Heavy Quark Results from STAR

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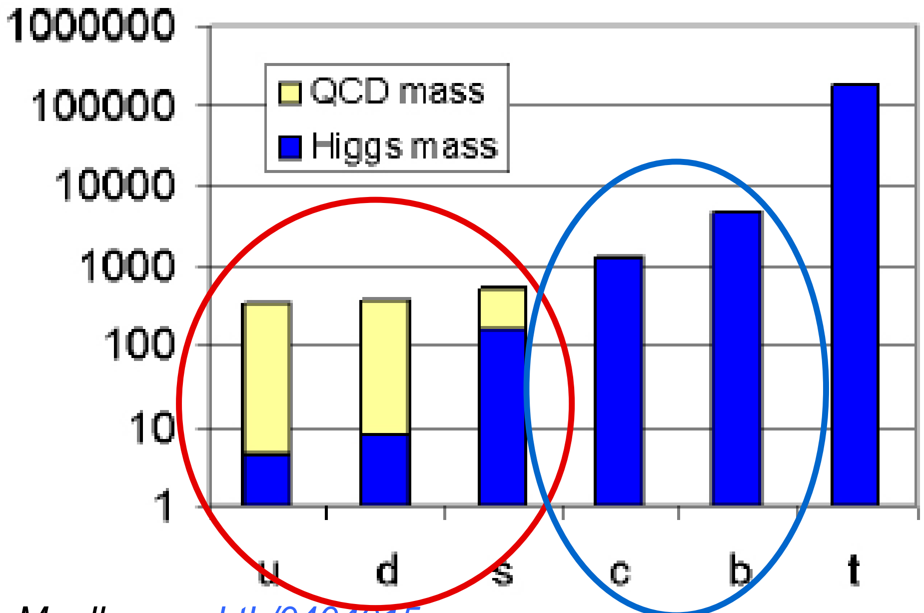
Outline

- Introduction
- Recent results
  - charm total cross section
  - charm transverse momentum spectra
  - heavy quark correlations
  - glance at Run 8 (y2008) data
- Summary & Outlook

Heavy Quarks – Probe & Quantify QGP

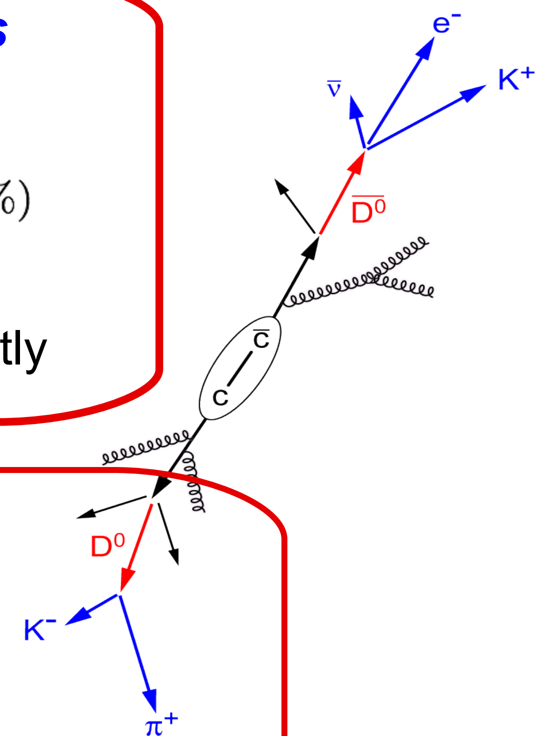


B. Mueller, nucl-th/0404015

Heavy !

- Heavy quarks created at early stage of HIC
  → total yields scaled by N_{bin}
- Sensitive to the partonic rescatterings
- Collectivity, flow
  → indication of light flavor thermalization (to some degree)

How to measure?



Reconstruction from hadronic decay channels

$$D^0 \rightarrow K^-\pi^+(3.8\%) \qquad c\tau = 123\mu m$$

$$D^{*+} \rightarrow D^0\pi_s^+(68\%), D^0 \rightarrow K^-\pi^+(3.8\%)$$

Combinatorial background!
Secondary vertex reconstruction will help significantly

Semi-leptonic decay channels

$$D^0 \rightarrow e^+ + X \quad (6.7\%)$$
$$D^+ \rightarrow e^+ + X \quad (17.2\%)$$

backgrounds (conversions and light hadron decays)

$$D^0 \rightarrow \mu^+ + X \quad (6.5\%)$$

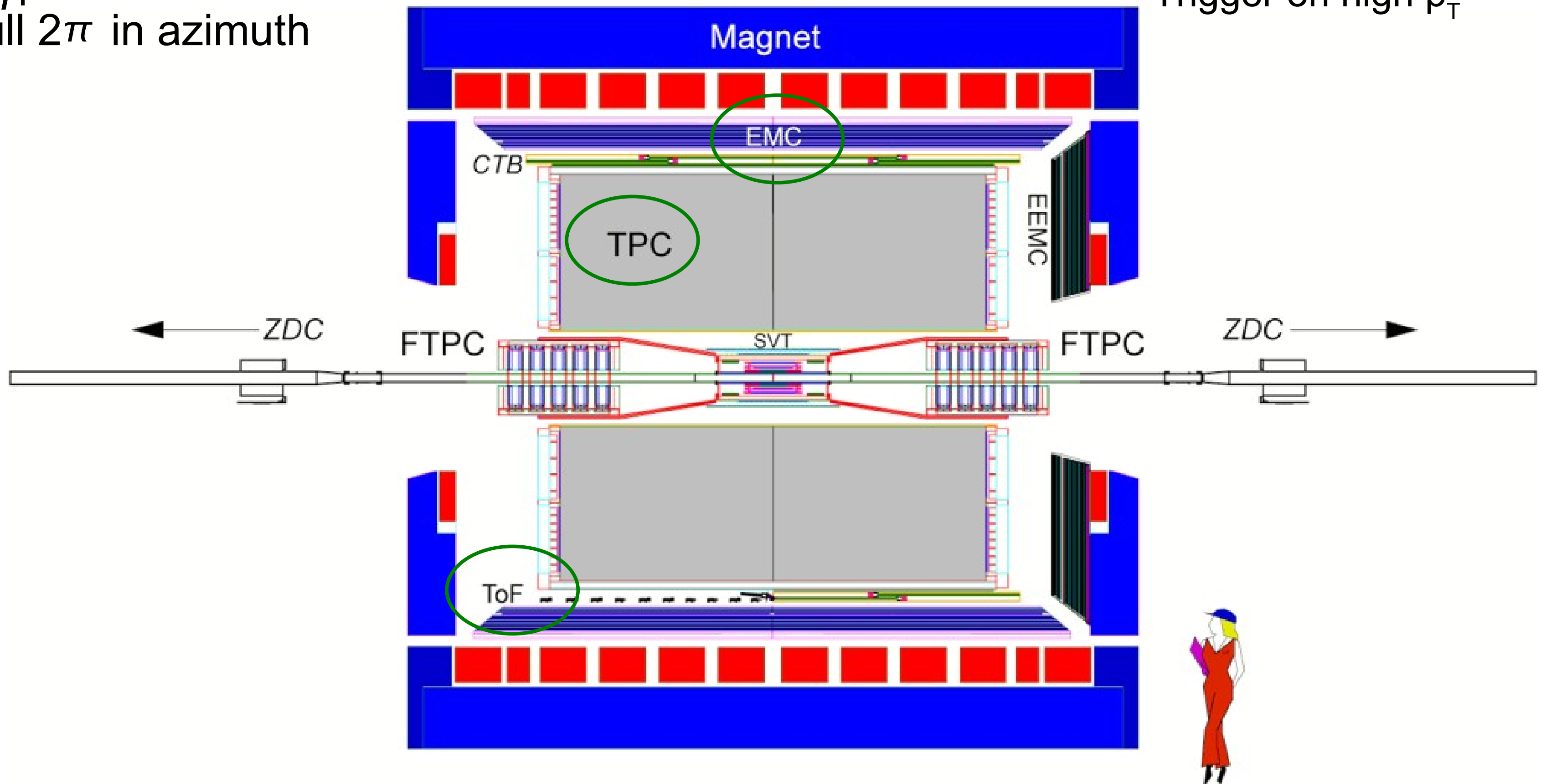
backgrounds (light hadron decays)

Mixture of charm (mesons/baryons) and bottom decays

STAR Detector

D reconstruction in the TPC
$|\eta|<1$
full 2π in azimuth

EMC:
Electron PID (~2-10 GeV/c)
Trigger on high p_T



TOF
(+dE/dx) Electron PID (~0.2 – 10 GeV/c)
Muon PID at low p_T (~0.2 GeV/c)

Large acceptance in mid-rapidity
Correlation measurements

Open Heavy Quark Measurements @ STAR

Transverse momentum spectrum

		D reconstruction	non-photonic electrons			low p_T muons
	Sub-systems	TPC	TPC+TOF	TPC	TPC+EMC	TPC+TOF
	p_T coverage (GeV/c)	$\sim 0.1-3$	$\sim 0.8-4$	$\sim 2-4$	$\sim 2-10$	$\sim 0.17-0.25$
200 GeV	$p+p$	–	✓	✓	✓	–
	d + Au	✓	✓	✓	✓	–
	Cu + Cu	✓	–	–	✓	–
	Au + Au	✓	✓	–	✓	✓

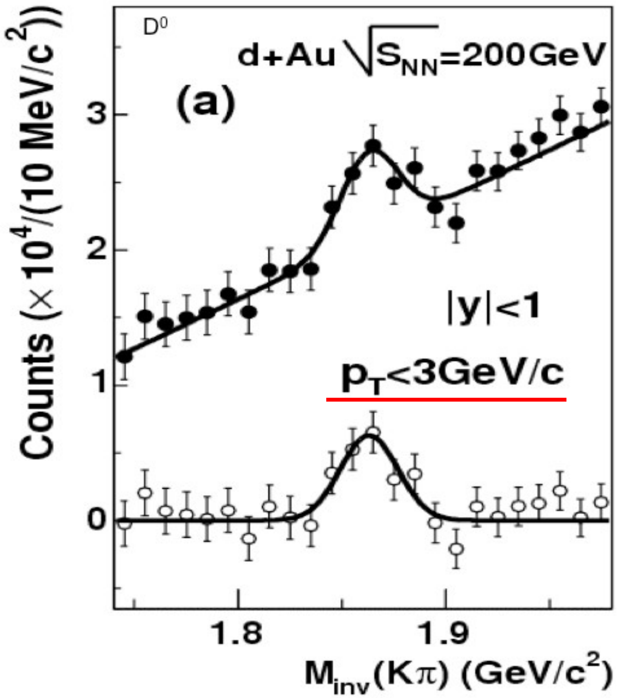
- cross section
- flow characteristics
- energy loss in A+A collisions

All measurements are self-consistent within STAR.

