Measurement of photon-jet correlations in p+p and central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by STAR

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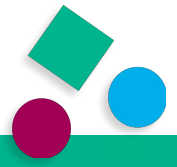
For the STAR Collaboration
March 18th 2025

Overview

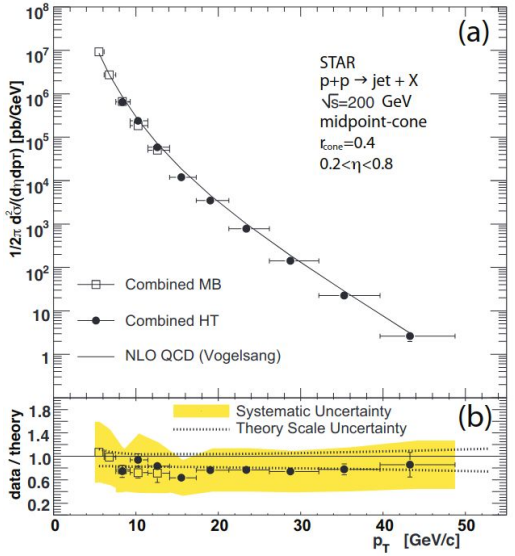
- STAR
- Motivation
- Jet Measurement
- Trigger Identification
- Corrections
- Systematics
- Conclusion and Prospects



Fully Reconstructed Jets Measured by STAR

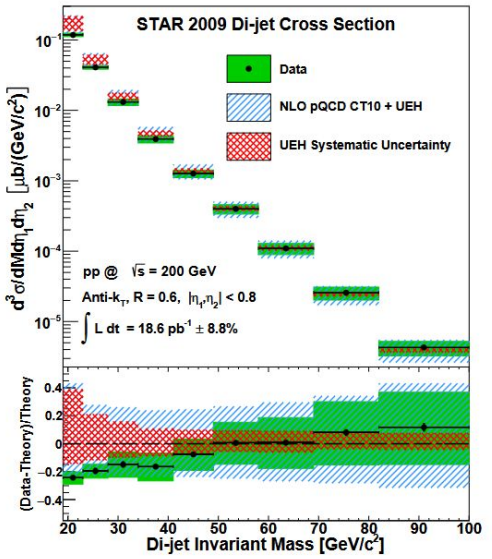
- STAR has done full jet reconstruction for pp at $\sqrt{s_{NN}}$ = 200 GeV previously

Inclusive differential cross section



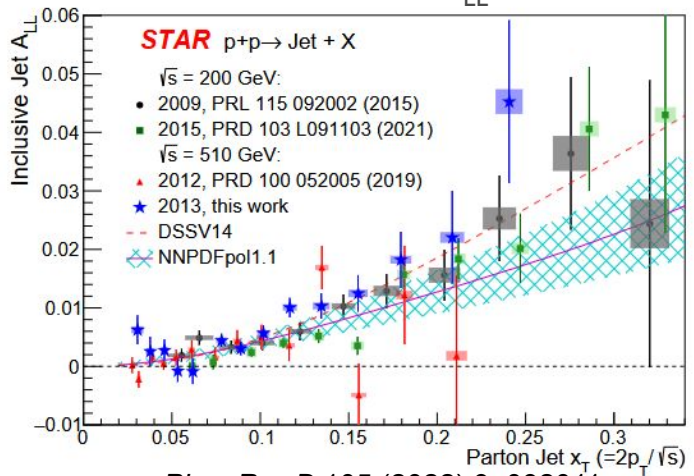
Phys.Rev.Lett 97 (2006) 252001

Di-jet Cross Section



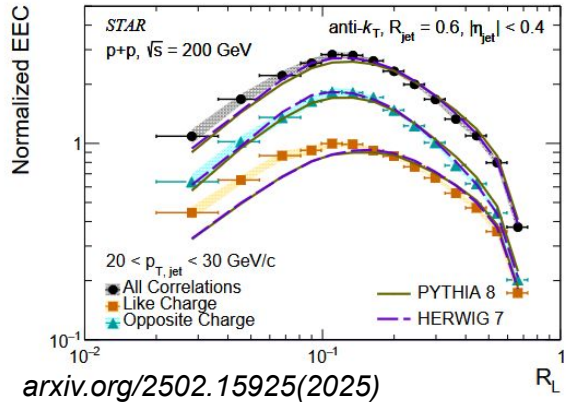
Phys.Rev.D 95 (2017) 7, 071103

Inclusive jet A_{LL}



Phys.Rev.D 105 (2022) 9, 092011

Normalized EEC

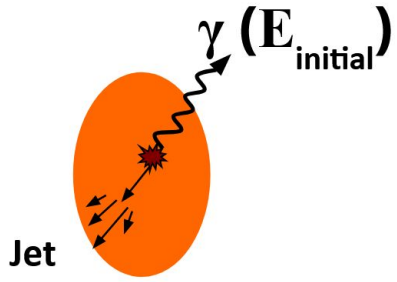


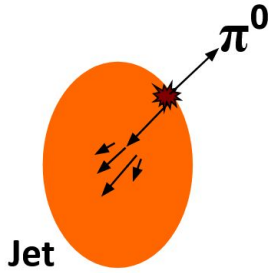
arxiv.org/2502.15925(2025)

