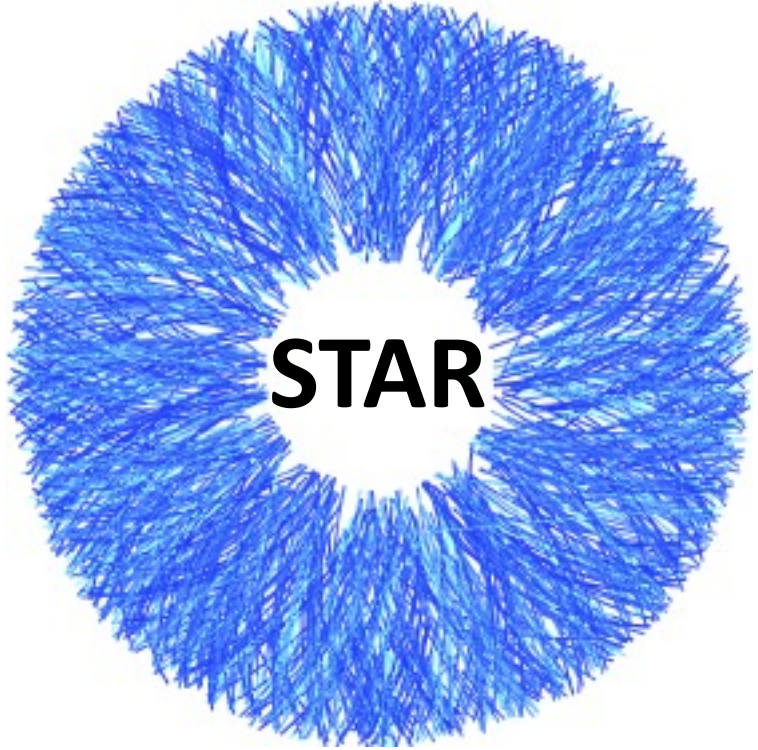

An Investigation of Charm Quark Jet Spectrum and Shape Modifications in Au + Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV

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U.S. DEPARTMENT OF ENERGY | Office of Science

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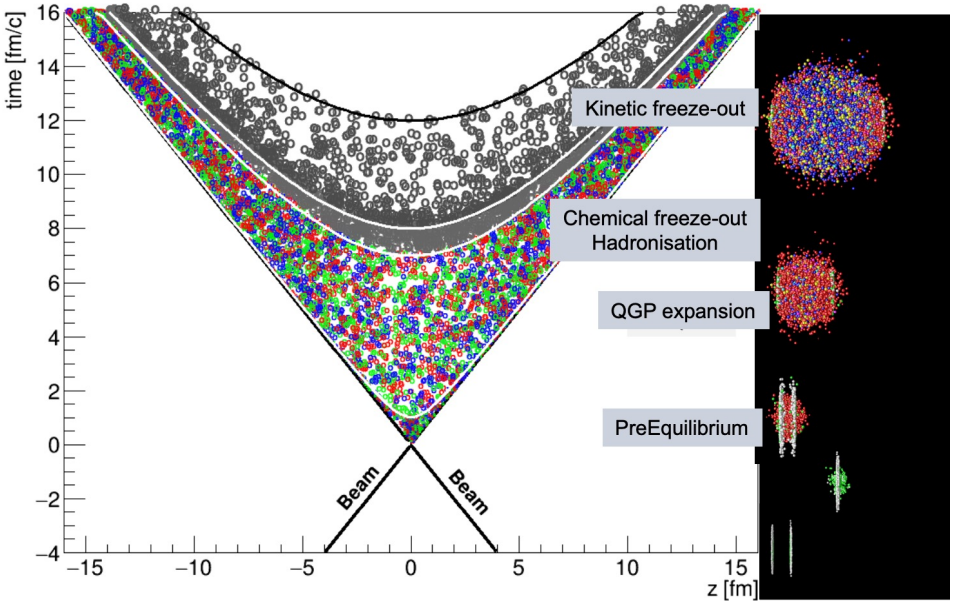
THE STATE UNIVERSITY OF NEW JERSEY

Introduction

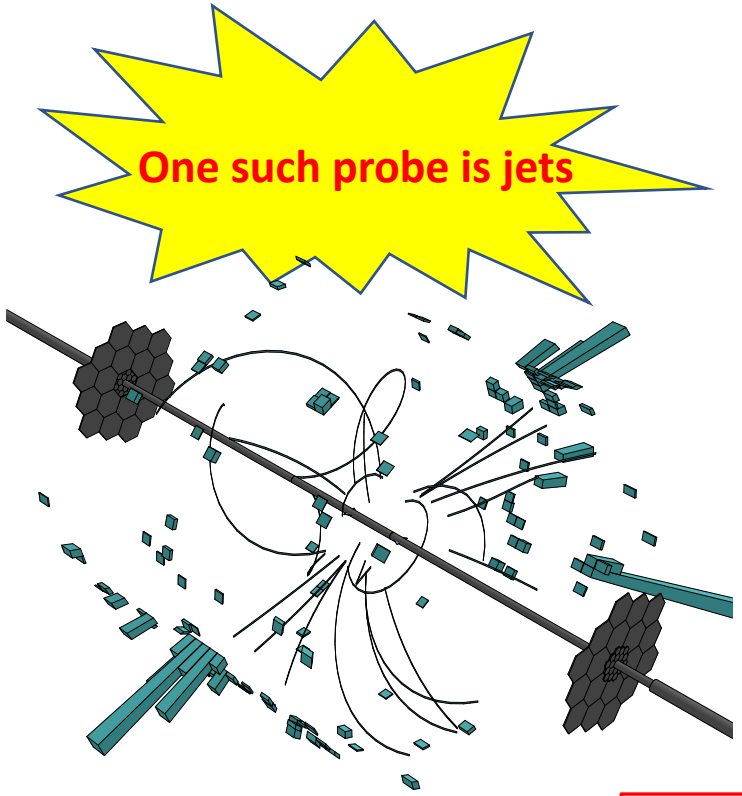
Lorentz Contracted Nuclei collide, form **Quark-Gluon Plasma**

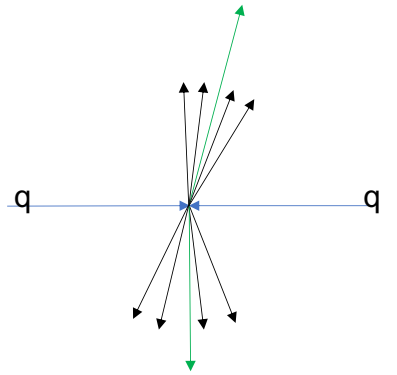


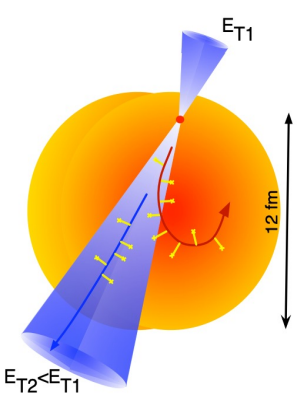
- Loss of energy and momentum in the QGP medium
- Broaden due to medium-induced radiation and scattering
- Reconstructed in experiment by a clustering algorithm, commonly anti-k_T [1]

