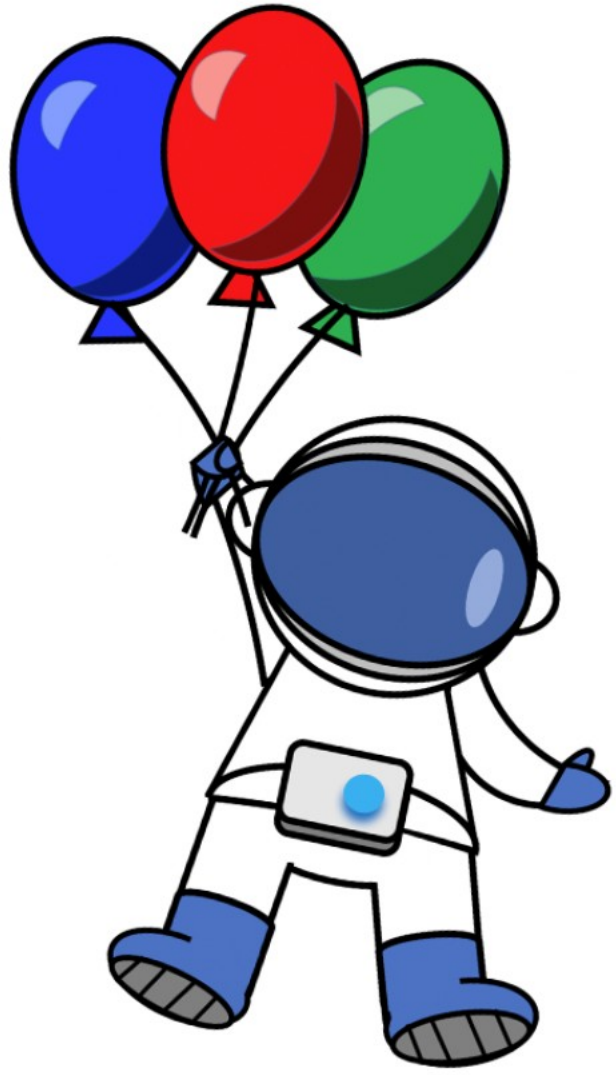
ALICE Overview

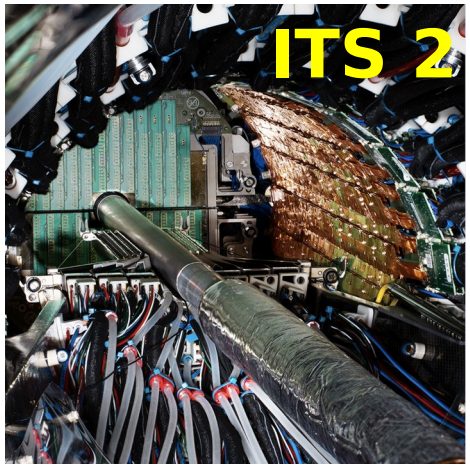
Ionut-Cristian Arsene*
for the ALICE Collaboration

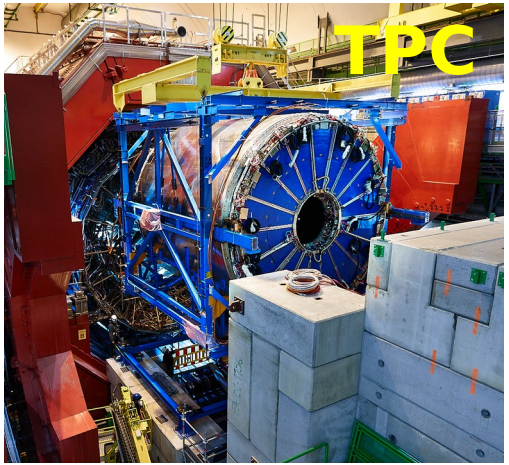
*University of Oslo

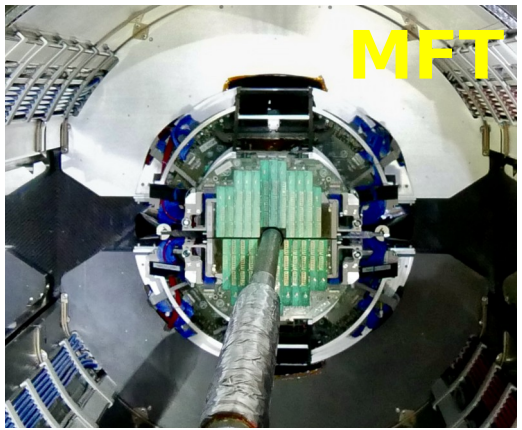


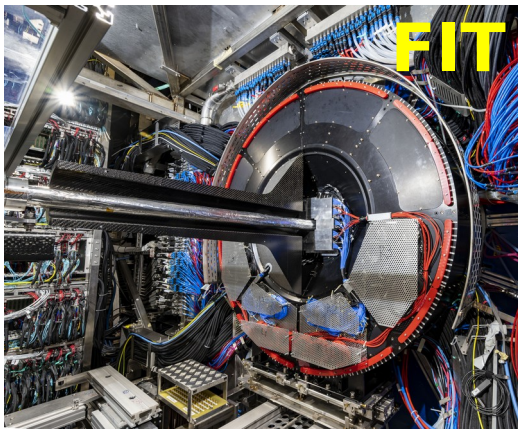
Quark Matter 2023 | Houston, USA | 4th September 2023

ALICE in Run 3 (ongoing)





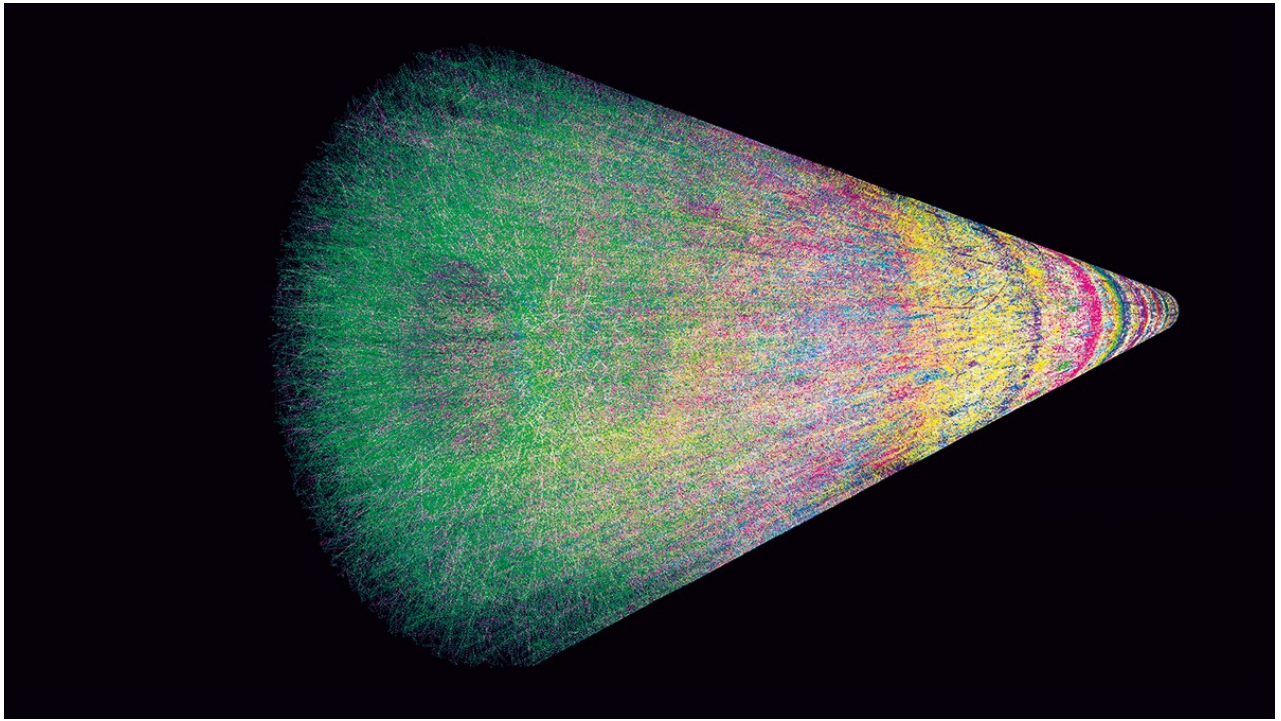




- Major upgrades installed in 2019-2021
- In production since 2022
- 50x increase in readout rate
- 3 to 6x improvement in pointing resolution
- Secondary vertexing for forward muons

ALICE upgrades: *arXiv:2302.01238*
ITS: *NIM 1032(2022)166632*
TPC: *JINST 16 P03022 (2021)*
MFT: *CDS link*
FIT: *NIM 1039 (2022) 167021*

ALICE in Run 3

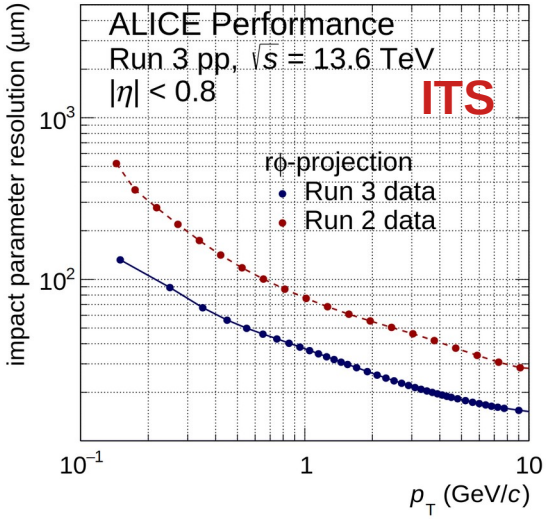


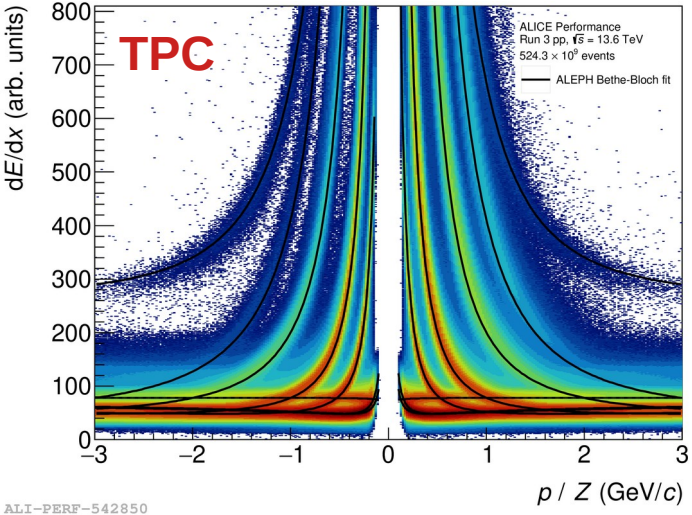
(2 msec time frame of Pb-Pb collisions at a 50 kHz interaction rate in the TPC)

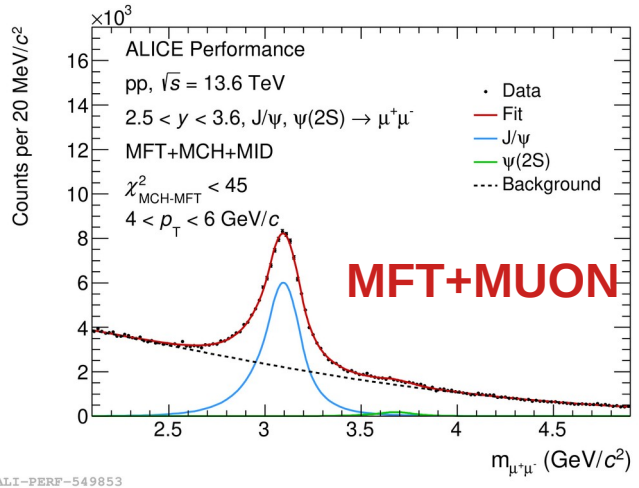
- Full Online and Offline software upgrade (O^2)

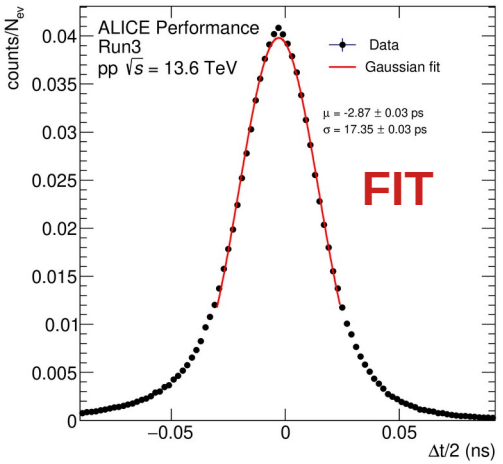
ALICE, CERN-LHCC-2020-018

Detector performance in Run 3



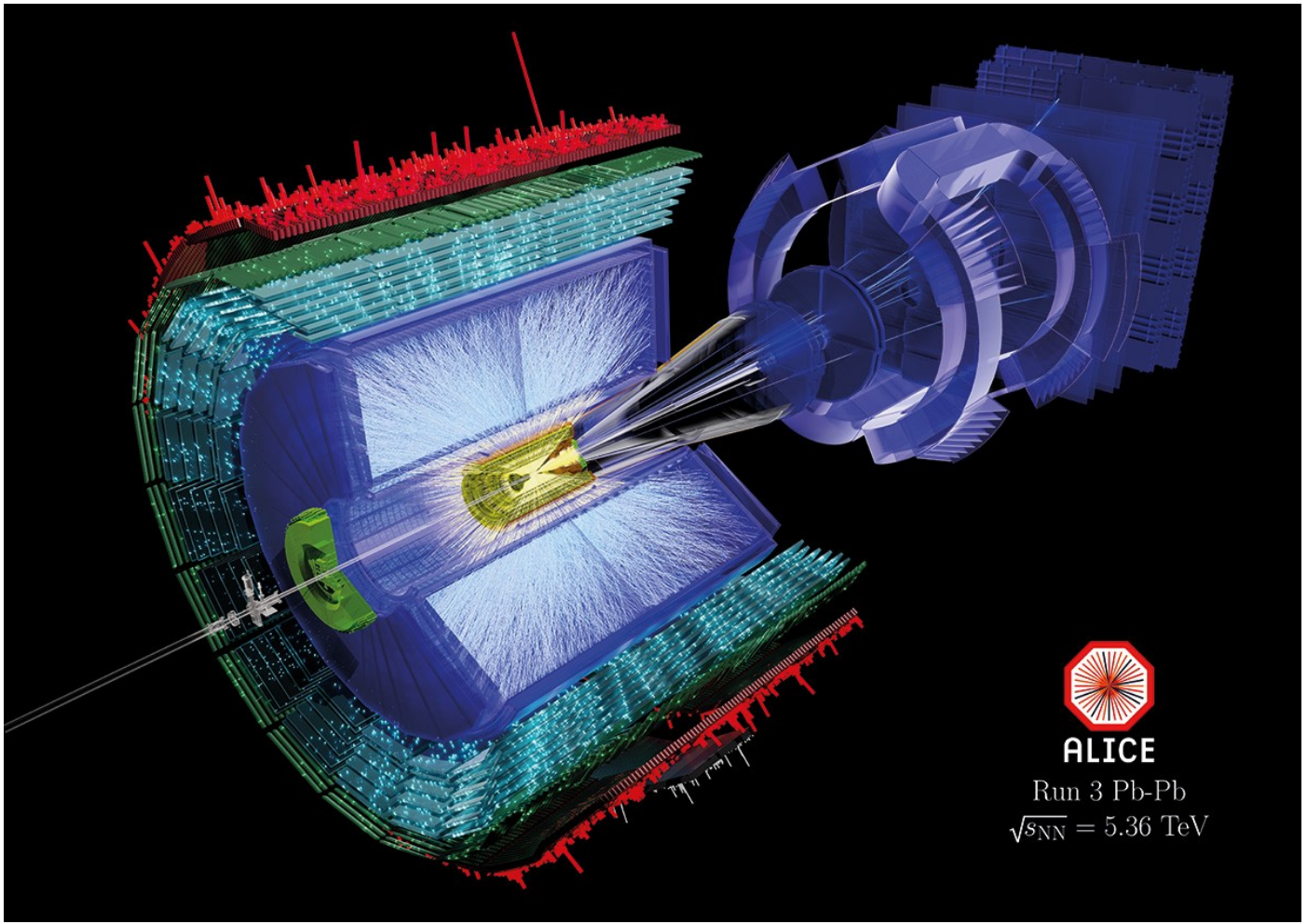




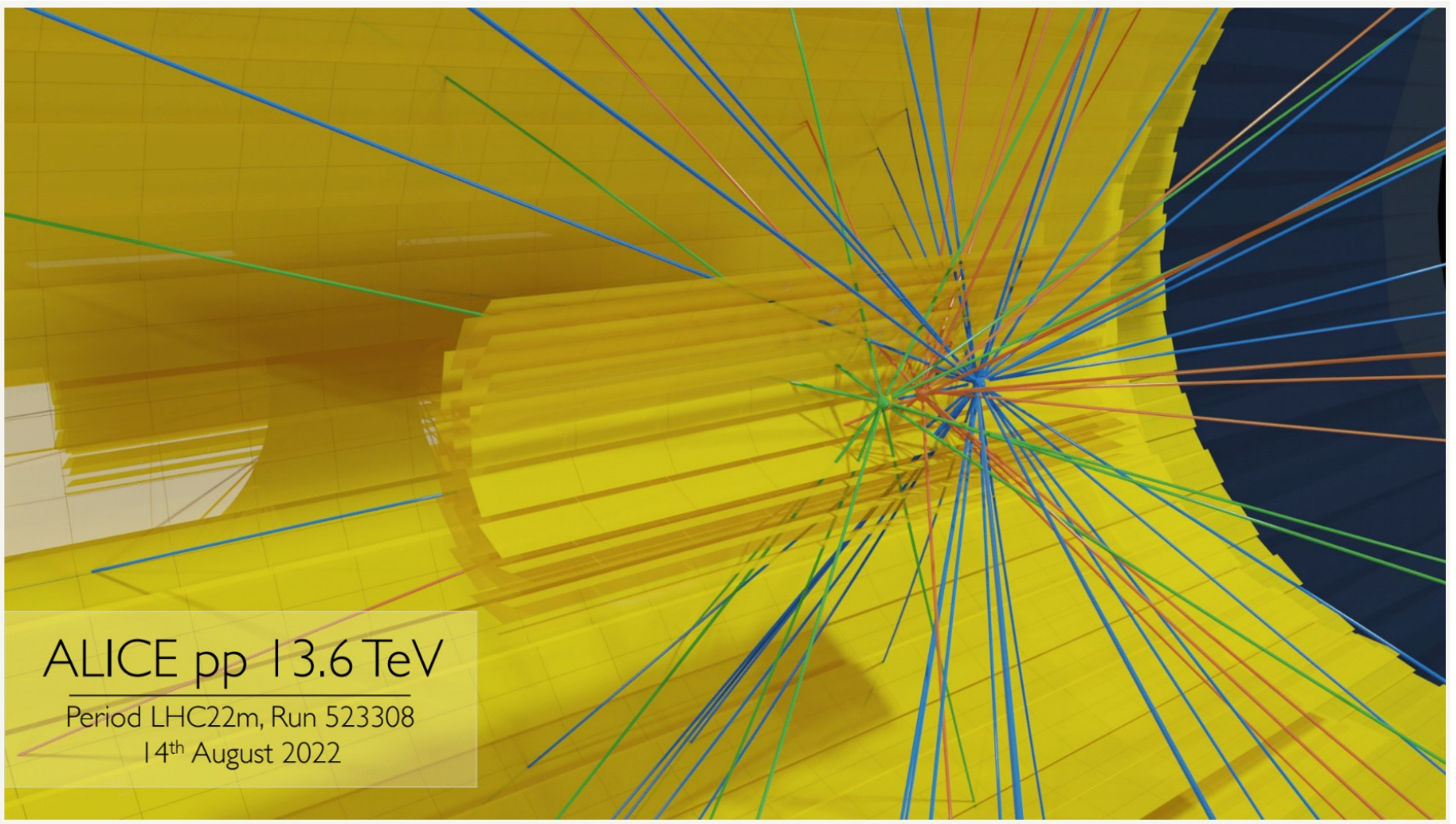


- Very good performance observed for all upgraded detectors
- Detector alignment, space charge corrections and calibrations still continuously improving