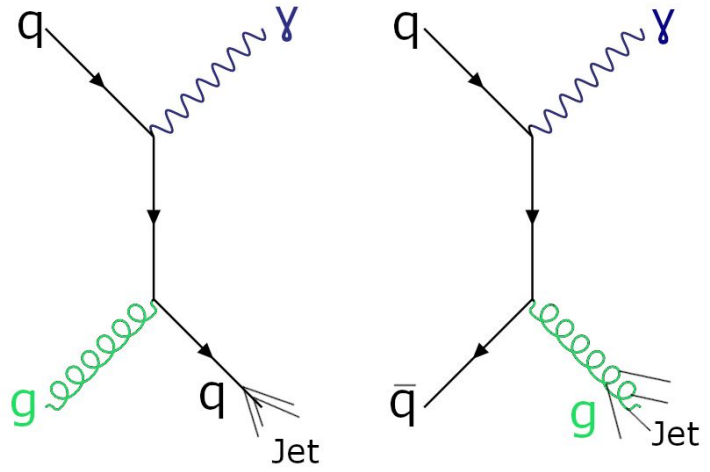
Motivation

- γ+jet provides reference scale for jet quenching
- Also useful to compare to QCD calculations
- Nuclear modification factor I_{AA} measures medium effect
- γ+jet vs. π^0+jet tests path length and quark vs. gluon dependence on energy loss
- Previous STAR γ/π^0+jet measurement with charged jets only (arxiv.org/abs/2309.00156)

