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2022 in Romania

ECAART14

14th European Conference on Accelerators in Applied Research and Technology

17-23 July 2022

SIBIU, ROMANIA

Abstract Book & Scientific Programme

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14th European Conference on Accelerators in Applied Research and Technology

Abstract Book and Scientific Programme

17-23 July, 2022
Sibiu, Romania

Welcome Address

On behalf of the local organizing committee, it is our pleasure to welcome you to the 14th European Conference on Accelerators in Applied Research and Technology (ECAART14).
This year's conference marks 33 years anniversary from the organization of the first ECAART conference that was held in Frankfurt in 1989. In all these years, ECAART has shown to be a high level conference, reporting the constant progress in the development of the accelerator technology and applications in many different scientific and industrial fields such as, material science, art, archaeology, life science, environment, etc.

ECAART14 conference is organized by Horia Hulubei National Institute for Physics and Nuclear Engineering, the largest research institute in Romania, covering a broad spectrum of basic and applied research areas, in cooperation with Brukenthal National Museum and International Atomic Energy Agency. Organization would not be possible without generous support from the Romanian Ministry of Research, Innovation and Digitalization, through the Institutional Development Project 36PFE/2021, International Atomic Energy Agency and many sponsors and exhibitors.

This year we have felt the pandemic effects, the number of participants being smaller than usual, anyhow we have accepted more than 80 abstracts, which will be presented in 12 oral and 2 poster sessions. We are grateful to welcome 9 invited speakers as well. Scientific sessions will cover all important aspects of the development of accelerators and their applications in the variety of research and industrial areas. Peer reviewed papers of the presentations given at the conference will be published in Nuclear Instruments and Methods in Physics Research B.

ECAART14 will be held in Sibiu. Sibiu is located in the southern part of Transylvania at about 270 km from Bucharest, the capital of the country. The city is an important cultural and economic center, with an approximate population of 430.000 inhabitants according to the 2012 census. Paltinis Winter Resort is 32 km away from the city center, and Balea Glacier Lake is about 75 km away. Sibiu is currently one of the cities with the highest level of foreign investment in Romania. In 2007 it was the European Capital of Culture, together with the city of Luxembourg .

ECAART14 will take place at the Ramada Sibiu hotel situated in the city center and close to tourist attractions. A half day trip to the Făgăraș will be an excellent opportunity to spend enjoyable moments with colleagues and friends. Some of them we have met already at previous ECAART conferences, some of them we will meet for the first time here in Sibiu.

We hope that you will enjoy the conference and all that Sibiu can offer.

Ion Burducea, Gihan Velisa, Dan-Gabriel Ghita, Mihai Straticiuc, Sabin-Adrian Luca,
IFIN-HH & Brukenthal National Museum

Organizers

In cooperation with

Conference chairs

- Ion Burducea, IFIN-HH (chair)
- Gihan Velisa, IFIN-HH (co-chair)
- Dan Gabriel Ghita, IFIN-HH (co-chair)
- Mihai Straticiuc, IFIN-HH (co-chair)
- Adrian-Sabin Luca, Brukenthal National Museum (co-chair)

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- Alexandra Olteanu, IFIN-HH
- Adriana Mara Tănase, IFIN-HH
- Alexandru Petre, IFIN-HH
- Adrian Socolov, IFIN-HH
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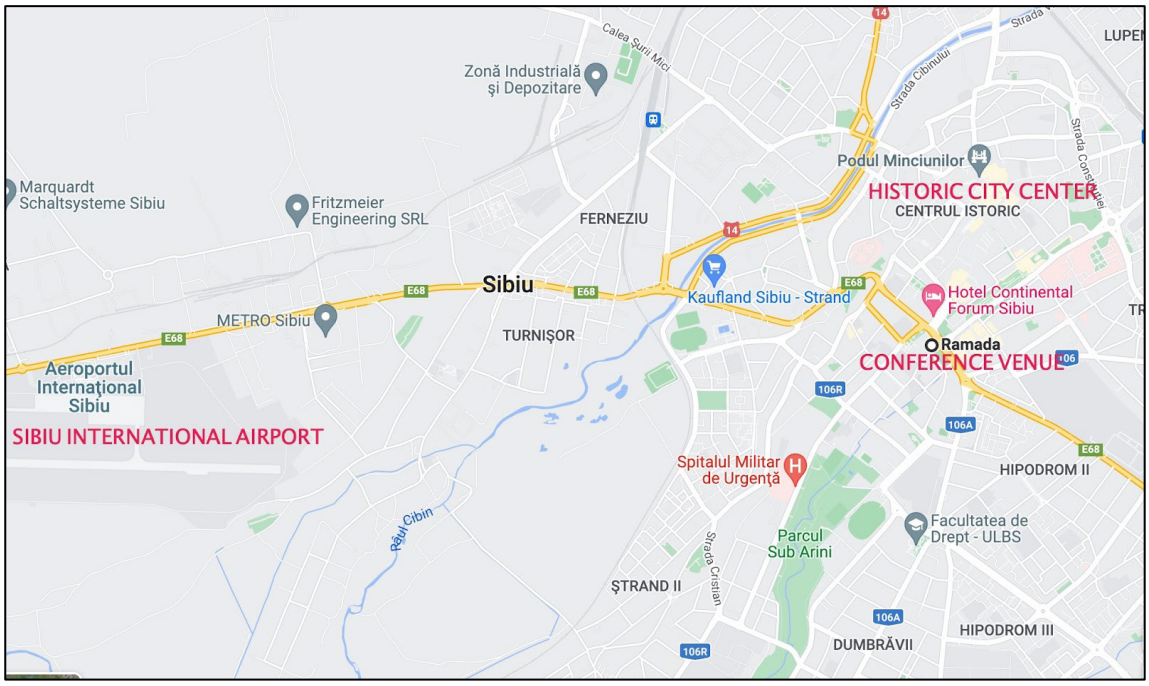
- D. Strivay, Belgium
- G. Terwagne, Belgium
- R. Webb, United Kingdom
- T. Sajavaara, Finland
- Z. Siketić, Croatia

Locations – Map

The conference venue is Ramada Sibiu Hotel, 2 Emil Cioran St, Sibiu, Romania.

All sessions will be held in the Atlass conference room situated on the first floor of the hotel. For more details please see the Scientific Program. The conference registration will be in the Alfa room located also on the first floor of the hotel.



Exhibitors and Sponsors

The exhibitors and sponsors are a very important part of every scientific conference. Not only that through the exhibition scientists get acquainted with the latest achievements in the equipment and instrumentation, this support also enables the cost of the registration to be kept to a minimum and provides additional support for the conference events, students and other activities. We are truly grateful to our sponsors and exhibitors.

General Information

Oral Presentations

Invited talks are 30 minutes long (25 minutes presentation and 5 minutes discussion). Contributed talks are 20 minutes long (15-17 minutes presentation and 3-5 minutes discussion). All the talks should be accompanied by PowerPoint or PDF slides. We will transfer the talk to the conference computer.

Projection Capability

Lecture hall will be equipped with a PC and LCD projection system. The PC will accept USB drives and will have Microsoft PowerPoint and Adobe Reader. You must have your presentation loaded before the start of your session.

Poster Displays

The size allocated for posters is A0 90 cm (width) by 110 cm (length). There will be two

poster sessions, the first one will be held on Monday, 18th of July, from 15:40 to 17:30 and the second one on Tuesday, 19th of July, from 16:10 to 18:00. Poster presenters should be available at their display during this time. Posters should be set up in the morning of the presenting day and taken down at 20:00 the same day. Please display your poster in the slot assigned with your number. Please contact the conference registration desk if you need assistance.

Awards for the best student poster will be presented during the conference banquet. Representatives of ECAART International Committee will review student posters during the poster sessions.

Conference Proceedings

The ECAART14 conference scientific works will be published in the journal Nuclear Instruments and Methods B: Beam Interactions with Materials and Atoms". All submitted papers must be clearly written in excellent English and contain only original work, which has not been published by or is currently under review for any other journal or conference. All manuscripts and any supplementary material should be submitted through the Elsevier Editorial System (EES). Papers will be reviewed to the same standards as for the regular NIMB papers. Please contact Gihan Velisa (gihan.velisa@nipne.ro) for other publication related questions.

Internet Access

Free internet access is available in the entire hotel and lecture hall.

Registration and Welcome Reception

Registration will be open on Sunday, 17th of July, from 17:00 to 19:00 and permanently for other conference days. The welcome reception will be held at the conference hotel (Ramada Sibiu) on Sunday, 17th of July, from 19:00 to 22:00.

Lunches

Lunch will be provided on Monday, Tuesday, Wednesday and Thursday at the conference hotel. Lunch is included in the conference fee.

International Committee Meeting

A meeting of the ECAART International Committee will be held on Thursday, July 21, before the conference dinner. The meeting will be held at the conference hotel.

Conference Outing

The Conference outing will be held on Wednesday, 20th of July, starting from 12:00. A half day trip will be organized which will provide the participants with the opportunity to enjoy Fagaras fortress and Sambata de Sus monastery.

Equipment: casual clothing appropriate for a hot summer day. The temperature most probably will be over 30°C.

Outing is included in the conference fee. Bus will leave from the Ramada Hotel at 12:10. Please be there on time!

Conference Banquet

The conference banquet will be held at Ramada Hotel, on Thursday, 21st of July, starting from at 18:30.

Banquet is included in the conference fee.

Other Details

We kindly ask participants to stick closely to the allocated duration of oral presentation and to the scheduling for posters. Please wear your conference badge at all times.

We have made special arrangements regarding lunches and refreshments, and your badge

needs to be visible at these venues. The Local organizing committee will be pleased to help and advise on travel, touring and other arrangements, or on any problem.

Meeting Questions

If you have any questions, please contact Alexandra Carlig or anyone from the local organizing committee. Here are some cell phone numbers that may be useful:
Ion Burducea, bion@nipne.ro, +40744522867
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Dan Gabriel Ghita, dan.ghita@eli-np.ro, +40746126492

Sponsors oral presentations

S1
Stephanie Stodola
National Electrostatics Corporation, USA
NEC: 2020 - 2022 In Review

S2
Radu Vasilache
Canberra Packard, Romania
Canberra Packard activities for developing new methods of measuring doses and LET in charged particle beams

S3
Matteo Corbo
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CAEN New Product Lines, Innovation and Integration

S4
Christophe Derycke
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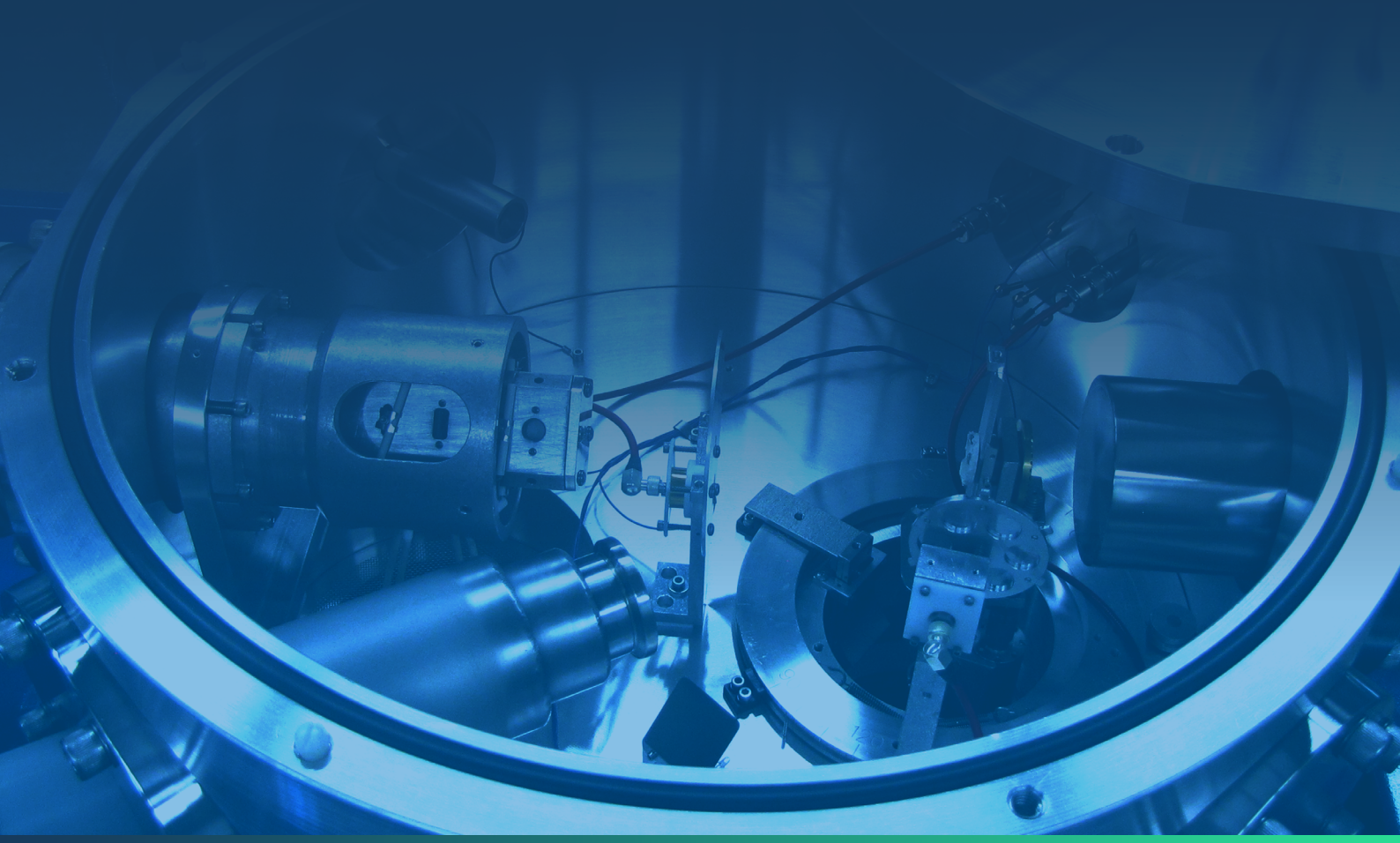

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- Process Growth
- Proton Beam Therapy
- Scanning Tunneling Microscopy
- Secondary Ion Mass Spectroscopy (SIMS)
- Surface Science (Other)
- Synchrotron Storage Rings
- Thermal Desorption Spectroscopy (TPD)
- X-ray Imaging
- X-ray Photoelectric Spectroscopy (XPS)

Global contacts

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Monday, July 18

08:30-09:00	**OPENING**	
Quantum technology applications/Ion beam modification of materials – Chair: Gihan Velisa		
09:00 - 09:30	**David Jamieson** *The University of Melbourne, Australia* Accelerators for a new technology era: 28-Si enrichment and donor doping for quantum devices (online)	I-1
09:30 - 10:00	**Roger Webb** *University of Surrey, UK* Implanted Layer Exchange Production of Isotopically Pure Si and Ge Layers for Quantum Computers	I-2
10:00 - 10:20	**Stefan Facsko** *Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresen-Rossendorf, Germany* Transnational Access to European Ion Beam Centers: RADIATE and beyond	O-1
10:20 - 10:40	**Mandla Msimanga** *Tshwane University of Technology, South Africa* A broad beam ion implantation technique based on heavy ion elastic recoil	O-2
10:40 - 11:00	Coffee Break	
Ion beam analysis and applications 1 – Chair: Roger Webb		
11:00 - 11:30	**Mikko Laitinen** *University of Jyväskylä, Finland* ToF-ERDA – applications, data and detectors	I-3
11:30 -11:50	**Olli Tarvainen** *STFC Rutherford Appleton Laboratory, UK* Ion source and low energy beam transport prototyping for a single-ended heavy ion ToF-ERDA facility	O-3
11:50 - 12:10	**Gyula Nagy** *Uppsala University, Sweden* In-situ characterization of synthesis and controlled oxidation of TiN thin films	O-4
12:10 - 12:30	**Mikko Kivekäs** *University of Jyväskylä, Finland* Elastic scattering and recoiling cross-sections measured by ToF-ERDA for low energy heavy ions	O-5
12:30 - 14:00	Lunch	
Ion beam analysis and applications 2 – Chair: Stefan Facsko		
14:00 - 14:20	**Michael Kokkoris** *National Technical University of Athens, Greece* Measurement and evaluation of differential cross sections for protons on natO in the energy range E= 4-6 MeV, suitable for EBS	O-6
14:20 - 14:40	**Johan Meersschaut** *IMEC, Belgium* High-accuracy Rutherford backscattering spectrometry	O-7
14:40 - 15:00	**Fotis Maragkos** *National Technical University of Athens, Greece* Systematic R–matrix Calculations for the 12C(3He,px)14N reaction suitable for NRA applications	O-8
15:00 - 15:20	**Evangelia Taimpiri** *National Technical University of Athens, Greece* Differential cross section measurements of the ^{6}Li (d, nγ_{1-0})^{7}Be, ^{6}Li (d, pγ_{1-0})^{7}Li, ^{7}Li (d, dγ_{1-0})^{7}Li and ^{19}F (d, pγ_{1-0})^{20}F reactions suitable for PIGE applications	O-9
15:20 - 15:40	Coffee break	
15:40 - 17:30	**Poster Session A**	

Tuesday, July 19

Accelerator Mass Spectrometry – Chair: Mihai Straticiuc		
09:00 - 09:30	**Christine Hatte** *Silesian University of Technology, Gliwice, Poland, LSCE, Universite Paris-Saclay, France* Soil dynamics revealed by cosmogenic nuclides	I-4
09:30 - 09:50	**Karin Hain** *University of Vienna, Austria* Developing Ion-Laser InterAction Mass Spectrometry (ILIAMS) for the analysis of environmental 99Tc	O-10
09:50 - 10:10	**Iuliana Stanciu** *IFIN-HH, Romania, TUM, Germany* Accelerator Mass Spectrometry of Plutonium: beyond isotopic ratios	O-11
10:10 - 10:40	**Martin Martschini** *University of Vienna, VERA Lab, Austria* Ion-Laser InterAction Mass Spectrometry – isobar suppression in AMS at eV-energies	I-5
10:40 - 11:00	Coffee Break	
Accelerator technology and development 1 – Chair: Timo Sajavaara		
11:00 - 11:20	**Sergey Kutsaev** *RadiaBeam Technologies, USA* Radioisotope replacement with compact electron accelerators	O-12
11:20 -11:40	**Eleni Ntemou** *Uppsala University, Sweden* Energy deposition by keV ions in single crystalline self-supporting Si and SiC foils	O-13
11:40 - 12:00	**Niels Claessens** IMEC, KU Leuven, Belgium RBS applied to 3D nanostructures	O-14
12:00 - 12:20	**Mihai Radu** *IFIN-HH, Romania* Low-energy accelerated protons effects on a blood brain barrier model	O-15
12:20 - 12:35	**Stephanie Stodola** *National Electrostatics Corporation, USA* NEC: 2020 - 2022 In Review	S-1
12:35 - 14:00	Lunch	
Applications to art and archaeology 1 – Chair: Michael Kokkoris		
14:00 - 14:20	**Thomas Calligaro** *Centre de Recherche et de Restauration des Musées de France, France* Carbon mapping in steel using 12C(d,p gamma)13C in external beam	O-16
14:20 - 14:40	**Charbel Koumeir** *GIP ARRONAX, France* High energy beam analysis of cultural heritage materials from middle age to the renaissance	O-17
14:40 - 15:00	**Roxana Bugoi** *Horia Hulubei National Institute for Physics and Nuclear Engineering, Romania* A pilot study on glass finds from the Geto-Dacian Cârlomăneşti and Gruiu Dării settlements, Buzău county, Romania	O-18
15:00 - 15:20	**Hanan Sa'adeh** *The University of Jordan, Amman, Jordan* Quantification and Speciation of Lead in Air Particulate Matter Collected from an Urban Area in Amman, Jordan, Using PIXE and XANES Techniques	O-19
15:20 - 15:35	**Radu Vasilache** *Canberra Packard, Romania* Canberra Packard activities for developing new methods of measuring doses and LET in charged particle beams	S-2
15:35- 15:50	**Matteo Corbo** *CAEN Spa* CAEN New Product Lines, Innovation and Integration	S-3
15:50 - 16:10	Coffee Break	
16:10 - 18:00	**Poster Session B**	

