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

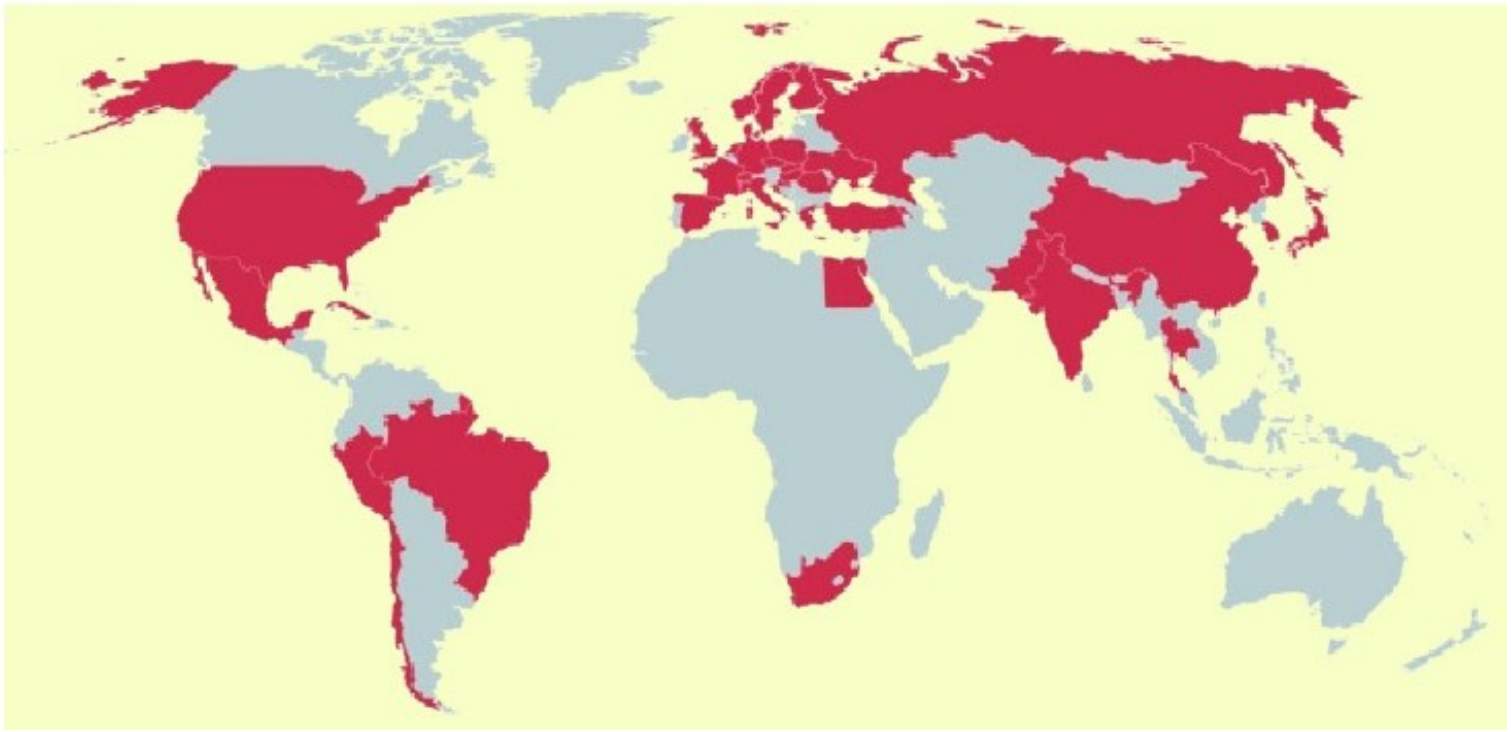
B.Batyunya

48th PAC, Dubna, 31.01.2018

A Large Ion Collider Experiment

European Organisation for Nuclear Research

ALICE Collaboration



42 coutries, 174 institutes, >1800 members

The ALICE JINR team:

-- 11 physicists including 2 PhD students;

-- 1 undergraduate student

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

Most interest activity of Dubna team

- **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.

- **Quarkonia physics:**
  Creation and updating of the special models using for an estimation of the detector efficiency and for understanding of J/ψ, and ϒ production mechanisms.

- **Ultraperipheral collisions of heavy ions:**
  Study of of charmonium state J/ψ and ρ^0 photoproduction in the Pb-Pb collisions.

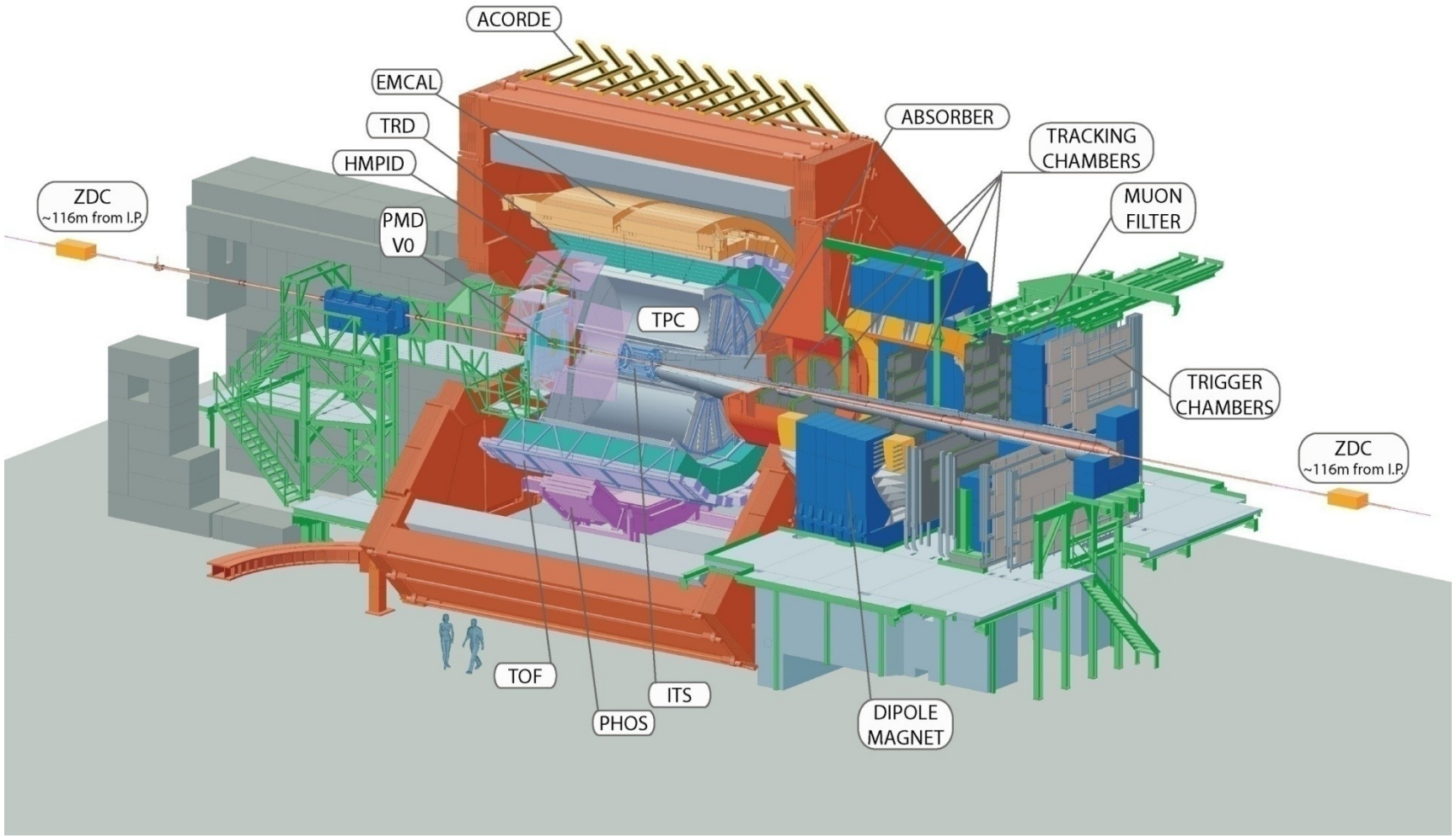
- **Tensor polarizasion physics of vector mesons (ϕ, K*):**
  With the team of P.J. Safaric University, Kosice, Slovakia (the collaboration protocol is under preparation).

