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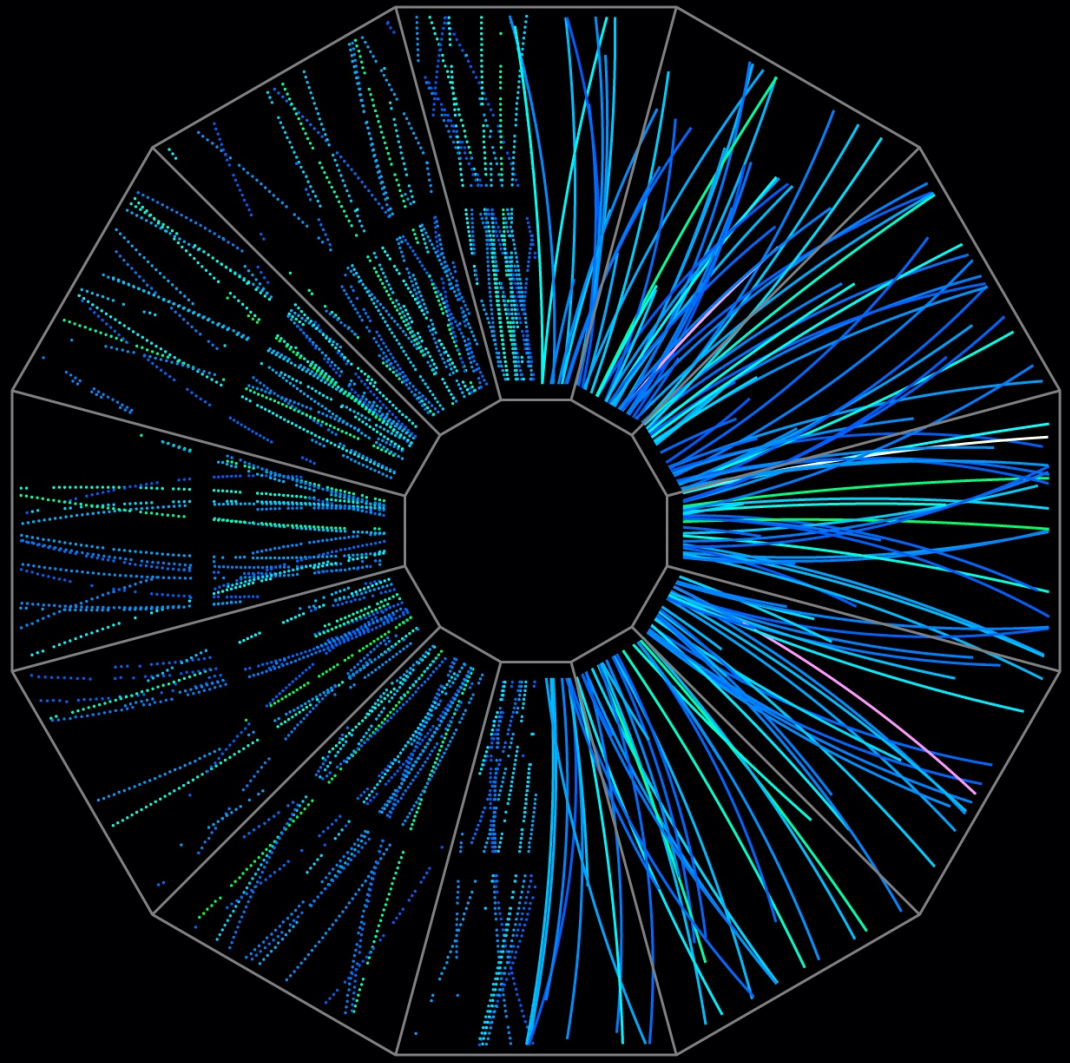
Exploring Flavor Dependence of Jet Shape Modifications in Quark Gluon Plasma



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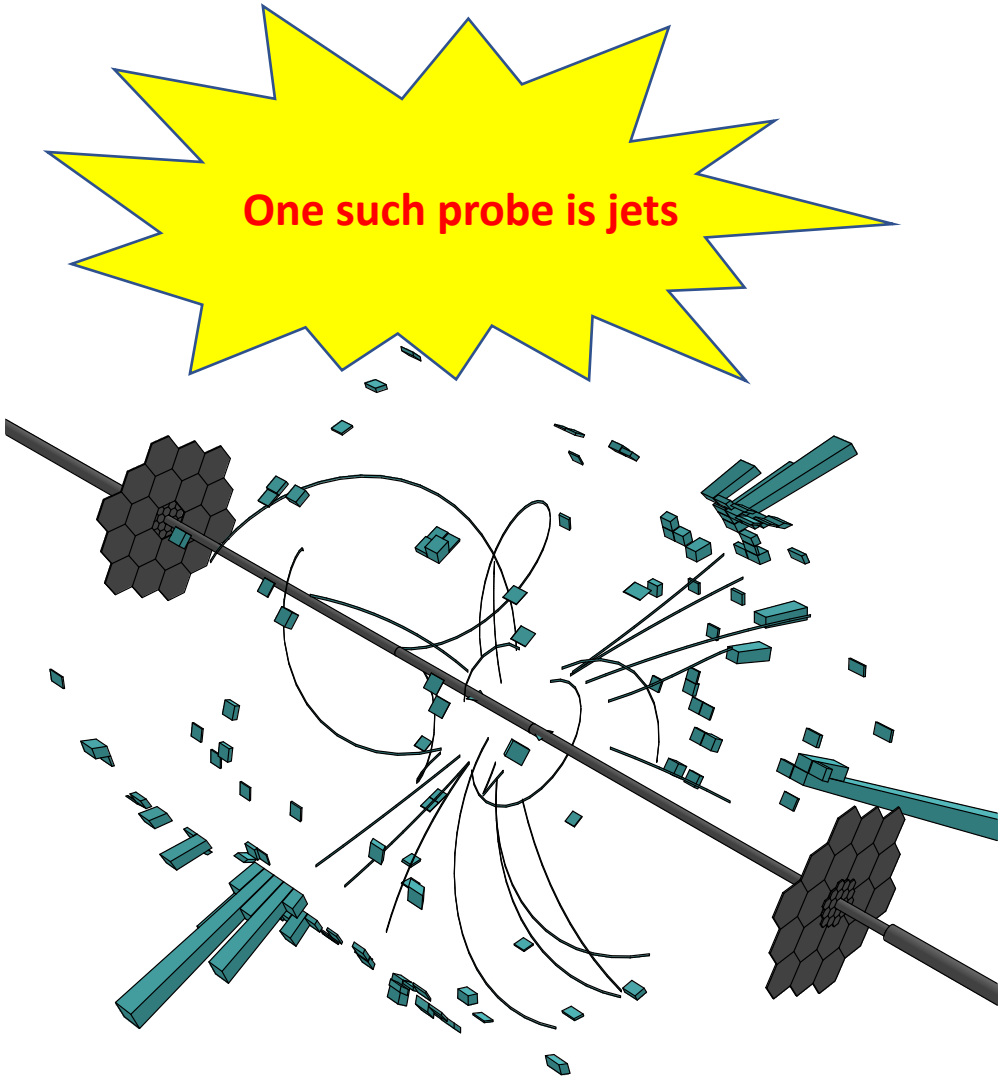
Motivation

How can we study the QGP properties?

1. Lifetime very short ($O(1 – 10$ fm/$c)$)
2. Not feasible to use external probes
3. Instead, pass a QCD-sensitive internal probe through it, then look for any modifications due to the medium

Processes with:
- Large momentum transfer (i.e., high Q^2)

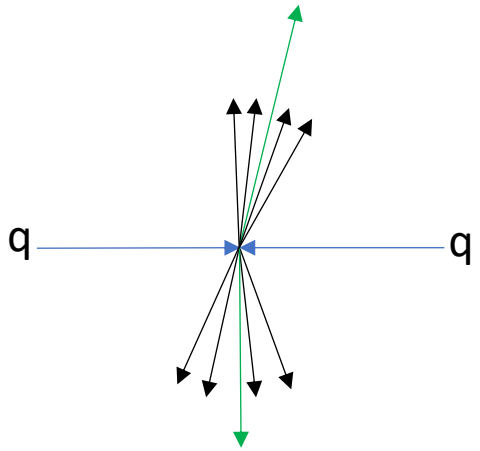
4. Measure an observable in ***p*+*p* & *p*+A** collisions
5. Measure the same observable in **heavy ion** collisions
6. Check for modifications



