Measurements of Bottom to Charm Ratio and Heavy Quark Interaction with the QCD Medium through Non-Photonic Electron-Hadron Correlations

Wenqin Xu
University of California, Los Angeles
For the STAR collaboration
At Quark Matter 2011
Annecy - France

Outline

1: Introduction

2: Analysis methods for Non-Photonic Electrons (NPE)

3: Updates on NPE spectrum in p+p collisions at 200GeV

4: NPE-hadron correlation in p+p collisions:

a handle on bottom contributions

5: NPE-hadron correlation in Au+Au collisions:

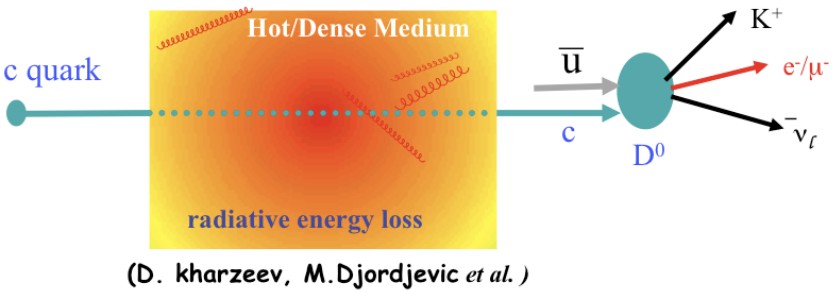
heavy flavor tagged jet-medium interaction

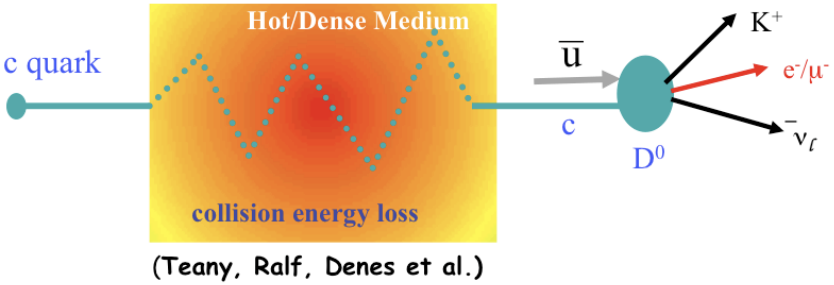
6: Summary

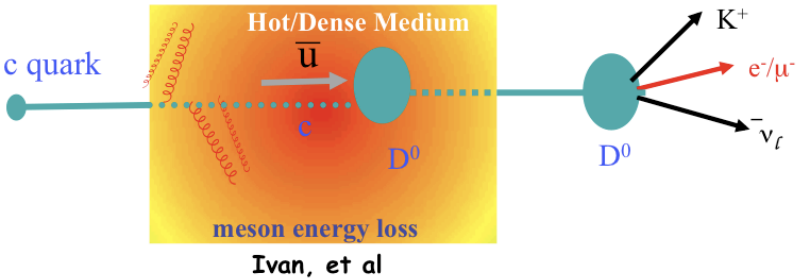
Motivation for NPE studies

NPE: semi-leptonic decays of open heavy flavor hadrons

$c \rightarrow e^{+} + anything(9.6\%)$ $B \rightarrow e^{+} + anything(10.86\%)$ PDG2010







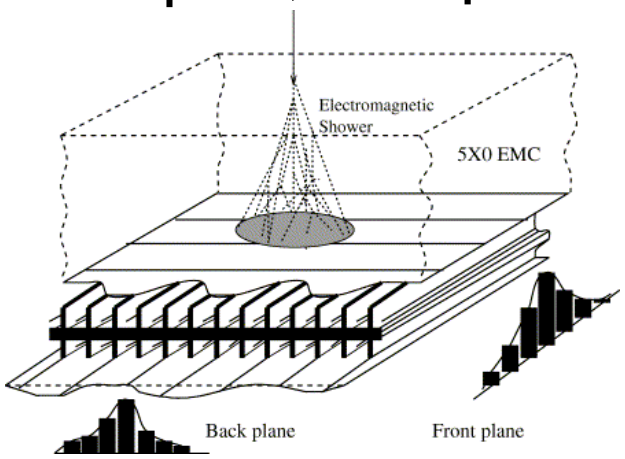
Picture courtesy of Wei Xie @ HP2010

NPE is the proxy of heavy flavor quarks

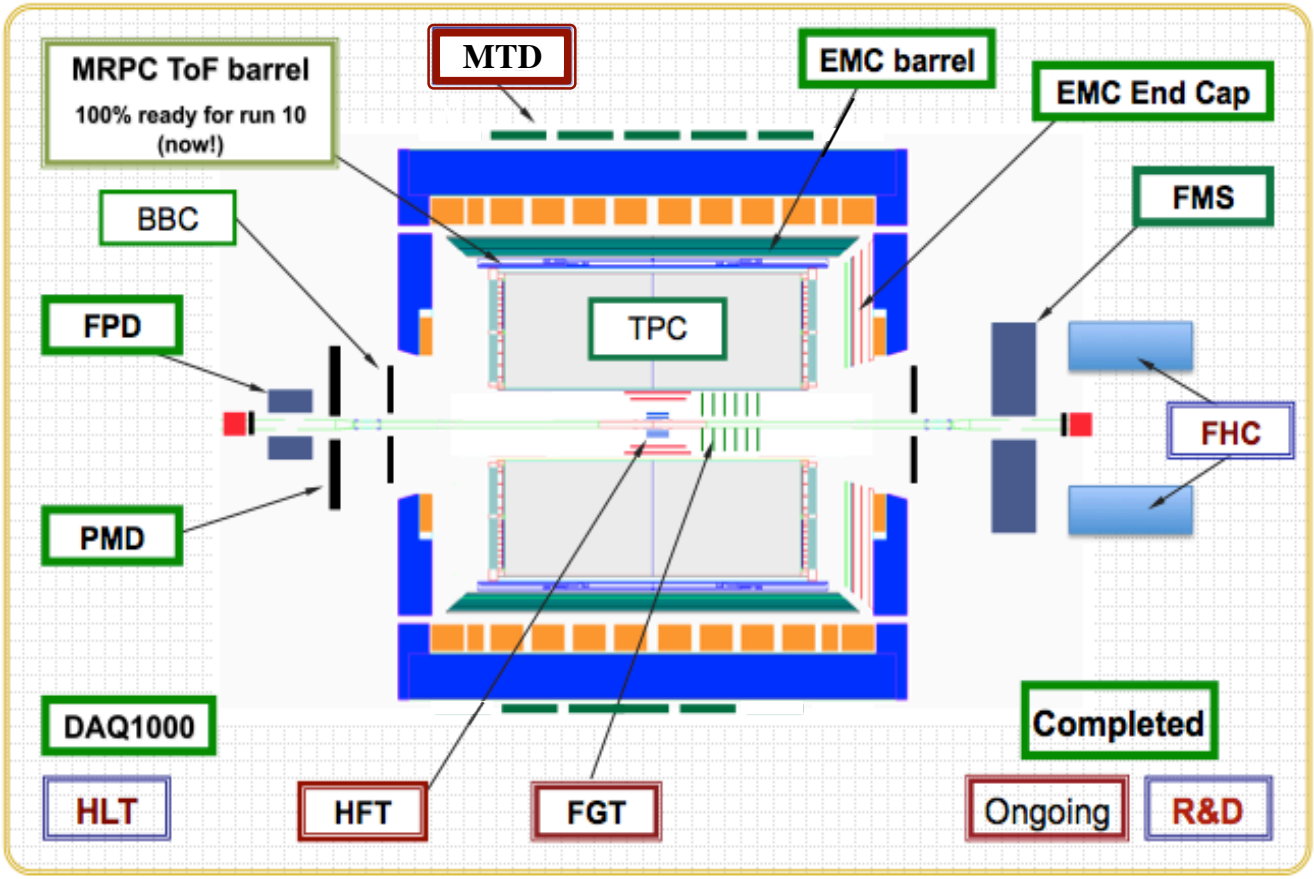
- Initial gluon fusion (hard process) dominates heavy flavor production – pQCD applicable.
- Study the interactions of heavy quarks with the hot and dense medium.
- Access to high p_T regime of heavy flavor quarks

STAR detector

Large acceptance:
$-1 < \eta < 1,\ 0 < \phi < 2\pi$



BSMD: embedded in BEMC.



Detectors in these NPE analyses:
Time Projection Chamber(TPC)
Barrel Electromagnetic Calorimeter(BEMC)
Barrel Shower Maximum Detector(BSMD)

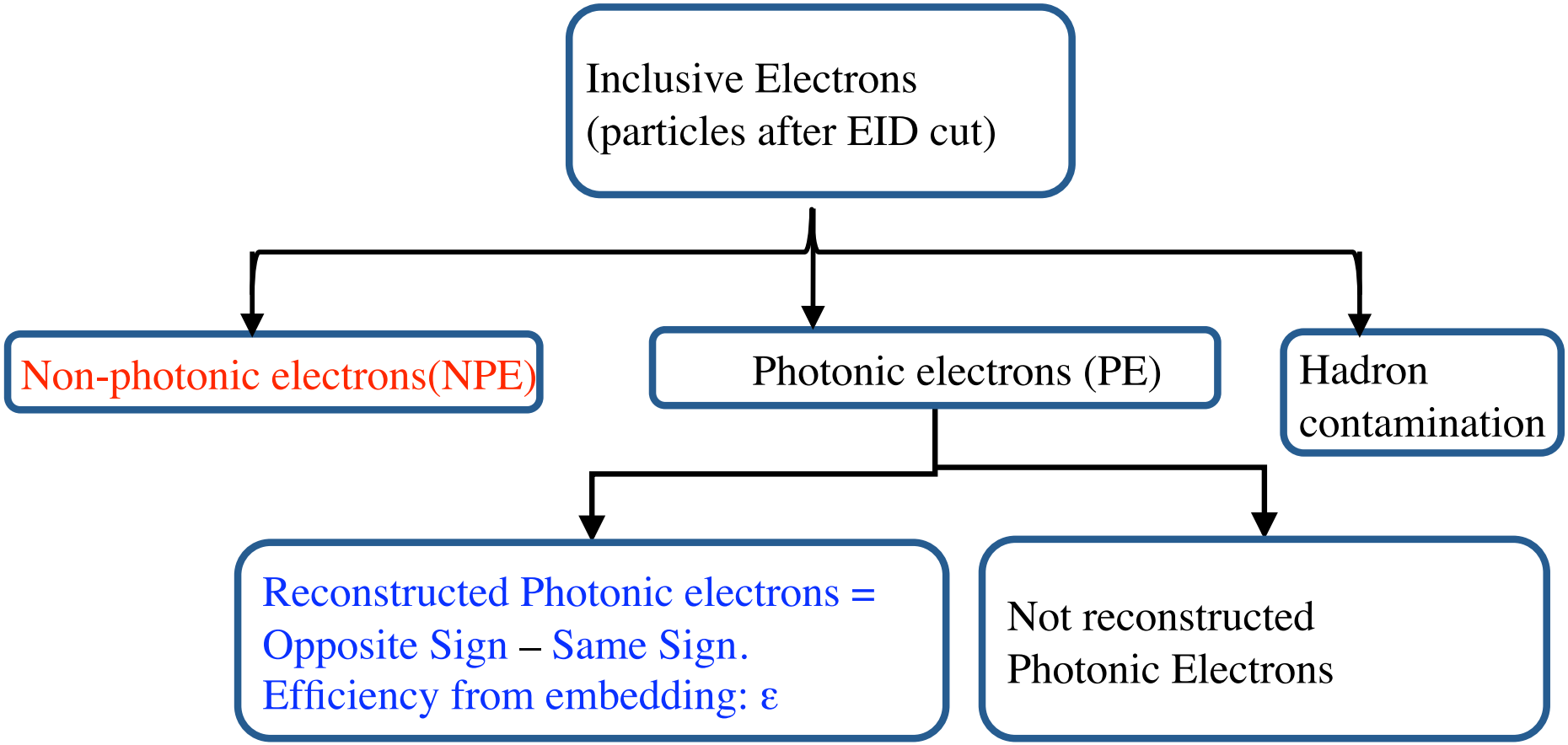
Data Sample:

