Research projects for future experiments at ELI-NP

2016-2019

Bucharest-Măgurele, ROMANIA
2021

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Brief Overview of ELI-RO Programme

The Extreme Light Infrastructure (ELI, https://eli-laser.eu/) is the world's largest and most advanced high-power laser research infrastructure. Due to high-performance technical features, this multidisciplinary facility will provide opportunities for studying fundamental processes that arise from the interaction between light and matter. ELI is a Landmark of the European Strategic Forum for Research Infrastructure Roadmap (ESFRI, https://www. https://www.esfri.eu/esfri-roadmap). ELI is a distributed research infrastructure based on three specialised and complementary facilities located in Czech Republic (ELI-Beamlines, https://www.eli-beams.eu/), Hungary (ELI-Attosecond, https://www.eli-alps.hu) and Romania (ELI-Nuclear Physics/ELI-NP, http://www.eli-np.ro/).

ELI-NP, the Romanian Pillar of ELI implemented by Horia Hulubei National R&D Institute of Physics and Nuclear Engineering (IFIN-HH, Măgurele), is the most advanced research facility in the world in the field of photonuclear physics. At ELI–NP, scientists in high-power lasers and nuclear physics have joined their efforts to build a new interdisciplinary facility and to define its research program. ELI-NP White Book (http://www.eli-np.ro/whitebook.php) and Technical Design Reports (TDRs, http://www.eli-np.ro/tdrs.php) were realized with the coordinated efforts of more than 100 international scientific authors from 30 countries. ELI-NP is the largest investment ever made in scientific research in Romania, co-financed by the European Commission and the Romanian Government from Structural Funds via the European Regional Development Fund (ERDF).

The goal of the ELI-RO Programme (https://www.ifa-mg.ro/eli/), component of the National Research-Development and Innovation Plan, is to strengthen the Romanian scientific and technological potential in the fields of ultra-high-power lasers and very intense gamma beams, in line with the scientific programme of ELI-NP. The management of the ELI-RO Programme is carried out by the Institute of Atomic Physics (IFA, https://www.ifa-mg.ro/), public institution subordinated to the state authority for research-development in Romania.

Within the ELI-RO Programme, the funding is provided on a competitive base, by launching calls for project proposals. The evaluation of the proposals and the monitoring of the funded projects is realized by the International Scientific Advisory Board (ISAB) of the ELI-RO Programme. The members of the board are recognised experts in field, appointed by the state authority for research-development in Romania. ISAB ELI-RO meets usually once per year, in conjunction with IFA's funding programme activity.

ISAB ELI-RO members at 2017 meeting (from left to right): *Antonio Lucianetti* (HiLASE Centre, Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic), *Thomas Kuehl* (GSI, Darmstadt, Germany), *Andreas Zilges* (University of Cologne, Koln, Germany), *Giles Chériaux* (Ecole Polytechnique, Palaiseau, France) – Chair, Medhi Tarisien (Centre d'Etudes Nucleaires de Bordeaux Gradignan/CENBG, France).

Twenty-seven ELI-RO projects were funded during 2016-2019, under two calls: 2016 (18 projects with maximum duration of 36 months) and 2017 (9 projects with maximum duration of 27 months). In the following tables are shown the topics of the two calls (and the number of projects per topic – with multiplicity, one project may address up to 3 topics), project titles, participant institution and project directors.

- **Call 2016** - 18 funded projects in the fields specified in the ELI-NP White Book:

No.	Code	Topic	No. of projects
3. Conceptual Design Report for the multi-PW laser system at ELI Nuclear Physics Facility			
1	3	Conceptual Design Report for the multi-PW laser system at ELI Nuclear Physics Facility	1
2	3.4	Alignment and Diagnostics	1
3	3.7	Coherent beam combining	1
5. The Scientific Case of ELI Nuclear Physics Pillar			
4	5.2	Experiments with the APOLLON-type Laser used stand-alone	8
5	5.3	APOLLON-Type Laser + γ/e─ Beam	5
6	5.4	Stand-alone γ/e─ Facility for Nuclear Spectroscopy	4
7	5.5	Stand-alone γ/e─ Facility for Astrophysics	1
8	5.6	Applications and Industry Relevant Developments at ELI-NP	10

- **Call 2017** - 9 funded projects in the fields specified in the ELI-NP TDRs:

No.	Code	Topic	No. of projects
1	RA1/II	Laser Beam Transport System	2
2	RA1/III	Monitoring and control system	3
3	RA2/I	Gamma-beam transport and diagnostics at ELI-NP	1
4	RA35/II	High-field physics and QED experiments at ELI-NP	1
5	RA35/III	Materials in extreme environments	3
6	RA35/IV	ELI-NP high power laser experiments	2
7	RA4/I	Gamma-beam experiments at ELI-NP	5
8	RA4/II	Gamma-beam applications at ELI-NP	2
9	RA1/II	Laser Beam Transport System	2
10	RA1/III	Monitoring and control system	3

- **Funded projects:**

No.	Project title	Coordinators/ Partners*	Project director
Call 2016			
1	Approaching Day-One Experiment with the GBS at ELI-NP (ADAGIO)	IFIN-HH	Sorin G. Pascu
2	Laser Pulse Propagation at Relativistic Intensities (ProPW)	ITIM / IFIN-HH	Valer Toșa
3	Quasi-classical Methods in Laser - Nucleus Interactions (QLASNUC)	IFIN-HH / INFLPR	Șerban Mişicu
4	Design Study of a Cryogenic Stopping Cell (CSC) demonstrator for ELI-NP IGISOL Beam Line (CSCDEMO)	IFIN-HH / UPB	Tiberiu Sava
5	Support Action for Gamma Beam Industrial Imaging Applications (ELITOMO)	ACCENT PRO 2000 / IFIN-HH	Mihai Iovea
6	Development of the National Technological Platform for Investigating the Interaction of Complex Biological Systems in the Context of ELI-NP (Astro-Bio-ELI)	IVB / IFIN-HH; UB-BIO	Mihai E. Hinescu
7	Interaction Chamber with Alignment Integrated System over Gamma Beam (ELICAM-GAMMA)	UTB / IFIN-HH; VIOSON	Paul N. Borza
8	Electromagnetic Shielding Structures to assure Biological Safety during Target Hitting Experiments Performed on PW Laser Facilities (BIOSAFE)	INFLPR / IFIN-HH	Aurelian Marcu

9	Surface Science with Positrons: Optimization of Solid Ne Moderators and First PAES Experiments (SuSciPo)	INFM	Cristian M. Teodorescu
10	eXtremely High Vacuum for ELI (XHVELI)	ICSI / IFIN-HH	Mihai Varlam
11	Development of a Novel 2D Array for Dosimetric Characterisation of ELI Laser Accelerated Charged Particle Beams (ELIDOSE)	INFLPR / UPB CANBERA ROMANIA	Dan C. Dumitraş
12	Studies concerning the Materials Behaviour used for Passive Dosimeter System in High Intensity Radiation Field at ELI-NP (OSL-SSNTD)	IFIN-HH	Dorina Aranghel
13	Temporally Resolved Diagnostics of Laser Produced Plasma for Electron Acceleration foreseen to be used at ELI-NP (TEDILAPLAS-ELINP)	INFLPR / IFIN-HH	Constantin Diplașu
14	Laser Targets for Ultra-intense Laser Experiments (TARGET)	INFLPR / IMT	Marian Zamfirescu
15	Development of New Experimental Setups and Materials for the Positron Converter and Moderator for the ELI-NP Positron Beam Line (COMPOSITE)	IFIN-HH / ICPE-CA INFLPR	Nikolay Djourelov
16	Advanced Modelling of Electrodynamical and Nuclear Interactions at ELI-NP (AMENI)	UB-FF	Virgil Băran
17	Development of THz Diagnostics and Imaging Instrumentation for High Power Laser Experiments at ELI-NP (TERAELI)	INFLPR / IFIN-HH	Mihai Dinca
18	Physical and Numerical Experiments for studying Laser Accelerated Particles and their Interaction with Crystalline Materials (ELICRYS-2)	UVT / IFIN-HH	Daniel Vizman
Call 2017 Projects			
1	Achievement of Technologies and Testing Methods for Resilient Mirrors under High Power Laser Pulses, suitable for CETAL and ELI Infrastructures (REMI)	PRO OPTICA	Daniel Oancea
2	Technical Developments in Support of the GBS Experiments (GBS-TD)	IFIN-HH	Constantin Mihai
3	FLUKA Based Radiation Shielding and Monitoring Optimization at ELI-NP (ELIFLUKA)	UPB / CANBERA ROMANIA	Maria-Ana Popovici
4	Security Applications Development at ELI-NP: Detecting Concealed Threatening Materials by using Nuclear Resonance Fluorescence and 2D/3D Tomography with Gamma Beams (ELI_THREAT_DETECT)	ACCENT PRO 2000 / IFIN-HH	Mihai Iovea
5	Versatile Approach to Integrated Large Data Acquisition System for Complex ELI-NP Experiments (VDAQ-CEX)	IFIN-HH / UPB	Gabriel Suliman
6	Simulation of Ultra-High Intensity Laser Pulse Interaction with Solid Targets (SIMULATE)	INFLPR / UPB	Olimpia Budriga
7	Physics and Engineering of Defects Incubation during fs-Laser Irradiation (PHEOLDI)	INFLPR	Doina Crăciun
8	On-line Measurement of Laser-driven Proton Beams Effect on Human Cells (ONLINEBIORAD)	INFM / IFIN-HH IBPCNS	Teodor Adrian Enache
9	Femtoseconds PW Laser Applications on Advanced Particle Acceleration (FLAP)	IFIN-HH	Petru Ghenuche

* Horia Hulubei National Institute for R&D of Physics & Nuclear Engineering (IFIN-HH), National Institute for R&D in Laser, Plasma and Radiation Physics (INFLPR), National R&D Institute of Materials Physics (INFM), Victor Babeş National Institute of Pathology (IVB), National R&D Institute for Microtechnologies (IMT), National Institute for R&D in Electrical Engineering (ICPE-CA), Institute of Cellular Biology and Pathology Nicolae Simionescu (IBPCNS), National Institute of R&D Isotopic and Molecular Technologies (ITIM), National R&D Institute For Cryogenic And Isotopic Technologies (ICSI), University Politehnica of Bucharest (UPB), University of Bucharest, Faculty of Physics (UB-FF), University of Bucharest, Faculty of Biology (UB-Bio), West University of Timișoara (UVT), Transilvania University of Brasov (UTB)

The budget allocated for the 2016 call was 20 Mil. RON (18 funded projects); 10 Mil. RON were allocated for the 2017 call (9 funded projects).

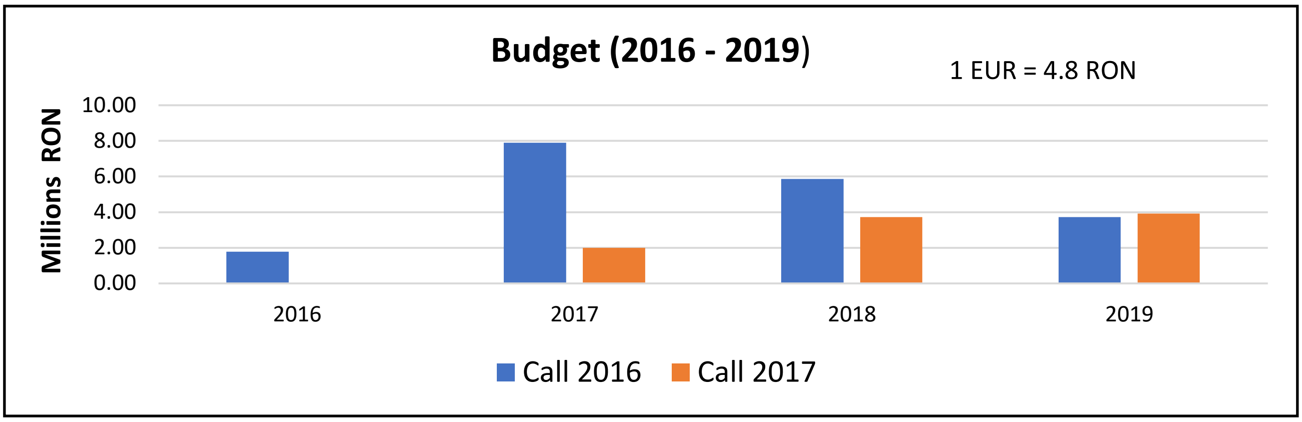


Fig. 1. – The budget allocated for 2016 and 2017 calls

In Fig.1 is presented the budget allocated for the period 2016-2019, while in Fig. 2 is presented the territorial distribution of the participating institutions in the 2016 and 2017 calls. On the map is indicated, for each participant institution, the total number of funded projects.

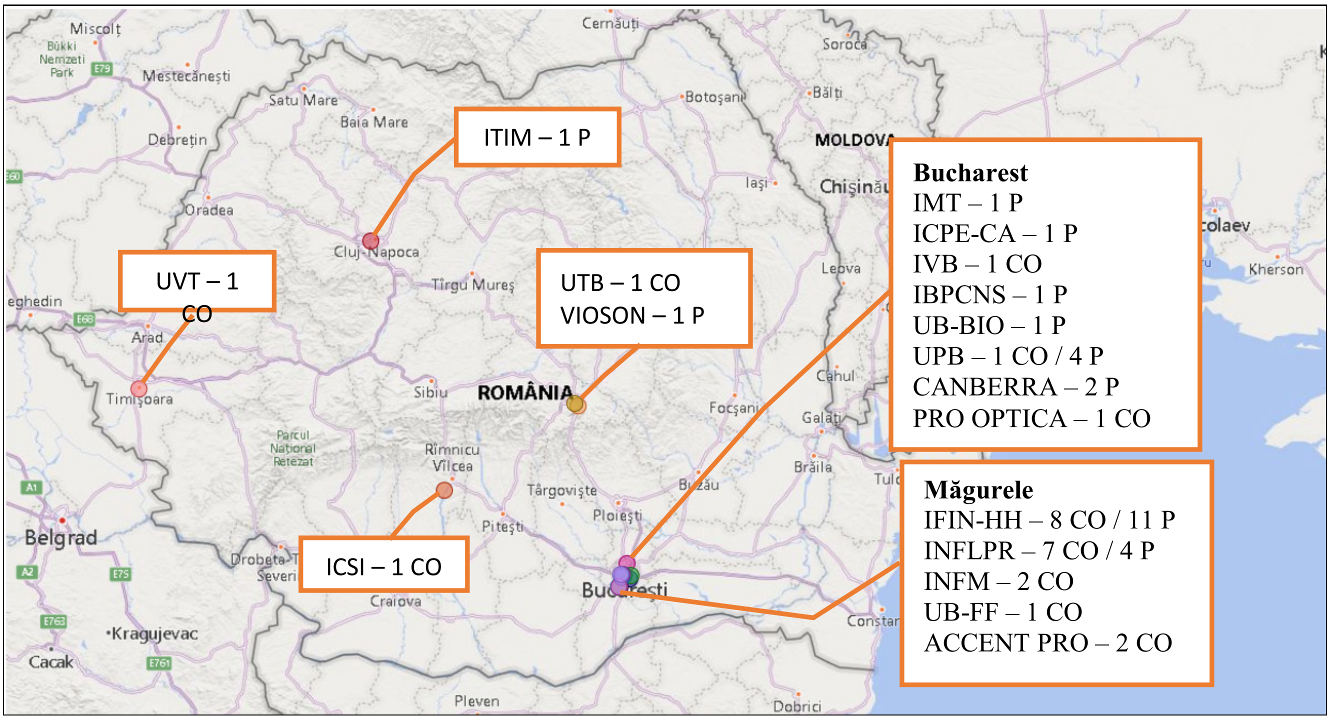


Fig. 2 Territorial distribution of the participating institutions in 2016 and 2017 calls (CO – Coordinator, P – Partner)

Fig. 3 presents, for both 2016 and 2017 calls, the distribution of personnel participant in the projects based on professional degrees. The total number of participants was 372 for the 2016 call and 183 for the 2017 Call. The average Full Time Equivalent (FTE) number per year for the whole period (2016-2019) period was around 100.

