

## Annual Summary Document RONIPALICE

### 1. Project team

- Prof. Dr. Mihai Petrovici (physicist) – team leader
- Senior researcher III Daniel Bartos (physicist)
- Senior researcher I Dr. Ionela Berceanu (physicist)
- Senior researcher III Dr. Alexandru Bercuci (physicist)
- Senior researcher II Gheorghe Caragheorghopol (electronics engineer)
- Senior researcher II Dr. Vasile Catanescu (electronics engineer)
- Senior researcher II Dr. Florin Constantin (physicist)
- Senior researcher II Viorel Duta (mechanical engineer)
- Senior researcher II Gheorghe Giolu (mechanical engineer)
- Senior researcher III Dr. Mariana Petris (physicist)
- Prof. Dr. Alexandrina Petrovici (physicist)
- Senior researcher I Dr. Amalia Pop (physicist)
- Senior engineer II Dr. Laura Radulescu (mechanical engineer)
- Senior researcher II Dr. Victor Simion (physicist)
- Computing coordinator Claudiu Schiaua (physicist)
- Researcher Cristian Andrei (physicist)
- Researcher Dr. Andrei Herghelegiu (physicist)
- PhD student Madalina Tarzila
- Technician Valerica Aprodu
- Technician Lucica Prodan
- Technician Andrei Radu
- Technician Constanta Dinca
- Financial coordinator Georgiana Rosu (economist)

- Specific scientific focus of group

Multiplicity and event shape analysis in pp collisions – subject proposed by our group within ALICE Spectra PAG – PWG-LF since 2009:

(<https://twiki.cern.ch/twiki/bin/view/ALICE/PWGLFPAGSPECTRAMultiplicityEventShapePP7>).

The aim is to evidence collective type phenomena in high charged particle multiplicity and close to azimuthal isotropy events in pp collisions at LHC energies.

- Summary of accomplishments in the last year

- comparison of pp, p-Pb and Pb-Pb systems in terms of collision geometry and its selection using experimental observables
- extension of the  $p_T$  range of kaons from 1.4 GeV/c to 2.5 GeV/c
- comparison of the Bayesian PID procedure with other PID methods used in ALICE
  - pile-up effect on charged particle spectra as a function of multiplicity
  - comparison of the experimental results with EPOS-LHC and EPOS3
  - TRD tracking activities
- configuration of the NAF and the accomplishment of the integrated video conferencing system
- upgrade of the Detector Laboratory
- shifts in the re-commissioning period of ALICE
  - outreach activities.

### 2. Scientific accomplishments – Results obtained in the last year.

In the last year the group activity focused on:

- comparison of pp, p-Pb and Pb-Pb systems as a function of multiplicity and centrality.

The ALICE Collaboration has recently presented detailed results, obtained by us, on transverse momentum spectra of  $\pi^+$ ,  $K^+$  and p measured at LHC in pp collisions at  $\sqrt{s} = 7$  TeV as a function of charged particle multiplicity. The charged particle multiplicity was measured in the central pseudorapidity region  $|\eta| \leq 0.8$  and the analysis was done in a narrower range of rapidity  $|y| \leq 0.5$ . The pT spectra were analyzed from 0.2 GeV/c, 0.3 GeV/c and 0.5 GeV/c up to 2.6 GeV/c, 1.4 GeV/c and 2.6 GeV/c for  $\pi^+$ ,  $K^+$  and p respectively and in eight bins of multiplicity up to  $\sim 50$  measured charged particle multiplicity density per unit of pseudorapidity.

The pT dependence of  $p/\pi$  for the second and highest multiplicity bins for pp and of  $(p + p)/(\pi^+ + \pi^-)$  ratio for p-Pb in 60–80% and 0–5% multiplicity classes and for Pb-Pb at 80–90% and 0–5% centralities show a push of protons towards larger pT values relative to pions with increasing centrality or multiplicity for all three systems. Quantitatively, the ratios of the  $p/\pi$  for the two bins show that the ratio for pp follows closely the p-Pb trend as a function of pT.

