SPONSORS:

European Commission, Brussels, Belgium
NIPNE, Bucharest Magurele, Romania
Minister of Education and Research, Romania
List of Invited Talks

D. Balabanski (Sofia/Leuven)  Trace element analysis of ice samples from the Livingston Island, Antarctica

F. Becker (Darmstadt)  Conversion electron and gamma spectroscopy using radioactive beams at GSI and GANIL

G. Blondiaux (Orleans)  Thin layer activation and ultra thin layer activation: 2 complementary techniques for wear and corrosion studies in various fields.

P. Cassette (Saclay)  Evaluation of uncertainties in radionuclide metrology using liquid scintillation counting methods

S. Dobrescu (Bucharest)  Multicharged ion sources - an efficient tool for nuclear research and applications

C. Freitas (Lisbon)  INAA and PIXE methods applied to environmental studies: on their accuracy and precision

B. Haas (Bordeaux)  Nuclear data for new fuel cycles and waste transmutation

R. Hellborg (Lund)  Production of clinical useful quantities of $^{18}$F by an electrostatic tandem accelerator

A. Korichi (Orsay)  Physics issue with a new gamma ray detector based on tracking: AGATA (Advanced GAmma Ray Tracking Array)

A. C. Mueller (Orsay)  Development of High Power Accelerators and Some of their Applications

Y. Nagame (Tokai)  Few atom nuclear decay measurements

D. Pantelica (Bucharest)  Characterization of SBN ($Sr_xBa_{1-x}Nb_2O_6$) thin films obtained by pulsed laser deposition

G. Skog (Lund)  Accelerator Mass Spectrometry as a Tool in Geology and Archaeology

C. Stan-Sion (Bucharest)  AMS depth profiling of tritium and deuterium - a new and sensitive tool for diagnose in fusion experiments

K. Stenstrom (Lund)  Radioecological applications of 14C measurements at the Lund Accelerator Mass Spectrometry (AMS) Facility

L. Thome (Orsay)  On the Use of Ion Beams for the Selection of Nuclear Waste Matrices

P. Van Den Winkel (Brussels)  New Plating and Electro - Recovery Technology for the Preparation of High Quality Solid Cyclotron Targets for Production of Medical Radionuclides and the Recycling of Enriched Material
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Trace element analysis of ice samples from the Livingston Island, Antarctica

Dimiter Loukanov Balabanski

Faculty of Physics, University of Sofia, BG-1164 Sofia, Bulgaria

Trace elements were studied in ice samples from several drilling sites in the vicinity of the Bulgarian base "St. Kliment Ohridski" at the Livingston Island from the South Shetlands in Antarctica. Both, accelerator based analytical methods (PIXE) and classical atomic spectroscopy (ICP-AES/USN) were used. Comparison of the sensitivity of the two experimental techniques for different elements, which were analysed, will be done.

The correlations between the measured abundances of different elements will be discussed.

The results allow to study the stability of the glacier layers in different parts of the Perunika glacier, as well as the glacier dynamics in the accumulation zone.

This work is done in collaboration with groups from the University of Sofia and the Mining University, Sofia, Bulgaria, and NIPNE, Bucharest, Romania.
Lichens As Biomonitor with Special Reference

To The Antarctic

Nesho Chipev

Central Laboratory of General Ecology, Gagarin Street 2, Sofia 1113, Bulgaria

Lichens are effective biomonitor of metal deposition. Lichens are slow growing and assimilate metals at a rapid rate but release them at a low rate. Metal concentrations in lichen thalli have been shown to correlate with atmospheric levels. Lichens have been first used as bioaccumulative indicators in relation to point emission sources. Lichens have also been used to assess deposition patterns and heavy metal burdens for larger scale monitoring purposes.

There are two problems to be kept in mind if lichens are to be effectively used as biomonitor. The first one is concerned with the chemical analyses. Results are more useful when background elemental levels are obtained. The choice of analytical method will depend on the purpose of the respective survey. Instrumental neutron activation analysis (INAA), atomic absorption spectrometry (AAS), Inductively coupled plasma emission spectrometry (ICP-ES) and epithermal neutron activation analysis (ENAA) are among the most commonly used methods. The second problem arises from the variability of lichens. Sources of variability include intra-individual variation, intra-species variation and variation due to microhabitat, locality or edaphic factors. Apart from individual variation, many of these sources of variation can be overcome by careful and thoughtful sampling and analysis of the selected species.

Lichens and mosses are the only vegetation in Antarctica. The absence of air pollution in the Antarctic suggests that lichens can be used as biomonitor of pollution at small scales around research bases. However, the unpolluted Antarctic environment presents opportunity for baseline studies on heavy metal bioaccumulation. Bioaccumulation in Antarctic lichens can allow a larger (global) scale insight into the airborne heavy metal circulation and deposition. Both high precision analytical methods and biological studies will be needed.
**Interlaboratories Comparison of Elements Content in Sediments by using Neutron Activation Analysis**

Lucretia C. Dinescu¹, Otilia A. Culicov², Octavian G. Duliu³,
Marina V. Frontasieva², and Cristiana D. Oprea²

¹**National Institute for Physics and Nuclear Engineering – Horia Hulubei, Magurele, P.O. Box MG-06, RO-76900 Bucharest, România**

²**Joint Institute of Nuclear Research, 6, Joliot Curie street, 141980, Dubna, Russia**

³**University of Bucharest, Department of Atomic & Nuclear Physics, Magurele, P.O. Box Mg-11, RO-76900, Bucharest, România**

An intercomparison concerning the concentrations of 23 major and trace elements in recent lacustrine sediments, as determined by Neutron Activation Analysis, has been performed by using epithermal neutrons (ENAA) at the Joint Institute of Nuclear Research, Dubna (Russia) and thermal neutrons (INAA) at the National Institute for Physics and Nuclear Engineering, Bucharest (Romania). All results have been interpreted within the Upper Continental Crust model. Sc, La, Tb, Yb, Th, Na, Rb, Cs, Ba, As, Sb, Hf, Cr, Fe, Co and Zn concentrations were coincident within one standard deviation, Ce, Sm, Lu, Ca, Br and Ta concentrations were coincident within 1.96 standard deviation while Eu concentrations were integrally discordant. Principal Components Analysis has shown that all elements form a single cluster, irrespective of the laboratory where the analysis has been performed, confirming the absence of any significant systematic errors connected to one laboratory. Such kinds of studies are very important in understanding the cause of discrepancies and consequently, in finding the adequate procedure to overcome them.


Radiometric and INAA of Environmental Specimens: Lacustrine Sediments from Danube Delta

Octavian Duliu

Department of Physics, University of Bucharest, Romania

The Danube River is the second most important river of the Europe. It has a drainage basin estimated as 817 000 km² and caries every year between 35 and 70 megatons of solid matter to the Black Sea, where the discharged sediments are forming the actual Danube Delta. At present time, the Delta continues to grow seaward at a rate of 25 - 35 meters annually. During its history, the evolution of the Danube Delta was closely connected with Danube’s three branches: Chilia (the youngest one) in the North, Sulina in the middle and Sf. Gheorghe (the oldest one) in the South. The fluctuation of both Danube River solid flow and the Blake Sea level determined a significant variability of the sediment composition. Now, these sediments mainly consist of silt, sand, shell debris, etc. Former studies has shown that the sedimentation process, occurring over the entire Delta, is characterized by great variability of the sedimentation rates which takes values between 0.6 mm/year and 100 mm/year. The highest sedimentation rate corresponds to the lakes close to the Danube main branches. Therefore, the total thickness of lacustrine sediments varies between 0.5 m in Matita Lake and 2.5 m to 3 m in Lake Golovita. At the same time, as proven by direct and radiographic investigations, the bottom sediments of almost all lakes of the Danube Delta are intensively bioturbated by the living activity of various invertebrates, such as fresh water mollusks and annelid worms, as well as insects (especially chironomid) larvae which spend their life cycle buried in the mud. Despite their variability, sediments represent a sui generis history of past events across the entire catchment basin of a river. Events that refer to actual or passed history such as pollutants discharge, radioactive contamination, climatic changes, etc., could be retrieved by carefully investigation of vertical profile of both trace elements and artificial as well as natural radionuclides. Radiometric as well as high sensitivity and high specificity analytical methods such as Instrumental Neutron Activation Analysis (INAA) could evidence more than 40 different elements at concentrations about ppm or lover. Unwanted events as atmospheric nuclear tests and Chernobyl accident discharged a great amount of radioactive $^{137}\text{Cs}$ that once fixed into sediments represents an excellent tracer for natural processes such as sediments transport, accumulation and redistribution during the last 40-50 years. For multielemental investigation of environmental samples such as soil, sediments, water or various minerals INAA is one of the most suitable technique. Presumably pollutants elements such as Cr, Co, Zn, As, Sb and Br as well as REE that could be easily determined by INAA are helpful indicators of the source as well as of the mechanism of deposition and incorporation of these components. Investigated in correlation with radiocesium distribution as well as some natural trace elements such as REE, Sc or Hf, their vertical profiles in sediments allows a rapid reconstruction of the history of recent pollution processes. Radiometric and INAA measurements have been performed “in tandem” for sediments collected from different lakes located in both Fluvial (western part) and Fluvio-maritime (eastern part and the Razelm-Sinoe lacustrine complex) sections of the Danube Delta, i.e. Lung, Mesteru, Matita, Furtuna and Merhei as well as Razelm and Leahova respectively. A review of these investigations concerning the vertical profiles of 4 major elements (Na, K, Ca and Fe), 15 trace elements (Rb, Cs, Ba, Sc, La, Ce, Sm, Eu, Tb, Yb, Lu, Th, U, Hf and Ta) as well as of 6 potential pollutants (Zn, Cr, Co, As, Sb and Br) in four lakes (Lung, Furtuna, Mester and Matita) together with anthropogenic $^{134}\text{Cs}$ and $^{137}\text{Cs}$ is presented. All these results reveal the great potential of radiometric as well as INAA in environmental as well as in geological investigations.
INAA and PIXE Methods Applied to Environmental Studies: on their Accuracy and Precision
M. Carmo Freitas
Instituto Tecnológico e Nuclear - Reactor, E.N. 10, Apartado 21, 2686-953 Sacavém, Portugal

Examples of the application of $k_0$ standardized Instrumental Neutron Activation Analysis ($k_0$ INAA) and Proton Induced X-Ray Emission (PIXE) to aerosols and biological monitors in the last 10 years at Instituto Tecnológico e Nuclear (ITN) are given herein. As an analytical technique, INAA, in association with the $k_0$ method and PIXE was applied to these materials in four different projects, aiming at monitoring concentrations of heavy metals and others elements in the Portuguese territory air ambient. In these studies we analysed the lichen Parmelia sulcata Taylor and olive tree bark as biomonitors as well as aerosol samples. For each project some representative results are presented. Accuracy and precision of the methods are discussed based on the comparison of even results.