1. Phys. Lett. B 641 (2006) 57-61

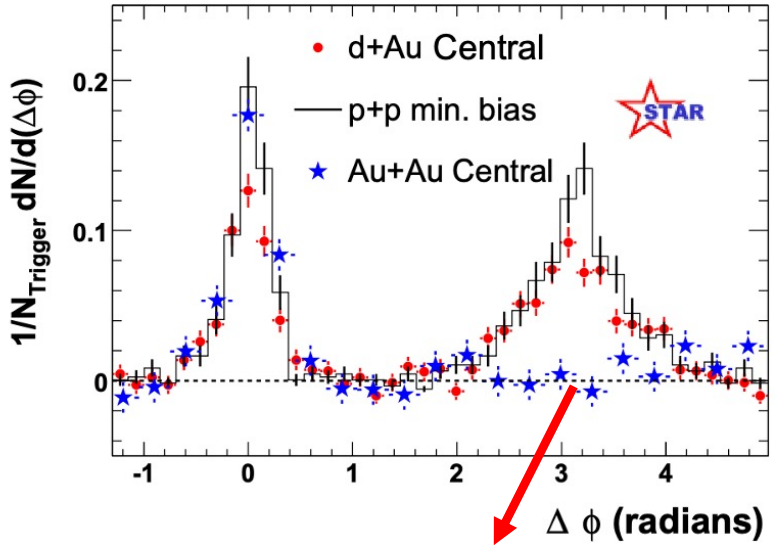
Hard probe → Strong interaction between high p_T partons and medium





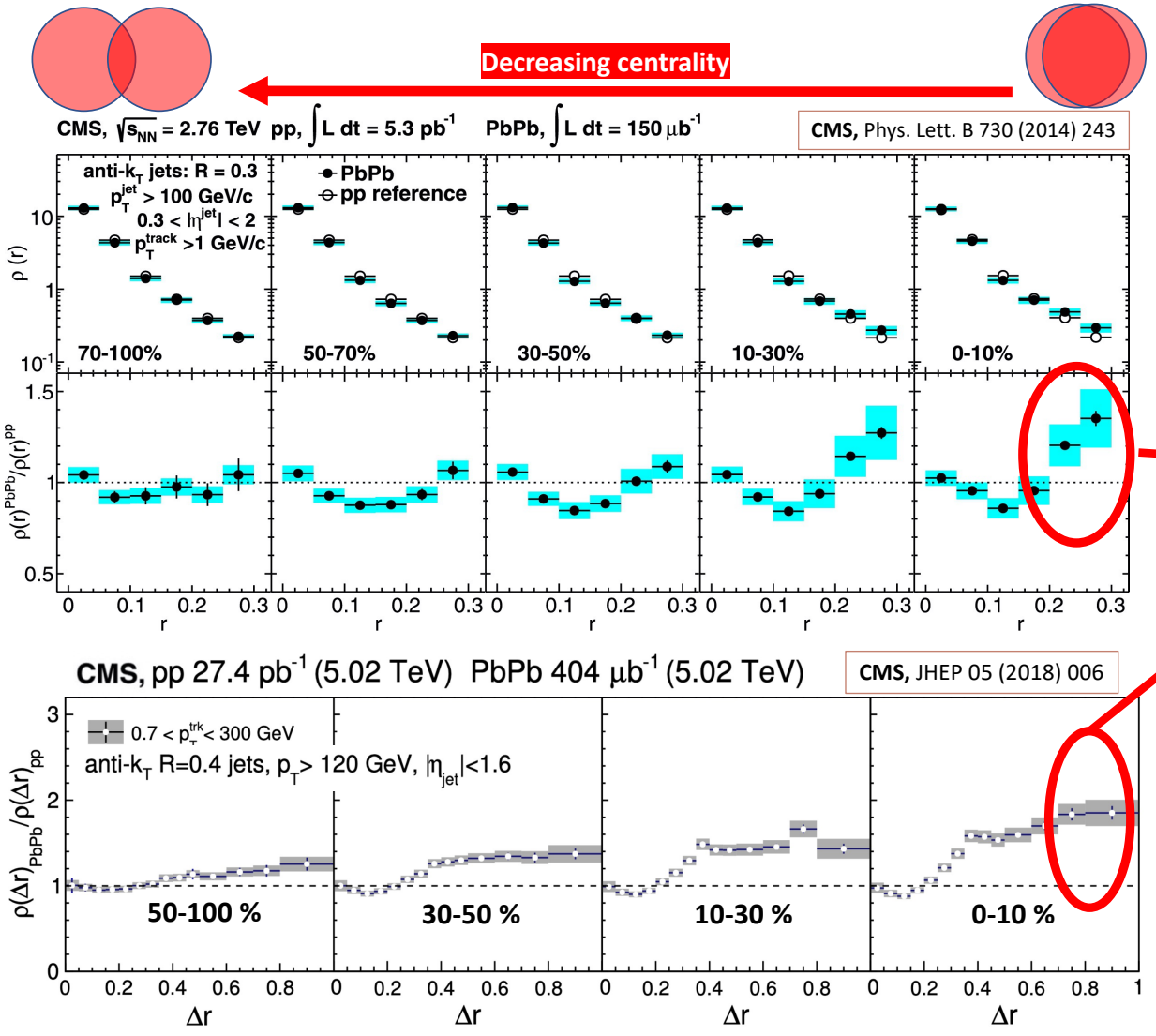


STAR, Phys. Rev. Lett. 91 (2003) 072304



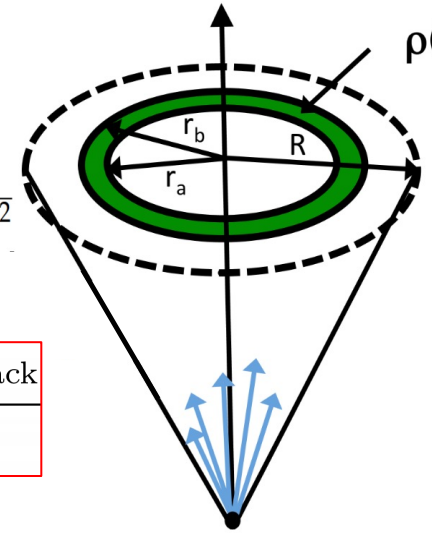
Far side jets are heavily quenched in the presence of QGP.

Previous Jet Results



$$r = \sqrt{(\eta_{\text{track}} - \eta_{\text{jet}})^2 + (\phi_{\text{track}} - \phi_{\text{jet}})^2}$$

$$\rho(r) = \frac{1}{\Delta r}\frac{1}{N_{\text{jet}}}\sum_{\text{jet}}\frac{\sum_{\text{track}\in(r_a,r_b)} p_{\text{T,track}}}{p_{\text{T,jet}}}$$



Jet energy is redistributed to large distances from the jet axis in the presence of QGP.

