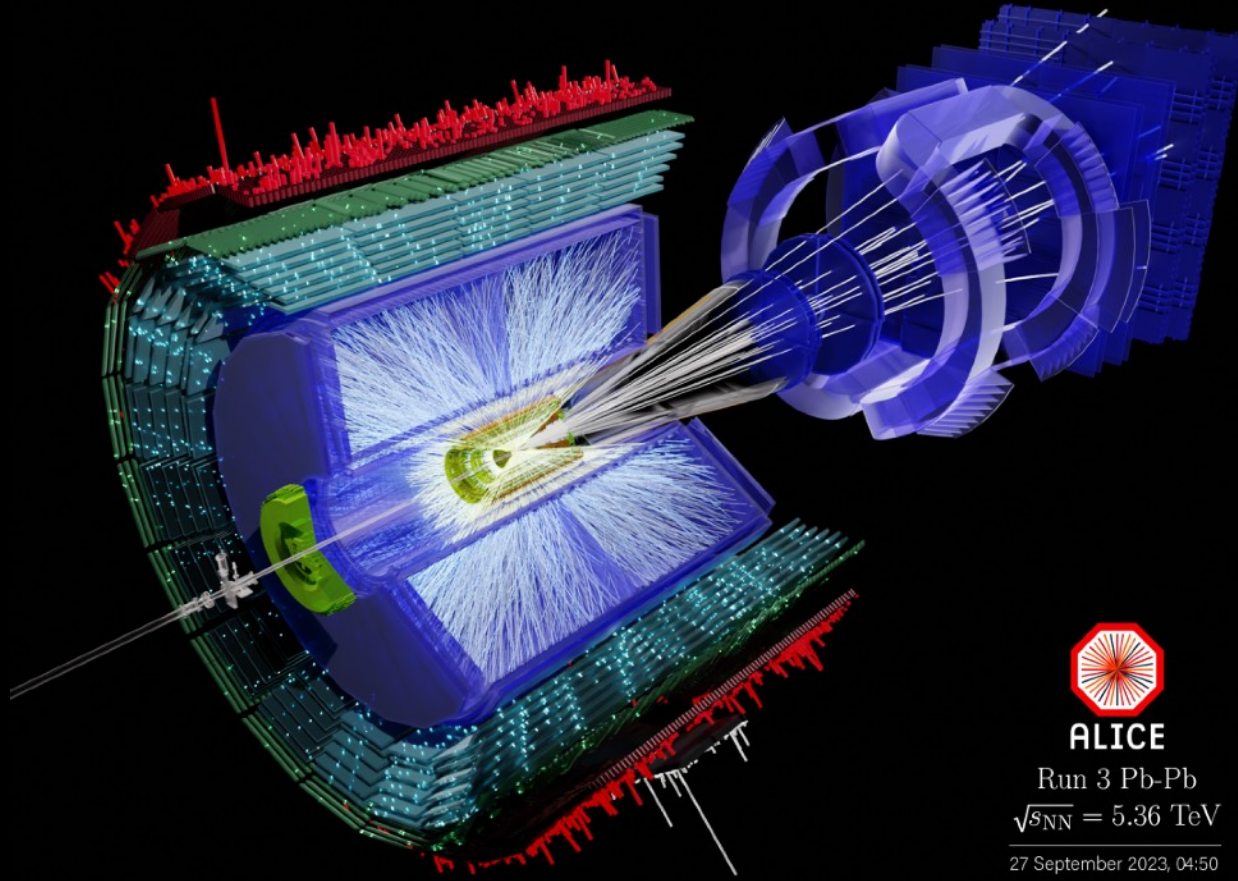


Status of ALICE and ALICE 3



ALICE

Run 3 Pb-Pb
 $\sqrt{s_{NN}} = 5.36 \text{ TeV}$

27 September 2023, 04:50



Alexander Schmah for the ALICE Collaboration
DPG Spring Meeting - March 2024



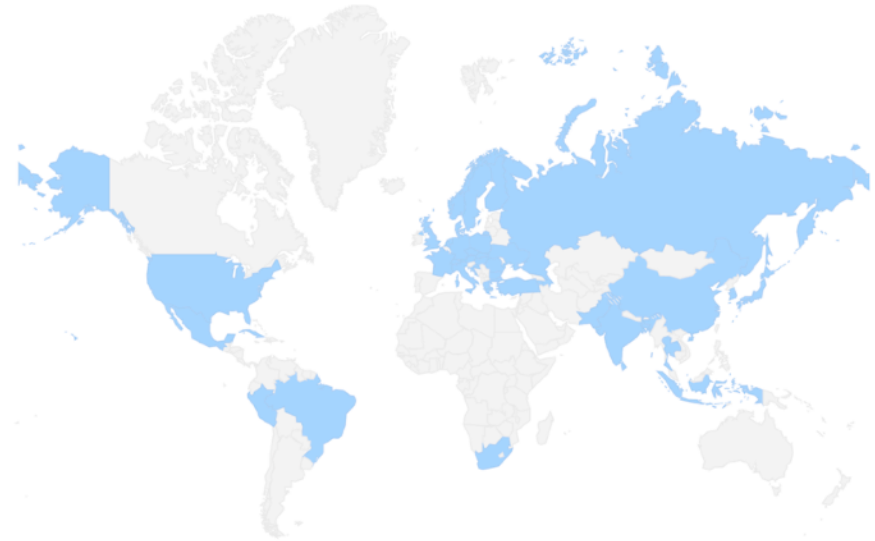
FSP ALICE
Erforschung von
Universum und Materie



ALICE Collaboration

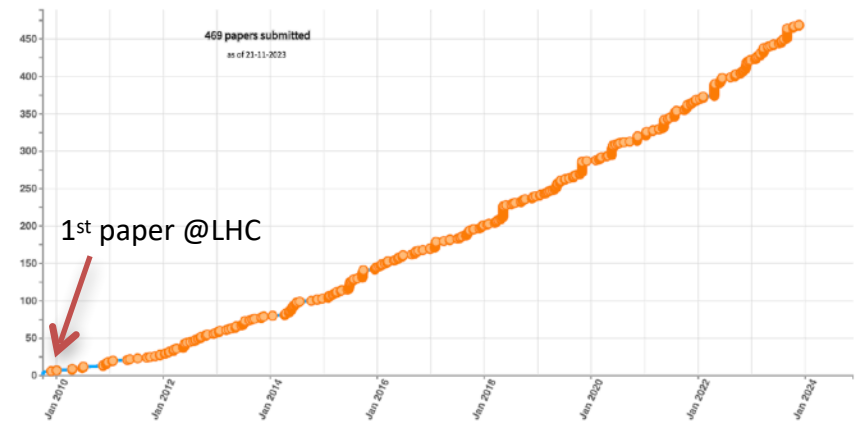
- 40 countries, 170 institutes
- 2002 members, 1034 scientific authors
- 377 doctoral students, 124 postdocs

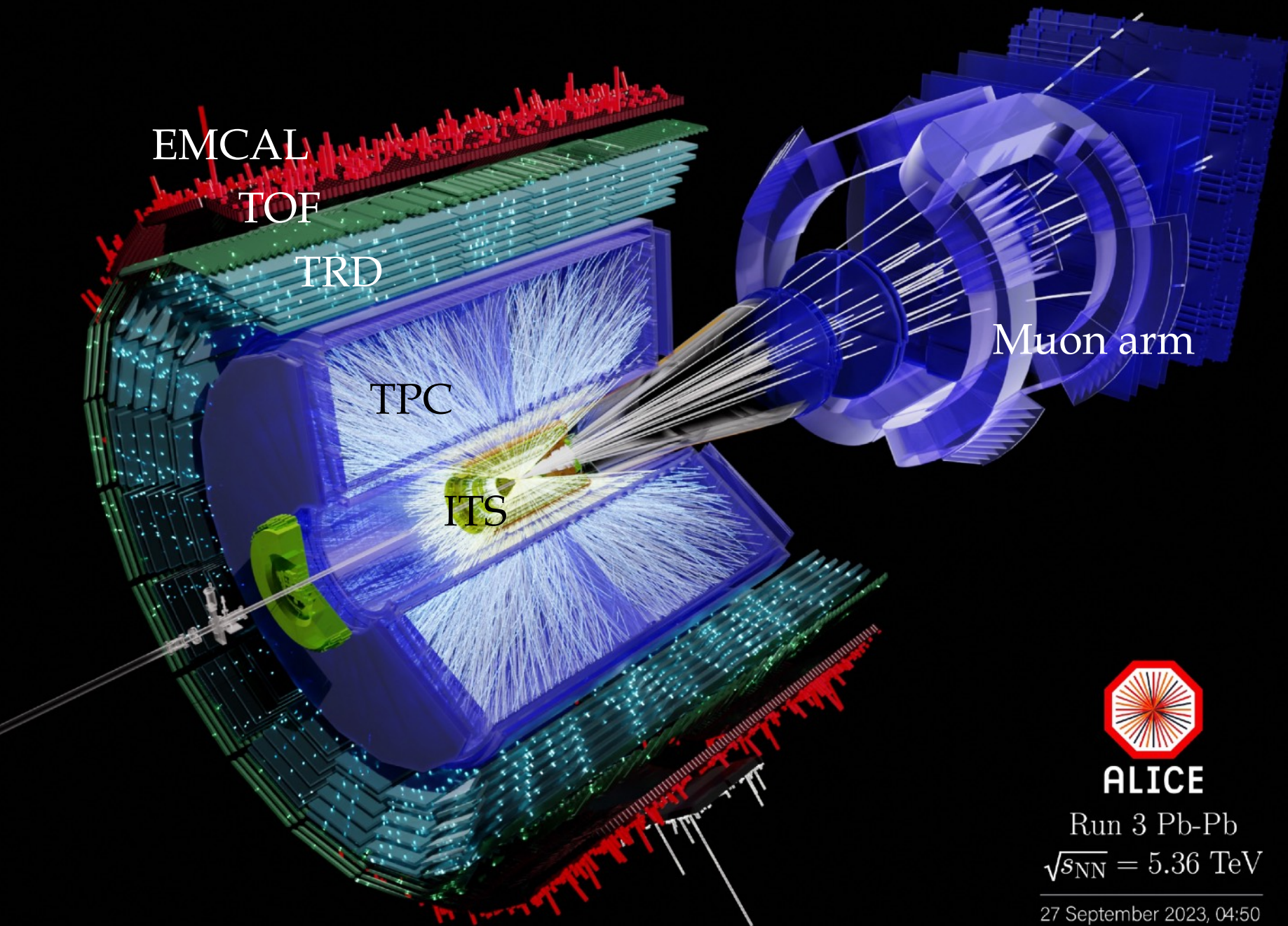
- 469 ALICE papers on arXiv
- 2x Nature, 3x Nature Physics
- 53x Phys. Rev. Lett.