- **GRID computing and software activities.**

- **Participation in the ALICE Shifts (66 shifts in 2017 year – JINR quota).**

- **ALICE Photon Spectrometer (PHOS) Upgrade R&D.**

ALICE Setup


ACORDE
EMCAL
TRD
HMPID
ZDC
~116m from I.P.
PMD
V0
ABSORBER
TRACKING
CHAMBERS
MUON
FILTER
TPC
TRIGGER
CHAMBERS
ZDC
~116m from I.P.
TOF
PHOS
ITS
DIPOLE
MAGNET

New results of the 3-D femtoscopic correlation analysis for identical K±K± pair production in Pb-Pb collisions at 5.02 TeV per nucleon pair (Run 2 at the LHC) were obtained (red points in the Fig.1) and compared with the Run 1 results at 2.76 TeV (green points in the Fig.1) already published [ALICE Collaboration, Phys.Rev.C96 (2017) 064613] The good agreement between two different data and also violation of the m_T-scaling for pions and kaons [$m_T=(m^2+p_T^2)^{1/2}$] discussed in the above-mentioned published paper is seen. These results were reported by the JINR team in the GDRE-2017 International Workshop (Nantes, France).

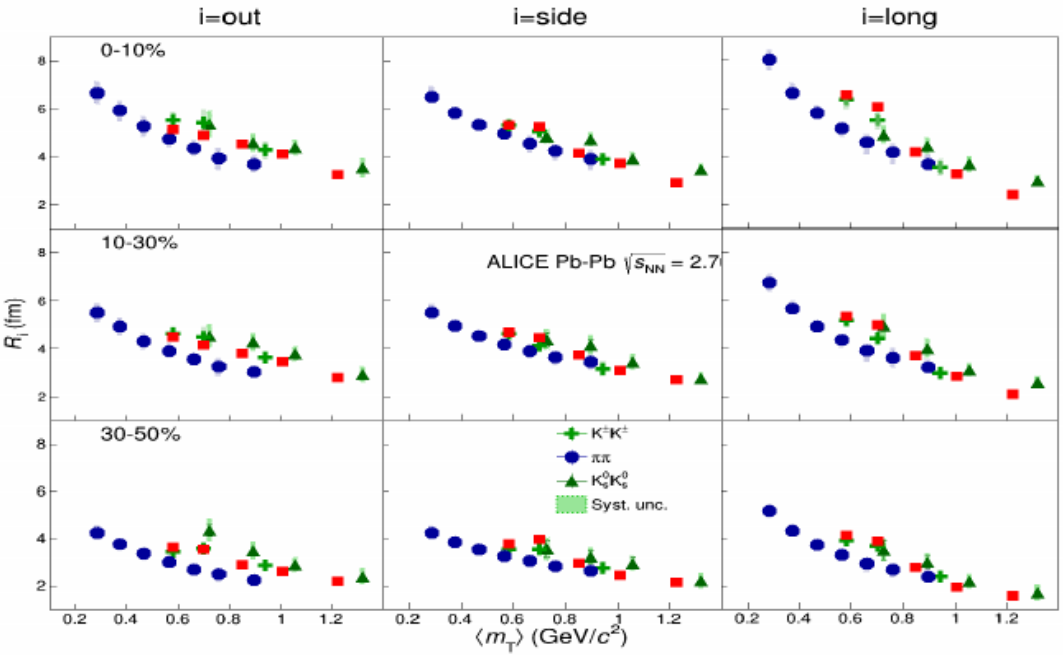


Fig.1. The 3-D particle emission source radii (Fig.2) versus transverse mass (m_T) for KK and ππ pairs for different collision centralities.