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Spearman R₆ (p-level)  Kendall R₆ (p-level)  gamma G (p-level)

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<td>Na</td>
<td>0.632 (.000)</td>
<td>0.492 (.000)</td>
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<tr>
<td>La</td>
<td>0.537 (.003)</td>
<td>0.376 (.005)</td>
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Top left: V results in 9-month exposed $P$. sulcata. Top right: V survey data obtained by INAA and PIXE. Table: statistics applied to $P$. sulcata and olive tree bark survey results; they are giving similar response. Bottom: Fe in PM2.5 and PM10, obtained by INAA and PIXE.
The article concerns about determination of Hg in the biological materials (furred game), which comes from 9 districts in Slovak Republic. In the fur there were determined the mercury contents, in g·kg$^{-1}$, as follows: roe deer game – Lučenec District, 12.3; Poltár Dis., 12.8; Prievidza Dis., 42.6; Revúca Dis., 23.5; Rimavská Sobota Dis., 16.7; Spišská Nová Ves Dis., 262.5; Veľký Krtíš Dis., 20.3; Žarnovica Dis., 11.5; Žiar nad Hronom Dis., 15.5; red deer game - Lučenec Dis., 13.6; Poltár Dis., 16.2; Rimavská Sobota Dis., 22.1; Žarnovica Dis., 9.6; fallow deer game - Poltár Dis., 41.9; boar game - Prievidza Dis., 257.6. The measurements were carried out by atomic absorption spectrometry using an AMA 254 instrument. The investigated animals were hunted during the hunting period in the year 1999. The biological samples were taken from healthy game without any strange changes of its behavior or colour. High mercury content in fur of roe deer game in Spišská Nová Ves District and also in fur of boar game in Prievidza District shows big air pollution in these districts, caused mainly by intensive industry, mining, reprocessing and energy technologies used in these districts. We can suppose that because of the environmental contamination there is also a high content of mercury in game internal organs. That’s why it would be useful to continue with analyzing the content of Hg in the biological material and environmental as well.
Measurement of beta-emitters in the air around the Paks NPP, Hungary

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

Institute of Nuclear Research of the Hungarian Academy of Sciences, Debrecen, Hungary

$^3$H, $^{14}$C and $^{85}$Kr are the three most important beta-emitters in the global air pollution caused by nuclear power plants. The equipments developed in the INR/HAS ensure the routine sampling of Kr-85 from the stack-air of Paks NPP, and collection of tritium- and radiocarbon samples from air.

Krypton measurements are performed in the Laboratory of Environmental Studies of the INR/HAS. The stack-air sampling of the NPP means gas collection into hermetic gasbags with 0.3 litre gas/day sampling rate. Integrated samples for a month are measured after cryogenic pre-treatment. $^{85}$Kr activity of the integrated samples is measured by a gas proportional counting system using inactive Kr-gas carrier. The detection limit using the low background proportional system is 0.25 mBq/sample.

A differential unit was developed by the INR/HAS for simultaneous $^3$H and $^{14}$C sample collection from the hydrogen, water vapour, carbon dioxide and hydrocarbon fractions of the air. Monthly, tritium is collected in HTO form, radiocarbon is trapped into NaOH solution.

The collection procedure is direct for HTO (absorption by molecular sieve) and CO$_2$ (chemical reaction with NaOH). HT and hydrocarbons are first converted by heated Pt/Pd catalyst to HTO and CO$_2$.

After description from the getter the water samples are measured by an LSC system. The $^{14}$C activity concentration of the air (both from CO$_2$ and the C$_n$H$_m$ fraction) after chemical extraction and separation is measured by the same gas proportional counting system as $^{85}$Kr.
Nuclear techniques, such as INAA and PIXE, are invaluable tools in environmental studies. Atmospheric biomonitoring, in particular, has been a preferential domain for their application, especially (yet not exclusively) due to their analytical robustness, minimal requirements as to sample preparation, and multi-elemental capabilities. The latter aspect is not just important for the complement they stand for each other, but also for the possibility of multiple determination, that may provide an in-depth picture of an elemental pool and, therefore, assist in data analysis, qualification and interpretation, even if some research had been originally designed to target specific, fewer elements. This paper addresses the relative magnitude of concentration patterns (by INAA) in epiphytic lichens (\textit{Parmelia} spp.) and olive tree (\textit{Olea europaea} Linn.) bark from an extended sampling in mainland Portugal, by looking at representative elements from natural and anthropogenic sources. Not seldom have higher plants been overlooked as indicators due to vascular and nutritional features, and also for supposedly yielding poorer analytical signals as a result of an inferior accumulation of airborne contaminants. A nonparametric assessment – correlation and sign trends – of raw and normalised (to a crustal reference) data has shown that while absolute concentrations are indeed (generally) higher in lichens, they also appear to be inflated by inputs from local circulation and/or re-suspension of previously deposited materials. On the contrary, the relative enrichment of non-crustal elements is almost invariably higher in bark than in lichens (see Figure), which seems definitely at odds with the dim-accumulation scenario mentioned above. Even when the opposite occurs, the corresponding differences are non-significant but for Cl. Judging from these results, the question of signal magnitude – and the problem of biased atmospheric indication at large – could eventually stem more from the impact of soil/rock/litter inputs from local sources, and less from any systemic characteristics of the present organisms.
Nuclear and Atomic Techniques in Air Pollution Studies by Transplant Lichens and Air Dust Collection on Filters in Romania

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Lichen transplants from relatively unpolluted sites are successfully used as heavy metal bioaccumulators for air pollution monitoring, significant element accumulations being generally revealed after 6 to 12 months of exposure. The simultaneous collection of bulk (wet and dry) deposition and airborne particulate matter on filters supplies information on the atmospheric availability of trace elements.

The potential of the lichen transplant technique and the high effectiveness of nuclear and atomic methods (INAA, XRFA and ICP-MS) applied to air pollution studies in Romania are presented.

The paper is mainly based on the study entitled “Air pollution monitoring by sampling airborne particulate matter combined with lichen bioaccumulator exposure,” which is in progress at IDRANAP (Inter-Disciplinary Research and Applications based on Nuclear and Atomic Physics) Center of Excellence of IFIN-HH as part of the EU project ICA1-CT-2000-70023.

In this study, Evernia prunastri and Pseudevernia furfuracea lichen species from the Prealps, northeastern Italy, were exposed during 6 and 12 months at six locations with different degrees and types of industrial activity, as well as on a background site with relatively clean air. Bulk deposition was collected for the same periods, while airborne particulate matter was collected for 2 months at each investigated location.

The accumulating capacity of Evernia prunastri and Pseudevernia furfuracea corresponding to these specific environmental conditions was compared with those of Cetraria islandica, Evernia prunastri, and Ramalina farinacea used in a previous comparative air pollution study involving exposure sites in Germany, Italy, and Romania (Project No. RUM-020-96, partly supported by the German Federal Ministry of Education and Research).

The lichen material was analyzed by INAA, XRFA, and ICP-MS, while the aerosol filters were analyzed by INAA and XRFA, and the bulk deposition by INAA. The main elements determined were: As, Br, Ca, Cd, Co, Cr, Cu, Fe, K, Mn, Ni, Pb, S, Sb, Sc, Se, V, and Zn. From among them, Cd, Co, Sb, and Sc could only be determined by INAA and ICP-MS, while Pb and S only by XRFA and ICP-MS. A statistical intercomparison of the results made it possible to assess the quality of our analytical methods for these specific matrices.
Radioactivity Level in Marine Ecosystem

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Major factors contributing to the deterioration of the Black Sea environment are pollution and improper use of natural resources. Monitoring the radioactivity in the Romanian sector of the Black Sea, we can establish the concentration levels of radionuclides in marine ecosystem and their capacity to self-cleaning, also to correlate the influence of the riverine load and the biogeochemical processes.

Radioactivity indicators have special location in the environmental quality state, mainly after anthropic influence.

Our research has been developed under national program and the recommendation of the International Convention to Protect Black Sea against Pollution. Samples of the sediments, water and biota (macroalgae, mollusks, fish) have been collected by network station, between Danube mouths and Vama Veche. Beta and gamma measurements have been used. Cs-137 is one radionuclide with radioecological significance. His level in marine components is between some tens of Bq/m3 (water) and one-two hundreds Bq/Kg dry (submerged sediments). The paper present radioanalitical details.
Accurate gamma-ray spectrometry of environmental samples: a challenge

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Accurate assessment of environmental radioactivity by gamma-ray spectrometry requires carefully designed sampling procedures, sample preparation, measurement and analysis.

In this contribution the problems concerning the efficiency calibration of the gamma-ray spectrometer are emphasized. Direct experimental calibration can be applied only for certain sample matrices, containing specific nuclides, measured in a limited number of configurations. In order to achieve a complete calibration of the spectrometer for all the cases of interest in a modern environmental radioactivity laboratory additional calibration procedures are required.

The GESPECOR software \cite{1} has been developed by us for this purpose. It can be applied for the computation of the efficiency of Ge detectors [coaxial, planar and well-type HPGe, Ge(Li)] for a wide class of measurement configurations. In specific cases \cite{2,3}, a non-uniform source distribution in the sample can be taken into account. Besides direct efficiency calculation, accurate efficiency transfer methods \cite{4,5} are provided in the program. Self-attenuation effects \cite{6}, which are required for the calibration of a volume source using a calibration standard with a different matrix and density, are properly evaluated for any matrix with assumed composition and density, or with known values of the linear attenuation coefficient. Nuclide specific coincidence summing effects are realistically evaluated \cite{7-9}; the decay data required for the computation are automatically prepared for a number of approximately 100 nuclides. It should be stressed that coincidence summing effects are enhanced in present day measurements due to the increasing use of high efficiency detectors and measurement configurations, in response to the need of achieving low detection limits.

In the paper specific applications of GESPECOR for accurate assessment of the radioactivity of environmental samples are presented.

The National Standard of the Radionuclides Activity Unit in Poland

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The National Standard of the Radionuclides Activity Unit, established in Poland in 1999, is applied and kept in the Radioisotope Centre POLATOM in Owierk. The standard consists of three measurement systems (see scheme), twelve absolute measurement method and two types of measurement sources. In the triple - double coincidences (TDCR) system, designed above all for the “pure” β- or EC-emitters standardisation, as well as in the 4π(LS)-γ coincidences and anticoincidences system, for the β-γ radionuclides, the technique of the Liquid Scintillation Counting (LSC) is applied. The radioactive solution (S) is mixed with the liquid scintillator. The scintillation photons are registered by photomultipliers (PMT) working in coincidence. The X-γ coincidences system, where the point source (P) on the Mylard foil is used, is designed for $^{125}$I standardisation.

Measurement methods are validated by the international comparisons of radionuclide activity measurements. The RC POLATOM participated in 27 intercomparisons till now. Standardised solutions of nearly fifty different radionuclides are used in the RC POLATOM for production of many secondary standards for calibration of various instruments used in science, nuclear medicine, or environmental measurements. The entire uncertainty of the standards is in general about ± 1% on the confidence level of 0,95.
Evaluation of uncertainties in radionuclide metrology using liquid scintillation counting methods

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The ISO Guide for the evaluation of Uncertainties in Measurements (GUM) gives a rational frame for the evaluation of uncertainties and is the reference in the metrology community. Nevertheless, uncertainty evaluation is never a simple procedure and requires a good knowledge of the physics behind the experiment.

We present in this paper our experience in the uncertainty evaluation for the standardization of $^{103}$Pd, a radionuclide used in nuclear medicine, using the Triple to Double Coincidence Ratio (TDCR) method in Liquid Scintillation Counting (LSC).

After a short presentation of $^{103}$Pd decay scheme, we give an overview on the LSC standardization technique and the TDCR method. We describe the calculation method for the detection efficiency, as a function of the experimental data and the input parameters of the calculation model. We discuss the main contributors to the final uncertainty and establish their covariance matrix.

