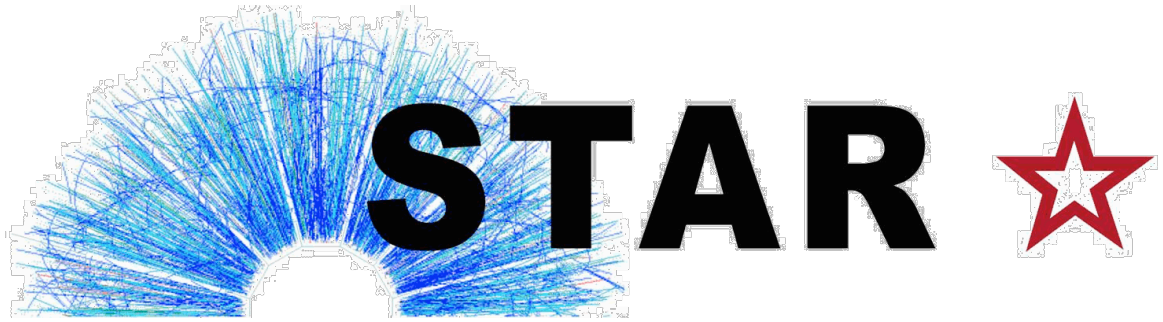

An Investigation of Charm Quark Jet Spectrum and Shape Modifications in Au + Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV

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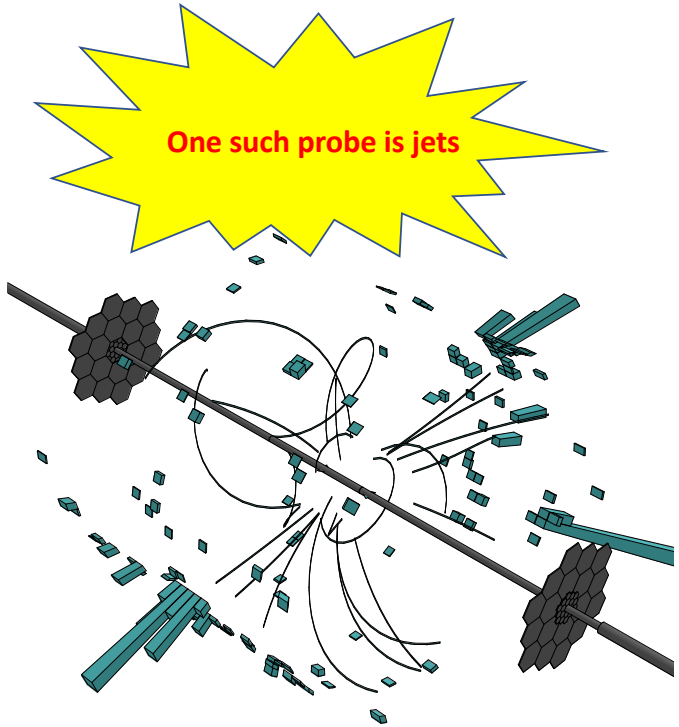
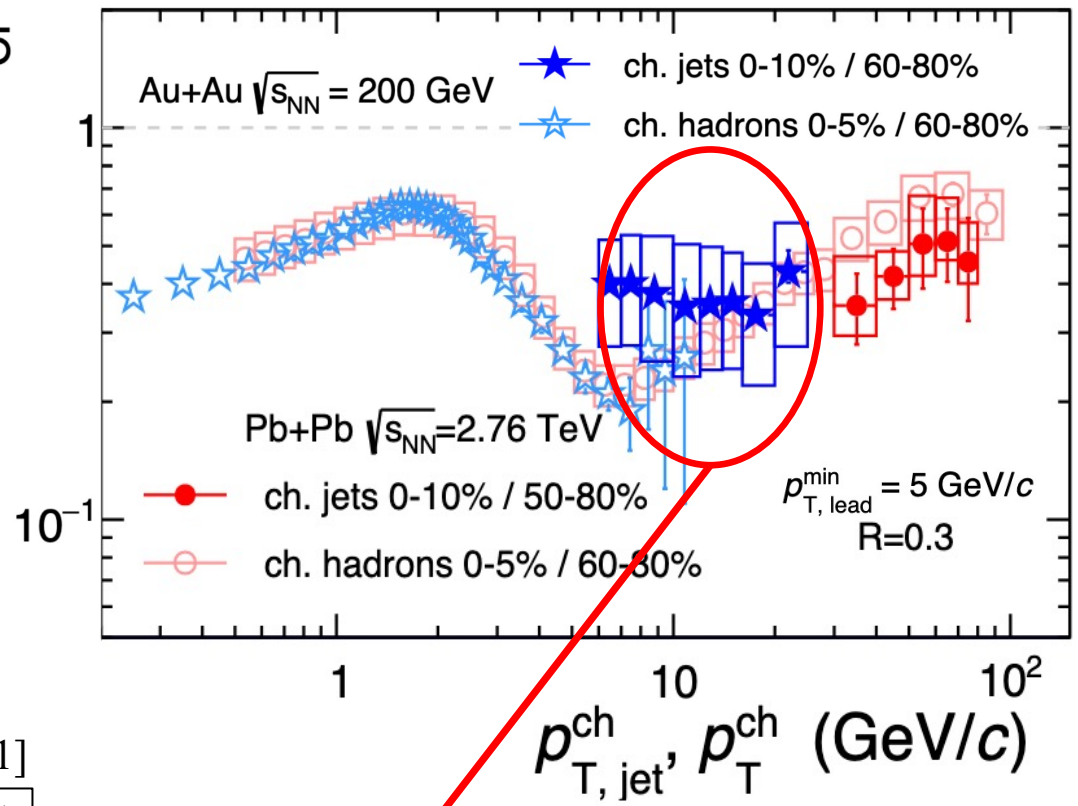
Jets in Heavy Ion Collisions

Strong interaction between high p_T partons and medium -> Way to probe Quark-Gluon Plasma



STAR, Phys.Rev.C 102 (2020) 5, 054913



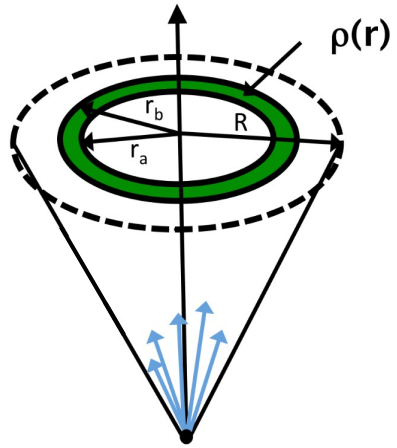
- Jets reconstructed in experiment by a clustering algorithm, commonly anti-k_T [1]
- **Loss of parton energy** in the QGP medium
- **Parton shower broadened** due to medium-induced radiation and scattering

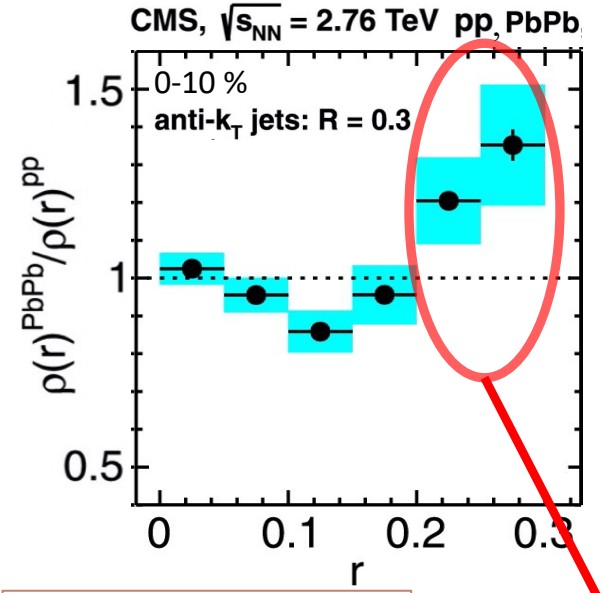
1. Phys. Lett. B 641 (2006) 57-61

Inclusive jets are heavily quenched in the presence of QGP

Previous Jet Shape Results

$$\rho(r) = \frac{1}{\Delta r}\frac{1}{N_{\text{jet}}}\sum_{\text{jet}}\frac{\sum_{\text{track}\in(r_a,r_b)} p_{\text{T,track}}}{p_{\text{T,jet}}} \qquad r = \sqrt{(\eta_{\text{track}}-\eta_{\text{jet}})^2+(\phi_{\text{track}}-\phi_{\text{jet}})^2}$$