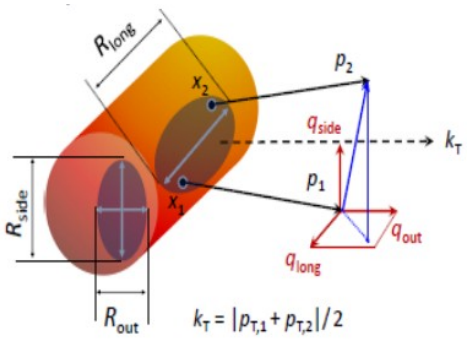
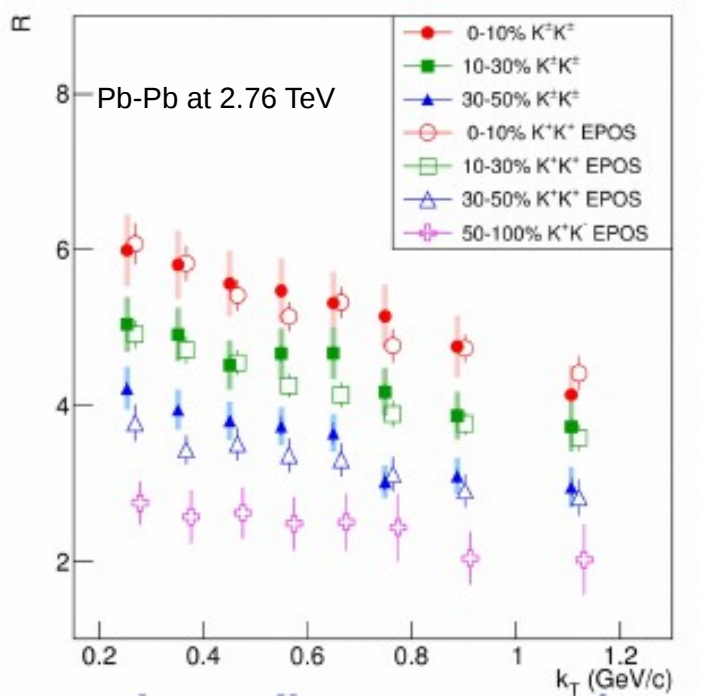
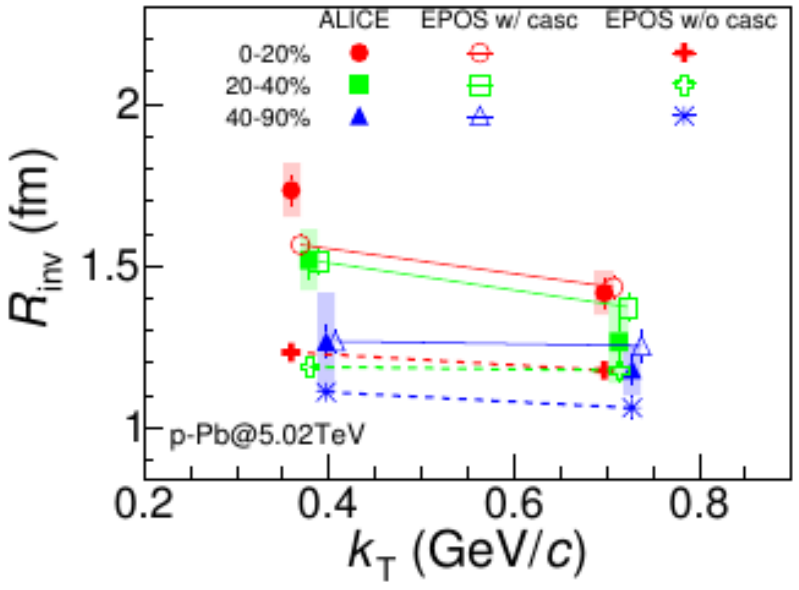


Fig.2. Image of the 3-D particle emission source radii (long || beam).

New comparison of the ALICE femtoscopic data for identical $K^{ch}K^{ch}$ pairs was done with the new version of the hydrodynamic EPOS-3 (string/flux-tube) model including hadronic rescattering phase (final state interactions) as the new step. Figures left and right (for Pb-Pb and p-Pb collisions respectively) show an agreement of the data and the model predictions if only the hadronic rescattaring phase is taken into account. This result is compatible with the one obtained befor by the JINR team [ALICE Collaboration, Phys.Rev.C96 (2017) 064613] for the comparison with the other HKM (Hydro-Kinetic) model. These results were reported by the JINR team in the GDRE-2017 International Workshop (Nantes, France).

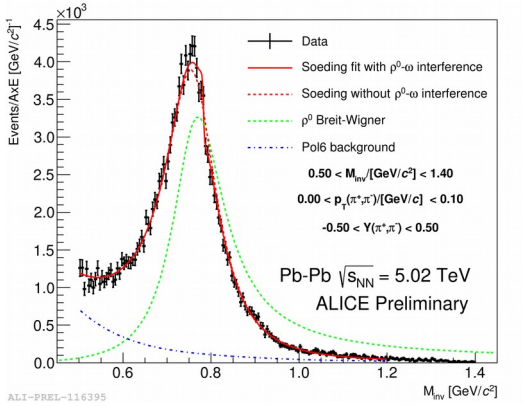




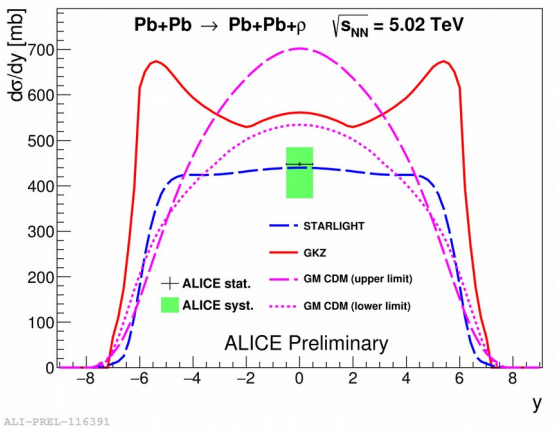
The 1-D particle emission source radii versus transverse momentum [$k_T = |p_{T1}+p_{T2}|^{1/2}$] of KK pairs for different collision centralities, obtained in the ALICE and in the EPOS-3 model. Left: for Pb-Pb collisions at 2.76 TeV, Right: for p-Pb collisions at 5.02 TeV.

New results were obtained with the JINR team participation for the ρ^0 and J/ψ coherent photoproduction (photons Interect through Pomeron with whole nucleus) in ultraperiferel Pb-Pb collisions (UPC) at 5.02 TeV per nucleon pairs.

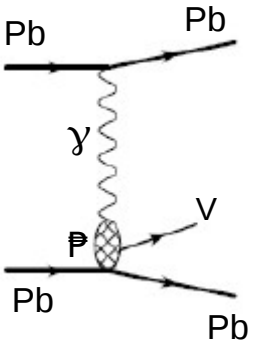
The results were reported by the JINR team in the EPS Conference on HEP, 2017 (Venice, Italy).

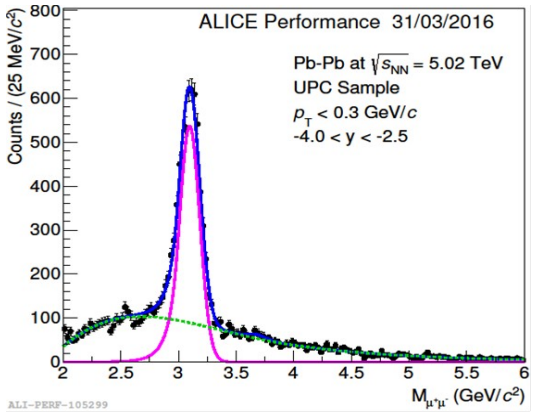


Mass spectrum of unlike signs particle pairs in Pb-Pb UPC.
The fit was done by Soding function (red): the convolution of Breit-Wigner (green) and background continuum (blue).

