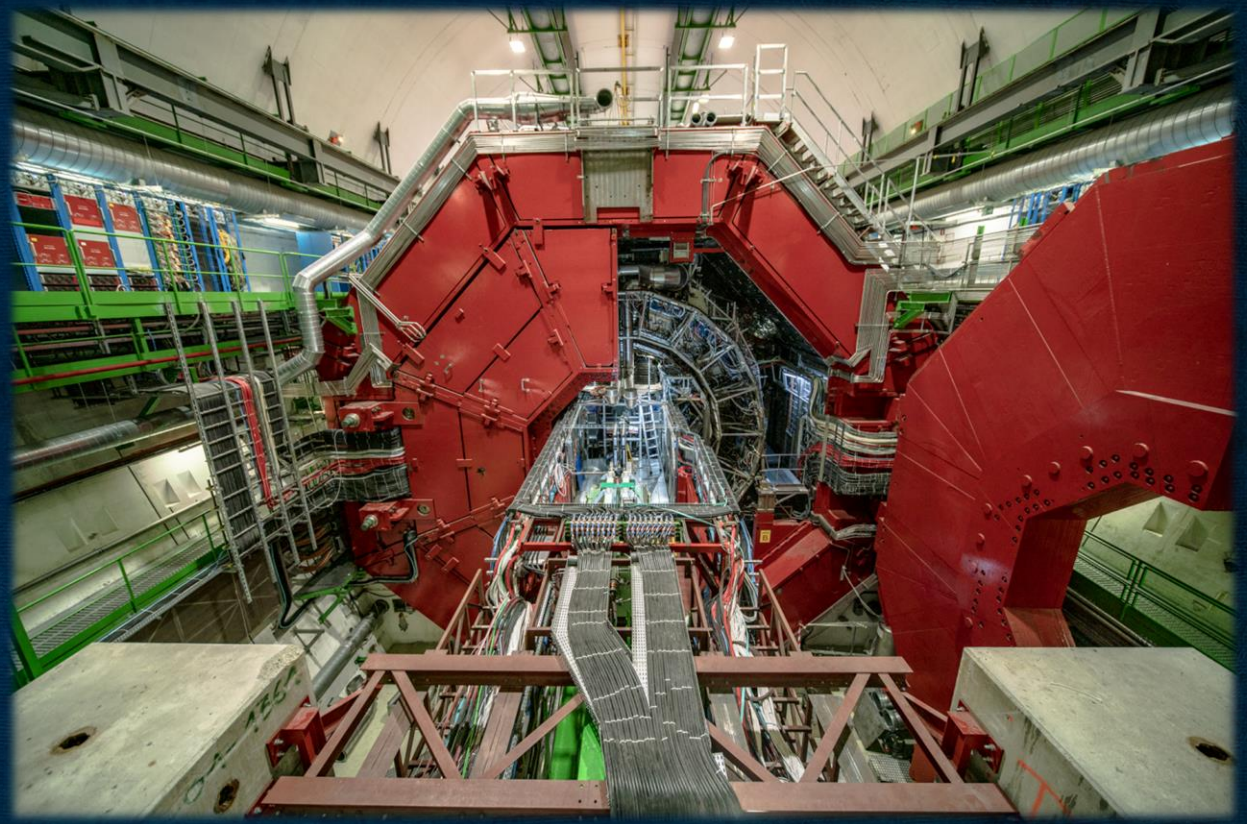
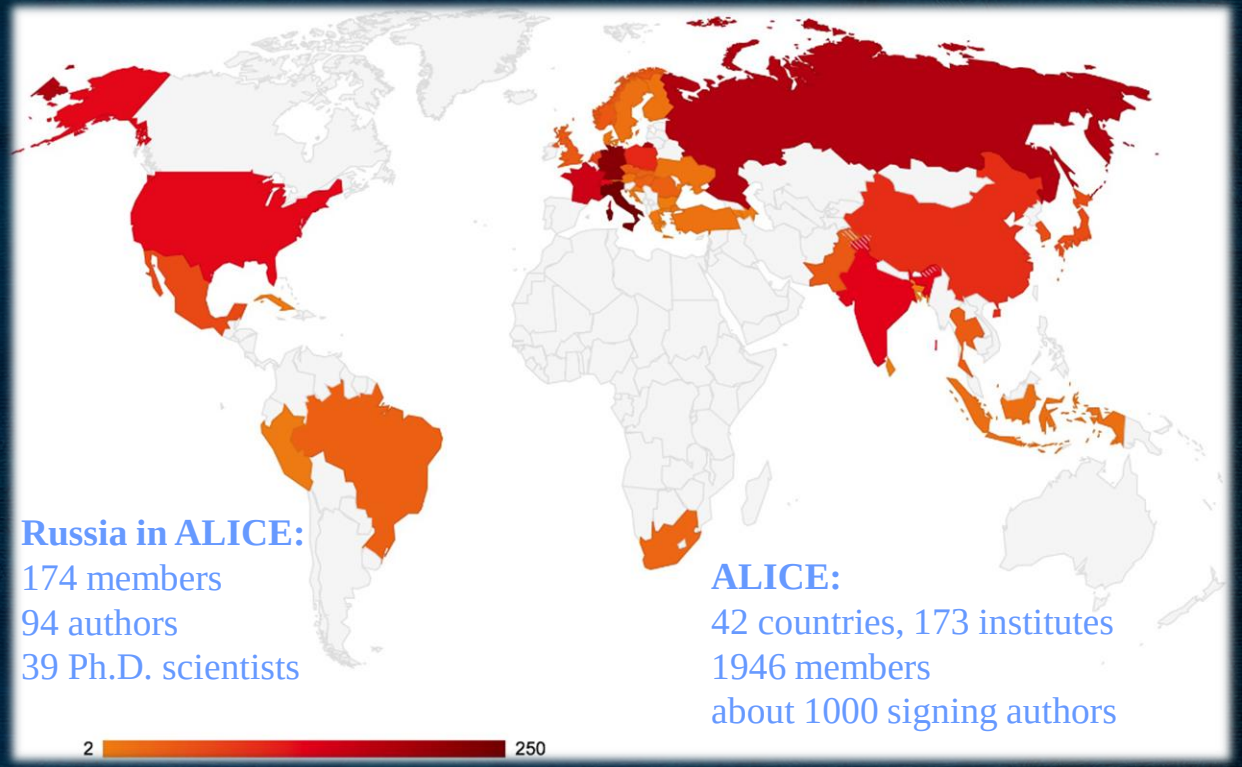
Report on JINR-ALICE team activity in 2021