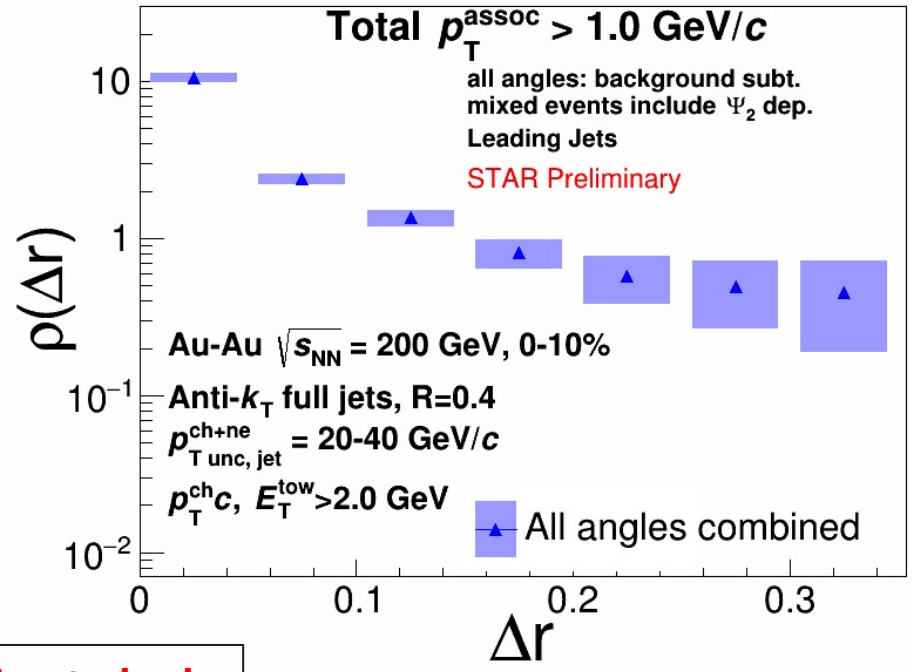


CMS, Phys. Lett. B 730 (2014) 243

Possible mechanisms:

- Multiple-scattering
- Medium-induced Bremsstrahlung
- Medium response

Dependent on the mass of the underlying parton

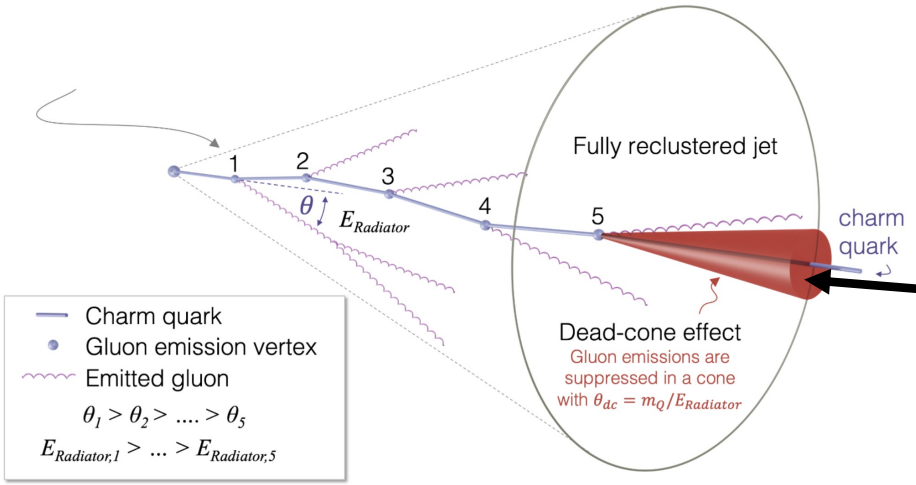


Jet energy is redistributed to large distances from the jet axis in the presence of QGP.

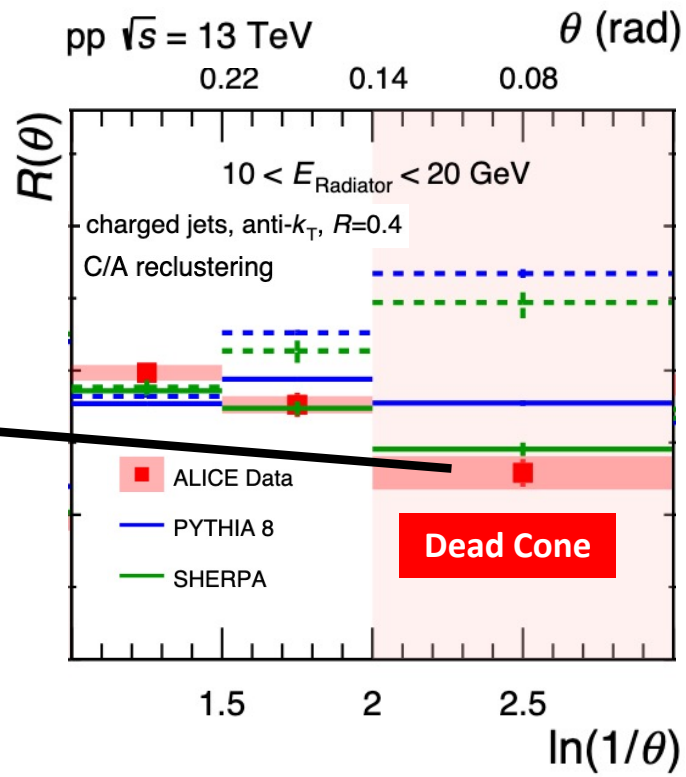
Motivation to look at heavy-flavor jets

Jets from Heavy Flavor

$$R(\theta) = \frac{1}{N^{\mathrm{D^0\,jets}}} \frac{\mathrm{d}n^{\mathrm{D^0\,jets}}}{\mathrm{d}\ln(1/\theta)} \Big/ \frac{1}{N^{\mathrm{inclusive\ jets}}} \frac{\mathrm{d}n^{\mathrm{inclusive\ jets}}}{\mathrm{d}\ln(1/\theta)}$$



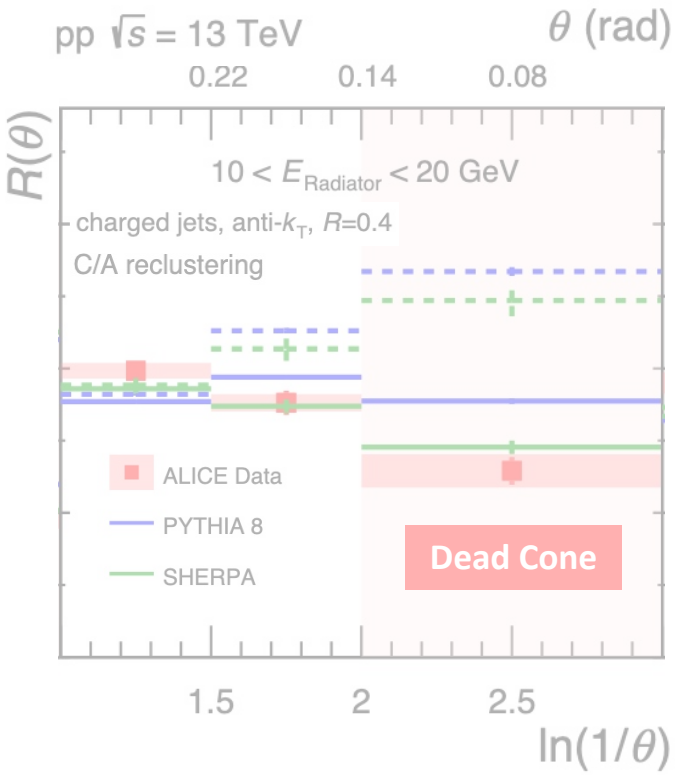
ALICE, arXiv:2106.05713 (2021)

