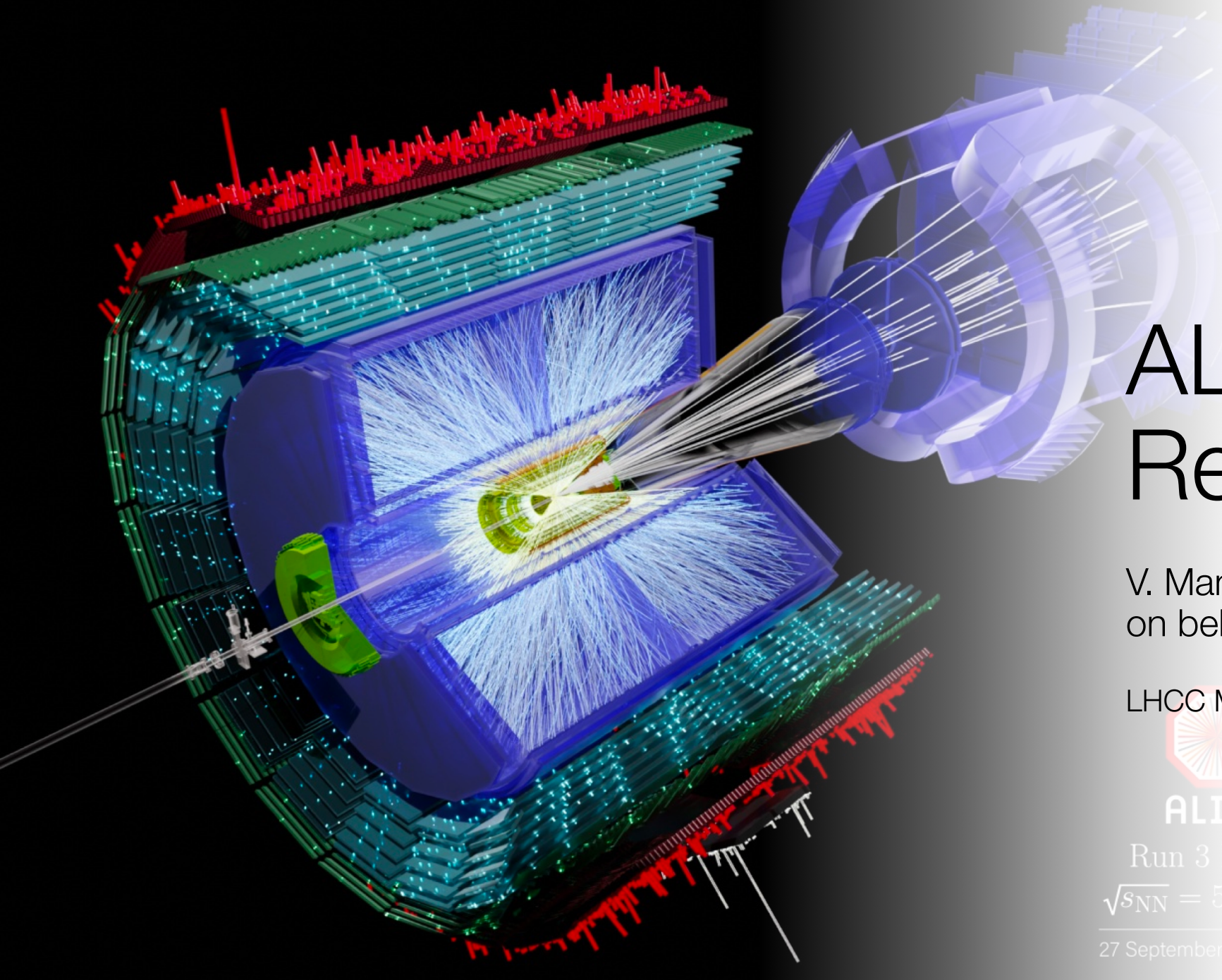


ALICE Status Report

V. Mantovani Sarti (TUM)
on behalf of the ALICE Collaboration

LHCC Meeting 28 Feb. 2024

Outline

ALICE 1 | ALICE 2 | ALICE 2.1 | ALICE 3

RUN 1 → RUN 2 → RUN 3 → RUN 4 → RUN 5 & 6

2009-2013
pp, p-Pb, Pb-Pb

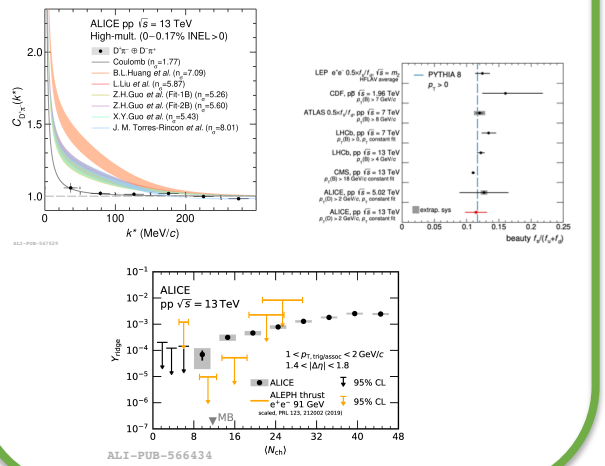
2015-2018
pp, p-Pb, Xe-Xe, Pb-Pb

2022-2025
pp, p-O, O-O, p-Pb, Pb-Pb

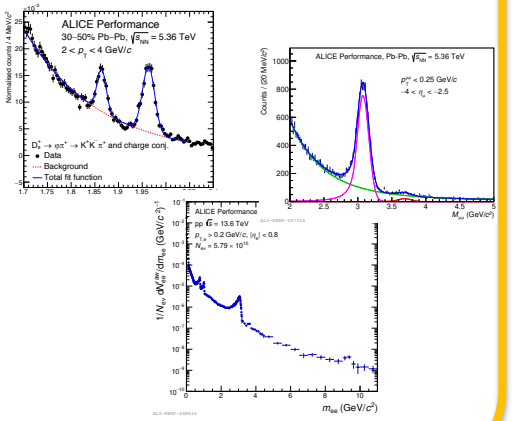
2029-2032
pp, p-Pb, Pb-Pb

from 2035

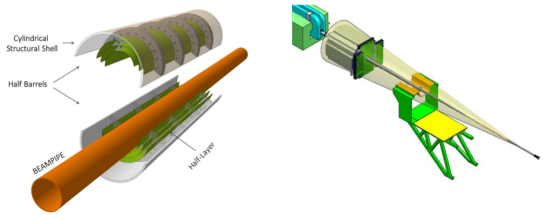
Recent physics publications



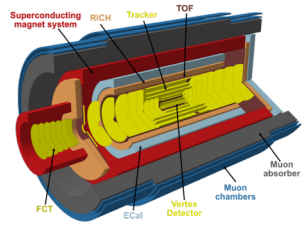
A first look to Run 3



ITS3 and FoCal updates



ALICE 3



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3 new publications since last LHCC

New Results shown today

1. Investigating the nature of the $\mathbf{K_0^*(700)}$ state with $\boldsymbol{\pi^{\pm}K_S^0}$ correlations at LHC *arXiv: 2312.12830*

2. Studying the interaction between charm and light-flavor mesons *arXiv: 2401.13541*

3. Measurement of beauty-quark production in pp collisions at $\sqrt{s}$=13 TeV via non-prompt D mesons
   arXiv: 2402.16417

Additionally discussed today:

- Common femtoscopic hadron-emission source in pp collisions at the LHC *arXiv:2311.14527*
- Emergence of long-range angular correlations in low-multiplicity proton-proton collisions *arXiv:2311.14357*
- Multiplicity dependence of charged-particle intra-jet properties in pp collisions at √s = 13 TeV *arXiv:2311.13322*

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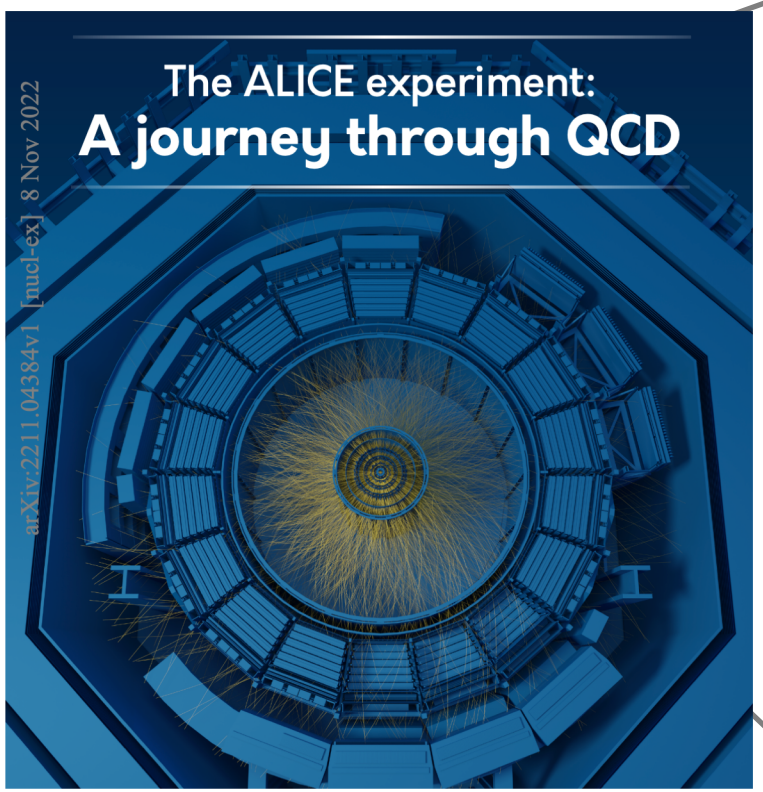
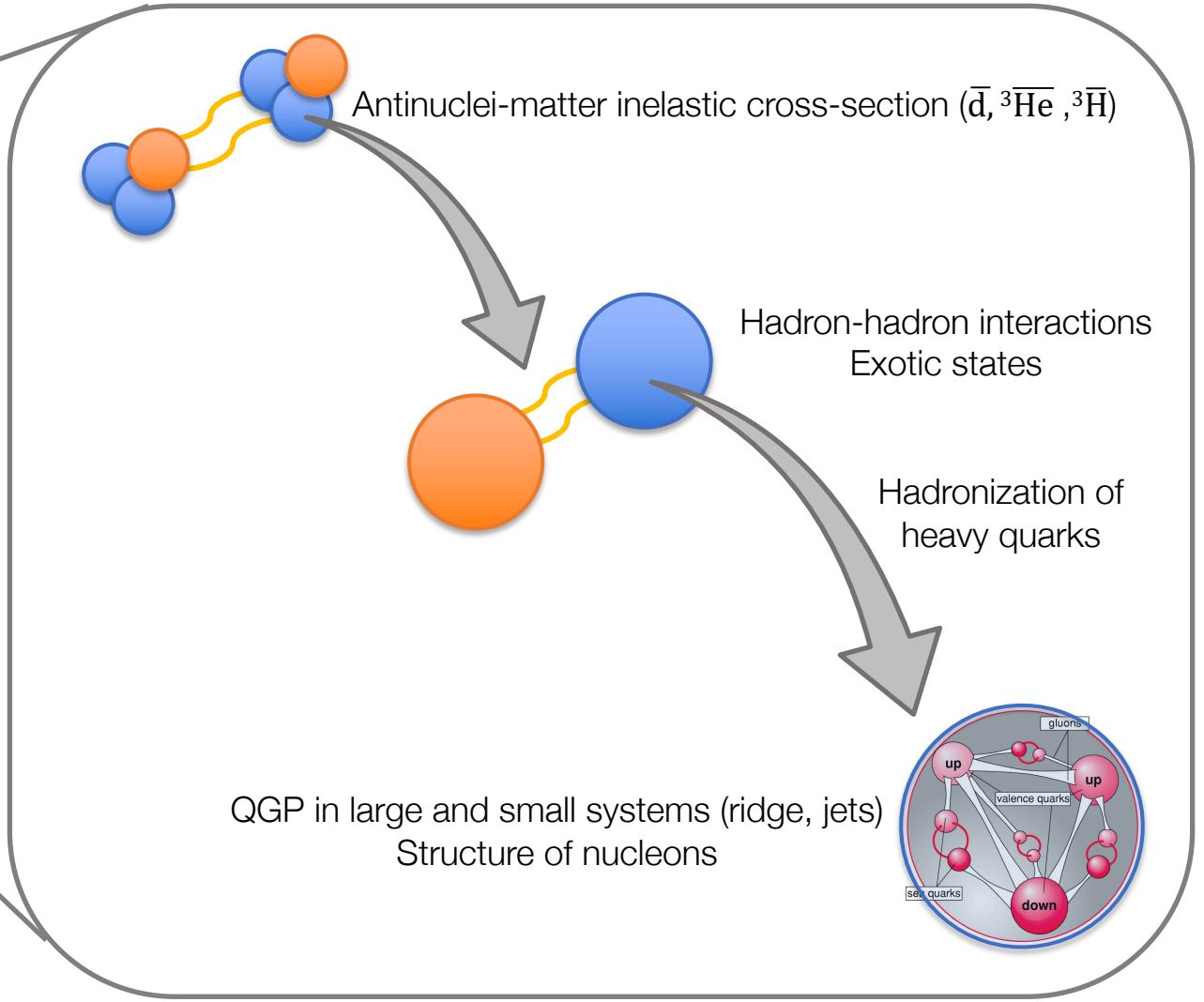
A (recent) journey through QCD



ALICE Coll. arXiv: 2211.04384 [nucl-ex]



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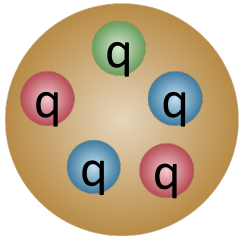
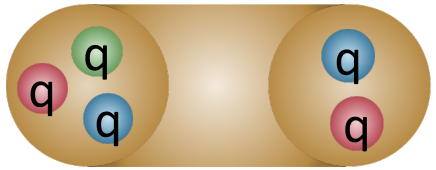
Investigating exotic states with correlations

- Several candidates for exotic states
  - many predicted in the charm sector
  - also in the light sector (u,d,s)

Multi-quark states



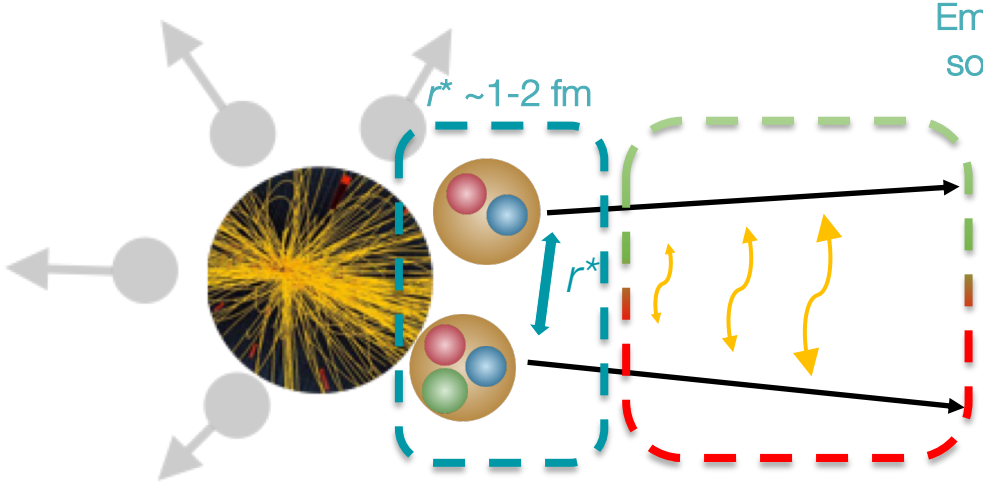
Molecular states



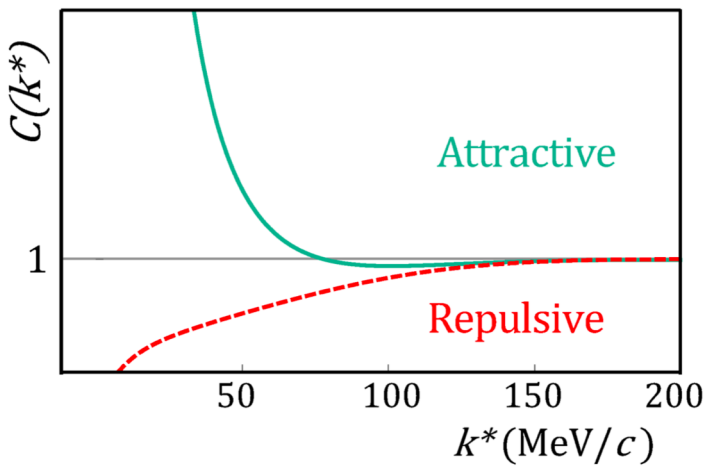
- Accessing hadronic final-state interaction with correlation functions measured in pp collisions

$$C(k^*) = \int S(\vec{r}^*) \left|\psi(\vec{k}^*, \vec{r}^*)\right|^2 d^3\vec{r}^*$$

