Jet modifications in small systems

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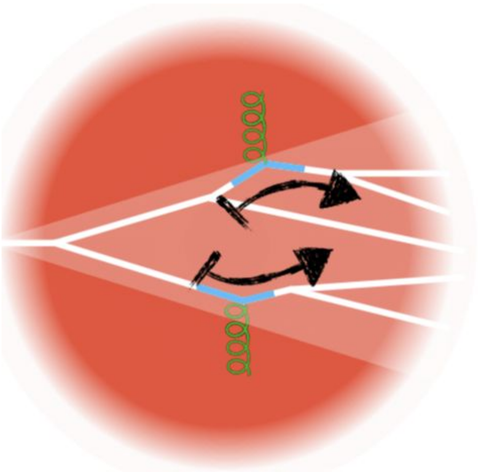
Workshop on Light Ions at the LHC
November 11th-15th 2024

Laboratory for Nuclear Science

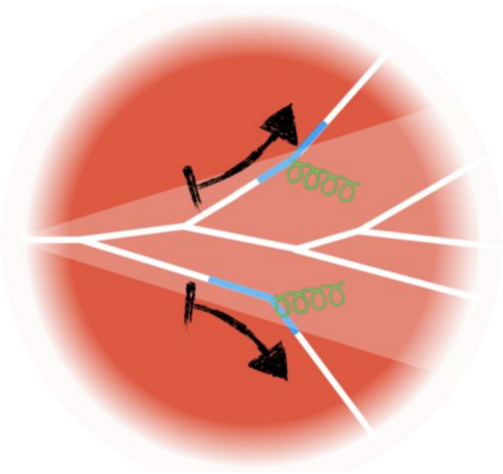
MIT HIG group's work was supported by US DOE-NP

Jet modifications in QGP produced in AA collisions

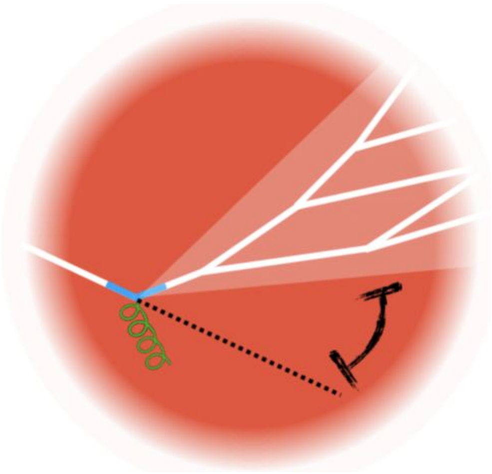
Medium induced radiation



Energy redistribution (“loss”)



Point-like scatterers
in the QGP (Quasi-particles)

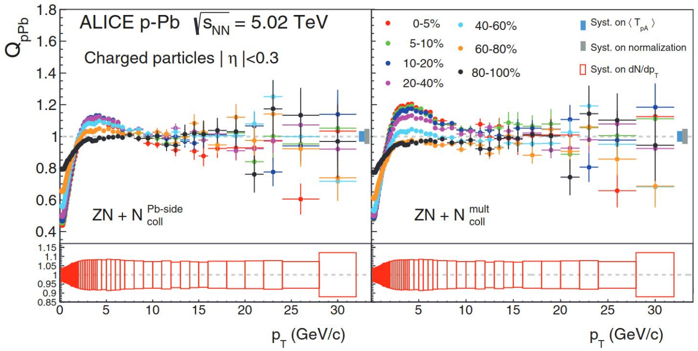


sketch from Rey Cruz

What about in proton-ion collisions?

