The High Transverse Momentum Non-Photonic Electron (NPE) Measurements in Au+Au Collisions at √s=200GeV at RHIC/STAR

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For the STAR collaboration

At PANIC 2011
MIT - Boston

Outline

1: Introduction

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

3: NPE spectrum

4: NPE elliptic flow (v_2)

5: NPE-hadron azimuthal correlation:

heavy flavor tagged jet-medium interaction

6: Summary

Motivation for NPE studies

NPE: semi-leptonic decays of open heavy flavor hadrons

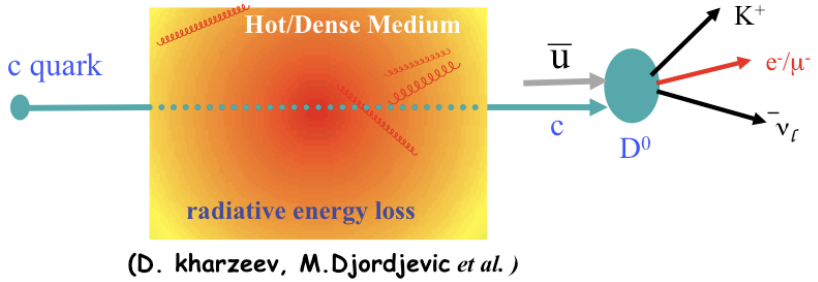
$c \rightarrow e^{+} + anything(9.6\%)$ $B \rightarrow e^{+} + anything(10.86\%)$ PDG2010

NPE is the proxy of heavy flavor quarks

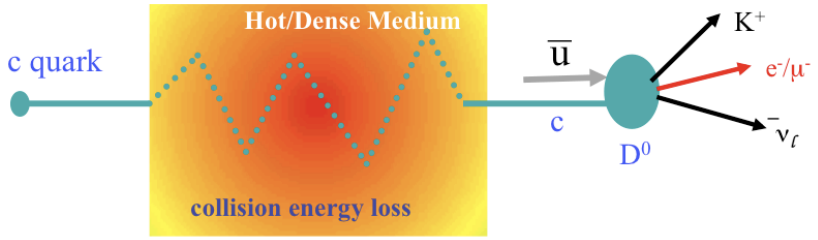
- Initial gluon fusion (hard process) dominates heavy flavor production – pQCD applicable.

- Study the interactions of heavy quarks with the hot and dense medium.
  - ✧NPE yield and nuclear modification factor R_{AA}
  - ✧NPE elliptic flow v_2
  - ✧NPE-hadron correlation

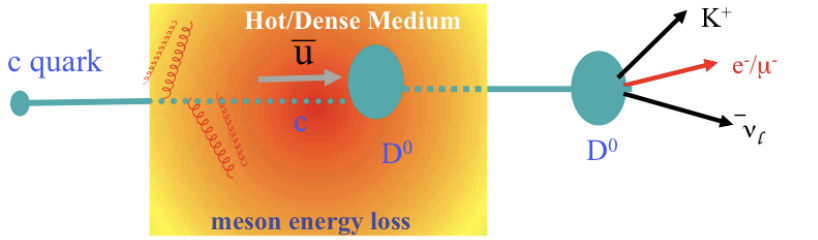
- Access to high p_T regime of heavy flavor quarks



(D. kharzeev, M.Djordjevic *et al.*)



(Teany, Ralf, Denes et al.)

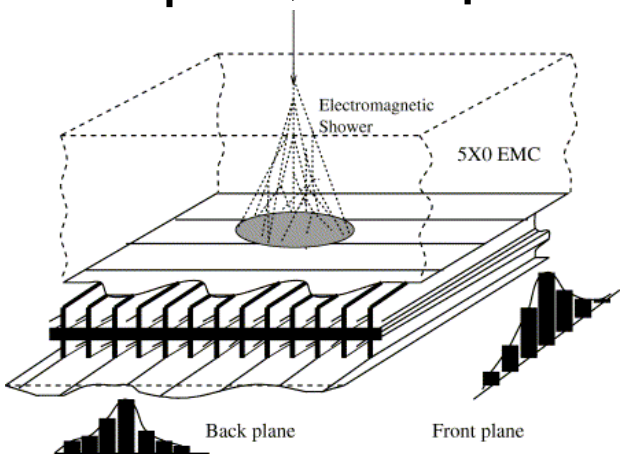


Ivan, et al

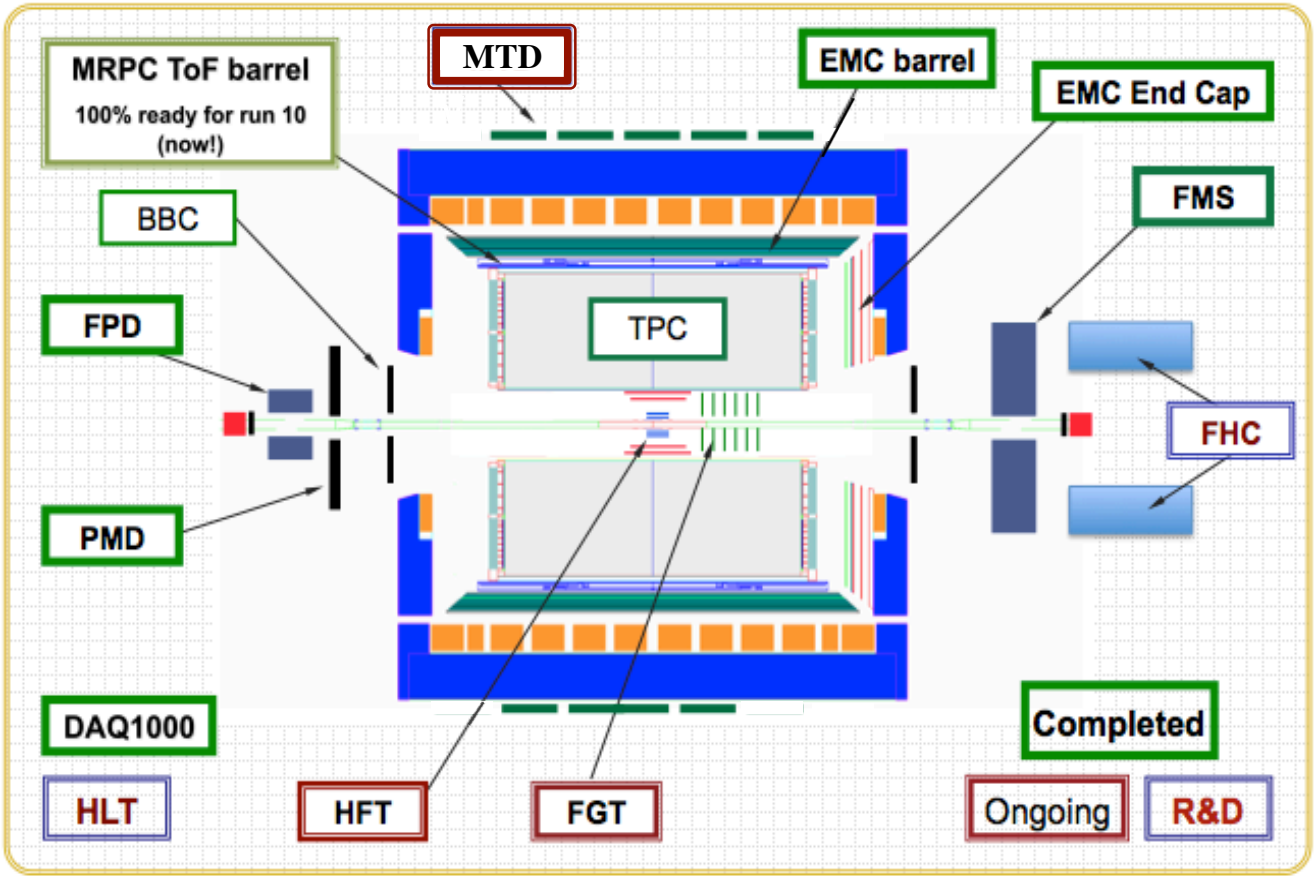
Cartoons of dynamical models

STAR detector

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



BSMD: embedded in BEMC.



