Jet fragmentation and hadronchemistry

Prottoy Das

for the

ALICE, ATLAS, CMS and LHCb collaborations

Jets: fragmentation and hadronchemistry

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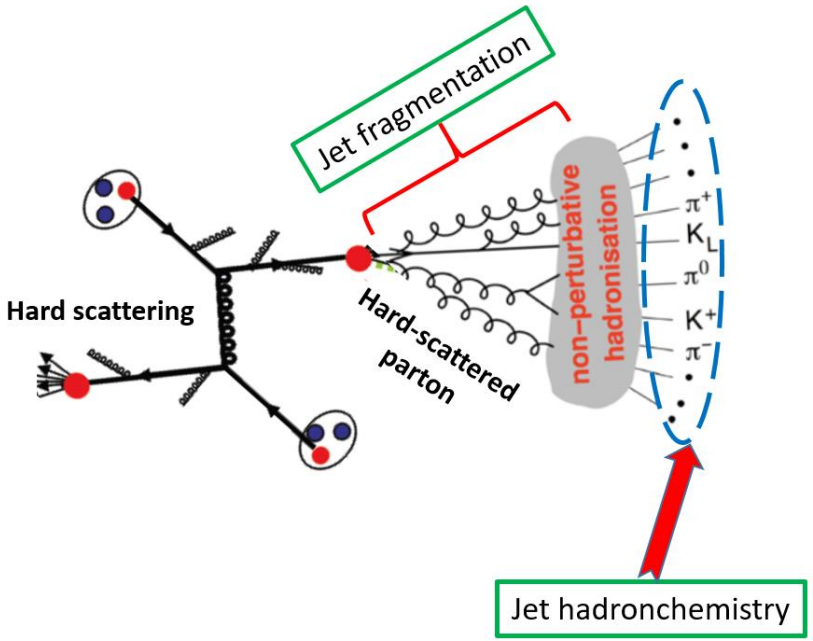

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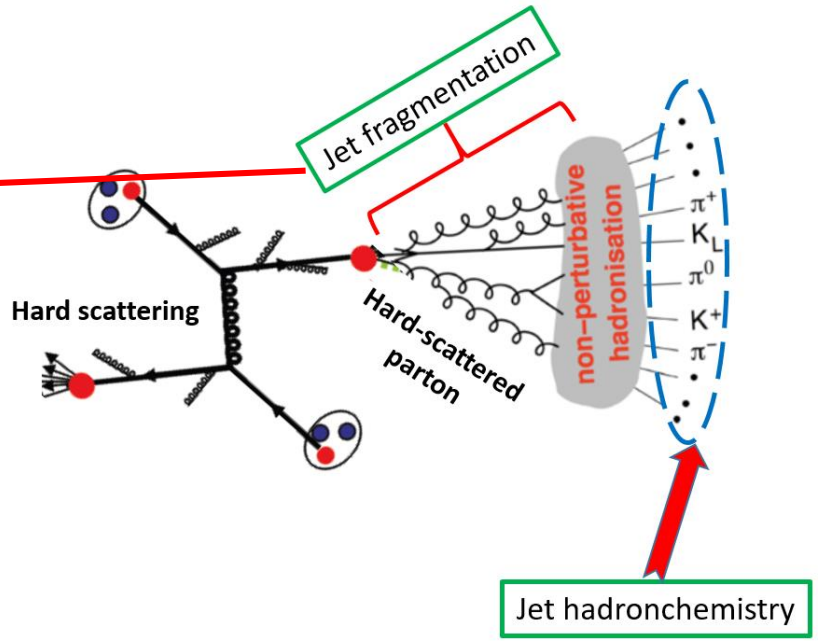

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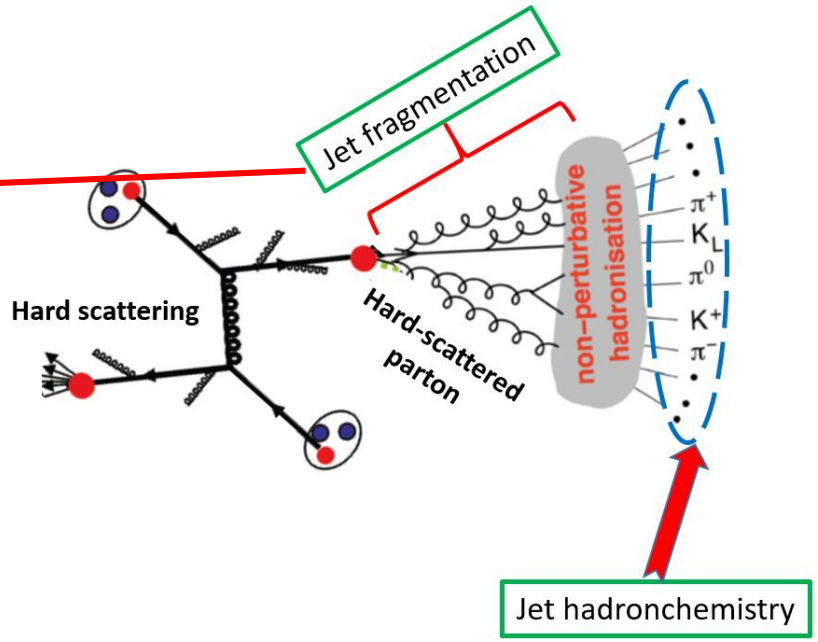

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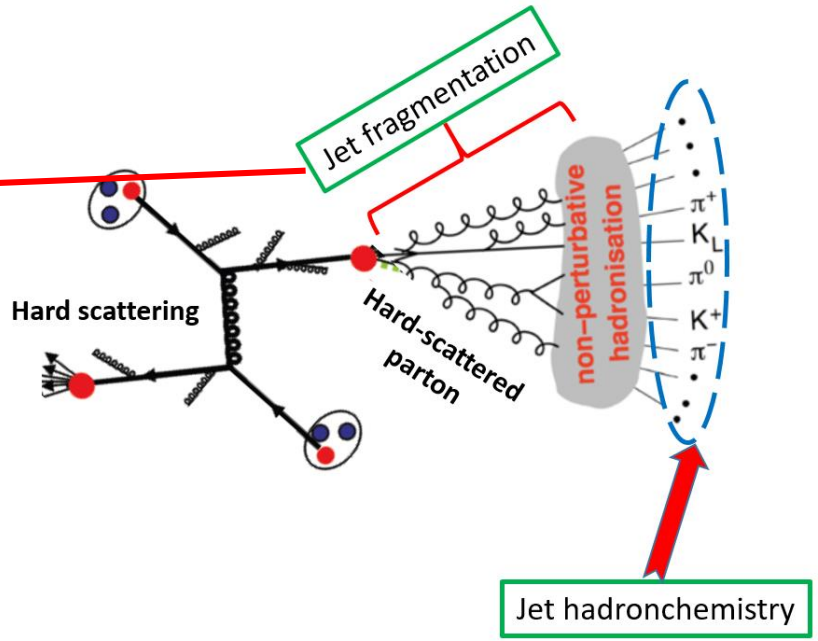

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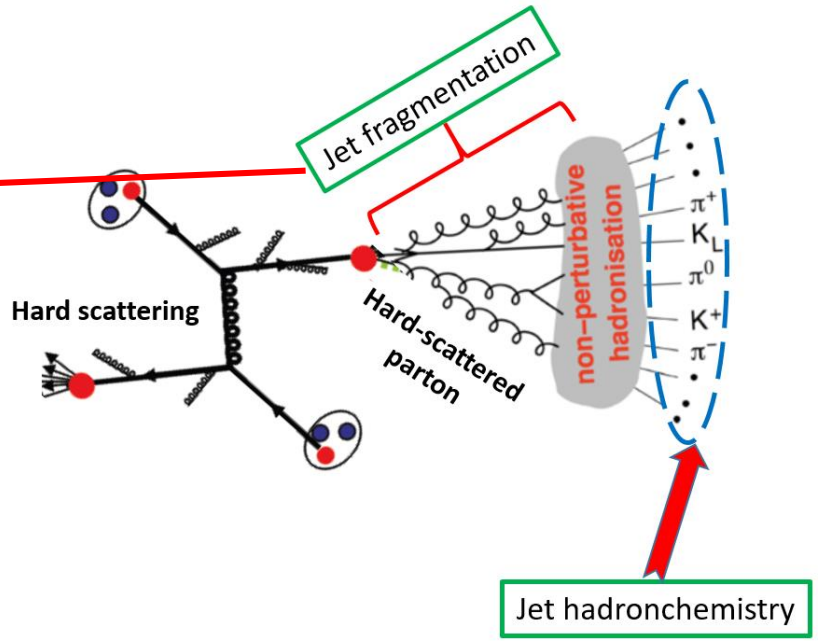

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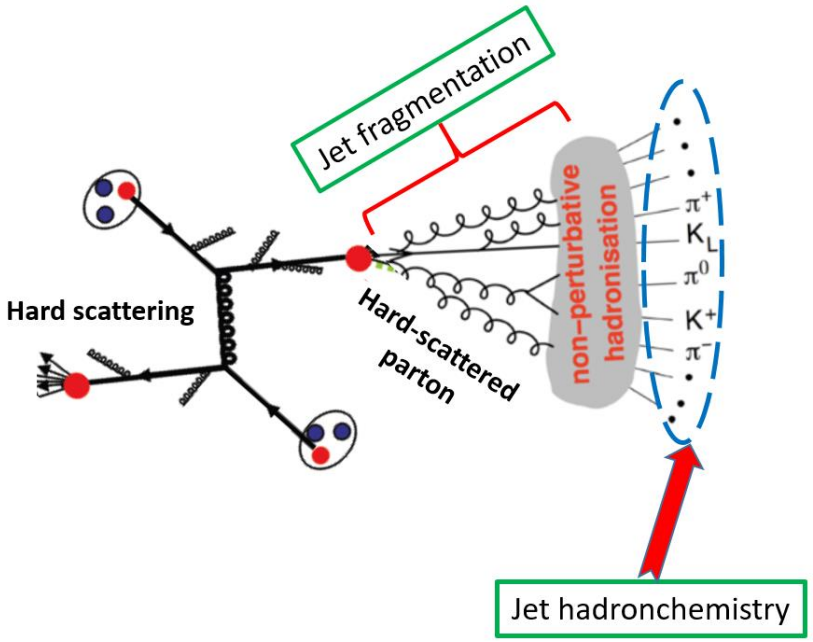

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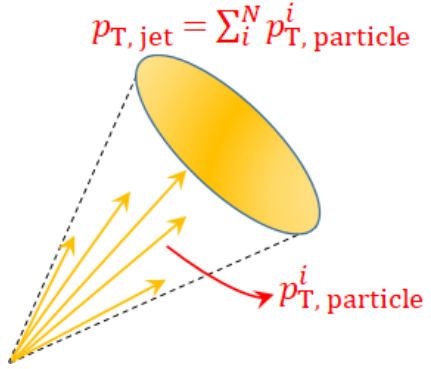

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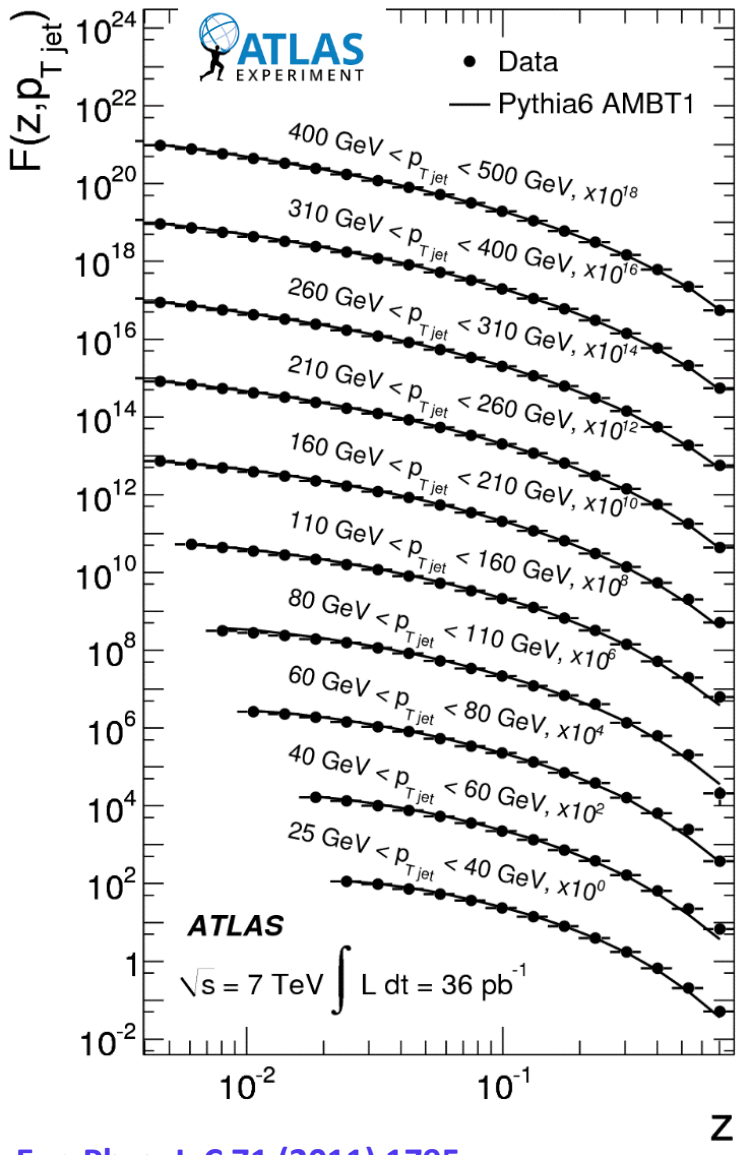

ATLAS, Eur. Phys. J. C 71 (2011) 1795

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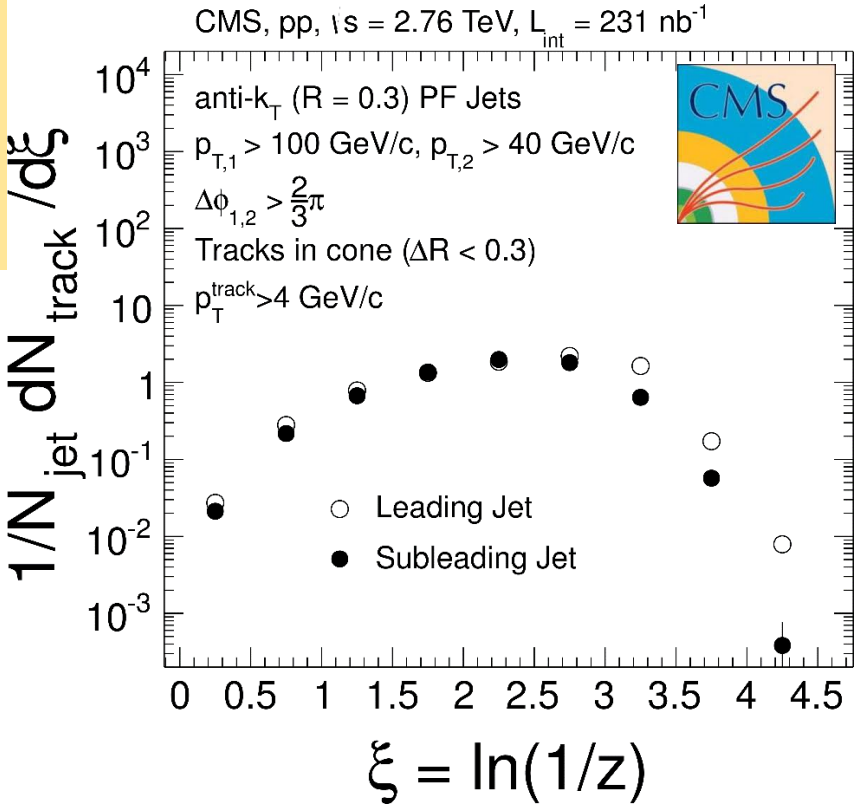

CMS, JHEP10 (2012) 087

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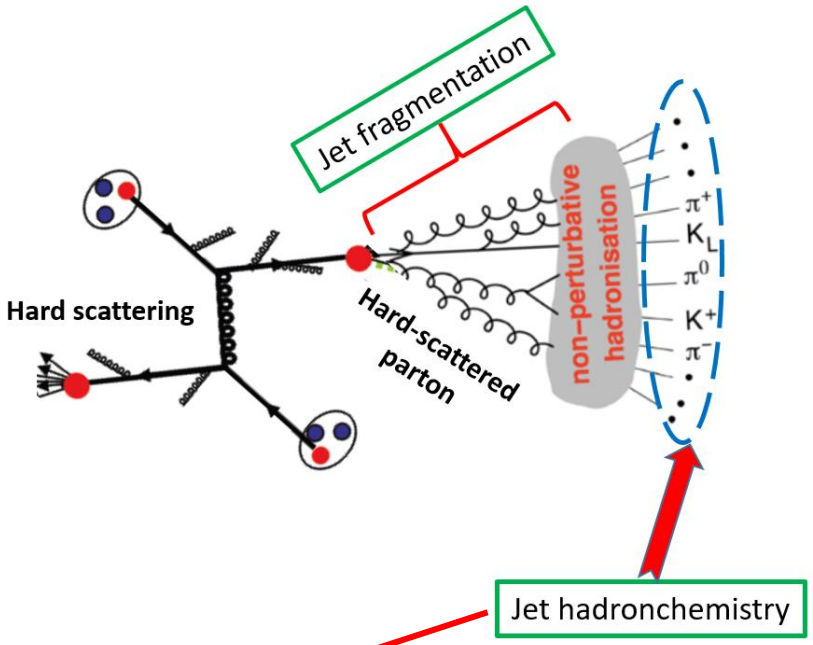

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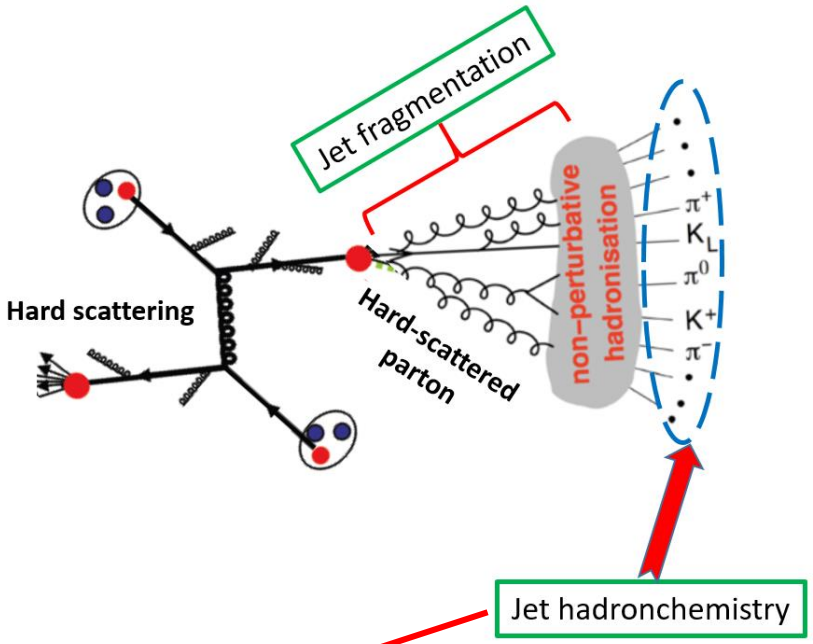

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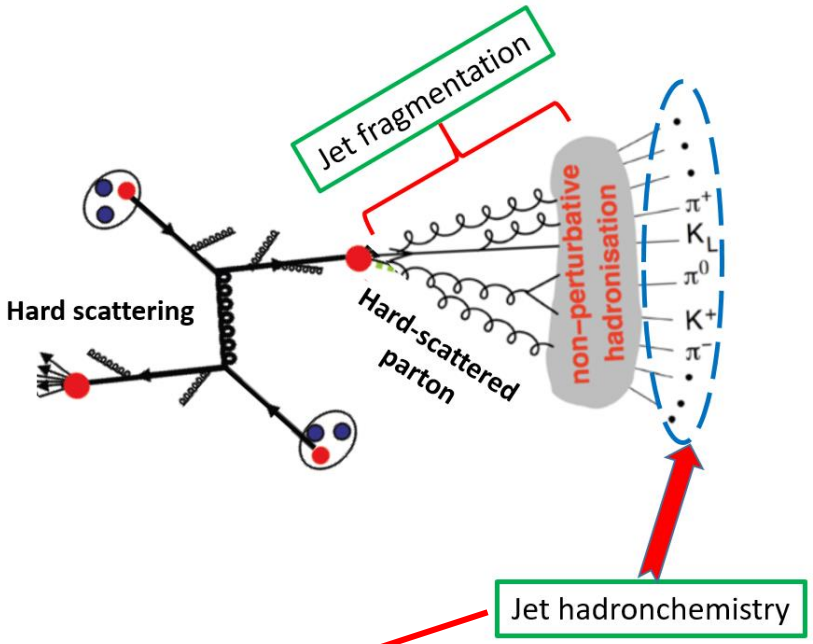

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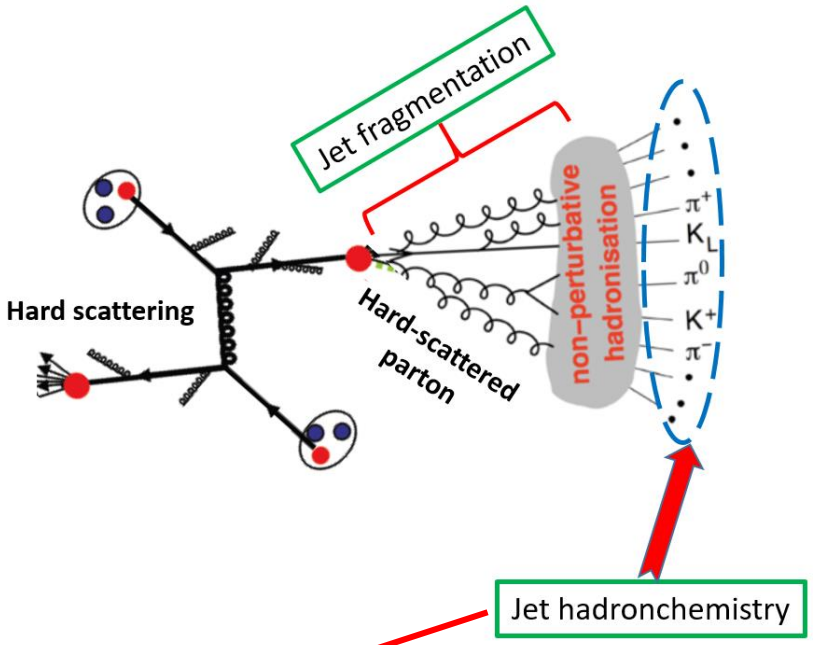

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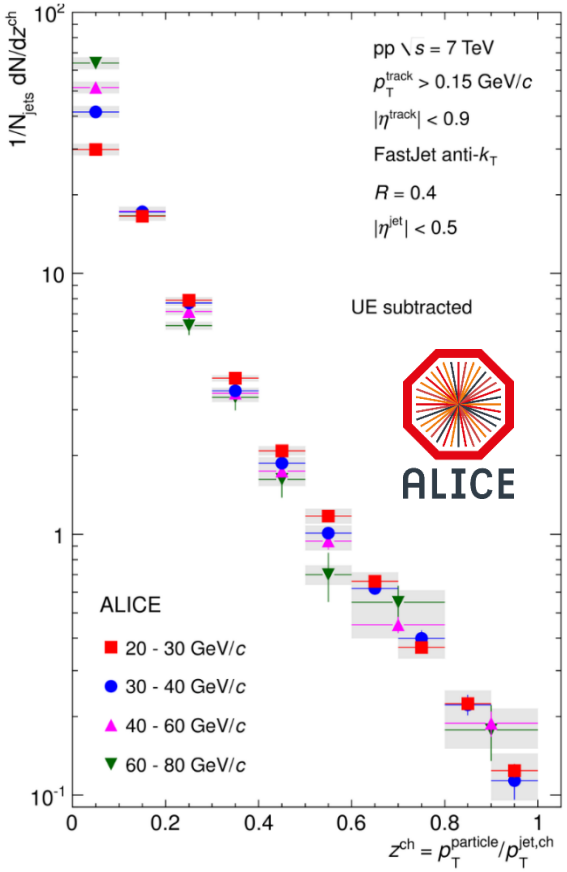
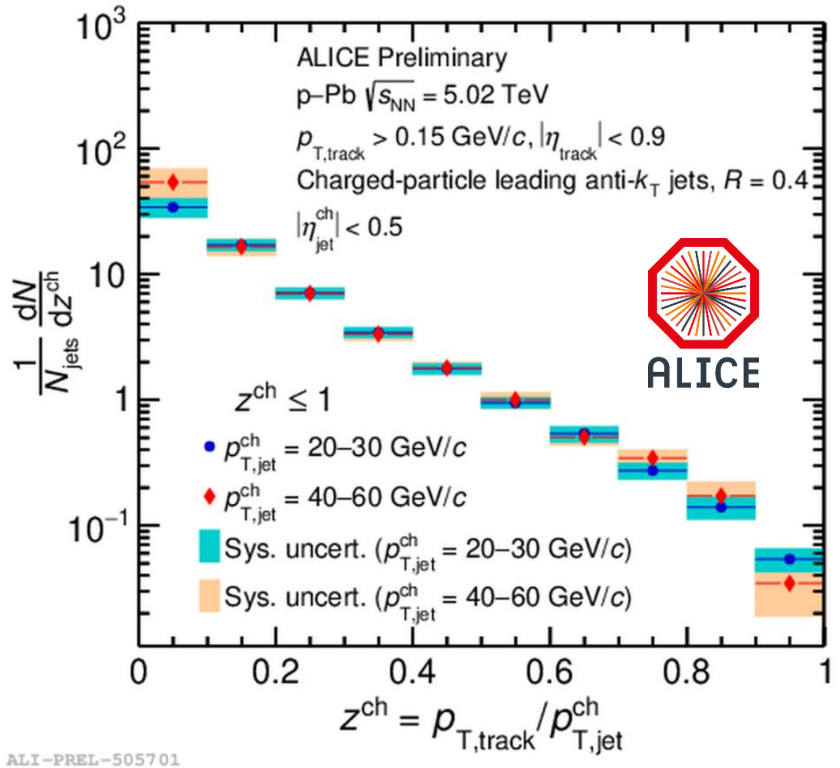
- Serves as a **characteristic of jet quenching**

Jet fragmentation

Scaling behavior of jet fragmentation: z for leading charged jets



ALICE, Phys. Rev. D 91 (2015) 112012



ALICE, PoS LHCP2022 (2023) 303

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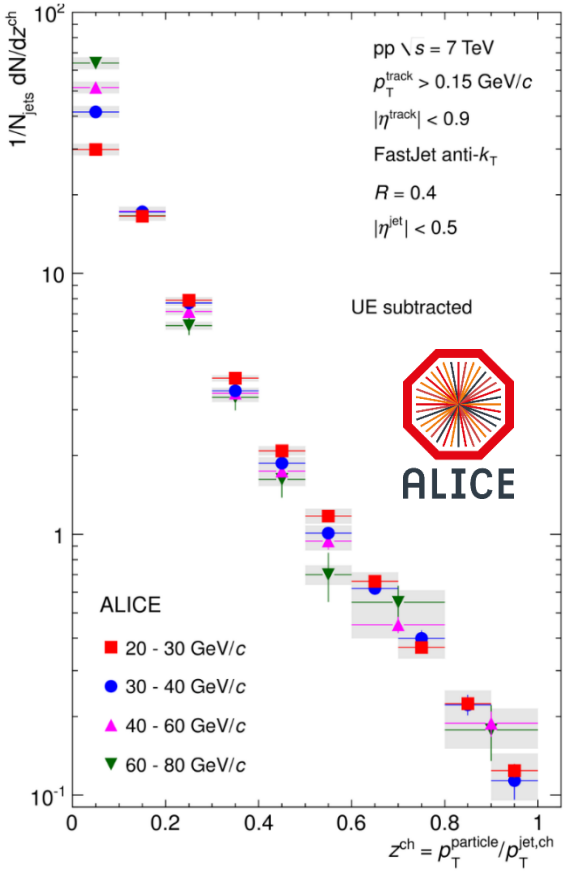

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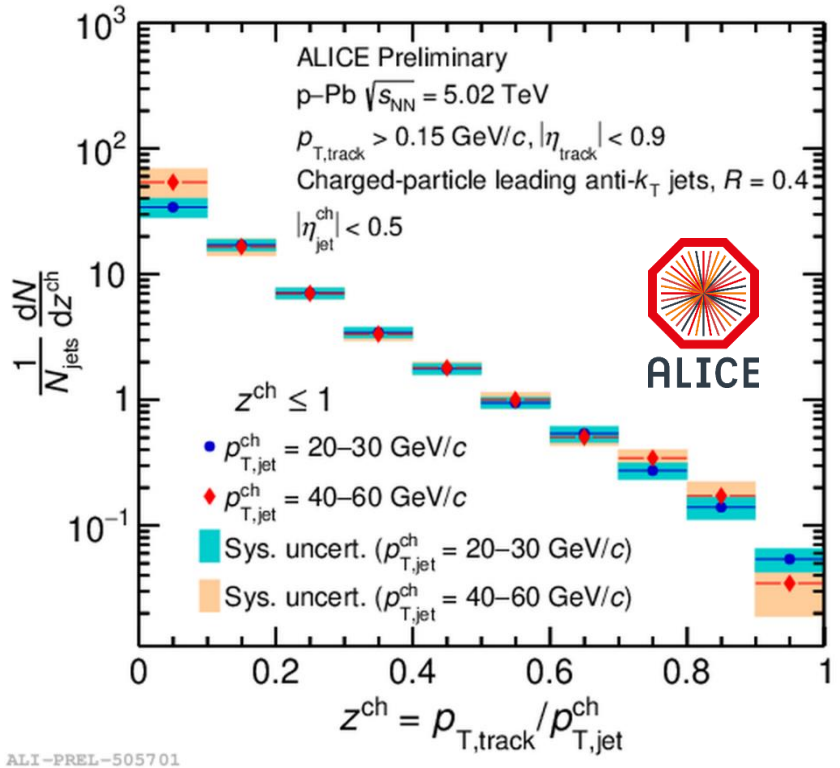

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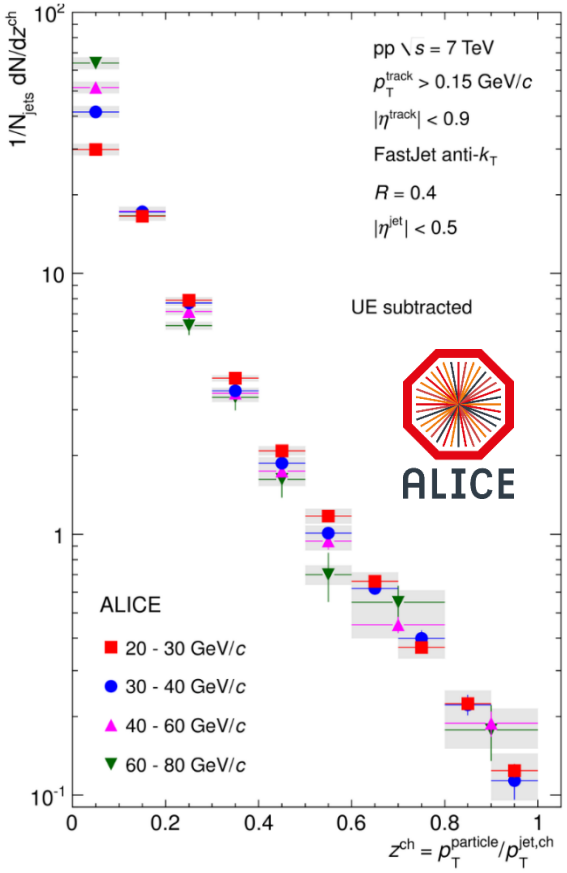

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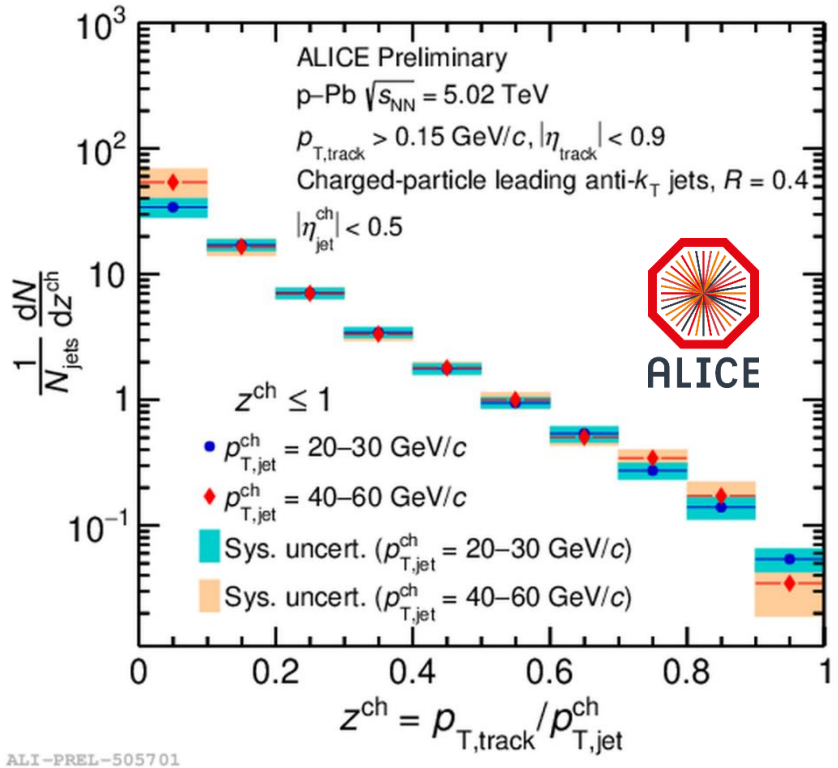

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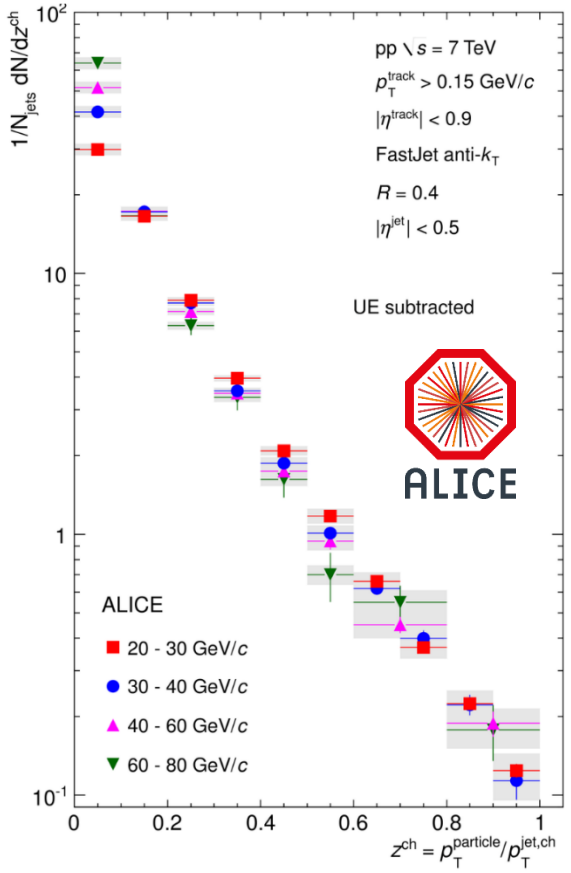

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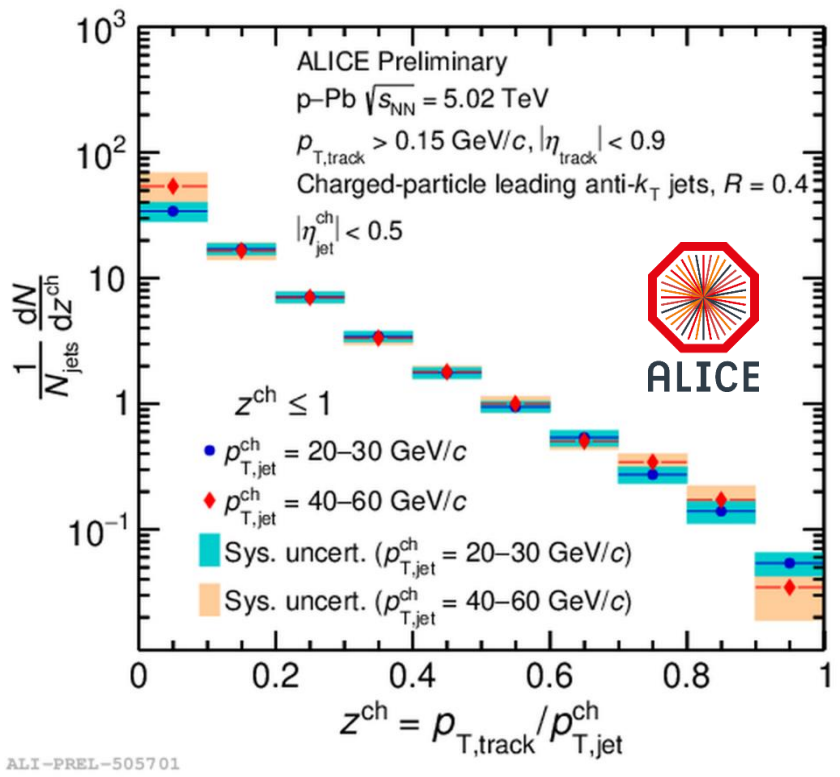

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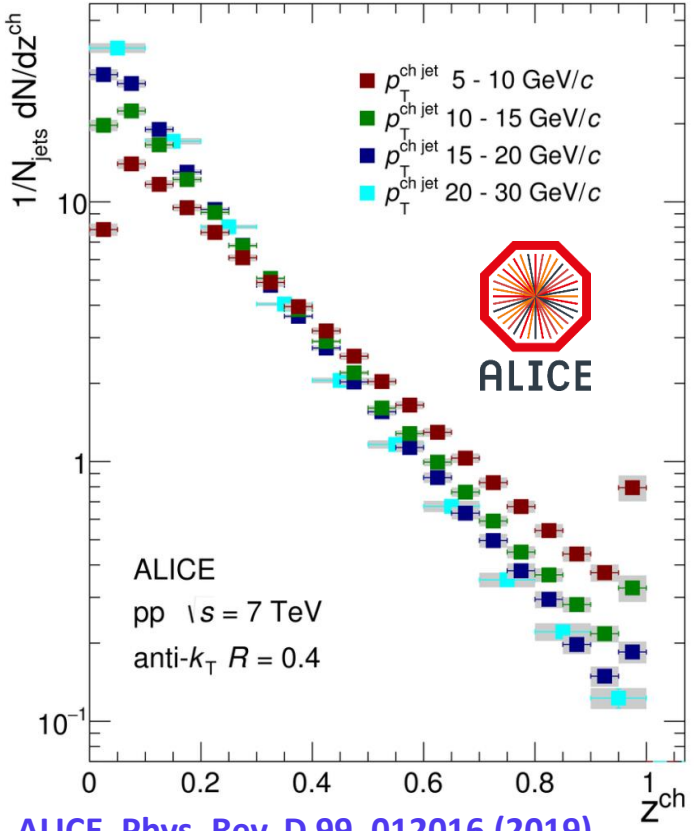

ALICE, Phys. Rev. D 99, 012016 (2019)

Scaling of jet fragmentation with jet p_T holds for p_T > 20 GeV/c (except at low z^{ch})

