Recent results and prospects from the ALICE experiment

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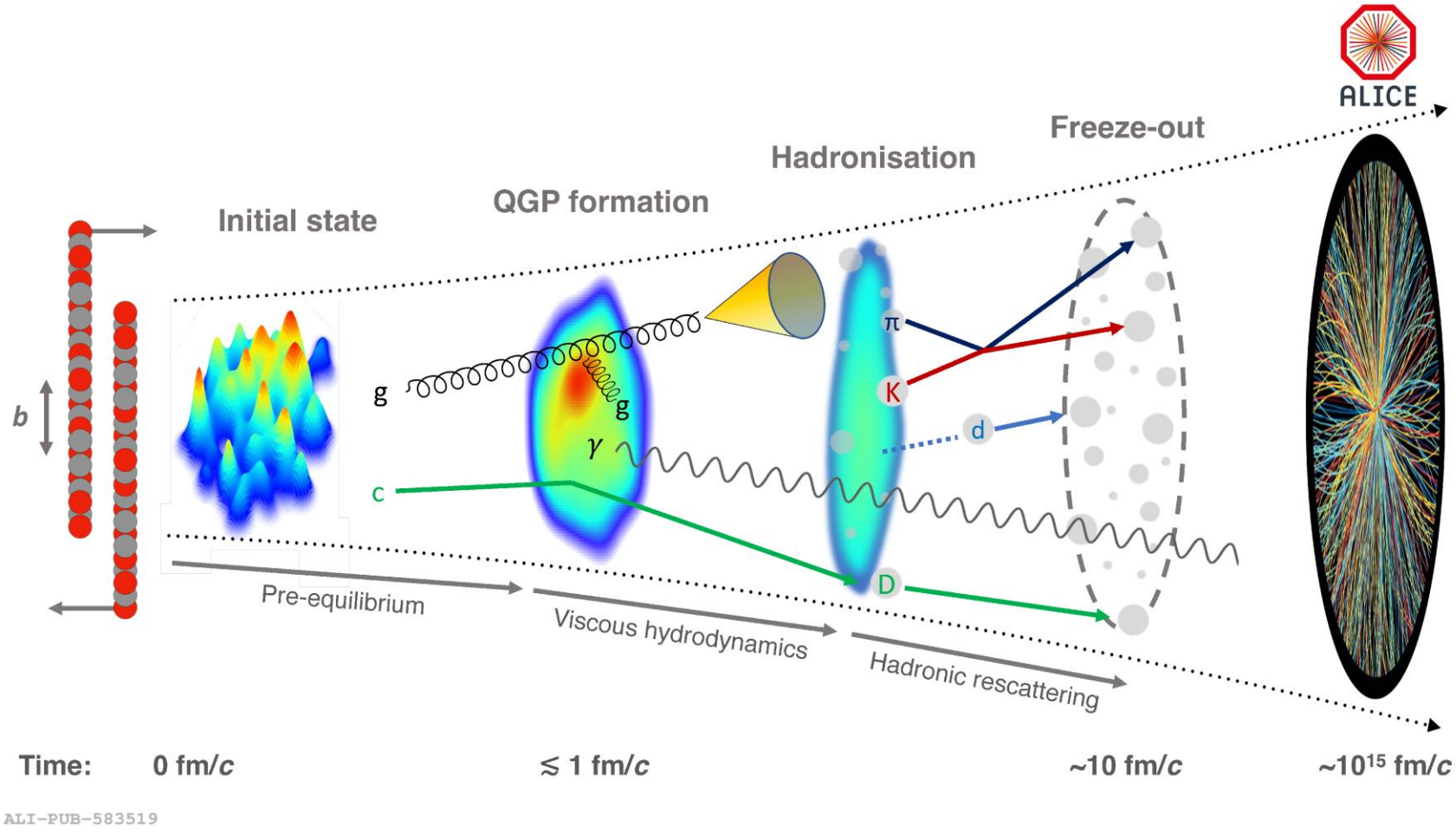
Overview

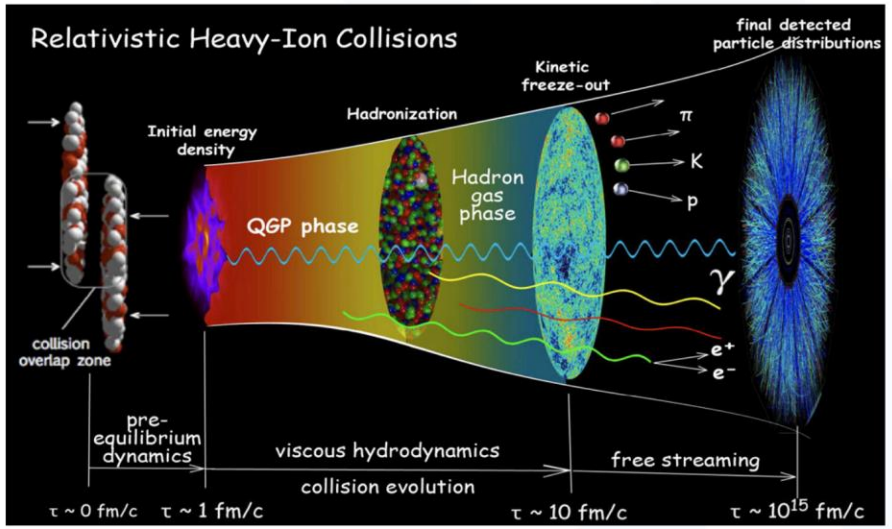
- The physics program of the ALICE experiment
- The ALICE detectors and systems
- Recent Run 2 results
- ALICE Run 3 upgrades, and results from the Run 3 data
- ALICE Run 4 upgrades and ALICE3

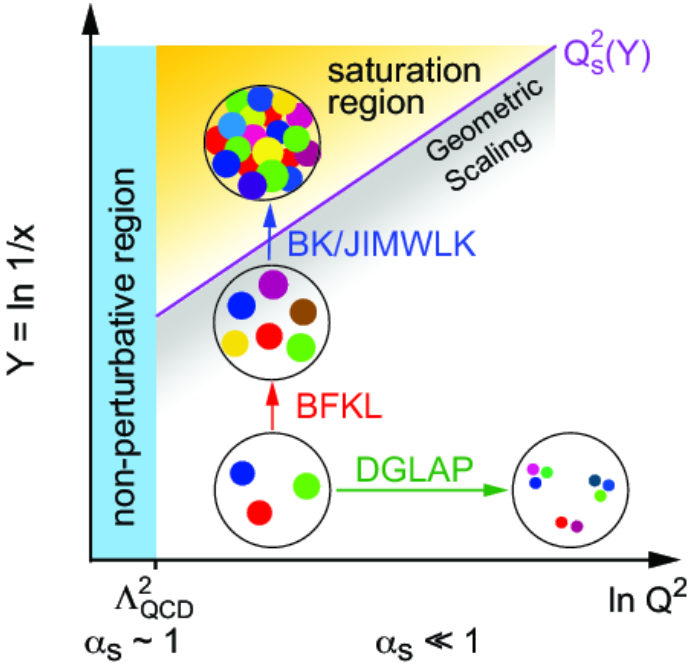
Physics motivation

Heavy ion collisions and the QGP evolution



Hot and cold QCD matter





Hot QCD

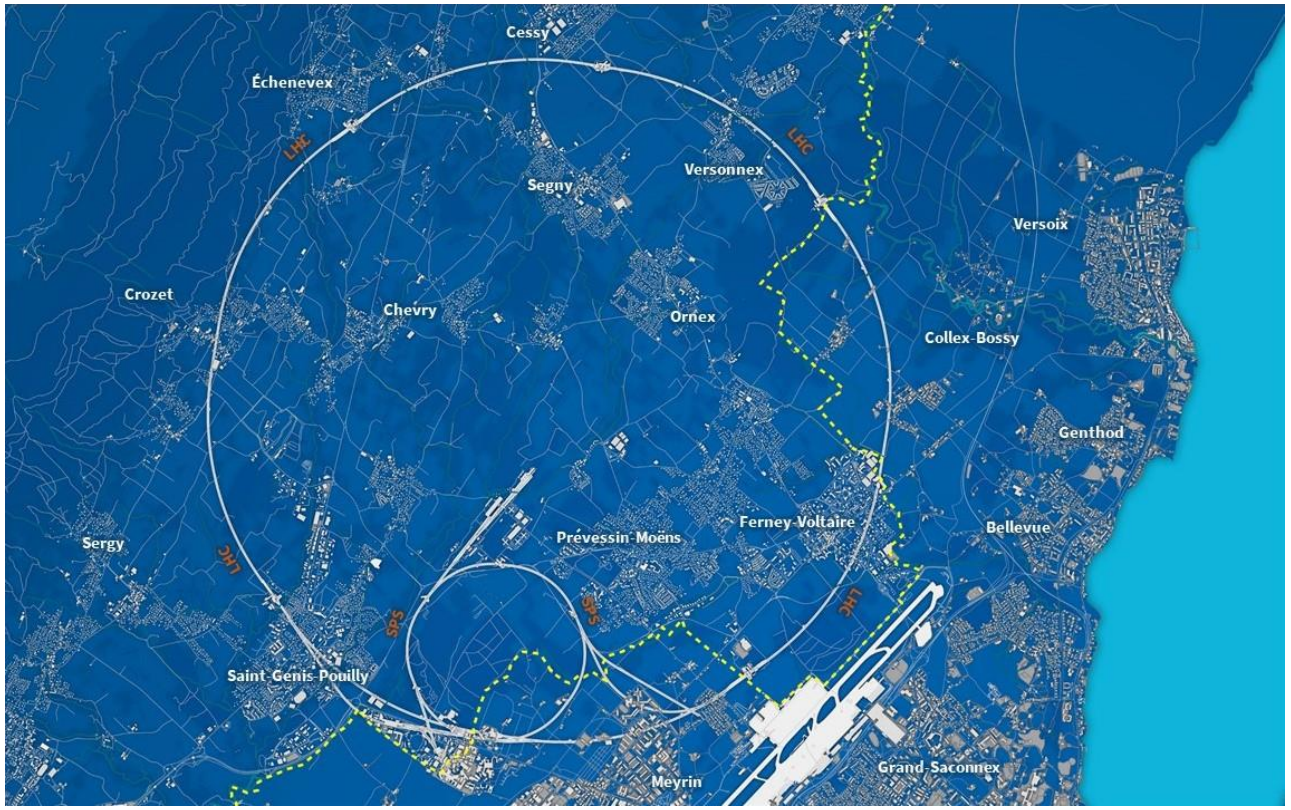
Re-creating the quark-gluon plasma (QGP) with very hot temperate and energy densities that existed in the early Universe. Deconfined state of quarks and gluons

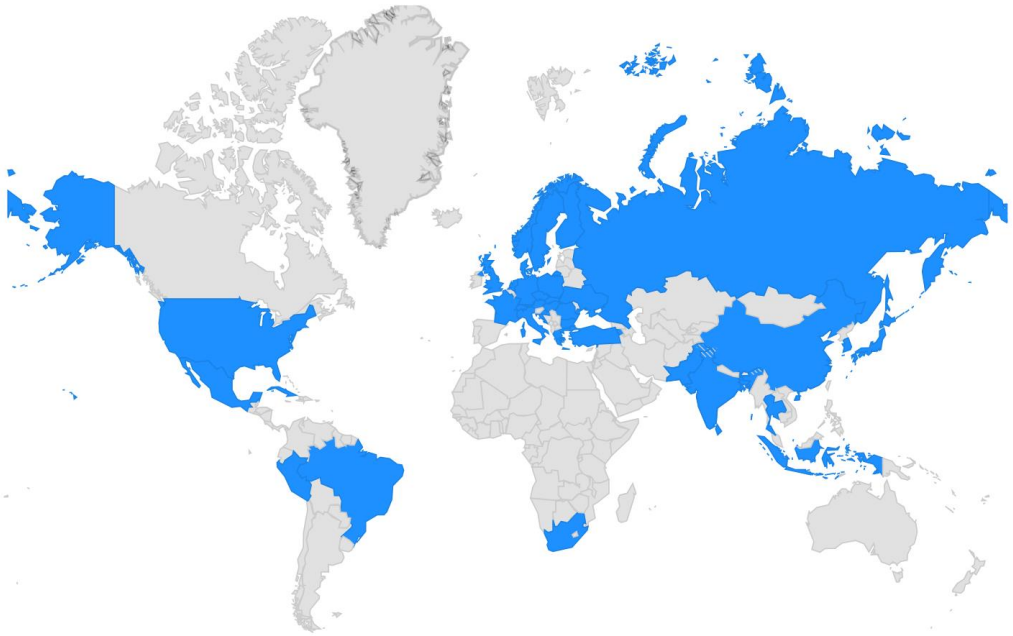
Cold QCD:

Studying the initial configuration of the colliding protons or ions, including the spatial structure of quark and gluons