E. Rogochaya

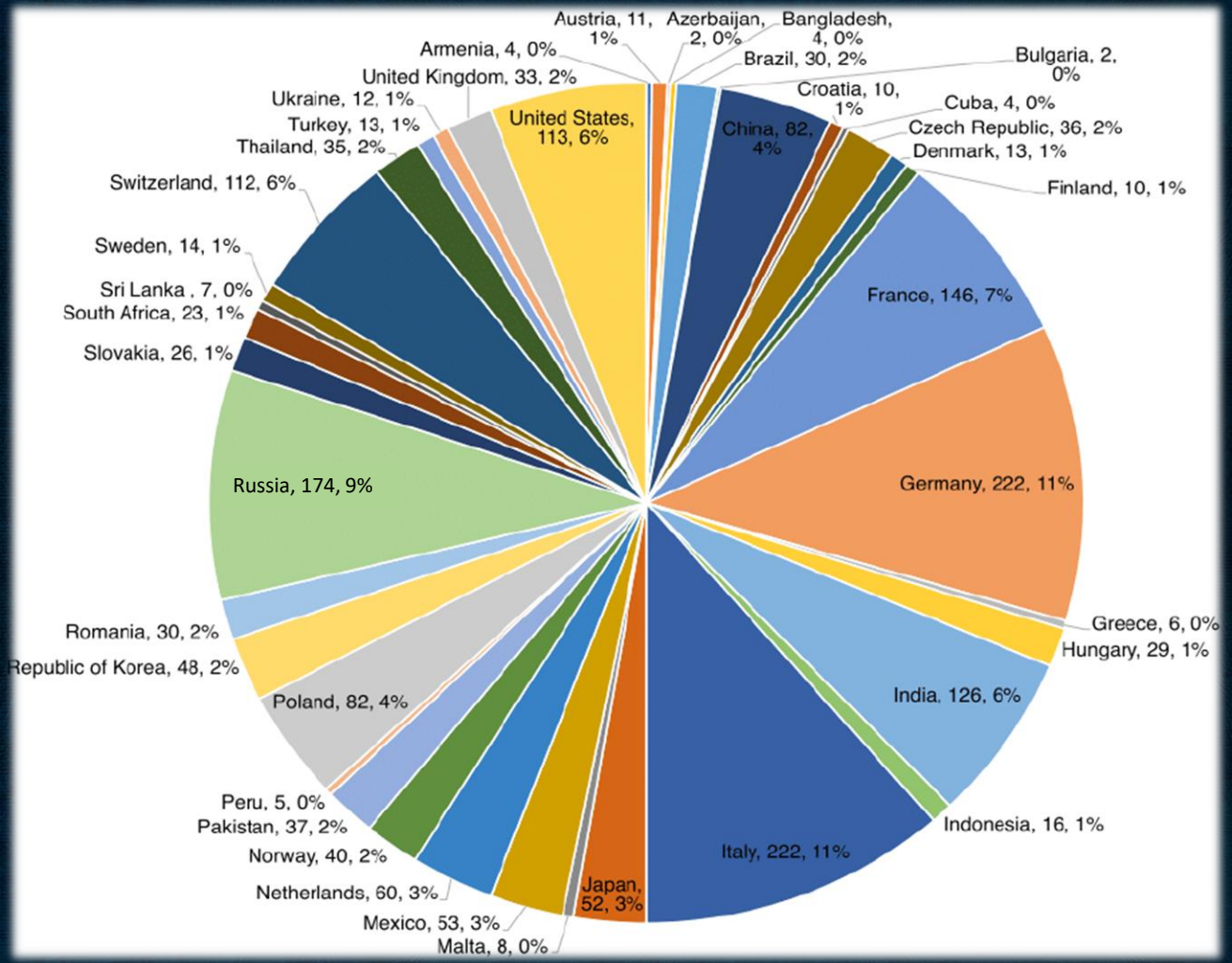
56th Program Advisory Committee
24 January 2022

The ALICE Collaboration



Russia in ALICE:
174 members
94 authors
39 Ph.D. scientists

ALICE:
42 countries, 173 institutes
1946 members
about 1000 signing authors



JINR-ALICE group:

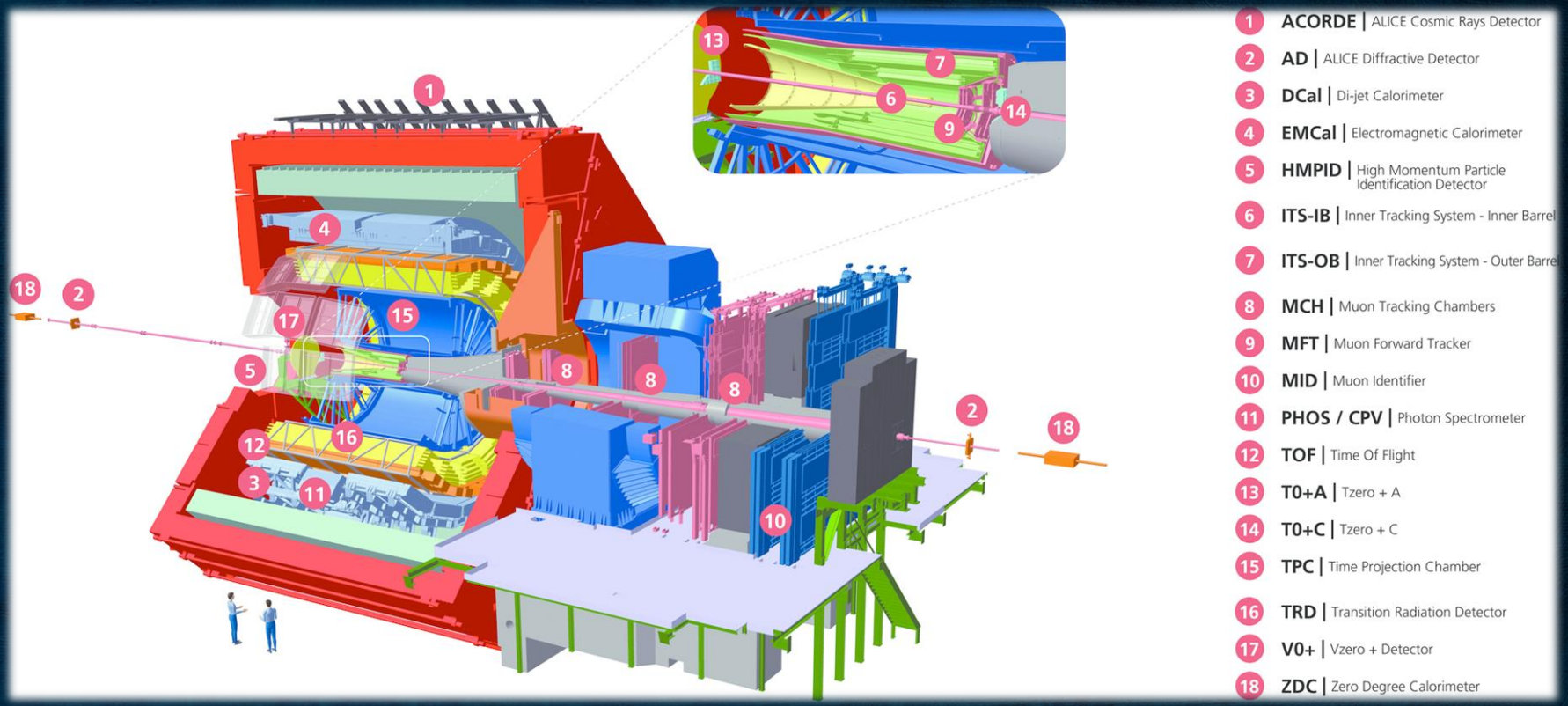
- ✓ 14 physicists (7 – analysis, 7 – PHOS)
- ✓ 3 PhD students
- ✓ 1 expert for ROOT software upgrade and GRID computing management

