Heavy Flavor Measurements in STAR and Future Measurements Using the HFT

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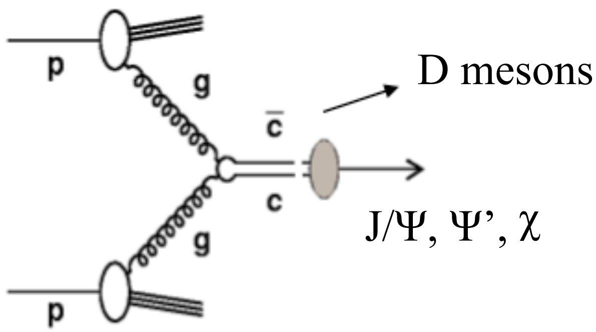
Outline

- Why study heavy flavors?
- Non-photonic electrons (NPE) in Au+Au and p+p
  - R_{AA} of NPEs
  - e^{HF}-h azimuthal correlations and the extraction of beauty's contribution to the NPE spectra
- D-Meson measurements
  - D^0 in Cu+Cu
  - Secondary vertexing technique using the SVT+SSD
- Future measurements using the HFT and ToF

Charm, Beauty, and the QGP

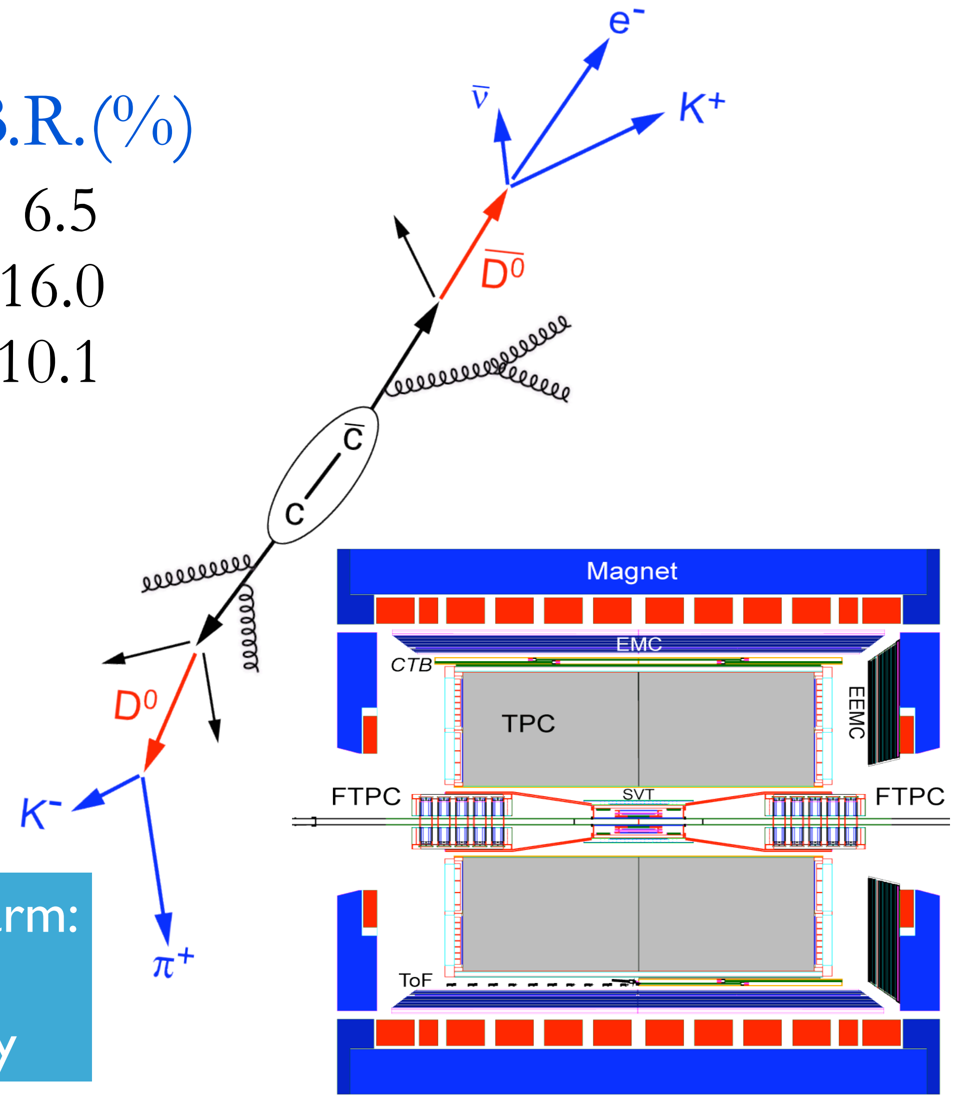


- Heavy flavor (HF) is produced dominantly from initial gluon fusion.
  - HF scales with number of binary collisions
  - HF produced in early stages of the collision, before thermalization
  - This makes HF an excellent probe of the medium
- Initially it was thought that the energy loss for heavy flavor would be smaller than that of lighter flavors (dead cone effect).
  Ref: Yu. Dokshitzer and D.E. Kharzeev, Phys.Lett. B 519 199-206 (2001)
- However, recent measurements have shown otherwise.
  Ref: B. Abelev et al (STAR), Phys. Rev. Lett. 98 192301 (2007)

Detecting Heavy Mesons

Semi-leptonic Channels	B.R.(%)
$D^0 \rightarrow e^+ +$ anything	6.5
$D^\pm \rightarrow e^\pm +$ anything	16.0
$B^0 \rightarrow e^+ +$ anything	10.1

Hadronic Channels	B.R.
$D^0 \rightarrow K\pi$	3.8
$D^\pm \rightarrow K\pi\pi$	9.2



Techniques used to measure open charm:
- Single electrons
- Reconstruction from hadronic decay

