Energy-energy correlator measurements in p-Pb collisions at 5.02 TeV with ALICE

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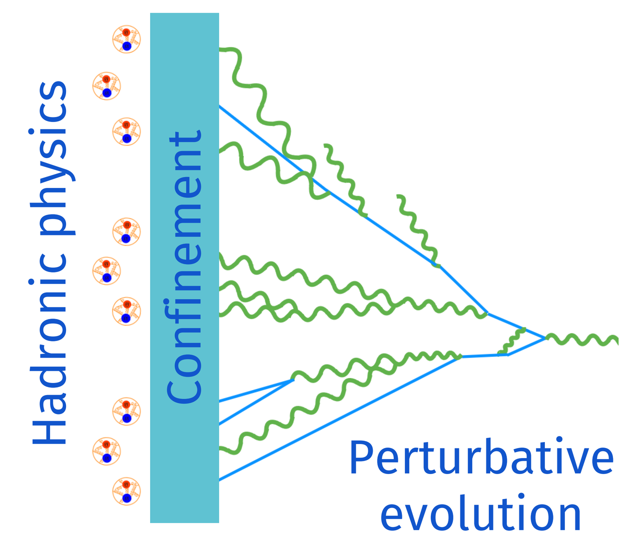
Introduction

Jet formation encodes rich QCD dynamics:

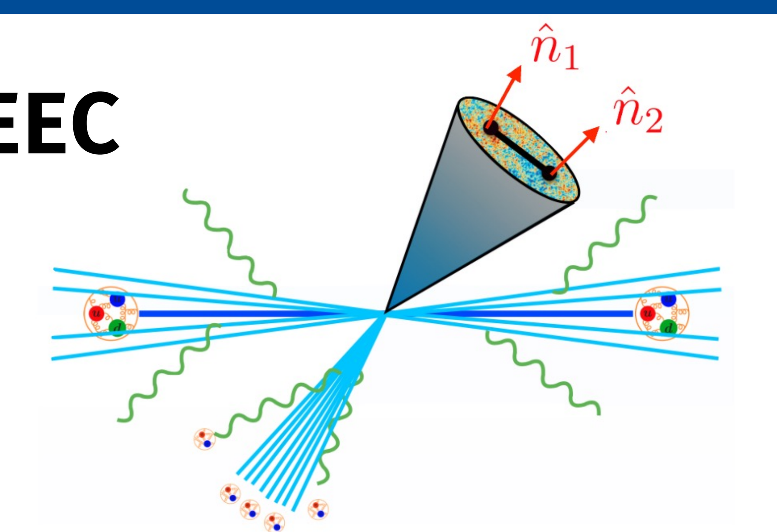
- high-energy, short time scale perturbative physics (quarks and gluons from initial hard process)
- low-energy, long time scale non-perturbative physics (collimated final state hadrons)



Energy-energy correlators are a jet substructure observable that measure statistical correlations of energy flux in jets. They are IRC-safe and well-defined in QFT, and pQCD calculations already exist.

$$\frac{d\sigma_{EEC}}{dR_L} = \sum_{i,j} \int d\sigma(R'_L) \frac{p_{T,i}\, p_{T,j}}{p^2_{T,jet}} \delta(R'_L - R_{L,ij}) \quad \text{where } R_L = \sqrt{\Delta\phi^2_{ij} + \Delta\eta^2_{ij}}$$

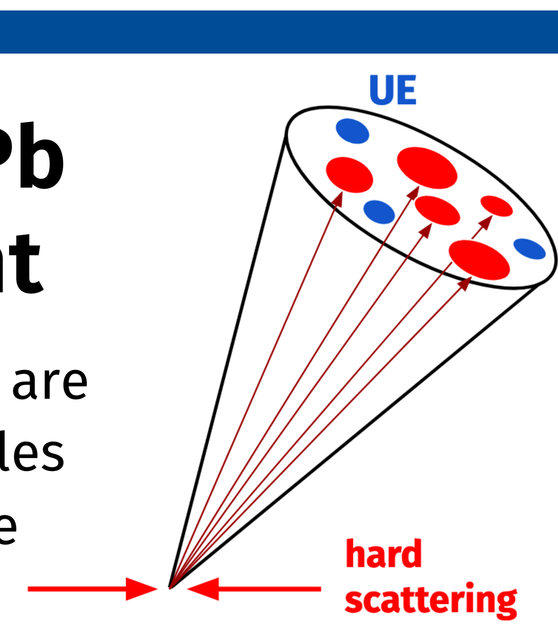
Calculating the EEC



- Cluster anti-k_T jets.
- Calculate the energy weight for each pair of tracks inside the jet.
- Count the number of weighted track pairs as a function of angular separation R_L.