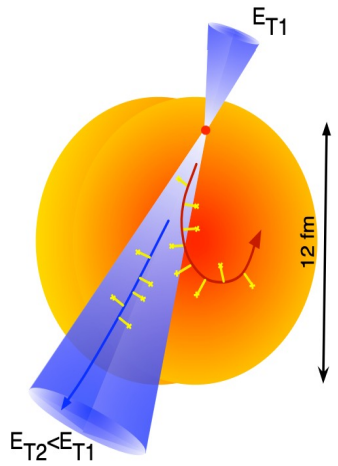
source: RHIC album © Brookhaven National Laboratory

Motivation

Jet observables



p + p

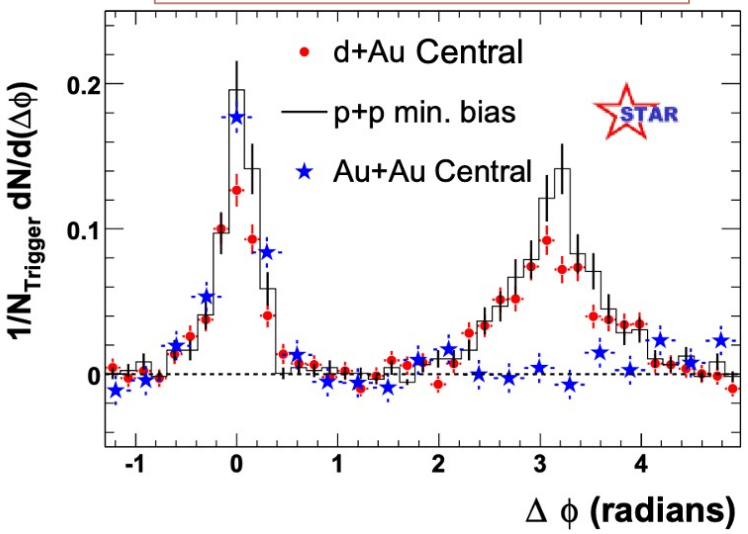


A + A

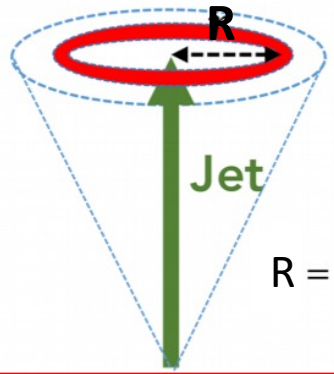
- Charm is one of the heavier quarks
  - ✓ Usually produced early in the collision, so have access to the full QGP evolution
- Medium modifications expected to be different for jets originating from a charm quark as compared to other light quarks
- *We study jets containing mesons with charm quarks (such as $D^0(c\bar{u})$)*

Far side jets are heavily suppressed in heavy ion collisions

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



$$\text{Radial Distribution} = \frac{1}{N_{jD}} \frac{dN_{jD}}{dR}$$

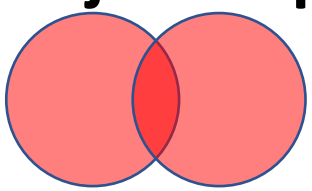


$$R = \sqrt{(\Delta\varphi)^2 + (\Delta\eta)^2}$$

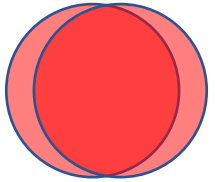
$$\text{Differential Jet Shape } \rho(R) = \frac{1}{\Delta R} \frac{1}{N_{\text{jet}}} \sum_{\text{jet}} \frac{\sum_{\text{track}\in(R_a,R_b)} p_{\text{T,track}}}{p_{\text{T,jet}}}$$

