Charm & bottom measurement @ RHIC

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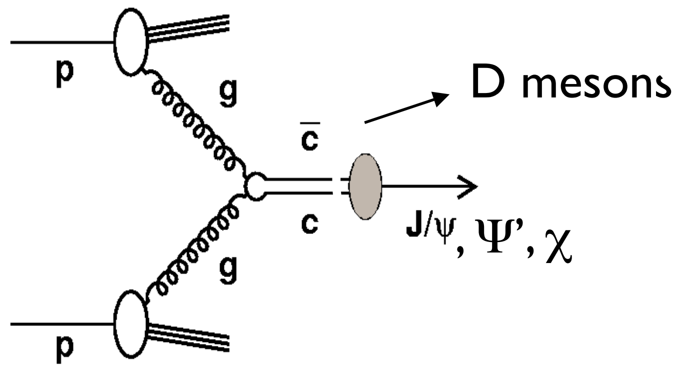
Outline

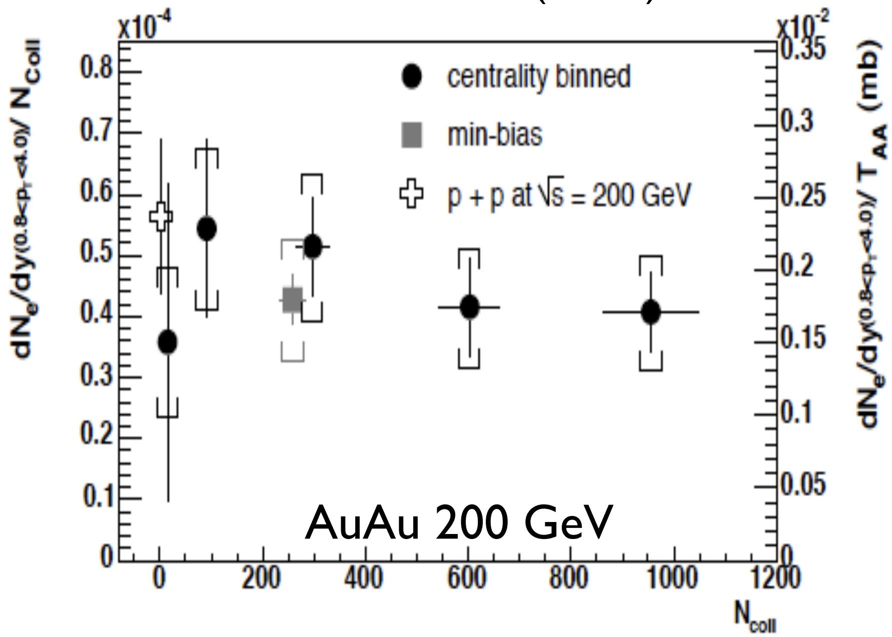
- Non-photonic e result in AuAu
- b/c separation in non-photonic electron by electron-hadron correlations @ pp
- Bottom production
- Discuss heavy flavor energy loss in the dense matter

Heavy flavor & HIC

- ✓ Heavy quarks (charm & bottom) are produced by gluon fusion in the initial collisions.
- ✓ Total charm yields in AuAu collisions @ RHIC is scaled by binary collisions
- ✓ heavy quarks are produced before the medium formed and through the matter.
- ✓ probe of QCD matter

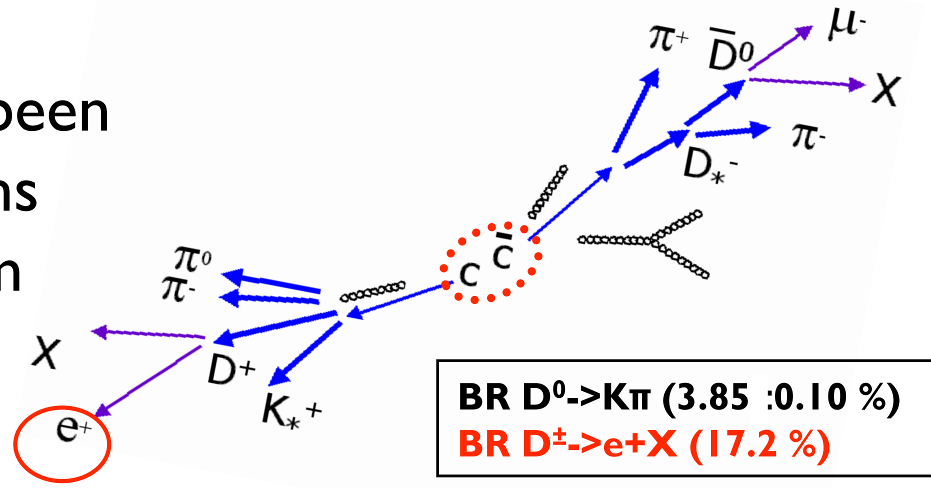


PRL 94, 082301 (2005)



Charm quark study @ RHIC

- Heavy flavor production has been studied by measuring electrons decay from charm and bottom (non-photonic electron) at RHIC



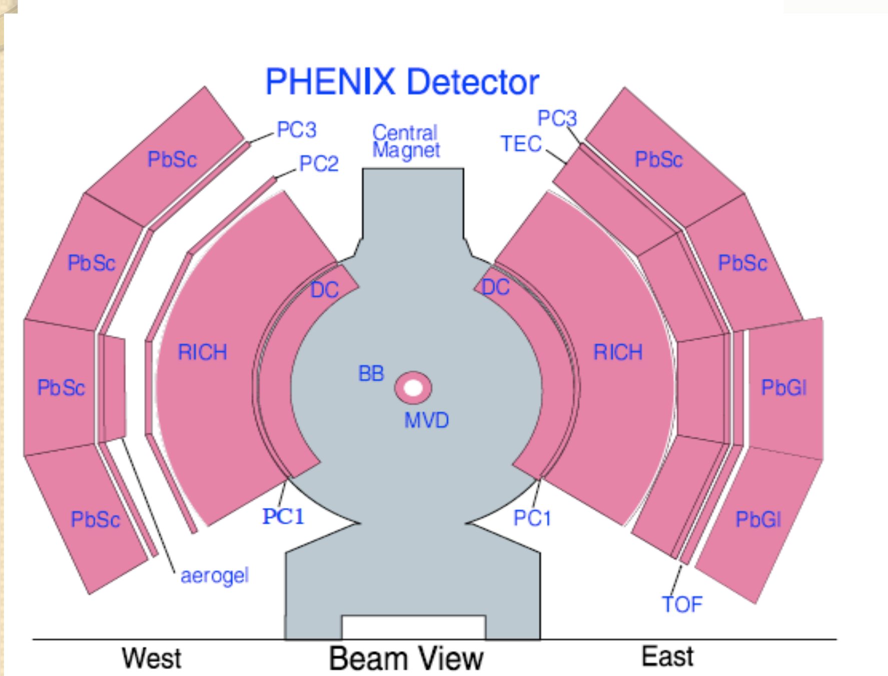
BR D^0->Kπ (3.85 :0.10 %)
BR $D^\pm$->e+X (17.2 %)

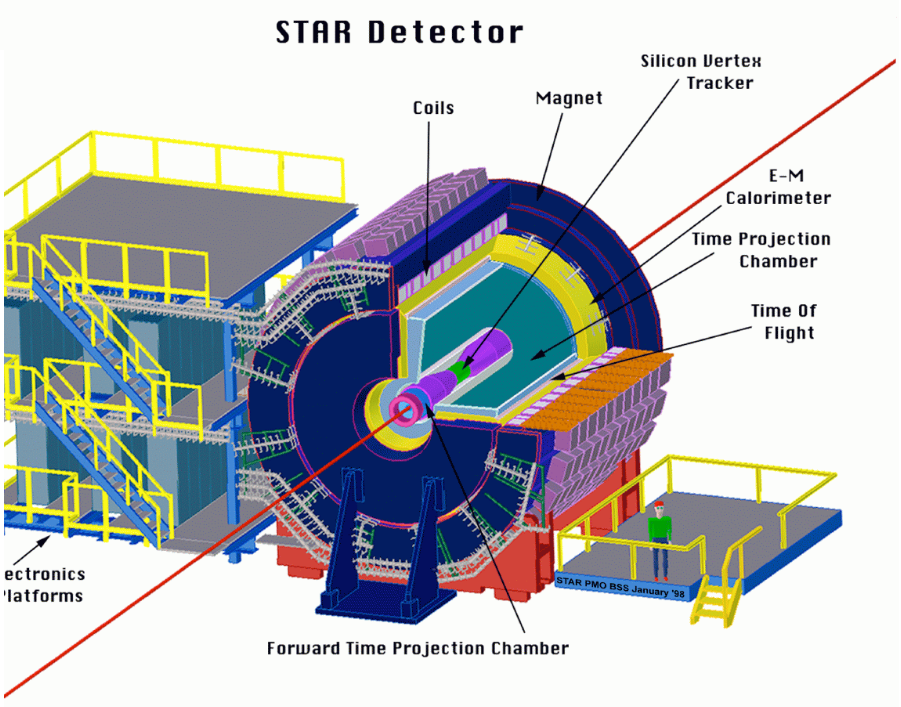
- Measured electron
  - Photonic electron
    - photon conversion
    - Dalitz decay
  - Non-photonic electron
    - primarily semi-leptonic decay of mesons containing c & b

