.

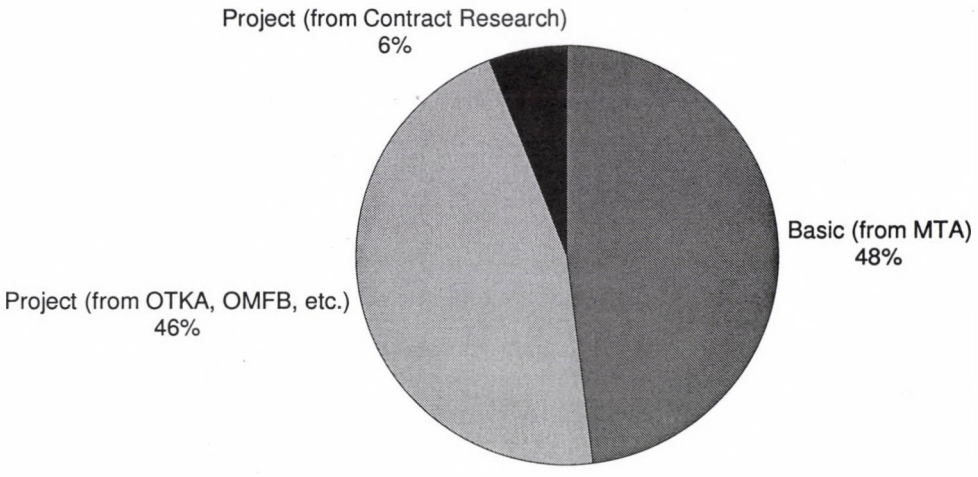

Figure 3: *Composition of the budget of the Institute*

MTA: Hungarian Academy of Sciences
OTKA: National Fund for Scientific Research
OMFB: National Committee for Technological Development

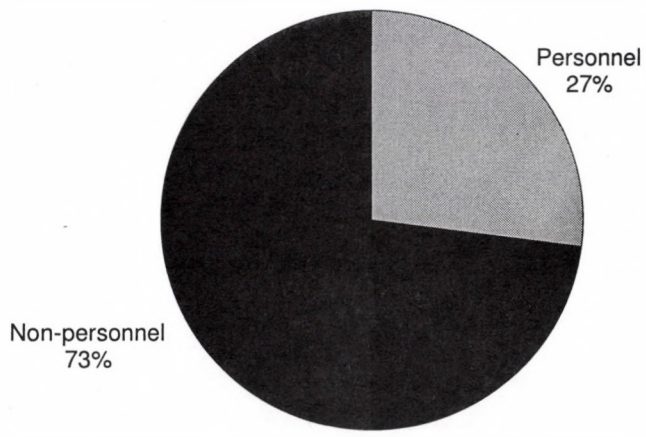

Figure 4: *Breakdown of expenditure into personnel and non-personnel expenditures*

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1.1 $\mathcal{PT}$-symmetric Potentials from Variable Transformations

G. Lévai, M. Znojil[a)]

Non-Hermitian problems, like complex quantum mechanical potentials have complex energy eigenvalues in general. Recently it was found that the spectrum of one-dimensional complex potentials of non-relativistic quantum mechanics have purely real energy eigenvalues if the potentials are invariant under the simultaneous action of the $\mathcal{P}$ space and $\mathcal{T}$ time reflection operations. These $\mathcal{PT}$-symmetric potentials have the property $[V(-x)]^* = V(x)$. Curiously enough, these potentials were found in numerical studies, and it was only later that exactly solvable $\mathcal{PT}$-invariant potentials were also identified. Many of these are the $\mathcal{PT}$-invariant versions of some well-known exactly solvable potentials.

In order to put these fragmented results into a more general framework, we performed a systematic search for exactly solvable $\mathcal{PT}$-invariant potentials by reconsidering a powerful method of generating exact solutions of the Schrödinger equation. This method is based on the transformation of a second-order differential equation with known solutions into the Schrödinger equation. Taking the original equation $F''(z) + Q(z)F'(z) + R(z)F(z) = 0$ one can show that the variable transformation $z \to z(x)$ transforms it into the Schrödinger-like equation $\psi''(x) + [E - V(x)]\psi(x) = 0$ with

$$E - V(x) = \frac{z'''}{2z'} - \frac{3}{4}\left(\frac{z''}{z'}\right)^2 + (z')^2\left(R(z) - \frac{1}{2}\frac{\mathrm{d}Q(z)}{\mathrm{d}z} - \frac{1}{4}Q^2(z)\right) \quad (1)$$

and with general solutions of the form

$$\psi(x) \sim (z')^{-\frac{1}{2}} \exp\left(\frac{1}{2}\int^z Q(z)\mathrm{d}z\right) F(z) \, .$$

Exact bound-state solutions $\psi_n(x)$ are then obtained if one particular term on the right-hand side of Eq. (1) is identified with the constant $E = E_n$, and it is possible to transfer all the dependence on n into this term. This requirement determines the function $z(x)$ through a first-order differential equation. Applying this procedure to real potentials an irrelevant coordinate shift appears as a constant of integration. We demonstrated that for $\mathcal{PT}$-invariant potentials this coordinate shift plays a major role if it is chosen to be imaginary [1].

We applied this procedure to problems with bound-state solutions containing Jacobi and generalized Laguerre polynomials and presented a systematic collection of $\mathcal{PT}$-invariant potentials [1]. We also showed that the energy eigenvalues are real by construction for these problems. The complex coordinate shift corresponds to shifting the integration path from the real axis to a trajectory in the complex plane parallel with the x axis, and this influences the normalizability of the states too. This procedure cancels singularities at the origin, so radial problems originally defined on the half axis can be extended to full axis. This also results in a richer energy spectrum.

This approach works for all the exactly solvable problems related to the Jacobi polynomials, however, among those based on the generalized Laguerre polynomials, it leads to normalizable solutions only in the case of the harmonic oscillator. To define the $\mathcal{PT}$ invariant version of the Coulomb problem, for example, a more general trajectory has to be chosen in the complex plane [2].

a) Nuclear Physics Institute of Academy of Sciences of the Czech Republic, Řež, Czech Republic.

[1] G. Lévai, M. Znojil, J. Phys. A **33**, 7165 (2000).

[2] M. Znojil, G. Lévai, Phys. Lett. A **271**, 327 (2000).

1.2 Algebraic Aspects of $\mathcal{PT}$-symmetric Potentials

G. Lévai, F. Cannata[a], A. Ventura[b]

$\mathcal{PT}$-symmetric one-dimensional quantum mechanical potentials have the invariance property $[V(-x)]^* = V(x)$, i.e. they are invariant under simultaneous space ($\mathcal{P}$) and time ($\mathcal{T}$) reflection. The energy spectrum of these potentials was found to be purely real in both numerical and and analytical studies.

Many exactly solvable potentials are known to possess some kind of symmetry property formulated in terms of algebraic constructions, therefore the question how this new symmetry concept, $\mathcal{PT}$-symmetry, is related to the existing ones emerges naturally. In our study [1] we focused on the potential group approach, which allows simultaneous description of the bound and scattering states of certain potentials in terms of unitary irreducible representations of a non-compact potential group. We considered the potential

$$V(x) = \left[-\lambda^2 - s(s+1)\right] \frac{1}{\cosh^2(x+\mathrm{i}\epsilon)} + \mathrm{i}\lambda(2s+1)\frac{\sinh(x+\mathrm{i}\epsilon)}{\cosh^2(x+\mathrm{i}\epsilon)} ,$$

which is $\mathcal{PT}$-invariant for real values of s, λ and ϵ. There is an SO(2,1) potential group associated with the Hermitian version of this potential: its generators are first-order differential operators and its Casimir invariant is related to the Hamiltonian as $H = -C_2 - \frac{1}{4}$. We generalized this algebraic construction to the $\mathcal{PT}$-invariant version of this potential, and we reached the following conclusions:

- The bound states belong to the discrete unitary irreducible representations of the non-compact SO(2,1) group (which is locally isomorphic with SU(1,1)), and this explains why the energy eigenvalues are real [1].
- Resonance states of the Hermitian version of this potential become (real-energy) bound states when $\mathcal{PT}$-invariance is imposed on the system. These states belong to the irreducible representations of another SO(2,1) group, and these irreducible representations are non-unitary in the Hermitian case, and become unitary when $\mathcal{PT}$-invariance is required. In the latter case the two sets of bound states belong to an SO(2,2) potential group, which is isomorphic with the direct sum of the two SO(2,1) groups [1,2].
- We studied scattering solutions of the $\mathcal{PT}$-invariant problem, and calculated the reflection and transmission coefficients. We showed that the $|R|^2 + |T|^2 = 1$ relation breaks down, which is due to the non-conservation of the flux [1].

a) Dipartimento di Fisica dell'Universitá and Istituto Nazionale di Fisica Nucleare, Bologna, Italy

b) Centro Dati Nucleari, ENEA, and Istituto Nazionale di Fisica Nucleare, Bologna, Italy

[1] G. Lévai, F. Cannata, A. Ventura, J. Phys. A **34**, 839 (2001).

[2] G. Lévai, F. Cannata, A. Ventura, in preparation.

1.3 Poincare Surfaces of Section for a Hydrogen Atom in a Uniform Magnetic Field

M. Hörndl[a)], S. Yoshida[a)], K. Tőkési and J. Burgdörfer[a)]

The dynamics of a hydrogen atom in a uniform magnetic field is described in scaled cylindrical coordinates [1] by

$$H(\rho, z, p_\rho, p_z) = \frac{1}{2}\left(p_\rho^2 + p_z^2\right) + \frac{L_z^2}{2\rho^2} - \frac{1}{\sqrt{\rho^2 + z^2}} + \frac{1}{8}\rho^2 + \frac{1}{2}L_z.$$

Putting $L_z = 0$, phase-space is spanned by the coordinates ρ, z and their canonically conjugate momenta p_ρ and p_z. At a fixed (scaled) energy classical motion is confined to the energy shell which is a three-dimensional subspace of the phase space. In the Poincare surface of section, a two-dimensional slice through the three-dimensional energy surface, all the crossings of a trajectory in a certain direction are recorded. These Poincare maps fully illustrate the structure of phase space: which regions of phase space show sensitive behaviour of trajectories to small changes in the initial conditions (i.e are chaotic) and which regions contain regular trajectories. Periodic orbits are characterized by a finite number of points in the map, regular orbits fill a one-dimensional subset of the two-dimensional map and irregular orbits densely fill a finite volume of the map. As an example, Fig 1 shows a Poincare map for $E = -0.8$ which is still very close to its integrable limit ($E \to -\infty$).

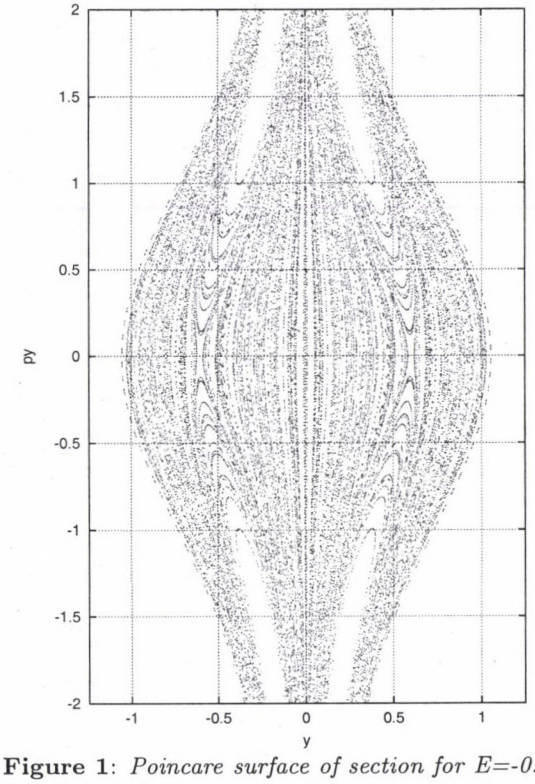

Figure 1: *Poincare surface of section for E=-0.8 (scaled units).*

a) Institute for Theoretical Physics, Vienna University of Technology Wiedner Hauptstr. 8-10, A–1040 Vienna, Austria

[1] Friedrich H. and Wintgen D., Phys. Rep. **183**, 37 (1989).

1.4 Charged Excitons and Biexcitons in Magnetic Field

J. Zs. Mezei, K. Varga[a] and R. G. Lovas

In semiconductor quantum dots the electrons (e) and the holes (h) are confined in all space directions on a length scale comparable to their de Broglie wavelength. The quantum confinement profoundly affects the Coulomb correlations between the charge carriers. The enhanced electron-hole correlations result in stable (e,h,h) (e,e,h) and (e,e,h,h) 'excitonic complexes'. The properties (e.g., spin configurations, binding energies etc.) of these species can be controlled by an external magnetic field as well as by manipulating the shape and size (that is the confining potential) of the quantum dot leading to various possible applications (quatum gates, lasers, single-electron transistors etc.).

The aim of this work is to investigate the properties of the excitonic complexes in a magnetic field. Due to the large effective dielectric constant and small effective masses, the magnetic field strongly modifies the ground states and the excited states of these Coulombic systems.

The Coulombic few-particle problem in an external magnetic field is solved by the stochastic variational method with a correlated Gaussian basis (SVM) [1]. To conform with the cylindrical geometry, a cylindrically symmetric correlated Gaussian basis is introduced. This basis has proved to be very efficient. Its application has improved the results of the best available calculations for H^- and He in magnetic fields by 2–3 digits.

The strength of the magnetic field and the electon-hole (effective) mass ratio were varied in a wide range (from 0.0008 to 100 a.u. and from 0 to 1, respectively). The calculations were performed for different spin and orbital angular momentum projections (Σ, Λ) with respect to the symmetry axis.

In the absence of a magnetic field only the ground state of (h,h,e) and the ground state and one excited state of (h,e,e) as well as (h,h,e,e) are bound, but there are an infinite number of bound states when the magnetic field differs from zero.

For the H^- and Ps^- ions the $(\Sigma = 0, \Lambda = 0)$ state is the ground state if the magnetic field is weak, but, due to the Zeeman energy, the $(\Sigma = 1, \Lambda = 1)$ state becomes the ground state as the magnetic field is increased. As an illustration, Fig. 1 shows how the energies of the lowest-lying states of the H^- system depend on the strength of the magnetic field.

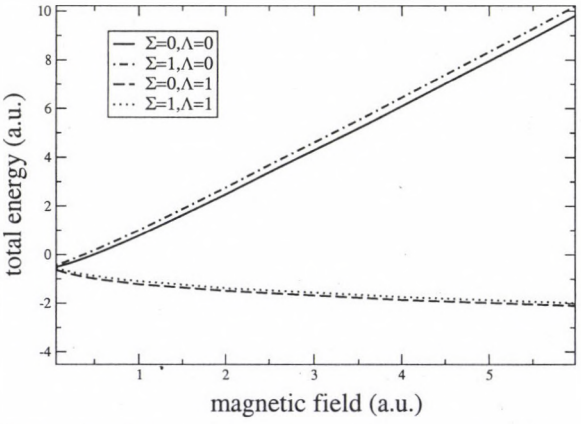

Figure 1: *H^- energies versus field strength with respect to the threshold of full disintegration.*

a) Present address: Solid State Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA.

[1] Y. Suzuki and K. Varga: Stochastic variational approach to quantum-mechanical few-body problems (Springer, Berlin, 1998).

1.5 Unbound States in Coulomb Few-body Systems

J. Zs. Mezei and R. G. Lovas

The discrete eigenstates of a physical system can be classified as bound and unbound states, and the latter includes resonances and antibound or virtual states. All these states can be identified with poles of the S-matrix of the system. The theoretical methods to describe few-body bound states are standard, mostly variational. The localization of the poles amounts to determining the energies and widths, and the theoretical methods mostly imitate the bound-state methods.

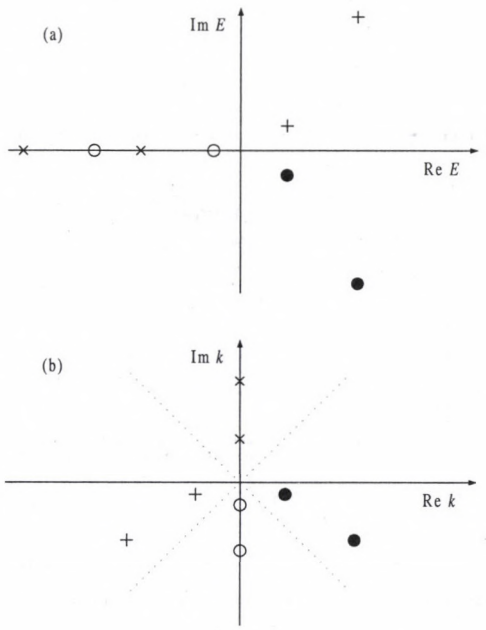

Figure 1: *Typical positions of the bound-state (×), resonance (•), antiresonance (+) and virtual-state (○) poles in the complex energy plane (a) and in the complex momentum plane (b).*

The poles of the S-matrix of a system with short-range attractive interactions and possible potential barriers are located as is shown schematically in Fig. 1. In these systems the poles can be moved between the bound- and unbound-state regions by varying the strength of an attractive potential term. This makes it possible to extrapolate the bound-state results to the unbound-state region. This method is called the method of analytic continuation in the coupling constant [1], and it has been successfully applied to nuclear few-cluster problems [2] in combination with correlated Gaussian bases [3]. Unlike all other bound-state-like methods, it works for broad resonances and for virtual states as well.

For pure Coulmb problems, this method does not seem to work so simply. The energy levels of the hydrogen atom will never cross the threshold by varying the strength of the Coulomb potential. Although the multiparticle Coulombic systems do have resonances, they behave somewhat similarly: their bound states will never get bound and their unbound states will never get unbound by scaling the unit charge.

In this work we nevertheless attempt to apply the ACCC method to purely Coulombic systems. The clue to the problem may come from the close analogy between a resonance of a Coulombic few-body system and that in a short-range potential. A H^- state can be visualized like the state of an electron captured by a short-range potential, which comes about by a polarization of the H atom by the electron. Any such resonance can be made bound by adding to the interaction an attractive short-range potential, and its original position can be restored in exactly the same way as in a nuclear case, by extrapolation.

The results obtained so far are encouraging.

[1] V. I. Kukulin, V. M. Krasnopol'sky and J. Horáček: Theory of Resonances (Kluwer, Dordrecht, 1989).

[2] I. Tanaka, S. Suzuki, K. Varga and R. G. Lovas, Phys. Rev. C **59**, 1391 (1999).

[3] Y. Suzuki and K. Varga: Stochastic variational approach to quantum-mechanical few-body problems (Springer, Berlin, 1998).

2.1 A Simultaneous Measurement of the QCD Colour Charges and the Strong Coupling from LEP Multijet Data

B. Dienes, Z. Trócsányi

e^--e^+ annihilation into hadrons at high energies provides a clean environment to test Quantum Chromodynamics (QCD). Basic ingredients of QCD are the strong coupling, α_s, and the underlying gauge group.

The simultaneous measurement of the strong coupling and the eigenvalues of the Casimir operators of the gauge group (called colour charges), C_F and C_A, provides a more general and comprehensive test of QCD than measurements of one of them alone.

To perform a simultaneous measurement of α_s and the colour charges we use the differential two-jet rate, $D_2(y_{23}) \equiv 1/\sigma_{\rm tot}\, {\rm d}\sigma/{\rm d}y_{23}$, where y_{23} is the $y_{\rm cut}$ value for which the two- and three-jet configurations are separated in a given event, and the four-jet rate, $R_4(y_{\rm cut}) \equiv \sigma_{4-{\rm jet}}(y_{\rm cut})/\,\sigma_{\rm tot}$.

We also use four-jet angular correlations (i) the Bengtsson-Zerwas angle, (ii) the modified Nachtmann-Reiter angle, (iii) the Körner-Schierholtz-Willrodt angle, (iv) the angle between the two lowest energy jets.

We defined the jets using the Durham clustering and selected four-jet events at $y_{\rm cut} = 0.008$. For jet-related variables both next-to-leading order (NLO) and next-to-leading logarithmic (NLL) perturbative results are known. In order to have the best possible theoretical description, we fit the experimental data to the matched NLL and NLO results.

In order to compare our (detector level) data to the parton level theoretical predictions the measured distributions were corrected for the effects of the detector and hadronization using bin-by-bin correction.

Having prepared the corrected distributions, we performed a χ^2 minimization to determine the values of the variables $\eta = \alpha_s C_F/(2\pi)$, $x = C_A/C_F$ and $y = T_R/C_F$ with the program MINUIT.

The systematic uncertainties were evaluated by considering the following effects: (i) the measurement process and accuracy of the Monte Carlo detector simulation, (ii) dependence on the model of hadronization, (iii) dependence on the choice of the renormalization scale, (iv) variation of the matching scheme, (v) variation of the fit range, (vi) the background from five parton events, (vii) variation of the parameter $y_{\rm cut}$.

The procedure outlined above yields

$$C_A/C_F = 2.25 \pm 0.08{\rm stat} \pm 0.14{\rm syst}\,,$$
$$T_R/C_F = 0.37 \pm 0.04{\rm stat} \pm 0.06{\rm syst}\,.$$

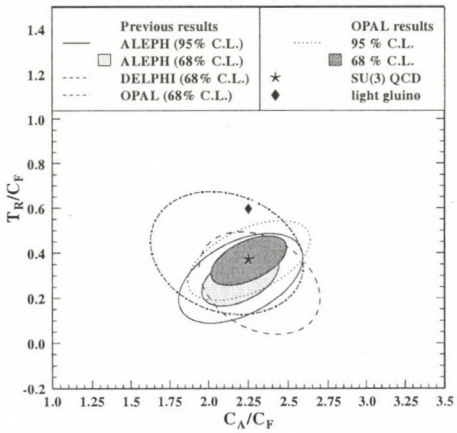

Figure 1: *Two dimensional plot of the ratios of the colour factors comparing with previous results of the LEP experiments. The legend in the top right corner describes this analysis. The contours are based on total uncertainties.*

To compare the results to previous measurements, we show the two dimensional 68% and 95% C.L. contour plots of the colour factor ratios based on total uncertainties in Fig. 1. Finally, we converted our measured parameters to the standard QCD parameters, which leads us to our main results:

$$\begin{aligned} \alpha_s &= 0.120 \pm 0.011{\rm stat} \pm 0.020{\rm syst}, \\ C_A &= 3.02 \pm 0.25{\rm stat} \pm 0.49{\rm syst}, \\ C_F &= 1.34 \pm 0.13{\rm stat} \pm 0.22{\rm syst}. \end{aligned}$$

These values are in agreement with SU(3) values of $C_A = 3$ and $C_F = 4/3$ as well as with measured values obtained previously at LEP and the corresponding strong coupling value is in agreement with the world average. Detailed description of this analysis can be found in [1].

[1] CERN-EP/2001-01, hep-ex/0101044

2.2 Threshold Behaviour of Electronic Stopping Power of Deuterons in ^{3}He Gas

LUNA Collaboration[a] *(Zs. Fülöp, Gy. Gyürky, E. Somorjai)*

The energy loss of deuterons in ^{3}He gas was measured at E_d =15 to 100 keV using the ^{3}He pressure dependence of the ^{3}He(d,p)^{4}He cross-section at a given incident energy. The measurements were carried out at the 100 keV accelerator of the Ruhr-Universität Bochum. A windowless ^{3}He gas target was bombarded by intense deuteron beam. The beam intensity was measured by a 4W calorimeter. The target pressure varied between 0.05 and 0.5 mbar and was measured by a Baratron capacitance manometer. The high energy protons from the ^{3}He(d,p)^{4}He reaction were detected by eight Si detectors placed around the beam axis.

Since the cross section of ^{3}He(d,p)^{4}He reaction drops exponentially with decreasing energy, the stopping power at a given incident energy can be determined from the reaction yield measured as a function of gas pressure. At the highest energies, the observed energy loss is in good agreement with a standard compilation [1]. However, with decreasing energy the experimental values drop steadily below the theoretical values and near E_d =18 keV they drop sharply (within 1 keV) reaching the domain of nuclear stopping power (Fig. 1). This threshold behavior is due to the minimum 1s $\rightarrow$ 2s electron excitation of the He target atoms: $E_{e,min}$ = 19.8 eV, which translates into a deuteron energy $E_d = (m_d/4m_e)(1+m_e/m_d)^2 E_{e,min}$ = 18.2 keV. Below this energy, the electron cloud of the He atom cannot be excited via an ion-electron interaction and thus the electronic energy loss vanishes leaving solely the nuclear stopping power.

Fig. 1 shows the measured and theoretical stopping power as a function of energy. The threshold effect is clearly visible. More details and some consequences are discussed elsewhere [2].

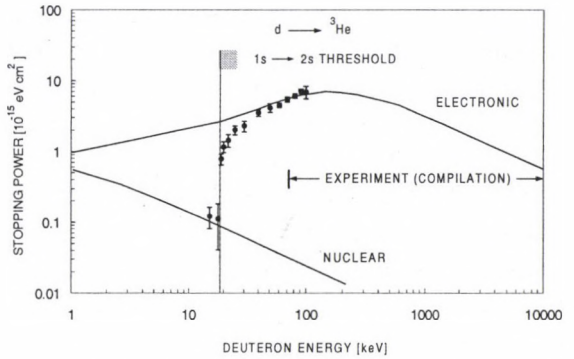

Figure 1: *Energy loss of deuterons in ^{3}He gas as function of deuteron energy. The "electronic" curve represents the electronic stopping power from the compilation [1] based on data above 80 keV [indicated as experiment(compilation)] and the "nuclear" curve is the expected nuclear stopping power [1]. The present data show a threshold effect in the electronic stopping power at E_d = 18 keV.*

a) for full list of authors see: Eur. Phys. J. **A8**, 443 (2000).

[1] H.Andersen, J.F. Ziegler, The Stopping and Ranges of Ions in Matter (Pergamon, New York, 1977) and SRIM-2000.

[2] A. Formicola *et al.*, Eur. Phys. J. **A8**, 443 (2000).

