



華中師範大學
CENTRAL CHINA NORMAL UNIVERSITY

Overview of jet measurements with ALICE

Yaxian MAO (毛亚显)

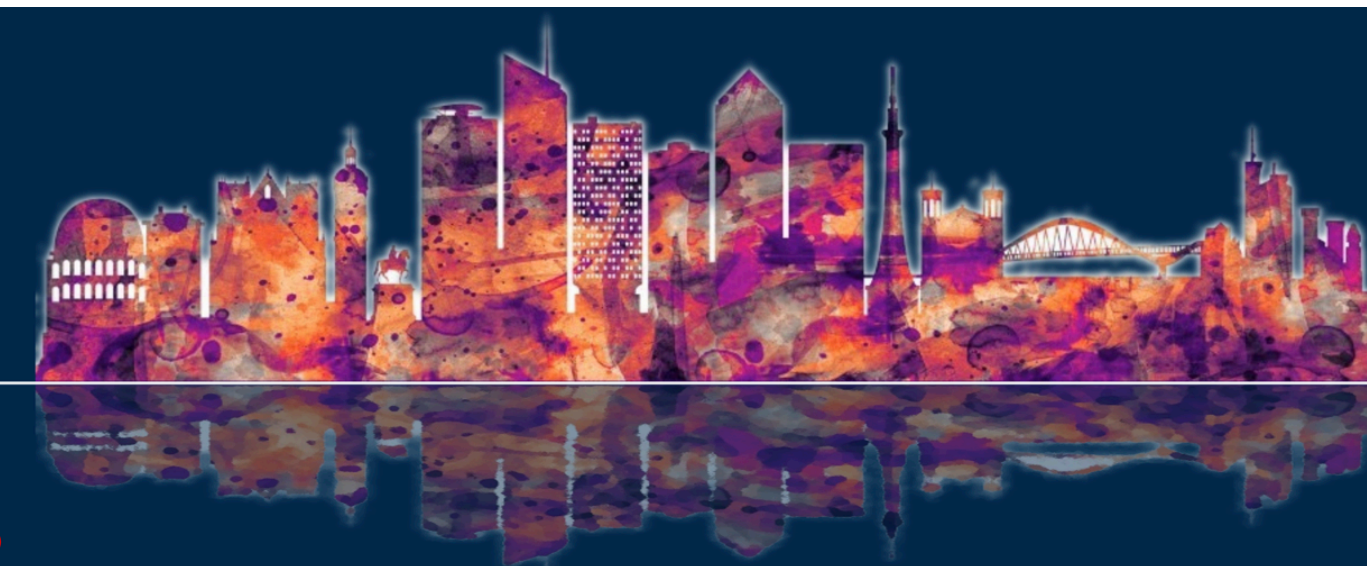
Central China Normal University (华中师范大学)

17th Workshop of the

FCPPN/L

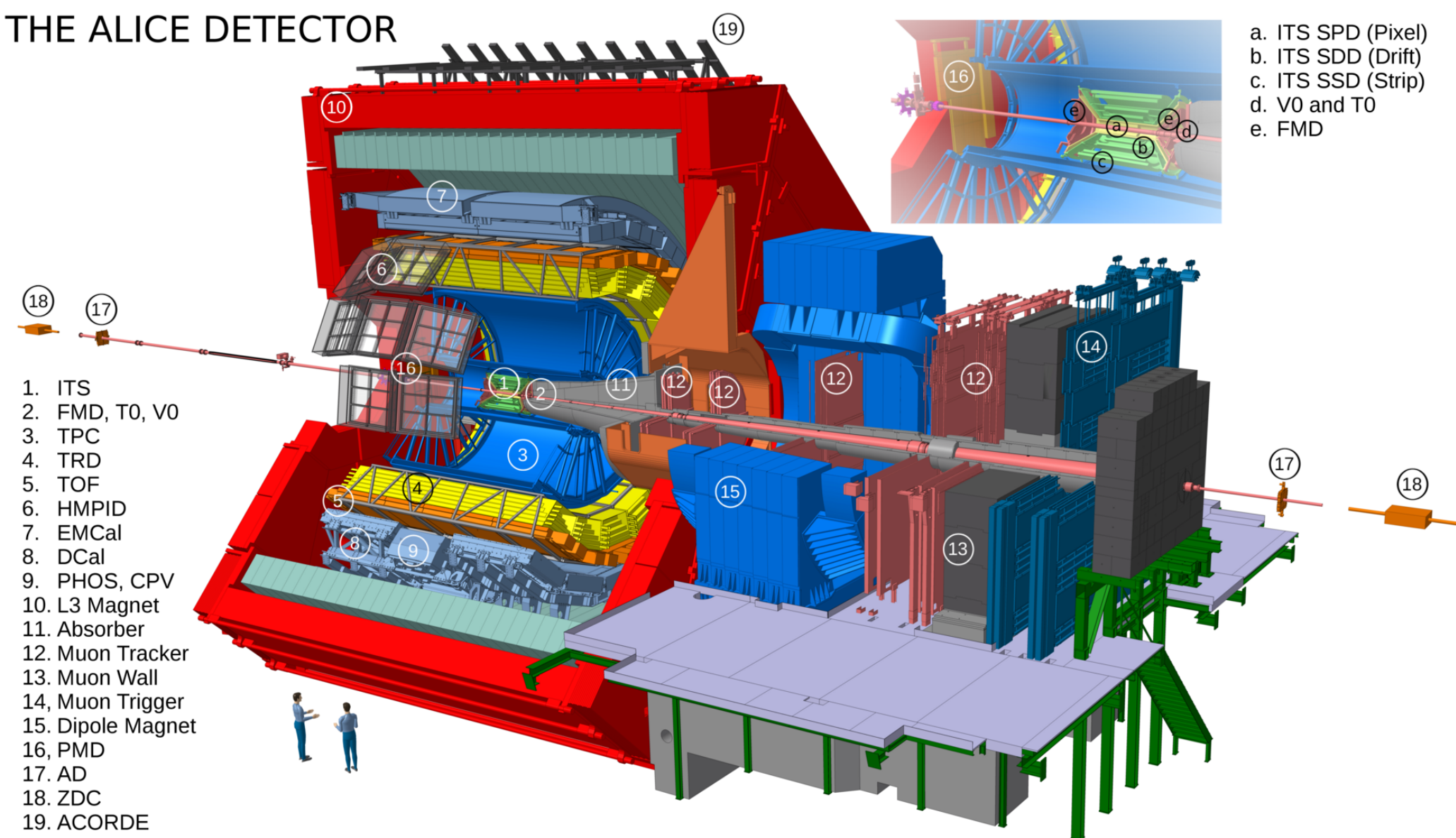
France-China Particle Physics Network and Laboratory

Lyon, France • 29 June – 3 July 2026

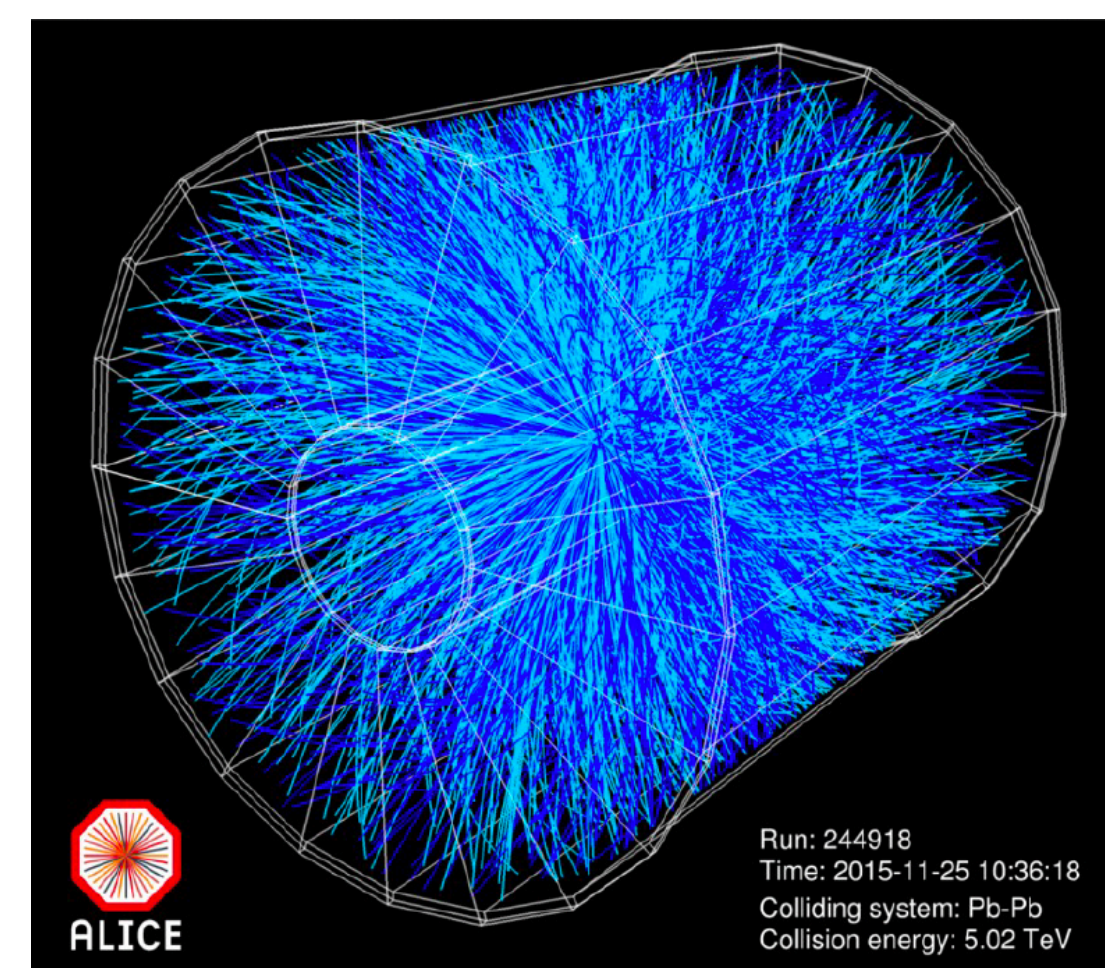


What makes ALICE unique

THE ALICE DETECTOR

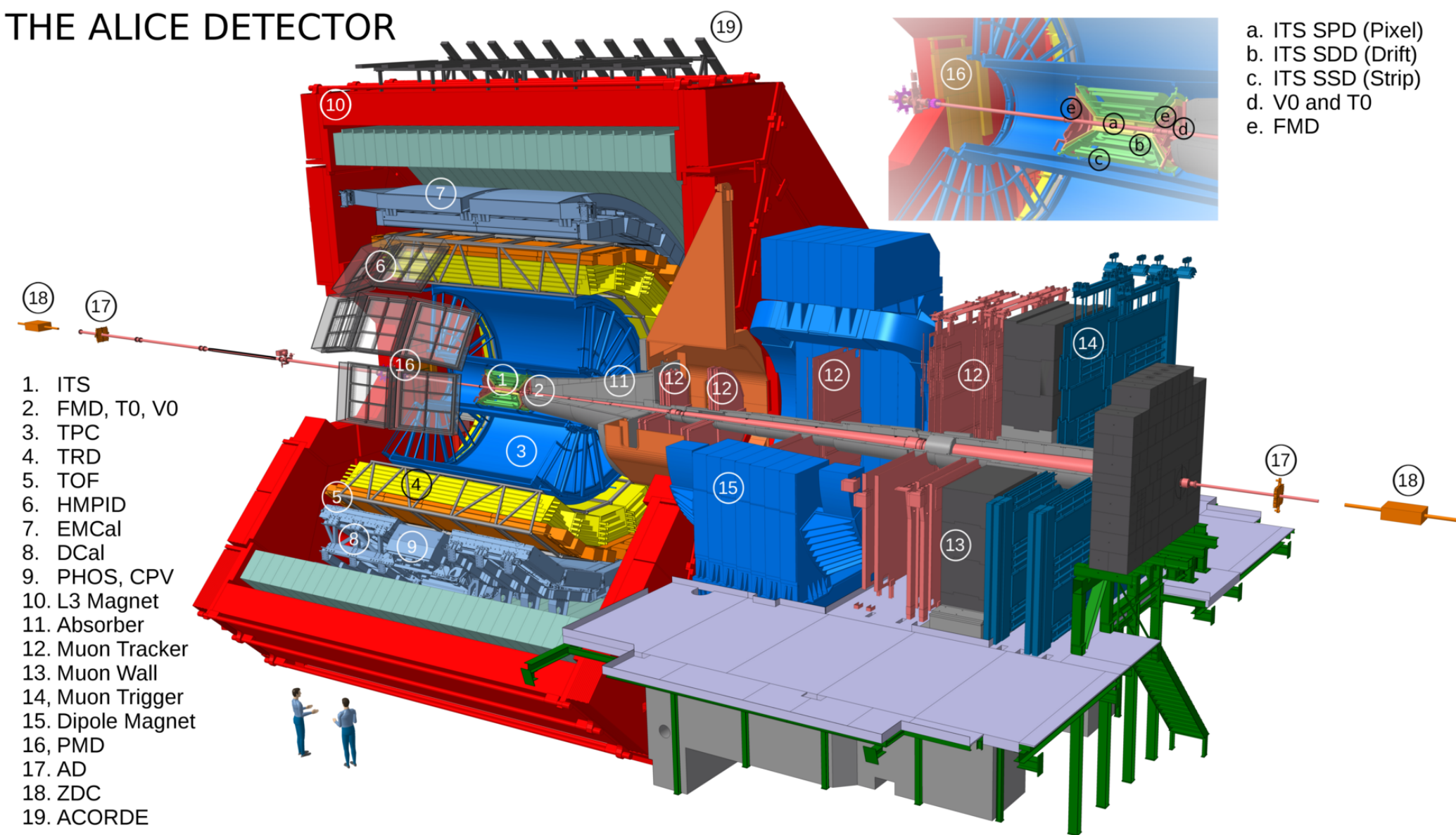


- High precision tracking and PID down to low p_T → access to bulk medium
- Large particle multiplicities → event-by-event analyses
- Sensitivity to heavy flavor, low-mass dileptons, and nuclei → different probes across multiple scales



What makes ALICE unique

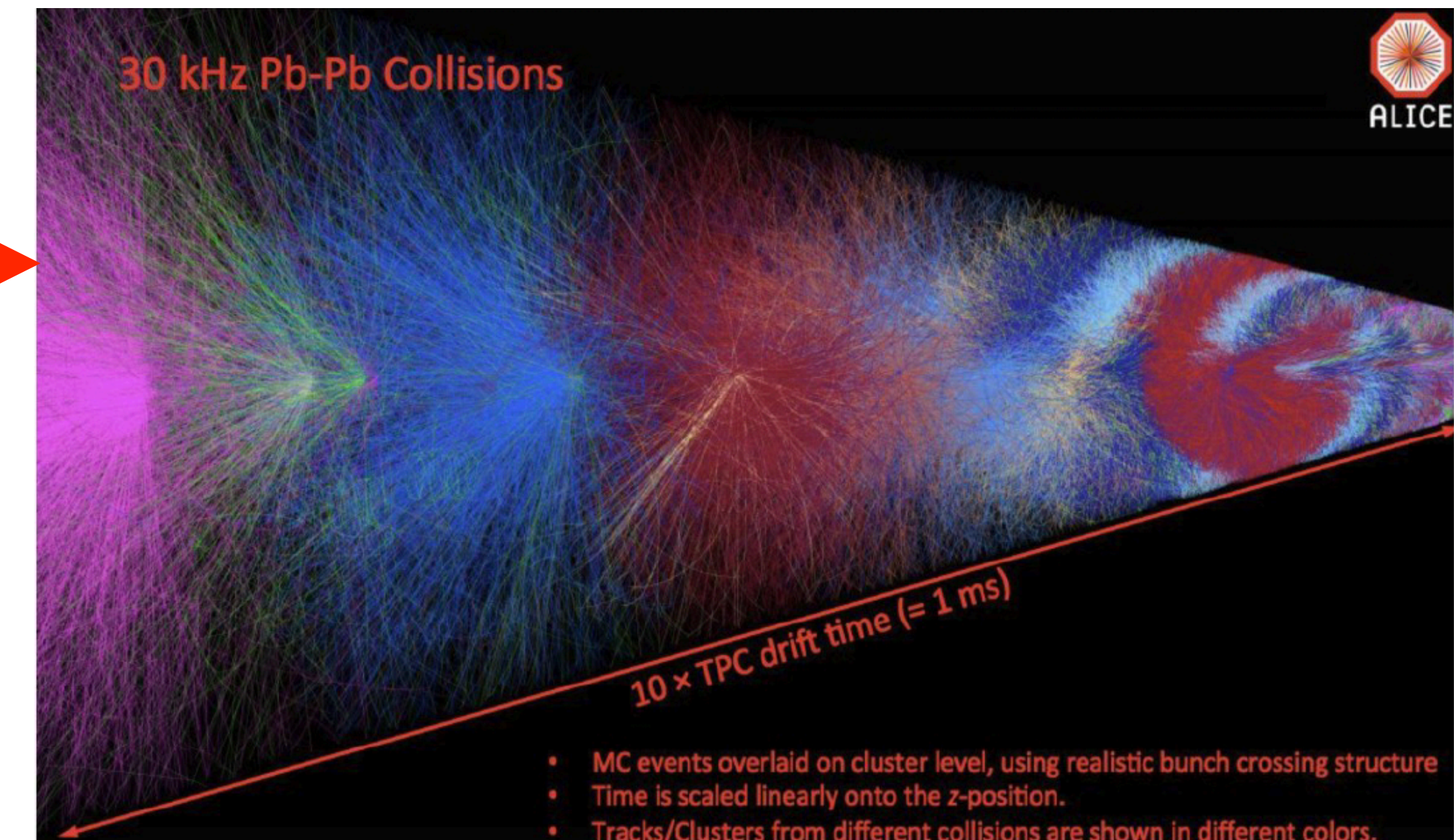
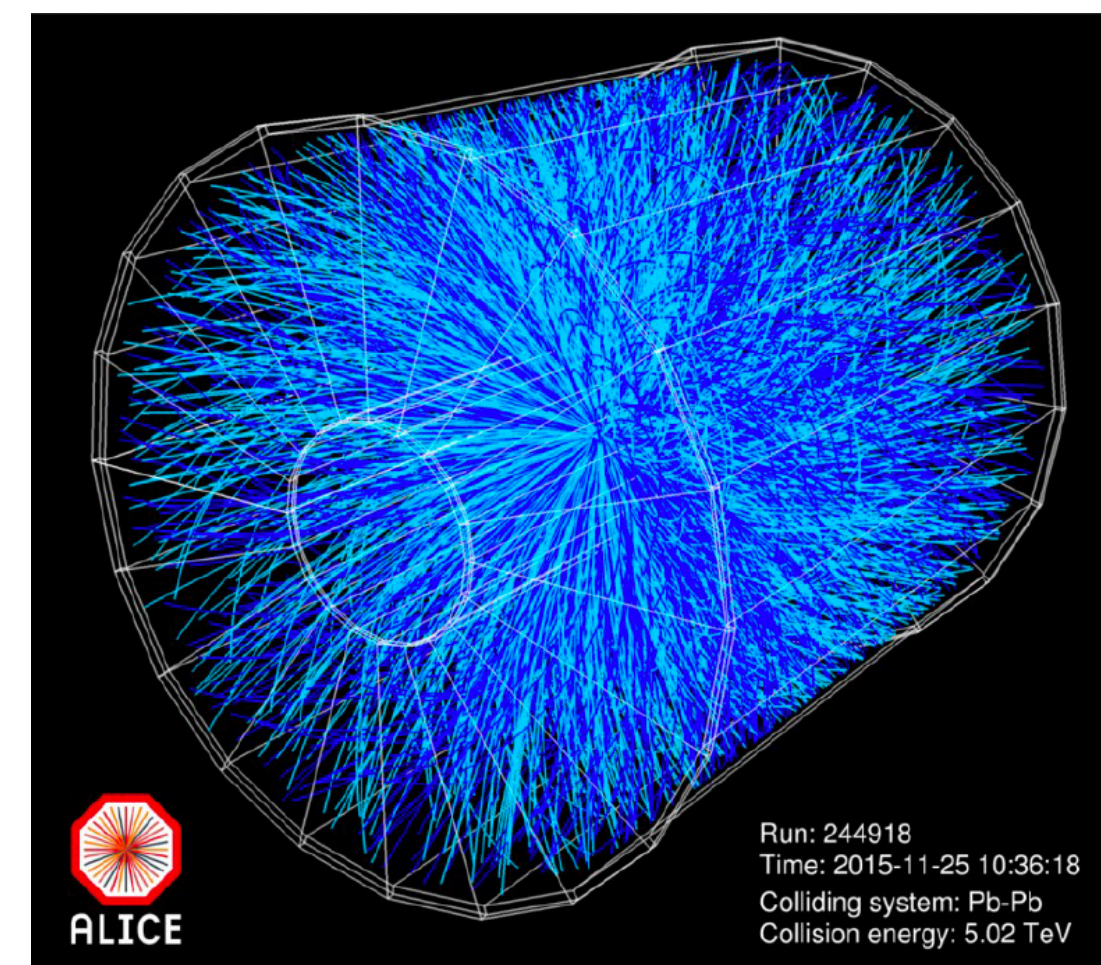
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ALICE upgrade during LS2 (2019-2021)

- Better vertexing + high efficiency at low p_T with ITS2
- Continuous readout $\rightarrow$ more statistics
- Online reconstruction and data compression



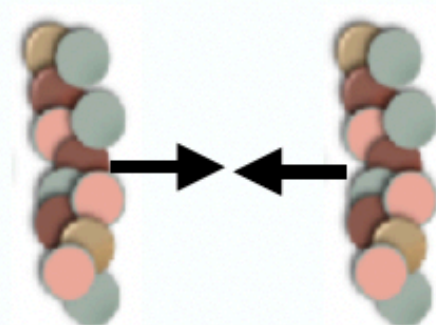
ALICE data taking in Run 3

Continuous readout at high interaction rate → record large data sample

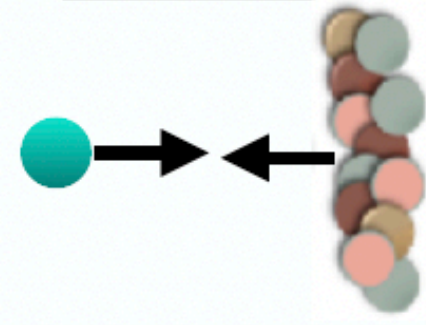
pp @ 13.6 TeV



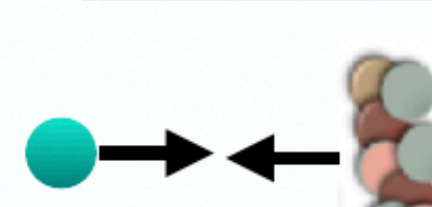
Pb-Pb @ 5.36 TeV



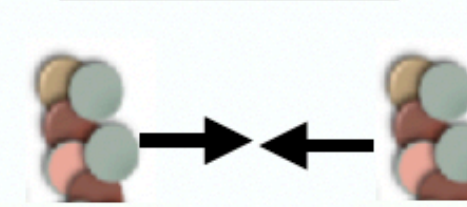
p-Pb/Pb-p



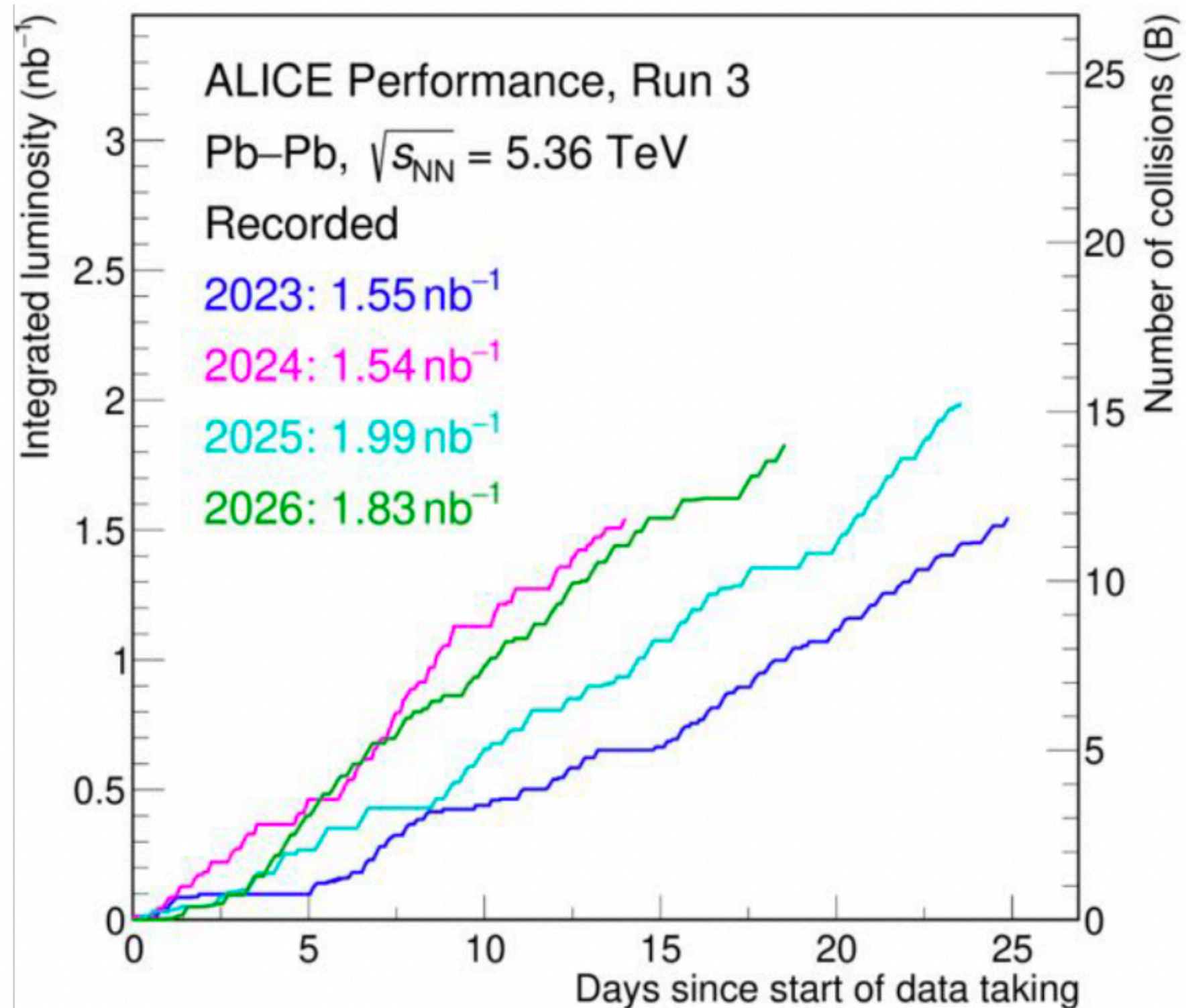
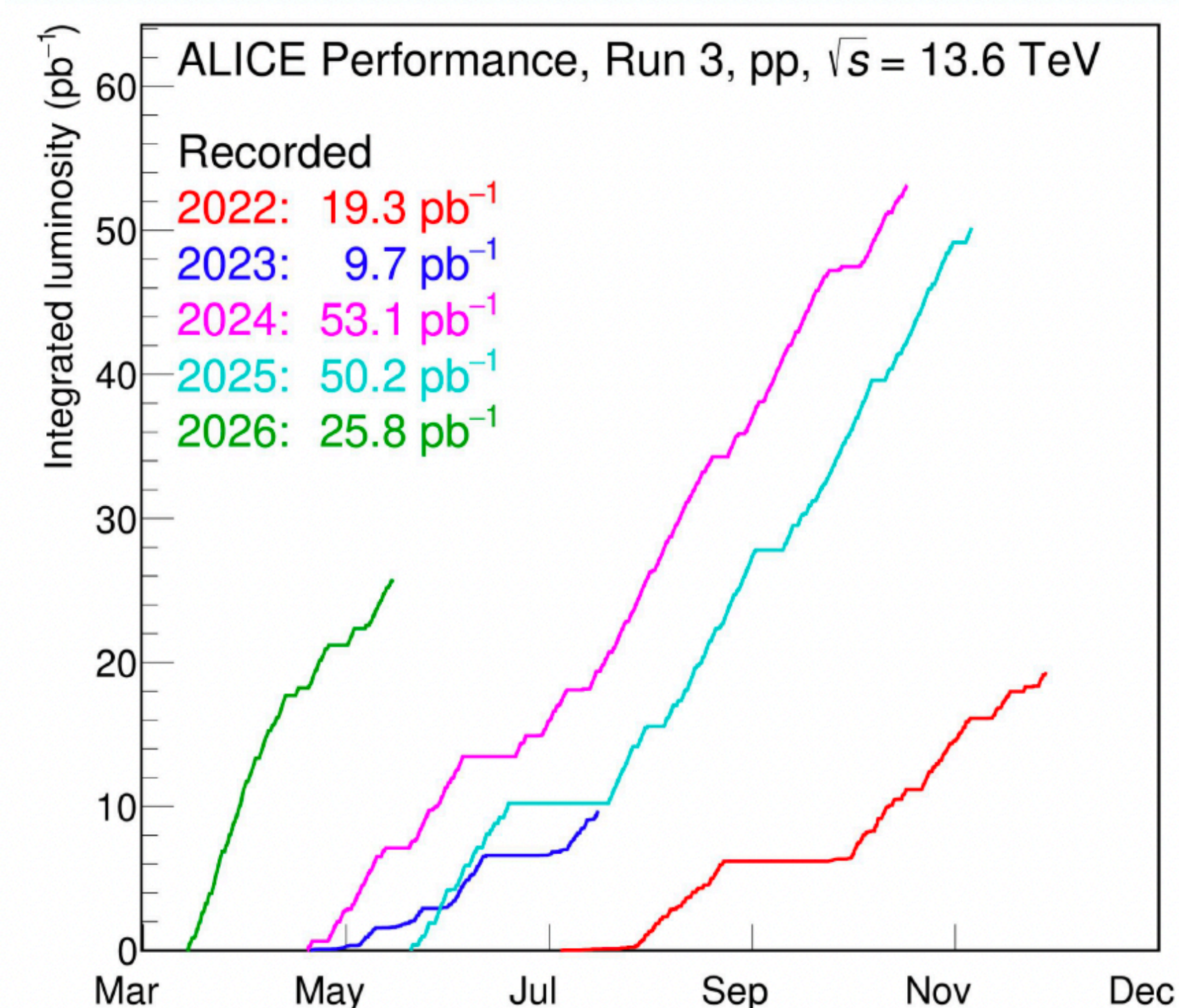
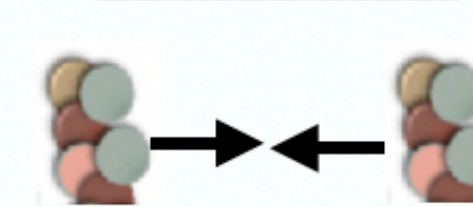
p-O