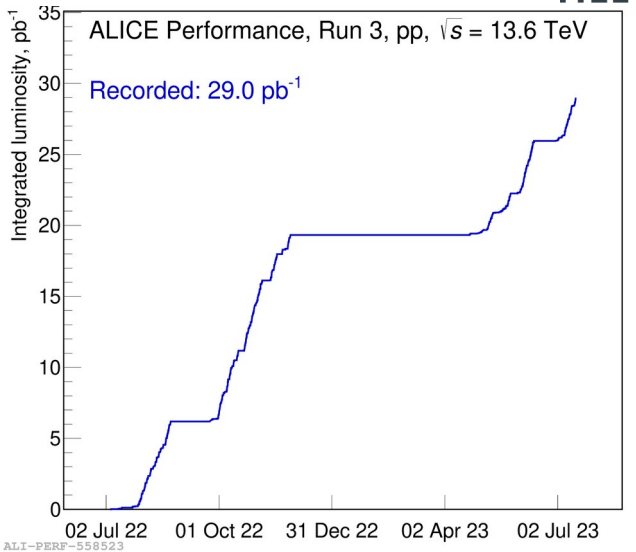
ALICE data taking in Run 3



ALICE data taking in Run 3



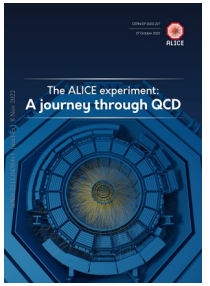
ALICE data taking in Run 3



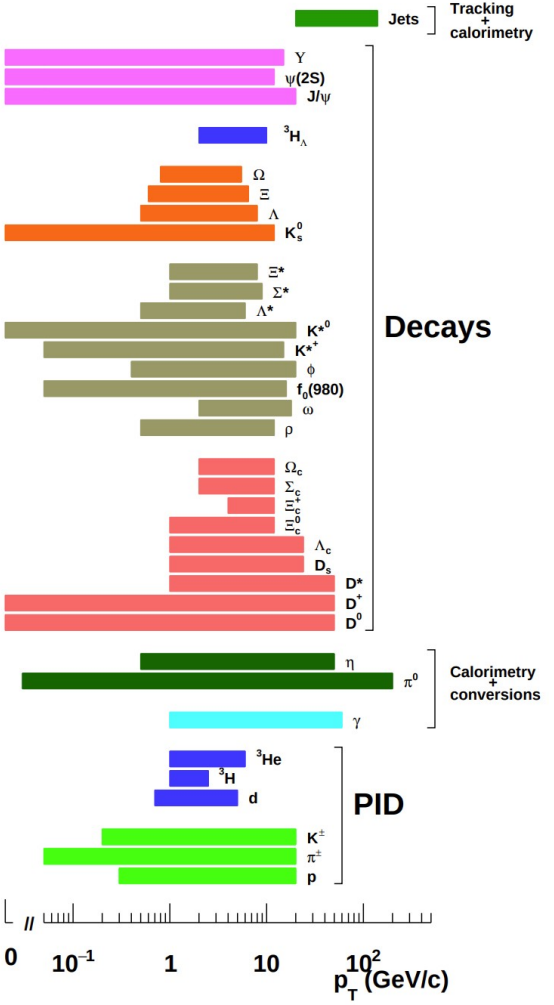
- Huge improvement in integrated luminosity wrt Run 1 and 2
  - Pb-Pb: x100
  - pp, p-Pb: x1000
- Already recorded (2022-2023):
  - pp collisions at $\sqrt{s}$ = 0.9 and 13.6 TeV (~30 pb^{-1})
  - small dataset for Pb-Pb at $\sqrt{s_{NN}}$ = 5.36 TeV
- Continuous readout with routine data taking at 500 kHz in pp collisions
- Analysis level event selection → compress data by a factor of up to 10^{-4}
- First Run 3 physics results already available (highlighted through the talk)
- Imminent Pb-Pb and pp reference runs (September-October)

A journey through QCD

- In 2022, ALICE published an overview of what we learned with the results from Run 1 and 2:
  1) Thermodynamic and global properties of the QGP
  2) Hydrodynamic and transport properties of the QGP
  3) Hadronization of the QGP
  4) Propagation of energetic hadrons in the QGP
  5) Deconfinement impact on the QCD force
  6) Limits of QGP formation
  7) Nature of the initial state of heavy-ion collisions
  8) Novel QCD effects
  9) Hadron-hadron interactions



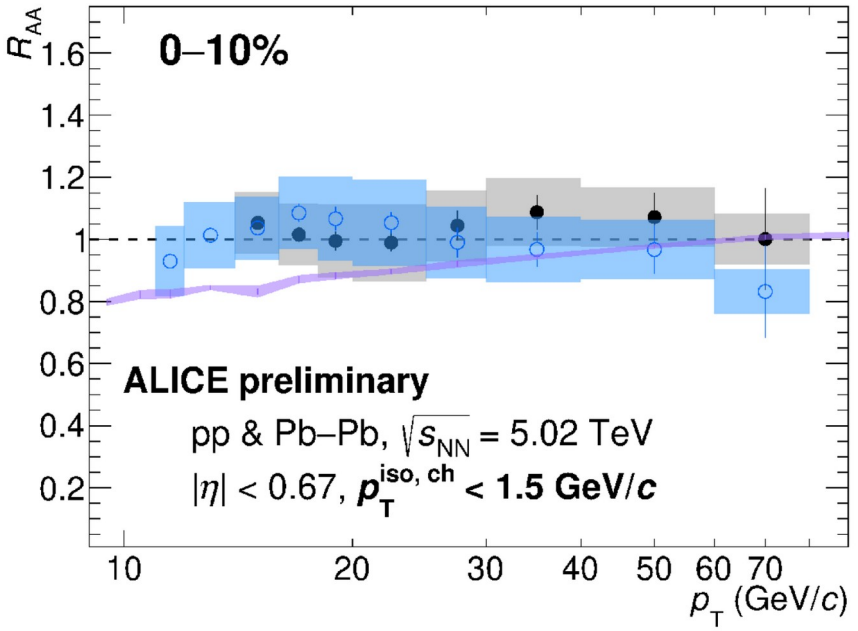
ALICE, arXiv:2211.04384

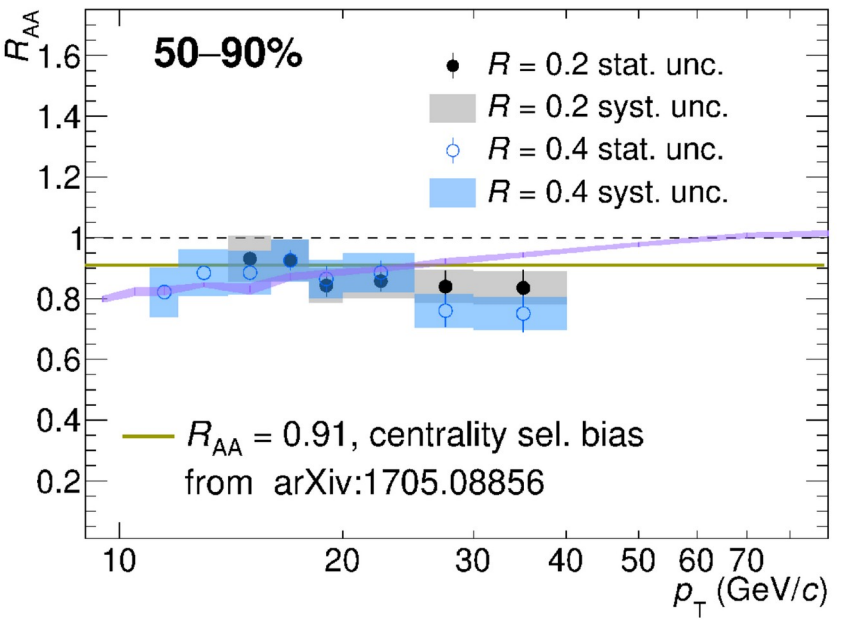


In this talk, highlights showing newer results from Run 3 and Run 2

Initial state

High-p_T isolated photon production in Pb-Pb collisions



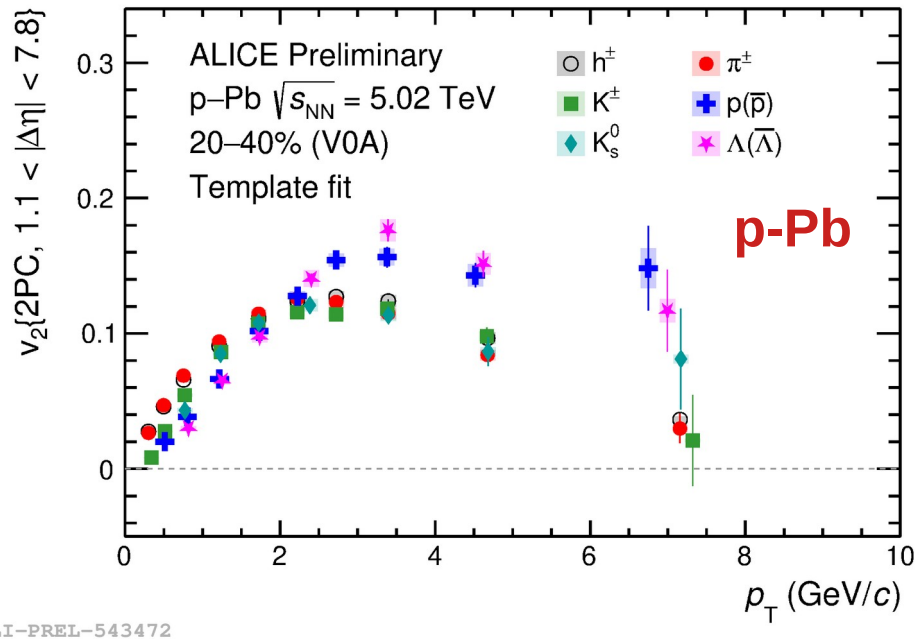


- No direct-photon suppression in the centrality range 0-50%
- Suppression in peripheral collisions (50-90%) explained by the centrality bias

Loizides et al., PLB773 (2017) 408

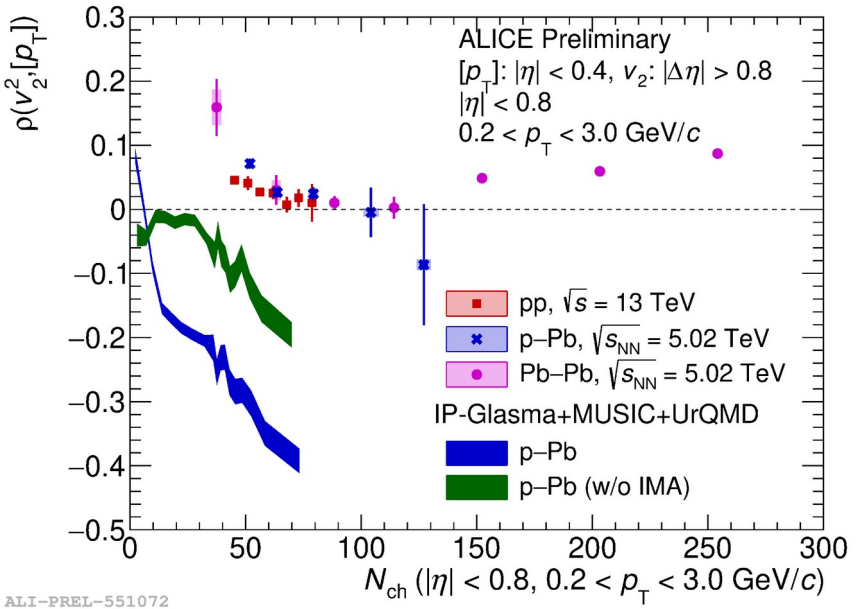
Carolina Arata
Tuesday 15:50 (174)

Elliptic flow in small systems



ALI-PREL-543472

pp p-Pb Pb-Pb



ALI-PREL-551072

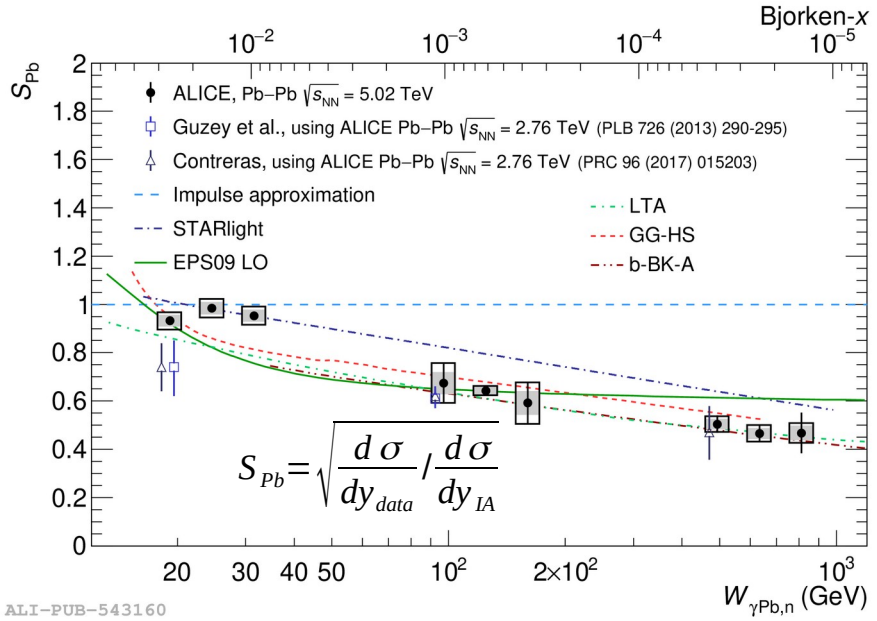
$$\rho_n\left(v_n^2, [p_T]\right) = \frac{\mathrm{cov}\left(v_n^2, [p_T]\right)}{\sqrt{\mathrm{var}\left(v_n^2\right)}\sqrt{\mathrm{var}\left([p_T]\right)}}$$

- Mass ordering for v_2 at low p_T
- Baryon-meson grouping at intermediate p_T

- $v_2 - p_T$ correlation used to probe the initial stage
  - Separate between geometric response vs Color-Glass Condesate ?

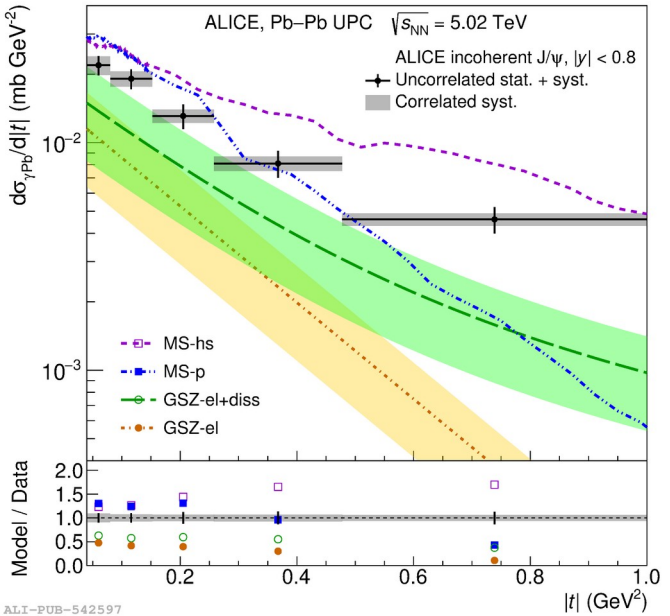
Mingrui Zhao
Tuesday 15:10 (457)

Photoproduction of J/ψ in UPC Pb-Pb



Simone Ragoni
Wednesday 09:10 (170)

(coherent J/ψ)



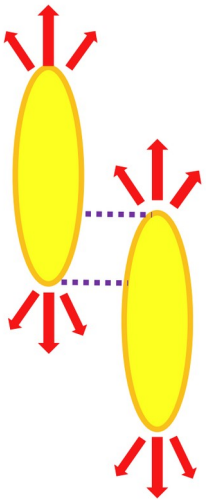
Adam Matyja
Tuesday 15:30 (173)

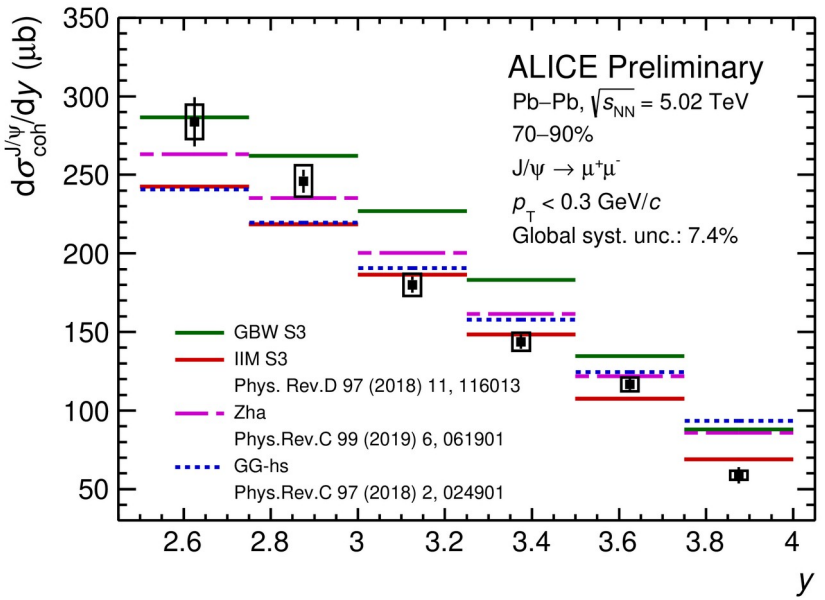
(incoherent J/ψ)