New phenomena expected for low-x gluons: gluon saturation

The ALICE experiment

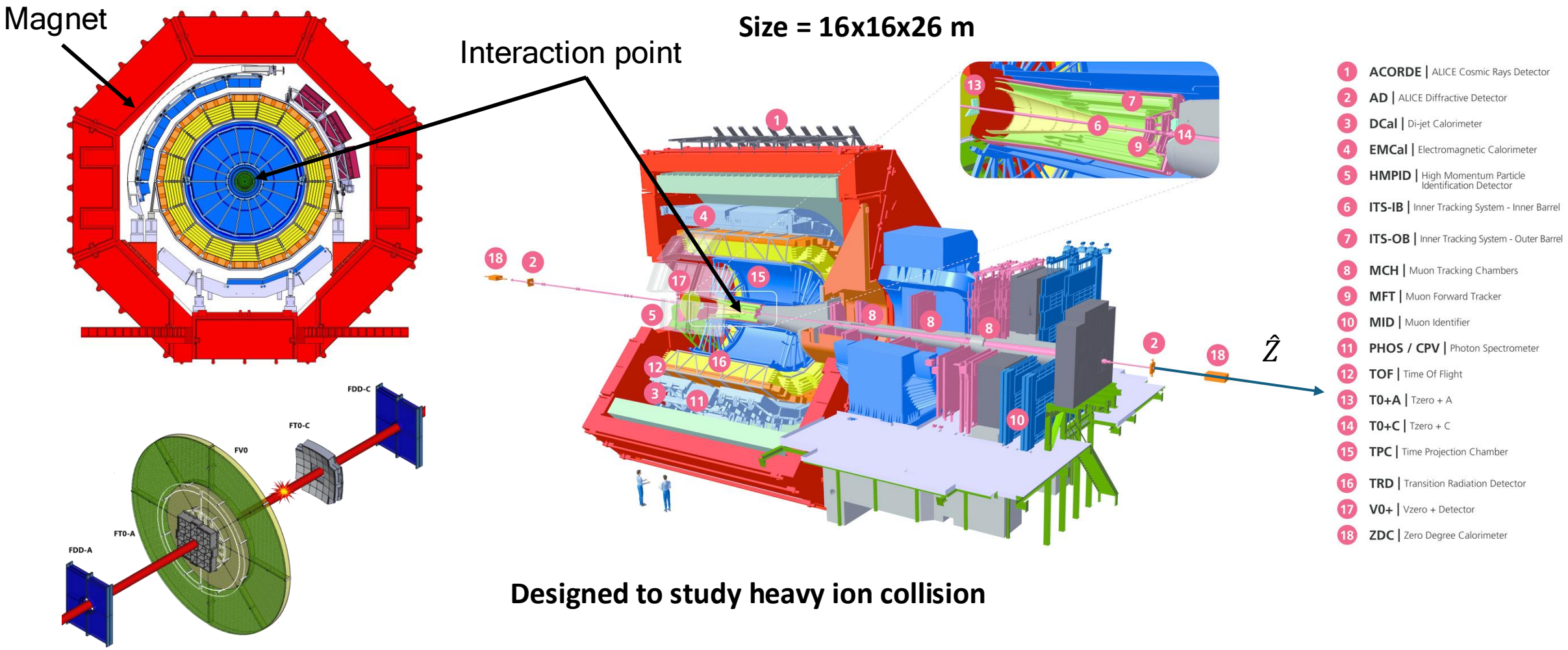




39 countries, 162 institutes, 1889 members

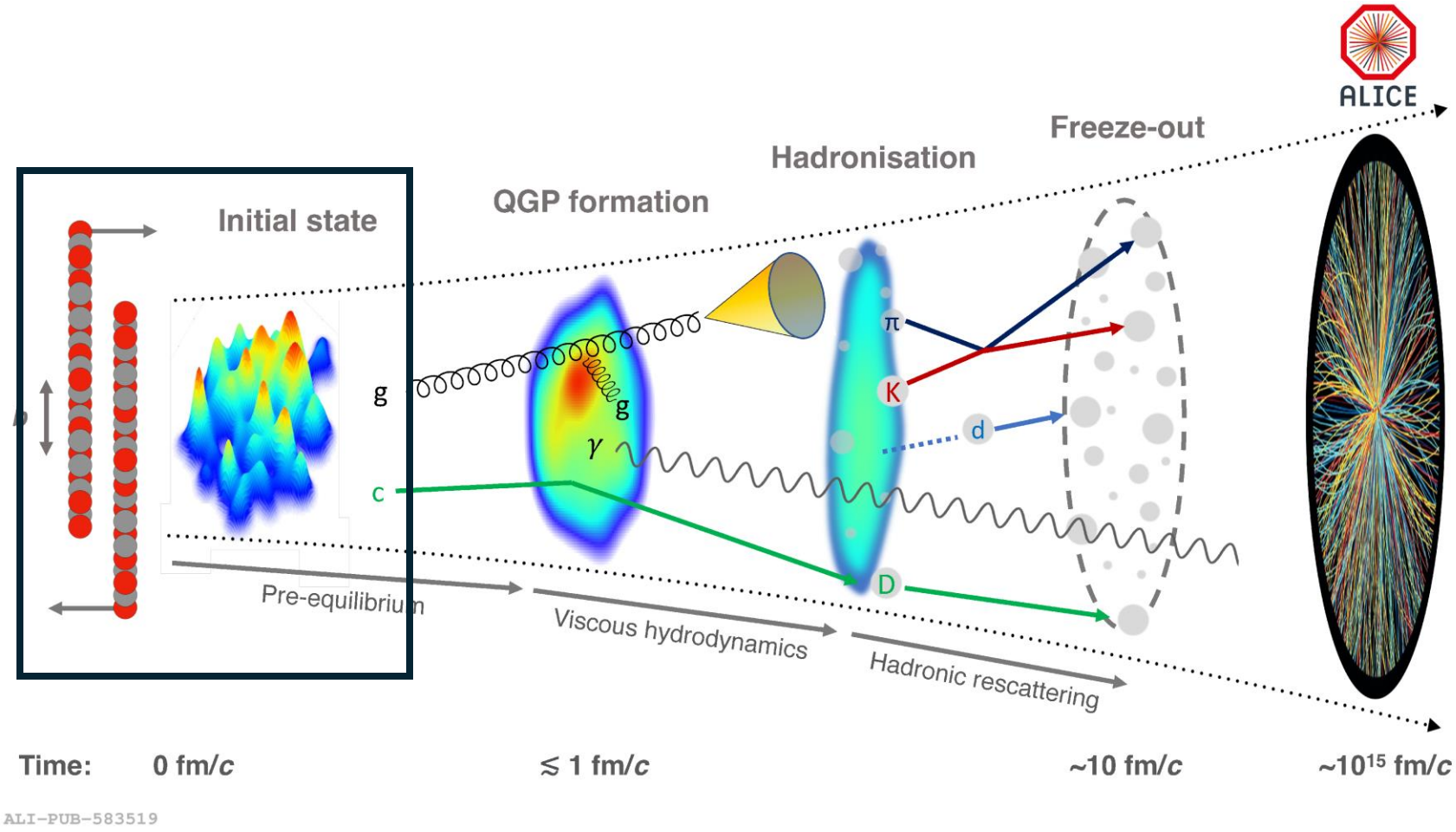
ALICE is located at the LHC point 2

ALICE: A Large Ion Collider Experiment

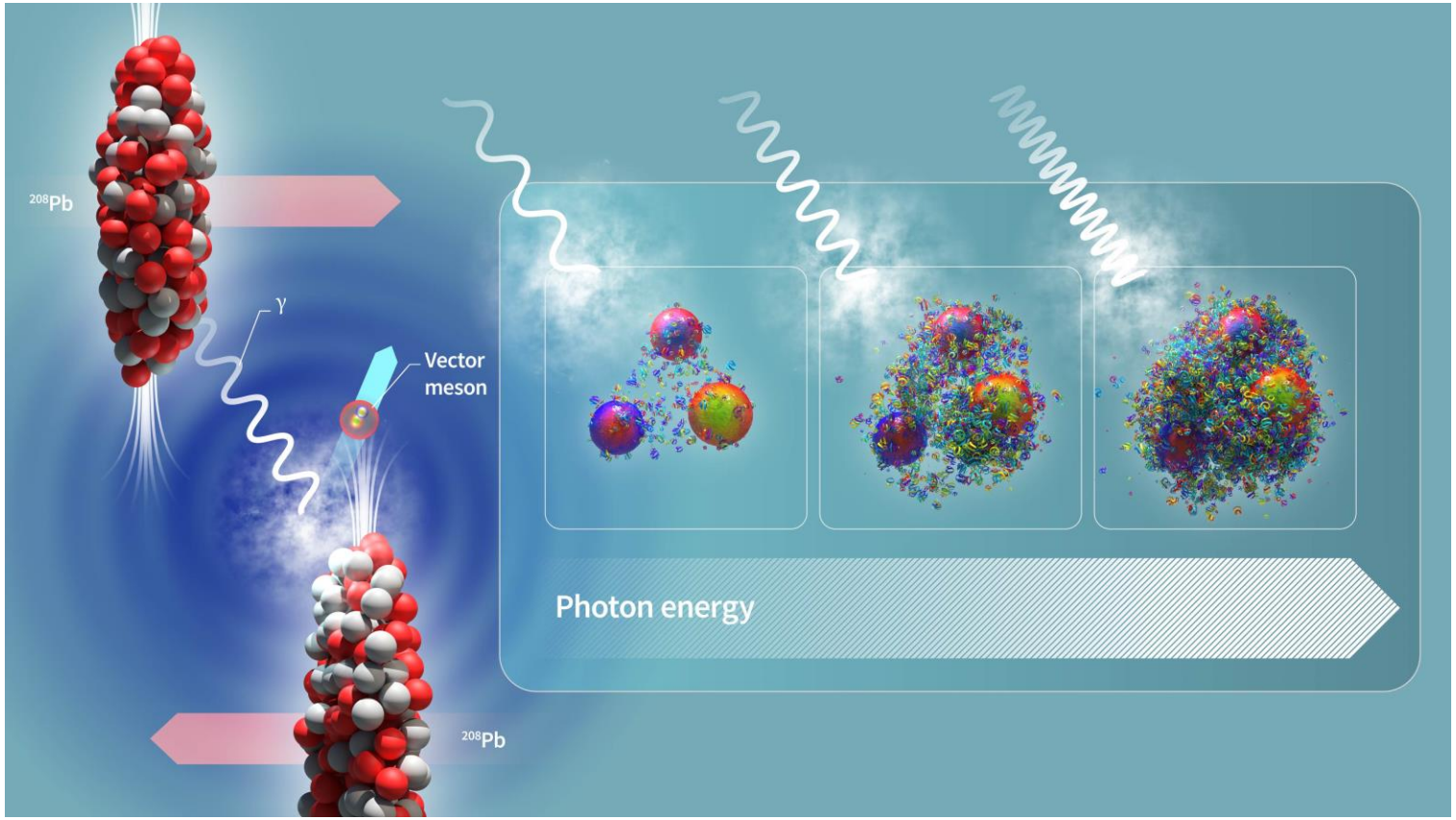


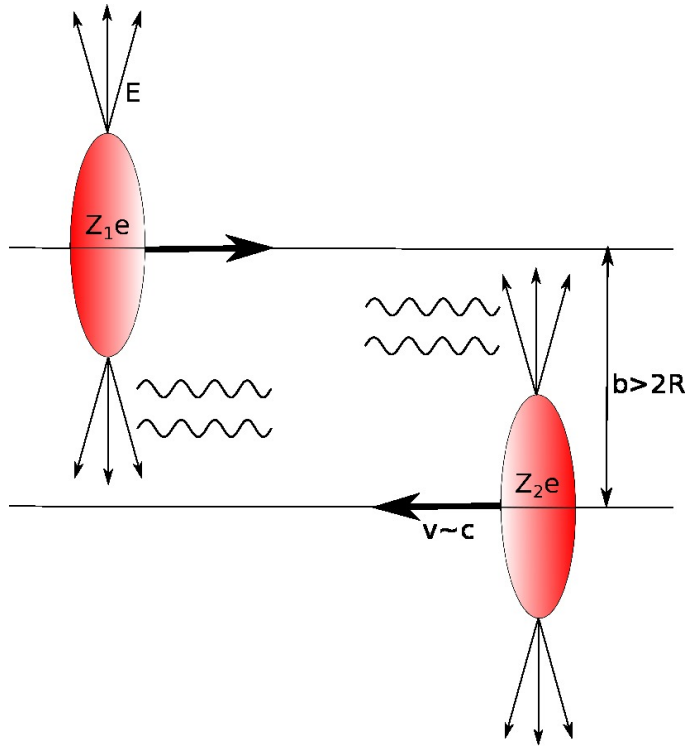
Designed to study heavy ion collision

Heavy ion collisions and the QGP evolution



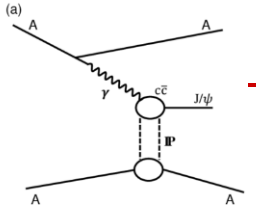
Probing gluon dynamics with UPCs

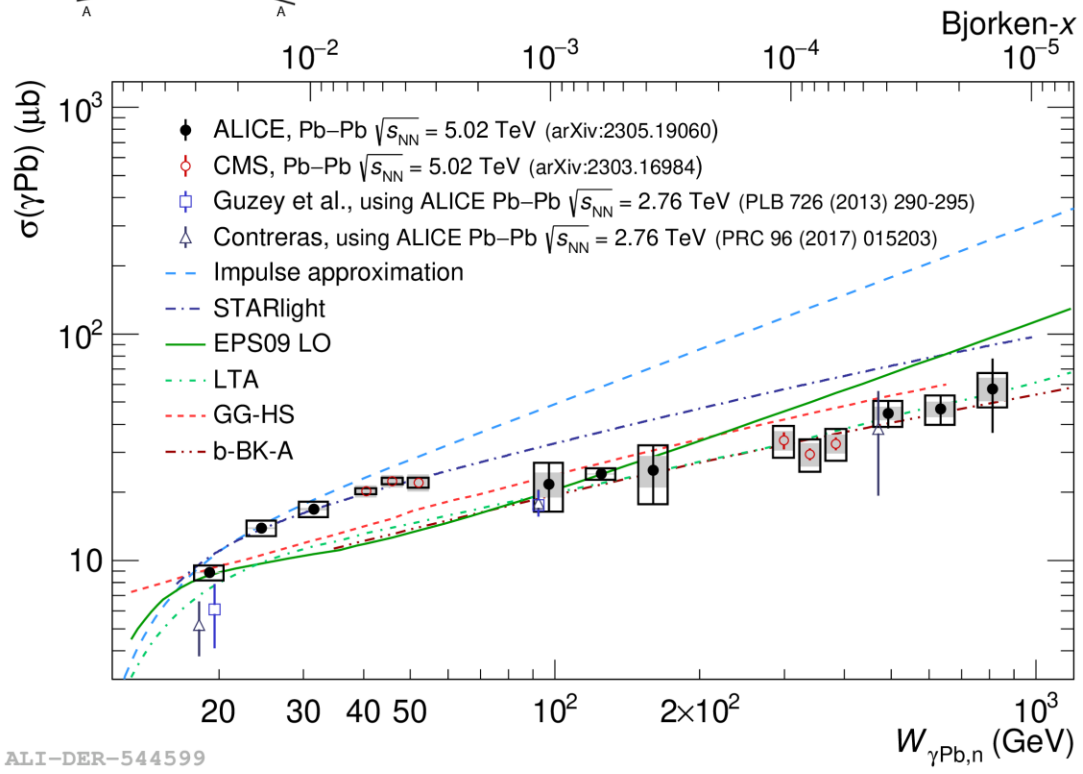


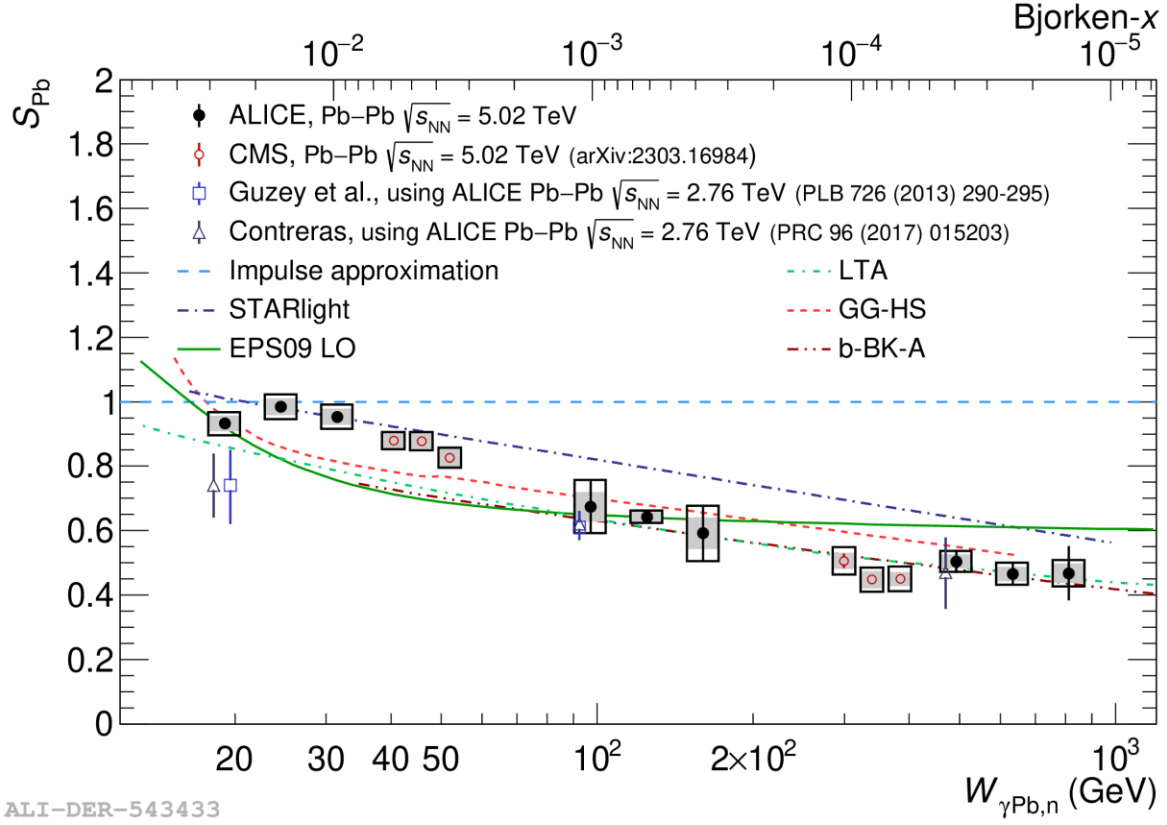


UPCs: Ultra Peripheral Collisions Exploring photon-induced processes at high energies

Energy dependence of coherent J/ψ meson in UPC



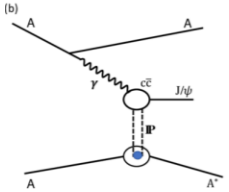


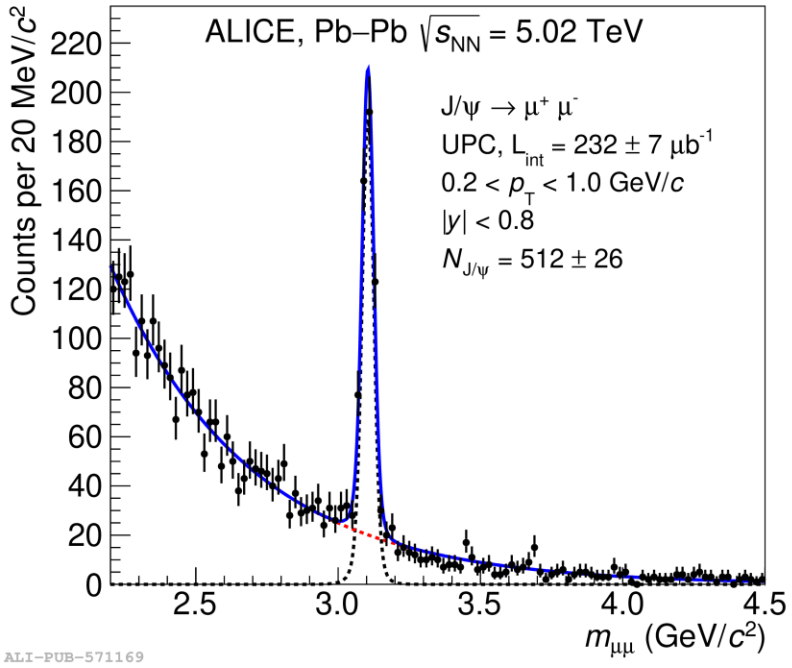


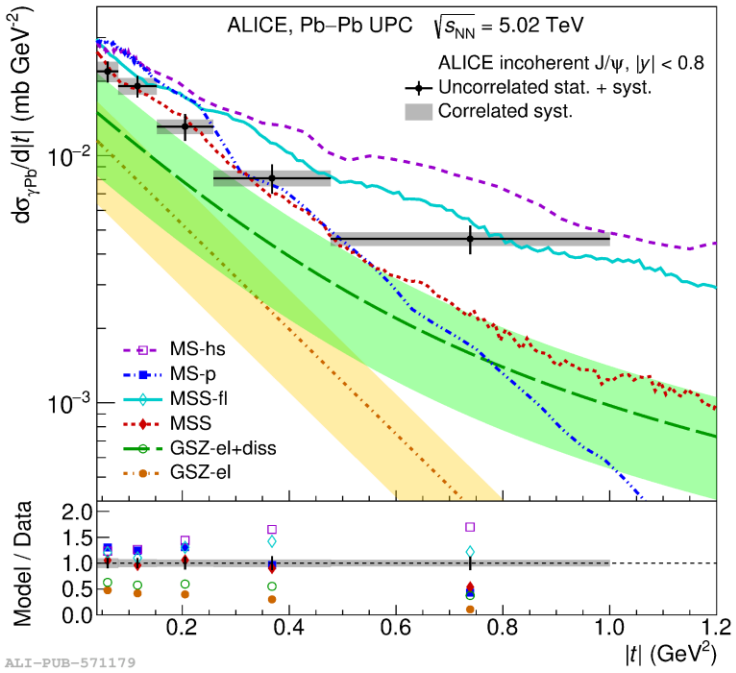
[JHEP 10 (2023) 119]

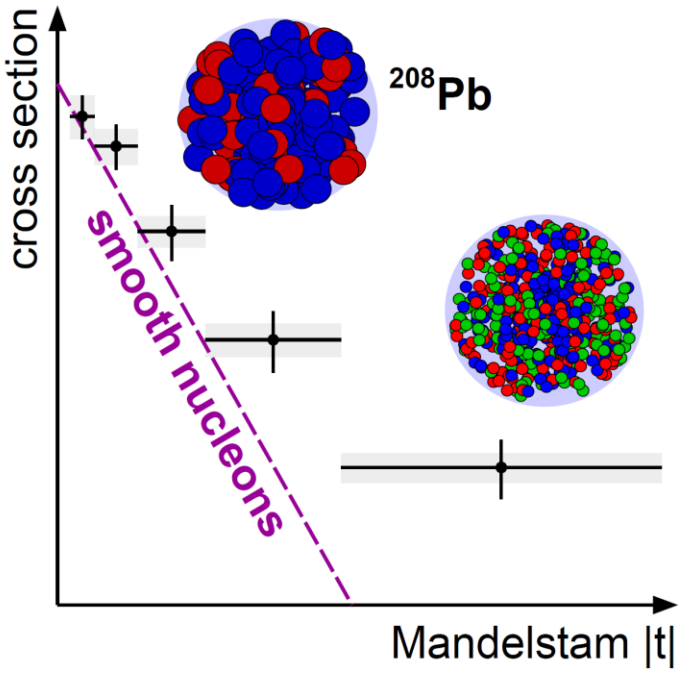
Low-x gluon regime consistent with gluon saturation or shadowing

