D Meson Measurements in Au+Au Collisions in STAR using the Silicon Inner Tracker

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Hot Quarks
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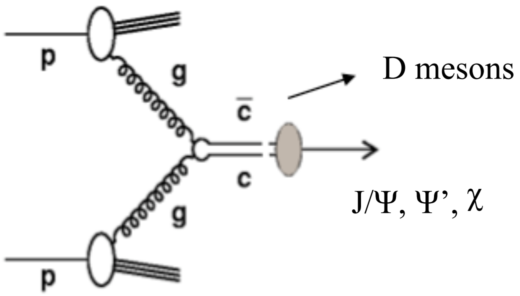
Outline

- Why should we study heavy flavors?
- Energy loss of heavy flavor non-photonic electrons
- D-Meson measurements
  - D^0 in Cu+Cu collisions
  - Secondary vertexing technique using the SVT+SSD
- Conclusions/Outlook

Charm Production and the QGP



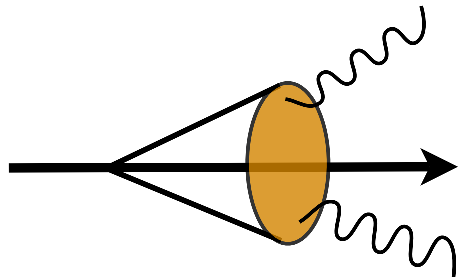
At RHIC collisional energies, charm is produced predominantly from initial gluon fusion.
Z. Lin and M. Gyulassy, Phys. Rev. C **51** 42177 (1995).

- Charm scales with number of binary collisions
- Charm produced in early stages of the collision, before thermalization

This makes charm an excellent probe of the medium

Energy Loss

Initially it was thought that the energy loss for charm quarks would be smaller than that of lighter flavors. Gluon radiation for a massive parton is suppressed at angles $< M_q/E_q$ - dead cone effect. Yu. Dokshitzer and D.E. Kharzeev, Phys.Lett. B **519** 199-206 (2001).



However, recent measurements have shown otherwise.
B. Abelev et al (STAR), Phys. Rev. Lett. **98** 192301 (2007)

Cross section

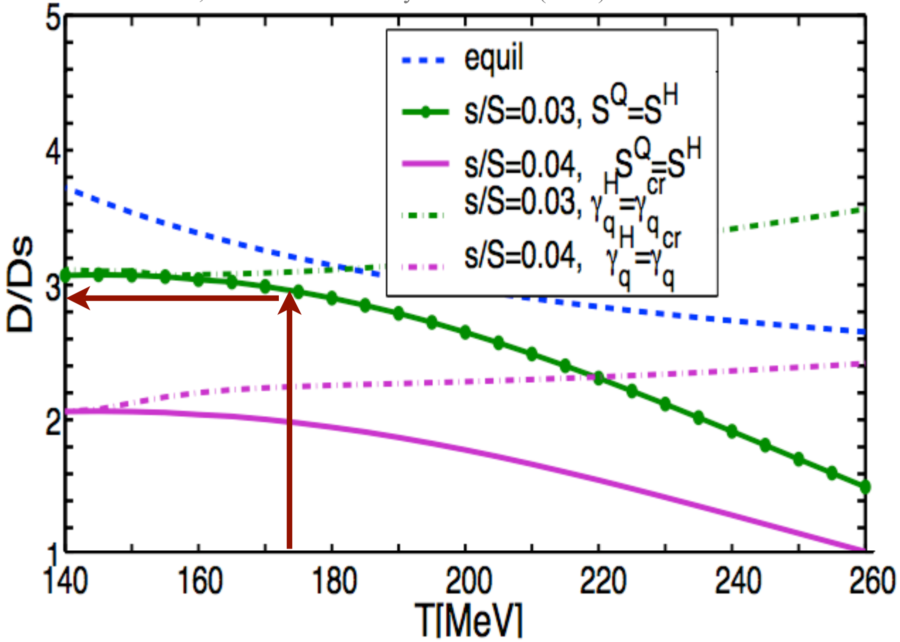
QCD (NLO/FONLL) used to predict charm cross section in p+p. A deviation from the prediction in Cu+Cu and Au+Au would indicate medium effects.
M. Cacciari, P. Nason, R. Vogt, Phys. Rev. Lett. **95**, 122001 (2005)

Charm Hadronization

Does charm hadronize statistically or through fragmentation? → Look at the D_{inc}/D_s ratio

where Dinc = $D^0+\overline{D^0}+D^++D^-$

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

- Strangeness enhancement in a QGP
- Free charm in the sQGP points to statistical hadronization
- The large s production should enhance D_s yield