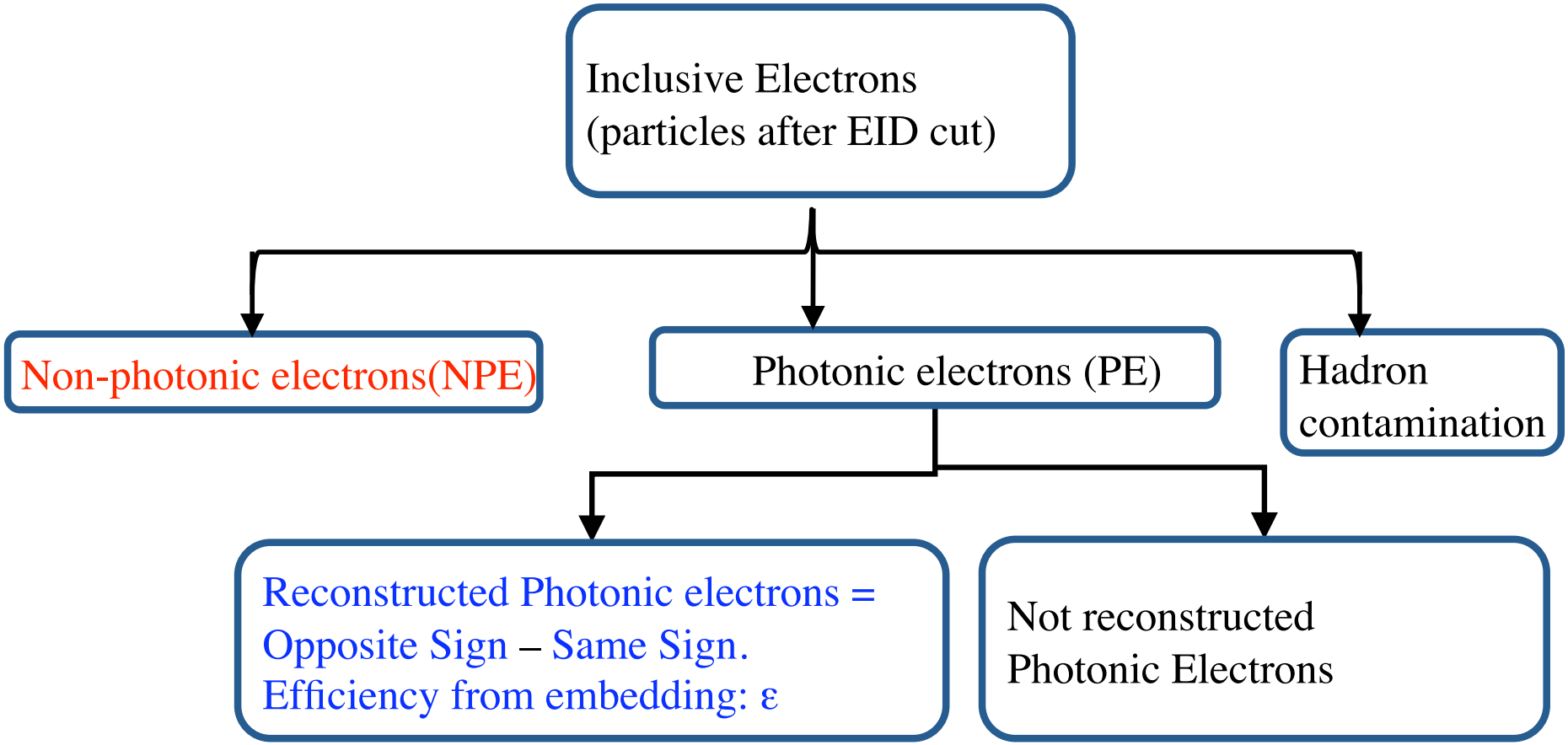
Detectors in these NPE analyses:
Time Projection Chamber(TPC)
Barrel Electromagnetic Calorimeter(BEMC)
Barrel Shower Maximum Detector(BSMD)

Data Sample:

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

- Mini-Bias Triggered Events (NPE spectrum, v_2)
- High-Tower Triggered Events (NPE-h correlation)

Analysis principle



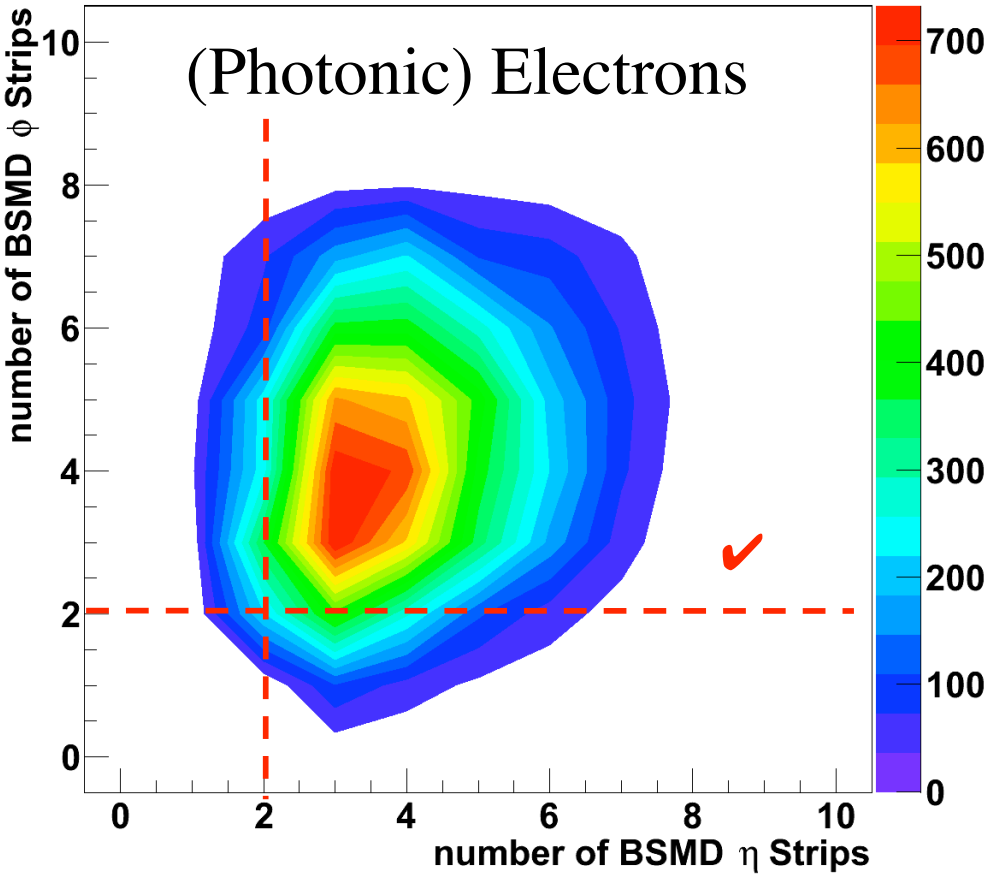
$$\Delta\phi_{NPE} = \Delta\phi_{inclusive} - (\Delta\phi_{OppoSign} - \Delta\phi_{SameSign})/\varepsilon - \Delta\phi_{hadron}$$

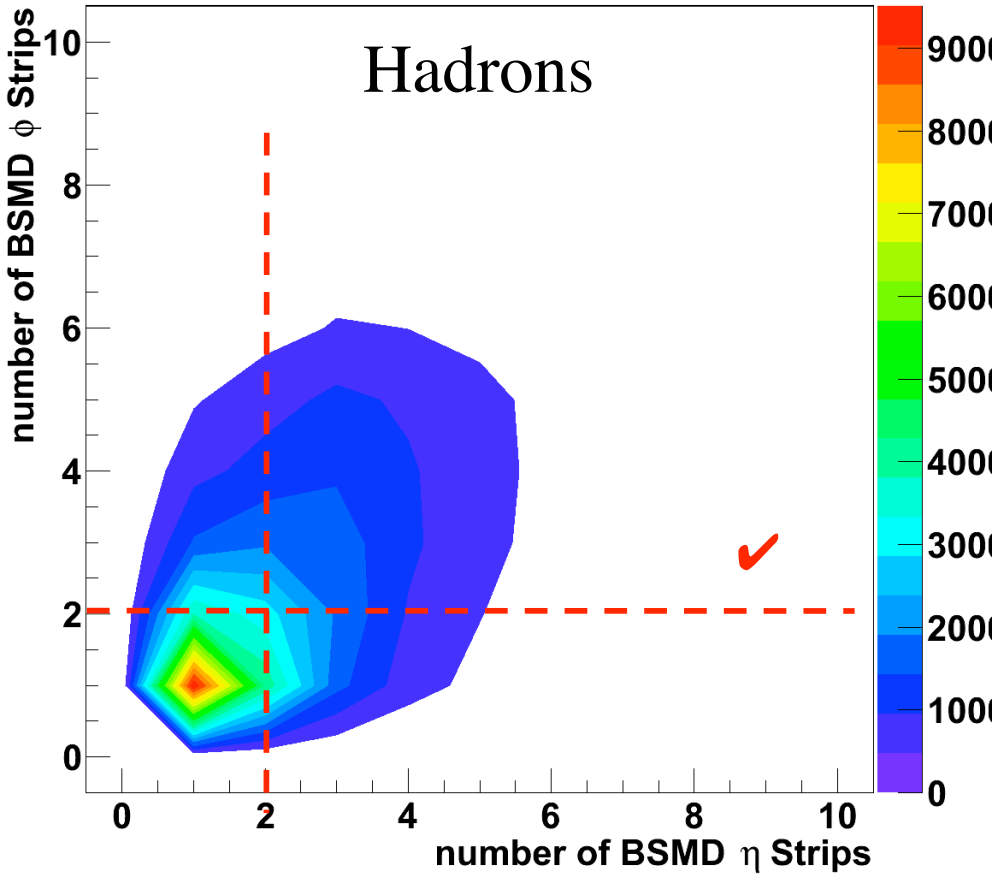
$\Delta\phi$ could be other variables, e.g. yield, elliptic flow (v_2), etc

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.





