CLHCP 2021
第七届中国LHC物理研讨会The 7th China LHC Physics Workshop (CLHCP2021)

Selected recent results from ALICE

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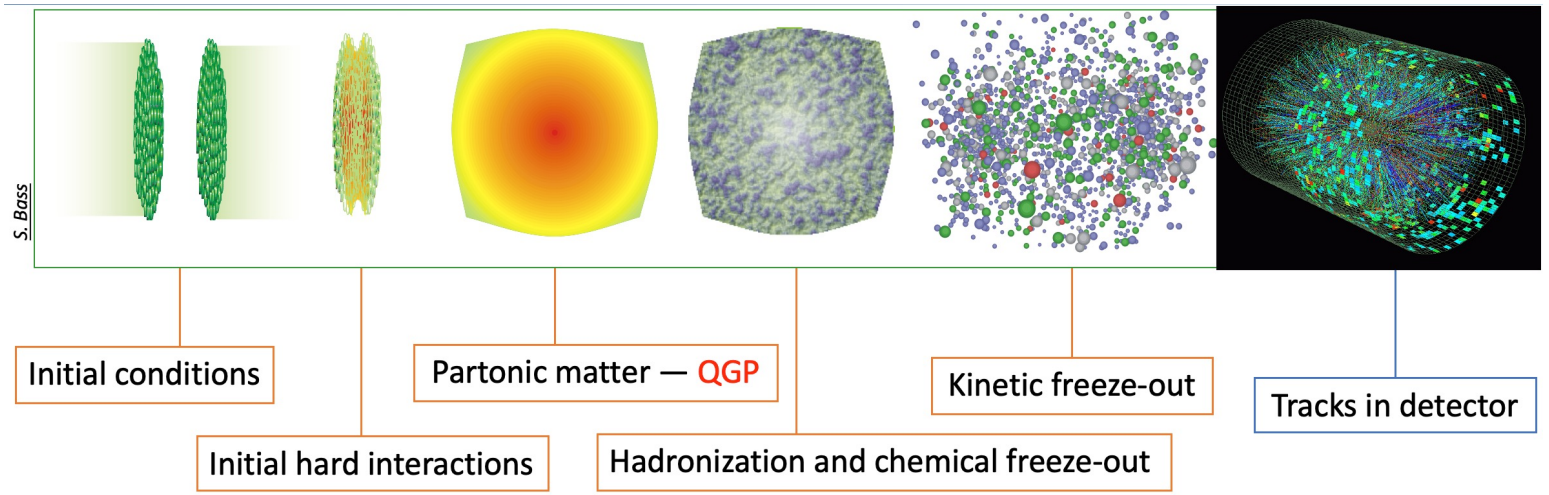
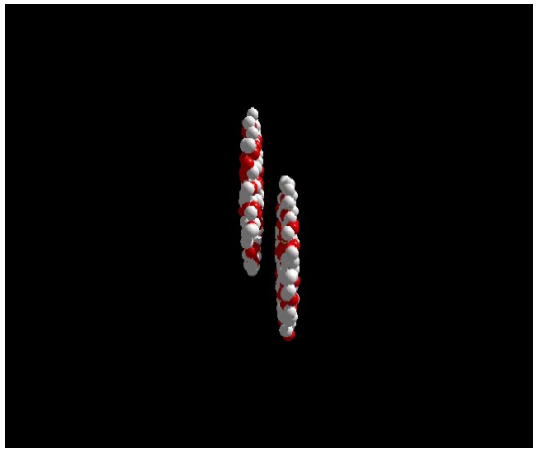
November 27, 2021

Outline

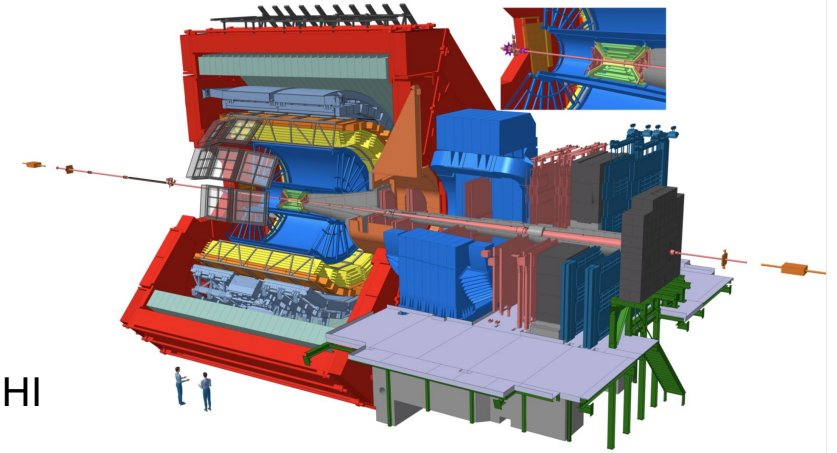
- Introduction
- Heavy-ion collisions for hot QCD matter
- Small system for beyond QGP physics
- Summary

Introduction





- Pb-Pb collisions
  - Partonic degree of freedom, hot QCD matter
- p-Pb collisions
  - CNM effect, hadronic process, link pp to Pb-Pb
- p-p collisions
  - Test pQCD, fragmentation and hadronization, reference for HI



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- Introduction
- **Heavy-ion collisions for hot QCD matter**
- Small system for beyond QGP physics
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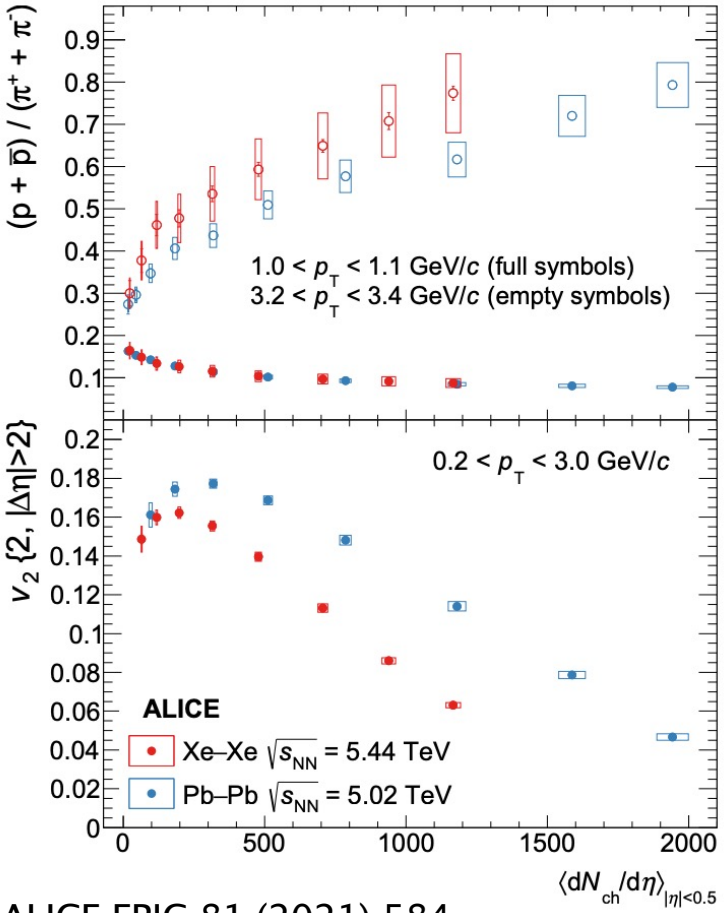
Identified hadrons in Xe-Xe and Pb-Pb

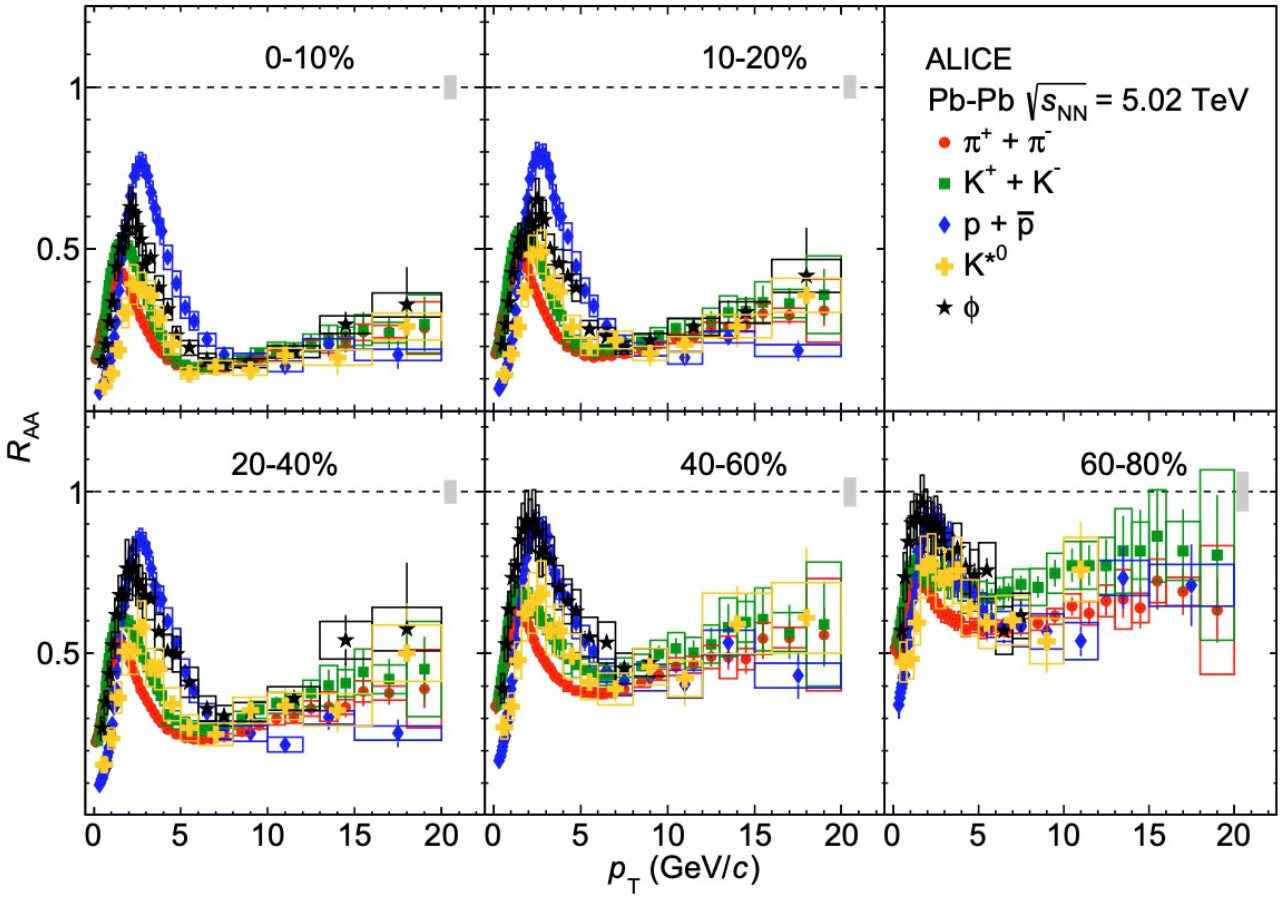
- p/π ratio at fixed p_T: sensitive to radial flow
  - Ratio in Xe–Xe consistent with Pb–Pb for similar N_{ch}.
- Elliptic flow v_2 vs. multiplicity
  - Differences between Xe–Xe & Pb–Pb for similar N_{ch}.
- Suggests that radial flow controlled primarily by the system size (charged-particle multiplicity)
  While anisotropic flow depends on both system size and geometry (eccentricity)