In this case, the calculation method cannot be reduced to an explicit function but relies on a numerical algorithm. As the general law of propagation of uncertainties requires the calculation of the partial derivative of the experiment transfer function, the procedure is here not straightforward. We present and discuss two calculation strategies to solve this problem: a method based on the numerical evaluation of the partial derivative of the detection efficiency function and a global Monte Carlo evaluation method.
Production and chemical separation

of 48-V radioisotope

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The positron emitter $^{48}$V isotope (T1/2=16d, gamma-lines: 511 keV (100%), 983.5 keV(100%), 1312 keV(97.6%)) deserves interest in several fields of science. This is available for the transmitting scanning in the validation process of PET-camera by its positron emission, can be used for as an industrial monitor isotope by its $\gamma$-photons having high energy and intensity and is also suitable for biological study since it is the only radioisotope of the biological trace element, of V, which can be a radiotracer by its longer half-life.

The $^{48}$V was produced by natTi(d,xn)$^{48}$V nuclear reaction in the U-120 cyclotron with activity of 6 mCi. The energy of irradiating beam was 13 MeV, its intensity was 5 mA, and the metallic Ti target dimension was 16x11x2 mm. For target cooling the circulated water in back side was used. After 3 cooling days only the $^{48}$V and some $^{46}$Sc (T1/2=84d) produced by the side nuclear reaction, $^{48}$Ti(d,a)$^{46}$Sc were found in the target. For the preparation of source of $^{48}$V, the Ti target was dissolved in HF and in sulfuric acid too. The ionexchanging separation was developed for both dissolving methods.
Standardization of $^{48}$V

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$^{48}$V disintegrates by positron emission and electron capture processes with a half life of 15.97d. It was standardized by a special classic variant of the coincidence method. An usual $4\pi$ proportional counter- NaI(Tl) scintillator system was used. A complication arised due to a significant $^{46}$Sc impurity. The low energy capture radiations were not registered and the $^{46}$Sc radiations were included in a new simplified decay scheme. The gamma contribution in the $4\pi$ counter was determined by an extrapolation procedure. In the gamma channel, an energy window centered on the main 1312 keV photon was employed as to eliminate the disturbing effect of a non coincident photon. Even so, summation effects, different for two disintegration branches in the decay scheme had to be estimated. “Get-out” summation effects were experimentally estimated and reduced with Pb absorbers. Their effect in the final calculus was of only 0.8%. A combined uncertainty of 1.4% was obtained, mainly from the impurity contribution. Two facts helped for a good standardization: use of a simplified decay scheme and equivalent photon energies for $^{48}$V and $^{46}$Sc.
Response function study of low-energy X-ray spectra obtained with semiconductor detectors

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Semiconductor detectors are in use in a number of applications and their energy resolution and the detailed shape of their response function are parameters of interest for accurate processing of low-energy X-ray spectra to be applied to elements identification and fundamental research studies. This has been determined for different semiconductor detectors (Si(Li), HPGe and SSD (silicon drift detector)) by means of a monochromatized synchrotron radiation (Super-ACO and DCI storage rings in LURE, Orsay) in the 1-20 keV energy range [1-2]. The spectrum shape strongly depends on the photons and photoelectrons interactions at the level of the semiconductor crystal-electrode interface. Part of low energy side of the peak is characterized by features resulting from electron interactions: escape of photoelectrons and Auger electrons from the active part of the crystal and penetration of photoelectrons and Auger electrons of the electrode into the detector active part. The experimental evidence is shown by the shape of the spectra obtained with an HPGe detector for different photon energies. The penetration of electrons from the nickel electrode is show with incident energies selected on both sides of the Ni K binding energy. At 8 keV, below the nickel K binding energy, the incident photon interaction occurs with L shell; there is no significant effect in the spectrum. At 8,5 keV, the ionization is mainly obtained via photoelectric effect on the K shell inducing Ni K photoelectrons and subsequent electronic rearrangement produces both K photons and Auger electrons. All these secondary particles can enter the detector thus giving either fluorescence peak (photons) or continuous distributions due to the electrons.

At higher energy, the effect of interaction in K germanium shell is also clearly demonstrated when incident energies are selected on both sides of Ge K binding energy (11 keV). At 10 keV, the spectrum shows the same components as at 8,5 keV. Just above the K binding energy, the primary interaction mainly occurs with Ge K electrons, thus inducing Ge K photoelectrons, and consequent rearrangement gives Ge K photons and Auger electrons. If the primary interaction occur near the crystal edge, all these particles can escape the active part, thus giving escape effect: the well-know escape peaks, and also continuous distribution due to the escape of photo- and Auger electrons. These different effects appear in figure 1.

Fig 1: Spectra obtained with monochromatic incident energy $E_{inc} = 12$ keV

The tunable incident radiation makes possible identifying these different features by fine scanning at the binding energies of the detector materials, thus improving the knowledge of the detector response function and the subsequent processing of complex X-ray spectra.

Determination of the main X and gamma-rays emission probabilities of $^{237}$Np / $^{233}$Pa and $^{65}$Zn

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The gamma-ray spectrometry is a simple and rapid analysis method, used in many applications based on the phenomenon of radioactivity. In the frame of an international cooperation, the emission probabilities of the main X and gamma-rays of $^{237}$Np / $^{233}$Pa (in equilibrium) and $^{65}$Zn were determined, by using X and gamma-rays spectrometry. The accurate measurements of the activity concentration of the radioactive solutions (performed by using absolute standardization methods) together with the high quality efficiency calibrations of the Ge-HP detectors used, allowed the computation of the emission probabilities of many X and gamma-rays of $^{237}$Np, $^{233}$Pa and $^{65}$Zn. Most of the results are characterized by competitive uncertainties; for instance, the emission probabilities of the most important gamma-rays originating from $^{237}$Np (29.4 keV), $^{233}$Pa (312.0 keV) and $^{65}$Zn (1115.5 keV) are 0.1350, 0.378 and 0.498 respectively, while the associated relative combined uncertainties are 1.2, 0.6 and 0.4 % respectively. The obtained results, partially reported at the international level, can be used in evaluations of nuclear and atomic decay data, radioactive waste monitoring and radiation protection. The subjects of the future collaboration between the authors, in the field of gamma-ray spectrometry, are also presented.
Preparation and standardization of a $^{153}$Sm Cl$_3$ radiopharmaceutical solution

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The paper presents the results obtained in the preparation and standardization of a $^{153}$SmCl$_3$ solution, to be used as a radiopharmaceutical. The radioactive material, $^{153}$Sm, was obtained by irradiation in the TRIGA SSR 14 MW Reactor. A $^{153}$SmCl$_3$ solution in HCl was prepared. The standardization was made by using the 4πPC-$\gamma$ coincidence method, in the efficiency extrapolation variant. Extrapolation graphs, type

$$\frac{N_{\beta} N_{\gamma}}{MN_{c}} = \frac{N_0}{M} \left[ 1 + (1 - K) \left( \frac{N_{\gamma}}{N_{c}} - 1 \right) \right],$$

where $N_{\beta}$, $N_{\gamma}$, $N_{c}$ are counting rates, $N_0/M$ is the activity concentration, and $(1-K)$ is the extrapolation graph slope, were obtained. Two efficiency intervals were used; first and second degree polynomials were calculated. The chosen values, for a linear graph, were: $N_0/M = (487.52 \pm 0.53)$ Bq g$^{-1}$; 1-K = 0.207 ± 0.006. The type A uncertainty, $u_A = 0.11%$; uncertainties were: 0.3% from various extrapolations, 0.015% and 0.03% from dead time and resolution time corrections, 0.1% from back ground correction and 0.05% from weighing. The combined uncertainty, for $k = 1$ confidence level, was 0.22%. The standardized solution was used for the calibration of a secondary standard equipment using a CENTRONIC IG12/20A ionization chamber. The response value, for a 10 ml vial, containing 4.6222 grams of solution was found experimentally as $R = (2.49 \pm 0.02)$ pA . MBq$^{-1}$. The obtained response value was compared with the calculated values and literature data. The calculated response value, from the separate contributions of bremsstrahlung radiations due to beta radiations, $R_{\beta} = 0.3$ pA . MBq$^{-1}$, and from the X and gamma rays, $R_{\gamma} = 2.13$ pA . MBq$^{-1}$, is $R = 2.43$ pA MBq$^{-1}$. The agreement with the experimental value is good. By comparing our results with other literature data, obtained by M.J.Woods (NPL – UK, 1998) similar values of the ratios between $^{188}$Re and $^{153}$Sm responses were found.
Accurate Measurements of Surface Emission Rate for Large-Area Alpha and Beta Reference Sources

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1. Introduction
For alpha emitters and beta emitters with maximum beta energy greater than 0.150 MeV, the characteristics of reference sources for the calibration of surface contamination monitors are specified by the international standard ISO 8769. According to this standard, the surface emission rate of reference sources has to be measured by absolute methods or by using an instrument that has been calibrated by means of sources that has been measured absolutely. Moreover, the surface emission rate has to be measured by the national standards laboratory with an uncertainty which must not exceed 3% (one standard deviation). In this paper, the counting system and the experimental conditions needed for accurate measurements of the surface emission rate are presented. The uncertainty of such measurements is much smaller than 3%. The evaluation of this uncertainty is also described.

2. Counting system and method of measurement
The counting system used for absolute alpha and beta surface emission rate measurements is composed of a large area, gas-flow, windowless proportional detector, an integral and a spectrometric counting channels. The method of measurement for alpha and beta surface emission rate is very simple but it is necessary to achieve the optimum experimental conditions of counting for obtaining accurate measurement results. Thus, the proportional detector has to work under a continuous and stable gas-flow and its plateau has to be long with a very low slope. To obtain a counting efficiency of 100%, it has to use a tight detector and a very pure counting gas. Additionally, the detector must be flushed and then operated under a steady gas-flow for several hours prior to measurements in order to be cleaned of air impurities.

3. Alpha and beta surface emission rate measurements
First, we have obtained the optimum conditions of counting. For beta sources, the discrimination level has been adjusted by means of a $^{55}$Fe source. Using this spectrum, we checked the stability of the counting system because the peak, corresponding to 5.9 keV X-ray, is very sensitive to gas impurities and gas-flow rate. We have measured four 100 x 150 mm² sources ($^{14}$C, $^{36}$Cl, $^{204}$Tl and $^{241}$Am) purchased from Amersham and certified by PTB. In Table 3 are compared our measurement results with certified results given by PTB. As it shown, a very good agreement is obtained.

<table>
<thead>
<tr>
<th>Source</th>
<th>E±u(E) (s⁻¹)</th>
<th>E(PTB)±u(E(PTB)) (s⁻¹)</th>
<th>E/ E(PTB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-14</td>
<td>4407.0±17.6</td>
<td>4397±73</td>
<td>1.002</td>
</tr>
<tr>
<td>Cl-36</td>
<td>5303.8±26.5</td>
<td>5320±88</td>
<td>0.997</td>
</tr>
<tr>
<td>Tl-204</td>
<td>1943.9±5.4</td>
<td>1904±32</td>
<td>1.021</td>
</tr>
<tr>
<td>Am-241</td>
<td>700.6±1.0</td>
<td>699±11</td>
<td>1.002</td>
</tr>
</tbody>
</table>

4. Conclusions
According to ISO 8769, four large-area sources emitting beta or alpha particles have been measured by using an absolute method. In order to obtain accurate measurements results, we have achieved the optimum experimental conditions of counting. Under these conditions, we have measured the surface emission rate with a relative standard uncertainty much smaller than the value of 3% required by ISO 8769. These measurement results are compared with the results certified by PTB and a very good agreement is found.
IMPROVEMENT OF THE INTERNAL GAS PROPORTIONAL COUNTING METHOD

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1. Introduction

In this paper, the counting losses due to non-ionizing beta particles are calculated analytically by means of the cross-section of electrons in order to avoid the use of the pressure extrapolation method in the internal gas proportional counting because it is costly and very laborious. These analytical calculations have been applied for activity measurements of gaseous \(^3\)H using the counting system with differential counters developed at the National Laboratory Henry Becquerel(LNHB)-Saclay. This system is composed of three proportional counters of different lengths, an electronic subassembly and a gas handling equipment.