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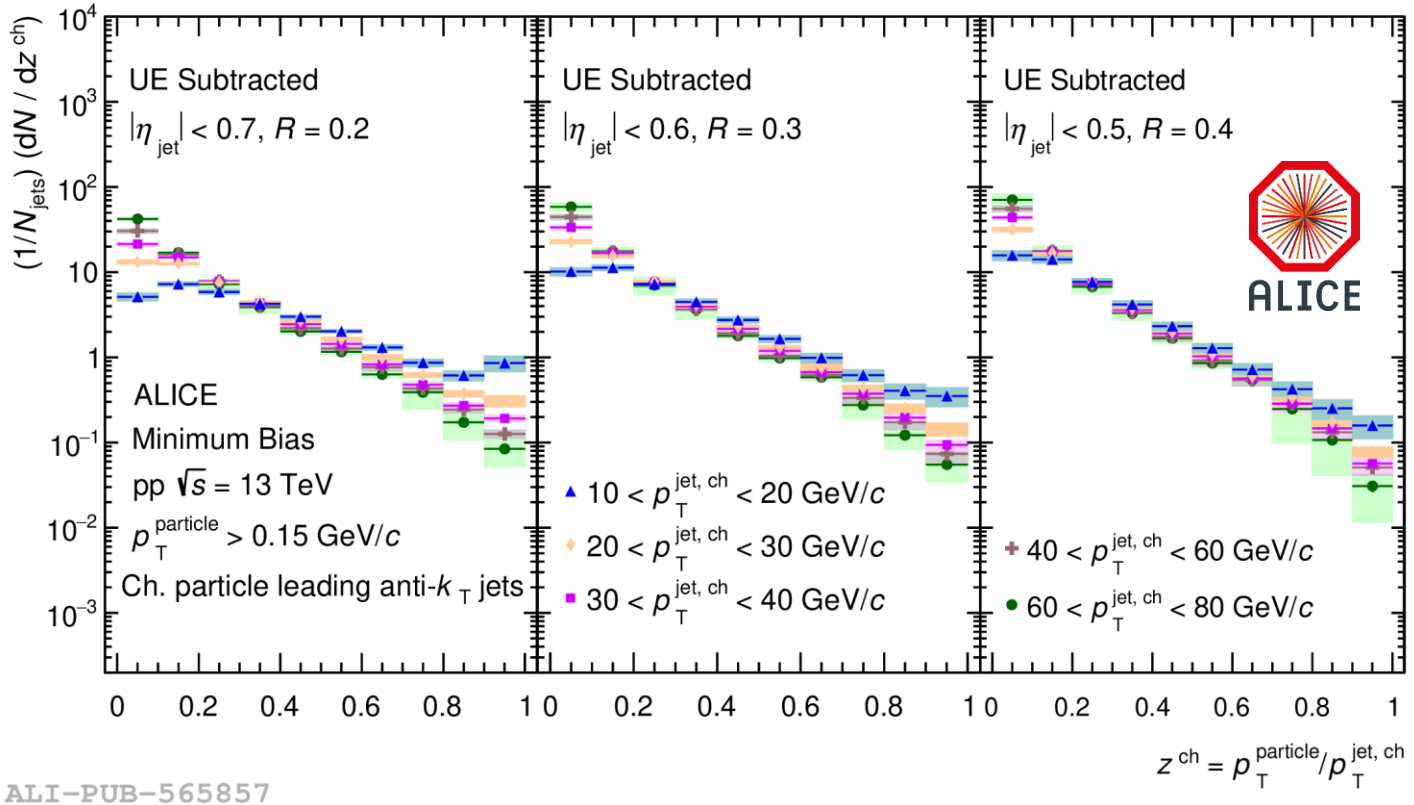
- Scaling breaks down for jet p_T < 20 GeV/c
- As jet p_T increases, onset of scaling behavior observed

Scaling behavior of jet fragmentation: z for leading charged jets

ALICE, arXiv: 2311.13322



ALI-PUB-565857

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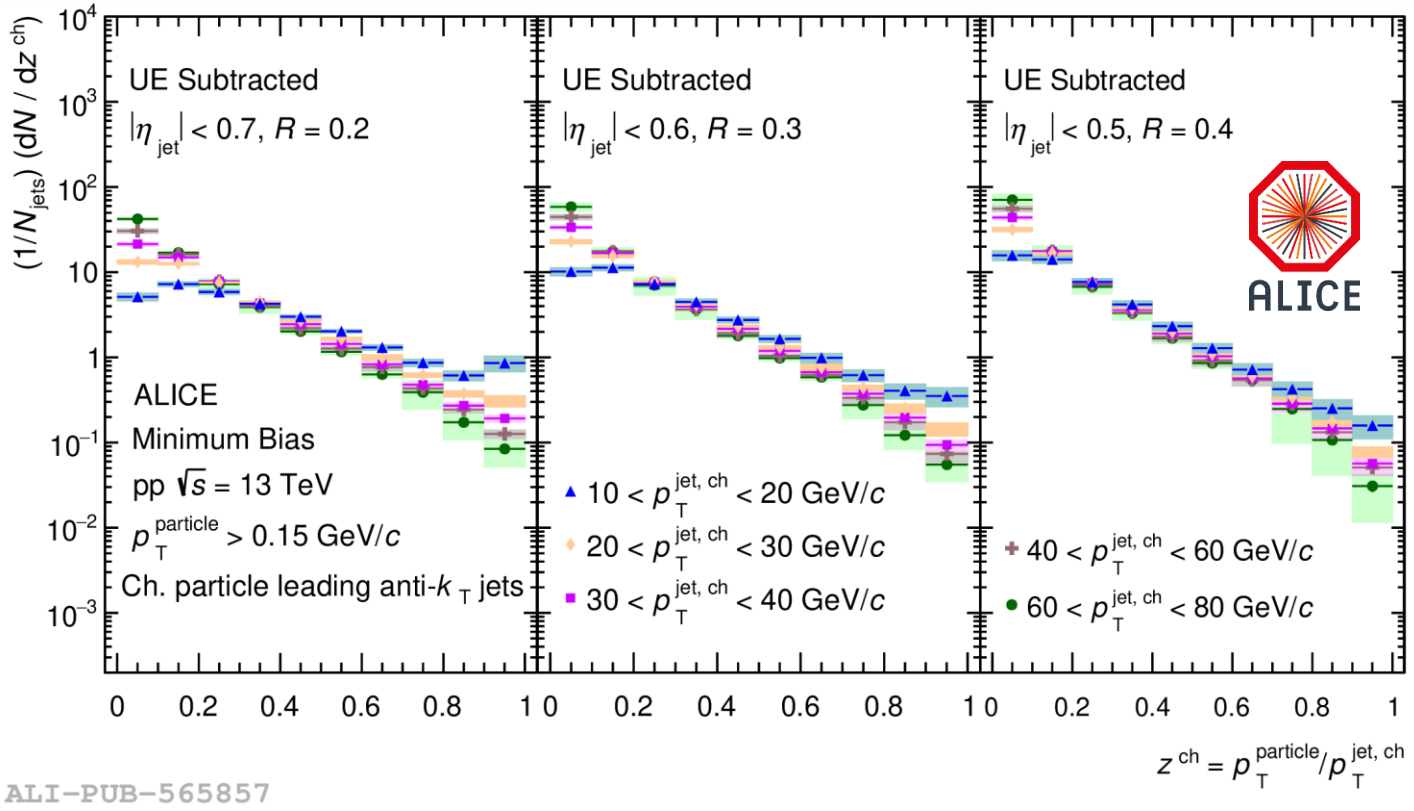

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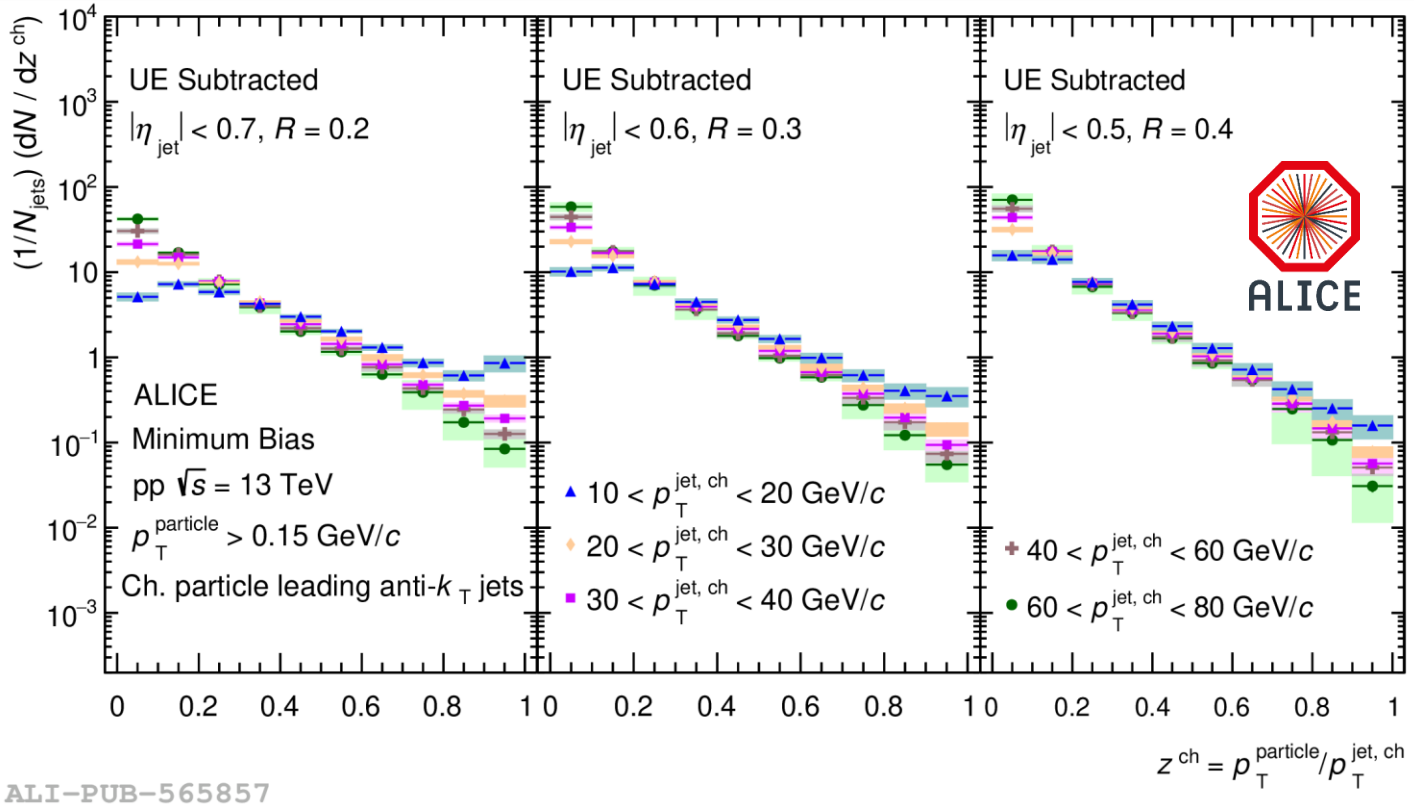

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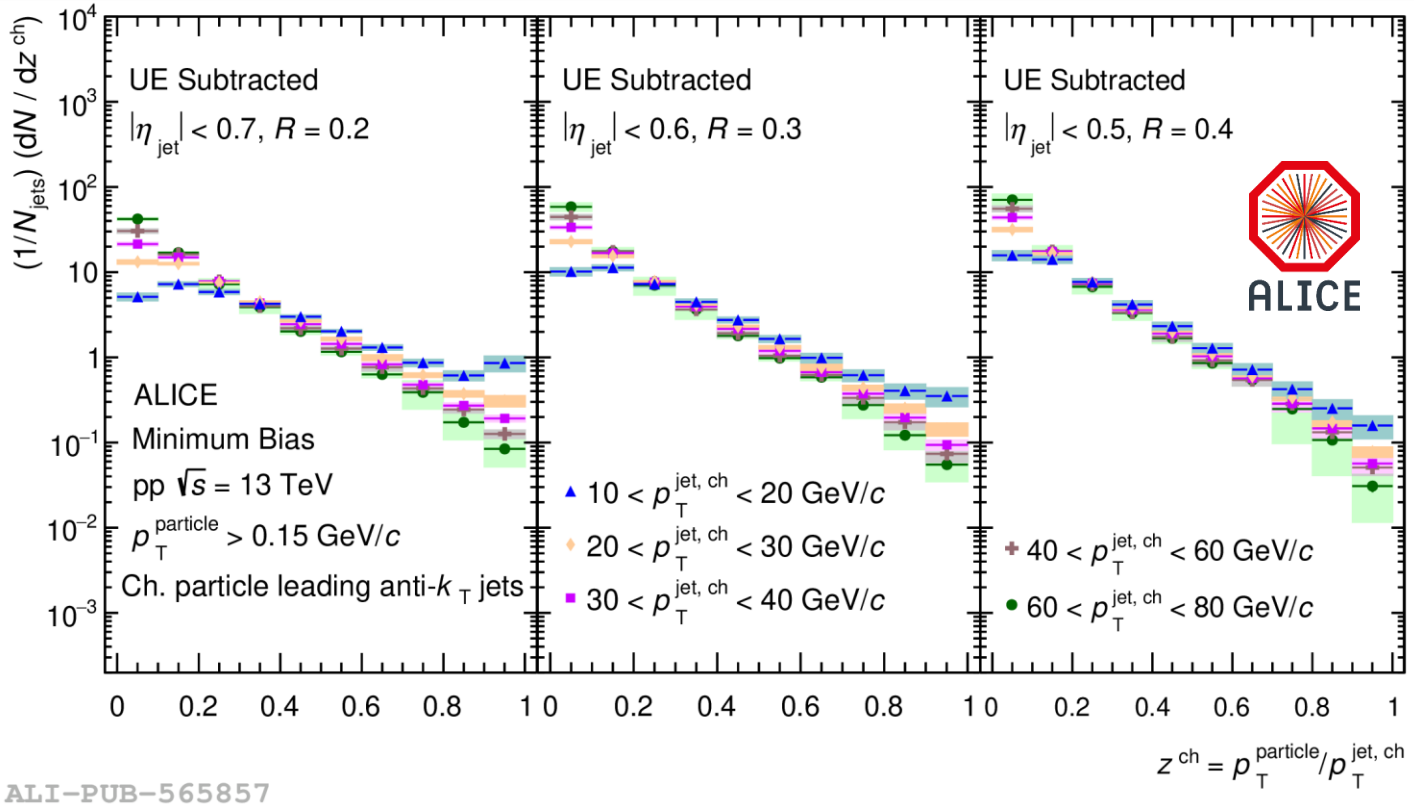

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Scaling behavior depends on jet radius and jet momentum

Jet fragmentation: ξ

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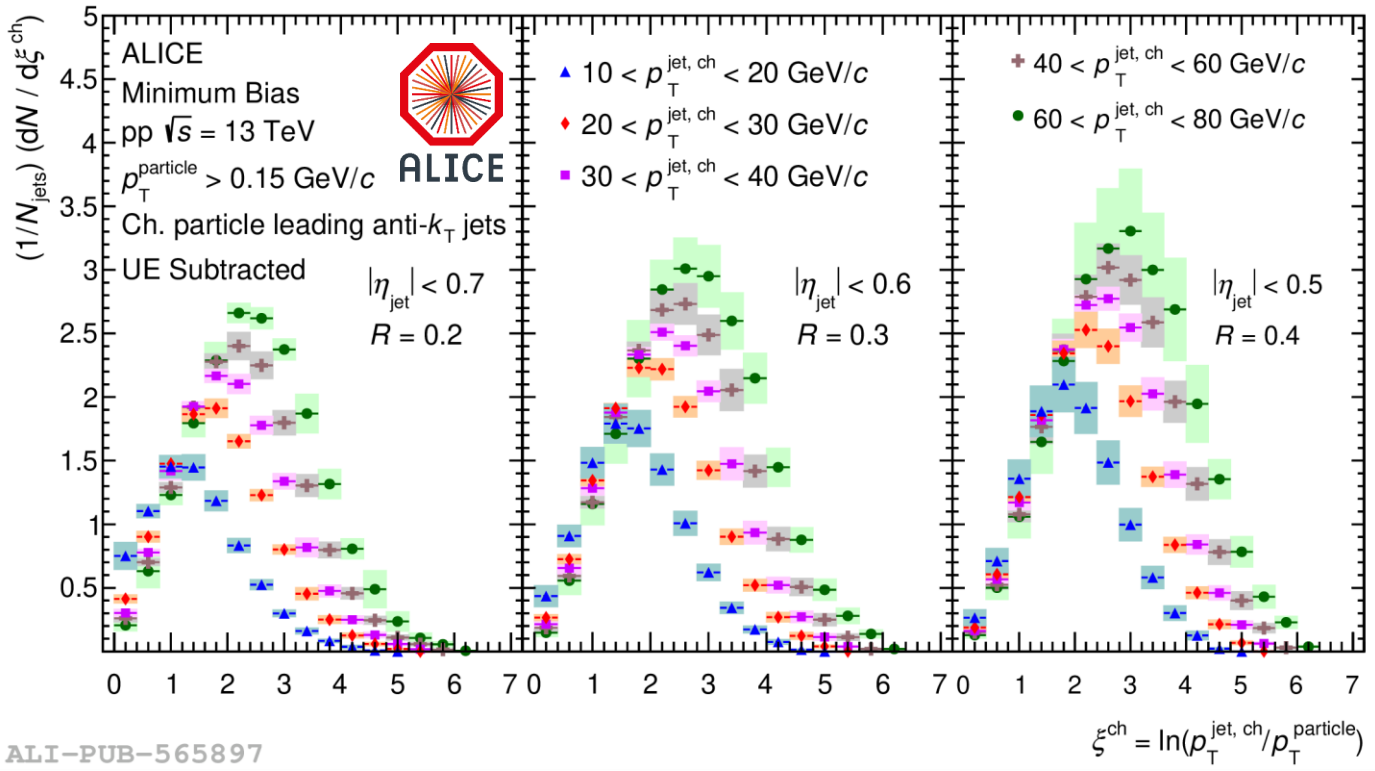

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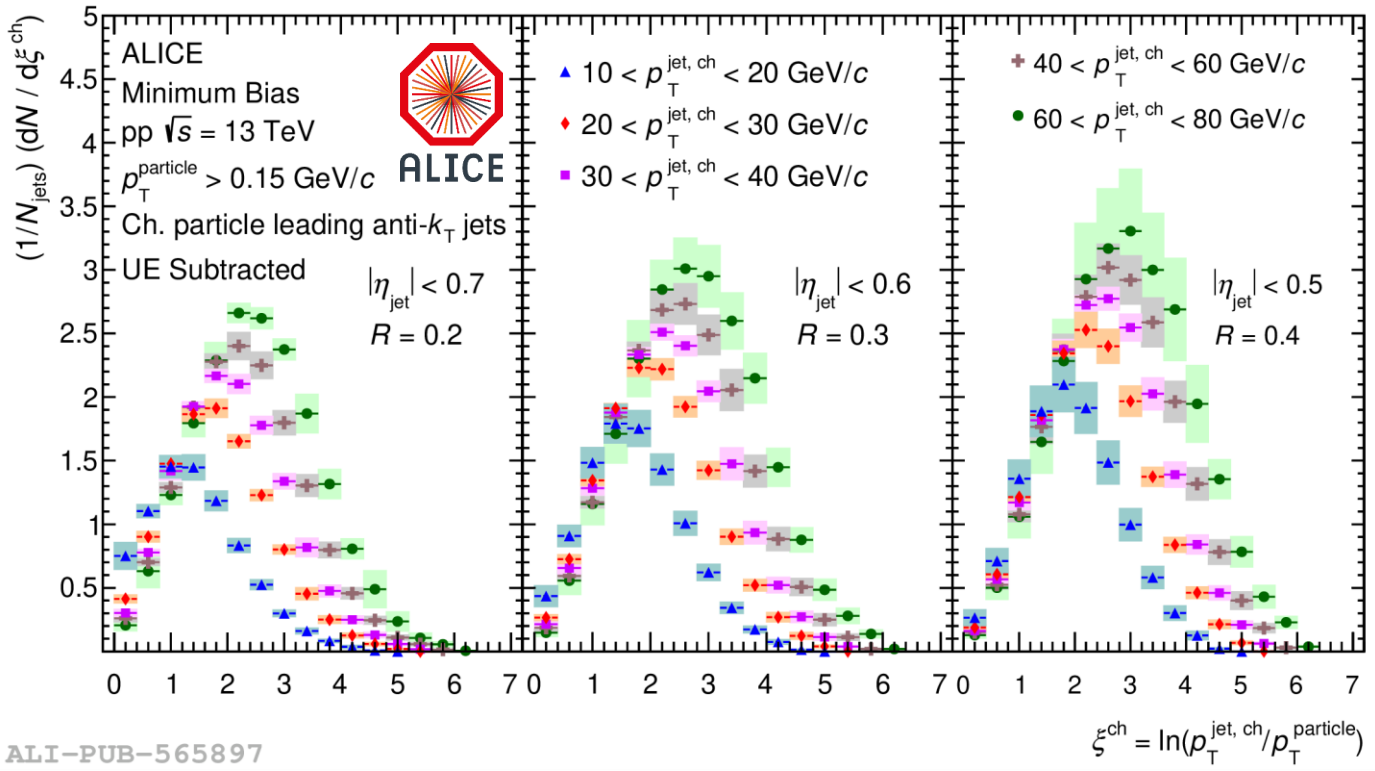

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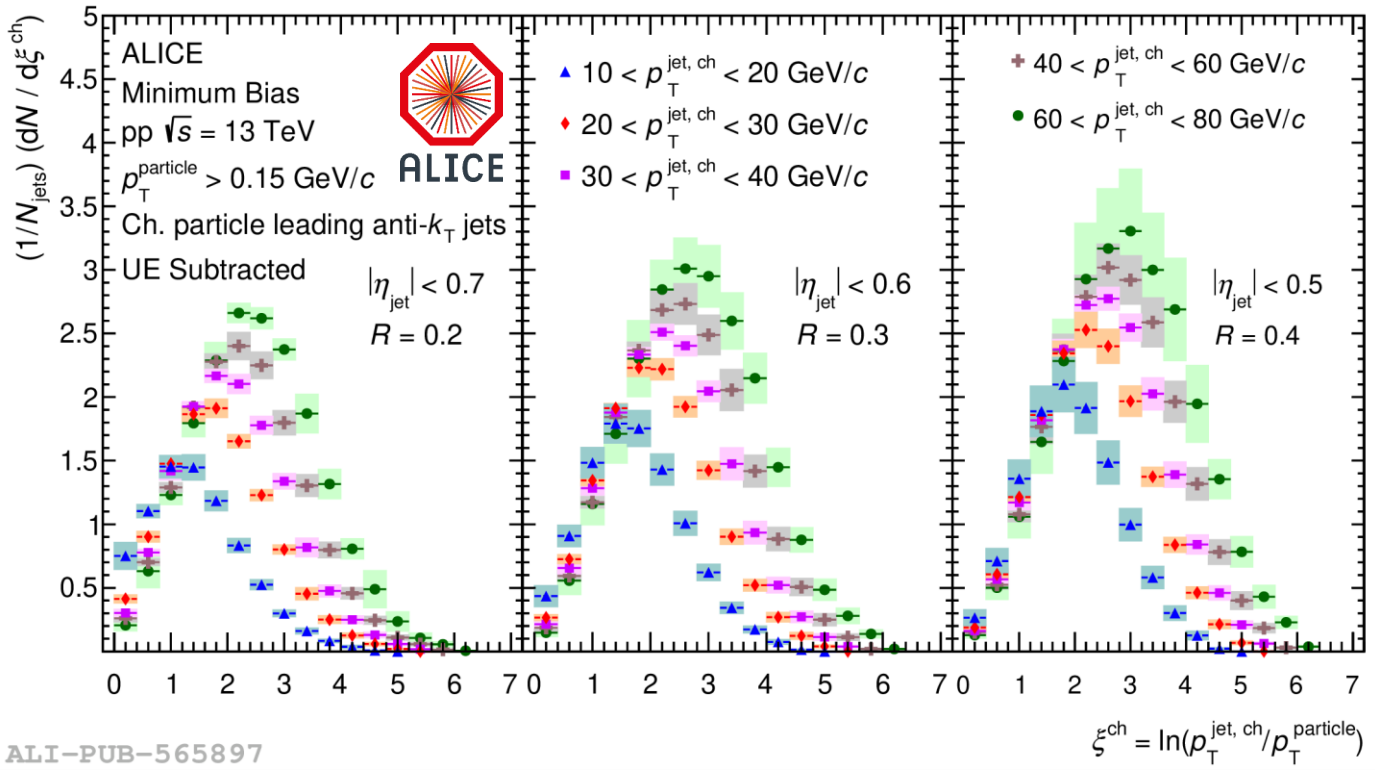

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Suppression of low momentum particle production due to QCD coherence

Fragmentation of Λ_c^+- and D^0-tagged jets

Enhancement of Λ_c^+/D^0 yield ratio observed in pp collisions compared to e^+e^- collisions [1,2]

More on charm fragmentation
from V. Feuillard, June 5, 2:18 PM

[1] ALICE, Phys. Rev. Lett. 128 (2022) 012001 [2] ALICE, JHEP 12 (2023) 086

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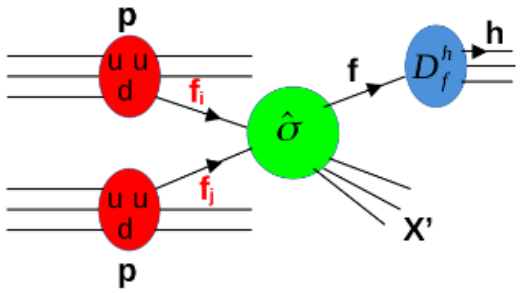

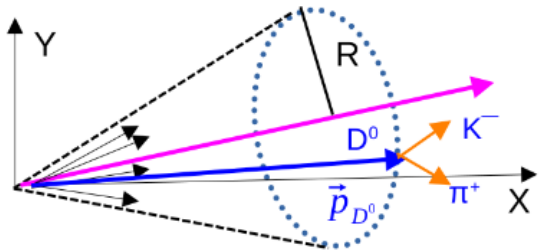

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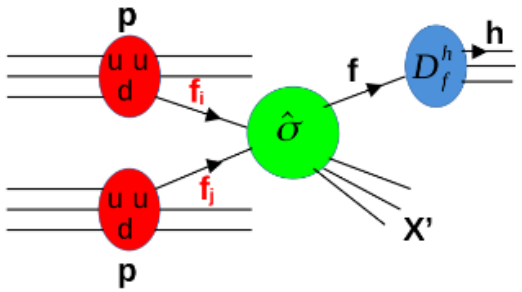

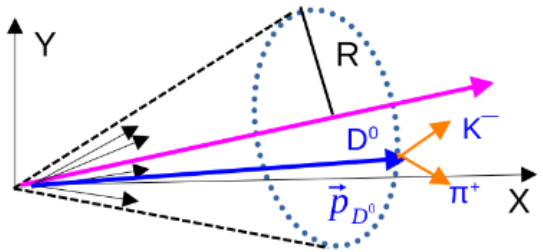

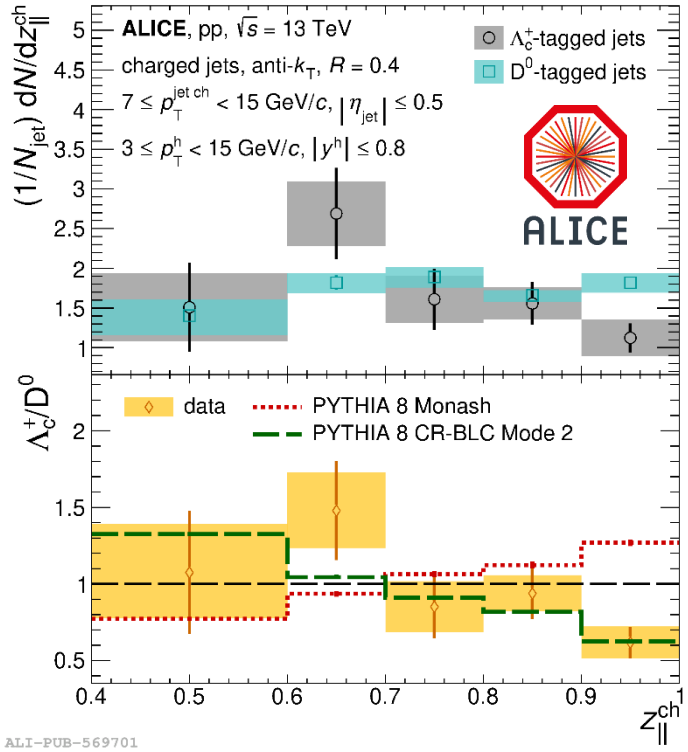

ALICE, Phys. Rev. D 109 (2024) 072005

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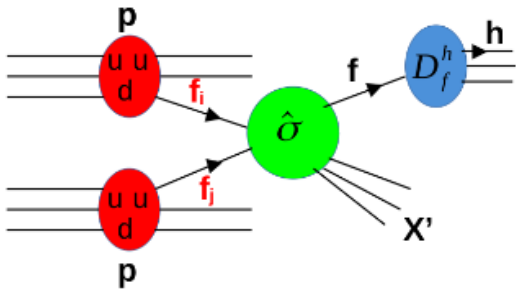

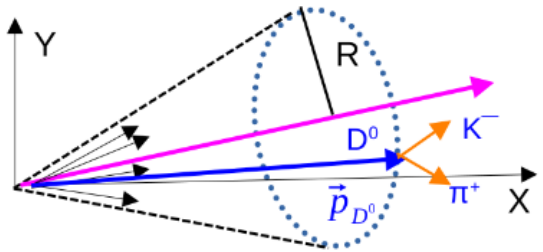

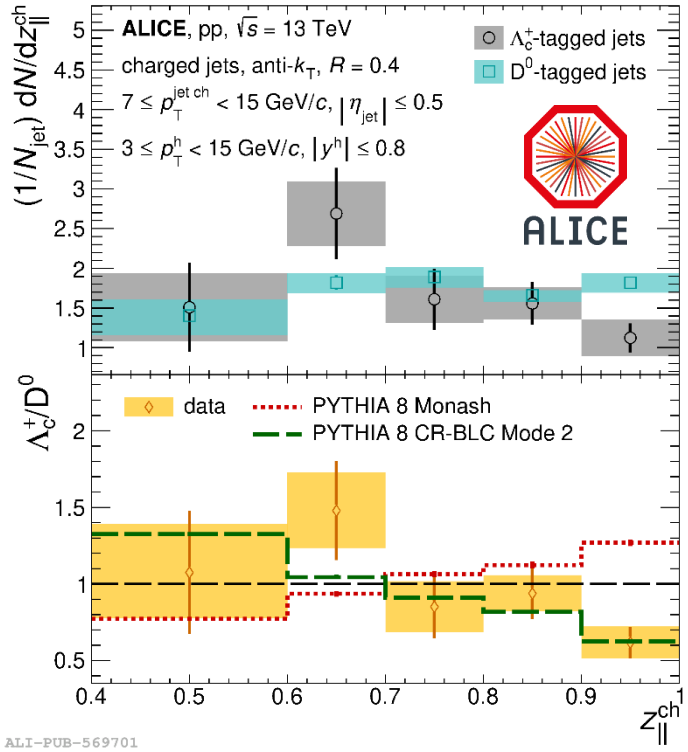

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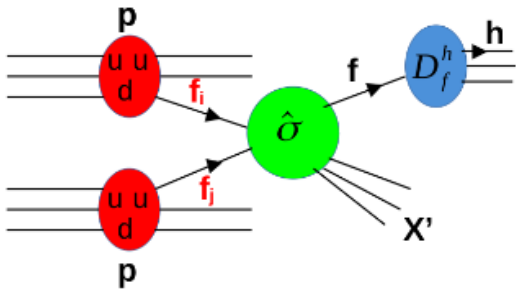

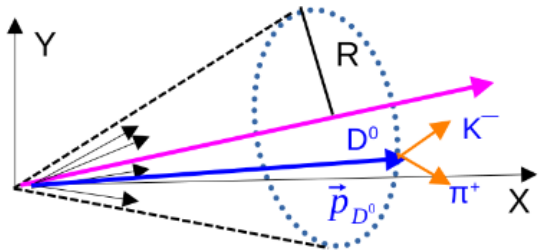

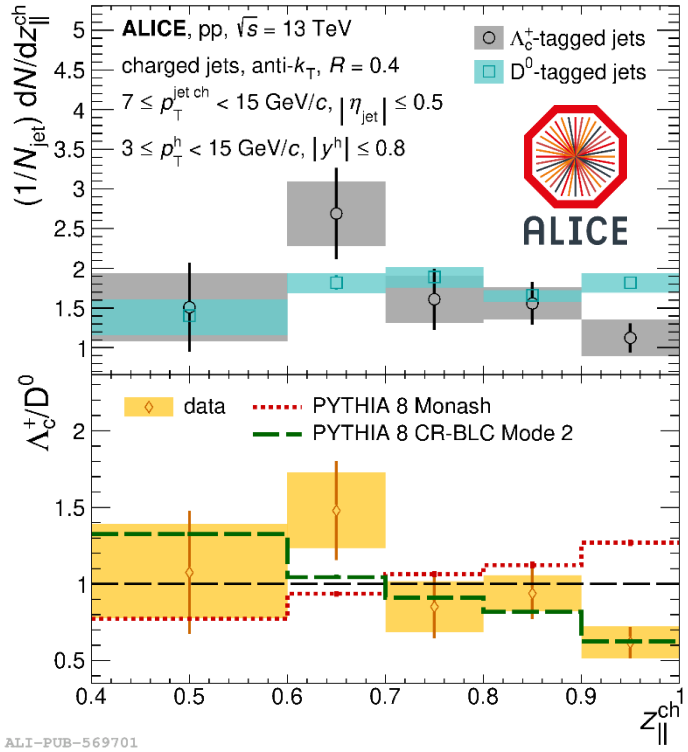

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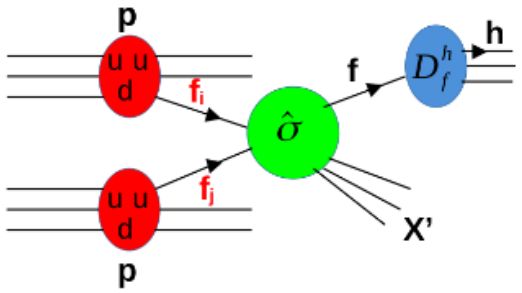

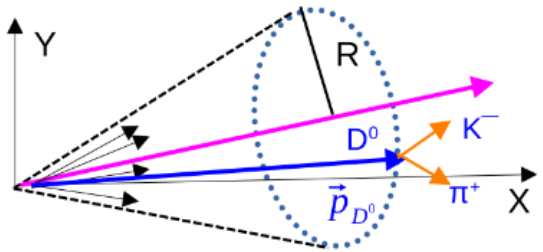

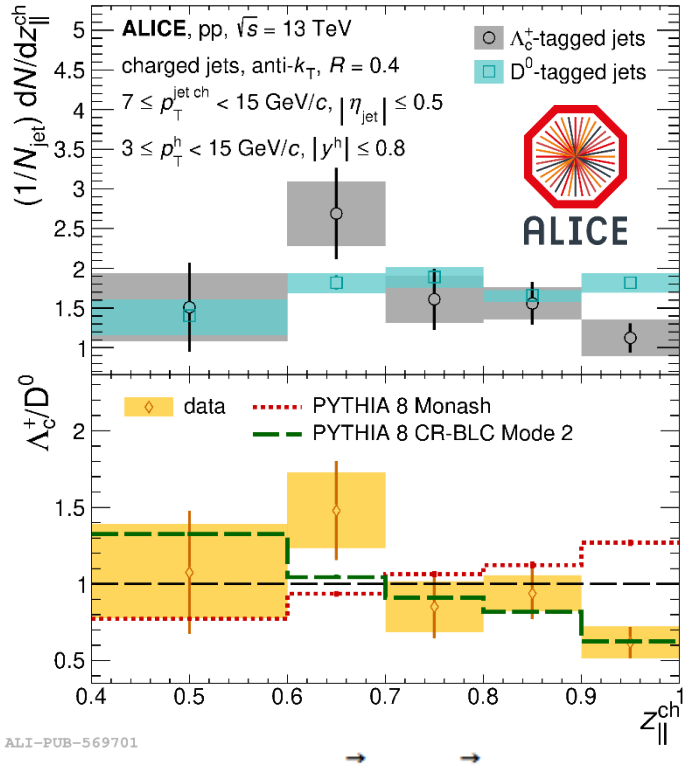

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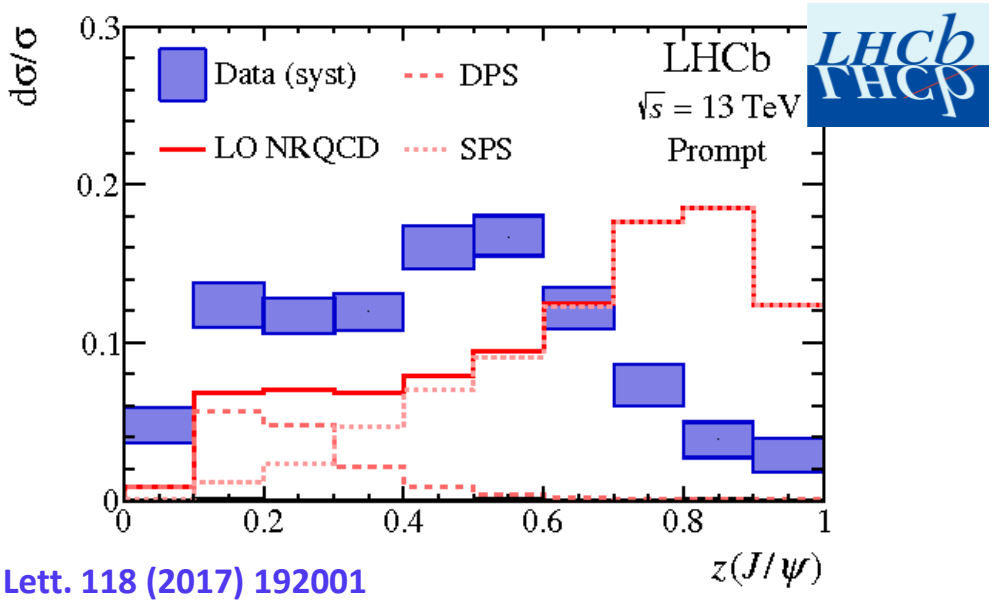

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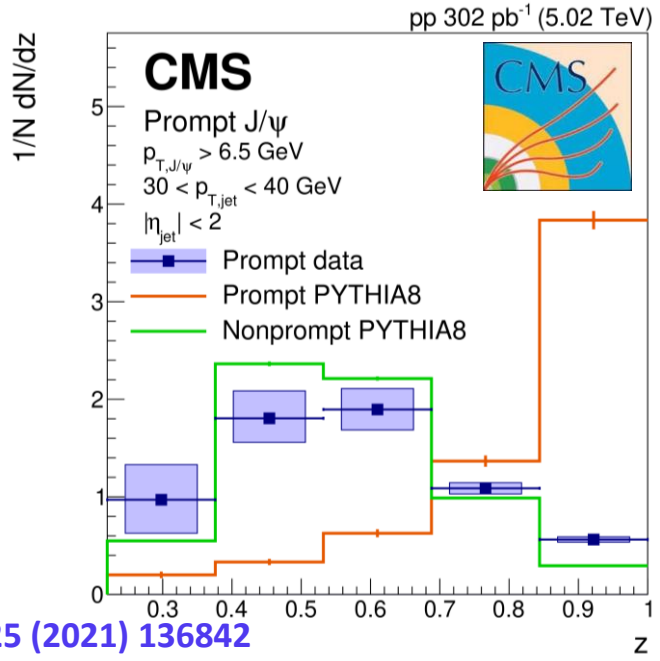