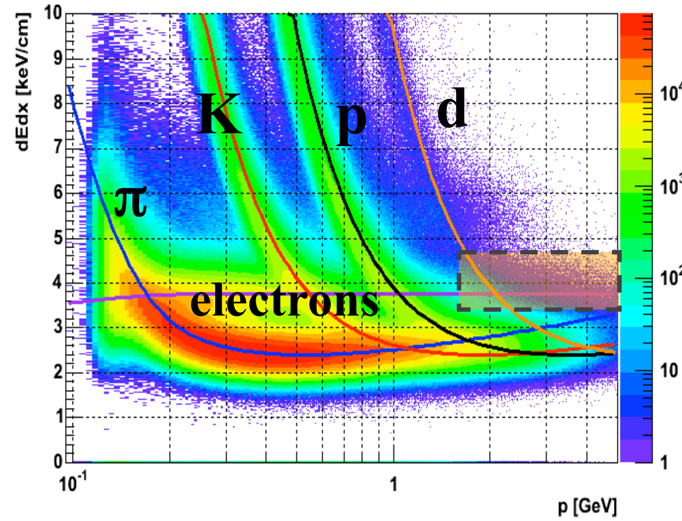
Electron Identification

TPC: dE/dx

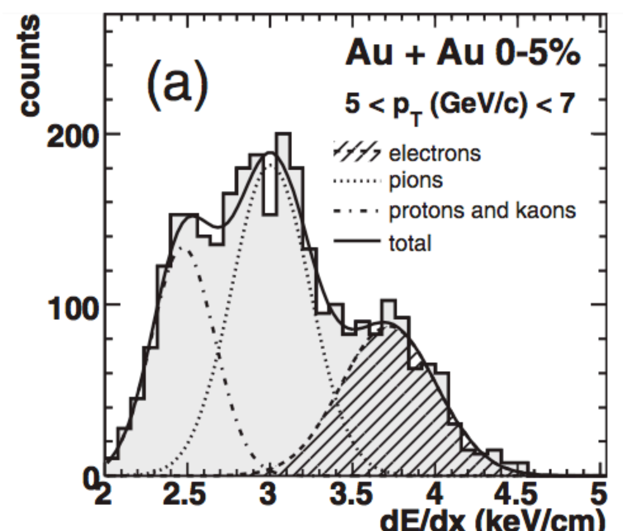
- Use primary tracks
- Good separation of $e^{\pm}$ from $\pi^{\pm}$ for p > 1.5 GeV/c

EMC:

- Tower E, in STAR p/E ~ 1 for $e^{\pm}$
- Shower Max Detector, the hadrons sample develops a different shape

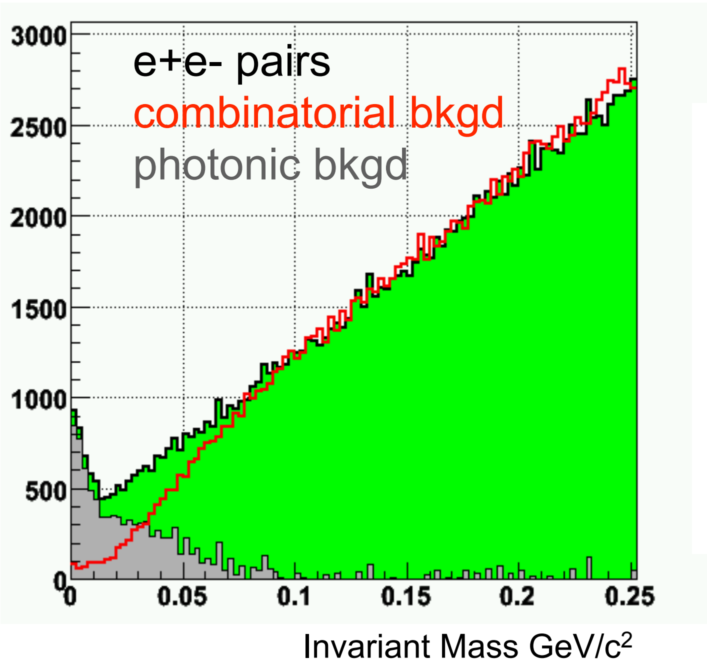


STAR: PRL 98 (2007) 192301



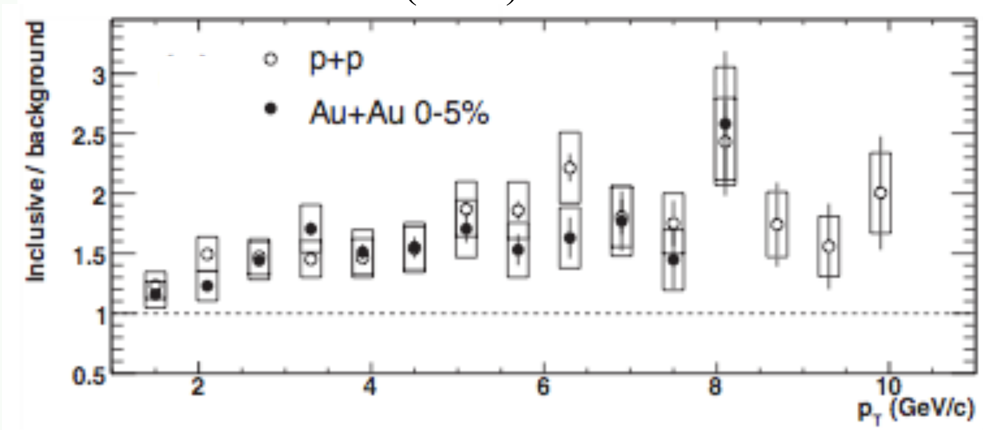
Photonic Electron Background

- **Background sources:**
  - γ conversions
  - π^0 & η Dalitz Decays



- **Rejection method:**
- Combine electron candidate with all TPC positron candidates
- If $M_{e+e-} < 0.14$ GeV/c² flag as photonic

