Group Annual Summary Report

- **Project team :**

- Prof. Dr. Mihai Petrovici (physicist) – team leader
- Senior researcher III Dr. Cristian Andrei (physicist)
- Senior researcher III Dr. Oana Andrei (physicist)
- Master student Dana Avramescu (physicist)
- Senior researcher III Daniel Bartos (physicist)
- Senior researcher II Dr. Alexandru Bercuci (physicist)
- Senior researcher II Gheorghe Caragheorgheopol (electronics engineer)
- Senior researcher II Dr. Vasile Catanescu (electronics engineer)
- Master student Catalina Cirneci(physicist)
- Senior researcher II Viorel Duta (mechanical engineer)
- Senior researcher III Dr. Andrei Herghelegiu (physicist)
- PhD student Amelia Lindner (physicist)
- 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, similarities and differences relative to A-A collisions.

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

Physics:

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

charged particles 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 sphericity in pp collisions at $\sqrt{s}$ = 7 TeV.

- Similar studies for pp collisions at 13 TeV are in progress.

- Considerations on the suppression of charged particles in high energy heavy ion collisions, submitted to Phys. Rev. C and ICHEP 2020 presentation.

- Studies on the core-corona interplay at LHC and RHIC energies based on experimental data and Glauber MC estimates.
The Glauber Monte Carlo wounded parton model has been alternatively used and the experimental data were analyzed within the core-corona picture based on this model.

- Preliminary results of a consistent treatment of Au-Au collisions at $\sqrt{s}$ = 200 GeV were obtained, being the subject of a master thesis

- Co-authors to 32 ALICE published papers

- Contribution to 8 conference presentations

- Simulating the initial stage of hadron-hadron collisions
D. Avramescu, IFIN – Young scientist days, Bucharest, December, 2019

- Towards understanding new features of hadron production mechanisms at LHC energies
A. Lindner, IFIN – Young scientist days, Bucharest, December, 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, January 27, 2020, continuation of the presentation on September 16, 2019

Computing:

- NIHAM maintained the leading position among Tier2s ALICE GRID centers.
A data storage capacity of 4.6 PB raw and 3.82 PB effective was installed.
A new data storage unit was purchased and transported from CERN to HPD.
New UPS stations are in progress. NAF was 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 $|\Delta\varphi| \sim 0$, 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 (v2) and third (v3) 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 3 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. Implementation of unfolding based on a multi-dimensional detector response matrix was first considered for identified charged hadrons.
We extended these studies towards multi-differential analyses complemented by correlation studies. The results were presented and published in prestigious international conferences and ISI journals, respectively. An extensive paper on multiplicity dependence of light flavour hadron production in pp collisions at $\sqrt{s}$ =7 TeV including most of the results obtained up to now related to this topic was published (Phys. Rev. C 99(2019) 024906). In order to exclude the effect of corona contribution from the observed experimental trends, we have done and published in Phys. Rev. C a detailed study of core-corona interplay in Pb-Pb collisions at $\sqrt{s_{NN}}$ =2.76 TeV. In the same journal we published two more papers on geometrical scaling from energies available at the BNL Relativistic Heavy Ion Collider to those at the CERN Large Hadron Collider and on multiplicity dependent transverse momentum distributions of identified particles in pp collisions at 7 TeV within the HIJING/BB v2.0 model.
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.

In the last year the group activity focused on:

- ***<u>Experimental data analysis and interpretation</u>:***

- The multi-differential analysis in terms of p_T distributions simultaneously conditioned on multiplicity, sphericity and within same-side, away-side and in between relative to the leading particle was continued by using an unfolding procedure based on a multi-dimensional detector response matrix. By applying this procedure charged particles p_T spectra as a function of charged particle multiplicity and sphericity in pp collisions at

$\sqrt{s}$=7 TeV were obtained and comparison with Pythia6 (Perugia0) has been done. We intend to continue with a more quantitative comparison of the p_T spectra, comparison with other phenomenological models, extension to other conditioning variables and eventually again to identified hadrons where the identification procedure and the lack of statistics makes the application of the unfolding method quite difficult. This effort will be finally focused on the 13 TeV pp data.

- The two-particle correlation studies as a function of charged particle multiplicity and event shape selection based sphericity for pp collisions at $\sqrt{s}$=7 TeV are close to be finalized.
$\Delta\varphi$ and $\Delta\eta$ distributions were analyzed. Comparison with PYTHIA, PHOJET and EPOS predictions have been done.
Similar studies for pp collisions at $\sqrt{s}$=13 TeV where much higher statistics is available have been started.