Wednesday, July 20

High-power laser driven accelerators – Chair: Dan Gabriel Ghita	
09:00 - 09:30	**Paolo Tomassini** I-6 *ELI-NP, LDED* High-brigthness GeV scale e-beam acceleration with the Resonant Multi-Pulse Ionisation injection
09:30 - 10:00	**Satyabrata Kar** I-7 *Queens University of Belfast, UK* Advances in laser-driven ion sources and prospectives (online)
10:00 - 10:20	**Domenico Doria** O-20 *ELI-NP, Romania* Recent results of the commissioning of the 1 PW laser system of ELI-NP
10:20-10:40	Coffee break
10:40 - 11:00	**Lucian Tudor** O-21 *ELI-NP, Romania* Characterization of laser-accelerated protons based on the excitation of nuclear isomeric states
11:00 - 11:20	**Alexandru Magureanu** O-22 *ELI-NP, Romania* Imaging diagnostics for laser plasma accelerators
11:20 - 12:00	Lunch
12:00 - 19:00	**Excursion**

Thursday, July 21

Ion beam modification of materials – Chair: Gihan Velisa		
09:00 - 09:20	**Maria-Diana Mihai** *Horia Hulubei National Institute for Physics and Nuclear Engineering, Romania* Ionization-induced transition from synergistic to competitive effect in defective $KTaO_3$	O-23
09:20 - 09:40	**Zoran Jovanovic** *Vinca Institute of Nuclear Sciences, Serbia* The effects of keV and MeV ion beam irradiation on the physicochemical properties of glassy carbon	O-24
09:40 - 10:00	**Ali Biganeh** *Nuclear Science and Technology Reserch Institute (NSTRI) of Iran* Ion beam based Coincidence Doppler broadening spectroscopy of thick sample	O-25
10:00 - 10:20	**Hafez Taghipour Aslani** *University of Sistan and Baluchestan, Zahedan, Iran* Differential cross sections measurement of 11B(d, p$\gamma_{1,2}$)12B reactions for analytical applications	O-26
10:20 - 10:40	Coffee Break	
Applications to art and archaeology 2 – Chair: Thomas Calligaro		
10:40 - 11:00	**Sabin Adrian Luca, Florentin Perianu, Raluca Teodorescu** *Brukenthal National Museum, Romania* Some ideas on the absolute dating of the site Tartaria-Gura Luncii, Alba county, Romania	O-27
11:00 -11:20	**Dragos Mirea** *Horia Hulubei National Institute for Physics and Nuclear Engineering, Romania* Characteristic X-ray study over a set of bracelets found in funerary context at Vânători, Galați county	O-28
11:20 - 11:40	**Sabin Adrian Luca, Raluca Teodorescu, Florentin Perianu** *Brukenthal National Museum, Romania* The absolute dating of the first wave of Neolithic colonization in Romania, Cristian I, Sibiu County	O-29
11:40 - 11:55	**Christophe Derycke** *Thales*	S-4
11:55 -13:00	Lunch	
Application to life science – Chair: Mihai Straticiuc		
13:00 - 13:30	**Maria Teresa Pinheiro** Instituto Superior Técnico, Portugal Energetic ion beams for nanotoxicology and cancer therapy (online)	I-8
13:30 - 13:50	**Mihaela Bacalum** Ultra-high dose rate irradiation induces senescence and cell cycle arrest of B16 cells *Horia Hulubei National Institute for Physics and Nuclear Engineering, Romania*	O-30
	Accelerator technology and development 2 – Chair: Ion Burducea	
13:50 - 14:10	**Ionel Chirita** *INCDIE ICPE-CA, Romania* Normal Conducting Magnets and Power Converters – ICPE-CA Participation to the In-Kind Contribution of Romania to the FAIR Project	O-31
14:10 - 14:30	**Adrian Rotaru** *ELI-NP, Romania* Ion Manipulation using the novel Harmonic Ion Transport System Developed at ELI-NP	O-32
14:30 - 14:50	Coffee break	
15:00 - 17:00	Visit Brukenthal National Museum (Brukenthal Palace / History Museum Altemberger House)	
17:00 - 18:30	**ECAART International Committee Meeting**	
18:30 - 22:00	**Conference dinner**	

Friday, July 22

Simulation and fundamentals – Chair: Roxana Bugoi		
09:00 - 09:30	**Roy Shiloh** Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany Electron acceleration using nanophotonic structures	I-9
09:30 - 09:50	**Iuliana-Mariana Vladisavlevici** West University of Timisoara, Romania Theoretical Study of Laser Energy Absorption towards Novel Bright Proton and Electron Sources	O-33
09:50 - 10:10	**Osman Murat Ozkendir** Tarsus University, Turkey Trace of Thermoelectricity on the XAFS Spectroscopy	O-34
10:10 - 10:40	Coffee Break	
10:40 - 11:30	**Final remarks & closing**	

Invited Talks

I-1

Accelerators for a new technology era: 28-Si enrichment and donor doping for quantum devices

David N Jamieson

School of Physics, University of Melbourne, Australia and the Australian Research Council Centre for Quantum Computation and Communication Technology.

With the support the International Atomic Energy Agency, my group has been a partner in a cooperative research program to explore applications of accelerators to the emerging second quantum revolution. This second revolution builds on the classical applications of the first with new applications that exploit quantum mechanical phenomena to store, process and transmit information in engineered devices with revolutionary capabilities difficult or impossible with classical techniques. My group is working on a new type of computer that uses the strange rules of quantum mechanics to process information encoded in quantum bits (qubits). Especially promising qubits are ion implanted donor atoms in isotopically pure semiconductors including silicon. The features of group-V-donor spins make them attractive qubits for potential large-scale quantum computer devices. Useful attributes include the long nuclear and electron spin lifetimes of 31-P, the hyperfine clock transitions in 209-Bi or electrically controllable 123-Sb nuclear spins [1]. However, practical architectures for scalable devices require the ability to fabricate deterministic arrays of individual near-surface dopant atoms placed with high yield. By using one-for-one ion sputtering from high-fluence 28-Si ion implantation at 45 keV we have demonstrated a method to locally deplete the non-zero nuclear spin isotope 29-Si to 250 ppm [2]. For implanting donor atoms, we localise the implants with a nanostencil fabricated in an AFM cantilever and employ on-chip electrodes with optimised charge-sensitive electronics to demonstrate the near room temperature implantation of single 14 keV 31-P ions with an unprecedented >99.8% detection confidence for near-surface implants [3]. These methods are potentially compatible with localised enrichment zones to house donor qubits in larger n-Si wafers by employing 28-Si++ beams produced by liquid eutectic alloy focused ion beam systems. Wafer-scale enrichment is also possible in an industrial fab which could potentially allow both 29-Si depletion and qubit donor array construction in the same ion implantation system for mass production. This presentation will review these and other applications of accelerators to the new era.

Acknowledgements: ARC Centre for Quantum Computation and Communication Technology (CE170100012), US Army Research Office (W911NF-17-1-0200). The contributions of collaborators in CQC2T, SQC, ANU, the University of Manchester and the IAEA CRP F11020 are gratefully acknowledged.

[1] A Morello et al, Adv Quant Tech 2020
[2] D Holmes et al, Phys Rev Mat 2021 [3] A Jakob at al, Adv Mat 2021

I-2

Implanted Layer Exchange Production of Isotopically Pure Si and Ge Layers for Quantum Computers

Jonathan England[(1)], Ella Schneider [(1)], Luke Antwis[(1)], Roger Webb[(1)]

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Donor spin qubits hosted in silicon are attractive quantum computing architectures with long coherence times, scalability and compatibility with CMOS industrial manufacturing. Having a readily available source of ^{28}Si is essential to research and future mass production of quantum computers. We are developing an implanted layer exchange (ILE) process [1,2] to produce isotopically pure Si and Ge layers for the manufacture of quantum computers. ILE uses standard implantation to implant ions of a single isotope into the surface of an Al film deposited on a substrate wafer. A post implant, layer exchange anneal causes the isotopically selected atoms to diffuse through the Al and grow on the substrate. Compared to enrichment by implantation directly into Si, ILE requires lower fluences, allows implantation energies where beam transmission is maximised, overcomes surface oxidation and self-getters isobaric impurities. A major challenge is to achieve an acceptable residual Al concentration in the ^{28}Si layer.

The ultimate ILE process must produce non-defective, single crystal, isotopically pure, ^{28}Si or ^{74}Ge layers of uniform thickness containing no Al contamination. We believe a key route to achieving these goals is to ensure that ions implanted into the surface of an Al film rapidly diffuse during the anneal to epitaxially grow on a substrate rather than nucleate at grain boundaries in the Al. To develop our approach, we have compared ILE of Si after large area implants in a Danfysik beamline implanter to ILE of Ge after small area (100 micron^2) implants using a SIMPLE (FIB based) implanter [2]. Suppressing epitaxial growth during the anneal by damaging the substrate surface during implantation or by poor removal of native oxide before Al deposition did indeed lead to the formation of large poly crystals. Interpretation of these observations has been aided by the use of TRIDYN [3] to model the implant profiles and a kinetic Monte Carlo model based on SPPARKS [4] is being developed to investigate the mechanisms that compete during the anneal part of the layer exchange process. We will present a selection of our observations and current understanding that identify the greatest challenges that will need to be overcome if we are to perfect our ILE method.

[1] Schneider, England, J Phys D submitted 2022
[2] England et al NIMB 461 (2019) 30
[3] Moller, Eckstein NIMB 2 (1984) 814
[4] Plimpton et al https://spparks.github.io.

I-3

ToF-ERDA – applications, data and detectors

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Elastic recoil detection analysis (ERDA) was first time used in 1976 for determining the depth distribution of light elements in heavy materials [1]. The light element analysis was, and is, challenging for the Rutherford backscattering spectrometry as RBS excels in "heavy materials on light substrate". The ToF-ERD technique in which both the time-of-flight (ToF) and energy (E) events are measured in coincidence, was introduced in 1983 [2]. Contrary to the RBS, ToF-ERD excels in "light materials on heavy substrate". Today, ToF-ERDA has enabled quantitative elemental depth profiling of all sample elements in the sample, including hydrogen but also the heaviest elements. The time-of-flight measurements are nowadays realized by detector design developed in the 80's [3]. Similarly, gas ionization detectors, were invented more than 80 years ago. However, despite the original principles being old, the state-of-the-art ToF-ERD detectors used today are a result of the continuous long-term scientific research [4]. As a one outcome of the scientific work, there has also been a push, from outside institutes, for commercial deliveries of such ToF-ERDA spectrometers. The most recent Jyväskylä delivery was a complete ToF-ERD spectrometer / end-station to the beam line at the University of Surrey 2022. In this talk, I will go through the gains of having ToF-ERD vs RBS, example analysis cases requiring Monte-Carlo calculations and show also issues where the 'physics' is still not right. The talk goes through the key characteristics of: a) timing and energy detectors, b) background/noise suppression and detection efficiency (of light elements) c) sample damage and depth resolution, and d) analysis of the data. These are combined with the short introduction of the aspects of the commercialization of the scientific equipment sales to other institutes.

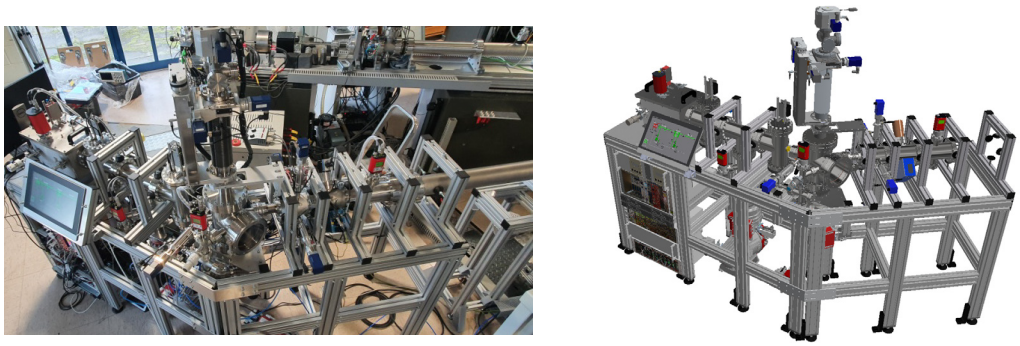

Figure. 1. ToF-ERDA end-station. Left at the University of Surrey, Jyväskylä CAD schematics in right.

[1] J. L'Ecuyer, C. Brassard, C. Cardinal, J. Chabbal, L. Deschenes, J. Labrie, B. Terreault, J. Martel, R.S. Jacques, J. Appl. Phys., 47 (1976) p. 381.
[2] R. Groleau, S. Gujrathi, J. Martin, Nucl. Instr. and Meth., 218 (1983) p. 11.
[3] F. Busch, W. Pfeffer, B. Kohlmeyer, D. Schüll, F. Pühlhoffer, Nucl. Instr. and Meth. 171 (1980) p. 71.
[4] M. Laitinen, M. Rossi, J. Julin, T. Sajavaara, Nucl. Instr. and Meth. B 337 (2014) p. 55

I-4

Soil dynamics revealed by cosmogenic nuclides

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Over the last few years, considerable attention has been devoted in the scientific literature and in the media to the concept of "ecosystem" services of soils. The monetary valuation of these services, demanded by many governments and international agencies, is often depicted as a necessary condition for the preservation of the natural capital that soils represent. Amongst the eleven recognized services of soil, at least four are associated to soil carbon dynamics and four to particles displacement. These are carbon sequestration, climate regulation, provision of food, nutrient cycling, habitat for organisms, flood regulation and foundation for human infrastructure.

Assessing the capacity of soils to provide these services is an immediate societal priority. Conventional solutions such as measuring carbon content, bulk density, particle size distribution, etc., don't always allow to reach the idea of dynamics and/or to answer questions quickly enough for a process reversal to take place. As an alternative method, measuring cosmogenic nuclides can be used directly to determine the timing of events and the dynamics of major pedological processes. They can provide clues to soil carbon dynamics and particle movement within the profiles themselves. Their use is thus beyond determining rates of erosion, denudation and uplift by analyzing the upper layers of soil profiles as typically done with such isotopes.

In this presentation, we will outline key elements delivered by cosmogenic nuclides to the soil sciences. They have been used alone or in combination with others isotopes. ^{14}C, 10Be, ^{137}Cs, ^{210}Pb will be discussed for the modeling of carbon dynamics in soils and for the transfer of fine particles in profiles.

I-5

Ion-Laser InterAction Mass Spectrometry – isobar suppression in AMS at eV-energies

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Accelerator Mass Spectrometry (AMS) is the technique of choice for the detection of long-lived radionuclides with typical isotopic abundances of 10^{-12} to 10^{-16} in the environment. Interferences from stable isobars, however, usually restricted the applicability of this method to selected nuclides. The novel Ion-Laser InterAction Mass Spectrometry (ILIAMS) technique at the Vienna Environmental Research Accelerator VERA can overcome this limitation in many cases by highly-efficient isobar removal at eV-energies in a gas-filled radiofrequency quadrupole. The virtually complete suppression of isobars serves two objectives: New nuclides can be measured for the first time with AMS while others become accessible also on low-energy AMS-systems with the benefit of unprecedented detection efficiencies and competitive blank values. This opens up exciting possibilities in environmental radioactivity research (^{90}Sr, ^{99}Tc, ^{135}Cs), astrophysics (^{182}Hf), and Earth sciences (^{26}Al, ^{36}Cl, ^{41}Ca) (Martschini et al. 2021). ILIAMS exploits differences in detachment energies (DE) within elemental or molecular isobaric systems by neutralizing anions with DEs smaller than the photon energy via laser photodetachment. In addition, molecular interactions with the buffer gas can further enhance isobar suppression, e.g. via breakup of ^{41}KF3^{-} into $^{41}KF_2^{-}$ + F or via O-pickup of $^{182}WF_5^{-}$. Thereby, the VERA-facility has recently achieved the most sensitive detection of ^{182}Hf and ^{90}Sr, the latter at the 15 attogram level. Furthermore, the laser-induced suppression of ^{236}U by $>10^3$ during measurements of ^{236}Np constitutes the first non-chemical isobar discrimination in AMS in the actinide region. For ^{41}Ca, the blank level with CaF_3^{-} and ILIAMS is $^{41}Ca/^{40}Ca = (1.5^{+1.7}_{-1.5})\times10^{-15}$. Recent tests also demonstrated that ^{41}Ca and ^{26}Al can now be measured directly in stony meteorites with sample sizes down to 1-2 mg without performing any chemical preparation, i.e. in the presence of □1000 ppm K and 15% Mg, respectively, allowing e.g. fast provenance checks for (extra)-terrestrial origin. This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008324 (ChETEC-INFRA) and No 824096 (Radiate). The work is partly funded by grants from the Austrian Science Fund (FWF): I 4803-N and P 31614-N28.

References: Martschini M., Lachner J., Hain K., Kern M., Marchhart O., Pitters J., Priller A., Steier P., Wiederin A., Wieser A., Golser R., 2021. 5 years of Ion-Laser Interaction Mass Spectrometry – Status and prospects of isobar suppression in AMS by lasers. Radiocarbon, DOI:10.1017/RDC.2021.73

I-6

High-brigthness GeV scale e-beam acceleration with the Resonant Multi-Pulse Ionisation injection

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The production of high-brilliance e-beams in Laser Wake Field Acceleration (LWFA) relies on the possibility to inject ultra-low emittance bunches in the plasma wave. A new bunch injection scheme (Resonant Multi-Pulse Ionization, ReMPI) has been conceived and studied in which electrons extracted by ionization are trapped by a large-amplitude plasma wave driven by a train of resonant ultrashort pulses [1]. The ReMPI injection scheme relies on currently available laser technology and is being considered for implementation of future compact X-ray free electron laser schemes [2]. Simulations with either a 200TW or a 1PW Ti:Sa laser system show that high-quality electron bunches with energy up to 5 GeV, with normalized emittance below 0.1 mm mrad and projected energy spread below 1% (below 0.1% in slice analysis) can be obtained with a single stage.

The LWFA source in the ReMPI configuration is flexible in beam energy, charge and duration and is able to generate beams with a remarkable low transverse size. The extremely low transverse size (down to 0.5 □m) and duration (down to less-than-1fs) of the e-beams make this accelerating scheme particularly appealing as a driver for Thomson/Compton sources delivering sub-fs X/gamma rays or ultra small-size sources suitable for phase-contrast imaging.

[1] P. Tomassini et al., The Resonant Multi-Pulse Ionization injection, Physics of Plasmas 24, 103120 (2017)

[2] EuPRAXIA collaboration, http://www.eupraxia-project.eu/; R. Assman et al., Eur. Phys. J. Spec. Top. 229, 3675–4284 (2020).

I-7

Advances in laser-driven ion sources and prospectives

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In the context of developing a compact, high current ion accelerator, the study of intense laser-driven acceleration mechanisms and optimization of the ion beams produced have been, over the past decade, very active areas of research. An appealing beam of ions will not only be crucial for their direct application in science, industry, and healthcare (cancer therapy, per instance); it can be beneficial towards the development of secondary radiation sources, such as neutrons. While significant progress has been made to control and optimize ion beam parameters produced by the well-known Target Normal Sheath Acceleration mechanism, exploring the possibility of ion acceleration from ultra-thin targets at the onset of radiation pressure effects have been one of the most attractive areas of research with recent highlights of delivering near 100 MeV protons. An overview of the recent progress in the development of laser-driven ion sources and prospects in light of the upcoming multi-petawatt and high repetition rate lasers will be presented.