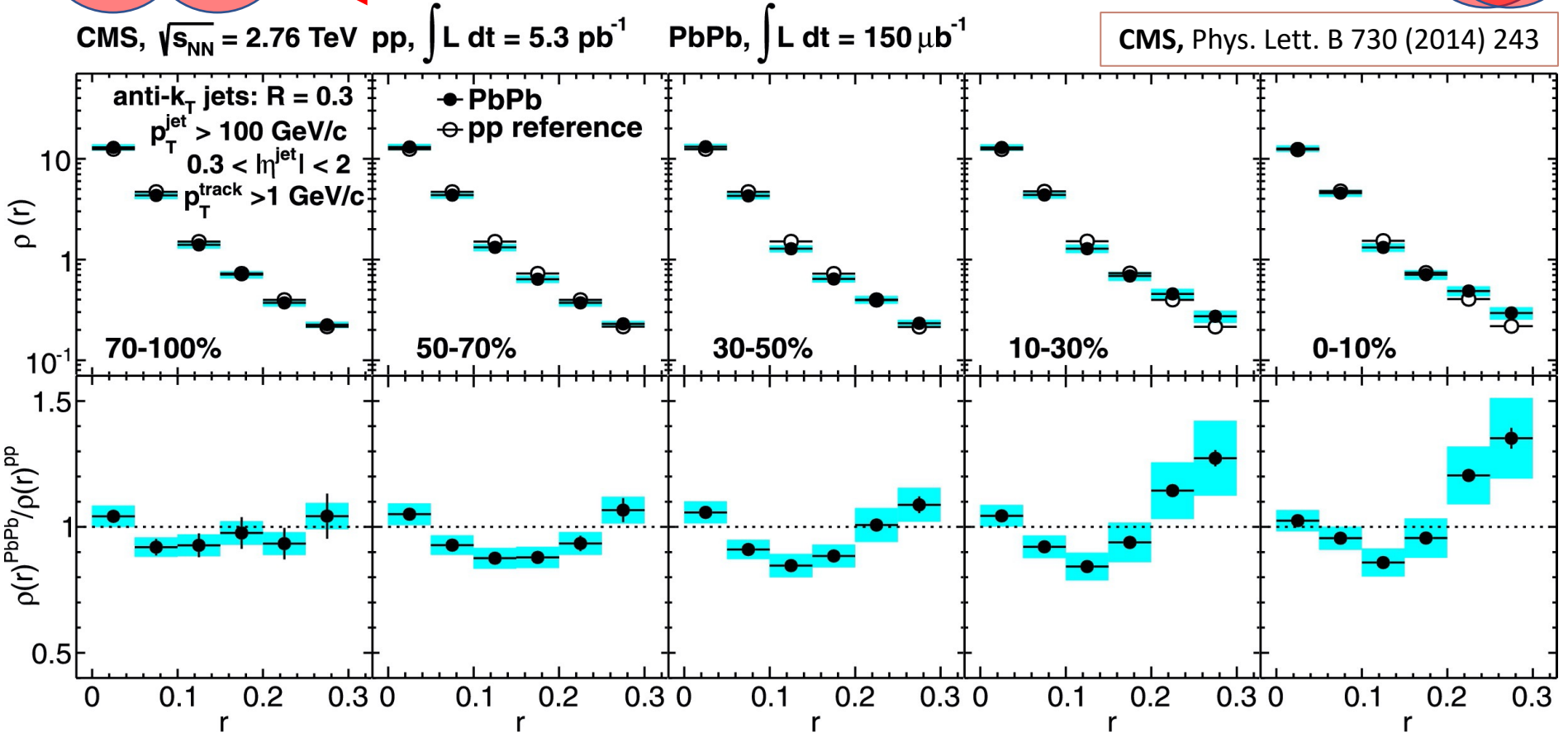
Motivation

Differential jet shape



Decreasing centrality





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

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

Motivation

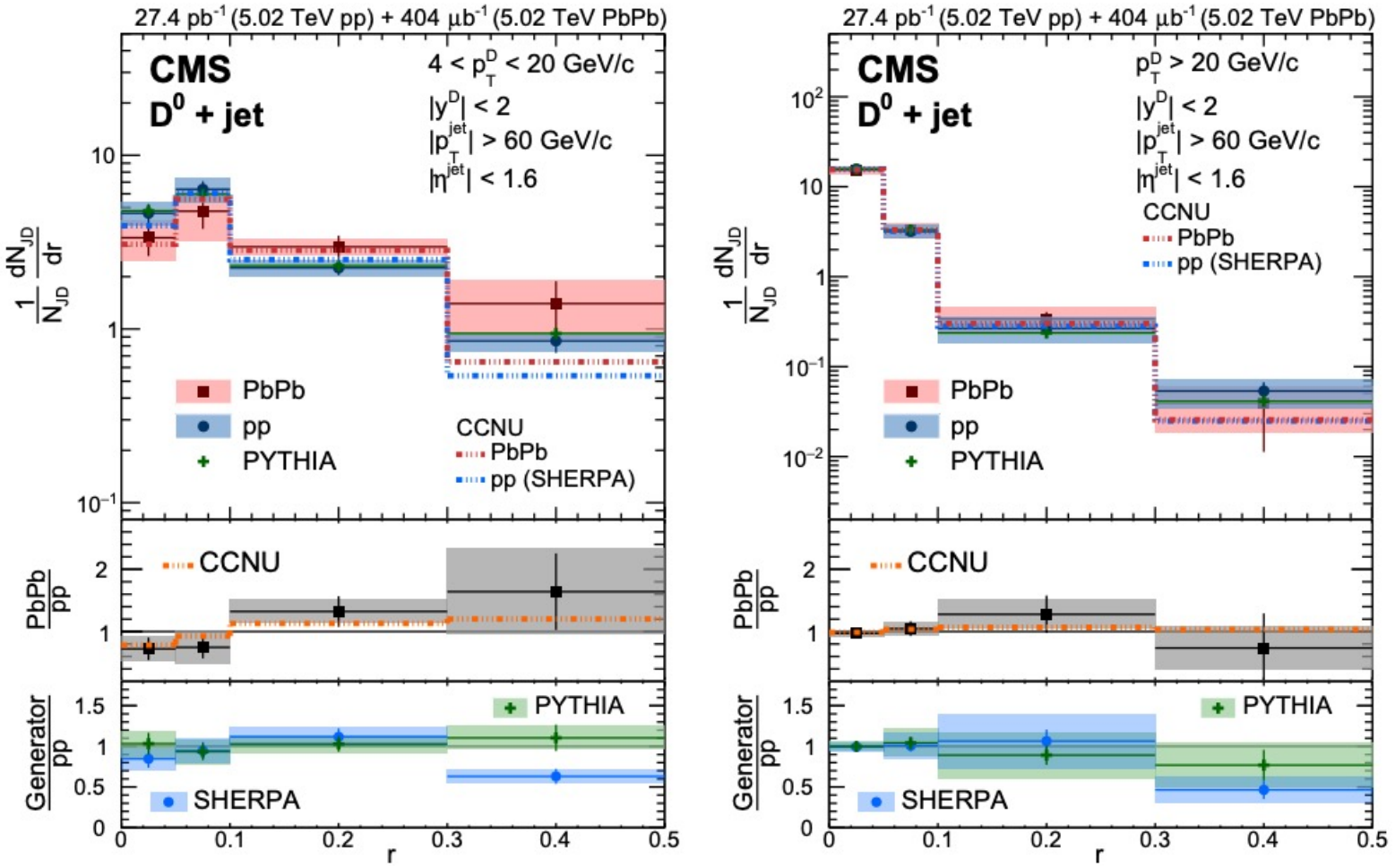
Radial distribution of D^0 mesons in jets

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

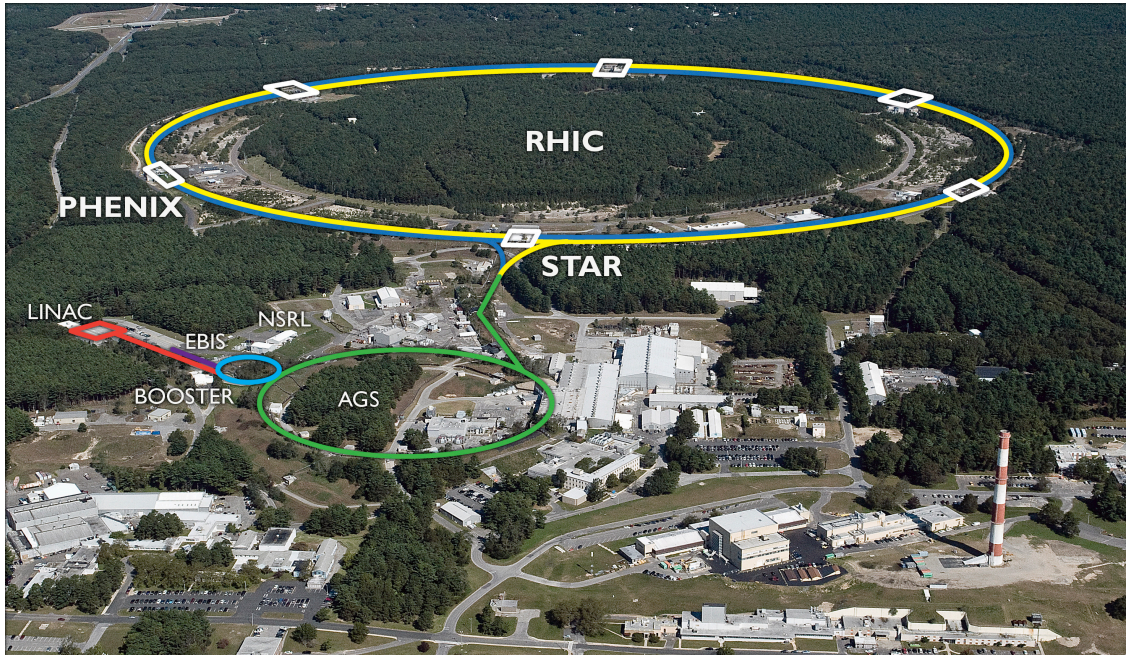
Hint of D^0 meson radial distribution modification for low p_T D^0 mesons

For high p_T, the modification disappears

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



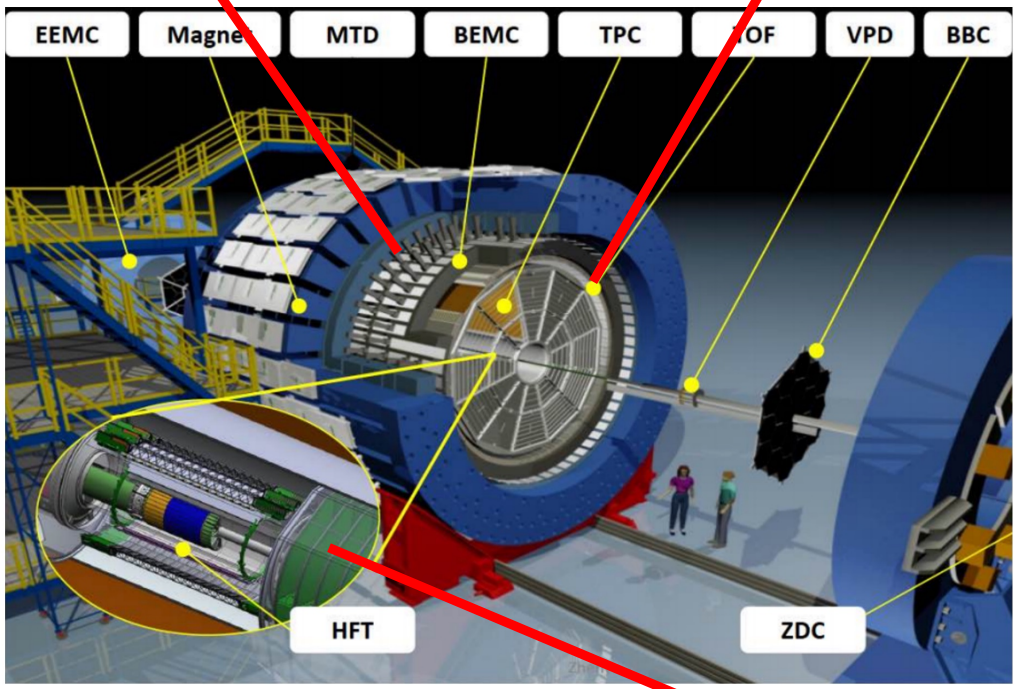
Apparatus



- Capable of colliding both proton and heavy ion beams
- Currently, the only running experiment is STAR
- 3.8 km long, has 6 intersection points
- Up to 510 GeV for proton-proton collisions
- Up to 200 GeV per nucleon pair for heavy ion collisions

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

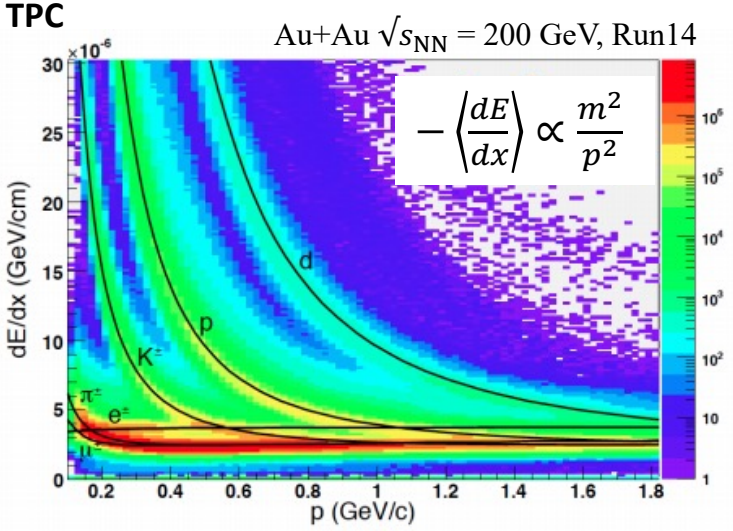
Time-of-Flight Detector (TOF)
- Identifies charged particles