Based on these similarities, information on collective type dynamics from the fits of experimental transverse momentum spectra using expressions inspired by hydrodynamical models were obtained. The average transverse expansion velocity ( $\langle \beta_T \rangle$ ) and kinetic freeze-out temperature ( $T_{kin}$ ) were obtained as fit parameters. The results of simultaneously fits on  $\pi^+$ ,  $K^+$  and p spectra, in terms of  $T_{kin} - \langle \beta_T \rangle$  correlation as a function of charged particle multiplicity were compared with the results obtained for Pb-Pb and p-Pb as a function of centrality and multiplicity classes, respectively. One could conclude that for pp collisions at 7 TeV, the  $T_{kin} - \langle \beta_T \rangle$  correlation as a function of charged particle multiplicity has a trend rather similar with the one observed in heavy ion collisions, i.e. the freeze-out kinetic temperature decreases and the average transverse expansion velocity increases with charged particle multiplicity (pp) or increasing centrality (A-A). However, there is a quantitative difference between pp and A-A collisions, i.e.  $T_{kin}$  is systematically lower and  $\langle \beta_T \rangle$  systematically larger than the pp values, the difference increasing towards higher centralities. Within the error bars, the results for p-Pb at 5.02 TeV are the same with the ones evidenced in pp. Such a correlation is not reproduced by PYTHIA for the pp case. Including the color reconnection mechanism it seems that the model starts to show a similar trend but with values of  $T_{kin}$  about 40 MeV lower. Another aspect worth to be mentioned is the correlation between the expansion profile ( $n$ ) and  $\langle \beta_T \rangle$ . This clearly shows that all three systems follow exactly the same correlation. Towards the highest multiplicity in the pp case, the expansion velocity becomes linear as a function of position within the fireball. The  $n - 1/T_{kin}$  correlation shows that the PYTHIA prediction is completely different than the experimental one.

However, a conclusion about similar mechanisms for the three systems has to be taken with caution. Detailed investigations based on theoretical approaches such as hydrodynamic models, parton based Gribov-Regge theory, Color Glass Condensate, Color Reconnection, will give insight to the underlying physics of this similar behavior observed at LHC energies.

- development of a new analysis software mainframe

The software mainframe used for data analysis followed in our department has suffered recently a major update to get aligned with the requirements of physics analysis put forward by the ALICE Offline Project - AliRoot. Thus the whole analysis was divided into 2 main parts:

- a general infrastructure used to gather all reconstructed data from the Event Summary Data (ESD) provided by the framework
- user specific tasks, following specific features of the generally derived reconstructed results.

- comparison of the Bayesian PID procedure with other PID methods used in ALICE.

In order to test the possibility to extend the pT range for the preliminary kaon transverse momentum distribution we analyzed approximately  $19 \cdot 10^6$  inelastic pp collisions collected by ALICE during the 2010 run at the LHC (period LHC10d, pass 2), using a minimum-bias trigger, at an injection

energy of  $\sqrt{s} = 7$  TeV. The Bayesian PID framework with priors obtained from the data using the iterative procedure, was used for the identification of charged hadrons. The TuneOnData and EtaCorrection options were switched on. The particle species with the highest probability was selected, without applying any purity cut. The identification of charged hadrons is based on the information delivered by the TPC and TOF subdetectors in the ALICE central barrel in different momentum ranges.

In order to check the performance of the method, the final MB  $p_T$  distributions from this analysis are compared with the  $p_T$  distributions of preliminary 7 TeV pp MB spectra obtained by merging results from the  $n\sigma$  method, the unfolding procedure and kinks. A very good agreement within the statistical uncertainties can be observed between the  $p_T$  spectra obtained using the two methods. Their ratios show an agreement within  $\pm 5\%$ . It must also be noted that this agreement was reached despite differences in the beam conditions between the periods under analysis.