I-8

Energetic ion beams for nanotoxicology and cancer therapy

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Over recent years we have seen an increase in the use of engineered nanoparticles and metallic nanosized complexes in a variety of applications, such as, technology, food, cosmetics and medical areas. The increased use of these nanosized entities raised concerns on their potential toxicity. On the other hand, a considerable amount of research focuses new metallic nanosized complexes and nanoparticles for different cancer therapy modalities. In both areas, it is urgent to understand how these nanosized entities interact with biological systems. One approach can be to quantitate the net amount uptake by cells and tissues. Other approach encompasses the direct visualization of the distribution of the metal content in the cell volume. This is essential to explain the uptake of the complexes and nanoparticles and their biological effects. Due to their small size, the identification and localization within cells is extremely challenging. Various cutting-edge techniques are required to detect and quantify metals and electron-dense nanoparticles inside the cells. However, few of these techniques are able to peer into cells combining nanometer probe-formation with elemental quantification and depth profile of the element of interest production 3D maps of its distribution inside cells. This is the prospect of nuclear microscopy techniques using MeV ion beams. Such type of ion probes can be used for whole-cell investigations delivering unique and relevant information, including the direct visualization of the distribution of nanosized metal complexes and particles and their depth profile in single cells. This will help elucidating their uptake efficiency and the specificity for different type of cells what is very important to infer the toxicity of these nanosized materials to cells and to shed light on mechanisms and cellular targets of nanosized compounds in cancer therapy. An overview of ion probes applications in nanotoxicology and cancer therapy will be given concerning visualization and quantification systems, their limitations and pitfalls.

I-9

Electron acceleration using nanophotonic structures

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Dielectric laser accelerators (DLA) are aimed at becoming a standard, low-charge, high-repetition rate miniature accelerator available in university labs. Such on-chip devices promise table-top compact sources of high-energy electrons (1…100 MeV) for tunable radiation generation, for example. By replacing the conventional approach of RF accelerating fields with high-repetition rate infrared laser power, and the large RF cavities with nanostructured silicon or other dielectric material, the larger damage threshold, ease of fabrication, and many novel research opportunities suggest a particularly appealing setting. Accelerating forces larger than 9 GV/m with an average acceleration gradient of 850 MeV/m [1] have already been demonstrated, along with attosecond bunch-train compression down to 280 as [2]. An important milestone recently achieved is the active transport of electrons through a nanophotonic chip using the alternating phase focusing technique [3,4]. The audience will be introduced to the fundamentals of DLA, current state-of-the-art, and future prospects.

[1] Cesar, D., Custodio, S., Maxson, J., Musumeci, P., Shen, X, E. Threlkeld, R. J. England, A. Hanuka, I. V. Makasyuk, E. A. Peralta, K. P. Wootton, and Z. Wu, **Communications Physics** 1, 46 (2018).
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Contributed Talks

O-1

Transnational Access to European Ion Beam Centers: RADIATE and beyond

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(2) on behalf of the RADIATE Consortium

Transnational access to research infrastructures plays a vital role in the European research landscape, enabling scientist from all over the world to travel and perform experiments at European facilities. Following former EU project, i.e., AIM, SPIRIT and ITS LEIF, in the Horizon 2020 project RADIATE, Research and Development with Ion Beams – Advancing Technology in Europe, transnational access to 13 ion beam centers is provided free of charge in the period of 2019 to mid of 2023. Important aims of the project are to further increase the visibility and the awareness of ion beam facilities and to create a lively web portal as a platform for information on ion beam research in Europe [1].

A further important objective of RADIATE is to achieve long-term sustainability of the proposed actions and thereby to transfor the national ion beam centers to a coherent and well aligned network of ion beam facilities sharing one common mission for providing researchers excellent capabilities to perform their research. One important step in this direction has already been taken by opening RADIATE for other European ion beam centers as associate partners. In this larger context, RADIATE has established itself as the network of European ion beam centers and joined the "network of networks" ARIE, Analytical Research Infrastructures in Europe [2]. ARIE represent now more than 120 research infrastructures providing access to photons, laser, ion, protons, high magnetic field, neutron, and electron facilities. Two joint position papers addressing the five Horizon Europe missions and viral and microbial threats have already been published [3] and joint proposals were submitted and are planned.

Future activities will concentrate on further strengthening the RADIATE network of ion beam facilities and on participating in future European transnational access calls.

[1] https://www.ionbeamcenters.eu
[2] https://arie-eu.org
[3] Analytical Research Infrastructures in Europe: A key resource for the five Horizon Europe Missions, Analytical Research Infrastructures in Europe: Viral and microbial threats

O-2

A broad beam ion implantation technique based on heavy ion elastic recoil

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Metallic and semiconductor nanoparticles (NPs) embedded in a dielectric host matrix offer a wide range of applications including electronics and optics, enhanced photovoltaics, plasmonics, and so on. Growth of these NPs is mostly achieved through chemical routes. Ion implantation is one physical method through which this can be achieved in a fairly predictable and reproducible manner, as opposed to trial and error routines typical of sol gel methods. In many instances of ion implantation the incident beam is of a fixed energy in order to have control over the implantation depth. This poses a limitation, however, when the region of interest is a thick (> 2 µm) layer since the implanted ions will accumulate in a fairly narrow region of the target. This submission reports on a novel method of ion implantation (or ion irradiation) using ions of a very broad energy distribution. The procedure is based on implantation of a host material with ions that are recoiled from an appropriate target by a heavy incident ion. In this work a 10 MeV Au^{4+} beam was used to forward recoil C and V from a VC/Si sample and Nb and N from a NbN/Si layer into polyethylene terephthalate (PET) dielectric foils used as host matrices. We show depth profiles of implanted metal species measured by proton RBS up to 4 µm deep. The effects of the implanted species on the structural and optical properties of the PET are discussed based on FTIR and UV-Vis measurement results, and are compared with single energy implantation at keV energies.

O-3

Ion source and low energy beam transport prototyping for a single-ended heavy ion ToF-ERDA facility

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We present the status of the ion source and low energy beam transport prototyping activities for a heavy ion time-of-flight elastic recoil detection analysis (ToF-ERDA) equipment, designed to accelerate 1-10 pnA of $^{40}Ar^{6-12+}$ ions to 3-6 MeV for depth profiling of light elements [1]. The prototype injector consists of a novel permanent magnet electron cyclotron resonance ion source CUBE-ECRIS [2,3] with a minimum-B quadrupole field topology, and a 90-degree permanent magnet dipole with adjustable field strength for charge state selection. We report experimentally measured argon beam currents obtained with the CUBE-ECRIS at the University of Jyväskylä accelerator laboratory, and present the detailed design of the dipole magnet prototype and its commissioning status at STFC's Daresbury Laboratory. The goal of the project is to build a single-ended ToF-ERDA facility with the ion source and low energy beam transport on a 500 kV platform without SF_6 electrical insulation.

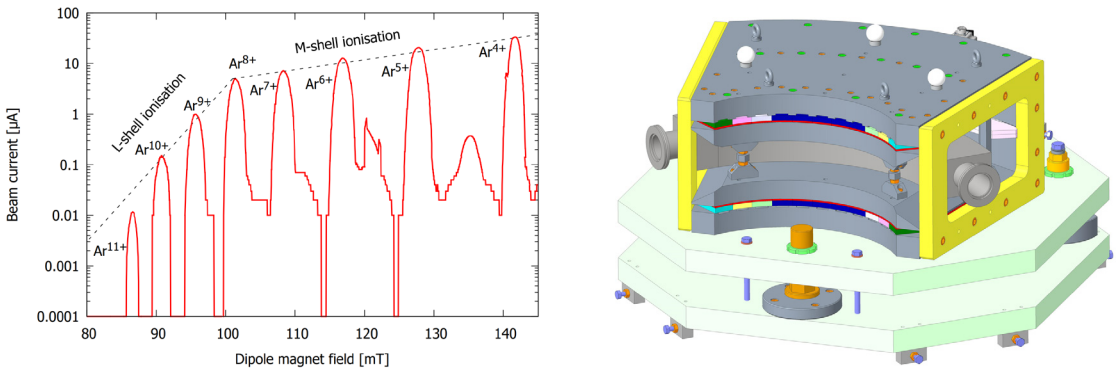

Figure 1. An example of the ^{40}Ar charge state distribution extracted from the CUBE-ECRIS (left) and the engineering model of the adjustable field permanent magnet dipole (right).

[1] J. Julin and T. Sajavaara, Nucl Instrum Methods Phys Res B, Vo. 406, Part A, 2017, pp 61-65.
[2] T. Kalvas, O. Tarvainen, V. Toivanen and H. Koivisto, 2020 JINST 15 P06016.
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O-4

Present status of the Uppsala scanning nuclear microprobe

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The Uppsala scanning nuclear microprobe, named SLIM-UP (Scanning Light Ion Microprobe in Uppsala), was originally installed in The Svedberg Laboratory, Uppsala University, during 1989/90 [1]. The main components of the facility, i.e. the object forming apertures, collimator apertures, magnetic deflection unit, probe forming quadrupole lenses and magnet driving power supplies were the first ones that were sold by Oxford Microbeams Ltd. Since then, the microprobe has undergone several minor and major modifications. The present configuration is a re-build of the SLIM-UP, now attached to the 5 MV tandem pelletron accelerator (NEC) of the Tandem Laboratory, at the Ångström Laboratory, Uppsala University.

In this contribution we give an overview about the present status of the Uppsala scanning nuclear microprobe facility, including a detailed description of the components, the most recent technical developments and the capabilities of the system. In addition, we present the most recent performance tests and some ongoing scientific applications, such as the elemental depth profiling of metal-organic framework (MOF) single crystals by Rutherford Backscattering Spectroscopy [2].

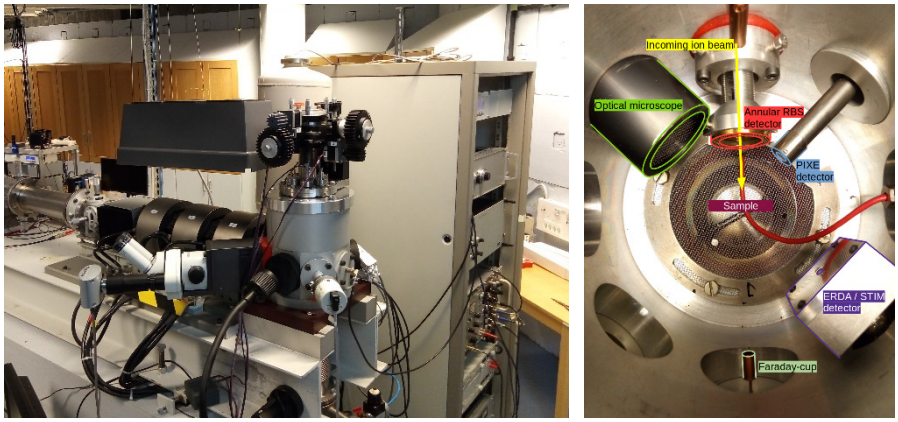

Figure: The Uppsala scanning nuclear microprobe.

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[2] B.D. McCarthy et al., J. Am. Chem. Soc. 143 (2021) 18626-18634.

O-5

Elastic scattering and recoiling cross-sections measured by ToF-ERDA for low energy heavy ions

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Time-of-Flight Elastic Recoil Detection Analysis (ToF-ERDA) is a powerful technique used for quantitative elemental depth profiling of thin film samples [1]. Using low energy heavy ion beam for ToF-ERDA has at least 3 benefits: increased film to substrate signal, less beam induced damage due to higher cross-sections and increased film depth resolution [2]. Use of low energy, heavy ion beams also introduce some drawbacks, one of which include heavily screened cross-sections for low energy heavy ions – or at least the obvious discrepancy between detected and calculation-based events in the detector. This discrepancy is now being investigated with experimental methods and the measurements using JYFL ToF-ERDA setup [1,3]. Co, Au, Y_2O_3 and La_2O_3 thin film compositions were characterized beforehand using 2 MeV RBS setup to where ToF-ERDA results are compared against to. Our results demonstrate a clear discrepancy for detected cross-sections relative to Rutherford cross-sections calculated from scattering and recoiling yields (Fig. 1). Detected relative cross-sections of scattering beam stay rather constant through the measured beam energy range, while relative cross-sections of recoiling target show strong incident ion beam energy dependency. Reason of this discrepancy is not yet well known, some of it might be due to more pronounced scattering of heavier ions in ToF telescope or errors in tabulated cross-sections for low energy heavy ion collisions. More detailed results together with the hypothesis of the origin of this discrepancy will be presented.

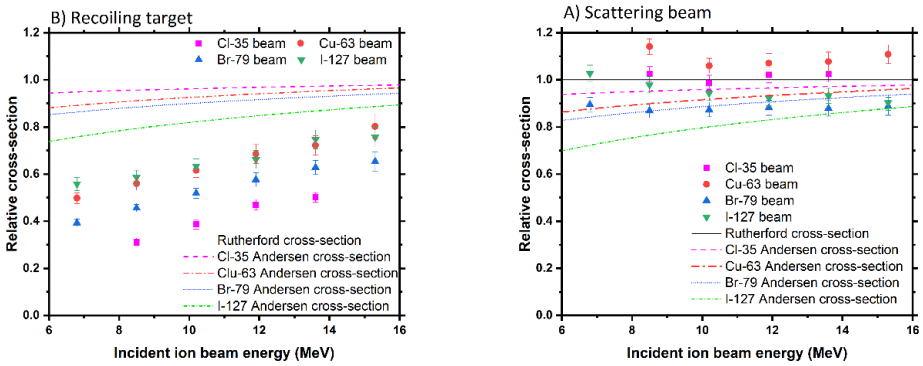

Figure 1: Detected relative cross-sections of Au film determined from A) scattered beam and B) recoiled target of ToF-ERDA measurements as function of incident ion beam energy. Data points for A) and B) for each beam and energy are from the same measurement.

[1] Mikko Laitinen, PhD Thesis (2013) Jyväskylä, Finland.
[2] S. Giangrandi et al, Nucl. Instr. and Meth. B 266 (2008) p. 5144.
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O-6

Measurement and evaluation of differential cross sections for protons on ^{nat}O in the energy range E= 4-6 MeV, suitable for EBS

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Oxygen is a highly reactive non-metal and thus, it can easily penetrate or diffuse deeply inside several matrices. Therefore, the accurate determination of oxygen depth profiles in various samples is of paramount importance, especially in the semiconductor industry, or in biological, geological, cultural heritage materials and superconductors. For this purpose, Ion Beam Analysis (IBA) techniques have proven to be very effective, and more specifically p-EBS, while d-NRA and ToF-ERDA are usually employed at smaller depths. For the implementation of EBS, evaluated differential cross sections are required, provided by the online R-matrix SigmaCalc 2.0 calculator (http://sigmacalc.iate.obninsk.ru/). The current evaluation for oxygen covers the energy range between 100 and 4080 keV, so the investigation of oxygen concentrations at even greater depths, is currently impeded by the lack of experimental and, consequently, evaluated data at higher proton beam energies. In this study we present the experimental differential cross sections of $^{nat}O(p,p_0)$ elastic scattering, determined via the relative measurement technique, in the proton beam energy range E_{lab}=4-6 MeV with a varying step (from 5-15 keV), at six backscattering detector angles between 120° and 170° (with a 10° step). The measurements were performed using the Van de Graaff Tandem 5.5 MV Accelerator of N.C.S.R. "Demokritos" in Athens, Greece.

Finally, R-matrix calculations have been performed using the publicly available AZURE code and the obtained results accurately reproduce the current evaluation, along with the differential cross-section datasets obtained in the present work and already existing ones in literature for this extended proton beam energy range. The observed peculiarities and discrepancies, along with the current needs for validation via accurate benchmarking experiments are discussed and analyzed.

O-7

High-accuracy Rutherford backscattering spectrometry

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Rutherford backscattering spectrometry (RBS) is used to determine the areal density and the composition depth profile of heavy elements in thin films on a low-Z substrate. RBS is advertised to reach an accuracy of 1 atom% for selected cases. However, there is no general methodology to estimate the uncertainty and precision for RBS.

We present the analysis of Rutherford backscattering spectra using the differential evolution optimization algorithm [1]. The algorithm helps to find, with very high precision, the sample composition profile that best fits the experimental spectra. The fitting error can be derived since the differential evolution algorithm is based on a stochastic process.

The other contributions to the uncertainty (experimental, counting statistics etc.) are derived from the analysis of synthetic Rutherford back-scattering spectra that are based on the best fit. The synthetic spectra are generated with a Monte-Carlo based spectrum generator. Thanks to the high precision attained by differential evolution it becomes possible to distinguish, for example, the counting statistical uncertainty from the fitting error. Thereby, we present a framework to disentangle and quantify the various contributions to the total uncertainty for the general case in RBS.

We illustrate the approach with the analysis of selected model systems. As examples, we present the uncertainty analysis for the characterization of a 75 nm thick $Sr_xTi_yO_z$ thin film on silicon, and for a 100 nm thick TiO_x thin film on silicon. Thanks to the very high accuracy and traceable uncertainty budgets, the characterized samples are attractive as reference materials for other materials characterization techniques.

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O-8

Systematic R–matrix Calculations for the $^{12}C(^{3}He,p_x)^{14}N$ reaction suitable for NRA applications

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Among the experimental techniques that Ion Beam Analysis offers for the determination of isotopic depth profiles, Nuclear Reaction Analysis (NRA) is usually the preferred one for the identification and quantification of low-Z isotopes in the presence of medium to high-Z elements. Although, traditionally, low energy proton and deuteron beams have been used in NRA applications, nowadays ^{3}He beams constitute a suitable alternative, since they offer all the advantages of the deuteron beams without the disadvantage of neutron production. Thus, ^{3}He-NRA plays an important role in fusion research in the study of plasma-facing components (PFCs) for determining the elemental transport and redeposition of certain light elements of scientific value.

Among these, carbon is of special interest due to the various carbon impurities that can be found in the PFCs. For the determination of carbon depth profiles the $^{12}C(^{3}He,p_x)^{14}N$ reaction channels are usually employed. However the differential cross section datasets available in literature exhibit large discrepancies. Following the systematic study of the $^{12}C(^{3}He,p_{0,1})$ reaction channels by Provatas et al [1] covering an angular range of 123° to 164° for beam energies up to E=2.86 MeV, measurements for the $^{12}C(^{3}He,p_{0,1,2,3,4,5})$ reactions were carried out at the Tandem accelerator at IPP, located in Garching, Germany for θ = 135°, 175° and E_{Beam} = 1.5 to 6 MeV [2].

In the present work the R-Matrix calculations that were implemented in the work of Provatas et al. have been expanded using the AZURE 2.0 code [3], and are now able to accurately reproduce the new experimental data by Hess et al. using only one set of parameters for all the available reaction channels. This successful theoretical reproduction forms the basis for a possible evaluation in the near future.

