Energy-energy correlator measurements in pp and p-Pb collisions at 5.02 TeV

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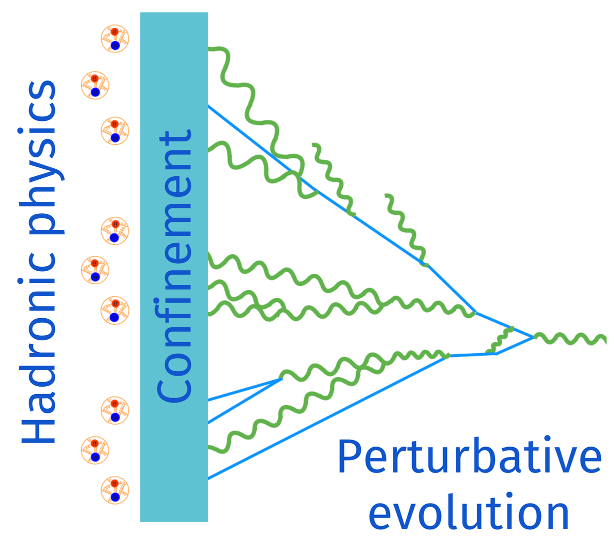
Introduction

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)

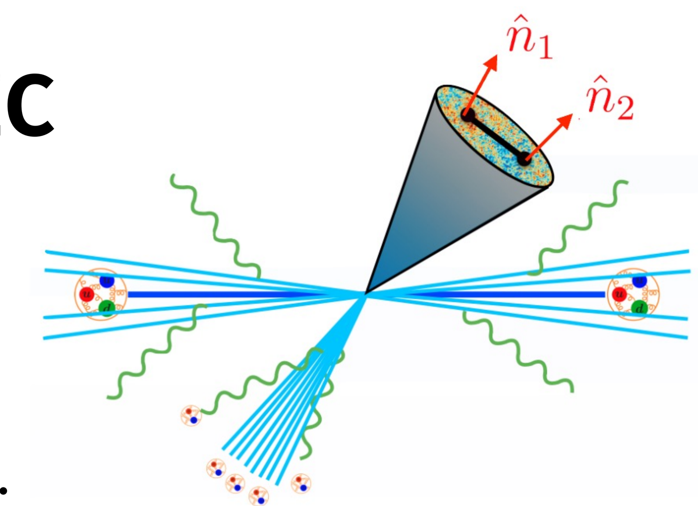


Energy-energy correlators are a jet substructure observable that measures statistical correlations of energy flux in jets. They are IRC-safe and well-defined in QFT, and pQCD calculations already exist.

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

Calculating the EEC

- First cluster jets.
- For each pair of tracks inside the jet, calculate the energy weight.
- Count the number of weighted track pairs as a function of R_L.