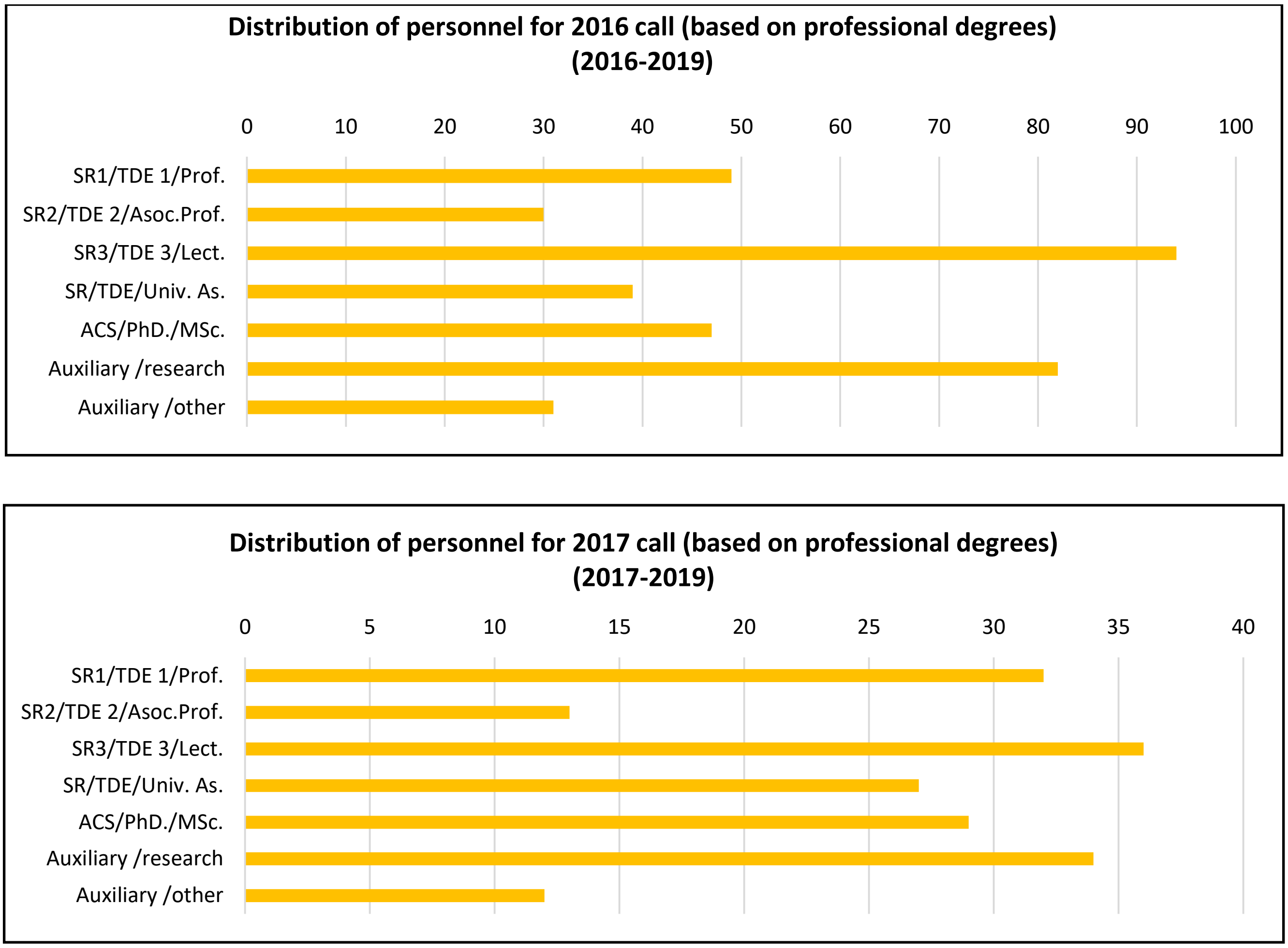


Fig. 3 *Personnel involvement in ELI-RO projects (SR – Scientific Researcher; TDE – Technical Development Engineer; ACS – Research Assistant)*

The main indicators for measuring the scientific output of the funded projects during 2016-2019 are summarised in Fig. 4.

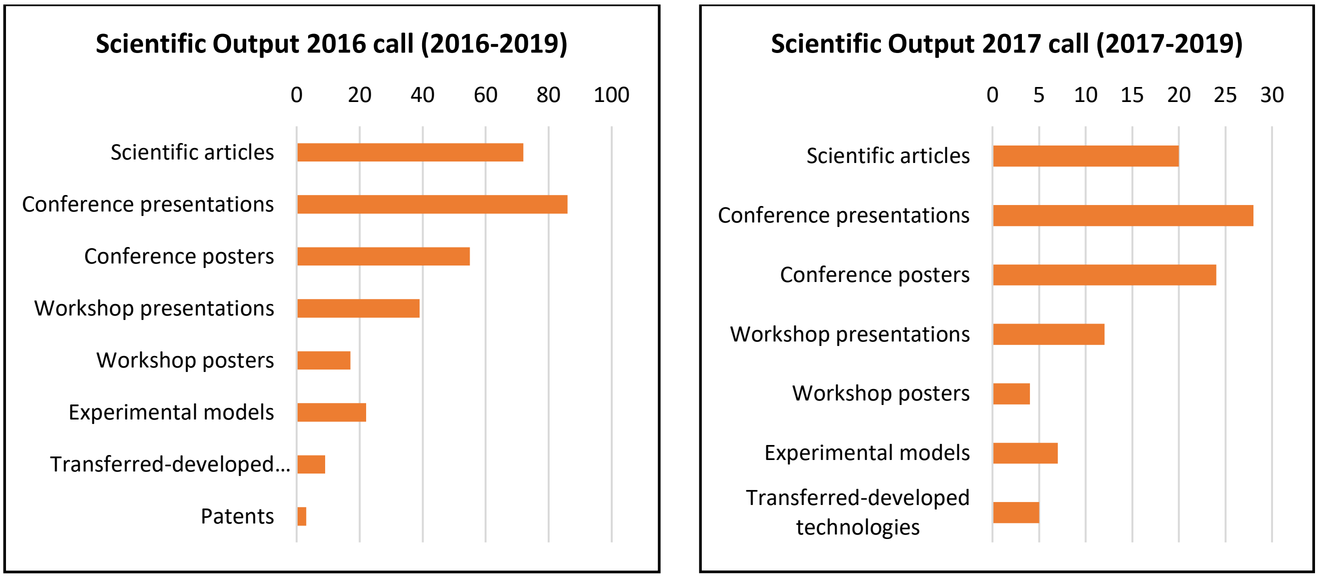


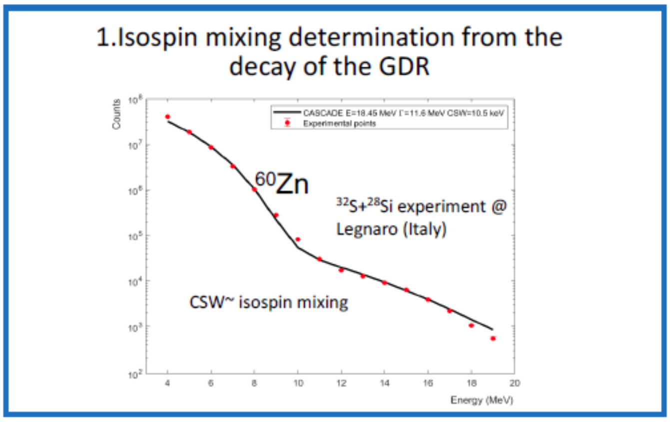
Fig. 4 *Main indicators for the scientific output of the funded projects under 2016 and 2017 calls*

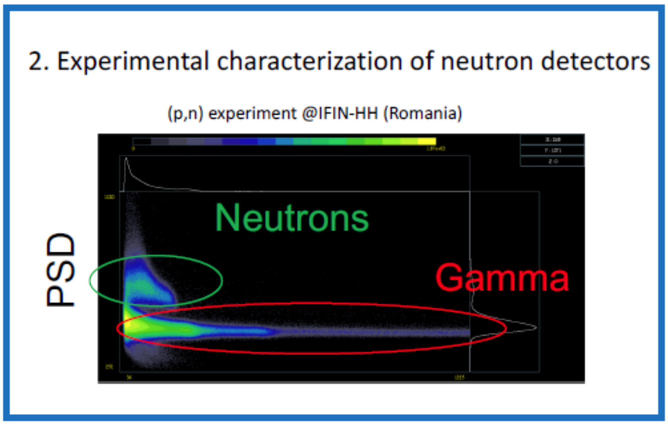
Approaching Day-One Experiment with the GBS at ELI-NP (ADAGIO)

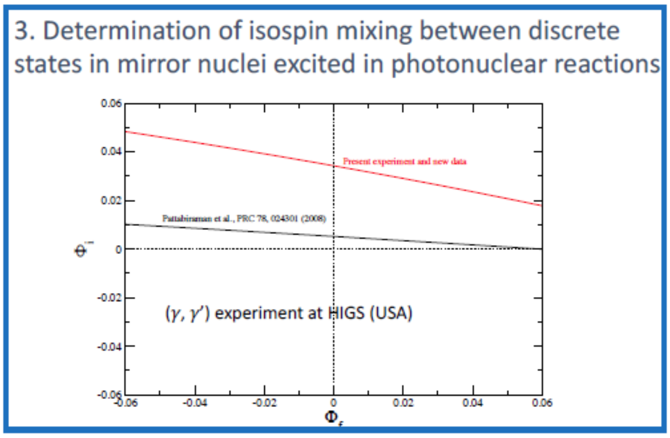
Project Leader: Dr. Sorin Gabriel PASCU
Project Coordinator: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Project code: Call 2016/01-ELI
Project webpage: http://proiecte.nipne.ro/eli-ro/01-eli/index_en.php

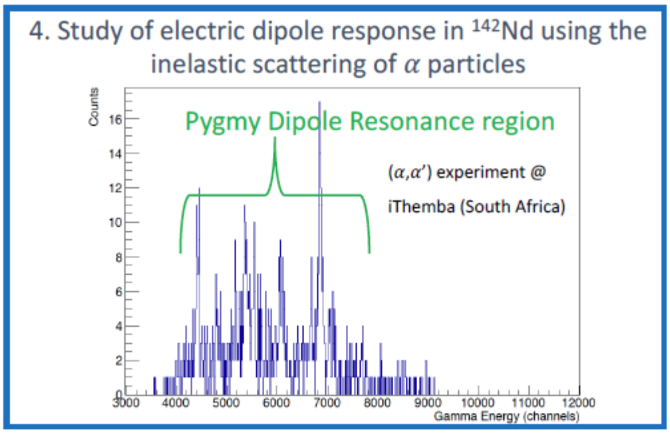
Extreme Light Infrastructure - Nuclear Physics (ELI-NP) is currently the most important project in Romania for studying the atomic nucleus. One of the most important components of this facility will be the Gamma Beam System (GBS) which will deliver photons with remarkable properties (very good energy resolution, small band-width, high intensity etc.). By using this equipment, an impressive amount of experiments is already envisaged by the scientific community to study different paradigms of the nuclear structure. Among these investigations, the study of the dipole response of the atomic nucleus plays a central role at GBS. Therefore, the present project was devoted to preparing for such upcoming investigations by constructing for the first time a Romanian team outside ELI-NP that will have the expertise to perform top experiments at the future facility.

The main topics of the project are presented below and refer to four experimental studies performed at various laboratories around the world to study different subjects in nuclear structure. These topics are closely related to the future experiments that will be performed at ELI-NP and include studies about the validity of the isospin symmetry, rigorous testing of different types of detectors ($LaBr_3$(Ce) and neutron detectors) that will be used at ELI-NP, or the complementary investigation of the Pygmy Dipole Resonance (PDR). The results we have obtained are an excellent starting point for building a community of Romanian users that will perform high-level research at ELI-NP.









Laser Pulse Propagation at Relativistic Intensities (ProPW)

Project Leader: Dr. Valer TOŞA
Project Coordinator: National Institute of R&D Isotopic and Molecular Technologies
Partners: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Project code: Call 2016/03-ELI
Project webpage: https://www.itim-cj.ro/eli3/index_files/home_en.htm

The main objective of the project is to characterize the laser pulse in time/frequency and in space. Any ELI-NP experiment needs the knowledge of the pulse in the focal region. However, in most of the cases one can obtain pulse characteristics in positions where the pulse intensity is moderate, so that measurements can be done. One useful instrument we developed uses the measured field outside the focus to obtain the field distribution in the focal region. Also, we built a model for coherent beam combining of two femtosecond pulses, assuming again that the two pulses have been measured outside the overlapping region (see Fig. 1 where the pulses are measured in regions A and B). The optimization of the beam combining can be investigated with this tool because the user can see the effect of non-ideal overlap of the two pulses, in space (missing common focus) or in time (different in arrival times in focus).

Pulse propagation in ionizing gas media is an important aspect of pulse interaction with matter. During such propagation the ionized gas will alter the pulse characteristics both in time/frequency and in space, see such an example in Fig. 2 where temporal shape is drastically changed. It is important to estimate the distortions because the *distorted* pulse will interact with matter, and these distortions will affect the interaction. The spatial distortion of the pulse has been exploited in a set-up aiming at changing the beam divergence. When the gas is propagating in a gaseous medium it behaves like a divergent lens due to the electron plasma which is more dense in the central than in the peripheral part of the beam. This defocusing can be used to manipulate the size and the shape of the beam (see in Fig.3 the set-up used to study beam divergence changes during propagation).