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O-9

Differential cross section measurements of the ^{6}Li (d, nγ_{1-0})^{7}Be, ^{6}Li (d, pγ_{1-0})^{7}Li, ^{7}Li (d, dγ_{1-0})^{7}Li and ^{19}F (d, pγ_{1-0})^{20}F reactions suitable for PIGE applications

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Light elements such as lithium and fluorine, are widely used in industry. As a result, their detection and accurate quantification, via the PIGE technique, is of great importance. Despite the fact that proton beams are ideal for quantifying ^{7}Li and ^{19}F, they fail in the case of ^{6}Li, due to the lack of an appropriate gamma – ray. In that case, deuteron beams were proposed as a more suitable approach. However, a survey of the existing literature proves that there is a lack of datasets at high energies and a rather narrow range of covered angles. In the present work, a thorough study of the reactions ^{6}Li (d, nγ_{1-0})^{7}Be, ^{6}Li (d, pγ_{1-0})^{7}Li, ^{7}Li (d, dγ_{1-0})^{7}Li at a broader energy and angular range is carried out. Results for the ^{19}F (d, pγ_{1-0})^{20}F reaction are also presented.

The differential cross section measurements took place at the 5.5 MV Tandem Van de Graaff accelerator of NCSR "Demokritos". The deuteron energy beam ranged from 1000 keV up to 2200 keV with a step of 20 keV, at the angles of 0˚, 55˚ and 90˚. For the detection of the γ-ray peaks of interest at E_{γ}=429 keV, E_{γ}=478 keV and E_{γ}=656 keV, two different LiF targets and three HPGe detectors of 80% relative efficiency were used. Additionally, in order to validate the differential cross section measurements, a benchmarking procedure was deemed necessary, using a ^{nat}LiF thick target. Comparing the present results with previous datasets from the literature [1], remarkable discrepancies were found.

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O-10

Developing Ion-Laser InterAction Mass Spectrometry (ILIAMS) for the analysis of environmental ^{99}Tc

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Concentrations of the long-lived fission product ^{99}Tc ($t_{1/2}$ = 2.1·10^5 yrs) in the general environment, mainly originating from nuclear weapons fallout, remain poorly investigated. Quantification of ^{99}Tc concentrations at environmental levels by Accelerator Mass Spectrometry (AMS) requires suppression of isobaric background from stable ^{99}Ru and a reliable normalization method to overcome the lack of a stable Tc isotope.

The novel technique of Ion-Laser Interaction Mass Spectrometry (ILIAMS), recently implemented at the AMS facility VERA (Vienna Environmental Research Accelerator) achieved a Ru suppression of 5 orders of magnitude when overlapping a green laser with the ion beam before injection into the accelerator [1]. On-going research is focusing on a suitable normalization method which is compatible with the ILIAMS method to obtain quantitative results. The most reliable normalisation can be expected from measurements relative to a second artificial Tc isotope ("spike") which is added to the sample before chemical separation. The analysis of the most promising spike isotope, ^{97}Tc ($t_{1/2}$ = 2.1·10^5 yrs), however, suffers from a strong isobaric background due to stable ^{97}Mo. Therefore, alternative approaches using ^{93}Nb or ^{103}Rh for normalisation in combination with a ^{95m}Tc spike ($t_{1/2}$ = 61 d) for monitoring the chemical recovery are being pursued. The use of fluoride extraction, as required for the strong isobar suppression with ILIAMS, and the associated elemental fractionation in the ion source, however, turns the normalisation to other elements very challenging. This presentation will compare the different normalization methods with respect to the reproducibility of the ^{99}Tc results and their applicability to measurements with ILIAMS.

This work receives funding from the Austrian Science Fund (FWF): P 31614-N28 and the European Union's Horizon 2020 research and innovation program under grant agreement No 824096 (Radiate).

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O-11

Accelerator Mass Spectrometry of Plutonium: beyond isotopic ratios

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Even though GW170817 and the associated kilonova from a neutron-star merger were detected in August 2017, the possible sites of r-process elements remain a vividly discussed question in nuclear astrophysics, including special kinds of core-collapse supernovae (CCSNe). A well-known supernova-produced 60Fe radioisotope has been found in several terrestrial reservoirs proving that material from the ejecta of a nearby supernova arrived on earth in the last several millions of years [1]. If live r-process isotopes were to be found in temporal coincidence with the 60Fe peak, it would provide strong evidence to the r-process occurring in CCSNe. The radioisotope 244Pu has been chosen, as it is an r-process only isotope and has a very long half-live, providing the same conditions as for 60Fe. Unfortunately, it is much less abundant than even 60Fe, and therefore a highly concentrated reservoir must be found. Candidates for this type of investigations were found in Atacama Desert, Chile, and Turkana Basin. A great challenge that arises during the 244Pu investigations is the inherent anthropogenic contamination with Plutonium isotopes released during the atmospheric nuclear weapon tests. The AMS (Accelerator Mass Spectrometry) measurements and sample preparation were carried out using the 1MV Tandetron Accelerator installed at the RoAMS Laboratory at IFIN-HH, Romania [2, 3]. Plutonium investigations of environmental samples started around 3 years ago, during this period we chemically processed more or less concentrated samples that could contaminated with atto to femto grams the laboratory. To quantify this unavoidable contamination, real and simulated swipe samples were used to examine the Plutonium concentration.

Acknowledgements: This research was supported by the Collaborative Research Center SFB1258 of the Deutsche Forschungsgemeinschaft (SFB1258), Romanian Government Programme through the National Programme for Installations of National Interest (IOSIN). We are grateful to Dr. Livius Trache, Dr. Gihan Velisa, Dr. Mihai Straticiuc and Dr. Lucio Gialanella for their unconditional institutional support.

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O-12

Radioisotope replacement with compact electron linear accelerators

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The international authorities have identified as a priority the replacement of radioactive sources with alternative technologies, due to the risk of accidents and diversion by terrorists for use in Radiological Dispersal Devices. Many of these sources can be replaced with the X-rays produced by electron beams accelerated to energies of 1-3 MeV. There are many reasons to reduce the size and weight of linacs for specific applications. For example, in security applications such as safeguard tools at nuclear facilities, field radiography and mobile cargo scanners, the systems must be highly portable to allow field operation. Another important consideration is the cost of the replacement sources, which should be comparable with the cost of radioisotopes.

RadiaBeam is developing a series of inexpensive compact electron accelerators in the MeV range for radioisotopes replacement such as Co-57, Ir-192, Cs-137 and Co-60 in insect sterilization, field radiography and safeguard systems [1-3]. These accelerators are based on an innovative split accelerating structure technology to fabricate the linac in two halves, which helps to reduce number of parts, brazing cycles and avoid labor-intensive tuning steps [4]. In this talk, we will overview RadiaBeam's activities on these linacs development, discuss the accelerator design, parameters and applications, and report current progress.

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O-13

Energy deposition by keV ions in single crystalline self-supporting Si and SiC foils

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Quantitative knowledge of the energy deposition of energetic ions in matter is a necessity for materials characterization and modification based on energetic ions, e.g. ion beam analysis, ion irradiation, implantation or sputtering. Moreover, knowledge of the energy loss of slow ions (0.25-3 of the Bohr velocity) in matter is the first step in understanding the contribution of different dynamic processes (e.g. charge exchange, creation of molecular orbitals) in target excitation.

Silicon (Si) is one of the most commonly employed materials in the semiconductor industry, omnipresent in electronic and optical devices. Silicon carbide (SiC), because of its superior physical and electronic properties e.g. high radiation tolerance and wide bandgap, is used in high-temperature power electronics and in harsh environments.

We performed experiments using the Time-of-Flight Medium Energy Ion Scattering System (ToF - MEIS) at the 350 kV Danfysik Implanter at Uppsala University. H, He, N and Ne pulsed beams with energies 20 - 330 keV were transmitted through Si and SiC single crystalline self- supporting foils with nominal thicknesses of 50 nm and 200 nm. Transmitted ions were detected by a large solid angle, position-sensitive detector.

Intensity and energy distributions were measured along random and several different channeling orientations for both Si and SiC. The specific electronic energy loss was extracted by calculation and subtraction of the nuclear energy loss using Monte Carlo simulations. For random geometries, the specific energy loss was compared with SRIM predictions and literature data. For all systems, energy deposition was found less efficient in channeling direction than in random orientation. This observation, in an energy regime, where excitation of localized electronic states in binary Coulomb collisions is excluded points towards different energy dissipation channels contributing. We identify dynamic phenomena such as energy dissipation due to formation of molecular orbitals as well as charge exchange and thus altered mean charge states along the ion trajectories as the source of the additional energy loss in close encounters. [1,2,3].

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O-14

RBS applied to 3D nanostructures

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Due to recent use of nm scale 3D-devices in the semiconductor industry, there is an urgent need for metrology for such structures. Rutherford backscattering spectrometry (RBS) is a quantitative, traceable, and highly accurate technique to probe the composition of samples at the surface and in-depth up to a few microns, commonly used to characterize planar devices. Our research aims at extracting the nanometer-resolved 3D compositional information using RBS, even though the probing beam does not reach the spatial dimensions of the devices. Instead of relying on a focused beam to generate a localized analysis in a 3D-device, this is achieved by analyzing a large ensemble of identical devices. The ensemble analysis allows to reach a drastically improved signal intensity and hence sensitivity. We exploit the energy loss effects of the ions within the nanostructures to retrieve site-specific information at the nanoscale. In this way, we determined the local areal density on the top, sides, and bottom surfaces of an array of fins with a width of 35 nm and nominal pitch of 90 nm with a precision of a few percent, and limit of detection of 10^{13} atoms/cm^2. Remarkably, the approach also allows to extract in-plane geometrical characteristics of the nanostructures like width, pitch, or under-etching. As a first example, we probe the selective removal of the SiGe layers in $Si_{75}Ge_{25}$/Si multi-layered fins with a width of 100 nm and pitch of 420 nm. We show that the Ge-signal in the RBS spectra correlate closely with the dimensional changes due to the applied selective etch of the $Si_{75}Ge_{25}$. The second example is an array of SiO_2 fins with a width of 35 nm and nominal pitch of 90 nm. The silicon signal in the RBS spectra shows distinct features which can be directly related to the pitch and the width of the structures. Complementary simulations of theoretical targets with varying pitch and width support this interpretation and demonstrate the sensitivity to these parameters.

O-15

Low-energy accelerated protons effects on a blood brain barrier model

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Hadron therapy main benefit is the low dose deposition in the tumor surrounding environment comparing with photons-based radiotherapy. Particularly, accelerated proton beams are described to deposit their energy in a finite fixed Bragg peak at depth in tissue with almost no dose beyond this point. Due to the limited access of cytostatics to the brain tumors determined by the blood brain barrier (BBB), radiotherapy is still the main therapeutic tool for such cases. However, only few studies have discussed the accelerated protons effects on BBB. The aim of our study is to analyze the functional activity changes induced by low-energy accelerated protons in brain microvascular endothelial cell cultures as an *in vitro* model of BBB.

Murine brain endothelial cells (bEnd.3) were irradiated to low-energy (< 12 MeV) accelerated protons in the IFIN-HH cyclotron TR19, in the dose range 0-10 Gy, dose rate 1Gy/min, low (~5 keV/□) or high (~10 keV/□) linear energy transfer (LET). The characterization of the proton beam was done by dosimetry measurements and Monte Carlo simulations. After irradiation, the cellular proliferation/viability and the genotoxic effects were evaluated. The functional changes induced by irradiation on adenosine triphosphate (ATP) triggered calcium transients and cellular migration rate were also explored.

DNA repair capacity was significantly inhibited by increasing radiation doses. High LET protons induced a more pronounced reduction of the cellular proliferation and migration rate at the intermediate dose values comparing with low LET ones□ _The irradiation significantly modified the ATP calcium transients' latency and amplitude.

Considering the usefulness of endothelial cell cultures as *in vitro* BBB models in the pharmaceutical industry, this study provides valuable data. Moreover, it is pointed out that the *in vitro* model of the BBB exposed to radiation could [3] Analytical Research Infrastructures in Europe: A key resource for the five Horizon Europe Missions, Analytical Research Infrastructures in Europe: Viral and microbial threats

O-16

Carbon mapping in steel using $^{12}C(d,p\gamma)^{13}C$ in external beam

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Carbon concentration and distribution has a major impact on mechanical properties of steel. In addition, the early manufacture of steel in the Middle Ages remains an important question in archaeometallurgy where the production process changes between indirect and direct modes. Steel incorporates up to a few % carbon in an iron matrix, heterogeneously clustered in carbide phases that can be imaged using metallographic microscopy after acidic attack. We report here a new approach allowing the direct, non-destructive and quantitative mapping of carbon using an external scanning deuterons beam and the detection of the γ-ray and protons emitted by the reaction $^{12}C(d,p\gamma)^{13}C$.

The 1.5 MeV deuteron micro-beam beam was produced in the external microbeam line of the New AGLAE facility of the Centre de Recherche et de Restauration des Musées de France in Paris, France. The sample and the detection setup were placed in a closed Plexiglas® chamber flushed with helium gas to avoid the contribution from carbon dioxide of the atmosphere. The 3089 keV γ-rays were recorded using a HPGe detector placed at 135° and the p0 proton group at 150° using a 1-inch diameter, 100-µm thick annular silicon detector screened by a 25-µm Mylar® foil. The choice of 1.5 MeV incident beam has two advantages: first, the maximum of the reaction cross section at 1.2 MeV is reached two microns below sample surface, reducing the contribution from a possible surface contamination. Second, since the deuteron beam has the same magnetic rigidity as the 3-MeV proton beam routinely employed for PIXE analysis, beam transport and focusing are optimized in the latter mode, avoiding this procedure under neutron hazards. The deuteron beam size was around 50 µm on the target and its intensity was varied from 10 to 30 nA. The beam dose was be monitored from the PIXE signal emitted by the silicon of the 100 nm Si_3N_4 exit foil. Point composition was calculated using SIMNRA program and checked against NIST reference steel standards while the carbon distribution maps were extracted of the from the γ-ray and particle spectra datacubes was obtained using the PYMCA package. The detection limit for carbon in single spot analysis for an integrated charge of 3 µC was around a 300 µg/g for γ-rays, mainly limited by the Compton background of the high energy γ-rays of the $^{14}N(d,p\gamma)^{15}N$ on nitrogen present in the exit foil, and 10 µg/g for protons. The results are exemplified by mapping carbon on an area of 5500 µm x 500 µm of a Middle Ages archaeological sample in 90 min with a total charge120 µC.

O-17

High energy beam analysis of cultural heritage materials from middle age to the renaissance

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Key words: ion beam analysis, XRF, trace element analysis, activation analysis, fire-gilding, tin soldering

The field of art and archaeology requires the development of non-invasive analytical methods to determine the elemental composition of precious objects without sampling. The GIP Arronax cyclotron provides high energy beam charged particles up to 70MeV, including alpha particles and protons [1]. The PIXE method has already been used for multi-elemental analysis to reach the ppm concentration of light elements [2,3]. By taking advantage of the high energy beam, heavier trace elements are detected by their K lines, and depth analysis can be performed for multi-layered samples such as paints and objects with a surface coating or corrosion [4,5,6]. In addition, radioisotopes are created in the irradiated materials by particles activation (PAA). In-depth analysis can be also performed after irradiation by gamma rays more energetic than X-rays [7]. Our applications cover different types of metal alloy objects. Historical issues such as provenance and manufacturing techniques are explored. We will present trace element analyses on a set of coins illustrating the silver trade in Europe in the 16th century. Elements such as In and Au are geographic tracers of silver and can be used to track the supply of minerals in this period [7]. Other work in progress includes the study of a Romanesque crucifix and a medieval water pipe. Both are related to the study of manufacturing techniques. The Christ figurine is made of brass gilded with mercury and is fixed on a cross, also gilded [8]. We will characterize the quality of the gilding by measuring its thickness at different areas of the crucifix by PIXE and compare the results with XRF analyser. The lead pipe is soldered with tin, a PAA analysis is performed to obtain a concentration profile comparing the Sn/Pb ratio in depth. High energy ion beam analysis are powerful methods to study cultural heritage object. We will show here main assets of those methods while mentioning their complementarity with more conventional techniques like XRF and MEB.

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O-18

A pilot study on glass finds from the Geto-Dacian Cârlomăneşti and Gruiu Dării settlements, Buzău county, Romania

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A set of 40 glass objects – vessel fragments and beads – discovered at Cârlomăneşti and Gruiu Dării, Buzău county, Romania and tentatively dated to the 1st c. BC – 1st c. AD were analysed for their chemical composition. The measurements were performed using either a combination of simultaneous PIXE-PIGE (Particle Induced X-ray Emission and Particle Induced Gamma-ray Emission) techniques at the AGLAE accelerator located in the basement of the Louvre Palace, Paris, France or only external PIXE at the 3 MV Tandetron accelerator of IFIN-HH, Bucharest. The goal of this archaeometric study was to get clues about the raw materials and manufacturing techniques of these exquisite vitreous items, also about the trade connections of the Geto-Dacian populations with the Hellenistic and Roman world. The glass finds under scrutiny belong to the archaeological collection of Muzeul Județean Buzău. These material finds have a particular significance for the archaeological record of the Carpatho-Danubian area from the Late Iron Age. Analytical data on coeval finds from selected Hellenistic and Roman archaeological sites were used as comparison terms. The compositional results showed that in all cases we deal with natron glasses, with overall recipes typical for that period. Just occasionally, recycling indicators were evidenced. The compositional analyses confirm the hypothesis that most of these vitreous artefacts were imported items made of fresh glass. Depending on the characteristics of each sample (colorless or intentionally colored), clues about the decolourizing agents (antimony, manganese) or glass chromophores (manganese, iron, cobalt, copper) were also obtained.

As analytical data on glass finds discovered in Geto-Dacian archaeological sites are completely missing from the literature, this study can be considered pioneering for the Romanian archaeometric landscape.

O-19

Quantification and Speciation of Lead in Air Particulate Matter Collected from an Urban Area in Amman, Jordan, Using PIXE and XANES Techniques

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Knowledge of elemental content and chemical composition of air particulate matter (PM), i.e., atmospheric aerosols, is essential for monitoring air quality as well as for understanding air pollutants and the identification of pollution sources. In Amman, Jordan, the University of Jordan has been interested in studying the characteristic features of atmospheric aerosols in the framework of the International Atomic Energy Agency (IAEA) regional technical cooperation projects [1, 2]. Over the last few years, more than 500 aerosol samples have been collected on Teflon filters on a sequential basis (24 h-sampling, 2-3 times a week). In this contribution, we present an investigation of lead (Pb) on a selected set of aerosol samples from Amman using PIXE (particle-induced X-ray emission) and XANES (X-ray absorption near-edge structure) techniques. PIXE measurements were performed using the external beam PIXE setup of the 3 MV Tandetron accelerator of the LABEC laboratory [3] of INFN, Florence, Italy. XANES measurements were performed using the IAEA X-ray spectrometry (IAEAXspe) endstation [4] at the XRF beamline [5] of Elettra-Sincrotrone Trieste, Italy. The obtained results, despite being for a few selected samples, are a step forward in the understanding of the presence of lead in Amman's atmosphere.