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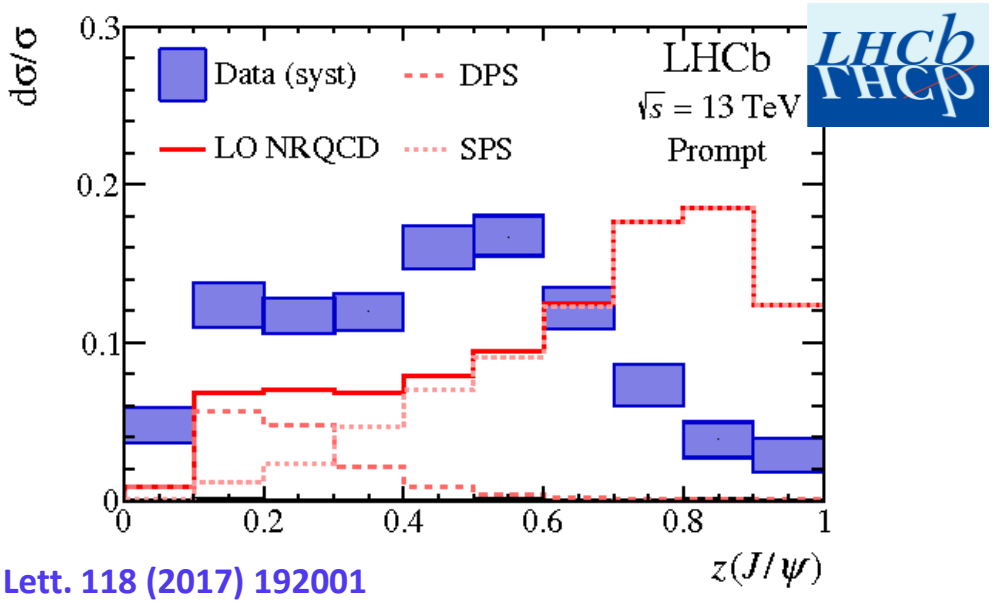

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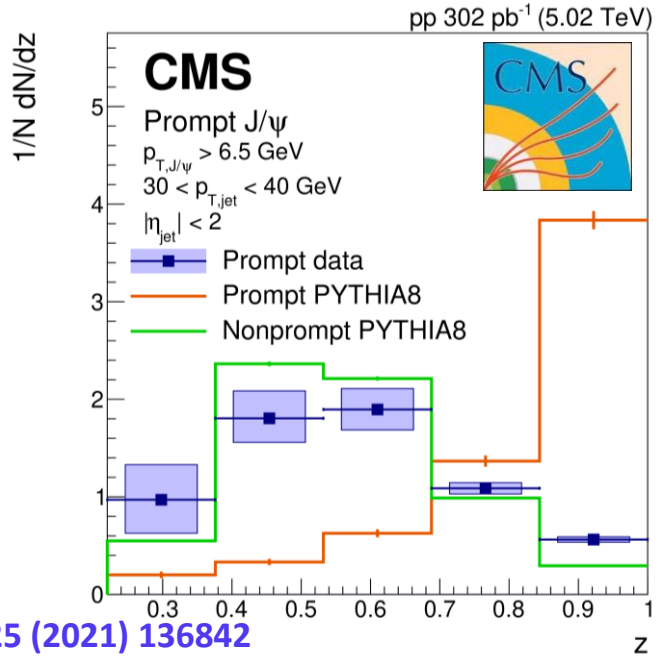

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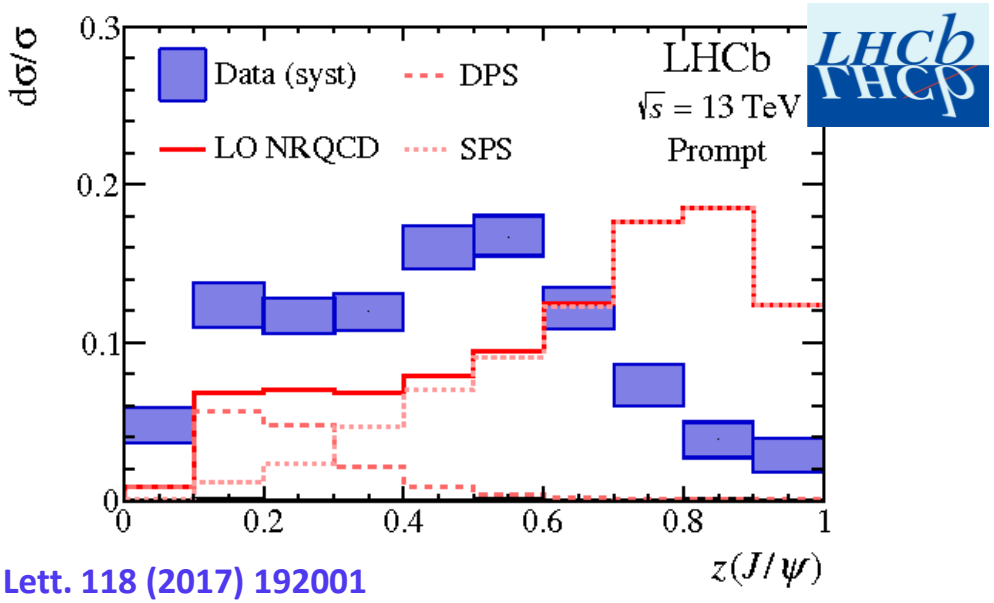

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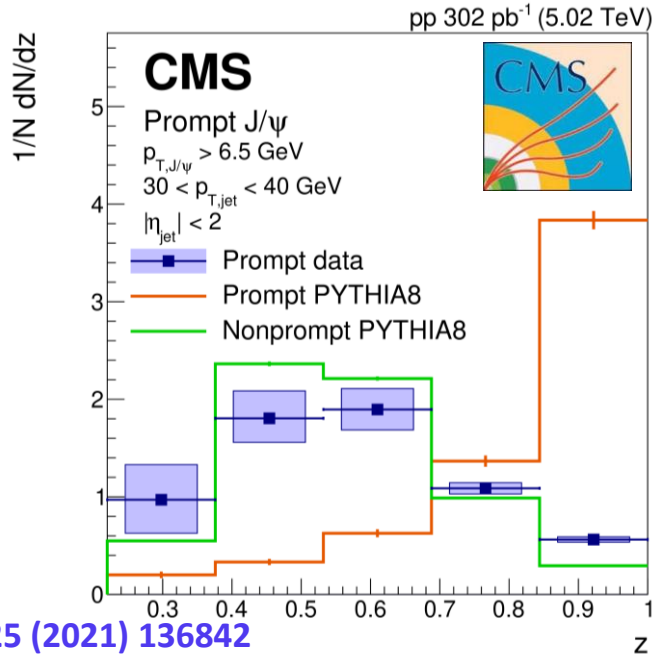

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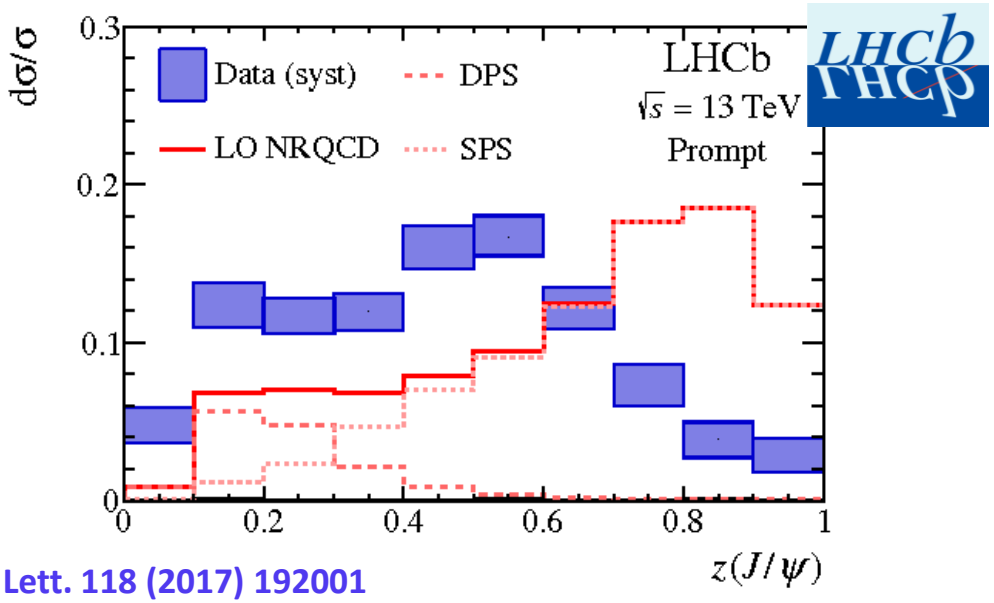

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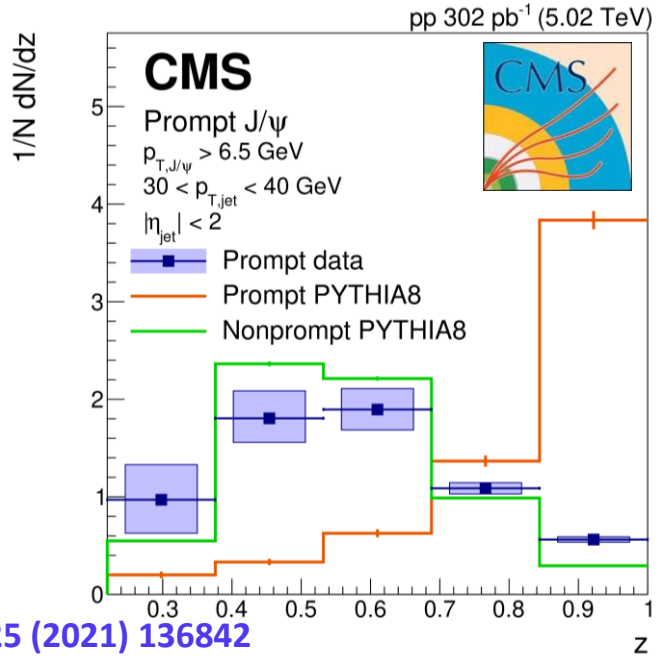

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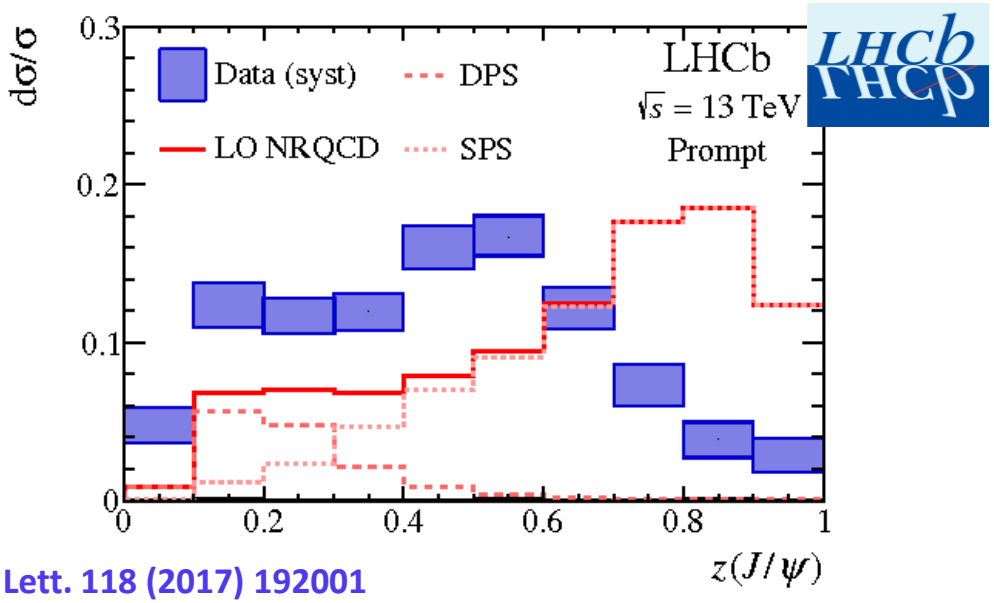

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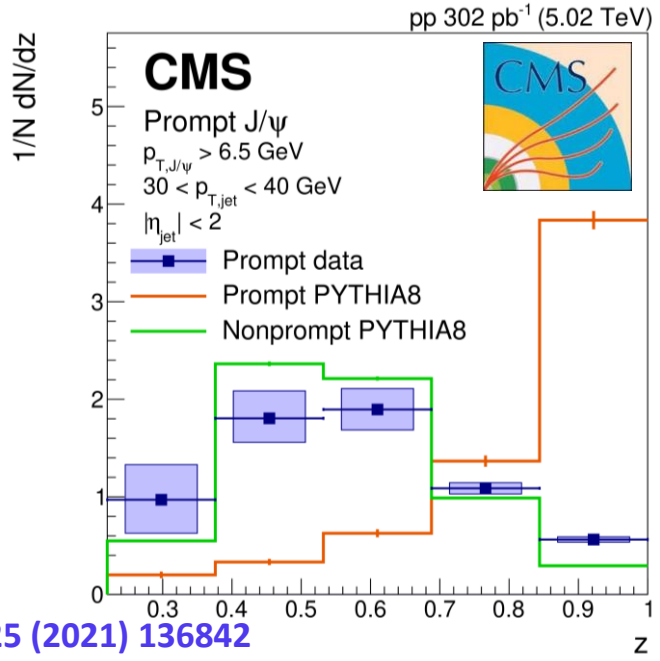

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Related to quarkonium polarization puzzle??

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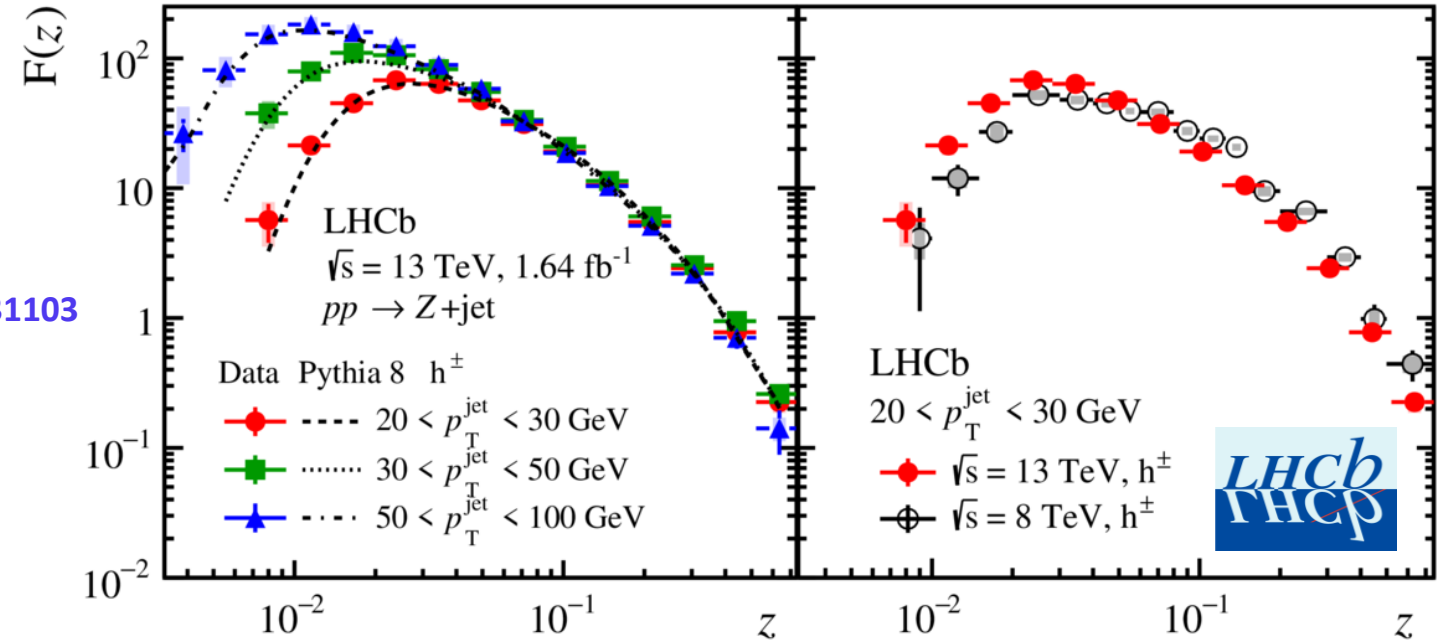

More on jet fragmentation of *Z*-tagged jets from T. Martin, June 7, 2:00 PM

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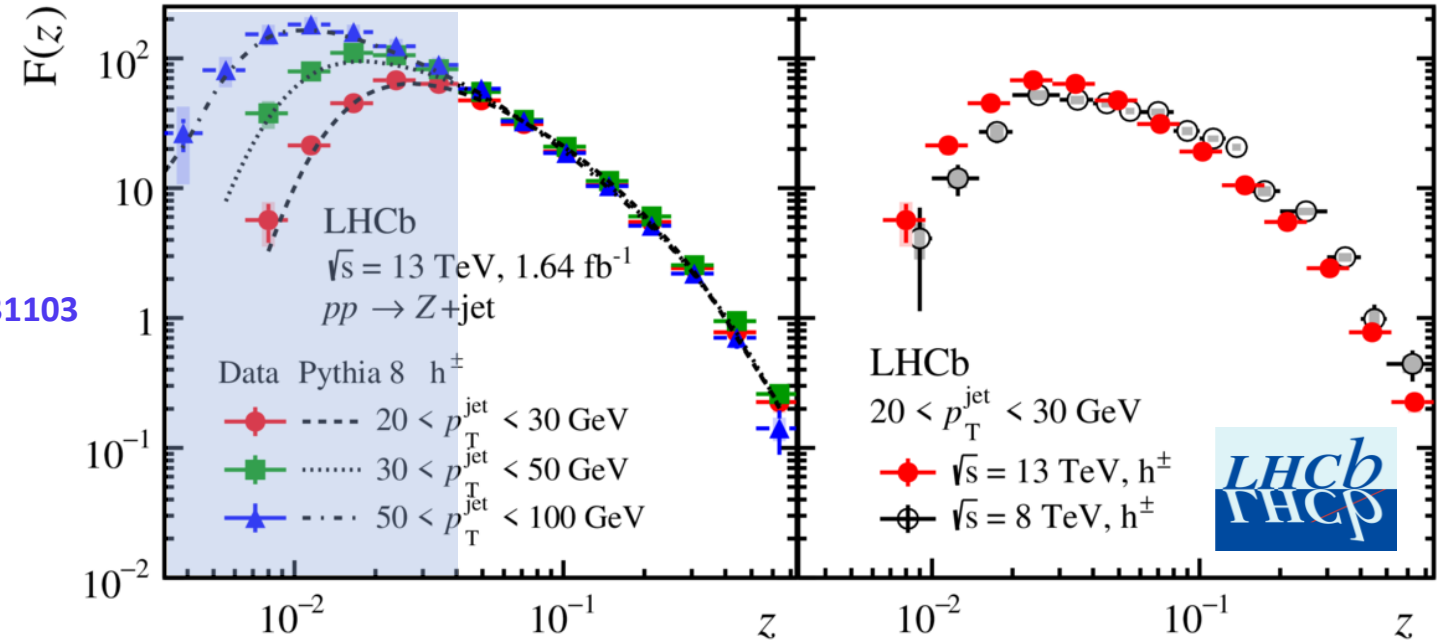

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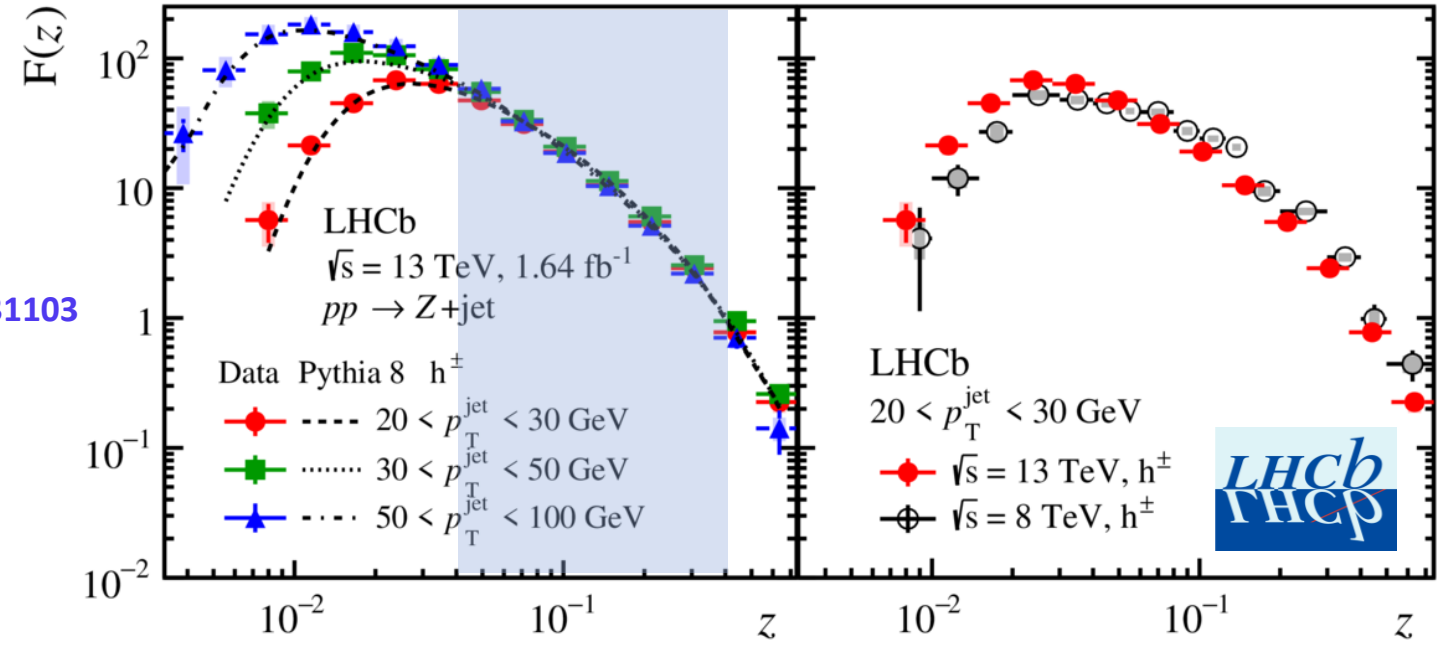

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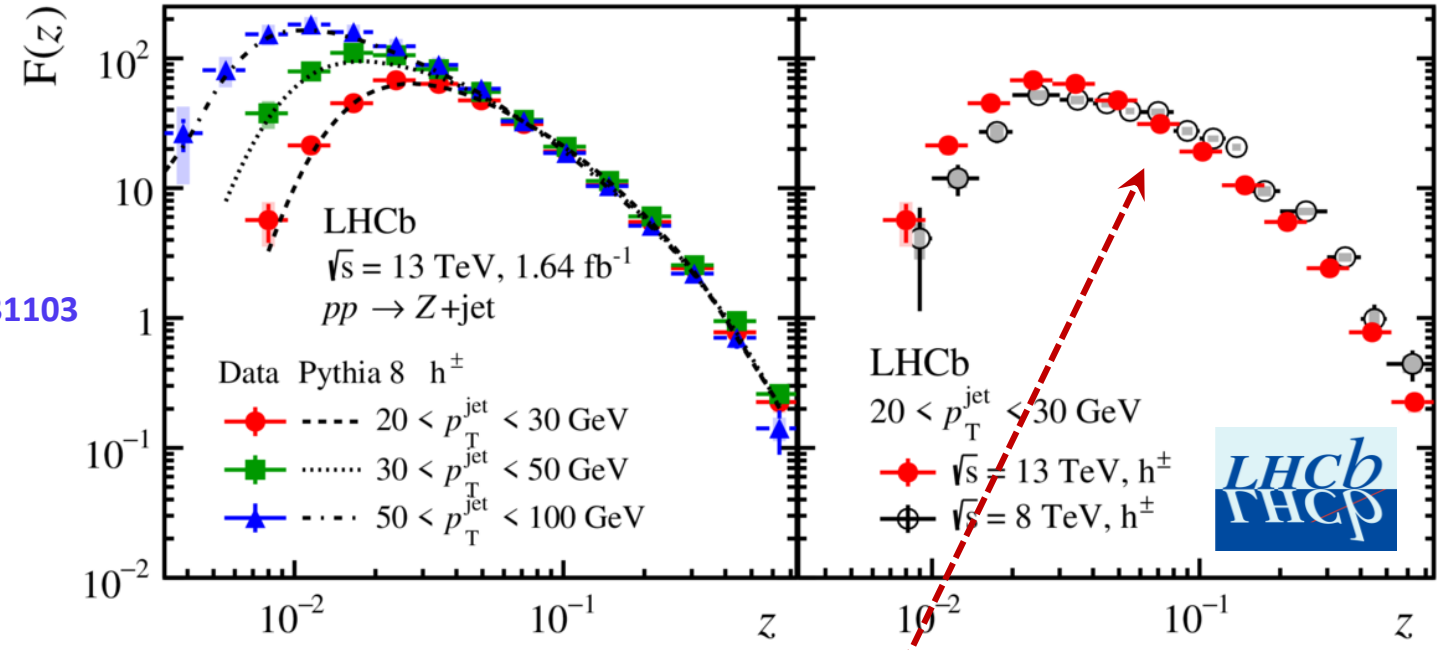

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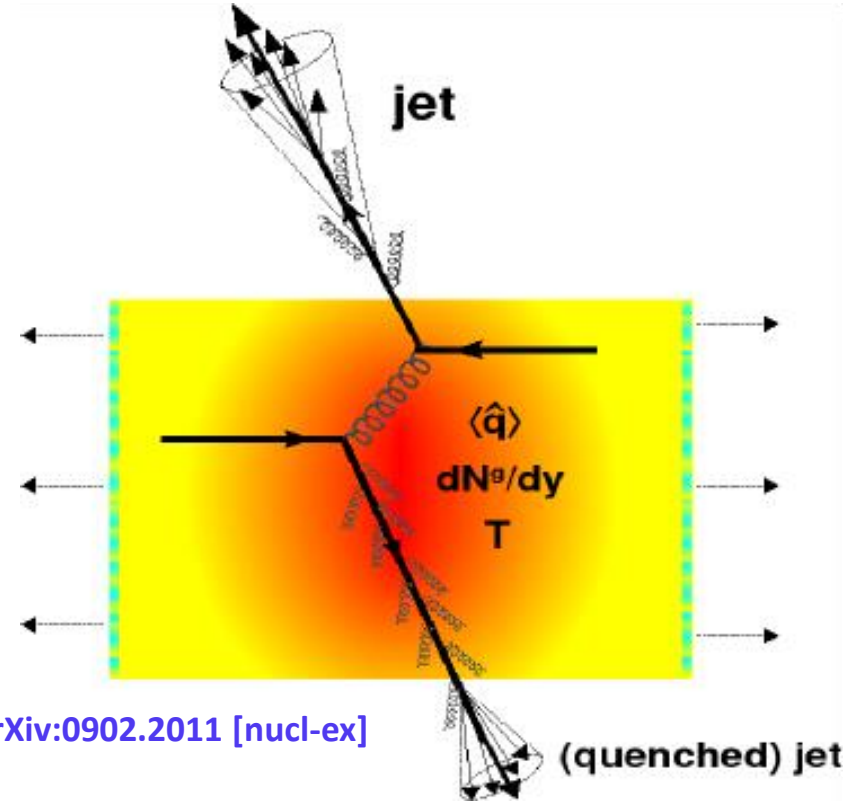
Jet fragmentation in heavy-ion collisions



arXiv:0902.2011 [nucl-ex]

More on jet quenching in presence of QGP
from
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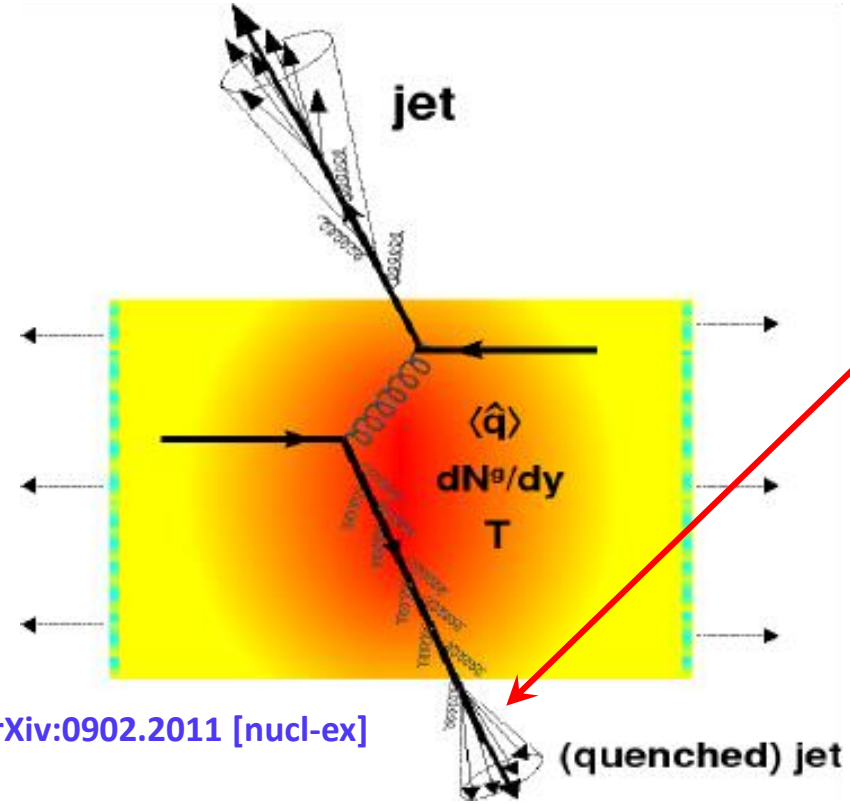

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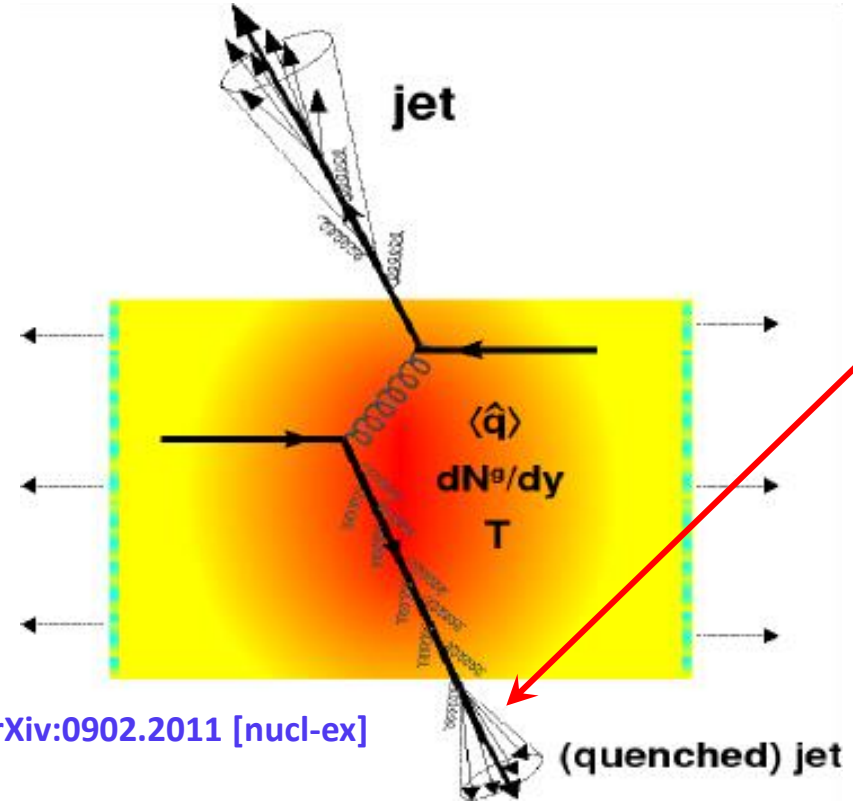

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Ratio of jet fragmentation distributions [*D(z)*] between heavy-ion and pp collisions gives the magnitude of modification

$$R_{D(z)} = \frac{D(z)_{AA-cent}}{D(z)_{pp}}$$

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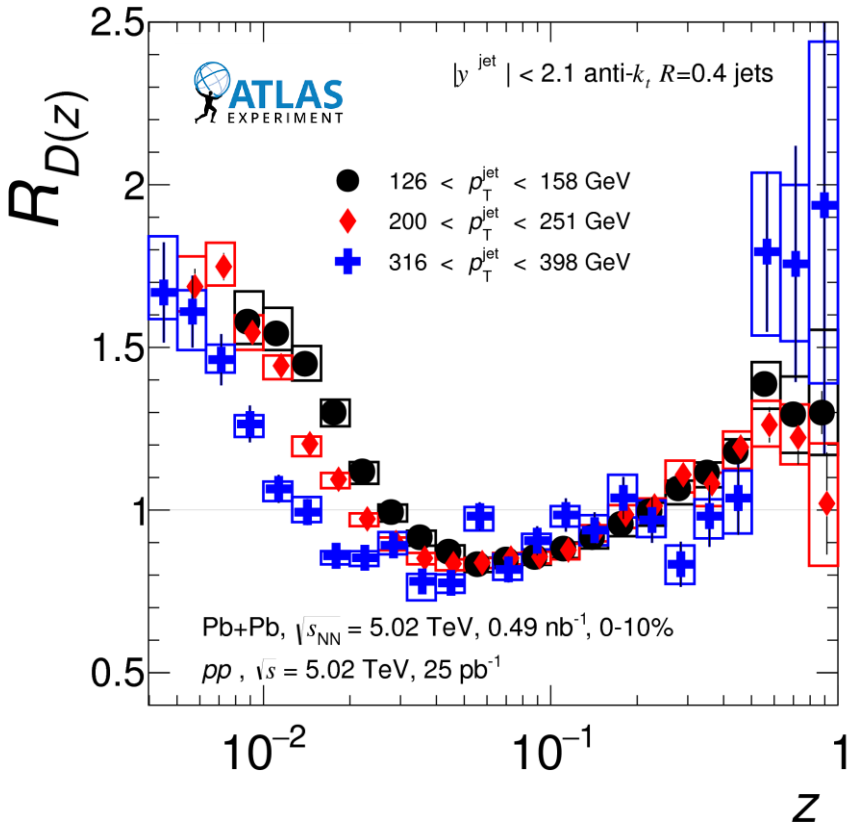

ATLAS, Phys. Rev. C 98, 024908 (2018)

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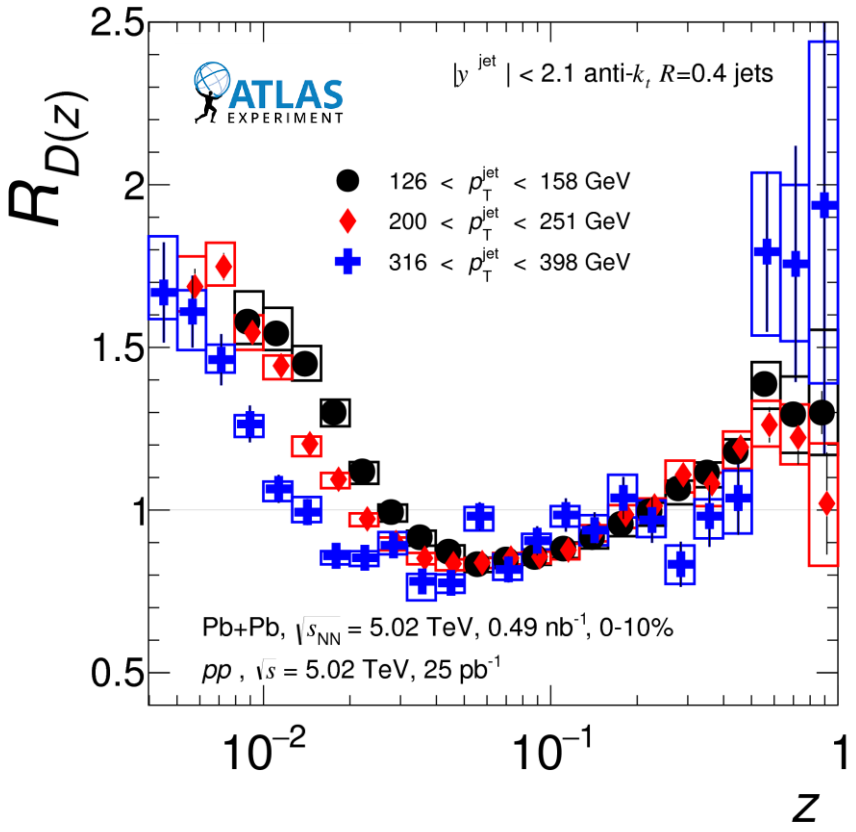

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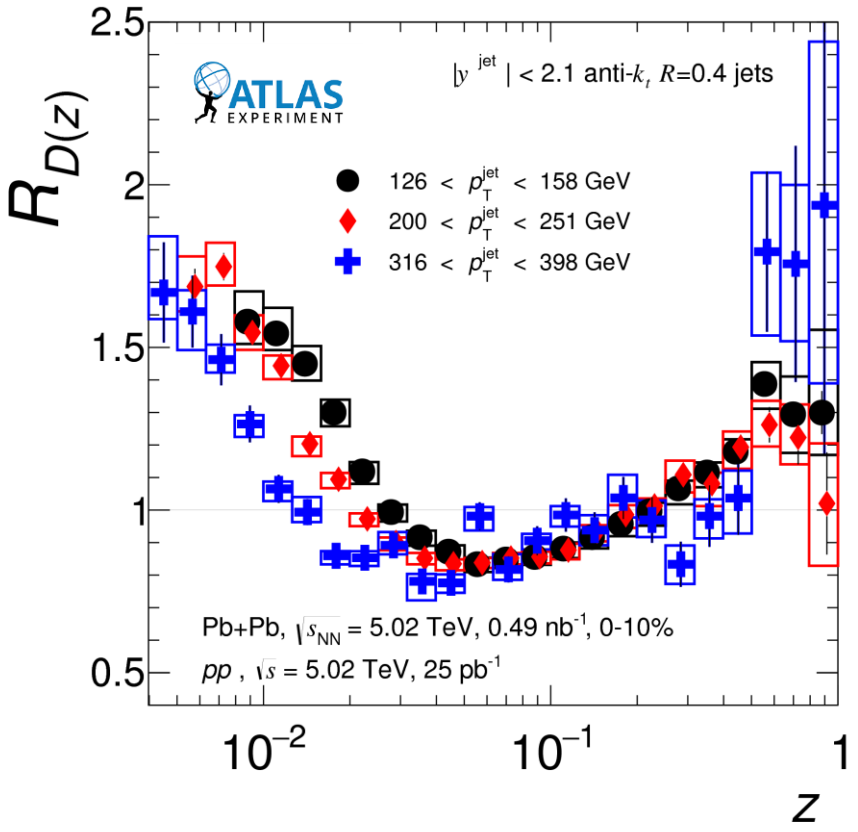

