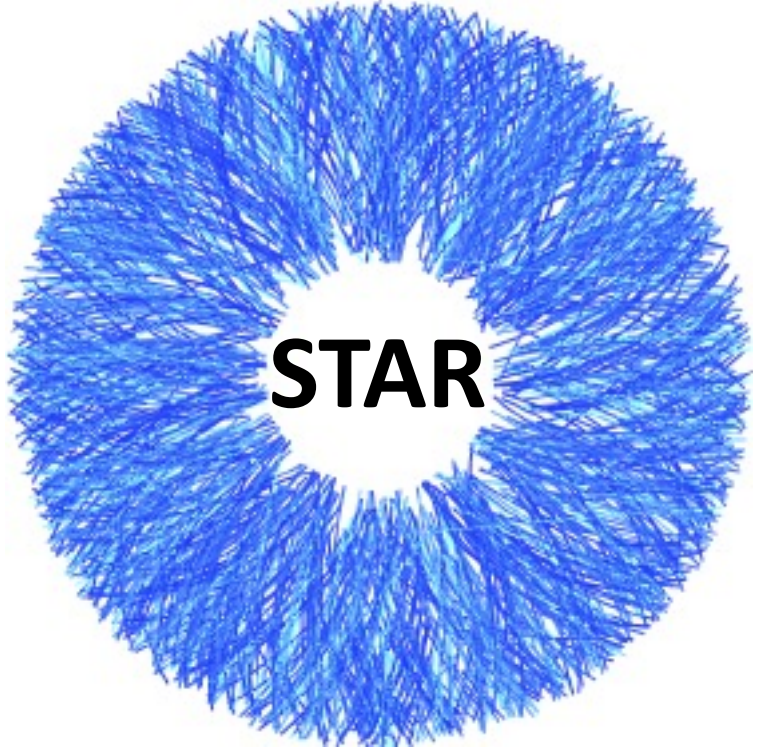


An Investigation of Charm Quark Jet Spectrum and Shape Modifications in Au + Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV

Diptanil Roy

For the *STAR Collaboration*

roydiptanil@gmail.com

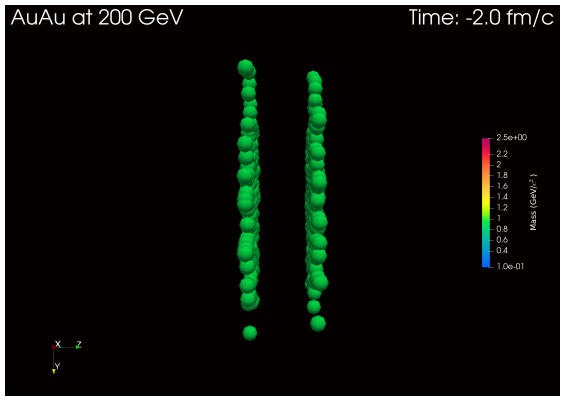
U.S. DEPARTMENT OF ENERGY | Office of Science

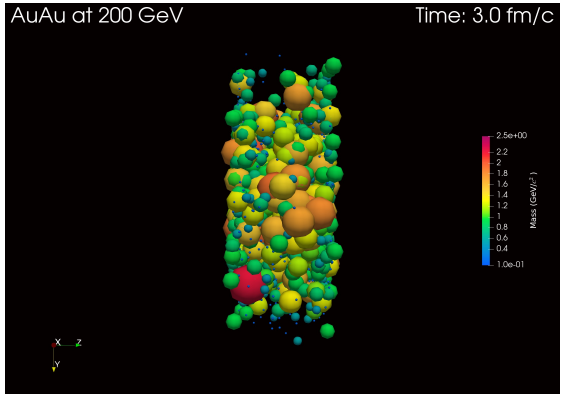
RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

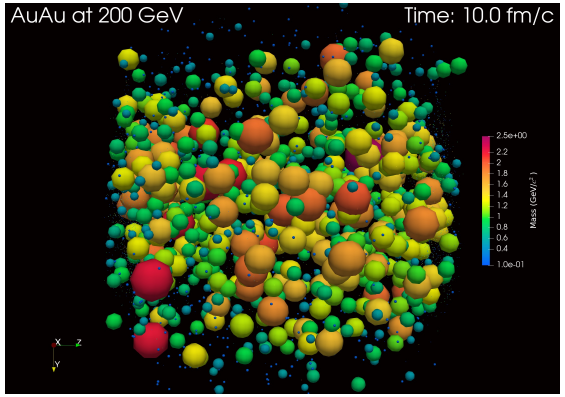
Introduction

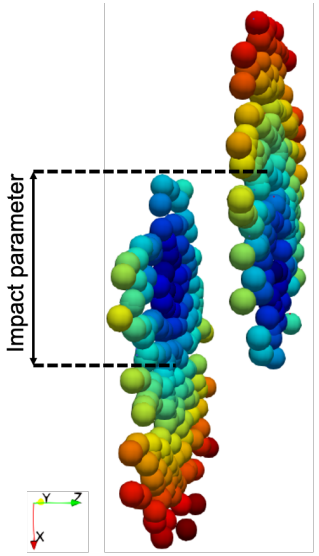
Heavy Ion Collisions

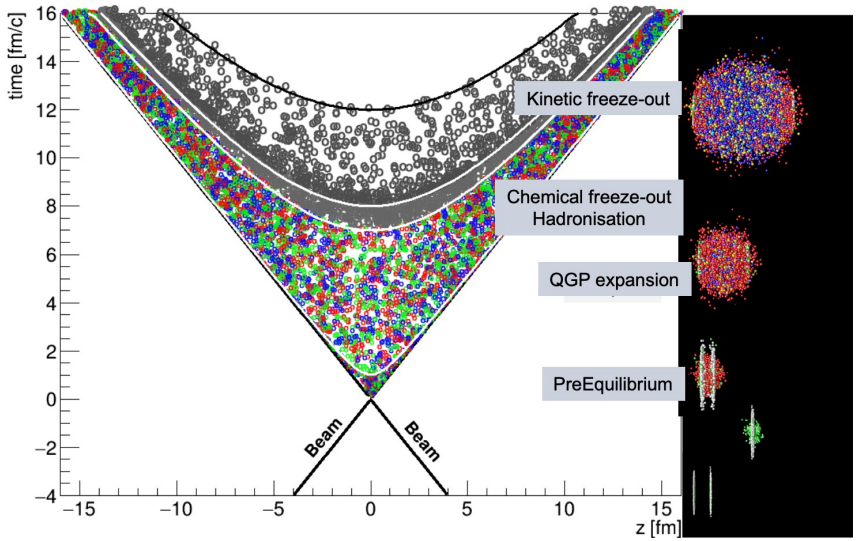
[SMASH] Phys.Rev.C 94 (2016) 5, 054905





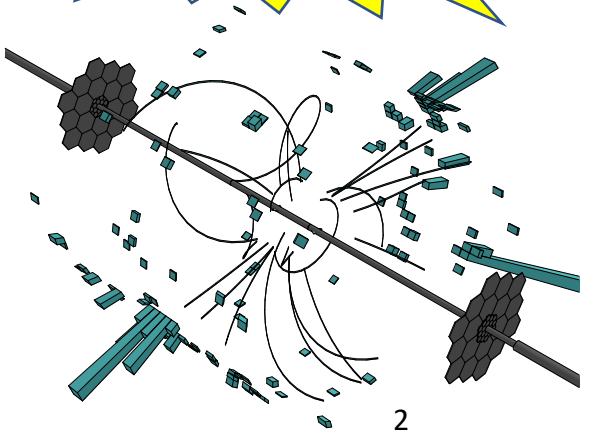






- Lorentz Contracted Nuclei (in the lab frame) collide, and form **Quark-Gluon Plasma**
- New particle formation stops after the first few fm/*c* s
- Hard probe → Strong interaction between high p_T partons and medium