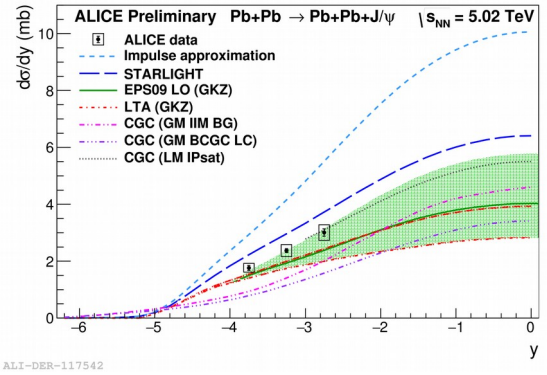


Differential cross section versus rapidity of ρ^0 production
In Pb-Pb UPC in comparison with different model predictions.



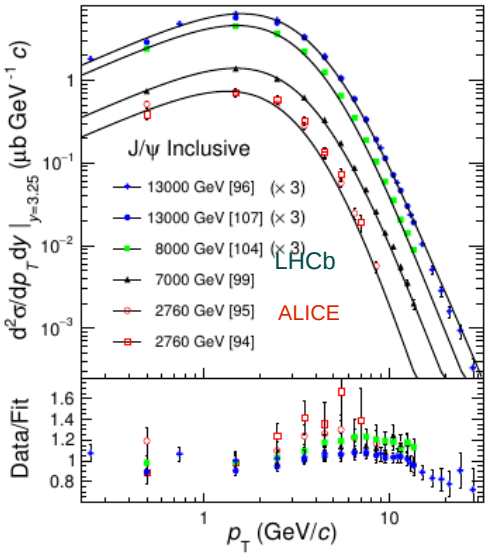


Spectrum of $\mu^+\mu^-$) pair invariant mass in Pb-Pb UPC.
Blue line is the fit result of the data with the convolution of Gauss function (pink) and background continuum (green).

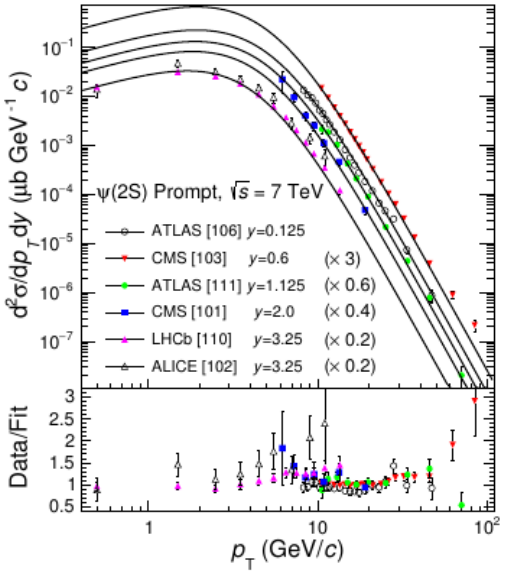


Differential cross section versus rapidity of J/ψ production
In Pb-Pb UPC in comparison with different model predictions
at different **gluon shadowing in nuclei** contributions
(the moderate one is best).

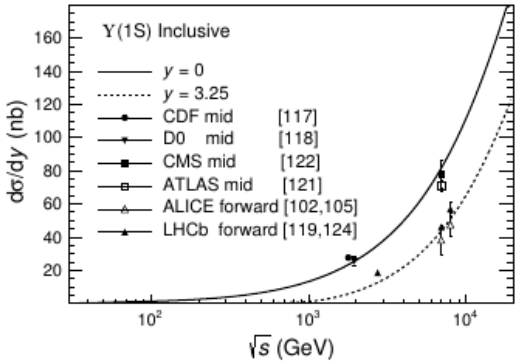
New thermal model is proposed in JINR ALICE team, based on the thermal Blast-wave Model (with expanding fireball) and the Tsallis distribution (a generalization of the Boltzmann-Gibbs one). The hadron differential spectra in pp-collisions were computed particularly for the Quarkonia (J/ψ, ψ(2s), ϒ). The results were reported by the JINR team in the CNFP-2017 Conference (Crete) and published in Phys.Rev. D95 (2017) 056021.



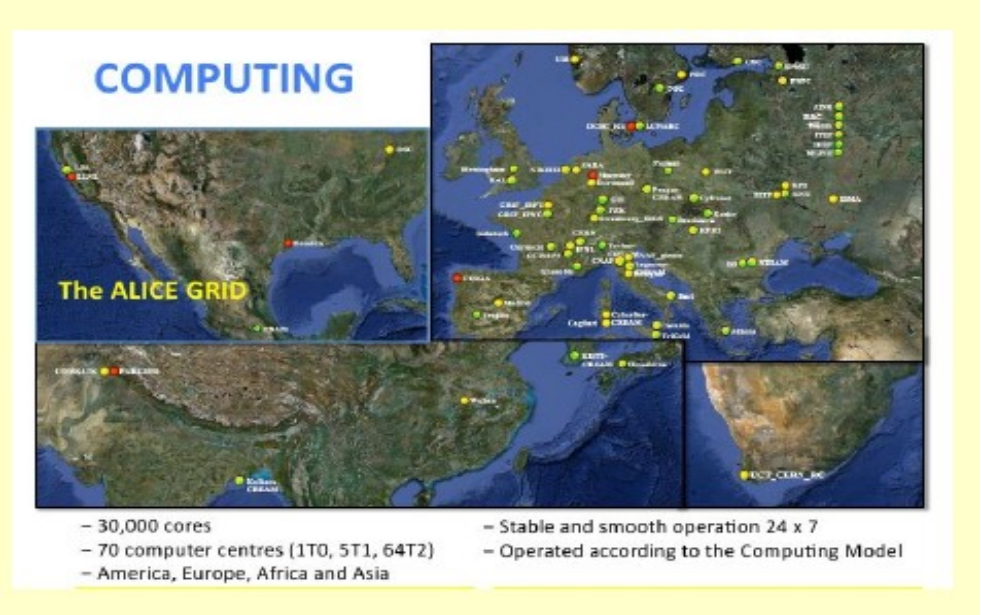
Differential cross-sections of J/ψ in pp collisions at different energies. The lines are the model fits.



Differential cross-sections of ψ(2s) in pp collisions at 7 TeV in different experiments. The lines are the model fits.