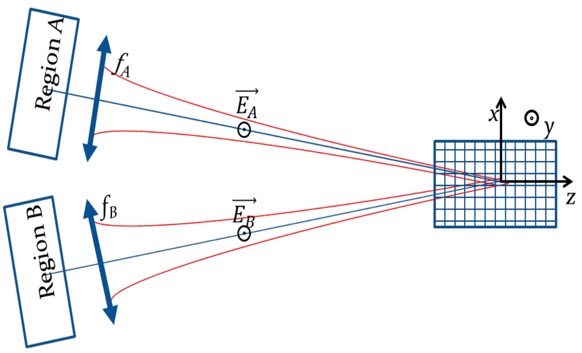


Fig.1 *Layout used for coherent beam combining of two femtosecond pulses*

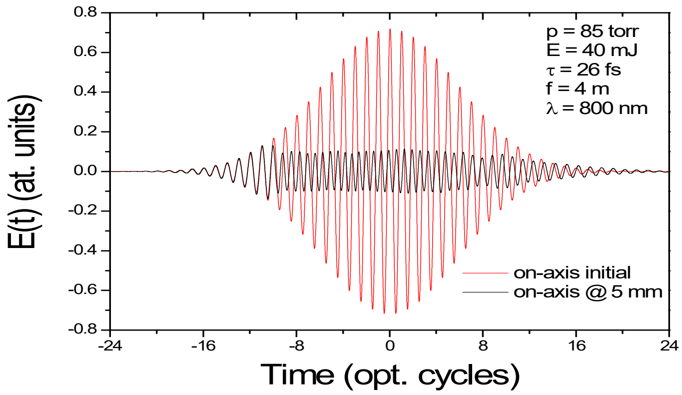


Fig. 2 *A 26 fs pulse before (red) and after propagation (black) in a gas medium*

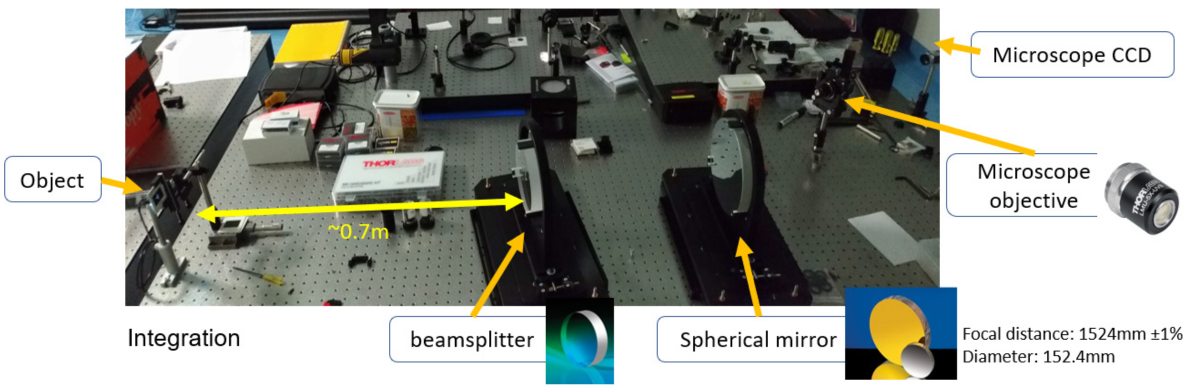


Fig. 3 *The experimental set-up to measure the beam divergence changes during propagation*

Design Study of a Cryogenic Stopping Cell (CSC) Demonstrator for ELI-NP IGISOL Beam Line (CSCDEMO)

Project Leader: Dr. Tiberiu Bogdan SAVA
Project Coordinator: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Partners: University Politehnica of Bucharest
Project code: Call 2016/07-ELI
Project webpage: N/A

We report the construction of the Cryogenic Stopping Cell (CSC demonstrator, Figure 1 (a), as a gas cell for radioactive ion beam (RIB) generation from actinide fission. The demonstrator is a complex gas chamber where fission recoils are thermalized and collected using low pressure gas flow, DC and RF electrical fields to form a secondary ion beam. The cell is divided in two sub-chambers, both working at pressures lower than the atmosphere. The lower chamber is designed to work at 200-300 mbar pressure, while the upper one will work at around 20-30 mbar. The chamber has been manufactured with various ports in order to be equipped with a high vacuum system, gas inlets, vacuum gauges ports, high-voltage feedthroughs, as well as electric connectors for sensors and diagnostic equipment. The gas system, Figure 1 (b), includes several mass flow meters, pressure regulators and diagnostic sensors, as well as an automatization interface created in LabView. The entire gas system is computer controlled.

At the present moment, after the preliminary gas circulation tests, the sub-chambers work ideally, showing stabilized pressures at 200 mbar in the lower part and 20 mbar in the upper part. This was obtained using two 0.3 mm gas nozzles between the sub-chambers and a 0.3 mm nozzle between the upper chamber and the preliminary vacuum pipeline (2.0×10^{-1} mbar). The entire demonstrator is provided with a double vacuum sealing, which can be used alternatively. The first chamber is based on a Viton sealing and thus able to work at room temperature conditions, while the second is prepared to work with copper gaskets suited to withstand cryogenic conditions.

For the latter type of chamber with differential vacuum pumping and DC/RF electrical fields, two parameters are of a significant importance, the overall extraction efficiency and the transit time. The first parameter is defined as the ratio between the input beam current (I_{beam}) and the detected ion rate (R_{ion}):

$$\varepsilon = R_{ion}/I_{beam}$$

The total efficiency is divided in several components depending on the component efficiencies, i.e. gas transportation efficiency (gas stopping, nozzle jets, etc), DC field drift efficiency, and RF carpet efficiency. The second important parameter is the total transit time, from the moment the ion is generated, up to the exit in the low vacuum volume, where the detection system is placed. The transit time is defined as:

$$t = t_{stop} + t_{DC} + t_{RF} + t_{nozzle\_jet}$$

These two parameters, efficiency and transit time, are estimated via in-beam experiments at the 9 MV Tandem in IFIN-HH. With this in-beam testing of the CSCDEMO we look to optimize the behaviour of this instrument with real charged particles bombarding the support gas. The estimation of the created space charge is measured by varying the intensity of the incident beam and the helium pressure. Transit time is measured by using the accelerated ion beam in pulsed mode and then make use of the detector/Faraday cup signals in a coincidence mode. From the gas simulations, as well as ion optics in DC and RF fields, we have a good measure of this transit time, which is in the order of tens of milliseconds. The in-beam testing is ongoing at 9 MV Tandem accelerator.

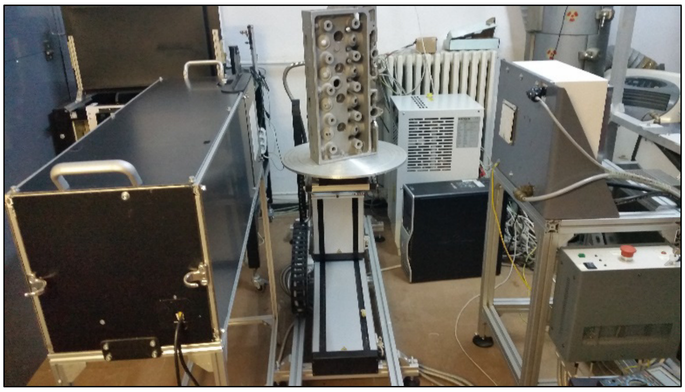
The CSC demonstrator will be used at the future ELI-NP IGISOL setup for photo fission experiments.

Support Action for Gamma Beam Industrial Imaging Applications (ELITOMO)

Project Leader: Dr. Mihai IOVEA
Project Coordinator: Accent Pro 2000 S.R.L. (AP2K)
Partners: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Project code: Call 2016/10-ELI
Project webpage: https://www.accent.ro/?q=projects/national-funded-projects/elitomo-project-2d-3d-tomography-for-large-size-objects-using-eli-np-ultrabright-gamma-beam-source

The ELITOMO project aimed at providing support for the development of industrial imaging applications at ELI-NP gamma beam system. We developed support actions for performing the necessary laboratory tests and improvements that were not foreseen in the TDR and are important for the operation of future digital radiography (DR) and industrial computed tomography (ICT) setups at ELI-NP. Prior to testing, the performance of the proposed experimental setups was assessed via analytical calculations and numerical simulations using the designed parameters of the gamma beam.
The main results are:

- Using Monte Carlo simulations, we modelled the Laser Compton Scattering (LCS) source and generated topographic data sets for the gamma beam tomography setup foreseen at ELI-NP in order to check the key imaging parameters, i.e. the spatial resolution capability, prior to installating the entire system at ELI-NP.
- For scanning large objects by using a very narrow pencil beam (<200 micro radians), an automatic positioning system has been designed and developed, capable of biaxial translation and one rotation with high accuracy in GBS (Gamma Beam System), based on a dedicated 3-axis mechanical scanner performing DR and ICT scanning trajectories of the objects to be investigated.
- Simulations of LCS photon sources in Geant4 for assessing the response of the detectors in conditions like those in a real experiment (IFIN-HH).
- Design and development of the scanning control procedure, data acquisition, data reconstruction algorithm integration for large objects in X-ray fan/pencil beam laboratory environment.
- A gamma-ray calorimeter detector for computed tomography applications (IFIN-HH): an experimental configuration for high energy photon generation for testing the gamma calorimeter prototype at 3MV Tandem.
- The tests and experiments carried out in this part of the project included the usage of a high-resolution Time Delayed Integration (TDI) detection, involving precise synchronization of object translations with the data recording.



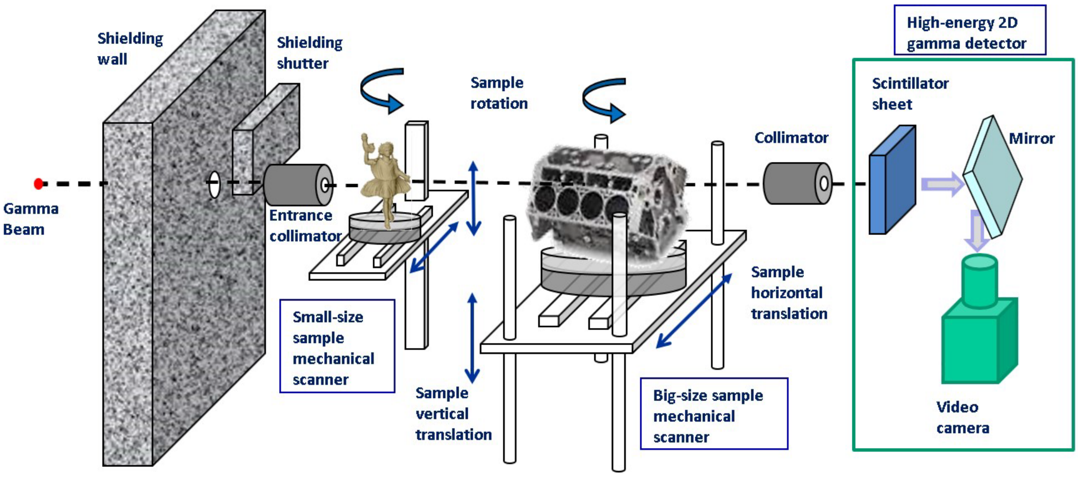


***Fig. 1** Experimental setup*

Development of the National Technologic Platform for Investigating the Interaction of Complex Biological Systems in the Context of ELI-NP (Astro-Bio-ELI)

Project Leader: Prof. Dr. Mihail Eugen HINESCU
Project Coordinator: Victor Babeş National Institute of Pathology
Partners: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering,
University of Bucharest, Faculty of Biology
Project code: Call 2016/13-ELI
Project webpage: http://www.ivb.ro/v3/project-13-eli/

Background: Advanced studies on the interaction of complex biological system with multi-component ionizing radiation mimicking space radiation will foster knowledge and technology and help to develop an improved, evidence-based radioprotection system for deep space missions with human crew and possibly for the establishment of permanent human habitats on Mars. It is expected that unique multi-component and multi-energetic radiations will be generated at ELI-NP, that will better mimic on-ground the interaction of cells and tissues with space-relevant radiations.

Project objective: To setup the national technology platform for astrobiology studies in the context of ELI-NP, and to test its functionality on cells and proteins using the available irradiation facilities, as a prerequisite stage for preparing the "first day" biological experiments at ELI-NP.

Achievements:

- An innovative cassette for exposing cells and proteins to complex radiations at ELI-NP was designed and the prototype was fabricated. Advanced simulations for various types of space-relevant radiations were made, and the obtained results greatly improved the device for exposing biological samples to radiation.
- Biological experiments were performed using irradiation facilities in Romania and Germany for validating the proposed innovative biomedical approach based on the concepts and the tools of "network medicine" and "systems biology". We have identified the network of genes that exhibit expression changes following the exposure of cells to radiation that unravels the intimate inter-connected processes through which cells attempt to repair the damages inflicted by radiation. Preliminary results highlight that the cytoprotective transcription factor NRF2 is a valuable therapeutic target for counteracting the deleterious effects of space-relevant radiations on normal cells.
- A project-dedicated biobank was established, that will be available for the consortium members and other potential partners for continuing biological investigations beyond the project.
- Three project-dedicated workshops were organized for promoting the project and the obtained results towards the academic community in the field of biomedicine and physics, for increasing their participation in experiments that will be performed at ELI-NP.
- Preliminary results were published in 6 ISI-quoted journals, and were communicated at 28 national and international scientific congresses in the field of cell biology and nuclear physics.
- Six PhD students were trained and had the opportunity to work in high-level research for building their scientific career.
- New projects in the field of nuclear physics and astrobiology were submitted at international calls.
- Various new and existing international collaborations were developed and sustained the project implementation. It is worth mentioning the newly established collaboration with the European Space Agency and the GSI Helmholtz Centre for Heavy Ion Research, Darmstadt, Germany.

In conclusion, the project provided the opportunity for building a multi-disciplinary team committed to apply fundamental and applied science for developing astrobiology applications at ELI-NP.

Electromagnetic Shielding Structures to assure Biological Safety during Target Hitting Experiments performed on PW Laser Facilities (BIOSAFE)

Project Leader: Dr. Eng. Aurelian MARCU
Project Coordinator: National R&D Institute for Lasers, Plasma and Radiation Physics
Partners: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Project code: Call 2016/17-ELI
Project webpage: https://cetal.inflpr.ro/newsite/eli-17

Laser-matter interactions, particularly for PW laser facilities proved to generate intense electromagnetic pulses (EMP) with a rather large spectral distribution (Fig. 1) and high intensities (up to few kV/m).

Even if no influences could be proved for short terms irradiation of living organisms or cells, the longer terms (48 -72 h) exposure of pre-B murine cells to much lower field intensities (0.2 – 1 V/m) have shown a drastic reduction of V(D)J recombination and the antibody production malfunction. The effect seems to be dependent both on field intensity and frequency (Fig. 2). Since the effects could not be correlated with cell DNA double brake, our proposed interpretation relay on a local polarization produced into the cell due to the non-linear response of the cell medium which should further affect the cell physico-chemical reactions and, in our case, the V(D)-J recombination processes. It only remains for us to speculate the extension of the observed recombination effects of the in vivo situation on the ability of our B cells to elicit an unaltered primary immune response in response to antigen challenge.

For electromagnetic radiation protection, shielding materials are generally used. In terms of shielding performances (the decrease of the monitored signal in Fig. 3), meshes proved to have better performances comparing with classic foil shielding, and multiple mesh layers further enhanced shielding efficiencies, particularly to higher frequencies where living cells seems to be more affected.

