Annex 2 – Registration Forms/ Form B-CERN

Financing CERN cooperation projects

Programme	**Capacities /Module III**
Project Type	**CERN Cooperation**
CERN Accelerator (Acronym)	**LHC**
CERN Experiment (Acronym)	**ALICE**
Cooperation Period according to MoU	**2015 with further extensions**
Project Title	***Properties and dynamics of strongly interacting matter***

B – Proposal Description

(1 copy in Romanian and English)

1. CERN Experiment Objectives

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Quantum Chromodynamics (QCD) predicts that at extreme conditions of temperature and/or density a phase transition from normal nuclear matter into a new state of matter, formed by quarks and gluons, takes place. The ultra-relativistic heavy-ion collisions provide a unique opportunity to create and study the properties of matter in extreme conditions of temperature and/or density in terrestrial laboratories. The **L**arge **H**adron **C**ollider (LHC) at CERN is designed to accelerate protons and Pb ions and collide them up to 14 TeV and 5.5 Tev in the center of mass, respectively. The only dedicated experiment for heavy ion collisions at LHC energy is the ALICE Experiment, i.e. , **A L**arge **I**on **C**ollider **E**xperiment. The main objective of ALICE experiment is to study nuclear matter in a regime of temperature largely exceeding the critical temperature where a phase transition toward the deconfined phase takes place. As the energy density reached at LHC will, by far, outrun those attained at RHIC, this will allow to explore the properties of nuclear matter at extremely high energy density and to study in detail the properties and dynamics of the new state of matter. ALICE takes advantage of the proton beam at LHC to collect reference data in dedicated p–p and p–A scientific programs, complementary to the programs addressed by the ATLAS and CMS experiments. The ALICE experiment has been designed to measure most of the particles produced in heavy-ion collisions, i.e. hadrons, electrons and photons in the central region and muons in a forward spectrometer. The central part, which covers polar angles from 45° to 135° and full azimuth, is embedded in a large solenoid magnet. It consists of: an Inner Tracking System (ITS) of high resolution silicon detectors; a cylindrical Time-Projection Chamber (TPC); a single-arm electromagnetic calorimeter (PHOS); and three particle identification arrays of: Time-Of-Flight (TOF) detector, Transition Radiation Detector (TRD); and a single-arm ring imaging Cherenkov (HMPID) detector. The forward muon arm covers polar angles 171° to 178° and consists of a complex arrangement of absorbers, a large dipole magnet, and fourteen planes of tracking and triggering chambers. Several smaller detectors, ZDC, PMD, FMD, T0, V0, for global event characterization and triggering are located at forward angles. An array of scintillators (ACORDE) on top of the L3 magnet is used to trigger on cosmic rays. Different detectors are cooperatively designed such to achieve particle identification over a broad range, extending from very low p_T (<100 MeV/c) up to high momentum (<100 GeV/c). This confers to ALICE the ability to explore the soft and hard phenomena in p–p and heavy-ion collisions. The challenge for ALICE is to perform high-quality and broad-range measurements in an environment of extremely large particle densities, which could be as high as 8,000 particles per rapidity unit. A set of Control and Computing Systems, including Triggers, DAQ and Detector Control Systems undertake this task. The ALICE offline software framework, AliRoot, is used for event simulation, reconstruction and data analysis. The Transition Radiation Detector (TRD) of which construction, installation, comissioning and operation takes place with a significant contribution of our team will act as an electron spectrometer to identify charm and beauty mesons through their semi-leptonic decay and charmonium-and bottomium-states through their e+e− decay channel. Furthermore, the fast tracking capability of TRD electronics will allow to trigger on the high momentum electron- and hadron-events, latter playing an important role in the jet-physics program.

