

Probing jet quenching in OO collisions with ALICE

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QCD phase diagram

Cross over:

$$T \sim (156 \pm 1.5) \text{ MeV}$$

$$\varepsilon \sim (0.42 \pm 0.06) \text{ GeV/fm}^3$$

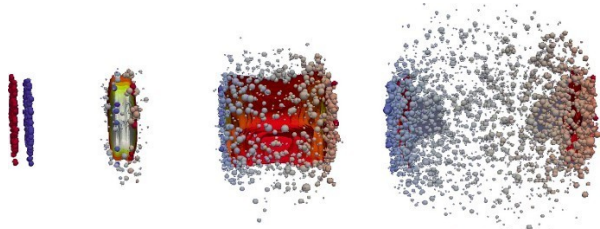
[Barazov et al. PLB 795 (2019) 15]

central Pb+Pb @ LHC:

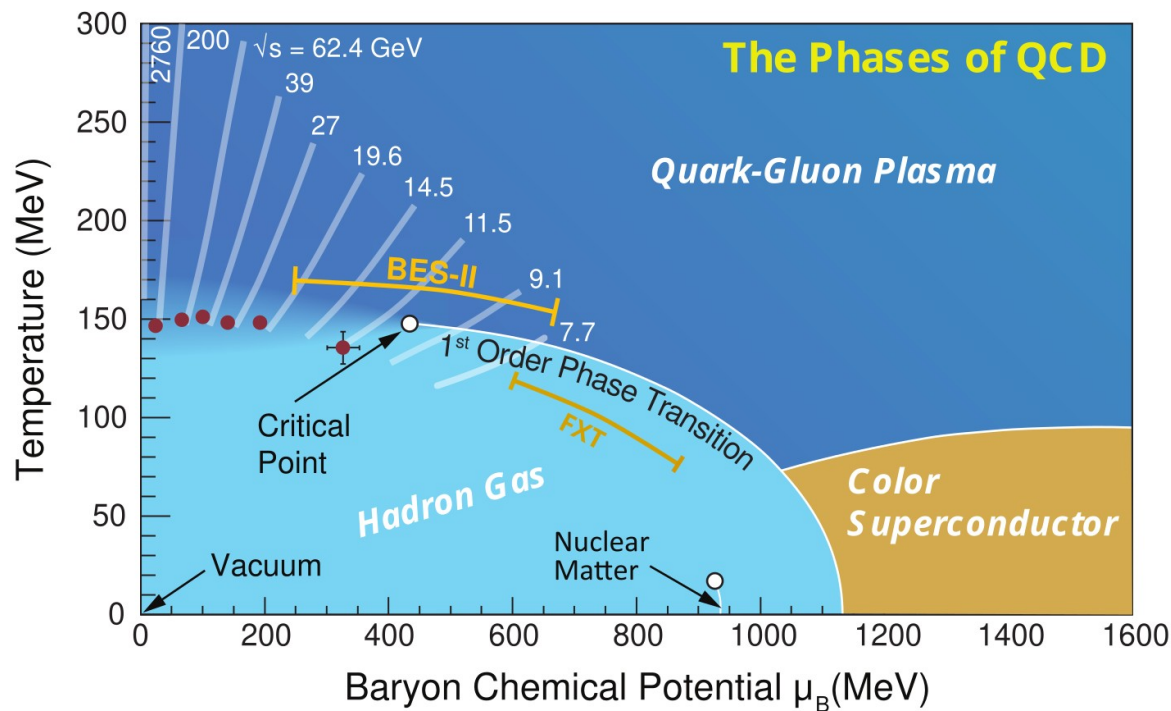
$$T_{\text{eff}} \sim 300 \text{ MeV}$$

$$\varepsilon > 10 \text{ GeV/fm}^3$$

[ALICE, EPJC 84 (2024) 813]

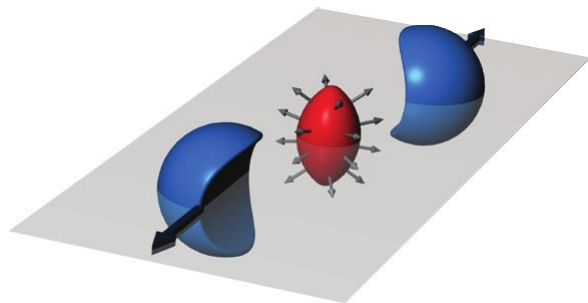


[Bernhard, J.E. arXiv:1804.06469]

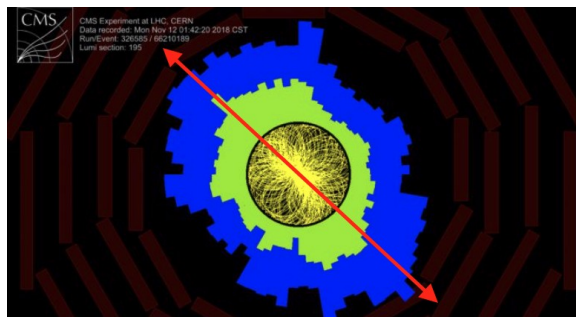


L. Du, A. Sorensen, M. Stephanov, Int.J.Mod.Phys. E33 (2024)

Elliptic flow



[Snellings, New J.Phys.13:055008,2011]