Run 1 Run 2

System	Year(s)	$\sqrt{s_{NN}}$ (TeV)	L_{int}
Pb-Pb	2010, 2011	2.76	$\sim 75 \mu\text{b}^{-1}$
	2015, 2018	5.02	$\sim 800 \mu\text{b}^{-1}$
Xe-Xe	2017	5.44	$\sim 0.3 \mu\text{b}^{-1}$
p-Pb	2013	5.02	$\sim 15 \text{nb}^{-1}$
	2016	5.02, 8.16	$\sim 3 \text{nb}^{-1}, \sim 25 \text{nb}^{-1}$
pp	2009-2013	0.9, 2.76, 7, 8	$\sim 200 \text{mb}^{-1}, \sim 100 \text{nb}^{-1}$ $\sim 1.5 \text{pb}^{-1}, \sim 2.5 \text{pb}^{-1}$
	2015, 2017	5.02	$\sim 1.3 \text{pb}^{-1}$
	2015-2018	13	$\sim 36 \text{pb}^{-1}$





EMCAL

TOF

TRD

TPC

ITS

Muon arm



ALICE

Run 3 Pb-Pb

$\sqrt{s_{NN}} = 5.36$ TeV

27 September 2023, 04:50

Inner Tracking System (ITS2)

7 layers, 10 m² silicon

based on MAPS, 12.5 B pixels

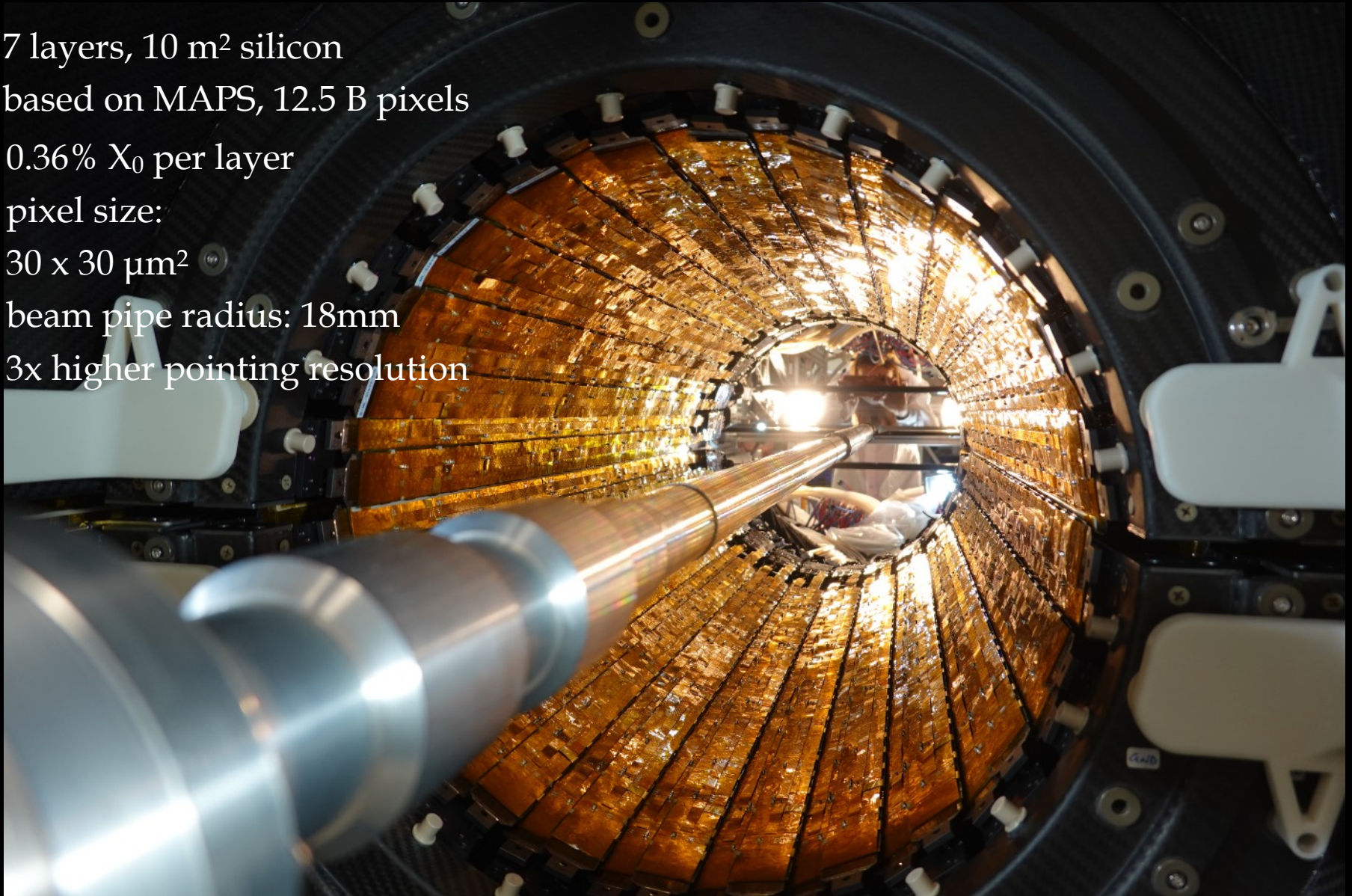
0.36% X_0 per layer

pixel size:

30 x 30 μm^2

beam pipe radius: 18mm

3x higher pointing resolution



Time Projection Chamber (TPC)



Time Projection Chamber (TPC)

$V = 88\text{m}^3$, $\Delta T < 0.1\text{ K}$

Quadruple-GEM readout

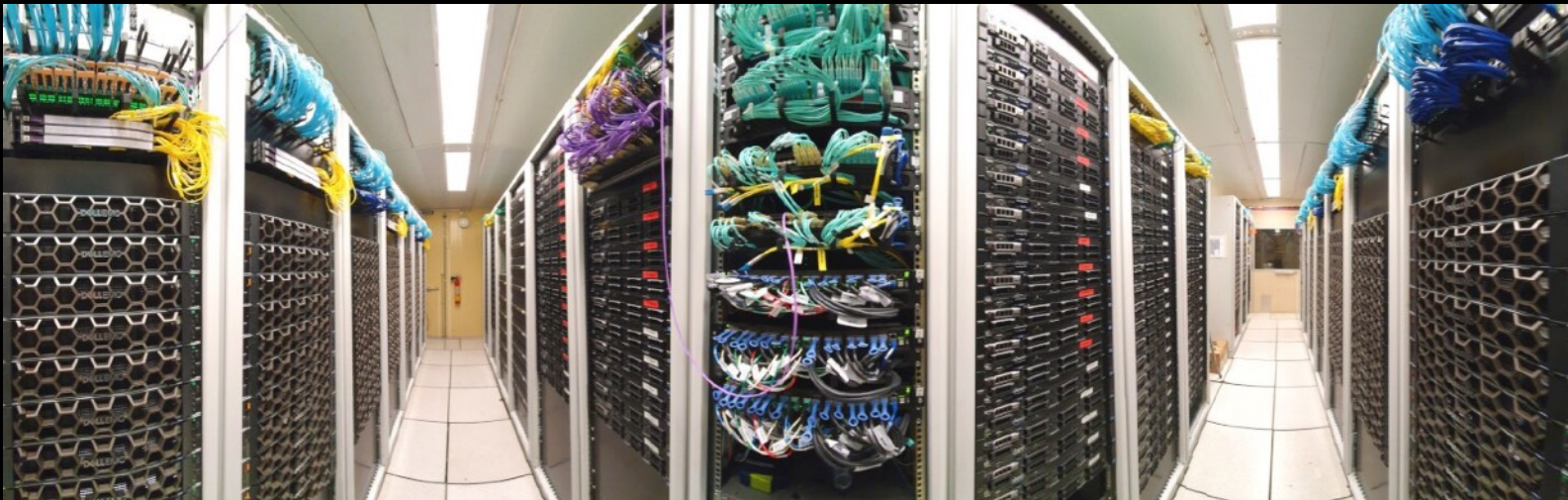
Continuous readout

3.4 TeraBytes/second

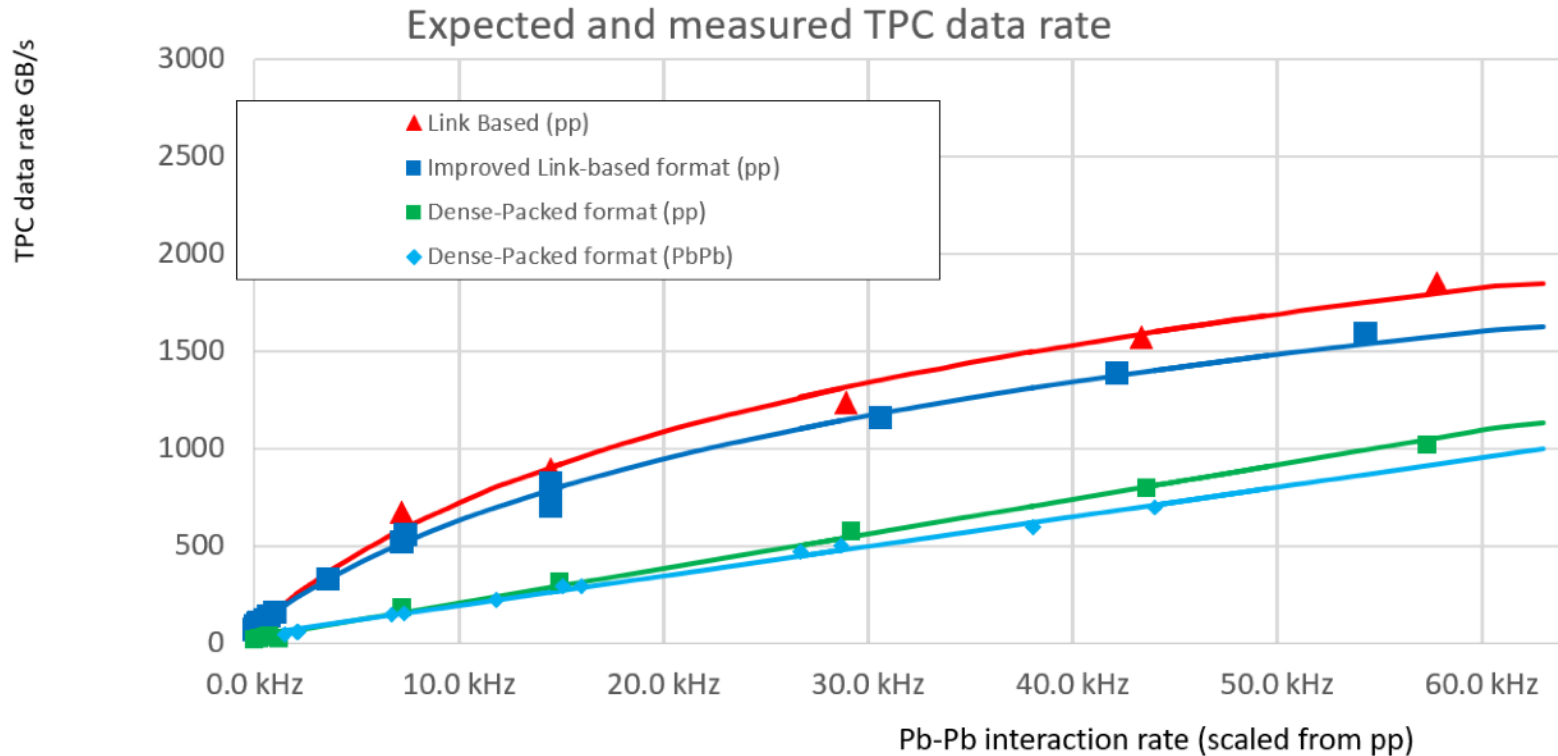
ALICE Computing



3.6 TeraBytes/s raw data
→ **up to 170 GBytes/s to disk**
50k CPUs
2700 GPUs
130 PetaBytes disk



TPC Data Rates in Run 3

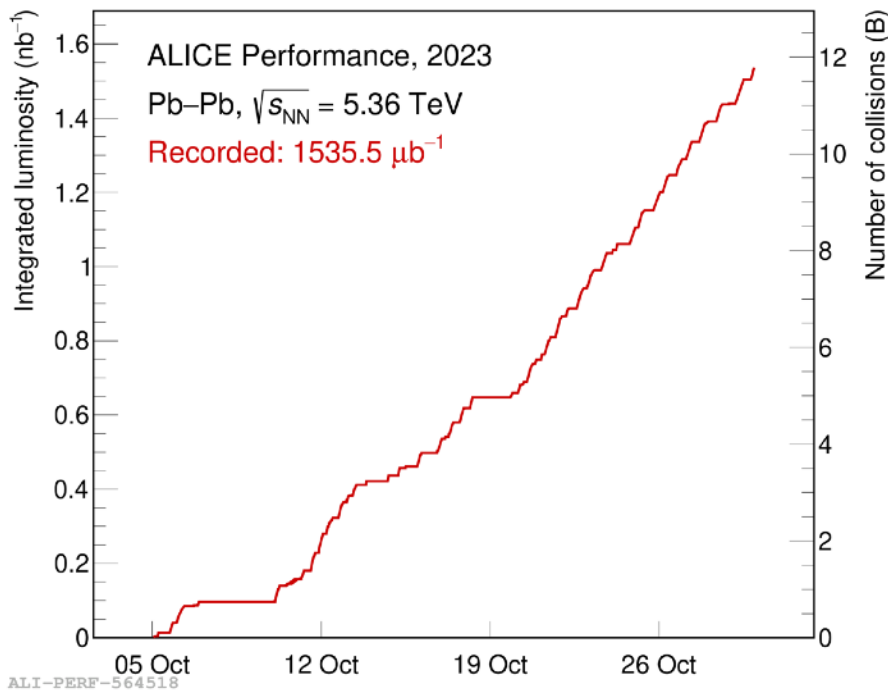


Dense packed format

~50 kHz Pb-Pb: 800 GBytes/s (CRU)