2. Romanian Participation/ Scientific/Technical Contribution according to MoU

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As it is mentioned in the TRD-**T**echnical **D**esign **R**eport, the 18 Super Modules (SM) of the ALICE-TRD subdetector contain 540 TRD chambers. The TRD chambers construction task was initially equally shared between 5 institutes, i.e. Physics Institutes of Heidleberg and Frankfurt Universities, GSI - Darmstadt, JINR - Dubna and Hadron Physics Department of the National Institute of Physics and Nuclear Engineering – Bucharest. TRD chambers construction and tests started in our Department in early 2005. It is well known by now that we succeeded to organize in our Department a Detector Laboratory at international standards, well known and appreciated at international level. The efficiency and quality of our activity for realization of TRD chambers, placed our group on a very good position within ALICE Collaboration. These activities were highly appreciated by numerous foreign scientists and delegations visiting our Department. It is worth to underline that all the objectives initially foreseen were completely fulfilled (130 TRD chambers, ~180 m^2 total surface, ~280.000 detection cells, realized by our group in the Detecor Lab. of HPD (**H**adron **P**hysics **D**epartment) of IFIN-HH). As far as concerns the TRD Front End Electronics, we had an essential contribution in designing the analogic CHIP–PASA. In our group were designed and realized electronic components required for the final tests of the TRD chambers constructed in our Laboratory. As a non profit organization, our

Department obtained the CADENCE software package at modest price, it was implemented on the local machines and is currently used for designing FEE for the new detector prototypes developed by us which could be considered for the ALICE upgrade program. Obviously our final goal was to access the experimental information expected to be obtained at ALICE once the LHC will start. This objective became reality due to our important contribution for realization of the experimental device and our efforts in organizing a proper infrastrucure for a Data Centre in terms of clearness, temperature and humidity, industrial UPSs and Diesel engine where the computing power and storage capacity is installed. At present our NIHAM (Nuclear Interaction and Hadronic Matter) Data Centre is among the most efficient components of ALICE GRID, delivering more than 6% of ALICE computing needs in 2010, at an efficiency higher than 95% , although a major upgrade of the computing and storage resources and of climatization infrastructure required a 2 months shutdown (http://pcalimonitor.cern.ch:8889).

A confirmation of the impact of our results at the international level is the organization of three successful International Workshops, Cheile Gradistei, Romania, September 24-28(2005), Sinaia, Romania, October 13-18(2006) and Sibiu, Romania, August 20-24(2008).

At present the members of our group are involved in monitoring the TRD SM (Super Modules) installed in the experiment, assembly, tests and installation of other SM in the experiment, development of the tracking software package for TRD, maintenance, operation of NIHAM, development of AliEn software packages for ALICE GRID monitoring, participation in ALICE experiments, experimental data and MC analysis for p + p collisions at 900 GeV and 7 TeV focused on p_T spectra for primary charged identified hadrons and event shape in order to study the possibility to evidence an axial isotropic flow in p+p collisions at 7 TeV. In parallel we are developing the necessary analysis environment for flow studies in central and mid-central Pb+Pb collisions which will be measured in the near future at 2,76 TeV at LHC.

3. Project Objectives

(Max. 1 page, Times New Roman 11 pt, 1.5 spacing)

Objective O1.

Assembly and tests of TRD chambers in supermodules (SM) and of supermodules in ALICE experiment in order to complete the TRD-ALICE detector

Objective O2.

Development of NIHAM Data Centre: ALICE GRID site and NAF (NIHAM Analysis Facility) components; M&O

Objective O3.

p+p; Pb+Pb and cosmic rays experiments using the ALICE detector.

Objective O4.

Analysis and interpretation of experimental p+p and Pb+Pb and MC data obtained with the ALICE detector.

4. Description and justification of proposed activities, highlighting each partner's contribution

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At present in the ALICE experiment are implemented only 7 TRD SMs from 18 of the complete TRD subdetector. All the five sites mentioned above, finalized the TRD chambers' construction, the electronics is implemented at Physics Institute of Frankfurt University, the equipped chambers are sent to Physics Institute of Munster University in order to be assembled in SMs and properly equipped with gas connections, cooling network, etc. Once the SM is assembled it is tested with cosmic rays. Taking into account the complexity of these operations and the fact that 11 SMs have to be assembled and tested, it is obvious that such activity cannot be accomplished by the Munster group alone. Therefore we have to contribute also to such activities.