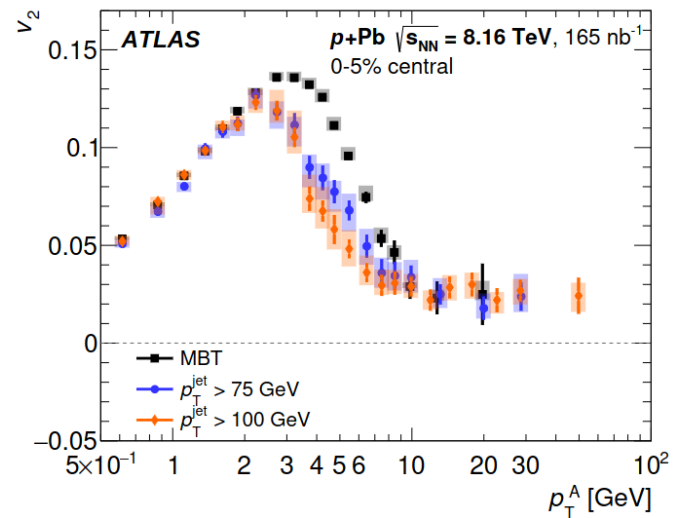


[Ollitrault, EPJ A 59 (2023) 236]

$$\frac{dN}{d\varphi} \propto 1 + \sum_n 2v_n(p_T) \cos(n\varphi - n\Psi_n)$$

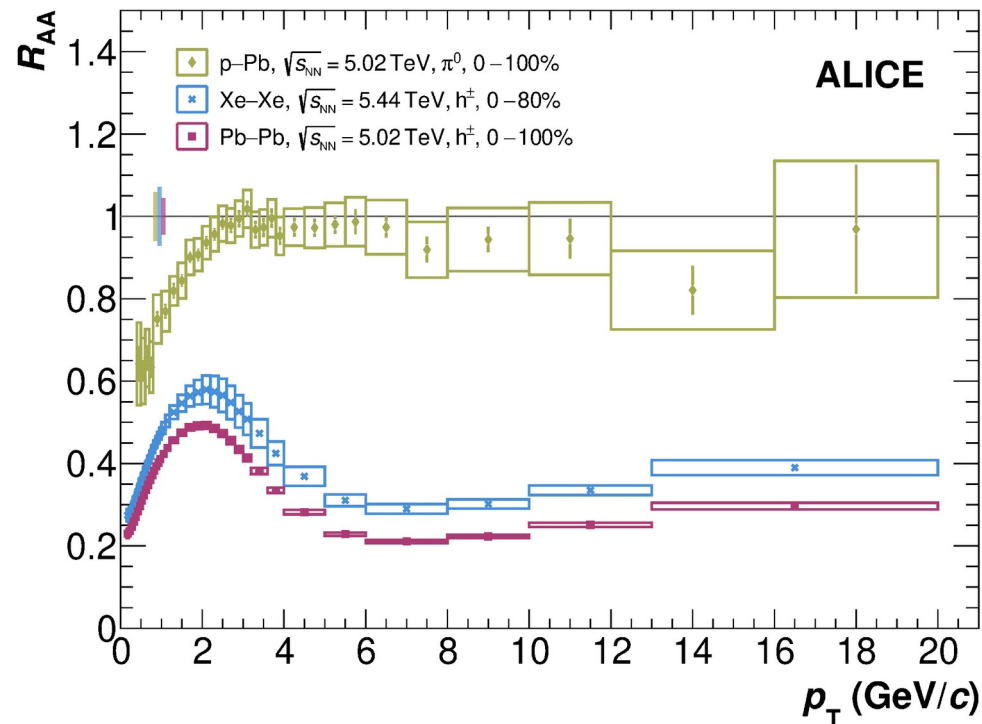
v_2 elliptic flow

- Expansion of the QGP medium creates correlation between φ angles of hadrons over wide range of their separation in η
- The feature is seen in high-multiplicity p-Pb as well as pp
- Positive v_2 observed for high- p_T hadrons resembles path length energy loss



ATLAS, EPJC 80 (2020), 73

Suppression of high- p_T hadrons



Nuclear modification factor for min. bias

$$R_{AA} = \frac{\frac{d\sigma_{AA}}{dp_T}}{A^2 \times \frac{d\sigma_{pp}}{dp_T}}$$

$\frac{d\sigma_{AA}}{dp_T}$ ← X section in A+A
 $\frac{d\sigma_{pp}}{dp_T}$ ← X section in p+p
 A^2 ← mass number

Partons lose energy in QGP → lower yield of high- p_T hadrons

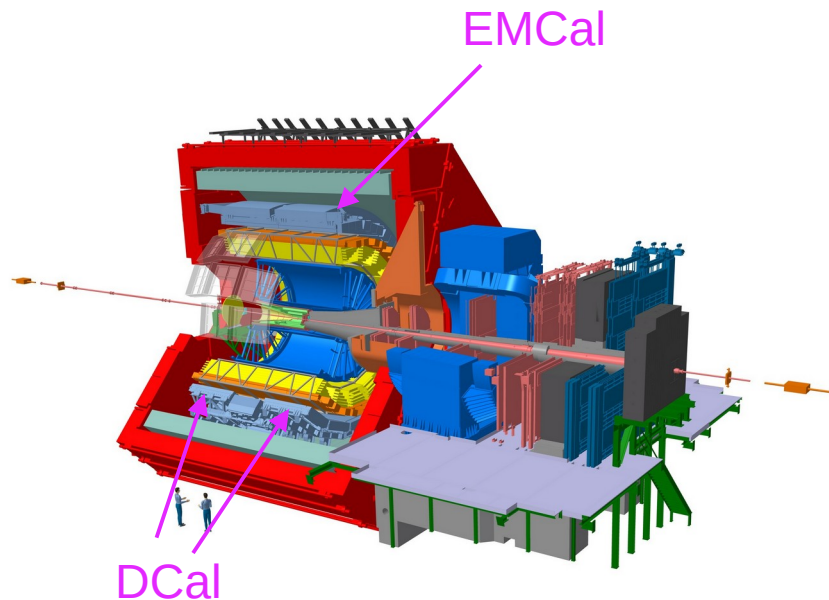
Inconclusive results about suppression in p-Pb

What is the smallest system where jet quenching is observed?