Run05, Run08 p+p collisions at $\sqrt{s_{NN}}$ = 200 GeV

Run09 p+p collisions at $\sqrt{s_{NN}}$ = 500 GeV

Run10 Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

Analysis principle



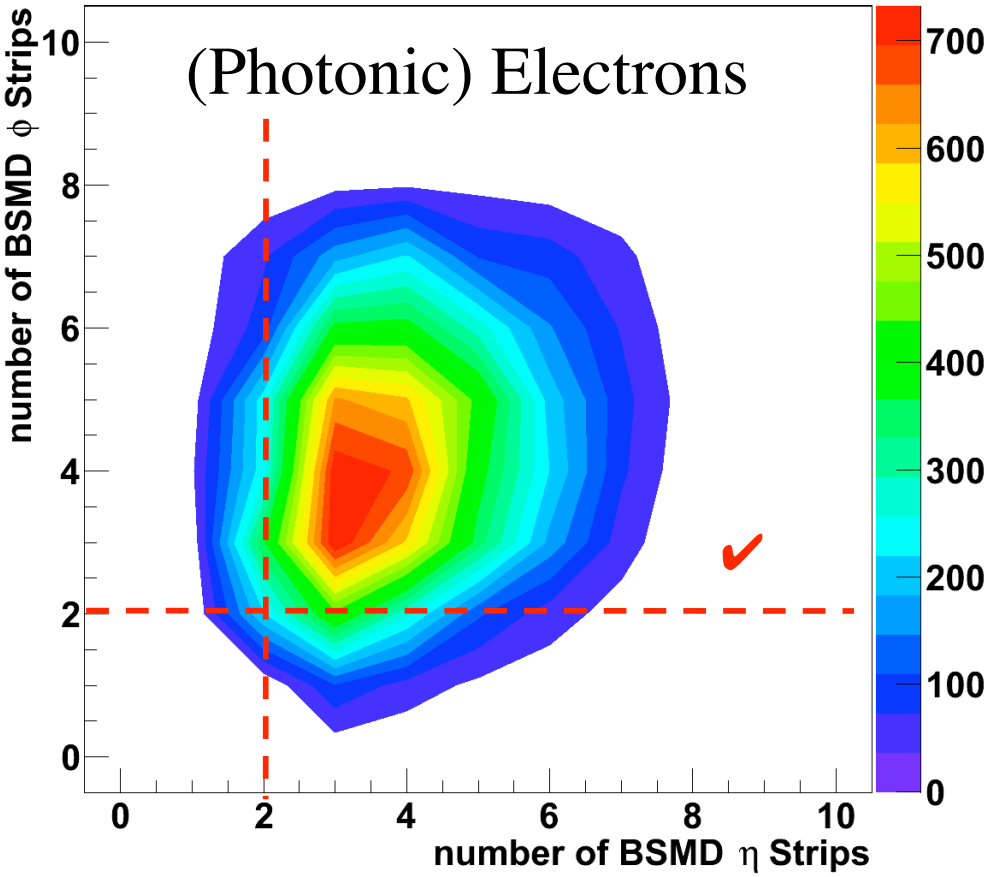
$$\Delta\phi_{NPE} = \Delta\phi_{inclusive} - (\Delta\phi_{OppoSign} - \Delta\phi_{SameSign})/\varepsilon - \Delta\phi_{hadron}$$

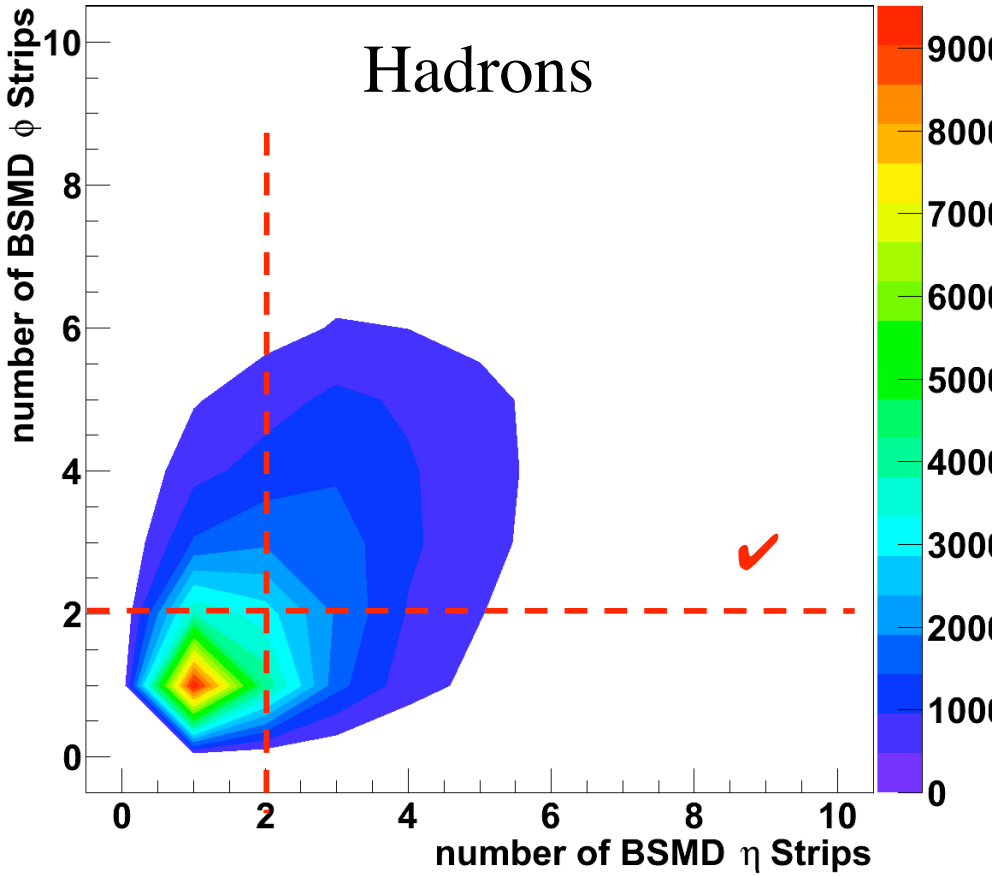
$\Delta\phi$ could be other variables, e.g. yield, elliptic flow (v_2), etc

Electron identification: shower profile

Electron showers are widely developed, firing several BSMD strips.

Hadron showers are much less developed, firing mostly one or zero strip.





Example from the NPE-hadron correlation in Au+Au 200GeV study,
where we apply number of bsmd η strips >=2 and number of bsmd ϕ strips >=2

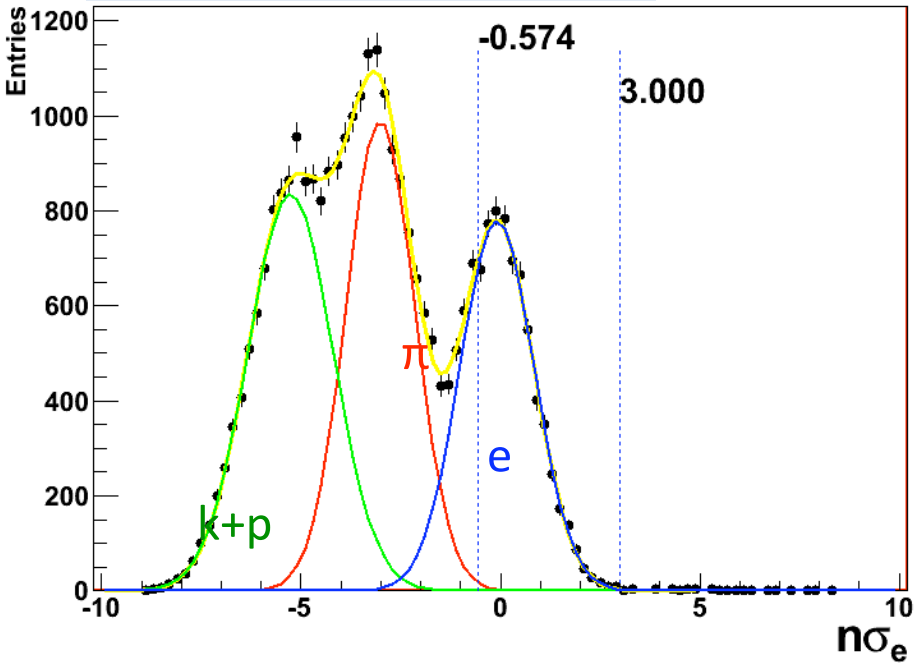
Electron identification: energy loss $n\sigma_{electron}$

