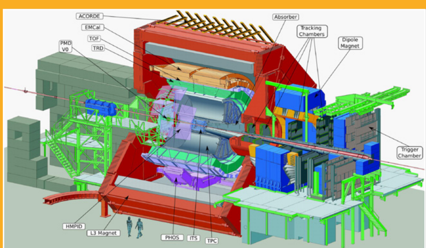
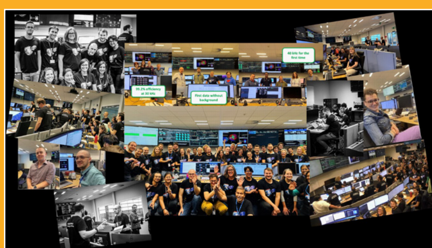
HPD COURIER

NUMBER 6 | MAY 2024

CERN 70th Anniversary

Romania in ALICE - 25th Anniversary



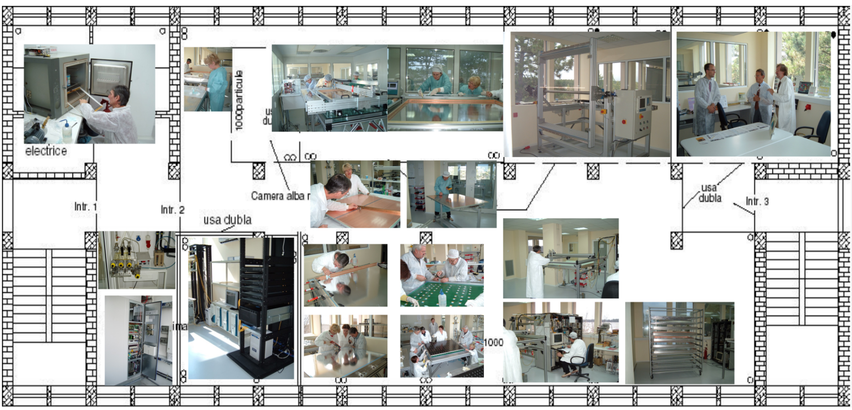


Based on the results obtained over the years in different international collaborations in the field of heavy ion collisions at low, intermediate and relativistic energies, in March 1999 our group from Hadron Physics Department of the Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), became member of the ALICE Collaboration at CERN.

ALICE is a dedicated experiment to study heavy ion collisions at ultra-relativistic energies delivered by the Large Hadron Collider (LHC), the main physics motivation being the production of deconfined matter and the study of the dynamics and properties of this new state of matter supposed to be characteristic at few µs after Big-Bang.

In order to guarantee a substantial contribution to a such experiment, we launched in 1999 a project at the national level which presented our planned activities in the ALICE Collaboration: detectors development, assembling and tests of important components of the ALICE experiment, front-end electronics, data processing, computing and last but not least data analysis focused on specific physics. After a rather long process to convince the political decision-makers at different levels that this is the only way to become visible and competitive in large scale international collaborations, inevitable in today's scientific research in particle and nuclear physics, the project was approved in 2003.

Within this project the financial support received from the Ministry of Education, Research and Youth gave us the possibility to organize a Detector Laboratory with proper clean rooms and infrastructure. An overview of the Laboratory with the main activities taking place in different areas can be followed below.



An overview of the Detector Laboratory and the main activities carried out.

The laboratory is divided into rooms that have the level of cleanliness from 50.000 part/ft^3 up to 250 part/ft^3, the equipments and tools being distributed accordingly to the cleanliness requirement for different operations.

The Detector Laboratory was inaugurated on October 25th, 2004. The inauguration was opened by four presentations related to the physics in ALICE, ALICE TRD subdetector, GRID computing and the main activities carried out for the configuration of the Laboratory delivered by Prof. Peter Braun Munzinger, Prof. Johanna Stachel, Dr. Iosif Legrand and Prof. Mihai Petrovici, respectively. Prof. Dr. Gheorghe Popa, State Secretary coordinating the research segment of the Ministry of Education, Research and Youth, Dr. Nicholas Koulberg, CERN adviser for non-member state affairs, directors of IFIN-HH , colleagues from other National Institutes from the Magurele campus, involved in CERN activities and others have participated to this event.

Prof. Dr. Gheorghe Popa and Dr. Nicholas Koulberg highly appreciated this achievement in such a short time creating the premisses for a fruitful contribution in one of the four main experiments at CERN. The presentations were followed by a visit of the Detector Laboratory. Some sequences of this event are presented in the following pictures.

Touring the Detector Laboratory.

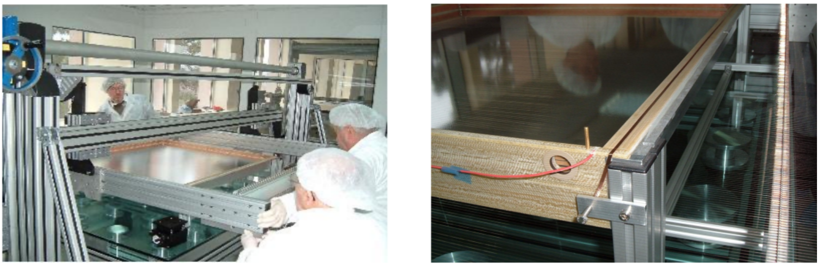
The DetLab, organised in an existing building (shown in the picture above), was intensively used for assembling and tests of 130 TRD chambers, i.e. 24% of the ALICE TRD detector.
(https://inspirehep.net/files/a956a092946a6e4aeb6496becdbb7b43)

An overview of the main steps followed when assembling a TRD chamber is presented in the following photos. First, the chamber frame assembling is shown. Once assembled, cross checks of pad connections and shorts were done. The pad plane assembling having as components the PCB with pads on one side and flat cables on the other and a rigid plane made out of honeycomb sandwiched by carbon fibers sheets with the corresponding cut-outs for flat cables can be followed next. Steps in the process of winding of multiwires electrodes are also presented. Lastly, the assembling of the multiwire electrodes on the detector frame, wires soldering and gluing, wire tension and pitch measurements, the connection of the voltage cables, chamber sealing and grounding, dark current measurement and 2D scanning.

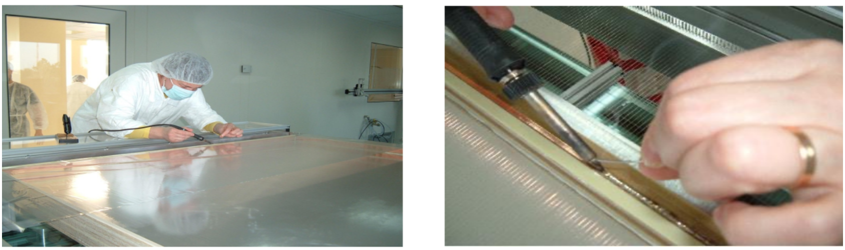
Frame assembly.

Pad plane assembly.

Winding and gluing of multiwire electrodes.



Alignment of multiwire electrodes.



Wires soldering.

Final gluing.

Wire tension measurement.

Wire electrical connections.

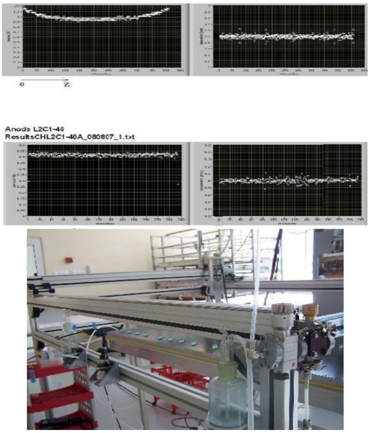
Chamber sealing.

Chamber grounding.

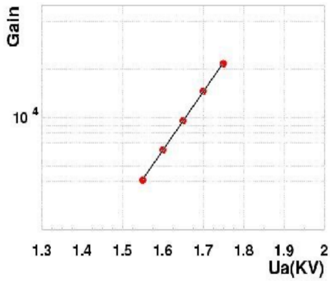
Dark current measurement.

Energy resolution and 2D gain scanning.