ALICE EPJC 81 (2021) 584

Light and strange hadrons in Pb-Pb

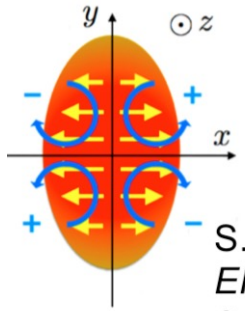
- More suppression in more central collisions.
- Similar suppression level for all particles at high p_T.
  - medium does not modify particle composition in the light quark sector.
- Difference at low p_T.
  - radial flow and rescatterings.



ALICE arXiv: 2106.13113

Λ Polarization in Pb-Pb

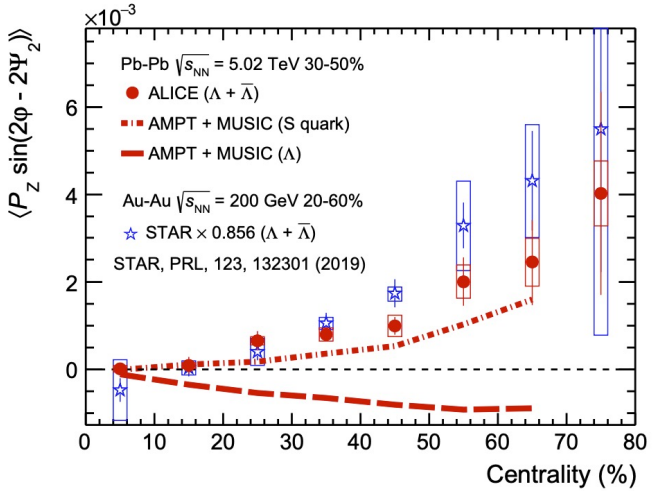
- Longitudinal polarization:

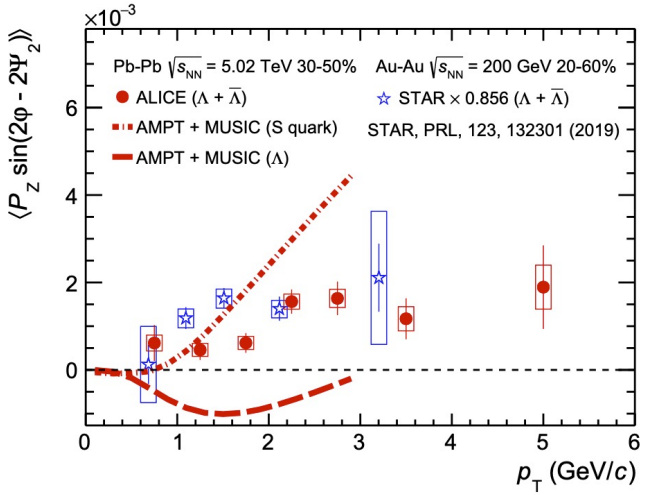


$$\langle P_z \sin(2\phi - 2\Psi_2) \rangle$$

S. A. Voloshin,
EPJ Web Conf.
171 07002 (2018)

- Signal similar at STAR & ALICE
- Evidence of a significant hyperon polarization along the beam direction due to elliptic flow induced vorticity

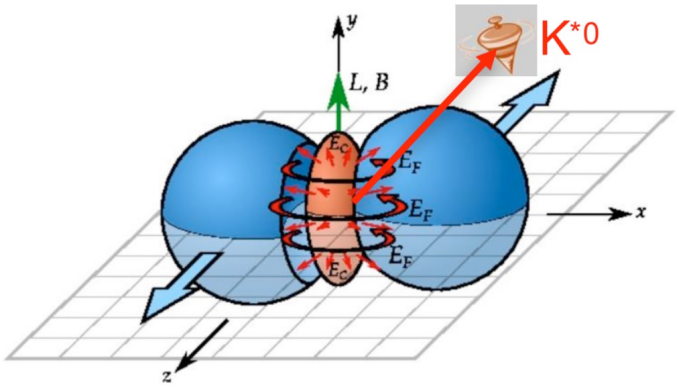




ALICE arXiv: 2107.11183

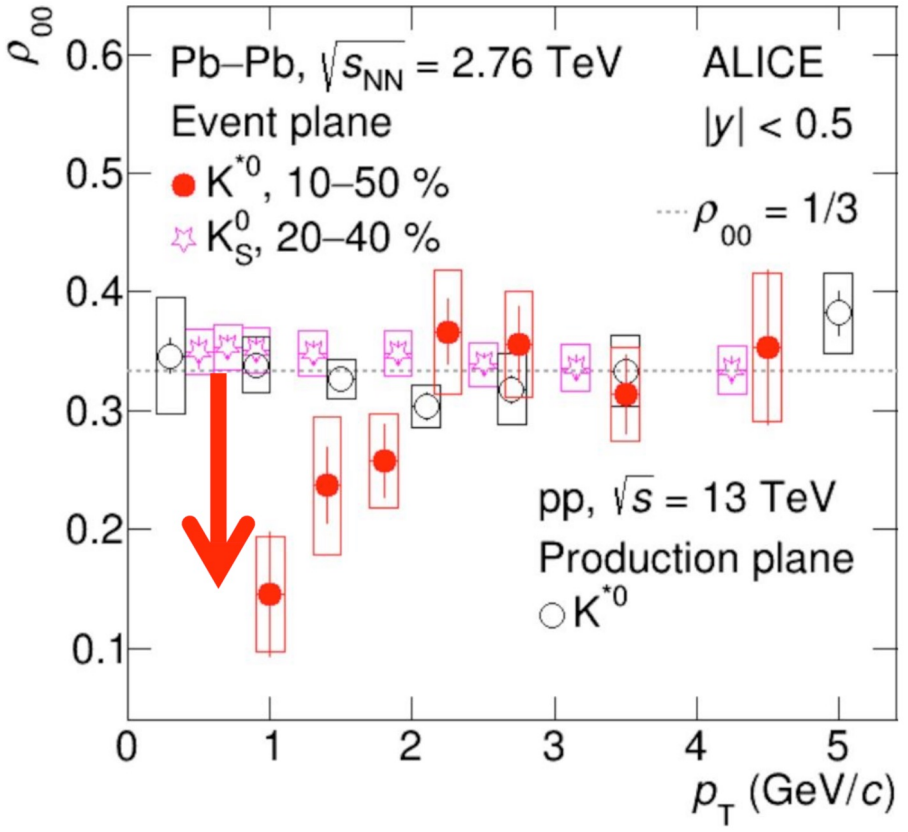
Spin alignment of vector mesons in Pb-Pb

- Large angular momentum L in non-central collisions
  - spinning QGP (~10^{21} revolutions per second)



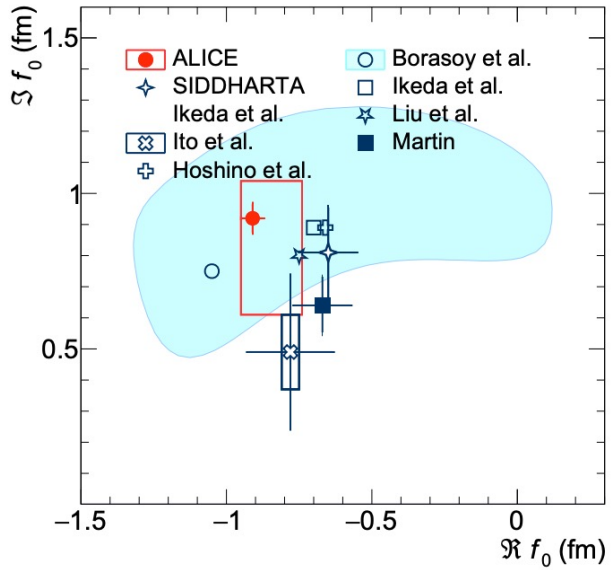
- Spin-orbit interactions expected to polarize quarks
  If quarks recombine to produce vector mesons, spin alignment could appear

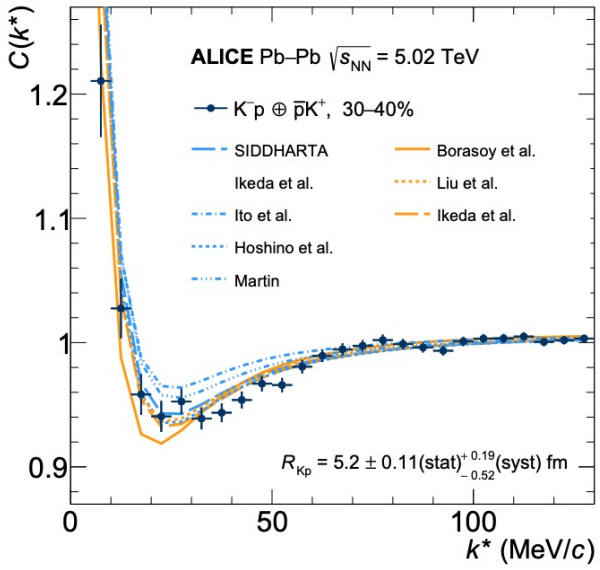
- Measurement using $K^{*0} \rightarrow K\pi$ decays shows a 3σ effect at low momentum. While it is not seen for K_s^0