Possible mechanisms:

- Spallation of the soft underlying event due to jet
- Multiple-scattering
- Medium-induced Bremsstrahlung
- Medium Response

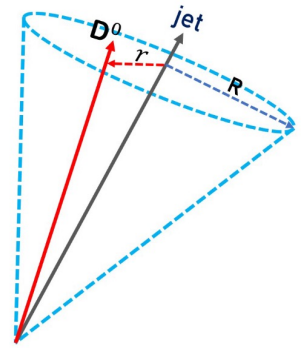
Dependent on the mass of the underlying parton

Motivation to look at heavy flavor jets

Previous Jet Results

Jets from Charm Quark

$$\text{Radial Distribution} = \frac{1}{N_{\text{Jet},D^0}} \frac{dN_{\text{Jet},D^0}}{dr}$$



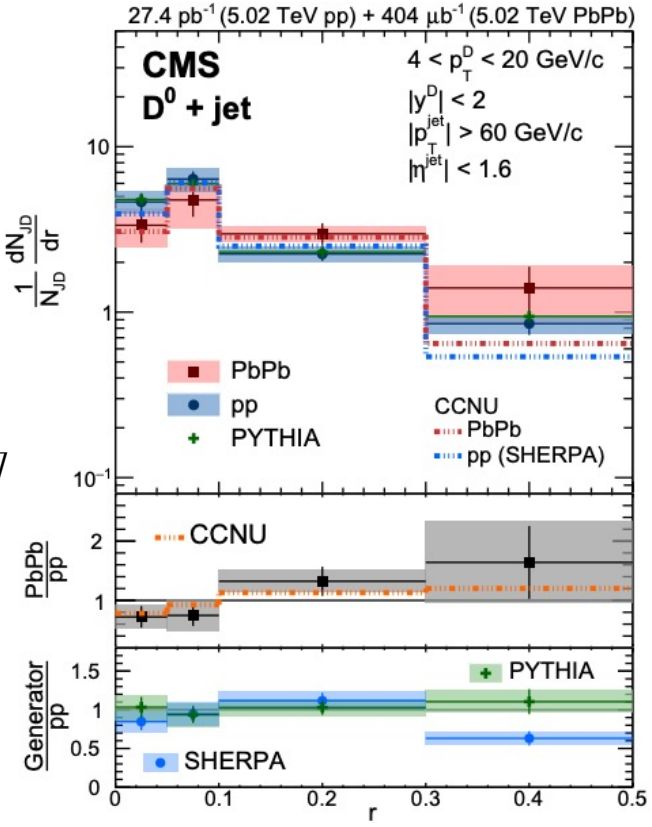
- Charm is one of the heavier quarks (m ~ 1.3 GeV/c^2)
  - ✓ Usually produced early in the collision, so have access to full QGP evolution
- Medium modifications expected to be different for charm quark vs light quarks
- Radiation for charm quarks suppressed due to '*dead cone*' effect [1]
  - ✓ Results in different emission spectra compared to light quarks
- We study jets containing mesons with charm quarks ($D^0(c\bar{u})$)

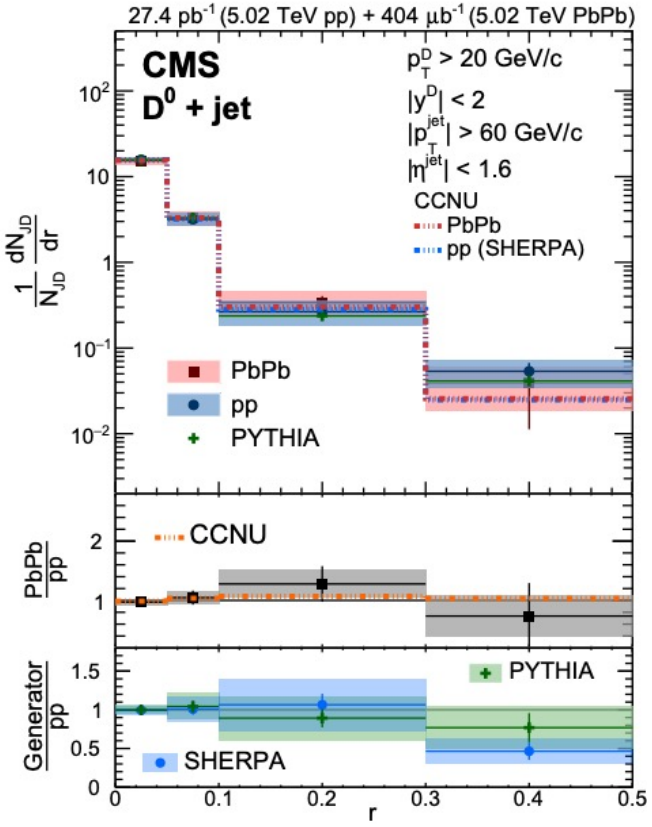
Low p_T D^0s diffused in the presence of QGP.
High p_T D^0s in jets do not show such modification.

~ Trend explained well by models with collisional and radiative corrections [2]

Better access to low p_T D^0 region at STAR energies

CMS, Phys. Rev. Lett. 125 (2020) 102001



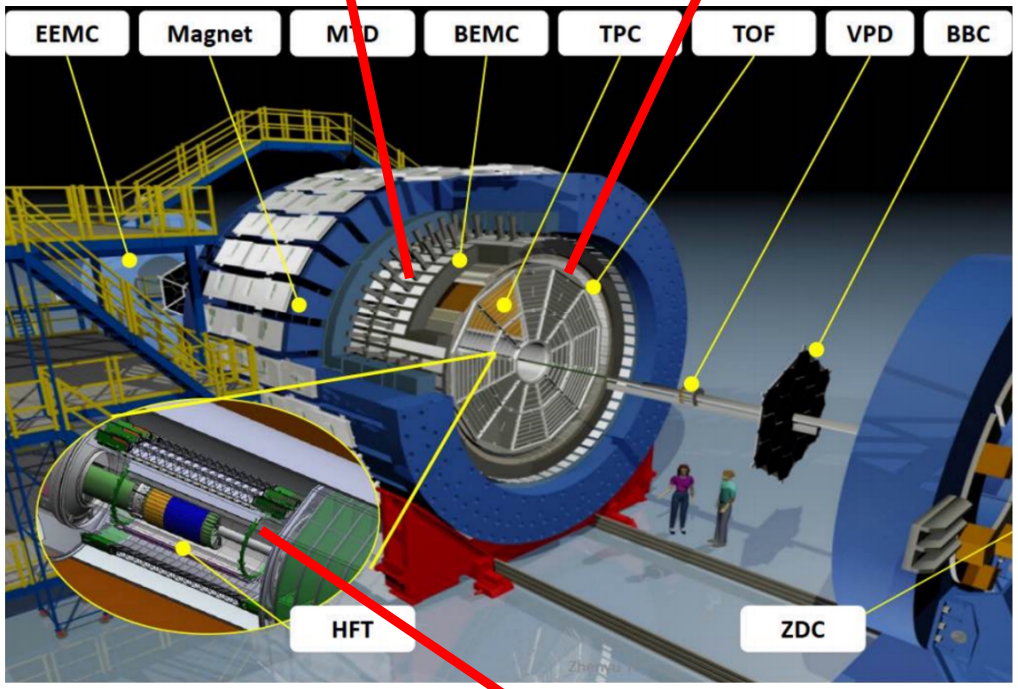


1. **ALICE**, arXiv:2106.05713
2. Eur.Phys.J. C79 (2019) 789

STAR Detector and Dataset used

Time Projection Chamber (TPC)
- Measures momentum, track trajectory, and identifies charged particles

Time-of-Flight Detector (TOF)
- Identifies charged particles



Heavy Flavor Tracker (HFT)
- Improves position resolution for tracks

Event Selection :

- Au+Au $\sqrt{s_{NN}}$ = 200 GeV, Run14
- Minimum bias (MB)
- Centrality ∈ [0, 80]% (3 bins: [0-10], [10-40], [40-80])

Track Selection :

