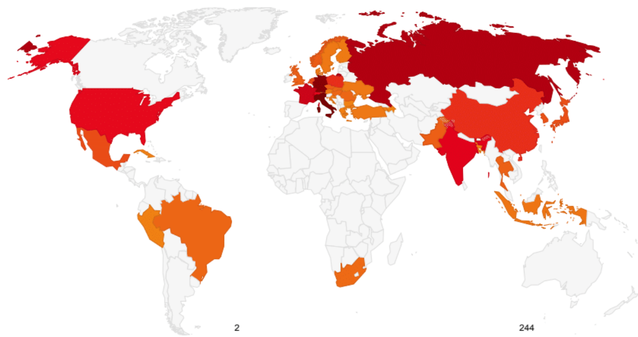
New results obtained in the ALICE experiment with a participation of the JINR team.

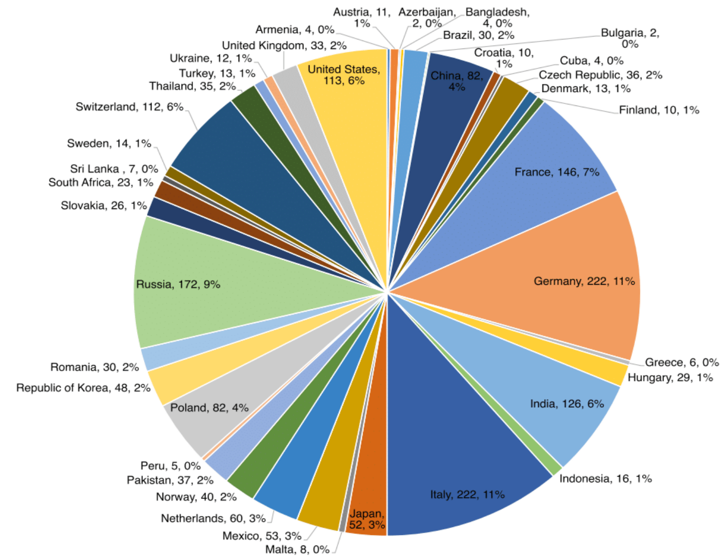
B.Batyunya

60th PAC, Dubna, 17.06.2024

ALICE

The ALICE Collaboration





40 Countries, 176 Institutes (including 19 Associates)

1946 Members, about 1000 signing authors

941 Physicists (including PhD Students)

- 587 PhD Physicists
- 355 PhD Students

52 Senior Engineers

The ALICE JINR group:

-- 11 physicists (4 - analysis, 7 - PHOS);

-- 1 PhD student;

-- 1 expert for the root software updating and GRID

computing management.

ALICE

Main activity of the Dubna team in ALICE

- Bothe-Einstein correlations (femtoscopy physics):

  Analysis of two-charged kaons correlations in p-p, p-Pb and Pb-Pb collisions. Updating of the analysis software.