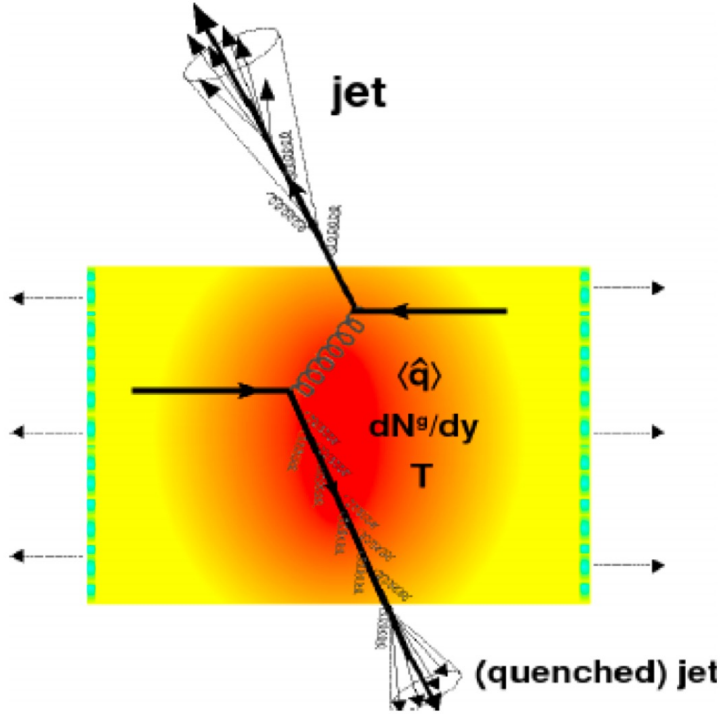
One such probe is jets



Introduction

Jets

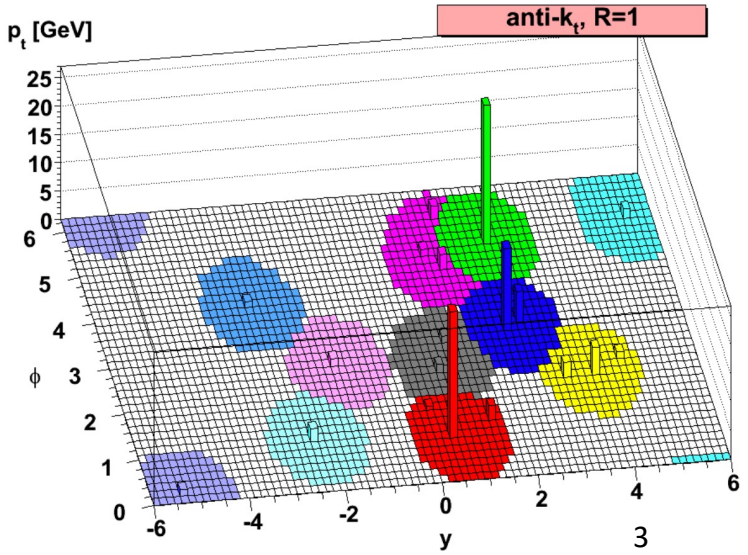
- Generated after collisions between hard scattered quarks and gluons (partons)
- Outgoing quark or gluon “fragments” into a spray of particles
- Lose energy and momentum in the QGP medium
- Broaden due to medium-induced radiation and scattering



Reconstructing jets in an experiment

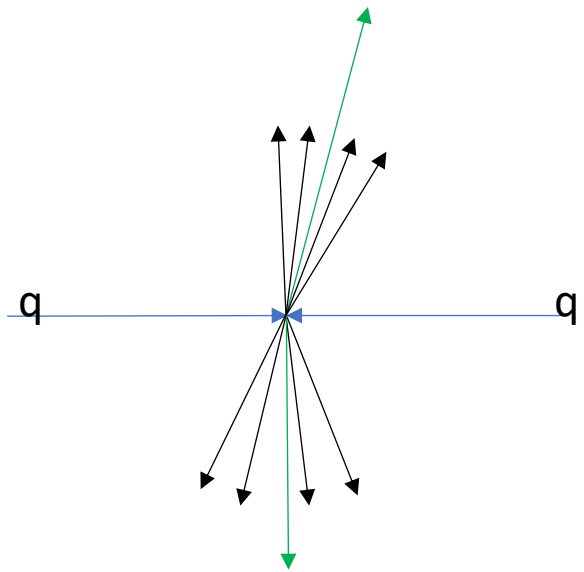
- Anti-k_T jet clustering algorithm used through the FASTJET package
- Sequentially clusters softer detected entities (charged particle tracks and calorimeter energy depositions) around harder entities
- Creates approximately conical jets with radii determined by the jet resolution parameter (R)

