Romanian research projects at FAIR

2014 - 2016

Bucharest-Magurele, ROMANIA
2016

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Strong interaction studies in antiproton annihilation (SISTINA)

Project Leader: Alexandru Mario BRAGADIREANU
Project Coordinator: IFIN-HH
Project web page: *http://www.nipne.ro/dpp/Collab/PANDA/*

The PANDA physics program, detailed in the Panda Physics Book[1], consists in a series of measurements dedicated to the study of: **QCD bound states** which include charmonium, D meson, baryon spectroscopy and exotic states such as gluonic hadrons (hybrids and glueballs), multiquark states; **Non-perturbative QCD Dynamics** by measuring the reactions of the type $p\bar{p} \to Y\bar{Y}$, where Y denotes a hyperon; **Hadrons in Nuclear Matter** aimed at understanding the origin of hadron masses in the context of spontaneous chiral symmetry breaking in QCD; **Hypernuclear Physics** and exotic Ξ^- atoms; **Nucleon Structure** using electromagnetic processes; **Electroweak Physics** by measuring rare D meson decays.

In order to accomplish this ample physics program, PANDA Collaboration should build (Fig. 1) a general purpose detector[2] which has to achieve near 4p acceptance, high resolution for tracking, particle identification and calorimetry, high rate capabilities and a versatile readout and event selection.

Because PANDA is now in the Construction phase the project short term objectives were focused on the research and development activities for PANDA Central Straw Tube Tracker (STT) sub-detector, coordination and integration of PANDA control system, PANDA grid computing.

The project accomplishments (so far) are:

- Straw Tube Tracker gas system prototype;
- Software development for the technical design of PANDA control(s) system;
- Maintenance of local PANDA grid middleware and software framework, monitoring of PANDA grid services.

Further group activities:

- Coordination and chairing of of PANDA DCS working group;
- Maintenance of PANDA DCS Wiki page.

List of papers (journal or conference proceeding):
Experimental access to Transition Distribution Amplitudes with the PANDA experiment at FAIR, B. Singh et al (PANDA Collaboration), Eur. Phys. J. A (2015) 51: 107

List of talks of group members (title, conference or meeting, date):

- *PANDA DCS status*, Plenary Session, LI PANDA Collaboration Meeting, 12 December 2014
- *PANDA DCS Technical Design*, Detector Control System Session, LII PANDA Collaboration Meeting, Giessen, 17 March 2015
- *Crate control via SNMP and EPICS*, Detector Control System Session, LIII PANDA Collaboration Meeting, Uppsala, 08 June 2015
- *PANDA DCS status*, Plenary Session, LV PANDA Collaboration Meeting, Wien, 03 December 2015

(Endnotes)
[1] PANDA Collaboration 2009, Physics Performance Report for PANDA: Strong Interaction Studies withAntiprotons, arXiv:0903.3905v1 [hep-ex]
[2] Technical Progress Report for: PANDA, *http://www-panda.gsi.de/archive/public/panda_tpr.pdf*

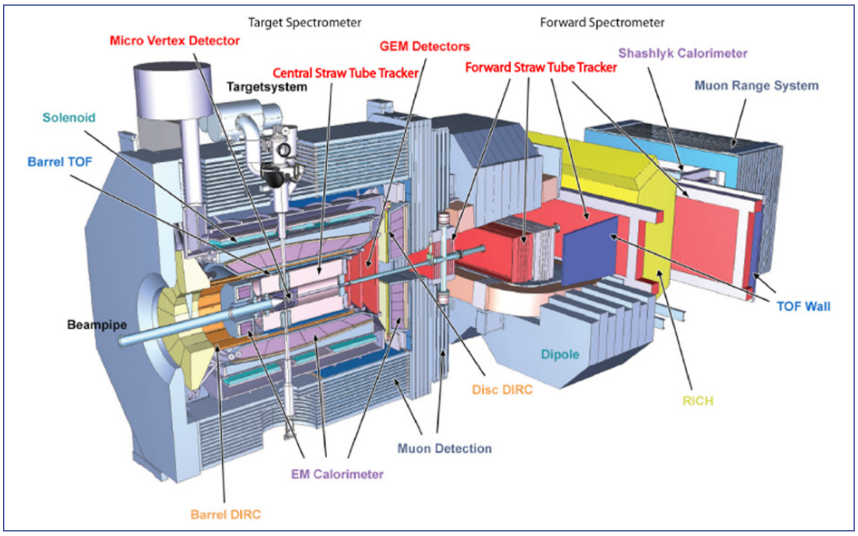


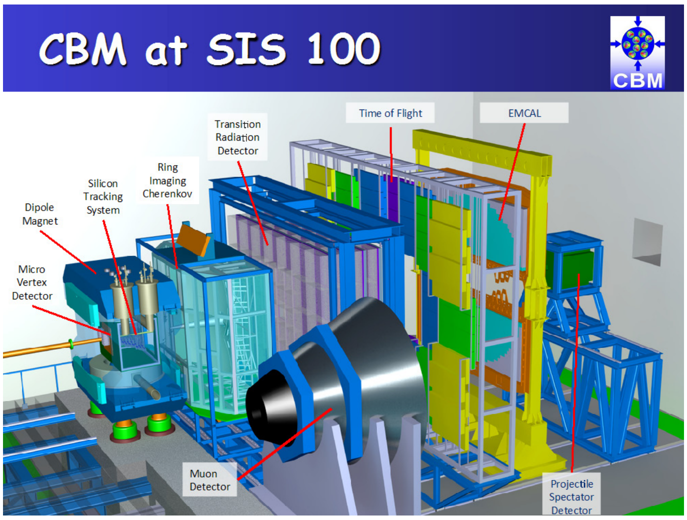
Fig.1 PANDA Detector

High Counting Rate PID Detectors and Front-End Electronics for CBM experiment (HICOR-DEFEND)

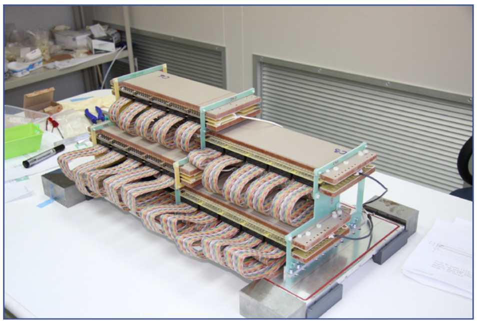
Project Leader: Mihai PETROVICI
Project Coordinator: IFIN-HH
Project web page: *http://niham.nipne.ro/RO-FAIR_CBM.html*

Worldwide experimental and theoretical efforts are devoted in our days to the exploration of the phase diagram of nuclear matter in extreme conditions of temperature and density. Normal nuclei with a net baryon density equal to one consist of protons and neutrons. At moderate temperatures and densities nucleons are excited to baryonic resonances which decay by the emission of mesons. Towards higher temperatures baryonantibaryon pairs are created. Such a mixture of strongly interacting baryons, antibaryons and mesons is called hadronic matter or baryonic matter if baryons prevail. At very high temperatures or densities the hadrons melt and their constituents, the quarks and gluons, become free and form a new phase of deconfined matter. For very low net baryon densities where the numbers of particles and antiparticles are approximately equal, theory predicts such a transition above a temperature of about 160 180 MeV. The inverse process, called hadronization, is supposed that happened in the Universe during the first few microseconds after the Big Bang. This is the region of the phase diagram where the transition is expected to be a smooth crossover from partonic to hadronic matter. QCD lattice calculations suggest a critical end point at relatively large values of the baryon chemical potential. Bellow this critical endpoint, for larger values of net baryon densities and lower temperatures, a phase transition from hadronic to partonic matter with a phasecoexistence region in between is expected. Inspired by large N_C (number of colors), limit of QCD, a new phase of so called quarkyonic matter could exist beyond the firstorder phase transition at large baryon chemical potentials and moderate temperatures. Highly dense and cold nuclear matter is expected to exist in the core of neutron stars and at very high densities correlated quark pairs are predicted to form superconducting quark matter. Therefore a rich structure of QCD phase diagram at finite values of baryon chemical potentials is predicted by theoretical models. The experimental exploration of these prominent landmarks of the QCD phase diagram is a real challenge. Quantitative experimental information on the properties of hadrons in dense matter will give information on chiral symmetry restoration and the origin of hadron masses. Hot and dense finitesize pieces of nuclear matter in a wide range of temperatures and densities could be created in the laboratory by colliding atomic nuclei at high energies. The goal of the experiments at RHIC and LHC is to investigate the properties of deconfined QCD matter at very high temperatures and almost zero netbaryon densities. Several experimental programs are devoted to the exploration of the QCD phase diagram at high netbaryon densities, i.e.: Beam Energy Scan (BES) program at RHIC, NA61 experiment at SPS, a heavyion collider project NICA at JINR and heavy ion program of RIKEN. However, due to luminosity or detector limitations these experiments are constrained to the investigation of abundantly produced particles. In contrast, the Compressed Baryonic Matter (CBM) experiment at Facility for Antiproton and Ion Research (FAIR) in Darmstadt is designed for precision measurements of multidimensional correlations among different observables including particles with very low production cross sections, hyperons, heavy flavor hadrons, hypernuclei and strange objects, using the highintensity heavyion beams provided by FAIR accelerators.

