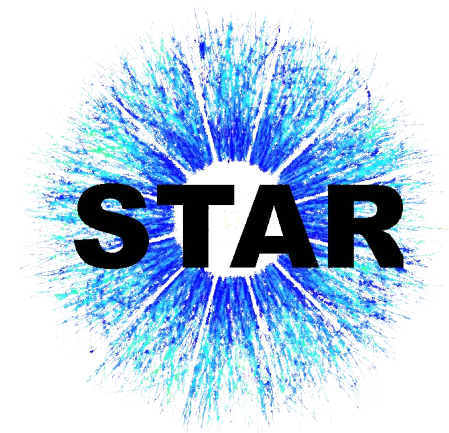# Measurement of photon-jet correlations in p+p and central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by STAR
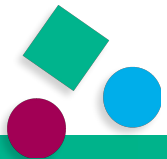
Jace Tyler
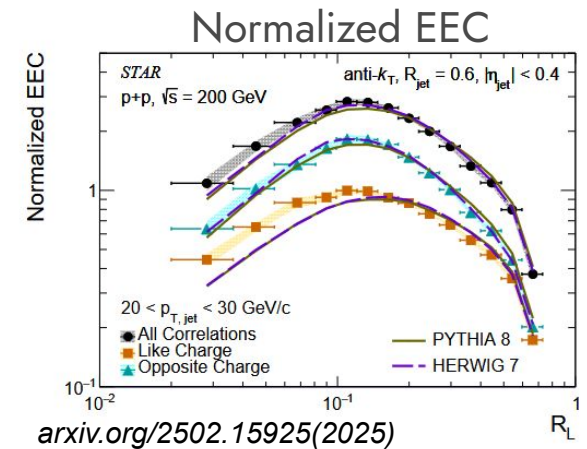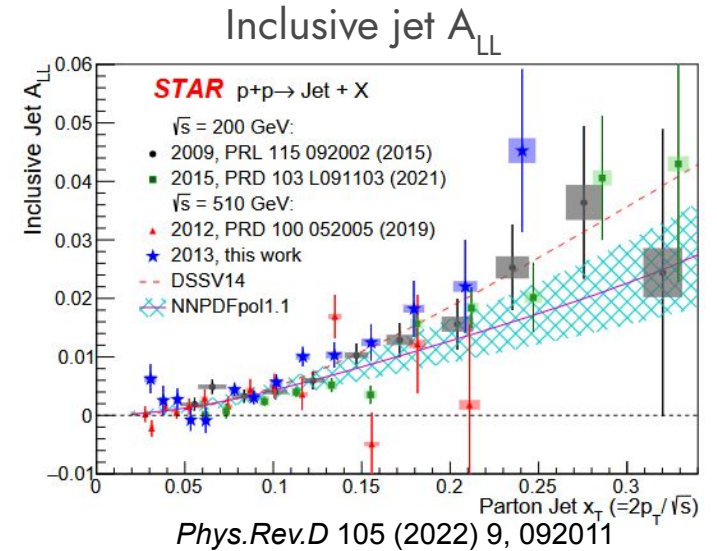
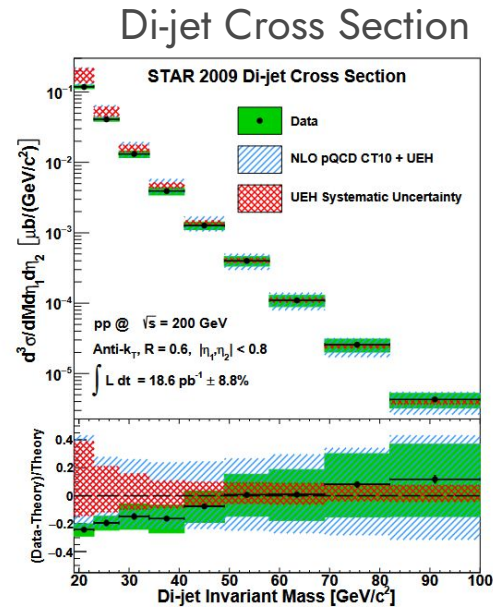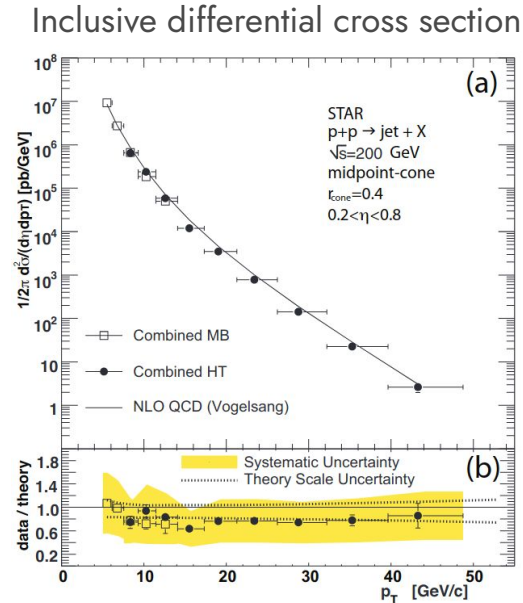For the STAR Collaboration