Incoherent J/ψ in UPC Pb-Pb







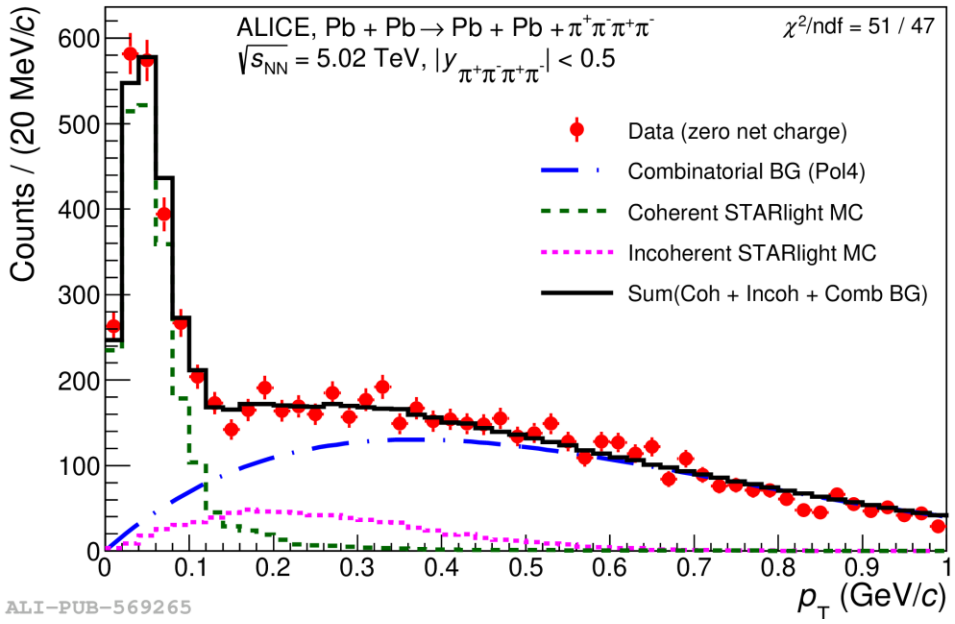


Phys. Rev. Lett. 132 (2024) 16

First observation of subnucleonic hot spots in the Pb target

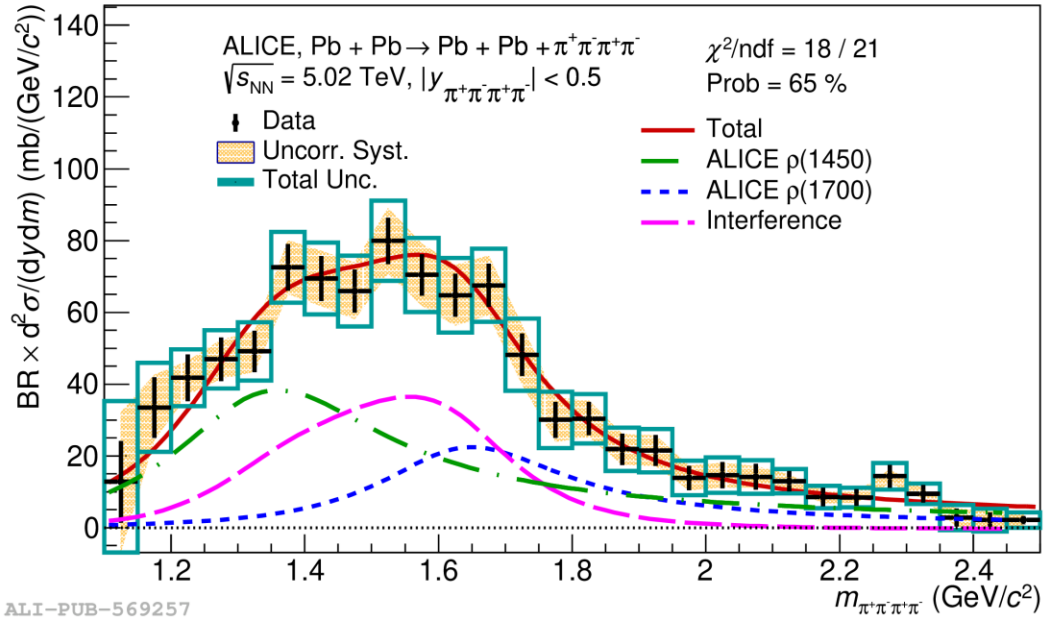
Exclusive four pions in UPC

Coherent events are at low pT



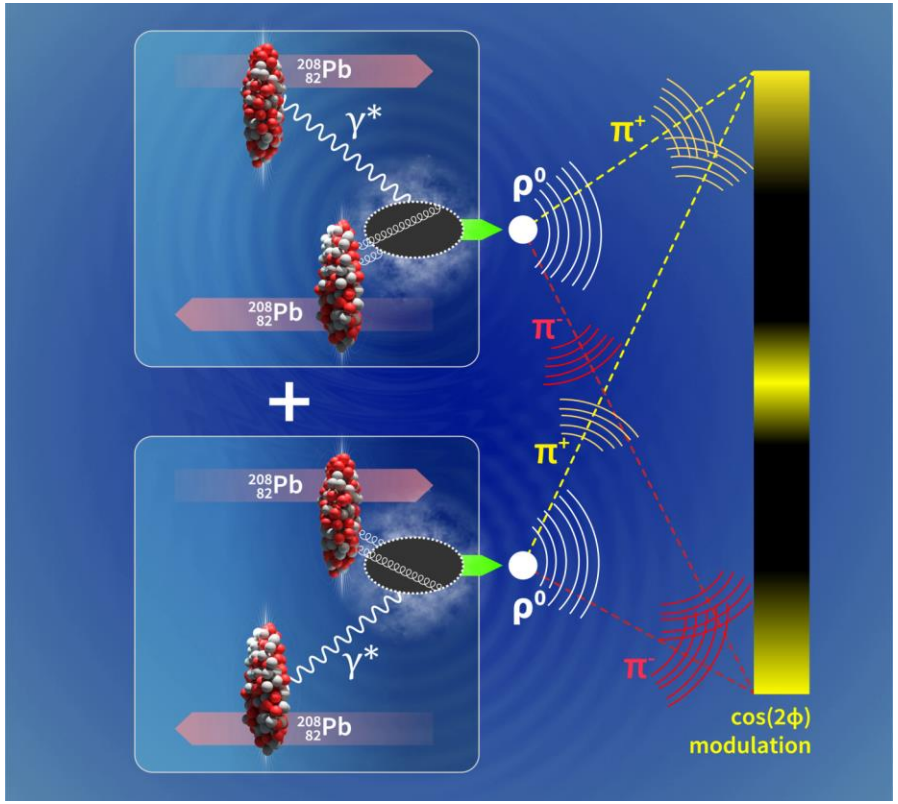
UPCs provide a clean laboratory for vector meson spectroscopy

ALICE data confirm two resonances ρ(1450) and ρ(1700)

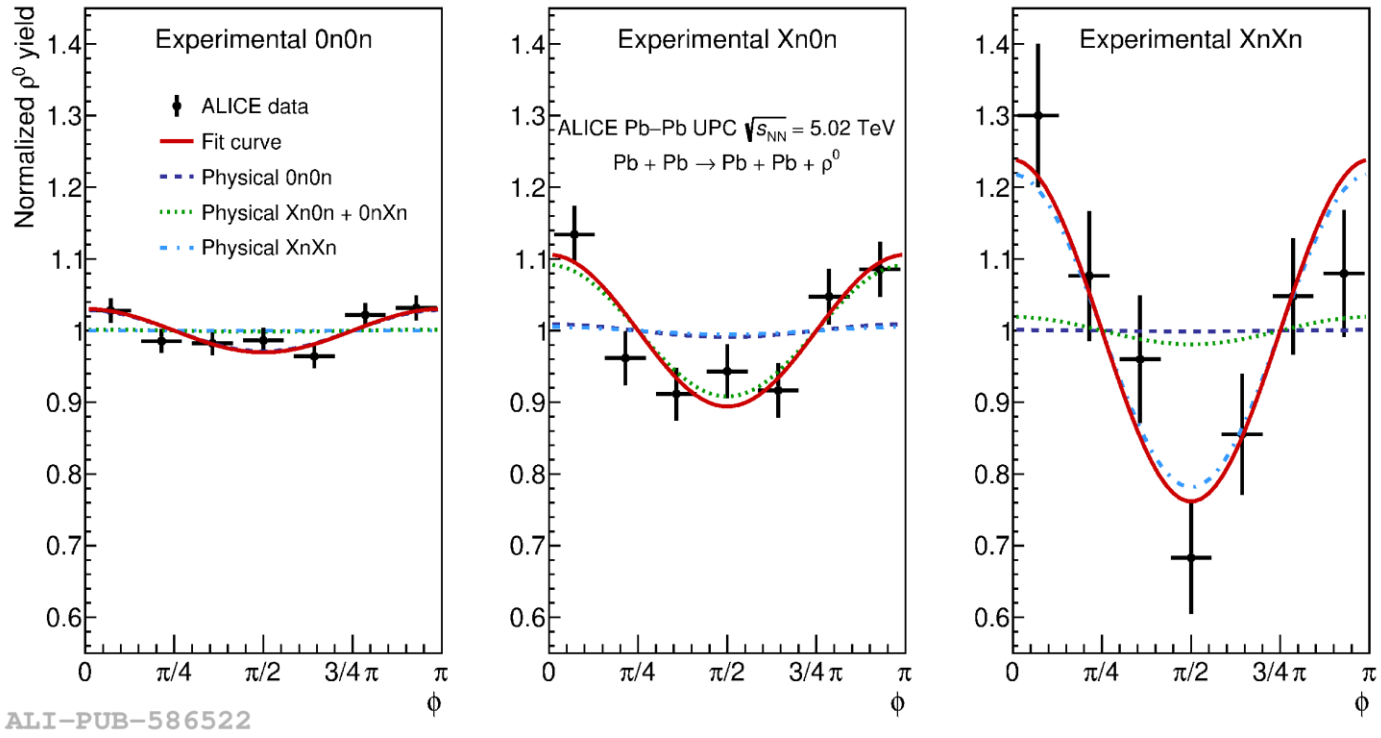


arXiv:2404.07542

Azimuthal correlation of UPC ρ^0



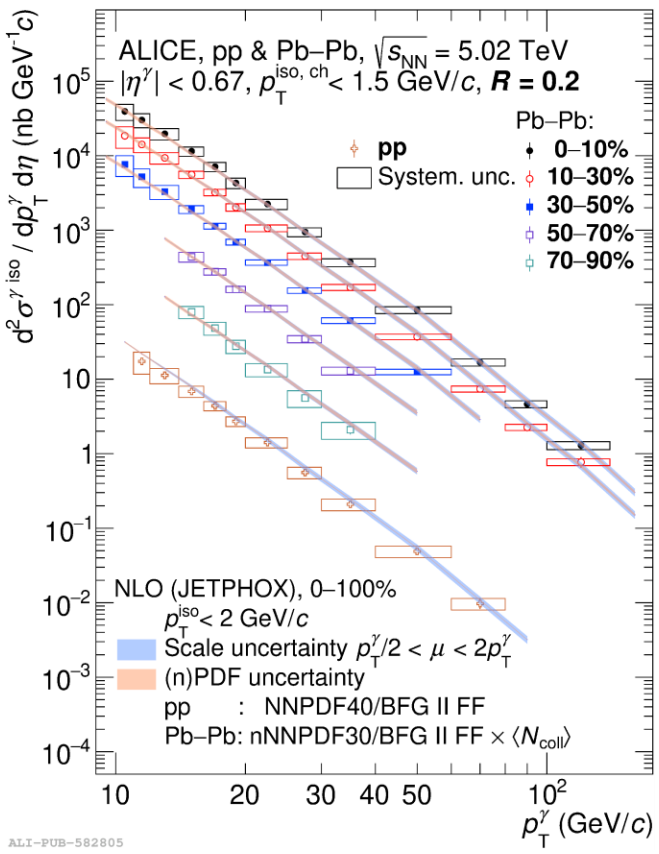
Decreasing impact parameter

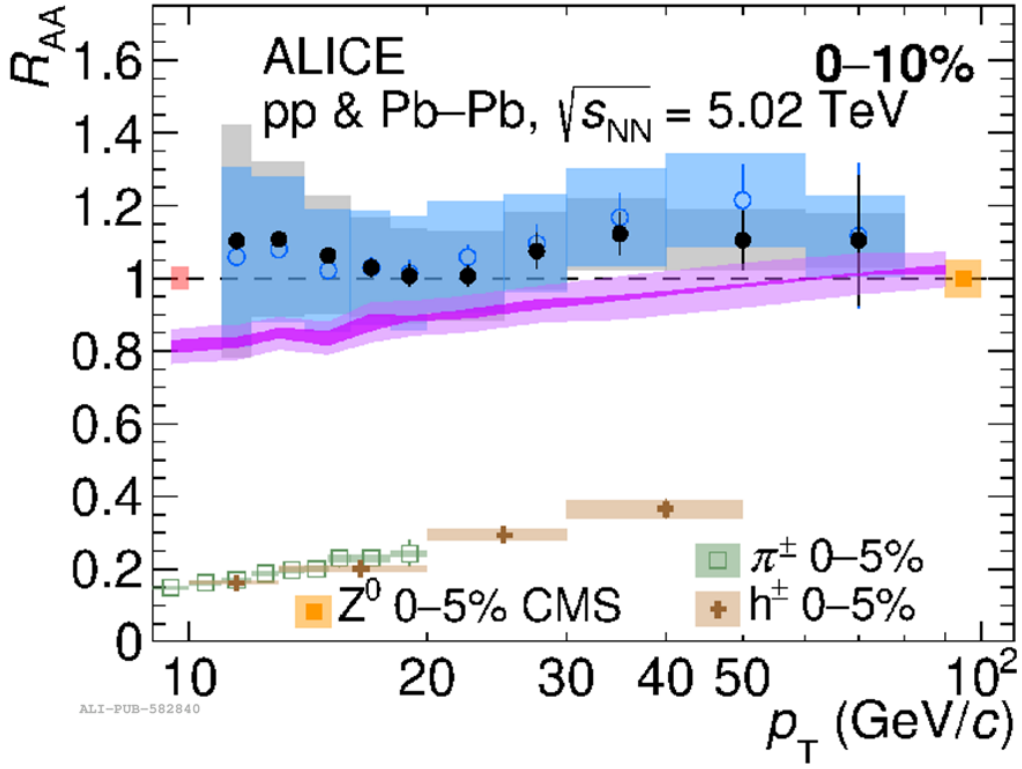


[Phys. Lett. B 858 (2024) 139017]

Azimuthal asymmetry due to interference

Isolated photon production

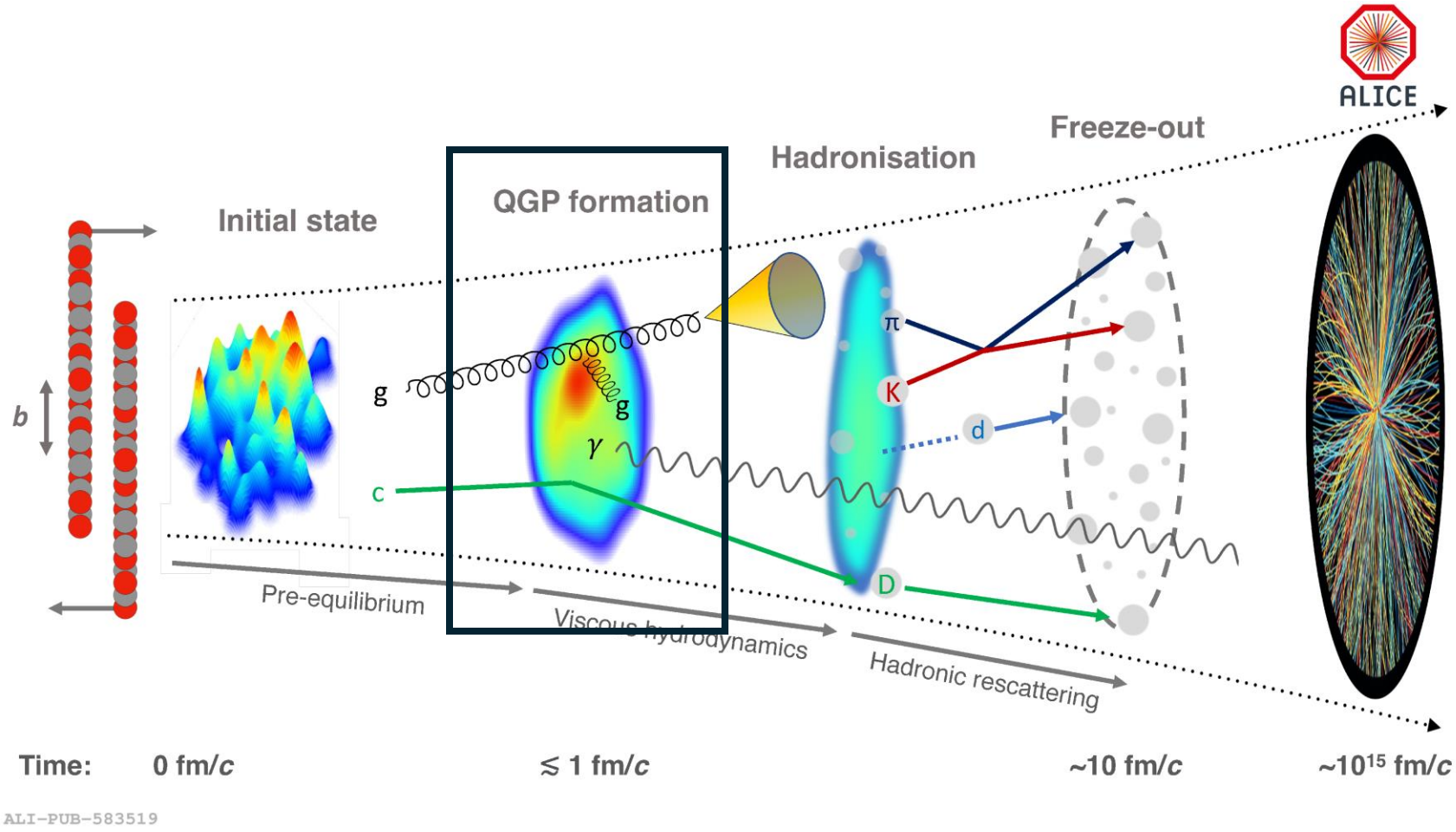




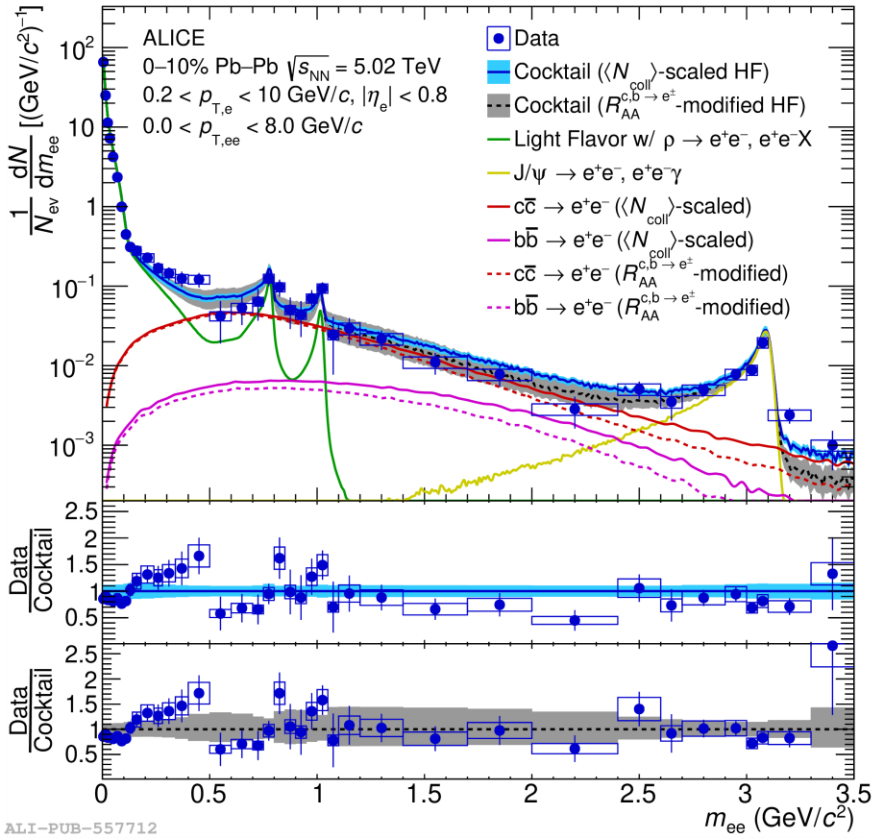
The nuclear modification in agreement with unity in all centrality classes
Result extended to lower p_T than previous measurements by ATLAS and CMS

