Programme / Sub-programme / Module	**5/5.2/CERN-RO**		
Project type	**RD**	**Continuing X**	**New ☐**
CERN Research Programme / Experiment	LHC/ALICE		
Project title / Acronym	**IFIN-HH contribution to the ALICE experiment at LHC/RONIPALICE**		
Project duration	2016-2018		

PROJECT DESCRIPTION

1. Objectives of the CERN experiment

By colliding heavy ions at relativistic and ultra-relativistic energies, transient pieces of matter at densities and temperatures where deconfinement is expected to take place can be produced. However, one has to consider that even in the case of colliding the heaviest nuclei, the size of the created system is rather small, its initial state is highly non-homogenous and dynamical effects play a crucial role, the system being characterized by a violent evolution. At ultra-relativistic energies even the hadrons become rather complex objects. A free hadron could be considered at each moment as a cloud of quasi-real partons belonging to a cascade whose density seen by a parton of a similar cascade from the colliding partner increases with the energy, expected to reach a saturation at very high energy. If a parton of a cascade meets on its way a parton of the colliding partner, interacts with it, the whole cascade changes, its coherence is broken, the partons can not assembly back and they continue to live and decay in secondary hadrons and last but not least the struck cascade could interact with the others. Such multiparton interactions and rescatterings could contribute to a large energy transfer in a collision volume of proton size, easily reaching the deconfinement conditions. If this is the case and considering that the mean free path of the constituents in a deconfined medium is of the order of 0.2-0.3 fm, a close to equilibrium deconfined initial state could be expected at very high energy pp collisions. Therefore, quite probable at such energies, a piece of matter of the proton size, with a radius few times larger than the mean free path, expands hydrodynamically once the energy transfer is significantly large, i.e. low impact parameter - high charged particle multiplicity.
Preliminary results obtained in Run1 at which our group had a significant contribution seem to support such a scenario. Run2, with a gain in energy of a factor of two for p+p and Pb+Pb collision and higher luminosity will create premises to perform such studies in a differential way, to extend them at even higher charged particle multiplicities and other species than identified charged hadrons and hyperons. Another important aspect worth to be studied is the possibility to discriminate between hard and soft processes. Preliminary studies along the possibility to select events close to azimuthal isotropy using global event shape observables like Directivity, Sphericity, Thrust or Fox-Wolfram moments have shown their performance in selecting soft, nearly azimuthal isotropic events. Although the correlation of each of these global event shape variables with multiplicity is rather good, at the largest multiplicities the global event shape variables have a rather broad distribution. Thus, a two dimensional condition in multiplicity and different event shape variables could significantly contribute in selecting events with specific azimuthal distribution for a given multiplicity. The two-dimensional distribution of particles in η-φ and p_x-p_y for azimuthal isotropic events selected using such event shape variables confirmed the expectation. These information plays crucial role in understanding the features observed in p+Pb and Pb+Pb collisions at LHC energies. Therefore, a special attention will be given to the comparison of dependence of different observables as a function of the collision violence among the three systems. In order to increase the ALICE capability for running in high luminosity conditions foreseen to be the case in Run3, a major upgrade program of the experiment is on the way. The 5 pillars of the ambitious upgrade program, i.e.: ITS - Inner Tracking System, TPC (Time Projection Chamber), MFT (Muon Forward Tracker), New Readout electronic and software, New architecture for Data Acquisition - DAQ and High Level Trigger have already approved Technical Design Reports (TDR) and construction and tests phase is on the way to start. The amount of data obviously will increase and therefore a special attention will be given to the

computing power and storage capacity delivered by ALICE-GRID infrastructure worldwide distributed.