EECs scan jet dynamics from perturbative (large R_L) to non-perturbative (small R_L) scales, separated by a transition region. EECs let us probe jet formation and confinement.

Treating the p-Pb underlying event



Reconstructed jets in p-Pb are contaminated by UE particles from processes besides the hard scattering: e.g. beam remnants and other semi-hard scatterings (MPI).

To correct jet p_T, the event is clustered with the k_T algorithm. The UE energy density per event can be estimated as:

$$\rho = \text{median}\left\{\frac{p^{k_T}_{T,jet}}{A^{k_T}_{jet}}\right\} \cdot C \qquad C = \frac{\sum_j A_j}{A_{acc}}$$

A perpendicular cone method is used to estimate the UE contribution to the EEC. Rotating the perp cone on top of the jet, pairs are tagged:

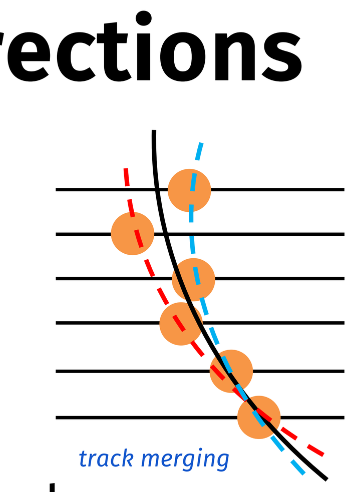
- jet-jet (sig-sig, sig-UE, UE-UE)
- jet-perp (sig-UE, UE-UE)
- perp-perp (UE-UE)

The background in the jet-jet EEC is estimated to be: jet-perp — perp-perp. Subtracting this from the overall jet-jet EEC leaves only the signal distribution of pairs from a hard scattering.

[2] arXiv:1207.2392 [hep-ex]

Detector effect corrections

EECs have to be corrected for single track resolution and efficiency, and pair efficiency.



Bin-by-bin correction method:

- ratio of simulated detector-level and truth-level EEC distributions
- ALICE's high angular resolution means there is very little R_L migration

$$f_{corr}(dR^{det}_L, p^{det}_{T,jet}) = \frac{dN^{det}_{pair} \,/\, dR^{det}_L(p^{det}_{T,jet})}{dN^{truth}_{pair} \,/\, dR^{truth}_L(p^{truth}_{T,jet})}$$

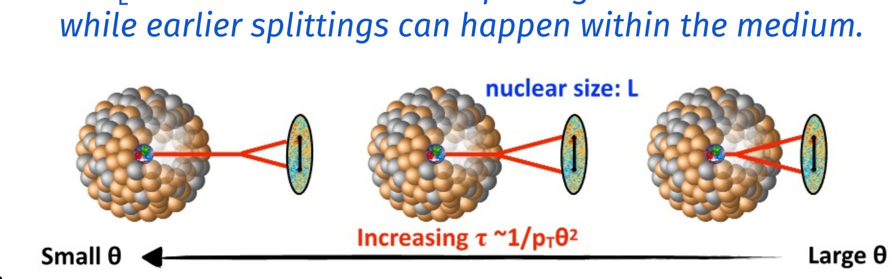
$$dN/dR_L(p^{truth}_{T,jet}) = \frac{1}{f_{corr}} \cdot dN/dR_L(p^{det}_{T,jet})$$

For more on EECs, see posters by Preeti Dhankher and Beatrice Liang-Gilman!

Looking at EECS in p-Pb data

- *Do interactions with cold nuclear matter modify EECs?*
- Differences from pp could be from changes in the initial state (nPDF, isospin) or from showering through a medium.

Small R_L is correlated with late splittings outside the medium, while earlier splittings can happen within the medium.