O-O



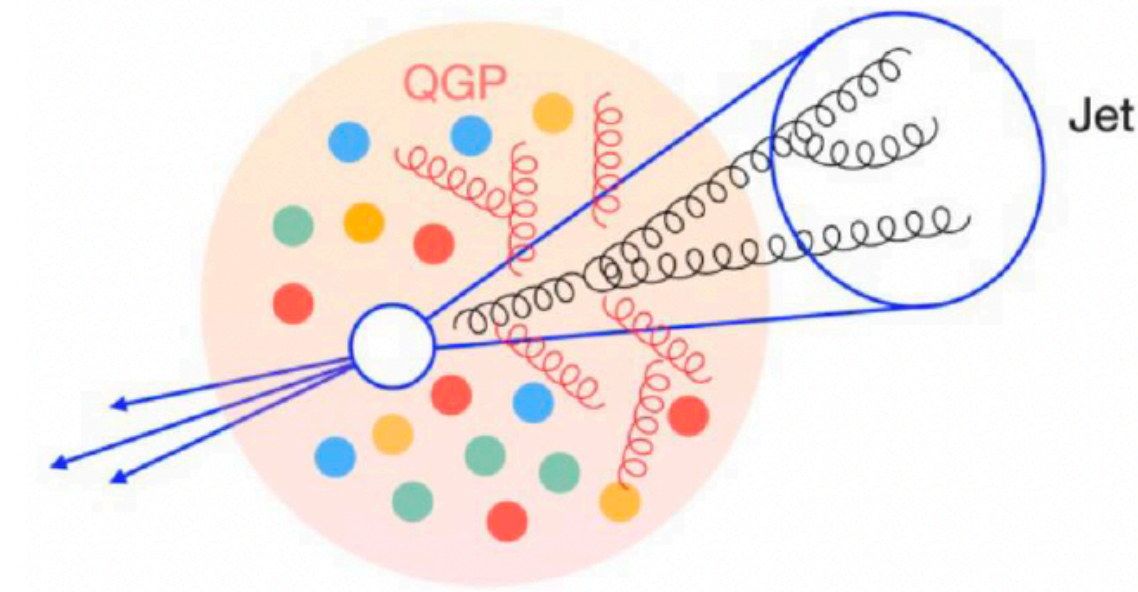
Ne-Ne



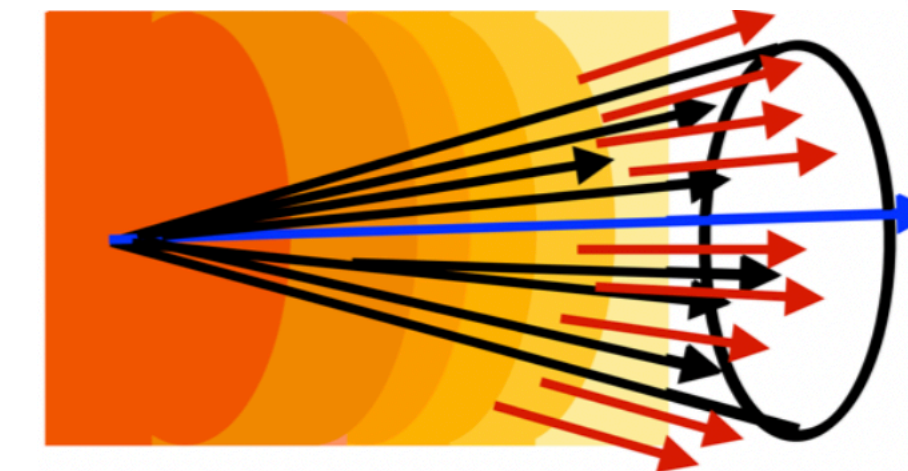
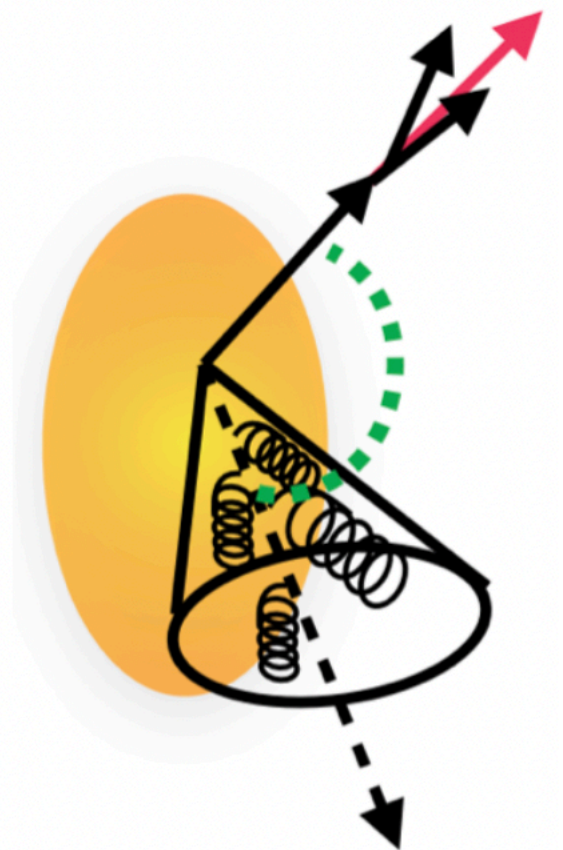
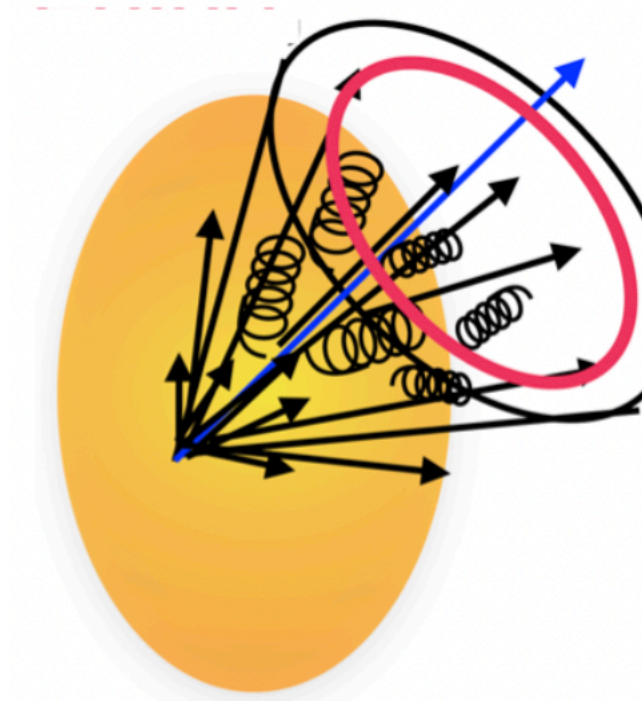
- pp data taking at 500 kHz
 - ~2000x more MB than in Run 1+2
- Pb-Pb data taking unto 50 kHz
 - ~100x more MB than in Run 1+2
- Software-based triggering: rich physics program

Jets: a tomographic probe of the medium

- Study structure of QGP by understanding jet modification from medium interaction (jet quenching)
- jet-medium interactions manifests in different ways, for example:
 - energy loss: energy transport outside jet cone
 - jet deflection via multiple soft scatters or single hard scatters
 - response of medium to (out-of-equilibrium) jet probe: wake effect

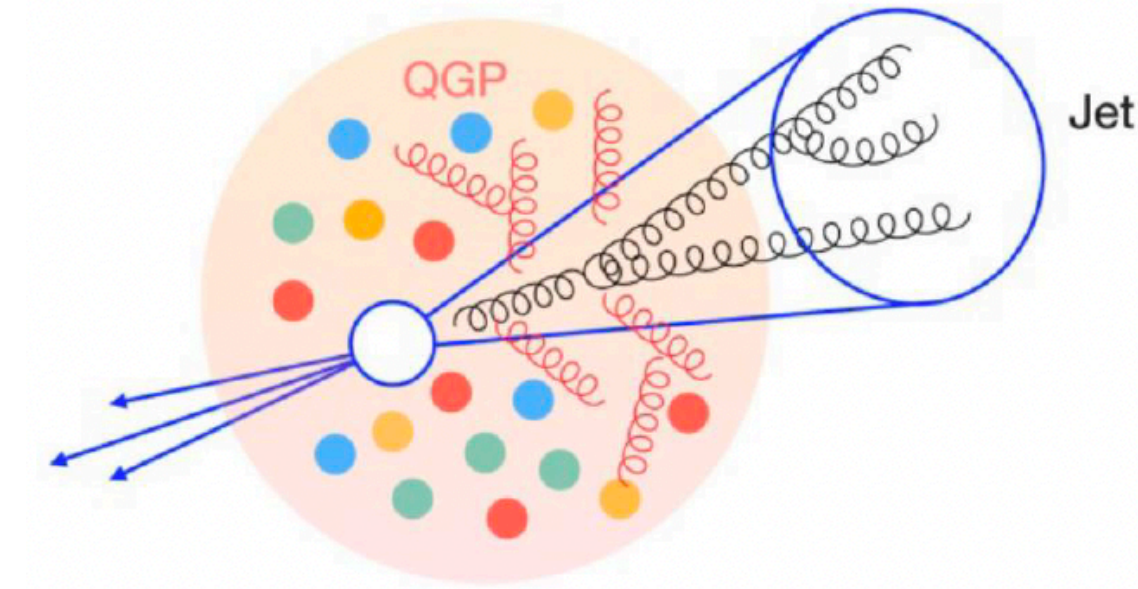


<https://www.int.washington.edu/node/776>

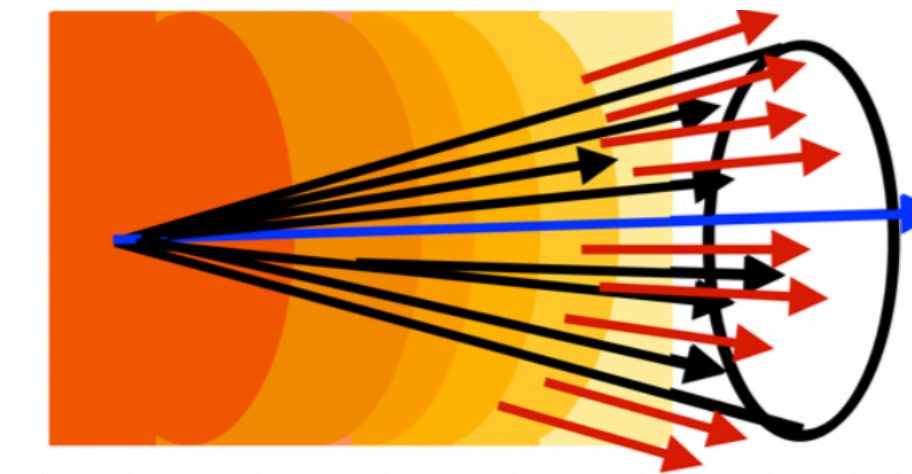
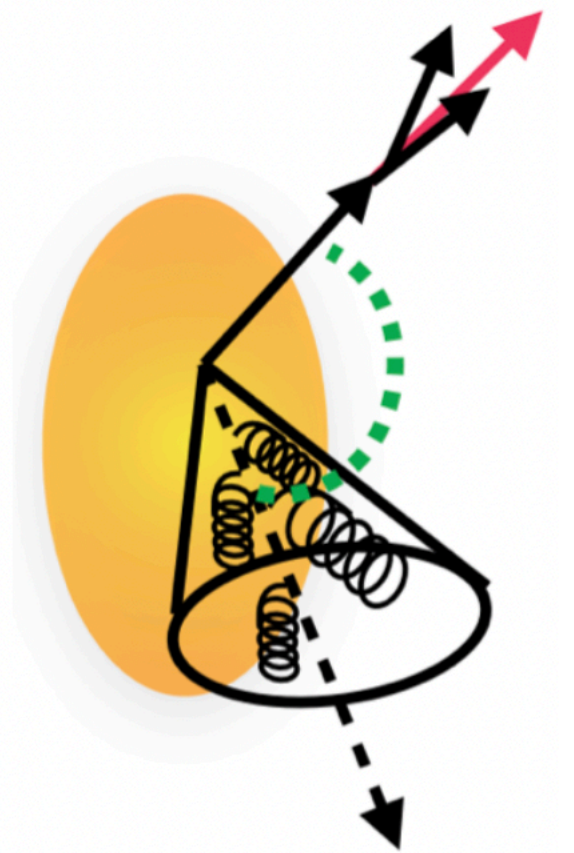
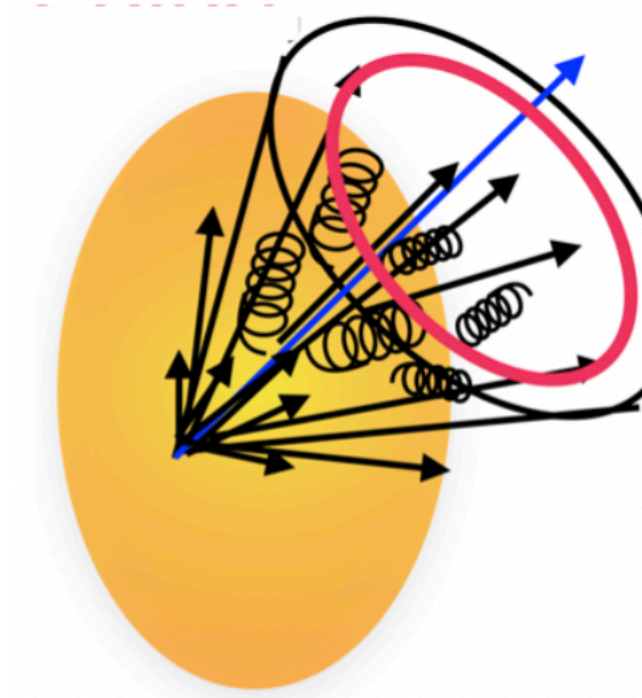


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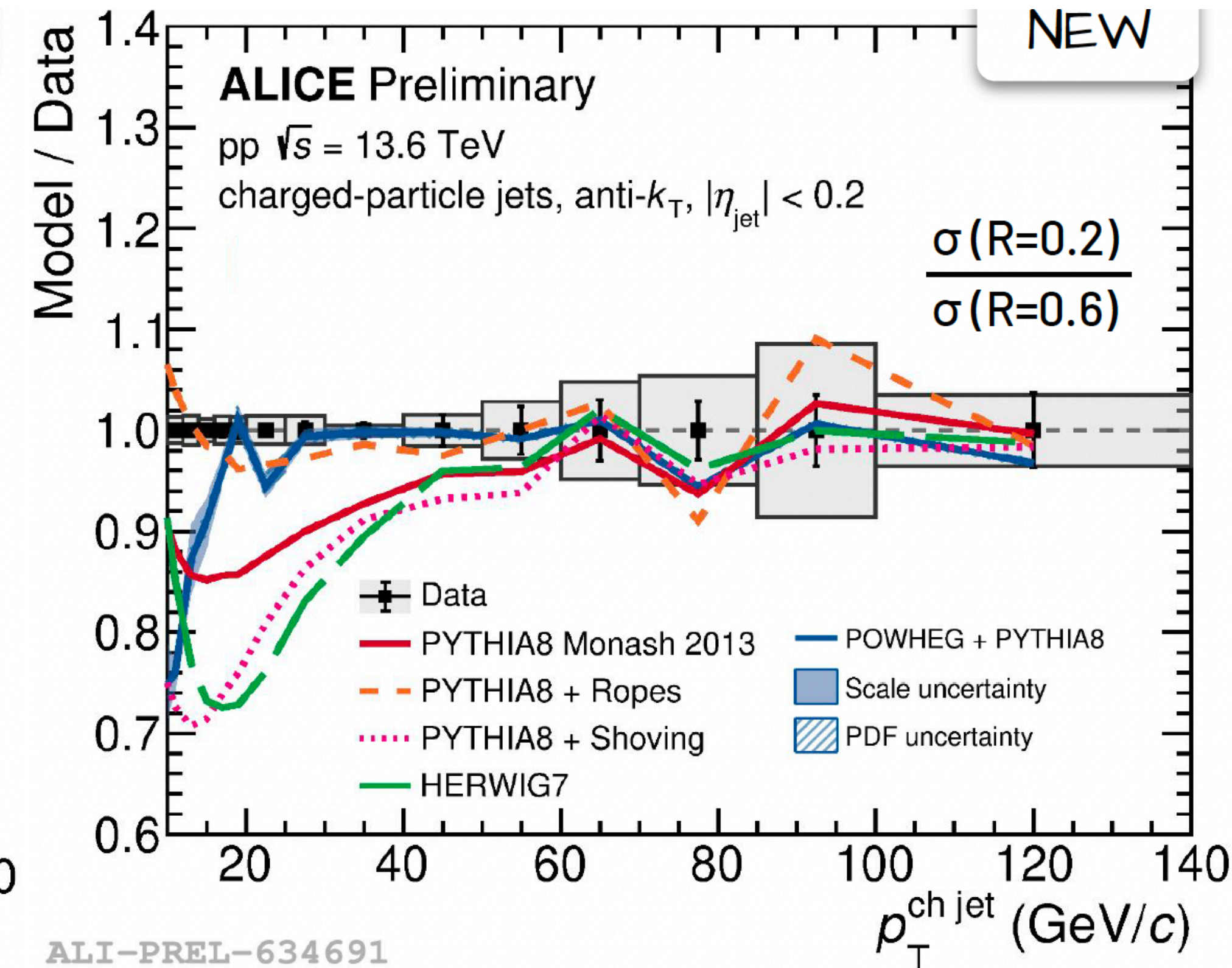
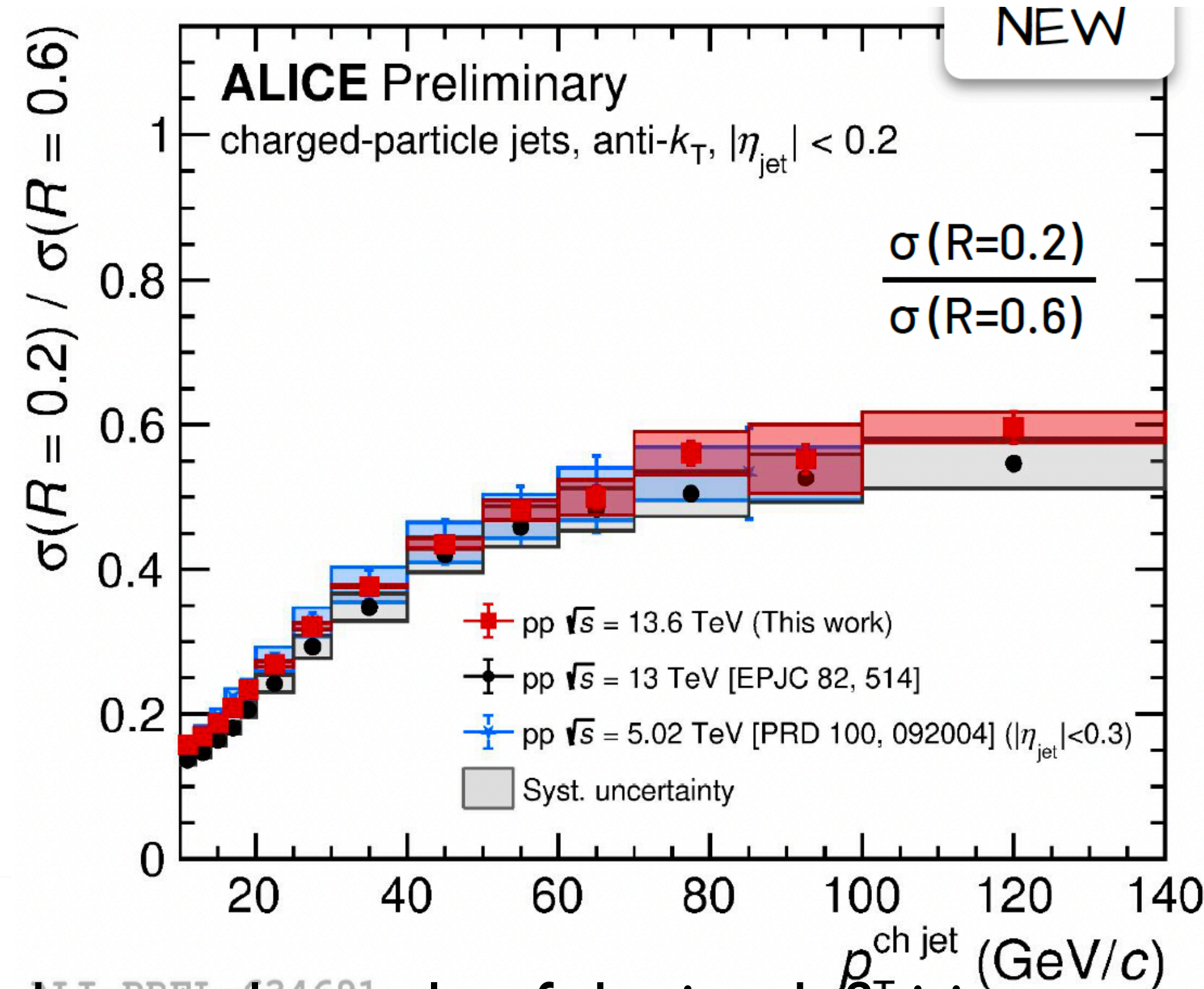
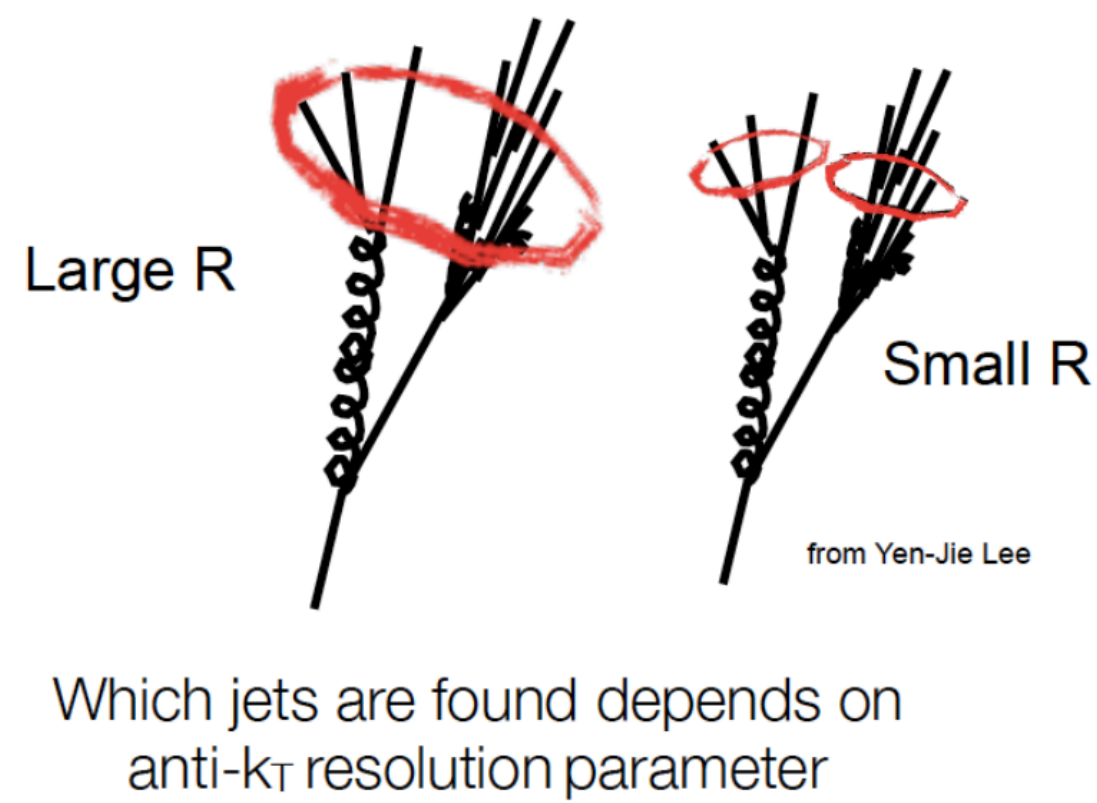


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→ Study of different effects in a complementary way must yield consistent picture

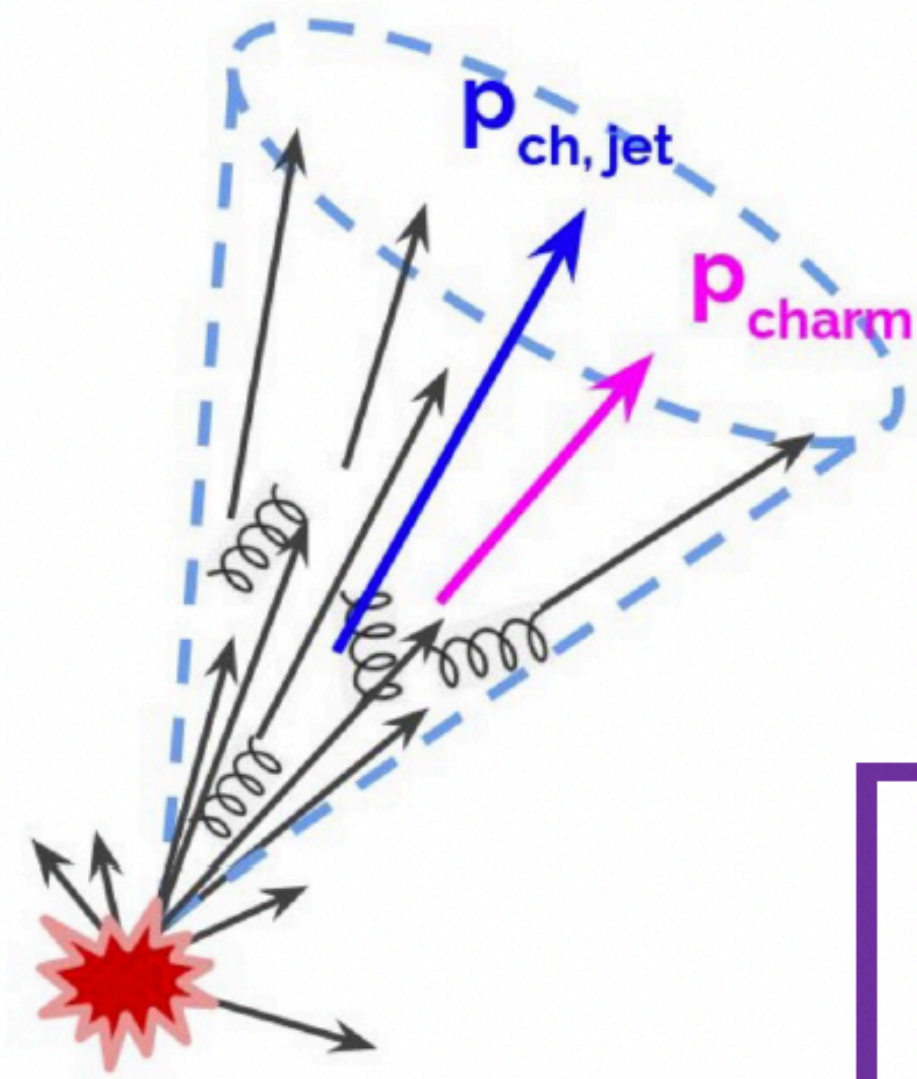
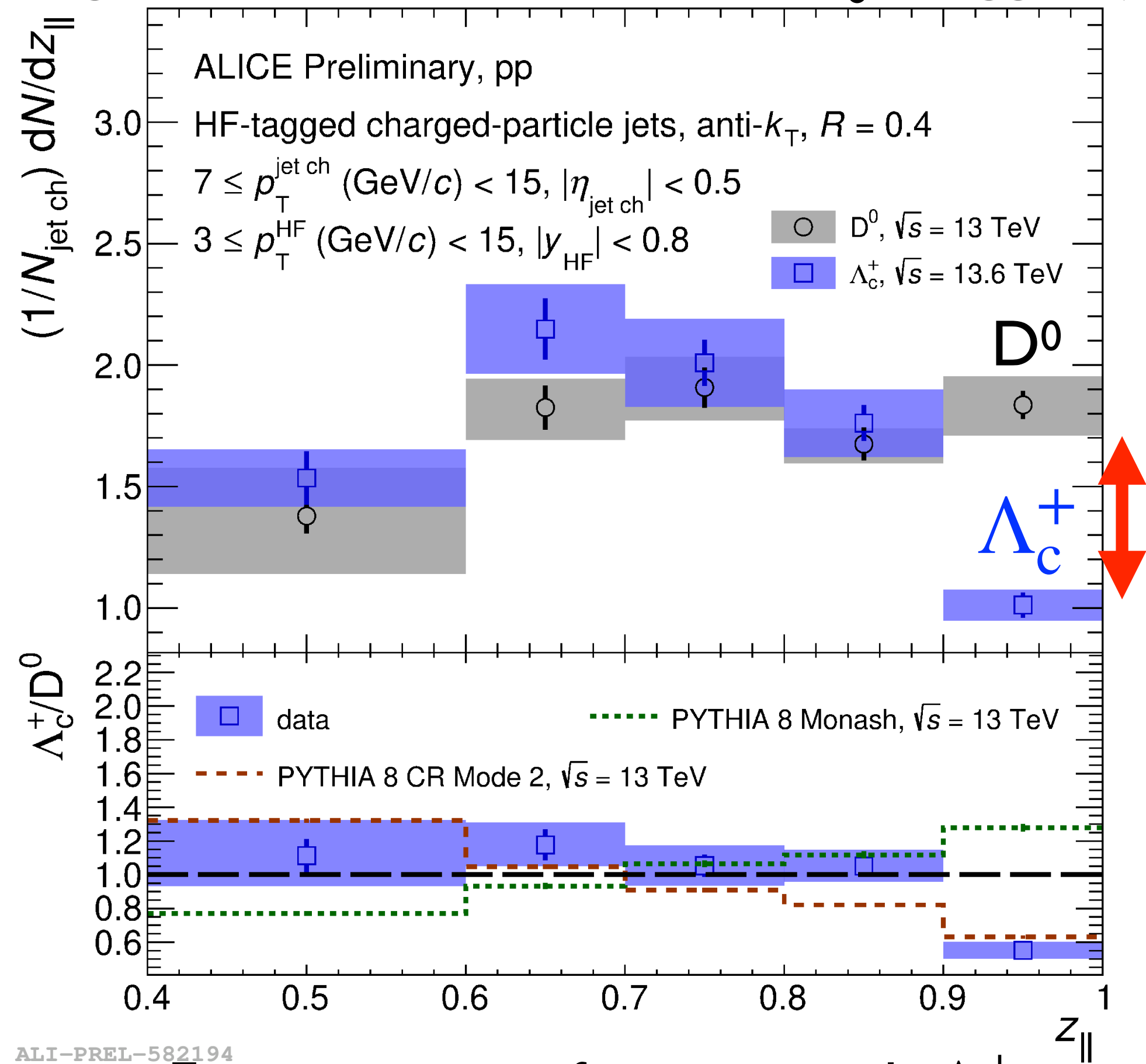
Angular scales of jet production in pp



- The **jet radius R** sets the angular scale of the jet definition:
 - small R : emphasizes the collimated jet core
 - large R : includes radiation at larger angles
- Improved precision compared to Run 2
 - ➔ at low- p_T , non-perturbative effects dominate, leading to larger differences among generators

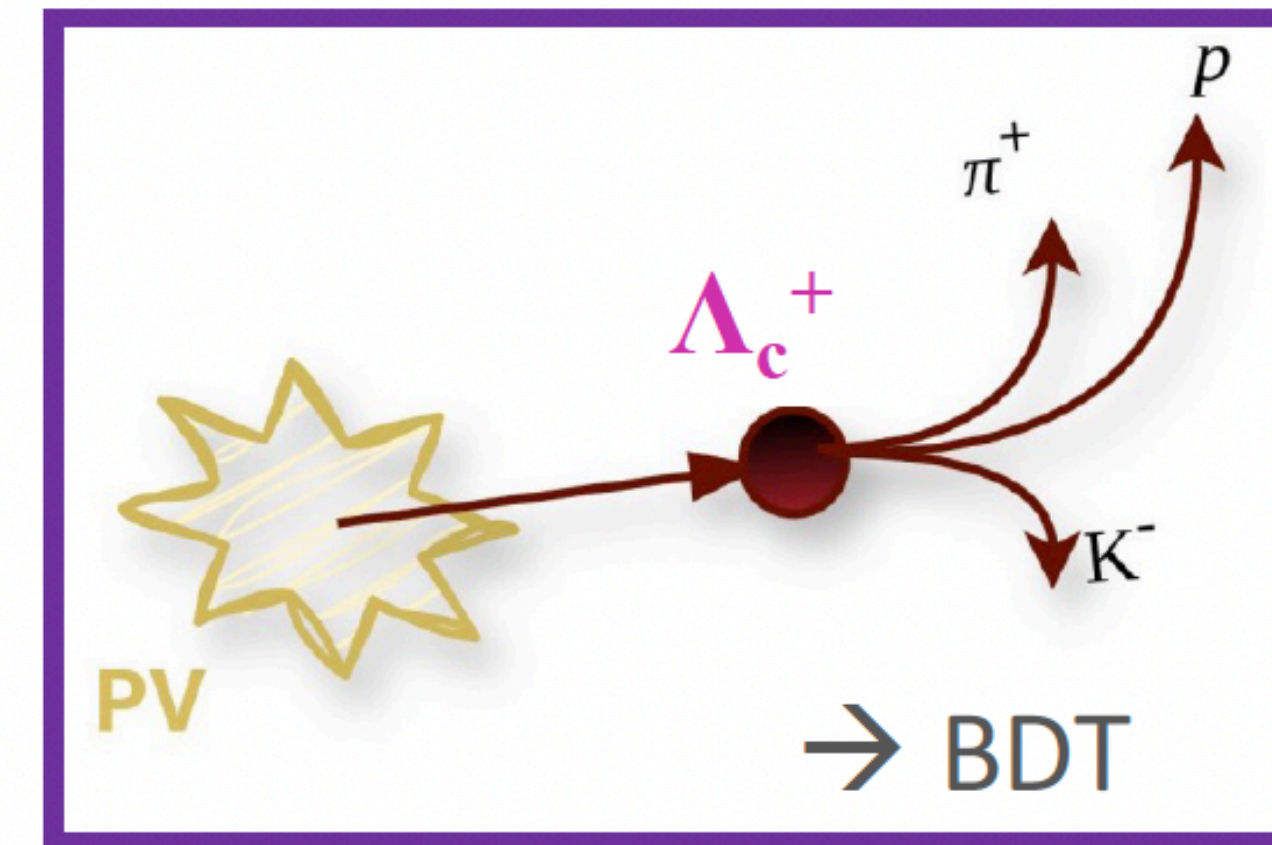
Improvements of jet analysis with Run 3 data