$$I_{AA} = \frac{Y^{Au+Au}(p_{T,jet}, R)}{Y^{p+p}(p_{T,jet}, R)}$$

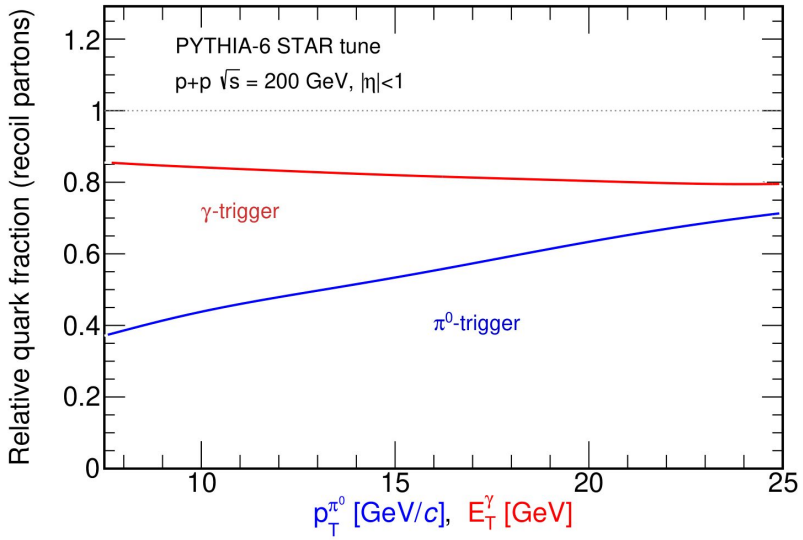






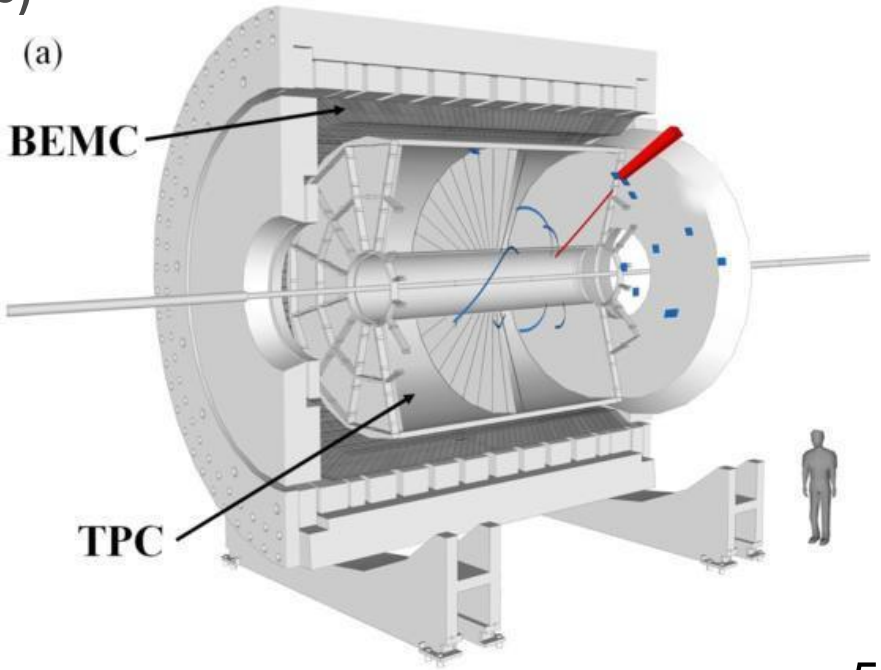
Primary mechanism compton scattering

Some q̄q annihilation



The STAR Detector

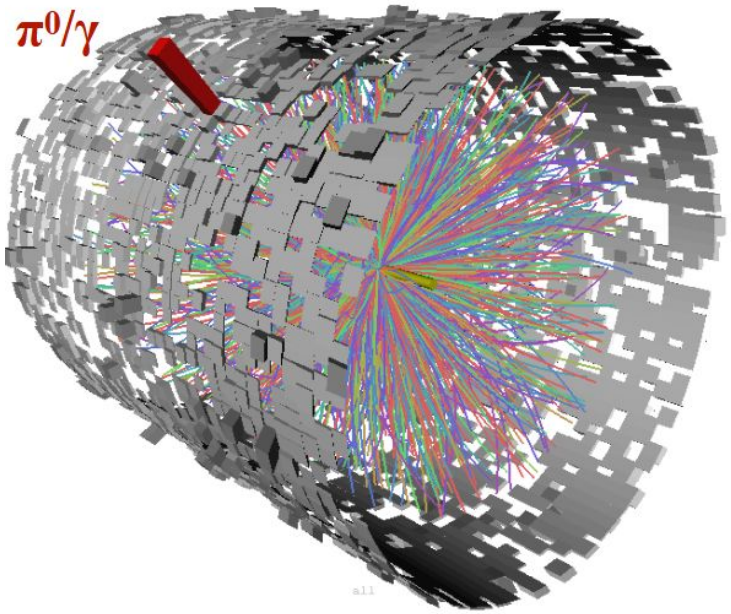
- The Solenoidal Tracker at RHIC (STAR) has three detectors of particular interest to this analysis
  - TPC for charged particles
  - BEMC for photons (direct and decay particles)
  - BSMD for π^0/γ discrimination



Jet Measurement

- Full includes charged **and** neutral energy
- Reconstruction using anti-k_T, R=0.2, 0.5
- Highest fidelity reconstruction of scattered quark energy
- Jet axis within $\pi \pm \frac{\pi}{4}$ relative to π^0 or γ trigger

Online trigger: BEMC High Tower (HT) trigger to select events of large energy depositions



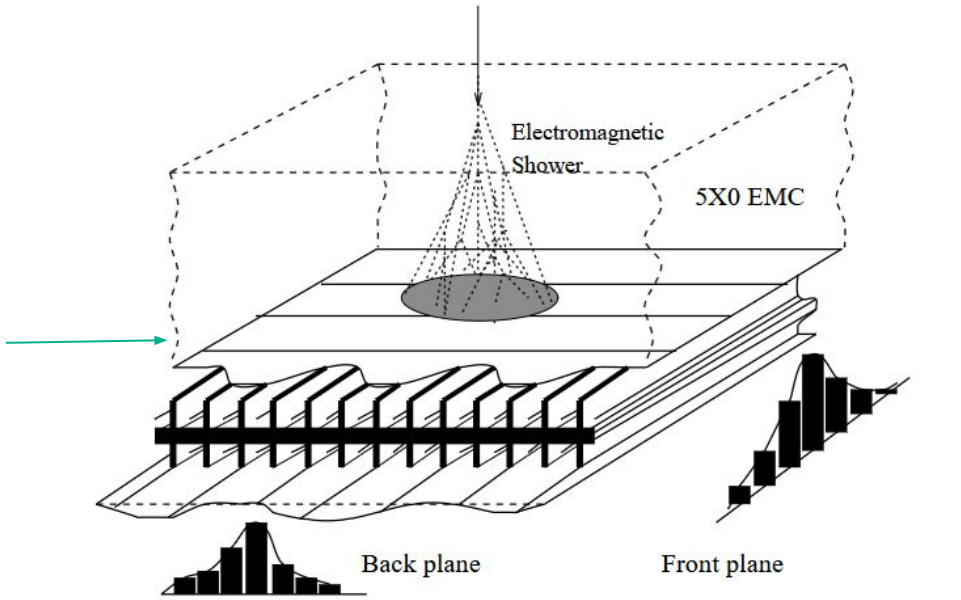
Event display
AuAu $\sqrt{s_{NN}}$= 200 GeV

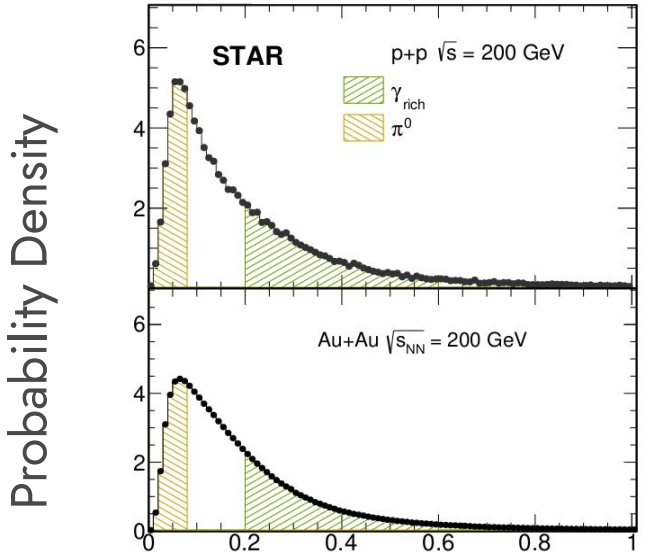
Trigger Identification

- BSMD measures shower shape for γ/π^0 triggers
- π^0 decays into two photons decreasing Transverse Shower Profile (TSP)

$$TSP = \frac{E_{Tower}}{\sum_i e_i \, r^{1.5}}$$

BSMD





(arXiv:2309.00156)