Correlations

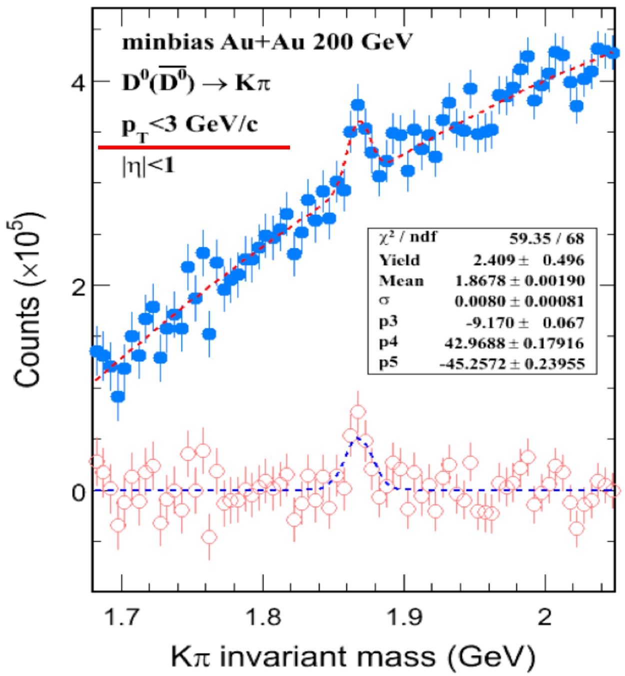
✔ e-h/D^0 in p+p - bottom contribution to non-photonic electrons
✔ D*-jets in p+p - charm production through gluon jets
✔ e-h in A+A - medium response with heavy quark triggers

Direct charm hadron reconstruction



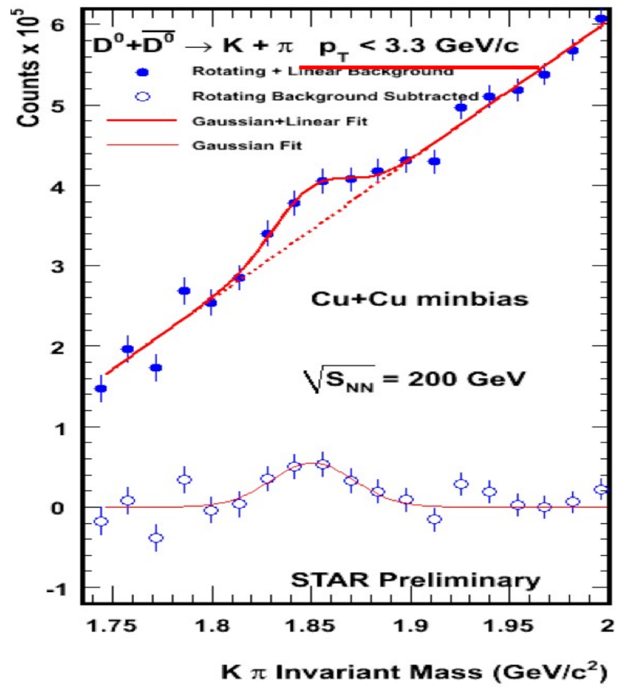
d+Au 200 GeV

PRL 94 (2005) 062301



Au+Au 200 GeV

arXiv: 0805.0364

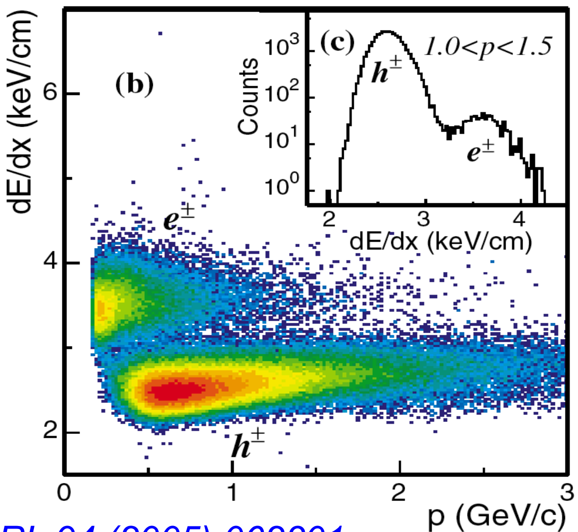


Cu+Cu 200 GeV

A. Shabetai, QM08

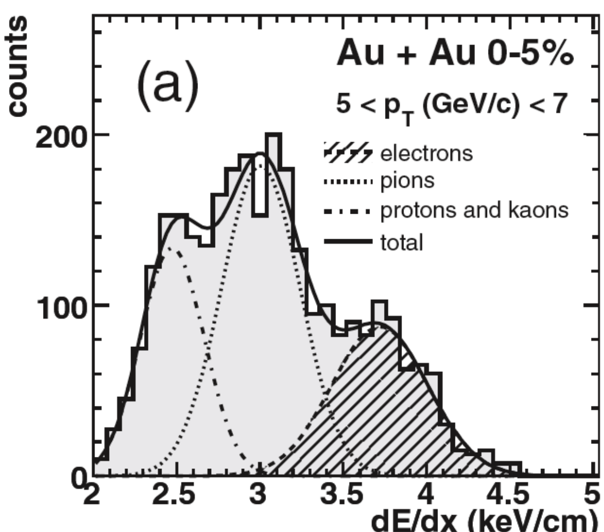
Current TPC track projection cannot allow us to topologically reconstruct D^0.
Large statistics to overcome the huge combinatorial background.

Electrons and photonic background



TPC+TOF

PRL 94 (2005) 062301

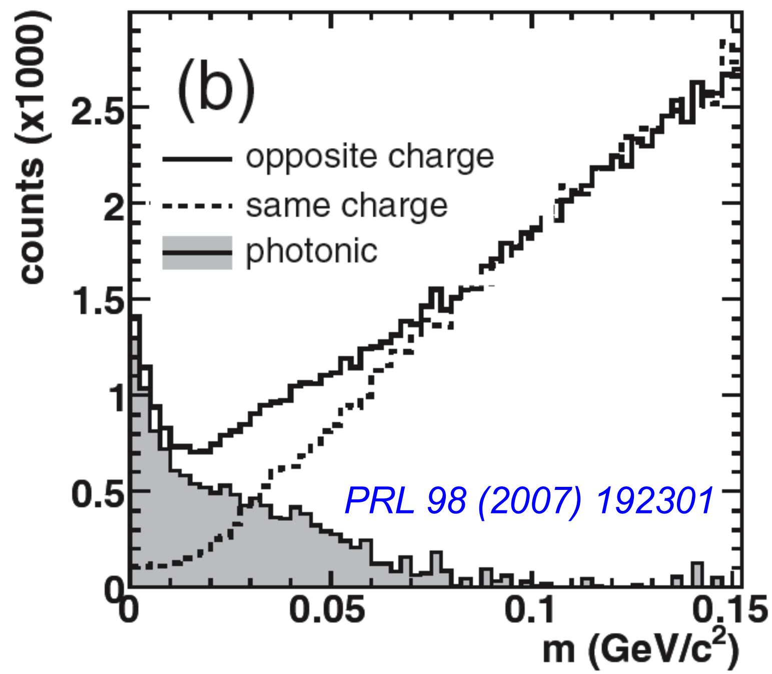


TPC+EMC

PRL 98 (2007) 192301

Electron PID:
TPC+TOF or TPC+EMC
covers 0.2 ~ 10 GeV/c in p_T, purity > 95%

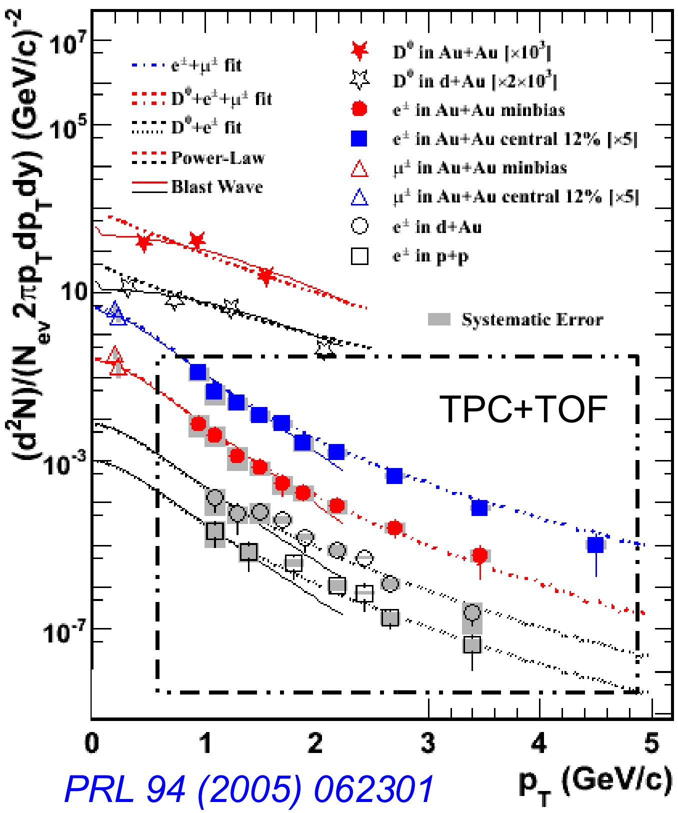
Photonic background:
Reconstruct the conversions and π^0 Dalitz decays benefiting from the large acceptance of the TPC.
Efficiency ~ 70-80% at p_T > 4 GeV/c.