- $0.2 < p_{T,track}$ [GeV/c] < 30 ; $0.2 < p_{T,tower}$ [GeV/c] < 30
- $|\eta_{track}| < 1$; $|\eta_{tower}| < 1$
- $D^0 \rightarrow K^- + \pi^+$ (and the conjugate) [B.R. = 3.82 %]
- For D^0 reconstruction: Tracks need at least two hits in HFT
- $1 < p_{T,D^0}$ [GeV/c] < 10

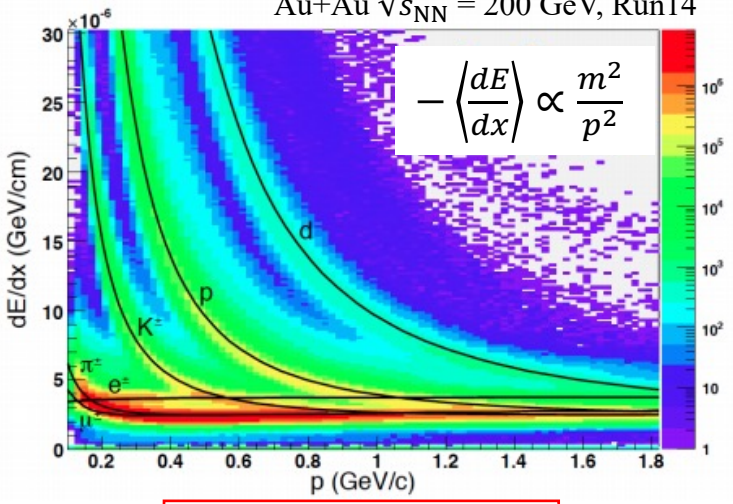
D^0 Jet Selection :

- Anti-k_T jets of radius R = 0.4, area-based background subtraction
- $3 < p_{T,Jet}$ [GeV/c] < 30
- $|\eta_{Jet}| < 0.6$

D^0 Reconstruction

TPC

Au+Au $\sqrt{s_{NN}}$ = 200 GeV, Run14

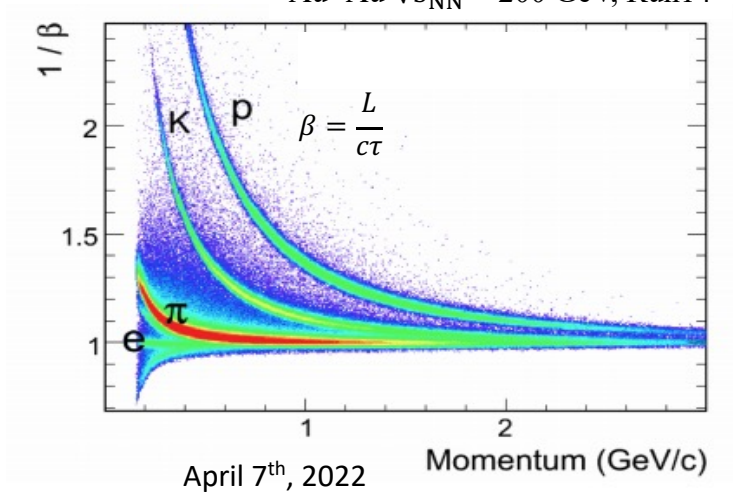


$|n\sigma_\pi| < 3.0; |n\sigma_K| < 2.0$

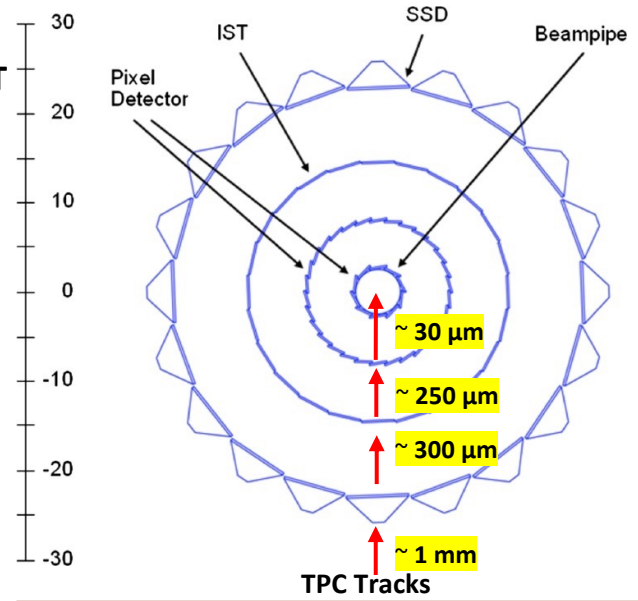
$|\frac{1}{\beta} - \frac{1}{\beta_{exp}}| < 0.03$