Searches for jet quenching in pPb

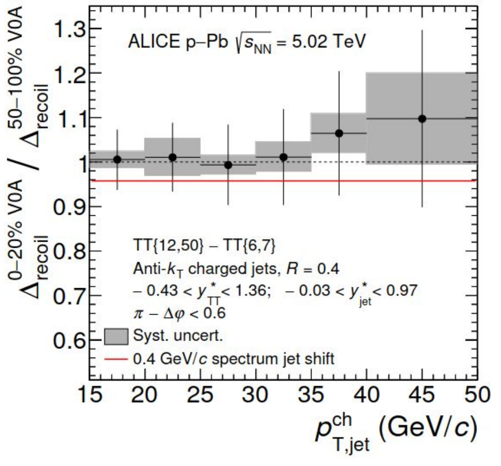
Single charged-particle yields



No strong suppression, Uncertainty on event selection bias through <N_{coll}>

ALICE, PRC (91) 064905

Hadron-jet correlation as function of event activity

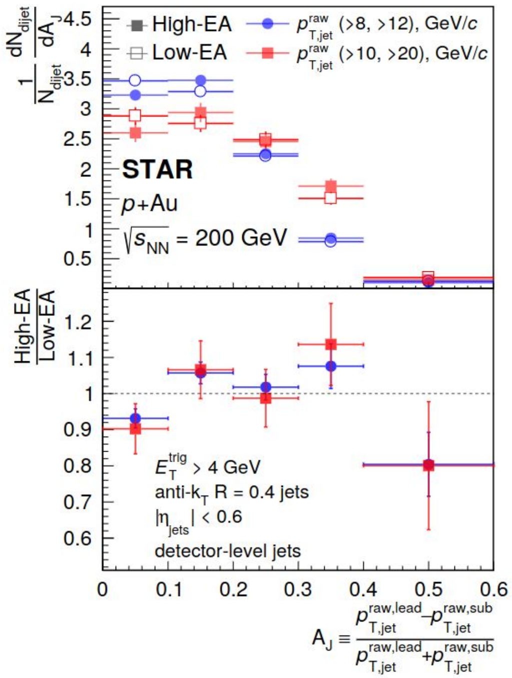


90% CL upperbound on medium-induced out-of-cone energy transfer of less than 0.4 GeV for 15 < $p_{ch,T}$ < 50 GeV

ALICE, PLB 783 (2018) 95

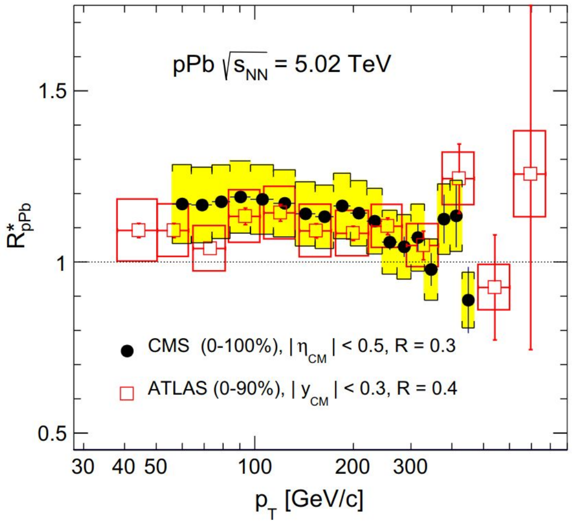
Nuclear modification & jet asymmetry in pA

STAR, PRC (2024) 110, 044908

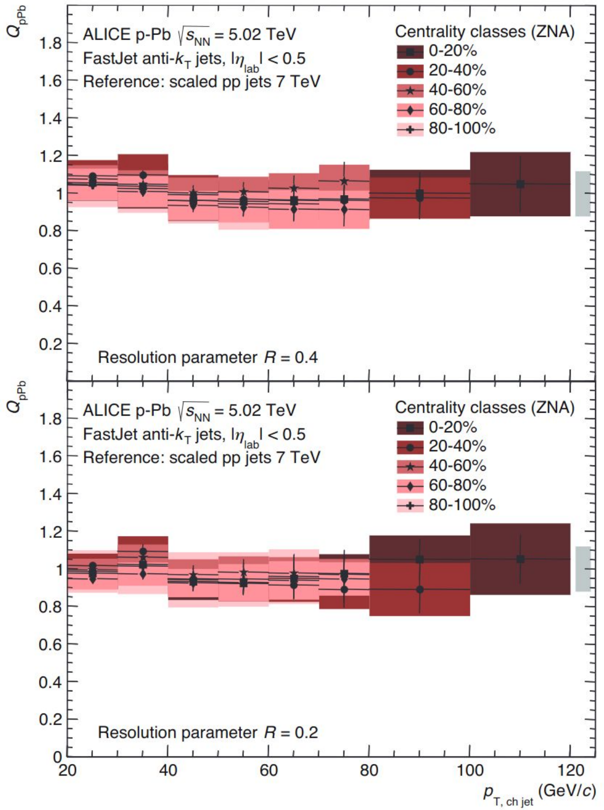


CMS, EPJC 76 (2016) 372

ATLAS, PLB 748 (2015) 392



ALICE, EPJ C76 (2016) 271



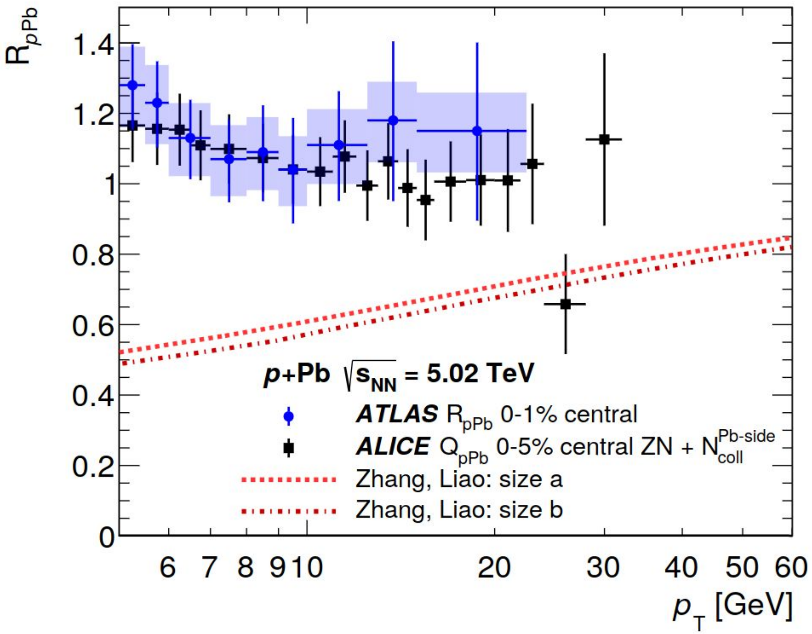
No clear signs of evidence for jet quenching via R_{pPb} (Q_{pPb}) or A_J asymmetry