Activities of JINR-ALICE group

- ✓ Femtoscopy (Bose-Einstein correlations, Coulomb and strong FSI):
  - analysis of two charged kaons correlations in pp, p-Pb and Pb-Pb collisions
  - elaboration of the related analysis software
- ✓ Ultra-peripheral collisions of heavy ions:
  - study of vector meson photoproduction in p-Pb and Pb-Pb collisions
- ✓ Development of the thermal model of particle production in pp and A-A collisions
- ✓ GRID computing and software activities
- ✓ Participation in the ALICE maintenance and operation tasks
- ✓ PHOS upgrade

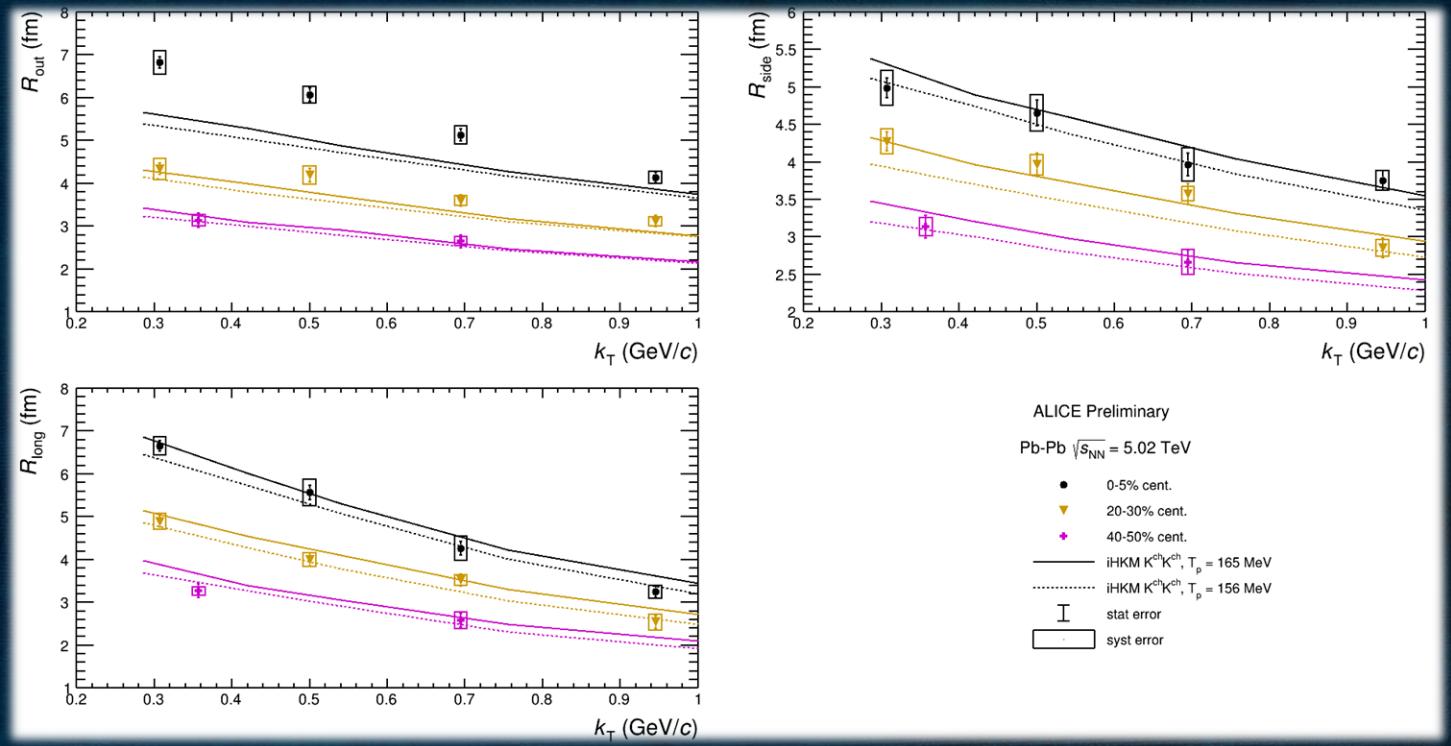
ALICE detector

Actual (Run 3) configuration:



- ✓ Tracking and vertex:
  - TPC
  - ITS
  - MCH, MFT
- ✓ Particle identification:
  - TPC
  - TOF
- ✓ Centrality determination or veto:
  - V0
  - ZDC
- ✓ Veto:
  - AD