The tested SMs will be shipped to CERN and they have to be installed in the ALICE experiment. As this activity has to take place during the shutdown periods of LHC and finalized in 2012, coherent interventions are needed. Detailed cross checks of all gas, voltage, optical fiber connections and tests using cosmic rays will follow. Obviously, as stipulated in the construction and installation MoU, members of our group will be involved in these activities, based on their previous experience.

Running the ALICE experiment is a demanding task which requires support from all experts, members of the Collaboration at the level of about 3 weeks of shifts per signing paper person.

As it was underlined above, a special attention will be given to the upgrade of NIHAM Data Centre and NAF computing infrastructure in such a manner as to guarantee a high level of efficiency of our contribution to the ALICE GRID and in view of developing software packages for data analysis and model calculations, respectively. This can be achieved if in parallel we will develop a proper control and monitoring infrastructure and tools for our Data Centre. The maintenance and operation of such a complex infrastructure in order to maintain the present level of efficiency is a demanding task.

Detailed corrections of all effects showing up in operating the TRD chambers in real experiment and performant tracking algorithms have to be improved in order to reach the highest performance of this important subdetector of theALICE experiment. We will continue our activities along these lines.

Our results at the baryonic level demonstrated the sensitivity of a multidimensional study of flow phenomena in terms of azimuthal distribution of mean kinetic energy of different species and of collective expansion, to the equation of state. We showed that the nuclear matter produced in heavy ion collisions at densities of about $2\rho_0$ and temperature of 70 MeV - 80 MeV is characterized by a soft equation of state.

Based on the experience obtained in studying flow phenomena at lower energies, we looked to the behavior of the mean transverse momentum as a function of mass using the existing information obtained by STAR Collaboration in p+p and Au+Au collisions at 200 AGeV. Fitting this experimental dependence with an expression obtained under the hypothesis of a local thermal equilibrium (T) boosted with a given collective velocity β, the two parameters were obtained. While for p + p collision the data are well reproduced without any expansion or a very low one and a temperature of 151 MeV or 108 MeV, respectively, in the Au + Au case, using all the hadrons, one obtains β=0.53 and T=112 MeV. If one does the fit separating the hadrons in two classes, i.e. those with high interaction cross section and the others with very low interaction cross section as the multi strange baryons and J/Ψ are, for the first class one obtains β=0.56 and T=104 MeV, the second class being characterized by β=0.36 and T=172 MeV. This tells us that quite probable the multi strange baryons and J/Ψ, having lower interaction cross section after hadronization, keep the characteristics of the collective expansion built up at the partonic level while the rest of hadrons continue to interact after hadronization, building up more expansion which obviously cools down the system, showing lower temperature (AIP Conf. Proc. ISSN-0094-243-2008).

We extended such studies at p+p collisions at 900 GeV and 7 TeV recently measured by the ALICE Collaboration at LHC. Preliminary results of our analysis were presented this year in two ALICE Week meetings, ALICE Physics Week – Paris and few meetings of working subgroups of ALICE PWG2. They show the importance of selecting high multiplicity and highly azimuthal isotropic events using event shape analysis in order to evidence precursors of collective expansion already in p+p collisions at 7 TeV. Results of software development where included in ALICE analysis train. Presently we are improving the statistics and plan to use high multiplicity trigger runs collected in the last period by the ALICE experiment in order to evidence a trend of the observed effect as a function of multiplicity for high multiplicity and highly isotropic events. Once the results will be confirmed at higher statistics and stronger constraints in event shape selection using global observables like directivity, thrust, sphericity, recoil or combinations of these and published, we will concentrate in extending such analysis in the case of hyperons in order to extract details on the origin of this phenomena which seems to show up even in p+p collisions at 7 TeV. Definitely such results are important also as reference data for Pb+Pb collisions where Corona contributions originating from single nucleon-nucleon collisions have to be considered before concluding on differences between heavy ion collisions relative to a simple superposition of nucleon-nucleon collisions.