2. Romanian contribution to the CERN experiment through the proposed project

As it is well known by now, A Large Ion Collider Experiment (ALICE) at CERN is a general-purpose heavy-ion experiment designed to explore the ultra-dense region of the QCD (Quantum ChromoDynamics) phase diagram, far above the critical temperature where a transition to a deconfined matter, formed by its basic constituents, i.e. quarks and gluons, is produced in nucleus-nucleus collisions at LHC energies. In addition to heavy systems, the ALICE experiment is devised such that collisions of lower-mass ions, pA and pp can be also studied. Such studies provide reference data for the nucleus–nucleus collisions and a number of genuine pp physics studies turned out to be of great interest once the new data became available from the first experiments at $\sqrt{s}$=7 TeV.
Up to now, our group proposed and worked out a physics topic, i.e. studies of hadrons transverse momentum distributions as a function of charged particle multiplicity and event shape in p+p collisions, which turned out to be one of the most interesting phenomena to be studied in detail at LHC energies. Transverse momentum distributions and their ratios for π, K and p at mid rapidity ($|y|$ <0.5) for different charged particle multiplicities in pp collisions at $\sqrt{s}$ = 7 TeV show an enhanced depletion of heavier species relative to the lighter ones in the low p_T region with increasing charged particle multiplicity. The quality of simultaneous fits of the experimental spectra using a Boltzmann-Gibbs Blast Wave (BGBW) expression and the dynamics of the extracted kinetic freeze-out temperature T_{kin}, average transverse expansion velocity $\langle\beta_T\rangle$ and its profile n as a function of multiplicity have been shown to be similar with those obtained in heavy ion collisions. Preliminary estimates of the Bjorken energy density for high multiplicity events indicate values at least of the same magnitude as the ones estimated for the central Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV. Selection of high multiplicity events close to azimuthal isotropy based on event shape global observables seems to be feasible. A direct comparison among pp, p-Pb and Pb-Pb as a function of charged particle multiplicity has to be taken with care. The results were presented and published in prestigious international conferences and ISI journals, respectively. Presently we are involved in finalizing the results for two more papers, one of them being an extensive presentation of most of the results obtained up to now related to this topic. In the next period we aim to obtain more information on the properties of the matter formed in such collisions and its subsequent dynamics up to the formation of the hadrons.
Our group will continue to contribute to the ALICE detector operation and data taking during Run2 by shifts in the ALICE experiment.
Improvement of the software packages related to the TRD calibration quality insurance and associated tracking and their use for obtaining final information to be analyzed for specific physics aimed to be extracted from the experimental data, is a natural continuation of our previous visible and competitive contribution in this segment of activity within ALICE Collaboration.
NIHAM Data Centre will continue to be one of the most efficient Tier2 components of ALICE GRID. It is also important to maintain at the same level of performance the NIHAM Analysis Facility (NAF) used for developing software packages for calibration, tracking, data analysis, large scale microscopic calculation using different theoretical models and fast local analysis.
We are involved in ALICE upgrade program with assembling and tests of OROCs (50%) based on GEM technology using the infrastructure, know-how and manpower of our Hadron Physics Department. The completion of the Detector Laboratories infrastructure with specific tools is required for this new activity which will start during 2016.
Within the Readout and Trigger System upgrade program we will be involved in the reconstruction of the TRD information for high rate experiments based on the online processed front-end data (tracklets).

3. Project objectives

O1. Analysis and physics interpretation of experimental p+p data obtained with the ALICE detector, comparison with Pb+Pb and p+Pb data and detailed Monte Carlo simulations.

Based on the results obtained up to now, more detailed analysis and comparison with models in order to understand the properties of the matter formed in pp collisions and its subsequent dynamics up to the formation of the hadrons and comparison with heavier systems is required.

O2. p+p; A+A; p+A and cosmic rays experiments using the ALICE detector.

In order to access high quality experimental information, the ALICE experiment has to be kept and run in continuous mode and best conditions as far as LHC delivers beam.

O3. Quality monitoring, Calibration & Tracking of ALICE TRD subdetector.

Online and offline monitoring of the performance of different detectors is equally important, our group having clear commitments in this respect related to the ALICE-TRD subdetector.