- First measurement of the nuclear suppression factor at Bjorken-*x* of *O*(10^{-5}) in UPC Pb-Pb with neutron emission
- Incoherent J/ψ cross section |*t*| dependence favours models with sub-nucleon fluctuations

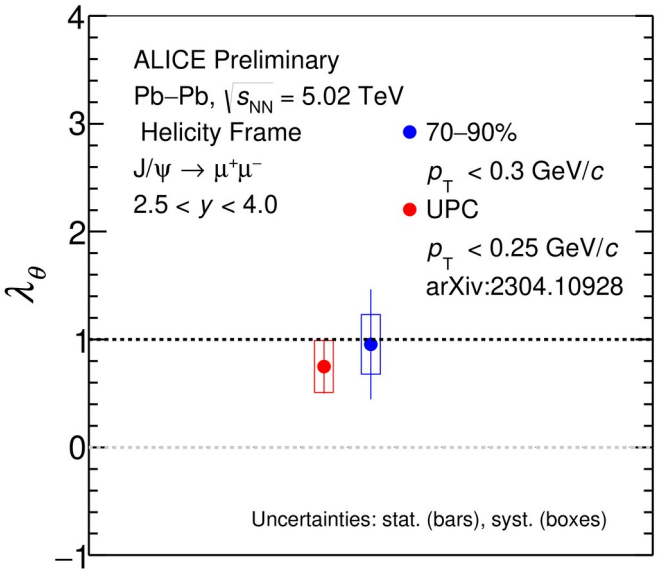
ALICE, arXiv:2305.19060
ALICE, arXiv:2305.06169

J/ψ photo-production in peripheral Pb-Pb collisions





ALI-PREL-547942



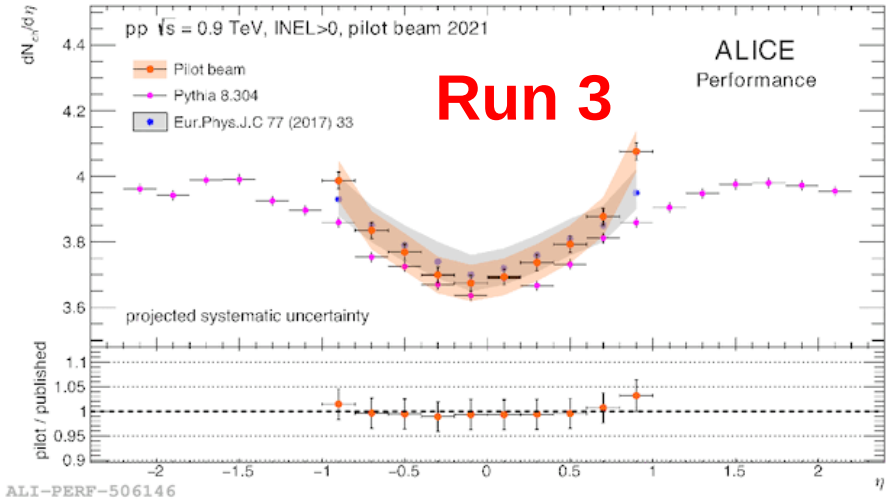
ALI-PREL-546778

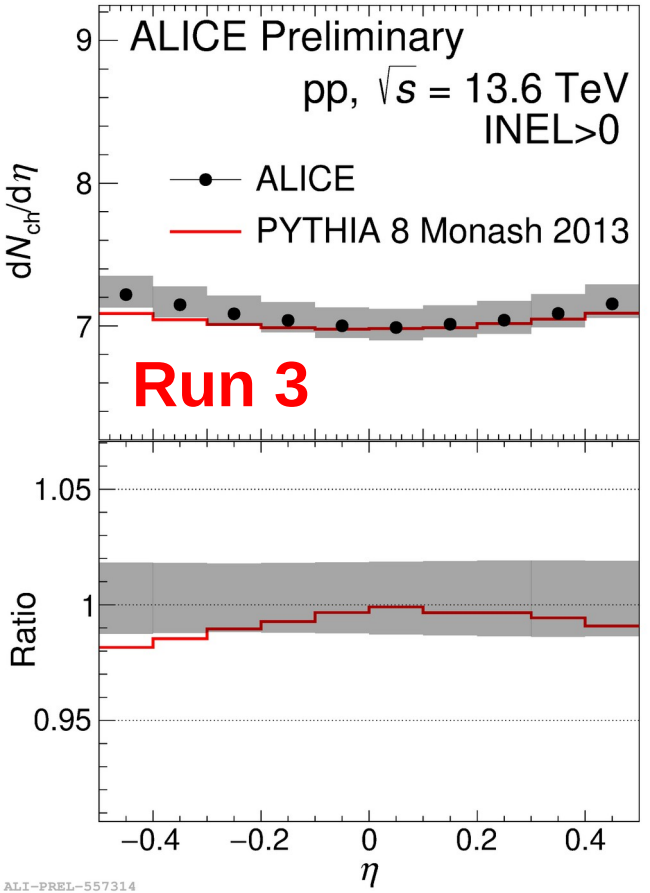
Afnan Shatat
Tuesday 14:50 (318)

- Measurement of the *y*-differential photoproduction cross section
- Inclusive J/ψ polarization for p_T<0.3 GeV/*c* compatible with transverse polarization as in UPC

Soft probes

Charged-particle multiplicity in pp collisions

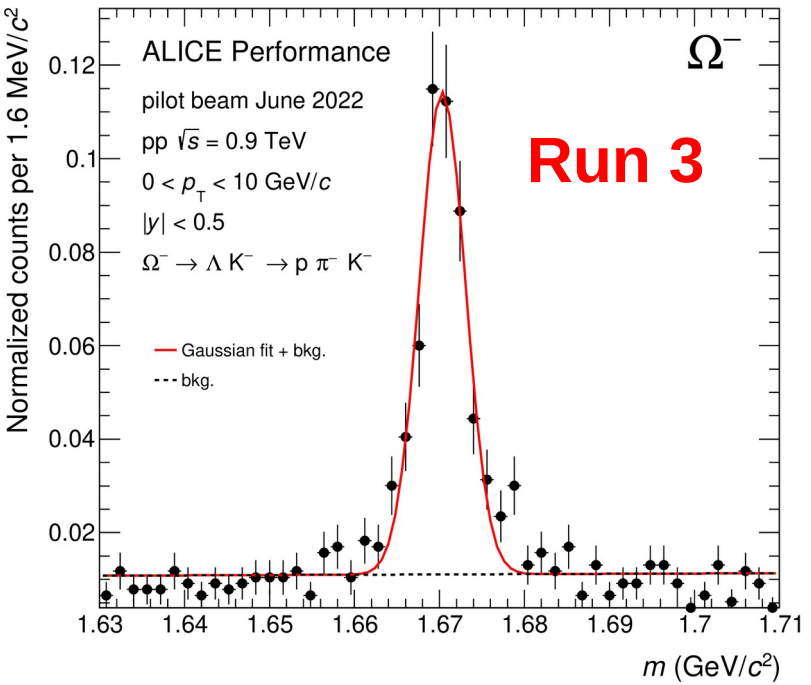


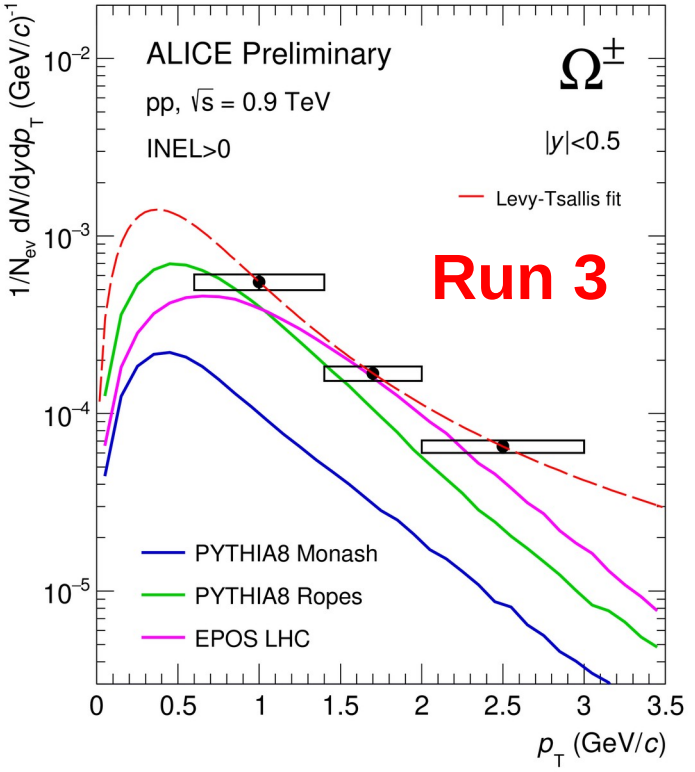


- First Run 3 results for dN_{ch}/dη at midrapidity
  - √s = 0.9 TeV
  - √s = 13.6 TeV
- Agreement with PYTHIA 8 at a few percent level

Alek Hutson
Wednesday 11:00 (312)

Strangeness production in pp collisions

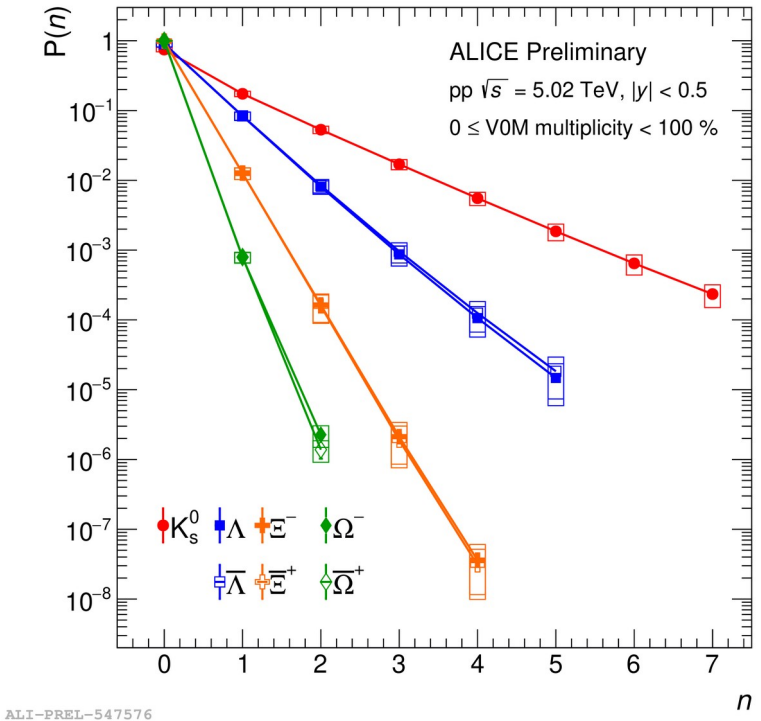


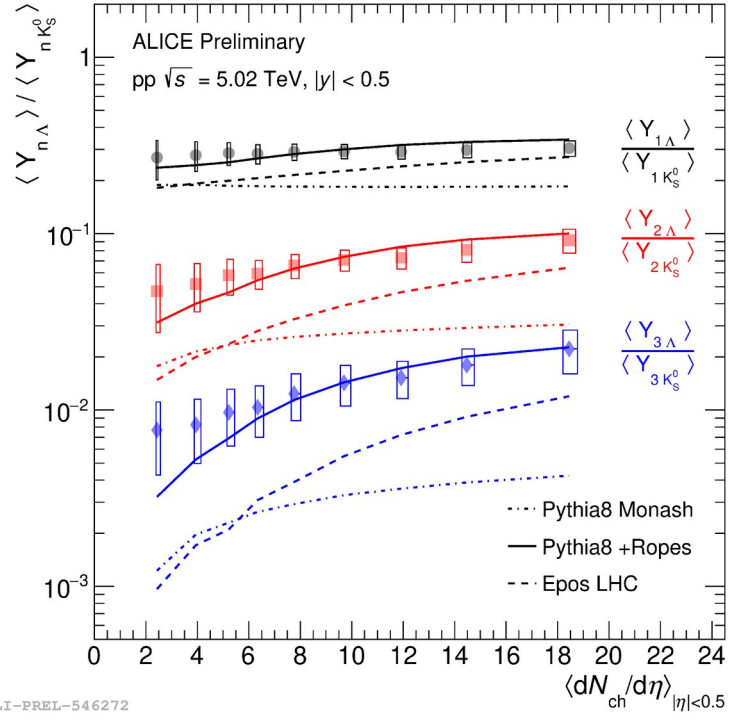


- First Ω baryon yields in pp at 900 GeV

Francesca Ercolessi
Tuesday 12:40 (405)

Strangeness production at the extremes

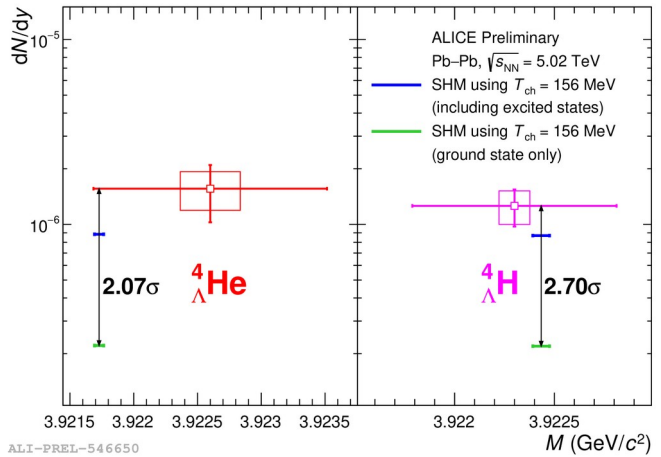




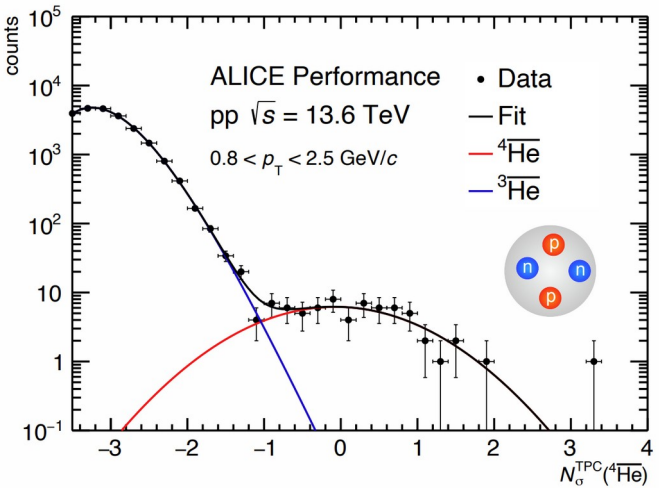
- First measurement of the production probability for > 1 strange particle per event
- Disentangle baryon-related from strangeness-related contributions

Sara Pucillo
Wednesday 17:30 (408)

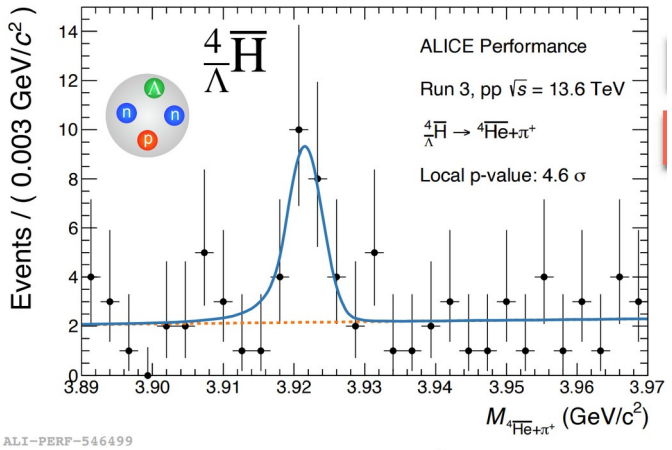
(Anti-)(hyper-)nuclei measurements



Run 3



Run 3

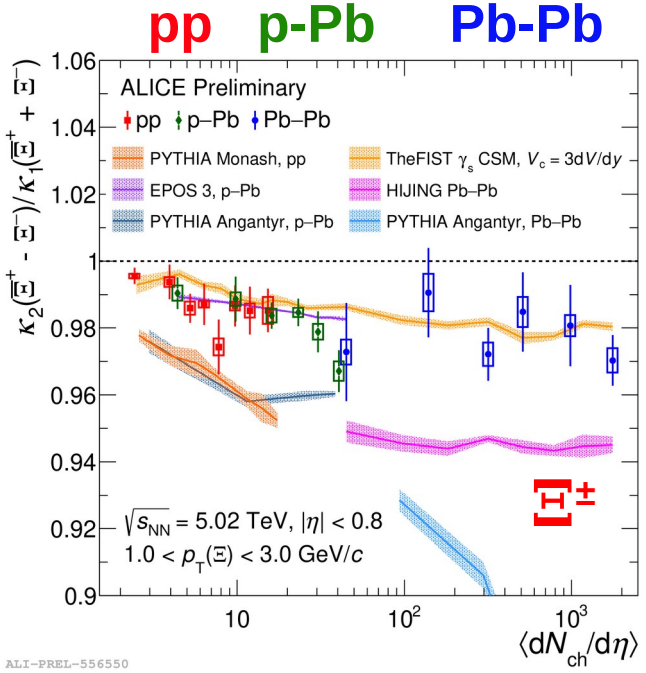


Chiara Pinto
Wednesday 12:40 (404)

Ivan Vorobyev
Wednesday 8:50 (380)

- Hyper-nuclear states with 4 baryons yields consistent with the thermal model
  - Yields are very sensitive to feed-down from excited states
- First signals of anti-(hyper) nuclear states in Run 3 pp thanks to the triggered data

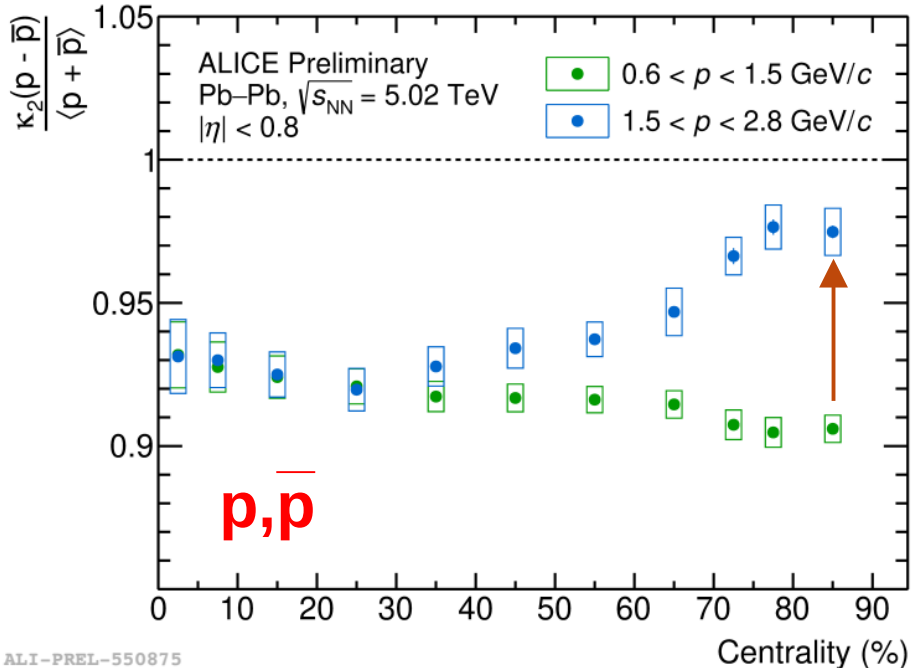
Event-by-event net-strange and net-baryon fluctuations