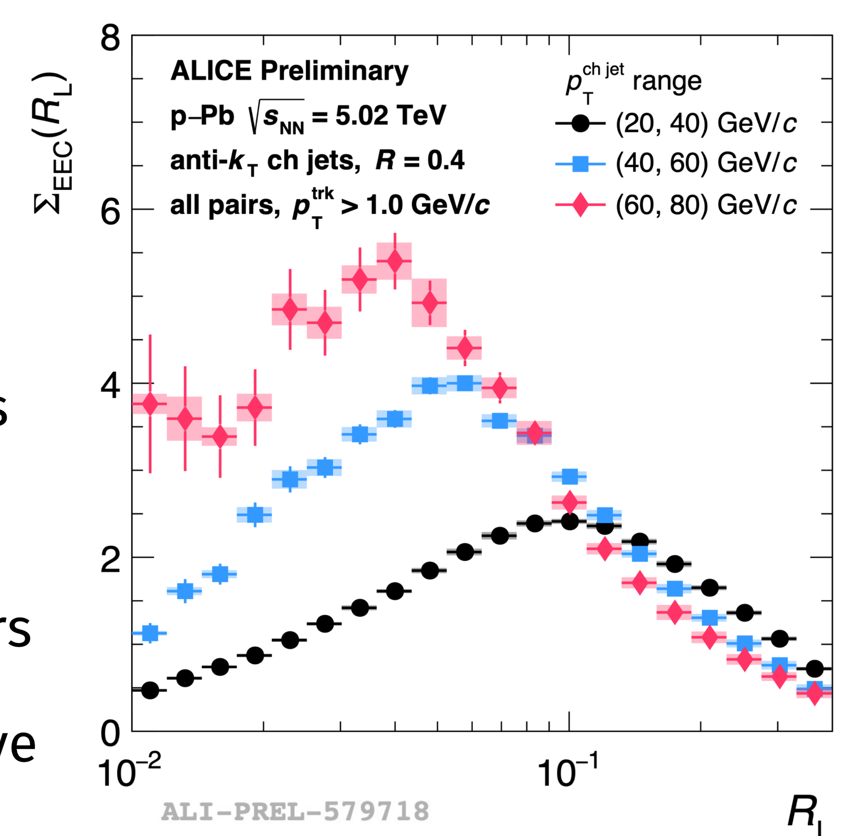


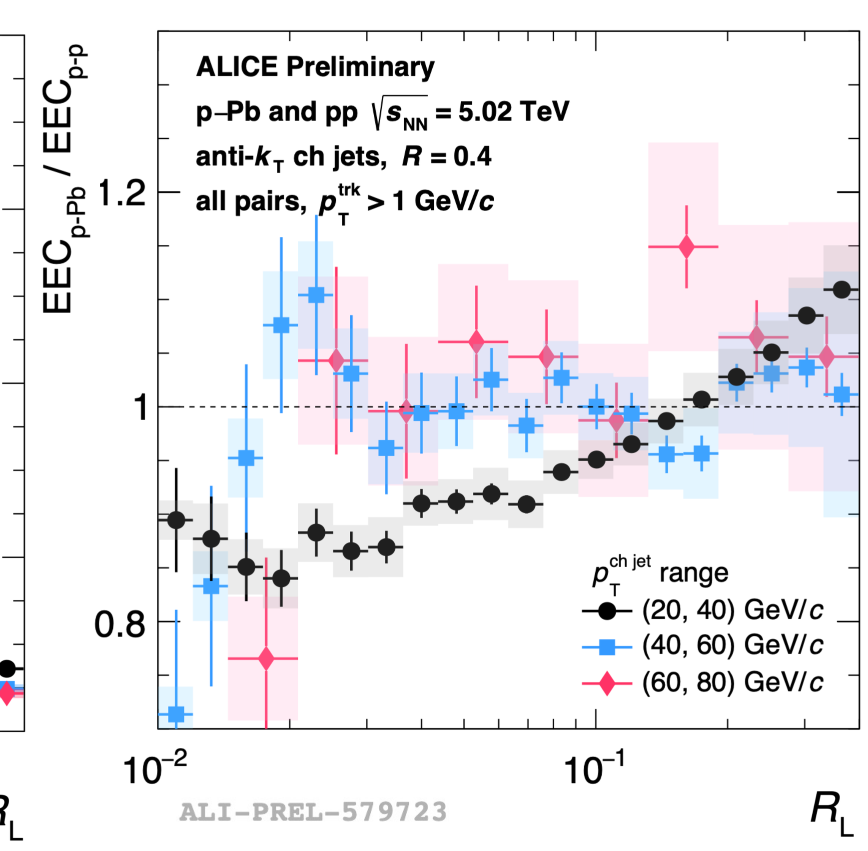
EECs in p-Pb data

About the data:

- 5.02 TeV p-Pb data
- charged-particle anti-k_T jets
- R=0.4 and $|\eta_{jet}| < 0.5$
- $p_T^{\text{ch jet}}$ in [20, 80] GeV/c
- p_T^{trk} > 1.0 GeV/c for EEC pairs

Clear separation of perturbative and non-perturbative regimes.