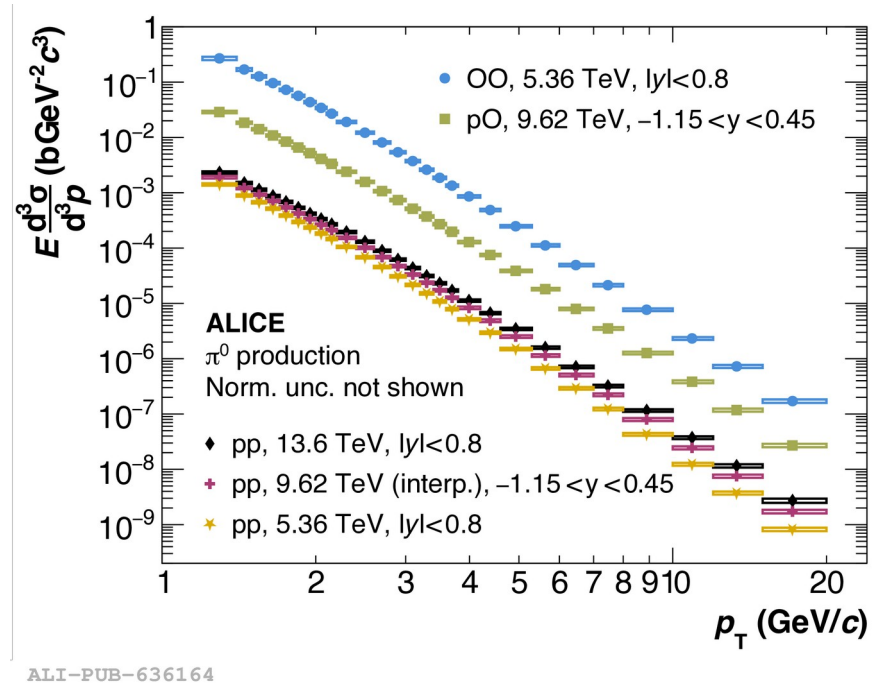
Huss et al., Phys. Rev. Lett. 126, 192301 (2021)

Inclusive π^0 measurement in OO and pO

ALICE arXiv:2606.19967



- $E_\gamma > 600$ MeV
- γ identified via shower shape



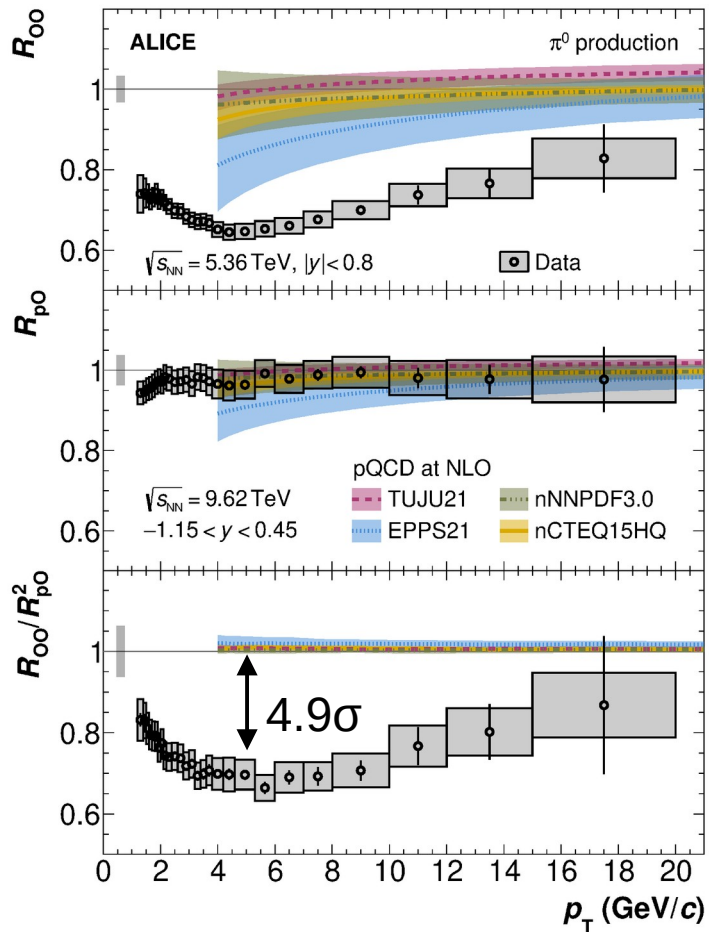
$$E \frac{d^3 \sigma \pi^0}{d^3 p} = \frac{N^{\pi^0}}{N_{\text{evt}}} (1 - S) \frac{1}{A \epsilon_{\text{rec}} 2\pi \Delta y} \frac{1}{p_T \Delta p_T} \frac{1}{B} \zeta_{\text{SL}} \times \sigma_{\text{vis}}$$

N_{evt} : number of coll.; S : secondary fraction; $A \epsilon$ acc. & effi.; B : branching ratio; ζ_{SL} : signal loss; σ_{vis} : visible cross section

interpolated pp reference @ $\sqrt{s} = 9.62$ TeV

R_{AA} of inclusive π^0 in OO and pO

ALICE arXiv:2606.19967



- pQCD calculations at NLO that incorporate CNM effects predict suppression at low p_T
 - Large uncertainties and spread ($\sim 20\%$) between predictions using different nuclear PDFs
 - Suppression of data beyond CNM predictions with significance of only 1.8σ
 - Nuclear PDF pQCD predictions describe R_{pO} data within sizable uncertainties
- ← The double ratio leads to almost perfect cancellation of CNM effects and reduces theory uncertainties
 [F. Jonas et al., EPJC 86 (2026) 681]