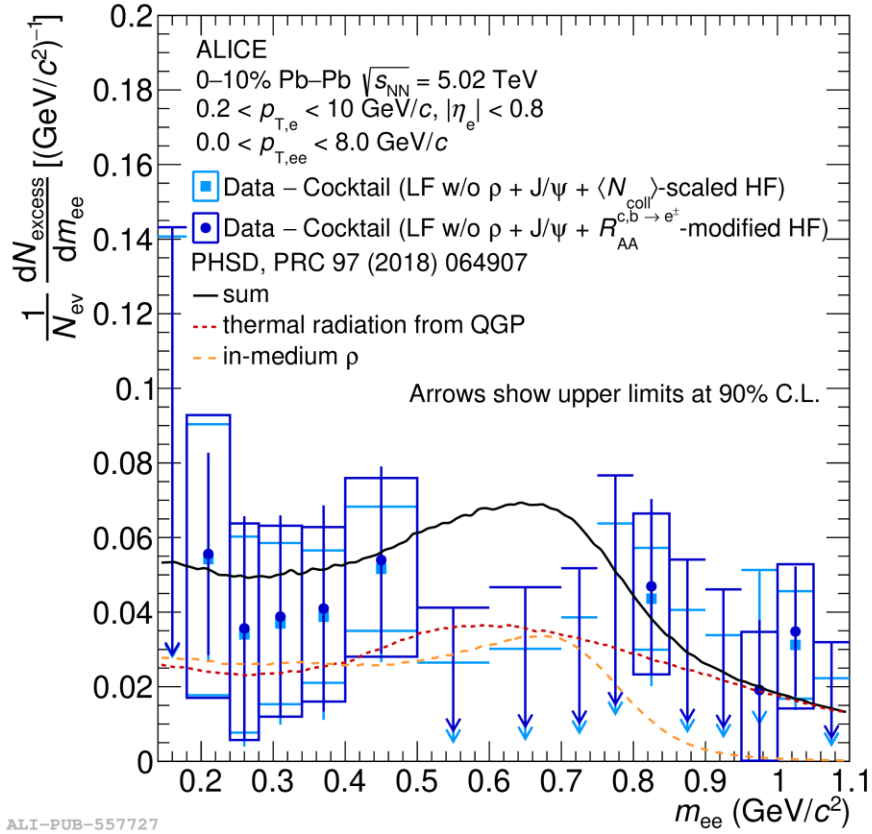
arXiv:2409.12641

Heavy ion collisions and the QGP evolution



First e^+e^- production at low mass at 5.02 TeV central Pb-Pb

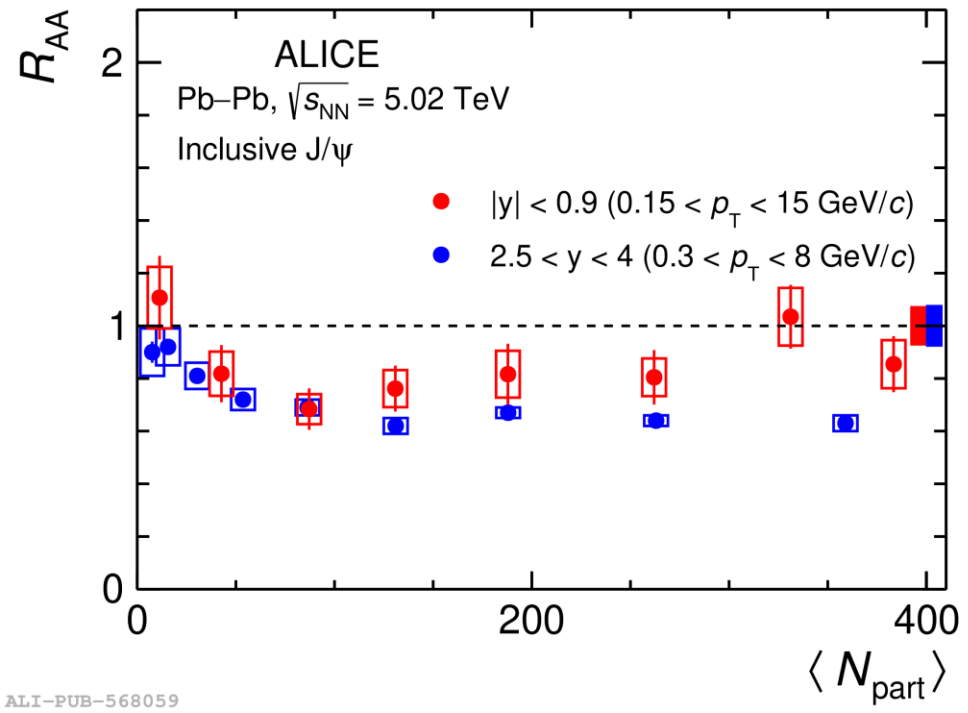




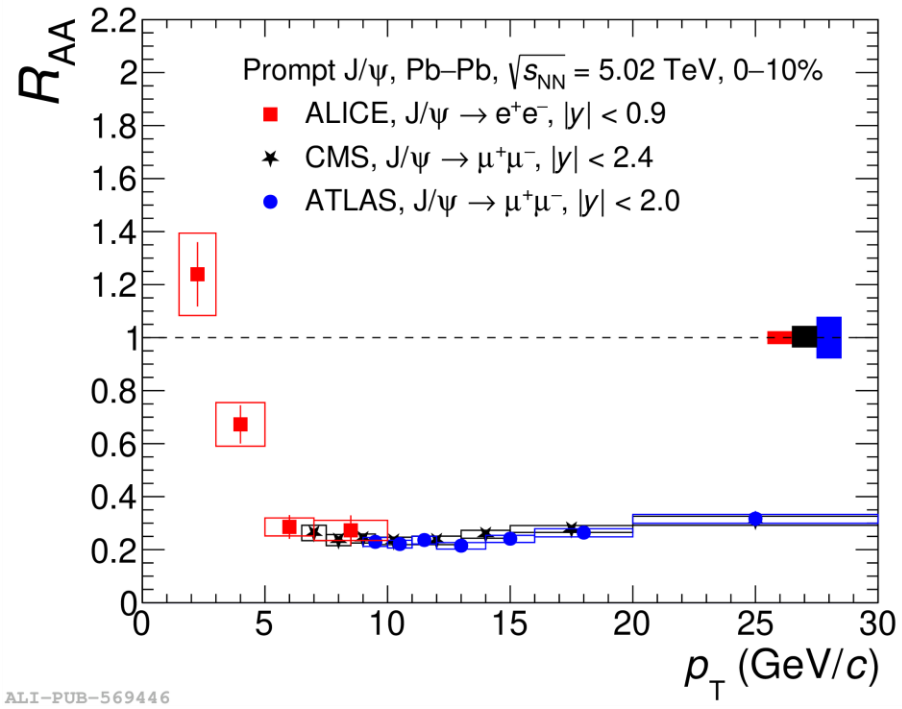
arXiv:2308.16704

Low masses: probe in medium modified spectra from vector mesons
Inter median masses: probe thermal radiation from QGP

J/ψ re-generation Pb-Pb collision



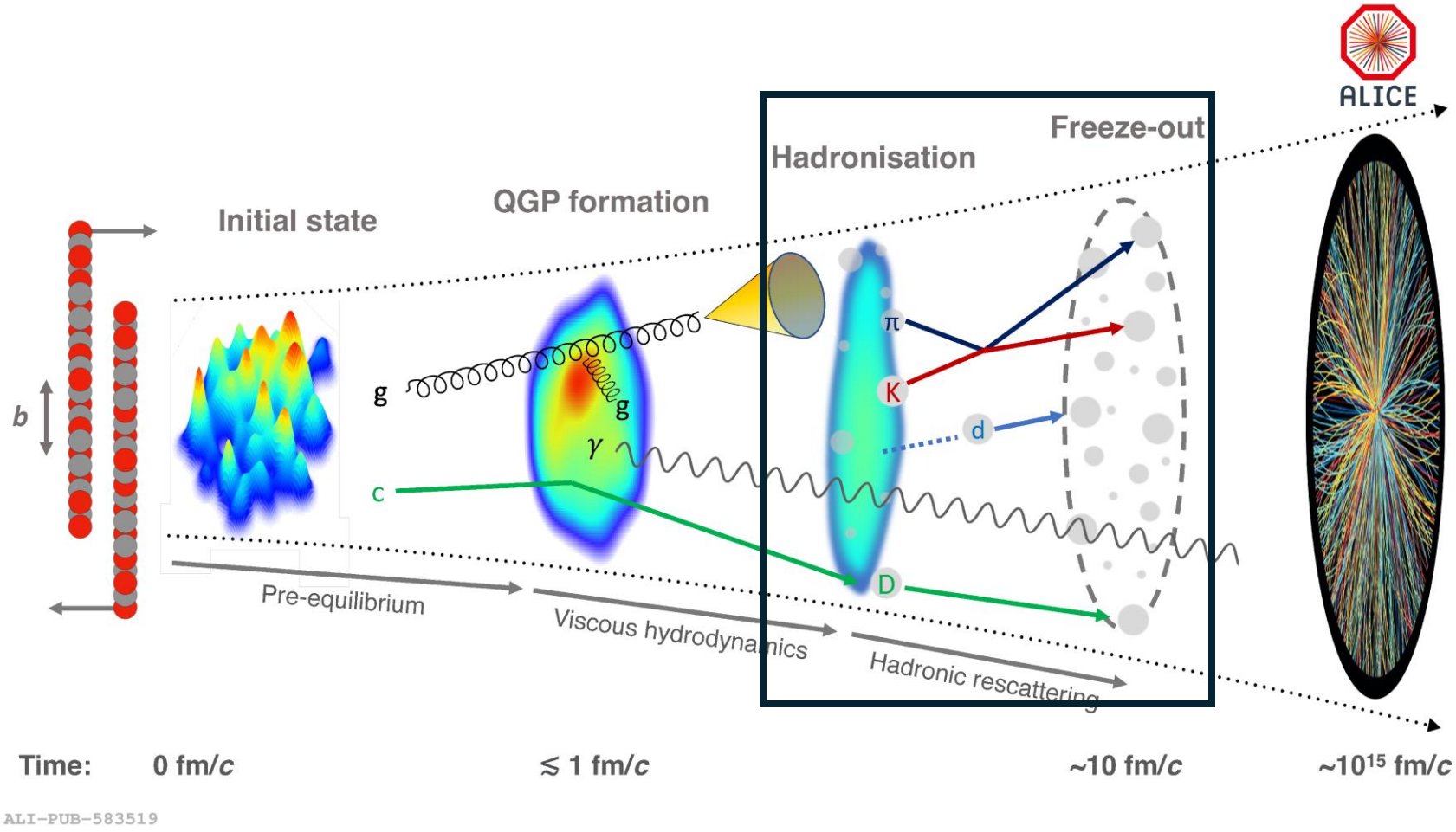
Phys. Lett. B 849 (2024) 138451



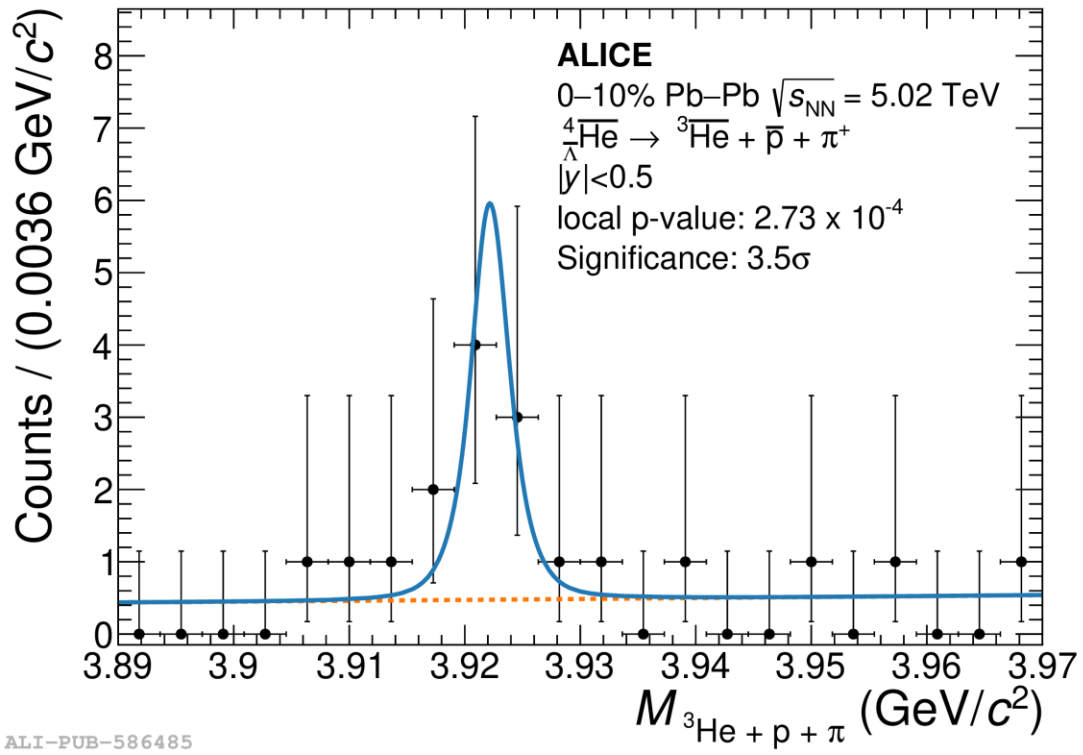
JHEP 02 (2024) 066

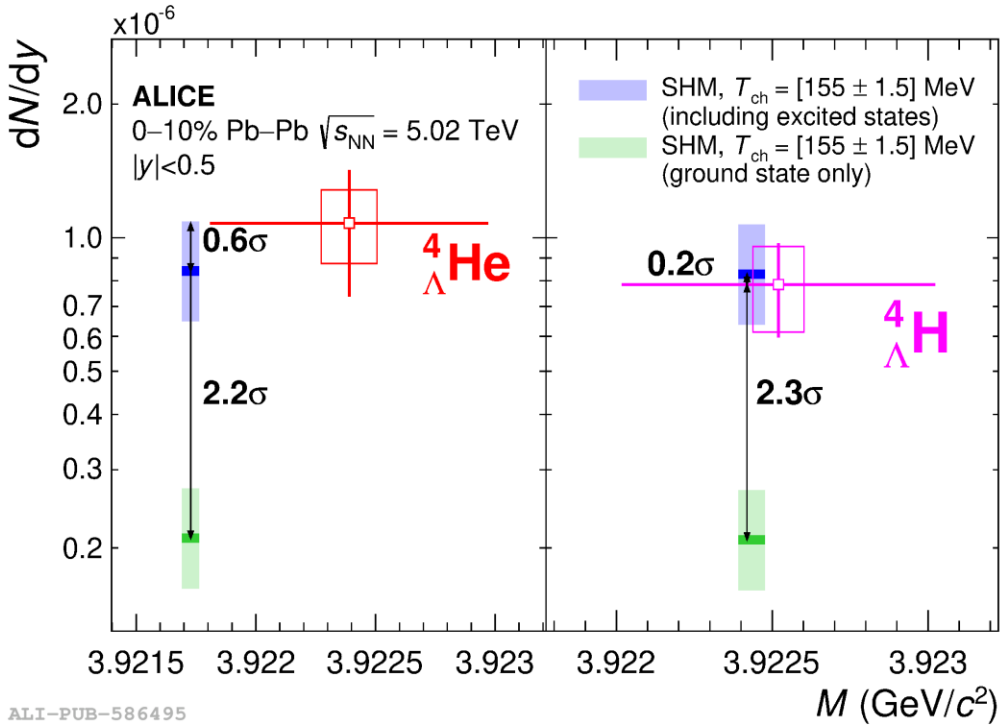
Evidence of J/ψ re-generation at low p_T
Measurement of nuclear modification factor R_{AA} extend to 1.5 GeV/c