Modifications compatible with dominance of cold nuclear matter effects

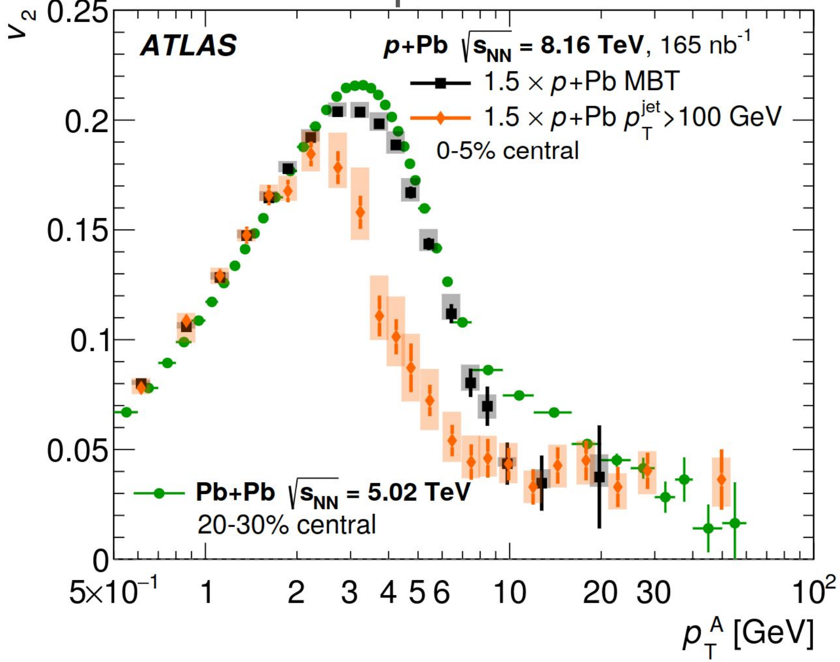
Puzzles of high-p_T in pPb

ATLAS, Eur. Phys. J. C 80 (2020) 73

high-p_T R_{pPb} ~ 1



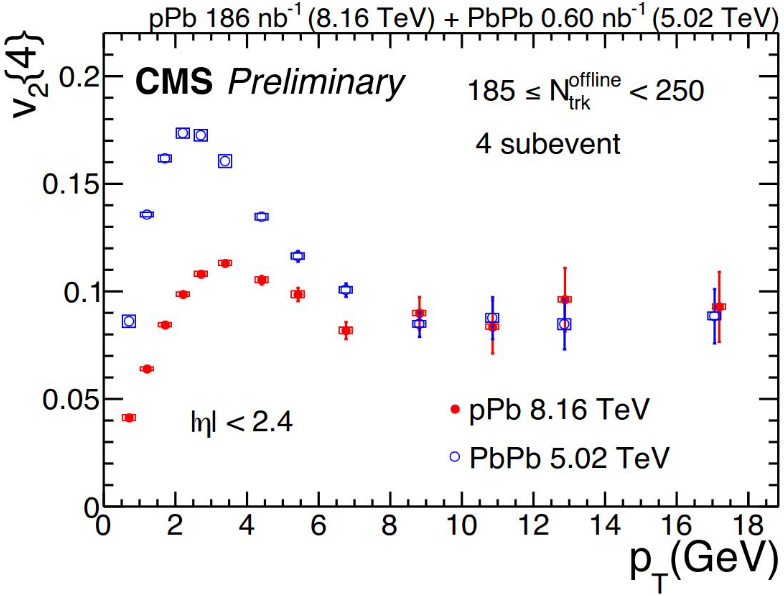
Large nonzero v_2 at high-p_T, similar shape as to PbPb