→ still about 20% margin

Data taken in Run 3



Run 1 + 2 (2009 - 2018)

pp : 0.032/pb minimum bias collisions, 2 billion events

Pb-Pb : 315 million minimum bias collisions, 149 million 0-10% central collisions

Run 3 (2022 - now)

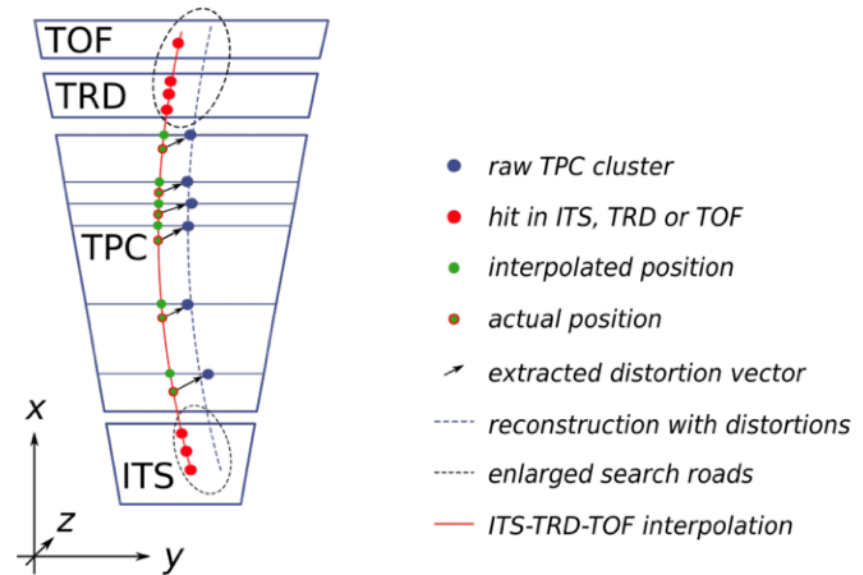
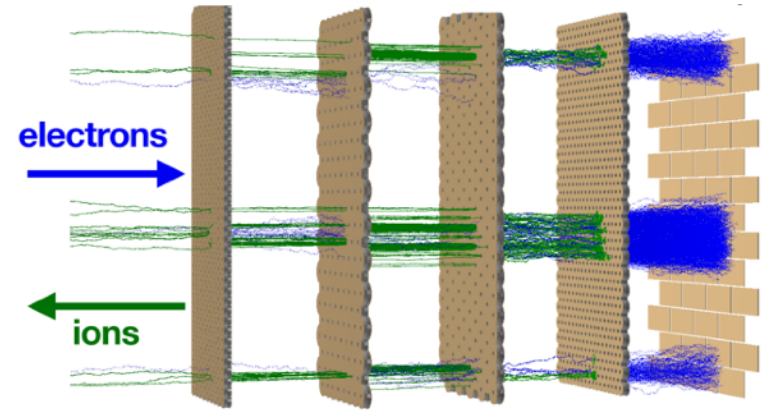
2022 pp: 19.3/pb or 1000 billion minimum bias collisions

2023 pp: 9.7/pb or 500 billion minimum bias collisions

2023 Pb-Pb: 1.5 /nb or 12 billion minimum bias collisions

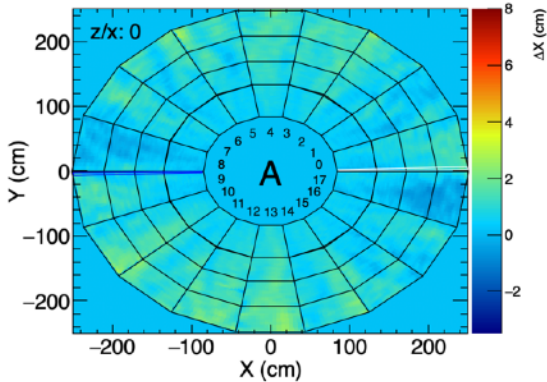
Space Charge Distortions

- Ions from the amplification stage move back into the drift volume
- Ions are slow (~200 ms for full drift)
 - Ions from large number of events pile up (~10k events @ 50 kHz IR)
 - Significant **space-charge density** (SCD) in drift volume
 - Large average **distortions** (O(5-10 cm))
 - Intrinsic TPC resolution: ~200 μm
 - $\rho_{SC} \sim I_{prim} \cdot gain \cdot IBF$
- Correction strategy based on reference tracks using ITS extrapolations.
- Corrections every few ms!
- Challenge for Run 3 with continuous readout

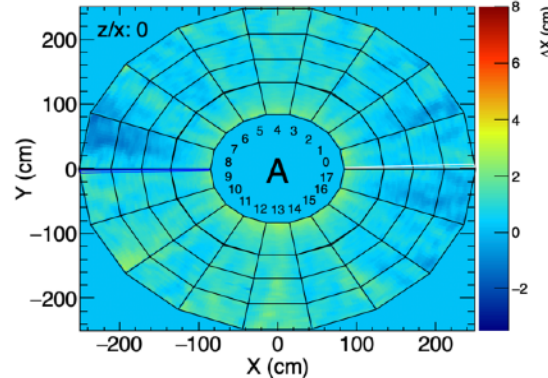


Space Charge Distortion Maps

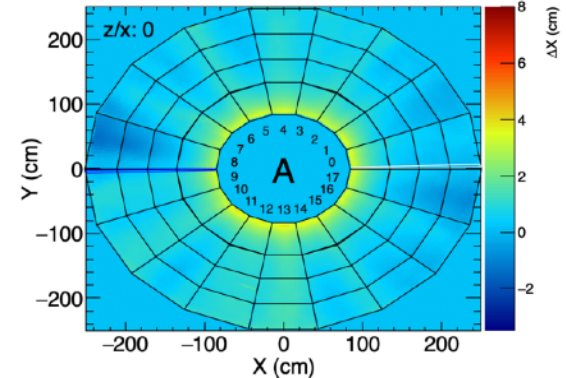
50 Hz



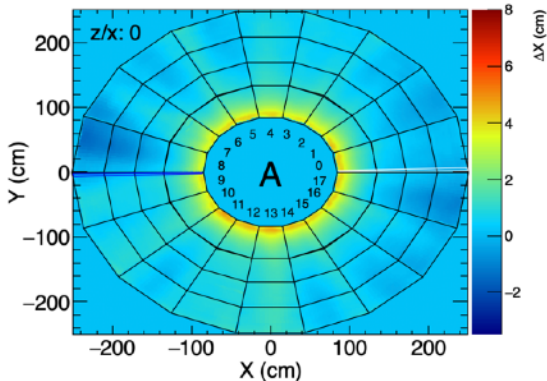
8 kHz



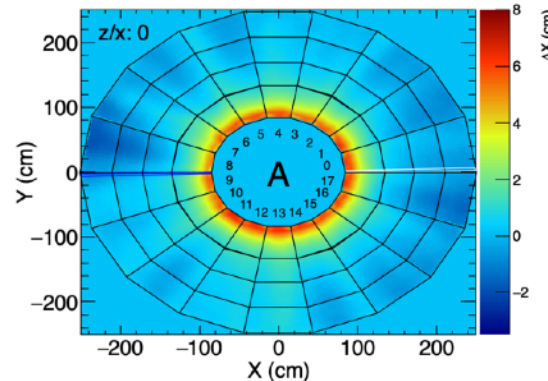
15 kHz



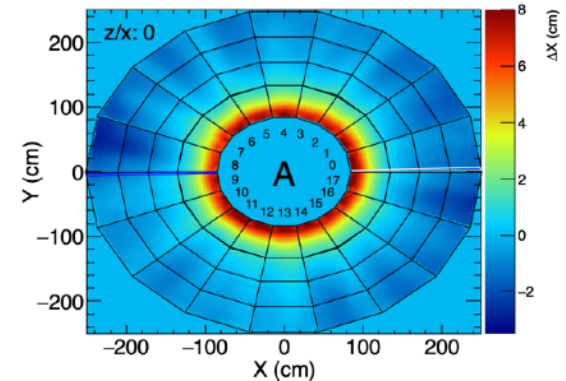
18 kHz



27 kHz



38 kHz

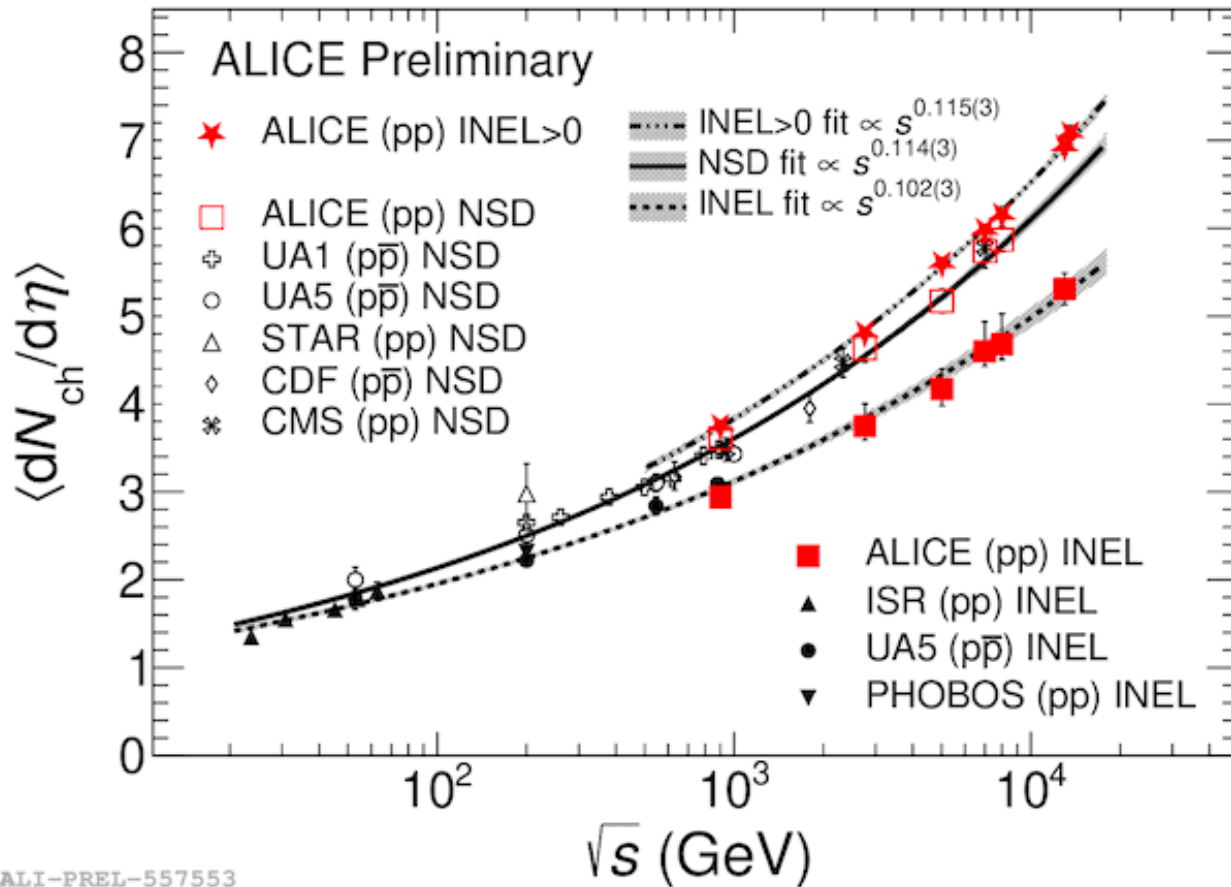


- Average maps. Fluctuations and IR dependence are treated on top.
- Distortions up to ~ 8 cm in radial direction!
- Corrections applied on the ms timescale to remove fluctuations.