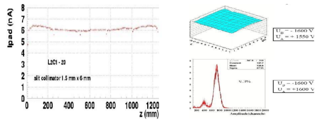
Some of the test results are exemplified below.



Top: Wire mechanical tension and gap size measurement. Bottom: Leak rate test.

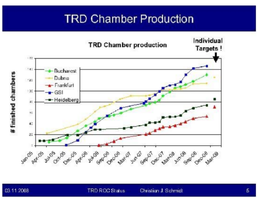


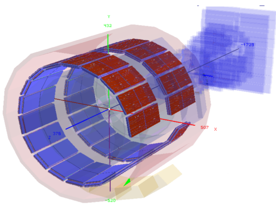
Gain measurements.



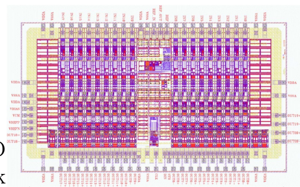
Scanning of the gain uniformity and energy resolution.

The TRD chamber production as a function of time, taking place at Frankfurt University, GSI-Darmstadt, Hadron Physics Department, Heidelberg University and JINR-Dubna is presented on the left side of the following figure. In the center one can see the region of the ALICE-TRD covered by the 130 chambers assembled and tested in HPD. We had also an essential contribution in designing a dedicated 16 channels charge sensitive preamplifier (PASA) CHIP, shown on the right.





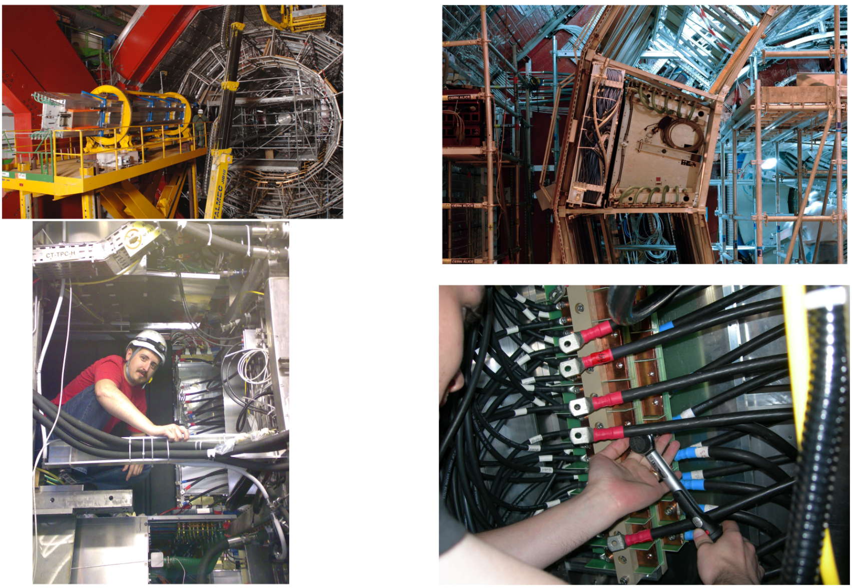
How the ALICE TRD subdetector would look equipped only with TRD chambers assembled and tested in Hadron Physics Department.



The produced chambers were stored in a dedicated storage area, packed in specially designed wooden boxes and transported to GSI by temperature controlled trucks.

TRD chambers transport.

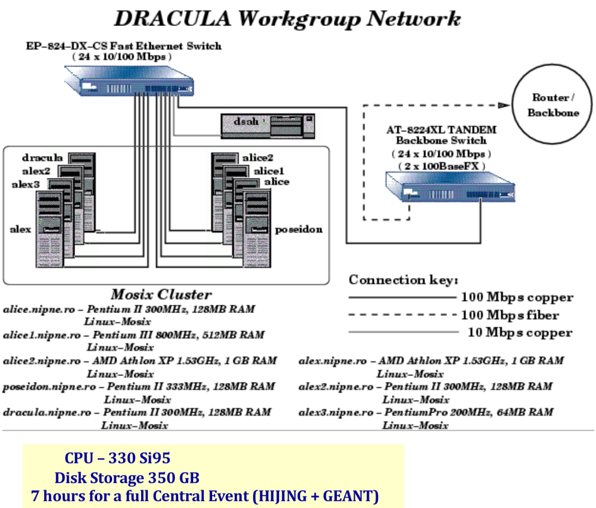
The chambers were transported from GSI to Munster where were equipped with electronics, assembled in super-modules and tested. The super-modules were transported to CERN and implemented in the ALICE experiment, our group being also involved in these activities (Nucl. Instr. and Meth in Phys. Research A881(2018)88).



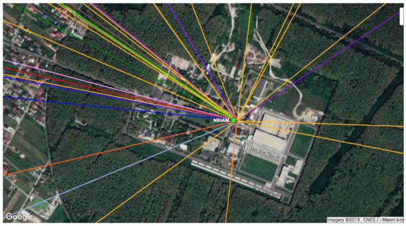
Installing the TRD Super-Modules (SM) in the Experiment

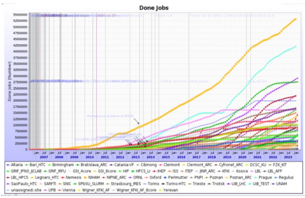
In 1999, being aware of the activities taking place at CERN for developing internationally distributed computing and storage infrastructures called GRID, to be used by the large international collaborations structured around the four large experiments, for the future LHC, similar activities were initiated also in our group having in mind the ambitious target to become, in time, a significant member of the ALICE GRID.

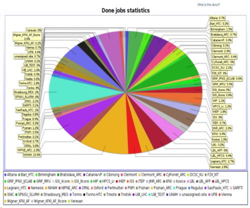
In 2002, a local distributed system connected to the ALICE GRID, became the first international GRID application in Romania.
Following a coherent strategy in developing a consistent computing and data storage of our department we used every available financial support to purchase different components, such that presently the NIHAM Data Centre is one of the most efficient Tier2 components of the ALICE GRID. A continuous operation of 24 hours per day and 7 days per week is guaranteed by additional infrastructure consisting of a 600 kW Diesel generator, industrial UPS, fire protection system and temperature and humidity sensors.
A general idea on how the NIHAM Data Centre looks like is presented on the next page (top left). A snapshot of the data between NIHAM and other centres of the ALICE GRID can be also followed (top right).
The contribution of NIHAM to the ALICE computing GRID in terms of done jobs (56 Mjobs, 10.6% of all Tier2 centres of ALICE GRID) and CPU time (254 Mhours, 8.3% of all Tier2 centres of ALICE GRID) in the last 18 years is presented by histograms and pie charts, respectively (bottom).

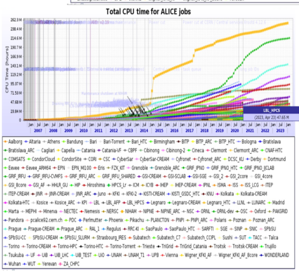


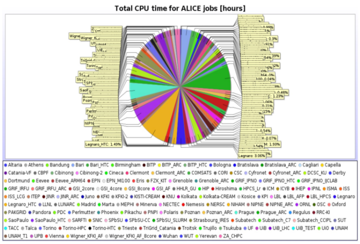
November 2002, the first international GRID application in Romania within AliEn.



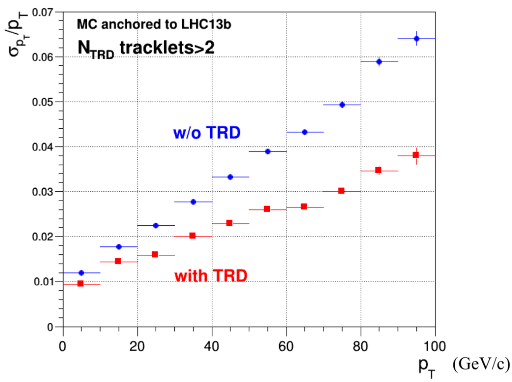








Once the experiment started and experimental data became available, we also had an important contribution in developing tracking algorithms for TRD chambers, which when implemented in the general tracking for the central barrel, has shown that a quite substantial improvement of the transverse momentum resolution can be obtained.