- Smooth evolution from small to large systems
- Deviation from Skellam baseline well described in the canonical SM (CSM)

Vovchenko et al., PLB 785 (2018) 171

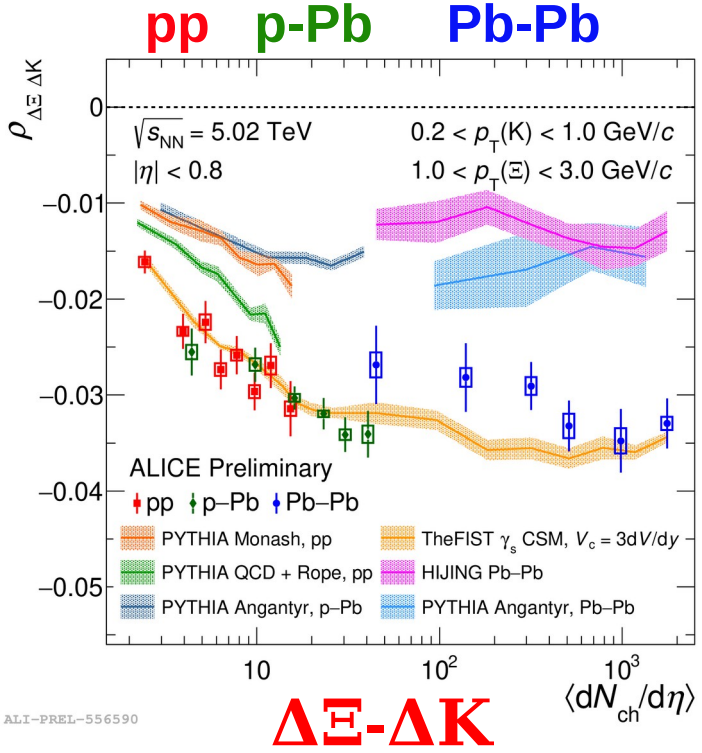
Mario Ciacco
Tuesday 13:00 (470)



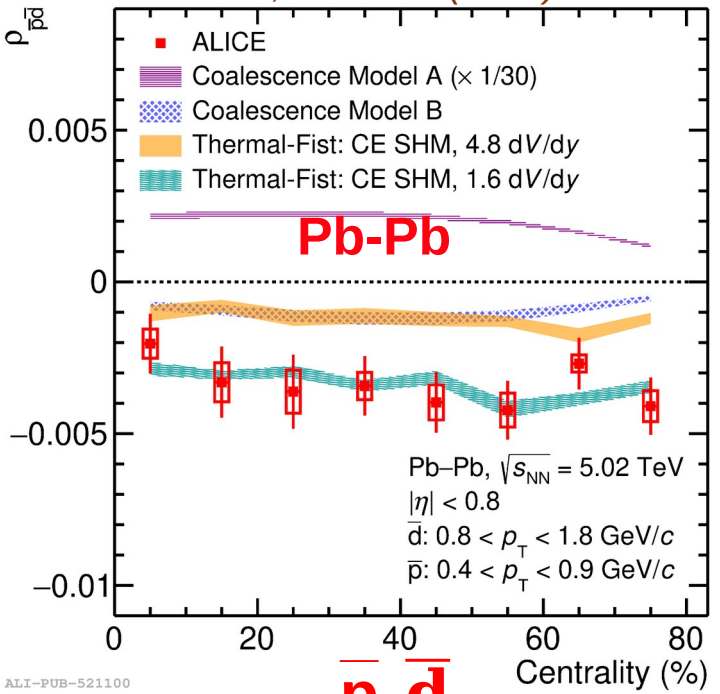
- Striking centrality dependence at high momentum
- Consistent with Lattice QCD expectations with strong magnetic field *Ding et al., arXiv:2208.07285*

Ilya Fokin
Poster 471

Event-by-event fluctuation correlations



ALICE, PRL 131 (2023) 041901



Mario Ciacco
Tuesday 13:00 (470)

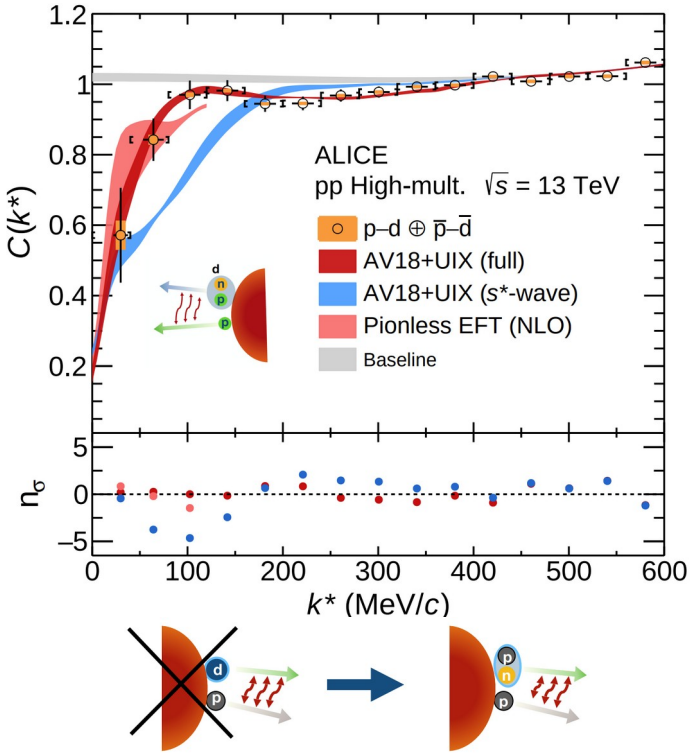
$$\kappa_{11}(a,b) = \langle (n_a - \langle n_a \rangle)(n_b - \langle n_b \rangle) \rangle$$

$$\rho_{ab} = \kappa_{11}(a,b)/\sqrt{\kappa_{2a}\kappa_{2b}}$$

- Anti-correlations of net-Ξ and net-kaon fluctuations
  - Consistent with the CSM model and a large strangeness correlation length
- Anti-deuteron-antiproton correlation is also negative but a smaller correlation length is favoured

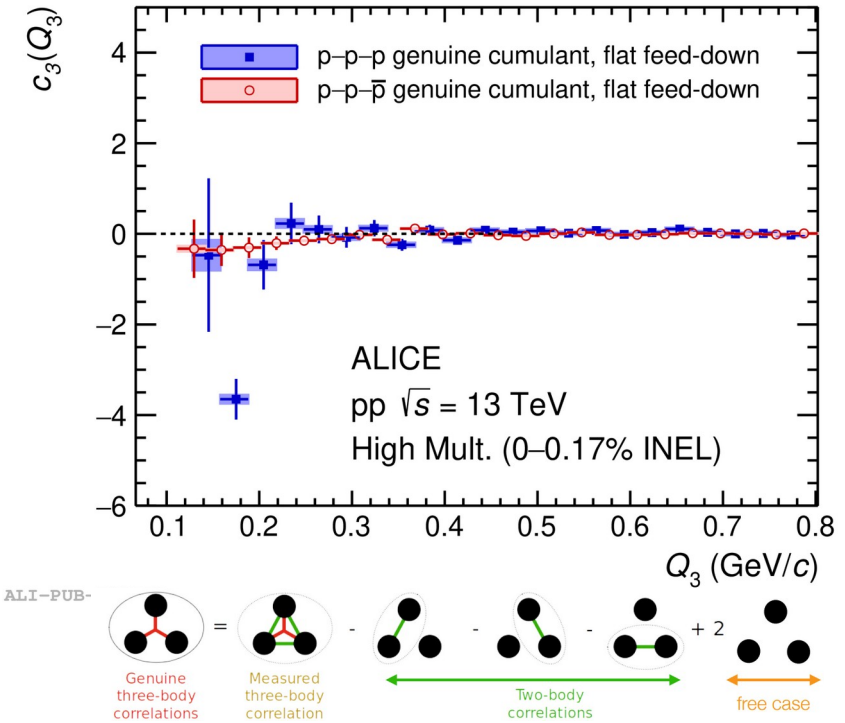
Femtoscopy: 3-body interactions

ALICE, arXiv:2308.16120



Viviani et al., arXiv:2306.02478v1

ALICE, EPJA 59 (2023) 145

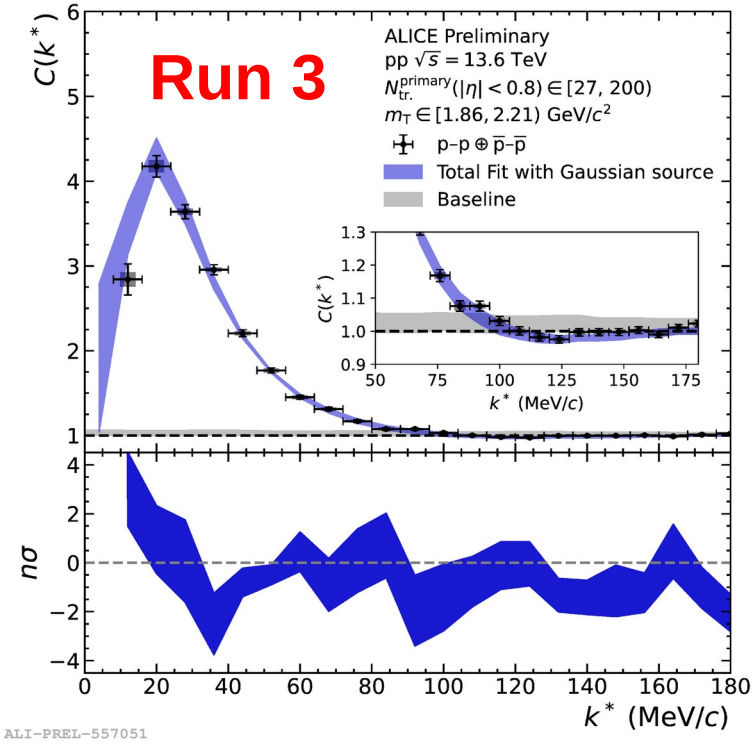


Del Grande et al., EPJC82 (2022) 244

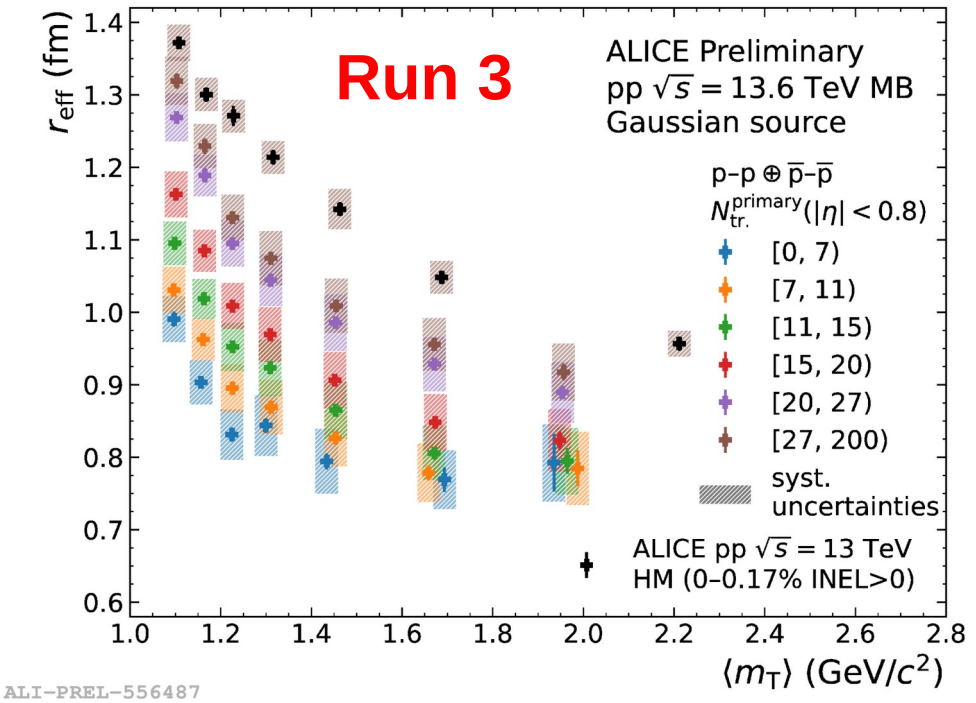
- Proton-deuteron femtoscopy: system modeled as a 3-body system
- Search for genuine 3-body interactions using 3-proton femtoscopy

Bhawani Singh
Wednesday 08:30 (461)

Two-body femtoscopy



p-p correlation function in high multiplicity pp



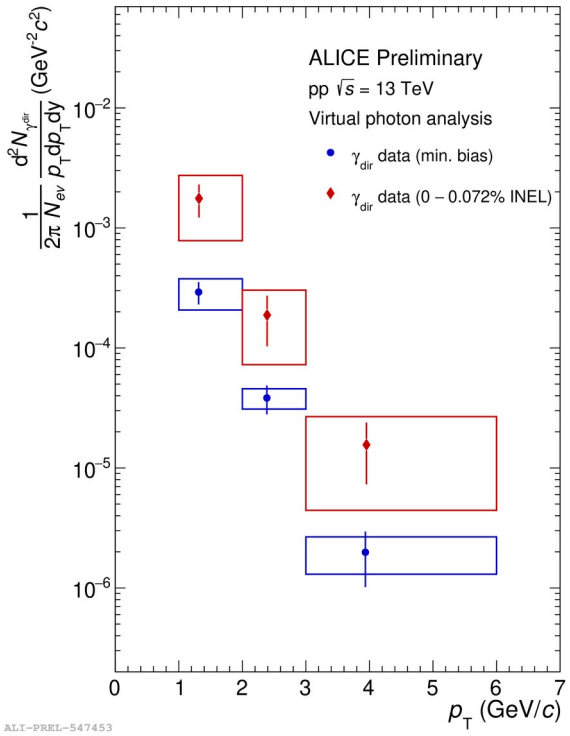
Effective source size as a function of multiplicity

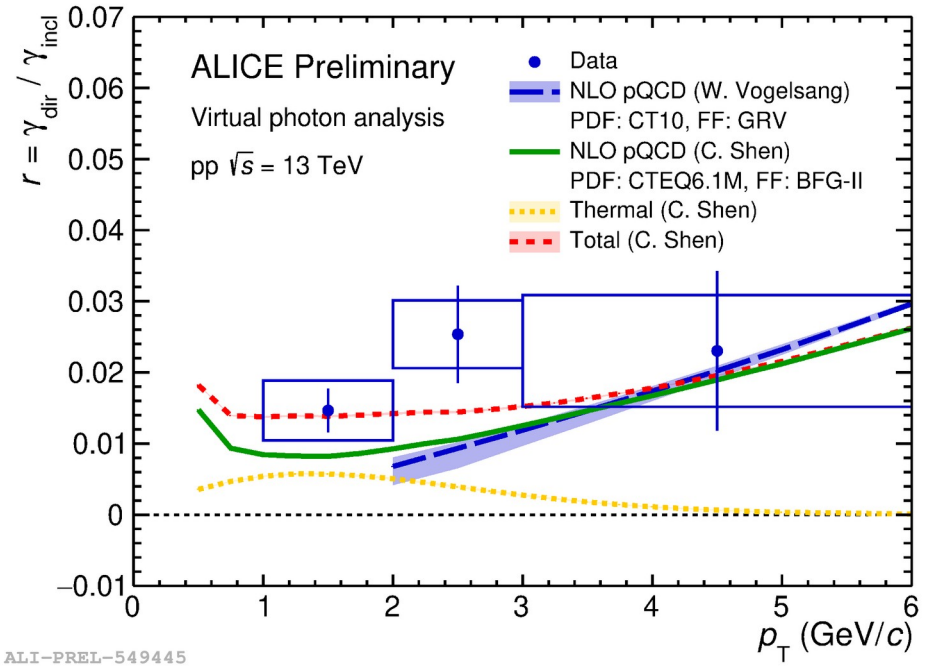
- Increase of the p-p pairs sample of 50x in pp collisions at 13.6 TeV

Bhawani Singh
Wednesday 08:30 (461)

Hard and electromagnetic probes

Virtual direct photon production in pp collisions

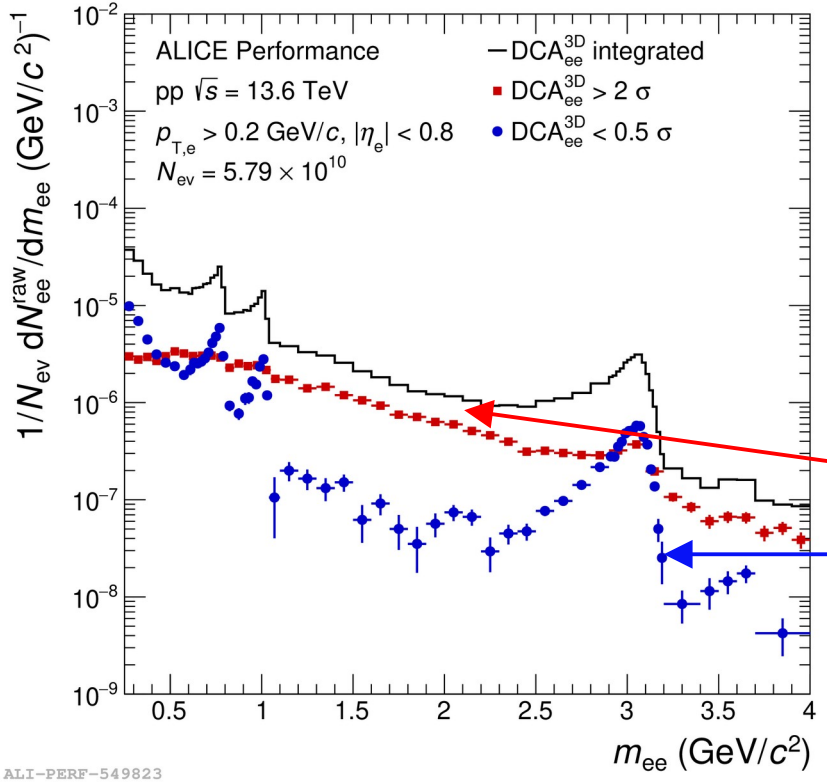




- Testing QGP effects in small systems with low p_T direct photons
- Most precise measurement at the LHC in pp collisions
- Significance of ~3(2)σ for MB(HM) pp collisions

Daiki Sekihata
Tuesday 16:10 (171)