2.3 Measurement of (p,γ) Cross Sections Relevant to Astrophysical p-process

Gy. Gyürky, E. Somorjai, S. Harissopulos[a)]

The p–process nuclei are the proton–rich isotopes that are blocked from production in the r– and s– processes by stable nuclei. Calculation of the abundances of the p–process nuclides tipically requires extensive numbers of reaction rates (many of which are either (p,γ) or (γ,p) reactions). Very few cross sections relevant to these processes, which involve light ions on relatively heavy nuclei, have been measured at energies appropriate to astrophysics, leaving these reaction networks dependent upon theoretical estimates calculated through statistical models. This fact has motivated the present work.

In the framework of a Greek-Hungarian collaboration we measured the (p,γ) cross section of all four stable Sr isotopes in astrophysically relevant energy range [1,2]. In case of three isotopes (^{84,86,87}Sr) the (p,γ) reaction product is radioactive, thus the cross sections can be measured using activation technique. This was carried out at the 5MV Van de Graaff accelerator of the ATOMKI in the energy range between 1.5 and 3 MeV with steps of 100 keV. The ^{88}Sr(p,γ)^{89}Y reaction was studied at the Dynamitron Accelerator of the Institute für Strahlenphysik in Stuttgart using on-line γ-detection. The energy range of 1.5–3.5 MeV was covered with steps of either 25, 50 or 100 keV.

The resulting cross sections are compared to Hauser-Feshbach statistical model calculations carried out using the MOST and NON-SMOKER codes. In case of two isotopes (^{84,88}Sr) the model calculations are in satisfactory agreement with the experimental results, while for the other two isotopes (^{86,87}Sr) both calculations strongly overestimate the measured data. As two examples the astrophysical S-factors derived from the measured and calculated cross sections as a function of center of mass energy can be seen in Fig. 1-2.

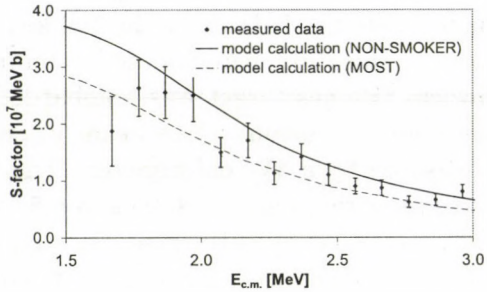

Figure 1: *Measured and calculated S-factor of the $^{84}Sr(p,\gamma)^{85}Y$ reaction. The calculations are in satisfactory agreement with the experiments.*

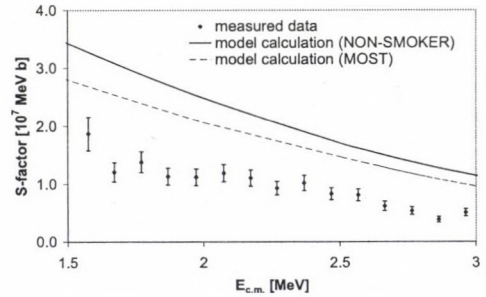

Figure 2: *Measured and calculated S-factor of the $^{87}Sr(p,\gamma)^{88}Y$ reaction. The calculations strongly overestimate the experimental data.*

a) Institute of Nuclear Physics, NCSR "Demokritos", Athens, Greece

[1] Gy. Gyürky *et al.*, Nucl. Phys. **A** (in press).

[2] S. Harissopulos *et al.*, Nucl. Phys. **A** (in press).

2.4 Coulomb Dissociation of ^{23}Al

T. Gomi[a], T. Motobayashi[a], K. Yoneda[b], S. Kanno[a], N. Aoi[c], Y. Ando[a], H. Baba[a], K. Demichi[a], Zs. Fülöp, U. Futakami[a], H. Hasegawa[a], Y. Higurashi[a], K. Ieki[a], N. Imai[c], N. Iwasa[d], H. Iwasaki[c], T. Kubo[b], S. Kubono[c], M. Kunibu[a], Y.U. Matsuyama[a], S. Michimasa[c], T. Minemura[a], H. Murakami[a], T. Nakamura[e], A. Saito[a], H. Sakurai[c], M. Serata[a], S. Shimoura[c], T. Sugimoto[e], E. Takeshita[a], S. Takeuchi[a], K. Ue[c], K. Yamada[a], Y. Yanagisawa[b], A. Yoshida[b], M. Ishihara[b]

It has been pointed out that the ^{22}Na yields obtained from the observation of cosmic γ rays are significantly lower compared to the calculated value for the hot Ne-Na cycle (^{20}Ne(p,γ)^{21}Na(p,γ)^{22}Mg($\beta^+\nu$)^{22}Na) [1]. This discrepancy might be due to the ambiguity of the employed reaction rates. Therefore, it is important to determine experimentally the rate of ^{22}Mg(p,γ)^{23}Al, which might lead to a decrease of the ^{22}Na.

Ground-state spin and parity J^π of ^{23}Al is known to be $5/2^+$, and the proton separation energy is 125±25 keV. The first excited state ($1/2^+$) is unbound, and the excitation energy has already been measured to be 460±60 keV using the transfer reaction ^{24}Mg(^{7}Li,^{8}He)^{23}Al [2]. This excitation energy close to the proton separation energy implies considerable contribution of the first excited state to the reaction rate. In the present work we observed the reaction ^{23}Al(γ,p)^{22}Mg to determine the $5/2^+ \rightarrow 1/2^+$ transition probability of ^{23}Al using Coulomb dissociation.

The experiment was performed at the RIKEN RIPS facility, where the 51 AMeV ^{23}Al beam was produced by projectile fragmentation reaction of a 135 AMeV ^{28}Si beam on a 1.11 g/cm^2 ^{9}Be target. The typical secondary beam intensity was around 2×10^4 cps. The purity of ^{23}Al beam was about 7%. The nucleus ^{23}Al and a main contaminant ^{22}Mg (56%) were separated using time-of-flight(TOF) information obtained from the signals of the cyclotron RF and of a 0.5 mm thick plastic scintillator located at a focal plane of the separator. The ^{23}Al beam bombarded a 80 mg/cm^2 ^{208}Pb target. A 38 mg/cm^2 ^{12}C target was also used to estimate contribution of nuclear interaction. The position and incident angle of the beam at the target were measured by two sets of parallel plate avalanche counters placed upstream of the target. A stack of sixty-eight NaI(Tl) scintillators was placed around the target to measure deexcitation γ rays. The products of the breakup reaction were detected by a silicon telescope and a plastic scintillator hodoscope [3] located 56 cm and 4 m downstream of the target, respectively.

The particle identification of the heavy reaction products was performed by the ΔE-E method using the silicon telescope, while for the light reaction products, such as proton, by the TOF-ΔE method using the scintillator hodoscope. The energy of ^{22}Mg was obtained from the total energy deposit on the silicon telescope and the velocity of proton was determined from the TOF information between the target and the hodoscope. In order to deduce the relative energy of the breakup reaction products measured in coincidence, the momentum vectors of the particles are determined from their energies combined with the hit position on the silicon telescope.

The analysis of the data is now in progress.

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c) University of Tokyo, Tokyo, Japan

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[1] H. Schatz *et al.*, Phys. Rev. Lett. **79** 3845 (1997).

[2] M. Wiescher *et al.*, Nucl. Phys. **A484** 90 (1988).

[3] I. Hisanaga *et al.*, RIKEN Accel. Prog. Rep. **31**, 162 (1998).

2.5 Study of Low Energy Alpha Scattering on ^{92}Mo

Zs. Fülöp, Gy. Gyürky, Z. Máté, E. Somorjai, L. Zolnai,
P. Mohr[a], M. Babilon[a], D. Galaviz[a], A. Zilges[a], H. Oberhummer[b]

α-nucleus potentials are important ingredients for the calculation of (γ,α) photodisintegration rates in the astrophysical γ-process. It has been shown that there are large uncertainties for the prediction of (γ,α) reaction rates because of the limited knowledge of α-nucleus potentials at the astrophysically relevant energies. For the reaction ^{148}Gd$(\gamma,\alpha)^{144}$Sm the uncertainty of the reaction rate could be reduced from a factor of about 10 to a factor of 2 by applying the systematics of α-nucleus potentials [1]. However, the improved prediction based on a scattering experiment [1] still overestimated the experimental data [2] at very low energies. Therefore, a new α scattering experiment on ^{92}Mo was performed at ATOMKI, Debrecen. For this $N = 50$ nucleus one expects almost the same behavior of the α-nucleus potential as for other semi-magic nuclei (like ^{144}Sm). For ^{92}Mo the α-nucleus potential can be determined at lower energies because of the lower Coulomb barrier. Additional astrophysical interest in this mass region comes from a strong underproduction of p-nuclei in the $A \approx 100$ mass region in nucleosynthesis calculations of the γ-process [3,4].

The setup for the scattering experiment was similar to our previous experiment [1]. A molybdenum-oxide target enriched to $(97.33 \pm 0.04)\,\%$ in ^{92}Mo with a thickness of about $200\,\mu g/cm^2$ was used to measure angular distributions at bombarding energies of about 14, 17, and 20 MeV. The count rates in the four main detectors were normalized to two monitor detectors mounted at 15° left and right to the incoming beam to eliminate systematic uncertainties. The experimental result at 20 MeV is shown in Fig 1.

The energy dependence of the ^{92}Mo-α potential can be extracted from the experimental scattering data at energies of 14, 17, and 20 MeV. This improved potential will be used to calculate the ^{96}Ru$(\gamma,\alpha)^{92}$Mo reaction rate, and the influence on the production factors of the light p nuclei will be analyzed in the near future.

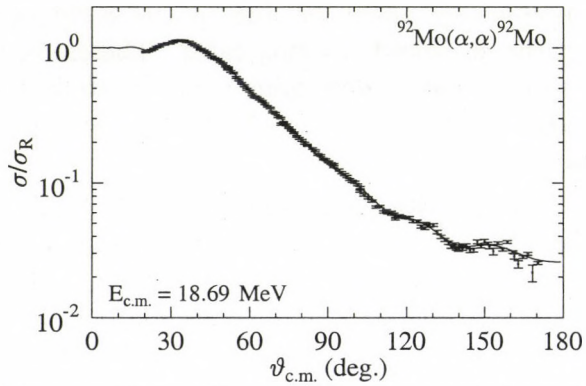

Figure 1: *Experimental cross section of ^{92}Mo$(\alpha,\alpha)^{92}$Mo compared to an optical model calculation with a real folding potential and an imaginary Woods-Saxon potential.*

a) Technische Universität, Darmstadt, Germany

b) Technische Universität, Vienna, Austria

[1] P. Mohr *et al.*, Phys. Rev. C **55** 1523 (1997).

[2] E. Somorjai *et al.*, Astron. Astrophys. **333** 1112 (1998).

[3] S. E. Woosley and W. M. Howard, Astrophys. J. Suppl. **36** 285 (1978).

[4] M. Rayet *et al.*, Astron. Astrophys. **298** 517 (1995).

2.6 Excitation of the Spin-dipole Resonance in the (^{3}He,t) Reaction as a New Tool for Measuring the Neutron-skin Thickness

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A new method was recently developed for studying the neutron-skin thickness [1]. It is based on the excitation of the spin-dipole resonance (SDR). This resonance can be strongly excited in charge-exchange reactions. In a recent experiment, the SDR in the Sb isotopes was excited by the (^{3}He, t) reaction at $E_{^3He}$ = 450 MeV [1]. It was demonstrated that there exists a correlation between the SDR cross section and the neutron skin of nuclei.

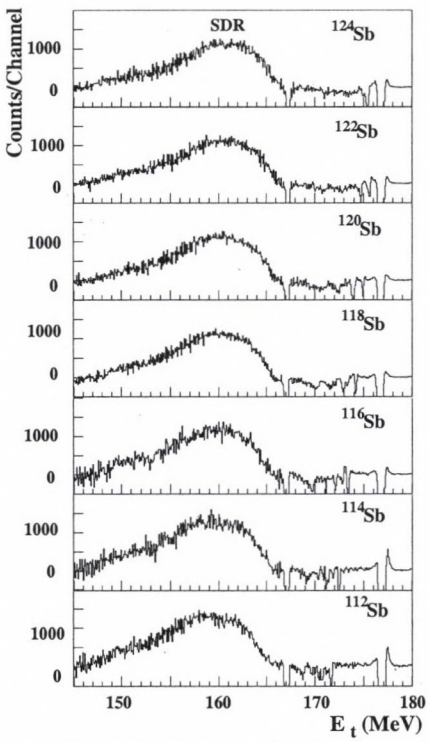

Figure 1: *The difference of the spectra obtained at $\Theta_{Lab} = 2°$ and $\Theta_{Lab} = 0°$, normalized to the strength of the transition to the Isobaric Analog State. The broad peak around 160 MeV corresponds to the SDR.*

The aim of a new experiment, performed at the KVI in Groningen at $E_{^3He}$ = 177 MeV, was to check the method at lower bombarding energy, where the spin-independent part of the nucleon-nucleon interaction is stronger. The targets were ^{112,114,116,118,120,122,124}Sn with a thickness between 4.75-12.7 mg/cm^2 and an isotopic enrichment between 75.0% - 96.6%. The tritons from the (^{3}He, t) reaction were detected in the focal plane of the Big-Bite Spectrometer and its focal-plane detection system constructed by the EuroSuperNova collaboration. By measuring the horizontal and the vertical angles of the outgoing tritons, the full scattering angle was determined.

For a preliminary analysis of the data, the difference of the spectra measured at 2° and 0° (shown in Fig. 1) have been integrated for the SDR energy region and the neutron-skin thickness was calculated in a similar way as in Ref. [1]. The results are compared to the previous experimental ones and to the recent theoretical predictions (cited in ref.1.). We have obtained consistent results. (Fig.2)

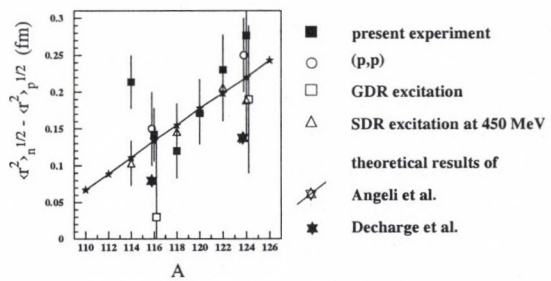

Figure 2: *The difference of the neutron and proton rms radii vs A_{Sn}*

In conclusion, the excitation of the dipole strength in charge-exchange reactions provides a new method for studying the neutron-skin thickness and it can be used for a wide range of neutron-rich unstable nuclei. A more precise multipole analysis of the data is in progress.

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b) KVI, Groningen, The Nederlands
c) RCNP, Osaka University, Osaka, Japan
d) Laboratorium voor Kernfysica Universiteit Gent, Gent, Belgium

[1] A. Krasznahorkay *et al.*, Phys. Rev. Lett. **82**, 3216 (1999).

2.7 The Half-life of ^{148}Gd

Zs. Fülöp, L. Bartha, Gy. Gyürky, E. Somorjai, S. Kubono[a], H. Kudo[b], D. Kaji[b]

^{148}Gd is a member of the rare earth alpha emitter group near the N=82 closed neutron shell, alpha-decaying with 100% branching ratio and with alpha energy of 3182.68 keV±0.24 keV [1]. The relative half-life error for isotopes having half-life between 1-400 years is below 3% on average, the accepted half-life of ^{148}Gd has also similar, 4% error: $T_{1/2}$=74.6±3.0 y [2]. The accepted value, however, is based on one experiment only, while other measurements — although quoting larger relative errors — also exist. Apart from two measurements carried out in the fifties [3,4] giving only upper limits (or rough values) on the half-life, there are three measurements, with results as follows: $T_{1/2}$=84±9 y [5], 97.5±6.5 y, [6] and the accepted 74.6±3.0 y [7]. The weighted average of the three values is $T_{1/2}$=81±10 y, and its relative error (12%) is much higher than the one of the accepted value or other alpha emitters. This is because the accepted half-life is much shorter than the previous values and the weight factor is not large enough to eliminate the effect of the other two data.

Better accuracy of the ^{148}Gd half-life also improves our knowledge on the nucleosynthesis of the p-elements. Somorjai et al. [8] determined one of the reaction rates responsible for the synthesis of the p-nucleus ^{144}Sm, i.e. the reaction rate of ^{148}Gd$(\gamma,\alpha)^{144}$Sm, using the ^{144}Sm$(\alpha,\gamma)^{148}$Gd reaction and detecting the alpha-decay of the produced ^{148}Gd nuclei. This activation method implies the knowledge of the half-life of the residual nucleus, and the error of the half-life in question directly affects the error in the reaction rate.

In order to determine the half-life we started to follow the alpha decay of a weak ^{148}Gd/^{241}Am mixed source with a compact dedicated system. The source stability as well as the electronics can be monitored by following the yield of the long lived ^{241}Am.

The system has been running for more than six months with data taking period of one day. From the so far obtained decay curve (see Fig 1) the preliminary result is $T_{1/2}$=65 ± 7 y. This value supports the validity of the accepted

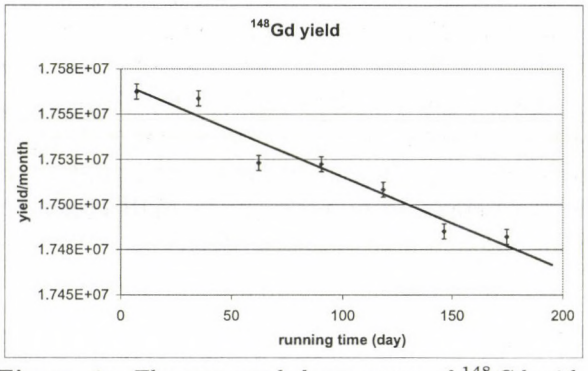

Figure 1: *The measured decay curve of ^{148}Gd with an exponential least-square fit.*

a) Tokyo University, Tokyo, Japan

b) Niigata University, Niigata, Japan

[1] A. Rytz, At. Data Nucl. Data Tables **47** 205 (1991).

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[5] A. Siivola, Ann. Acad. Sci. Fennicae, Ser A VI, No.109 (1962).

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[8] E. Somorjai *et al.*, Astr. and Astrophys. **333** 1112 (1998).

2.8 Beta Decay Study of ^{148}Tb Using Total Absorption Technique

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Precise measurements of the β-decay strength are necessary to obtain information on nuclear structure and to have a better understanding of the weak process. From this point of view particularly interesting cases are the nuclei in the A$\sim$150 region, which represent the heaviest nuclei where the $\sigma\tau$ resonance is populated in β^+-decay.

The main experimental difficulty in this kind of measurements is related to the precise determination of the β-decay feeding at high excitation energies. Due to the high level densities, and to the large number of possible decay paths at high excitation, the determination of the feeding from conventional high resolution techniques becomes an almost impossible task. One possible solution to overcome this problem is the use of a total absorption device which is sensitive to the β-population of the nuclear levels rather than to the individual gamma rays. A total absorption spectrometer of this type has been installed in the GSI [1]. It is based on a large NaI crystal covering almost 4π geometry, with a set of two Si detectors for the detection of the β particles and a small Ge detector for the detection of the X-rays. The use of these ancilliary detectors gives the possibility of measuring the signals in the NaI crystal in coincidence with the betas ($\beta^{\pm}$ decay) or with the X-rays (EC process). This device has been used to measure the β^+/EC decay of ^{148}Tb and ^{150}Ho. In both cases there are two β^+ decaying isomers, which can be produced separatedly using different compound reactions.

Simple shell model considerations predict the observation of little β-strength in the case of the ^{148}Tb 2^- decay and a resonance at aproximately four times the pairing gap in the case of the ^{150}Ho 2^- decay. The resonance of the ^{150}Ho case has been experimentally observed using the TAS technique [2]. Here we present the results of our complex analysis for the ^{148}Tb 2^- decay. The analysis process requires the deconvolution of the measured spectra with the response function of the detector. For the determination of the response function the GEANT3 Monte Carlo code was used.

In Fig. 1 we present the strength obtained after the deconvolution of the TAS spectra measured in coincidence with the X-rays. This work was supported by the AEN99-1046-C02-02 CICYT project (Spain), the HPMF-CT-1999-00394 (EU) and by the MTA-CSIC collaboration.

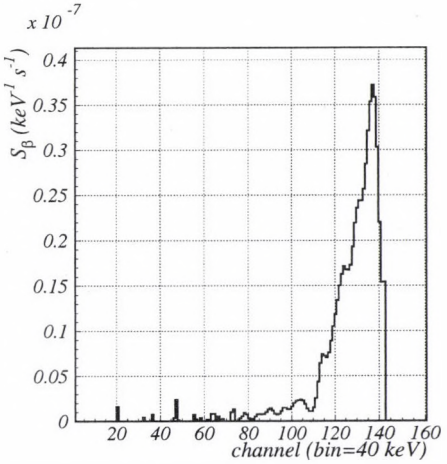

Figure 1: *Gamow-Teller strength measured in the decay of ^{148}Tb 2^- from the EC process.*

a) ATOMKI and IFIC,Valencia, Spain

b) IFIC,Valencia, Spain

c) CIEMAT, Madrid, Spain

d) University of Warsaw, Warsaw, Poland

e) GSI, Darmstadt, Germany

f) NPI, St. Petersburg, Russia

[1] M. Karny *et al.*, NIM **126** (1997) 411.

[2] A. Algora *et al.*, Nuc. Phys. **A654** (1999) 727c.

2.10 Shape Effects on the Clusterization of Heavy Nuclei

A. Algora[a], J. Cseh, P. O. Hess[b] and M. Hunyadi

Following our former studies on the extention of the applicability of the SACM (Semimicroscopic Algebraic Cluster Model) to heavy nuclei, we have performed a sistematic study of the effects of nuclear deformation on the clusterization of heavy nuclei. For these studies we have applied the U(3) selection rule [1] combined with 'effective' U(3) representations [2]. The effective U(3) representations that characterize the nuclei of interest were determined following the prescription outlined in ref [3].

There are many interesting questions that can be addressed in this rather simple framework. One of particular interest is if there are allowed clusterizations in case we change the deformation of the parent nucleus (for example from normal deformation to superdeformation or hyperdeformation). With this purpouse in mind we have studied all the possible binary clusterizations of normal deformed and of an 'hypothetical' superdeformed ^{252}Cf. The obtained results are presented in Fig. 1. As in the former calculations the daughter nuclei (clusters) are considered to have ground state deformations.

It is interesting to see that in the normal deformation case there are not allowed clusterizations for ^{252}Cf, but a clear tendency to cluster radioactivity can be deduced from our results. For the superdeformed case, as a main difference, we have allowed clusterizations as well. The regions of allowed clusterizations correspond to two particular cases: 1. both clusters having large prolate quadrupole deformation (region with $Z_{light} \sim 36$), 2. one cluster with prolate quadrupole deformation and the other with oblate deformation (region with $Z_{light} \sim 22$).

In comparison with the penetrability calculations, our structure considerations reflects another aspect of the fission process. The penetrabilities are mainly related to the Coulomb forces, while the structural effects are governed by the Pauli principle. This work was supported by the OTKA (No. T22187) and by the MTA-CONACyT collaboration (E120-550/95).

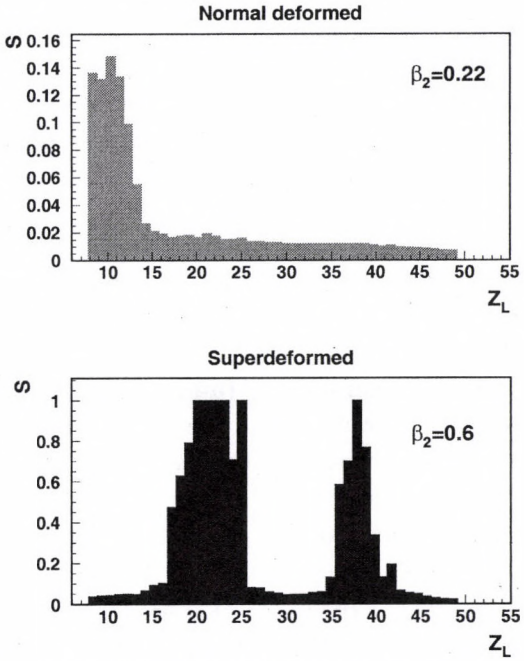

Figure 1: *The reciprocal forbiddenness S (see ref [3]) versus the Z_{light} of the studied fission channels. Z_{light} fully determines the fission channel for binary fission channels. The values of S correspond to mean values over channels that have the same Z_{light} and different A_{light}. In the upper part of the figure the parent nucleus has a deformation $\beta \sim 0.22$. In the lower part of the figure the parent nucleus has a 'hypothetical' superdeformation $\beta \sim 0.6$ The Z dependence clearly shows a non-uniform behavior.*

a) ATOMKI and IFIC, Valencia, Spain

b) Instituto de Ciencias Nuclerares, UNAM, Mexico

[1] J. Cseh and W. Scheid, J. Phys. G **18**, 1419 (1992); J. Cseh, J. Phys. G **19**, L97 (1993)

[2] D. J. Rowe, Prog. Part. Nucl. Phys. **37**, 265 (1996).

[3] A. Algora *et al.*, J. Phys. G **24**, 2111 (1998)

2.11 Coexisting Cluster Configurations and their Symmetries

J. Cseh

An atomic nucleus may show evidence for different cluster configurations in different regions of the excitation energy, or even at the same energy. The wave functions of these configurations are not orthogonal to each other, they may have considerable overlap. By applying harmonic oscillator functions this kind of overlaps have been studied extensively by several authors (see e.g. [1] and references therein).

In the semimicroscopic algebraic cluster model (SACM) [2] the clusterization of atomic nuclei is described in a fully algebraic way, i.e. not only the basis states are symmetric, but the interactions (and other physical quantities) as well (they are represented by operators with well-defined symmetry properties). Therefore, we can study in this framework the possible dynamic symmetries of the Hamiltonians of the coexisting cluster configurations, too. Recently it has been shown [3] that a symmetry which connects two binary fragmentations is related to the Talmi-Moshinsky-Smirnov transformations [4] of an underlying three-cluster configuration.

We consider two different clusterizations of an atomic nucleus, both of them consisting of two clusters:

$$c : C_1 + C_2, \quad d : D_1 + D_2. \tag{1}$$

(An example is the ^{24}Mg + ^{4}He and ^{12}C + ^{16}O configurations of the ^{28}Si nucleus.) Their relation can be established as follows.