Emitting source — Interaction



ALICE Coll. Nature 588 (2020) 232-238



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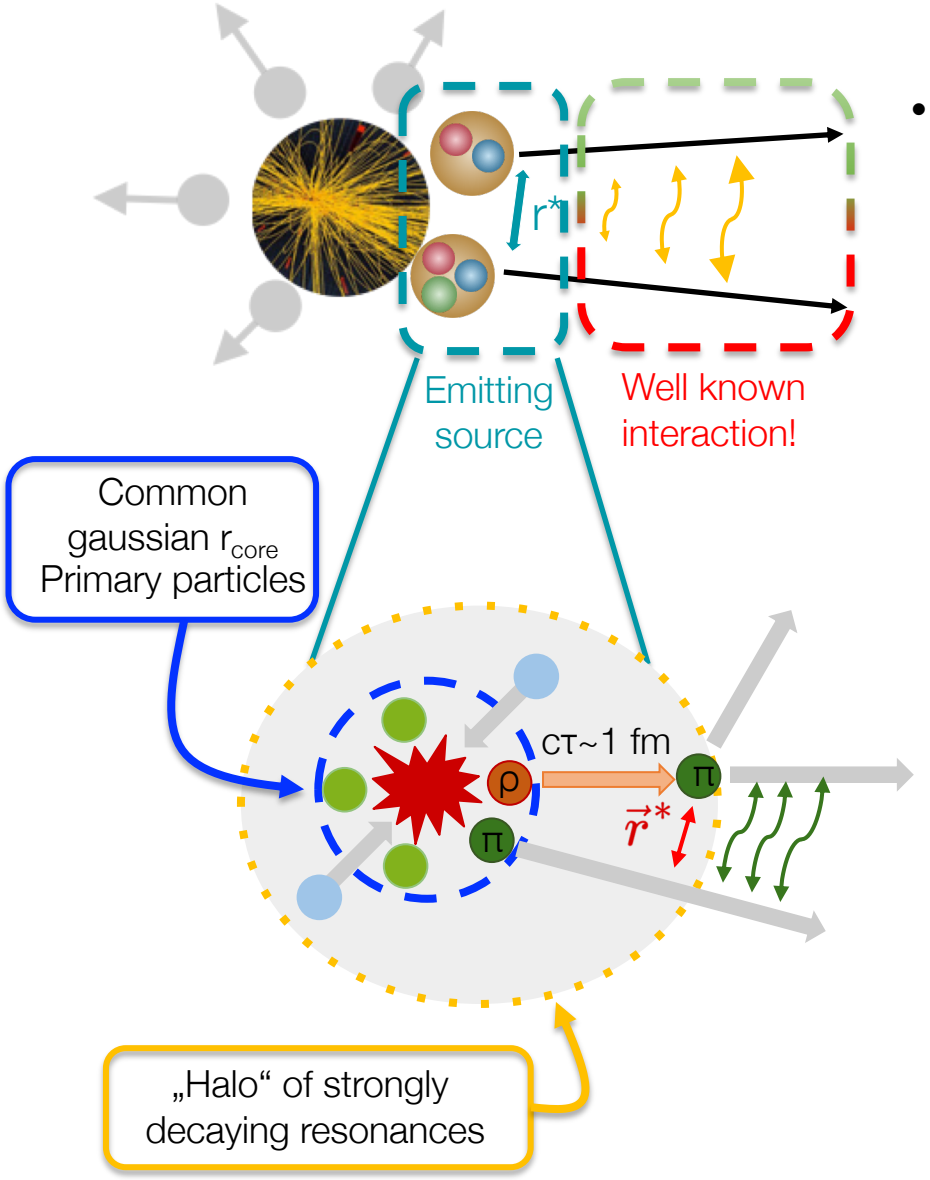
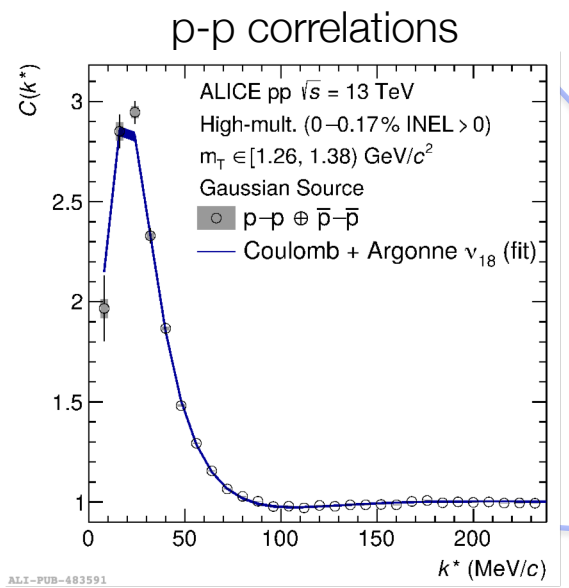
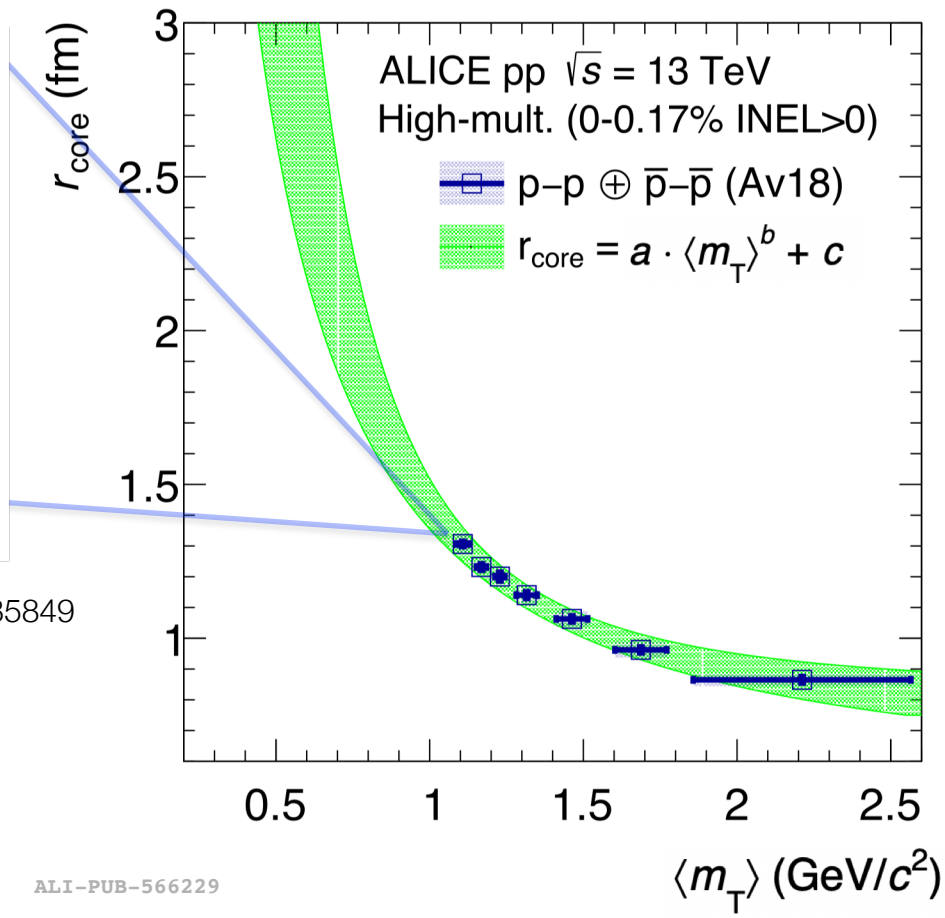
Studying the emitting source in pp collisions



- **Universal** scaling of core source size observed for baryons (p-p, p-Λ)



ALICE Coll. Phys.Lett.B 811 (2020) 135849



ALICE Coll. arXiv: 2311.14527

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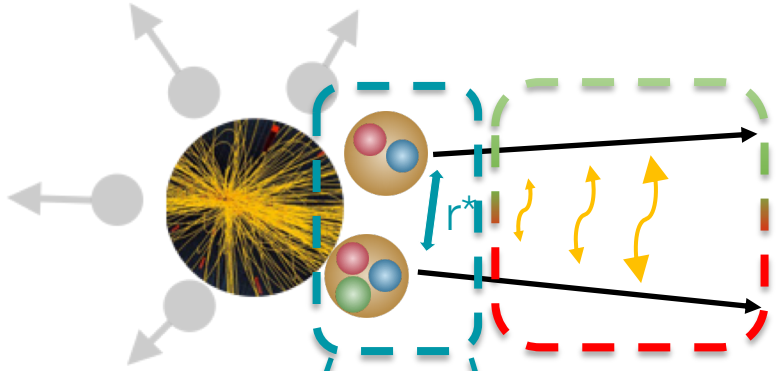
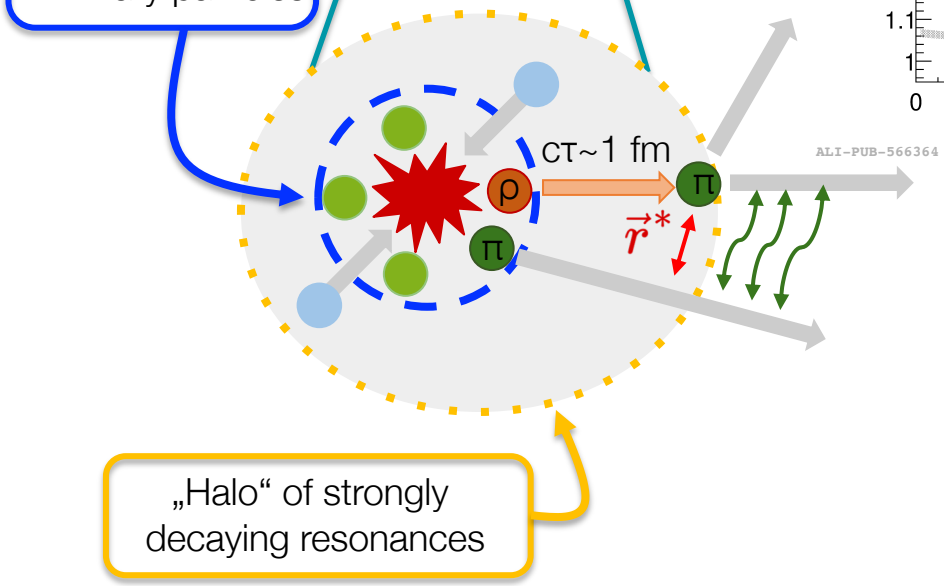
Studying the emitting source in pp collisions

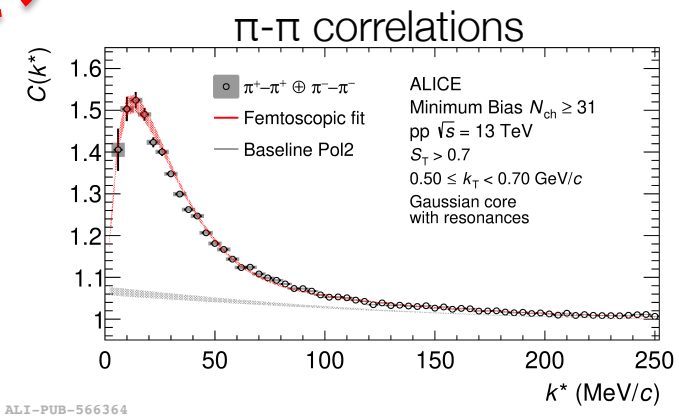


Common gaussian r_{core} Primary particles

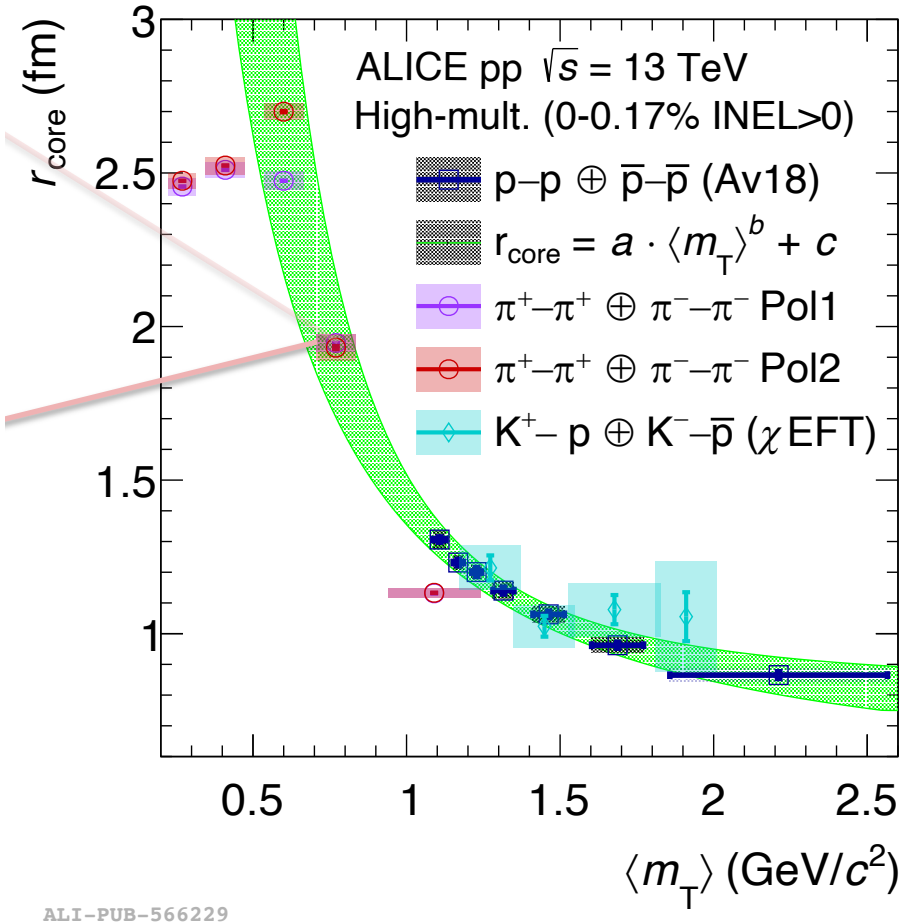


„Halo“ of strongly decaying resonances

- **Universal** scaling of core source size observed for baryons (p-p, p-Λ)
- Same source size and scaling observed for π-π and K^+-p



Common emitting source for hadrons in pp collisions

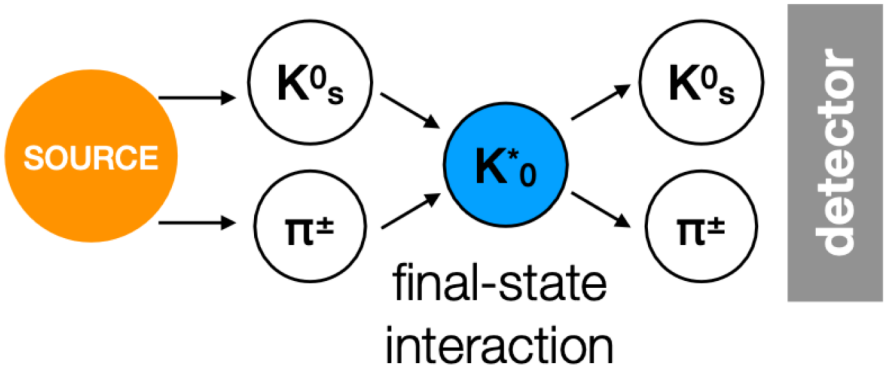


ALICE Coll. arXiv: 2311.14527

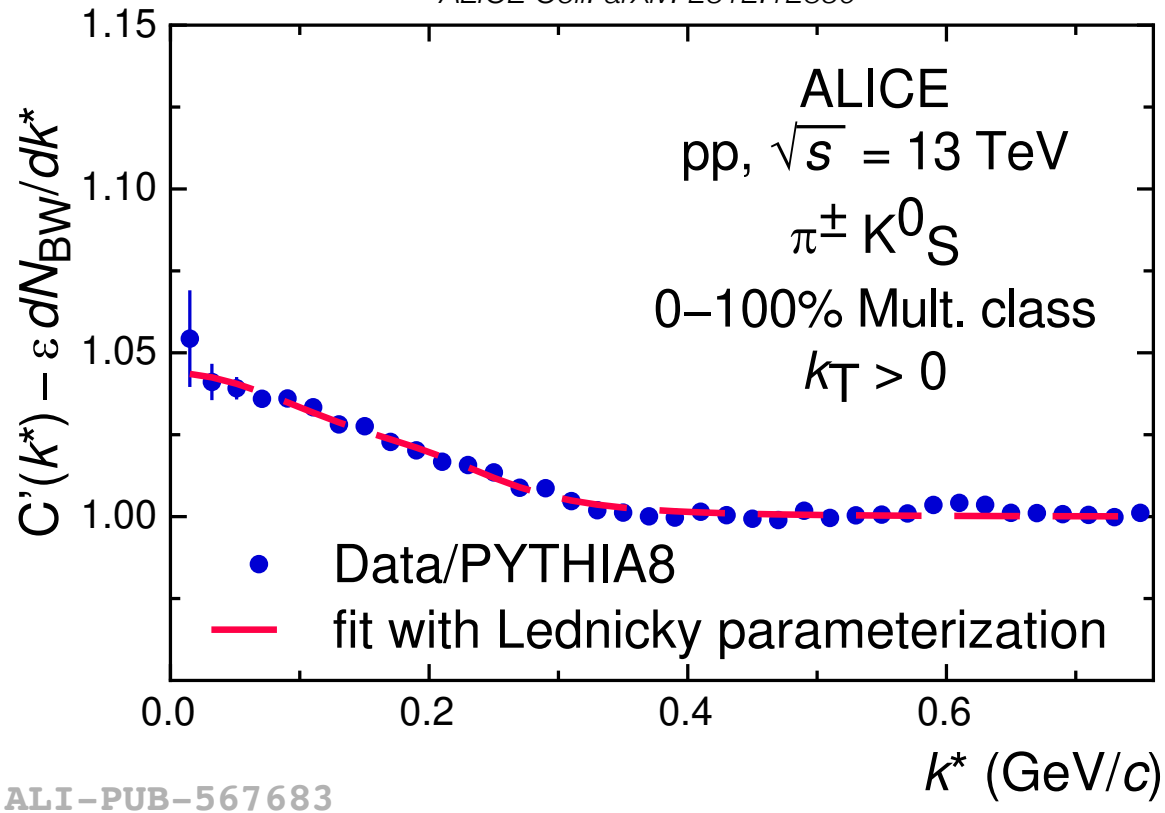
Studying the nature of the $K_0^*(700)$ state

- **First measurement** of $\pi^{\pm}K_S^0$ correlations in pp 13 TeV
  - similar studies with $K_S^0K_S^0$ and $K_S^0K^{\pm}$
    ALICE Coll. PLB 833, 137335 (2022); PLB 790, 22 (2019); PLB 774, 64 (2017)

- Agreement with $\pi^{\pm}K_S^0$ FSI via production of $K_0^*(700)$



ALICE Coll. arXiv: 2312.12830



ALI-PUB-567683

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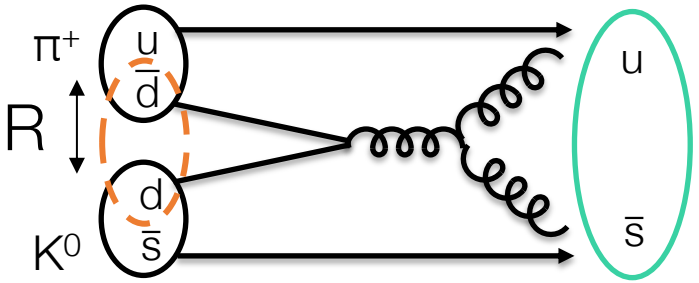
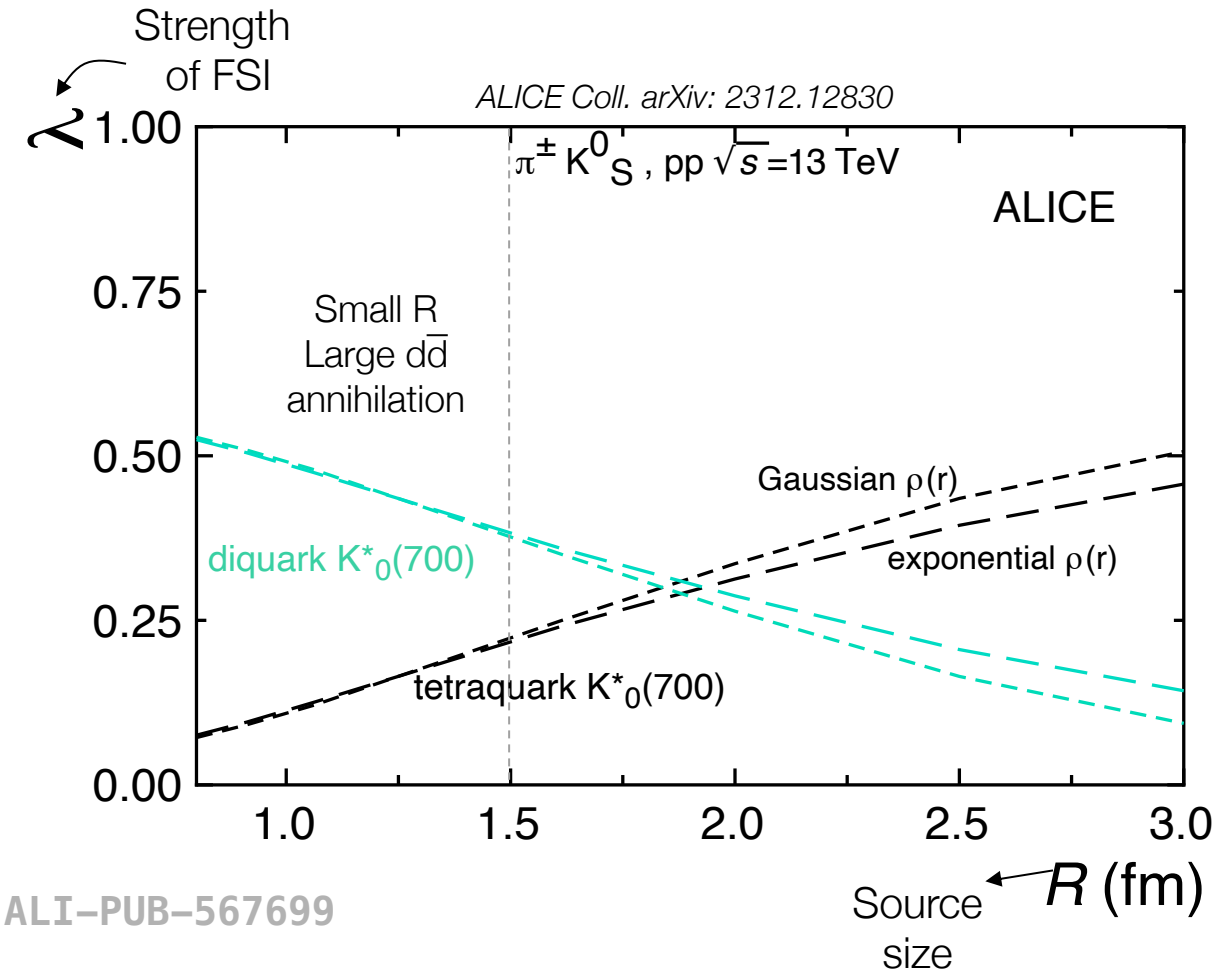
Studying the nature of the $K_0^*(700)$ state