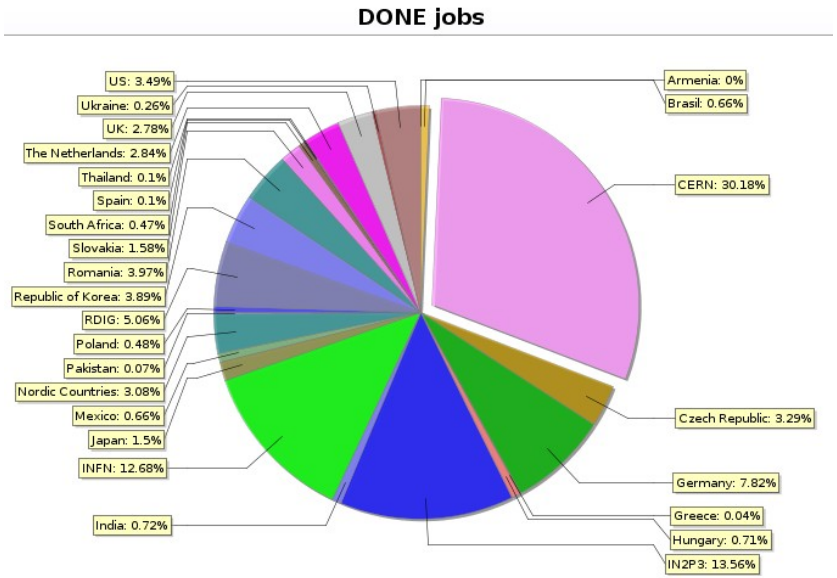
Differential cross-sections versus energy of ϒ for pp collisions in different experiments. The lines are the model fits.



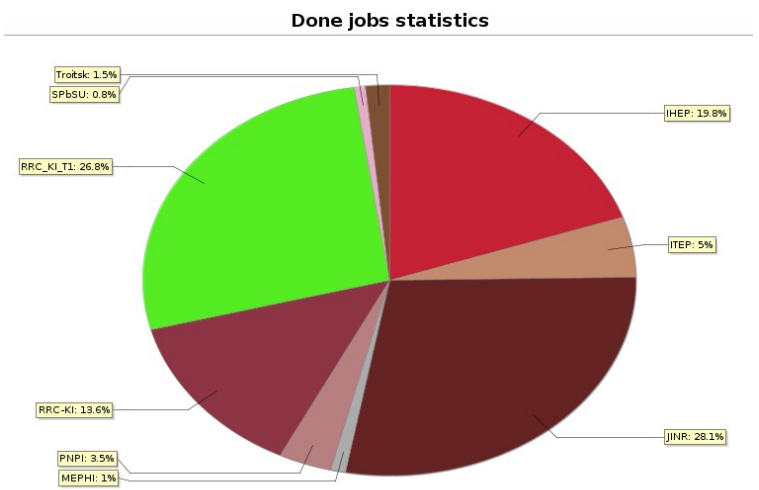
The JINR ALICE GRID is going in the Frame of 9-th Russian ALICE GRID Centers (RDIG – Russian Data Intensive Grid).

The resource of JINR GRID Farm: 6500 cores CPU, 438 Tb Disk-SE.

In additional there is ALICE analysis Farm: 48 cores, 14 Tb Disk-SE.



RDIG contribution to the ALICE-GRID is 5.6%



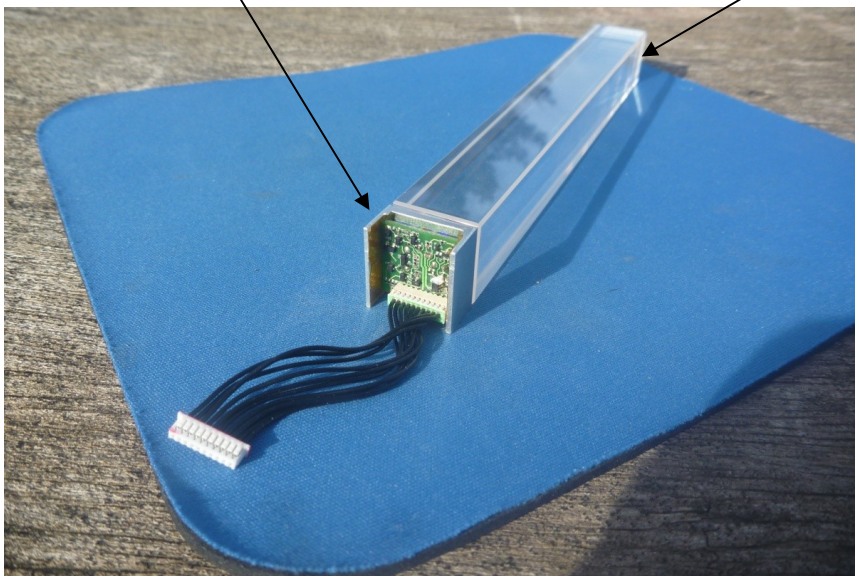
JINR contribution to the RDIG-GRID is 22% (near 8×10^5 events per year).

JINR-ALICE Photon Spectrometer (PHOS) Upgrade R&D

(in collaboration with NRC "Kurchatov Institute")

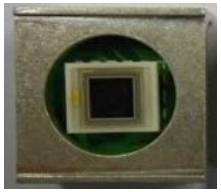
Chip of electronics

Crystalline element of PHOS: lead tungstate, $PbWO_4$,
2.2×2.2 cm^2 cross section and 18 cm length.



Current PHOS setup:

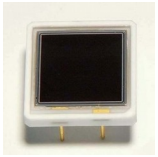
Avalanch photo-detector (APD)
(5×5 mm^2)



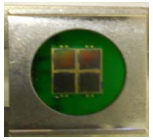
Operating temperature: -28°C
Time-of-flight resolution
σ_t = 2000-3000 ps at 1 GeV
(useless for photon identification !)

Ways for upgrade:

(1) New APD (10×10 mm^2): near the same energy resolution at +18°C and σ_t = 400 ps at 1 GeV.