When the assembling and tests of the ALICE TRD chambers started, we organized a Workshop at Cheile Gradistei, a rather new touristic resort located at the foot of the Bucegi Mountains. After making the first GRID application in Romania, in 2006 we organized in collaboration with Particle Physics Department, Computing Department, Theory Department of IFIN-HH and Technical University of Bucharest a dedicated International GRID Workshop at Sinaia. Before starting the experiments at LHC, we organized in Sibiu an ALICE Workshop focused on TRD subdetector issues, offline software, GRID activities and physics. The posters and group photos of these events can be seen in the following pictures:

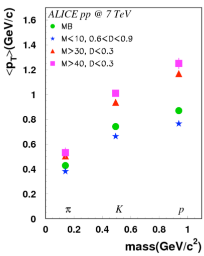
The motivation of such efforts was to have access to the experimental data and to analyze it focused on some physics aspects we were studying at lower energies, i.e. collective type phenomena.

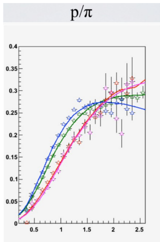
Having in mind the Gribov prediction supported by the results obtained at DESY in e-p collisions concerning the partonic cascades density at low values of x and Q^2 we initiated an analysis of charged particles and identified charged particles p_T spectra as a function of charged particle multiplicity and event shape in pp collisions at LHC energies.

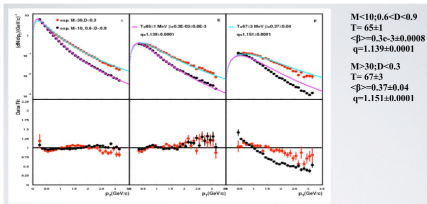
The first signatures for similarities between Pb-Pb and pp collisions at LHC energies (ALICE Week, PWG2-Soft Physics, 9.11.2010) were obtained at the same time as the near side long range correlations in pp collisions at large charged particle multiplicity were highlighted by the CMS Collaboration.

Some of these results in terms of average transverse momentum $\langle p_T \rangle$ for pions, kaons and protons as a function of mass for minimum bias (MB), and high charged particle multiplicity for jetty-like events and close to azimuthal isotropic events selected using Directivity (Eq.1) observable, respectively, are presented bellow.

$$D = \frac{|\Sigma_i p_t^i|}{\Sigma_i |p_t^i|}|_{\eta>0} \qquad (Eq.1)$$







The ratio of the p_T spectra of protons relative to pions for the same selection in charged particle multiplicity and directivity has evidenced a depletion of protons at lower p_T values similar with what was observed in A-A collisions at lower energies, such a push to higher values of p_T being interpreted as the result of radial expansion.

As far as at LHC energies the spectra at larger values of p_T is contaminated by jet contributions, we used boosted Tsallis expression (Eq.2) for a simultaneous fit of the pions, kaons and protons spectra obtained in the above mentioned conditions. The fit and resulting parameters are presented in the figures above.

$$\begin{aligned} f(p_t) = m_t \int_{-Y}^{Y} cosh(y)dy \int_{-\pi}^{\pi} d\phi \int_0^R rdr(1 + \frac{q-1}{T} \\ \times (m_t cosh(y)cosh(\rho) - p_t sinh(\rho)cos(\phi)))^{-1/(q-1)} \end{aligned} \qquad (Eq.2)$$

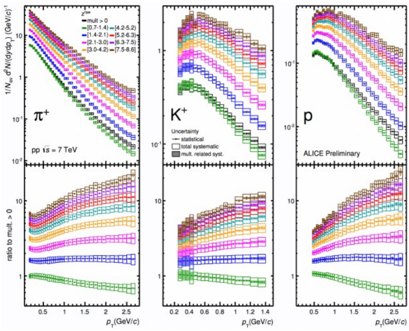
where $\rho = tanh^{-1}\beta_r$ and $\beta_r(r) = \beta_s \left(\frac{r}{R}\right)^n$.

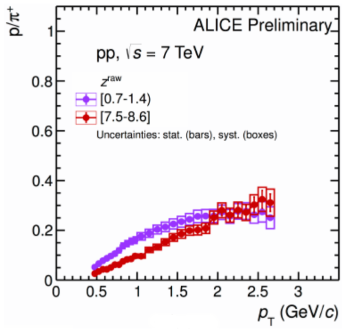
As it can be seen, a large transverse expansion is observed for large multiplicity and close to azimuthal isotropic events relative to the case of low multiplicity and jetty-like events. Obviously, such rather unexpected phenomena in pp collisions came as a surprize, taking some time to be scrutinized within the ALICE Collaboration. Once the p-Pb data became available and similar trends were observed, the message was clear and at Quark Matter 2014 details on such similarities were presented (Nucl.Phys. A931(2014)888).

$$\langle N_{ch}^{raw} \rangle_{mult>0} = 9.6, |\eta| < 0.8 \qquad (Eq.3)$$

N_{ch}^{raw}	z^{raw}
7 - 12	0.7 - 1.3
13 - 19	1.4 - 2.0
20 - 28	2.1 - 2.9
29 - 39	3.0 - 4.1
40 - 49	4.2 - 5.1
50 - 59	5.2 - 6.2
60 - 71	6.3 - 7.4
72 - 82	7.5 - 8.6

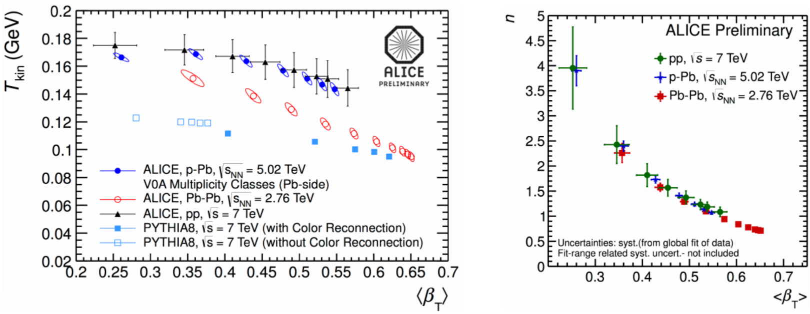
$$z^{raw} = \frac{(N_{ch}^{raw})_{limit}}{\langle N_{ch}^{raw} \rangle_{mult>0}} \qquad (Eq.4)$$





The results for pp were obtained using cuts in the measured charged particle multiplicity in the central barrel, Eq.3, and different multiplicity bins (see the above Table). Different representations were done as a function of the ratio between the mean value of the measured charged particle multiplicity in a given bin and measured MB charged particle multiplicity (z^{raw}). The figures above show the p_T spectra and their ratios to MB ones for pions, kaons and protons in different bins of z^{raw} and the ratio between p_T spectra of protons relative to pions for the lowest and largest z^{raw}.

The push of protons toward larger values of p_T relative to pions highlighted in the very preliminary analysis mentioned before is present. A simultaneous fit of the p_T spectra for pions, kaons and protons using this time a Boltzmann Gibs Blast Wave (BGBW) expression (Eq.5) was performed and the average transverse expansion



($\langle\beta_T\rangle$), kinetic freeze-out temperature (T_{kin}) and flow profile (n) fit parameters and their correlation as a function of charged particle multiplicity or centrality for pp, p-Pb and Pb-Pb are presented above.