Fragmentation function with Λ_c^+ -tagged jets



longitudinal momentum fraction

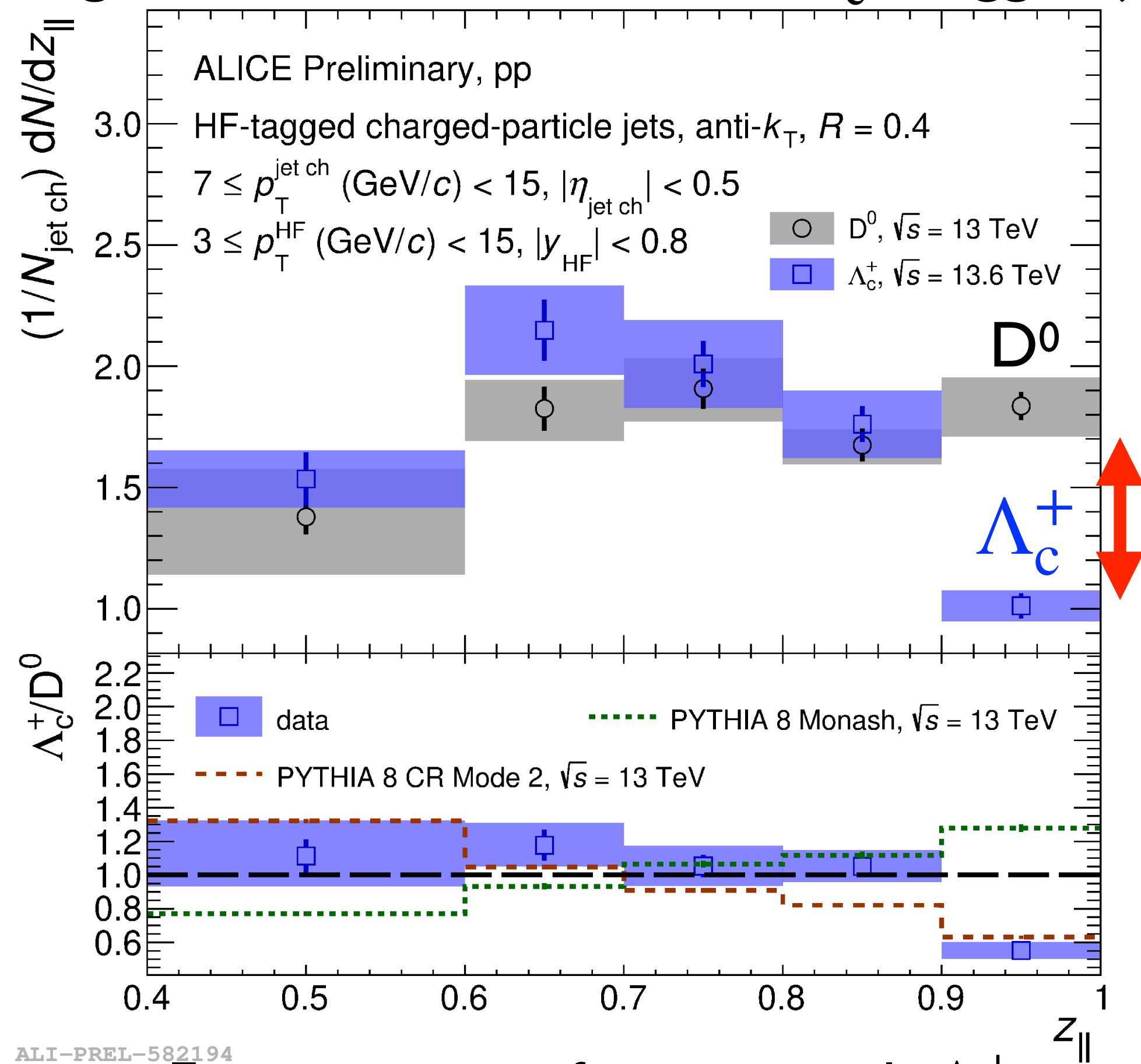
$$z_{||} = \frac{\vec{p}_{\text{ch, jet}} \cdot \vec{p}_{\text{HF}}}{\vec{p}_{\text{ch, jet}} \cdot \vec{p}_{\text{ch, jet}}}$$



- Fragmentation function with Λ_c^+ tagged jets shows much improved sensitivity to hadronisation mechanisms $\rightarrow$ hints of softer fragmentation of charm into Λ_c^+ than D^0

Improvements of jet analysis with Run 3 data

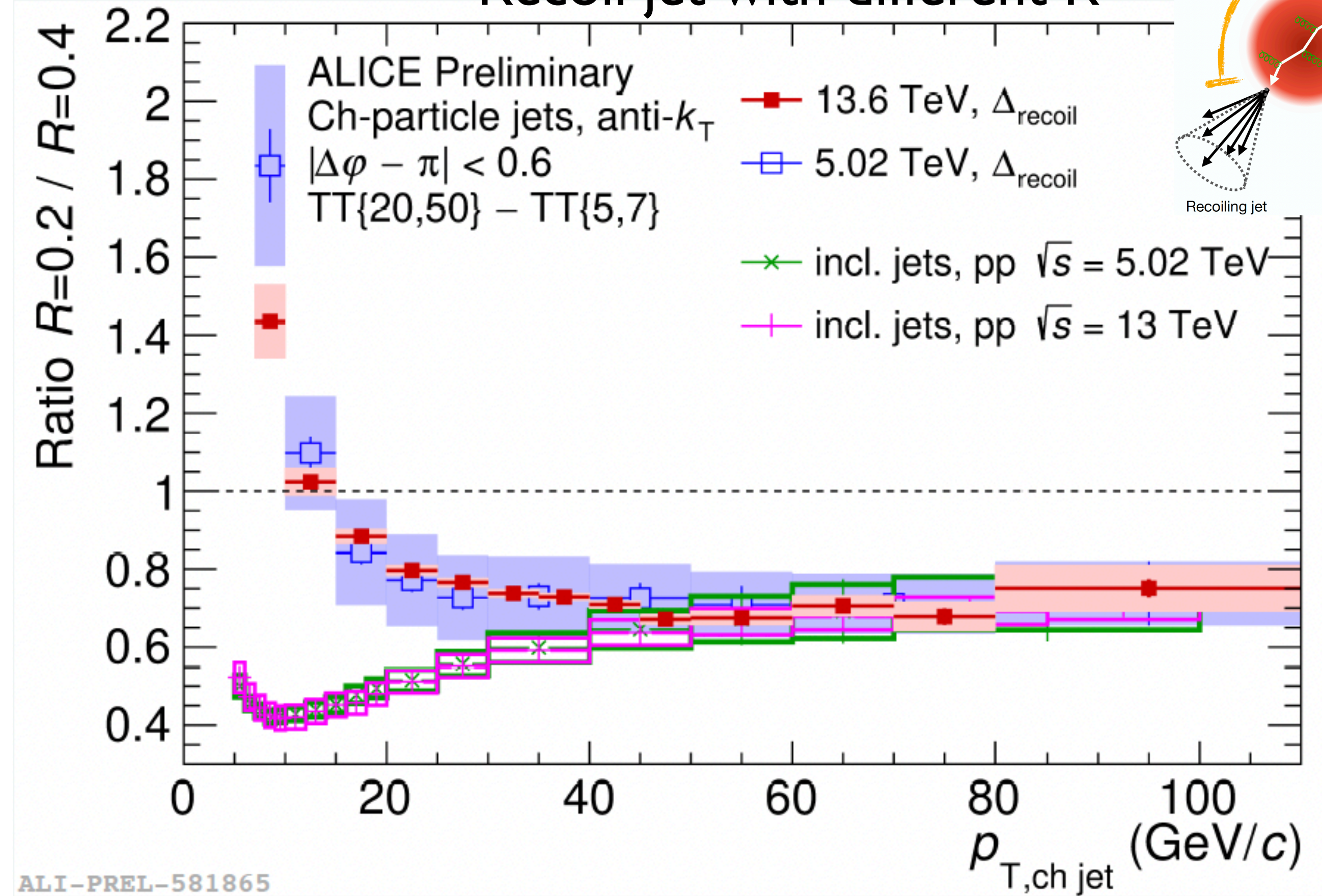
Fragmentation function with Λ_c^+ -tagged jets



ALI-PREL-582194

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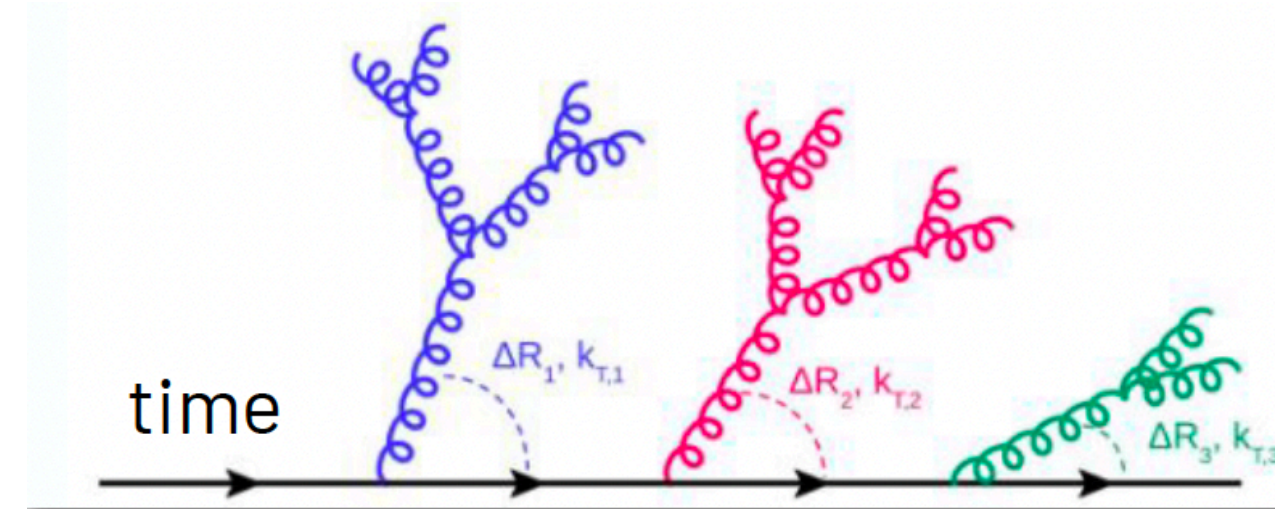
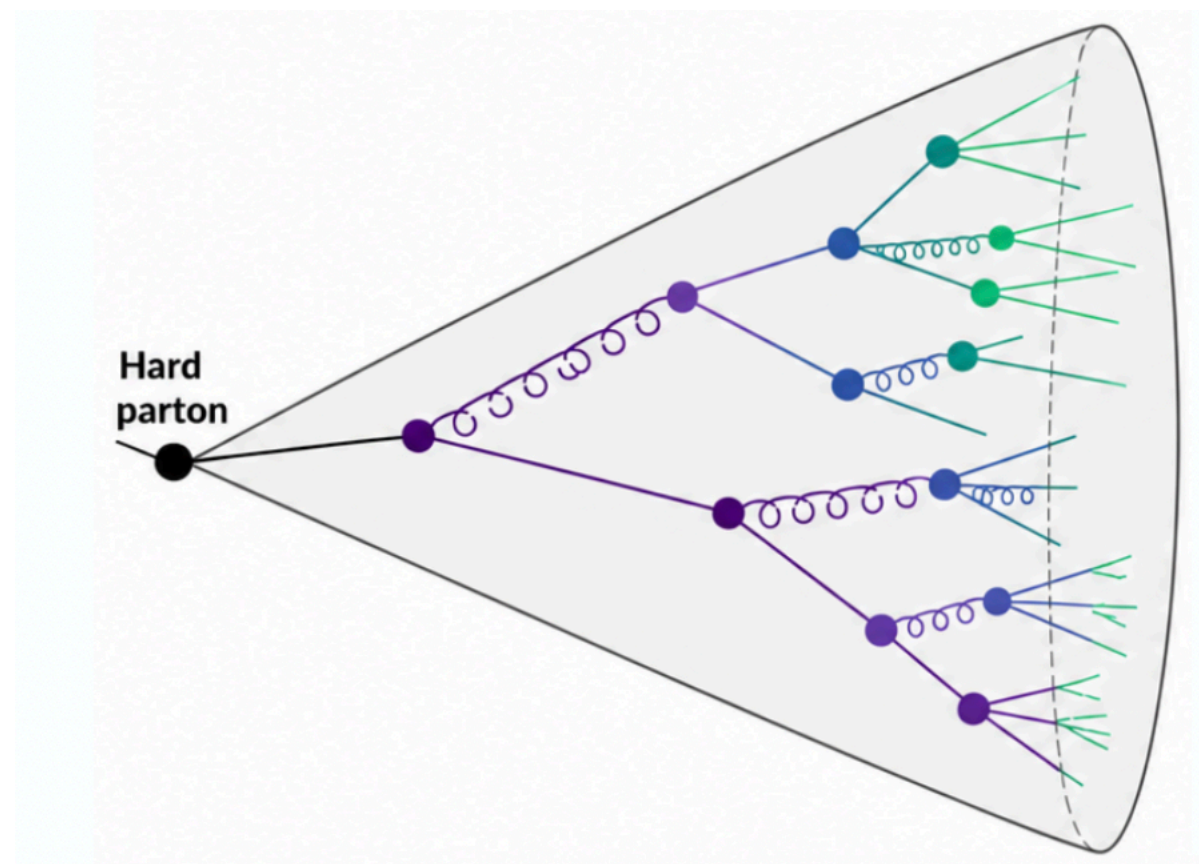
Recoil jet with different R



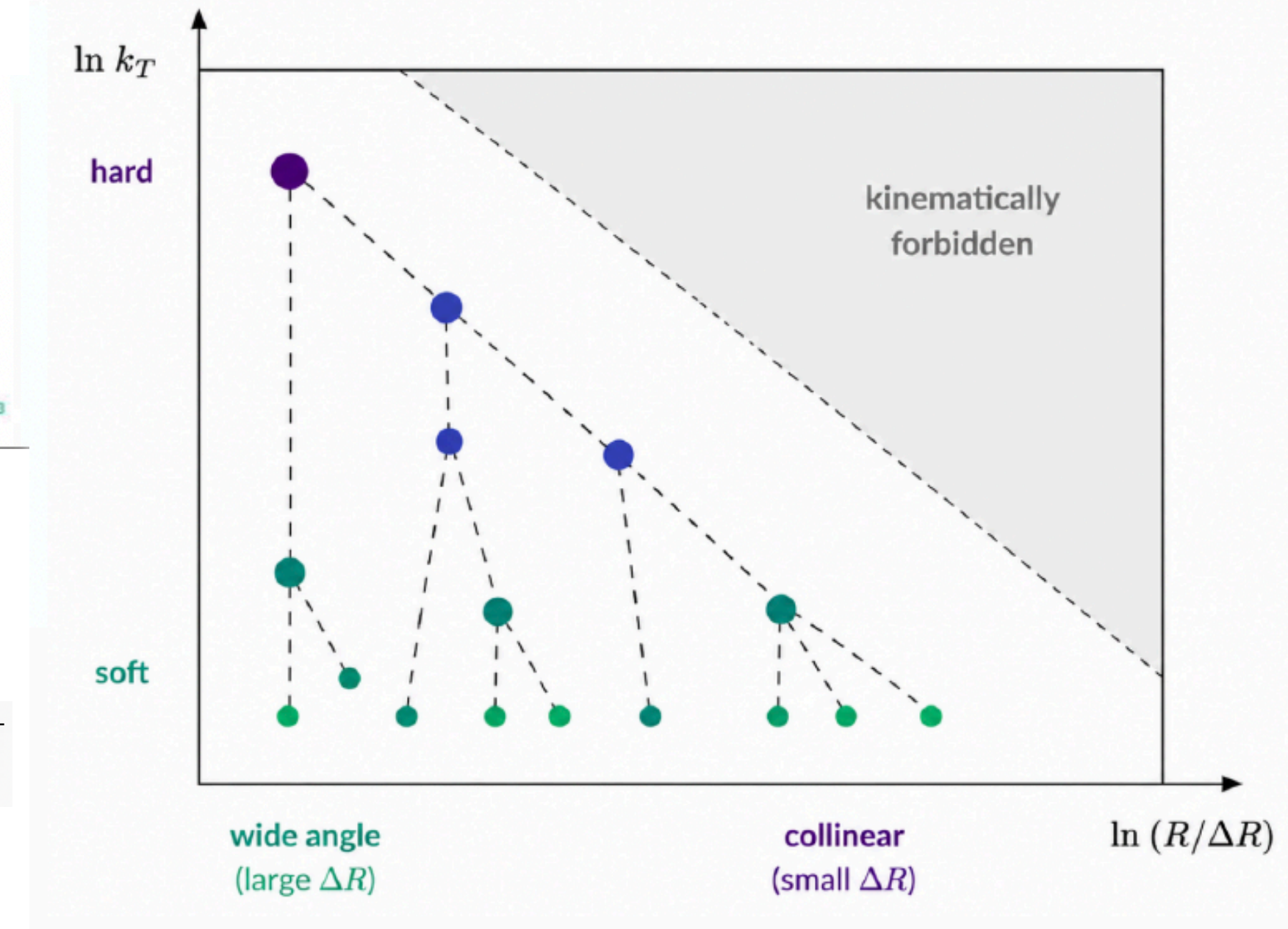
ALI-PREL-581865

- Recoil jet measurements show much better precision with respect to Run 2

Mapping the jet evolution with the Lund Plane

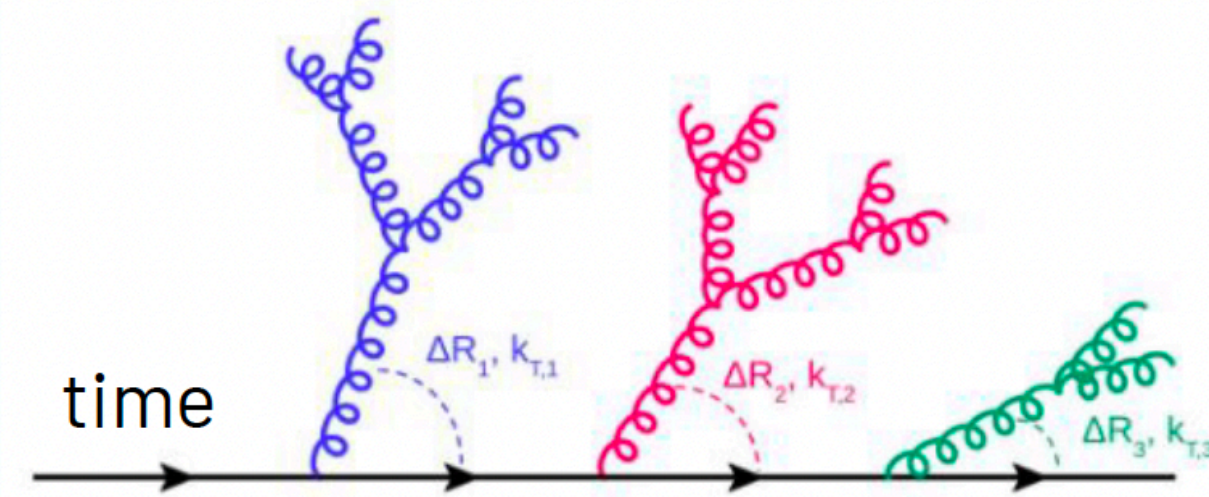
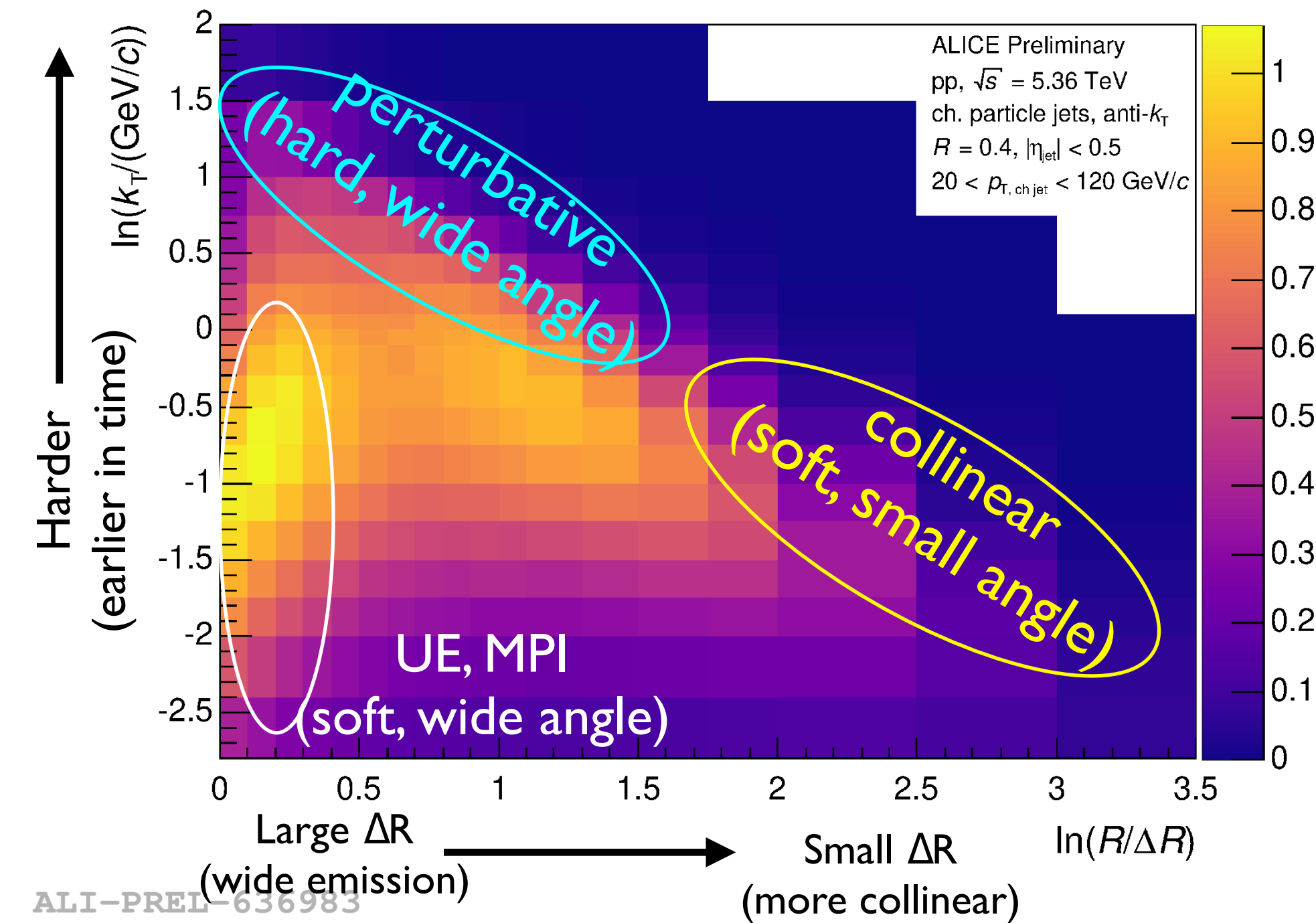


$$k_T = p_{T,\text{soft}} \Delta R_{ij} \quad \Delta R_{ij} = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$

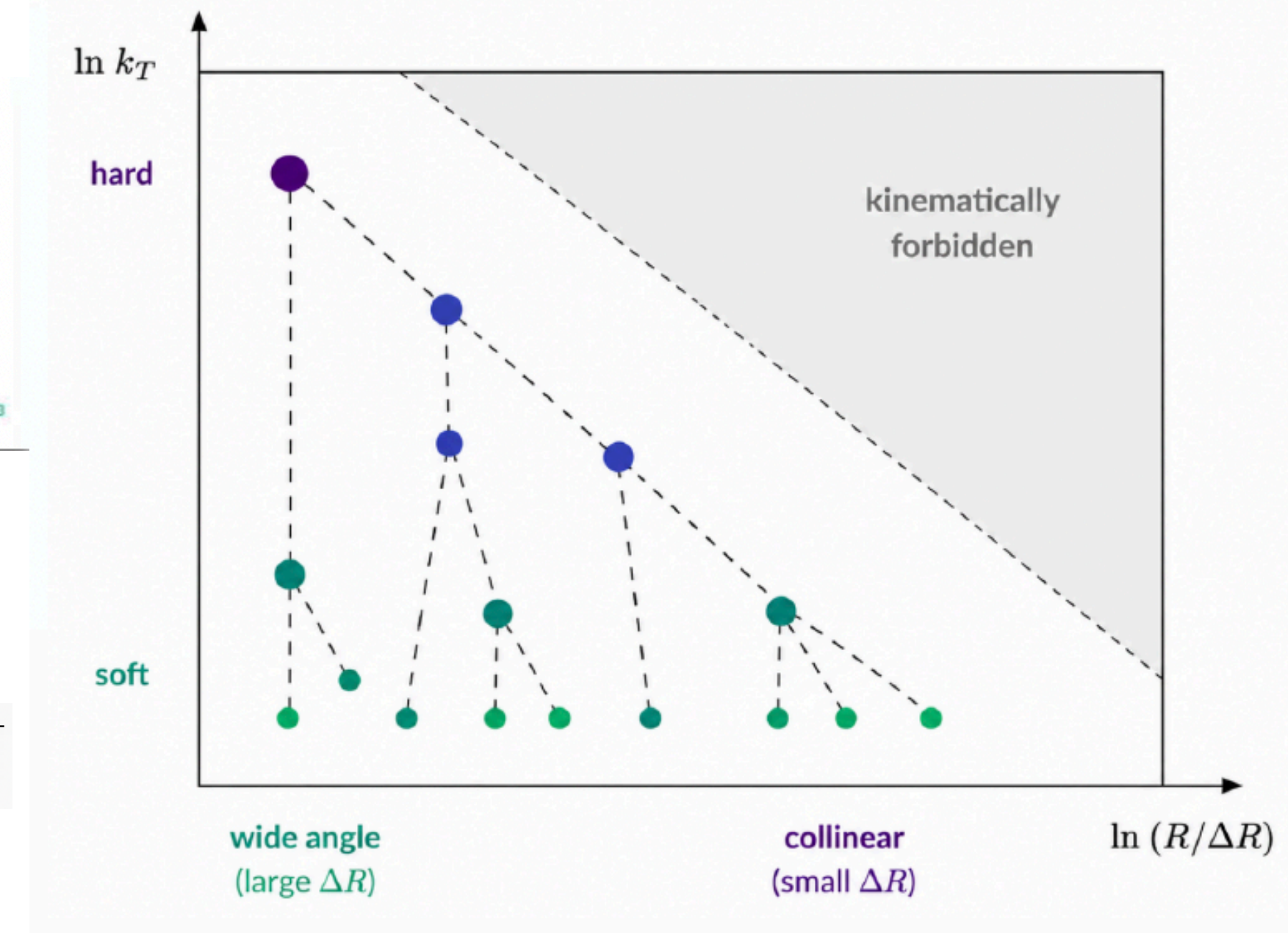


- Jets evolve from hard, wide-angle splittings to soft, collinear radiation
 - the Lund jet plane (LJP) makes this evolution visible (mapping emissions into k_T and ΔR coordinates)
 - LJP is filled by iterative declustering on the leading branch