D meson
- ✓ M = 1.869 [GeV]
- ✓ $\tau \sim 10^{-12}$ [s]
- ✓ $c_\tau \sim 300$ [μm]

PHENIX vs. STAR detector

- electron ID is carried with



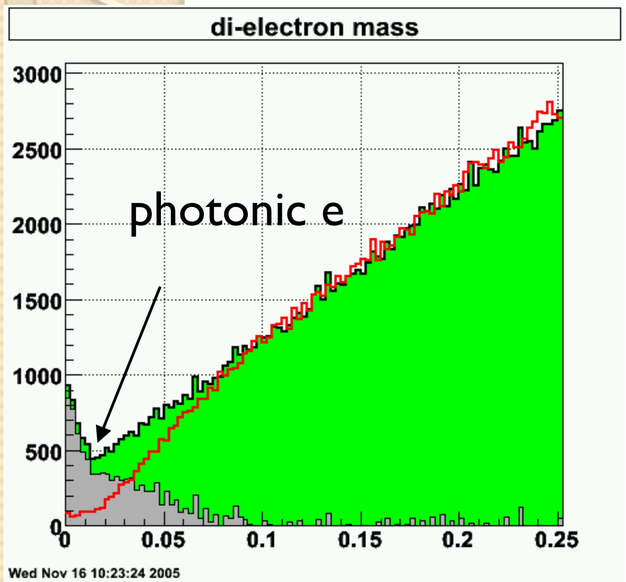


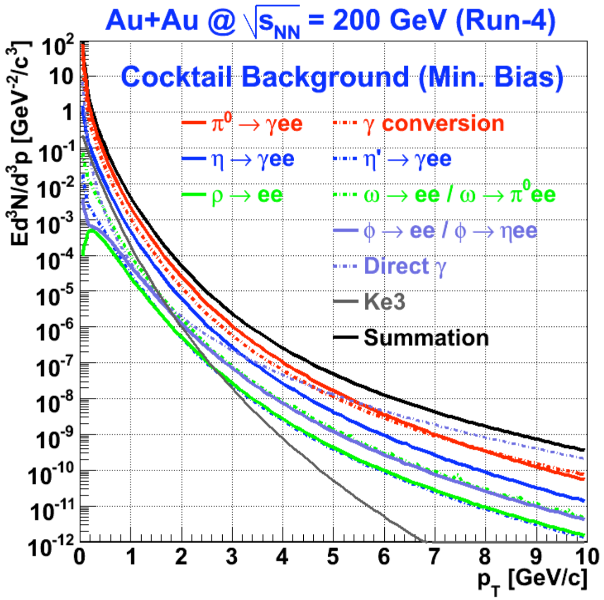
○ DC + PC ; momentum
○ RICH ; ring image
○ EMC ; energy

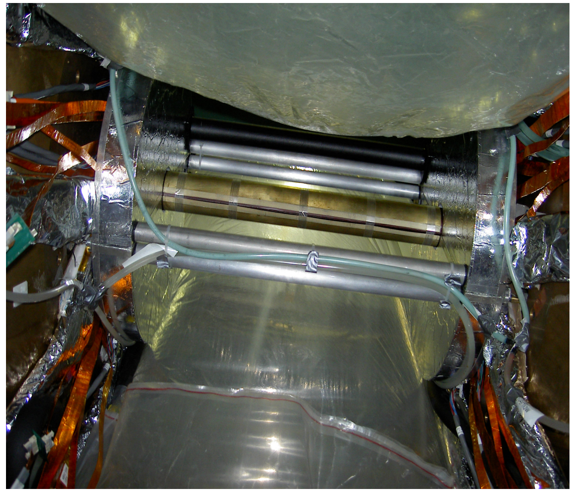
○ TPC ; momentum, dE/dx
○ EMC ; energy
○ SMD ; shower shape

Photonic electron determination

- Main background in electron measurement is photonic electron







- Invariant mass

Reconstruct photonic electron by calculating Inv. Mass of ee (STAR)

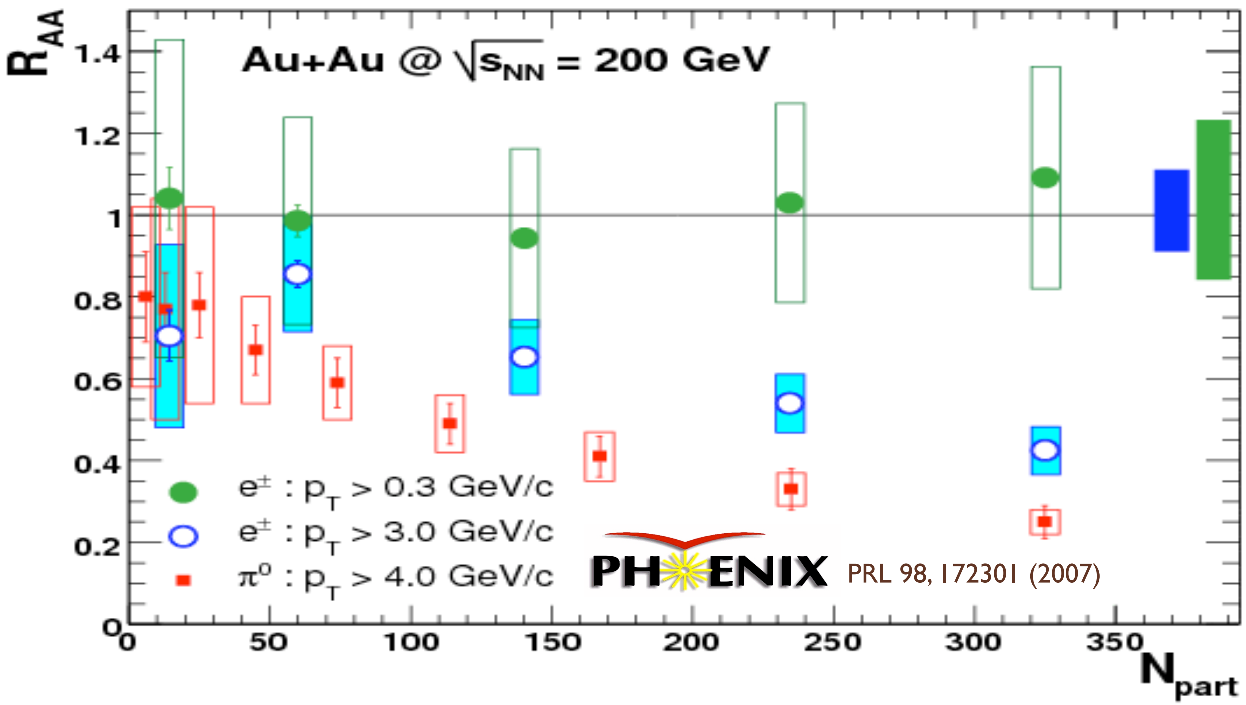
- Cocktail method

Calculate photonic electron by using measured photonic sources (PHENIX)

