



Study of jet modifications using ALICE Run 3 data at LHC

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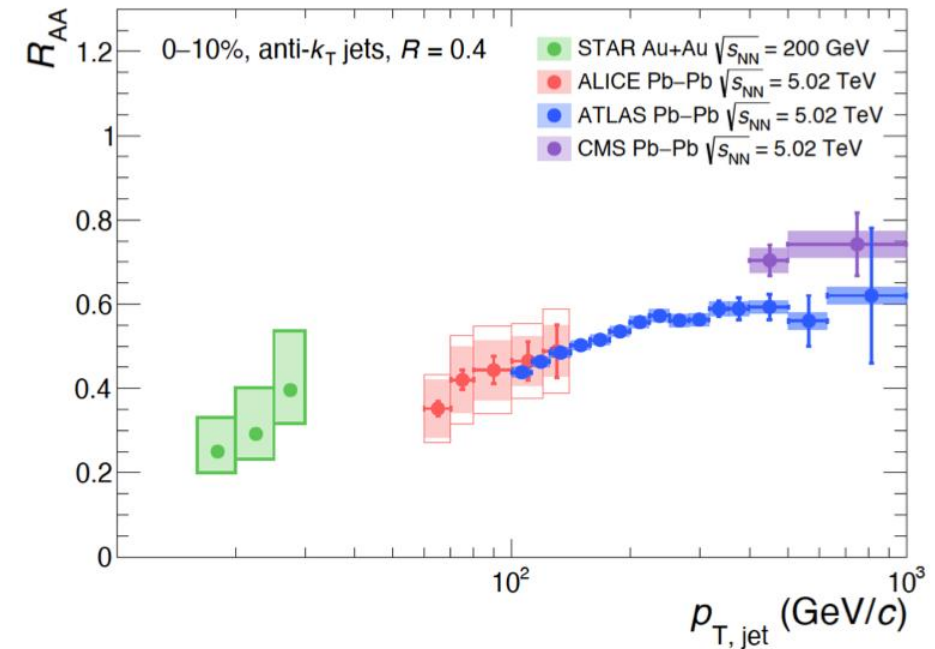
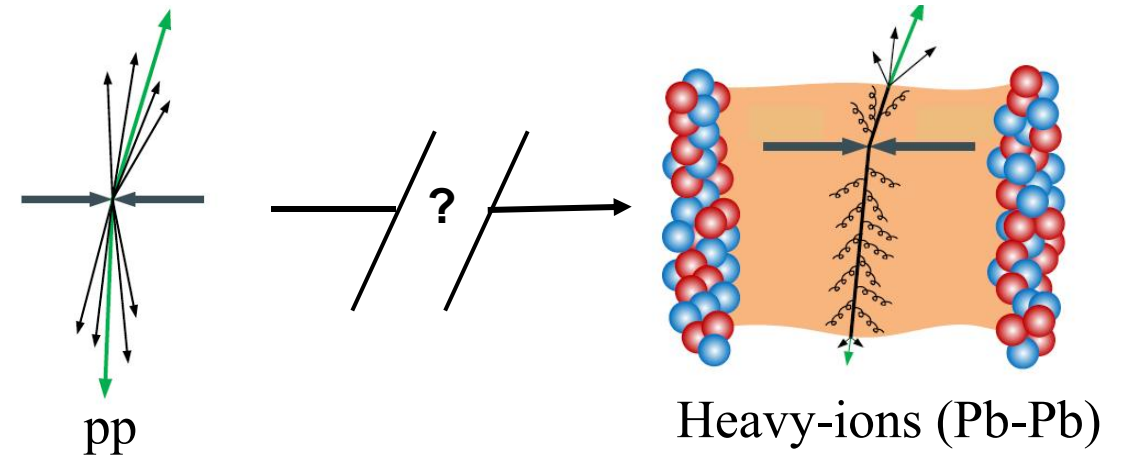
2026年10月31日, 湖北

第十二届中国LHC物理会议 (CLHCP2026)

Jets as a probe of the QGP

Eur. Phys. J. C. (2024) 84:247

- **Jet:** a collimated cluster of hadrons produced by the fragmentation of high-energy quarks or gluons.
 - High- p_T parton is expected to lose energy when traversing the hot and dense medium in heavy-ion collisions (**jet quenching**).
- ➔ Jets can serve as hard probe of the QGP medium!
- Jet suppression observed in Pb-Pb collisions.

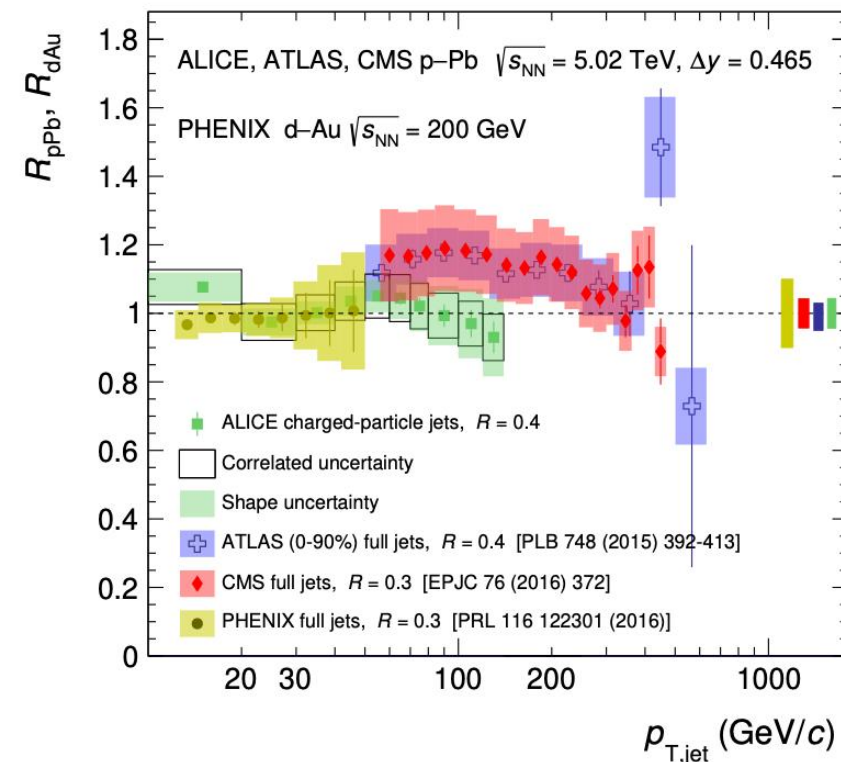


➔ *What happens in an intermediate system?*

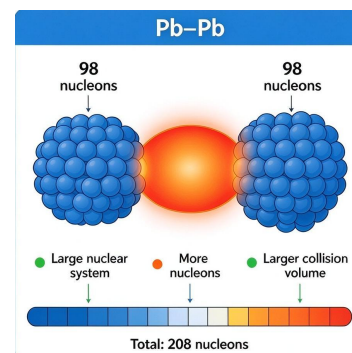
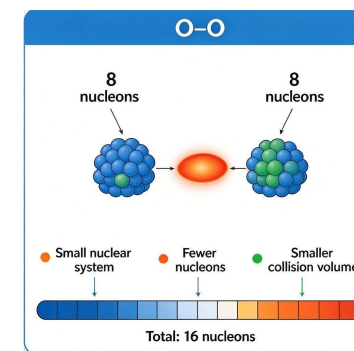
Jet suppression across systems

- In small systems (pp and p-Pb):
 - QGP-like signatures have been observed in high-multiplicity events.
 - No jet quenching observed so far.
- Minimum bias OO collisions provide an ideal environment to study jet quenching in small systems:
 - OO collisions significantly smaller than Pb-Pb
 - MB event selection: no high-multiplicity bias like pp and p-Pb

[JHEP 05 \(2024\) 041](#)

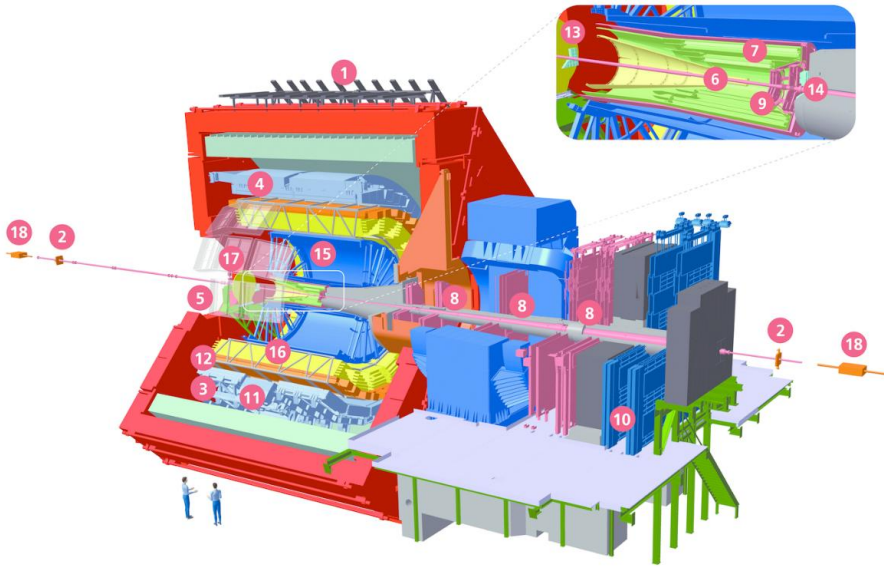
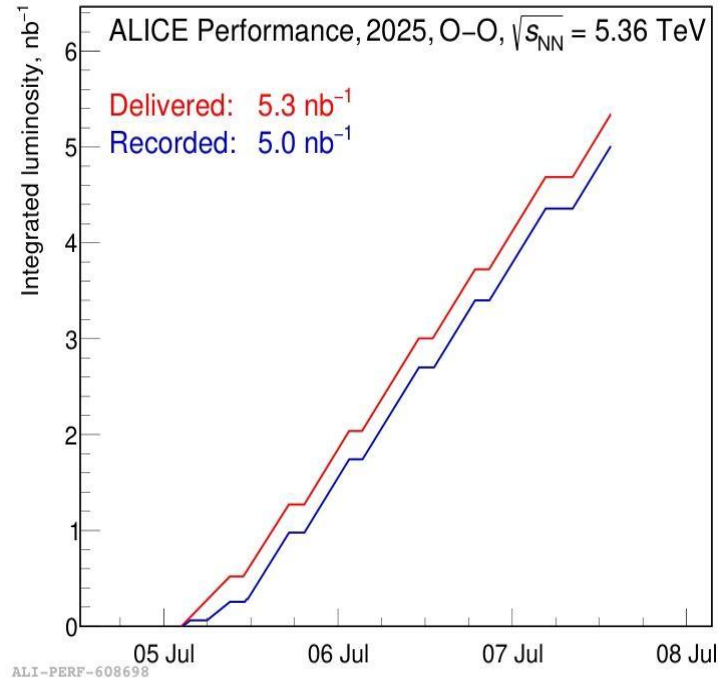


→ Are OO conditions sufficient for QGP formation ?