- pile-up effect on charged particle spectra as a function of multiplicity

The main activities were focused on refining the evaluation of systematic errors estimations as well as on decreasing the statistical errors of the charged particle transverse momentum distributions as a function of multiplicity. These two activities complemented each other and were done in parallel. The systematic errors were concentrated mainly on the pileup effect (more than one collision in each event) which could introduce an important bias in the charged particle transverse momentum spectra at high luminosities. Since the transverse momentum spectra have different shapes as a function of multiplicity, the effect of the pileup can be observed in the shape of the spectra and, therefore, the evaluation of the pileup effect was done by comparing the spectra in different multiplicity bins for runs recorded at different luminosities. The ALICE experiment recorded during the 2010 period also higher luminosity runs. This allowed us to investigate to which extent we could include in our analysis also runs with higher  $\mu$  values. In the analysis were included all the runs for which  $\mu$  was independently estimated. Adding more statistics to the data sample allow us to decrease the statistical errors and, also, expand the momentum and multiplicity range of the analysis without the need to rebin the histograms. This investigation has implications on the usage of the LHC10e period that includes a high multiplicity trigger and  $\mu$  values up to 0.079. Once the LHC10e runs are validated and the high multiplicity trigger is shown to be unbiased, up to three extra multiplicity bins can be added to the standard analysis done using the minimum bias trigger. Since the statistical errors can be reduced by increasing the data sample analyzed, these studies have implications also on the evaluation of the statistical errors for high multiplicity and high transverse momentum bins. A rebin procedure was also investigated as a possibility to extend the  $p_T$  range after all the available statistics was used.

- comparison of the experimental results with EPOS-LHC and EPOS3 (low statistics)

EPOS is a sophisticated multiple scattering approach based on partons and Pomerons (parton ladders), with special emphasis on high parton densities. The latter aspect, particularly important in proton-nucleus or nucleus-nucleus collisions, is taken care of via an effective treatment of Pomeron-Pomeron interactions, referred to as parton ladder splitting. In addition, collective effects are introduced after separating the high density central core from the peripheral corona. EPOS is the successor of the NEXUS model.

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 MB and all the multiplicity bins. As a conclusion 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 and to the answer of the question: Do we see collective radial flow in pp collisions at LHC?

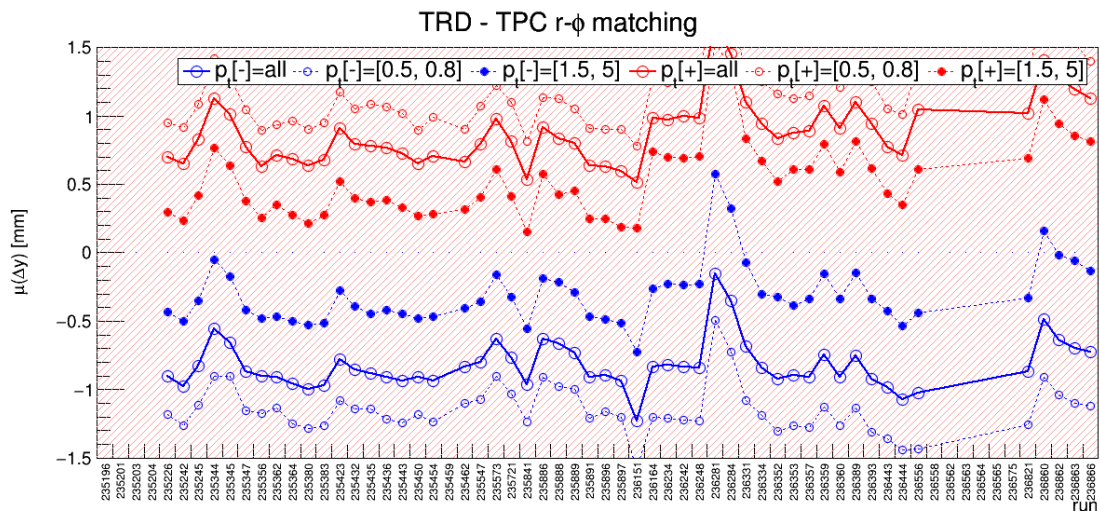
In our studies it is important to use an unbiased multiplicity estimator. EPOS3 was used to build correlation matrices between different estimators in terms of the  $\eta$  range. Forward pseudorapidity estimators seem to introduce a saturation at high multiplicities.