Jet Reconstruction

- Data points Raw per trigger jet yield
- Full reconstruction extends kinematic range cf. charged

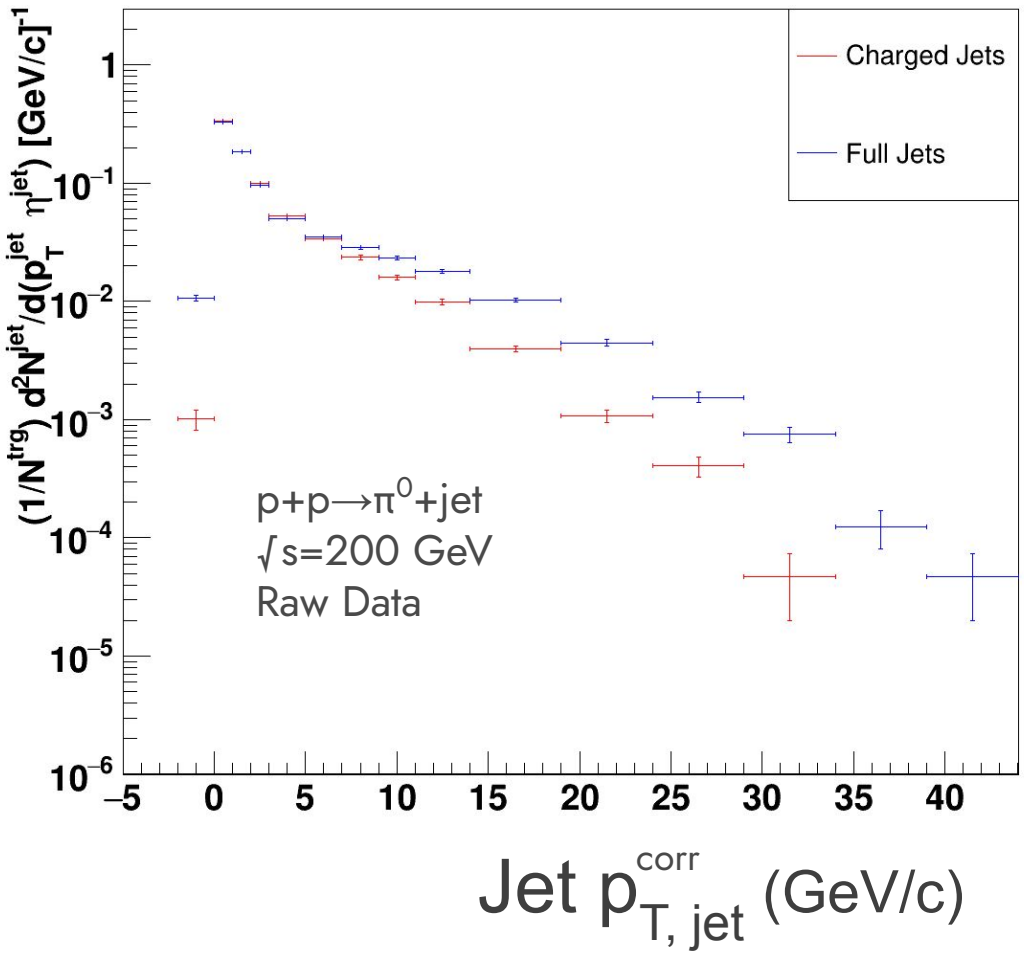
$p_{T,jet}^{raw}$ = raw jet transverse momentum