- Converter method

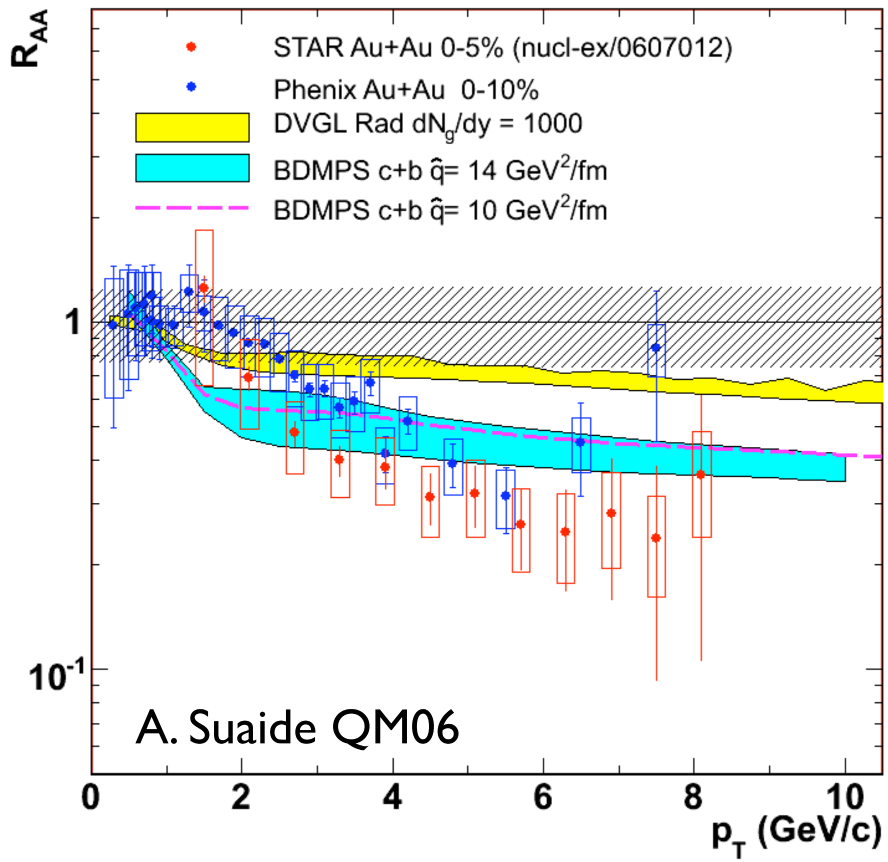
Install additional converter. Then compare yield w. w/o converter (PHENIX)

Non-photonic e production in AuAu



- binary scaling of total $e^{\pm}$ yield from heavy flavor decay
  => hard process production
- high p_T $e^{\pm}$ suppression increasing with centrality
  => heavy flavor energy loss
  => very high dense matter is formed in AuAu collisions

Models for energy loss



- radiative energy loss with typical gluon densities is not enough (Djordjevic et al., PLB 632(2006)81)
- models involving a very opaque medium agree better (Armesto et al., PLB 637(2006)362)
- collisional energy loss / resonant elastic scattering (Wicks et al., nucl-th/0512076, van Hees & Rapp, PRC 73(2006)034913)

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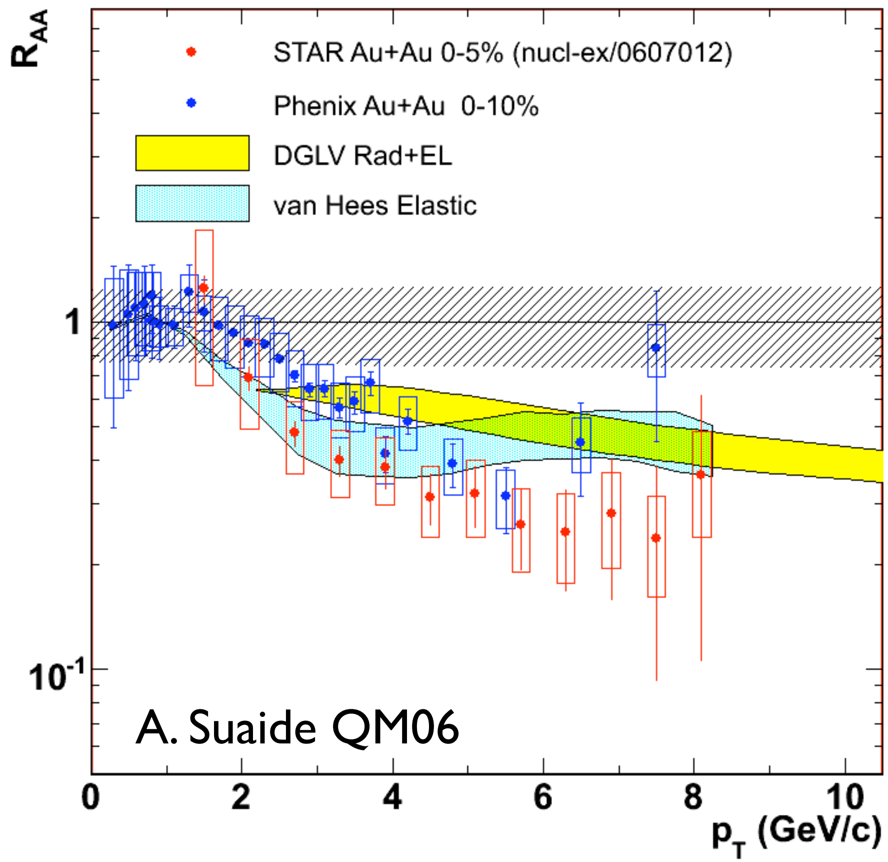

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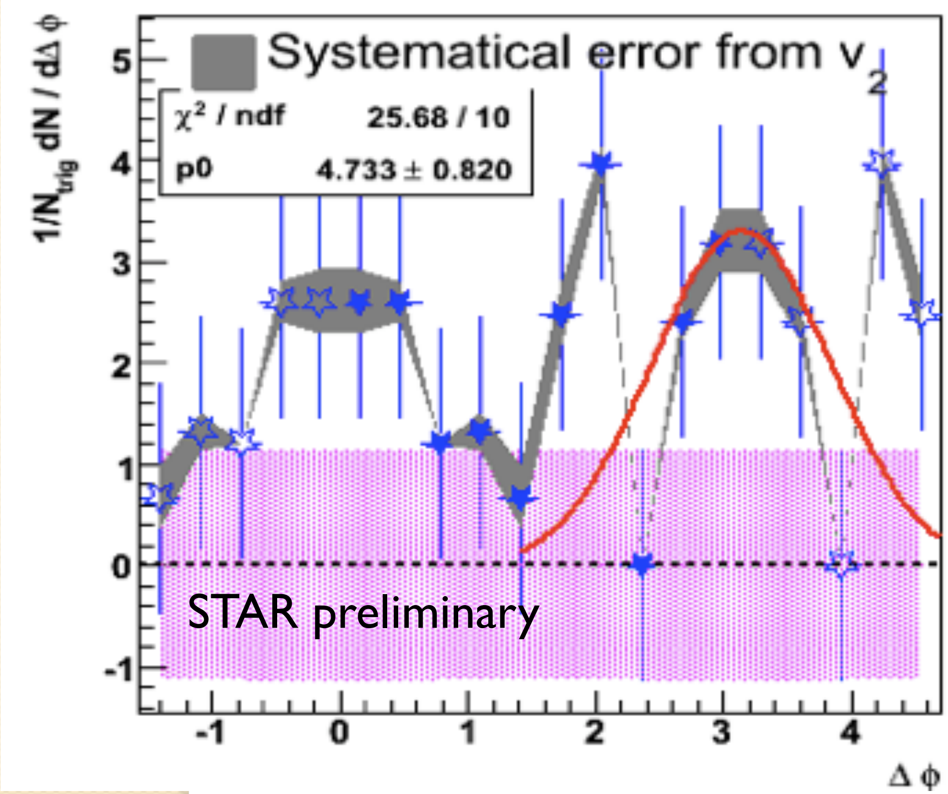
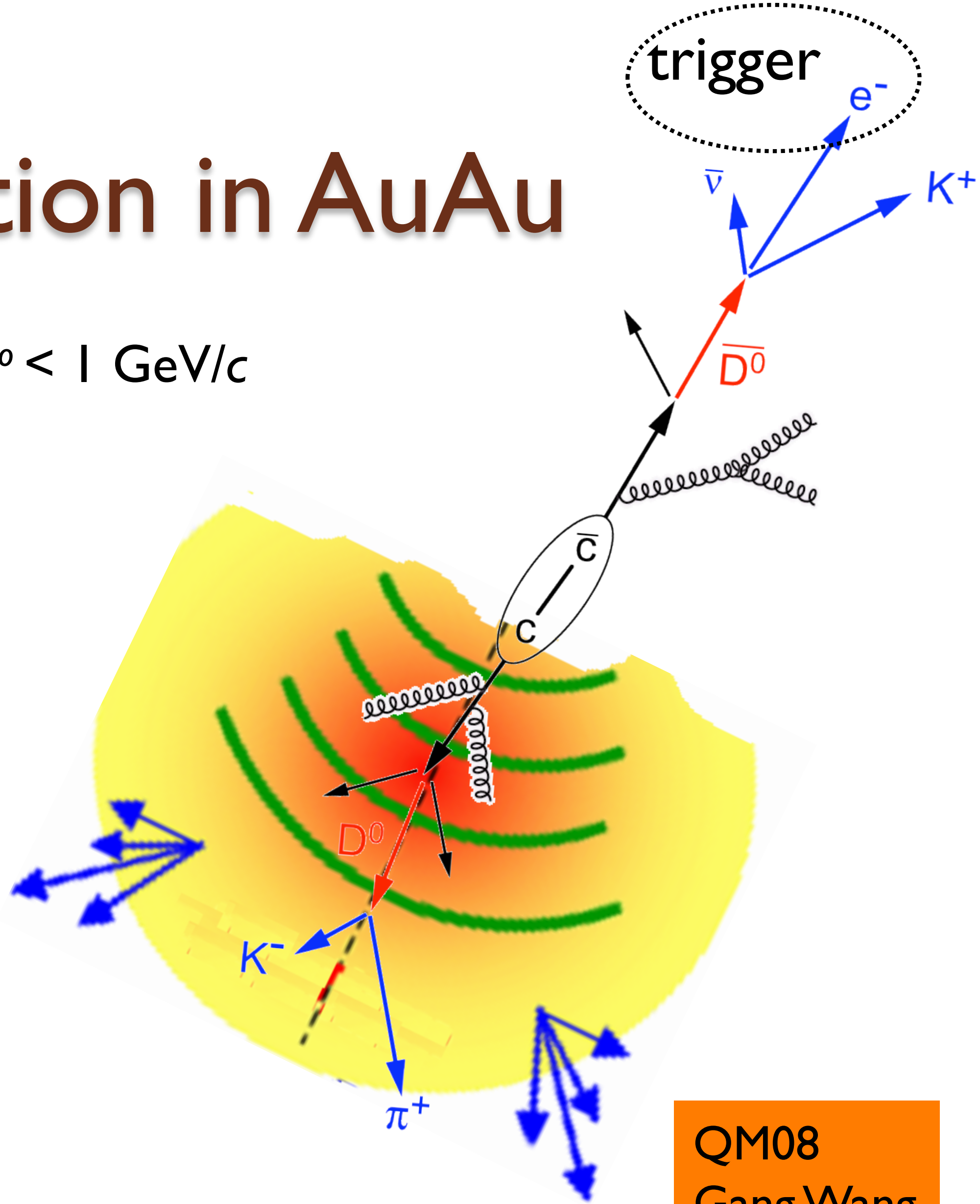
- Uncertainty from bottom quark contribution not only theory but also experiment @ high pT