R_{AA} of inclusive jets in OO

Input tracks:

$|\eta_{\text{track}}| < 0.9$
 $p_{T,\text{track}} > 150 \text{ MeV}/c$

Charged particle jets in OO:

anti- k_T $R = 0.4$ with E -scheme

$|\eta_{\text{jet}}| < 0.9 - R$

Leading jet constituent $p_T > 5 \text{ GeV}/c$

$$p_{T,\text{jet}}^{\text{corr}} = p_{T,\text{jet}}^{\text{raw}} - \rho \cdot A_{\text{jet}}$$

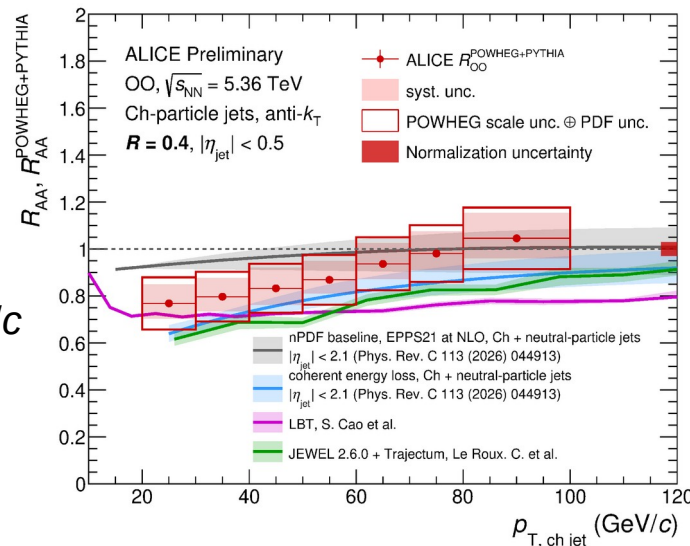
ρ underlying event density

A_{jet} jet area

Jet spectra corrected for
instrumental effects and local p fluctuations

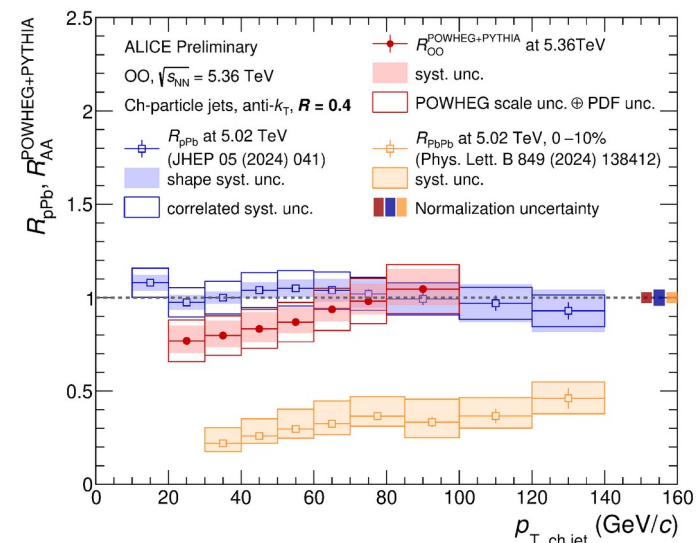
pp reference POWHEG+PYTHIA

- Experimental and pp reference uncertainties do not allow firm conclusions on quenching scenarios
- Hint of R_{AA} ordering $R_{pPb} > R_{OO} > R_{PbPb}$ at low jet p_T



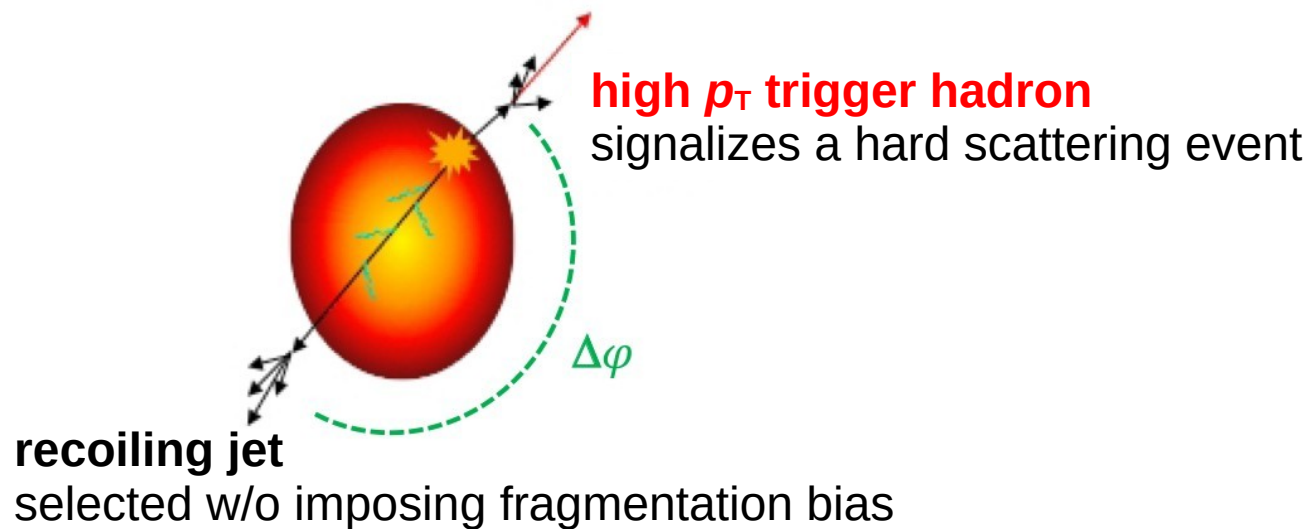
ALI-PREL-635348

[LBT arXiv:2512.12715]
[JEWEL arxiv:2509.04299]