Let us suppose that the relation of the mass-numbers of the clusters are:

$$A_{C_1} \geq A_{C_2}, \; A_{D_1} \geq A_{D_2}, \; A_{D_1} \geq A_{C_1}, \tag{2}$$

what can be done without any loss of generality. (In the example of the ^{28}Si nucleus, mentioned before, C_1:^{16}O, C_2:^{12}C, D_1:^{24}Mg, D_2:^{4}He.) Let us consider the three-cluster configuration

$$(C_1)+(CD)+(D_2), \; (CD) = (C_2 - D_2). \tag{3}$$

(In the example: ^{16}O + ^{8}Be + ^{4}He.) We choose the following two sets of Jacobi coordinates:

$$\begin{array}{l} \mathbf{t}_c = \mathbf{r}_{D_2} - \mathbf{r}_{CD}, \; \mathbf{s}_c = \mathbf{r}_{C_1} - \\ (M_{D_2}\mathbf{r}_{D_2} + M_{CD}\mathbf{r}_{CD})/(M_{D_2} + M_{CD}); \\ \mathbf{t}_d = \mathbf{r}_{C_1} - \mathbf{r}_{CD}, \; \mathbf{s}_d = \mathbf{r}_{D_2} - \\ (M_{C_1}\mathbf{r}_{C_1} + M_{CD}\mathbf{r}_{CD})/(M_{C_1} + M_{CD}), \end{array} \tag{4}$$

where M is the mass and $\mathbf{r}$ is the space vector of the corresponding cluster. Then, obviously, the clusterization $C_1 + C_2$, corresponds to the coordinate-set c with some restriction on $\mathbf{t}_c$, while clusterization $D_1 + D_2$ corresponds to the coordinate-set d with some restriction on $\mathbf{t}_d$.

The transformation from the clusterization $C_1 + C_2$ to that of $D_1 + D_2$ amounts up to a transformation between the two sets of Jacobi coordinates: $\mathbf{t}_c, \mathbf{s}_c$ and $\mathbf{t}_d, \mathbf{s}_d$. These kind of transformations are known as the Talmi-Moshinsky-Smirnov transformations [4]. They have a $U_q(2)$ group structure [5], where q refers to the quasispin group, which acts in the particle index space [6].

Work is in progress in order to fully explore the group-structure of the multichannel symmetry, and construct its physical operators.

The multichannel symmetry is very restrictive (in the sense of requiring very strong correlations between the different cluster configurations), and due to the same reason it seems to have a strong predictive power [7].

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2.12 Heavy-ion Resonances and the $U(3)$ Selection Rule

J. Cseh

A simple selection rule, based on the microscopic nuclear structure, may provide us with a straightforward explanation for several interesting features of the molecular resonances. As an illustrative example we consider here the ^{24}Mg + ^{24}Mg system.

The $U(3)$ selection rule is based on the connection between the $U(3)$ basis states of the shell model and the cluster model [1]. In brief, it requires a matching between the $U(3)$ quantum numbers of the shell-model state, and the direct product of the quantum numbers corresponding to the (shell model) states of the clusters and relative motion(s). It can be applied in relation with bound-states, as well as with resonant states of light nuclei (in which the $U(3)$ symmetry is approximately valid) [2].

In particular, a two-cluster configuration is allowed if the $[n_1, n_2, n_3]$ Young pattern of the leading representation of the whole nucleus matches with one of the results of the direct product representations of the two clusters and the relative motion: $[n_1^{C_1}, n_2^{C_1}, n_3^{C_1}] \otimes [n_1^{C_2}, n_2^{C_2}, n_3^{C_2}] \otimes [n, 0, 0]$.

The $U(3)$ selection rule is based on the microscopic structure (it takes into account the consequence of the antisymmetrization), and incorporates the (cilindrical or triaxial) deformation of the nuclei, as well as the possibility that they may have arbitrary orientation with respect to the molecular axis.

In the ^{24}Mg + ^{24}Mg reactions the experiments show narrow, high-lying quasibound states [3]. The preferred exit channels are the elastic and inelastic scattering, while the alpha-transfer channel has much smaller reduced width. The level density is larger than that of the shape resonances, but smaller than that of the compound states.

Several studies, based on the potential energy surfaces, associate these resonances with a pole-to-pole configuration of the two prolate nuclei [3].

The $U(3)$ selection rule applies to this case as follows. The (Pauli-allowed) pole-to-pole configuration of the two ^{24}Mg nuclei with [16,8,4] leading representation results in a [84,12,12] symmetry, which corresponds to a 3:1 ratio of the main axes, i.e. to a hyperdeformed state [4]. Based on the selection rule, one can determine the allowed and forbidden cluster configurations. If we restrict our interest on binary clusterizations, and on ground-state-like configurations of the clusters, it turns out that the allowed mass channels are the (approximately) symmetric ones: (24+24), (25+23), (26+22), (27+21), while the more asymmetric channels, including those of the alpha-transfer, are forbidden. Therefore, the structural forbiddenness may provide a natural explanation for the small reduced width of the transfer reaction.

As for the level density of the resonances, the molecular picture has a simple candidate for the relevant degrees of freedom, too: namely, the coupling between the relative motion and the internal structure of the clusters. This certainly results in an intermediate level density between those of the shape resonances and compound states.

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2.13 Proton Emission from Gamow Resonance

B. Barmore[a)], A. T. Kruppa, W. Nazarewicz[a)], T. Vertse

The newly developed non-adiabatic coupled-channel equations are used [1,2] to study proton radioactivity. The new method, working in the weak coupling regime of the particle-plus-rotor model, allows for the inclusion of excitations in the daughter nucleus. This can lead to very different predictions for lifetimes and branching ratios as compared to the standard, adiabatic approximation. Calculations are performed for a ranged of experimentally seen, non-spherical nuclei beyond the proton drip-line. By comparing theory and experiment we are able to deduce the angular momentum content of the proton's single-particle orbital.

Just beyond the proton drip-line are nuclei unstable against proton emission. In these nuclei there is competion between the Coulomb repulsion between protons and the significant Coulomb barrier. This leads to lifetimes from microseconds to full seconds for these nuclei. While this is a complicated, many-body problem, much insight may be gained by considering the simplified problem of a single proton penetrating the Coulomb barrier of the remaining core. It has been found that this simple, one-body picture works surprisingly well. In many cases we have been able to determine the angular momentum content of the resonance and the associated spectroscopic factor.

The past few years have seen a explosion of exciting discoveries in this field including new ground state and isomeric proton emitters and the first evidence for fine structure in proton decay. The focus of recent investigations has been on well deformed nuclei which exhibit collective motion. These are of particular interest due to the interplay between proton emission and angular momentum.

The theoretical description of long-lived proton emitters requires a detailed understanding of narrow resonances. For spherical systems there are many methods on the market which give similarly precise descriptions. The array of tools available for deformed emitters is not as well developed. Those that have been developed fall into three general categories. The first family of calculations is based on the reaction-theoretical framework of Kandenskiĭ. The second suite uses the theory of Gamow (resonance) states. Recently a third approach based on the time-dependent Schrödinger equation has been introduced.

In all of these previous attempts the strong coupling approximation of the particle-plus-rotor model has been used. The core is taken to be a perfect rotor with infinite moment of inertia. This has the effect of collapsing the rotational spectrum of the daughter to the ground state and neglecting the Coriolis coupling. Recently we have introduced a technique which includes a realistic rotational spectrum and full Coriolis coupling by working in the weak coupling scheme. Within this method we have direct access to branching ratio which can differ significantly from attempts to calculate the branching ratio in the strong coupling approximation. In addition, we have seen rotational bands built on Nilsson levels in the parent system.

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2.14 Shell Corrections of Superheavy Nuclei in Self-Consistent Calculations

A. T. Kruppa, M. Bender[a)], W. Nazarewicz[b)], P.-G. Reinhard[a)], T. Vertse, and S. Ćwiok[c)]

Shell corrections to the nuclear binding energy as a measure of shell effects in superheavy nuclei are studied [1] within the self-consistent Skyrme-Hartree-Fock and Relativistic Mean-Field theories. Due to the presence of low-lying proton continuum resulting in a free particle gas, special attention is paid to the treatment of single-particle level density. To cure the pathological behavior of shell correction around the particle threshold, the method based on the Green's function approach has been adopted. It is demonstrated that for the vast majority of Skyrme interactions commonly employed in nuclear structure calculations, the strongest shell stabilization appears for Z=124, and 126, and for N=184. On the other hand, in the relativistic approaches the strongest spherical shell effect appears systematically for Z=120 and N=172. This difference has probably its roots in the spin-orbit potential. We have also shown that, in contrast to shell corrections which are fairly independent on the force, macroscopic energies extracted from self-consistent calculations strongly depend on the actual force parametrisation used. That is, the A and Z dependence of mass surface when extrapolating to unknown superheavy nuclei is prone to significant theoretical uncertainties.

The stability of the heaviest and superheavy elements has been a long-standing fundamental question in nuclear science. Theoretically, the mere existence of the heaviest elements with Z>104 is entirely due to quantal shell effects. Indeed, for these nuclei the shape of the classical nuclear droplet, governed by surface tension and Coulomb repulsion, is unstable to surface distortions driving these nuclei to spontaneous fission. That is, if the heaviest nuclei were governed by the classical liquid drop model, they would fission immediately from their ground states due to the large electric charge. However, in the mid-sixties, with the invention of the shell-correction method, it was realized that long-lived superheavy elements (SHE) with very large atomic numbers could exist due to the strong shell stabilization.

In spite of tremendous experimental effort, after about thirty years of the quest for superheavy elements, the borders of the upper-right end of the nuclear chart are still unknown. However, it has to be emphasized that the recent years also brought significant progress in the production of the heaviest nuclei. During 1995-96, three new elements, Z=110, 111, and 112, were synthesized by means of both cold and hot fusion reactions. These heaviest isotopes decay predominantly by groups of α particles (α chains) as expected theoretically. Recently, two stunning discoveries have been made. Firstly, hot fusion experiments performed in Dubna employing ^{48}Ca+^{244}Pu and ^{48}Ca+^{242}Pu "hot fusion" reactions gave evidence for the synthesis of two isotopes (A=287 and 289) of the element Z=114. Secondly, the Berkeley-Oregon team, utilizing the "cold fusion" reaction ^{86}Kr+^{208}Pb, observed three α-decay chains attributed to the decay of the new element Z=118, A=293. The measured α-decay chains ^{289}114 and ^{293}118 turned out to be consistent with predictions of the Skyrme-Hartree-Fock (SHF) theory and the Relativistic Mean-Field (RMF) theory.

The goal of the present work is to study shell closures in SHE. To that end we use as a tool microscopic shell corrections extracted from self-consistent calculations. For medium-mass and heavy nuclei, self-consistent mean-field theory is a very useful starting point. Nowadays, SHF and RMF calculations with realistic effective forces are able to describe global nuclear properties with an accuracy which is comparable to that obtained in more phenomenological macroscopic-microscopic models based on the shell-correction method.

In previous work, shell energies for SHE elements were extracted by subtracting from cal-

culated HF binding energies the macroscopic Yukawa-plus-exponential mass formula. In another work, based on the RMF theory, shell corrections were extracted for the heaviest deformed nuclei using the standard Strutinsky method in which the positive-energy spectrum was approximated by quasi-bound states. Neither procedure can be considered as satisfactory. A proper treatment of continuum states is achieved with a Green's function method.

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2.15 A Supersymmetry Scheme of α-cluster Systems

G. Lévai, J. Cseh, P. Van Isacker[a)]

Following the formalism of supersymmetry-inspired nuclear structure models based on the Interacting Boson–Fermion Model (IBFM), we proposed a supersymmetry scheme describing core+α-particle type cluster systems [1]. In this approach the bosons are oscillator quanta assigned to the relative motion of the clusters, while the fermions are *holes* on the p-shell, thus the model describes simultaneously α-cluster states of neighbouring nuclei with mass number $A \leq 20$. It is based on the Semimicroscopic Algebraic Cluster Model (SACM), which has been applied successfully for the description of the spectroscopic properties of cluster systems in this mass range. Our work was motivated by two factors: *i)* Previous studies demonstrated that the model parameters of the SACM vary smoothly in the A =16 to 20 region, indicating correlations between neighbouring core+α-type cluster systems; *ii)* Cluster bands of nuclei in this region are often interpreted as each other's correspondents, regardless of the models employed.

The group structure relevant to this problem is an extension of the $U_R(4) \times U_C(3) \times U_C^{ST}(4)$ group structure of the SACM: first the $U_C(3)$ orbital and the $U_C^{ST}(4)$ spin-isospin groups of the core are embedded into the $U_C(12)$ group (corresponding to applying the Elliott model to the p-shell core), and then this latter group is embedded into U(4|12) together with the $U_R(4)$ group describing the relative motion of the clusters. (In the supersymmetric formalism it is more appropriate to change the subscripts C and R indicating "core" and "relative" to F and B standing for "fermionic" and "bosonic" degrees of freedom.) The basis states which now describe α-cluster states of *several* neighbouring nuclei can be labelled as

$$|\mathcal{N} N_B n_\pi, (\lambda_F, \mu_F); (\lambda, \mu) L S J M_J T M_T\rangle \ .$$

Here we kept only the essential labels and omitted those which are uniquely determined by others, such as the total fermion number $N_F = \mathcal{N} - N_B$ and the $U_F^{ST}(4)$ labels which, for p-shell nuclei are determined by the (λ_F, μ_F) orbital $SU_F(3)$ labels through the adjoint Young patterns of the spin-isospin and orbital structures.

As a first example we analysed the spectroscopic information on the α-cluster states of the ^{20}Ne and ^{19}F nuclei. These correspond to $N_F = 0$ and $N_F = 1$, respectively, i.e. systems with zero and one fermion [1]. We considered a phenomenologic Hamiltonian similar to that used in the SACM, and fitted its parameters to 20 ^{20}Ne and 25 ^{19}F states. We found that there is correlation between the energy spectra of these two nuclei in the sense that separate and joint fits to the two systems resulted in rather similar parameter sets. Our conclusions were similar regarding the electric quadrupole transitions of the ^{20}Ne and ^{19}F nuclei. We found [1] that the "goodness" of the U(4|12) supersymmetry is not worse (is even better) than that of the U(6|4) supersymmetry associated with the ^{190}Os and the ^{191}Ir nuclei.

As a further test we analysed one-nucleon transfer data from the ground state of ^{20}Ne to various ^{19}F states. In the supersymmetry scheme these processes correspond to annihilating a boson and creating a fermion, i.e. they are described by a generator of U(4|12). We found that the predictions of the model for the relative intensity of transitions to two different $J^\pi = \frac{3}{2}^+$ ^{19}F states agrees well with the experimentally established value [1].

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3.1 A Parallel Plate Analyzer with Time Focusing

Á. Kövér and G. Laricchia[a)]

Parallel plate analyzers (PPA) are widely used in atomic physics to measure the energy spectra of charged particles. In spite of their simplicity, this type of instrument has second order focusing properties at 30° where the angular aberration has a minimum.

In the last decade, a tandem (two analyzers in series) parallel-plate analyzer has been developed for measuring the energy distribution of electrons or positrons ejected from positron - atom collisions [1,2]. The analyzer was later altered in order to measure coincidences between the ejected electrons and the scattered positrons flying into the same direction (around 0°) [3].

As the measured energy is decreased, the full width at half maximum (FWHM) of the time peak becomes progressively larger. The amplitude of the time peak becomes correspondingly smaller due to the increasing time of flight spread caused by the different length of the trajectories of the particles inside the analyzer.

In order to reduce the width of the time peak, and thus increase its amplitude, we have developed a modified tandem parallel plate analyzer for which the time-of-flight is nearly the same for every entrance angle. Our modified twin PPA has been designed such that the angle between the two base plates is 120° and correspondingly the entrance angle at the second stage is $\theta_2 = 60° - \theta_1$, where θ_1 is the entrance angle of the first stage.

Figure 1 shows the comparison of the line shape of the time peak for the conventional and the new PPA for at 15 eV pass energy and for 4 mm extended target. As can be seen, the improvement is outstanding. Allowing for the time spread caused by the extended target, the FWHM of this peak is more than 10 ns for the conventional PPA while for the new PPA is only about 3 ns and, as a consequence, the peak amplitude is much higher for the latter.

The new analyzer was built in the University College London and has been used to extend our investigation of the electron capture to continuum process (ECC) by positron impact by measuring coincidences between electrons and positrons ejected into the same direction around 0° 50 eV e^+ - H_2 collision [4]. The improved capabilities of the analyzer enable measurements of the ECC peak to energies as low as 15 eV.

More detailed information about the calculation, design and performances will be found in [4,5].

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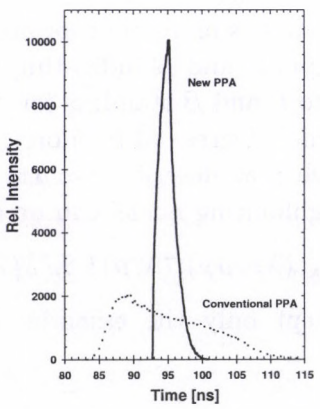

Figure 1: *Comparison of the calculated time peaks.*

3.2 A Photo- and Auger Electron Coincidence Study

S. Ricz, Á. Kövér, D. Varga, J. Molnár, S. Aksela[a)] and M. Jurvansuu[a)]

In the previous Annual Report [1] a preliminary paper was presented on the coincidence between photoelectrons and Auger electrons. Recently the experimental investigation has been completed. The Ar $L_{23}MM$ Auger electrons were measured in the 199-208.5 eV energy range in coincidence with the $2p_{1/2}$, $2p_{3/2}$ photoelectrons at 440 eV photon impact.

The measurement was carried out at the beam line I411 on the third generation MAX-II storage ring in Max-Lab, Lund, Sweden with the Esa-22 electrostatic analyzer [2]. In the present study the relative energy resolution of the analyzer was set to $\Delta E/E \approx 3\times10^{-3}$ and 1.5×10^{-3} for the Auger and photoelectron side, respectively. The 440 eV photon energy were chosen in order to reduce the time spread caused by the time of flight of electrons. The photoelectrons ejected from the Ar $2p_{1/2}$ or the Ar $2p_{3/2}$ subshells were measured with a position sensitive channel plate (CP) in the 0°-180° angular region relative to the beam direction. The LMM Auger electrons were detected by channeltrons in the 15°-165° angular region at every 15°, simultaneously.

Fig. 1 shows the Ar L_{23}-$M_{23}M_{23}$ Auger spectrum at 440 eV photon impact. The solid line is the well-known single Auger spectrum (without coincidence condition), the circle with error bars represents the coincidence spectrum. The figures clearly show that we could eliminate the overlap between the L_{23}-$M_{23}M_{23}$ and other satellite Auger transitions in the coincident spectrum. This coincidence investigation opens a new way to determine the correct intensity ratios of the Auger transitions. E.g. we found an anomalous intensity ratio at the $^2P_{3/2}$-$^3P_{012}$ / $^1D_2$ peaks. It differs from the previous ratios measured in single spectra. The existing theories overestimated both rations determined from single and coincidence spectra. More detailed investigation will be published soon [3].

The authors thank to the Program Advisory Committee at MAX-lab for granting the beam time and the excellent working conditions. This work is supported by the Hungarian Science Research Found (OTKA No T025325).

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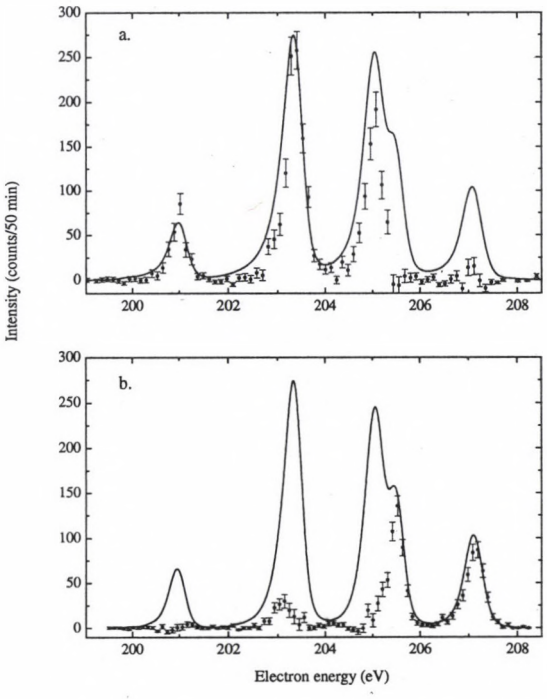

Figure 1: *Fig* **a** *and* **b** *show the single and coincidence spectra of Ar LMM Auger electrons.* Solid line*: single spectra:* Circles*:* **a***: coincidence with* $2p_{3/2}$*, photoelectrons;* **b***: coincidence with* $2p_{1/2}$ *photoelectrons.*

3.3 Energy Shift and Broadening of the Spectra of Electrons Backscattered Elastically from Solid Surfaces

D. Varga, K. Tőkési, Z. Berényi, J. Tóth, L. Kövér

Studying the energy loss process of fast (20-40 keV) electrons backscattered quasi-elastically from crystalline surfaces, Boersch et al. [1] found a simple model based on the assumption of single elastic scattering on quasi-free atoms having thermal motion for describing both the energy shift and the broadening of the elastic peak. Using the high energy resolution property of our electron spectrometer (ESA-31, developed in ATOMKI [2]) the spectra of electrons backscattered elastically from surfaces of different solid samples were measured. Fig. 1. shows, that the effect of both the energy shift and broadening due to elastic scattering at angle 130° and thermal motion of atoms are well measurable also at the much lower energy (5 keV) of electrons. The results on the elastic peak energy shifts and widths (FWHM) obtained experimentally for the 1-5 keV energy range, were compared with results of calculations for single elastic scattering on free atoms having Maxwell-Boltzmann thermal velocity distribution. The effect of multiple scattering on the yield of the backscattered electrons, energy shifts and Doppler broadenings have been studied by Monte Carlo simulations. The calculated values shows a good agreement with the experiment in the case of Au and Ni samples, however, the measured line broadenings are larger (by 15-25 %) for Si and (by 30-60 %) for carbonic samples than the calculated ones. The differences between the experimental and calculated values could be explained by the presence of argon atoms (implanted during sputtering) in the surface layer of Si, but in the case of carbonic samples further studies are necessary.

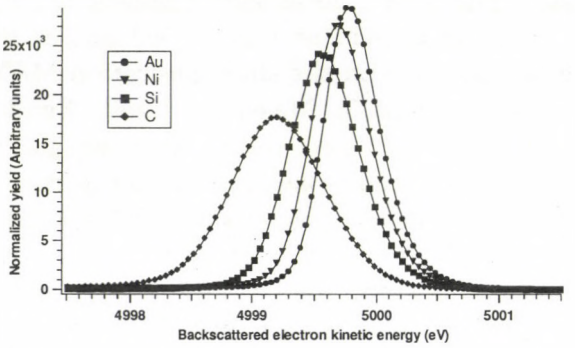

Figure 1: *Energy distributions of electrons backscattered elastically from surfaces of homogeneous samples of Au, Ni, Si and C (normalized by peak area), as derived experimentally using 5 keV primary beam energies.*

This work was supported by research projects INCO COPERNICUS ERBIC 5CT960800 (EU), OTKA T026514, T030433, T032306.

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3.4 Cusp-electron Production due to Transfer Ionization in He^{2+}+He Collisions

L. Sarkadi, L. Lugosi and Á. Kövér

Cusp-electron emission (i.e., continuum electrons emitted along the ion beam direction and travelling with the beam velocity) has been investigated in 25–75 keV/amu He^{2+} on He collisions. Two processes which contribute to cusp electrons for this collision system, Electron Capture to the Continuum (ECC) and Transfer Ionization (TI), were distinguished by detecting the electrons in coincidence with the charge-state analyzed outgoing He^{2+} and He^{+} projectiles, respectively. Spectra obtained at 25 keV/amu impact energy are presented in Fig. 1. In this work we were particularly interested in the two-electron TI process in which the continuum-electron emission is associated with capture of a second electron into one of the bound states of the projectile. The ratio of the electron yields for the TI and ECC channels provides information on the role of the electron – electron interaction (correlation). We obtained a surprisingly large value for the TI/ECC ratio at 25 keV/amu, 1.43 ± 0.14, which means that the probability of the two-electron process exceeds that of the one-electron process. This result is unexpected, because in a previous experiment [1] for Ar target we obtained a smaller value (0.799 ± 0.080) at the same impact energy. Calculations in the framework of the *classical trajectory Monte Carlo* (CTMC) model are in progress for interpretation of the experimental results.

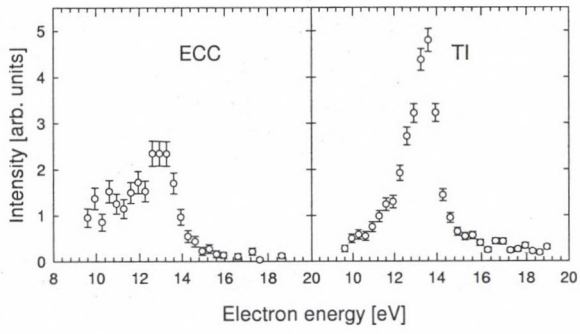

Figure 1: *Spectra of electrons emitted via ECC and TI process in 25 keV/amu He^{2+} on He collisions.*

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3.5 Hot Electrons from Intermediate Velocity C^+ + Xe Collisions: Evidence for Fermi-Shuttle Ionization

B. Sulik, Cs. Koncz, K. Tőkési[a)], A. Orbán and D. Berényi

In recent years, considerable attention has been devoted to the Fermi-shuttle acceleration in the ionization process by heavy particle impact. The mechanism had been proposed by Fermi [1] as a possible origin of cosmic rays; specifically, giant magnetic fields, moving against each other in space, can accelerate charged particles to high energies in long sequences of reflections. It was shown later that similar acceleration can also be produced by the microscopic fields of moving atoms or molecules [2].