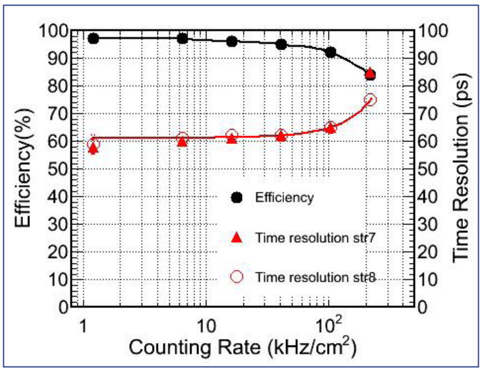
Our group from HPD (Hadron Physics Department)-IFIN-HH is involved in CBM experiment, one of the main experiments at FAIR, since the collaboration was initiated, more than 10 years ago. We embarked on R&D activities for developing a new generation of detectors for two detection subsystems of the CBM experimental setup: the Time of Flight (ToF) and Transition Radiation Detector (TRD).



The CBM ToF wall will be built based on the state of the art Multigap Resistive Plate Chambers (MRPC). With a surface of ~150 m^2 it covers polar angles between 2.5º to 25º with a full azimuthal coverage. A system time resolution better than 80 ps is needed with detection efficiency better than 95%. The challenge for ToF detectors is to maintain this performance even at the highest anticipated rates. The counting rate goes from 25 kHz/cm^2 in the most inner zone to less than 1 kHz/cm^2 at the ToF wall edges. We have developed RPC prototypes, addressed to the most inner zone of the ToF wall, which maintain their performance in high counting rates and high multiplicity environment. In order to reach this goal we used lower resistivity, thinner glass electrodes and a novel architecture of the read-out electrodes.

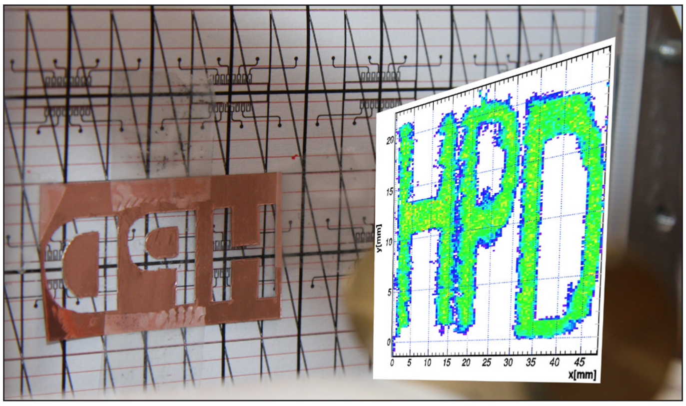


Basic structure for the inner zone of CBM-ToF subdetector based on the RPC architecture developed by our group

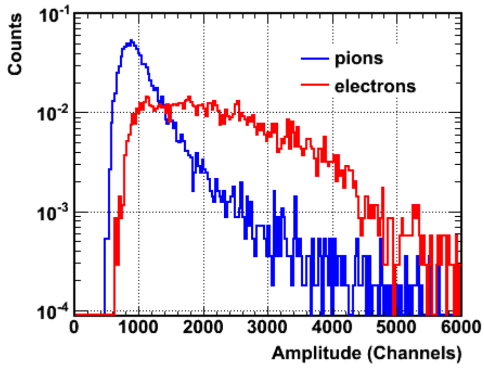


Efficiency and time resolution as a function of counting rate

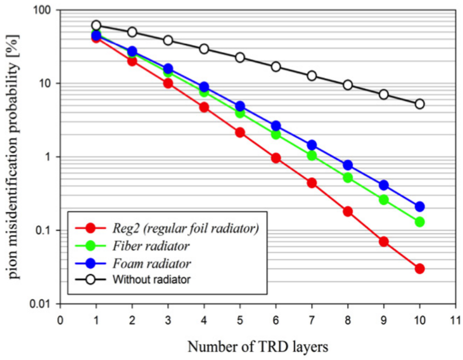
The TRD subdetector should perform intermediate tracking between STS and ToF for the charged particles with a position resolution across the pads of 200 – 300 μm, 3-30 mm along the pads and provide electron identification with a pion rejection factor better than 100. This performance has to be maintained up to about ~100 kHz/cm^2 counting rate anticipated for the most inner zone of the first TRD station. The CBM TRD subsystem for SIS100 will comprise four layers. The total area of the detector will be about 240 m^2. Our group developed a completely new architecture of the read-out electrode, based on which besides a very good electron/pion rejection also high position resolution in two-dimensions can be accessed in high counting rate environment.



Exploded view of a TRD prototype with a collimator on the entrance window with Hadron Physics Department acronym cutout (left) and position reconstruction of X rays of ^{55}Fe radioactive source reaching the detector (right side)



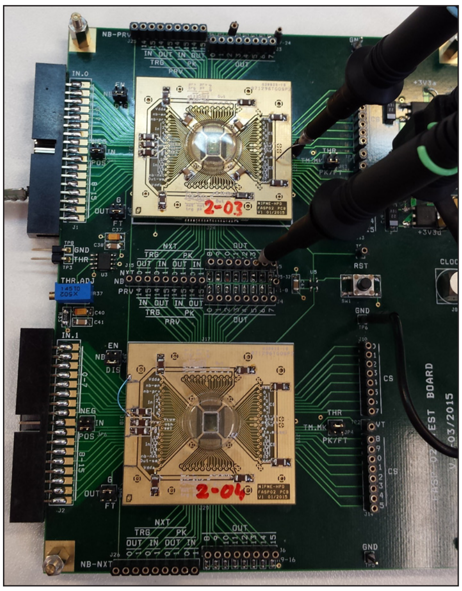
Pulse high distribution of electrons (red) and pions (blue)



Electron-pion rejection performance

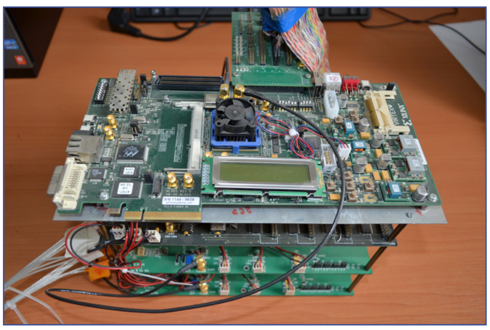
Based on the experimental information obtained with the very first TRD prototypes, a new generation of front-end electronics was designed within our group. These developments include a new ASIC coined Fast Analog Signal Processing (FASP) and associated motherboards for interfacing this CHIP with the detector and Data Acquisition System.

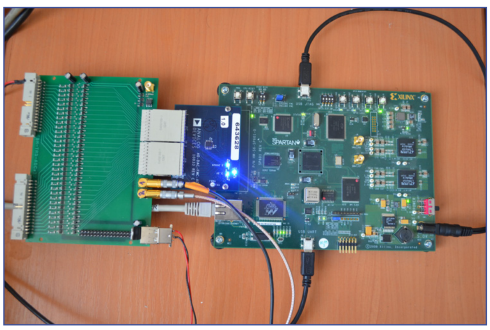
Two versions of free running mode DAQ systems were also developed in collaboration with Applied Nuclear Physics Department in order to integrate our front-end electronics with the CBM architecture of data processing.