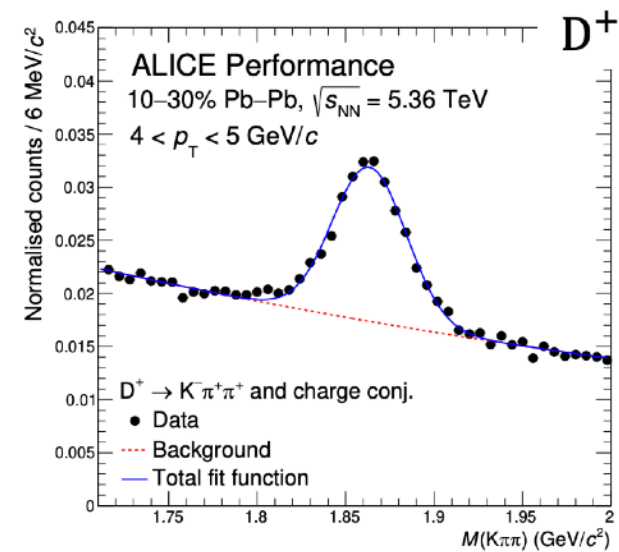
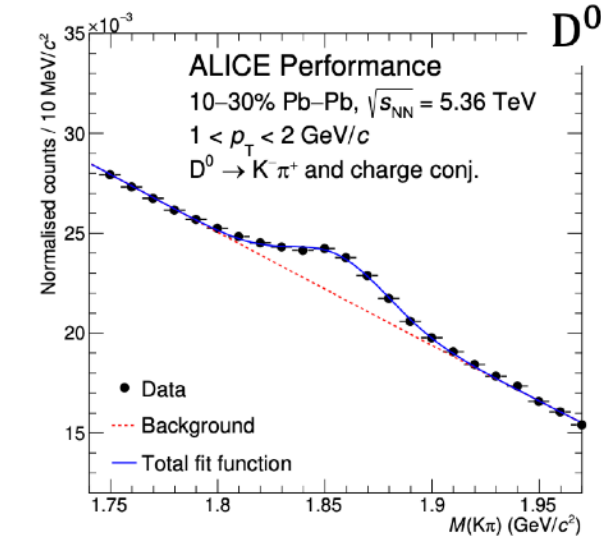
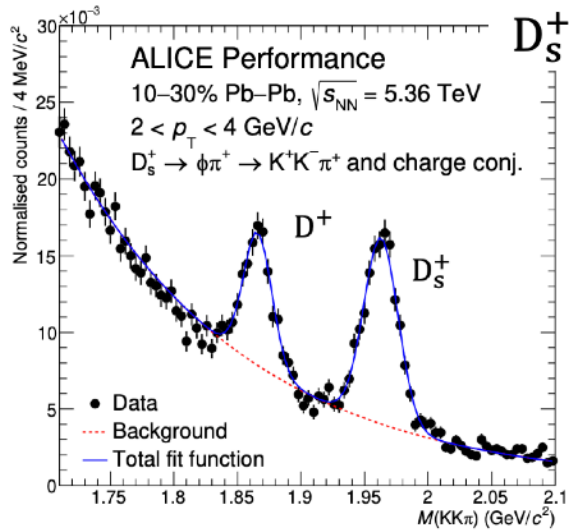
First Performance Results from Run 3

Charged Particle Multiplicity



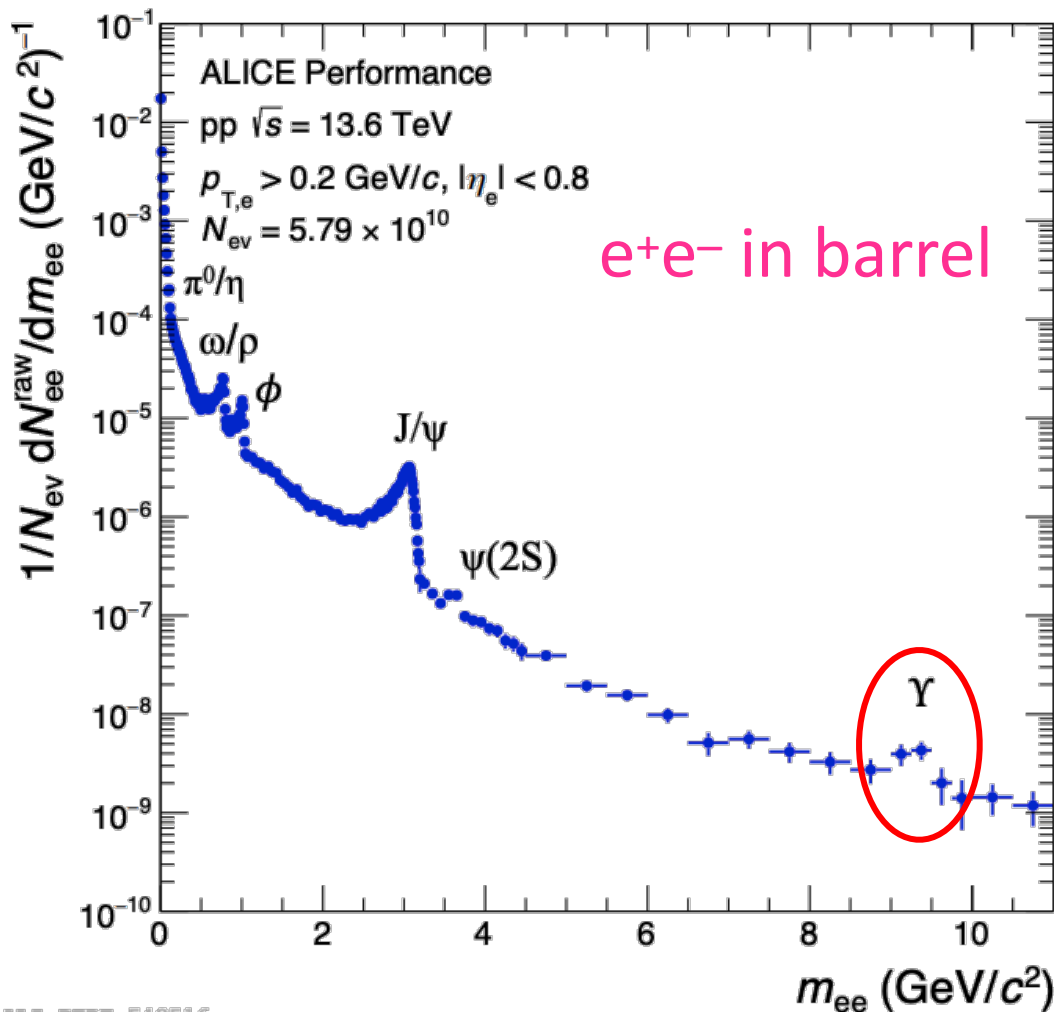
- Charged particle multiplicity from Run 3 in agreement with world data.

D mesons in Pb-Pb at 5.36 TeV



- Good performance in D-meson signal extraction in Run 3.

Low Mass Dielectrons

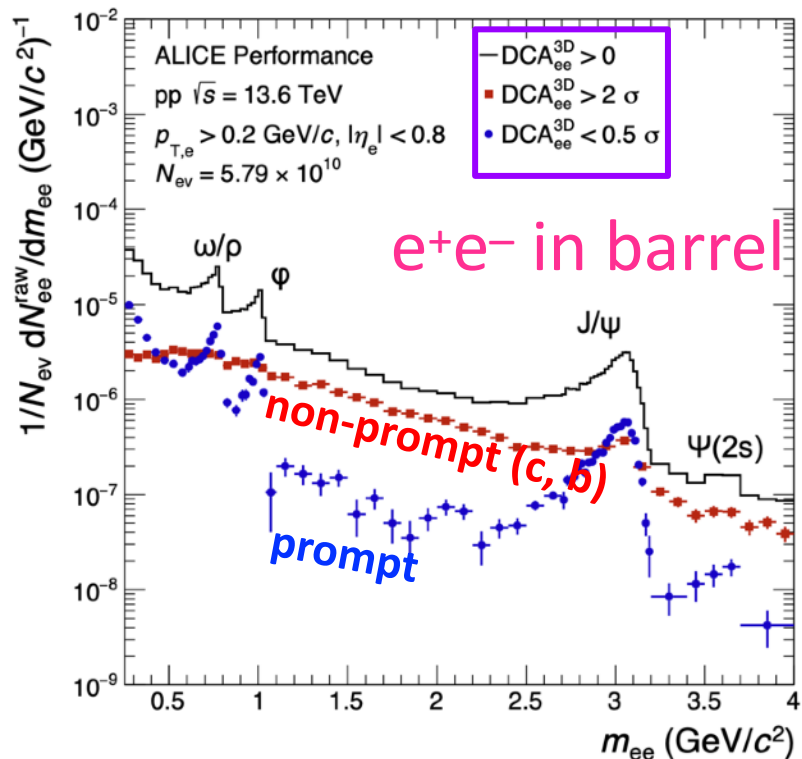


ALI-PERF-548516

Huge pp statistics analyzed:

- 0.97 pb⁻¹ (2022) for this figure
- 0.03 pb⁻¹ in Run 2

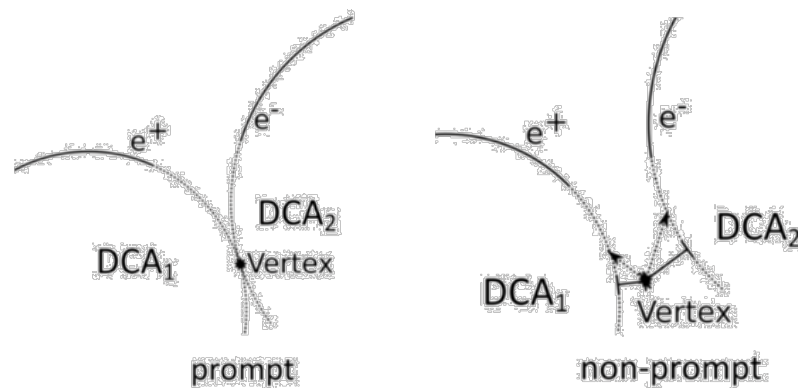
Low Mass Dielectrons



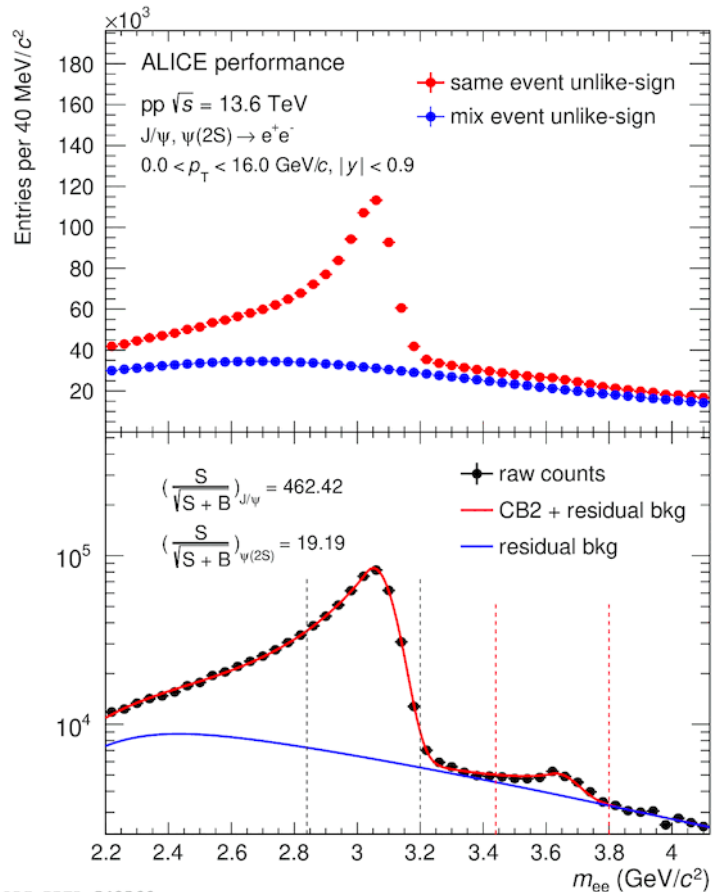
$c\tau \sim 150 \mu\text{m}$ for D mesons
 $c\tau \sim 500 \mu\text{m}$ for B mesons

Huge pp statistics analyzed:

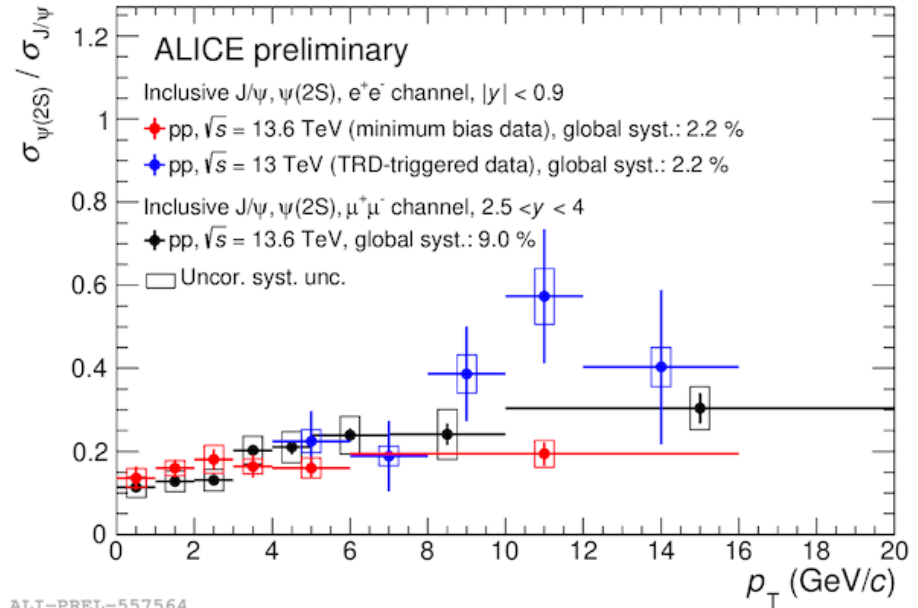
- 0.97 pb^{-1} (2022) for this figure
- 0.03 pb^{-1} in Run 2
- New ITS → improved DCA resolution, better control of charm & beauty background!
- Promising to look for thermal radiation in pp



Quarkonia in pp at 13.6 TeV



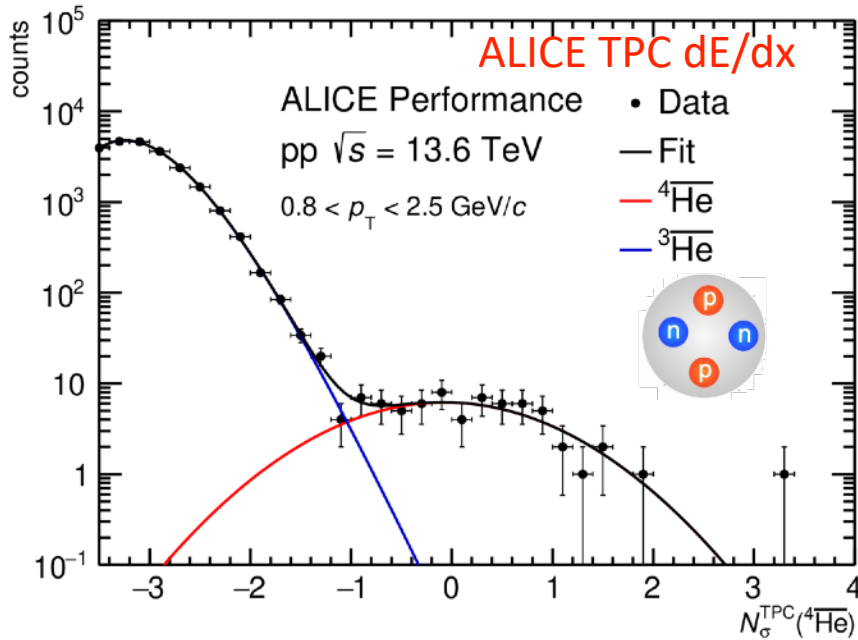
ALI-PREL-548566



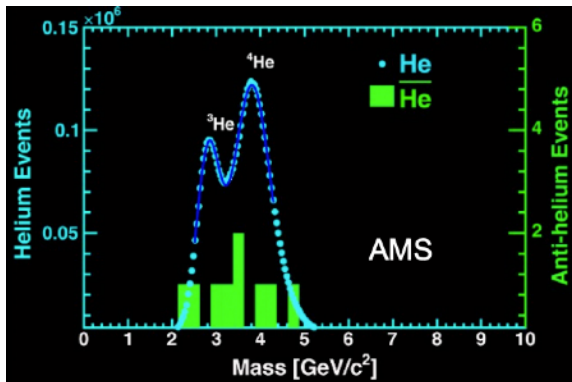
ALI-PREL-557564

- First $\psi(2S)$ measurement in pp at mid-rapidity.
- Run 2: TRD triggered
- Run 3: Analysis trigger
- First quarkonium results in both barrel and MUON arm.

Antihelium-4 in pp Collisions



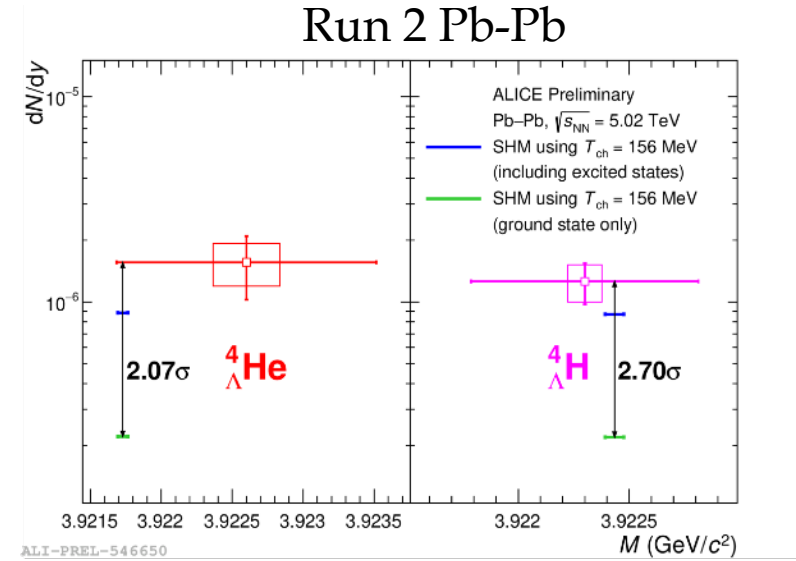
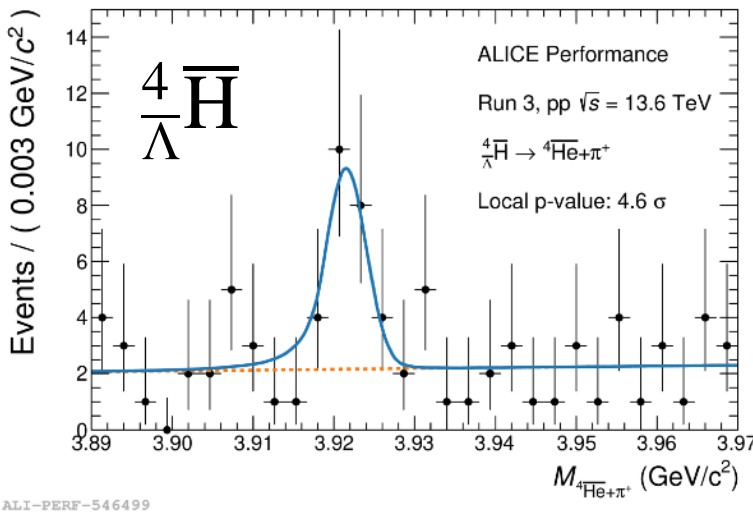
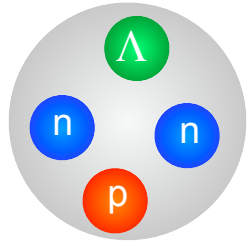
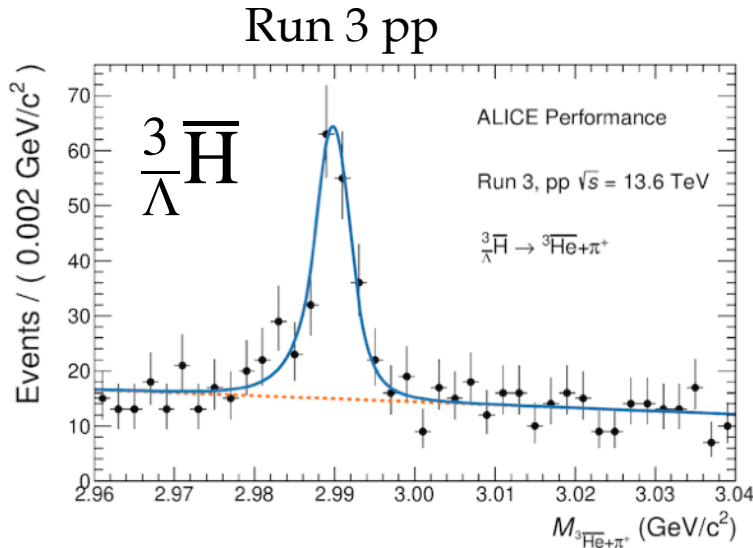
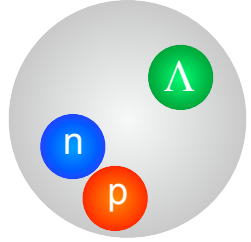
ALI-PERF-547176



- First signal of ${}^4\overline{\text{He}}$ in pp collisions
- Fundamental to constrain ${}^4\overline{\text{He}}$ production in interactions between cosmic rays and interstellar medium

→ dominant background for dark matter searches in space experiments (AMS observes an unusual high flux)

Antihypernuclei in Small Systems



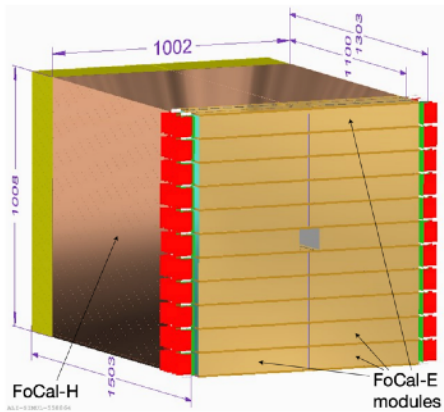
- Observation of $\frac{3}{\Lambda} \bar{H}$ and $\frac{4}{\Lambda} \bar{H}$ in Run 3 minimum-bias pp collisions at 13.6 TeV.
- Measurements of their yields will be crucial to constrain production models of such heavy and loosely-bound states.