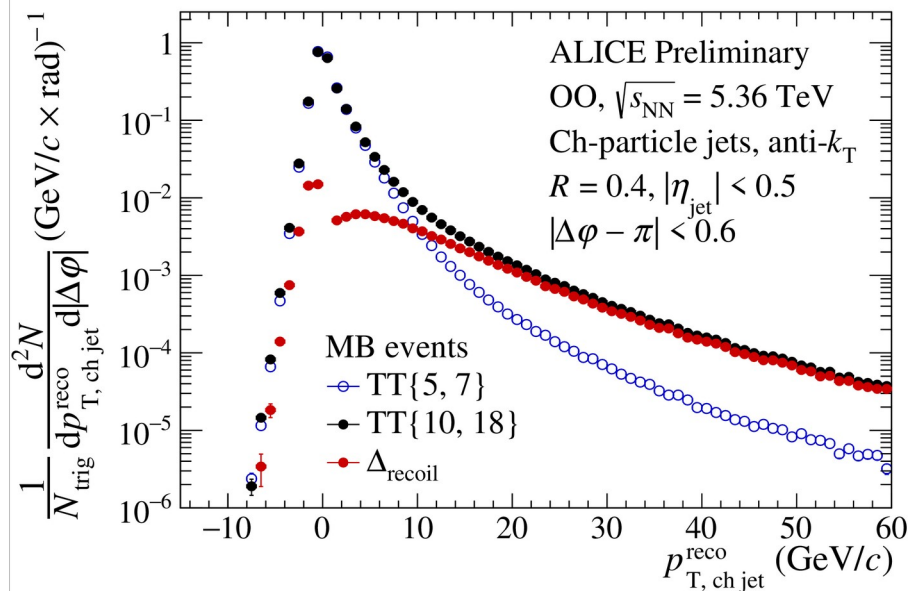
ALI-PREL-635358

Search for jet quenching in OO with semi-inclusive observables



$$\frac{1}{N_{\text{trig}}^{AA}} \frac{d^2 N_{h/\text{jet}}^{AA}}{dp_T d\Delta\varphi} \Big|_{p_{T,\text{trig}}} \xrightarrow{\text{if there is no final state interaction with QGP}} \frac{1}{N_{\text{trig}}^{pp}} \frac{d^2 N_{h/\text{jet}}^{pp}}{dp_T d\Delta\varphi} \Big|_{p_{T,\text{trig}}}$$

Raw semi-inclusive distribution of recoil jets



ALI-PREL-638287

- Trigger hadron: 10-18 GeV/c & 5-7 GeV/c
- Recoiling jets back-to-back to trigger in φ

$$p_{T, \text{ch jet}}^{\text{reco}} = p_{T, \text{ch jet}}^{\text{raw}} - \rho \cdot A_{\text{jet}}$$

ρ underlying event density

A_{jet} jet area

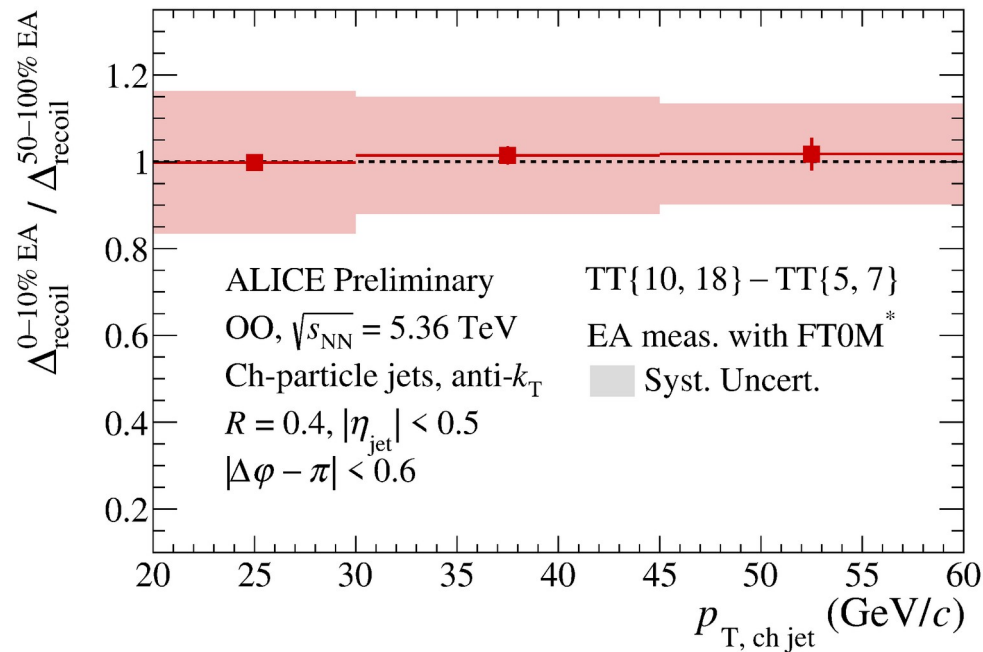
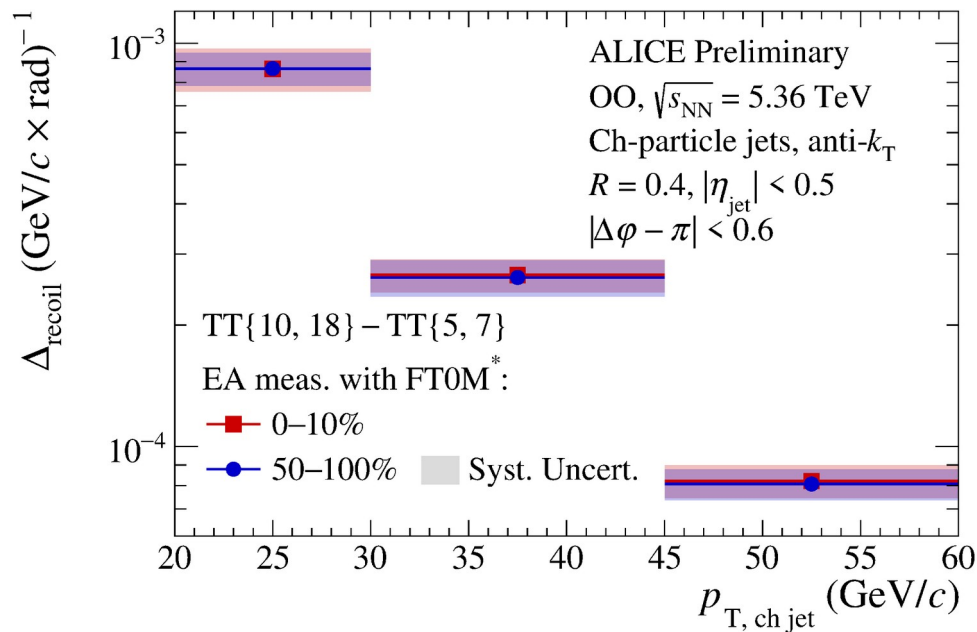
- Jets uncorrelated to TT dominate at low jet p_T
- **Removal of uncorrelated jet yield**