STAR: PRL 98 (2007) 192301

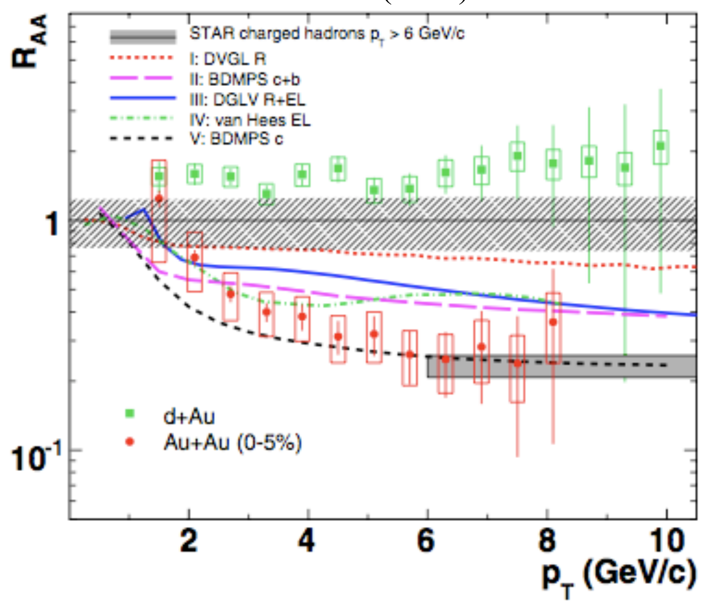


Excess over photonic observed for all systems and centralities.

➠ **Non-photonic signal**

R_{AA} of Non-photonic Electrons

STAR: PRL 98 (2007) 192301

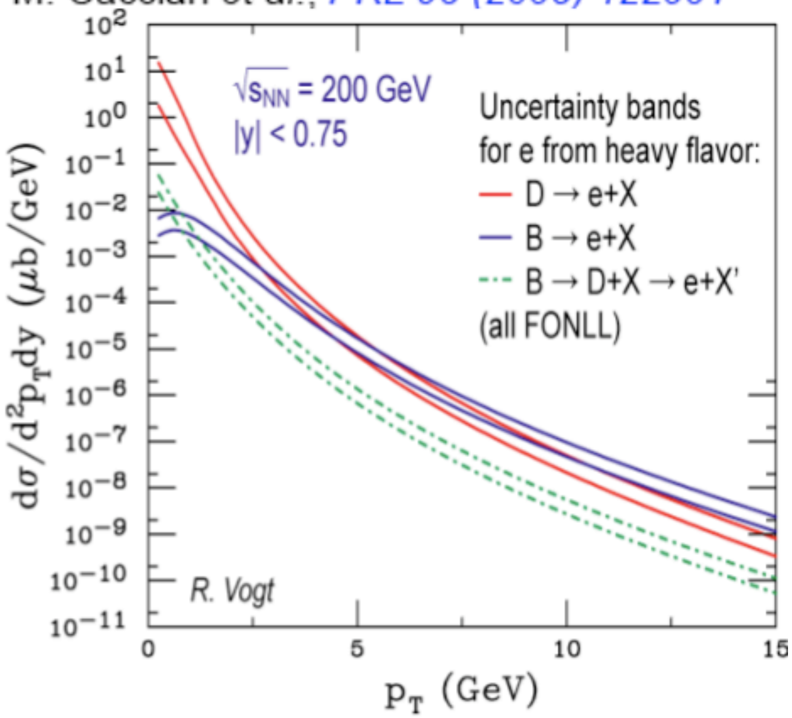


- NPEs show a similar magnitude of suppression as light flavor in Au+Au collisions
- We don't know how much beauty contributes to the NPEs.
- If the contribution is significant, energy loss for beauty is greater than expected
- There has not been a D or B measurement in STAR at high pt
- So how much is the B contributing to the NPE spectra?

pQCD Prediction for Beauty

- Because charm and beauty are heavy, pQCD can be used to predict their production
- FONLL predicts beauty contribution to become comparable to charm near 5 GeV/c

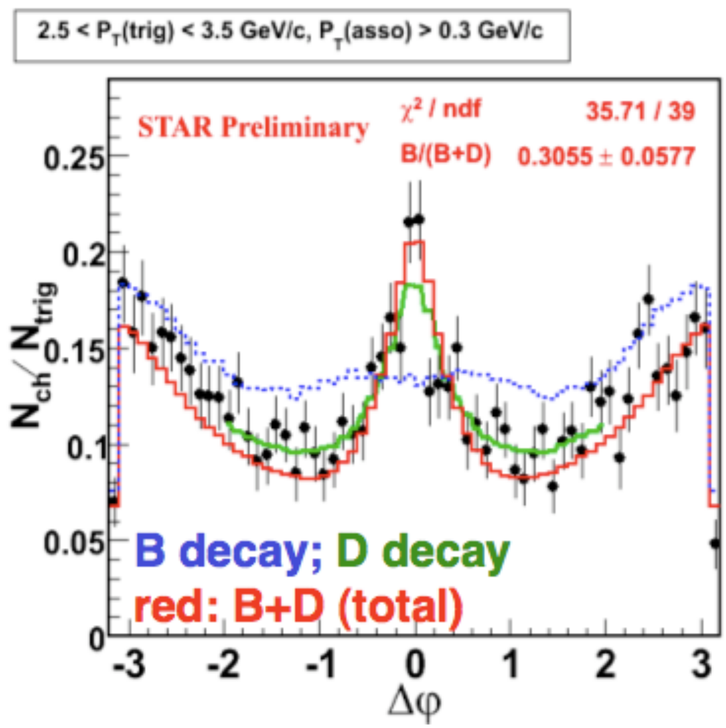
M. Cacciari *et al.*, PRL 95 (2005) 122001



How can we separate the charm from the beauty???