- TRD tracking activities

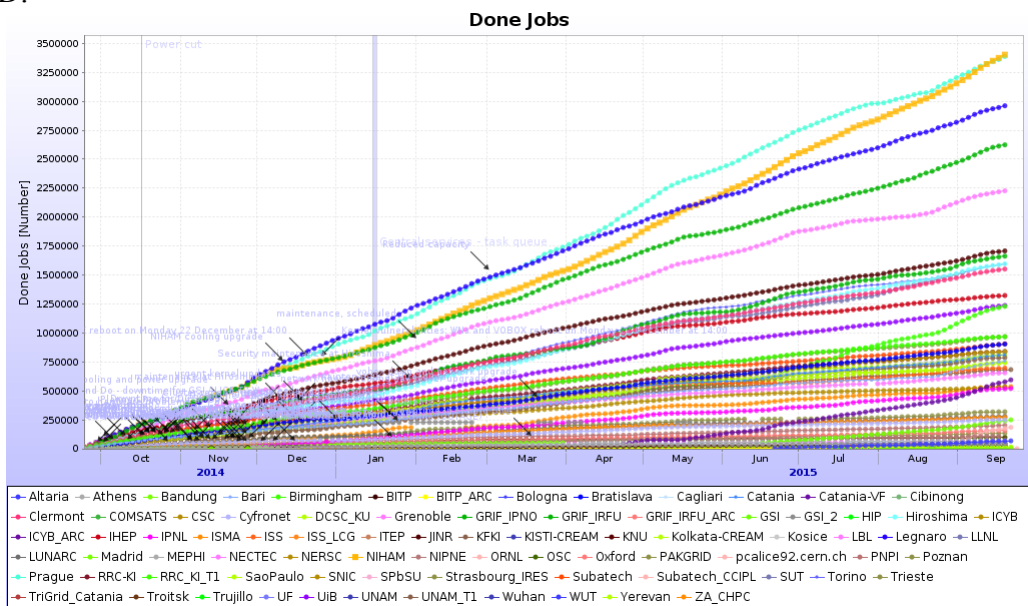
### TRD QA

- Prepare the TRD-QA for running as a regular production on GSI servers and have the results published on the public domain of CERN (<http://aliquatrd.web.cern.ch/aliquatrd>)
- Train a PhD student for TRD-QA service task and regular reports on the dedicated ALICE QA meetings.

[http://aliquatrd.web.cern.ch/aliquatrd/data/2015/LHC15i/pass1/TPC-TRD\\_matching\\_yshift.png](http://aliquatrd.web.cern.ch/aliquatrd/data/2015/LHC15i/pass1/TPC-TRD_matching_yshift.png)

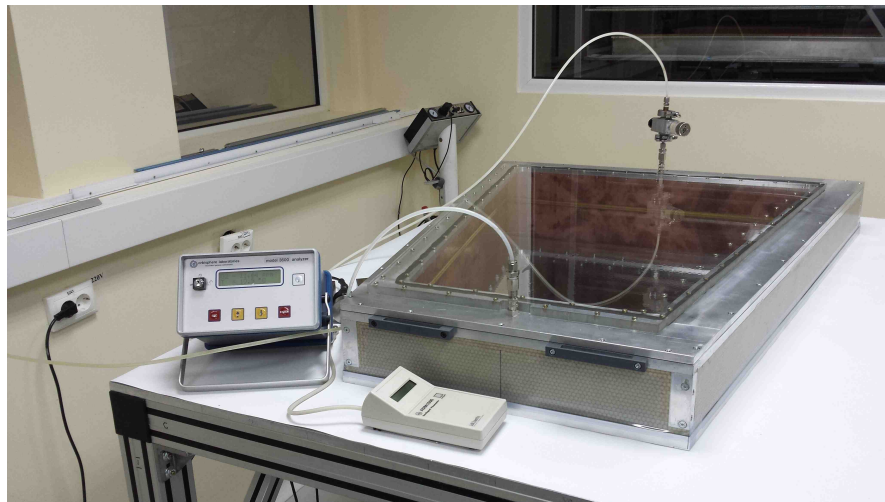


- NIHAM Data Centre continues to be one of the most efficient Tier2 components of ALICE GRID.



This is a direct consequence of continuous efforts for permanent monitoring, in due time interventions, replacement of failing all type of hardware components, efficient interaction with offline ALICE experts.

- Preparatory activities for assembling and tests of OROCs based on GEM technology for ALICE-TPC upgrade
  - The new ISO6 room of the DetLab was equipped with a two-dimensional optical device based on a microscope and video-camera interfaced with a computer.
  - A group of experts from our Department participated in Munich and CERN at GEM foils framing and tests and assembling and tests of an OROC, respectively.
  - Based on our previous experience we proposed designed, assembled and successfully tested a light and low absorption 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.