O4. Operation and development of NIHAM Data Centre: ALICE GRID site and NAF components.

In order to have access to the experimental information and perform physics analysis on it we have to continue our efforts at least to maintain the present position of NIHAM data centre within ALICE-GRID.

O5. Contributions to the ALICE-TPC and ALICE-TRD Upgrade.

In order to increase the ALICE capability for running in high luminosity conditions foreseen to be the case in Run3, a major upgrade program of the experiment is on the way.
As a consequence of our local infrastructure, previous contributions to the ALICE experiment and expertise, we have clear commitments in two of the five ALICE upgrade pillars, i.e. TPC and New architecture for Data Acquisition - DAQ and High Level Trigger especially for the TRD detector. Both of these have already approved TRDs and preparatory activities already started.

4. Main project activities

Following our scientific goal to answer to the question: “Do we see collective radial flow in pp collisions at LHC?”, we will focus on obtaining more refined information by analyzing the experimental data. Thus:

- Precise estimates of the Bjorken energy density as a function of charged particle multiplicity, with the aim to find meaningful comparison among p-p, p+Pb, Pb+Pb such to pin down the origin of the observed similarities and differences will be done.

- The influence of the charged particle multiplicity phase space selection on the obtained results, biased and unbiased selections and the comparison among the three very different systems, i.e. p-p, p-Pb and Pb-Pb will be studied.

- Detailed studies of the dependence of corrections applied to raw spectra on the event shape global variables, the key ingredients in order to access unbiased information, on their selection power and properties of the specific events selected by them will be done.

- The experimental data will be analyzed following the same type of analysis in terms of transverse momentum distributions, yields, average transverse momentum and their systematics, by applying two dimensional cuts in charged particle multiplicity and event shape. Thus the recent extension of the in-house existing codes to other phenomenolgical model fit formulas of the spectra will be of help to study the dependence of the fit parameters on the different systems and energies.

- Differential studies of two-particle correlations as a function of multiplicity and event shapes will be developed.

- A factor two in the collision energy enlarges the dynamical range of such studies and the expected higher statistics in Run2 will give access to extend them at heavy flavor hadrons and comparison with the results obtained in Pb-Pb collisions

- Detailed comparisons with PYTHIA, EPOS and other model predictions will be done. EPOS LHC and EPOS3 codes have been implemented in our group. The preliminary p_T distributions for pions, kaons and protons in pp collisions at $\sqrt{s}$ =7 TeV have been compared with both versions of the model for minimum bias and all the multiplicity bins. Preliminary results show that the EPOS LHC version provides a slightly better overall description of the data as compared to EPOS3 version. Nevertheless, very accurate final experimental distributions which will be obtained by us and the comparison with theoretical predictions will contribute to the refinement of the EPOS3 model based on hydrodynamical calculations.

In order to obtain experimental information of high quality, it is obvious that such a complex experiment as ALICE has to run at its highest performance in a continuous mode as long as LHC delivers beam. During the Run2 period, members of our group will continue to follow the tutorial and training courses specific to different tasks of the shift team and any other type of informal meetings organized at the Collaboration level such that their shifts will be of high quality and efficiency. Specific information gained up to now by different members of our group will be discussed within the group such to increase the coherence of our contribution to this segment of activities. This will be done following the shifts sharing algorithms which will be established by the Collaboration and balanced with other tasks essential for the experiment, committed by our group.

Online and offline monitoring of the performance of different detectors is mandatory in order to guaranty the quality of experimental information taken during running the experiment. Part of it is considered to be a service task which has to be fulfilled by a PhD student during the period in which the PhD is elaborated. Having in house the expertise in developing and running the software packages for TRD tracking, our PhD student embarked on this service task and will continue to do it during the Run2 period. As the understanding of the ALICE experimental set-up matures over time and the interaction rates increase a new paradigm has to be accommodated. Thus the TPC detector is no longer regarded as the main player in the ALICE barrel with ITS and TRD becoming more relevant. The new paradigm is focused on developing a common alignment and calibration framework built on adjusting all the 3 detectors relative to each other. Development of the software packages related to the TRD calibration and associated tracking has to follow suite and align to this common framework. New effective calibration parameters has to be defined and implemented such to accommodate a more versatile interpretation of data in a situation where the reference (as was TPC previously considered) is missing. The implication of our group in these developments come as a natural continuation of our previous visible and competitive contribution in this segment of activity within the ALICE Collaboration.