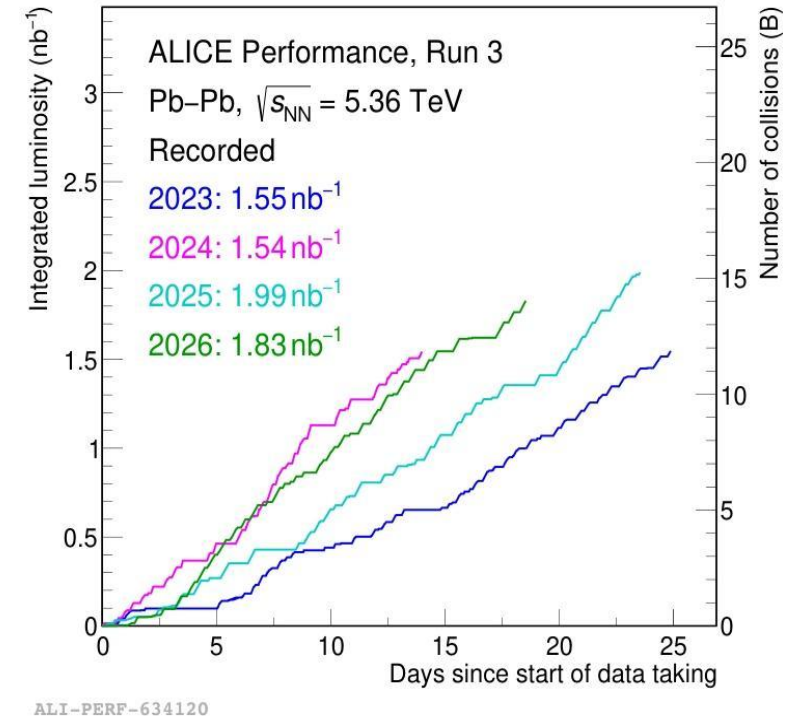


ALICE in Run 3

ALICE detector in Run 3



$\sim 6.5 \times 10^9$ MB events in
Oxygen – Oxygen



$\sim 53 \times 10^9$ events in **Pb-Pb**
 $\times 160$ more than Run 1+2

ALICE new capabilities in Run 3:

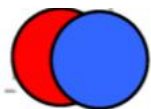
- Continuous readout enhances data-taking
- High interactions rates:
→ Pb-Pb up to 50 kHz

- We take advantage of the Run 3 statistics.
→ multi-dimensional measurements

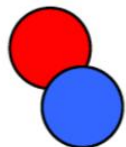
Jet suppression in Pb-Pb and OO

- Observable in **this talk**: nuclear modification factor in **Pb-Pb** and minimum bias **OO** at $\sqrt{s_{NN}} = 5.36$ TeV

□ Central to peripheral ratio R_{CP} :

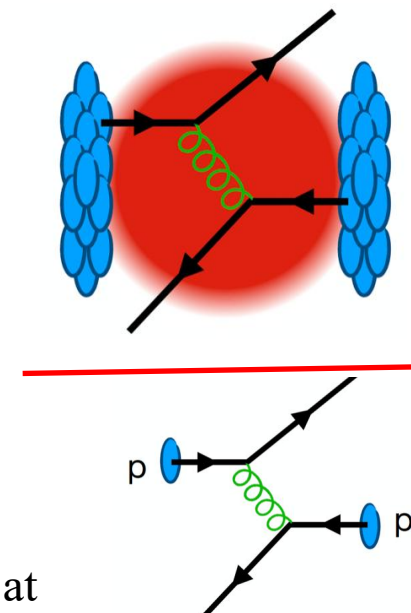


$$R_{CP} = \frac{\langle N_{coll}^P \rangle \frac{d^2 N_{jets}^C}{dp_T d\eta}}{\langle N_{coll}^C \rangle \frac{d^2 N_{jets}^P}{dp_T d\eta}}$$

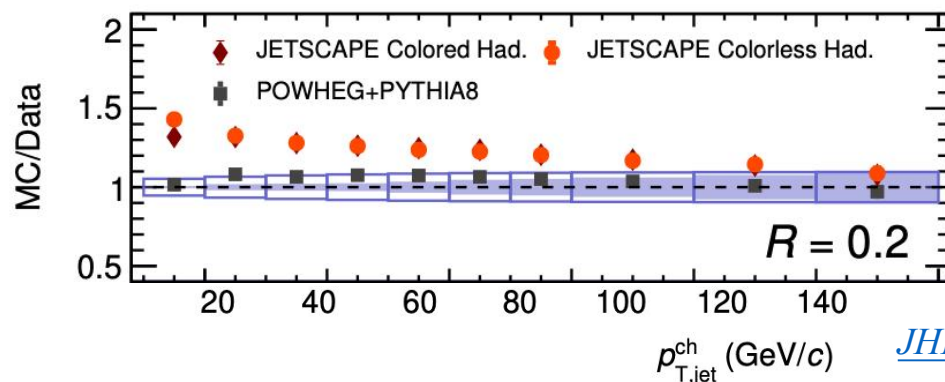


□ Nuclear modification factor R_{AA} :
with AA = **Pb-Pb** or **OO**

$$R_{AA} = \frac{dN_{AA}/dp_T}{N_{coll} dN_{pp}/dp_T}$$



- POWHEG+PYTHIA agrees with pp data at $\sqrt{s_{NN}} = 5.02$ TeV
→ use as a reference



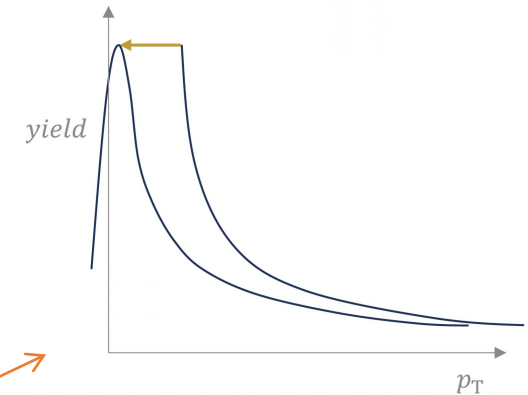
$$R_{AA}^{POWHEG+PYTHIA} = \frac{1}{\langle T_{AA} \rangle} \frac{d^2 N_{jets}^{AA}/dp_T d\eta}{d^2 \sigma_{jets}^{pp, POWHEG+PYTHIA}/dp_T d\eta}$$

Analysis details

- ALICE data at $\sqrt{s_{\text{NN}}} = 5.36$ TeV:
 - **Pb-Pb**: 2023 data-taking (more statistics to come with 2024, 2025 and 2026).
 - **OO**: 2025 data-taking.
- Analysis selections:
 - **Pb-Pb**: centrality classes 0-10%, 10-30%, 30-50%, 50-80%
 - **OO**: minimum bias events
 - **Charged-particle jets**: anti- k_{T} , $R = 0.2$ and 0.4 , $|\eta| < 0.9 - R$
 - $p_{\text{T, track}}^{\text{lead.}} > 5 \text{ GeV}/c$ for **Pb-Pb** $R = 0.2$;
 $p_{\text{T, track}}^{\text{lead.}} > 3 \text{ GeV}/c$ for **OO** $R = 0.2$; $5 \text{ GeV}/c$ for **OO** $R = 0.4$

Analysis details

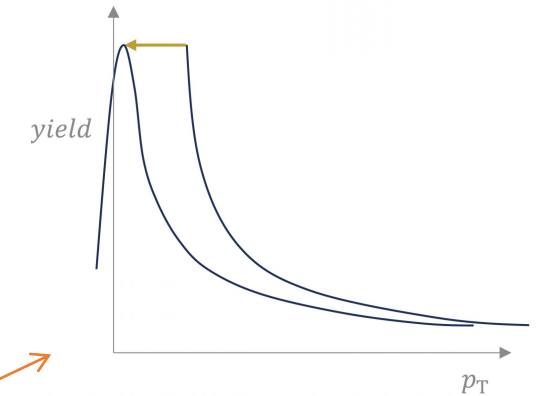
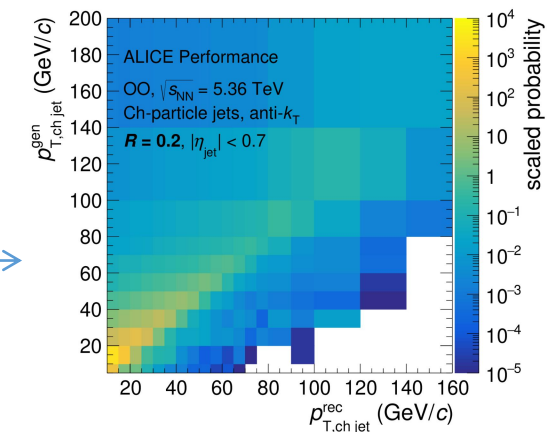
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- Background subtraction:
 - Remove pedestal underlying event from jets based on jet area
$$p_{\text{T}}^{\text{bkg. corrected}} = p_{\text{T}}^{\text{raw}} - A_{\text{jet}} \cdot \rho$$
 - Apply leading track cut to remove combinatorial jets