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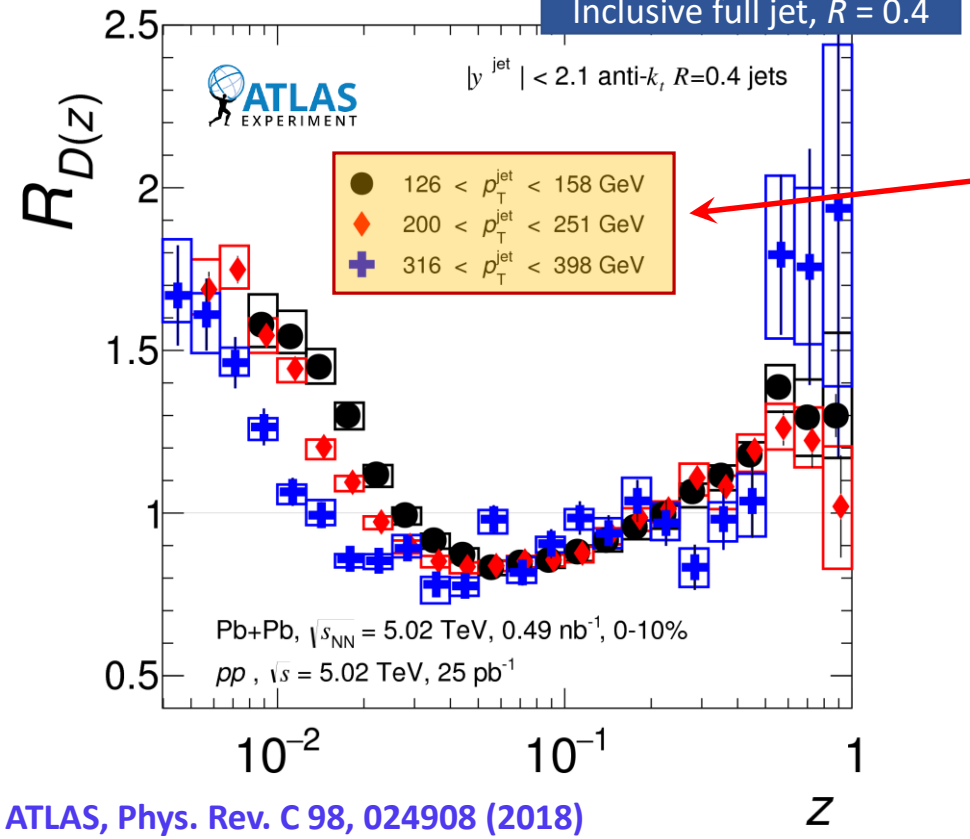
- Modification of z distribution in heavy-ion collisions compared to pp collisions
- Enhancement of low- and high-z particles, suppression at intermediate z
- Transition from enhancement to suppression for soft fragments occurs at lower z for larger jet p_T

Modification of jet fragmentation: heavy-ion vs small collision systems

Inclusive full jet, $R = 0.4$



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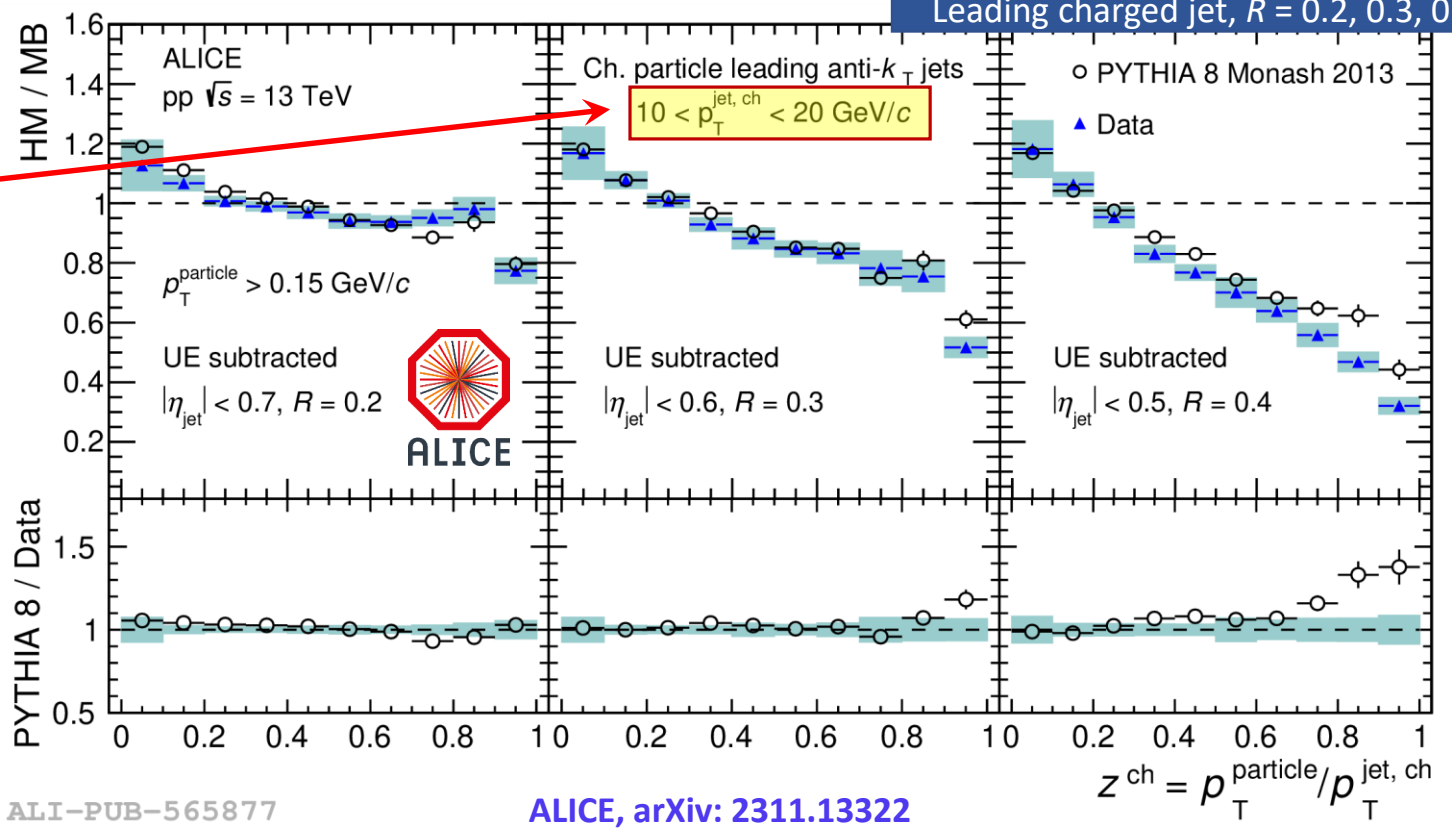
Leading charged jet, $R = 0.2, 0.3, 0.4$



ALI-PUB-565877

ALICE, arXiv: 2311.13322

System	Jet p_T	Low z	Intermediate z	High z
Central Pb-Pb	> **126** GeV/c	Enhancement	Supression	Enhancement
HM pp	**10-20** GeV/c	Enhancement	Supression	Suppression

More on jet quenching in small collision systems from F. Krizek, June 5, 11:36 AM

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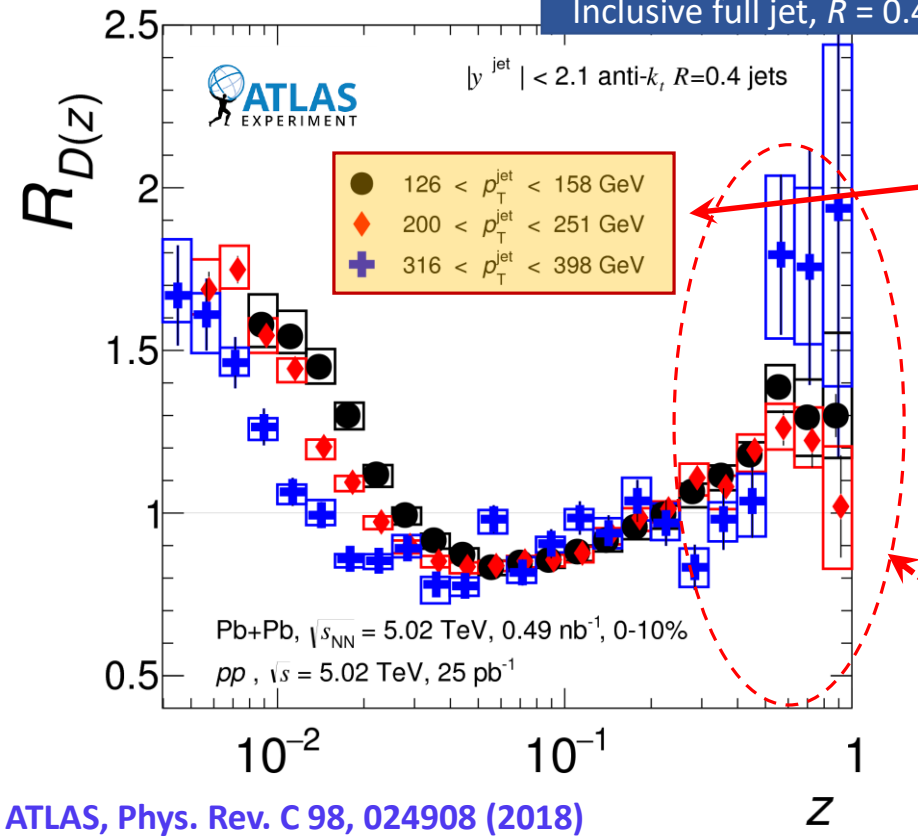

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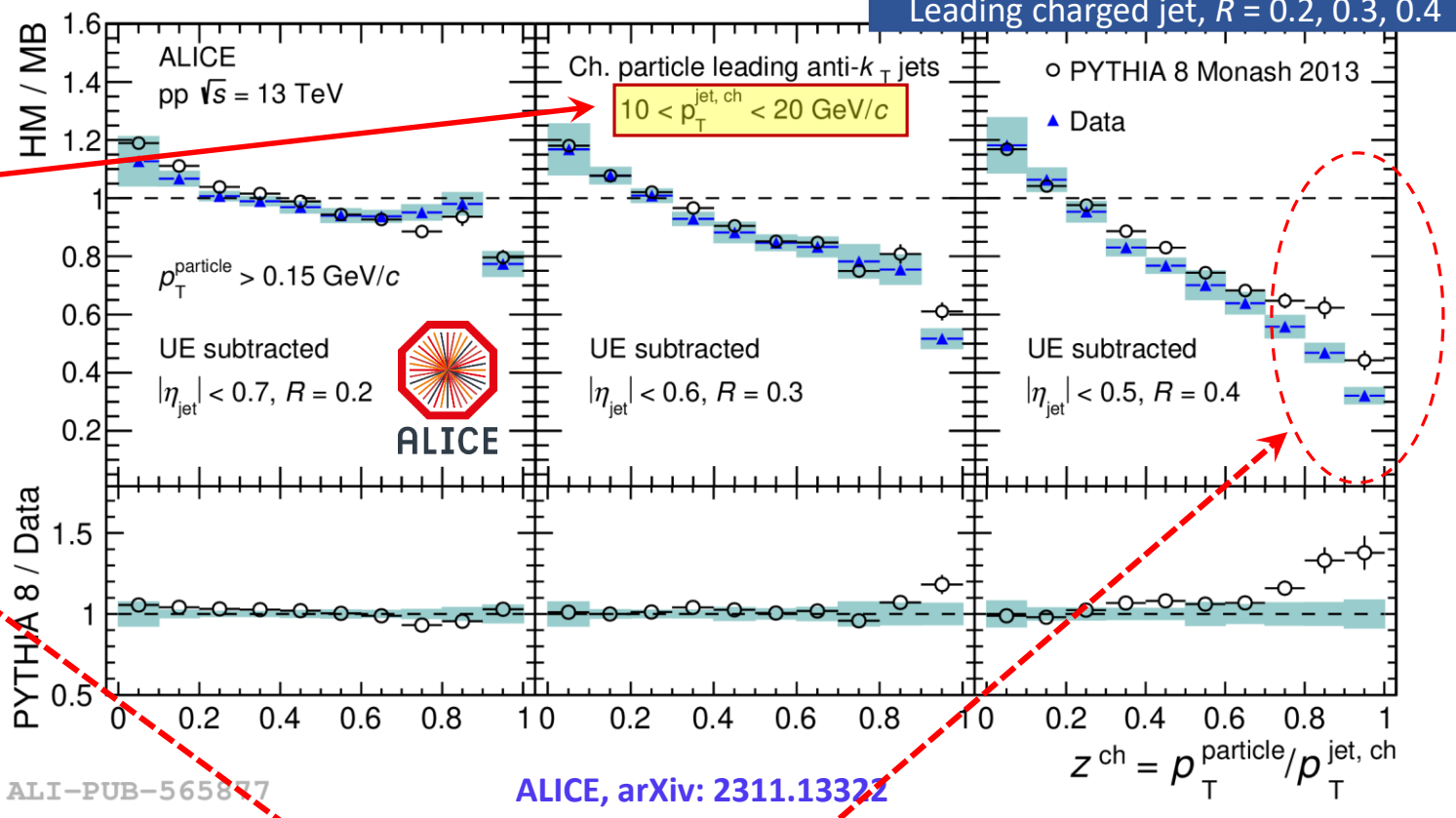

ALI-PUB-565857

ALICE, arXiv: 2311.13322

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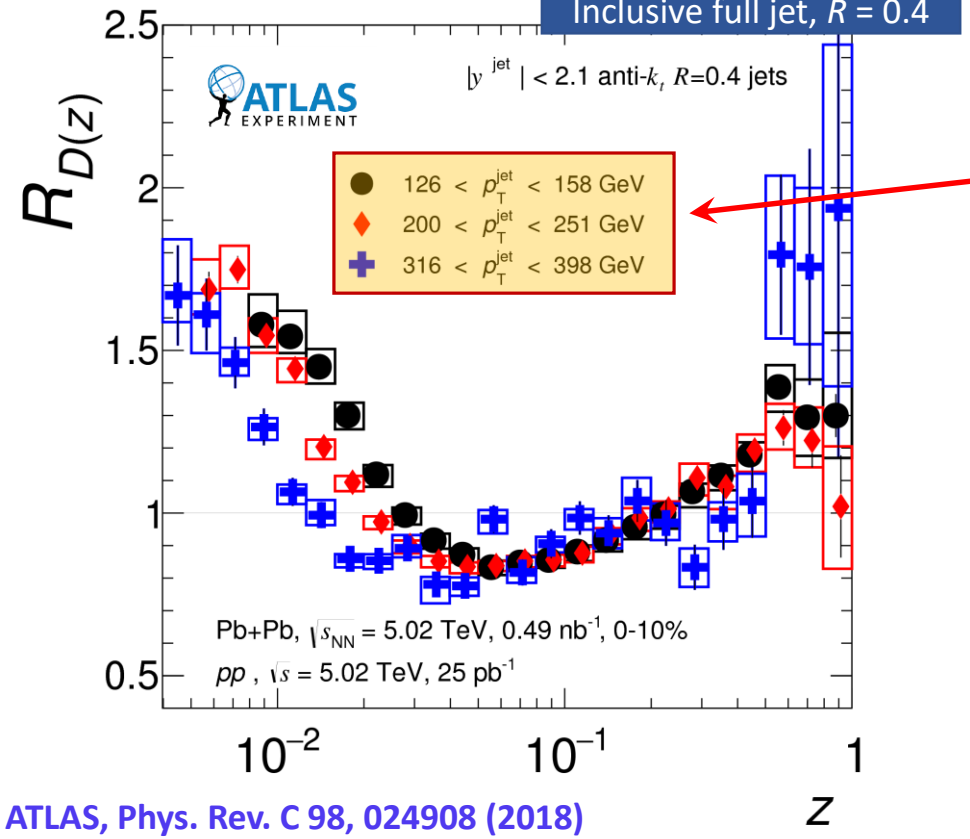

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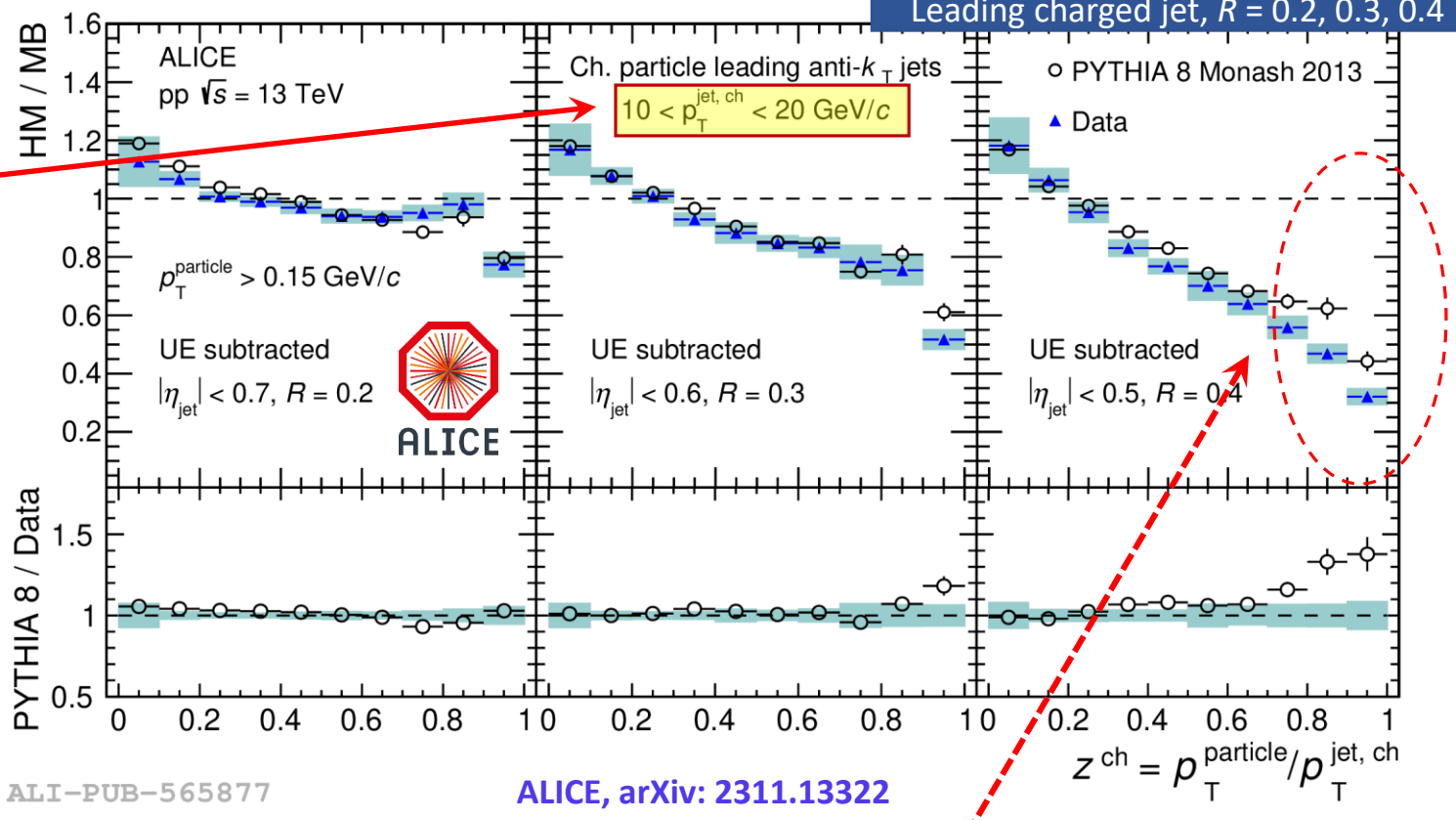

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PYTHIA 8 shows similar trend as data in HM pp collisions → **questions the possibility of jet quenching**

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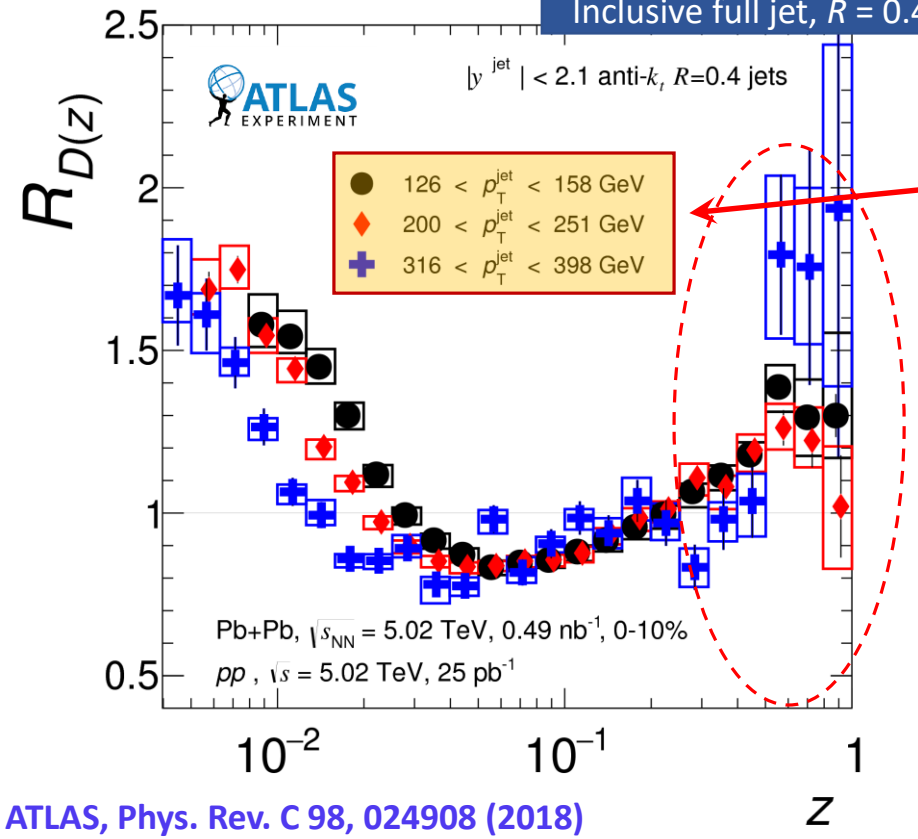

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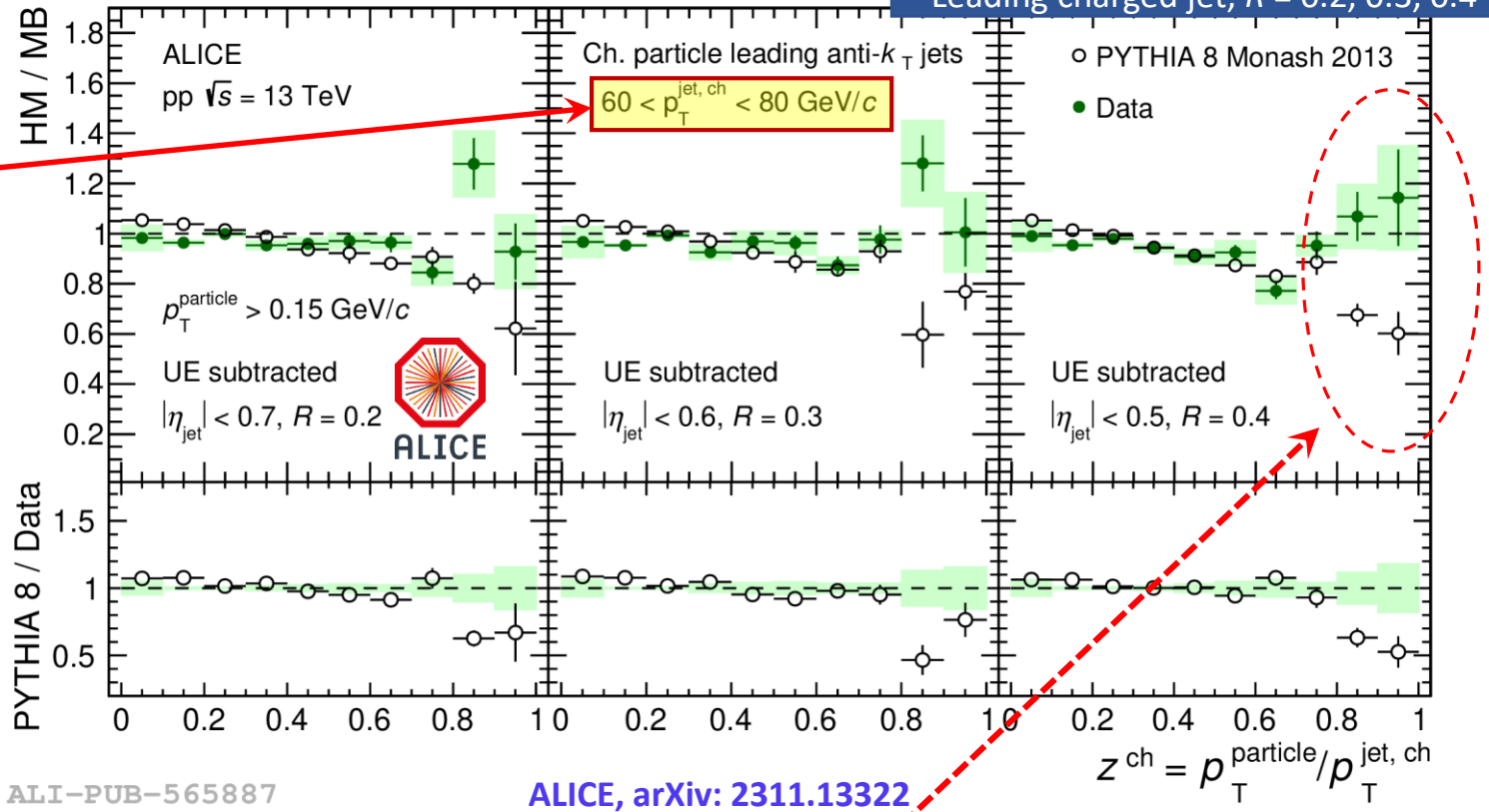

ALI-PUB-565887

ALICE, arXiv: 2311.13322

System	Jet p_T	Low z	Intermediate z	High z
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Modification of jet fragmentation: heavy-ion vs small collision systems

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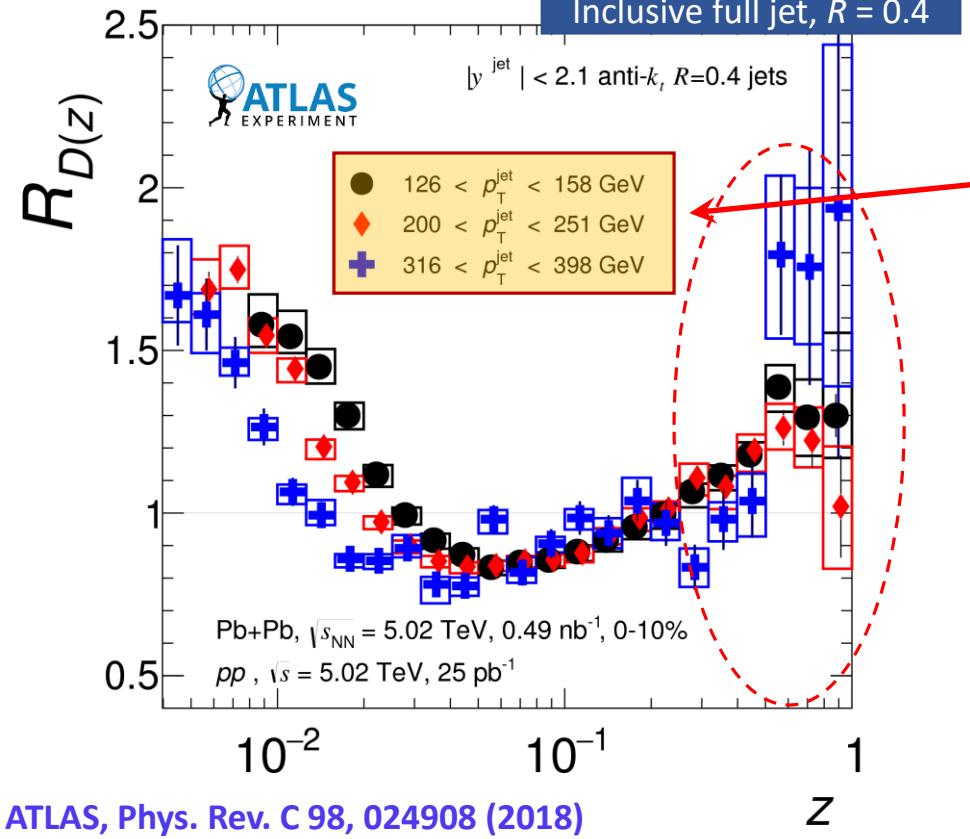

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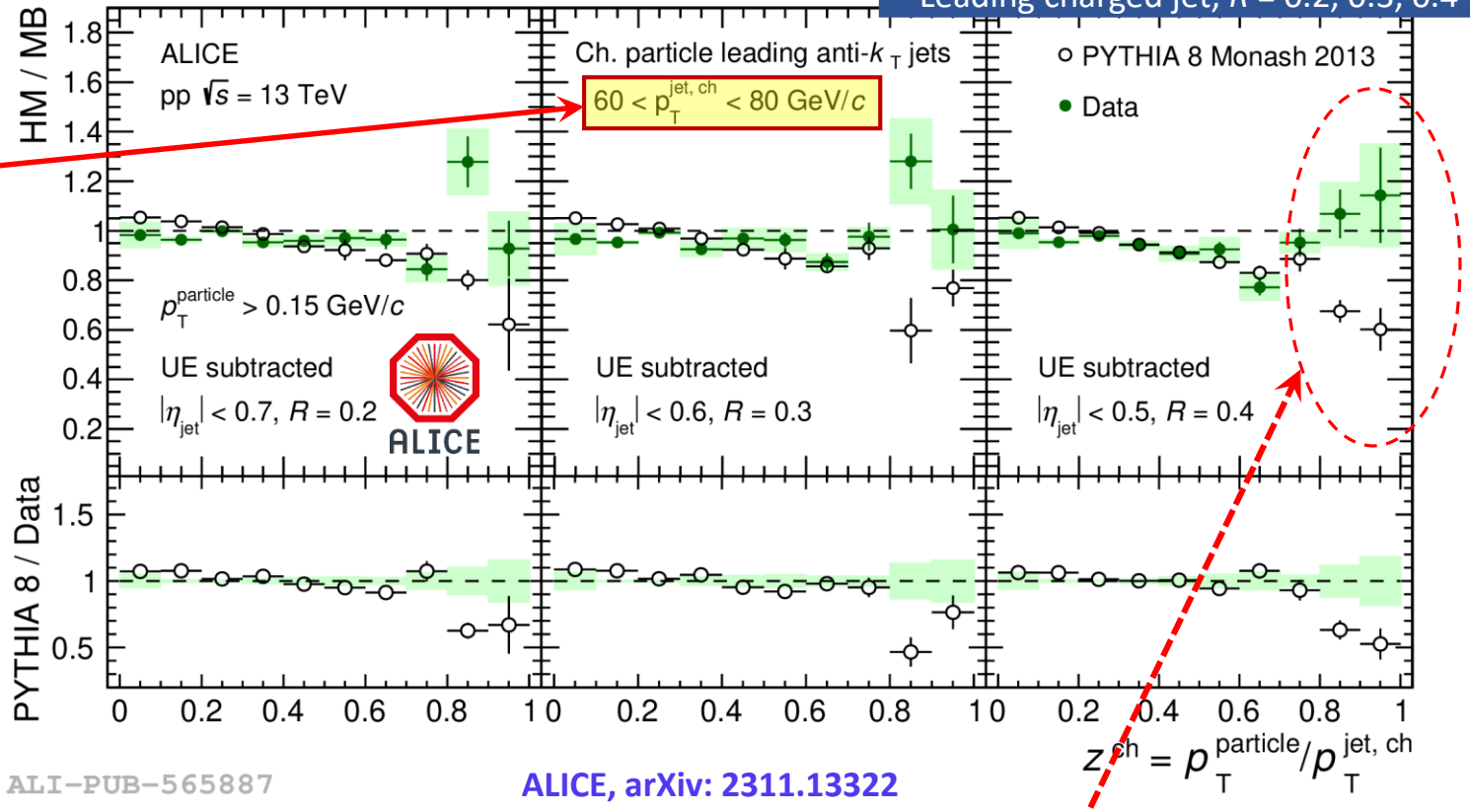

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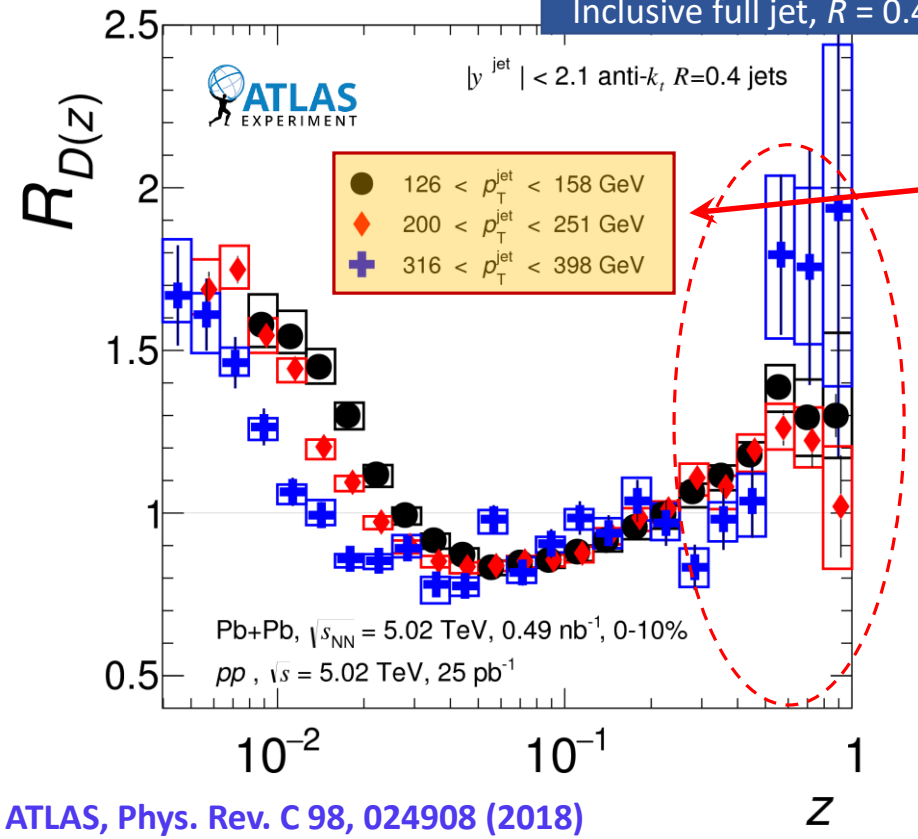

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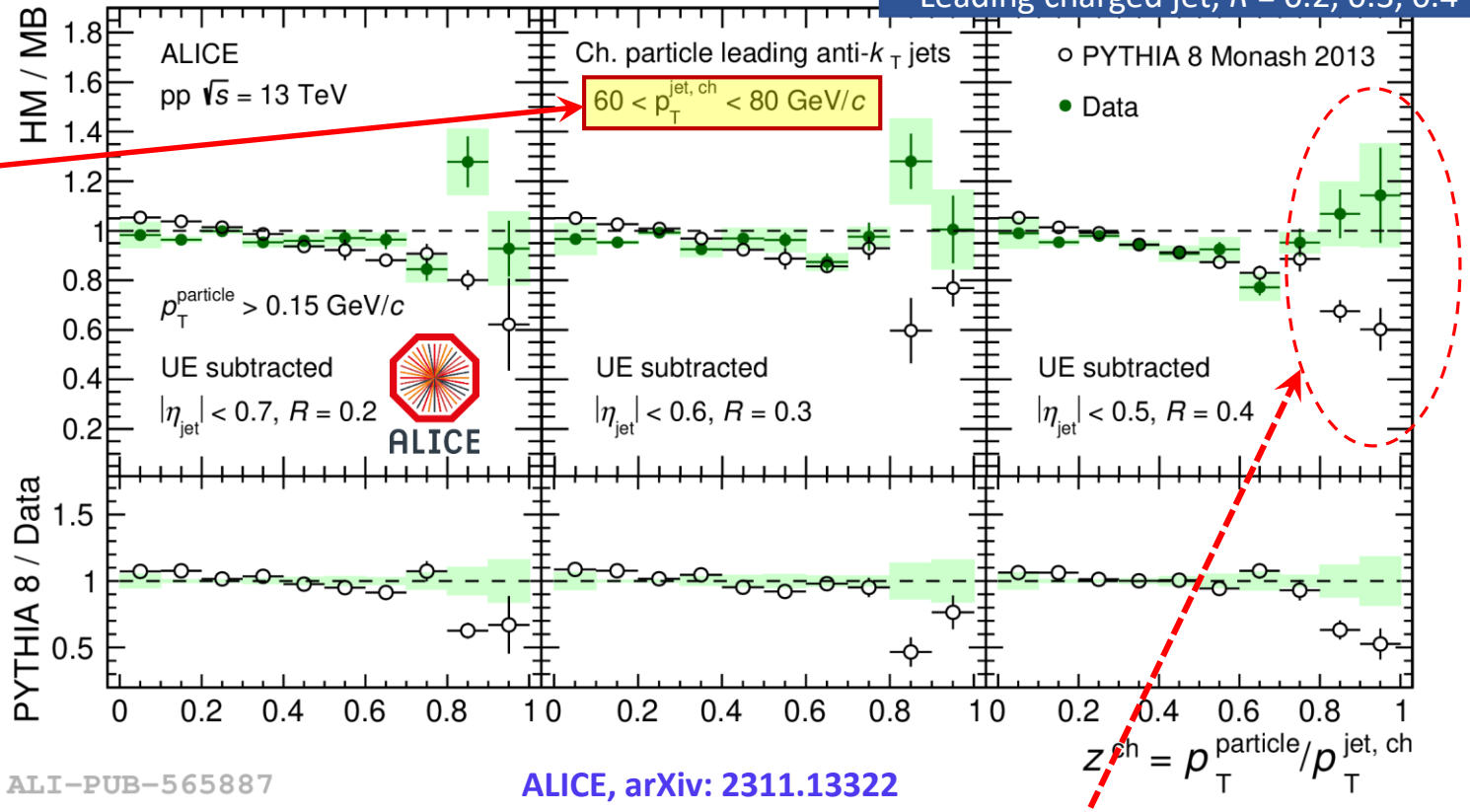

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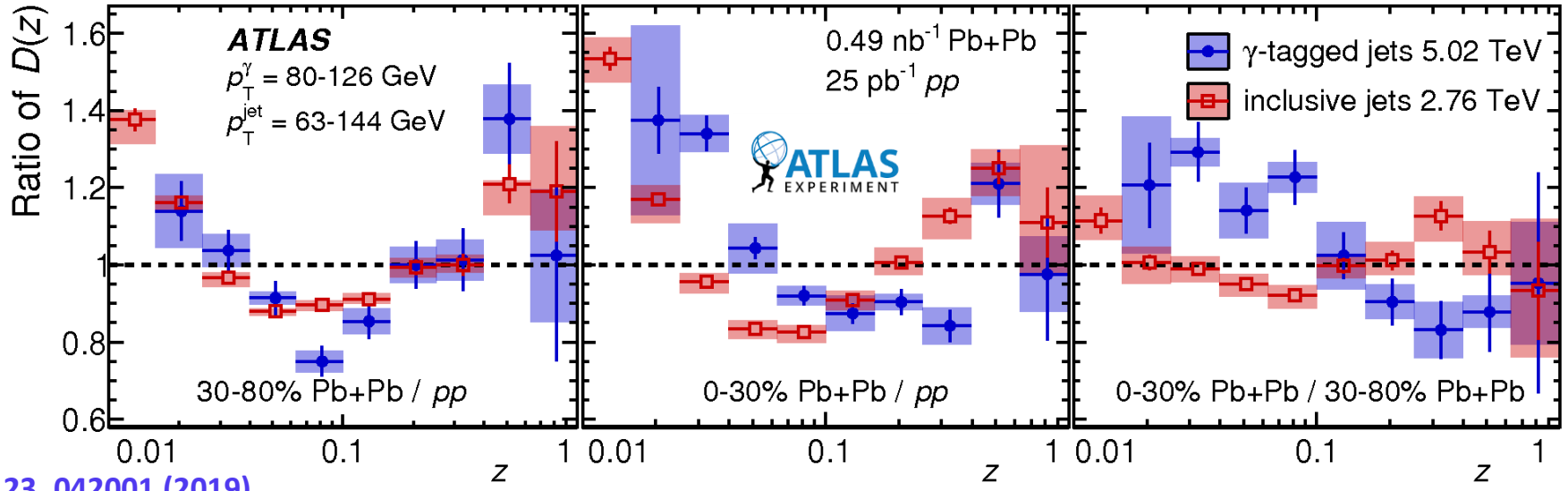