2. Evaluation of counting losses due to non-ionizing beta particles

In order to calculate the proportion of non-ionizing beta particles \(\varepsilon_{ni}\), we consider first the beta particles of energy \(E\) which reach the cathode of the proportional detector without producing ionization. It is known that

\[
\varepsilon_{ni}(E) = \frac{(1-\eta) \lambda_i(E)}{2R}.
\]  

(1)

where \(\eta\) is the backscattering coefficient of electrons on the detector cathode, \(R\) is the inner radius of the cathode and \(\lambda_i(E)\) is the mean free path of electrons with energy \(E\) in the counting gas. Based on the definition of the normalized spectrum distribution \(f(E)\) and using eq. (1), we have

\[
\varepsilon_{ni} = \frac{(1-\eta)A}{2RN_A \rho} \int_0^{E_{max}} \frac{f(E)}{\sigma_i(E)} dE
\]

(2)

where \(N_A\) is the Avogadro number, \(A\) is the atomic mass, \(\rho\) is the density of the counting gas for the temperature \(T\) and pressure \(p\), \(\sigma_i(E)\) represents the ionization cross-section for electrons in the counting gas and \(E_{max}\) is the maximum energy for the beta spectrum of the radioactive gas. To calculate \(\sigma_i(E)\) we used the results obtained by Chouki and Segur. Based on eq.(2) and Spebeta code for evaluating \(f(E)\), we have written a programme runing on a PC for evaluating \(\varepsilon_{ni}\).

3. Measurement results

The experimental results presented in this paper have been obtained by measuring two samples of \(^3\)H collected from a cylinder. The correction factor \(f_d\) has been calculated from the differential spectra. To compute \(\varepsilon_{ni}\), the pressure and the temperature of the counting gas from the inside of the detector have been measured. The calculated values for \(f_d\) and \(\varepsilon_{ni}\) are shown in Table 1. Also, in Table 1 are presented the values of the measured activity per unit volume in STP conditions together with their relative standard uncertainties.

<table>
<thead>
<tr>
<th>Sample</th>
<th>(f_d) ±(u(f_d)) (%)</th>
<th>(\varepsilon_{ni}) ±(u(\varepsilon_{ni})) (%)</th>
<th>(\Lambda_V^0) ±(u(\Lambda_V^0)) (Bq/cm(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>0.50±0.01</td>
<td>0.02±0.001</td>
<td>197.1±0.9</td>
</tr>
<tr>
<td>Sample 2</td>
<td>0.20±0.02</td>
<td>0.02±0.001</td>
<td>194.6±0.8</td>
</tr>
</tbody>
</table>

4. Conclusions

In this paper, the counting losses due to non-ionizing beta particles are calculated analytically and then applied for measuring gaseous tritium (\(^3\)H). As it shown in Tab.1, the corrections due to non-ionizing beta particles are very small. Consequently, it is not necessary to be used the pressure extrapolation method for \(^3\)H measurements by internal gas proportional counting.

In conclusion, the analytical calculations of counting losses due to non-ionizing beta particles are useful because by means of them we can improve the internal gas proportional counting.
Calibration Comparative Results For X - and Gamma Ray Spectrometry With HPGe and BEGe Detectors for A Radon Reference Chamber

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Inhaled decay products of $^{222}\text{Rn}$ are the dominant components of the natural radiation exposure being responsible for about 30% of the whole human radioactive exposure. Field instruments for $^{222}\text{Rn}$ and his progeny monitoring are calibrated in “radon climate rooms”, where is possible to vary and monitor $^{222}\text{Rn}$ and the indoor air parameters ( temperature, humidity , ventilation rate, aerosol concentration ).

German radon reference chamber used was developed and installed at the Physikalisch-Technische Bundesanstalt in order to serve as a metrological standard for radon and his progeny calibration of active and passive, indoor and outdoor radon monitoring devices in air climate [1].

The basic parts of experimental setup for this $\gamma$ and X -ray spectrometry analysis consists of a $\gamma$ -X ray source in a lead shield/collimator, the detectors, the electronics necessary for pulse-height analysis (PHA) to obtain energy spectra [2,3]. For calibrating system with $^{226}\text{Ra}$ standard sources (multienergy X ray and gamma emitters ), two germanium detectors HPGe ( 12.5 nominal efficiency ) and BEGe ( 22.5 nominal efficiency ) were used.

Germanium detectors are semiconductor diodes having a P-I-N structure in which the Intrinsic(I)region is sensitive to ionizing radiation, particularly X-rays and gamma rays. The BEGe is designed with an electrode structure that enhances low energy resolution and is fabricated from select germanium having an impurity profile that improves charge collection ( thus resolution and peak shape ) at high energies which is really important in analysis of the complex spectra for uranium and finally for $^{226}\text{Ra}$ [4]. MAESTRO MCA software and GNUMPLOT program were used for spectra acquisition and respectively spectra analysis.

The main aim of this paper was to do a comparatively analysis of the detectors performances for this radon chamber spectrometric chain. The calibration data analysis includes energy calibrations for both detection systems as well as comparative X and gamma rays spectra analysis. Was stressed that BEGe detector is suited for low energies of X-rays while HPGe detector is better suited for gamma higher energies monitoring.

SELECTED REFERENCES

A Romanian Network in the field of Biomaterials

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Politehnica University of Bucharest, Biomaterials Research Center

In this paper we intend to present the effort of the people who was involved in the field of biomaterials from different specialities, like electron microscopy, optical microscopy, corrosion, wear or computer simulation. This people intend to make a Romanian Network in the field of Biomaterials, and the characterization techniques for biomaterials is one components in this network.
Thin layer activation and ultra thin layer activation: 2 complementary techniques for wear and corrosion studies in various fields.

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Thin layer activation (TLA) is widely used since more than 25 years to study surface wear or corrosion. This well known technique use most of the time charged particles activation, which give sensitivity in the range of the micrometer, except when the fluids mode of detection is utilized. In this case application of the method is limited to phenomena where we have transport of radioactive fragments to detection point. The main disadvantage of this procedure is error due to trapping phenomena between the wear or corrosion point and detection set up. So the ultra thin layer activation (UTLA) has been developed to get nanometric sensitivity without using any fluid for radioactivity transportation, which is the main source of error of the TLA technique. In this paper we shall briefly describe the TLA technique and the most important fields of application. Then we shall emphasis on UTLA with a presentation of the principle of the method and of application actually running.

The main problem concerning UTLA is calibration which requires the use of thin films (usually 10 to 100 nanometers) deposited on substrate. This process is time consuming and we shall demonstrate how running software developed in the lab can solve it. We shall finish the presentation by giving some potential application of the technique in various fields.
Archaeometrical Studies on Medieval Silver Coins at the Bucharest Tandem Accelerator

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The analysis of archaeological objects requires simultaneously, non-destructive, fast, versatile, sensitive and multielemental methods. The purpose of our work is to help Romanian curators to identify objects provenance (workshops, technologies, mines) and to explain commercial, military and political aspects. Medieval Moldavian (XIV-XVI Centuries) silver coins (groschen) were studied to determine the evolution of the coinage (debasement, metal sources, minting technologies). For these coins, two methods were used: 3 MeV protons PIXE (Proton Induced X-ray Emission) and 241Am source based XRF (X-Ray Fluorescence). XRF was used to determine the heavier elements concentrations. Comparing the trace elements results (Bi, Pb, Zn, Au, Sb) obtained on these samples with the ones on coins from the neighboring countries (Hungary, Poland, Tatar Khanate, Bohemia) we concluded that a lot of Moldavian emissions were made by melting foreign coins, probably obtained as customs taxes. For some coins, the Hg presence is an indication of the use of local silver ores to manufacture local money. The relationship between the silver content of the coins and the military conflicts during various periods is discussed.
Trace elements in cutaneous tissue by PIXE and INAA


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The research objective was to examine the content levels of some micro- and macro-elements found in the tumor tissue of patients having skin cancer disease, namely basal cell carcinoma (BCC), squamous cell carcinoma (SCC), malignant melanoma (MM) and nevus. The proton induced X-ray emission (PIXE) and instrumental neutron activation analysis (INAA) analytical methods were used. Skin samples from 22 cancer patients, aged 32-88 years, 11 males and 11 females were collected. Controls were health skin samples (histopathological diagnose) from patients having skin cancer. The concentration results generally show a large spread in the same type of samples, giving rise to large standard deviations of the mean values. By comparing with the control samples, the tumor results put in evidence the following:
- an increase of P, S and K concentrations (ratios between 2.3±0.9 and 8.8 ±6.5);
- an increase of Ca concentrations in the BCC and nevus samples (3.3 and 6.1, respectively), and in a smaller degree in the other cases;
- rather elevated concentrations of Fe and Zn, especially for MM and nevus groups;
- levels of Cl, Ti, Cr, Mn and Cu not significantly different in the tumors compared to the control samples.
22Na Positron Source for Annihilation Positron Spectroscopy

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To extend the nuclear physics applications and to perform the study of vacancy – type defects in metals, semiconductors, polymers etc., we decide to promote positron annihilation techniques. In order to this goal we started a project of dedicated positron sources produced at the IFIN-HH U-120 Cyclotron. We have used the nuclear reaction: 24Mg(d, α)22Na and deuterons of 13 MeV energy. The paper present the main steps of this procedure like as: general conditions asked for 22NaCl sources, reactive chamber and characteristics of Mg target, parameters for the irradiation, radiochemical procedures to separate Na from Mg after the irradiation and geometrical or mechanical requirements for dedicated NaCl source for positron annihilation spectrometry. In the e⁺ lifetime measurements the e⁺ “death – stop” signals are always provided by γ - quanta generated by the e⁺ e⁻ annihilation and the “birth – start” signals may be obtained from “prompt” γ - quanta emitted from the NaCl source (the 1.275 MeV photons). The 22 NaCl stock solution obtained by radiochemical separation will be keeping in the quartz sealed ampoules in dry places and will be dropped between the studied materials before used by positron spectrometry.
An overview on the mechanism of wear particles generation for polymeric materials

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The mechanism of particle generation during friction processes takes into account the combination of material characteristics (elasticity, viscosity, plasticity) and work conditions (pressure, velocity, temperature). The stress and strain field at the contact area and the material properties influence the mechanism of particle formation. The main models developed to predict particles formation due to wear are outlined and some experimental results are presented. The particle energy model (Davies-Rabinovicz) considers the mutual energy exchange between the two surfaces in contact. The particle size depends on material mechanical properties, given by surface toughness and elastic modulus and on adhesion energy between the two surfaces. The elastic friction fatigue wear model takes into account the maximum equivalent elastic stress in the material substrate and the number of load cycles. For the case when the elasticity limit is passed is considered the low cycle fatigue wear model. The critical plastic strain is evaluated as a function of geometric parameters of the friction pair and of the material behavior at friction fatigue. This case is frequently encountered at total joint prostheses where one of the two elements of the friction pair is made of polyethylene. The friction plastic flow model takes into account the correlation between asperity geometry (shape and attack angle) and mechanical properties of the softer material. The wear particles can be microchips, thin sheets, ripples, pulls, rolls, shreds and filaments. The particles can appear after a single load cycle or after multiple load cycles, depending mainly on the asperity attack angle.
Apparatus Set Cyclotron – Ion Implanter

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In the article, the apparatus set consisting of an ion implanter and a little cyclotron (ion path radius in magnetic field of 24 cm), working in the Institute of Physic, Maria Curie – Skłodowska University, Lublin is described. The implanter delivers ion beams practically of all of all elements appearing in the nature including the radioactive element. The intensity of the ion beams achieves 1 mA and its energy is the range of 20 – 100 keV. The cyclotron allows to obtain proton and á particle beams of energy in the range from 0.8 to 5 MeV with an energetic dispersion not greater than 1% and with an intensity dispersion up to 0.05 mA.