Similar studies will be done once the experimental information from Pb+Pb collisions at 2.76 TeV, expected to be accessed in the near future, will be available from the ALICE experiment. For understanding the influence of the initial collision geometry on the expected phenomena at LHC, we improved a Glauber Monte-Carlo program developed by us, used to estimate the number of nucleons suffering different number of collisions and their topological distribution within the overlapping area and study the influence of the initial azimuthal distributions of the nucleons with different number of collisions on the subsequent dynamics of the interacting zone. We will concentrate on studies related to flow phenomena in peripheral and highly central collisions at LHC energies, developing methods for substracting the contribution coming from jets. We envisage a multidimensional analysis of the p_T spectra and their associated moments as a function of mass of different hadrons, azimuthal angle, impact parameter dependence, as sensitive tools studying details of the expansion dynamics of extremely hot and dense strongly interacting matter formed in heavy ion collisions at LHC energies. As it was mentioned above, a special attention in these studies will be given to the strange and multistrange hadrons and charm and beauty mesons through their semi-leptonic decay and charmonium-and bottomium-states through their $e+e-$ decay channel, TRD subdetector playing an essential role in their reconstruction. The results will be compared with theoretical predictions based on phenomenological and microscopic transport models.

Following the above mentioned objectives, the activities foreseen to take place in the near future are :

Objective O1.

- Super Modules assembly, HV, leakage and cosmic rays tests
- installation of SMs in ALICE experiment
- commissioning - cosmic rays and in-beam tests

Objective O2.

- Upgrade of NIHAM Data Centre
- Upgrade of NAF (**N**IHAM **A**nalysis **F**acility)
- Upgrade of controlling and monitoring infrastructure of NIHAM Data Centre
- Developing associated software packages for increased efficiency and monitoring
- Maintenance and Operation of NIHAM Data Centre

Objective O3.

- Running ALICE experiment at LHC for p+p and Pb+Pb collisions

Objective O4.

- Development of high efficiency tracking for TRD chambers
- Developing the software environment for analysis and interpretation of the Monte Carlo simulated and experimental data concerning the flow phenomena in p+p collisions at 900 GeV, 7 TeV and 2.76 TeV
- Developing the software environment for analysis and interpretation of the Monte Carlo simulated and experimental data concerning the flow phenomena in central and mid-central Pb+Pb collisons at 2.76 TeV.

5. Project Development and Expected Results

Multi-step presentation (Max.1.5 pages, Times New Roman 11 pt, 1.5 spacing)

Objective Code	Objective description	Achievement indicative (measurable)	Planned value (unity of measurement)	Time schedule justification
O1	Assembly, installation and comissioning of TRD super-modules in order to finalize the TRD-ALICE detector in 2012.	number of supermodules; test reports; presentation at workshop	12 SMs 1 presentation 1 paper	Depending on the general schedule at the level of ALICE Collaboration, shutdown periods of LHC, all TRD subgroup activities will be tailored such to have the whole ALICE TRD subdetector installed by 2012.
O2	Development of NIHAM Data Centre: GRID and NAF components	number of installed servers, storage media and management consoles reports, presentation at workshop	~ 12 servers ~ 200 TB HDD management consoles - replacement of broken components 1 presentation	A permanent analysis of performance/costs of computing power and storage capacity versus the specific needs of our group and ALICE Collaboration will be done in order to optimize the purchasing period and technical specifications of the corresponding items. The repair and replacement of the broken components in order to maintan the achieved performance.
O3	Experiments with	shift reports;	Cosmic rays,	Cosmic rays runs are