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

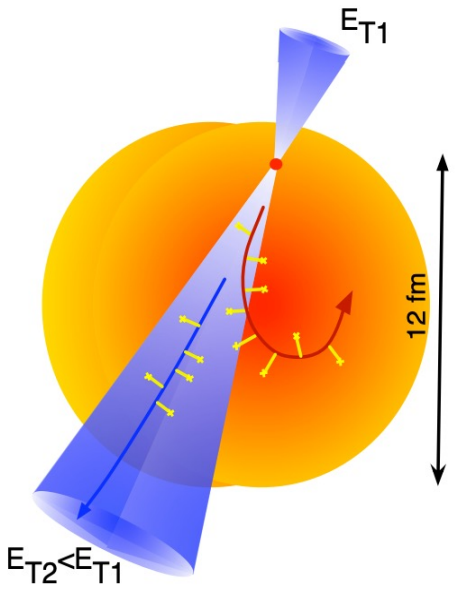


Previous Jet Results

Jet Quenching

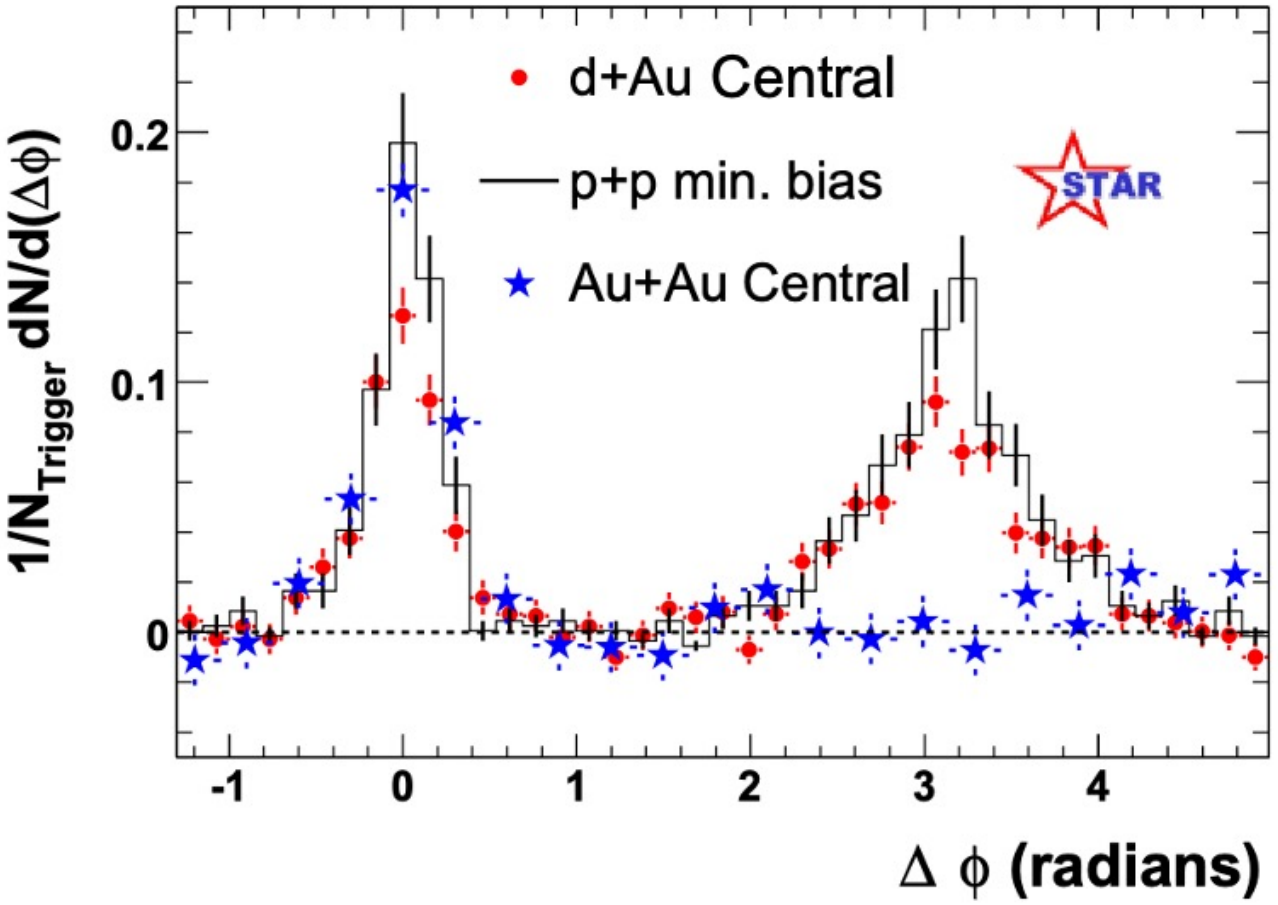


p + p



A + A

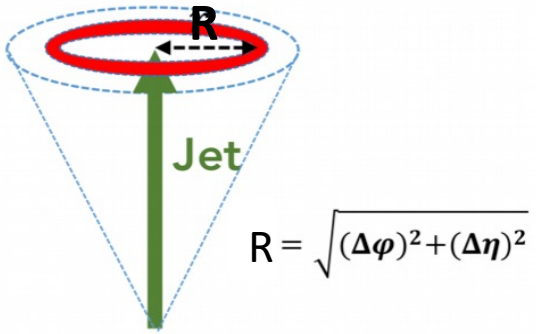
STAR, Phys. Rev. Lett. 91 (2003) 072304



Far side jets are heavily suppressed in the presence of QGP at STAR.

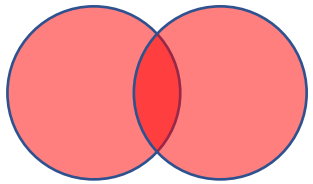
Previous Jet Results

Jet Broadening

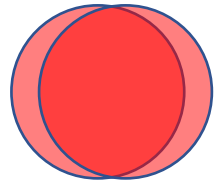


$$R = \sqrt{(\Delta\varphi)^2+(\Delta\eta)^2}$$

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

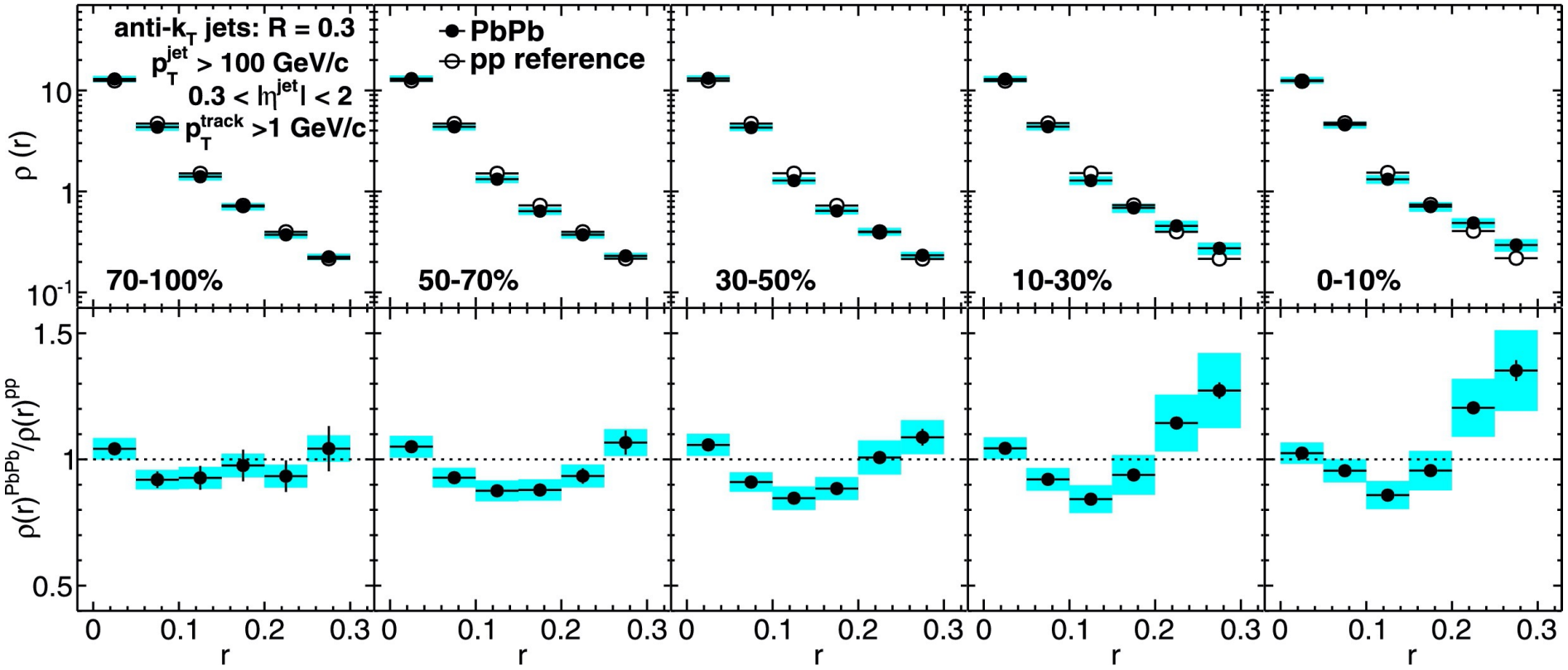


Decreasing centrality



CMS, $\sqrt{s_{NN}}$ = 2.76 TeV pp, $\int L\,dt$ = 5.3 pb^{-1} PbPb, $\int L\,dt$ = 150 μb^{-1}

CMS, Phys. Lett. B 730 (2014) 243

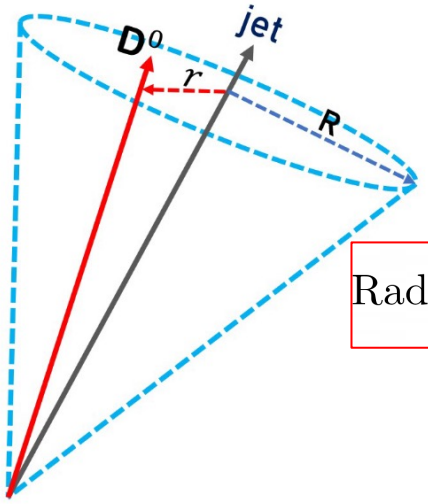


The jet energy is redistributed inside the jet cone in the presence of QGP at the LHC.

