Jet nuclear modifications in Pb-Pb and OO collisions with ALICE

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Jets as a probe of the QGP

- **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?*

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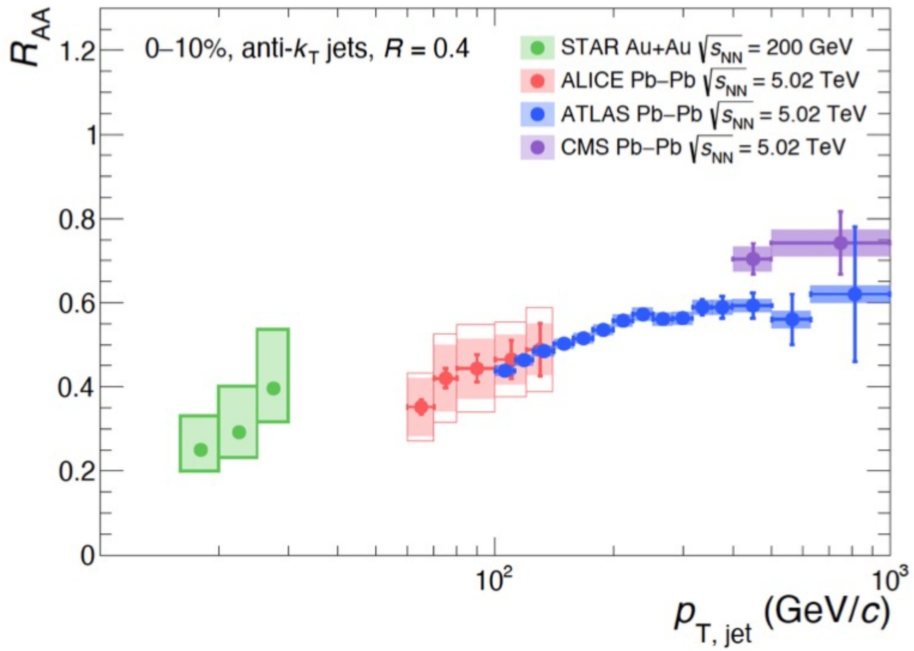

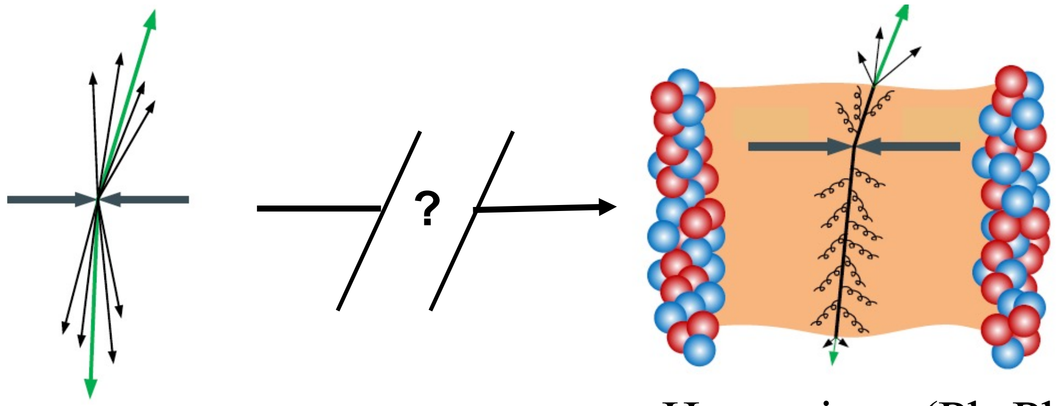

Jet suppression across systems

- 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* ?

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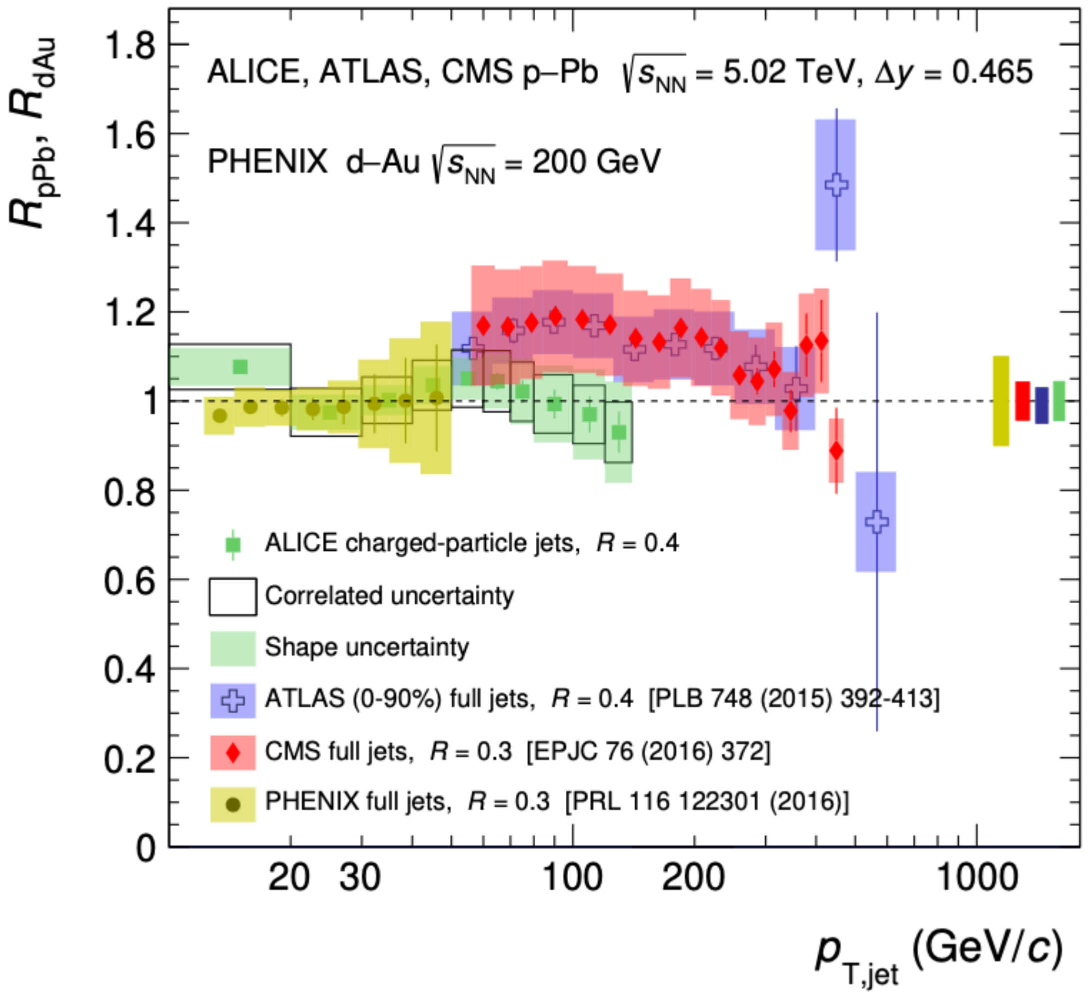

