

Group Annual Summary Report

- **Project team :**

- Prof. Dr. Mihai Petrovici (physicist) – team leader
- Senior researcher III Dr. Cristian Andrei (physicist)
- Master student Dana Avramescu (physicist)
- Senior researcher III Daniel Bartos (physicist)
- Senior researcher II Dr. Alexandru Bercuci (physicist)
- Senior researcher II Gheorghe Caragheorghopol (electronics engineer)
- Senior researcher II Dr. Vasile Catanescu (electronics engineer)
- Senior researcher II Viorel Duta (mechanical engineer)
- Senior researcher III Dr. Andrei Herghelegiu (physicist)
- Master/PhD student Amelia Lindner (physicist)
- Master/PhD student Adrian Sorin Mare (physicist)
- Senior researcher II 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)
- PhD student Madalina Tarzila (physicist)
- Technician Valerica Aprodu
- Technician Lucica Prodan
- Technician Andrei Radu
- Technician Constanta Dinca
- Financial coordinator Georgiana Rosu (economist)
- Lathe and milling machine operator, Gheorghe Dima (mechanical worker)

- **Specific scientific focus of the 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 and understand their origin.

- **Highlights of accomplishments in the last year:**

Physics:

- Studies for obtaining p_T spectra simultaneously conditioned on multiplicity, directivity and within same-side, away-side and in between relative to the leading particle for

identified charged hadrons in pp collisions at $\sqrt{s} = 7$ TeV.
Implementation of unfolding based on a multi-dimensional detector response matrix.

- Studies of two charged particles correlations as a function of multiplicity and directivity in pp collisions at $\sqrt{s} = 7$ TeV.
Cross-checks and similar studies for pp collisions at 13 TeV are in progress.
- Studies on the core-corona interplay at LHC and RHIC energies based on experimental data and Glauber MC estimates.
The existing experimental data were carefully analyzed, extrapolations and interpolations of p_T spectra were performed in a consistent way, final results are expected soon.
- 15 presentations in ALICE meetings (TPCU)
- Contribution to 17 conference presentations
- Co-authors to 30 ALICE published papers
- Color Glass Condensate inspired scaling variable and system size dependence
A. Lindner, Annual Scientific Meeting, University of Bucharest, 21-22 June, 2019
- Towards Color Glass Condensate at LHC energies
D. Avramescu, IFIN – Young scientist days, Bucharest, 17 December, 2018
- Dependence of different observables on the CGC inspired variable for light flavor hadrons in pp and A-A collisions at RHIC and LHC energies
A. Lindner, IFIN – Young scientist days, Bucharest, 17 December, 2018
- Geometrical scaling for pions, kaons, protons and strange particles in pp collisions at $\sqrt{s}=7$ and $\sqrt{s}=13$ TeV and Pb-Pb; Xe-Xe at 5.02 and 5.44 TeV, respectively
- preliminary results
- Multiplicity dependence of light-flavor hadron production in pp collisions at $\sqrt{s} = 7$ TeV; PC members
Phys.Rev.C99(2019)024906
- Why pp collisions at 14 TeV ?
C. Andrei, D. Avramescu, I. Berceanu, A. Bercuci, A. Herghelegiu, A. Lindner
M. Petrovici, A. Pop, C. Schiaua, M. Tarzila
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- Charged particle multiplicity and event shape dependence of two charged particle correlations in pp collisions at $\sqrt{s} = 7$ TeV
M.Tarzila, C.Andrei, M.Petrovici, A.Pop
ALICE Week, PWG-MM mini workshop, March 28, 2019

- What's really new at LHC energies ?
C. Andrei, D. Avramescu, I. Berceanu, A. Bercuci, A. Herghelegiu, A. Lindner, M.Petrovici, A. Pop, C. Schiaua, M. Tarzila
Spectra PAG , September 16, 2019

- R_{AA} , R_{CP} and normalized ratios, with and without Core-Corona corrections – scaling as a function of N_{part} – in progress

- A consistent treatment of pp and A-A collisions at LHC energies was started. First results within CGC framework for pp and Pb-Pb collisions at LHC energies were obtained – work in progress

- NIHAM Status and Performance
C. Schiaua
9th Annual ALICE Tier-1/Tier-2 Workshop, 14-16 May, Bucharest, 2019

ALICE upgrade:

- 20 OROCs were successfully assembled and tested, all being transported at CERN, passing the upon arrival tests, installed in the TPC and preliminary tests are in progress

Computing:

- NIHAM maintained the leading position among Tier2s ALICE GRID centers. A new data storage capacity of 4.6 PB Raw and 3.82 PB Effective was installed and is currently in operation.
An upgrade with 50% more data storage will be done in the next months.
Two new cooling units were purchased and their installation is in progress.
NAF is efficiently managed.