Mapping the jet evolution with the Lund Plane

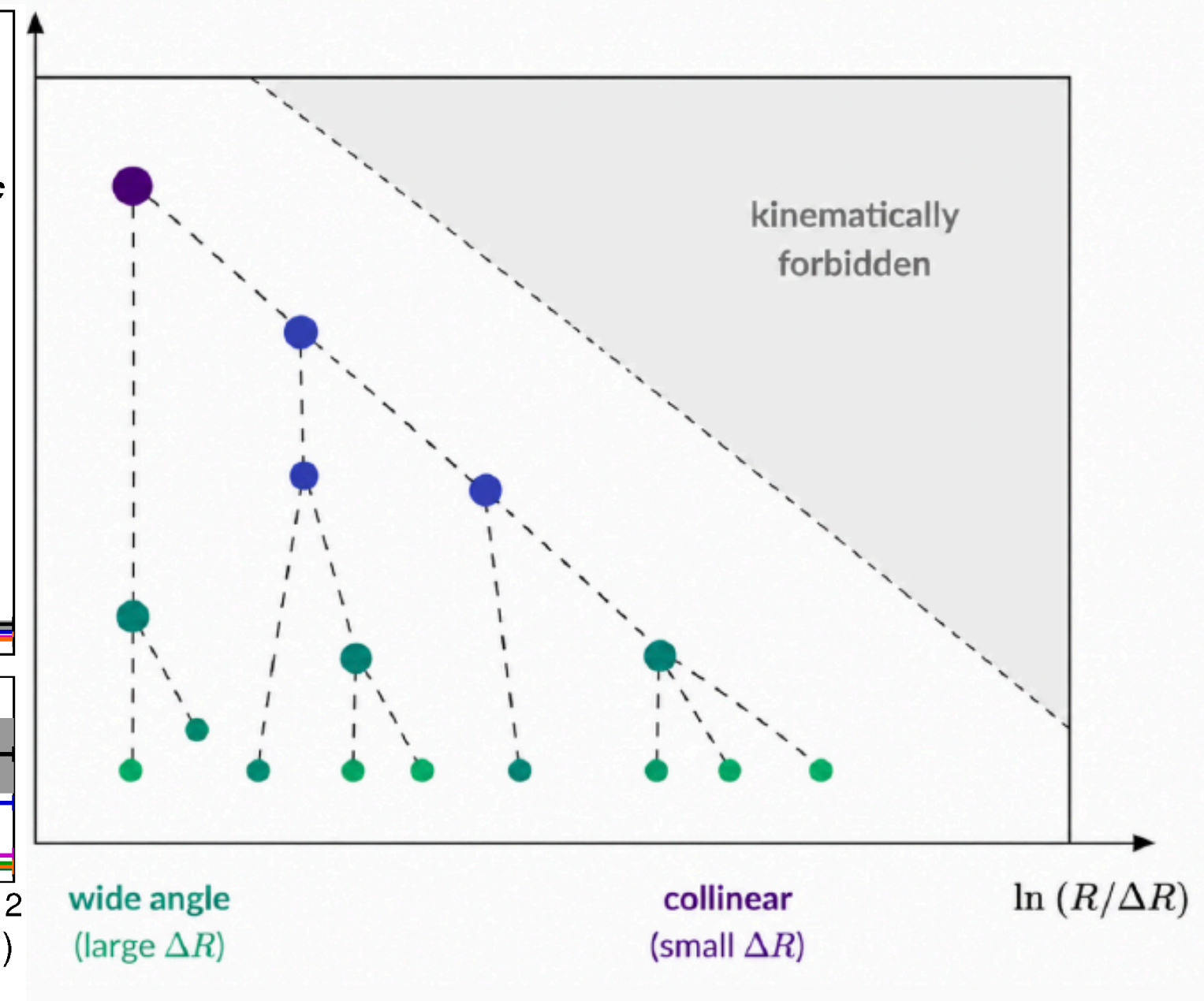
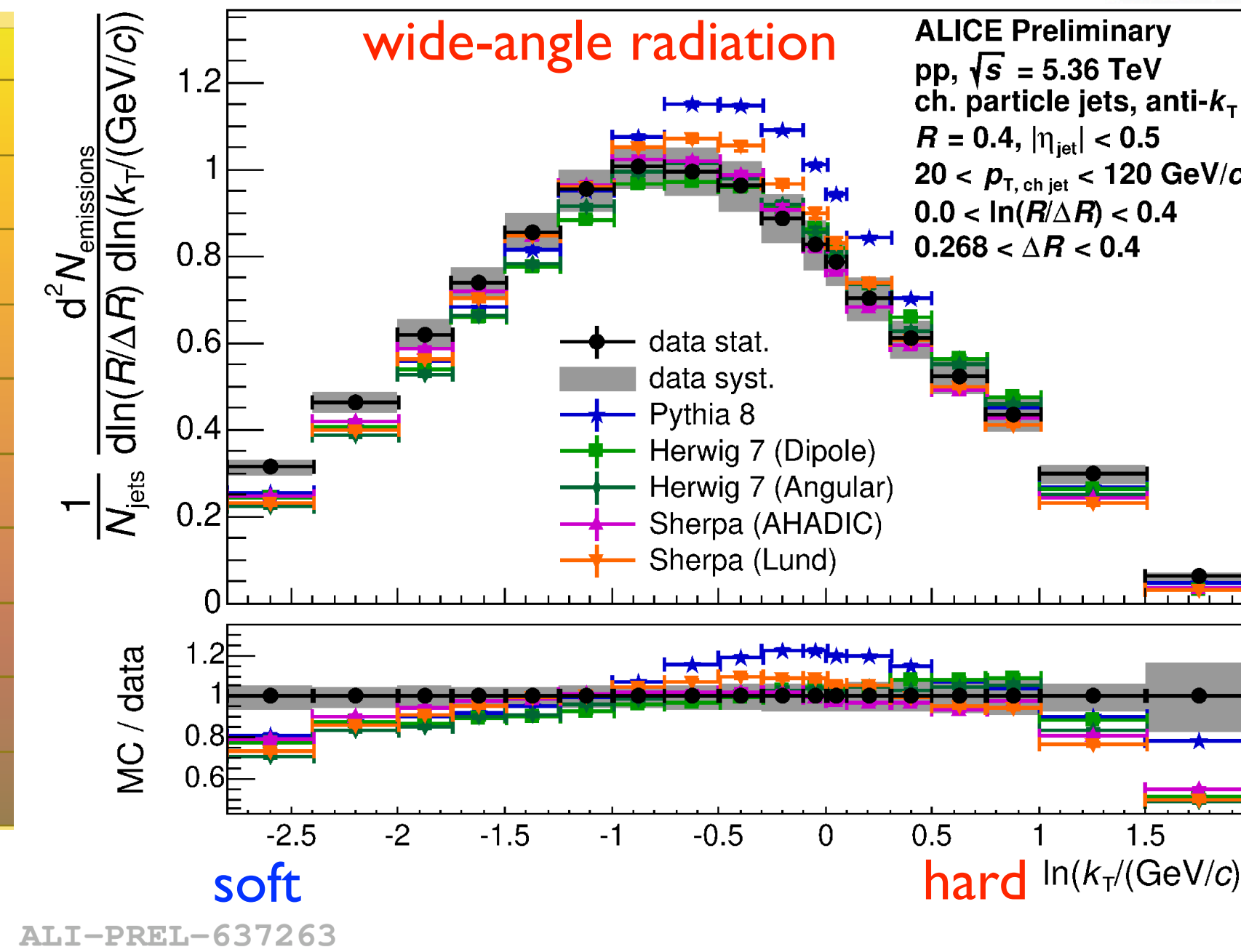
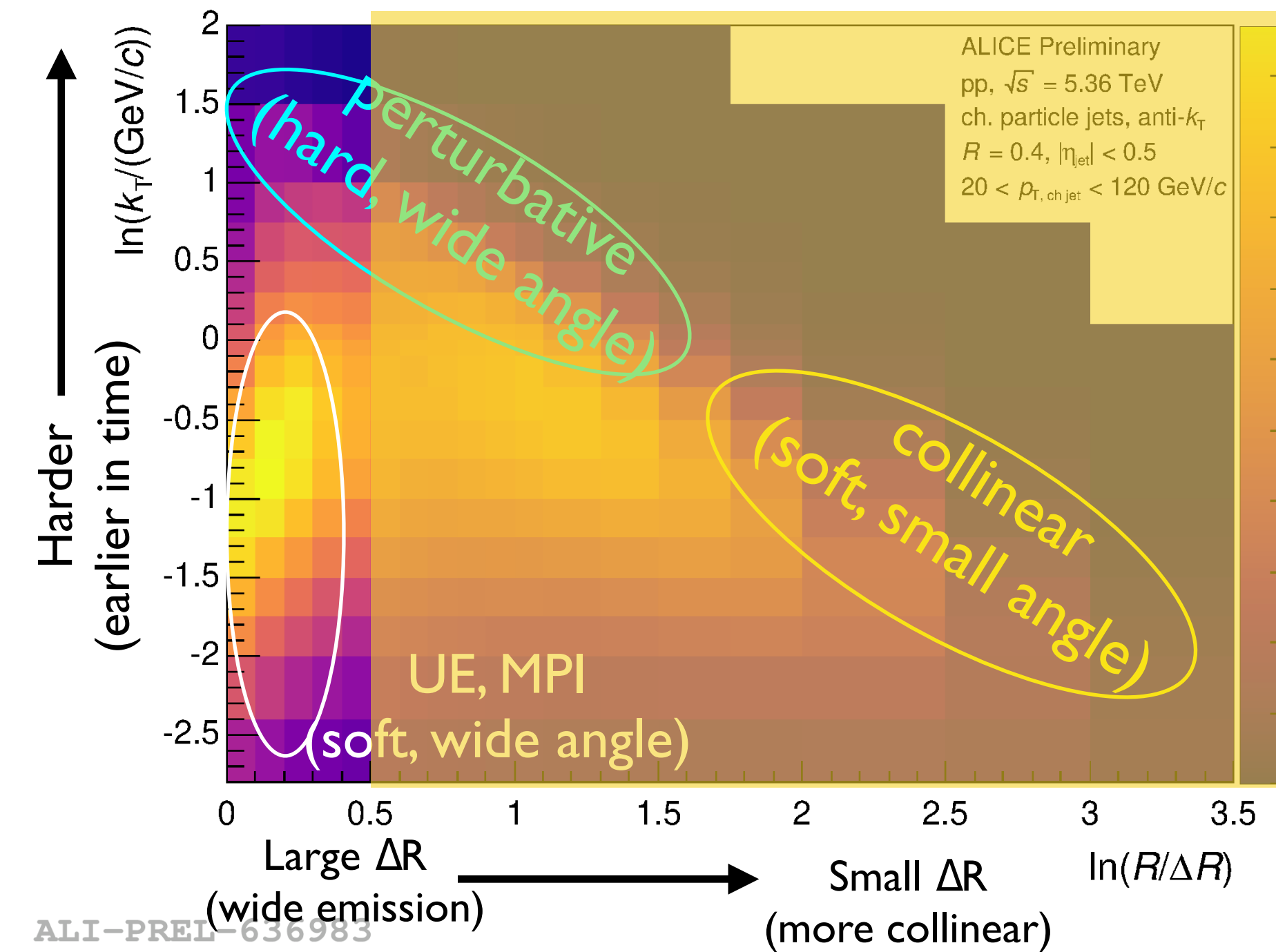


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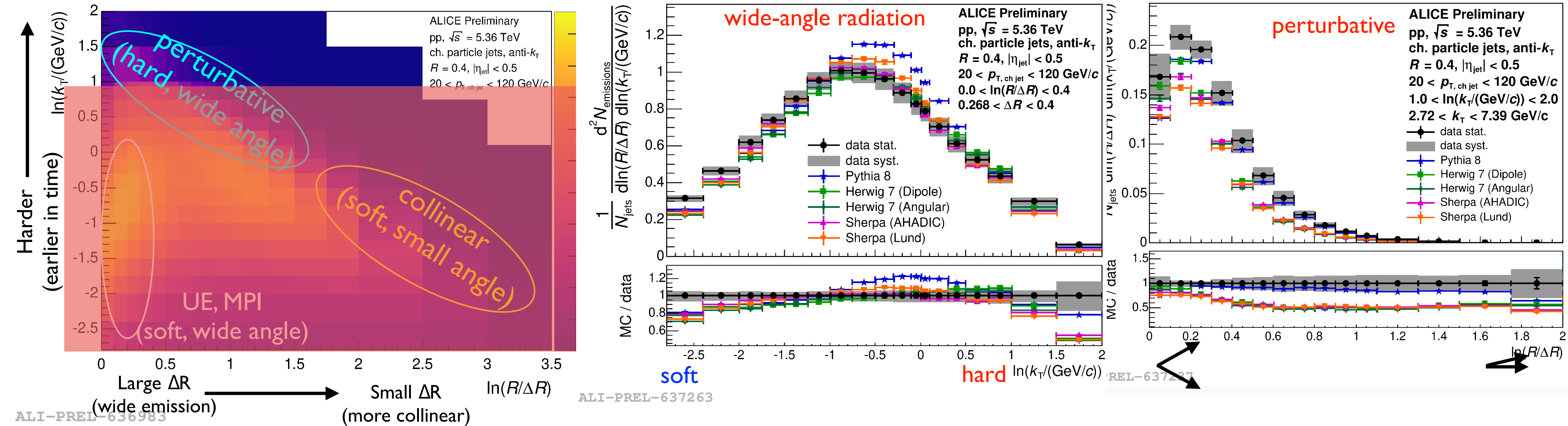
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Mapping the jet evolution with the Lund Plane



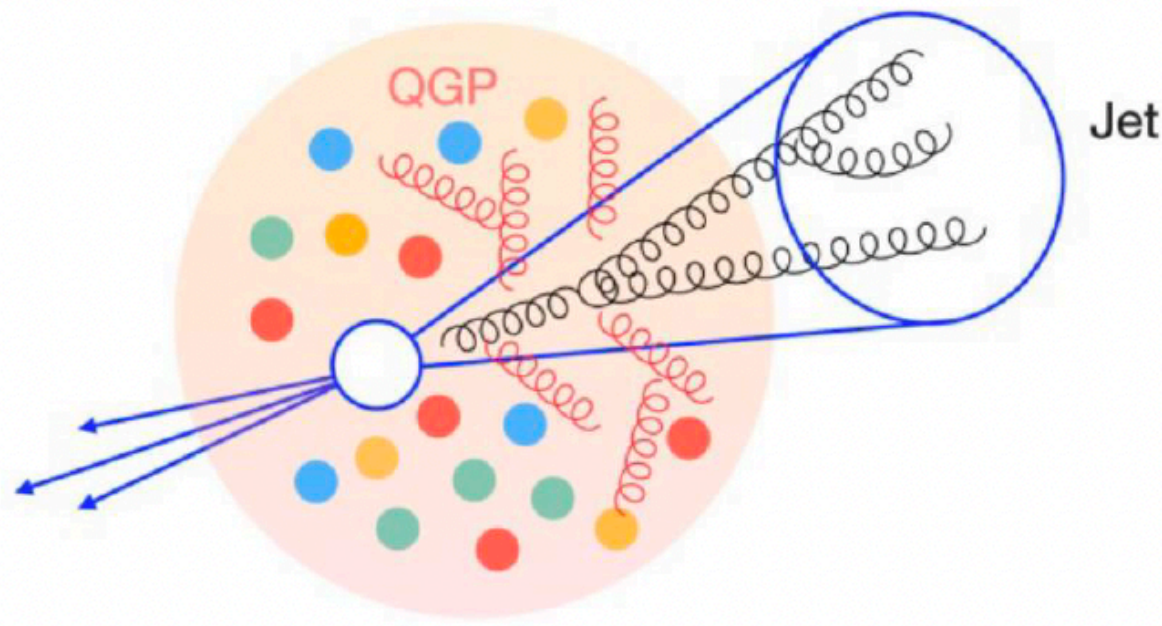
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Jet suppression in Pb-Pb collisions



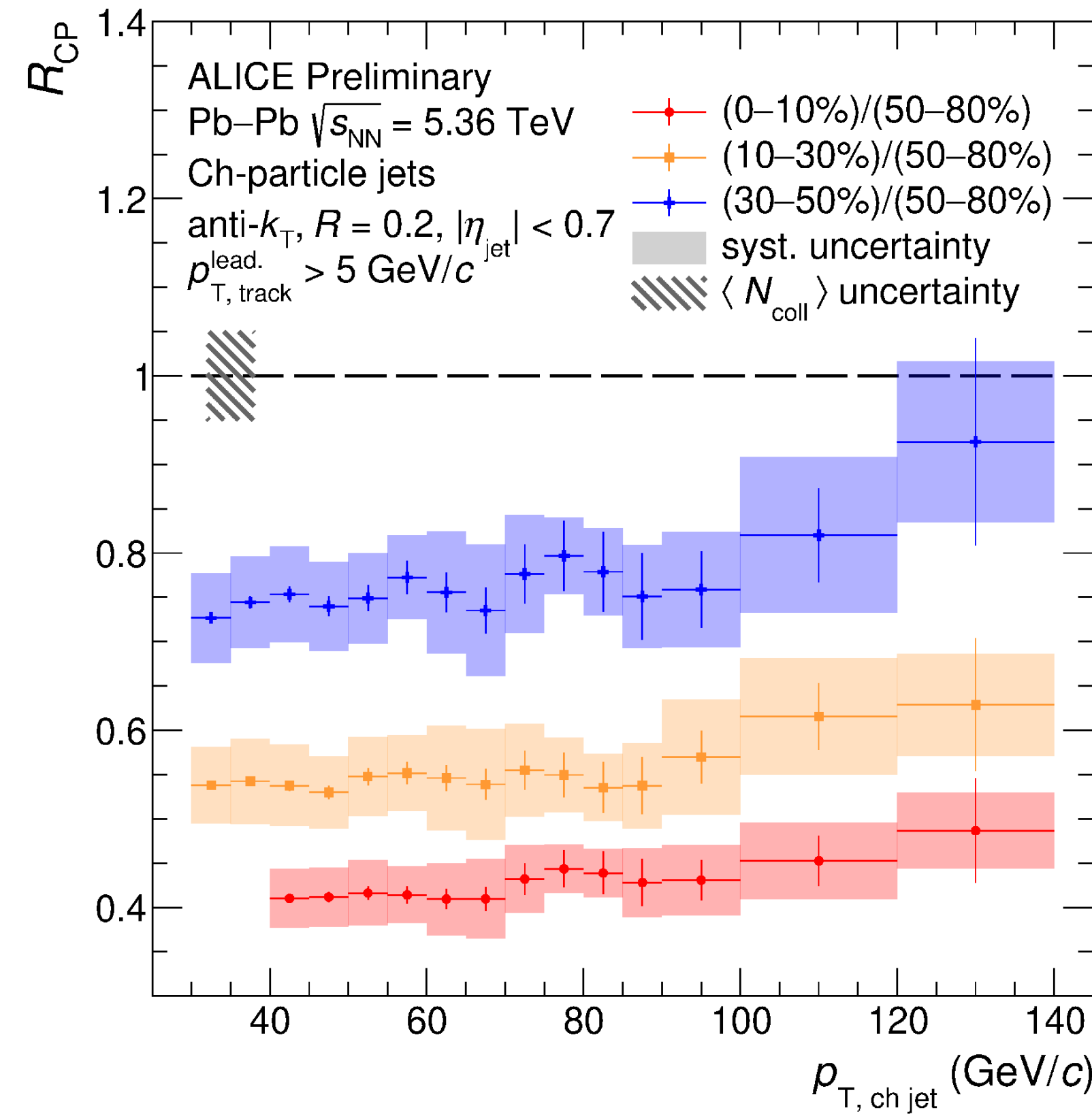
<https://www.int.washington.edu/node/776>

Nuclear modification factor

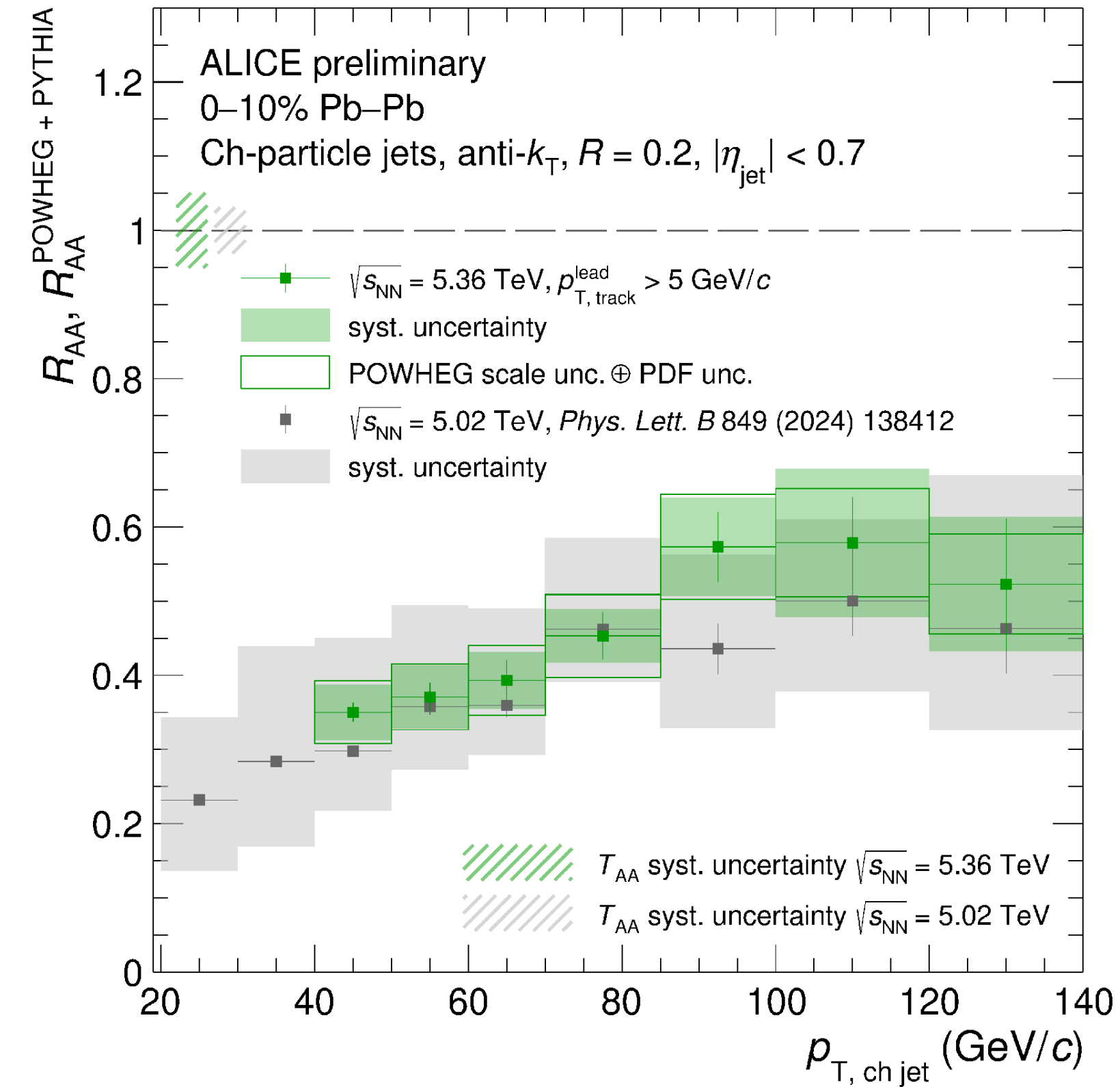
$$R_{AA}^{\text{ch jet}} = \frac{1}{\langle N_{\text{coll}} \rangle} \frac{d^2 N_{AA}^{\text{ch jet}} / dp_T}{d^2 N_{pp}^{\text{ch jet}} / dp_T}.$$

Central-to-Peripheral Ratio

$$R_{CP} = \frac{\langle N_{\text{coll}}^P \rangle}{\langle N_{\text{coll}}^C \rangle} \frac{d^2 N_{\text{jets}}^C / dp_T d\eta}{d^2 N_{\text{jets}}^P / dp_T d\eta}$$



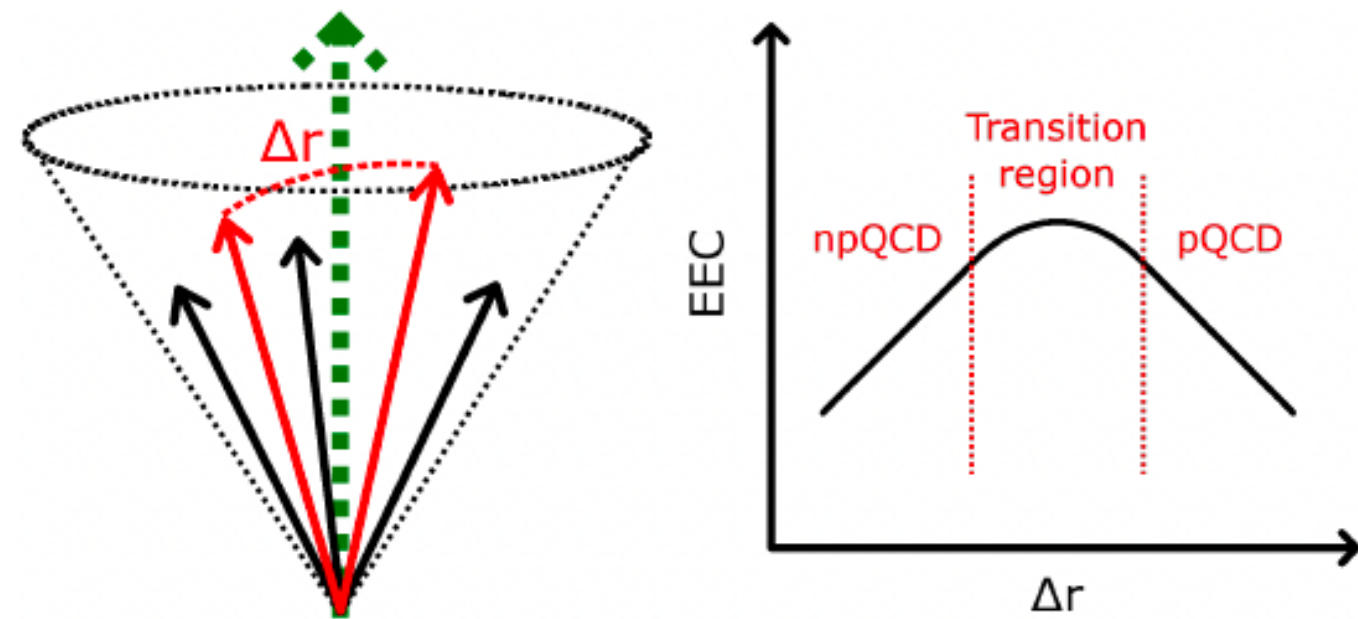
ALI-PREL-635261



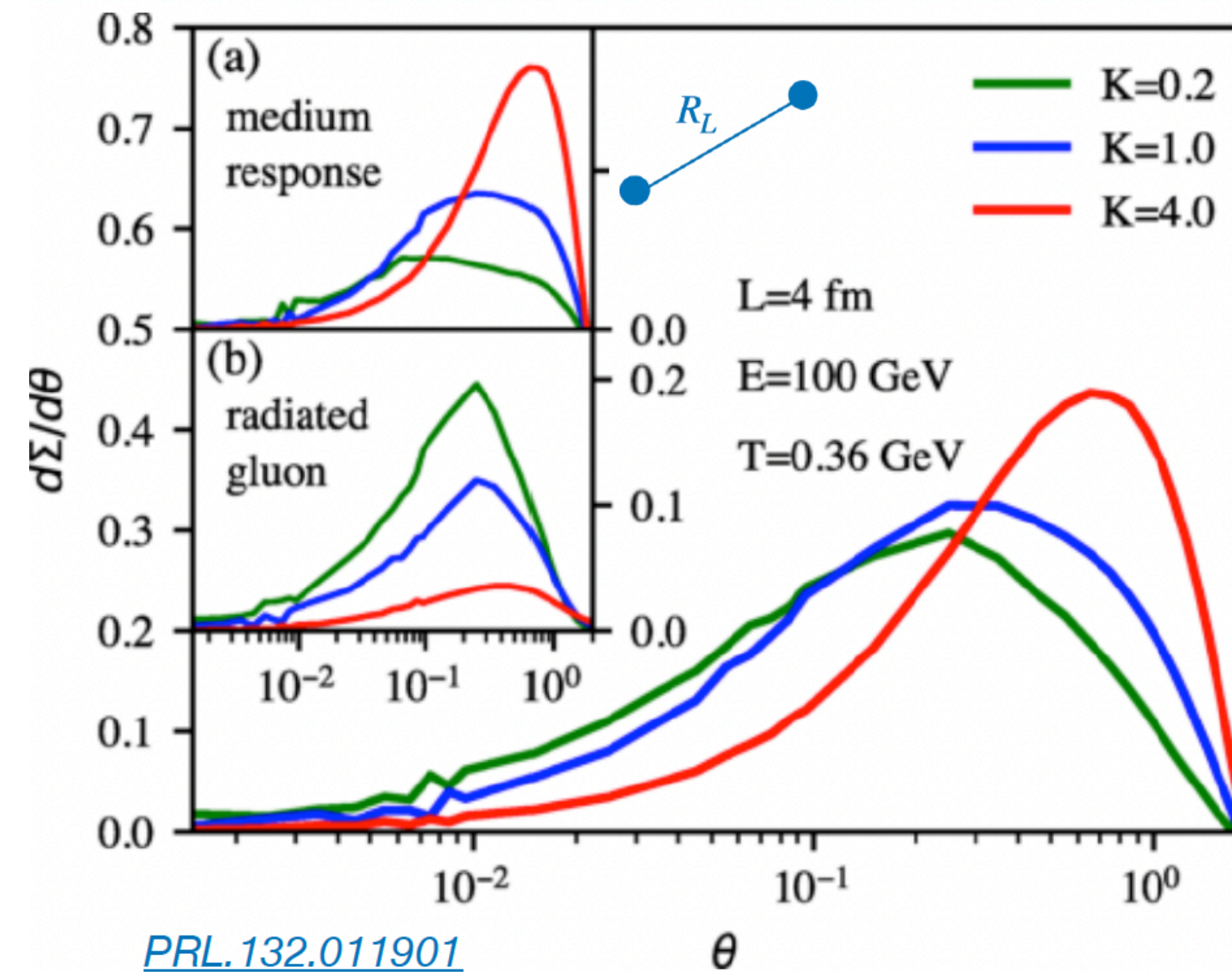
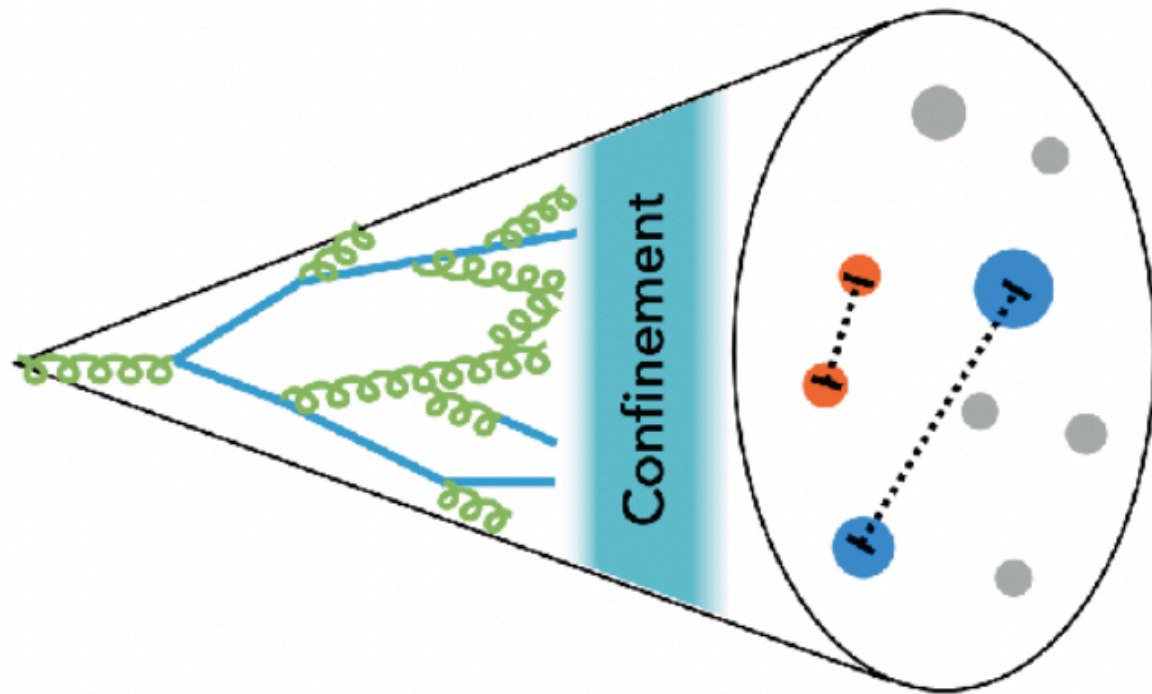
ALI-PREL-635277

- Jet suppression as a clear signature of parton energy loss in medium
- First jet measurements with Run 3 Pb-Pb data
 - ➔ Highlights evolution of jet modification as a function of centrality
 - ➔ a benchmark study to validate background subtraction and upgraded analysis framework

