Experimental overview of recent (selected) heavy-ion results

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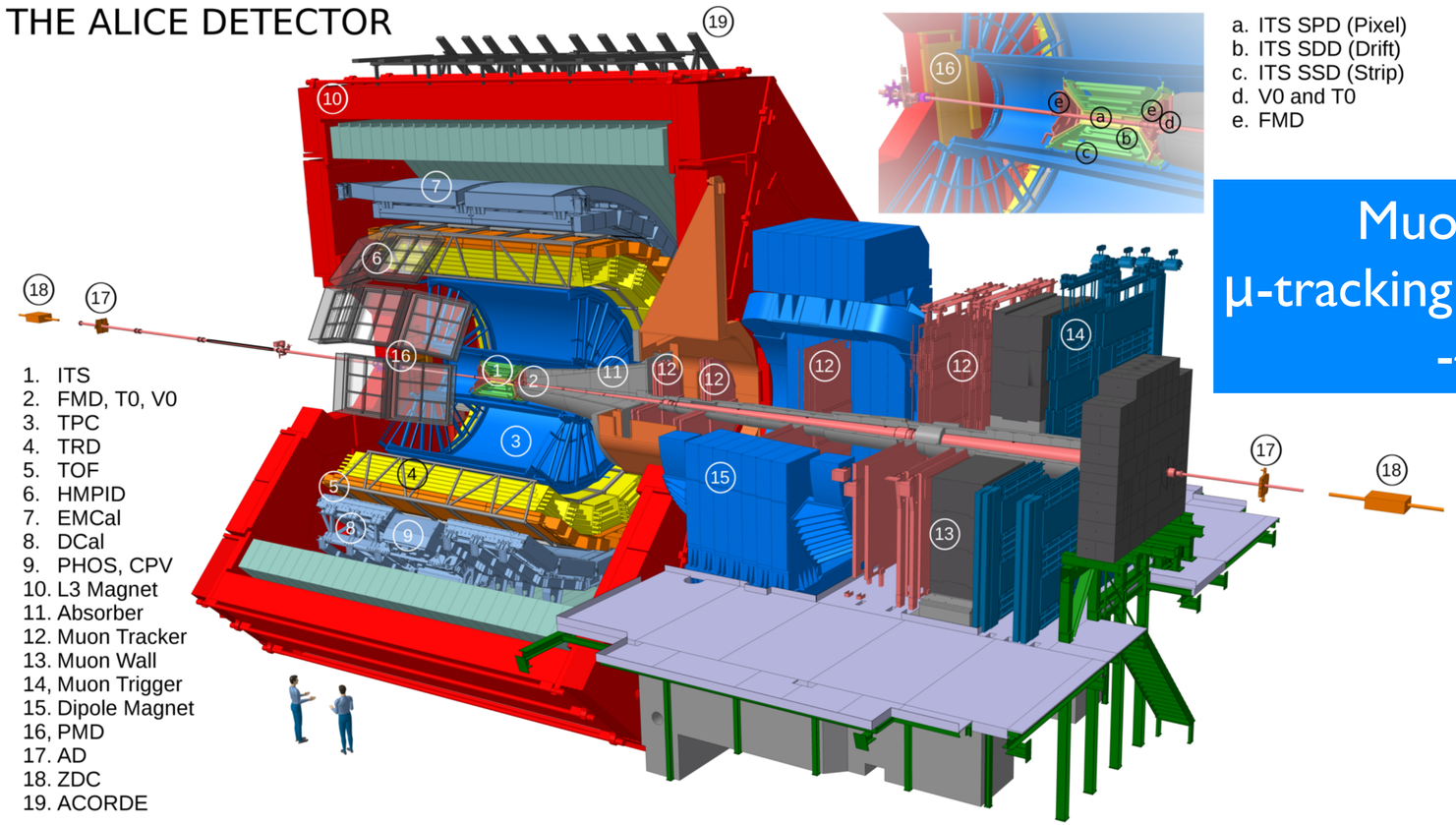
ALICE Run 2 setup

JINST 3 (2008) S08002
IJMPA 29 (2014) 1430044



Muon spectrometer
μ-tracking and trigger chambers
$-4 < \eta < -2.5$

Central barrel:
vertexing, tracking, PID, EM Calos
$|\eta| < 0.9$

Forward detectors:
multiplicity, trigger, centrality, time zero

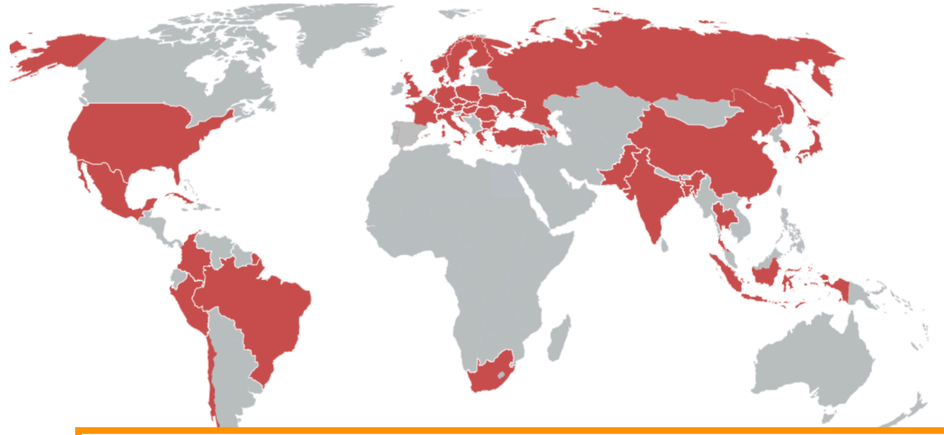
- A dedicated heavy-ion experiment at the LHC, excellent PID

ALICE data (so far…)

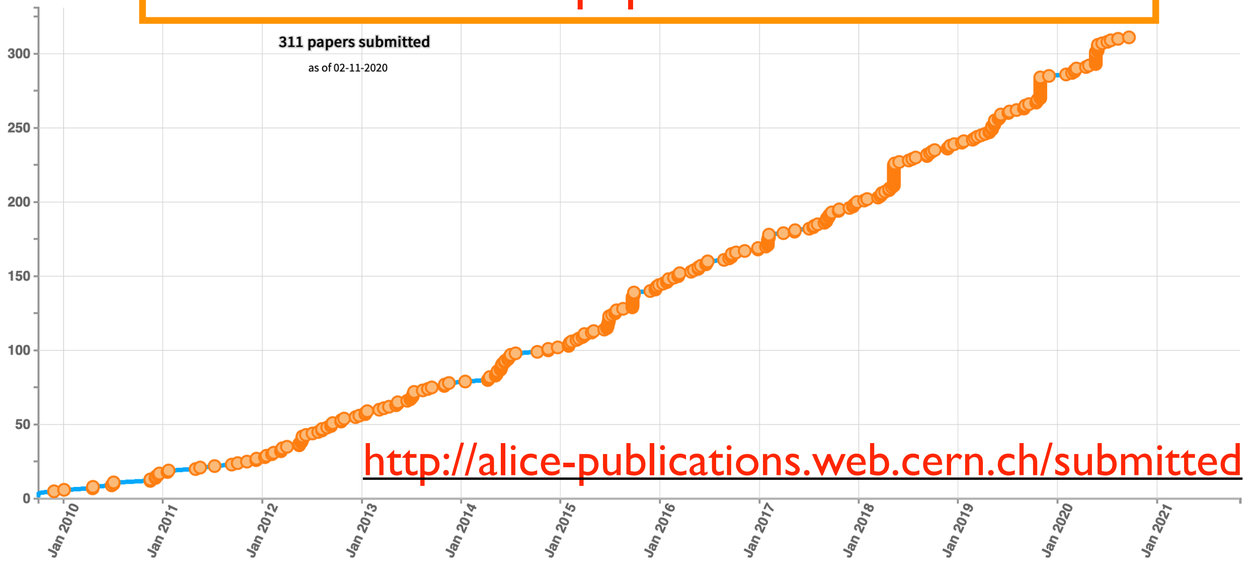
System	year(s)	$\sqrt{s_{NN}}$ (TeV)	L_{int}
pp	2009-2013	0.9	200 μb^{-1}
		2.76	100 nb^{-1}
		7	1.5 pb^{-1}
		8	2.5 pb^{-1}
	2015, 2017	5.02	1.3 pb^{-1}
	2015-2018	13	36 pb^{-1}
pPb	2013	5.02	15 nb^{-1}
	2016	5.02	3 nb^{-1}
		8.16	25 nb^{-1}
Xe-Xe	2017	5.44	0.3 μb^{-1}
Pb-Pb	2010-2011	2.76	75 μb^{-1}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

- Harvest of the past 10 years operation
- Large integrated luminosity in Run 2 allows precise measurements, new observables

39 countries, 175 institutes, 1927 members

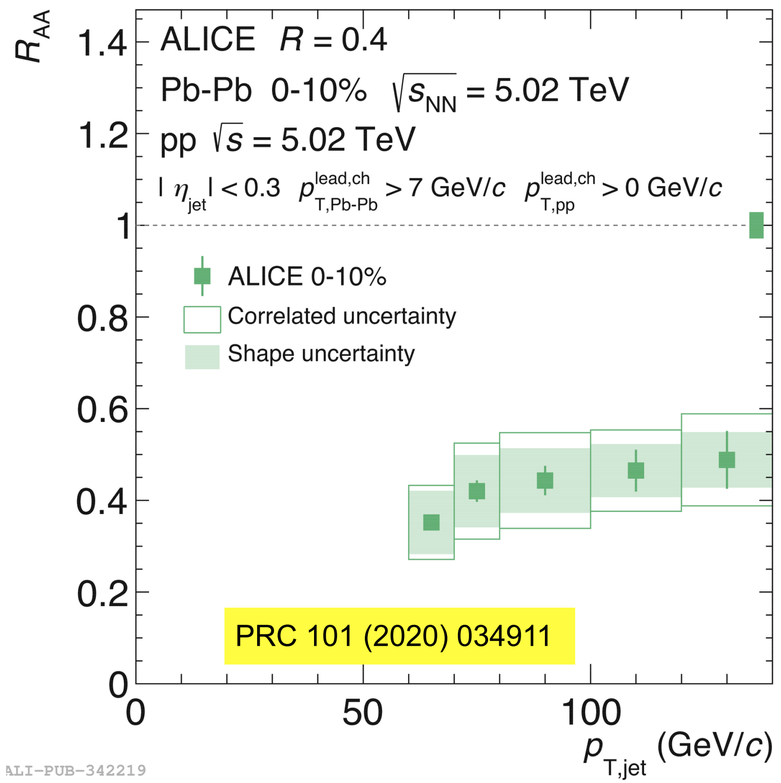


311 papers submitted
34 new papers in 2020

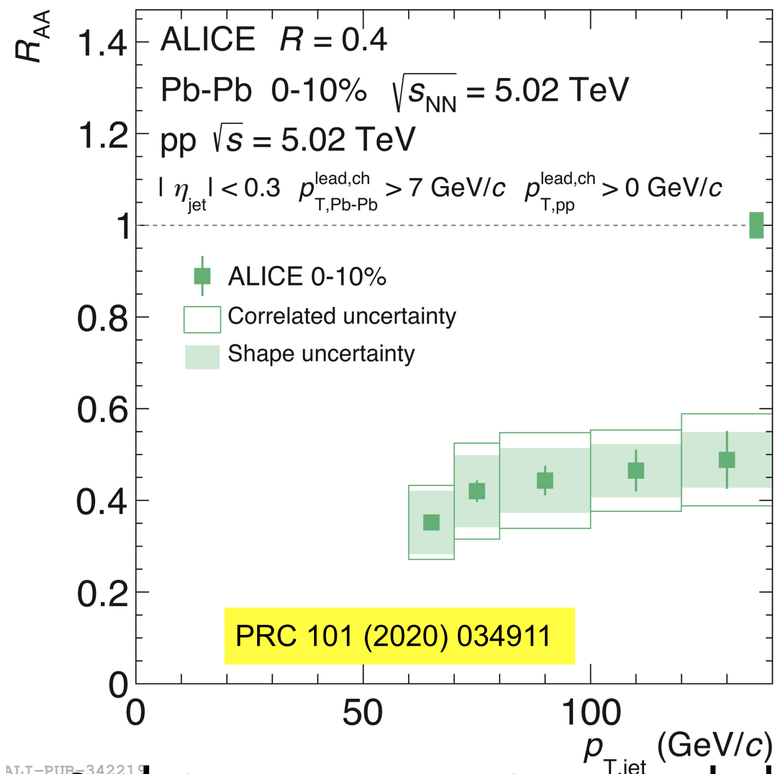


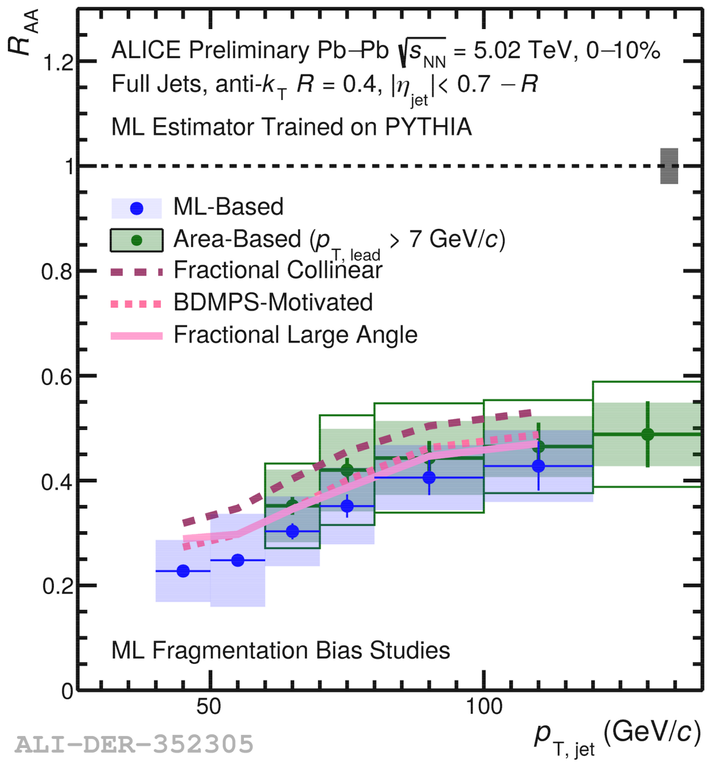
http://alice-publications.web.cern.ch/submitted

Jet R_{AA}


R_{AA}
ALICE $R = 0.4$
Pb-Pb 0-10% $\sqrt{s_{NN}} = 5.02$ TeV
pp $\sqrt{s} = 5.02$ TeV
$|\eta_{jet}| < 0.3$ $p_{T,Pb\text{-}Pb}^{lead,ch} > 7$ GeV/c $p_{T,pp}^{lead,ch} > 0$ GeV/c
ALICE 0-10%
Correlated uncertainty
Shape uncertainty
PRC 101 (2020) 034911
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
$p_{T,jet}$ (GeV/c)
ALI-PUB-342219