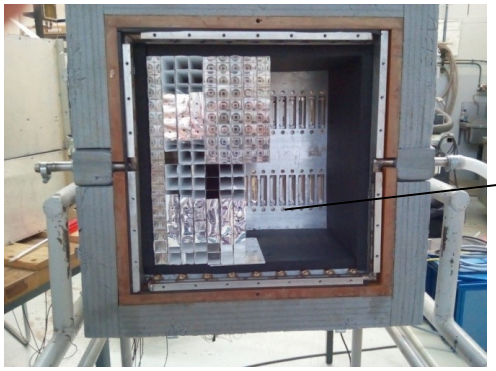


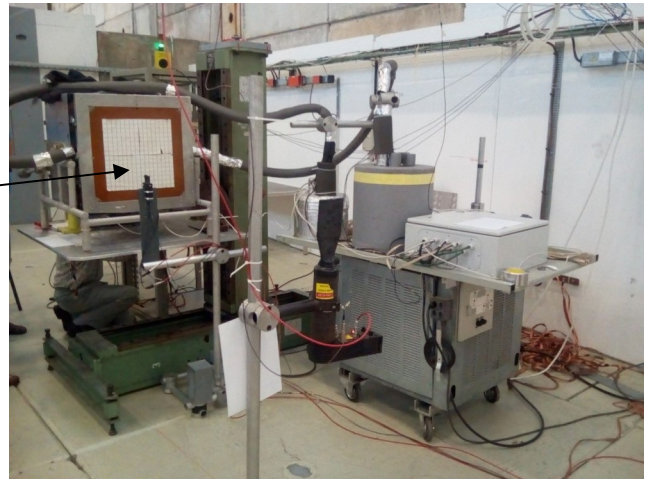
(2) Replace APD by silicon photo-multiplier, SiPM, (6×6 mm^2, 15 μm pixels): σ_t = 150-200 ps at 1 GeV, near the same energy resolution at +18°C, no preamplifiers.



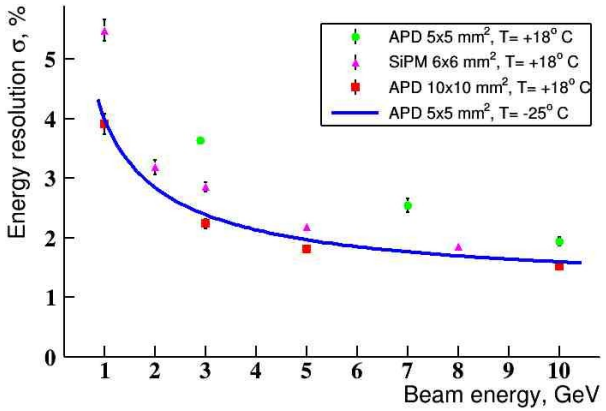
PHOS upgrade R&D: Test results in 2017 year using CERN PS electron beam.

The special electronics module (TQDC-16E), which has an Ethernet interface, was used to measure pulse arrival time, charge and puls shape. This module was elaborated in the LHEP of JINR and may be the prototype of the mesuring card for the modified PHOS.

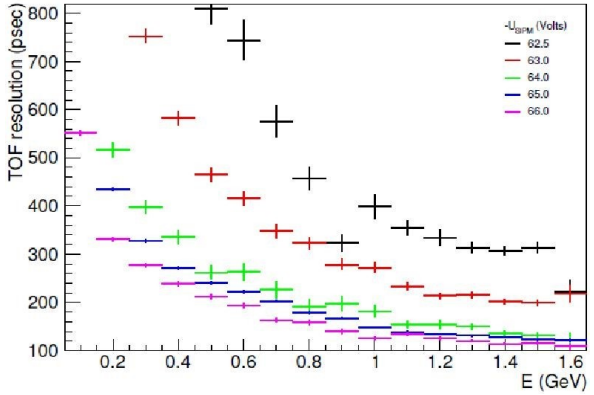




PHOS prototype (256 channels) installed in the electron test beam of the CERN PS (1-8 GeV beam).



Energy resolution versus electron beam energy for different types of the photo-detector.



Time resolution of the SiPM detector versus energy excretion in the crystal for different voltage in the detector at +18°C.

The energy resolution is better for the APD 10x10 mm² at +18°C than for the APD 5x5 mm² at -25°C. For the SiPM the energy resolution is a bit worse but the TOF resolution is two time better.

Publications in the 2017 year with a most activity of JINR group:

1. “Kaon femtoscopy in Pb–Pb collisions at $(s_{NN})^{1/2}$ = 2.76 TeV”, ALICE Collaboration (S. Acharya et al.), Phys. Rev. C96 (2017) 064613

2. “ Measuring $K^0_S K^{\pm}$ interactions using Pb-Pb collisions at $(s_{NN})^{1/2}$ = 2.76 TeV. “

   ALICE Collaboration (S. Acharya et al.), Phys.Let. B774 (2017) 64.

3. “ Using the Tsallis distribution for hadron spectra in pp collisions: Pions and quarkonia at $\sqrt{s}$ = 5 – 13000 GeV..”, S. Grigoryan, Phys.Rev. D95 (2017) 056021.

4. “ J/ψ supression at forward rapidity in Pb-Pb collisions at $(s_{NN})^{1/2}$ = 5.02 TeV”, ALICE Collaboration “ (J. Adam et al.), Phys.Lett. B766 (2017) 212.

5. “J/ψ production as a function of charged-particle pseudorapidity dencity in p-Pb collisions at $(s_{NN})^{1/2}$ = 5.02 TeV.”, ALICE Collaboration (D.Adamova et al.), Phys.Lett.B776 (2018) 91.

Conferences in the 2017 year:

1. K. Mikhaylov (JINR/Moscow ITEP), “Kaon femtoscopy with EPOS3 model”, GDRE Workshop, Subatech, Nantes, July 2017.

2. L.Malinina (JINR/Moscow St. University, SINR), “$K^{ch}K^{ch}$ femtoscopy of PbPb collisions at 2.76 and 5.02 TeV ”, GDRE , Subatech, Nantes, July 2017.

3. E, Rogochaya (JINR), “ Charged kaon femtoskopy correlations in p-Pb collisions at 5.02 TeV with ALICE at the LHC”, XII WPCF, June 2017, Amsterdam.

4. V.Pozdnyakov (JINR), “Measurements of vector meson photoproduction with ALICE in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV”, EPS Conference on HEP, 2017 (Venice, Italy).

5. S.Grigoryan (JINR), “ Using the Tsallis distribution for hadron spectra in pp collisions: Pions and quarkonia at $\sqrt{s}$ = 5 – 13000 GeV..” CNFP-2017 (Crete).

Conclusions

– The JINR ALICE team carries out successfully the physical analysis of the experimental data.

– All analysis results were reported in the International Forums and some finished ones were published in the Periodical Journals. Some other publications are under preparation.

– The JINR ALICE GRID is going with good results.

– The special electronics module, TQDC-16E, was tested successfully in the frame of the PHOS Upgrade R&D. The good energy and time resolutions were obtained for the suggested new APD and SiPM detectors.

JINR plans for the 2018 year.

