



Study of jet modifications using ALICE Run 3 data at LHC

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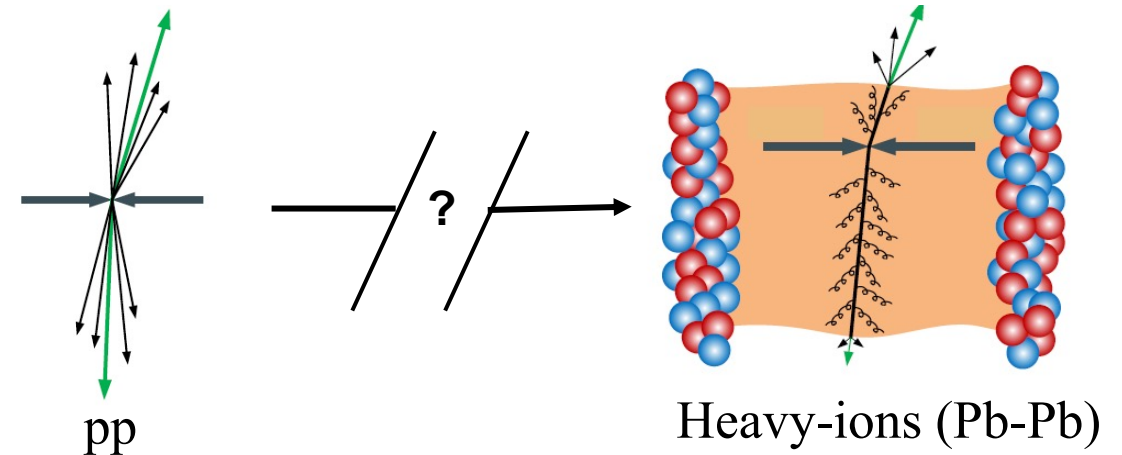
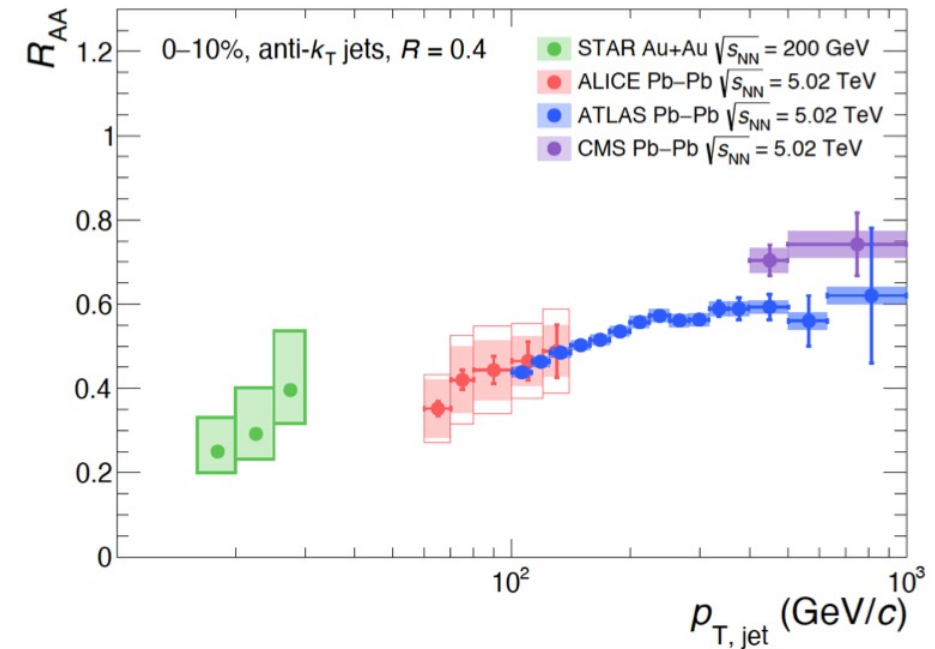
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Jets as a probe of the QGP

[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 in interactions with 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.



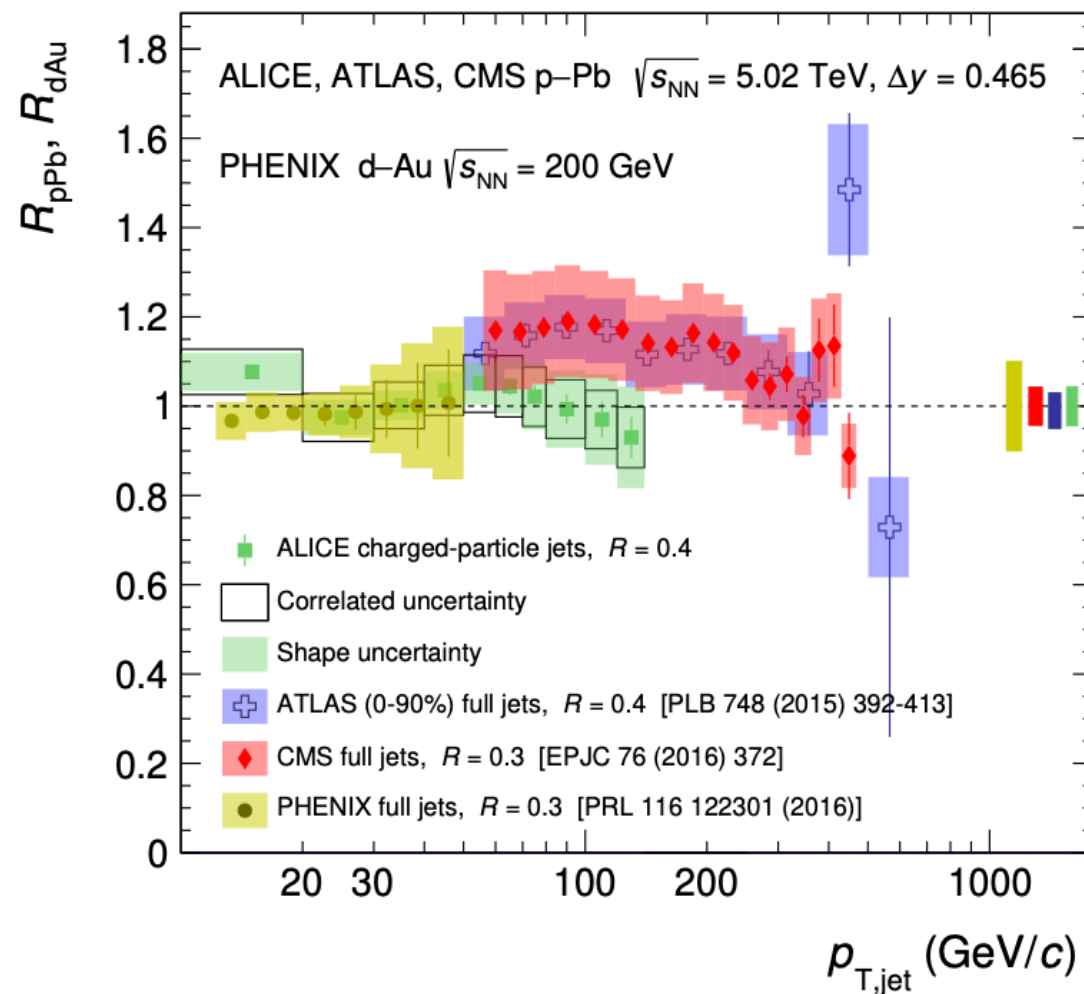
➔ *What happens in an intermediate system?*

Jet suppression across systems

- In small system pp and p-Pb:
 - QGP-like signatures have been observed in high-multiplicity events.
 - No jet quenching observed to date.
- 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

→ Are OO conditions sufficient for QGP formation ?