TOF

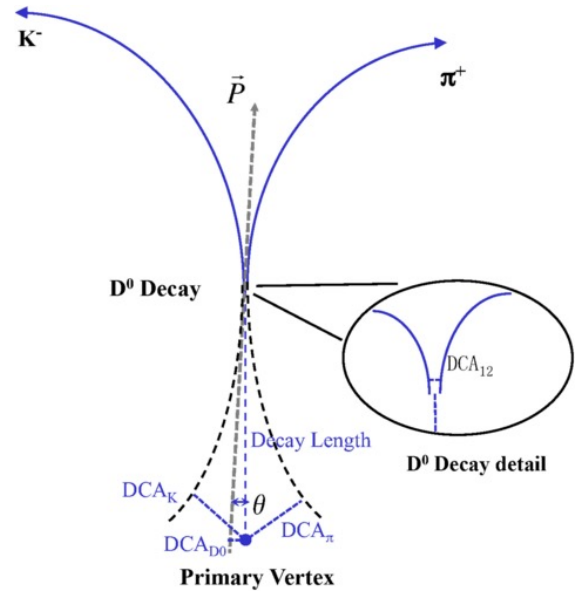
Au+Au $\sqrt{s_{NN}}$ = 200 GeV, Run14



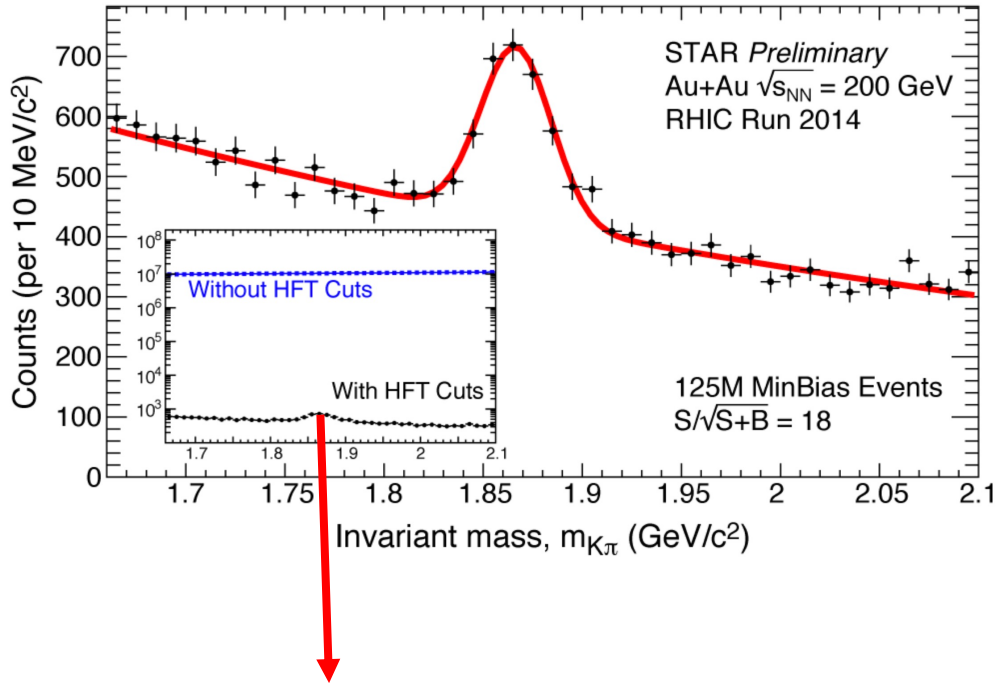
HFT



STAR, Phys. Rev. C 102 (2020) 014905



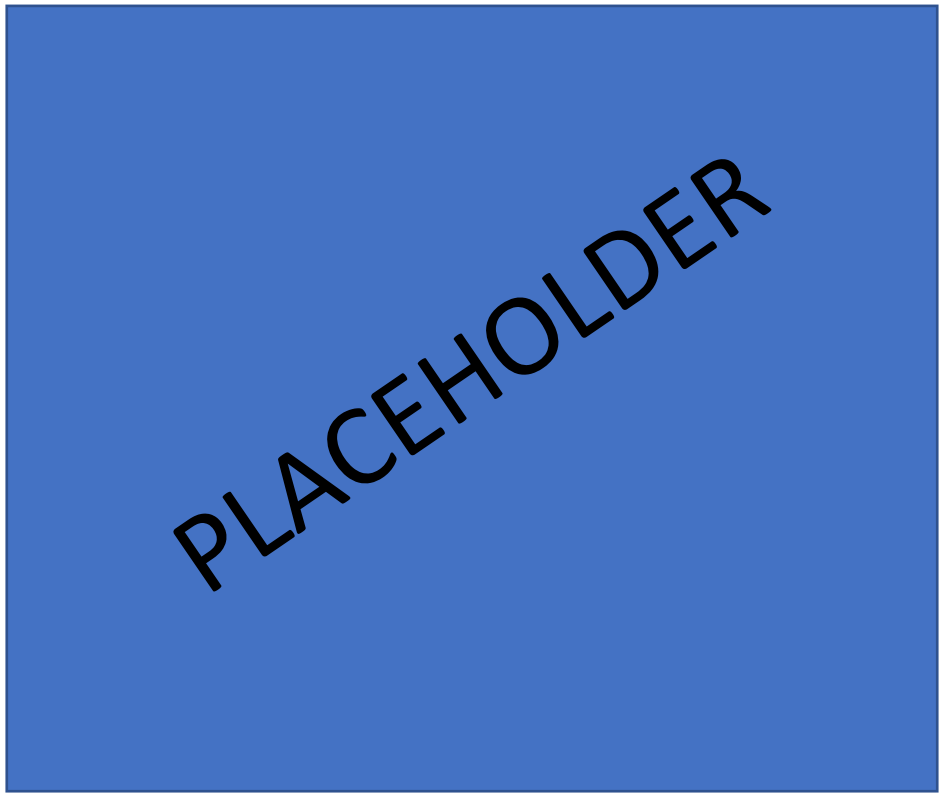
- Decay Length of D^0 ~ 123 μm.
- HFT has a resolution of 30 μm for kaons at ~ 1.2 GeV/c
- HFT can reconstruct D^0 candidates based on the decay kinematics



Topological cuts on the D^0 candidates improve signal significance

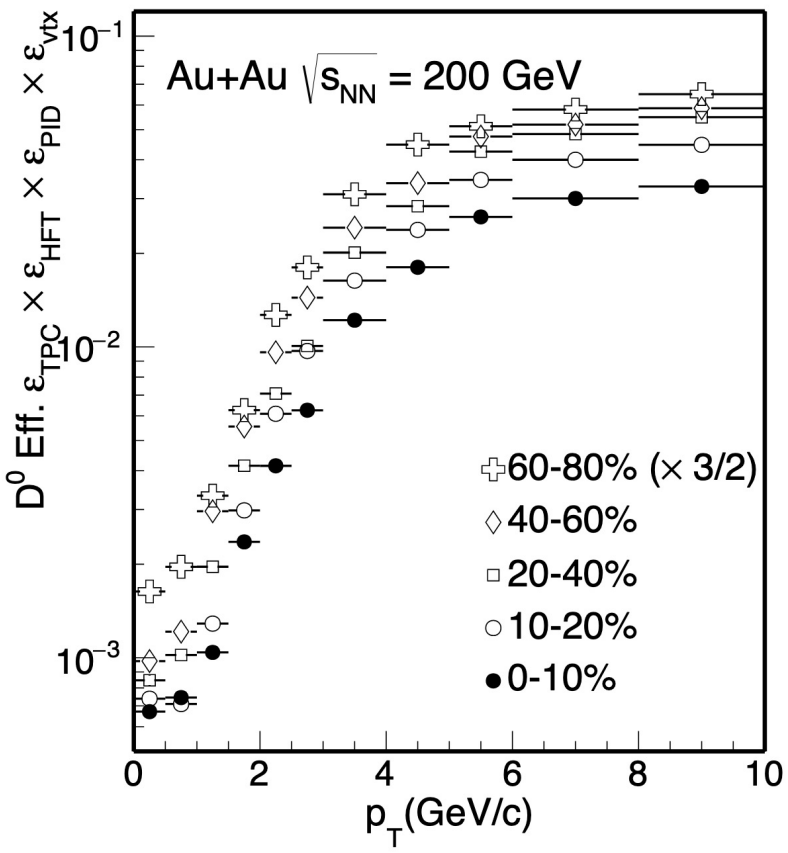
D^0 Reconstruction

sPlot Method (Short Method and yield comparison plot for one bin)



Efficiency Corrected D^0 Jet Yield

STAR, Phys. Rev. C 99 (2019) 034908



D^0 yield corrected for reconstruction efficiency

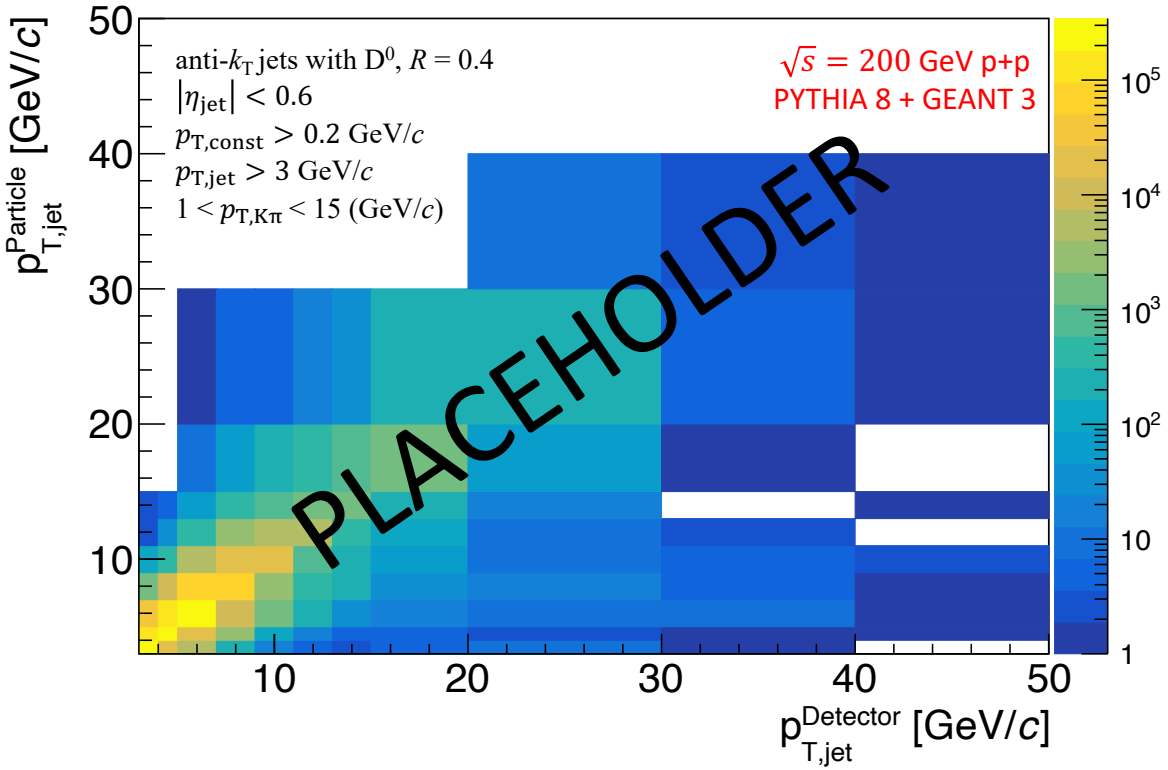
The efficiency weights were derived using a data-driven fast simulation method