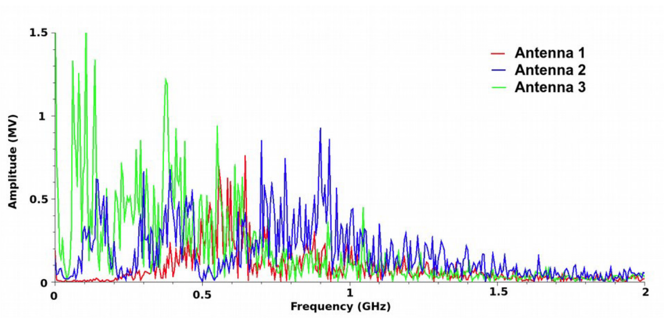


Fig. 1 *EMP spectral distribution in a laser based electron acceleration process*

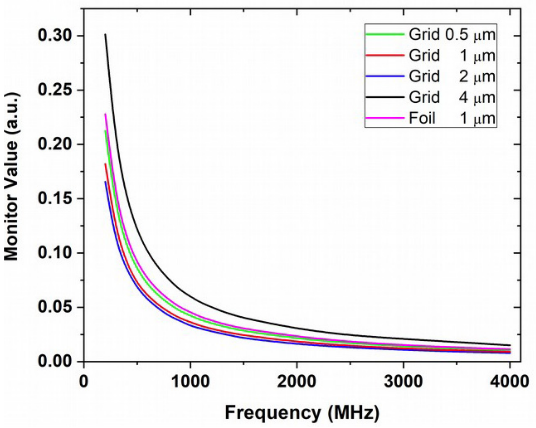


Fig. 2 *Cell recombination response curves at two constant field intensity A) 0.2 V/m and B) 0.4 V/m*

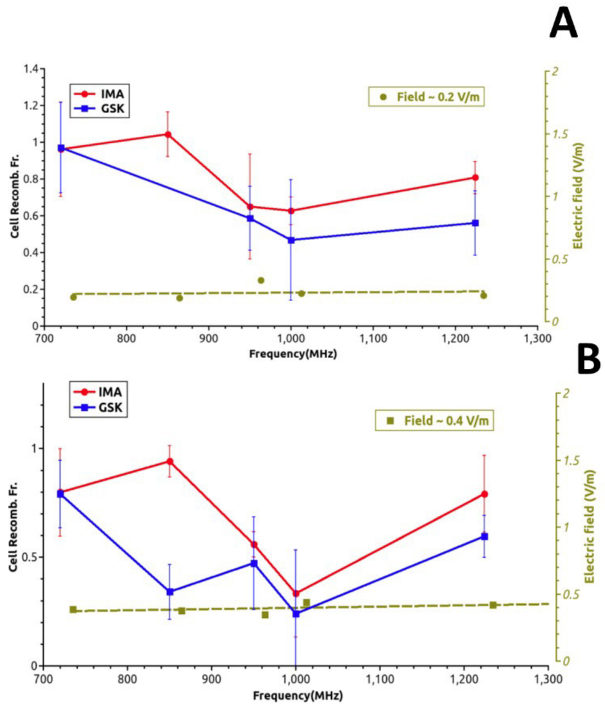


Fig. 3 *Shielding performances of mesh structures with different mesh sizes*

Surface Science with Positrons: Optimization of Solid Ne Moderators and First PAES Experiments (SuSciPo)

Project Leader: Dr. habil. Cristian Mihail TEODORESCU
Project Coordinator: National R&D Institute of Materials Physics
Project code: Call 2016/18-ELI
Project webpage: http://www.infim.ro/eli/SuSciPo

Positron annihilation-induced Auger electron spectroscopy (PAES) is amongst the highest surface sensitive techniques to date. In surface science, X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES) are widely used for chemical characterization of materials with surface sensitivity. The surface sensitivity for these techniques stems in the relatively low (about 1 nm) inelastic mean free path (IMFP) of ejected electrons with kinetic energies ranging from some tens of eV to slightly over 1 keV. In the case of positron annihilation, the following additional phenomena have to be taken into account: (i) Most materials exhibit a “negative work function” for positrons; low energy positrons cannot penetrate inside the material, which may be viewed as a “positive jellium” repelling positively charged particles; (ii) Therefore, low energy positrons directed towards a material form metastable state near the outer surface of the material; (iii) Positrons temporary stabilized near surface annihilate with electrons belonging to atoms from the very first layer at the surface; some positrons annihilate with core electrons from these atoms, leaving metastable core vacancies; (iv) These vacancies are filled in by ejection of Auger electrons, originating from the very first atomic layer.

In order to have an efficient PAES installation working with positrons emitted by conventional beta decay, one needs to moderate these positrons, i. e. to decrease their kinetic energy of a few eV. This is achieved by using different materials as moderators and the most efficient positron moderator is solid Ne, because it is the solid with the largest band gap known (21.7 eV). Practically, positrons with kinetic energy of the above value cannot loose energy by electron-hole excitation, and the interaction with phonons is also quite weak at the low temperatures needed to stabilize a solid neon matrix. Then, a setup has been built with a cryogenic head where the positron source is mounted, then solid Ne is condensed on it in a base vacuum as low as possible (10^{-11} mbar), to avoid the contamination of the solid Ne matrix. The greatest achievements of the Project were the purchase of the ^{22}Na positron source with 10 mCi activity, and the authorization of the new laboratory by the national authorities in radioprotection. A home-made sample manipulator was adapted for sample cleaning, together with other devices needed for characterization: electron energy analyser for Auger electron spectroscopy, quadrupole mass spectrometer for checking the gas cleanness, devices for rapid outgassing of the sample and of the cryostat. Amongst the first scientific results obtained, one remarks the confirmation of the extreme high surface sensitivity of (P)AES and the ability of this technique to quantify surface band bending at surfaces of ferroelectric materials, in a more precise way than by XPS. An independent research was conducted to compute positron annihilation cross sections on different atomic subshells as function of the positron kinetic energy, and these computations proposed an alternate method of chemical characterization.

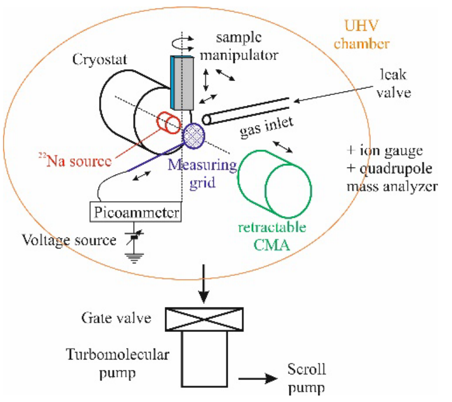


***Fig. 1** Diagram positron source*

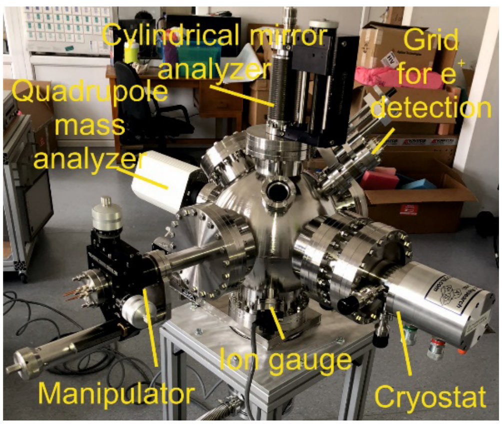


***Fig. 2** PAES setup*

eXtremely High Vacuum for ELI (XHVELI)

Project Leader: Dr. Fiz. Mihai VARLAM
Project Coordinator: National R&D Institute for Cryogenic and Isotopic Technologies
Partners: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Project code: Call 2016/19-ELI
Project webpage: www.icsi.ro/eli_xhveli/

In the frame of the project a concept of test vacuum chamber has been developed. Having a cylindrical shape, 600 mm outer diameter and 500 mm height this vacuum chamber is equipped with four vacuum ports of 200 mm nominal diameter each and with adequate ports for measure and vacuum pumps. To allow the alignment with the laser beam the support of test chamber is adjustable on height. Four breadboards placed inside help us to fix different optical and mechanical components inside the chamber. The scheme of the test vacuum chamber and the associated differential pumping system are presented in fig. 1. The test chamber has been connected to a turbo molecular vacuum pump bolted directly to the 200 mm vacuum port of chamber 1. Inside this chamber there is a second chamber, smaller than chamber no.1, called also-interaction chamber -where an extremely high vacuum has been produced. A small aperture of 5 mm diameter allows the passing of laser beam. The interaction chamber was firstly vacuumed using a combination of ion pump and titanium sublimation pump. This combination of vacuum pumps allowed to obtain inside the interaction chamber an extremely high vacuum. Completely equipped the test vacuum chamber has been in house tested at ICSI, as can be seen from fig. 2, and finally transferred to ELI-NP. During tests done at ICSI, the best value for vacuum inside the interaction chamber was 6.3^{-10} Pa. This value was obtained by using, besides vacuum pumps mentioned above, a cold head of cryo refrigerator, SHI RDK 415D, acting as cryogenic pump, connected to the interaction chamber. Subsequently, the vacuum chamber developed in the framework of the project has been installed in the ELI-NP vacuum laboratory, where it has been integrated in the existing infrastructure, using the equipment at ELI-NP. The final design for the differential pumping system, fig. 3, to be used on the E4 interaction chamber and the detailed design based on expertise gained from operating test chamber have also been done. In the commissioning experiments performed at ELI-NP, in the E4 area featuring 2x100TW laser beams, the quality of the attained vacuum near the focusing points of the laser beam is critical for the measured signal to noise ratio. This was one of the main motivations for the ultra-high vacuum R&D at ELI-NP, pursued in the XHVELI project in collaboration between ICSI and ELI-NP. Due to the fact that no material window can be placed in the way of the ultra-high intensity laser pulse, and also to the fact that quite a lot of optical and mechanical components (including motion stages) are required by the experimental setup to be placed in the vacuum chamber where the beams are focused, two main lines of action have been considered. First, to study and to ensure that the outgassing of the components in this vacuum chamber is known and as small as possible. It is important to know both the composition (in order to avoid optics contamination) and the integrated outgassing of the components. Second, a differential pumping scheme has been implemented, which improved with 2-3 orders of magnitude the vacuum level around focusing point.

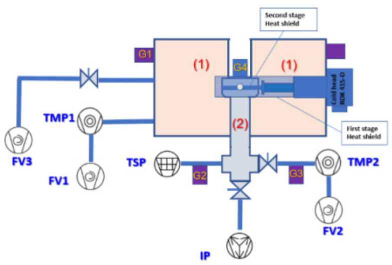


Fig. 1 *Basic design configuration for test vacuum chamber and pumping system:(1) - High vacuum chamber; (2) - Extreme vacuum chamber; FV1 - fore vacuum pump - scroll pump (IDP5); FV2 - fore vacuum pump - scroll pump (TS300); FV3 - fore vacuum pump - scroll pump (TS600); TMP1, TMP2 - turbomolecular pump (TV551 Navigator); IP - ion pump (Vaclon Plus 300); TSP - titanium sublimation pump; G1 - Inverted Magnetron Gauge (IMG 100); G2 - Pirani Inverted Magnetron Gauge (FRG-700/702); G3 - Pirani Bayard-Alpert Gauge (FRG720); G4 - Hot cathode ionization gauge (AxTRAN IS2)*

Fig. 2 *Test vacuum chamber – in house tests setup*

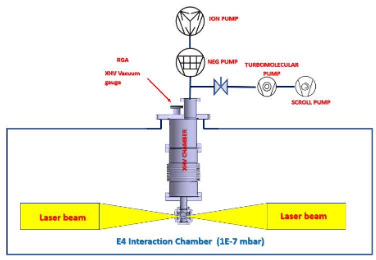


Fig. 3 *Differential pumping system – final configuration*

Development of a Novel 2D Array for Dosimetric Characterisation of ELI Laser Accelerated Charged Particle Beams (ELIDOSE)

Project leader: Prof. Dr. Dan C. DUMITRAȘ
Project coordinator: National R&D Institute for Lasers, Plasma and Radiation Physics
Partners: University Politehnica of Bucharest, Canberra Packard SRL
Project code: Call 2016/20-ELI
Project webpage: N/A

One of the research directions at ELI-NP is to make use of laser-accelerated proton beams for radiobiology experiments. In order to perform these experiments, one must first set up a proper dosimetry method for those experiments, to have a clear image of the radiation doses delivered to the cells. This would help us to better understand the effects of these beams on living cells and thus, ultimately, to optimise our methods for treating cancers. The measurement of the dose can be done through various means, but the ion chamber method is considered the gold standard. In radiation medicine, due to its high accuracy. A major problem related to the dosimetry measurements is the fact that at ELI-NP high intensity laser pulses are extremely short (a few femtoseconds) and thus, the proton beams produced by these lasers are expected to have a duration of only a few nanoseconds. This makes the measurements with ion chambers difficult because of the recombination occurring inside these chambers. In short pulse measurements, many of the ion pairs generated inside the ion chamber will recombine before we get the chance to collect all of them, resulting in a loss of signal. This means we will end up with an inaccurate result if we do not take this recombination into account. To overcome the issues associated with recombination we have designed a new type of ion chamber array, the QADRO-fm (**Q**uad **A**rray detector for **D**ose and **R**ec**O**mbination factor measurement), as can be seen in figure 1. This uses four ion chambers, each of them polarised at a different voltage. These chambers are used in pairs to measure dose, bias polarity effect and recombination effect in a single shot. In order to determine the minimum distance between the chambers, we used FLUKA (a Monte-Carlo simulation code) to simulate the cross-talk between the chambers at different distances between their centres and we have shown that the chambers that we used for prototyping can be placed in close contact. In order to apply also the energy corrections needed for an accurate measurement, we used Gafchromic films in axial geometry, a method that we proved to be very effective in low energy proton beams, where the Bragg peak is less than 1 cm depth (see figure 2). Our results show that the QADRO-fm detector is a viable solution for measuring doses in pulsed beams of charged particle and that, paired with radiochromic films, can provide an accurate measurement in a single shot even in very short pulses. We have also shown that we can use FLUKA for calculating the calibration factors for various beam qualities. The QADRO-fm detector has wide applications both in the future biophysics experiments performed at ELI-NP as well as in clinical use in particle therapy and will provide a feasible solution for the dosimetry in short pulsed particle beams, where the dosimetry measurements are a significant challenge.

Fig. 1 *The first demonstrative prototype of the QADRO-fm detector, with the dual channel electrometers for readout.*

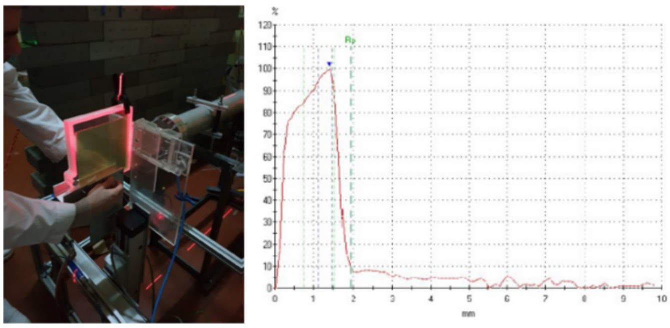


Fig. 2 *The measurement of the energy of the proton beam using Gafchromic EBT3 films in axial presentation.*

Studies concerning the Materials Behaviour used for Passive Dosimeter System in High Intensity Radiation Field at ELI-NP (OSL-SSNTD)

Project Leader: Dr. Dorina ARANGHEL
Project Coordinator: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Partners: N/A
Project code: Call 2016/23-ELI
Project webpage: www.nipne.ro/proiecte/eli-ro/23-eli/index.php

The properties and the behaviour in the high intensity radiation field of materials used for personnel dosimetry were investigated by two techniques of radiation detection: Optically Stimulated Luminescence (OSL) and Solid-State Nuclear Track Detection (SSNTD). The dosimeters that use these technologies are designed to provide X, gamma, beta and neutron radiation monitoring. These technologies are applicable to situations where real-time information is not needed.

The detector materials used in this project were beryllium oxide for the OSL dosimetry and a plastic polymer, CR-39 (allyl diglycol carbonate) for the neutron dosimetry.

The OSL dosimetry is a method that is used for measuring the whole-body dose for X, gamma and beta radiation exposures. OSL materials contain–defects in their crystal structure that trap electrons or holes inside of the OSL material by exposure to radiation and these are subsequently freed by stimulation with light.

The neutron dosimetry by track detectors is carried out by the registration of the number of fission tracks and alpha particles per unit area or of the recoil products generated by neutrons in plastic or polymer materials. SSNTD is widely used for personal neutron dosimetry.

In order to characterize the performance of OSL dosimetry systems, tests were performed in gamma reference radiation fields as required by the SR EN 62387-1:2012 in IFIN-HH at the energy range of 0.6617 MeV from 137Cs in the range of 0.35 mSv and 5 mSv. The test bench of IFIN-HH was calibrated in order to assure the capability of testing and calibrating the dosimeters for measurements in the range of 100 µSv/h to 3500 µSv/h. The OSL dosimeter response falls in the linear range and the statistical fluctuations are below 15% (Fig 1 and 2). Fading tests were performed and the response to natural radiation was determined. The signal of the irradiated detectors lasts for 45 days. The response to natural radiation and self-irradiation did not influence the signal of the dosimeter.