- Testing **conventional or exotic structure** of $K_0^*(700)$
  - probing FSI strength vs source size via a simple geometrical approach

Diquark



Tetraquark



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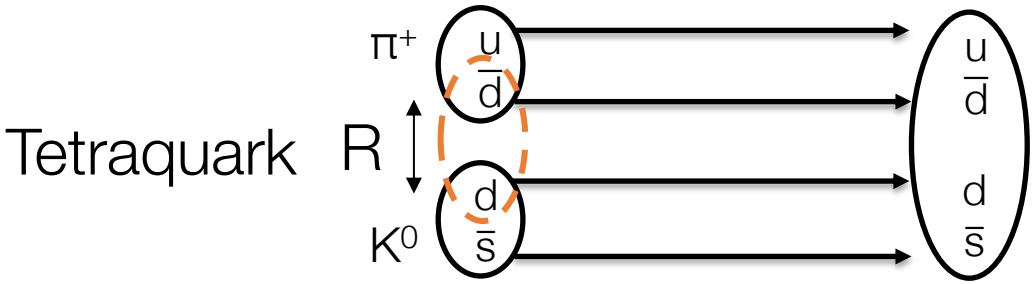
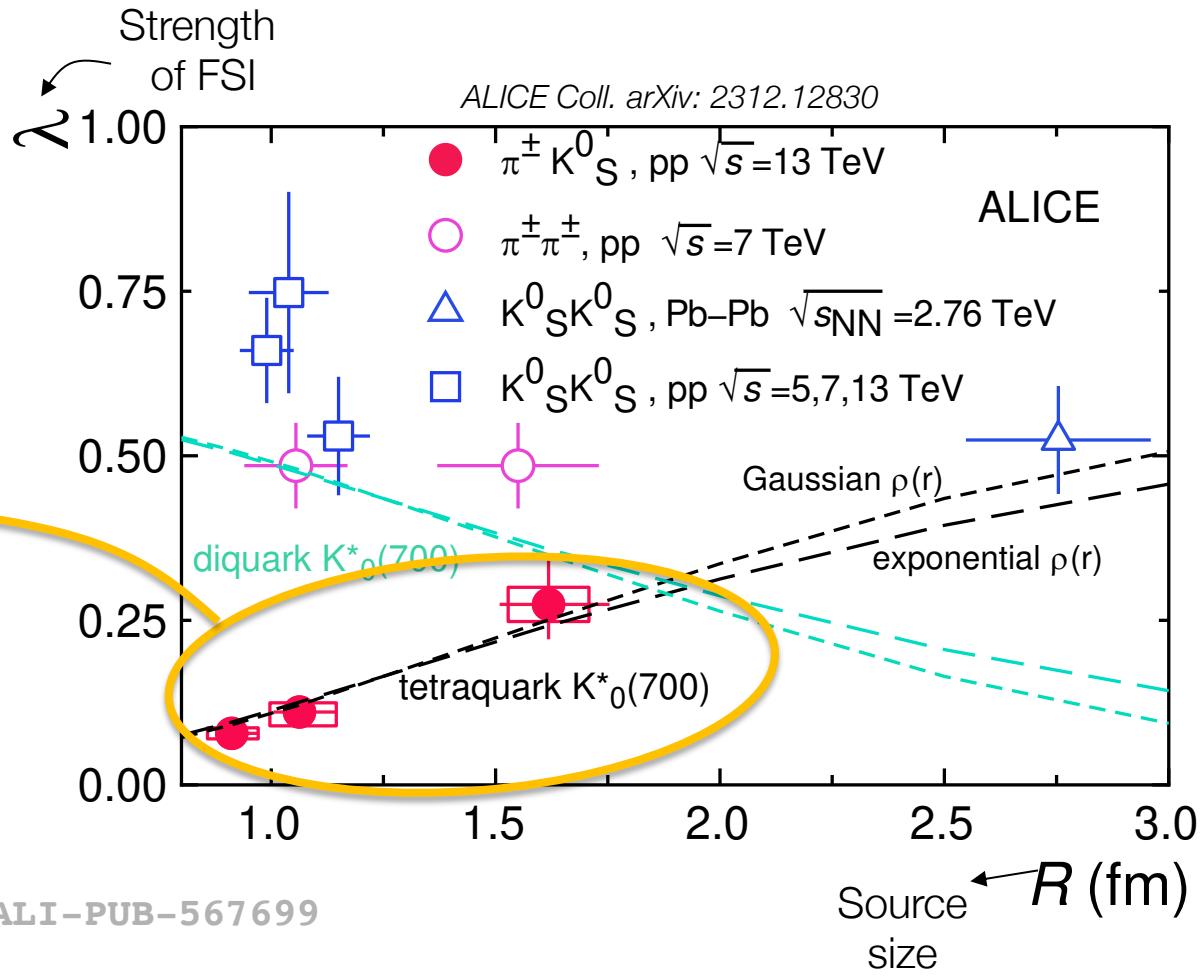
Studying the nature of the $\mathbf{K_0^*(700)}$ state

- Testing conventional or exotic structure of $\mathbf{K_0^*(700)}$
  - probing FSI strength vs source size via a simple geometrical approach

Tetraquark configuration favoured by the data





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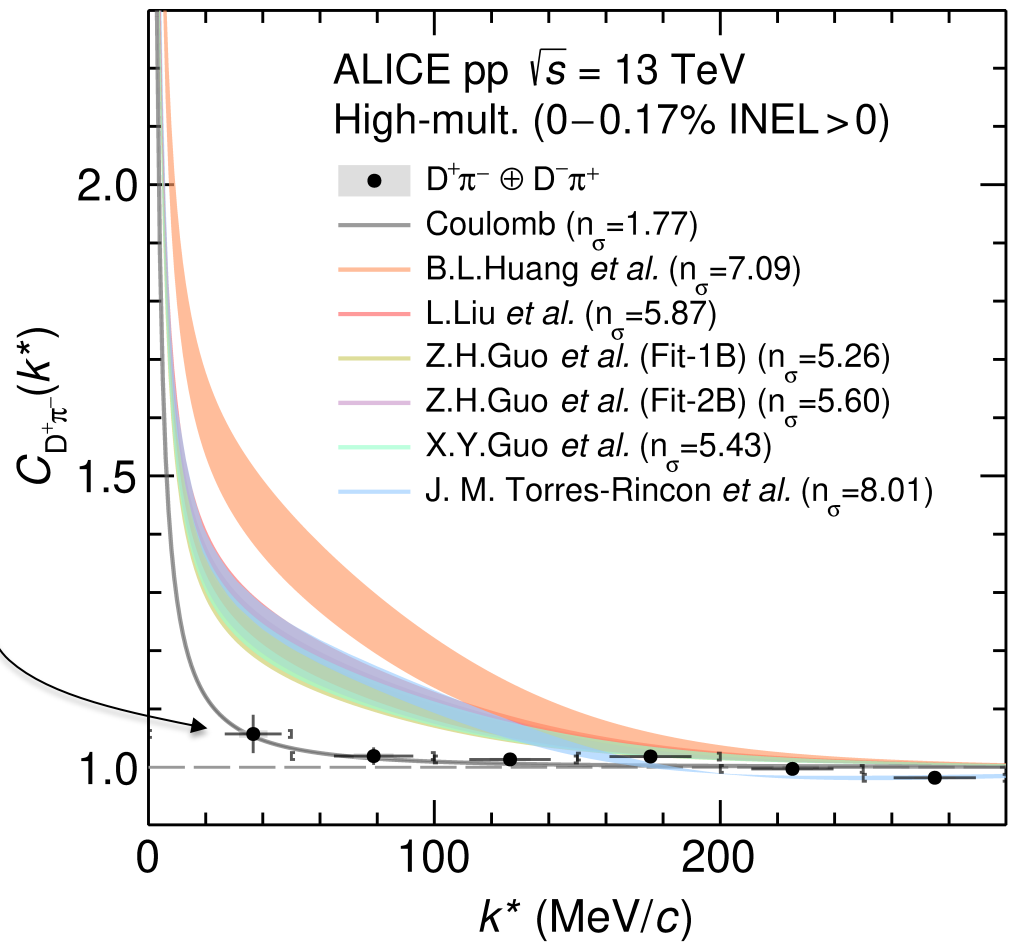
Interaction between charm and light mesons

- **First measurement** of interaction between $(\mathrm{D}, \mathrm{D}^*)$ and (π, K)
  - Predictions of exotic charm states $(D_{s0}^*(2317), D_0^*(2300))$
  - Heavy-flavour dynamics in hadronic phase of heavy-ion collisions
- Data well reproduced by **Coulomb-only attraction**

Shallow strong interaction between charm and light mesons

$D^+\pi^-$ correlation function



ALICE Coll. arXiv: 2401.13541

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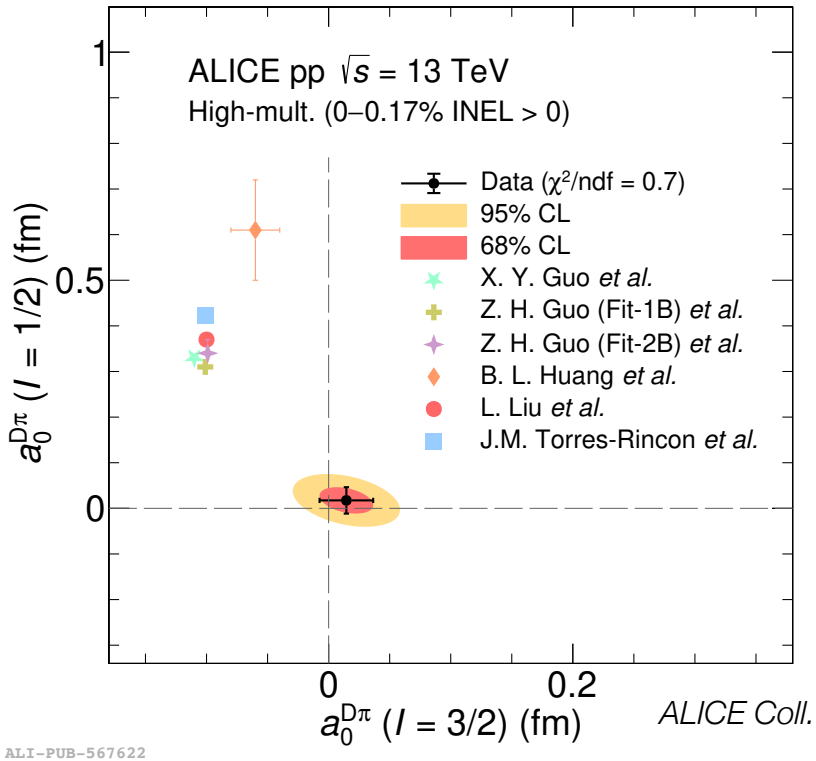
Measuring the scattering length for Dπ and D*π systems

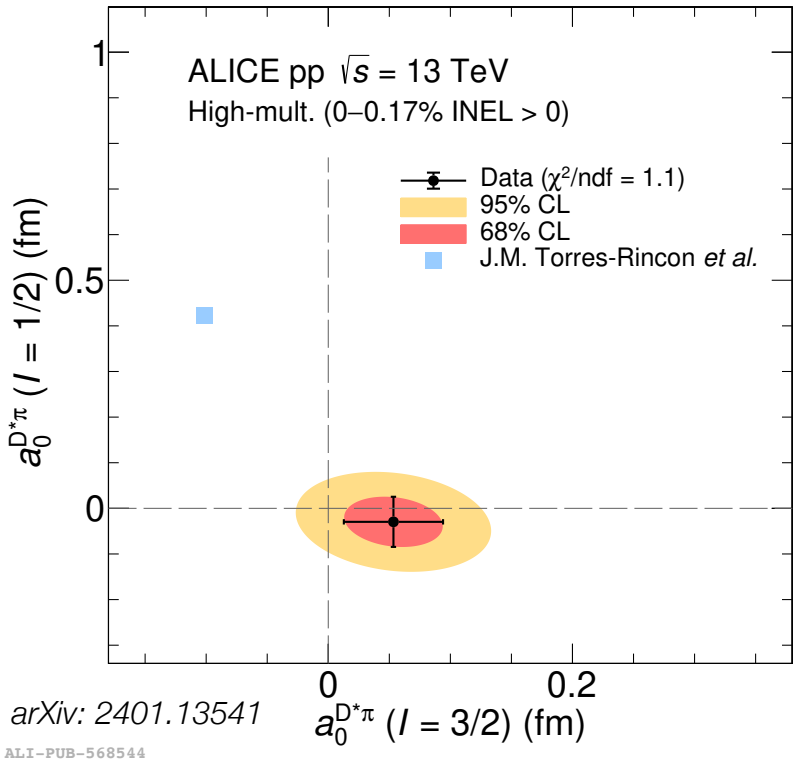
- Extracted **scattering lengths compatible with zero**
  → No influence of the hadronic phase on heavy-flavour observables in heavy-ions
- Tension with available theoretical models
  → Novel possibility to constrain effective QCD models in the charm sector!

Dπ system



ALI-PUB-567622

D*π system



ALI-PUB-568544

ALICE Coll. arXiv: 2401.13541

First experimental constraints available for D$^{(*)}$ - light mesons dynamics

To be continued with more charming correlations in ALICE 3
ALICE 3 LOI, CERN-LHCC-2022-009

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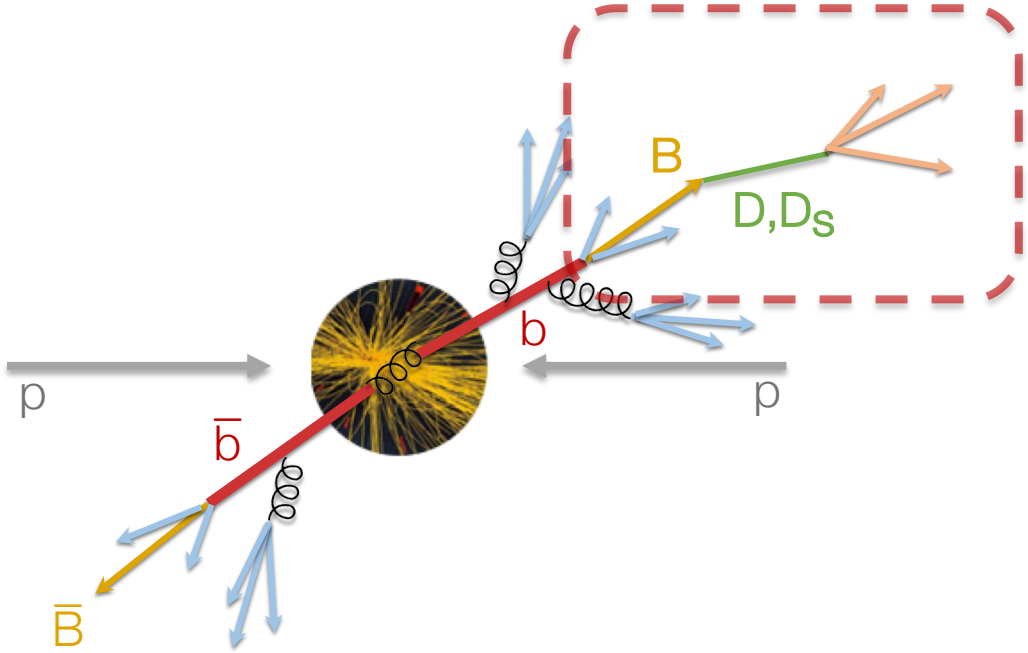
Studying beauty-hadron production in pp collisions

- Understanding how heavy-flavour hadrons are produced in pp collisions
  - Testing perturbative QCD calculations
  - Reference for similar measurements in heavy-ions
- Use of non-prompt D mesons as proxy to access beauty-hadron production in pp



How does the hadronization process of heavy-quarks depend on the collision system?

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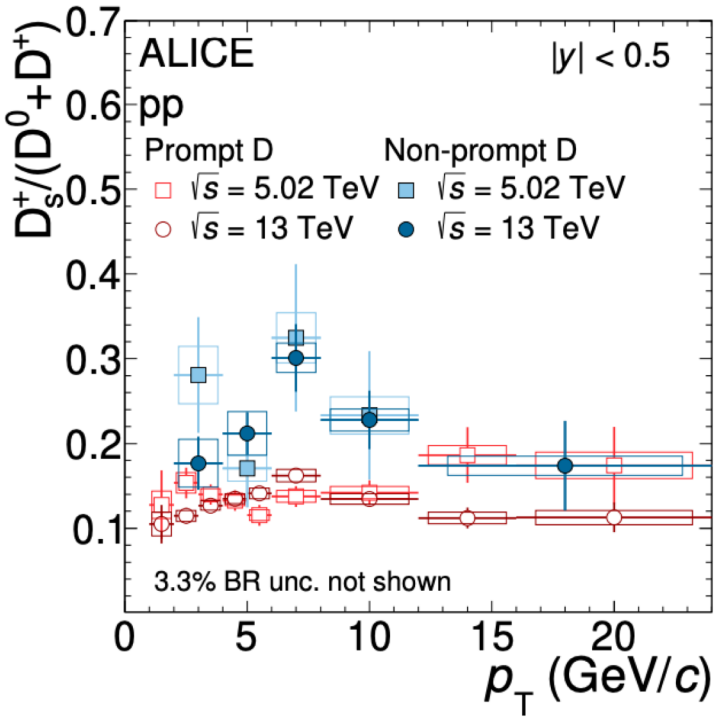
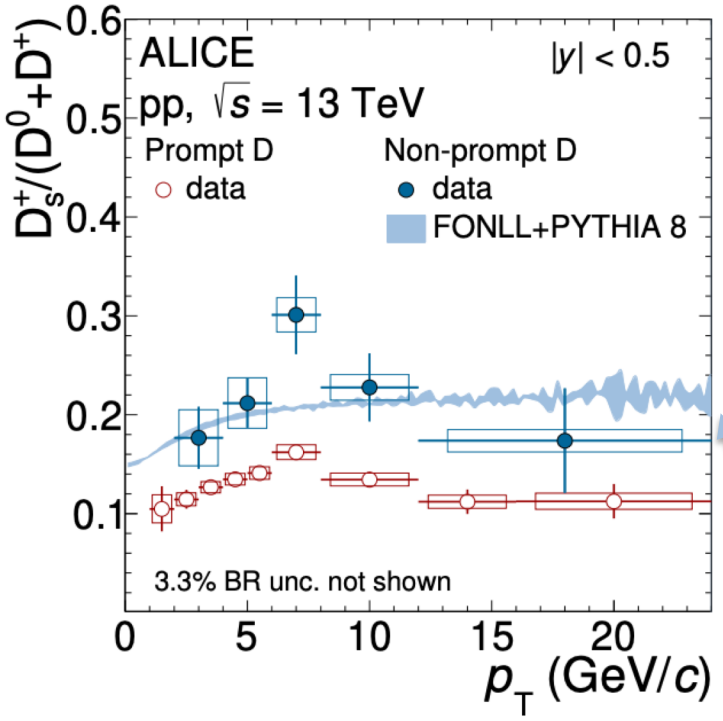
Studying beauty-hadron production in pp collisions