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



Jet suppression in Pb-Pb and OO

- Observable in **this talk**: jet energy loss in **Pb-Pb** and minimum bias **OO** at $\sqrt{s_{\text{NN}}} = 5.36$ TeV

□ Central to peripheral ratio R_{CP} in **Pb-Pb**

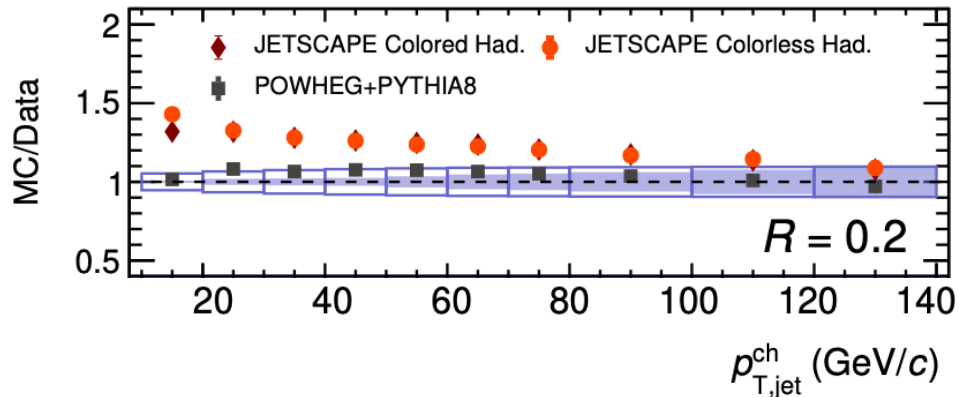
□ Jet cross section ratio in **OO**

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

$$\frac{\sigma(R = 0.2)}{\sigma(R = 0.4)}$$

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

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

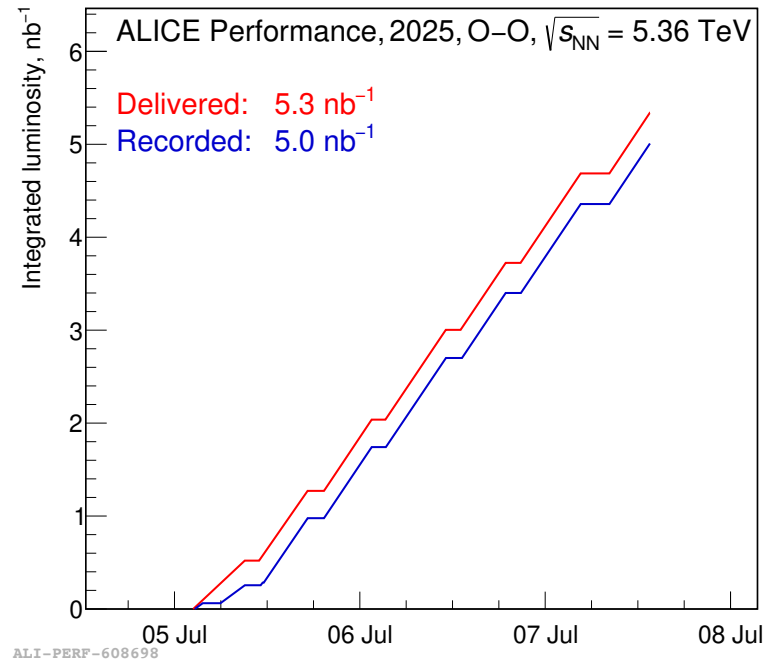
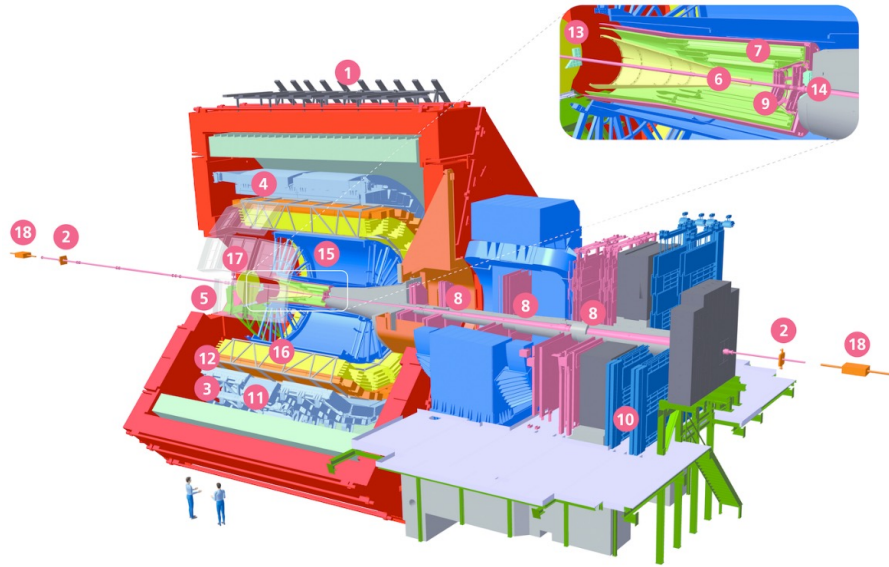


- POWHEG+PYTHIA agrees with pp data at $\sqrt{s_{\text{NN}}} = 5.02$ TeV
→ use as a reference

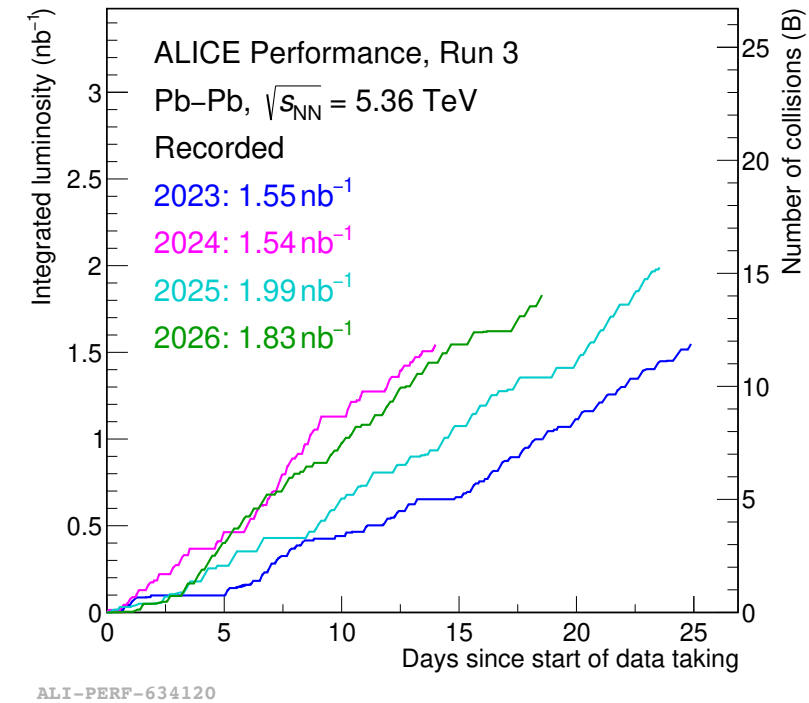
$$R_{\text{AA}}^{\text{POWHEG+PYTHIA}} = \frac{1}{\langle T_{\text{AA}} \rangle} \frac{d^2 N_{\text{jets}}^{\text{AA}} / dp_{\text{T}} d\eta}{d^2 \sigma_{\text{jets}}^{\text{pp, POWHEG+PYTHIA}} / dp_{\text{T}} d\eta}$$