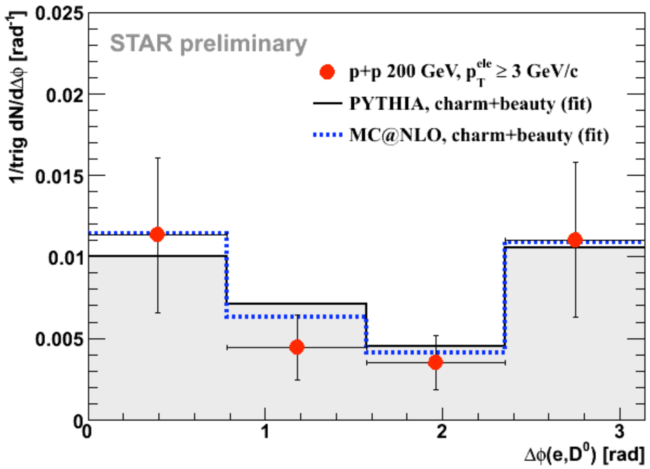
- Find B/(B+D) using e^{HF}-h correlations
- Find B/D ratio with e-D0 correlations
- Directly measure D mesons

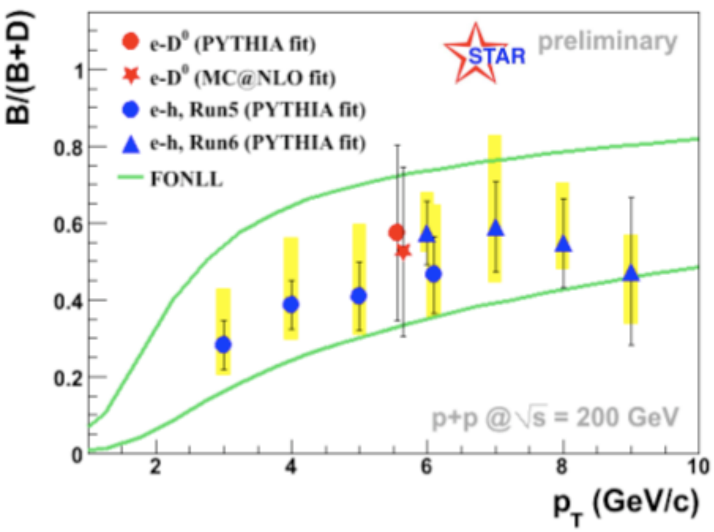
e-h Azimuthal Correlations



- Near side width for B decay is significantly wider compared to D due to decay kinematics.
- Measure e-h contribution in p+p, fit using MC with B/(B+D) as a parameter

e-D^0 correlations & Beauty's Contribution





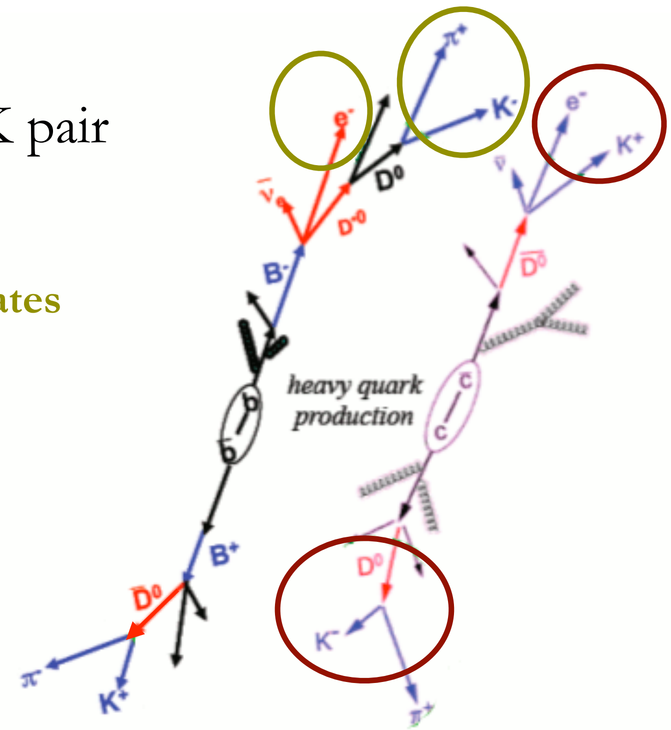
Use like sign e-K pair

- Near side:

  Beauty dominates

- Away side

  Mostly charm



The B contribution to the NPE spectra increases with p_T and is comparable to the D contribution at and above 5 GeV/c

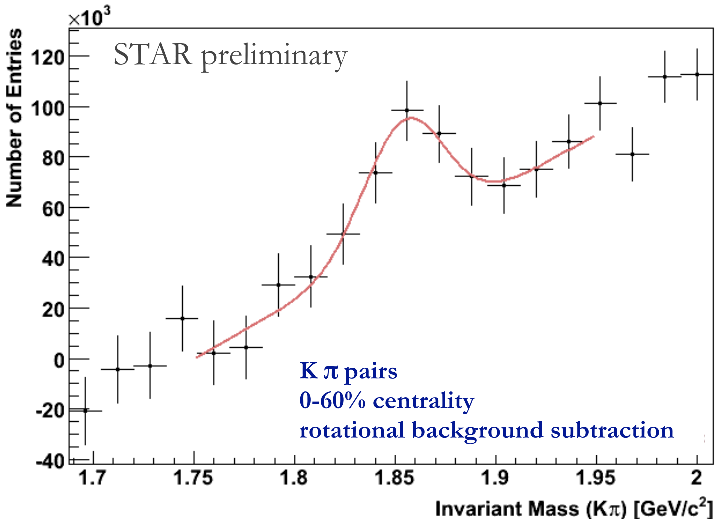
Direct measurements of D or B are essential!