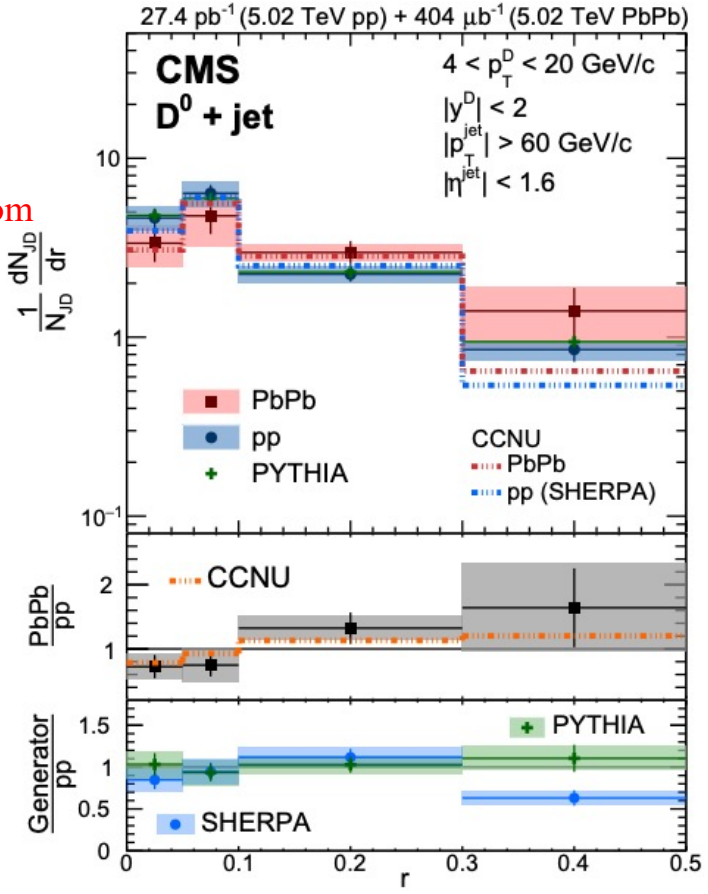
Jets from Charm Quark

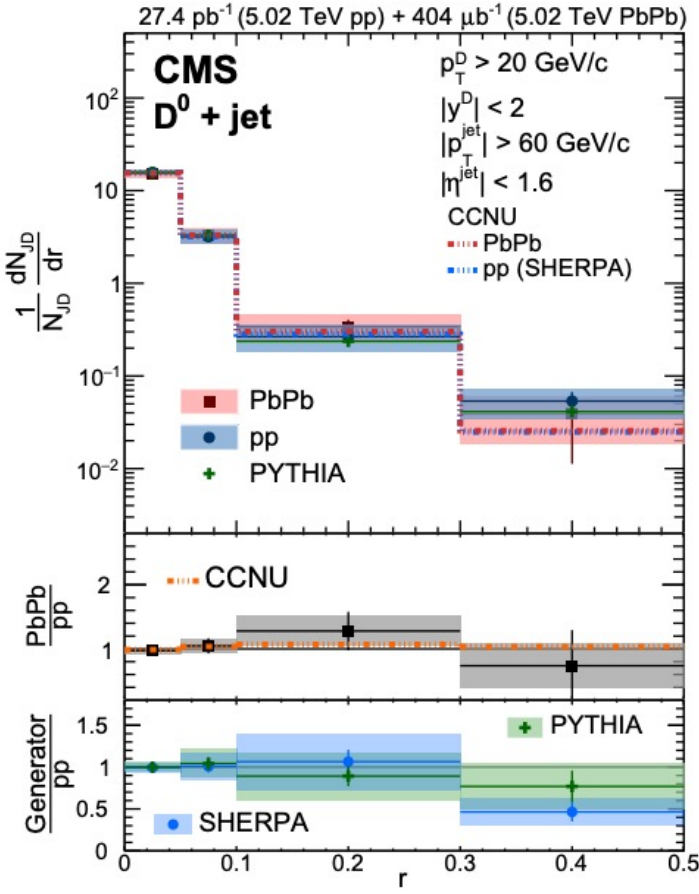
CMS, Phys. Rev. Lett. 125 (2020) 102001

- 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 jets originating from a charm quark as compared to other light quarks
- Radiation for charm quarks suppressed due to '*dead cone*' effect
  - ✓ Results in different emission spectra compared to light quarks
- *We study jets containing mesons with charm quarks ($D^0(c\bar{u})$)*



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





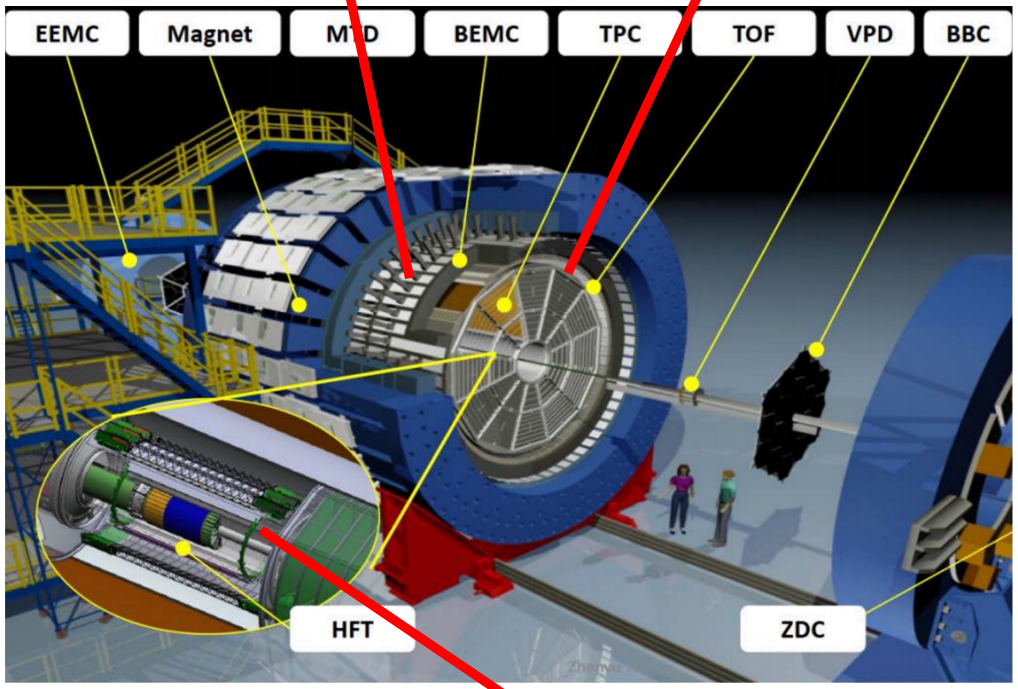
Hint of D^0 meson radial distribution modification for low p_T D^0 mesons which disappears for high p_T D^0 mesons

Qualitatively, the modification is different from that of the light flavor hadrons

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

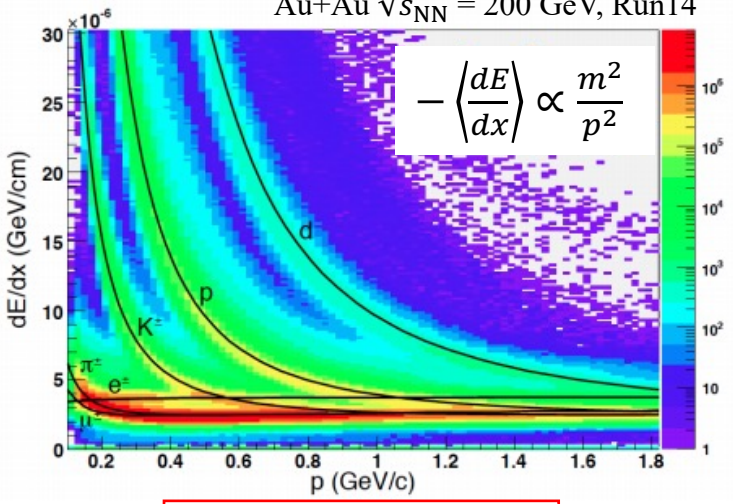
D^0 Jet Selection :

- 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

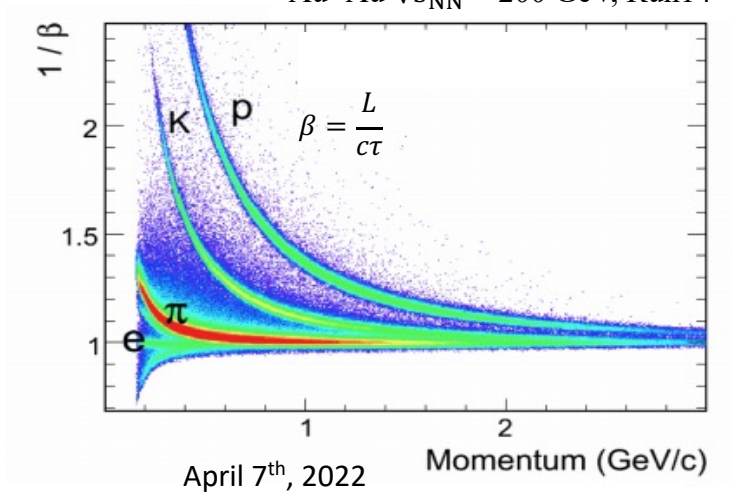


$|n\sigma_{\pi}| < 3.0; |n\sigma_{K}| < 2.0$

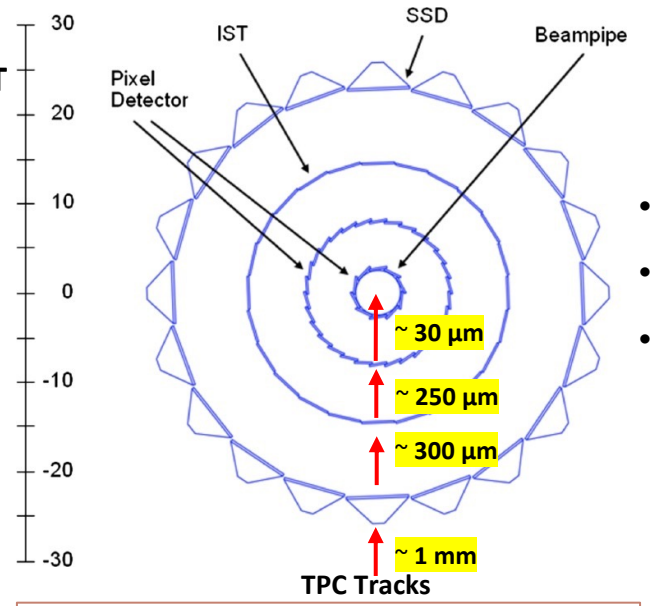
$|\frac{1}{\beta} - \frac{1}{\beta_{exp}}| < 0.03$