We would like to mention here that more than 10 years ago, we realized the first international GRID application in Romania within ALICE-GRID. Over the years, our NIHAM Data Centre was developed such that presently it is one of the most efficient Tier2 components of ALICE GRID. In order to have access to the experimental information and perform physics analysis on it we have to continue our efforts at least to maintain the present position of NIHAM data centre in ALICE-GRID. This can be achieved by permanent monitoring, in due time interventions, replacement of failing hardware components, efficient interaction with offline ALICE experts. It is also important to maintain at the same level of performance the NAF (NIHAM Analysis Facility) used for developing software packages for calibration, tracking, data analysis, large scale microscopic calculation using different theoretical models and fast local analysis in order to validate them before being released on ALICE-GRID. The NIHAM data centre performance can be followed on: http://pcalimonitor.cern.ch:8889/map.jsp.

Two of the 5 pillars of ALICE upgrade program for high luminosity LHC conditions foreseen to be in Run3 are TPC and New architecture for Data Acquisition - DAQ and High Level Trigger which have already approved TDRs and the associated activities already started.
Based on our essential contribution in assembling and testing 24% of the ALICE-TRD chambers in our Department, we are embarked in the ALICE-TPC upgrade program with assembling and testing in HPD 50% of the Outer (largest) ReadOut Chambers (OROCs) of ALICE-TPC based on GEM technology. Up to now, preparatory activities for assembling and tests of OROCs based on GEM technology for ALICE-TPC upgrade were carried out, i.e. a new ISO6 room of the DetLab was organized and equipped with a two-dimensional optical device based on a microscope and video-camera interfaced with a computer ; in-house OROC positioning and transport device was designed, different components were machined in our workshop and assembled ; few experts from our Department participated in Munich at GEM foils framing and tests and at CERN in assembling and tests of an OROC ; we proposed, designed, assembled and successfully tested a light and low absorbtion test housing box for ROCs, two more are on the way to be finalized, one for GSI DetLab and one for in-beam tests at SPS, etc.
Gas mixture device, picoampermeters, HV units for operating and testing the OROCs will be installed and comissioned in the next period. A ISO5 clean room for OROC storage after their assembling and tests, before being transported at CERN will be finalized in the next period. An upgrade of the two-dimensional scanning device interfaced with a computer and data acquision system, which will be used for extensive tests of the assembled OROC in our laboratory will be done. In the meantime we are working on developping a system for packing and transportig OROCs in a very clean atmosphere, with neglijable contamination of Oxigen and H_2O. All these activities have to be finalized in the first half of 2016 such that starting from mid 2016 the main activity of assembling and tests of OROCs could start. Until the end of 2018 20 OROC chambers, i.e. half of them, the other half being assembled and tested at GSI-Darmstadt, Germany, have to be finalized and transported at CERN. This will be another unique contribution of a Romanian research Institute to a large international Collaboration such as ALICE is.