$$\Delta_{\text{recoil}} = \underbrace{\frac{1}{N_{\text{trig}}} \frac{d^2N}{dp_{T, \text{ch jet}}^{\text{reco}} d|\Delta\varphi|}}_{\text{TT} \in (10, 18) \text{ GeV/c}} - c_{\text{Ref}} \times \underbrace{\frac{1}{N_{\text{trig}}} \frac{d^2N}{dp_{T, \text{ch jet}}^{\text{reco}} d|\Delta\varphi|}}_{\text{TT} \in (5, 7) \text{ GeV/c}}$$

$c_{\text{ref}} \sim 1$ factor to correct for limited acceptance shared by correlated and uncorrelated jets

Fully corrected Δ_{recoil} spectra in OO collisions

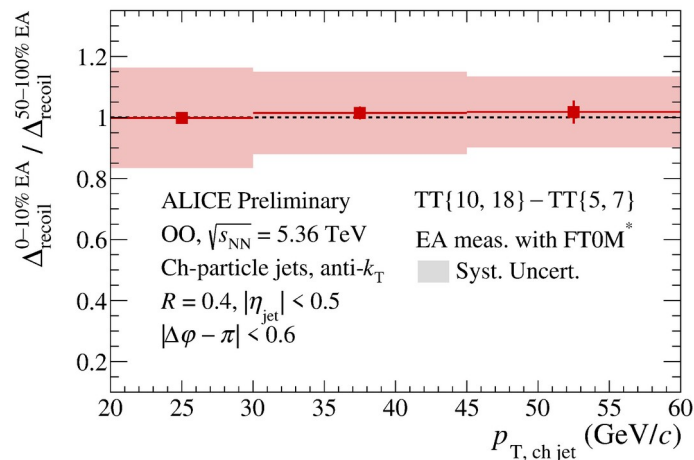
- Δ_{recoil} spectra were corrected for detector effects and residual background fluctuations
- No statistically significant difference in recoil jet yield between high EA compared to low EA
- In ratio plot, systematic uncertainty for tracking eff. was treated uncorrelated



Sensitivity of Δ_{recoil} to jet quenching

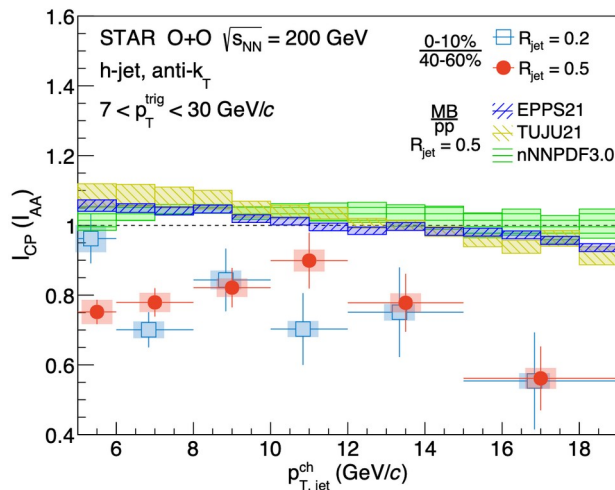
- STAR reports significant suppression of recoil jet yield in high-EA OO collisions estimated jet energy shift by STAR 0.7 GeV/c
- ALICE sees I_{CP} for Δ_{recoil} compatible with unity within uncertainties
- Flatter recoil-jet spectrum at LHC reduces yield response to jet energy loss