$$n\sigma_e = \frac{\log(\frac{dE/dx}{B_e})}{\sigma_e}$$

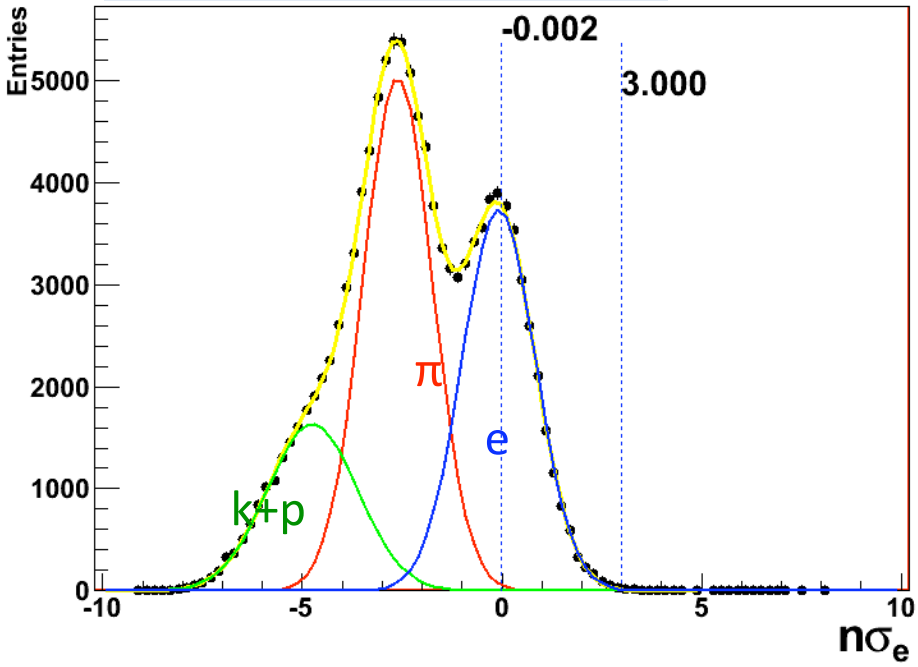
B_e is the expected mean electron dE/dx from Bichsel[1] function, and σ_e is TPC resolution of $\log((dE/dx)/B_e)$

Hadron contamination< 1%

$n\sigma_e$ for $3<p_T<4$GeV



$n\sigma_e$ for $4<p_T<6$GeV



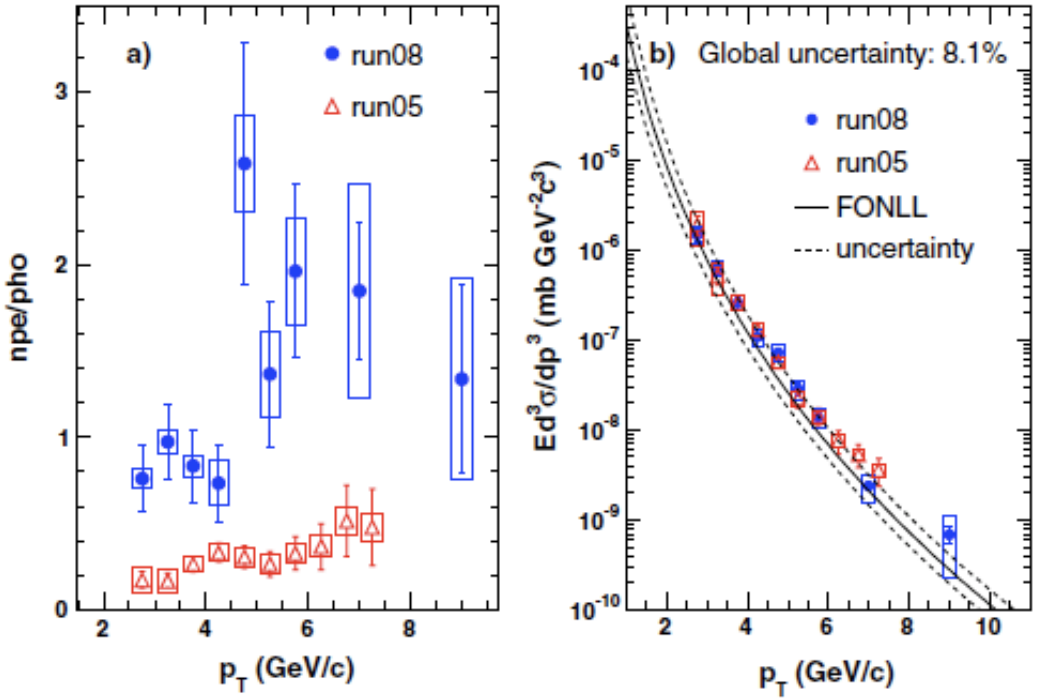
Example from the NPE in Au+Au 200GeV study

[1]:H. Bichsel, Nucl. Instrum. Methods Phys. Res., Sect. A 562, 154 (2006).

NPE spectrum in p+p at 200GeV

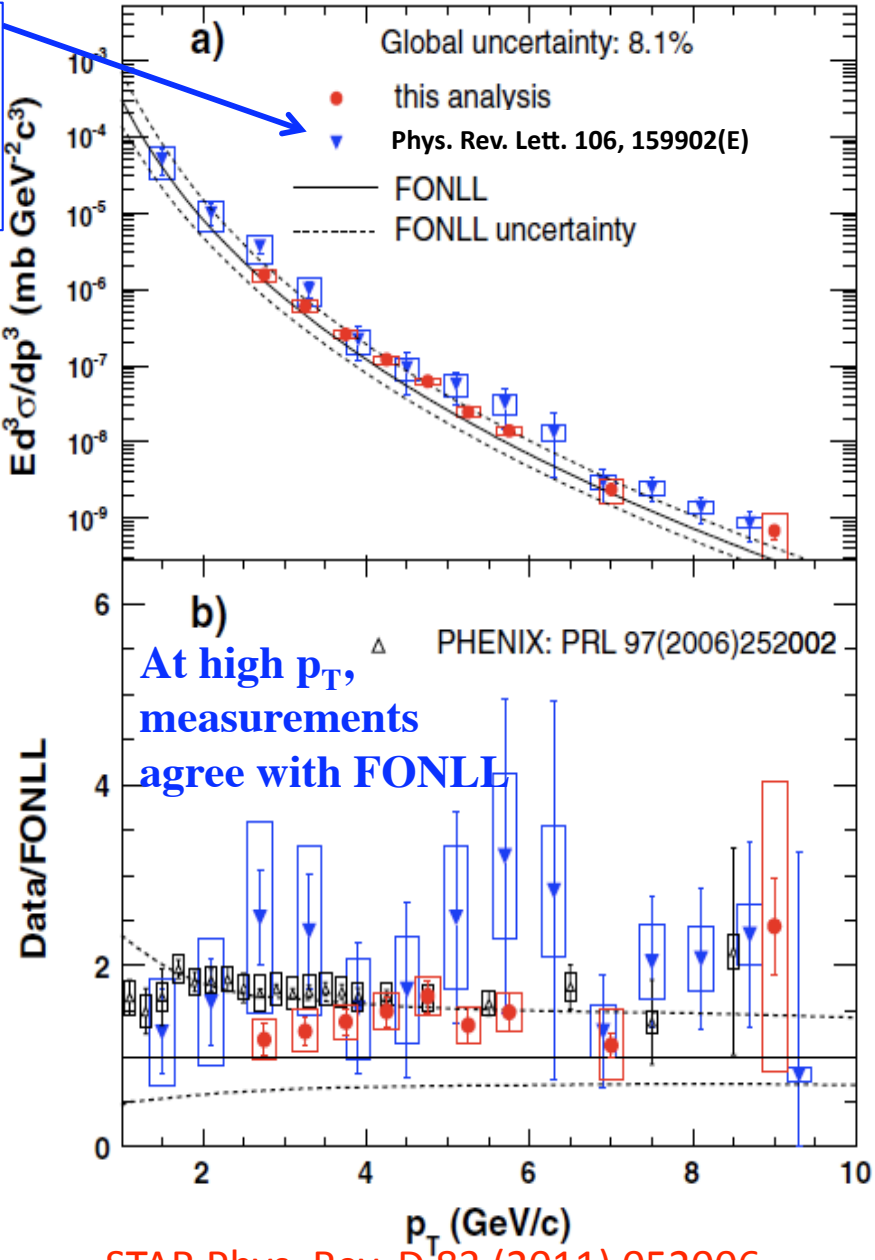
✧ We found an error in the previous analysis based on Run03 data