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$$p_{\text{T}}^{\text{bkg. corrected}} = p_{\text{T}}^{\text{raw}} - A_{\text{jet}} \cdot \rho$$
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- Unfolding correction: correct bkg. fluctuations + detector effects

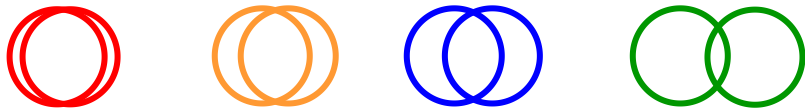


Jet yields in Pb-Pb at 5.36 TeV

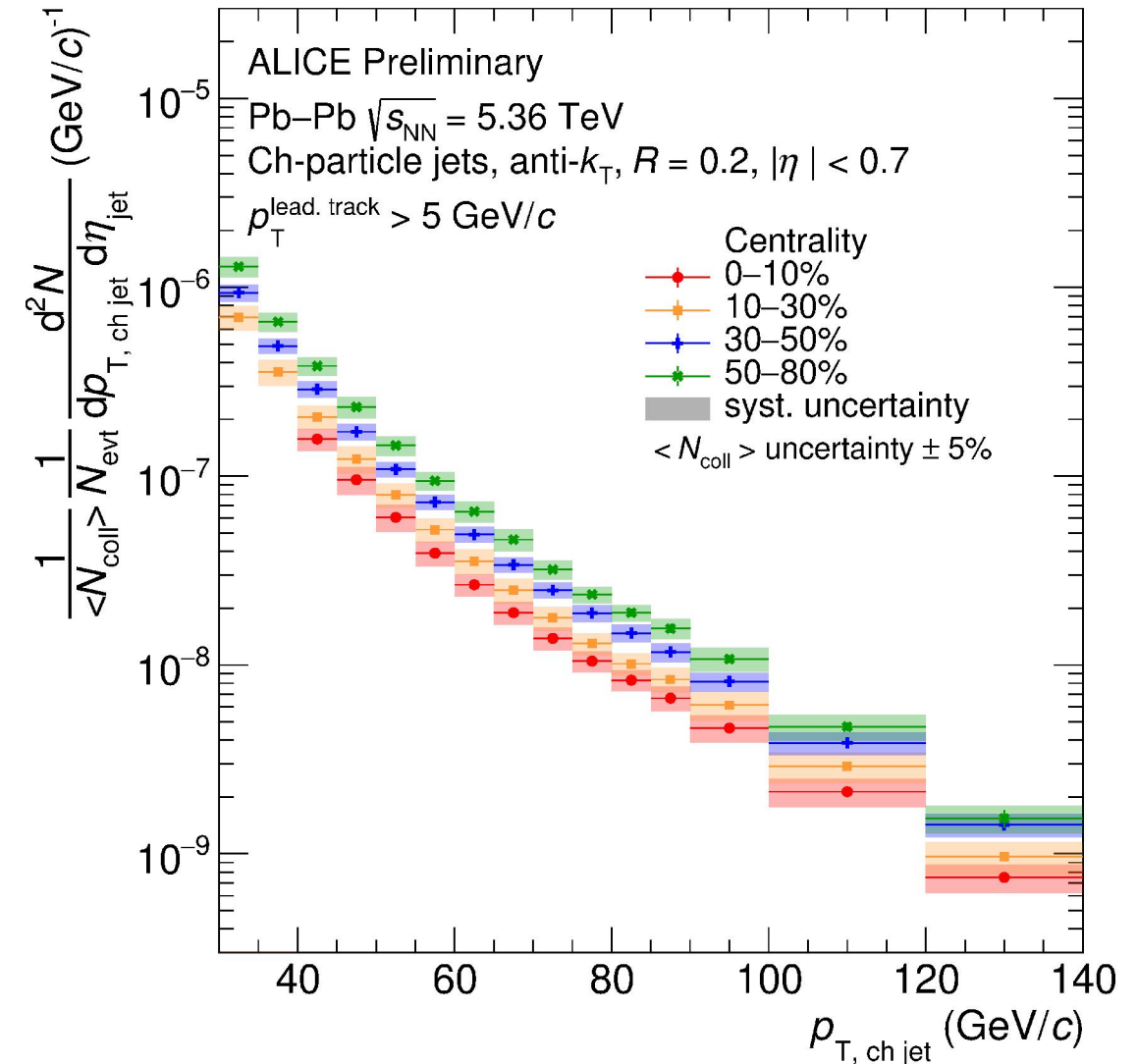
- First inclusive charged-particle jet ($R=0.2$) measurement in Pb-Pb at $\sqrt{s_{NN}} = 5.36$ TeV:

- Centrality classes:

0-10%, 10-30%, 30-50% and 50-80%



- Increasing normalized yield from central to peripheral.

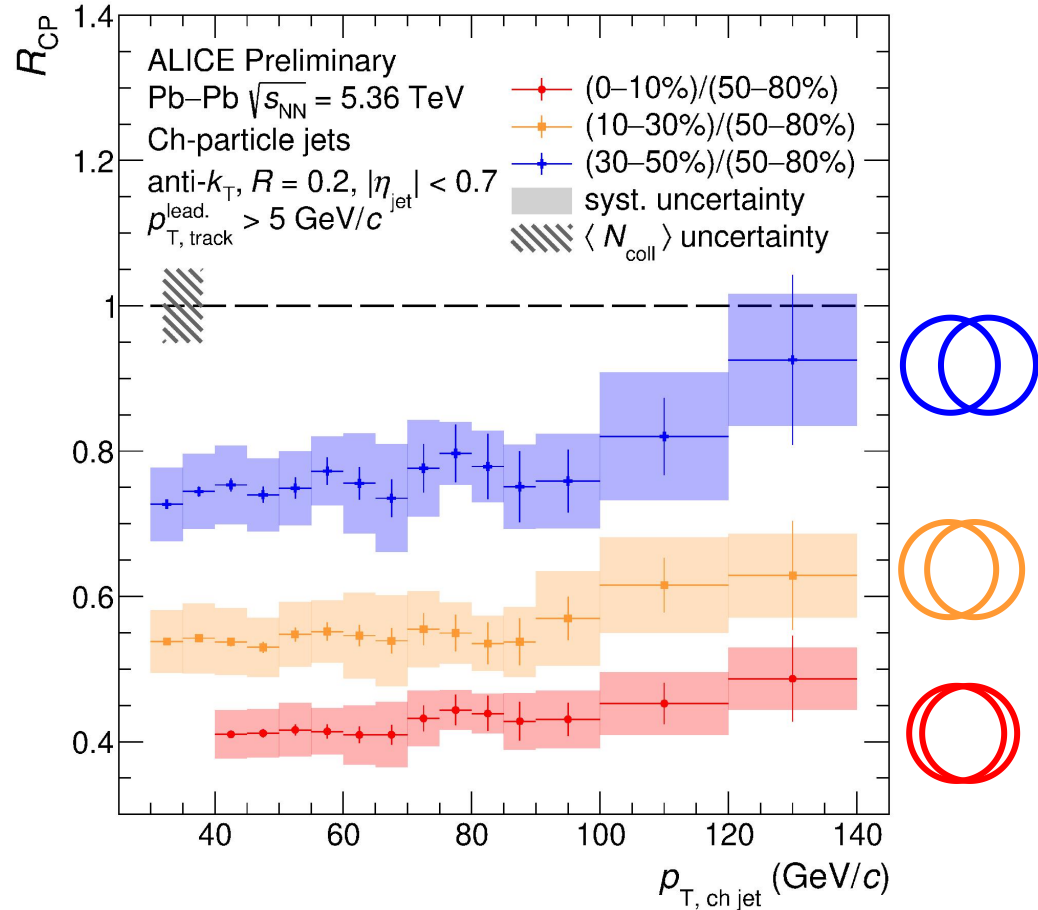


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Central to peripheral ratio in Pb-Pb

$$R_{CP} = \frac{\langle N_{coll}^{50-80\%} \rangle}{\langle N_{coll}^C \rangle} \frac{d^2 N_{jets}^C / dp_T d\eta}{d^2 N_{jets}^{50-80\%} / dp_T d\eta}$$