Search for medium response through energy-energy correlator



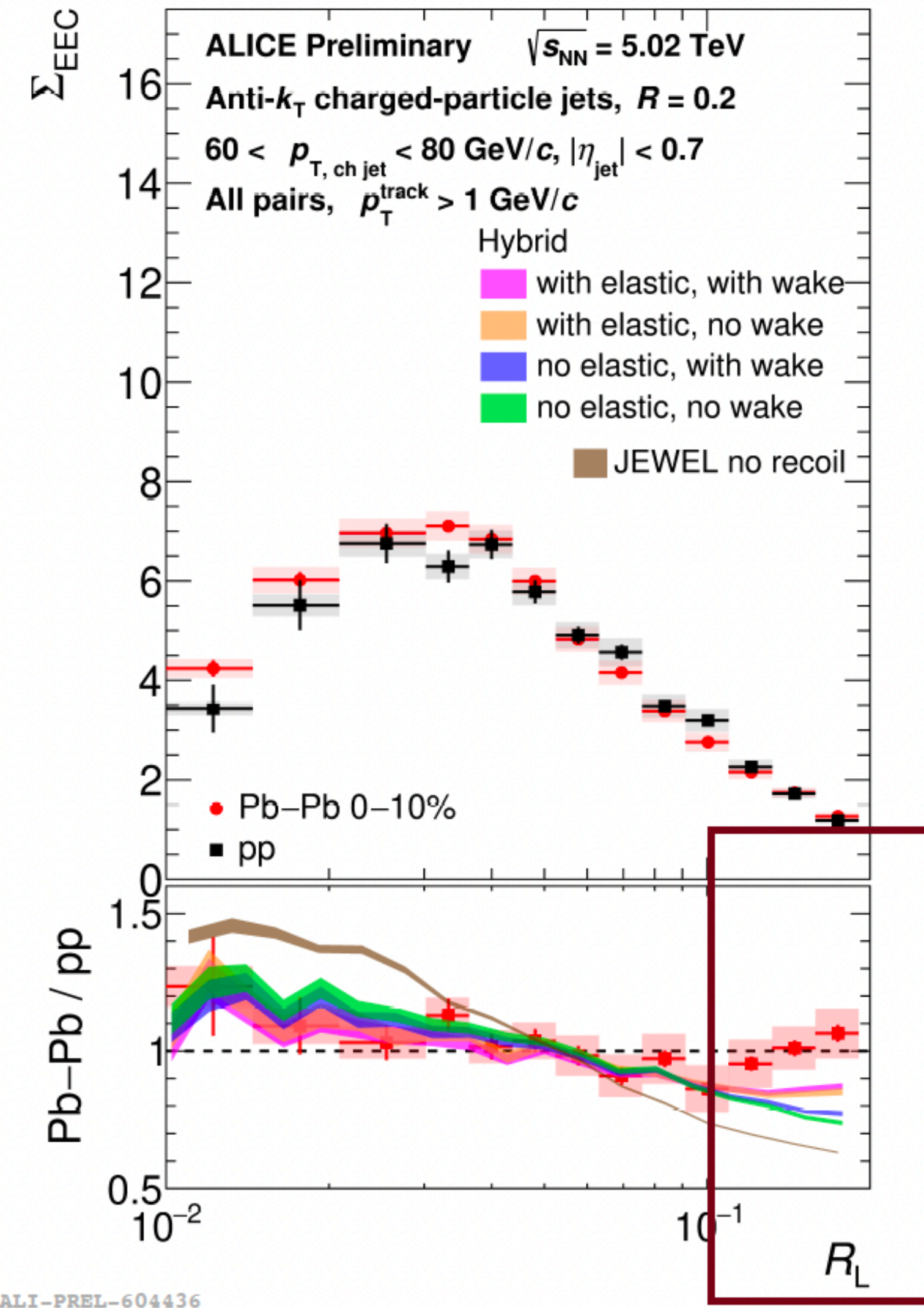
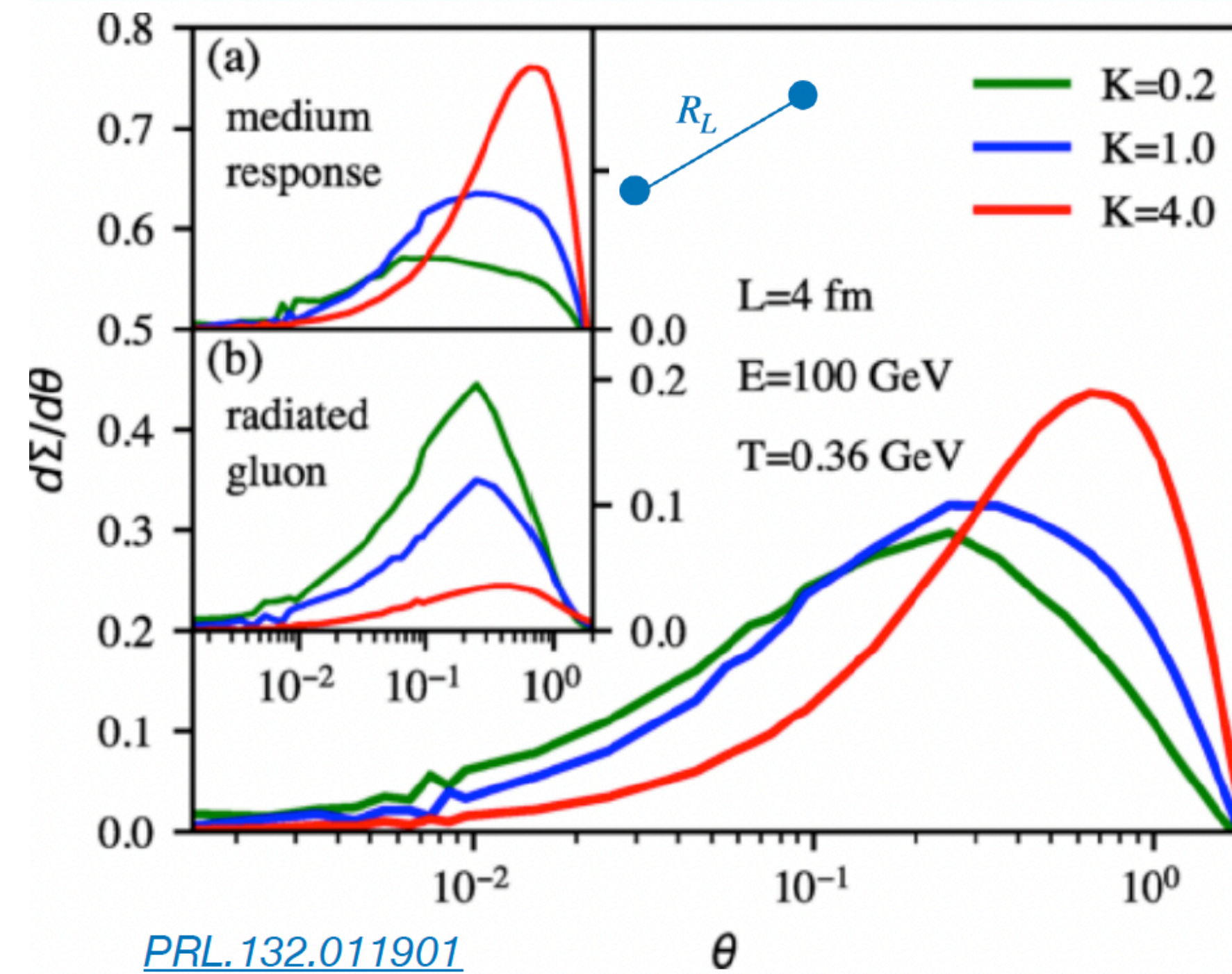
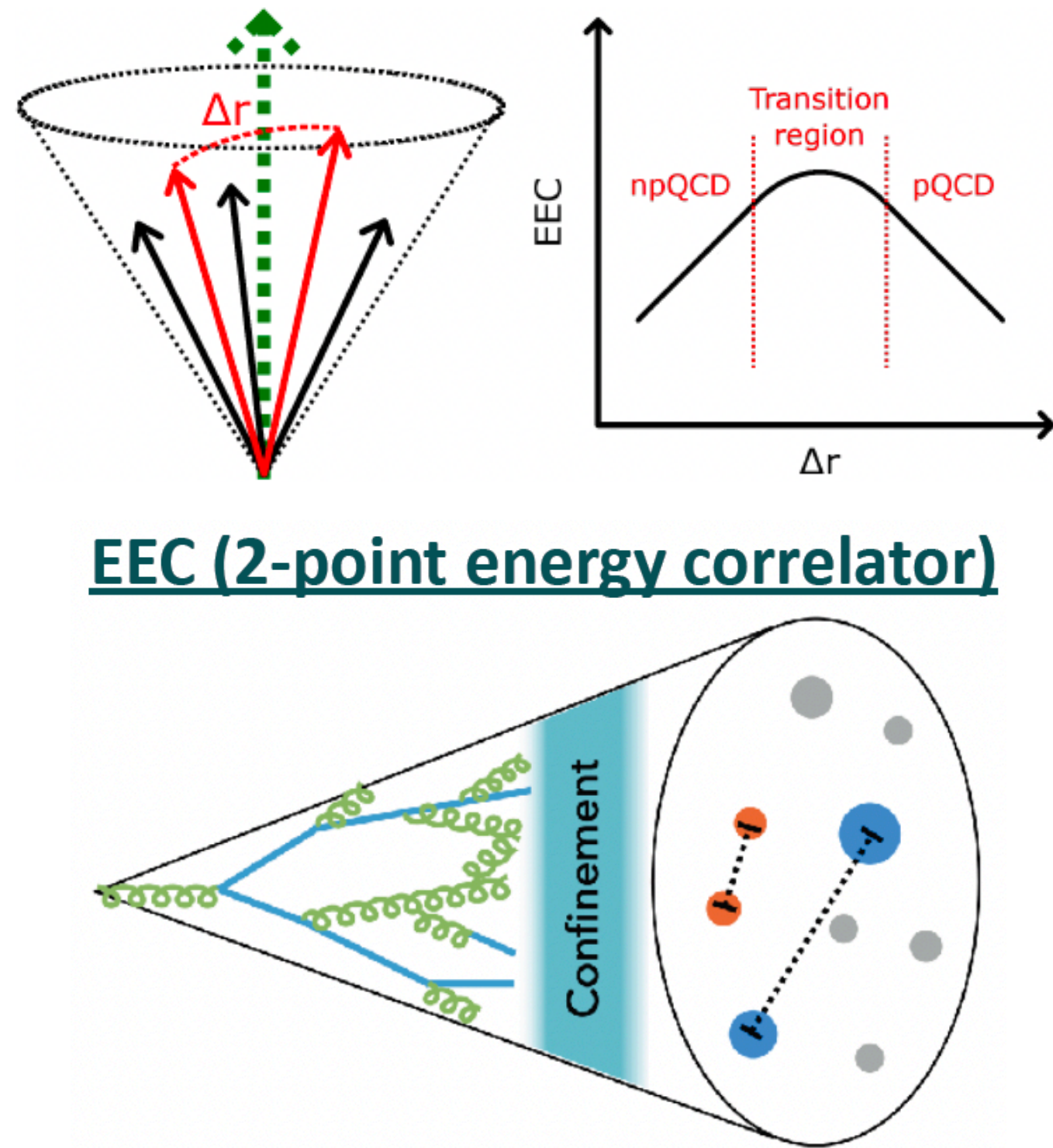
EEC (2-point energy correlator)



[PRL.132.011901](#)

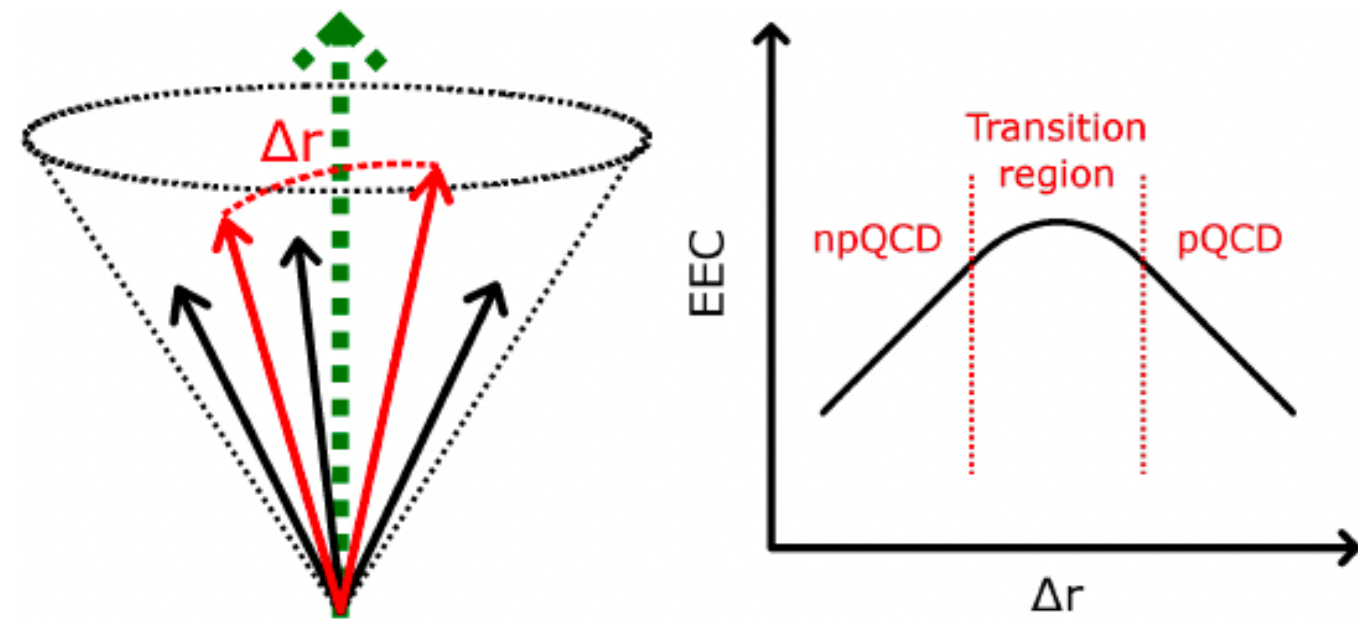
- The response of the medium are expected to change the EEC shape at larger angles

Search for medium response through energy-energy correlator

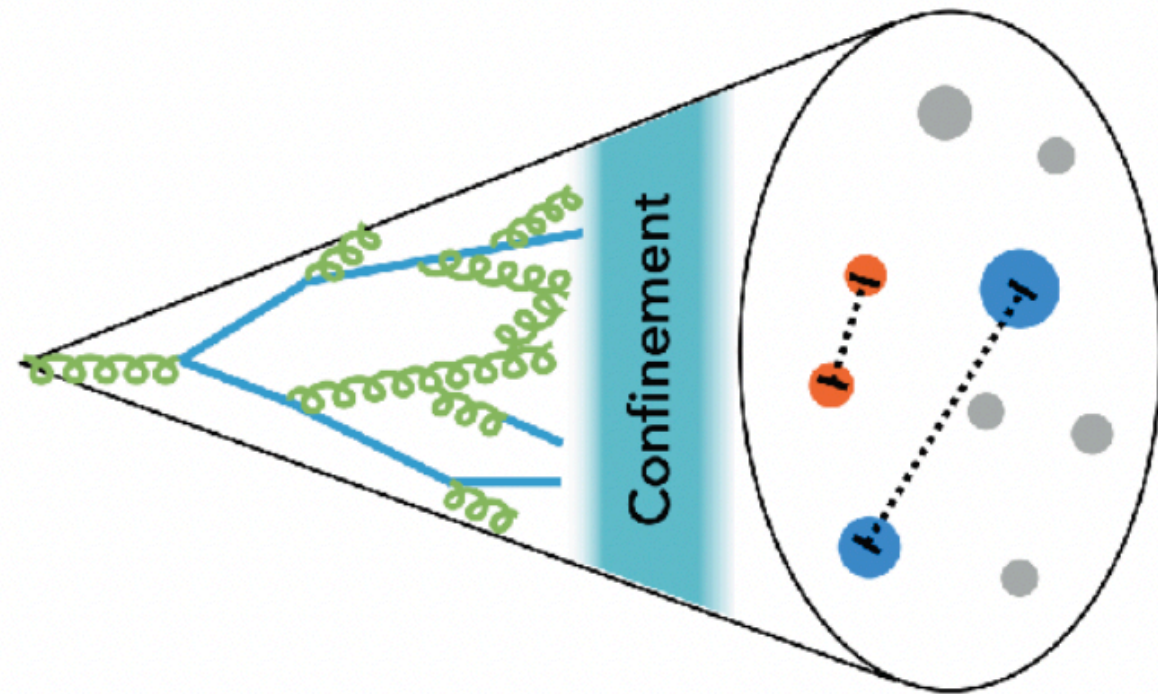


- The response of the medium are expected to change the EEC shape at la angles
- Hints of enhancement at low R_L and suppression at high R_L

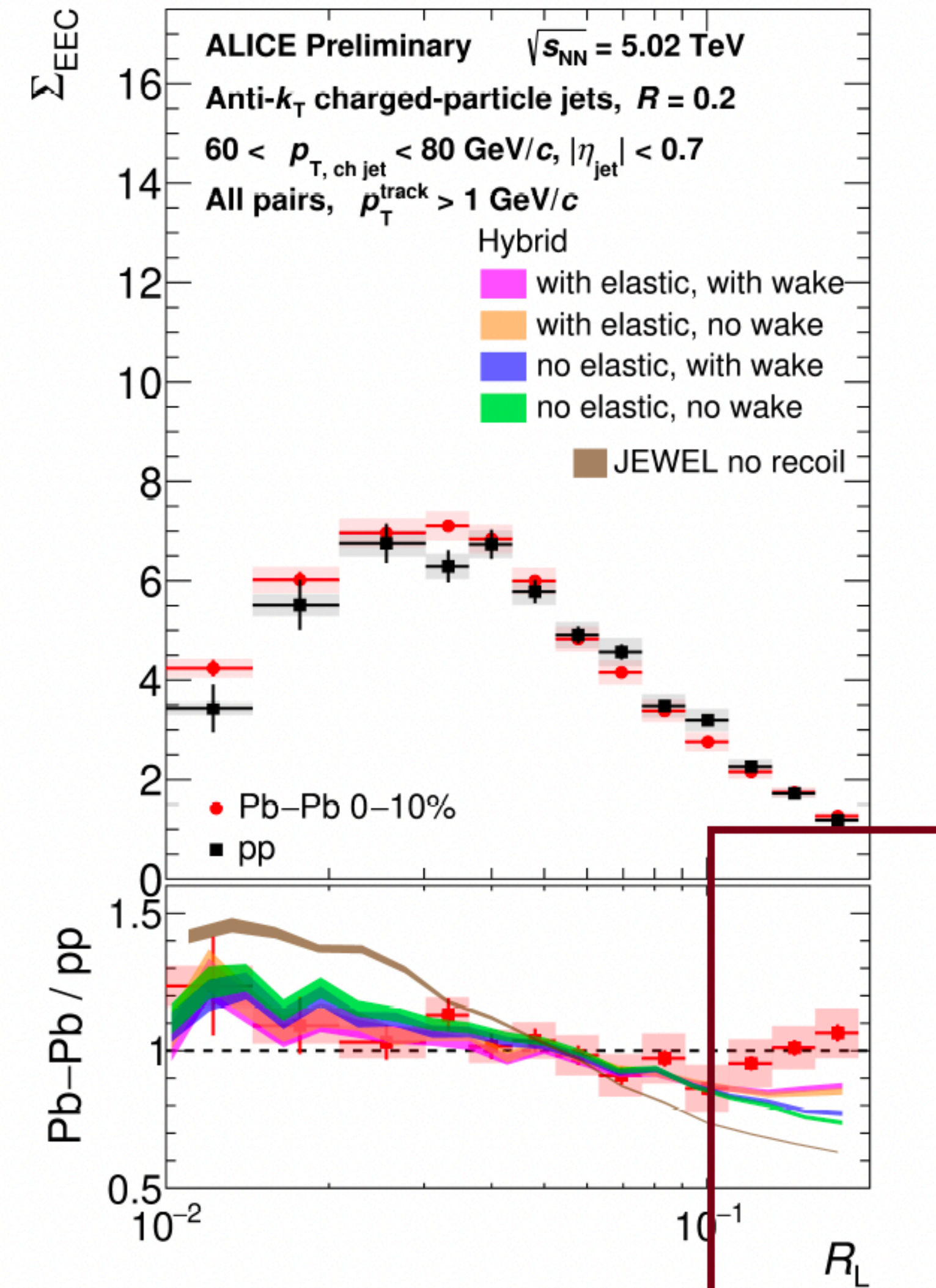
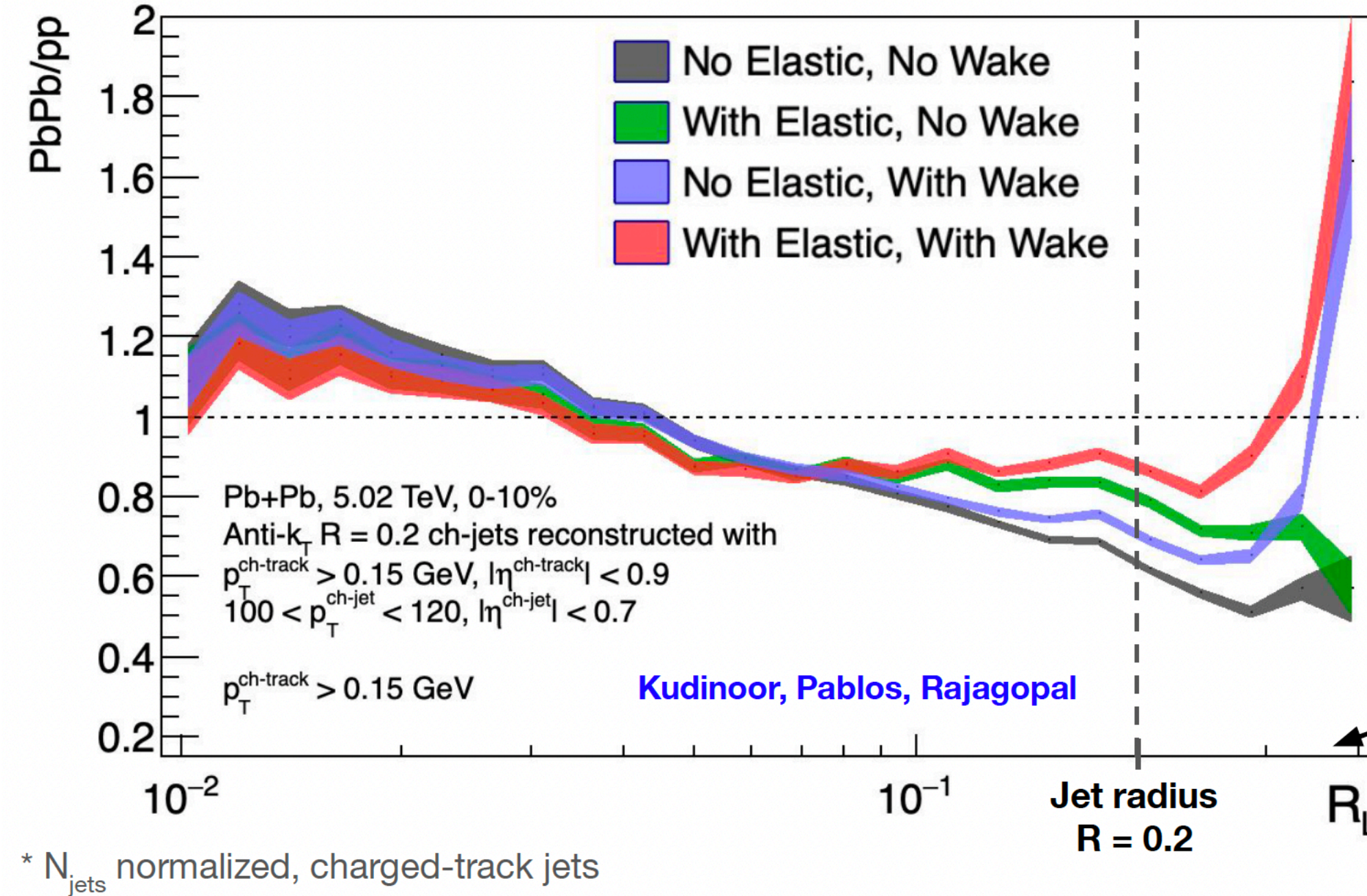
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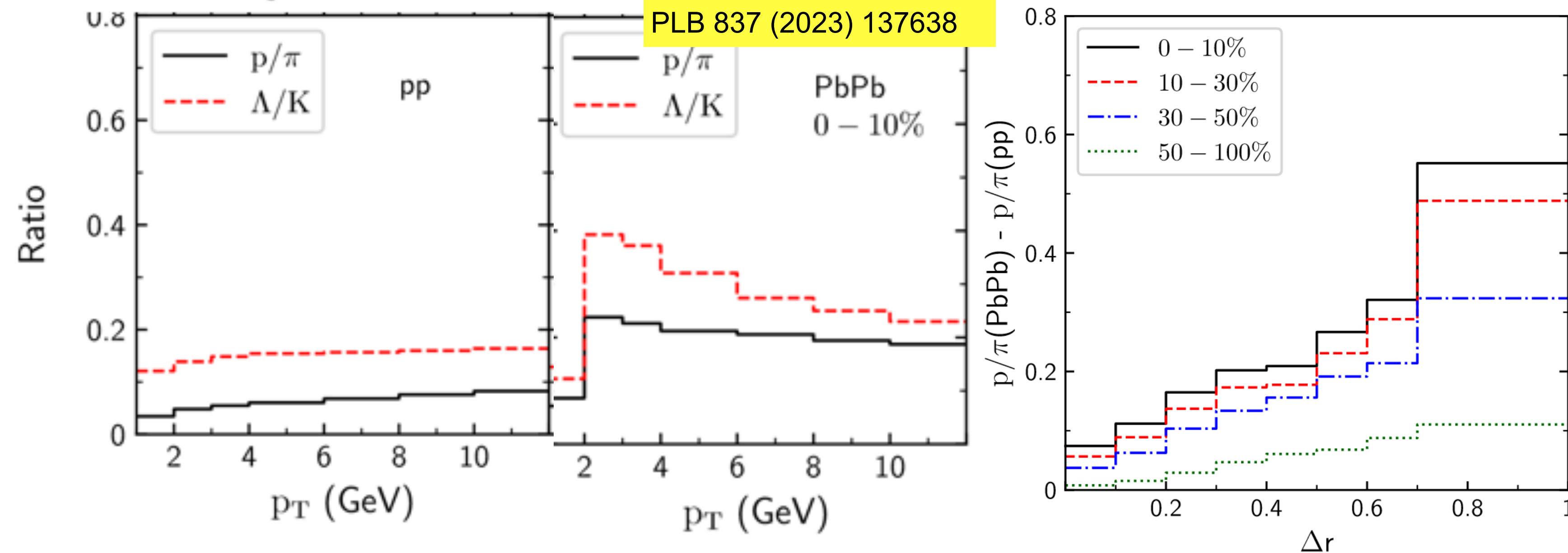
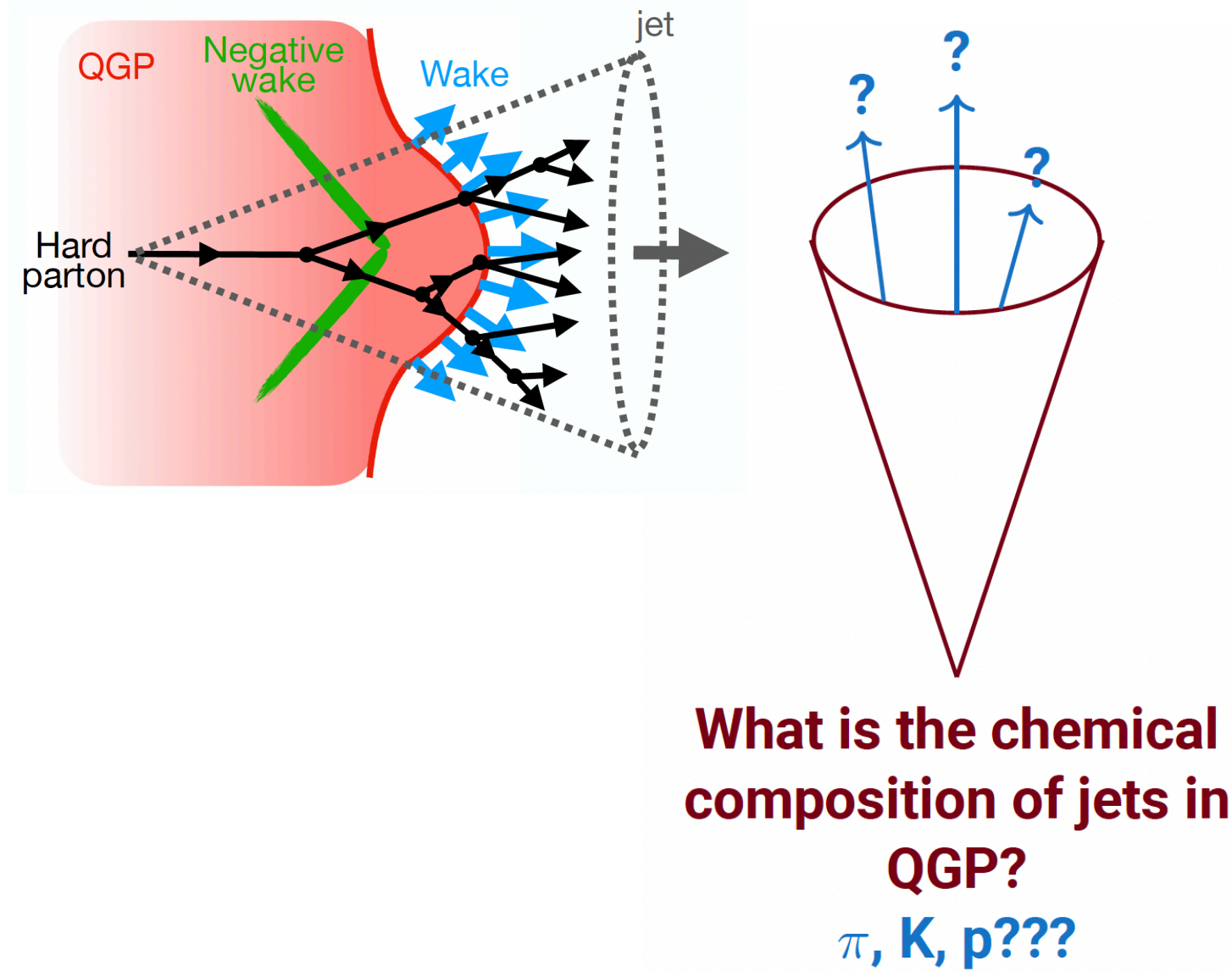


R = 0.2 Charged Jet EECs: $p_T^{\text{ch-track}} > 0.15 \text{ GeV}$ Predictions for ALICE



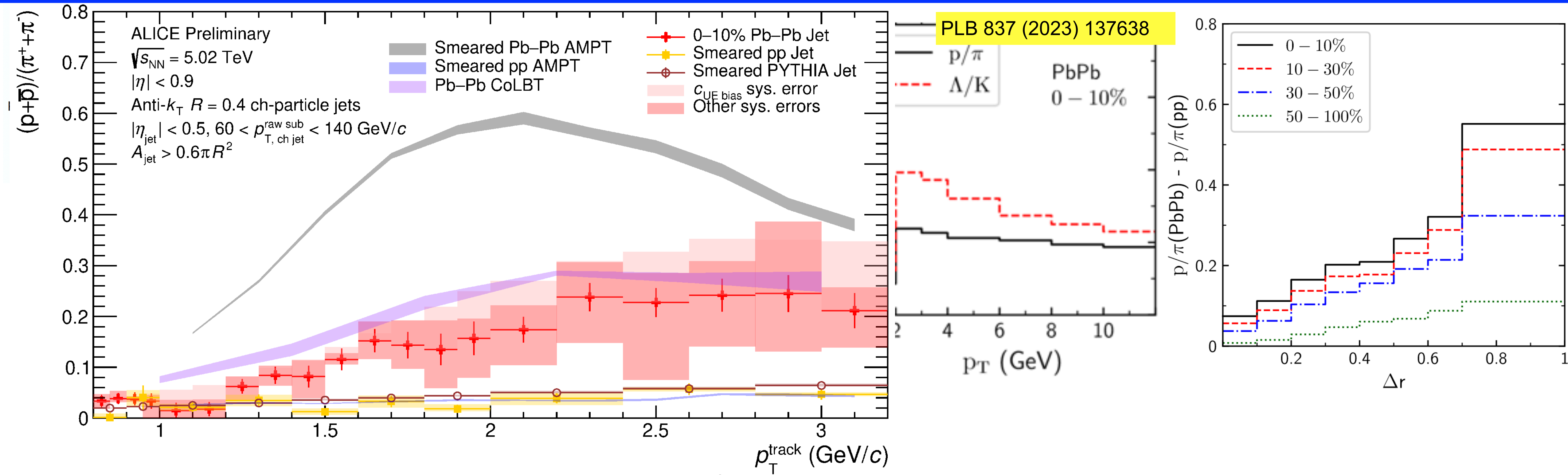
- The response of the medium are expected to change the EEC shape at large angles
- Hints of enhancement at low R_L and suppression at high R_L
- Predictions by theorists suggest to enlarge jet-radius and lower p_T in order to search wake effects → accessible with Run 3 data