Participation to the ALICE upgrade program encompass besides TPC-OROC construction also a significant contribution to the TRD reconstruction software needed to decode high interaction rates data foreseen for the ALICE Run 3 conditions. As the front-end level read out will be changed from the current format (discreet signals) to more tracking oriented data (online tracklets) the offline reconstruction has to handle the new data format and adapt to the particularities of it. Besides the implication in the offline reconstruction which the new running conditions will bring, there is also an open question on the optimized format of the online tracklets. The new format has to conserve within the limited amount of band-width available (128bits/MCM), fixed by construction, as much as possible the quality of TRD physics output in terms of position reconstruction precision and particle identification capabilities. Such collaboration between online and offline processing is a challenge as any non-optimal decision made in the online data format may have damaging effects on the data acquisition impossible to correct offline as might be the case now.
Besides the proper reconstruction which has been discussed before the TRD detector is foreseen to have a high role in the global calibration of the ALICE barrel detectors and particularly for the TPC detector which is a much slower one. In view of this task a possible new development might be needed in which TRD will be asked to provide its best estimates on particle position independent of the rest (the best scenario being with TPC bridging the gap between ITS and TRD). In such a case a totally independent standalone TRD tracking will be developed/adapted to the new data format.

Although such code is already developed it was never matured enough to enter in the production mode. This time it becomes mandatory. Local expertise in the TRD tracking development was the reason for which ALICE collaborators asked us to continue our involvement in this project and try to cover all topics mentioned above.

As up to now, a special attention will be payed to outreach activities. This usually consists of yearly Summer Student Program, guided visits of our Department for groups of pupils from middle and high school, students, official delegations, open doors day. Other activities will be envisaged according to similar activities organized by our Institute, CERN, at national or international level. The web page of our Department (http://niham.nipne.ro) will be permanently updated.

5. Project development and expected results

Multi-step presentation. Milestones and expected results.

Obj. Code	Objective description	Milestones	Expected result	Time schedule justification
O1.	Following the previous results, we will focus on obtaining more complete physics information by analyzing the experimental data on pp collisions and compare the results with heavier systems.	1. Precise estimates of the Bjorken energy density as a function of charged particle multiplicity. 2.Transverse momentum distributions, yields, average transverse momentum, fits with phenomenological models by applying two dimensional cuts in charged particle multiplicity and event shape. 3. Two-particle correlations as a function of event shape - A f4. A factor two in the collision energy enlarges the dynamical range of such studies and the expected higher statistics will give access to extend them at heavy flavor hadrons and compare with the results obtained in Pb-Pb collision. 5. Detailed comparisons with PYTHIA, EPOS and other model predictions.	1. Completion of analysis and data base for comparison of different systems 2.Confirmation of the flow phenomena in pp collisions by trying to select soft and hard components. 3. A complementary study on flow phenomena in pp collisions. 4. Same type of previous studies on other particles. 5. Disentangling between models with and without flow	1. Preliminary results by the end of year 2016 are expected. 2. Preliminary multidimensional efficiency corrections and the multiplicity selector study at the end of 2016. First physics results at the end of 2017. 3. Being a new type of analysis physics results are expected by the end of 2018. 4. Results are envisaged at the end of 2018. 5. Will accompany any new physics result.
O2.	Contribution to the ALICE detector operation and data taking during Run2	Shifts at the central systems of the ALICE experiment.	Contribution to the continuous data taking in good conditions	Years 2016,2017,2018 according to the ALICE LHC schedule

Obj. Code	Objective description	Milestones	Expected result	Time schedule justification
O3.	Offline monitoring of the performance of the ALICE-TRD subdetector.	1. Maintaining and development of the offline tracking of the ALICE-TRD subdetector 2. PhD student task sevice	1. Improvement of the software packages related to the TRD calibration and associated tracking. 2. ALICE TRD performance in Run2.	Years 2016,2017 according to the requirement of data analysis quality in Run2 Years 2016,2017 (this service task ends by the end of 2017)
O4.	Efforts to at least maintain the present position of the NIHAM data centre within ALICE-GRID.	1. NIHAM Data Centre will continue to be one of the most efficient Tier2 components of ALICE GRID. 2. Maintain at the same level of performance the NAF used for developing software packages for calibration, tracking, data analysis, large scale microscopic calculation using different theoretical models and fast local analysis.	1. ALICE-GRID high performance. 2. Maintain and improve NAF utility	Years 2016,2017,2018 Years 2016,2017,2018 Permanent activity.
O5.	Assembling and tests of OROCs (50%) based on GEM technology using the infrastructure, know-how and manpower of our Hadron Physics Department. Fast tracklets reconstruction at the front-end level of ALICE-TRD.	1. The completion of the Detector Laboratories infrastructure with specific tools is required for this new activity and the activity will start during 2016. 2. Assembling and tests of OROCs (50%) based on GEM technology 3. Contribution to RUN 3 TRD upgrade	1. Complete the infrastructure of the Detector Laboratories of HPD 2. 50% of the OROCs 3. ALICE-TRD new tracking for Run3.	3rd semester of 2016 till the start of production Years 2016,2017,2018 according to ALICE- TPC Upgrade schedule Year 2018 according to ALICE-TRD Upgrade schedule