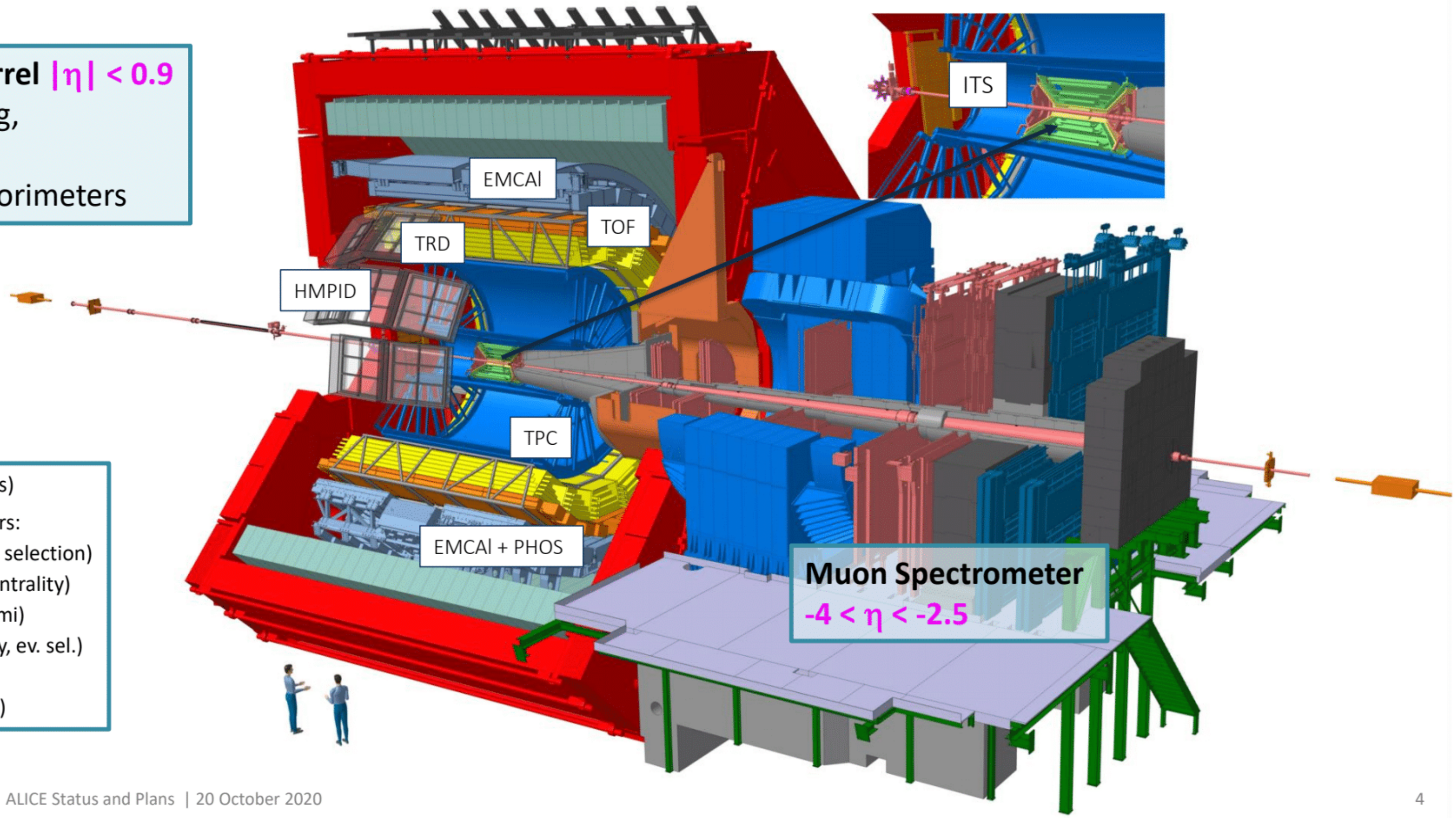
- Ultraperipheral collisions of heavy ions:

  Study of vector meson photoproductions in the Pb-Pb and p-Pb collisions.

- Thermal model of particle production in pp and A-A collisions.
- GRID computing and software activities.
- Participation in the ALICE shifts and service tasks.
- Photon Spectrometer (PHOS) upgrade.

The ALICE detector (Run 2)

Central Barrel $|\eta| < 0.9$
- Tracking,
- PID
- EM-Calorimeters



ACORDE (cosmics)

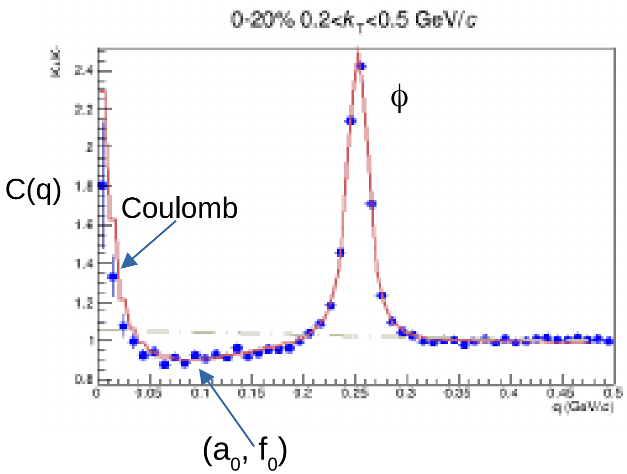
Forward detectors:
- AD (difraction selection)
- V0 (trigger, centrality)
- V0 (timing, lumi)
- ZDC (centrality, ev. sel.)
- FMD (N_{ch})
- PMD ($N\gamma$, Nch)