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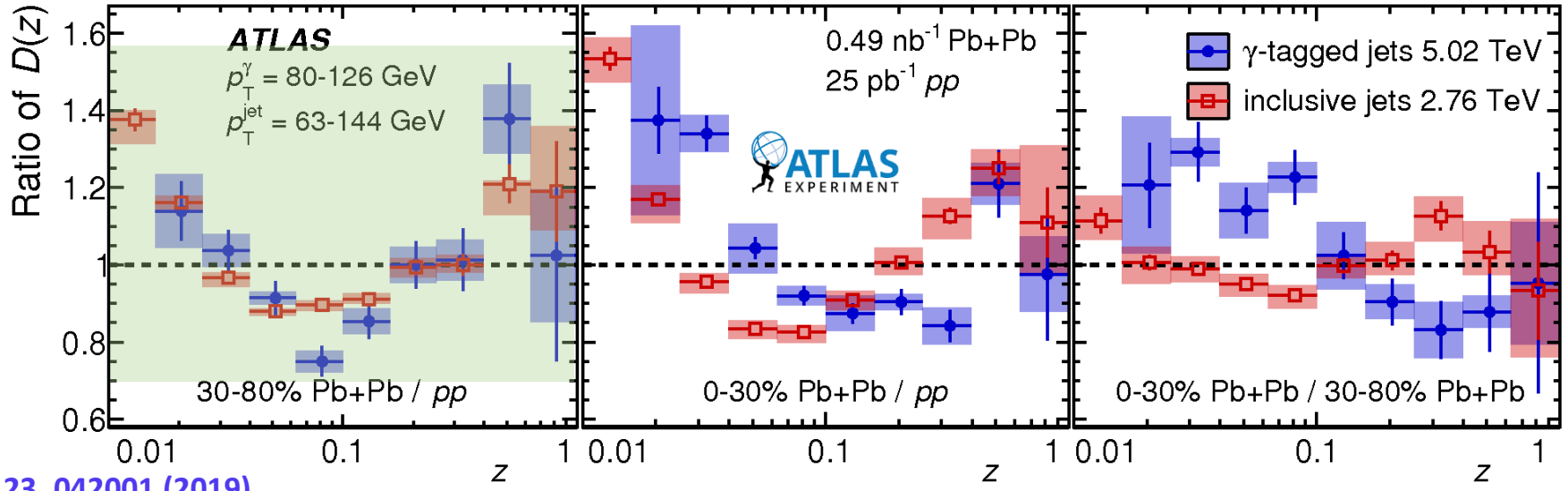

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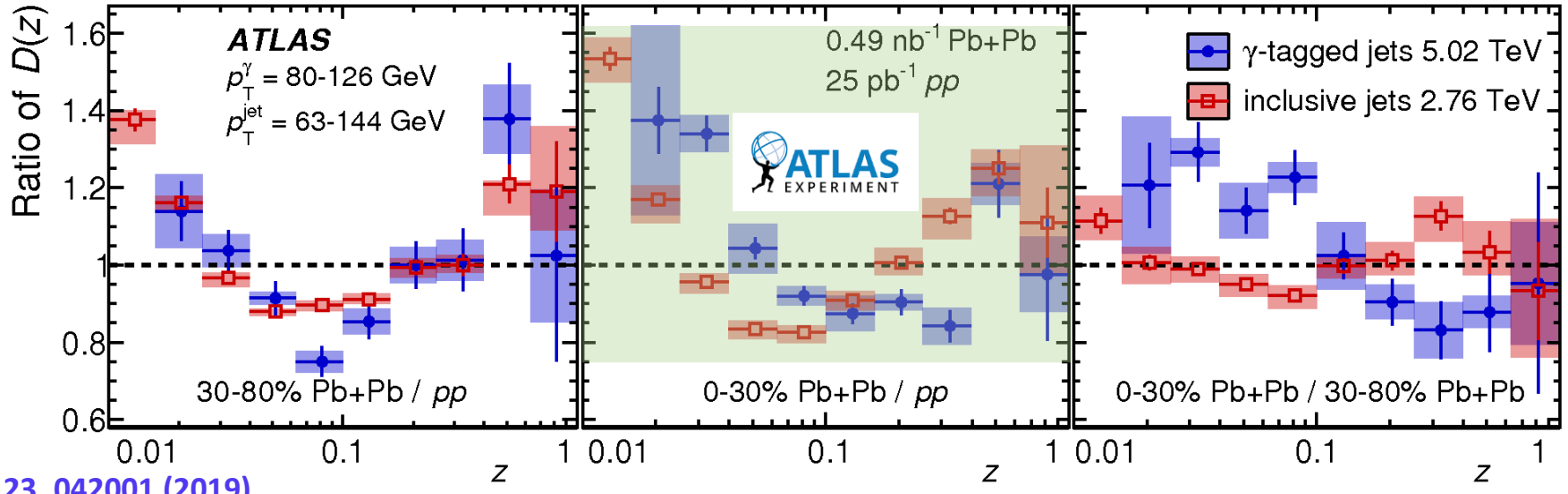

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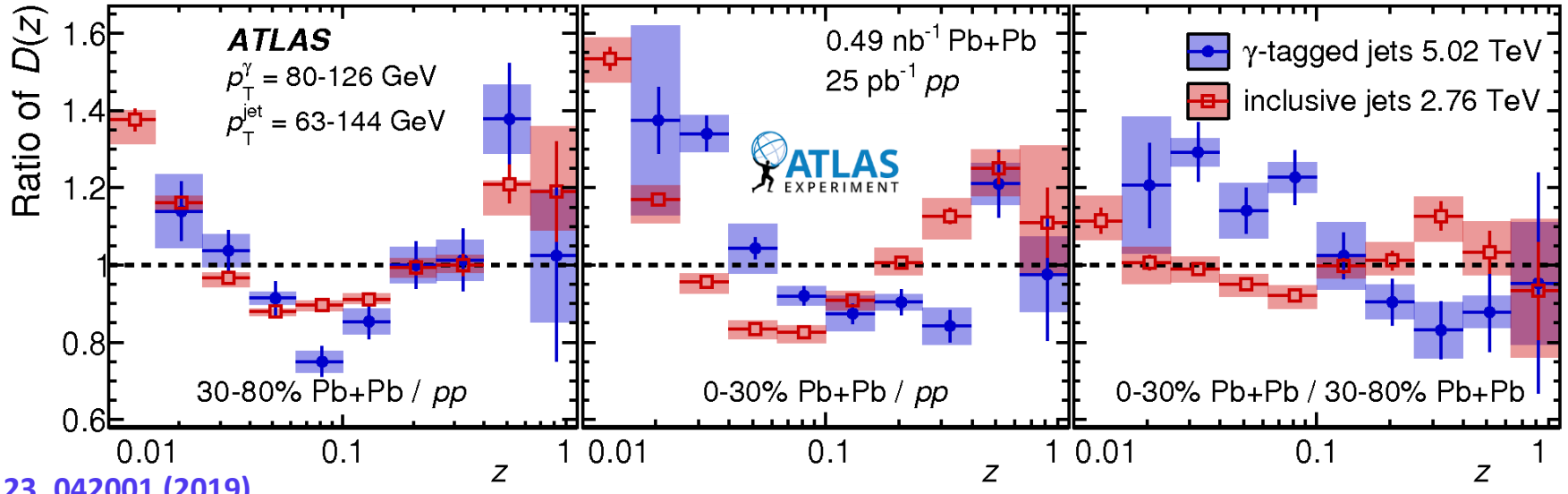

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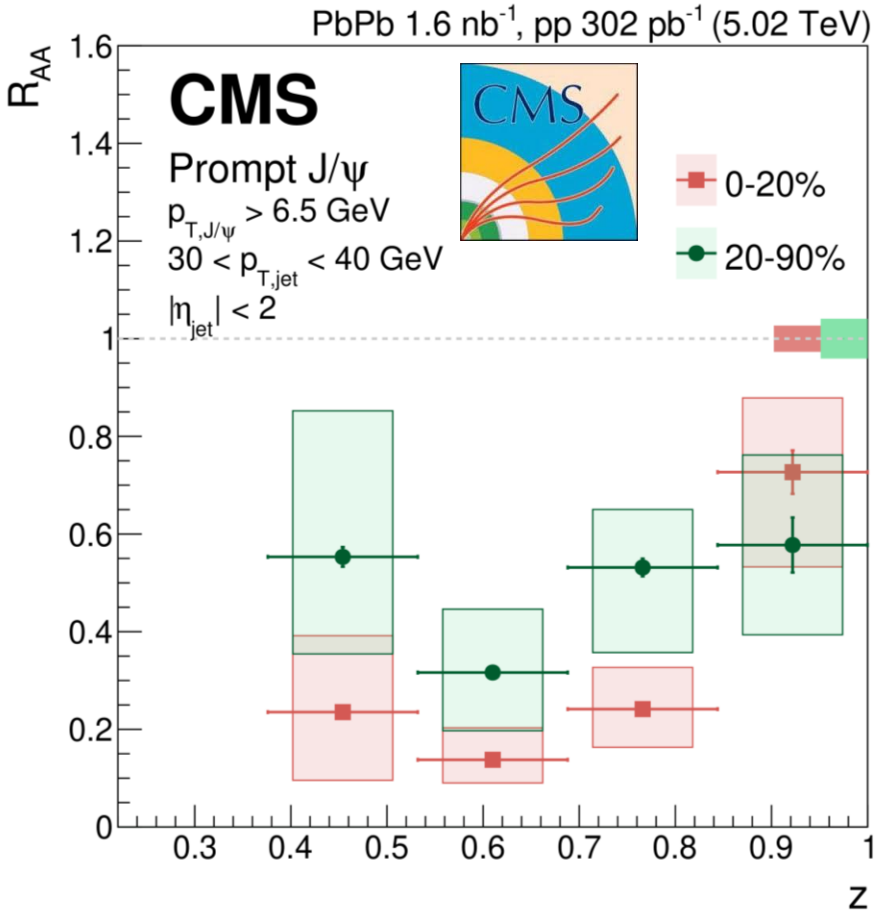
In central collisions, γ-tagged jets are modified in a different way than inclusive jets

Fragmentation of jets containing prompt J/ψ in heavy-ion collisions



CMS, Phys. Lett. B 825 (2021) 136842

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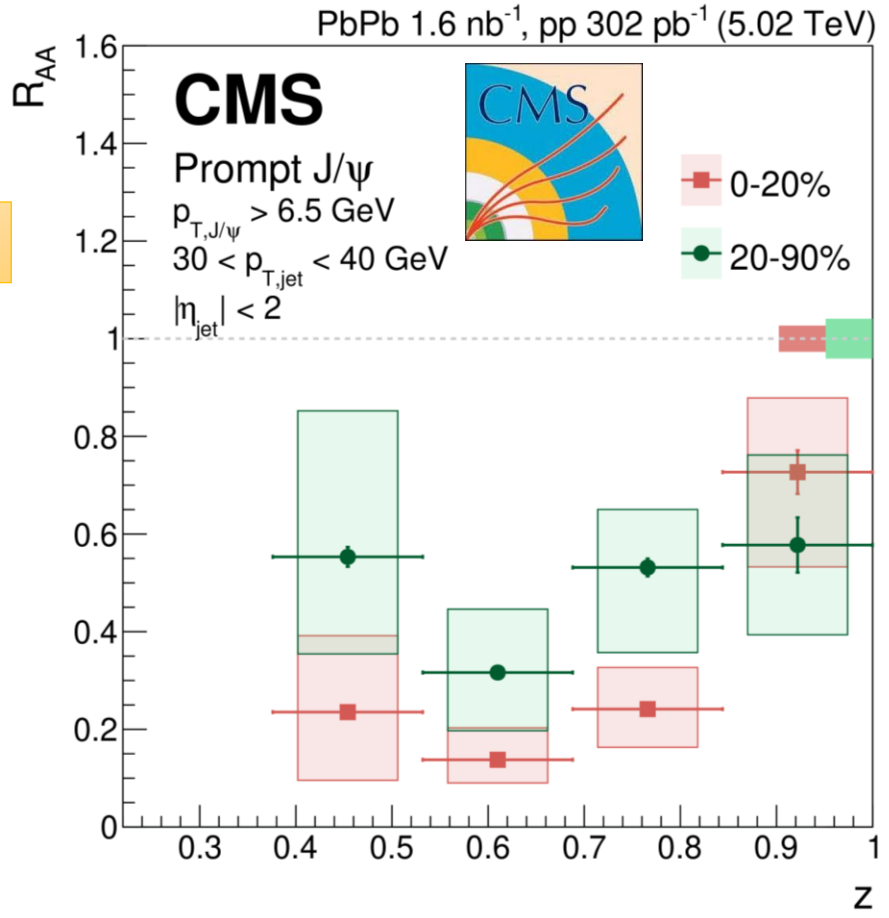

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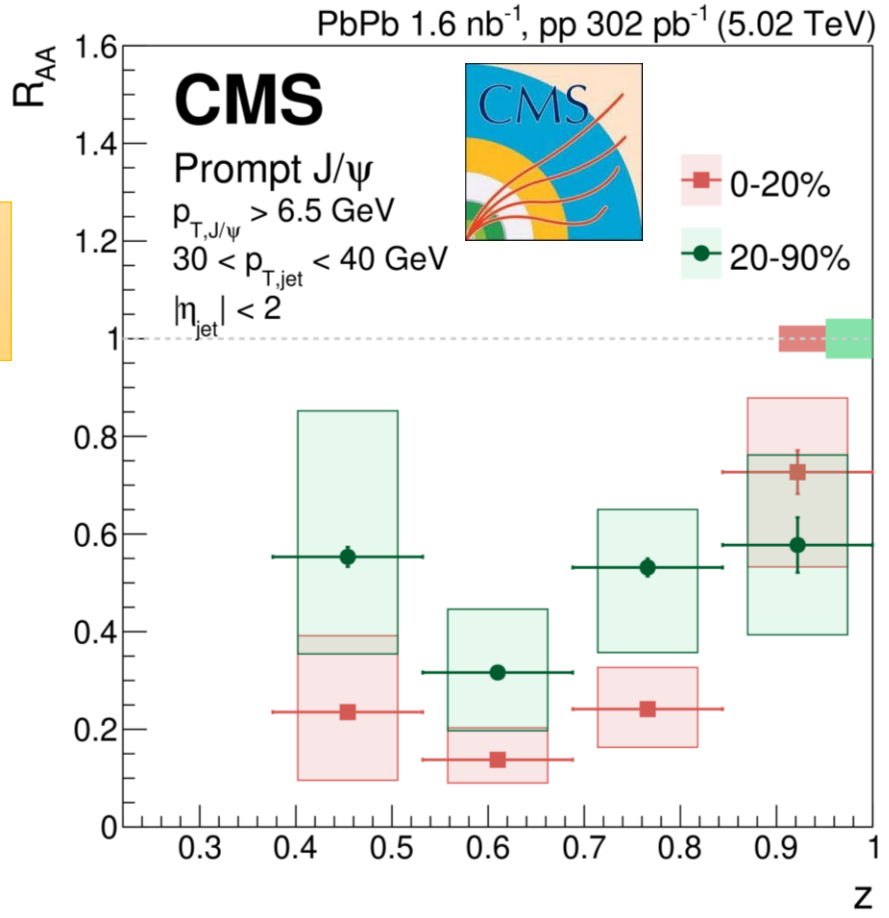

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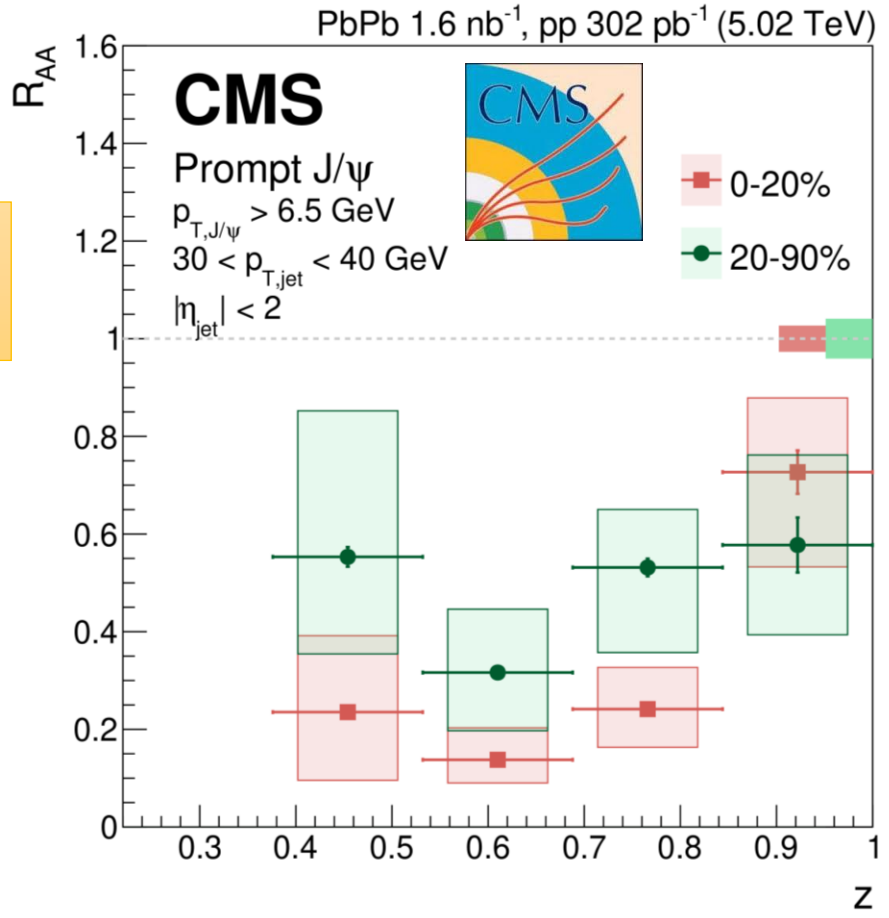

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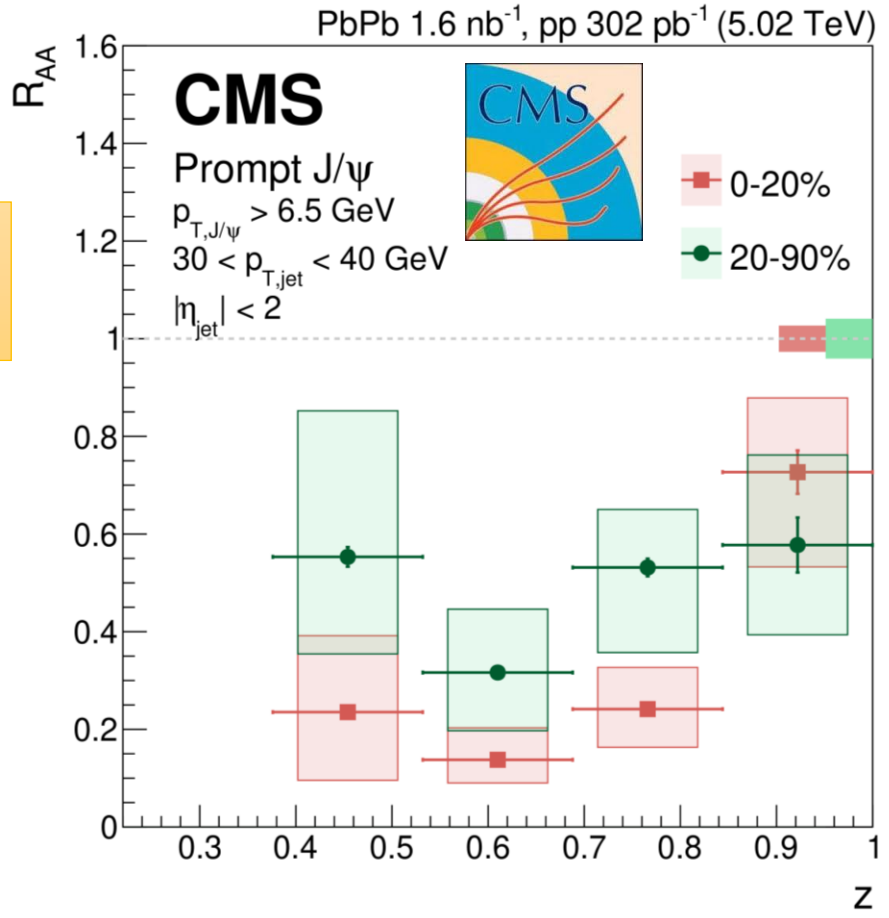
Highlights the importance of incorporating jet quenching mechanism in models of J/ψ suppression



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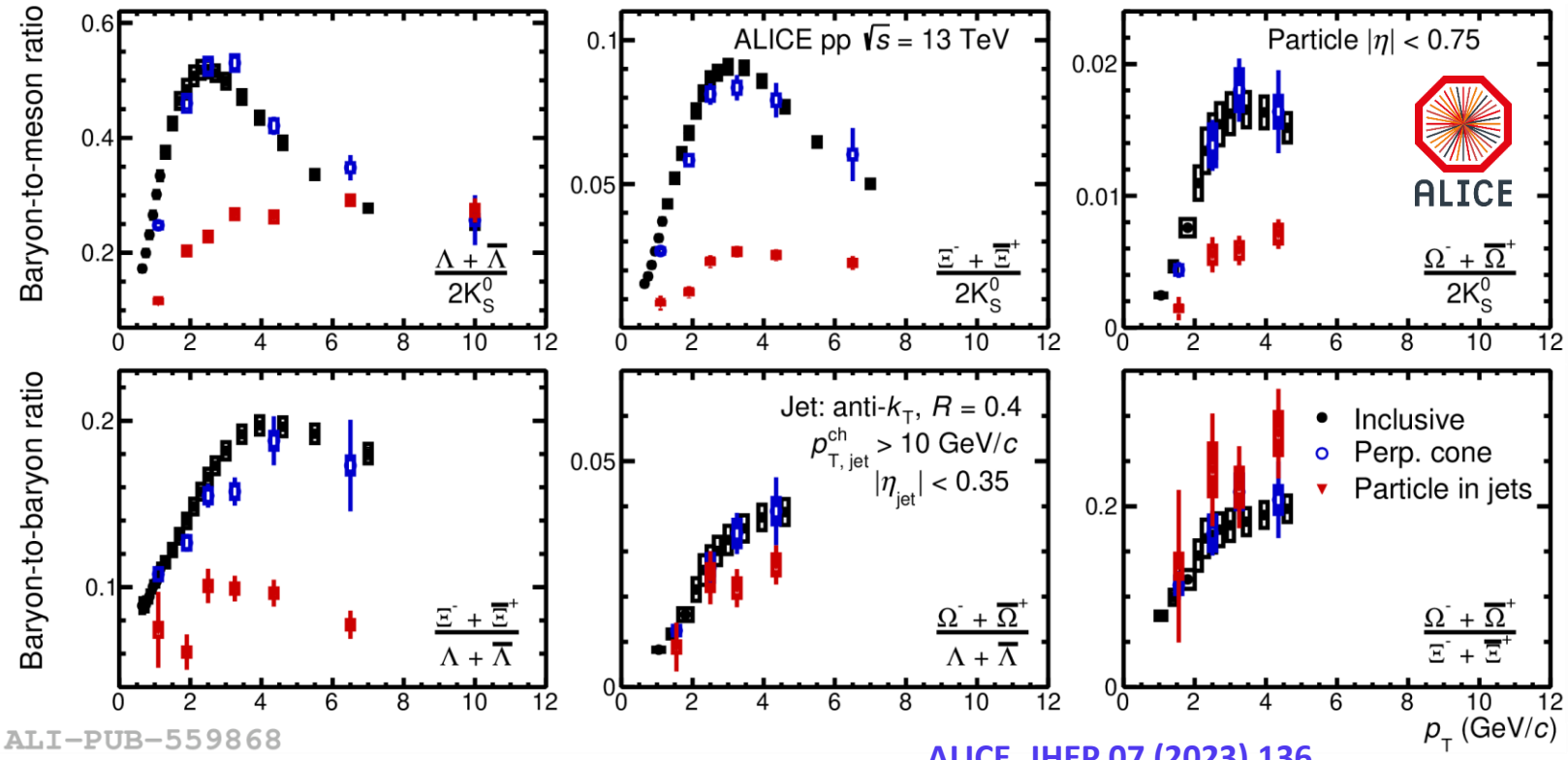
Jet hadronchemistry

Strange hadronchemistry in and out of jets

Strange baryon-to-meson ratios:



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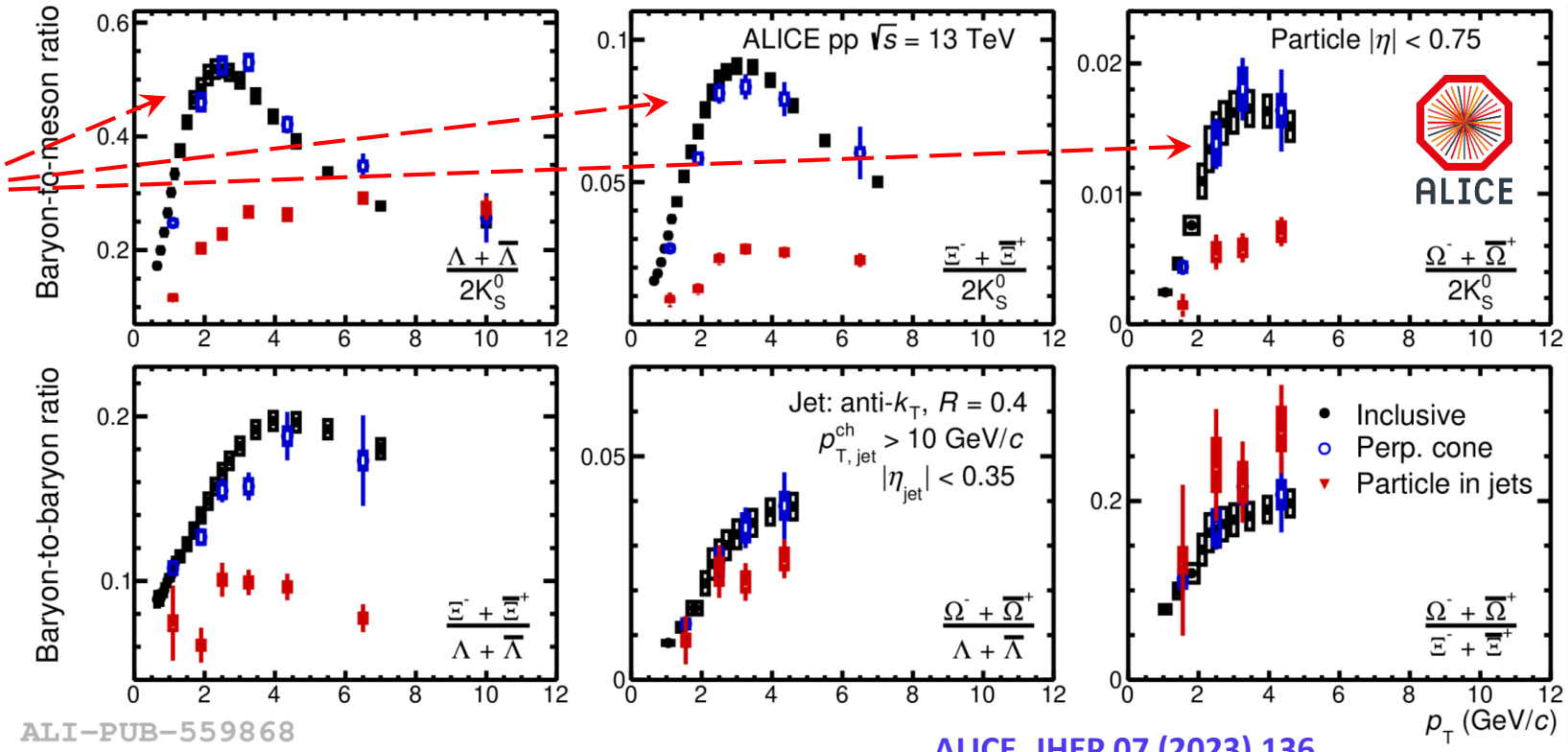

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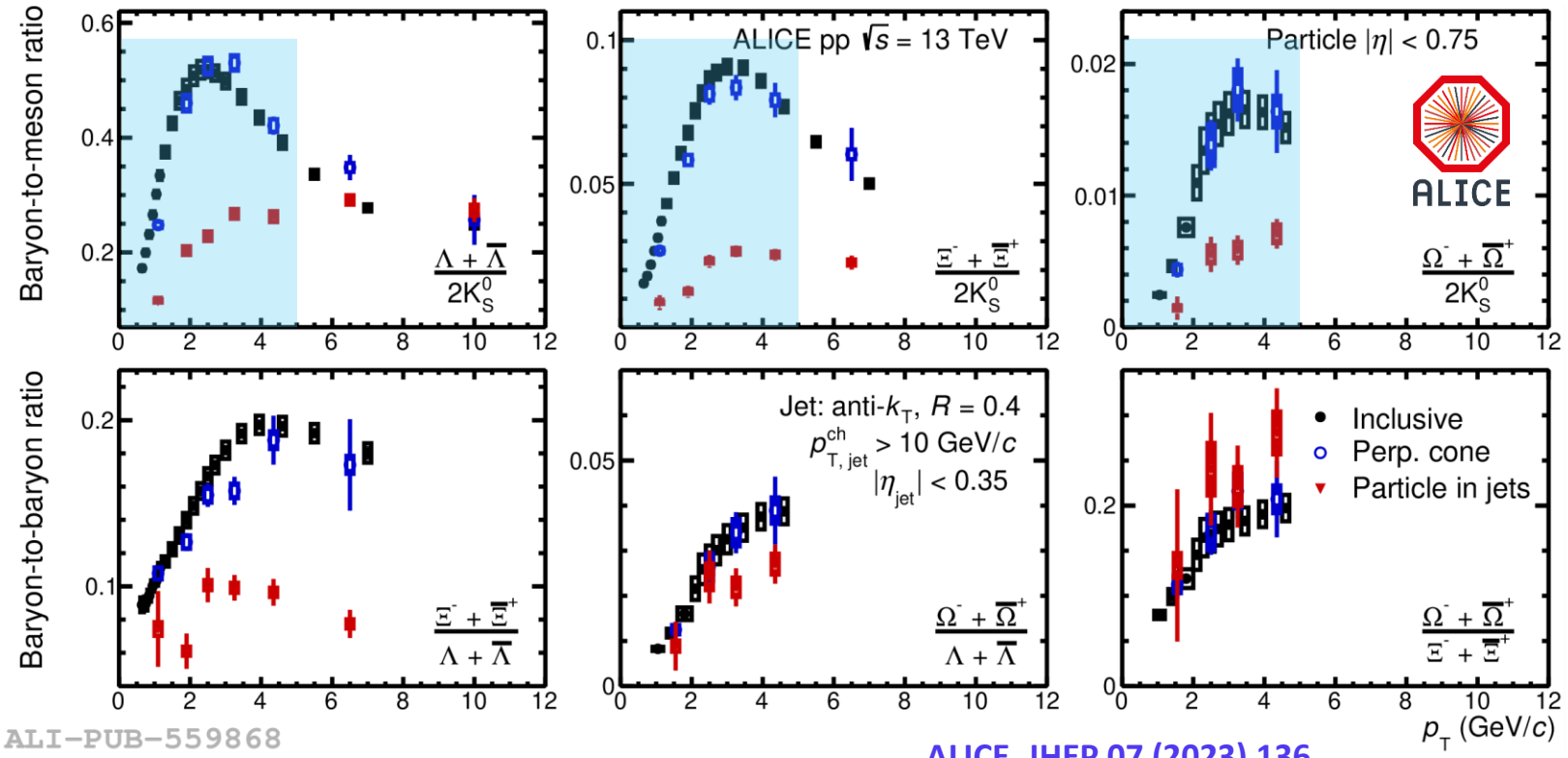

ALI-PUB-559868

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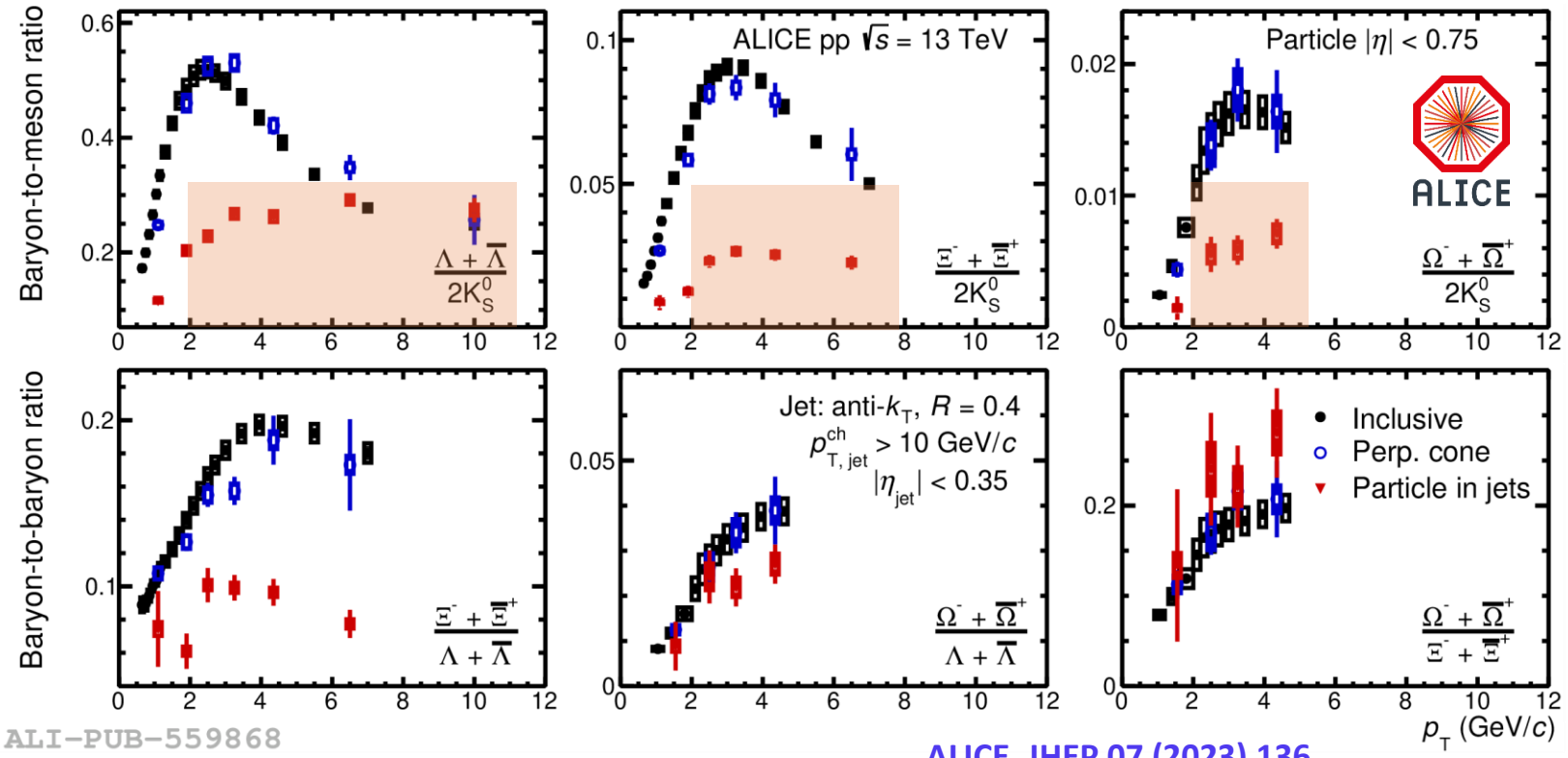

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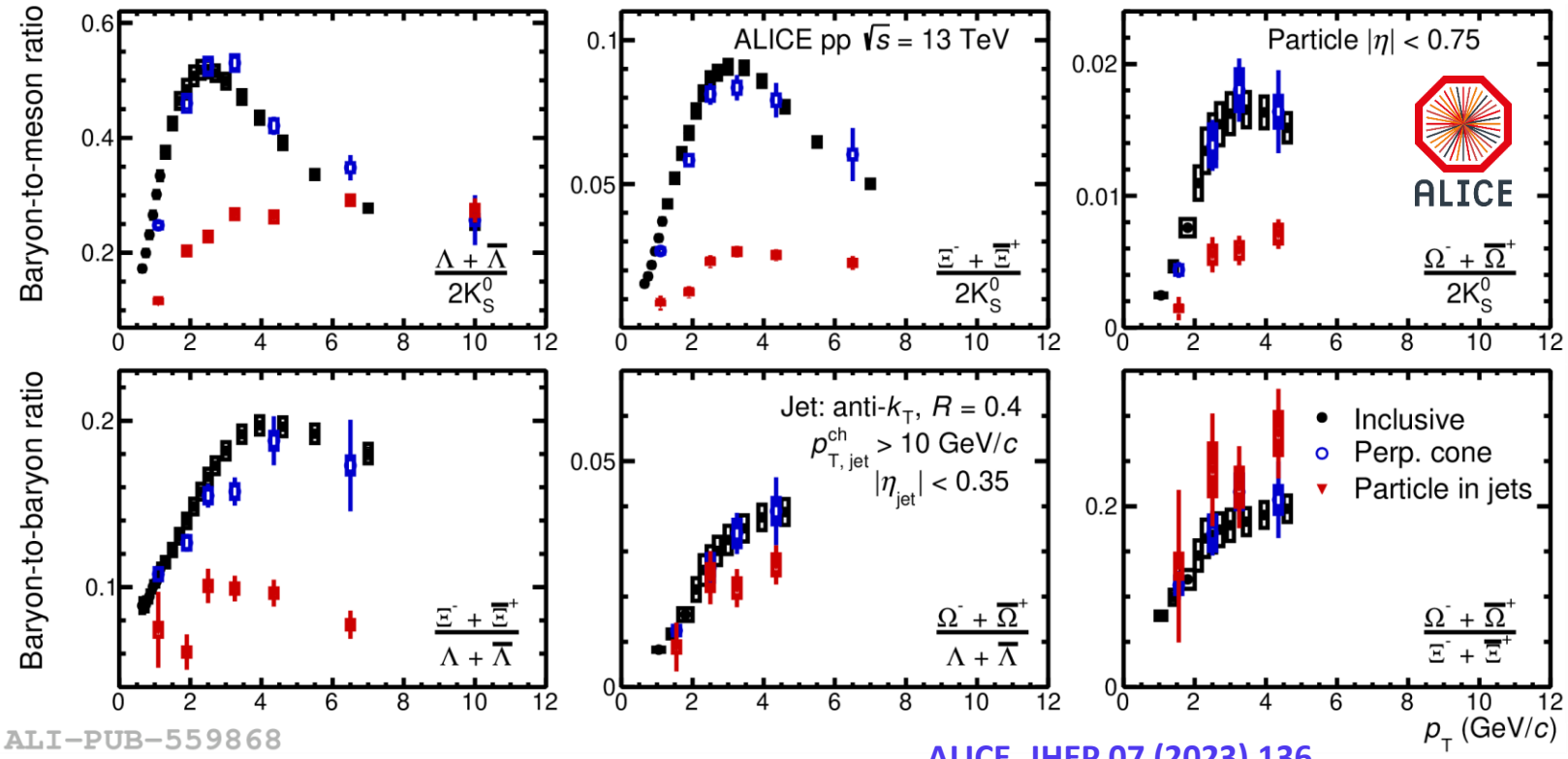