Jet suppression in Pb-Pb and OO

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

❑ Central to peripheral ratio $R_{\rm CP}$ in Pb-Pb

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

❑ Jet cross section ratio in OO

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

❑ Nuclear modification factor $R_{\rm AA}$:
with AA = Pb-Pb or OO

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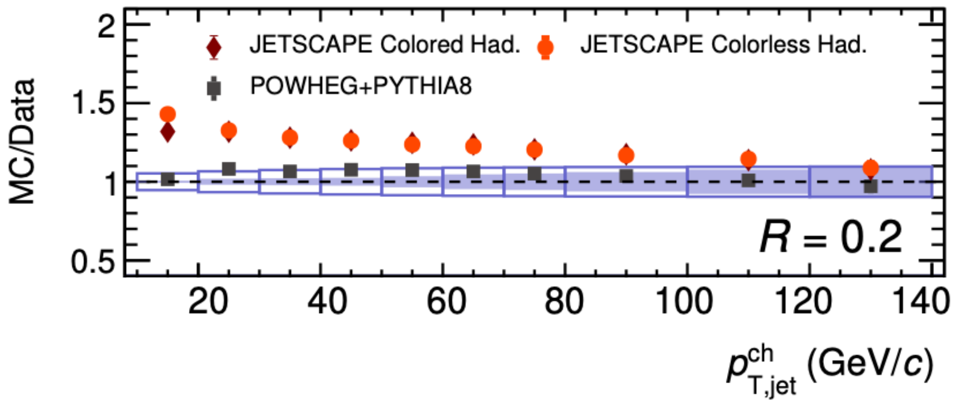
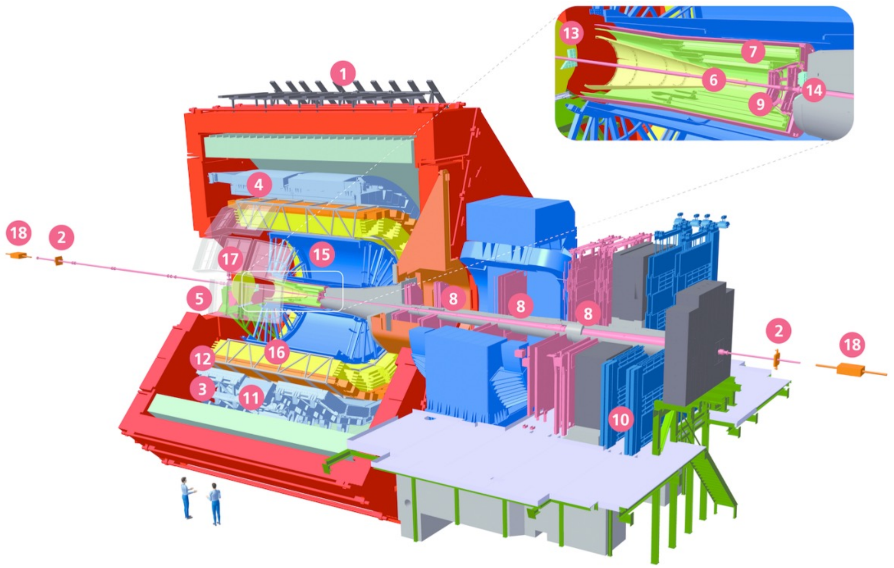


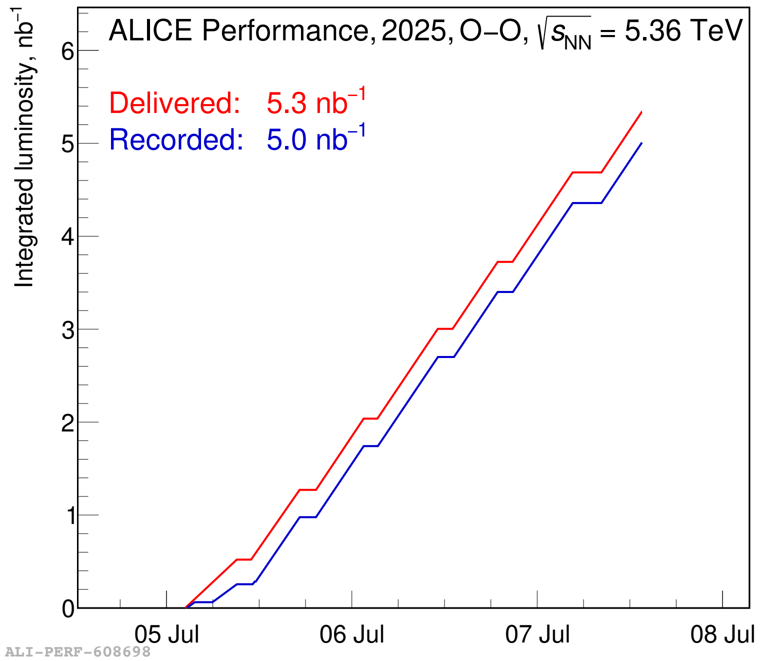
- POWHEG+PYTHIA agrees with pp data at $\sqrt{s_{\rm NN}} = 5.02$ TeV
→ use as a reference

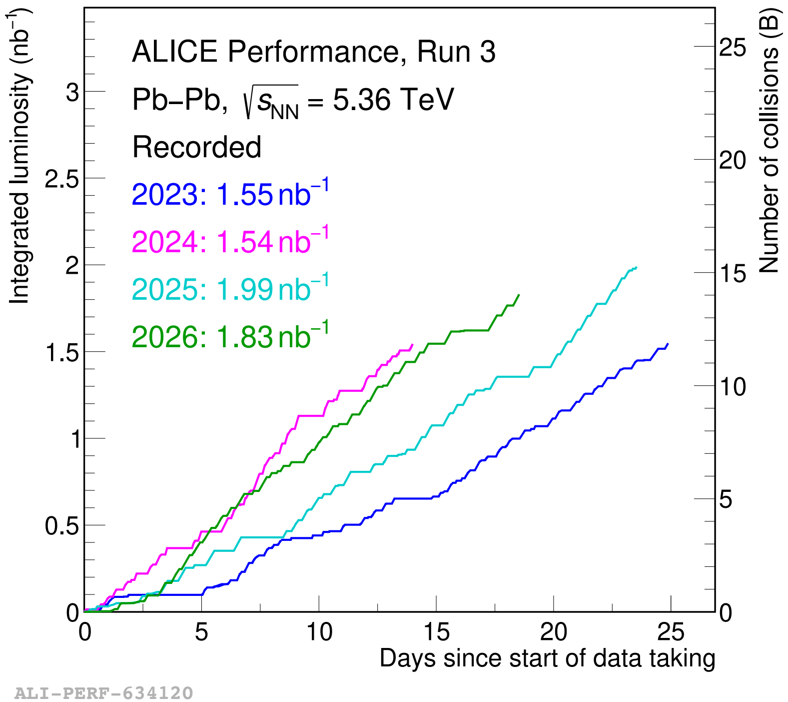
$$R_{\rm AA}^{\rm POWHEG+PYTHIA} = \frac{1}{\langle T_{\rm AA}\rangle} \frac{d^2N_{\rm jets}^{\rm AA}/dp_{\rm T}d\eta}{d^2\sigma_{\rm jets}^{\rm pp,\,POWHEG+PYTHIA}/dp_{\rm T}d\eta}$$

ALICE in Run 3

ALICE detetctor in Run 3







~6.5×10^{9} MB events in
Oxygen – Oxygen

~53×10^{9} events in Pb-Pb
×160 more than Run 1+2

ALICE new capabilities in Run 3:

- Contiunous 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 $\sqrt{s_{\mathrm{NN}}} = 5.36$ 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}, $\boldsymbol{R} = \mathbf{0.2}$ and **0.4**, $|\eta| < 0.9 - R$
  - $p_{\mathrm{T,track}}^{\mathrm{lead.}} > 5\ \mathrm{GeV}/c$ for Pb-Pb $R = 0.2$;
    $p_{\mathrm{T,track}}^{\mathrm{lead.}} > 3\ \mathrm{GeV}/c$ for OO $R = 0.2$; 5 GeV/c for OO $R = 0.4$

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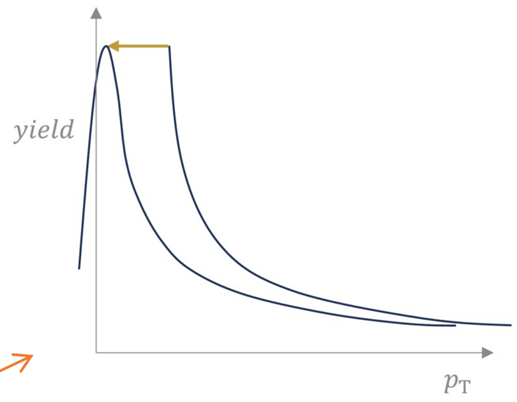
- Background subtraction:
  - Remove pedestal underlying event from jets based on jet area

$$p_{\mathrm{T}}^{\mathrm{bkg.\,corrected}} = p_{\mathrm{T}}^{\mathrm{raw}} - A_{\mathrm{jet}} \cdot \rho$$

  - Apply leading track cut to remove combinatorial jets



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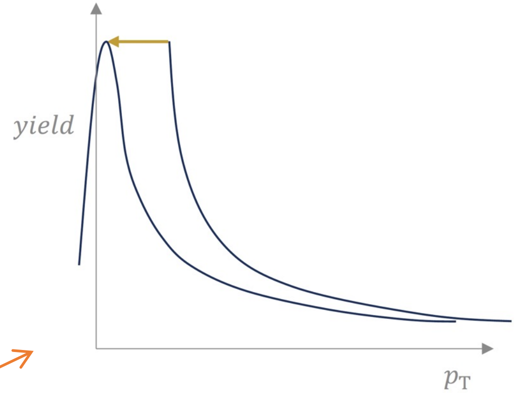
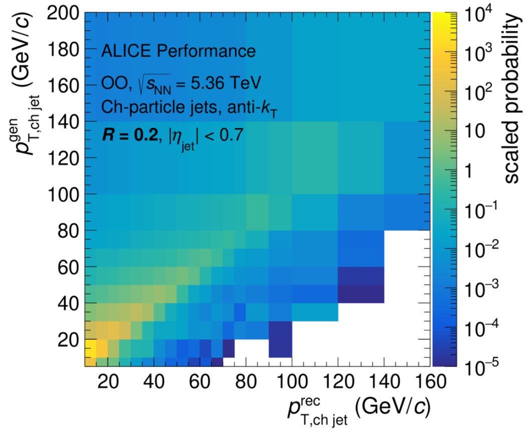
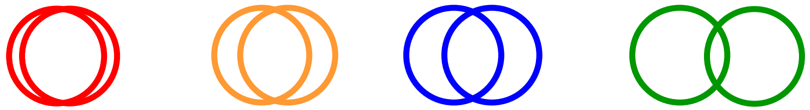
  - Apply leading track cut to remove combinatorial jets
- Unfolding correction: correct bkg. fluctuations + detector effects



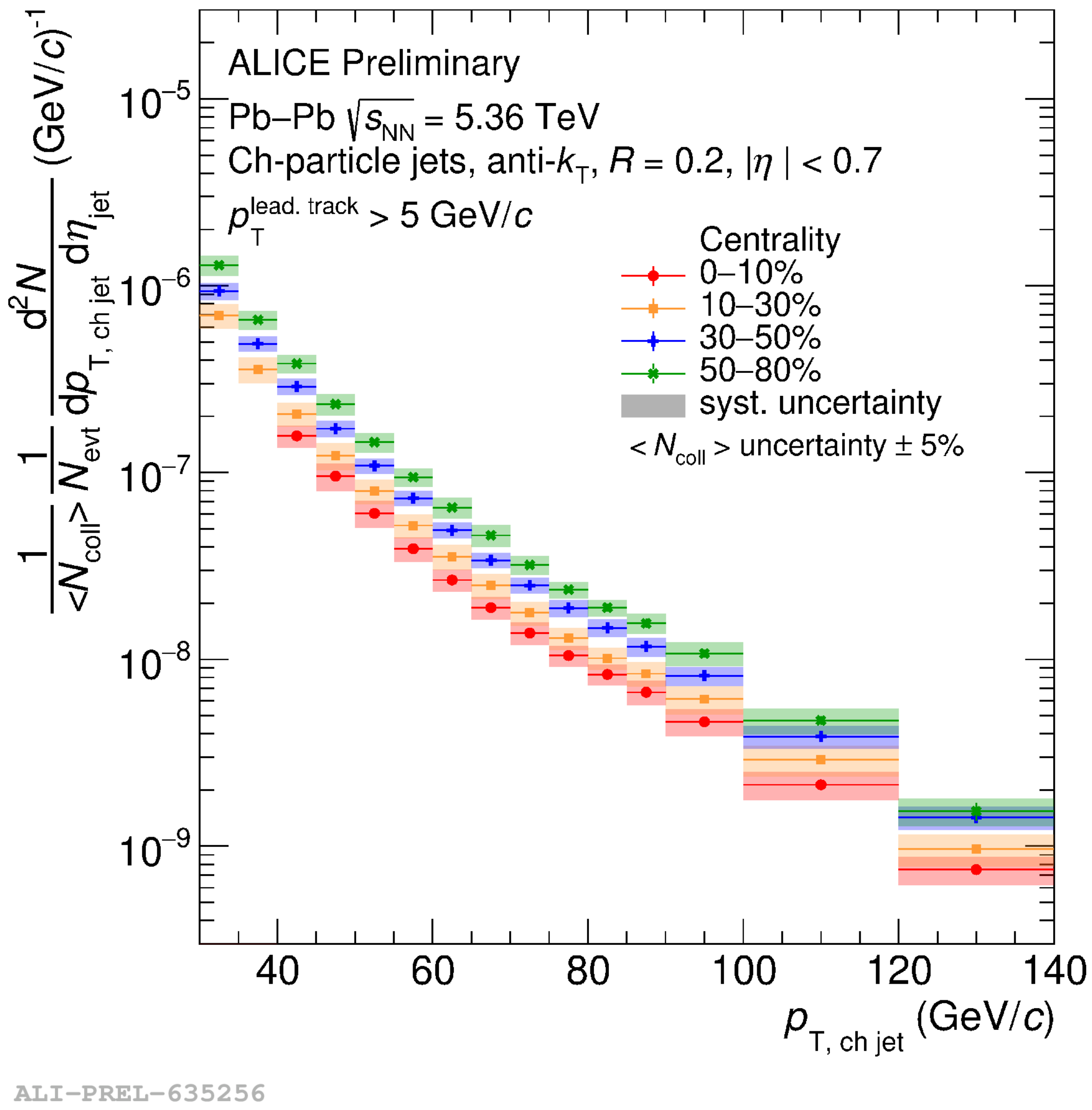


Jet yields in Pb-Pb at 5.36 TeV

- First inclusive charged-particle jet (R=0.2) measurement in Pb-Pb at $\sqrt{s_{\mathrm{NN}}} = 5.36$ TeV:
  - Centrality classes:
    0-10%, 10-30%, 30-50% and 50-80%