FASP CHIP with 16 imput channels

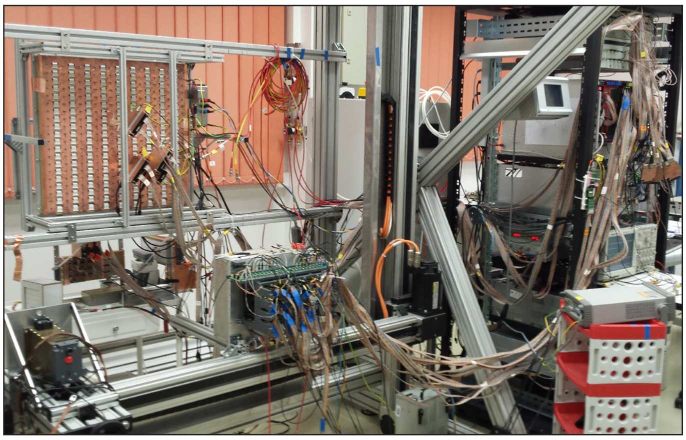
1st version of free running DAQ



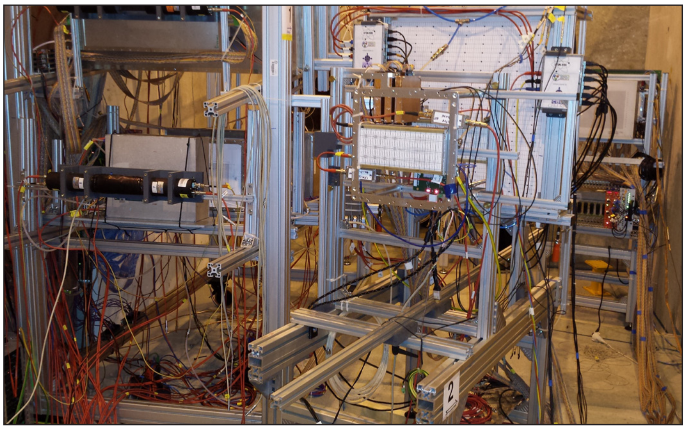


2nd version of free running DAQ

The results obtained in tests performed up to now using radioactive sources, cosmic rays, electron, pion, proton and heavy ion beams demonstrated that our prototypes and associated electronics perform in terms of two-dimension position resolution and electron-pion discrimination in high counting rate environment with minimum amount of processed information. As a natural consequence, our group will be involved in the assembling and tests of essential parts of the RPC-ToF and TRD subdetectors for CBM experiment using the local infrastructure of HPD.



One of the detector test laboratories of HPD

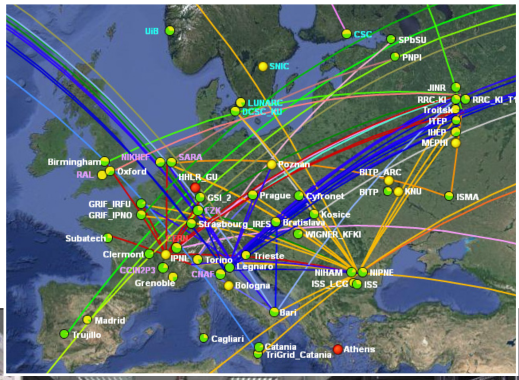


Experimental set-up used for the in-beam tests at SPS-CERN

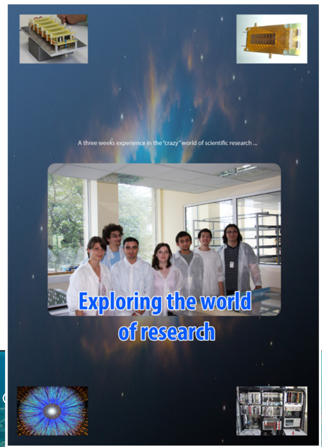
Selected published papers by our group:

*Nucl.Instr. and Meth. in Phys.Res. 487A(**2002**)337*
*Nucl.Instr. and Meth. in Phys.Res. 579A(**2007)961***
*Rom. Journ. Phys.56(**2011)349***
*Rom. Journ. Phys. 56(**2011)654***
*Nucl.Instr. and Meth. in Phys.Res. A646(**2011**)27*
*Nucl.Instr. and Meth. in Phys.Res. 661, Suppl.1, (**2012**) S129-S133*
*Journal of Instrumentation Volume 7(**2012**)P11003*

The Data Centre of our Department, i.e. NIHAM, one of the most efficient Tier2 centre of ALICE GRID will be involved at the right moment in similar activities for CBM.

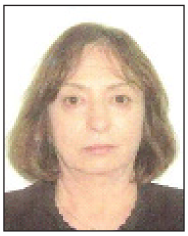


A special attention is given to maintain and develop the local infrastructure, teaching and outreach activities. Every year a Summer Student Program is organized by HPD.



An exemple of booklet edited by one of the Hadron Physics Department participating groups to the Summer Student Program

Atomic interactions in supercritical fields: theoretical and experimental investigations for FAIR/SPARC (SCAFI)



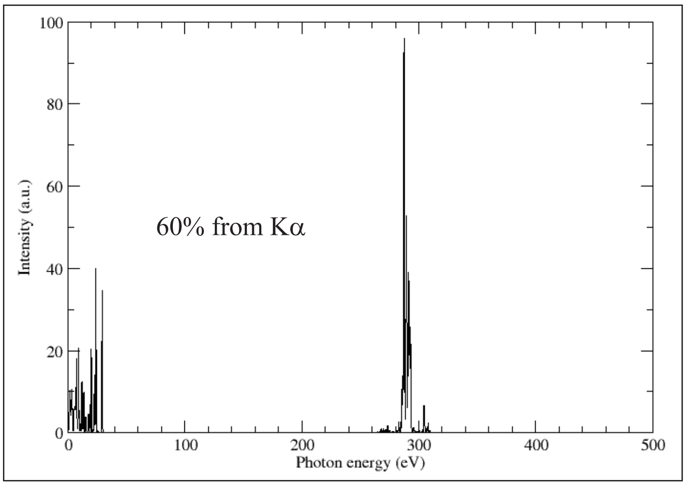
Project Leader: Viorica STANCALIE
Project Coordinator: INFLPR
Partners: IFIN-HH, ISS
Project web page: *http://atomic.inflpr.ro/f03/*

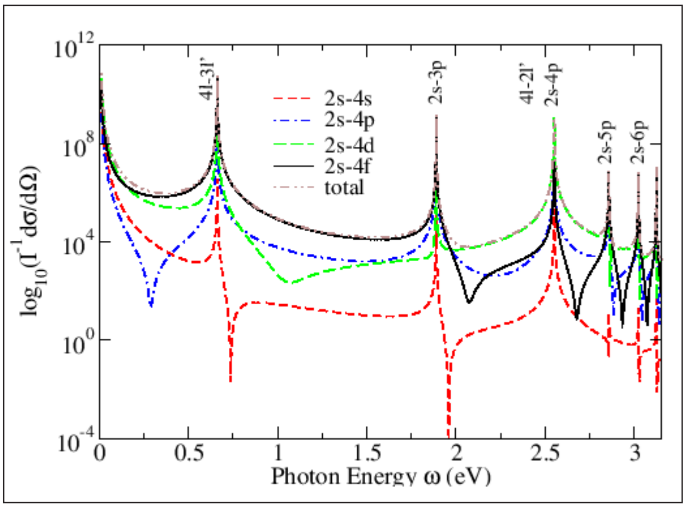
The international accelerator Facility for Antiproton and Ion Research (FAIR) which is under construction in Darmstadt will provide highest intensities of relativistic beams of both stable and unstable heavy nuclei in combination with the strong electromagnetic fields generated by high-power lasers opening up exciting and far-reaching perspectives for atomic physics research. The atomic physics community organized within the Stored Particle Atomic physics Research Collaboration (SPARC) has an ideal opportunity to explore broad range of interesting physics phenomena, fundamental aspects of atomic structure, dynamics in the relativistic domain of strong fields, nuclear structure, reactions near the Coulomb barrier, and at the intersection of atomic and nuclear physics. The updated strategy of the SPARC collaboration involves an early realization of CRYRING@ESR enabling research on slow, highly charged ions of stable and exotic isotopes.

The present joint research project states the collaboration between three partners each of them being member of the SPARC Collaboration. The following project objectives were envisaged in support of specific planned experiments: *i*) the development of effective techniques producing highly efficient electron beams. Study the fundamental mechanisms governing their acceleration; *ii*) the development of x-ray laser experiments and theoretical modeling of the high harmonic generation. The planned experiments at the HESR storage ring will combine the Doppler shift of the stored ions with an efficient x-ray laser the wavelength of which can be varied via the target material. This kind of experiments, representing a critical test of state-of-the-art atomic structure theory, will provide an absolute method for the measurement of fine structure splitting in a heavy, highly ionized ion; *iii*) study of inelastic electron scattering by excited hydrogen atoms in a laser field. This activity contributes to the new findings in the domain of laser assisted electron-atom scattering; *iv)* evaluation of detection performances of a vacuum compatible diamond-based segmented detector for relativistic highly-charged ions. The accomplishments can be summarized as follows.