Jet hadronchemistry to probe medium response



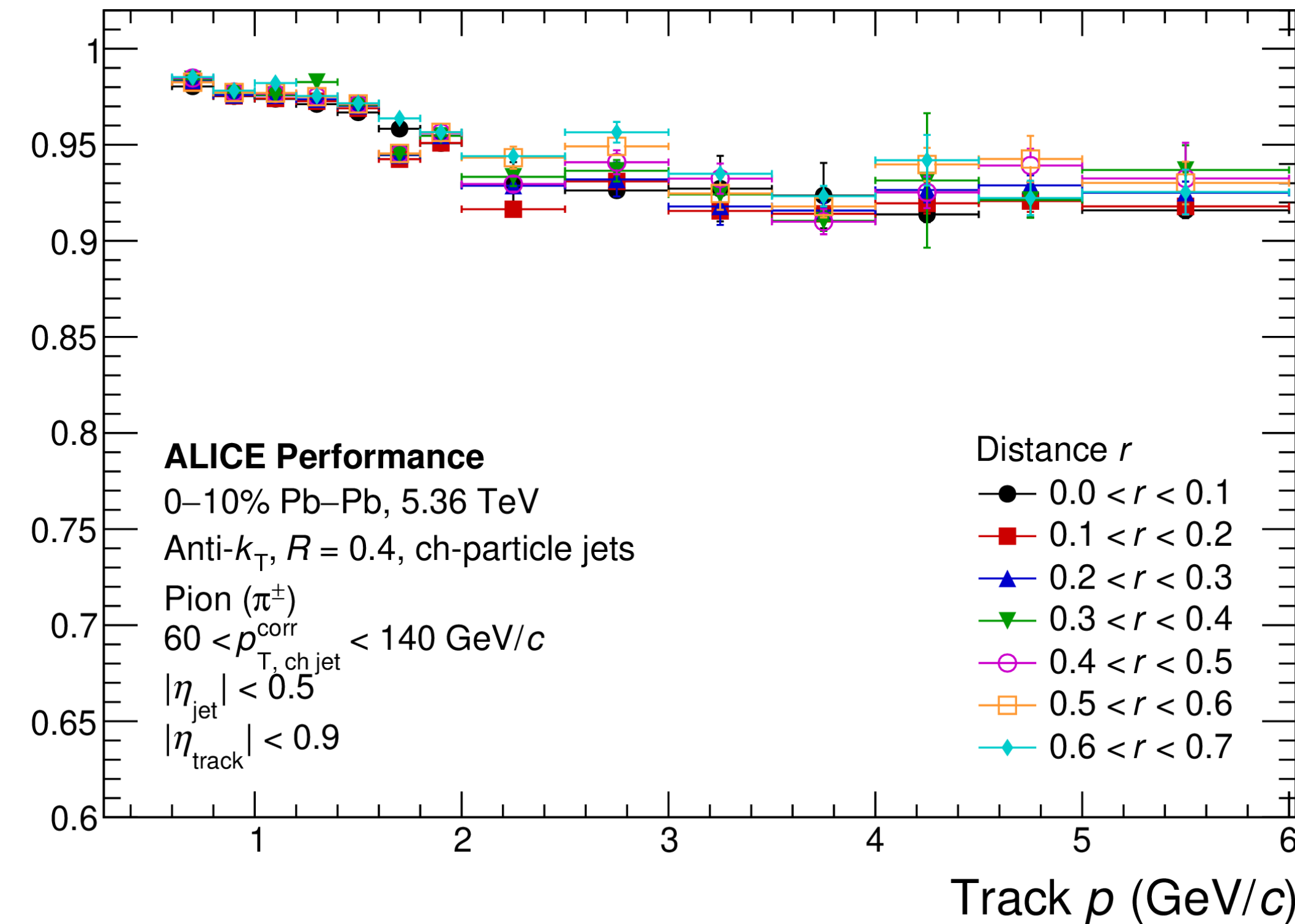
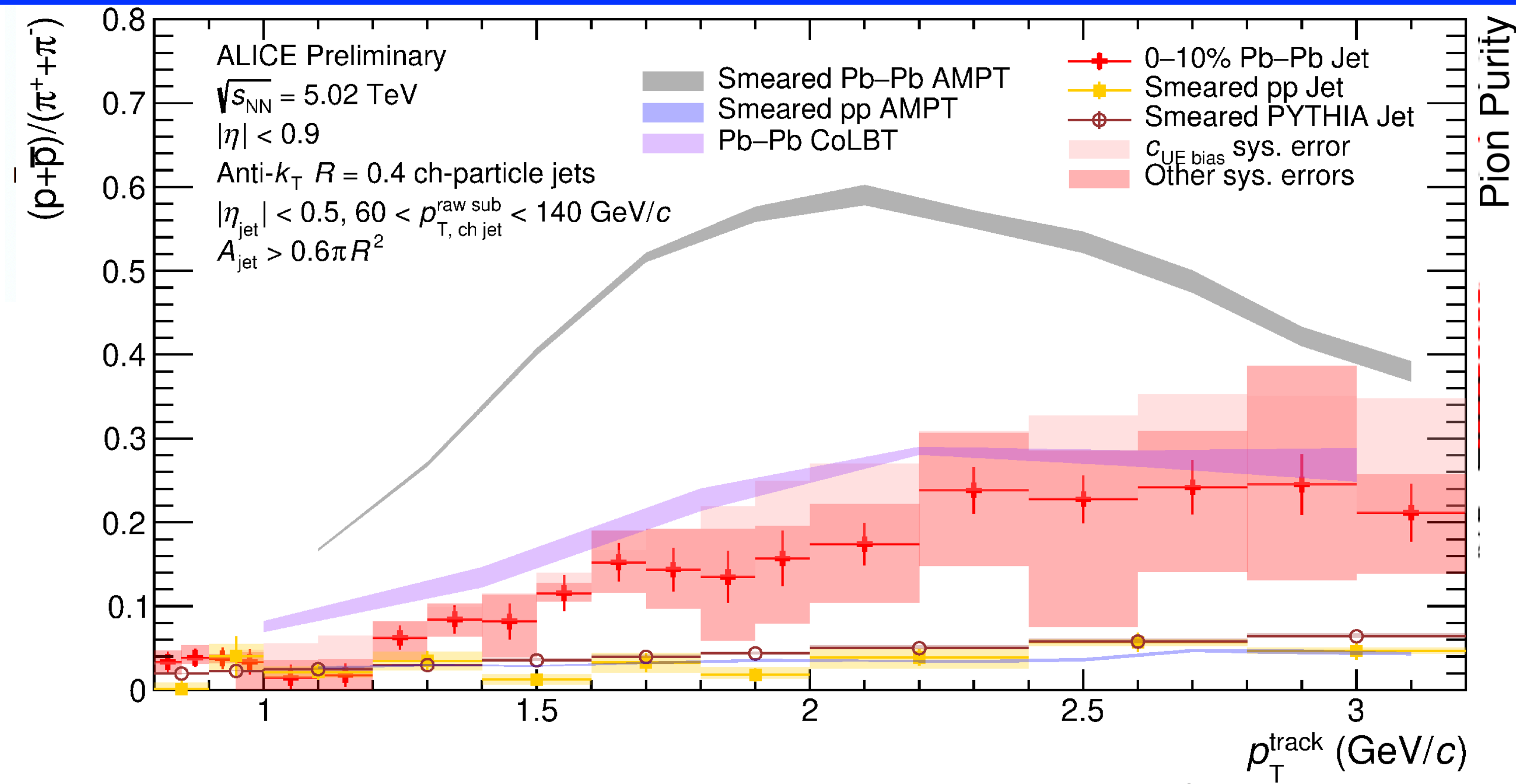
- Theory predicts jet-medium interactions modify baryon-to-meson ratios
 - ➔ Enhancement of B/M ratios at intermediate p_T (2-6 GeV/c) for larger distance with respect to jet axis using jet-hadron correlations (explained by coalescence of medium excitations)

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- Experiments measured in-jet p/π ratio in central AA and pp collisions
 - ➔ Hints of excess of in-jet B/M ratio in central AA with respect to pp

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 - ➔ Hints of excess of in-jet B/M ratio in central AA with respect to pp
- ➔ excellent opportunity for ALICE Run 3

Chasing the small size-limit of QGP

- Collective-like effects present in high multiplicity pp and p-Pb collisions
- But: No jet quenching observed in pp, p-Pb (d-Au) at high multiplicities
- Open questions:
 - ➡ How plasma-like properties emerge in QCD?
 - ➡ What is the smallest droplet of QGP?

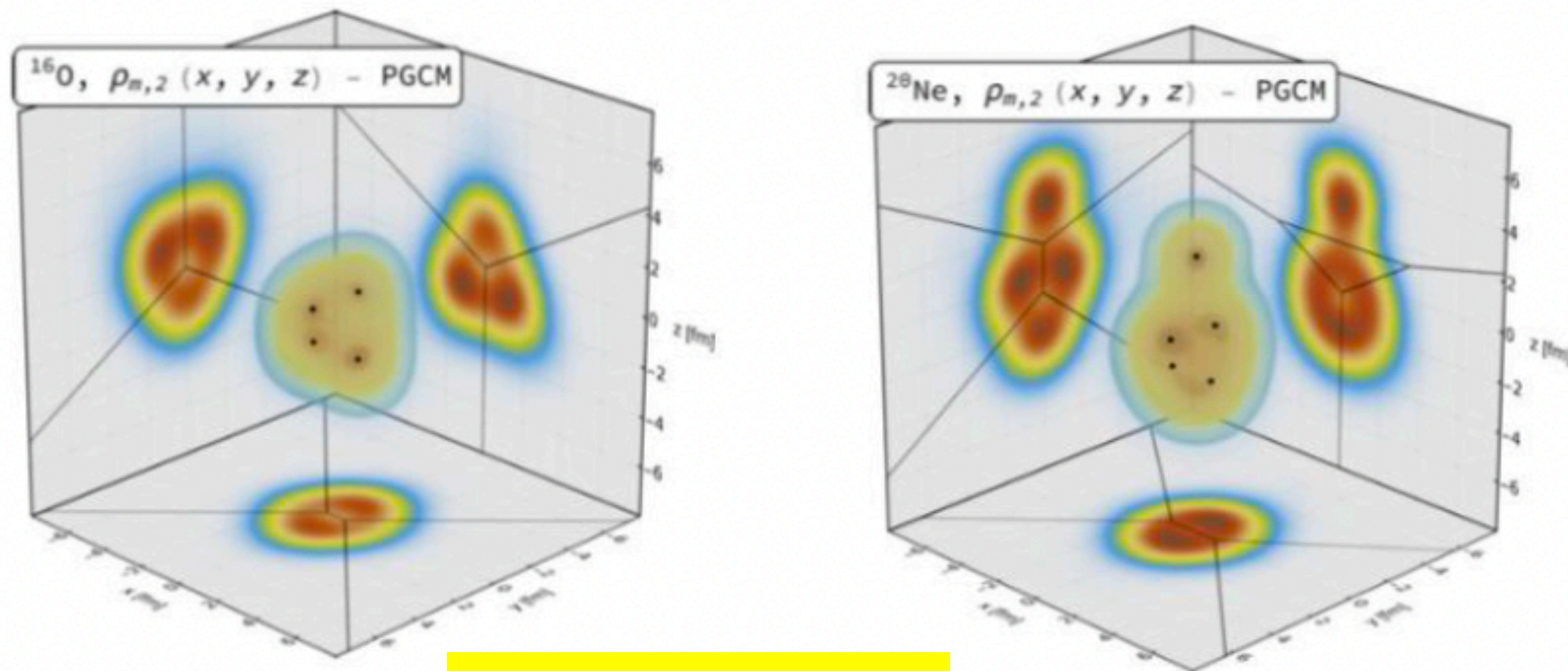


Chasing the small size-limit of QGP

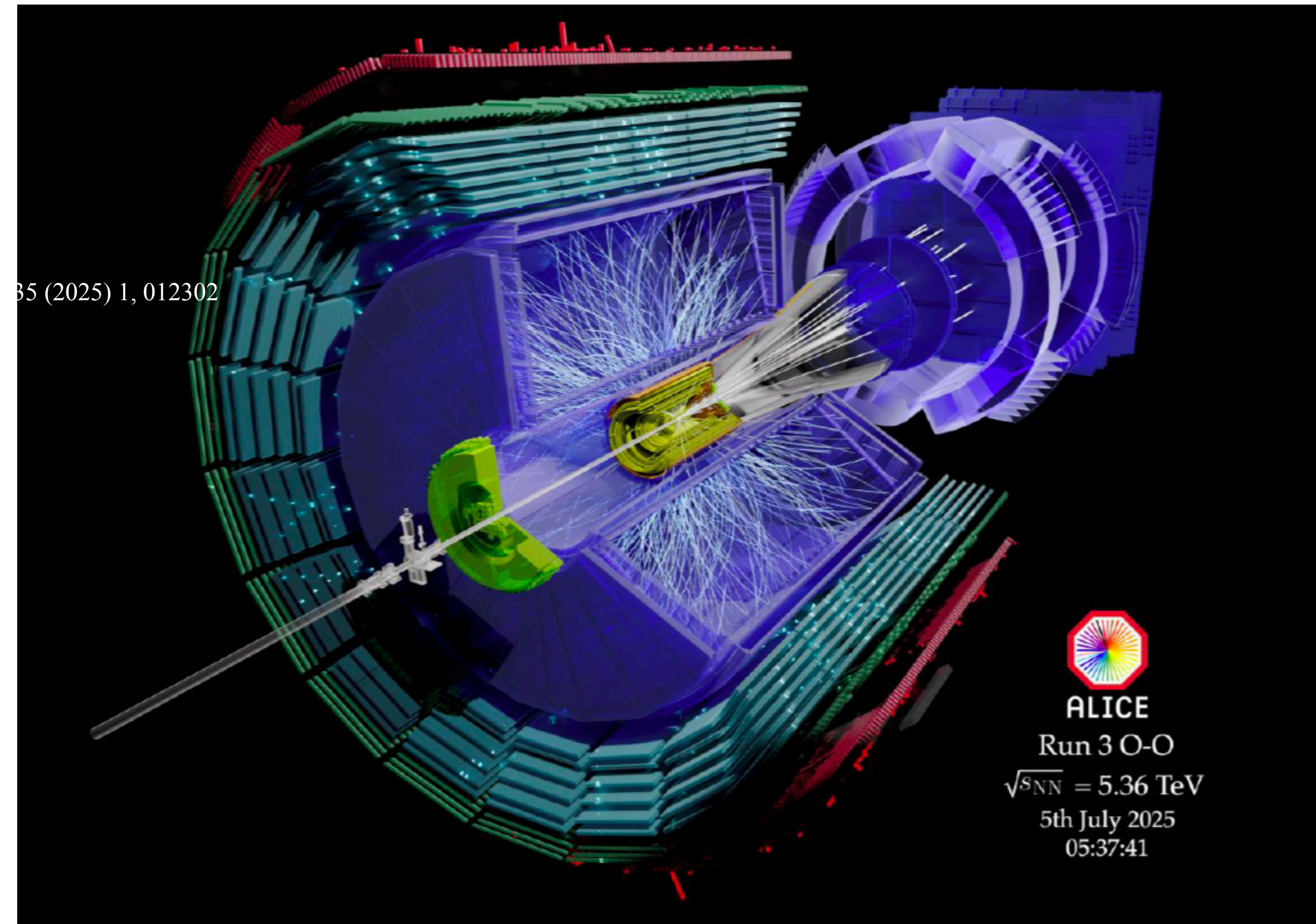
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July 2025:

O-O, Ne-Ne, p-O data taking



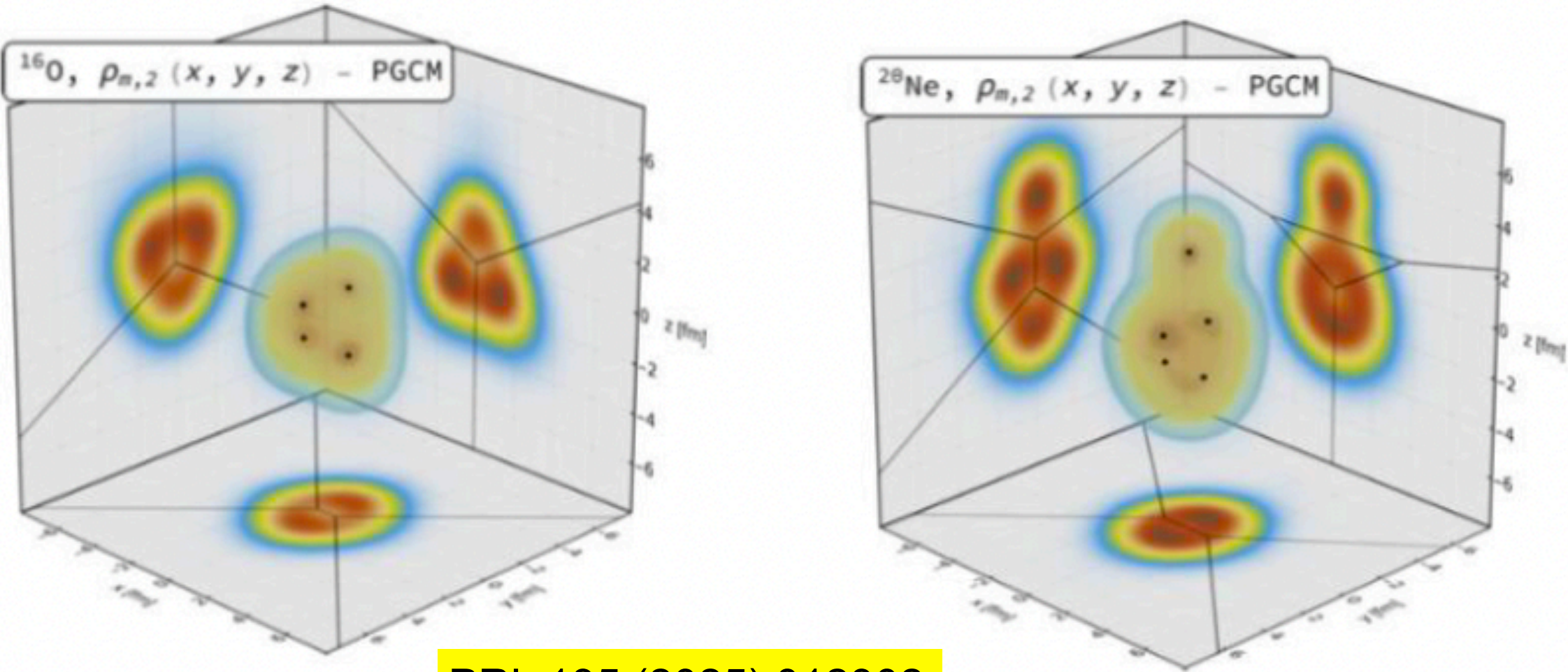
PRL 135 (2025) 012302



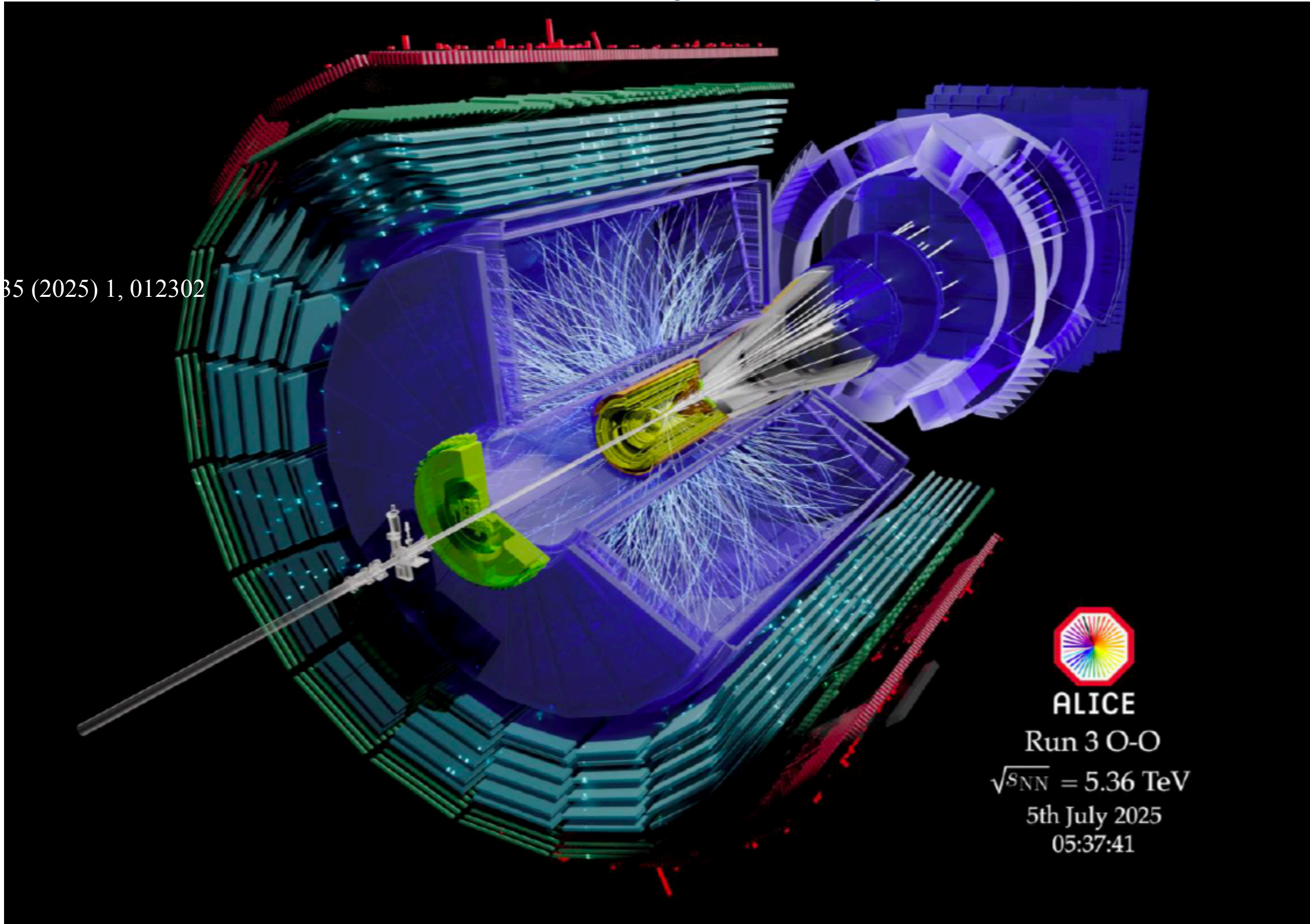
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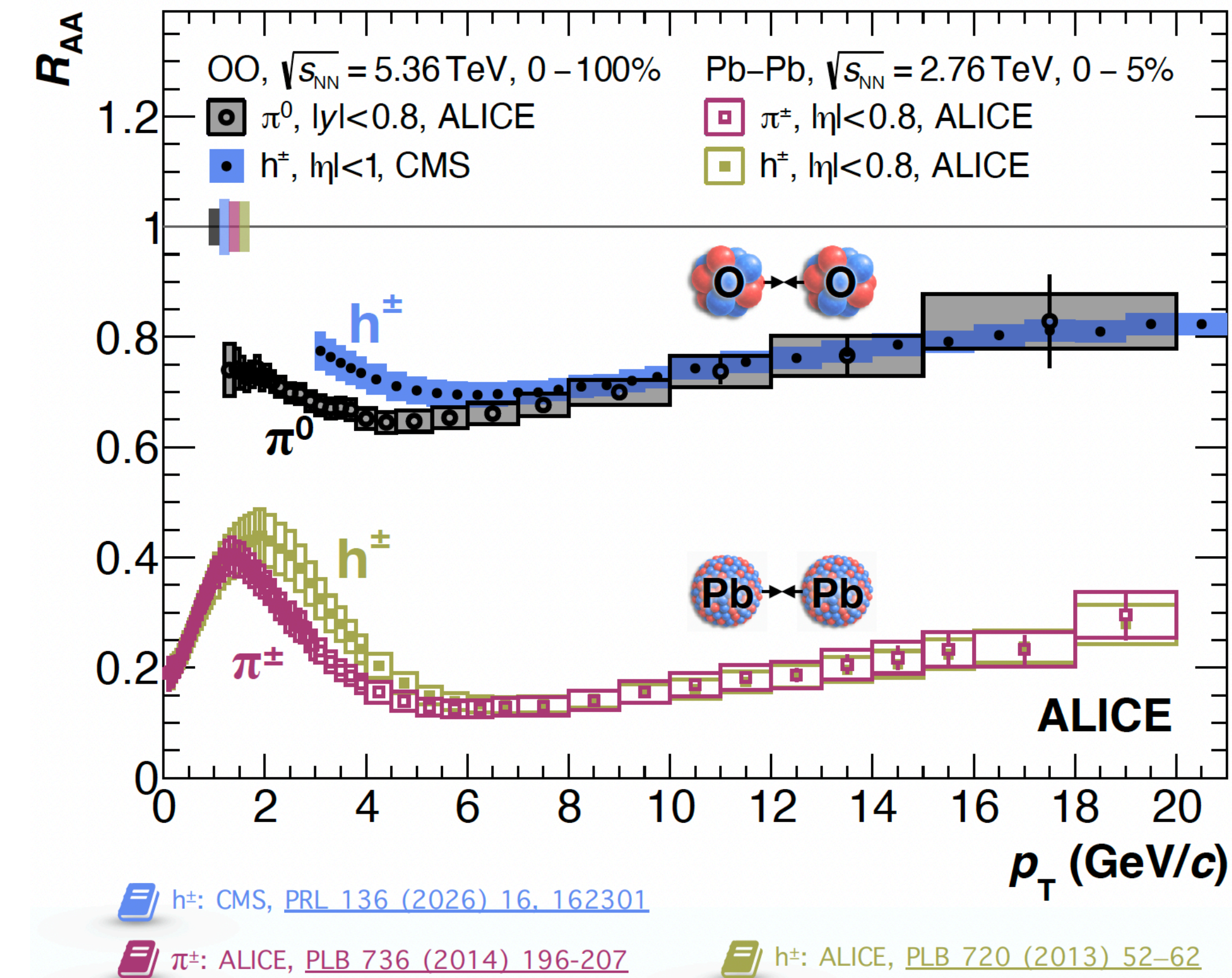
	p0	00	NeNe	pp
$\sqrt{s_{NN}}$	9.62 TeV	5.36 TeV	5.36 TeV	5.36 TeV
Rate	15 kHz	35 kHz	~35 kHz	~1 MHz
μ	0.04	0.09	0.09	0.033
$\mathcal{L}_{int}^{rec}$	7.3 nb ⁻¹	5.0 nb ⁻¹	0.8 nb ⁻¹	5.3 pb ⁻¹



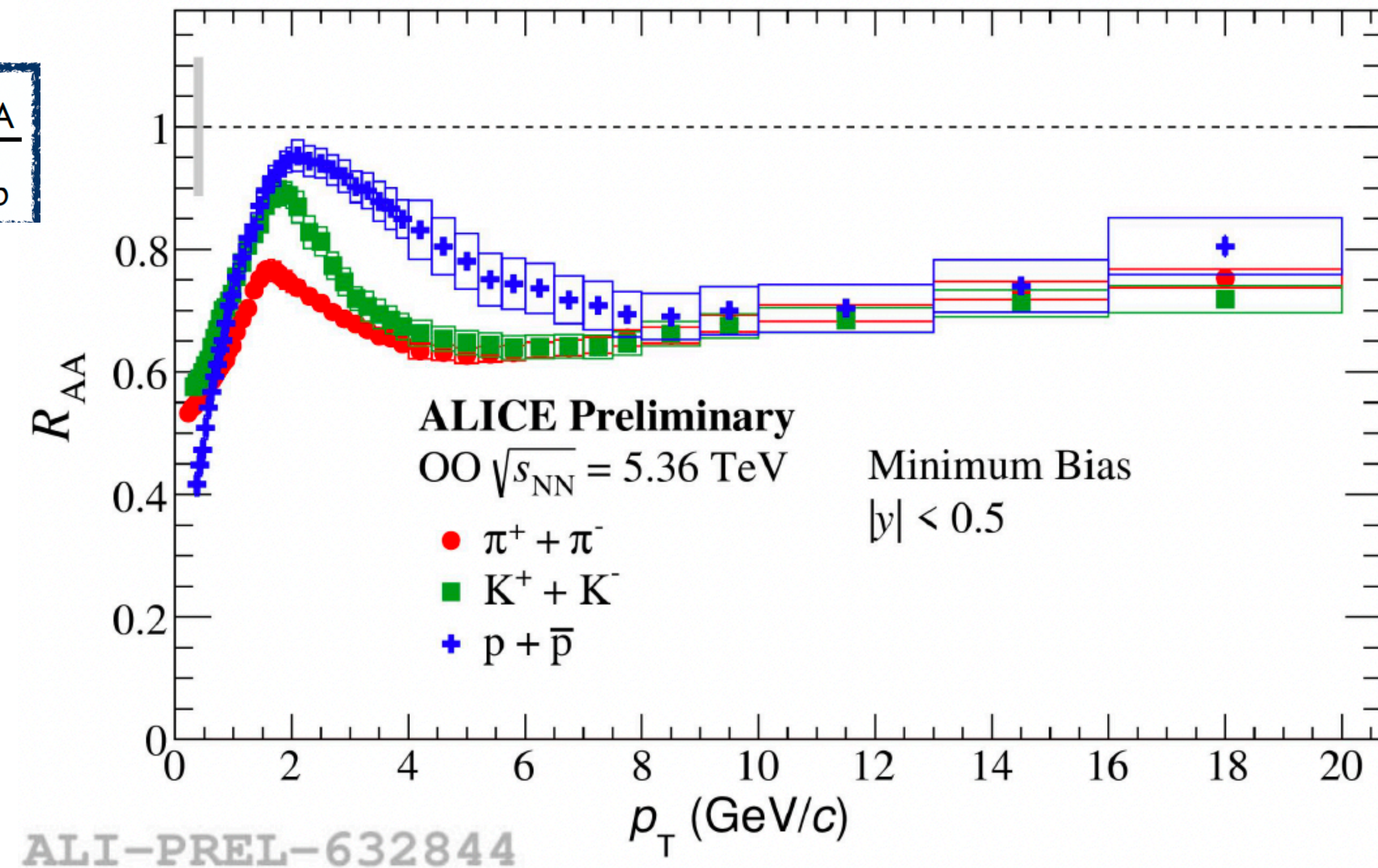
PRL 135 (2025) 012302



Search for jet quenching in OO

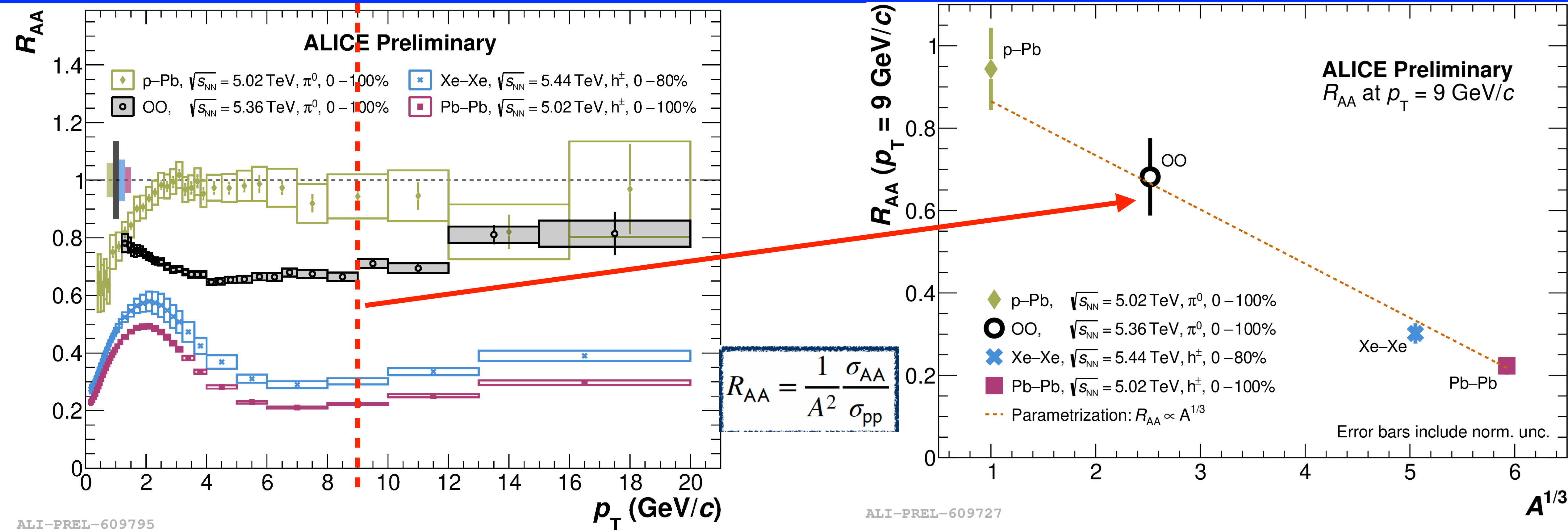


$$R_{AA} = \frac{1}{A^2} \frac{\sigma_{AA}}{\sigma_{pp}}$$



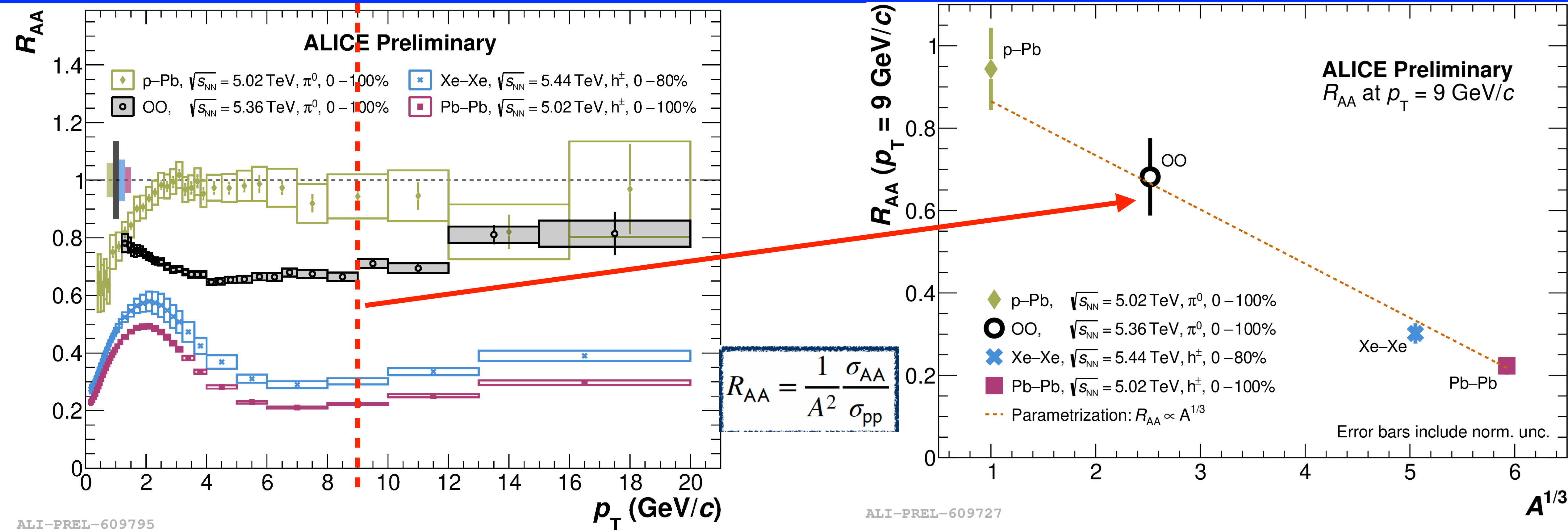
- Nuclear modification factor (R_{OO}) of neutral pion and identified particle production measured → **suppression observed**
- Comparison with CMS charged hadron results: good agreement within uncertainties
- Comparison to Xe-Xe and Pb-Pb results: suppression increases with larger ion size