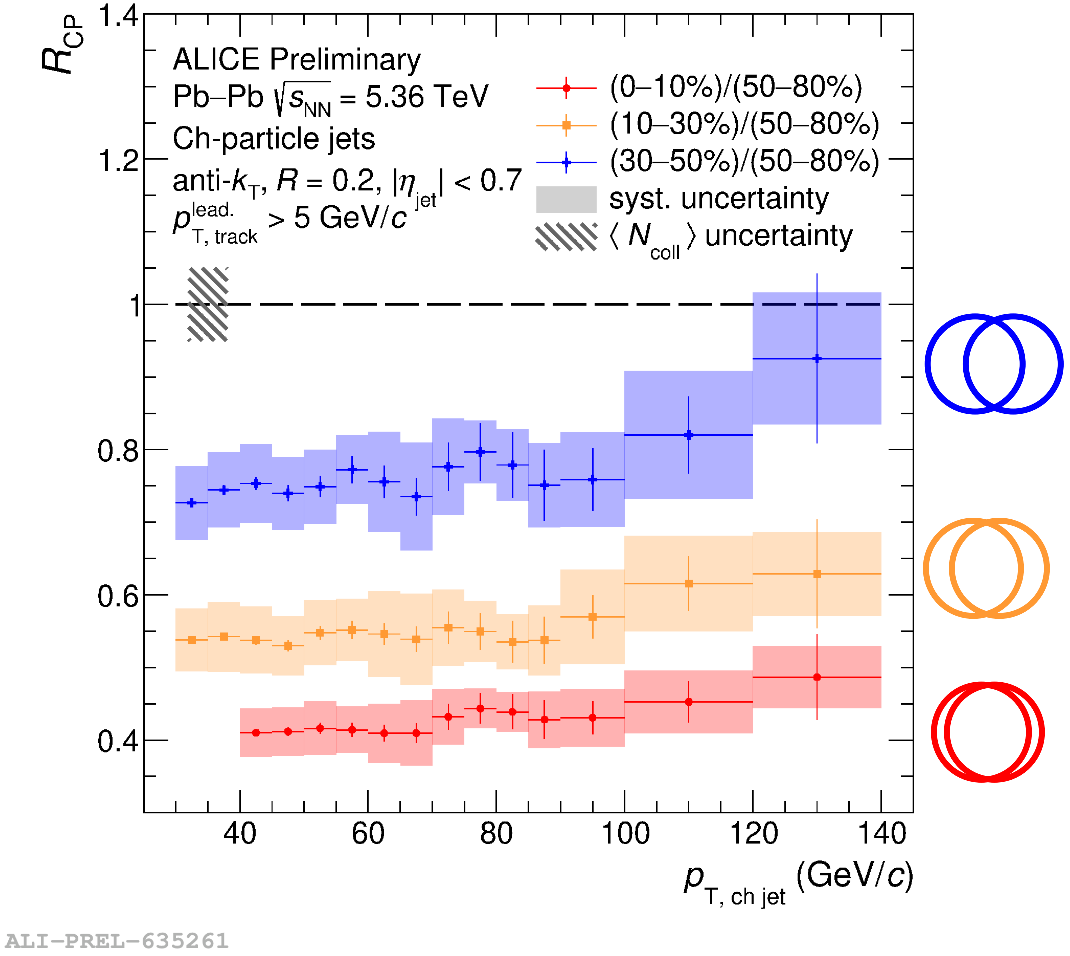
- Increasing normalized yield from central to peripheral.