- Considerations on the suppression of charged particles in high energy heavy ion collisions.
Experimental results related to charged particle suppression obtained at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven for Au-Au (Cu-Cu) collisions and at the Large Hadron Collider (LHC) at CERN for Pb-Pb (Xe-Xe) collisions are compiled in terms of R_{AA} , R_{CP} and the ratio of the p_T spectra for each centrality to the pp minimum bias or to the peripheral one, each of them normalized with the corresponding charged particle density $dN_{ch}/d\eta$, namely the newly introduced quantities R^N_{AA} and R^N_{CP}, as a function of N_{part} and $dN_{ch}/d\eta$. The studies are focused on a p_T range in the region of maximum suppression evidenced in the experiments. The scaling as a function of N_{part} and $dN_{ch}/d\eta$ is discussed. The core contribution to R_{AA} is also presented. Different considerations based on phenomenological pictures are done.
An article has been submitted to Phys. Rev. C and an oral presentation at ICHEP 2020 was given.

- We continued the investigations of core-corona interplay. These were alternately approached on the basis of a Glauber Monte Carlo wounded parton model which is phenomenologically successful in reproducing multiplicities of particle production and allows to study the nucleon substructure fluctuation effects. Different observables attributed to the core contribution for Pb-Pb at LHC and Au-Au at RHIC collisions, have been obtained. A paper draft is in progress.

- A consistent treatment of Au-Au collisions at $\sqrt{s}$=200 GeV energy was continued and first results of p_T spectra and v2 distributions were obtained.

- ***<u>GRID activities</u>***

- NIHAM Data Centre maintained the leading position among Tier2s ALICE GRID centres.
A new data storage capacity of 4.6 PB raw and 3.82 PB effective was installed and is currently in operation. Another data storage unit of 2.3 PB raw and 1.91 PB effective was

purchased and transported from CERN to HPD. New UPS stations of ~120 KVA are about to be installed.
NAF is efficiently managed and was intensively used by our group members.

4. Group members

Name	Analysis (%)	R&D (%)	Detector operation (%)	Detector construction (%)	Infrastructure Planning Financial, Outreach Contracts (%)
Mihai Petrovici	25				5.44
Daniel Bartos		10			5.61
Alexandru Bercuci	15				6.3
Gheorghe Caragheorgheopol		8			15.65
Vasile Catanescu		10			9.73
Viorel Duta		3.66			12
Mariana Petris	7	16.65			
Alexandrina Petrovici	15				15.28
Amalia Pop	8.46				
Laura Radulescu		10			6.95
Victor Simion		0.76			
Claudiu Schiaua					32.49
Andrei Cristian	21.1				
Andrei Oana	8.48				10
Andrei Herghelegiu					
Madalina Tarzila	20.03				
Amelia Lindner	20.73				
Adrian Mare	10.71				10
Dana Avramescu	11.51				
Catalina Cirneci	2.84				
Valerica Aprodu		8			6.45
Lucica Prodan		6.97			15
Andrei Radu		10			9.55
Constanta Dinca		5.15			10

Gheorghe Dima					19.07
Georgiana Rosu					1.52

Total: 4.45 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 Cirneci	Master student	Research assistant Temporary employment

5. Papers and talks in last year

Papers:

- Considerations on the suppression of charged particles in high energy heavy ion collisions, M. Petrovici, A. Lindner, A. Pop, submitted to Phys. Rev. C

GRID (computation and storage) support:

- Co-authors to 32 ALICE published papers

Conferences and ALICE PWG presentations:

- Considerations on the suppression of charged particle production in high energy heavy ion collisions, M. Petrovici, A. Lindner, A. Pop, 40th International Conference on High Energy Physics, 2020, Prague, online
https://indico.cern.ch/event/868940/contributions/3814460/

- Simulating the initial stage of hadron-hadron collisions
D. Avramescu, IFIN – Young scientist days, Bucharest, December, 2019

- Towards understanding new features of hadron production mechanisms at LHC energies
A. Lindner, IFIN – Young scientist days, Bucharest, December, 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, January 27, 2020, continuation of the presentation on September 16, 2019

- Contribution to 8 conference presentations on behalf of ALICE Collaboration

6. Further group activities

- ***Collaborations, local synergies, education, outreach***

R&D activities

- 2x2 new RPC prototypes for mCBM FAIR Phase0 @ SIS18 were assembled and tested.
- TRD - tracking performance studies have been done.

Readout chain, Hardware status

FASP:
- ~40 already bonded, need individual testing
- 190 dies available, bonding in progress
- bonding board and testing boards were designed, built and tested.

FASPRO:
- 9 boards available, tests in progress.
- components available for another ~20 boards.

GETS:
- 10 boards available, tests in progress
- components available for another ~20 boards

Adapter boards (GETS→SATA, SATA→ CROB): passive boards, available for connecting 30 GETS.

Teaching:

- *Summer Student Program* prepared and received applications - cancelled because of COVID pandemic conditions.
- 1 master thesis was finished.

Outreach:

- The 2nd and 3rd numbers of the HPD Courier were issued (https://niham.nipne.ro/HPD_Courier.html)
- visit of the Prime Minister adviser
- a movie related to the ALICE-TPC upgrade is close to be finalized
- 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/

ZOOM was implemented on the the versatile audio-video infrastructure of HPD.