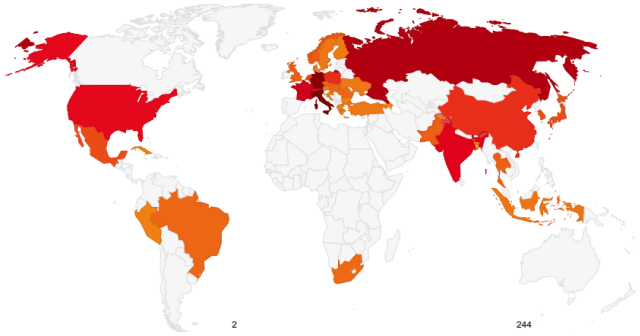
ALICE

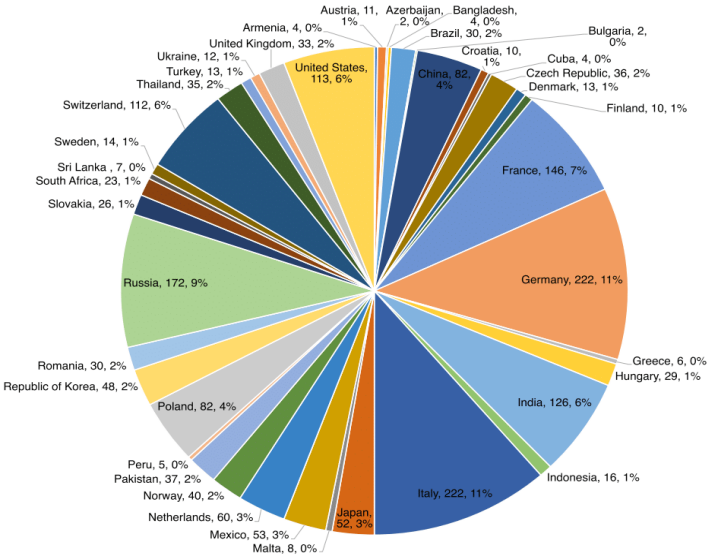
New results obtained in the ALICE experiment with a participation of the JINR team.

B.Batyunya

57th PAC, Dubna, 24.01.2023

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:

-- 13 physicists (6 - analysis , 7 - PHOS);

-- 1 PhD student;

-- 1 expert for the root software updating and GRID computing management.