✧ An Erratum was published



➢Run05, Run08 have very different material budgets

➢p_T>2.5GeV/c agree with each other



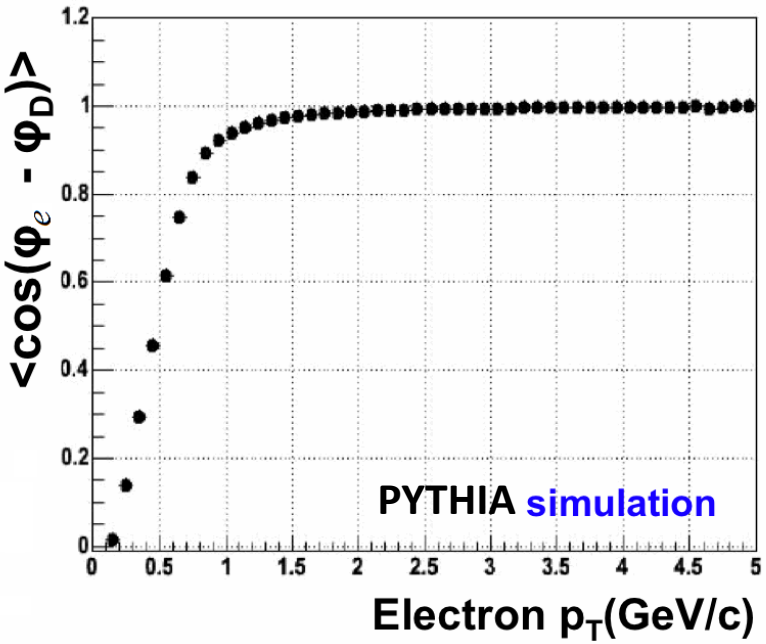
STAR Phys. Rev. D 83 (2011) 052006

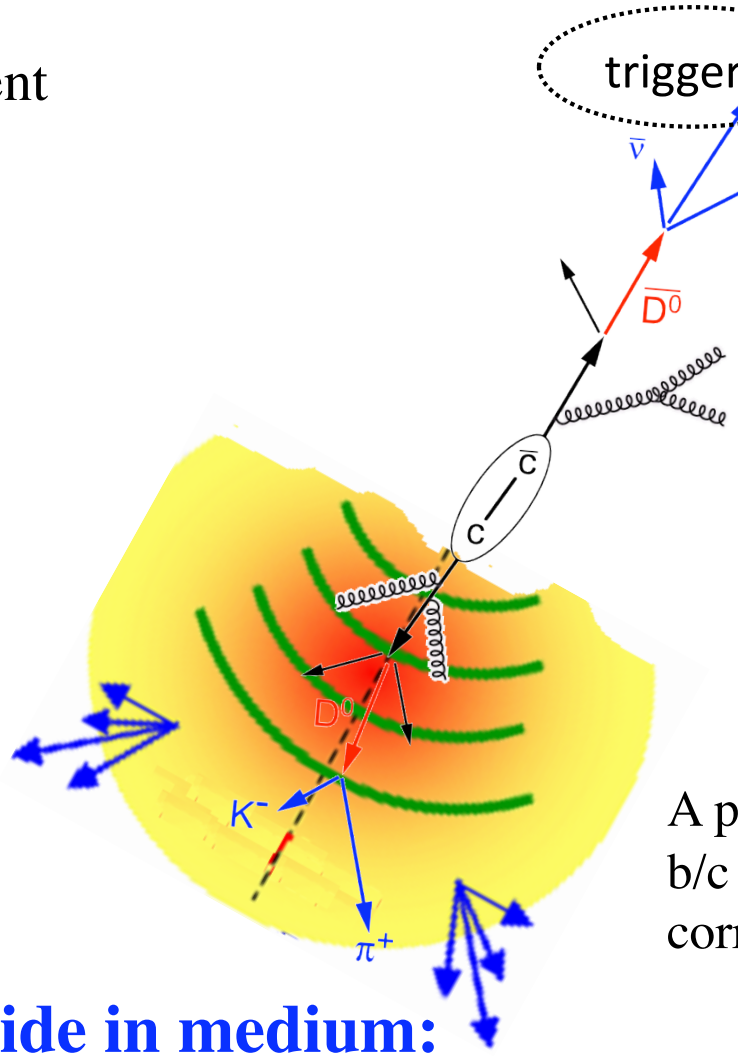
See Xin Li's poster (#44, session 2) for more details

FONLL: M. Cacciari, P. Nason and R. Vogt, Phys. Rev. Lett. **95, 122001 (2005);** M. Cacciari, R. Vogt, private communications.

NPE-hadron azimuthal correlations

Heavy flavor daughter electrons represent parent momentum directions well, when p^e_T>1.5 GeV/c for D case, and when p^e_T > 3 GeV/c for B case.





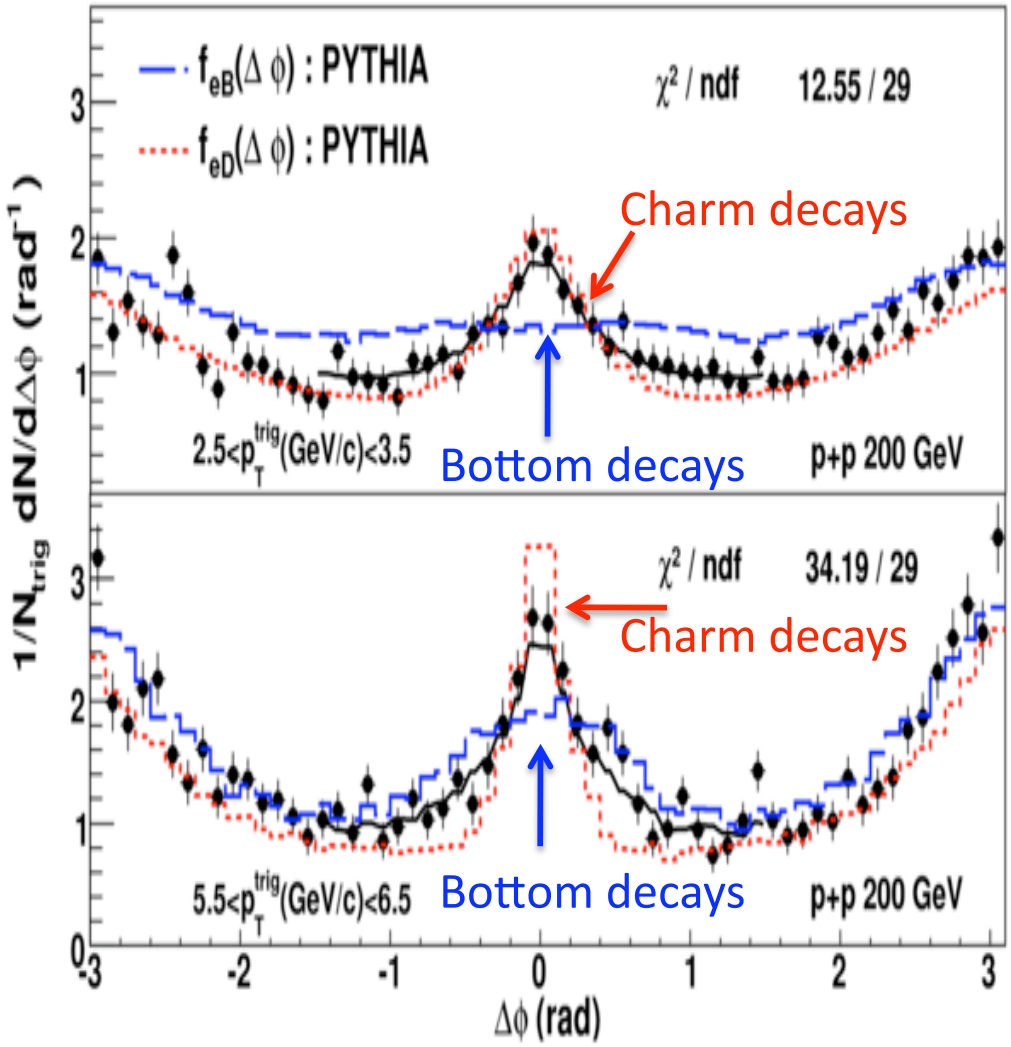
Near Side:
Decay Kinematics
B/D separation

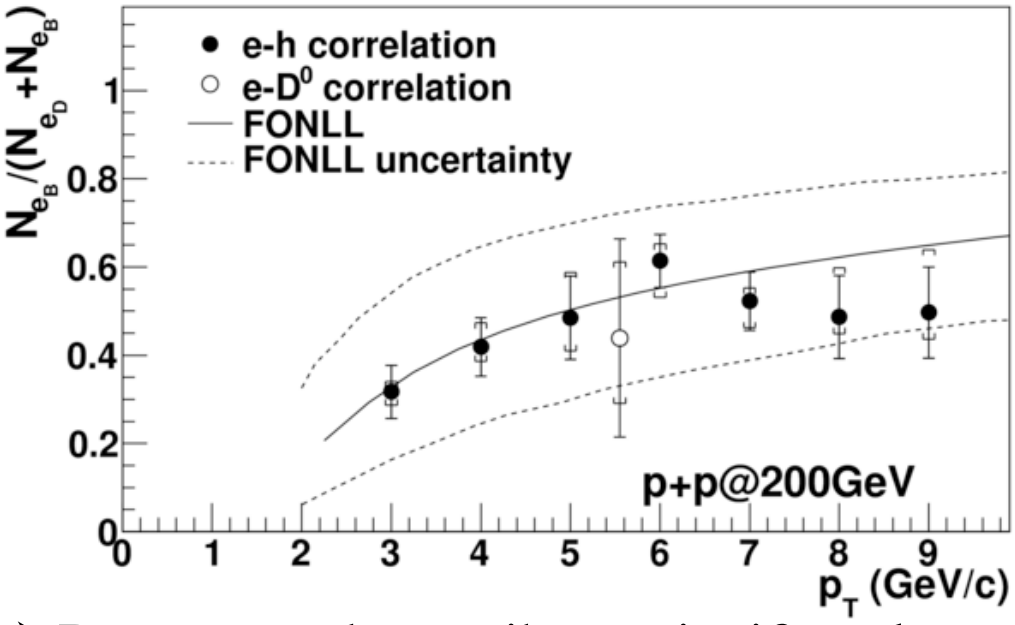
A proxy to b/c quark-hadron correlation

Away Side in medium:
How does B/D lose energy?
Any pattern like what seen in di-hadron?

Near side correlation in p+p 200 GeV

Different decay kinematics for charm and bottom hadrons
→Crucial for charm and bottom discrimination.