ALICE Upgrades

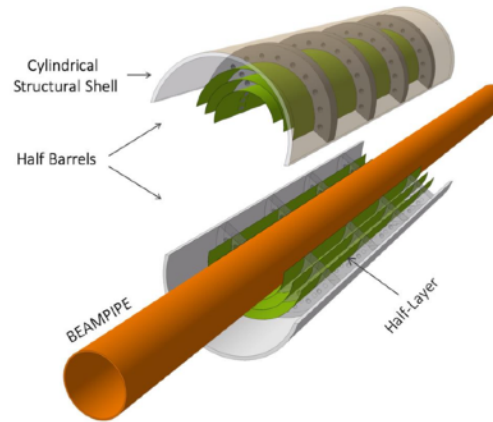
ALICE Upgrades

Forward Calorimeter



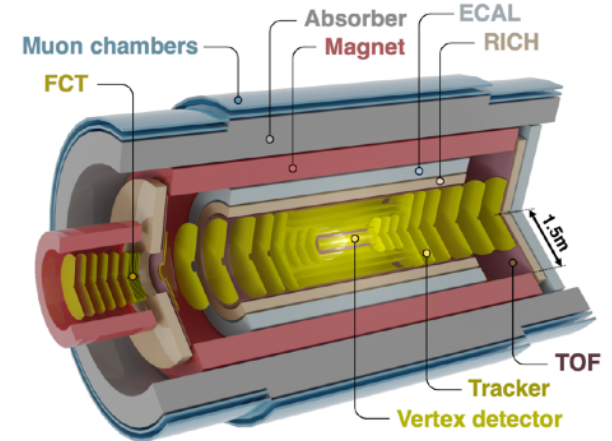
FoCal Lol:
[CERN-LHCC-2020-009](#)

ITS 3



ITS3 Lol:
[CERN-LHCC-2019-018](#)

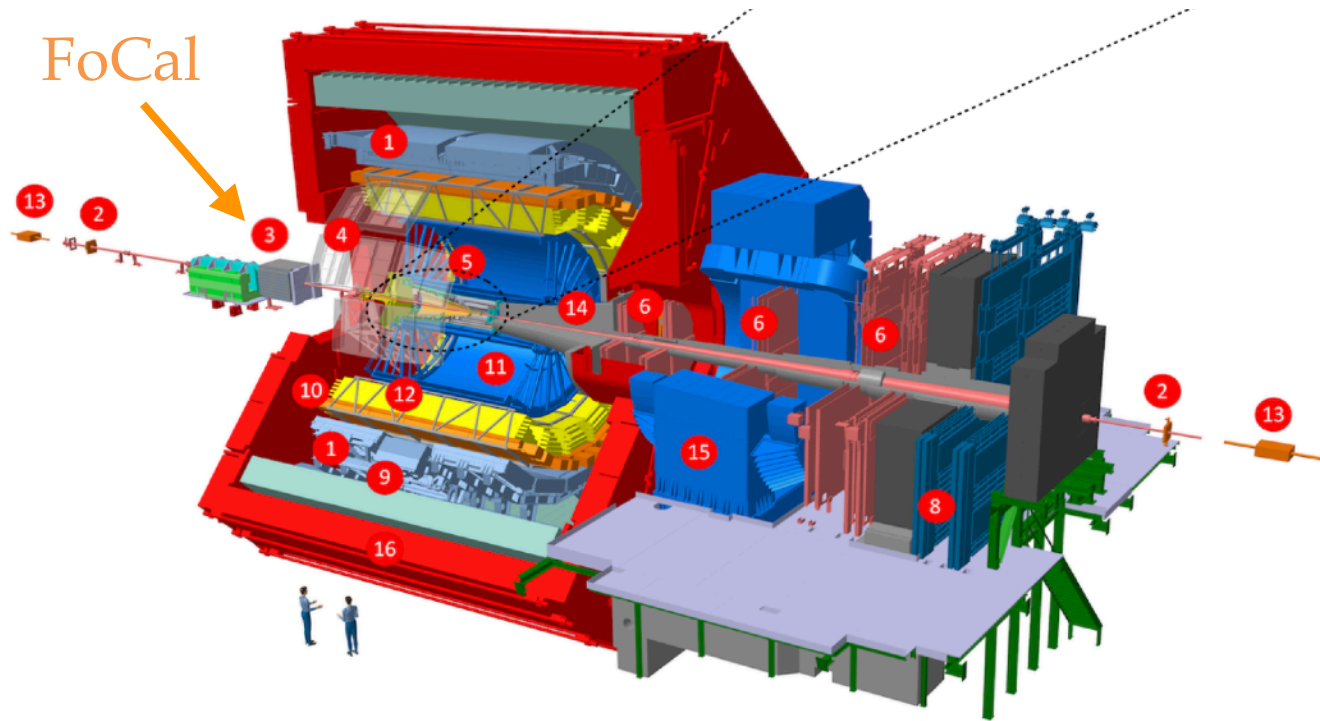
ALICE 3



ALICE 3 Lol:
[CERN-LHCC-2022-009](#)

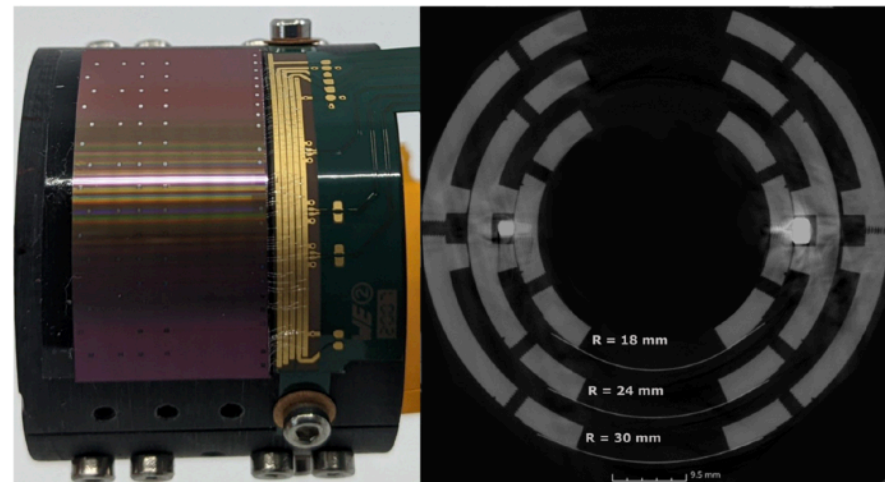
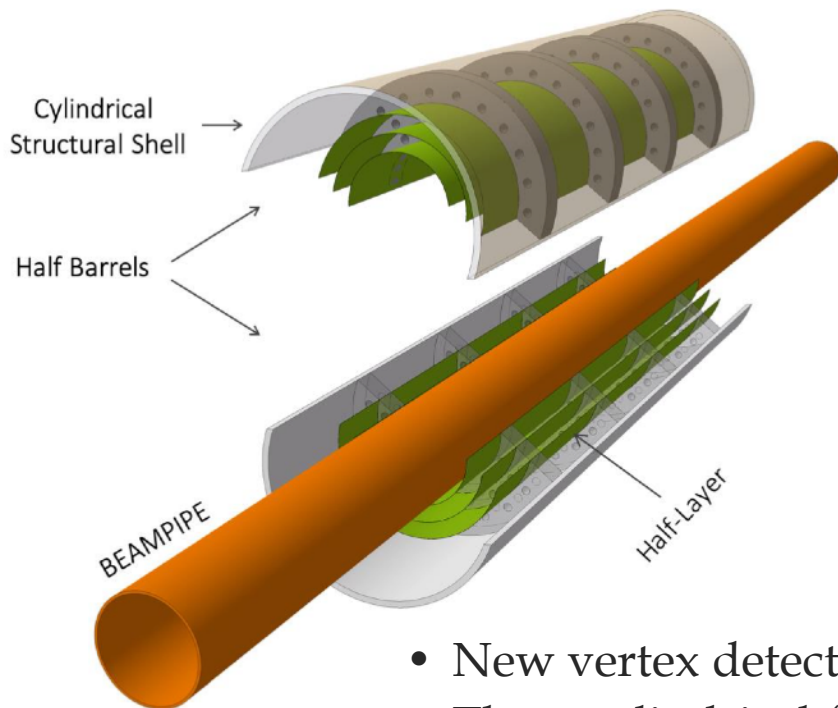


Forward Calorimeter



- FoCal-E: Direct photons and high p_T neutral pions in forward direction
- FoCal-H: Jets + photon isolation
- High-granular Si-W EM calorimeter + conventional hadronic sampling calorimeter
- $3.4 < \eta < 5.8$

Inner Tracking System 3



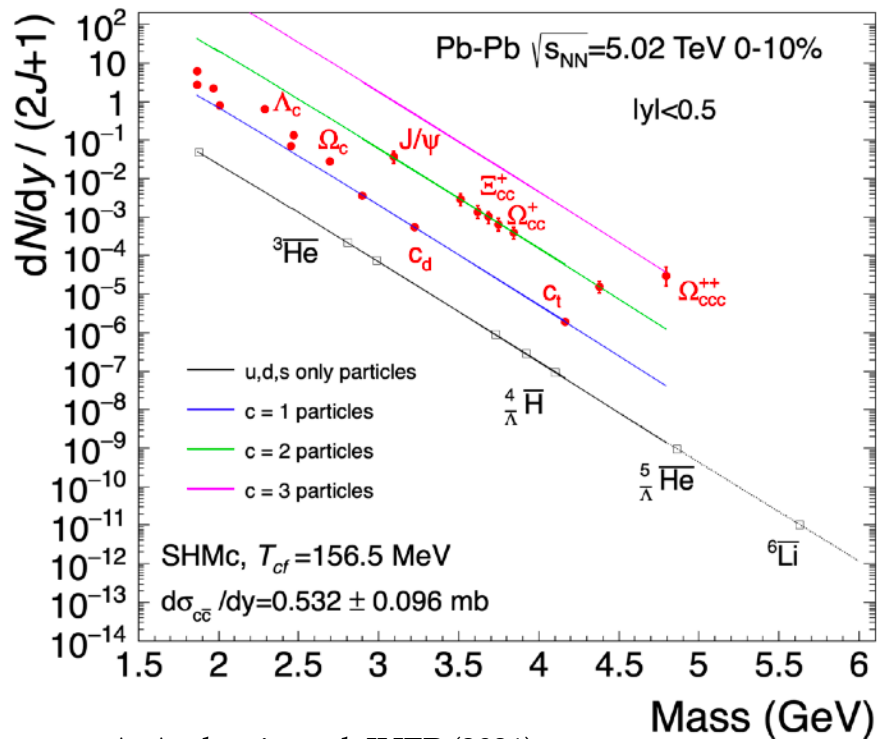
- New vertex detector for ALICE 2.
- Three cylindrical (bent) layers of Monolithic Active Pixel Sensors.
- Bent ALPIDE, performance unchanged after bending!
- 0.05% X_0 per layer (reduction of material budget by a factor of 6).
→ charm, beauty, low mass di-leptons!