e^{HF}-h correlation in AuAu

0 – 20%: $3 < p_T^{trig} < 6$ GeV/c & $0.15 < p_T^{asso} < 1$ GeV/c

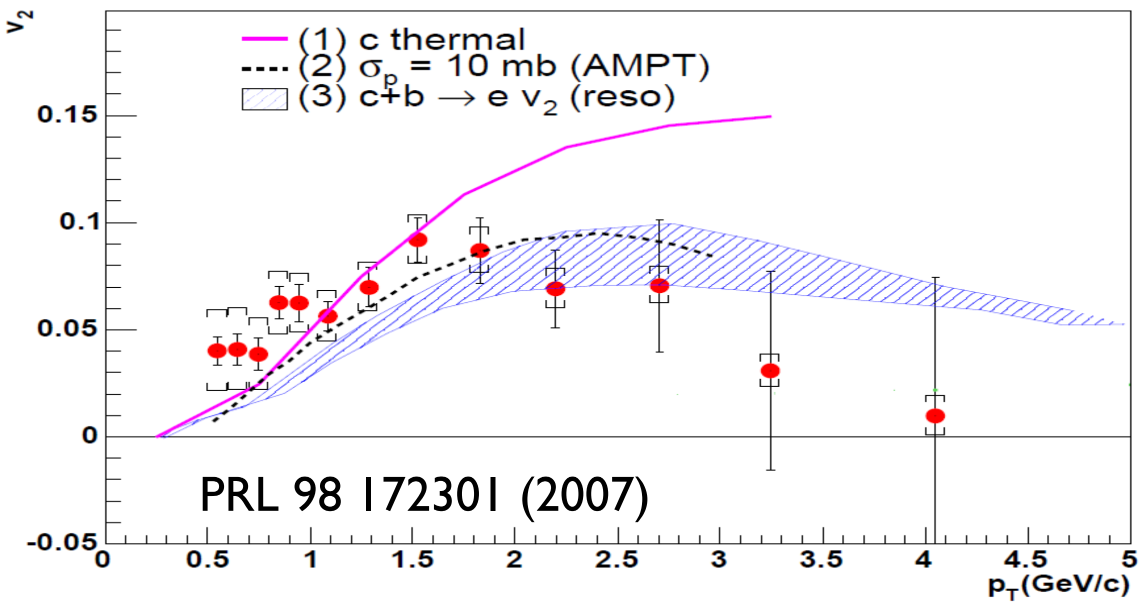




QM08
Gang Wang

- Away side structure is similar to mach cone shape
- The other evidence of heavy quark energy lose

Non-photonic electron v_2



- Strong elliptic flow for non-photonic electron

(1) Charm quark thermal + flow [Phys.Lett. B595 202-208]
(2) large cross section ; ~10 mb [PRC72,024906]
(3) Elastic scattering in QGP [PRC73,034913]

- charm quark flow -> partonic level thermalization
- There is also uncertainty from bottom @ high pT

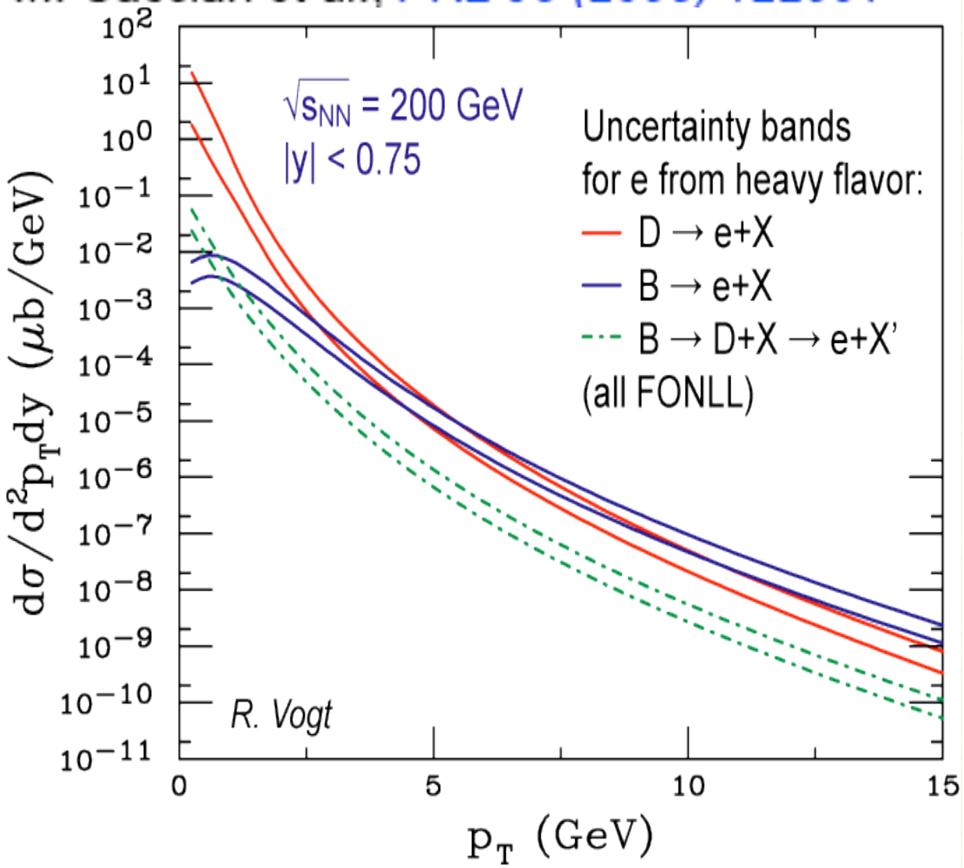
pQCD prediction for Bottom

- Since charm and bottom are heavy, their production have been predicted by pQCD

- FONLL predicts bottom quark contribution significant (c/b = 1) around 5 GeV/c in non-photonic electron yield with large uncertainty.