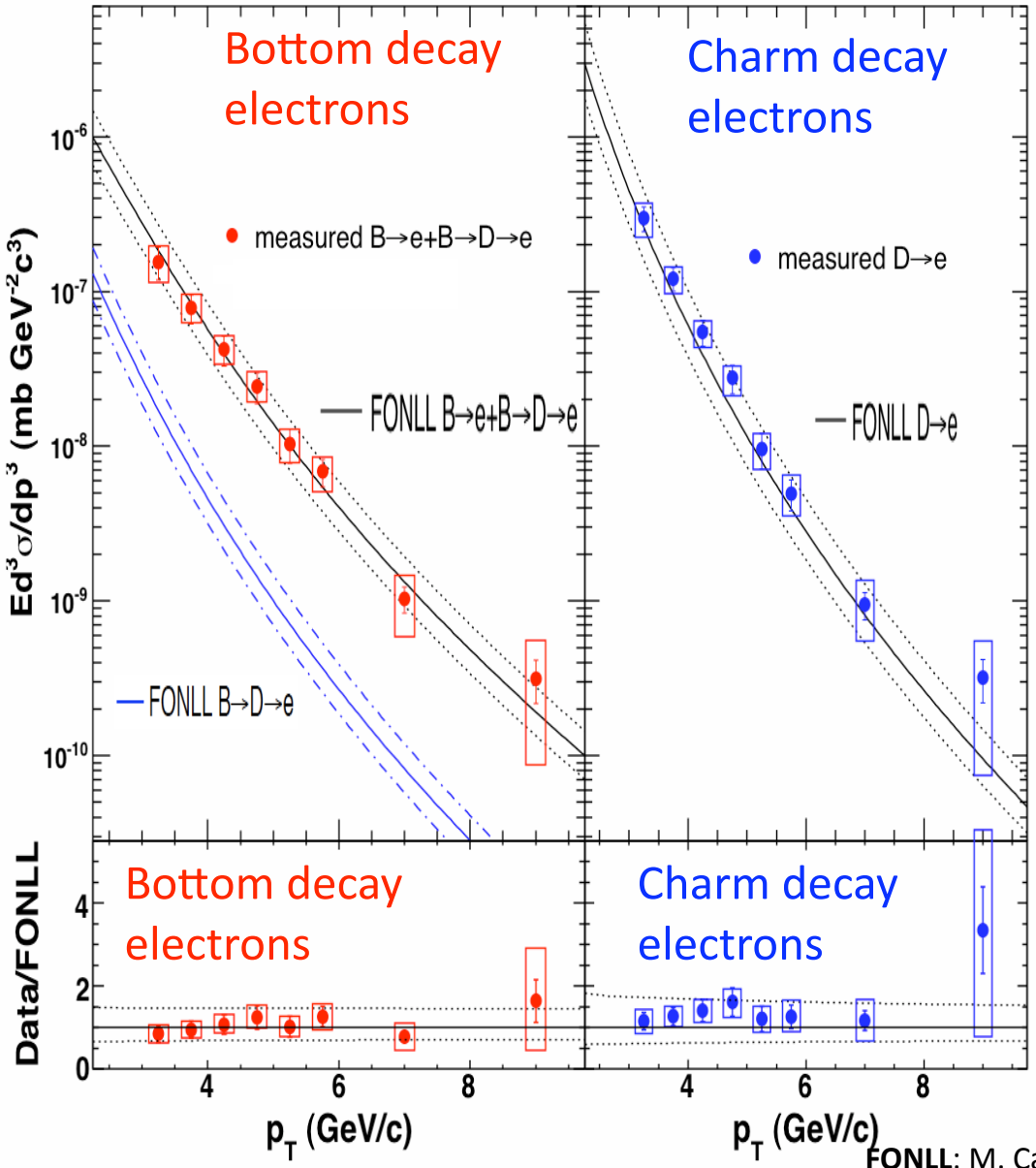


- Bottom quark contributes significantly in interested p_T ranges
- Apply to NPE R_{AA}: Bottom suppressed

STAR: PRL 105, 202301 (2010)

Separated Bottom/Charm decay electrons

Apply the ratios to NPE spectrum in p+p @ 200GeV, with J/ψ, ϒ, Drell-Yan feeddown subtracted.



With spectrum shapes from model calculations, the production cross section of bottom in p+p collisions at 200GeV, extrapolated to be:

$\sigma_{b\bar{b}} = 1.34\mu b$ PYTHIA, MiniBias Mode

$\sigma_{b\bar{b}} = 1.83\mu b$ PYTHIA, MSEL=5 Mode

results bear 12.5% (stat.) and 27.5% (sys.) experimental uncertainties

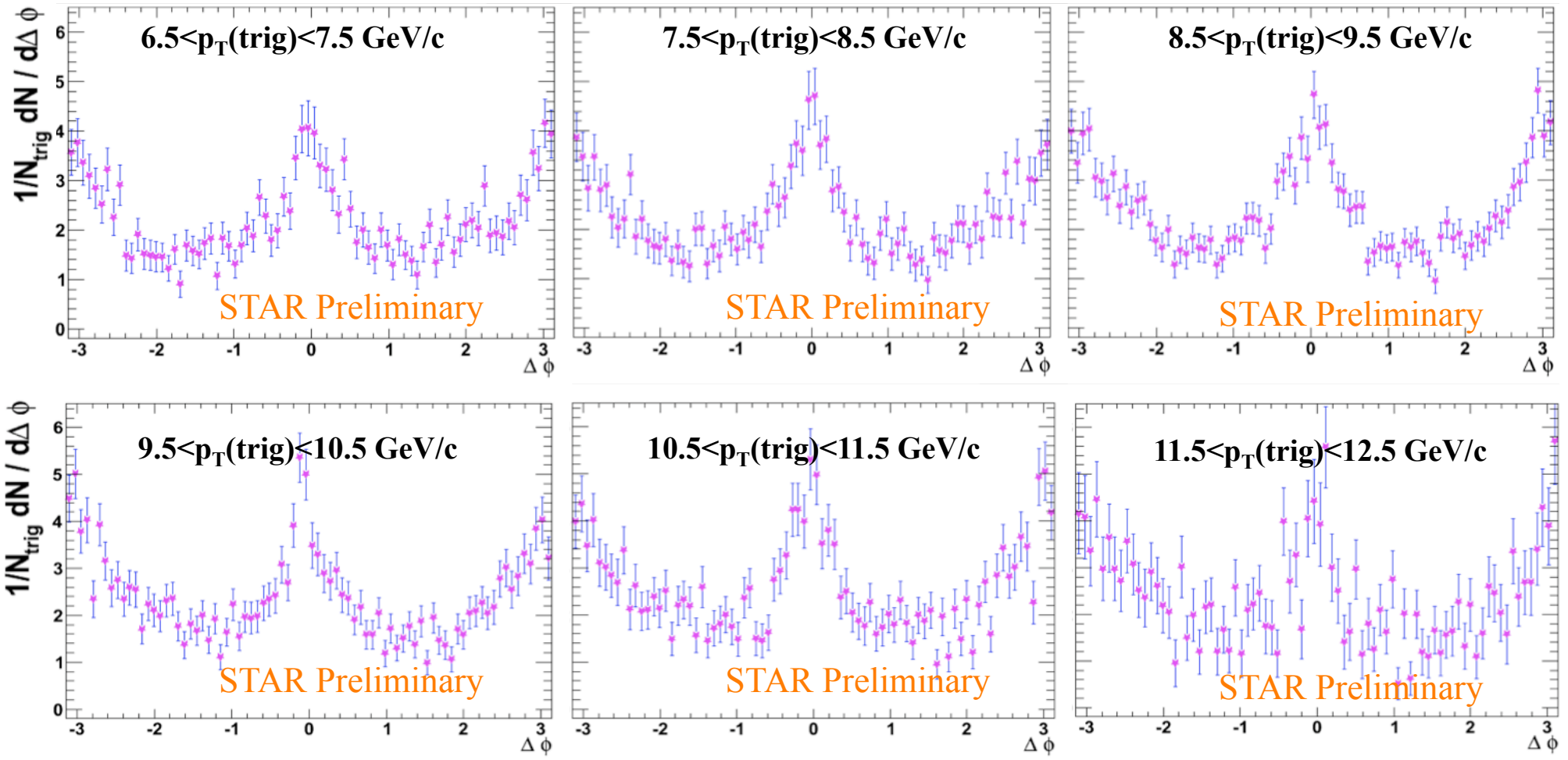
FONLL calculation: $\sigma_{b\bar{b}} = 1.87^{+0.99}_{-0.67}\mu b$

FONLL is consistent with data within the uncertainties.

STAR Phys. Rev. D 83 (2011) 052006

FONLL: M. Cacciari, P. Nason and R. Vogt, Phys. Rev. Lett. **95, 122001 (2005);** M. Cacciari, R. Vogt, private communications.

Near side correlation in p+p 500 GeV



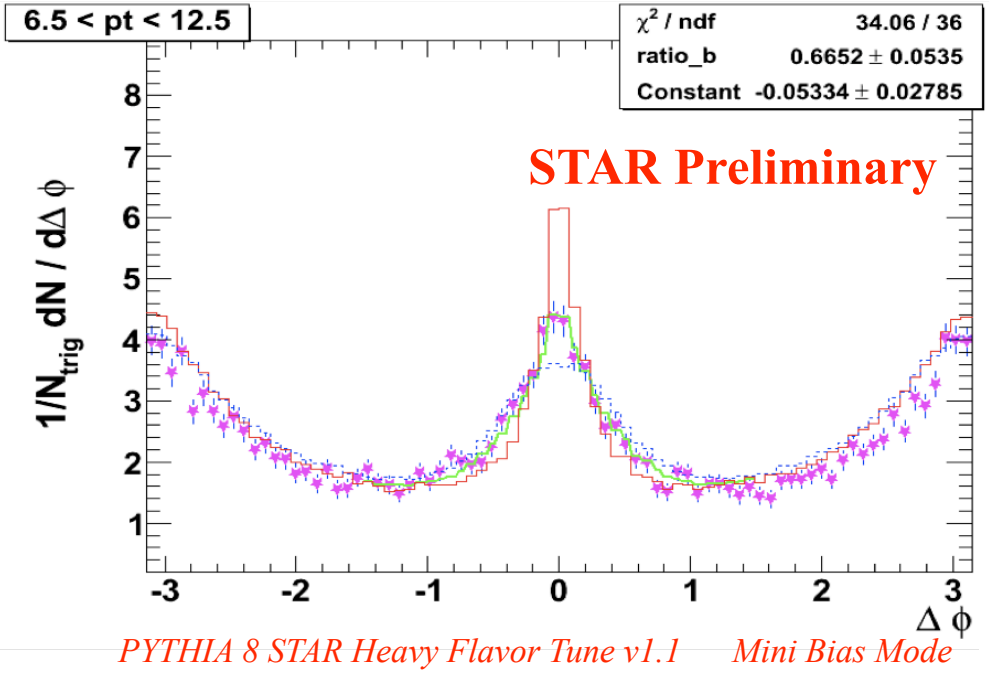
HT3 triggered events with max E_T > 7.4GeV.
Trigger tracks are NPE at different p_T.

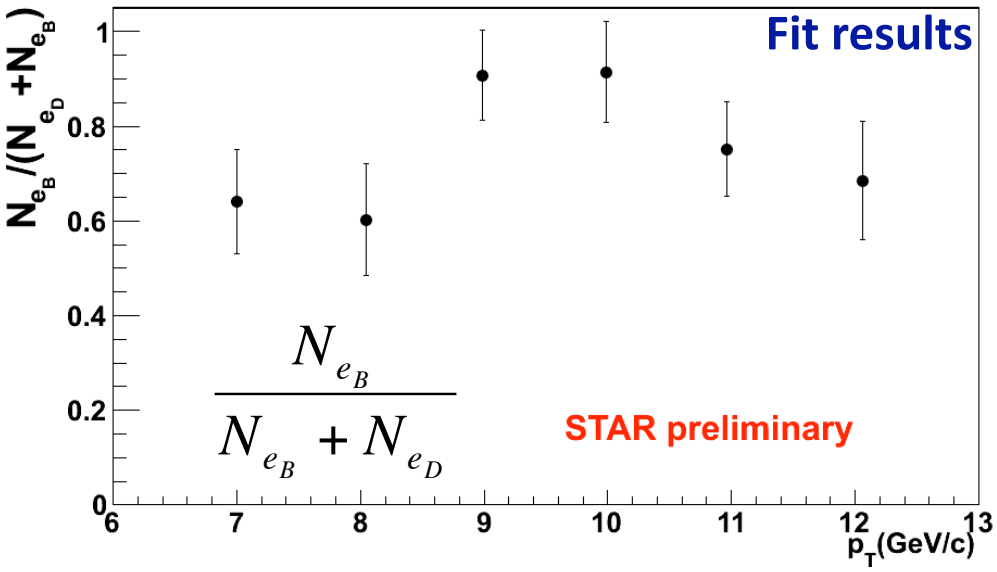
Associated p_T > 0.3 GeV/c

See Wei Li's poster (#43, session 2) for more details

Bottom/Charm contributions in p+p 500 GeV

Bottem/Charm contributions to their decay electrons are obtained by comparison against PYTHIA