For the dosimetry system sensitive to neutron radiation, type tests were realized at Czech Metrology Institute and National Physical Laboratory in the energy range of thermal and fast neutron from 0.05 mSv to 20 mSv at 0, 30 and 60 degrees. Also, according to the requirements of ISO 21909-1:2015, at NPL irradiations of personal dosimeters for 5 monoenergetic neutron energies (144 keV, 250 keV, 565 keV, 1.2 MeV and 16.5 MeV) were carried out. The dosimeters were etching, readout and analysed. For high intensity radiation the tracks in the CR 39 detectors were observed. For ^{252}Cf, the value of the calibration factor was in the range (320- 350) tracks / mSv (Fig 3).

All these studies are supported by the Dosimetry Laboratory from ELI-NP that will implement the radiological monitoring programmes of occupationally exposed persons using passive integrating dosimetry systems: OSL and CR 39.

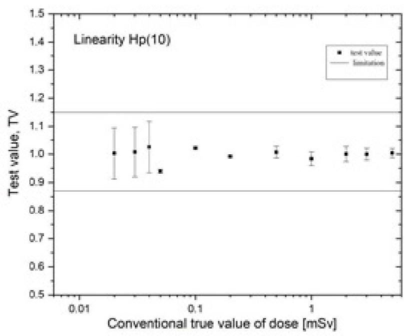


Fig. 1

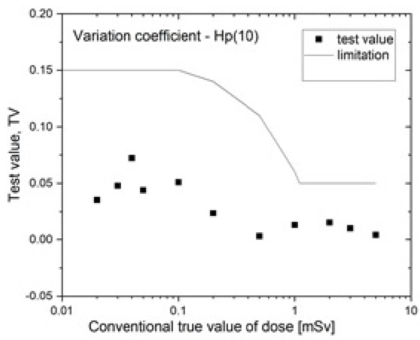
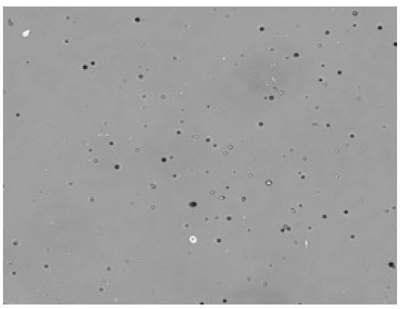


Fig. 2



Setting the calibration factor to ^{252}Cf

Fig. 3

Temporally Resolved Diagnostics of Laser Produced Plasma for Electron Acceleration foreseen to be used at ELI-NP (TEDILAPLAS-ELINP)

Project Leader: Dr. Constantin DIPLASU
Project Coordinator: National Institute of R&D for Lasers, Plasma and Radiation Physics
Partners: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Project code: Call 2016/24-ELI
Project webpage: http://cetal.inflpr.ro/projects/CETAL-PW/eli-24

Main goals of the project

- Spatial and temporal characterization of plasma resulted from high power laser interaction with matter;
- Development of various complementary techniques for plasma diagnostics;
- Implementation of these plasma diagnostic techniques to particle acceleration experiments at ELI-NP infrastructure, particularly at E6 experimental area.

Three complementary methods for temporal based diagnosis of the acceleration plasma were developed and tested at CETAL facility in Măgurele: transversal interferometry technique, wave-front analysis method and single shot analysis of the transmitted probe pulse with temporal chirp.

The measurements of the density of a refractive medium (e.g. gas jet, plasma, etc.) are based on phase variation introduced by the medium with respect to a reference phase map obtained in the absence of the medium.

Nomarski interferometer - tests on supersonic gas jet:
Nomarski interferometer was constructed in CETAL-PW interaction chamber and tested on supersonic gas jet pulses produced with a SourceLab system composed of a high pressure valve, 3mm diameter nozzle, and a triggered valve controller. Fringe shifts in the region where the gas flows were observed, marking the boundaries of the gas jet, pretty well defined in the vicinity above the nozzle surface as it is shown in ***Fig. 1***.

Wave-front sensor density measurement method – tests on supersonic gas jet
It was used a modified Shack Hartman Wave front sensor patented by Phasics, which contains a second mask so that a two-dimensional diffraction grating is created, which replicates the incoming beam into four identical waves propagating along different directions. The probe laser beam passes just over the gas valve nozzle and its transversal section is captured by SID4 camera (Phasics) whose analysis mask was set at about 500 μm above the nozzle. The phase recovery routine is provided by the manufacturer. The obtained gas density distribution is presented as 3D graph in ***Fig. 2 (a)***. Gas density profiles at various delay time with respect to the trigger signal applied to the controller unit of the gas valve are presented in ***Fig. 2 (b)***.

Probe beam able to characterize plasma filaments that accelerate electron beams
By focusing the main laser pulse so that we have an intensity of about 10^{19}W/cm^2 on a 3 mm diameter supersonic gas jet of He-N_2 mixture, electron beams with high energies up to ~350 MeV were produced for the first time in Romania, proving that high-density plasma filaments were obtained. In ***Fig. 3*** is shown an example of the accelerated electron beam footprint detected on the scintillating screen (LANEX) placed on the electron extraction window at the extremity of the interaction chamber.
In order to characterize (visualize) the plasma filaments, a specific optical configuration was constructed. The probe beam together with the main beam is presented in ***Fig. 4***. Shadow-graph samples of the plasma filaments for probe beam delays in the range 0 - 13.2 ps are presented in ***Fig. 5 (a)***. The profiles of the filament (***Fig. 5 (b)***) can be seen entirely for 9.9 ps delay, which is expectable as the filament length can be 3 mm maximum.

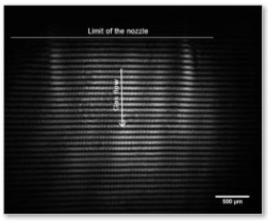


Fig1

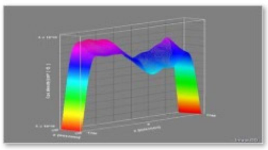


Fig2a

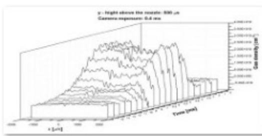


Fig2b

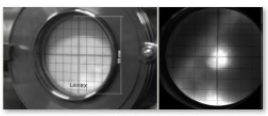


Fig3

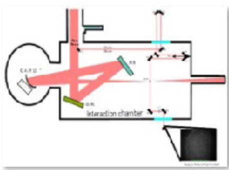


Fig4

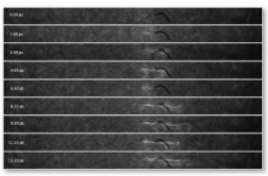


Fig5a

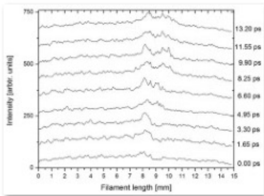


Fig5b

Laser Targets for Ultra-intense Laser Experiments (TARGET)

Project Leader: Dr. Marian ZAMFIRESCU
Project Coordinator: National R&D Institute for Lasers, Plasma and Radiation Physics
Partners: National R&D Institute for Microtechnologies
Project code: Call 2016/25-ELI
Project webpage: http://cetal.inflpr.ro/projects/eli-25

Laser target engineering allows for efficient interaction between ultra-intense laser beam and materials for generating accelerated energetic particles such as ions, electrons, protons or coherent electromagnetic radiations (XUV, X-ray). The aim of this project is to develop techniques for fabrication and manipulation of micro-targets for laser-matter interaction in ultra-intense fields. The project took place from September 2016 to November 2019 and had the following main activities:

- PIC (Particle in Cell) numerical simulations for ultra-thin targets (membranes) of polymers and metals and 3D conical shaped micro-targets;
- development of micro-lithography protocols for obtaining ultra-thin membranes;
- development of 3D laser lithography protocols for obtaining targets with complex geometries;
- hardware configuration of the systems for the target positioning and alignment;
- development of algorithms for autofocusing and positioning the targets.

The main results of the project are:

- Method for obtaining metallic membranes for targets used in high power laser interaction;
- Method for obtaining 3D targets used in high power laser interaction;
- 3D conical targets and 2D ultra-thin targets;
- System with multiple axes for positioning the targets in vacuum;
- Method for remotely control the target positioning system;
- Documentation of the technology for fabrication and manipulation of the 3D targets for the interaction with ultra-intense lasers;
- Dissemination at workshops, conferences and ISI articles.

After the completion of the project, it is envisaged that this new type of target will be used in high power laser installations CETAL-PW and TEWALAS from INFLPR, and will be available for future laser infrastructures such as ELI infrastructure. The methods of manufacture and manipulation of the targets developed in this project will allow an efficient use of laser installations, significantly reducing the operating costs for each laser pulse.

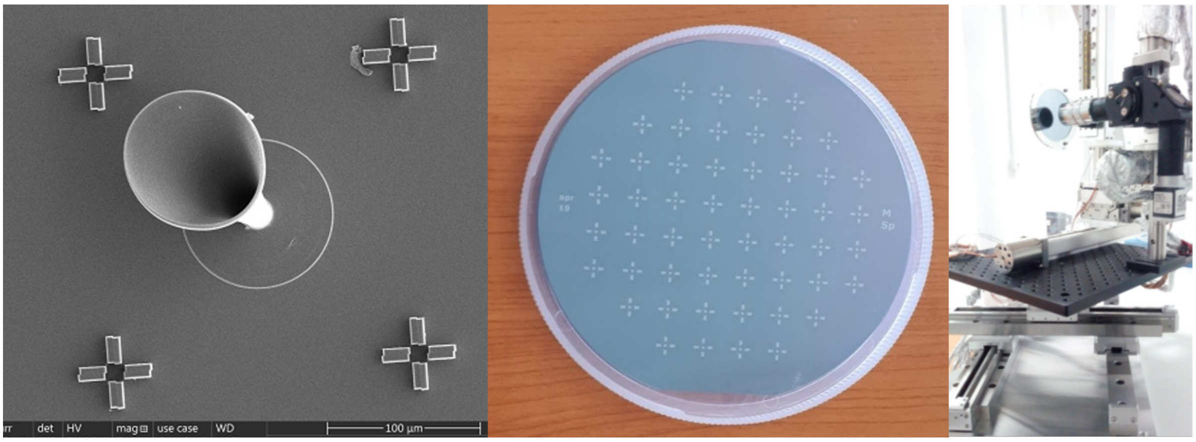


Fig. 1 3D targets produced by 3D laser lithography (left), arrays of 3D targets – Si wafer (middle), device for alignment of targets substrates (right)

Development of New Experimental Setups and Materials for the Positron Converter and Moderator for the ELI-NP Positron Beam Line (COMPOSITE)

Project Leader: Dr. Nikolay DJOURELOV
Project Coordinator: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Partners: National Institute for R&D in Electrical Engineering,
National R&D Institute for Lasers, Plasma and Radiation Physics
Project code: Call 2016/27-ELI
Project webpage: http://27eliro-composite.simplesite.com

The aims of the project were the design of the convertor/moderator assembly (CMA) for ELI-NP Positron Laboratory, as well as studies on new materials for application as e^+ moderators, with improved moderation efficiency and optimized geometry. The 3D models of the Converter/Moderator Assembly (CMA) and $_{22}$Na source chambers have been analyzed (Fig.1). Comsol simulations on realistic 3D models have been performed to estimate the cooling power which will be required to cover the radiation heat losses. The technical specifications of cryocoolers to serve as cold places to freeze neon have been determined. Station for neon solidification has been build. A vacuum cryostat chamber has been equipped with a 4.2 K cryocooler with a closed-loop He-compressor. Neon gas supply system has been assembled. An extension to the 4.2 K cold stage of the cryocoolers has been manufactured to mimic the ^{22}Na source holder. The extension and cold stage has been surrounded by a thermal shield designed to limit the thermal radiation heat loses. Neon gas supply has been electronically operated to allow access of a well-determined amount of gaseous neon into the cryostat. The formation of a solid neon layer has been monitored with a CCD camera. A model of the CMA with foils and electrically insulated by sapphire thin disk has been manufactured. The insulation provides GOhm resistance suitable for high voltage application. Tests have been performed on the way the gaseous neon is fed into the cryostat chamber in front of the CMA foils. The neon supply has been modified to multi-point type with individual supply to each CMA cell. The modified supply proved to ensure a better thickness uniformity of the solid neon layer.

GaN films have been grown by RF sputtering using the UHV deposition cluster from ELI-NP Targets Laboratory. Different substrates [Si (001), Si (111), Al_2O_3 (0001), ZnO (0001), TiO_2 (001)] have been used. The grown GaN thin films (~100 nm) have been subjected to microstructural, morphological, and compositional studies by X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDS), Atomic Force Microscopy (AFM), optical profilometry, and X-ray Photo electron Spectroscopy (XPS). The data showed that the GaN films grown on TiO2 had cubic structure, c-axis oriented, with a tetragonal deformation. For the GaN/Al2O3 the hexagonal (000l)-oriented GaN phase was stable only at the interface, while the (h000) phase become stable after the film relaxation. GaN/ZnO showed a single hexagonal phase, c-axis oriented. Hexagonal, single phase, c-axis oriented GaN films, free of cracks and with homogeneous morphology could be obtained only on ZnO (0001). Fig.2 shows data of commercial GaN on 6H-SiC (0001).

Experiments with slow e^+ have been performed at IHEP, China. From the depth profiles using Doppler Broadening Spectroscopy (DBS), the longest e^+ diffusion length has been obtained as ~ 60 nm among the studied samples. Since this value for a defect-free GaN layer should be > 90 nm, the search for a technology to be able to produce defect-free quality thin GaN film is worth to continue.

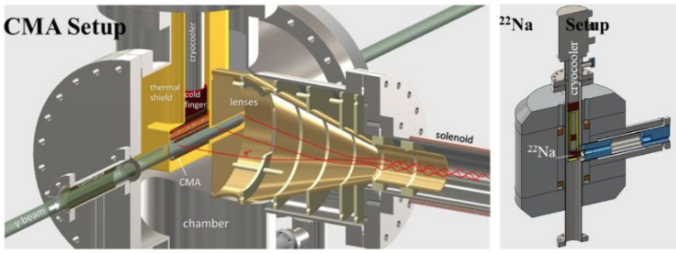


Fig. 1 3D models of the CMA and ^{22}Na setups for e^+moderation by solid neon

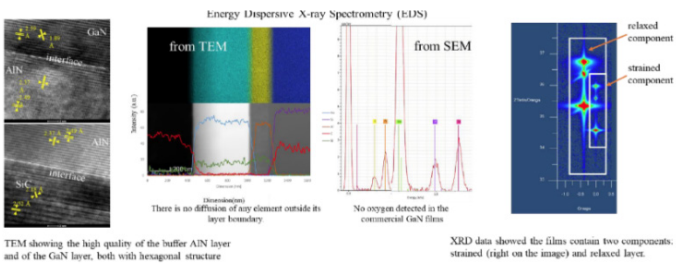


Fig. 2 3D models of the CMA and ^{22}Na setups for e^+ moderation by solid neon

Advanced Modelling of Electrodynamical and Nuclear Interactions at ELI-NP (AMENI)

Project Leader: Prof. Dr. Virgil BĂRAN
Project Coordinator: University of Bucharest
Project code: Call 2016/29-ELI
Project webpage: http://www.nicolin.info/WWW/ELIROWeb.htm

The project on "Advanced modelling of electrodynamical and nuclear interactions at ELI-NP" focused on i.) scattering of intense electromagnetic radiation on electrons, ii.) theoretical studies on double Compton scattering, iii.) theoretical and computational approaches for nuclear structure and collective dynamics, and iv.) bridging the electrodynamic calculations with transport models with applications to the physical cases of interest at ELI-NP. The results obtained for the first three objectives allow us to extend the current framework for computational plasma dynamics based on transport codes (such as Particle-In-Cell – PIC) through the inclusion of realistic cross-sections for aforementioned processes, thereby providing improved computational models for ELI-NP.