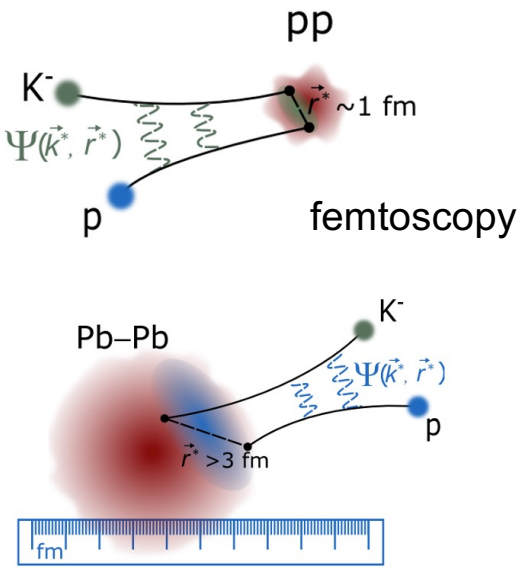


ALICE PRL 125, 012301 (2020)

K-p strong interaction in Pb-Pb





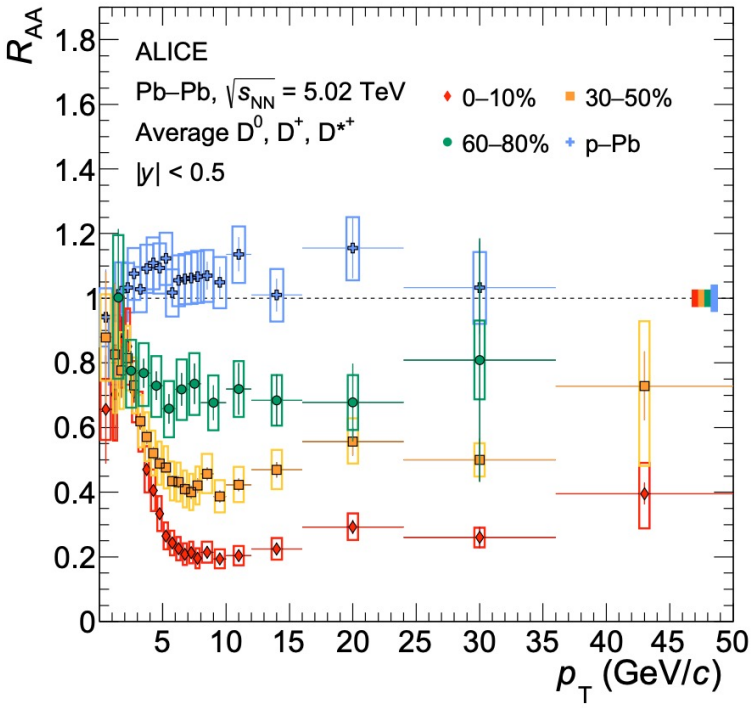


ALICE PLB 822 (2021) 136708

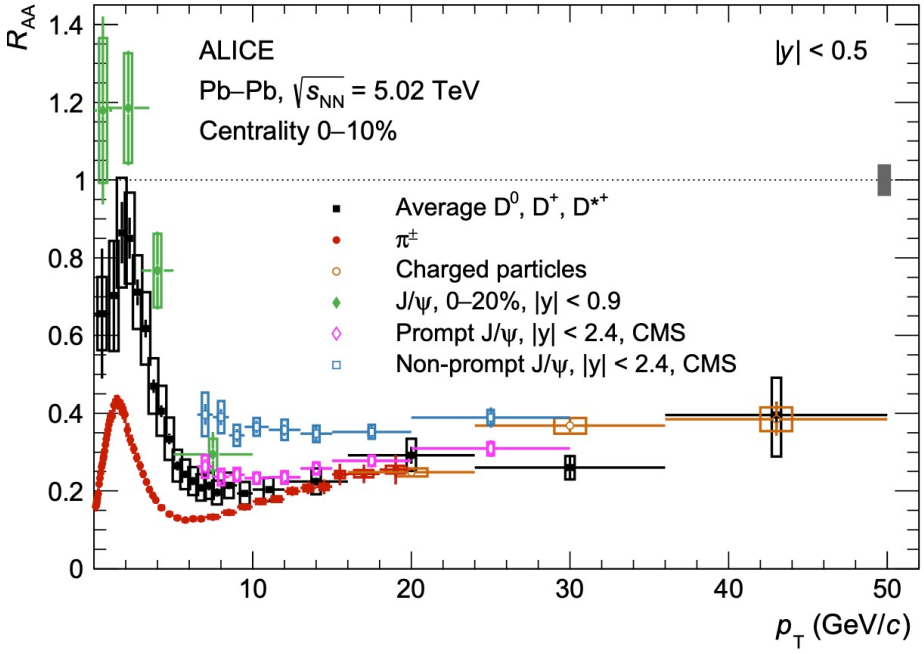
- Significant strong interaction between kaon and proton in Pb-Pb at 5.02 TeV.
- The scattering length between kaon and proton is around 1 fm via a Lednický–Lyuboshitz fit.

More in Qiye Shou‘ talk @ Sat. morning session

Heavy flavor R_{AA} in Pb-Pb



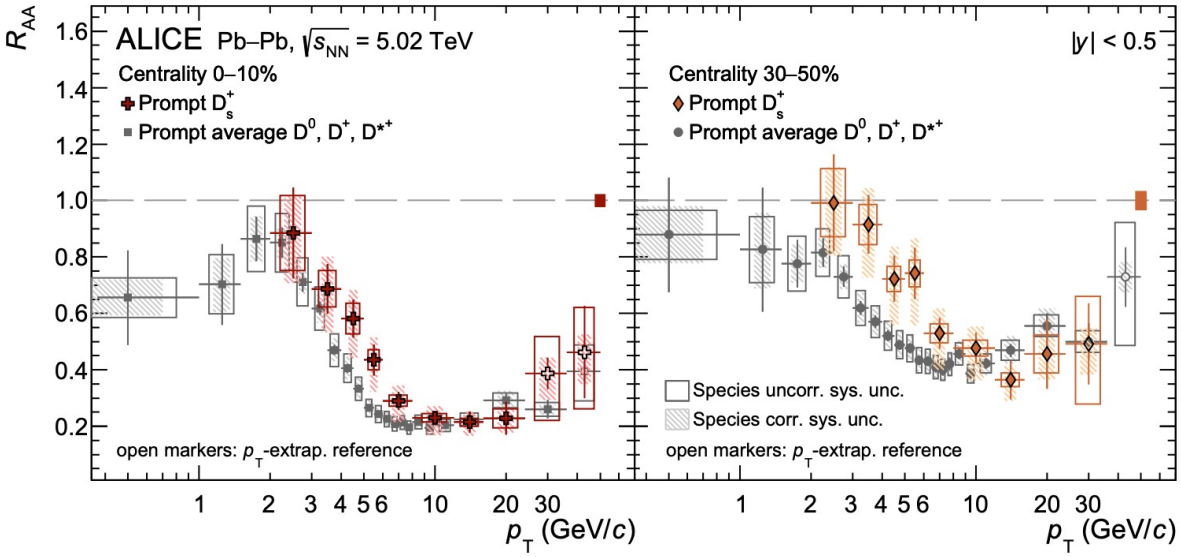
ALICE arXiv: 2110.09420



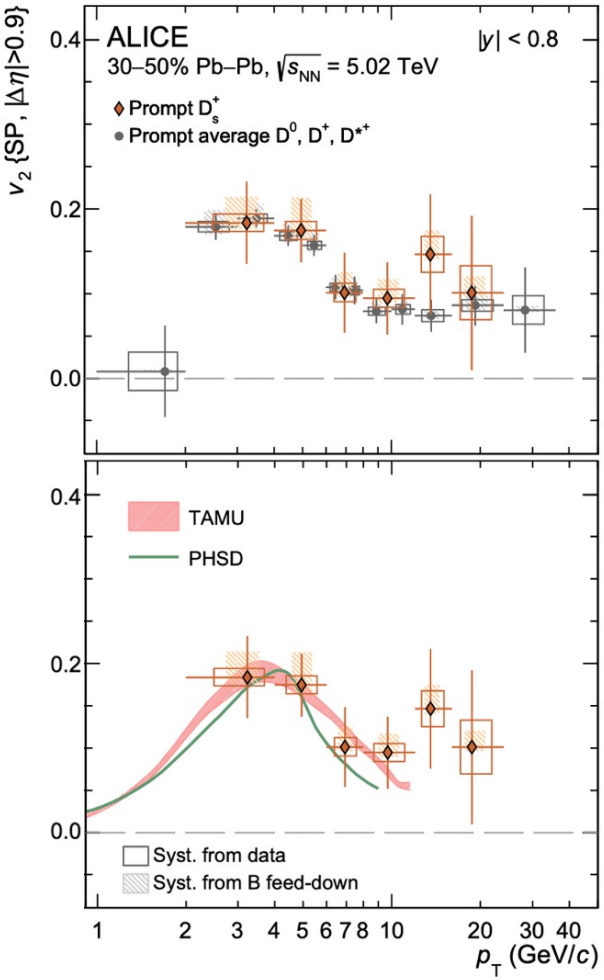
- More suppression observed in hotter medium.
- In low and intermediate p_T region, R_{AA} of non-prompt J/Ψ > J/Ψ >~ D > π/h

  => Mass-dependent parton energy loss.