2. Scientific goals

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 energy region of the Phase Diagram of Quantum Chromodynamics (QCD), far above the critical temperature where a transition to a deconfined matter, formed by its basic constituents, i.e. quarks and gluons, is predicted to happen in nucleus-nucleus collisions at such energies. In addition to heavy systems,

the ALICE experiment is devised such that collisions of lighter combinations, p-A and pp, can be also studied. These studies turned out not only to provide reference data for the A-A collisions, a number of genuine pp physics becoming of primary interest once the new data from the first experiments at $\sqrt{s}=7$ TeV became available. multiparton interactions and re-scatterings could contribute to a large energy transfer in a collision volume of proton size and a close to equilibrium deconfined initial state could be expected in very high energy pp collisions. A piece of matter of proton size, with a radius of few times larger than the mean free path of the constituents of a deconfined medium, expands hydrodynamically once the energy transfer is significantly large, i.e. low impact parameter - high charged particle multiplicity.

The results obtained in Run1 at which our group had a significant contribution are supported by the results obtained in Run2 at $\sqrt{s}=13$ TeV.

Another important aspect worth to be studied is the possibility to discriminate between hard and soft processes. Preliminary studies performed by us 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 highest 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. Correlation techniques are powerful tools which can provide essential information on the nature of the medium produced in ultra-relativistic heavy-ion collisions. The idea is to select a sample of high p_T particles, referred to as leading particles or "triggers" and then to study the correlation between the leading particle and all other particles in the same event, called associated particles. The first studies of two-particle correlation functions in the highest-multiplicity pp collisions at the LHC performed by the CMS Collaboration showed an enhanced production of pairs of particles at $|\Delta\phi| \sim 0$, extending over a wide range in $\Delta\eta$, a feature frequently referred to as a "ridge". These structures can be quantified by azimuthal Fourier coefficients, mostly of second (v_2) and third (v_3) order. Many of the physics mechanisms proposed to explain the pp ridge include multiparton interactions, parton saturation and collective expansion of the final state.

This information plays a crucial role in understanding the features observed in p-Pb and Pb-Pb collisions at LHC energies. Therefore, a special attention is given to the comparison of dependence of different observables as a function of the collision violence among the three systems.

In order to extract signals originating from multiparticle interactions it is mandatory to remove, as much as possible, based on experimental information, the contribution coming from single collisions in case of Pb-Pb and p-Pb or low density hadronic matter overlap in case of pp, known as corona contribution. Systematic studies on core-corona interplay and the dependence on the centrality of the extracted core contribution for different observables will give the possibility to evidence different types of scaling suggested by QCD inspired models.

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, our team being involved in the ALICE-TPC upgrade program.

The amount of data will obviously increase and therefore a special attention will be given to the computing power and storage capacity delivered by the worldwide distributed ALICE-GRID infrastructure.

3. Scientific achievements in the last four years corresponding to the actual program funding

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 pp 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} , the average transverse expansion velocity $\langle \beta_T \rangle$ and its profile n as a function of multiplicity has been shown to be similar with those obtained in heavy ion collisions. We started to extend these studies towards multi-differential analyses complemented by correlation studies.

A detailed comparison of pp ($\sqrt{s} = 7$ TeV), p-Pb ($\sqrt{s_{NN}} = 5.02$ TeV) and Pb-Pb ($\sqrt{s_{NN}} = 2.76$ TeV) based on ratios of p_T spectra at different multiplicity/centrality relative to the p_T spectra for the minimum bias pp collision at the same collision energy, each of them normalized to the corresponding average charged particle density, free of any model assumption, has been done. The strong similarities between the three very different systems in the low region of p_T and the observed trends as a function of charged particle density/centrality and mass of the analysed species point to a similar boost type dynamics.

In the last year the group activity focused on:

- **Experimental data analysis and interpretation:**

- Cross-checks of the two-particle correlation studies as a function of charged particle multiplicity and event shape selection based on directivity and sphericity for pp collisions at $\sqrt{s}=7$ TeV and comparison with PYTHIA, PHOJET and EPOS predictions were accomplished. Similar studies for pp collisions at $\sqrt{s}=13$ TeV are in progress.
- We continued the investigations of core-corona interplay and presently we are extracting different observables attributed to the core in Pb-Pb at LHC and Au-Au at RHIC.
- Preliminary results of R_{AA} , R_{CP} and normalized ratios as a function of N_{part} .

- A consistent treatment of pp and A-A collisions at LHC energies was started.
- Unfolding procedure using multi-dimensional detector response matrix is under control. Obtaining p_T spectra simultaneously conditioned on multiplicity, directivity and within same-side, away side and in between relative to the leading particle for identified charged hadrons in pp collisions at $\sqrt{s} = 7$ TeV is close to be finalized.

- **GRID activities**

NIHAM Data Centre continues to be one of the most efficient Tier2 centre of ALICE GRID. This is a result of a continuous effort to improve the monitoring tools, in due time interventions, replacement of failing hardware components, efficient interaction with offline ALICE experts. The new storage capacity was installed and is presently in use. Two cooling units were purchased and their installation is in progress.