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O-20

Recent results of the commissioning of the 1 PW laser system of ELI-NP

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The experimental campaign for the commissioning of the 1 PW laser system and the target area E5 of the Extreme Light Infrastructure - Nuclear Physics (ELI-NP) has begun last summer and now has almost been accomplished [1-4]. The purpose of the experimental campaign is to characterize the laser beam properties through the interaction with different types of targets at different laser power. The features of the particle beams emerging from the interaction give important information regarding the quality of the laser. In this regards, a comparison of the results of the experimental campaign with the literature ones, obtained under similar conditions, is really useful. This is an indirect method to characterize the laser, that jointly with the direct measurement of some laser parameters, at low and high power, provides a powerful way to characterize the High-Power Laser System (HPLS). The HPLS of ELI-NP is a Ti:Sa-based laser system with central wavelength around 810 nm. It can deliver to the E5 area a two laser beams with a maximum energy of 24 J, and pulse duration at best compression of about 24 fs, at the repetition rate of 1 Hz [5]. During the commissioning, the interaction of the laser with both solid and gas targets was investigated by looking at the acceleration of ions and electrons, via TNSA and LWFA, respectively. The shots on solid targets were performed by using a short focal parabolic mirror, which provided a best focus of 3.4 μm at FWHM; while the shots onto gas targets were done by focusing the laser beam down to about 25 μm at FWHM by means of a long focal parabolic mirror. The full power laser shots were very reproducible having a shot-to-shot energy fluctuation of about ±2% about the requested value. The laser focal spot oscillation at the target position was about 2 μrad, that is less than a laser spot size. At the beginning of the commissioning, we have been seeking for laser temporal contrast issues, such as pre-pulses and light back-reflected from the target. We have identified and fixed most of the issues. In the first part of the campaign, we have employed solid targets and investigated the TNSA mechanisms by performing shots with or without a Single Plasma Mirror (SPM) to better characterize the contrast level. We have accomplished several shots and achieved proton energy up to about 60 MeV. In the second part of the campaign, we have used gas-jet or gas-cell target, up to 2 cm long, with pure He gas, or admixture to study the electron acceleration via the "bubble regime". We have observed electron beams with energy above 2 GeV. The results of the commissioning are generally consistent with what reported in the literature and will be presented here.

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O-21

Characterization of laser-accelerated protons based on the excitation of nuclear isomeric states

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A method for on-line characterization of laser-accelerated protons with PW laser class, based on the population of nuclear isomeric states in secondary targets, is presented. The detection of the γ de-excitation of reaction products was performed in-situ by using $LaBr_3{:}Ce$ scintillation crystals. The method's feasibility was demonstrated in a 4 PW laser experiment at the CoReLS facility. Three isomers, ^{113m}In (649.7 keV, $T_{(1/2)}$=80.4 s), ^{90m}Nb (124.7 keV, $T_{(1/2)}$=18.8 s) and ^{79m}Kr (129.8 keV, $T_{(1/2)}$=50 s), produced from the proton reactions on Cd, Zr and Br target nuclei, respectively, have been used to detect and characterize protons accelerated from the interaction of ultra-high contrast multi-PW laser pulse with ultra-thin solid target [1].

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O-22

Imaging diagnostics for laser plasma accelerators

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Imaging diagnostics are a powerful tool for offering precious information, in real-time, about the laser driven plasma during high-power laser experiments. In this report, we present the design and implementation of a shadowgraphy system and wavefront sensor measurements in the commissioning experiments of the ELI-NP facility. The shadowgraphy system was used for imaging the plasma generated by 1PW laser pulses focused on both a solid target for proton acceleration on Target Normal Sheet Acceleration regime and a gas cell target for Laser Wake Field Acceleration of electrons. To derive the plasma density, the wavefront sensor measured the phase change of the probe beam wavefront going through the plasma channel generated by the focused pulse in the gas cell.

O-23

Ionization-induced transition from synergistic to competitive effect in defective $KTaO_3$

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Potassium tantalate ($KTaO_3$) is a major contender in the emerging field of functional oxide electronic due to its tunable electronic and physical properties via ion irradiation processes. While the response of virgin $KTaO_3$ to electronic energy deposition (S_e) can be predicted a priori because it is reasonably well understood [1]; in contrast, the response of defective $KTaO_3$ to ionizing irradiation is more difficult to predict a prior due to complex interaction between S_e and pre-existing defects. In this regard, pre-damaged $KTaO_3$ has been irradiated with several ion species (5 MeV C, 7 MeV Si and 12 MeV O ions) over an extended selection of ion fluences at 300 K. For Si ions, both designed experiments and MD simulations, clearly shows that the synergistic effect is active and induces the formation of small ion tracks. However and surprisingly, for C and O ions, RBS/C measurements reveal unprecedented transition from ionization enhanced defect production to damage recovery process. These findings, in addition to its essential role for understanding the fundamentals of electronic interactions of ions with pre-existing defects in this material, may provide new possibilities to tune the functionalities of $KTaO_3$ via ion irradiation processes.

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O-24

The effects of keV and MeV ion beam irradiation on the physicochemical properties of glassy carbon

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When placed in extreme environments, materials can behave in unexpected and unpredictable ways. Thus, understanding the material behavior in such cases is critical to designing new advanced materials and assuring their safety and reliability.

In the present study the effects of swift heavy ion irradiation (167 MeV Xe^{26+}, 6×10^{11} – 1×10^{14} ions cm^{-2}) on the structural properties of glassy carbon have been examined by using Raman spectroscopy, X-ray diffraction (XRD) and transmission electron microscopy (TEM). XRD analysis has shown an increase of disorder in irradiated samples *i.e.* reduced crystallinity and increased interlayer spacing. More precise structural information was obtained by analyzing the cross-section of the samples. TEM analysis identified four regions whose total thickness is matching the penetration depth predicted by SRIM. Besides region of reduced crystallinity, the TEM analysis revealed that topmost layer (~320 nm) is being amorphized. Raman analysis revealed regions in which structural degradation is either dominated by electronic or nuclear losses. Moreover, it helped to identify a region in which *sp*-carbons chains are being formed due to interaction with ions.

The obtained results improve the understanding of structural changes appearing in glassy carbon upon swift heavy ion irradiation and will be discussed from the point of view of extreme conditions created in the interaction with ions.

O-25

Ion beam based Coincidence Doppler broadening spectroscopy of thick samples

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Coincidence Doppler Broadening Spectroscopy (CDBS) is a well-established technique for defect assessment in alloys. CDBS technique is based on the annihilation of positrons in the sample and detection of annihilation radiation using a high-resolution HPGe detector [1]. The conventional CDBS technique uses ^{22}Na as a standard positron emitter source. The maximum energy of the emitted positrons is about 0.5 MeV and it cannot penetrate more than 100 µm in alloys. So, conventional CDBS of alloys provides no information about the bulk of the sample. In this work, we designed the first ion beam-based CDBS technique using a 3MV Van de Graaff accelerator for analysis of thick sample via positron generation inside the depth of the sample. Figure .1 shows the set-up of the experiment. In this configuration a 2.5 MeV proton beam from the accelerator bombards an Ag coated PTFE target to generate high energy gamma through $^{19}\mathrm{F}(\mathrm{p},\alpha\gamma)^{16}\mathrm{O}$ nuclear reaction. The produced gamma-rays (6.1, 6.9, and 7.1 MeV) are guided to the sample using a lead collimator. The high-energy gamma rays produce positron inside the investigated sample via the pair-production mechanism and eventually annihilate in the sample and provides two nearly 511 keV gamma rays for CDBS experiment. The performance of the established technique is evaluated by the CDBS analysis of five low-carbon steel samples annealed and preloaded during the uniaxial tension test. The correlation between the S-parameter and the stress-strain curve is investigated and discussed. The results confirmed that the presented technique is sensitive enough to identify the defects in thick and high-Z materials.

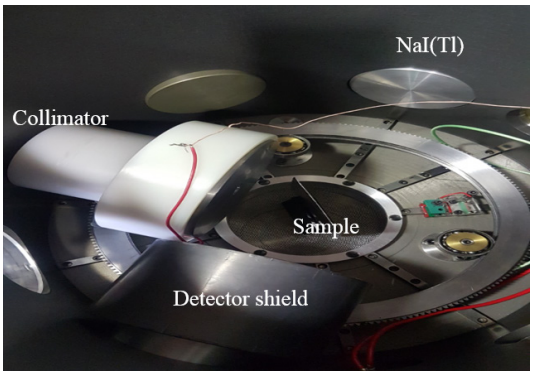

Figure 1. The set-up of gamma-driven CDBS experiment.

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O-26

Differential cross sections measurement of $^{11}B(d,p\gamma_{1,2})^{12}B$ reactions for analytical applications

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Boron is a highly regarded technological element and has numerous applications in various fields. Natural boron is comprised of 81.1% 11B and 19.9% 10B. It is widely used in the semiconductor industry as a dopant for Si and Ge substrates, and it is also an essential ingredient of hard coatings on the walls of thermonuclear plants. Thus, the accurate quantitative determination of the Boron is of great importance [1]. In the present work the differential gamma-ray producing cross sections of the $^{11}B(d,p\gamma_{1-0})^{11}B$ (E_γ= 953 keV) and $^{11}B(d,p\gamma_{2-0})^{12}B$ (E_γ= 1674 keV) nuclear reactions were measured for Boron determination by DIGE method. The measurements were carried out in the 600-2000 keV energy range at the laboratory angle of 90° using the deuteron beam of the 3 MV Van de Graaff electrostatic accelerator of Nuclear Science and Technology Research Institute (NSTRI). A thin B_2O_3 target evaporated onto a self-supporting Ag film was used for cross section measurements. An HPGe detector placed at an angle of 90° with respect to the beam direction was employed to collect gamma-rays while an ion implanted Si detector placed at a scattering angle of 165° was used to detect backscattered deuterons. The obtained cross section data were compared with the only previously reported data [2]. The thick target gamma-ray yields were measured in the same experimental setup for deuteron energies between 900 and 2000 keV (100 keV steps), using a natural thick BN target. The validity of the obtained cross sections was verified through a thick target benchmarking experiment. In this way, the thick target yields calculated from the integration of the obtained differential cross sections over the target thickness were compared with those of the measured thick target yields [3,4].

Keyword: Differential Cross Section; DIGE; ^{11}B; Thick Target Benchmarking

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O-27

Some ideas about the absolute dating of the site Tărtăria-*Gura Luncii* Alba County, Romania

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The systematic research started in 2010 at Tărtăria continues to this day. At this moment we have 11 surfaces in which we work year after year. To clarify the problem of the absolute chronology of the site we have researched a zone from the SI surface (2019-2021) and carried out bone and coal samples for radiocarbon dating.

In this short presentation we will talk about the Tărtăria-*Gura Luncii* site, systematic researches from 2019 and some short results after radiocarbon dating. In this campaign we discovered some Mesolithic features, period about we did not expect to be in this site. Radiocarbon analyses helped us to know more things about what, how and how long communities lived here, especially Petreşti and Vinča.

O-28

Characteristic X-ray study over a set of bracelets found in funerary context at Vânători, Galați county

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A set of 8 bracelets were unveiled in funerary context at the Vânători archaeological site, Galați county, Romania. This archaeologic site started being explored in 1970 by M. Brudiu [1] and later by M. Florescu and M. Nicu [2]. The explorations were continued between 2017-2019 over an area of 2000 m^2. The findings were placed in multiple centuries (XIVth-VIIIth c. BC) certifying the fact that this site represented a long-lasting settlement. The bracelets hoard was unveiled near a double grave to which they can be linked.

The present study was performed in order to identify the alloy composition and bring into the light the funerary practices typical for that period of time. The bracelets were analyzed using the PIXE and XRF techniques, applied at IFIN-HH. The 3MV Tandetron particle accelerator was used to apply the in-air PIXE technique, while a handheld Bruker Tracer S1 Titan apparatus was used to apply the XRF technique.

Both techniques identified the composing alloy as a bronze alloy, but with significantly lower tin percentages, with respect to other bronze artifacts discussed by literature [3, 4]. In order to obtain a more precise view over the period of time when these bracelets were manufactured, a few bone samples recovered from the site were dated using ^{14}C. The measurements were performed at the RoAMS laboratory from IFIN-HH.

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O-29

The absolute dating of the first wave of Neolithic colonization in Romania – Cristian I, Sibiu County

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The preventive archeological researches made on the 4th Sector of Sibiu – Orăştie highway in the site called Cristian I revealed the existence of a settlement and a sacred / ritual camp – overlapped – belonging to Early Neolithic, Starčevo-Criş culture, phase I.

This archeological site's chronology is the following one:

The first Horizon – the sanctuary composed by the ritual pits;

The second Horizon – the settlement, partially contemporary with the sanctuary;

The third Horizon – the abandonment of the sanctuary and site.

The paper presents the absolute dating of these horizons.

O-30

Ultra-high dose rate irradiation induces senescence and cell cycle arrest of B16 cells

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Due to its unique characteristics the proton beam is more effective in killing tumor cells, minimizing normal tissue injury that will negatively impact the patients' life. Ultra-High Dose Rate (FLASH) Radiotherapy has emerged as more efficient as it is able to deliver a single high dose at a dose rate higher than 40 Gy/s in order to obtain a good irradiation of the tumor, while preserving normal tissues from damage.

The aim of this study was to investigate the effects induced by ultra-high dose rate irradiation in B16 cells. The 3 MV Tandetron^{TM} accelerator (IFIN-HH), was used to irradiate the cells with doses between 0 - 3 Gy at different dose rates ranging from 5 Gy/s up to 250 Gy/s.

We investigated ROS formation, senescence and cell cycle at 24 h post irradiation. The results showed that the highest effect regarding ROS production and senescence was found at a 250 Gy/s dose rate, while the irradiation condition induced G_2/M cell cycle arrest.

Acknowledgments: This work was supported by the Romanian Ministry of Research, Innovation, and Digitalization, through the National Core Program No. PN 19 06 02 03/2019, PN 19 06 02 01 /2019 and PN 19 06 02 02, Romanian Government Programme through the Programme for Installations of National Interest (IOSIN).

O-31

Normal Conducting Magnets and Power Converters – ICPE-CA Participation to the In-Kind Contribution of Romania to the FAIR Project

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FAIR - Facility for Antiproton and Ion Research project aims to develop near Darmstadt, Germany, a particle accelerator system which will provide high-energy ions and antiprotons beams for high level research in atomic physics, antimatter physics, nuclear physics in extreme conditions, plasma physics and related applications.

Romania has been involved in the FAIR project since 2007, as a shareholder in the company created to implement the project - FAIR GmbH and as a member of the consortium created to design and build the High Energy Storage Ring - HESR, important component of FAIR. The in-kind contribution of Romania for the realization of HESR is provided by the National Institute for Research and Development in Electrical Engineering ICPE-CA Bucharest and consists of 119 normal-conducting magnets and 72 power converters for these magnets.

The paper presents the equipment manufactured, tested and delivered by ICPE-CA to FAIR, as well as the main capabilities developed within the institute for the design, manufacture and testing of normal-conducting magnets for particle accelerators.

O-32

Ion Manipulation using the novel Harmonic Ion Transport System Developed at ELI-NP

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A novel technology for the manipulation of heavy ions is presented, using Printed Circuit Boards constructed from an array of metallic strips on which radio-frequency signals are applied for the creation of a cvasi-stable propoagation field, named the Harmonic Field. We present the initial research into RF Carpets that led towards this novel aplication, as well as the simulations that prove the concept. We also present our experimental work using this technology, as it is currently developed.

O-33

Theoretical Study of Laser Energy Absorption towards Novel Bright Proton and Electron Sources

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Our main goal is to describe and model the energy transfer from laser to particles, from the transparent to less transparent regime of laser-plasma interaction in the ultra-high intensity regime, and using the results obtained to optimize laser ion acceleration. At the interaction of an ultra-high intensity laser pulse (I ≥ 1018W/cm2) with a plasma, the plasma constituents will absorb a significant part of the laser energy and will be accelerated up to relativistic velocities for electrons. The most predominant mechanisms of energy transfer from the laser pulse to the plasma constituents are collisionless in this regime, being done by collective effects in plasma. The absorption of laser energy depends on the initial laser and target parameters [1, 2, 3]. The target transparency or opacity depends on the interaction process itself: a slightly over dense target can absorb or reflect the laser energy according to the laser amplitude [4]. We propose a theoretical model of energy transfer, assuming that most of the laser energy will be transferred to hot electrons. The model proposed is further tested and corrected through 2D particle-in-cell (PIC) simulations performed with SMILEI (Simulating Matter Irradiated by Light at Extreme Intensities) [5]. Varying the target density and thickness, we studied the optimal parameters for the maximum conversion efficiency of the laser energy to particles. We investigate a model for a near-critical density plasma between 0.5 – 20 nc (where nc ≈ 1.1·1021 cm-3 is the critical density) driven by a laser pulse of intensity in the range 1018 – 1023 W/cm2 and the pulse duration in the range 10 – 100 fs. The laser absorption mechanisms determine the characteristics of the accelerated particles. Theoretical modelling of the predominant laser-plasma interaction mechanisms predicts the particle energy and conversion efficiency optimization [6]. The transition from the opaque to the transparent regime can lead to an enhancement of the ion acceleration process [7]. Our studies led to an optimization of the target areal density for maximizing proton acceleration for a laser intensity of 1022 W/cm2, which is in good agreement with [8].

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O-34

Trace of Thermoelectricity on the XAFS Spectroscopy

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The x-ray absorption fine structure spectroscopy (XAFS) technique is a well-known and popular synchrotron based technique due to its broad energy range for data collection process. XAFS can provide us very precious data on both the electronic and crystal structure properties of the interested atom in the studied material. Besides, most importantly, a good XAFS data can help us to obtain the exact positions of the atoms' in the crystal. Additionally, the technique has the ability to determine the crystal structure of the material with appropriate analysis. In this study, traces of thermoelectricity on the crystal structure were analyzed by the XAFS technique by temperature dependent calculations using FEFF 8.20 code for the popular thermoelectric materials Bi2Te3 and Bi2Se3. In this manner, the deterioration in scattering densities was thought to be indirectly related to thermoelectric conversion power, and the studied material analysis revealed so much interesting data confirming the relationship of the thermoelectric properties of the materials with the decrease in the number of electrons in the outer-shell electrons that are actively involved in the scattering mechanisms. The results of the study show high agreement with the thermoelectric properties of the studied materials, as reported in the literature.

Keywords: XAFS Spectroscopy, Thermoelectricity, Crystal Structure, Li-ion Batteries

Poster Sesion A
Monday, July 18th, 2022

P-A-1

Contribution of Scatter Neutrons in the Neutron Source Calibration Facility at PTB

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At neutron calibration facilities, routine calibration measurements of dosimetric devices are performed in special calibration rooms, thus the neutron survey meter is subject not only to the direct neutrons fluence coming from the source but also to a component that reaches the device after interactions with the air, walls and other equipment inside the calibration room. In practice, the shadow method is used to separate the scattered neutron component from the direct one [1], but it is difficult to distinguish between the air scattered neutrons and those returning from the room and surrounding equipment, especially if the dimensions of the room are not sufficiently large. In these circumstances, the Monte Carlo simulation method is very useful because the influence of each component can be calculated separately. In this work, a detailed simulation study of the irradiation room and neutron sources used at the Physikalisch-Technische Bundesanstalt (PTB) was performed using the code MCNP6 and the latest proposed spectrum data for moderated and unmoderated ^{252}Cf sources [2,3]. The contribution of scattered neutrons from the air, wall, and equipment in the room was calculated for ^{252}Cf, D_2O-^{252}Cf, and ^{241}Am-Be sources at different reference points. The results show that the air in-scatter and out-scatter neutrons change with source type and the contribution from the wall increase with the distance from the source. The total contribution of the scatter neutrons to the total fluence at the reference point 170 cm away from the source are 50 %, 55 % and 46 % for the ^{252}Cf, D_2O-^{252}Cf and ^{241}Am-Be sources respectively.

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P-A-2

The influence of thermal annealing and ion implantation on electrical hysteresis of multilayered titanium dioxide memristors

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While thin layer memristors are well suited for hebian electronics and neuromorphic applications, certain applications require comparatively bigger volume of these devices. This poses important challenges to the development of suitable devices in regard to desired characteristics [1].

The degrading of electrical characteristics of memristive devices has been known to be a problem, which becomes especially challenging when increasing the volume of such devices. There are multiple ways in which desired characteristics for memristive devices can be obtained [2], by thermal annealing, multilayer deposition, heavy ion implantation, nonstoichiometric composite materials usage, electrical forming to name a few.

This poster presents our progress regarding the modifications of electrical hysteresis curves multilayered titanium dioxide memristors in respect to thermal annealing and ion implantation and constitutes our work towards developing memristors for sensing applications.