Large scale theoretical atomic calculation have been performed in order (*i*) to elucidate observations of the earlier reported space resolved X-ray spectra recorded at the nhelix-test bed facility at GSI [1], and (*ii*) to investigate the *K*-shell photo-ionization x-ray lasing [2,3] related to the experimental possible combination of a heavy ion storage ring and an x-ray laser at the HESR storage ring; Inner shell photoionization x-ray lasing in C+ has been simulated [4] for an incoherent x-ray source generated from the ultra short high intensity laser interaction with Cu absorber.

The development of x-ray laser experiments at the TEWALS –INFLPR laser facility was focused on the implementation of a multiple-pulse generation scheme. It is based on a modification of the optical stretcher of a Chirped Pulse Amplification (CPA) laser system to allow the generation of two pulses with variable energy ratios from 0% to 30% and delays up to 600 ps at the output of the CPA system.

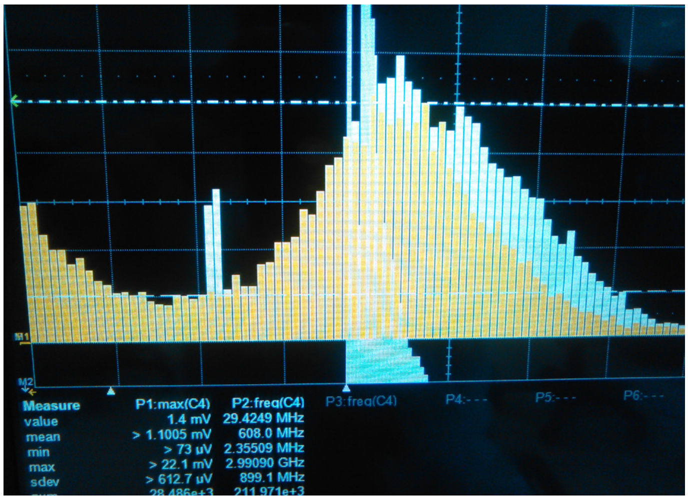


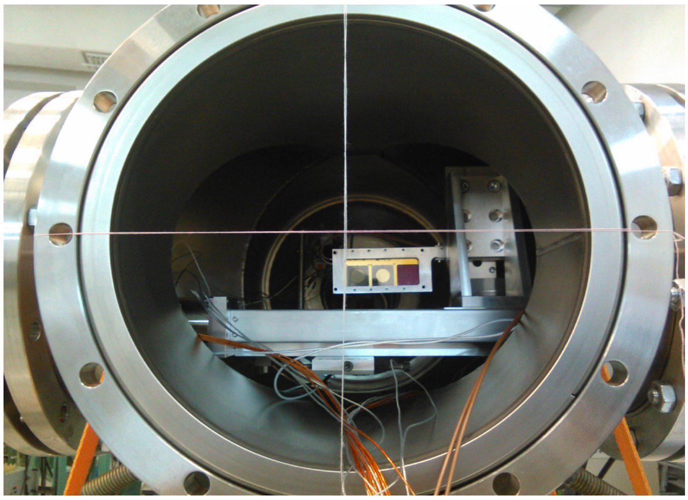


We have theoretically studied the *inelastic* scattering of fast electrons by H(*2s*) in a laser field of moderate intensities, a process that is accompanied by the change of the initial state of the atom. Detailed analytical formulas were obtained [5] for the differential scattering cross section (DCS) in the first-order Born approximation for laser-assisted e-H(*2s*) inelastic scattering for the *2s-nl* excitation accompanied by one-photon absorption at moderate field intensities. Numerical results are provided for the excitation of the *n=4* level of Hydrogen. We discussed the origin of the peaks in the resonance structure of the DCSs as a function of the photon energy, for laser-assisted inelastic e-H(*2*s) scattering. For the studied range of photon energies our analysis showed important differences from the dynamics of laser-assisted *elastic* scattering that are mainly due to the dipole coupling of the final *4l* state with intermediate *2l`* and *3l`*states (*l`=l ±1*). As perspective we intend to explore the polarization effects for inelastic electron-atom scattering in an electromagnetic field.

The present project proposed the manufacturing of a diamond-based detector prototype, lab tests and in-beam assessment of its performances. The main features of the device are moderate position resolution (500 to 300 micrometer), high rate capability (up to 1 MHz integral) high and stable detection efficiency. Single and double-face segmented devices with appropriate read-out methods are to be investigated with the goal of reaching an optimum between the performance and the cost. The accomplishments can be summarized as follows.

To evaluate the existing possibilities to test the performances of diamond detectors intended for SPARC collaboration, first tests of charge collection efficiency, count rate capability, high ionization density effects and radiation hardness of the detector, depending on the material properties (thickness, material quality), beam energy and intensity were made in IFIN-HH: - at the 3 MV tandem accelerator, with Alpha source and C beams with different intensities and energies, on a continuous position sensitive PCVD diamond detector with resistive electrodes, finished with strips of metal oriented 90 degrees on both sides, and - at the 9 MV tandem accelerator, with C^{6+} , 8.74 MV high voltage on terminal, around 62 MeV energy of the projectile and different beam current intensities on the target (less than 100 µA), on 2 PCVD diamond detectors with thicknesses of 60 and 80µm.





References

[1] C. Iorga, V. Stancalie, *A quantitative study of the forbidden and intercombination transitions arising from Li-like Al autoionizing levels*, Can. J. Phys. **93**:1413-1419 **(2015)**.

[2] V. Stancalie, *State selective photo-recombination cross sections in Be-like C and Al ions*, Eur. Phys. J. D **67**:223 **(2014)**.

[3] V. Stancalie, *Static and dynamic polarizability for C2+ in Rydberg states*, AIP Advances **5** : 077186 **(2015).**

[4] V. Stancalie, C. Iorga, V. Pais, *Theoretical investigation of inner shell photo-ionization x-ray lasing*, Rom. Rep. Phys. **67**, 4 : 1261-1270 **(2015)** .

[5] G. Buica, *Inelastic scattering of electrons by metastable hydrogen atoms in a laser field*, Phys. Rev. A, **92**: 033421 **(2015).**

Nuclear structure researches connected with NuSTAR@FAIR (NUSTAR)

Project Leader: Nicolae Marius MARGINEAN
Project Coordinator: IFIN-HH
Project web page: *http://proiecte.nipne.ro/pn2/157-proiecte.html*

This project (http://proiecte.nipne.ro/pn2/158-proiecte.html) is well integrated in a more general context at European level, where the study of the structure of atomic nuclei is expected to get a boost from the major investment projects in the field like FAIR in Germany, SPIRAL2 in France or, more recent, ELI-NP in Romania. The members of the project team are involved in the NUSTAR (Nuclear Structure and Astrophysics) experiment at FAIR, many of them have also a consistent involvement in ISOLDE and contribute to the definition of the experimental part of ELI-NP. This follows our main idea to study different aspects of nuclear structure at the facility that offers the best experimental conditions for the problem to be investigated and on the same time to insure a very solid experimental basis in the local laboratory as training basis for the students and to work on isotopes not very far of the stability line. Reflecting at smaller scale the structure of NUSTAR collaboration, this project gives support to complex activities structured in three main directions: preparing the NUSTAR in-kind contribution of Romania at FAIR (developments, equipment testing, contributions to the TDR's), preparatory experiments in Bucharest end other facilities, and theoretical studies concerning exotic nuclei.

The involvement in NUSTAR is of particular importance since Romania is one of the shareholders of the new facility and will provide a consistent in-kind contribution to the experiments: only the NUSTAR part amounts to ~2 millions euro according to the FAIR cost book. One of our major contributions in NUSTAR regards FATIMA, the fast-timing array for decay spectroscopy. In this case the Romanian know-how and infrastructure are excellent, granting us a first-rank role within the collaboration. Moreover, the ROSPHERE array from the TANDEM Laboratory of IFIN-HH is used for test and preparatory experiments within FATIMA collaboration.

