Call: CERN-RO/RDI/2024

Project acronym: RONIPALICE

CERN Research Programme / Experiment: 5.9/5.9.2/CERN-RO/ALICE

Annual Summary Document[1]

Year: 2024

Months : 1

Project Title: IFIN-HH Contribution to the ALICE experiment at CERN/RONIPALICE

Project Work Plan

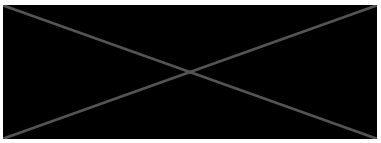
Stage: I.

Participation and specific contributions of IFIN-HH to the ALICE experiment in 2024

Activities:

I. 1.

Study of similarity between pp and A-A collisions in terms of <pT>/<dN/dy>/S$^{\perp}$ dependence on the collision energy



[1] [2] Please fill in all the required items and do not alter the template

Annual Summary Document

Summary / Cover Page

- **Group list:**

- Prof. Dr. Mihai Petrovici (physicist) – team leader
- Senior researcher III Dr. Cristian Andrei (physicist)
- Senior researcher III Dr. Oana Andrei (physicist)
- Senior researcher III Dr. Andrei Herghelegiu (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)
- Senior researcher II Viorel Duta (mechanical engineer)
- Senior researcher II Dr. Iosif Legrand (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)
- Computing coordinator Claudiu Schiaua (physicist)
- Researcher Dr. Madalina Tarzila (physicist)
- Engineer Naziru Andrei Bogdan
- Research assistant Iulian Florin Andreicovici
- Research assistant Florin Daniel Gila
- Chemistry-Physics Assistant Madalina State
- Technician Valerica Aprodu
- Technician Andrei Radu
- Technician George Stoian
- Technician Constanta Dinca
- Financial coordinator Georgiana Bagu (economist)
- Lathe and milling machine operator, Gheorghe Dima (mechanical worker)

- **Specific scientific focus of group :**

The dependence of p_T distributions and two-particle correlations of charged and identified hadrons on multiplicity, event shape, $\Delta\varphi$ and $\Delta\eta$ relative to the leading particle in pp collisions at LHC energies - 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 as well as their similarities and differences relative to A-A collisions.

The detailed systematics based on existing experimental data in terms of energy density, entropy density, their correlations, centrality and collision energy dependence is another subject followed by us.

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

Physics:

- Very preliminary results within O^2 environment in terms of transverse momentum spectra obtained for isotropic and jetty events conditioned with multiplicity and modified Fox-Wolfram moments (FWM).
- Study of similarity between pp and A-A collisions in terms of $\langle p_T \rangle / \langle dN/dy \rangle / S_\perp$ dependence on the collision energy.
- M. Petrovici,
QCD Challenges,
Workshop on Advances, Innovations, and Future Perspectives in High-Energy Nuclear Physics
19–24 October 2024
Wuhan, China
https://indico.cern.ch/event/1430136/contributions/6174522/
- M. Petrovici,
QCD Challenges
General Seminar IFIN-HH, 21 November 2024
- Co-authors to > 4 ALICE published papers
- Contribution to > 5 conference presentations on behalf of ALICE Collaboration

Computing:

NIHAM Data Centre was one of the most efficient Tier2s ALICE GRID centres.
NIHAM Analysis Facility (NAF) is efficiently managed and running.

Detailed report, highlighting the results obtained during the reporting period and the objectives fulfilment, conclusions;

2. Scientific goals (2 pages) - narrative stating in more detail

A Large Ion Collider Experiment (ALICE) at CERN was 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. As a general-purpose heavy-ion experiment, the ALICE experiment is devised such that in addition to heavy systems, collisions of lighter combinations, p-A and pp, can be also studied. Far from being only a benchmark for A-A collisions, the pp and p-A collisions have been shown to reveal genuine physical phenomena that have aroused great interest as soon as, under certain conditions, similarities with A-A collisions were highlighted. Thus, a close to equilibrium deconfined initial state could be expected at very high charged particle multiplicity in very high energy pp collisions.