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P-A-3

Ionization-induced annealing of preexisting defects in silicon single crystal

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A long-standing objective in materials research is to use beams of energetic particles to introduce defects into the material and thus influence its properties, or to effectively heal fabrication defects. Ion implantation is an extensively used technique for material modification. Using this technique, we can tailor the morphological, mechanical, optical and electronical properties of materials. Because crystalline silicon (c-Si) is one of the most important materials in today's technology, understanding Si responses to energy deposition from energetic charged particles is a very important aspect for different kind of applications, from defect engineering, ion-beam processing, particle detectors and nuclear energy applications. Previous investigations [1] indicated that ionization effects due to the energy loss to target electrons can anneal pre-existing defects, and therefore may effectively modify or alter microstructure evolution, but without identifying the threshold value of electronic energy loss for initiating the ionization-induced annealing process at room temperature. In order to check the occurrence of such a phenomenon at much lower electronic energy loss values, pre-damaged Si single crystals has been irradiated with 12 MeV O ions over an extended selection of ion fluences, at 300 K. Ion channeling measurements reveals significant recovery of pre-existing defects when exposed via inelastic ionization. These findings can contribute to Si-based device fabrication by providing a room-temperature approach to repair atomic lattice structures, to enhanced radiation tolerance and reliable performance prediction for materials in extreme radiation environments.

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P-A-4

Shedding new lights on Late Antique pottery from Histria, Romania

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An assemblage of ninety Late Antique pottery shards discovered at Histria, Romania dated to the 4th-7th c. AD, was studied using Optical Microscopy (OM) and PIXE (Particle Induced X-ray Emission) technique, in order to get insights into the raw materials and manufacturing techniques, as well as into the commercial links of this settlement from the Black Sea with the rest of the Roman Empire. Histria was a colony founded by the Greek city of Miletus in the second half of the 7th century BC on the western coast of the Black Sea; its vivid life ceased at the beginning of the 7th century AD. Nowadays Histria is one of the most important archaeological sites of Romania, being excavated for more than one hundred years. The fine ware shards subjected to archaeometric analyses were discovered in the Acropolis Centre-South (ACS) Sector, Histria. They originate from vessels with well described typology that were manufactured either in some Oriental or some North-African workshops and subsequently imported to Histria alongside other commodities. Several shards identified as regional products, i.e. fragments of vessels shaped in some Pontic workshops, were also chosen for investigations.

The petrographic characterization by OM led to the classification of potteries into six groups differentiated by the amount of matrix, the presence or absence of temper (carbonatic concretions, ceramoclasts) and by the quantity of clasts. Clues about the firing temperatures were suggested by the type of clasts and the presence of untransformed carbonatic concretions.

Chemical composition of the shards was determined by PIXE at AN2000 accelerator of LNL, INFN, Italy. The statistical analysis of the PIXE data was coherent – in most cases – with the stylistic attribution and suggested provenance of the original vessels.

P-A-5

Present status of the Uppsala scanning nuclear microprobe

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The Uppsala scanning nuclear microprobe, named SLIM-UP (Scanning Light Ion Microprobe in Uppsala), was originally installed in The Svedberg Laboratory, Uppsala University, during 1989/90 [1]. The main components of the facility, i.e. the object forming apertures, collimator apertures, magnetic deflection unit, probe forming quadrupole lenses and magnet driving power supplies were the first ones that were sold by Oxford Microbeams Ltd. Since then, the microprobe has undergone several minor and major modifications. The present configuration is a re-build of the SLIM-UP, now attached to the 5 MV tandem pelletron accelerator (NEC) of the Tandem Laboratory, at the Ångström Laboratory, Uppsala University.

In this contribution we give an overview about the present status of the Uppsala scanning nuclear microprobe facility, including a detailed description of the components, the most recent technical developments and the capabilities of the system. In addition, we present the most recent performance tests and some ongoing scientific applications, such as the elemental depth profiling of metal-organic framework (MOF) single crystals by Rutherford Backscattering Spectroscopy [2].

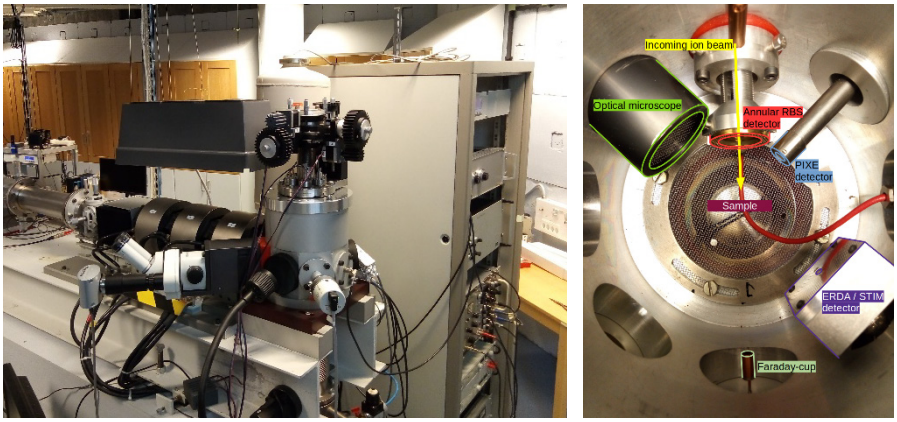

Figure: The Uppsala scanning nuclear microprobe.

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P-A-6

Reconstructing prehistoric diets by CT studies on coprolites from Schela Cladovei, Romania

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Coprolites are fecal materials both paleoethological and archaeological contexts preserved by either mineralization or desiccation [1]. As such they can provide important data on past environments and human behaviour: changes in diet, health, and environment that typically cannot be obtained through other analytical methods [2]. The present poster reviews the preliminary results of an ongoing coprolite study by computed tomography on the coprolite assemblage originating in the prehistoric (Mesolithic and Early Neolithic, ca. 7400-5600 cal BC) archaeological site at Schela Cladovei, Romania [3], [4]. CT images clearly indicate the presence in the human/ mammal coprolite of a significant amount of vertebrate and fish bones, and very likely, vegetal remains (fibre and grain), indicated by voids of specific shape. It also suggests variable dietary patterns of different individuals. The CT data collected so far strongly supports the existing information provided by stable isotope studies - N, C and S [5] which indicates a high-riverine intake in the diet of the local Mesolithic and Early Neolithic communities. It is also in accordance with recent hypothesis suggesting the vegetal terrestrial compound of the diet was more important than previously thought. Future directions of the present project aim at precise (DNA) identification of the coprolites origin, the identification of the fish and mammal bones present and their species of origin, as well as of the vegetal remains identified in the CT images. Considering the significant amount of coprolite remains recovered from the site, with proper ^{14}C dates of the contexts of origin, we aim for a high-resolution identification of the dietary patterns of the individuals at the site, most likely on a seasonal basis. Last but not least, is the first of its kind in Romanian archaeology.

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P-A-7

Developments of the ETH/Ionplus Cs-Sputter Ion Source towards high Brightness

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In the frame of a joint research activity within the European RADIATE project [1] various investigations and experiments have been conducted at ETH and Ionplus with the aim of improving the performance of the ETH/Ionplus Cs-sputter ion source for AMS relevant nuclides.

An experimental platform with two beam profile monitors was installed at ETH to perform phase space measurements and to test new ion source components such as in-house designed ionizers or high conductance Cs nozzles. Ion optical simulations using the COMSOL code [2] were made to obtain a better understanding of the ion-optical dependencies on the electric field configuration and the charge carrier densities.

Furthermore, the thermal distribution in the ion source was simulated and measured by placing eight thermocouples at selected positions on the Cs-nozzle and reservoir. This way the thermal response time of the ion source was investigated and determined. Different versions of the extractor lenses, target holder materials and geometries were tested with AMS facilities available at Ionplus and ETH. This contribution will discuss and summarize the most important results and outcome of these investigations.

[1] European Union's Horizon 2020 research and innovation program under grant agreement No 824096, www.ionbeamcenters.eu/radiate/
[2] www.comsol.com

P-A-8

Supplementary steps in the purification of quartz from geological samples used in surface exposure dating by Accelerator Mass Spectrometry with ^{10}Be and ^{26}Al

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Surface exposure dating (SED) is a technique that utilises the concentration of cosmogenic nuclides produced in minerals (especially quartz) at the surface of the Earth to date landforms [4]. The annual rate of production per gram mineral, concentration per gram and rate of decay of cosmogenic nuclides (i.e. ^{10}Be, ^{26}Al, ^{36}Cl) are used to determine exposure ages, burial ages, or erosion rates of rocks and sediment for a variety of landforms and geomorphological processes such as deglaciation, landslides, sediment transport and deposition rates, formation of fluvial terraces, volcanic eruptions, uplift and incision rates [5]. Methods of extracting Be and Al from a rock sample have been described in Merchel and Herpers (1999), Ivy-Ochs (1996), Kohl and Nishiizumi (1992) and Nishiizumi et al. (1989). The processing of the raw samples follow the order: quartz purification, spike addition, HF digest, Be and Al separation by cation and anion exchange and precipitation methods, oxidation and AMS measurements. In order to accurately surface exposure dating, the amount of dissolved quartz needs to be well determined. This assumes an accurate weighing and that the dissolved quartz has no impurities. Furthermore, depending on the particularity of the rocks, sometimes are encountered problems during the chemical processing: e.g. presence of unknown non-magnetic minerals which affect the proportion of pure quartz analysed. In this scope, for purification of target mineral, is necessary to perform some extra cleaning steps prior the HF digest. In this study we try to use some chemical treatments and heavy liquid solids separation in order to obtain a higher purity of quartz and will perform a qualitative and quantitative analyses on the samples to evaluate the composition of unknown elements. First preliminary results will be presented in the ECAART 14 Conference.

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P-A-9

Radioactive tracers in industry: Thin Layer Activation of non-metallic materials

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The application of radioactive isotopes has long history and many instances in medicine. Their application in industry has been also established similarly long ago, but it has not been spread so widely. Nowadays the radioactive tracing in industry and agriculture shows a growing trend again, especially due to the effort of the International Atomic Energy Agency (IAEA).

One of the special areas of the radioactive tracers is the Thin Layer Activation (TLA)[1]. During the TLA the radioactive tracer isotopes are produced within the volume of the material to be investigated, sometimes with neutron activation, but mainly (when really thin activated layer is required) by charged particle activation. The goal of the investigation is to study the wear, corrosion and/or erosion of the parts in economic and rapid way by using their gamma-ray emission. For this purpose, a charged particle accelerator is necessary to be used and considering the necessary beam energies a medium energy cyclotron can do this task best. The majority of such kind of investigations is performed on metallic parts (pure metal or alloy) because most of the structural material contains such elements (Fe, Co, Ni, Ti, Cu, Zn, …), which are perfect to produce proper radioisotopes by charged particle irradiation. The applicability of the produced radioisotopes depends on their production yield, half-life, gamma-energy and gamma-intensity.

Nowadays the modern structural materials are not always made of metallic alloys but contain special non-metallic surface layers (plastic, DLC (diamond like carbon)). Fortunately, those materials/layers contain carbon and on carbon there is a proper nuclear reaction for producing $_{7}$Be. It has reasonable production yield for $_{3}$He particles, proper half-life and usable gamma energy for wear measurement. In spite of the very high price of the $_{3}$He gas used in the ion-source, there is a growing request for this kind of activation. In this paper we present the nuclear physics background for this reaction and show the results on different carbon containing materials and layers.

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P-A-10

Early Middle Ages Metal Artefacts from Dobruja under PIXE and XRF Lenses

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About a decade ago, three metal processing centers were discovered near Preslav (Bulgaria), in Nadarevo, Novosel and Zlatar, whose activity took place in the 10th century [1, 2, 3, 4]. The discoveries offered new directions of analysis in the study of the organized process of metal art on the Lower Danube in the early Middle Ages. The appearance of moulds and lead moulds revealed that many types of belt ornaments and adornments were created here, previously considered to be brought mostly from Byzantium, the northern Black Sea territories and the Pannonian Plain. For each production center, Particle Induced X-ray Emission (PIXE) or X-Rays Fluorescence (XRF) analyses were performed on representative samples, following which some sources of raw materials were identified and the technical modalities for making the parts (basic elements and so-called trace elements) were established for each workshop. Within this study 40 belt ornaments, mostly bronze (clean metal surfaces), found at Adamclisi, Oltina, Valu lui Traian, Tufani, Hârșova, Capidava, Cochirleni or passim were analyzed by PIXE and XRF, two highly sensitive multi-elemental analytical techniques. If PIXE was enabled by MeV ion beams delivered by the 3 MV Tandetron™ from IFIN–HH [5], XRF method was applied with a Tracer 5i handheld spectrometer from Bruker Instruments [6].

In terms of metal parts from the 9th-11th centuries, our approach represents a premiere for Dobruja, and, as far as we know, among the first in Romania. Preliminary results helped us determine that most of the belt ornaments are cast of tin-lead bronze (Cu-Sn-Pb) with highest percentage of copper content and a variable content of tin and lead. In many items, the alloy contains a significant amount of zinc (Zn). The presence of iron (Fe) has been confirmed in several specimens. Most of the compositional similarities are observed with the discoveries from Novosel. One piece has over 50% lead, like some belt ornaments found in Nadarevo. These may suggest a possible production, for some specimens discovered in Dobrudja, in the Bulgarian workshops, a conclusion that is also reinforced by Principal Component Analysis (PCA).

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P-A-11

Enhancement of Tape Targets at VEGA

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We present and compare experimental studies and prospects of high repetition rate (HRR) targetry for the interaction of relativistic laser pulses at intensities of several 10^{20} W/cm^2 with solid density targets. So-called tape targets are rewound in vacuum conditions in order to always expose a new section of undisturbed surface to the laser focus. The requirements for the target are high resistance to ionizing radiation released by laser-matter interaction and immunity to electromagnetic pulses. Studies consider both high-power 30 fs duration lasers at CLPU (Salamanca, Spain), VEGA-2 with 200 TW and VEGA-3 with 1 PW. The creation of ultra-fast sources of ion beams with large spectra in the MeV-range is one typical application of the interaction of such lasers with matter. Experiments at VEGA 3 show typical proton spectra for the so-called Target Normal Sheath Acceleration mechanism. Ramping up of the intensity with the energy in the laser pulse, beneficial for the maximum energy of accelerated protons, leads to a destruction of the tape target. One observes welding of the tape to the support structure when the heated region approaches the size of later. We present mitigation strategies. Building upon the study, we pinpoint prospects for a target geometry mitigating EMP and potentially applicable to particle beam collimation.

P-A-12

Resistive and Superconducting Magnets for Nuclear Physics

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The paper present some of the results of the applied research performed at National Institute for R&D in Electrical Engineering ICPE-CA Bucharest - Applied Superconductivity in Electrical Engineering Laboratory, in last decade, in the field of normal conducting (resistive) and superconducting electromagnets designed for nuclear physics and medical applications.

These electromagnets developed by ICPE-CA, ranging from dipole to quadrupole types and also of solenoidal type, generating magnetic flux densities up to 4 T [1] and gradients of 20 T/m, are suitable for various tasks in nuclear physics. Medicine also benefited due to the improvements of imaging methods for investigating the human body (MRI devices or superconducting computed tomography), as well as ultramodern treatment systems of various types of tumors located in sensitive areas of the body, brain, internal organs, etc.), through hadron therapy which also needs powerful electromagnets.

The discovery and realization of both new high temperature superconducting materials (HTS) [2, 3] and the improvement of existing technologies based on low temperature superconductors (LTS) [4], have increased the performance of various types of electromagnets used in particle accelerators, leading to higher acceleration energies and new discoveries in physics and knowledge in general.

Thus, the realization of these types of normal conducting and superconducting electromagnets, including solenoid type, are crucial for the top applications in physics and medicine.

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P-A-13

Laser-assisted negative ion production in caesium sputter ion source

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The negative ion formation in the caesium sputter ion sources occurs on the surface of a cathode containing the ionized material. The cathode is covered by a thin layer of caesium (Cs), which lowers the work function of the surface enhancing the negative ion formation. Vogel [1] recently introduced a hypothesis that the negative ion current can be enhanced by exposing the cathode to a laser beam. According to [1] this should resonantly excite neutral caesium atoms to electronic states, acting as a catalyst for negative ion production via so-called ion pair production. Recent experiments at the JYFL-ACCLAB have revealed that the photo-assisted production of negative ions can be provoked by lasers at various wavelengths with the photon energy exceeding a certain threshold, which questioned the resonant ion pair production hypothesis [2]. Furthermore, the laser-assisted production of negative ions of oxygen (O^-) as well as aluminium (Al^-) was observed with the off-resonance diode lasers [3]. This observation opens the door for practical applications of photo-assisted negative ion production also for other negative ion species, not just those with their electron affinity states in resonance with the excited states of neutral Cs. Figure 1 (a), (b) shows the laser assisted effect on the O^- beam currents with three different laser wavelengths, and powers, at 50 s and 100 ms laser pulses respectively [2]. Figure 1 (c) shows the example of laser-assisted beam current enhancement result obtained with 445 nm, 6 W diode laser [2]. In this presentation we introduce the new results and the corresponding qualitative explanation for the laser-assisted effect.

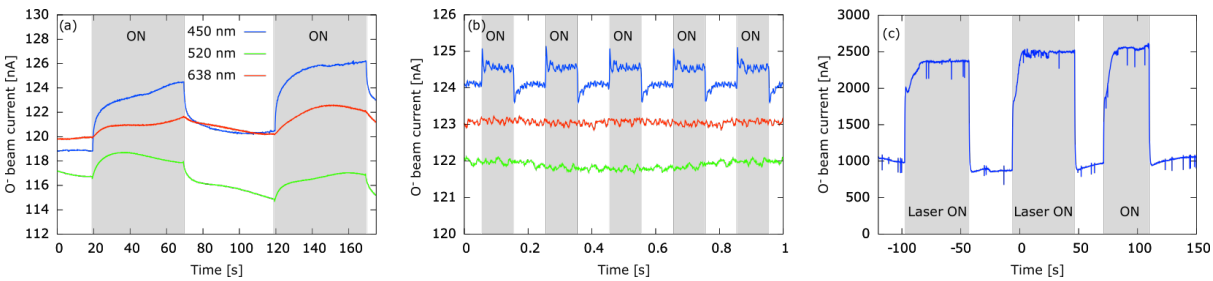

Figure. 1. The effect of (a) 50 s and (b) 100 ms laser pulses at 450 nm / 1.6 W, 520 nm / 1.0 W and 638 nm / 0.7 W wavelengths / powers on the O^- beam current. The best recorded example of the 445 nm, 6 W laser on the O^- beam current is presented in (c). [2]

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P-A-14

Development of SiC semiconductor-based dosimeter for the evaluation of clinical dose distribution in the carbon cancer therapy field

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The realization of a dosimeter with excellent energy resolution has been desired for better quality control and assurance (QA/QC) for heavy-ion cancer therapy, where multiple species of ions are planned to be utilized [1]. The conventional ionized chamber, which is widely used for QA/QC, generally does not support quality discrimination with different radiation species. Several types of energy-dispersive dosimeters are being studied to fulfill such a demand, including Silicon SOIs [2]. With good radiation hardness, other wide bandgap semiconductors, including SiC and diamond, are being studied to be utilized in the clinical cancer therapy field. This study utilized a 4H-SiC Schottky barrier diode (SBD) for energy-dispersive dosimetry in the clinical carbon therapy field at Gunma University Medical Center for Heavy Ion Beam Medicine (GHMC). Estimation of the Relative Biological Effectiveness (RBE) from linear energy transfer (LET) spectra was accomplished in both pristine carbon beam with an energy of 290 MeV/n and spread-out Bragg peak (SOBP) beam utilizing LQ or MKM model [3]. Results suggested that the SiC-based dosimeter is successfully used in the detailed characterization of clinical dose distribution in the carbon cancer therapy field.