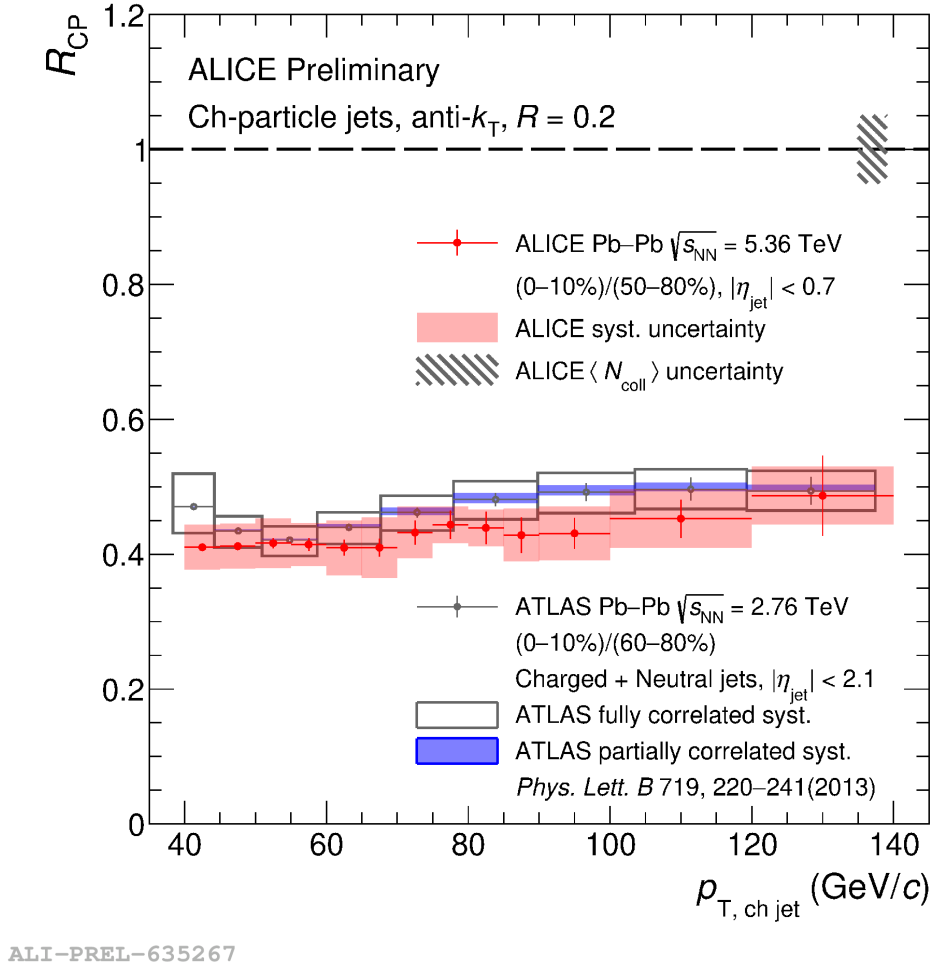
Central to peripheral ratio in Pb-Pb

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

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



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

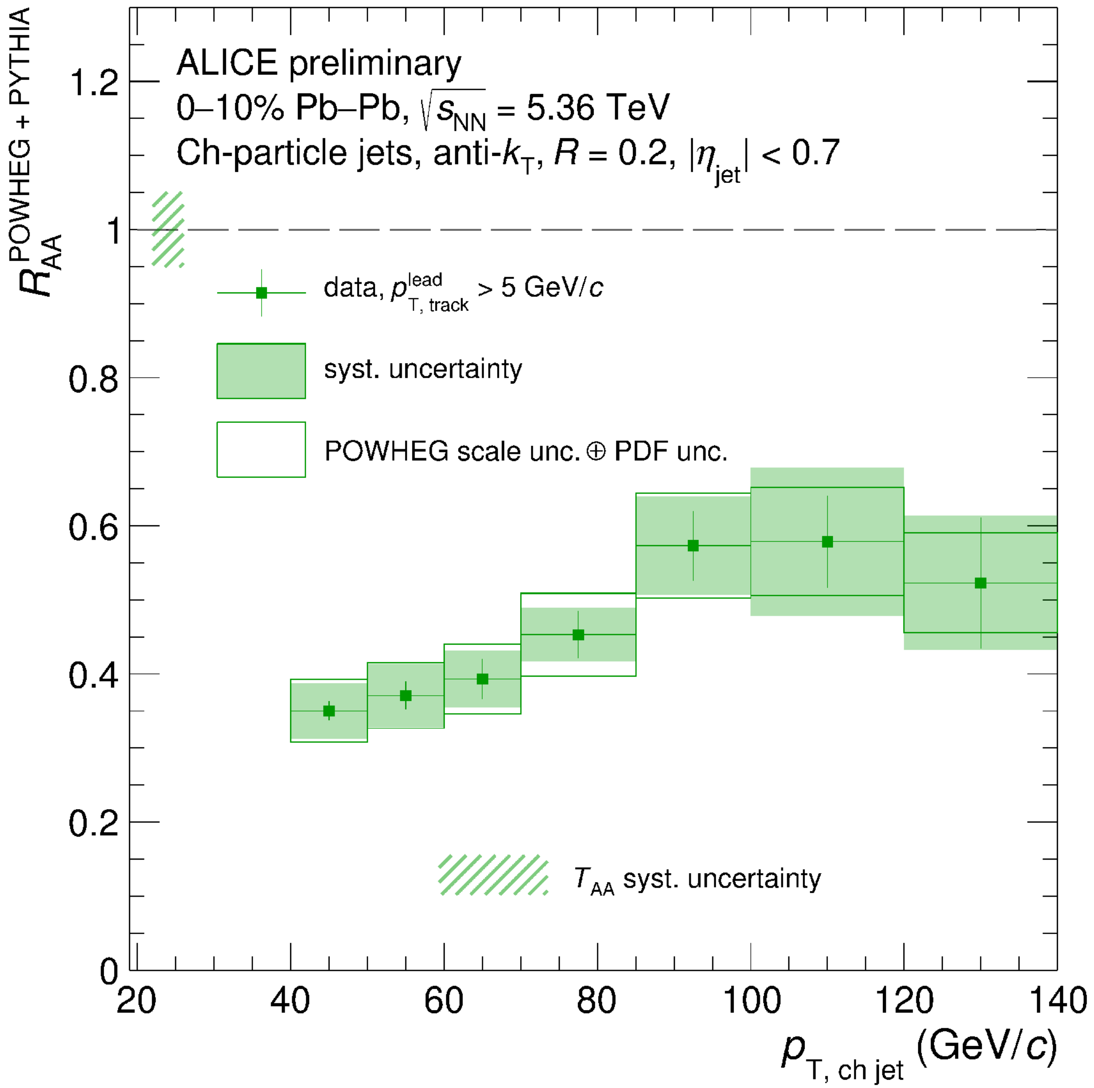


- Evolution of jet modification as a function of centrality
- Consistent with ATLAS results at $\sqrt{s_{NN}} = 2.76$ TeV

R_{AA} in Pb-Pb

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

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



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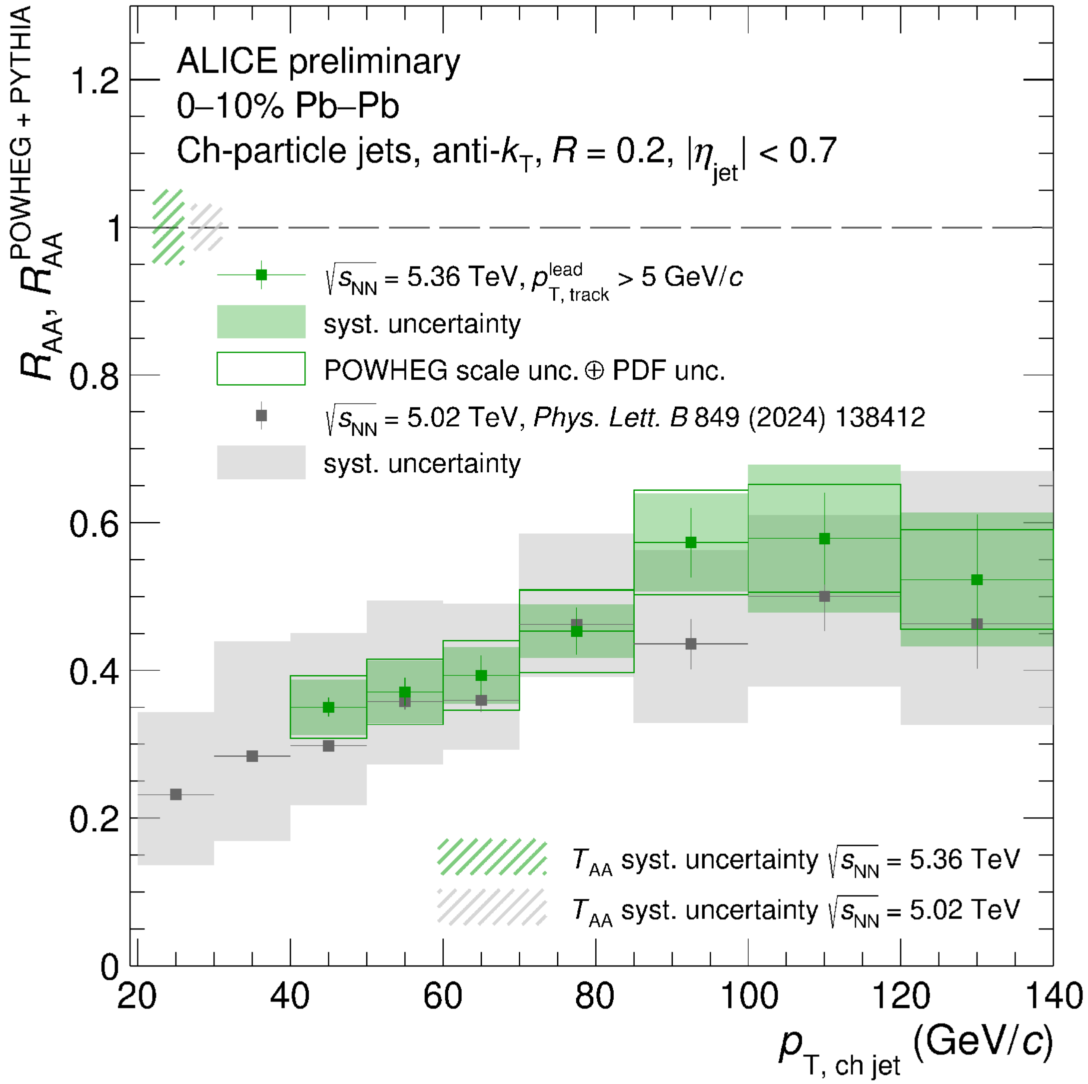
R_{AA} in Pb-Pb