TOF

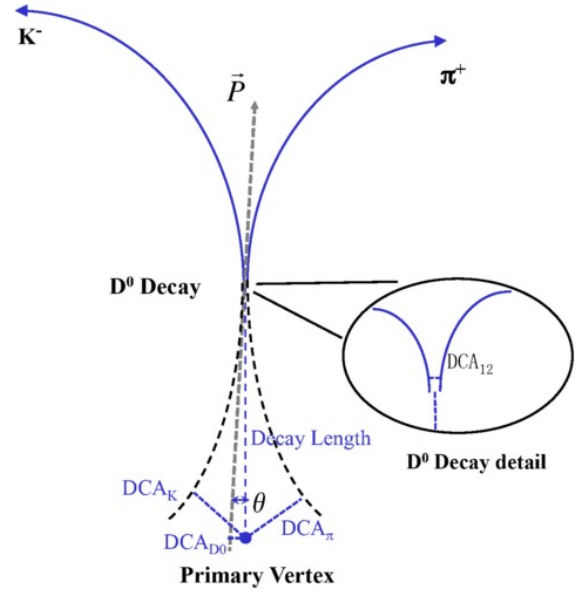
Au+Au $\sqrt{s_{NN}}$ = 200 GeV, Run14



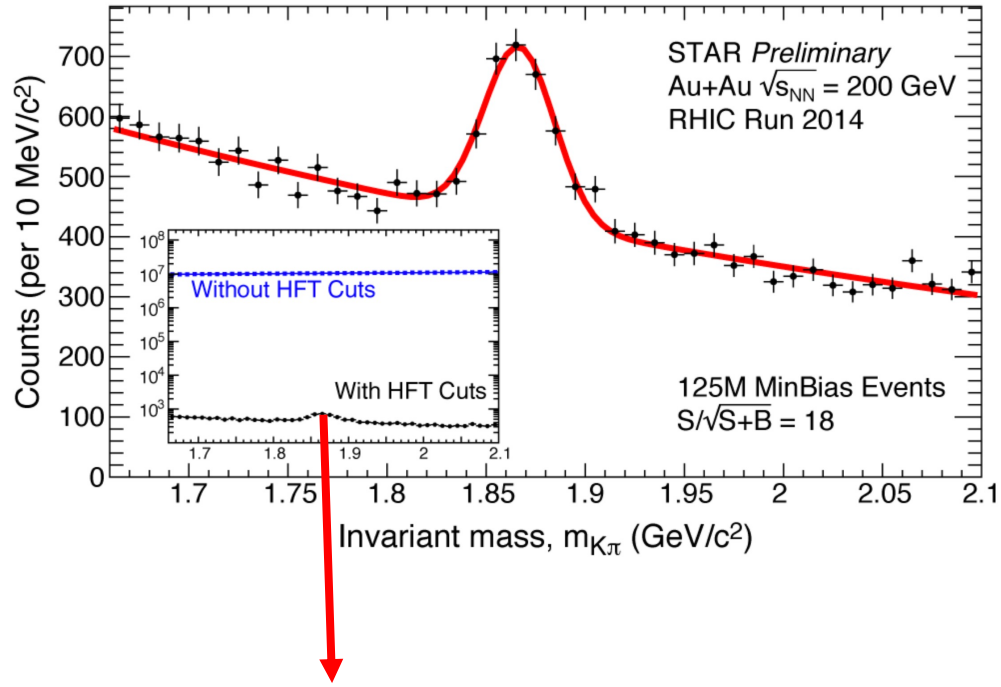
HFT



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



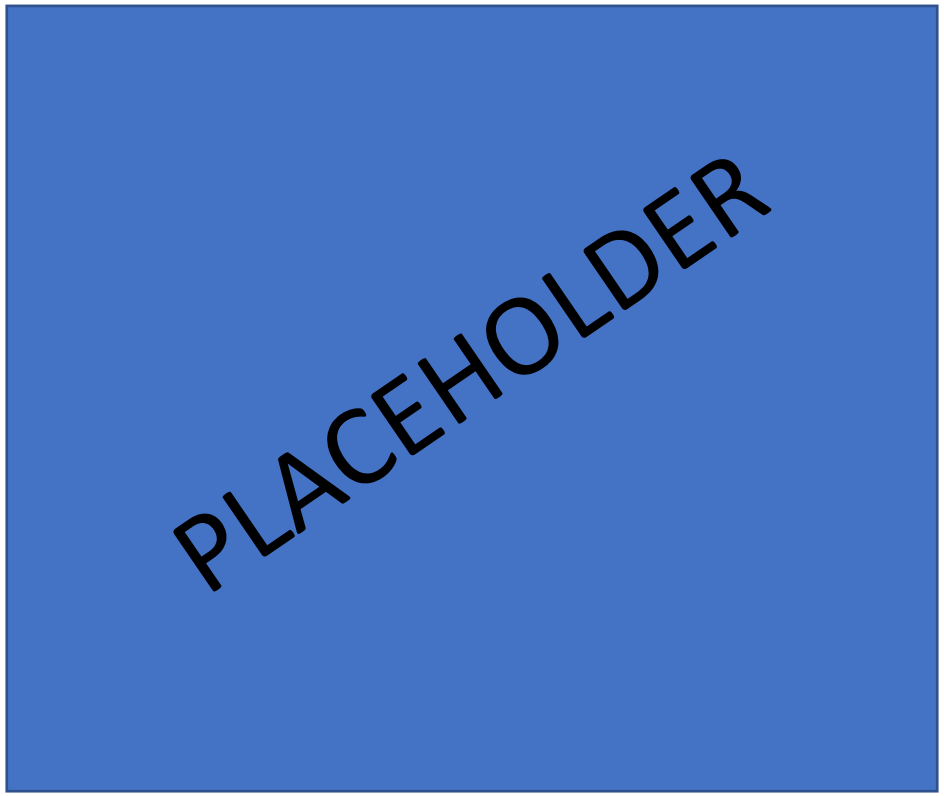
- Decay Length of D^0 ~ 123 μm.
- HFT has a resolution of 30 μm for kaons at ~ 1.2 GeV/c
- HFT can reconstruct D^0 candidates based on the decay kinematics