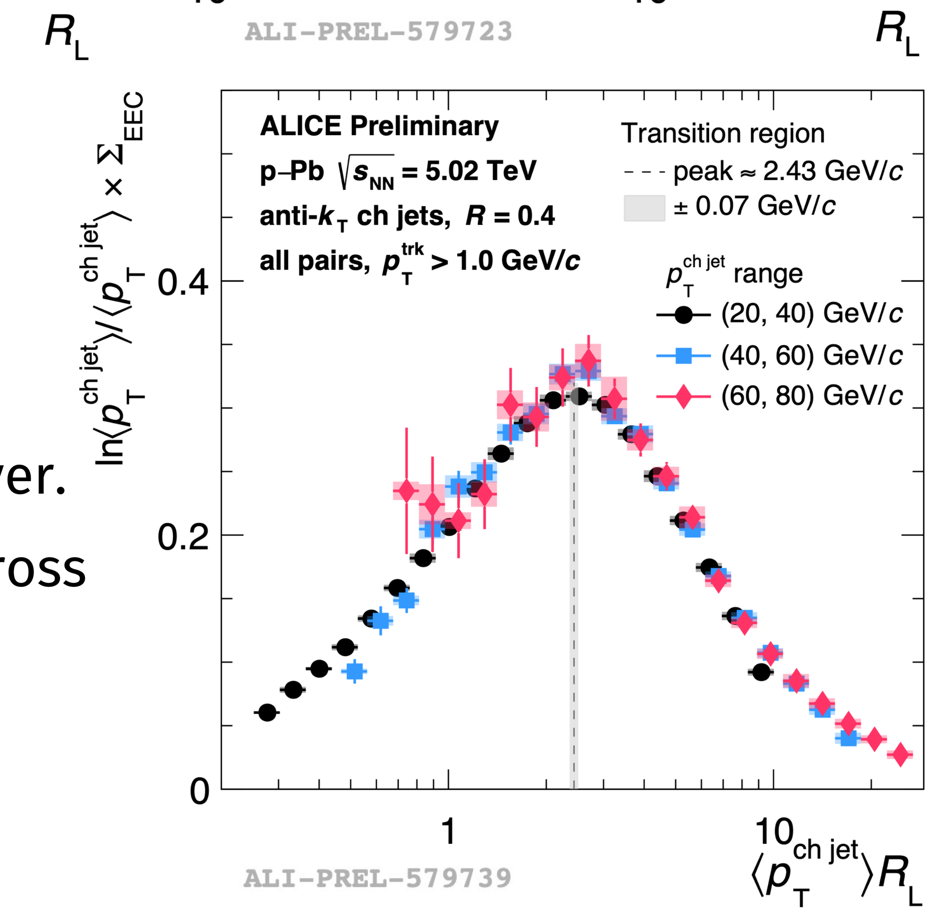




From the ratio: modification in the lowest jet p_T bin!