	cosmic rays and p+p and Pb+Pb collisins using the ALICE detector.	in beam results	p+p collision, Pb+Pb collision data	mandatory for detector calibration and time settings within concrete ALICE environment. In-beam experiments obviously will depend on the machine schedule.As it is planned, the ALICE will measure p+p collsions about 10 months/year and Pb+Pb collsions about 1 month/year until the long shut down period of LHC planned for 2012.
O4	Analysis and interpretation of Monte Carlo simulated and experimental data obtained with the ALICE detector in p+p and Pb+Pb collisions.	report on data analysis and model calculations; presentation; scientific paper	Software with documentation; 5 presentations; 2 scientific papers	Detailed analysis of collective effects in p+p and central and semi-central Pb+Pb. Event shape and efficiency corrections analysis based on MC simulated data. Glauber MC estimates and their impact on the final azimuthal distributions and different types of scaling.

6. Ways to Turn the Cooperation Results to Good Account

Publications, reports, joint patents, know-how, mock-ups, other (specify).

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The results obtained during the construction and tests of the TRD modules and associated electronics were already published as scientific reports, presented at international meetings and conferences in Romania and abroad and papers in prestigeous international journals. A comprehensive ALICE-TRD paper will be published in the near future.

For the intermediate steps scientific documents will be produced and published in IFIN-, GSI- or CERN – Reports. The results of our analysis of experimental data obtained in p+p and Pb+Pb collisions will be published in international scientific journals and presented in ALICE meetings, international workshops and conferences.

The considerable know-how and achievements obtained by the Bucharest group as partner in different international collaborations, quite well known by now at national level, will be transferred into the country and will have a strong impact on the field of design and production of detection systems, CHIPs for the associated front-end electronics, special motherboards for interfacing the CHIP with different type of detectors and data processing systems and hardware and sofware structures for distributed computing.

The present visibility of the group will be increased updating continously the WWW-page (http://niham.nipne.ro) and organizing international events in Romania. This year we organized a summer student program with a successful outcome, our aim being to continue this innitiative to become a tradition. In the present situation when Romania becomes a CERN member we are convinced that our contribution to ALICE Collaboration will be enhanced in future.

7. Project Impact

Potential for development of new cooperation to be concretized in projects proposed for funding through regional, European and international programmes or initiatives.

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Some of the implications of the present project on the physics reasearch, economy and society in our country are listed below:

The successful, visible and competitive participation of the Romanian group to the production, test, installation and monitoring of the TRD chambers for one of the major subdetectors of ALICE experiment at CERN guarantee future participation of Romanian scientists in physics experiments with extreme impact on human knowledge, accessible only on the basis of common scientific and financial efforts at the international level.

Our group is deeply involved in I3HP JRAs activities in FP7 and developed few highly performant prototypes of TRD and RPC detectors and the associated fron-end electronics at chip level for high counting rate environment on which quite probable important components of CBM experiment at FAIR will be based. Based on these results our group organized the 16th CBM Collaboration Meeting in Romania in 2010, highly appreciated by all participants.

We also presented a proposal for future PID within the last call of FP7 supposed to be financed, once accepted, starting from 2012.

Fitting out of a technological infrastructure and training people for detector production, test and integration allowed not only to participate in TRD subdetector construction for the ALICE experiment, but later on, to be involved in other projects at European level of similar complexity.

Experience in modern electronics design, situates our group in a leading position in establishing and disseminating state of the art technology for chip design in all of Romania. Funds invested in such a design capability will surely pay back in the coming years.

Hardware and sofware structures of distributed computing network type which are and foreseen to be implemented in our group will serve not only the group's needs for computing, but also connect Romania to the international efforts to develop the new technology of grid computing. Our NIHAM Data Center had the largest contribution among the Romanian sites involved in EGEE III project and has the largest contribution in LCG.

As a common practice in scientific research domain, students and graduate students will continue to be involved in the group's activities to prepare their diploma works and PhD theses. They will become highly qualified specialists, extremely useful in various branches of activity.