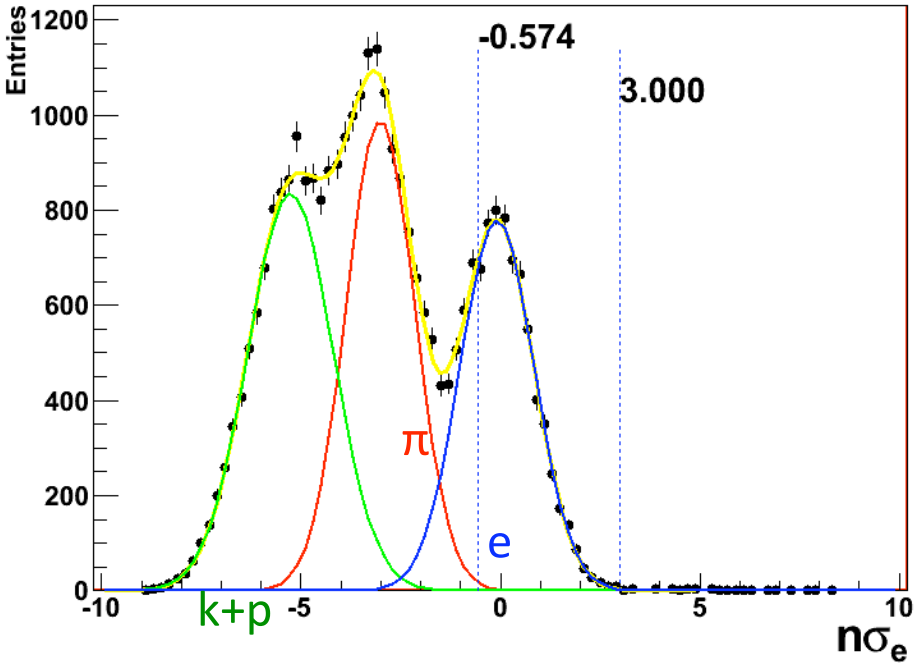
Example from the NPE-hadron correlation in Au+Au 200GeV study,
where we apply number of bsmd η strips >=2 and number of bsmd ϕ strips >=2

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

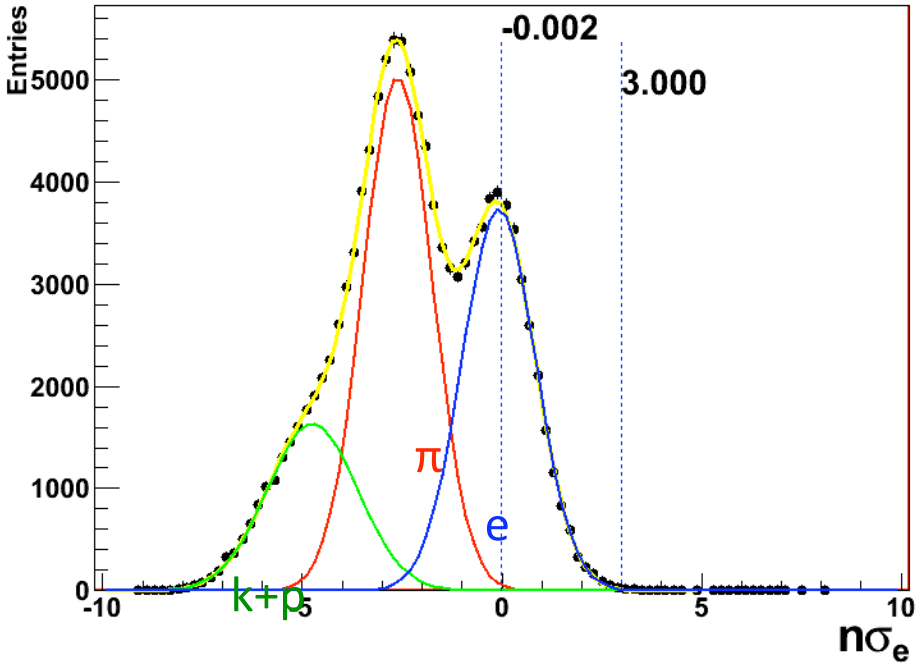
$$n\sigma_e = \frac{\log(\frac{dE/dx}{B_e})}{\sigma_e}$$

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

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



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

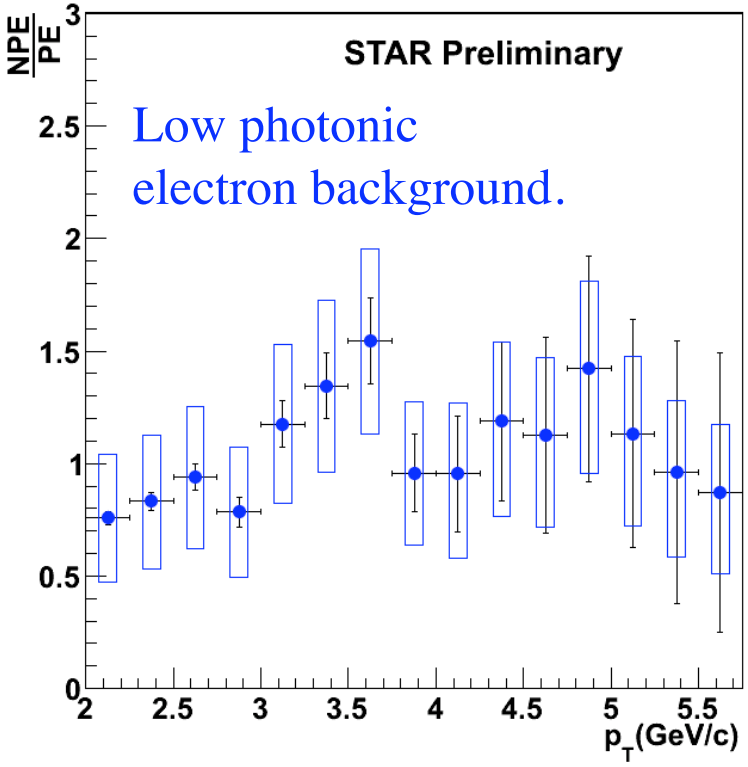


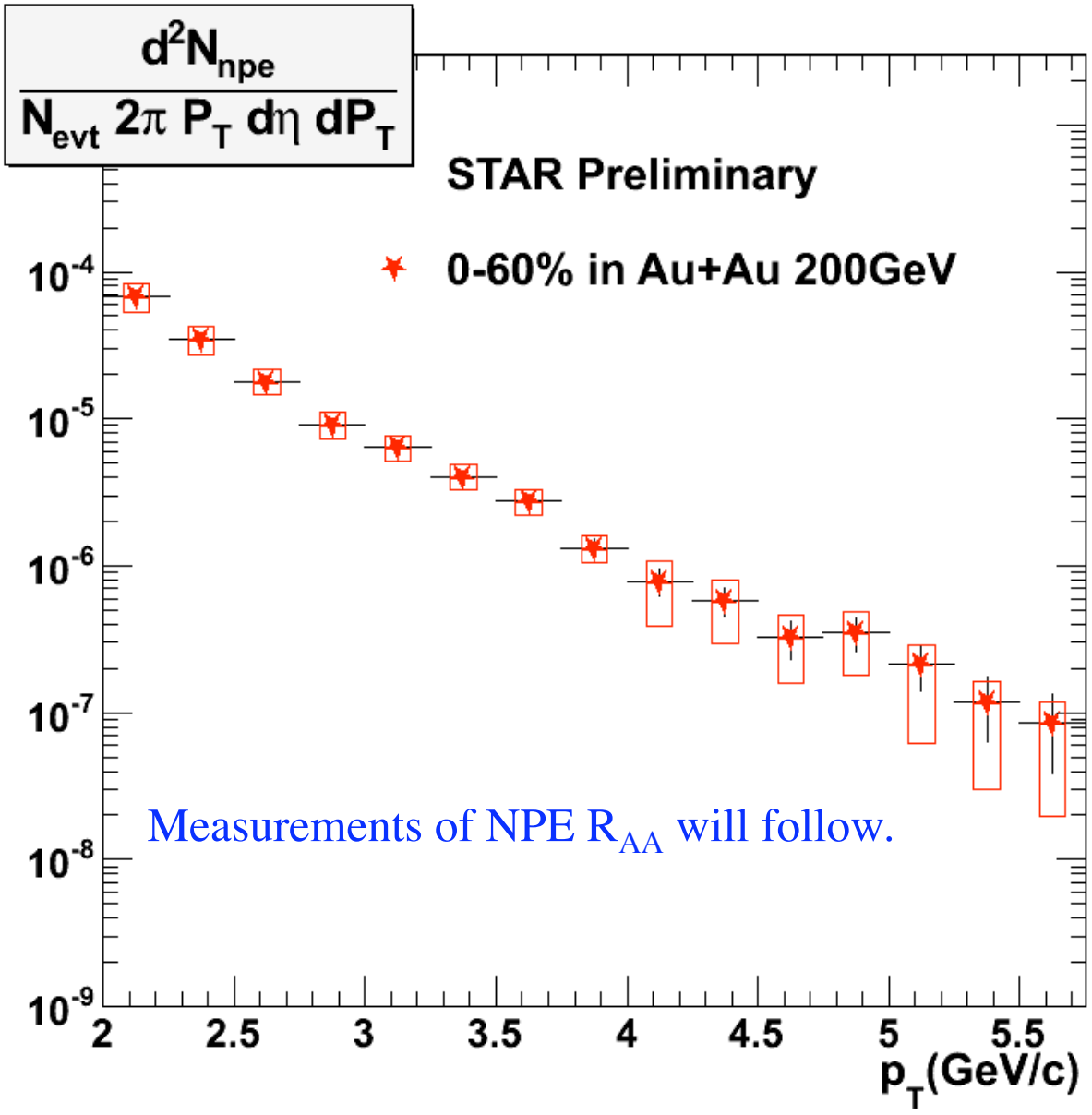
Examples from the NPE-hadron correlation study, where hadron contamination is <1% with tight σ_e cuts.