– Publication of 1-D femtoscopic analisys for charged kaon pairs in p-Pb at 5.02 TeV.

– Finish of the femtoscopic analysys for K^+K^- pairs in Pb-Pb collisions at 2.76 TeV.

Using the large new statistics for minimum bias events (~1700 M of pp at 13 TeV, ~760 M of p-Pb at 5.02 TeV, ~160 M of Pb-Pb at 5.02 TeV):

– 3-D femtoscopic analysys for $K^{ch}K^{ch}$ pairs in Pb-Pb collisions at 5.02 TeV .

– 1-D(3-D) femtoscopic analysys for $K^{ch}K^{ch}$ pairs in the p-p collisions at 13 TeV.

– 3-D femtoscopic analysys for $K^{ch}K^{ch}$ in p-Pb collisions at 5.02 TeV.

-- Study of J/ψ and ρ^0 photoproduction in the ultraperiferal Pb-Pb collisions at 5.02

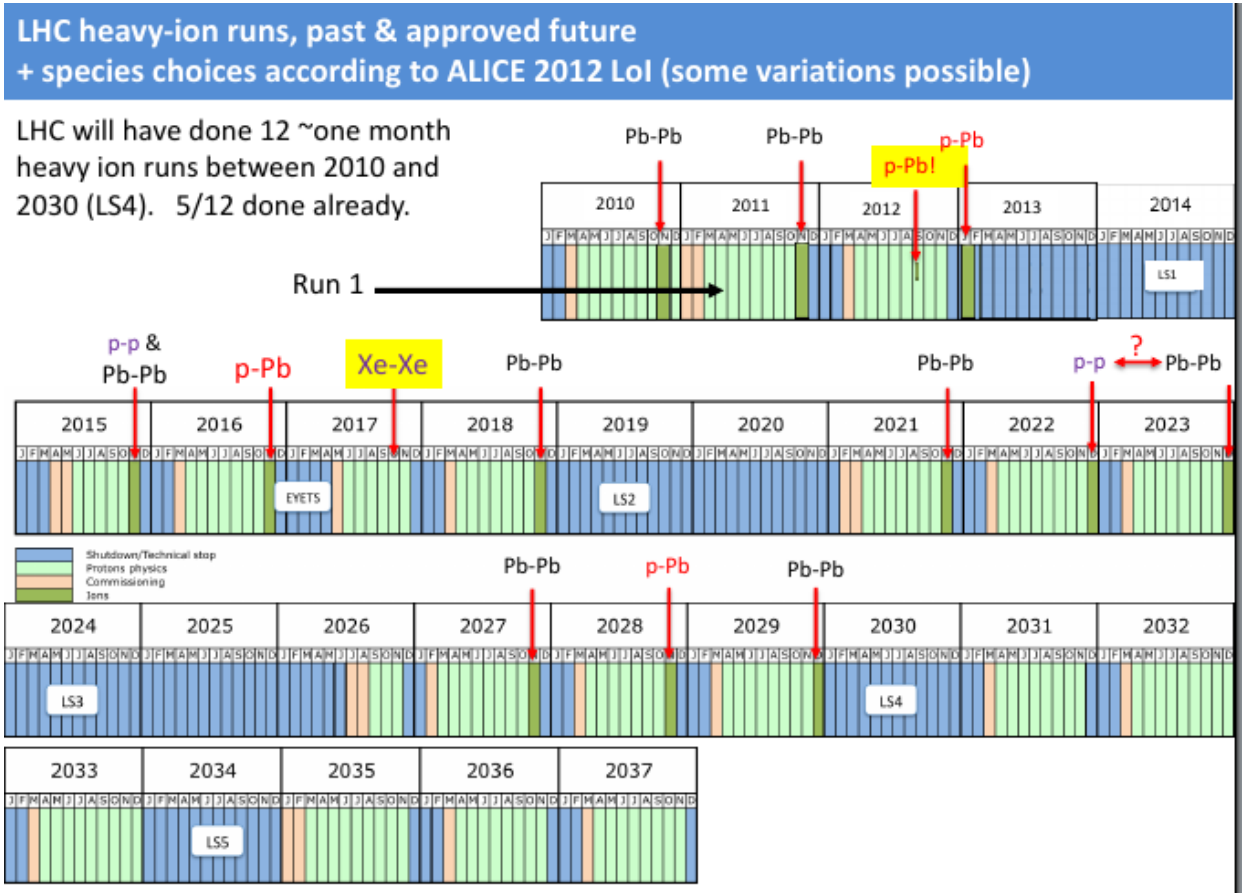
– Update and support of the quarkonia production software and generators.

– Maintenance of the ALICE GRID software in the JINR computing system.

– Participation in the ALICE shifts.

– New tests of the detectors and electronics in the frame of PHOS Upgrade R&D.

ALICE future (perspective) plans.



Fore Pb-Pb at 5.02 TeV:

– 2015-2018 years: Run-2, ~1 nb^{-1} of integrated Luminosity (L_{int})

– 2021-2023 years: Run-3, $L_{int} \cong 6\ nb^{-1}$; start of High Luminosity LHC (HL LHC) with the $L_{peak} = 6\times10^{27}\ cm^{-2}s^{-1}$

– 2018-2023 years: the Medium Term Plan approved by CERN Council with strong support.

– 2026 -2029 years: Run-4, HL LHC, $L_{int} \cong 7\ nb^{-1}$;

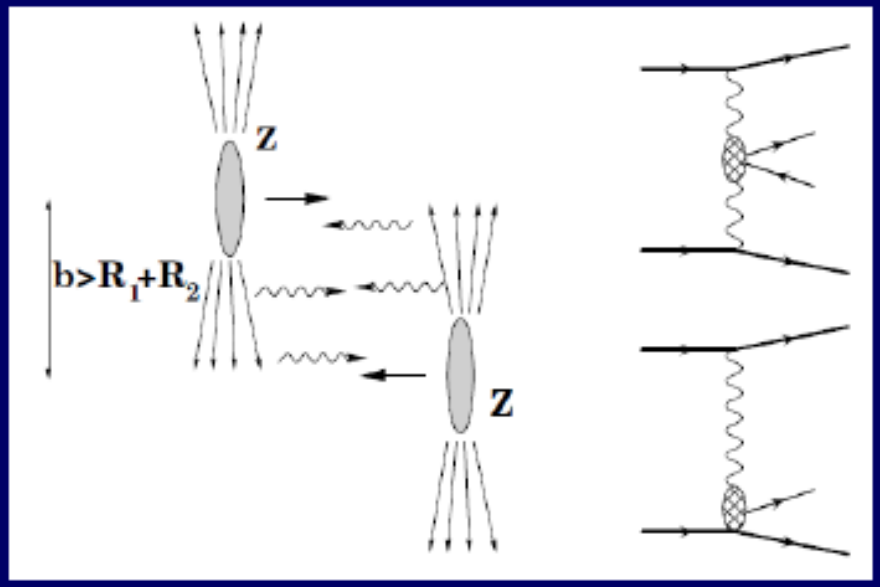
– up to 2037 year: HL LHC → Run5, Run6, but (?) possible start of the Future Circular Collider (FCC).