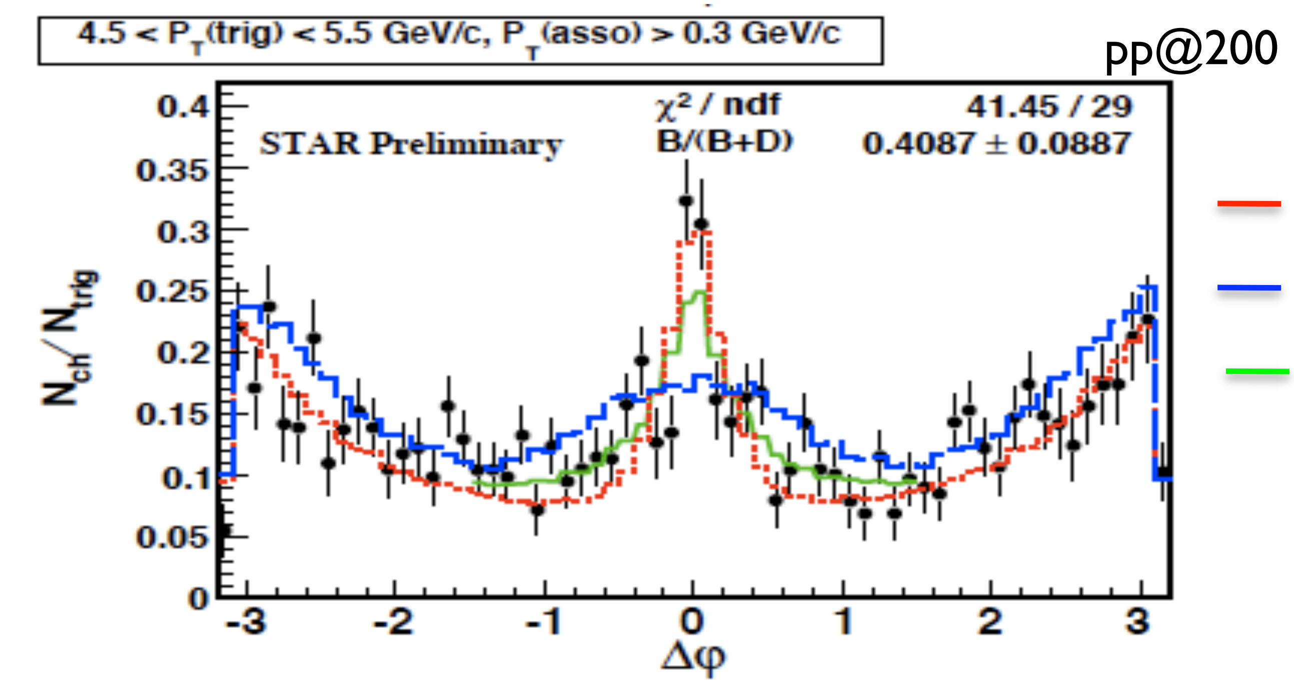
- Separate charm/bottom by using e-h correlations

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



*Uncertainty comes from mass, PDF, etc in the calculation
*FONLL
=A Fixed-Order plus Next-to-Leading-log

e^{HF} and hadron correlation



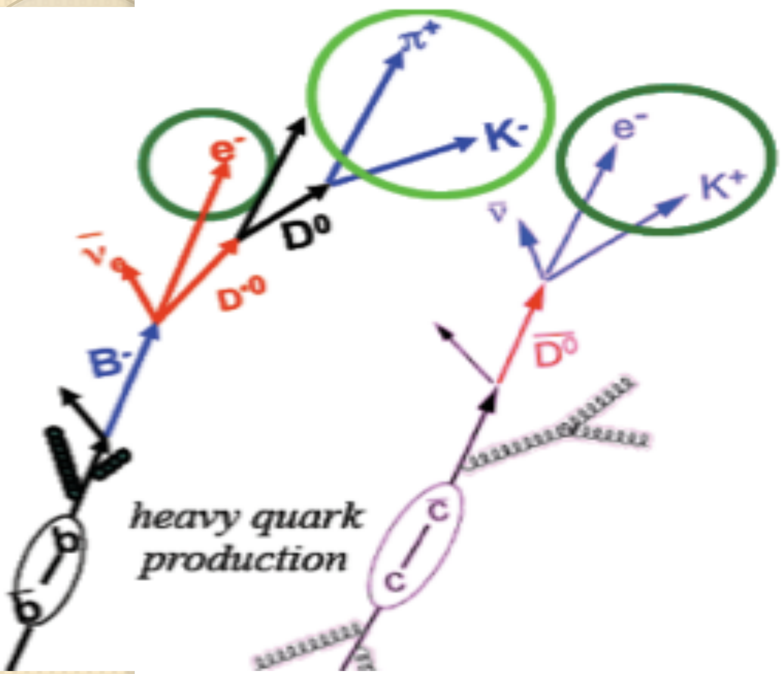
pp@200 GeV

- e^D – h (MC)
- e^B – h (MC)
- fitting

- Near side width for B decay is wider than that of D decay due to decay kinematics
- measuring e-h correlation in pp & fit by MC with B/(B+D) as parameter

$$\Delta\phi_{e-h}^{\exp} = R_B \Delta\phi_{e^B-h}^{MC} + (1-R_B)\Delta\phi_{e^D-h}^{MC}, \quad R_B = e_B/(e_D+e_B)$$

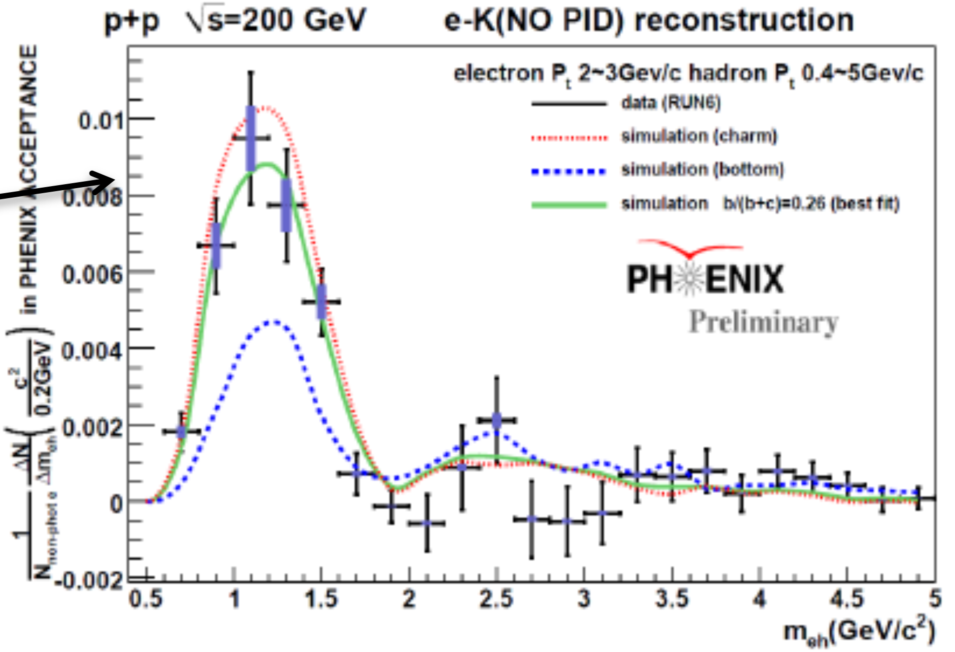
e and K correlation



- Electron-Kaon charge correlation
  - D meson decay
    => opposite sign eK pair
  - B meson decay
    => same sign eK pair