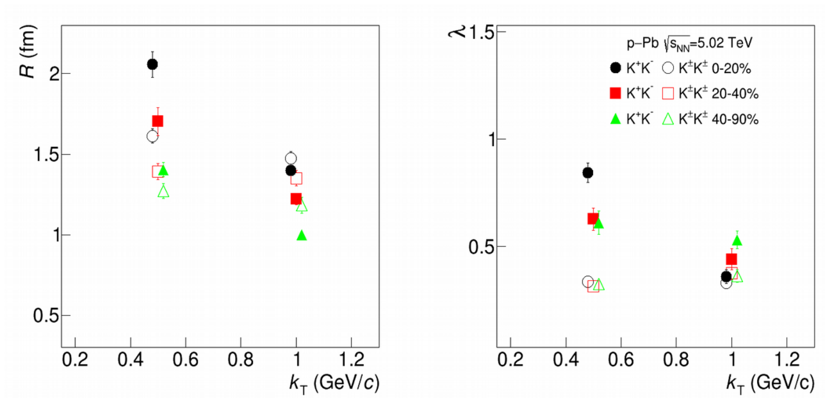
Muon Spectrometer
$-4 < \eta < -2.5$

New results were obtained for femtoscopic K^+K^- pairs correlation analysis in p-Pb at 5.02 TeV.

The correlation function C(q) was checked with the Lednický-Lyuboshits model using the formula

$C(q) = 1 + \lambda \left(C^{FSI}_{a_0, f_0}(q,R) + C_{\phi}(q,R) \right)$ for fitting of the data (the left figure), where q = (p1-p2), p1 and p2 are the 4-momenta of kaons, C^{FSI} is the correlation function in the model for influence of the final state interaction through the a_0 and f_0 resonances, C_{ϕ} – convolution of the Gaussian and Breit-Wigner functions for ϕ meson production, R is the kaon emission source radius, λ is the correlation strength.





The right figures show the parameters R and λ versus pair transverse momentum $k_T = |p_{T1} + p_{T2}|/2$ for different centralities in comparison with the data obtained earlier for identical kaons. The known strong R decrease is a consequence of the collective effects, predicted in the hydrodynamic models. One can see also some difference of the R values for non identical and identical kaon pairs that is in contradiction with the results obtained before for the Pb-Pb collisions (Phys.Rev.C107,054904,2023).

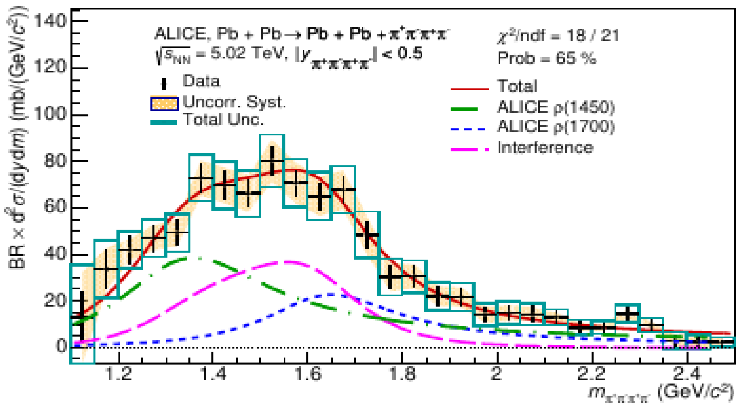
This contradiction is under discussion now.

New results were obtained with the JINR team participation for four pions coherent

photoproduction in ultraperiferel Pb-Pb collisions (UPC) at 5.02 TeV (per nucleon pairs). In this process vertual photon

fluctuates into ρ^0,$\rho^{0'}$ mesons which next interact with whole nucleus through pomeron exchange with decays to four pions.