- Measurement of **production cross-sections** of <u>non-prompt</u> D^0, D^+, D_S^+ from beauty hadrons in pp 13 TeV



No dependence on collision energy



Compatible with predictions constrained to e^+e^- collisions

Strange/non-strange fraction of heavy-quarks hadronizing into mesons independent of collision system

ALICE Coll. arXiv: 2402.16417

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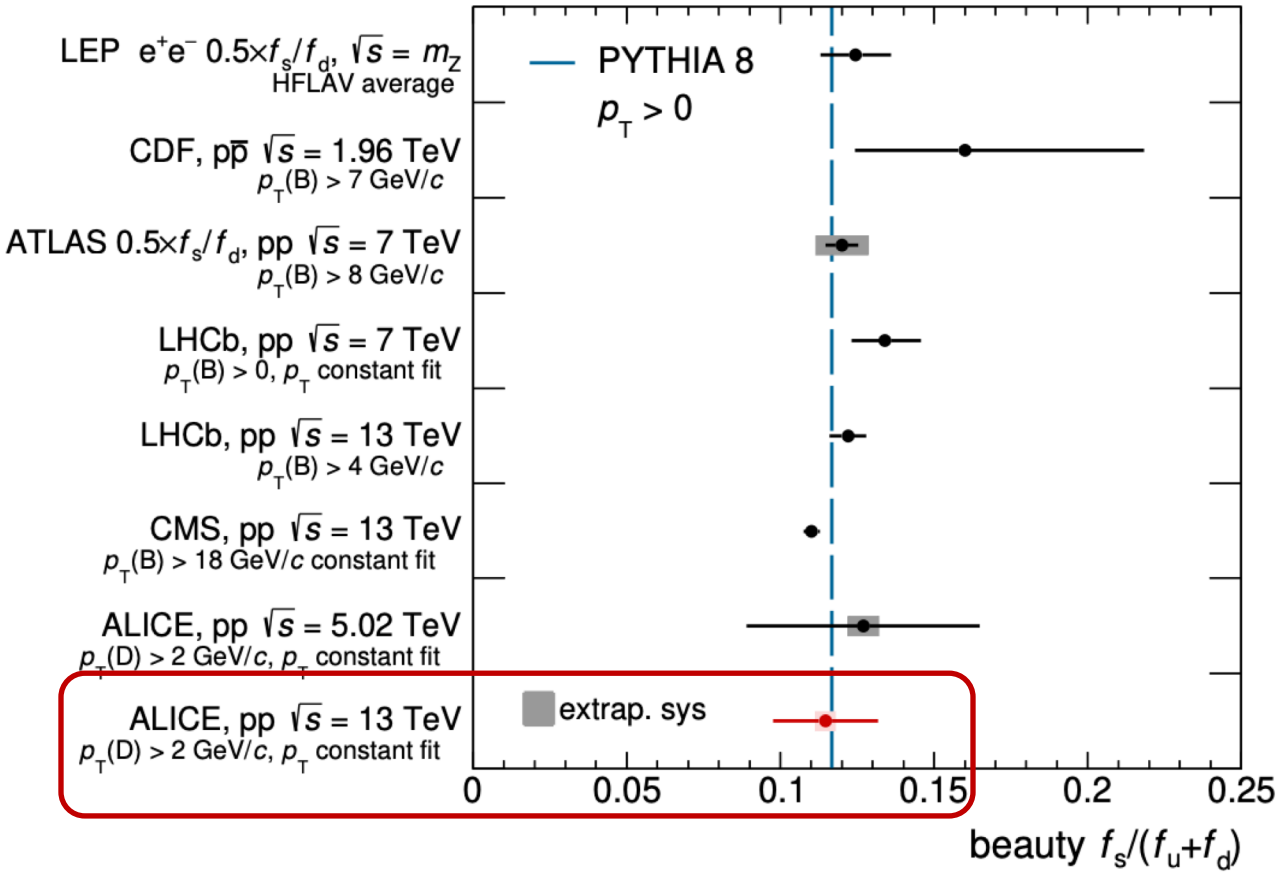
Fragmentation of b-quarks into B-mesons in pp 13 TeV

$$\left(\frac{f_s}{f_u + f_d}\right)_{\text{beauty}} = 0.114 \pm 0.016\ (\text{stat.}) \pm 0.006\ (\text{syst.})$$



ALICE Coll. arXiv: 2402.16417

- Higher precision achieved in pp 13 TeV
- Compatible results amongst different collisions systems and energies
- In agreement with similar measurements performed in the charm sector
  ALICE Coll. JHEP 12 (2023) 042

Universality of heavy-quarks fragmentation into strange/non-strange B,D mesons

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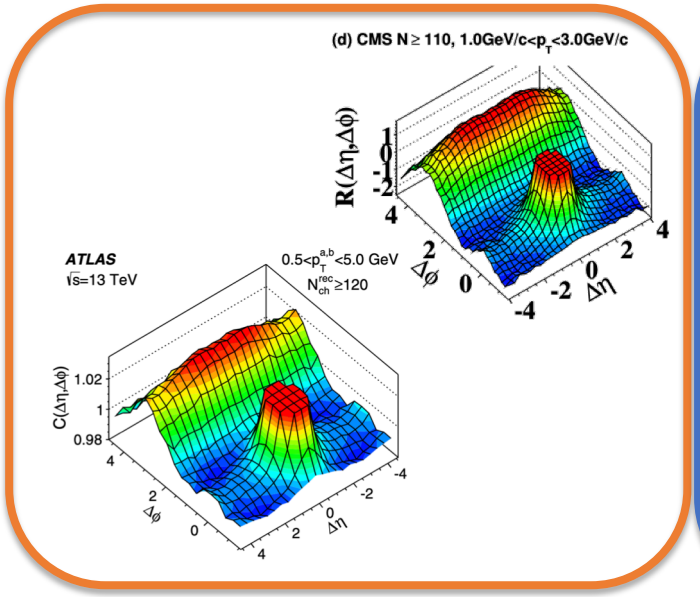
Investigating quark-gluon plasma effects in pp collisions

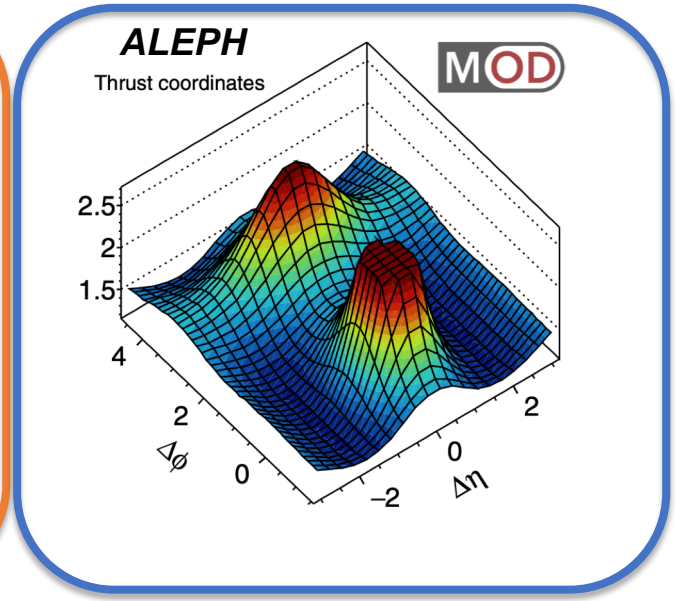
- Several signatures in HICs for QGP:
  - Focus on long-range angular correlations, jet quenching
- Some observed also in smaller systems
  - Long-range correlations in pp collisions at high-multiplicity, pA,..

CMS Coll., JHEP 09 (2010) 091
ATLAS Coll., Phys.Rev.Lett. 116 (2016) 17, 172301

pp



e^+e^-



Produced in initial state or later due to interaction with a strongly-coupled medium?

- Not observed in e^+e^- collisions, no QGP
  ALEPH Coll., Phys.Rev.Lett. 123 (2019) 21, 212002
- Need more precise measurements in pp collisions at low multiplicity

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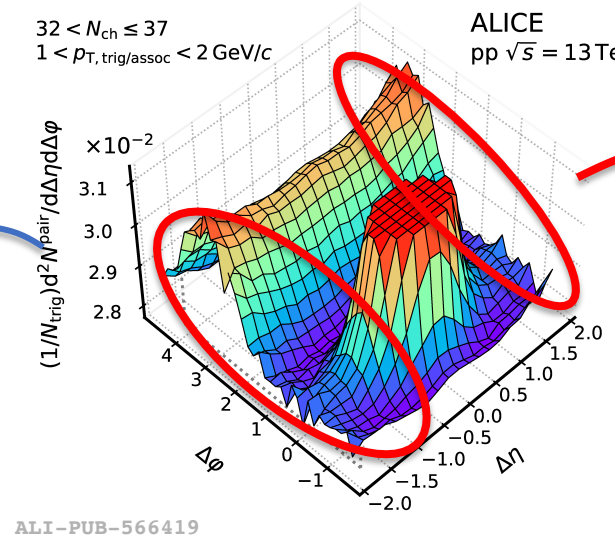
Measuring the ridge in low-multiplicity pp collisions

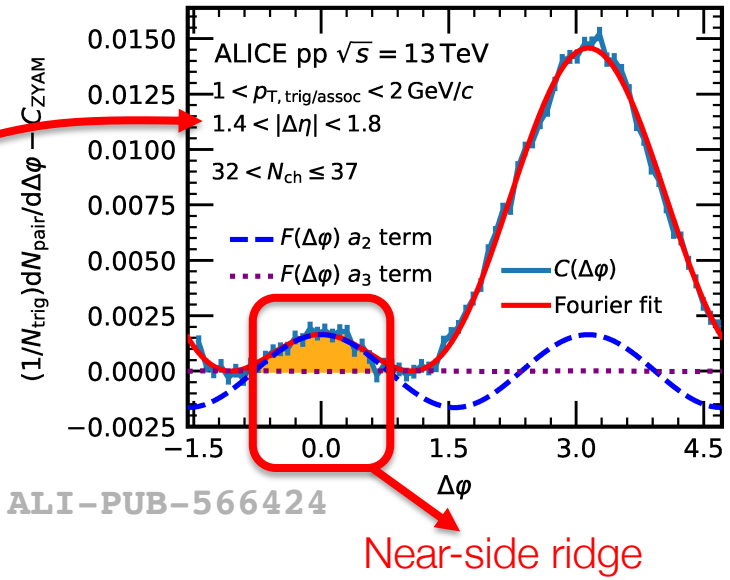
ALICE Coll. arXiv:2311.14357

- Precise measurements of ridge yields in pp 13 TeV down to low multiplicities

Two-particle azimuthal correlation
$|\eta|<1.0$, $p_T > 0.2$ GeV/c

$$\frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}^2 N_{\mathrm{pair}}}{\mathrm{d}\Delta\eta\,\mathrm{d}\Delta\varphi}$$





Near-side ridge

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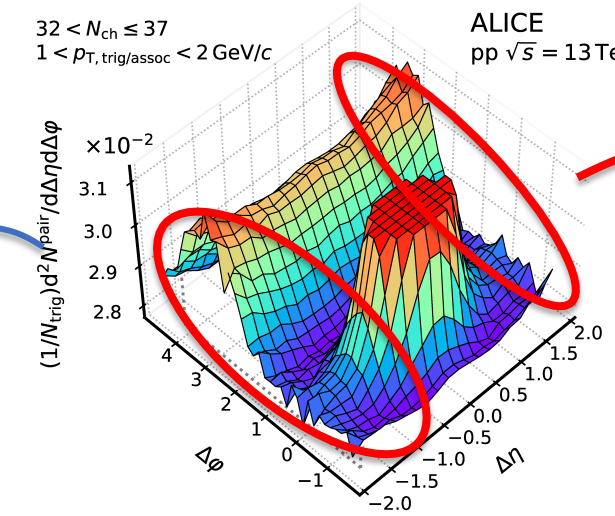
Measuring the ridge in low-multiplicity pp collisions

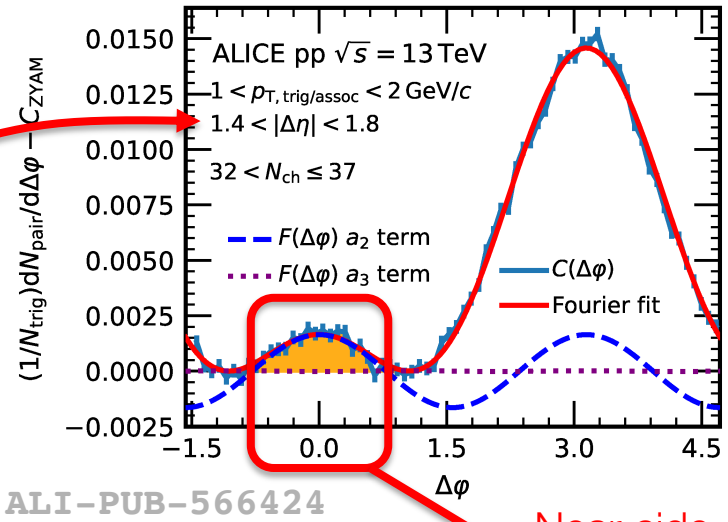
- Precise measurements of ridge yields in pp 13 TeV down to low multiplicities

Two-particle azimuthal correlation
$|\eta|<1.0$, $p_T > 0.2$ GeV/c

$$\frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}^2 N_{\mathrm{pair}}}{\mathrm{d}\Delta\eta\,\mathrm{d}\Delta\varphi}$$

ALICE Coll. arXiv:2311.14357

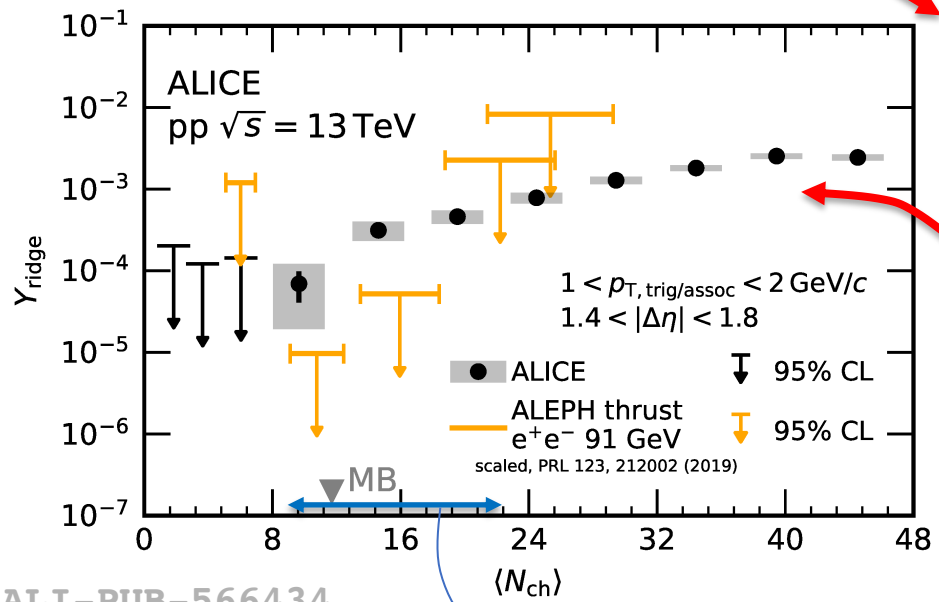




- Ridge yield as a function of multiplicity
  → **Non-zero down to very low multiplicity**

- Comparison with ALEPH e^+e^- results
  → **Larger pp yield observed**

Observing more than initial state effects in pp!



Near-side ridge → Integrating around $\Delta\varphi$=0

Y.-C. Chen et al. arXiv: 2312.05084

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Jet properties in pp collisions

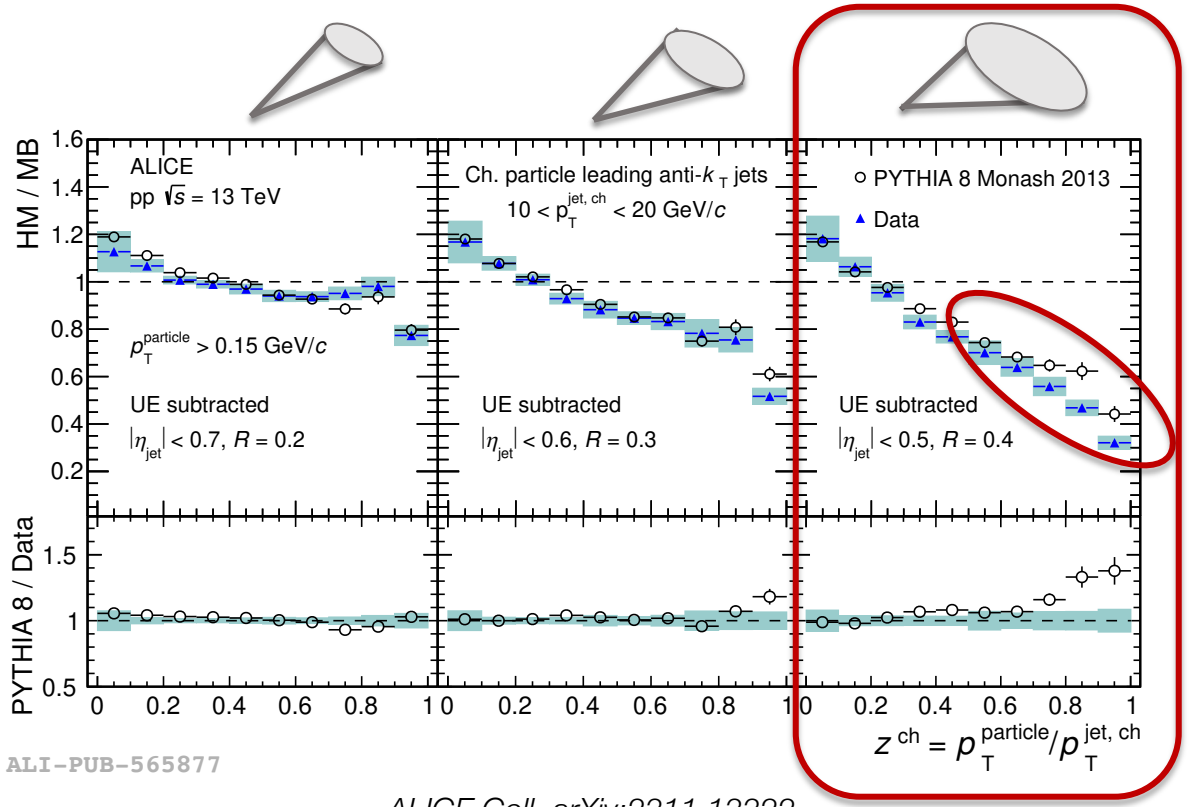
- No conclusive evidence of jet quenching in pp collisions
  → Better understanding of jet fragmentation dynamics

- First measurement of intra-jet properties in pp 13 TeV (MB, HM)
  - three jet-p_T intervals and jet size R

- Difference observed in HM/MB ratio for both fragmentation functions
  - Qualitatively reproduced by PYTHIA 8

- Detailed study in PYTHIA indicates large role played by multiparton dynamics and gluon-initiated jets