- The tightness was tested. With a over- and under-pressure flow of  $\sim 6\text{l/hour}$ , the level of Oxygen was below 10 ppm after 24 hours.
- Proposed, designed and partly worked-out the prototype for ROCs transport in safe and clean atmosphere from the production sites to CERN.
- Gas mixture device, picoamps, HV units for operating and testing the OROCs were purchased
- In-house OROC positioning and transport device was designed, different components were machined in our workshop and assembled.

- shifts in the re-commissioning period of ALICE

Although the above mentioned activities, our group tries to fulfil also the duties related to the allocated shifts necessary to run the ALICE experiment. This year we took the necessary tutorials and made already 7 shifts and 3 more are booked until the end of this year at the DAQ+HLT+CTP system.

### 3. Group members

- List each member, his/her role in project and the Full Time Equivalent (FTE) % time in project. The FTE formula to be used is:  $\text{FTE} = \text{Total number of worked hours in the last year} / 1020 \text{ hours}^1$ ;

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1020 hours = 170 average monthly hours x 6 months

Name	Analysis	R&D	Detector operation	Detector construction	Infrastructure Planning Financial issues Outreach Contracts
Mihai Petrovici	35%		5%		32.13%
Daniel Bartos		44.33%			
Ionela Berceanu	57.2%				
Alexandru Bercuci	51.8%		5%		
Gheorghe Caragheorgheopol		57.15%			
Vasile Catanescu		57.15%			
Florin Constantin		22.14%			
Marin Duma					
Viorel Duta					23.31%
Gheorghe Giolu					42.28%
Iosif Legrand					
Mariana Petris		56.8%			
Alexandrina Petrovici					10.54%
Amalia Pop	62.76%		20%		10.0%
Laura Radulescu		16.59%			10.0%
Victor Simion		57.15%			
Claudiu Schiaua			10%		48.94%
Andrei Cristian	41.8%		15%		
Andrei Herghelegiu	36.8%		20%		
Madalina Tarzila	36.8%				20.0%
Petre Zaharia					41.87%
Valerica Aprodu		40.73%			
Lucica Prodan		25.00%			35.55%
Andrei Radu		30.00%			31.47%
Constanta Dinca		15.00%			21.22%
Georgiana Rosu					56.81%

- List of PhD/Master students and current position/job in the institution.

Name	PhD student	Present status
Madalina Tarzila	X	Research assistant IFIN-HH

#### 4. Deliverables in the last year related to the project:

- Papers:**
  - Suppression of  $\Upsilon(1S)$  at forward rapidity in Pb–Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV, ALICE Collaboration, Phys. Lett. B (2014) 361-372
  - Performance of the ALICE Experiment at the CERN LHC, ALICE Collaboration, Int. J. Mod. Phys. A 29 (2014) 1430044

- [Beauty production in pp collisions at  \$\sqrt{s} = 2.76\$  TeV, measured using semi-electronic decays, ALICE Collaboration, PLB 738 \(2014\) 97-108](#)
- Transverse momentum dependence of inclusive primary charged-particle production in p-Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV, ALICE Collaboration, Eur. Phys. J. C 74 (2014) 3054
- Azimuthal anisotropy of D meson production in Pb-Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV, ALICE Collaboration, [Phys. Rev. C 90 \(2014\) 034904](#)
- Measurement of quarkonium production at forward rapidity in pp collisions at  $\sqrt{s} = 7$  TeV, ALICE Collaboration, [Eur. Phys. J. C 74 \(2014\) 2974](#)
- Production of charged pions, kaons and protons at large transverse momenta in pp and Pb-Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV, ALICE Collaboration, PLB 736 (2014) 196-207
- Centrality, rapidity and transverse momentum dependence of  $J/\Psi$  suppression in Pb-Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV, ALICE Collaboration, [Phys. Lett. B 743 \(2014\) 314-327](#)
- Measurement of charged jet suppression in Pb-Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV, ALICE Collaboration, JHEP03 (2014) 013
- $J/\Psi$  production and nuclear effects in p-Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV, ALICE Collaboration, JHEP02 (2014) 073
- Two and Three-Pion Quantum Statistics Correlations in Pb-Pb Collisions at  $\sqrt{s_{NN}} = 2.76$  TeV at the LHC, ALICE Collaboration, Phys. Rev. C 89 (2014) 024911
- Upgrade of the ALICE Inner Tracking System - Technical Design Report, ALICE Collaboration, J. Phys. G. 41 (2014) 087002