Hadronic Reconstruction of D-Mesons

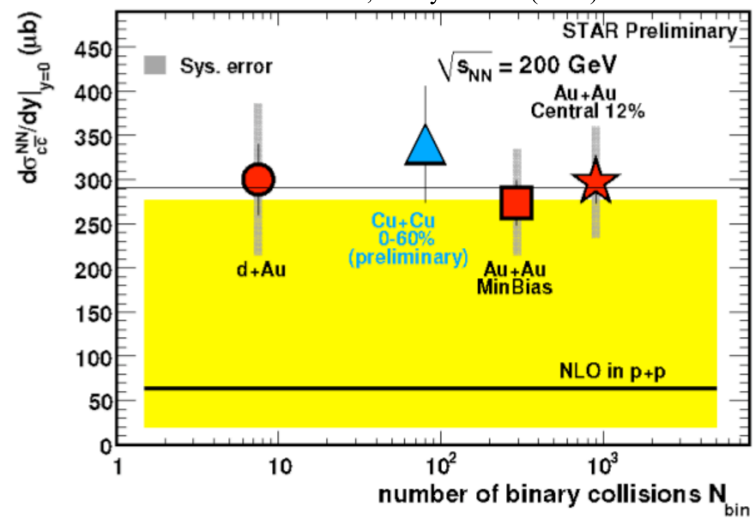
Two ways to extract a signal

1. **TPC:**
   - Use primary tracks
   - Use dE/dx from TPC to do PID
   - Combinatorial method
   - Extract signal after a **mixed event or rotated** background has been subtracted
2. **TPC+SVT+SSD:**
   - Use global tracks
   - Use dE/dx from TPC to do PID
   - Combinatorial method, also require the tracks to have a crossing point → **secondary vertexing technique**
   - Use geometrical cuts from the decay to reduce the background and retain the signal

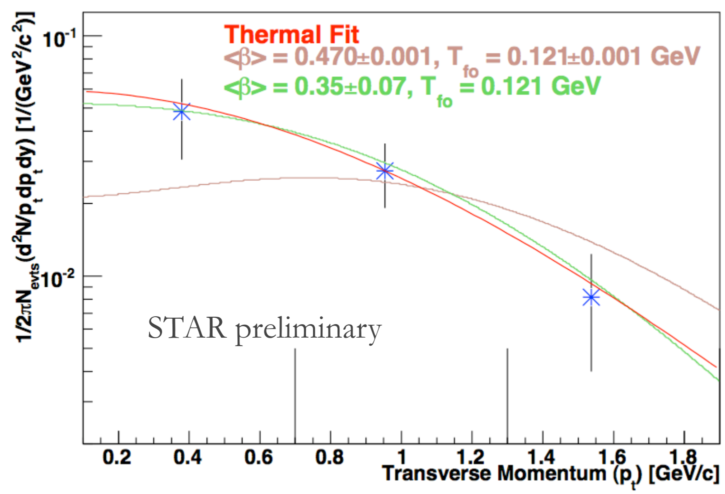
$D^0+\bar{D}^0$ in Cu+Cu 200 GeV collisions



A. Shabetai et al., J. Phys. G. 35 (2008) 104112



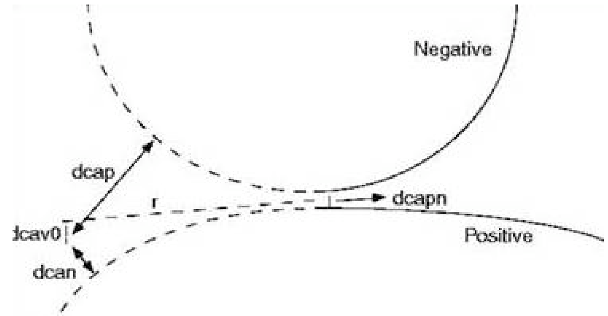
- Blast Wave fit using parameters extracted from π, K, and p spectra of 0-60% central Cu+Cu collisions
- Assuming T_{fo} and power-law dependence of flow velocity on radius is the same for D^0s as it is for lighter species, fit spectrum and extract <β>



<β> of 0.35 suggests that D^0 does not have as strong a radial flow as the light quark hadrons

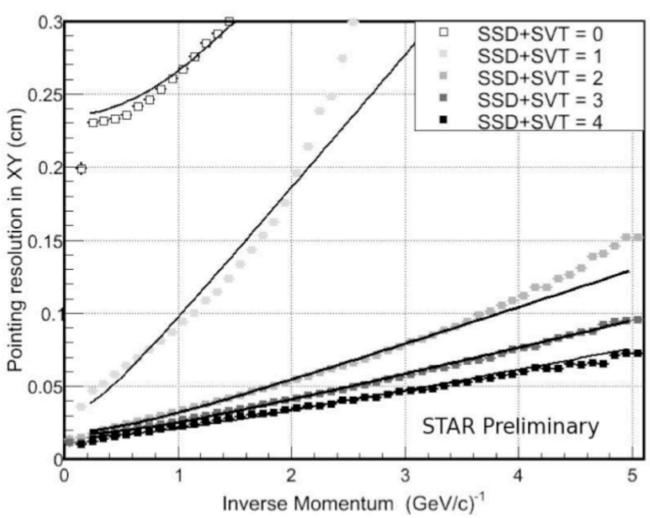
Secondary Vertex Reconstruction

The mean lifetime of D-Mesons is very short
cτ for D^0 ~ 123 μm
cτ for D^+ ~ 312 μm
*most decay vertices lie within 1mm of the primary vertex