ALICE OO @ 5.36 TeV



ALI-PREL-639460

STAR OO @ 200 GeV



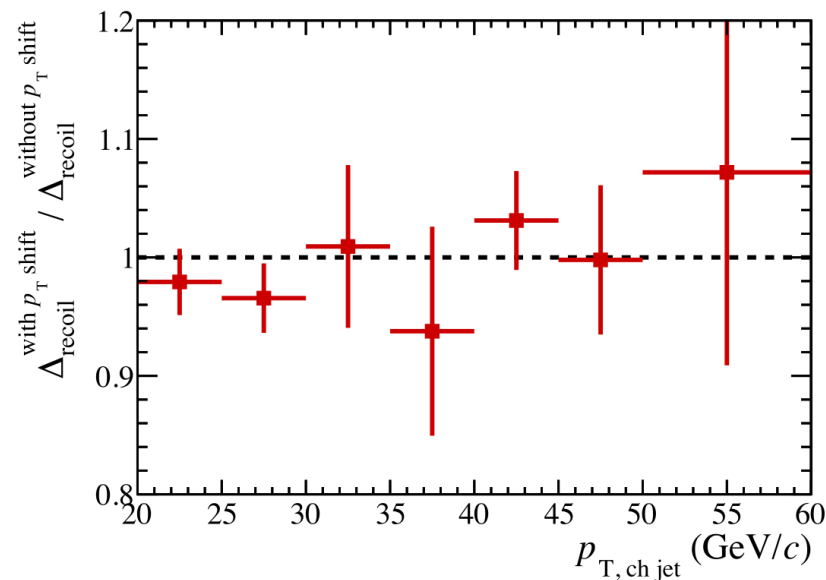
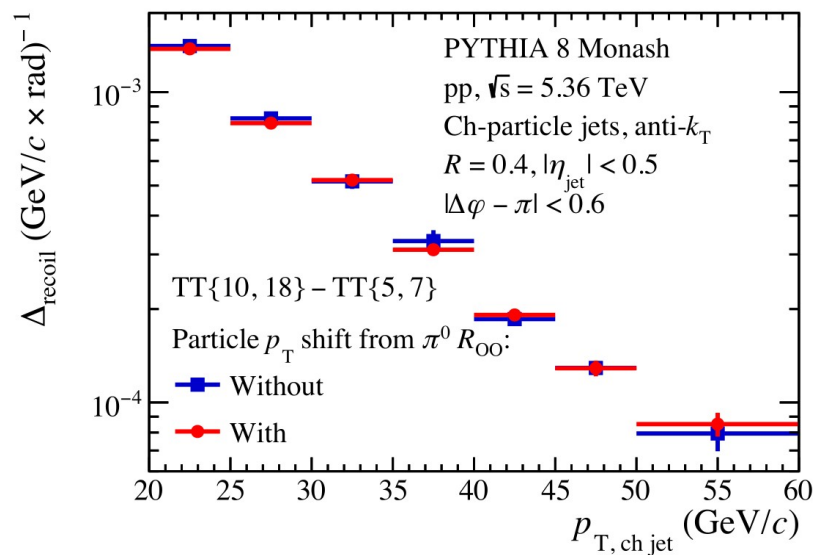
$$I_{\text{CP}} = \frac{\Delta_{\text{recoil}}^{\text{Cent.}}}{\Delta_{\text{recoil}}^{\text{Periph.}}} = \exp\left(-\frac{\bar{s}}{b}\right)$$

for exponential Δ_{recoil} with slope b
& $\bar{s}$ energy shift due to quenching

[STAR Collaboration, <https://arxiv.org/abs/2604.13935>]

Sensitivity of Δ_{recoil} to average p_T shifts inferred from π^0 R_{OO} in toy MC model

- ALICE inclusive π^0 measurement in OO $\rightarrow$ hadron p_T shifts corresponding to the observed R_{AA}
- Apply the p_T shift to charged particles in PYTHIA before charged-jet reconstruction
- Ratio of Δ_{recoil} obtained with and without the shift remains compatible with unity



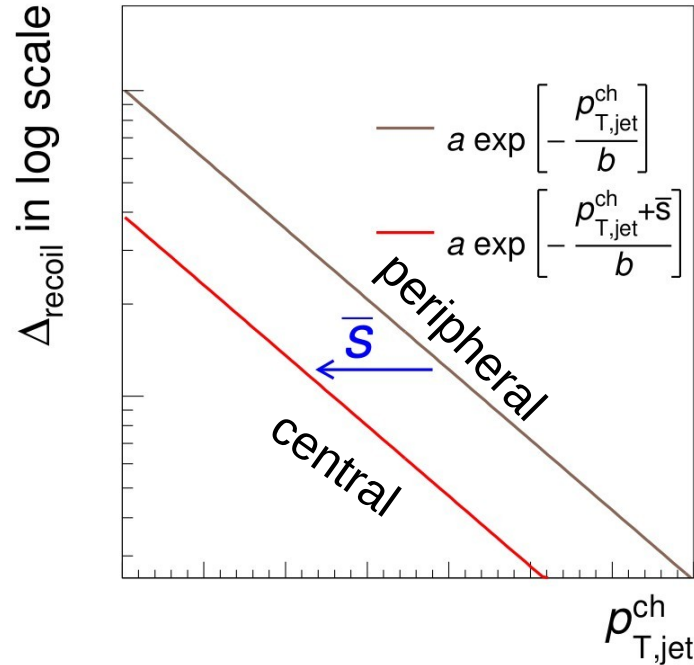
- Absence of visible suppression does not imply absence of energy loss
- Observable sensitivity is reduced for flatter spectra