Prompt D_s^+ in Pb-Pb

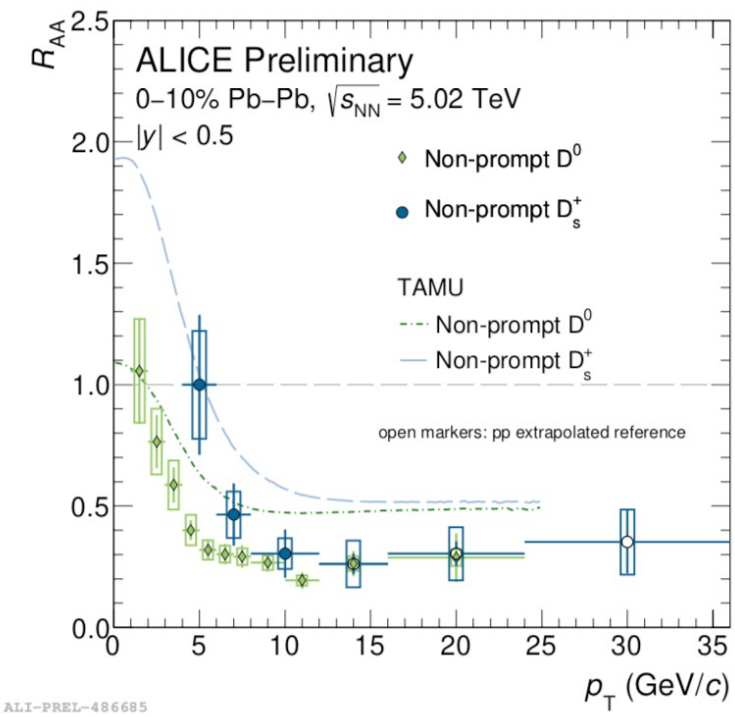


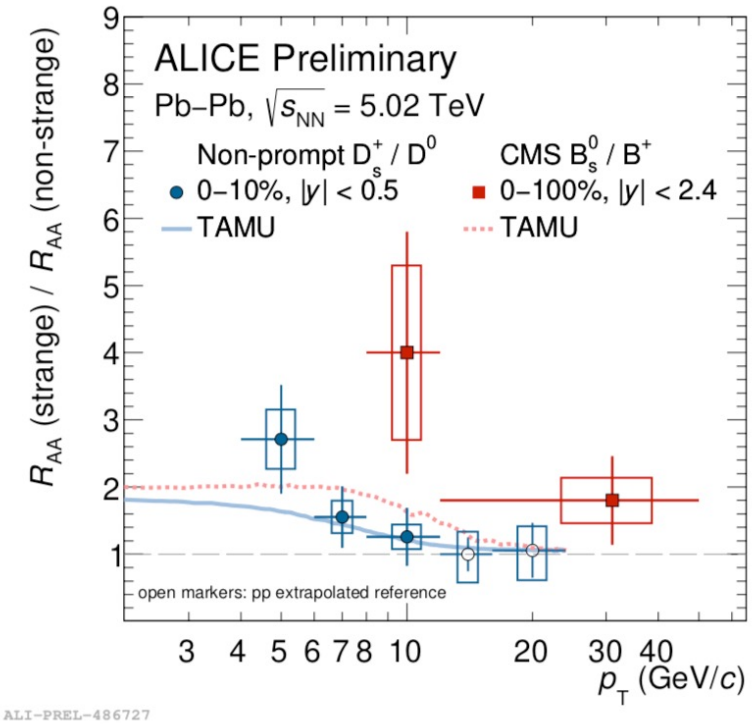
ALICE arXiv:2110.10006



- Hit of less suppression of strange D-meson compared to non-strange.
  - Strangeness enhancement in intermediate p_T region.
- No significant difference between strange and non-strange D-mesons.
- Comparable with TAMU and PHSD predictions within uncertainties.

Non-prompt D^0 and D_s^+ in Pb-Pb

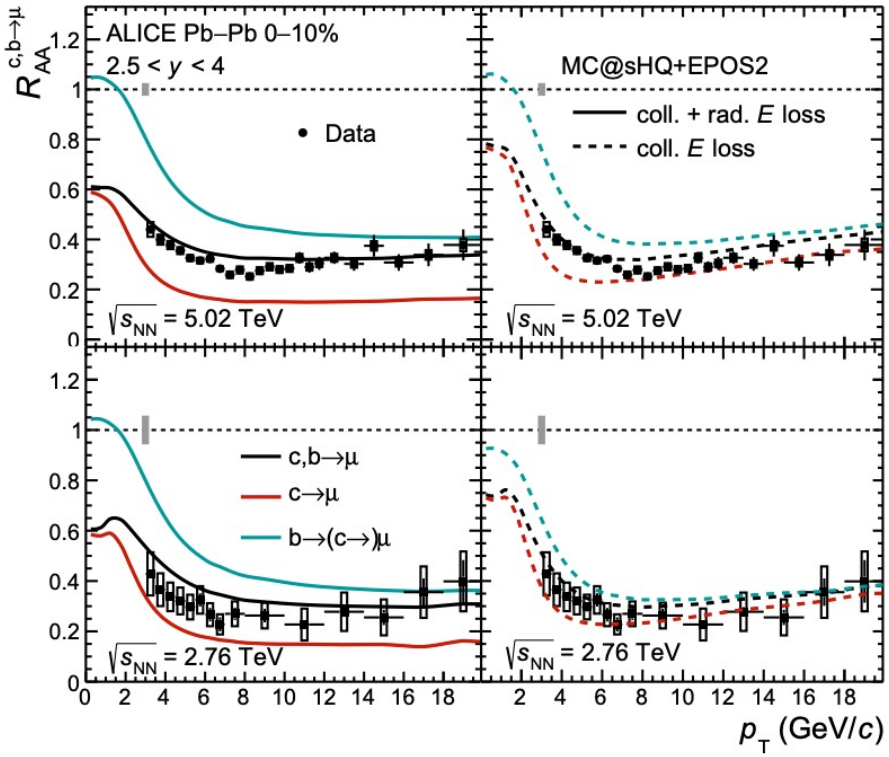




- Hint of less suppression of non-prompt D_s^+ than non-prompt D^0

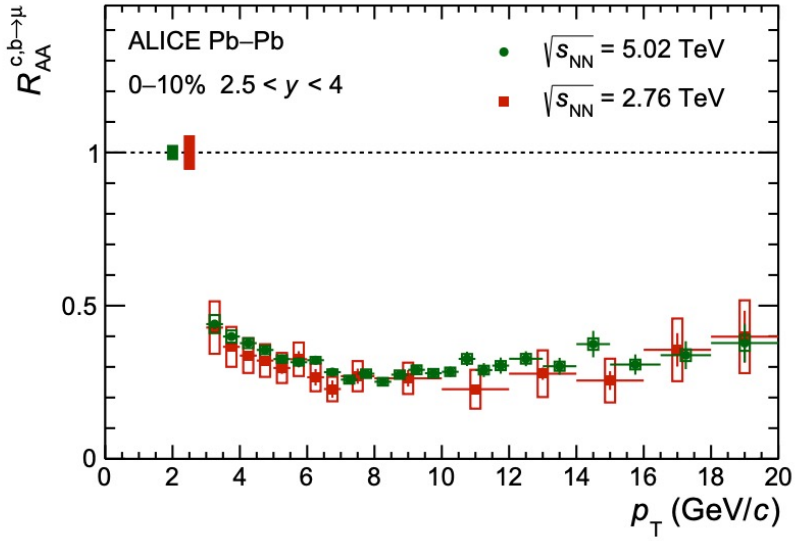
  => Possible b-quark coalescence and strangeness enhancement

Inclusive muon R_{AA}



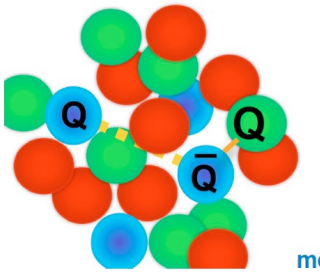
ALICE PLB 820 (2021) 136558.

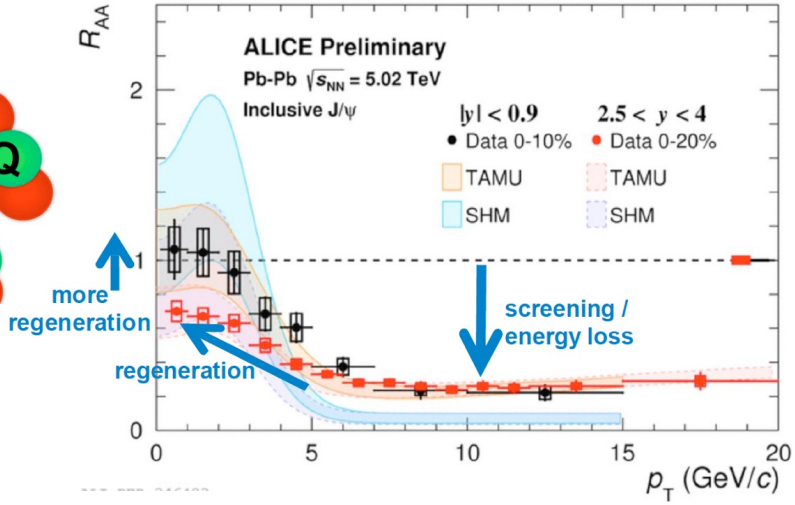
MC@sHQ: PRC 89 (2014) 014905;

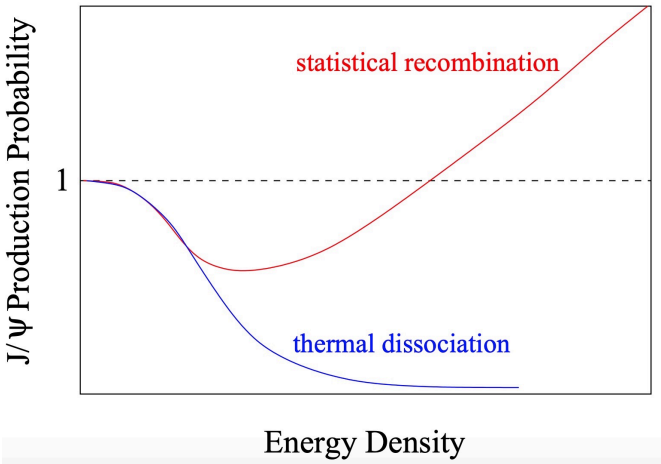


- High p_T , bottom contributions dominant, indication of bottom energy loss.
- No clear energy dependence. Harder spectra and denser medium counterbalance.
- New constraints on models.