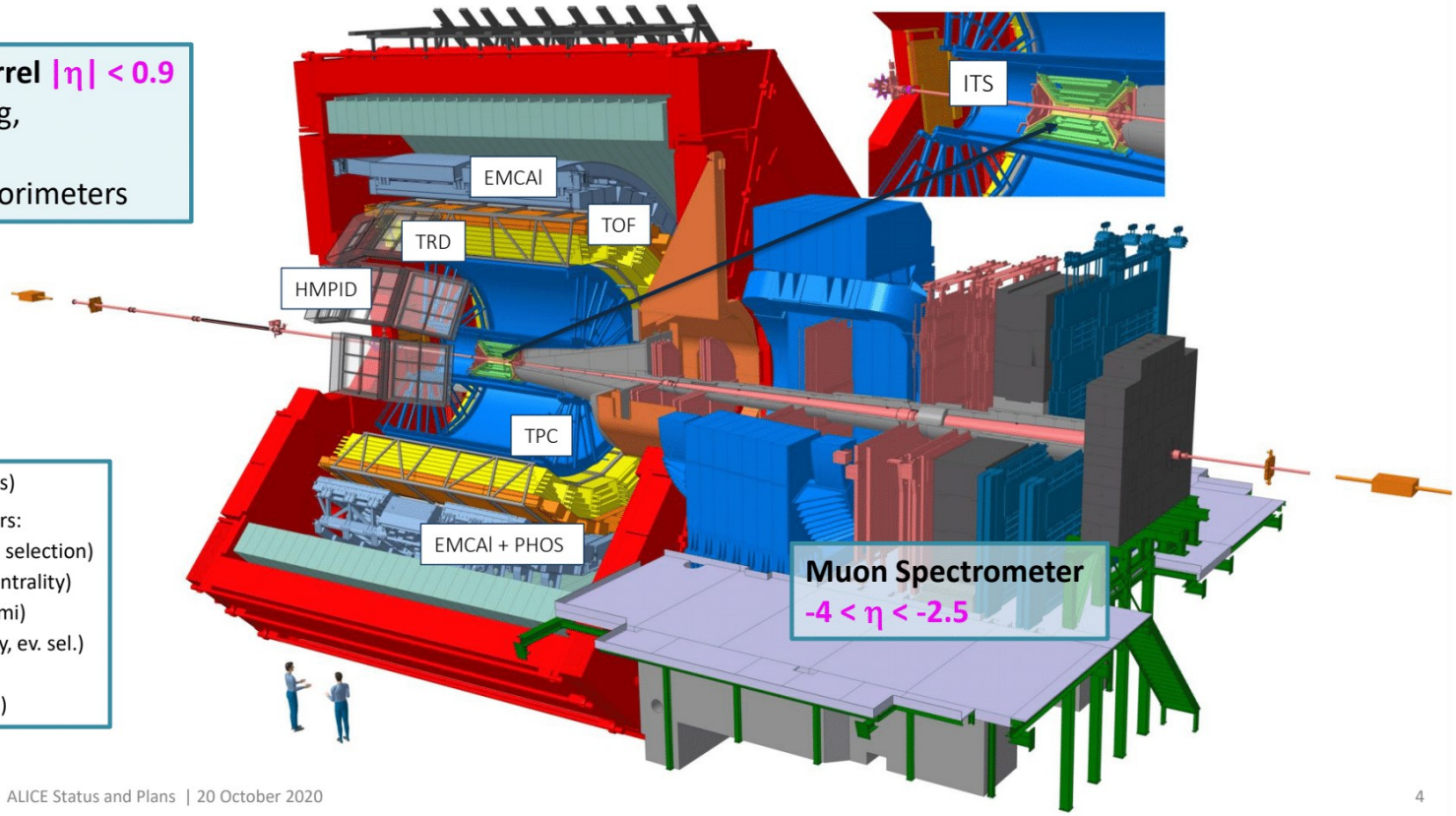
ALICE

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)

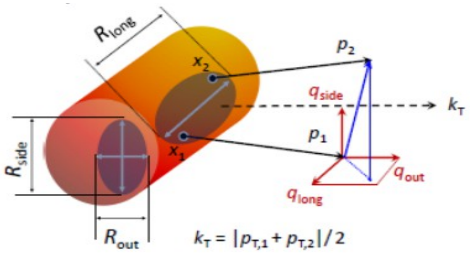
Central Barrel $|\eta| < 0.9$
- Tracking,
- PID
- EM-Calorimeters



ACORDE (cosmics)

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

New results were obtained in 3-D femtoscopic correlation analysis for identical $K^{\pm}K^{\pm}$ pair production in Pb-Pb collisions at 5.02 TeV. Kaon emission time (τ) was extracted using a source radii R_{long} (top figure) dependence from transverse pair mass (m_T), the formulas in the iHKM model and special combined fit.



long || beam

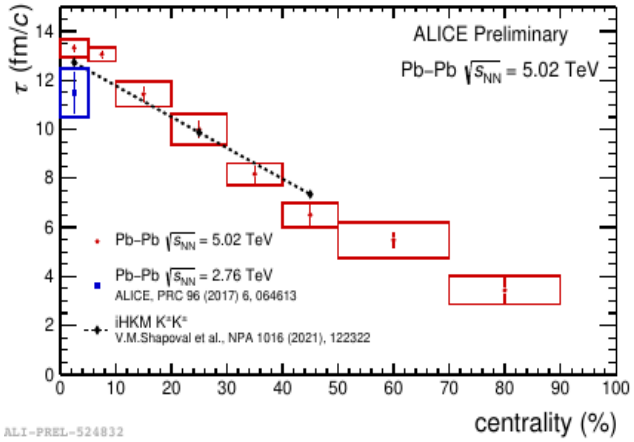
$$p_0 \frac{d^3N}{d^3p} \propto \exp\left[-\left(\frac{m_T}{T} + \alpha\right)\sqrt{1-\bar{\nu}_T^2}\right]$$

, ν_T- transverse collective velocity,

$$R^2_{long}(m_T) = \tau^2\lambda^2\left(1+\frac{3}{2}\lambda^2\right)$$

$$\lambda^2 = \left(\frac{\lambda_l}{\tau}\right)^2 = \frac{T}{m_T}\sqrt{1-\bar{\nu}_T^2}$$

, λ_l- longitudinal homogeneity length, α-strength of collective flow, T-temperature, $m_T=(k^2_T+m^2)^{0.5}$, $k_T=(p_{T1}+p_{T2})/2$, m and p_T are mass and transverse momenter of kaon.