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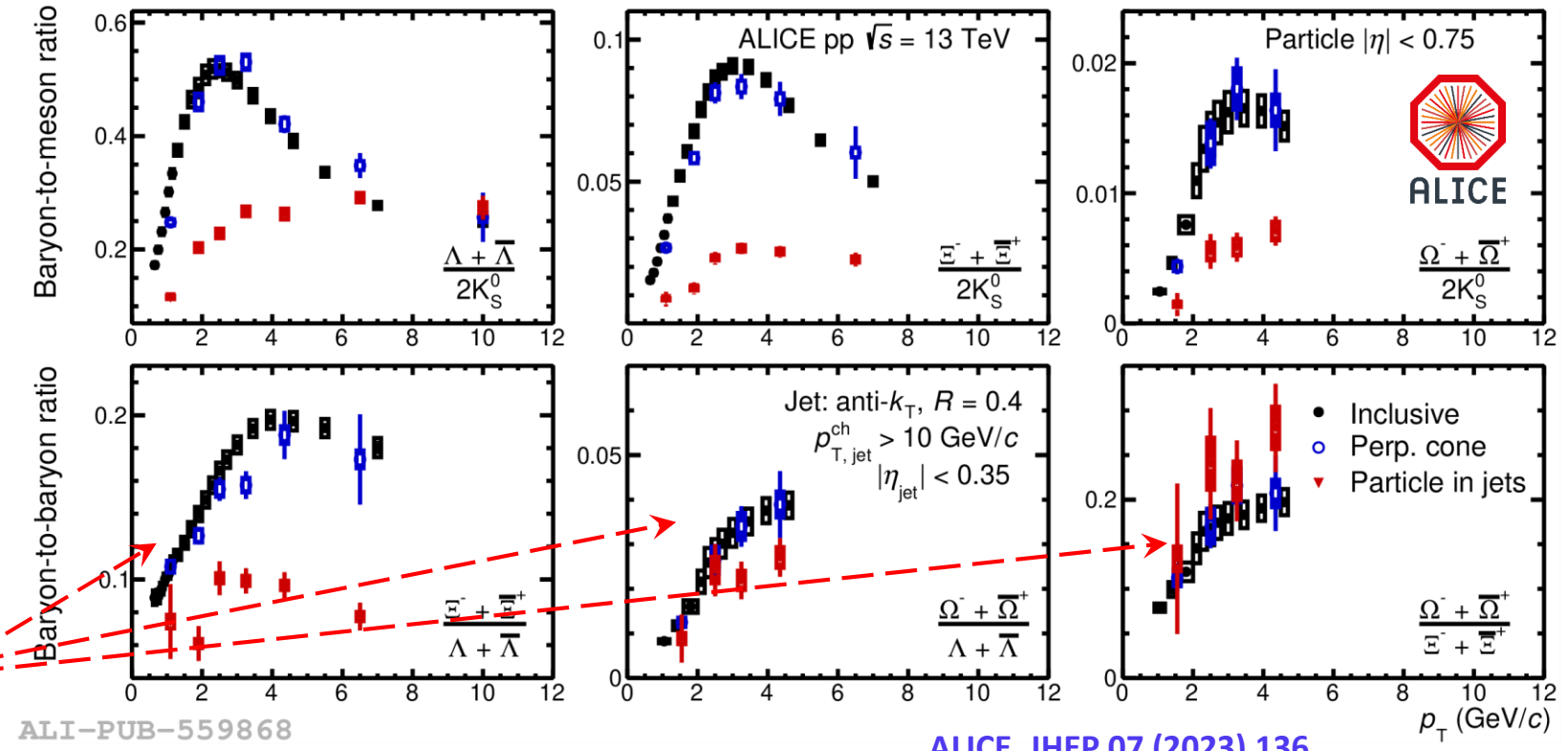

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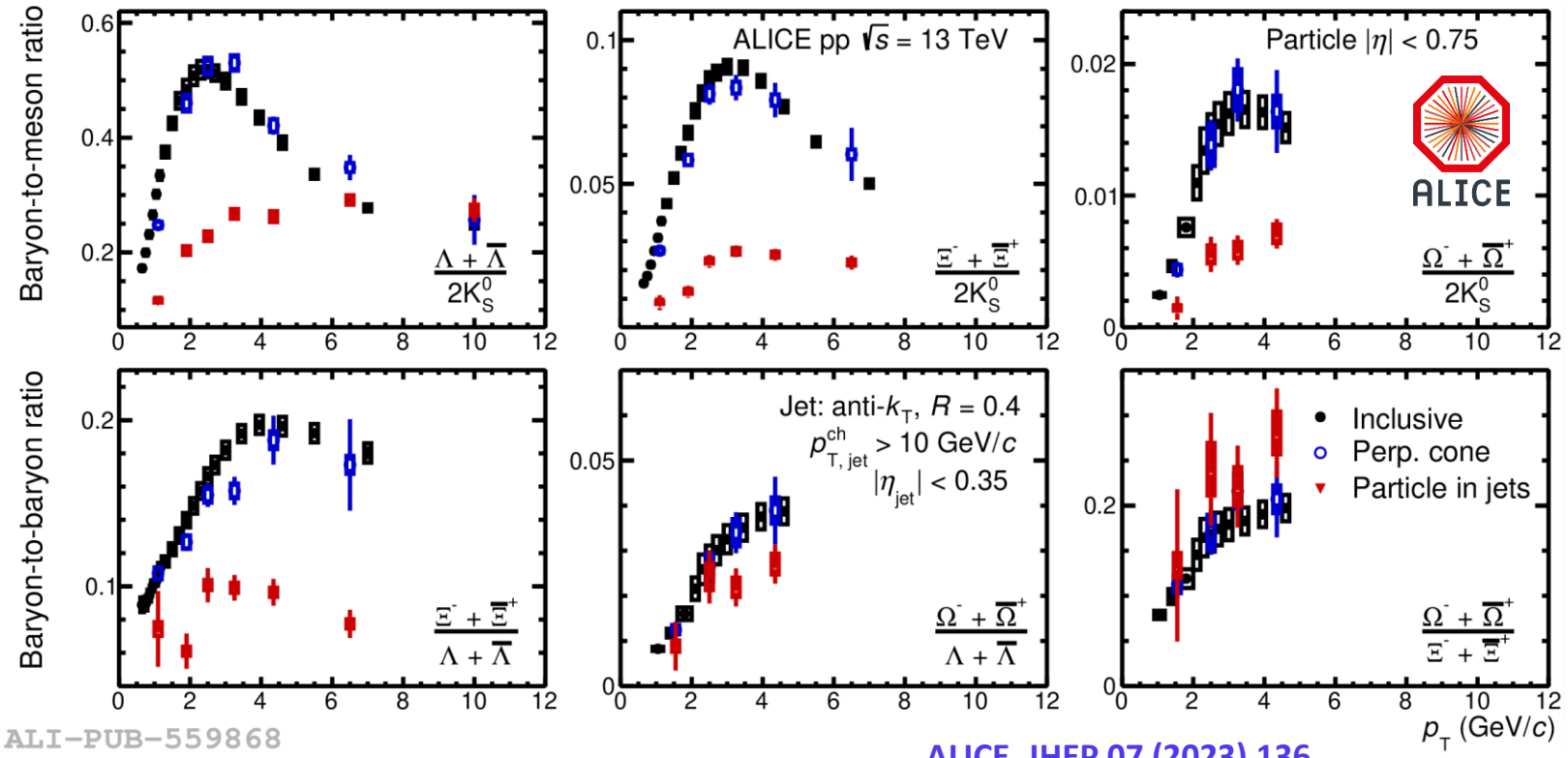

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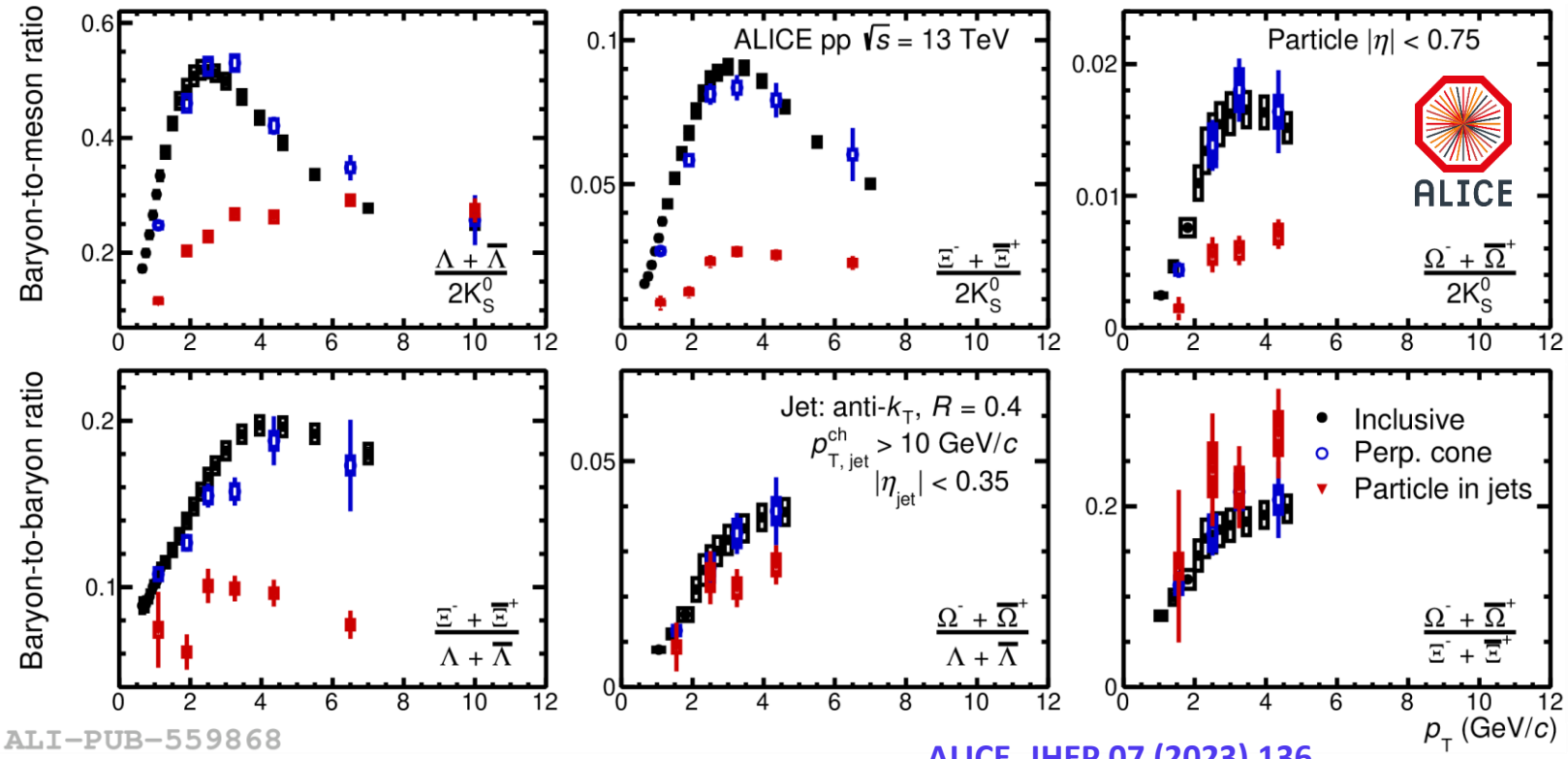

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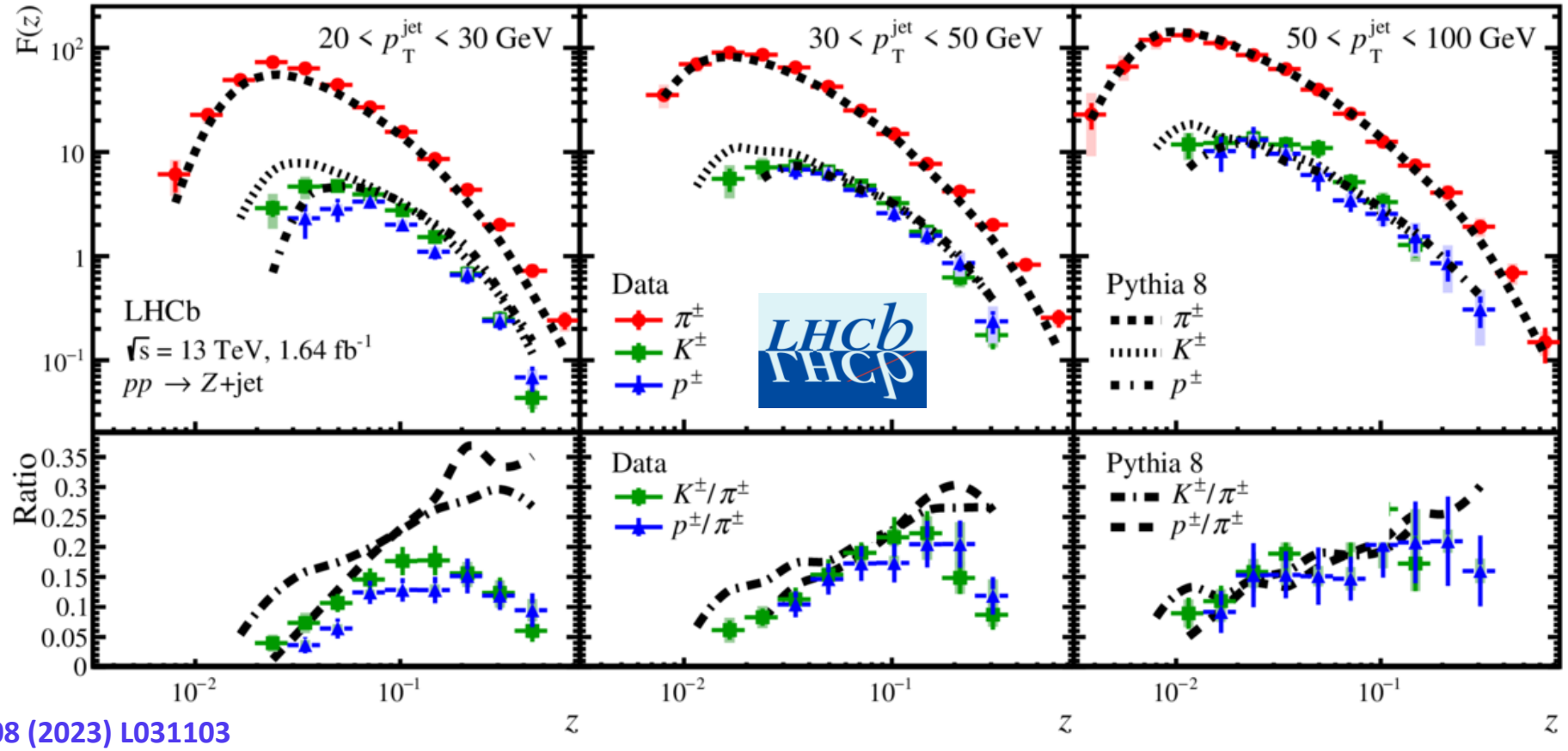
Similar trends observed in different multiplicity classes of p-Pb collisions at 5.02 TeV

Hadronchemistry of Z-tagged jets



LHCb, Phys. Rev. D 108 (2023) L031103

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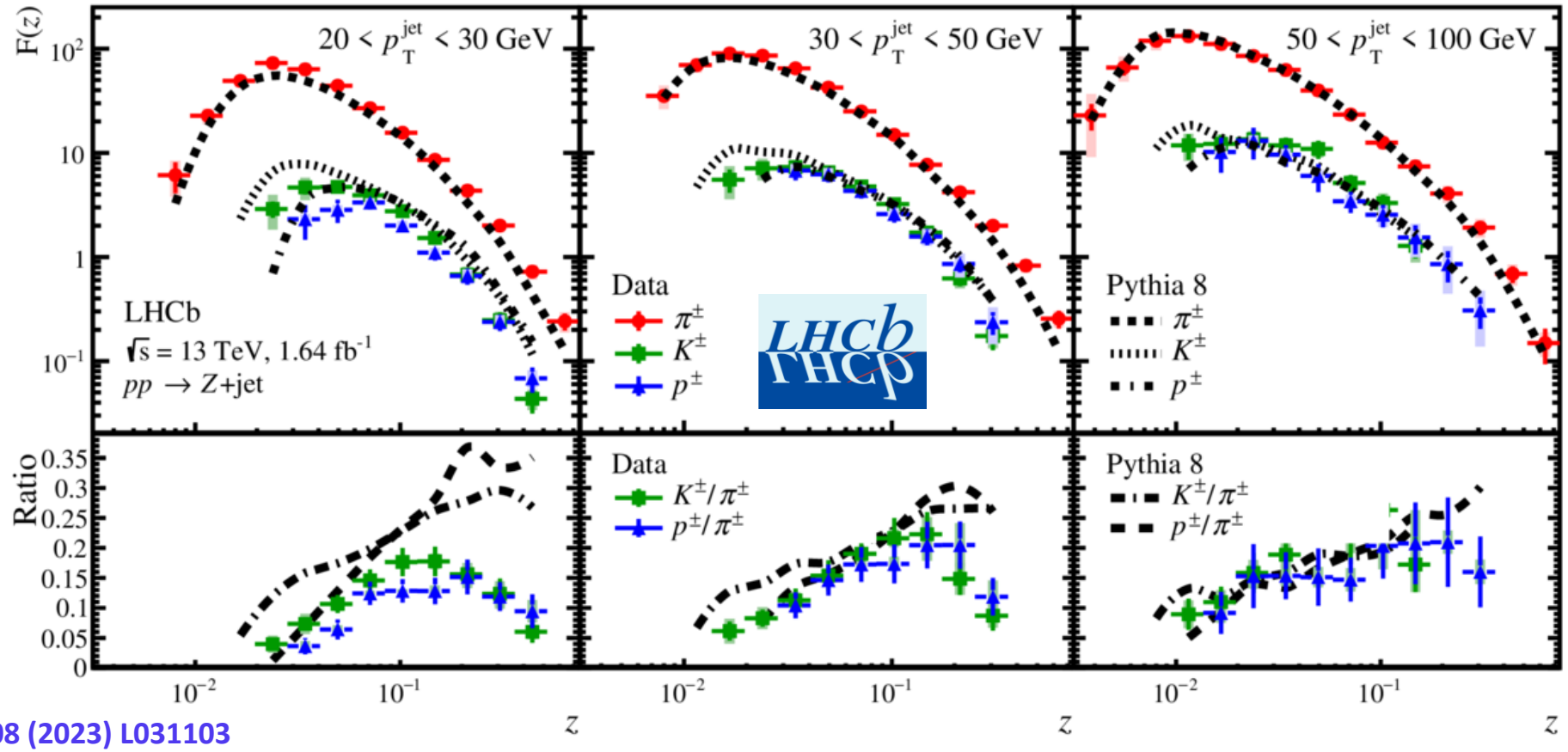

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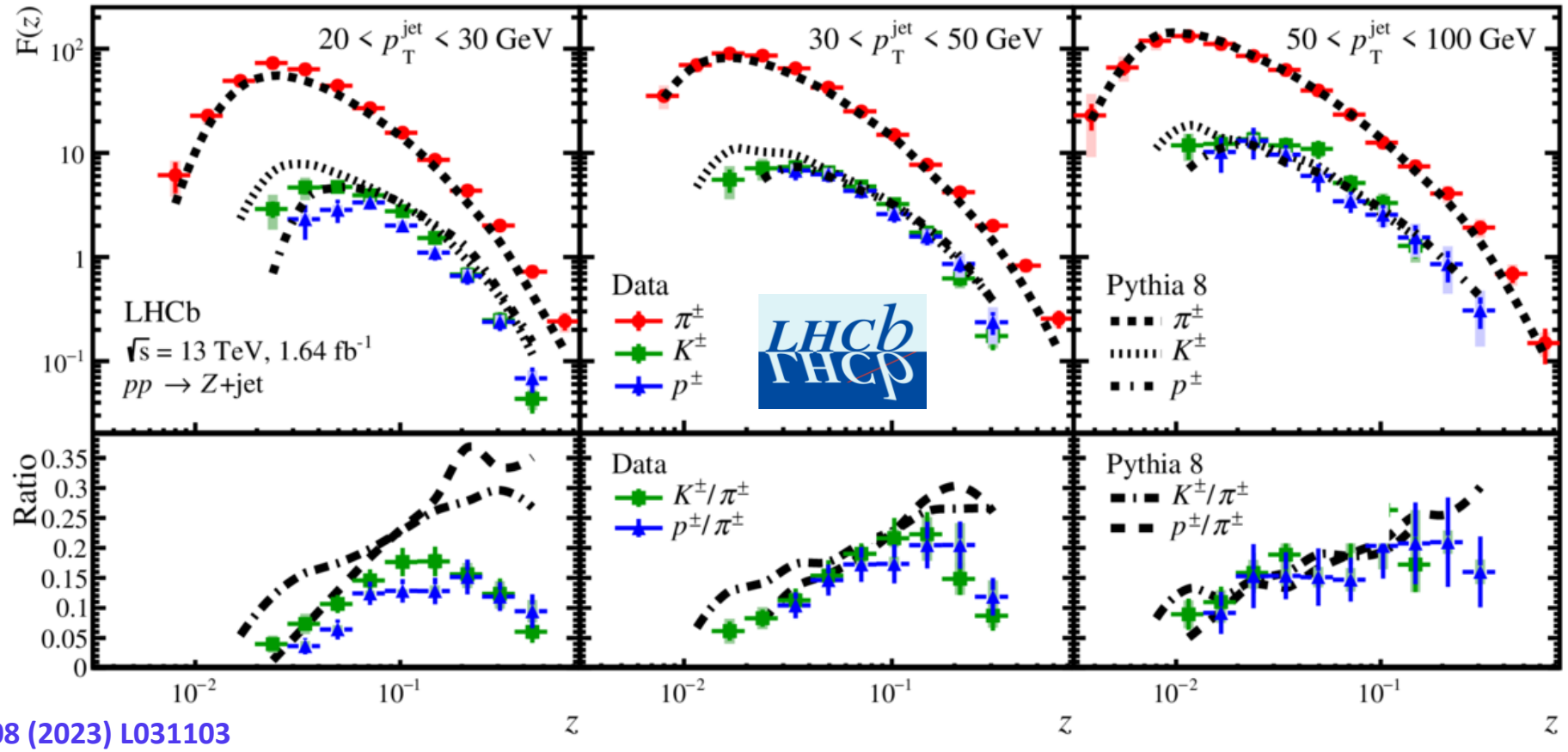

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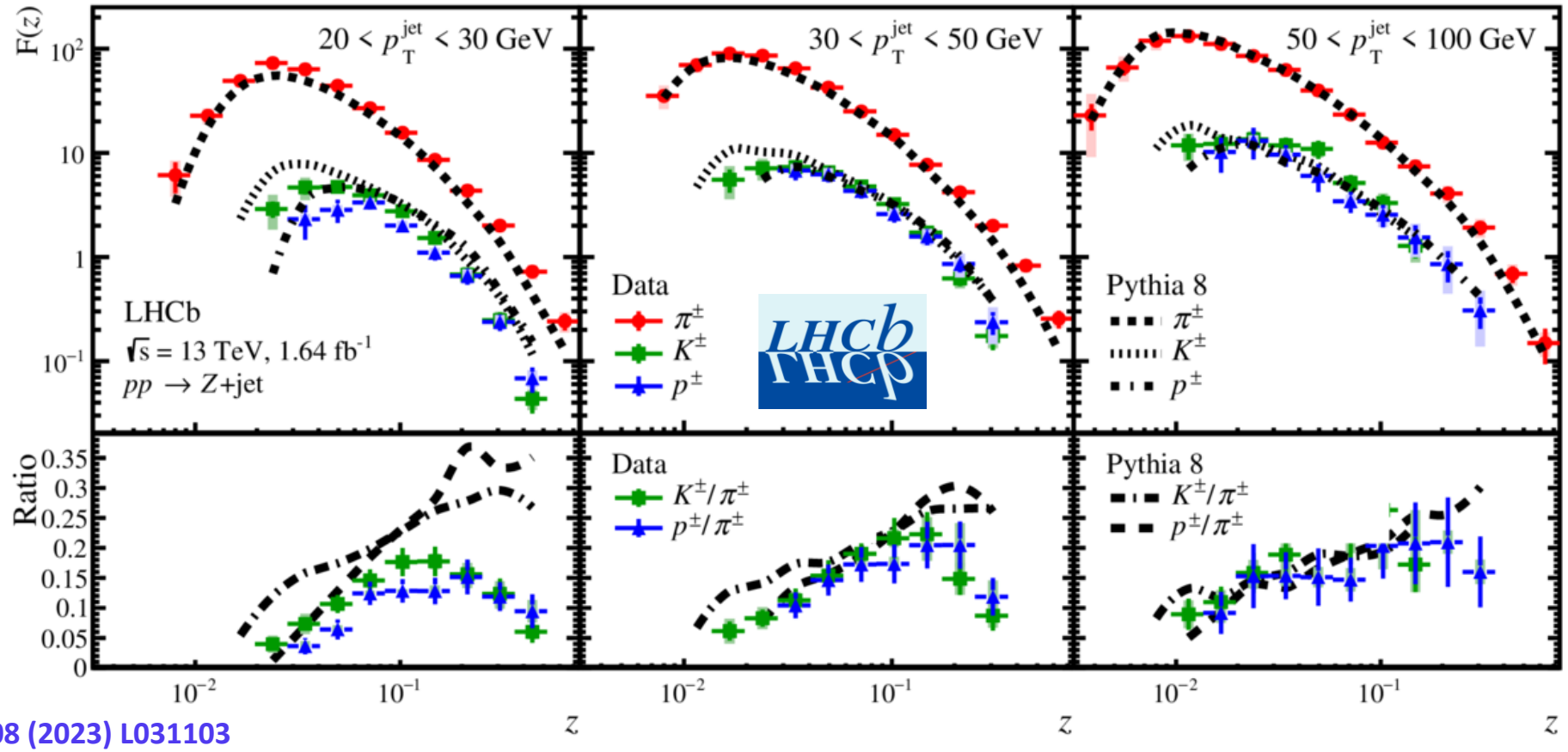

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Related to quark-flavor content inside the proton??

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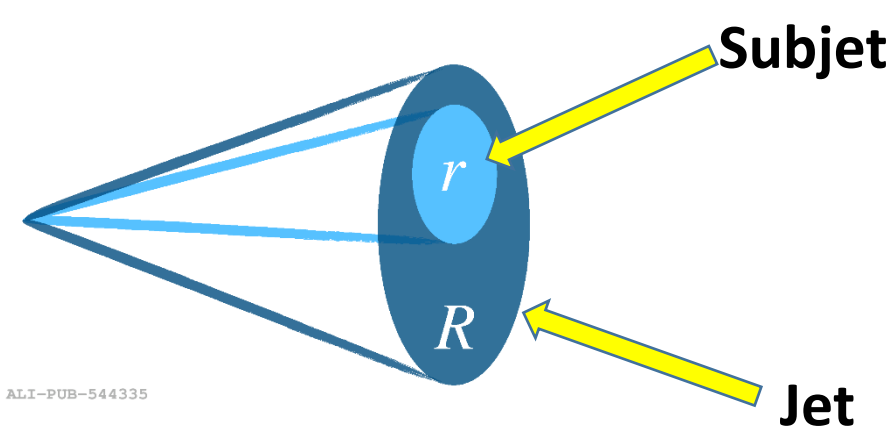
Thank you for your kind attention

Backup

Subjet fragmentation



Subjet observables are sensitive probes of jet quenching in heavy-ion collisions. They can

- *Probe high-z fragmentation*
- *Test the universality of jet fragmentation in QGP*
- *Measure energy loss at the cross section level*

ALICE, JHEP 05 (2023) 24

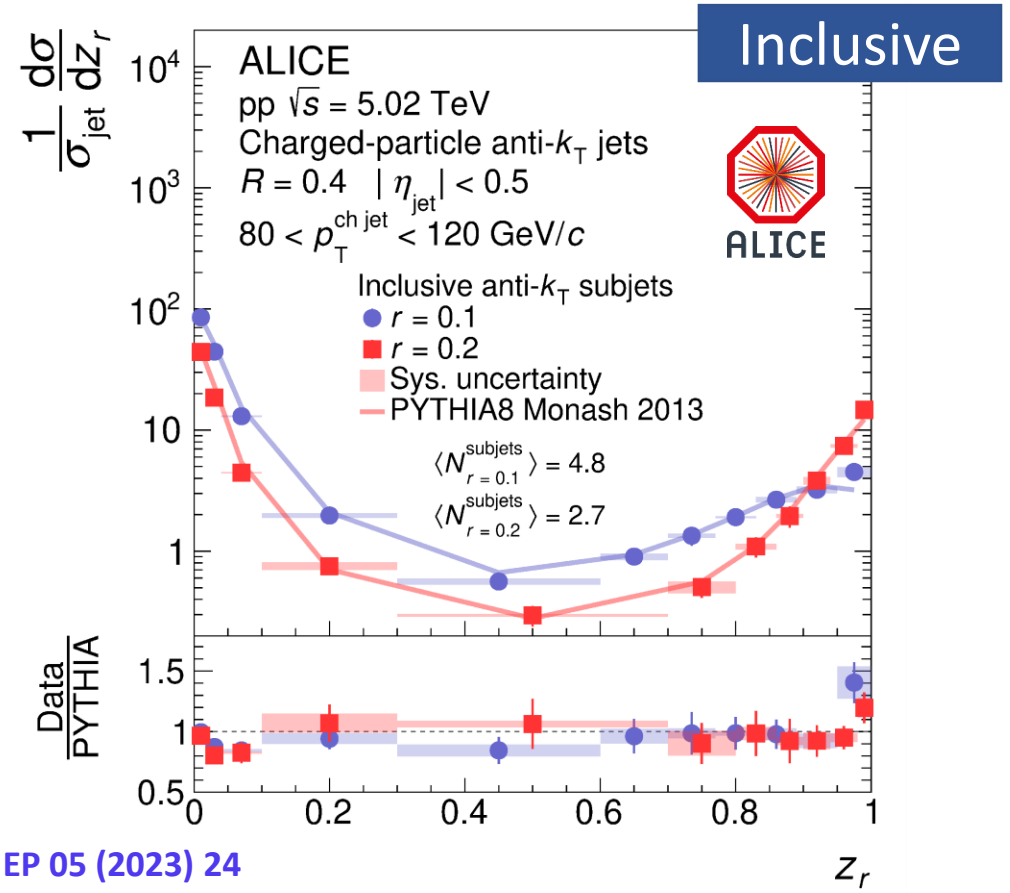
Subjet reconstruction

- Cluster inclusive jets with radius *R*
- Recluster with anti-k_T algorithm with radius *r*

Subjet fragmentation can be described by

$$z_r = \frac{p_T^{\text{ch subjet}}}{p_T^{\text{ch jet}}}$$

Inclusive and leading subjet fragmentation in pp collisions



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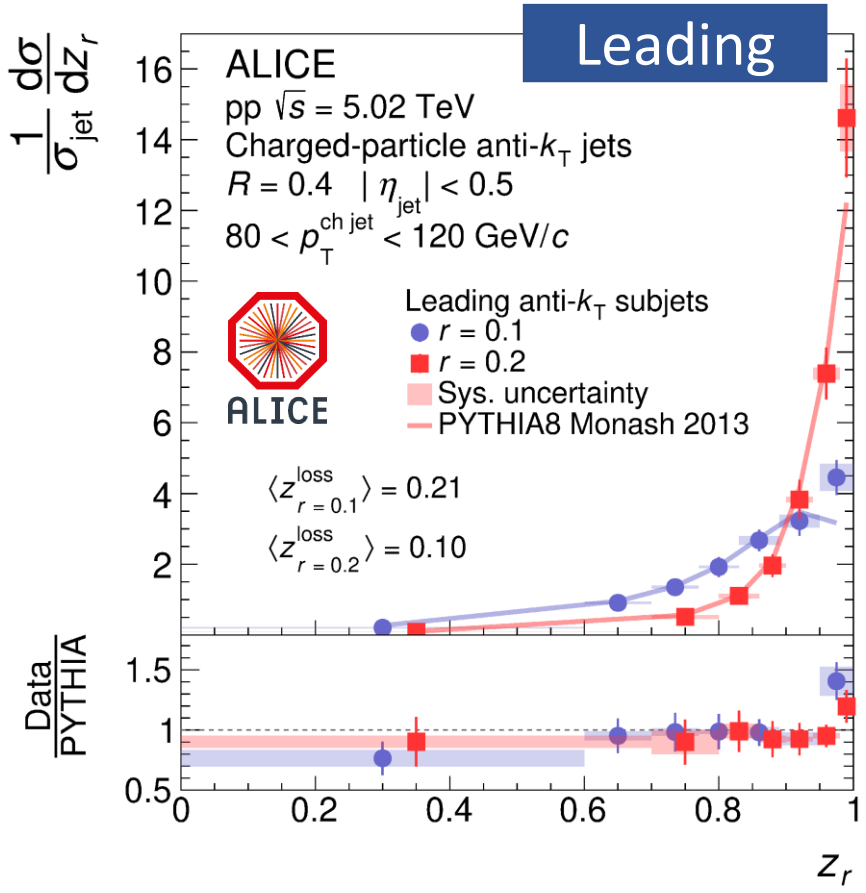

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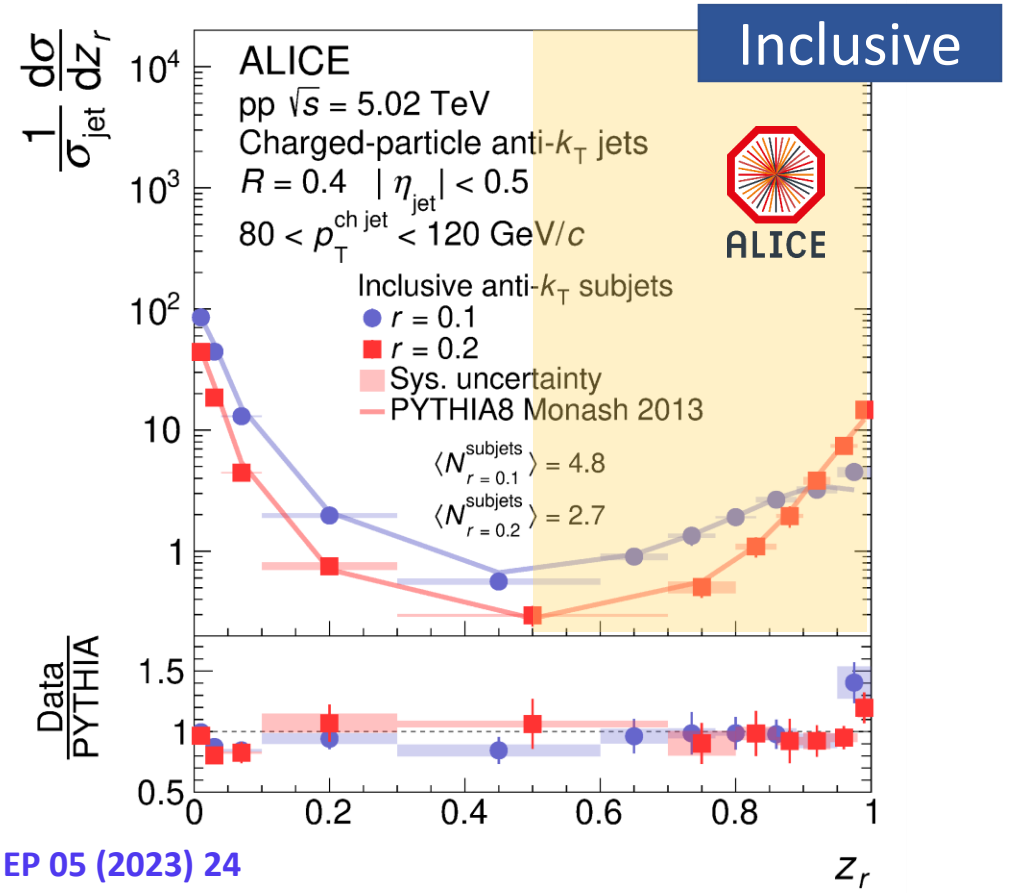

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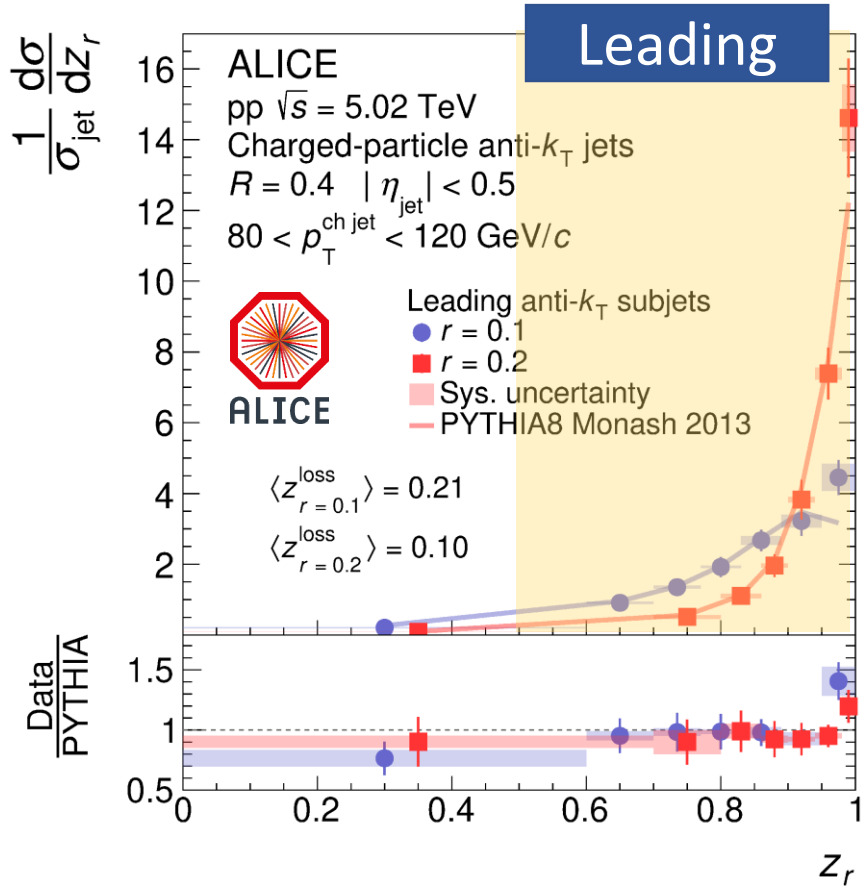