Dielectron measurements in pp collisions in **Run 3**



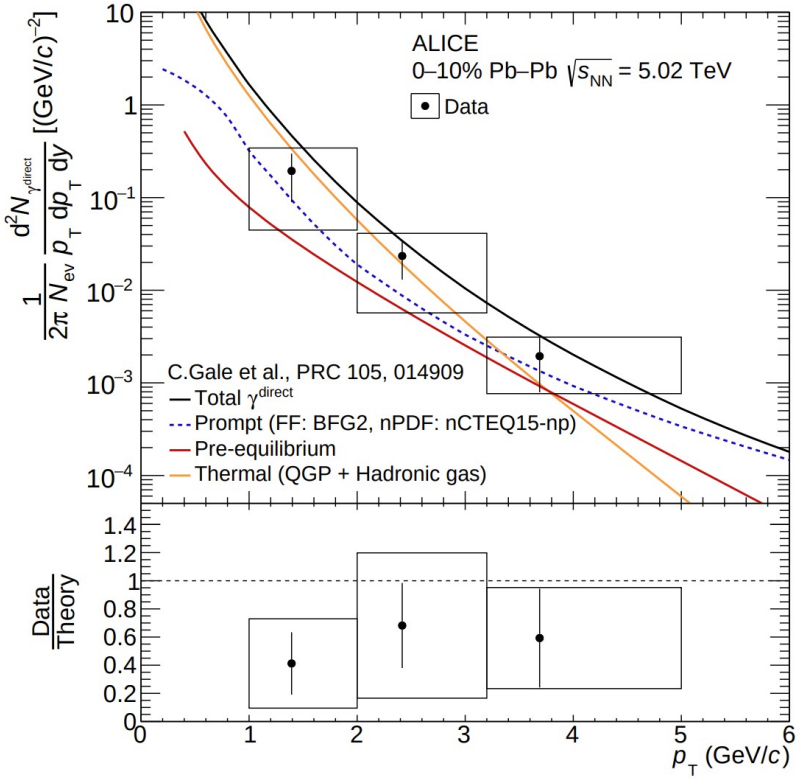
Daiki Sekihata
Tuesday 16:10 (171)

non-prompt

prompt

- New measurements in pp collisions at √s=13.6 TeV
- Using vertexing to separate heavy-flavour contributions

Virtual direct photon production in central Pb-Pb collisions

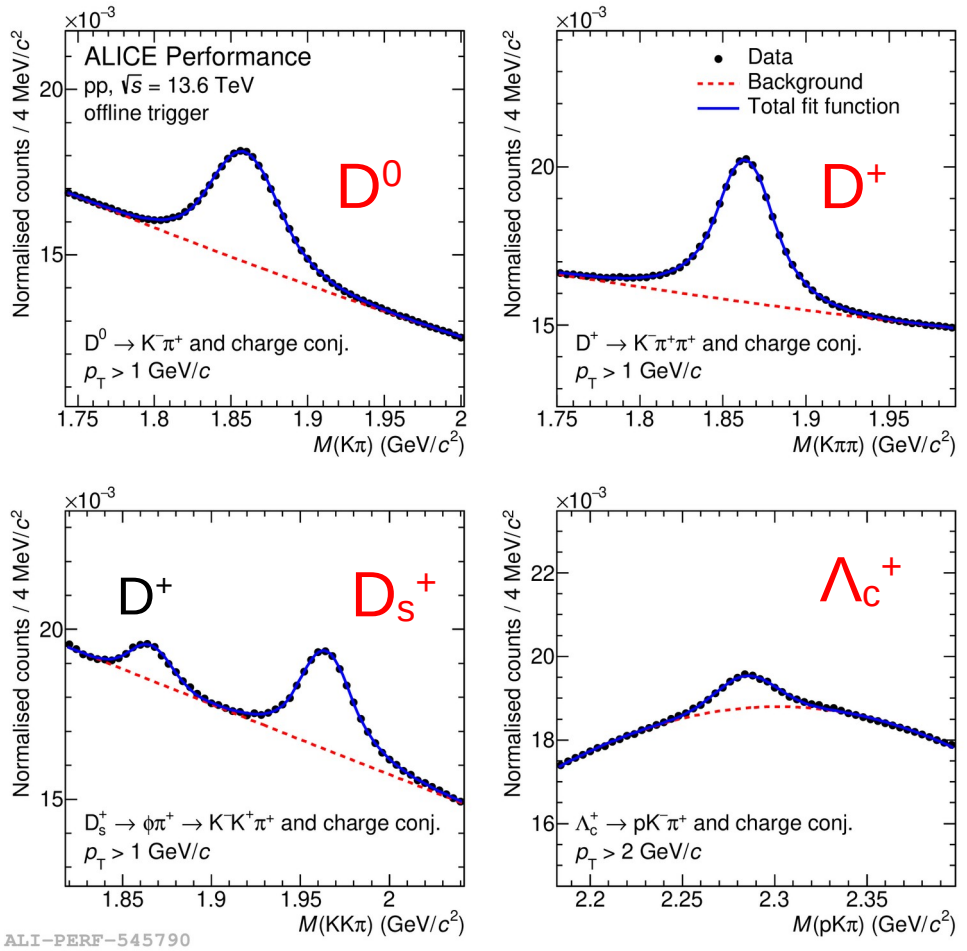


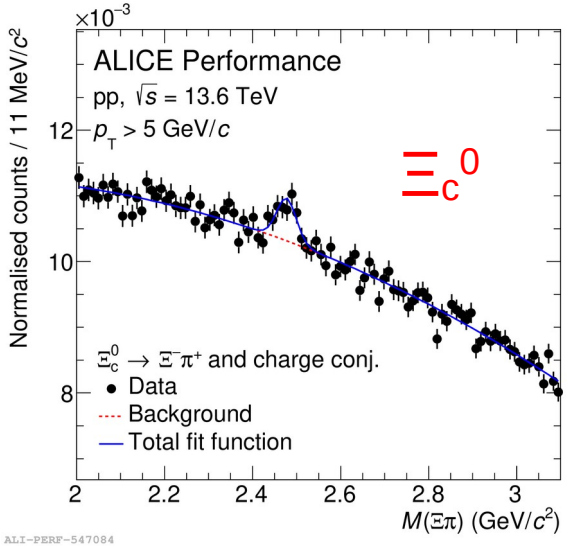
- First ALICE direct photon measurement via dielectrons in Pb-Pb collisions
- Data compared with calculations including prompt, pre-equilibrium and thermal photons

Daiki Sekihata
Tuesday 16:10 (171)

ALICE, arXiv:2308.16704

Open heavy flavour in pp collisions at √s = 13.6 TeV



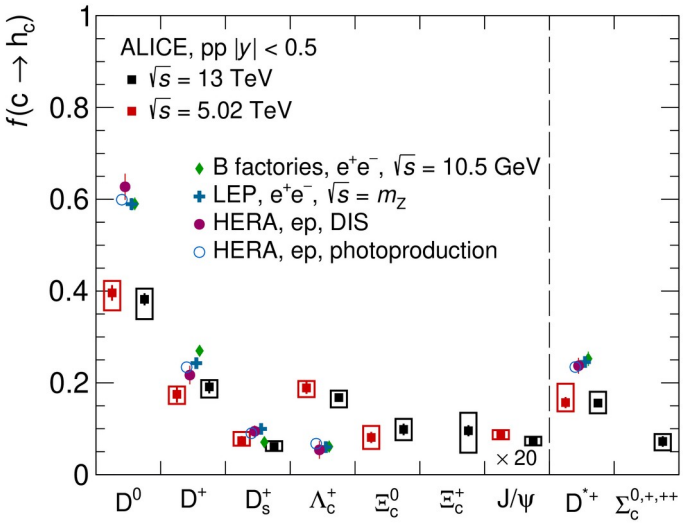


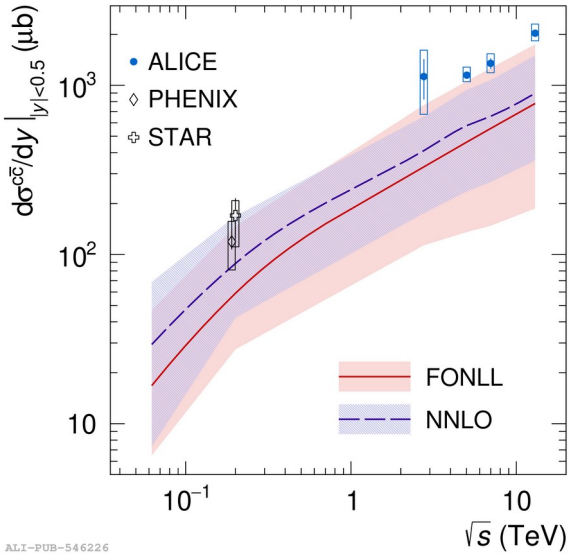
Run 3

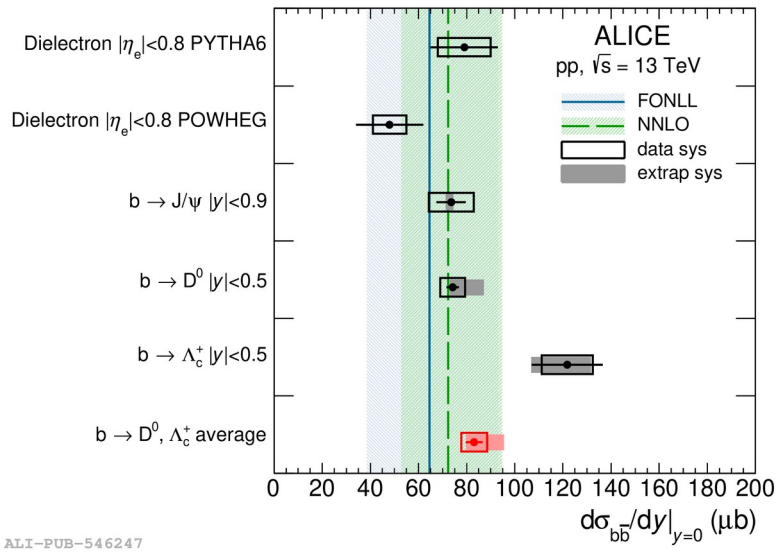
- First open heavy flavour signals from Run 3

Jianhui Zhu
Wednesday 16:50 (475)

Heavy flavour production in pp collisions at √s=13 TeV







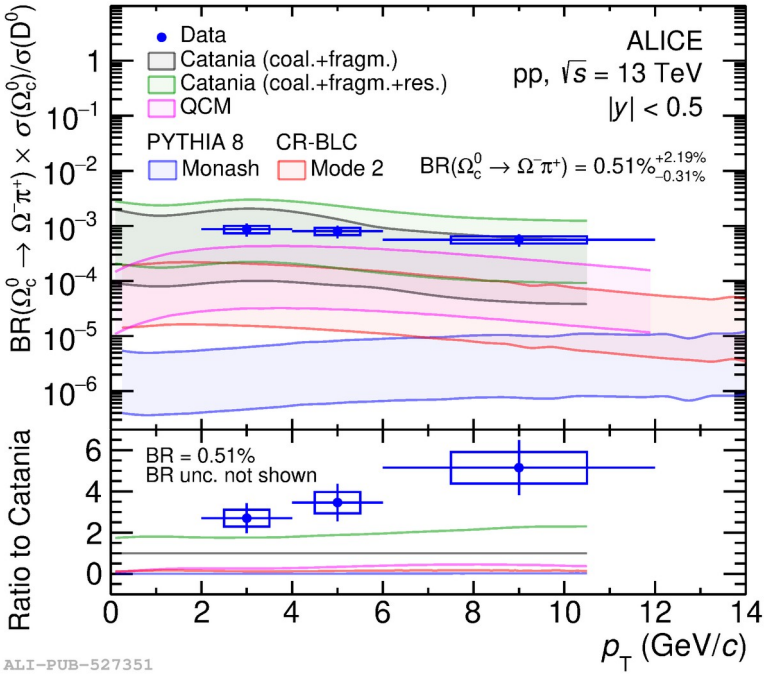
ALICE, arXiv:2308.04877

ALICE, arXiv: 2308.04873

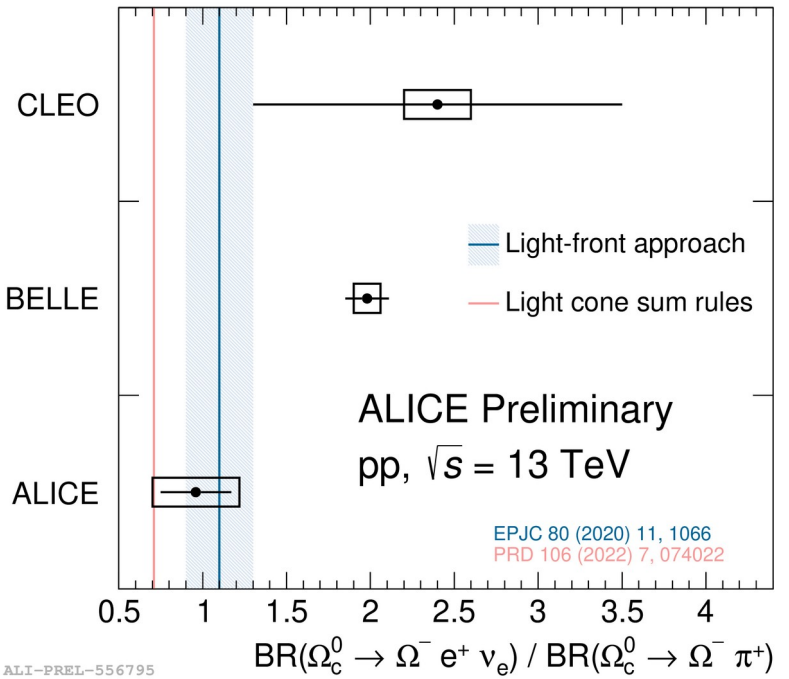
Jianhui Zhu
Wednesday 16:50 (475)

- Charm quark fragmentation to D mesons, charm baryons and J/ψ
- Total cc̄ cross-section on the upper edge of FONLL and NNLO calculations
- Total bb̄ cross-section from extrapolations are in agreement with calculations
  - Outlook: measure exclusive decay channels down to very low p_T

Hadronic and semi-leptonic decays of Ω_c^0 baryons in pp



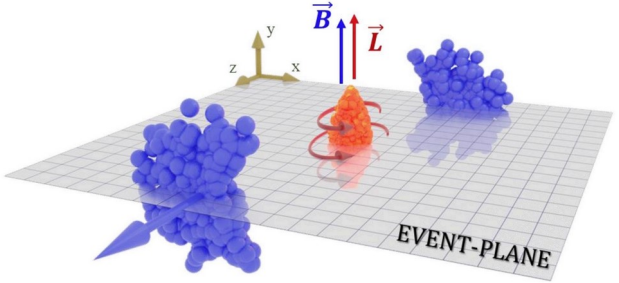
ALICE, arXiv:2205.13993



- Interpretation of Ω_c^0 measurements via hadronic decays limited by BR uncertainties
- ALICE can provide precision measurements of rare decay channels
  - Constraints of charm quark fragmentation models
  - Expect large improvement in Run 3

Jianhui Zhu
Wednesday 16:50 (475)

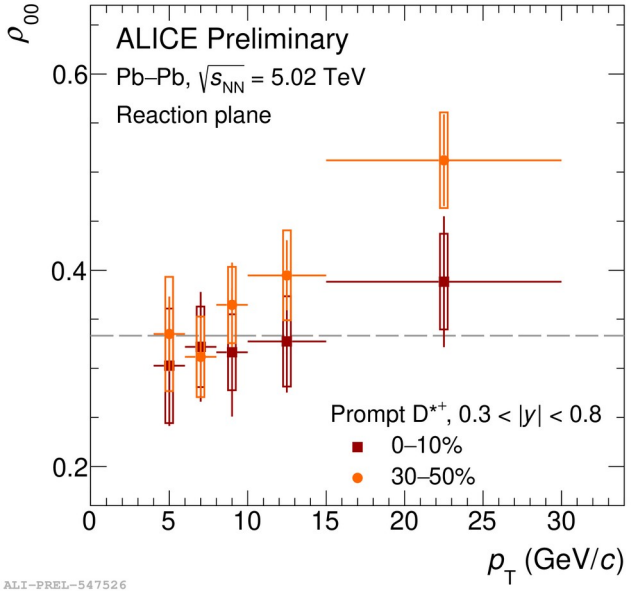
D^{*+} and J/ψ spin alignment wrt reaction plane in Pb-Pb