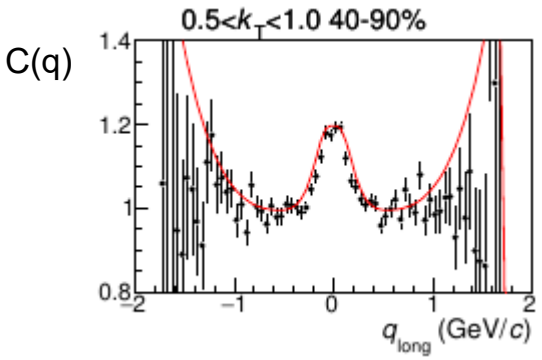
Centrality [%]	T [MeV]	α_K	τ_K [fm/c]
0–5	134.2 ± 3.5	2.50 ± 0.04	$13.33 \pm 0.28_{stat} \pm 0.09_{sys}$
5–10	137.0 ± 3.4	2.51 ± 0.04	$12.75 \pm 0.27_{stat} \pm 0.06_{sys}$
10–20	141.9 ± 3.3	2.61 ± 0.04	$10.77 \pm 0.22_{stat} \pm 0.05_{sys}$
20–30	146.3 ± 3.7	2.81 ± 0.04	$9.10 \pm 0.22_{stat} \pm 0.07_{sys}$
30–40	152.4 ± 4.4	3.32 ± 0.22	$7.08 \pm 0.22_{stat} \pm 0.18_{sys}$
40–50	150.2 ± 4.7	3.70 ± 0.05	$5.78 \pm 0.32_{stat} \pm 0.20_{sys}$
50–70	151.0	4.11 ± 0.02	$5.02 \pm 0.30_{stat} \pm 0.14_{sys}$
70–90	151.0	5.12 ± 0.02	$2.74 \pm 0.46_{stat} \pm 0.04_{sys}$

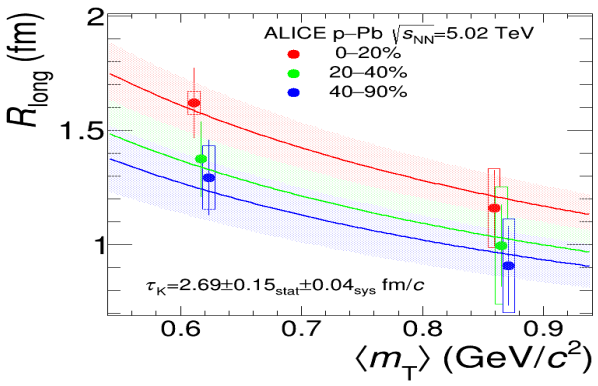
The τ values versus centrality (lower figure) corresponds to the model prediction. The fit parameters are shown also in the table. The results were presented in the Nucleus – 2022 Conference, Moscow.

New results were obtained in 3-D femtoscopic correlation analysis for identical kaon pairs production in p-Pb collisions at 5.02 TeV. The three radii components were extracted from the fit with the formula for a correlation function C(q), q = (p1-p2), λ – correlation strength, K – Coulomb factor,

$$C(\mathbf{q}) = N(1-\lambda) + N\lambda K(q)\left[1+\exp\left(-R_{\mathrm{out}}^2 q_{\mathrm{out}}^2 - R_{\mathrm{side}}^2 q_{\mathrm{side}}^2 - R_{\mathrm{long}}^2 q_{\mathrm{long}}^2\right)\right]$$ D(q), **D(q) — polynomial baseline**

C(q) is shown for the longitudinal direction in the left figure. The red line is the fit result by the formula.