Heavy ion collisions and the QGP evolution



First measurement of A = 4(anti)hypernuclei



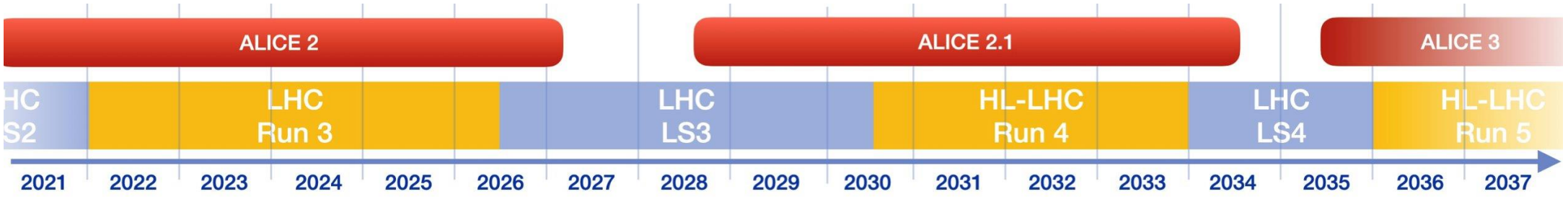


Antiparticle-to-particle ratios in agreement with unity

Masses are compatible with the world-average values within the uncertainties

arXiv:2410.17769

ALICE 2


ALICE 2
ALICE 2.1
ALICE 3
HC
S2
LHC
Run 3
LHC
LS3
HL-LHC
Run 4
LHC
LS4
HL-LHC
Run 5
2021
2022
2023
2024
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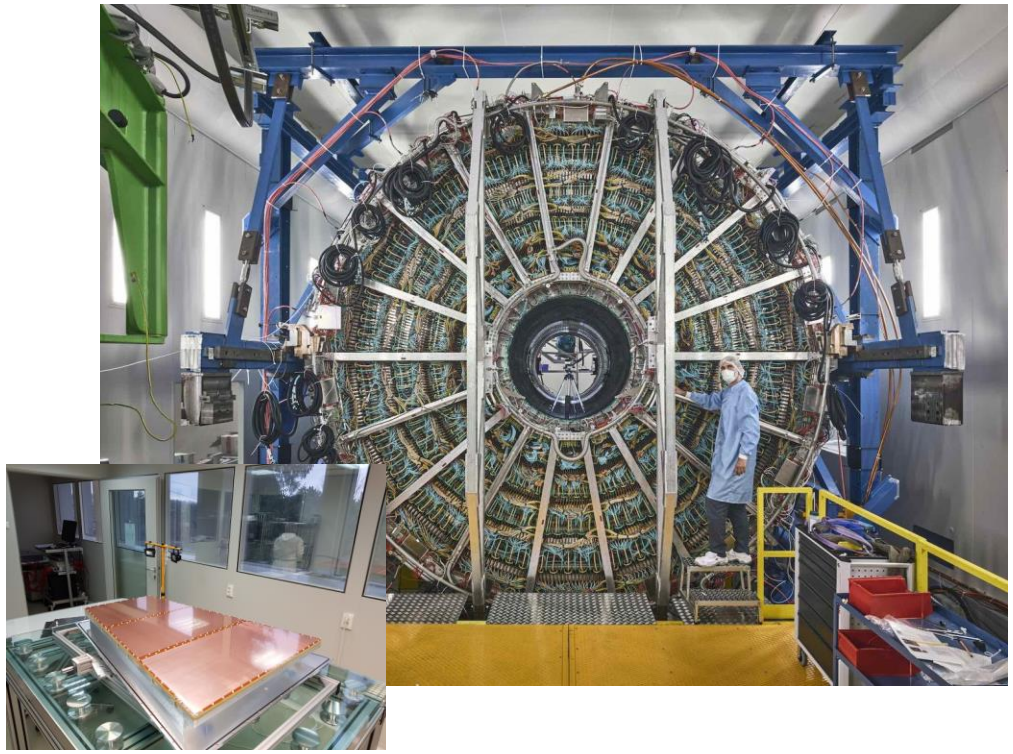
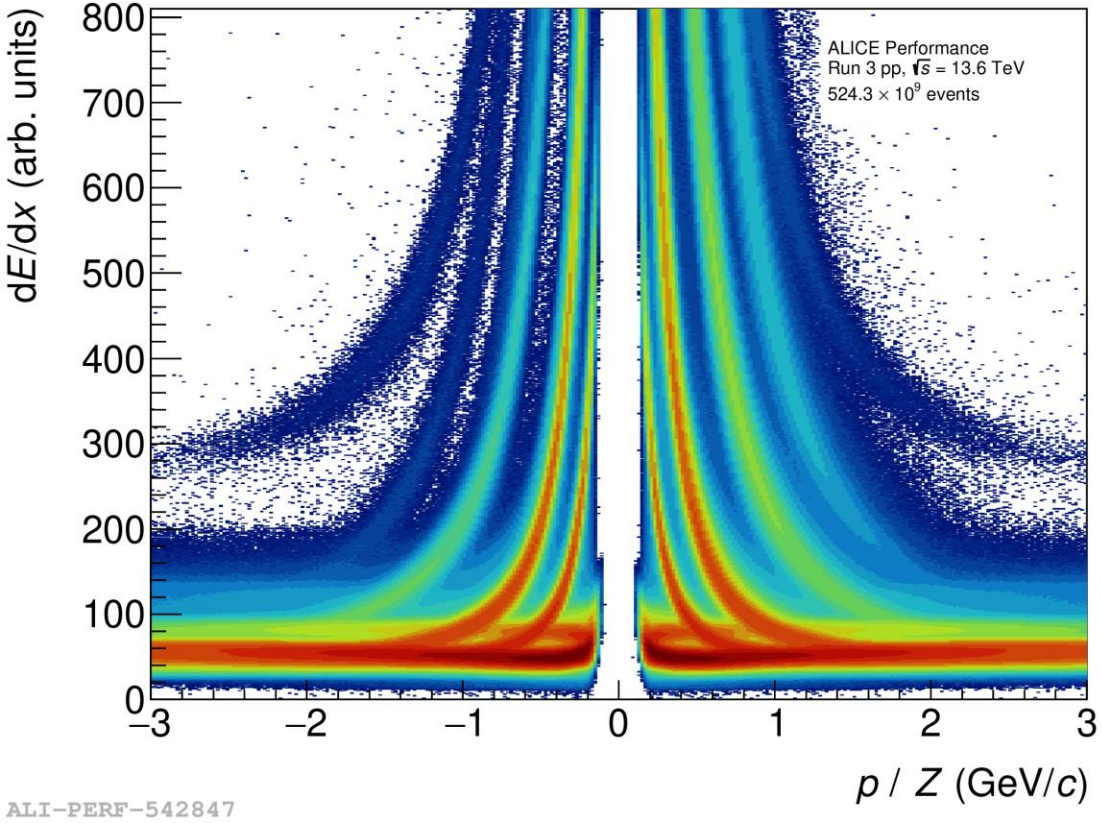
TPC upgrade





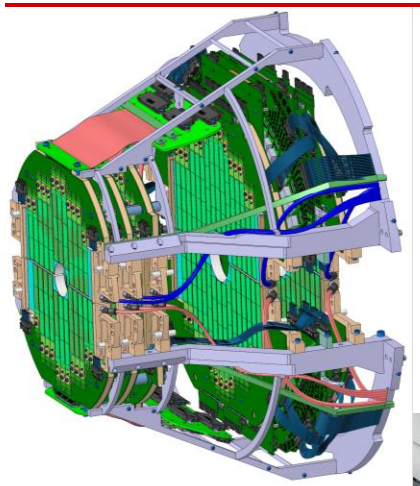
Upgraded with GEM and continuous readout

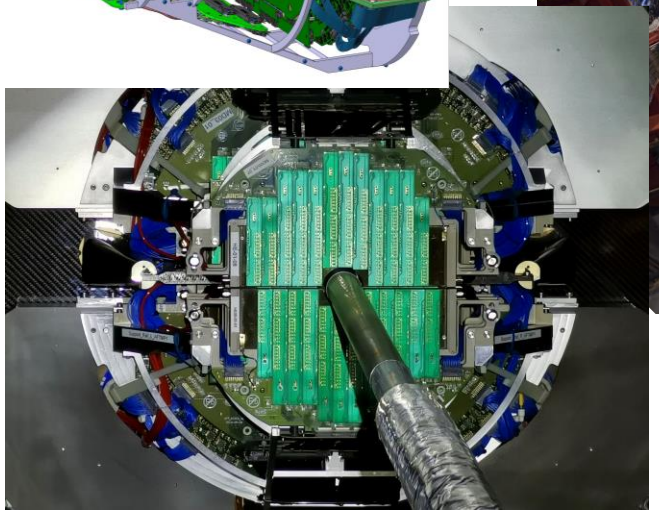
pp data taking at 500 kHz

Pb-Pb data taking at 50 kHz

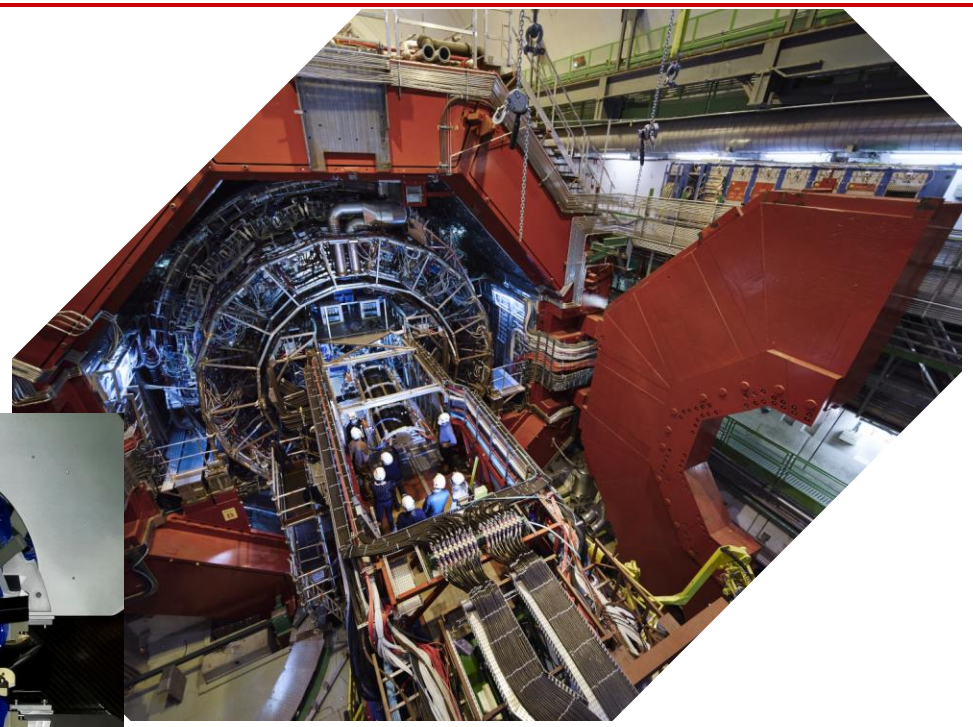
ALICE TPC collaboration *et al* 2021 *JINST* **16** P03022

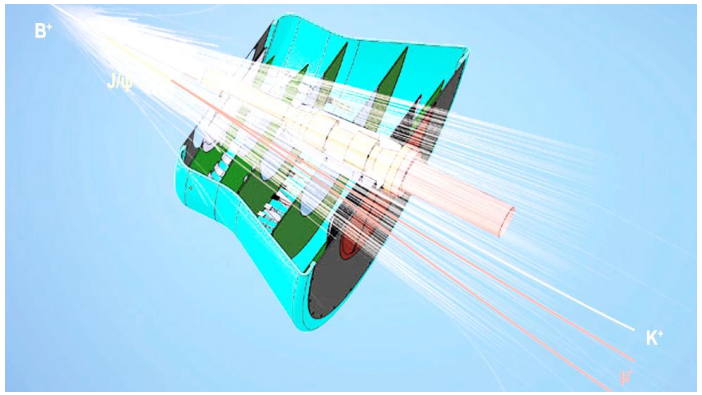
ALICE LS2 Upgrades: MFT





Muon Forward Tracker





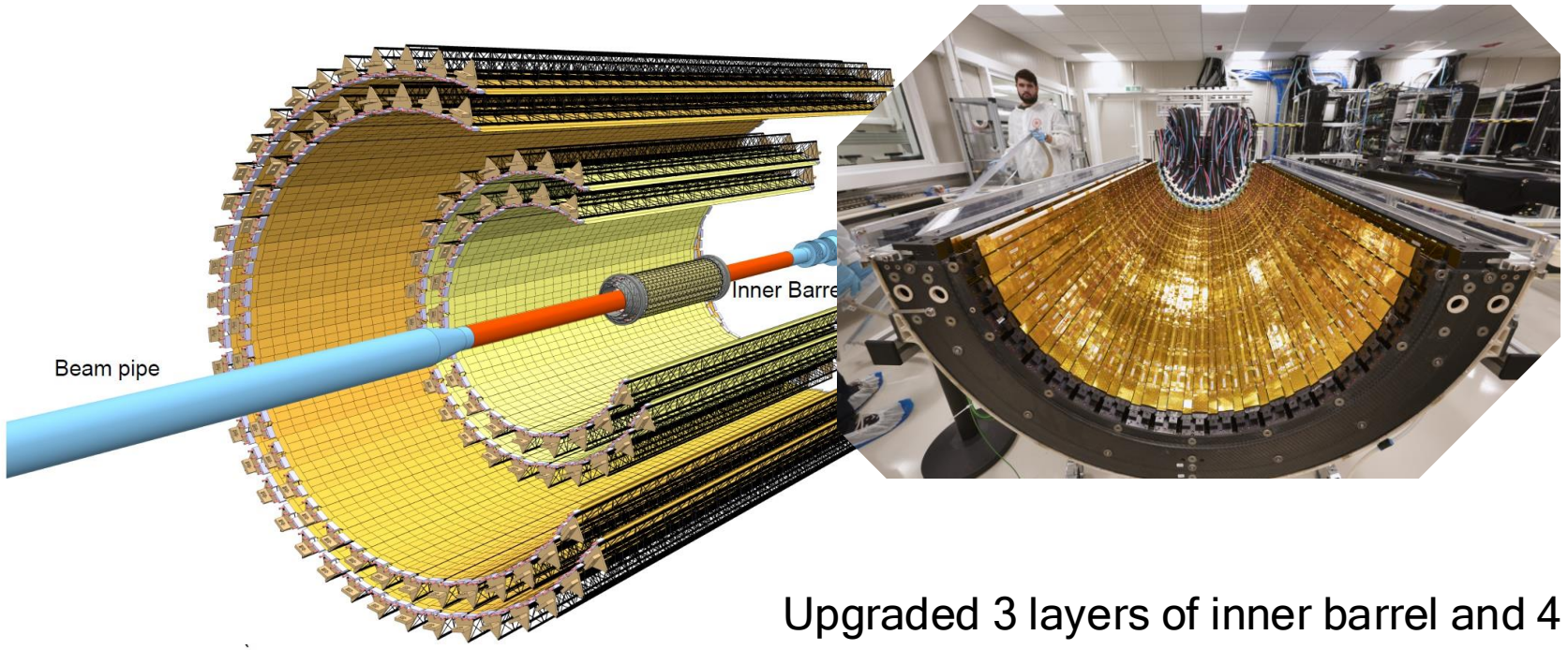
Add vertexing capacity to muon chamber

Extend the precision measurement of QGP fundamental studies

Monolithic Active Pixel Sensor technology(MAPS)
Pixel size: 27 μm x 29 μm
Spatial resolution of 5 μm
5 μs integration time

CERN-LHCC-2015-001 ; ALICE-TDR-018

ALICE LS2 Upgrades: ITS2



Inner Tracking System

Observable	Current, 0.1 nb^{-1}		Upgrade, 10 nb^{-1}	
	$p_{\mathrm{T}}^{\mathrm{min}}$ (GeV/c)	statistical uncertainty	$p_{\mathrm{T}}^{\mathrm{min}}$ (GeV/c)	statistical uncertainty
Heavy Flavour				
D meson R_{AA}	1	10 %	0	0.3 %
$\mathrm{D_s}$ meson R_{AA}	4	15 %	< 2	3 %
D meson from B R_{AA}	3	30 %	2	1 %
J/ψ from B R_{AA}	1.5	15 % (p_{T}-int.)	1	5 %
B^+ yield	not accessible		2	10 %
Λ_{c} R_{AA}	not accessible		2	15 %
$\Lambda_{\mathrm{c}}/\mathrm{D}^0$ ratio	not accessible		2	15 %
Λ_{b} yield	not accessible		7	20 %
D meson v_2 ($v_2 = 0.2$)	1	10 %	0	0.2 %
$\mathrm{D_s}$ meson v_2 ($v_2 = 0.2$)	not accessible		< 2	8 %
D from B v_2 ($v_2 = 0.05$)	not accessible		2	8 %
J/ψ from B v_2 ($v_2 = 0.05$)	not accessible		1	60 %
Λ_{c} v_2 ($v_2 = 0.15$)	not accessible		3	20 %

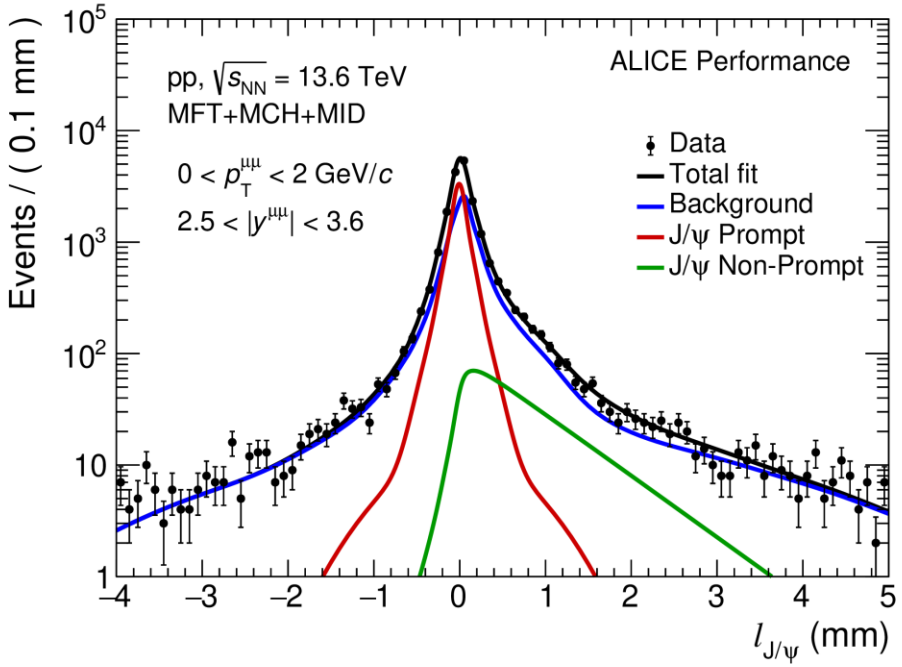
Upgraded 3 layers of inner barrel and 4 layers of outer barrel

Reduced distance from interaction point from 39 mm to 23 mm

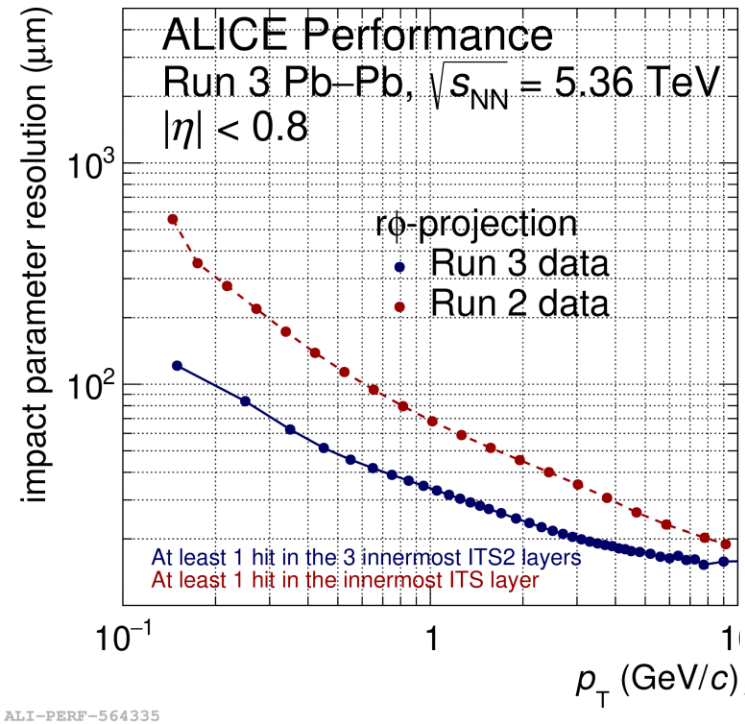
Reduced pixel size: from 50 x 425 μm^2 to 29 x 27 μm^2