ϱ = median background energy density

A_{jet} = jet area $\quad p_{T,jet}^{corr} = p_{T,jet}^{raw} - \varrho A_{jet}$

Raw Data Jet p_T Spectra

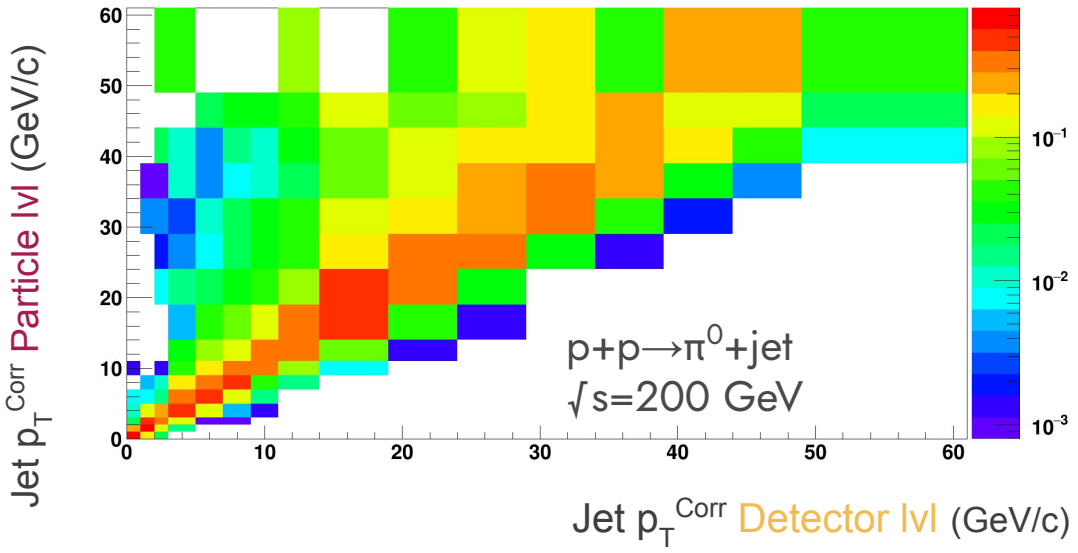
E_T π^0 = 9-11 GeV R=0.5



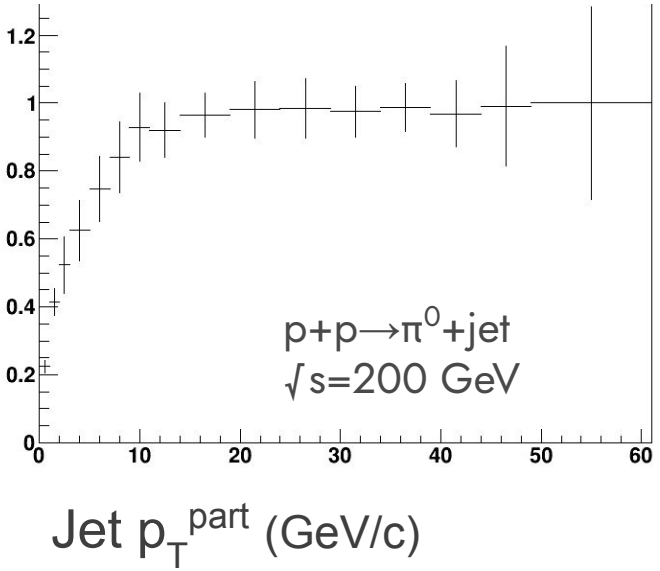
Corrections

- Detector effects correction handled by embedding
- Simulated di-jet jets from Pythia
- Run through GEANT & embedded in min bias data
- Matched based on closest in η-φ
- Efficiency: ratio of matched sim jets to total sim jets by jet-p_T bin

Response Matrix for E_T π^0 = 9-11 GeV R=0.5 full jets



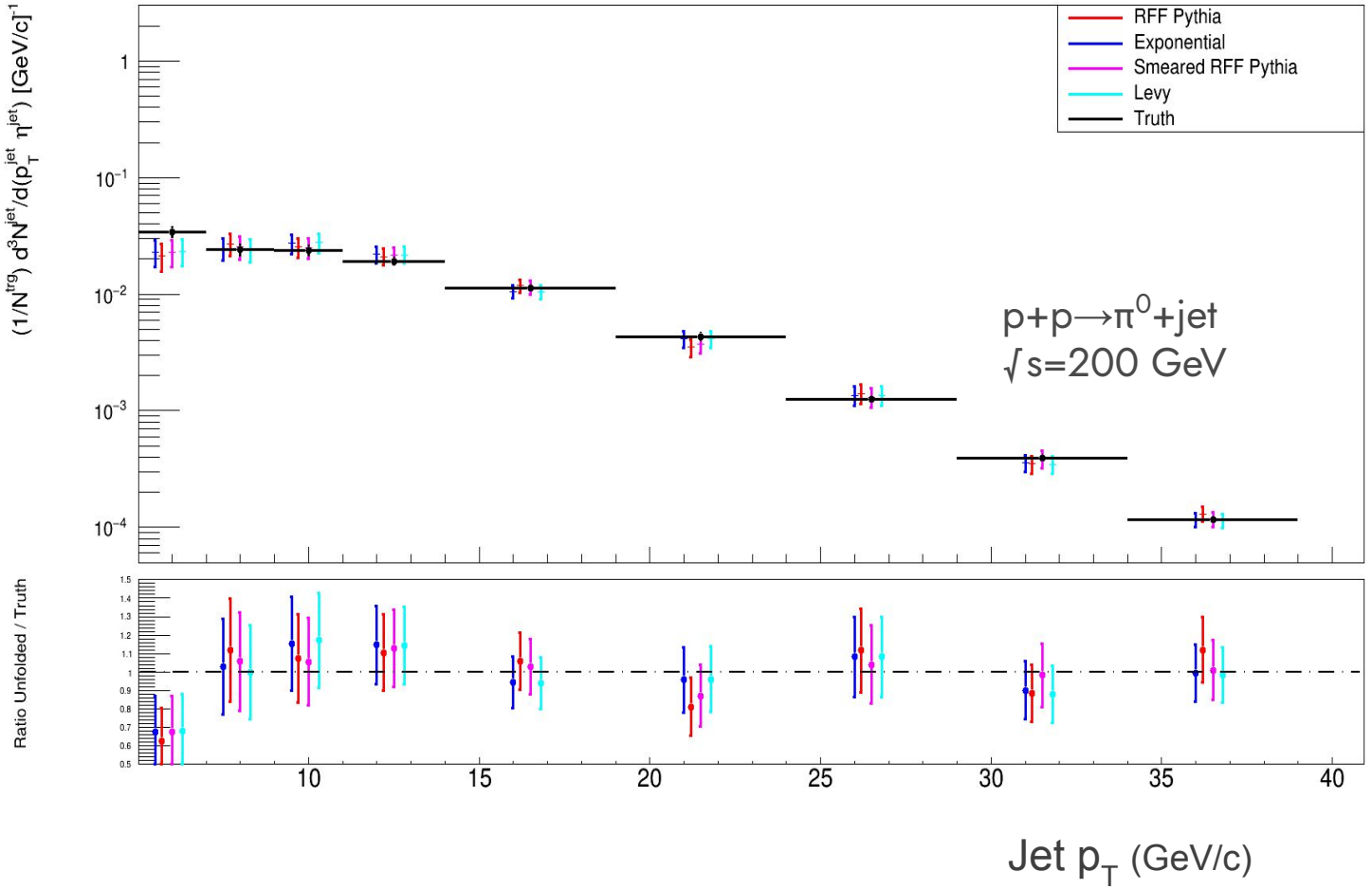
Jet Matching Efficiency for E_T π^0 = 9-11 GeV R=0.5 full jets