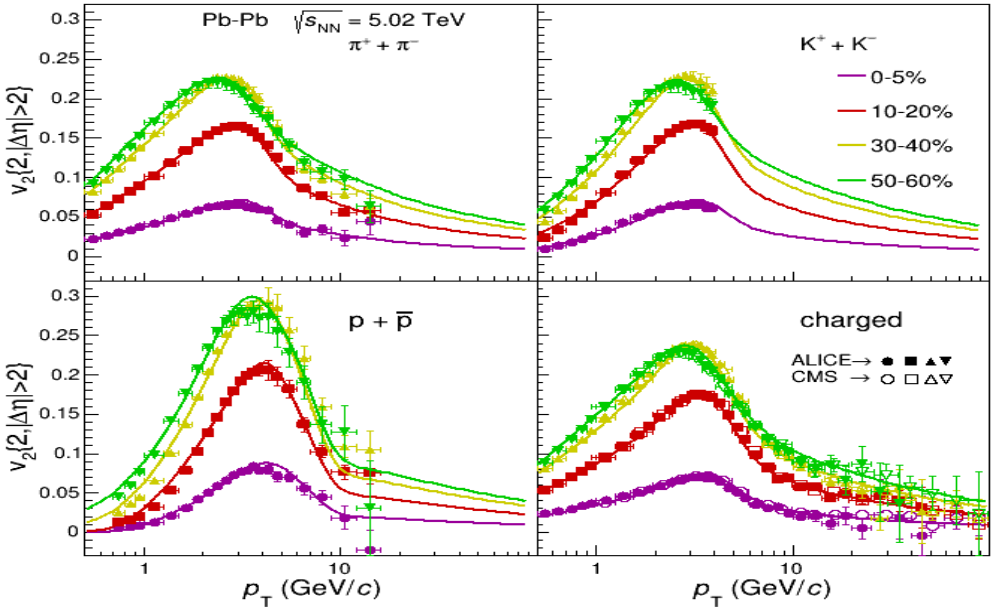
Using the R_{long} versus m_T (the right figure) and the method described in the previous slide a first result of the kaon emission time for more central events was obtained of 2.60 ± 0.26 ± 0.04 fm/c, i.e. near 4 times smaller than in the Pb-Pb central collisions and corresponds to the most peripheral Pb-Pb ones. The results were presented in the ALICE Meeting (21.12.2022) and the publication preparation was approved.

New results were obtained in JINR team for Thermal model of particle productions in A-A collisions.

(Modification of the previous model version, S.Grigoryan, Eur. Phys. J. A57 (2021) 328)

The model consists of three components: the Boltzmann-Gibbs thermal distribution for flow effect, the Tsallis distribution for resonance decays, the power-law form for the QCD hard processes.

A good coincidence of the model and experimental results from ALICE and CMS was obtained and is seen in the figures for the elliptic flow parameter v_2 versus transverse momentum (p_T) of pions, Kaons, protons and all charged particles at different event centralities in Pb-Pb collisions.



The results are almost ready for the new version publication preparation.

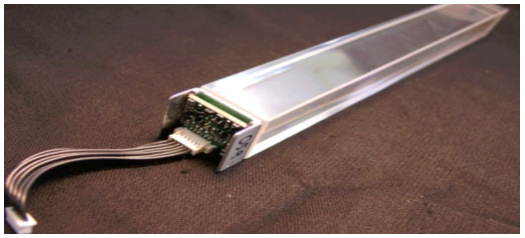
R&D for the ALICE Photon Spectrometer (PHOS) Upgrade

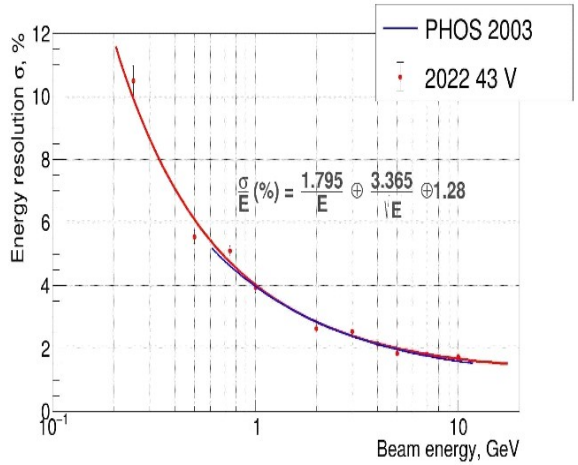
– Currently PHOS consists of tungsten-lead (PbWO4) monocrystals, 22x22x18 mm^3 with photodetector — the avalanche photodiodes of 5x5 mm^2 (the left top figure), with the time resolution (σ_t) of 4-5 ns.