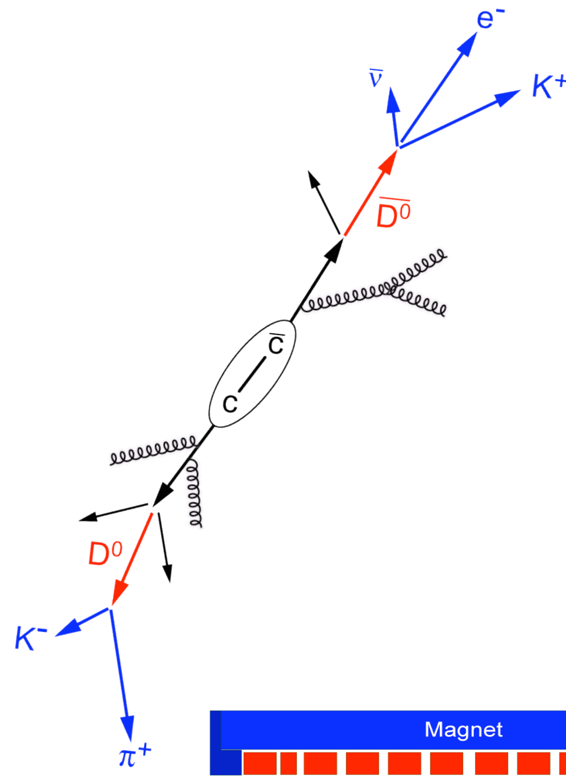
Measuring Heavy Mesons

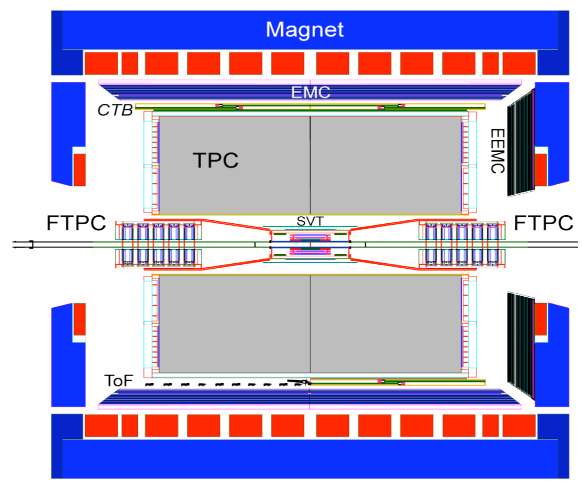
Semi-leptonic Channels B.R. (%)

- $D^0 \rightarrow e^+ +$ anything 6.5
- $D^\pm \rightarrow e^\pm +$ anything 16.0
- $B^0 \rightarrow e^+ +$ anything 10.1

Hadronic Channels B.R. (%)

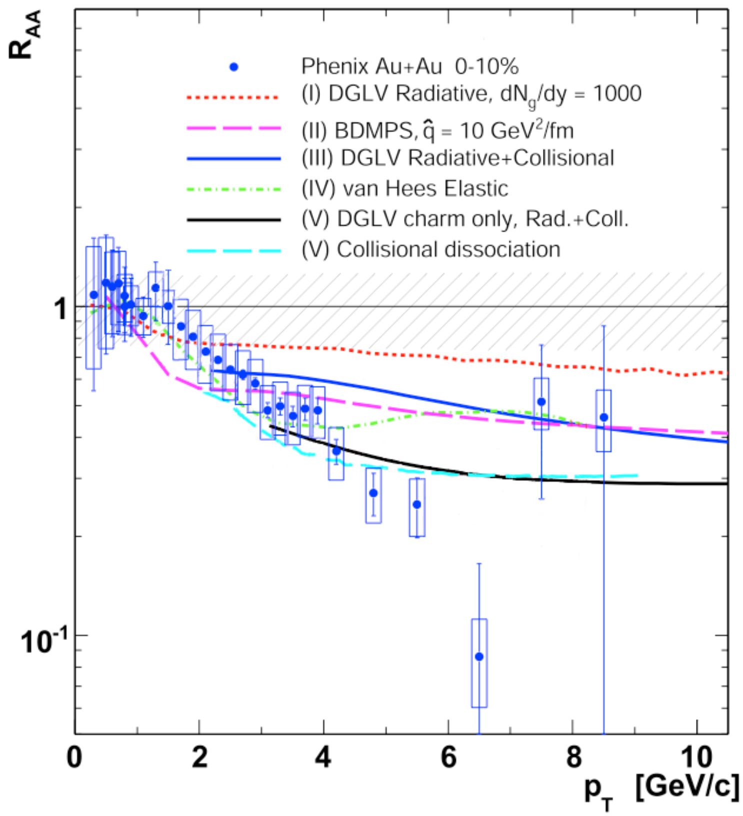
- $D^0 \rightarrow K\pi$ 3.8
- $D^\pm \rightarrow K\pi\pi$ 9.2
- $D_s \rightarrow \phi\pi$ 4.4





Techniques used to measure open charm:
Single electrons (TPC+EMC)
Hadronic decay (TPC+Silicon Inner Tracker)

Non-photonic e$^{\pm}$ - Energy Loss



Model predictions

I - radiative E loss via hard scatterings

II - radiative E loss via multiple soft collisions

Heavy quarks at RHIC may be experiencing collisional E loss!

III - collisional and radiative E loss

IV - E loss by elastic scatterings

Once again, the calculation does under-predict the suppression observed.