On the side of modelling intense radiation scattering we have obtained new results in the study of the trident process, consisting of the production of pairs by a high energy electron colliding with an ultra-intense laser field. The previous methods offered a detailed study of only the two-step process, which dominates for long laser pulses, while our new method allows us to evaluate all the terms that contribute to the probability density.

During the course of the project, we have extended the method for polarization analysis of the emitted photon in the linear single Compton scattering to the case of Non-Linear Compton Scattering and have investigated the polarization effects and polarization – spin correlations in the double Compton scattering in an intense laser field.

We have investigated the properties of the pygmy dipole resonance using both self-consistent Random-Phase Approximation (RPA) models and numerical transport models which use the celebrated Vlasov equation (see Fig. 1). Our results have shown good agreement between the two approaches in the regions of interests. The same domain of values for several observables in both approaches suggests a collective component consistently described at the level of quantum microscopic RPA and semi-classical transport framework based on Vlasov equation. Our numerical results on the test particle method for the Vlasov equation reached an unprecedented accuracy of 8000 test particles for nucleon and allowed us to perform a detailed study of the transition densities.

Finally, we have performed systematic 2D and 3D PIC simulations on the dynamics of plasma in intense laser fields observing the properties of the electron jets in different setups (see Fig. 2). Our simulations will allow us to create a single transport computational framework for ELI-NP which bridges between the PIC and Vlasov equation solved through the test particle method.

The project resulted in ten scientific articles already published in prestigious peer-reviewed journals such as Phys. Rev. A, Phys. Rev. D, Phys. Lett. B, etc. and a few other manuscripts are in various publication stages, as well as presentations at national and international conferences.

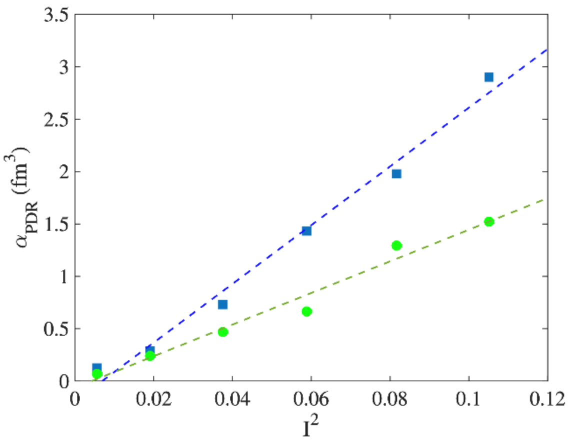


Fig. 1 *- The contribution to dipole polarizability of the Sn isotopes due to the pygmy dipole resonance as a function of square of isospin degree of freedom from Vlasov simulations. The green circles correspond to the asysoft case while the blue squares to the asysuperstiff. In both cases the dashed lines represent the linear fit.*

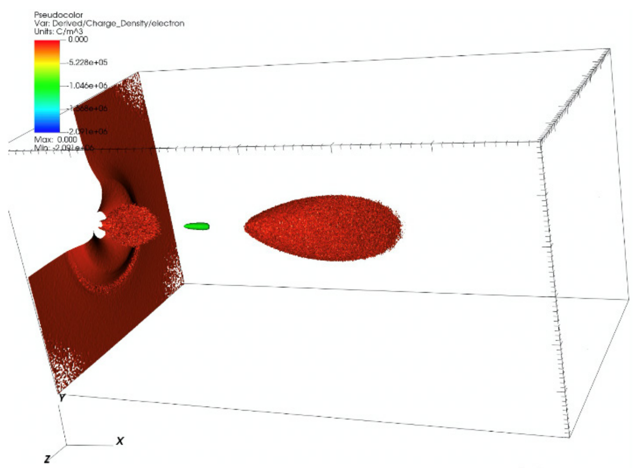


Fig. 2 *Charge density distribution of electrons obtained from an EPOCH-based 3D PIC simulation of a PW-class laser pulse which hits a He low-density gaseous target.*

Development of THz Diagnostics and Imaging Instrumentation for High Power Laser Experiments at ELI-NP (TERAELI)

Project Leader: Conf. Dr. Mihai DINCĂ
Project Coordinator: National Institute for R&D for Lasers, Plasma and Radiation Physics
Partners: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Project code: Call 2016/30-ELI
Project webpage: http://ecs.inflpr.ro/Proiect%20TERAELI-30-ELI_2016.html

The aim of this project was to develop a single-shot THz radiation diagnosis system used to characterize and optimize the processes arising from the laser-target interaction. To achieve this objective, the research activities that were carried out had the following results:

- A theoretical study on the photo-current model for the laser-plasma interaction during "two-color" filamentation for the in-line configuration. For this experimental configuration the laser plasma interactions depend on three parameters: the angle α between the polarization of the incoming laser beam and the extraordinary axis of the BBO crystal, the phase retardation φ between fundamental frequency components polarized along the ordinary and extraordinary directions, and the relative phase θ between the extraordinary polarized fundamental and second harmonic. Symmetry and periodicity relations were observed which led to a deeper understanding of the phenomenon of THz radiation generation and, of course, to its optimization.
- THz generation experiments by two-color air filamentation of Bessel and Gaussian beams. An increase in the energy of the THz pulse was observed with increasing of the filament length. Using the Bessel beam, the efficiency conversion infrared to THz radiation was increased by one order of magnitude in comparison with the configuration with a Gaussian type laser beam.
- The single-shot THz radiation diagnosis system was developed. THz single-shot imaging system is based on a pair of echelon mirrors which splits the incident probe beam into an array of tiny" beamlets" that are delayed incrementally by the same interval. In our case, the laser pulse is transformed into a 2D array of 30X30 pulses, with temporal separation of 68 femto-seconds and the overall temporal probing window is of 61 picoseconds. Modulation of the pulse train in time is mapped onto modulation of intensity in the image, making it possible to record the entire THz trace with a single laser pulse. Before using the echelon mirrors, preliminary experiments were performed using a pair of IR broadband plane mirrors and also a conventional delay line. Temporal evolution of the THz pulse was detected by electro-optic detection and an imaging technique. A LabView application was realised to post- process the images taken by the cameras.

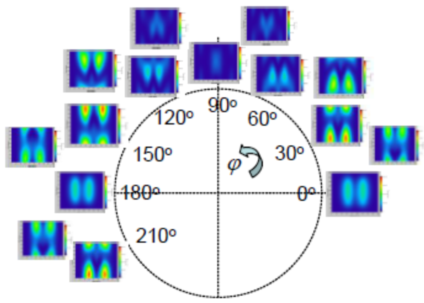


Fig. 1 *The THz field intensity as a function of the angles θ and α for different values of the angle φ. The figure highlights the symmetry properties*

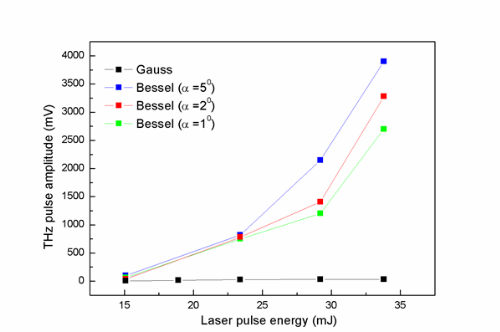


Fig. 2 *THz pulse amplitude measurement for plasma filaments formed by the interaction with gases of the laser beams having different transversal intensity profiles*

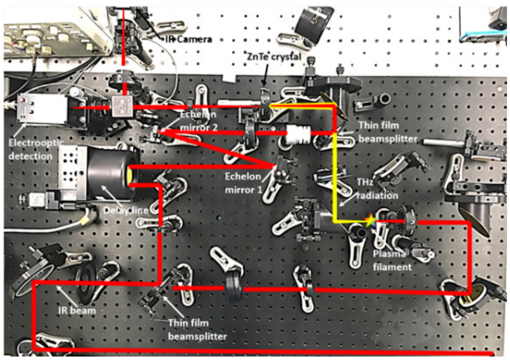


Fig. 3 *THz sigle-shot imaging system*

Physical and Numerical Experiments for studying Laser Accelerated Particles and their Interaction with Crystalline Materials (ELICRYS-2)

Project Leader: Prof. Dr. Daniel VIZMAN
Project Coordinator: West University of Timișoara
Partners: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Project code: Call 2016/32-ELI
Project webpage: https://physics.uvt.ro/~vizman/ELICRYS2/

In preparation of future experiments at ELI-NP, the current project aims: (1) to optimize through simulations the conditions for laser-based production of very high fluxes of energetic radiations, in particular of protons and gamma rays and (2) - to study the effects of radiation on materials and devices, both at theoretical level through modelling and at experimental level through irradiation with protons and gamma at existing facilities.

The following specific actions were performed:
The activities within the first objective were defined to investigate the effect of gamma irradiation on the optical and dielectric properties of ErF_3 or YbF_3 doped MeF_2 (Me = Ca, Ba) crystals. Based on the WUT expertise in crystal growth, different RE:MeF_2 optical crystals has been grown. The effect of gamma irradiation on the obtained crystals has been assessed through optical absorption (Figure 1) and dielectric spectra before and after irradiation. These investigations have provide information about the RE ions charge conversion efficiency linked to the crystals scintillation performances. For the fundamental research, as well as for the applicative one, the growth and characterization of ErF_3 or YbF_3 doped MeF_2 crystals (Me = Ca, Ba) for radiation detectors constitutes an important up-to-date direction in "Materials Science" domain. The researches axed on the growth of these crystals and on the improvement of the known scintillation performances by doping the crystals are very up-to-date.

The activities within the second and third objectives have been defined for optimizing the laser-based production of particles fluxes. Laser-plasma accelerators have been proposed as a next generation of compact accelerators because they can sustain greater electric fields. However, it has been difficult to use them efficiently for applications because the particle beams produced have poor quality and large energy spreads. The project tackles this problem through PIC (Particle-in-Cell) numerical studies intended to determine the optimal parameters for electron acceleration in order to improve the gamma flux production. Also PIC numerical simulations for proton acceleration from gas and foam like target, and later on from microstructured targets, have been done. The studies on near critical and microstructured targets have the purpose of increasing the maximum number of accelerated protons, in order to obtain large-flux proton beams (Figure 2).

The fourth objective has been defined for acquiring technical and scientific skills aiming to use the ELI-NP facilities for accelerated testing the degradation of the solar cells performance in space-like environments. Beyond the progress in knowledge, it can be thought as a testing service that ELI-NP can provide to manufacture the space solar cells. Commercially available space solar cells (SC-3GA-2 based on GaAs, conversion efficiency 28.5%) were irradiated with protons. The cells characteristics were measured before and after irradiation (Figure 3).

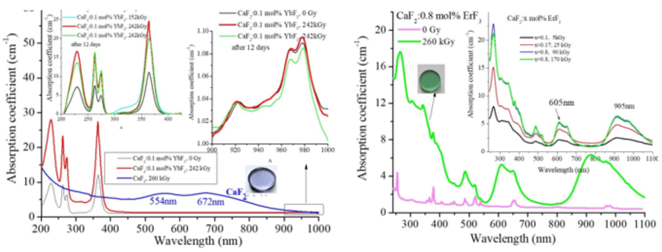


***Fig. 1** The effect of gamma irradiation on the crystals*

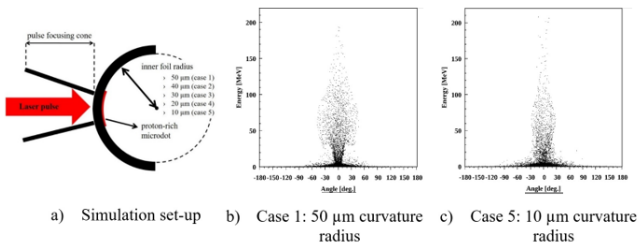


***Fig. 2** Angular distribution of the proton energies*

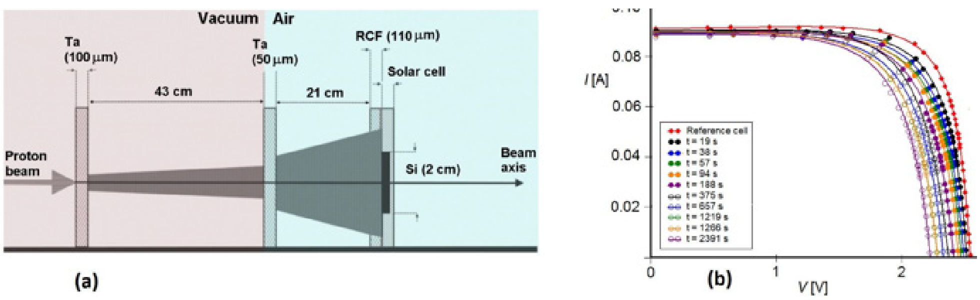


***Fig. 3** (a) Irradiation set-up (b) I-V characteristics degradation after different times of exposure at a proton flux*

Achievement of Technologies and Testing Methods for Resilient Mirrors under High Power Laser Pulses, suitable for CETAL and ELI Infrastructures (REMI)

Project Leader: Dr. Daniel OANCEA
Project Coordinator: S.C. Pro Optica S.A.
Project code: Call 2017/ELI-RO_2017_02
Project webpage: http://www.prooptica.ro/remi

Introduction: The research done within the project 02 ELI / 18.10.2017 had as main objective the design and manufacture of laser mirrors for transport of femtosecond laser beams with high power densities. After the study stage we decided to focus our research on designing and manufacturing flat mirrors, having: 150mm as effective diameter; a reflection higher than 98.5%, at 800 (+/-50)nm and 45 deg. incidence angle; a Group Delay Dispersion (GDD) less than 100fs^2; a flatness better than λ/8; a roughness less than 2nm and a Laser Induced Damage Threshold (LIDT) better than 0.3 Joules for at least 500 pulses. The achievement of laser mirrors involved research activities in three main directions: Substrate processing; Optical coatings; Tests and measurements.

Regarding the substrate processing, in a short description, we mention that the most important stage of the technological chain was the polishing procedure and the biggest advantage was the fact that Pro Optica owns a last generation polishing equipment, called „Lapmaster - Wolters" that is capable to process substrates having a diameter up to 400mm and achieving a flatness up to λ/20 (fig.1) and a roughness less than 2nm. Using this equipment, a lot of substrates were achieved, with diameters from of 25mm (test-plates) to 150mm (the deliverables).

Regarding the optical coatings, tests and measurements, the activities were interconnected and mutually supportive. These were focused on investigations on the fabrication flux in order to improve the quality of the final product, by tuning the technological parameters for mirror fabrication and finally, to achieve the deliverable. Firstly, in order to build the coating package we tested the following materials: TiO_2; Ta_2O_5; HfO_2 as high index materials/ SiO_2 as low index material and Al2O3 used to test whether its excellent mechanical properties help to strengthen the optical coating. There followed a period in which dozens of batches were performed in order to test the different combinations of materials and technological parameters. In this regard, a testing session was organized in 2018, in partnership with CETAL laboratory. The solutions selected after this testing session were improved during 2019, through a program of batches and rapid tests. At the final, two combination of materials were chosen in order to fabricate the prototypes (fig.2): HfO_2/SiO_2 (26 layers) and Mix of TiO_2-Al_2O_3/SiO_2 (26 layers).