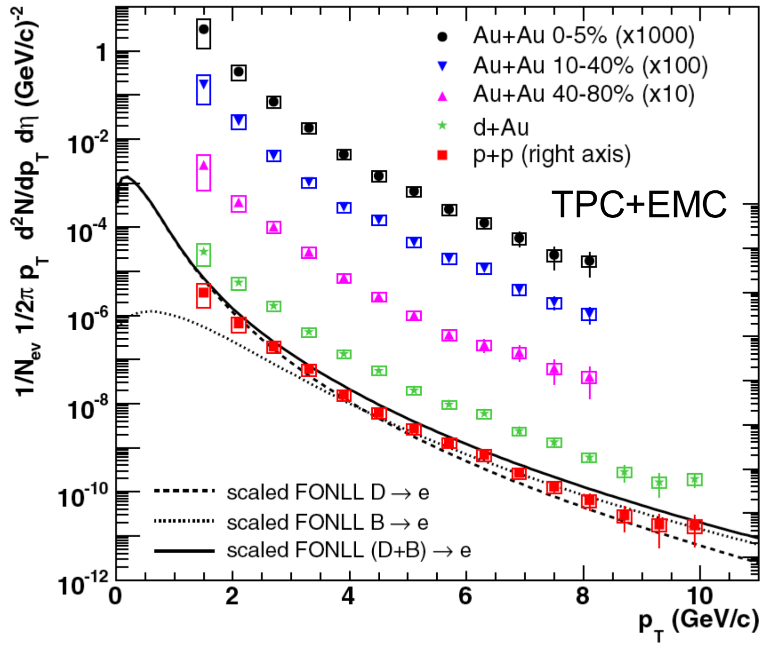
Non-photonic electrons

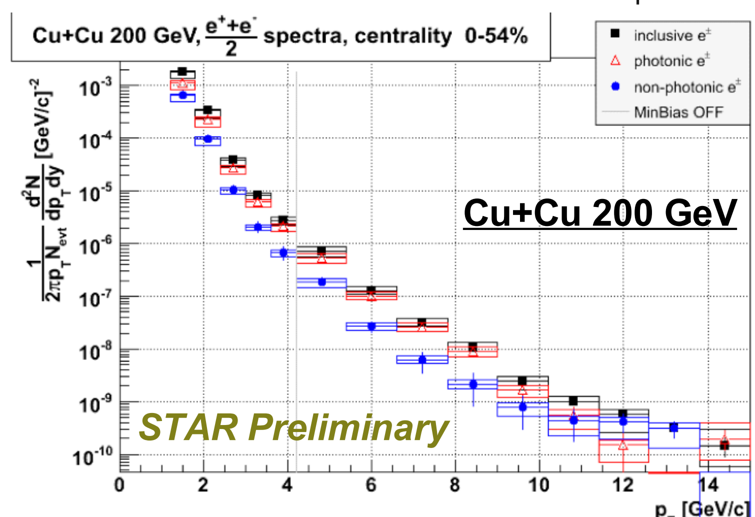
p+p, d+Au & Au+Au 200 GeV

Non-photonic electron spectra from TPC+TOF & TPC+EMC are consistent in the overlap region.