V - III but for charm alone

VI - Collisional dissociation, multiple times

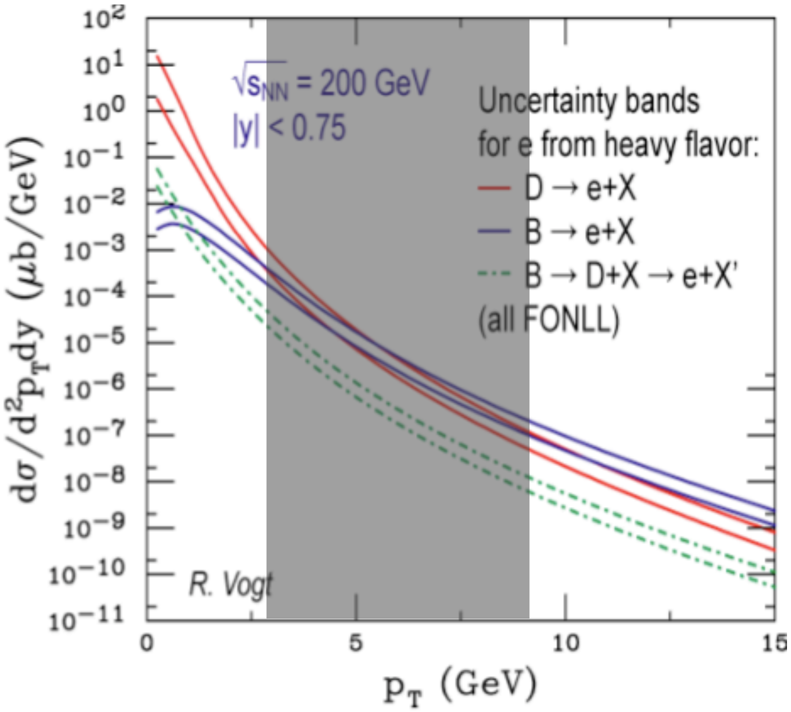
- Similar magnitude of suppression as light flavor in Au+Au collisions (p_T > 6 GeV)
- What is beauty contributing to the heavy flavor non-photonic e$^{\pm}$.
- A significant contribution ⇒ energy loss for beauty is greater than expected
- There has not been a D or B measurement in STAR at high pt

Beauty's Contribution

How much is beauty contributing?

- 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



Experimentally

1. Find B/D ratio using e-h azimuthal correlations

A. Mischke et al., Eur. Phys. J. C 61 807 (2009)
G. Wang et al., J. Phys. G: Nucl. Part. Phys. 35 104107 (2008)

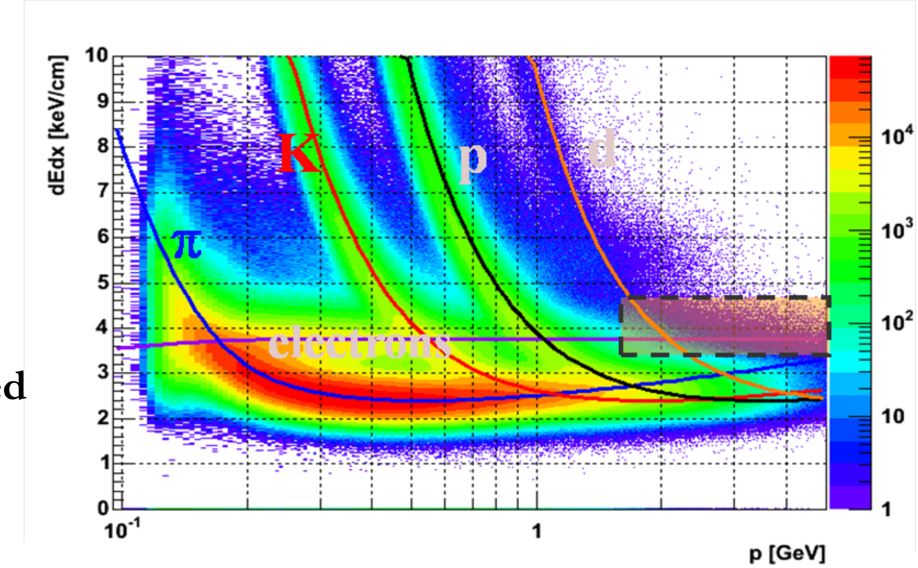
* B contribution is comparable to D at and above 5 GeV/c

2. Directly measure D to separate out the c contribution

Hadronic Reconstruction of D Mesons

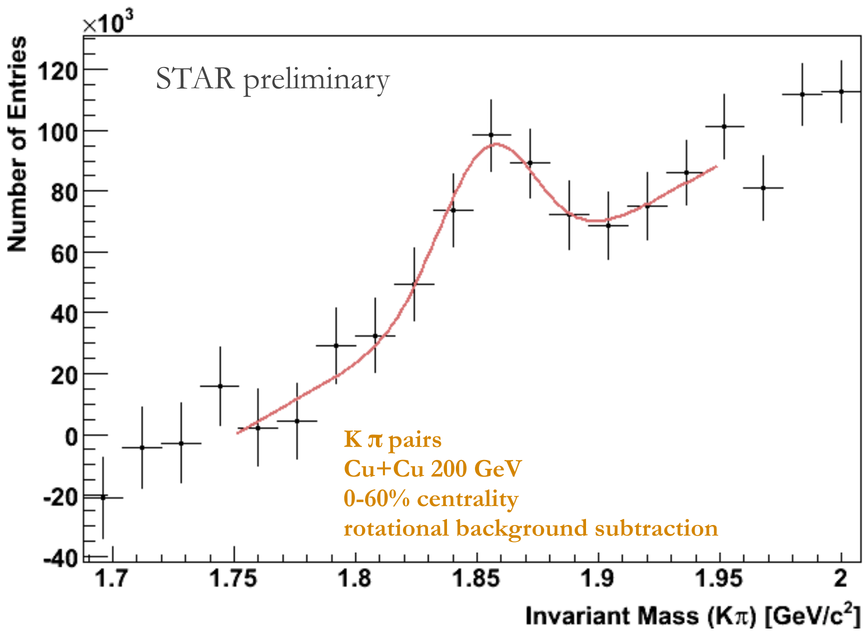
Two methods for measurement

1. **TPC:**
   - Primary track pairs
   - dE/dx from TPC to Id K and π
   - Invariant mass analysis
   - Extract signal after a **mixed event or rotated** background has been subtracted