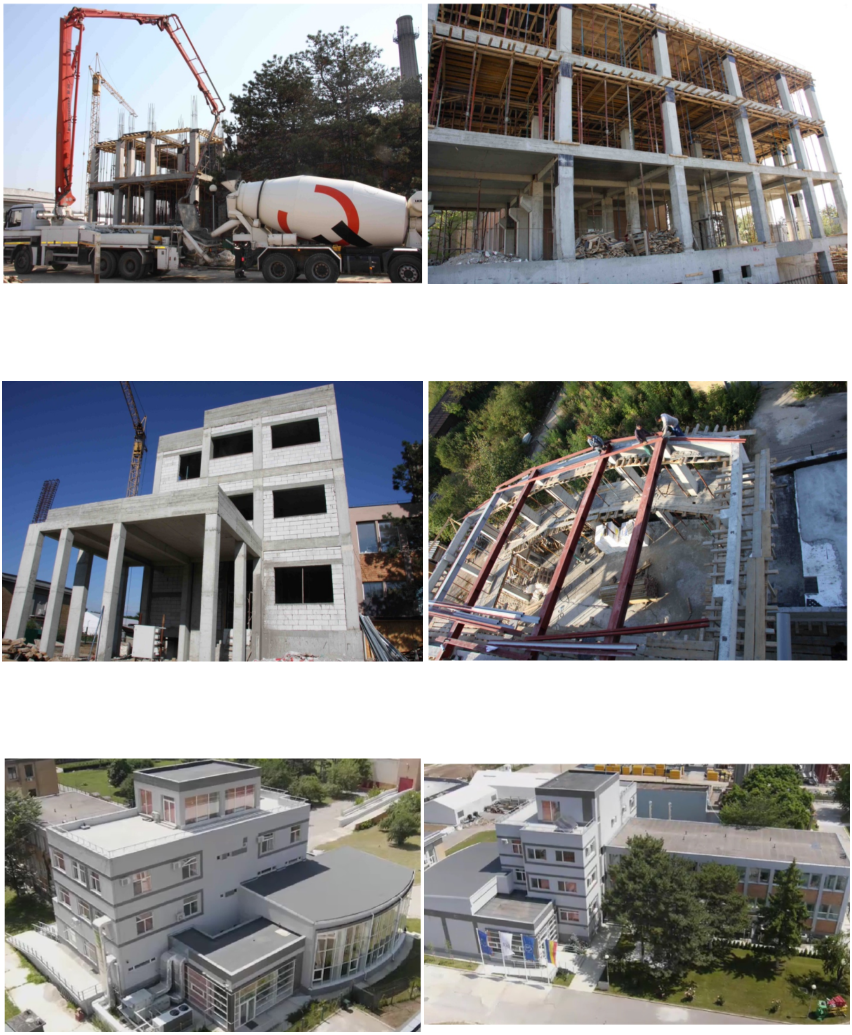
$$E\frac{d^3N}{dp^3} \sim f(p_T) = \int_0^R m_T K_1(m_T cosh\rho/T_{kin}) I_0(p_T sinh\rho/T_{kin}) r dr \qquad (Eq.5)$$

where $m_T = \sqrt{m^2 + p_T^2}$, $\beta_r(r) = \beta_s(\frac{r}{R})^n$

A clear similarity between pp, p-Pb and Pb-Pb collisions can be observed. In order to have a detailed understanding of the physics behind such similarities in terms of different trends observed in pp and Pb-Pb collisions at LHC energies, a multi-differential analysis is mandatory. This and many other types of topics of physics followed in ALICE and the other experiments at LHC required higher luminosities, implicitly higher collision rates. This was the reason for the ALICE Collaboration to embark on an upgrade program of some of the detectors, electronics and data processing strategy.

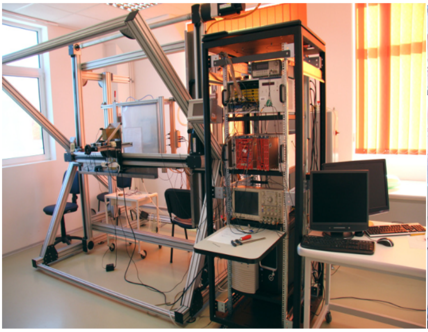
In Run1 and Run2 campaigns, the read-out chambers of the TPC were based on multi-wire proportional chambers. The positive ions back flow, in high counting rate operation builds up large positive space charge with negative impact on the performance of the detector. In order to minimize such an effect, a decision was taken to replace the TPC read-out chambers by new ones based on GEM technology (ALICE TPC upgrade TDR,
https://inspirehep.net/files/11c10c25be338dc1fc068fb853a51210).

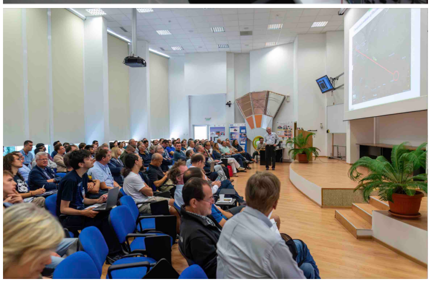
Argued by the results summarised above and many others, not directly related to the ALICE Collaboration, we succeeded to obtain the financing of another essential project under the IMPACT national program to expand our infrastructure. Snapshots of different steps taken during the construction period of an extension of the existing building are displayed in the following pictures.



Snapshot of different stages of the civil construction.

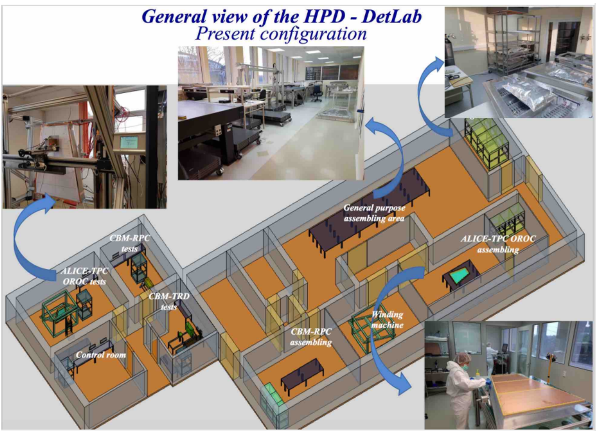
In the new building, we organized offices for permanent staff, guests, for diploma, master and PhD students, meeting rooms, 3 detector test laboratories, a control room, 2 electronic laboratories, a bonding laboratory and 2 laboratories for thin layer deposition for applied research. For seminars, workshops, conferences, etc. with larger audience, a Conference Hall with 160 seats was set-up. Worth mentioning that all meeting rooms, seminar room and Conference Hall are equipped with an integrated audio-video system for zoom connections.





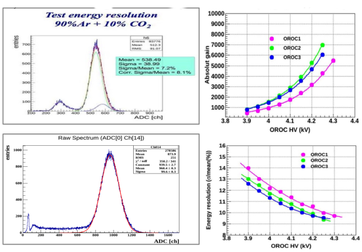
In the basement, near to the NIHAM Data Centre, was organized a rather similar computing infrastructure, NIHAM Analysis Facility (NAF), for large scale calculations for nuclear structure and dynamics, different phenomenological models of relativistic hadronic interactions, developing codes for ALICE data analysis before releasing them on ALICE GRID infrastructure.

Our previous experience in assembling and tests of different detector prototypes and especially in assembling and testing the 130 TRD chambers for the experiment, allowed us to embark on the ALICE Collaboration effort in upgrading the Time Projection Chamber (TPC) based on GEM technology. The commitment was to test and assembly 50% of the upgraded TPC outer read-out chambers (OROCs). A general view of partition of assembling and testing areas is also shown below.

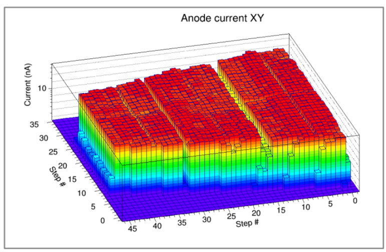


The main steps in the assembling and testing process of the OROCs can be followed in the next figures.

Once a chamber was assembled in the cleanest room, it was closed in a special in-house designed housing box based on honeycomb technology in order to go through a series of tests in terms of energy resolution, energy resolution and gain as a function of applied high voltage, gain uniformity and long term test in very high X ray flux delivered by two X-ray tubes. The chambers passing these tests were packed in tight metal transport boxes filled with nitrogen and with negligible water and oxygen content and stored in a clean room. Their transportation to CERN was done using special vans from our institute. At arrival at Point 2, the chambers passed transport survival tests, before being ready to be inserted in the ALICE-TPC.



Energy resolution and gain tests.