Acknowledgments: The authors sincerely thank Dr. N. Hoshino and Dr. H. Tsuchida of the Central Research Institute of Electric Power Industry (CRIEPI) for the material processing of silicon carbide wafers. This research was supported in part by Nakatani Foundation for Advancement of Measuring Technologies in Biomedical Engineering and JSPS Gant-in-aid for scientific research (JP18K11916, JP22H03013).

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P-A-15

Measurement of radiation induced current (RIC) utilizing SiC Schottky Barrier Diode (SBD) in the clinical carbon therapy field

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Dosimeters based on semiconductor detectors have been proposed for complex dose evaluation in heavy ion cancer therapy. Si semiconductor on insulator (SOI)s is already utilized such application [1], but their radiation tolerance remains an issue. Our previous study demonstrated linear energy transfer (LET) measurement of carbons by using 4H-SiC Schottky barrier diodes (SBDs) with better radiation hardness [2]. However, it did not allow us to obtain physical dose distributions of clinical carbons. In this study, we aimed real-time physical dose evaluation by utilizing SiC-SBDs. For such purpose, we focused on radiation induced current (RIC) generated in SiC SBDs under clinical carbon beam irradiation. A SiC-SBD semiconductor detector (with a 69 μm-thick epitaxial layer, 9.1×10^{14} cm^{-3} impurity concentration, and 1 mm square electrodes) was employed. Carbons with an energy of 290 MeV/n were irradiated to SiC-SBD with a maximum flux of therapeutic intensity (10^9 pps) at the Gunma University Heavy Ion Medical Center (GHMC). The transition of the RIC value at any depth point in the Bragg curve was evaluated by changing the thickness of water tank placed in front of SiC-SBD. RIC from the SiC SBD was obtained with applied voltage up to 100V for each moderator thickness. Also, the physical dose distribution was measured with a commercial ionization chamber. The Bragg peak was confirmed through RIC distribution, and the transition was similar to that observed with a commercial ionization chamber.

Acknowledgments: The authors sincerely thank Dr. N. Hoshino and Dr. H. Tsuchida of the Central Research Institute of Electric Power Industry (CRIEPI) for the material processing of silicon carbide wafers. This research was supported in part by Nakatani Foundation for Advancement of Measuring Technologies in Biomedical Engineering and JSPS Gant-in-aid for scientific research (JP18K11916, JP22H03013).

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P-A-16

Tailoring Hydrogen Fuel Cells with keV-MeV Ions

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The aim of the present study is to improve Proton Exchange Membranes (PEM), in particular PFSA (perfluorosulfonic acid) such as Nafion by ion beam implantation. A paramount application of PEM membranes is being represented by the hydrogen fuel cells with a great potential in the alternative energy field. Au and Pt ion implantation may enhance PEMs catalytic characteristics and electrical contact that allows a more efficient charge collection and makes the chemical adhesion more efficient [1]. Several ion implantation tests were performed at different energies, using the facilities within IFIN-HH: an ECR (Electron Cyclotron Resonance) ion source was used for low energy and high fluence, implanting Cu^{5+} ions at 50 keV with $10^{17}\ ions/cm^2$, while the 3 MV Tandetron™ accelerator provided 1 MeV Au ions with a fluence in the range of $10^{13} ions/cm^2$.[2] At the microscopic level certain defects that may occur in PEM can be studied by positron annihilation spectroscopy (PAS) [3]. Lifetime Spectroscopy (PALS) and Coincidence Doppler Broadening Spectroscopy (CDBS) techniques revealed information about free volume properties induced by the implanted ions [4, 5].

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P-A-17

Radiation Hardness Tests of YAP:Ce Detectors Used for CRYRING@ESR

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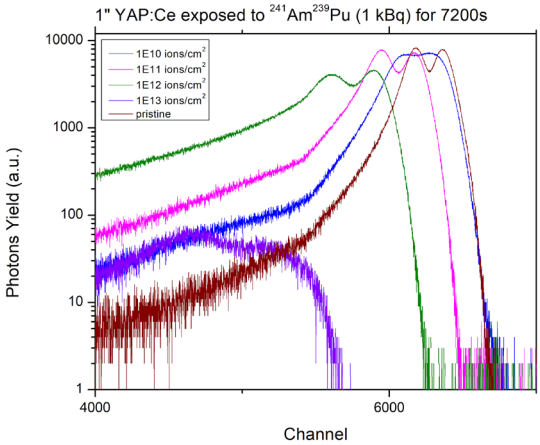
CRYRING facility from FAIR requires the usage of dedicated beam diagnostics systems compatible with ultra-high vacuum (UHV) conditions (up to10^{-12} $mbar$), mechanical strength, high temperature resistance and good tolerance for radiation. [1,2]



An elegant, yet simple approach consists of using scintillator crystals (YAP:Ce) installed inside UHV that are coupled through a quartz window to an external photomultiplier. [3,4] For this study an electrostatic 3 MV Tandetron™ accelerator from IFIN-HH was used to produce a few keV/u gold ion beams, while the total fluence was delivered in several steps in the range of 10^{10}-10^{13} ions/cm^2.[5] Between irradiation sessions YAP:Ce crystals were tested in a traditional spectrometric manner with an ^{241}Am^{239}Pu alpha source. Preliminary results indicate a dose limit threshold at 10^{13} ions/cm^2, after which YAP:Ce efficiency dropped by a factor of 100, which can be translated into 10^6 beam injections at CRYRING. Further studies need to be conducted with finer irradiation steps and more ion species in order to assess the precise trend of the damage rate.

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P-A-18

Polylactic acid-based polymer containing gold nanoparticles produced by laser ablation in an organic solvent

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The design of new materials with improved mechanical, optical and electrical properties is a major interest in tissue engineering, nanotechnology, and material science. This study presents the synthesis of polylactic acid (PLA) foil decorated with nanoparticles. Nanoparticles of gold were produced by laser ablation in an organic liquid. The control of the size and shape of produced nanoparticles was monitored by scanning electron and atomic force microscopies. The Au concentration was probed by Rutherford Backscattering Spectroscopy analysis. The composite films containing different concentrations of nanoparticles were manufactured through the drop-casting method and then the optical and electrical properties were tested by spectroscopic ellipsometer and by current-voltage (I–V) characteristic measurement using the standard 2-point method respectively. The modification of the native hydrophobicity of the composite surfaces was analysed by wettability measurements for possible cell adhesion application. The research has been carried out at the CANAM (Centre of Accelerators and Nuclear Analytical Methods) infrastructure LM 2015056. This publication was supported by OP RDE, MEYS, Czech Republic under the project CANAM OP, CZ.02.1.01/0.0/0.0/16_013/0001812 and by the Czech Science Foundation (GACR No. 22-10536S).

P-A-19

The comparison of Au implanted GaN and ZnO channelling maps obtained using one Si-PIPS and new 680 mSr Hedgehog detector

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The drawback of metal ion implantation into mono-crystals is a structural damage introduction that can play a significant role in the properties of the prepared structure. The investigation of crystal quality, lattice defects and damages requires an analytical method that is destruction free and can obtain information about the concentration of defects. One such powerful method is a Rutherford Back-scattering Spectrometry in a channelling mode (RBS-C). The RBS-C disadvantage is a need for rather high ion fluence for good statistics due to a small back-scattering cross-section. This is time-consuming and in sensitive crystals can lead to further damage. The long exposure time can be partially compensated by a bigger beam spot, which has a negative influence on geometric straggling, or by a high beam current, which leads to a sample heating, damaging and pile-up increasing. The solution to these is RBS-C measurement on a multi-detector setup "RBS hedgehog" with a high solid angle (680 mSr) located at a 3 MV tandem accelerator of the HZDR Ion Beam Center. The hedgehog setup contains 76 independent Si-PIPS detectors arranged in 5 concentric rings sitting on ion scattering angles in the range from 165° to 105°. This arrangement allows fast and sensitive measurement of mono-crystal channelling maps or angle scans for subsequent analysis of crystal-matrix quality and damage. The proposed work was focused on the RBS-C study of structural changes and defects in crystalline structures produced by Au ion implantation. ZnO and GaN single-crystal wafers with different crystallographic orientations were implanted with Au ions using the energy of 1 MeV at the fluence over 1×10^{16} cm^{-2}. The RBS-C analysis was performed in the standard way with one Si-PIPS detector and long-time exposure and by short-term mode with a "hedgehog" detector. The influence of the time exposure on crystal damage was compared. The resulting image scans from both methods were compared with the FLUX code simulation.

P-A-20

Lattice-site location of Mn in Mn-doped Sb_2Te_3 topological insulators using MeV ion channeling

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Topological insulators are materials which are insulators in the bulk and can support the flow of electrons on the surface. In combination with ferromagnetism topological insulators show a quantum anomalous Hall effect with intriguing potential for applications in high precision metrology, spintronics and topological quantum computation. Indeed, ferromagnetic topological insulators can be obtained for $MnSb_2Te_4$ films for a few percent Mn excess [1]. Even though $MnSb_2Te_4$ films were thoroughly characterized by X-ray Diffraction (XRD) and high-resolution Scanning Transmission Electron Microscopy (STEM), the determination of the lattice site of the excess Mn in the crystal remains challenging.

In the present work we investigate the system of $MnSb_2T_4$ in simultaneous channeling Rutherford Backscattering Spectrometry (RBS) and channeling Particle Induced X-ray Emission (PIXE) experiments to shed further light on the location of Mn in the crystal. Experiments were carried-out at the 5-MV 15SDH-2 Pelletron Tandem accelerator at Uppsala University using 2 MeV He^+ ions. The RBS detector was a passivated implanted planar silicon detector mounted at 170° while for PIXE, a silicon drift detector, with a 26.5 µm mylar foil placed in front of it, mounted at 135° with respect to the primary beam axis was used. The goniometer can be tilted in two directions without moving the point of interaction with the primary ion beam. The samples were two $Mn_xSb_2Te_{3+x}$ films of 200 nm nominal thickness epitaxially grown on BaF_2 (111) substrates with different amounts of incorporated Mn. We obtained extensive channeling maps in a number of different crystal orientations as well as high resolution angular scans to directly identify the lattice site occupied by Mn.

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Poster Sesion B
Tuesday, July 19th, 2022

P-B-1

JaBS: Simulation and fitting code for RBS, EBS, NRA

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Simulation code JaBS [1] has been recently developed to simulate Rutherford backscattering spectrometry (RBS) spectra. The C/C++ code runs on Windows, macOS and Linux and is distributed under the GPL open source license, allowing users to modify and distribute the code under the terms of the license and use it free of charge for whatever purpose.

JaBS is computationally similar to the popular SIMNRA program and in many cases produces identical simulated spectra, within numerical accuracy, but since the code is still quite new not all the features of NDF and SIMNRA 7 [2] have been implemented. On the other hand, some features are already present that cannot be found in other codes.

The physics models of JaBS have been, since its initial release, upgraded to include support for particle-particle nuclear reaction analysis (NRA) and energy broadening due to finite beam spot and detector size among many other improvements. Already earlier arbitrary detector and sample geometries were possible and roughness of layers could be modeled. User-provided R33 cross-section files are needed for elastic backscattering (EBS) and NRA, while built-in cross sections can be used for RBS and ERDA. Multiple spectra from detectors in different geometries can be simulated and fitted at the same time, the fit routine is based on Levenberg–Marquardt algorithm from the GNU Scientific Library (GSL). Atomic data and electronic stopping and straggling data are obtained from the Jyväskylä ion beam analysis library (JIBAL) and all data necessary to make an RBS simulation are included in the distribution.

The code can be used with a Qt 6 based graphical user interface (GUI) or from the command line. The intended use is for users to write simple human readable scripts to define e.g. ion beam parameters and fitting ranges. The aim is to create a program which is easy to use interactively, but flexible enough to be used for semi-automated scripted analysis for analyzing batches of samples.

This presentation discusses the capabilities of the code in its current state with examples of use in real-world scenarios.

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P-B-2

Development of an experimental setup for ion beam analysis in the transmission geometry

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Ion beam analysis is used for the elemental quantification of materials. The high sensitivity of Rutherford backscattering spectrometry (RBS) [1] to high-Z elements in a thin film on a low-Z substrate is well recognized. However, the accurate elemental quantification of nanometer thin (self-supporting) foils that are composed of light elements such as boron and carbon is technically challenging. The difficulties relate to the intrinsically low count rate for light elements, the unwanted carbon growth on the surface that accompanies the exposure of the sample to an ionizing beam, and the accurate measurement of the primary beam current.

Yet, the accurate characterization of self-supporting nanometer thin films and carbon nanotube (CNT) pellicles is of utmost importance. For example, SiN windows are used in many applications, and CNTs pellicles are expected to become an essential component in EUV lithography tools that enable advanced chip manufacturing.

We developed an experimental setup for RBS analysis in the transmission mode. Firstly, the scattering chamber is designed and built to reach ultra-high vacuum. Secondly, the detector solid angle is maximized by means of a multidetector system [2]. Thirdly, a novel beam current monitoring system is introduced. Lastly, the low energy background is suppressed by shielding against diffuse and multiple scattering.

We describe the experimental setup and the experimental studies that become possible with it. For example, we investigated the carbon deposition rate caused by exposure to the primary ion beam as a function of the base pressure. Besides, we present a procedure to quantify the initial unexposed areal density of carbon. The uncertainty and reproducibility of the developed methods is discussed.

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P-B-3

Developments towards an advanced radiofrequency quadrupole for AMS

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Accelerator Mass Spectrometry (AMS) is the most sensitive method for the detection of trace amounts of long-lived radionuclides with isotopic ratios in the range of 10^{-12} to 10^{-16}. The interference of stable isobars is the limiting factor for a variety of AMS radionuclides. Recently, the Ion-Laser InterAction Mass Spectrometry (ILIAMS) setup at the Environmental Research Accelerator (VERA) has demonstrated excellent isobar suppression capabilities overcoming this limitation using laser photodetachment in a gas-filled radiofrequency quadrupole (RFQ). The technique gives access to new AMS isotopes for research on environmental radioactivity (^{90}Sr, ^{99}Tc, ^{135}Cs), astrophysics (^{182}Hf) and geology (^{41}Ca) [1].

An advanced RFQ ion cooler is currently under development based on the ILIAMS technique. It is designed to efficiently decelerate, focus and trap anions with high ion beam emittances, e.g., SrF_3^-. Based on the injection unit of ISOLTRAP [2] an elliptic injection electrode was developed, which should improve the transmission into the cooler compared to ILIAMS by at least 10%. Currently, the RFQ ion cooler is set up on a test bench at VERA to conduct experiments on the performance of the ion cooler. After completion of the test measurements at VERA, the ion cooler will be taken to the AMS facility in Cologne and installed there. In this contribution, we will present first results from the performance tests regarding ion beam transmission and stability of the system.

This project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824096 (Radiate).

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P-B-4

Radiocarbon dating of historical bones from Târgșoru Vechi village

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The early medieval settlement identified in 2019 to the west of Târgsoru Vechi is one of the largest settlements so far investigated in Wallachia, dating from the end of the first millennium AD. Sampling for radiocarbon analysis was done from inside the houses (especially in the area of the fireplace), from the graves, as well as from one of the possible wells. Supplementary samples were also taken from a group of tombs (oriented west-east) previously studied [1].

In this study, several pretreatment methods were applied to historical bones and teeth from the Târgsoru Vechi site, in order to remove different contaminates [2] to ensure accurate AMS analysis [3]. The C/N atomic weight ratio of the untreated and pretreated bones was observed to be a useful indicator for the most suitable processing method. After collagen was extracted, in RoAMS laboratory from IFIN-HH, it was graphitized using the Automated Graphitization Equipment (AGE3) and the isotopic ratios $^{14}C/^{12}C$, $^{13}C/^{12}C$ were measured with the 1MV Tandetron Accelerator [4]. The radiocarbon age was in the estimated archaeological range between 1097 and 1321BP. After obtaining the calendar ages, using the IntCal20 calibration curve [5] the placement of the studied archeological site in time was confirmed, which paves the way for an extensive Târgsoru Vechi site investigation.

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P-B-5

The catalytic properties of graphene oxide, polylactic acid and polyethylene terephthalate implanted by low energy copper ions

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In this work, we focused on a study of catalytic properties of graphene oxide (GO), polylactic acid (PLLA) and polyethylene terephthalate (PET) implanted using 20 keV Cu ions and three implantation fluences. First ion fluence was below the threshold of growth of carbon clusters (3.75×10^{12} cm^{-2}). The second ion fluence was in the range, when carbon-enriched islands grow (3.75×10^{14} cm^{-2}) and the last one was the ion fluence, which exceeds the threshold of metal nano-particles formation (1.0×10^{16} cm^{-2}). The only very shallow layers of the sample were modified as low energy ions deposited energy mostly in the upper layer (about ~30 nm). Upon irradiation, the modified foils were characterised using Rutherford Backscattering Spectrometry (RBS), Elastic Recoil Detection Analysis (ERDA) and analytical methods such as X-ray Photoelectron Spectroscopy (XPS), Scanning Electron Microscopy (SEM) and wettability. The electric properties were measured by two points method. The photo-catalytic properties were tested in the dark chamber with rhodamine B using 254 nm UV light and subsequently study using ellipsometry. The removal of oxygen/hydrogen species, related carbonization and increase of C-C bonds lead to the conductivity enhancement after ion irradiation. The copper present in the GO and polymer structures also improved their catalytic and sensory properties, which was most evident in the case of GO sample. The instrumental development has been carried out at the CANAM (Centre of Accelerators and Nuclear Analytical Methods) infrastructure LM 2015056. This publication was supported by OP RDE, MEYS, Czech Republic under the project CANAM OP, CZ.02.1.01/0.0/0.0/16 013/0001812. The scientific results were obtained with the support of the GACR Project No. 22-10536S and University of J. E. Purkyne project UJEP-SGS-2021-53-005-2.

P-B-6

Determination of Boron traces concentrations in graphite matrices by AMS

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The ability to find or obtain suitable graphite in the field of nuclear fission reactors, as a neutron moderator, has been shown, in World War II history, that it could partly influence the outcome of a war. To act as a moderator, graphite must have a boron content of less than 5ppm, so that the isotopic ratio should be below $5x10^{-6}$ B/C.

In a previous work, we have developed preliminary method to measure the trace level of boron in graphite [1], using typical ^{10}Be measurement experiments by Accelerator Mass Spectrometry (AMS), where ^{10}B appears as the molecular interference.

To perform more accurate such measurements, in this study we have developed the preliminary method, changing the injection of the two isotopes (^{10}Be and ^{12}C) in accelerator from the manual mode to the automatic one. In this scope, the slow sequential injection mode (used in Pu isotopes measurements) allowed the automatic change of transport parameters of ^{10}B and ^{12}C.

Non-irradiated samples were measured from graphite samples provided from the reserve of the VVR-S type nuclear reactor installed in Bucharest, in 1965, but also from a graphite plate from the Polytechnic University of Bucharest. The sensitivity of the method reached values on the order of 10^{-12} for the B / C isotopic ratio.

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P-B-7

Actual ^{129}I concentration levels in the Black Sea

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Currently, several locations of the North Atlantic Ocean have the ^{129}I concentration levels 10^4–10^5 times higher than those of the pre-nuclear era. As a consequence, the south eastern part of Europe, with its rivers and seawaters, should be influenced by the outspread through the atmospheric and hydrospheric transport of iodine-129. This is a long lived fission isotope and a "low beta emitter". It can be used as long-term tracer for nuclear pollution if the concentration of ^{129}I is known in the investigated geographical region. This AMS study has determined the ^{129}I concentrations in water of Black Sea between 2017- 2020.