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

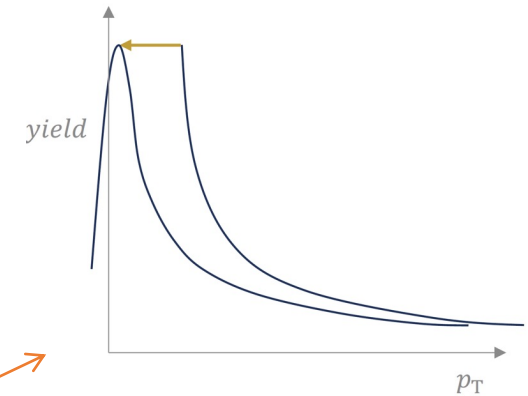
- We take advantage of the Run 3 statistics.
→ multi-dimensional measurements

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 , $|\eta| < 0.9 - R$
 - $p_{\text{T,track}}^{\text{lead.}} > 5$ GeV/ c for **Pb-Pb** $R = 0.2$;
 $p_{\text{T,track}}^{\text{lead.}} > 3$ GeV/ c for **OO** $R = 0.2$; 5 GeV/ c for **OO** $R = 0.4$

Analysis details

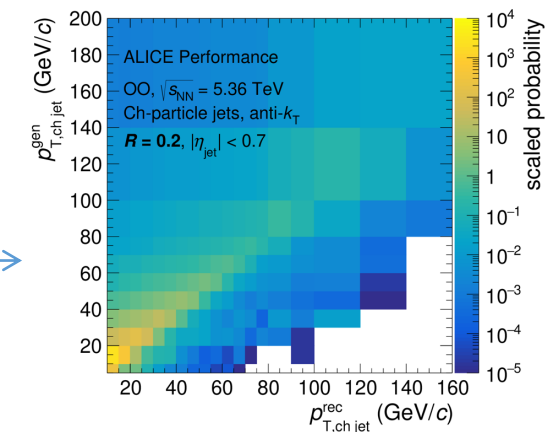
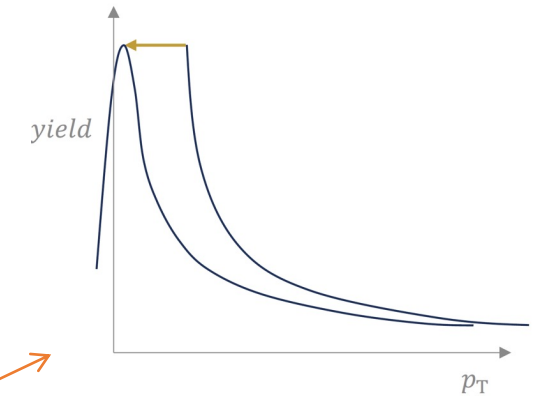
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- Background subtraction:
 - Remove pedestal underlying event from jets based on jet area
$$p_{\text{T}}^{\text{bkg. corrected}} = p_{\text{T}}^{\text{raw}} - A_{\text{jet}} \cdot \rho$$
 - Apply leading track cut to remove combinatorial jets



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$$p_T^{bkg. corrected} = p_T^{raw} - A_{jet} \cdot \rho$$
 - Apply leading track cut to remove combinatorial jets
- Unfolding correction: correct bkg. fluctuations + detector effects

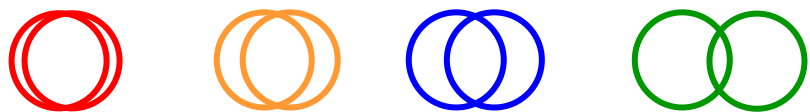


Jet yields in Pb-Pb at 5.36 TeV

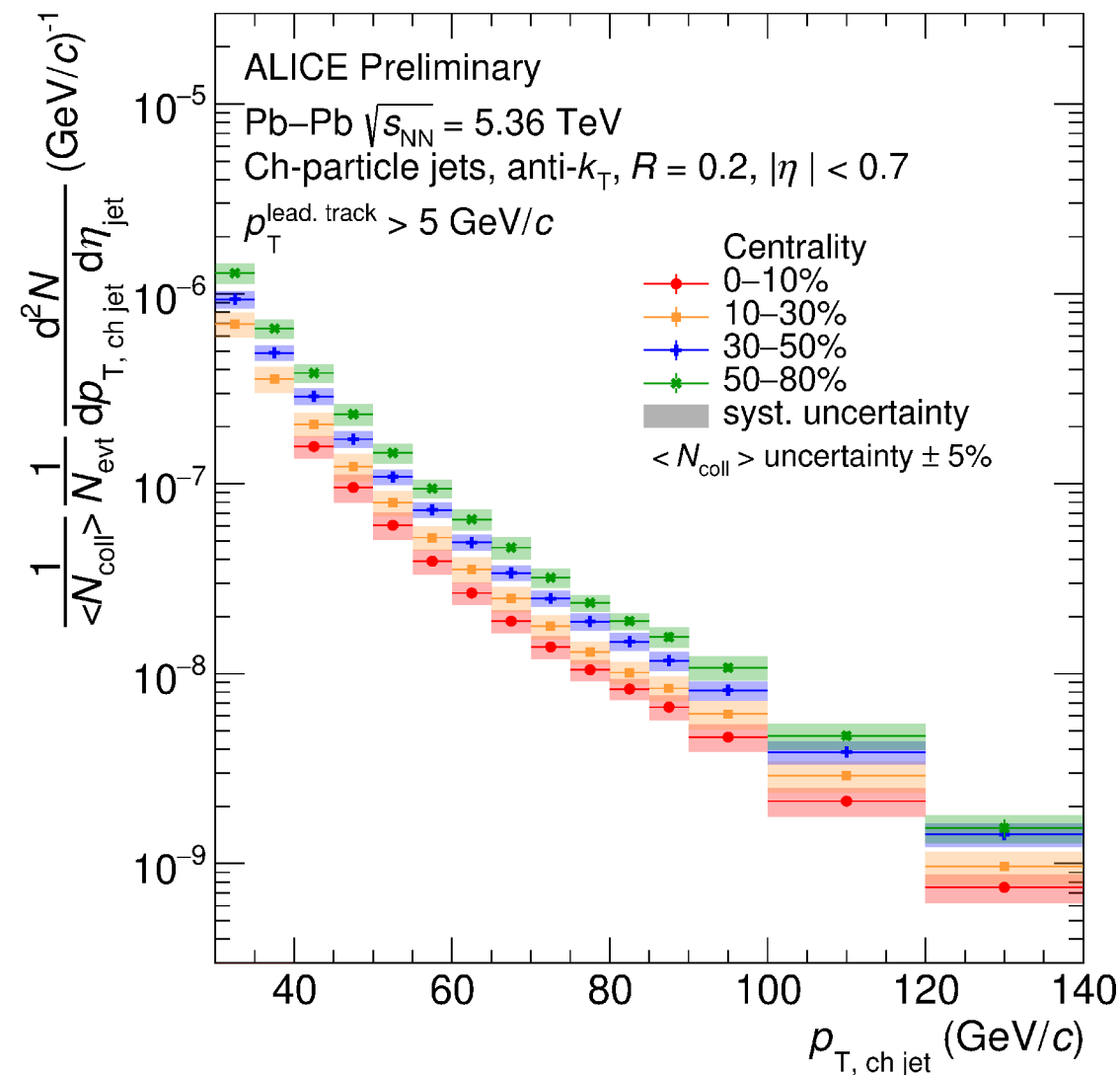
- First inclusive charged-particle jet ($R=0.2$) measurement in Pb-Pb at $\sqrt{s_{NN}} = 5.36$ TeV:

- Centrality classes:

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



- Increasing normalized yield from central to peripheral.