The best fit results for invariant mass distribution of 4 pions (shown in the figure) have been obtained



using two Breit-Wigner (BW) functions for the contribution of two ρ^0 resonance states:

$$\frac{d\sigma}{dm} = |A \cdot BW_1 + e^{-i\varphi} \cdot B \cdot BW_2|^2, \quad BW_{\text{part}} = \frac{\sqrt{m_{\text{part}} \cdot m_{\text{event}} \cdot \Gamma_{\text{event}}}}{m_{\text{event}}^2 - m_{\text{part}}^2 + i \cdot m_{\text{part}} \cdot \Gamma_{\text{event}}},$$

$$\Gamma_{\text{event}} = \Gamma_{\text{part}} \cdot \frac{m_{\text{part}}}{m_{\text{event}}} \cdot \left(\frac{m_{\text{event}}^2 - k \cdot m_\pi^2}{m_{\text{part}}^2 - k \cdot m_\pi^2}\right)^{3/2}$$

, m_{part} , Γ_{part} are resonance mass and width, m_{event} and Γ_{event} are mass and width of 4π distribution, and φ is the missing interference angle between the two resonances.

The following parameter values have been found from the fit:

m_1 = 1385 ± 14 (stat.) ± 36 (syst.) MeV/c^2, Γ_1 = 431 ± 36 (stat.) ± 82 (syst.) MeV/c^2,

m_2 = 1663 ± 13 (stat.) ± 22(syst.) MeV/c^2, Γ_2 = 357 ± 31 (stat.) ± 49 (syst.) MeV/c^2,

φ = 1.52 ± 0.16 (stat.) ± 0.19 (syst.) rad.

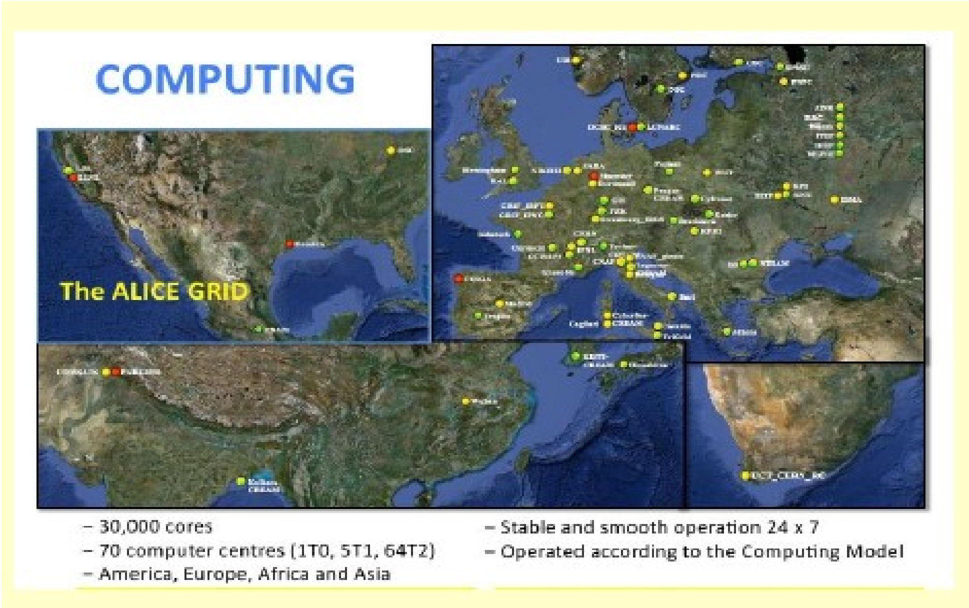
These masses and widths are consistent within the errors with PDG's values of the ρ^0(1450) and the ρ^0(1700).

The cross sections were measured also for the resonance productions with the values:

24.8 ± 2.5 (stat.) ± 8.1 (syst.) mb and 10.1 ± 2.3 (stat.) ± 5.3 (syst.) mb for first and second resonances respectively.

These values are in good agreement with KGTT model prediction using the Reggeon and Pomeron pole exchanges.

These results were published in the arXiv:2404.07542.