In the Fermi-shuttle ionization process, the liberated electron can be backscattered by the projectile and the target center (denoted by P and T respectively). If we denote the impact velocity of the projectile by V, scattering sequences starting with target ionization produce electrons emitted with the mean velocity $2nV$ in both forward and backward directions, where n is the number of encounters with the projectile. Starting with projectile ionization, the corresponding mean velocity is $(2n+1)V$.

In a recent work [3], experimental evidence has been found for consecutive projectile-target-projectile (P-T-P) and projectile-target-projectile-target (P-T-P-T) "ping-pong" scattering of ionized target electrons in the high-energy part (300 - 3400 eV) of the electron spectra emitted in single C^+ + Xe collisions at 150 and 233 keV/u impact energies. Distinct signatures for triple and quadruple electron scattering have been separated and identified by the help of control measurements with a He^+ projectile.

At high electron energies (where the velocity of the emitted electron is larger than two times the projectile velocity), first-Born calculations for ionization of the xenon atom agree well with the experimental data for the helium projectile (see Fig. 1). For the C^+ ion at different impact velocities, the agreement between experiment ant theory is similarly good, except for the appearance of the broad structures around $4V$. These latter shoulders above the first-Born curves are attributed to the P-T-P process in C^+ + Xe collisions.

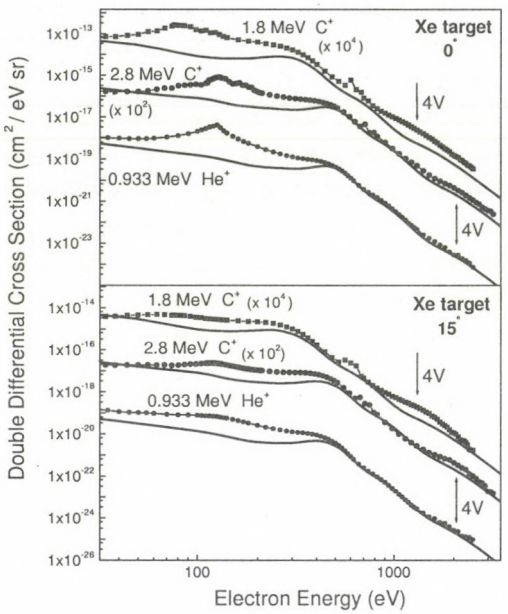

Figure 1: *Comparison between experiment and first-Born theory at 0° and 15° emission angle. The impact velocity is 2.5 au for the 1.8 MeV C^+ projectile, and 3.05 au for the 2.8 MeV C^+ and 0.933 MeV He^+ ions. Symbols: experiment, lines: target ionization theory.*

Non-perturbative CTMC calculations have also provided independent confirmation for identifying the distinct signitures of the P-T-P triple and the P-T-P-T quadruple scattering processes in the electron spectra.

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3.6 The Angle-resolved Kr $L_{2,3}M_{4,5}M_{4,5}$ Auger Multiplet Following Proton Impact Ionization

B. Paripás[a)], U. Kleiman[b)], Gy. Víkor[c)], B. Lohmann[b)] and S. Ricz

The angle-resolved Kr $L_{2,3}M_{4,5}M_{4,5}$ Auger spectra induced by proton ionization were measured at 1.0, 2.6 and 3.6 MeV impact energies where high-resolution spectroscopy techniques have been applied (ESA-21 spectrometer). In the evaluation of the experimental Auger spectra, a post-collision interaction distorted line-shape was used [1]. The more realistic line-shape treatment resulted in a better separation of the strongly overlapping peaks of the multiplet. This was also confirmed by our multiconfigurational Dirac-Fock calculation [2].

The alignment parameter A20 of the singly ionized krypton atoms has been extracted from the experimentally accessible anisotropy parameter A_2 applying a special method, which requires the theoretical values of the angular distribution parameter α_2. Within the considered energy interval (1-3.6 MeV), the ionic alignment A_{20} decreases rapidly with increasing proton energies (from 0.19 to -0.03). This finding is in accordance with some earlier results obtained for transition elements and heavy atoms [3].

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	Our experiment		*Our calculation*			*Aksela[4]*		*Werme[5]*	
State$_{final.}$	En. [eV]	$I_{rel.}$	En. [eV]	$I_{rel.}$	α_2	En. [eV]	$I_{rel.}$	En. [eV]	$I_{rel.}$
$^1P_{0,1}$			1.08;1.17	0.4;0.9	-1,0			1.0;1.1	20.8
	1.20(10)	7.8(8)				1.01	31.2		
$^1D_2$			1.15	6.0	-0.275				
$^3P_2$	2.5(10)	8.4(6)	2.73	9.4	0.084	2.7	14.0	2.5	11.3
$^3F_2$	4.40(10)	3.0(5)	5.23	12.6	0.294	4.70	19.9	4.9	9.4
$^3F_3$	4.96(3)	20.2(8)	5.78	12.5	0.434	5.85	27.3	5.4	13.2
$^3F_4$	6.28(3)	21.7(8)	6.91	21.8	0.668	6.91	15.6	6.6	22.6

Table 1: *Experimental and numerical data of the Kr $L_3M_{4,5}M_{4,5}$ Auger spectrum. The Auger energies and line intensities are given relative to the $^1G_4$ peak and are compared with earlier experimental data.*

3.7 Influence of Post Collision Interaction on the Line-shape of Auger-electron Spectra at Electron Impact Ionization

B. Paripás[a)], G. Vitéz[a)], Gy. Víkor[b)] and K. Tőkési

In this work the peak-shape of the $2p(^2P_{3/2}) \rightarrow 3p(^1D_2)$ diagram line of the **Ar** $L_{2,3}M_{2,3}M_{2,3}$ Auger group at $0^o, 15^o, 30^o, 45^o, 60^o, 75^o, 90^o$ emission angles is studied by electron impact. The effect of post collision interaction (PCI), i.e. the distortion due to the Coulomb interaction between the Auger-, the scattered projectile- and the electron, ejected during the inonization, to the emission of the Auger electron is significant. The Auger peak-shape distorted by PCI (asymmetry of the peak) is well measurable parameter. The line-shape of Auger-electrons is known theoretically for entire fixed collision kinematics [1], i.e. when both secondary electrons (scattered projectile and ionized prompt) are measured in coincidence with the Auger-electron (triply coincidence experiments). The Auger peak-shape in non-coincidence experiments (when the secondary electrons are not detected) can be obtained by integration over the non- measured quantities using the differential cross sections for secondary electrons. In the present work the cross sections for secondary electrons are determined by a classical trajectory Monte Carlo method. After the numerical integration the Auger peak-shape is evaluated in the same way as for the experimental spectra. On the basis of our calculations and comparisons with our experimental data [2,3] the following conclusions can be made:

- The Auger peak-shapes for non-coincidence experiments can be described by the formulas deduced for fixed collision kinematics with considerable success (Fig. 1).
- The overall agreement with experimental peak-asymmetries is remarkably good at low primary energies (300 and 500 eV) but differ about 25% at 2 keV primary energy.
- The peak-asymmetry is larger at larger Auger emission angle at every primary energies.
- The angular dependence of the peak-asymmetry has maximum at 500 eV, where the electron energies are almost the same and thereby the relative velocities strongly depend on the orientation of velocity vectors.

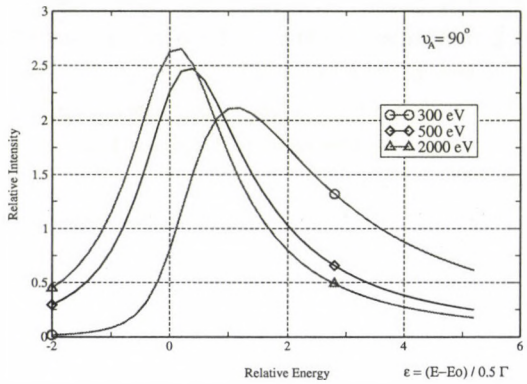

Figure 1: *The calculated peak-shape of the* $2p(^2P_{3/2}) \rightarrow 3p(^1D_2)$ *diagram line of the* ***Ar*** $L_{2,3}M_{2,3}M_{2,3}$ *Auger group at* 90^o *emission angle at different electron impact energies.*

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3.8 Triple Differential Ionization Cross Section of H_2 by 50eV e^+ Impact

Á. Kövér, K. Paludan[a)], G. Laricchia[a)]

In our previous paper [1], the results of the first triple differential measurement for ionization of H_2 by 100eV positrons were presented. A small broad peak was found in the ejected electron spectrum at 0° in coincidence with positrons scattered into the same direction. It was the first clear experimental evidence of the occurrence of electron-capture-to-the-continuum (ECC) by positron impact.

In this study, we present the results of an investigation at 50eV positron energy incident on H_2. The experimental apparatus, the coincidence circuit and the procedure for data collection were similar to that of our previous experiment. The main difference was to use a newly designed parallel plate analyser (PPA) which has an additional benefit of time focusing [2].

The experimental data were normalised to the theoretical values calculated by Fiol *et al.* [3] who convoluted them with the angular acceptance and energy resolution of our system. The maximum of the theoretical distribution is at 17.3eV. Convolution with the experimental resolutions, shifts the calculated peak to 16.5eV. In contrast, the experimental data rise to a maximum at ~15eV, after which they decrease rapidly. In comparing experimental and theoretical results, an energy shift is observed between the two distributions. In fact, the agreement between them would be fair were the theoretical results shifted by 1.6eV towards lower energies.

Due to the characteristically low positron beam intensities, we are unable to calibrate the PPA in an absolute manner (e.g. via electrons from autoionising or Auger processes) and hence cannot categorically exclude an energy miscalibration of the PPA due for example to contact potential effects. However, this would seem unlikely, because the energy calibration procedure adopted in this work is the same as that used previously [1], where good correspondence was found between theory and experiment.

A physical effect which could give rise to the shift would be the occurrence of ionization *simultaneous* to another energy loss, e.g. vibrational excitation or molecular dissociation of the target. If ECC resulted in dissociation of the remnant ion, the energy of the cusp peak would be shifted to lower energies by around ($E_d/2$), where (E_d = 2.65eV) is the dissociation energy of H_2^+. Recently, Mukherjee and Ghosh [4] have studied the vibrational excitation of H_2^+ by positronium formation in e^+ - H_2 collision for the channels ν=2,3,4 whose thresholds are (0.6, 0.9 and 1.1) eV, respectively. They found that the simultaneous occurrence of these processes is probable at 50eV e^+ impact while it is negligible at 100eV impact.

To investigate this hypothesis further, we plan to study the ECC process from atomic target such as He or Ar and increase the sensitivity of the kinetic energy measurements of Ps formed from H_2.

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3.9 Study of the Transfer-Loss Process in Collision of F^{6+} Ions with He Target at Low Energies

B. Sulik, T.J.M. Zouros[a)], A. Orbán and L. Gulyás

The method of zero-degree projectile Auger spectroscopy was applied earlier to measure the state selective K- shell excitation of the Li like F^{6+} and O^{5+} ions incident in the 3 ~10 a.u. impact velocity region on He and H_2 target [1]. An example for a studied process:

$$O^{5+}(1s^2 2s) + He \rightarrow O^{5+}(1s2s2p) + He^+ + e^-.$$

For the projectile final state there exists three alternatives which can be marked with the spectroscopic notations: ^4P, $^2P_-[(^3P)^2P]$, $^2P_+[(^1P)^2P]$.

One of the possible mechanism resulting these final states is the so called transfer-loss process (TL): the ionization of a $1s$ electron of the projectile and the a transfer of a target $1s$ electron to the projectile $2s$ shell.

TL is the dominant process for producing the $1s2s2p$ projectile configuration at low (3-10 MeV) impact energies. We calculate the transfer-loss probability using the independent particle model (IPM) by taking the product of the transfer (capture) and loss (ionization) probabilities:

$$P_{TL} = P_T P_L$$

The cross section for a specific m is:

$$\sigma_{TL}^{1s2s2p_m} = 2\pi \int_0^\infty dbbP_{TL}^{1s2s2p_m}(b)$$

The electron transfer probabilities have been calculated within the framework of the continuum distorted wave (CDW) approximation [2]. Calculations for the projectile excitation and ionization probabilities were performed by a semiclassical approximation (SCA) code in first order [3]. Both the CDW and SCA results were corrected by the help of the unitarization method introduced by Sidorovich *et al.*[4].

A qualitative agreement with experimental data for the TL contribution to the ^4P Auger production is demonstrated in Figure 1. [5].

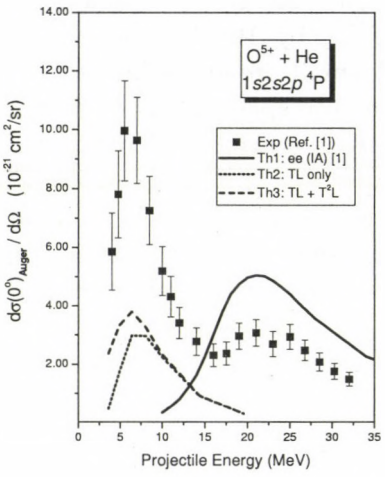

Figure 1: *Double differential cross section for the production of 1s2s2p ^4P states in O^{5+}+He collisions. Symbols: experiment [1]; Solid line: calculated dielectronic excitation (eeE) contribution [1]; Dotted line: TL calculation; Dashed line: sum of TL and double transfer and loss T^2L.*

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3.10 An Improved Evaluation of the Multiple Ionization $M\alpha,\beta N^i$ Satellites of Ta

I. Török

Several years ago the $M\alpha,\beta N^i$... satellites of Ta were measured in our laboratory [1-3]. The spectra were taken by our laboratory built crystal spectrometer, at excitation by ions: 0.8, 2.0, 3.2 MeV protons, 1.6, 3.2 MeV He^+ ions. At another spectrometer a fluorescence spectrum was taken too. The satellite-to-diagram intensity values were calculated and compared to other experimental and theoretical values. The published results were only a zero-approximation, we did not find proper natural line-widths, proper spectrum evaluation software, proper calculated values for comparision. Now we plan to reevaluate these data, using better such tools. Now available are: a better natural widths data set [4], a new version of the EWA evaluation package [5], and newer calculations of the satellite-to-diagram ratio in the geometrical model [6]. We hope to get intensity ratio values matured enough for submission to one of the leading journals of the field.

The work was supported by OTKA No. T016636.

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3.11 On the Nature of the New Satellite Found in the F KLL Spectra of Fluorides

L. Kövér, I. Cserny, J. Tóth, D. Varga and M. Uda[a)]

Unassigned satellite lines at kinetic energies higher, than the main peak, were found earlier in the F KLL Auger spectra of alkali fluorides and interpreted on the basis of a new concept, the resonant orbital rearrangement (ROR)[1]. These satellite lines show a very strong change in their relative intensity (compared to that of the main $^1D_2$ KLL Auger peak) for different alkali and alkaline-earth fluorides. In the frame of the ROR model a resonance is assumed between the highest occupied molecular orbital (HOMO) of the K^0L^0 ground state and the lowest unoccupied molecular orbital (LUMO) of the K^1L^0 ionized state. During the resonant transition an electron of the F^- ion in the fluoride, occupying an orbital of mainly F 2p character in the ground state (HOMO) is supposed to move to an orbital of the ionized state (LUMO) having mostly F 3s character, leading to an Auger transition with a participator excited electron.

This model seems to provide a good agreement between the predicted and measured satellite intensity values in the case of the alkali fluorides [1]. Obtained with a considerably improved peak to background ratios in the F KLL Auger spectra by using near threshold photoexcitation with $Cu\ L\alpha$ X-rays and a high resolution hemispherical electron spectrometer [2], our recent results for polycrystalline rutile type fluorides $CoF_2, MgF_2, NiF_2, ZnF_2$ and for polycrystalline NaF [3] indicate the existence of an approximately linear correlation between the relative satellite intensity and the energy width (Full Width at Half Maximum, FWHM) of the satellite peaks (Fig.1).

From Fig 1 the strong correlation between satellite intensity and energy width can be seen clearly, in spite of the considerable experimental error (mainly due to the systematic error in the inelastic background correction [3]) because the changes in satellite intensity and energy width are very large. The results reflect a strong effect of the atomic environment around the ionized fluorine atom on the density of the unoccupied electron states available for the electrons excited by the sudden appearance of the core hole during photoionization or by resonant processes.

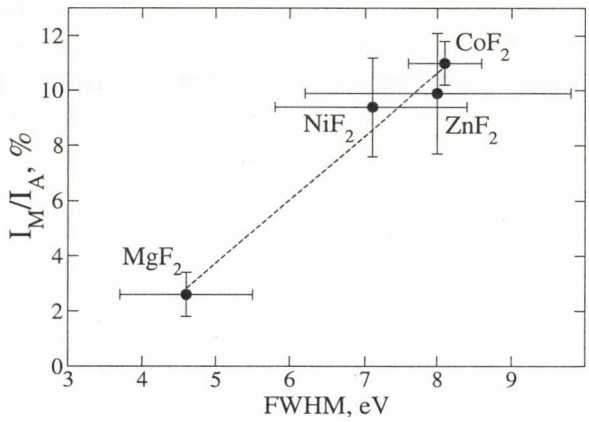

Figure 1: *Relative intensities I_M/I_A of the satellite peaks M compared to that of the main peak A in the F KLL spectra of fluorides as a function of the energy width (FWHM) of the satellite peaks [3].*

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3.12 Low-energy Electron Ion Recombination in a Magnetic Field

M. Hörndl[a)], S. Yoshida[a)], K. Tőkési and J. Burgdörfer[a)]

The electron-ion recombination in cold magnetized plasmas is currently intensively studied both experimentally and theoretically. The gas of electrons in a cooler of a storage ring can be viewed, in the rest frame of the ion, as a low-temperature one-component plasma in which the ion is immersed. The electron gas is magnetized by the confining field. Recent storage ring experiments show a dramatic enhancement of the radiative recombination rate for high Z ions relative to what standard radiative recombination rates predict [1,2]. We analyze the role of classical chaotic dynamics and unstable periodic orbits which may bring an electron to multiple visits to the target ion (Fig 1) and enhance the recombination. A difficulty comes from the fact that the electron motion involves cyclotron (asymptotic region) and Kepler (target ion region) motions with two vastly different length scales. This disparity in length scales implies that classical scattering trajectories have to be followed from "infinity" at almost macroscopic distances to the target for reliable predictions requiring a huge amount of computational time. We employ classical scaling invariance [3] to reveal the systematic dependence on magnetic filed B and nuclear charge Z. To improve statistical sampling of relevant trajectories we perform a numerical scattering experiment "in reverse" by exploiting the time reversal symmetry of the Hamiltonian.

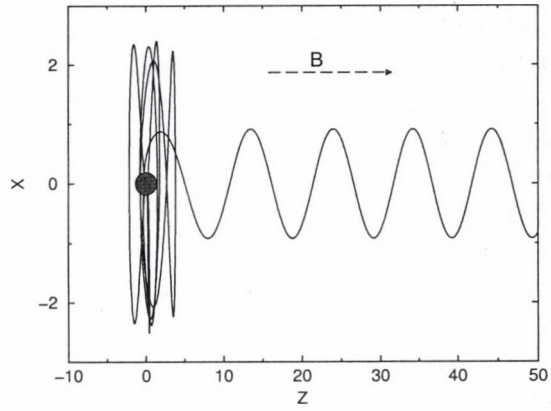

Figure 1: *Trajectory (solid line) launched near the target ion (filled circle at the origin). For the visualization, a trajectory with the relatively small number of traversals is chosen in this plot.*

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3.13 Electronic Relativistic Effects in Inner-shell Ionization by Heavy-particle Impact

L. Lugosi and L. Sarkadi

This study is an extension of a previous work [1] in which a computer program (called MTRXCOUL) was developed to calculate the matrix elements of the Coulomb interaction between a charged particle and an atomic electron, $\langle\psi_f(\boldsymbol{r})|\ |\boldsymbol{R}-\boldsymbol{r}|^{-1}\ |\psi_i(\boldsymbol{r})\rangle$. These quantities play a central role in the theoretical description of the excitation, ionization processes of atoms by impact of charged particles. In MTRXCOUL the initial and final states are represented by non-relativistic hydrogenic wave functions.

It is known that at low collision velocities and for heavy target atoms the inner-shell ionization cross sections are considerably affected by electronic relativistic effects. Therefore, for an accurate description of the inner-shell processes the use of relativistic electronic wave functions is unavoidable. In the present work the program MTRXCOUL was further developed: We replaced the non-relativistic wave functions by one-electron Dirac bispinors.

As an application of the developed computer program, we calculated K-, L- and M-shell ionization cross sections for proton on gold collisions in the semiclassical approximation (SCA). For the K shell our results are shown in Fig. 1. The cross sections plotted in the figure were obtained from the following calculations: SCA and RSCA – straight-line version of the semiclassical approximation with use of non-relativistic and relativistic wave functions, respectively (present work); PWBA and RPWBA – non-relativistic and relativistic plane-wave Born approximation [2]. The SCA and the PWBA cross sections are one order of magnitude smaller than the cross sections obtained in the relativistic version (R) of these models. Furthermore, the K-shell ionization cross sections were computed also with the RSCA applying hyperbolic projectile trajectory (H) and the united-atom approximation (UA). The latter model, denoted by HRSCA-UA, is in good agreement with the experimental data [3].

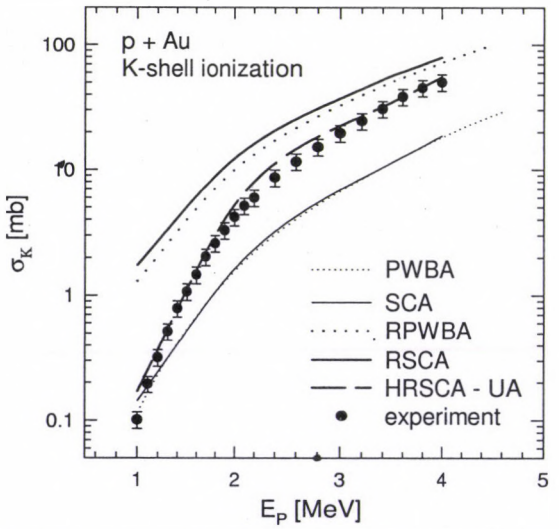

Figure 1: *K-shell ionization cross sections for gold bombarded by protons as a function of the incident energy.*

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3.14 A Simple Model for Positronium Formation in Positron-hydrogen Atom Collisions

L. Lugosi and I. K. Gyémánt[a)]

Positronium formation in positron-hydrogen collisions is a three-body charge rearrangement process in which an electron is transferred from a bound orbital centered on the proton to a bound orbital around the moving positron. Various theories have been applied to this problem as reviewed in a recent paper by Walters [1]. In this work we used the first order plane-wave Oppenheimer-Brinkman-Kramers approximation (OBK1) for the description of the process.

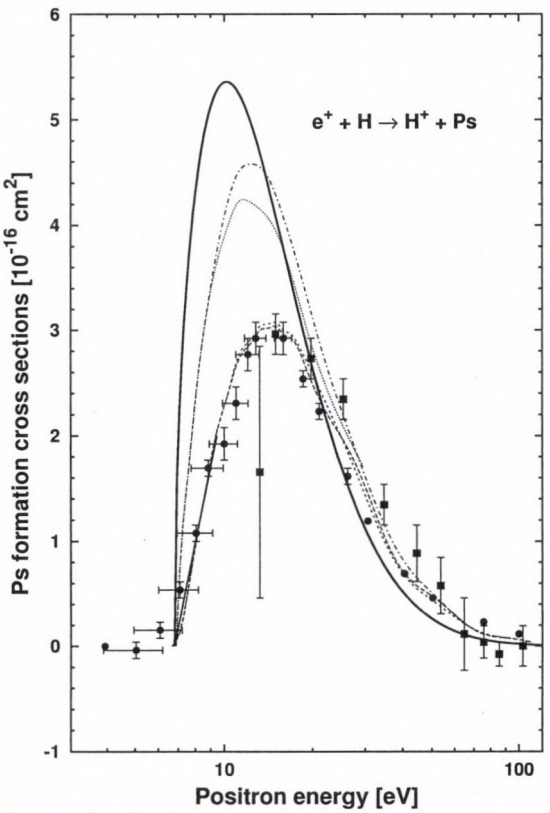

Figure 1: *Positronium formation cross sections for e^+ - H scattering. Theory : thick solid line, present work; dotted curve, Massey and Mohr [4]; full curve with dots, Straton [5]; long broken curve, Mitroy [6]; short broken curve, Kernoghan et al. [7]; thin solid line, Brown and Humberston [8]. Experiment : circles, Zhou et al. [2]; squares, Weber et al. [3].*

In Fig. 1. the calculated total Ps-formation cross section is compared with the experimental results of Zhou et al. [2] along with prior measurements of Weber et al. [3] and several theoretical values [4,5,6,7,8] as a function of the positron energy. Compared to the accurate 33-state coupled-channel calculations of Kernoghan et al. [7], our calculated cross sections increase more rapidly close to the positronium formation threshold. It predicts 70% larger value for the maximum of the cross section and 4 eV lower projectile energy for the position of the maximum. This discrepancy is due to the fact that such low energy processes cannot be treated satisfactorily by first-order perturbation theory. Furthermore, the OBK1 approximation has a serious shortcoming. The wave functions in the entrance and exit channels do not satisfy the correct asymptotic Coulomb boundary conditions. However, the obtained cross sections are close to the measured data of Zhou et al. [2] in the intermediate collision energy range (between 20 eV and 30 eV).

For proton-hydrogen collision it is known that the Thomas-type double scattering mechanism is the dominant process at high energies in the case of electron capture. The second order Born approximation which was applied to describe this process gives a v_p^{-11} asymptotic velocity dependence of the double scattering cross section σ_{DS}. In contrast, the OBK1 cross section σ_{OBK1} varies as v_p^{-12}. From the different velocity dependence it comes that σ_{DS} dominates over σ_{OBK1} above a certain projectile energy. In Fig. 1. a similar effect can be observed for positron – hydrogen collision. The values of the σ_{Ps} cross sections are less than the cross sections calculated within the higher-order approximations and the measured data at high impact energies. Although not accurate, our elementary treatment gives a qualitative, but at the same time analytical description of the Ps formation.