Closure of Method

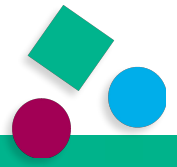
- Divide embedding sample into two groups
- Unfold first group using Response and Efficiency from second
- Vary prior by fitting Pythia to function Pythia subsample, Exponential fit, Levy-Tsalis fit, measured spectrum
- Compare with truth from embedding

Comparison of Unfolded subsamples by prior choice
E_T π^0 = 9-11 GeV R=0.5



Systematics

- Detector:
  - Tracking efficiency / resolution
  - BEMC Tower efficiency / resolution
- Unfolding:
  - Prior
  - Regularization
- π^0 background for direct-γ triggers
- Fragmentation model



Conclusion and Prospects

- In pp, unfolding with full systematic studies underway
- In AuAu, in addition to detector effects, heavy ion background must be accounted for

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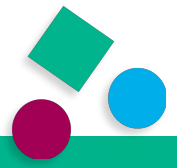
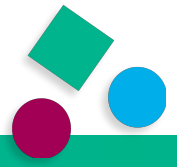
Questions



Backup Slides

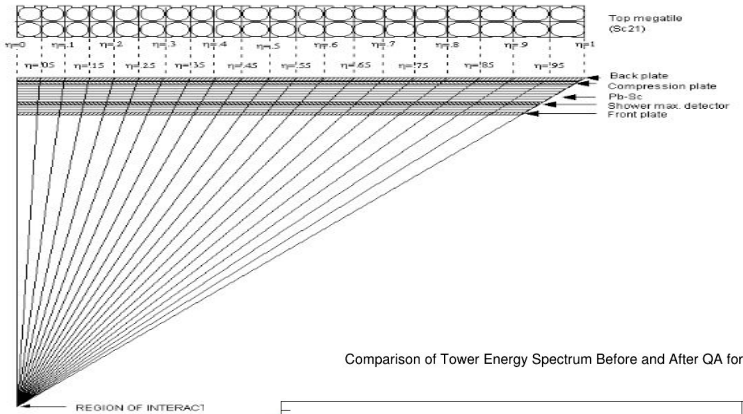
- Detector Descriptions
- Hadronic correction
- Prior Choices
- Corrections in Heavy Ion Environment
- Systematics

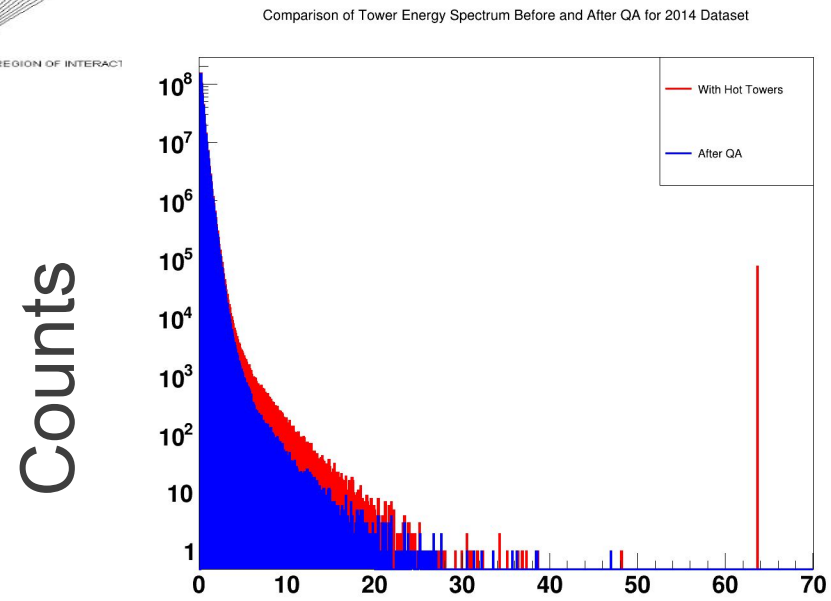


Barrel Electromagnetic Calorimeter

- projective nature of towers pictured top
- Towers with # of hits > 5σ from mean are rejected as "hot"
- Tower energy distribution for non-trigger towers in Au+Au dataset before QA (red) and after QA (blue) pictured bottom