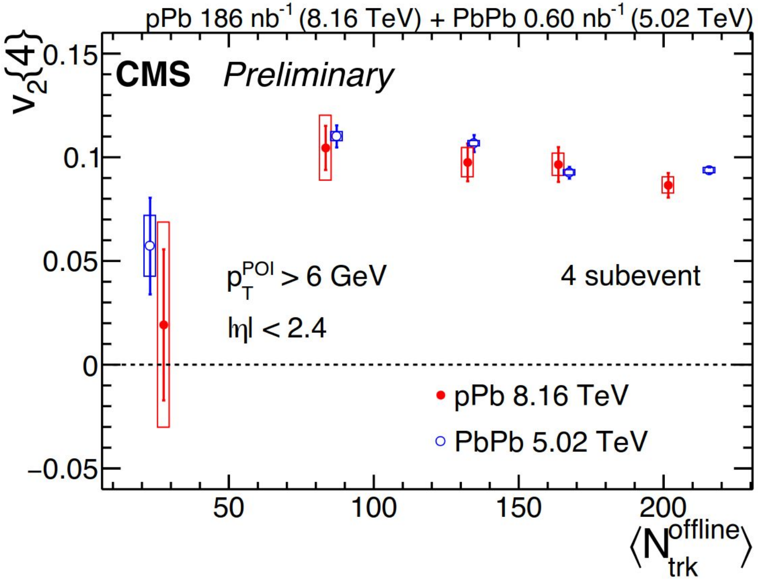


Challenging to describe v_2 and R_{pPb} via energy loss simultaneously (Zhang, Liao, arXiv:1311.5463)

Nonzero v_2 at high-p_T

CMS-PAS-HIN-23-002





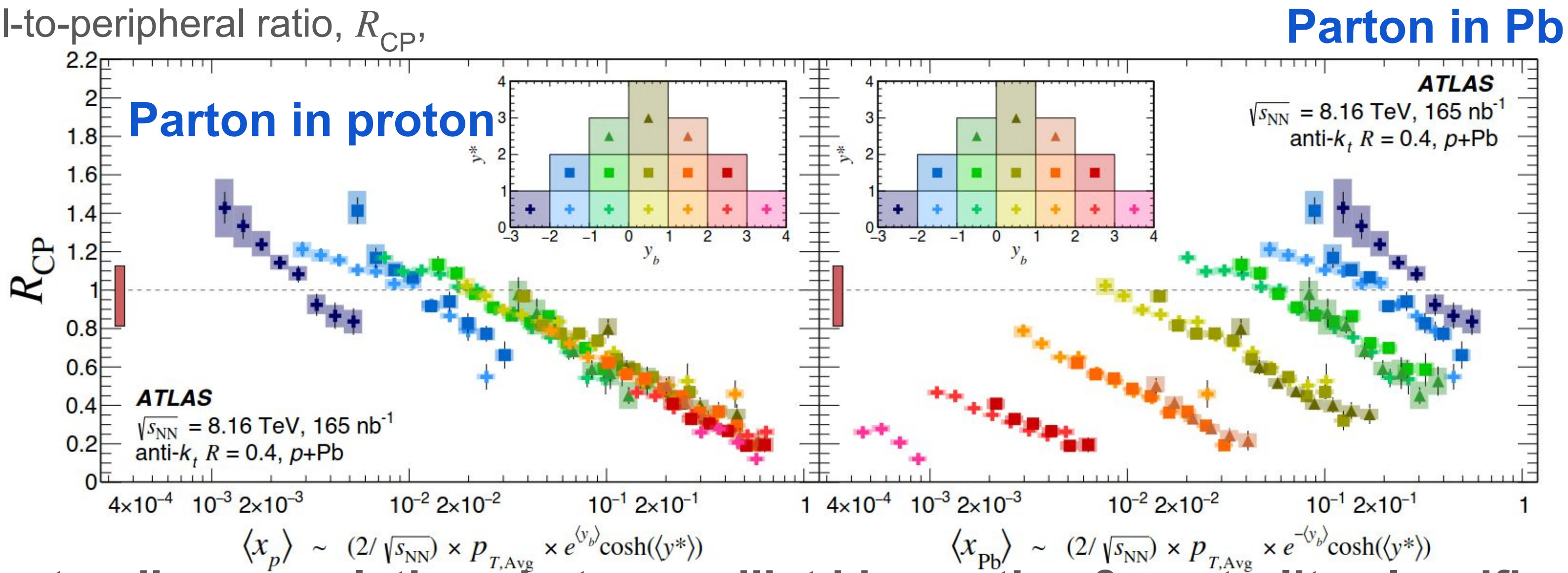
Nonzero v_2 at high-p_T in pPb (nonflow subtracted via subevent cumulant analysis)

Similarity between pPb and PbPb at high-p_T and large N_{trk}

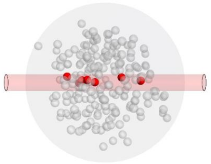
Centrality dependence of the dijet yield in p-Pb

ATLAS, Phys. Rev. Lett. 132 (2024) 102301

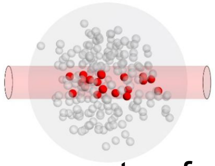
Central-to-peripheral ratio, R_{CP},



Understanding correlations between dijet kinematics & centrality classification



high-x parton from proton
⇒ peripheral



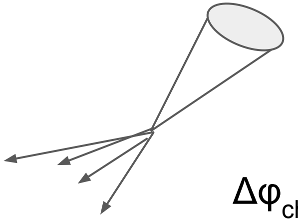
low-x parton from proton
⇒ more central

Qualitatively in agreement with the x_p-dependent color fluctuation effects
Phys. Rev. D 98 (2018) 071502