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3.15 A Simple Model for Estimating Relative Capture Cross Sections

A.L. Landers[a], *A. Orbán, J.-Y. Chesnel*[b], *J.A. Tanis*[a], *B. Sulik*

The overlap of the momentum-space wave functions or distributions of the initial (target) and final (projectile) states in a common frame of reference can be considered as a rough measure of the probability of the specific $i \rightarrow f$ electron transfer in the collision. With increasing projectile velocity, this overlap decreases drastically. In our present work, we suggest to use a quick estimation for the relative transition probabilities. The method is based on the one-dimensional overlap integral of the Compton profiles belonging to the initial and final states.

$$\int_{-\infty}^{\infty} J_T(v) J_P(v + v_p) dv$$

where $J_{T,P}(v)$ is the Compton-profile of the target and projectile states respectively. We consider the above integral as a quantity proportional to the capture cross section at higher projectile velocities.

Using H like Compton- profiles in the integral, we found satisfactory agreement with the velocity dependence of experimental data for simple collision systems (e.g., He^{2+} + H) at relatively high energies (25-250 keV) [1].

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b) Centre Interdisciplinaire de Recherche Ions-Lasers, Unité Mixte, CEA-CNRS-ISMRA et Université de Caen, Caen, France

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3.16 Electronic Screening Effect in Impact-Parameter Calculations

A. Orbán and B. Sulik

We calculate the electronic screening effect of the projectile on the amplitude of a target atomic transition within the framework of the semiclassical approximation (SCA). The aim is to elaborate a general tool for accounting projectile electronic screening in impact parameter calculations, even when the target or projectile wave functions are numerical. Our calculation is based on Ref. [1]. When the projectile electronic wave functions are approximated by hydrogenic or Slater-type orbitals [2] and supposing no electronic transitions on the projectile the spherically symmetric screening potential has the following form:

$$V_s(|\mathbf{R}-\mathbf{r}|) =$$

$$= \frac{N}{|\mathbf{R}-\mathbf{r}|} - \sum_{k=0}^{F} c_k |\mathbf{R}-\mathbf{r}|^{n_k-1} e^{-a_k|\mathbf{R}-\mathbf{r}|}$$

where F is an integer, c_k, n_k are real and a_k is a positive number. For numerical projectile wave functions we use a nonlinear least-squares fitting technique to estimate the screening potential parameters [3].

Following Ref. [1] we utilized the multipole expansion:

$$\frac{e^{-a|\mathbf{R}-\mathbf{r}|}}{|\mathbf{R}-\mathbf{r}|} =$$

$$\sum_{L=0}^{\infty} \frac{2L+1}{\sqrt{Rr}} I_{L+1/2}(ar_<) K_{L+1/2}(ar_>) P_L(\hat{R}\hat{r}) \,,$$

where $I_{L+1/2}$ and $K_{L+1/2}$ are the modified Bessel functions of fractional order and $r_< = min(R,r)$ and $r_> = max(R,r)$, and the identity:

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

We have elaborated closed expressions, recursive relations and integral representation routines for the nth order derivation of the modified spherical Bessel function of first and third kind and respectively for their products. The numerical stability against the arguments, the order of functions and the order of derivation has also been analyzed.

In Fig.1 we present the radial part of the transition matrix element (G_L- function) in case when the projectile screening effect is taken into account. The target states are described with hydrogen-like wave functions while for the projectile states we use hydrogen-like [1] and Roothaan-Hartree-Fock type wave functions [2].

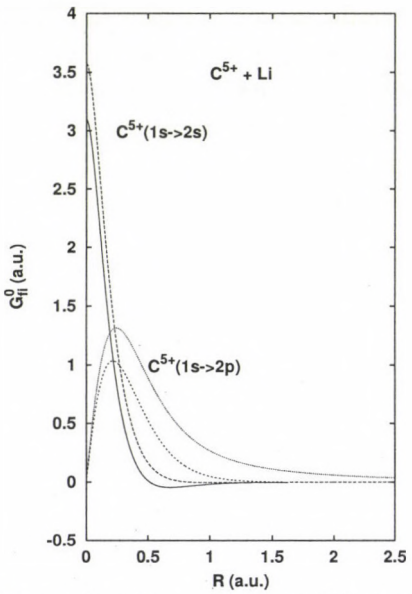

Figure 1: *The radial part of the transition matrix element in function of the internuclear distance.*

Screened hydrogenic and RHF results practically coincide for He. This is not true, however for many other elements Fig.1 shows e.g., that there is a significant difference between the two models for Li. It is more pronunced when the final state angular momentum is greather than zero.

Preliminary results have been accepted for publication in Scientific Herald of Uzhgorod University, Serial Physics.

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3.17 Interference Effects in Electron Emission from H_2 by 60.5 MeV/u Kr^{34+} Impact

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Within the field of particle-induced ionization, particular attention has been devoted to the molecular target H_2. Since the two hydrogen atoms are indistinguishable, their contributions to ionization add coherently and interference effects might be expected in the ionization process [1-3]. Such electron emission from H_2 may be closely related to Young's two-slit experiment, which played an important role in the pioneering period of quantum mechanics.

To identify interference effects, we measured cross sections for electron emission in 60.5 MeV/u Kr^{34+} + H_2 collisions for electron energies ranging from 2-300 eV at the GANIL accelerator facility in Caen, France [4]. To guide the search for interference, model calculations were performed showing that the ratio of cross sections for the H_2 molecule and the two independent H atoms exhibits an oscillatory pattern described by $1 + sin(x)/x$. For fast collisions, i.e., small momentum transfer $q \rightarrow 0$, the parameter $x \rightarrow kd$ is determined by the electron momentum k, and the internuclear separation d of the two H_2 centers. With $d = 1.42$ a.u. we expect a sinusoidal oscillation in the momentum (velocity) range of the electron from 0 to 4.3 a.u.

In Fig. 1 the results for experimental-to-theoretical [5] cross section ratios show a full sinusoidal-like oscillation within the electron velocity range up to $\sim$ 4.3 a.u. in good agreement with the model calculations. The oscillatory structure is found to be essentially the same for observation angles of 20°, 30°,150°, and 160°. In future experiments we plan to study higher-order effects in the electron scattering between the two H_2 centers, which may give rise to the finer structures seen in the cross section ratios in the region between 0.5-1.5 a.u.

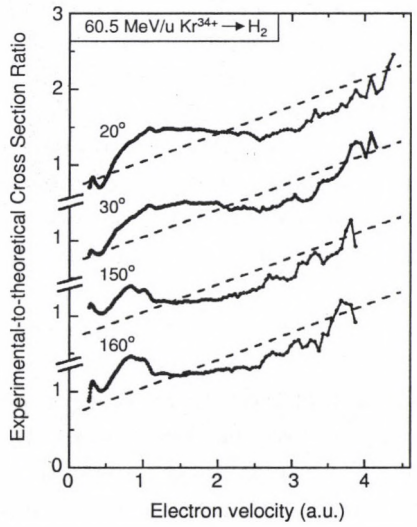

Figure 1: *Oscillatory structure of the experimental to theoretical cross section ratio. The dashed lines are inserted to guide the eyes.*

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[2] H.F. Busnengo *et al.*, Phys. Rev. A **56**, 1042 (1997)

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4.1 Micro-RBS as a Technique for Studying the Surface Topography of Bi Film Prepared by Pulsed Laser Deposition

A. Simon, Z. Kántor[a)], I. Rajta, T. Szörényi[a)], Á. Z. Kiss

Pulsed laser deposition (PLD) is a well developed technique for preparation of thin films of metals, semiconductors, insulators, ceramics etc., and multilayers based on these films. For fundamental and technological reasons a lot of work have been performed to improve the understanding of the mechanisms involved both in the ablation and deposition steps. The greatest drawback of PLD seems to be the emission of particles from the laser irradiated surfaces so that they are transferred to the substrate and are incorporated into the growing film.

Several methods have been reported to minimise the droplet formation. In case of ablation of a liquid target instead of a solid one the target deterioration is almost completely solved for different metals, but for Bi films some peculiarities have been arisen. Submicrometer and micrometer size drops are observed on the film and the drop formation could not be totally avoided. The deposition of the particulates not only influences the quality of the thin films, but also diminishes the reliability of various surface analysis methods, since the information on the thin film composition and quality is usually mixed with that of the droplets.

Rutherford backscattering spectrometry combined with He^+ microbeam was applied for analysing the distribution of Bi, the areal density of separate species and the surface topography. The separated RBS spectra of rough and smooth surfaces provide more precise data for the theoretical calculations than the spectra of total area which were used before. We have demonstrated that the droplets and free thin film areas can be detected and separated in the analysis, thus the chemical composition of the thin film and the micron-sized droplets can be measured independently.

Tomographic images were created for the illustration of the thickness (in)homogeneities and determination of the shape of the surface features, as well. In this way the cross-sectional thickness profile of the particulates gives more detailed information about the surface topography than the RBS spectra themselves. Furthermore in certain cases, thicknesses larger than the probing depth can be measured, too. This unique combination of possibilities makes micro-RBS a powerful technique for the complete analysis of thin PLD films even if particulates are present [1].

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[1] A. Simon *et al.*, Nucl. Instr. and Meth. (in press)

4.2 Rutherford Backscattering Analyses within the Framework of the IAEA Co-ordinated Research Programme G4.02

A. Simon, A. Csik[a)], G. A. Langer[a)], Á. Z. Kiss, D. L. Beke[a)], L. Daróczi[a)], Z. Erdélyi[a)], A. P. Kobzev[b)], M. Khaliquzzaman[c)]

The IAEA Co-ordinated Research Programme G4.02: "Application of MeV ion beams for development and characterisation of semiconductor materials utilising particle accelerators" provided us a possibility to take part in the following research works at our Van de Graaff accelerator:

Determination of the interdiffusion coefficient in amorphous Si/Ge multilayers

The interdiffusion and thermal stability of amorphous Si/Ge multilayers with thicknesses of few nanometers were studied previously by the co-authors in experiments where low-angle X-ray diffraction was used. Since at these thicknesses the intermixing can be influenced by the stress effects, interdiffusion measurements are desirable in thicker layers. Multilayers of 10-40 nm repeat length were used for our experiments. At these layer thicknesses, using glancing incidence geometry, RBS is an appropriate, non-destructive technique to gain direct information on the interdiffusion process. For the calculation of the interdiffusion coefficient ($\tilde{D}$) the concentration modulation of Ge was evaluated from the RBS spectra as a function of annealing time. Our results confirm the theoretically predicted strong concentration dependence of ($\tilde{D}$). Therefore the value $\tilde{D} = (4.35 \pm 0.22) \times 10^{-22} m^2 s^{-1}$ obtained for the beginning of the interdiffusion process characterises the Si diffusion in pure Ge. After a long annealing treatment (150 hours at 683 K) $\tilde{D} = (4.55 \pm 0.25) \times 10^{-23} m^2 s^{-1}$, which is characteristic for a $Si_{0.2}Ge_{0.8}$ alloy. Using a better energy resolution RBS detection facility, the above results were checked and confirmed in Dubna.

Cross-comparison measurements of thin films

Evaporation is an easy and therefore commonly used method in many laboratories for preparing thin films. After evaporation annealing is usually required for the rearrangement of the deposited atoms. In case of large difference in melting points of the components, the final samples do not bear the same quantitative atomic ratio as the starting materials. Therefore a reliable analytical method is necessary to determine the stoichiometry of the films. Within the IAEA project cross comparison measurements of $CuIn_{1-x}Ga_xSe_2$ and $CuInSe_2$ samples (prepared in Dhaka) have been started to see whether RBS could provide unique composition data. Our first result shows the elemental composition, but the determination of the exact stoichiometry is difficult as the mass resolution of our RBS setup is not high enough at the present to resolve well Cu and Ga compound masses. Further improvements of the measuring conditions are in progress.

a) Kossuth Lajos University, Department of Solid Sate Physics, Hungary

b) Joint Institute for Nuclear Research, Dubna, Russian Federation

c) Atomic Energy Centre, Dhaka, Bangladesh

4.3 Application of Micro-PIXE and Micro-PIGE Techniques in the Field of Archaeology

Z. Elekes, K. T. Bíró[a)], I. Uzonyi, A. Simon, I. Rajta, B. Gratuze[b)], Á. Z. Kiss

Particle Induced X-Ray Emission (micro-PIXE) analysis of prehistoric pottery finds from an intensively-studied Hungarian archaeological site, Vörs-Máriaasszonysziget has been carried out at our nuclear microprobe facility [1]. The aim of our investigations was to find some unambiguous relations between the elemental and microstructural composition of pottery samples and their ages. The fragments were originated from different closed archaeological units of various ages.

It was proved that potteries may contain significant amount and various type of temper materials which, however, do not properly characterize the ages. The lack of Cu-rich inclusions in the specimens from the Early Neolithic indicated that chalcopyrite was not used as temper material in that age. It was also shown that the firing process, the usage and the interaction of the soil with the material of the clays can alter the concentration of elements. Therefore, cross sectional measurements of the potteries were applied for their characterization. In this way, to a certain extent, a classification could be performed among the samples, where clusterization reflects the raw material differences rather than the production technique of the specimens. This result suggests that raw material from different sources should have been used, which raises the possibility of trade activities with other populations or other clay sources nearby.

In a second study geochemical characterization of radiolarite samples from the Carpathian Basin has been performed [2]. Radiolarite is a very important raw material of the prehistoric age. In this study, samples from geological and archaeological sites of the Carpathian basin, Greece and Austria were measured by two complementary ion beam analytical methods, namely by Proton Induced Gamma-Ray and X-Ray Emission (micro-PIGE/PIXE) techniques. The aim of this study was to deduce classification criteria from the analytical results and their macroscopic features.

From the analytical results it follows that radiolarites can be distinguished from similar non-radilolarite samples by means of their K, Rb and Fe contents. Elements (Ni, Cu, Zn) proved to be characteristic for the provenance of samples, while the other detected ones (Li, F, Na, Mg, Al...) have no relevance at all in this respect. Cluster analysis revealed that samples from the Vienna-basin can be separated unambiguously into a cluster with a special type (namely Tata-type) of Transdanubian radiolarite (cluster 1). Specimens from the Bakony-region and the Mecsek Mountain (radiolarites) could be grouped together in cluster 3. Gerecse-type Transdanubian, Carpathian radiolarites and the Greek samples have fallen into two clusters mixed. It was also proven that there are no correlations between the measured concentration data and the colour of the samples, as well as the type numbers of the pieces based on macroscopic (visual) grouping.

This work is partly the continuation of our previous ones [3-5] carried out in the framework of the international collaboration COST Action G1.

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b) Centre de Recherches Ernest Babelon, CNRS, 3D rue de la Férollerie, F-45071 Orléans cedex, France.

[1] Z. Elekes *et al.*, Nucl. Instr. Meth. (in press)

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[3] B. Gratuze *et al.*, British Archaeological Reports (in press)

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4.4 Determination of Energy Loss of Highly Charged Ions by Time Dependent Density Functional Theory

K. Tőkési, X.-M. Tong[a], C. Lemell[b] and J. Burgdörfer[b]

We studied the energy loss of highly charged ions (HCI) undergoing grazing interaction with the walls of microcapillaries by time-dependent density functional theory. The ions approach the walls close enough to suffer a significant amount of energy loss without, however, experiencing charge exchange. Electron-electron correlation is taken into account within the linear response theory.

We assume that the isotropic semi-infinite solid treated as a jellium is located in the $z < 0$ half space. When an HCI moves in front of the metal surface, it induces electronic excitations in the medium. Due to the interaction with the induced electronic potential (Φ_{ind}) the ion loses energy and will also be deflected. The energy loss of the HCI can be obtained from an integration of the friction force (stopping power, $S = -dE/dx$) over the trajectory of the HCI. The key element in the description of the energy loss is therefore the stopping power.

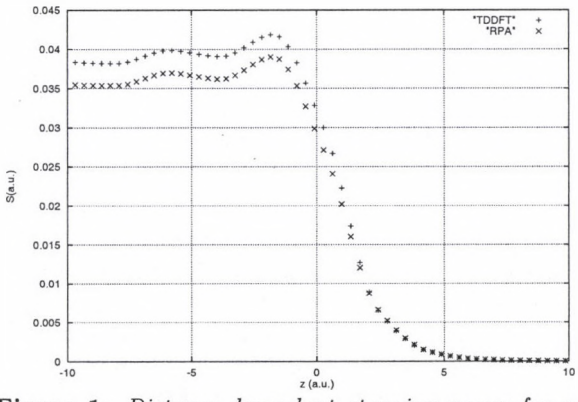

Figure 1: *Distance-dependent stopping power for a proton moving in a parallel trajectory with velocity v=0.29 a.u. in front of a Al surface*

Fig. 1 shows the distance-dependent stopping power for protons moving parallel to a Al surface with velocity $v = 0.29$ a.u. The induced potential was calculated by time-dependent density functional theory (TDDFT) and by random-phase approximation (RPA; i.e. TDDFT without exchange-correlation).

The difference between the RPA with and without exchange-correlation contributions in the kernel can be easily understood from the different contributions of two parts of the induced potential. The Coulomb interaction is repulsive while the exchange-correlation contribution is attractive. Therefore, with the exchange-correlation taken into account (TDDFT), the stopping power is larger than that calculated in RPA.

For the study of energy loss of HCI in microcapillary transmission, we have performed a classical trajectory Monte Carlo simulation with an ensemble of 10^7 primary trajectories. We perform the simulations for a metallic microcapillary of Al. As projectile we use Ar^{18+} with an energy of 2.1 keV/amu. Details of the simulation are given elsewhere [1].

The dominant fraction of the incident beam will undergo only small angle scattering and suffer negligible energy loss (≤ 1 eV). Larger energy loss (≥ 10 eV) which occurs for ≈ 2 % of the transmitted ions should be experimentally observable for $\theta > 1°$. The correlation pattern of exit angle and energy loss suggests that the surface dielectric properties of the capillary material at large distances, or equivalently, in the long-wave limit can be clearly probed by measuring the energy loss of HCI transmitted through microcapillaries.

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b) Institute for Theoretical Physics, Vienna University of Technology Wiedner Hauptstr. 8-10, A–1040 Vienna, Austria

[1] K. Tőkési, L. Wirtz, C. Lemell, and J. Burgdörfer, Phys. Rev. A **61** (2000) 020901(R).

4.5 Angular Distribution of Highly Charged Ions Transmitted Through Microcapillaries

K. Tőkési, L. Wirtz[a)], C. Lemell[a)] and J. Burgdörfer[a)]

The angular distribution of highly charged ions (HCIs) transmitted through microcapillaries is studied theoretically by a classical trajectory simulation. The simulation is based on the classical-over-the-barrier model modified for dynamical image potential of open cylindrical surfaces. The multi-electron evolution and relaxation is taken into account as a stochastic event sequence. As projectiles we consider N^{6+} with an energy of 2.1 keV/amu and as target a metallic microcapillary of Ni. Details of the simulation are given elsewhere [1].

Fig. 1 shows the angular distributions for HCIs for different charge states. At the exit of the capillary the charge states are clearly separated with respect to the scattering angle. The larger the scattering angle the lower the charge state. However, this clear separation breaks down at macroscopic distances as a result of relaxation. The number of effective single capture events is strongly enhanced compared with other charge states. Nevertheless, these angular distributions can be used to identify different phases of hollow ion formation. At macroscopic distances we can distinguish three region for the single capture N^{5+} states:

1) Within the scattering angle between 1.12 and 1.17 degrees, the ion which preserved its originally captured *one* electron from the surface. These trajectories never flew closer to the surface than $d_c(N^{4+})$, where d_c is the critical capture distance for N^{4+}. This corresponds to the first stage of hollow atom formation: the capture of single electron into a Rydberg state.

2) From scattering angle 1.17 to 1.21 degrees only N^{5+} ion can be seen in the angular distributions. But in this region, the *original* one electron capture states are contaminated by the one electron capture states generated by relaxation. The second region represents predominantly the second stage of hollow atom formation with double capture followed by a single Auger relaxation.

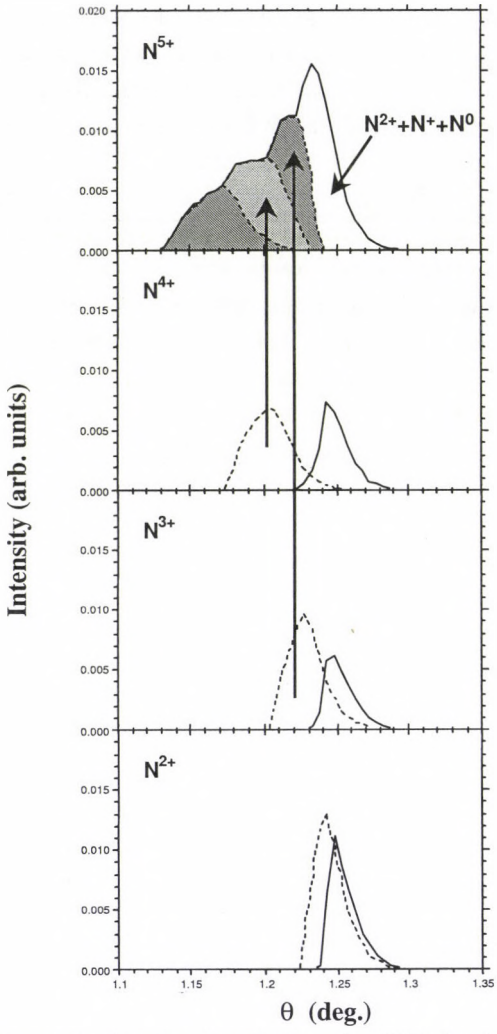

Figure 1: *Angular distributions for HCIs for different charge states. Solid lines: at 5×10^7 a.u. distance from the surface (after Auger relaxation), dashed lines: at the exit surface of the capillary. Contributions of different charge states from to the distribution N^{5+} after Auger relaxation is denoted by different shadings.*

3) While in the previous two regions N^{5+} is the *only* charge state observed asymptotically, at larger scattering angle than 1.21 degree the asymptotically observed charge state N^{5+} is mixed with other charge states. Lower charge states can be seen in the angular distributions. Because of the overlap between the angular distributions of N^{5+} and N^{4+} at exit, some coincident information would be required to completely disentangle the stages. For ex-

ample, detecting an electron (of any energy) in coincidence with a projectile in the second angular sector (without a charge state analysis) would permit to unambiguously identify the second stage of hollow atom formation. For angles larger than 1.25°, N^{5+} originates from the multiple Auger decay of an (almost) neutral hollow atom, primarily from N^{2+} and N^{+}. Clearly, extending this analysis to later stages gets progressively more involved. Depending on the number and energy of ejected electrons or photons, more detailed information may be extended.

a) Institute for Theoretical Physics, Vienna University of Technology Wiedner Hauptstr. 8-10, A–1040 Vienna, Austria

[1] K. Tőkési, L. Wirtz, C. Lemell, and J. Burgdörfer, Phys. Rev. A **61** (2000) 020901(R).

4.6 Relativistic Electron Transport Through Carbon Foils

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Understanding the ionisation process in ion-atom and ion-solid collisions is fundamental from an experimental and theoretical point of view. Studying the energy and angular distribution of the ejected electrons provides basic information about the underlying collision dynamics. In the relativistic energy region, the convoy electrons were detected for the first time recently [1]. We study the electron loss to continuum (ELC) by transmission of a relativistic highly charged ion (Ar^{17+}) with an energy of 390 MeV/amu through carbon foils with thickness varying between 25 and 9190 mg/cm^2. Our approach is based on the solution of the classical Langevin equation. The random walk of the relativistic electron initially bound to the argon nucleus is simulated by a Monte Carlo method. As a result of a series of stochastic elastic and inelastic collisions during transport, the projectile is excited or ionised. For given initial parameters, equations of motion were integrated with respect to time as independent variable by the standard Runge-Kutta method. The simulated electron spectra at 0° (convoy electron spectra) are in good agreement with the recent experimental results [1]. Two major components of the electron spectra are clearly visible (Fig. 1): 1) ELC peak 2) the loss peak due to multiple scattering. The full width at half maximum (FWHM) is initially decreasing for increasing thickness as a result of higher probability for ELC from intermittently formed Rydberg states. For thicker targets the FWHM is increasing because of a longer random walk of electrons in the solid subsequent to ionisation leading to an enhanced collisional broadening of the spectrum.

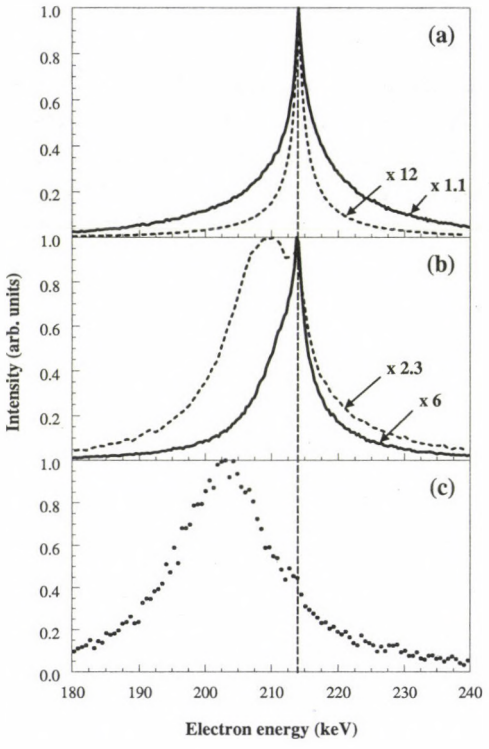

Figure 1: *Convoy electron spectra resulting from the transmission of 390 MeV/amu Ar^{17+} ions through amorphous carbon foils of different thicknesses: (a) 50 $\mu g/cm^2$ (full line) and 530 $\mu g/cm^2$ (dashed line); (b) 3080 $\mu g/cm^2$ (full line) and 5400 $\mu g/cm^2$ (dashed line); (c) 9190 $\mu g/cm^2$. The acceptance angle is $\Delta\theta = \pm 1°$. The maxima of the convoy peaks are normalized to one. The numbers by each curve represent the relative intensity of the spectrum with respect to the spectrum in (c). The vertical dashed line indicates the energy where the electron velocity equals the projectile velocity.*

[1] Y. Takabayashi et al, Physica Scripta **T80** (1999) 249.