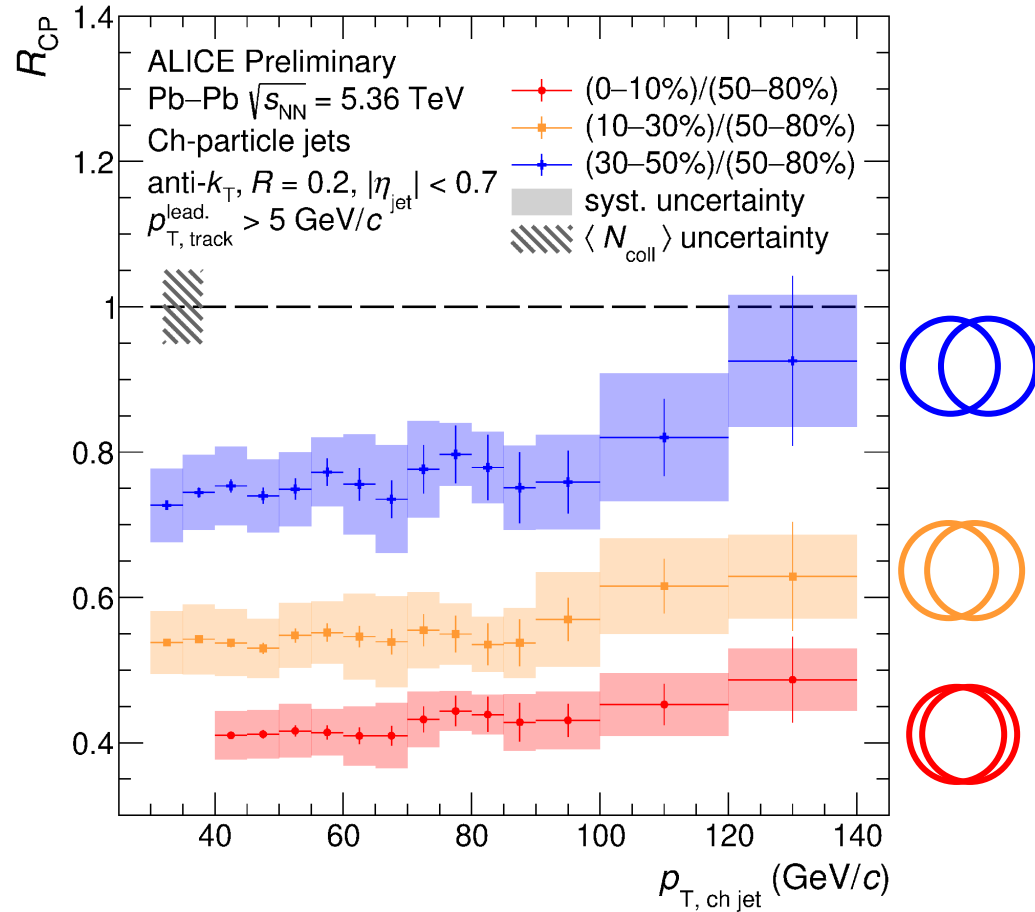


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Central to peripheral ratio in Pb-Pb

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

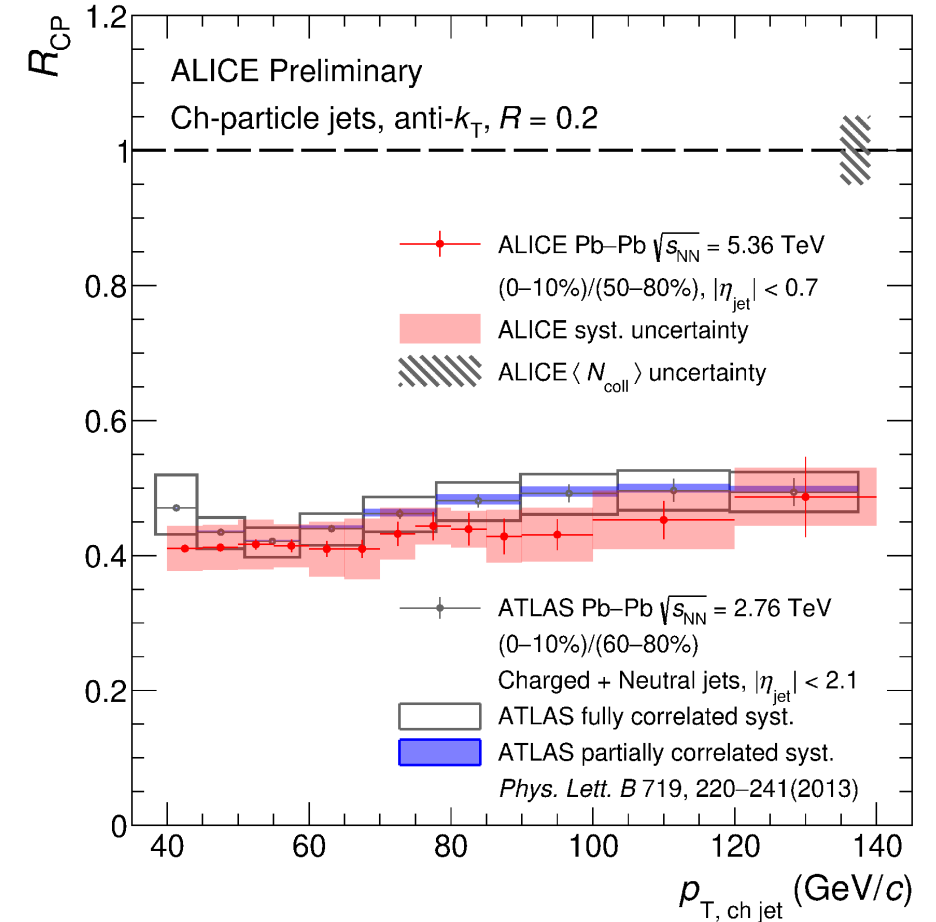
- R_{CP} in 0-10%, 10-30% and 30-50% Pb-Pb



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○ Evolution of jet modification as a function of centrality