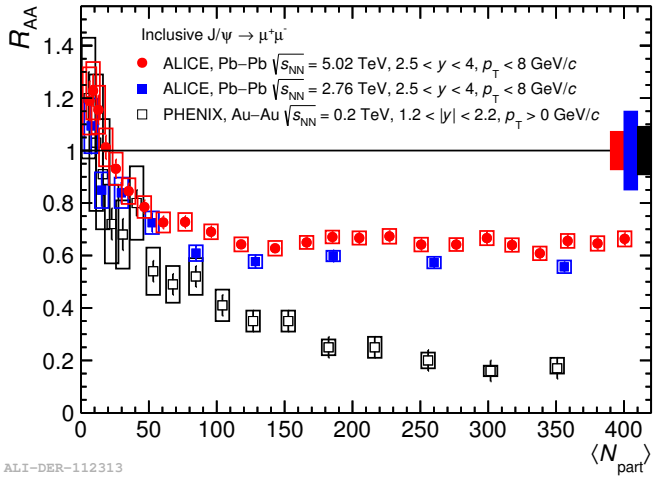
Hidden charm R_{AA}







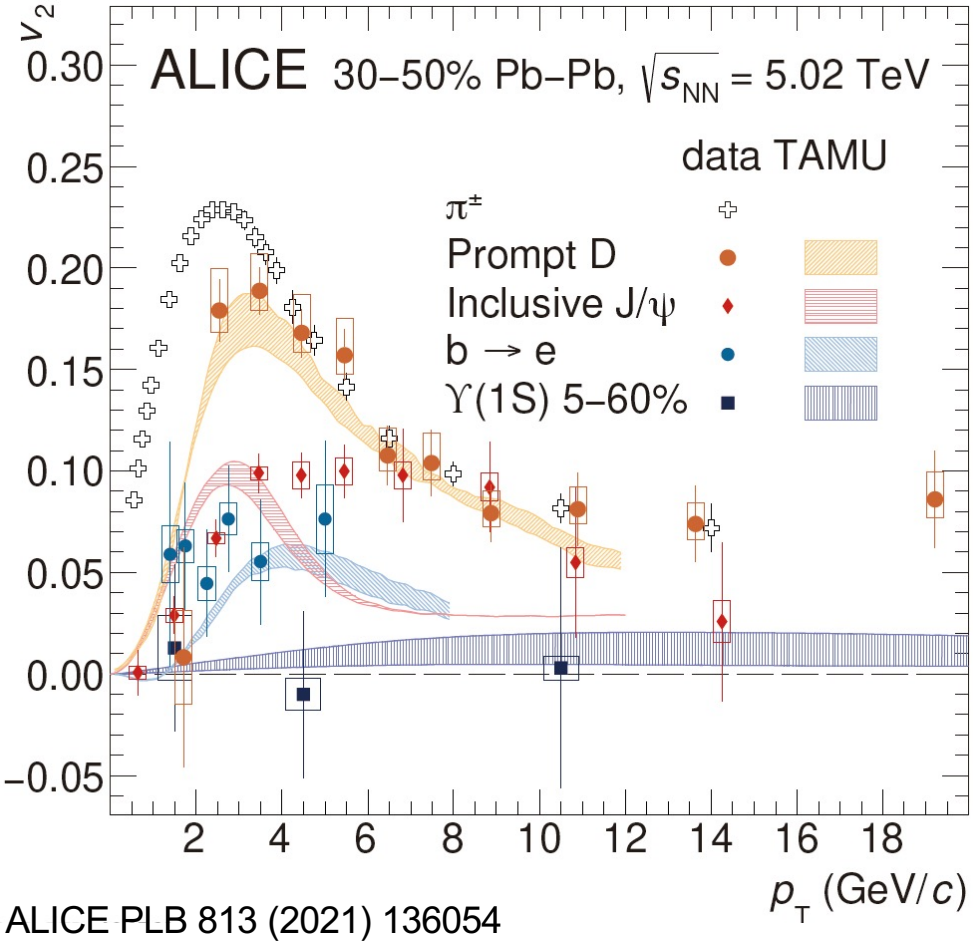
P. Braun-Munzinger, J. Stachel, Nature 448 (2007) 302
P. Braun Muzinger, J.Stachel, PLB 490 (2000) 196
R. Thews et al, Phys.Rev.C 63:054905 (2001)
Kluberg, Satz, arXiv:0901.3831



- Color screening / energy loss
  - ➡ smoking gun of QGP formation
- $c\bar{c}$ regeneration: LHC > RHIC

D. Zhou, X. Bai @ QPT21

Flavor dependence of v_2 in Pb-Pb



ALICE PLB 813 (2021) 136054

- Non-zero v_2 of electron from open beauty hadron decays
- v_2 of Y(1S) is compatible with zero and lower than J/ψ
- Precise measurements of different hadron species crucial for setting constraints to models

  $1.5 < 2\pi T_c D_s < 7$

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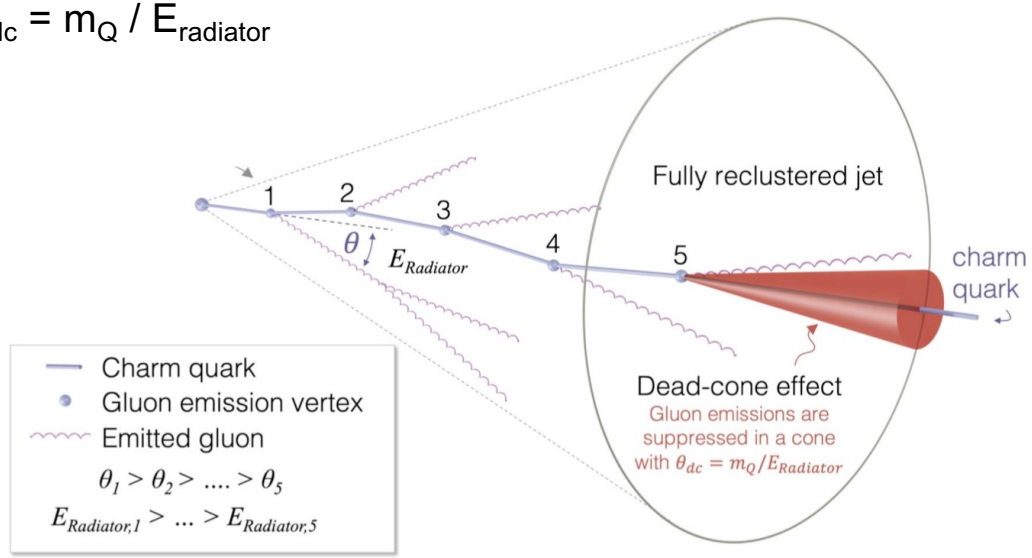
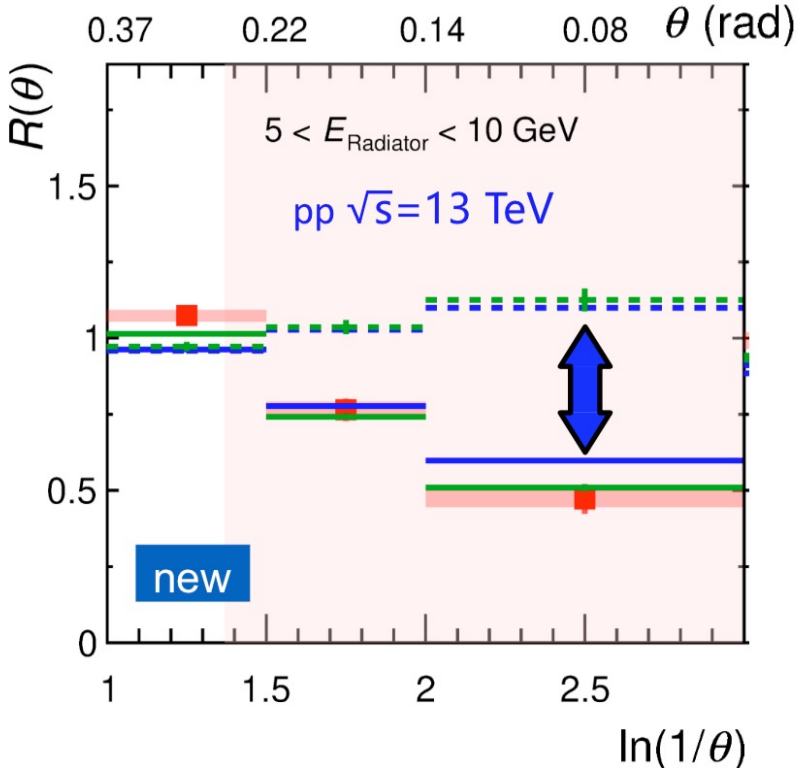
Direct observation of dead-cone in pp

Dead cone effect:

Gluon emission suppressed in a cone with

$\theta_{dc} = m_Q / E_{radiator}$



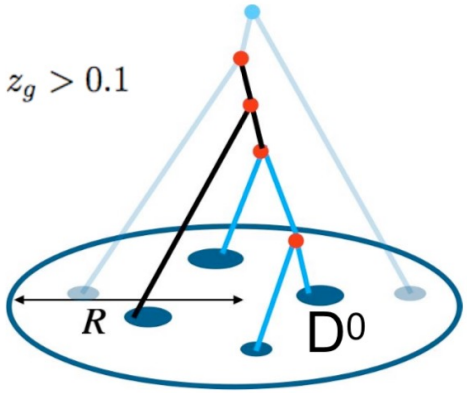


- A fundamental QCD feature (holds for gauge quantum field theories)
- Clear dead-cone effect observed for low charm quark energies
  $\Delta E_b < \Delta E_c < \Delta E_{u,d,s}$ in the QGP