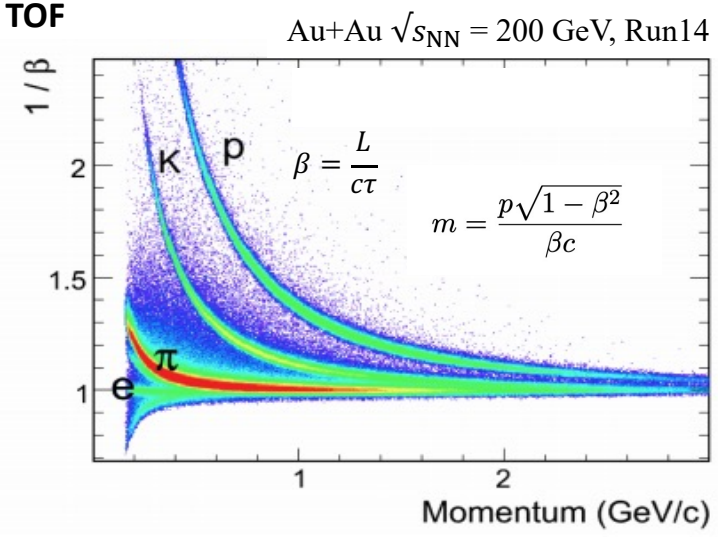
Heavy Flavor Tracker (HFT)
- Improves position resolution for tracks