Part of the ALICE Collaboration, our group had a significant contribution to the construction of the TRD and TPC-OROC, based on GEM, or to activities of general interest for the collaboration. The final goal was realized by proposing and addressing physics topics related to collective type phenomena in pp collisions, core-corona relative contribution to different observables, similarities between pp and A-A collisions, geometrical scaling of different observables for pp and A-A collisions and systematic studies of charged particle suppression as a function of collision energy, results presented at international conferences and published in ISI journals.

For pp collisions at $\sqrt{s}$ = 13 TeV, we will extend our previous studies, in terms of a multi-differential selection in charged particle multiplicity, event shape and $\Delta\eta - \Delta\varphi$ • relative to the leading particle in obtaining transverse momentum distributions using a multi-dimensional detector response matrix and two particle-correlations, to identified hadrons, exploring also other global event shape observables more effective in selecting close to isotropy events. Multi-differntial studies are a very challenging task and thus permanently we will compare between them the results obtained with different unfolding procedures developed by us and with other similar analyses in order to validate the obtained results. The extended multiplicity coverage from Run 3 and Run 4 will enable more systematic studies based on multi-differential analyses. The analyses will be implemented in the O^2 environment and comparison with

previous analyses will be done. A comparison with theory in the greatest detail can constrain the parameters of the models and lead to the understanding, in an unambiguous way, of the physics behind. The description of the p_T distributions and derived quantities, such as yields and average transverse momenta, based on new fit formulas derived from phenomenological models will help in understating and systematizing the obtained results.The aim is to configure paper drafts to be published within the ALICE Collaboration.

A special attention will be given to the comparison of the dependence of different observables as a function of the collision energy and collision geometry between different systems and at LHC energies, between pp and A-A. The existing experimental data and the predictions of modern phenomenological models will constitute the object of an attempt to systematize the observed phenomena and to explore the performances of some observables. Theoretical model frameworks implemented in-house will be useful tools in understanding the physics behind the observed experimental trends. The aim is to configure also paper drafts to be published by our group members.

Having in mind detector development for future experiments at LHC and based on our long experience, R&D activities will be carried out along the lines of improving the time resolution of high count rate RPC detectors which can be used as forward detectors having a large pseudorapidity coverage.

Our NIHAM Data Centre was permanently one of the most efficient among Tier2s ALICE GRID centres more than 10 years. Within the present project we aim to maintain and develop the performance of the NIHAM Data Centre in terms of storage capacity and computing power..

Our group will pay a special attention to the contribution for running the ALICE experiment either as Run Manager, Shift Leader or by fulfilling the on-site shifts, to service tasks and service-works and to the participation in the ALICE publishing activity.

To attract staff inspired by our activities, the educational activity from bachelor's level to doctorate and outreach activities will be in our constant attention, especially now that the Summer Student Program has been revived after the pandemic and Romanian Science Gateway has taken shape.

3. Scientific achievements in the last three years corresponding to the actual program funding (2 pages)

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, have been done. These studies were extended towards multi-differential analyses. The implementation of an unfolding approach based on a multi-dimensional detector response matrix is a complex task which allowed to obtain transverse momentum distributions simultaneously conditioned on multiplicity, sphericity and within the same-side, away-side and in between relative to the leading particle. Preliminary comparisons between the phenomenological models PHYTIA and EPOS, available in ALICE database, have been done. An Internal Note: "Charged particle transverse momentum spectra as a function of unfolded charged particle multiplicity, event sphericity and azimuthal angle relative to the leading particle in pp collisions at $\sqrt{s}$ = 7 TeV"
https://indico.cern.ch/event/1056062/contributions/4438294/attachments/2275968/3866416/CAndrei_Spectra_05072021.pdf was released. Similar studies for pp collisions at $\sqrt{s}$ = 13 TeV are in progress. Thus, a detailed investigation of the comparison of Bayesian unfolding method, which is not a transparent and very easy to handle one, with another simpler correction approach has started and is taking shape in terms of obtaining spectra and associated quantities.