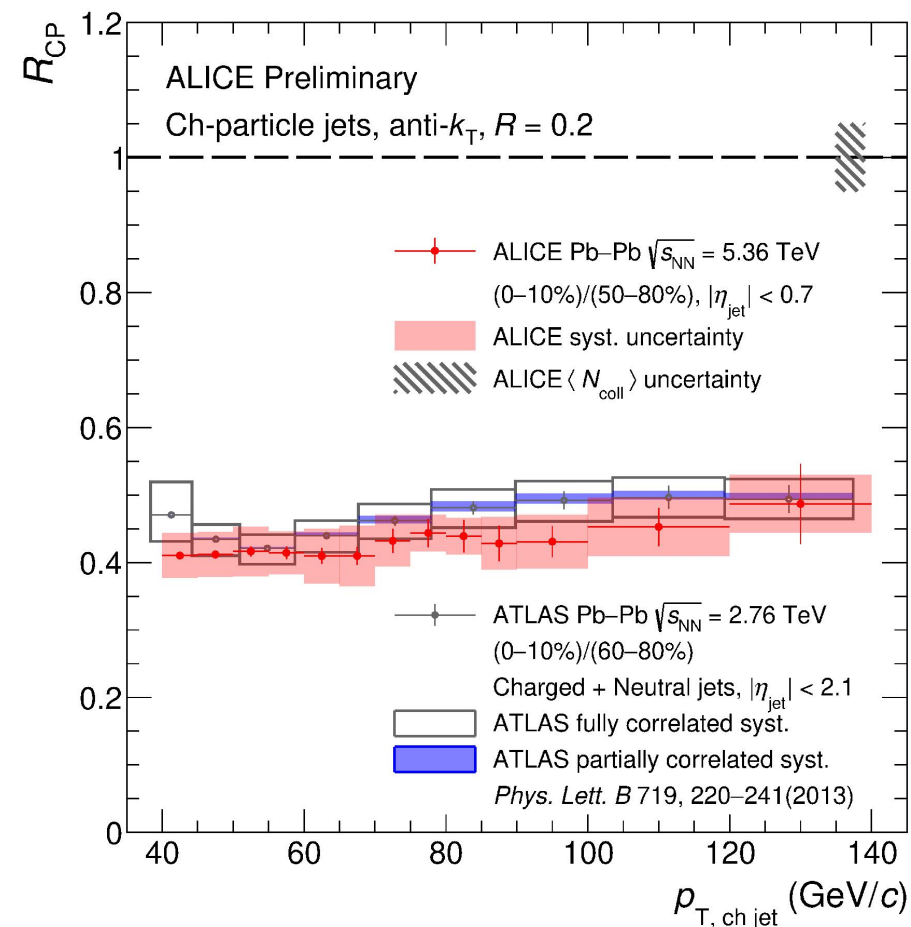
- R_{CP} in 0-10%, 10-30% and 30-50% Pb-Pb



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○ Evolution of jet modification as a function of centrality

- R_{CP} in 0-10% Pb-Pb compare with ATLAS



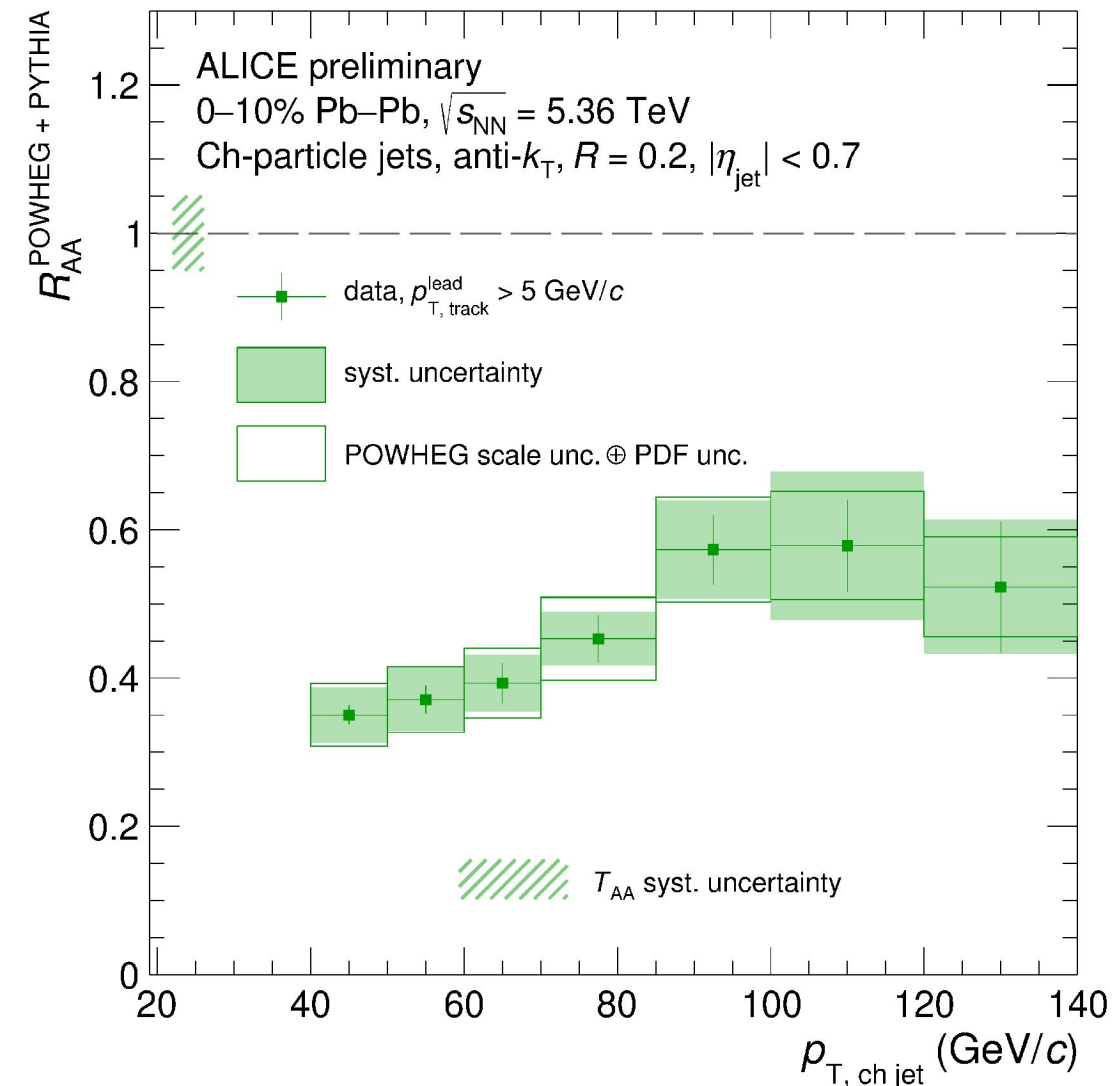
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○ Consistent with ATLAS results at $\sqrt{s_{NN}} = 2.76$ TeV

R_{AA} in Pb-Pb

$$R_{AA}^{\text{POWHEG+PYTHIA}} = \frac{1}{\langle T_{AA} \rangle} \frac{d^2 N_{\text{jets}}^{\text{AA}} / dp_T d\eta}{d^2 \sigma_{\text{jets}}^{\text{pp, POWHEG+PYTHIA}} / dp_T d\eta}$$

- Jet suppression observed comparing to pp model in 0-10% Pb-Pb collisions at $\sqrt{s_{NN}} = 5.36$ TeV

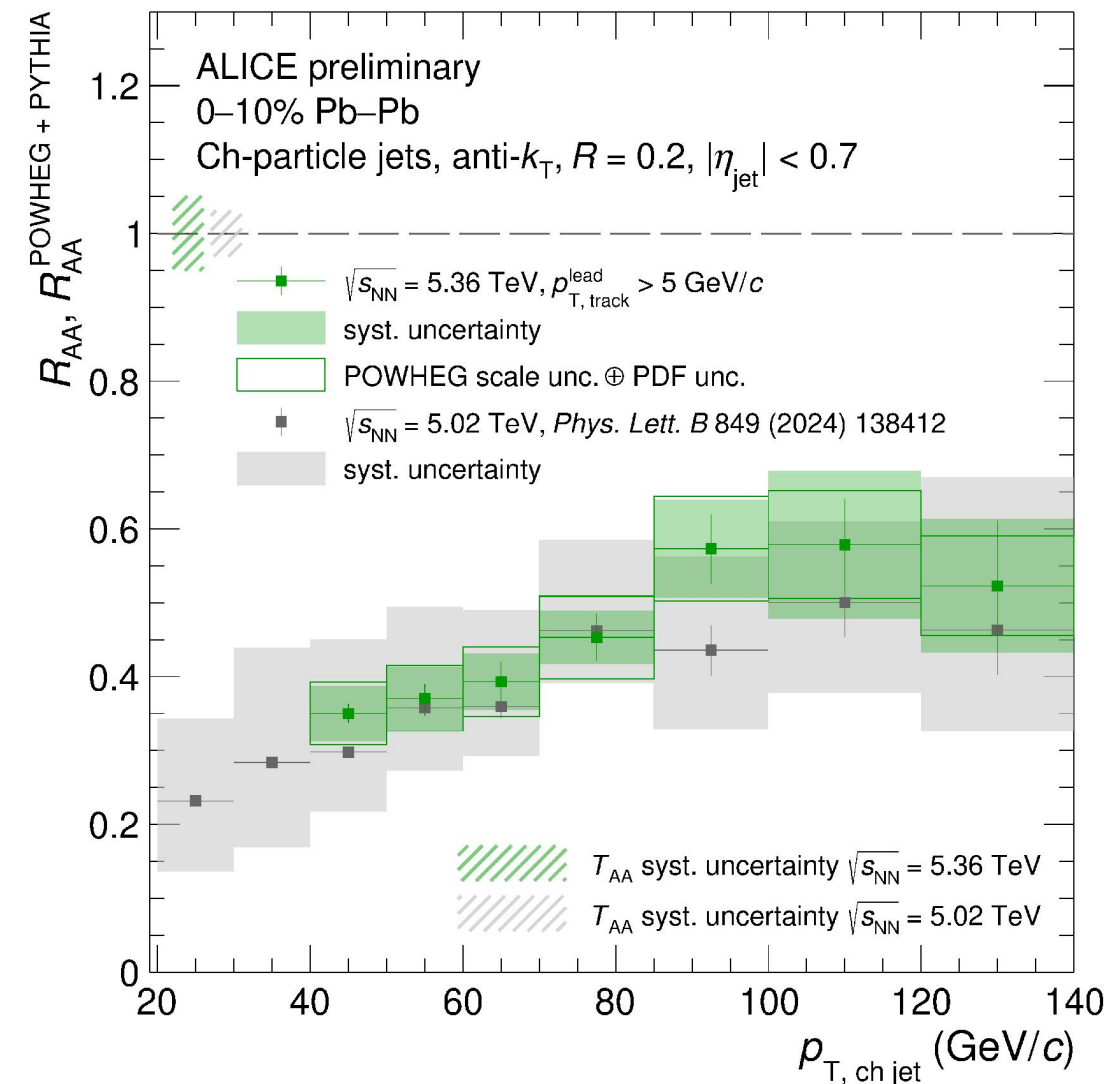


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R_{AA} in Pb-Pb

$$R_{AA}^{\text{POWHEG+PYTHIA}} = \frac{1}{\langle T_{AA} \rangle} \frac{d^2 N_{\text{jets}}^{AA} / dp_T d\eta}{d^2 \sigma_{\text{jets}}^{\text{pp, POWHEG+PYTHIA}} / dp_T d\eta}$$