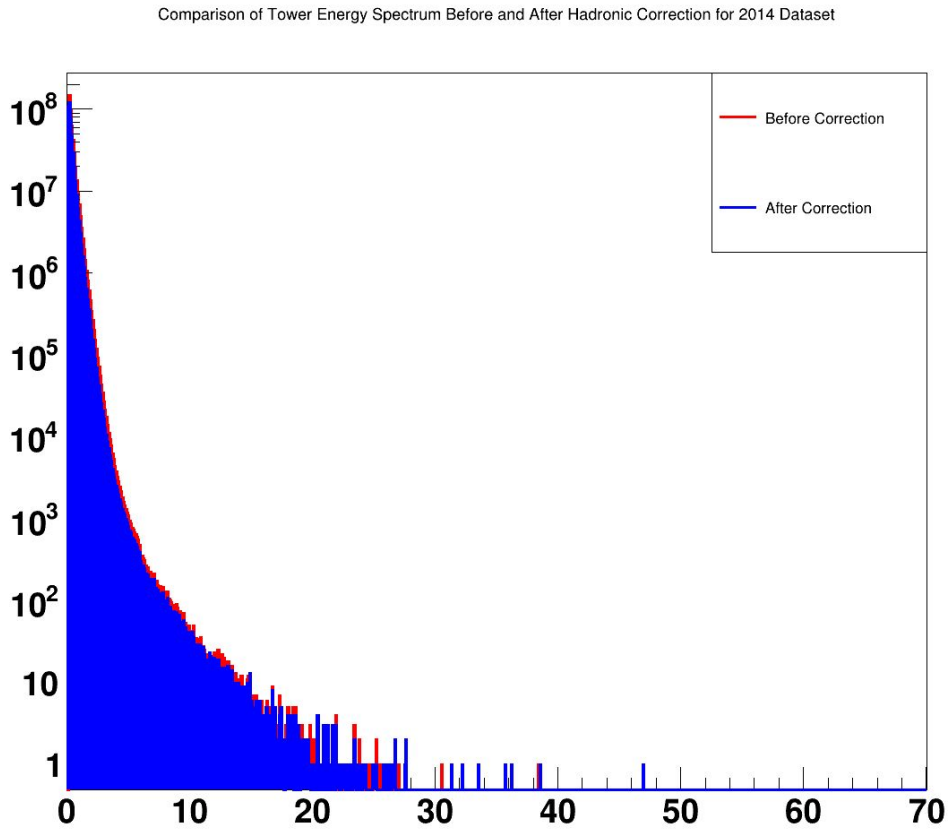
Single module of the BEMC covering Δη = 1, Δφ = 0.1