- **Fit function:**

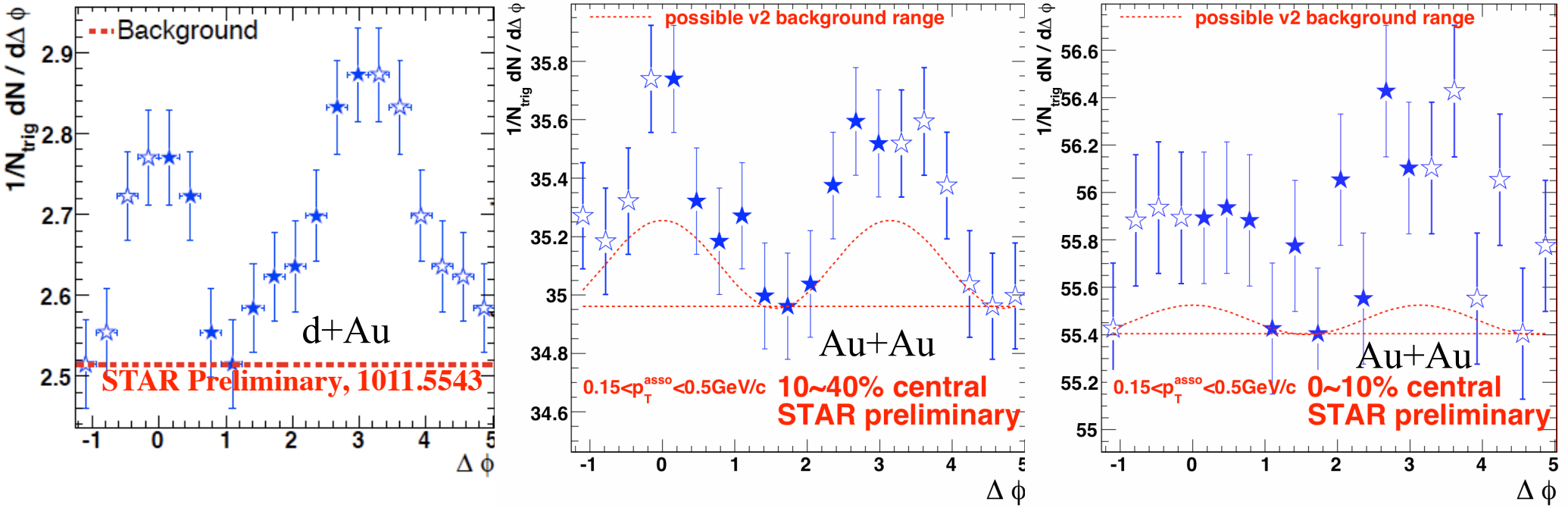
$$r_B f_{e_B}(\Delta\phi) + (1 - r_B) f_{e_D}(\Delta\phi) + const.$$

r_B is relative B contribution

f_{e_B} , f_{e_D} **are the correlations from PYTHIA**

- **The extracted $e_B/(e_B+e_D)$ ratio is higher than 60% within the current statistics.**
- Error bars are statistical only.

Away side correlation: d+Au *vs* Au+Au



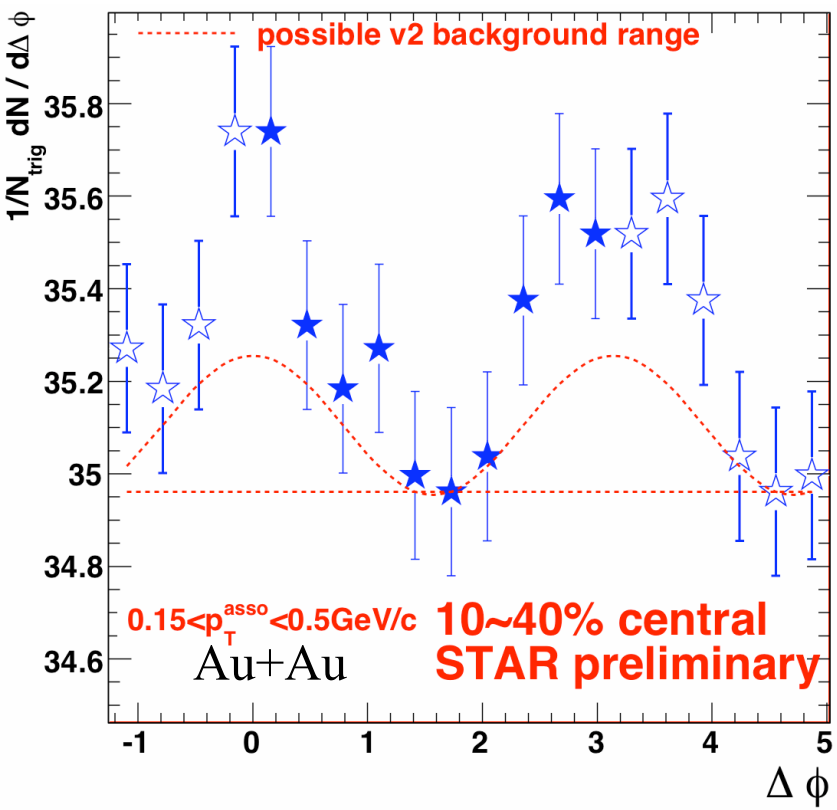
Asso. tracks p_T 0.15 ~ 0.5GeV/c, |η|<1; NPE p_T 3~6GeV/c

Vertical error bars are statistical only. The open star data points are reflected points.

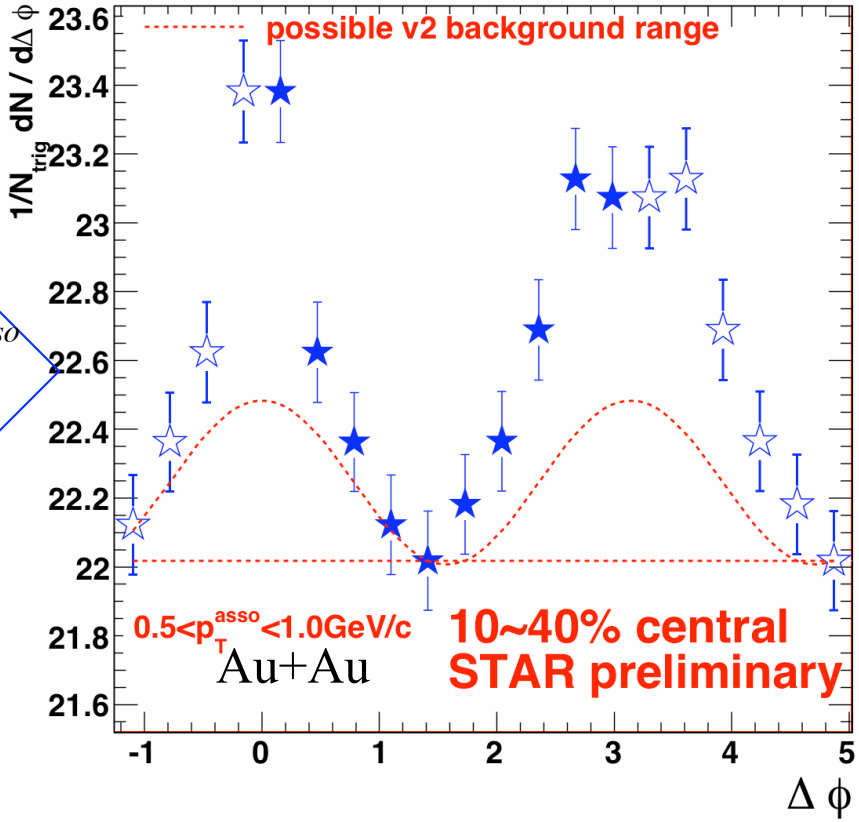
Red dashed curves: v_2 background range set with NPE v_2 being zero and hadron v_2.

Very large uncertainties associated with the background, currently under study, not subtracted.

Associated tracks with higher p_T



higher p_T^{asso}



Asso. tracks p_T 0.15 ~ 0.5GeV/c, |η|<1

Asso. tracks p_T 0.5 ~ 1GeV/c, |η|<1

Vertical error bars are statistical only. The open star data points are reflected points.
Red dashed curves: v_2 background range with by NPE v_2 being zero and hadron v_2.

- **We see both near side and away side correlations**
- Background studies are in progress
- ~half statistics in Run10

Summary

✧We corrected the NPE spectrum in p+p 200GeV.

✧Bottom and Charm contributions to NPE in p+p 200GeV are disentangled.

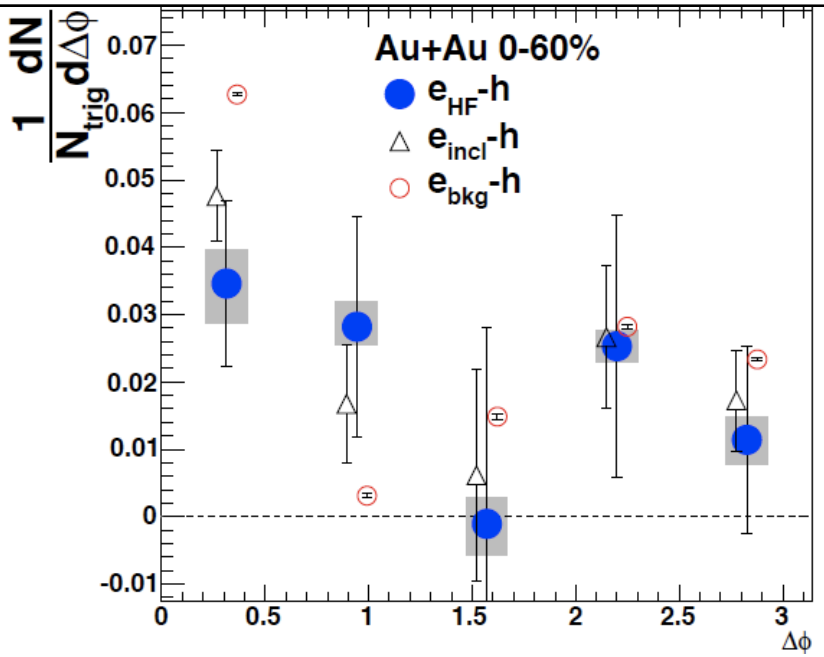
✧Bottom decay electron spectrum and extrapolated Bottom cross-section in p+p 200GeV are consistent with FONLL calculations.

$$\sigma_{b\bar{b}} : 1.34 \sim 1.83 \mu b$$

✧We can study the heavy flavor tagged jet-medium interactions by using the NPE-h correlations in Au+Au 200GeV.
More studies are required. Higher statistics are forthcoming.