A complementary analysis based on correlation studies was addressed and finalized being also the subject of a doctoral thesis. Angular correlations of charged particle pairs with $1 \leq p_T \leq 2$ GeV/c within $|\eta| < 0.8$ measured with the ALICE detector at LHC in proton-proton collisions of $\sqrt{s}$=7 TeV were studied. A multi-dimensional analysis was performed including the dependence on the sphericity as event shape observable as well as the charged particle multiplicity. The same studies were performed using several Monte Carlo event generators: PYTHIA, PHOJET and EPOS. The comparison with the predictions of the models indicates that Monte Carlo models do not fully reproduce the data. This type of analysis was extended to proton-proton collisions at $\sqrt{s}$ = 13 TeV and a comparison with MC models and the results

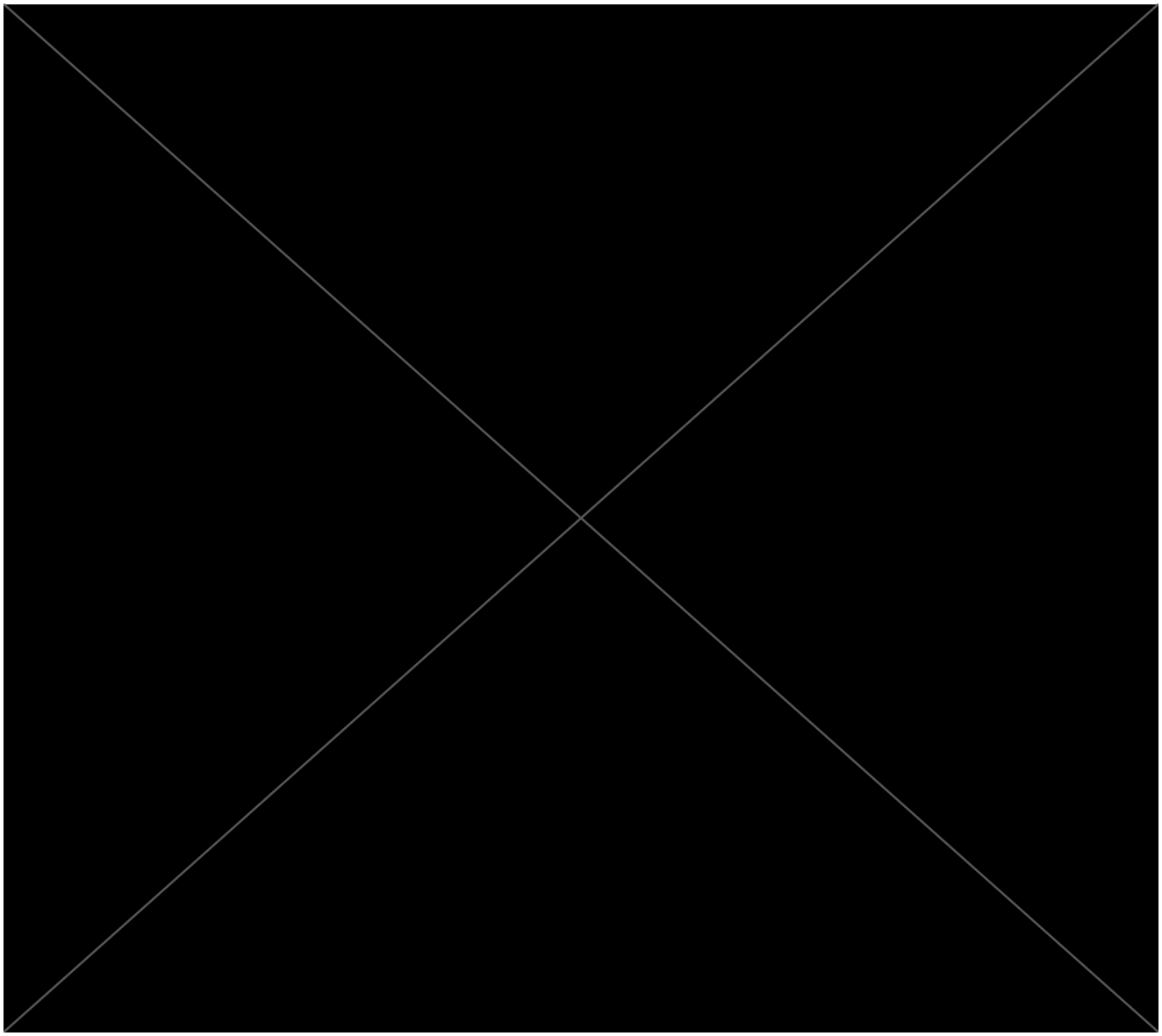
from $\sqrt{s}$ = 7 TeV are about to be finalized. The systematic errors evaluation, a new normalization procedure and the detailed comparison with other published results are steps towards a successful publishing process.
After a systematic survey of published experimental results the data from AGS, SPS, RHIC and LHC were analyzed for further studies on the systematics of heavy ion collisions related quantities as a function of energy. These studies were published in several papers and reported at international conferences:
-Phys. Rev. C 107, 034913 (2023)
-Features of strangeness production in pp and heavy ion collisions, A. Pop, M. Petrovici, arXiv:2402.19115v2, accepted for publication in Phys. Rev. C
-Features of strangeness production in pp and heavy ion collisions, oral presentation - European Nuclear Physics Conference 2022 (EuNPC 2022), October 24-28, 2022, University of Santiago de Compostela, https://indico.cern.ch/event/1104299/contributions/5055299/attachments/2536779/4366087/EuNPC_talk_mp.pdf ,
- What is really new at LHC energies?
Invited talk - Carpathian Summer School of Physics, July 2-15, 2023, Sinaia https://indico.nipne.ro/event/230/sessions/43/#2023071
- QCD Challenges from pp to AA, 2024, Munster, Germany, 2-6 October 2024, M. Petrovici
Our group participated in running the ALICE experiment by performing Run manager, Shift Leader and DCS shifts.
Service work and service task activities were done in O^2 FLP and Data Preparation working groups.
NIHAM Data Centre was permanently one of the most efficient among Tier2s ALICE GRID centres.