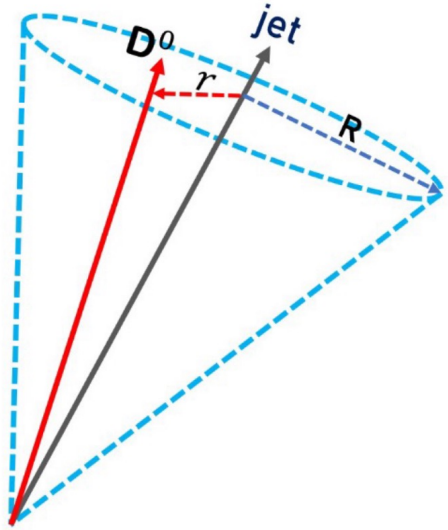


Heavy-flavor emission spectra modified due to dead-cone in vacuum

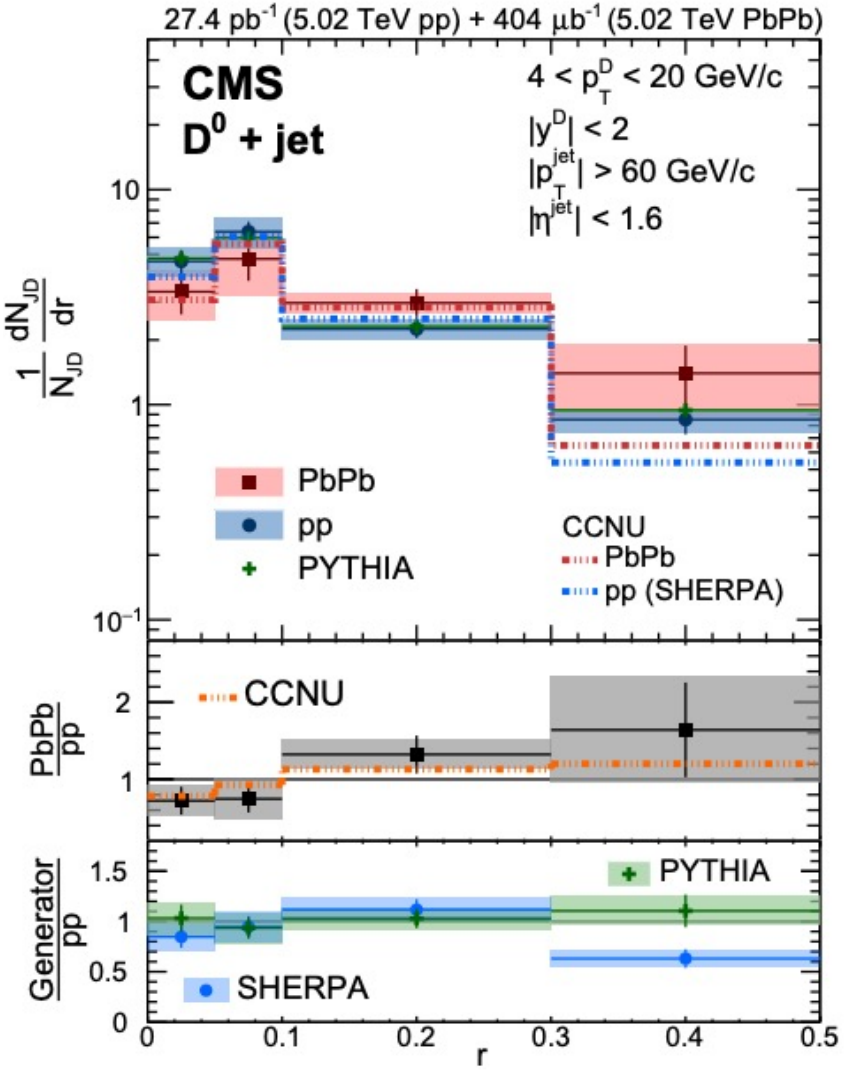
Jets from Heavy Flavor

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





Low p_T D^0 mesons diffused in the presence of QGP



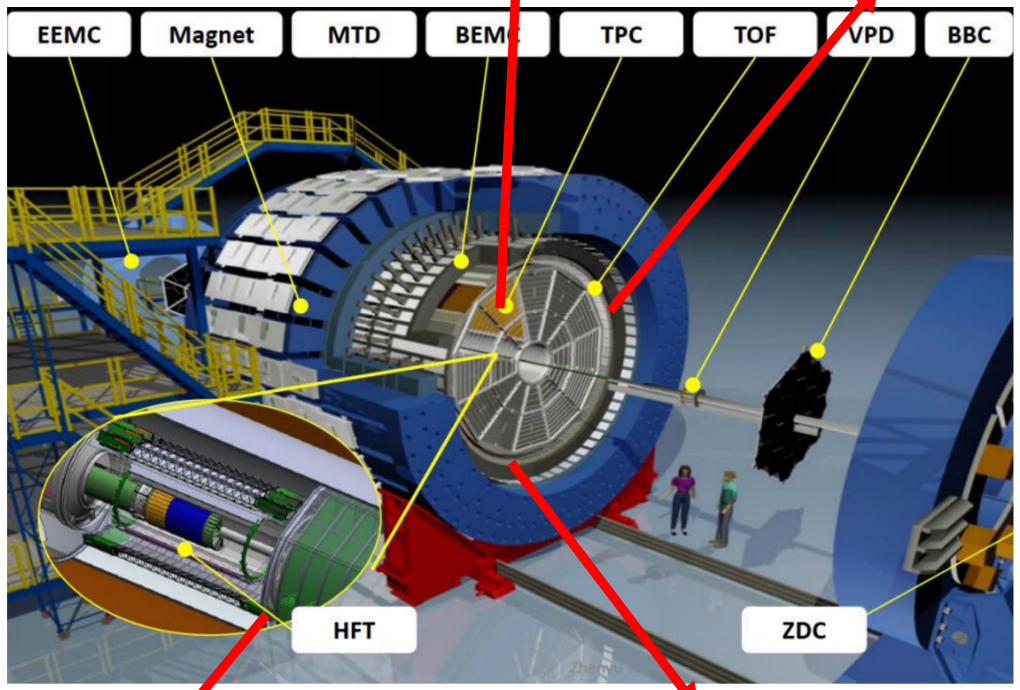
Heavy-flavor emission spectra modified due to dead-cone in vacuum

At RHIC energies, stronger modification expected as energy is closer to charm quark mass

STAR Detector & Selection Criteria

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

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



Barrel Electromagnetic Calorimeter
- Measures neutral component of energy in jets

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])

Constituent Selection :

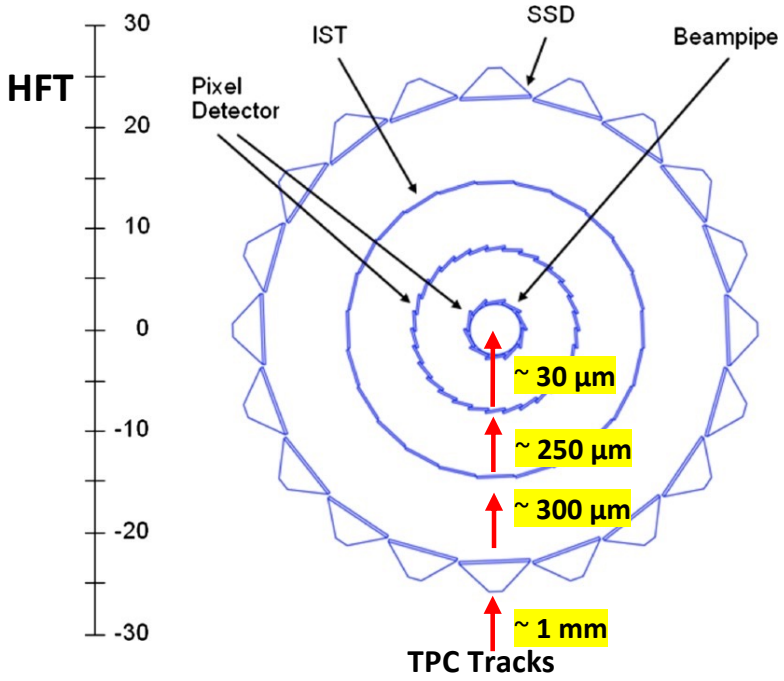
- $0.2 < p_{T,track}$ [GeV/c] < 30 ; $0.2 < p_{T,tower}$ [GeV/c] < 30
- $|\eta_{track}| < 1$; $|\eta_{tower}| < 1$
- $D^0 \rightarrow K^{\mp} + \pi^{\pm}$ [B.R. = 3.82 %]
- For D^0 reconstruction: Tracks need at least two hits in HFT
- $5 < p_{T,D^0}$ [GeV/c] < 10