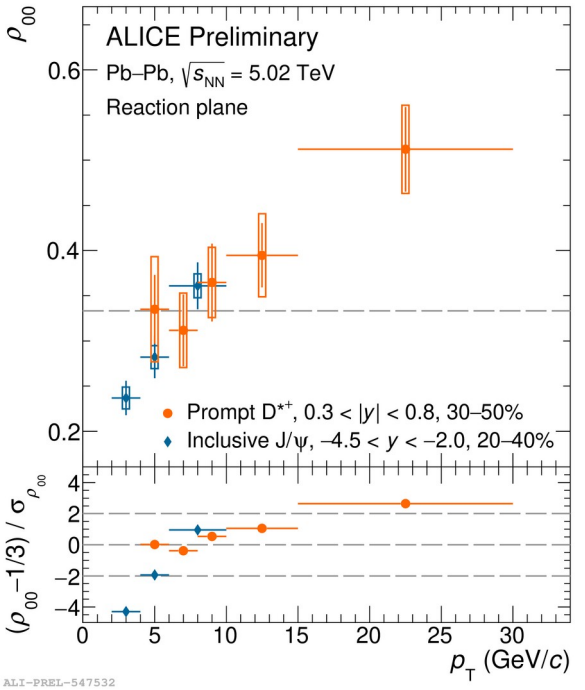
$$W(\cos\theta) \propto (1 - \boldsymbol{\rho_{00}}) + (3\boldsymbol{\rho_{00}} - 1)\cos^2\theta$$

$$\lambda_\theta = \frac{1 - 3\rho_{00}}{1 + \rho_{00}}$$

$\rho_{00} = 1/3$ no spin alignment



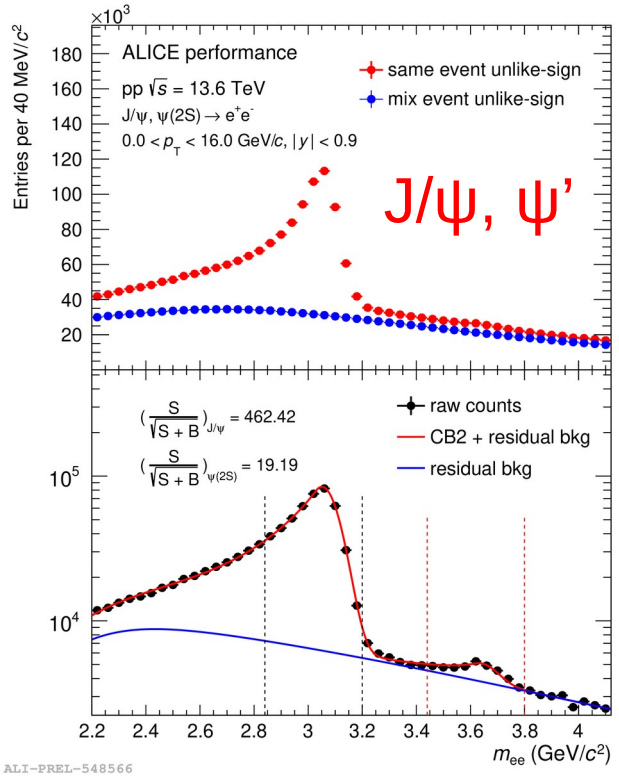
J/ψ: *ALICE, PRL131 (2023)042303*



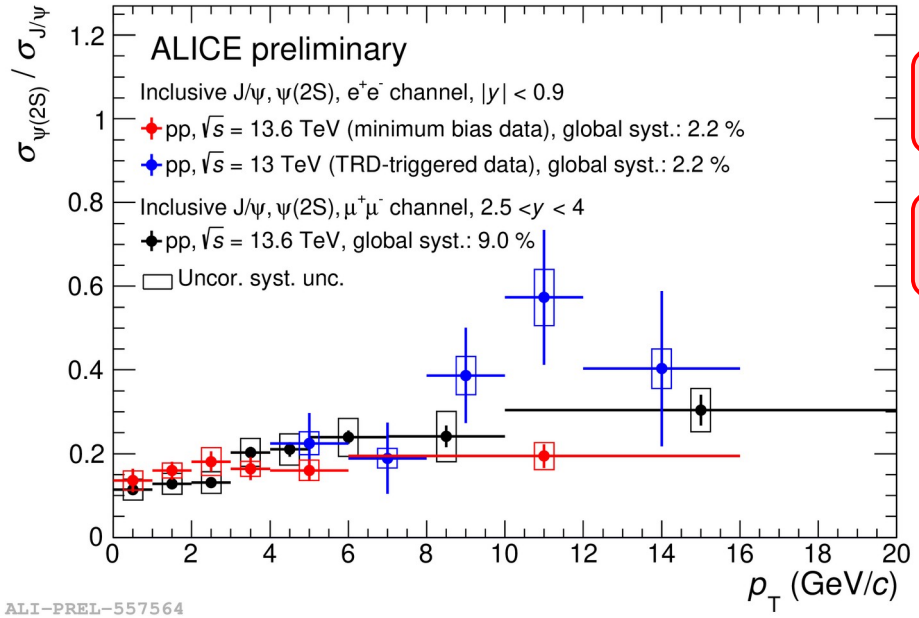
- First measurement of D*+ spin alignment wrt reaction plane
- Hint of polarization for p_T > 10 GeV/*c*
- Alignment sign opposite wrt previous observations for low-p_T J/ψ and light vector mesons
- Theory guidance still missing

Luca Micheletti
Tuesday 14:50 (479)

Quarkonia in pp at √s = 13.6 TeV in **Run 3**



Yuan Zhang
Poster 197



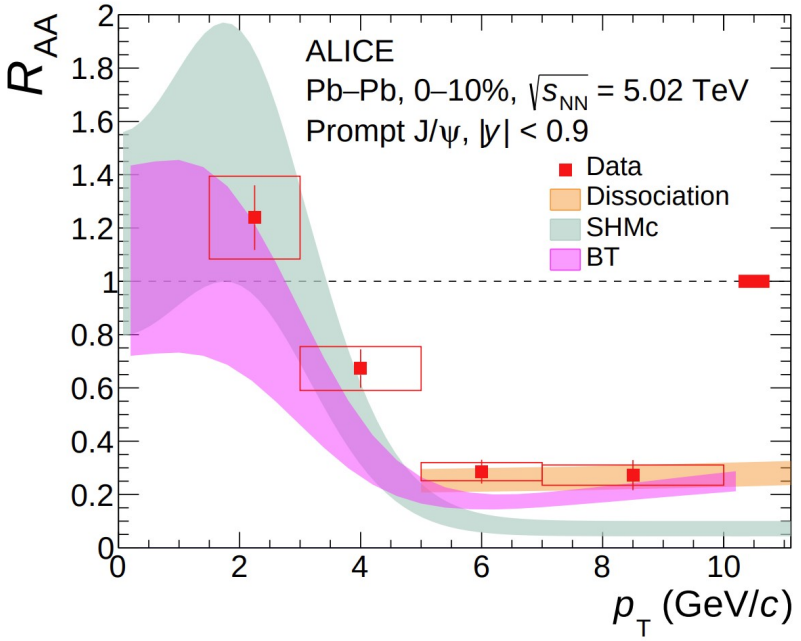
Subikash Choudhury
Tuesday 12:00 (320)

Xiaozhi Bai
Tuesday 08:30 (321)

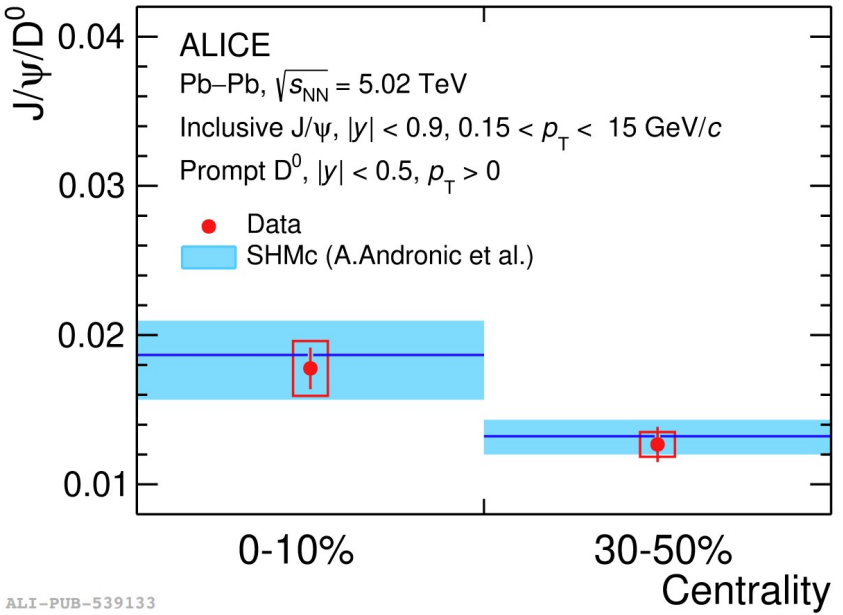
- First ψ(2S) measurements in pp at midrapidity
  - Run 2: TRD triggered
  - Run 3: analysis trigger
- First Run 3 quarkonium results in both barrel and MUON arm

J/ψ R_{AA}

ALICE, arxiv: 2308.16125



ALICE, arxiv: 2303.13361

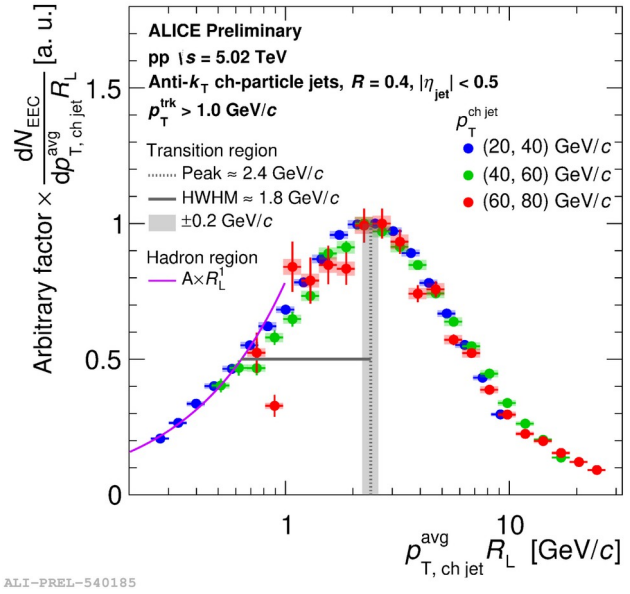


- Prompt J/ψ R_{AA} shows a clear regeneration signal at low-p_T
  - Large model uncertainties due to $c\bar{c}$ cross section in Pb-Pb
- Ratio of inclusive J/ψ to D^0 in good agreement with SHMc

Xiaozhi Bai
Tuesday 08:30 (321)

Jet substructure studies in pp collisions

(energy-energy correlator)

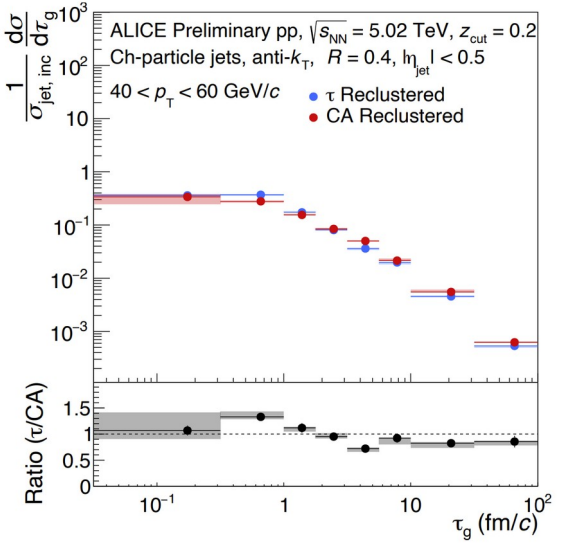


$$\frac{d\sigma_{EEC}}{dR_L} = \sum_{i,j} \int d\sigma(R'_L) \left(\frac{p_{T,i}\, p_{T,j}}{p_{T,jet}^2} \right) \delta(R'_L - R_{L,ij})$$

Energy weight

Komiske et al., PRL130 (2023) 051901

(τ-declustering)



$$\tau \approx \frac{p_{T,1} + p_{T,2}}{p_{T,1} p_{T,2} (\Delta R)^2}$$

Apolinário et al., EPJC81 (2021) 561

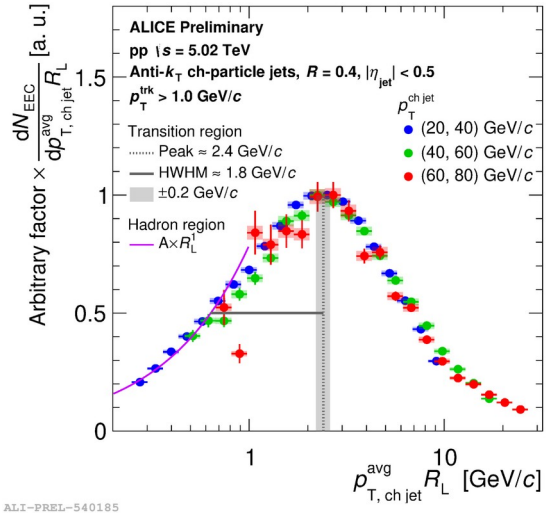
Wenqing Fan
Wednesday 8:50 (454)

Hannah Bossi
Tuesday 11:20 (450)

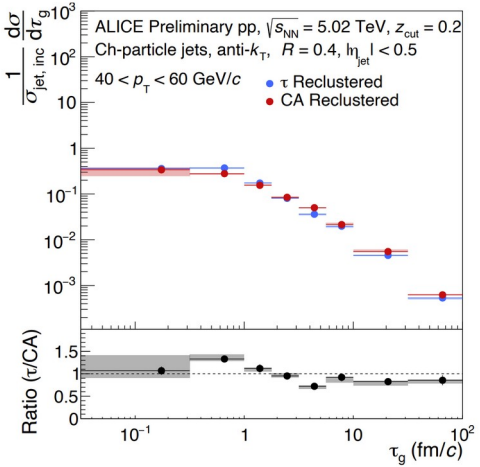
- Innovative new jet substructure observables explored in pp collisions

Jet substructure studies in pp collisions

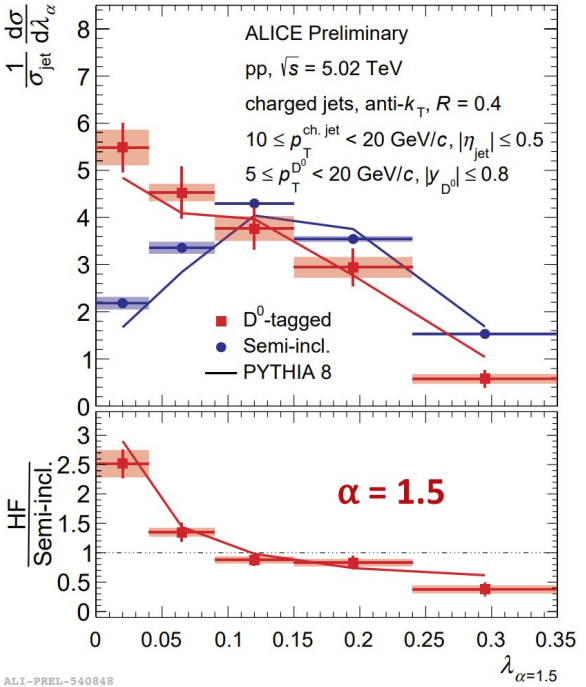
(energy-energy correlator)



(τ-declustering)



(generalized angularities)

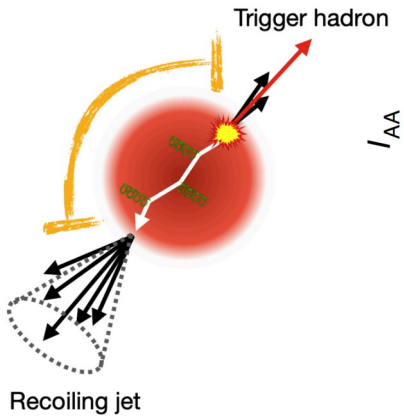


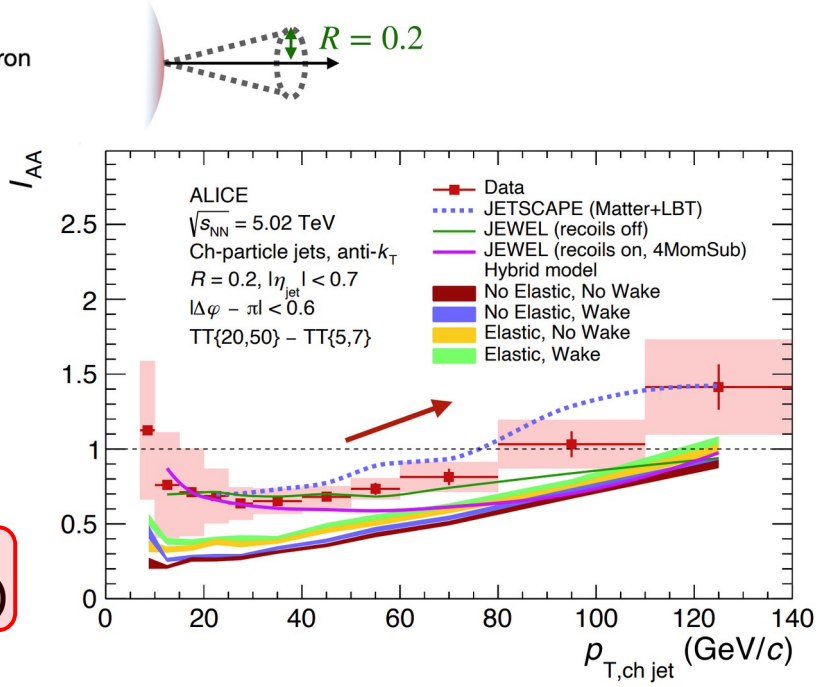
$$\lambda_a^k = \sum_{I \in jet} \left(\frac{p_{\mathrm{T,i}}}{p_{\mathrm{T,jet}}}\right)^{\kappa} \left(\frac{\Delta R_{\mathrm{jet,i}}}{R}\right)^{\alpha}$$

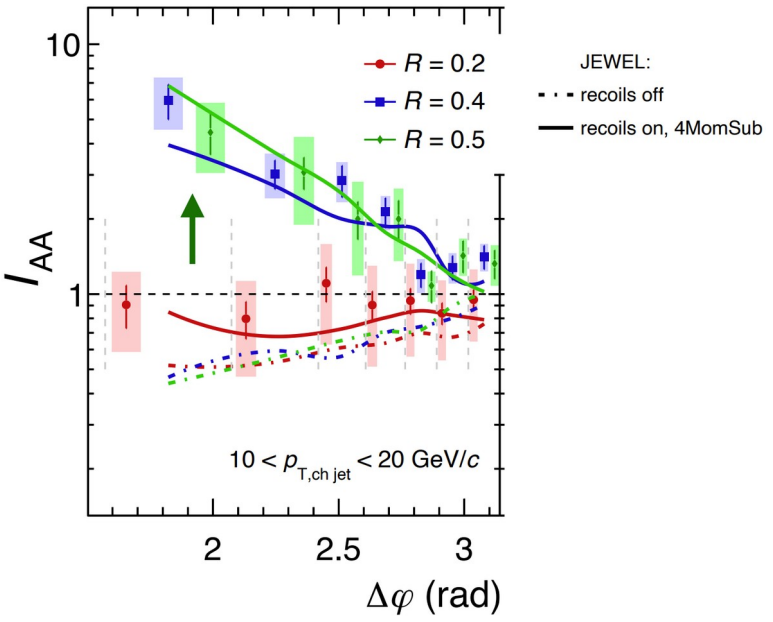
- Innovative new jet substructure observables explored in pp collisions
- Generalized angularities measured for both charged and D-tagged jets
  - D-tagged jet emissions concentrated in the core

Nima Zardoshti
Wednesday 16:50 (453)

Jet broadening and deflection in Pb-Pb collisions







Jamie Norman
Wednesday 9:50 (446)