ALICE arXiv: 2106.05713

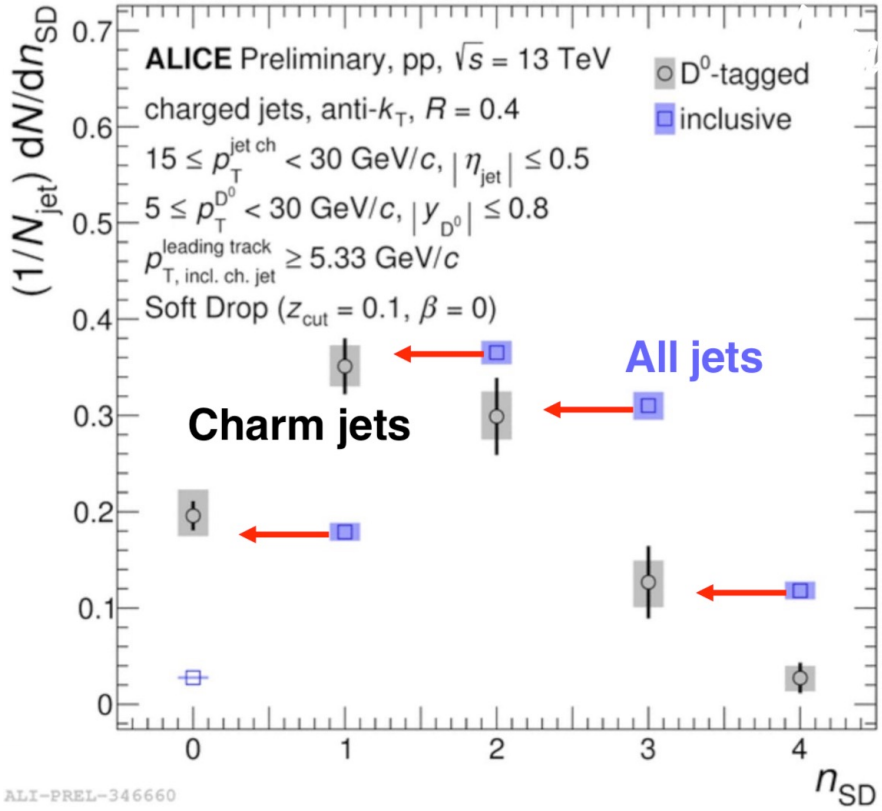
Dissecting soft charm jets in pp

$$z_g = \frac{\min(p_{\perp,1}, p_{\perp,2})}{p_{\perp,1} + p_{\perp,2}} \qquad z_g > 0.1$$

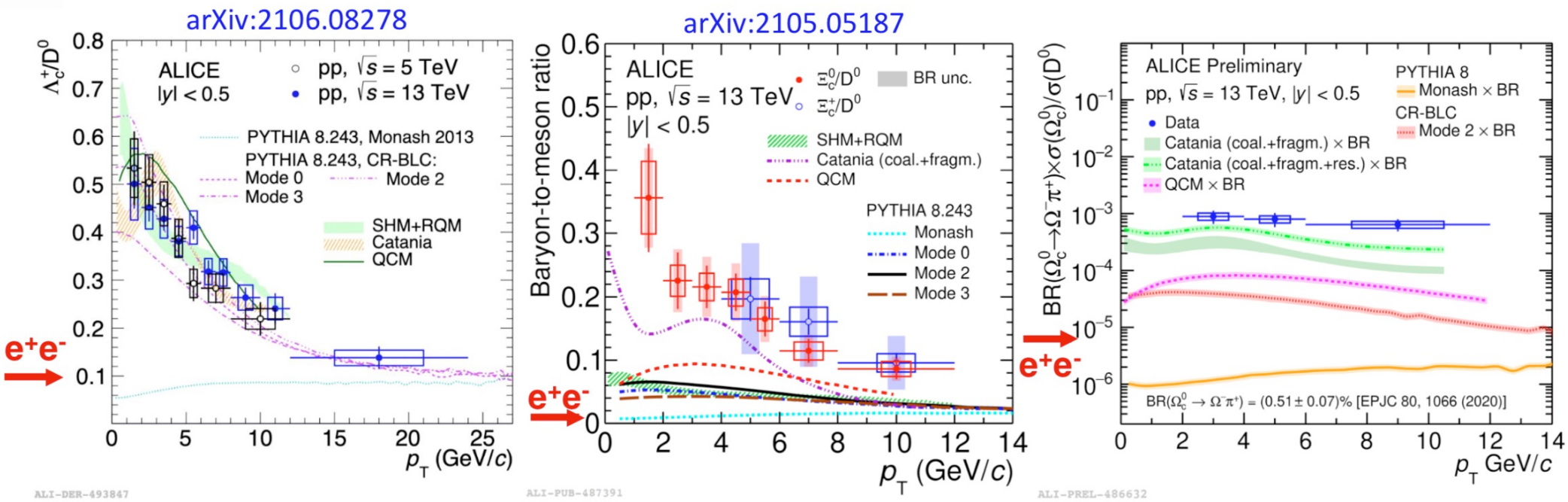


- Jet grooming techniques used to count the number of hard splittings in jet fragmentation
  n_{sd} = No. of splittings with > 10% p_T radiation

- Charm jets have less hard splittings than inclusive jets
  - connection to harder fragmentation of heavy wrt light quarks/gluons



Charm hadronization in pp

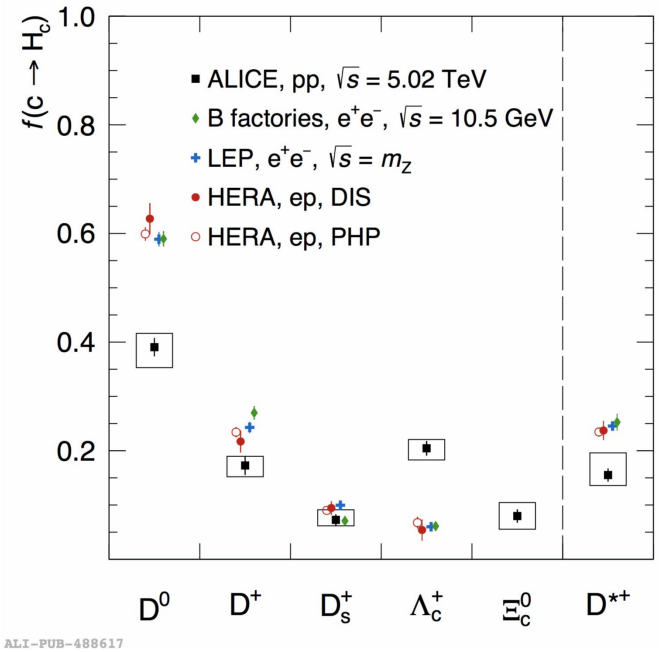


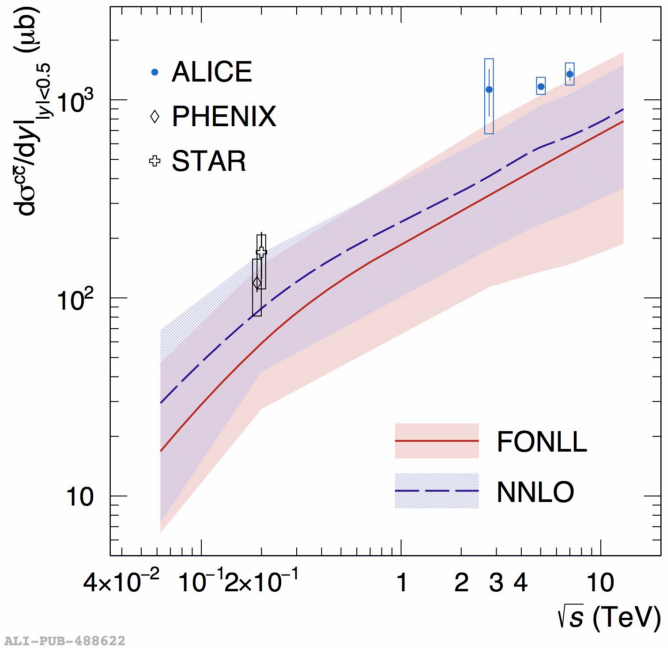
- Production of charm baryons enhanced in pp w.r.t. ee and ep
  - hadronisation is different in the dense pp environment
- Models with "high-density" effects describe Λ_c but fail to describe Ξ_c and Ω_c
- Catania (coalescence+fragmentation) closer to the data

Charm fragmentation in pp

ALICE JHEP 2110 (2021) 159
arXiv:2105.06335 accepted by PRD

H_c	$f(c \to H_c)[\%]$
D^0	$39.1 \pm 1.7(\text{stat})^{+2.5}_{-3.7}(\text{syst})$
D^+	$17.3 \pm 1.8(\text{stat})^{+1.7}_{-2.1}(\text{syst})$
D_s^+	$7.3 \pm 1.0(\text{stat})^{+1.9}_{-1.1}(\text{syst})$
Λ_c^+	$20.4 \pm 1.3(\text{stat})^{+1.6}_{-2.2}(\text{syst})$
Ξ_c^0	$8.0 \pm 1.2(\text{stat})^{+2.5}_{-2.4}(\text{syst})$
D^{*+}	$15.5 \pm 1.2(\text{stat})^{+4.1}_{-1.9}(\text{syst})$