Constraints on jet quenching in centrality-dependent pPb

ATLAS, Phys. Rev. Lett. 131 (2023) 072301

I_{pPb} = ratio of per-jet yields of pPb/pp

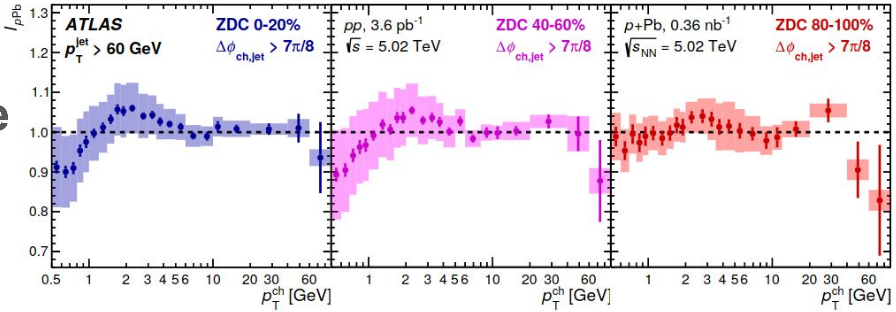


Jet ``tag”

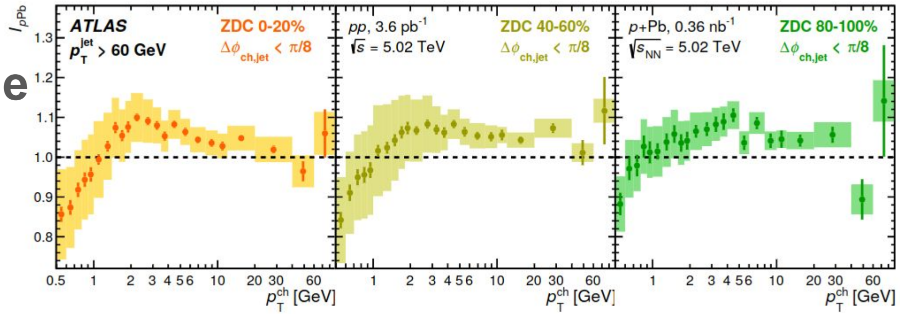
$\Delta\varphi_{ch,jet} = |\varphi_{ch}-\varphi_{jet}|$

Charged particles

Away-side



Near-side



Corrected for UE using MB events with similar forward calo energies.

- Centrality ZDC (spectator neutrons)
- **Enhancement at near-side**
- “Cronin-like” enhancement at moderate p_T

Constraints on jet quenching in centrality-dependent p-Pb

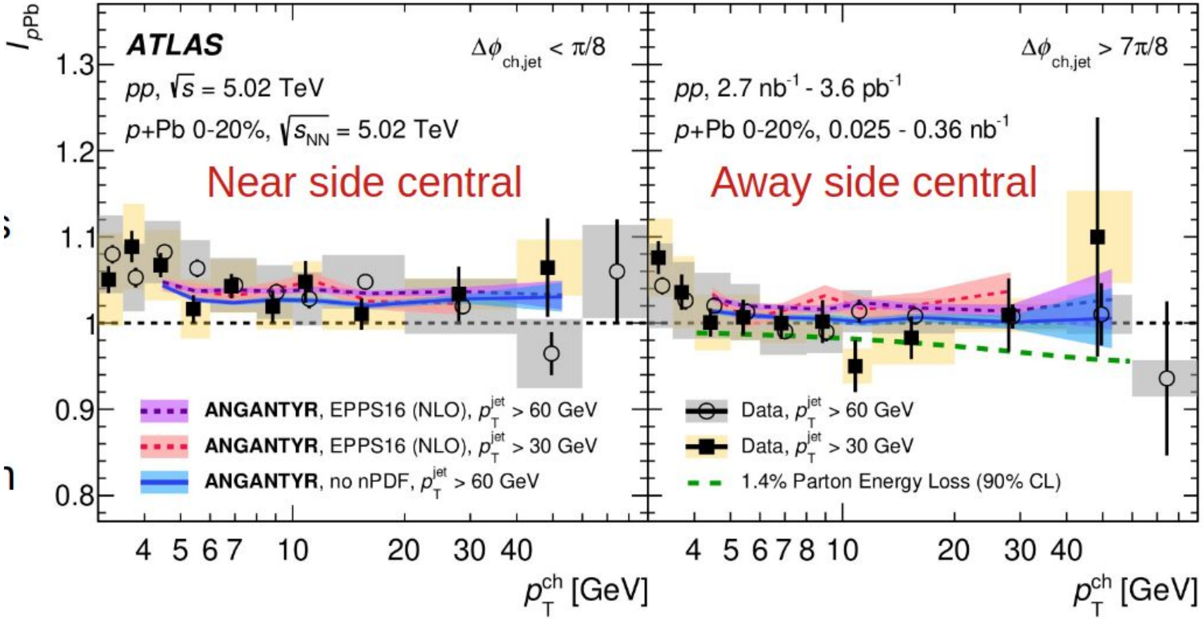
ATLAS, Phys. Rev. Lett. 131 (2023) 072301