In the last year 2024 – 1 month, the group activity focused on:

- Very preliminary results within O^2 environment in terms of transverse momentum spectra obtained for isotropic and jetty events conditioned with multiplicity and modified Fox-Wolfram moments (FWM) : study of the power of selection and selection limits of FWM and comparison with transverse sphericity; isotropic and jetty event shapes and associated transverse momentum spectra in pp collisions at 13 TeV-experimental data and Pythia model; study of the necessity for the correction of raw data results.
- Study of similarity between pp and A-A collisions in terms of $\langle p_T \rangle / \langle dN/dy \rangle / S_\perp$ dependence on the collision energy. In more detail in [1].
Previous papers [2, 3] confirmed the model prediction based on local parton-hadron duality (LPHD) [4] and dimensionality argument [5, 6] concerning the behavior of the $\langle p_T \rangle / \langle dN/dy \rangle / S_\perp$ ratio as a function of centrality and collision energy for pions, kaons and protons. In the case of strange K^0_S, $\bar{\Lambda}$, Ξ^- and similar with the trends shown for pions, kaons and protons [2], a decrease of $\langle p_T \rangle / \langle dN/dy \rangle / S_\perp$ with centrality at all collision energies and as a function of collision energy at a given centrality is found.
$\langle p_T \rangle / \langle dN/dy \rangle / S_\perp$ decreases from $\sqrt{s_{NN}}$ = 7.7 GeV up to 200 GeV, the values corresponding to LHC energies being slightly lower than those corresponding to the top RHIC energy.
The geometrical transverse overlap area ($S_\perp^{geom}$) of the two colliding nuclei for a given incident energy and centrality was estimated on the basis of a Glauber Monte-Carlo (GMC) approach as explained in [3] where the calculated values were compiled. These values are used in the present paper. The total final state particle multiplicity per unit rapidity, $\langle dN/dy \rangle$, a measure of the entropy produced in the collision, was estimated by taking into consideration all the measured particles and anti-particles depending, from system to system and case to case, on the most complete published experimental information.
In [5] following the LPHD scenario [6] where one gluon produces n-charged hadrons after fragmentation and based only on the dimensionality argument it is shown that: $\langle p_T \rangle / \langle dN/dy \rangle / S_\perp \sim 1/n\sqrt{n}$. Assuming inverse power law functions for the $\langle dN/dy \rangle$ dependence of these distributions, their exponents were extracted. In the case of the dependence on centrality, the exponent increases with increasing $\sqrt{s_{NN}}$, while in the case of the dependence on collision energy, it decreases from central to peripheral collisions. Similar to A-A collisions, a clear decrease of the $\langle p_T \rangle / \langle dN/dy \rangle / S_\perp$ distributions with $\langle dN/dy \rangle$ for π, K,