System size dependence of particle suppression



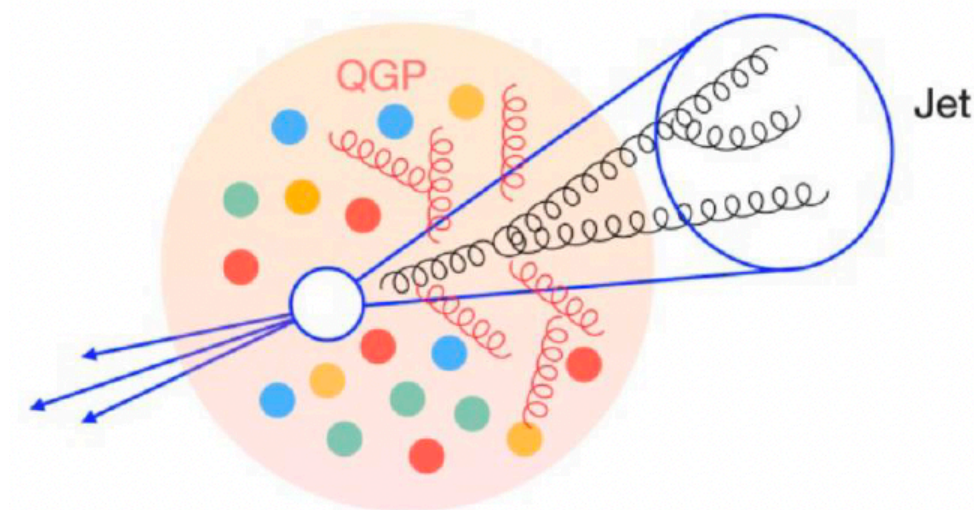
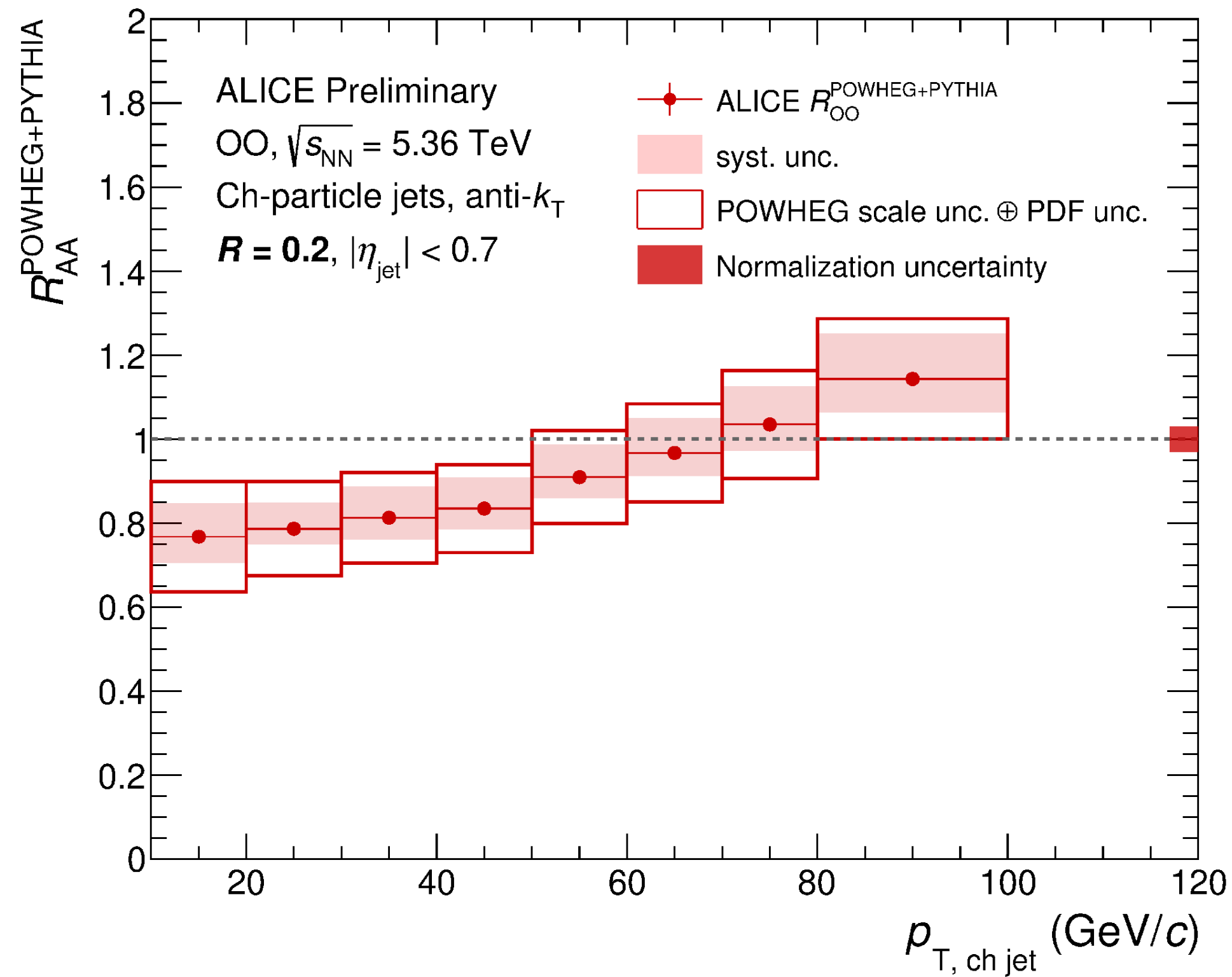
- Observed suppression is consistent with linear dependence on $A^{1/3} \rightarrow$ what does this tell us about the path-length dependence of energy loss?
- Theoretical predictions for A-dependence of energy loss & comparison to data would be very interesting
- A-dependence of other effects needs to be considered (initial state etc.)

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- A-dependence of other effects needs to be considered (initial state etc.) **what happens to jets?**

Jet modification in OO collisions

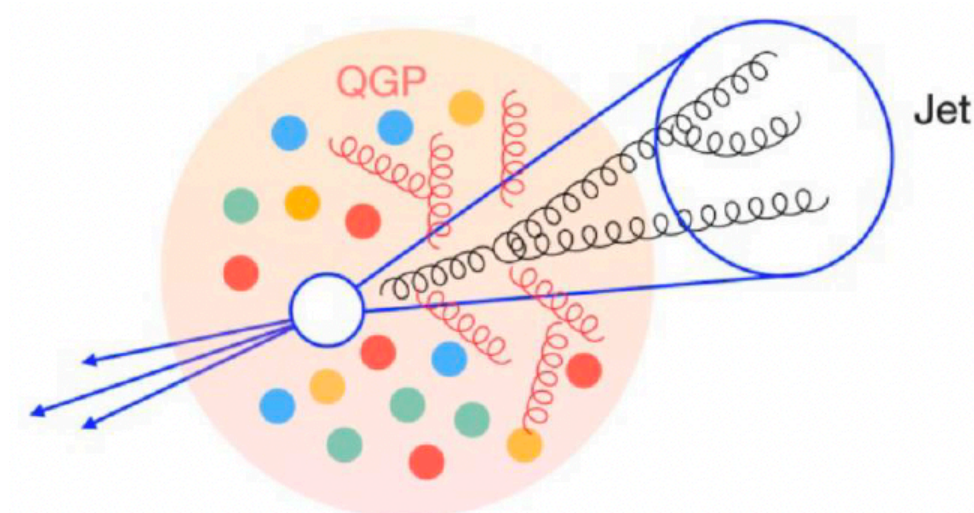
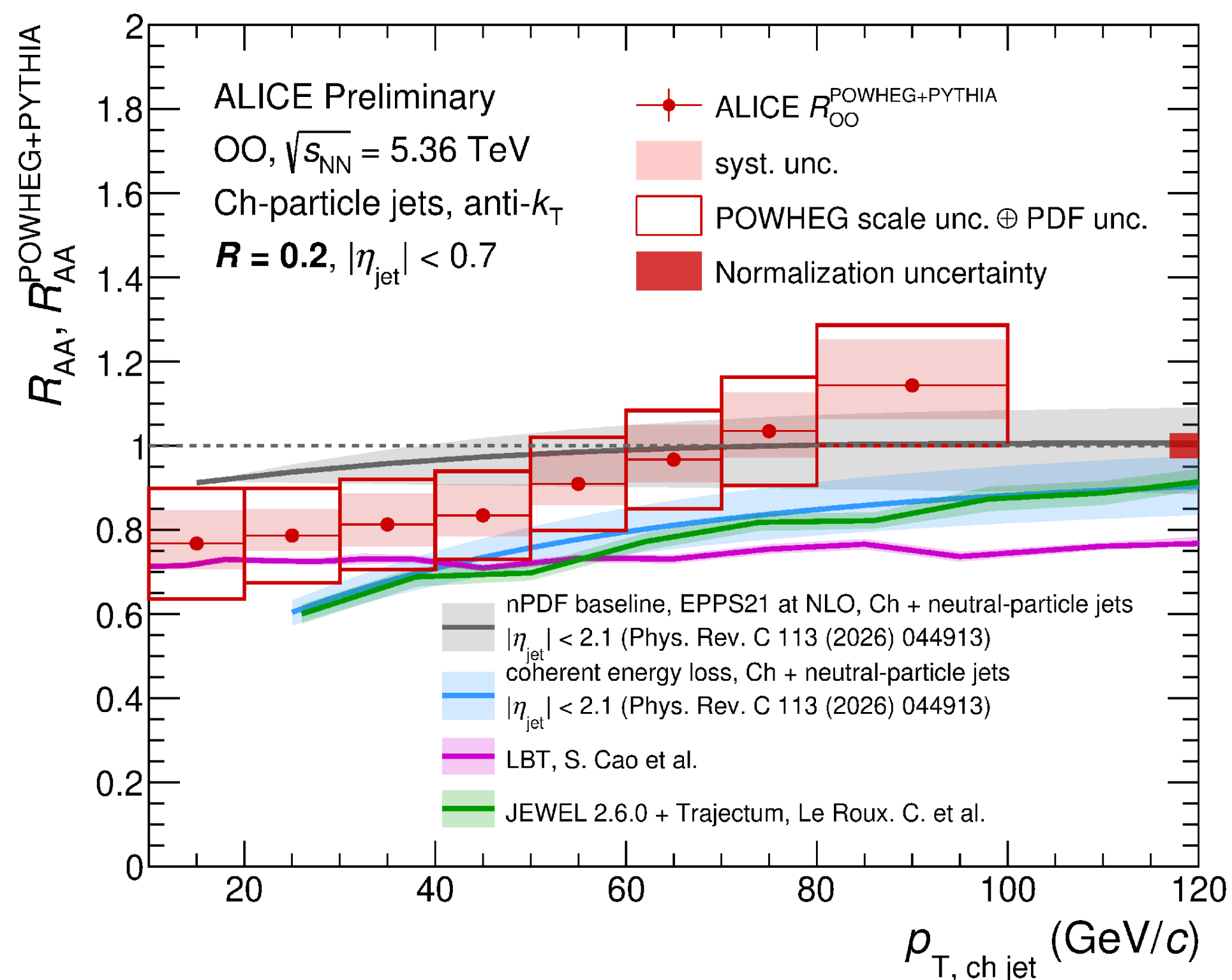


<https://www.int.washington.edu/node/776>

$$R_{AA} = \frac{1}{A^2} \frac{\sigma_{AA}}{\sigma_{pp}}$$

- Hints of jet suppression at low p_T

Jet modification in OO collisions



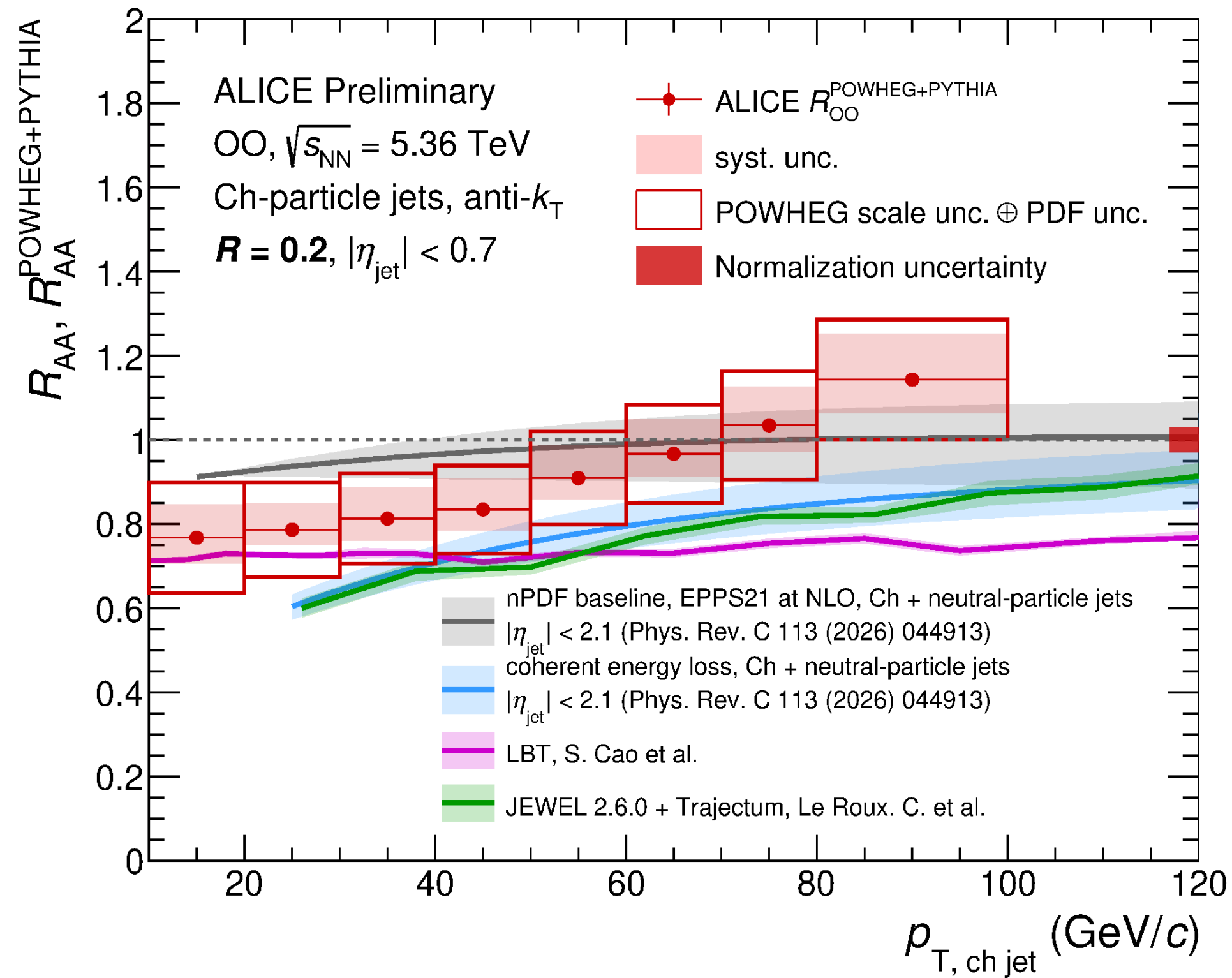
<https://www.int.washington.edu/node/776>

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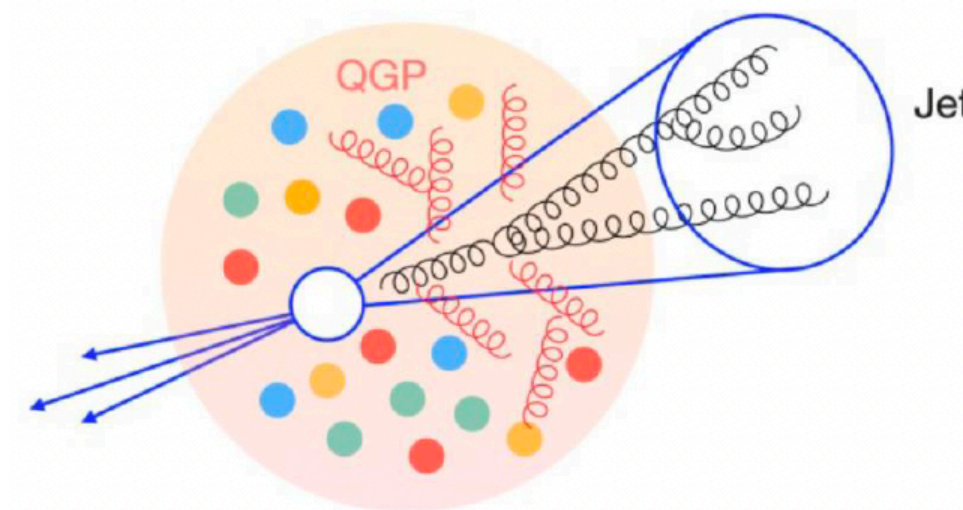
ALI-PREL-635343

- Hints of jet suppression at low p_T
- Current uncertainties do not allow a clear discrimination between different energy loss scenarios

Jet modification in OO collisions

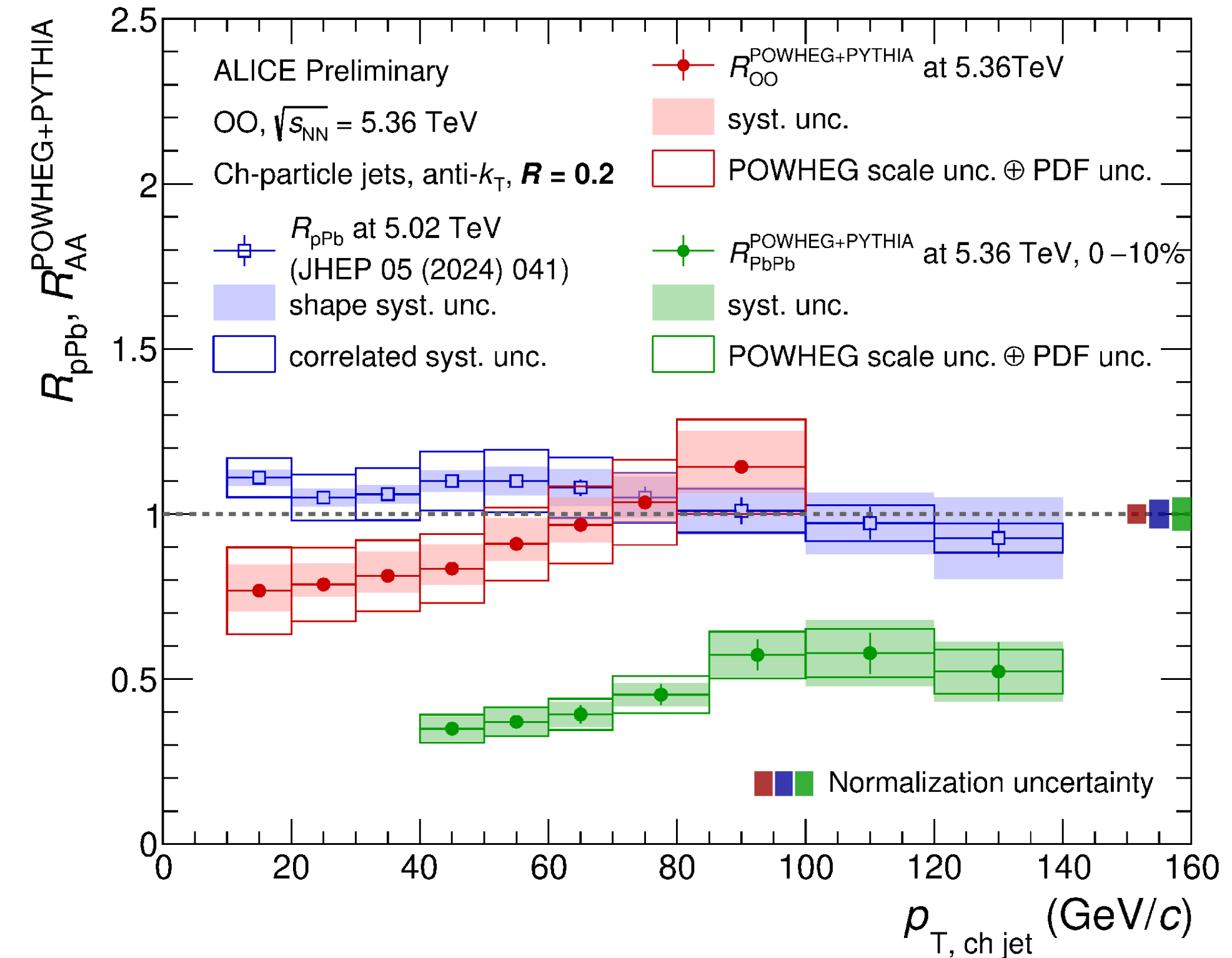


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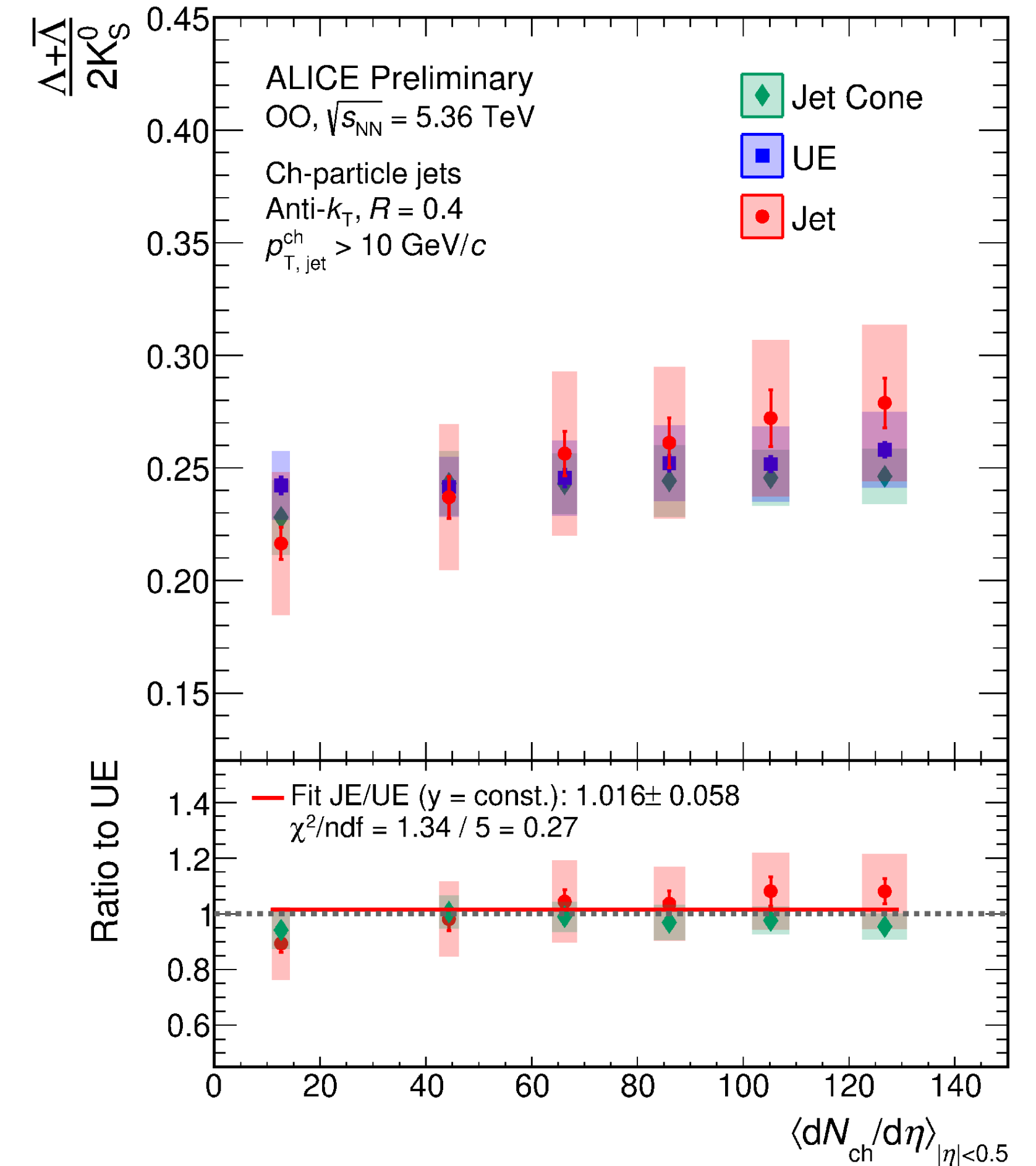
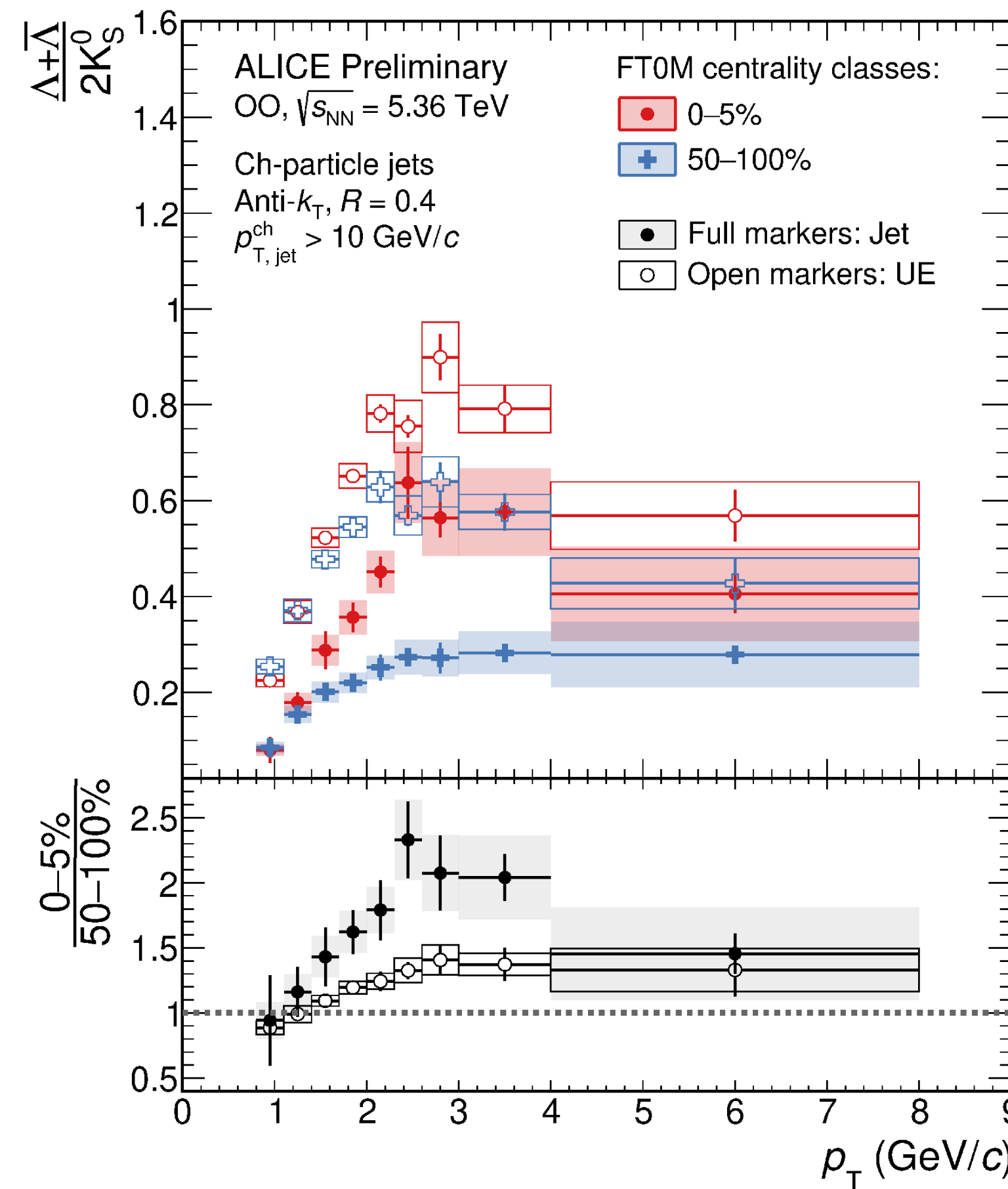
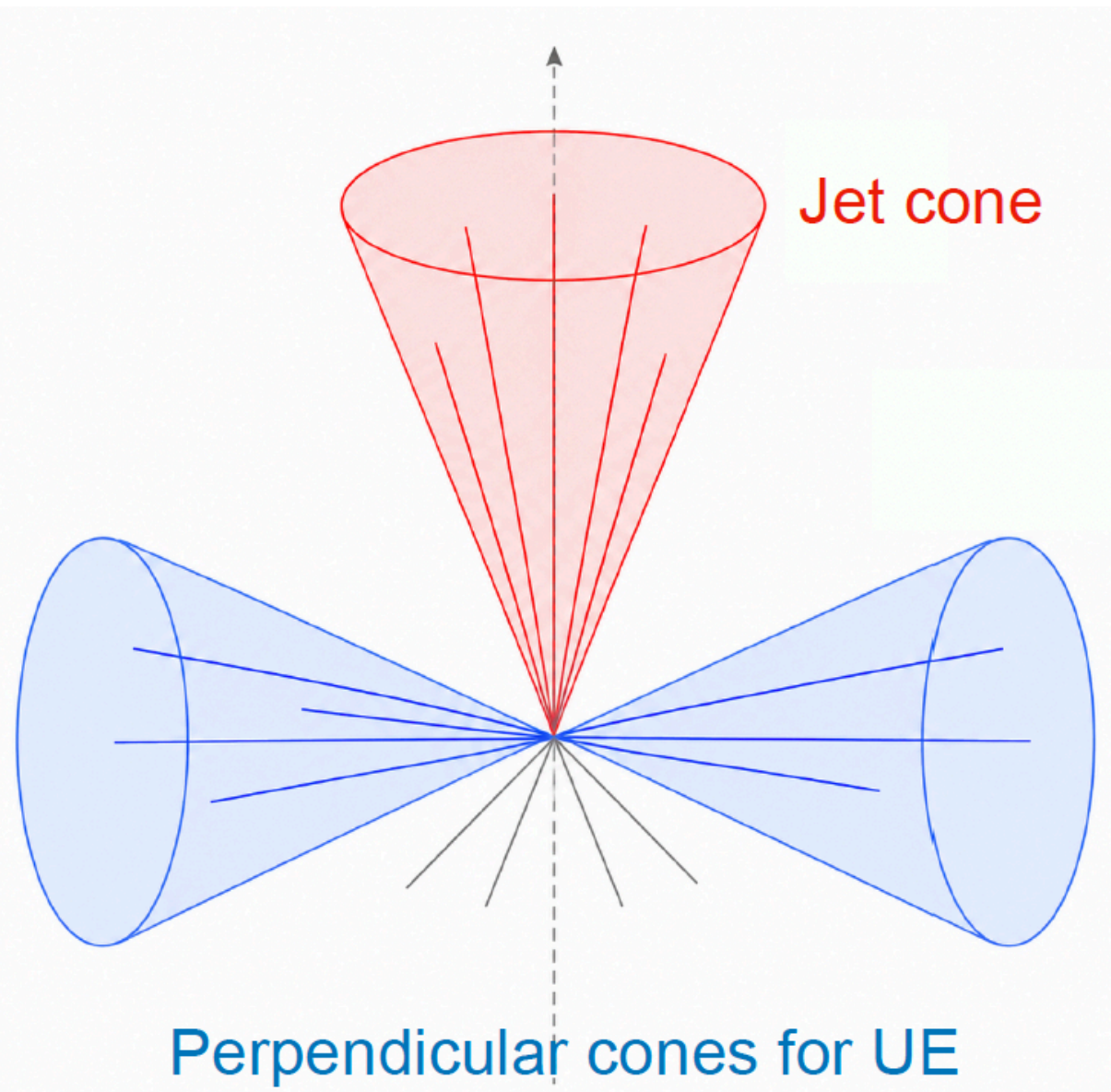
$$R_{AA} = \frac{1}{A^2} \frac{\sigma_{AA}}{\sigma_{pp}}$$