The preparatory experiments address problems that might be further extended within NUSTAR at FAIR, but the initial steps are accessible at existing facilities. During the last years there were performed within the collaboration many tests using $LaBr_3$(Ce) detectors, and one of the critical observations was the existence of a relatively fast instability in the amplitude of the signals of the $LaBr_3$(Ce) detectors. Consequently we investigated the nature of this fast instability and we found that is directly related with the incident photon flux on the detector, probably due to small charge distributions accumulating near the dynodes of the photomultiplier. In a high background environment like the one expected at FAIR this might critically affect the energy resolution of $LaBr_3$(Ce) detectors and might compromise entire experiments, therefore finding a practical solution in the Technical Design phase is absolutely necessary. The inspection one-by-one of the detector over short periods of time for arrays with ~100 elements is time prohibitive and practically unfeasible, therefore within the present project we developed a very robust and fast solution: a dedicated software for automatic gain matching optimized for $LaBr_3$(Ce) detectors. This software makes use of our experimental finding that the fast instability on the amplitude manifests only as a bare gain change, without modifying the offset or introducing additional nonlinearity.During 2015 we focused on two such experiments at the Bucharest 9 MV Tandem, one concerning the N=Z nucleus ^{50}Mn and one aiming to measure the lifetime of the

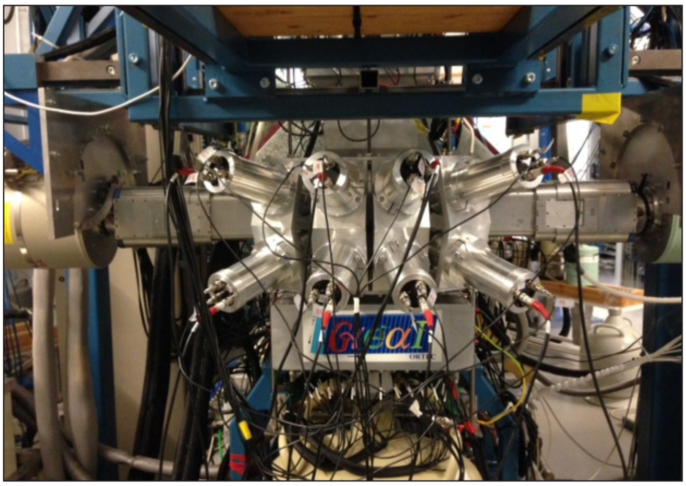
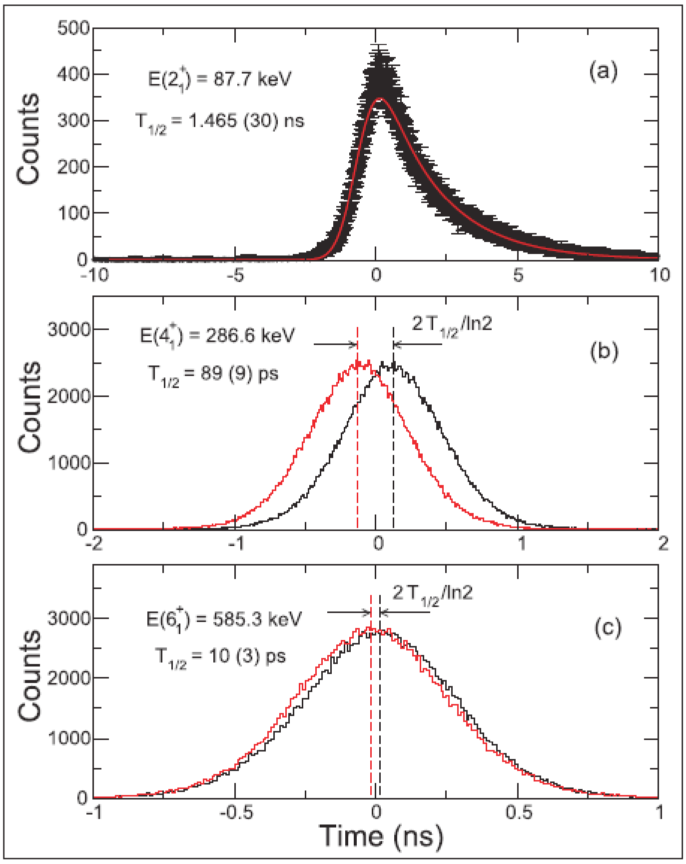


Fig. 1 *The ROSPHERE array at IFIN-HH Bucharest (left) and 8 FATIMA $LaBr_3$(Ce) installed at the focal plane of RITU spectrometer al Jyvaskyla (right)*

first 2^+ state in the neutron-rich ^{194}Os. Moreover, at Jyvaskyla a small array of 8 $LaBr_3$(Ce) detectors from FATIMA (the NUSTAR Fast Timing Array) was successfully installed and commissioned by a UK-Romanian-Finnish team, the results of the commissioning being very promising and the way to make real fast-timing experiments in the focal plane of RITU during 2016 is opened. These experiments might be extremely useful also for developing data analysis algorithms for fast-timing experiments with large surface sources, when the difference of optical path from the emission point to the detector produces sizeable effects in the time spectra of the fast scintillators, as expected in the SuperFRS focal plane.

On the theoretical side we addressed several questions concerning the nuclear structure and dynamics, mostly near the drip lines where it can provide tests of fundamental interactions and symmetries with relevance for nuclear astrophysics. Nuclei with extreme neutron-to-proton ratios are expected to present a completely different structure and dynamics from what is known for the stable ones. Our studies are based on the beyond mean field microscopic many-body variational approaches belonging to the Vampir model family adequate to describe the structure and dynamics of exotic medium mass nuclei manifesting shape coexistence. Based on the self-consistent description of β-decay properties under terrestrial conditions we can present reliable predictions for stellar environment. Our recent results on the structure of the low-lying states and their electromagnetic properties as well as β-decay properties under terrestrial conditions for ^{68}Se are in agreement with the experimental data. Excited Vampir predictions on stellar weak decay rates of the waiting point nucleus ^{68}Se indicate a reduction of factor 4 of the half-life at the typical rp-process density and temperature with respect to the terrestrial one. Another theoretical study done within the project concerns the coherence length by comparing the density dependent delta (DDD) pairing interaction to the Gaussian interaction with different width parameters.



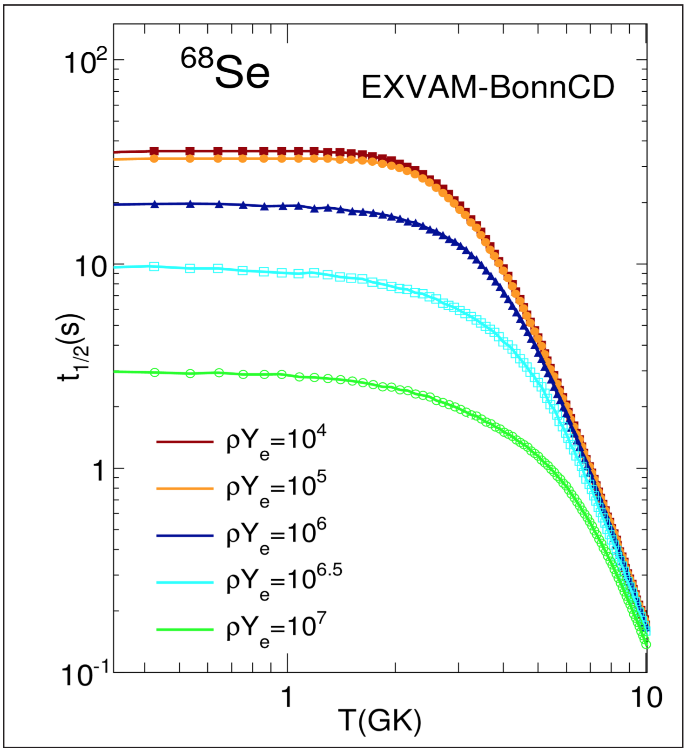


Fig. 2 *Example time distributions obtained in-beam with ROSPHERE array (left) and the theoretical halflife of ^{68}Se function of temperature (right)*

Field quality characterization of the HESR NC Magnets as preparatory action for PANDA Experiment (CARE-PANDA)

Project Leader: Eros-Alexandru PATROI
Project Coordinator: IICPE-CA
Project web page: *www.icpe-ca.ro*

On October 4, 2010, Romania signed the International Convention on the participation in the international project FAIR, becoming, through the Ministry of National Education - MEN, shareholder in the new company created, FAIR GmbH and supporting ~ 1% of the project costs through cash contribution, in-kind contribution and participation in the experiments that will be conducted after construction of the FAIR facility.

Most of the in-kind contribution will be provided by ICPE-CA, by manufacturing, testing and installation in the HESR component of FAIR, a number of 119 normal conducting magnets, 66 sextupol magnet type and 53 steerer magnet type and a number of 82 power supplies for these electromagnets, with a total value of about 4 million Euros. This contribution is subject to a contract signed in November 2013 between the FAIR GmbH - as beneficiary, MEN - as shareholder and ICPE-CA - as provider.