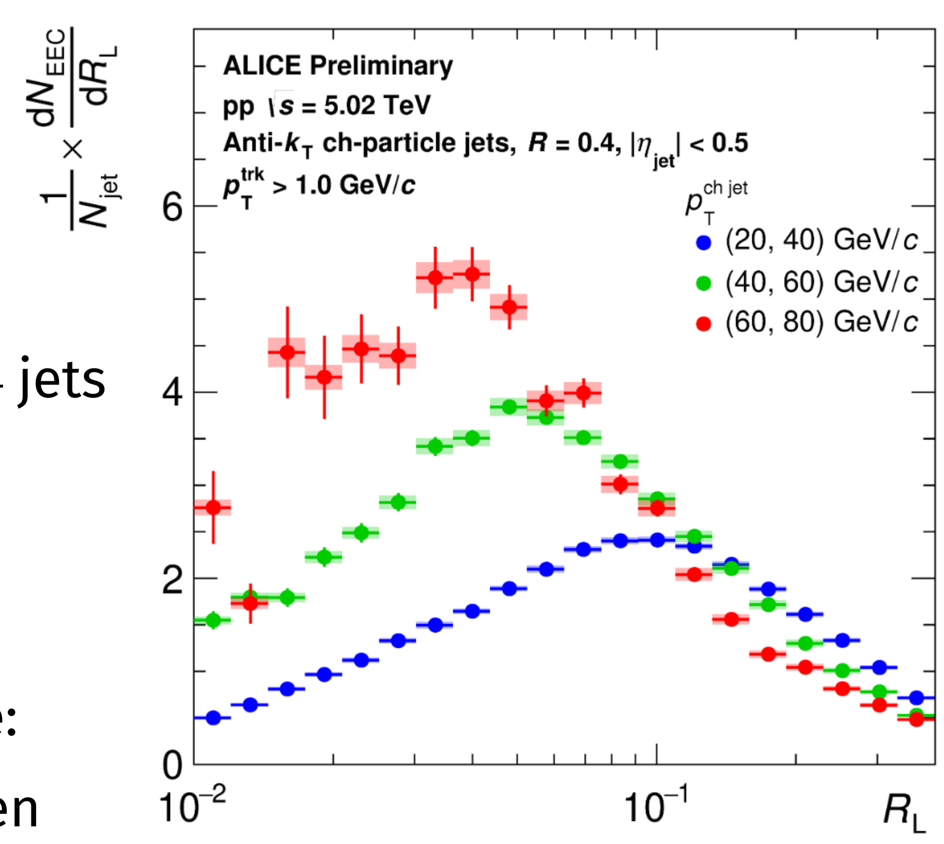


EECs scan jet dynamics from perturbative (large R_L) to non-perturbative scales (small R_L), separated by a transition region. EECs let us probe jet formation and confinement.

EECs in pp data

About the data:

- 5.02 TeV pp 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
- $p_{T,\text{particle}} > 1.0$ GeV