D^0 Jet Selection :

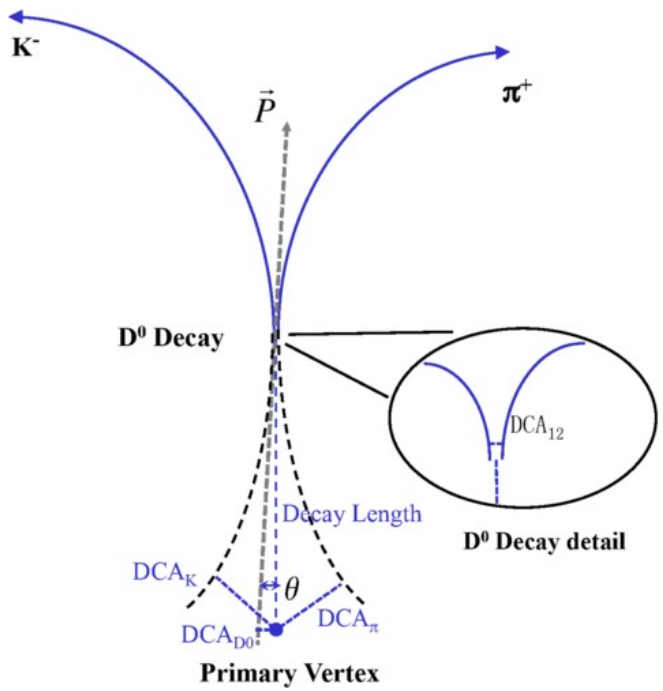
- Anti-k_T full-jets of radius R = 0.4, area-based background subtraction
- $|\eta_{Jet}| < 0.6$

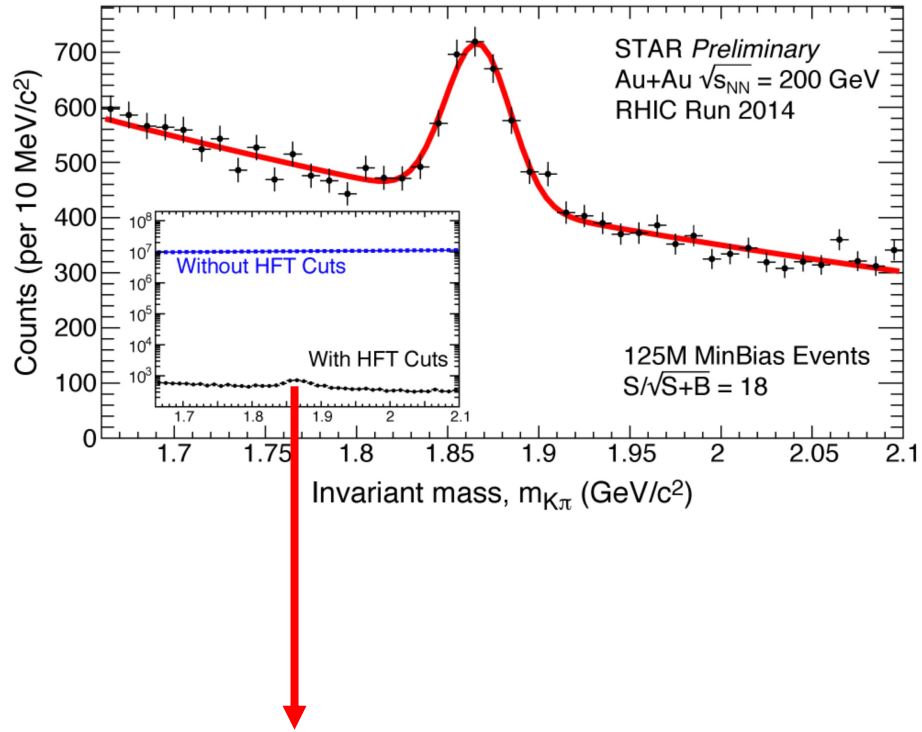
D^0 Reconstruction

- Kaon and Pions identified with hybrid PID from TPC and TOF



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 - Jet Yield Extraction

sPlot Method

- Native class in RooStats + widely used in HEP
- Unbinned maximum likelihood fit to invariant mass integrated over all kinematics
- $p_{T,Jet}$ and ΔR histograms with all D^0-jet candidates using sWeights
- Trivial to include reconstruction efficiencies versus D^0 kinematics