3D femtoscopic $K^{\pm}K^{\pm}$ correlation analysis in Pb-Pb at 5.02 TeV



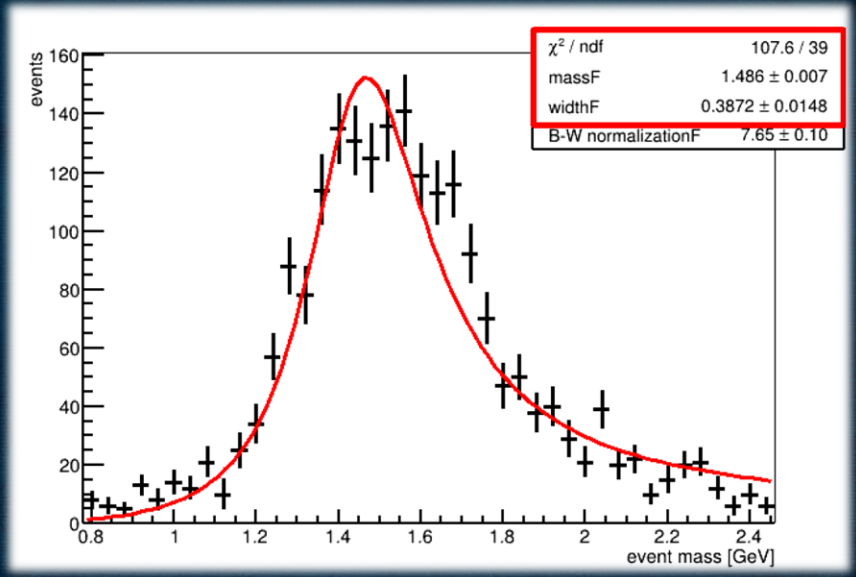
- ✓ Comparison with hydrokinetic model iHKM [V.M.Shapoval, Yu.M.Sinyukov, Phys.Rev.C100 (2019) 044905].
- ✓ Two cases of particlization temperature (calculated with two different EoS) were considered: 165 MeV and 156 MeV.
- ✓ Both calculations are in a good agreement with experimental data.

- ✓ *Precision of the experimental data does not allow distinguishing between the two considered model scenarios.*
- ✓ *Both scenarios fail to describe R_{out} in central collisions, the reason is unknown for the moment, this is the best description ever achieved.*

G.Romanenko (PhD)
L.Malinina (supervisor)

Reported at ALICE femto-meeting by G.R. on 15.12.2021.

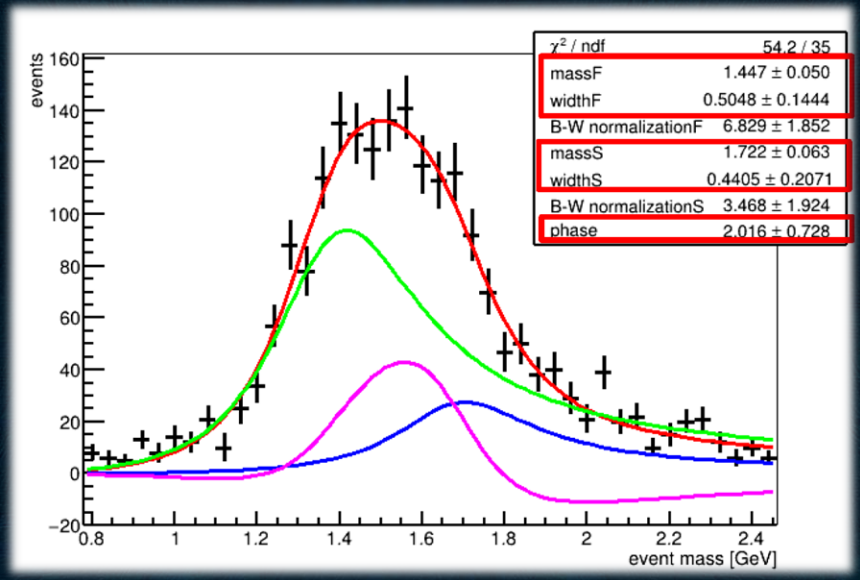
Vector meson photoproduction in UPC Pb-Pb at 5.02 TeV



Four pion invariant mass distribution fit with:

- ✓ one Breit-Wigner (BW) function (left)
- ✓ two Breit-Wigner functions with interference between them (right)

- ✓ green – first BW
- ✓ blue – second BW
- ✓ pink – interference between two BWs