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



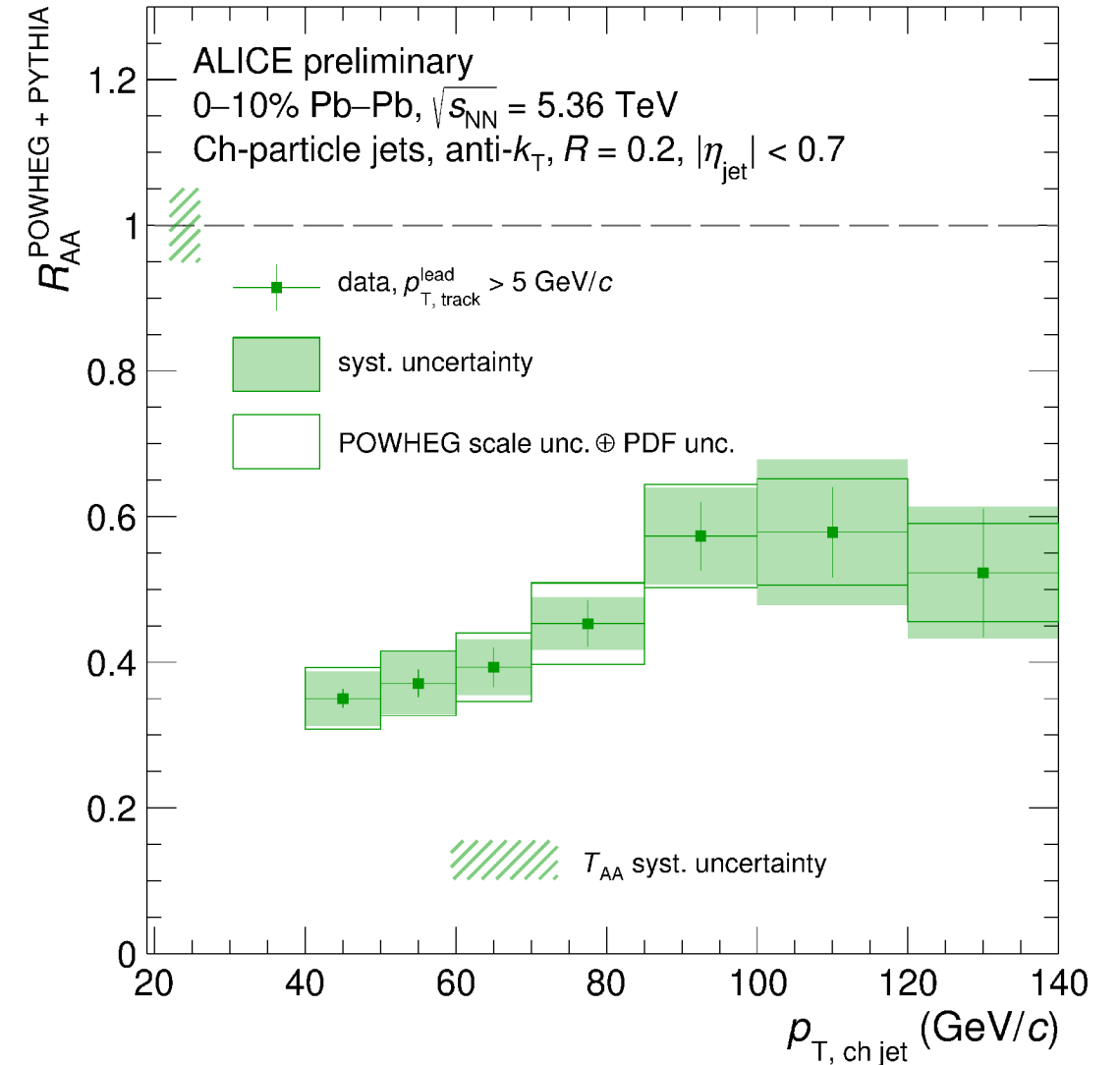
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○ Consistent with ATLAS results at $\sqrt{s_{NN}} = 2.76$ TeV