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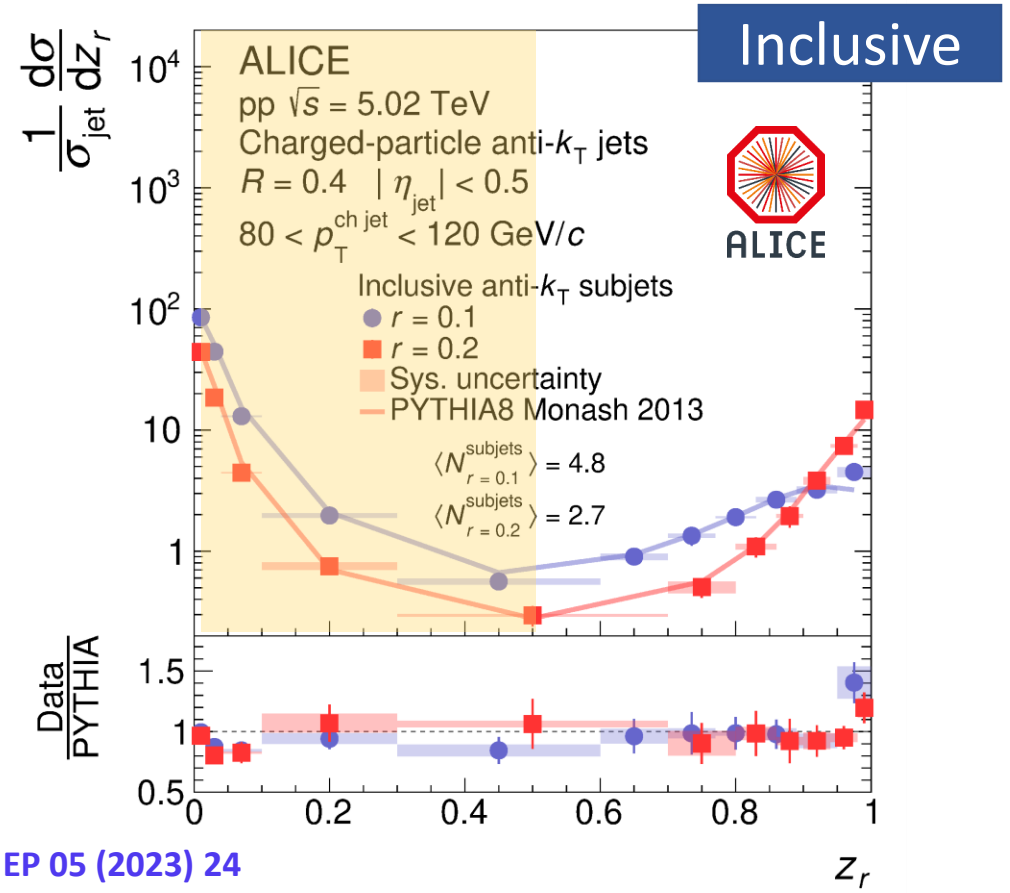
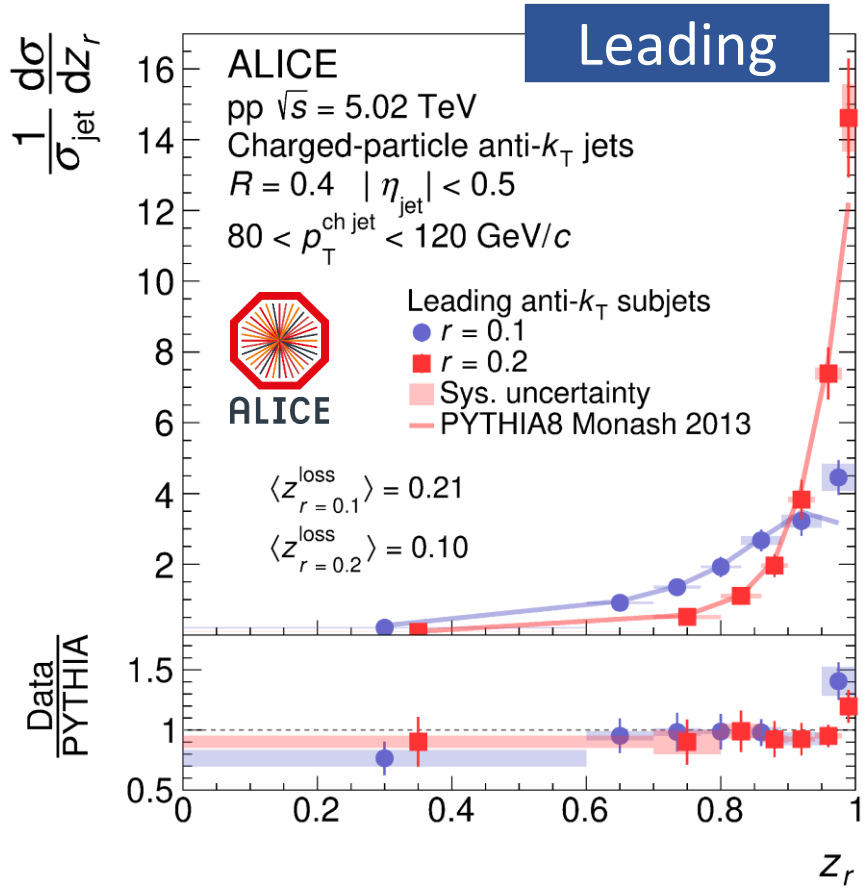
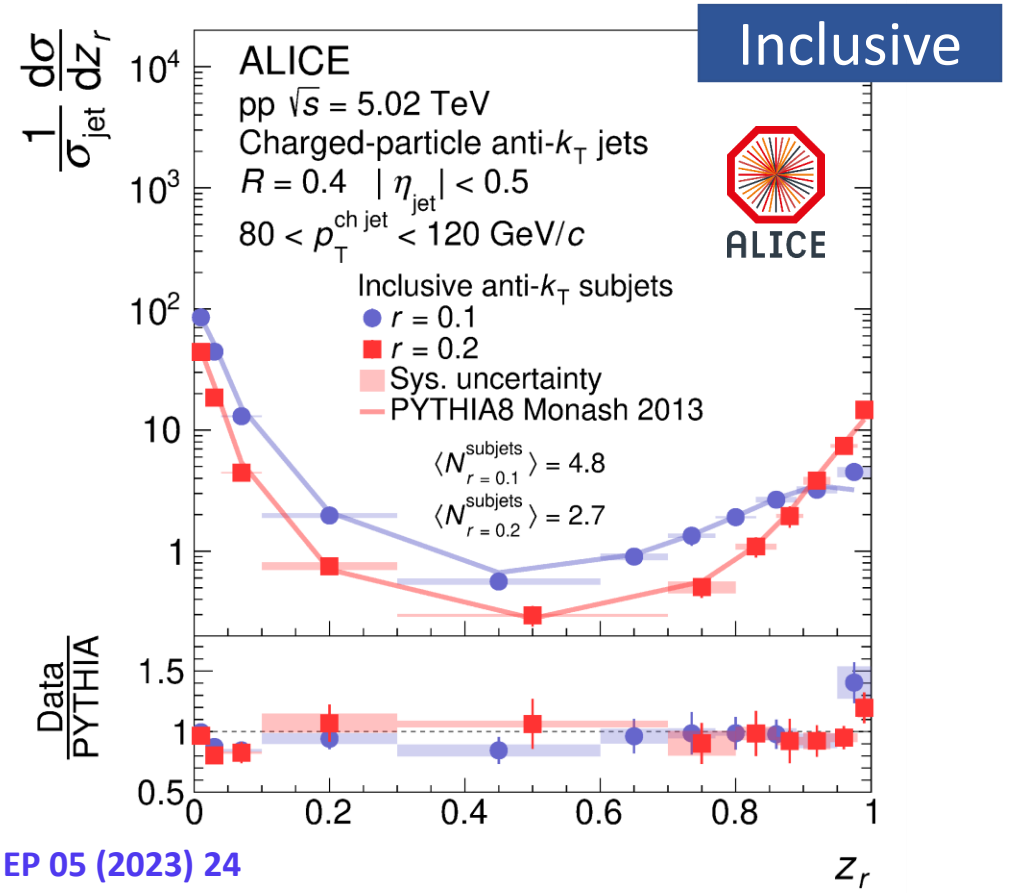




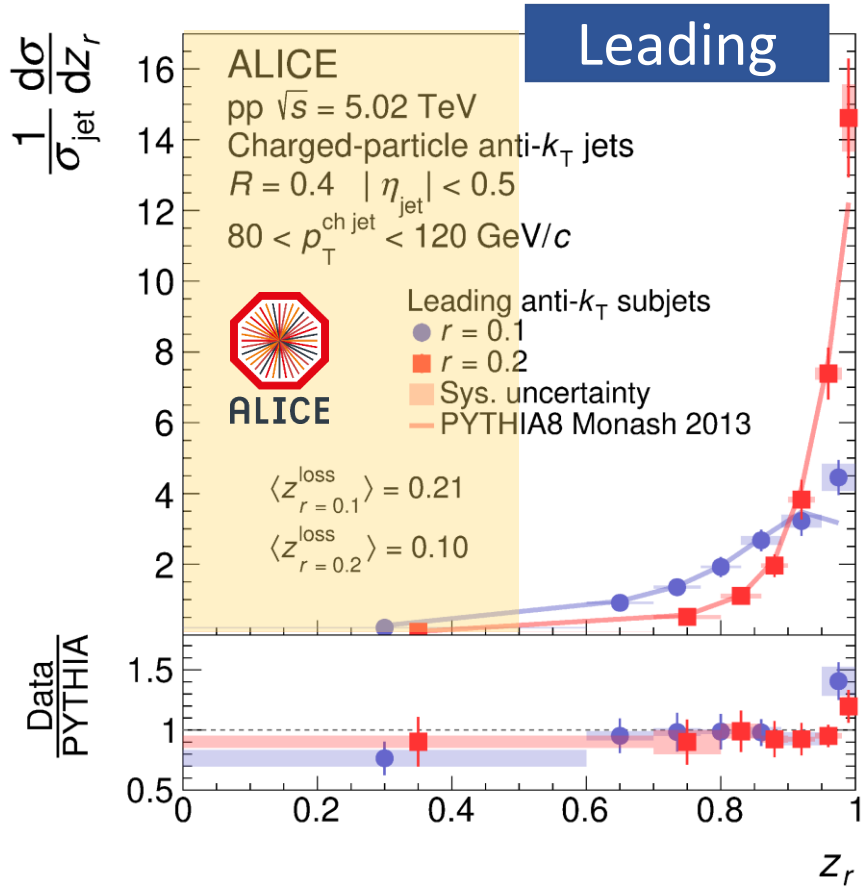
ALICE, JHEP 05 (2023) 24

- For z_r > 0.5, leading and inclusive subjet distributions are identical
- As z_r becomes small,
  - Inclusive subjet distribution grows due to soft radiations emitted from leading subjet

Inclusive and leading subjet fragmentation in pp collisions

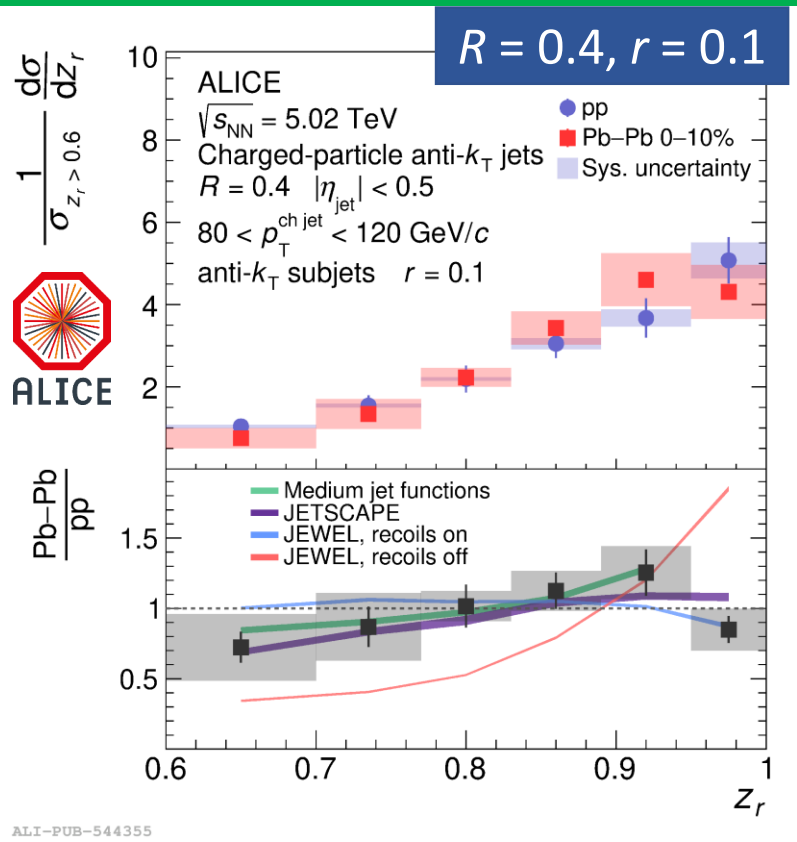


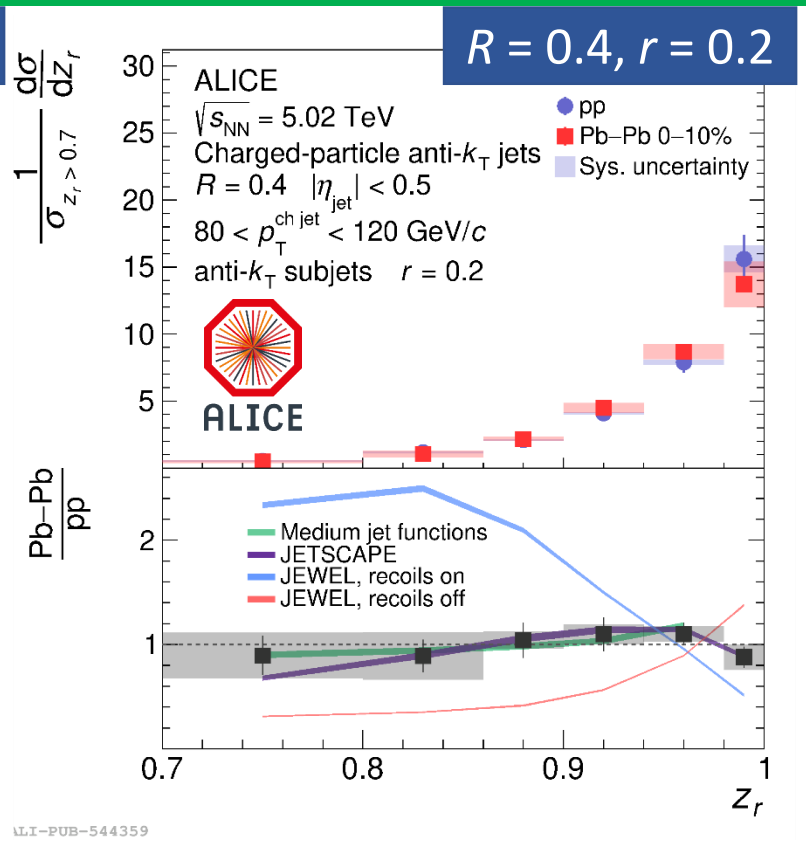
ALICE, JHEP 05 (2023) 24



- For $z_r > 0.5$, leading and inclusive subjet distributions are identical
- As z_r becomes small,
  - Inclusive subjet distribution grows due to soft radiations emitted from leading subjet
  - Leading subjet distribution falls to zero

Leading subjet fragmentation in heavy-ion collisions

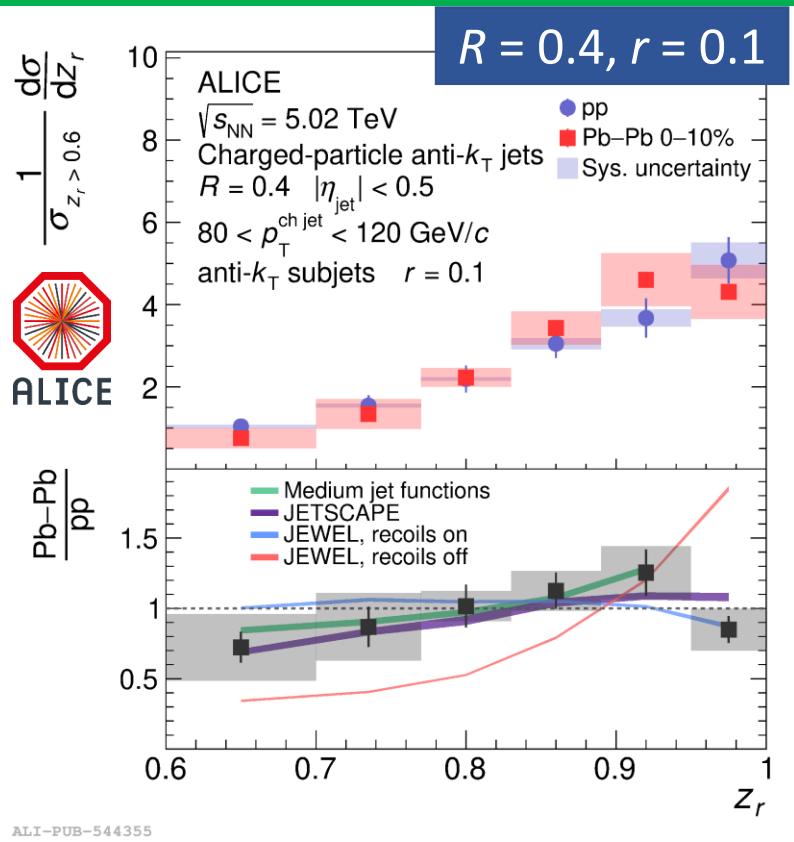


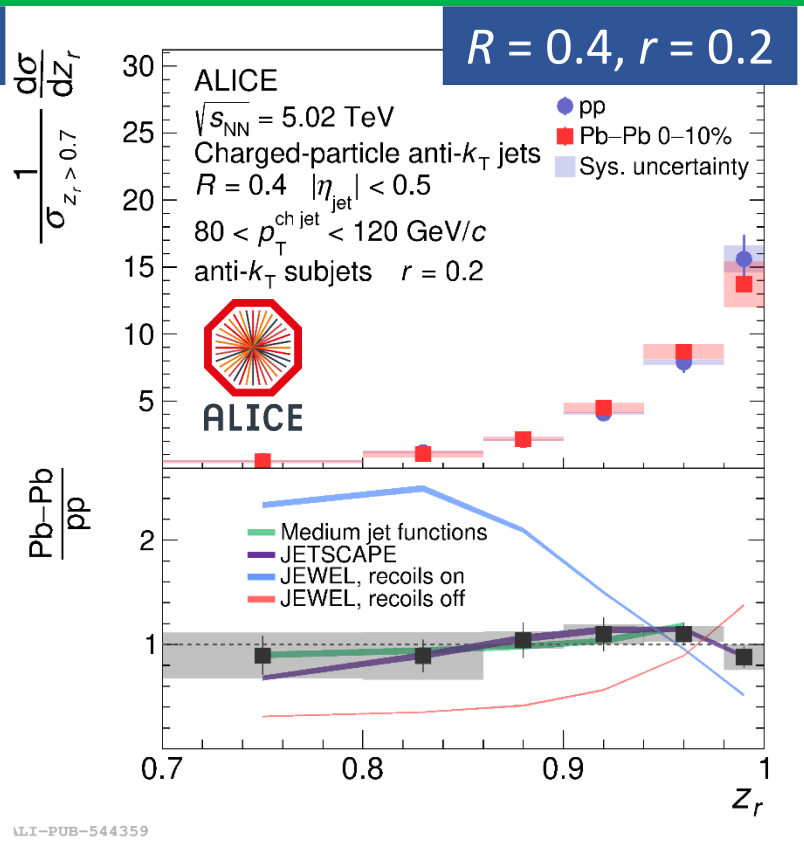


ALICE, JHEP 05 (2023) 24

- **No modification of z_r distribution** in central Pb-Pb compared to pp collisions within uncertainties

Leading subjet fragmentation in heavy-ion collisions

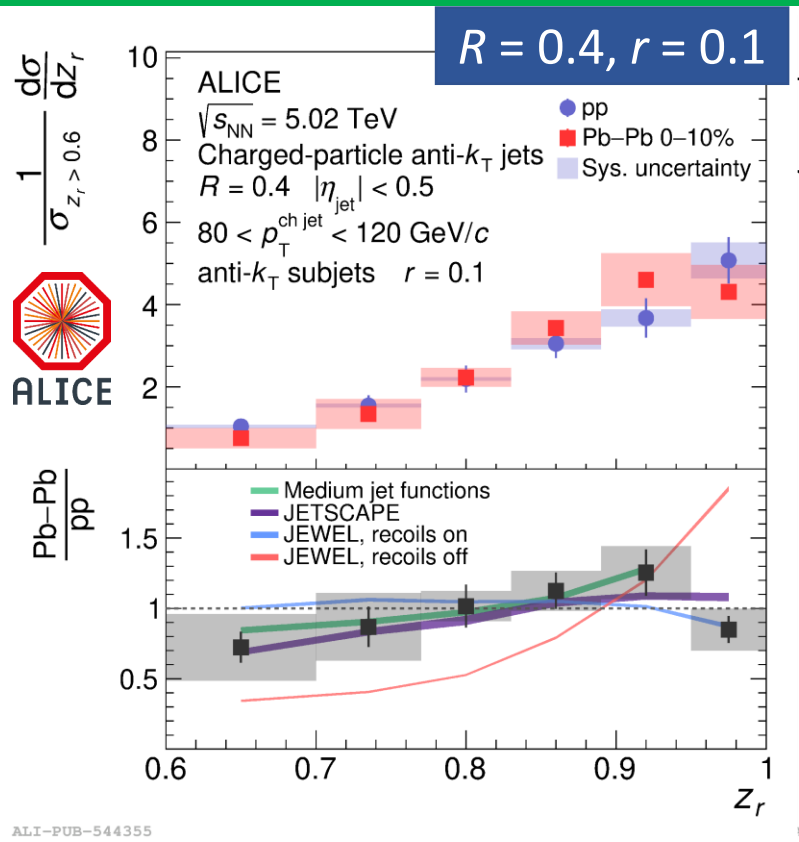


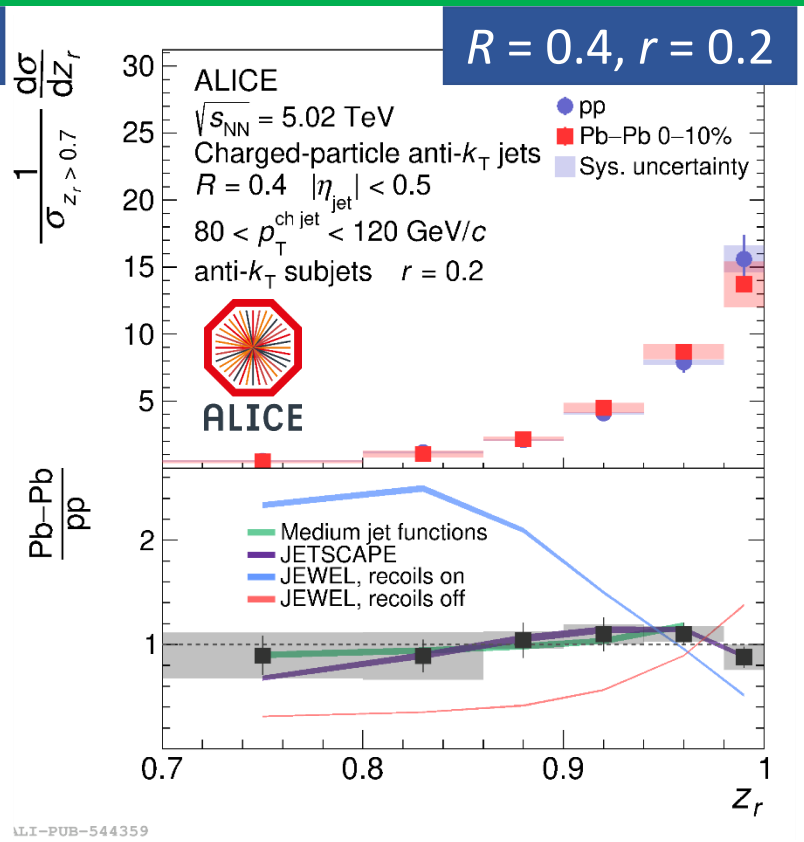


- **No modification of z_r distribution** in central Pb-Pb compared to pp collisions within uncertainties
- Quenched jets at **larger z_r (region of quark-dominated jets)** are narrower in JEWEL and JETSCAPE than in data

ALICE, JHEP 05 (2023) 24

Leading subjet fragmentation in heavy-ion collisions





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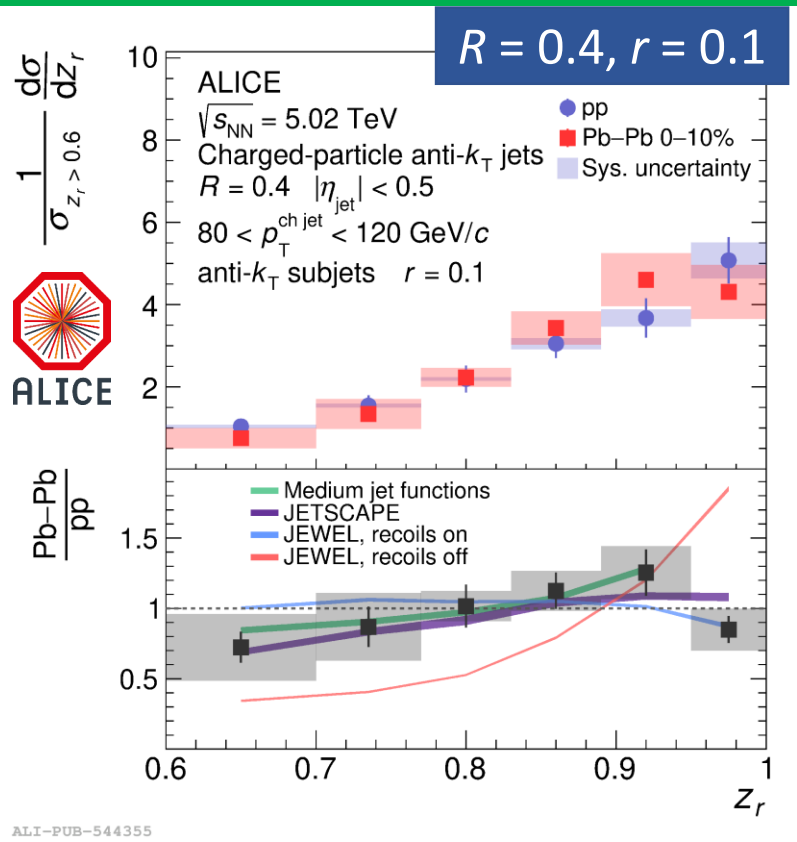
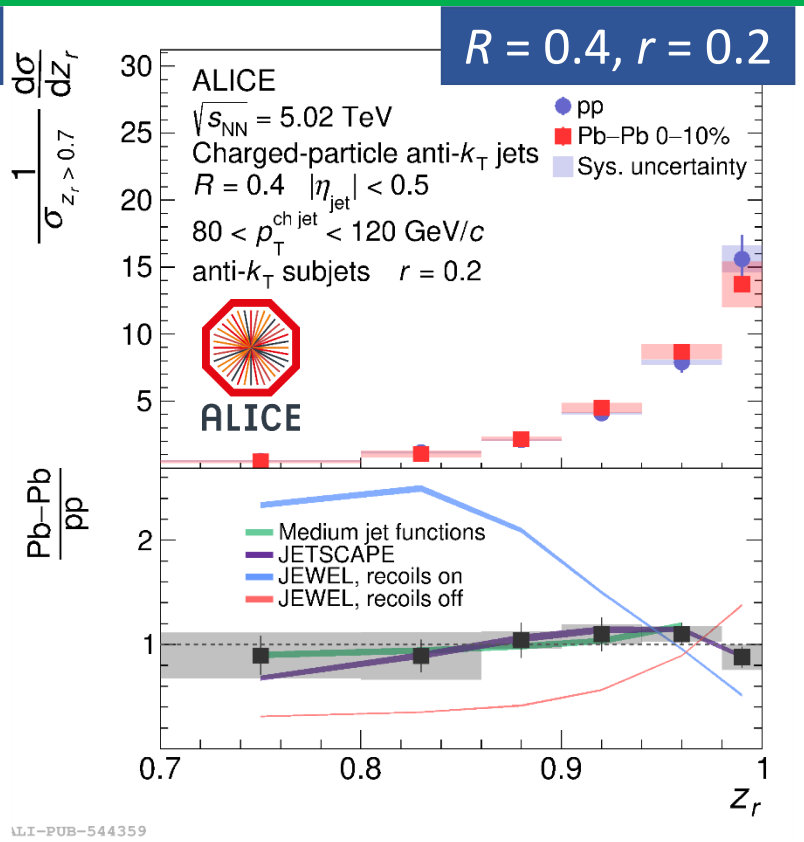
Hint of hardening effects in Pb-Pb

ALICE, JHEP 05 (2023) 24

Leading subjet fragmentation in heavy-ion collisions





ALICE, JHEP 05 (2023) 24

- **No modification of z_r distribution** in central Pb-Pb compared to pp collisions within uncertainties
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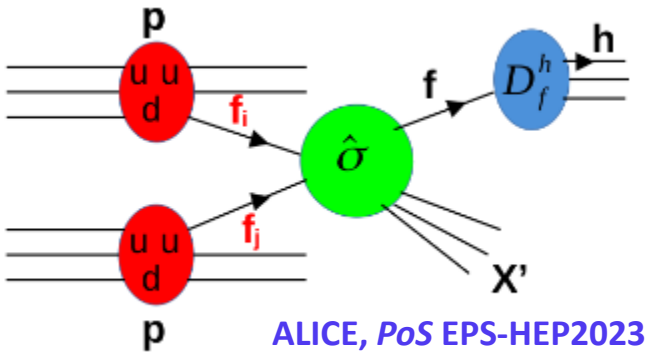
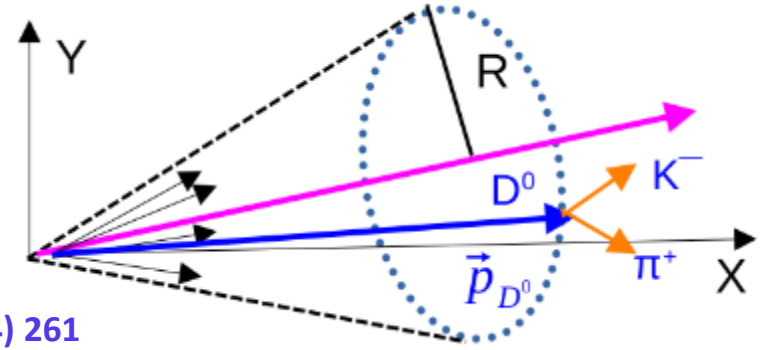
Hint of hardening effects in Pb-Pb

The **large-z_r region,** although theoretically challenging even in pp, is interesting to study jet modification in heavy-ion collisions

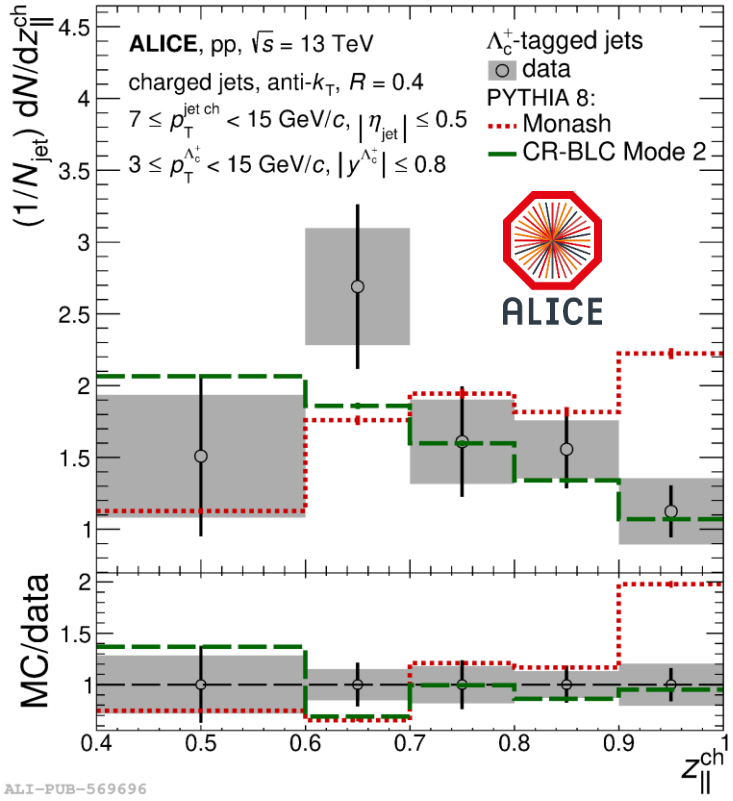
Fragmentation of Λ_c^+- and D^0-tagged jets





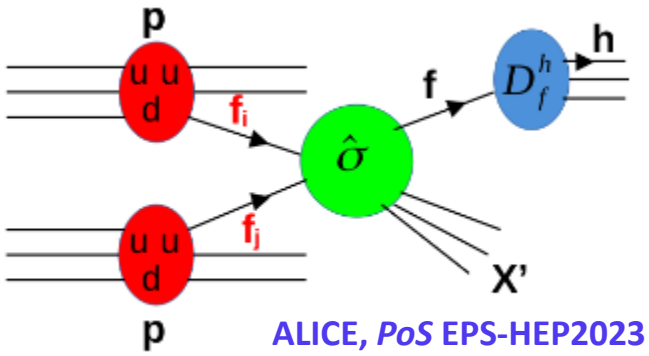
$$z_{\parallel}^{\mathrm{ch}} = \frac{\vec{p}_{\mathrm{ch\ jet}} \cdot \vec{p}_{\mathrm{H_Q}}}{\vec{p}_{\mathrm{ch\ jet}} \cdot \vec{p}_{\mathrm{ch\ jet}}}$$

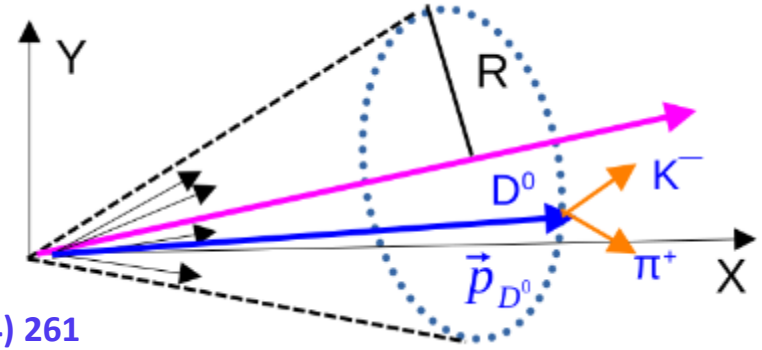
ALICE, *PoS* EPS-HEP2023 (2024) 261



ALICE, Phys. Rev. D 109 (2024) 072005

Fragmentation of Λ_c^+- and D^0-tagged jets





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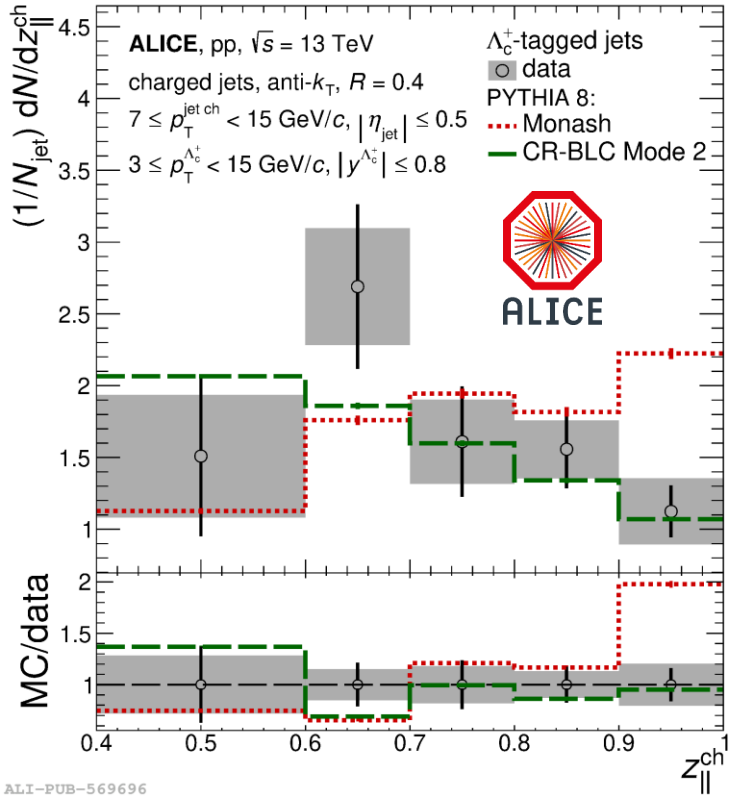
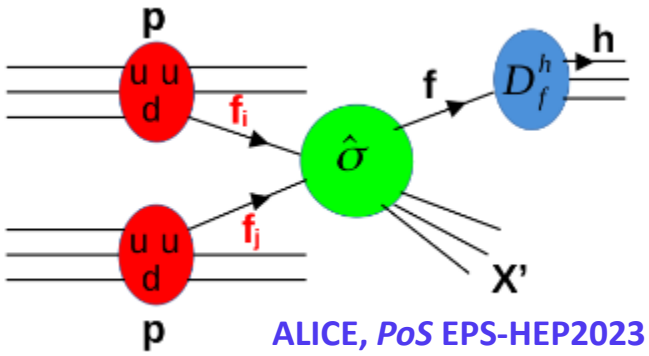
ALICE, *PoS* EPS-HEP2023 (2024) 261

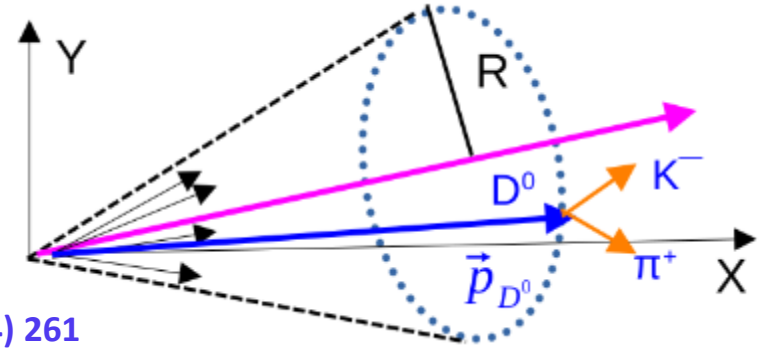


Data shows better agreement with **CR-BLC** than **Monash** tune of PYTHIA 8

ALICE, Phys. Rev. D 109 (2024) 072005

Fragmentation of Λ_c^+- and D^0-tagged jets





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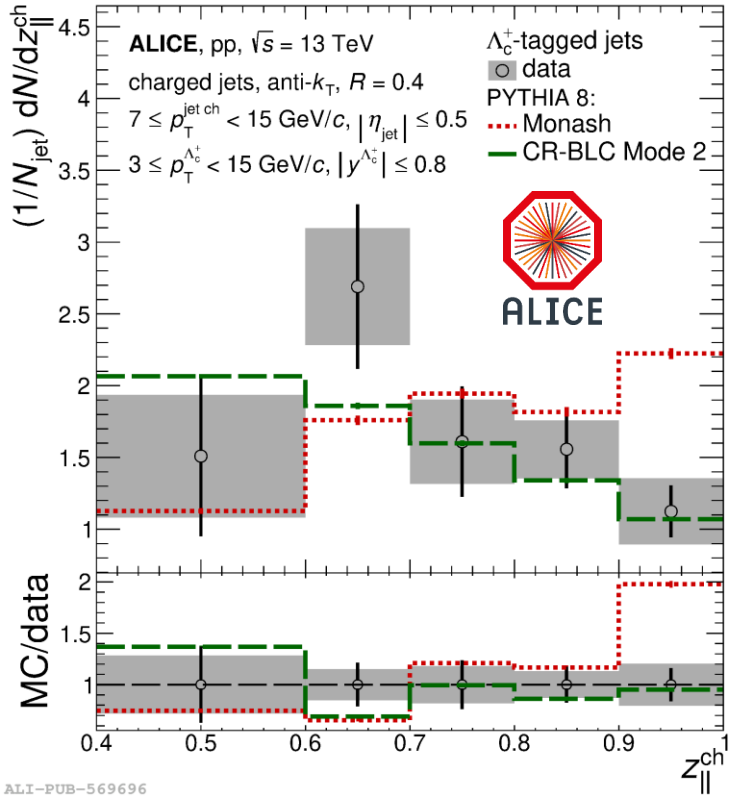
ALICE, *PoS* EPS-HEP2023 (2024) 261