Invariant Mass

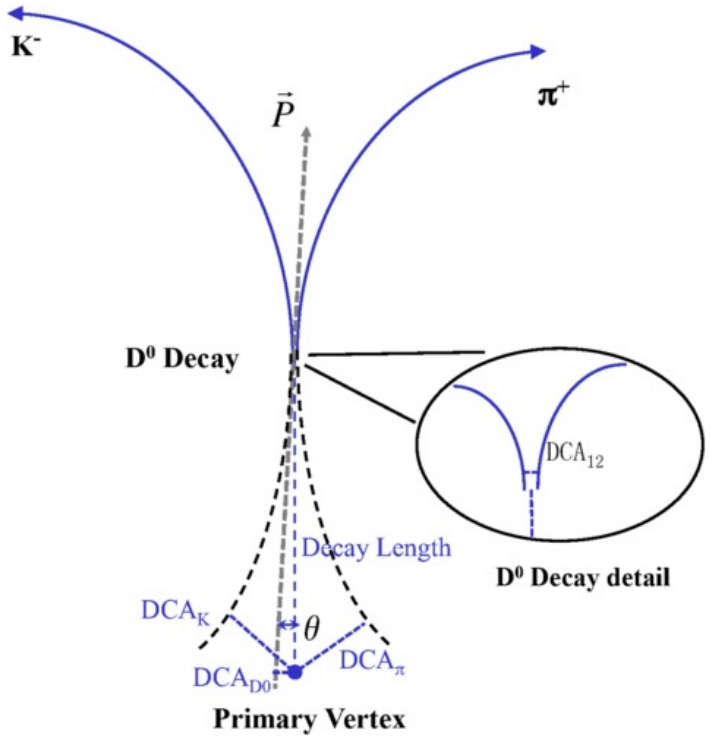
TPC

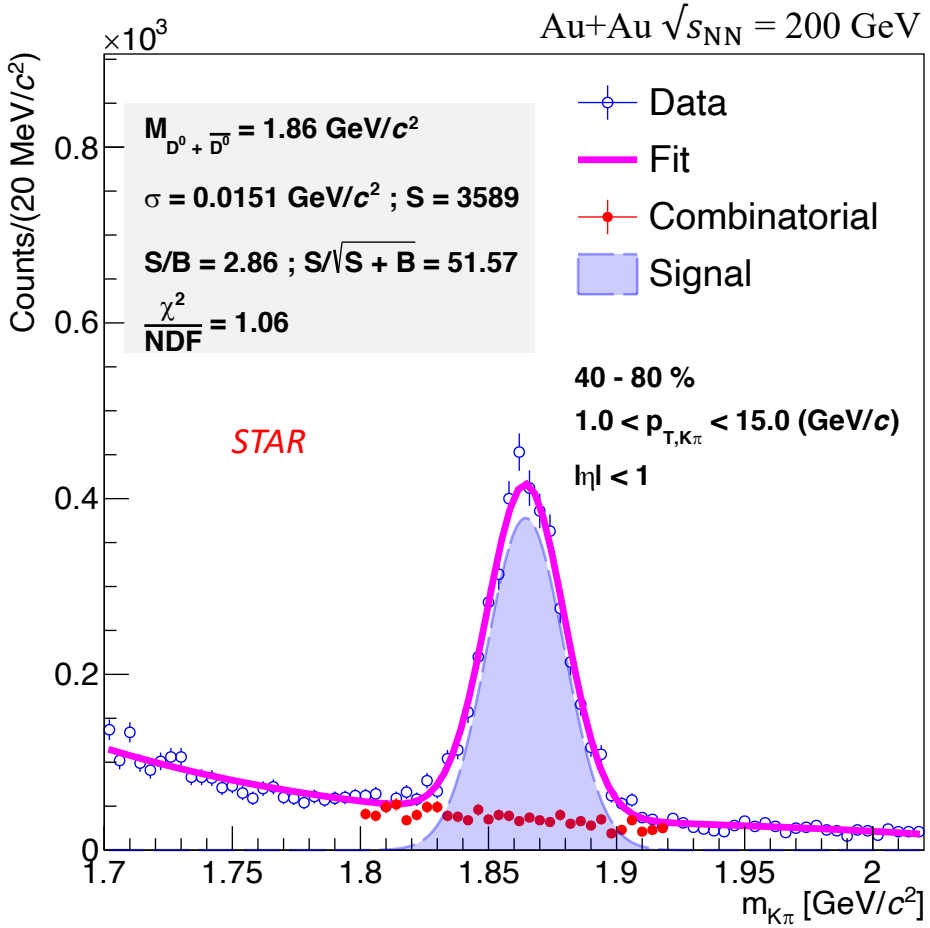


TOF



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



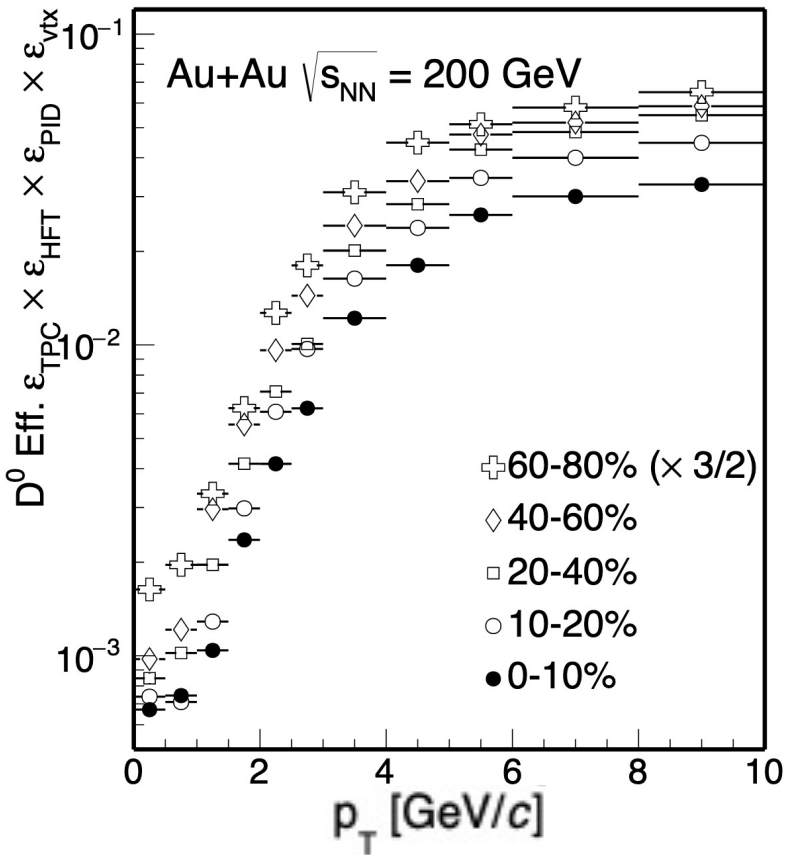


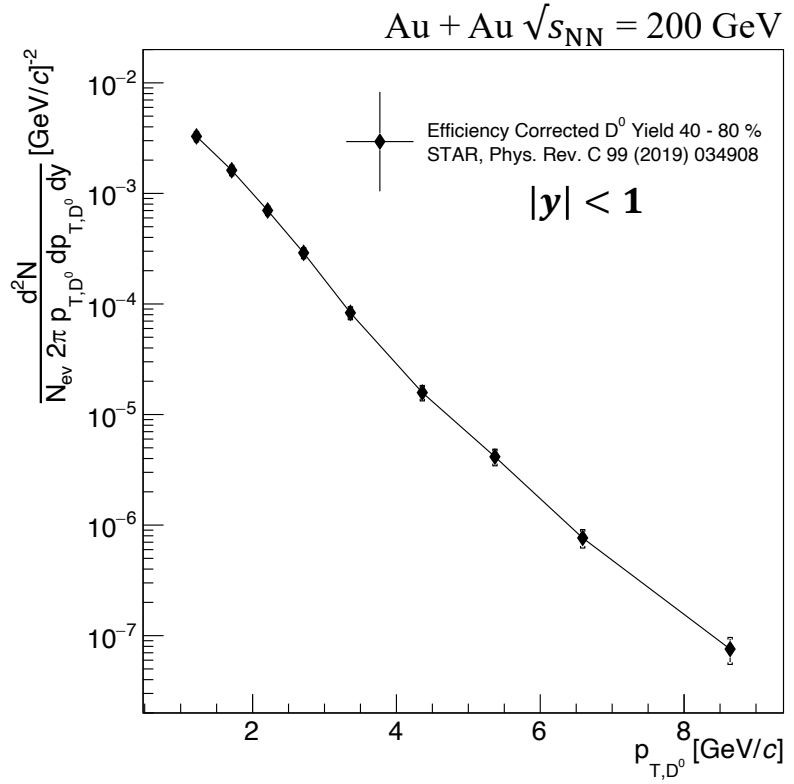
Decay Length of D^0 ~ 123 μm.
HFT has a resolution of 30 μm for kaons at ~ 1.2 GeV/c
HFT can reconstruct D^0 candidates based on the decay kinematics

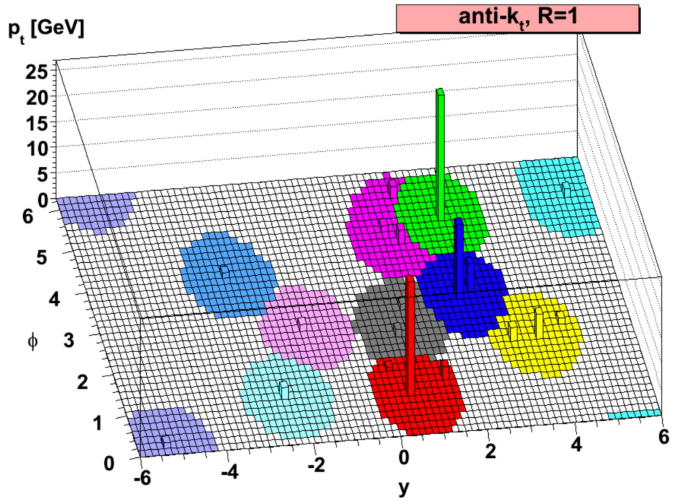
Topological cuts on the D^0 candidates improve signal significance

Efficiency Corrected D^0 Production

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





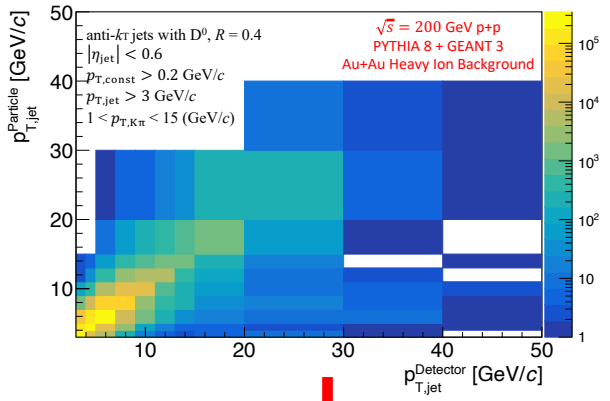


- anti-k_T full jets (charged + neutral constituents) in $\eta - \phi$ plane with R = 0.4
- D^0 candidates as constituents
- Fit invariant mass distribution to extract the D^0 jet yield for each kinematic bin

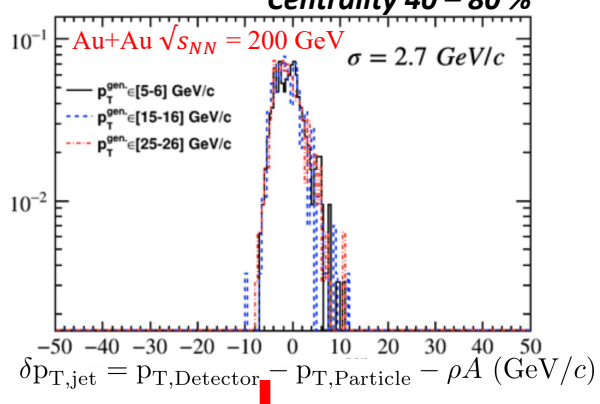
D^0 yield corrected for reconstruction efficiency

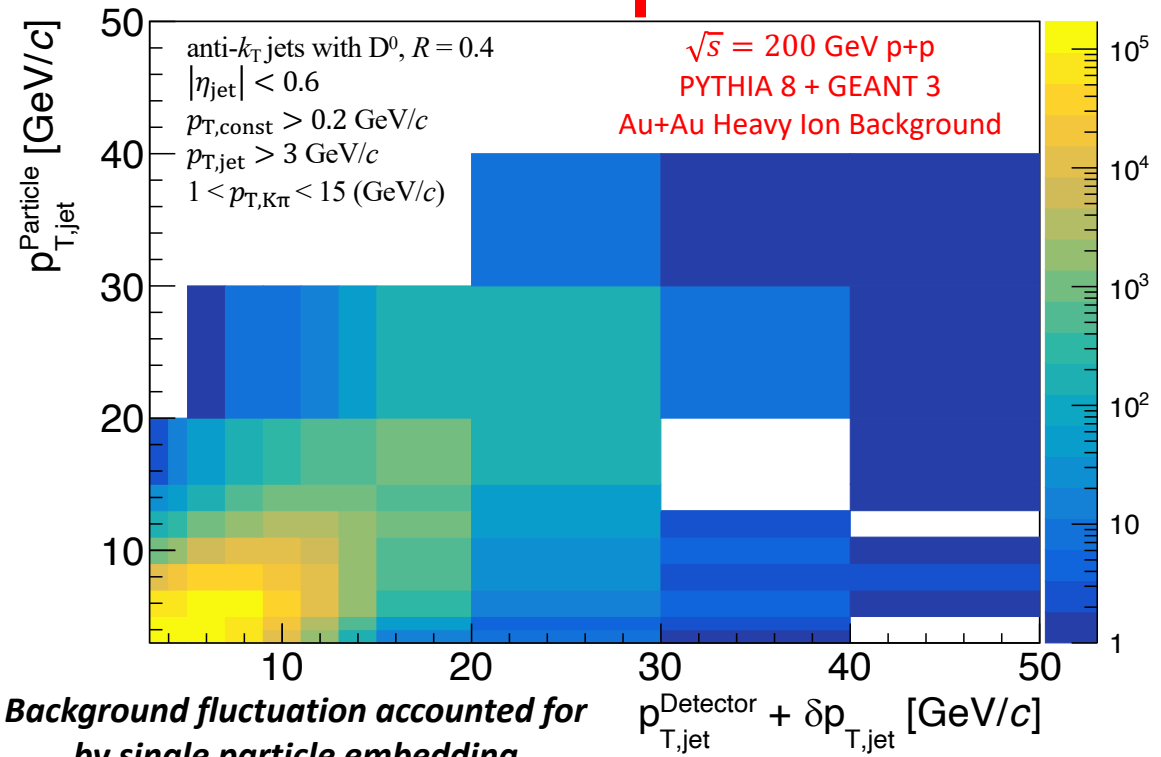
The efficiency weights were derived using a data-driven fast simulation method