Gain uniformity test.

Storage room for the OROCs.

Preparing the van for OROCs transportation to CERN.

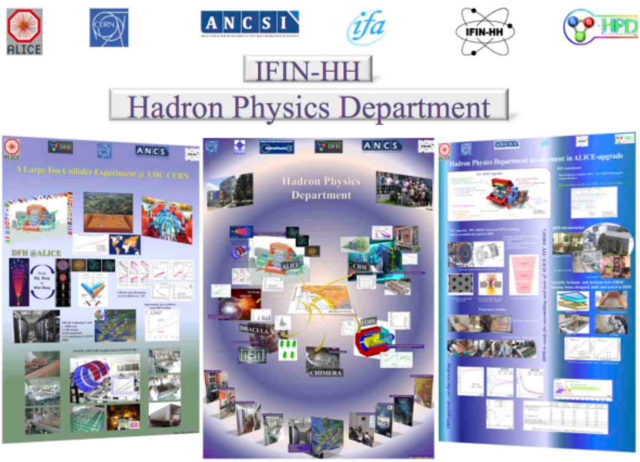
Transporting the OROCs to CERN.

Transport survival tests at P2.

Such results, as those summarized above and many others obtained by other Romanian research groups involved in CERN experiments like ATLAS, LHCb, ISOLDE, nTOF, NA62 or individuals working at CERN, having permanent or temporary positions, have been the main arguments for Romania to apply to become a CERN member. The official ceremony took place on the 5th of September 2016 in the presence of the President of Romania Klaus Werner Johannis and CERN General Director Fabiola Gianotti.

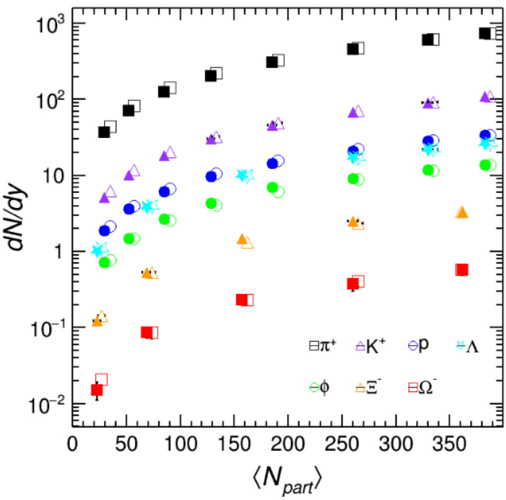
Romanian's flag raised at CERN
September 5, 2016

Some of the posters with our contributions within the ALICE Collaboration prepared for this event are presented bellow.



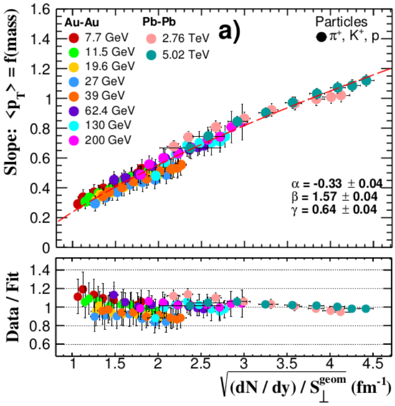
In parallel with the activity related to our involvement in the ALICE-TPC upgrade, we continued the physics program on two fronts, i.e. multi-differential analysis of p_T spectra and two-particle correlations for charged particles and identified charged particles as a function of charged particle multiplicity and event shape for different regions in $\Delta\varphi$ and $\Delta\eta$ relative to the leading particle and different studies based on published results from AGS up to LHC energies.

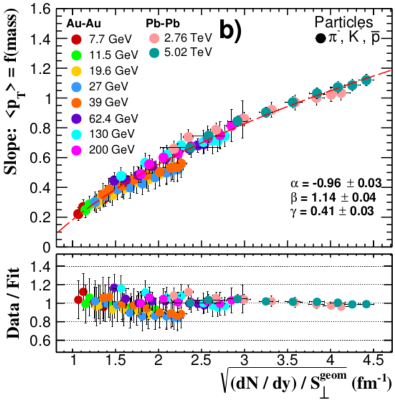
A simple approach to separate the wounded nucleons in an A-A collision in two categories, those suffering single collisions (corona) and the rest (core), estimated within a Glauber Monte Carlo model, explains the centrality dependence of the light flavor hadron production in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. The results show that, at energies available at the CERN Large Hadron Collider, the corona contribution still plays an important role, and it has to be considered in order to evidence the centrality dependence of different observables related to the core properties and dynamics (Phys. Rev. C 96, 014908 (2017)).

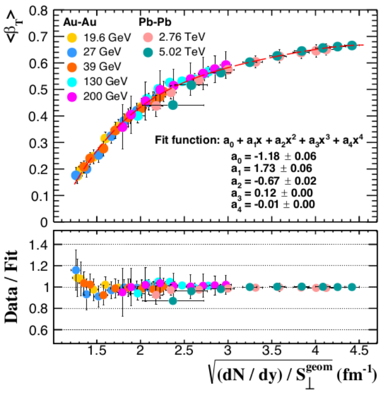


The estimated light flavour yields as a function of the number of participants $\langle N_{part} \rangle$ for the Pb-Pb collision at $\sqrt{s_{NN}} = 2.76$ TeV: open symbols - the result of core-corona relative contribution; full symbols - experimental data. To be visible, the open symbols are shifted by 5 units in $\langle N_{part} \rangle$.

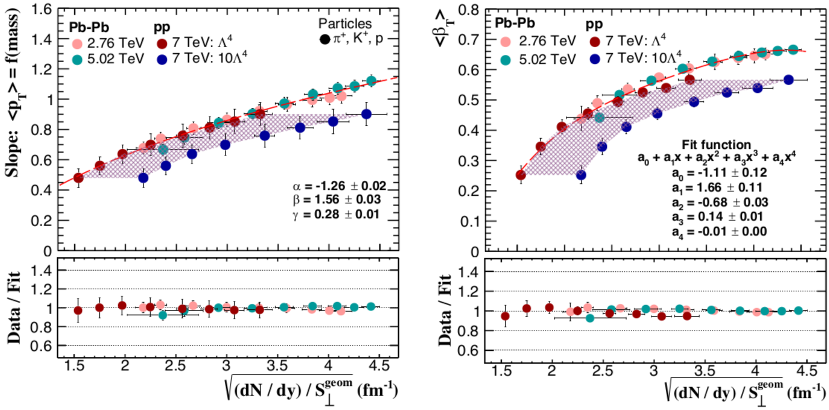
Using the RHIC and LHC experimental results, the $\langle p_T \rangle$ dependence of identified light flavour charged hadrons on $\sqrt{(dN/dy)/S_\perp}$, relevant scale in gluon saturation picture, was studied from $\sqrt{s_{NN}} = 7.7$ GeV up to 5.02 TeV. This study was extended to the slopes of the $\langle p_T \rangle$ dependence on the particle mass and the $\langle \beta_T \rangle$ parameter from Boltzmann-Gibbs Blast Wave (BGBW) fits of the p_T spectra. As could be followed in the next figures the slopes of the $\langle p_T \rangle$ particle mass dependence and the $\langle \beta_T \rangle$ parameter from BGBW fits scale well with $\sqrt{(dN/dy)/S_\perp}$.


a)
Au-Au
Pb-Pb
7.7 GeV
11.5 GeV
19.6 GeV
27 GeV
39 GeV
62.4 GeV
130 GeV
200 GeV
2.76 TeV
5.02 TeV
Particles
π^+, K^+, p
α = -0.33 ± 0.04
β = 1.57 ± 0.04
γ = 0.64 ± 0.04
Slope: $\langle p_T \rangle$ = f(mass)
Data / Fit
$\sqrt{(dN/dy)/S_\perp^{geom}}$ (fm^{-1})