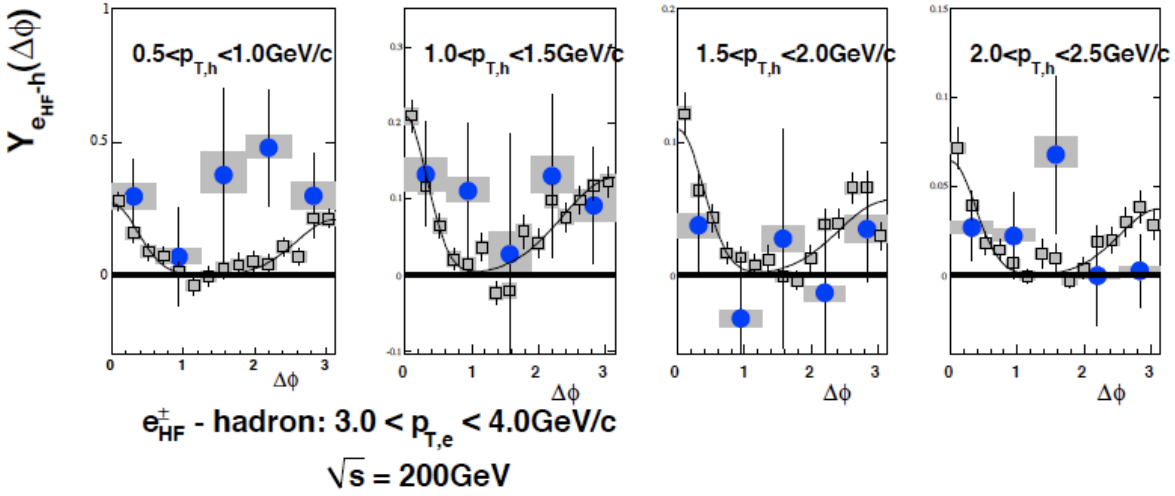
Backup

PHENIX NPE-hadron corr



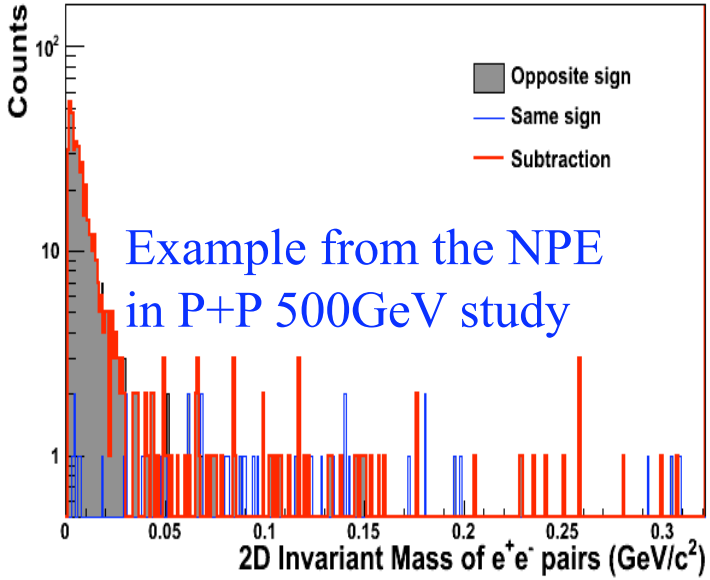
arXiv:1011.1477

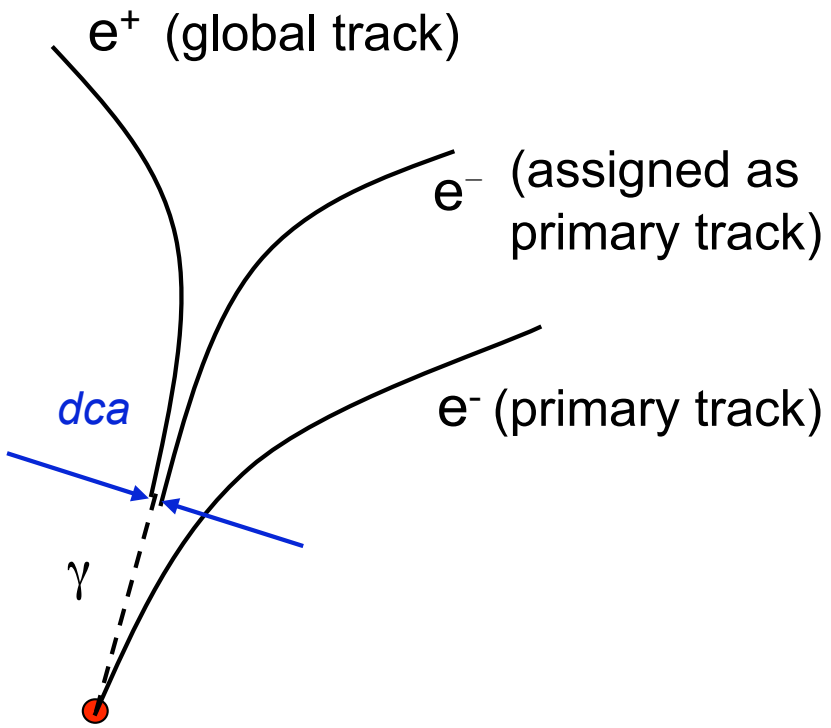
FIG. 4: (color online) $e_{inc} - h$, $e_{bkg} - h$ and $e_{\rm HF} - h$ (solid circles) for p+p (top panel) and Au+Au (bottom panel) collisions for 2.0< $p_{T,e}$ <3.0 GeV/c and 1.5< $p_{T,h}$ <2.0 GeV/c. The overall normalization uncertain of 7.9% in p+p and 9.4% in Au+Au is not shown.

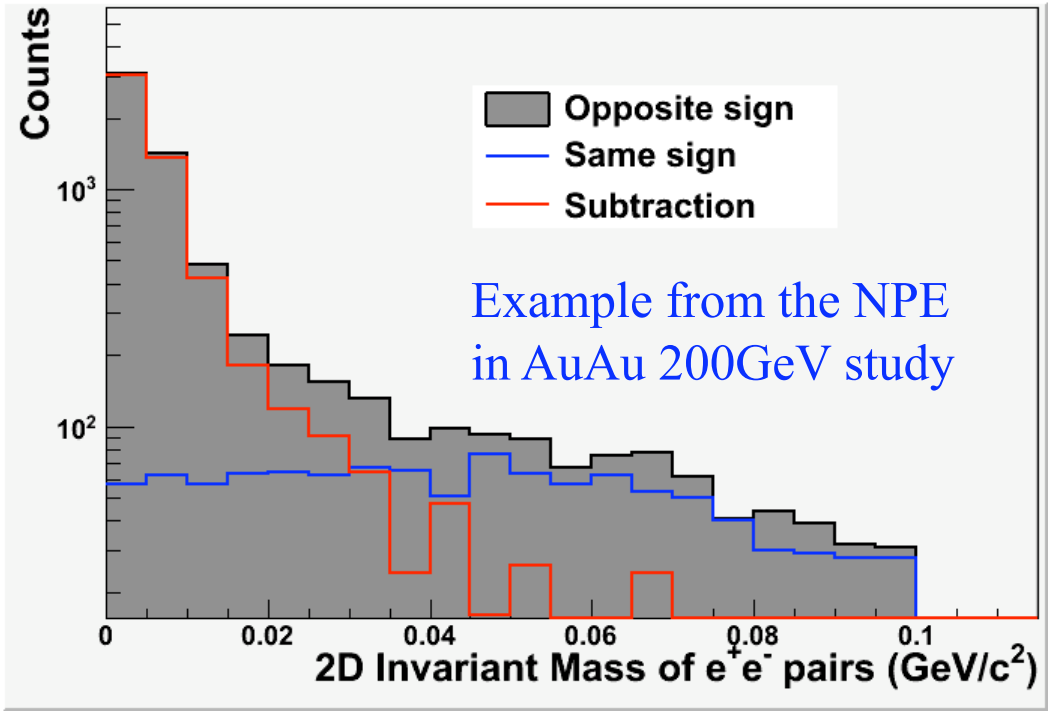


eHF – h jet functions for Au+Au (solid blue circles) and p+p collisions for 3.0–4.0 GeV/c Electron triggers and the hadron-pT bins indicated.