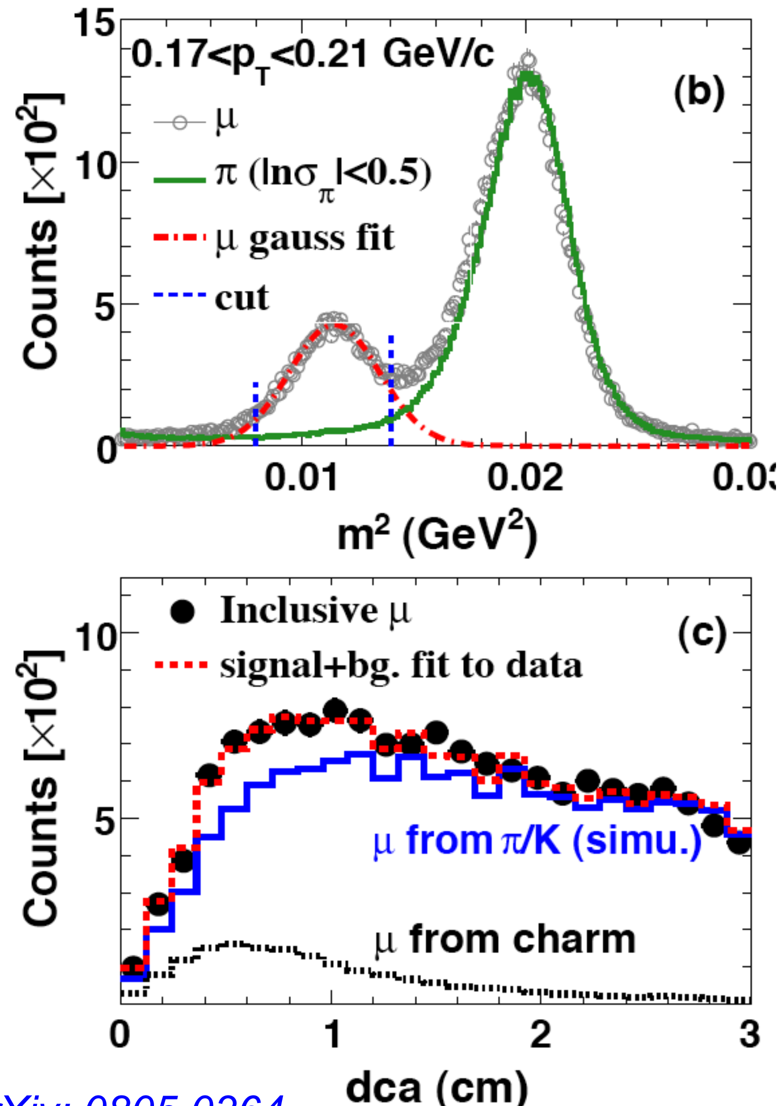


PRL 94 (2005) 062301
PRL 98 (2007) 192301
arXiv: 0805.0364



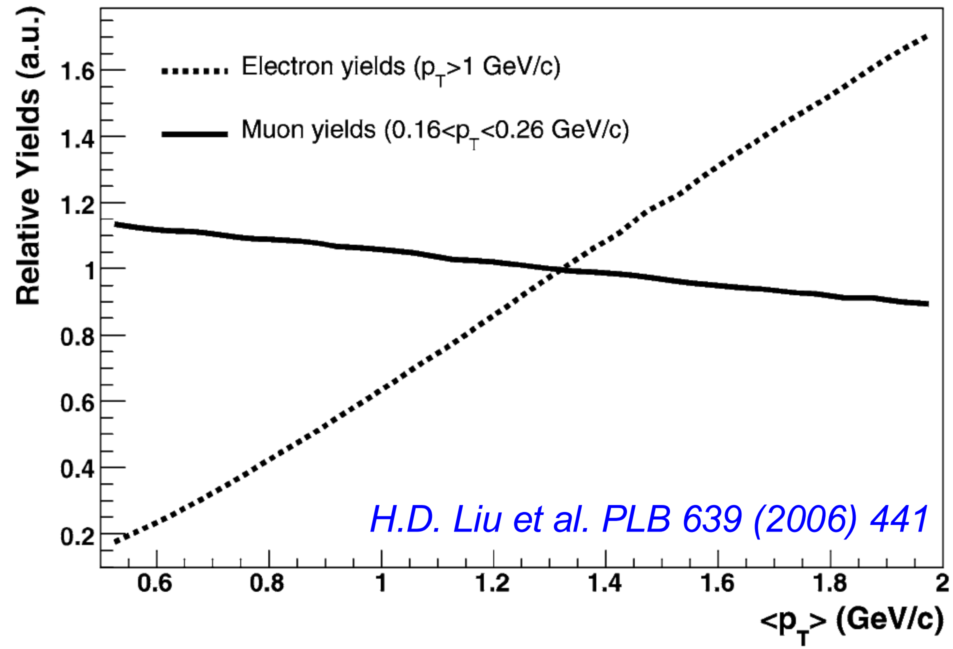


Muons at low p_T



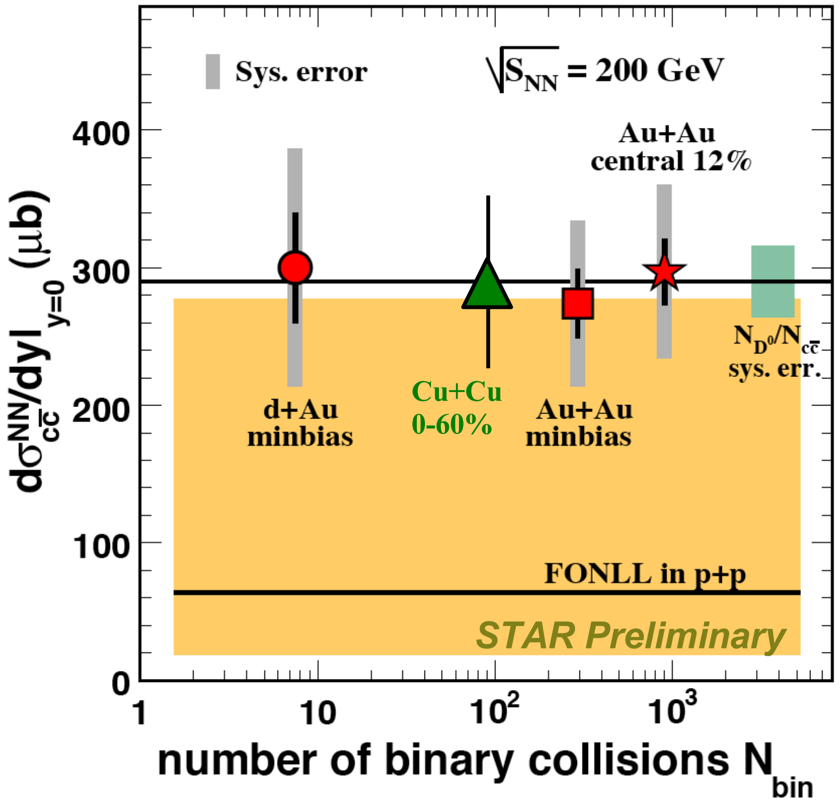
arXiv: 0805.0364

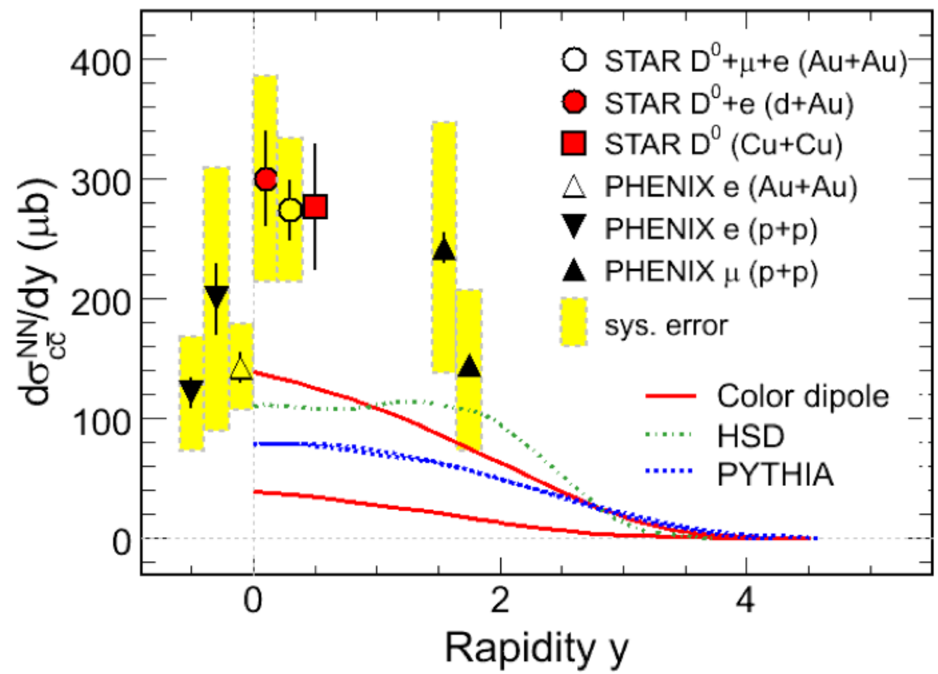
Fix total charm cross section
Vary power-law <p_T>



Muon yield at low p_T is
more sensitive to the total charm yield
less sensitive to the charm spectrum shape.

X-sec



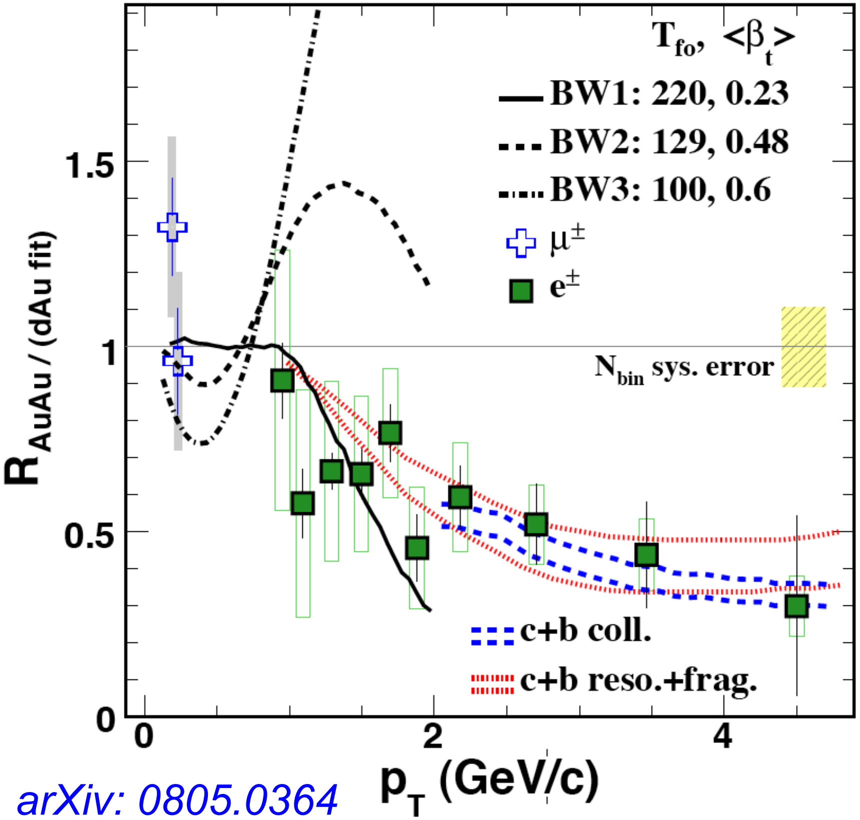


- Combined fit for D^0+e+μ spectra.
- Charm X-sec is approximately scaled by N_{bin}.
- Big uncertainties in both experimental and theoretical results.
- STAR centroid ~ 2 x PHENIX centroid

Phys. Rev. Lett. 94 (2005) 062301
arXiv: 0805.0364
A. Shabetai, QM08

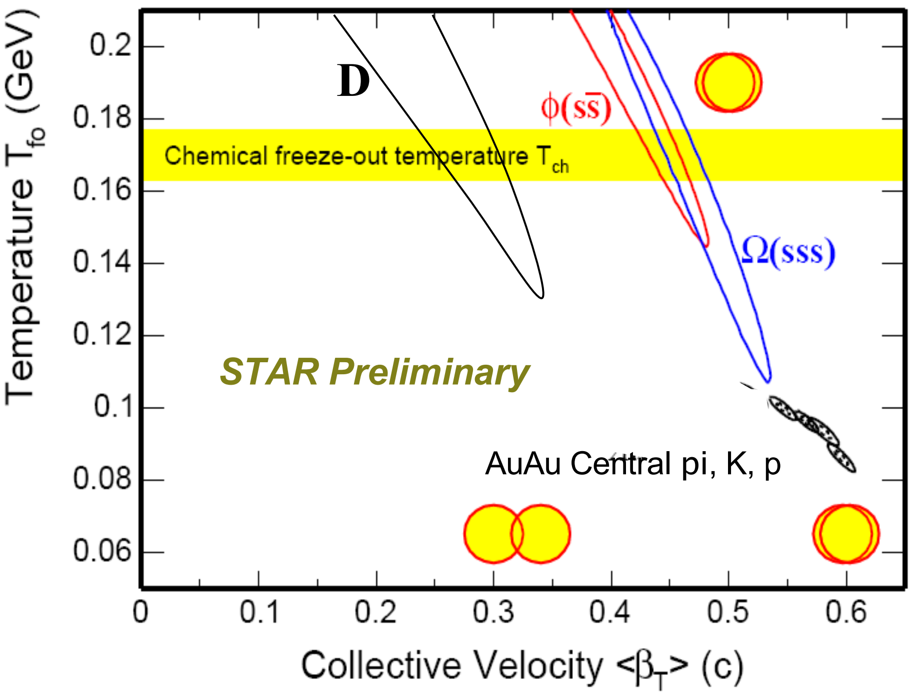
Precision measurement of X-sec needed -> calibration for charmonium results

Charm Flow?