Topological cuts on the D^0 candidates improve signal significance

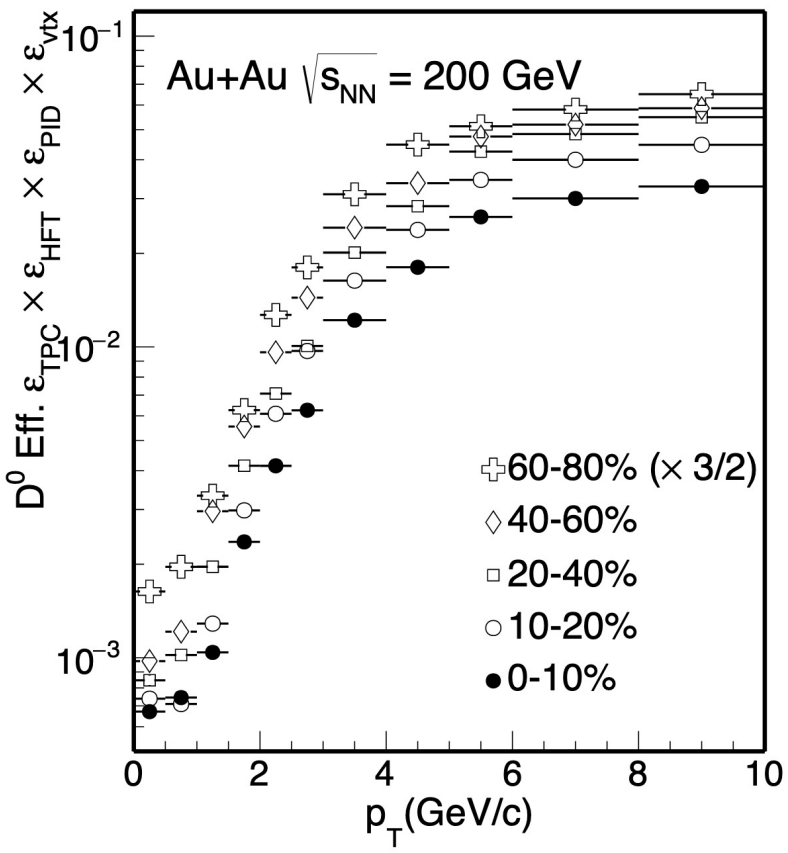
D^0 Reconstruction

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

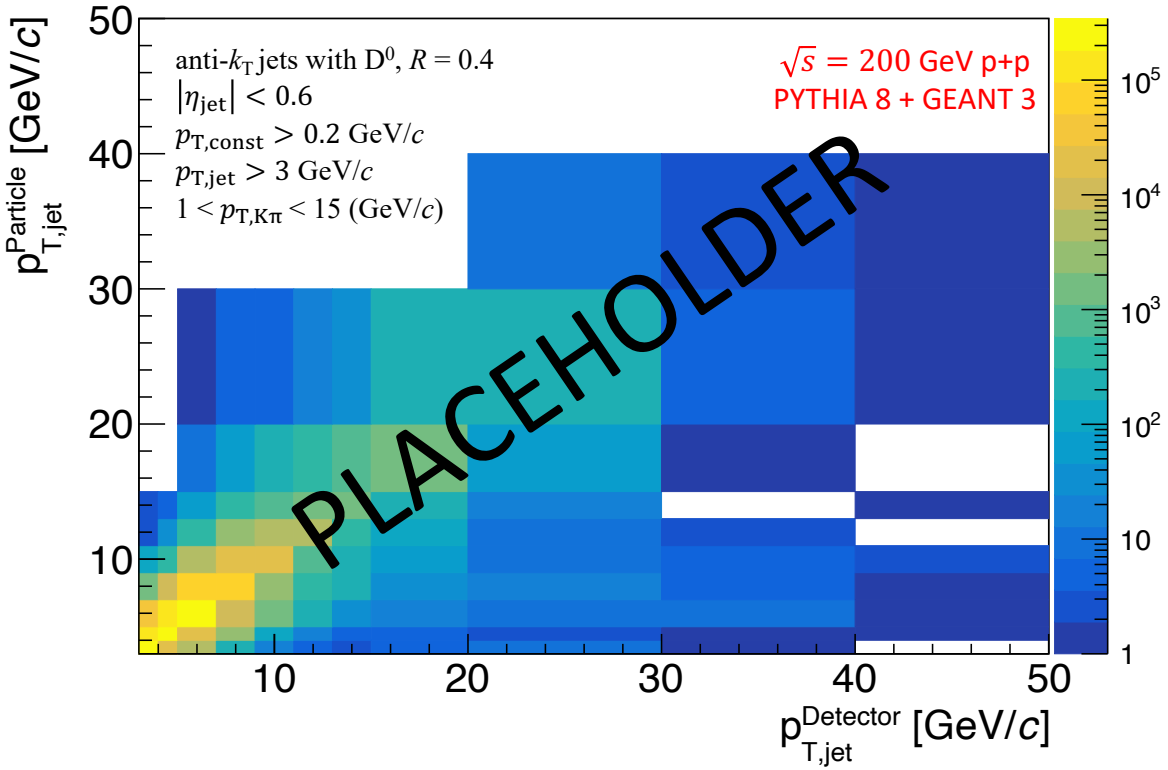
The efficiency weights were derived using a data-driven fast simulation method

PLACEHOLDER

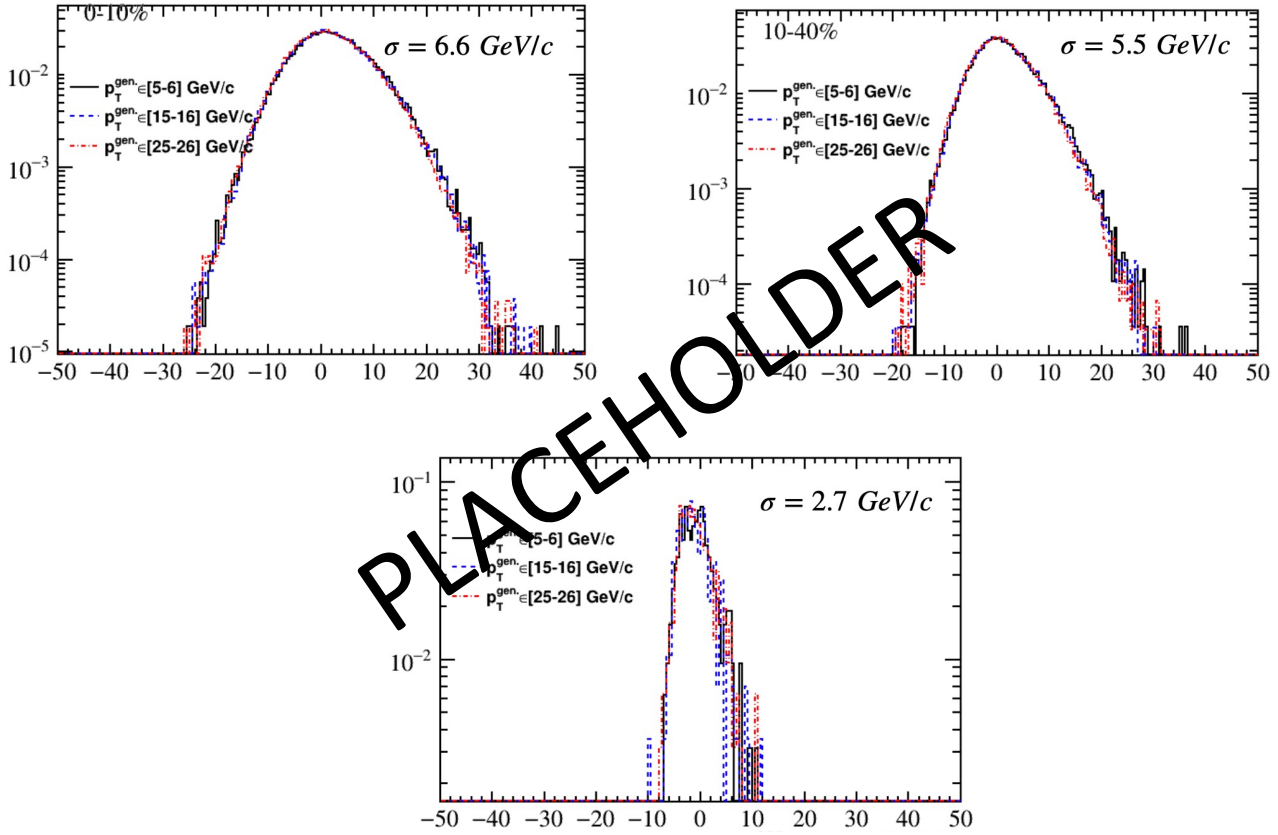
Raw Au + Au D^0 Jet Spectrum and Radial Distribution of D^0 in Jet