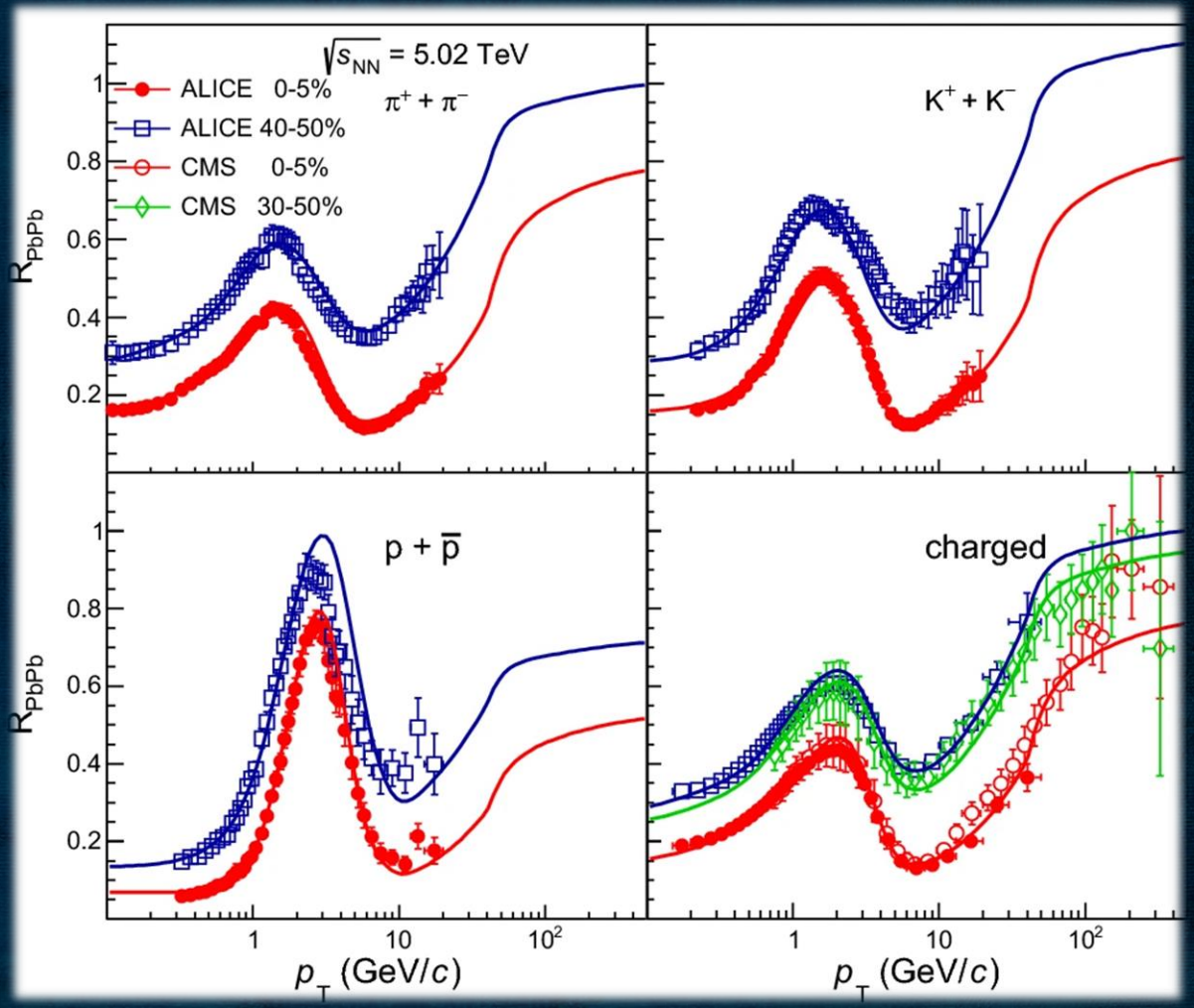


- ✓ *one resonance (left) is obtained: ρ(1450)*
- ✓ *two resonances (right) are obtained: ρ(1450) and ρ(1700)*
- ✓ *the best description is with two BW (better χ^2) → indication of presence of two ρ mesons*

- ✓ Reported at ALICE UPC meeting by V.P. on 02.11.2021.

B.Rumyantsev (PhD)
V.Pozdniakov (supervisor)

Thermal model of particle production in pp and A-A collisions



Published in [S.Grigoryan, Eur.Phys.J.A57 (2021) 12, 328]

Model consists of 3 components:

1) Boltzmann-Gibbs thermal distribution $\xrightarrow{\text{for}}$ flow effect
2) Tsallis distribution $\xrightarrow{\text{for}}$ resonance decays
3) power-law form $\xrightarrow{\text{for}}$ QCD hard processes

Nuclear modification factor:

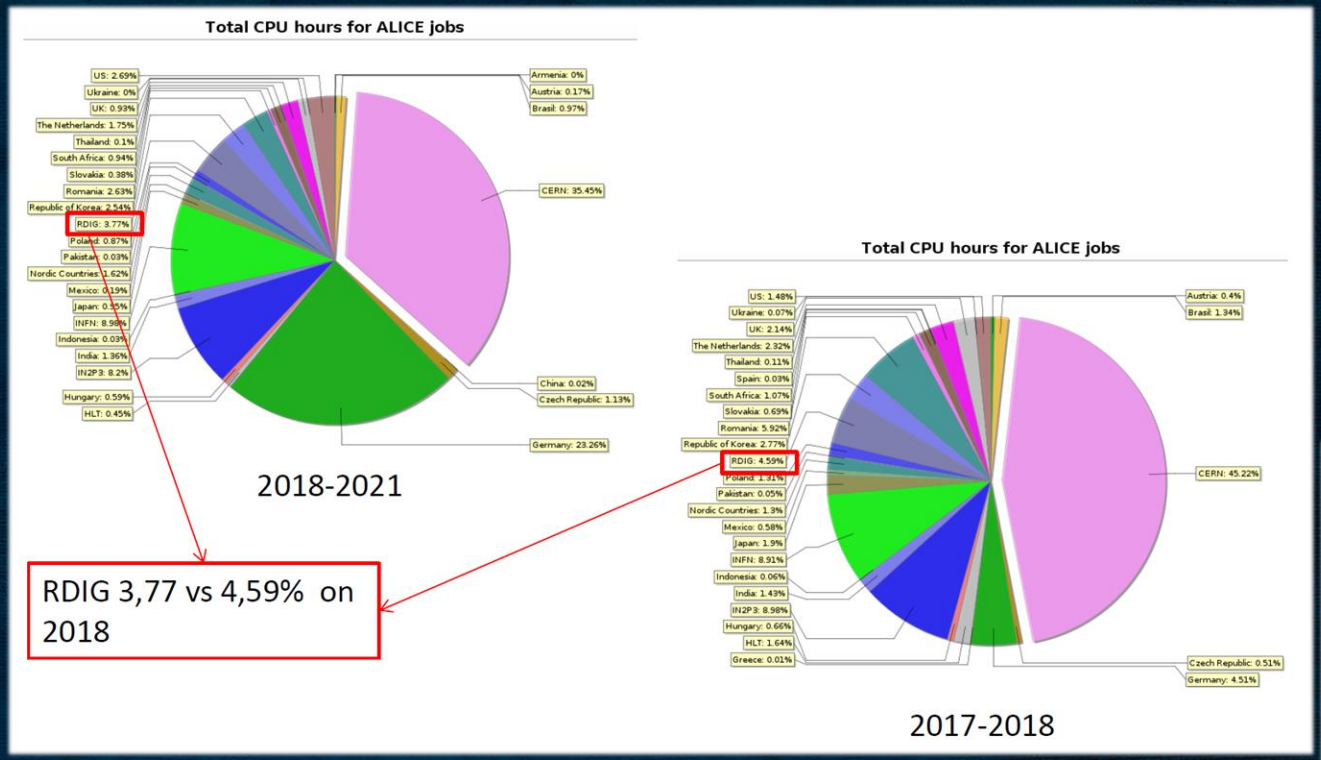
$$R_{\mathrm{PbPb}} = \frac{\mathrm{d}^2 N_{\mathrm{PbPb}}/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}{\langle N_{\mathrm{coll}}\rangle \mathrm{d}^2 N_{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}$$

$\langle N_{\mathrm{coll}}\rangle$ - number of NN binary collisions averaged over PbPb events of the given centrality and calculated in the Glauber model.

Calculations are in a very good agreement with the ALICE and CMS data.

Modification of the previous model version, [S.Grigoryan, Phys Rev. D95 (2017) 056021].