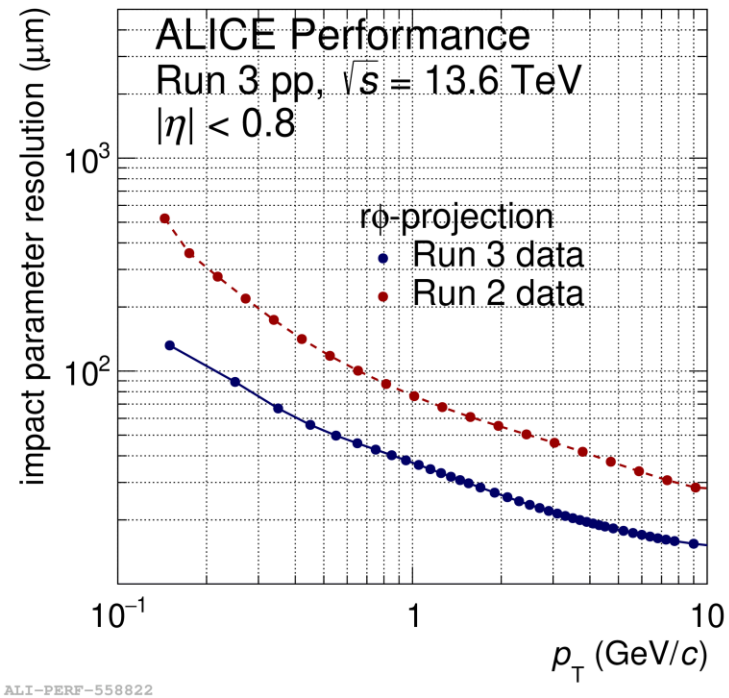
CERN-LHCC-2013-024 ; ALICE-TDR-017

Performance of the ITS2 and MFT



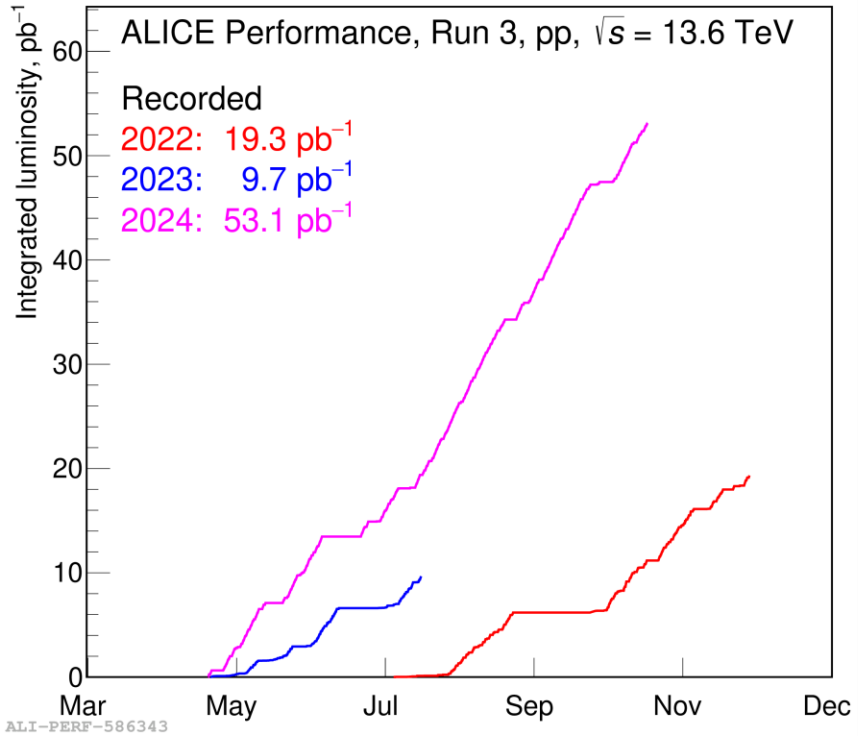
Separation of J/ψ contribution form beauty-hadron decay

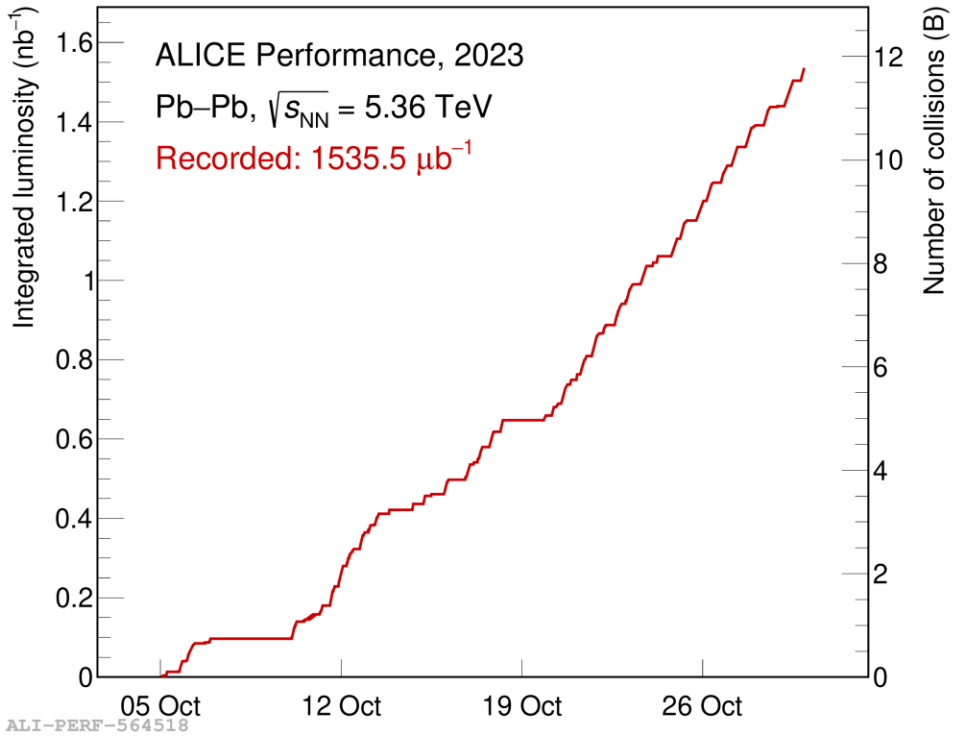




Improved pointing resolution at midrapidity by factors of 2 in transverse plane and factor of 6 in beam direction

Run 3 data taking

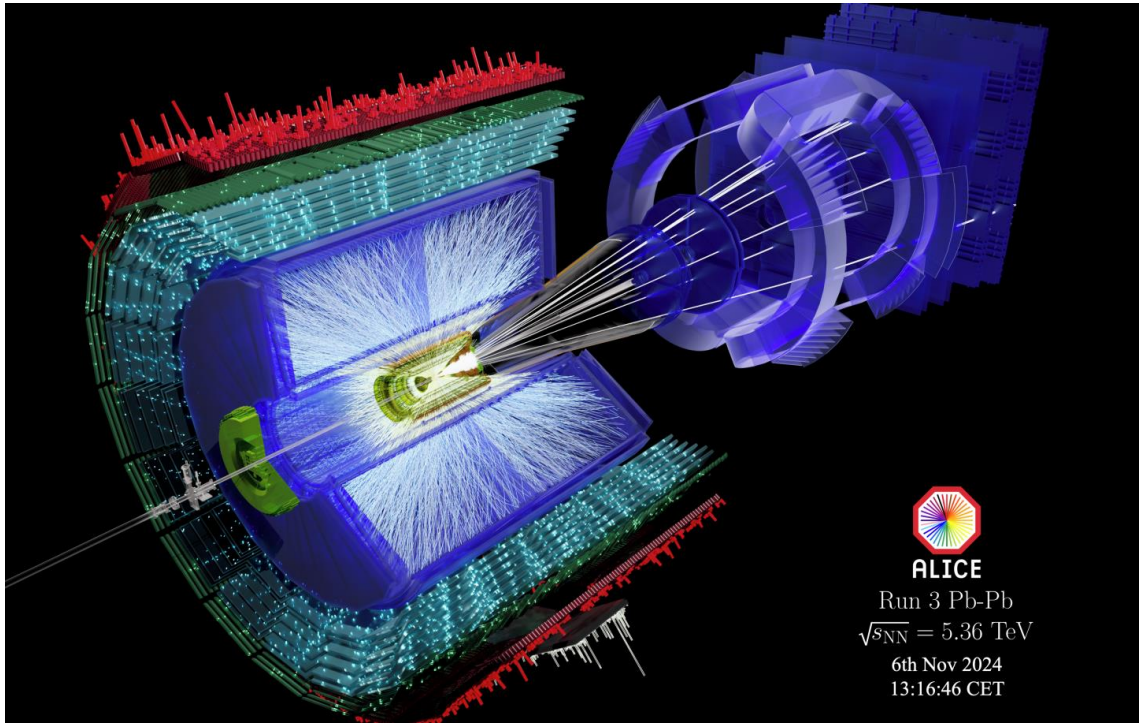




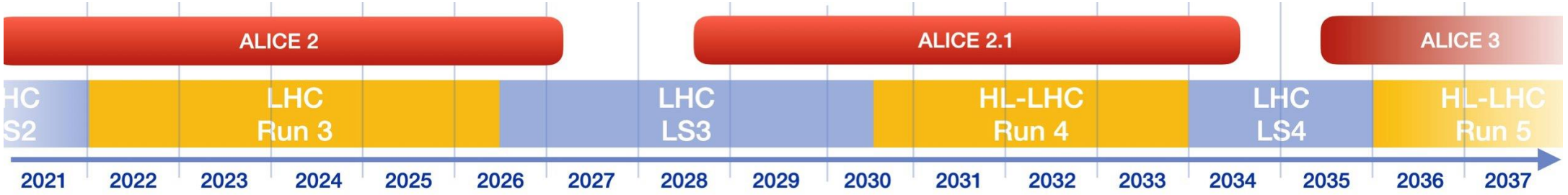
2024 Pb-Pb run completed on November 25

ALICE 2024 pp run completed

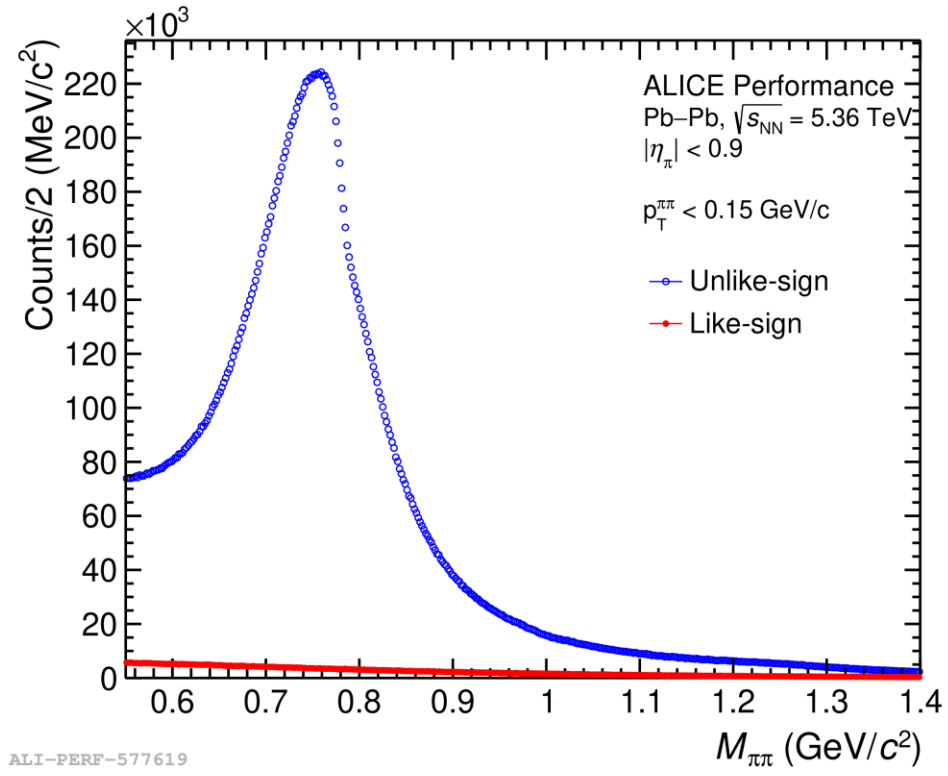
ALICE Pb-Pb run in November 2024



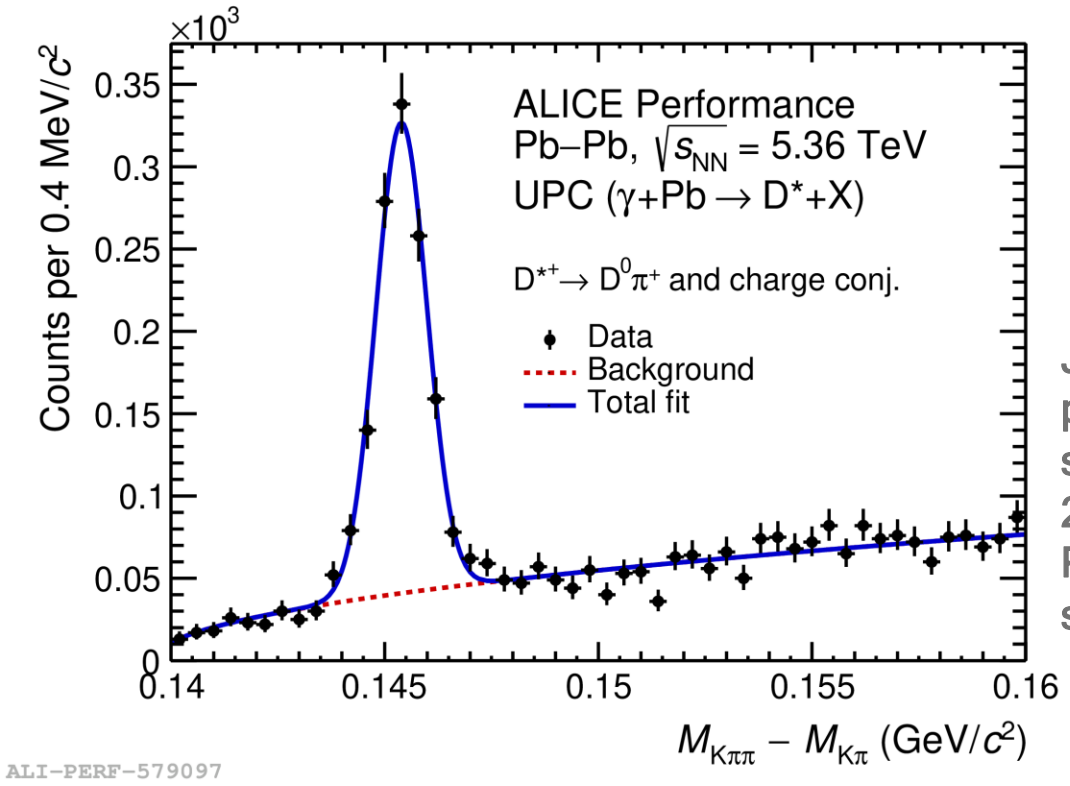
Run 3 results



Promising UPC program in Run 3



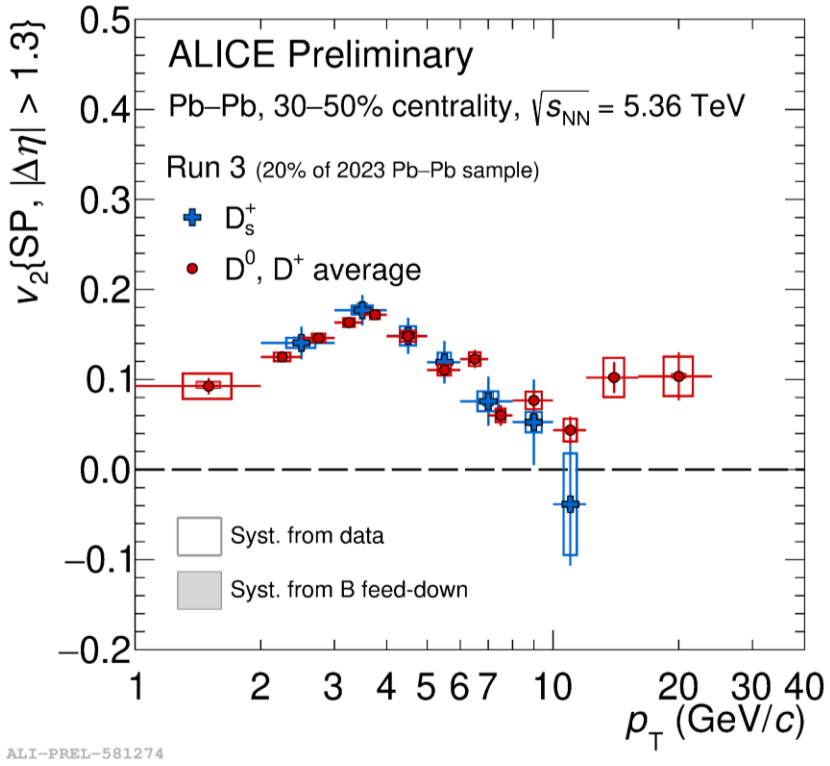
Large increase in statistics exclusive vector meson

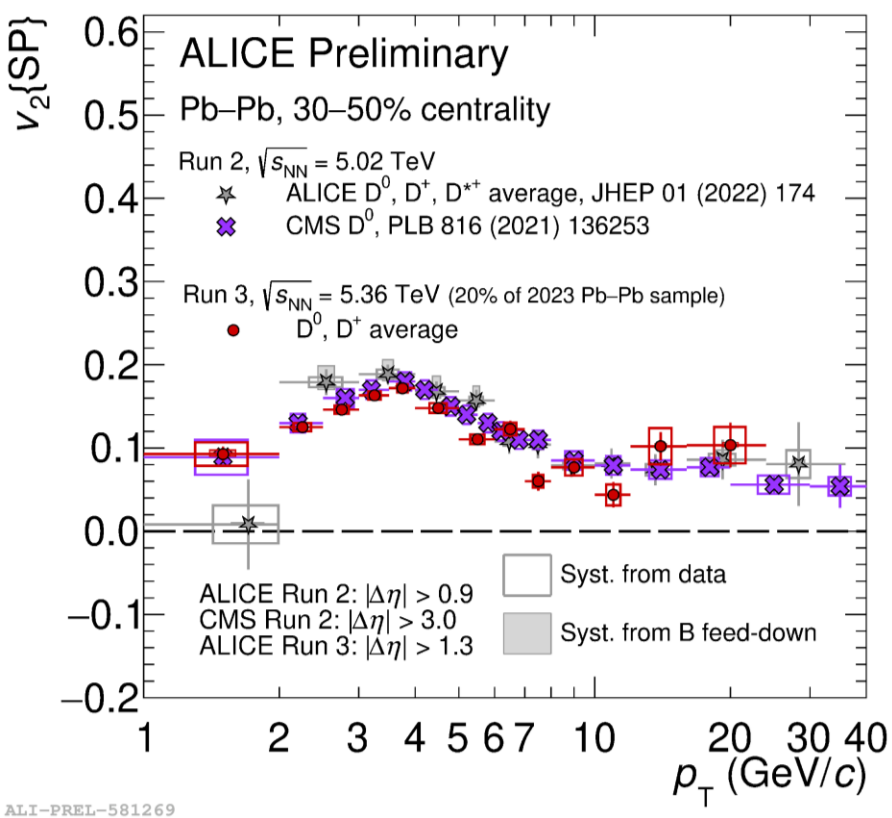


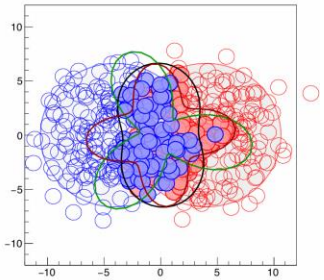
New type of UPC topology possible in Run 3

Just 20 percent statistics of 2023 Run3 Pb-Pb sample

D-meson elliptic flow in Pb-Pb collisions







Just 20 percent statistics of 2023 Run3 Pb-Pb sample

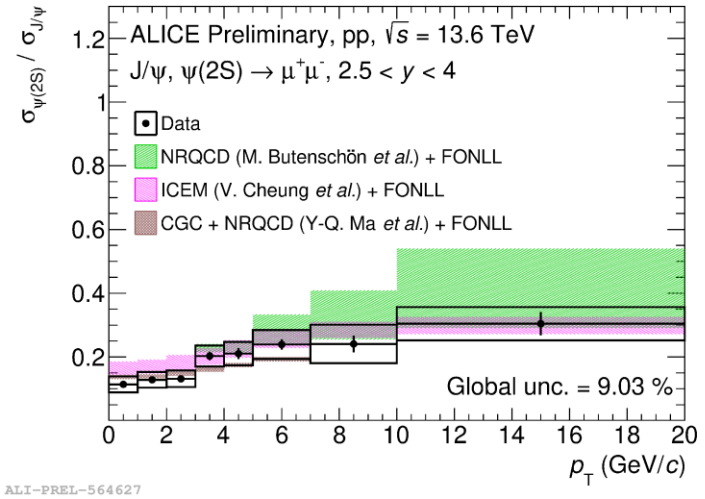
Four times larger data than Run 2

First measurement of prompt D-meson v_2 measured using Run 3 Pb-Pb data sample

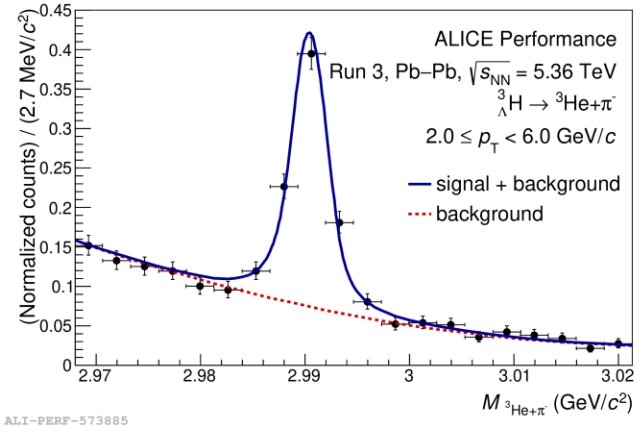
No Significant difference between D^0 and D_s