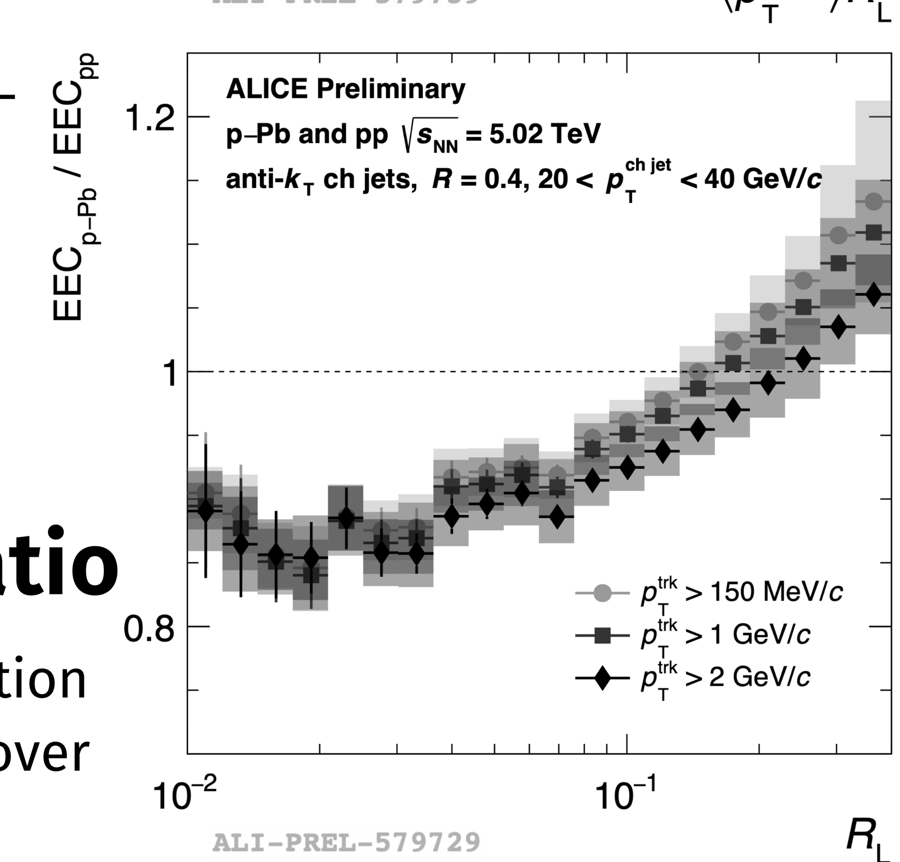
Universal transition behavior

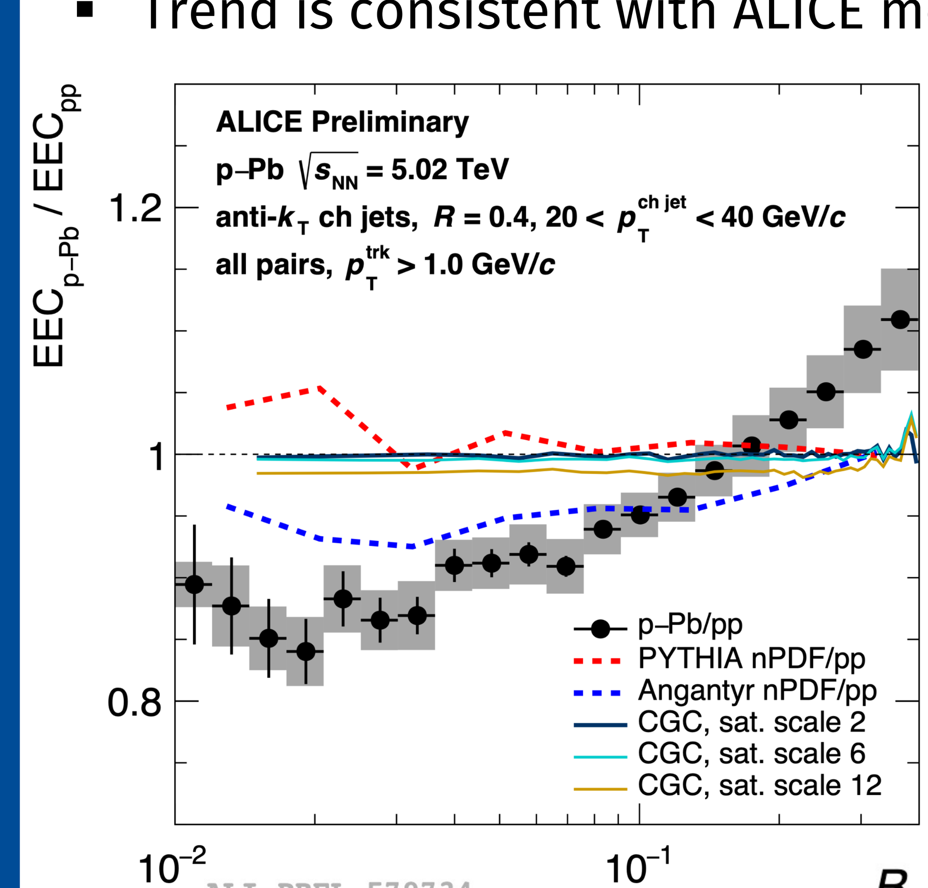
- After scaling R_L by the average jet p_T, the EECs are similar.
- When the virtuality approaches 2.4 GeV/c, the EECs turn over.
- The location of the EEC peak is approximately constant across jet p_T and collision system — not quite for the height.



Investigating the p-Pb/pp EEC ratio

- Suppression at small R_L and enhancement at large R_L
- Varying the track p_T cut changes the level of enhancement — it becomes stronger when softer particles are included
- Suggests that the origin of the effect lies in softer interactions at small x
- Trend is consistent with ALICE measurement of p-Pb z_{ch}





Modeling the ratio

- Preliminary CGC prediction from Haoyu Liu et. al., over different Q_{sA} values
- PYTHIA uses EPPS21 nPDF
- Models indicate small-R_L suppression and large-R_L enhancement.

Models do not capture the data!

The p-Pb/pp EEC ratio seems to be affected by more than just initial-state effects in p-Pb.