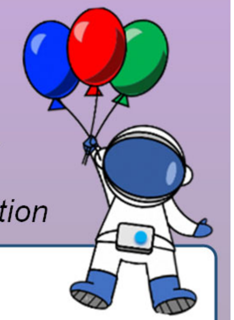
Measurement of Two-Point Energy Correlators Within Jets in *pp* Collisions at $\sqrt{s}$ 200 = GeV

QM 2023



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Abstract

Jet substructure can provide valuable insight into the time evolution of a jet, which involves perturbative fragmentation well described by quantum chromodynamics. However, the regime of jet evolution in which non-perturbative effects begin to dominate, leading to hadronization, is of great interest to study. A novel substructure observable in hadronic collisions, the Energy-Energy Correlator (EEC) examines jet evolution as a function of correlations between all constituents of the jet, separating its behavior into independent regimes dominated by non-perturbative and perturbative dynamics respectively, highlighting the transition between the two.

Motivation: Jet Evolution

Jets in vacuum undergo fragmentation and eventually hadronize and are measured in detectors

Evolution across both perturbative and non-perturbative regimes – time information is encoded onto angular scales [1]

Formation Time: $t_f \propto \frac{1}{\Delta R^2}$ Smaller angle ➡ later time

Angular scales between all particles separate out these regimes of jet evolution and isolate transition between them - onset of hadronization

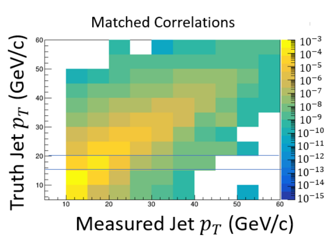
STAR Experiment and $p_{\mathrm{T,jet}}$ Correction

Time Projection Chamber:

-High angular precision on charged tracks for determination of angular distance

Electromagnetic Calorimeter:

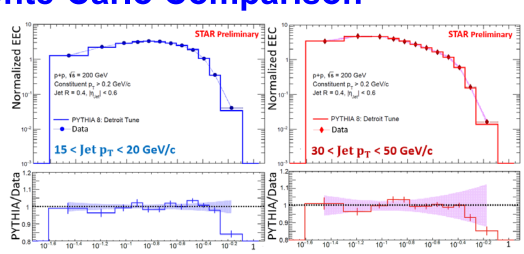
-Allows for determination of full jet momentum
Detector effects simulated and corrected for via PYTHIA6 + GEANT3 embedding



Construct $p_{\mathrm{T,jet}}$ mapping from tracks measured in both GEANT (measured level) and PYTHIA (truth level) samples

Add measured distributions together in ratios determined from a selection on truth $p_{\mathrm{T,jet}}$ in the response matrix

Monte-Carlo Comparison



All stages of jet evolution in vacuum in EEC distribution are well described by PYTHIA8 Detroit Tune within errors – useful as baseline for future studies of medium interaction

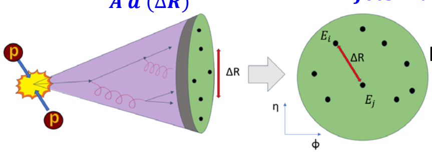
1 Apolinário et al. 2021 EPJC 81, 561
2 *Cruz-Torrez, Hard Probes 2023*
3 Lu, BOOST 2023
4 Komiske et al. Phys. Rev. Lett. 130 (2023) 5, 051901
5 Andres et al. Phys. Rev. Lett. 130 (2023) 26, 262301
6 Lee, Moult (2023): arXiv:2308.00746

Energy-Energy Correlator (EEC)

Examines the correlations between all possible pairs of two particles differential in their angular scale (ΔR) weighted by their energy product

Normalized EEC $= \frac{1}{A}\frac{d(A)}{d(\Delta R)}$ **where** $A = \sum_{Jets}\sum_{i \neq j}\frac{E_i E_j}{{p_{T,jet}}^2}$

Transverse jet momentum: $p_{T,jet}$



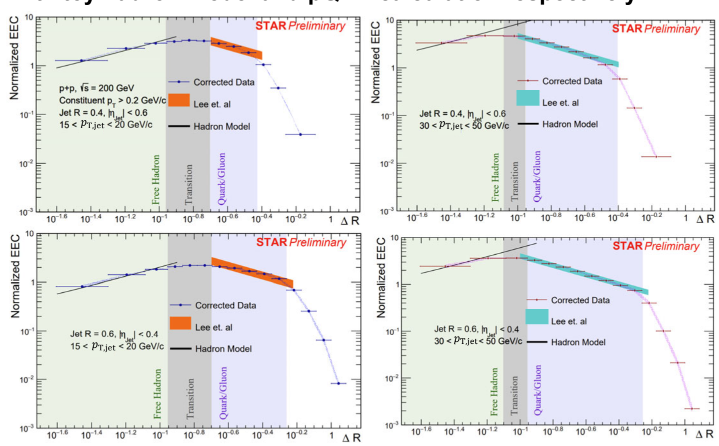
Energy of one charged constituent in pair: E_i

Results

Expected behavior in non-perturbative and perturbative regimes recovered, compared with toy hadron model and pQCD calculation respectively

R=0.4

R=0.6



15 < Jet p_T < 20 GeV/c **30 < Jet p_T < 50 GeV/c**

Transition moves to lower angles (later times) at higher jet energies
- Consistent with measurements from ALICE [2] and CMS [3]

Transition region occurs at consistent scale proportional to $p_{\mathrm{T,jet}} * \Delta R_{Turnover}$ ~ 2-3 GeV -> Implies consistent scale of hadronization [4]

Turnover $\propto \frac{\Lambda_{\mathrm{QCD}}}{p_{\mathrm{T,jet}}}$

Jet radius has small effect on location of turnover regime, but extends phase space for observing perturbative effects

Summary and Outlook

First Measurement of EEC at STAR - separates non-perturbative and perturbative effects into angular scales, many future applications

Potentially resolve scales of interaction with Quark-Gluon Plasma [5]

In future, can probe how hadronization changes across correlations with different charge signs [6]
– see poster by Youqi Song for charge-correlator ratio measurement

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The STAR Collaboration

https://drupal.star.bnl.gov/STAR/presentations