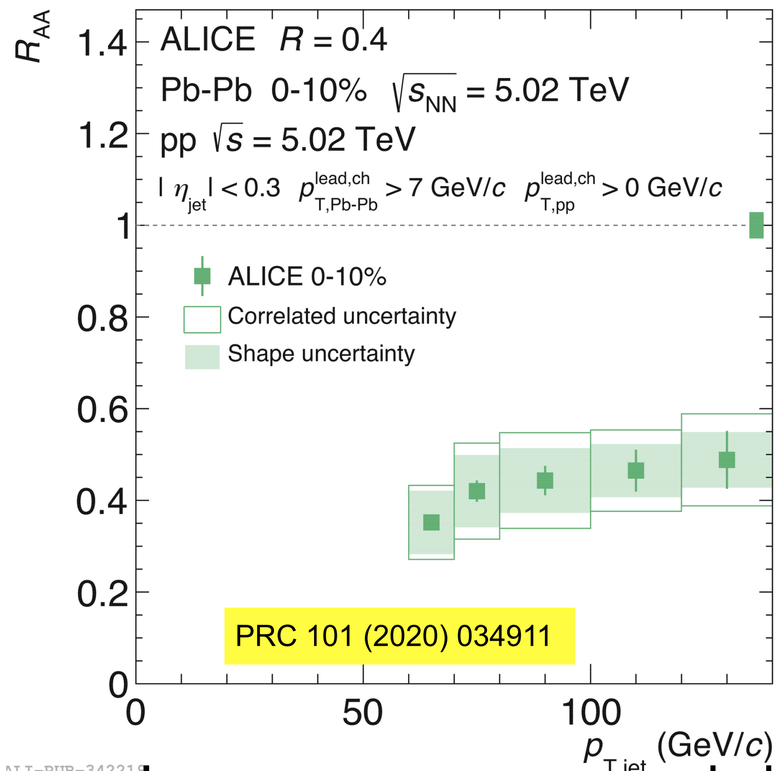
Jet R_{AA}

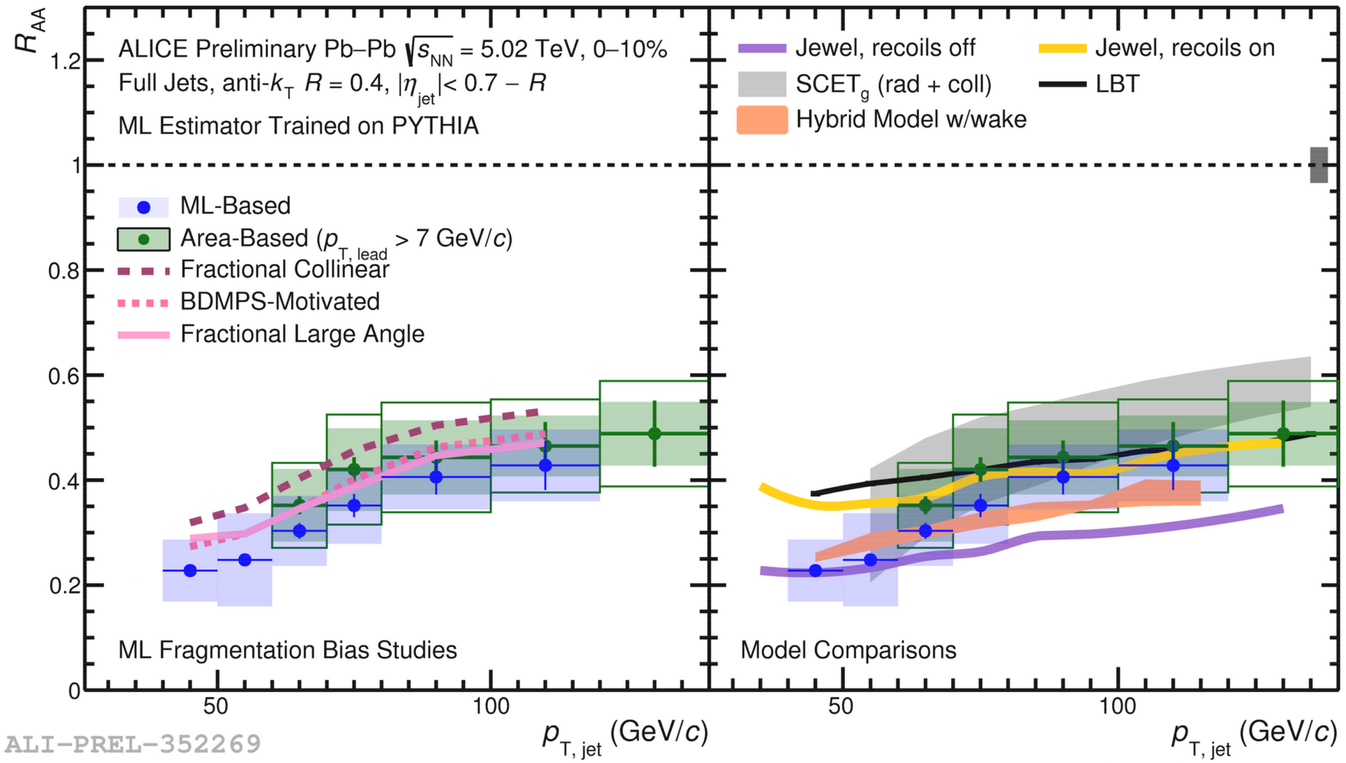




- Jet measurements extended to lower jet p_T and large R using machine learning (ML)
  - improvements on background subtraction and systematics
- ML training based on PYTHIA fragmentation, fragmentation may differ in HI
  - results affected by assumed fragmentation model for ML training by 10-40%

Jet R_{AA}

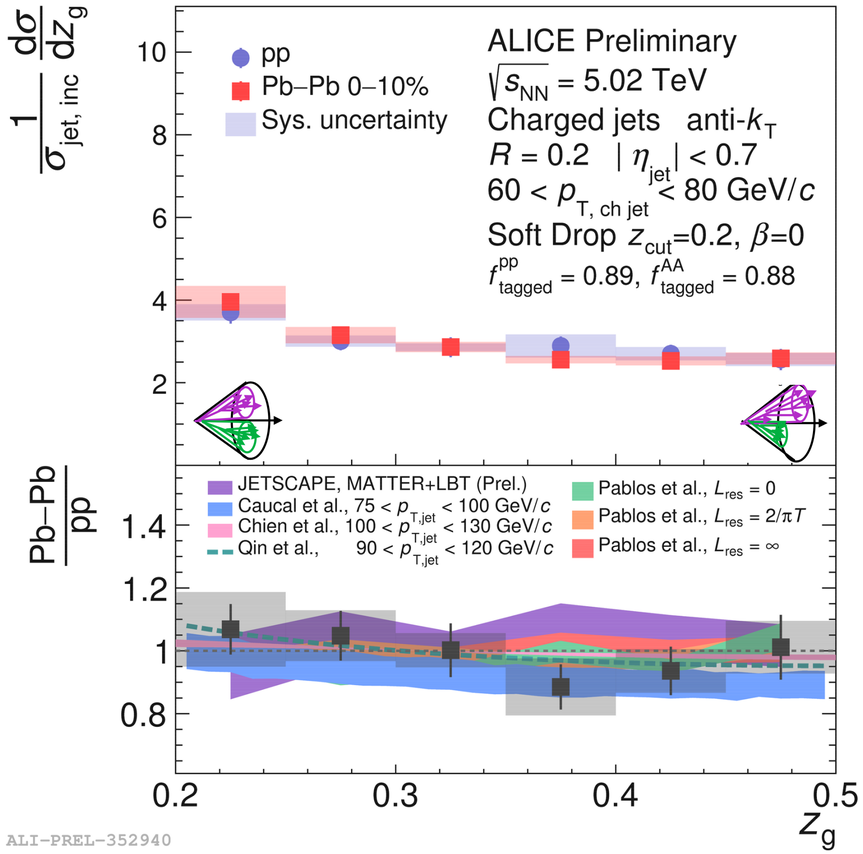




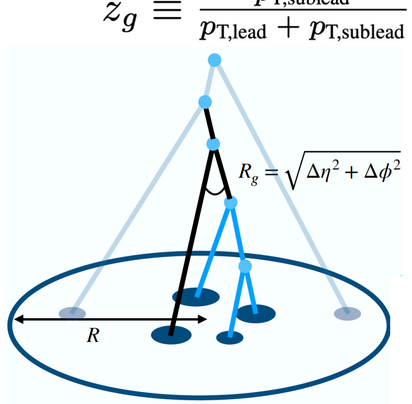
- Jet measurements extended to lower jet p_T and large R using machine learning (ML)
  - improvements on background subtraction and systematics
- ML training based on PYTHIA fragmentation, fragmentation may differ in HI
  - results affected by assumed fragmentation model for ML training by 10-40%
- Jet R_{AA} can be described by model predictions, with potential discrimination at low p_T

Jet substructure in central Pb-Pb collisions

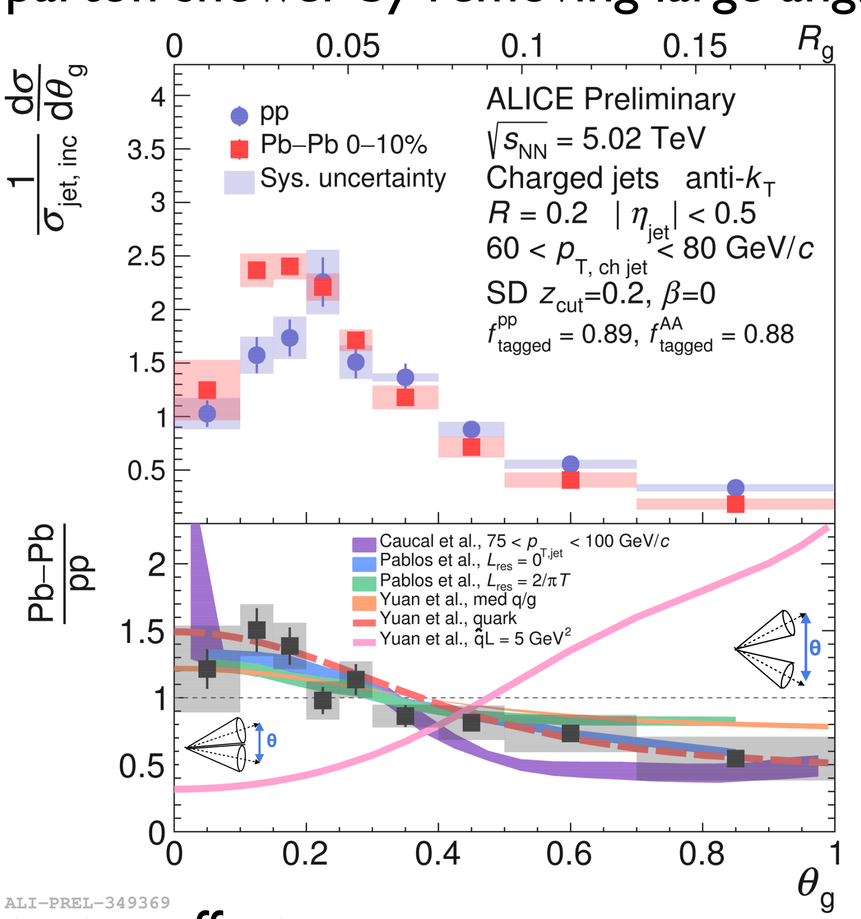
- Soft drop grooming allows to study medium modified parton shower by removing large angle soft radiation



$$z_g \equiv \frac{p_{T,sublead}}{p_{T,lead} + p_{T,sublead}}$$



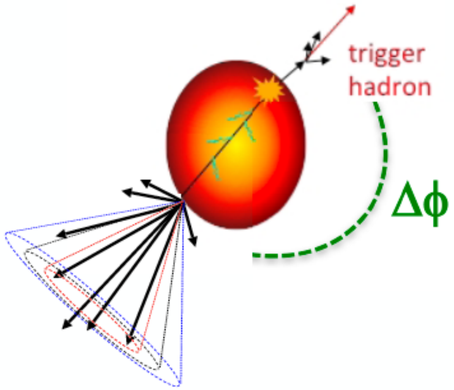
$$\theta_g \equiv \frac{R_g}{R}$$

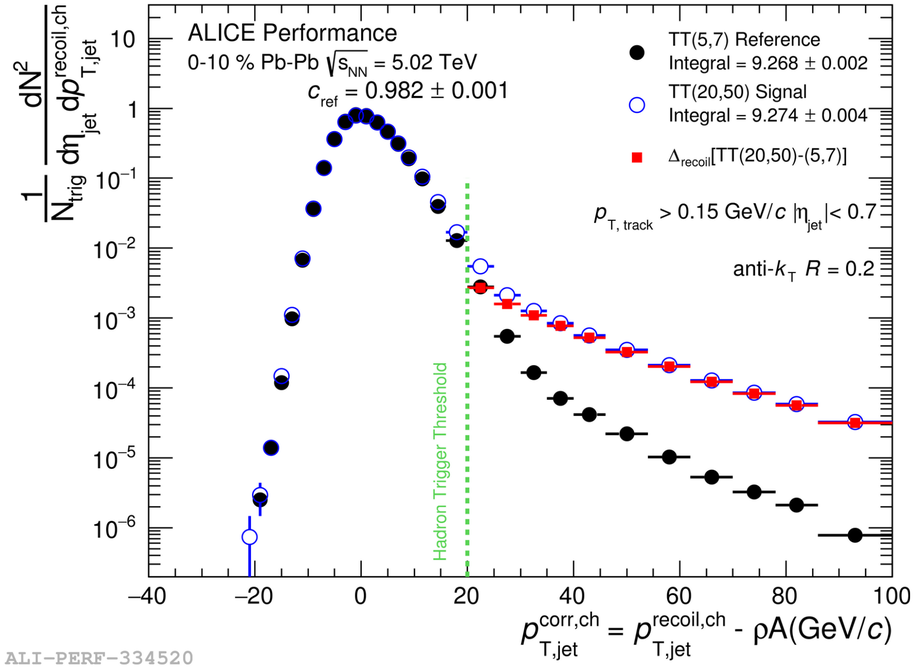


- Results are fully corrected for background and detector effects
  - No significant modification in z_g distribution
  - Modification of θ_g → narrowing jets

Jet acoplanarity via h-jet correlations

- Construct jets recoiling from a high-p_T trigger track and study the correlations between jets and trigger
  - ➡ Access low p_T recoil jets
- Acoplanarity sensitive to multiple soft scattering and large-angle deflection