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

NPE spectrum

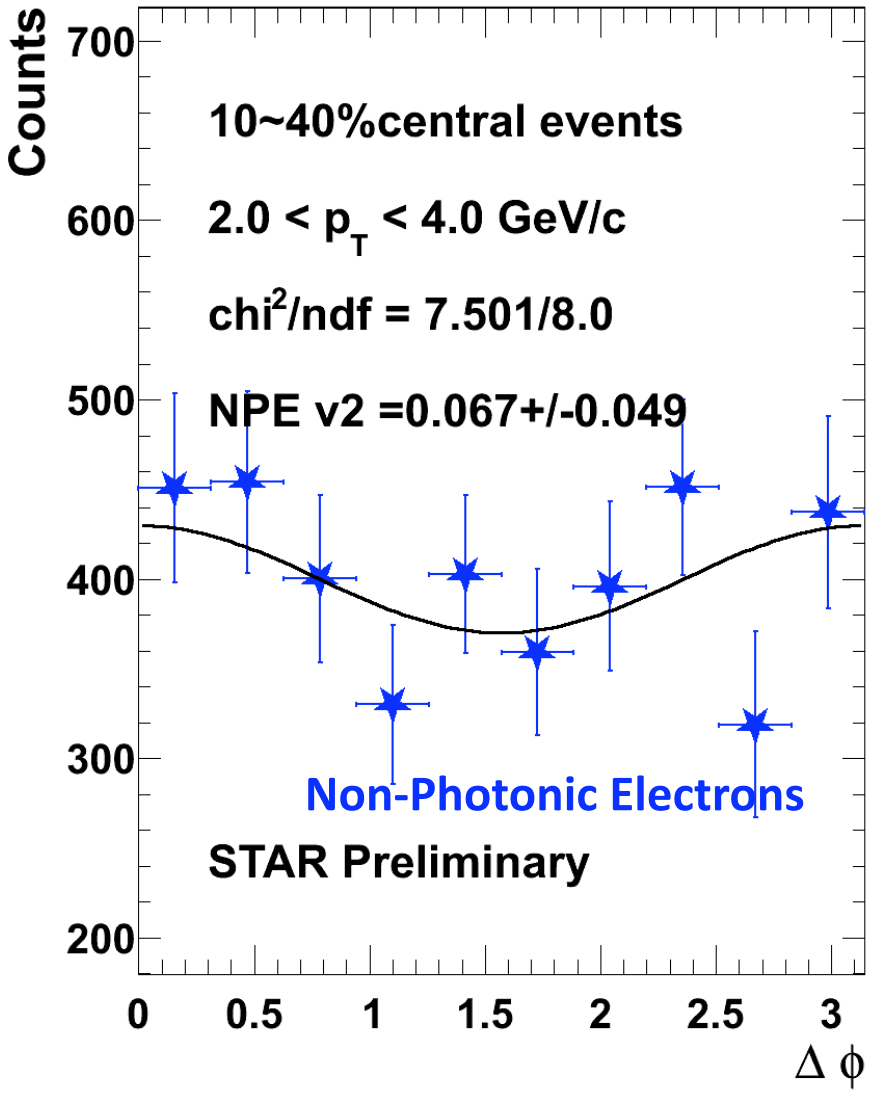
NPE production in Mini-Bias triggered events collected by STAR.
~38Million events analyzed here.
~10% of the entire data sample.

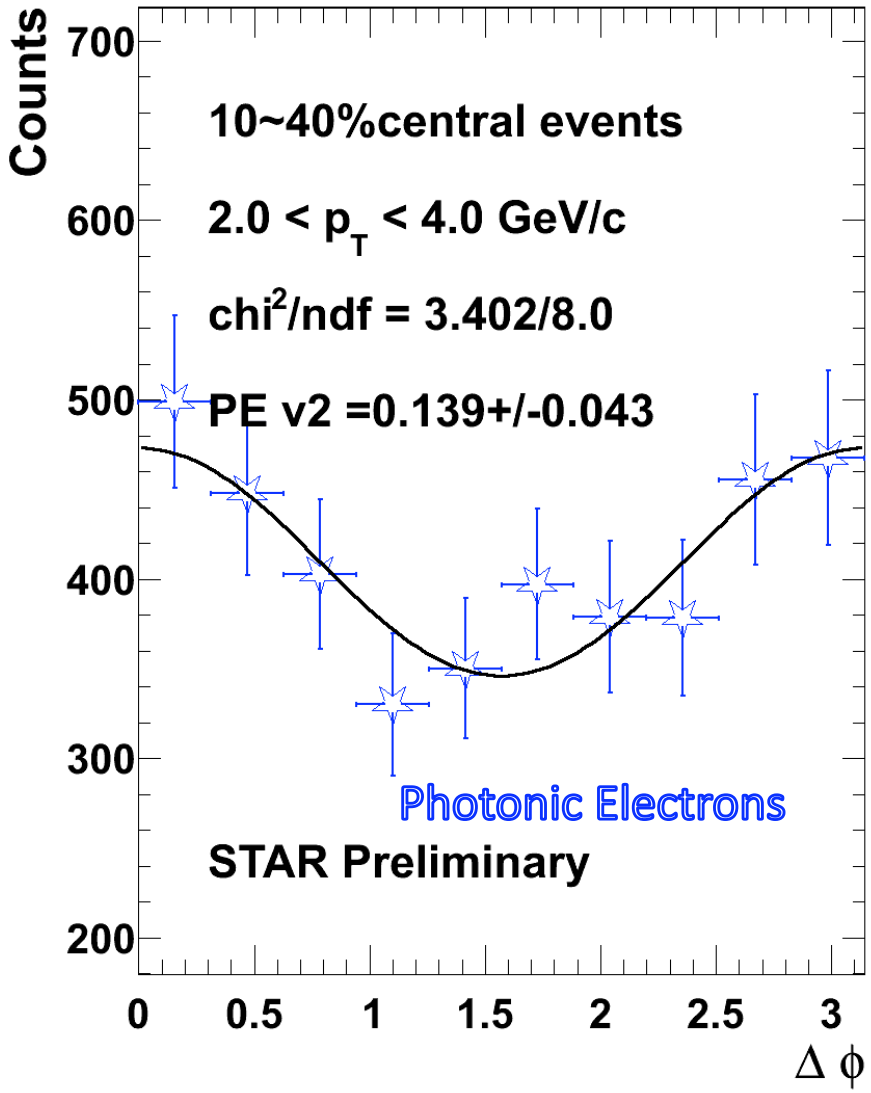




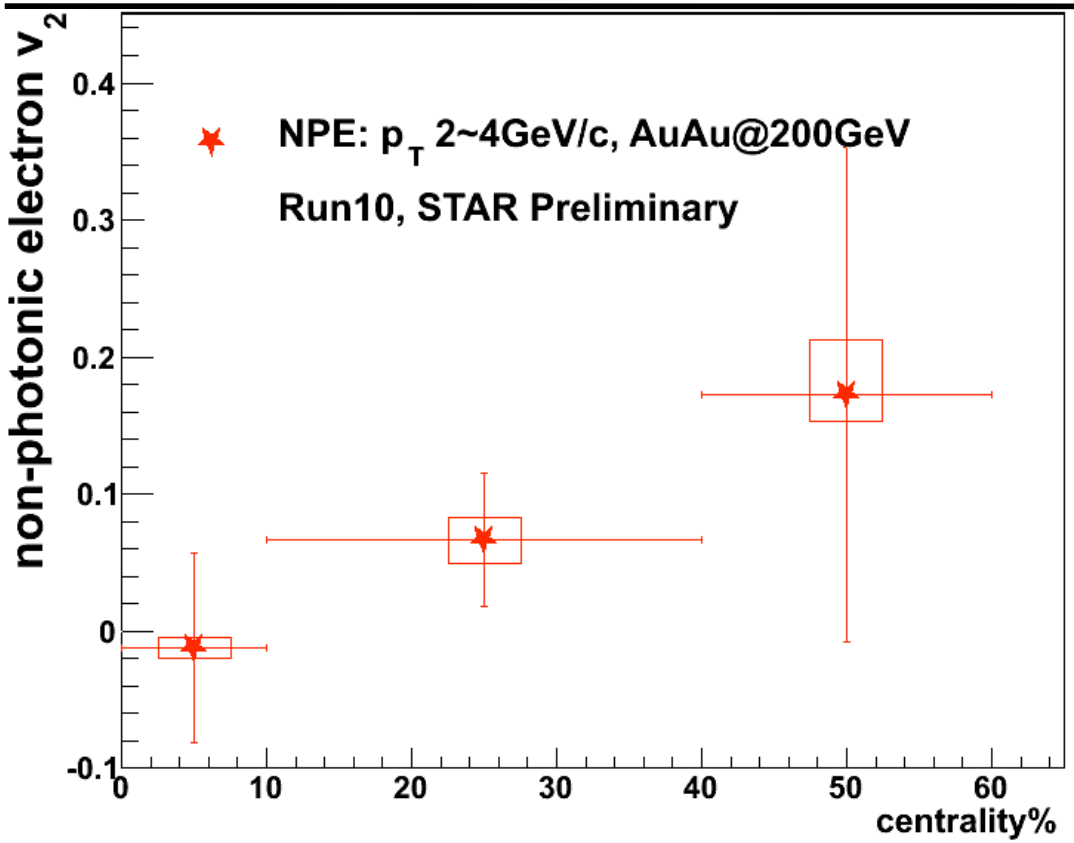
NPE elliptic flow

NPE elliptic flow (v_2) in Mini-Bias triggered events
obtained by fitting electron-event plane correlations