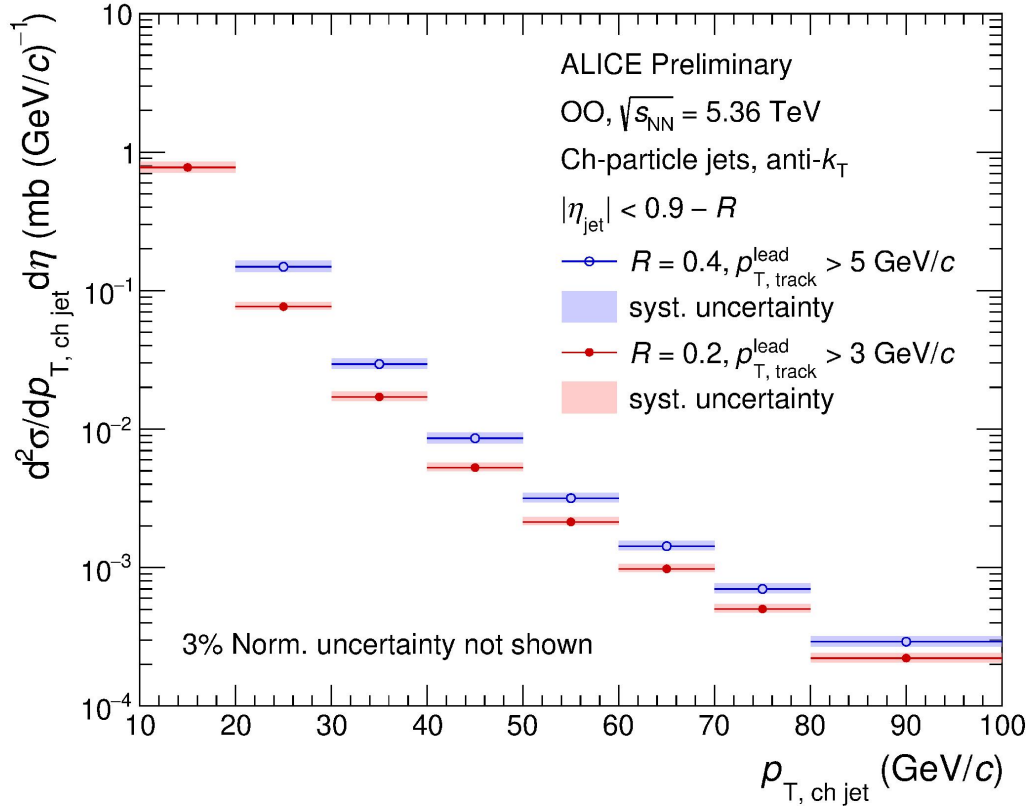
- Jet suppression observed comparing to pp model in 0-10% Pb-Pb collisions at $\sqrt{s_{NN}} = 5.36$ TeV:
 - pedestal background subtraction
 - Run 2 machine learning based bkg. subtraction at $\sqrt{s_{NN}} = 5.02$ TeV.
 - Consistent results between two energy scales.
- Improve statistics at $\sqrt{s_{NN}} = 5.36$ TeV by combining full data samples (2024-2026)



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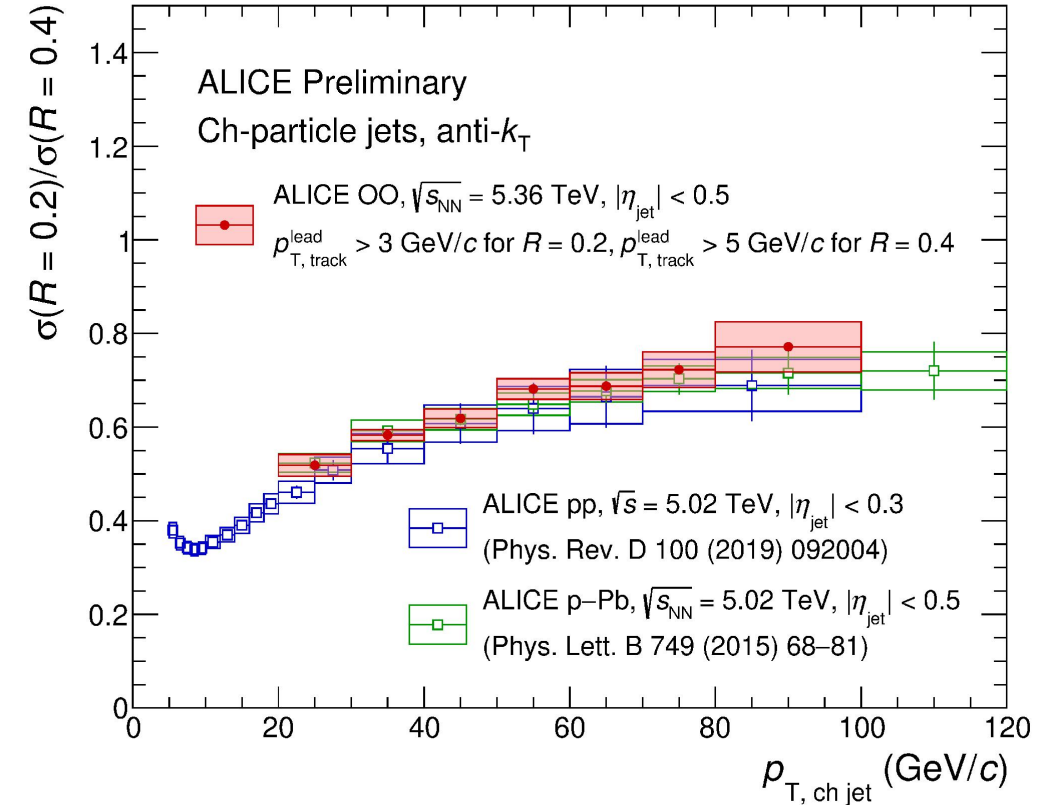
Jet cross section in OO

- Inclusive charged-particle jet cross section for $R = 0.2$ and $R = 0.4$:



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- $\frac{\sigma(R=0.2)}{\sigma(R=0.4)}$ ratio in OO comparing with other collision systems:



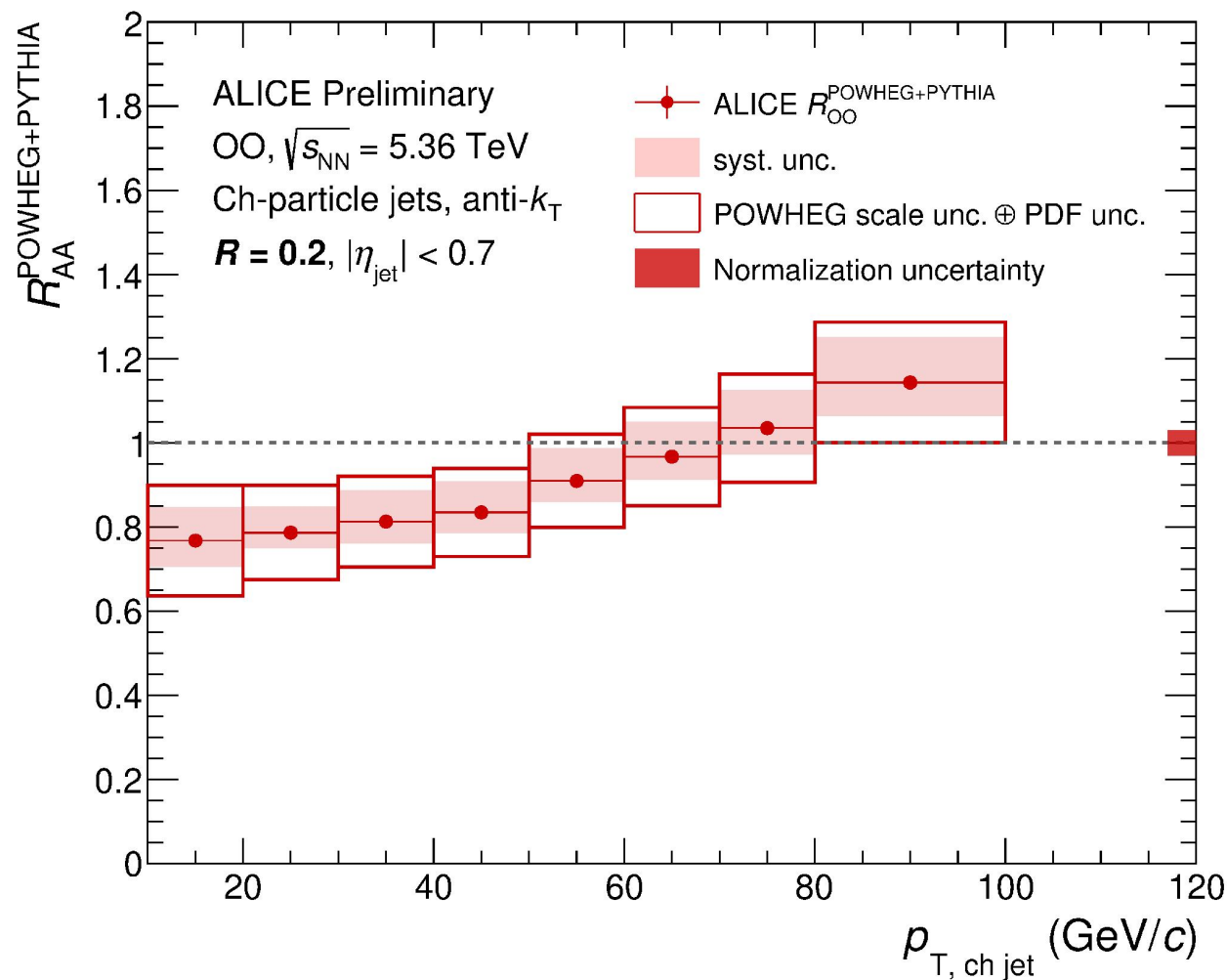
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○ Show consistency across collision systems

R_{AA} in OO

$$R_{AA}^{\text{POWHEG+PYTHIA}} = \frac{1}{A^2} \frac{d^2 \sigma_{\text{jets}}^{\text{AA}} / dp_T d\eta}{d^2 \sigma_{\text{jets}}^{\text{pp, POWHEG+PYTHIA}} / dp_T d\eta}$$

- Show jet suppression at low p_T
- Current uncertainties do not allow a firm conclusion on jet quenching.