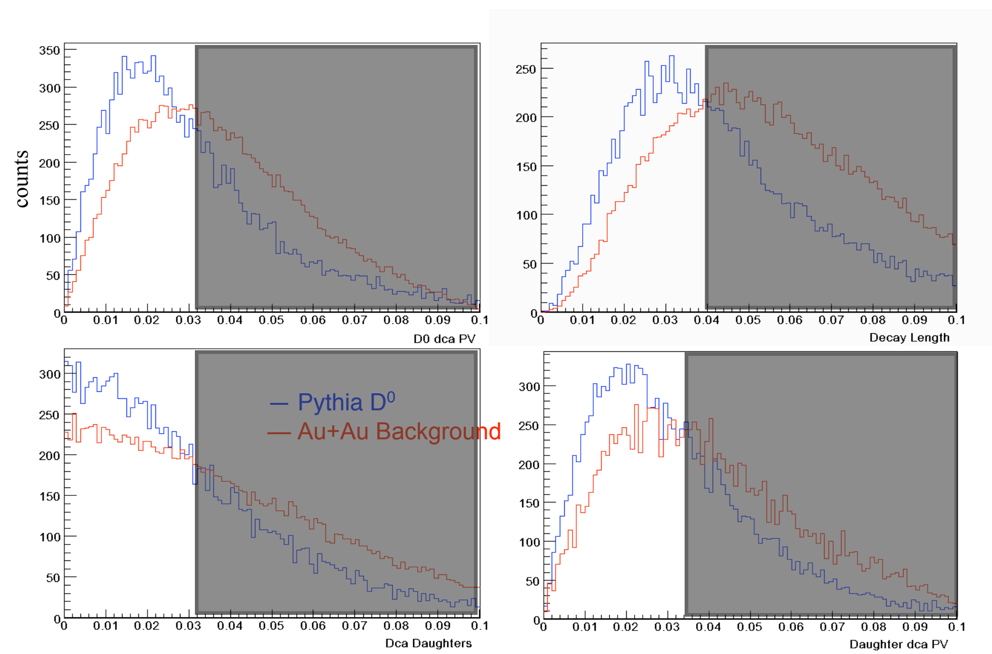


What do we need?

Pointing resolution (σ_{xy}) needs to be comparable to decay length
TPC alone ~ 3.1mm @ p = 1 GeV/c
TPC+SVT+SSD ~ 210 μm



Study geometrical variables to optimize s/b and significance



D^0 in A+Au 200 GeV Collisions

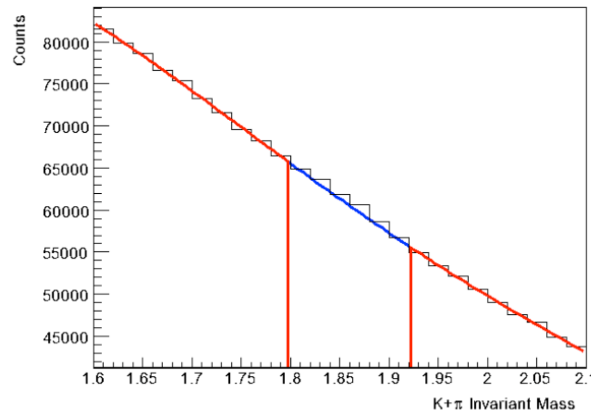
17 M minimum bias events

Track cuts:

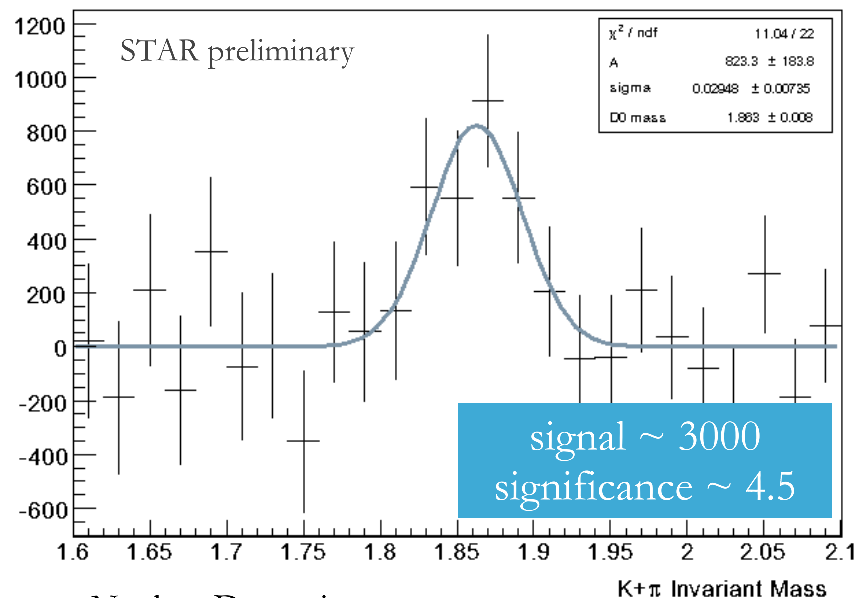
- p > 200 MeV/c
- TPC hits ≥ 25
- SVT hits ≥ 3
- PID from dE/dx

Optimized geometrical cuts:

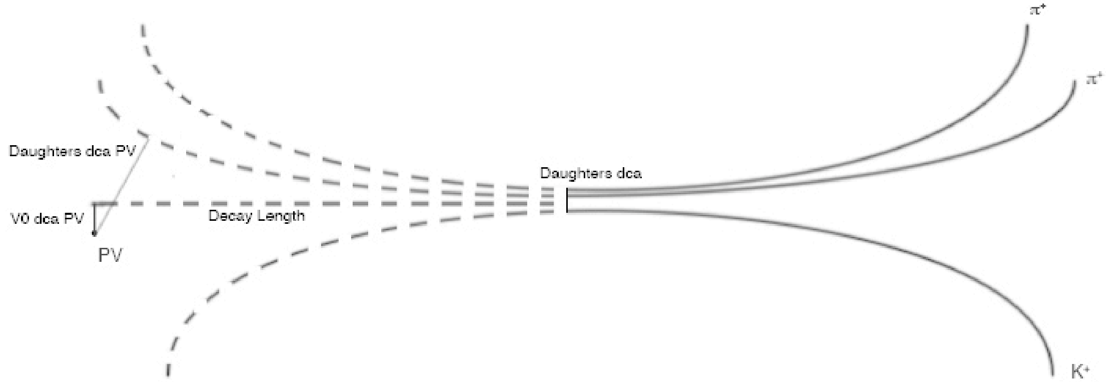
- 150 < D0 decay length < 350 μm
- D0 DCA to PV < 300 μm
- DCA Daughters < 50 μm
- 100 < Daughters DCA to PV < 300 μm