Angantyr:
extension of PYTHIA for pA, AA
(no jet quenching)

Consistent with data:

Hints of flat ~3% enhancement on near side

Unity value on away side

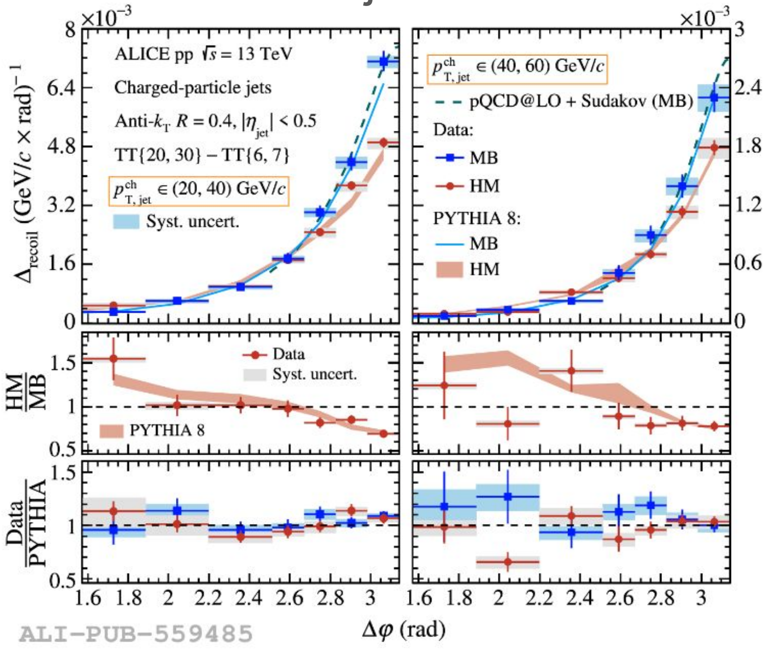


No large effect from nPDF;
unclear source of enhancement in the model

Search for jet quenching in high-multiplicity pp

ALICE, JHEP 05 (2024) 229

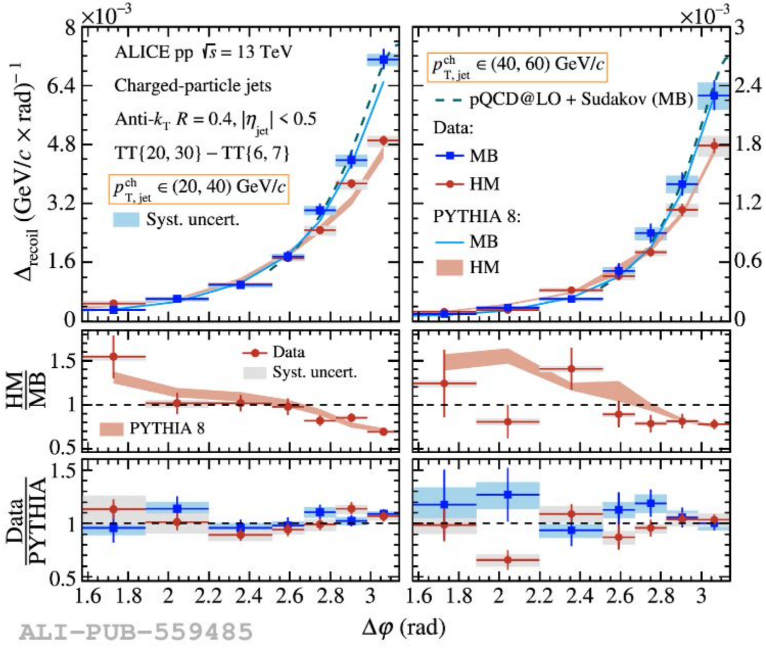
Hadron-jet correlations



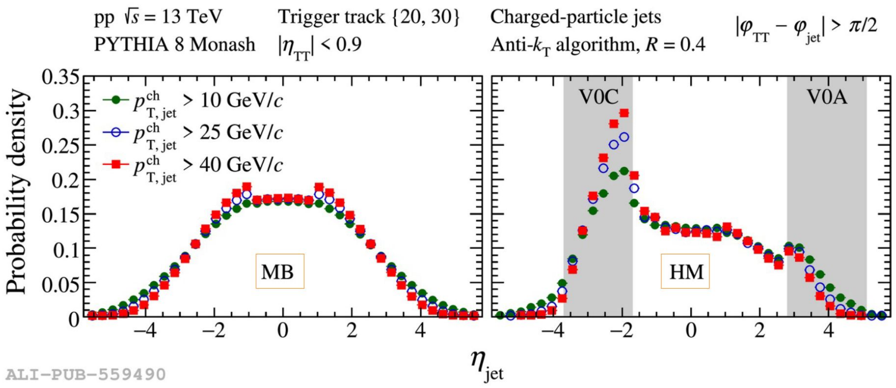
Suppression of back-to-back correlations in high-multiplicity w.r.t. min . bias