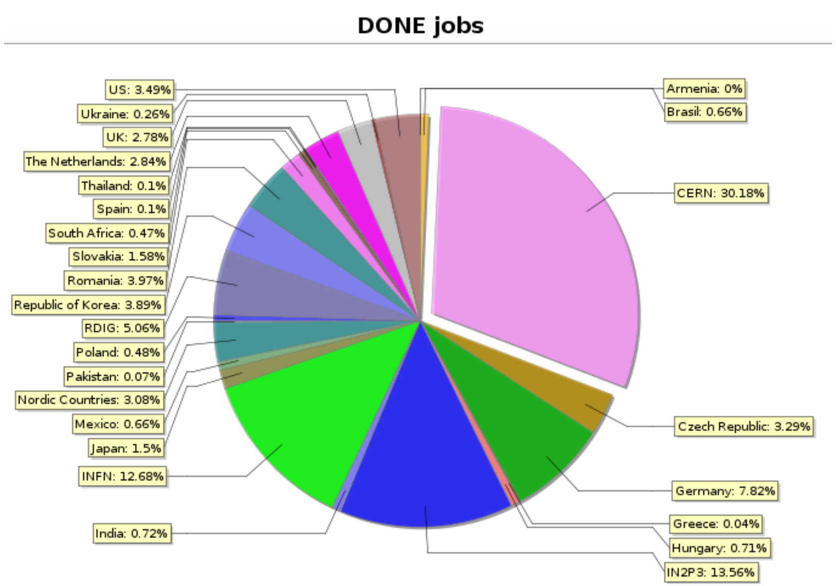
JINR GRID participation

The JINR ALICE GRID is a part of 7-th Russian ALICE GRID Tier 2 Centers (RDIG – Russian Data Intensive Grid).

The resources of JINR GRID Farm:

13500 cores CPU (40% of the RDIG),

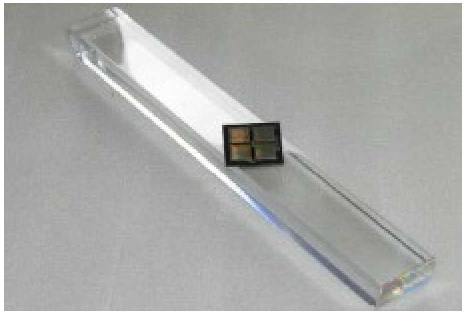
2000 Tb Disk-SE. (64%).



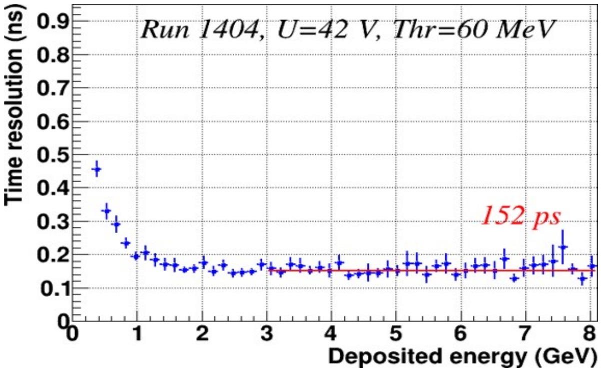
The contribution of JINR to the RDIG jobs is 48% .

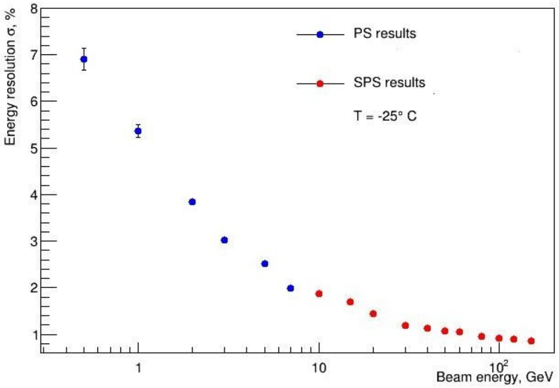
RDIG contribution to the ALICE-GRID is 5.1%

New results were obtained for a test of the PHOS with Silicon Photo Multiplayer (SiPM) detectors (HAMAMATSU, Japan) at the SPS (CERN) energy.



PWO_4 monocrystal and 4 SiPM in the side (top left figure) of different types for high and low energies were used.
The test setup consists of 25 (5x5) crystals with a such the SiPM combinations. The electronics and FEC32 (reading) card are the production of JINR and Kurchatov institute





The time detector resolution of near 100 ps was obtained in the electron beam energy range 1-10 GeV (the left lower figure with taking into account of 50 ps the start detector resolution). The energy resolution (up to 1%) versus energy is shown in the right lower figure.