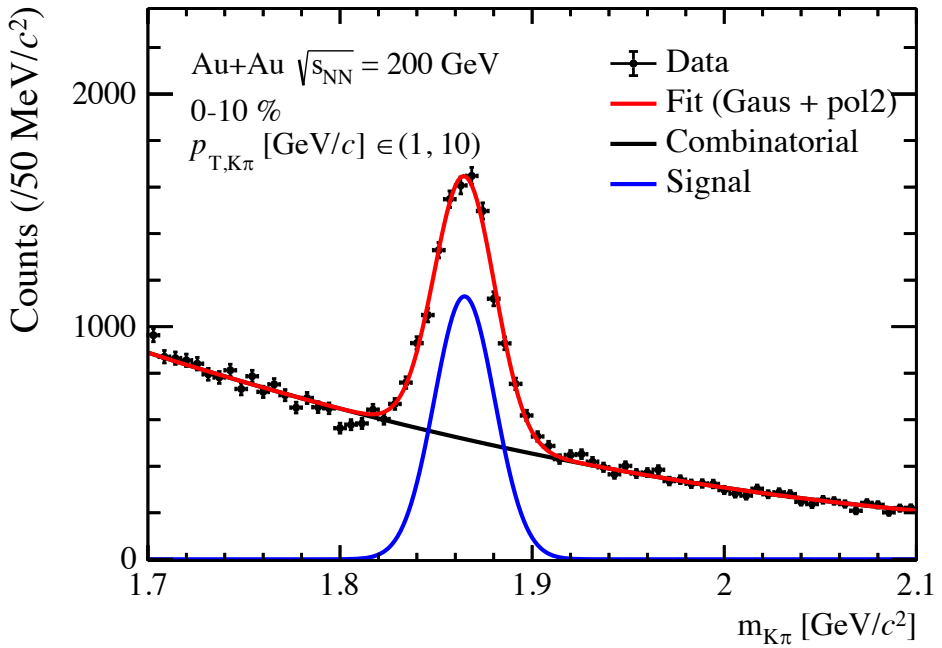
sWeights →

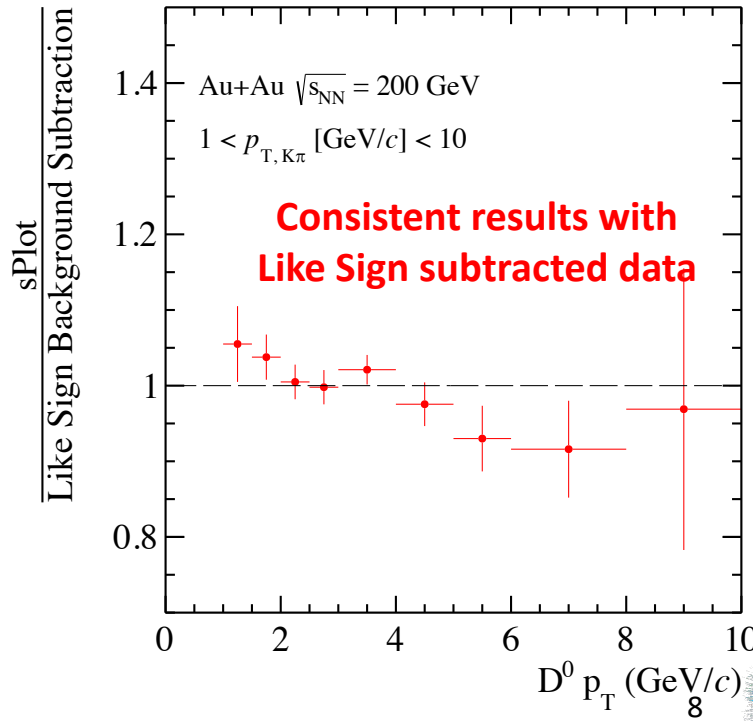
$$ {}_s\mathcal{P}_n(m_{K\pi,i}) = \frac{\sum_{j=1}^{N_T} V_{nj} f_j(m_{K\pi,i})}{\sum_{k=1}^{N_T} N_k f_k(m_{K\pi,i})} $$

Unbinned max. likelihood fit
n = n-th fit component(sig/bkg)
N_k = k-th yield (T=2)
$f_k(m_{K\pi,i})$ = per-event PDF value with k^{th} hypothesis
V = cov. matrix

Efficiency Correction in sWeights →

$$ {}_s\mathcal{P}_n(m_{K\pi,i}) \rightarrow \frac{{}_s\mathcal{P}_n(m_{K\pi,i})}{\varepsilon(m_{K\pi,i})} $$

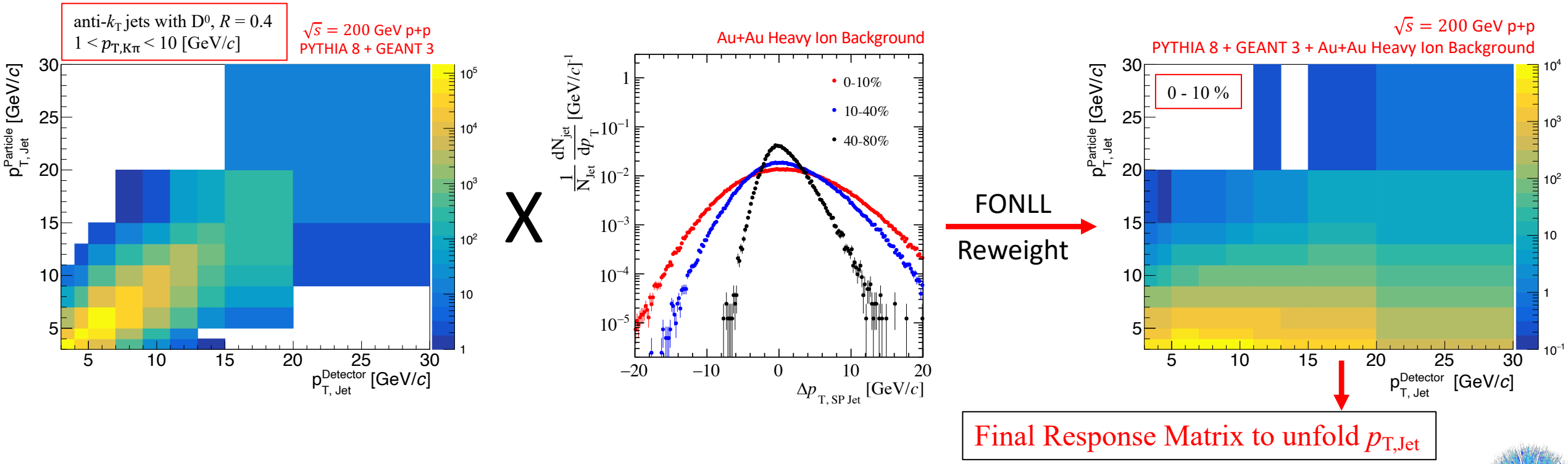




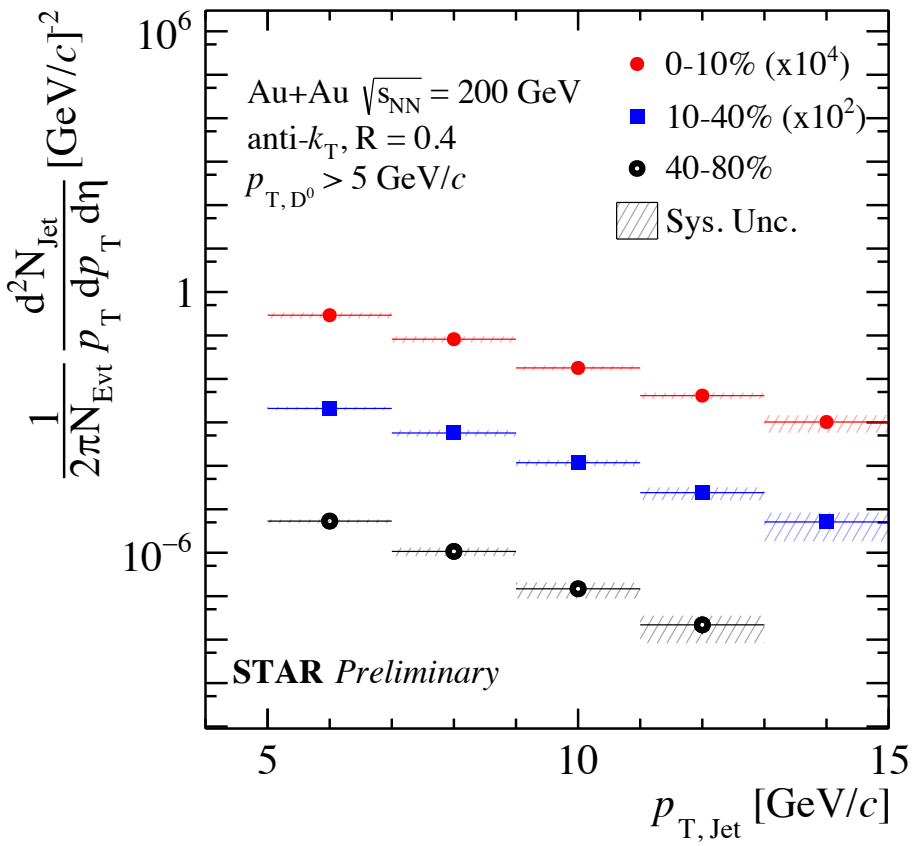
For more information about sPlot, visit poster by Matthew Kelsey.