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)
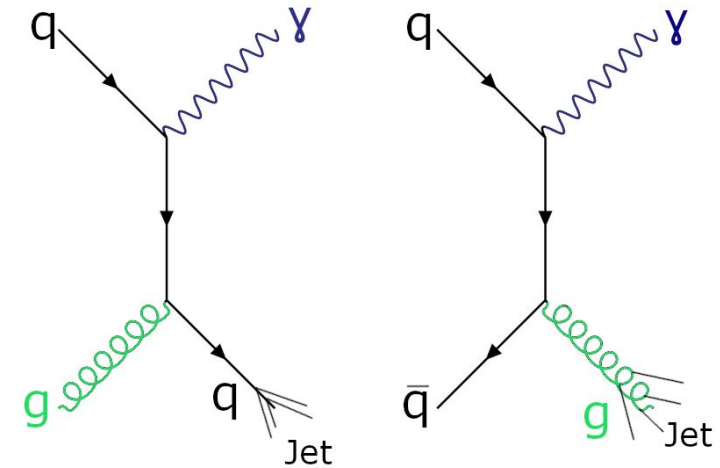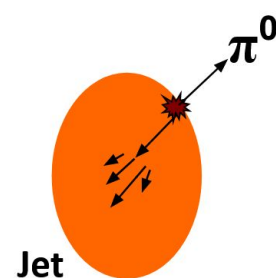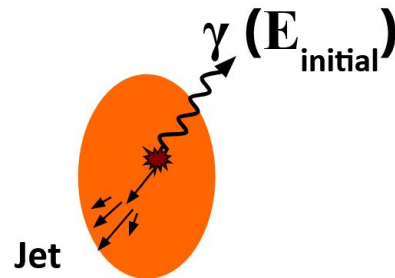
APS | Global Physics Summit

The STAR Detector

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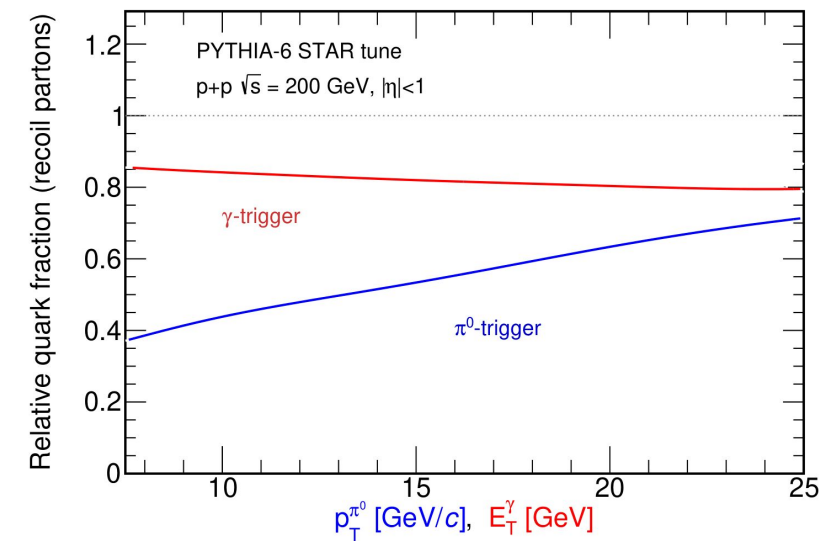

(a)

BEMC

TPC
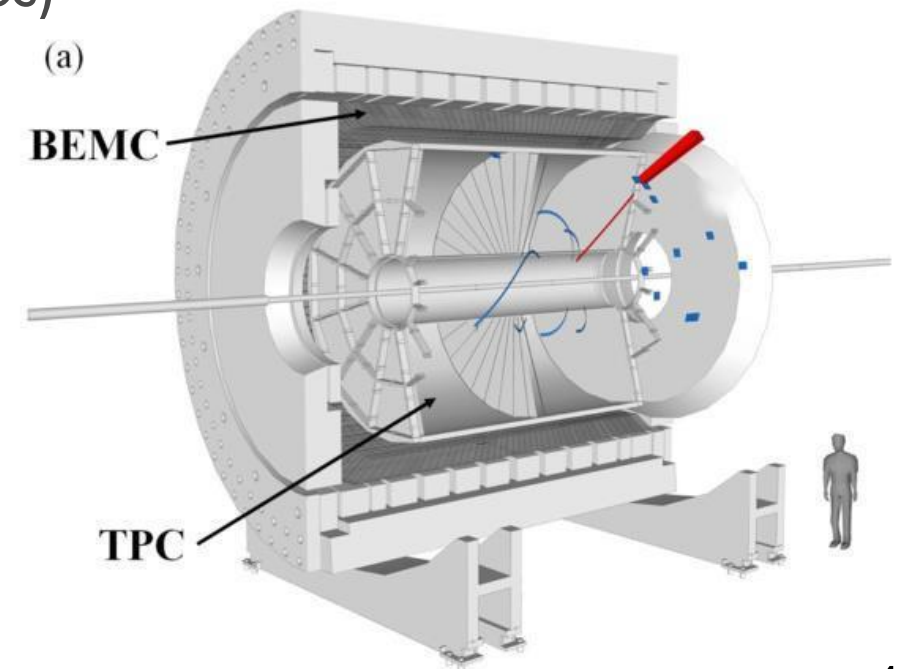
Motivation

- γ+jet provides reference scale for jet quenching
- Also useful to compare to QCD calculations
- Nuclear modification factor I_{AA} measures medium effect
- 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 $\bar{q}q$ annihilation