Unfolding To Correct For $p_{T,jet}$ Spectrum



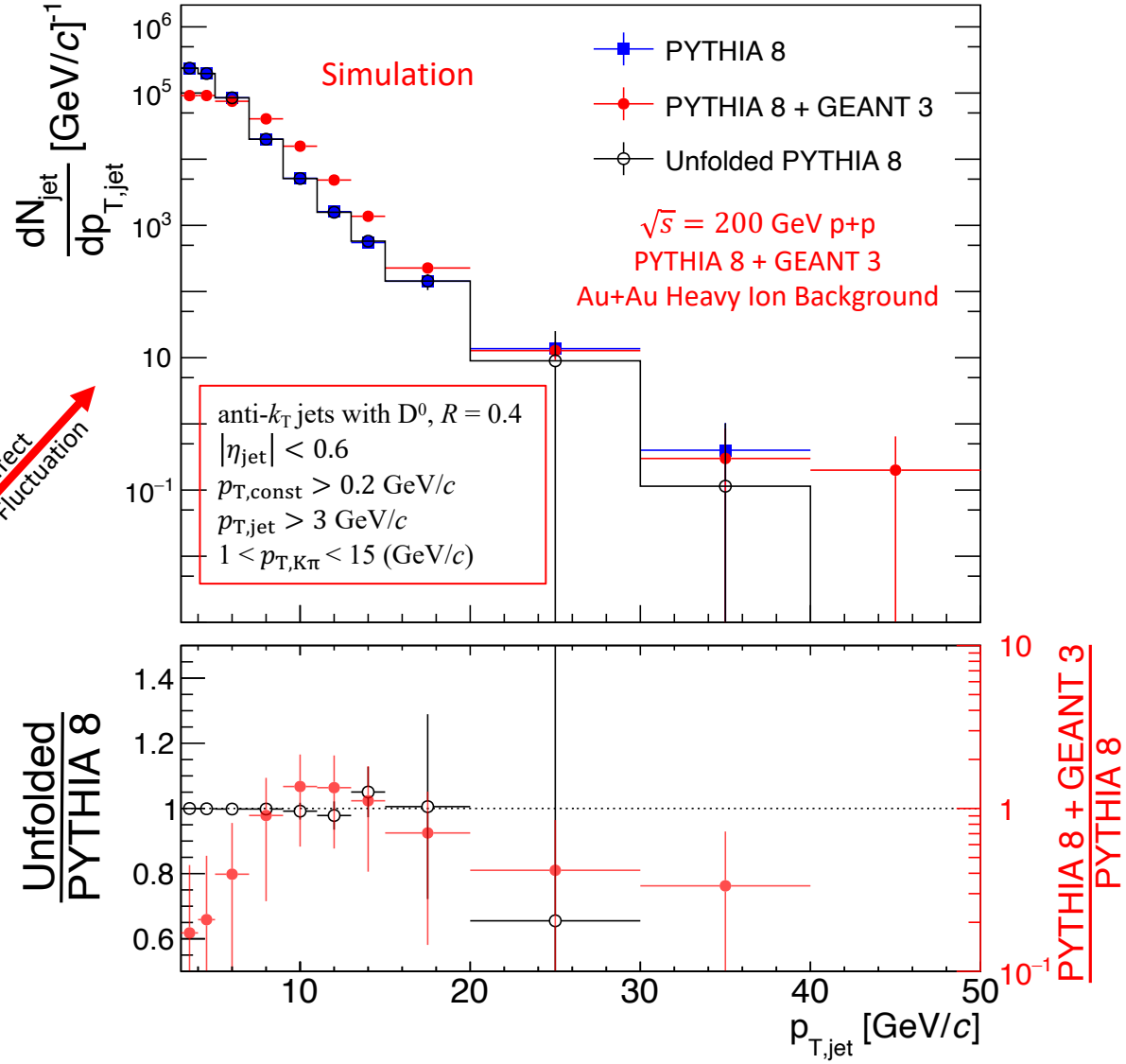
X





Background fluctuation accounted for by single particle embedding

Detector Effect
Background Fluctuation



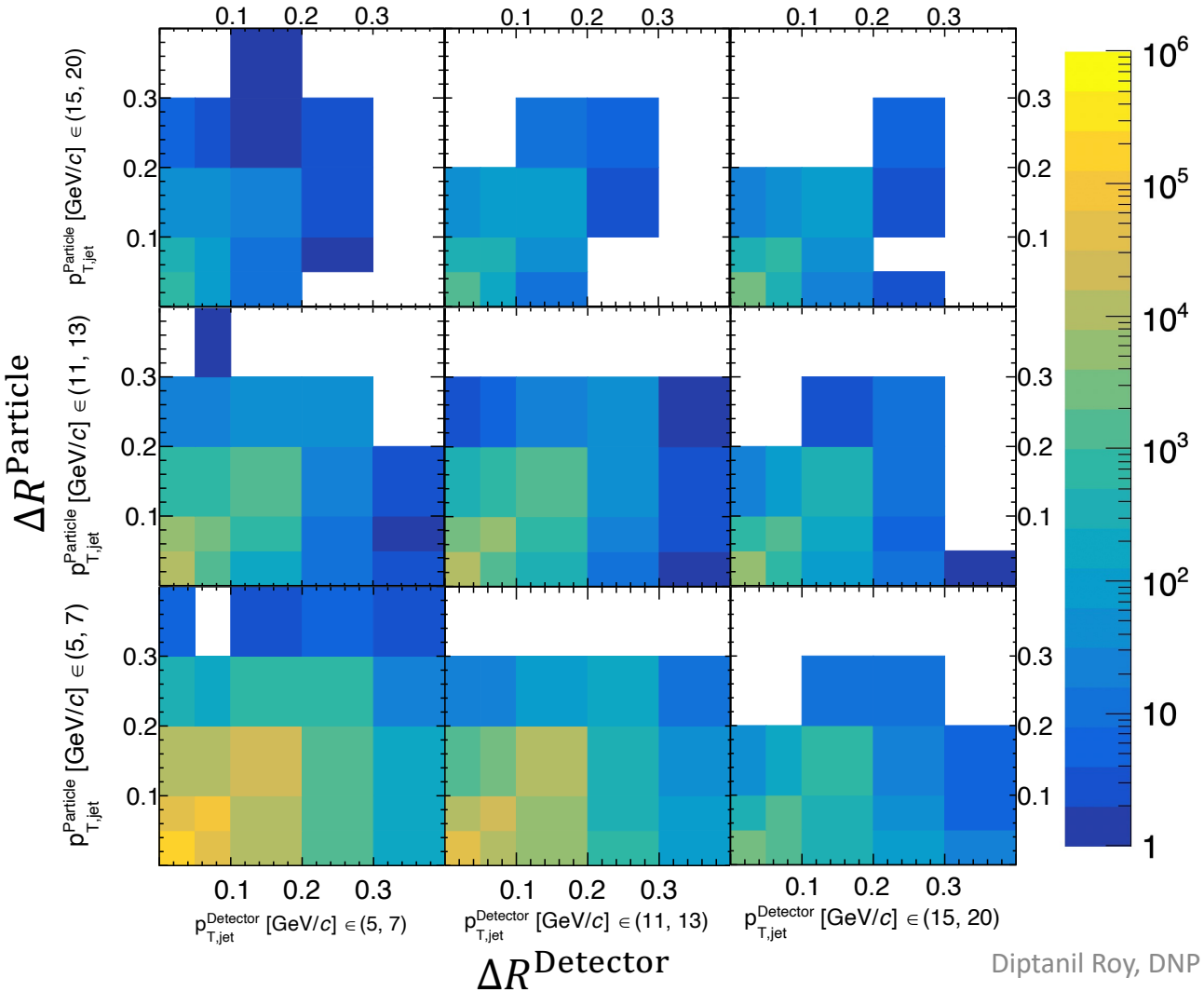
Closure test shows that we can reproduce the particle level $p_{T,jet}$ spectrum using unfolding