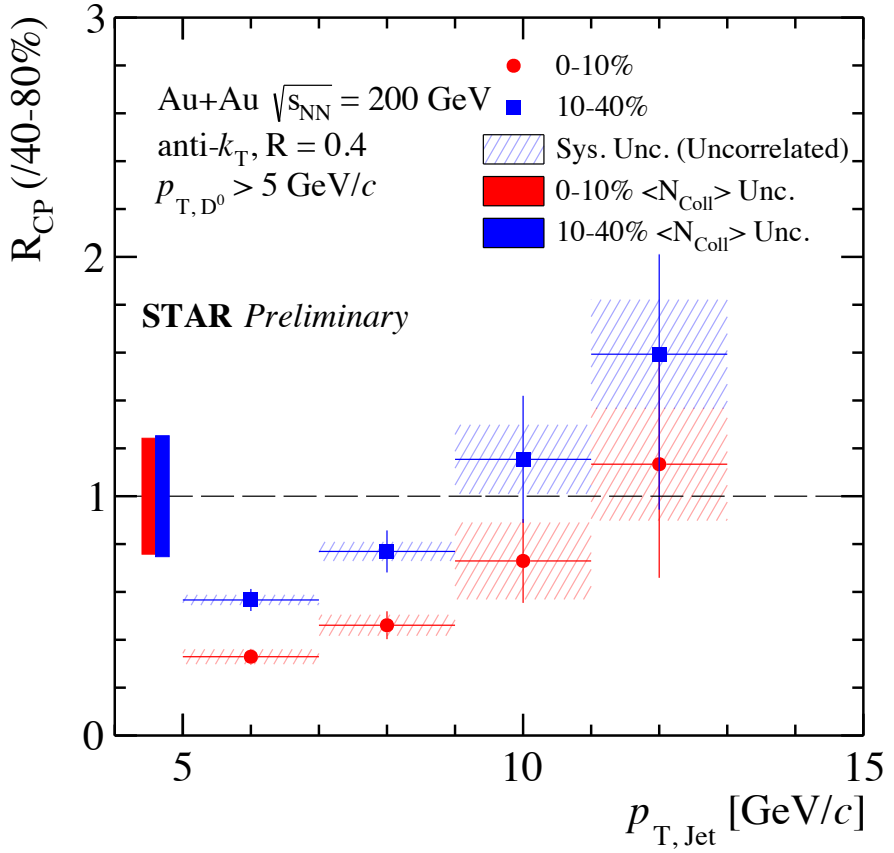
Unfolding for jet reconstruction inefficiencies

1. Response Matrix for p+p $\sqrt{s}$ = 200 GeV from PYTHIA and GEANT3 to get the detector response
2. Single Particle Embedding in heavy ion event to model fluctuations in area-based background subtraction
3. Reweight PYTHIA with a prior (FONLL c-quark) to match the shape of the jet p_T spectra
4. Heavy-flavor jet fragmentation modeled from PYTHIA



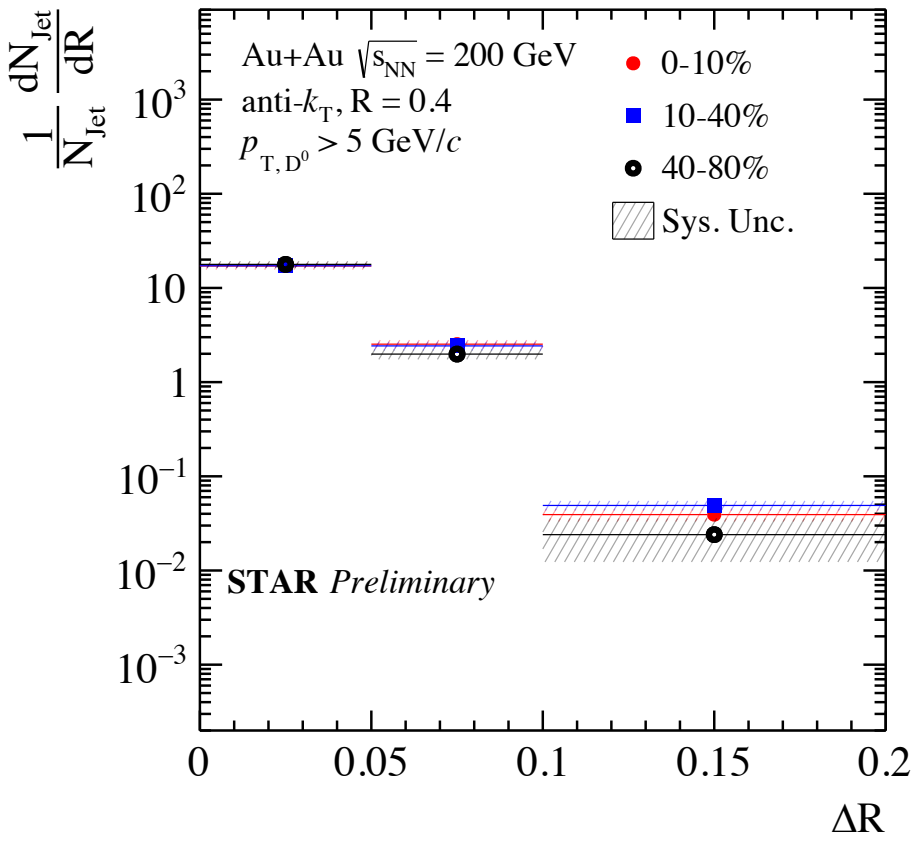
Jet Spectra

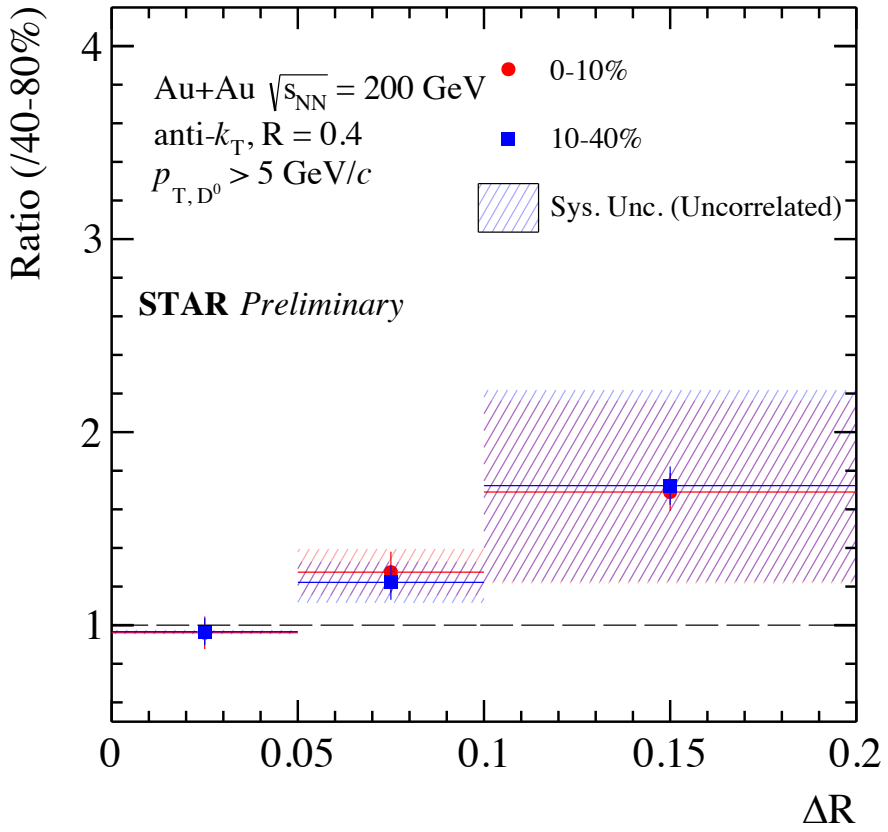




- For central and mid-central, we can measure the spectra upto about 15 GeV/c
- Peripheral has limited statistics with the D^0 p_T cut. R_{CP} is severely limited by peripheral statistics.
- p+p baseline for R_{AA} calculation at STAR would be beneficial