The ^{129}I concentrations measured in the Black Sea were in the range of $(0.8–1.4)\times10^8$ atoms/L, which equals the range values of the North Atlantic Ocean at latitudes (31°–50°N) of $(0.4–1.3)\times10^8$ atoms/L [1]. The averaged results of ^{129}I measurements provided the actual baseline of $(1.2 \pm 0.1)\times10^8$ atoms.

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P-B-8

Proton irradiation induced reactive oxygen species promote apoptosis and G2/M-phase arrest in HepG2 cells

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The number of proton therapy centers worldwide have begun increasing steadily over time, with more than two million cancer patients treated so far. Despite this development, more questions on proton radiobiology still call for more thorough research. The open issues at hand are the on-going discussion on an energy-dependent varying proton RBE (relative biological effectiveness) and a better characterization of proton irradiation side effects. The aim of this study was to investigate the effects induced by the proton beam in hepatocarcinoma cells. An existing facility in IFIN-HH, a 3 MV Tandetron TM accelerator, was used to irradiate HepG2 human hepatocarcinoma cells with doses between 0 - 3 Gy.

Colony formation was used to assess the influence of radiation on cell long-term replication. Also, the changes induced at the mitochondrial level were shown by increased ROS and ATP levels as well as a decrease of the mitochondrial membrane potential. An increased dose leads to G2/M cell cycle arrest with apoptosis as the main mechanism through which the cells are destroyed. Finally, the morphological and ultrastructural changes were observed at the membrane level and the nucleus of the irradiated cells.

Acknowledgments: This work was supported by the Romanian Ministry of Research, Innovation, and Digitalization, through the National Core Program No. PN 19 06 02 03/2019, PN 19 06 02 01 /2019 and PN 19 06 02 02, Romanian Government Programme through the Programme for Installations of National Interest (IOSIN).

P-B-9

The sensory properties of graphene oxide and polyimide implanted by 1500keV Cu ions

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We present a study of graphene oxide (GO) and polyimide (PI) implanted with copper for humidity sensory application. The ion irradiation is an efficient technique for chemical and functional property modification. When the ion fluence during implantation exceeds 1×10^{13} cm^{-2}, the π-bonded carbon clusters grow, aggregate and form a network of conjugated carbon bonds [1]. The decorating of graphene or polymer by implanted metal particles increases their sensory and catalytic properties, and the metal implantation with fluences above 1×10^{16} cm^{-2} can lead to the formation of metal nano-particles in irradiated substrates [2, 3]. In this work, the 50 µm thick GO and PI were implanted at room temperature using 1500 keV Cu with three implantation fluences (3.75×10^{12} cm^{-2}, 3.75×10^{14} cm^{-2}, and 1.0×10^{16} cm^{-2}). The elemental composition of irradiated foils was characterised using nuclear analytical methods - Rutherford Backscattering Spectrometry, Elastic Recoil Detection Analysis and obtained Cu depth profiles were compared with SRIM simulation. Also, other analytical methods, such as Raman spectroscopy, Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy and Electron Microscopy were used. The electrical properties were investigated by sheet resistance measurement and the humidity sensory properties were tested in an atmospheric chamber and compared with BME 280 combined humidity and pressure sensor. The copper present in the GO and polymer structures improved their sensory properties, which was most evident in the case of GO sample. The instrumental development has been carried out at the CANAM (Centre of Accelerators and Nuclear Analytical Methods) infrastructure LM 2015056. This publication was supported by OP RDE, MEYS, Czech Republic under the project CANAM OP, CZ.02.1.01/0.0/0.0/16 013/0001812. The scientific results were obtained with the support of the GACR Project No. 22-10536S and University of J. E. Purkyne project UJEP-SGS-2021-53-005-2.

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P-B-10

Expertise and Capabilities held by Normal-Conducting Magnets Laboratory from ICPE-CA

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The Laboratory of Normal-Conducting Magnets which is part of the Electromechanical Systems and Technologies Department from National Institute for Research and Development in Electrical Engineering ICPE-CA, has capabilities and expertise of analytical computation and numerical simulations using software packages (COMSOL, SolidWorks and MATLAB) to determine and optimize parameters for the geometry of the magnetic circuit and for the coils that fit in the normal-conductor electromagnets, but also for modeling and simulations of the mechanical, thermal, fluidic and electromagnetic phenomena, which occur in the operation of other electromechanical products.

The laboratory is specialized in modeling of 3D CAD design and 2D drawings of technical manufacturing documentation for electromechanical products using SolidWorks software, also the laboratory has expertise and equipments intended for mechanical, hydraulic, electrical and magnetic testing of normal-conducting electromagnets.

In the Laboratory of Normal-Conducting Magnets has been implemented and developed the successful international project **FAIR** - Facility for Antiproton and Ion Research, project aimed to achieve in Darmstadt, Germany, an integrated system of particle accelerators for research excellence in the field of nuclear physics. The involvement of ICPE-CA in the project was materialized by manufacturing, testing and delivery to FAIR project, an in-kind contribution of Romania consisting in: Sextupole magnets– 66 pcs.; Horizontal Steerer magnets – 27 pcs.; Vertical Steerer magnets– 26 pcs.; Power converter for magnets– 72 pcs.

P-B-11

Tandetron computer control upgrade

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Computers that drive particle accelerators in general are typically connected to very specific hardware and other special equipment that make an accelerator laboratory work and run. The only issue that arises over time is aging of hardware and equipment that needs replacing. This alone brings forward various problems and challenges every laboratory faces when old hardware is replaced with new equipment. The computer communication connections are new and different, the component drivers do not support obsolete operating systems and so on.

At JSI the control system of Ljubljana tandem ion accelerator undergone replacement of all existing hardware and software features of the original control system of the Ljubljana tandetron, delivered during its initial installation in 1996/1997.

The new control computer contains standard, commercially available communication interfaces for connection with other hardware components of the control system. Brief overview of the computer and hardware replacement operation with additional new features is presented.

P-B-12

Analysis of the gain and the interpad distance of low gain avalanche diodes using an ion beam microprobe

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Relatively new concept of radiation detector based on Si is the low gain avalanche diode (LGAD) [1]. In this type of detector, a thin highly doped p^+ layer (gain layer) is diffused below the n^+ electrode in a pn junction. When the incoming radiation ionizes the medium, it produces free carriers (electrons/holes) which can drift under the influence of the applied electric field. The highly doped p^+ layer induces a high electric field region that can produce secondary ionization process for electrons during their motion, increasing the total collected charge and improving the performance of the detector. During the last years, the development of position-sensitive detectors using multipads configuration as radiation monitors and for timing applications became increasingly important for their applications in high-energy physics experiments. In this work, a complete characterization of the spectroscopy properties of these types of detectors was carried out at the ion beam microprobe at the Ruđer Bošković Institute (Zagreb, Croatia) using the ion beam induced current technique (IBIC) [2]. In this experiment, two LGAD sensors from Hamamatsu, 200 μm thick, 50 μm sensitive depth, and arranged in a 1x1 and a 2x2 pad array configuration with a nominal interpad distance (IPD) between 70-90 μm were analyzed. Different ion species (proton and carbon) in the MeV range were used to modify the ionization density under the gain layer. The experimental results showed the gain suppression for bias close to the onset depletion voltage of the highly doped layer due to the existence of the screening effect of the electric field and its dependence on the ionization density produced by the ion beam. The IPD in the multipad configuration increases with the ion penetration depth due to the bending of the electric field lines towards Junction Termination Extension (JTE), a phenomenon that has been imaged using proton beams with various energies.

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P-B-13

Measurement of the stopping power in diamond for protons in the 1.6 - 6 MeV energy range

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One of the important applications of diamond single crystals is microdosimetry in which the possibility to create micrometer sized detector structure with excellent spectroscopy properties, radiation hardness, and chemical stability has been utilized [1]. The key parameter for the accurate calculation of the applied radiation dose that MeV proton beams deposit in the material is the knowledge of the continuous energy loss per unit path length, known as stopping power. However, only scarce experimental results have been published for carbon [2]. Therefore, in this work characterization of the stopping power was carried out with the measurement of the energy loss when a mono-energetic ion beam passes through a thin target. By measuring the energy loss of transmitted ions ΔE and knowing the thickness of the target Δx, it is possible to estimate the stopping power S(E) of the proton beam when the ionization profile is nearly flat along the trajectory of the incoming ion: $S(E) \approx \Delta E/\Delta x$. For the correct evaluation of S(E), a thin single-crystal CVD diamond membrane was prepared using deep Ar/O_2 plasma etching to produce good quality self-supported membrane of few micrometers [3]. The determination of the membrane thickness was carried out by means of two different methods. The first method takes advantage of the intensity attenuation of X-rays after passing through the membrane measured using a Si(Li) detector. The second method involves imaging of diamond cross section using the scanning electron microscopy (SEM) technique. From these two approaches, the thickness was estimated in (3.5±0.2) µm. The aim of this work was to cover an energy range for sc-CVD diamonds where the experimental stopping power data are not fully assessed in the literature for protons. The scanning transmission microscopy technique (STIM) was used for the energy loss measurements of the protons with energies ranging from 1.6 MeV to 6 MeV. The obtained experimental results will be presented and compared with the values obtained using the Monte Carlo stopping power calculator code SRIM [4].

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P-B-14

Anthropogenic Actinides as Potential Markers for the Anthropocene analyzed by AMS

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The Anthropocene is a proposed geological epoch dominated by human influence on the environment. To define the Anthropocene's basis, a stratigraphic signal that proves human alteration of geological processes is required. This signal needs to be unique, distributed globally, and well preserved in geological archives for a long time. No distortion of the signal by a younger input must be present. Long-lived anthropogenic radionuclides, released by atmospheric nuclear weapons testing may have produced such a signal. [1]

The anthropogenic actinides ^{233,236}U, ^{237}Np, ^{239,240,241}Pu, and ^{241}Am were analyzed in different environmental reservoirs using Accelerator Mass Spectrometry (AMS). Due to the different chemical properties of these elements, their behavior in the environment varies, thus changing the original pattern of the global fallout deposition. Isotopic ratios do not experience such chemical fractionation in the environment and enable us to identify emission sources so that younger inputs caused by nuclear industry can be distinguished from nuclear weapons fallout.

The analyzed environmental samples included a lake sediment core taken from Lake Hallstatt (Austria) and urban sediments taken from a construction site at Karlsplatz in Vienna (Austria). All the radionuclides mentioned before have been successfully detected in layers corresponding to the active phase of nuclear weapons testing, even in the strongly heterogeneous urban sediments. The novel signature ^{233}U/^{236}U [2] marks the onset of the Anthropocene whereas the concentrations of the other radionuclides in general increase towards the year of 1963. The presentation will discuss the measurement results and interpret the isotope ratios in terms of emission source identification and their suitability as geological markers.

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P-B-15

A detailed chronology of the sedimentation in the Danube abyssal fan records the major episodes of the late-Holocene Black Sea evolution

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The construction for the high-resolution Bayesian sedimentation model spanning the last 5500 years based on 25 AMS radiocarbon dated sediments of bulk organic matter (OM) sampled from the NW Black Sea anoxic waters of the continental slope is presented in this paperwork. The corrections for the 14C ages due to marine reservoir effect (MRE) and detritus organic carbon are correlated with exogenous information such as 210Pb dating, metallurgy pollution and human-induced soil erosion, highlighting the Danube influence on the geochemistry and chronology of the NW Black Sea sediments through the input of terrigenous organic matter. The results show excellent agreement with some of the previous studies, supporting a total age offset for the bulk OM of 60 years as MRE and 580 years as detritus organic carbon influence. The revisited chronology pinpoints the first and second invasion of the coccolitho-phores Emiliania huxleyi at 2524 ± 87 and 625 ± 65 years cal. BP. The sedimentation rate shows an increase of about three times with the starting of the late Medieval, which corresponds to the highest observed sediment discharge of the Danube as are considered the last 500-300 years. This type of high-resolution sedimentation model is an important step for constructing the carbon budget in bottom waters of variable oxygen concentration.

P-B-16

Numerical study on the effects of laser pulse incidence angle on plasma mirror reflectivity

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In ultraintense laser-solid interactions the amplified spontaneous emission (ASE) pedestal and the sub-ns pre-pulses that arrive prior to the main pulse can have intensity large enough to create a pre-plasma which changes the laser-matter interaction. Plasma mirrors have been envisaged and experimentally tested so as to dramatically reduce the impact of the prepulses. A plasma mirror functions as an optical shutter, changing from transmissive to reflective on a time scale of the order of tens of picoseconds. This makes it a promising tool to filter out the ASE and and pre-pulses, transmitting only the main pulse. However, since high intensities are usually required for laser-solid (e.g Target Normal Sheat Acceleration or TNSA) experiments, it is crucial to optimize the plasma mirror setup such that the reflectivity is as high as possible.

We present a numerical study of the effects that changing the incidence angle of the laser pulse on the target has on the reflectivity in the plasma mirror setup. It is well-established from both experimental work and theoretical studies [1] that the reflectivity is a function of the intensity and polarization of the laser pulse, as well as of the laser pulse incidence angle on the target. Using the PIC code Smilei, we performed a parameter scan of the incidence angle, from 7.5 to 45 degrees, in increments of 7.5 degrees. The laser pulse used in the simulations is linearly p-polarized, with a wavelength of 820 nm, while the target is a fully ionized aluminium slab with a thickness of 4.5 μm and a pre-formed exponential plasma with a scale length of 0.5 μm.

Simulations performed with the SMILEI and EPOCH codes in a 2D geometry and with an intensity on the plasma mirror (i.e. still not for a focused pulse) of $5 \cdot 10^{17}$ W/cm^2 show that there is a minimum reflectivity at ~30 degrees incidence, with the highest reflectivity being observed at the smallest angles.

[1] W. Kruer, The Physics Of Laser Plasma Interactions, CRP Press, 2003

P-B-17

Characterization of self-supporting carbon nanotube membranes by means of Rutherford backscattering spectrometry

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Thanks to their exceptional mechanical strength, carbon nanotube (CNT) pellicles have attracted much interest in recent years for applications in the extreme ultraviolet (EUV) lithography as a EUV-transparent filter to protect the photomask from fall-on particles. Not only the carbon atom areal density of CNTs within the membrane, but also the composition of the pellicle plays an important role on its physical properties. Consequently, it is necessary to characterize the composition of the pellicle using a sub-monolayer sensitive method.

The precise measurement of the areal density of light elements (C, N, O...) present in the CNT pellicle self-supporting membranes is a great challenge for many experimental techniques. We developed a transmission geometry RBS setup to perform ion beam analysis with a multi-detector assembly. By using the multi-detector system, the measurement time is greatly shortened, and the measurement efficiency improved. It is shown that with this setup, we can characterize the composition of the pellicle precisely. It allows to simultaneously obtain the areal density of both light and heavy elements on CNT membranes.

We found a good correlation between the experimental and the calculated EUV light transmittance (EUVT), from which the contribution of O to the increase in the absorbance of the pellicles is clear. In other words, we found that the EUV light transmittance (EUVT) is strongly related to the oxygen areal density of the CNT pellicle: the higher the oxygen areal density, the lower EUVT. This correlation was then corroborated with XPS measurements where we found the oxygen element to be present in the CNT membrane in the form of iron oxide.

P-B-18

Optimization of PIC simulations for LWFA

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Particle-in-Cell (PIC) codes represent a robust method of describing the laser wakefield acceleration (LWFA) process, by substituting collection of particles in plasma by a smaller number of large pseudo-particles. Due to their large computational resource demand, PIC codes enter the class of high performance computing. The process of LWFA has experienced significant growth in interests since its proposal in 1979 by Tajima and Dawson 1979 [1], due to its innovative potential of strongly accelerating particles.

During the LWFA process the non-linear varying electric field of the laser expels the electrons towards the back part of the pulse, thus creating a charge separation, from the much heavier ions which remain practically immobile. This process creates an ion cavity, or bubble, in which electrons externally injected, or self-injected are highly accelerated, reaching GeV-order energies over cm-long distances.

The number of cells chosen for simulation influences the accuracy of the energy of the accelerated electrons. Thus, by increasing the number of cells on the horizontal axis, the energy is increased until, it approaches a convergence tendency. However, this increase of computational accuracy comes with the cost of a longer time necessary for running the code. Moreover, the energy suffers also significant variations when the number of cells on vertical axis is changed.

In order to find the proper parameters for an accurate and not too computationally expensive simulation, we performed PIC simulations in EPOCH code, of 10 ps duration and we will present the plots obtained for different numbers of cells horizontally, vertically and after changing the number of particles per cell.

[1] Tajima, T. and J. M. Dawson (July 23, 1979). "Laser Electron Accelerator". In: Physical Review Letters 43.4, pp. 267–270. doi: 10.1103/PhysRevLett.43.267.

P-B-19

Channeling electronic stopping power of Li ions in silicon crystal: Monte Carlo study

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In this study we have calculated electronic energy loss of ^{7}Li ions for channeling and random directions in Si crystal as a function of the incident ion energy. The channeling calculation cover a varied energy range between 200 keV and 9 MeV, along the <100>, <110> and <111> directions in Silicon crystal. The calculated electronic stopping power for the axial channeling of ion have been investigated by the Monte Carlo simulation simulations, making comparisons with the channeling experiments. The channeling electronic stopping power values calculated in the channeling direction were then discussed in the frame of the random energy stopping predictions calculated using Monte Carlo simulations. The channeling electronic stopping power values decrease with increasing ion energy. The ratio between the channeling and random ion stopping powers ε(E) as a function of the ion beam incoming angle for 3 and 6 MeV ^{7}Li ions was presented. Results obtained by our simulation are in good agreement with the experimental results.

P-B-20

The importance of particle accelerators for studying the structure of asteroids and methods of teaching

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The topic of Astrophysics, approached in this paper presents the study of the structure of fragments of the asteroid 162173 Ryugu, fragments collected by Hayabusa2 spacecraft, a mission operated by the Japanese space agency, JAXA [1]. The result of the methodological didactic research of the students guided by the professor and presented in this paper refers to the studies carried out by the team of scientists from Argonne, Illinois, USA one of the few groups in the world, chosen to study tiny fragments of an asteroid. The Argonne research team used the ultra-bright X-ray method of a baseball-sized particle accelerator at Argonne's Advanced Photon Source to examine asteroid samples [2]. Inquiry-based learning also spelled as enquiry-based learning, EBL is a form of active learning that starts by posing questions, problems or scenarios. EBL covers a spectrum of approaches, related to: Problem - Based Learning, with exploration of scenario driven learning experience; Small scale Investigations; Projects and Research [3].

In this paper, are presented methodical aspects of teaching through the EBL method, a topic of Astrophysics, within an optional course in Computational Astronomy, taught at the University of Craiova. The topic of Astrophysics to which we refer aims to highlight the importance of particle accelerators in studying the structure of asteroids. The activities during the course and the applied seminar took place over a period of 14 weeks of teaching, with a number of 4 hours of teaching-learning each week, and the resources used by the teacher in the teaching activities, respectively for students have fost: Guides, Papers, Technical guides and online learning, Dissemination, Primary resources online [4]. At the end of the course, the students made a reference, in work teams, for which they were evaluated and graded by the teacher.

[1] https://www.anl.gov/
[2] https://news.uchicago.edu/story/dust-collected-speeding-asteroid-analyzed-massive-accelerator
[3] http://www.ceebl.manchester.ac.uk/ebl/, Centre for Excellence in Enquiry-Based Learning, University of Manchester.
[4] J. Dostál, Inquiry-based instruction: Concept, essence, importance and contribution, Olomouc: Palacký University, 2015, page 7-16.

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