Efficiency Correction Using Unfolding

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

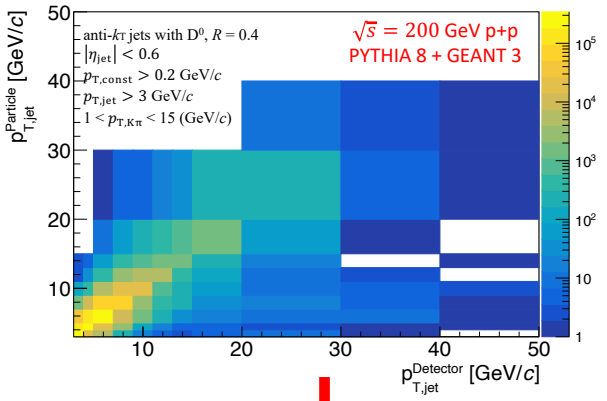


HI background fluctuation estimated by embedding a hard track in min-bias events

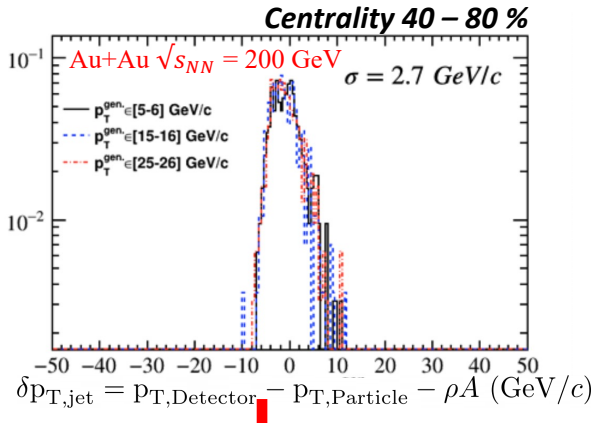


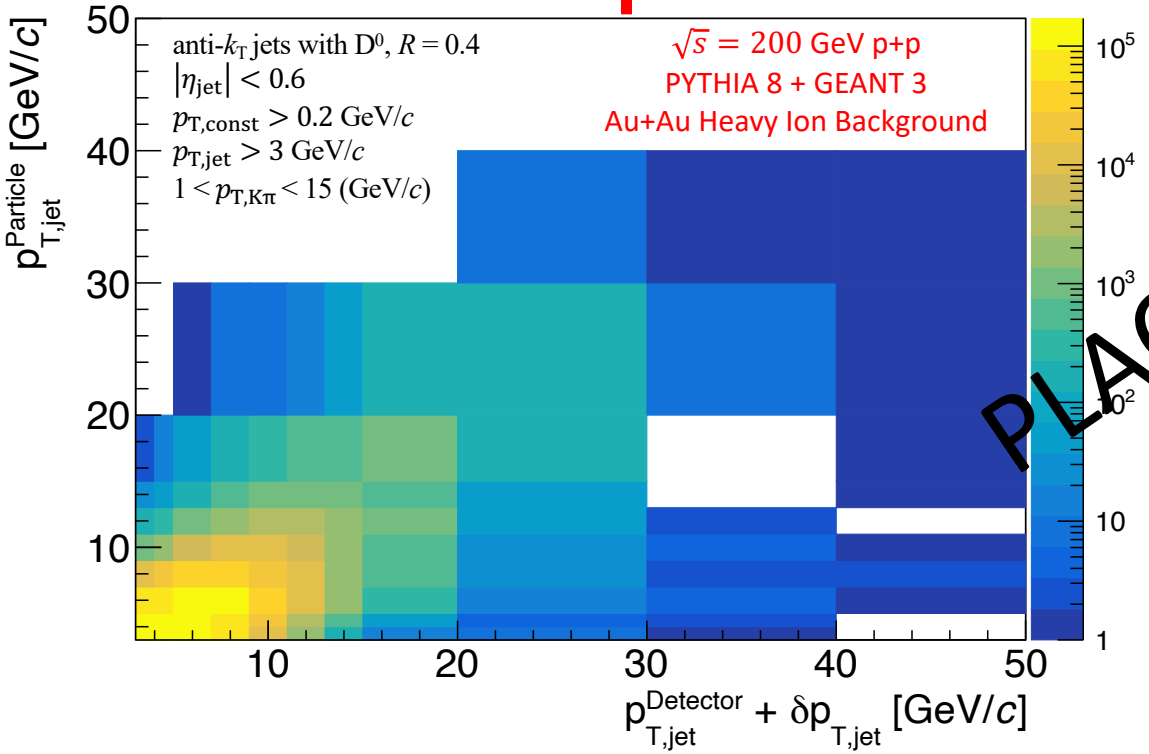
Background fluctuation is independent of p_T of hard track