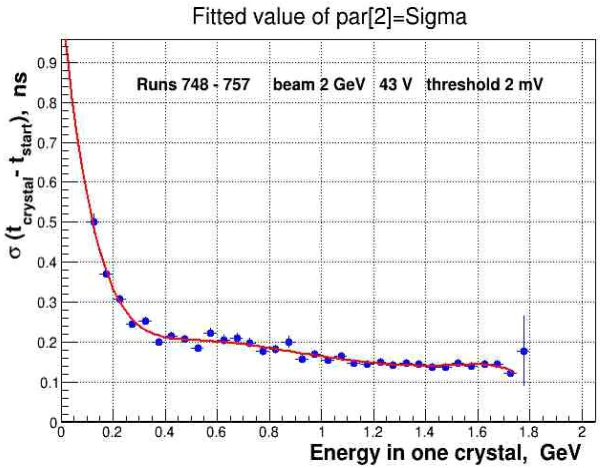
– To reduce the time resolution for the selection of (a)neutrons as a wrong photons extensive tests of Silicon Photomultipliers (SiPM) with new readout electronics were done in the last years.

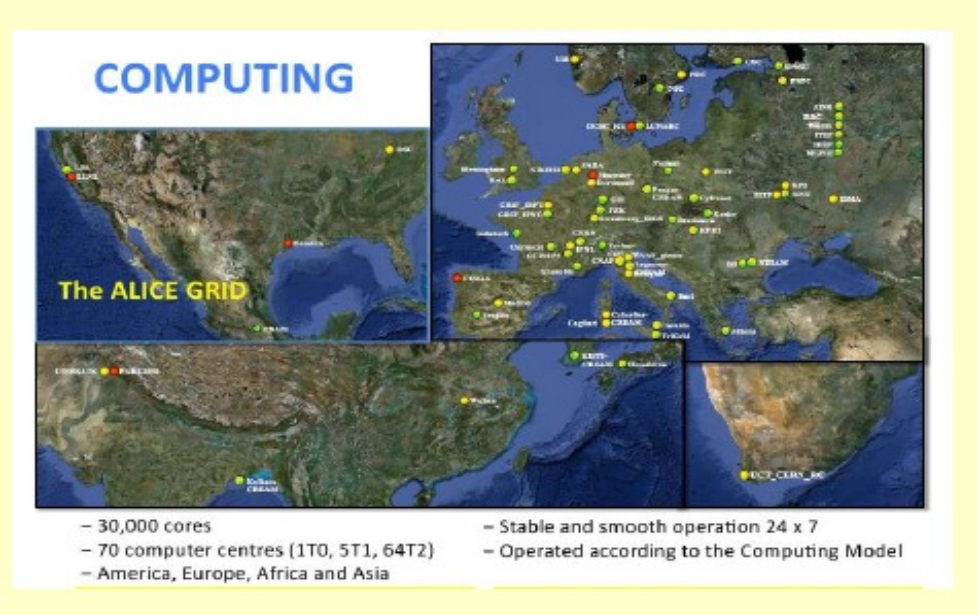
– To provide a large dynamic range in energy, the final decision was taken in 2022 year using the combination of three SiPM of 6x6 mm^2 and one SiPM of 3x3 mm^2.

– The good energy detector resolution, up to 2%, (the left lower figure) and the best $\sigma_t \cong 0.14$ ns (the right lower figure) were obtained during October test experiment with the second e^- beam in the East Hall of the PS CERN (the right top figure with the experimental setup).