PLACEHOLDER

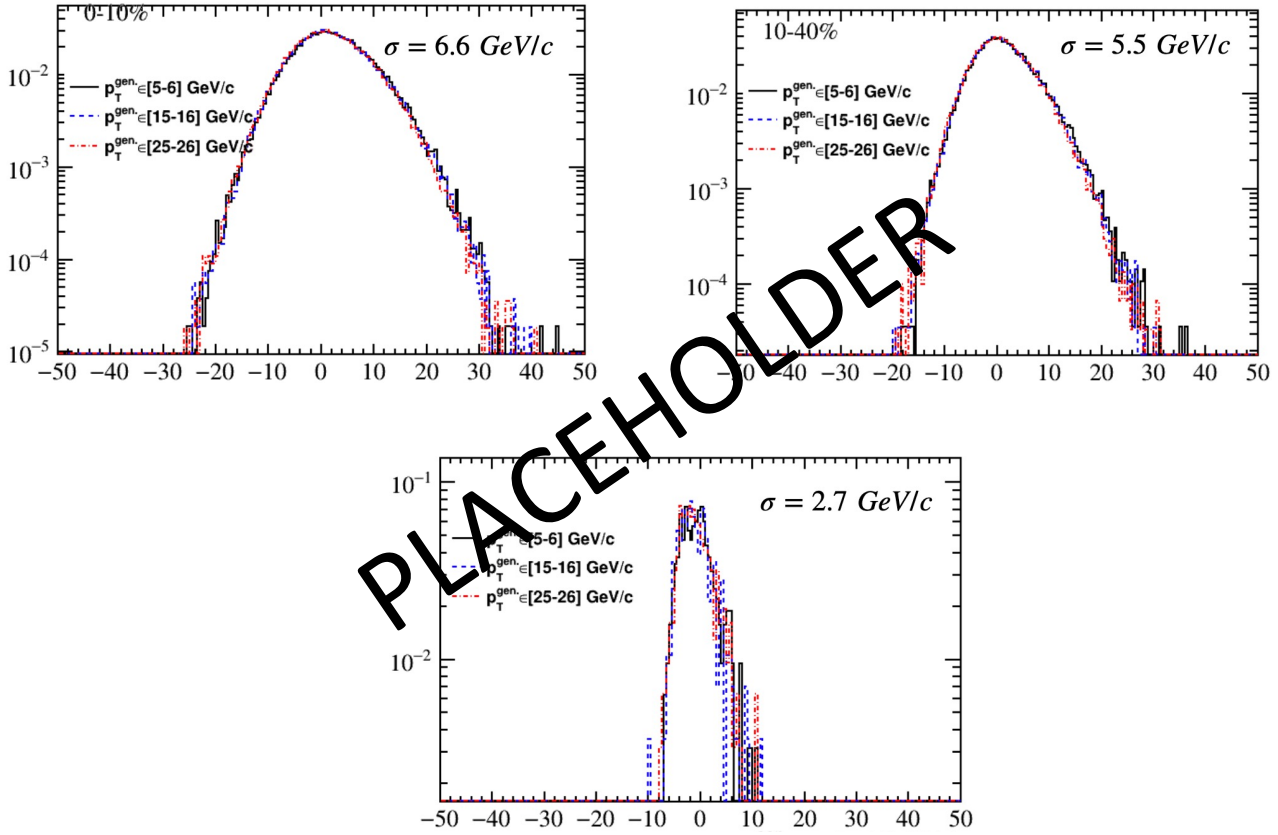
Raw Au + Au D^0 Jet Spectrum and Radial Distribution of D^0 in Jet

Efficiency Correction Using Unfolding

Instead of a full embedding sample, existing fast simulation method along with a *PYTHIA 8* simulation to estimate detector effects.