- **Conferences:**

- Collectivity phenomena search in pp, pPb and PbPb collisions with ALICE at the LHC  
Stefania Bufalino for the ALICE Collaboration, International Workshop on Discovery Physics at the LHC, 1-6 December 2014, Kruger Park, South Africa
- Transverse momentum spectra of light-flavor hadrons measured with ALICE in pp, p-Pb and Pb-Pb collisions at the LHC, Jacek Otwinowski for the ALICE Collaboration,  
6<sup>th</sup> International Workshop on Multiple Partonic Interactions at the LHC, 3-7 November 2014, Cracow Poland
- Identified light-flavour particles production measured with ALICE at the LHC as a probe of soft QCD and hot hadronic matter, B. Guerzoni for the ALICE Collaboration,  
[Hot Quarks 2014, 21-28 September 2014, Las Negras, Andalucia, Spain](#)
- Transverse Momentum Distributions of Identified Particles in p-Pb Collisions at  $\sqrt{s_{NN}} = 5.02$  TeV, J. Anielski for ALICE Collaboration, 14th International Conference on Strangeness in Quark Matter (SQM2013), Journal of Physics: Conference Series 509 (2014) 012106,  
doi:10.1088/1742-6596/509/1/012106
- Identified charged hadrons production in pp, p-Pb and Pb-Pb collisions at LHC energies with ALICE, Giacomo Volpe for the ALICE collaboration, ICNFP 2014, 3rd International Conference on New Frontiers in Physics, to appear in Conference Proceedings( EPJ Web of Conferences) 28 July – 6 August 2014, Kolymbari, Crete, Greece
- Identified particle production in pp, p-Pb and Pb-Pb collisions measured with ALICE at the LHC energies, Raúl Tonatiuh Jiménez Bustamante (for the ALICE collaboration), XXXVII Symposium on nuclear physics, Cocoyoc, México, January 6-9 2014, to appear in Conference Proceedings (volume of the IOP Journal of Physics: Conference Series)  
<http://www.nucleares.unam.mx/7Esnp/Cocoyoc2014/abstracts/jimenez.pdf>
- Identified charged pion, kaon and proton production in pp, p-Pb, Pb-Pb collisions at LHC energies measured with ALICE, Peter Christiansen for the ALICE Collaboration, SPAATIND 2014, Nordic Conference on Particle Physics, January, 2-7, 2014  
<http://indico.hep.lu.se//getFile.py/access?contribId=3&sessionId=0&resId=0&materialId=slides&confId=1361>

- Identified particle production in p–Pb collisions measured with the ALICE detector, Peter Christiansen, for the ALICE Collaboration, IS2013 — International Conference on the Initial Stages in High-Energy Nuclear Collisions, Illa de A Toxa, Galicia, Spain, 8–14 September 2013, Nuclear Physics A 926 (2014) 264–269, <https://indico.cern.ch/event/239958/session/15/contribution/58>

- Light-flavour hadron production in p–Pb collisions measured with the ALICE detector at the LHC, F. Barile, for the ALICE Collaboration, IS2013 — International Conference on the Initial Stages in High-Energy Nuclear Collisions, International Conference on the Initial Stages in High-Energy Nuclear Collisions, Illa de A Toxa, Galicia, Spain, 8–14 September 2013, Nuclear Physics A 926 (2014) 177–185, <https://indico.cern.ch/event/239958/session/17/contribution/102/material/slides/0.pdf>

- *Talks of group members:*

- Oral presentation at Quark Matter 2014, Darmstadt, Germany, 19-24 May 2014 :  
*Light flavor hadron spectra at low pT and search for collective phenomena in high multiplicity pp, p–Pb and Pb–Pb collisions measured with the ALICE Experiment*  
C. Andrei for ALICE Collaboration, *Nuclear Physics A 931 (2014) 888–892*
- Invited lecture – Carpathian Summer School of Physics 2014 – Sinaia, Romania, July 13-26, 2014  
*Recent results and open questions on collective type phenomena from A-A to pp collisions*  
M. Petrovici, C. Andrei, I. Berceanu, A. Bercuci, A. Herghelegiu, A. Pop  
<http://cssp14.nipne.ro>; will be published in an AIP Publishing Volume, arXiv:1411.0869v1[nucl-ex] (2014)