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4.7 Identification of a Disordered Magnetic Phase in Pure Nanocrystalline Iron

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Vibration ball milled nanocrystalline iron powder was prepared under helium atmosphere for the first sample and in vacuum for the second one. The average grain size was found to be 30 nm and 20 nm for the two samples, respectively. Temperature dependence of low and high field magnetization was measured by a vibrating sample magnetometer.

Low-field magnetization measurements were performed in a magnetic field range of ±30 mT. The characteristics were almost linear with a slight hysteresis and had an average slope increasing with increasing temperature.

Measurements of the saturation magnetization and coercivity were carried out in a magnetic field range of ±5 T at different temperatures. The magnetization of the unmilled powder gave the expected saturation value but that of the nanocrystalline samples was reduced by 10-20% compared to the value for pure iron.

The temperature dependence of field-cooled (FC) and zero-field-cooled (ZFC) magnetic moments were measured for initial and milled powders at different static magnetic fields. We found monotically increasing ZFC magnetization for both samples up to 280 K. The shape of the ZFC curves are different for the two samples but the FC-ZFC curves linearly scale with the applied external magnetic field in the studied field range.

As a result, we can state that a ball-milled iron behaves much like a two-component magnetic system. The larger component, providing about 70% of the magnetization at 5 K, appears to be reversible as indicated by the very small coercivity and behaves like a normal ferromagnet. It can be reasonably assumed that the hysteretic part of the magnetization and the narrowing magnetization loops with increasing temperature indicate the existence of a magnetically random frozen phase, which gradually melts with increasing temperature. A transition from a high temperature ferromagnetic phase is not indicated by any of our results and therefore the intreplay between spin-glass freezing in the grain boundaries and a re-entrant transition of the grains are doubtful. Further measurements, aimed as the influence of sample preparation and as relaxation phenomena, are in progress.

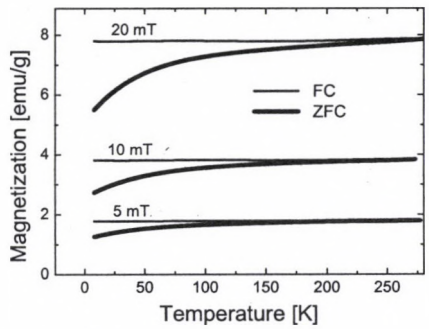

Figure 1: *FC and ZFC magnetization curves in different magnetic fields for the He milled sample.*

a) Department of Solid State Physics, Debrecen University, H-4010 Debrecen, P.O.B. 2, Hungary

b) Van der Waals-Zeeman Instituut, Universiteit van Amsterdam, NL-1018 XE Amsterdam

4.8 Effect of Superstructures on the Critical Layer Thickness for Three-dimensional Islanding in Stranski-Krastanow Growth

L. G. Wang[a)], K. Varga, S. T. Pantalides[a)] and Z. Zhang[a)]

In Stranski-Krastanow (SK) growth, an important quantity is the critical layer thickness beyond which the growth proceeds via the formation of three-dimenional (3D) coherent islands. To date, the precise physical factors defining the critical thickness, h_c, in SK growth have not been fully understood. Here we show that for the prototype SK growth system of Ge/Si(001), one must include the effect of the (2XN) superstructure in the growth front in order to determine h_c accurately. Specifically, our calculations within the density functional theory show that if the growth front is assumed to preserve the (2x1) reconstruction of the Si(001) substrate, the resulting h_c is lower than what has been observed experimentally. But with a proper inclusion of the (2xN) reconstruction as the first stress-relieving mechanism, three-dimensional islanding is delayed just to the experimental value of 3 monolayers.

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4.9 Oscillatory Surface Intermixing in Binary Metallic Alloys

K. Varga, L. G. Wang[a)], S. T. Pantalides[a)], and Z. Zhang[a)]

The creation of a surface of a metallic system often leads to an oscillatory charge density distribution propagating into the bulk [1], which may further induce an oscillatory interlayer lattice relaxation [2]. Oscillatory intermixing has also been frequently observed in disordered alloys, with one of the constituents enriched or depleted from layer to layer. Here we investigate the oscillation of the concentration profiles in the first few layers of different alloys using the density functional theory, with the Mo-Re and Mo-Ta systems as specific examples. The Re (Ta) atom has charge excess (deficiency) with respect to the host Mo atom. The Re (Ta) is found to follow the maxima (minima) of the oscillatory charge density distribution of the Mo surface layers, thus elucidating the microscopic origin of the oscillation of the alloy concentration at different layers.

a) Solid State Division, Oak Ridge National Laboratory, Oak Ridge, TN-37831, USA

[1] N.D. Lang and W. Kohn, Phys. Rev. B 1 4555 (1970).

[2] J.-H. Cho, Ismail, Z. Zhang and E.W. Plummer, Phys. Rev. B 59 1677 (1999).

4.10 Micro-PIXE Analysis of Press Felts Used by Paper Industries

Á. Z. Kiss, R. Olli[a)], J. Räisänen[b)], A. Simon, I. Uzonyi, A. Virtanen[b)]

In paper industry felts are used both to transport the web of paper through the manufacturing process and to remove water from the web. Therefore, the condition of the felt can strongly influence to the quality of paper as well as the effectiveness of the overall manufacturing process. This is why felt-producers are continuously seeking for new analytical tools which help to reveal the causes of wearing out or malfunctioning of these materials.

During the paper manufacturing process, the web is pressed between rolls and a continuous felt (i.e. the press felt) in order to remove its water content. In the press section the increased water pressure in the web makes the water flow into the felt. The structure of the press felt affects the dry content of the web. A higher dry content improves machine runability and reduces the need for energy at drying. On the other hand felt properties affect the printability and other paper qualities [1]. Therefore, it is important to know whether the elemental composition and distribution of impurities on the used felts provide information on wearing out process.

The microanalytical studies were done at ATOMKI nuclear microprobe in Debrecen. Exterior surfaces of eight used pressure felts were scanned by 2 MeV proton-microbeam within an area of 1mm x 1mm. The micro-PIXE method provided multielemental quantitative analysis from C to U, practically to Fe. Elemental maps were generated for the study of elemental distributions.

The results unambiguously show that the impurities (Na, Mg, Al, Si, P, S, Cl, K, Ca, and Ti) are in different quantities on the paper- and roll sides of the worn out felts. It suggests that during the pressure process the above elements diffuse into the felt by changing its quality. Elemental maps also show that these elements are unevenly distributed and, in many cases, grains or localised precipitation of elements can be seen in the valleys between neighbouring fibres of the felts. Because the origin of the elements is not exactly known the influence of these factors will be evaluated in further studies.

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[1] Annual report of Tamfelt Group, 1999

4.11 Experimental study of surface excitation effects by REELS-EPES

G. Gergely[a)], M. Menyhard[a)], S. Gurban[a)], A. Sulyok[a)], J. Tóth, D. Varga, S. Tougaard[b)]

In the chemical analysis of solid surfaces the most often used electron spectroscopic methods are Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy XPS, reflection electron energy loss spectroscopy REELS and eleastic peak electron spectroscopy (EPES). The detailed knowledge of the surface excitation effect is very important in the usage of the above mentioned electron spectroscopic techniques for quantitative surface analysis. The excitation and electron emission processes are affected by competitive surface excitation. Impinging and escaping electrons suffer losses in the solid surface region, producing surface plasmons. The surface excitation is characterized by the surface excitation parameter Pse. A new experimental procedure described for the determination of Pse. It is based on REELS-EPES, using the elastic peak as reference. The procedure is valid for materials having surface and volume plasmon loss peaks, like Si, In and Sb. It can be applied for estimating Pse. on materials exhibiting a surface loss peak decreasing with energy, like Ag. The ratio of the integrated surface and volume loss peaks is composed and compared with the elastic peak. Experimental results in the E=0.2-5 keV energy range are represented for several solids (Pd, Ag, In, Sb, Fe). Similar studies were made for Al by Werner [See the ICESS-8 Int. Conf. (8-12.,Aug. 2000, Berkeley, California, USA) Proceedings to be appeared in the Journal of Electron Spectroscopy and Related Phenomena and articles in it by W. M. S. Werner *et al.*].

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4.12 Medium Energy Range HREELS as a Tool for Analytical and Structural Determination*

J. Tóth

In electron Rutherford backscattering (e^-RBS), recoil effects were revealed long time ago Boersch et. al [1]. The usage of the effect as analytical tool was introduced by Igonin, Makarov, Nakhodkin and Melnik [2,3] in the electron kinetic energy range 10-30 keV. In the medium energy range 0.5 - 5 keV, which is quite surface sensitive, less studies were made, Laser, Seah, Goto and Shimizu [4,5]. In the present paper experimental results on recoil broadenings of elements and some analytical applications on composite materials are presented. The results from different aspects were presented before at international workshops and conferences: IMFP2000 Int. Workshop Budapest 2000 Jan.; ECASIA-99, Oct. 1999., Seville, Spain; ISSR, June 2000., Kudova, Poland; JVC8 June 2000, Pula, Croatia; QSA-11, July 2000., Surrey, UK. [6].

By the help of a home developed instrument (XPS-XAES-REELS-AES) Varga et al [7] high energy resolution elastic peak spectra were measured for Ni (polycristalline), Si (amorphised by Ar^+ sputtering), graphite (C) (polycristalline) and Au [(polycristalline) as reference because of its high atomic mass] samples. For the proper setup of the instrument a preliminary study was also important [8]. The samples were cleaned in situ in UHV by Ar^+ etching, except C, which was scraped by stainless steel knife in UHV. Cleanness tests were made by XPS-XAES-AES-EPES. The HSA based electron spectrometer used of ESA-31 (home-made, ATOMKI, Debrecen) is an XPS-XAES-e-AES-REELS-EPES measurements system [7] working in pulse counting mode equipped with computer control and data acquisition [I. Cserny] and with data evaluation software package of EWA code [J. Végh]. The electron energy range of the ESA-31 is up to 10 keV, in the present experiments the 0.5- 5 keV range was used. In the experiments the scattering angle was: $\Theta = 130°$, the HSA energy resolution (($\Delta E_{anal}/E_{pass}$)=0.0054) was 0.54 % determined experimentally [8] (the 0.54 % is well matched with the theoretical value of the ESA-31 HSA resolution [10]) which ensured quite good relative energy resolution by the usage of the FRR (fixed retardation ratio) working mode in the retardation ratio range of k (k=E_{kin}/E_{pass}) from 2 to 198. The analyzer resolution in this way were in the 68-287 meV range. By the help of this excellent analyzer resolution, the "instrumental resolution", that is the total FWHM of Au elastic peak as "resolution standard" was about 0.4-0.6 eV (analyzer+electron gun broadening+Au own broadening). The high resolution was very important from the point of view of the precise measurement of the elastic peak FWHM. The elastic peak high kinetic energy side background level was better than 0.01 %. But even the low kinetic energy side was very good, the background level was in the 0.3-1 % range as relative amplitude to the elastic peak maximum. The electron source was LEG62 type (VG Microtech). All of the electron gun operating parameters were optimized experimentally and well adjusted to the ESA-31 acceptance area by the help of XPS and REELS-EPES methods [Varga et. al unpublished]. This high resolution experimental conditions were used in the IMFP measurements - by EPES - which are cited in Ref. 9.

The experiments were made in the vacuum level of $7 \cdot 10^{-10}$ mbar in the measurement chamber, and $3 \cdot 10^{-9}$ mbar in the preparation chamber.

For Si and C the recoil broadenings follow a function of nearly squareroot of ($E_{primary}/M$) (M: atomic mass of the target material) as it is waited on the basis of text books in basic physics (solid state, etc.). It is also evident that not only the broadenings but the energy shifts are also remarkable which can be detected easily with the energy resolution used in our experiments. The recoil shifts at first ap-

proximation follow the simple single scattering formula of electron-RBS assuming quasi elastic scattering [1].

Presently the detailed description of the recoil effect in the energy range mentioned here is not the aim (see the forthcoming papers soon in international journals -Vacuum, SIA- by the persons mentioned in Ref. [6]. Presently the aim only to demonstrate the analytical capability of the method by the help of composite materials, compounds from low atomic mass elements f. e. polymers doped with 'high atomic number' elements. That is the aim is to present a "fully experimental" method, the so called HR-EPES (High Resolution EPES) which can be a powerful analytical tool in some special cases [1,2,3,4]. (See the contributors who are cooperators from Warsow ICHF, PAS and MFA-Budapest and ATOMKI-Debrecen, HAS) of the development of HR-EPES in the conference materials mentioned in the references).

The idea of EPES (Elastic Peak Electron Spectroscopy) originally suggested by Schilling and Webbs, but in practice was originally developed by Gergely, Jablonski, Menyhard and Sulyok and about the same time by Nakhodkin, Melnik and their colleagues as well to determine the inelastic mean free path (IMFP) of electrons. Recently the quantitative EPES (Q-EPES) was published in an excellent review article by Powell and Jablonski, see all here mentioned names and their articles in Ref. [9].

The IMFP is an important parameter in the analytical and structural electron spectroscopic techniques: XPS-XAES, e-AES, REELS.

The HREPES (originally suggested in the medium energy range by Laser and Seah) gives a new perspective in the above mentioned techniques not only scientific point of view, but from applications point of views as well. Especially important fields are, for example, new materials construction, like conductive polymers for opto-electronics and/or catalysis and revealing single crystal structures as well. (And may be the reveal of environmental specimens).

The HREPES method is a good help in the development of theoretical models as well for that cases when only the conventional EPES can be used.

The HREPES method gives a new perspective in the experimental determination of the IMFP more precisely in some special cases giving a new possibility to reach the engineering precision of the above mentioned electron-spectroscopic methods.

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*THE PRESENT PAPER IS DEDICATED TO RESEARCH PROFESSORS OF ME IN ELECTRON-SPECTROSCOPIC INSTRUMENTAL DEVELOPMENT AND THE USAGE OF THEM IN THE SCIENCE AND TECHNOLOGY FIELD.

- To Dr. Dénes BERÉNYI D. Sc. member of the Hungarian Academy of Sciences (HAS) in the occasion of his 70+2 birthday, former director of ATOMKI.
- To Dr. György GERGELY D. Sc., (MFA, HAS) in the occasion of his 77 birthday, scientific consultant, former head of the Surface Physics Research Group.
- To Dr. Dezső VARGA C. Sc., (ATOMKI, HAS) in the occasion of his 60+1 birthday, head of the Electron Spectr. and Mats. Sci. Dept.

Note: The paper was presented at ICESS-8 International Conference, 8-12, Aug., 2000., Berkeley, California, USA.

5.1 Geological Applications of Micro-PIXE Technique

P. Rózsa[a)], Gy. Szöőr[a)], Z. Elekes, I. Uzonyi, J. Simulák[a)], A. Simon, Á. Z. Kiss

Phenocrysts inclusions in obsidian glasses have been studied by Particle Induced X-Ray Emission (micro-PIXE) method at the nuclear microprobe of the ATOMKI. Analytical data were evaluated in co-operation with the Department of Mineralogy and Geology of the University of Debrecen [1].

Obsidians are natural glasses having no or very low (less than 5 %) crystalline phase. The aim of this study was to analyse minerals found in some obsidian glasses. Samples were collected in Armenia, Greece, Hungary and Slovakia. In the obsidian samples the following minerals of various sizes (10-500 μm) were identified: pyrrhotite, chalcopyrite, pyrite, zircon, pyroxene, amphibole, biotite, plagioclase feldspar, quartz and anhydrite.

On the basis of the study of phenocrysts observed in the obsidian glasses some petrologic conclusions can be drawn. Hf contents of zircon crystals in obsidian samples from two localities of the Tokaj Mts. (Sima in Hungary and Viničky in Slovakia) show definite differences. It seems that Ca-poor orthopyroxene crystal in the sample from Sima (Hungary) is in equilibrium, while Ca-rich pyroxene crystals of obsidians from Melos and Giali (Greece) may be in equilibrium with the residual glass. Henceforth, it is possible that these crystals can not be regarded as xenocrysts. However, Ca-rich plagioclase feldspars detected in samples from Viničky and Melos while quartz crystals in the specimen from Giali have supposedly been incorporated in the glass during its formation process. Anhidrite-chalcopyrite and pyrrhotite-pyrite-chalcopyrite assemblages in obsidians from Aragats Mountain (Armenia) and Viničky were formed by hydrotermal activity. Notwithstanding, it is questionable whether the solid obsidian rocks suffered the hydrothermal activity or these crystals were incorporated by the rhyolitic melts.

In another geological study, magnetic spherules from several localities in Hungary were analysed by micro-PIXE method [2]. It is worth mentioning that this study can be regarded as a continuation of our previous investigations on Carpathian and other spherules [3,4]. In this case the question to be answered was whether the particles are cosmic dusts or markers of a meteoritic impact? From the analytical data it could be inferred that the magnetic spherules from Üveghuta (Mórágy Granite Complex) show the fingerprint of a meteoritic impact in the past.

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5.2 Long Range Tendencies and Meteorological Effects in Aerosol Concentrations

I. Borbély-Kiss, Zs. Kertész, E. Koltay, Gy. Szabó, K. Tar[a)]

Systematic investigation of regional air quality has been started in the Institute of Nuclear Research in 1991. Integral sampling has been made in measurements covering a time period of 10 years with a single stage Nuclepore sampler. Since 1993 atmospheric aerosol samples have been collected with a "Gent" stacked filter unit (SFU). Particle masses (PM) of the samples have been measured by the use of a Sartorius microbalance. "Black Carbon" component (BC) collected on the fine stage samples has been measured by a Smoke stain reflectometer. Proton induced X-ray emission analytical method (PIXE) has been applied for deducing absolute concentration data (in ng/m3) on elemental constituents (Al, Si, P, S, Cl, K, Ca, Ti, V, Mn, Fe, Ni, Cu, Zn, (As), Br, Ba, Pb) of the samples

Seasonal variations, correlations with the amount of precipitation and wind sector distributions were observed for separate elements. Absolute principal component analysis revealed four typical factors contributing to the aerosol burden.

On Fig.1 we show one of our results obtained by PIXE analyses of fine mode aerosol, collected in Debrecen (urban sampling site). Here the total mass and BC content, together with the concentrations of elemental constituents of fine mode aerosol can be seen. The summer and winter maximum of the constituents can be explained with the seasonal variation of the anthropogenic emission (heating period), and the seasonal variation of the natural emission (soil erosion).

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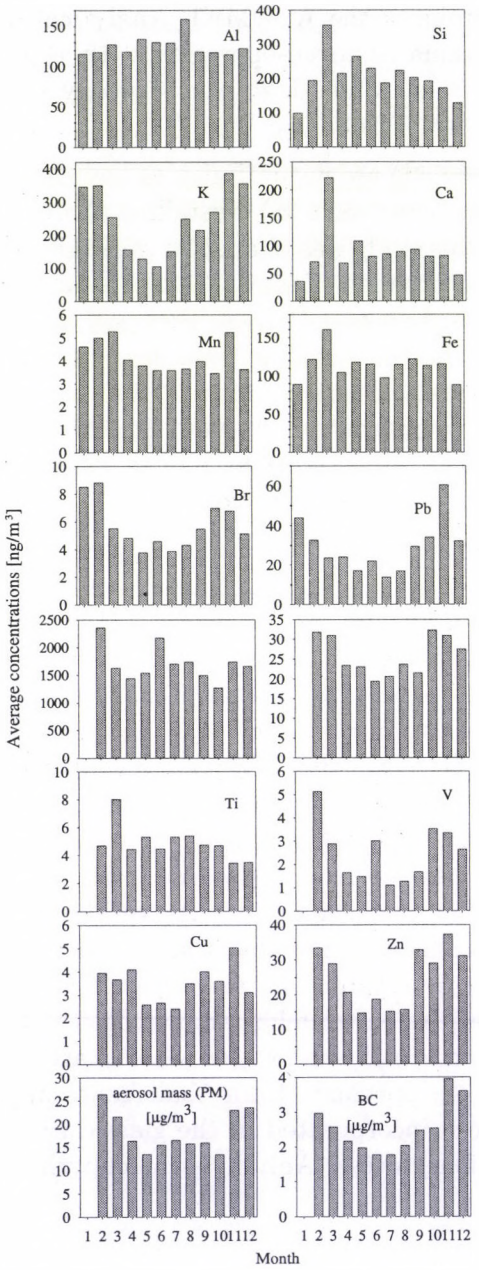

Figure 1: *Monthly average concentrations of fine mode aerosol constituents*

5.3 Gas Formation in L/ILW Packages

M. Molnár, L. Palcsu, É. Svingor, Zs. Szántó, I. Futó

Low and intermediate level radioactive waste (L/ILW) generated in Paks NPP consists mainly of spent ion exchange resins used for water purification, contaminated trash and scrap, protective clothes, gloves, towels, and ash from incineration of combustible radioactive waste. Operational waste is packed into containers of steel (drums), in some cases first solidified (conditioned). The L/ILW operational waste contains only very small amounts of long-lived radionuclides. It needs to be disposed in a repository, although it will decay to harmless levels in a relatively short time.

During the storage significant quantities of gas may be generated within the drums, principally by the coupled processes of metal corrosion and microbial degradation of organic, particularly cellulosic wastes. It is likely that a small proportion of the generated gas will be radioactive, principally as a result of the incorporation of the isotopes ^{3}H and ^{14}C that are present within the waste.

If gas were to be contained within the repository, a build-up of pressure would occur. This could have an effect on the engineered structure and host rock, and lead to a disturbance of the pressure-head gradients and groundwater flows in the vicinity of the repository. On the other hand, if gases escape from the repository into the geosphere, various possible consequences should be considered. Within the geosphere, the gas might have an effect on the local groundwater flow regime. Within the biosphere, there are potential hazards associated with the release of radioactive and flammable gases.

Gas composition measurements have been carried out by mass spectrometry analysis of samples taken from the headspace of ten drums temporarily stored at Paks NPP. Four drums contain compacted solid waste, three drums are filled with grout sludge and three drums contain not compacted solid waste. The drums have been equipped with special gas outlet systems to make repeated sampling possible. We found significant differences in the gas composition among the drums. The composition of these gases depended on the type of the waste and its conditioning. The drums were inhermetic so the internal pressure was not higher than 1,2 bar in any of them. In most of the drums the headspace was depleted in oxygen. Significant increase of hydrogen was found only in some of these drums. Organic compounds appeared in the drums filled with compacted solid waste.

These results represent only the first stage of a long-run investigation. Continuous sampling of these drums can help us to understand gas-formation processes in different type of low and intermediate level radioactive wastes.

5.4 Headspace Gas Analysis of Closed Radioactive Waste Vaults in the RWTDF of Püspökszilágy

I. Futó, M. Molnár, L. Palcsu, É. Svingor, Zs. Szántó

As a part of a national safety assessment research programme of the Centralised Radioactive Waste Treatment and Disposal Facility of Hungary (RTTDF) situated near village Püspökszilágy, two near surface radioactive waste container vaults were opened at 15^{th} March 2000. This 'A' type vaults were closed in 1972, when they were full.

Before removing the protective lids sampling of the headspace gas of the vaults was performed by a special gas outlet system through the concrete bed. One of the cells (Code: A5) contains non-conditioned L/ILW radioactive waste directly filled into the container vault. The other one (Code: A6) contains cemented waste, so there was a small gas field between the top of the surface of cemented waste and the lid of the vault.

Using the same method qualitative gas analysis of the two headspace gases were carried out in situ in the vicinity of the disposal facility. During the gas-analysis with an OMNISTAR quadrupole mass spectrometer, gas samples were collected from both cells into 7 l-volume stainless steel bulbs using a special gas-handling system. Helium, carbon and oxygen isotope ratios, respectively ^{14}C and tritium contents of gas samples were measured in the Laboratory of Environmental Studies of the INR. After separating the different gas components radiocarbon content was measured with a proportional counter, tritium content was measured with an LSC (TRICARB 3170 TR/SL). The helium content and isotope ratios were measured with a VG-5400 noble gas mass spectrometer and the other stable isotope ratio measurements were carried out with a stable isotope mass spectrometer.

Compositions of the headspace gases were very similar to the ones of air. No significant hydrogen production or oxygen depletion was detected. The carbon-dioxide content was sixty-times more in the gas of the A5 cell and six-times more in the A6 cell compared to the air. The $\delta^{13}C$ and $\delta^{18}O$ isotope ratios show that this surplus is the result of decomposition of organic materials. The specific radiocarbon activity of carbon dioxide was about 3 Bq/cm^3 in both cells.

The tritium activity content of headspace gas was two orders of magnitude higher in the A5 cell (8.8 Bq/l) than in the A6 cell (0.04 Bq/l). These results are in good agreement with the total tritium content of contained waste in the individual cells. The higher ^3He content in the cells is due to tritium decay and shows that the gas migration from the cells to outside is not considerable.

5.5 Application of a Noble Gas Mass Spectrometric System in Environmental Studies

I. Futó, M. Molnár, L. Palcsu, É. Svingor, Zs. Szántó

Tritium labelling makes possible the study of short-term transport, mixing processes and exchange in the groundwater (in particular the ^3H labelling allows for determination of mean residence times of unconfined groundwater in fractured and sedimentary aquifers). The qualitative detection of tritium is a certain prove of the presence in a sample of recently recharged groundwater [1].

The most often used measurement technique is the tritium-helium method determining the tritium concentration of water by helium-3 ingrowth.

The measurements were done by a VG5400 noble gas mass spectrometer.

Tritium concentration in different area of a groundwater basin used for drinking water in NE Hungary was determined.

The pilot area of the investigation was Kótaj in (NE) Hungary. The basic problem of the Kótaj basin is the poor knowledge of the origin of its water. The present exploration and plans for further investigation were performed in order determine the origin of water in the nearby aquifer by the measurement of the tritium content of the water. Fig 1. shows the relation between tritium concentration and depth of different boreholes. The tritium concentration does not exceed 1TU in any of the examined boreholes.

An evident trend can be observed: the deeper borehole the lower tritium concentration. In case of well Kótaj 2/A however the measured 220 mTU could indicate a possible infiltration.