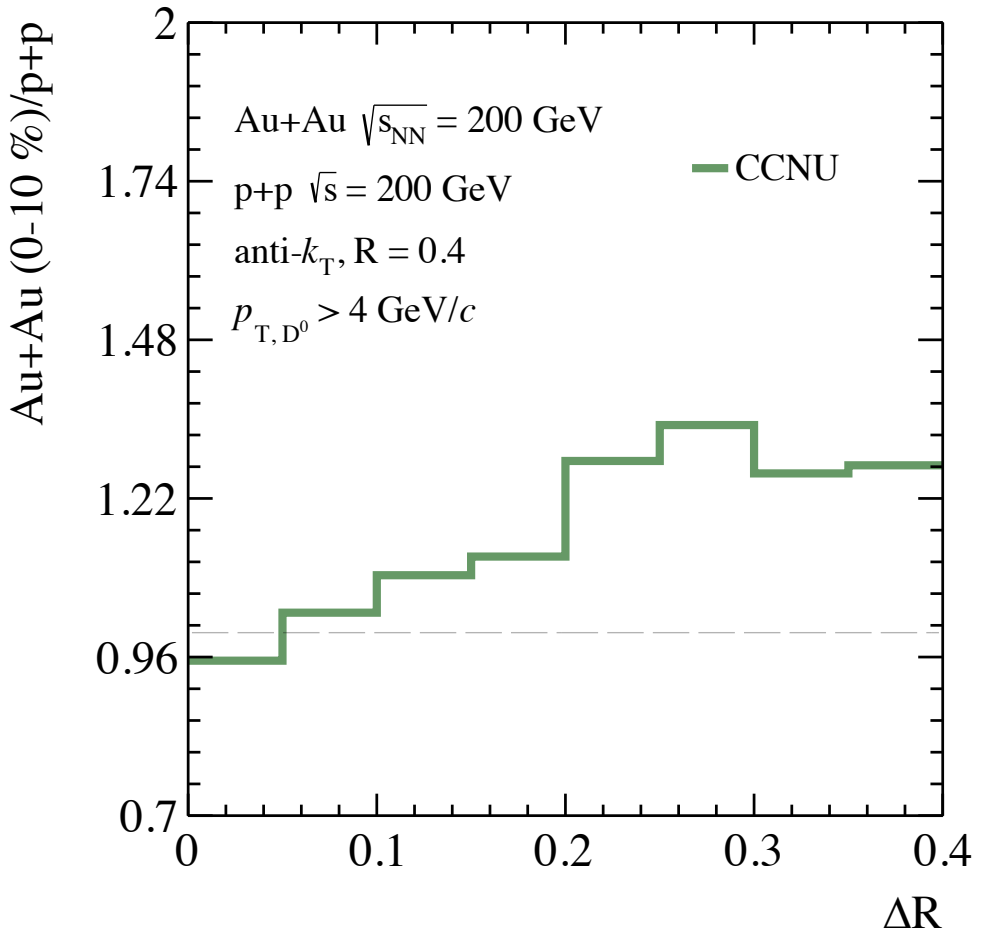
Radial Distribution of D^0 Mesons in Jets

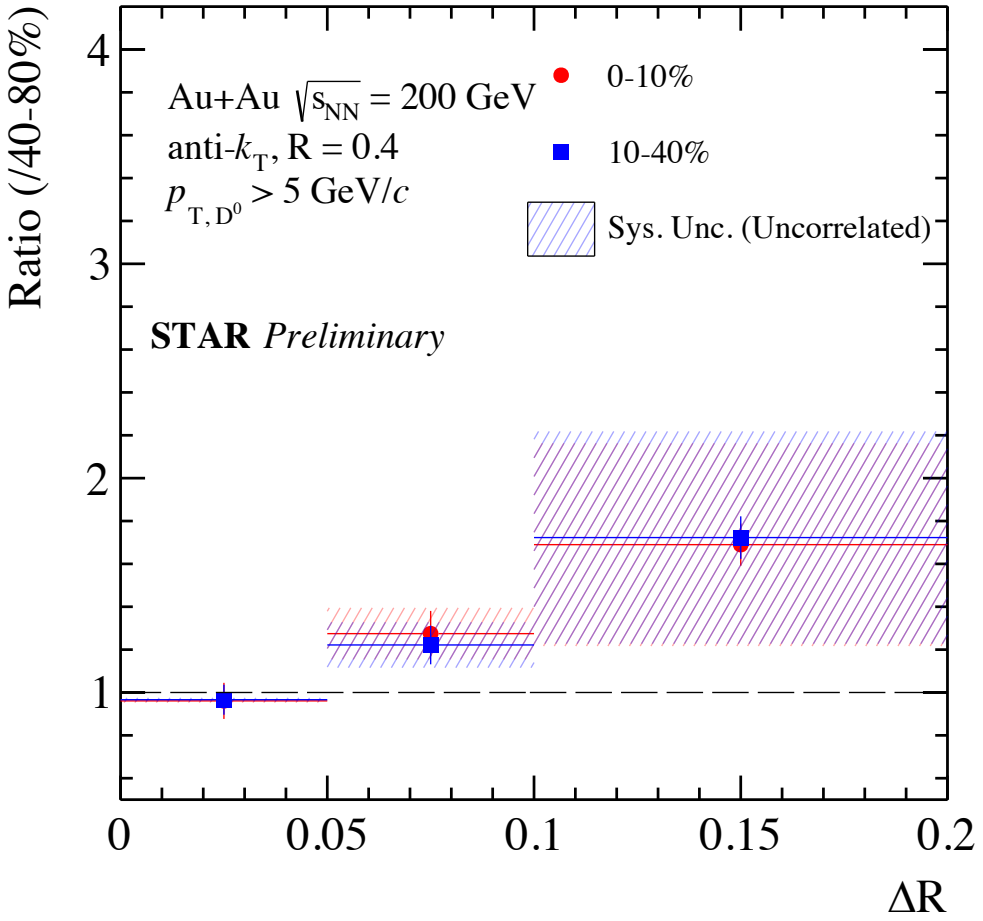




- Small hint of diffusion in the presence of QGP at STAR energies

Ratio of Radial Distributions





- Qualitatively, similar to the predictions from CCNU for R_{AA}

Diptanil Roy, Quark Matter 2022

Summary

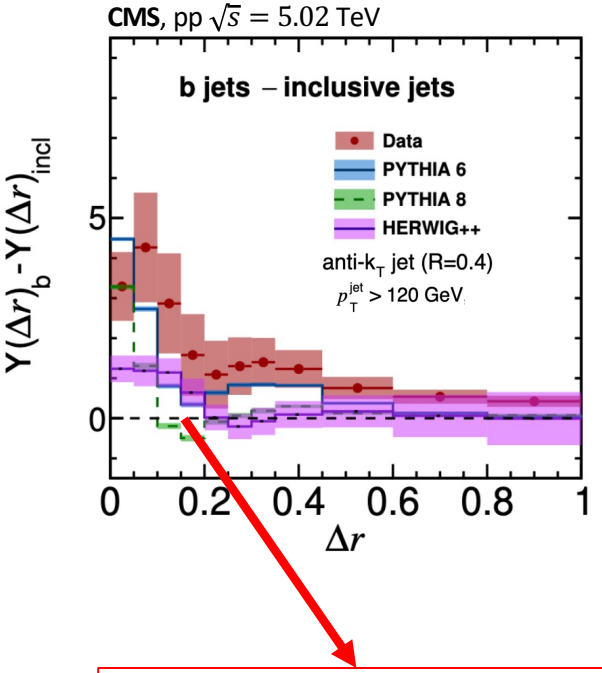
Backup

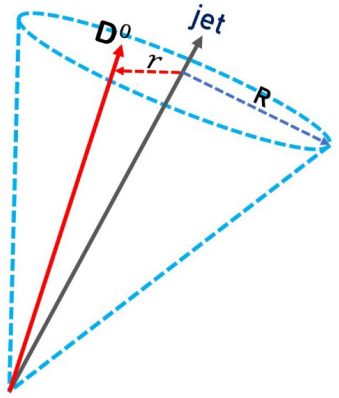
Previous Jet Results

Jets from Heavy Flavor

CMS, JHEP05 (2021) 054

$$Y(\Delta r) = \frac{1}{N_{\text{jets}}} \frac{\mathrm{d}^2 N_{\text{trk}}}{\mathrm{d}\Delta r \mathrm{d}p_{\mathrm{T}}^{\text{trk}}}$$