Results: The witness plates of the prototypes were tested at CETAL, using the upgraded TEWALAS facility by the „S on 1" testing procedure and the final results, containing the main features of the laser mirrors selected as deliverables were as follows:

- Reflection @ 800nm and 45 deg. as incidence angle = 99%
- For HfO_2/SiO_2: H0@500 pulses = 0.34J/cm^2; H50@500 pulses = 0.5J/cm^2; H0@10^8 pulses = 0.26J/cm^2
- For mix of TiO_2-Al2O3/SiO_2: H0@500 pulses = 0.3J/cm^2; H50@500 pulses = 0.44J/cm^2; H0@10^8 pulses = 0.3J/cm^2 where: Hx = x% damage probability.
- The measured value of GDD was less than 50fs^2 on the interested wavelength interval (800+/-50 nm) (fig.3 a and b).

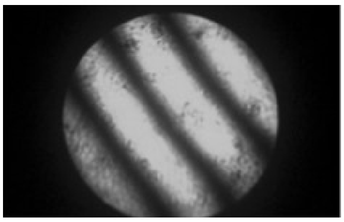


***Fig. 1** Interferometric fringes of a measured optical surface*

***Fig. 2** The Prototypes*

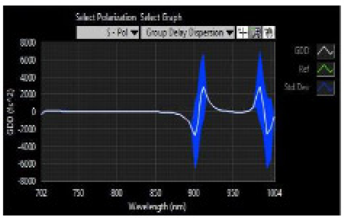


***Fig. 3** (a) GDD Measurement Results for "S" polarization*

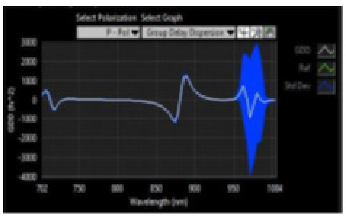


***Fig. 3** (b) GDD Measurement Results for "P" polarization*

FLUKA Based Radiation Shielding and Monitoring Optimization at ELI-NP (ELIFLUKA)

Project leader: Dr. Maria - Ana POPOVICI
Project coordinator: University Politehnica of Bucharest
Partners: Canberra Packard SRL
Project code: Call 2017/ELI-RO_2017_04
Project webpage: N/A

In this project a realistic modelling of the experimental areas E1/E6, and E5 was performed, by entering geometry data from the latest version of the Catia drawing files of the ELI-NP building in the FLUKA Monte Carlo radiation transport code. Here we added those construction elements (neglected in preliminary studies) which, due to their size, composition and relative position, were bound to change the radiation fields in the interaction chambers and their neighborhoods. As expected, sizeable changes in the fields outside the bunker walls were not observed.

FLUKA transport code calculations of dose, dose equivalent, fluence, energy fluence spectra were performed using source terms published in the Technical Design Reports, covering all the ranges of primary particles and energy values, not only "the worst-case scenario" ones. For these calculations FLUKA detector regions were defined throughout the experimental area E1/E6 and the neighboring areas. The main components of the secondary radiation fields were investigated.

The results were used to assess the existing shielding by using fluence and dose rates in the areas neighboring the bunkers, to optimize the existing shielding by using fluence and dose rates inside the experimental areas and subsequently proposing supplementary local mobile shielding for the experimental apparatus and designing a monitoring network adapted for each experiment (fluence and dose rates per field component as well as energy fluence spectra).

It was concluded that the main components of the secondary radiation fields were gamma radiation and neutrons. Both gamma and neutron detectors should be able to cover dose rates ranging up to 1 mSv/h and energy ranging up to 100 MeV. Both should be able to measure in pulsed beams. The best choice for gamma detection is the use of pressurized ion chambers, because they can measure accurately in pulsed fields, cover a wide energy range and have a low energy dependence. The calibration above 1.3 MeV remains a serious problem, although tests can be performed up to 7 MeV in various metrology labs. Proposals for the positioning of the dosimetry monitors at the experimental areas E1 and E6 - see Figure 1, for example.

Another result of ELIFLUKA was the evaluation of the feasibility of biophysics experiments for biological effectiveness of proton beams at different energies (PDDs and LET spectra at 250 MeV and 500 MeV protons). The simulations led us to two important conclusions: for the proton beams generated via laser interaction at energies between 100 and 300 MeV, the dose and LET behaviour is similar as for the clinical cyclotrons, which means that the RBE experiments at ELI-NP can be translated into clinical practice for the treatment planning. At higher energies, the behaviour of the dose and LET is more complex and the RBE experiments need to be conducted in such a way that both the low and high depth components are considered - see Figure 2, for example.

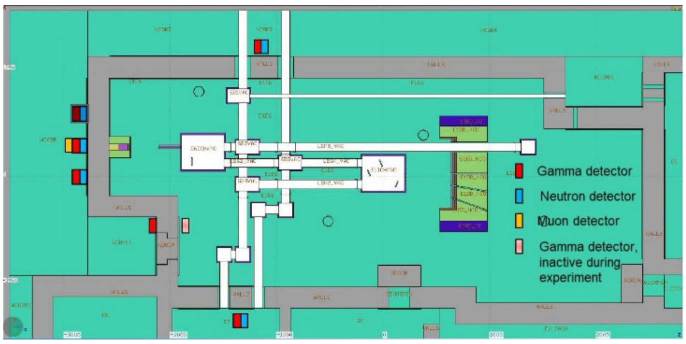


***Fig. 1** Dosimetry monitors at the E6 experimental area*

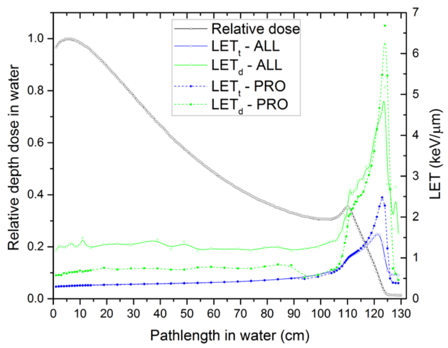


***Fig. 2** PDD, LET$_t$ and LET$_d$ for protons and all particles at 500 MeV*

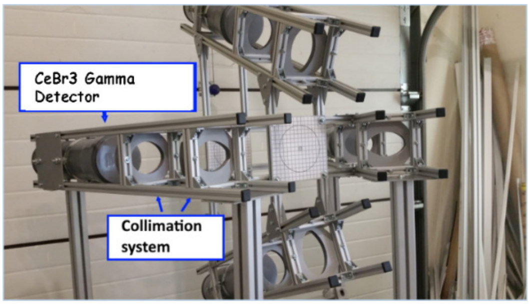
Security Applications Development at ELI-NP: Detecting Concealed Threatening Materials by using Nuclear Resonance Fluorescence and 2D/3D Tomography with Gamma Beams (ELI_THREAT_DETECT)

Project Leader: Dr. Mihai IOVEA
Project Coordinator: Accent Pro 2000 S.R.L.
Partners: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Project code: Call 2017/ELI-RO_2017_07
Project webpage: https://www.accent.ro/?q=projects/national-funded-projects/security-applications-development-at-eli-np-detecting-concealed-threatening-materials-by-using-nuclear-resonance-fluorescence-and-2d-3d-tomography-with-gamma-beams

The project combined the expertise of AP2K in security (single, dual and multi energy, diffraction X-ray, Digital Radiography and Computer Tomography (CT) for baggage scanners and non-destructive testing of materials (gamma and X-ray imaging) with the equipment and the know-how available at ELI-NP to deliver new opportunities for security applications development. The main results are:

- A materials database, subject of illicit cargo traffic was created with 36 substances categorized in classes: Special Nuclear Materials, gamma sources, toxic substances & chemical weapons, narcotics, and precious metals. It contains information regarding chemical composition, physical properties, atomic structure and nuclear data used in identification with nuclear resonance fluorescence (NRF).
- NRF Simulations and CT Reconstruction for testing different experimental architectures: analytic simulation was done, simulating scan of a 5 cm Steel wall thickness container with 2 cylinders inside, one of Plutonium and one of Uranium. The results showed that the Plutonium object can be clearly identified using NRF data.
- A Monte Carlo simulation program was developed for designing, optimizing the experimental configuration and evaluating the NRF signals for different threatening materials in the presence of shields and with other materials having similar attenuation.
- TEST CONTAINER: an experimental container was built for positioning inside different threatening materials. The container is a multi-chamber box with replaceable walls for simultaneous test of different objects shielded by layers of different materials and thickness.
- A special scanning procedure based on multiple translations and rotations was designed to achieve a complete scan of an object larger than the narrow gamma cone beam size. For tomography reconstructions a dedicated software application was developed for 2-D and 3-D scanning architectures.
- A simulation code, used with GEANT4 (a toolkit for simulating the passage of particles through matter), that include NRF process and photon elastic scattering was used to optimize setup and to produce data for algorithm testing.
- A detection system: NRF-DETECT was designed and built. It contains 4 gamma-ray spectroscopic detectors in a mechanical shielded and collimated design, mounted in an adequate positioning frame, dedicated for measurement of the NRF spectra emitted by the threatening objects placed inside the test container. A special collimating system was designed to maximize the detection efficiency, by ensuring that the entire detection volume of a detector is seeing the full-investigated line along the gamma-beam line.
- NRF-detect system and NRF experimental configurations were tested with Monte Carlo. The simulation was designed to test the capability of NRF experimental assembly to detect the presence of threatening materials hidden in a shielded container and the capabilities to localize these materials using CT reconstruction techniques.

The ELI_THREAT_DETECT project created the necessary equipment, analysis algorithms, skilled scientists and engineers for further continuing the security applications development at ELI-NP.



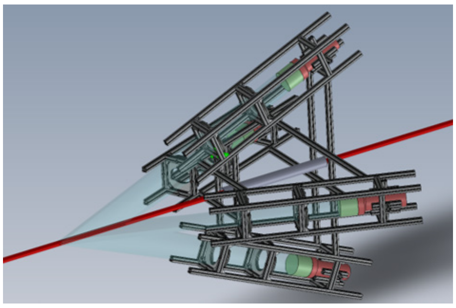


Fig. 1 CeBr3 Gamma Detector and Collimation System CAD design and setup

Versatile Approach to Integrated Large Data Acquisition System for Complex ELI-NP Experiments (VDAQ-CEX)

Project Leader: Dr. Gabriel SULIMAN
Project Coordinator: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Partners: University Politehnica of Bucharest
Project code: Call 2017/ELI-RO_2017_13
Project webpage: http://www.nipne.ro/proiecte/eli-ro/VDAQ-CEX/

The "Versatile approach to integrated large data acquisition system for complex ELI-NP experiments/ VDAQ-CEX" project was aimed at supplementing the experimental activities that can be undertaken using the detectors of the ELIADE (ELI Array of Detectors) array [1].

The ELIADE array is made of eight segmented clover detectors and four LaBr3 detectors. Each of the segmented clovers is a rather complex system, with important requirements in terms of electronics and support systems, but it delivers highly sought after properties in gamma detection, making it one of the most desirable detector types for experiments at ELI-NP. The project implemented the independent operation of clover detectors or together with other types of detectors, not initially planned to be used with the ELIADE array, namely neutron and particle detectors. The performed tests showed that we can reliably integrate Deconvolutional Single Shot Detector (DSSD) and neutron detectors in the ELIADE DAQ and data analysis.

A significant part of the work carried out during the project is centred on the software for the analysis of the data. The data is produced by the digitizer boards processing the signal from the detectors. The purpose of the data analysis software is to aggregate the data from all these sources (two to eight computers, one for each segmented clover detector) and to allow scientists to analyse it using conventional gamma-ray spectroscopy techniques. The complexity is given by the high number of channels in the array (more than 300 channels), and the specifics of the data streams coming from the detectors (highly variable rates over time and across detector types). Another layer of complexity is added by the opportunity of using parallel computing for these software tasks, using existing modern computers with a significant number of independent computer cores.

The developed code uses the C++ programming language and was built around the ROOT framework developed at CERN [2]. It is comprised of several smaller codes and is based on a few data analysis classes that are creating successive layers of abstraction for the data, allowing a high degree of configurability to the data analysis. The configuration of the data analysis is done through simple text files, which allow people without detailed information about the inner workings of the code to properly configure it.

The impact of the project is significant, both from a technical and educational point of view. From the technical point of view, the code base developed during the project will serve as the backbone of the data analysis of the ELIADE array. The project made possible to have a much more robust and flexible code structure. The use of parallelization techniques provides a great step forward in the execution speed of this data analysis codes.

From an educational point of view, the project put together, in a coherent team, young researchers in two very different fields: experimental nuclear physics and software development.

References

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[2] root.cern.ch

Simulation of Ultra-High Intensity Laser Pulse Interaction with Solid Targets (SIMULATE)

Project Leader: Dr. Olimpia BUDRIGĂ
Project Coordinator: National R&D Institute for Lasers, Plasma and Radiation Physics
Partners: University Politehnica of Bucharest
Project code: Call 2017/ELI-RO_2017_16
Project webpage: http://ssll.inflpr.ro/SIMULATE

Laser-ion acceleration experiments are envisioned in the near future at the 10 PW facility of ELI-NP. Our work was dedicated to find the optimal parameters of different kind of solid targets for which collimated beams of protons with energies higher than 200 MeV can be obtained. For this propose we performed two dimensional Particle-in-Cell simulations of the interaction of an ultra-high intensity laser pulse with a solid target. The laser pulse had the parameters of the 10 PW laser of ELI-NP. We analyzed the spatio-temporal dynamics of the electromagnetic field based on the finite-difference time-domain method in order to isolate the geometric effects which affect the incoming laser-plasma interaction. We proposed two new types of plastic cone targets for laser-ion acceleration [1]. The first type is a flat-top cone with a nano-layer foil in the tip of the cone. The second one is a flat-top cone with a flat-top foil consisting of two nano-layers: the first nano-layer is composed of nanospheres with the same diameter and tangential to each other and the second one is a nano-layer foil. We obtained more energetic protons and carbon ions at the interaction of a circularly polarized ultra-high intensity laser pulse with a cone with nanospheres. We proved also for a cone with nanospheres that the protons are accelerated through a hybrid mechanism composed by the target normal sheath acceleration (TNSA) and radiation pressure acceleration (RPA) (Fig. 1).

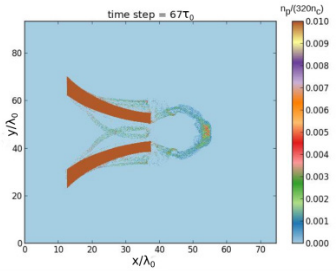

Fig. 1 *The distribution of the proton density at the simulation time t=178 fs, when a CP laser pulse with an intensity of 4.32x10*^{22} *Wcm*$^{-2}$ *interacts with the cone with nanospheres*

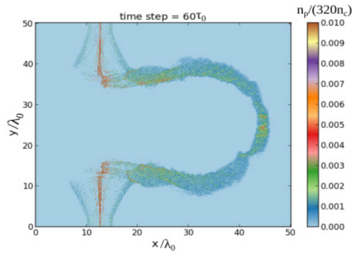

Fig. 2 *The distribution of the proton density at the simulation time t=160 fs, when a CP laser pulse with an intensity of 4.32x10*^{22} *Wcm*$^{-2}$ *interacts with a nanostructured foil*

In the case of the interaction of an ultra-high intensity laser pulse with a nanostructured foil target we saw that the maximum proton energy has a strong dependence on the diameter of the nanospheres [2]. The nanospheres diameter are in the range of tens of nanometers. We proved for the first time in the case of the nanostructured foil targets that the protons are accelerated in a hybrid regime, a combination of RPA and TNSA regimes, same as for the cone with nanospheres (Figure 2). We showed a more than ten times enhancement of laser focused intensity through a re-entrant cone in the pettawatt regime [3]. The intensification reaches the maximum value when the laser beam and the cone tip centers are superimposed, which corresponds to the case of a micro-cone tip diameter of 5 microns (Figure 3). A multiple beam interference and reflections are produced being transposed into bright and dark fringes and explaining the enhancement of the laser pulse intensity. The electric field is also amplified by the electrostatic field, created by the hot electrons. After the laser beam hits the micro-cone tip it starts to be partially reflected by the micro-cone tip with a lower energy and a focus spot diameter smaller than the initial one (Figure 4).