2. **TPC+SVT+SSD:**
   - Global track pairs
   - dE/dx from TPC to Id tracks
   - Invariant mass analysis, also require the tracks to have a crossing point → **secondary vertexing technique**
   - Geometrical cuts from the decay → **Increase signal to background**

D^0 in Cu+Cu Collisions at 200 GeV



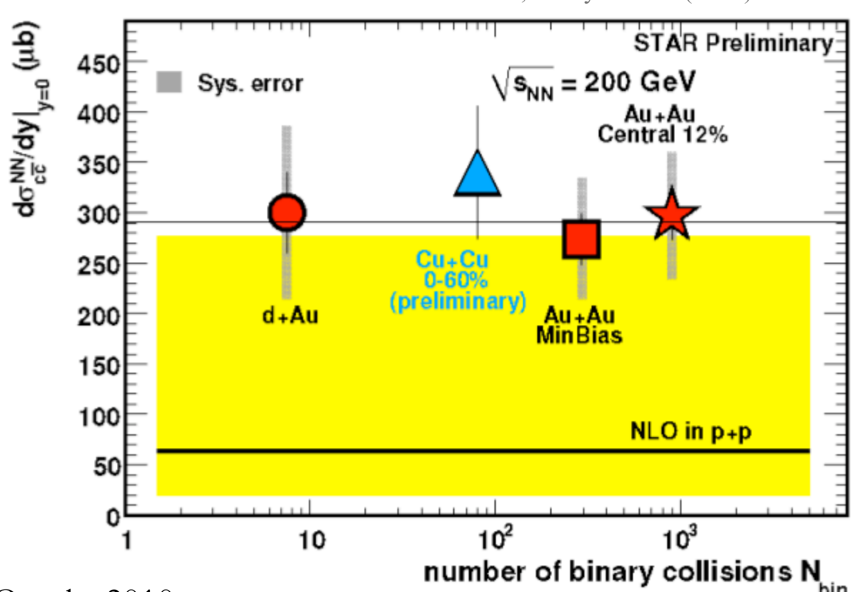
Mixed Event Analysis

Combine all pairs from the same event
Signal + Background

Combine pairs from different events
Background

Same event spectra – Mixed event spectra
Signal

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

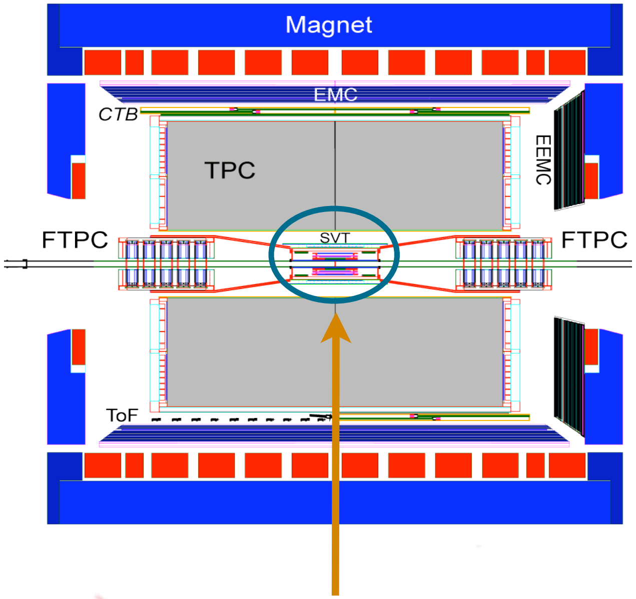


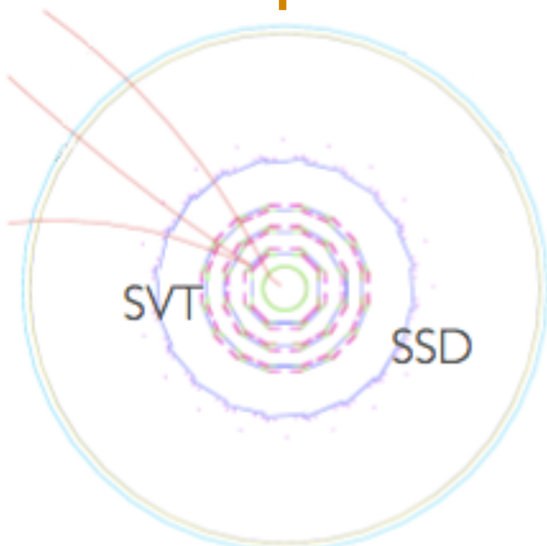
✓Consistent with Binary Scaling

✓Consistent within errors with NLO Calculations

Disadvantages
- low signal to background
- small pT range, below 2 GeV/c

The STAR Silicon Inner Tracker (SVT+SSD)