Closure for Unfolding Jet Spectrum



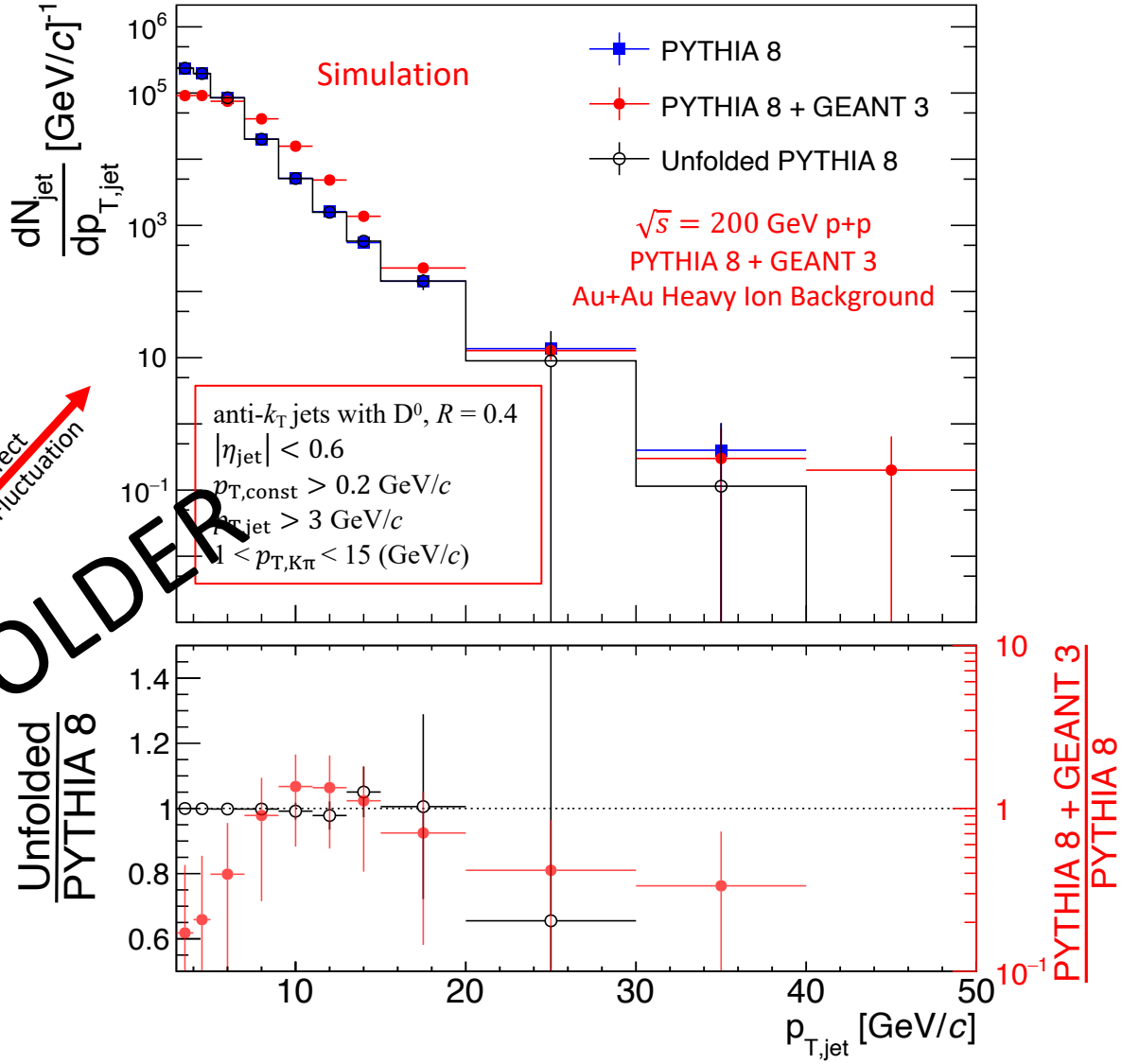
X





Detector Effect
Background Fluctuation

PLACEHOLDER



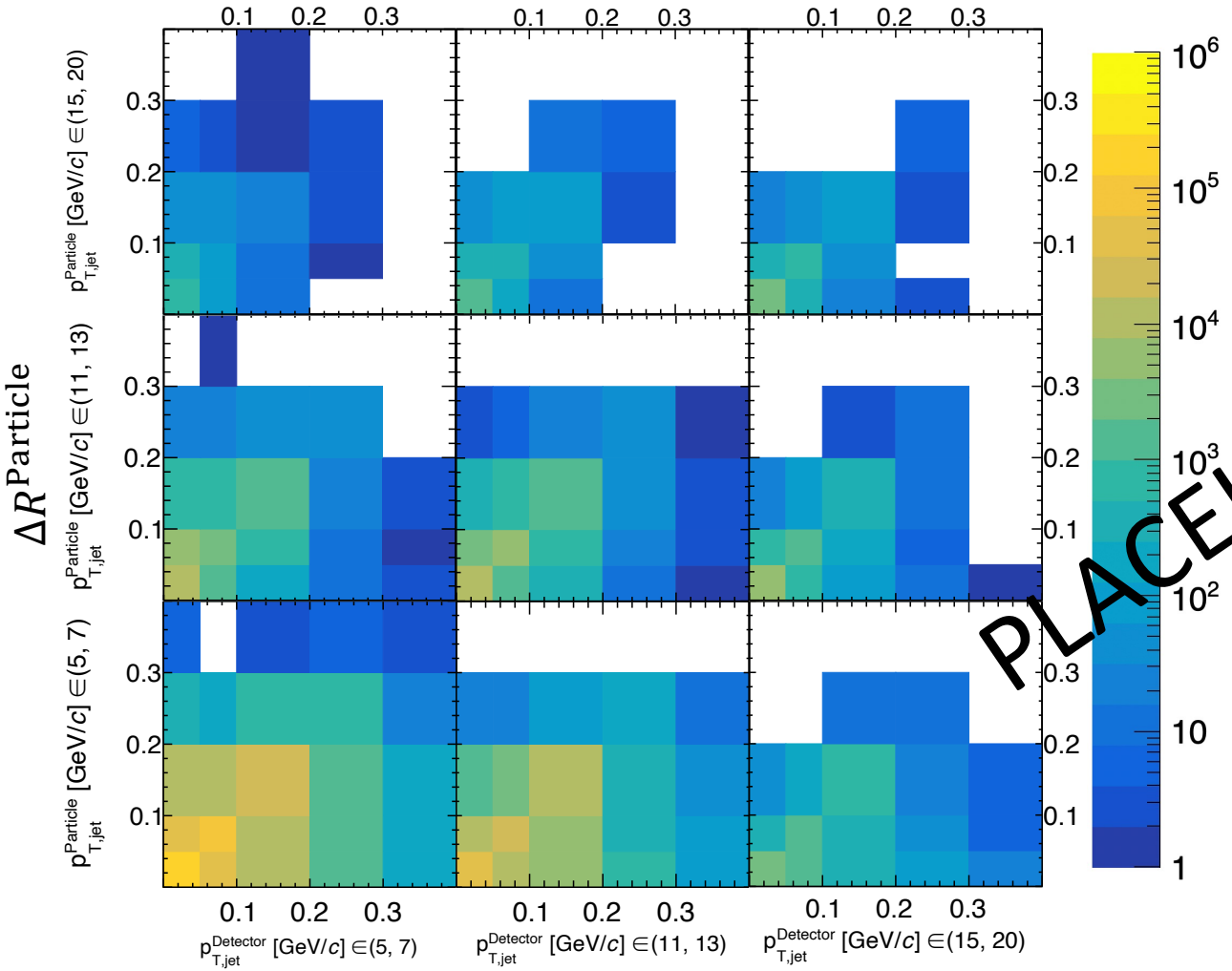
Closure test shows that we can reproduce the particle level $p_{T,jet}$ spectrum using unfolding

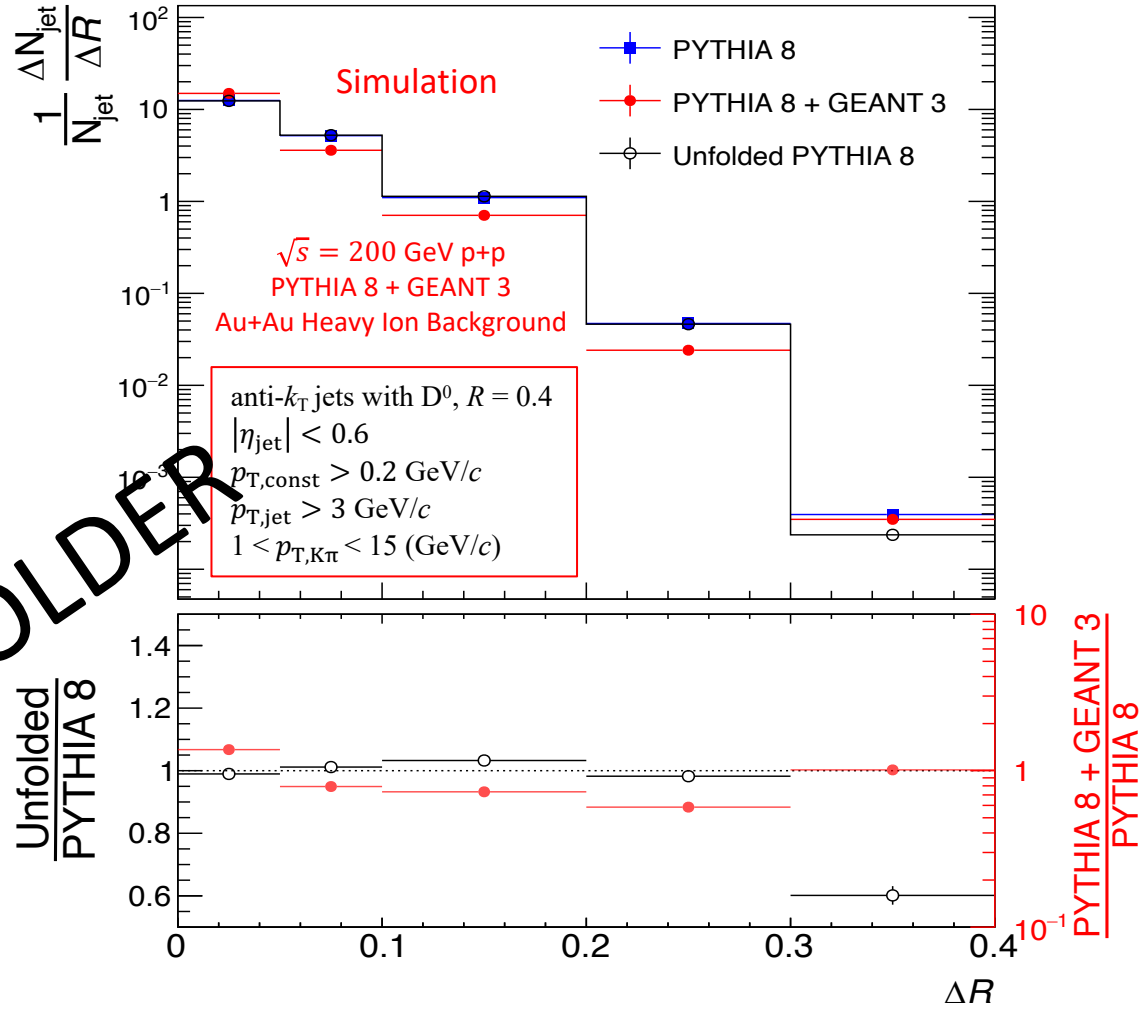
Closure for Unfolding Radial Distribution of D^0 Mesons in Jets

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)

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

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





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