Another possibility to improve the PHOS time resolution by the software development was studied (in collaboration with NRC "Kurchatov Institute" IHEP)

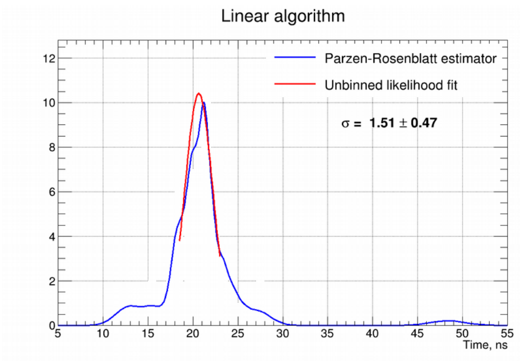
To improve the current time resolution (3 – 4 ns) the following algorithms have been tested to get the PHOS time:

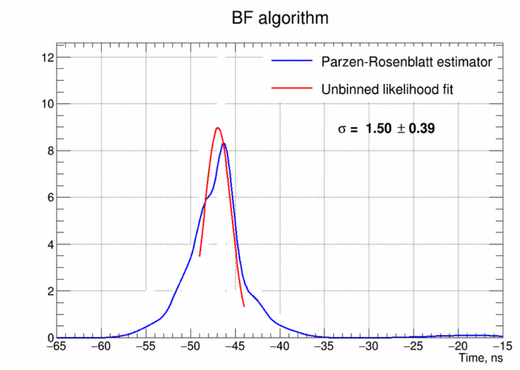
-- "Linear" method is based on linear fitting of the front samples of signals (it is used in the current software);

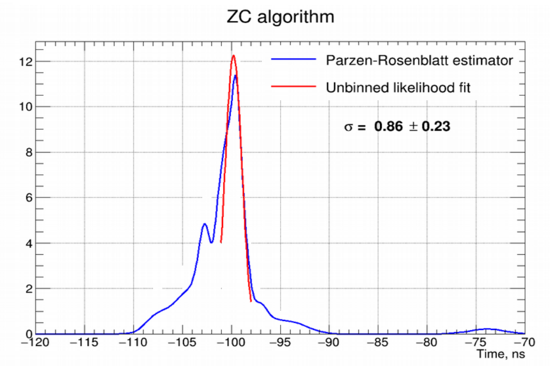
-- "BF" method is based on fitting of the signal samples by semi-Gaussian function;

-- "ZC" method is based on linear fitting of transformed signal samples.

Next, Parzen-Rosenblatt estimator and likelihood fit were used for the analysis of the experimental time distributions. The results are shown in the three figures. One can see that the best time resolution, $\sigma \sim 0.9$ ns, has been achieved for with the "ZC" method .







In addition, this time resolution may be improved near two times after taking into account all the channels belonging to the electromagnetic shower.

These results are a part of the PhD Thesis of our PhD student.

Conference presentations .

1. K. Mikhaylov (NRC, JINR, on behalf of the ALICE Collaboration), “Charged kaon femtoscopy with ALICE at the LHC.”, Session of Russian Academy of Sciences, Dubna, April 1-5, 2024.

2. E. Rogochaya (JINR, on behalf of the ALICE Collaboration), “Particle-emitting source dynamics via femtoscopy at the LHC energies with ALICE.”, PASCOS 2024, QUY NHON, Vietnam, July 7-13, 2024.

ALICE publications with key contributions from the JINR group.

1. Femtoscopic correlations of identical charged pions and kaons in pp collisions at $s^{1/2}$ = 13 TeV with event-shape selection., ALICE Collaboration (S. Acharya et al.), Phys. Rev. C 109, (2024) 2-024915.

2. Exclusive four pion photoproduction in ultraperipheral Pb-Pb collisions at $(s_{NN})^{1/2}$ = 5.02 TeV, ALICE Collaboration (S.Acharya et al), arXiv:2404.07542 (2024).

3. Studying the interaction between charm and light-flavor mesons. ALICE Collaboration (S.Acharya et al), arXiv:2401.13541 (2024).

Other scientific activities.

– Participation E. Rogochaya (JINR), in the ALICE Review Committees for the ALICE publications.

– Participation in the 44 ALICE - DCS shifts (56% of the year quota)

Conclusions

– The JINR ALICE team carries out successfully the new physical analysis of the experimental data for the Femtoscopic Correlations in p-Pb collisions.

– The new analysis was finished and published for the UPC study in Pb-Pb at 5.02 TeV. It was shown that the best description of invariant mass 4-pions spectrum is the fit by two BW functions which leads to the two $\rho^{0'}$ states consistent with the ones in the PDG.