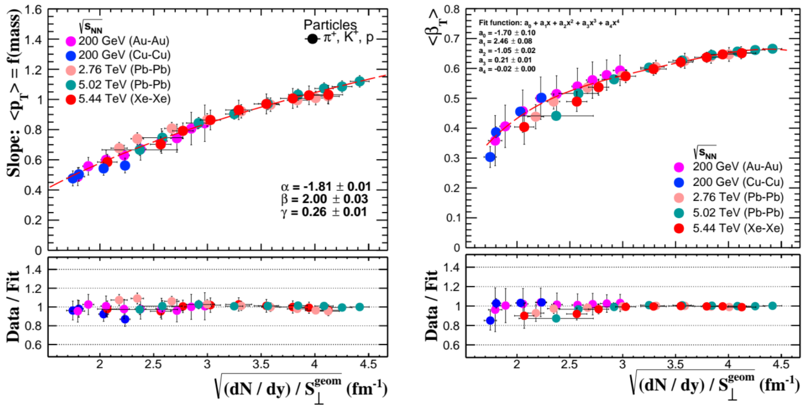

b)
Au-Au
Pb-Pb
7.7 GeV
11.5 GeV
19.6 GeV
27 GeV
39 GeV
62.4 GeV
130 GeV
200 GeV
2.76 TeV
5.02 TeV
Particles
π^-, K^-, $\bar{p}$
α = -0.96 ± 0.03
β = 1.14 ± 0.04
γ = 0.41 ± 0.03
Slope: $\langle p_T \rangle$ = f(mass)
Data / Fit
$\sqrt{(dN/dy)/S_\perp^{geom}}$ (fm^{-1})


Au-Au
Pb-Pb
19.6 GeV
27 GeV
39 GeV
130 GeV
200 GeV
2.76 TeV
5.02 TeV
Fit function: $a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4$
a_0 = -1.18 ± 0.06
a_1 = 1.73 ± 0.06
a_2 = -0.67 ± 0.02
a_3 = 0.12 ± 0.00
a_4 = -0.01 ± 0.00
$\langle \beta_T \rangle$
Data / Fit
$\sqrt{(dN/dy)/S_\perp^{geom}}$ (fm^{-1})

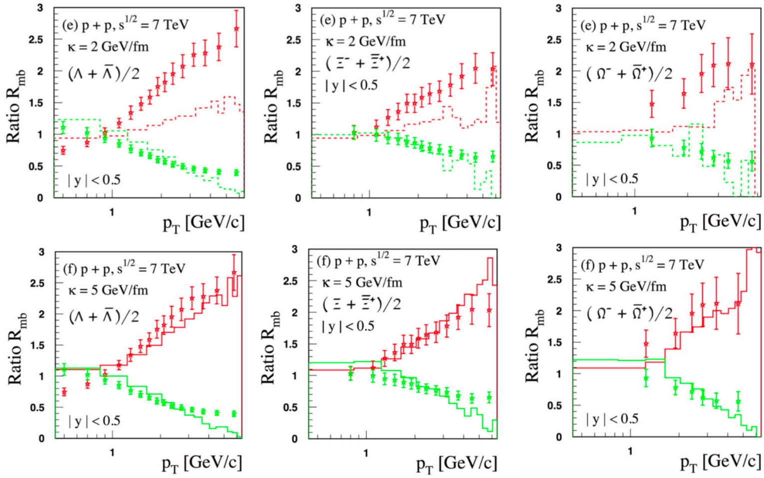
Similar trends for pp at $\sqrt{s}$ = 7 TeV are in a good agreement with the ones corresponding to Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV and 5.02 TeV, pointing to a system size scaling (Phys. Rev. C 98, 024904 (2018)).



As it can be observed in the presented figures, the slopes of the $\langle p_T \rangle$ particle mass dependence and the $\langle \beta_T \rangle$ parameter from BGBW fits as a function of $\sqrt{(dN/dy)/S_\perp}$ scale nicely for Cu-Cu, Au-Au at top RHIC energy with Xe-Xe and Pb-Pb results from LHC energies (AIP Conference Proceedings 2076(2019)040001).



We also investigated the effects of strong longitudinal colour fields (SLCF) on the identified (anti)particle transverse momentum (p_T) distributions in pp collision at $\sqrt{s} = 7$ TeV within the framework of the HIJING/BBbar v2.0 model.

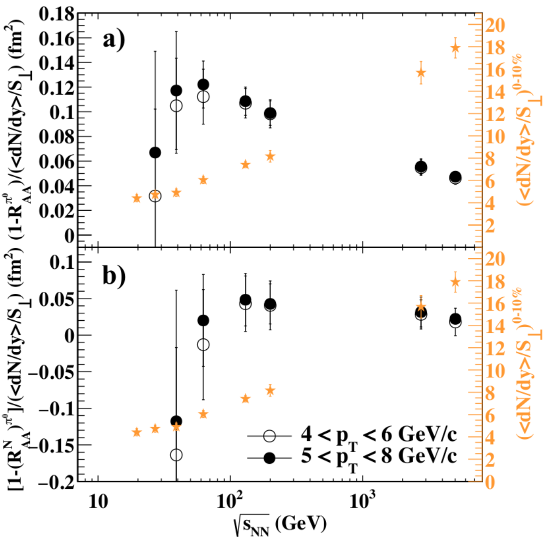


The ratios R_{mb} obtained using k = 2 GeV/fm - top row and k = 5 GeV/fm bottom row. The data and model results are represented by green and red colours corresponding to LM and HM class, respectively. The model results are represented by dashed histograms for k = 2 GeV/fm and solid histograms for k = 5 GeV/fm. The experimental ratio R_{mb} was calculated by us based on the average values extracted from p_T spectra of particle and anti-particle measured by ALICE Collaboration. Only statistical error bars are shown.

The comparison with the experiment was done in terms of the correlation between mean transverse momentum ($\langle p_T \rangle$) and multiplicity (N_{ch}) of charged particles at central rapidity, as well as the ratios of the p_T distributions to the one corresponding to the minimum bias (MB) pp collisions at the same energy, each of them normalized to the corresponding charged particle density, for high multiplicity (HM) and low multiplicity (LM) class of events (R_{mb}).
The theoretical calculations show that an increase of the strength of colour fields (as characterized by the effective values of the string tension k), from k=2 to k=5 GeV/fm, from LM to HM class of events, respectively, led to a ratio at low and intermediate p_T (i.e., 1 GeV/c $< p_T <$ 6 GeV/c), consistent with recent data obtained at the Large Hadron Collider by the ALICE Collaboration. These results point out the necessity of introducing a multiplicity (or energy density) dependence for the effective value of the string tension.
Moreover, the string tension k=5 GeV/fm, describing the p_T spectra of identified particles (anti)particle in pp collisions at $\sqrt{s} = 7$ TeV for high charged particle

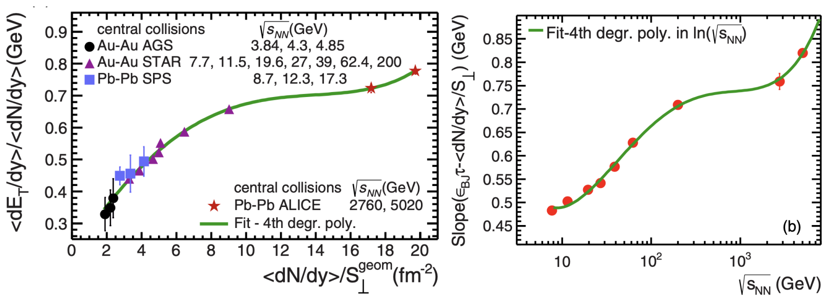
multiplicity event classes, has the same value as the one used in describing the p_T spectra in central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV. Therefore, one can conclude that at the LHC energies the global features of the interactions could be mostly determined by the properties of the initial chromo-electric flux tubes, while the system size may play a minor role (Phys. Rev. C 98(2018)064903).