PYTHIA-6 STAR tune
p+p $\sqrt{s}$ = 200 GeV, |η|<1

γ-trigger

π^0-trigger

Relative quark fraction (recoil partons)

$p_T^{\pi^0}$ [GeV/c], E_T^γ [GeV]

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 $\boldsymbol{\pi \pm \frac{\pi}{4}}$ relative to π^0 or γ trigger

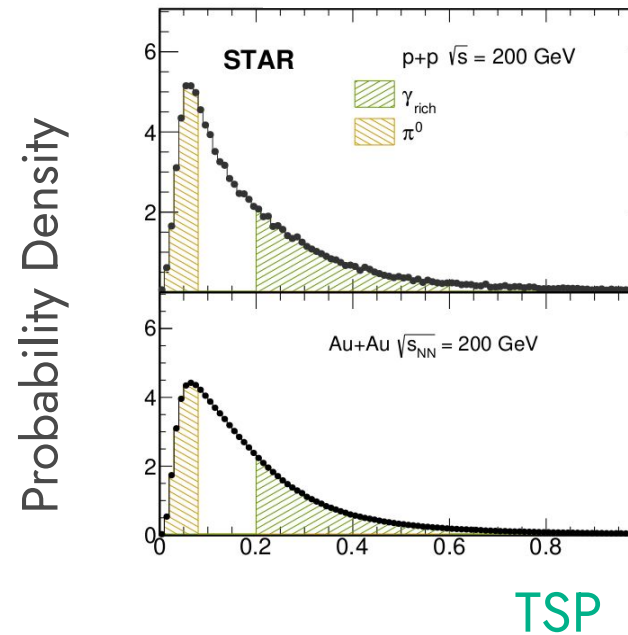Online trigger: BEMC High Tower (HT) trigger to select events of large energy depositions
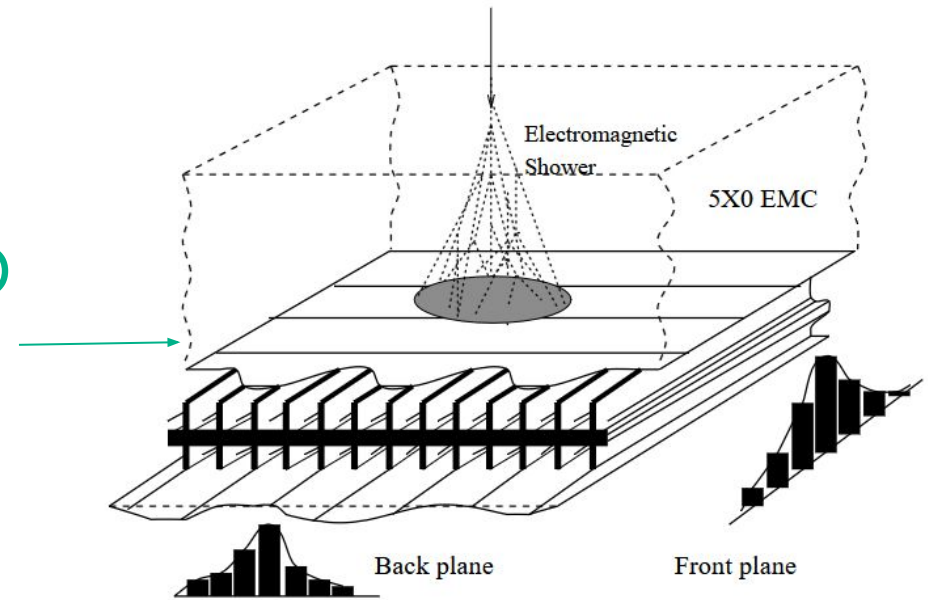
π^0/γ
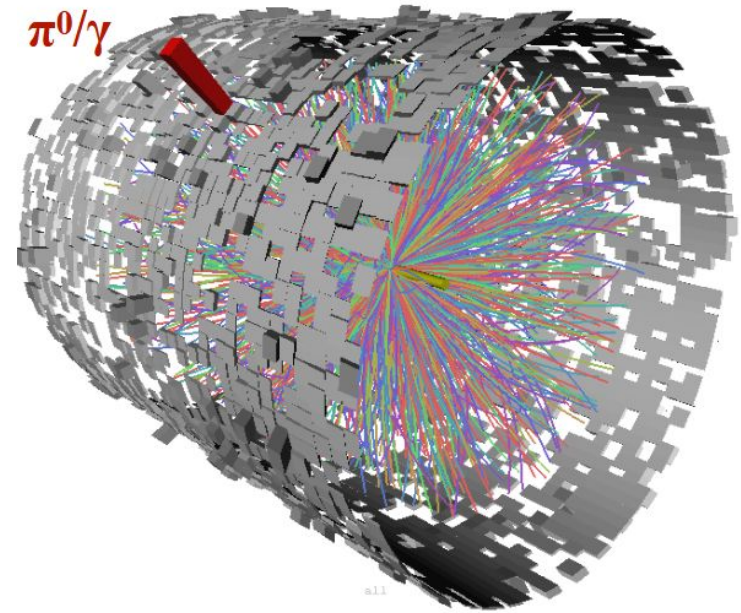
Event display
AuAu $\sqrt{s_{NN}}$ = 200 GeV