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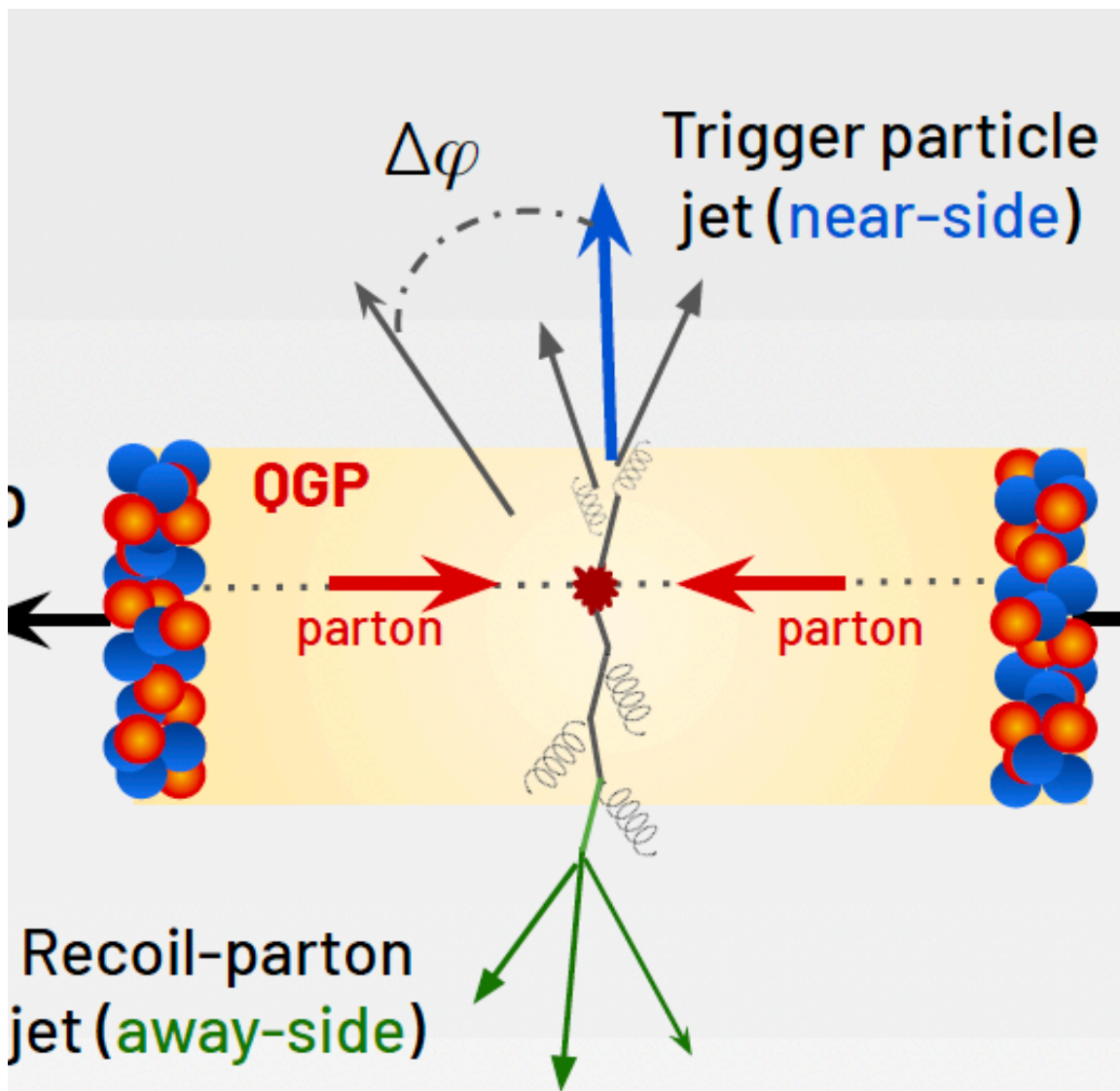
- Hints of jet suppression at low p_T
- Current uncertainties do not allow a clear discrimination between different energy loss scenarios
- Indication of nuclear modification factor hierarchy for low p_T jets ($R_{AA}(\text{Pb-Pb}) < R_{OO} < R_{p\text{-Pb}} (\sim 1)$)

Strangeness in jets in OO collisions



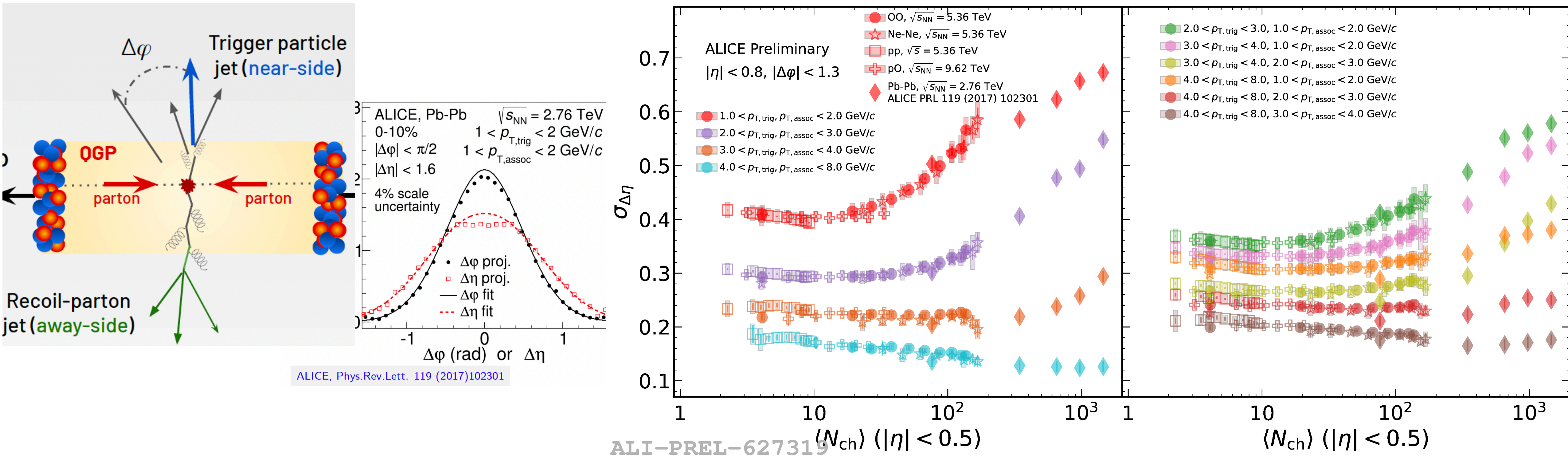
- Multiplicity-driven enhancement of strange-hadron production is stronger in the UE than in jets
- The p_T -integrated Λ/k_s^0 ratio shows no significant multiplicity dependence
- No significant difference is observed between jet and UE regions

Two-particle correlations in OO collisions



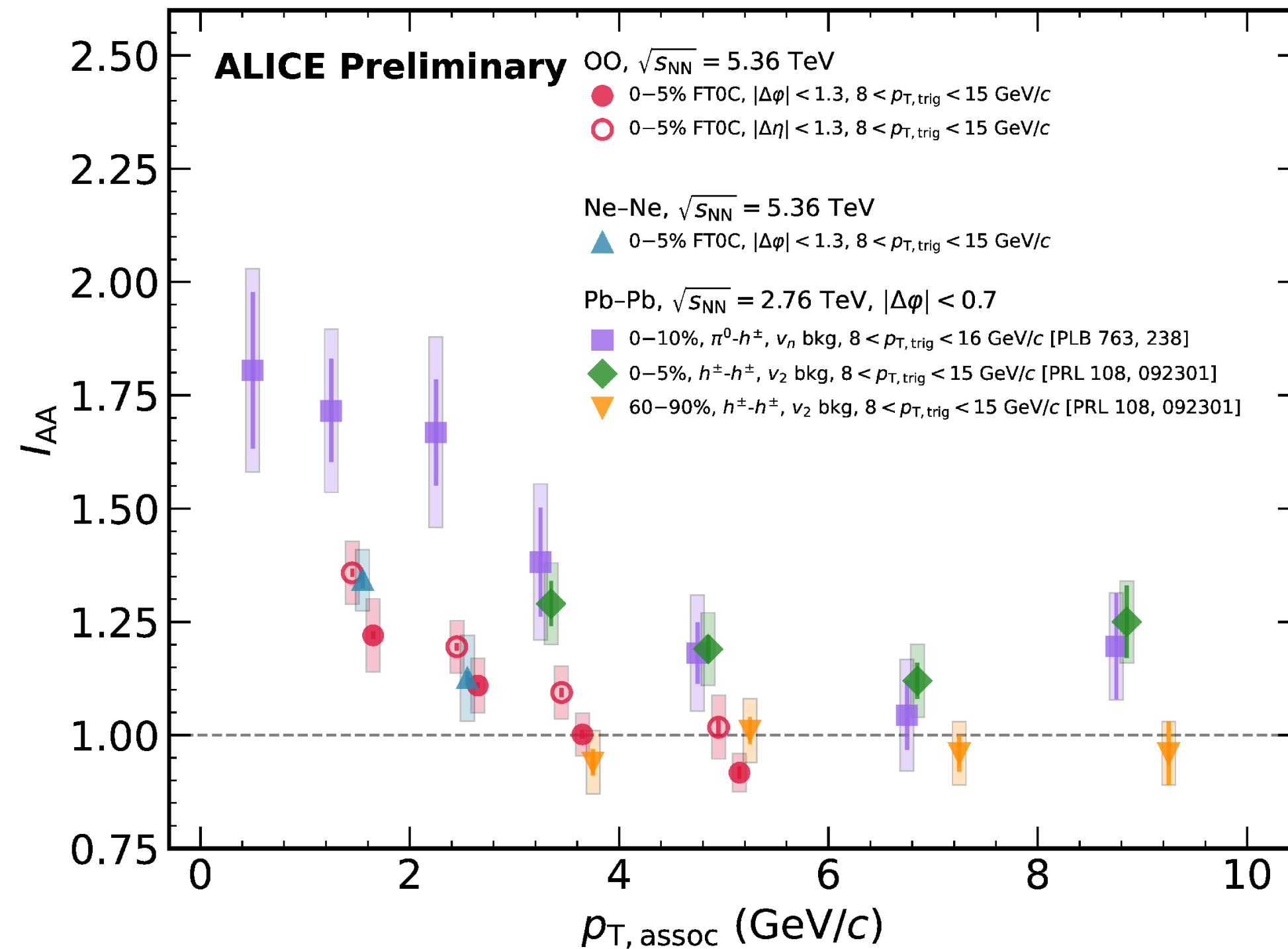
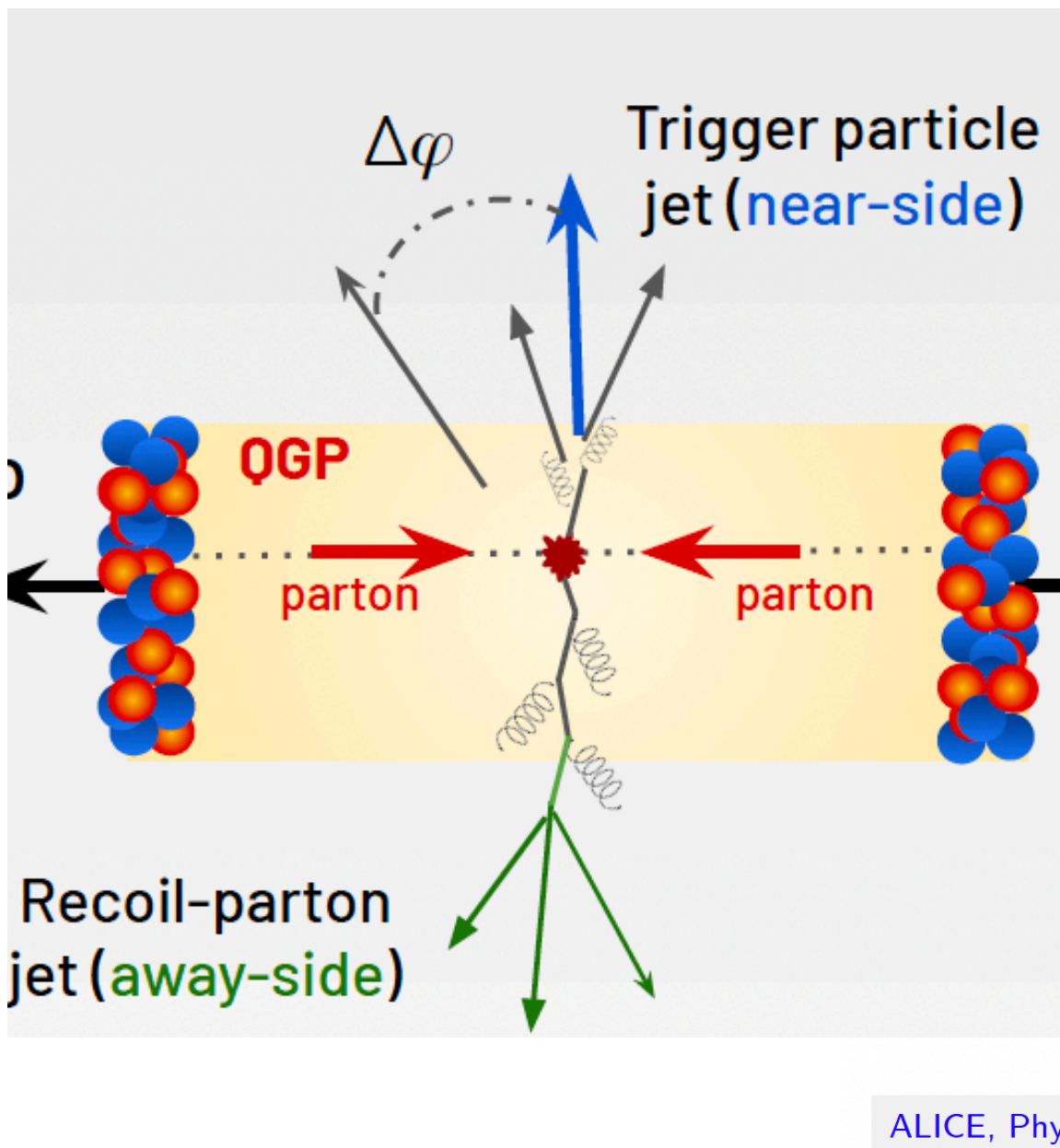
- An alternative method to study jet quenching is to use two particle correlations and study the peak width ($\sigma_{\Delta\eta}$) and the associated particle yields

Two-particle correlations in OO collisions

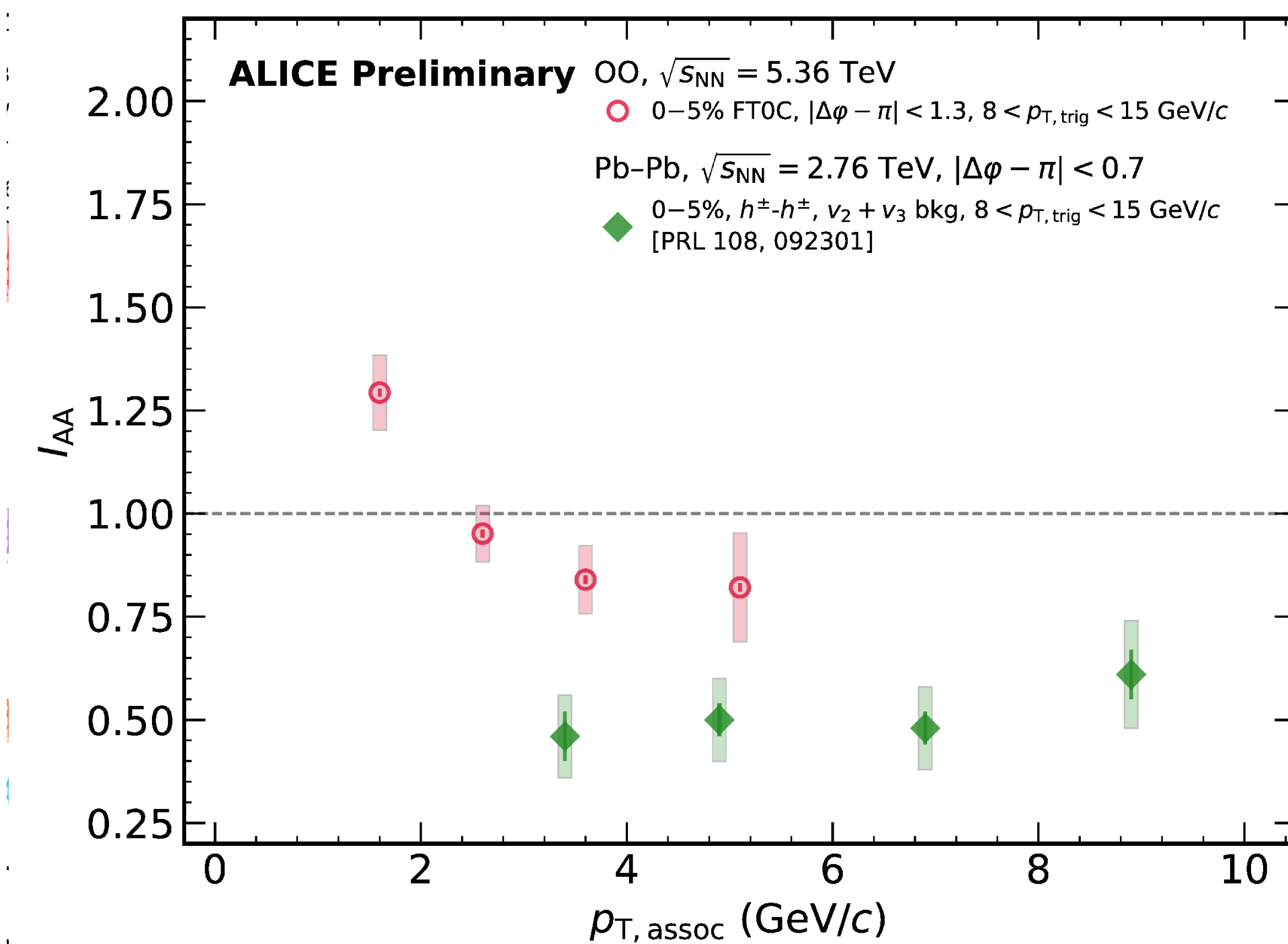


- An alternative method to study jet quenching is to use two particle correlations and study the peak width ($\sigma_{\Delta\eta}$) and the associated particle yields
- Hints of system size dependence of $\sigma_{\Delta\eta}$ as a function of $\langle N_{ch} \rangle$ at low $p_{T, trig} \rightarrow$ broadening of peak with smooth transition across different systems

Two-particle correlations in OO collisions



ALI-PREL-635754

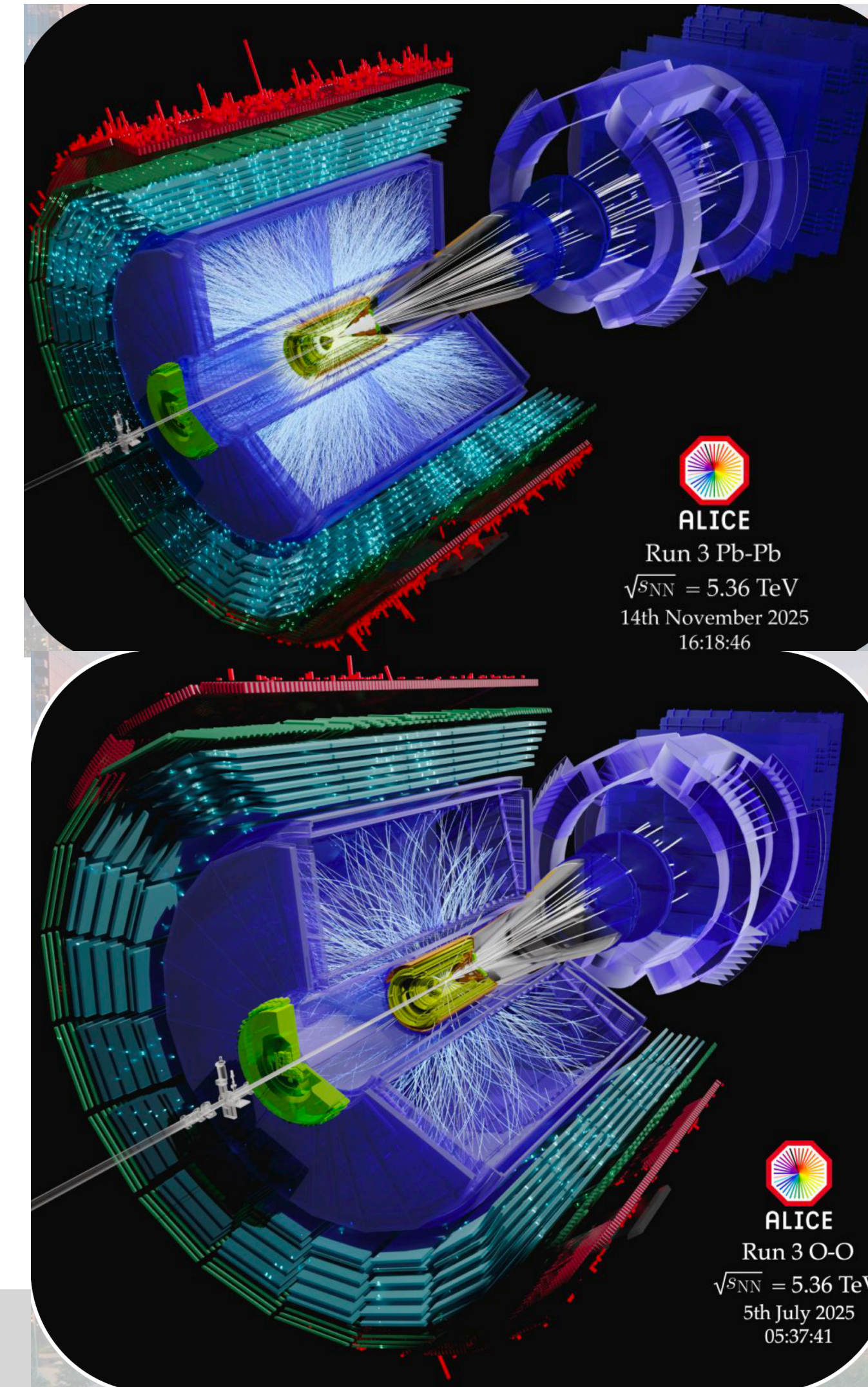
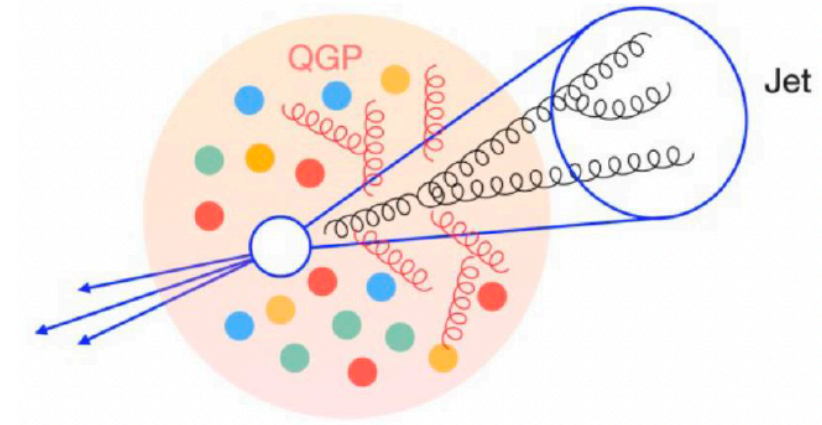


ALI-PREL-635765

- An alternative method to study jet quenching is to use two particle correlations and study the peak width ($\sigma_{\Delta\eta}$) and the associated particle yields
- Hints of system size dependence of $\sigma_{\Delta\eta}$ as a function of $\langle N_{\text{ch}} \rangle$ at low $p_{T, \text{trig}}$ → broadening of peak with smooth transition across different systems
- Indication of enhancement of low p_T particles for both NS and AW yield, while decreasing trend for high p_T

Summary

- A few selected recent jet measurements to discuss some aspects of jet-medium interactions
 - ➔ explore QCD across collision systems and scales, from the vacuum to strongly interacting matter
- Run 3 opened to the era of precision studies in the jet sector, and to more differential analysis for the QGP investigation
- Results from light-ion collisions are helping determine when and under which conditions **QGP-like effects** emerge
- Full exploitation of Run 3 data has just begun



Stay tuned! Thanks for your attention!



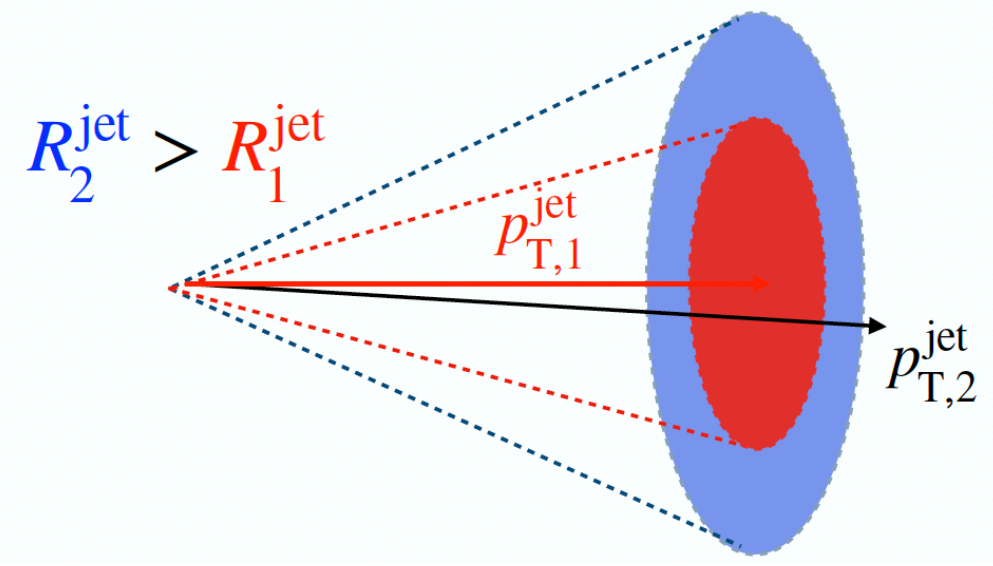
Backup



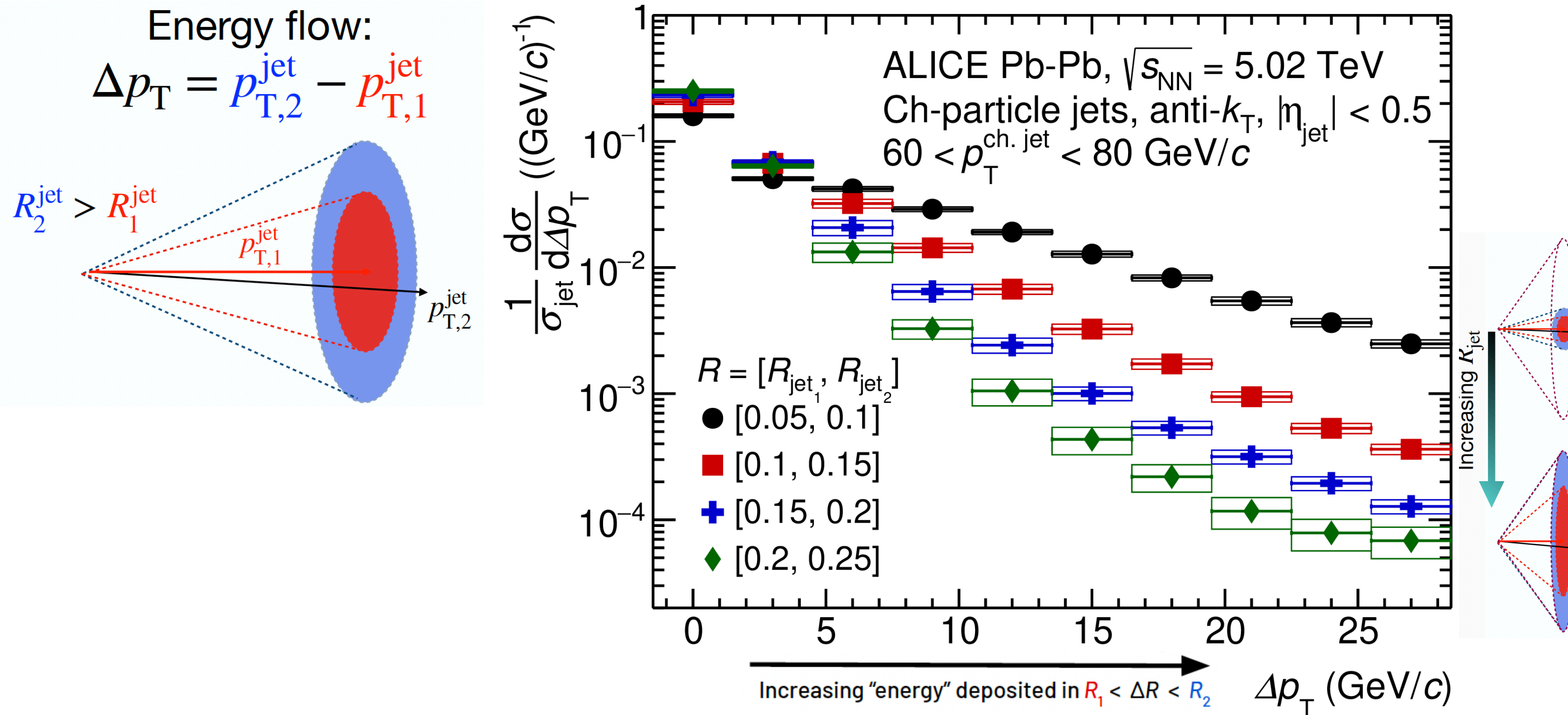
Quantifying the jet energy redistribution

Energy flow:

$$\Delta p_T = p_{T,2}^{\text{jet}} - p_{T,1}^{\text{jet}}$$



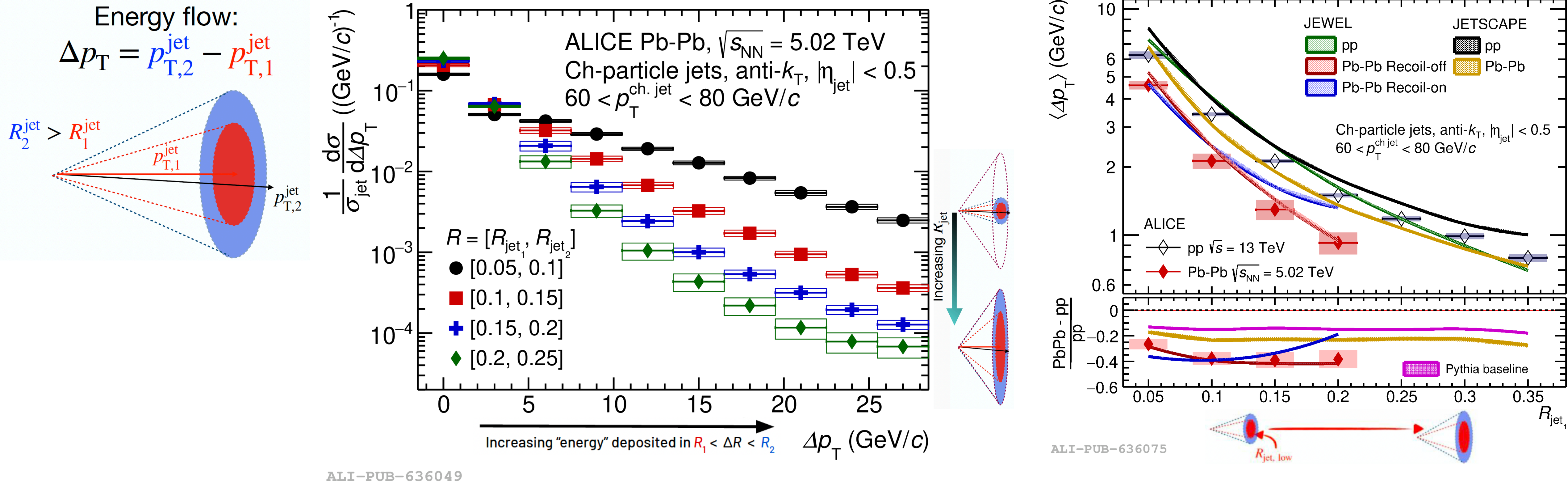
Quantifying the jet energy redistribution



ALI-PUB-636049

- Jets in Pb-Pb are also highly collimated:
 - Jet is concentrated around a hard core
 - $\langle \Delta p_T \rangle$ decreases rapidly with R

Quantifying the jet energy redistribution



- Jets in Pb-Pb are also highly collimated:
 - Jet is concentrated around a hard core
 - $\langle \Delta p_T \rangle$ decreases rapidly with R
- Pb-Pb jets contain less energy in ΔR than in pp:
 - Out-of-cone radiations in Pb-Pb and energy redistributions
 - Narrowing of surviving jet cores