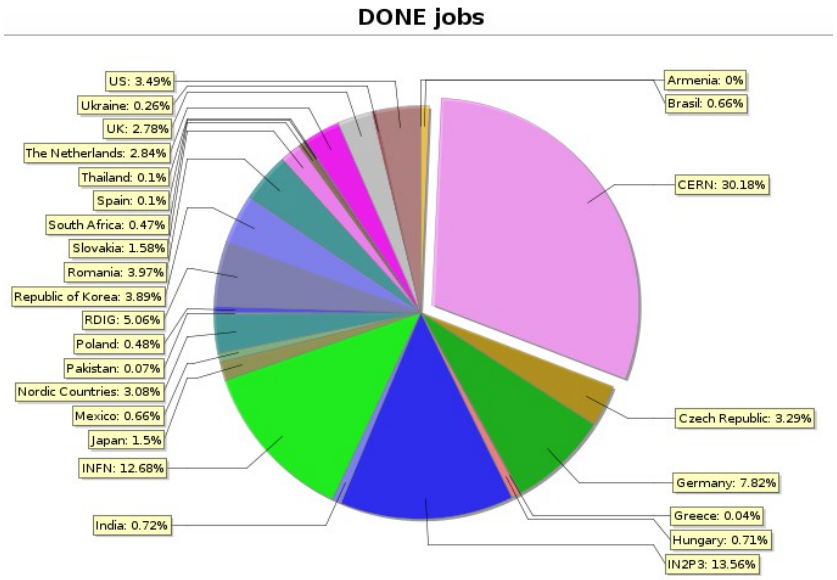




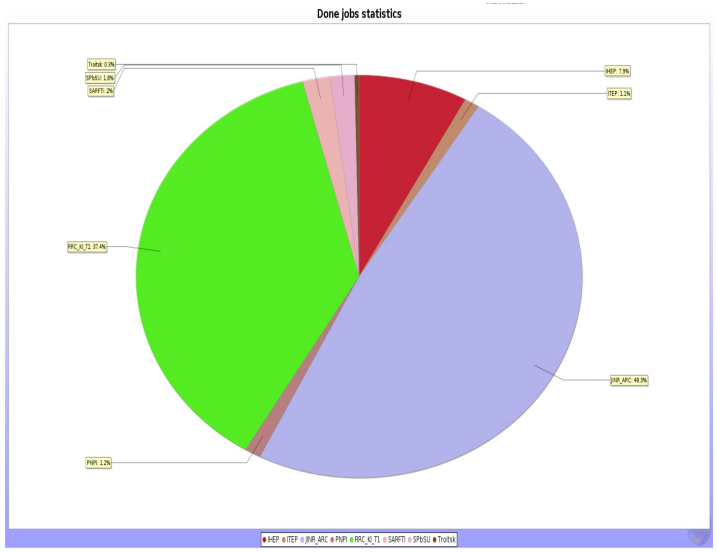


The JINR ALICE GRID is a part of 7-th Russian ALICE GRID Tier 2 Centers (RDIG – Russian Data Intensive Grid).

The resources of JINR GRID Farm:
13500 cores CPU (40% of the RDIG),
2000 Tb Disk-SE. (64%).



RDIG contribution to the ALICE-GRID is 5.1%



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

Conference presentations .

1. G. Romanenko (JINR, on behalf of the ALICE Collaboration) “Identical charged kaons femtoscopic analisys in PbPb collisions at 5.02 TeV in ALICE”, Nucleus-2022, Fundamental problems and applications, Moscow State University, 2022.

2. V.Pozdnyakov (JINR, on behalf of the ALICE Collaboration), Photoproduction of vector mesons in Ultra-peripheral heavy-ion collisions with ALICE, 56th Rencontres de Motiond 2022, Italy.

3. V.Pozdnyakov (JINR, on behalf of the ALICE Collaboration), Recent results on ultra-peripheral heavy ion Collisions with ALICE at the LHC, 14th Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2022), Orlando, Florida, USA, 2022.

ALICE publications with key contributions from the JINR group.

1. Investigation of K+K- interactions via femtoscopy in Pb-Pb collisions at $(s_{NN})^{1/2}$ = 2.76 TeV at the LHC., ALICE Collaboration, arXiv: 2211.15194, 2022 (submitted to the Phys. Rev. C).