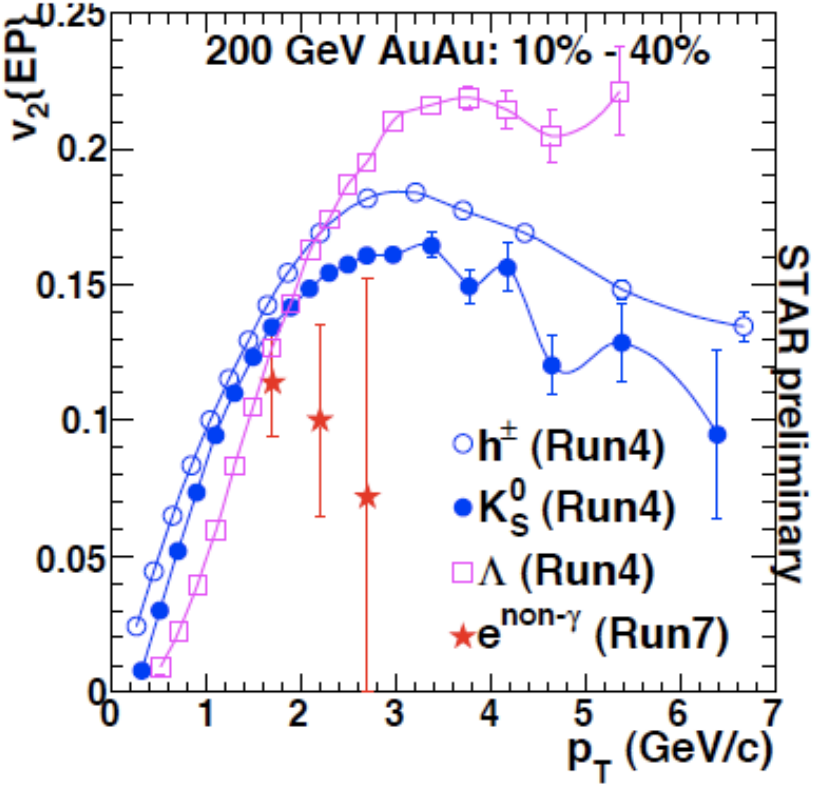




Compare to charged hadrons



This analysis of NPE v_2 in Run10



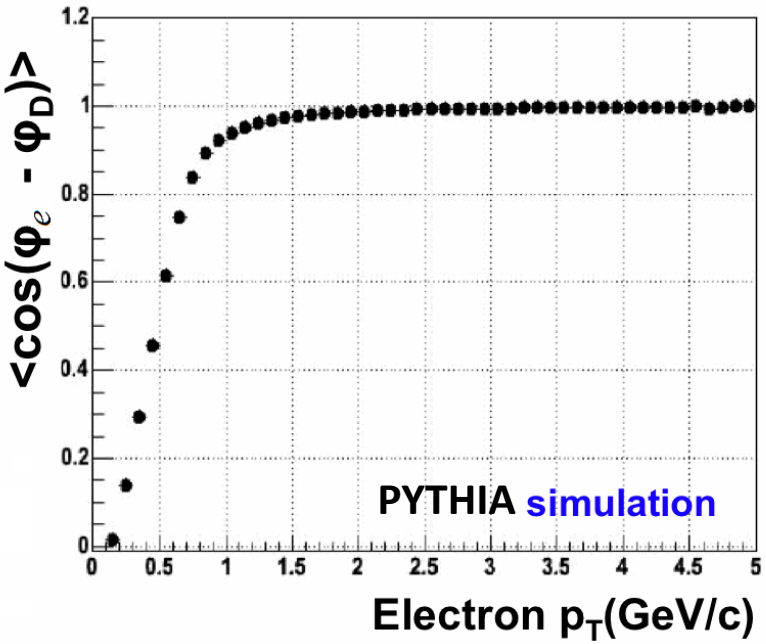
STAR Preliminary results shown in Hard Probes 2010, arxiv: 1011.5543

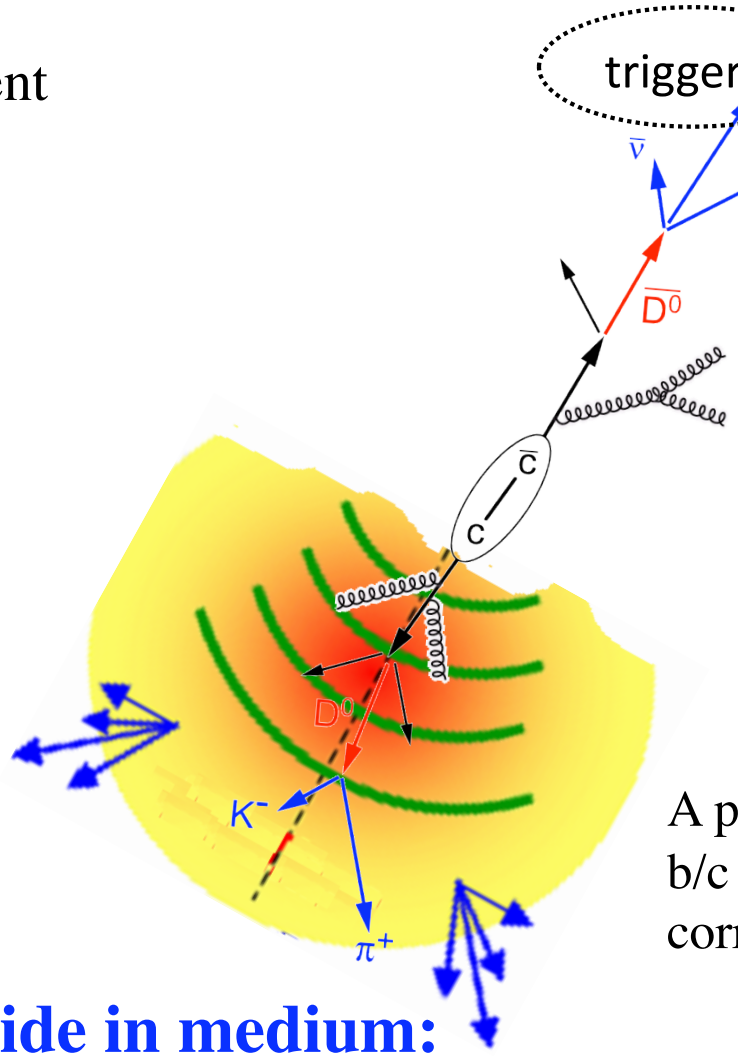
Hadron v_2: B. I. Abelev *et al.*, *Phys. Rev. C* ***77 (2008) 54901.***

- NPE v_2 in Run10 is **finite** and consistent with Run07
- **Lower** than v_2 of charged hadrons (or K_s^0 ,Λ) at the same p_T

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.



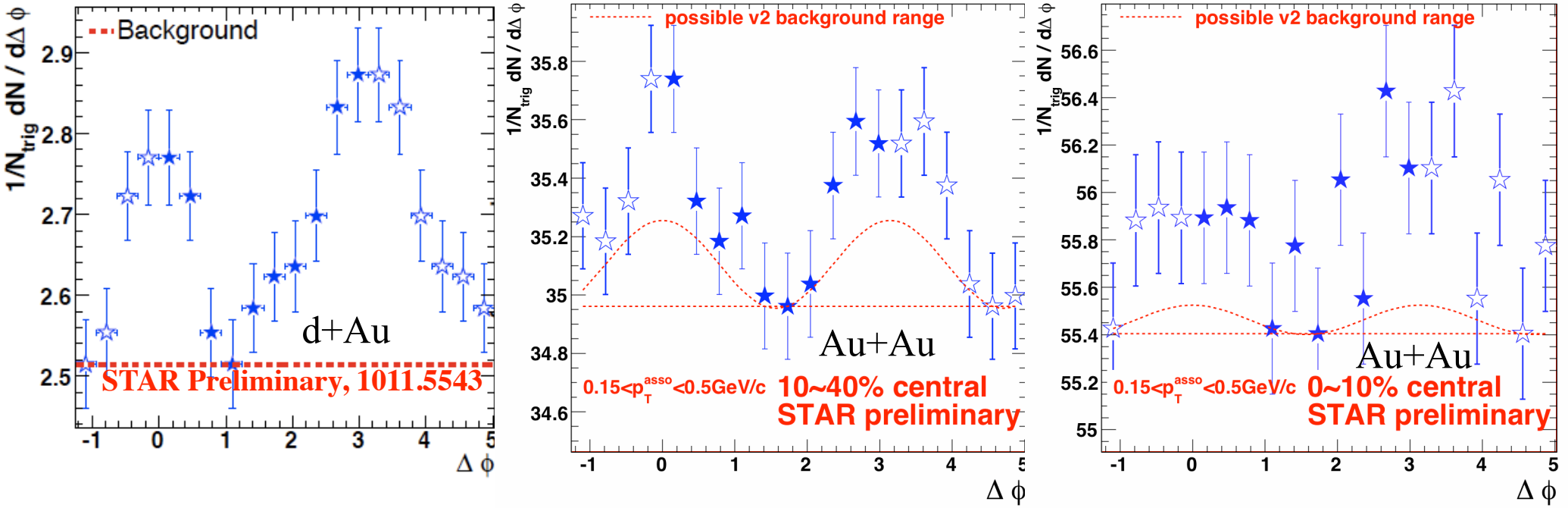


Near Side:
Decay
Kinematics
B/D separation

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?