Since 2007 ICPE-CA has been adopted in the HESR consortium, created to develop the High Energy Storage Ring, important part of the FAIR project. With a circumference of 574 m the HESR is dedicated to strong interaction studies with antiprotons in the momentum range from 1.5 to 15 GeV/c and will allow conducting the PANDA experiment, one of the most important experiment that will be conducted at FAIR.

In the HESR consortium, ICPE-CA researchers have established a close collaboration with researchers from Nuclear Physics Institute - IKP, within FZJ - Forschungszentrum Jülich, Germany, the coordinator of the consortium, together with have been made so far the prototypes of two electromagnets, one sextupol type and one steerer type and the prototype of a power supply for these electromagnets.

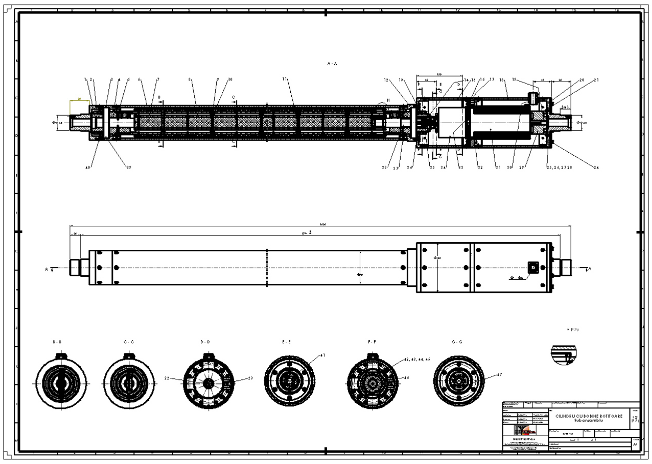
After signing the contract on the mentioned in-kind contribution, ICPE-CA started the work necessary to prepare the manufacture and testing of the equipments covered by the in-kind contribution, which involves the drafting documents for the execution of the magnets, the working procedures for manufacture, assembling and testing the magnets, arrangement of the laboratory for magnets assembling and mechanical, electrical and magnetic testing, identification of materials and test equipment required and their acquisition or construction.

The proposed project will result in achieving a high performance system for control the production of the magnets subject to the in-kind contribution, allowing to integrate in HESR equipments characterized by magnetic field parameters with a very high level of quality in terms of precision and uniformity, making it possible to conduct valuable scientific experiments. Very detailed testing and refinement of the magnets will also allow to provide to HESR users the information leading to the optimization of of the accelerator operation, thus contributing to a very good control of input parameters for experiments conducted in the future. The specific objectives of the proposed project relates to:

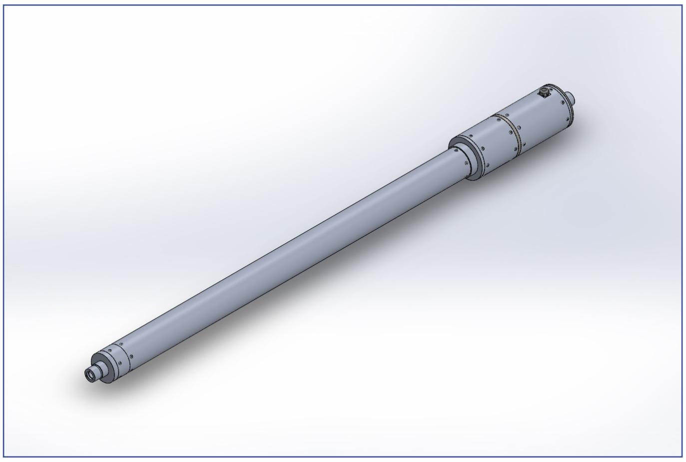
- Developing of the research infrastructure by creating the system characterization and new software
- Participation of ICPE-CA to international research programs, in consortium with universities or famous scientific research institutions in the field of particle acceleration and accessing the European funds;
- Increasing the degree of the research infrastructure by providing high-tech services to IMM, R & D entities, universities, etc.
- Unlocking the potential and the resources of R & D at the regional and European level by improving cooperation of INCDIE ICPE-CA with industry;

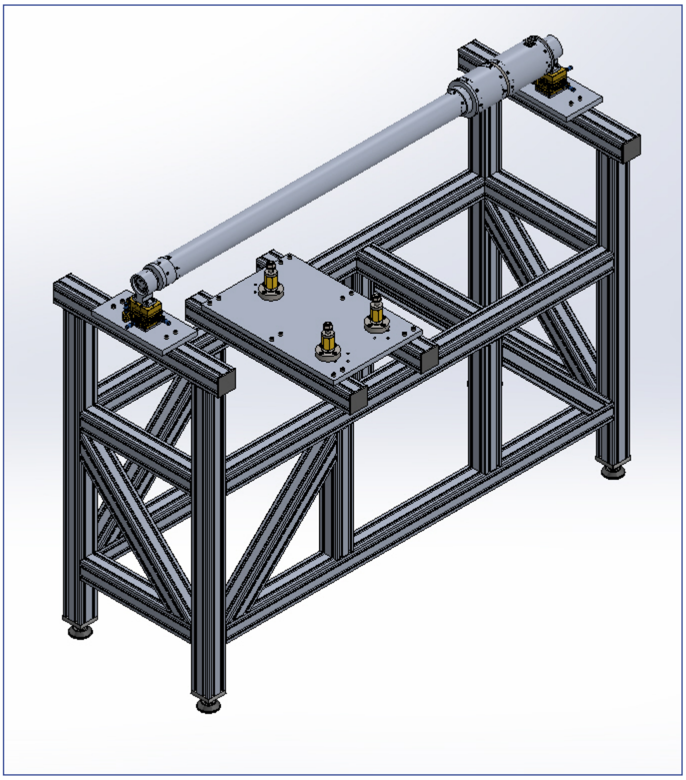
By imposing these general and specific objectives clearly defined and structured, we believe the project proposal fits into the core objectives of RO-CERN, contributing in a large measure to the construction and operation of FAIR center, namely to the construction of electromagnets for ion storage ring HESR.

- For achieving the objectives and targets of our project we have already made the first step by signing the contract no. IKC2.11.2.3. In-kind contribution of the following components HESR (sextupol magnets, horizontal steerer magnets, vertical steerer magnets, sextupol food sources, steerer food sources) for the construction of FAIR; The relationship between time-money-quality imposed as leading line in the characterization of systems field / devices that require:
- short time for obtaining the necessary data about the properties of magnetic field of the electromagnets;
- Reduced costs of characterization if it is possible with the, minimizing the necessary supplies - do not require higher qualifications for specialists who perform measurements;
- quality of the specifies measuring must be higher and the measurement uncertainty to be as good.



One such system is the characterization of the harmonic coils.





Stages / Activities / Time

Phase I Distribution determination of the magnetic field in electromagnets dipole, quadrupole and sextupol for identifying the input parameters of the characterization system. 01/07/2014-30/11/2014

Phase II Design and system development characterization of magnetic field distribution 01/12/2014-15/12/2015 **Phase III** Validation of the system characterization and development of software solutions for tracking performance electromagnets16/12/2015-30/06/2016

1. Autors: Daniel Dan, Ionel Chirita, Nicolae Tanase, Simona Malureanu, **Title:** Analysis, Characterization And Optimization Of a Steerer Magnet Prototype, **Conference:** The 9th INTERNATIONAL SYMPOSIUM ON ADVANCED TOPICS IN ELECTRICAL ENGINEERING May 7-9, 2015 Bucharest, Romania

2. Autors: Ionel Chirita, Daniel Dan, Nicolae Tanase, **Title:** Magnetic And Mechanical Optimization Of a Sextupole Magnet Prototype **Conference:** The 9th INTERNATIONAL SYMPOSIUM ON ADVANCED TOPICS IN ELECTRICAL ENGINEERING May 7-9, 2015 Bucharest, Romania

As a result of the experiments that are ongoing, the project team is working on three papers ISI.