* background estimated using a 4th order polynomial fit to 'side bands'



D → Kππ Reconstruction



1. Find two Kπ pairs

2. Require pair #1 and #2 to have the same K

3. Require pair #1 and #2 to not have the same π

Advantages over D^0 measurement

- B.R. of 9.82%
- Greater mean lifetime, 312 μm
- Mean lifetime above resolution of the detectors

One disadvantage is the increase in background from requiring 3 tracks

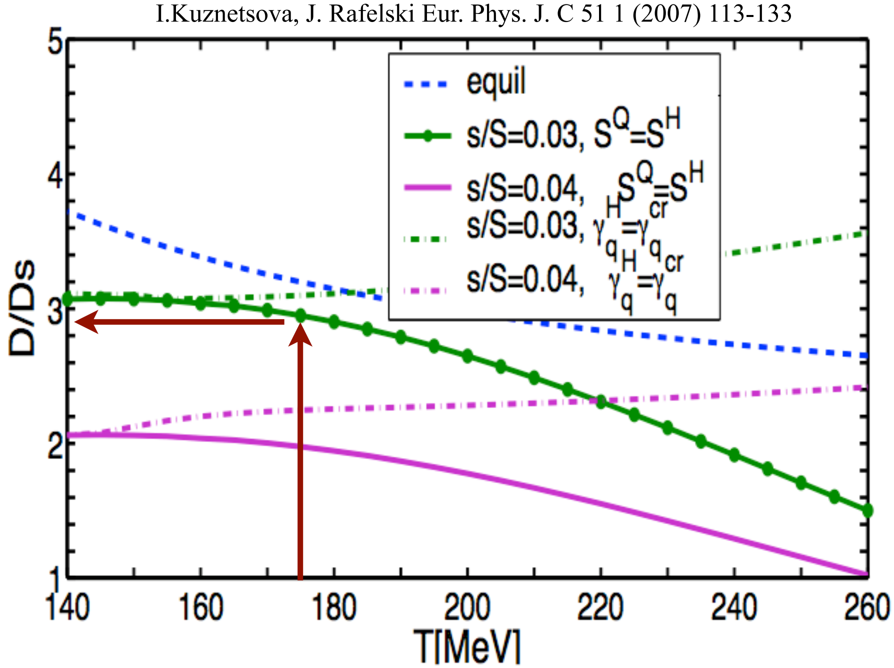
An analysis using this decay channel is currently being pursued

The Hadronization of Charm

Does charm hadronize from fragmentation or statistical → One check, look at the D_{inc}/D_s ratio

- Free charm in the sQGP = statistical hadronization
- Large s production should enhance D_s yield