- *Internal notes:*

- Multiplicity dependence of transverse momentum spectra for positive pions, kaons and protons in pp collisions at 7 TeV, C. Andrei, I. Berceanu, A. Bercuci, A. Herghelegiu, M. Petrovici, A. Pop [https://twiki.cern.ch/twiki/pub/ALICE/PWGLFPAGSPECTRAMultiplicityEventShapePP7/Internal\\_Note\\_Paper\\_Proposal\\_300414\\_mp.pdf](https://twiki.cern.ch/twiki/pub/ALICE/PWGLFPAGSPECTRAMultiplicityEventShapePP7/Internal_Note_Paper_Proposal_300414_mp.pdf)
- Evaluation of the Bayesian PID in the central barrel of ALICE  
C. Andrei, P. Antonioli, F. Noferini, R. Romita, A. Rossi, K. Schweda, J. Wiechula, J. Wilkinson  
<https://aliceinfo.cern.ch/Notes/node/310>
- Charged particle density, C. Andrei, I. Berceanu, A. Bercuci, A. Herghelegiu, M. Petrovici, A. Pop [https://twiki.cern.ch/twiki/pub/ALICE/PWGLFPAGSPECTRAMultiplicityEventShapePP7/charged\\_part\\_density\\_discussion.pdf](https://twiki.cern.ch/twiki/pub/ALICE/PWGLFPAGSPECTRAMultiplicityEventShapePP7/charged_part_density_discussion.pdf)

- *Presentations in the Collaboration:*

- PWG-PP\_PID, Spectra PAG, PWG-LF, Physics Forum: 7
- PWG-PP: 2
- TRD Weekly Meetings: 3
- CWG6 & CWG7 joint meeting: 1

## 5. Further group activities

### Collaborations:

- involvement in the TPC-ALICE upgrade – construction of at least 9 of OROCs based on GEM technology:
- A new architecture for the housing box of OROCs for X rays and in-beam tests and transport was proposed, designed and the construction is in progress.
  - CBM Experiment at FAIR:
- Detailed in-beam tests of high counting rate RPC and high counting rate TRD prototypes realized in our group were carried out using reaction products and mixed beams at SIS18-GSI and PS-CERN, respectively.



- Version 2 of FASP-FEE designed was finalized, the CHIP was produced at AMS-Austria, the design of the associated motherboards is in progress and electronic and real signal tests will be performed in the near future.

Education – courses at the Doctoral School of the Faculty of Physics – Bucharest University

### Outreach

- numerous visits of students, local and foreign delegations.
  - on the occasion of CERN's 60<sup>th</sup> and IFIN-HH's 65<sup>th</sup> anniversaries:
    - oral presentation at special events organized on the occasion of CERN's 60<sup>th</sup> anniversary:
      - July 19, 2014 - Sinaia – with the participation of Rolf Heuer – CERN DG
      - September 26 – Bucharest – with the participation of Livio Mapelli, head of Physics Division at CERN
- posters  
- movie  
- booklet  
- magic cubes.

## **6. Research plan and goals for the next year**

- The analysis along the lines mentioned above based on Run1 data will be finalized and redone once the new 2010 reprocessed data will be available
- Substantial statistics will be generated based on EPOS3 and EPOS-LHC models and comparison with experimental results will be done
- The influence of the phase space in which the charged particle multiplicity is selected on the obtained result
- Event shape selection based on different event shape global variables
- Contribution to the detector operation in Run2
- TRD tracking
- Operating NIHAM data centre – component of ALICE GRID at its standard efficiency
- Service task for PhD students
- Setting up the local infrastructure of the Detector Lab for ROC production for ALICE - TPC upgrade
- Starting the construction and tests of OROCs based on GEM technology for ALICE-TPC upgrade
- Outreach activities
- Summer Student Program
- Once the new data at the highest LHC energy will become available we will start similar studies as the ones at 7 TeV.