arXiv: 0805.0364

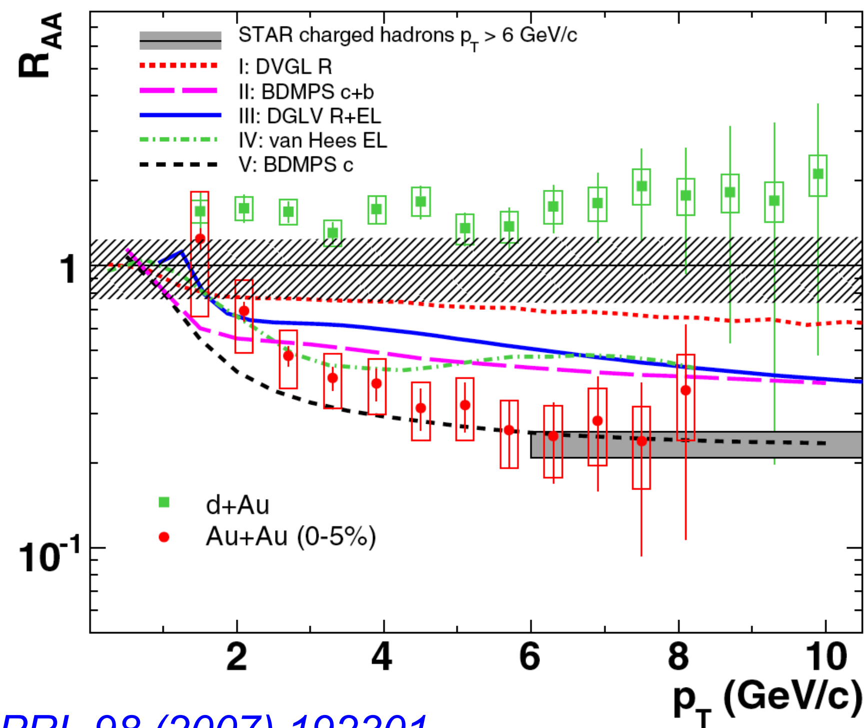
Y. Zhang, SQM 2006



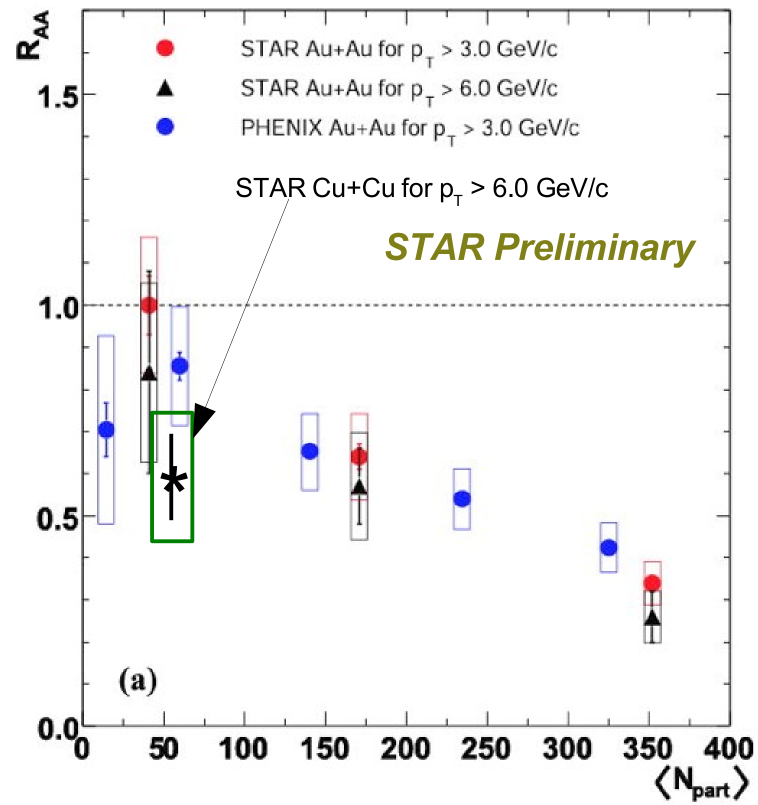
BW3: π, K, p
BW2: multi-strange hadrons
BW1: Fit to charm hadrons

Expected to freeze out earlier
– T > 140 MeV
Small collective velocity
$<\beta_T> < \phi, \Omega$
disfavor large radial flow!

High p_T suppression



PRL 98 (2007) 192301



$R_{AA}(e) \sim R_{AA}(h)$ at p_T>6 GeV/c

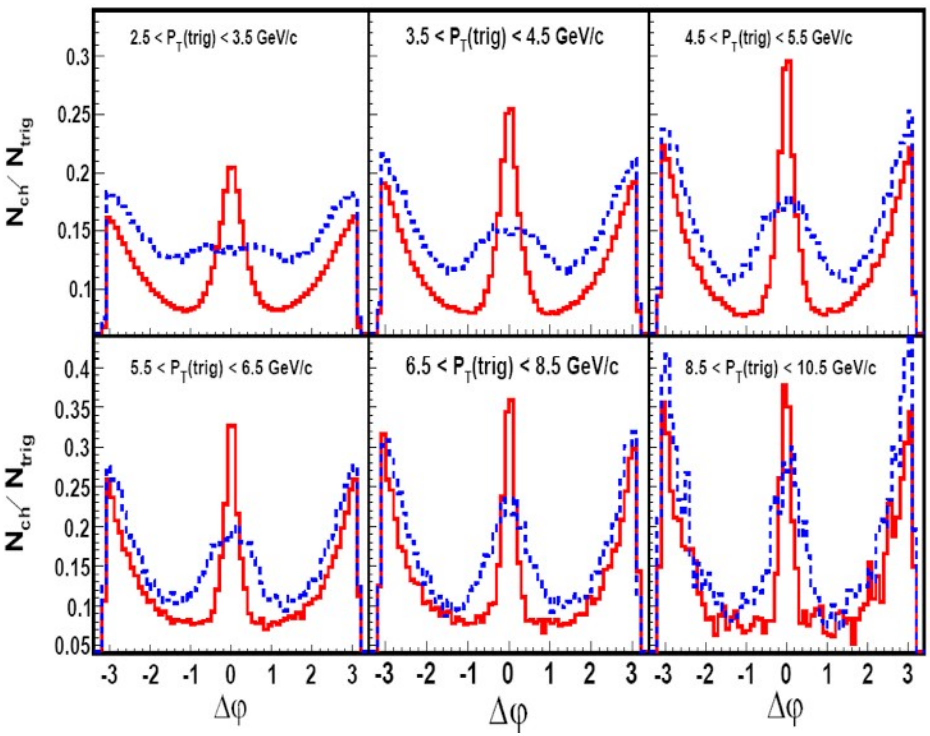
Revisit the energy loss mechanism!

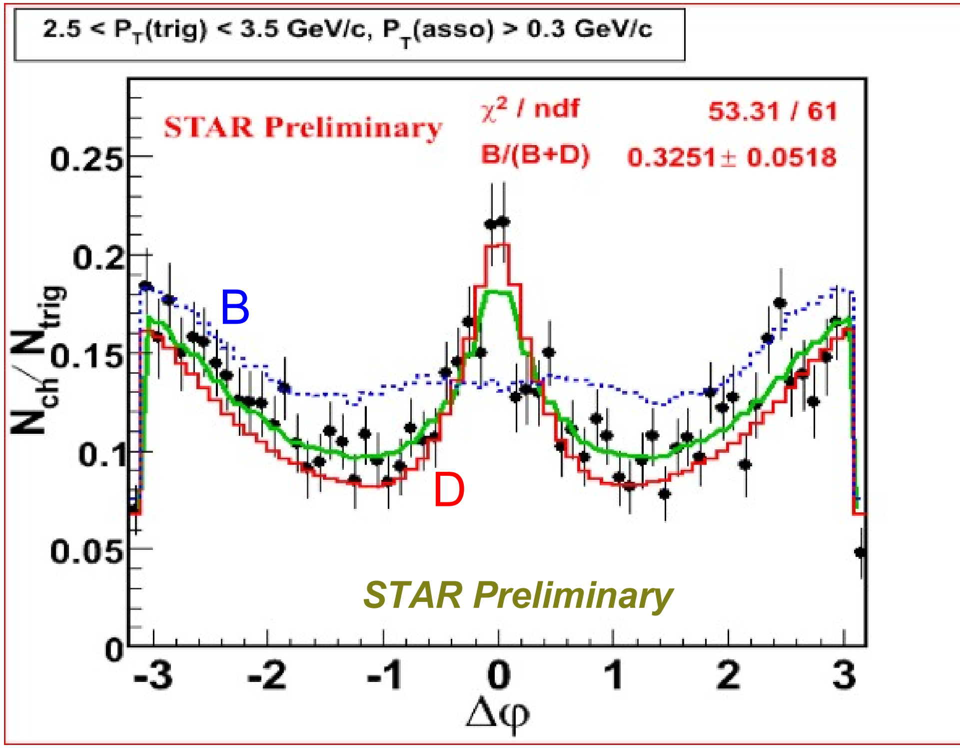
Suppression in Cu+Cu follows the N_{part} trend

Bottom contribution ?

e-h correlation

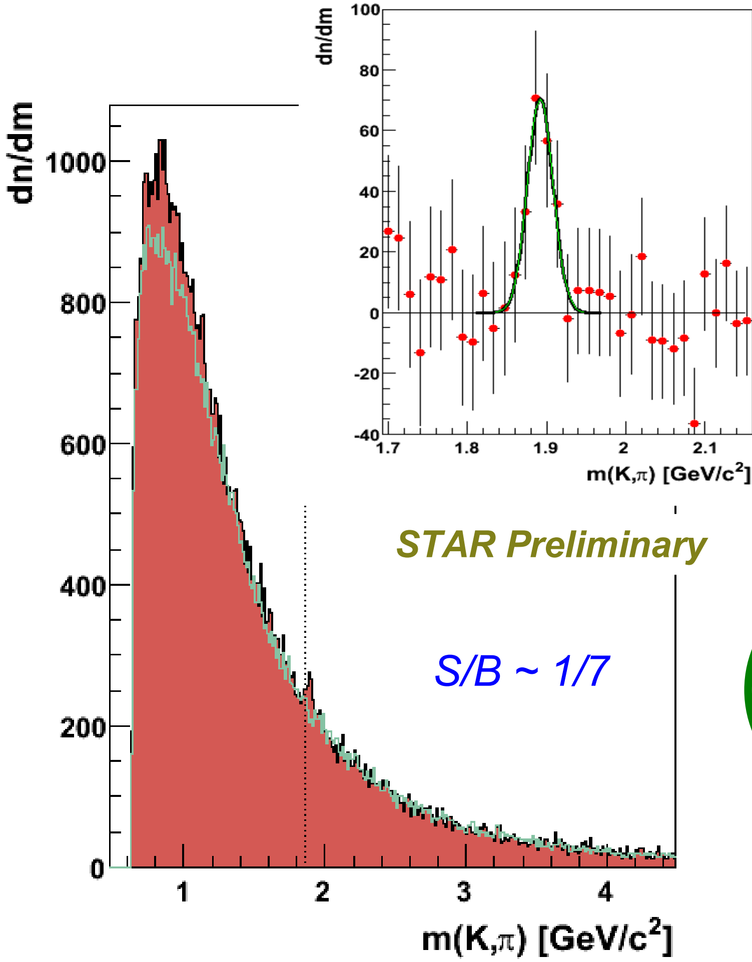
Azimuthal distribution fit benefiting from the kinematic difference
-- poor man's approach to obtain the relative bottom contribution to the non-photonic electrons.