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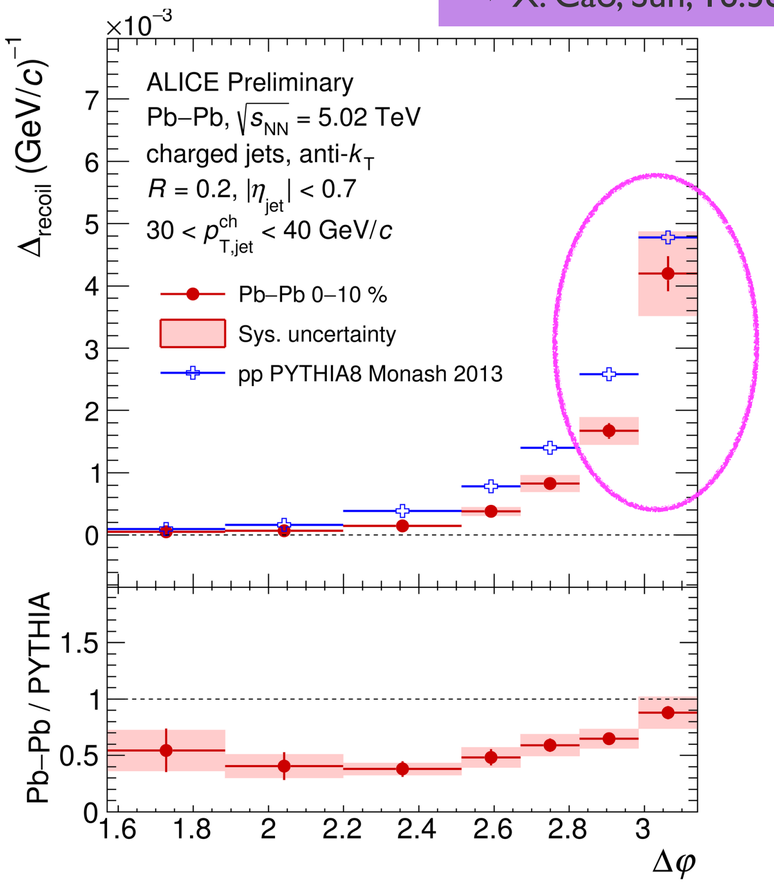
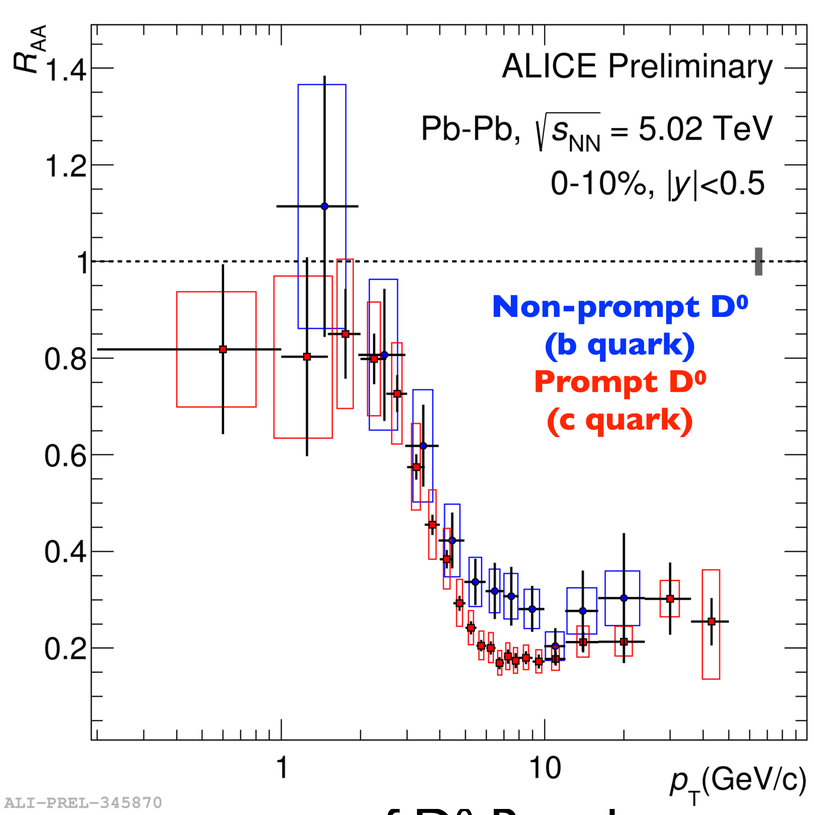
→ X. Cao, Sun, 16:38

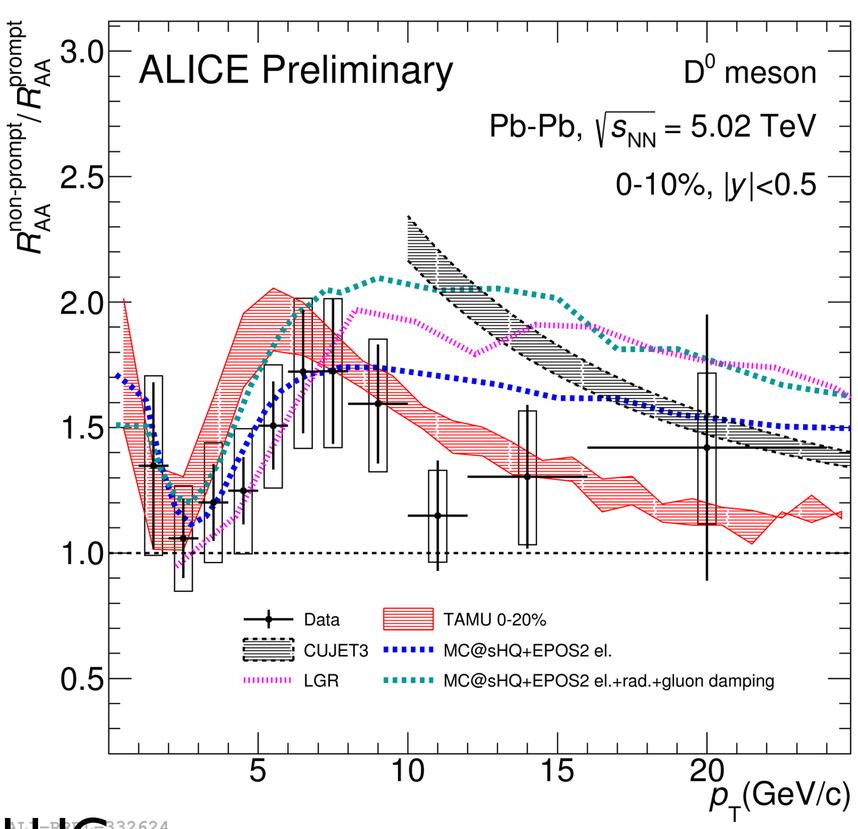


ALI-PREL-353019

- First measurement of jet acoplanarity down to low p_T recoil jets
  - ➡ Recoil jets narrower than PYTHIA vacuum expectation

Heavy quark energy loss: R_{AA}

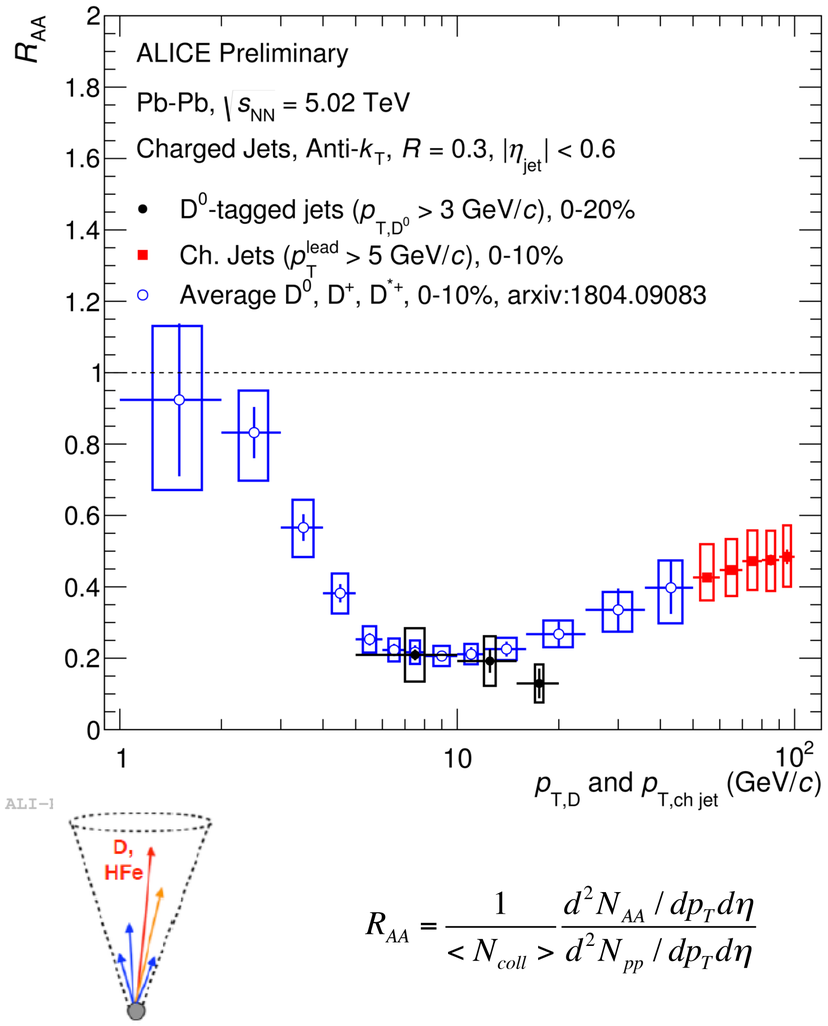




→ X. Peng, Sat, 14:00

- First measurement of D⁰ R_{AA} down to p_T = 0 at LHC
- Smaller suppression of D⁰ mesons from b than prompt ones at intermediate p_T
- Theoretical models including both collisional and radiative energy loss describe our data
- Consistent with mass dependence of energy loss → dead cone effect ($\Delta E_c > \Delta E_b$)

Heavy flavor jet R_{AA}

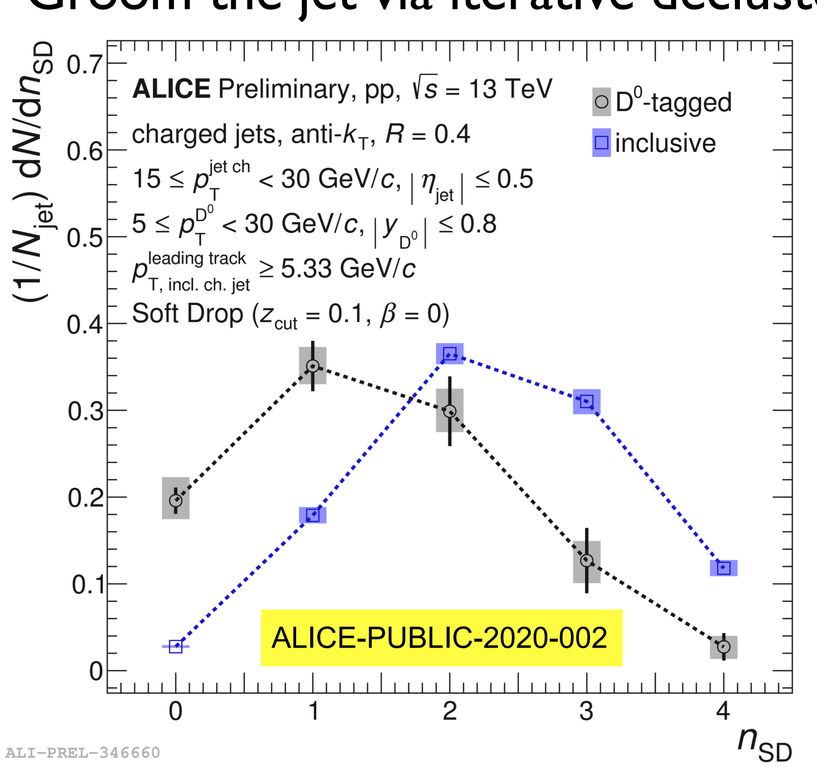


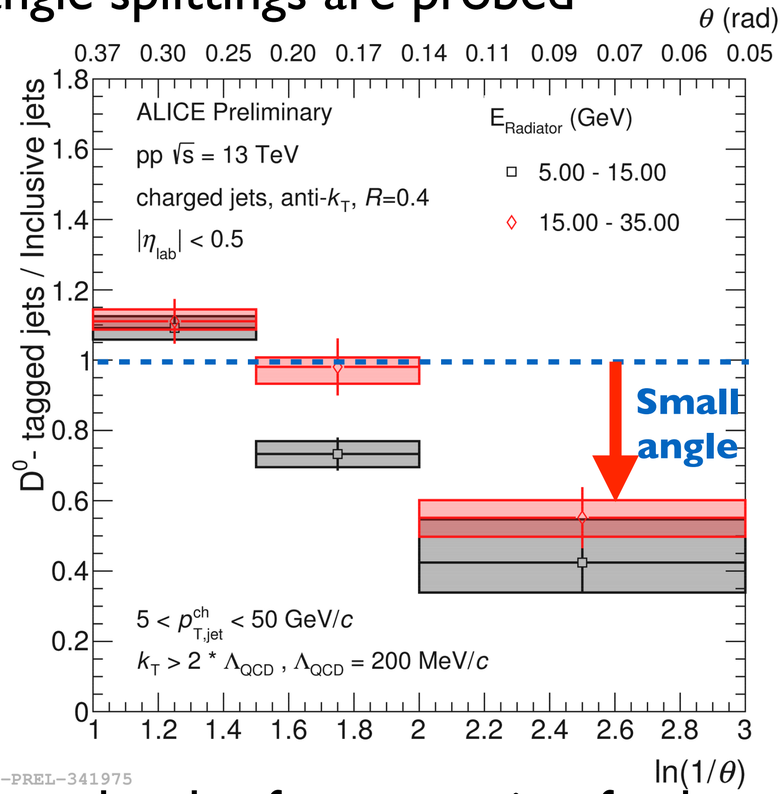
$$R_{AA} = \frac{1}{< N_{coll} >} \frac{d^2N_{AA}/dp_T d\eta}{d^2N_{pp}/dp_T d\eta}$$

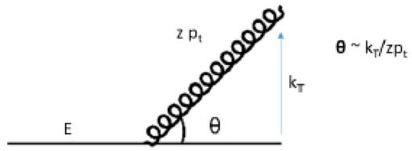
- Jet containing a D meson with p_T > 3 GeV/c in 0-20% compared with R_{AA} of D mesons and charged jets in 0-10% collisions
  - ➡ Strong suppression of D^0-tagged jets with p_T > 5 GeV/c
  - ➡ Similar to D meson R_{AA}
  - ➡ Hints of more suppression at low p_T D^0-tagged jets than inclusive jets at higher p_T
  - ➡ Importance of collisional energy loss for heavy flavor jets
- ➡ Current data is not precise enough to draw conclusion without same kinematical range

D-tagged jet substructure in pp at 13 TeV

- Jet grooming used to count the number of hard splittings in jet fragmentation: n_{SD}
- Groom the jet via iterative declustering until small-angle splittings are probed