Data shows better agreement with **CR-BLC** than **Monash** tune of PYTHIA 8

PYTHIA 8 Monash ⟷ Data ⟷ PYTHIA 8 CR-BLC

Includes **leading-color formalism of hadronisation**

Includes **color reconnection beyond leading-color approximation** (mechanisms sensitive to surrounding particle density)

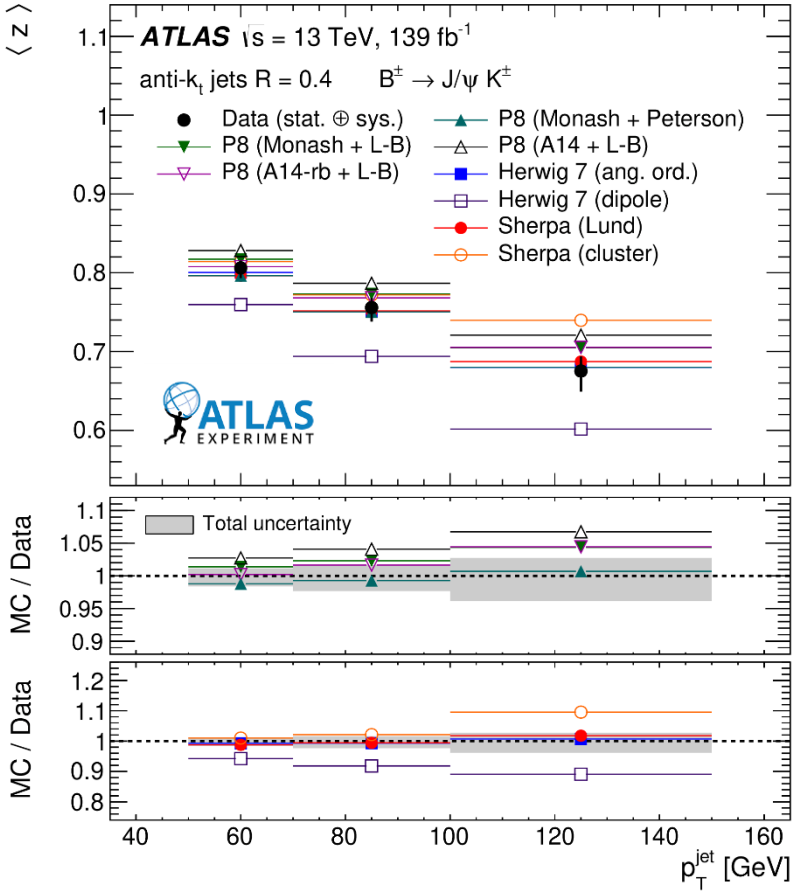
ALICE, Phys. Rev. D 109 (2024) 072005

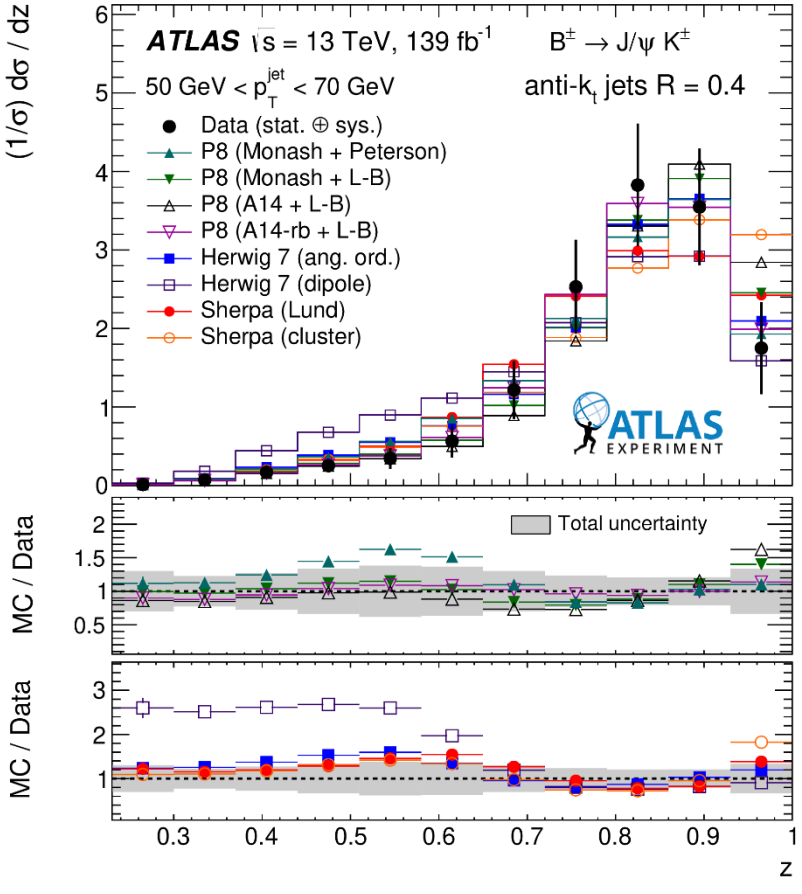
Fragmentation of b-jets

- High jet p_T → lower $\langle z \rangle$

Gluon splittings, $g \rightarrow b\bar{b}$, occur with a larger probability at high values of jet p_T

Angle-ordered parton shower provides a better description of data than dipole-based parton shower





ATLAS, JHEP 12 (2021) 131

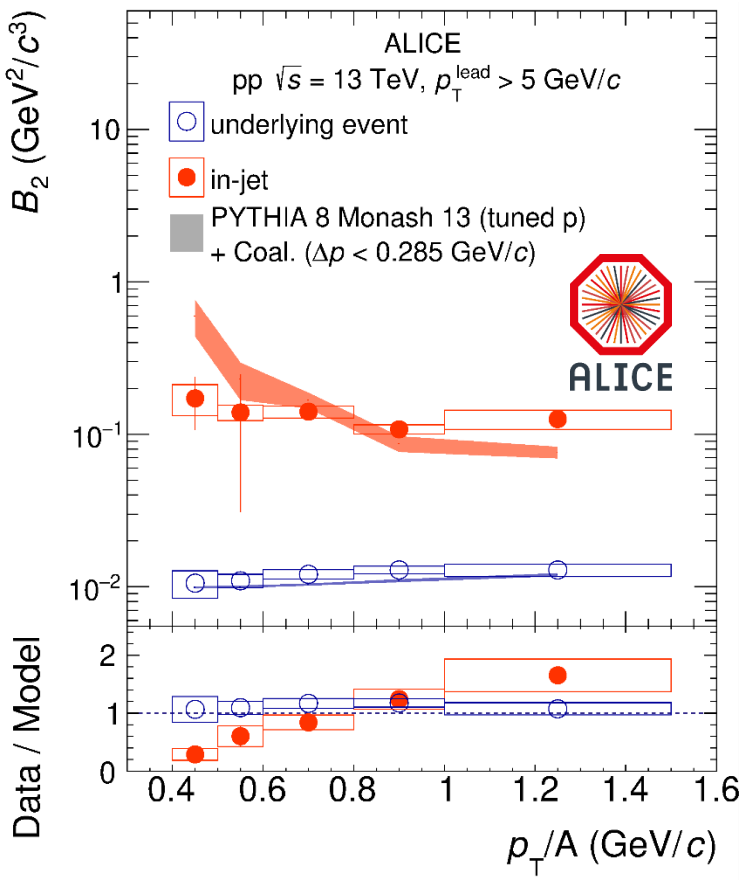
More on b-jets from E. Lusiani, June 4, 2:00 PM

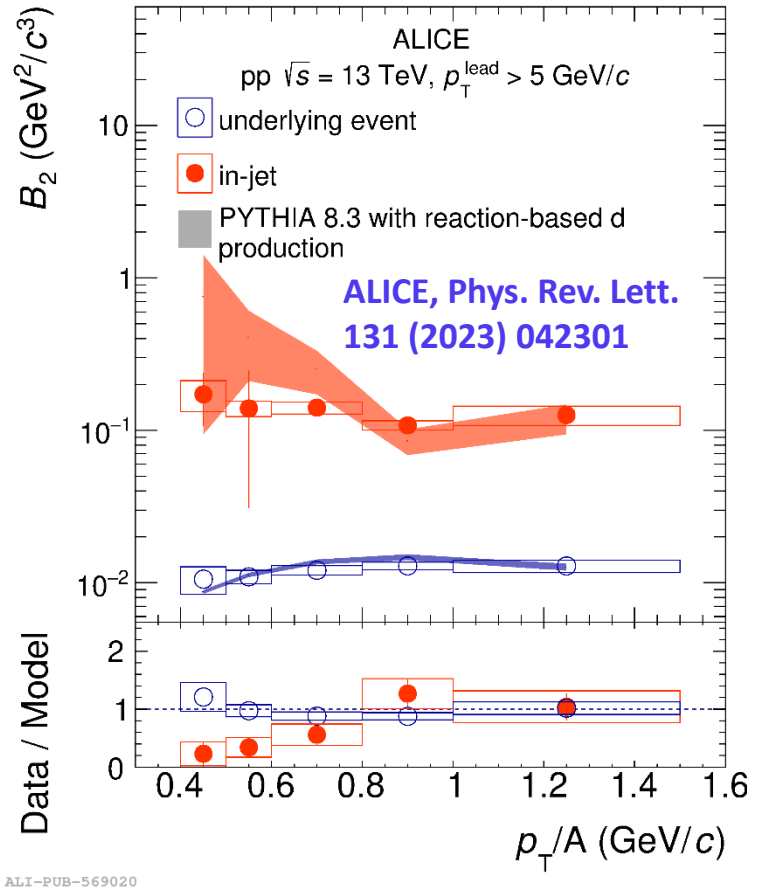
Enhanced deuteron coalescence probability in jets

- Measurements of light (anti)nuclei production in and out of jets may provide important input for the estimates of the background of (anti)nuclei in indirect dark matter searches
- Hadrons in jet cone are closer in phase space than those out of the jets, resulting in larger coalescence probability in jets
- The coalescence probability for deuterons can be quantified by the coalescence parameter B_2:

$$B_2 = \left(\frac{3}{2\pi p_{\mathrm{T}}^{\mathrm{d}}}\frac{d^2N_{\mathrm{d}}}{dydp_{\mathrm{T}}^{\mathrm{d}}}\right)/\left(\frac{3}{2\pi p_{\mathrm{T}}^{\mathrm{p}}}\frac{d^2N_{\mathrm{p}}}{dydp_{\mathrm{T}}^{\mathrm{p}}}\right)$$

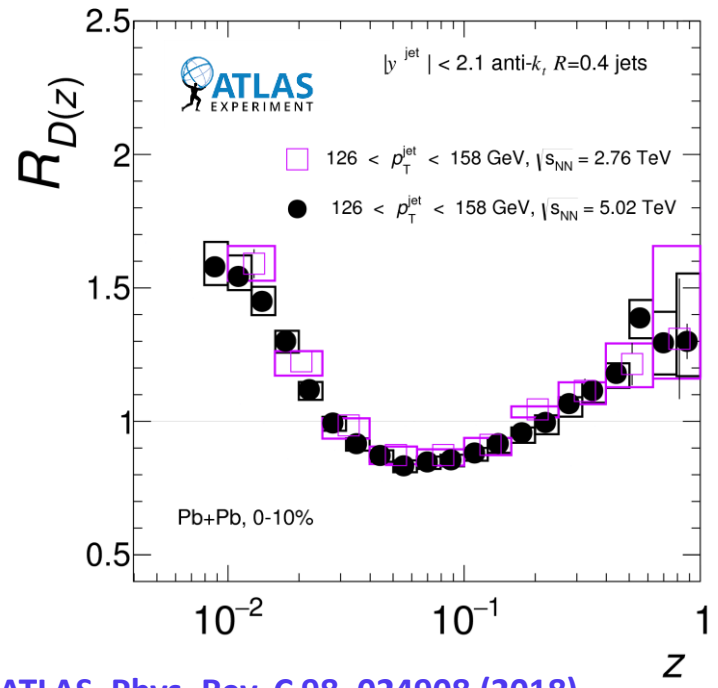
where the labels d and p indicate deuteron and proton, respectively



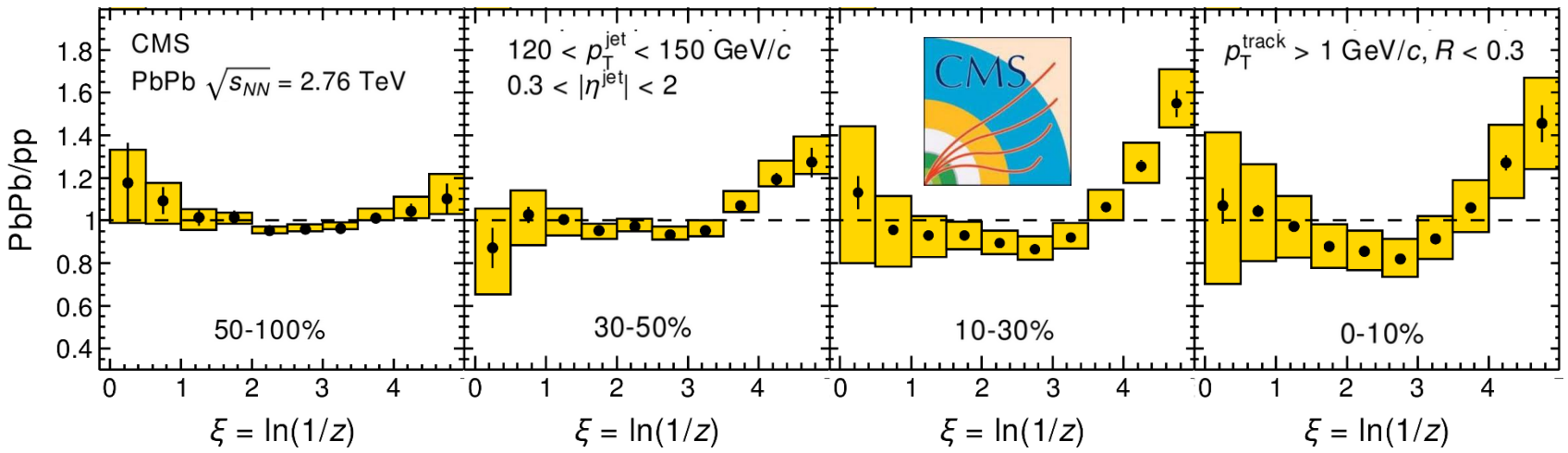


- Enhancement of deuteron coalescence probability in jets is observed compared to underlying events, by a factor ~10
- Decisively proves the formation of bound states by coalescence when nucleons have a smaller average phase-space distance, as in jet cone
- Further investigations of coalescence parameters will provide useful insights into the production mechanisms of (anti)nuclei in our galaxy and help to constrain the coalescence models

Jet fragmentation in heavy-ion collisions



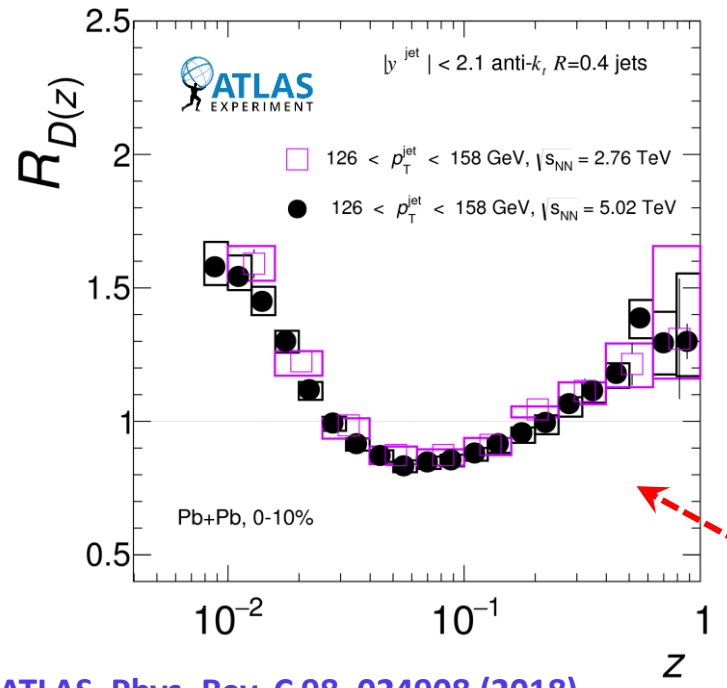
ATLAS, Phys. Rev. C 98, 024908 (2018)



CMS, Phys. Rev. C 90 (2014) 024908

- Modification of z and ξ in heavy-ion collisions

Jet fragmentation in heavy-ion collisions



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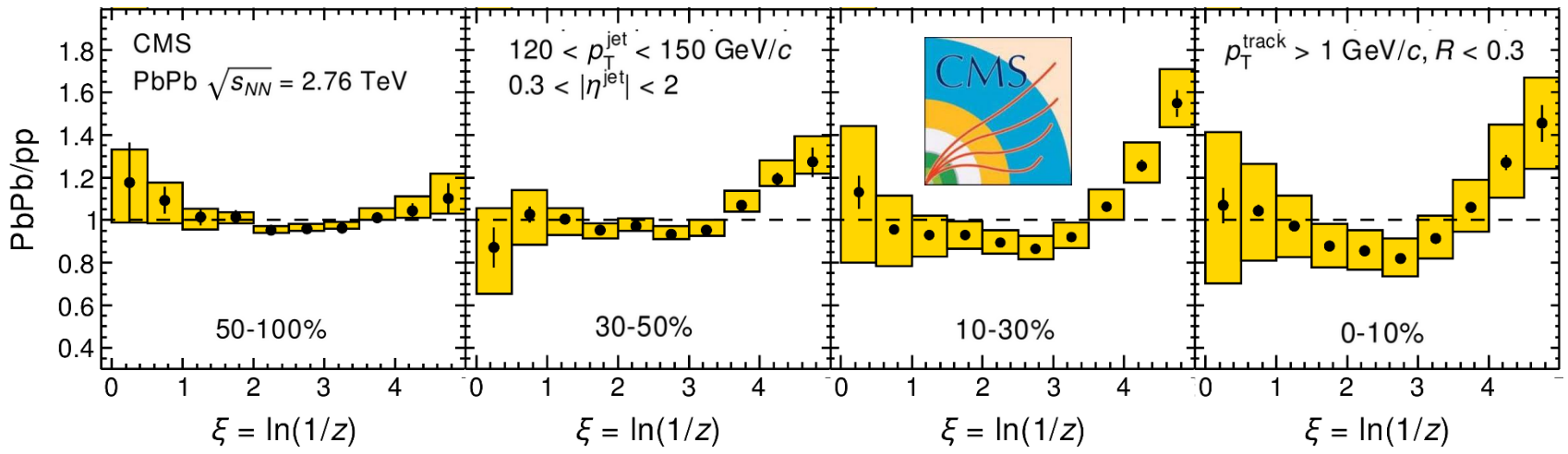
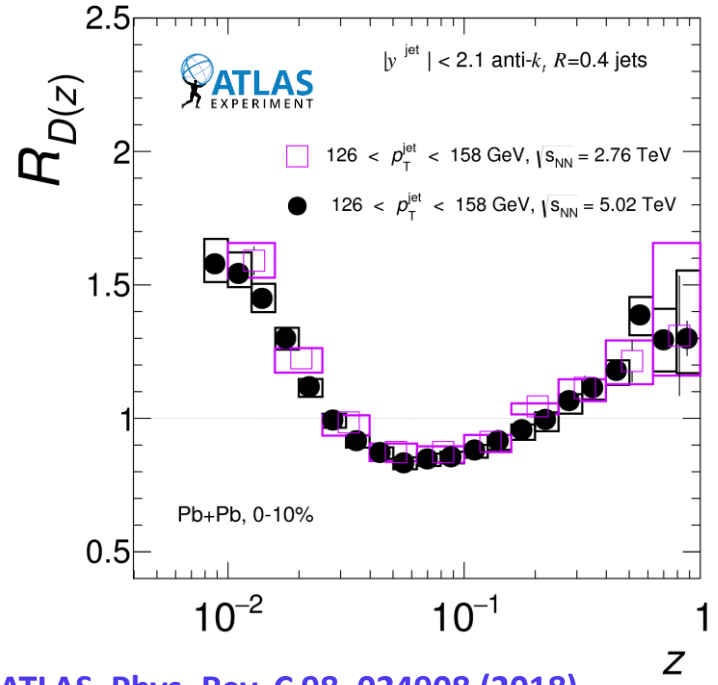


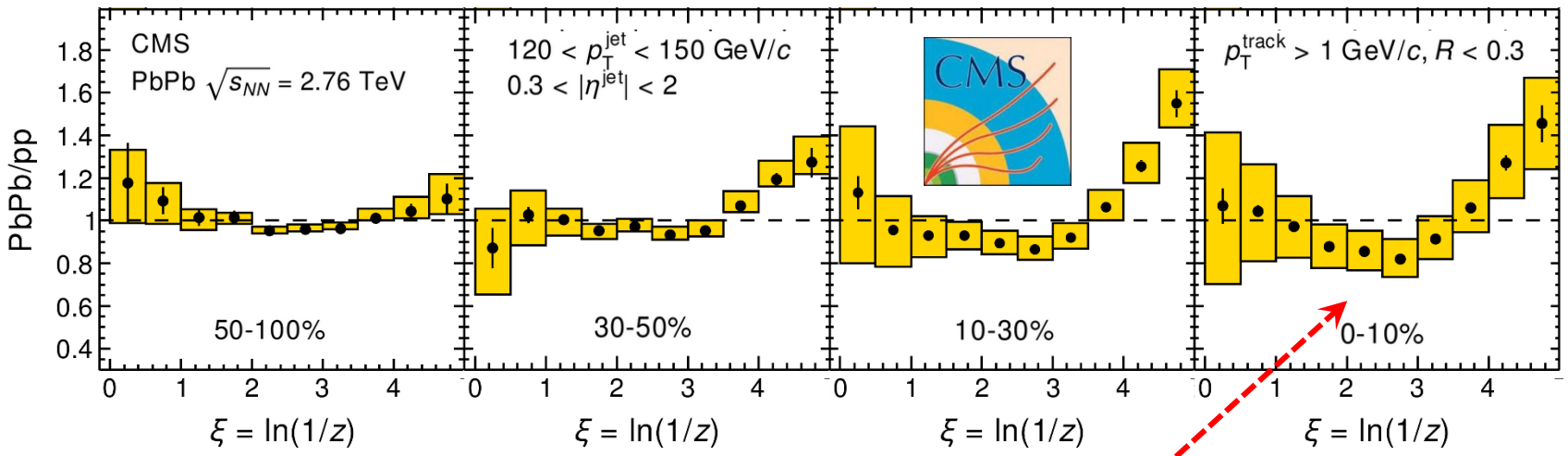
CMS, Phys. Rev. C 90 (2014) 024908

- Modification of z and ξ in heavy-ion collisions
- Enhancement at low and high z, suppression at intermediate z

Jet fragmentation in heavy-ion collisions



ATLAS, Phys. Rev. C 98, 024908 (2018)



CMS, Phys. Rev. C 90 (2014) 024908

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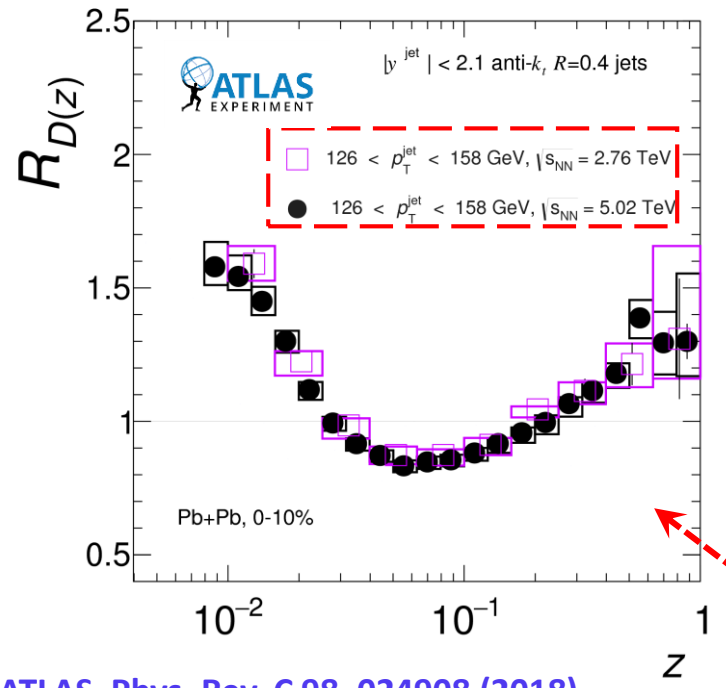
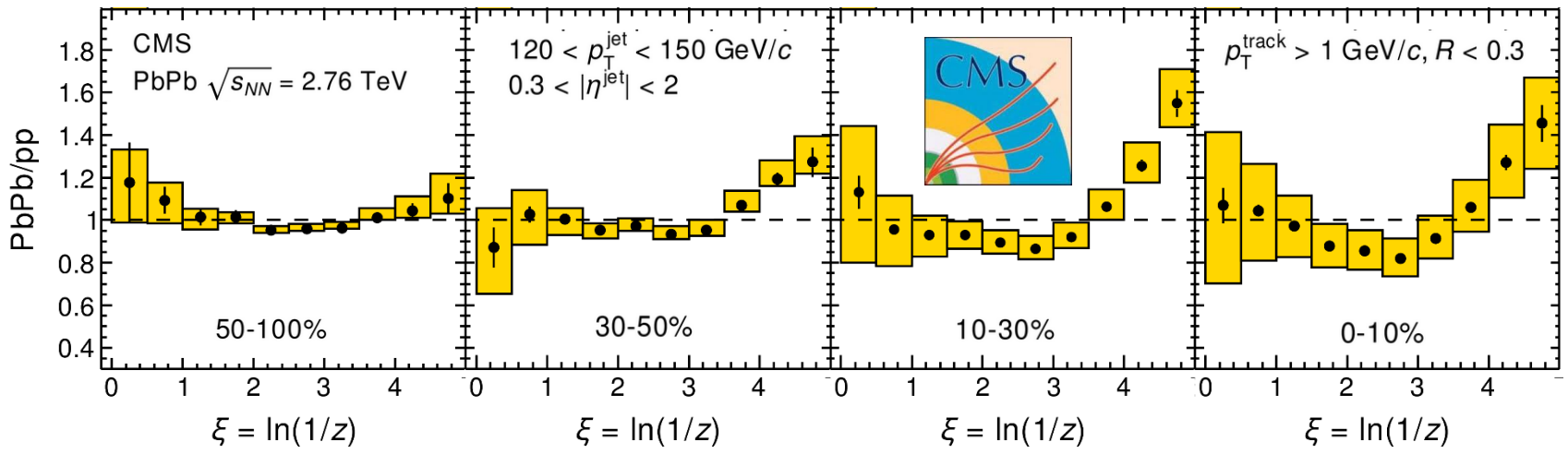
- Enhancement at low and high z, suppression at intermediate z
- Enhancement at high ξ, suppression at intermediate ξ

Jet fragmentation in heavy-ion collisions



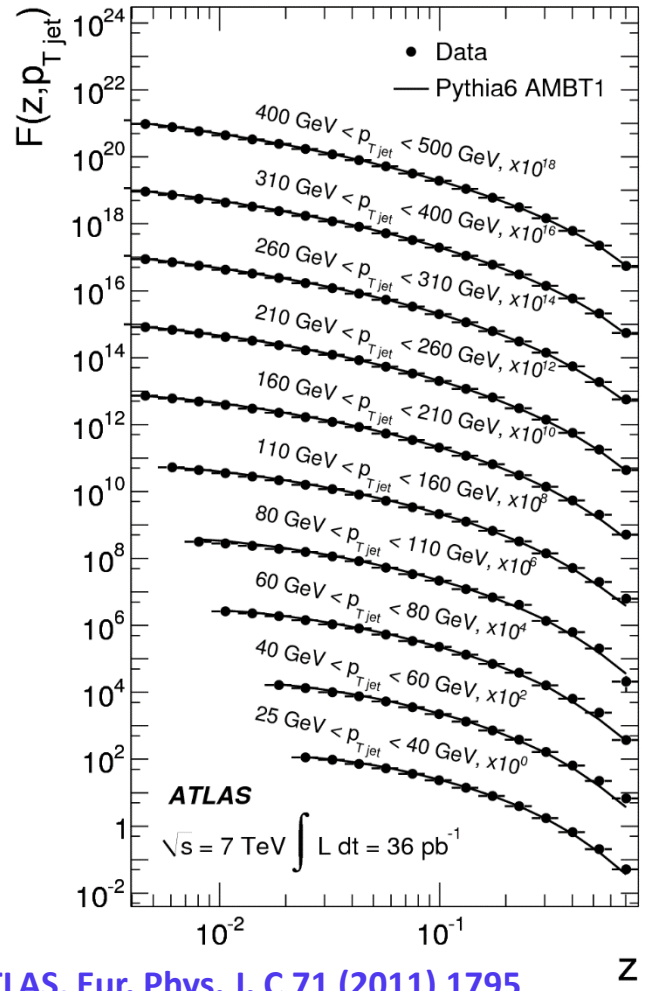
ATLAS, Phys. Rev. C 98, 024908 (2018)



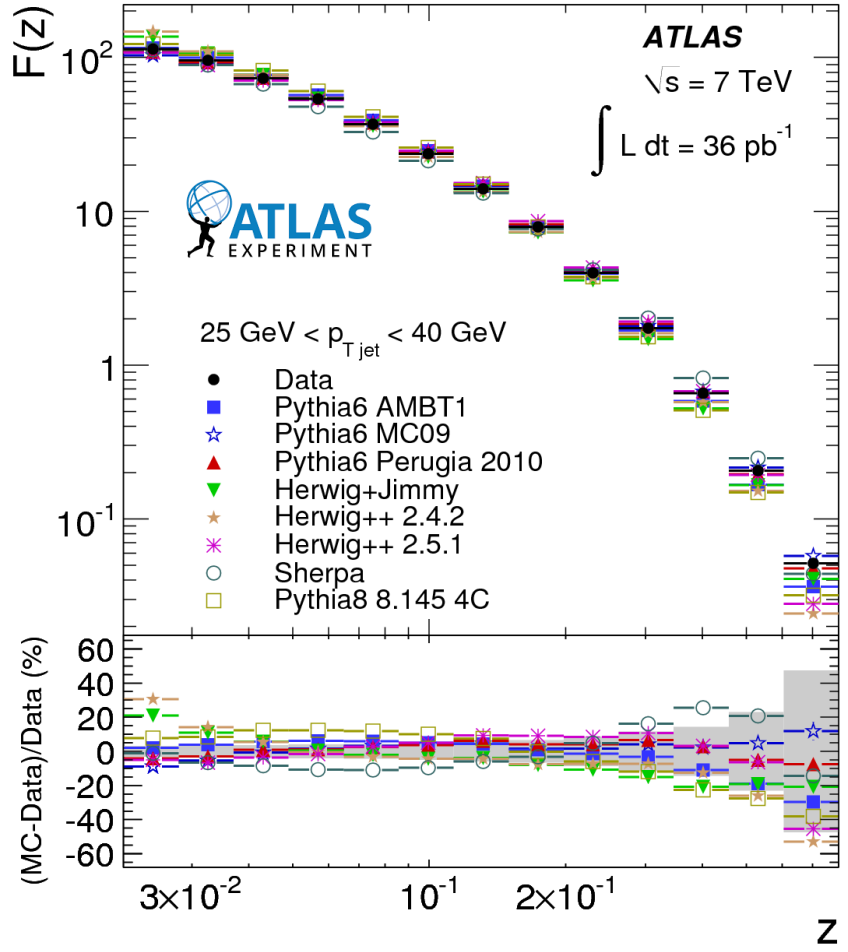
CMS, Phys. Rev. C 90 (2014) 024908

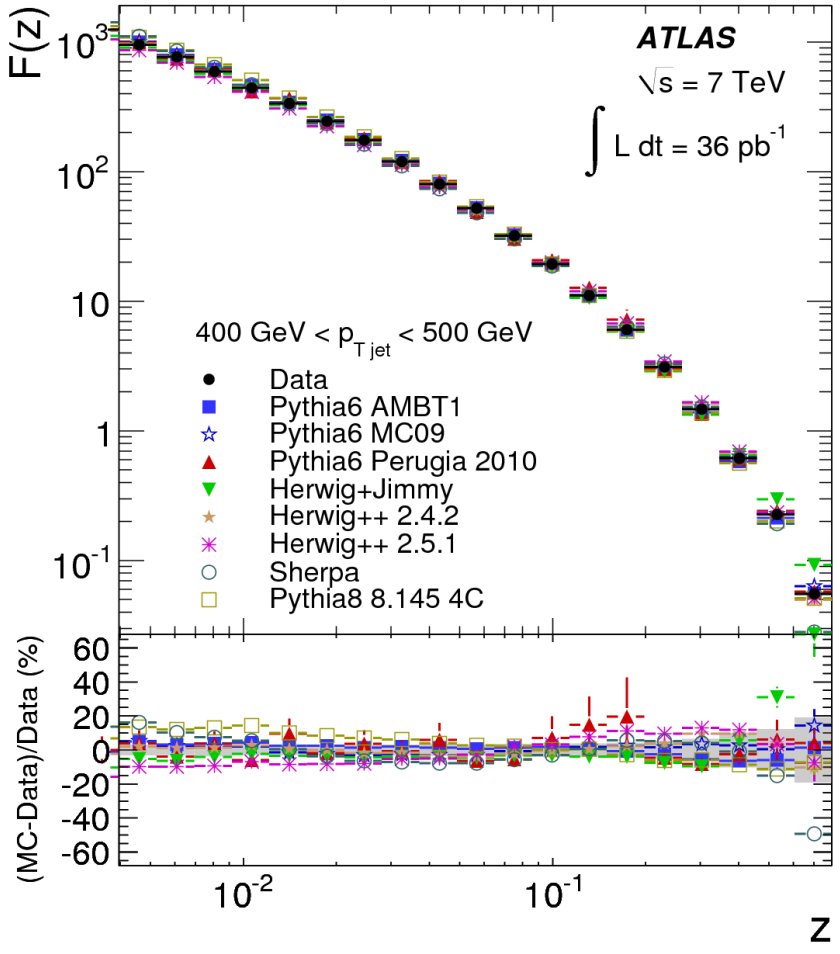
- Modification of z and ξ in heavy-ion collisions
- Enhancement at low and high z, suppression at intermediate z
- Enhancement at high ξ, suppression at intermediate ξ
- Modification of z distribution independent of collision energy (at TeV energy scale)

Jet fragmentation: z



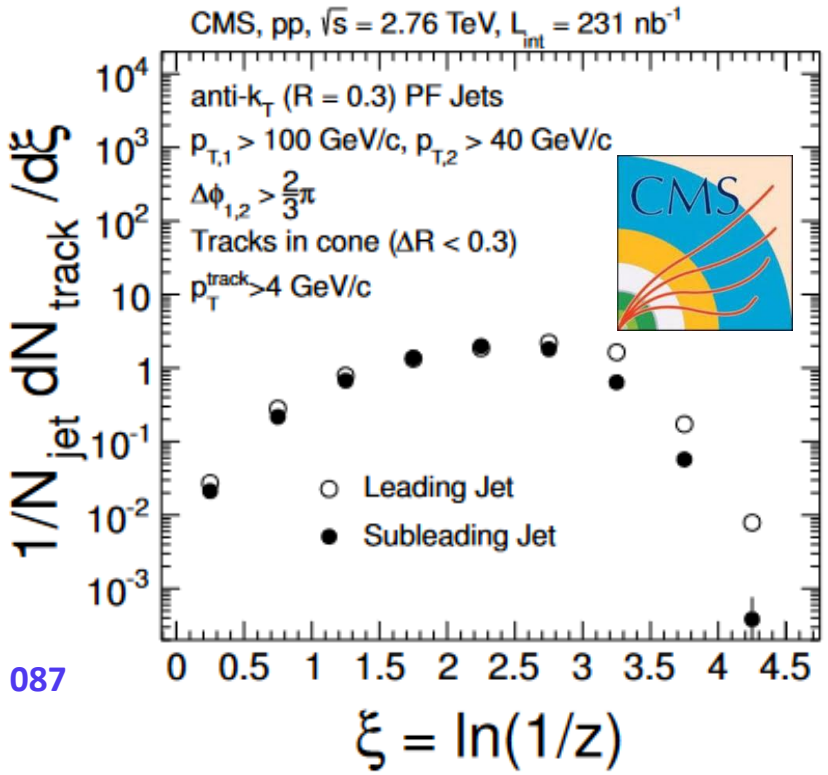
ATLAS, Eur. Phys. J. C 71 (2011) 1795



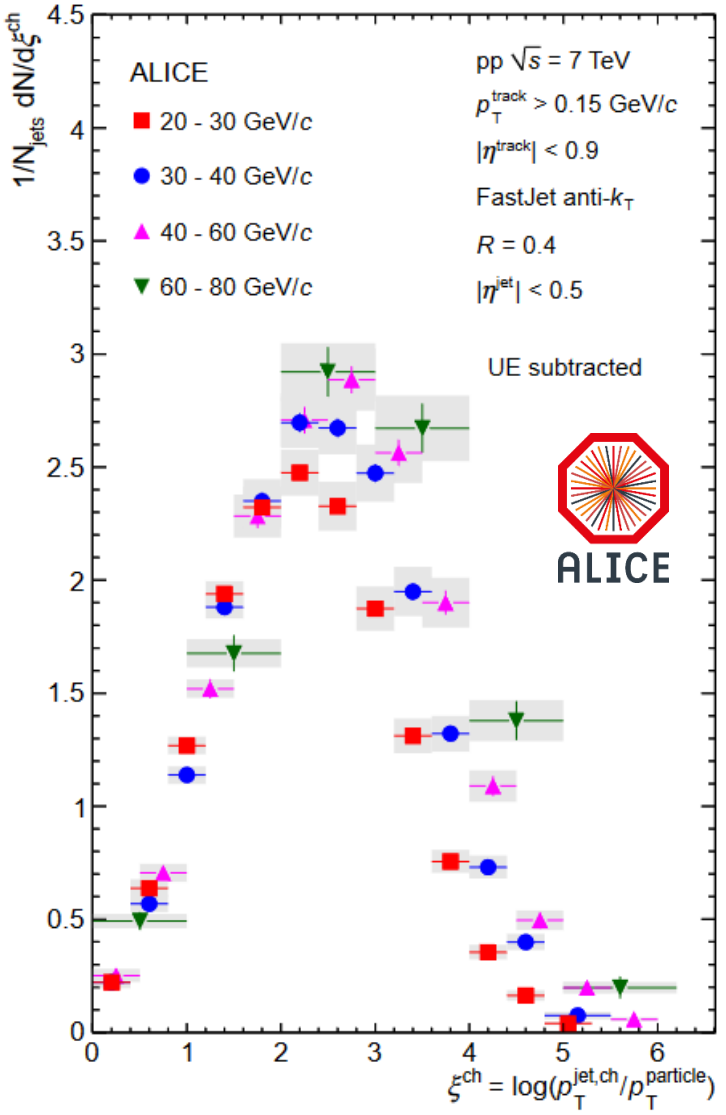


- Jet fragmentation for inclusive jets
- All the P YTHIA 6 tunings show good agreement with data
- Different tunes of Herwig show discrepancies with data
- PYTHIA 8 and Sherpa provide a poor description of data

Jet fragmentation: ξ



CMS, JHEP10 (2012) 087



ALICE, Phys. Rev. D 91 (2015) 112012

- ξ distribution highlights the low-z region
- Hump-back plateau structure observed
- Suppression of low momentum particle production by QCD coherence