High Multiplicity / Minimum Bias



ALICE Coll. arXiv:2311.13322

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Run 3 results

ALICE 1 | ALICE 2 | ALICE 2.1 | ALICE 3

RUN 1 → RUN 2 → RUN 3 → RUN 4 → RUN 5 & 6

2009-2013
pp, p-Pb, Pb-Pb

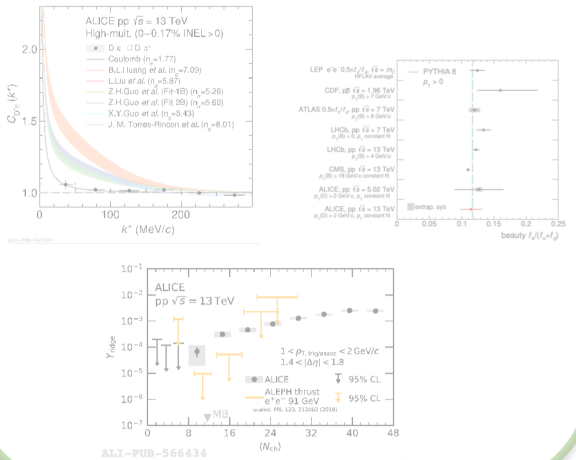
2015-2018
pp, p-Pb, Xe-Xe, Pb-Pb

2022-2025
pp, p-O, O-O, p-Pb, Pb-Pb

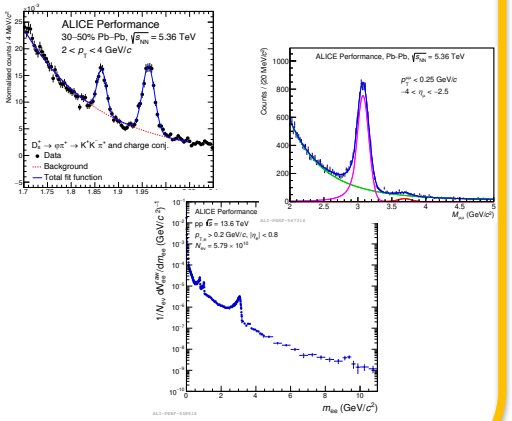
2029-2032
pp, p-Pb, Pb-Pb

from 2035

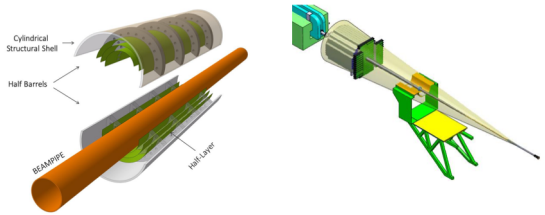
Recent physics publications



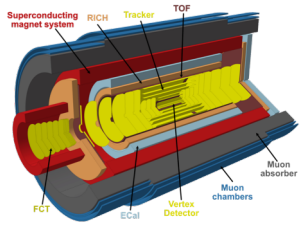
A first look to Run 3



ITS3 and FoCal updates



ALICE 3



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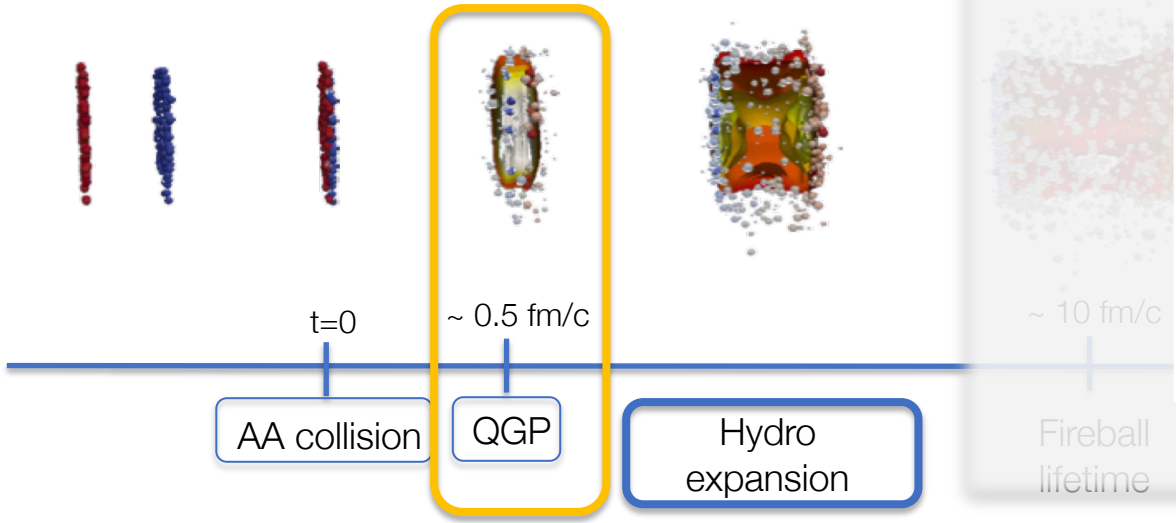
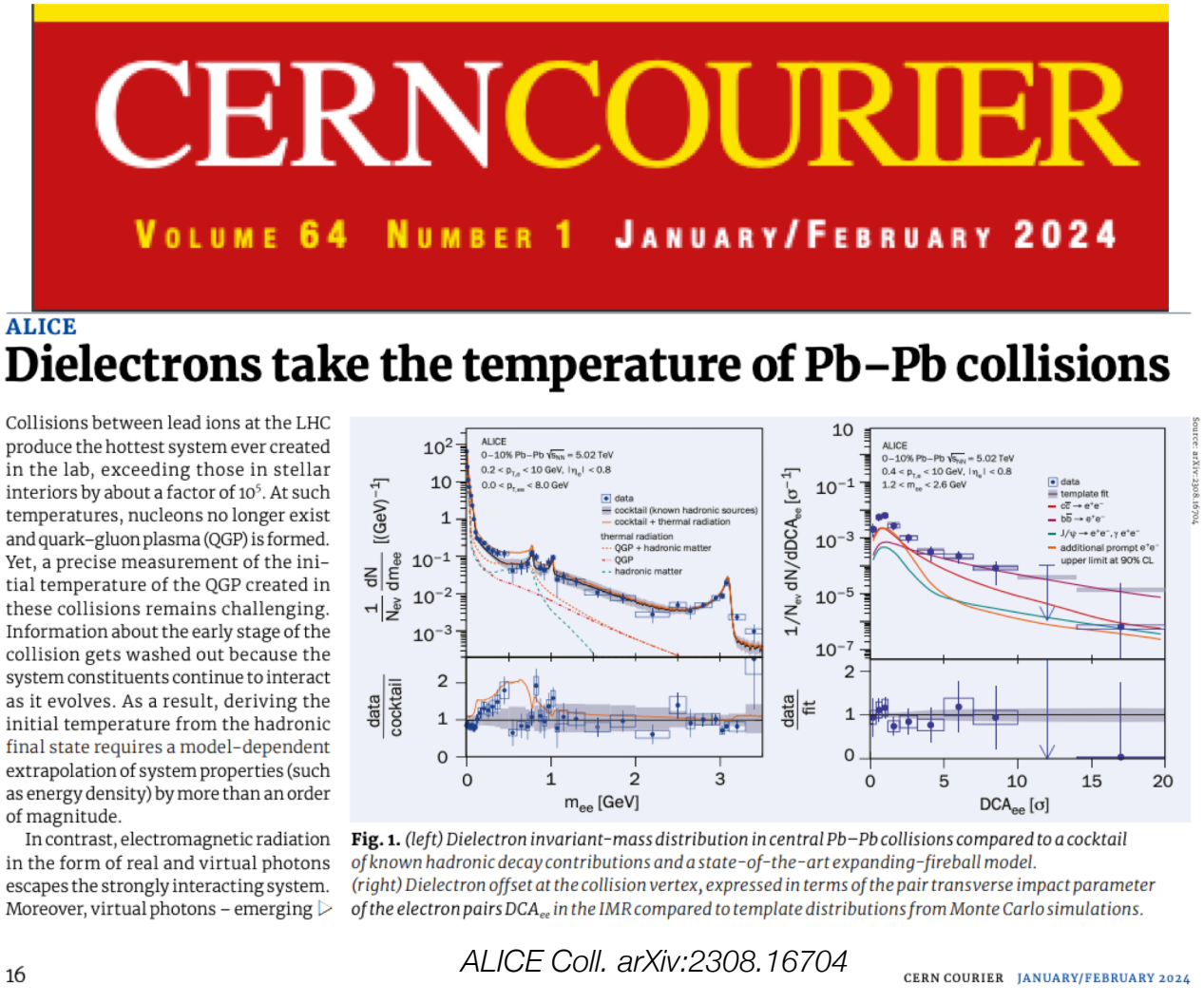
Measuring the QGP temperature with dileptons in Run 3

- Dielectrons spectrum in **intermediate mass region**
  → Perfect probe to extract temperature of QGP
- **Novel approach** based on DCA templates
  → Independent of hadronic cocktail (c, b)
- Thermal contribution isolated at 1σ for now
  → More statistics in Run 3/4!




CERN COURIER

VOLUME 64 NUMBER 1 JANUARY/FEBRUARY 2024

ALICE

Dielectrons take the temperature of Pb–Pb collisions

Collisions between lead ions at the LHC produce the hottest system ever created in the lab, exceeding those in stellar interiors by about a factor of 10^5. At such temperatures, nucleons no longer exist and quark–gluon plasma (QGP) is formed. Yet, a precise measurement of the initial temperature of the QGP created in these collisions remains challenging. Information about the early stage of the collision gets washed out because the system constituents continue to interact as it evolves. As a result, deriving the initial temperature from the hadronic final state requires a model-dependent extrapolation of system properties (such as energy density) by more than an order of magnitude.

In contrast, electromagnetic radiation in the form of real and virtual photons escapes the strongly interacting system. Moreover, virtual photons – emerging ▷

Fig. 1. *(left) Dielectron invariant-mass distribution in central Pb–Pb collisions compared to a cocktail of known hadronic decay contributions and a state-of-the-art expanding-fireball model. (right) Dielectron offset at the collision vertex, expressed in terms of the pair transverse impact parameter of the electron pairs DCA_{ee} in the IMR compared to template distributions from Monte Carlo simulations.*

ALICE Coll. arXiv:2308.16704

Measuring the QGP temperature with dileptons in Run 3

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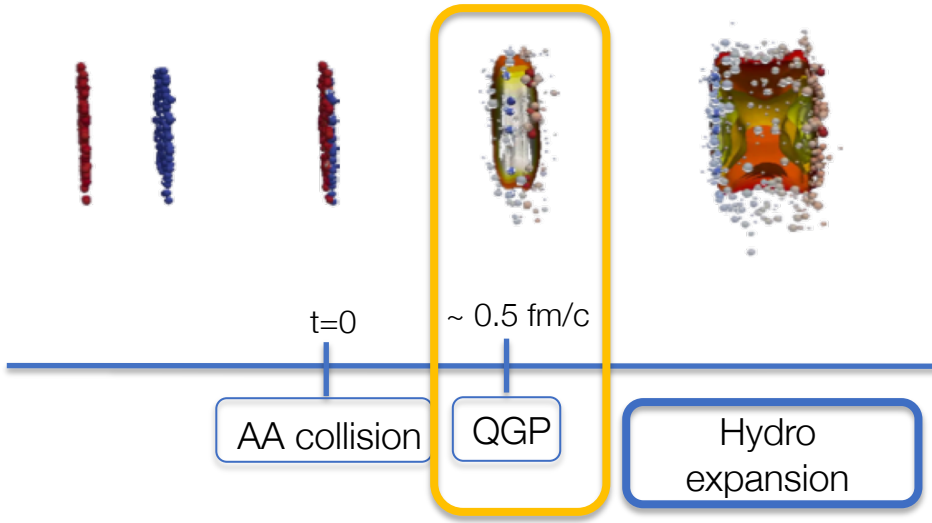
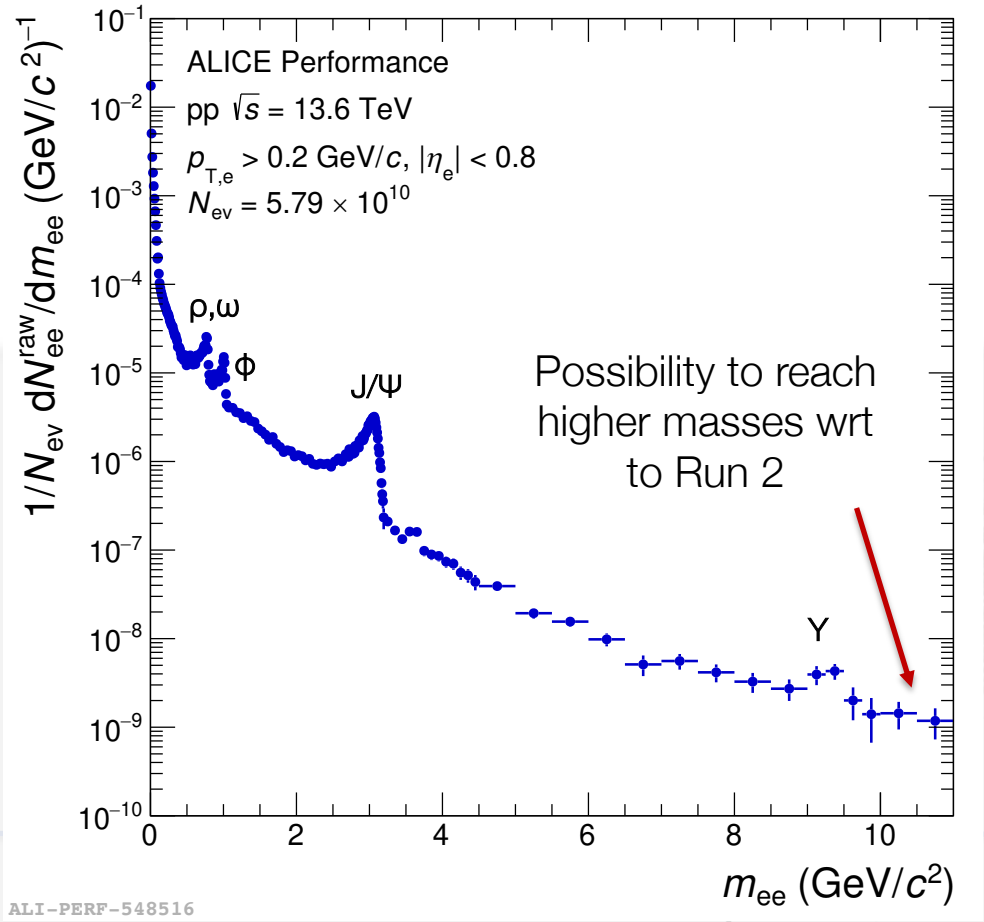


Dielectrons in pp collisions Run 3



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Accessing the internal structure of hadrons in HICs

Accepted Paper

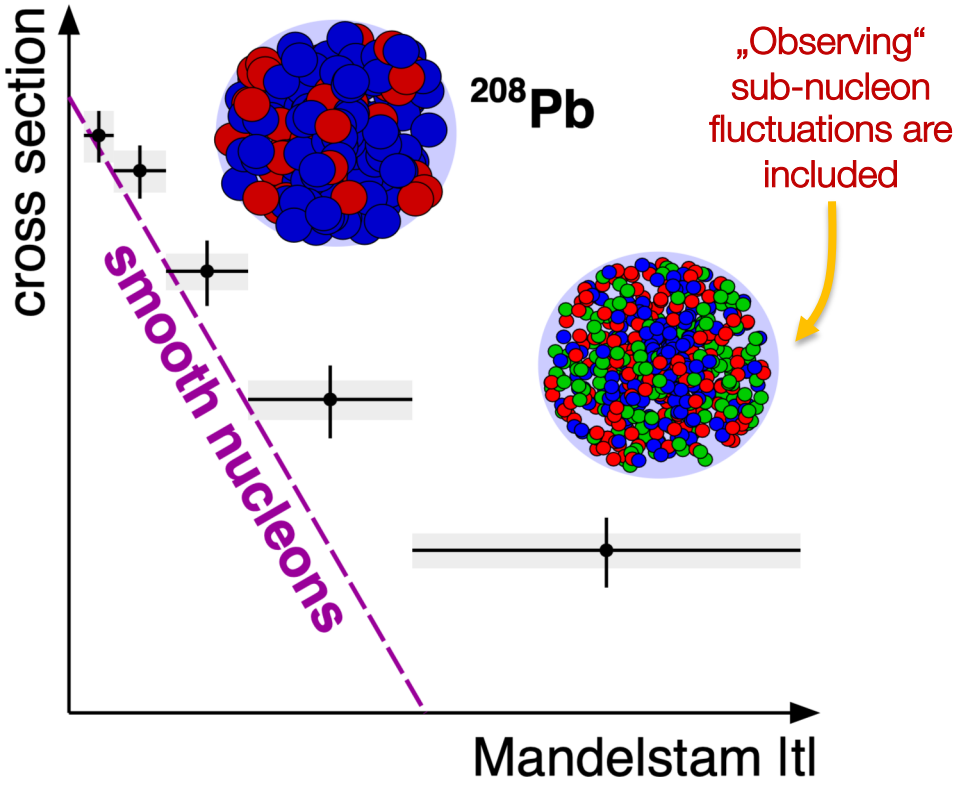
First measurement of the $|t|$ dependence of incoherent J/ψ photonuclear production

Phys. Rev. Lett.