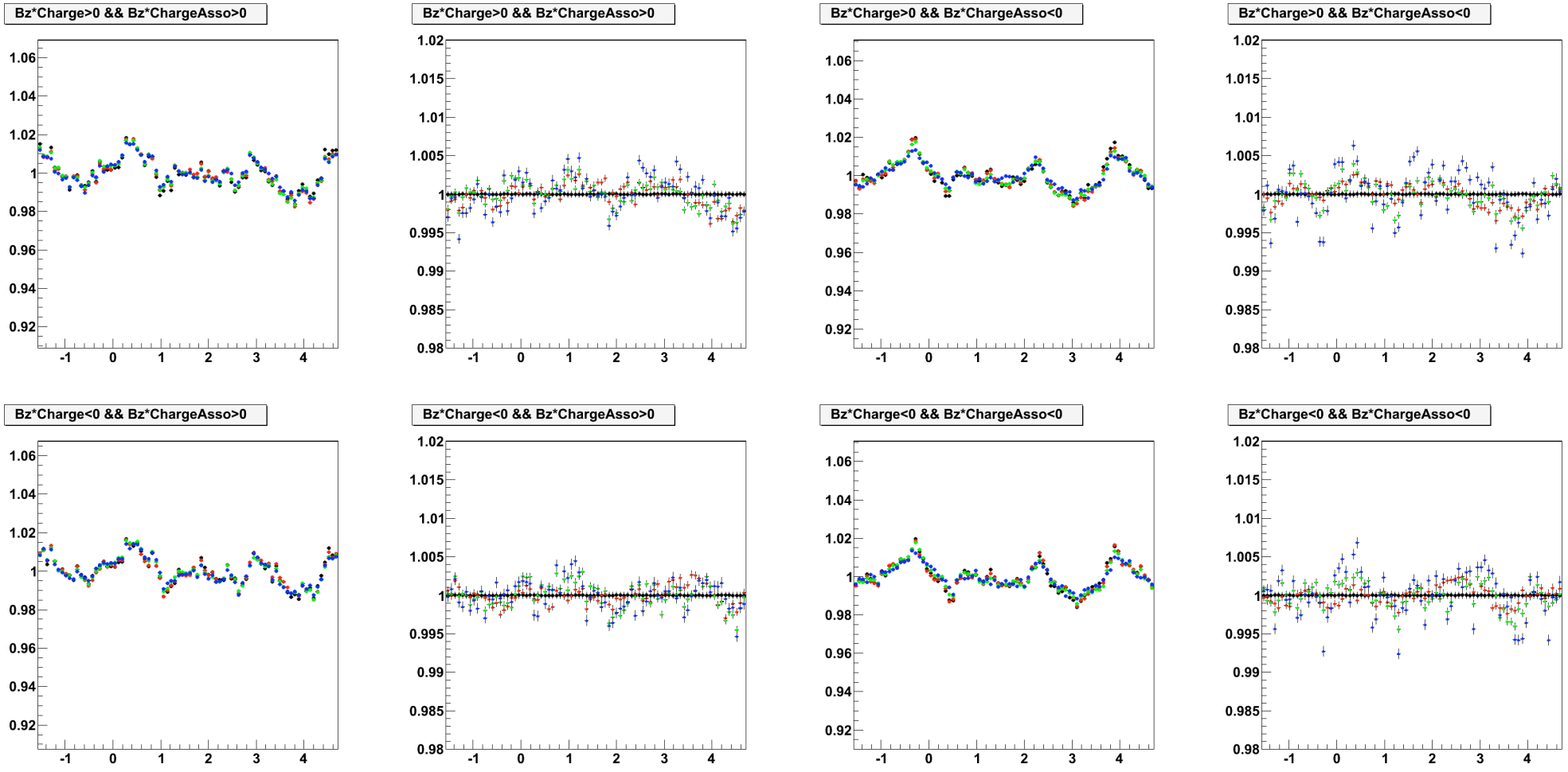
Photonic electron (PE) reconstruction





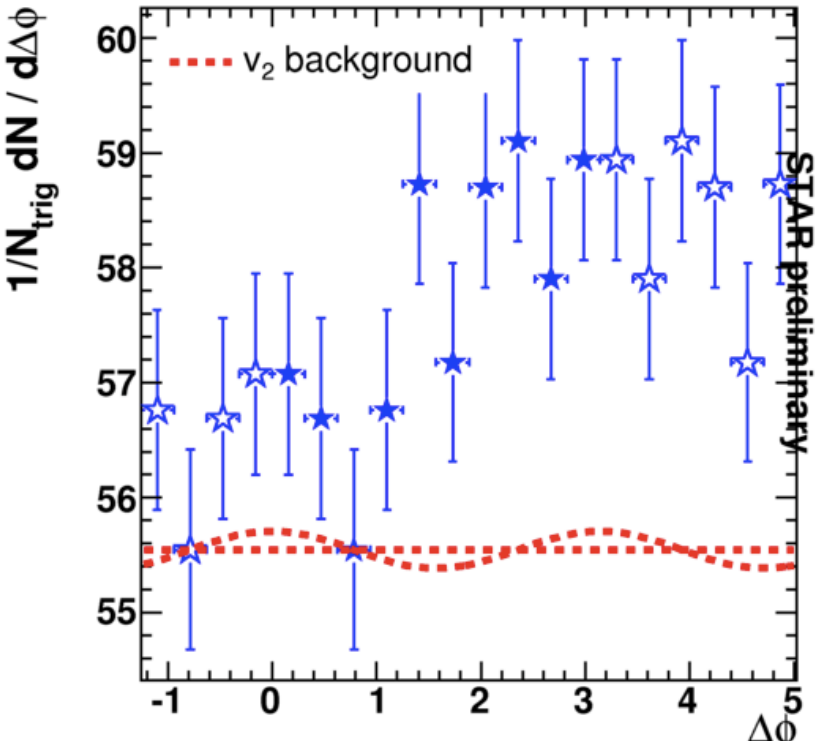


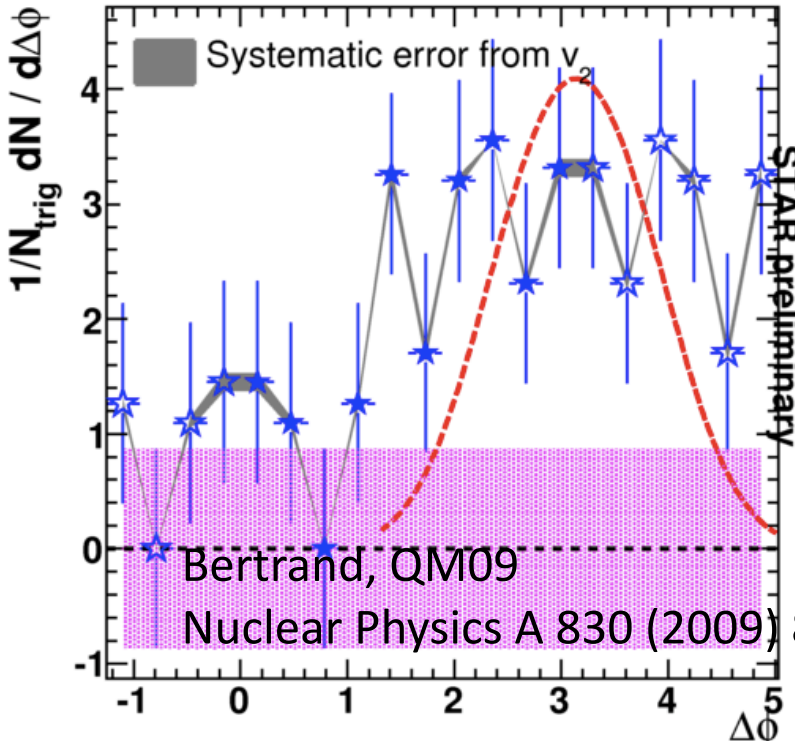
STAR NPE-h correlation mixing event backgrounds



Inclusive trigger tracks-hadron (asso p_T 0.15~0.5GeV) correlations from mixed events
The background for NPE-h correlation.

4 centrality bins:
Black dots: 0~5%
Red dots: 5~10%
Green dots:10~20%
Blue dots: 20~30%

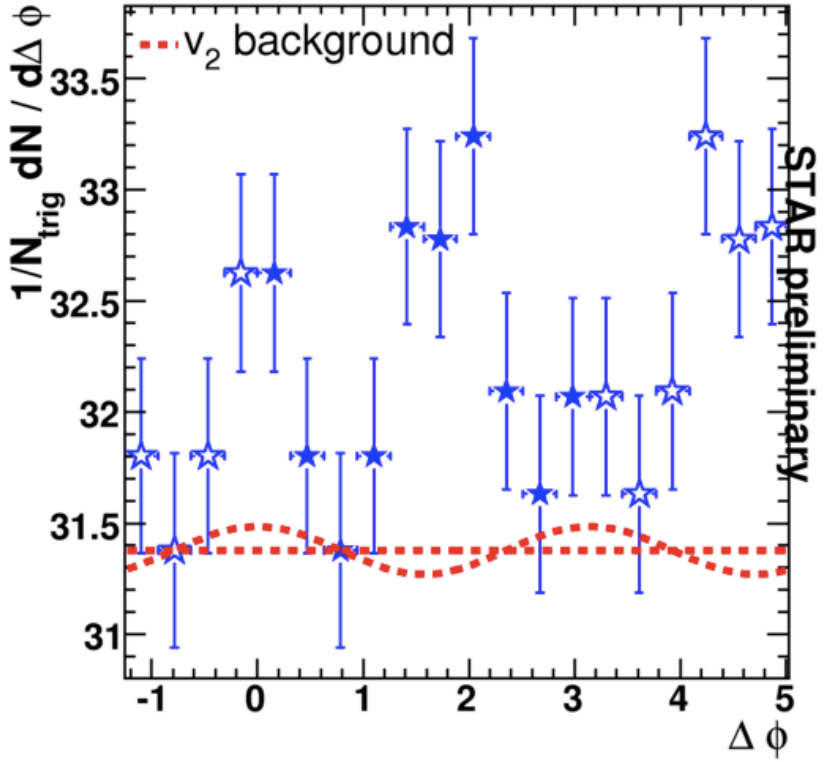


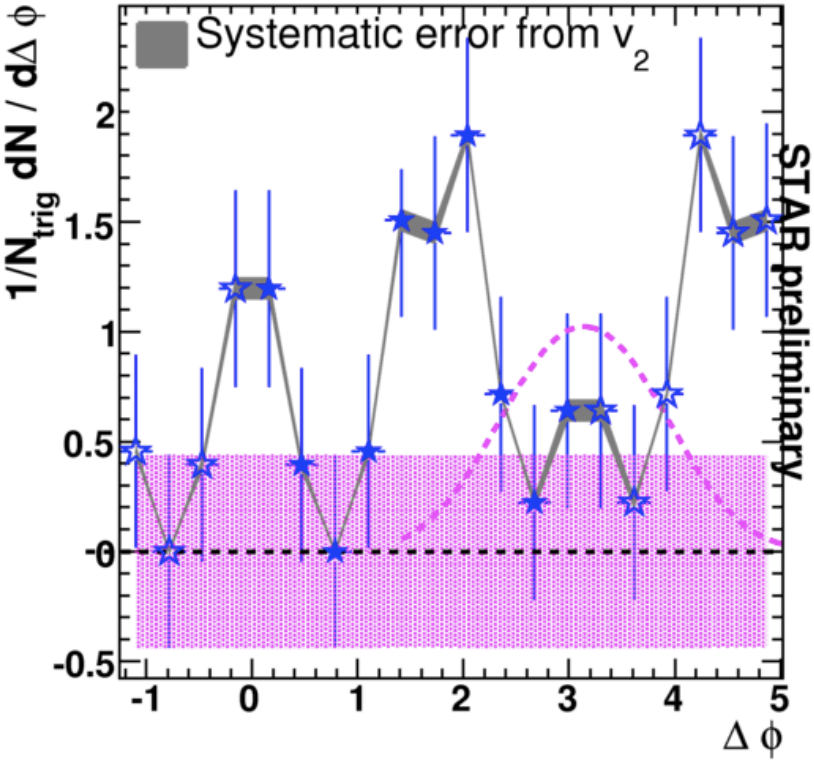


AuAu at 200 GeV

Bertrand, QM09

Nuclear Physics A 830 (2009) 849c–852c





CuCu at 200 GeV