2. $K^0_S K^0_S$ and $K^0_S K^{\pm}$ femtoscopy in pp collisions at $(s)^{1/2}$=5.02 and 13 TeV, ALICE Collaboration (S.Acharya et al), Phys. Lett. B833(2022) 137335.

Other scientific activities.

– Elena Rogochaya was the ALICE convener of Femtoscopy Analysis Team.

– Participation of K. Mikhaylov (JINR, NRC-ITEP Moscow), L.Malinina (JINR, SINP MSU Moscow) and E. Rogochaya (JINR) in the Internal Review Committees (IRC) for the different ALICE publications.

– JINR Institute review for one of the ALICE publication.

– Participation in the 81 ALICE - DCS shifts.

Conclusions

– The JINR ALICE team carries out successfully the new physical analysis of the experimental data for the Femtoscopic Correlations in Pb-Pb and p-Pb collisions. It was found first that kaon emission time in the p-Pb most central collisions is near four times smaller then in the Pb-Pb ones and corresponds to the most peripheral Pb-Pb collisions.

– The new version of the (JINR) Thermal model for A-A collisions was prepared with the good agreement of theoretical and ALICE experimental v_2 parameter for particle elliptic flow in the Pb-Pb interactions at 5.02 TeV.

– All analysis results were reported in the ALICE Meetings and the publications are under the preparation.

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

– To provide a large dynamic range in energy the new decision of the Photon Spectrometer (PHOS) with the combination of the different SiPM was tested. The good energy, up to 2%, and time resolution, up to 140 ps, were obtained.

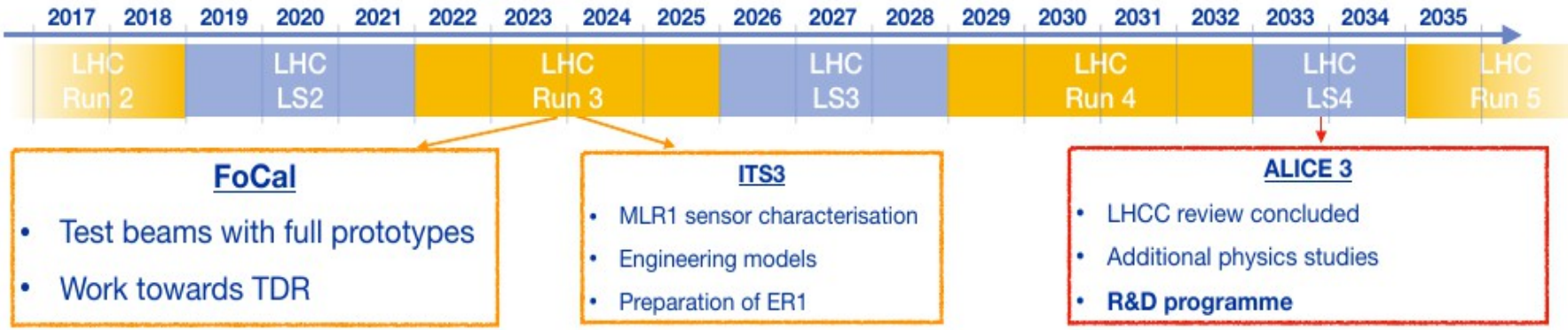
JINR plans for the 2023 year.

- Finish the publicvation for 1-D femtoscopic analysis of identical charged pion and kaon pairs in the p-p collisions at 13 TeV with the event sphericity selection.
- Go on 1D and 3-D femtoscopic analysis for $K^{ch}K^{ch}$ pairs in Pb-Pb and p-Pb collisions at 5.02 TeV with the preparation of publications.
- Start the 1-D femtoscopic analysis for $K^{+}K^{-}$ pars in p-Pb collisions at 5.02 TeV.
- Go on the analysis of ρ^0 states photo-productions in the four particles Ultra-Peripheral Pb-Pb collisions at 5.02 TeV with the publication preparation.
- Start the analysis of ρ^0 meson photo-productions in the Ultra-Peripheral 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.
- Develop and manufacture new dual-channel photodetector assemblies for the PHOS based on 6x6 mm^2 cells with 15 μ^2 silicon photomultipliers.
- To test at CERN SPS the PHOS prototype on the electron beam with energy of 10-200 GeV for different variants of photodetectors.
- ALICE GRID support in the JINR computing system.
- Participation in the ALICE shifts and service tasks.