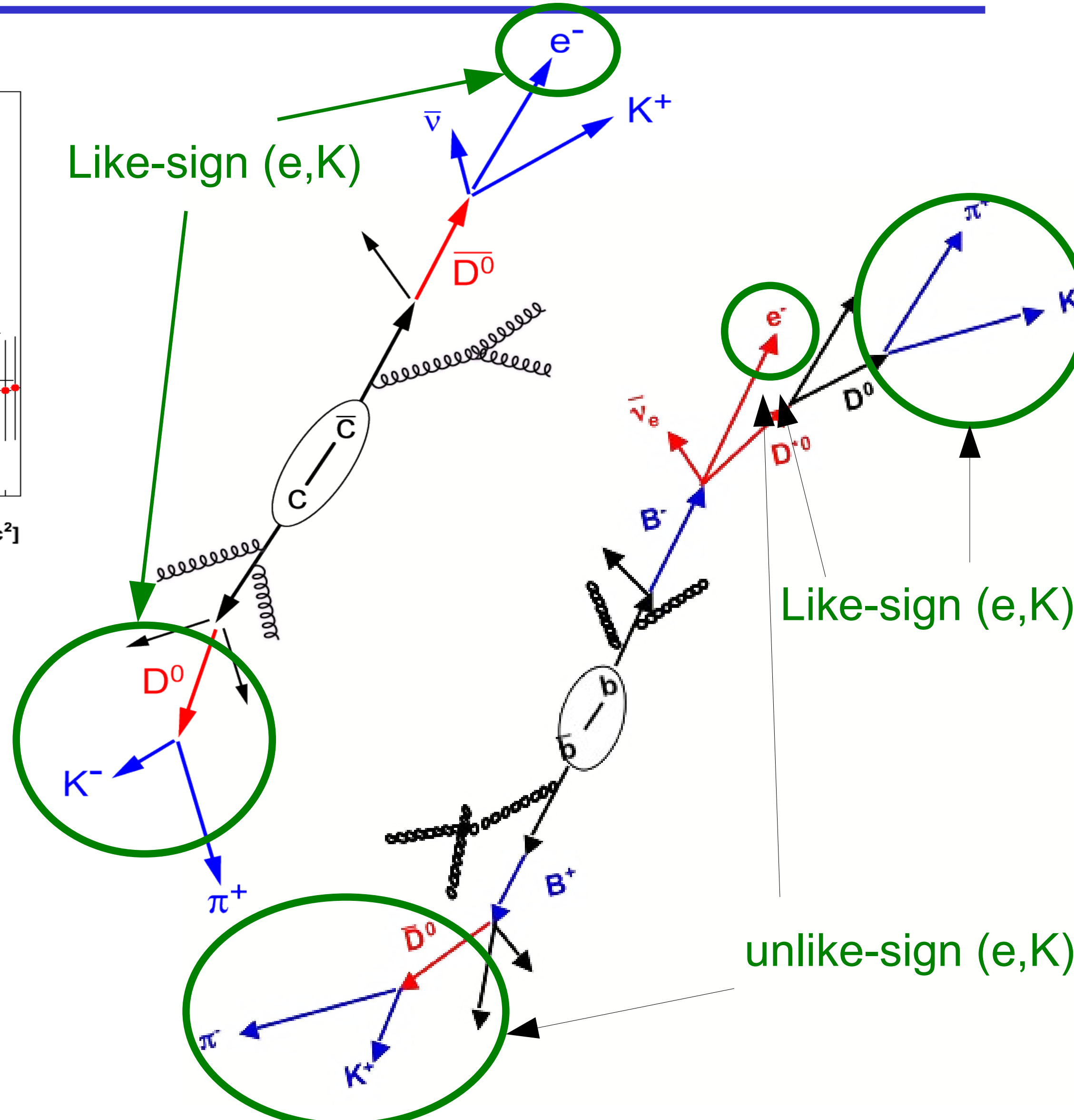




X. Lin, QM06

e-D^0 correlation



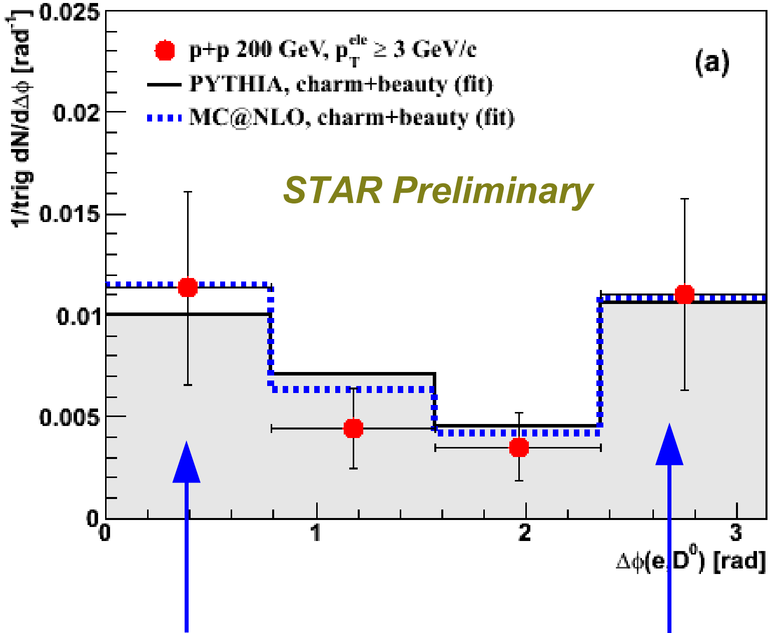


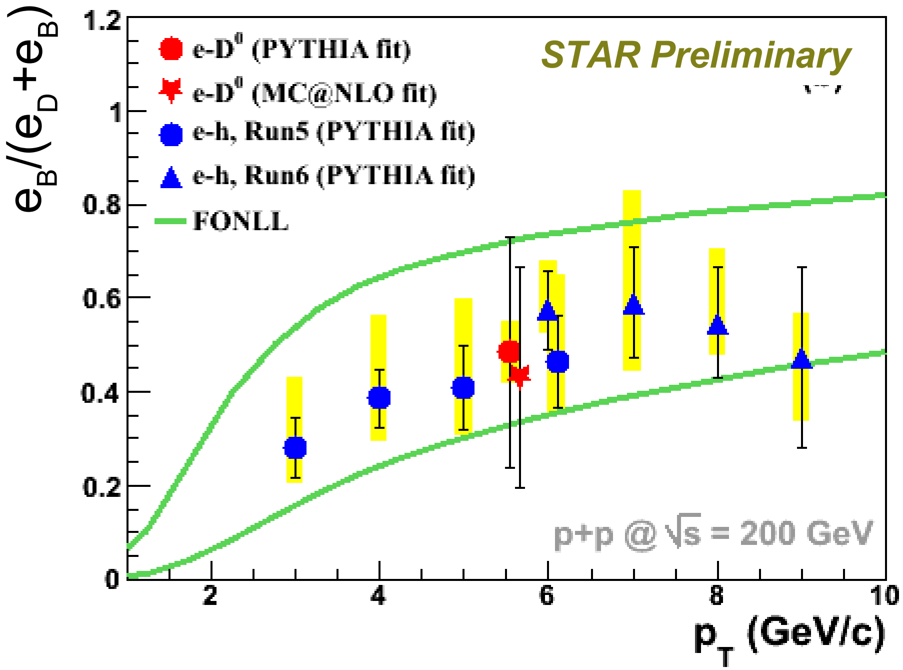
A. Mischke, QM08

Bottom contribution

A. Mischke, QM08
G. Wang, QM08

e^--D^0 correlation





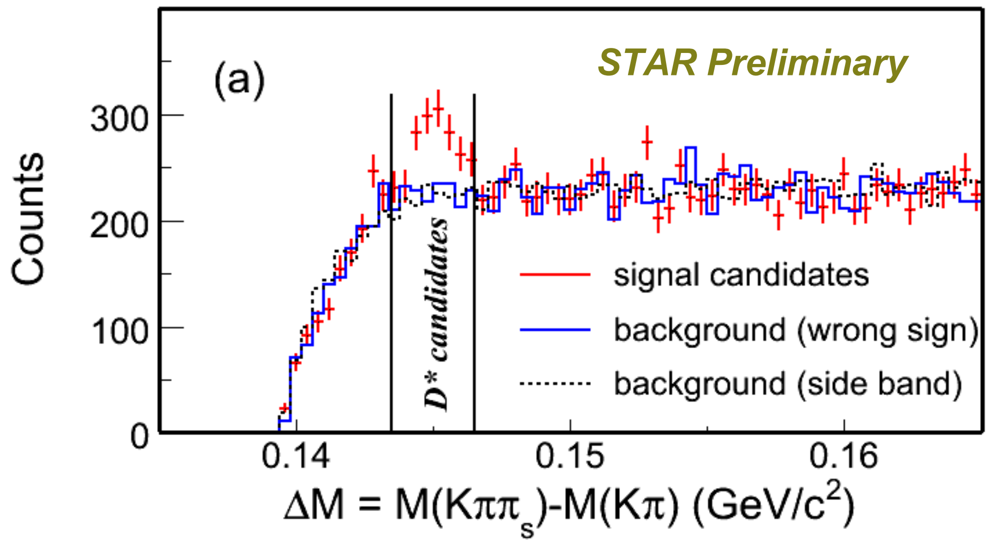
Essentially from B decay

Charm + Bottom decay

Bottom contribution to non-photonic electrons is important at high p_T, and it is consistent with FONLL calculations.