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

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

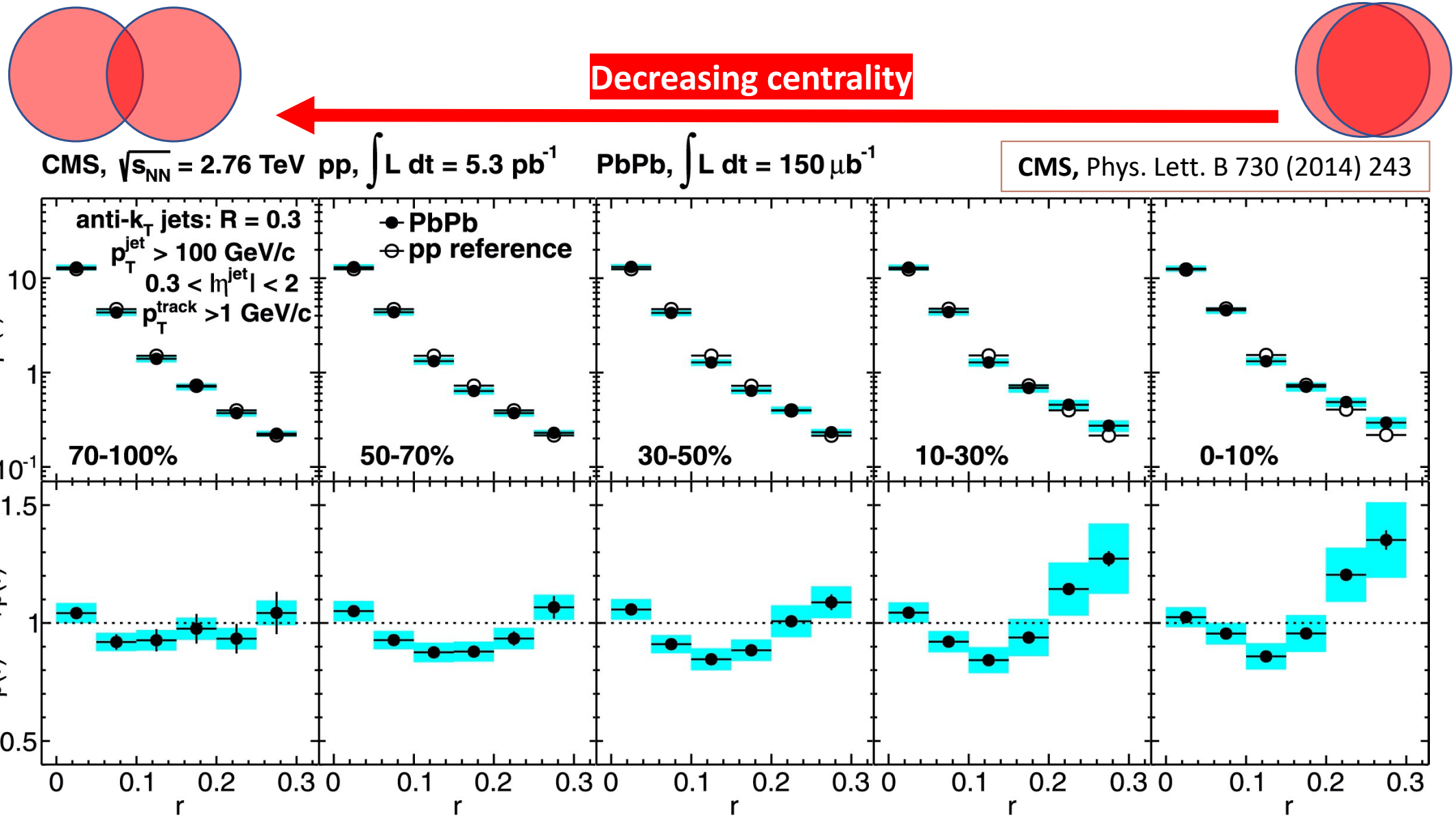
Higher yields of low p_T charged-particle close to jet axis in b-Jets vs inclusive jets in vacuum

~ Different fragmentation pattern for heavy quarks

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

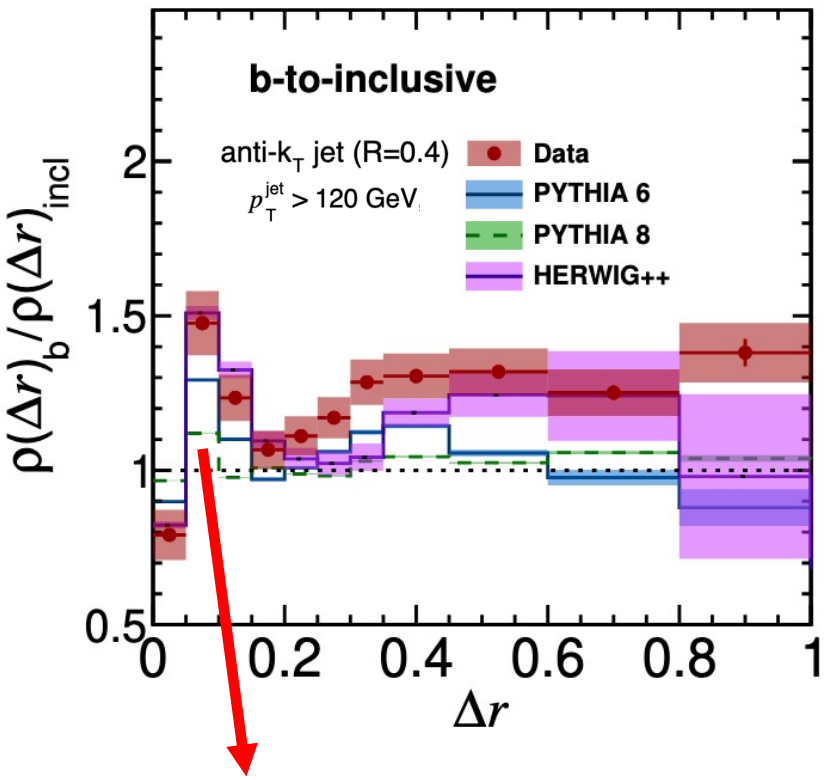
~ Trend explained well by models with collisional and radiative corrections [1]

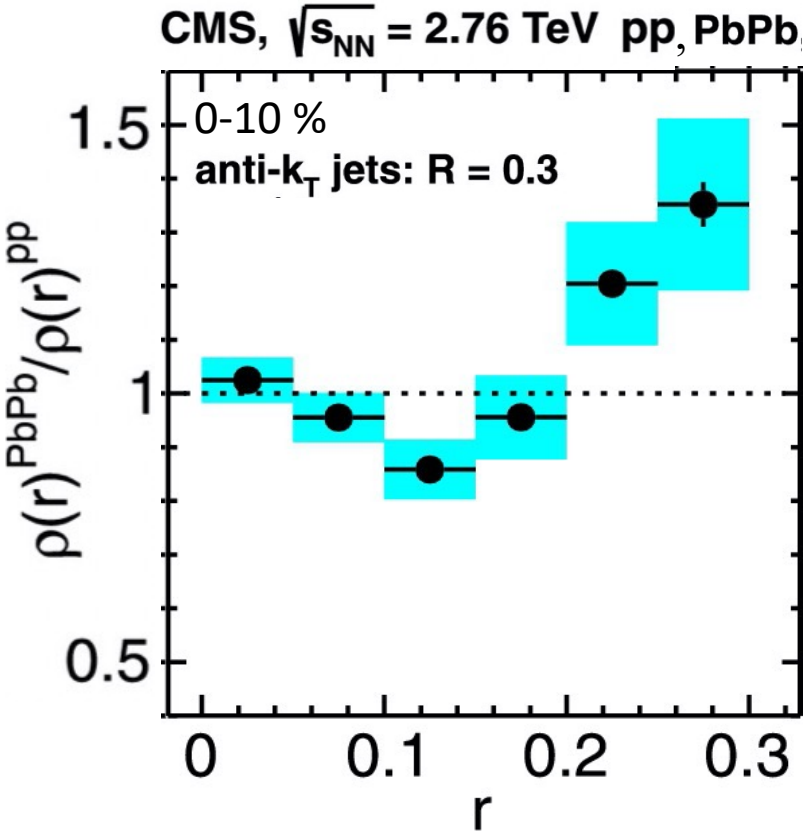
1. Eur.Phys.J. C79 (2019) 789



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

CMS, JHEP05 (2021) 054




CMS, $\sqrt{s_{NN}}$ = 2.76 TeV pp, PbPb
0-10 %
anti-k_T jets: R = 0.3
$\rho(r)^{PbPb}/\rho(r)^{pp}$
1.5
1
0.5
0
0.1
0.2
0.3
r