Simulations with YaPT system and predictions for nuclear matter flowing in relativistic nuclear collisions at CBM Experiment (YaPT-CBM)

Project Leader: Alexandru JIPA
Project Coordinator: FF-UB
Partners: UMC
Project web page: *http://brahms.fizica.unibuc.ro/sitecentru/F09.htm*

One of the main objectives of the research of the nuclear collisions at relativistic energies is the study of nuclear matter phase diagram and locating of the critical point of the phase transition. The quark-gluon plasma phase is one of the most important. At FAIR-GSI there is the possibility to perform collisions over a wide range of energies using the same detector system, but at lower temperatures and at higher baryon chemical potential, in comparison with experiments performed at other international laboratories. The predictions indicate, in this case, that a first-order phase transition can be obtained and the critical point is the point which connects the first-order phase transition to the region of the second order phase transition, continuous type, in the small baryon chemical potential region. The main objective of the project was to associate different types of flow of nuclear matter formed in the participant region with different phases of nuclear matter formed in collision. Taking into account the expected behavior near the critical point - increasing fluctuations - an objective of interest was the fluctuation investigation by analyzing the ordinary and factorial moments associated with distributions of interest, especially those of multiplicity, transverse momentum and rapidity. Other interesting physical quantities are strangeness fluctuations, temperature, net charge and baryon number fluctuations. Our integrated on-line system for the study of the interactions in High Energy Physics, called YaPT, developed at the Research Centre „Nuclear Matter in Extreme Conditions", have been used for a systematic study of the Au-Au collisions at SIS-100 and SIS-300 (FAIR-GSI) energies, with a few simulation codes (UrQMD, AMPT), as well as phenomenological geometric picture of the relativistic nuclear collisions. For achieving of the proposed objectives, the improvement of the YaPT simulation system performance was done by adding of new features: parallel processing implementation for each request made from the web interface, prioritization of the simulations, implementation of new analysis modules in agreement with the project objectives. The new codes included in the YaPT system (PYTHIA6, PYTHIA8, GiBUU), together with the existing ones (UrQMD, AMPT and GEANT) included many useful elements for the description of the collective behavior of the high excited and extreme dense nuclear matter formed in nucleus-nucleus collisions at SIS-100 and SIS-300 energies. Different analysis modules were introduced in order to permit calculation of the high order moments in the analysis of the multiplicity distributions of the emitted particles and to study the elliptic flow.

Many simulations with different codes for symmetric and asymmetric collisions at the available energies at SIS-100, SIS-300, respectively, have been done. The simulated data were used in analysis of the flow processes. The possibility of using multi-particles correlations methods for the elliptic flow studies as an alternative to Event Plan Method (EVM) has been tested. The results on the feasibility of the LYZ method, applied for Au-Au collisions at 10 A GeV, using YaPT system, are presented bellow. All charged particles with the rapidity in the range $0,6<y<2,6$ have been considered. The evaluations for the generating function, for 3 centrality ranges, permitted to compare the values of the elliptic flow parameter, v_2, obtained from UrQMD for the two mentioned methods. Few results are included in Fig.1 and in Table I. The limitation of LYZ method is related to statistical fluctuations. We need to increase the statistics and comparison with other methods. Tests with different types of other orders correlations, as well as with different cumulants are in progress.

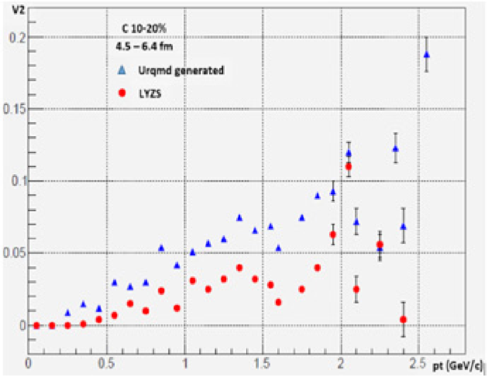
Education

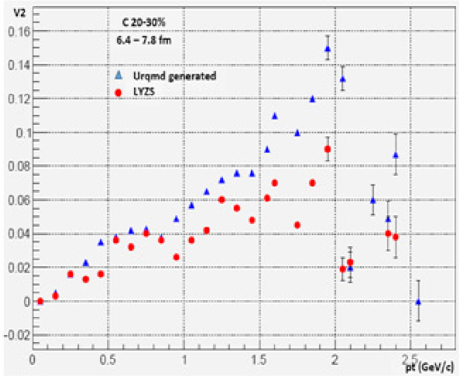
The YaPT system was used at the practical classes associated to the course of the High Energy Nuclear and Particle Physics Phenomenology – Master studies in the field Physics of atom, nucleus, elementary particles, Astrophysics and applications - second study year, first semester of the academic year 2014-2015; 2015-2016 and for scientific research of students for their Bachelor, Master and PhD Theses.

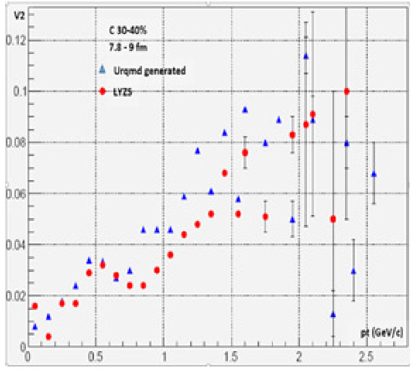
Outreach

Different topics of relativistic nuclear collisions Physics have been presented at the following young people meetings: Pentagon of the major Romanian Physics faculties, Bucharest-Măgurele, July, 29th, 2014 (Prof.univ.dr. Al. JIPA), 90th Anniversary of the Military High School „Ștefan cel Mare" Câmpulung Moldovenesc, 21.XI.2014 (Prof.univ.dr. Al. JIPA), „School, otherwise" – April 7th 2015 – at the visit of the young people from „Paul Georgescu" High School Țăndărei, Ialomița County (Prof.univ.dr. Al. JIPA), Workshop – Physics as gate to universal knowledge. Teaching and communication of the Sciences for young peoples from schools and high schools – 21-27.IX.2015, Bucharest-Măgurele (Prof.univ.dr. Al. JIPA).

The most significant results have been included in 4 scientific articles (CMBE v05 Implementation of a toy-model for chaos analysis of relativistic nuclear collisions at the present BNL energies - I.V.Grossu, Al.Jipa et al – *Computer Physics Communications 185(11)(2014)3059-3061*; Support for massless particles in Chaos Many-Body Engine simulations of nuclear collisions at relativistic energies - I.V.Grossu, Al.Jipa, et al - *Computer Physics Communications 195(2015)218-220*; Development of an integrated on-line system for the study of the hadronic interactions in High Energy Physics - S.Cioranu, Al.Jipa, M.Potlog – *Romanian Reports in Physics 67(3)(2015)819-830*;



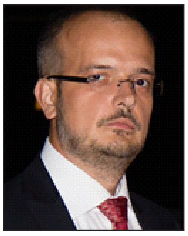




c[%]	10-20	20-30	30-40	40-50	50-60	60-70	70-80
v_2[UrQMD]	0,0119	0,0244	0,0276	0,0270	0,0247	0,0135	0,0065
v_2[LYZS flow]	-	0,0291±0,0005	0,0335±0,0005	0,0337±0,0005	-	-	-

Hydrodynamic flow and phase transitions in relativistic nuclear collisions reflected by Hubble type fireball evolution - C. Ristea, A. Jipa et al - *accepted for publication to Romanian Reports in Physics 68(2016)*), 2 papers in conference proceedings and different works presented at national and international conferences (Annual Session of Scientific Communications of the Faculty of Physics of the University of Bucharest 2015 - 7 oral presentations, The 9th International Physics Conference of the Balkan Physical Union (BPU9), 24-27 August 2015, Istanbul, Turkey (Turkey) - 2 oral presentations, European Nuclear Physics Conference, Groningen (Holland) - 2 oral presentations and 1 poster, The XXV International Conference on Ultrarelativistic Nucleus-Nucleus Collisions (Quark Matter 2015), Kobe, Japan - 5 posters).