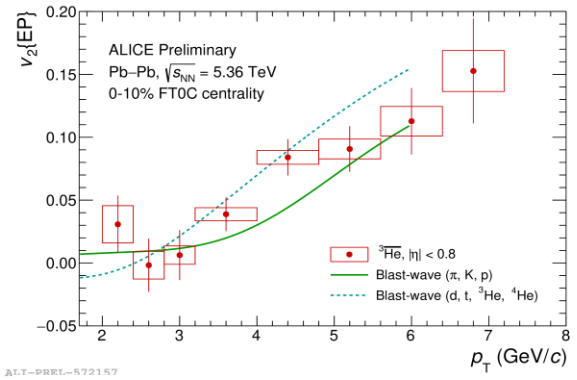
Lots of new exciting Run 3 results coming up

J/ψ to ψ_{2s} ratio in pp collision

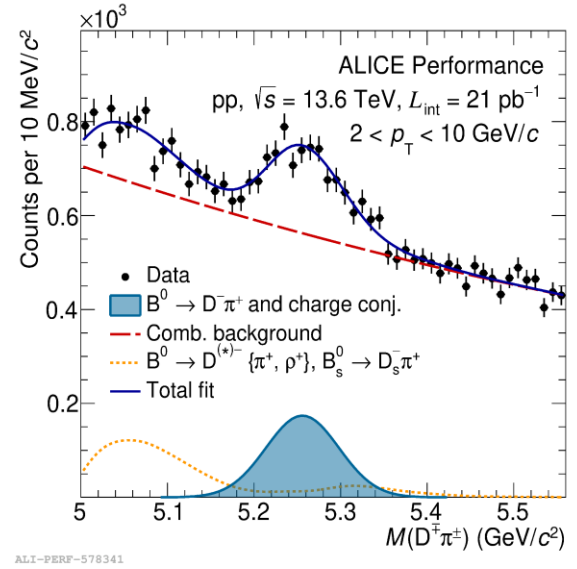


Hypertriton in pp collision



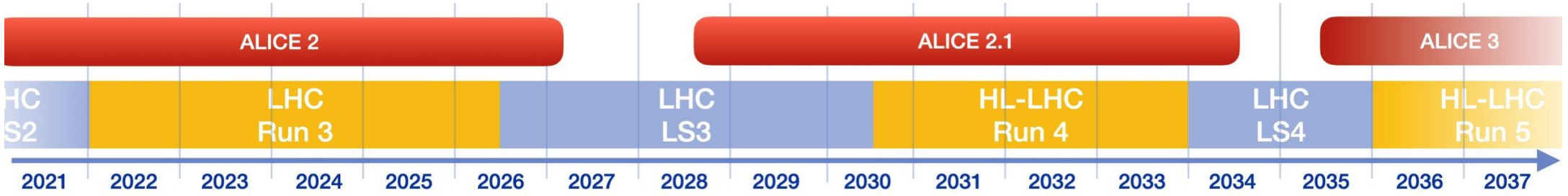


anti-nuclei v_2

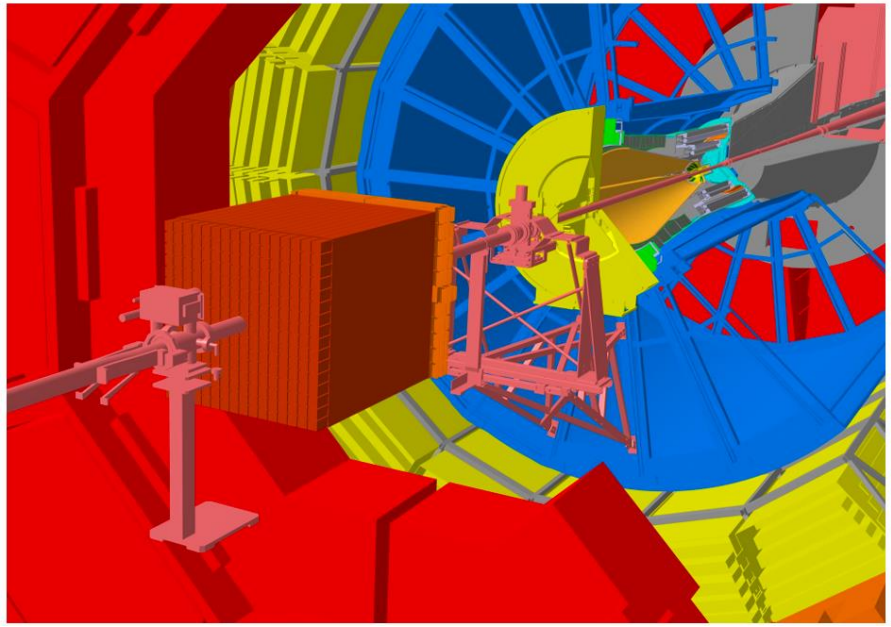


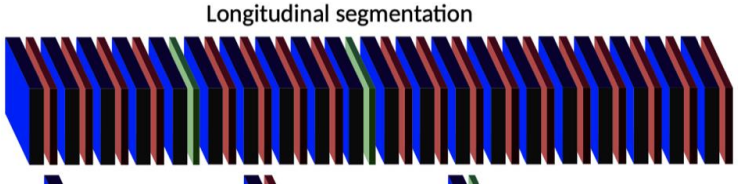
B-meson at mid rapidity

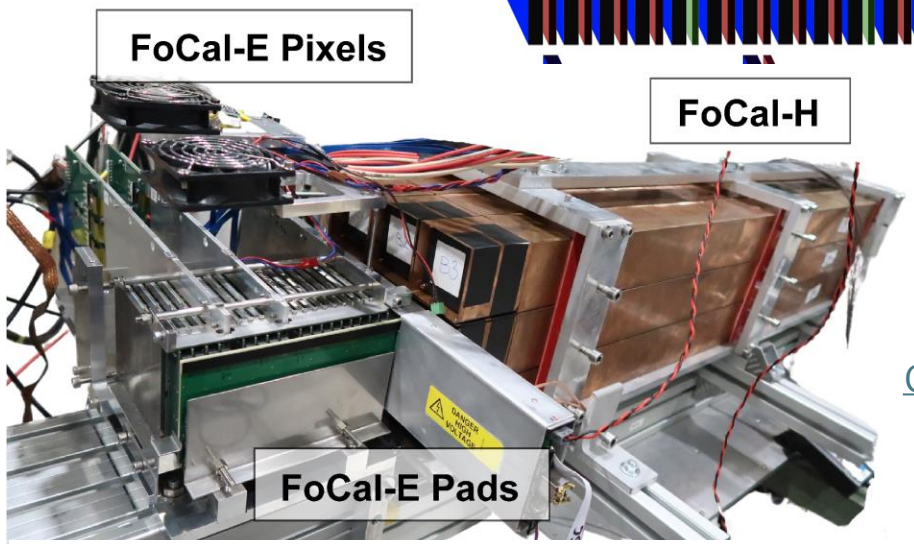
ALICE upgrades for Run 4



High granularity forward Calorimeter: FoCal







Prototypes produced and tested with beams at PS and SPS

TDR approved

Starting production

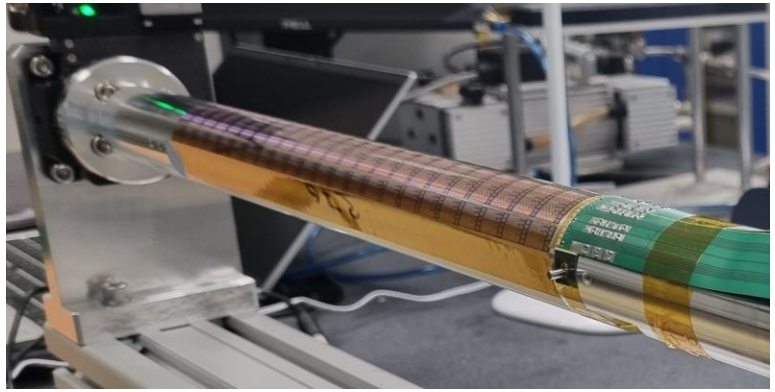
CERN-LHCC-2024-004 ; ALICE-TDR-022

Pseudo rapidity coverage: $3.4 < \eta < 5.8$
Study isolated direct photon, $\pi^0, J/\psi$, ... in forward region
Sensitive to low-x gluon dynamics

Electromagnetic calorimeter FoCal-E:
High Granularity Pixel and
low granularity Si pad sensors
tungsten as absorber

Hadronic calorimeter FoCal-H: Cu tube with scintillating fibers

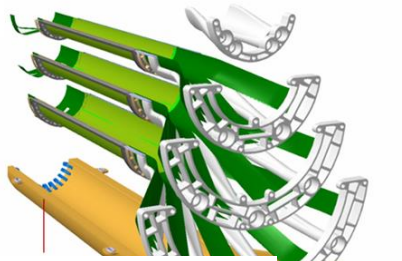
Inner Tracking System : ITS 3

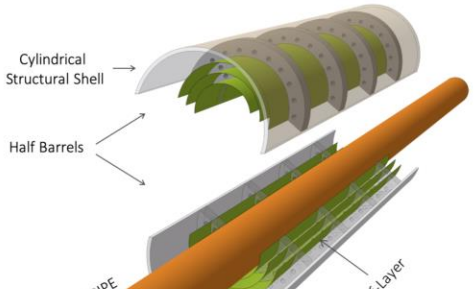


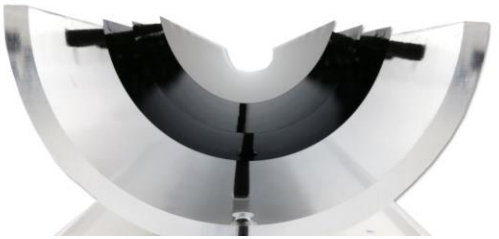
3 Inner layer of ITS2 will be changed
Using MAPS: bent sensors
Reduced material budget

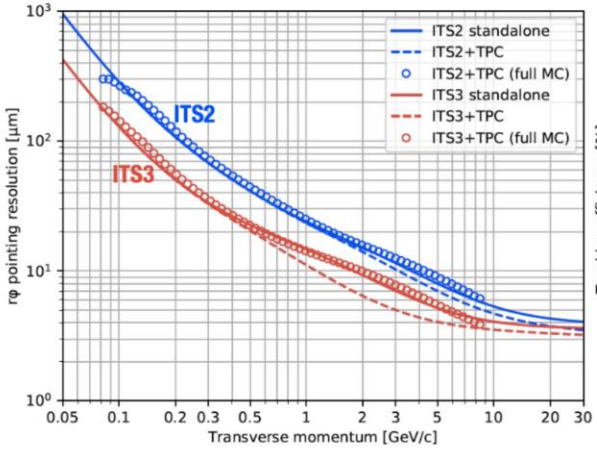
TDR approved

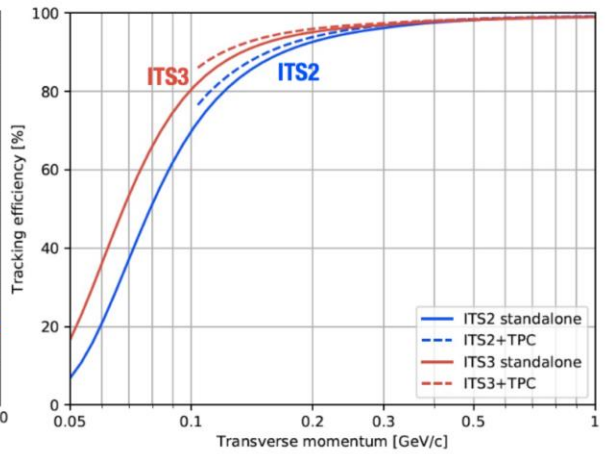
Final design ongoing

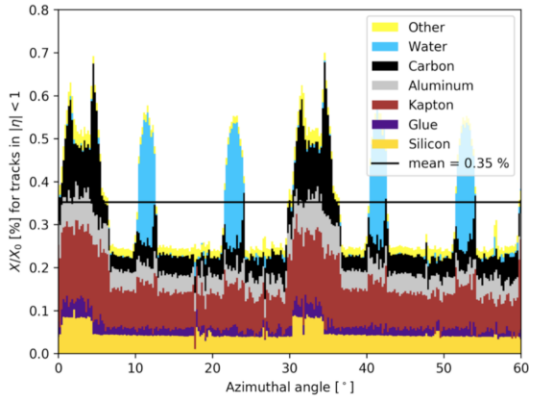


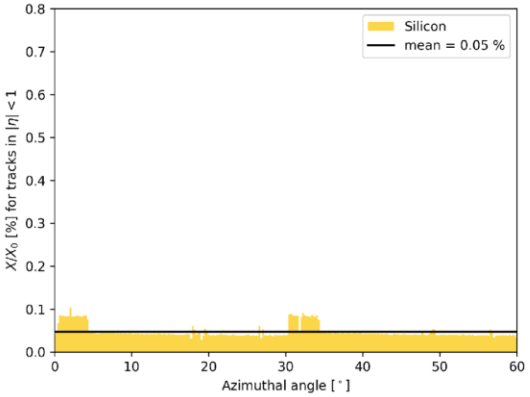




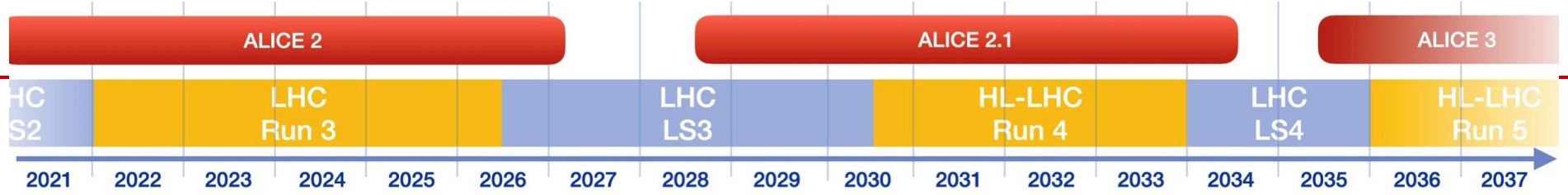








ALICE 3 for Run 5



Large acceptance $|\eta|<4$

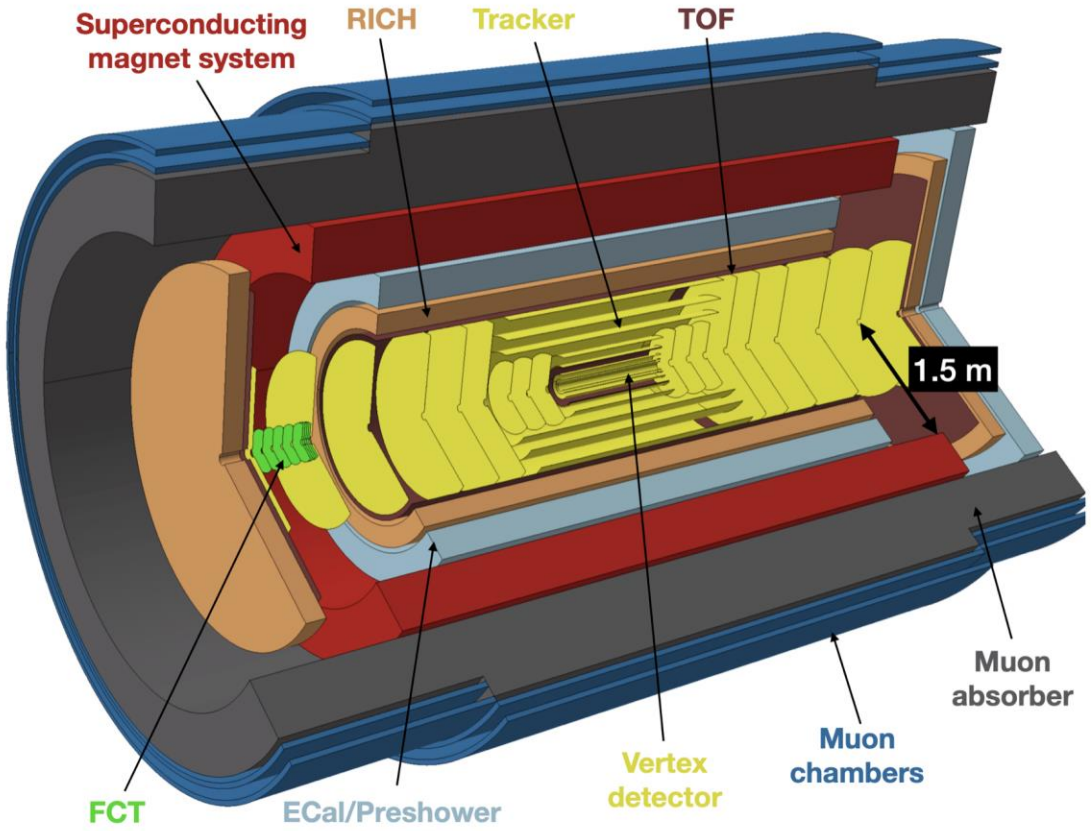
Retractable vertex detector

Enhanced particle identification

Continuous redout and online processing

R&D for possible sensors ongoing

Test beams for TOF, RICH, MID ongoing.



arXiv:2211.02491

Summary

- **ALICE Physics Program:**
  Extensive coverage of various colliding systems and energies for heavy-ion physics research
  Probing key QCD questions like deconfinement and low-x gluon dynamics

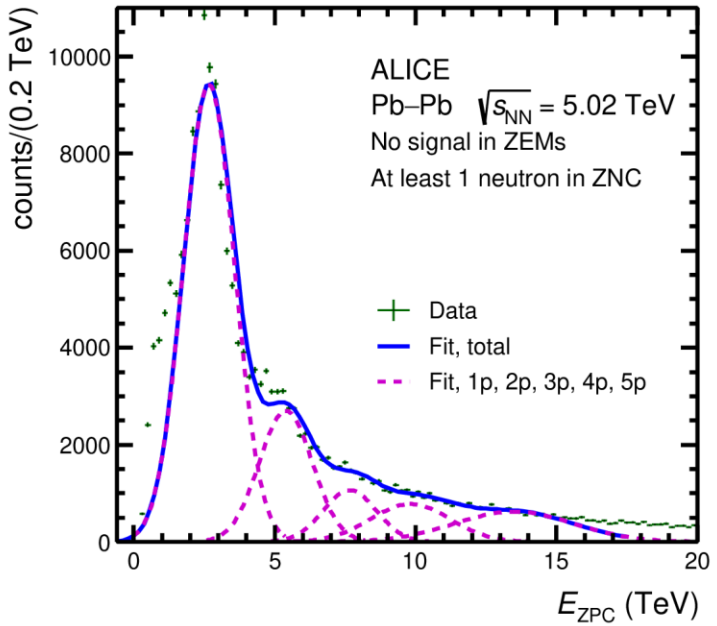
- **ALICE 2:**
  Introduction of new detectors and upgrades and implementation of streaming readout from Run 3
  Smooth and successful Run 3 data collection so far
  Potential for several new measurements

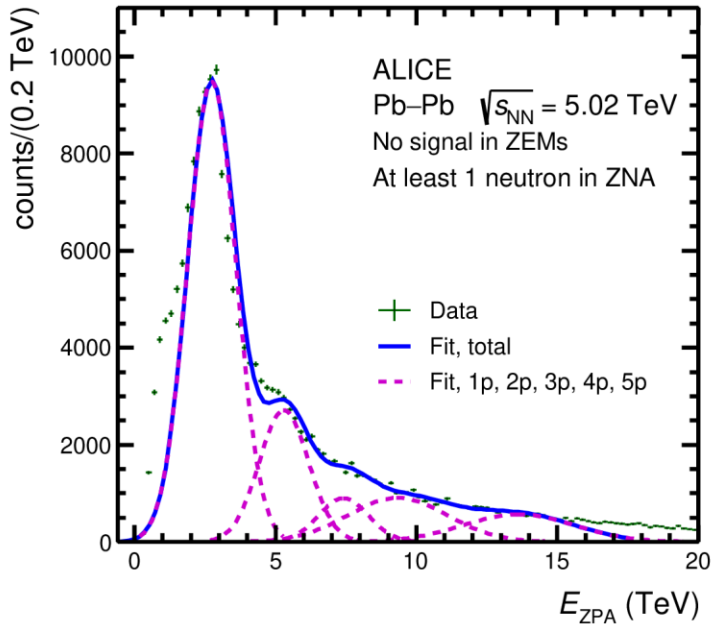
- **Future Upgrades:**
  Progress on Run 4 upgrades (ITS3 and FoCal) from 2030 (ALICE 2.1)
  Plans for ALICE 3 are ongoing
  Exciting developments in physics and detector technology ahead

Join us to continue advancing the physics of strong interactions!