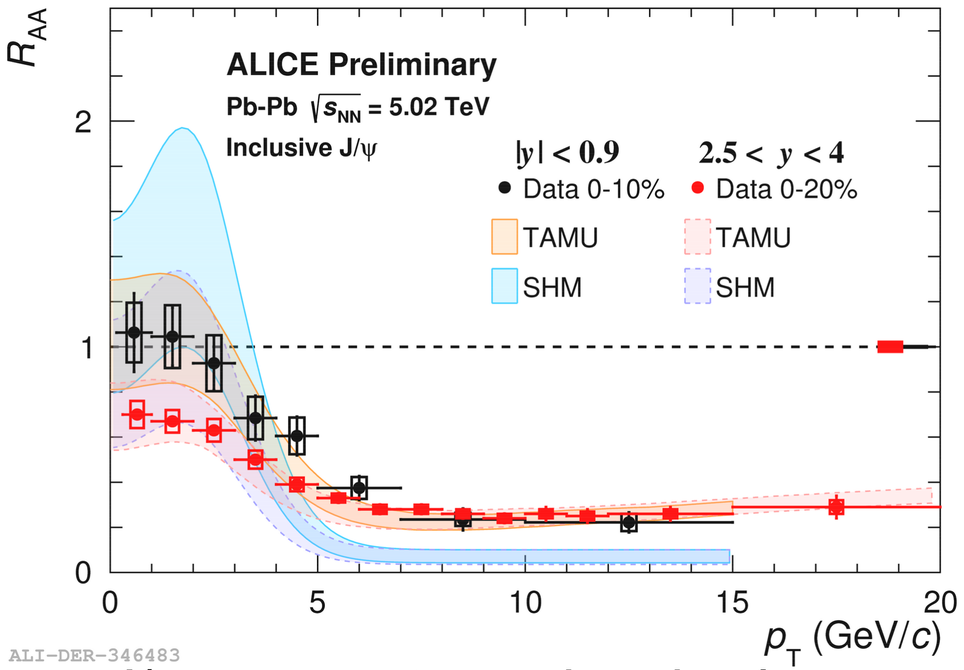


- Less hard splittings for charm jets than inclusive ones → harder fragmentation for heavy quarks
- First direct measurement of the dead cone (suppression of emissions from a radiator within $\theta<m_q/E_q$)

➡ Significant suppression of radiation in D-tagged jets towards small angles

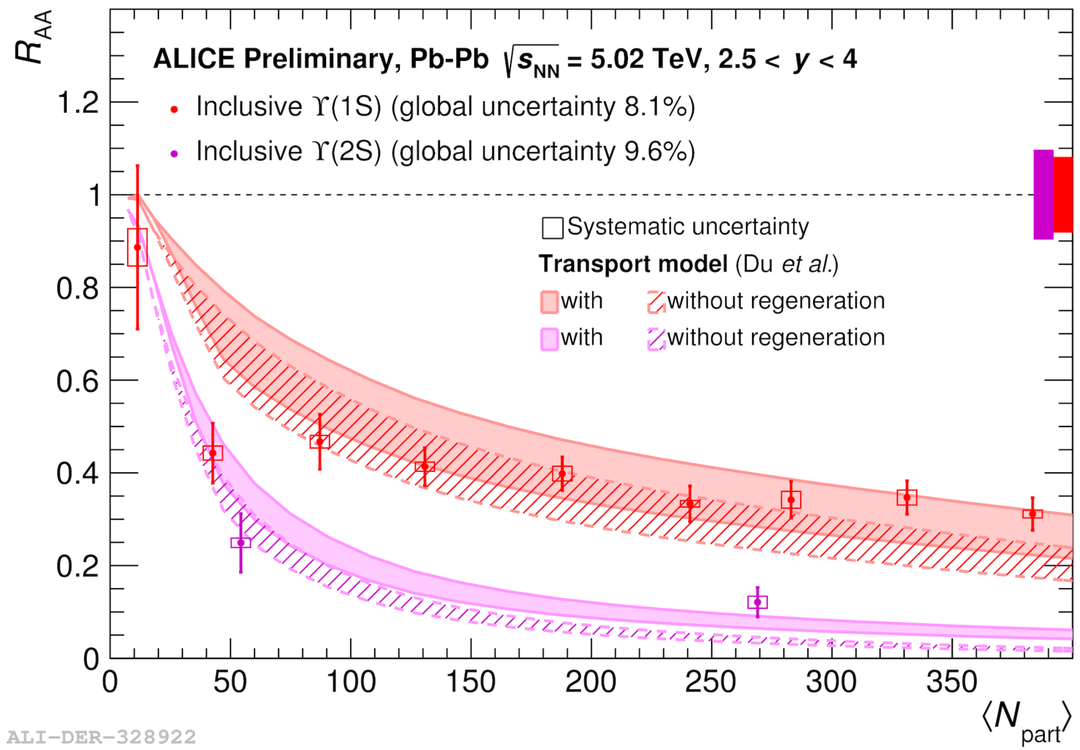
R_{AA} of quarkonia

J/ψ



Υ(1S), Υ(2S)

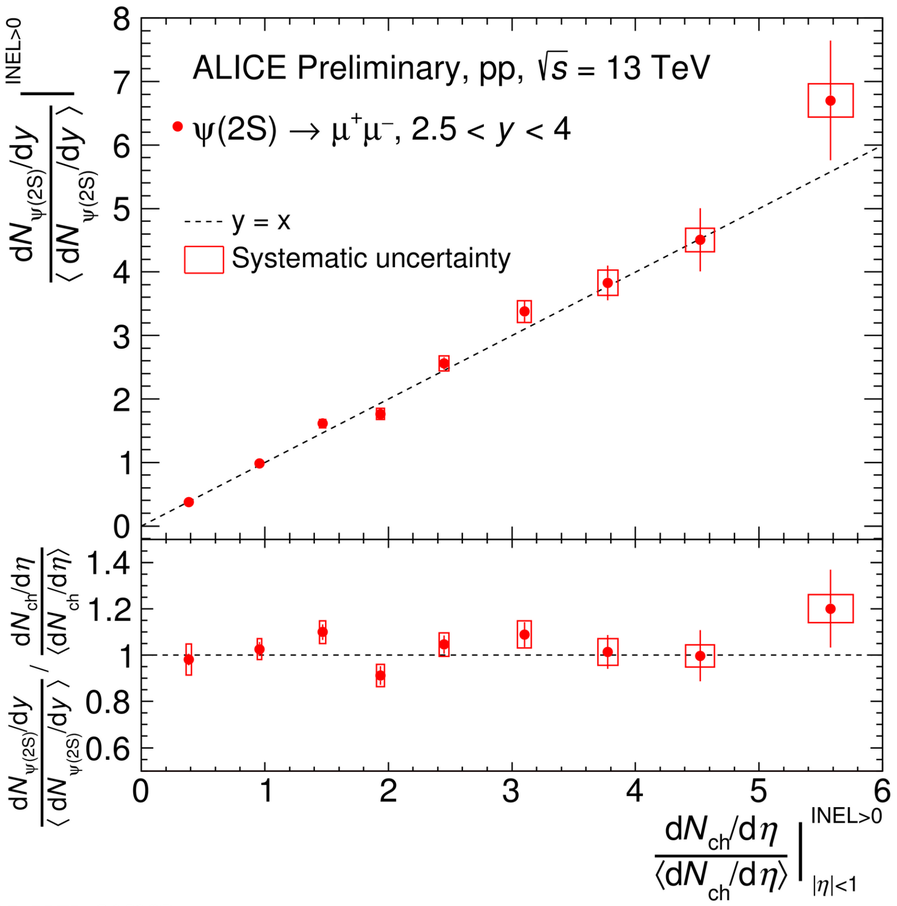
→ X. Bai, Fri, 17:50

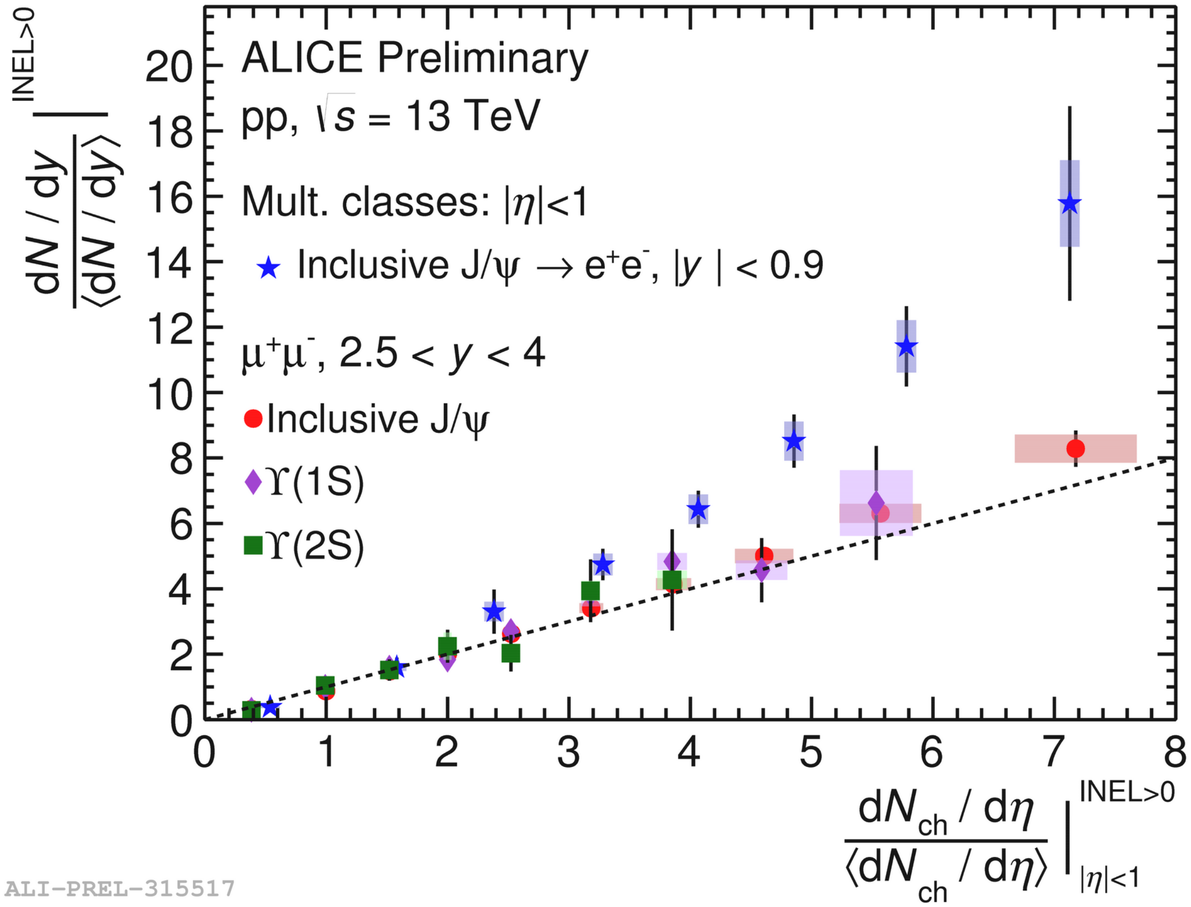


- J/ψ suppression reduced at low p_T
  - ➡ $c\bar{c}$ regeneration
- Reduced suppression from forward to central rapidities at low p_T
  - ➡ Larger $c\bar{c}$ cross section at mid-rapidity (regeneration probability)
- Stronger suppression of Υ(2S) compared to Υ(1S)

Multiplicity dependent quarkonia production

→ Y. Ding, Sat, 15:12

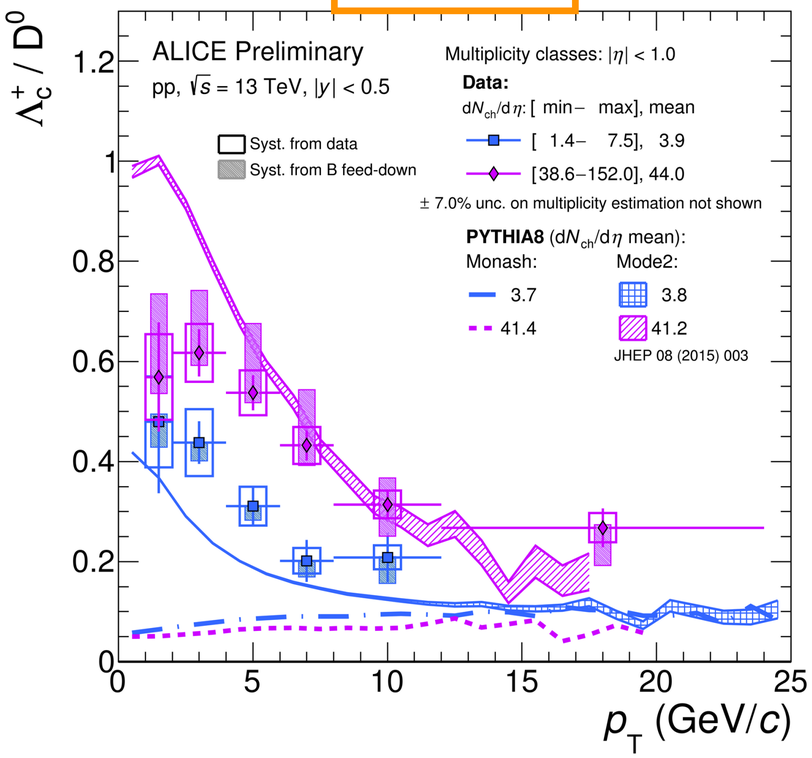




- ψ(2S) production at forward rapidity compatible with linear dependence on multiplicity at mid rapidity
- No indication of 2S/1S state modification for both charmonium and bottomonium