R=0.2 jets: suppression for $20 < p_{T,jet} < 80$ GeV/c

- Intra-jet recovery seen for R=0.5 jets

Azimuthal broadening has striking transition at low $p_{T,jet}$

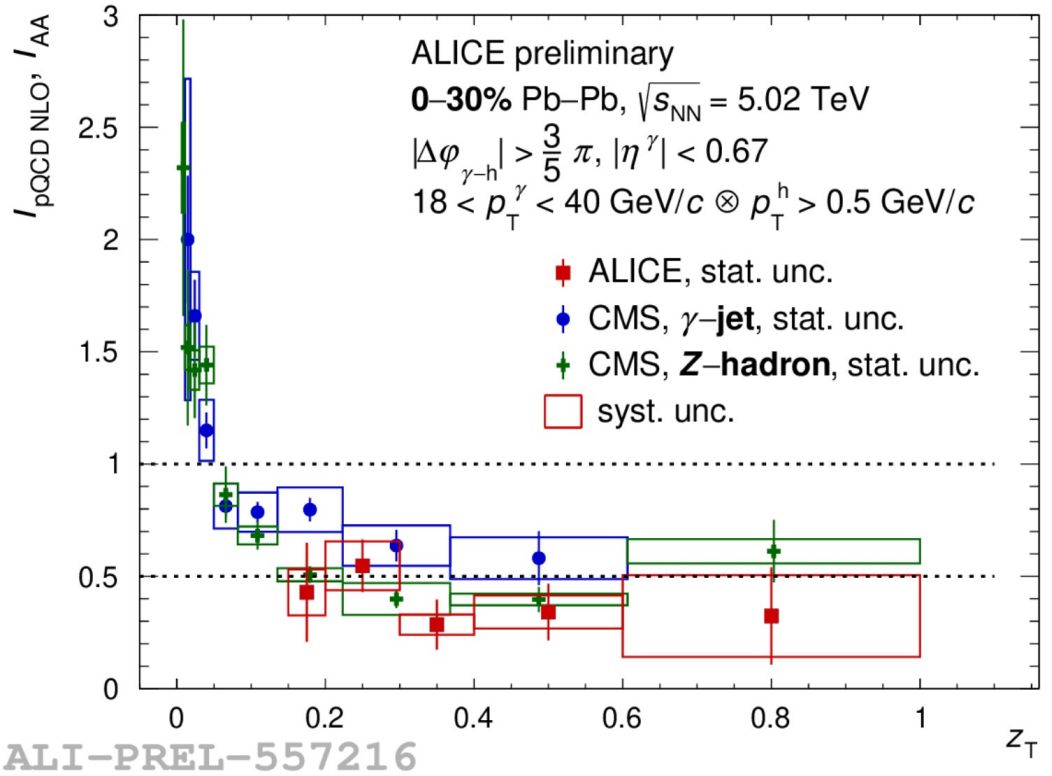
- Characteristic to medium response

ALICE, arXiv:2308.16128

Photon – hadron azimuthal correlations in Pb-Pb collisions

$$z_T = p_T^{hadr} / p_T^{\gamma}$$

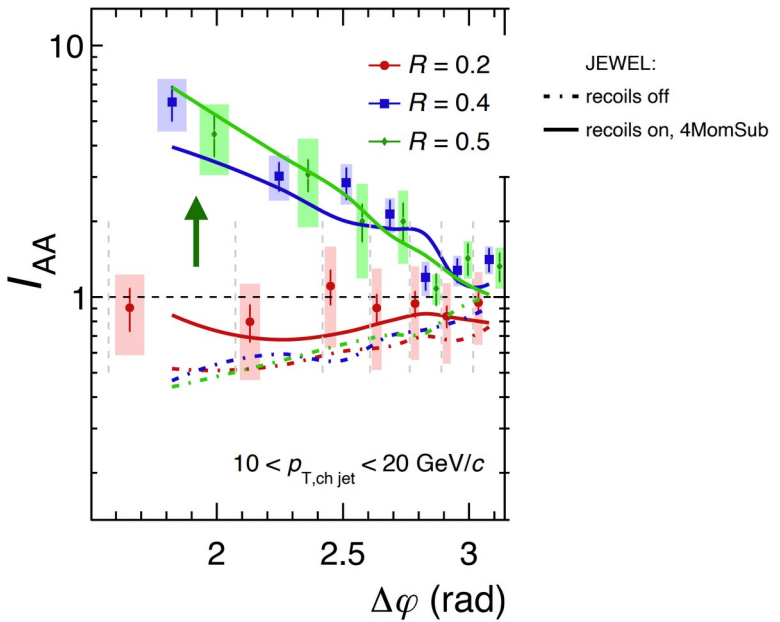
$18 < p_T^{\gamma} < 40$ GeV/c
$p_T^{h} > 0.5$ GeV/c



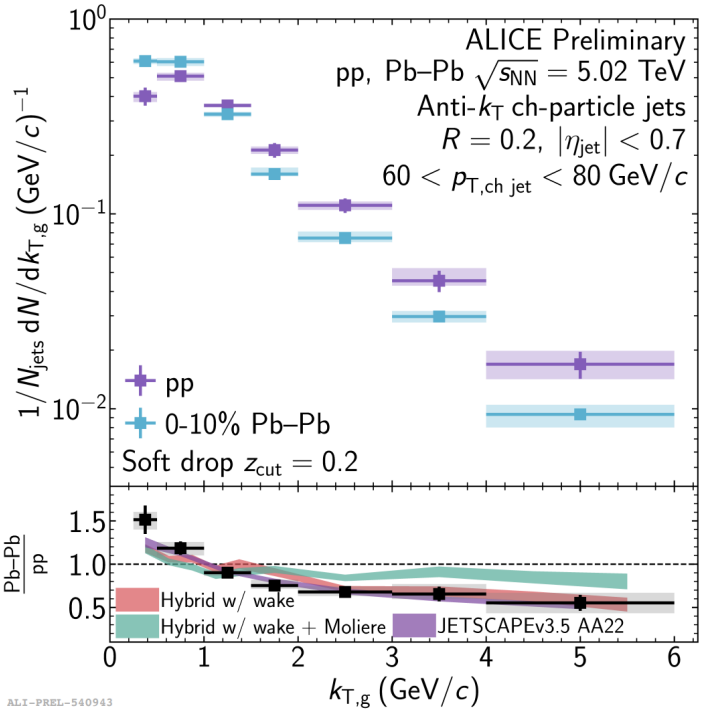
Carolina Arata
Tuesday 15:50 (174)

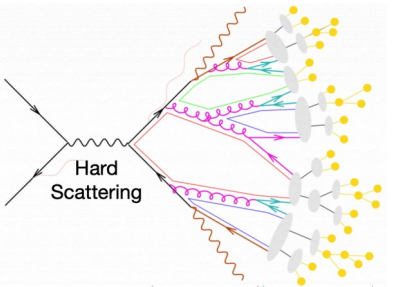
- z_T distribution of recoils in Pb-Pb strongly suppressed wrt pp

Jet substructure modification in Pb-Pb collisions



(k_T of the hardest split)

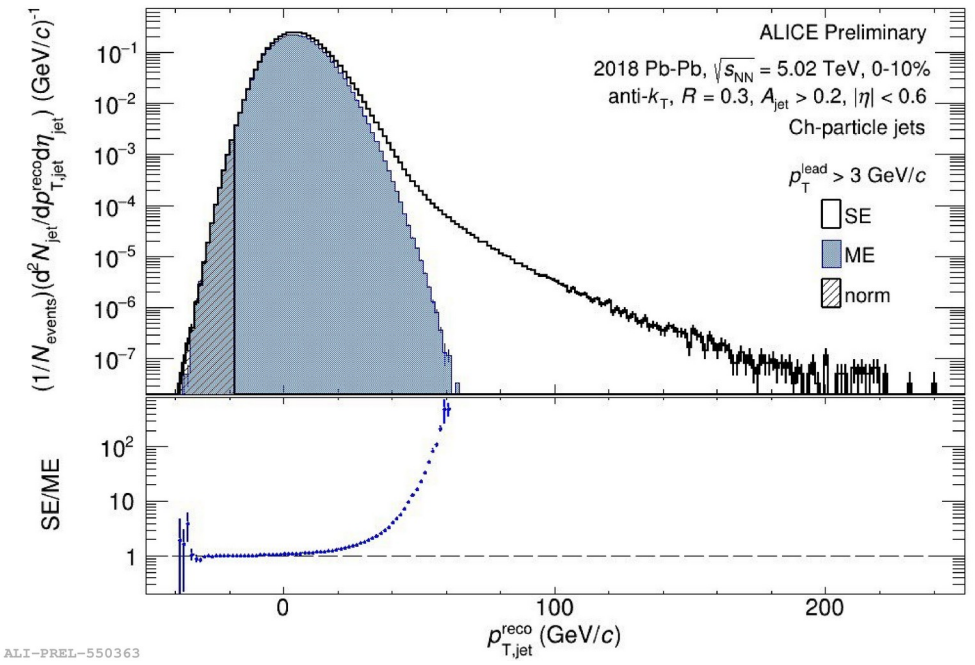


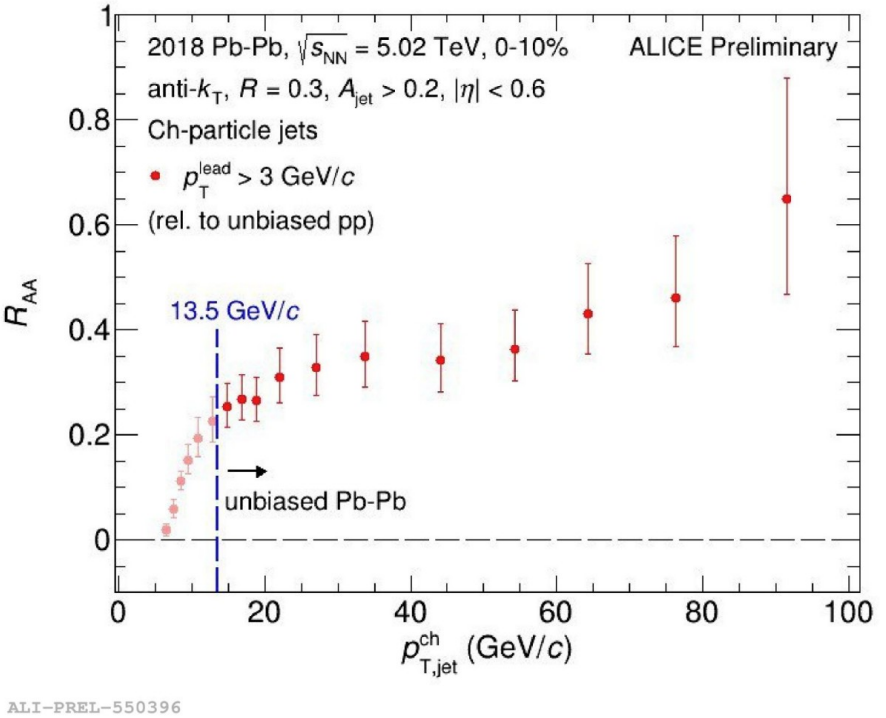


Hannah Bossi
Tuesday 11:20 (450)

- Explore jet broadening in Pb-Pb collisions using substructure observables
  - Data disfavors hard Molière scattering scenario

Jet R_{AA}

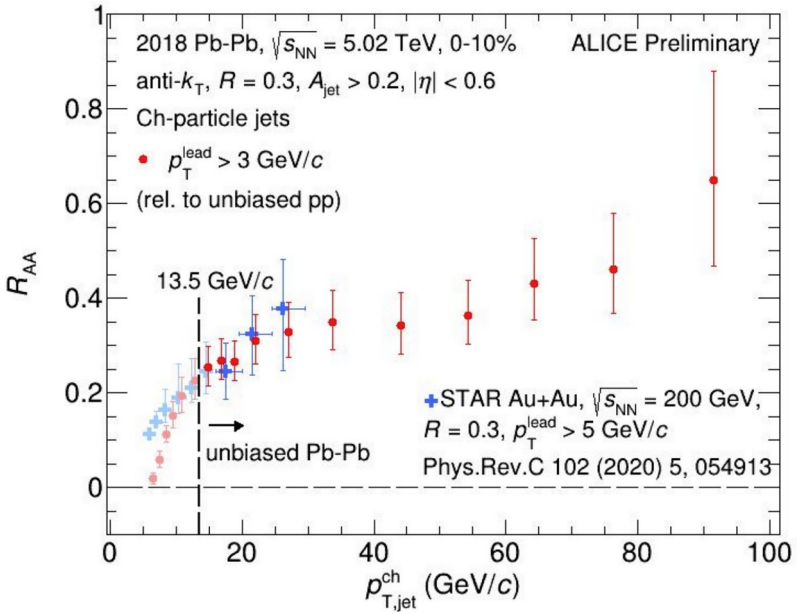


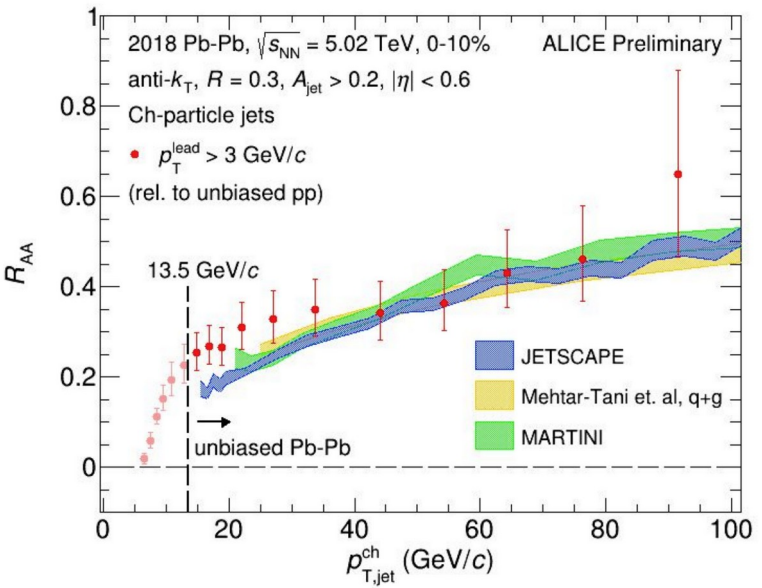


- Jets reconstructed using a new mixed-event technique for background estimation

Nadine Gruenwald
Tuesday 11:40 (444)

Jet R_{AA}



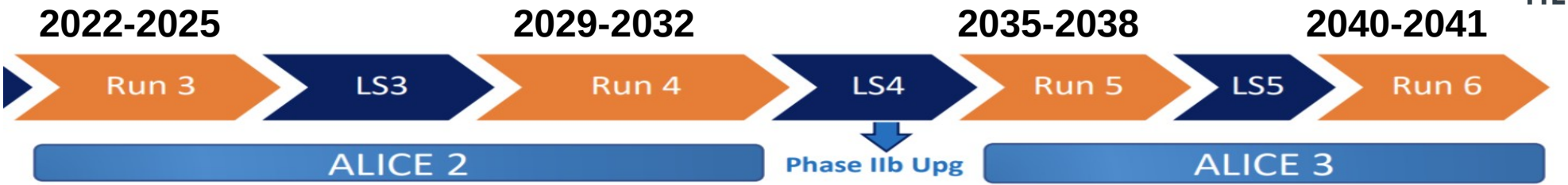


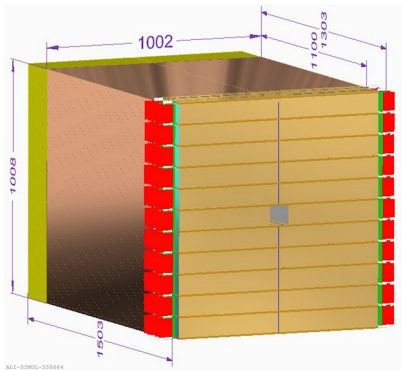
- First direct comparison of inclusive jet R_{AA} values between RHIC and LHC
  - Similar R_{AA} values, but underlying spectrum shape are very different
- Qualitative agreement with models

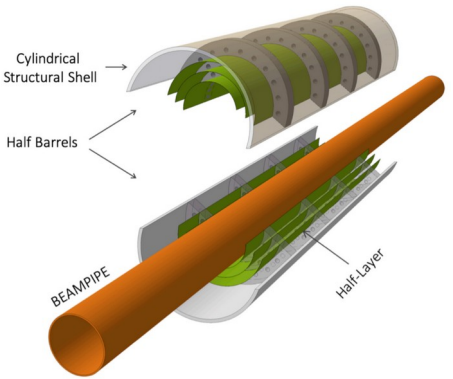
Nadine Gruenwald
Tuesday 11:40 (444)

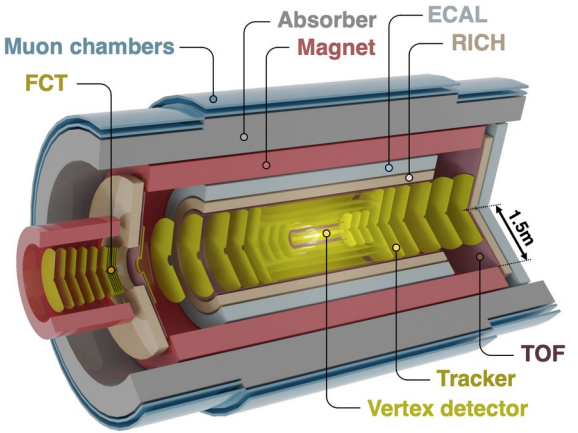
ALICE Upgrades

ALICE upgrades timeline







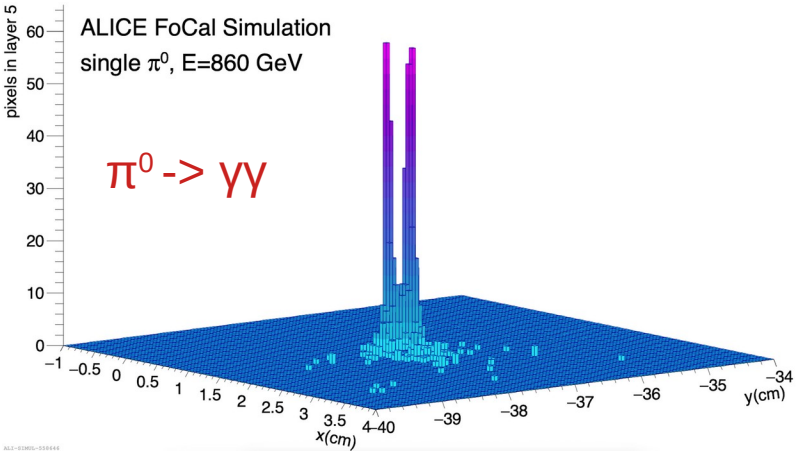


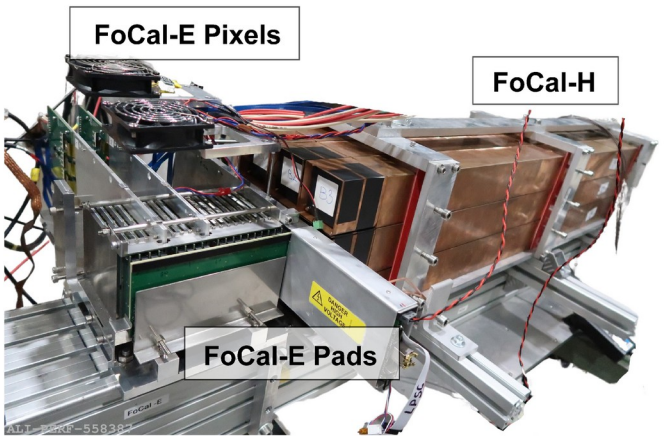
FoCal and ITS3

ALICE3

Forward Calorimeter (FoCal)

- Forward electromagnetic and hadronic calorimeter
  - FoCal-E: low and high granularity
  - FoCal-H: Cu-scintillator with “Spaghetti” design
- Acceptance: $3.2 < \eta < 5.8$
- Main physics motivation
  - Non-linear QCD evolution at small-*x*
- Observables
  - Direct photons, mesons, jets, J/ψ, correlations