Search for jet quenching in high-multiplicity pp

ALICE, JHEP 05 (2024) 229



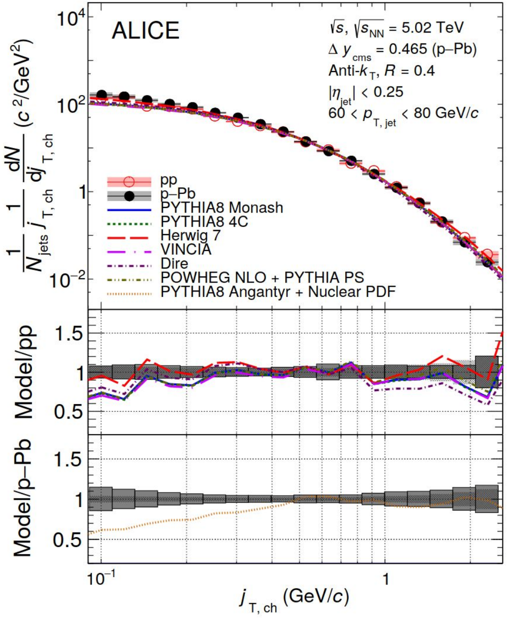
Suppression of back-to-back correlations in high-multiplicity w.r.t. min . bias



NB: high-multiplicity selection **preferentially selects jets with higher p_T in forward region** (selection biases are at play)

Jet fragmentation functions in proton-ion

ALICE, JHEP 09 (2021) 211



$$D(z) \equiv \frac{1}{N_{\text{jet}}} \frac{dN_{\text{ch}}}{dz}$$

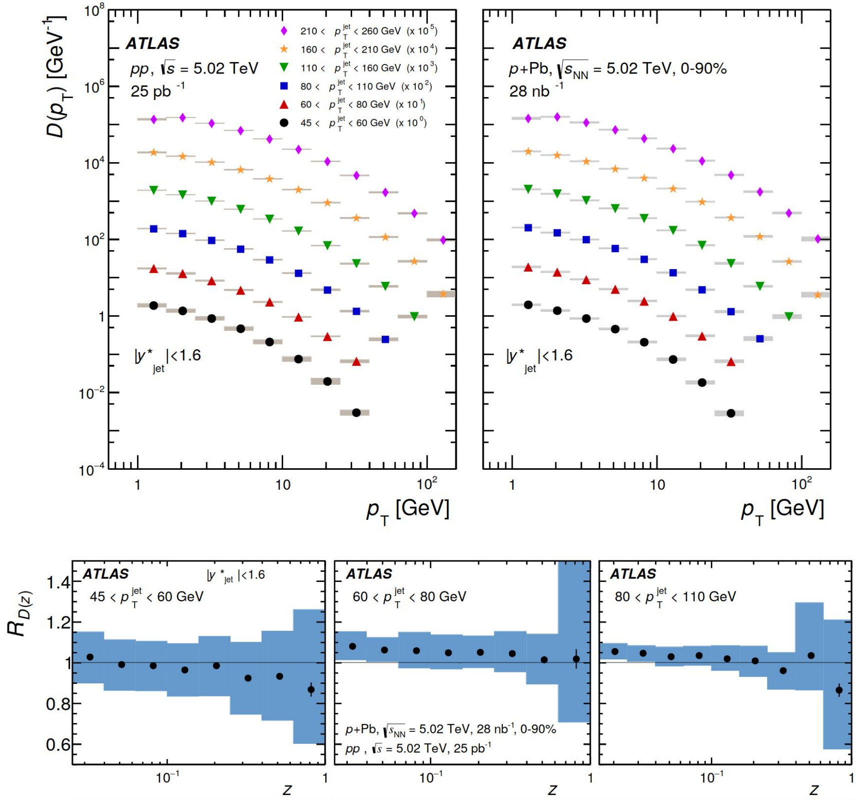
Parallel to jet

$$z \equiv p_T \cos \Delta R \, / \, p_T^{\text{jet}}$$

Transverse to the jet

$$j_T = \frac{|\vec{p}_{\text{jet}} \times \vec{p}_{\text{track}}|}{|\vec{p}_{\text{jet}}|}$$