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



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

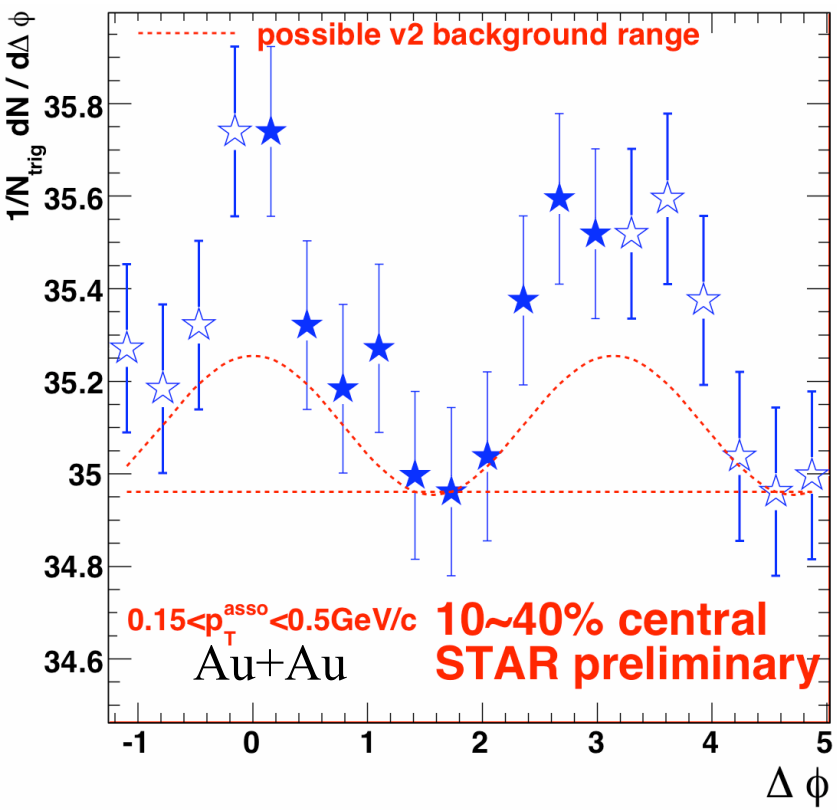
NPE p_T 3~6GeV/c, based on High Tower triggered events in Run10.

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

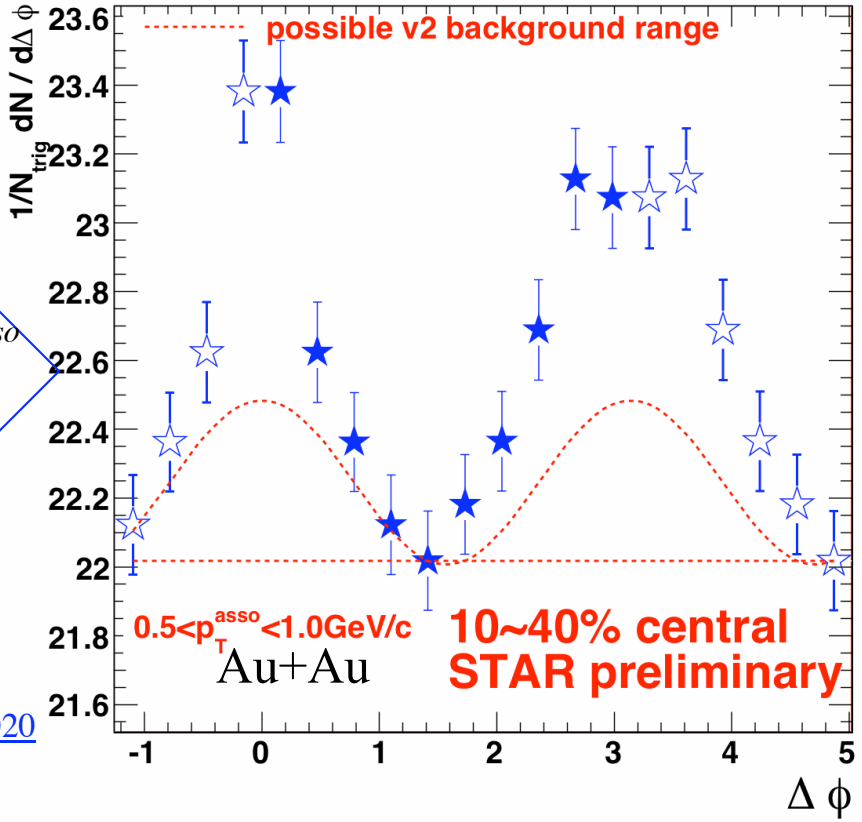
Red dashed curves: v_2 background range set with NPE v_2 being zero and hadron v_2.

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

Associated tracks with higher p_T



higher p_T^{asso}



arXiv:1106.6020

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 of High Tower triggered events in Run10

Summary

We presented NPE spectrum in 0 - 60% central Au+Au collisions at $\sqrt{s}$ = 200GeV. Measurements of NPE R_{AA} are also forthcoming.

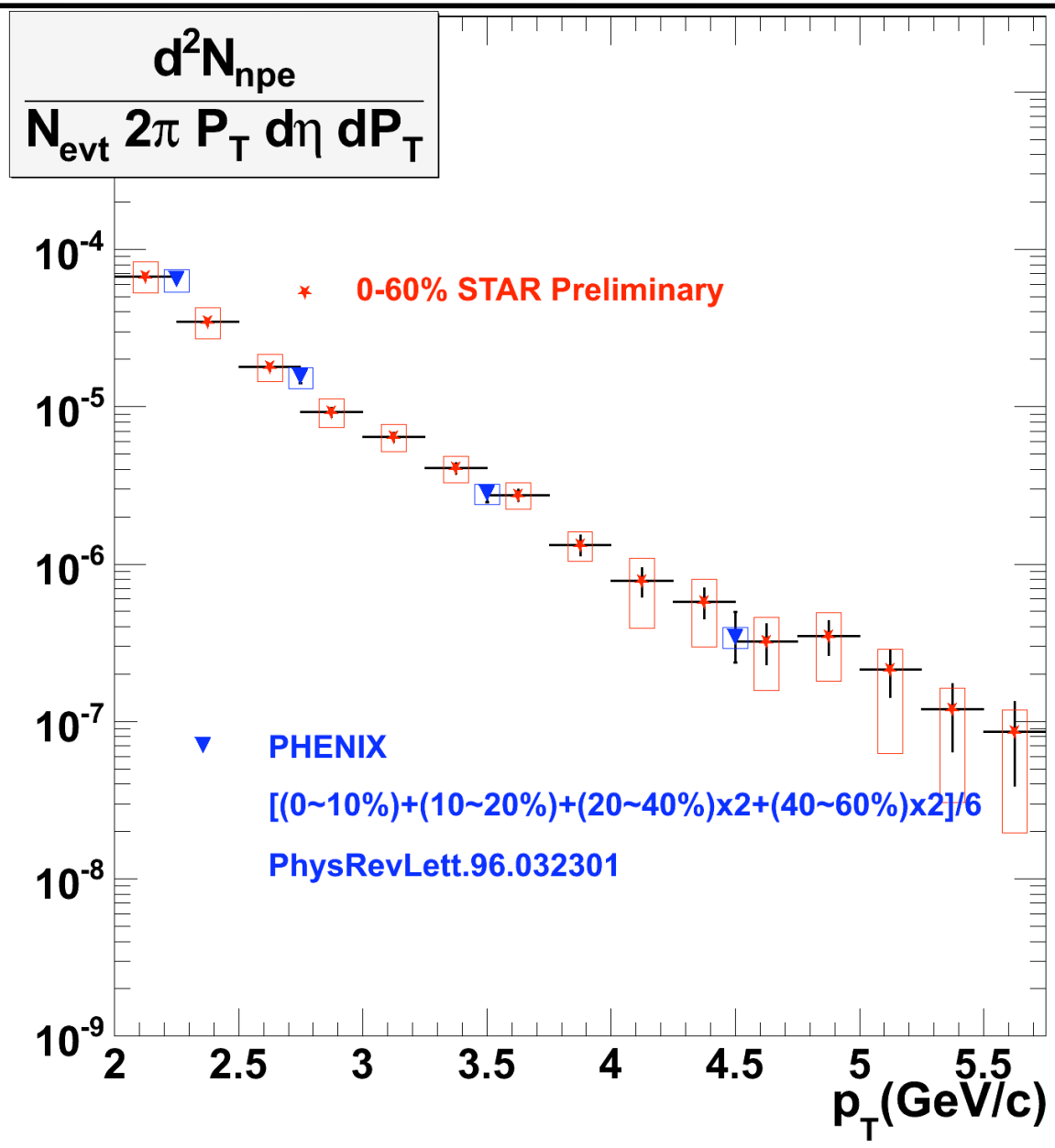
NPE has finite elliptic flow in 10% - 40% centrality
➔ possible heavy quark coupling to the QCD medium. Need more precise measurements.