- **TPC upgrade contribution:**

The assembling and test activities in our Department were very successful in many respects. The local infrastructure, expertise and know-how have been crucial in finalizing in due time the ambitious commitment of assembling and testing 50% of the outer readout chambers (OROCs) based on GEM technology. The results in terms of energy resolution, 2D gain distribution and its reproducibility, the results of the long term tests in high flux of X-ray were reported weekly in the ALICE-TPCU video meetings. The 20 OROCs were transported to CERN and installed in the TPC.

4. Group members

Name	Analysis (%)	R&D (%)	Detector operation (%)	Detector construction (%)	Infrastructure Planning Financial, Outreach Contracts (%)
Mihai Petrovici	7	3.16		6	3
Daniel Bartos		6		4.93	
Alexandru Bercuci	20		4	20	20,50
Gheorghe Caragheorgheopol			30	15	15.29
Vasile Catanescu		20	14		5.44
Viorel Duta			20	20	17.18
Mariana Petris			1.41	10	
Alexandrina Petrovici					15.87
Amalia Pop	8.42			2	
Laura Radulescu			10.93		
Victor Simion		17.18	20	20	
Claudiu Schiaua					22.09
Andrei Cristian	10.68				
Andrei Oana					4.52
Andrei Herghelegiu	9.83				
Madalina Tarzila					
Amelia Lindner	76.93				
Adrian Mare					16.21
Dana Avramescu	70.04				9
Catalina Carneci	22.88				
Topor-Pop Vasile					
Valerica Aprodu				16.28	
Lucica Prodan				60	16.97
Andrei Radu			32.22	30	

Constanta Dinca					10.85
Gheorghe Dima				8.34	
Georgiana Rosu					3.14

Total: 7.65 FTE

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

Name		Present status
Madalina Tarzila	PhD student	Research assistant Temporary employment
Amelia Lindner	PhD student	Research assistant Temporary employment
Adrian Mare	PhD student	Research assistant Temporary employment
Dana Avramescu	Master student	Research assistant Temporary employment
Catalina Carneci	Master student	Research assistant Temporary employment

5. Papers and talks in last year

Papers:

- Multiplicity dependence of light-flavor hadron production in pp collisions at $\sqrt{s} = 7$ TeV; PC members
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- Why pp collisions at 14 TeV ?
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GRID (computation and storage) support:

- Co-authors to 30 ALICE published papers

Conferences and ALICE PWG presentations:

- Color Glass Condensate inspired scaling variable and system size dependence
A. Lindner, Annual Scientific Meeting, University of Bucharest, 21-22 June, 2019

- Towards Color Glass Condensate at LHC energies
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- NIHAM Status and Performance
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- Contribution to 17 conference presentations on behalf of ALICE Collaboration

TPC Upgrade:

- 15 presentations in ALICE TPCU meetings
- 20 OROCs finalized and already transported to CERN

6. Further group activities

- *Collaborations, local synergies, education, outreach*

R&D activities for a new generation of high counting rate RPC and TRD detectors, associated front-end electronics and free running mode data processing

- 2 new RPC prototypes with the final architecture for CBM-ToF inner zone tested at mCBM at SIS18 - GSI Darmstadt
- 2D position sensitive TRD operated with FEE and DAQ, designed by our Department, were implemented in CBMRoot and the results based on UrQMD event generator and GEANT show the high performance of the architecture proposed and developed by us in terms of tracks reconstruction

- International Conferences and Meetings:

- 15 presentations at CBM Collaboration meetings
- 5 contributions to the CBM Annual Report
- 1 oral presentation at ICHEP-10-2019
- M.Petris et al., EPS-HEP2019, 10 - 17 July 2019, Ghent, Belgium
- M.Petris et al., XXIII International School on Nuclear Physics, Neutron Physics and Application, 23-27 September 2019, Varna

- Papers:

- M.Petris et al., Nucl.Instr. And Meth., A920(2019)100

Summer Student Program:

Quite successful, i.e. 3 participants: 2 from Faculty of Physics, University of Bucharest and 1 from Universidad Complutense de Madrid, Spain.

Lectures were presented by HPD members (<http://niham.nipne.ro/lectures.html>)

Outreach:

- Numerous visits of Romanian and foreign delegations, Romanian pupils winners of International Competitions in Physics
- The first number of the HPD Courier was issued
http://niham.nipne.ro/HPD-Courier_electronic-version.pdf
The second one will be dedicated to the 70th anniversary of the Institute for Physics of Romanian Academy, founded by Horia Hulubei, the precursor of IHIN-HH and will be issued in December 2019
- visit of the participants to the 9th Annual ALICE Tier-1/Tier-2 Workshop, 14-16 May, Bucharest, 2019

- CERN Courier January 24, 2019, ALICE revitalised
- FOPI Photo selected on the occasion of GSI 50th Anniversary
- More details could be seen in:
 - <https://niham.nipne.ro>
 - <https://www.youtube.com/watch?v=OJd4fA0xUh0>
 - <https://www.facebook.com/Hadron-Physics-Department-211078852968333/>