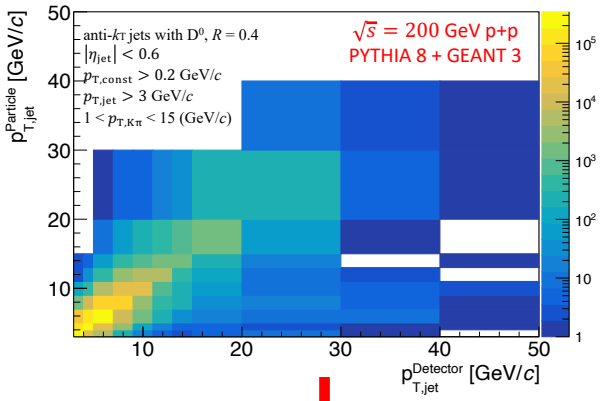


HI background fluctuation estimated by embedding a hard track in min-bias events

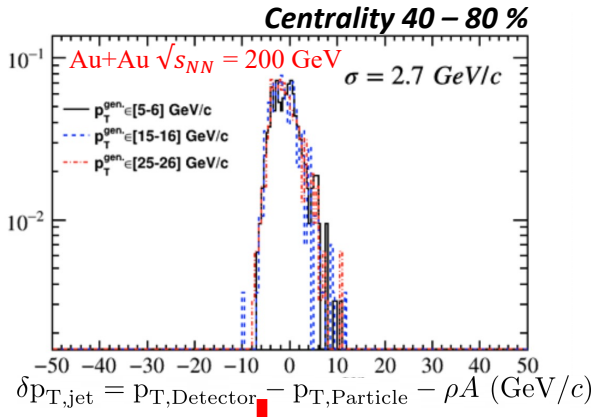


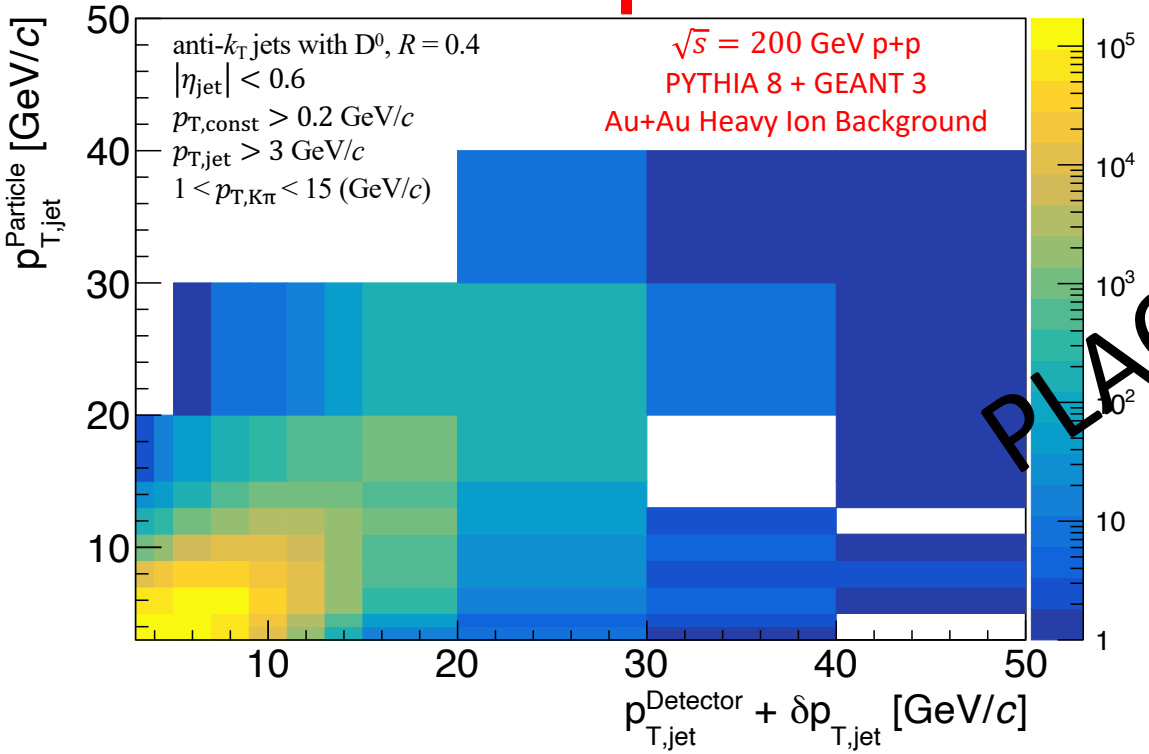
Background fluctuation is independent of p_T of hard track