S. Acharya et al.

Accepted 23 January 2024

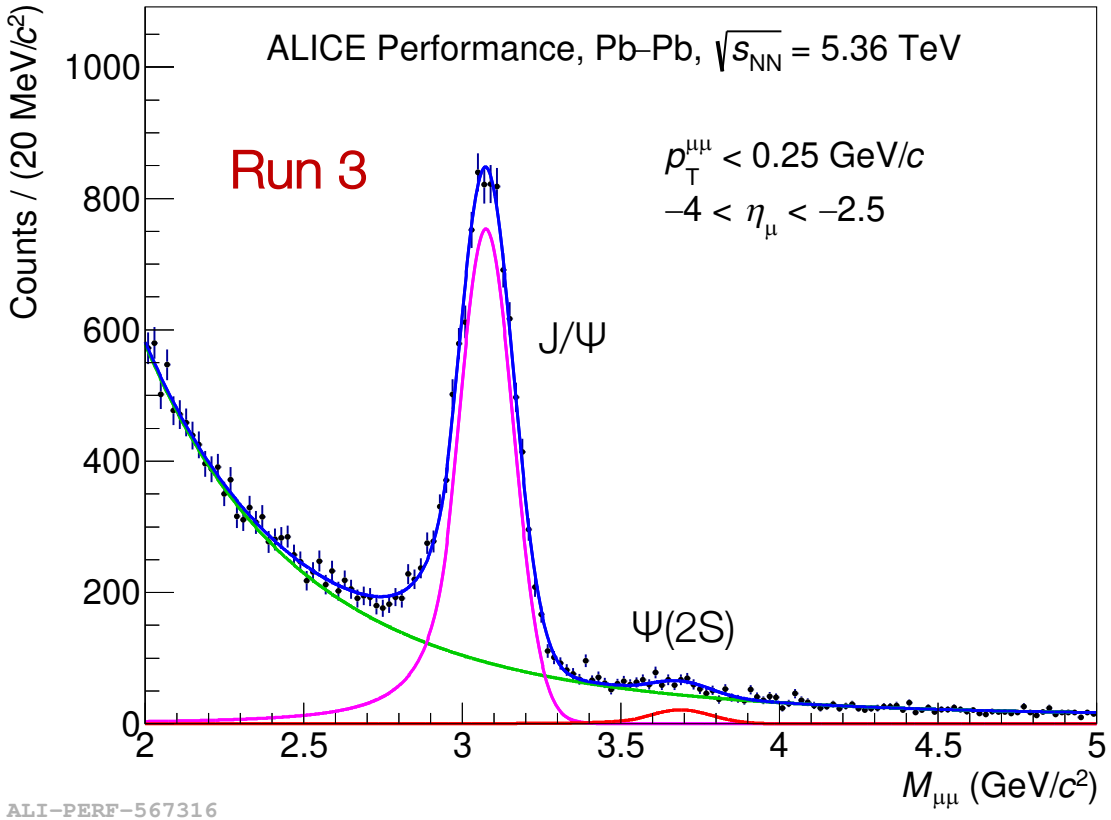
PRL Editor´s suggestion



ALICE Coll. arXiv:2305.06169

To be continued with ultra-peripheral Pb-Pb collisions in Run 3

Selection of coherent J/Ψ in dimuon channel



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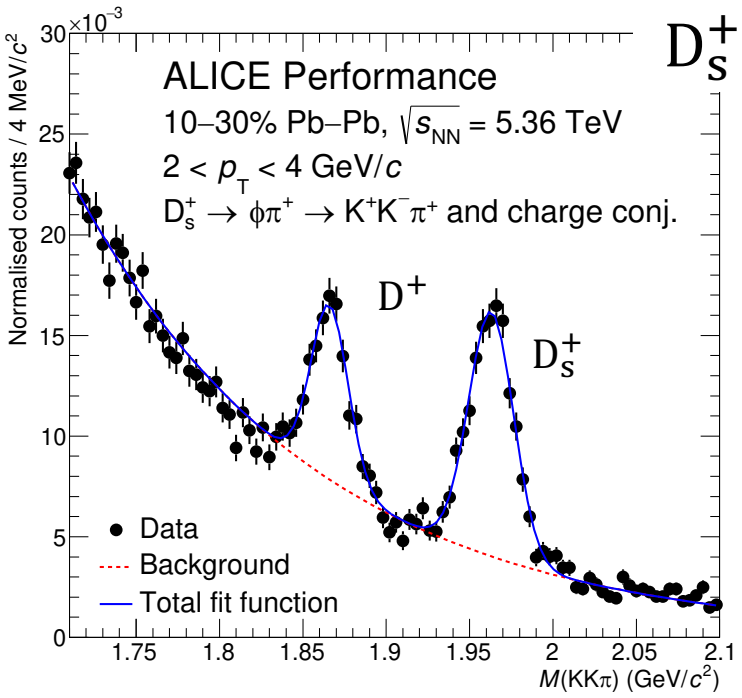
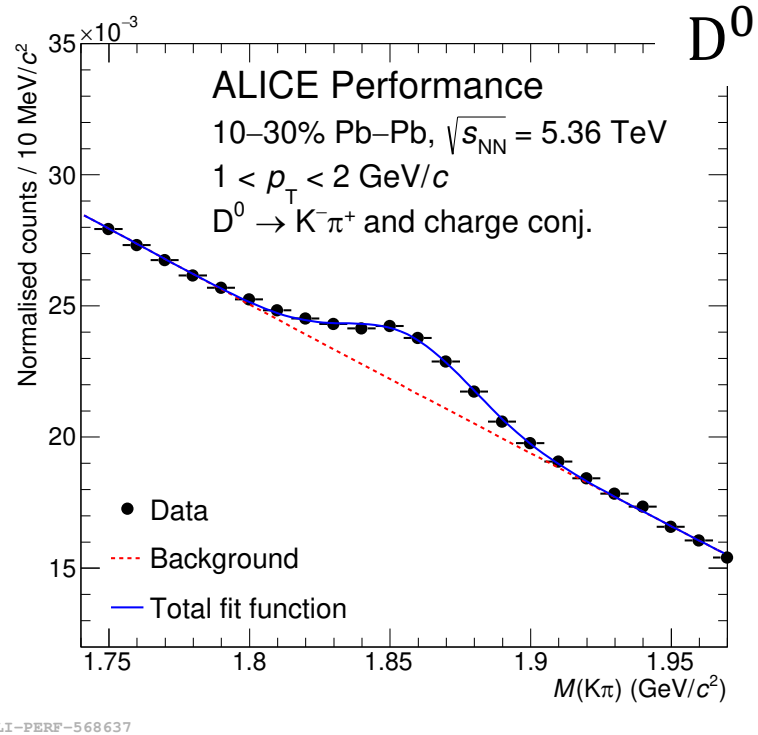
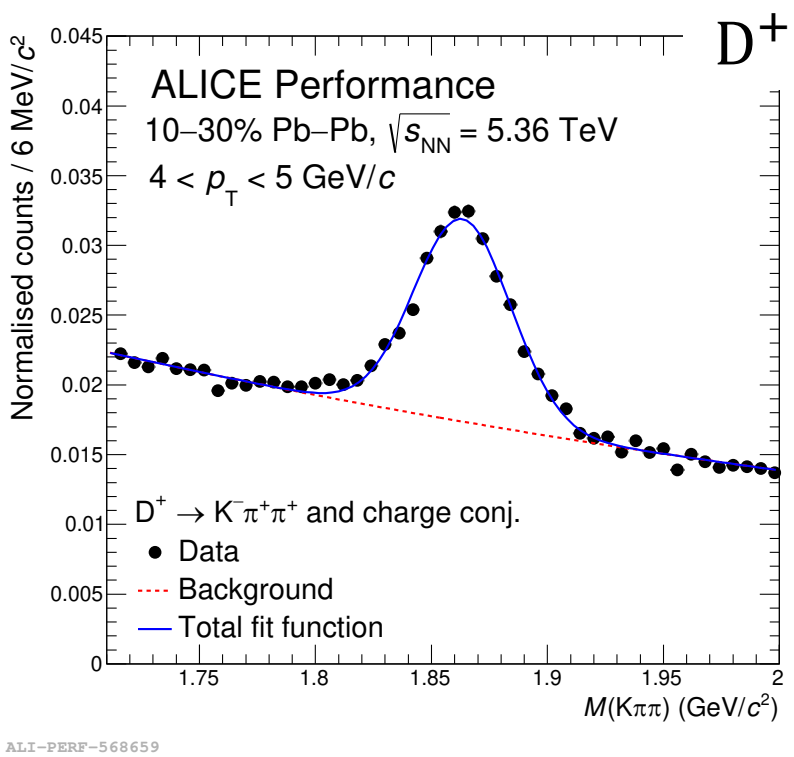
First D mesons signal extraction in Pb-Pb at 5.36 TeV

- Good performance in D-mesons signal extraction in Run 3







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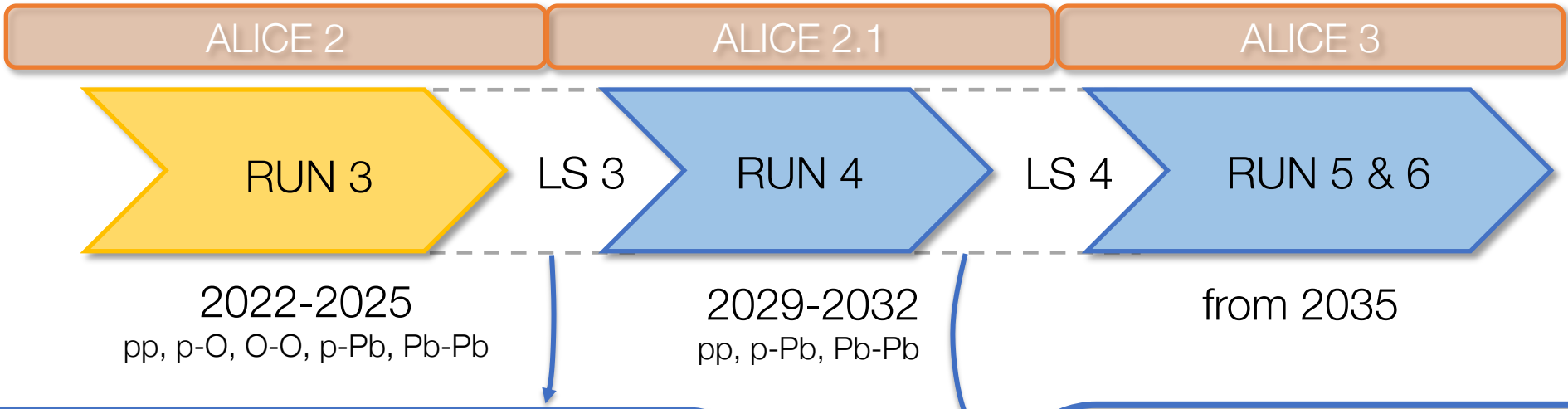
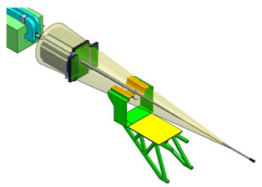
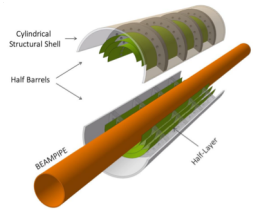
Upgrade results



FoCal and ITS3

- Prototype tests in laboratory and with beam
- Both TDRs completed and reviewed by LHCC referees



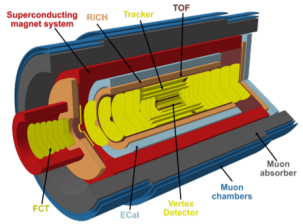


FoCal LoI: [CERN-LHCC-2020-009]

ITS3 LoI: [CERN-LHCC-2019-018]

ALICE 3

- Scoping Document close to completion
- R&D well underway, test beams of prototype sensors



ALICE 3 LoI: [CERN-LHCC-2022-009]

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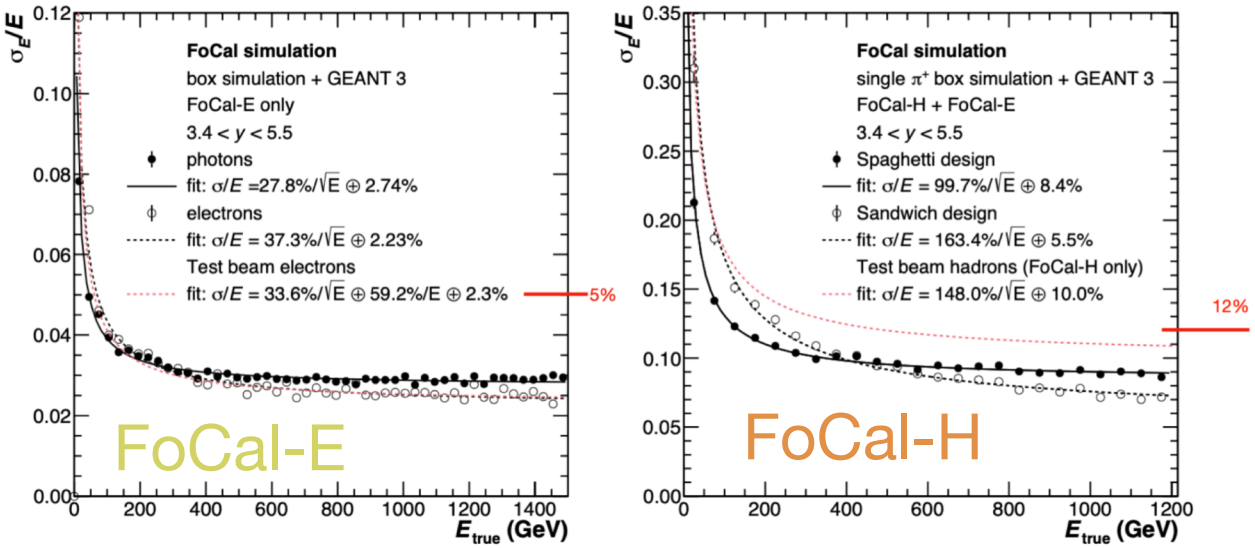
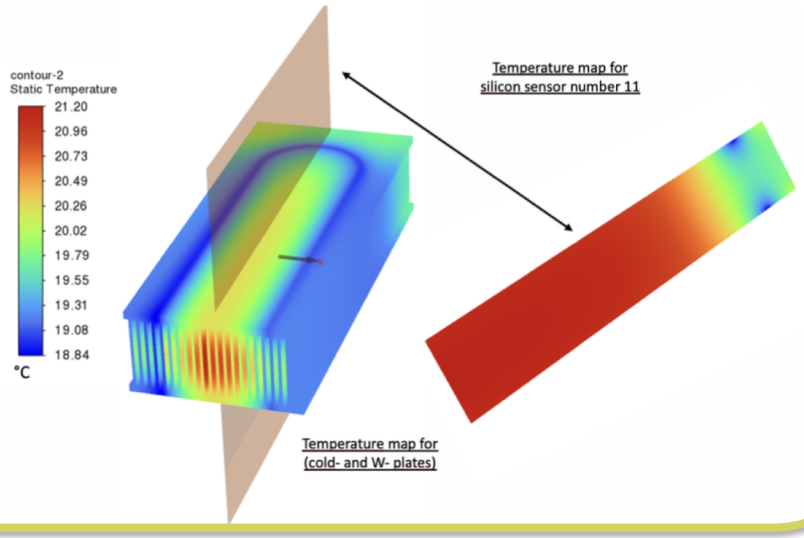
FoCal: from performance to integration



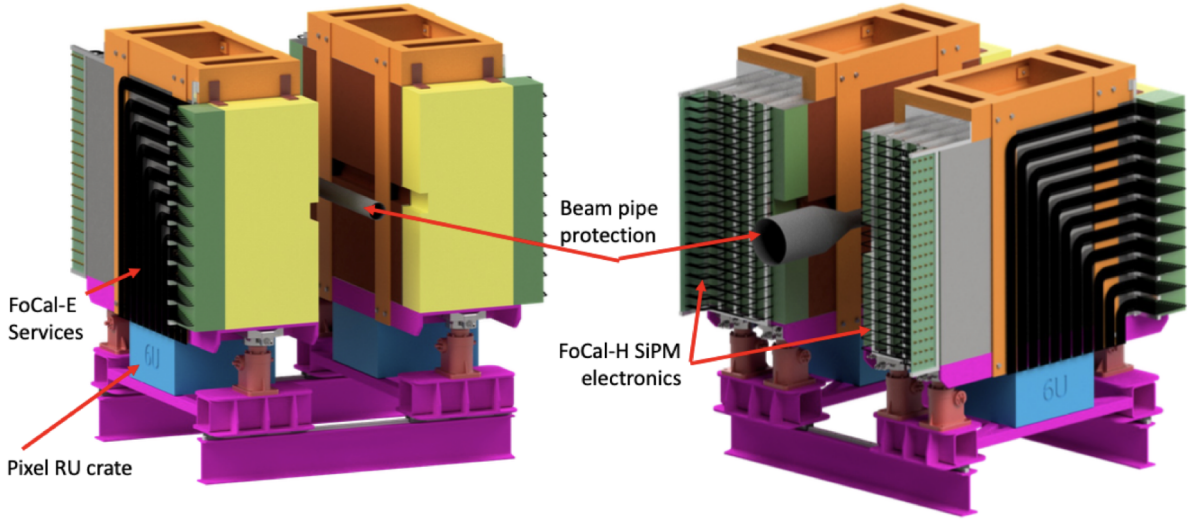
Cooling design for silicon sensors



Energy resolutions within specs from prototype tests in beam

Test-beam paper: https://arxiv.org/abs/2311.07413

Integration studies of FoCal-E and FoCal-H around beampipe at 7<z<8 m (3.2<η<5.6)



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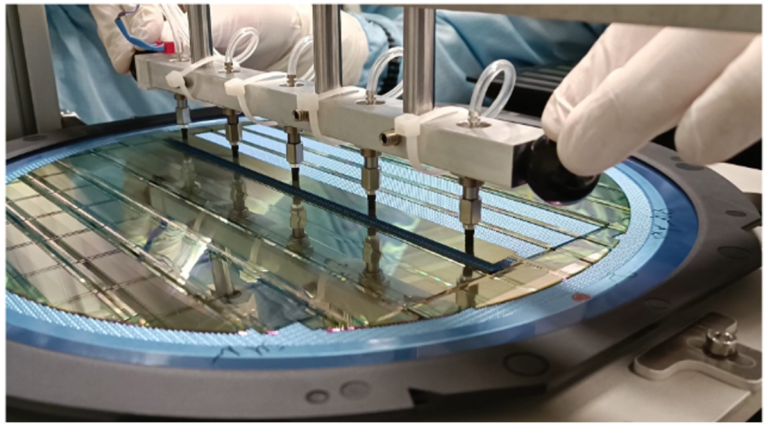
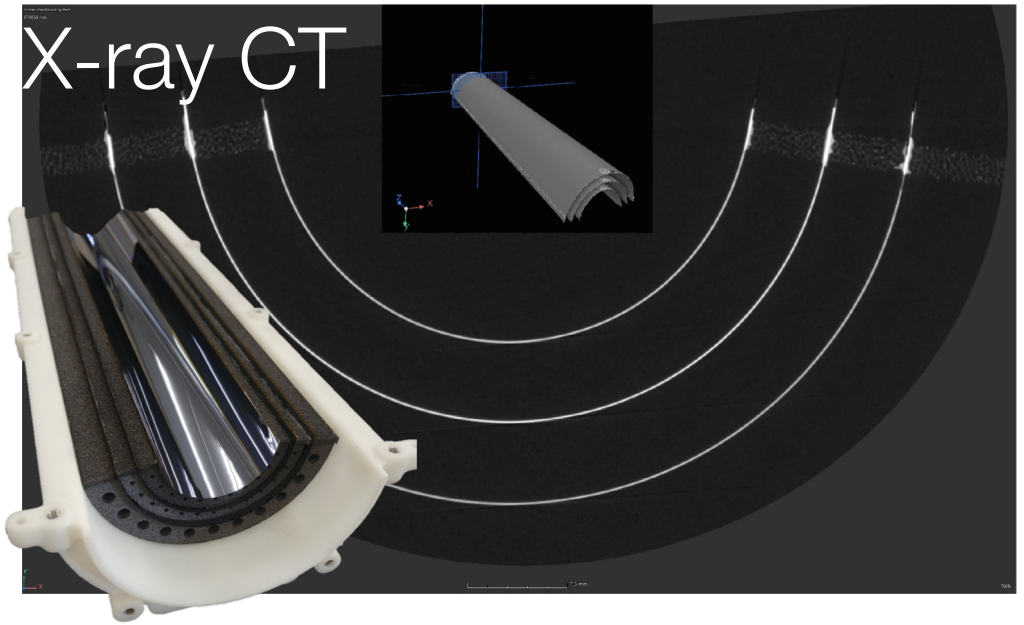
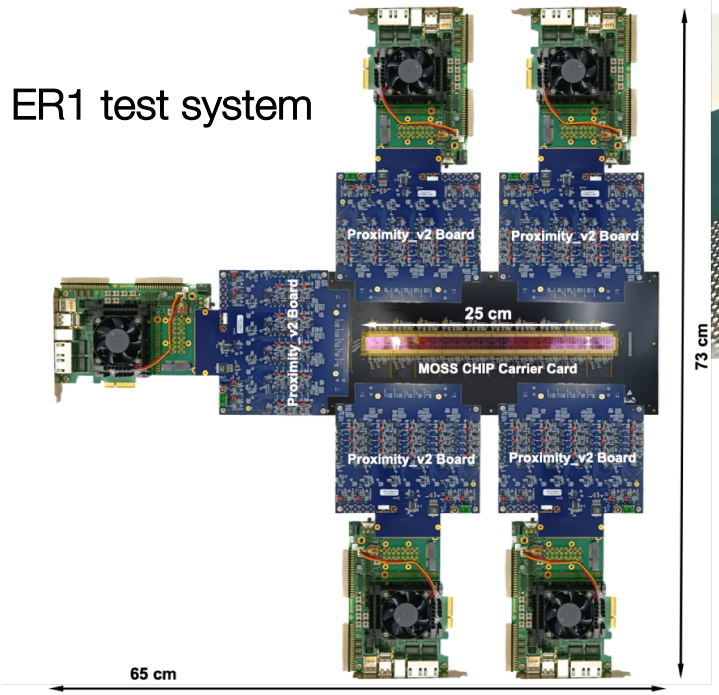
ITS3: from ER1 qualification to integration