K^0_S , p, Λ , Ξ, Ω and for pp collisions at √s = 7 TeV and √s = 13 TeV supports the expectations based on CGC and percolation models. Applying to the distributions a fit function with an inverse power law dependence on <dN/dy> resulted in an exponent which increases with collision energy, being of the same order of magnitude but larger for pp than for heavy ions.
This study can help those who want to constrain complex phenomenological model parameters.
It is evidence of another similarity between pp and Pb-Pb collisions at LHC energies and will be part of the physics motivation for a master's thesis in which a multi-differential analysis of the transverse momentum distributions obtained in pp collisions at √s = 13 TeV is conducted.

[1] A. Pop and M. Petrovici, arXiv:2402.19115v2 , accepted for publication in Phys. Rev. C.
[2] M. Petrovici and A. Pop, Phys. Rev. C 107, 034913 (2023).
[3] M. Petrovici, A. Lindner, and A. Pop, Phys. Rev. C 98, 024904 (2018).
[4] Y. L. Dokshitzer, V. A. Khoze, and S. I. Troyan, J. Phys. G: Nucl. Part. Phys. 17, 1585 (1991).
[5] E. Levin and A. H. Rezaeian, Phys. Rev. D 83, 114001(2011).
[6] T. Lappi, Eur. Phys. J. C 71, 1699 (2011).



- List former students (in last 5 years) and current position/job and institution

Name		Current position/job and institution
Madalina Tarzila	PhD	Researcher Permanent employment "Horia Hulubei" National Institute for R&D in Physics and Nuclear Enginnering, Bucharest-Magurele
Amelia Lindner	PhD student	Software engineer lino Biotech AG Zürich, Switzerland
Adrian Mare	PhD	Design Engineer Microdul AG Zürich, Switzerland
Daniel-Ion Dorobantu	Master thesis	Research assistant – "Horia Hulubei" National Institute for R&D in Physics and Nuclear Enginnering, Bucharest-Magurele, ELI-NP Division
Dana Avramescu	Master thesis	Doctoral Researcher Department of Physics University of Jyväskylä
Catalina Cirneci	Master student	Consultant ERM: Environmental Resources Management Bucharest
Iulian Florin Andreicovici	Master student	"Horia Hulubei" National Institute for R&D in Physics and Nuclear Enginnering, Bucharest-Magurele, Hadron Physics Department
Florin Daniel Gila	Master student	"Horia Hulubei" National Institute for R&D in Physics and Nuclear Enginnering, Bucharest-Magurele, Hadron Physics Department
Madalina State	Student	"Horia Hulubei" National Institute for R&D in Physics and Nuclear Enginnering, Bucharest-Magurele, Hadron Physics Department

Publications list, conference presentations, list of attended meetings and list of deliverables covered in the present report

5. Papers and talks in last year

- M. Petrovici,
QCD Challenges,

Workshop on Advances, Innovations, and Future Perspectives in High-Energy Nuclear Physics
19–24 October 2024
Wuhan, China
https://indico.cern.ch/event/1430136/contributions/6174522/

- M. Petrovici,
QCD Challenges
General Seminar IFIN-HH, 21 November 2024

GRID (computation and storage) support:

- Co-authors to > 4 ALICE published papers

Conferences and ALICE PWG presentations:

- Contribution to > 5 conference presentations on behalf of ALICE Collaboration

Other activities and Budget

6. Further group activities (1 page)

- Collaborations, local synergies, education, outreach

- HPD 2025 Calendar

- Efforts have been made towards the construction of an informational panel of IFIN-HH, related to the new CERN-RO exhibition set up as part of the DUROCERN project.