GRID computing and software activities



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

	2020		2021		2022	
	DISK	CPU	DISK	CPU	DISK	CPU
JINR	1200	12000	2000	13500	2300	15525
NRC KI	316	4488	~~316~~	~~4488~~	0	0
IHEP	297	2631	314	3017	314	3017
ITEP	180	2700	180	2700	180	2700
PNPI	168	2640	168	2640	168	2640
INR RAS	113	641	113	641	113	641
SPSU	158	3696	158	3696	158	3696
SARFTI	210	7466	210	7466	210	7466
	2642	36262	3459	38148	3443	35685

- ✓ *JINR contribution (in percentages) decreased due to the 6 times increased contribution of Germany*
- ✓ *JINR provides and increases storage (Tb) and computing (CPU cores) resources for ALICE*

Conferences

- ✓ E.Rogochaya, “Determination of the strong interactions for hyperon-nucleon pairs with ALICE”, The 55th Rencontres de Moriond “QCD & High Energy Interactions”, March 27- April 3, La Thuile, Italy, 2021.
- ✓ V.Pozdnyakov, “Coherent photoproduction of ρ^0 vector mesons in ultra-peripheral Pb-Pb and Xe-Xe collisions with ALICE”, XXVIII International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS-2021), Stony Brook University, NY, USA, April 12-16, 2021.
- ✓ V.Pozdnyakov, “Recent results on ultra-peripheral collision studies with ALICE at LHC”, The 20th Lomonosov Conference on Elementary Particle Physics, Moscow State University, Moscow, Russia, August 19-25, 2021.

ALICE publications with key contributions from the JINR-ALICE group:

- ✓ "Investigating the role of strangeness in baryon-antibaryon annihilation at LHC", ALICE Collaboration (S.Acharya et al.), arXiv:2105.05190, 2021, submitted to Phys. Rev. Lett.
- ✓ "Exploring the NΛ-NΣ coupled system with high precision correlation techniques at the LHC", ALICE Collaboration (S.Acharya et al.), arXiv:2104.04427, 2021, submitted to Phys. Rev. Lett.
- ✓ "Kaon-proton strong interaction at low relative momentum via femtoscopy in Pb-Pb collisions at the LHC", ALICE Collaboration (S.Acharya et al.), Phys.Lett.B822 (2021) 136708.
- ✓ "First measurement of coherent ρ^0 photoproduction in ultra-peripheral Xe-Xe collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.44 TeV", ALICE Collaboration (S.Acharya et al.), Phys.Lett.B820 (2021) 136481.
- ✓ "$K^0_S K^0_S$ and $K^0_S K^{\pm}$ femtoscopy in pp collisions at $\sqrt{s}$= 5.02 and 13 TeV", ALICE Collaboration (S.Acharya et al.), arXiv:2111.06611, 2021, submitted to Phys. Lett. B.

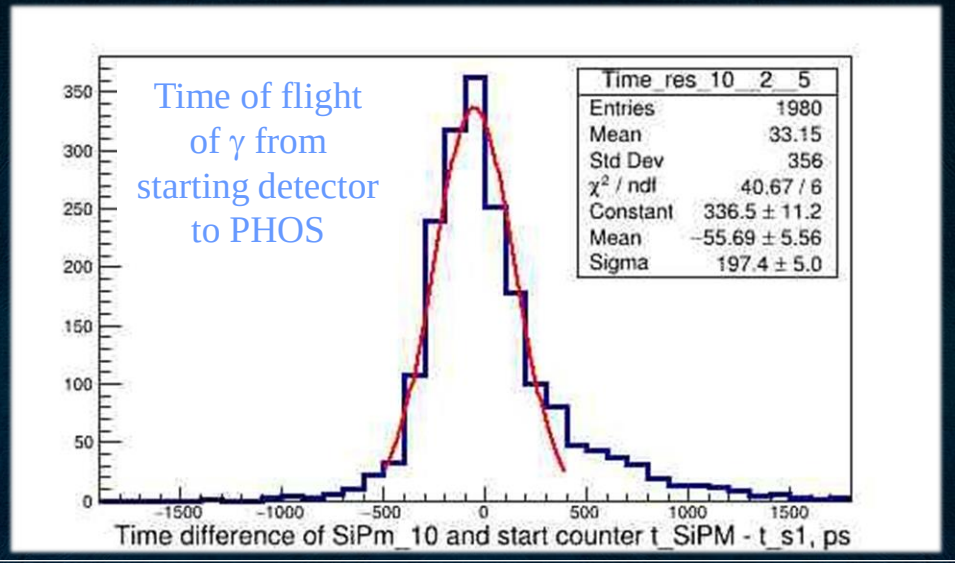
Other scientific activities:

- ✓ E.Rogochaya is one of the two ALICE femto-PAG conveners until the end of 2022.
- ✓ K.Mikhaylov (chair person) and E.Rogochaya participate actively in Internal Review Committees (IRC) of various ALICE publications.
- ✓ JINR Institute Review of one of the ALICE publications.
- ✓ Participation in the ALICE-ITS-Upgrade and ALICE central shifts.

PHOS

- ✓ Currently it consists of $PbWO_4$ (PWO) rectangular crystals, 22×22×180 mm^3, with photodetector – the Hamamatsu avalanche photodiodes (APD) with the active area of 5×5 mm^2.
- ✓ To increase the light yield of the PWO crystal (by a factor of 3) and to reduce the electronic noise, the PHOS modules were cooled down to -25°C (stability ~0.2°C).
- ✓ Extensive R&D was performed during 2012-2020 for PHOS upgrade aiming to significantly reduce the time resolution of PHOS from 4-5 ns to less than 500 ps.
- ✓ Various APD and silicon photomultipliers (SiPM) with new readout electronics were tested on the CERN PS and SPS beams.
- ✓ The final decision was taken in the beginning of 2021 to use large area SiPM detectors.

- ✓ Beam tests of the chosen option were performed on October 2021.
- ✓ Excellent time resolution of 100 ps was achieved for 2 GeV beam energy.
- ✓ *PHOS upgrade proposal will be prepared and submitted to the Collaboration by the PHOS ALICE team in 2022.*



Summary

- ✓ JINR-ALICE team
  - carries out successfully physical analyses of experimental data on femtoscopic correlations in pp, p-Pb and Pb-Pb
  - studies vector meson photoproduction in ultra-peripheral p-Pb and Pb-Pb
  - constantly improves the three-component theoretical model of particle production

- ✓ All analyses results were reported at ALICE meetings and the finished ones were prepared for publication in peer-reviewed journals.