QM08
Y. Morino

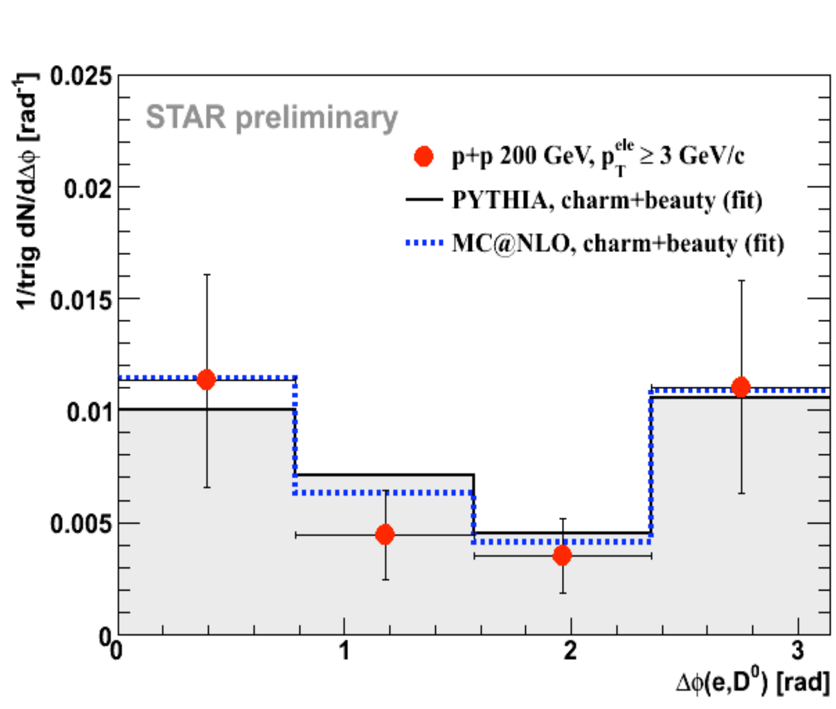
$$M_{eK}^{opp} - M_{eK}^{same}$$

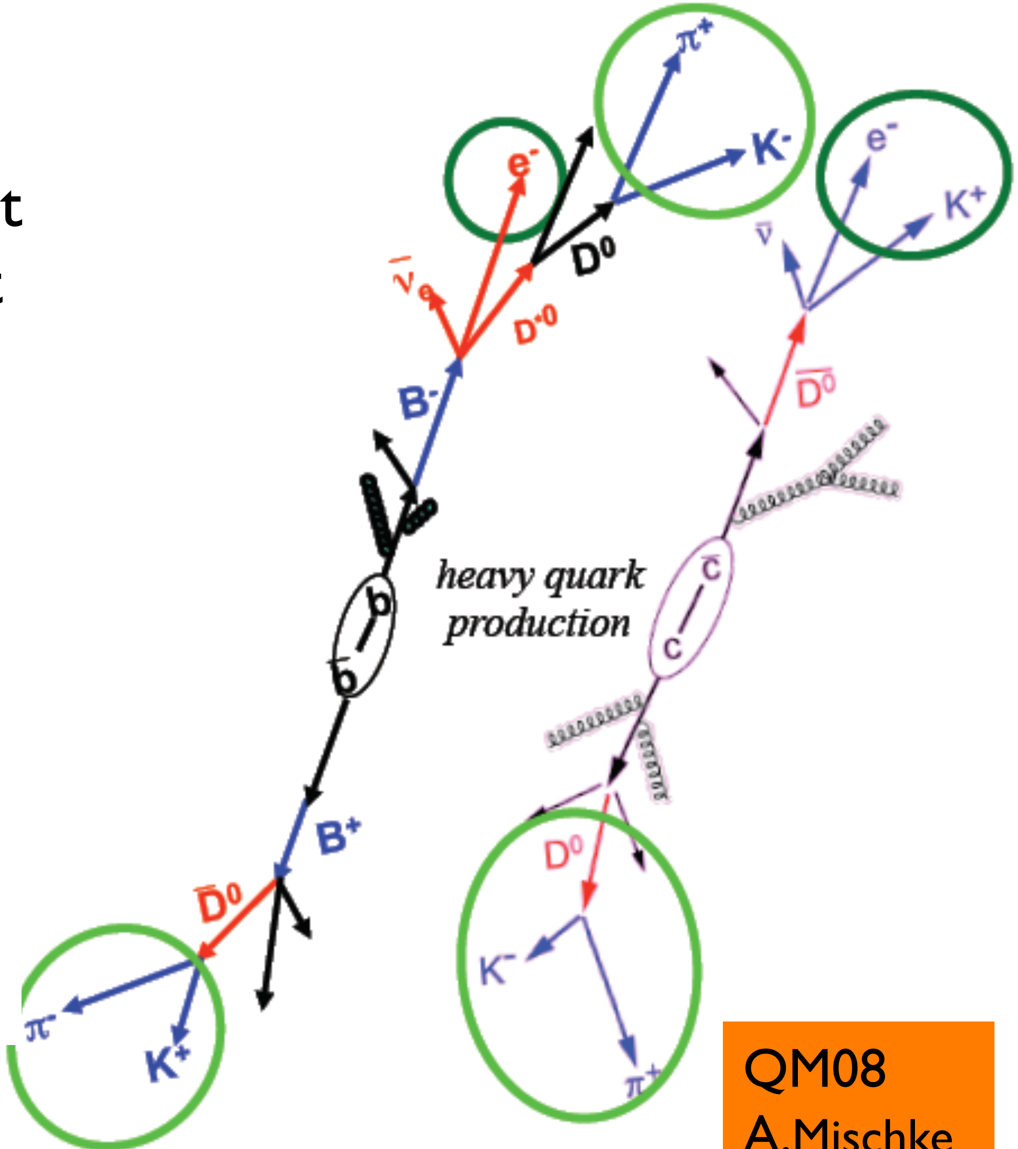


disentangle charm and remaining bottom contribution via (PYTHIA) simulation

e and D0 correlaion

- Request like-sign e-K pair
  - near-side ; bottom dominant
  - away-side ; charm dominant