Trigger Identification

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

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

BSMD

(arXiv:2309.00156)

TSP

7

Jet Reconstruction

- Data points Raw per trigger jet yield
- Vertical length statistical uncertainty
- Horizontal length bin width
- Full reconstruction extends kinematic range cf. charged

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

ϱ = event background energy density

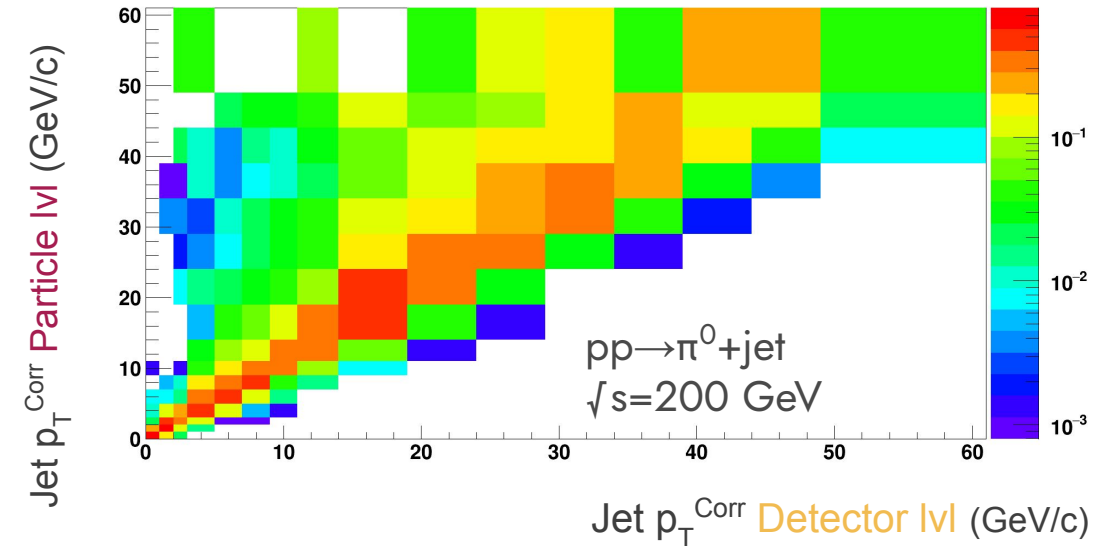A_{jet} = jet area $p_{T,jet}^{corr} = p_{T,jet}^{raw} - \varrho A_{jet}$