There is a NPE-h correlation beyond statistical uncertainties
➔heavy flavor tagged jets do interact with the QCD medium.
Quantitative measurements yet to emerge and theoretical comparisons are required to understand the physical picture.

We are exploring heavy flavor quark-medium interactions.
The centrality dependence of these measurements will reflect properties of the QCD medium and provide strong constrains on dynamical models.

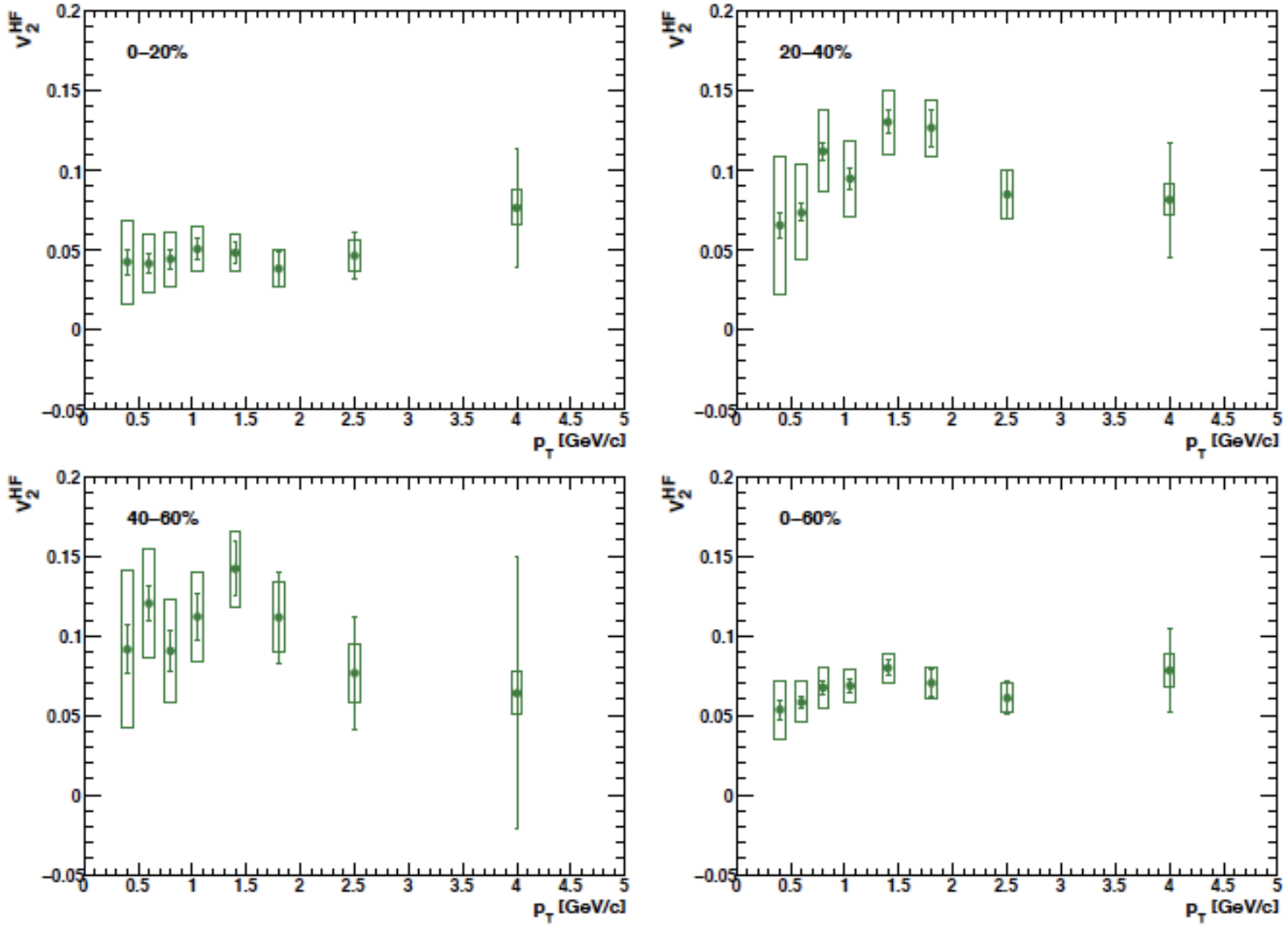
Backup

PHENIX NPE production



http://www.phenix.bnl.gov/phenix/WWW/info/data/ppg056/non_photonic_electrons.txt

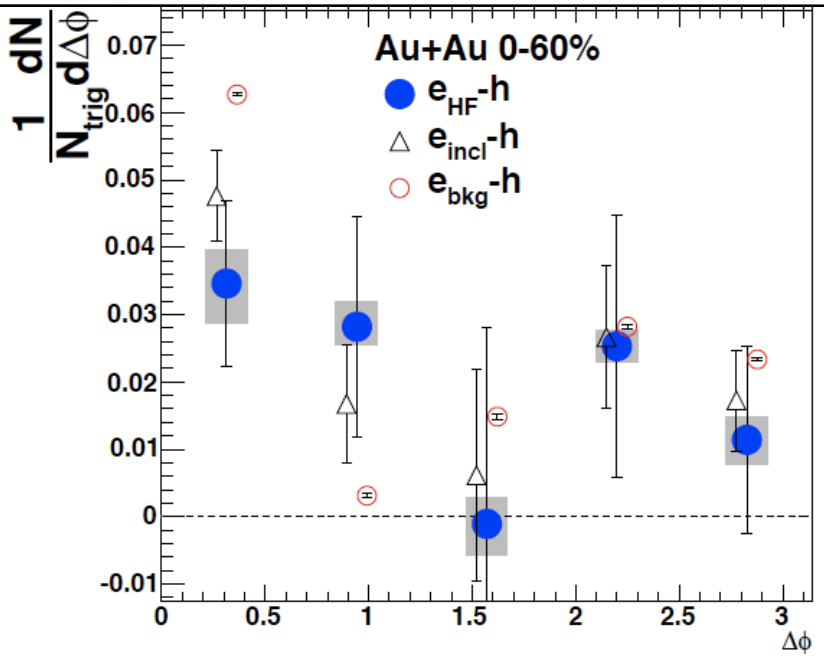
PHENIX NPE v2



Arxiv:1005.1627

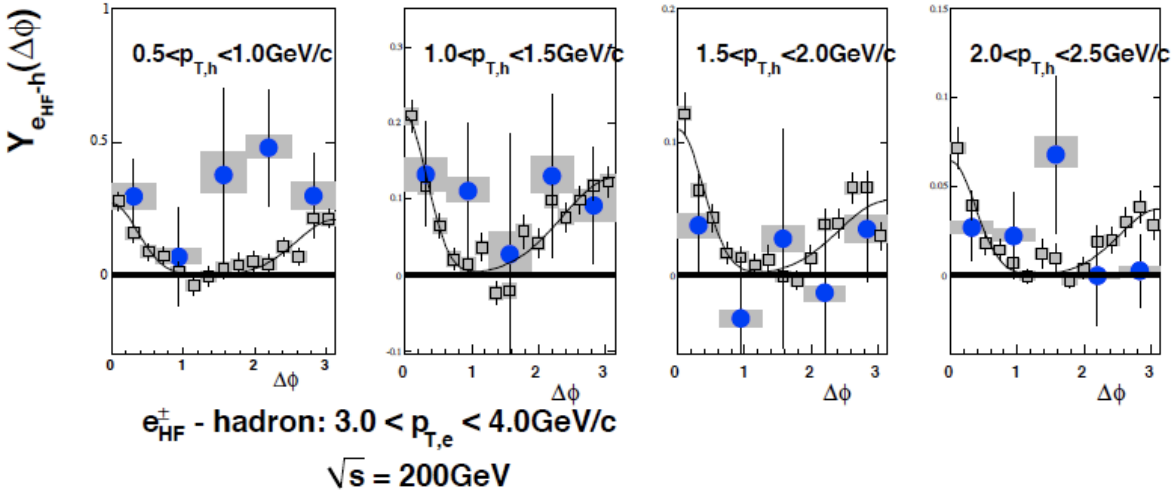
FIG. 38: (Color online) v_2^{HF} for the indicated centralities.