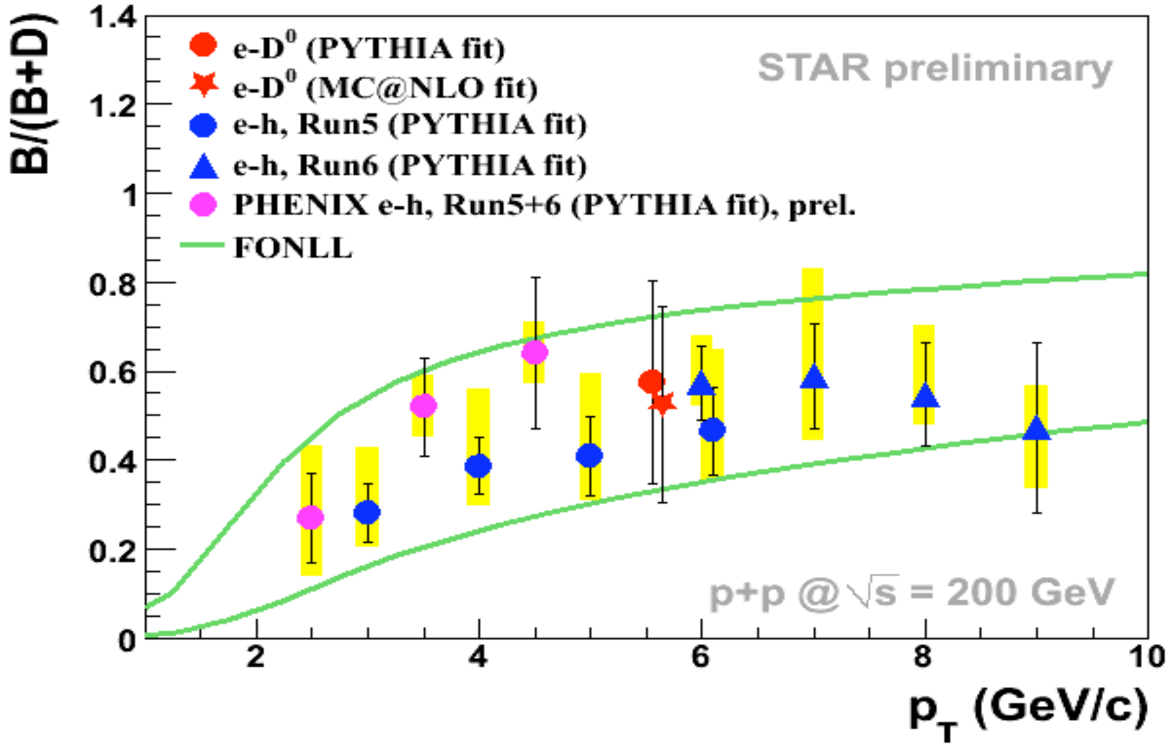




compared with MC simulations to get B/D ratio

QM08
A.Mischke

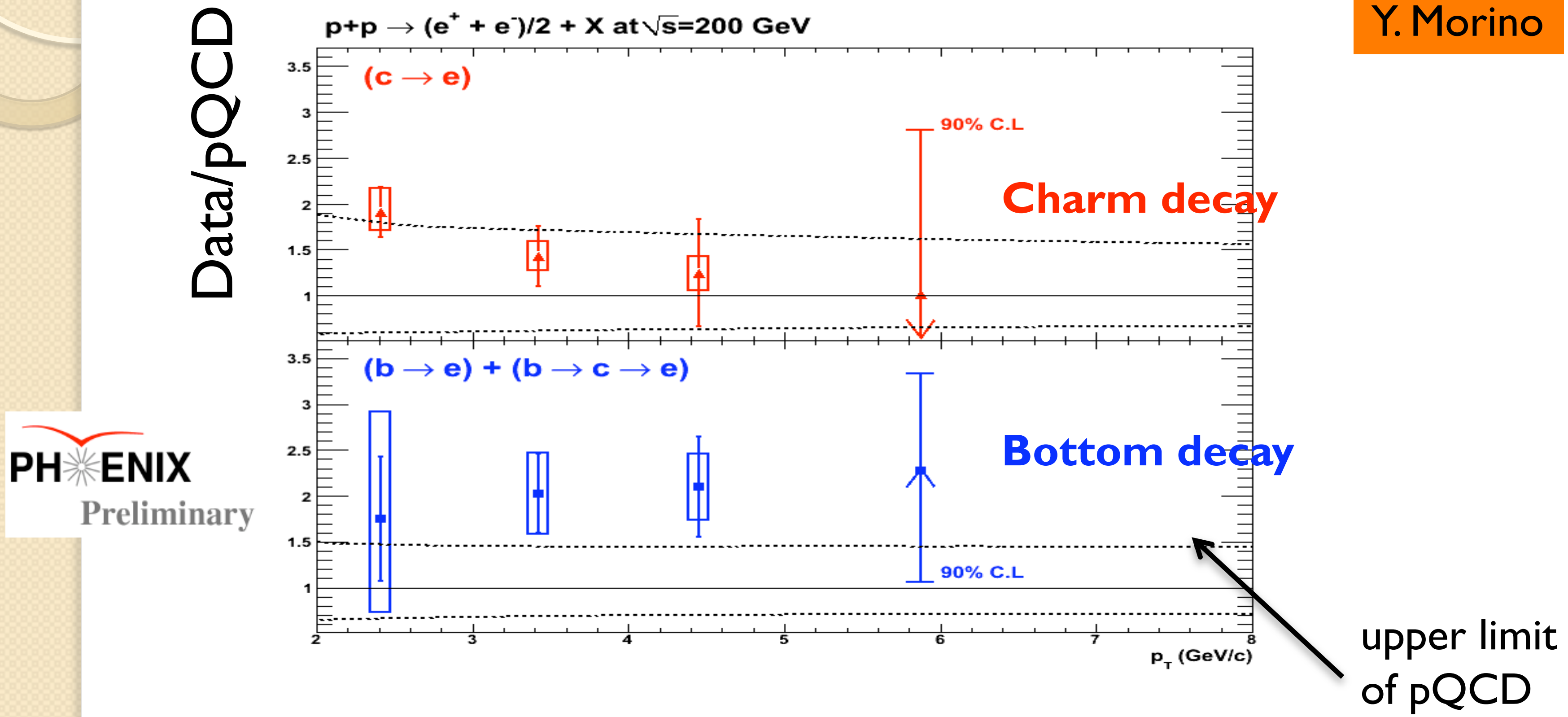
B decay contribution



- B decay contribution to non-photonic electron
- Three independent method (STAR & PHENIX) are consistent
- B decay contribution increase with pT
- <u>> 50% e decay from B above 4-5 GeV/c</u>
- good agreement with pQCD (FONLL) prediction

Bottom production @ pp

QM08
Y. Morino



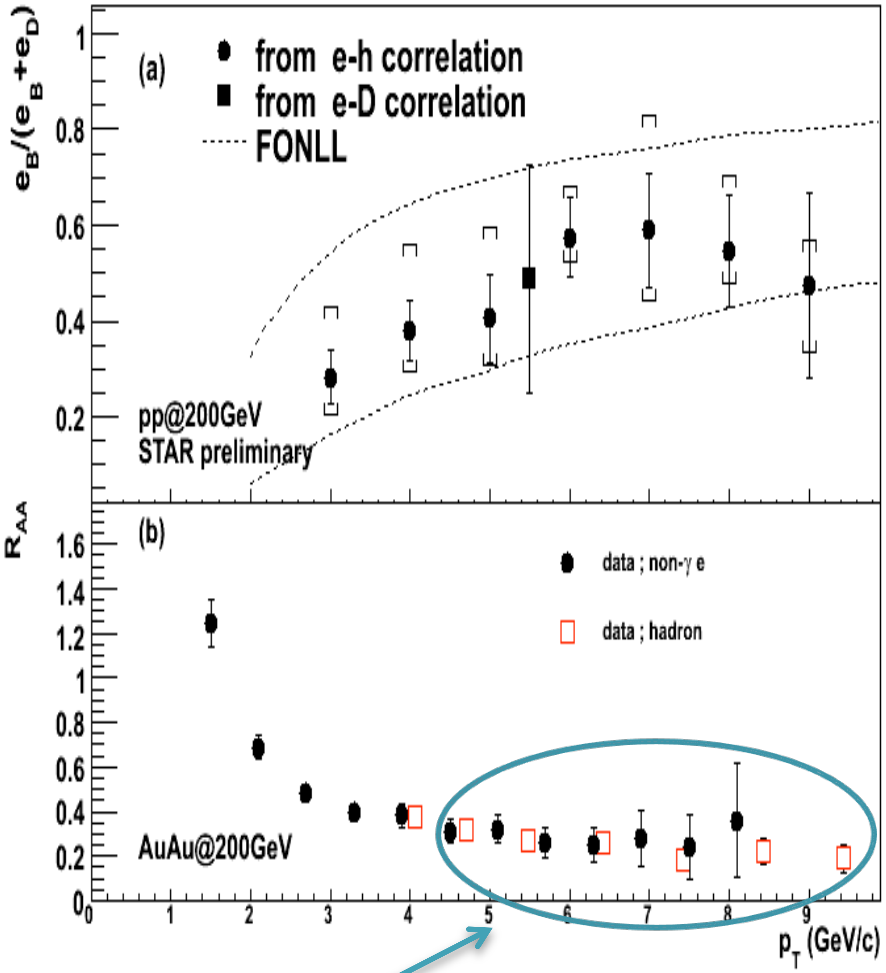
- ☐ data (c->e & b->e)/pQCD from PHENIX
- ☐ ratio is almost flat -> pQCD well represent the p_T shape
- ☐ $\sigma_{data}/\sigma_{FONLL}$ ~2 reasonable value

Large Bottom energy loss ?

- Bottom quark contribution is ~50% above 4-5 GeV/c @ pp
  => there would be significant bottom contribution in AuAu, too

- R_{AA} for non-photonic electron consistent with hadrons

⟹ Indicate large energy loss not only charm but also bottom in the dense matter



C:B ~ 1:1 @ pp

R_{AA}^{c} & R_{AA}^{b} correlation (I)

Relation between R_{AA} for charm and bottom decay

$$R_{AA} = \frac{e_B^{AA} + e_C^{AA}}{N_{bin}(e_B^{pp} + e_C^{pp})}$$

$$= \frac{e_B^{AA}}{N_{bin} e_B^{pp}} \cdot \frac{e_B^{pp}}{(e_B^{pp} + e_C^{pp})} + \frac{e_C^{AA}}{N_{bin} e_C^{pp}} \cdot \frac{e_C^{pp}}{(e_B^{pp} + e_C^{pp})}$$