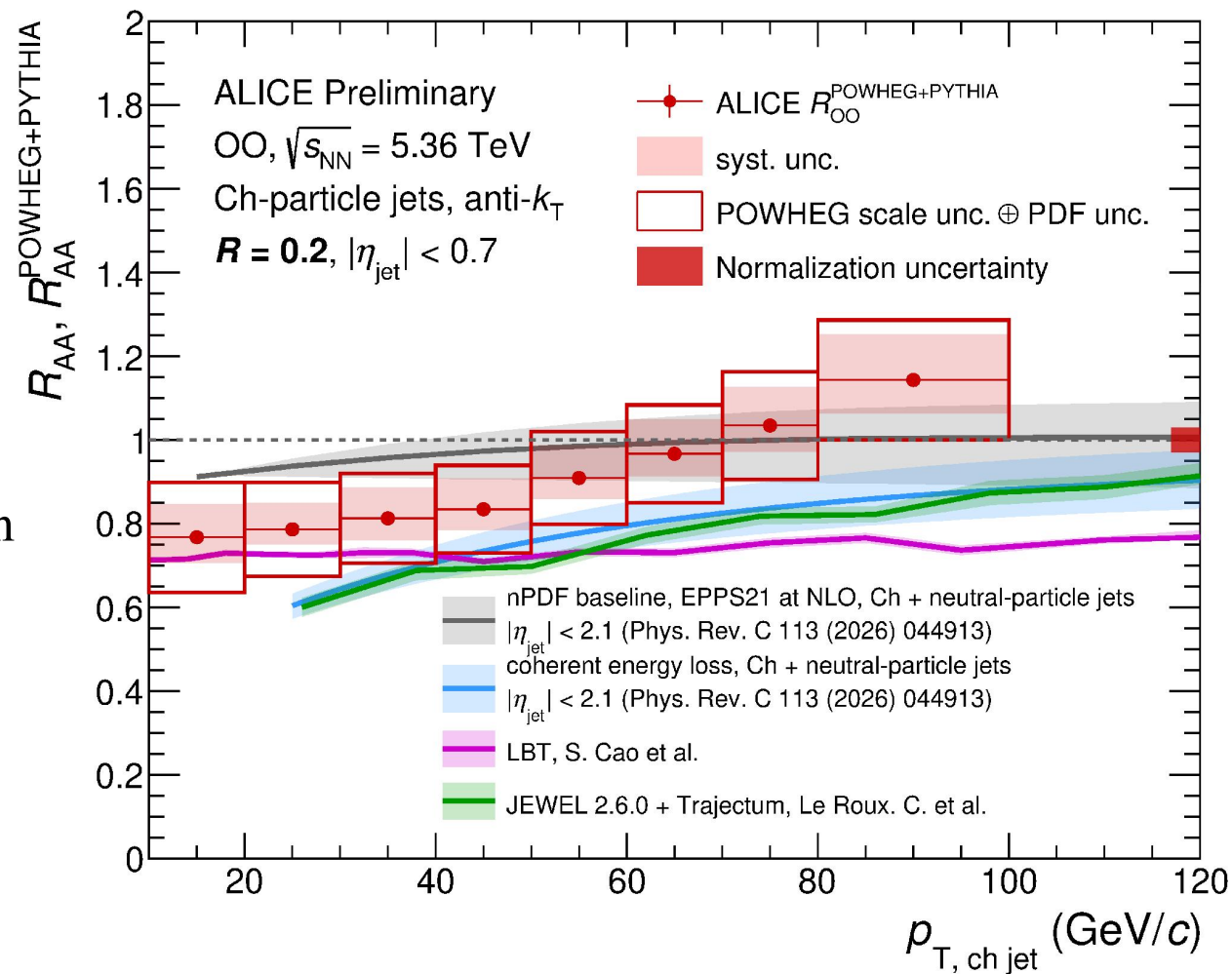
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R_{AA} in OO for $R=0.2$

$R = 0.2$

○ Theoretical prediction models:

- No-quenching baseline: NLO+LL QCD vacuum model with nPDF effects
 - Coherent energy loss: same model with above one, with hydro and coherent energy loss model
 - LBT: parton transport in QGP with recoil (arXiv:2512.12715)
 - JEWEL + Trajectum: jet energy loss from medium interaction (arXiv:2509.04299)
- Improve precision of data measurement to distinguish model with and without quenching.
 - LBT model seems to over-estimate jet suppression at high p_T .



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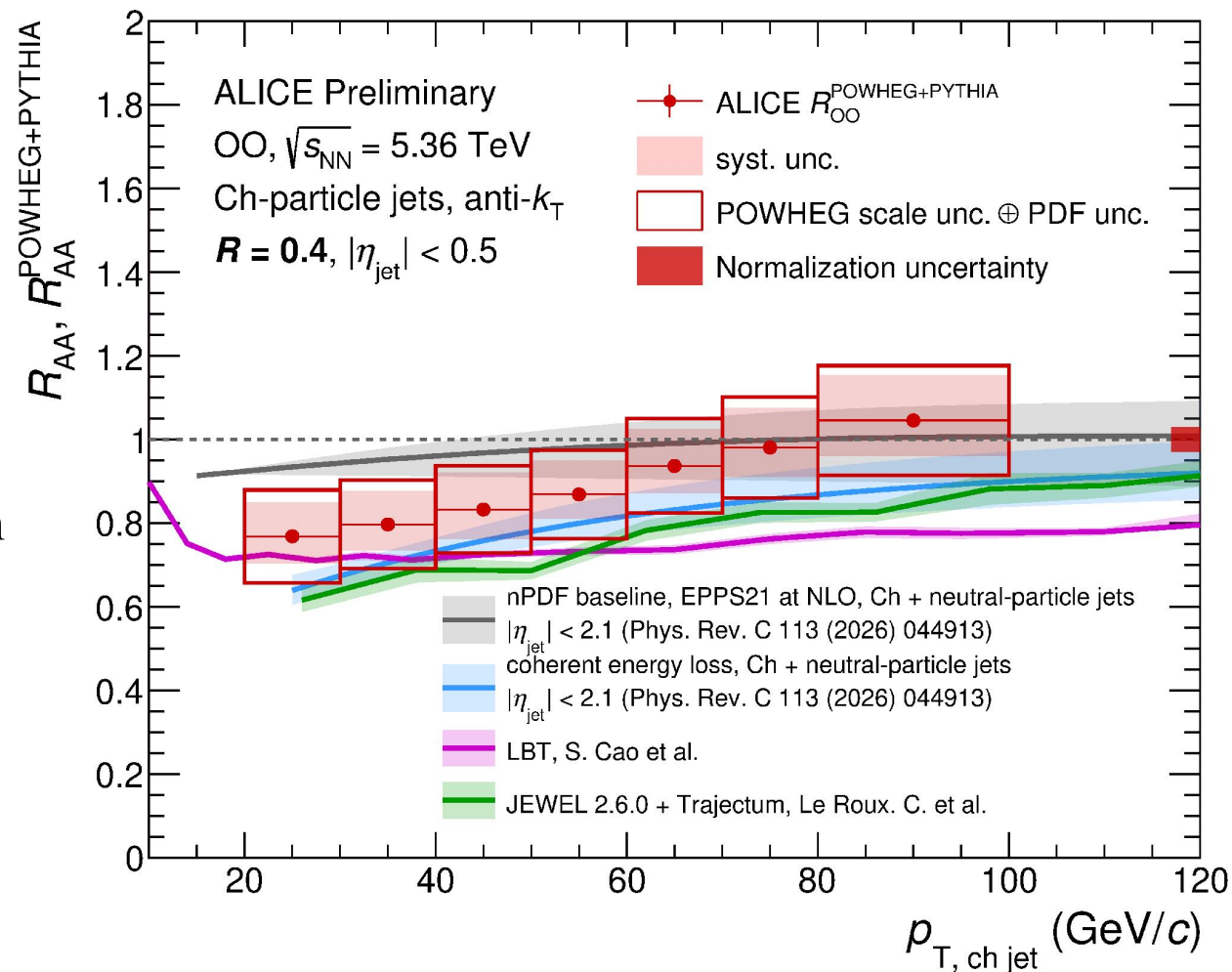
R_{AA} in OO for R=0.4

$R = 0.4$

○ Theoretical prediction models:

- No-quenching baseline: NLO+LL QCD vacuum model with nPDF effects
- Coherent energy loss: same model with above one, with hydro and coherent energy loss model
- LBT: parton transport in QGP with recoil (arXiv:2512.12715)
- JEWEL + Trajectum: jet energy loss from medium interaction (arXiv:2509.04299)

- Improve precision of data measurement to distinguish model with and without quenching.
- LBT model seems to over-estimate jet suppression at high p_T .