Laboratory for development and testing of accelerating, transport and diagnostics systems for charged particle beams (ACCELTEST)



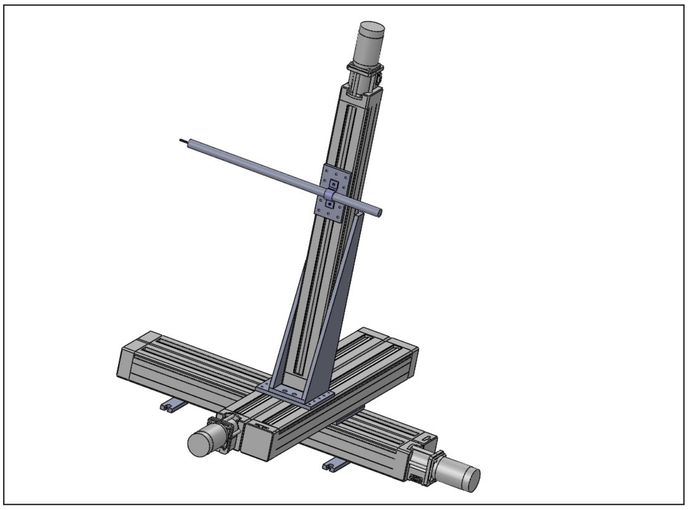
Project Leader: Dan Gabriel GHITA
Project Coordinator: IFIN-HH
Partners: ICPE-CA
Project web page: *www.nipne.ro*

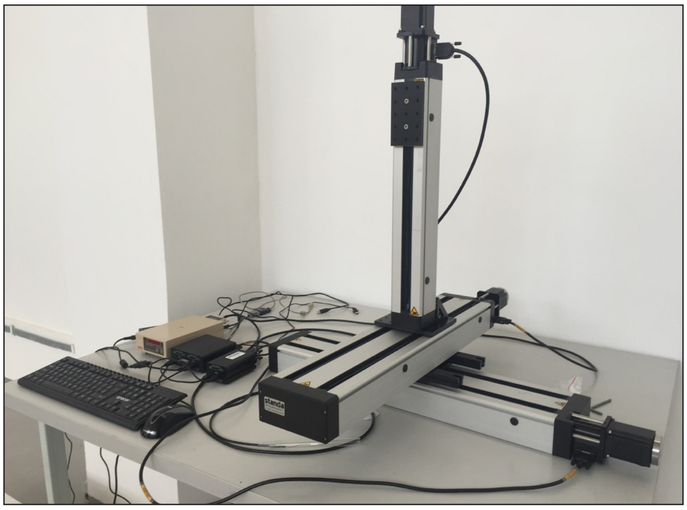
Romania is one of the founding members of the Facility for Antiproton and Ion Research (FAIR) under construction now at GSI in Darmstadt, Germany. From the total amount of Romanian contribution to the project (11.87 M€), the in-kind contribution to accelerator facilities and experimental setups is 9.4 M€. The only in-kind contributor to the experiments is IFIN-HH who is a member in NUSTAR, PANDA, SPARC, and CBM collaborations and ICPE-CA who is an important in-kind contributor to the particle accelerators and storage rings, having an important contribution with magnets for HESR facility.

At the same time, the ELI-NP (Extreme Light Infrastructure – Nuclear Physics) facility being constructed in Magurele, Romania, aims to build a nuclear physics research centre, around two important facilities: a 10 PW class laser and a high brilliance gamma beam facility.

Taking into account that IFIN-HH has a great contribution to both FAIR and ELI-NP, being responsible for complex experimental setups, and the partner ICPE–CA is responsible with a very important part of the HESR collaboration at FAIR, the present project is a very good opportunity to improve the existing infrastructure, opening new possibilities to develop prototypes of accelerating structures, transport sections and beam diagnostic systems and detector assemblies for the new machines and experimental setups that are going to be built at FAIR in Germany or at ELI-NP.

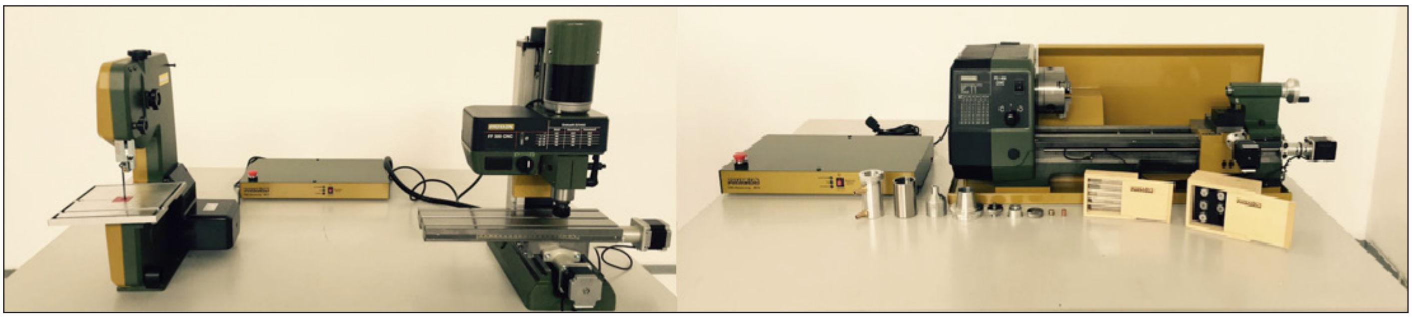
An important development in this category is the high-precision, 3 axis magnetic mapping system. This was designed and constructed with high precision linear stages and Hall probes. It can be used for precise mapping of magnetic fields for ion-optics elements and mass spectrometers, just to name a few applications of the device.





CAD rendering of linear stages (left); experimental setup with linear stages for magnetic field mapping (right)

For manufacturing and processing different materials (metallic, polymer, other), the laboratory was tooled up with high precision machining equipment and a resin based 3D printer.

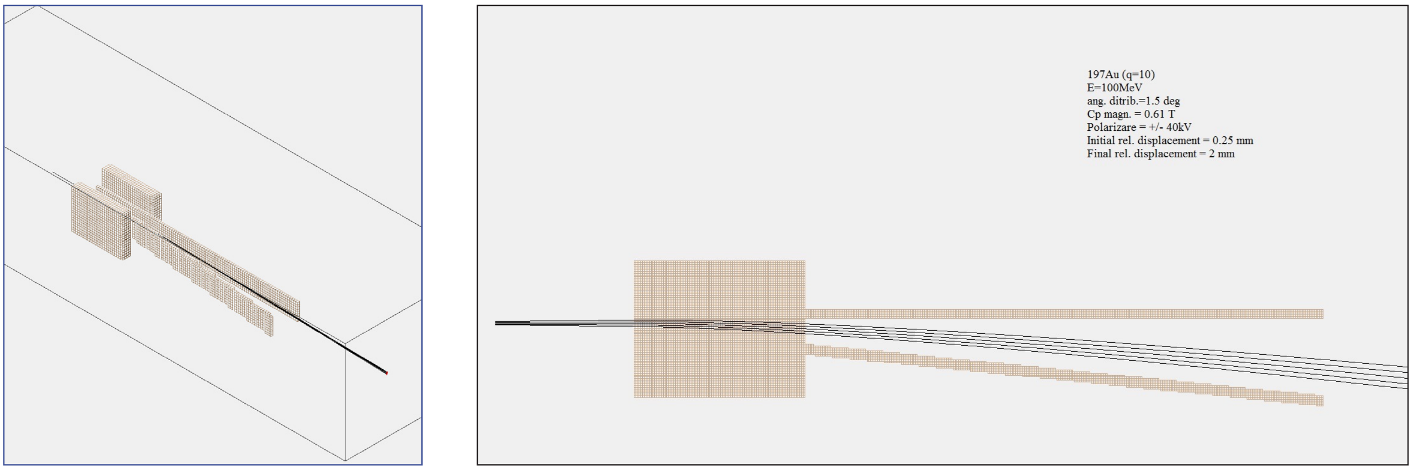


Vertical cutting machine and high precision milling CNC (left); high precision lathe CNC (right)

A high precision 5 axes CNC machine was also installed, as part of the present project. The high precision will allow us to design and produce any kind of accelerator or experimental setup part. The instrument also allows machining to very high volumes (X: 762 Y: 435 Z: 510 mm) for the parts.

As an exercise of R&D we are trying to develop a Thomson parabola mass spectrometer. This was divided into 2 phases. First we have simulated the device using ion beam simulation software at different parameters (Simion). Following the complete analysis of this type of spectrometer we will design a blueprint using CAD software.

In conclusion, we have constructed a new laboratory for development of complex experimental setups. We have already designed and developed several small experimental systems for the Tandem accelerators and test setups for the implementation phase of ELI-NP. This project helped us to start improving our technical capabilities and we hope to further expand our design and prototyping capacity by adding new equipment in the future.



Design and simulation of a Thomson parabola mass spectrometer

FAIR – Facility for Antiproton and Ion Research
www.fair-center.eu

ANCSI – Romanian Authority for Scientific Research and Innovation
www.mct.ro

IFA – Institute of Atomic Physics
Executive Agency for funding projects within the FAIR – RO Programme
www.ifa-mg.ro

Participating institutions in the FAIR – RO Programme 2014-2016

Horia Hulubei National Institute of Physics & Nuclear Engineering
www.ifin.ro

National Institute for R&D in Laser, Plasma and Radiation Physics
www.inflpr.ro

Institute for Space Sciences
www.spacescience.ro

University of Bucharest
www.unibuc.ro

National Institute for R&D in Electrical Engineering
www.icpe-ca.ro

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