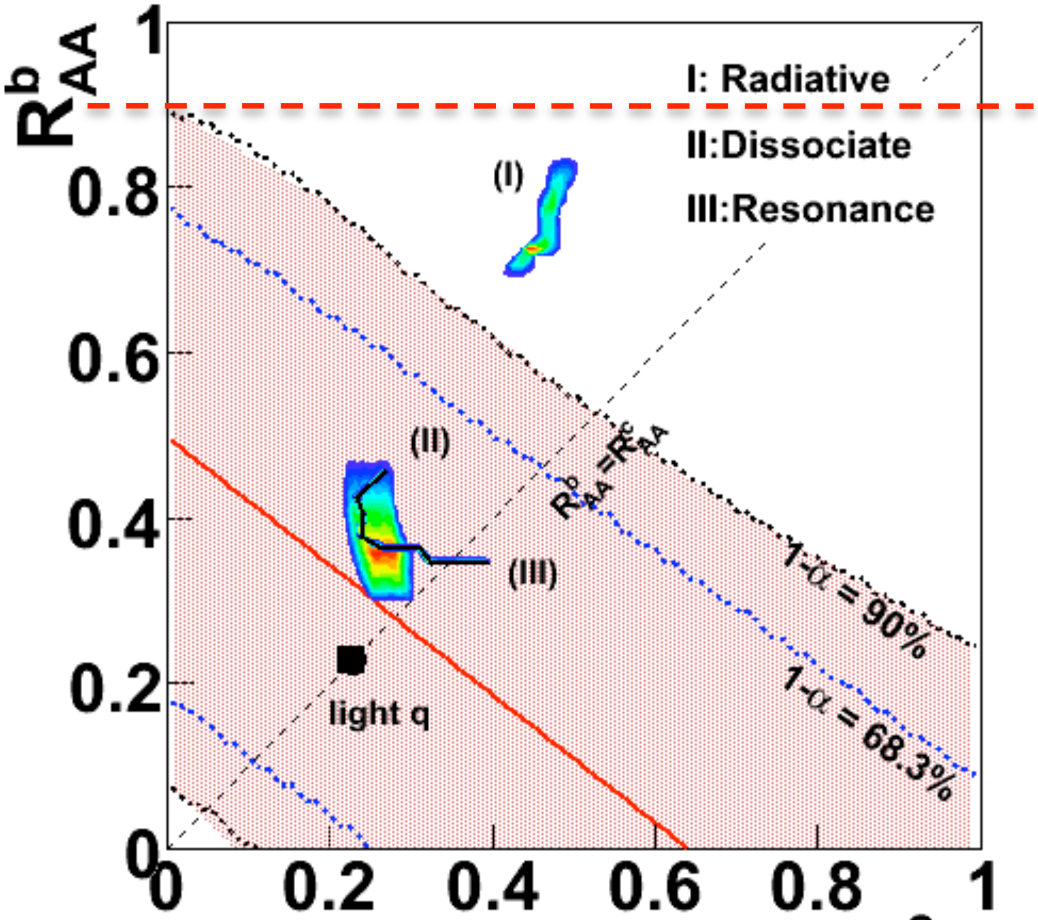
$$= R_{AA}^{B} r + R_{AA}^{C}(1 - r)$$

$$r = e_B^{pp} / (e_B^{pp} + e_C^{pp})$$

- R_{AA}^{C} and R_{AA}^{B} are connected B decay contribution @ pp
- With the measurements of r @ pp and R_{AA},
  we can derive a relationship between R_{AA}^{c} and R_{AA}^{b}.

$R_{AA}{}^c$ & $R_{AA}{}^b$ correlation (2)

p_T>5 GeV/c



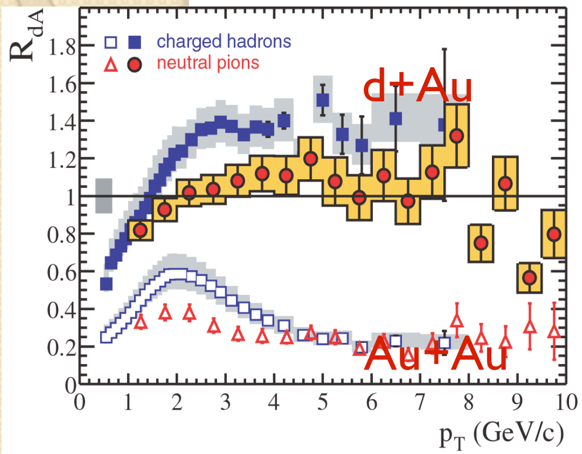
STAR preliminary

- $R_{AA}{}^c$ & $R_{AA}{}^b$ correlation from STAR
- Dominant uncertainty is normalization in R_{AA} analysis
- $R_{AA}{}^b$< 1 ; B meson suppressed
- prefer Dissociate and resonance model (large b energy loss)

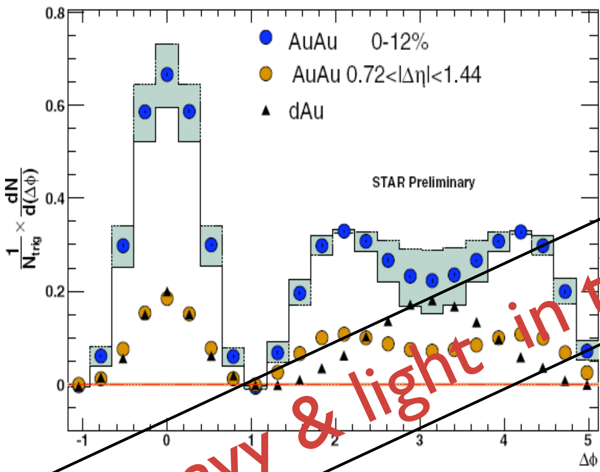
I; Phys. Lett. B 632, 81 (2006) ; $dN_g/dy = 1000$
II; Phys. Lett. B 694, 139 (2007)
III; Phys.Rev.Lett.100(2008)192301

Summary

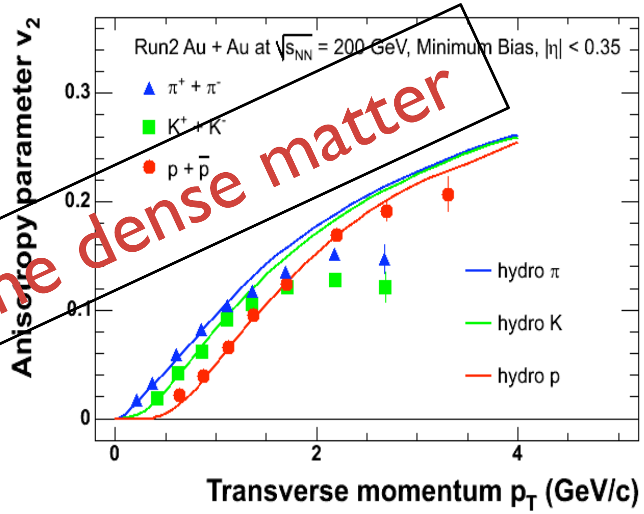
R_{AA}



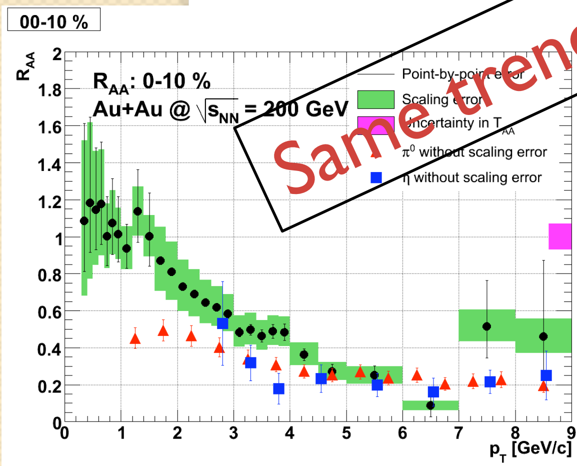
Azmuthal correlation

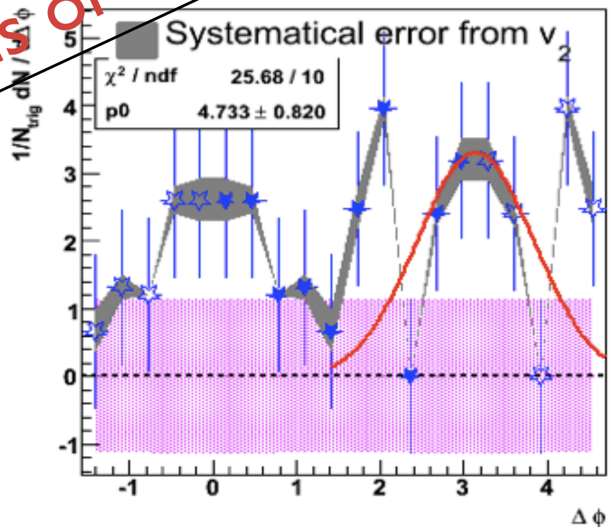


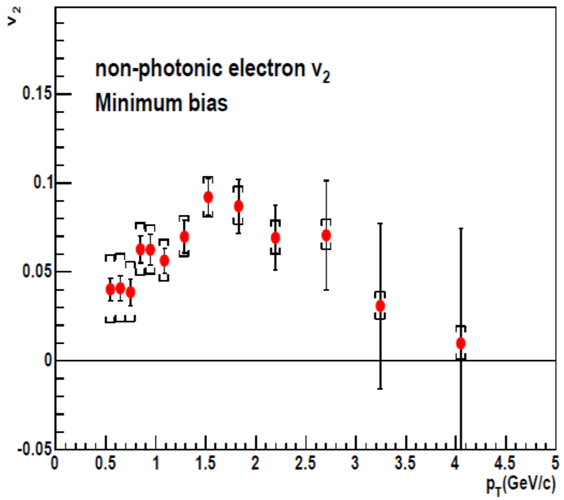
v_2



Same trends of heavy & light in the dense matter







Summary

- Heavy quark behavior is same as light quark
  in the hot & dense matter @ RHIC
  => energy loss & flow
- STAR & PHENIX extract B decay contribution
  in non-photonic electron by using electron-hadron
  correlations in pp.
- B decay contribution is more than 50% above
  5 GeV/c in pp collisions
- PHENIX study bottom production @ pp
  and it is consistent with pQCD prediction.
- STAR study bottom energy loss and the result show
  B meson suppression with 90% C.L.