Closure for Unfolding Jet Spectrum



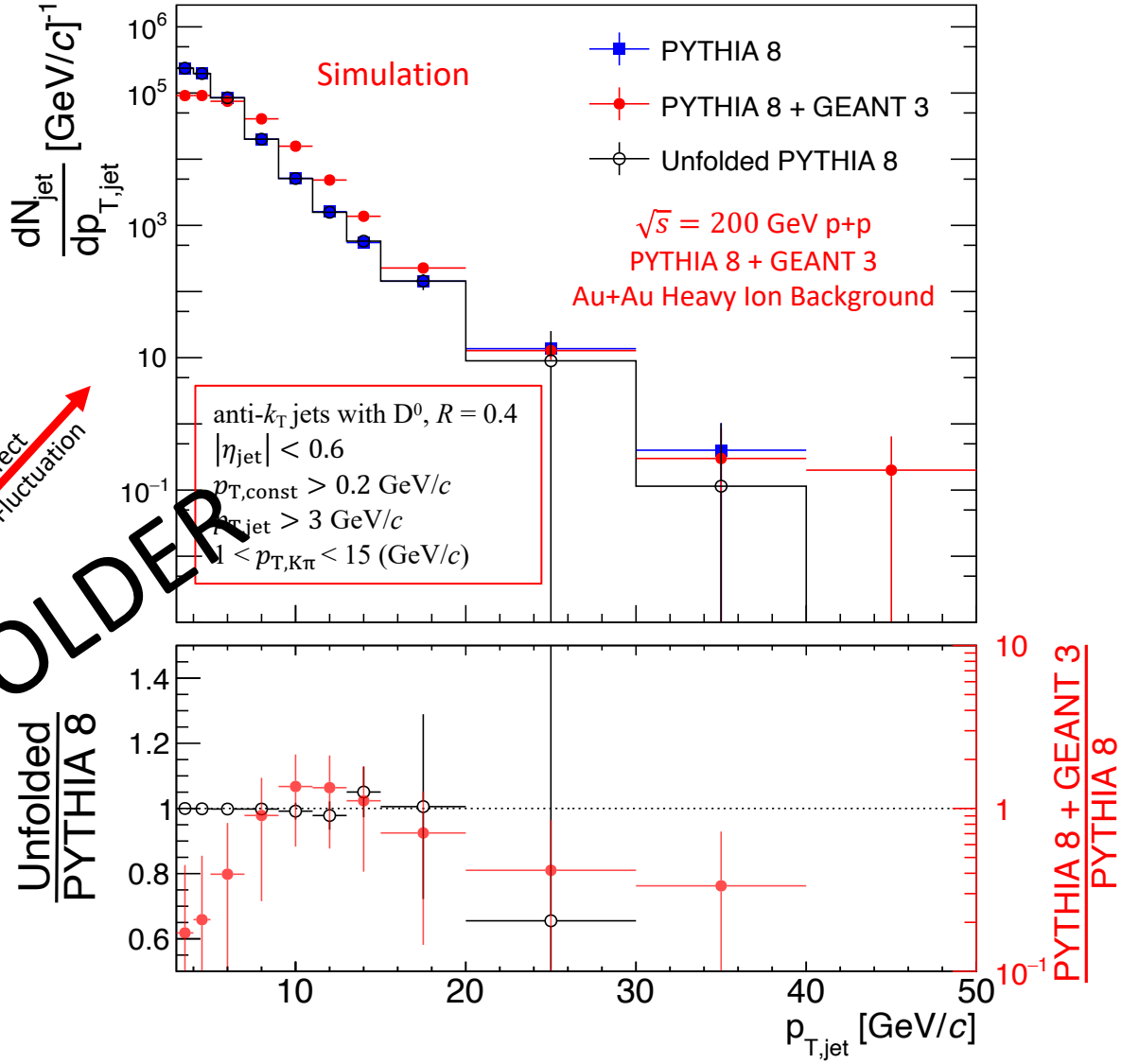
X





Detector Effect
Background Fluctuation

PLACEHOLDER



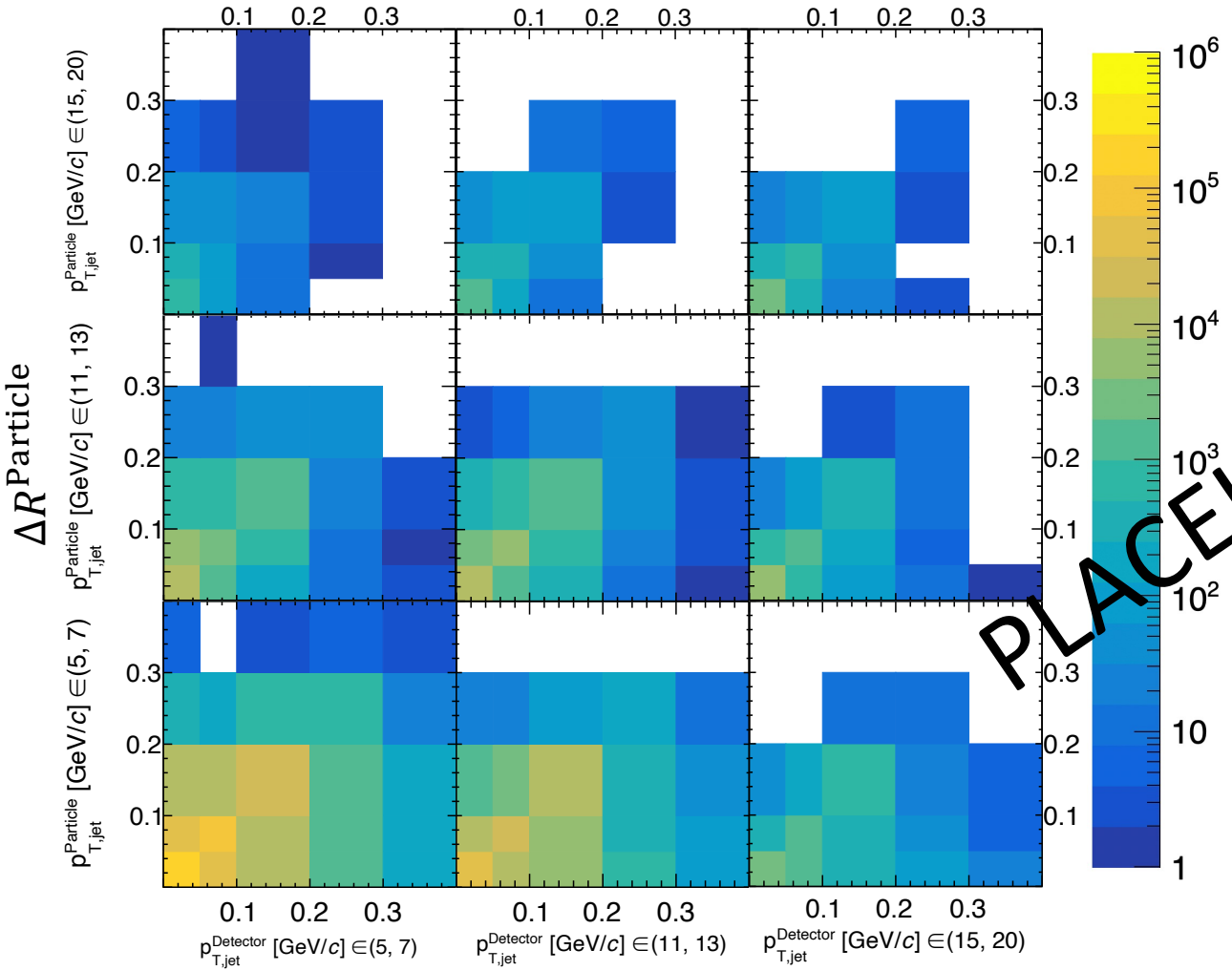
Closure test shows that we can reproduce the particle level $p_{T,jet}$ spectrum using unfolding

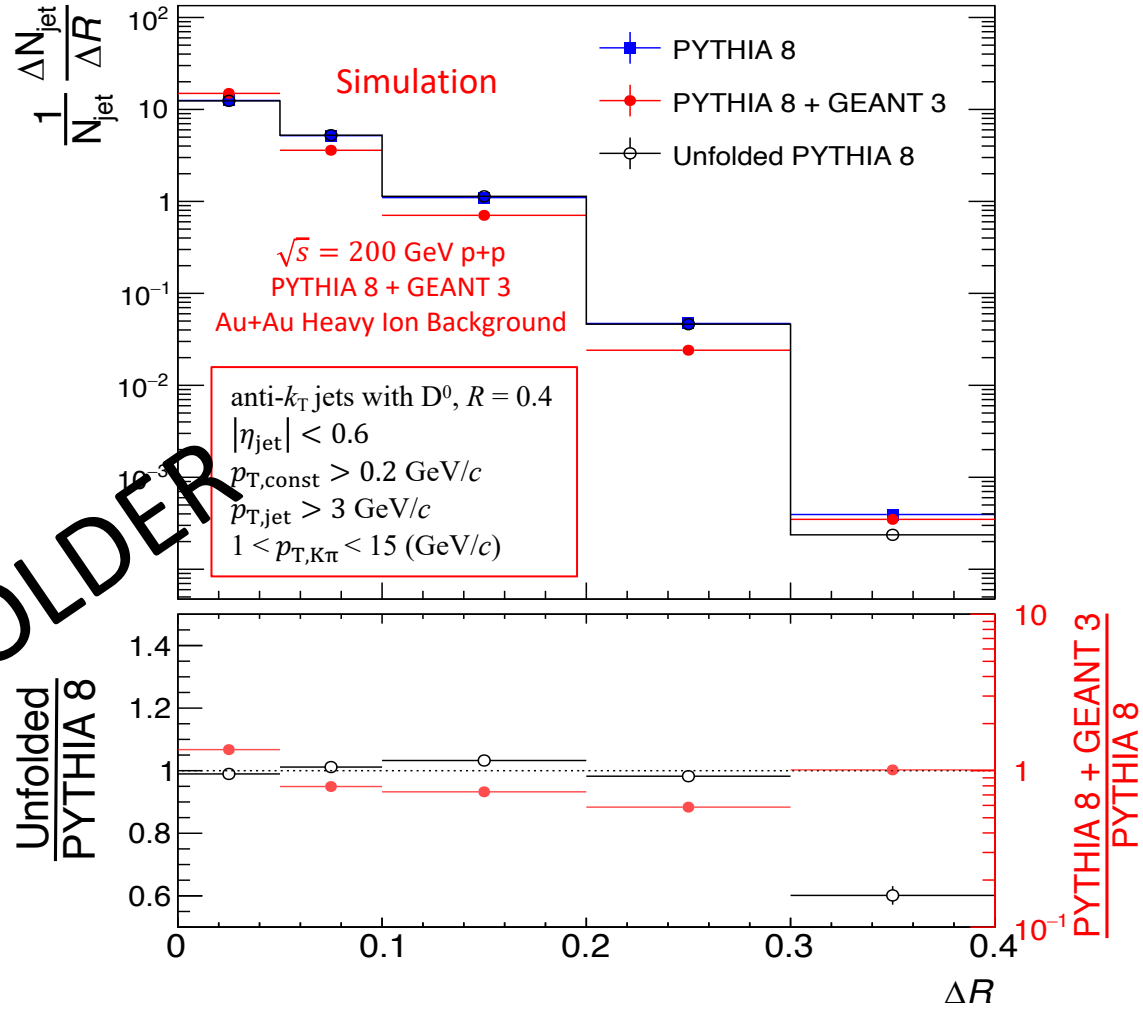
Closure for Unfolding Radial Distribution of D^0 Mesons in Jets

anti-k_T jets with D^0, $R = 0.4$
$|\eta_{jet}| < 0.6$
$p_{T,const} > 0.2$ GeV/c
$p_{T,jet} > 3$ GeV/c
$1 < p_{T,K\pi} < 15$ (GeV/c)

$\sqrt{s} = 200$ GeV p+p
PYTHIA 8 + GEANT 3
Au+Au Heavy Ion Background

Radial distribution is unfolded along with the $p_{T,jet}$





PLACEHOLDER

- **Closure test shows that we can reproduce the radial distribution of D^0 mesons for low and mid ΔR using 2D unfolding**

Jet Spectrum and R_{CP}

Probable comparison to inclusive charged jets RCP, D0 RCP here

Radial Distribution of D^0 Mesons in Jets and R_{CP}

RCP in two D0 pT bins (1-4, 4-10). Comparison with CCNU (???)

Summary