Near side: Charm from gluon splitting?

D*-jet correlation

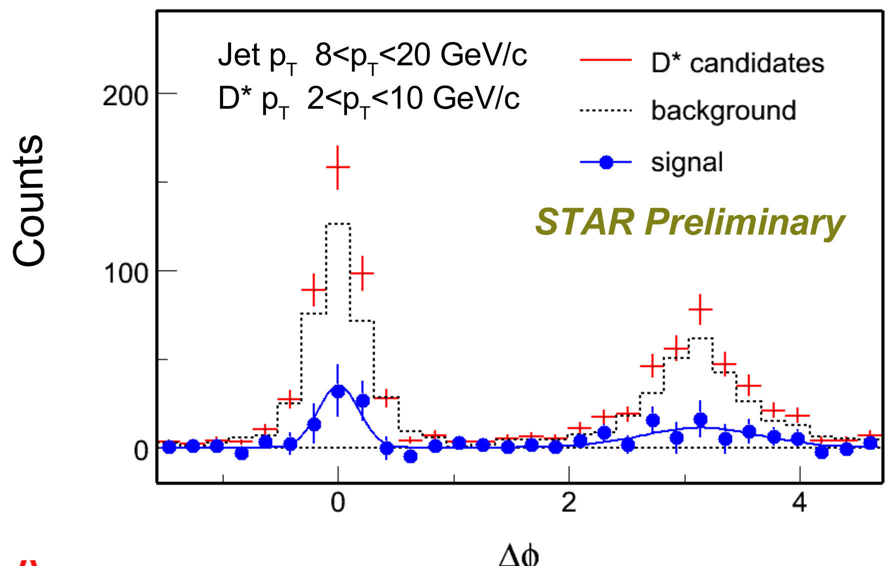


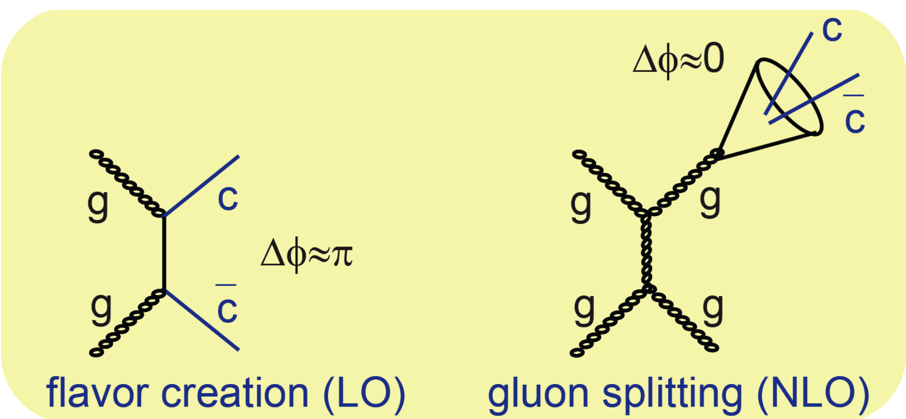
$$D^{*+} \rightarrow D^0\pi_s^+(68\%), D^0 \rightarrow K^-\pi^+(3.8\%)$$

Jet reconstruction

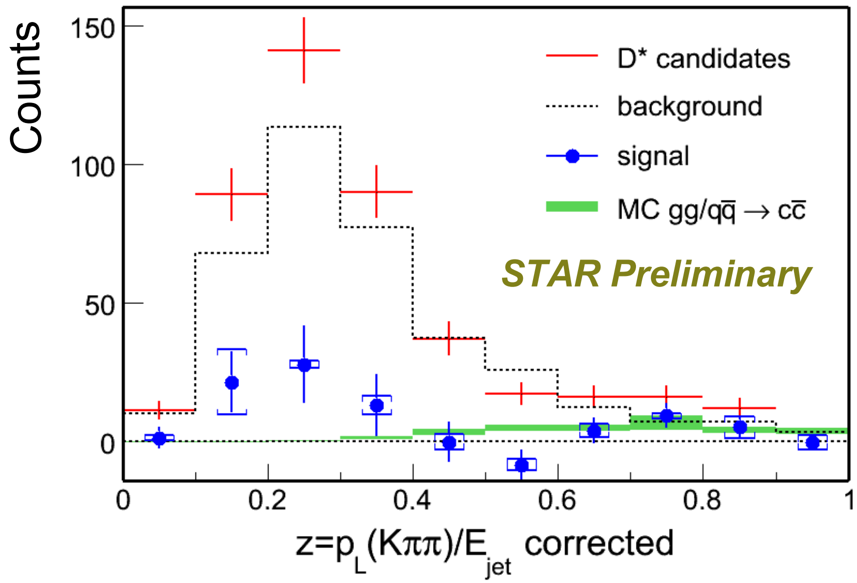
- mid-cone point method
- widely used in STAR spin analysis
- *PRL 97 (2006) 252001*

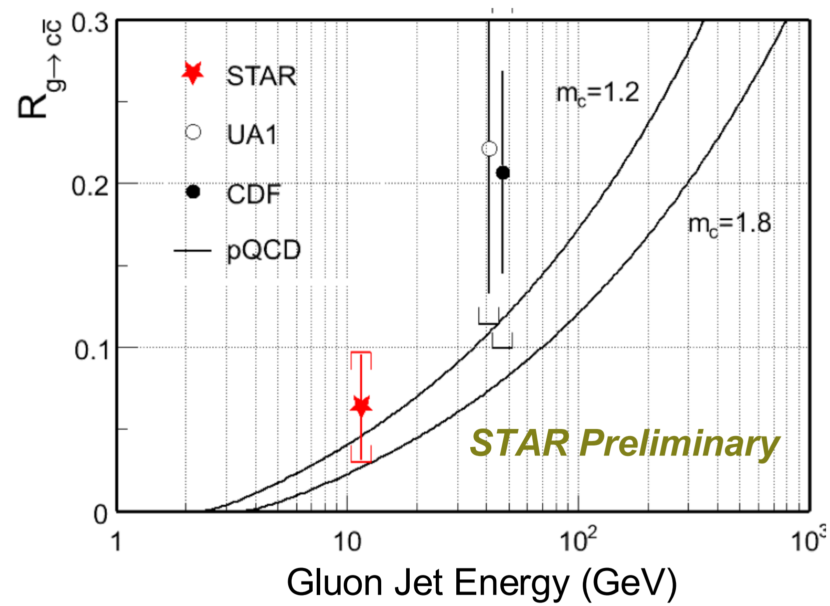
The study of D* production in jet sheds light on understanding the charm production mechanism at RHIC energy.





Charm production in jets





High z yields match the MC for direct flavor creation process.
Low z excess is expected to originate from gluon splitting.

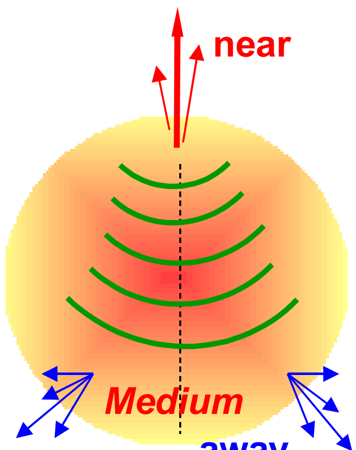
$N(D^{*+}+D^{*-})/N(jet) = 0.015 \pm 0.008 \pm 0.005$ $(0.2<z<0.5, \langle E_T \rangle \sim 11.5$ GeV$)$

- Gluon splitting rate to ccbar is consistent with pQCD calculations!
- Charm content in jets has a small contribution from gluon splitting and dominated by jets initiated by charm quarks!