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Comparison of R_{AA} across systems

- R_{AA} comparison across collision systems:

$$R_{Pb-Pb}^{POWHEG+PYTHIA} \text{ at } \sqrt{s_{NN}} = 5.36 \text{ TeV}$$

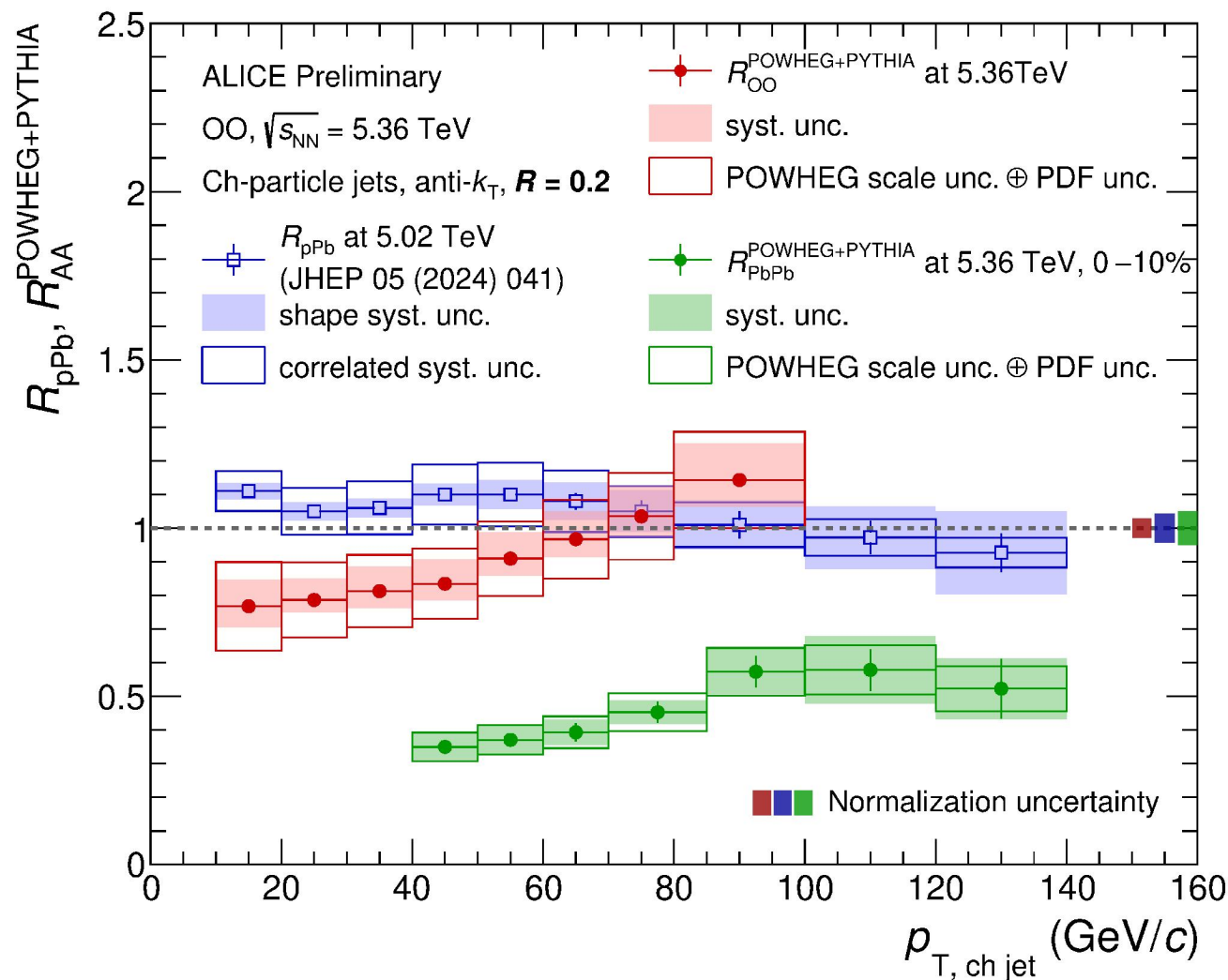
$$R_{OO}^{POWHEG+PYTHIA} \text{ at } \sqrt{s_{NN}} = 5.36 \text{ TeV}$$

$$R_{p-Pb} \text{ at } \sqrt{s_{NN}} = 5.02 \text{ TeV}$$

- Suppression at low p_T in OO indicate nuclear modification factor hierarchy:

$$R_{Pb-Pb}^{POWHEG+PYTHIA} < R_{OO}^{POWHEG+PYTHIA} < R_{p-Pb} (\approx 1)$$

- Current uncertainties do not allow a firm conclusion on whether jet quenching is present in OO.

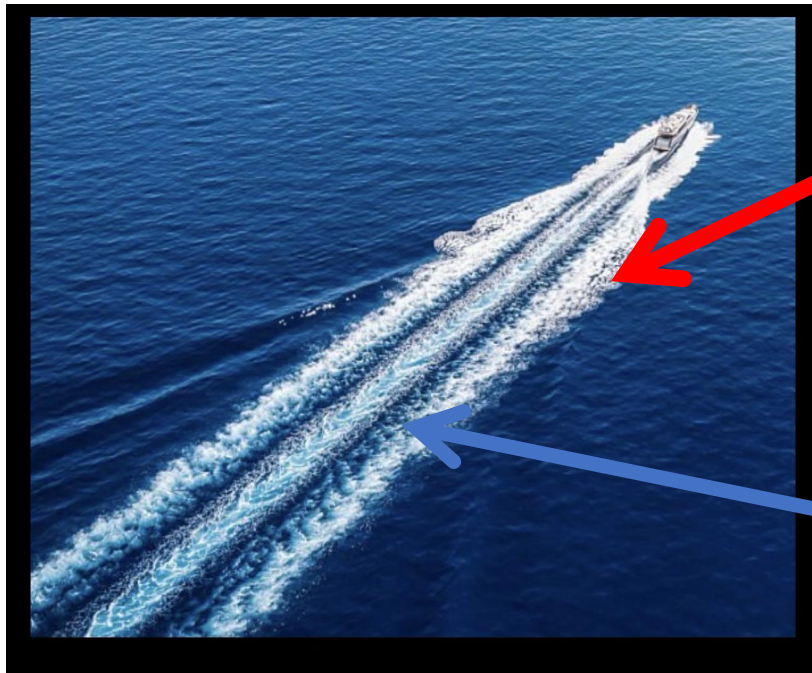


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Jet interaction with the medium

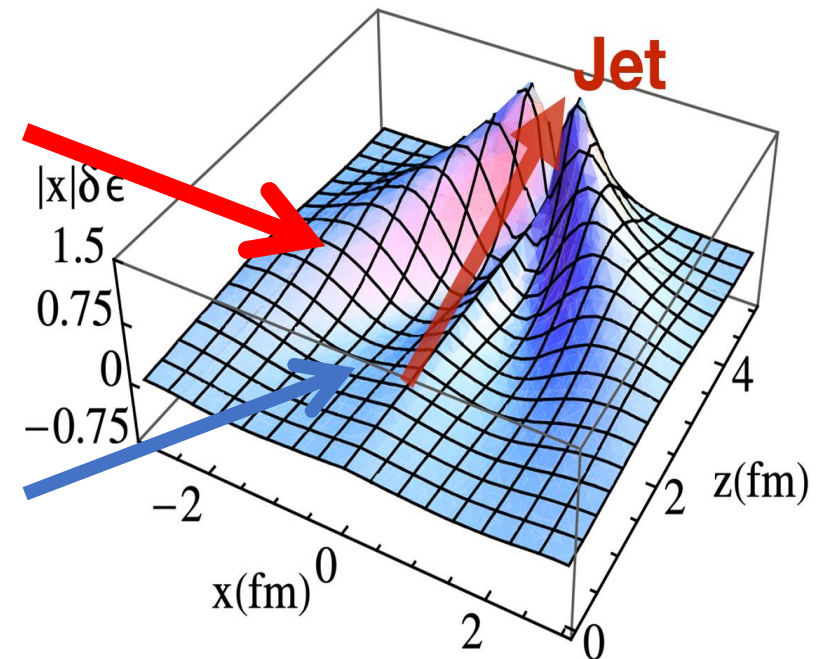
- **In heavy-ion:** when a high- p_T parton loses energy in medium, the energy may be transferred to the medium. This leads to the medium response.
- Typical structures of medium response:
 - ➡ enhancement in the jet direction.
 - ➡ depletion in the opposite jet direction.