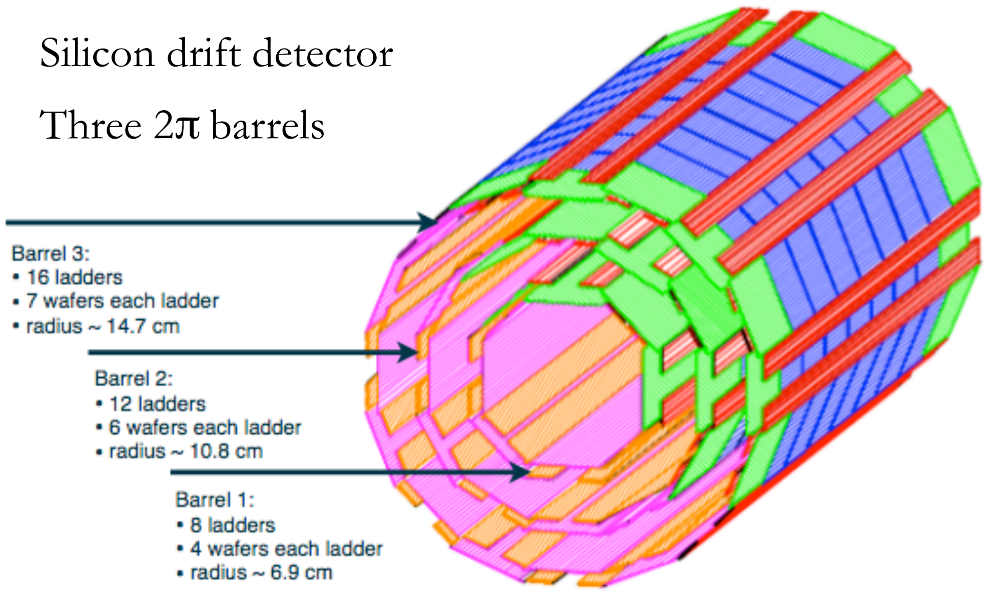




Silicon Vertex Tracker (SVT)

Silicon drift detector

Three 2π barrels

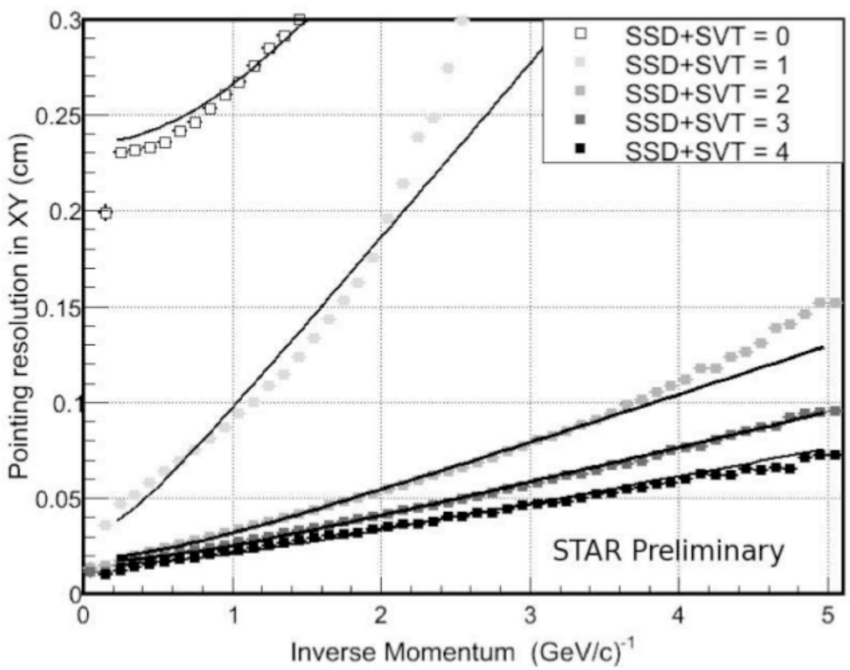


Silicon Strip Detector (SSD)

One layer at 23 cm

Secondary Vertex Reconstruction

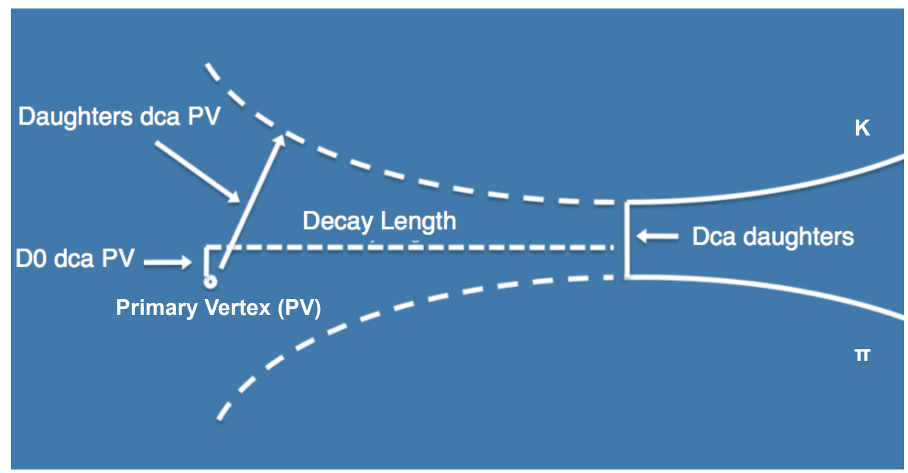
Mean lifetime of D-Mesons
cτ for D^0 ~ 123 μm
cτ for D^+ ~ 312 μm
*most decay vertices lie within a few mm of the primary vertex



What do we need?