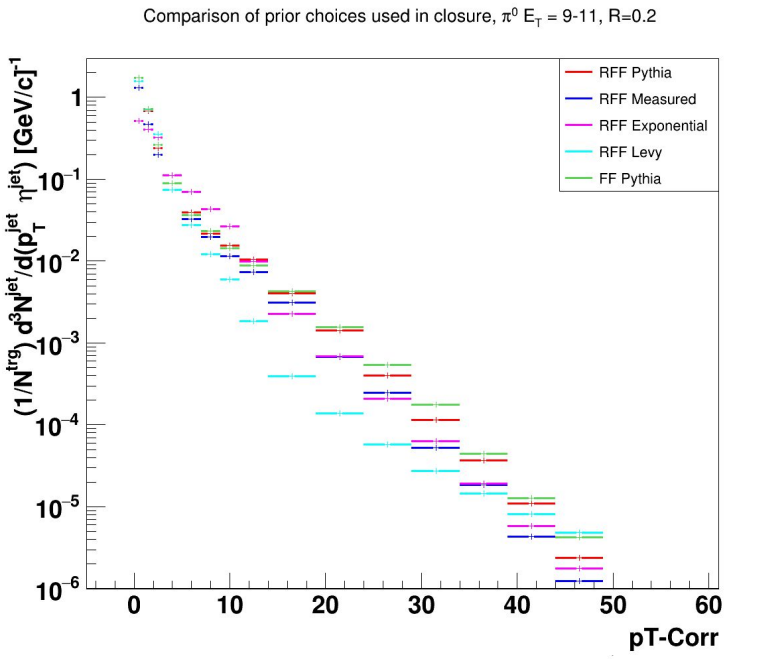
Hadronic Correction

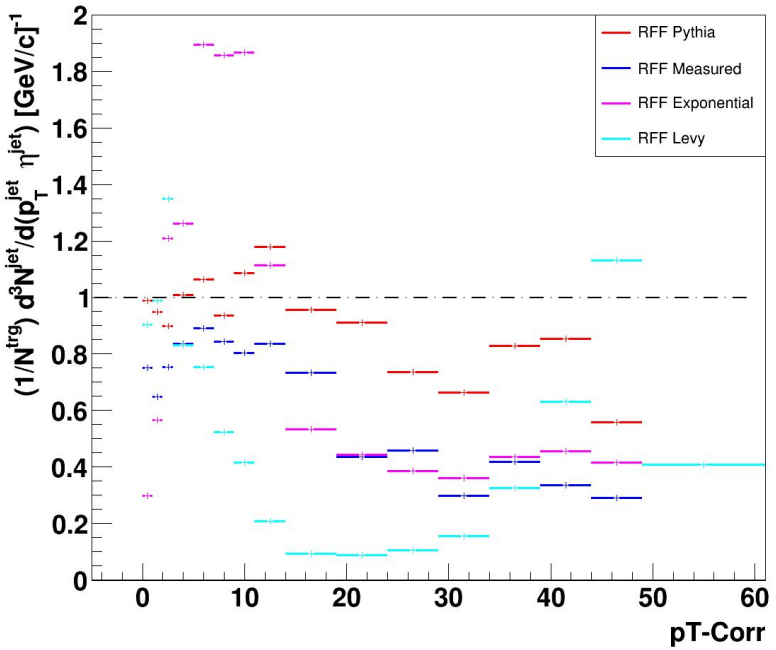
- Reduce tower energy by 100% of energy recorded by TPC as hitting tower
- Comparison of tower energy spectrum before (red) and after (blue) hadronic subtraction pictured right



Choice of Prior

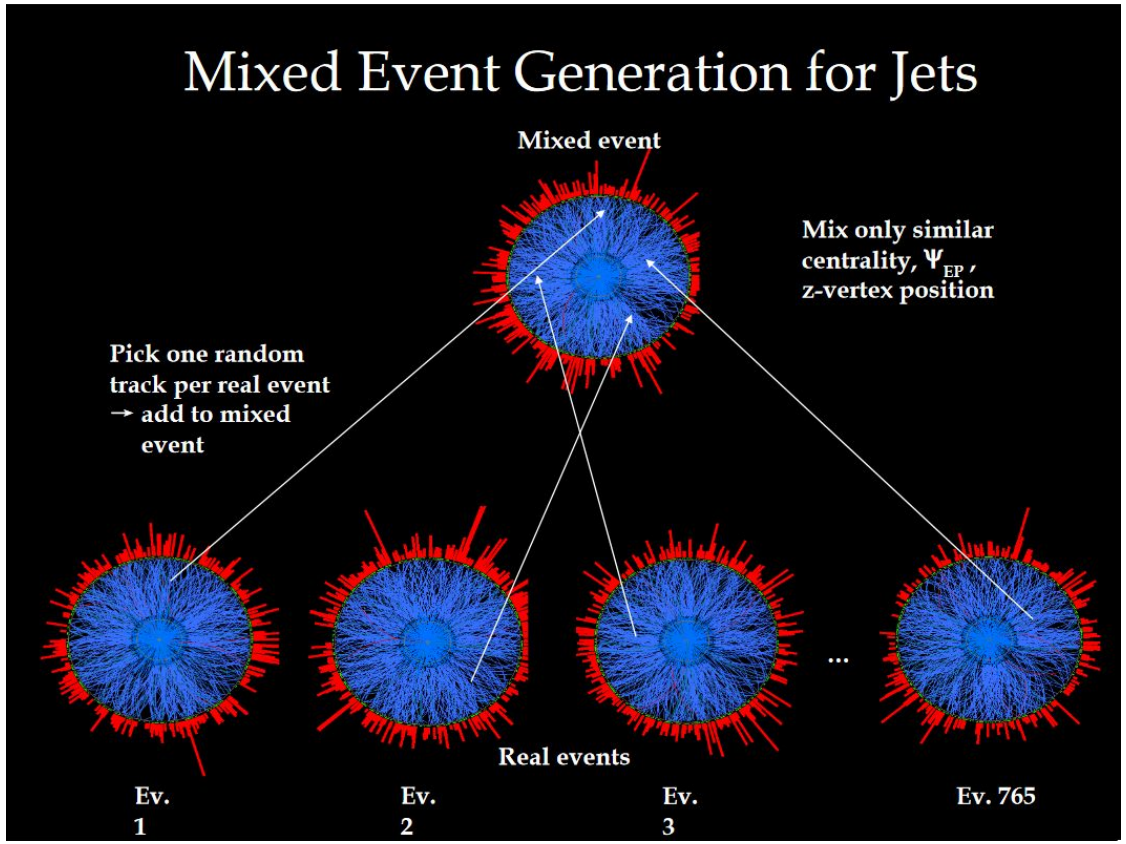
- Four choices of prior were used in unfolding
- Pythia subsample (red),
- Exponential fit (dark blue),
- Levy-Tsalis fit (light blue),
- measured spectrum (purple)
- Jet pT spectrum pictured top
- Prior / truth pictured bottom





Heavy Ion Background

- Central Au+Au events contain many jets that are "combinatoric"
- Event mixing takes tracks and towers randomly assigned into a new "mixed event"
- Same event statistics but none of the underlying physics correlations



A figure describing event mixing for tracks