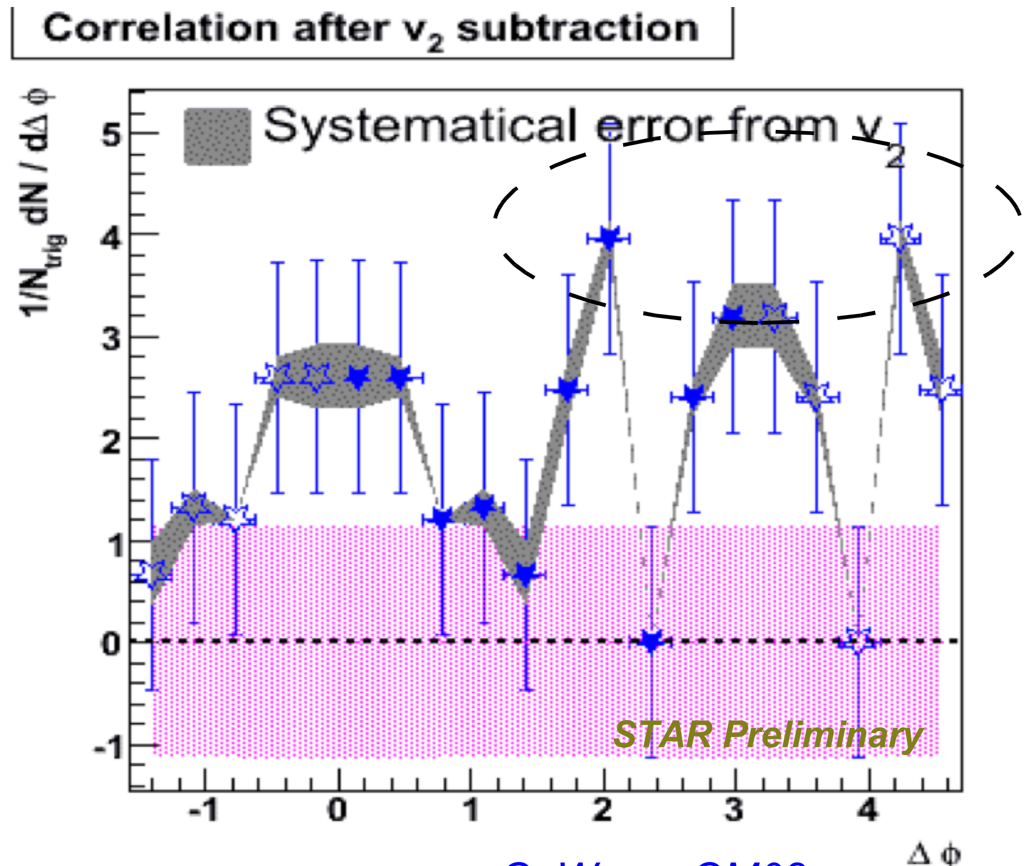
STAR Jet X-sec: *PRL 97 (2006) 252001*

e-h in A+A

Mach-cone Shockwave?
Cerenkov radiation?



Au+Au 200 GeV 0-20%, $3<p_T^{trig}<6$ GeV/c, $0.15<p_T^{assoc}<1$ GeV/c



G. Wang, QM08

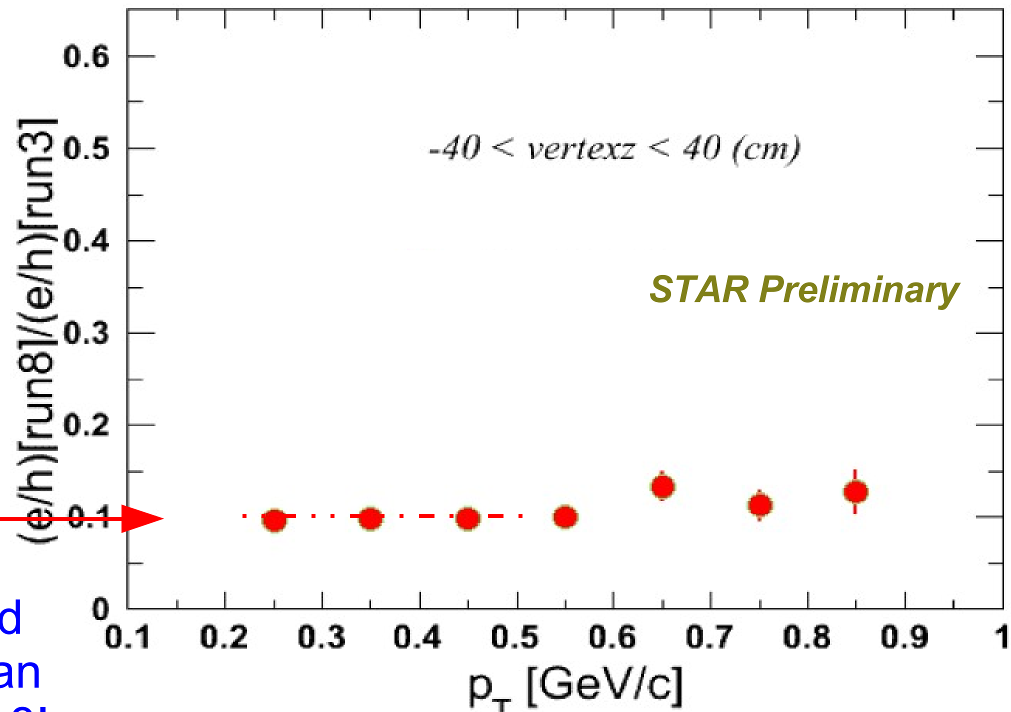
A good start! Hungry for statistics!
Heavy quark will provide a unique probe to characterize the medium property.

First look from Run 8 data

Run 8:

d+Au & p+p 200 GeV
SVT & SSD were removed
(Very) low material run

Background reduced by a factor of 10



Heavy quark decay electron yield is comparable or even higher than the photonic background in Run 8!

~ 3 M p+p tpxtof triggered events from Run 8
76 M p+p tpxtof triggered events in total, and
3-4 pb^{-1} EMC high tower triggered data.

Summary

STAR detector is unique to perform multi-measurements in one experiment

- open charm hadron reconstruction
- non-photonic electrons
- heavy quark decay muons
- correlations between them due to large (eta,phi) coverage

Qualitative conclusions

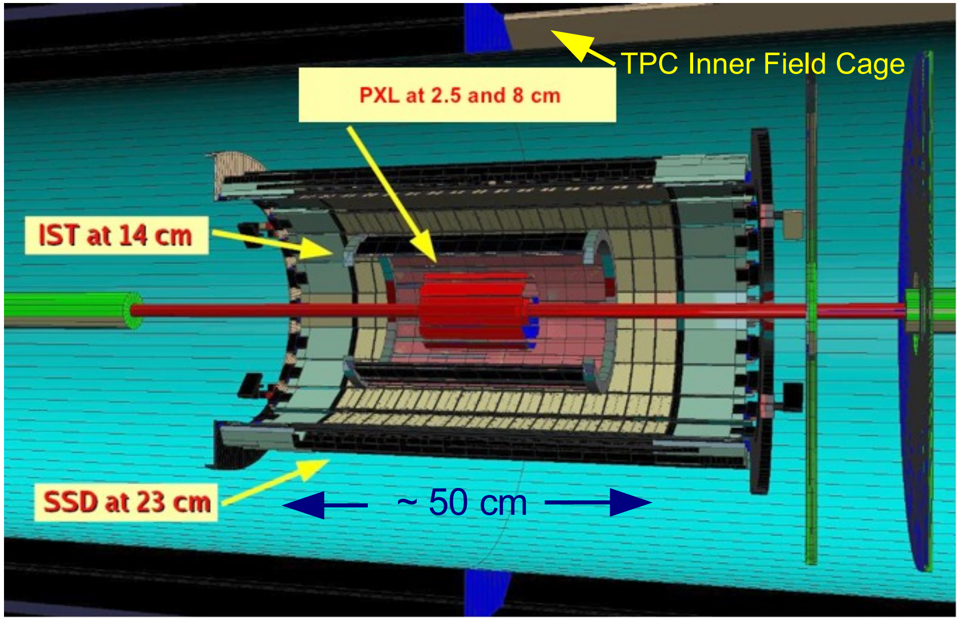
Charm production X-sec is approximately scaled by N_{bin}	to xx%
Charm hadron seems to not have a large radial flow	significance?
$R_{AA}(e) \sim R_{AA}(h)$ at high p_T	to xx%
Bottom contribution in non-photonic electrons is important	to xx%
Charm from gluon jet splitting is small	< xx%
e-h correlation in AA seems to show a similar broadening in the away side	significance?

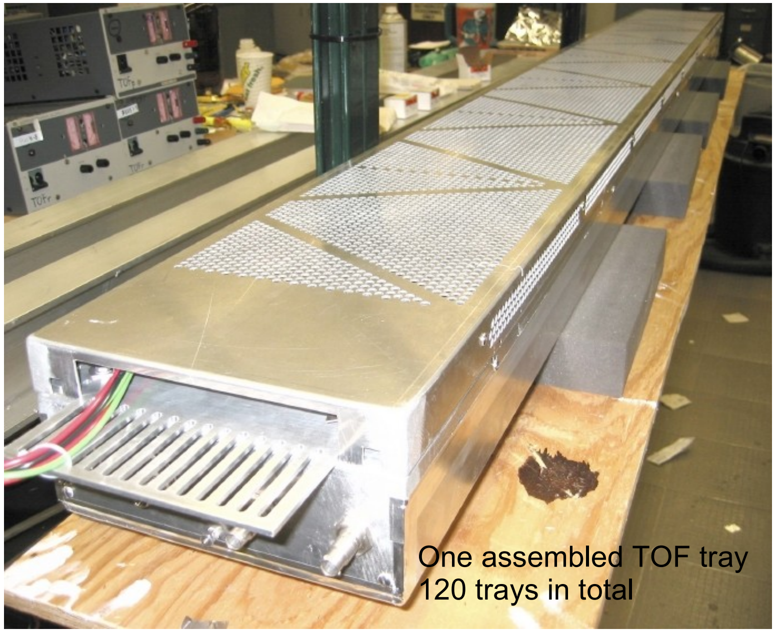
Quantitative measurements are called for

Improve the precision on charm total/differential cross sections in A-A/p-p collisions
Quantify the medium properties and EoS.

Topologically reconstruction of identified open heavy quark hadrons is ultimate!

STAR Upgrade Plans





Heavy Flavor Tracker (HFT)

Barrel Time-Of-Flight (TOF)

Topological reconstruction of the secondary vertices at precision 20-40 μm

Direct *identified* charm (bottom) hadron reconstruction

Improve the stable particle PID capability
π/K to 1.6 GeV/c
(π, K)/p to 3 GeV/c

Improve the S/(S+B) ratio
by ~ 10-20 for D^0 (0-5 GeV/c)