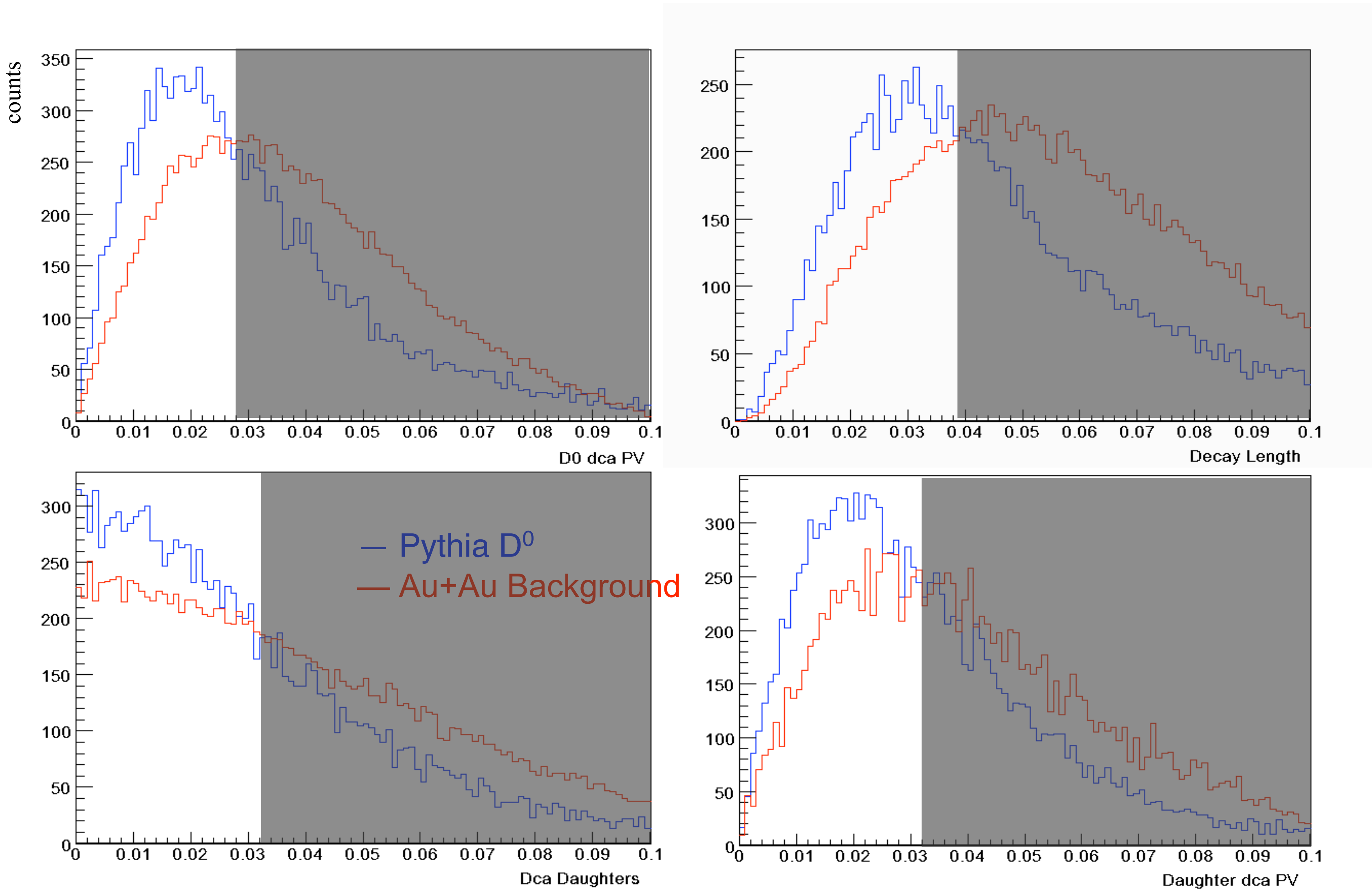
Pointing resolution (σ_{xy}) needs to be comparable to decay length

TPC alone ~ 2.6 mm @ p = 1 GeV/c
TPC+SVT+SSD ~ 210 μm



Study geometrical variables to optimize signal to background and significance

Geometrical Distributions



D⁰ in Au+Au 200 GeV Collisions

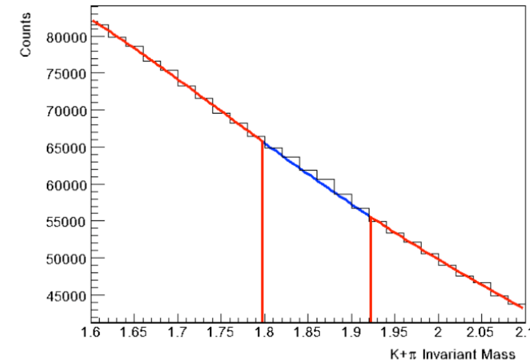
23 M minimum bias events

Track cuts:

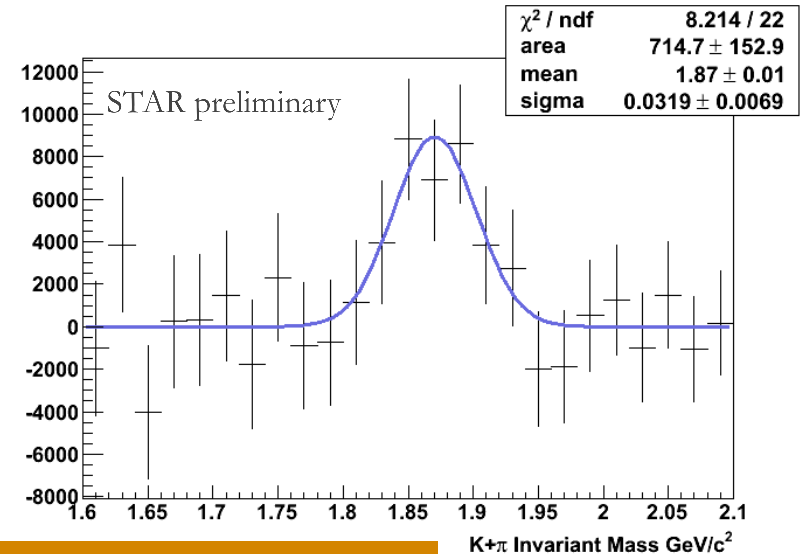
- p > 200 MeV/c
- TPC hits ≥ 20
- SVT hits ≥ 2
- PID from dE/dx