[G.-Y. Qin, A. Majumder, H. Song, and U. Heinz, Phys. Rev. Lett. 103, 152303 \(2009\)](#)



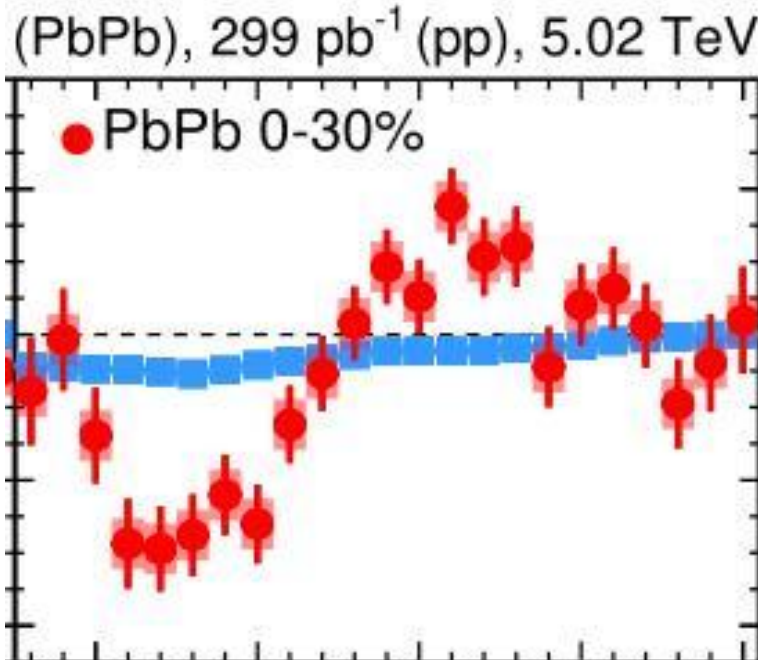
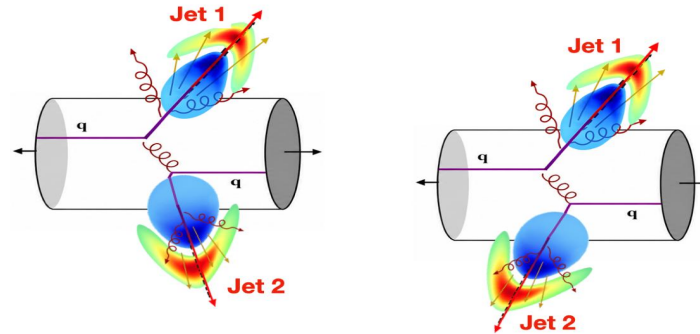
Enhancement
around jet

depletion
opposite to jet



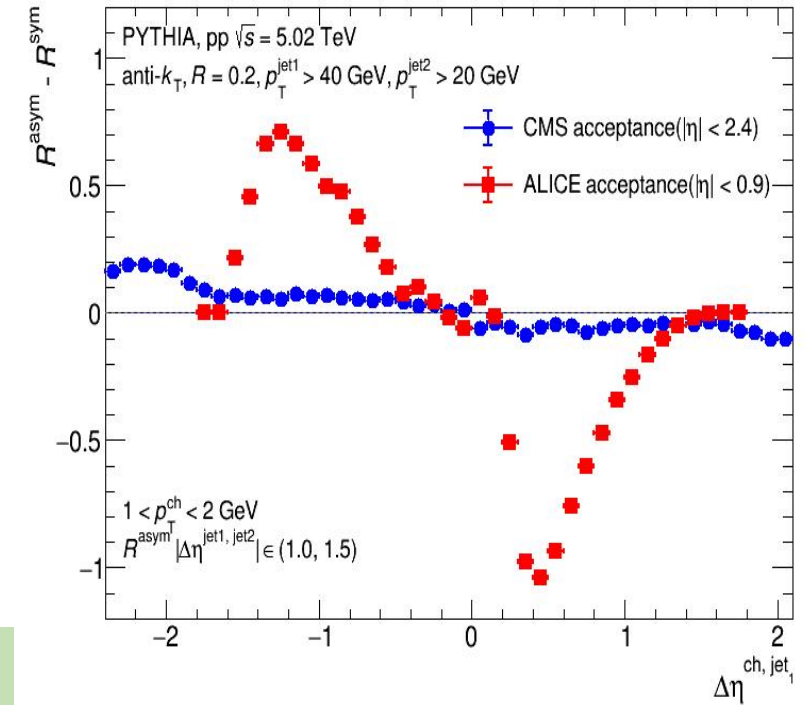
Medium-response studies via di-jet rapidity asymmetry

- CMS uses the dijet hadron-jet correlation method using $\Delta\eta_{hadron,jet1}$ to study rapidity asymmetry for medium response.
- Events are sorted into two $\Delta\eta^{jet1,jet2}$ intervals, and the difference between them is taken as the observable.
- However, due to the smaller η acceptance in ALICE, we cannot perform same analysis with large η gaps.



$$R^{sym}: |\Delta\eta^{jet1,jet2}| < 0.5$$

$$R^{asym}: |\Delta\eta^{jet1,jet2}| \in (1.0, 1.5)$$

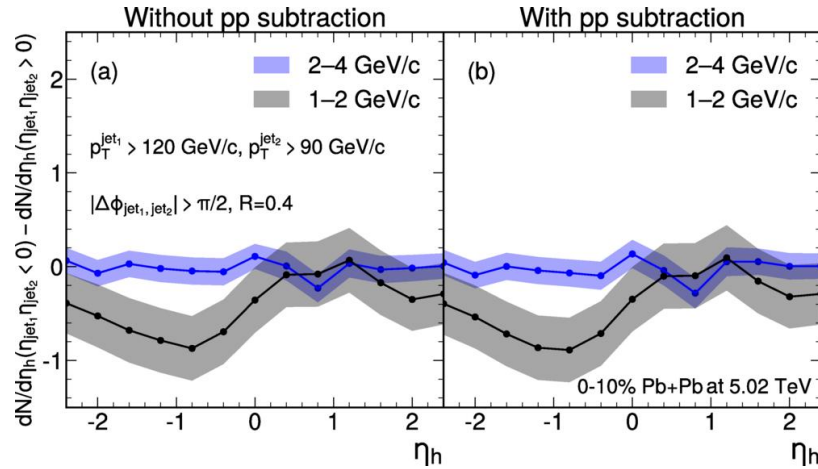
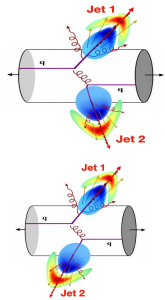


$$R^{asym} - R^{sym} = N_{AA}(1.0 < |\Delta\eta_{jet1,jet2}| < 1.5) - N_{AA}(|\Delta\eta_{jet1,jet2}| < 0.5)$$

<https://arxiv.org/abs/2602.19431v2>

Medium-response studies via di-jet rapidity asymmetry

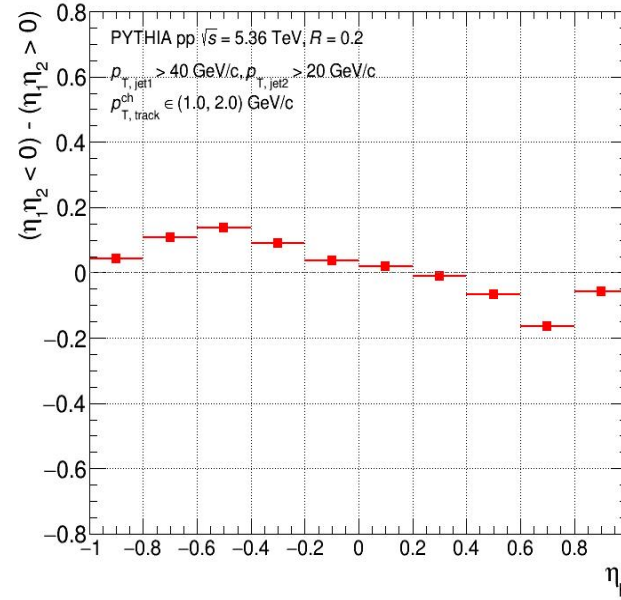
Z. Yong, X.-N. Wang, Phys. Rev. C 113, L031901



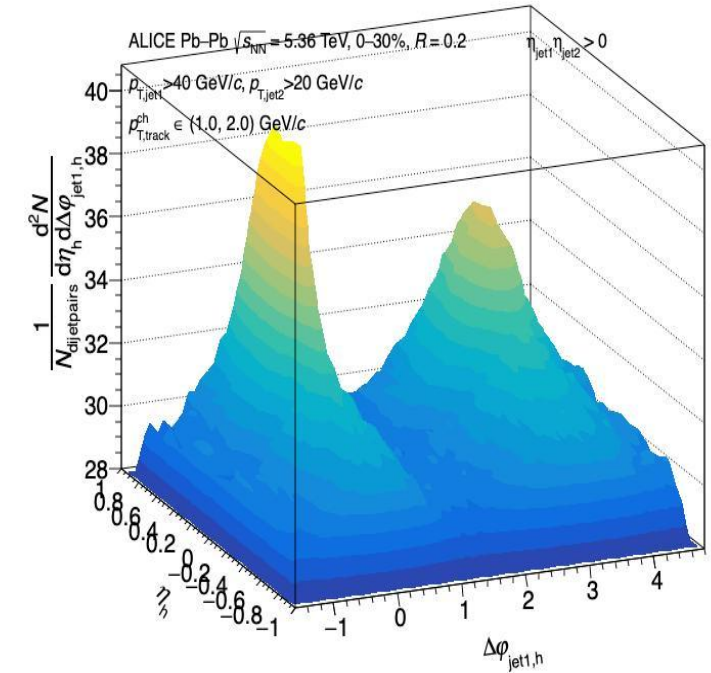
same sign: $\eta_{jet1} \times \eta_{jet2} > 0$

opposite sign: $\eta_{jet1} \times \eta_{jet2} < 0$

pp PYTHIA simulation



Pb-Pb



$$N_{AA}(\eta_{jet1}\eta_{jet2} < 0) - N_{AA}(\eta_{jet1}\eta_{jet2} > 0)$$

- Theorists proposed the new hadron- η observables as an alternative after dijet selections.
- We use PYTHIA pp simulations to check its feasibility, which demonstrates the observable is quite robust
- Currently ALICE is performing the (Pb-Pb and OO) data analysis using this approach and the results are aiming to be released for QM2027.

Summary and outlook

Summary

- First inclusive jet spectrum and modification measurements in Run 3 at $\sqrt{s_{\text{NN}}} = 5.36$ TeV:
 - Significant suppression in Pb-Pb.
 - Suppression at low p_{T} in OO, but current uncertainties do not allow a firm conclusion on whether jet quenching is present.
- Di-jet rapidity-asymmetry studied with PYTHIA pp established a robust observable for medium-response search within ALICE acceptance.

Outlook

- Combine more Pb-Pb statistics for jet $R_{\text{AA}}/R_{\text{cp}}$ analysis
- pp reference results will be released soon
- Search for medium response by using dijet rapidity asymmetries using Run3 data in ALICE

Thanks for your attention!