The JINR team considers the suggestions for a participation in the future HL LHC and possible FCC experiments with up to $(s_{NN})^{1/2}$ = 39 and 63 TeV for Pb-Pb and p-Pb collisions, respectively.

Thank you for your attention

Backup

Ultra-Peripheral Collisions (UPC) of heavy ions



Ultra-peripheral collisions (UPC) occur when ions collide at impact parameter *b* greater than sum of nuclear radii. Thus UPC are photon-induced reactions.

Electromagnetic field in UPC is described by a flux of virtual photons within Weizsäcker-Williams approach and intensity of the field is proportional to Z^2

UPC offer pure EM two-photon or photo-nuclear collisions

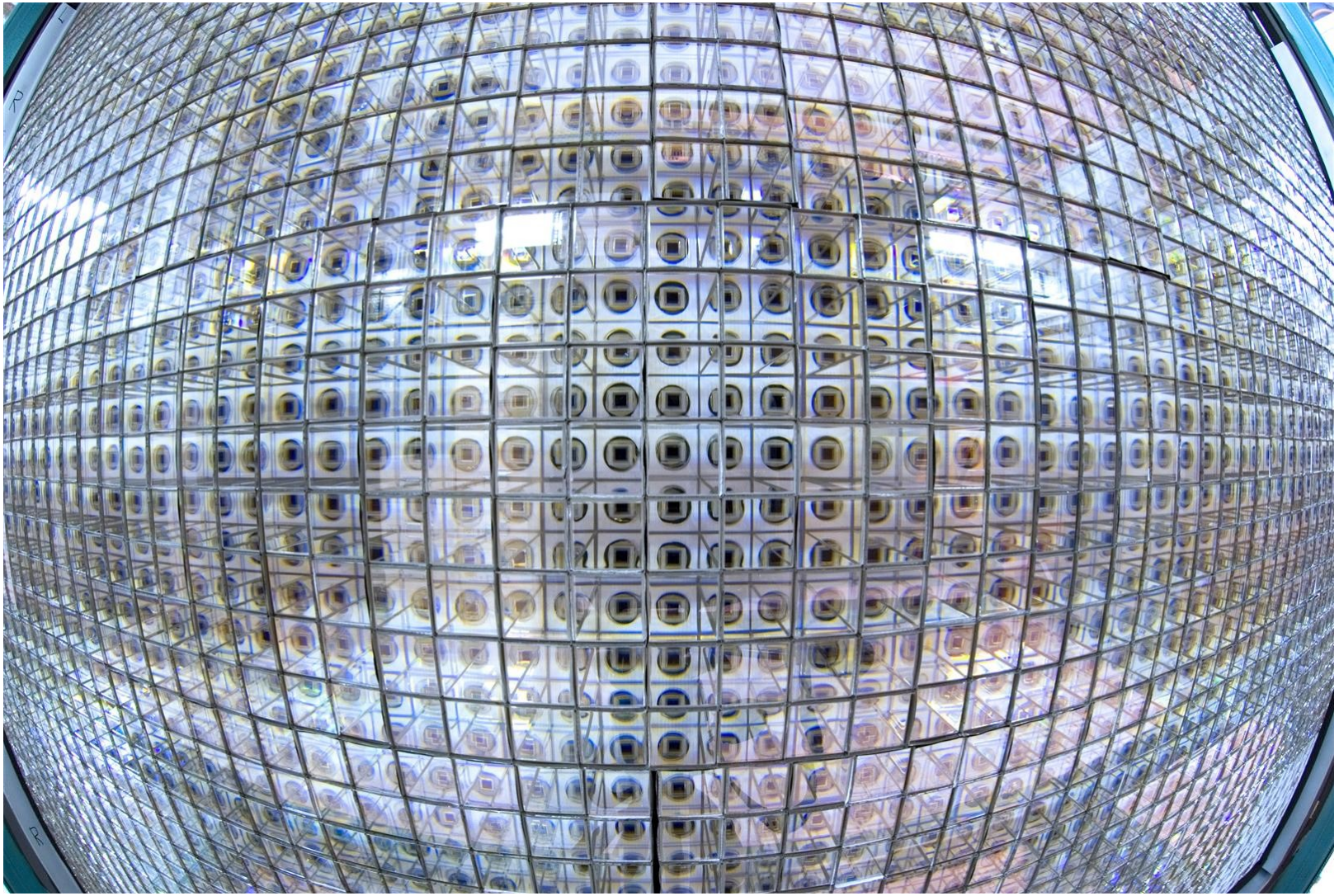
The LHC in heavy-ion mode works as a powerful source of quasi-real photons

Vector meson (VM) photoproduction (photon-Pomeron exchange) can occur either coherently off whole nucleus (p_T~30 MeV/c) or incoherently off nucleons (p_T~300 MeV/c)

UPC studies are mainly intended to address gluon shadowing in nuclei

UPC review : A.J. Baltz et al., Phys.Rept. 458 (2008) 1.

The PHOS detector consists of near 3.5 moduls installed at a distance of 4.6 m from the interaction point. PHOS covers the acceptance of near 100^{o} in azimuthal angle (φ) and In pseudorapidity $|\eta| < 0.13$. Each module has 3584 detection channels. Each channel consists of a lead tangstate, PbWO4, crystal of 2.2.X2.2 cm^2 cross section and 18 cm Length, coupled to an Avalanch Photo Diod and a preamplifier.



One of the ALICE PHOS modules

Future Circular Collider Study
Goal: CDR for European Strategy Update 2018/19

International FCC collaboration (CERN as host lab) to design:

- ***pp*-collider (*FCC-hh*)**
  → main emphasis, defining infrastructure requirements

~16 T ⇒ 100 TeV *pp* in 100 km

- **80-100 km tunnel infrastructure** in Geneva area, site specific
- ***e*⁺*e*⁻ collider (*FCC-ee*),** as a possible first step
- ***p-e* (*FCC-he*) option,** one IP, FCC-hh & ERL
- **HE-LHC** w *FCC-hh* technology