I.Kuznetsova, J. Rafelski Eur. Phys. J. C 51 1 (2007) 113-133



D_{inc}/D_s

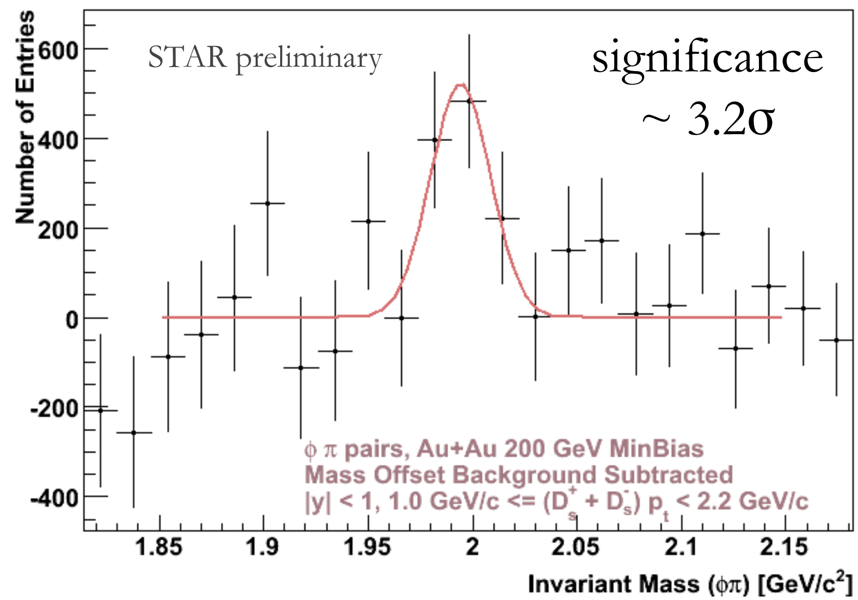
PYTHIA: 7.3

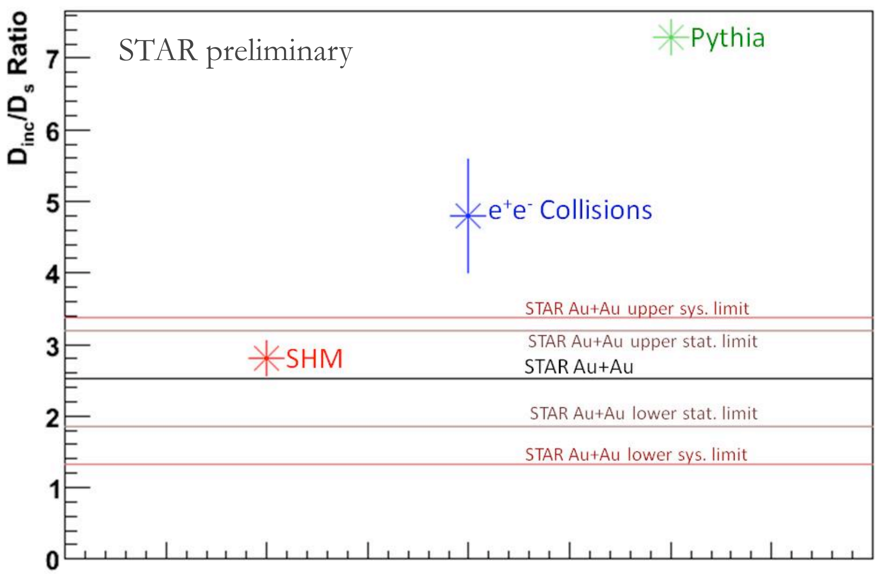
e^+e^- data: 4.8 ± 0.79

It may affect our estimation of total charm cross section

D_s using Silicon Vertex Tracker

- Assume p_T distribution shape similar to D^0, 47% yield is covered
- $D^{+/-}$ yield estimated using e^+e^- data. $D^0/D^{+/-}$ not predicted to change





Preliminary result suggests statistical hadronization

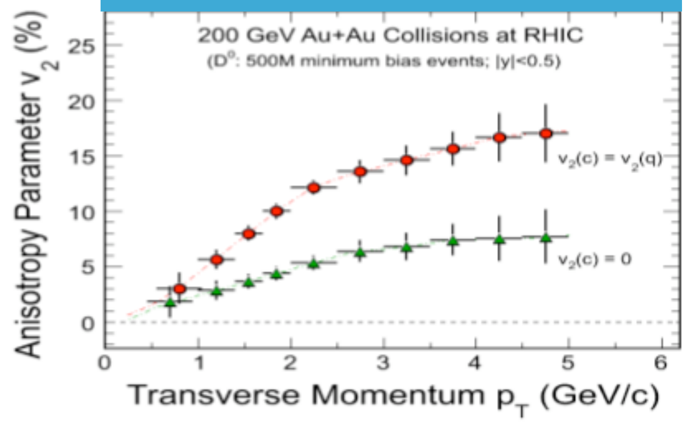
HFT/ToF - Future Measurements

- PID from ToF
- Vertexing with Heavy Flavor Tracker
- Very good charm measurements
- Disentangle D and B decays

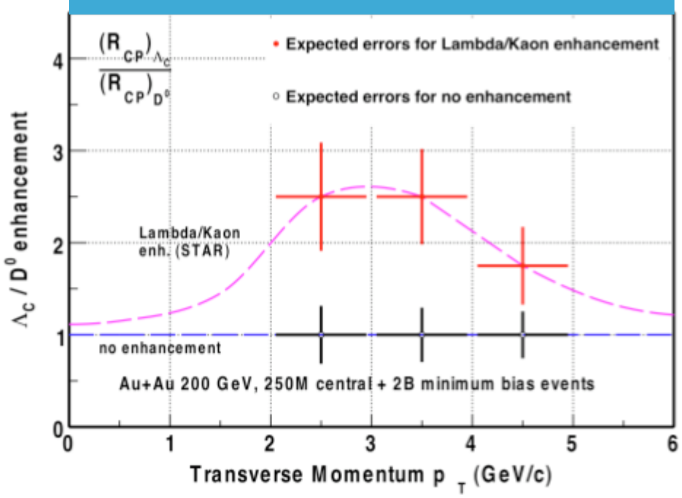
Error projections from simulation

E. Anderssen *et al.* , A Heavy Flavor Tracker for STAR

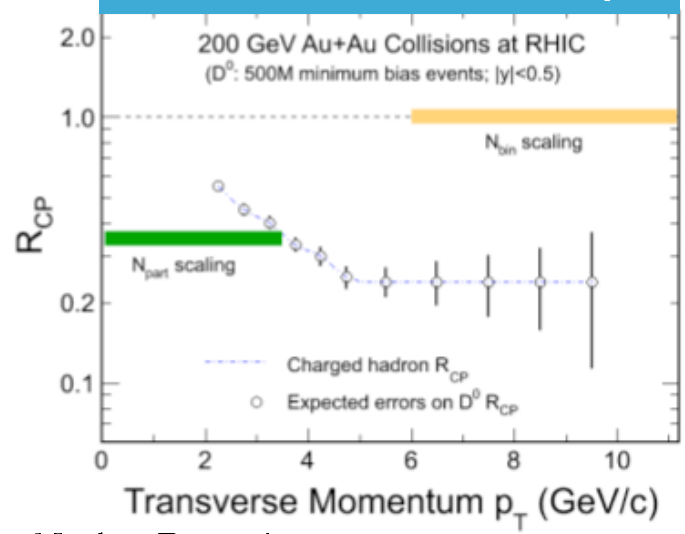
Does charm flow?



Coalesense of charm ?



Interaction of charm with QGP



And to summarize...

- Heavy flavor electrons exhibit a similar suppression to that of the light hadrons. Need new models to understand heavy quark energy loss.
- STAR extracts B contribution using electron tagged correlations and a significant B contribution above 5 GeV/c is observed
- Blast Wave model fit, assuming T_{fo}, to D^0 p_T spectra indicates D^0s do not have as strong a radial flow as light quark hadrons
- First D-Meson measurements in heavy ion collisions using secondary vertexing technique. May contribute to determination of D and B contribution to NPE spectrum and offer insight of charm's interaction with the QGP
- Preliminary D_s measurement from secondary vertexing hints at statistical hadronization
- Future measurements from ToF and HFT offer to provide a solid understanding of how heavy flavor interacts with the medium