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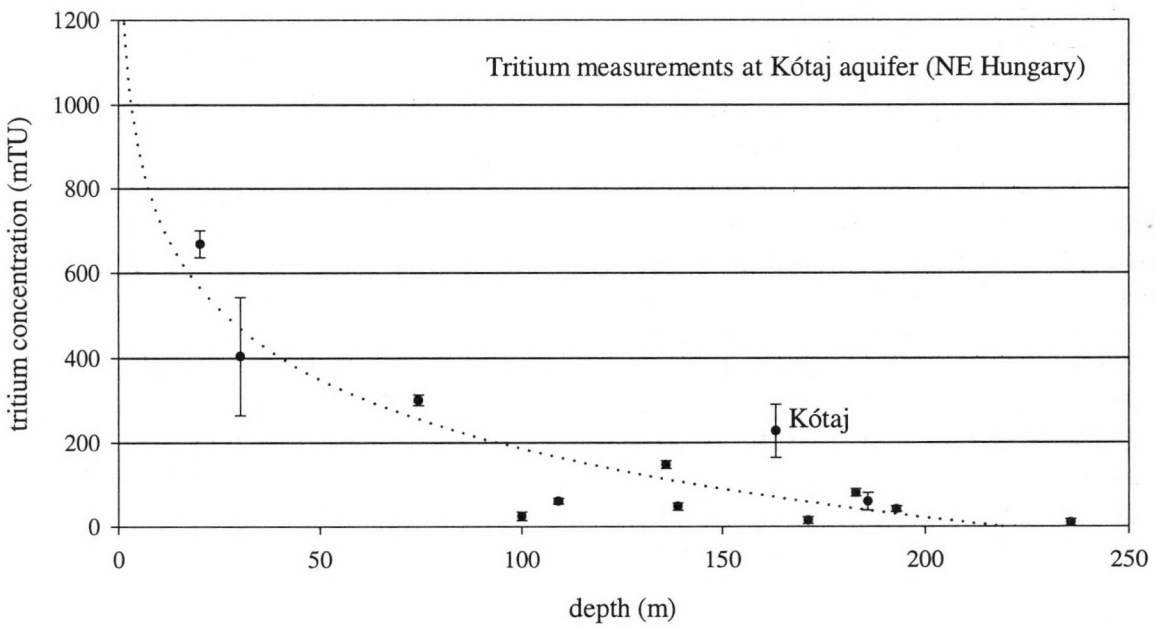

Figure 1: *Tritium concentrations in function of depth*

6.1 Novel Oxidation Method of [^{11}C]Carbon Monoxide

É. Sarkadi-Priboczki, P. H. Elsinga[a)], J. Medema[a)], W. Vaalburg[a)], G. Horváth[b)], Z. Kovács

During the last two years the Fe/ZSM-5 catalyst was investigated in relation to the reaction mechanism of the partial oxidation of [^{11}C]methane to [^{11}C]methanol by nitrous oxide at room temperature (1). To improve the radiochemical yield (it was only 3-5 % for EOB) the required, pre-reduced form of Fe/ZSM-5 zeolite was tested by a simple reaction of [^{11}C]CO to [^{11}C]CO_2 by nitrous oxide.

After adsorption of nitrous oxide on the catalyst at room temperature, the tube containing the catalyst was cooled to below -15°C and the [^{11}C]CO was trapped on Fe-zeolite. The decomposition of nitrous oxide and oxidation of [^{11}C]CO was performed simultaneously at 250°C. After the reaction, the remaining [^{11}C]CO was flushed by helium and the catalyst was heated further to 280°C to collect the radiolabelled products from Fe-zeolite for analysis. The radiochemical yield was 15 % (EOB). The radioactive product and the unchanged N_2O were analysed by radio-gas chromatography (HayeSep Q normal column, 8°C for 1 min, warmed to 30°C, TCD- and scintillation detector). Inactive gas mixture (CO, CO_2) was added for identification of [^{11}C]compounds.

The simple oxidation of [^{11}C]CO to [^{11}C]CO_2 is model reaction to test the Fe/ZSM-5 zeolite as a catalyst. Our target reaction is the synthesis of [^{11}C]CH_3OH from [^{11}C]methane on this zeolite with high yield. This process is more complex and difficult because [^{11}C]methane can oxidize in different ways depending on the experimental conditions. Our measurements confirm two suggestions in the literature that the presence of reductants ([^{11}C]CO) facilitate the partial oxidation on the catalyst and that the Fe-$(O)_\alpha$-Fe complex is unstable resulting in lowered radiochemical yield of 3-5 % during more time-consuming processes (2,3).

This work was financially supported by the Hungarian Scientific Research Fund No. T 031764 and the Royal Netherlands Academy of Arts and Science. Fe/ZSM-5 zeolite was prepared by the Department of Inorganic Chemistry and Catalysis, Utrecht University, The Netherlands and the Applied Chemistry Department of Szeged University, Hungary.

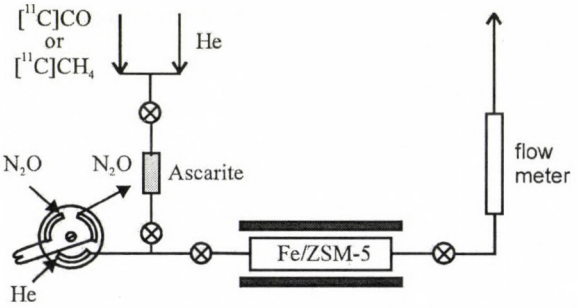

Figure 1: *Apparatus for novel oxidation method of* [^{11}C]CO *or* [^{11}C]CH_4 *on Fe-zeolite*

a) PET-Center, Groningen University Hospital, Groningen, The Netherlands

b) University of Debrecen, Medical and Health Science Center, PET-Centre

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7.1 The ECR Ion Source as Fullerene Accelerator

S. Biri, A. Valek, L. Kenéz and A. Jánossy[a)]

As a new domestic collaboration we started to product and study endohedral fullerene molecules and ions. In the B-minimum trap of the ECR ion source the confinement time of the charged particles can be much longer than in other, conventional ion sources. A special low-temperature mini-oven was constructed and placed close to the plasma chamber of our ECRIS. The mini-oven first was tested with Zn and with Pb. Highly ionised Zn and Pb plasmas and beams were successfully produced.

In the fullerene experiments we successfully produced N@C_{60} molecules in nitrogen plasma (here the N located in the centre of the carbon ball). Aprrox. 200 mg pure C_{60} powder was placed into the crucible of the oven and the temperature was slowly increased to reach a slow, regulated evaporation point of about 470 C. Meanwhile the normal ECR-plasma was ignited with nitrogen gas using very low (several watts) microwave power. This way a dense mixed plasma of mainly N, N_2, C and C_{60} is produced. The probability of producing endohedral (and other) fullerenes is increasing if the plasma is tuned well. The tuning of the plasma is carried out by extracting the total beam and by analysing the C_{60}^+ ions by a 90 degree bending magnet with extremely narrow slits. The extraction voltage was as low as 500 V.

Majority of the plasma particles (C, C_{60}, N@C_{60} etc) are collected on a cooled, removable Al tube inside the plasma chamber. Using the electron-spin-resonance (ESR) technique the N@C_{60}/C_{60} ratio was measured off-line. During the first series of experiments this ratio was found more than 2 times higher than our earlier typical results (using other, non-ECR, conventional techniques).

In the extracted beam spectrum we successfully analysed C_{60}^+, C_{60}^{++} and C_{60}^{+++} ions (see figure). The highest measured C_{60}^+ beam current was 4 nA at U=500 V extraction voltage. We also found a fraction of beam with atomic mass larger than 720 (between 730 and 740). The ratio of this unknown beam intensity to the C_{60}^+ current is about 5E-3.

We note that there are many heavy cluster carbon ions (e.g. C_2^{q+}, C_3^{q+}, C_4^{q+} , q: ion charge) in the spectrum which includes the opportunity to use the ECRIS for cluster plasma and beam production in the future.

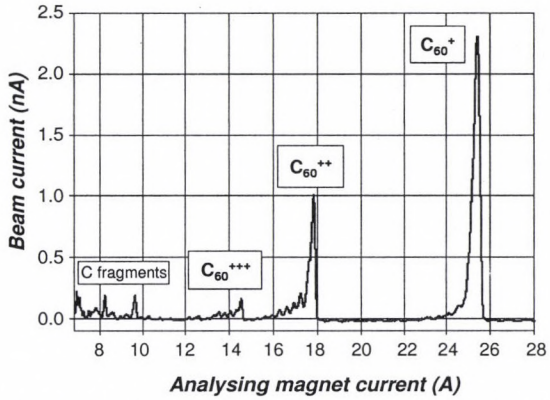

Figure 1: *Typical fulleren beam spectrum produced by the ATOMKI-ECRIS.*

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7.2 Signal Amplitude and Measurement Time with Linear Analogue Signal Processors

G. Kalinka

Baldinger and Franzen [1] has derived useful approximate expressions for the amplitude and measurement time at the output of a linear amplifier due to finite duration detector signal. In the present work an extension of their idea is given for finite and infinite input signals, accounting for the influence of the preamplifier and finite risetime of the electronics as well.

Let the output signal be $g(t)$ due to an ideal $i(t) = \delta(t)$ input signal, and its amplitude be equal to $g_0 = g(t_0)$, t_0 being the measurement time. Let there be a complete signal processing chain with exponentially decaying preamplifier signals ($R_f C_f = 1/Y$), and consisting of a linear amplifier with pole zero compensated differentiator input ($R_d C_d = \tau_d$), and a parasitic integrating term, somewhere in the chain ($R_d C_d = K$). Then for an arbitrary input signal $i(t)$ of finite duration T the output signal can be described by the following integral

$$S(t) = \int_0^1 i(z) \int_0^{\frac{t-zT}{K}} e^{-x} \int_0^{t-zT-xK} e^{(y-zT+xK-t)(Y+\tau_d^{-1})} \times [g'(y) + g(y)/\tau_d]\, dy\, dx\, dz.$$

Its maximum value, the amplitude

$$A_m(T,Y,K) = g_0 + \sum_{n=1}^{\infty} \frac{1}{n!} \left[T\frac{\partial}{\partial T} + Y\frac{\partial}{\partial Y} + K\frac{\partial}{\partial K} \right]^n A_m \Big|_{T,Y,K=0}$$

is reached at measurement time

$$t_m(T,Y,K) = t_0 + \sum_{n=1}^{\infty} \frac{1}{n!} \left[T\frac{\partial}{\partial T} + Y\frac{\partial}{\partial Y} + K\frac{\partial}{\partial K} \right]^n t_m \Big|_{T,Y,K=0}.$$

The Taylor expansion approximation is justified by the fact that in most practical cases neither t_m, nor A_m can be given analytically. The lowest order coefficients, can be expressed as

$$t_m^{(1,0,0)} = \begin{cases} \alpha_1, & \text{for finite duration signal} \\ \alpha_{E1}, & \text{for exponential detector signal,} \end{cases}$$

$$t_m^{(0,1,0)} = \frac{g_0(\tau_d - t_0) + \beta_1}{\tau_d},$$

$$t_m^{(0,0,1)} = \alpha_{E1},$$

$$A_m^{(1,0,0)} = A_m^{(0,0,1)} = 0,$$

$$A_m^{(0,1,0)} = \beta_1 - g_0 t_0,$$

$$A_m^{(2,0,0)} = \begin{cases} g_2(\alpha_2 - \alpha_1^2), & \text{for finite signal} \\ g_2(\alpha_{E2} - \alpha_{E1}^2), & \text{for exponential signal,} \end{cases}$$

$$A_m^{(0,2,0)} = -\frac{\tau_d^2}{g_2}\{2\beta_1^2 + 2\beta_1[2g_0(\tau_d - t_0) + g_2\tau_d^2 \times (t_0 - 2\tau_d)] - \beta_2 g_2 \tau_d^2 + g_0[2g_0(\tau_d - t_0)^2 + g_2\tau_d^2 t_0(4\tau_d - t_0)]\},$$

$$A_m^{(0,0,2)} = g_2(\alpha_{E2} - \alpha_{E1}^2),$$

$$A_m^{(1,1,0)} = A_m^{(0,1,1)} = A_m^{(1,0,1)} = 0,$$

where:

$$g_n = g^{(n)}(t_0),$$

$$\alpha_n = T^{-n} \int_0^T i(t)\, t^n\, dt,$$

$$\alpha_{En} = \int_0^{\infty} e^{-t}\, t^n\, dt = n!,$$

$$\beta_n = \int_0^{t_0} e^{\frac{x-t_0}{\tau_d}}\, t^n [g'(t) + g(t)/\tau_d]\, dt.$$

As an important quantity, the relative ballistic deficit due to a finite detector signal of duration T, or to an infinite exponential one with decay time constant T, i.e. the loss of amplitude relative to those due to an infinitely fast detector signal can be written as

$$B = 1 - \frac{A_m(T,Y,K)}{A_m(0,Y,K)}.$$

[1] E. Baldinger and W. Franzen, Advances in Electronics and Electron Physics **8**, 256 (1956)

7.3 1/f Noise Index of Double Gated Integrator Shaper with Differentiating Prefilter

G. Kalinka

Recently J. Gál [1] has analysed in detail series (delta) and parallel (step) noise indices of double gated integrator (DGI), and established that using a differentiating prefilter (DPF), these indices coincides with that of the single gated integrator (SGI) with integrating prefilter (IPF) designed by Kandiah [2]. The step and delta noise indices of the latter shaper were first determined by Deighton [3], then Llacer [4] was the first who calculated its 1/f noise index, all in time domain. A recent calculation in the frequency domain [5] resulted in, however 12 % higher 1/f noise index. In the present work, therefore a thorough check of both methods is given, and attention is paid to difficulties arising during numerical calculations.

Since aside from a multiplication constant the step response function of DGI-DPF and SGI-IPF circuits is $g(t) = e^{-t/\tau} + t/\tau - 1$, where τ is the time constant of the prefilter, they can be considered to be equivalent.

The 1/f noise index in the time and frequency domain, respectively, is expressed as

$$\left\langle N_{1/f}^2 \right\rangle = \begin{cases} \int_0^\infty U_{1/f}^2(t)\, dt \\ \int_{-\infty}^{\infty} \dfrac{|H(j\omega)|^2}{\omega}\, d\omega \end{cases}$$

From the

$$U_S(t) = \begin{cases} g(t) & 0 \le t \le T \\ g(T)\, e^{(T-t)/\tau} & T \le t \le \infty \end{cases}$$

step noise residual function the 1/f noise residual function is obtainable as

$$U_{1/f}(t) = \int_0^\infty \frac{\sqrt{2}}{\sqrt{t-\zeta}} \frac{dU_S(\zeta)}{d\zeta}\, d\zeta =$$

$$\frac{2\sqrt{2}}{g(T)\sqrt{\tau}} \begin{cases} \sqrt{\alpha x} - e^{-\alpha x} F(\sqrt{\alpha x}), \\ \sqrt{\alpha x} - e^{-\alpha x} F(\sqrt{\alpha x}) - \sqrt{\alpha (x-1)} \\ -(\alpha - 1) e^{\alpha(1-x)} F(\sqrt{\alpha(x-1)}, \end{cases}$$

for $0 \le t \le T$ and $T \le t < \infty$ respectively. Here T is the duration of integration, and

$$F(y) = \int_0^y e^{\zeta^2}\, d\zeta\ ,\ x = t/T\ ,\ \alpha = T/\tau\ .$$

From the Fourier transform of the step noise residual function one gets

$$|H(j\omega)|^2 =$$

$$2\left(\frac{\tau}{g(T)}\right)^2 \frac{1 - \omega^2 T^2 - \cos(\omega T) - \omega T \sin(\omega T)}{\omega^2 T^2 (\omega^2 T^2 + 1)}$$

Integrating these functions numerically the following results for 1/f noise index are obtained, where previous calculations are also shown:

α	Time domain	Frequency domain	[4]	[5]
0.5	5.228	5.229		5.228
1	4.685	4.686		4.686
1.333	4.565	4.566	4.05	4.563
1.852	4.517	4.517		
2	4.521	4.521		4.572
2.098	4.526	4.526		
4	4.809	4.809		4.805
10	5.785	5.785		

Present data obtained by both methods are consistent with each other, therefore can be considered as reliable and almost coincides with that of [5], whereas of [4] proves to be erratic.

It is worth noting that the 1/f noise index reaches a smooth minimum value at $\alpha = 1.872$, close to 2.098, the minimum for the combination of step and parallel noise indices.

[1] J. Gál, accepted for publication in Nucl. Instr. and Methods A (in press)

[2] K. Kandiah, Report No. AERE-R 5019, Harwell, 1965

[3] M.O. Deighton, Nucl. Instr. and Methods **58**, 201 (1968)

[4] J. Llacer, Nucl. Instr. and Methods **130**, 565 (1977)

[5] K. Husimi and M. Kuwata, Nucl. Instr. and Methods **A416**, 397 (1998)

7.4 Ballistic Deficits due to Planar Detector Signals

G. Kalinka

Baldinger and Franzen [1] has shown that the ballistic deficit caused by an arbitrary detector signal $i(t)$ of finite duration T can be expressed in lowest (2nd) order approximation as

$$B = -\frac{g''(t_0)}{2\,g(t_0)}\left(\alpha_0 - \alpha_1^2\right)T^2,$$

where $g(t)$ stands for the output signal shape of the processor due to an infinitely short detector signal, t_0 for the peaking time, and the α_n moments are defined as

$$\alpha_n = \frac{1}{T^n}\int_0^T i(t)\,t^n dt.$$

For a given electrode of an arbitrary detector the induced current due to $i = e, h$ charge carriers is given by the Ramo- Shockley equation:

$$i_i(t) = -q_i(t)\,\vec{v}_i\left[\vec{r}_i\,(t)\right]\vec{E}_w\left[\vec{r}_i\,(t)\right],$$

where, for trapping with no detrapping $q_i = q_{i0}exp(-t/\tau_i^+)$ is the moving charge inducing the signal, τ_i^+ being the trapping time, $\vec{r}_i$ is the position-, $\vec{v}_i$ the velocity-, while $\vec{E}_w$ is the weighting field-vector. For ideal planar detector, where $\vec{E}_w = 1/w$ with w being here the sensitive thickness, $\vec{r}_i = x$ the distance measured from the negatively biased electrode, and $\vec{v}_i = const.$, the expression for the induced current from charge carriers created at relative depth $a = x/w$, significantly simplifies, enabling to obtain α_{ni} in the following analytic forms

$$\alpha_{ne} = \frac{1}{n+1}\left[a\left[\frac{a}{\gamma\,(1-a)}\right]^n A_{hn}^+ + (1-a)\,A_{en}^+\right],$$

for $a < a^*$, and

$$\alpha_{nh} = \frac{1}{n+1}\left[a\,A_{hn}^+ + (1-a)\left[\frac{\gamma\,(1-a)}{a}\right]^n A_{en}^+\right]$$

for $a < a^*$, with $a^* = \gamma/(1+\gamma)$, depending on wheather electron or hole transit times are longer, where $\gamma = \nu_h/\nu_e$ and A_{in}^+ the trapping moments are given by

$$A_{in}^+ = \frac{(n+1)!}{y_i^{n+1}}\left[1 - e^{-y_i}\sum_{k=1}^{n}(1+\frac{y_i^k}{k!})\right]$$

Here $y_e = (1-a)T_e/\tau_e^+$, $y_k = aT_e/(\gamma\tau_k^+)$, $T_e = w/\nu_e$, while the total detector signal duration is

$$T = \begin{cases}(1-a)\,T_e & \text{if } a \le a^* \\ \dfrac{a}{\gamma}\,T_e & \text{if } a \ge a^*.\end{cases}$$

In the case of no trapping, when $\tau_i^+ = \infty$ and $A_{in}^+ = 1$, the ballistic deficit can be written in the simple

$$B = \frac{1}{24}\frac{g''(t_0)}{g(t_0)}\Big[3a^4(1+\frac{1}{\gamma})^2 - 4a^3(2+\frac{3}{\gamma}+\frac{1}{\gamma^2}) + 6a^2(1+\frac{1}{\gamma}) - 1\Big]T_e^2$$

form. For the $\gamma = 1/3$ case, typical of Si, Ge, etc., this reduces further to

$$B = -\frac{1}{24}\frac{g''(t_0)}{g(t_0)}(48a^4 - 80a^3 + 24a^2 - 1)\,T_e^2.$$

If preamplifier output signals have an $\sim exp(-tY)$ decay then it modifies effective balistic deficit in linear appproximation to [2]:

$$B_{eff} \approx \frac{B}{1 + \dfrac{Y}{g(t_0)}\left(\dfrac{\partial A_m}{\partial Y}\right)_{Y=0}}$$

where $A_m = A_m[i(t), Y]$ is the detector signal shape and preamplifier decay dependent output signal amplitude.

[1] E. Baldinger and W. Franzen, Advances in Electronics and Electron Physics **8**, 256 (1956)

[2] G. Kalinka, in this Annual Report p.62.

7.5 Diagnostic Research of ECR Plasma using Langmuir Probe

L. Kenéz[a)], *S. Biri, A. Valek, J. Karácsony*[a)]

Langmuir probes are successfully applied diagnostics tools which in many practical applications provided reliable results. Diagnostic research of ECRIS plasma using electrostatic probes is yet an untapped research field. The plasma of the source is complicated and conditions are difficult to handle which make limitations of the probe's applications. Both the theoretician and the experimentalist have to face difficulties: the plasma is created by a high frequency electromagnetic field, it is confined in a strong and inhomogeneous magnetic mirror configuration, depending on the plasma conditions the electrons can have non-Maxwellian energy distribution, presence of ions with different charge states etc. With careful design and experimental approach many of these difficulties can be handled or can their influence be minimised for certain plasma conditions. Because of the above mentioned difficulties in case of an ECRIS plasma we do not expect to determine absolute values, but the evolution of some local plasma parameters in the course of external effects such as e.g. electron injection, gas-mixing etc.

Last year we started to built at the ATOMKI ECRIS a probe diagnostic set-up. To perform more precise characteristic measurements, the needed bipolar power supply [1] and the driver mechanisms has been built and put into operation. Evaluation of the characteristics is a difficult task. As a starting point we have considered a single Maxwellian electron distribution function which is suitable in many applications even in ECR plasmas.

The figure below shows the evolution of the local plasma parameters (plasma potential, electron temperature and density) on the axis of the plasma chamber. The measurements were carried out in an oxygen plasma optimized for O^{3+} extraction at $P_{rf} = 100W$ microwave power. In the future we plan to continue the experiments in different plasmas and also do efforts to make measurement in the hotter regions of the plasma. We also plan to find better theoretical electron distribution functions (multiple Maxwellian and/or non-Maxwellian) and to extend the theoretical analysis to the case of different charged ions.

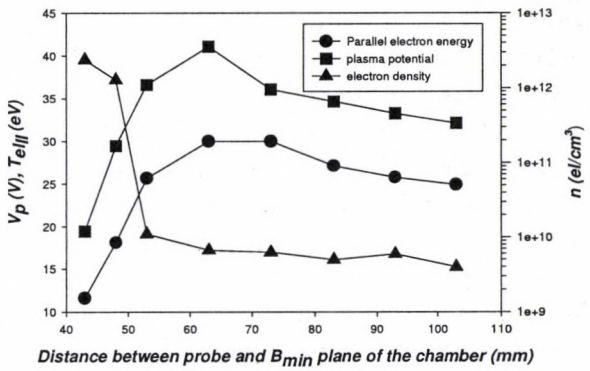

Figure 1:

a) Babeş-Bolyai University Cluj-Napoca, 3400, Str. Kogălniceanu Nr.1, România

[1] L. Kenéz *et al.*, ATOMKI Annual Report 1999, 75

7.6 Hardware and Software Tools for the Radiation Hardness Test of a QuickCam Camera

G. Székely, J. Molnár, D. Novák[a)]

Abstract

A 9-channel counter together with some basic test software and a PC program for saving the pictures taken in regular time intervals during irradiation of a QuickCam camera are described. These tools were successfully used in collaboration with colleagues from Royal Institute of Technology Stockholm in an experiment held in Uppsala University on 25th November 2000. Some initial results of the 2-hour irradiation are discussed.

1. Introduction

QuickCam [1] is a 64-level grayscale CCD camera. It has low weight, requires low power and it is easy to operate through an LPT port of a PC. Because of these nice features it was selected to be the on-board camera of the nano satellite Hugin [2]. To check how much radiation it can tolerate during its mission in the space some hardware and software tools had to be developed. A counter needed to measure the irradiation dose along the time scale and a measuring program required for collecting pictures in equidistant time points.

2. 9-channel counter

Its main part is a BS2-IC Basic stamp microcontroller [3] controlling three I8253 counter chips. Each chip can handle three 16-bit counters. The Basic stamp can communicate via its serial port using RS232. A code developed in Basic programming language on a PC can be downloaded to the microcontroller. After having a proper control program in BS2-IC, another PC program can communicate with it via a COM port. Simple test programs were developed both in Pascal and C languages to demonstrate the usage of the device. Fig 1 shows the upper part of the screen displayed by the test program. Here the logical structure of the device and the program options can be seen.

3. Code for collecting QuickCam pictures in regular time intervals

QuickCam has a distribution CD when purchased, but it contains only some Windows executable programs. As the payload computer of the satellite will not have Windows operating system some lower level code was needed to handle the camera through the LPT port. This program was tested already under DOS, so it had to be extended with some special timing and saving functions.