– The JINR ALICE GRID site continues to provide a stable operation.

– The new results were obtained on the study for possible improve of the PHOS time resolution.

JINR plans for the 2024-25 years.

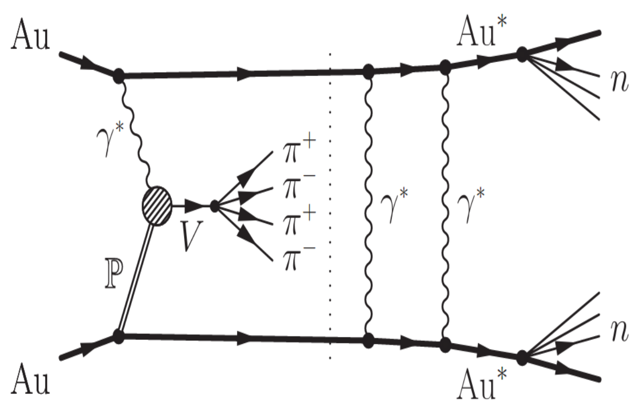
- Finish and publish 1D and 3-D femtoscopic analysis for $K^{ch}K^{ch}$ pairs in Pb-Pb Collision at 5.02 TeV.
- Finish and publish 1D and 3-D femtoscopic analysis for $K^{ch}K^{ch}$ pairs in p-Pb Collision at 5.02.
- Start the 1-D femtoscopic analysis for $K^{+}K^{-}$ pars in p-Pb collisions at 5.02 TeV.
- Preparation of the publication for the new version of Thermal model of particle production in A-A collisions.
- ALICE GRID support in the JINR computing system.
- Participation in the ALICE shifts and service tasks.

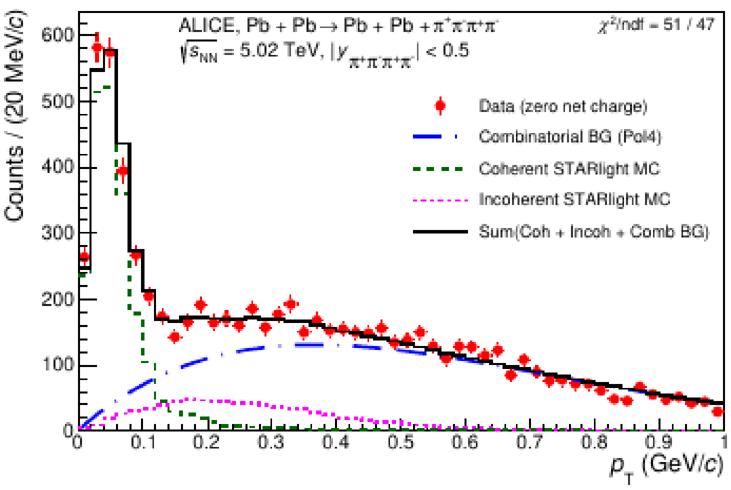
Thank you for your attention

Backup

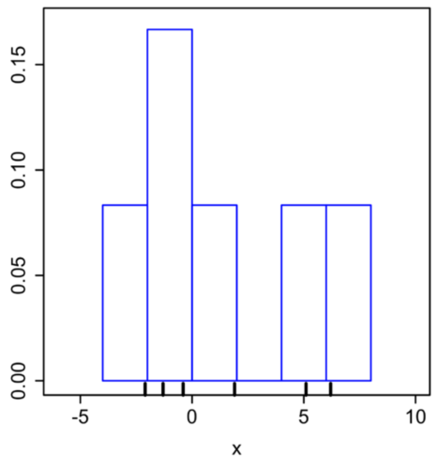
In the process of four pions coherent photoproduction through the vector meson decays in the ultraperiferel collisions (UPC). The vector mesons interact with whole nucleus through pomeron exchange as it's shown by the diagram in the left figure.