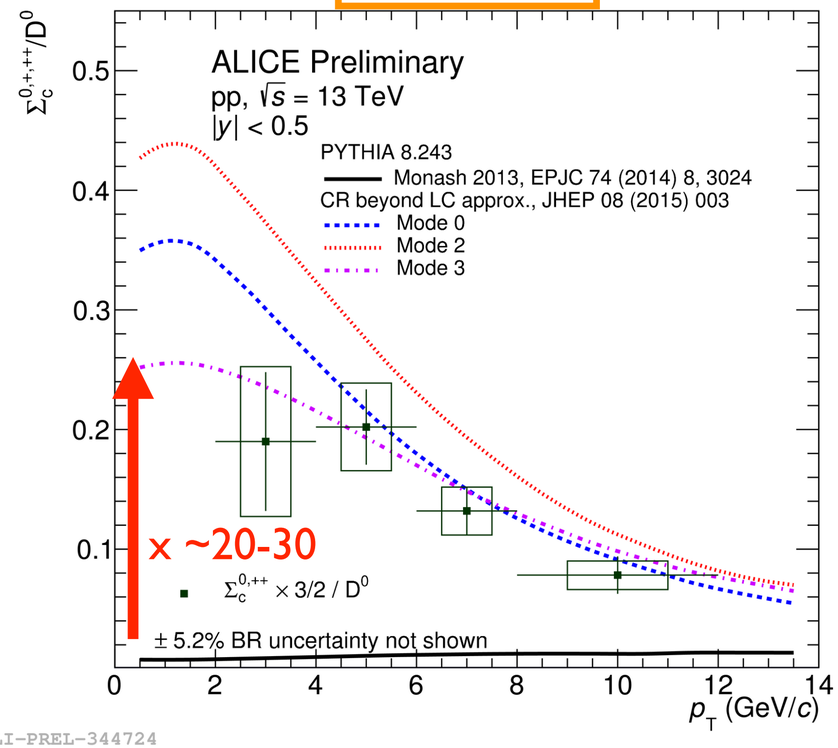
Heavy quark hadronization

Λ_c^+/D^0



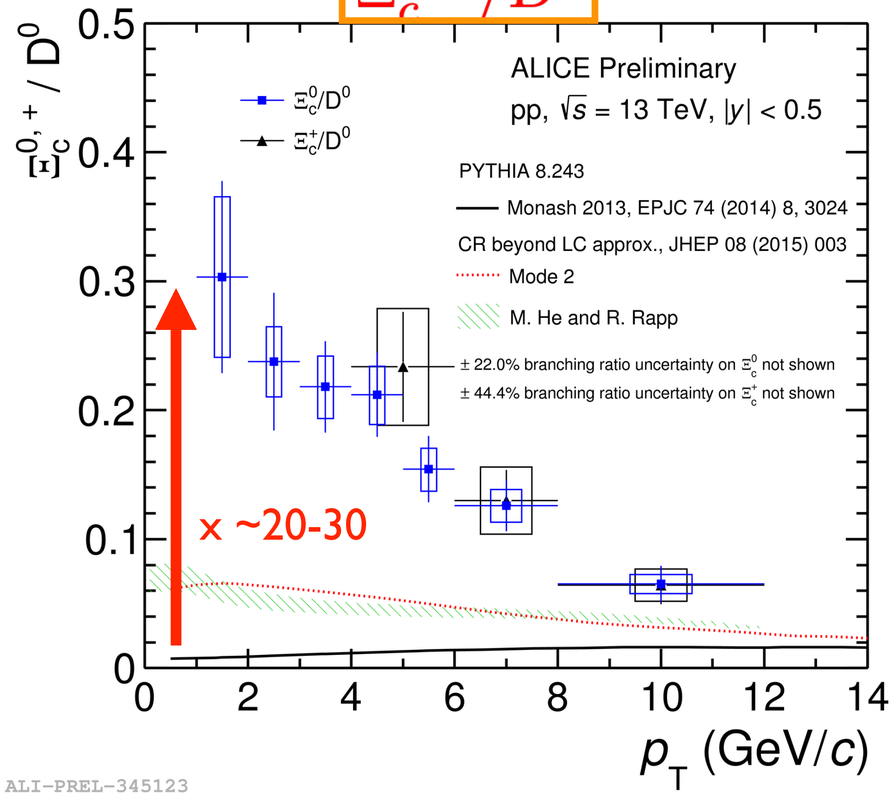
ALI-PREL-336442

$\Sigma_c^{0,+,++}/D^0$



ALI-PREL-344724

$\Xi_c^{0,+}/D^0$

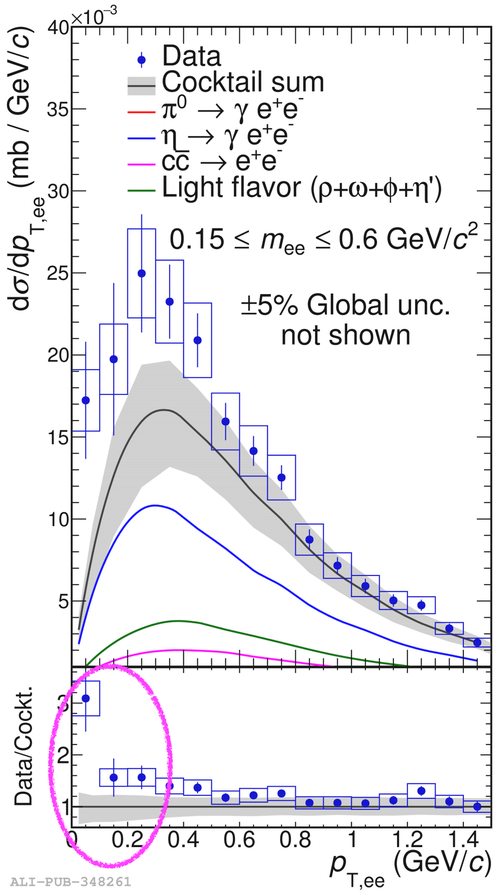


ALI-PREL-345123

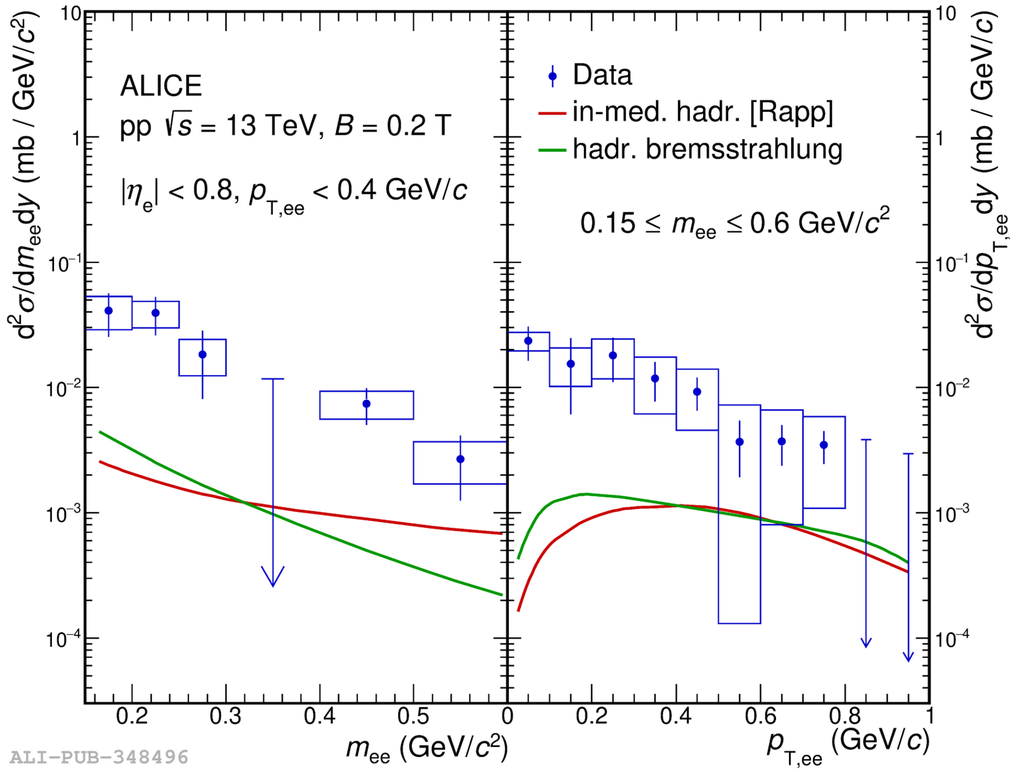
- Multiplicity dependent baryon/meson ratio observed
- Enhancement of baryon to meson ratios in charm sector at low p_T
- Baryon to meson ratio well described by PYTHIA including color reconnection but not for $\Xi_c^{0,+}$

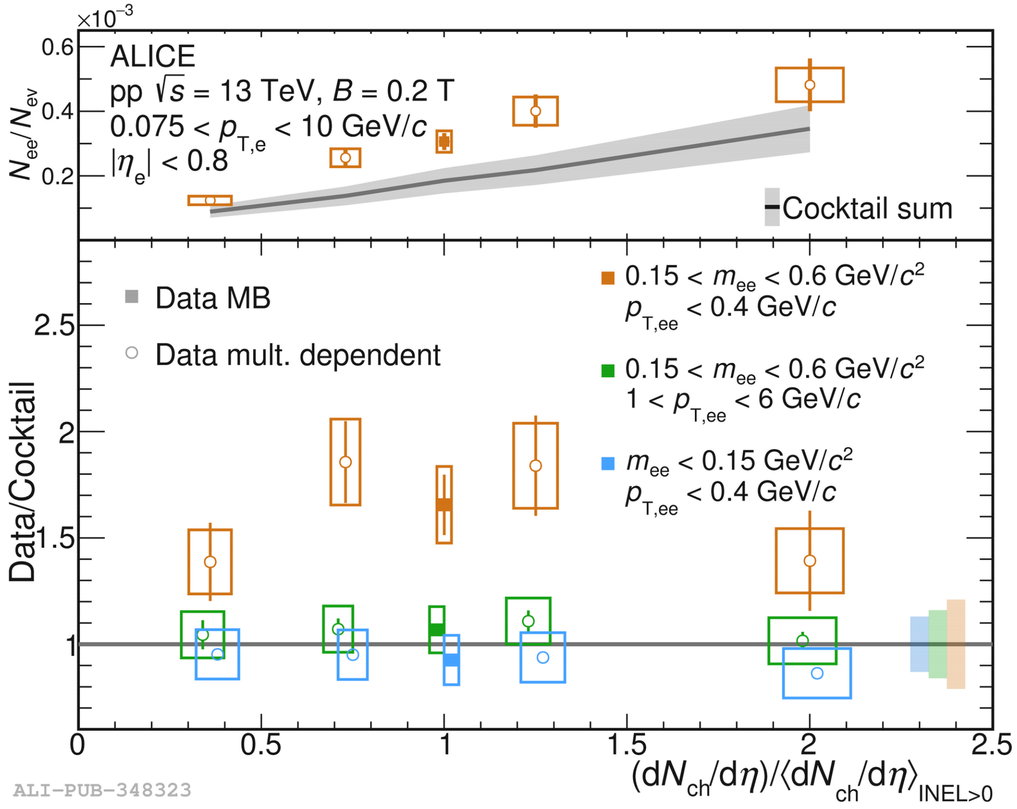
→ J. Zhu, Sat, 14:18
→ T. Chen, Fri, 17:32

Low-mass dielectron production in pp



arXiv: 2005.14522



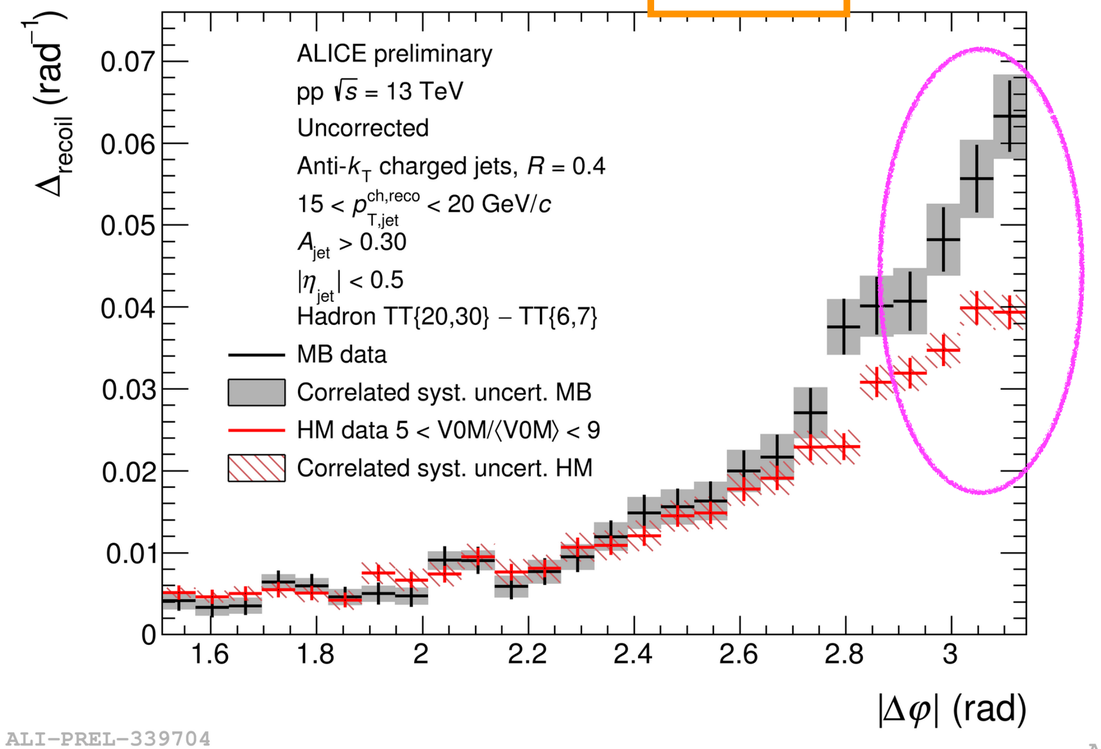


- Hint of excess observed in the mass region ($0.15 < m_{ee} < 0.6$ GeV/c^2) at low p_T
- Excess yields can't be described by thermal radiation or hadronic bremsstrahlung
- No significant multiplicity dependence

Search for jet quenching in HM pp

- Significant suppression and acoplanarity in HM with respect to MB → jet quenching?
- Investigate the effect using PYTHIA

Data



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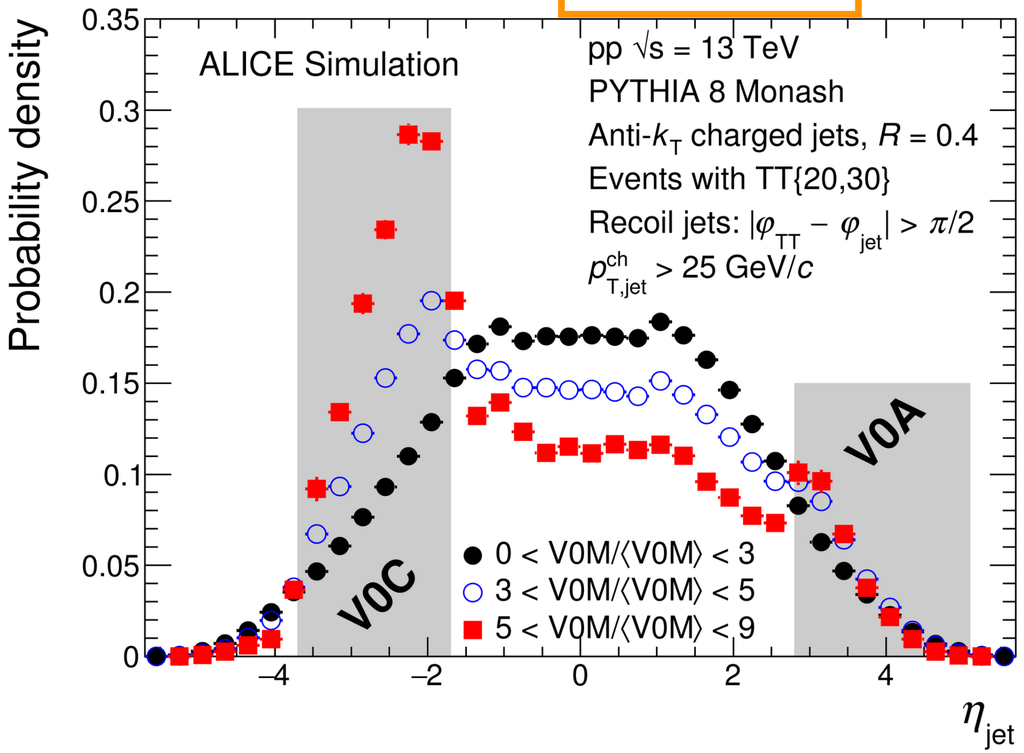
PYTHIA 8



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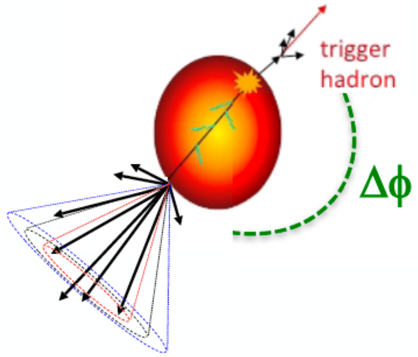