Characterizing the analog signal behavior of APTS chips for ALICE ITS3 Upgrade at the LHC — •Alexander Musta, Tue, 16:45, HK 16.4
Advancements and application of Monolithic Active Pixel Sensors (MAPS) for future tracking detectors using the example of the ALICE ITS3 — •Pascal Becht, Wed, 15:45, HK 39.1
Material budget studies for the ALICE ITS3 — •Simon Groß-Bölting, Tue, 16:30, HK 16.3

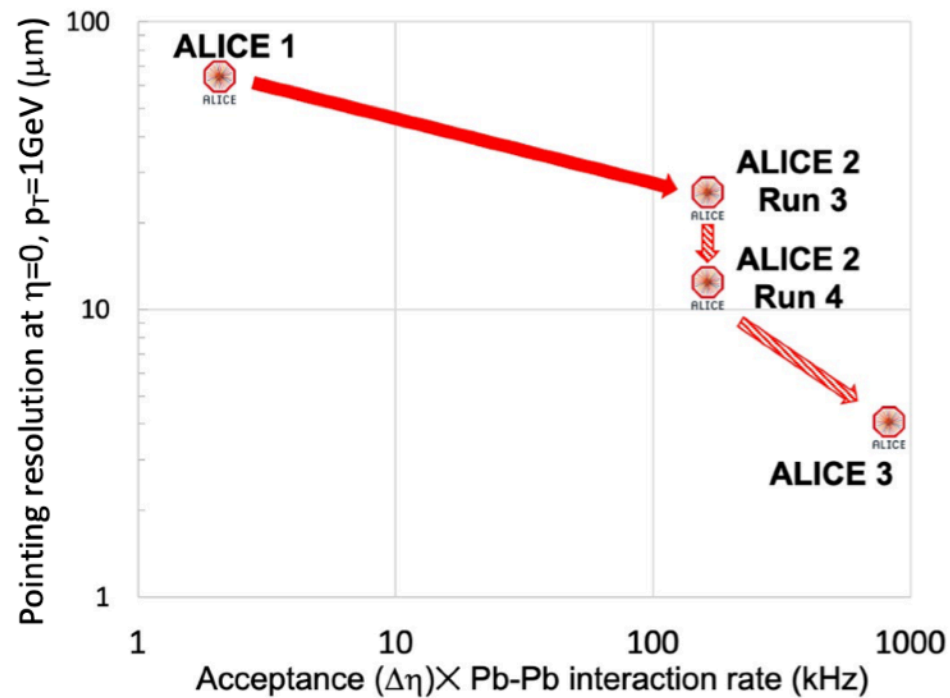


ALICE 3

Acceptance x IR Rate: New Opportunities



A. Andronic et al. JHEP (2021)



[CERN-LHCC-2022-009](https://cds.cern.ch/record/2811000)

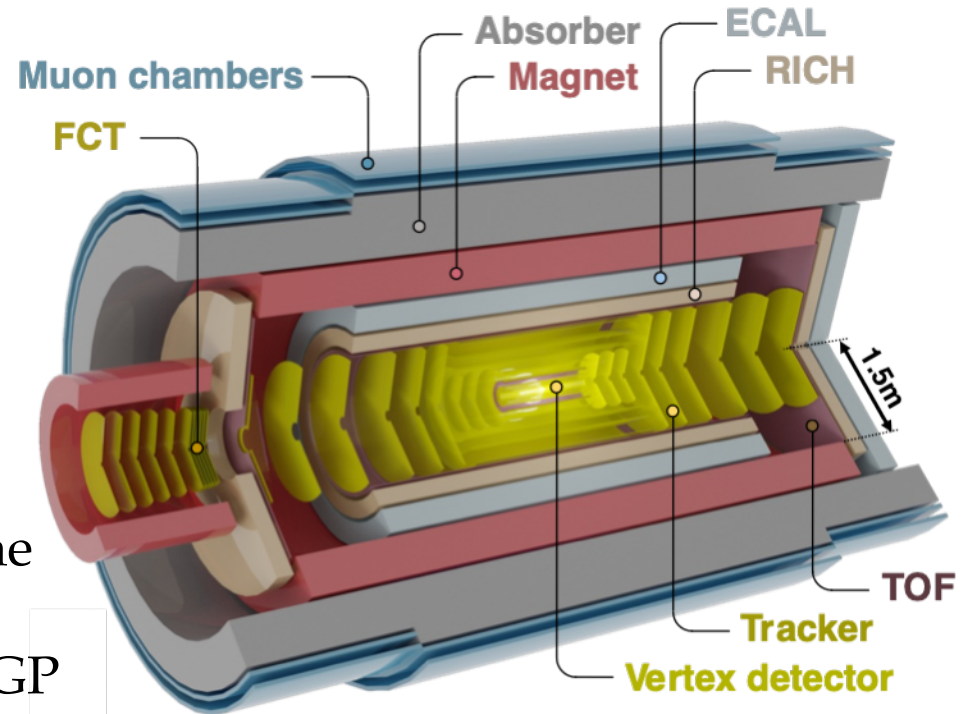
- Multi-charm baryons: unique probe of hadron formation.
- Requires recombination of multiple charm quarks.
- Statistical hadronisation model: very large enhancement in AA.
 → requires high statistics and excellent vertexing!

Detector Overview

- Tracking precision $\times 3$: $< 10 \mu\text{m}$ at $p_T > 200 \text{ MeV}/c$
- Acceptance $\times 4.5$: $|\eta| < 4$ (with particle ID)
- A-A rate $\times 5$ (pp $\times 25$)

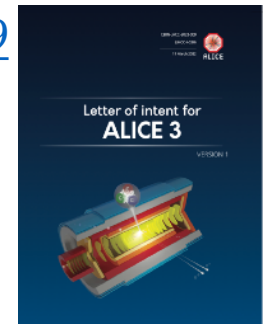
Enables unique physics in Runs 5-6:

- QGP thermal radiation and its time dependence
- Chiral symmetry restoration in QGP
- Multi-charm hadrons
- Charm - anticharm angular (de)correlation
- Charm h-h residual interaction
- ...
-



Letter of Intent:
[CERN-LHCC-2022-009](https://cds.cern.ch/record/2800097)

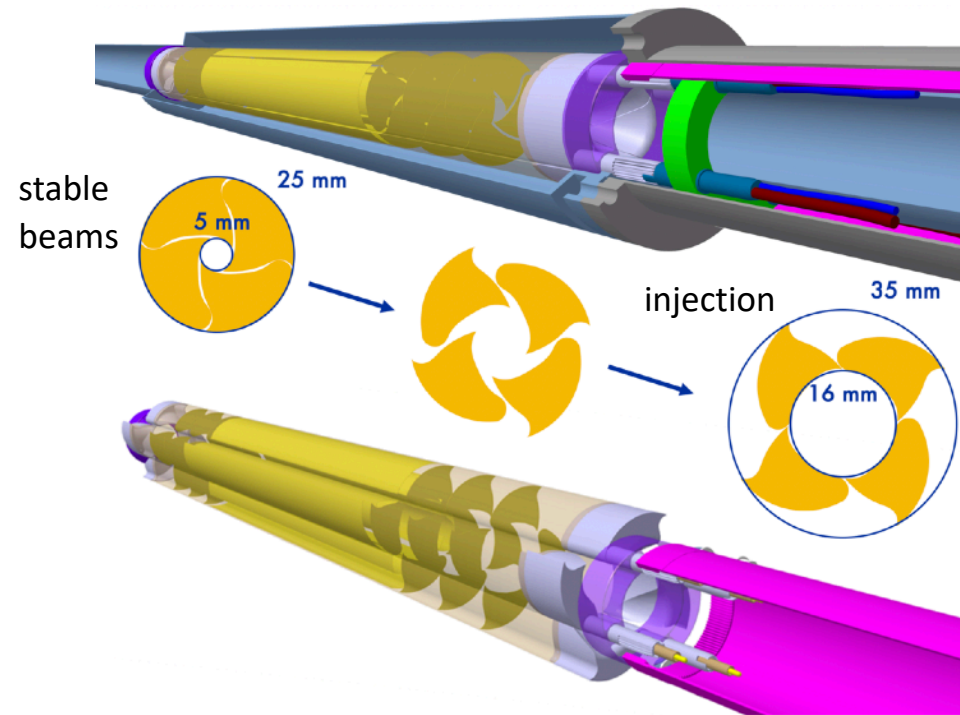
**Positive review by
 LHCC in March 2022
 Scoping document
 soon!**



Vertex Detector

Retractable vertex detector concept inside beampipe (Iris):

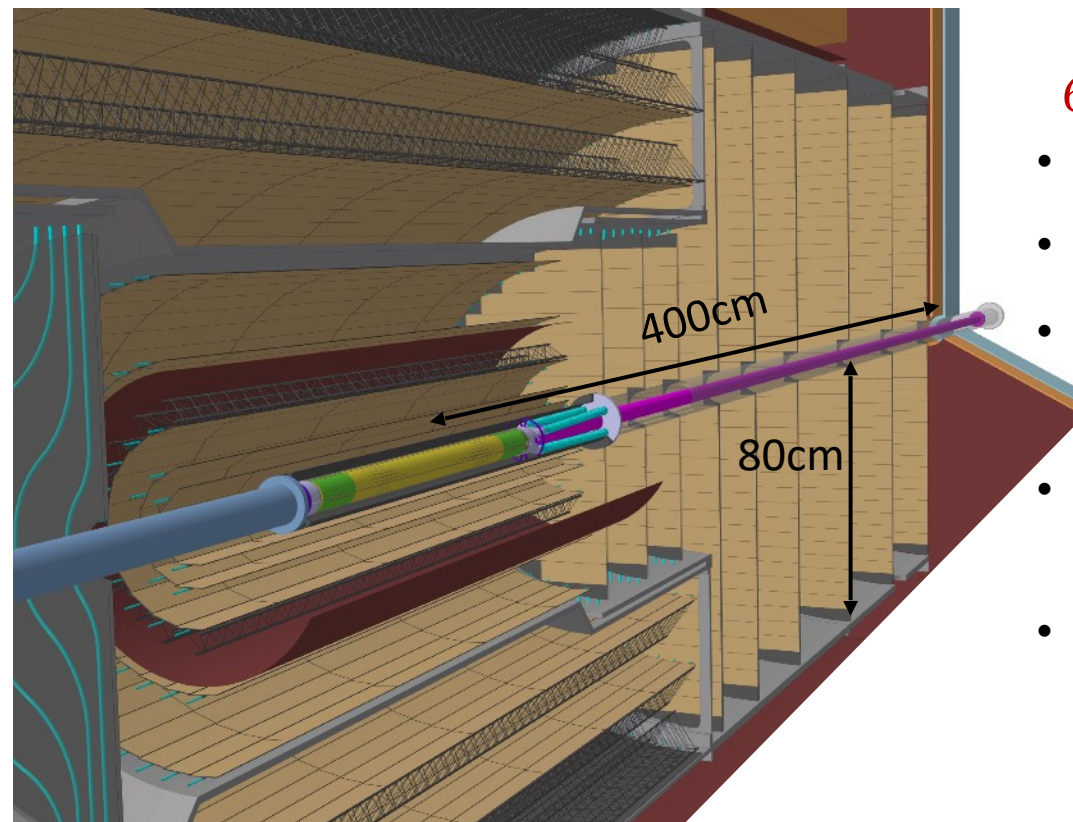
- closed to $R_{\text{inner}} = 5 \text{ mm}$ during *stable beams*
- opened to $R_{\text{inner}} = 16 \text{ mm}$ for beam injection/adjustments



Component	Material	Thickness (μm)	Radiation length	
			(cm)	($\%X_0$)
Sensor	Si	30	9.37	0.032
Support	Be	250	35.28	0.071
Glue		50	35	0.014
Total				0.117

Table 9: Material for the first layer of the vertex detector.