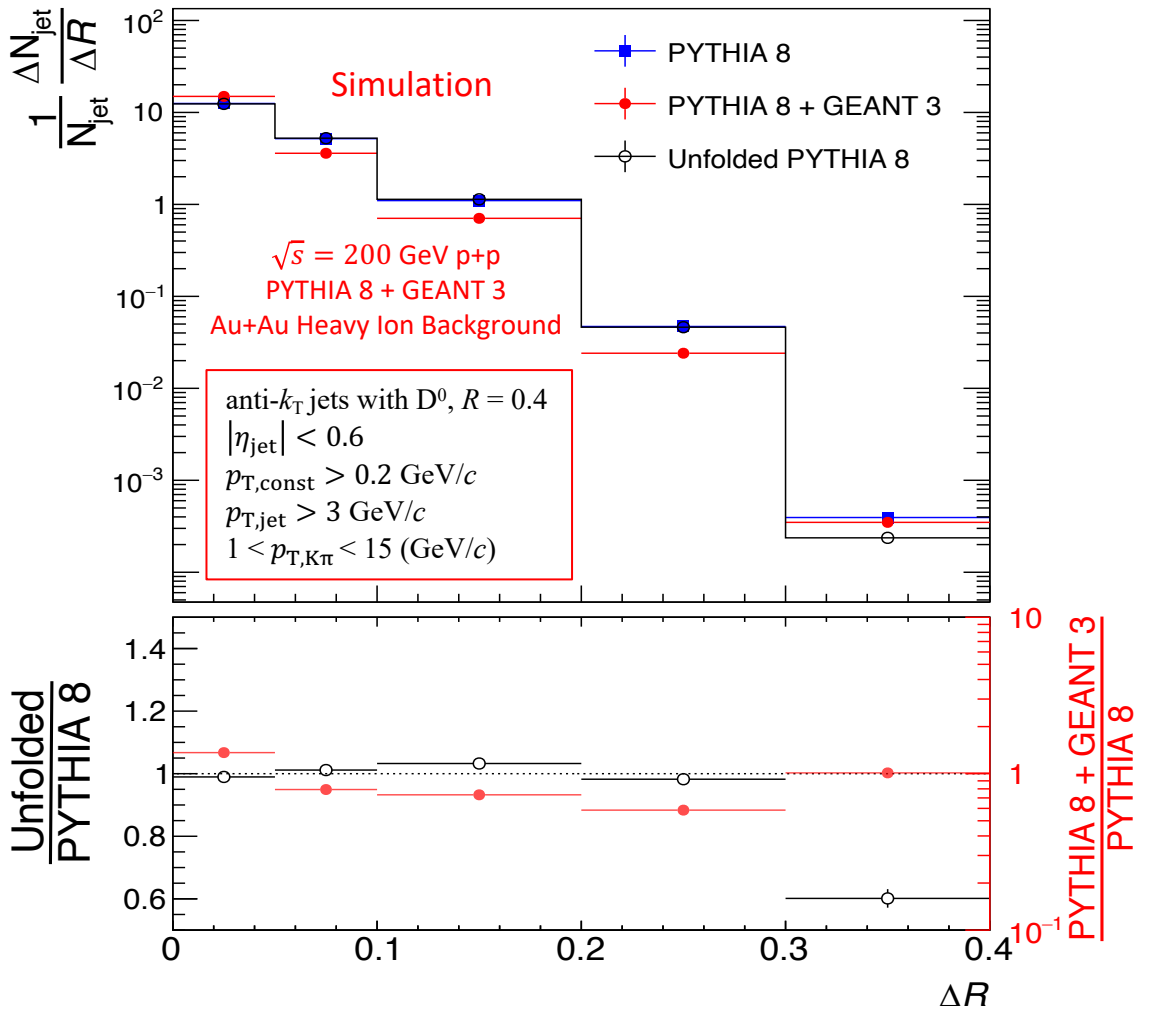
Unfolding To Correct For Radial Distribution of D^0 Mesons in Jets

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

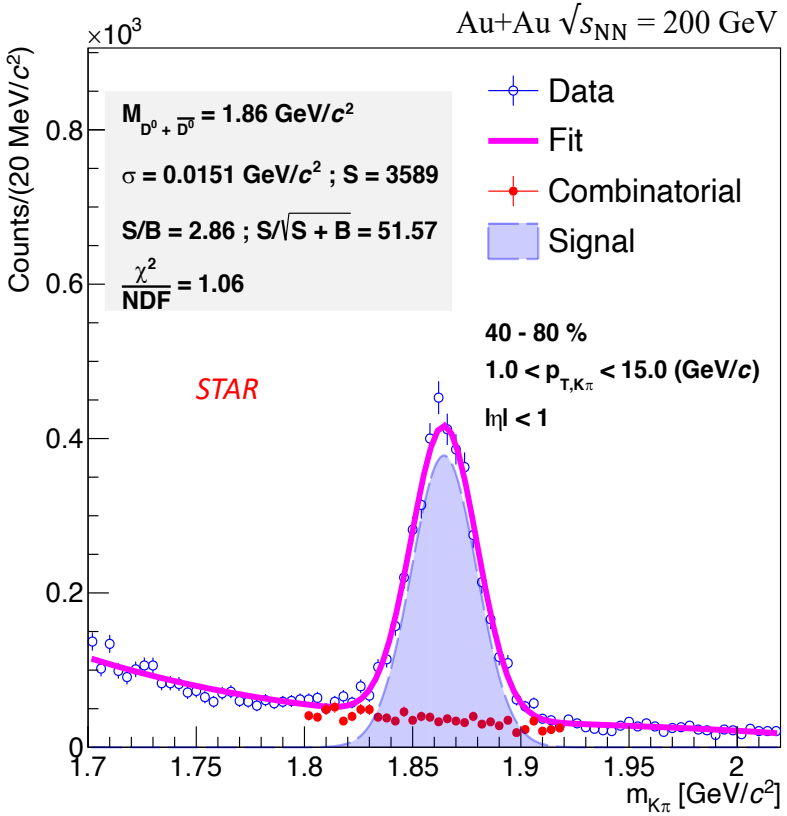
Radial distribution is unfolded along with the $p_{T,jet}$

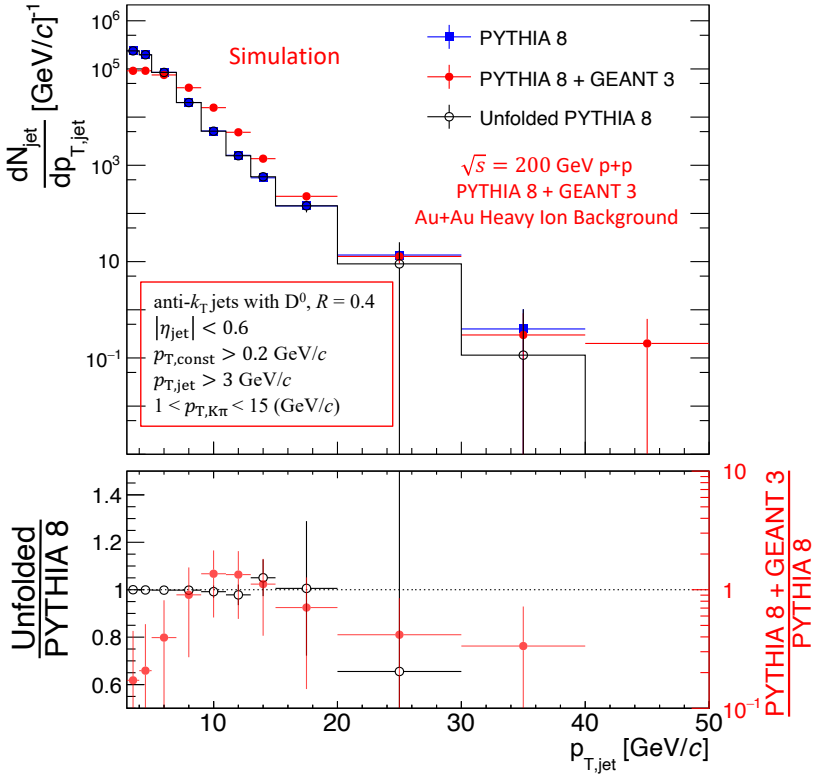


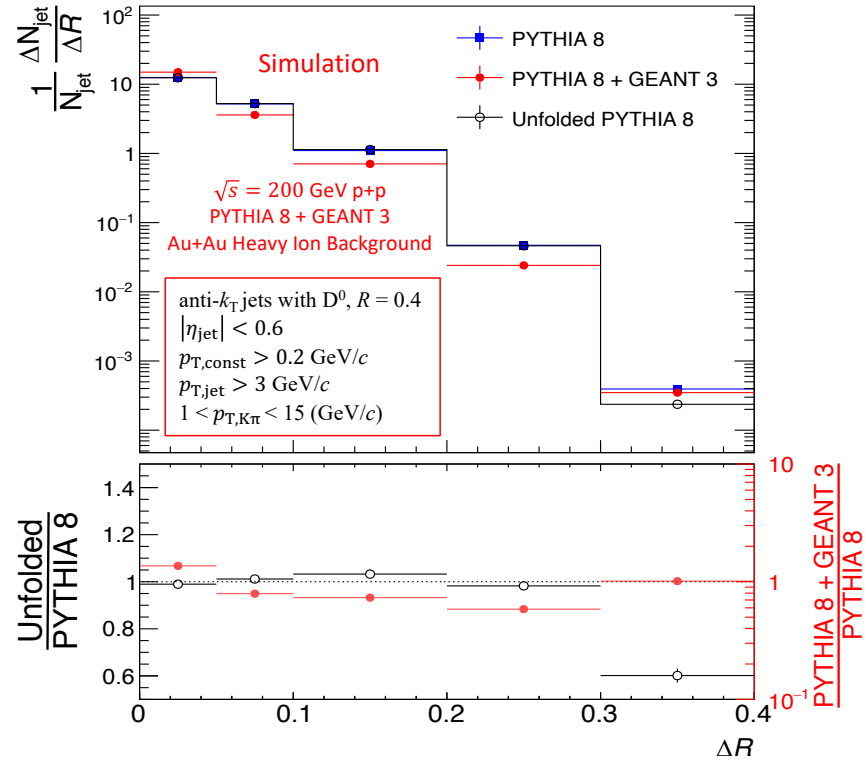


- **Closure test shows that we can reproduce the radial distribution of D^0 mesons for low and mid ΔR using 2D unfolding**
- **The closure for the last bin can be improved by increasing the simulation statistics**