Experimental results related to charged particle and π^0 suppression obtained at the Relativistic Heavy Ion Collider at Brookhaven for Au-Au (Cu-Cu) collisions and at the Large Hadron Collider at CERN for Pb-Pb (Xe-Xe) collisions were compiled in terms of the usual nuclear modification factors, R_{AA} and R_{CP}, and of the newly introduced R^N_{AA} and R^N_{CP} as a function of $\langle N_{part}\rangle$ and $\langle dN_{ch}/d\eta\rangle$. The studies are focused on a p_T range in the region of maximum suppression highlighted in the experiments. Considerations on the missing suppression in high charged particle multiplicity events for pp collisions at 7 TeV were presented. The trends of R_{CP} and R^N_{CP} for charged particles and $R^{\pi^0}_{AA}$ and $(R^N_{AA})^{\pi^0}$ as a function of $\sqrt{s_{NN}}$, measured at RHIC in Au-Au collisions and at LHC in Pb-Pb collisions, show a suppression that becomes larger from $\sqrt{s_{NN}}$ = 39 GeV up to $\sqrt{s_{NN}}$ = 200 GeV, followed by a saturation up to the highest energy of $\sqrt{s_{NN}}$ = 5.02 TeV in Pb-Pb collisions. A clear change in the dependence of $(1 - R^{\pi^0}_{AA})/\langle dN/dy\rangle$ for the most central collisions as a function of collision energy is observed in the region of $\sqrt{s_{NN}}$ = 62.4 - 130 GeV (Phys. Rev. C 103, 034903 (2021)).



a) $(1 - R^{\pi^0}{}_{AA})/\langle dN/dy\rangle$ as a function of collision energy; b) $(1 - (R^N_{AA})^{\pi^0})/\langle dN/dy\rangle$ as a function of collision energy (bullets)-left scale and $(\langle dN/dy\rangle/S_\perp)$ (stars)-right scales for the 0-10% centrality.

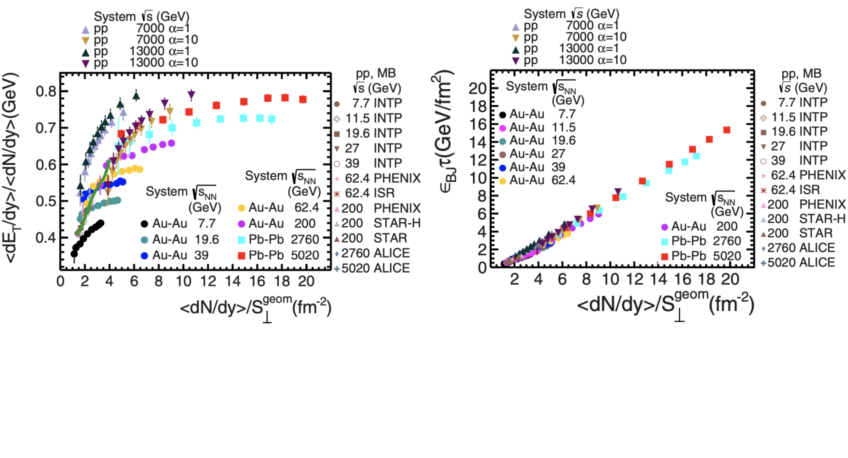
Previous extensive studies on the dependence of the average transverse momentum and its slope as a function of the hadron mass and the average transverse expansion on the particle multiplicity per unit rapidity and unit transverse overlap area of the colliding partners were extended to the ratio of the energy density to the entropy density.



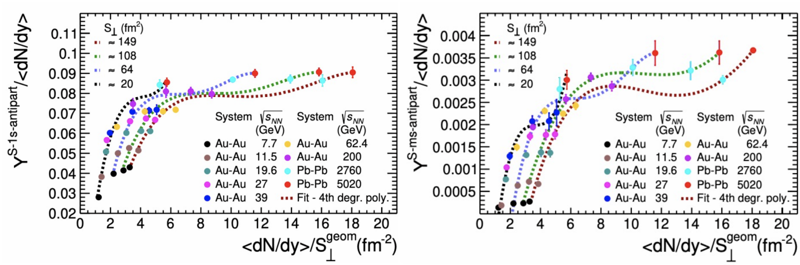
The behaviour of $\langle p_T\rangle/\sqrt{(dN/dy)/S_\perp}$ ratio as a function of collision energy for a given centrality or as a function of centrality for a given collision energy supports the predictions of Color Glass Condensate (CGC) and percolation based approaches. The dependence of the ratio of the energy density $\langle dE_T/dy\rangle/S_\perp$ to the entropy density $\langle dN/dy\rangle/S_\perp$ at different collision centralities for A-A collisions from AGS, SPS, RHIC and LHC energies was studied.

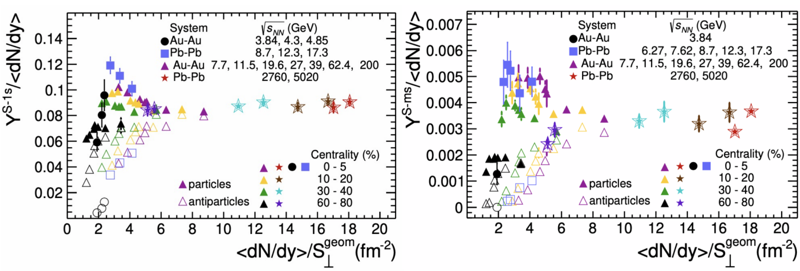
The increase of this ratio towards a plateau at the highest RHIC energies followed by a steep rise at LHC energies is in agreement with theoretical predictions made 40 years ago that indicate this behaviour as a signature of a phase transition. The observed trend of the slopes of the $\varepsilon_{Bj}\cdot\tau$ dependence on the entropy density $\langle dN/dy\rangle/S_\perp$, as a function of the collision energy, is similar with the ones highlighted in the $\langle dE_T/dy\rangle/\langle dN/dy\rangle - \langle dN/dy\rangle/S_\perp$ correlations.

The $\langle dE_T/dy\rangle/\langle dN/dy\rangle - \langle dN/dy\rangle/S_\perp$ and $\varepsilon_{Bj}\cdot\tau$ - $\langle dN/dy\rangle/S_\perp$ correlations for pp collisions at $\sqrt{s}$ =7 TeV and 13 TeV follow qualitatively the ones corresponding to Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.

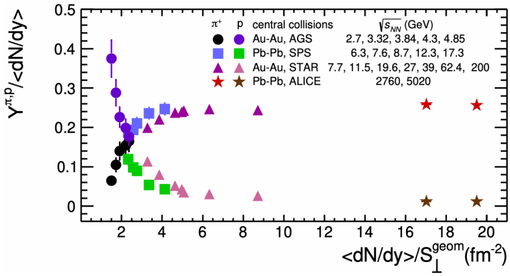


These studies were extended to various systematics related to strange hadrons and anti-hadrons. The $\langle p_T \rangle / \sqrt{(dN/dy)/S_\perp}$ ratio as a function of collision energy for a given centrality or as a function of centrality for a given collision energy for strange hadrons, similar with the ones corresponding to pions, kaons and protons, supports the predictions of CGC and percolation based approaches.
The dependence on the square root of entropy density of the slope and offset, extracted from the $\langle p_T \rangle$-particle mass correlation and the average transverse expansion velocity and kinetic freeze-out temperature parameters obtained from Boltzmann-Gibbs Blast Wave fits of the p_T spectra for strange hadrons compared with the trends observed for identified charged hadrons indicates differences in terms of freeze-out temperature and expansion velocity.

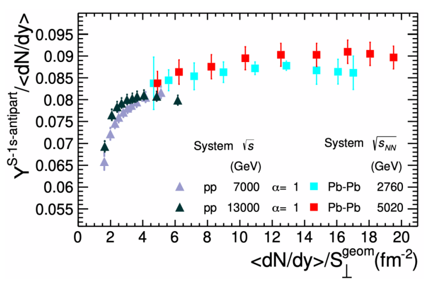


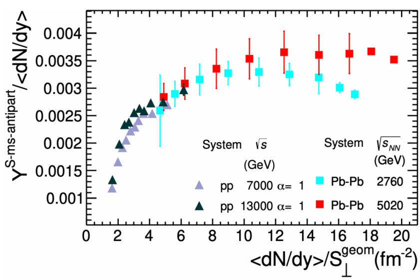


The correlation between the $Y^s/\langle dN/dy\rangle$ ratio of the single- and multi- strange anti-hadrons as a function of the fireball size shows similar trends as those observed in $\langle dE_T/dy\rangle/\langle dN/dy\rangle - \langle dN/dy\rangle/S_\perp$ correlations. A maximum is highlighted for the strange hadrons for central collisions, in the region where a transition from the baryon-dominated matter to the meson-dominated one takes place. Within the experimental error bars, the position of this maximum does not depend on the mass of the corresponding strange hadron.