Optimized geometrical cuts:

- D0 decay length < 200 μm
- D0 DCA to PV < 300 μm
- DCA Daughters < 200 μm

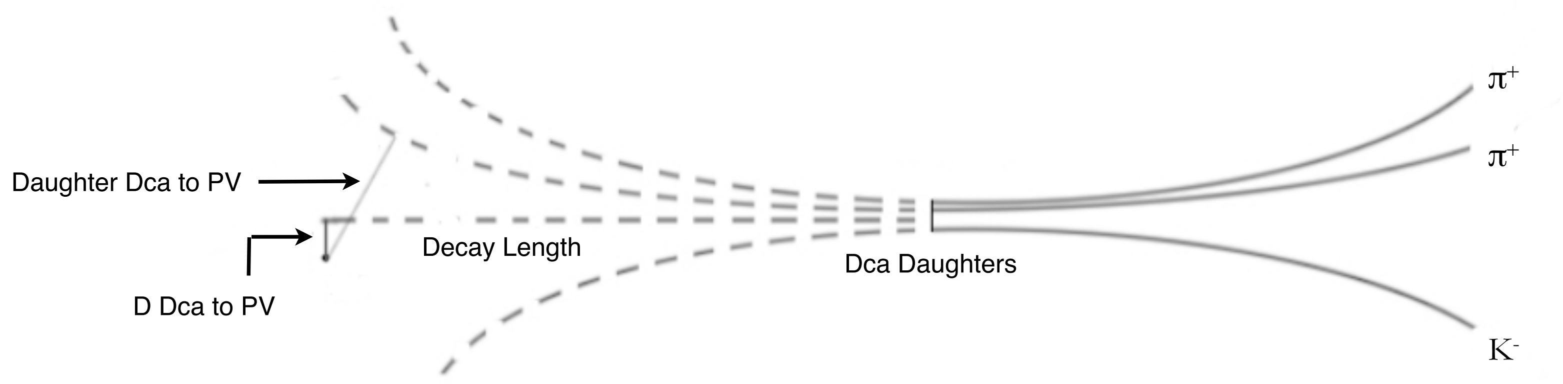


* background estimated using a 4th order polynomial fit to 'side bands'



s = 35734 ± 7542 (stat.)
σ ~ 5.0

$D \rightarrow K+\pi+\pi$ Reconstruction



Method

1. Find two $K\pi$ 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

- Branching Ratio = 9.8% (factor ~3 larger than $D0 \rightarrow K+\pi$)
- Greater mean lifetime, 312 μm
- Mean lifetime above resolution of the detectors

One disadvantage - background increases (3 track requirement)

First results look promising !

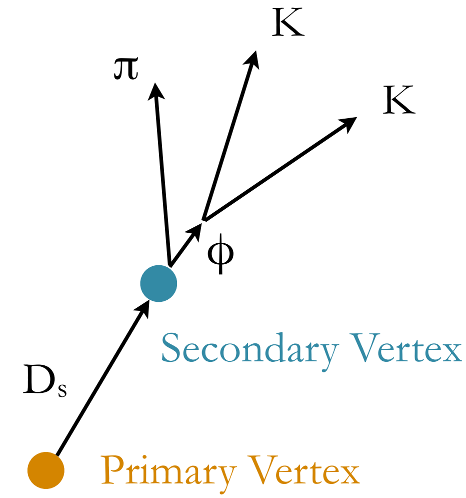
$D_s \rightarrow \phi+\pi$ Reconstruction