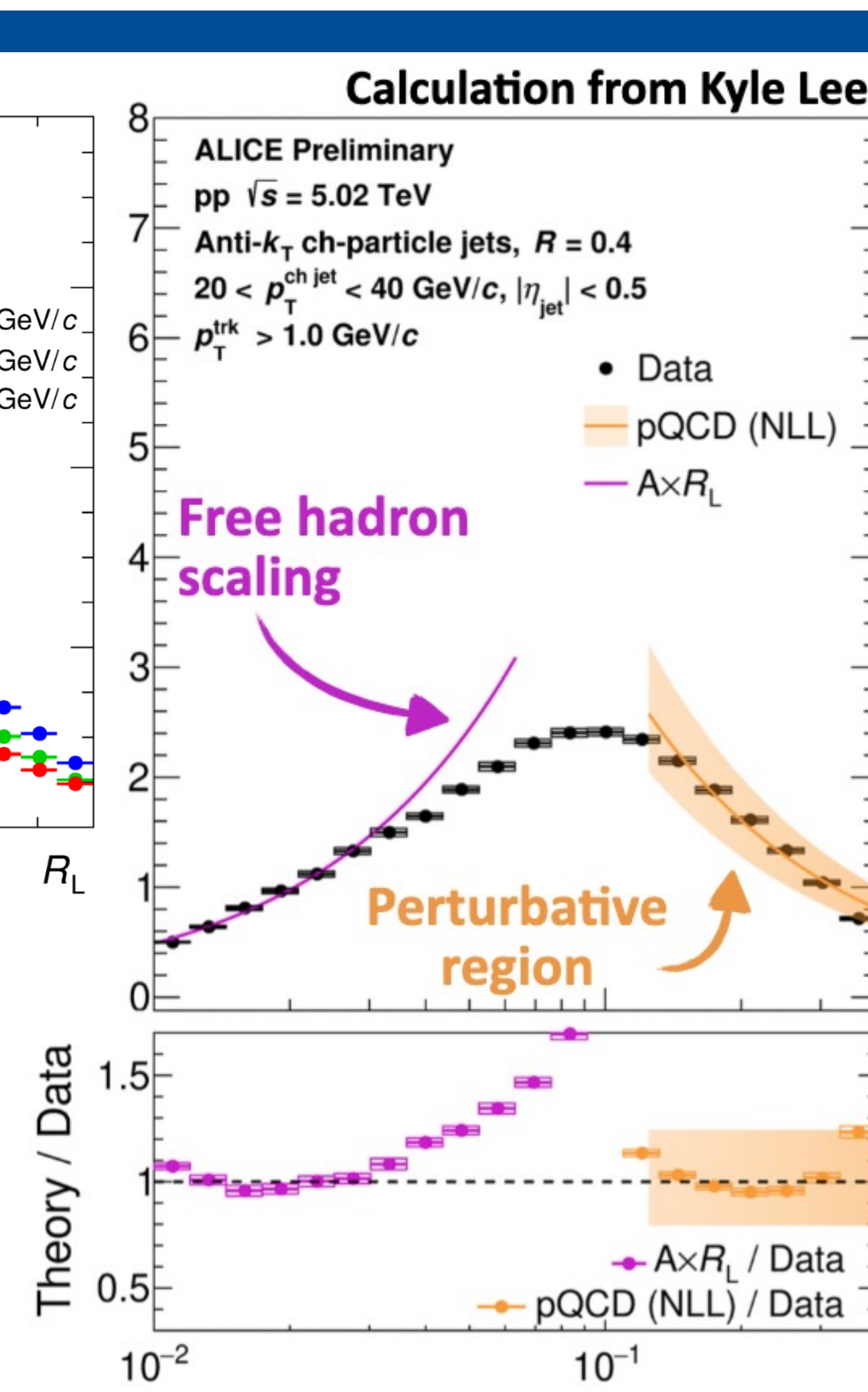


From the EEC plots, we see:

- clear separation between perturbative and non-perturbative regimes.
- Well-defined transition region shifts to lower R_L for higher jet p_T, consistent with more collimated jets.

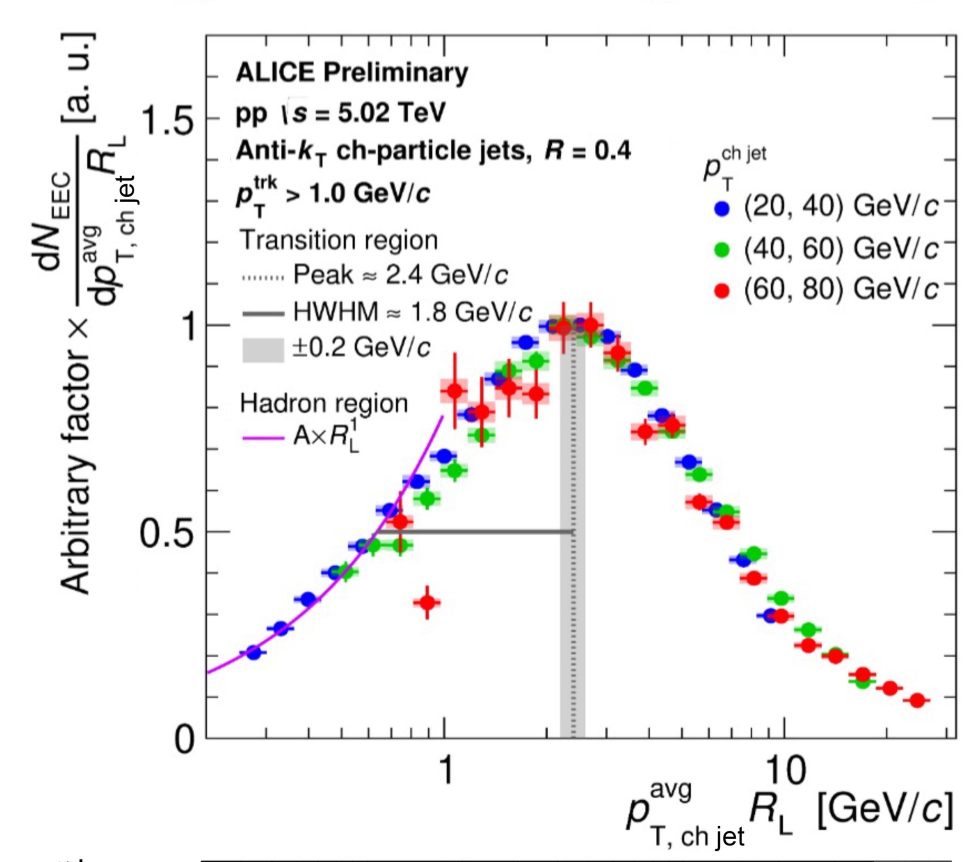
Comparison to theory[1] shows agreement between data and NLL in the perturbative region. Deviations appear near transition region. Good agreement between data and free hadron scaling in the NP region, consistent with uniformly distributed hadron scaling behavior.