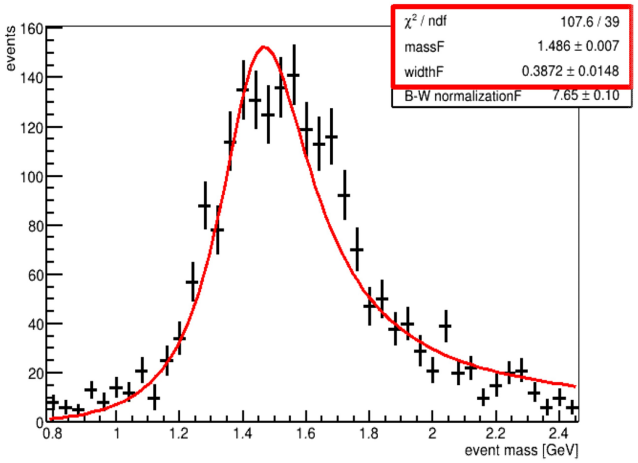
Thank you for your attention

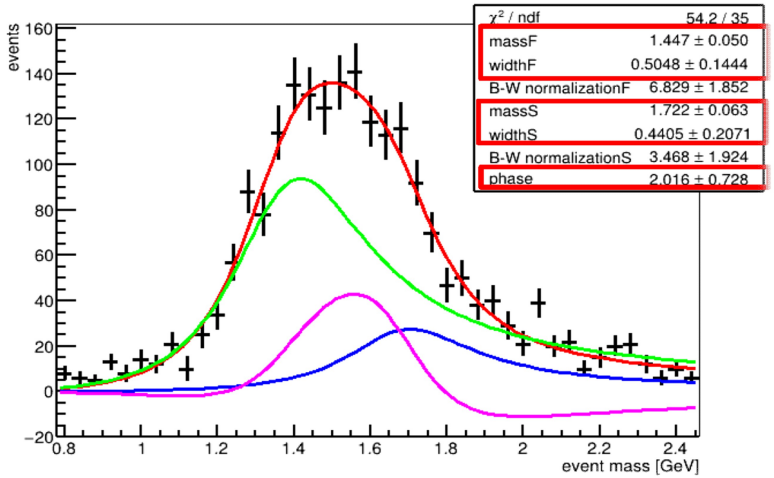
Backup

Upgrade projects



The analysis results of coherent four particles production in Ultra-Peripheral Pb-Pb collisions at 5.02 TeV (the end of 2021).





In the left figure the fit (red curve) is by one Breit-Wigner (BW) function for ρ^0 (1450).

In the right figure the fit is by two Breit-Wigner functions for ρ^0 (1450) (green curve) and for ρ^0 (1700) (blue curve) and interference between these two BWs (pink curve).

The details of tasks for PHOS modernization preparation in 2023.

1) To test at SPS the prototype PHOS calorimeter on the beam of electrons with energy 10-200 GeV for two variants of photodetectors:

A) Assembly of three 6x6 mm^2 with 15 μ^2 cells silicon photomultipliers for 0-20 GeV range + one 3x3 mm^2 SiPM with 10 μ^2 cells for 10-200 GeV range (there were optical contact problems for the small SiPM in 2022).

B) Assembly of three 6x6 mm^2 SiPM with 15 μ^2 cells silicon photomultipliers for 0-20 GeV range + one 6x6 mm2 SiPM with 15 μ^2 cells with 1/16 attenuators for 10-200 GeV range.

To compare the quality of optical contacts of photodetectors with PWO_4 crystals and corrections for nonlinearity at high energies. Choose the best variant.

2) Develop cable connections of photodetectors with recording electronics.

3) Develop a digital filter based on FPGA (field-programmable gate array) for ADC with 60 MHz sampling rate to calculate the maximum pulse amplitude and its integral.

4) Integrate 60 MHz ADC into data acquisition system and compare the results with traditional amplitude-sensitive ADC.

5) Finalize the signal preparation unit for the high energy range 20-200 GeV.