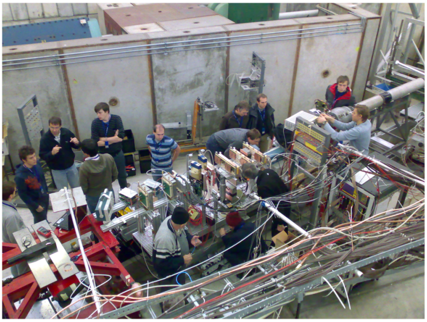


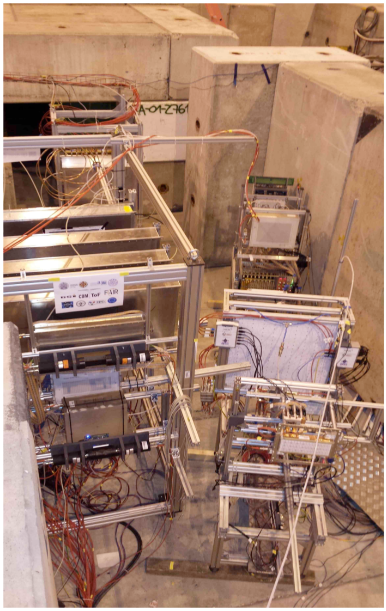
Comparison with pp experimental data reveals another similarity between pp and Pb-Pb collisions at the LHC energies (arXiv:2402.19115 [hep-ph]).





It is worth to mention that our group performed in-beam tests of new generation of high counting rate, high granularity and radiation hard 2D position sensitive Multi-Strip Multi-Gap Resitive Plate Counters (MSMGRPC) and Multiwire Proportional Counters (MWPC), associated FEE and free running DAQ at PS and SPS CERN facilities.

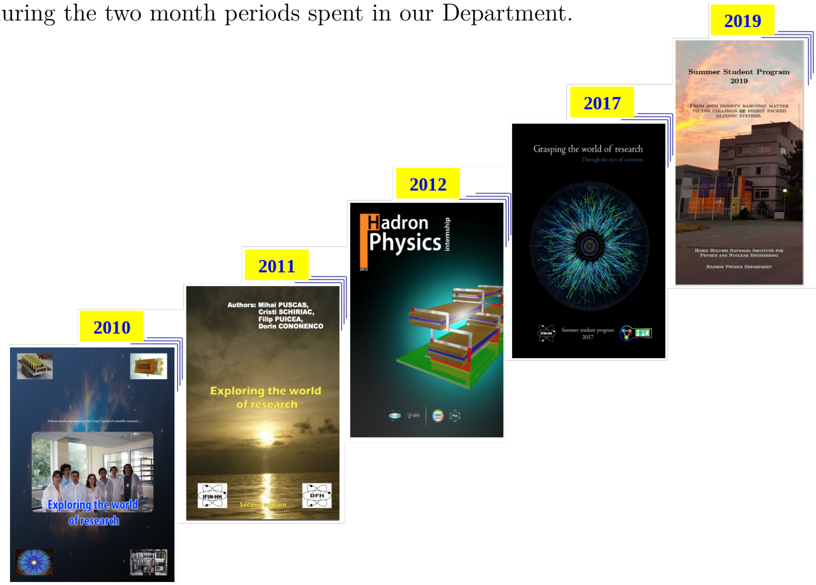




The received support from the Electronic Department of CERN in bonding some of our FASP CHIPs specially designed for operating the new padplane architecture of the 2D MWPC developed by us, is deeply appreciated.

Another important segment of our activity is to provide the opportunity for students to enhance their educational experience. Many diploma, master and PhD theses were accomplished under the coordination of members of our Department. We are organizing regular "Summer Student Program" attended by students from Romanian and foreign universities.

The participants were asked to issue booklets or flyers with their results obtained during the two month periods spent in our Department.

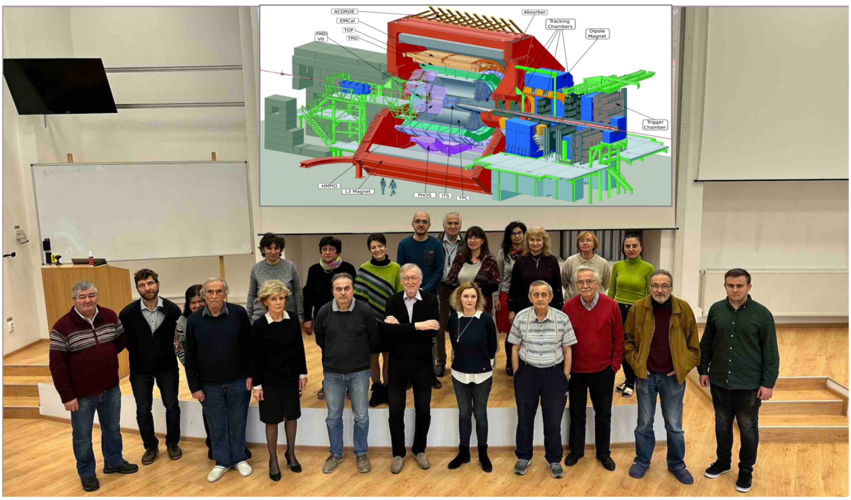


We are pleased to mention that very good participants to such programs decided to stay with us and prepare their diploma, master or PhD thesis along the topics in which they were involved during the Summer Student Programs.

Last but not least, it is worth mentioning that we received messages from many of them confirming the high standards of infrastructure, scientific atmosphere and challenging activities in which they were involved, relative to other places where they have been for similar training programs.

The main, present and former, actors behind the achievements summarized above:

Cristian Andrei, Oana Andrei, Anton Andronic*, Valerica Aprodu,
Dana Avramescu*, Daniel Bartos, Ionela Berceanu+, Alexandru Bercuci,
Gheorghe Caragheorgheopol, Vasile Catanescu, Mircea Ciobanu*,
Gheorghe Dima, Petre Dima+, Constanta Dinca, Dan Duhovnicu*, Marin Duma*,
Viorel Duta, Gheorghe Giolu*, Andrei Herghelegiu, Elena Ionescu*, Iosif Legrand,
Amelia Lindner*, Adrian Mare*, Constantin Magureanu*, Gheorghe Mateescu,
Nelu Mihai*, Dorin Moisa*, Gigi Nagel+, Mariana Petris, Alexandrina Petrovici,
Mihai Petrovici, Amalia Pop, Lucia Prodan*, Andrei Radu, Laura Radulescu,
Claudiu Schiaua, Victor Simion+, Gabriel Stoicea*, George Stoian,
Madalina Tarzila, Petre Zaharia*.
(* former members, + deceased)



We would like to express our gratitude to the Ministry of Research, Innovation and Digitalization for the financial support we received over the years. Our results are highly appreciated at the level of our Ministry, especially the State Secretary Prof. Tudor Prisecaru. Our activity and results led to the award, by the President of Romania Klaus Werner Johannis, of the Order of Faithful Service in the rank of Commander.

This issue of the HPD Courier is dedicated to the 70^{th} CERN Anniversary and 25^{th} Anniversary of our membership within ALICE.

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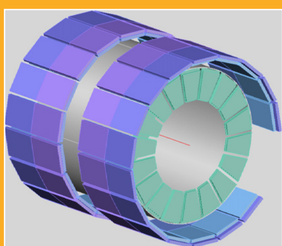
CERN 70th Anniversary

ALICE

Romania in ALICE - 25th Anniversary



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