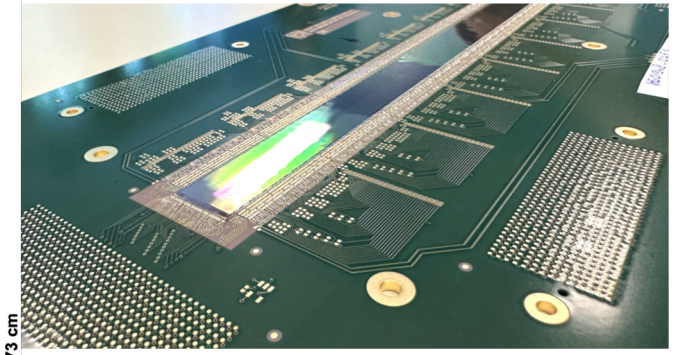


ER1 MOSS test in progress

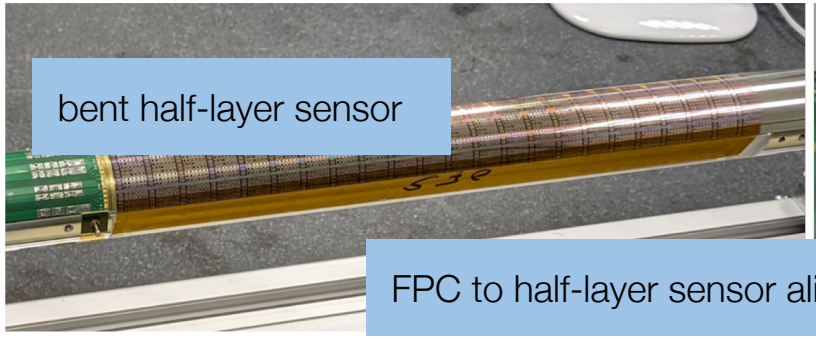
- from ER1 yield estimate: full production, including one spare barrel, with 18 wafers (plan to produce 50 wafers)
- defined specifications for MOSAIX (ER2 ASIC)

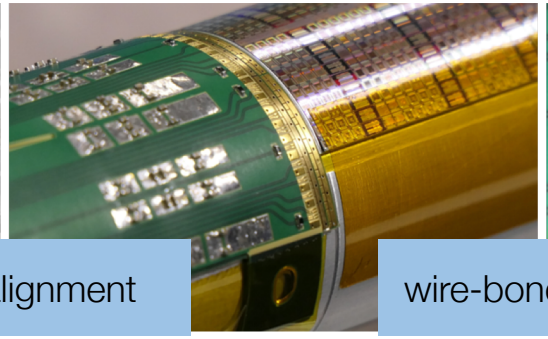


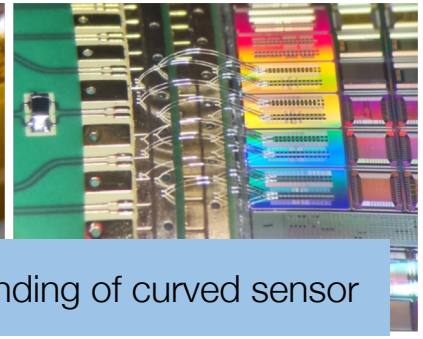




Finalized mechanical support structure design (carbon foam half-rings) and half-layer assembly (gluing + interconnection)







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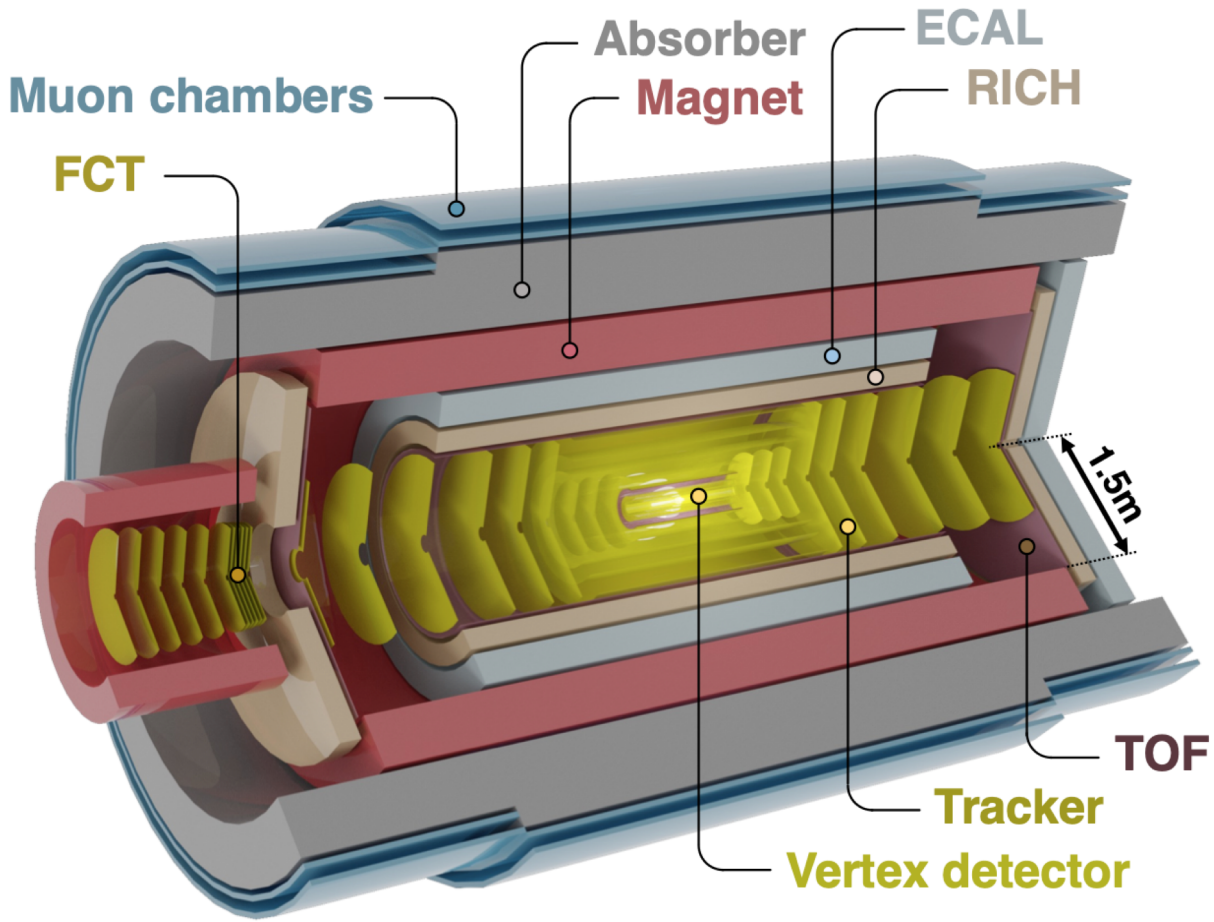
ALICE 3 detector for Runs 5-6

Novel detector concept

- Compact and lightweight all-silicon tracker
- Retractable vertex detector with R_{min}= 5 mm
- Extensive particle identification
- Large acceptance $|\eta|<4$
- Superconducting solenoid, B = 2 T
- Continuous read-out and online processing

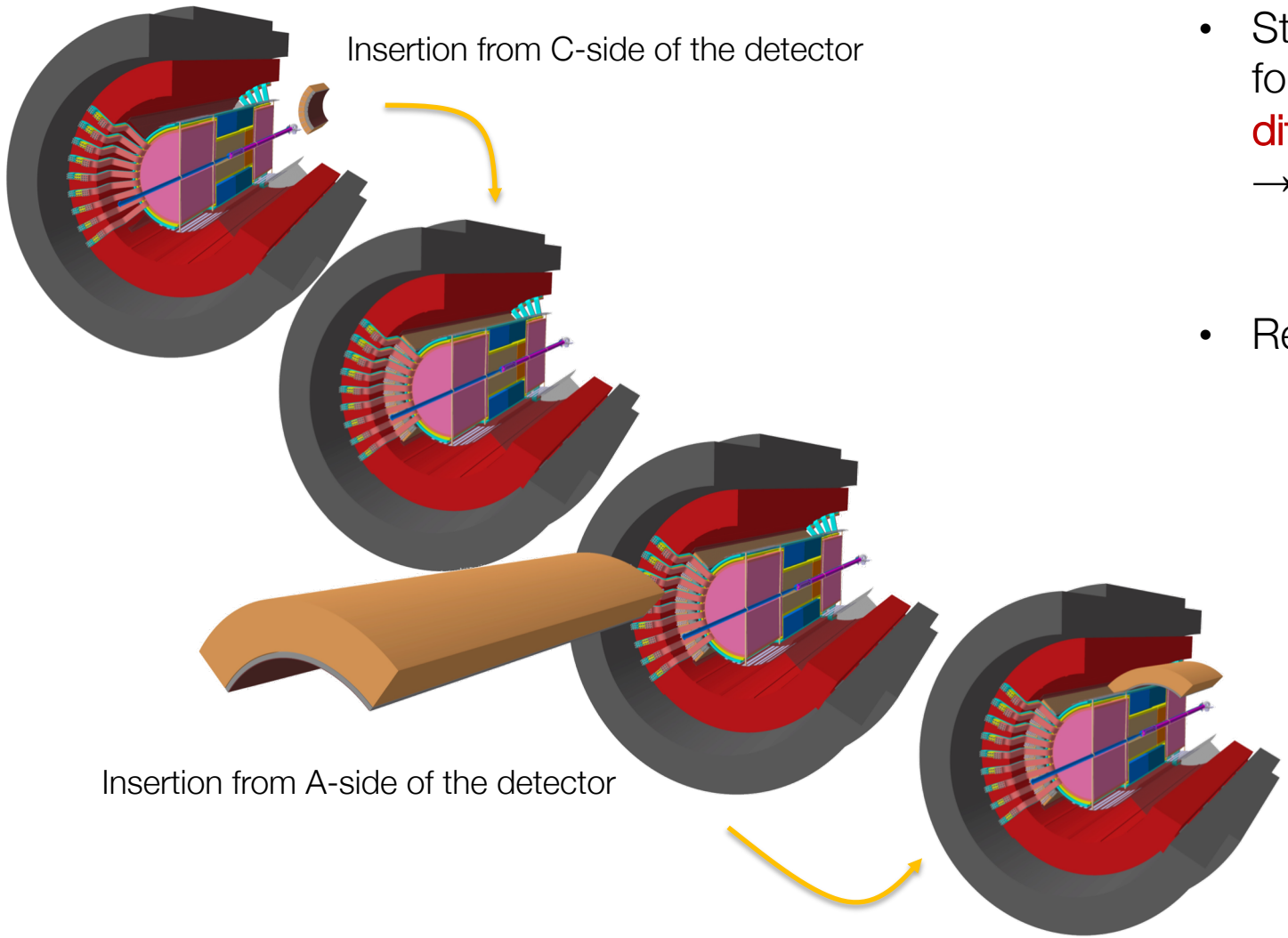
Scoping Document in preparation

- Definition of reference configuration
- Scoping options: without ECal, reduced magnetic field (1 T)
- Detailed assessment of resources and schedule



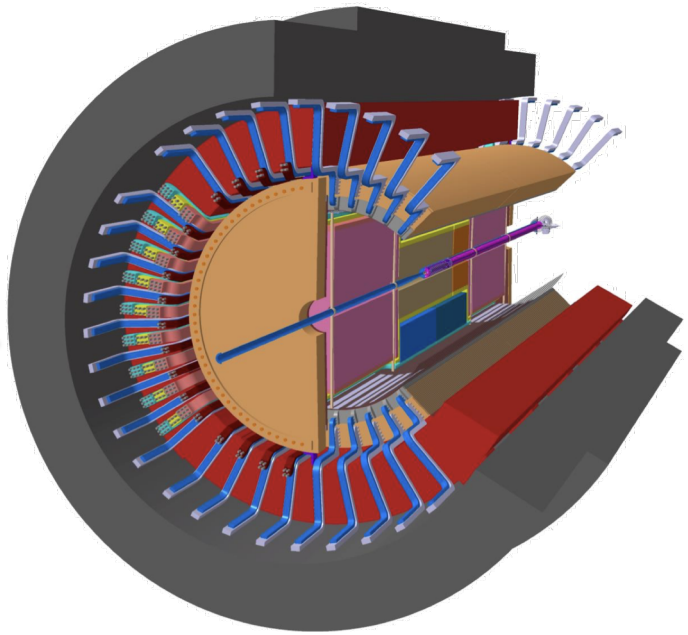
ALICE 3 LOI: arXiv:2211.02491

ALICE 3: integration studies



- Study of **integration scheme** with layout allowing for modular and independent installation of different detectors
  → Tracker endcaps, RICH and TOF barrels, RICH and TOF endcaps
- Reduces impact of delays on LS4 schedule

All services installed



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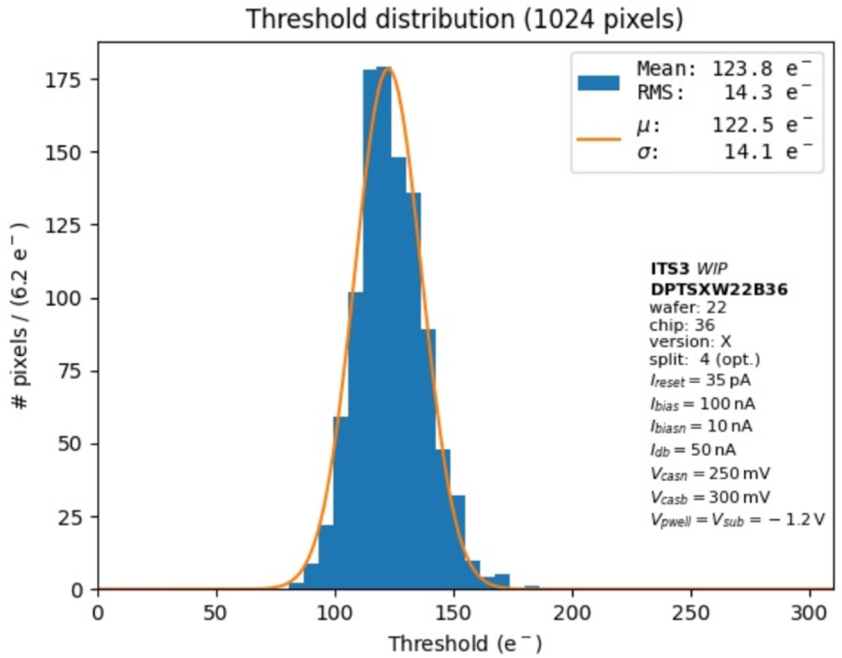
R&D for Tracker

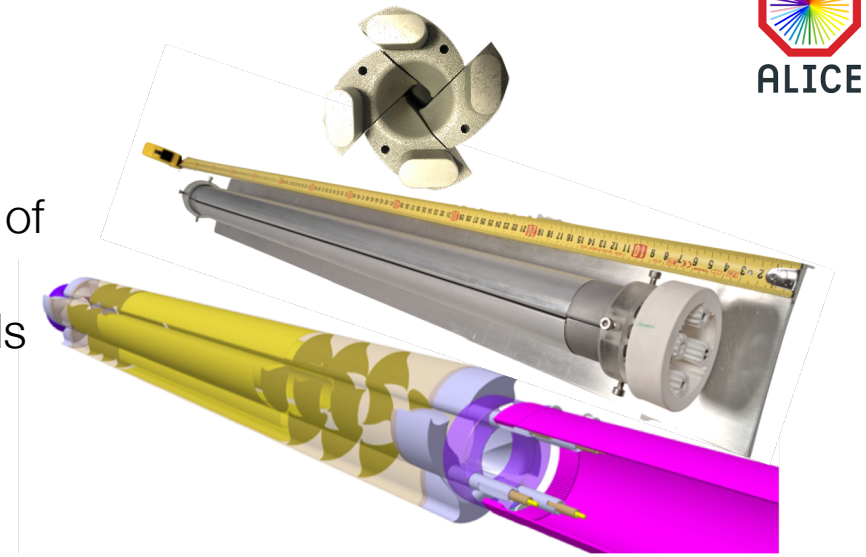
Pixel Sensors with 65nm technology (ITS3 → ALICE 3 R&D):

- Test of small-scale ITS3 prototype sensors at -10° C and -20° C
- Operational for a NIEL radiation load of $2x10^{15}$ 1 MeV n_{eq}/cm^2 (1/5 of ALICE 3 Vertex Detector spec)



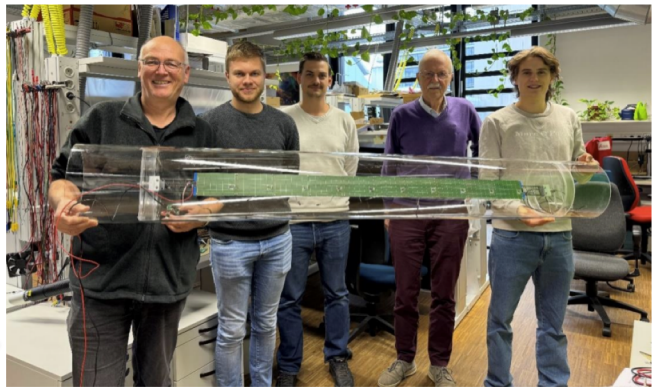
Full-scale mechanical models of Iris Vertex Detector

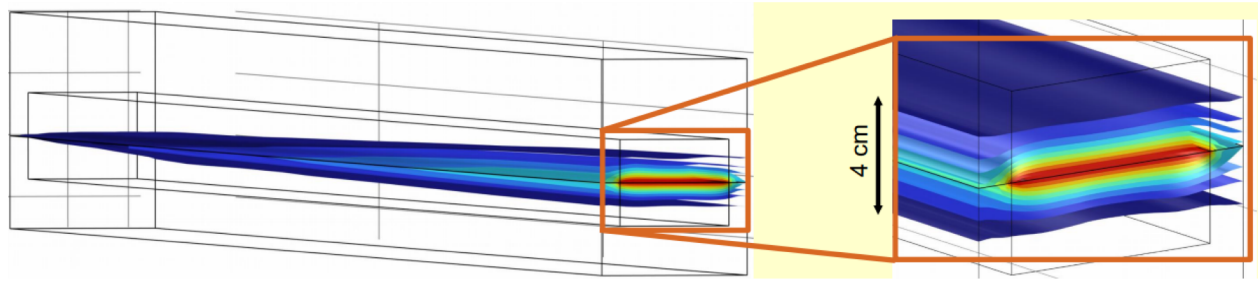
- 3D-printed aluminium petals
- 0.5 mm wall thickness