Summary







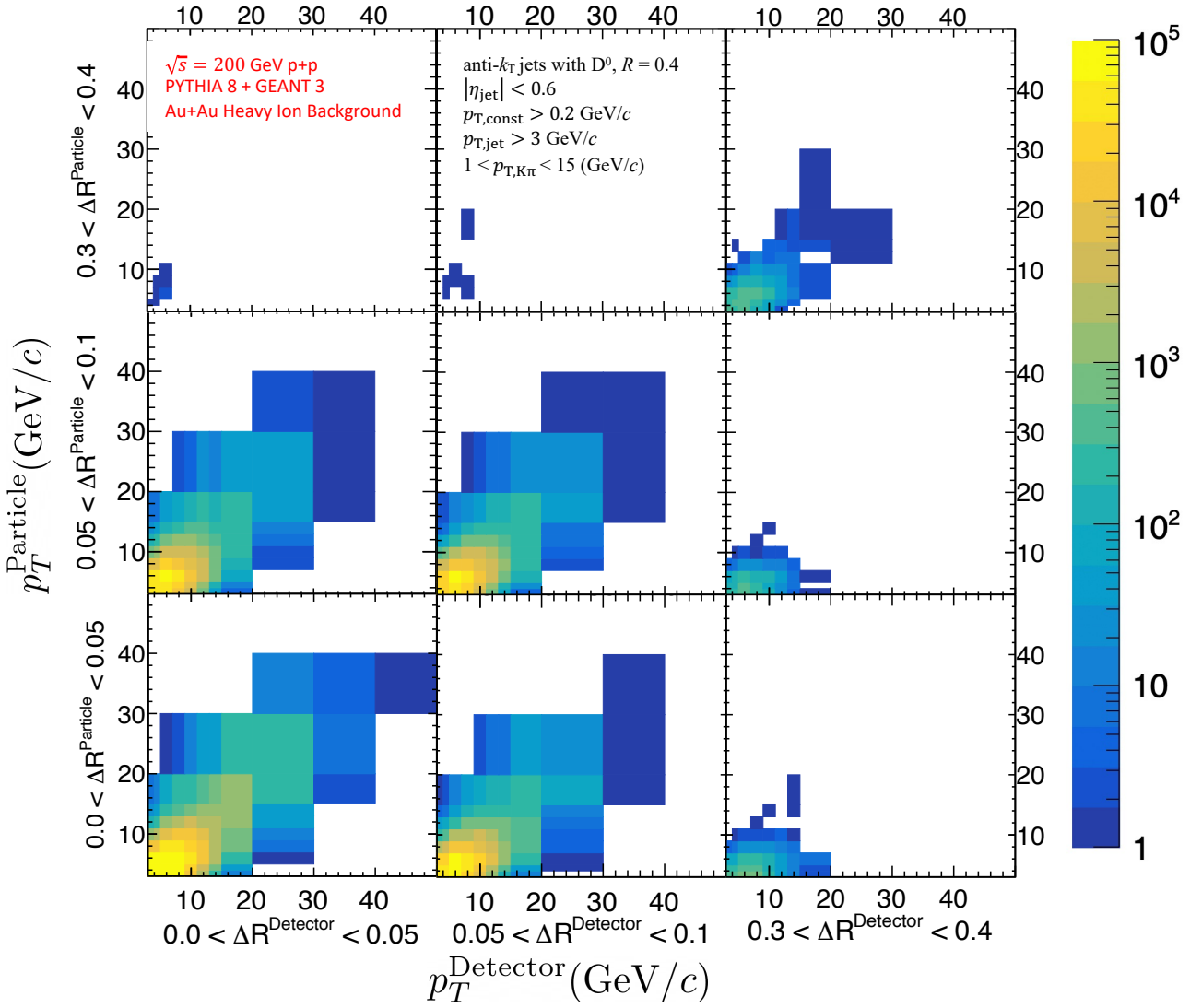
- Efficiency corrected D^0 meson counts in the peripheral collision is presented in this study
  - Unfolding as a method to correct for detector effects is studied. **The closure tests validate our correction procedure**
  - The study will be extended with larger MC samples, and other MC generators
- Analysis underway with large statistics data sample to measure D^0 jet substructure

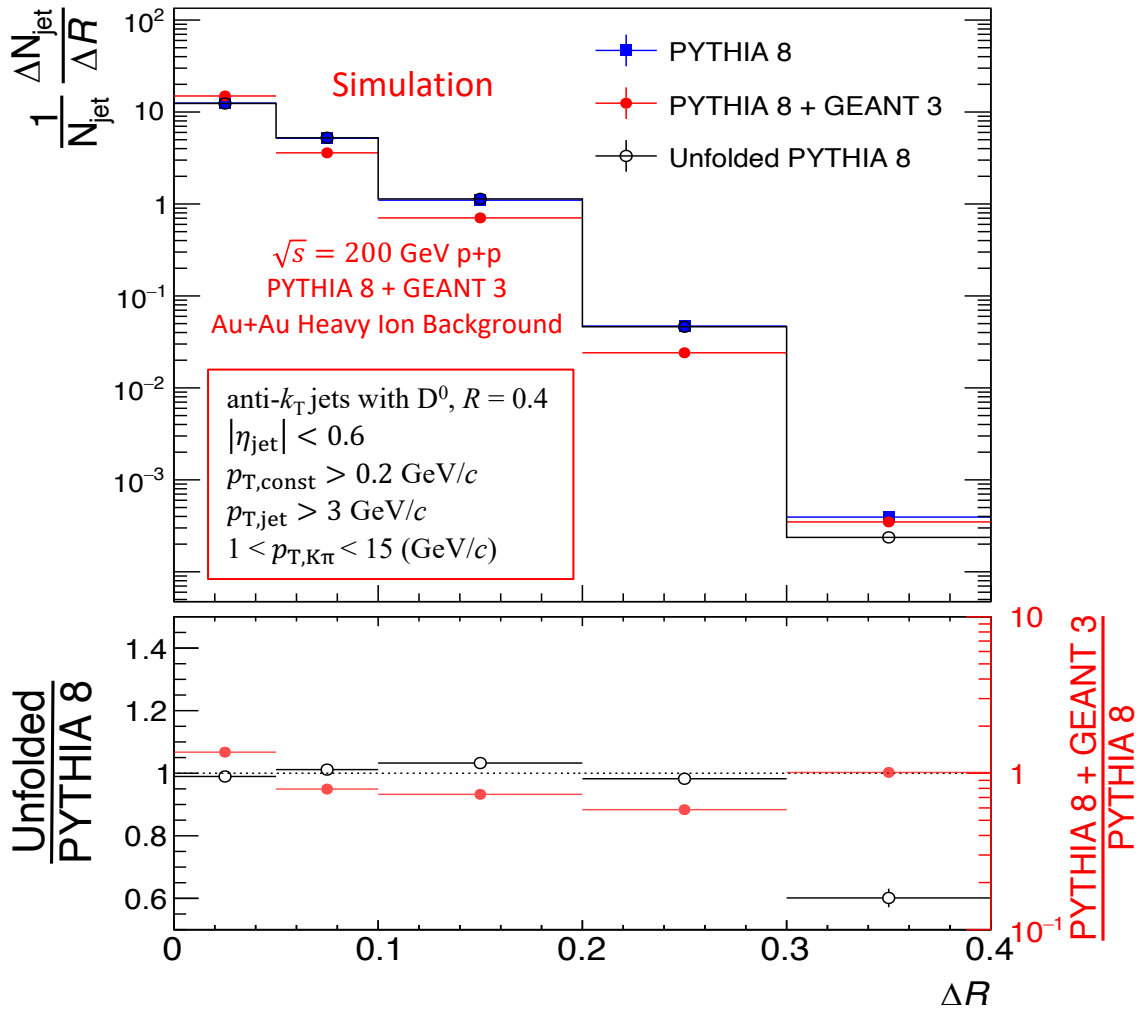
STAY TUNED

Unfolding To Correct For Radial Distribution of D^0 Mesons in Jets

Backup

Radial Distribution is unfolded along with the Jet p_T





- **Closure test shows that we can reproduce the radial distribution of D^0 mesons for low and mid ΔR using 2D unfolding**
- **The closure for the last bin can be improved by increasing the simulation statistics**