[1] arXiv:2205.03414 [hep-ph]



Universal transition behavior

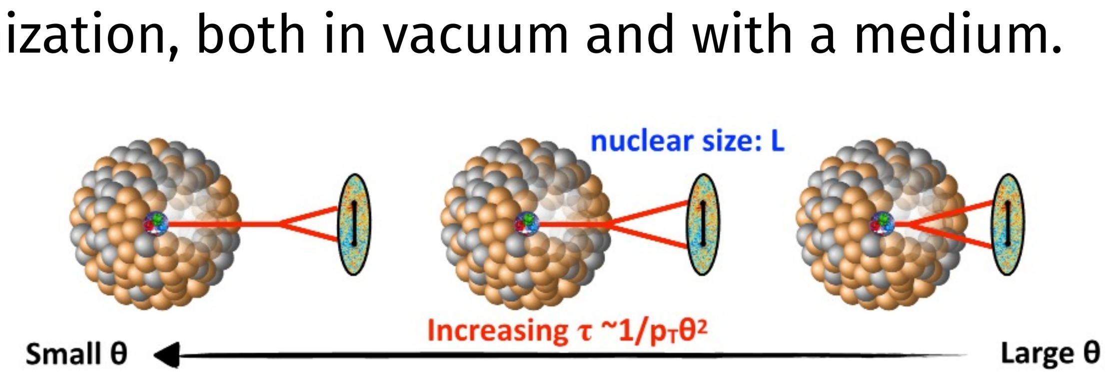
- After scaling R_L by jet p_T, the EECs are similar as a function of virtuality ~ $p_T R_L$.
- When the virtuality approaches $\mathcal{O}(\Lambda_{QCD})$, we see onset of the transition region and confinement.
- The transition peak positions are all near 2.4 GeV.