- ✓ JINR ALICE GRID facility continues to provide stable computing operation and steady increase of its capacity.

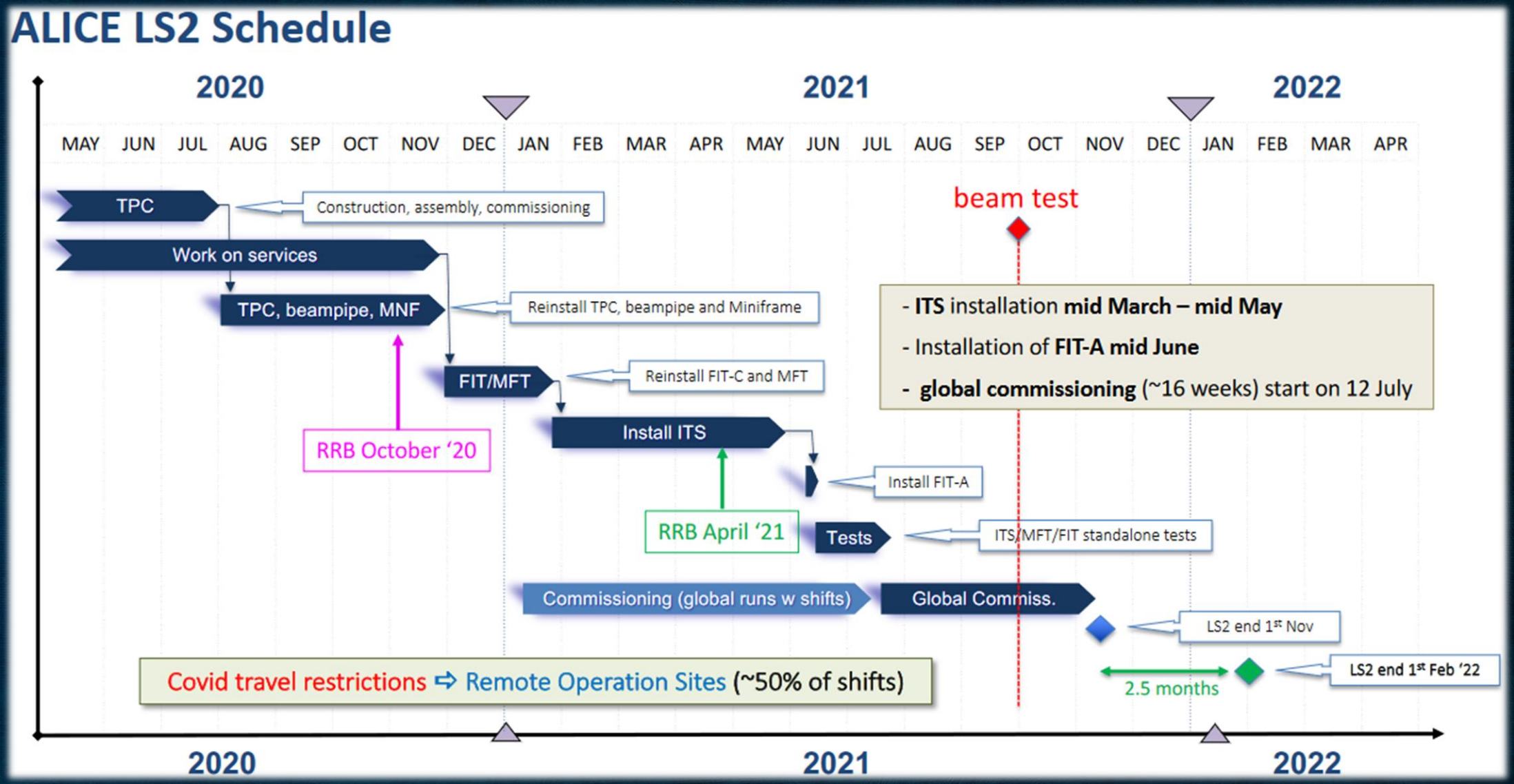
- ✓ PHOS: Excellent time resolution of 100 ps was achieved with large area SiPM for 2 GeV beam energy.

Plans for 2022

- ✓ Publish the paper on 1D femtoscopic analysis for K^+K^- correlations in Pb-Pb collisions at 2.76 TeV.
- ✓ Publish the paper on 1D femtoscopic analysis for $\pi^{\pm}\pi^{\pm}$ and $K^{\pm}K^{\pm}$ correlations in pp collisions at 13 TeV with event shape selection.
- ✓ Prepare paper proposal on 1D and 3D femtoscopic analyses for $K^{\pm}K^{\pm}$ correlations in Pb-Pb collisions at 5.02 TeV.
- ✓ Finalize 3D femtoscopic analysis for $K^{\pm}K^{\pm}$ correlations in p-Pb collisions at 5.02 TeV.
- ✓ Continue the analysis of vector meson photoproduction in ultra-peripheral Pb-Pb collisions at 5.02 TeV.
- ✓ ALICE GRID support in the JINR computing system.
- ✓ Participate in the ALICE shifts and service tasks.
- ✓ Participate in preparation and submission of the PHOS upgrade proposal to the ALICE Collaboration.

THANK YOU FOR YOUR ATTENTION!