Full-scale mock-up of Outer Tracker stave

- cooling studies
- mechanical support studies





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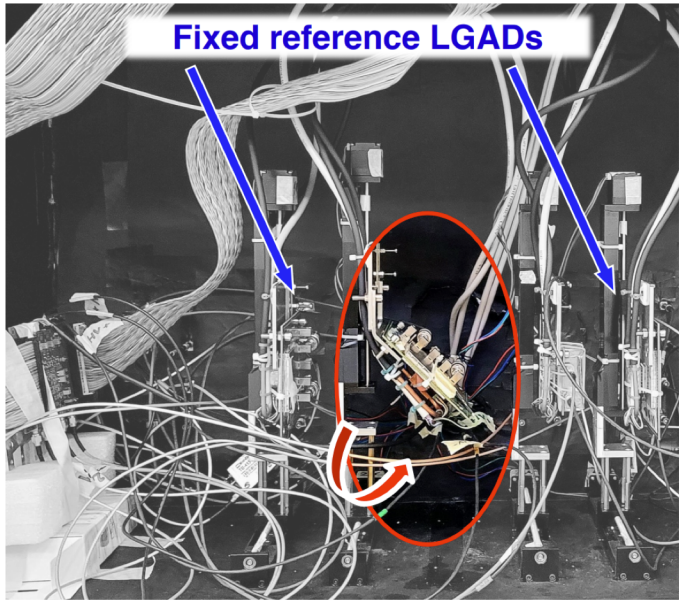
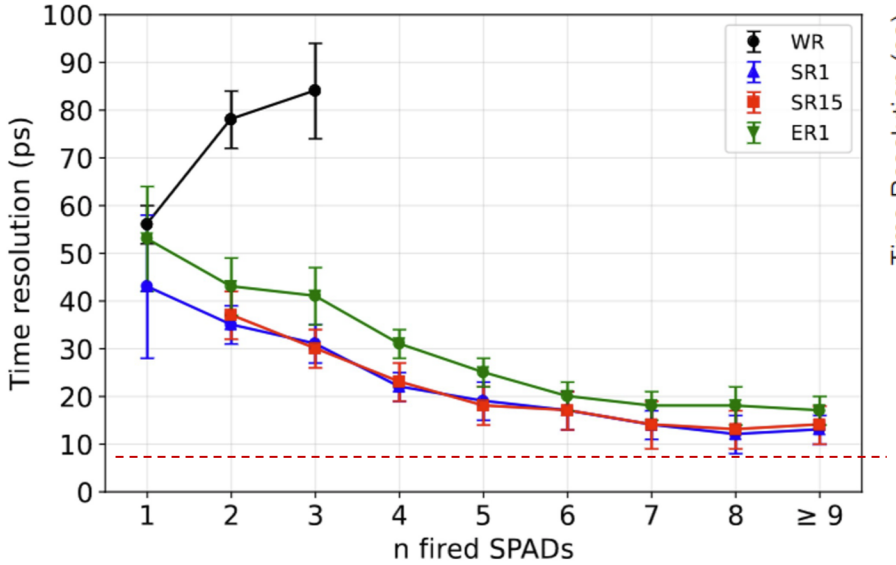
R&D for TOF

- Required time resolution for PID: 20 ps
- Tests with beam in July and October ‘23 at CERN PS, different technologies under study
  1. SiPM with w and w/o different resins
  2. Single and double LGADs 20 µm, 25 µm, 35 µm thick
  3. 50 µm thick CMOS-LGAD (ARCADIA MAPS with gain layer)

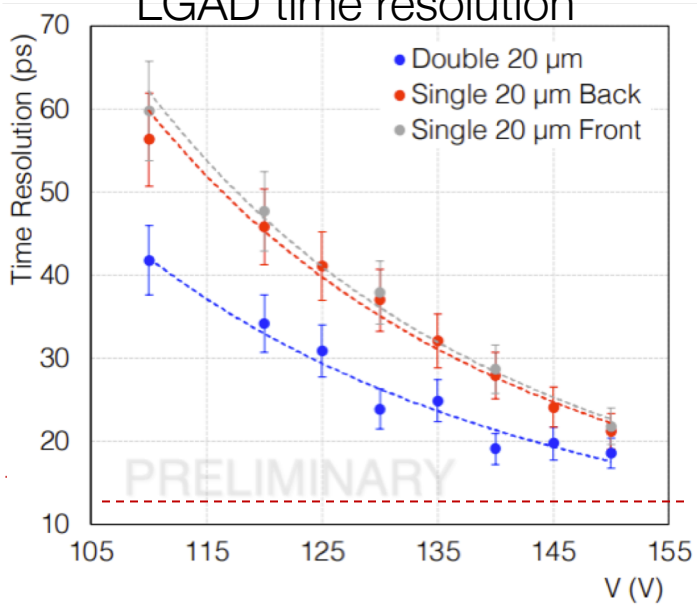


SiPM time resolution

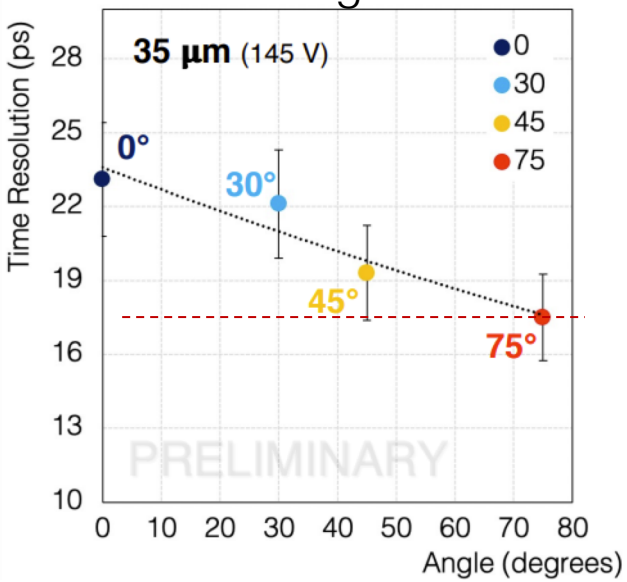


Carnesecchi, F., et al Eur. Phys. J. Plus 138, 788 (2023)

LGAD time resolution



Track angle scan



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Conclusions: ALICE continuing its journey through QCD

Publications from RUN 2 data keep improving our understanding of how QCD acts at the perturbative and non-perturbative level

Successful Run 3 pp and Pb-Pb collisions
Reconstruction on-going,
promising extraction of D mesons, J/Ψ and dielectron signal

LS3: FoCal and ITS3 TDRs submitted
LS4: ALICE 3 Scoping document close to completion

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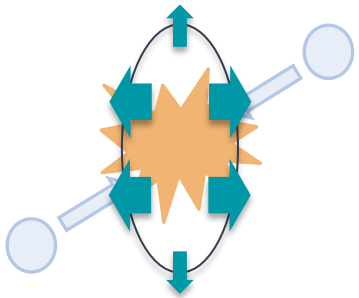
Additional slides

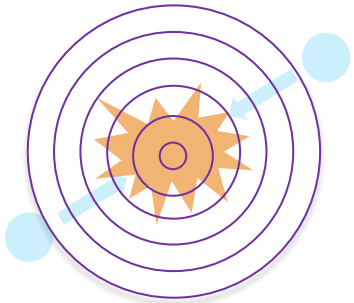
Small Sources: Collective Effects and Strong Resonances

Elliptic flow



Anisotropic pressure gradients within the source

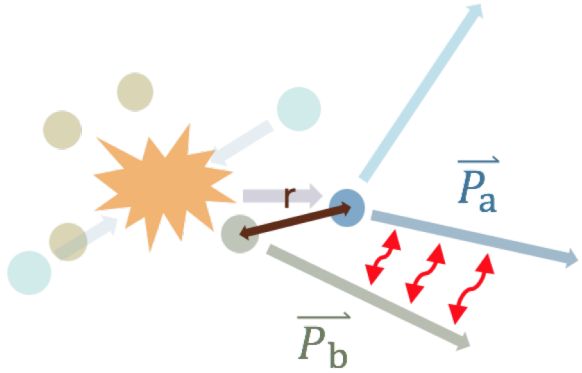
Radial flow



- Expanding source with constant velocity
- Different effect on different masses

Strong decays of broad resonances

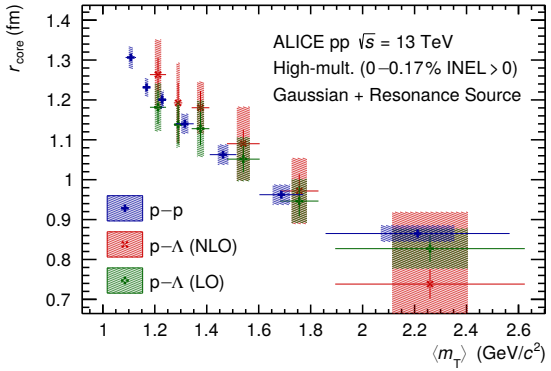
U. A. Wiedemann, U. W. Heinz, Phys.Rept. 319, 145-230 (1999)



- Resonances with $c\tau \sim r_0 \sim 1$ fm (Δ^*, N^*, Σ^*) introduce an exponential tail to the source
- Different for each particle species

Particle	Primordial fraction	Resonances <cτ>
Proton	33 %	1.6 fm
Lambda	34 %	4.7 fm

Core Radius



Strong decays of specific resonances

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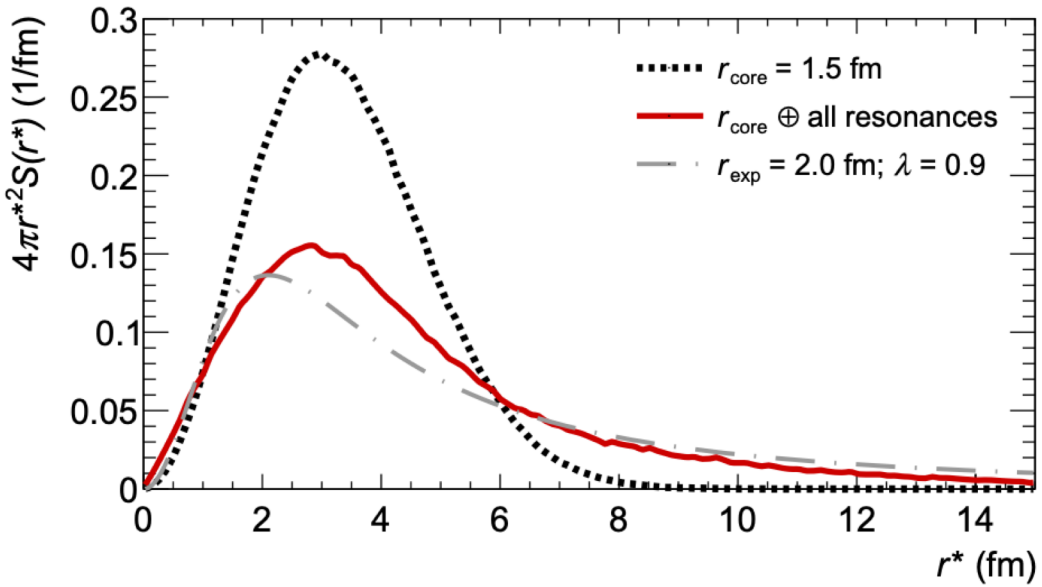
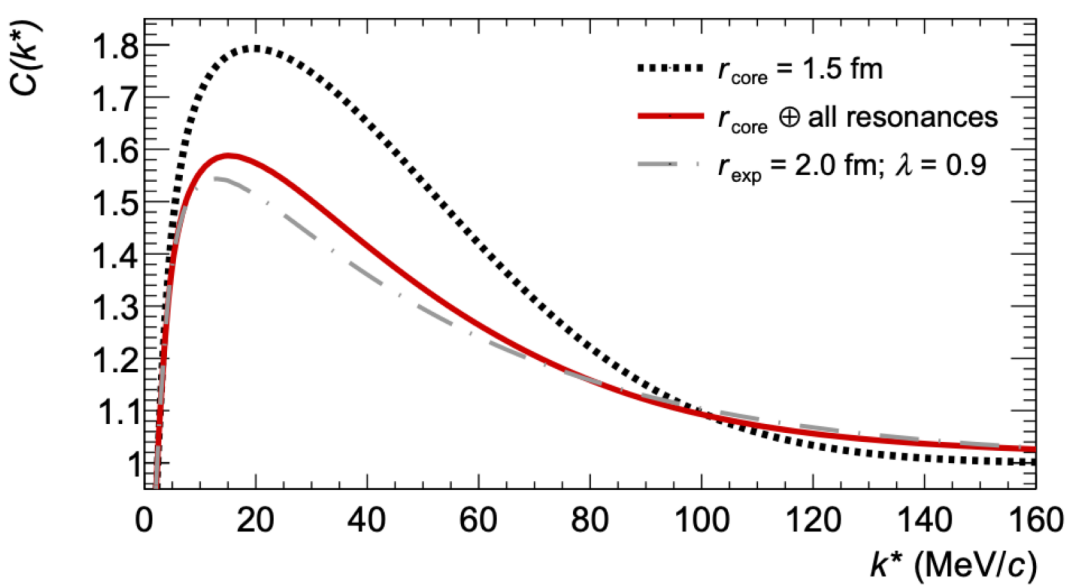
Effect of resonances on the emitting source for pions





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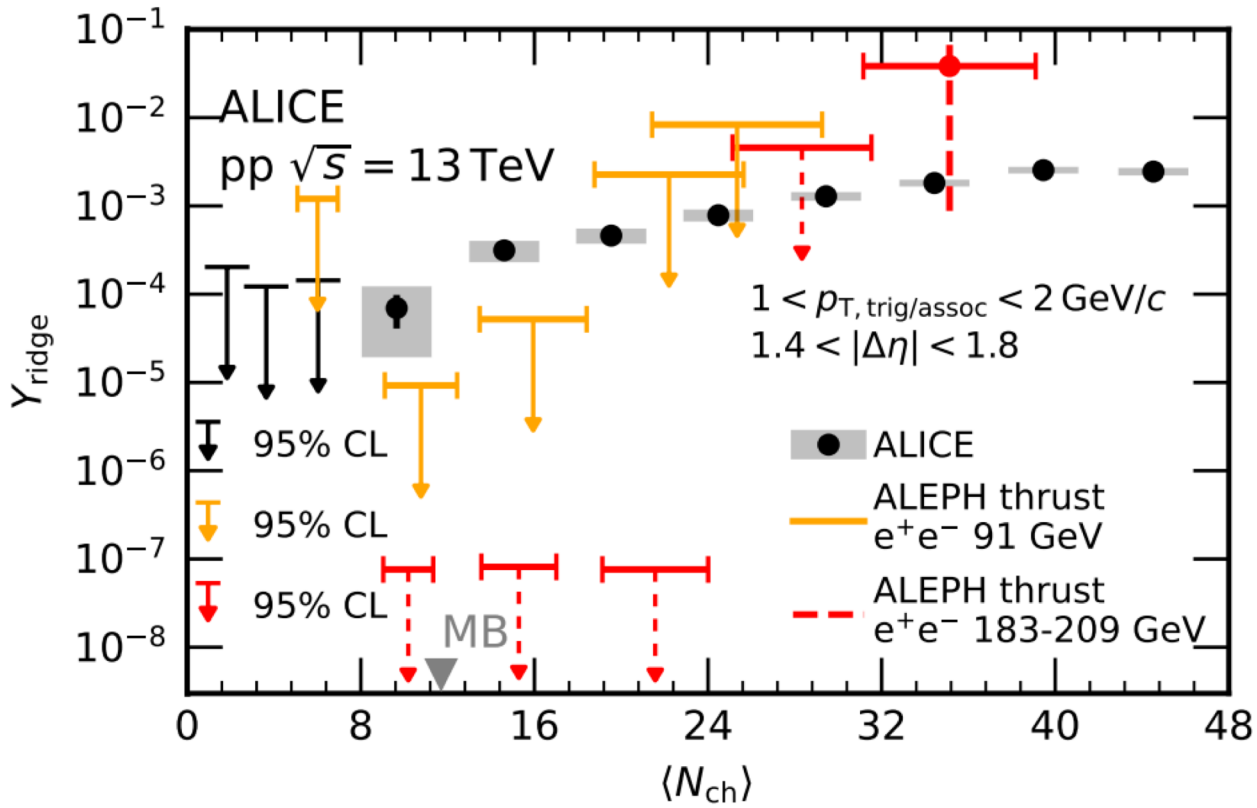
Ridge in low-multiplicity pp collisions and e^+e^- collisions

- Comparison with recent ALEPH e^+e^- results higher energies
  → Confirming the larger pp yield



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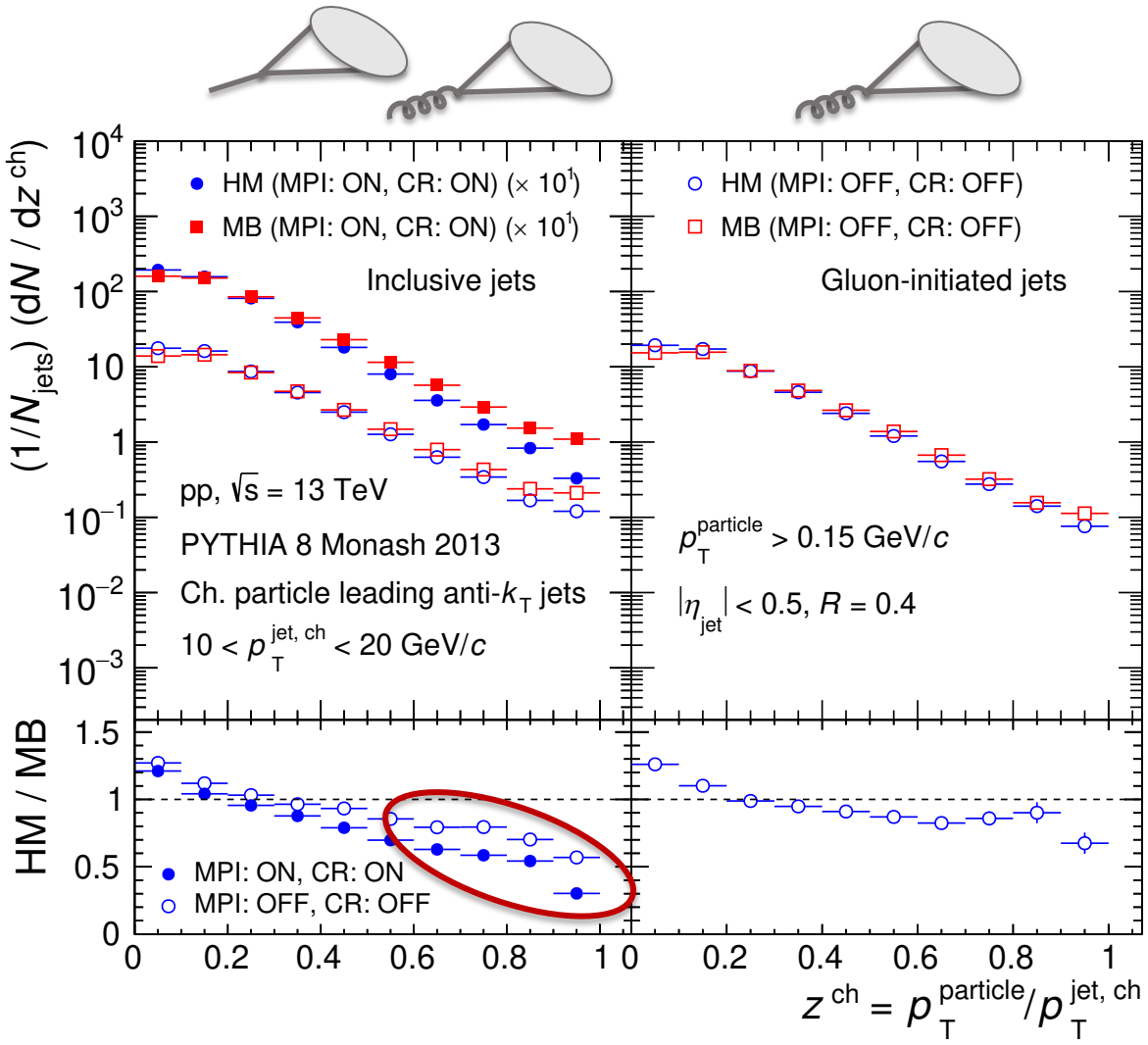
PYTHIA studies on jet modifications in pp collisions



- Two types of events
  - Multiparton inter. + Color Rec. ON/OFF
- Does the jet gets modified depending on the type of initiating parton?
  - Gluon-initiated jets in HM and MB show residual difference

Dependence of jet modification on MPI and CR

ALI-PUB-565892

ALICE Coll. arXiv:2311.13322

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