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

- 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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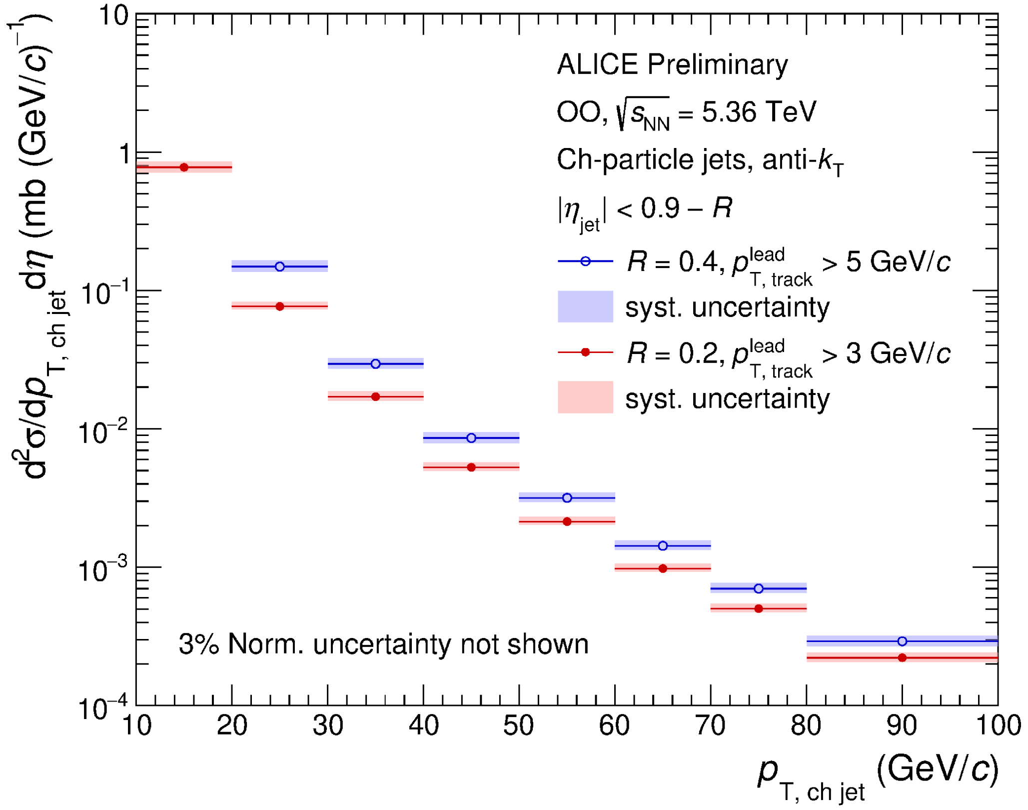
Jet cross section in OO

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



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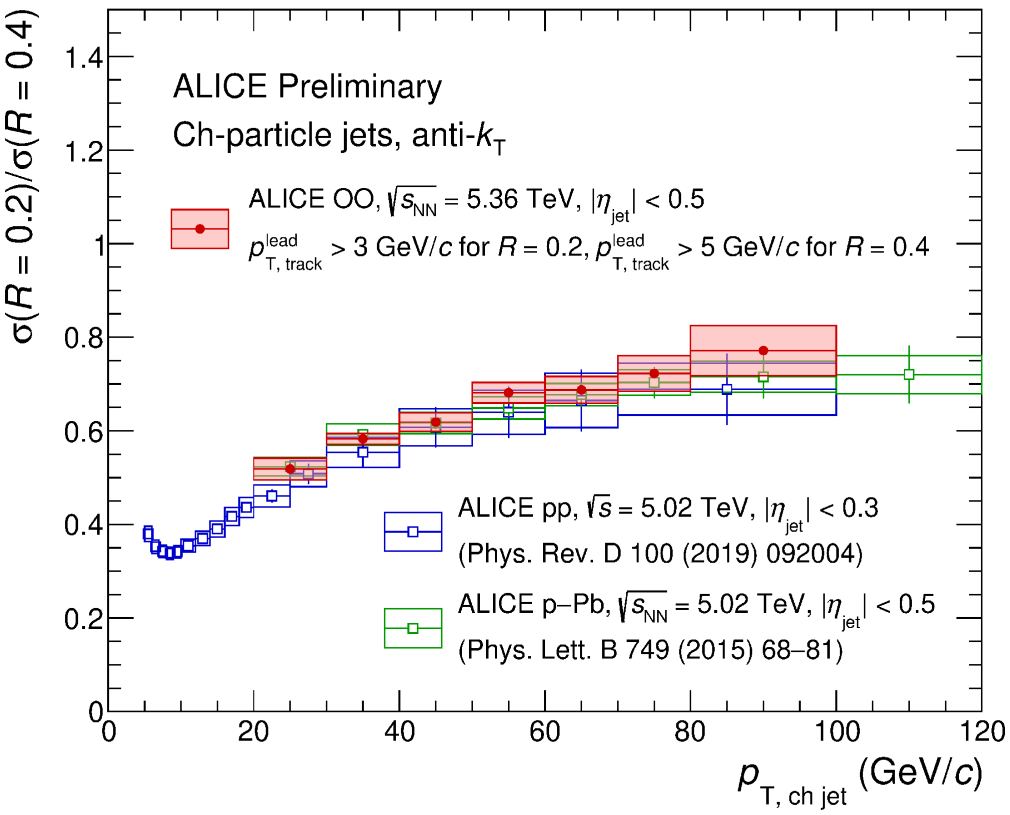
- $\frac{\sigma(R=0.2)}{\sigma(R=0.4)}$ ratio in OO comparing with other collision systems:



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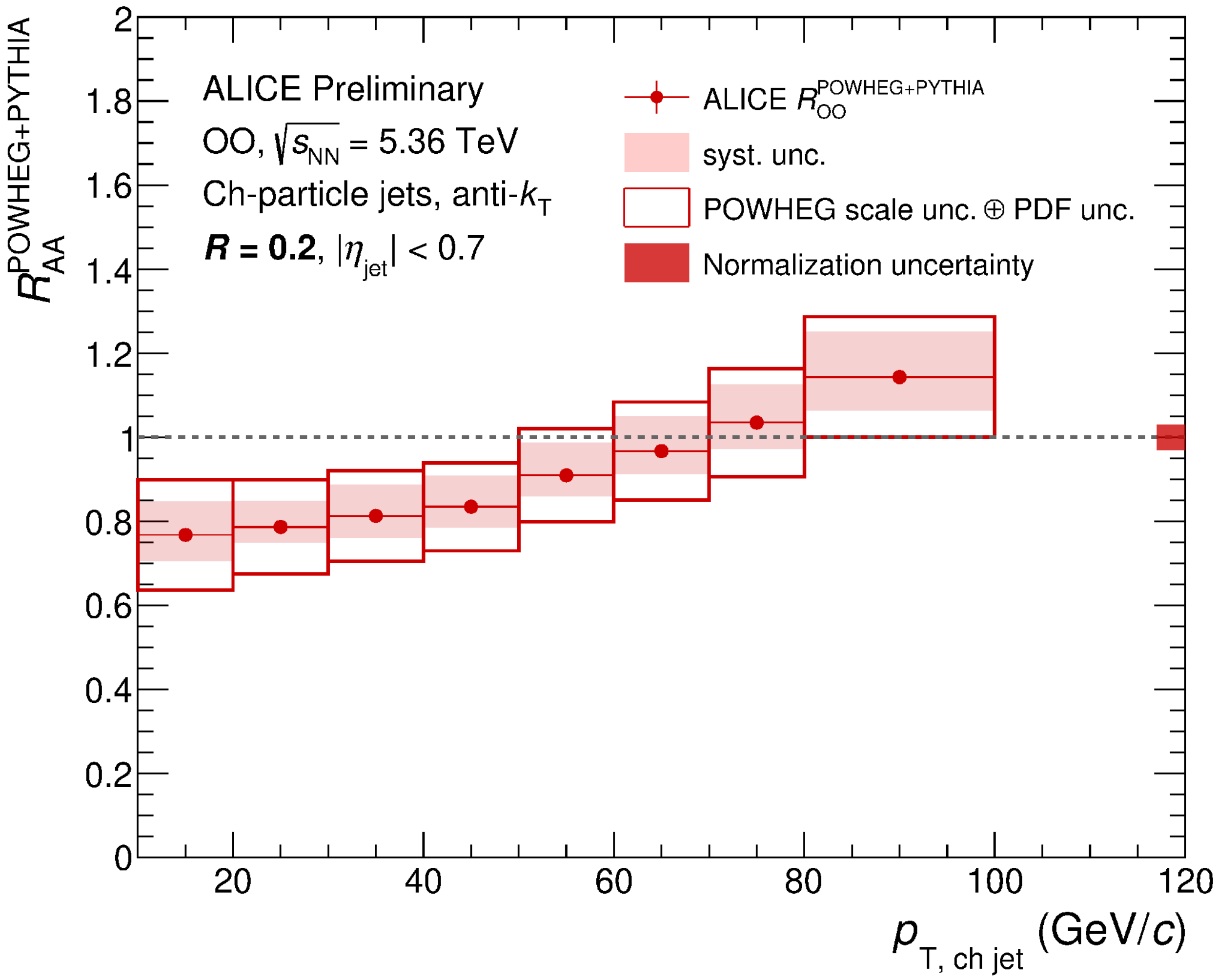
- Show consistency across collision systems

R_{AA} in OO

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

- Show jet suppression at low p_{T}
- Current uncertainties do not allow a firm conclusion on jet quenching.



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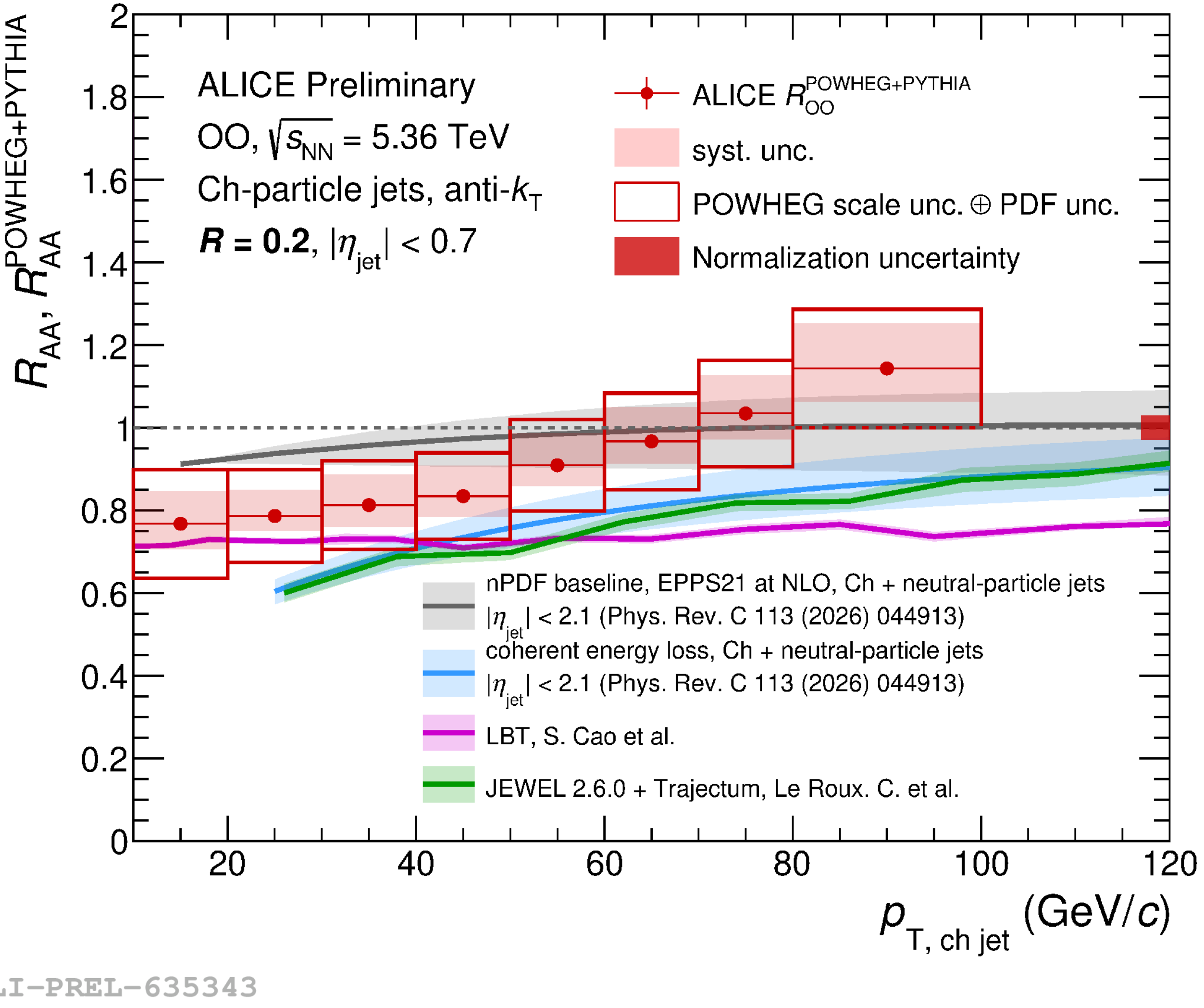
R_{AA} in OO for R=0.2

- 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)

R = 0.2



- Improve precision of data measurement to distinguish model with and without quenching.

- LBT model seems to over-estimate jet suppression at high p_T.

R_{AA} in OO for R=0.4

○ Theoretical prediction models:

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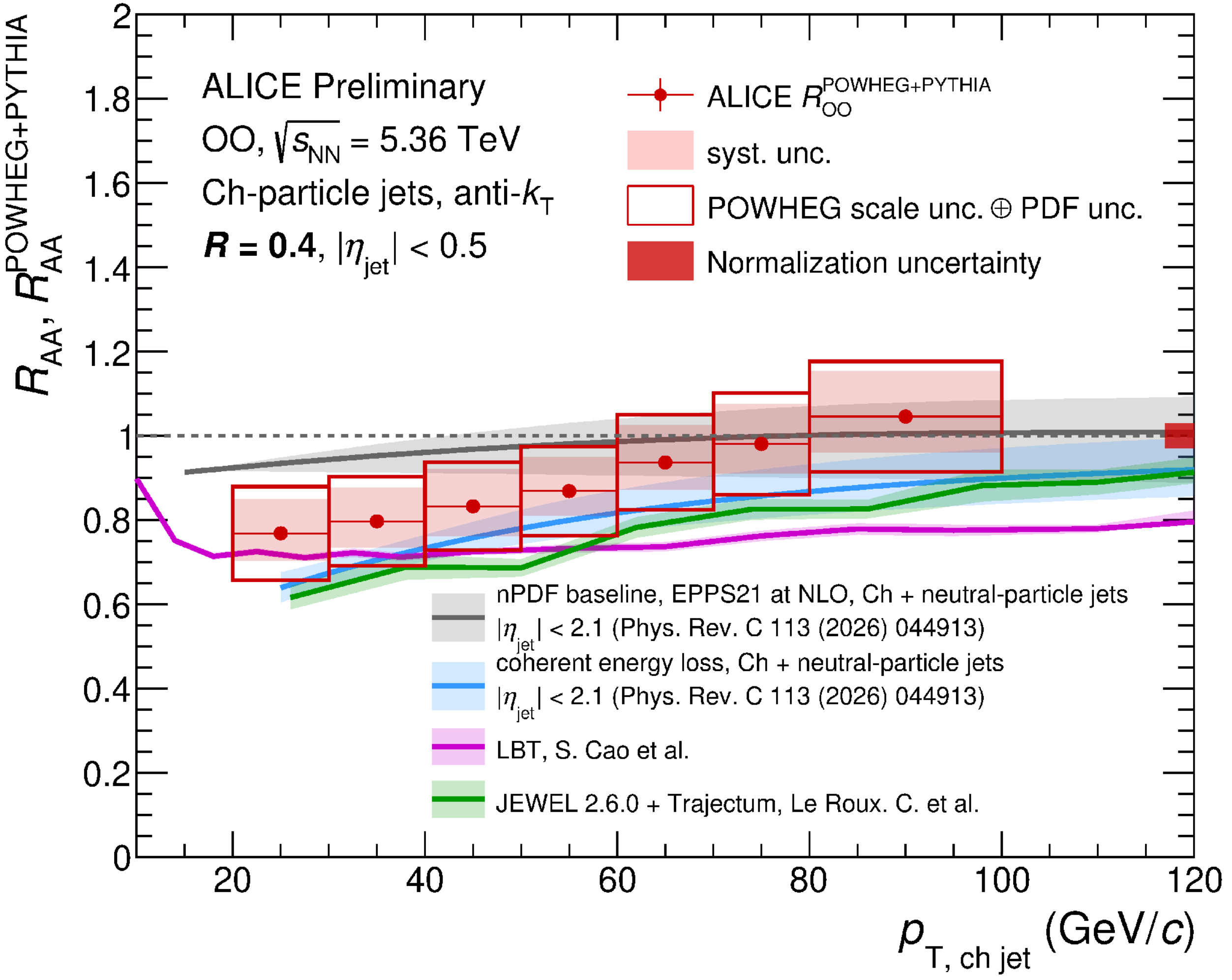
- Coherent energy loss: same model with above one, with hydro and coherent energy loss model
- LBT: parton transport in QGP with recoil (arXiv:2512.12715)
- JEWEL + Trajectrum: jet energy loss from medium interaction (arXiv:2509.04299)

- Improve precision of data measurement to distinguish model with and without quenching.

- LBT model seems to over-estimate jet suppression at high p_T.

$R = 0.4$



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Comparison of R_{AA} across systems

- R_{AA} comparison across collision systems:

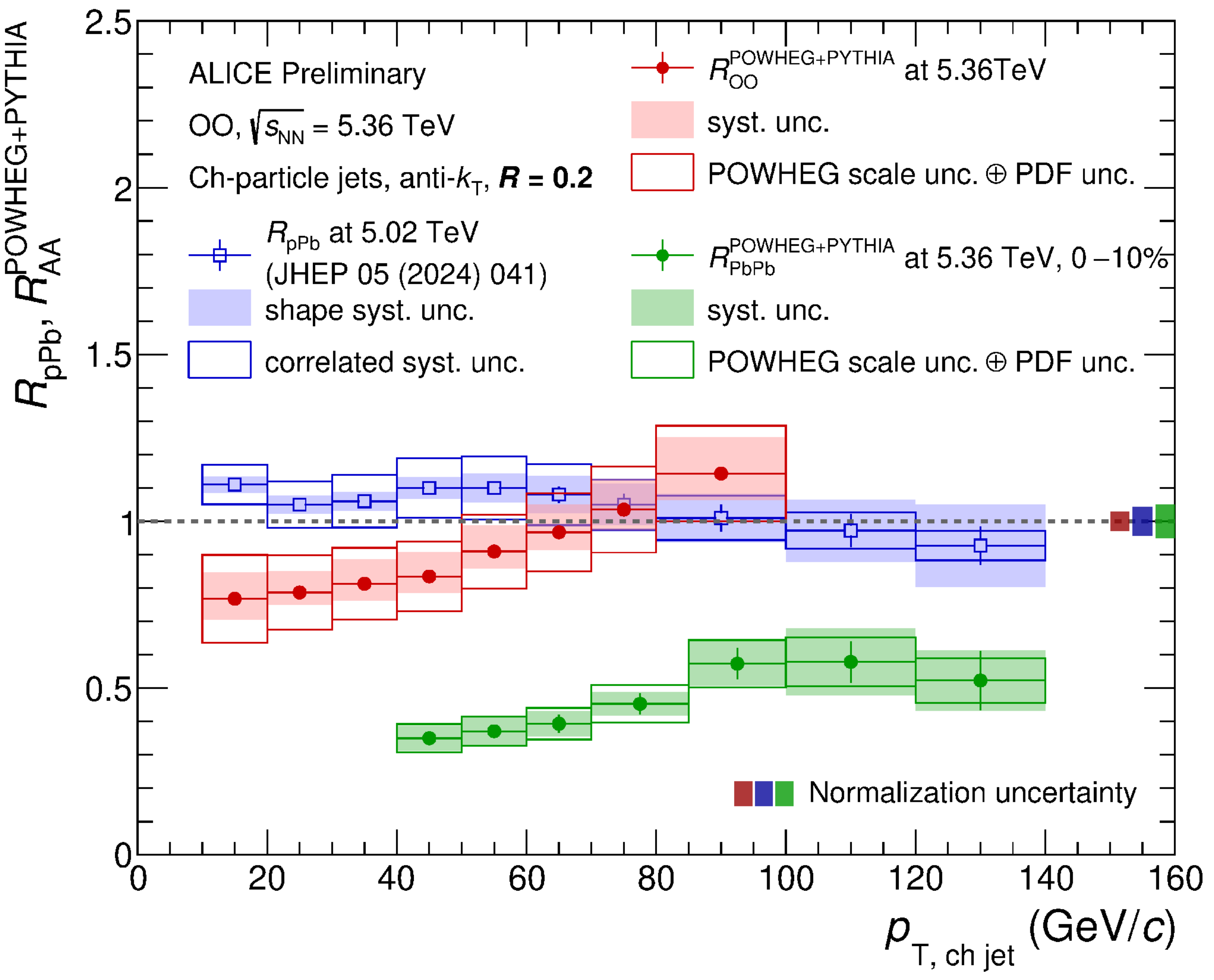
  $R_{Pb-Pb}^{POWHEG+PYTHIA}$ at $\sqrt{s_{NN}} = 5.36$ TeV

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

  R_{p-Pb} at $\sqrt{s_{NN}} = 5.02$ 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 $\sqrt{s_{\mathrm{NN}}} = 5.36$ 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!