Raw Data Jet p_T Spectra
$E_T \pi^0$ = 9-11 GeV R=0.5

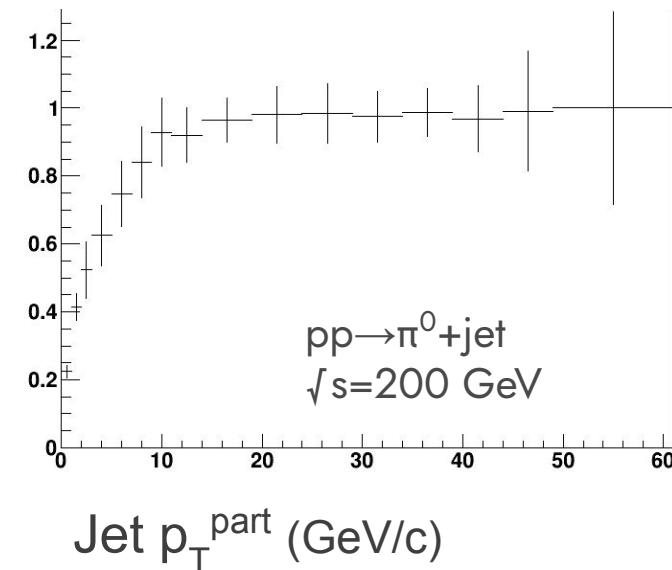pp→π^0+jet
√s=200 GeV
Raw Data

Jet $p_{T, jet}^{corr}$ (GeV/c)
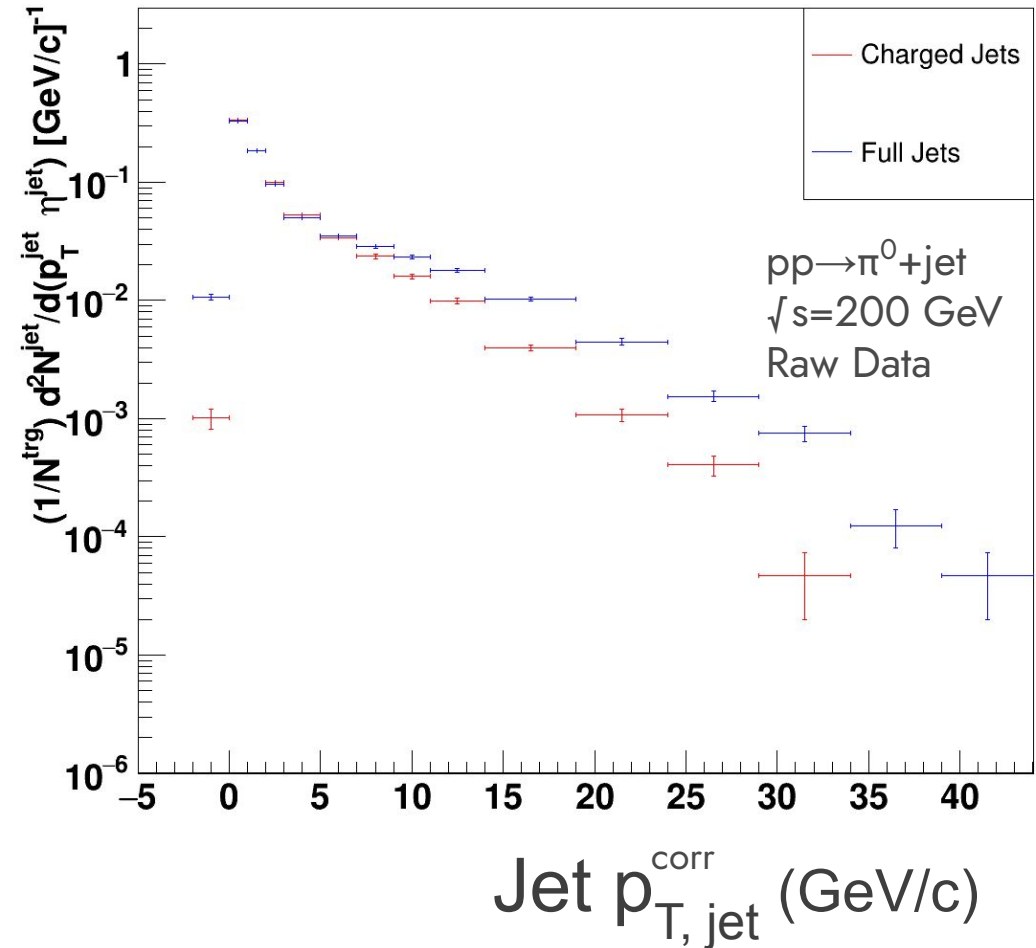
Corrections

- 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 p_T^{Corr} Particle lvl (GeV/c)
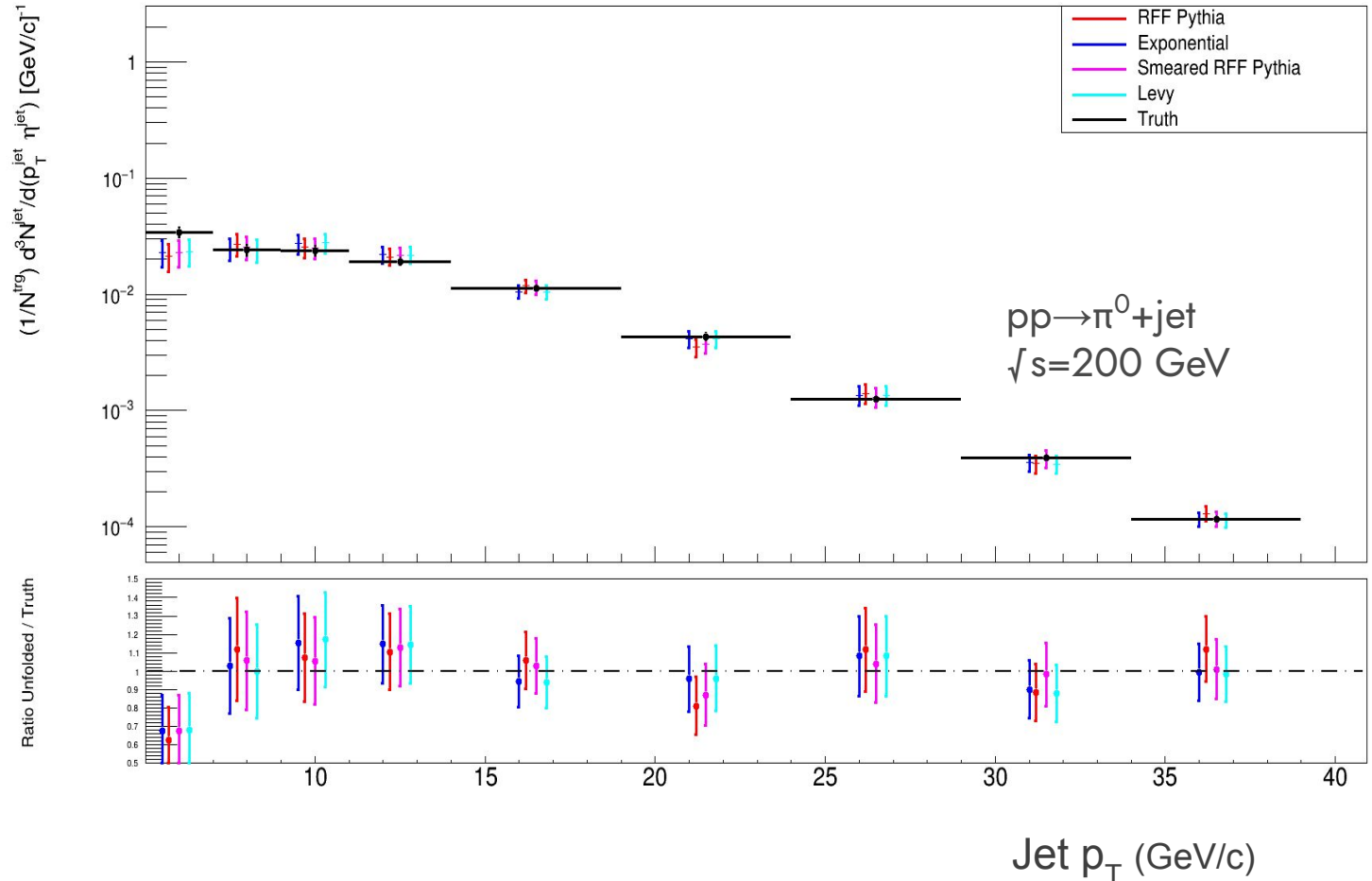
Jet p_T^{Corr} Detector lvl (GeV/c)