R_{AA} in Pb-Pb

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

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

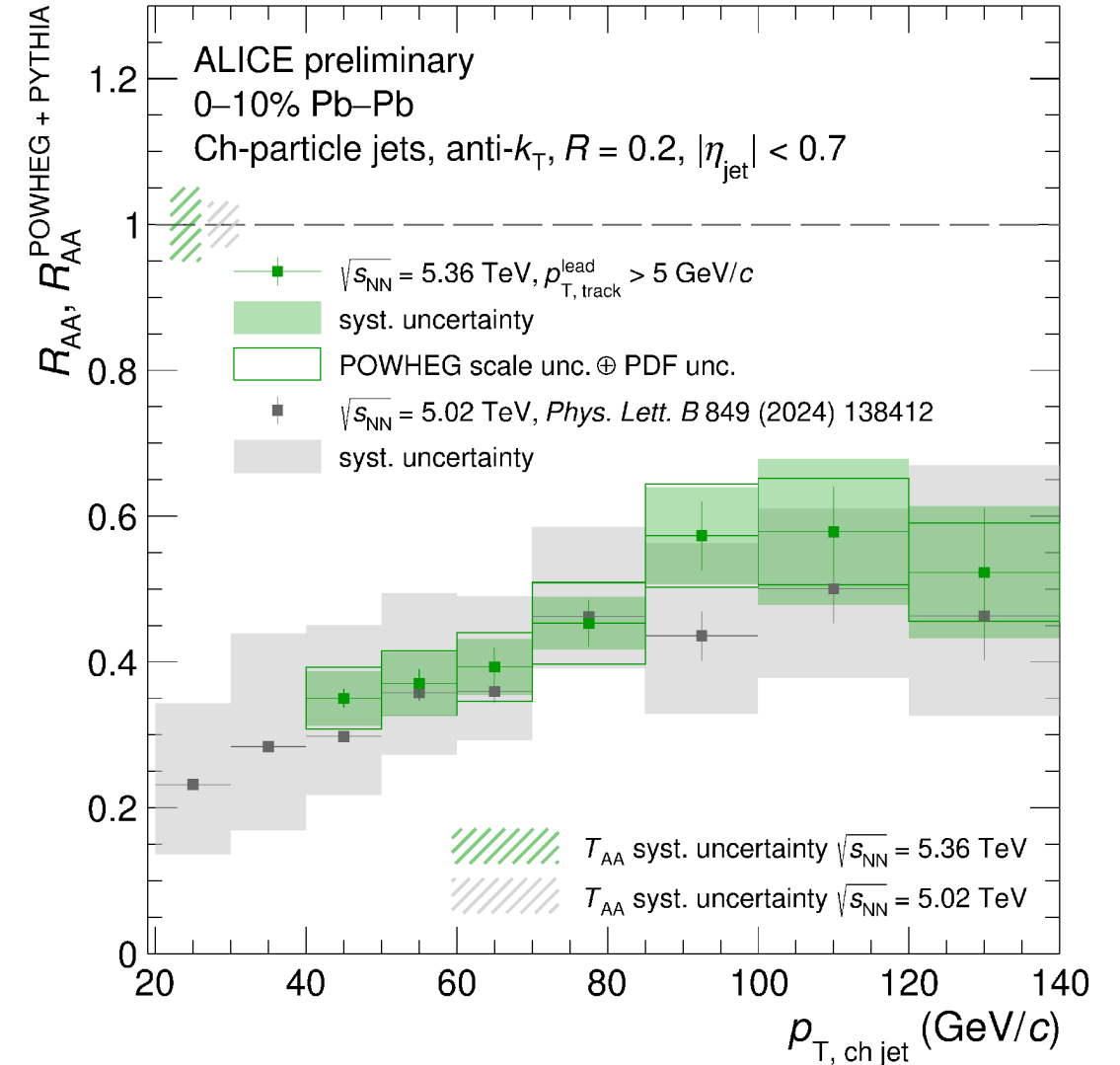


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R_{AA} in Pb-Pb

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

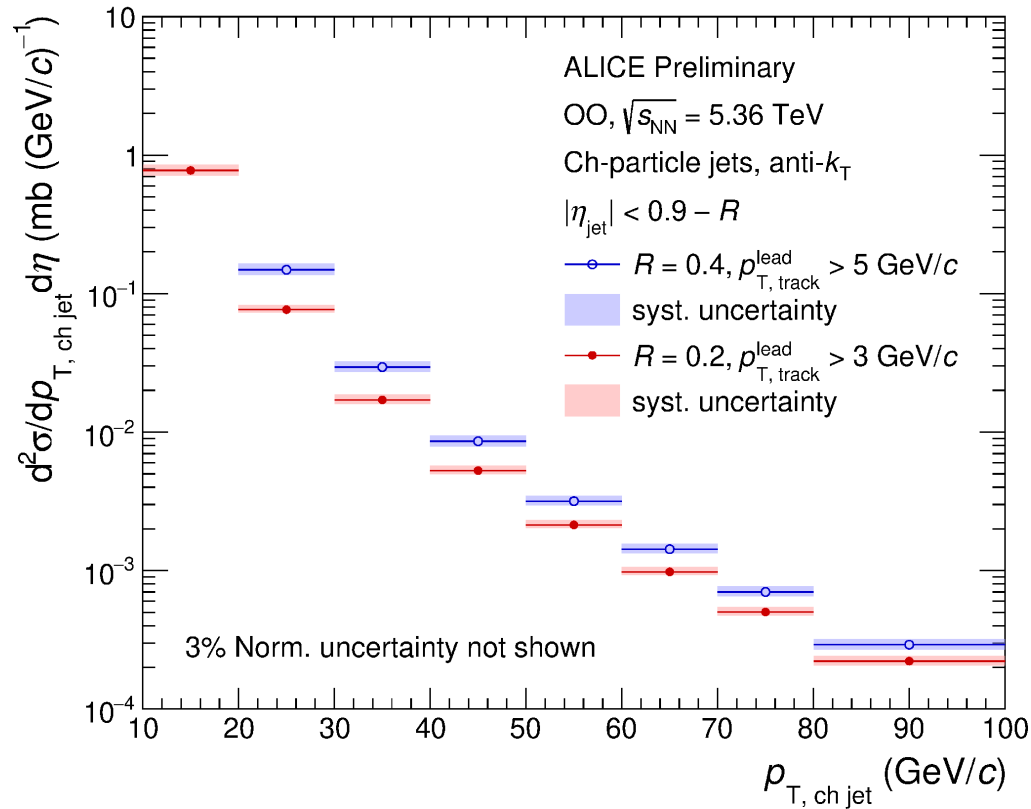
- Jet suppression observed comparing to pp model in 0-10% Pb-Pb collisions at $\sqrt{s_{NN}} = 5.36$ TeV:
 - pedestal background subtraction
 - Run 2 machine learning based bkg. subtraction at $\sqrt{s_{NN}} = 5.02$ TeV.
 - Consistent results between two energy scales.
- Improve statistics at $\sqrt{s_{NN}}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



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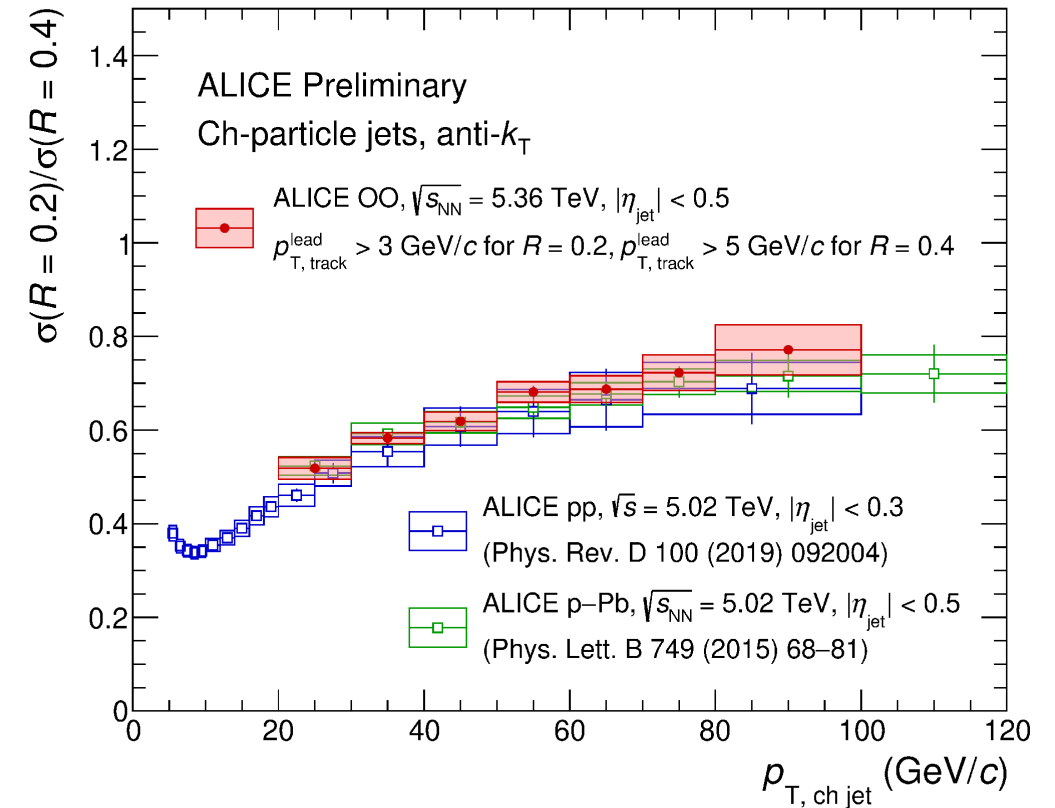
Jet cross section in OO

- 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:



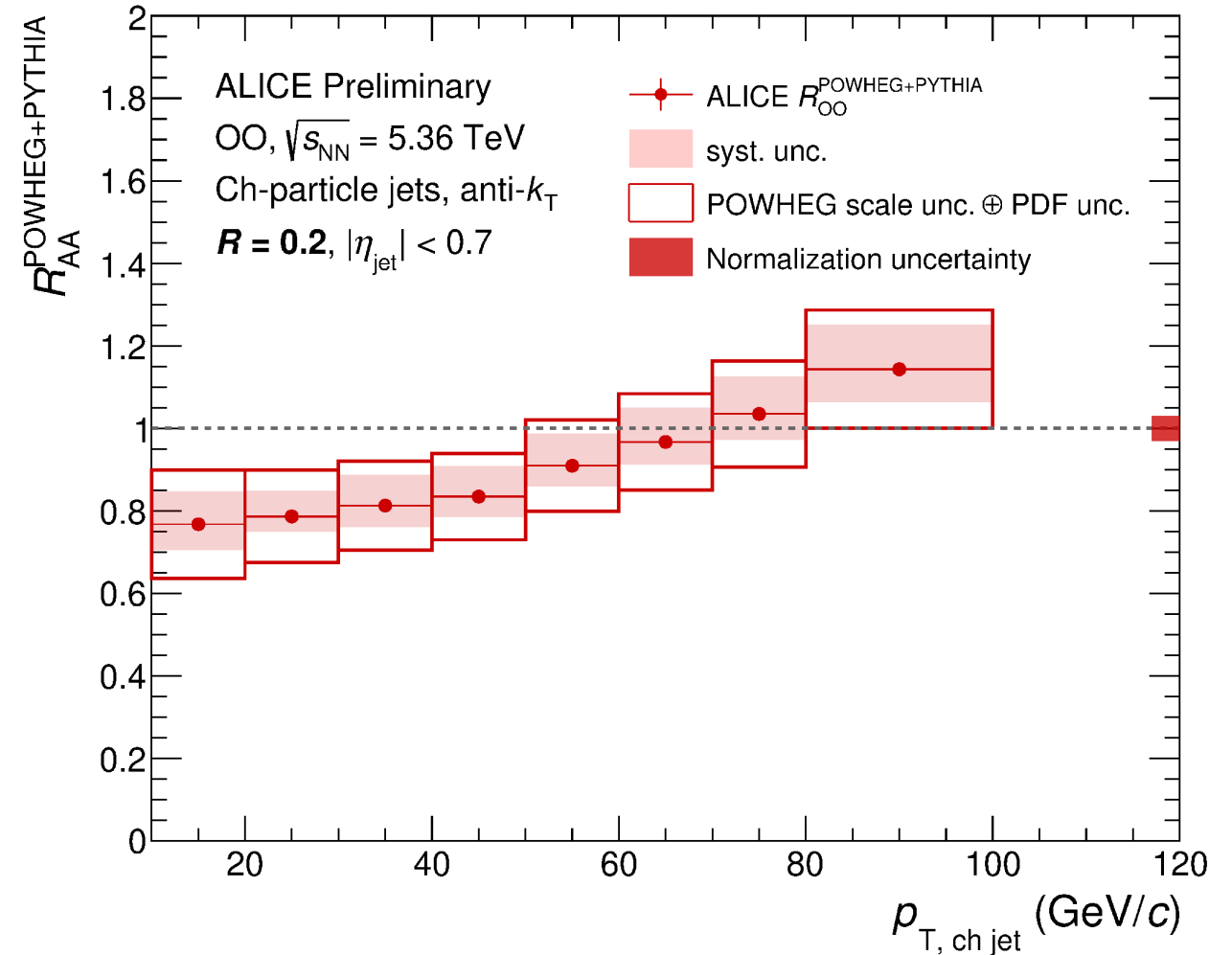
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○ Show consistency across collision systems

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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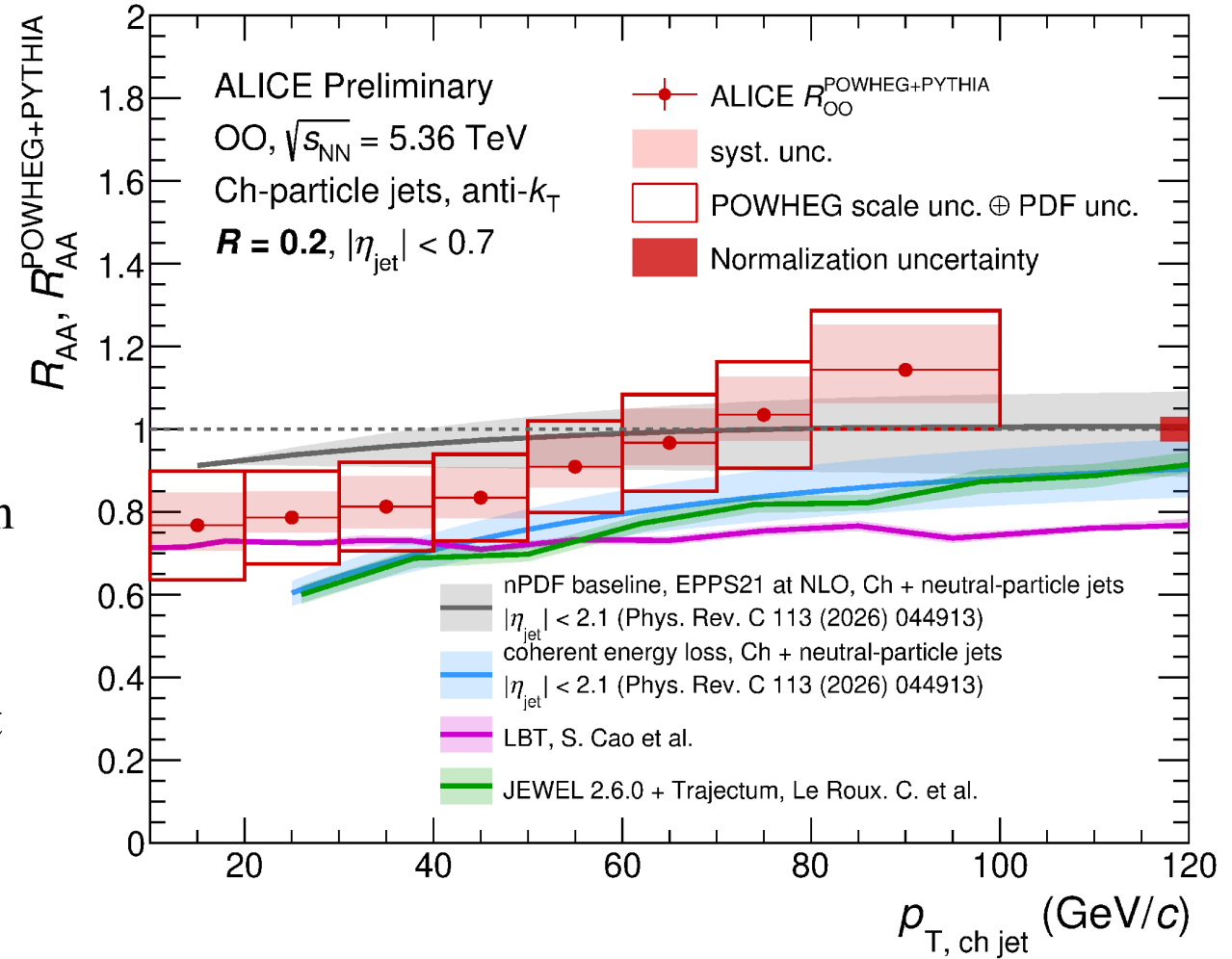
R_{AA} in OO for R=0.2