ALICE 3 Outer Tracker



60 m² silicon pixel detector

- large coverage: 8 pseudorapidity units
- compact: $R_{\text{out}} \approx 80 \text{ cm}$, $z_{\text{out}} \approx \pm 400 \text{ cm}$
- high-spatial resolution: $\sigma_{\text{pos}} \approx 10 \mu\text{m}$
→ pixel size $\sim 50 \times 50 \mu\text{m}^2$
- low material budget: $x/X_0 \sim 1\%$ per layer
- low power density: $\approx 20 \text{ mW/cm}^2$

R&D focusses on

- concept of module $\sim 10 \times 10 \text{ cm}^2$ based on **industry-standard processes for assembly and testing**
- services: **reduce** (eliminate) **interdependence** between modules (→replacement of single modules)



Conclusions

- Very successful Run 2 operations + publications!
- Huge amount of data already collected in Run 3 (7x central, 40x MB), first results from heavy flavour and di-leptons look very promising.
- Upgrades of ALICE (FoCal + ITS3) are on their way.
- ALICE 3 in the planning.



ALICE Talks at DPG - I

Reports:

Charmed baryon measurements in proton-proton collisions at $\sqrt{s}=13.6$ TeV with the ALICE experiment in Run 3 — •Federica Zanone, Mon, 17:15, HK 8.2

Reconstruction of heavy-flavor hadrons with ALICE in Run 3 — •Phil Lennart Stahlhut, Mon, 17:30, HK 8.3

Charmonium production measurement at midrapidity using TRD-triggered data in ALICE — •Jinjoo Seo Mon, 17:45, HK 8.4

Soft ω meson production in pp collisions at $\sqrt{s} = 5.02$ TeV with ALICE — •Merle Luisa Wälde, Mon, 17:30, HK 9.3

Material budget studies for the ALICE ITS3 — •Simon Groß-Bölting, Tue, 16:30, HK 16.3

Characterizing the analog signal behavior of APTS chips for ALICE ITS3 Upgrade at the LHC — •Alexander Musta, Tue, 16:45, HK 16.4

Optimizations of the specific energy loss measurement and data to Monte Carlo matching for the ALICE TPC in Run 3 — •Tuba Gündem, Tue, 16:00, HK 18.2

TPC cluster shape analysis — •Janis Noah Jäger, Tue, 16:15, HK 18.3

J/ ψ measurements with machine learning and Kalman filter techniques with ALICE at the LHC — •Pengzhong Lu, Tue, 16:15, HK 21.3

Mid-rapidity J/ ψ production as a function of multiplicity in p-Pb collisions at $\sqrt{s_{NN}}=5.02$ TeV with ALICE — •Tabea Eder, Tue, 16:30, HK 21.4

Multiplicity dependence of prompt and non-prompt J/ ψ production in pp collisions with ALICE — •Gauthier Legras, Tue, 16:45, HK 21.5

Jet-hadron correlations in PbPb collisions at $\sqrt{s_{NN}}=5.02$ TeV with ALICE — •Luisa Bergmann, Tue, 17:00, HK 21.6

Elliptic flow of non-prompt D^0 in Pb-Pb collisions at $\sqrt{s_{NN}}= 5.02$ TeV with ALICE — •Biao Zhang, Tue, 16:15, HK 22.2



ALICE Talks at DPG - II

Differential multiharmonic flow correlations in ALICE and CBM — •Ante Bilandzic, Tue, 17:00, HK 22.5

Accessing the p - Σ^+ interaction via femtoscopy with ALICE — •Benedict Heybeck, Tue, 16:45, HK 23.4

Simulation and analysis of pixel cluster shapes in the ALPIDE monolithic active pixel sensor — •Fabian Königstein, Tue, 18:00, HK 27.2

Ω_c^0 production in pp collisions at $\sqrt{s} = 13$ TeV with ALICE — •Tiantian Cheng, Tue, 18:30, HK 32.4

Charm quark thermalization in the quark gluon plasma at RHIC — •Rossana Facen, Tue, 18:45, HK 32.5

Modeling charged-particle spectra of pp collisions with deep neural networks — •Maria A. Calmon Behling, Tue, 18:00, HK 33.2

Measurement of Net-Proton Fluctuations in Pb-Pb Collisions with ALICE — •Ilya Fokin, Tue, 18:30, HK 33.4

Bayesian inference of quark-gluon plasma transport coefficients from transverse momentum spectra and flow observables — •Rafet Kavak, Tue, 18:30, HK 34.4

Advancements and application of Monolithic Active Pixel Sensors (MAPS) for future tracking detectors using the example of the ALICE ITS3 — •Pascal Becht, Wed, 15:45, HK 39.1

Characterizing Cluster Behavior and Alignment Strategies in Cylindrical MAPS Detectors for ALICE at the LHC — •Berkin Ulukutlu, Wed, 16:30, HK 39.3

Cooling studies for the Outer Barrel of ALICE3 — •Laszlo Varga, Wed, 16:45, HK 39.4

Development of a Dummy Chip for the ALICE 3 Outer Tracker — •Lars Döpfer, Wed, 17:00, HK 39.5

Measurement of $A=4$ (anti-)hypernuclei production in heavy-ion collisions at the LHC — •Janik Ditzel, Wed, 16:30, HK 44.4



ALICE Talks at DPG - III

- Strangeness tracking with the upgraded ALICE Inner Tracking System in Run 3 at the LHC** — •Carolina Reetz, Wed, 17:00, HK 44.6
- Dielectron production in Pb–Pb collisions with ALICE** — •Jerome Jung, Wed, 16:00, HK 46.2
- Measurement of dielectrons in pp collisions at $\sqrt{s} = 13.6$ TeV with ALICE in Run 3** — •Florian Eisenhut, Wed, 16:45, HK 46.5
- Measurement of dielectrons in Pb-Pb collisions with ALICE in Run 3** — •Emma Ege, Wed, 17:00, HK 46.6
- Simple readout system of ALICE silicon detectors** — •Bent Buttwill, Wed, 18:15, HK 50.3
- The Event Processing Nodes: technical operation and performance of the ALICE GPU-based processing farm and computing model for synchronous and asynchronous data reconstruction** — •Federico Ronchetti, Wed, 18:00, HK 54.3
- Modern C++ with SYCL as Multi Paradigm Programming Language for FPGA-Based Detector Readout** — •Thomas Janson, Wed, 18:15, HK 54.4
- Software trigger in ALICE** — •Victor Feuillard, Wed, 18:45, HK 55.6
- Photon reconstruction in the Transition Radiation Detector of ALICE** — •Peter Stratmann, Wed, 17:30, HK 56.1
- Measurement of direct photons in Pb-Pb collisions in ALICE at $\sqrt{s_{NN}} = 5$ TeV** — •Stephan Stiefelmaier, Wed, 17:45, HK 56.2
- Development of a ML algorithm for neutral meson and photon reconstruction using PCM in ALICE** — •Abhishek Nath, Wed, 18:15, HK 56.4
- Measurement of neutral meson and photon production in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with the ALICE EMCal** — •Marvin Hemmer, Wed, 18:30, HK 56.5
- Measurement of neutral meson production in small collision systems with ALICE** — •Joshua König, Wed, 18:45, HK 56.6
- Performance of photon measurements using PCM with ALICE in Run 3** — •Alica Marie Enderich, Wed, 19:00, HK 56.7



ALICE Talks at DPG - IV

The bridge between two-body nucleon-hyperon data and the nuclear equation of state —

•Dimitar Mihaylov, Wed, 18:00 HK 57.2

The first study of the $\Lambda\pi$ strong interactions with ALICE — •Marcello Di Costanzo, Wed, 18:15, HK 57.3

Study of p - p - π^\pm and p - π^\pm femtoscopic correlations with ALICE at the LHC — •Marcel Lesch, Wed, 18:30, HK 57.4

Simulation studies of the Forward Conversion Tracker for ALICE 3 — •Cas van Veen, Thu, 16:15, HK 63.3

Space-point distortion calibrations for the ALICE TPC in LHC Run 3 — •Matthias Kleiner, Thu, 15:45, HK 64.1

Gain Calibration of the ALICE TPC with a Krypton source — •Ankur Yadav, Thu, 16:15, HK 64.2

Photon Reconstruction with ALICE's TPC in Run 3 — •Felix Schlepper, Thu, 17:00, HK 64.5

Measurement of p - d and Λ - d correlations in Pb-Pb and pp collisions — •Michael Jung, Thu, 15:45, HK 69.1

Ξ -baryon reconstruction with ALICE in LHC Run 3 data — •Tim Weinreich, Thu, 16:00, HK 69.2

Sexaquark Search with ALICE — •Andres Borquez, Thu, 16:15, HK 69.3

Measurement of inclusive jet suppression in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with a novel mixed-event approach — •Nadine Alice Grünwald, Thu, 16:45, HK 69.5

Measurement of mass $A=4$ hypernuclei in LHC Run 3 with ALICE — •Michael Hartung, Thu, 15:45, HK 71.1

Common femtoscopic hadron-emission source in pp collisions at the LHC — •Maximilian Korwieser, Thu, 16:15, HK 71.3

p - d femtoscopy and p - p source size measurement in PbPb collisions with ALICE at the LHC — •Dongfang Wang, Thu, 16:30, HK 71.4



ALICE Talks at DPG - V

Studying the interaction between charm and light-flavor mesons — •Daniel Battistini, Thu, 17:00, HK 71.6

Pre-filter methods in dielectron measurements in pp collisions at $\sqrt{s} = 13.6$ TeV at ALICE in Run 3 — •Davud Sokolovic, Thu, 17:15, HK 72.14

A simulation-based feasibility study of the measurement of K_L^0 in ALICE — •Laura Gans-Bartl, Thu, 17:15, HK 72.31

Influence of the pixel mask on the EPICAL-2 calorimeter performance — •Dani Ateyeh, Thu, 17:15, HK 72.34

First measurement of proton-deuteron and lambda-deuteron correlation function with data taken by ALICE in Run 3 — •Anton Riedel, Thu, 17:15, HK 72.37

The future of three-body interactions: femtoscopic p-p-p and p-p- Λ correlations in ALICE Run 3 — •Laura Serksnyte, Thu, 17:15, HK 72.38

Methods for three-particle correlation function analyses: from cumulants to full-fledged three-body calculations — •Raffaele Del Grande, Thu, 17:15, HK 72.39

Source Size Measurement in Jets — •Lars Jørgensen, Thu, 17:15, HK 72.43

Inelastic cross section of antinuclei in Run 3 with ALICE — •Rafael Manhart, Thu, 17:15, HK 72.50

Exploring deuteron production with pion-deuteron femtoscopy — •Bhawani Singh, Thu, 17:15, HK 72.51

First differential measurement of the femtoscopic source with data taken by ALICE in Run 3 — •Georgios Mantzaridis, Thu, 17:15, HK 72.52



ALICE Talks at DPG - VI

Group and invited reports:

Probing hadronisation effects with heavy-flavour particles with ALICE at the LHC — •Jeremy Wilkinson, Mon, 18:00, HK 2.5

Molecular and bound states searches with femtoscopy — •Valentina Mantovani Sarti, Thu, 15:00 HK 60.3

Unlocking the mysteries of nuclear interactions and their astrophysical impact — •Laura Šerkšnyte, Mon, 15:45, SYMD 1.4