pp→π^0+jet
$\sqrt{s}$=200 GeV

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

pp→π^0+jet
$\sqrt{s}$=200 GeV

Jet p_T^{part} (GeV/c)

Global Physics Summit

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

$pp \rightarrow \pi^0 + jet$
$\sqrt{s}$ = 200 GeV

Legend:
- RFF Pythia
- Exponential
- Smeared RFF Pythia
- Levy
- Truth

y-axis: $(1/N^{trg})\ d^3N^{jet}/d(p_T^{jet}\ \eta^{jet})$ [GeV/c]$^{-1}$

Ratio Unfolded / Truth

Jet p_T (GeV/c)

Systematics

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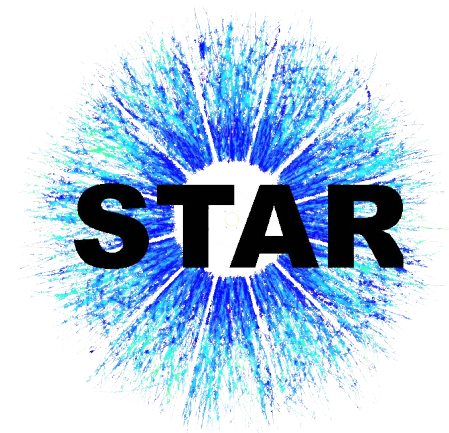- Fragmentation model

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
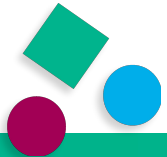
Supported in part by

Global Physics Summit

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 $\Delta\eta = 1$, $\Delta\varphi = 0.1$

Comparison of Tower Energy Spectrum Before and After QA for 2014 Dataset
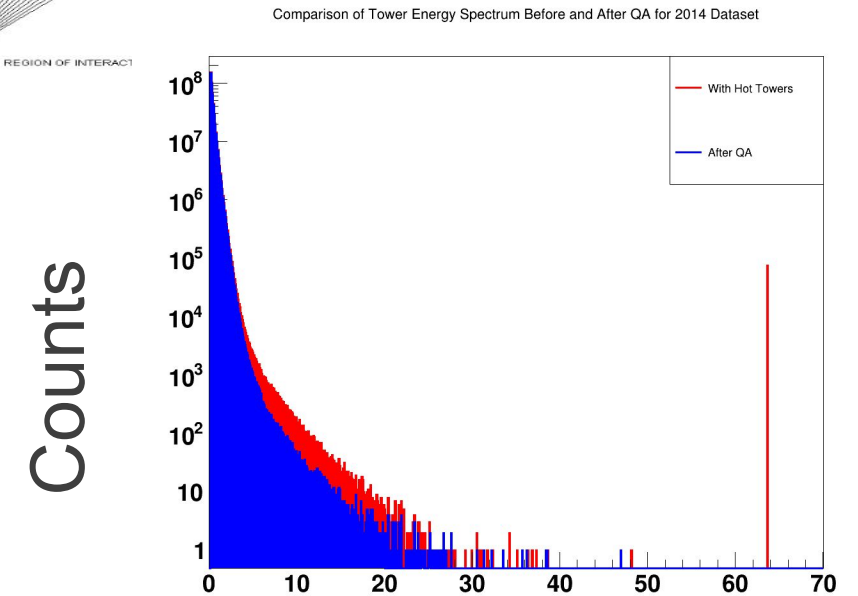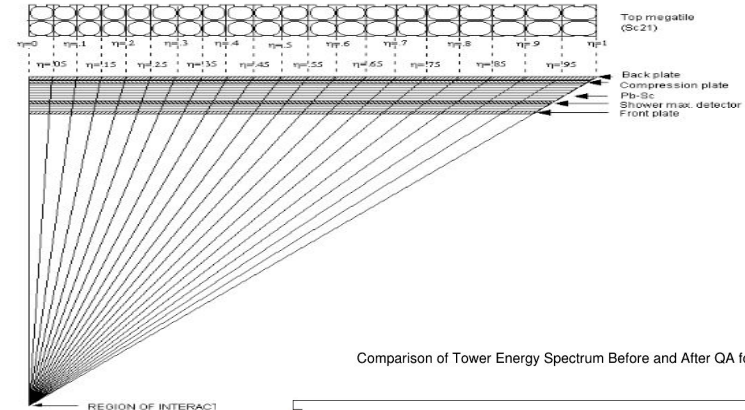
Hadronic Correction