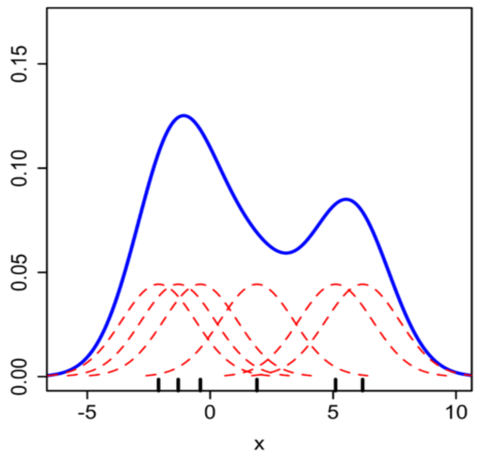
The coherent process is selected with the transverse momentum of four pions $p_T(4\pi) < 0.15$ GeV/c according a prediction of STARlight model as it is seen in the right figure.





Parzen – Rosenblatt estimator vs histogram





Parzen - Rozenblatt estimator (solid blue curve) converge faster (compared to the histogram) to the true underlying density for continuous random variables.

Let $(x_1, x_1, \ldots, x_n)$ be independent and identically distributed samples drawn from some univariate distribution with an unknown density f at any given point x. Its Parzen - Rosenblatt estimator is

$$\hat{f}(t) = \frac{1}{nh} \sum_{i=1}^{n} \left(K\left(\frac{t - x_i}{h} \right) \right)$$

where K is the kernel, a non-negative function, and h>0 is a parameter called the bandwidth (or window). In the RooFit algorithm K is Gaussian.

The details of the RooFit algorithm are described here:

Cranmer KS, Kernel Estimation in High-Energy Physics. Computer Physics Communications 136:198-207,2001 - e-Print Archive: hep ex/0011057

Original works:

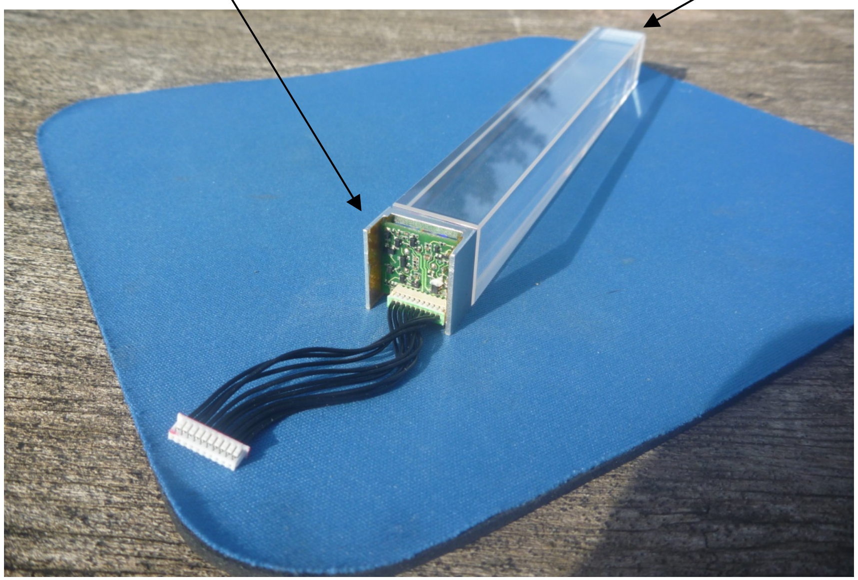
Rosenblatt M. Remarks on Some Nonparametric Estimates of a Density Function. The Annals of Mathematical Statistics. 1956
Parzen E. On Estimation of a Probability Density Function and Mode. The Annals of Mathematical Statistics. 1962

ALICE Photon Spectrometer (PHOS)

Crystalline element of PHOS: lead tungstate, $PbWO_4$,

$2.2 \times 2.2\ cm^2$ cross section and 18 cm length.

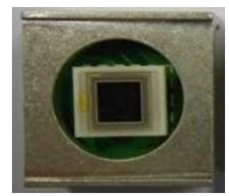
Chip of electronics



Current PHOS setup:

Avalanch photo-detector (APD)

($5 \times 5\ mm^2$)



Operating temperature: -28°C

Time-of-flight resolution

$\sigma_t = 4 - 5$ ns at 1 GeV

(useless for photon identification !)

Upgrade projects

FoCal

- Test beams with full prototypes
- Work towards TDR

ITS3

- MLR1 sensor characterisation
- Engineering models
- Preparation of ER1

ALICE 3

- LHCC review concluded
- Additional physics studies
- **R&D programme**