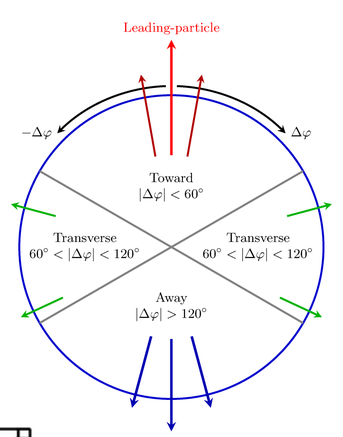
- HM requirement biases towards multi-jet final states

→ Important for all studies of high multiplicity events in small collision systems

A jet-free multiplicity estimator: R_T

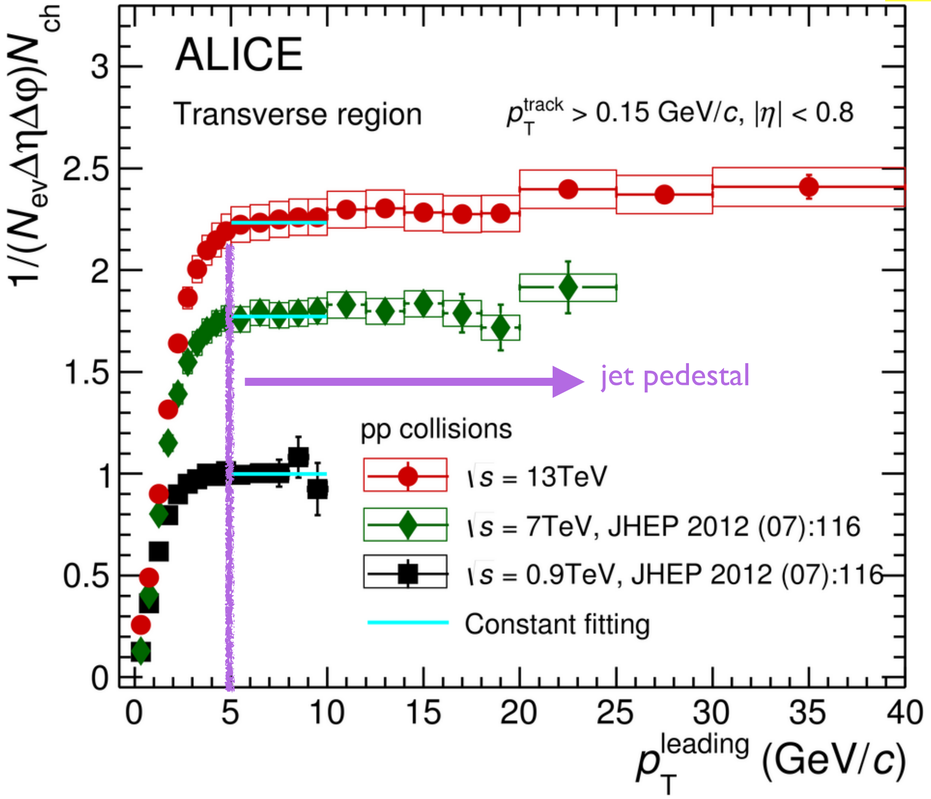
A new variable R_T is proposed $R_T = \frac{N_{inclusive}}{\langle N_{inclusive} \rangle}$

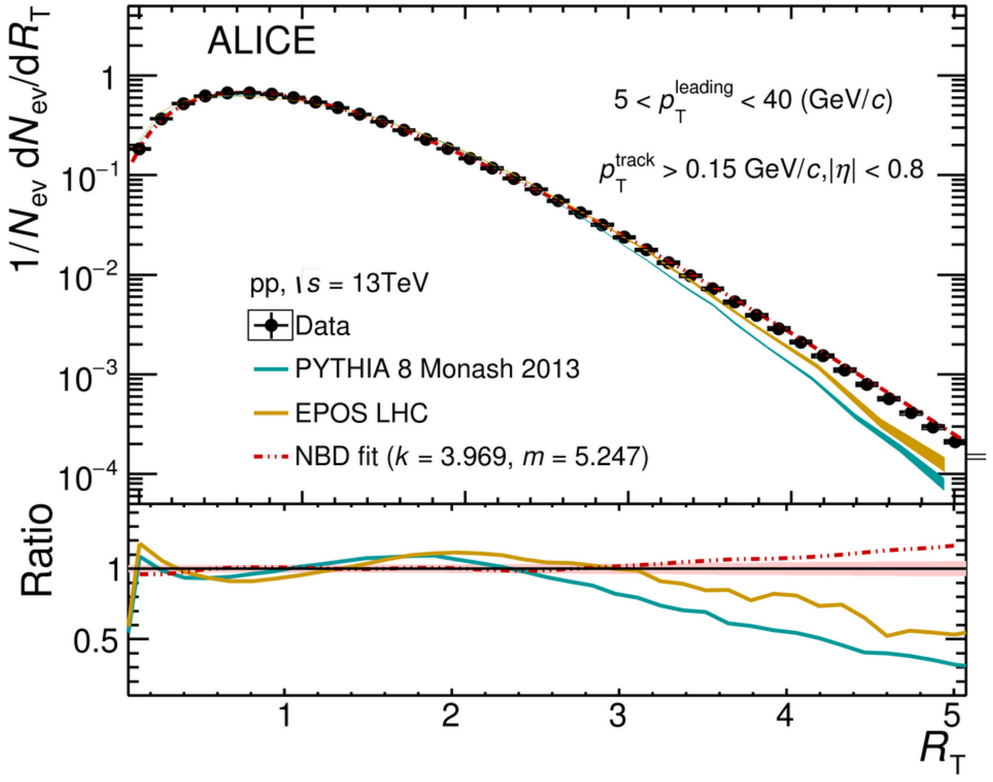
- not influenced by the initial hard parton scattering
- can discriminate among soft and hard events



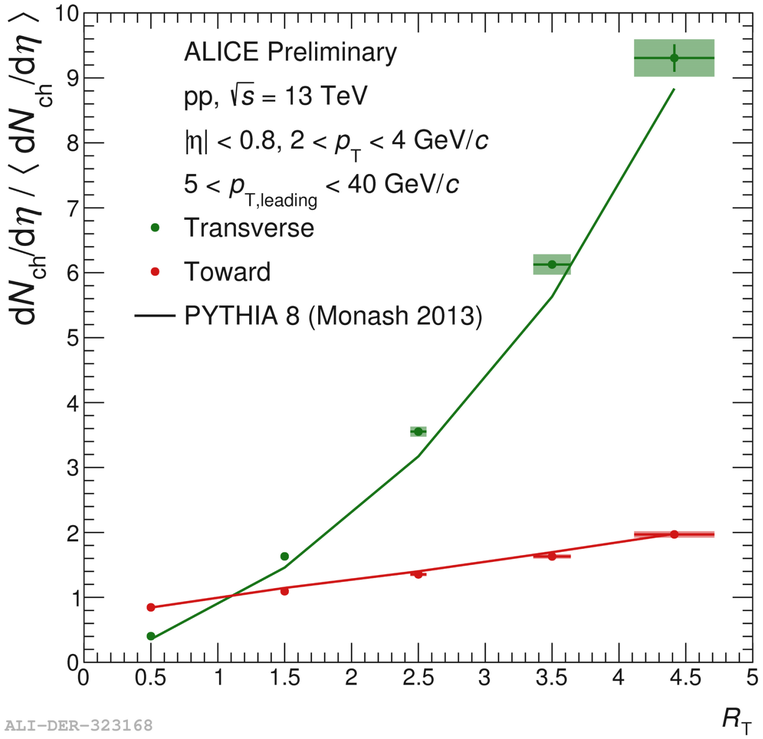
- Define the relative transverse activity classifier R_T in the jet pedestal region (JHEP 20 (2020) 192)

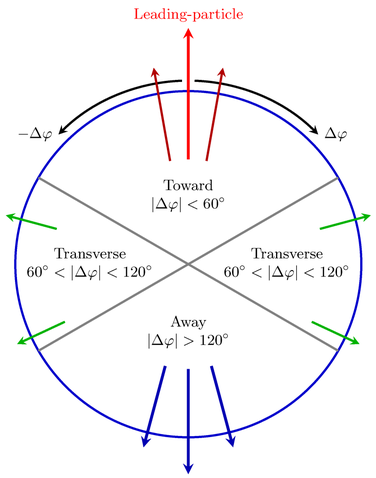
JHEP 20 (2020) 192



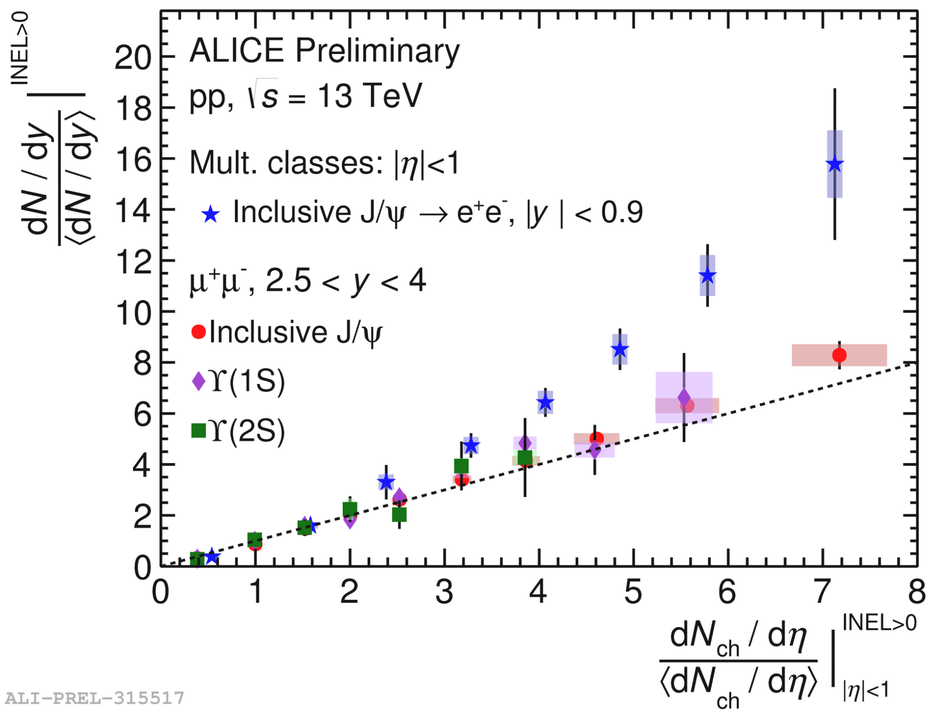


R_T dependent charge particle density



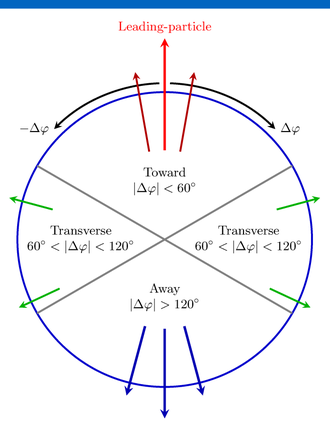


$$R_T = \frac{N_{inclusive}}{\langle N_{inclusive} \rangle}$$



- Yield vs R_T in transverse region rising more quickly than in toward region
  - ➡ clean separation among soft (UE) and hard part (jet) of the events
- Using R_T as event classifier explains the behavior observed using mid-y based multiplicity estimator
  - ➡ no autocorrelation effects at play!

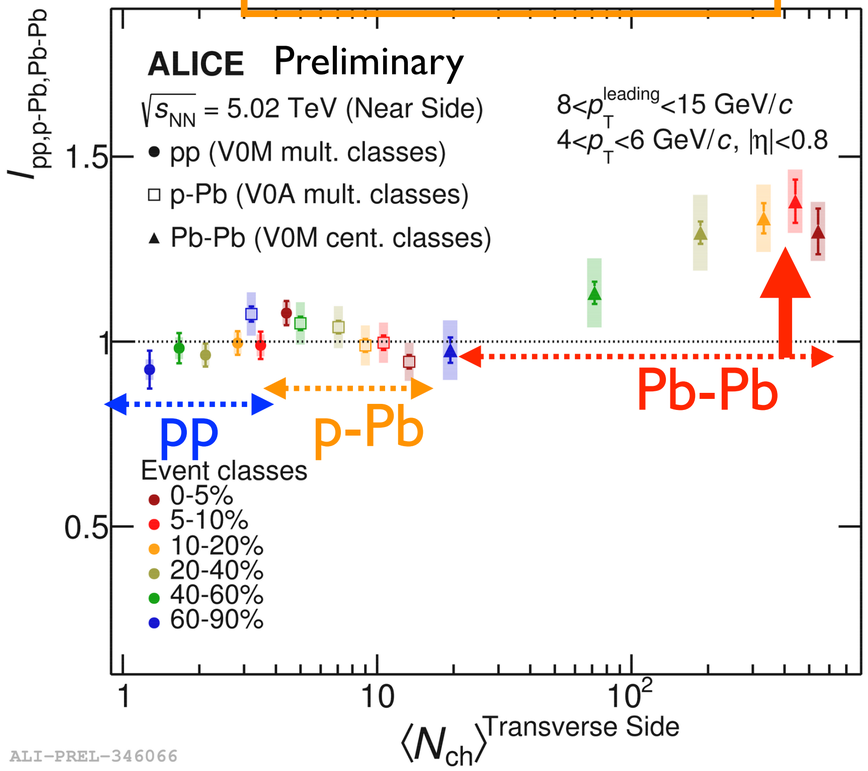
Jet quenching in small collision systems?