Backup: ALICE schedule

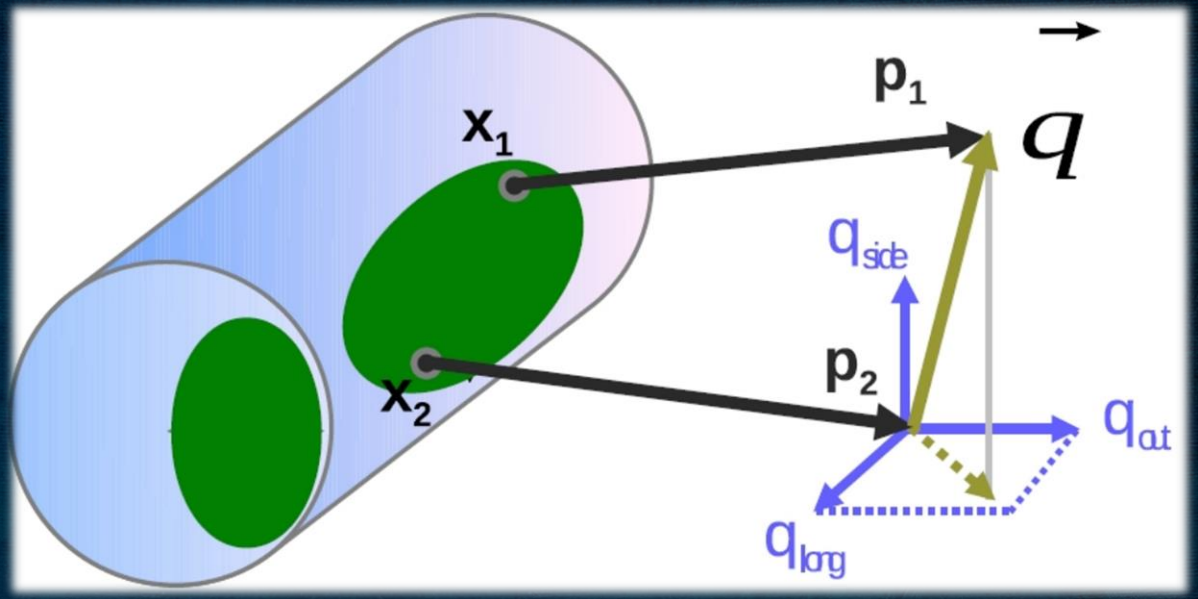


Backup: LCMS

$$C(q_{\text{out}}, q_{\text{side}}, q_{\text{long}}) = 1 + \lambda \exp(-R^2_{\text{out}} q^2_{\text{out}} - R^2_{\text{side}}\, q^2_{\text{side}} - R^2_{\text{long}}\, q^2_{\text{long}})$$

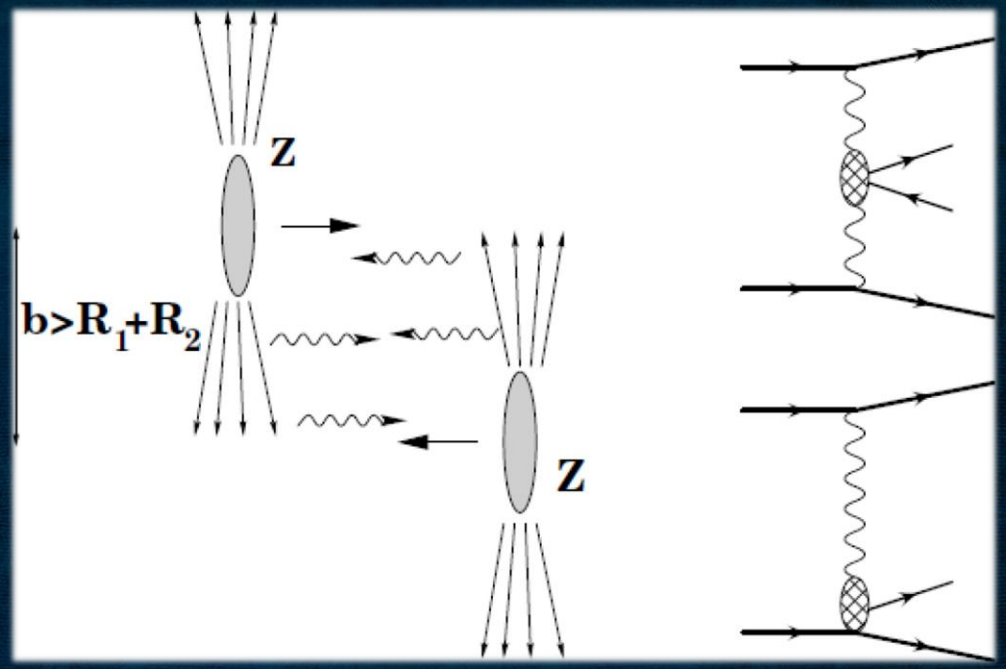
correlation strength λ represents a fraction of correlating particles emitted by independent sources,

R_{out}, R_{side}, R_{long} characterize the size of the emitting source and are defined in the **Longitudinally Co-Moving System**:



long ‖ beam direction
out ‖ pair transverse momentum k_T
side ⊥ (out,long)

Backup: Ultra-Peripheral Collisions



- ✓ UPC occur when ions collide at impact parameter *b* greater than sum of nuclear radii → *UPC are γ-induced reactions*
- ✓ *vector meson photoproduction* (γ-Pomeron exchange) can occur either *coherently* off whole nucleus (p_T~30 MeV/*c*) or *incoherently* off nucleons (p_T~300 MeV/*c*)

- ✓ in *γ-induced reactions*, the γ can be represented as a coherent superposition of hadronic fluctuations (mainly ρ, ω and φ) that subsequently interact with the target
- ✓ large charges of colliding ions → production of huge γ fluxes → UPC can be accompanied by another γ exchange → EM nuclei excitation → neutron emission which can be detected (in ZDC) together with scattered vector meson

PHOS upgrade schedule (aiming Run 4)

- ✓ Ongoing works:
  - R&D on new FEE (continuation of work started in 2014)
  - R&D on photodetector choice and test beams
  - R&D on new mechanical construction
  - preparation of PHOS Upgrade TDR
- ✓ Designing and manufacturing FEC (2021-2025)
- ✓ Adapting and manufacturing RU for PHOS FEC (2021-2024)
- ✓ Procurement of photodetectors (2023-2025)
- ✓ Designing and manufacturing new PHOS module mechanics (2021-2025)
- ✓ Reassembling the PHOS modules during LS3 (2025-2026)

- ✓ ***Kurchatov Institute/Moscow*** – coordination, new FEE development and production, testing of prototypes
- ✓ ***IHEP/Protvino*** – new FEE development and production, readout unit development and testing, new mechanical construction development
- ✓ ***MIPT/Moscow*** – performance studies, FEE production
- ✓ ***VNIIEF/Sarov*** – development of new mechanical construction, upgrade of cooling system, DCS development
- ✓ ***JINR/Dubna*** – new FEE development, testing of prototypes
- ✓ ***National Centre for Nuclear Research/Warsaw*** – photodetector procurement, FEE production
- ✓ Other institutes are welcome to join!

Project cost estimate breakdown (kCHF)

	R&D excluding already accounted in 2012-2020	Construction	Total
SiPM	30	600	600
Preamplifiers	20	130	180
FEE	150	1300	1450
Readout units		240	240
Mechanics and Cooling system	50	100	150
Total	250	2370	2620