The particular attention was paid to the description of the ion source, collaborating with the cyclotron and the implanter, because its adequate work quality determines mainly a possibility of using the whole experimental apparatus. In the present work, the plasma ion source with a gap optics assuring the generation of suitable ion beams for the cyclotron was described, as well as the basic characteristic of its work is presented. The different kind of sources, collaborating with the implanter, are presented, including a thermoemission ion source and a particular plasma source with a screen grid destined for an effective ionisation of the radioactive element. Possibility of the obtaining of the two different charged particle beam at the same time creates unique conditions for the surface properties investigation of solids modified with those beams. Especially it allows for:
- solids surface investigation by means of RBS, RDS, and nuclear resonance reaction methods,
- quality and quality analysis of micro-amounts of substances (PIXE and RBS methods),
- ion implantation (at low and high energy) of the sable and radioactive element isotopes,
- research of radiation defects and other damage of crystals with the RBS and channelling methods,
- investigation of the secondary “on – line” processes connected with the ion implantation and the studs of the implantation kinetics process (“in situ” methods).
Analysis of Biological Materials by RBS and PIXE Methods

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A problem of the exact determination of the element composition of different substances is of essential significance, especially in medical, biological, as well as environment protection investigations. For this purpose some chemical and physical methods are used such as very sensitive and precise techniques: PIXE and RBS. The main advantage of those methods is the sensitivity on ppm level and very small sample amount necessary for the carrying out the investigations. In this article the investigation results of the PIXE and RBS methods for the metal contents in cow milk (18 various samples were studied) as well as the heavy metal admixtures in a brain of the living domestic animals (6 cows, 6 dogs and 17 rats) are presented. The samples were prepared for the analysis in a liofilization process, then they were mixed with a spectral pure graphite. The PIXE and RBS investigations were performed using a proton beam of the diameter about 2 mm, the intensity of about 10 nA and energy of 2.5 MeV from the Van-de-Graaf generator, FLNP, JINR, Dubna. The measurement of the characteristic spectrum were carried out by means of a Si (Li) detector with the resolving power of 200 eV at the energy of 6.4 keV. Generally in all samples of milk and brain we could identify 20 element, among them 13 (C, N, O, P, Cl, K, Ca, Fe, Cu, Zn, Br, Rb, Sr) appeared in all of the studied samples. The difference in the concentration of the most of those elements between samples was in the range of 15 – 20 %. This says about a good accuracy of the used methods of measurement. Especially our attention was payed to the presence of Sr, Rb and Br, practically in all the milk samples. This fact requires further investigations. Such elements as Pb, As, Ni, Co, Mn, V and Ti were found in some samples, including all samples coming from regions of a high urbanization. It is characteristic that the milk samples coming from villages located considerably far-away from cities and from communication tracks, practically do not include heavy elements. We observed in the brain of all animals, except of C, O, and N elements, also Rb, Sr and Br ones which, as we know, play a very important role in the metabolism of the living organism. There is some surprise of finding arsenic element (As) in all the brain samples of the rats but their absence in the dogs and the cows brains. On the other hand, lead (Pb) was observed only in dogs not finding it completely in the cows and rats. These results seem to point clearly on the important role of the environment conditions in which the animals live.
Elastic recoil detection analysis (ERDA) has been applied to determine the composition of carbon nitride and hydrogenate carbon nitride thin films prepared by laser-induced plasma chemical vapor deposition and hollow cathode discharge process. The films were deposited on Si(111), Si(100) and TiN/Si substrates. The influence of the deposition parameters on the films properties was investigated. A compact dE(gas)-E(solid) telescope was used for the detection and Z separation of the recoils. The calibration procedure of the telescope is described. The software used for the evaluation of the ERDA spectra is also presented.
**PIXE and ERDA analysis of composites for restorative dentistry**

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Dental composites, made by silicates and oxides particles embedded in an organic polymer, replaced largely silver amalgam in dentistry. However they bring in the organism exogeneous elements whose biological action is poorly understood. In the mouth element transfer and reactions can take place leading eventually to adverse effects of dental composites [1]. Due to market pressure composites show a dynamic evolution, but they are rather expensive. Recently, Romanian biomaterials offered a low-cost alternative, and control of impurities appeared clinically essential. Sensitive surface multielement analysis required for these problems is rendered by ion beam methods. Particle-induced X-ray emission (PIXE) was used in studies of dental hard tissues (e.g. [2]) and composites [3]. Though highly sensitive for trace elements, PIXE usually fails to observe low Z elements. These can be detected by elastic recoil detection analysis (ERDA). We applied PIXE and ERDA in a study on dental composites at the 8.5 MV HIPNE-HH tandem accelerator. Thick composite samples with a flat surface were prepared by polymeri-zation of 14 commercial materials and of 3 Romanian products. Measurements were performed with: 3 MeV protons, a HP Ge detector, and using 0 or 30 µm Al foil for PIXE; and with 80 MeV $^{63}$Cu$^{10+}$ ions, using a compact ΔE(gas)-E(solid) telescope detector for ERDA. Alltogether, PIXE spectra (Fig. 1) evidenced up to 24 elements with Z > 16 (Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Sr, Y, Zr, Nb, Ag, Cd, Ba, Nd, Ho, Yb, Hf, Au, Pb, many of them at trace levels), while ERDA detected up to 13 elements with Z < 21 (H, B, C, N, O, F, Na, Al, Si, P, Cl, K, Ca). Relative concentrations evaluated from the PIXE spectra using X-ray yields calculated for a simplified matrix allowed classification of the 14 biomaterials in two distinct groups: older generations dominated by Z = 17 - 30 elements and recent generations containing one or two elements such as Sr, Zr, Ba, Yb (plus Ca in some cases). Composites with close levels of one major element (e.g. Ba) were clearly differentiated either by concentration ratios or by trace elements. ERDA evidenced depth profiles for H, C, N, F, Al and Si in two composites.

On the Use of Ion Beams for the Selection of Nuclear Waste Matrices

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The safe and long-term control of radioactive waste arising from nuclear power plants is generally considered as the major challenge to future use of nuclear energy. Due to the emergence of increasingly sources of nuclear waste, there is a strong interest in the selection of new forms for radiotoxic element disposal and the development of inert fuel matrices for actinide burning [1-2]. The evaluation of nuclear waste matrices relies on numerous conditions concerning the physico-chemical properties of the selected materials, such as high melting point, good thermal conductivity, resistance against oxidation or aqueous corrosion, stability in a radiative environment and capability to retain radioactive elements. Although various classes of materials fit most of these critria, a particular attention was recently focused on single-phased oxide ceramics.

Ion beams provide efficient tools for the evaluation of nuclear ceramics. They address three major issues: (i) the simulation by ion irradiation of the radiation damage which alters the structure of the crystalline lattice; (ii) the doping of the matrix with stable or radioactive elements which simulate the species to be confined; (iii) the characterization of the material via nuclear microanalysis techniques. This paper presents illustrative examples in the case study of zirconia with an emphasis on experimental results obtained by the use of nuclear microanalysis techniques.

AMS measurements of the $^{25}$Mg(p,$\gamma$)$^{26}$Al reaction at stellar energies

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The interest in the stellar production of the $^{26}$Al began with the observation of an excess of $^{26}$Mg in the Allende meteorite, which was thought arising from in-situ $\beta^+$ decay of star-ejected $^{26}$Al ($T_{1/2}=0.716$ Myr). It was then predicted that the $\gamma$-radiation arising from these $^{26}$Al nuclei should be observable. In 1982 its characteristic 1.809 MeV cosmic $\gamma$-line was finally detected$^{11}$. Nowadays $\gamma$-ray telescopes on satellites trace maps of the $^{26}$Al production sites within our galaxy, constraining astrophysical nucleosynthesis models$^{[2]}$. According to these models, the main $^{26}$Al production path, the $^{25}$Mg(p,$\gamma$) reaction, occurs at energies in the range of $E_{CM}=100$-400 keV, which is well below the Coulomb barrier of this system ($E_{CM}=2.86$ MeV). Thus, the cross sections involved are extremely small and the production is dominated by narrow resonances$^{[3]}$. The strength of these resonances have been measured down to $E_{CM}=189$ keV by applying the common on-line detection of prompt $\gamma$-rays originating from the deexcitation of $^{26}$Al compound nuclei$^{[4-6]}$. In order to avoid the problems of interfering $\gamma$-backgrounds of on-line measurements we propose the determination of the produced $^{26}$Al nuclei using the high sensitive Accelerator Mass Spectrometry (AMS) technique$^{[7]}$. $^{25}$MgO targets are bombarded with proton beams (0.1-1 mA) at the resonance energies using an implanter$^{[8]}$ at the Forschungszentrum Rossendorf. These targets are then chemically processed with the addition of $^{25}$Al carrier, in order to separate Al from Mg. Finally, the $^{26}$Al/$^{27}$Al ratio is determined by means of AMS at the Munich tandem accelerator$^{[9]}$. $^{26}$Al AMS measurements are commonly performed using atomic the $^{26}$Al ions since the interfering isobar $^{26}$Mg does not form stable negative ions. Nevertheless, in this work we extract molecular $^{30}$AlO$^-$ from the ion source, since the efficiency of producing this negative ion is up to 20 times higher than the corresponding for Al ion. Considering that molecular MgO ions are also formed readily in the ion source, a highly selective chemical separation of Mg in conjunction with an efficient AMS system is required in order to suppress the interfering isobar $^{26}$Mg. Chemical separation down to 5 ppm of $^{26}$Mg was achieved for Al samples with masses of 300 µg. In combination with the Gas Filled Analysing Magnet separation system$^{[10]}$ measurements down to $^{26}$Al/$^{27}$Al $\sim 10^{-14}$, i.e. 10$^2$ $^{26}$Al atoms, are possible. Initial measurements with this method were successfully carried out at resonance energies of $E_{CM}=418$, 373 and 303 keV. Measurements at resonance energies down to 92 keV are carried out presently. Another approach being tested by our AMS measurements is the reaction in inverse kinematics$^{[11]}$ $^3$H(p,$\gamma$)$^{26}$Al. In this case, a methane (CH$_4$) gas stripper at the terminal of the tandem accelerator acts as target. Injecting $^{25}$MgH, $^{25}$MgO or $^{25}$MgF$_2$ at the low energy side of the tandem, the reaction energies of interest can be reached applying terminal voltages between 7.6 and 12.7 MV. The $^{26}$Al produced in the gas stripper is further accelerated on the high energy side and the most probable charge state is selected by the analysing magnet, while interfering ions ($^{25}$Mg as well as spurious $^{26}$Mg) are separated by common AMS techniques.