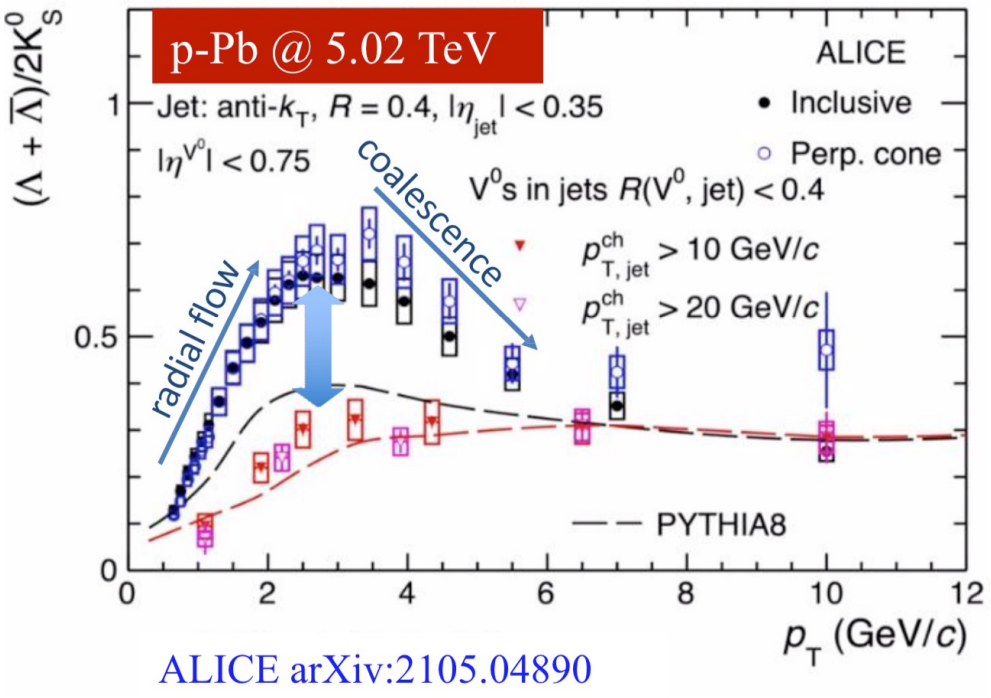


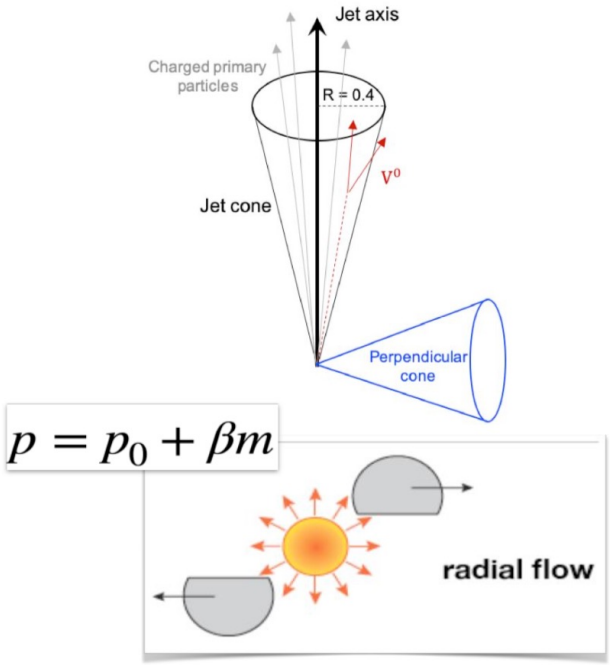


- Precision measurement on charm fragmentation ratios in pp at 5.02 TeV.
- Not universal compared to ee and ep collisions.
- First midrapidity charm production cross section in pp collisions at 5.02 TeV

  Consistent with FONLL/NNLO upper edge $\mathrm{d}\sigma^{c\bar{c}}/\mathrm{dy}|_{|y|<0.5} = 1165 \pm 44(\text{stat})^{+134}_{-101}(\text{syst})\ \mu\text{b}$

Strange baryon-to-meson ratio in pPb

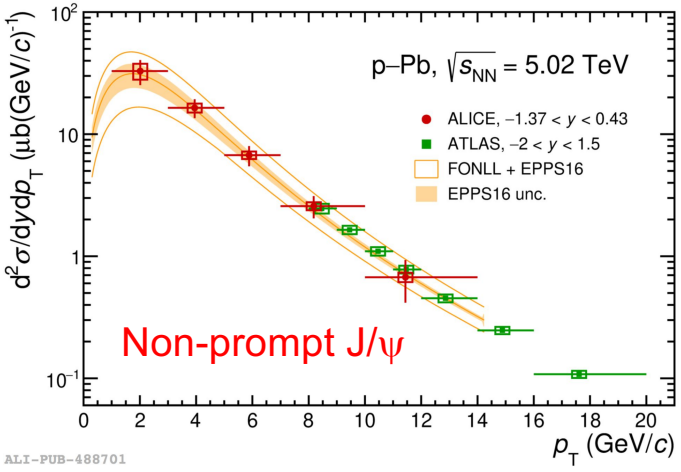


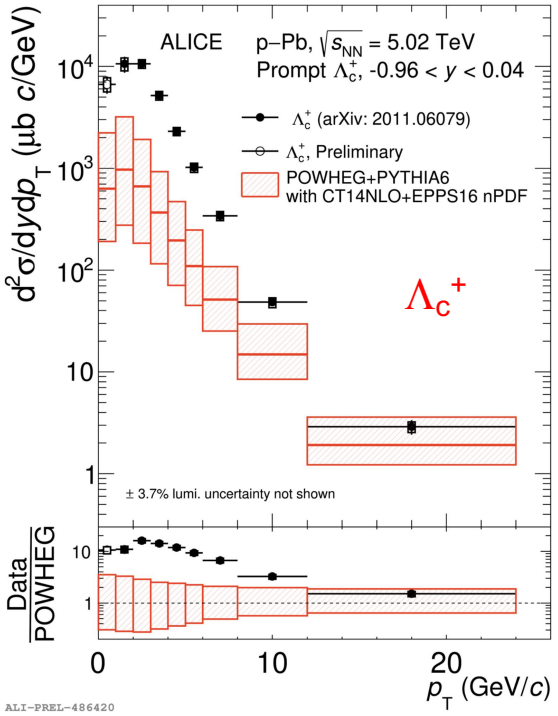


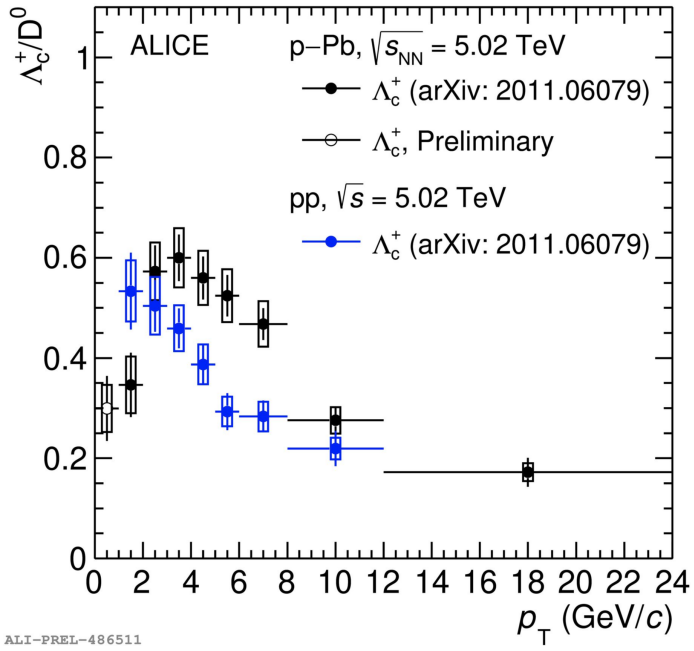
- Clear enhancement seen for inclusive strange b-to-m ratio compared to PYTHIA8
  - possible coalescence hadronization mechanisms in pPb (need deeper model study)
- No enhancement observed in jets , hard process does not enhance b-to-m ratio.