Summary

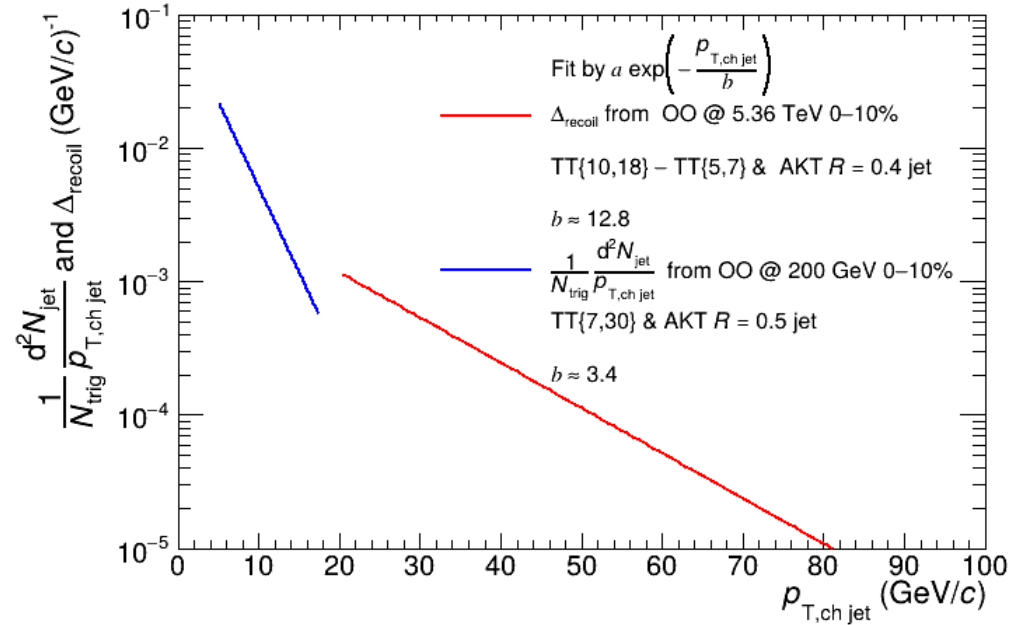
- OO evidence of jet quenching - suppressed production of inclusive high- p_T hadrons and jets
- Jet yield correlated with high- p_T hadron in high event activity events does not exhibit suppression wrt low event activity events
- PYTHIA study suggests that Δ_{recoil} is less sensitive at LHC energies to p_T shift inferred from neutral pion R_{AA}

Backup

Recoil jet spectrum slopes in OO



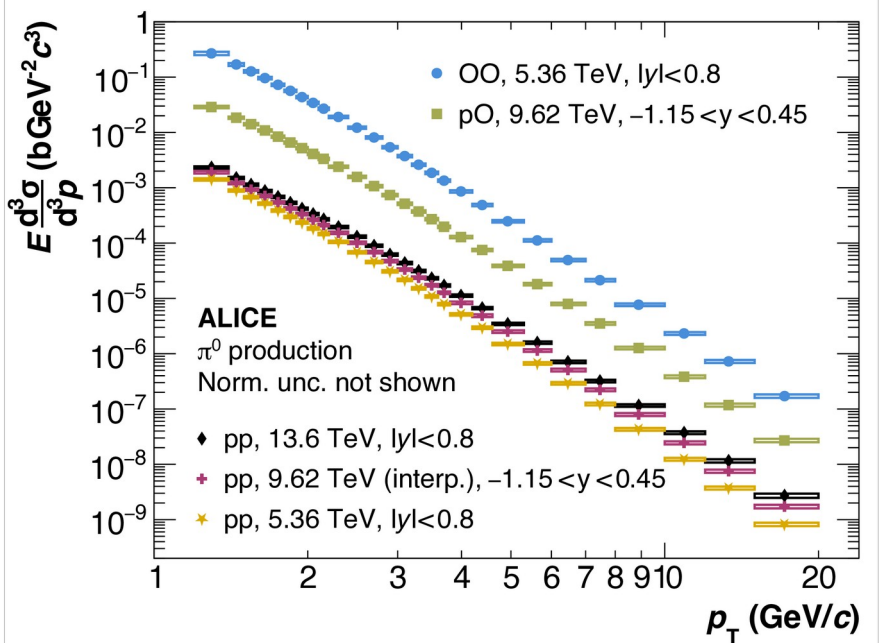
$$\frac{\Delta_{\text{recoil}}|_{\text{central}}}{\Delta_{\text{recoil}}|_{\text{peripheral}}} = \exp\left(-\frac{\bar{s}}{b}\right)$$



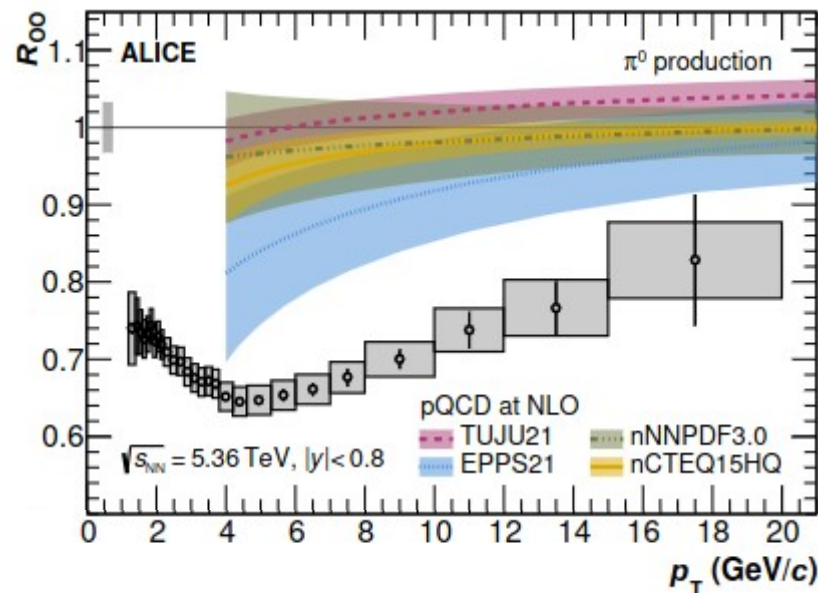
Red curve is fit of ALICE preliminary Δ_{recoil} spectrum from OO
 Blue curve is fit of data from [STAR, <https://arxiv.org/abs/2604.13935>]

Estimate of hadron energy shift in OO

Figures from ALICE arXiv:2606.19967



ALI-PUB-636164



b = slope of inclusive spectrum
 $\bar{s} = p_T$ shift

$$R_{OO} = \exp\left(-\frac{\bar{s}}{b}\right) \longrightarrow \bar{s} = -b \cdot \ln R_{OO}$$