6. Scientific and technological output of the project

Minimum estimated number of ISI publications, reports, joint patents, know-how, mock-ups, other (specify).

Scientific publications in ISI international publications ~ 20/year

- Communications to scientific national and international meetings ~ 10 /year
- Internal Presentations in the Collaboration ~ 10/year
- PRC participation ~ 2/year
- Analysis Notes ~ 3/year
- Public Notes ~ 1/year
- Continuous Update of the NIHAM web pages
- Upgrade developments and results and their sharing to the ALICE Community
- Development and operation in good security conditions of our Data Centers – NIHAM and NAF
- If all conditions are fulfilled , involvment of new members in any form of support in our group on temporary or permanent positions
- Diploma and PhD thesis
- Outreach products
- Run 2 Shifts: at least 75% (of our quota)/year.

7. Project impact

Scientific/technological/educational/social (etc) impact.

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

The envisaged scientific output, i.e. to produce and study states of matter which might have been characteristic for the very first moments of the Universe or the inner core of neutron stars belongs to the challenging tasks of humankind to find answers to ultimate questions. This is one of the front-end segment in basic research of our days in which we are embarked in a visible and competitive way.

The involvement of our group in assembling and testing (50%) of the TPC-OROCs based on GEM technology is a natural consequence of the successful, visible and competitive participation of the Romanian group to the production, test, installation and monitoring of the TRD chambers for ALICE experiment at CERN in the previous period.

Based on the infrastructure realized in our Department and the know-how built up during the activities mentioned above, we developed a few highly performing prototypes of TRD and RPC detectors and the associated front-end electronics at chip level for high counting rate experiments on which important components of CBM experiment at FAIR will be based.

Fitting out of a technological infrastructure and training people for detector production, test and integration will allow not only to have a visible and competitive participation at large international collaborations like ALICE and CBM are, but also to be involved in other projects at European level of similar complexity. We were involved in the I3HP within FP6, HadronPhysics2 and HadronPhysics3 of FP7 and we are coauthors to a proposal within HORIZON 2020 Program of the European Commission.

Experience in modern electronics design, places 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 and the impact on the activities related to the basic research, will surely pay back in the coming years.

Hardware and software structures of distributed computing network type which have shown their performance 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 WLCG.

The new type of two-dimensional position sensitive detectors and their front-end electronics developed by our group, highly appreciated at Geneva Salon of Inventions have high potentiality to be transferred towards applied physics and technology.

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, master and PhD theses.

They will become highly qualified specialists, extremely useful in various branches of activity.

During the last years in our group were finalized 3 Master Theses, 2 PhD Theses and one PhD is in progress. Based on the results obtained in this project to members of our group were promotted to Scientific Researcher 2nd Degree, 2 to Scientific Researcher 3rd degree and one to Thechnological Engeneer 2nd degree.

A regular Summer Student Programme was initiated by our Department, becoming by now a tradition, which facilitates the direct access of the students of different faculties to all segments of activities involved in our research. As up to now we will contribute to lectures for the Doctoral School of Physics Faculty of Bucharest University and educational intitiative for special schools organized for pupils wining national and international competitions in Physics and Mathematics.