Charm and beauty in pPb

ALICE arXiv:2105.04957

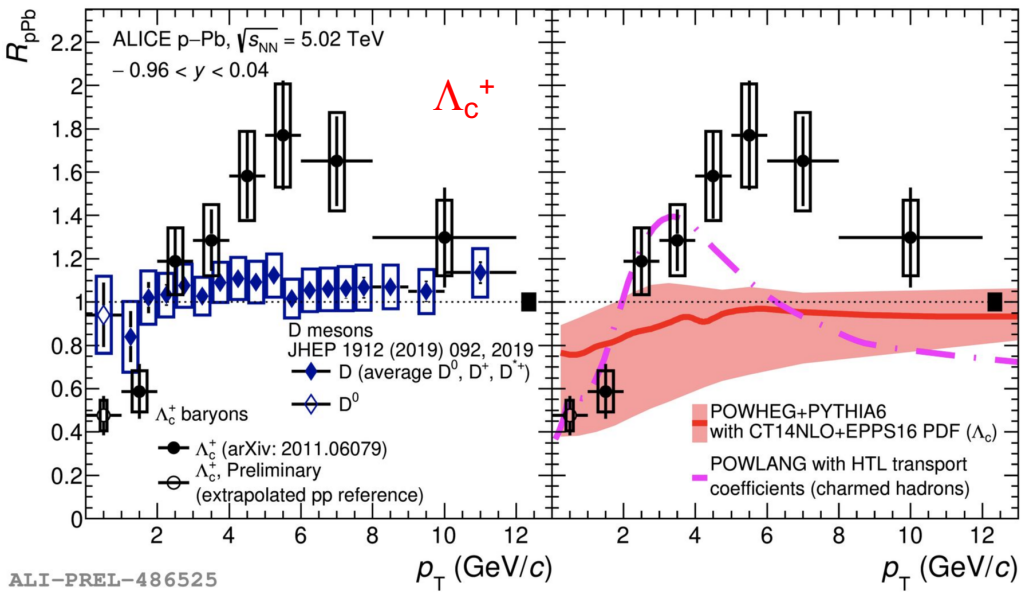


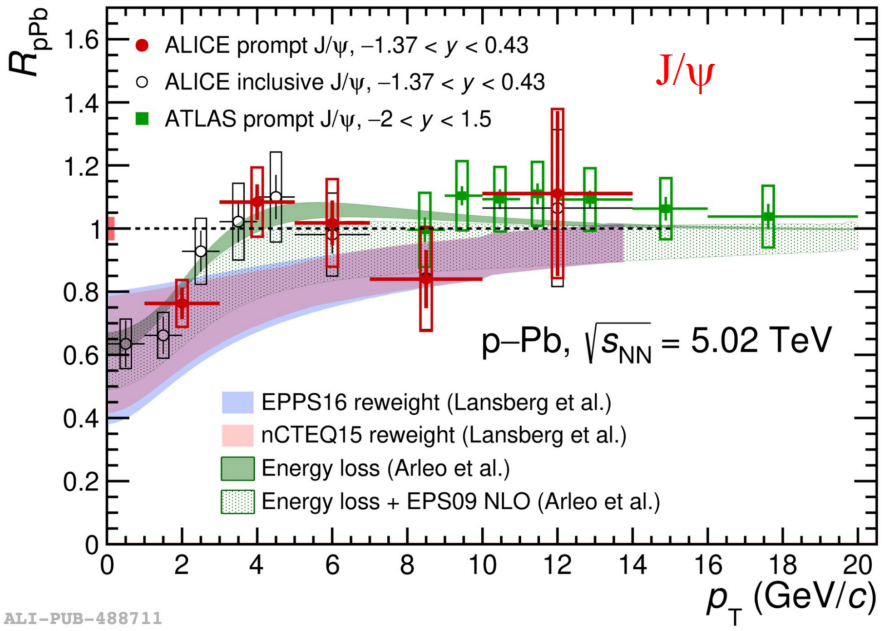




- FONLL+nPDF describe non-prompt J/ψ measurement in p-Pb collisions over wide p_T and y range
- First measurements of Λ_c down to zero p_T in p-Pb collisions!
  - pQCD calculations underestimate data especially at low p_T → different FF in p-Pb wrt ee
- Λ_c/D^0: significant difference wrt to pp → radial flow or multiplicity dependence of hadronisation?

R_{pPb} for Λ_c and J/ψ

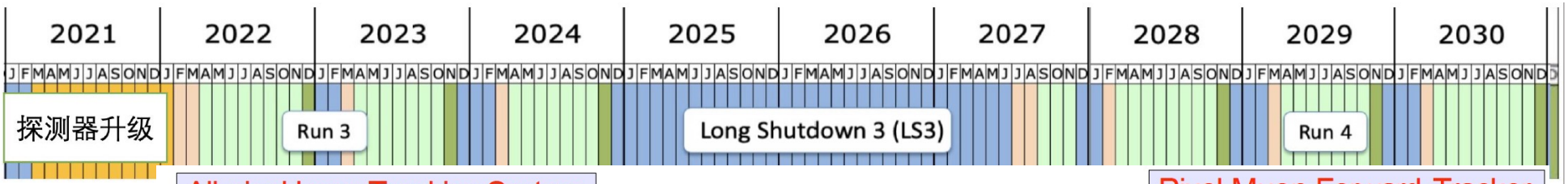




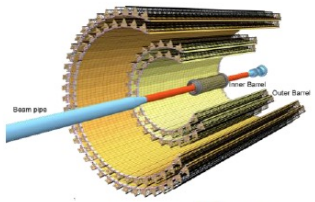
ALICE arXiv:2105.04957

- R_{pPb} larger than unity for $4 < p_T < 8$ GeV/c for Λ_c → radial flow, Cronin effect or hadronization?
  - similarities with strange sector (CMS: Phys. Rev. C 101, 064906 (2020), ALICE: arXiv:2011.06079)
- Significant suppression of Λ_c and J/ψ for $p_T < 2$ GeV/c – radial flow, shadowing?

ALICE2 upgrade

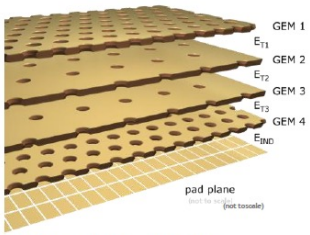


All-pixel Inner Tracking System

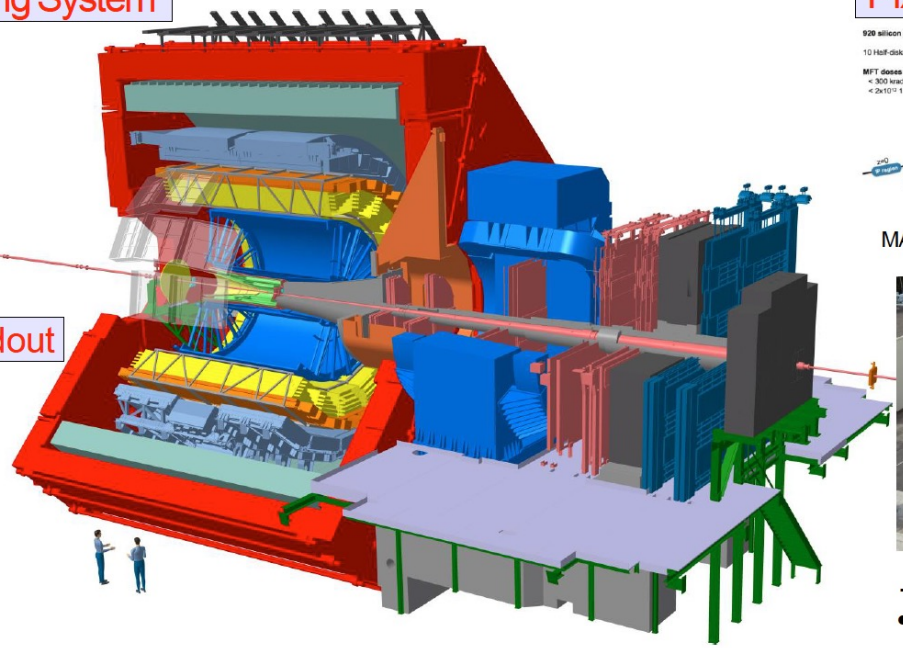


Monolithic Active Pixel Sensors

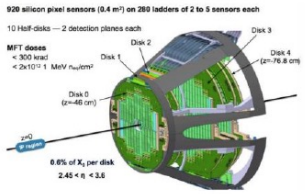
GEM-based TPC readout



GEM readout chambers



Pixel Muon Forward Tracker



MAPS-based forward tracker

D. Zhou @QPT21

x 50 faster readout

operation at high interaction rates
(50 kHz of Pb–Pb collisions)

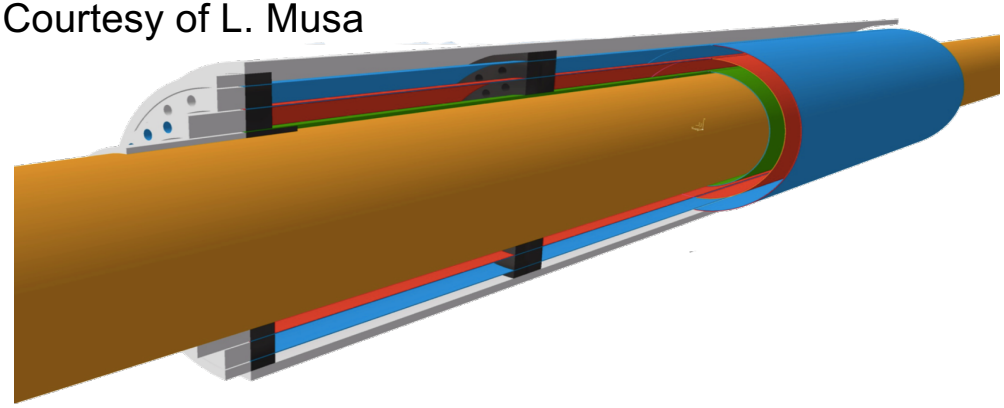
- Improve tracking resolution at low p_T
  → thinner, more granular

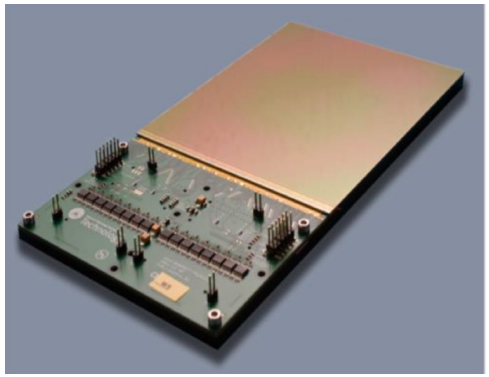
… and much more:

- Fast Interaction Trigger
- New Online-Offline system
- Readout upgrade of MUON TOF, EMCAL, PHOS

Next generation of Si detector

Courtesy of L. Musa





Letter of Intent https://cds.cern.ch/record/2703140
On track for TDR in 2022

Ultra low material budget ~ 0.05%X_0/layer

fast to sample large luminosity
~50 – 100x Run 3/4

excellent spatial resolution
innermost layer: σ < 3 mm
outer layers: σ ~ 5 mm

All Silicon design as an option for

ALICE ITS3

More in Hua Pei 's talk@ Nov. 28 morning

Summary

- Many new results in heavy-ion and small system collisions with ALICE for QGP study and beyond QGP physics (new insights to QCD).
- 30 ALICE papers this year and China contribution is 16.7% (much higher in this talk).
- High energy and precision frontier with ALICE upgrades/future plans.
  - Well on track for Run3
  - New ultra-thin inner tracker layers on track for Run 4
  - Forward calorimetry – nucleon structure at smallest x in Run 4
  - ALICE 3 for Run 5 and beyond – in preparation

References

- Highlights and Perspectives from ALICE – QPT2021 – Daicui Zhou
- ALICE中国组进展报告 – Nov. 25 morning – Xiaoming Zhang
- Measurement of EW bosons production with ALICE – Nov. 25 afternoon – Mingrui Zhao
- Jet production with ALICE – Nov. 25 afternoon – Haidar MAS\'UD ALFANDA
- Measurement of the jet-particle v_2 in pPb and PbPb collisions at 5.02 TeV with ALICE at the LHC – Nov. 25 evening – Siyu Tang
- Search for bound states using momentum correlations in ALICE experiment – Nov. 27 morning – Qiye Shou
- Charmed baryon production with ALICE – Nov. 27 afternoon – Tiantian Cheng
- Non-prompt D production with ALICE – Nov. 27 afternoon – Xinye Peng
- ALICE upgrade – Nov. 28 morning – Hua Pei

My apology to those not be mentioned in this talk!

Thanks for your attention !