[10] http://www.bl.physik.uni-muenchen.de/gams
AMS measurement of the neutron capture cross section \( ^{209}\text{Bi}(n,\gamma)^{210}\text{Bi}^{9-} \)

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Bismuth (\(_{83}\text{Bi}\)) is both the heaviest and the neutron richest stable element used as target in a spallation neutron source. The long-lived daughter nuclei produced by using Bi as target in the nuclear reactor are \(^{208}\text{Bi}\) (0.37 Ma) and \(^{210}\text{Bi}^{9-}\) (3.0 Ma). Known experimentally up to now are the cross sections: \(\sigma(\text{Bi}(n,2n)^{208}\text{Bi}) = 2.3\text{b}\) and \(\sigma(\text{Bi}(n,\gamma)^{210}\text{Bi}^{1-}) = 23\text{mb}\). The aim of this work was to test the experimental conditions and feasibility for the difficult AMS experiment at very heavy masses as required by the measurement of the cross section \(\sigma(\text{Bi}(n,\gamma)^{210}\text{Bi}^{9-})\).
When classifying waste material from nuclear facilities before final disposal it is of great importance to know the distribution of organic and inorganic $^{14}$C. This is due to the fact that organic carbon is released sooner to the environment (and is therefore more difficult to model).

The first nuclear research reactor built in Sweden was dismantled in the beginning of the 80’s. It was equipped with a graphite reflector, which now is ready for final disposal. The classification of this reflector requires measurement of the distribution of organic and inorganic $^{14}$C. Samples of gram size have been taken from different parts of the reflector. To perform measurements of the content of $^{14}$C - organic as well as inorganic - in these samples, a combustion and CO$_2$ absorption system has been built and optimized. Samples obtained from the combustion and CO$_2$ absorption system have been analyzed by a liquid scintillation counter.

Ten samples have up till now been analyzed. The results show a mean value for the organic $^{14}$C of 519 Bq/g and for the inorganic $^{14}$C a mean value of 1033 Bq/g. The combustion system and the obtained results and their quality will be discussed.
Biomedical Tritium Applications with AMS detection

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There are various applications for Tritium isotope in biomedical field commonly used together with liquid scintillation detection method. The use of accelerator mass spectrometry (AMS) as a new detection method will enlarge and open up new possibilities for tritium applications in biomedicine. In the case of AMS detection the samples are required to be transformed from the biological matter to the form of suitable for the AMS accelerator system, i.e. to the form yielding high output of negative hydrogen current from transformed matter. The transformation is done in two steps: firstly extracting water from the biological sample and secondly, extracting hydrogen/tritium from the water and forming chemically suitable compound for the AMS system.

This paper will report our first successful results developing a chemical sample preparation for tritium AMS and will discuss first test measurements of tritiated water with known activity using AMS detection method.
Recycling of bomb produced $^{36}\text{Cl}$

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The success of accelerated mass-spectrometry (AMS) has allowed the measuring of very small quantities of radioactive nuclides with the ratio to their stable isotope up to $10^{-14}$. With the help of this method the concentration of $^{36}\text{Cl}$ in natural samples can be investigated. The main sources of $^{36}\text{Cl}$ in the atmosphere are

a) the natural production in nuclear reactions induced by the interaction of high energy cosmic rays with atmospheric Ar

b) the production by the interaction of high neutron fluxes emitted during nuclear weapon tests with stable chlorine

c) the production in nuclear plants with the following release (Chernobyl accident)

The analysis of $^{36}\text{Cl}$ time profile in Greenland showed the fast removal of chlorine from the atmosphere so that nowadays only the natural production of $^{36}\text{Cl}$ is of importance. However the measurement of $^{36}\text{Cl}$ in modern precipitation revealed the significant excess of its concentration over the simulated predictions.

The recycling of chlorine as an explanation of the observed discrepancy is argued. The biosphere took up a part of the fallen down bomb produced $^{36}\text{Cl}$ and releases it into the troposphere in the form of CH$_3$Cl. To check the hypothesis the experiment to collect methyl chloride from the air and to measure $^{36}\text{Cl}$ was set up. The high observed ratio $^{36}\text{Cl}/\text{Cl}$ proves that the chlorine recycling takes place. Additionally in order to get more information about the distribution of $^{36}\text{Cl}$ fluxes the measurements of the nuclide concentration in lakes with long flushing times were performed. With the help of modeling the different sources of $^{36}\text{Cl}$ can be distinguished. In most of European lakes $^{36}\text{Cl}$ from Chernobyl accident prevails.
Dating of Some Fossil Romanian Bones

by Accelerator Mass Spectrometry

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Some Romanian fossil bones from Romanian territories have been dated by accelerator mass spectrometry (AMS) using the pelletron system from Lund University. The preparation samples has been the classical procedure to produce from bones specimens, pure graphite. The Paleolithic site from Malu Rosu, near Giurgiu was extended analyzed. 2 human fossil skulls from Cioclovina and Baia de Fier of special archaeological importance have been estimated to be of an age around 30 000 years, a conclusion with great implications for the history of ancient Romania. By this physical analysis, a long scientific dispute was finished. The two fossil human skulls are the only ones of this age from Romania. One could advance the hypothesis that the skulls belong to a certain type of a branch of Central European Cro-Magon, the classical western type, considering both the chronological and the anthropological features. They constitute eastern limit of the Cro-Magnon man type.
Tritium detection by AMS

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Tritium and deuterium depth profiling measurements in carbon samples have been performed at the Rossendorf AMS facilities during the past seven years. The samples have been cut from tiles of the inner walls of the fusion reactors ASDEX-upgrade/Garching, JET/Culham and TFTR/Princeton. The samples from the European fusion experiment JET, which had been operated part time with a D,T plasma showed tritium contents up to six orders higher compared to the samples from ASDEX-upgrade. This required a dedicated AMS facility to prevent any contamination of the versatile 3 MV Tandetron. It is based on an SF$_6$-insulated 100 kV tandem accelerator equipped with a diamond-like carbon (DLC) stripper foil of about 1 µg/cm$^2$. Depth profiles of deuterium and other light elements can be measured simultaneously using a Faraday cup at the entrance of the accelerator (SIMS-mode of the facility) or in case of very low concentrations after acceleration using a Si-detector (AMS-mode).
Accelerator Mass Spectrometry as a Tool in Geology and Archaeology

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Since its introduction more than twenty years ago, as a new method for 14C-dating, accelerator mass spectrometry (AMS) has become an increasingly important tool for geologists and archaeologists. The possibility to use samples of a few mg or even smaller samples has opened for new applications in the field of 14C-dating. Even more important is perhaps that AMS has made other, extremely rare cosmogenic isotopes like 10Be, 26Al and 36Cl available for earth science.

Some examples of new applications in geology and archaeology for 14C and other cosmogenic isotopes will be given.
AMS Depth Profiling of Tritium and Deuterium – A New And Sensitive Tool for Diagnose In Fusion Experiments

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The upgraded Ultra Clean Injector (UCI) of the Munich Accelerator Laboratory was used to measure T and D depth profiling with Accelerator Mass Spectrometry (AMS). The measurements were performed on carbon long term samples (LTS) placed between the vessel wall protection tiles of the ASDEX-Upgrade fusion experiment. The improvement of plasma confinement and stability after introducing the CDH-mode has been determined. The localisation of a plasma disruption phenomenon was demonstrated. Complete toroidal and poloidal distribution of tritium depth profiles and inventory of tritium release in the tokamak were measured. Depth profiling of deuterium provided information about the quality of the neutral beam injection and efficiency of the fusion reaction in the tokamak.
**Radioecological applications of 14C measurements at the Lund Accelerator Mass Spectrometry (AMS) Facility**

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14C is one of the radionuclides which are produced to different degrees by neutron-induced reactions in all types of nuclear reactors. Part of the 14C created is continuously released as air-borne effluents in various chemical forms (such as CO2, CO and hydrocarbons, depending on the type of reactor) during normal reactor operation. Also fuel-reprocessing plants are known to release substantial amounts of 14C. Because of the biological importance of carbon and the long half-life of 14C it is of interest to measure the releases and their incorporation into living material in the surroundings of nuclear facilities. It has been estimated that of all radionuclides released by the nuclear power industry, 14C is likely to produce one of the largest collective dose commitments. In this paper we present the program for radioecological applications of 14C performed at the Lund accelerator mass spectrometry (AMS) facility. Some recent results of measurements from the surroundings of the CANDU reactor in Cernavoda, Romania, are presented.
In beam \((n,\alpha)\) cross-section measurements for nuclei from the Th-U cycle


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For in-beam neutron radiative capture reactions, it is important that the efficiency of the photon detector be independent of the capture \(\alpha\)-ray spectrum which may vary strongly according to the target nucleus and to the energy of the bombarding neutron. In the past, this requirement was partially fulfilled through the use of large scintillators and a \(4\pi\) geometry. However, these detectors usually failed to detect all capture events resulting in the emission of a single high-energy \(\alpha\)-ray. To overcome this problem, one can use so-called total energy detectors which are composed of liquid scintillators of smaller size (Ne213 and C6D6) to which a weighting method is applied. This technique consists of appropriately weighting the detected events according to their photon pulse height amplitude information in order to achieve a capture detection efficiency proportional to the total \(\alpha\)-ray energy emitted.

Experimentally, the weighting function can be deduced knowing the efficiency and the response function of the detector. These two quantities were obtained by measuring \(\alpha\)-ray transitions in the energy range 122 keV-6 MeV from radioactive sources (up to 2.6 MeV) and from \((p,\alpha)\) resonance reactions using a high resolution germanium detector operating both in single mode and in coincidence with the scintillator. Using two fold \(\alpha\)-ray multiplicities, the efficiency can be derived from the ratio between the peak areas of the complementary \(\alpha\)-ray in the coincidence and singles Ge spectra. Similarly, the response function of a given \(\alpha\)-ray is obtained from those scintillator pulses which are in coincidence with a full energy peak of a complementary transition. The experiments were performed at the 4 MV Van de Graaff accelerator of the CENBG Bordeaux. Targets of \(^{34}\)S and \(^{27}\)Al were used with a proton beam of the order of 10 \(\mu\)A and energy of 1.2-1.4 MeV. The experimental set-up consists of a Ge detector and a liquid scintillator (either a C6D6 or an Ne213 counter).

The angles with respect to the beam-axis of the Ge detector (55°) and the liquid scintillator (180°) were chosen in order to minimize angular distribution and correlation effects.

The response functions deduced from those measurements will be applied for the neutron capture cross-section measurements of nuclei like \(^{232}\)Th and \(^{233}\)Pa which are particularly important for the new Th-U fuel.