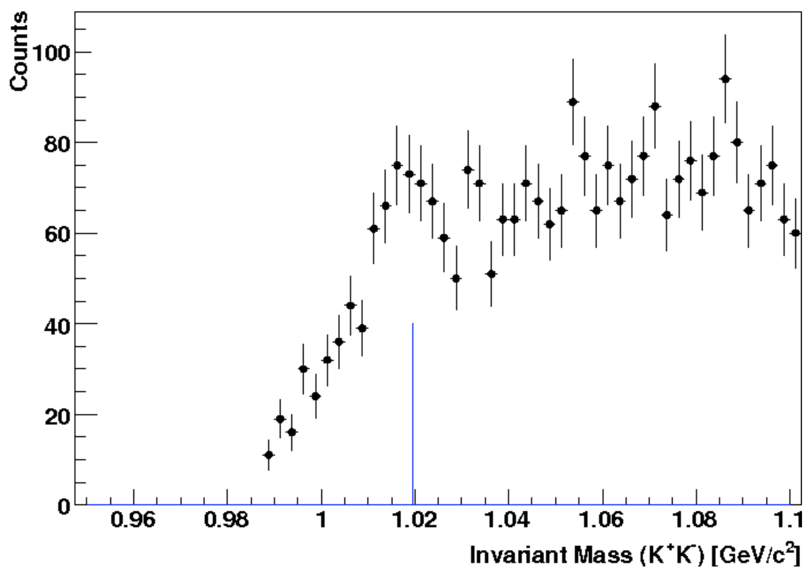
The mean lifetime = 149.9 μm

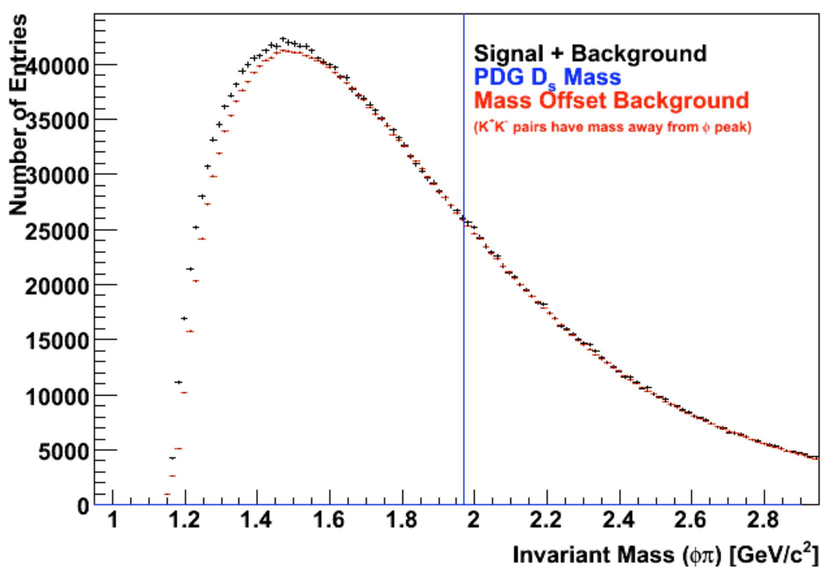
$D_s \rightarrow \phi\pi$, with $\phi \rightarrow K^+K^-$ B.R. = 2.18%

ϕ mean lifetime ~ 45 fm

Subtract off background using K^+K^- that have invariant mass away from ϕ peak







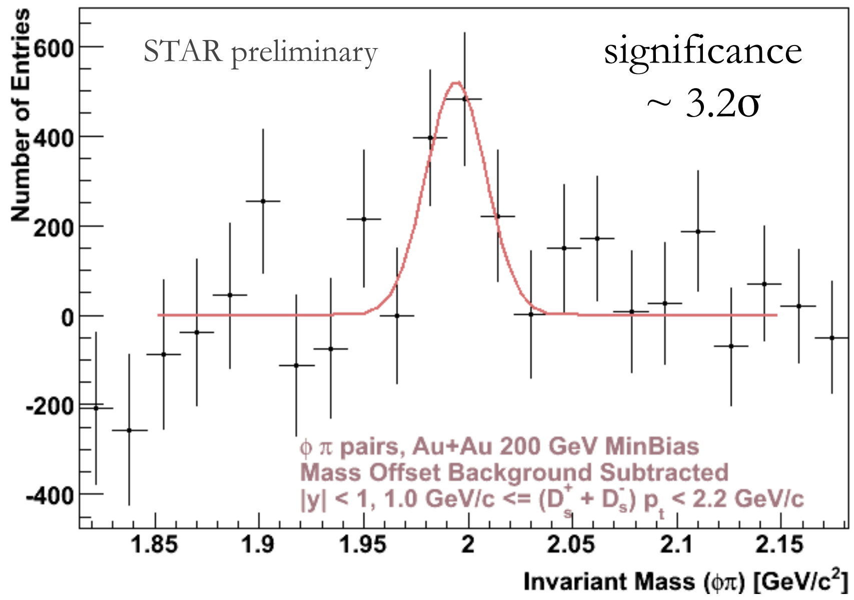
D_s in Au+Au Collisions

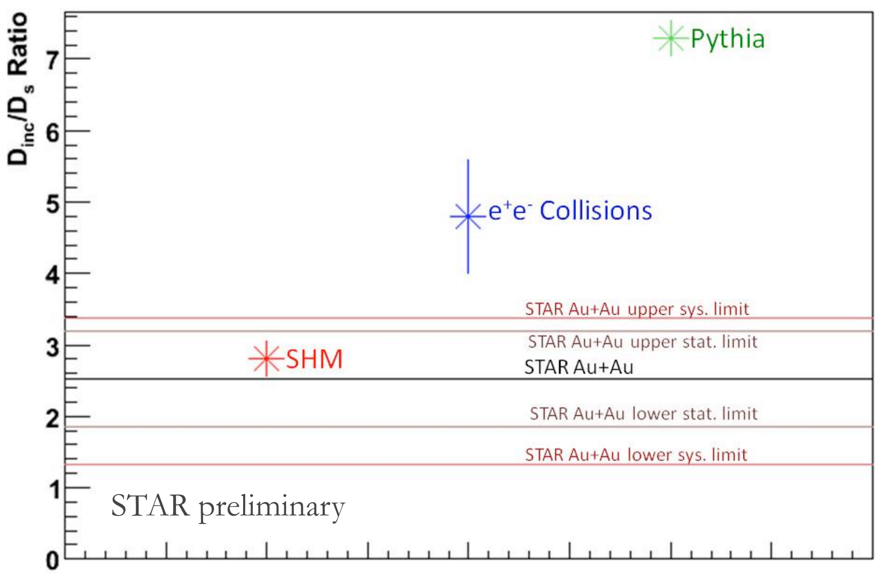
Track cuts:

- TPC hits ≥ 20
- SVT hits ≥ 2
- PID from dE/dx

Geometrical cuts:

- 100 < D_s decay length < 400 μm
- D_s DCA to PV < 300 μm
- DCA Daughters < 300 μm





Preliminary result suggests statistical hadronization

* Assume p_T distribution shape similar to D^0, 47% yield is covered

* $D^{\pm}$ yield estimated using e^+e^- data. $D^0/D^{\pm}$ not predicted to change

This may affect our current estimation of total charm cross section

Conclusions

- Heavy flavor electrons exhibit a similar suppression to that of the light hadrons. New models are needed help better understand heavy quark energy loss.
- 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