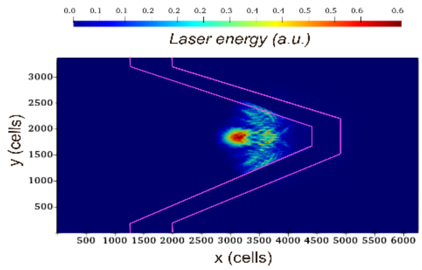

Fig. 3 *Electric field distribution at the simulation time t=255 fs for a micro-cone with a tip diameter of 5 µm*

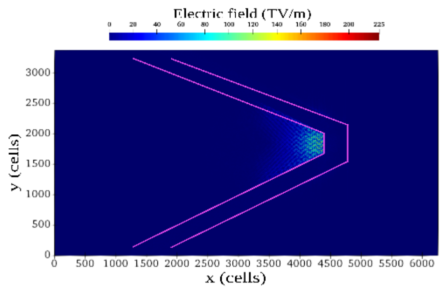

Fig. 4 *The distribution of the instantaneous laser energy at the simulation time t=319 fs for a micro-cone with a tip diameter of 5 µm*

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Physics and Engineering of Defects Incubation during fs-Laser Irradiation (PHEOLDI)

Project Leader: Dr. Doina CRĂCIUN
Project Coordinator: National R&D Institute for Lasers, Plasma and Radiation Physics
Project code: Call 2017/ELI-RO_2017_17
Project webpage: http://taf.inflpr.ro/index.html

To account for changes induced in optical coatings by the fs-laser irradiation at fluences lower than the laser induced damage threshold (LIDT) fluence, a general term, *incubation*, is used. The goal of this research project was to understand the physical and chemical modification in optical coatings generically described as incubation. Based on these findings, better dielectric layers for fs-laser mirrors, beam-splitters, etc. could be designed and manufactured, which will save money during the operation of large fs-laser installations such as ELI-NP.

The first step was to obtain high quality dielectrics layers that could be laser irradiated and then investigated. Thin films of HfO2 and ZrO2 were deposited on quartz and Ag covered Si wafers using the pulsed laser deposition technique. After characterizations using advanced techniques such as Rutherford backscattering spectrometry, X-ray grazing incidence diffraction, X-ray reflectivity, X-ray photoelectron spectroscopy, the LIDT values for a 25 fs long laser pulse at 100 consecutive pulses were determined. Once the LIDT values were measured, the deposited films were irradiated at subthreshold fluence values for 100 pulses.

Two techniques were found to be sensitive enough to observe changes during the incubation period. First, the electron paramagnetic resonance (EPR) investigations of dielectric films turned out to be one of the most sensitive technique to oxygen content and hence to the deposition conditions or irradiation effects.
In Fig. 1 the EPR signals acquired from a HfO_2 film before (black) and after fs-laser irradiation (red) are displayed. One could note that after fs-laser irradiation at a fluence below the LIDT, the signal intensity and width remained almost unchanged; however, two new very narrow bands appeared. These bands are associated with new defects induced by the fs-laser irradiation.
The other sensitive technique for monitoring the effect of fs-laser irradiation on dielectric layers is the measurement of the leakage current. In Fig. 2 there is an examples of I-V curves measured on an as prepared sample and in a location that was irradiated with a fs-laser at a fluence equal to 0.7 of the LIDT value. One could notice that the leakage current after fs laser irradiation is about one order of magnitude higher than that measured initially.

In conclusion, we found two techniques to monitor the effect of the fs-laser irradiations at fluences below the LIDT value. It is clear that such irradiations can induce defects that alter the structure and the leakage current. Based on these results we optimized the deposition process and succeeded to obtain films exhibiting LIDT values similar to those reported in the scientific literature.

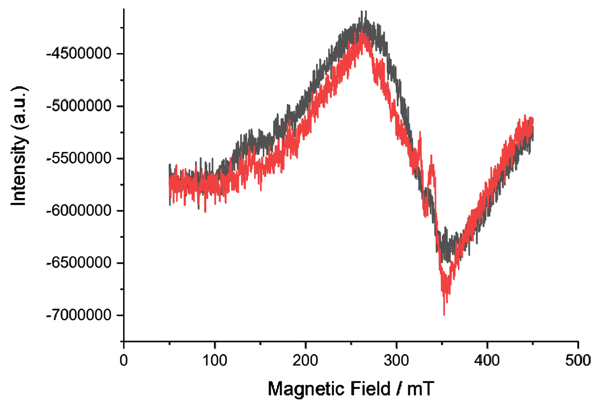

***Fig. 1** EPR signal recorded from an as-grown HfO2 film under 3×10^{-2} mbar O2 and after fs-laser irradiation at 0.7 of LIDT (red trace)*

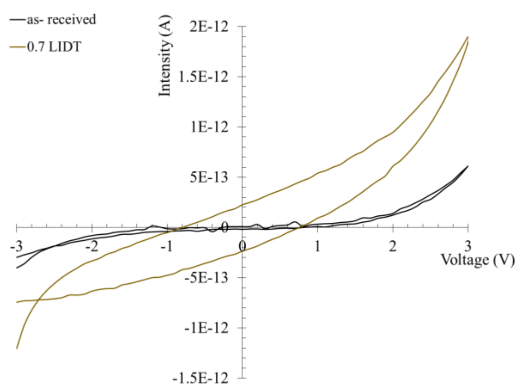

***Fig. 2** Leakage current values measured on a ZrO_2/Ag/Si sample before and after laser irradiation at 0.7 of the LIDT fluence*

On-line Measurement of Laser-driven Proton Beams Effect on Human Cells (ONLINEBIORAD)

Project Leader: Dr. Teodor Adrian ENACHE
Project Coordinator: National R&D Institute of Materials Physics
Partners:
National R&D Institute for Lasers, Plasma and Radiation Physics
Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Institute of Cellular Biology and Pathology Nicolae Simionescu
Project webpage: https://infim.ro/en/project/on-line-measurement-of-laser-driven-proton-beams-effect-on-human-cells/

The interaction of radiation with biological systems takes place through energy transfer and is accomplished especially by ionized atoms or molecules and involves multiple physical, chemical and biological steps. Direct effects result in a large number of reactive oxygen species (ROS) and nitrogen species (RNS) within and outside cells, which are responsible for oxidative stress. In this context, the development of sensor platforms to observe in real time the interaction between different kinds of radiation with biological materials has a great relevance in fields such as aeronautics for reducing radiation effects on flying crews and radiobiology for managing various diseases.

The goal of this project," On-*line measurement of laser-driven proton beams effect on human cells*" - **ONLINEBIORAD**, was the development of a detection system to be used for analyzing and quantifying the effects of laser-induced proton beam on cell cultures. First two objectives of the project were dedicated to design, development, characterization and optimization of detection system, proton beam and biological assays and the last one to the evaluation of the impact of proton beam on cell cultures.

Using the photolithographic masks (**Fig. 1**), specially designed within this project, the sensor platform (**Fig. 2**) was developed at National Institute of Materials Physics (**INCDFM**) and, after the optimization of the proton beam at National Institute for Laser, Plasma and Radiation Physics (**INFLPR**), the bare sensor was tested under irradiation using a proton beam energy estimated at about 5 MeV. The irradiation process didn't affect the sensor integrity since no significant variation on the sensor response was observed after irradiation.

For sensing of cell cultures exposed under proton beam irradiation, a sealing chamber (**Fig. 3**), to protect cell culture from the vacuum of irradiation chamber, was designed and fabricated at INFLPR. At the same time, at Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (**IFIN-HH**) and Institute of Cellular Biology and Pathology "Nicolae Simionescu" (**IBCPNS**), cellular assays were conducted for the evaluation of sensor components biocompatibility, the detection/identification of ROS and RNS produced by cells after irradiation, as well as the molecular and genetic response of cell exposed to radiation. Finally, the new developed detection system was employed for the evaluation of cells before and after irradiation and the results were compared with those obtained for oxidative stress induced by chemical triggers. It was found that the irradiation of cells with a dose of 2 Gy induces an oxidative stress comparable with the one induced by 100 μM H_2O_2 (**Fig. 4**), an average value produced by human body during normal metabolism. The contributions of this project were scientific and institutional. First, it contributed to the development of new strategies for real-time biological monitoring. Second, from institutional point of view, it was an excellent opportunity to bring together researchers specialized in different fields and to broaden their scientific expertise by working in a multidisciplinary field.

Fig. 1

Fig. 2

Fig. 3

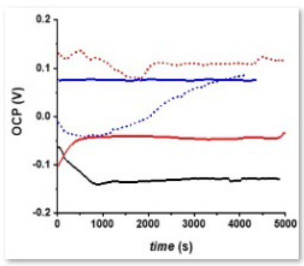

Fig. 4

Femtoseconds PW Laser Applications on Advanced Particle Acceleration (FLAP)

Project Leader: Dr. Petru GHENUCHE
Project Coordinator: Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
Partners: National R&D Institute for Lasers, Plasma and Radiation Physics
Project webpage: http://www.nipne.ro/proiecte/eli-ro/flap/

The main goal of this project was to contribute in setting up all the tools needed for successful PW experimental campaigns. To reach this goal, the FLAP team worked, in the last two and a half years in activities ranging from operation plans and diagnostics to actual PW-class experiments.

Operating a facility such as CETAL requires careful planning and a comprehensive training and hands-on preparation program for all its operators and users. The first steps were dedicated to the design of the operational and facility procedures for PW class laser experiments.

In 2018 the project team set a complete laser-plasma proton acceleration setup. Intensities well above 10^{19} W/cm^2 were reached for the first time at CETAL by implementing the transport line optimization methods developed in the previous year. A set of calibrated detectors were, for the first time, employed to characterize the accelerated particles, the results being in line with the scaling laws for laser-plasma accelerated protons. While the first energies obtained were modest, it represented a good start for the next experimental campaigns, enabling applications like proton radiography or ion irradiation of materials.

In the last year, the activities of the project were focused on the alignment of the laser system with the electron acceleration setup. It included the alignment of the long focal length parabolic mirror and the gas jet system together with the associated setups for laser/plasma and electron beam diagnostics.

Laser-Plasma Accelerated Electron beams with energies exceeding 100 MeV were obtained for the first time in Romania. Close to the state-of-the-art in the field for several J of laser energy, it opens the way for highly energetic GeV electron beams and hard X-rays generation. A series of simulation tools and data management apps and procedures were also developed to store, manipulate and interpret the experimental output. All these activities ranging from procedures to diagnostics are upgrading the existing research infrastructure for future users.

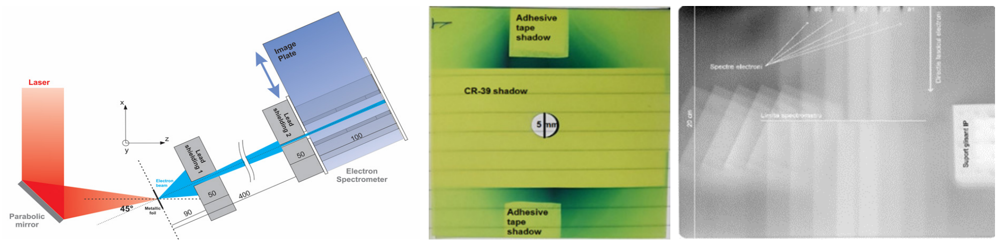

Fig. 1 *Scheme of the experimental setup (left); RCF exposed with a proton beam with energies between 2.64 and 4.2 MeV (middle); Image plate scan (IP) for several laser shots showing accelerated electrons to MeV energies (right).*

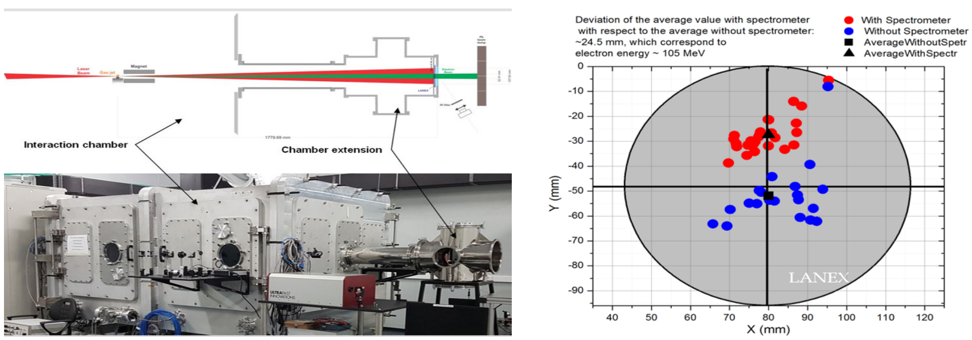

Fig. 2 *Experimental setup for electron acceleration (left) and the distribution of the electron beam center observed on the electron spectrometer LANEX screen for a series of laser shots. We represent in red the case when the electrons are deviated by the magnetic field and in blue the shots when the magnet is retracted. We estimate an electron pointing stability of up to 25 mrad. (rigth)*

Participating institutions in the ELI-RO Programme 2014-2016

Horia Hulubei National R&D Institute of Physics & Nuclear Engineering (IFIN-HH)
www.nipne.ro

National R&D Institute for Laser, Plasma and Radiation Physics (INFLPR)
http://www.inflpr.ro/ro

National R&D Institute of Isotopic and Molecular Technologies Cluj-Napoca Romania (INCDTIM)
http://www.itim-cj.ro/

National R&D Institute in Materials Physics (INFM)
http://infim.ro/

National R&D Institute in the Pathology and Biomedical Sciences Victor Babeș (IVB)
www.ivb.ro

National R&D Institute in Electrical Engineering (ICPE-CA)
http://www.icpe-ca.ro/ro/

National R&D Institute for Microtechnologies (IMT)
https://www.imt.ro/

National R&D Institute for Cryogenic and Isotopic Technologies
https://www.icsi.ro/

Institute of Cellular Biology and Pathology Nicolae Simionescu (IBPCNS)
http://www.icbp.ro/

University of Bucharest (UB)
www.unibuc.ro

Politehnica University of Bucharest (UPB)
http://www.upb.ro/

Transilvania University of Brasov (UTB)
https://www.unitbv.ro/en/

West University of Timișoara (UVT)
http://www.uvt.ro/ro/

SC Canberra Packard SRL
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https://www.accent.ro/

Pro Optica
https://prooptica.ro/

VIOSON PRODCOMIMPEX S.R.L.
http://vioson.ro/ro/

INSTITUTE OF ATOMIC PHYSICS
407 Atomistilor St., Măgurele, ILFOV, 077125, P.O.Box MG-3, ROMANIA
Phone/Fax: (+4) 021 457 44 93, 021 457 44 56
www.ifa-mg.ro