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Structure and dynamic investigations by neutron scattering technique at NIPNE HH

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Neutron scattering provides basic information on the structure and dynamics of materials and made outstanding contributions to our detailed understanding of condensed matter science at a microscopic level, not only in physics but also in the fields of materials science. The behavior of materials is determined by the arrangement of atoms and the forces between them. Therefore the neutron is an ideal probe for the investigation of the physics of the condensed matter and based on this property. The neutron scattering led to many advances in the physics of technically impulse materials as well as of the fundamental phenomena. Here we present a part of the main experimental results obtained by means of the inelastic scattering of the neutrons diffraction started at VVR S reactor in Bucharest and after that is continued at higher performance neutron sources such as: the fast pulsed reactor IBR 2 at FLNP in Dubna, the research reactor BER II in HMI BENSC Berlin and at the Orphee! reactor of LLB, CEA Saclay. The results of all measurements, a part of them already published, other are in course of publication or are to be published or obtained in the frame of the international user competition.
**Phonon Density of States of Superconducting**

\[ \text{Bi}_{1.6}\text{Pb}_{0.4}\text{Sr}_{1.8}\text{Ba}_{0.2}\text{Ca}_2\text{Cu}_3\text{O}_\delta \]

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Bi-based cuprates consist of at least of three superconducting phases with very similar crystal structures. The general chemical formula for these phases can be written as Bi\(_{2}\)Sr\(_{2}\)Ca\(_{n-1}\)Cu\(_n\)O\(_{2n+4+y}\) where \(n=1,2\) and 3 corresponds to the 2201 (\(T_C=10\)K), 2212 (\(T_C=80\) K) and 2223 (\(T_C=110K\)) phases, respectively. The high-\(T_C\) (2223) phase is difficult to prepare in a single phase. Partial substitution of Pb for Bi aids the growth of the 2223 phase. The Cu-O sheets are primarily responsible for the superconductivity in the HTSCs. It is well established that in conventional superconductors the coupling between electrons and phonons (collective vibrations) leads to charge carrier pairing, and therefore superconductivity. The role of this coupling in copper-oxide superconducting materials is still a subject of intense research efforts. Raman scattering experiments have demonstrated the coupling between the superconducting electrons and the phonons in HTSCs. In this way the inelastic neutron scattering may also be a powerful tool.

No vibrational study either by Raman or INS method was performed so far on Bi(2223) compound. The paper presents new results obtained by means of the inelastic slow neutron scattering taken on a high resolution time-of-flight spectrometer at BER II reactor of BENSC, Berlin.
Spin-resolved off -specular neutron scattering from magnetic domains using polarized $^3$He gas spin filter.

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The exchange bias (EB) phenomenon is associated with interfacial coupling between ferromagnetic (F) and antiferromagnetic (AF) layers, which results in an unidirectional magnetic anisotropy. Macroscopically one observes: (1) a shift of the hysteresis loop as the system is cooled in an applied magnetic through the Neel temperature ($T_{\text{Neel}}$) of the AF layer; (2) exchange bias field $H_{\text{EB}}$ deviates from zero at the blocking temperature ($T_B<T_{\text{Neel}}$) and its absolute value increases as the system is cooled down; (3) coercive field $H_C$ increases as well and, sometimes exhibits peak-like dependence close to $T_B$; (4) the magnetization reversal might be different for the ascending and descending part of the hysteresis loop. Several theoretically models have been proposed for describing possible mechanisms of the EB effect. So far the understanding of the coupling at the interface between F and AF is still under debate.
A neutron scattering study of the motions performed by the protons on different time scales in low-concentration Zr hydrides

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A hydrogen atom dissolved in a metallic lattice may perform motional processes on very different time scales. At very short times the H atom vibrates against its metallic neighbors which due to their much heavier masses do not participate in this high frequency vibrations. Depending on H concentration and H-H interaction they can be considered either as local or optical modes. At the time scale of the acoustic vibrations of the host lattice, the H atoms moves according to the distortion pattern imposed by the host phonons. Whether these motions - called the band modes - mirror or not the host density of states is still a not well resolved problem. At much longer times the H is able to leave its interstitial site and to diffuse by jump mechanisms to other sites. The techniques of inelastic (INS) and quasielastic (QENS) neutron scattering are the most powerful methods for a complete investigation of these motions offering simultaneous measurement of both their time and space development. Recent results obtained on the H mobility in low concentration Zr hydrides are reported here.
Conversion electron and gamma spectroscopy at GSI and GANIL

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The GANIL facility provides both secondary and reaccelerated secondary radioactive beams. An example for the first case is the fragmentation of a $^{78}$Kr beam at 73 MeV/u using the LISE3 spectrometer. The technique of combined conversion electron and γ-ray spectroscopy was applied. Isomer decays of radioactive nuclei in the mass A = 70 region were studied. The Coulomb excitation campaign with radioactive SPIRAL beams represents the second case. Neutron-deficient Kr isotopes were investigated with the EXOGAM spectrometer.

The fragment separator (FRS) at GSI delivers very high intensity radioactive beams with energies up to 1 GeV/u. A new project (RISING), dealing with the use of the EUROBALL detectors, aims to perform fragmentation and Coulomb excitation reactions of in-flight separated rare isotopes from the FRS. To identify the out coming products after the secondary target by mass and charge, a specifically designed calorimeter telescope (CATE) is planned to be used.

Furthermore, the presently available pion beams at GSI give a new possibility to perform high resolution γ-spectroscopy of hyper-nuclei.
Multicharged ion sources – an efficient tool for nuclear research and applications

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The multicharged ion beams are widely used in nuclear physics research carried out with particle accelerators, in atomic physics due to their large coulomb potential that induce various interactions on atoms and surfaces even at low kinetic energies and in many industrial and medical applications.

The multicharged ion beams are mainly produced in electron cyclotron resonance (ECR) ion sources. The working principle of this type of ion sources is shortly presented as well as the actual state of the art in this field.

Finally, the 14 GHz ECR ion source RECRIS built in Bucharest is shortly described.
Computer Axial Tomography (CAT) is one of the most adequate non-invasive techniques for the investigation of the internal structure of a large category of objects. Initial designed for medical investigations, this technique, based on the attenuation of X- or gamma-ray (and in some cases neutrons), generates digital images which map the numerical values of the linear attenuation coefficient of a section or of the entire volume of the investigated sample. Shortly after its application in medicine, CAT has been successfully used in archaeology, life sciences, and geosciences as well as for the non-destructive industrial control. Depending on the energy of the utilized radiation as well as on the effective atomic number of the sample, CAT can furnish, with a spatial resolution of 0.01 - 0.5 mm, quantitative as well as qualitative information concerning local density, porosity or chemical composition of the sample.

At present two types of axial Computer Tomographs (CT) are in use. One category, consisting of medical as well as industrial CT are equipped with X-ray tubes while the other use isotopic gamma-ray sources. CT provided with intense X-ray sources (equivalent to 12-15 kCi or 450-550 TBq) has the advantage of an extremely short running time (a few seconds and even less) but presents some disadvantages known as beam hardening and absorption edge effects. These effects, intrinsically related to the polychromatic nature of the X-ray generated by classical tubes, need special mathematical or physical corrections. A polychromatic X-ray beam can be made almost monochromatic by crystal diffraction or by using adequate multicomponent filters, but these devices are costly and considerably diminish the output of X-ray generators.

In the case of CT of the second type, monochromatic gamma-rays generated by radioisotopic sources, such as $^{169}$Yb (50.4 keV), $^{241}$Am (59 keV), $^{192}$Ir (310.5 and 469.1 keV ) or $^{137}$Cs (662.7 keV), are used in combination with energy dispersive detectors such as NaI(Tl) or HPGe (High Purity Germanium). In this case there are no beam hardening or absorption edge effects. Gamma-ray generated by a single radioisotope source or by pairs of sources can be used. The use of gamma-rays with different energies makes it possible to measure simultaneously both the density and effective atomic number of the absorbent, techniques known as dual energy CAT.

The majority of isotopic gamma-sources have an activity a few orders of magnitude lower than X-ray tubes, which proportionally increases the acquisition time. Despite this inconvenience, dual energy CT equipped with gamma-ray sources can generate useful true density or effective atomic number maps of the investigated sections.

In both cases, the use of finite diameter beam of X- or gamma-ray determine the final spatial resolution CAT images, resolution that can not be lower than beam diameter. This peculiarity generate another effect known as partial volume effect as so as the linear attenuation coefficient corresponding to a voxel is in between numerical values of its components.

In geosciences, CAT has been successfully applied to the determination of bulk density, moisture content or macroporosity of the soil, soil-plant-water system, oil sand or shales, small scale heterogeneities in siltstone or sandstone, diamonds in kimberlite, mineralization layers in manganese nodules, layered structure of metamorphic gneiss, spatial distribution of different minerals that compose basalt, local structure of marine sediments or coal composition. Indirect information concerning both major and minor components of investigated rocks can be obtained by interpreting CT images histograms. CAT method has also been used for the investigation of the rock mechanical properties, rock permeability, fracture network, two or three-phase flow or residual oil distribution in carbonate cores. A review of the actual applications of CAT in soil science, sedimentology, petrology, coal geology as well as rock mechanics is presented. All these applications reveal the great potential of CAT in geoscience investigations.
Picobarn cross section fusion reactions for production of superheavy nuclei

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The crucial practical problem of how to produce superheavy elements besides in the fact that fusion cross sections are extremely low. A suitable theoretical two-center shell model is presented to provide target-projectile pairs in favorable combinations which allow the transition from two different systems to one. In such a way, the potential energy surfaces, as they are calculated in the framework of the deformed two center shell model, exhibit pronounced valleys, as these provide promising doorways to the fusion of superheavy nuclei for certain target-projectile combinations around spherical partners. Certain situations when one or both fragments are deformed are also investigated. Such an approach yields to cold valleys due to deformed shell structure even though these valleys are less pronounced than for spherical fragments. Calculations and results are presented for the synthesis of A=306 Z=122. An advanced asymmetric single-particle shell model describing the transition from one nucleus energy level scheme to two separated ones is presented. The potential is based on two deformed oscillators smoothly joined one to the other by a necking region. The neck is generated by a centrifugal type potential. The total potential describes spheroidal fragments with a spherical neck in between. In order to allow continuity between the three potentials within the Hilbert space, three matching potential surfaces are found: one between the two deformed oscillator potentials describing each of the fragments, and another two between every oscillator and the neck potential. In this way every of the potentials is confined within a defined region in space, edged by these matching surfaces. A diagonalization basis is found for a much simplified two-center potential, and the total Hamiltonian is diagonalized.

We are first interested in applying the model to investigate superheavy nuclei. Two crucial practical problems are addressed: how to find the optimal target-projectile pairs to produce superheavy elements and which is the way these massive nuclei decay by fission. Both cannot be answered realistically unless a suitable microscopic model is available to provide the transition from two different quantum systems to one and the smooth splitting of the synthesized nucleus into two final fragments. Despite the fact that fusion valleys appear especially around magic or double-magic partners, it is not always possible to combine spherical nuclei from known regions, because the compound system would be severely neutron-deficient. Therefore, due to the form of the chosen potential within our two-center shell model, situations where one or both fusion partners are deformed can be investigated. Such an approach yield to cold valleys due to deformed shell structure within the overlapped target-projectile region in the fusion process. Potential energy surfaces are computed within a 5-dimensional space of deformation including the distance between the two centers, the necking radius, the ratios between the two semi-axes of the spheroids of each of the partners and the mass asymmetry. Fusion valleys of A=306, Z=122 are presented and the energetically most favoured fusion and fission channels are emphasized.
At the present rate of consumption, the known uranium resources on earth will be sufficient to continue its use as fuel for nuclear energy production for no longer then about 200 more years. Other fuels such as oil and gas probably face an even shorter life before exhaustion of known resources. At the same time the actual rate of radioactive waste production associated with this energy generation requires technical solutions that will permit the continuous support of economic growth and improved quality of life, together with a minimal impact to environment. Worldwide new research programmes for radioactive waste management have recently been undertaken. In France, at the French National Research Council (CNRS), various groups are presently working on the development of new technologies to reduce the present inventory of nuclear wastes and simultaneously on more efficient ways to use the thorium natural resources to generate nuclear energy while minimizing waste production during many centuries.