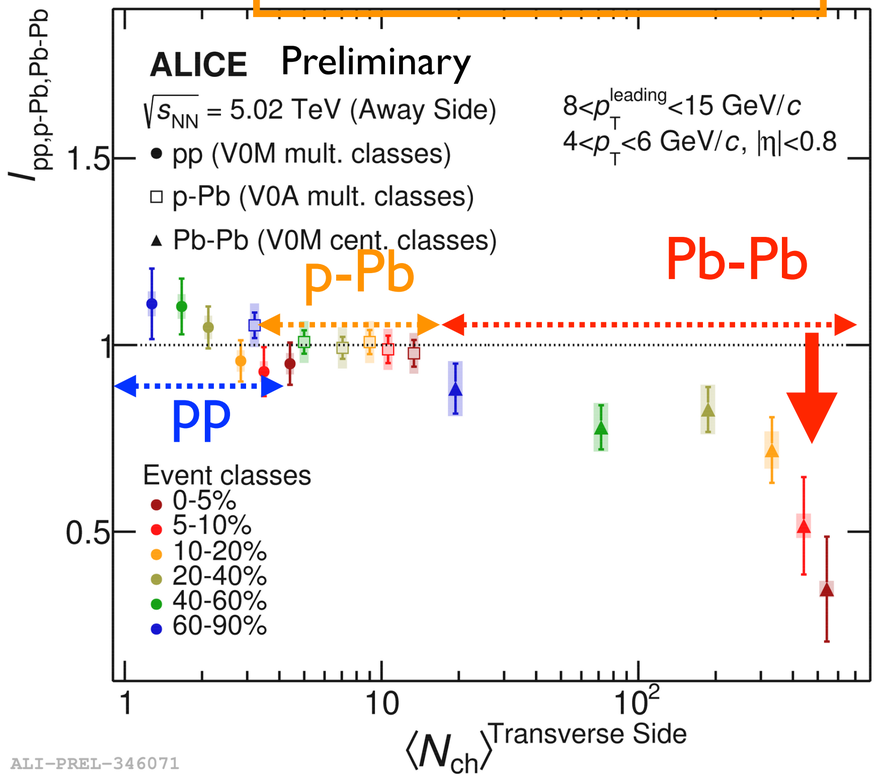
$\Delta\varphi = |\varphi_{leading} - \varphi_{associate}|$

$$I_{\mathrm{pp/pA/AA}} = \frac{Yield^{\mathrm{pp/pA/AA}}_{\mathrm{NS/AS}}}{(Yield^{\mathrm{pp/pA/AA}}_{\mathrm{NS/AS}})_{\mathrm{min.bias}}}$$

Near side: $|\Delta\varphi| < 60°$



Away side: $|\Delta\varphi| > 120°$

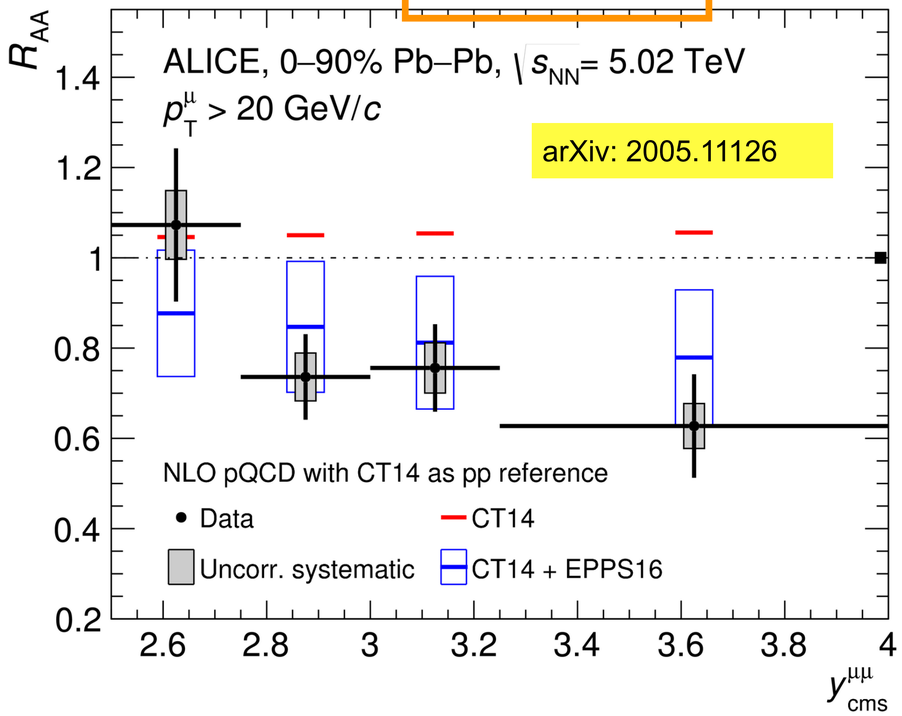


- Using multiplicity in transverse region as event activity classifier to better separate soft and hard processes
- No enhancement (suppression) observed for Near (Away) side in pp and p-Pb collisions

➡ No indication of jet quenching in small collision systems

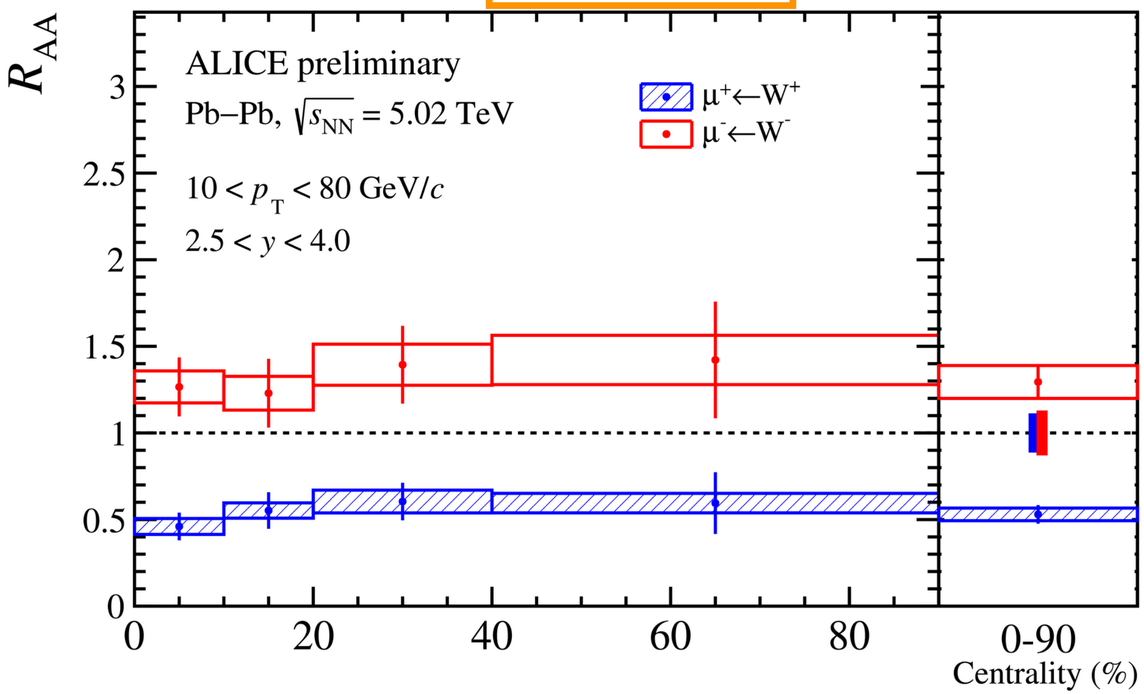
Probing nPDFs with forward W and Z bosons

Z bosons



ALI-PUB-347354

W bosons



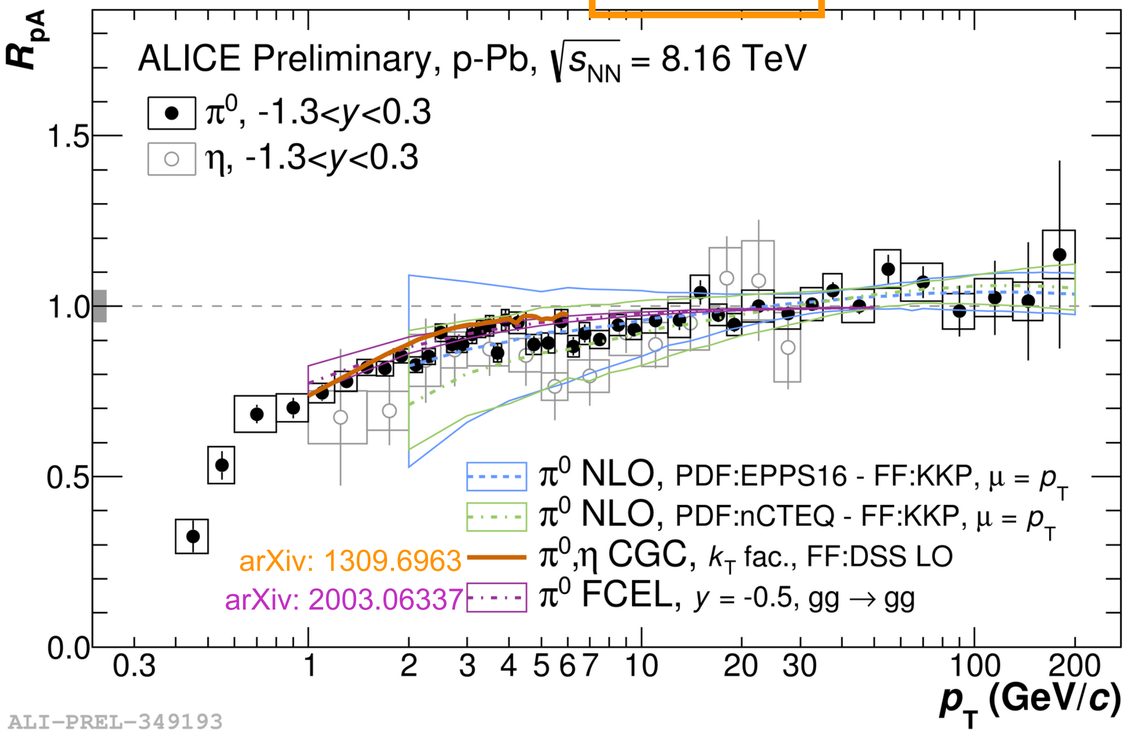
ALI-PREL-350693

→ Z. Lu, Sun, 18:08

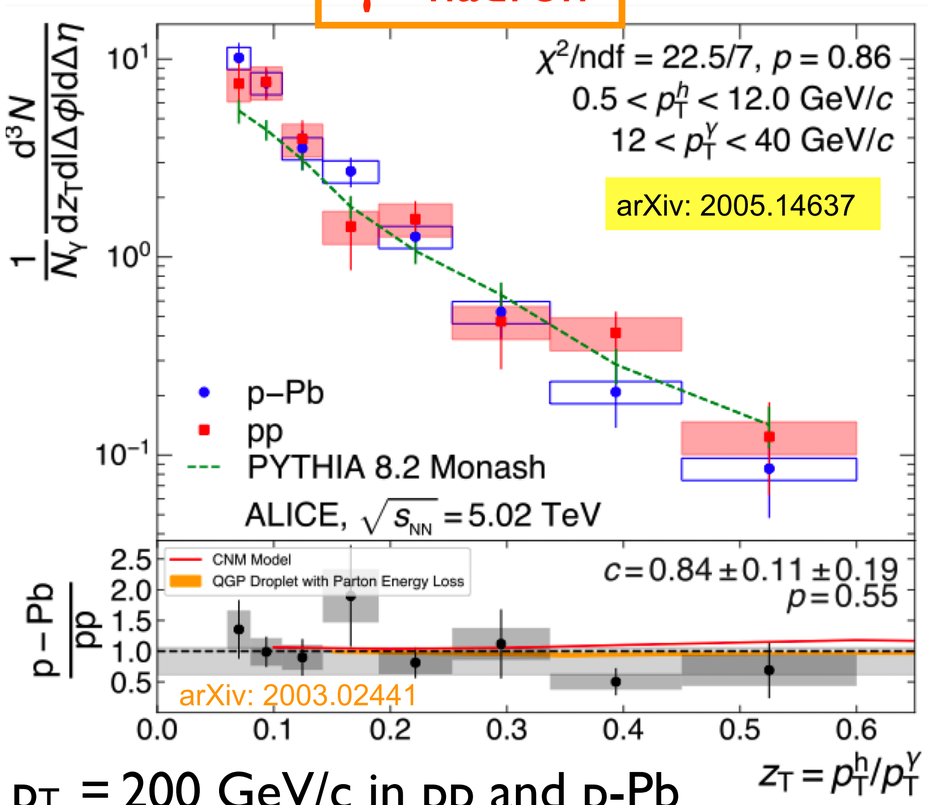
- Color neutral probes (Z, W) used to study initial state effects with Pb-Pb (shown) and p-Pb
  - Z boson R_{AA} consistent with theoretical calculation including nPDFs (EPPS16)
  - Strong deviation of Z boson R_{AA} at large rapidity with respect to free-nucleon PDF calculation
  - No centrality dependence of W boson R_{AA}

Probing CNM effects with π^0 and γ-hadron correlations

π^0



γ - hadron



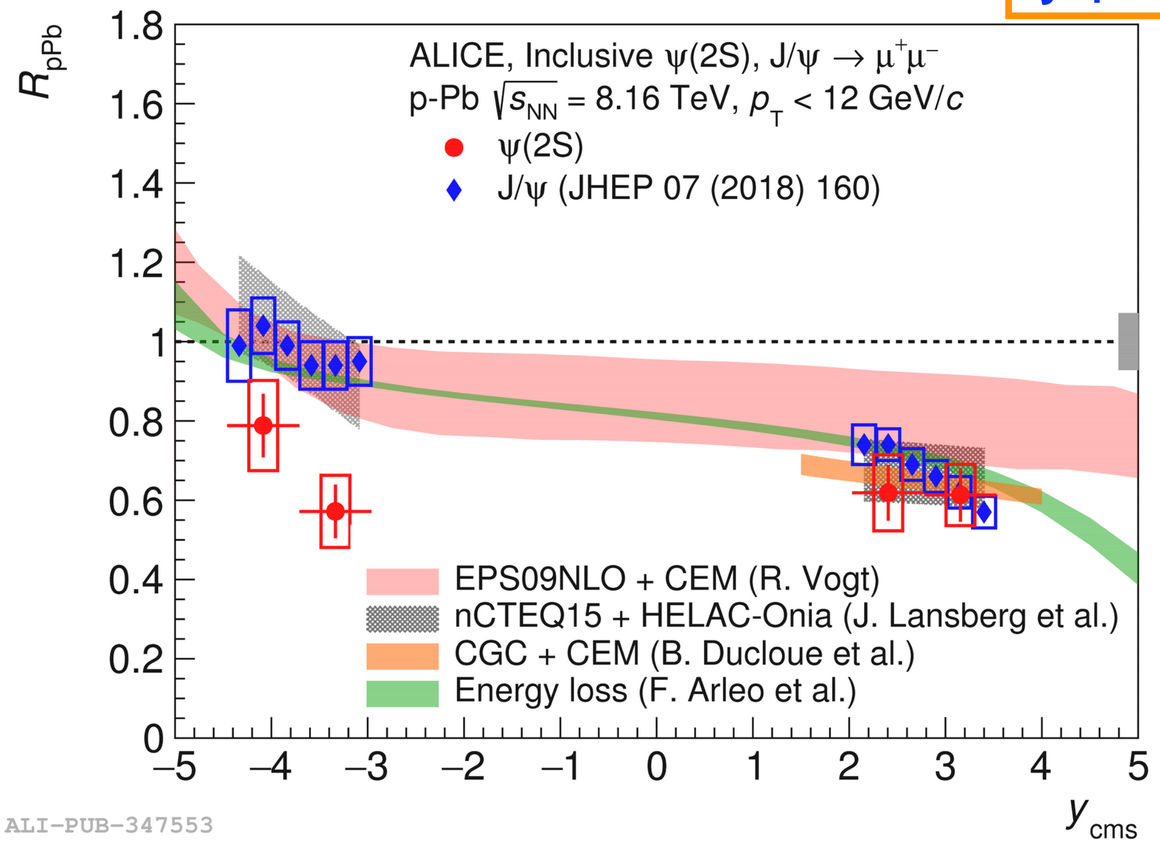
- First measurement of neutral meson production up to p_T = 200 GeV/c in pp and p-Pb
  - Described by both nPDFs (EPPS16) and CGC (T. Lappi)
- Isolated photon-hadron correlations to study jet fragmentation properties
  - no significant CNM effect observed