$R = 0.2$

○ 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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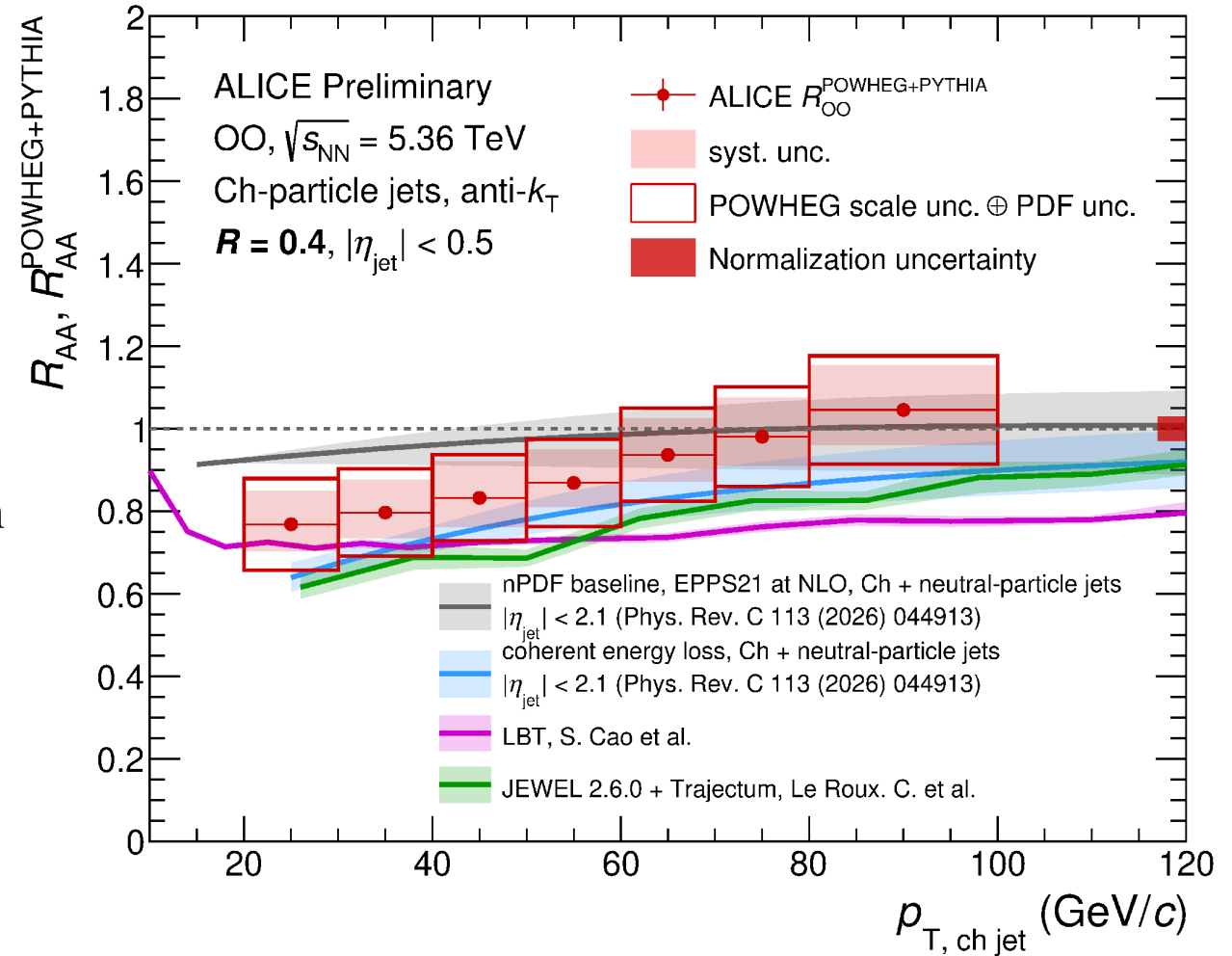
R_{AA} in OO for R=0.4

$R = 0.4$

○ 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 + Trajectrum: 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:

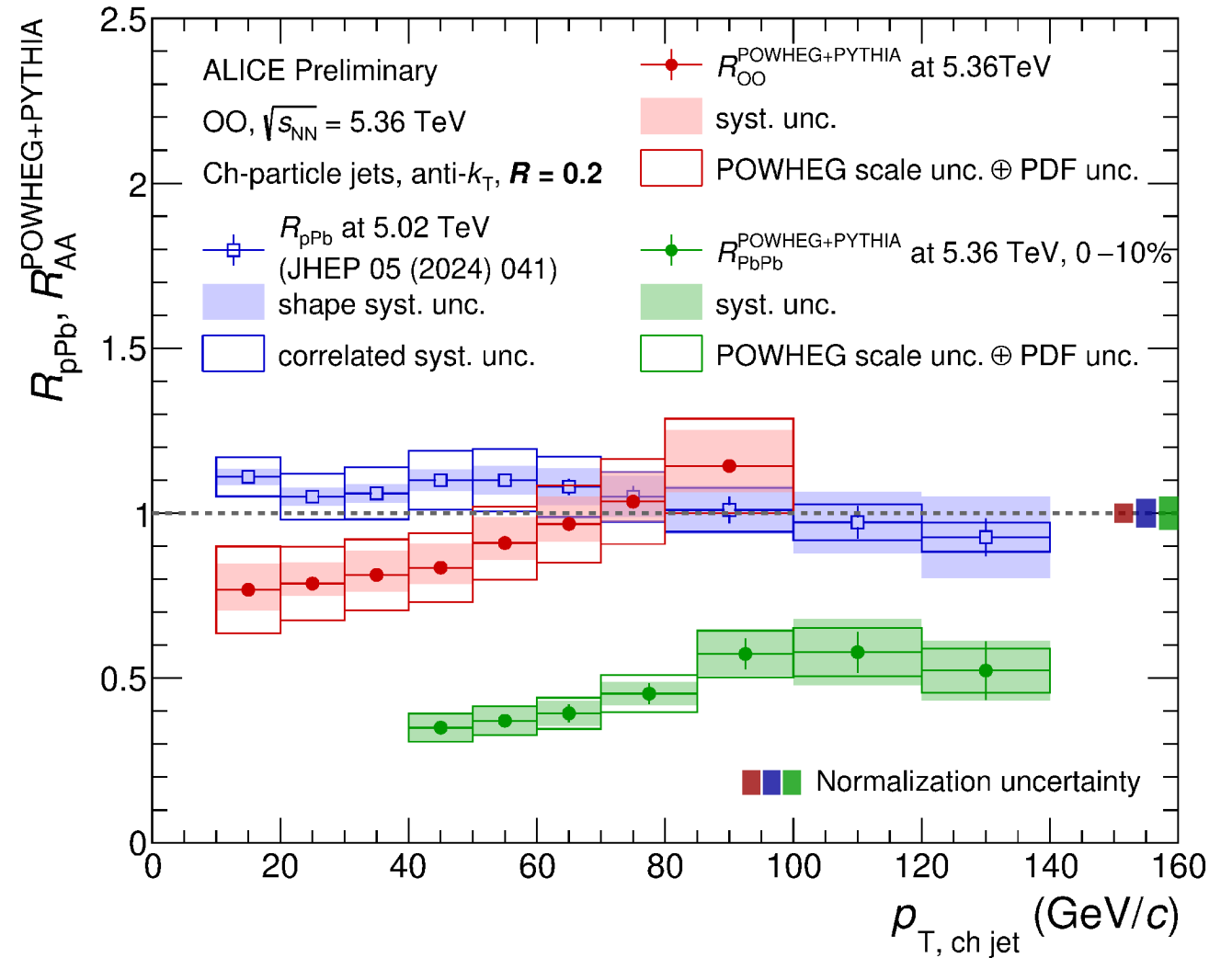
$$R_{Pb-Pb}^{POWHEG+PYTHIA} \text{ at } \sqrt{s_{NN}} = 5.36 \text{ TeV}$$

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

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

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

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



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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.

Outlook

- Combine more Pb-Pb data samples (2024-2026 data-taking).
- Upcoming pp reference results
- Low p_{T} reach by different background subtraction:
 - Machine-learning based subtraction.
 - Mixed-event technique for combinatorial jets.

Thanks for your attention!