4. Initial results

Although the data (42 Mbytes) collected during the radiation have not yet analyzed in detail, the first views of the pictures taken in different phases of the irradiation show rather clear effects. Fig 2. contains two consecutive pictures scanned by QuickCam (2 upper boxes). The left middle box contains their difference, the right middle one shows the number of cases where the pixel value varied with the same amount (absolute value in [0,63]). The radiation sessions along the time scale are displayed on the lower diagram. The straight vertical line is drawn at the time position of the measurement. The "snowing" effect was increasing when the camera was put closer to the beam.

a) Royal Institute of Technology, Stockholm

[1] http://www.quickcam.com/html/

[2] V. Becanovic, U. Eklund, S. Grahn, Th. Lindblad, R. Lundin, C.S. Lindsey, O. Norberg, J. Waldemark, K. Waldemark: HUGIN a small satellite trying to be intelligent. VI-DYNN'98 Ninth International Workshop on Virtual Intelligence and Dynamic Neural Networks, KTH Stockholm, Sweden, 22-26 June 1998

[3] http://parallaxinc.com/

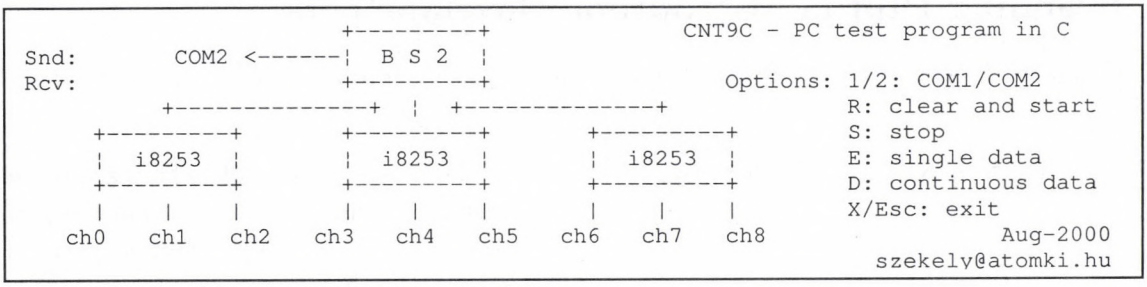

Figure 1: *Screen capture of the test program (upper part)*

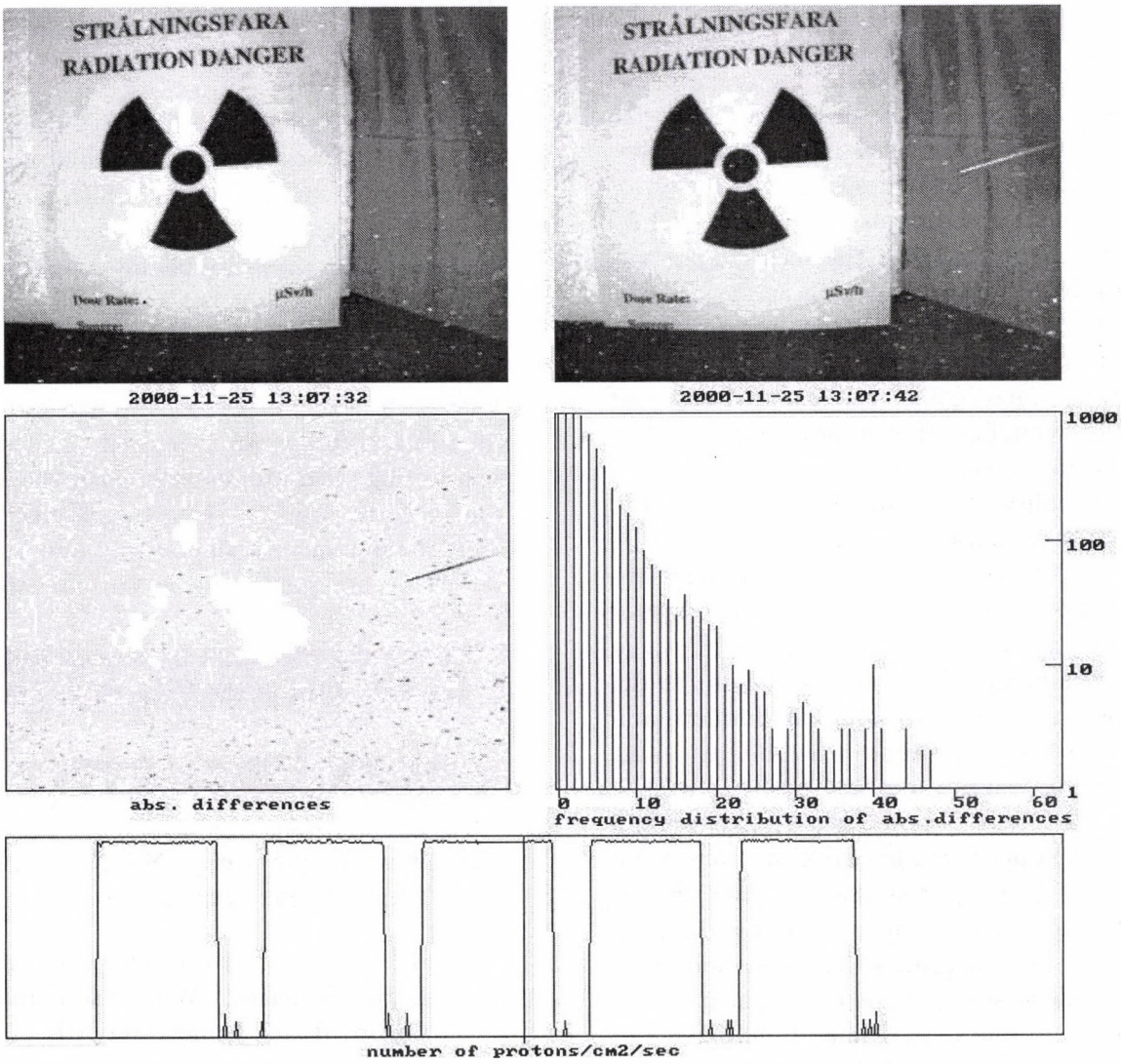

Figure 2: *Comparing 2 consecutive pictures during irradiation*

7.7 Scanning Proton Microprobe Developments

G. W. Grime[a)], I. Rajta, D. G. de Kerckhove[a)], M. B. H. Breese[b)], R. Wogelius[c)], M. Farqhuar[c)], P. Hill[c)]

The High Resolution Scanning Proton Microprobe

There are strong reasons to reduce the spatial resolution into the 100nm regime, especially if sufficient beam current for PIXE analysis can be maintained. These include the determination of elemental distributions within single biological cells, the characterisation of high density semiconductor devices and the analysis of single fine fraction aerosol particles.

The optimum usable spatial resolution of a nuclear microbeam system is determined by many factors. Probably the most important measure of performance for an analytical system is the count rate from the detector, since this determines the time (and cost!) required to obtain statistically significant data, and hence the number of samples which can be analysed in a given period.

The quality of the quadrupole field in the high precision lenses was measured using the 'grid shadow' technique in which the relationship between radial position and convergence angle in a focused beam is visualised by projecting the image of a grid placed close to the focus onto a screen placed further downstream. First each lens was tested individually. Using each lens in turn in their final position, a horizontal and vertical line focus were formed on a 2000 mesh copper grid placed in the target position, and the projected image of the bars was recorded on a fluorescent screen at a distance of 250mm from the grid. Fitting a second order curve to the position of the bars indicates that for each lens, the peak value of the magnetic sextupole contaminant field is less than 0.1% of the quadrupole field. The measurement was repeated using the complete spaced triplet system. In this case only spherical aberration was observed at high divergences, but using the collimator slits at their normal setting, this was also negligible.

Total Reflection PIXE

In Total Reflection PIXE (TR-PIXE) the ion beam is incident onto a highly polished surface at a grazing angle which is smaller than the surface channeling angle. Under these conditions the majority of the beam does not penetrate the matrix but is guided along the surface by the string potentials of the surface atoms before being reflected. The relatively long path length of the ions in the surface region results in a much increased probability of interacting with atoms decorating the surface and a corresponding reduction of the excitation of the atoms in the matrix, and hence to very low detection limits for surface atoms.

These developments have been performed at the SPM Unit of the University of Oxford.

a) University of Oxford Department of Materials, Parks Road, Oxford, UK

b) University of Surrey School of Physics, Guildford, Surrey, UK

c) University of Manchester Department of Earth Sciences, Williamson Building, Oxford Road, Manchester, UK

7.8 Activities at the Van de Graaff Accelerator Laboratory

L. Bartha and E. Somorjai

During 2000 the beam time of the VdG-1 machine amounted to 378 hours. The accelerator delivered helium beam used for low energy atomic physics experiments.

The 5 MV Van de Graaff machine was operating for 1742 hours during this period. Proton (71.0 %), H_2^+(1.7 %), D^+(9.3 %) and He^+ (18.0 %) particles were accelerated.

The beam time was distributed among different research subjects and education (laboratory practices for undergraduate and PhD students) as it is shown in Table 1.

Field	**Hours**	**%**
Atomic physics	0	0.0
Nuclear astrophysics	347	19.9
Analytical studies	214	12.3
Analyses on the microprobe	1110	63.7
Education	46	2.7
Machine tests	25	1.4
Total	**1742**	**100**

Table 1: *Time distribution among different research activities at VdG-5*

7.9 Status Report on the Cyclotron

Z. Kormány

The operation of the cyclotron in 2000 was again concentrated to the usual 9 months; January, July and August were reserved for maintenance and holidays. The overall working time of the accelerator was 4227 hours, the breakdown periods amounted to 22 hours last year. The cyclotron was available for users during 3793 hours, the effectively used beam-on-target time is summarized in Table 1. (FERMI: Front-End Readout Microsystems, Radiation hardness measurements, CERN RD-16). The time required for machine setup and beam tuning or spent waiting for the start of an irradiation totalled to 480 hours.

The obsolete, relay-based and only manually operated control system of the cyclotron and beam line power supplies (the total number of 35) has been completely renewed during the year. The power supplies were equipped with two-channel (control and measurement) optically isolated digital interface modules, allowing their connection to the programmable logic controller (PLC) system and their control was changed from analogue to digital. This transition required new adjustment elements for the power supplies, which are easy and convenient to use and can be connected to any D/A channel for value setting. Two new adjustment units with optical shaft encoders have been designed and built for this task.

The digital control values of the power supplies can be saved and loaded easily. A database program was developed to store and fetch all those values which are necessary to repeat a successful setting of the cyclotron and/or the beam lines. As a result, the tuning time of the different beam regimes has been decreased by about a factor of 10. The reproducibility is also excellent, just a few very small adjustments are needed to optimise the setting after loading the stored values from the database.

Projects	**Beam time (hours)**	**%**
Nuclear spectroscopy	590	35
Nuclear astrophysics	290	17
FERMI	72	4
Nuclear data	136	8
Isotope production	597	36
Total	**1685**	**100**

Table 1: *Distribution of the irradiation (beam-on-target) time*

8.1 Papers Published in 2000

1. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., et al.: *Search for R parity violating decays of scalar fermions at LEP.* European Physical Journal "C" **12** (2000)1.

2. Abbiendi G., Dienes B., Horváth D., Pálinkás J., Trócsányi Z., et al.: *Search for acoplanar lepton pair events in e^+e collisions at $\sqrt{(s)}$ = 161, 172 and 183 GeV.* European Physical Journal "C" **12** (2000)551.

3. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., et al.: *Search for neutral Higgs bosons in e^+e^- collisions at $\sqrt{(s)}$ 189 GeV.* European Physical Journal "C" **12** (2000)567.

4. Abbiendi G., Dienes B., Horváth D., Pálinkás J., Trócsányi Z., et al.: *Measurement of the B+ and B0 lifetimes and search for CP(T) violation using reconstructed secondary vertices.* European Physical Journal "C" **12** (2000)609.

5. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., et al.: *Measurement of the production rate of charm quark pairs from gluons in hadronic Z0 decays.* European Physical Journal "C" **13** (2000)1.

6. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., et al.: *Search for pair-produced leptoquarks in e^+e interactions at $\sqrt{(s)}$ = 183 GeV.* European Physical Journal "C" **13** (2000)15.

7. Abbiendi G., Dienes B., Horváth D., Pálinkás J., Trócsányi Z., et al.: *A study of parton fragmentation in hadronic Z0 decays using Lanbda-anti-Lambda- correlations.* European Physical Journal "C" **13** (2000)185.

8. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., et al.: *A study of three-prong tau decays with charged kaons.* European Physical Journal "C" **13** (2000)197.

9. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., et al.: *Tau decays with neutral kaons.* European Physical Journal "C" **13** (2000)213.

10. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., et al.: *Measurement of inclusive semileptonic branching fractions of b hadrons in Z0 decays.* European Physical Journal "C" **13** (2000)225.

11. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., et al.: *Tests of the standard model and constraints on new physics from measurements of fermion-pair production at 189 GeV at LEP.* European Physical Journal "C" **13** (2000)553.

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152. Tóth J.: *Felületi- és mikroanalitikaI módszerek alkalmazása szálló por vizsgálatában (ipari és városi környezet).* 5. Magyar Aeroszol Konferencia. Szeged, 2000. okt. 5-6.

153. Tóth J.: *Medium energy range HREELS as a tool for analytical and structural determination of solid surfaces (Abstr.: 3D-034, p. 314).* 8th International Conference on Electronic Spectroscopy and Structure. Berkeley, Calif., USA, 8-12 Aug., 2000.

154. Tóth J.: *Auger electron hologram.* Symposium on Holography and High Resolution Measurement Techniques Including Information Processing and Precision Measurement Techniques. Budapest, Hungary, 5-6 June, 2000.

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159. Trócsányi Z.: *Studies of the strong coupling.* ICHEP 2000. Osaka, Japan, July 27 - Aug. 2, 2000.

160. Trócsányi Z.: *Calculation of power corrections to hadronic event shapes of tagged b events.* LEP2 QCD Workshop. CERN, Geneva, Switzerland, Feb. 10-11, 2000.

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163. Uzonyi I., Rajta I., Bartha L., Kiss Á. Z., Nagy A.: *Realization of the simultaneous micro-PIXE analysis of heavy and light elements at a nuclear microprobe. (Final program and abstracts, p. 71).* 7th International Conference on Nuclear Microprobe Technology and Applications. Cité Mondiale, Bordeaux, France, 10-15 Sept., 2000.

164. Uzonyi I., Elekes Z., Simon A., Rajta I., Kiss Á. Z.: *Pásztázó nukleáris mikroszondára alapozott kutatások az Atomki-ban.* őszi Radiokémiai Napok 2000. Hévíz, 2000. okt. 18-20.

165. Varga K.: *Gambling in physics.* 16th International Conference on Few-body Physics. Taipei, Taiwan, 6-10 March, 2000.

166. Varga K.: *Recent progress in the stochastic variational method.* 16th International Conference on Few-body Physics. Taipei, Taiwan, 6-10 March, 2000.

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170. Vertse T., Kruppa A. T., Barmore B., Nazarewicz W., Ixaru L. Gr., Rizea M.: *Proton emission from Gamow resonance.* Exotic Aspects of Nuclear Decay by Light-Particle Emission. Trento, Italy, Nov. 20-24, 2000.

171. Vető I., Futó I., Hertelendi E.: *A baktériumok által elpusztított üledékes szervesanyag mennyiségének becslése a karbonát stabil C izotóp arány alapján.* Izotópgeokémiai Ankét. Budapest, 2000. április 25-26.

172. Vető I., Futó I., Hertelendi E., Fórizs I.: *Alföldi rétegvizekben oldott metán stabilizotóp összetételi vizsgálata.* Izotópgeokémiai Ankét. Budapest, 2000. április 25-26 (2000)0.

173. Vincze Á., Solymosi J., Vajda N., Molnár Zs., Bódizs D., Svingor É., Szántó Zs., Ormai P., Fritz A., Frigyesi F., Gresits I., Tölgyesi S., Mell P.: *Radioactive waste characterization by scaling technique at NPP Paks (Book os Abstr.: Section 3/12).* 5th International Nuclear Technology Symposium. Paks, Hungary, Oct. 4-6, 2000.

174. Zelenka T., Balázs E., Balogh K., Kiss J., Kozák M., Nemesi L., Pécskay Z., Püspöki L., Székyné-Fux V., Ujfalussy A., Ravasz Cs.: *Buried Miocene volcanic structures in Hungary.* International Conference Geology and Prospecting in the Carpathians. Herlany, Slovakia, Sept. 4-6, 2000.

8.7 Other talks, posters, and abstracts

1. Balogh K.: *Az Ar-Ar kormeghatározási módszer és fejlesztésének lehetőségei.* Izotópgeokémiai Ankét. MTA, Budapest, 2000. ápr. 25-26.

2. Balogh K.: *Az Ar-Ar módszer fejlesztésének lehetőségei.* Magyarhoni Földtani Társulat. Ásványtan-Geokémiai Szakosztály. Budapest, 2000. szept. 18.

3. Balogh K.: *K/Ar and Ar/Ar dating: theory, methods, results.* University of Beograde, Faculty of Geology. Beograde, Yugoslavia, 20 April, 2000.

4. Cseh J.: *A Sakata-model-based extension of the nuclear mass formula.* KEK Seminar. Tokyo, Japan, Febr. 29, 2000.

5. Cseh J.: *Spontaneous fission and clusterization.* Nuclear Physics Colloquium. Hokkaido University. Sapporo, Japan, March 22, 2000.

6. Cseh J.: *Symmetries in mechanics.* Sivankharinwirot University., Department of Physics, Bangkok, Thailand, Nov. 20, 2000.

7. Gál J.: *The VXI signal processor of the ancillary charged particle detector system for the EUROBALL gamma-ray facility.* Osaka Electro-communication University. Neyagawa, Japan, 22 April, 2000.

8. Gál J.: *Analog pulse processors for high resolution and high rate spectroscopy.* Osaka Electro-Communication University. Neyagawa, Japan, 19 April, 2000.

9. Gyürky Gy.: *Cross section measurements relevant to the nucleosynthetic p-process.* "Demokritos" National Laboratory, Athens, Greece, 28 Sept., 2000.

10. Juhász B.: *DAIR measurements in 2000.* ASACUSA Collaboration Meeting. CERN, Geneva, Switzerland, Nov. 28-29, 2000.

11. Kalinka G.: *Recent results on the low energy background of silicon semiconductor detectors.* KETEK GmbH, Munich, Germany, Nov. 2, 2000.

12. Kalinka G.: *New trend technique detectors of high resolution and high counting rate: charge collection and signal formation.* Osaka Electro-Communication University. Neyagawa, Japan, 19 April, 2000.

13. Kalinka G.: *Development of high-performance scintillation charged particle detectors for EUROBALL.* Osaka Electro-communication University. Neyagawa, Japan, 22 April, 2000.

14. Kertész Zs.: *Városi és barlangi aeroszolok mintavétele és elemösszetételének vizsálata PIXE és mikro-PIXE módszerrel.* Atomki, Debrecen, 2000. május 25.

15. Kis-Varga M.: *New trend of EDXRF and quantitative analysis.* Osaka Electro-Communication University. Neyagawa, Japan, 19 April, 2000.

16. Koltay E.: *Atommagfizika: utak, célok, hatások.* MTA Fizikai Tudományok Osztálya: A Fizika Magyarországon: múlt, jelen, jövő. című tudományos ülés. Budapest, 2000. május 18. A tudományos gondolkodás Magyarországon c. közgyűlés rendezvénysorozat.

17. Kövér Á.: *Atom collision research in Atomki, Debrecen, and MAXLAB, Lund.* Department of Physics, Univeristy of Oulu, Finalnd. 13 Sept. 2000.

18. Kövér Á.: *Electron ejection from ionizing positron - atom collision.* Department of Physics, University of Oulu, Finland, 20 Sept., 2000.

19. Kövér Á.: *Atomic collision physics with positrons.* Institut für Kernphysik, JWG-Universitat, Frankfurt, Germany, 25 Febr., 2000.

20. Krasznahorkay A.: *Superdeformation, hyperdeformation and clustering in the actinide region.* Japan Atomic Energy Research Institute (JAERI) Tokai Research Establishment. Jan. 24, 2000.

21. Lakatos T.: *New trend technique of digital pulse processor for high resolution and high rate spectroscopy.* Osaka Electro-Communication University. Neyagawa, Japan, 19 April, 2000.

22. Lévai G.: *Supersymmetric quantum mechanics and solvable potentials.* Instituti de Fisica CINVESTAV. Mexico City, Mexico, 26 Jan., 2000.

23. Lévai G.: *Symmetry aspects of nuclear cluster systems.* Instituto de Ciencias Nucleares, UNAM, Mexico City, Mexico, Jan. 24, 2000.

24. Lévai G.: *Symmetry aspects of nuclear cluster systems.* Notre Dame University, South Bend, Indiana, USA, Nov. 6, 2000.

25. Lévai G.: *A supersymmetric scheme for cluster systems.* UNAM, Mexico DF, Mexico, Nov. 30, 2000.

26. Lévai G.: *Some aspects of PT symmetric quantum mechanics.* Universite Libre de Bruxelles. Bruxelles, Belgium. Aug. 23, 2000.

27. Lévai G.: *Solvable quantum mechanical problems and their symmetries.* University of Illinois at Chicago. Chicago, Illinois, USA, Nov. 7, 2000.

28. Lovas R. G.: *Kétség és egység a magfizikában.* MTA Fizikai Tudományok Osztályának tudományos ülése. Budapest, 2000. december 13.

29. Márton E., Pécskay Z.: *Miocén ignimbrit vulkanizmus a Bükk alján: A paleomágneses és K/Ar izotóp adatok komplex kiértékelése.* Általános Földtani Szakolsztály, Budapesti és Észak-Magyarországi Területi Szervezet közös előadóülése. MÁFI. Bp., 2000. november 24.

30. Pécskay Z.: *Tertiary magmatism in the Carpathian-Pannonian region.* Babes-Bolyai Egyetem, Kolozsvár, Románia, 2000. január 12.

31. Pécskay Z.: *Space and time distribution of Tertiary magmatism in the Rhodopes, Bulgaria.* Department of Mineralogy and Petrology, University of Tessaloniki. Greece, June 6, 2000.

32. Pécskay Z.: *K-Ar age determination; applications and principles.* Department of Mineralogy and Petrology, University of Tessaloniki. Greece, June 6, 2000.

33. Pécskay Z.: *Kárpát-Pannon medence neogén-kvarter vulkanizmusa.* G.E.K.K.O. (Erdélyi Geológus Társulat), Kolozsvár, Románia, 2000. január 13.

34. Pécskay Z.: *Radiometrikus kormeghatározási módszerek alkalmazása a geológiában.* G.E.K.K.O. (Erdélyi Geológus Társulat), Kolozsvár, Románia, 2000. január 13.

35. Pribóczki É., Elsinga Ph.: *Partial oxidation of (11C) methane to (11C) methanol over Fe-zeolite.* Groningen University Hospital. Groningen, The Netherlands, Oct. 12, 2000.

36. Simon A.: *Mikro- és makronyalábbal végzett Rutherford-visszaszórásos spektrometria anyagtudományi kutatásokban.* Atomki szeminárium. Debrecen, 2000. november 23.

37. Somorjai E.: *Experiments for p-process.* Institut of Nuclear Physics. NCSR "Demokritos" Athens, Greece, 27 Oct., 2000.

38. Sulik B.: *Ütköző atomi rendszerek ping-pong játszmái.* Babes-Bolyai Tudományegyetem, Kolozsvár, Románia, 2000. november 14.

39. Sulik B.: *Fermi-shuttle accelerators and virtual photon showers in atomic collisions.* Babes-Bolyai Tudományegyeten, Kolozsvár, Románia, Nov. 13, 2000.

40. Svingor É.: *Facility monitoring: input data for the safety assessment.* RER/9/057 Regional Workshop on the Use of Safety Assessment Methodologies for Upgrading the Safety of Existing Near Surface Disposal Facilities. Budapest, 15-19 May, 2000.

41. Tőkési K.: *Determination of energy loss of HCi by TDDFT.* Institute for Theoretical Physics, Vienna University of Technology. Vienna, Austria, June 20, 2000.

42. Trócsányi Z.: *Recent developments in calculating power corrections to hadronic event shapes.* CERN Theory Division seminar, Geneva, Switzerland, March 3, 2000.

43. Uray I.: *A sugárvédelem oktatásának kérdései az Atomki-ban és a Debreceni Egyetemen.* őszi Sugárvédelmi Találkozó. Veszprémi Egyetem, Veszprém, 2000. november 17.

44. Uray I.: *A sugárvédelem oktatása a média és a lakossági tájékoztatás területén.* őszi Sugárvédelmi Találkozó. Veszprémi Egyetem, Veszprém, 2000. november 17.

45. Varga K.: *Artificial atoms (Colloquium).* Louisville University, Louisville, Kentucky, USA, Dec. 1., 2000.

46. Varga K.: *Stochastic variational approach to quantum dots.* Oak Ridge National Laboratory. Oak Ridge, Tenn., USA, 19 April, 2000.

47. Varga K.: *Quantum dots.* Vanderbilt University. Nashville, Tenn., USA, 18 April, 2000.

48. Varga K.: *Stochastic variational approach to quantum dots.* Vanderbilt University, Nashville, Tennessee, USA, April 18., 2000.

49. Zelenka T., Pécskay Z.: *A Tokaji-hegység vulkanizmusának fejlődéstörténete.* A Tokaji-hegység paleovulkáni értékelése előadóülés. Ásványtan-Geokémiai Szakosztály és Általános Földtani Szakosztály rendezésében. Budapest, ELTE, 2000. december 11.

50. Zelenka T., Pécskay Z.: *A Mátra hegység miocén vulkanitjainak komplex földtani (kőzettan-geokémiai, radiometrikus kormeghatározás) és vulkanológiai vizsgálata.* Ásványtan-Geokémiai Szakosztály és az Általános Földtani Szakosztály előadóülése. ELTE, Bp., 2000. november 13.

8.8 Hebdomadal Seminars in 2000

1. January 13: *Micro-PIXE studies at the scanning proton microprobe of ATOMKI*, I. Uzonyi
2. February 24: *State of affairs*, M. Pálinkás, R. Lovas
3. March 2: *Nuclei with exotic matter distribution*, A. Krasznahorkay
4. March 16: *Nuclei decaying with particle emission: resonances*, A. Kruppa
5. March 23: *New colleagues in ATOMKI*
6. March 30: *X-ray diffraction study of nanostructures*, M. Kis-Varga
7. April 6: *Experiments on photon-induced nucleosynthesis of heavy nuclei*, P. Mohr (Darmstadt)
8. April 13: *The electron spectrometer ESA-22 and first results at the Lund synchrotron*, S. Ricz
9. April 20: *Relativistic electron transport on carbon foil*, K. Tőkési (ATOMKI and Vienna)
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