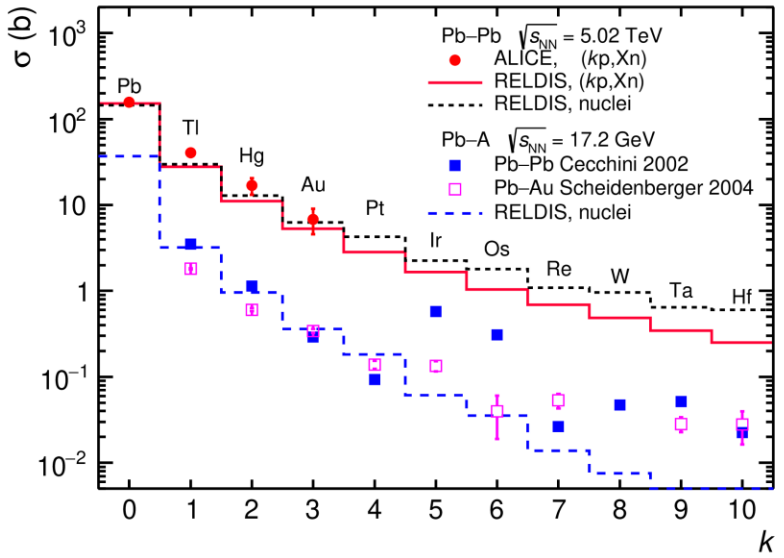
Additional slides

Proton emission in UPC PbPb





ALI-PUB-587894



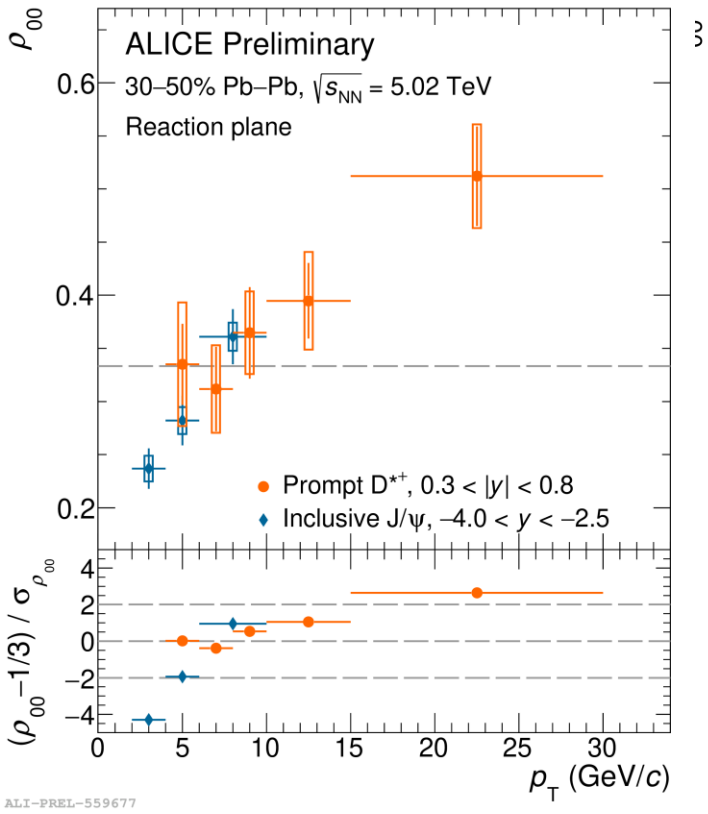
ALI-PUB-587906

First measurement of proton emission cross section in UPC Pb nuclei
Production of Pb, Ti, Hg and Au isotopes determined using proton emission cross-section

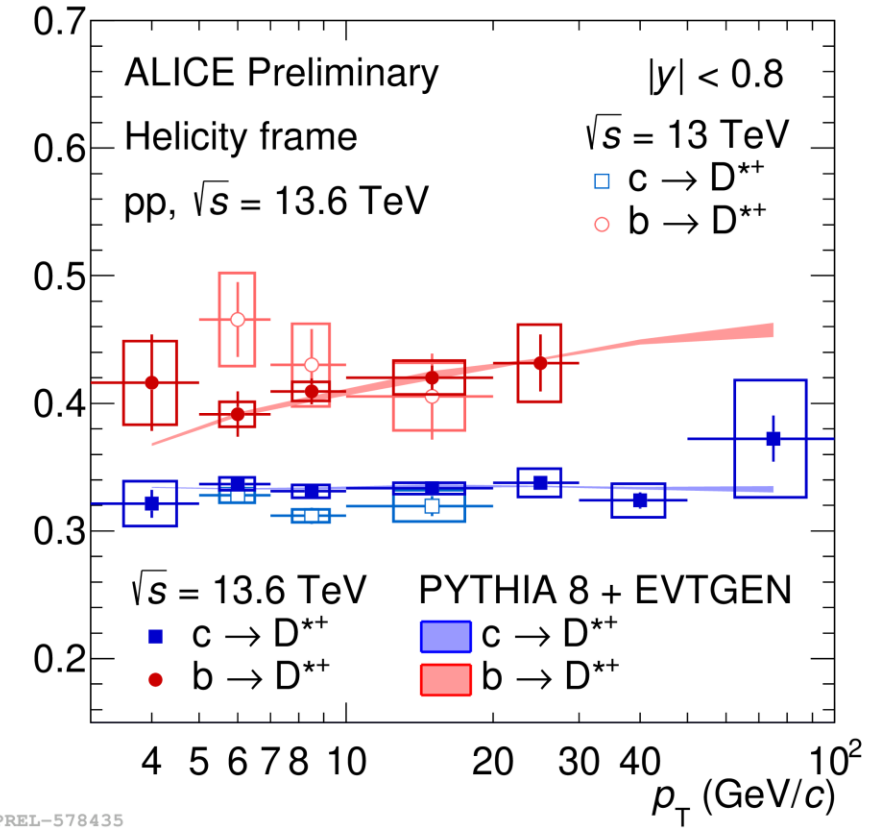
arXiv:2411.07058

spin alignment of prompt and non-prompt D*+ mesons

Run 2 PbPb

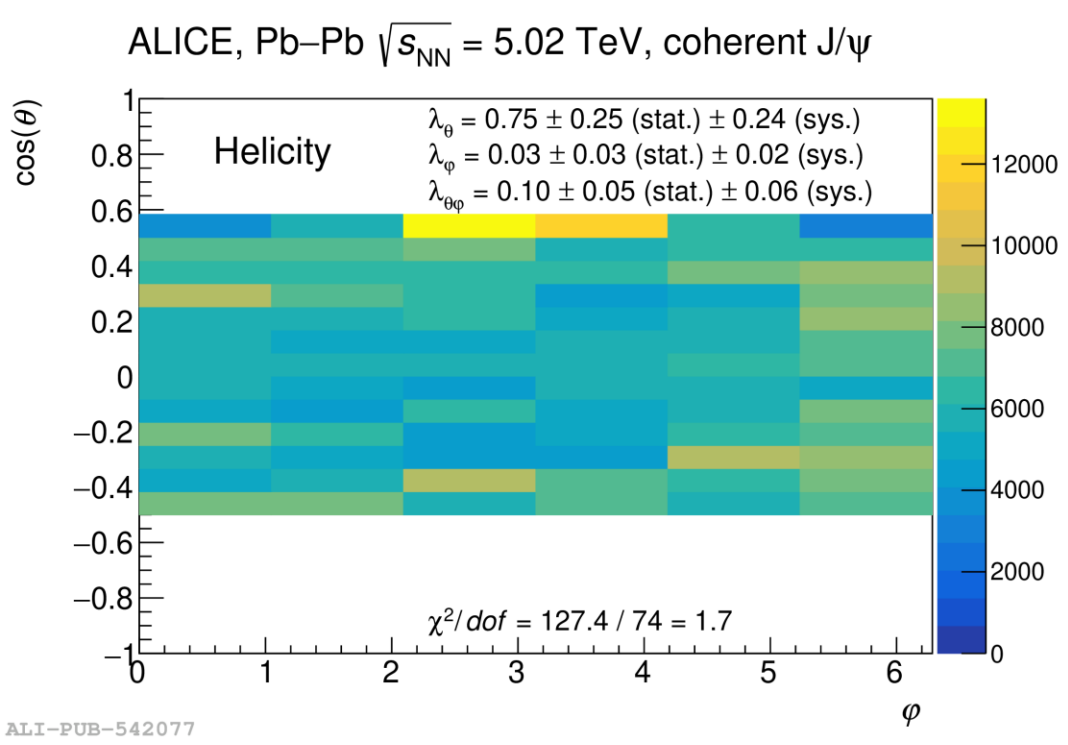


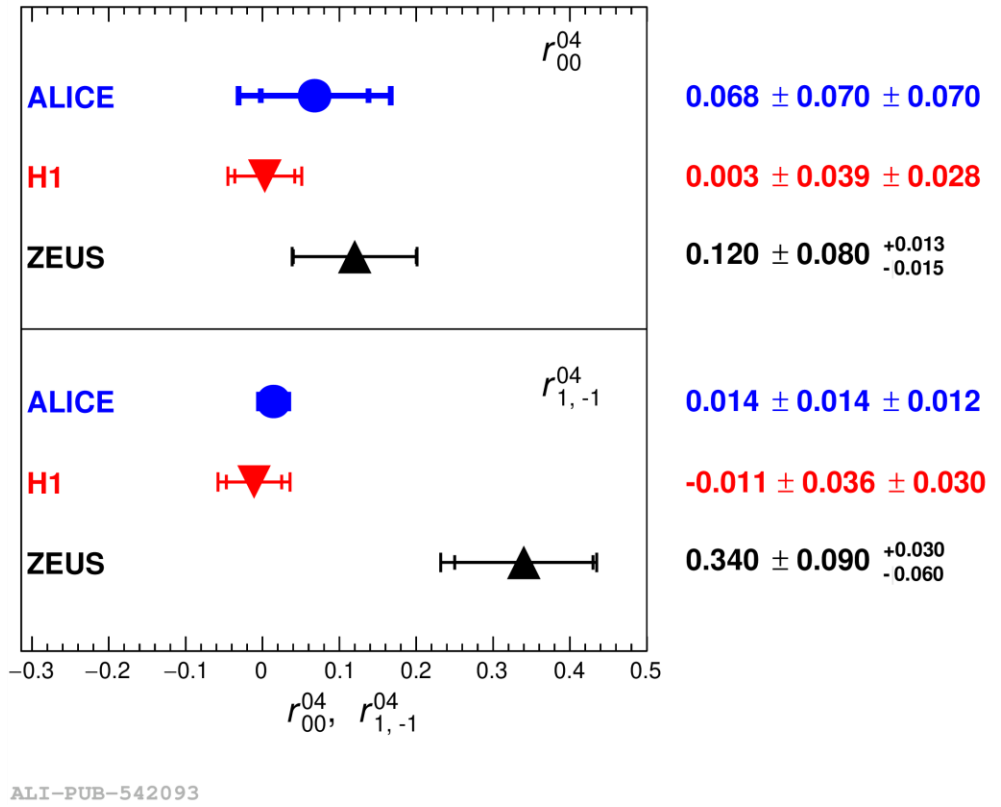
Run 3 preliminary pp



New measurement in run 3 pp provide important baseline for Pb Pb

Polarization of coherent J/ψ

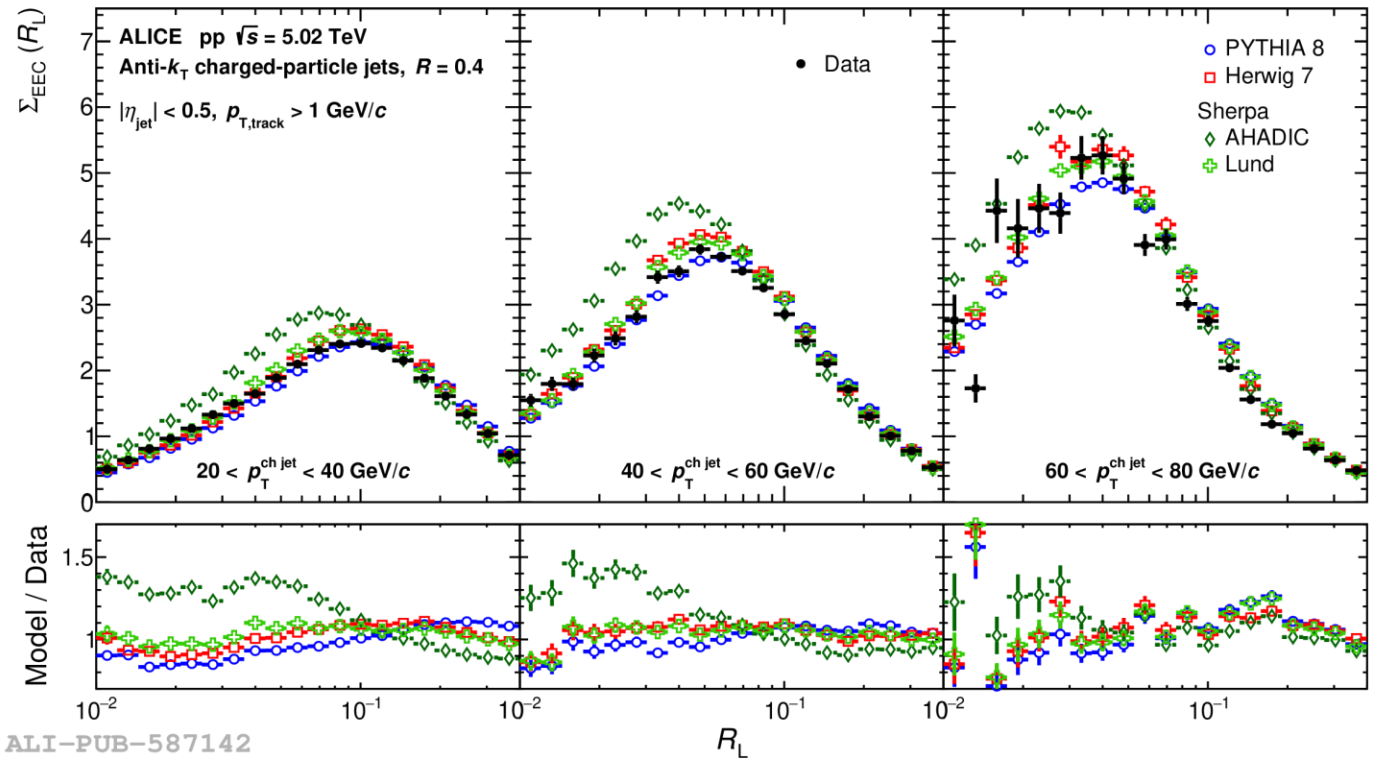


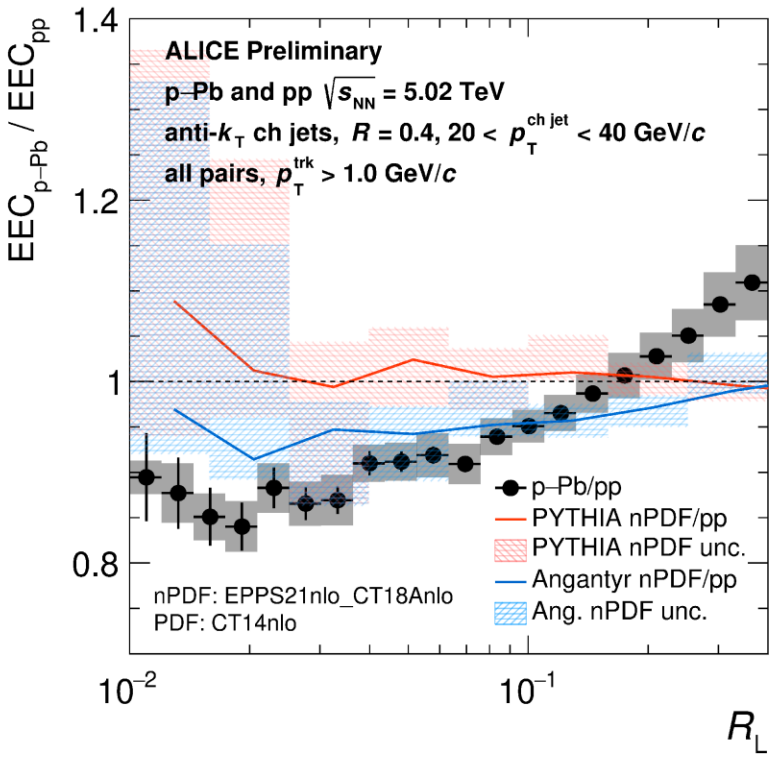


arXiv: 2304.10928

Data consistent with transverse polarization

Energy-energy correlation in Jets in pp and p-Pb collision





arXiv:2409.12687

Separation of perturbative and non perturbative QCD

Modification of energy-energy correlator observed in p-Pb collisions