At the Centre d’Etudes Nucléaires in Bordeaux we have undertaken a programme of cross-section measurements for neutron-induced reactions with energies ranging from a few MeV to 6 MeV. We have in particular measured the \((n, \alpha)\) and/or the \((n,\text{fission})\) cross-sections for three nuclei \(^{232}\text{Th}, ^{233}\text{Pa}\) and \(^{233}\text{U}\) playing an important role for the Th-U cycle. This fuel offers a number of advantages (in particular a factor 100 less minor actinides produced) compared to the commonly used uranium fuel in light water pressurized reactors. Furthermore we have also remeasured the transmutation rate for the long-lived fission products \(^{129}\text{I}\) which have a half live of \(1.6\times10^7\) years. The various experiments have been performed at the 4 MV Van de Graaff accelerator in Bordeaux and at the Tandem accelerator of the Institut de Physique Nucléaire in Orsay.

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Production of clinical useful quantities of $^{18}$F by an electrostatic tandem accelerator

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The 3 MV electrostatic tandem accelerator in Lund, Sweden, is routinely used for production of the short lived (half-life 110 minutes) isotope $^{18}$F. A beam of 5.7 MeV protons irradiates an open silver-target containing 0.5 ml H$_2^{18}$O water, enriched to 97%. Using a beam current of 10-12 µA and an irradiation time of 60-120 minutes, the nuclear reaction $^{18}$O(p,n)$^{18}$F gives a $^{18}$F-yield of typically 2.7-4.5 GBq. The produced $^{18}$F is used for synthesis of 2-$^{18}$FDG. This radio pharmaceutical (an analogue to glucose) is used in oncological positron emission tomography (PET) studies at the nearby hospital.

In this report technical details of the production, as well as a short outline of the synthesis and application in oncology, are given.
Physics issues with a new gamma ray detector based on tracking:

AGATA (Advanced GAmma Tracking Array)

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During the last two decades the development and improvement of very efficient $4\pi$ Ge detectors have provided an enormous amount of information on the structure of the atomic nucleus. One of the most important of these nuclear structure physics was the prediction and the observation of superdeformed (SD) shapes [1]. The fascinating phenomenon of identical SD bands [2] has also been one of the most exciting discoveries, but for its understanding a global and consistent theory is still lacking. Even though the arrays such as Euroball [3](in Europe) or Gammasphere [4] (in the USA) still enable new interesting studies at high angular momentum and will allow experiments at very low cross section with radioactive beams facilities in the next few years, their performance is close to the ultimate limit that can be obtained with escape-suppressed devices. The new generation of $\gamma$-ray detectors such as GRETA [5] in the USA and AGATA [6] in Europe, will provide a dramatic gain in efficiency above any presently existing array. A new Research and Development is required to implement the next generation of Ge arrays. The aim is to design a $4\pi$ Ge array based on a new concept of detection using gamma ray tracking and recent advances in crystal segmentation technology. This concept is based on the ability to locate, within few mm, each interaction point in the Ge detector and consequently track the scattering sequence of an incident $\gamma$-ray. The tracking method will consist of the reconstruction of the full energy by combining the appropriate interaction points. As a result this will provide a significant gain in efficiency because the Compton shields will not be necessary and will be replaced by active Ge detectors to give for the first time a real $4\pi$ Ge ball. In this talk, the emphasis will be on few examples of physics cases [7] which can be addressed in nuclear structure with the new generation of $\gamma$-ray detectors. The limitations of the current arrays will be discussed and the capabilities of AGATA will be described.

Optimal deuteron energy for a neutron rich nuclei source based on fission

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A neutron rich nuclei source can be conceived by using the neutron induced fission process. A high neutron flux can be obtained through the deuteron break-up reaction in the so-called converters. The number of fission events and their isotopic distributions produced in an uranium target depend on the deuteron incident beam energy, the characteristics of the converter, the geometry of the combination. A theoretical approach is presented in order to optimize the number of fission events in the uranium target as function of the above mentioned parameters. The initial kinetic energy of the deuteron beam, the nature of the converter and its geometry determines the angular and energy distributions of the emerging neutrons.

The models used to simulate these distributions are essentially based on the Serber's approximation. The fission is treated in a microscopic-macroscopic approach using the two center shell model. A new concept is used to determine the isotopic distribution of the fission fragments as function of the neutron energy. A sudden dumping of the neutron energy is produced in the compound nucleus which modifies the two humped fission barrier and produces changes of the penetrabilities associated to each binary partition and therefore, in the isotopic distribution. Finally, our results show that a good value of the incident deuteron energy suitable for the production of neutron rich beams is in the vicinity of 80 MeV [1].

Development of High Power Accelerators and Some of Their Applications

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Strong R&D programmes are underway in Europe for the Development of ultra-high intensity injector Accelerators and for Super Conducting Cavities. There are many fundamental and applied motivations for this new type of accelerators. We report on these issues with a particular emphasis on the EU programmes for a radioactive beam facility ("EURISOL") and for a transmutation of nuclear waste demonstrator ("XADS" = Experimental Accelerator - Driven System).
Studies of chemical properties of the transactinide elements - starting with element 104 (Rf) - offer the unique opportunity to obtain information about trends in the Periodic Table at the limits of nuclear stability and to assess the magnitude of the influence of relativistic effects on chemical properties. To explore experimentally the influence of relativistic effects of electron shell structure, we are studying chemical properties of the transactinide elements.

So far, we have developed some experimental apparatuses for the study of chemical properties of the transactinide elements: a beam-line safety system for the usage of the gas-jet coupled radioactive \(^{248}\)Cm target chamber for the production of transactinides, a rotating wheel catcher apparatus for the measurement of \(\alpha\) and spontaneous fission decay of transactinides and an automated rapid chemical separation apparatus based on high performance liquid chromatography.

The transactinide nuclide, the element 104, \(^{261}\)Rf \((t_{1/2}=78 \text{ s})\) has been successfully produced via the reactions of \(^{248}\)Cm\(^{(18}\text{O,5n})\) at the JAERI (Japan Atomic Energy Research Institute) tandem accelerator. The evaluated production cross section was about 10 nb, indicating that the production rate was approximately 2 atoms per min. Because of the short half-life and the low production rate of Rf, each atom produced decays before a new atom is synthesized. It means that any chemistry to be performed must be done on an "atom-at-a-time" basis. Therefore rapid, very efficient and selective chemical procedures are indispensable to isolate the desired transactinide \(^{261}\)Rf. To perform fast and repetitive ion-exchange separation of Rf, we have developed the apparatus AIDA (Automated Ion exchange separation system coupled with the Detection apparatus for Alpha spectroscopy).

Recently, ion-exchange behavior of Rf in acidic solutions has been studied with AIDA, and the results indicate that anion-exchange behavior of Rf is quite similar to that of the group-4 elements Zr and Hf; the results clearly show that Rf is the member of the group-4 elements.

The present status of the atom-at-a-time chemistry of Rf at JAERI is reviewed.
We studied the fusion gain for the center-of-mass collision of two clusters of radius $r$, particle concentration $n$ and incident velocity $v$. We have assumed, as previously, that as a result of the impact of the two clusters a region of hot plasma is created of temperature $T$, expressed in keV, the radius of the region being $2^{1/3} r$. The gain has been evaluated as $G = n(\langle \sigma v \rangle r/v_T) (E_Q/3T) [1+(Z_1+Z_2)/2]^{-1}$, where $Z_1$ and $Z_2$ are the charges of the reacting nuclei, and $E_Q$ is the energy released in a fusion process. In this section it will be assumed that the particle concentration $n$ is that corresponding to the normal, uncompressed state of the incident clusters. The gain $G$ has been represented in Fig. 1 for DT processes as a function of the plasma temperature $T$ for several values of the radius $r$, using $n=4.5 \times 10^{22}$ particles/cm$^3$, $E_Q=17.6$ MeV. Due to the relatively large values of $\langle \sigma v \rangle$ for the DT fusion processes, it can be seen from Fig. 1 that a gain $G=1$ could be achieved for incident clusters having a radius of the order of $r=1$ mm, for a plasma temperature of the order of 20 keV. In this model, the gain decreases linearly with the radius $r$. The gain parameter $G$ has been also calculated for $p^{11}B$ fusion processes, for $n=3.34 \times 10^{23}$ nuclei/cm$^3$, which corresponds to $B_{9}H_{15}$, and $Q_{e}=8.68$ MeV. The $p^{11}B$ fusion process is in principle interesting, and the maximum gain for the $p^{11}B$ processes occurs for a plasma temperature $T$ around 200 keV. We have calculated the radius of the clusters for which the gain is $G=1$ as a function of the plasma temperature $T$, for various possible fusion processes. The most suitable process for the production of fusion reactions by cluster impact remains the DT reaction, both as regards the dimensions of the incident clusters and as regards the incident energy per nucleon, with the $p^{11}B$ reaction sensibly far behind, but still interesting. In Fig. 2 we show the incident energy required in the center-of-mass system to obtain a gain $G=1$ at a plasma temperature $T$ by cluster impact. The requirement on the incident energy for $G=1$ by uncompressed cluster impact is of about 1 MJ for DT reactions, and is very much larger for the other fusion processes.
Neutrino masses from double-beta decay

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A systematic study of the two-neutrino and neutrinoless double-beta decay matrix elements (ME) for the nuclei with \( A = 76, 82, 96, 100, 116, 128, 130 \) and 136 is done. The calculations are performed with four different quasi random phase approximation QRPA-based methods (i.e. the proton-neutron QRPA, the renormalized proton-neutron QRPA, the full-RQRPA, second-QRPA) and a critical analysis of the results is presented. A better stability against the change of the s.p. basis used and a good fulfillment of the Ikeda Sum Rule allow to reduce the uncertainties in the values of the neutrinoless ME predicted by the QRPA-based methods to about 50% from their magnitude. Taking the most recent experimental limits for the neutrinoless half-lives, we deduce new upper limits for the neutrino masses. The recent claim of the experimental evidence for the neutrinoless double-beta decay mode is also discussed. Finally, for each nucleus scales are estimated for the neutrinoless double-beta decay half-lives that the experiments should reach for exploring neutrino masses around 0.1 eV. This might guide the experimentalists in planning their set-ups.

New Plating and Electro-Recovery Technology for the Multiple Production of High Quality Solid Cyclotron Targets and the Recycling of Enriched Material*

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A brand-new electro-technology allowing the simultaneous preparation of eight high quality flat (external) or curved (internal) Tl-203 cyclotron targets by ac constant current electrolysis and allowing the fast quantitative recovery of enriched material from twelve irradiated targets by controlled cathode potential electrolysis was developed.

The electroplating involves the application of an asymmetric bipolar chopped saw-tooth to eight copper carriers mounted in appropriate windows of a cylindrical plating vessel fitted with a single axial anode and a bi-directional, perforated cylindrical electromechanical stirrer surrounding the Platinum anode wire. The plating solution is an alkaline EDTA solution containing an anodic depolarizer and suitable amounts of a non-incorporated neutral tenside. The plating current efficiency is higher than 99.9 %, one batch requires less than 6 hours and the plating bath can be used up to ten times.

The recovery of enriched material involves the selective separation of copper (acid medium), thallium (alkaline EDTA) and zinc (strong alkaline solution). Thallium is recovered on a Platinum gauze electrode in less than two hours with a yield higher than 99.9 %.

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The End