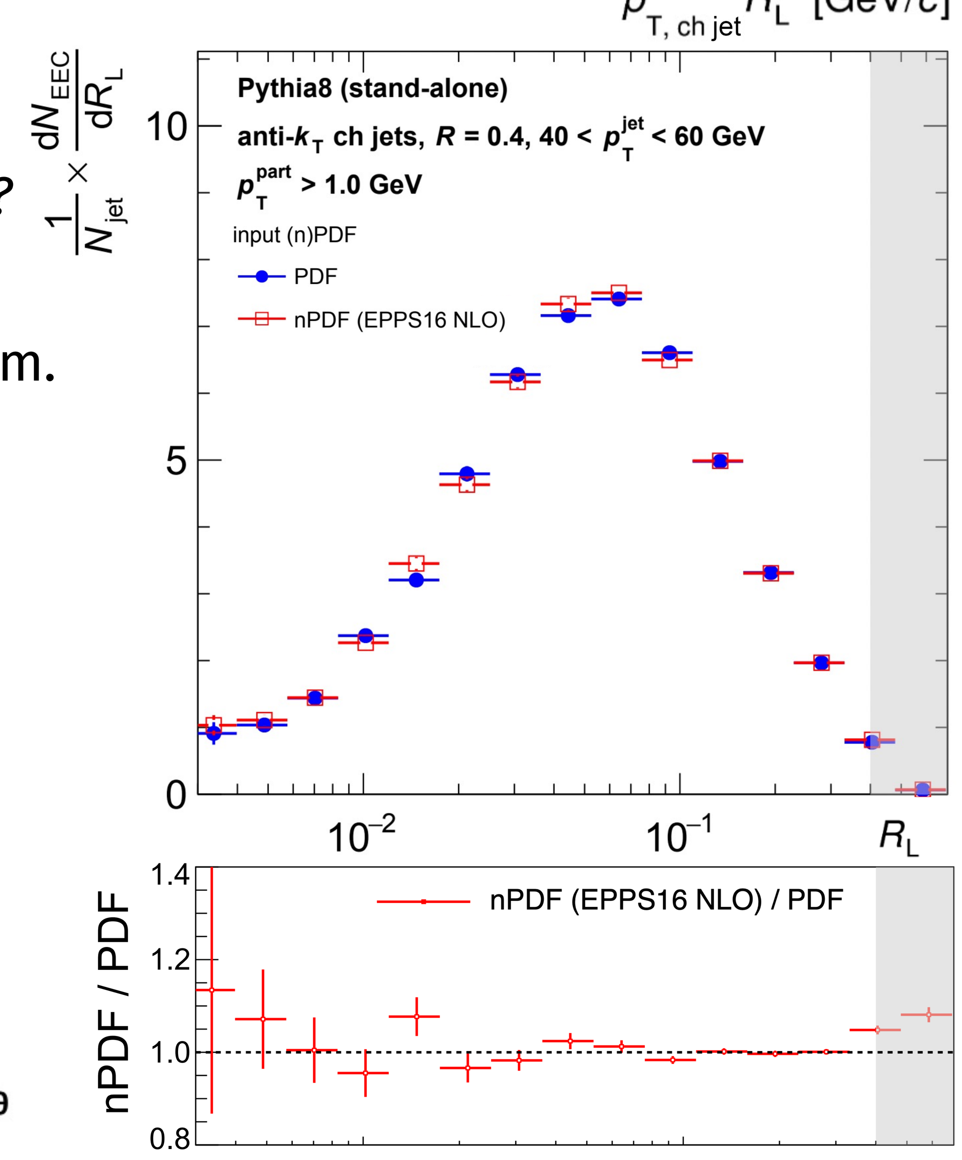


Looking at EECS in p-Pb data

- *Do interactions with a cold nuclear medium modify EECs?*
- Differences from pp could be from changes in the initial state (nPDF, isospin) or from showering through a medium.
- Machinery to analyze p-Pb is established! Results soon.
- Goal: compare p-Pb EECs to pp, determine if there are medium-induced modifications.
- We'll also investigate charge-separated EECs for insights into hadronization, both in vacuum and with a medium.

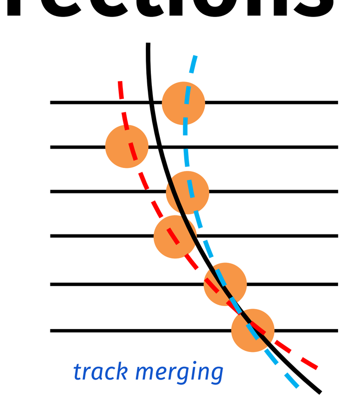
Small R_L splittings occur outside the medium, while larger R_L splittings happen within the medium.





Detector effect corrections

We have to correct for single track resolution and efficiency, as well as the pair efficiency.

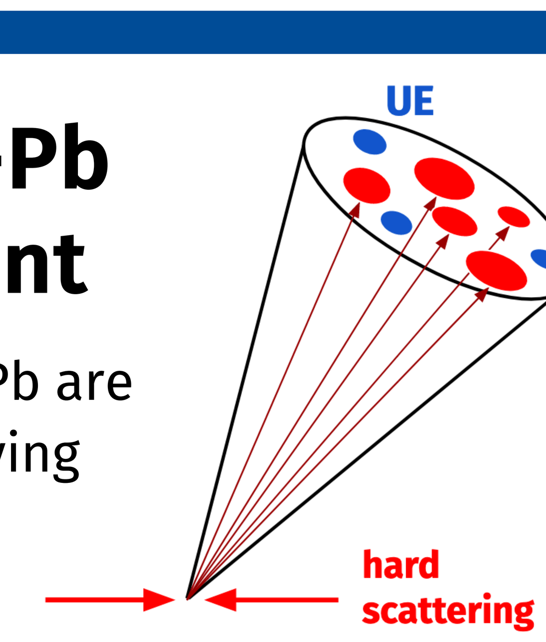


We do a bin-by-bin correction, using the ratio of simulated detector-level and truth-level EEC distributions. This is possible because of ALICE's high angular resolution, so we expect little R_L migration. This has been used in pp and will be for p-Pb as well.

$$f_{corr}(dR_L^{det}, p_{T,jet}^{det}) = \frac{dN_{pair}^{det} \;/\; dR_L^{det}(p_{T,jet}^{det})}{dN_{pair}^{truth} \;/\; dR_L^{truth}(p_{T,jet}^{truth})}$$

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

Treating the p-Pb underlying event



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

We use the CMS median subtraction[2] method to correct jet p_T. With k_T jets, we can find the UE energy density per event.

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

We embed pp PYTHIA into minimum bias p-Pb data to estimate the UE in EEC, by tagging three types of pairs inside jets.

- signal-signal (PYTHIA-PYTHIA)
- signal-background (PYTHIA-data)
- background-background (data-data)

This yields background EEC distributions which we can subtract from the raw data EEC.

[2] arXiv:1207.2392 [hep-ex]

For more on EECs, see Wenqing Fan's talk at 8:50 AM in tomorrow morning's HF session!