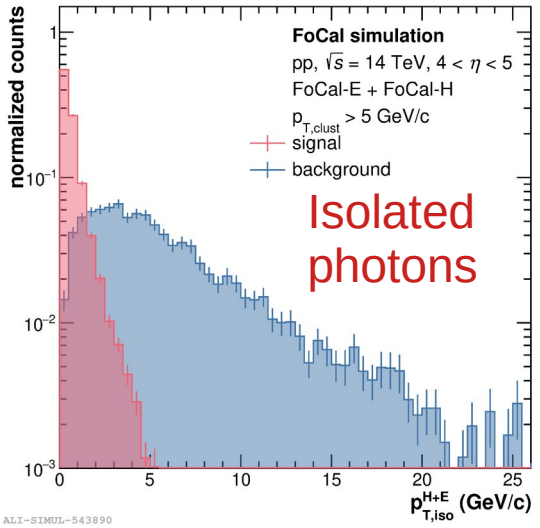
LoI: *ALICE, LHCC-I-036 (2020)*

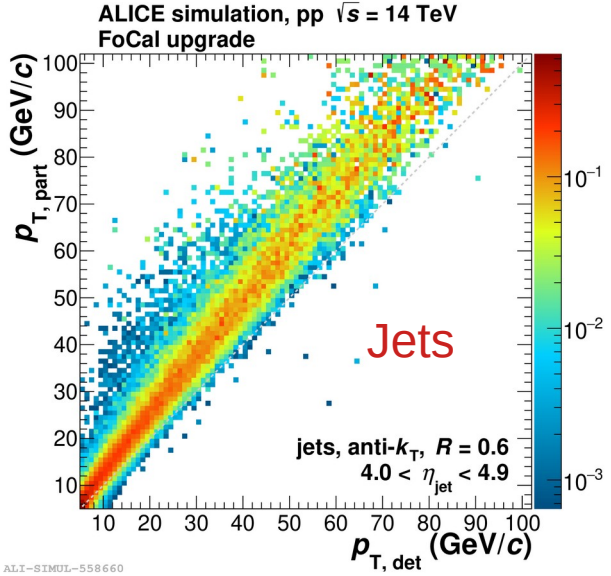
Physics case: *ALICE-PUBLIC-2023-001*

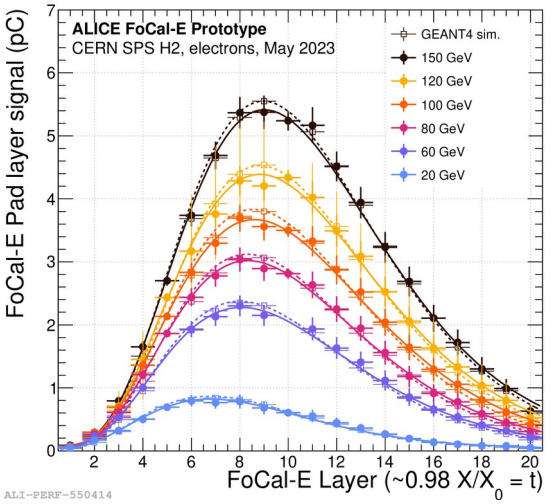
Physics performance: *ALICE-PUBLIC-2023-004*

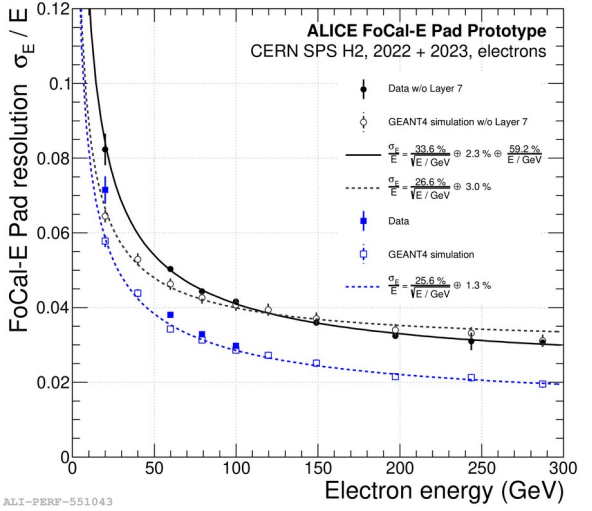
Florian Jonas
Wednesday 11:40 (315)

FoCal physics performance and test beams









Florian Jonas
Wednesday 11:40 (315)

- Preliminary test beam results show excellent performance
- Good agreement between data and simulations
- Technical Design Report by end of 2023

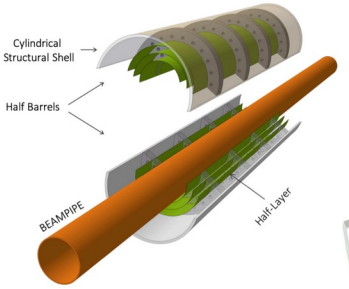
ITS3

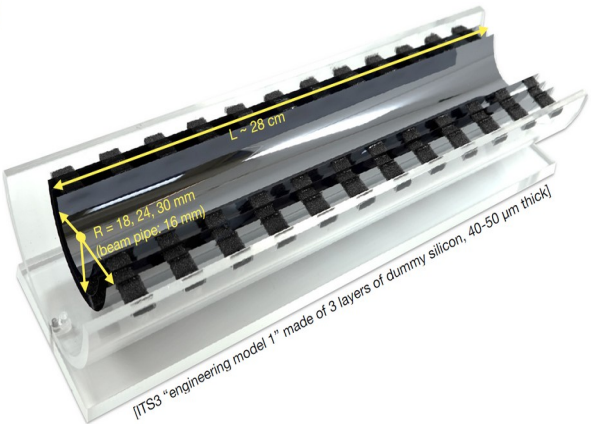
Isabella Sanna
Wednesday 11:20 (317)

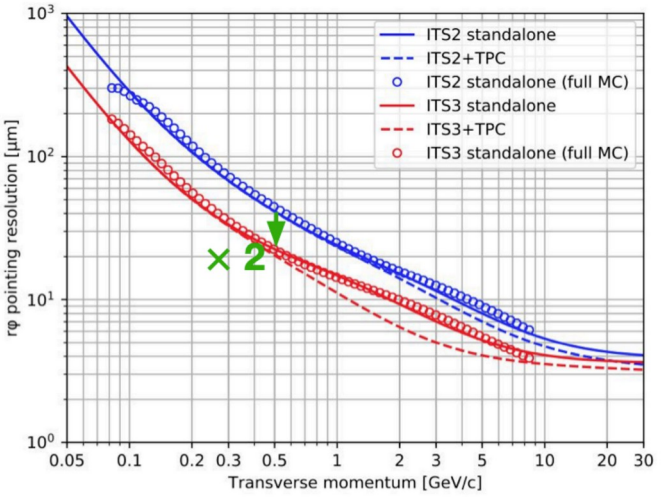
- Upgrade the innermost 3 layers of the ITS
  - Truly cylindrical (sensor bending)
  - 65 nm MAPS sensors
  - Sensor stitching (30 cm wafers)
- Main motivation
  - Improve performance for open heavy flavour and dielectron measurements
- TDR by end of 2023

LoI: *CERN-LHCC-2019-018*

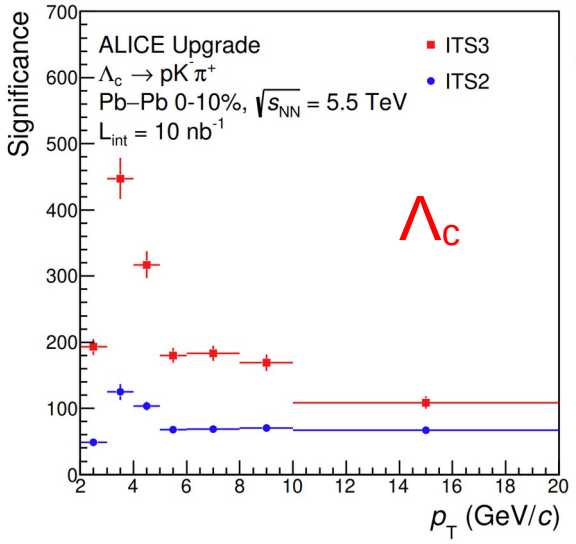
Physics performance: *ALICE-PUBLIC-2023-002*

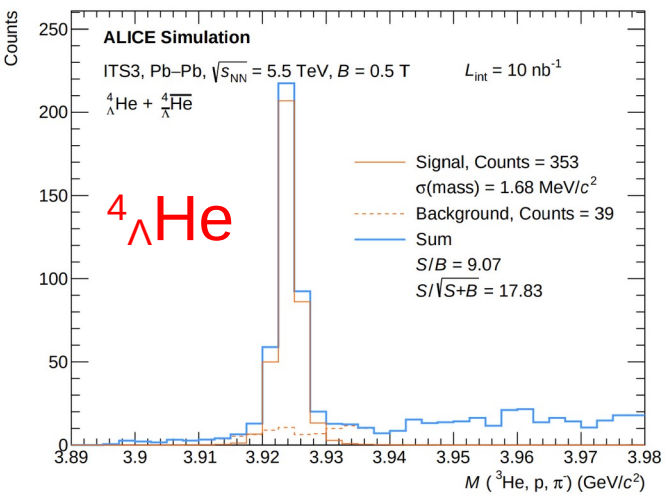




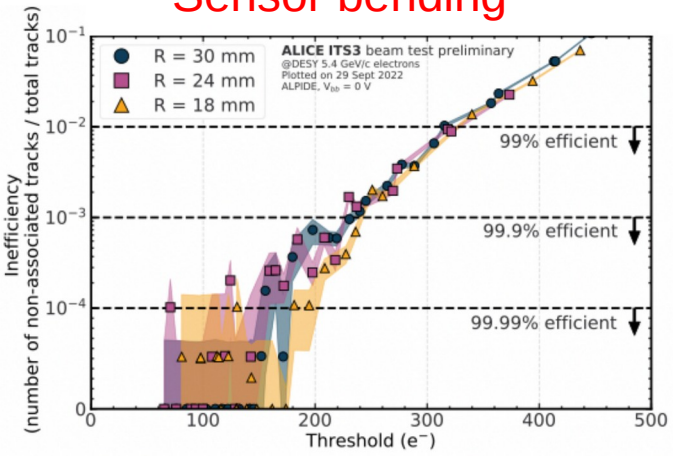


ITS3 physics performance and test beams

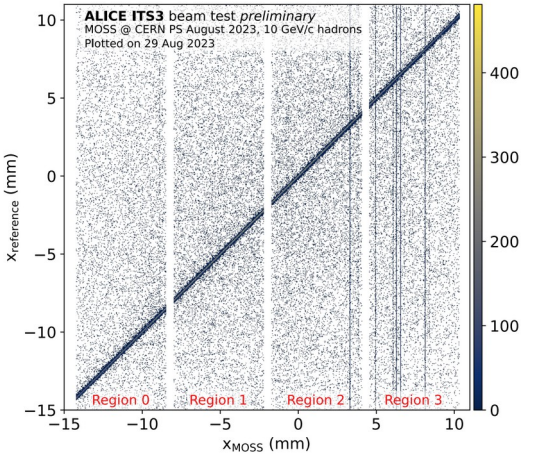




Sensor bending



Sensor stitching



Beam tests show excellent performance

- Bending: no changes in sensor performance
- Stitching: all basic functionalities are verified, full characterization ongoing

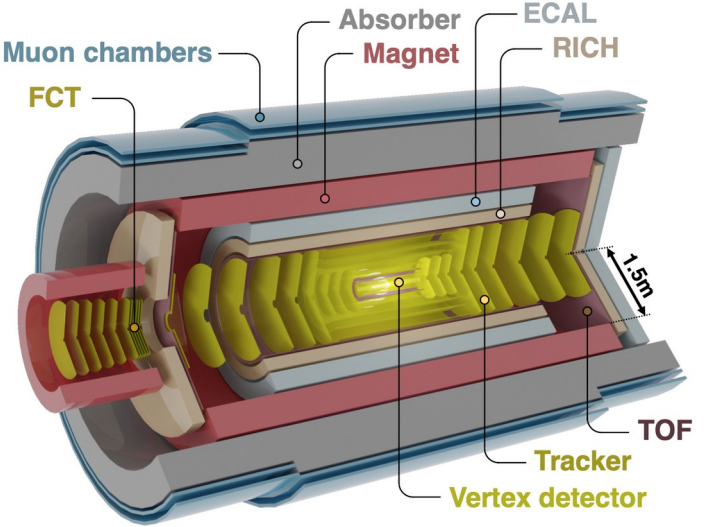
Physics performance: *ALICE-PUBLIC-2023-002*
Test beam: *NIM A 1028(2022) 166280*

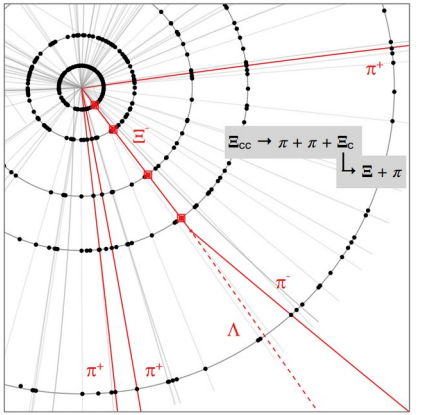
Isabella Sanna
Wednesday 11:20 (317)

Beyond Run 4: ALICE3

Isabella Sanna
Wednesday 11:20 (317)

- Main physics goals
  - Charm and beauty hadronization in the QGP
    - Multi-charm hadrons and quarkonia
  - Thermal radiation and chiral symmetry restoration
    - Dileptons, photons, vector mesons
  - Light (hyper)nuclei and searches for charmed hypernuclei
  - Ultra-soft photons
  - Fluctuations of conserved charges
  - BSM searches
- Performance requirements
  - Increased readout rate and η acceptance
  - Improved tracking and vertexing performance at low p_T
  - Enhanced PID capabilities

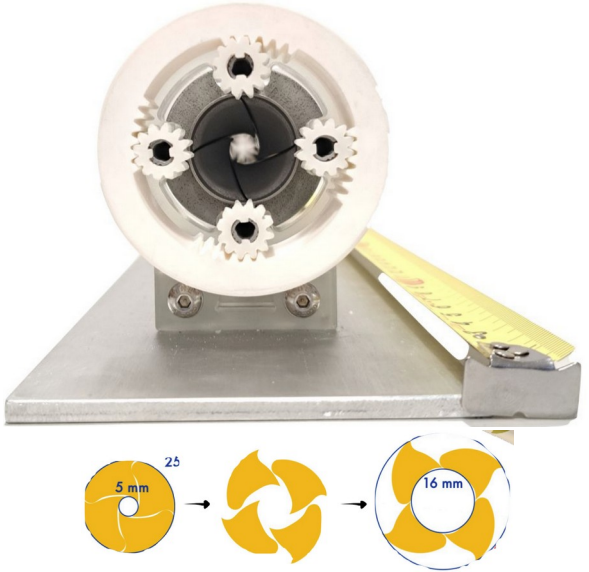




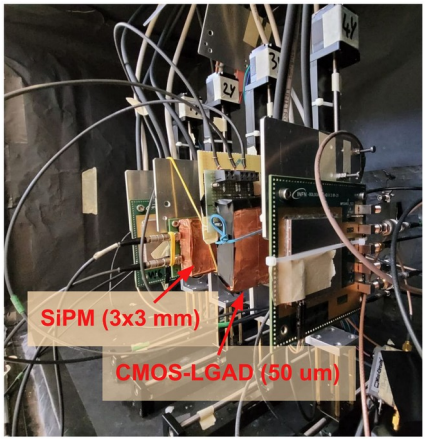
Loi: CERN-LHCC-2022-009

Beyond Run 4: ALICE3

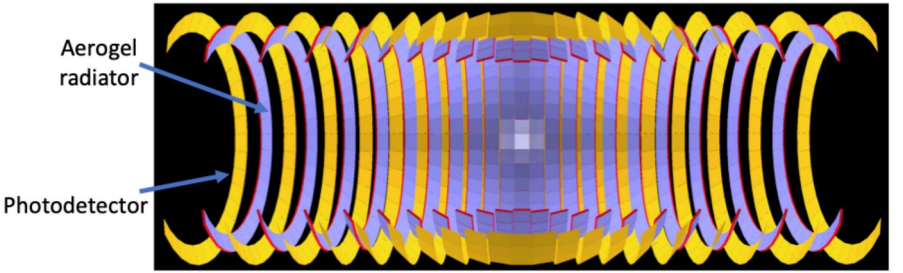
Isabella Sanna
Wednesday 11:20 (317)



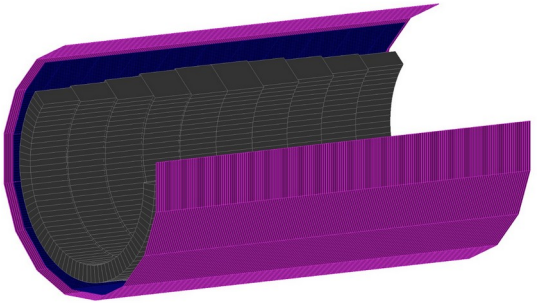
Vertex detector latest breadboard model:
- Retractable concept (iris)
- Closed/open: 5/16 mm



Time of Flight:
- Test beam for several technologies



RICH:
- Prototype preparation in progress: test beam Oct'23



Muon identification detector setup

- Sensor R&D and specific choices of the detector setup are in full swing

Summary

- Run 3 data taking ongoing with a huge boost in recorded luminosity
  - Stay tuned!
- Many new Run 3 and Run 2 results to be presented at this Quark Matter
  - 30 talks
  - 60 posters
- Upgrade projects for Run 4 (FoCal and ITS3) and ALICE3

ALICE talks at QM'23

Chirality
Chunzheng Wang, Tuesday 08:50

Small systems
Mingrui Zhao, Tuesday 15:10
Alek Hutson, Wednesday 11:00
Austin Schmier, Wednesday 11:20
Jianhui Zhu, Wednesday 16:50
Sara Pucillo, Wednesday 17:30

Collective dynamics
Cindy Mordasini, Wednesday 10:10

Light/Strange flavours
Sonali Padhan, Tuesday 11:40
Neelima Agrawal, Tuesday 12:20
Francesca Ercolessi, Tuesday 12:40
Bhawani Singh, Wednesday 08:30
Ivan Vorobyev, Wednesday 08:50

QCD
Mario Ciacco, Tuesday 13:00

Astrophysics
Chiara Pinto, Wednesday 12:40

EM probes
Afnan Shatat, Tuesday 14:50
Carolina Arata, Tuesday 15:50
Daiki Sekihata, Tuesday 16:10

Heavy flavours
Xiaozhi Bai, Tuesday 08:30
Subikash Choudhury, Tuesday 12:00
Ravindra Singh, Tuesday 09:10
Wenqian Fan, Wednesday 08:50
Nima Zardoshti, Wednesday 16:50

Initial state
Luca Micheletti, Tuesday 14:50
Adam Matyja, Tuesday 15:30

Jets
Hannah Bossi, Tuesday 11:20
Nadine Gruenwald, Tuesday 11:40
Jamie Norman, Wednesday 09:50

UPC
Simone Ragoni, Wednesday 09:10

Future facilities
Isabella Sanna, Wednesday 11:20
Florian Jonas, Wednesday 11:40