ATLAS, Nucl. Phys. A 978 (2018) 65

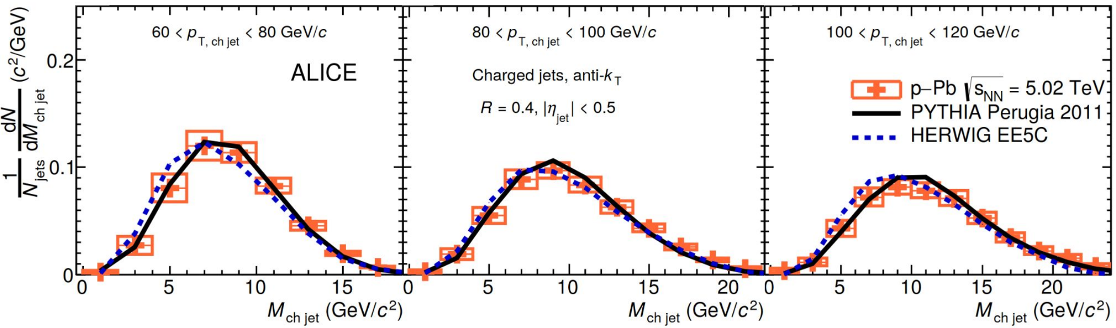


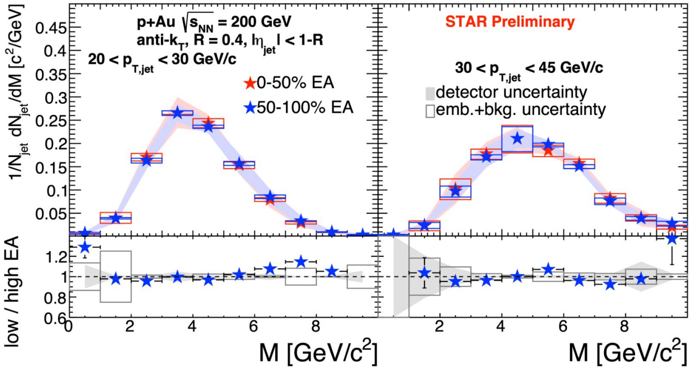
No strong modification of jet fragmentation functions in p+Pb collisions

Jet substructure in pPb

ALICE, PLB 776(2018) 249

STAR, arXiv:2009.04962

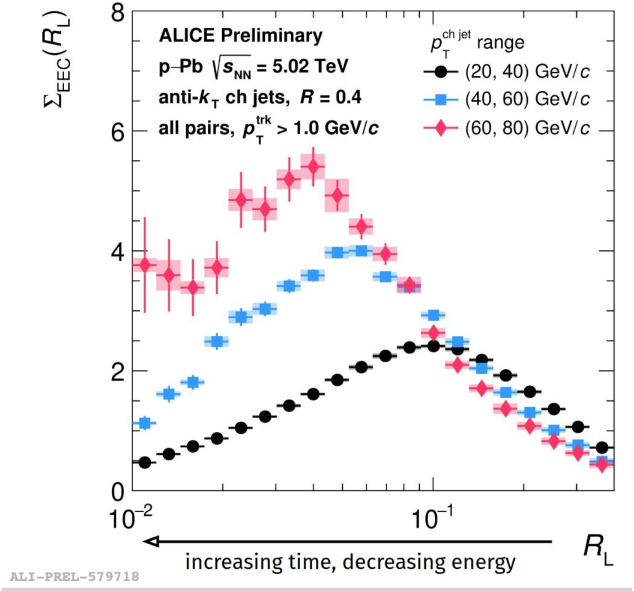


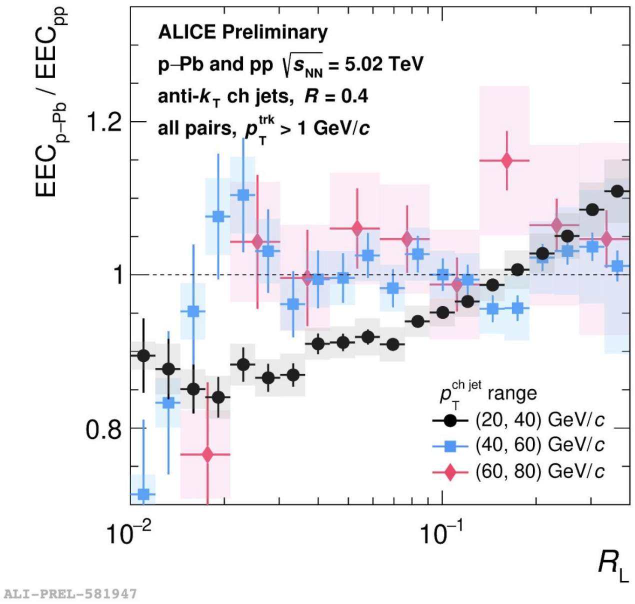


Jet mass distribution compatible with vacuum shower predictions

Energy-energy correlators in pPb

$$\frac{d\sigma_{EEC}}{dR_L} = \sum_{i,j} \int d\sigma(R'_L) \boxed{\frac{p_{T,i}\, p_{T,j}}{p^2_{T,jet}}} \delta(R'_L - R_{L,ij})$$





Larger differences in the lowest jet p_T bin

To be understood to what extent this is due to initial-state or final-state effects

A. Nambrath @ HardProbes2024

Summary

- Jet quenching in small collision systems not seen yet;
  but interesting trends in data to be understood

- Modifications can be mimicked by effects (antishadowing effects, selection biases)
  →need to think how to disentangle these carefully

- Opportunity to continue pushing boundaries of small systems and onset of
  jet modification effects in near future (**pO/OO in 2025 and pPb (?) in Run-4 at LHC**)