- 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

Comparison of Tower Energy Spectrum Before and After Hadronic Correction for 2014 Dataset
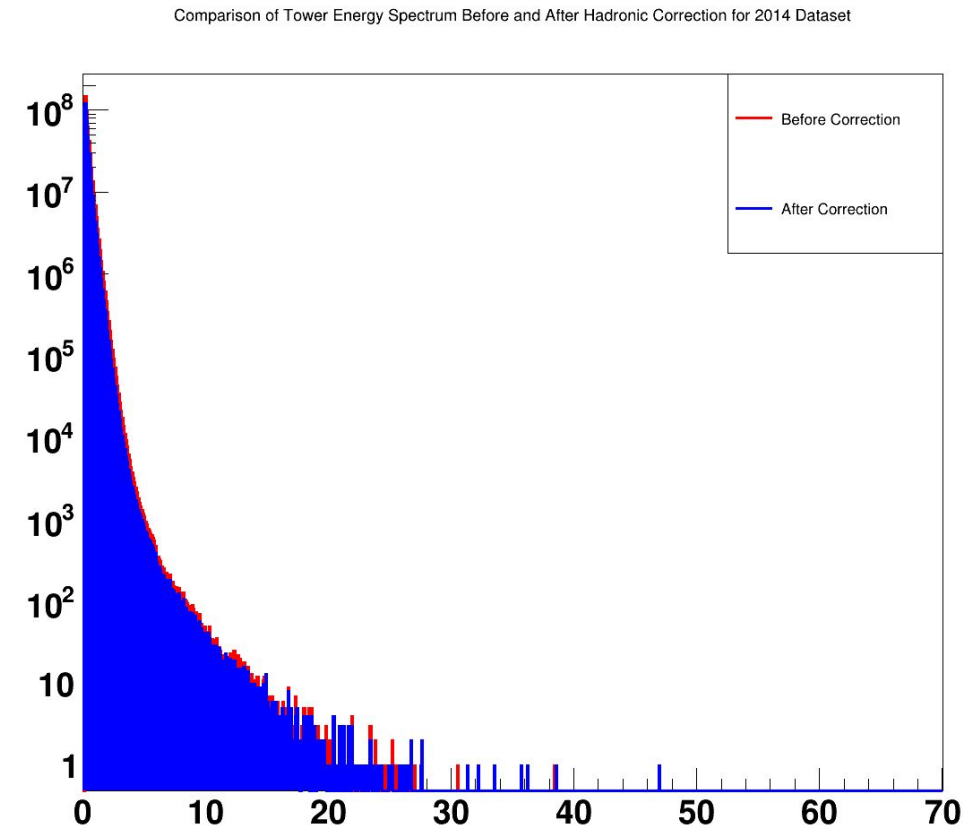
Choice of Prior