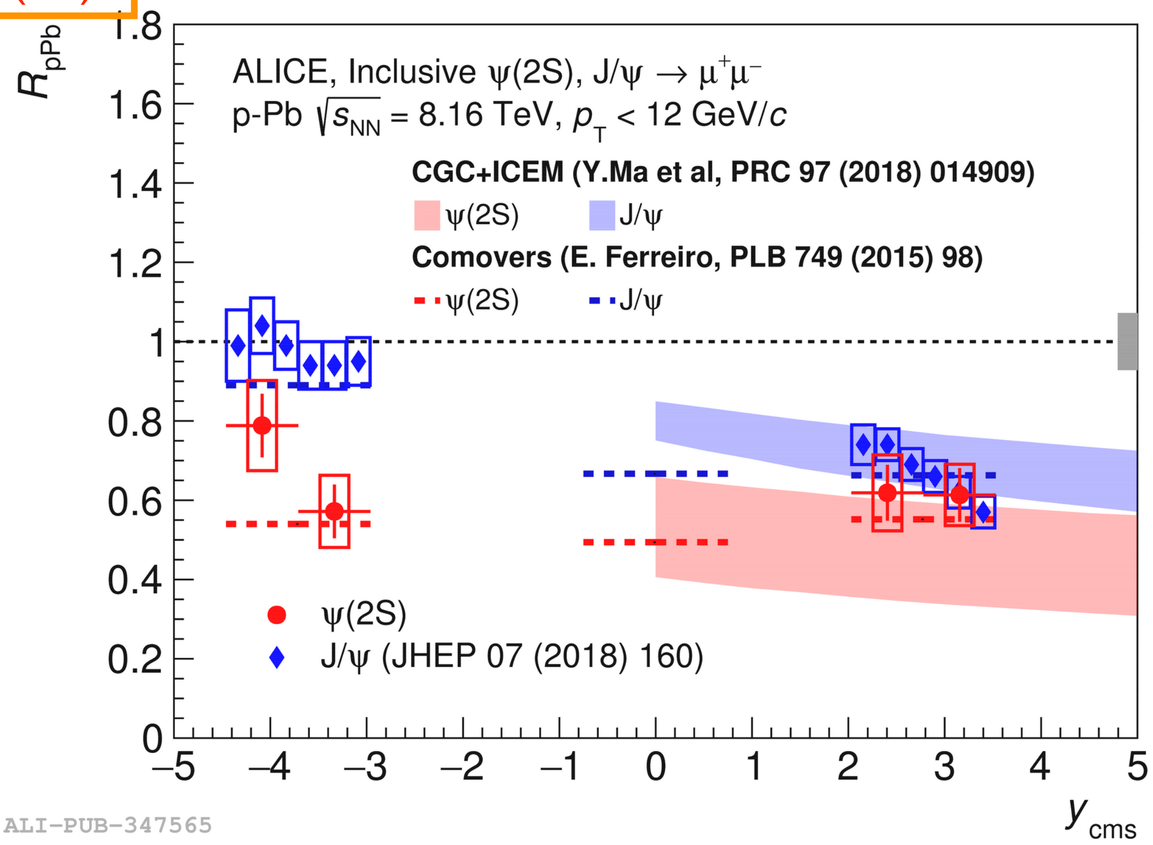
Probing CNM effects on charmonia

J/ψ, ψ(2S)

arXiv: 2003.06053

→ X. Bai, Fri, 17:50



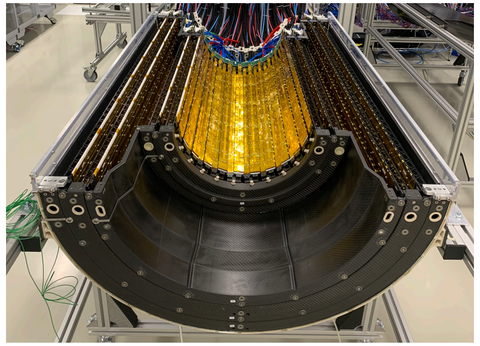


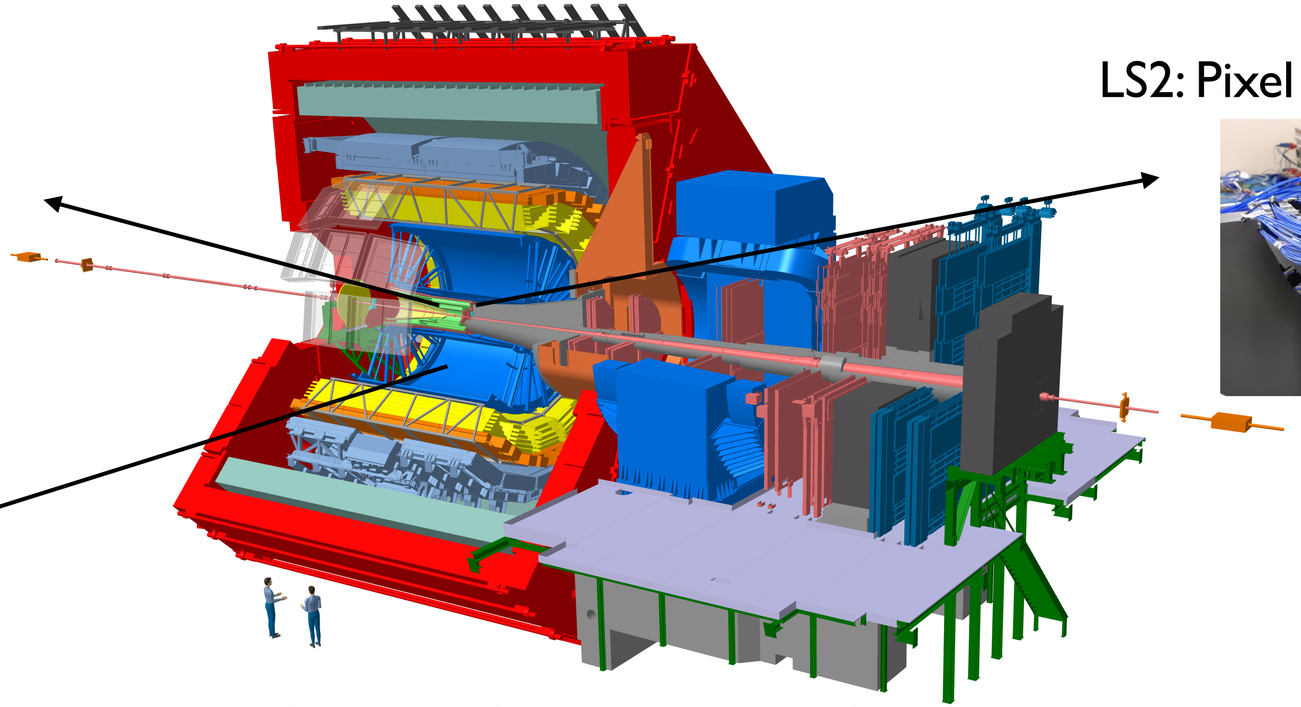
- Significant modification of the production in the p-going direction, in line with model predictions
- Stronger suppression for ψ(2S) with respect to J/ψ in the Pb-going direction → final state effect?

ALICE upgrade for Run 3

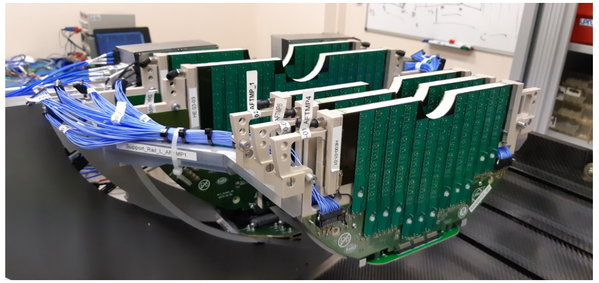
→ Z.Yin, Mon, 9:25

LS2: All-pixel Inner Tracking System

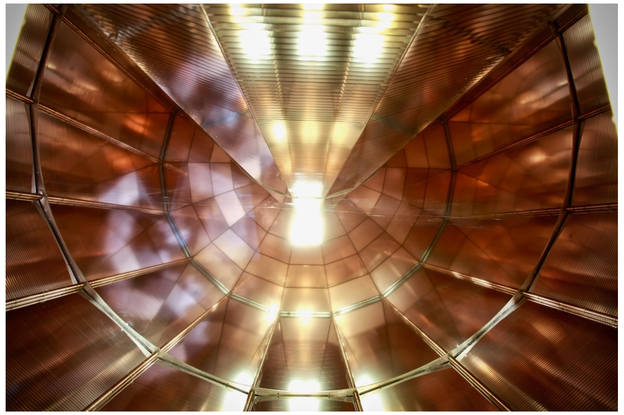




LS2: Pixel Muon Forward Tracker



LS2: GEM-based TPC readout



- Improved tracking resolution down to low p_T

  ➡ thinner, more granular

- Access low S/B "untriggerable" signals

  ➡ x 50 faster readout

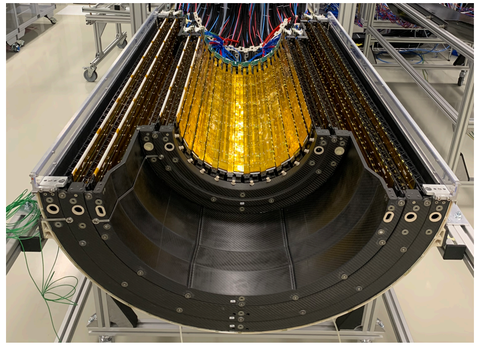
… and much more:

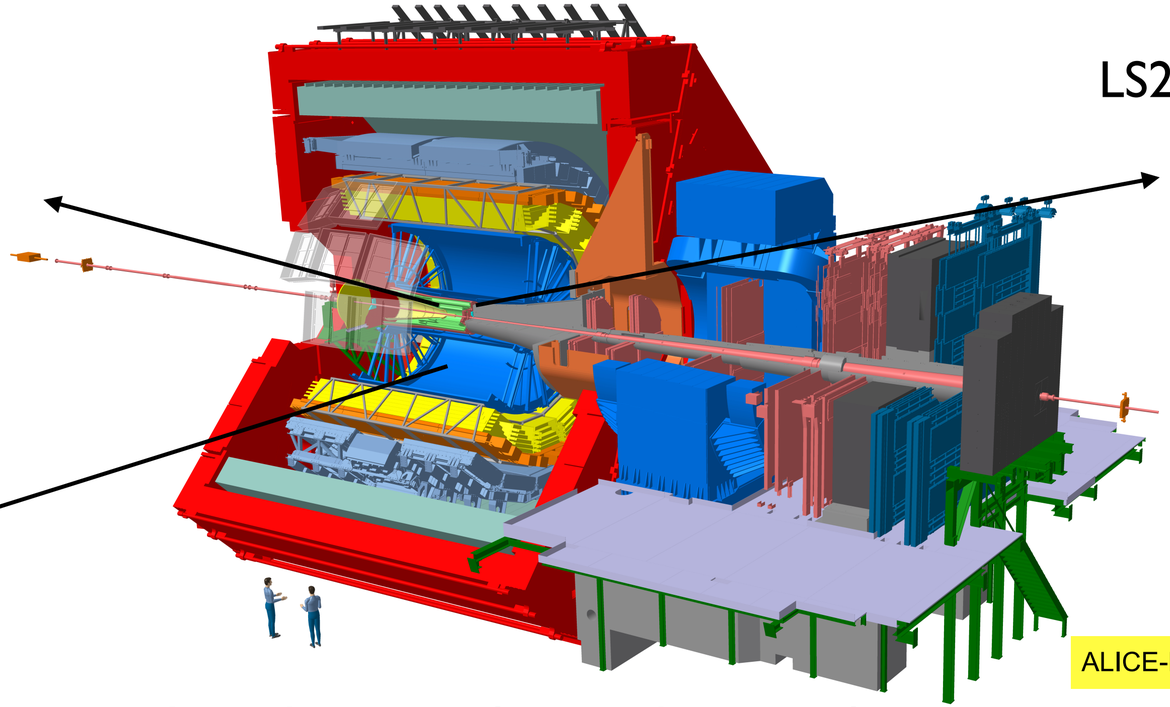
- Fast Interaction Trigger
- New Online-Offline system
- Readout upgrade of MUON, TOF, EMCAL, PHOS

ALICE upgrade for Run 3 and proposals for Run 4

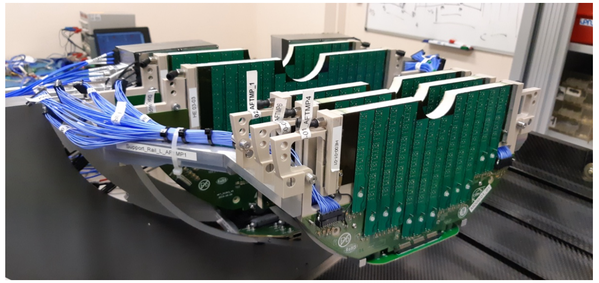
→ Z.Yin, Mon, 9:25

LS2: All-pixel Inner Tracking System

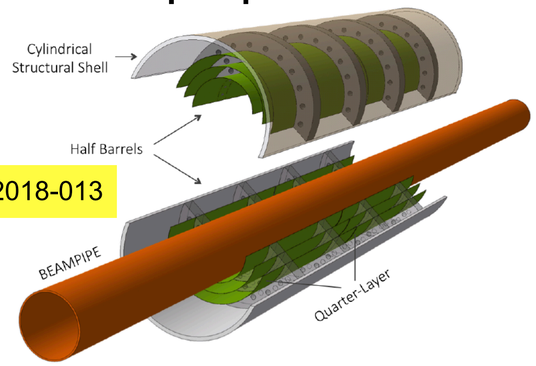




LS2: Pixel Muon Forward Tracker

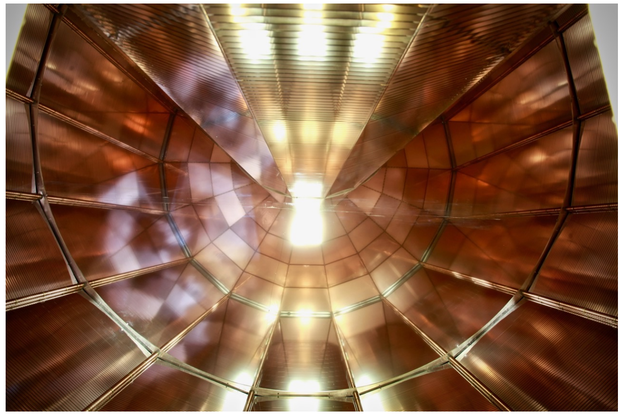


LS3: proposed ITS3



ALICE-PUBLIC-2018-013

LS2: GEM-based TPC readout



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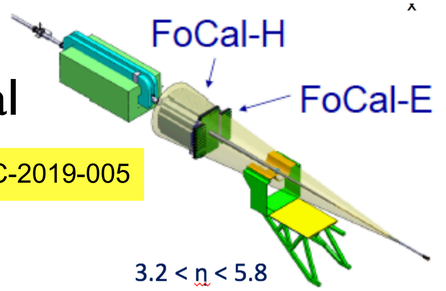
LS3: proposed FoCal



ALICE-PUBLIC-2019-005

Summary

- Large number of results based on full Run 2 data sample
  - More precision, extending to low p_T, more differential, new analysis
- Detailed insight on the QGP properties
  - Heavy quark interactions, hadronization, jet modifications…
- Rich QCD research program in small collision systems
- Major LS2 upgrade on track in view of restart in 2021

Enjoy the conference with new results!

For all results please see:
http://alice-publications.web.cern.ch/submitted
http://alice-figure.web.cern.ch/preliminary_fig_pub

Backup