- 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

Comparison of prior choices used in closure, π^0 E_T = 9-11, R=0.2
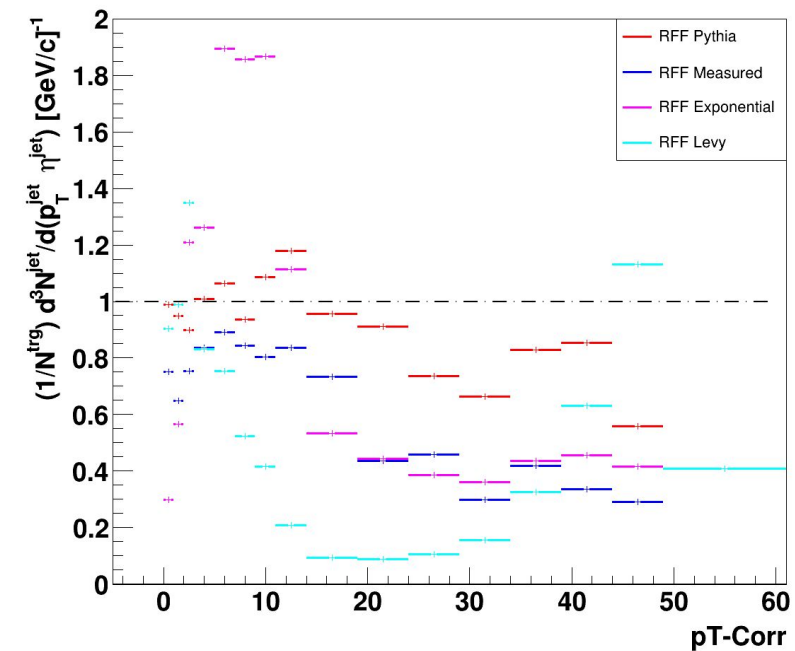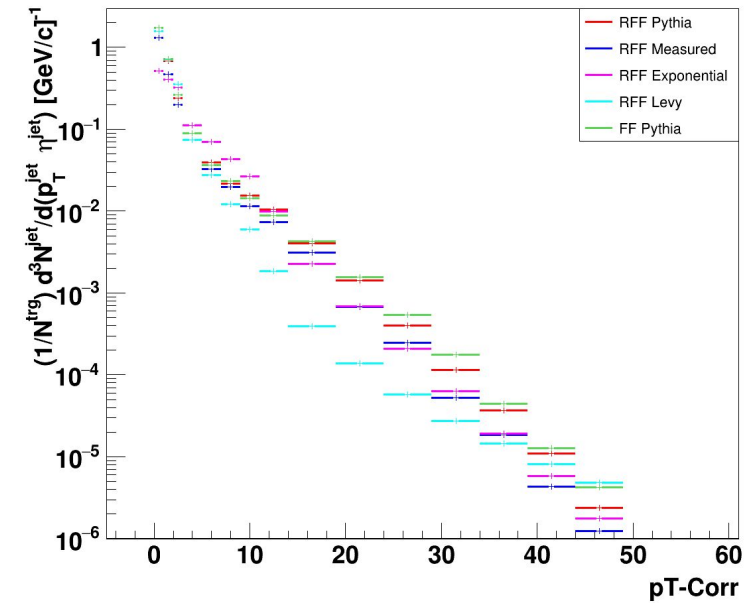
Heavy Ion Background

- 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
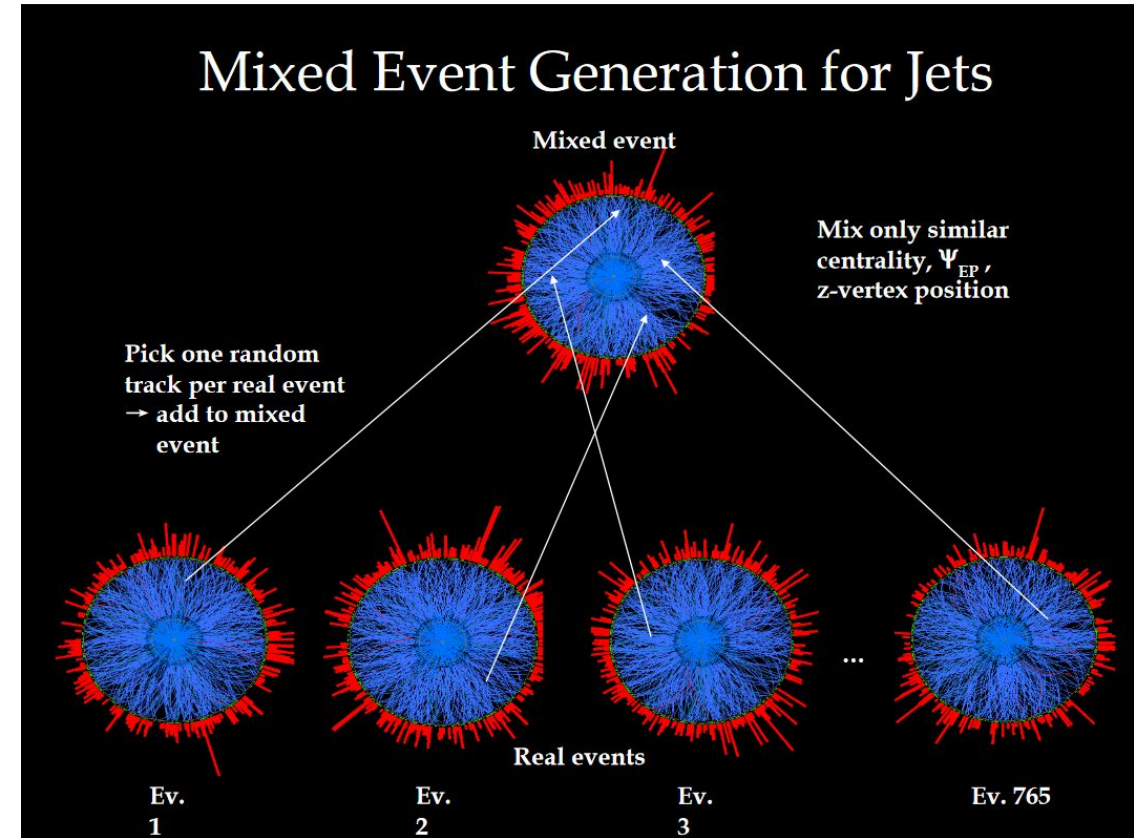
A figure describing event mixing for tracks