PHENIX NPE-hadron corr



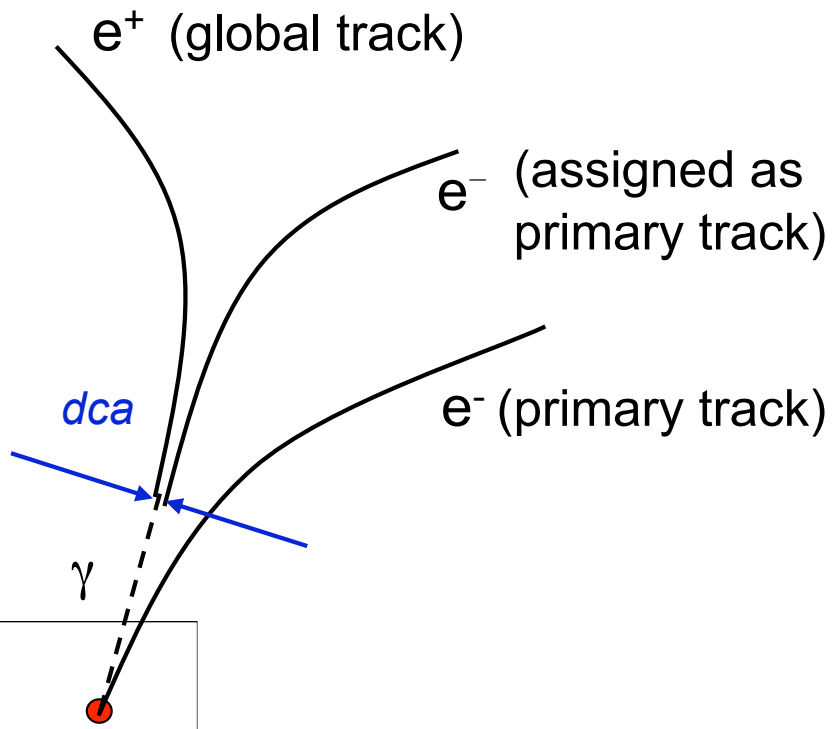
arXiv:1011.1477

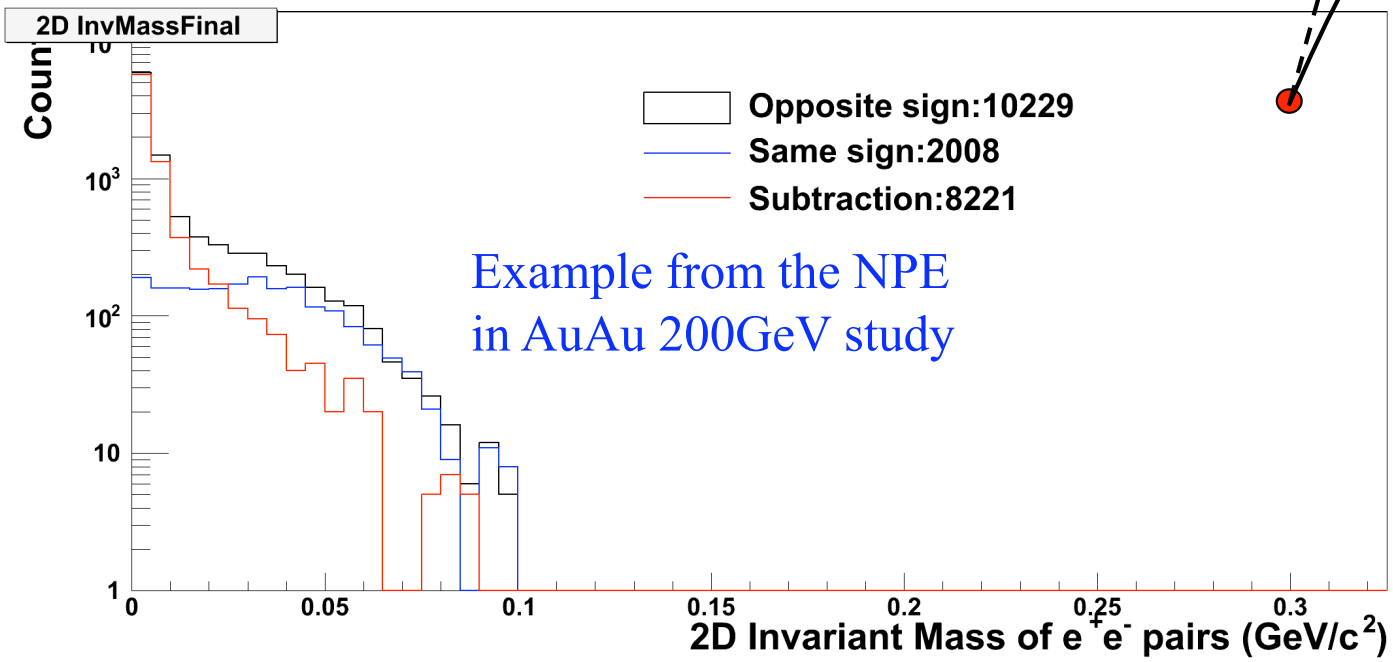
FIG. 4: (color online) $e_{inc} - h$, $e_{bkg} - h$ and $e_{\rm HF} - h$ (solid circles) for p+p (top panel) and Au+Au (bottom panel) collisions for 2.0< $p_{T,e}$ <3.0 GeV/c and 1.5< $p_{T,h}$ <2.0 GeV/c. The overall normalization uncertain of 7.9% in p+p and 9.4% in Au+Au is not shown.



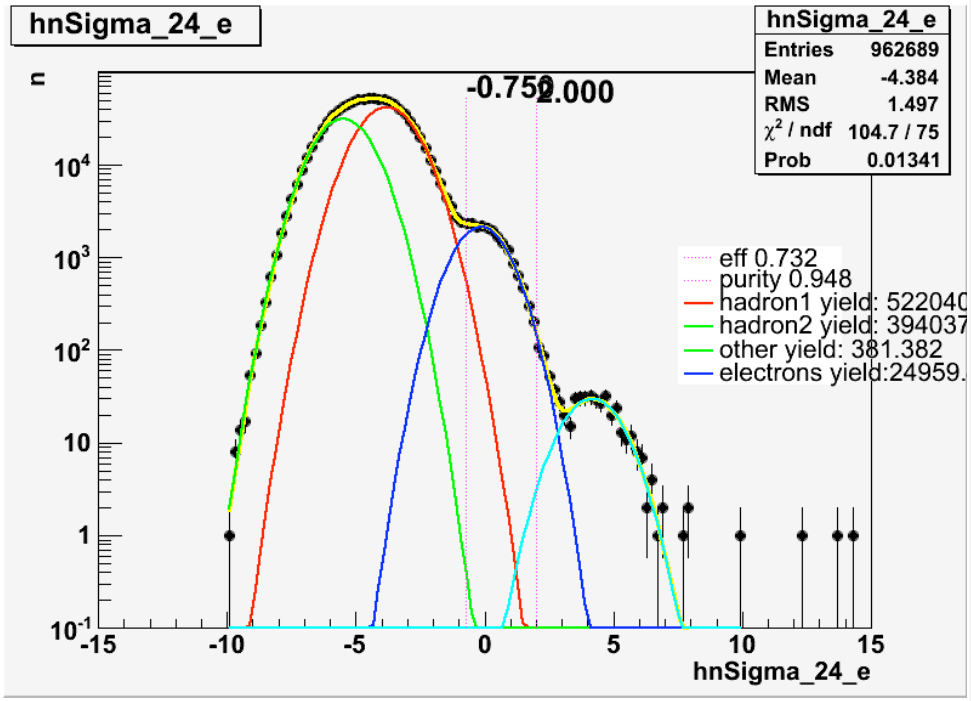
eHF – h jet functions for Au+Au (solid blue circles) and p+p collisions for 3.0–4.0 GeV/c Electron triggers and the hadron-pT bins indicated.

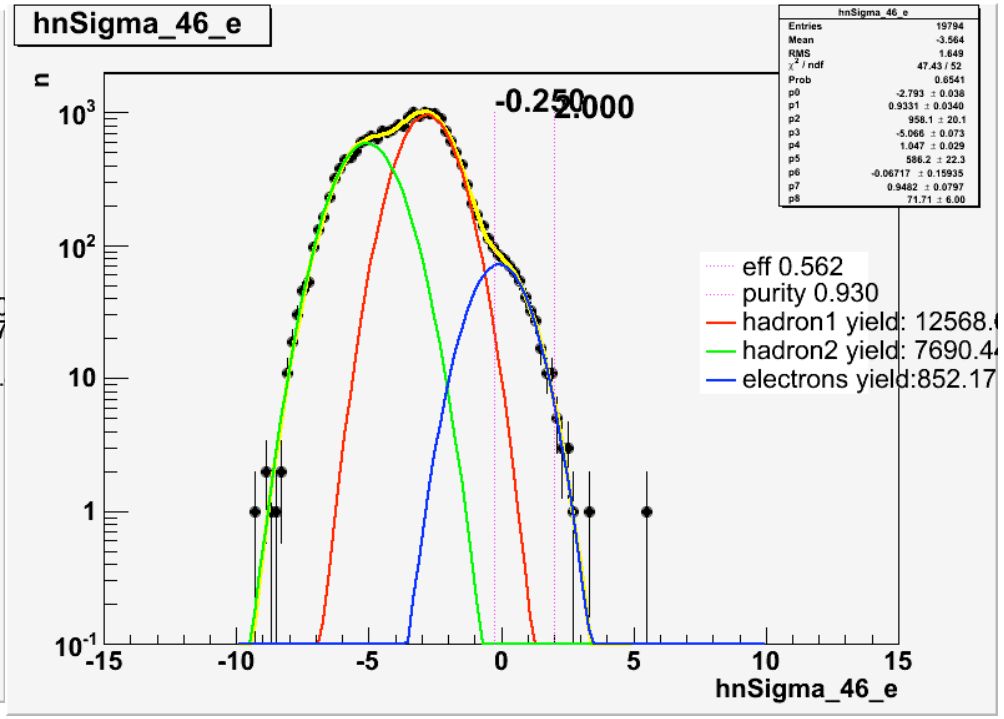
Photonic electron (PE) reconstruction



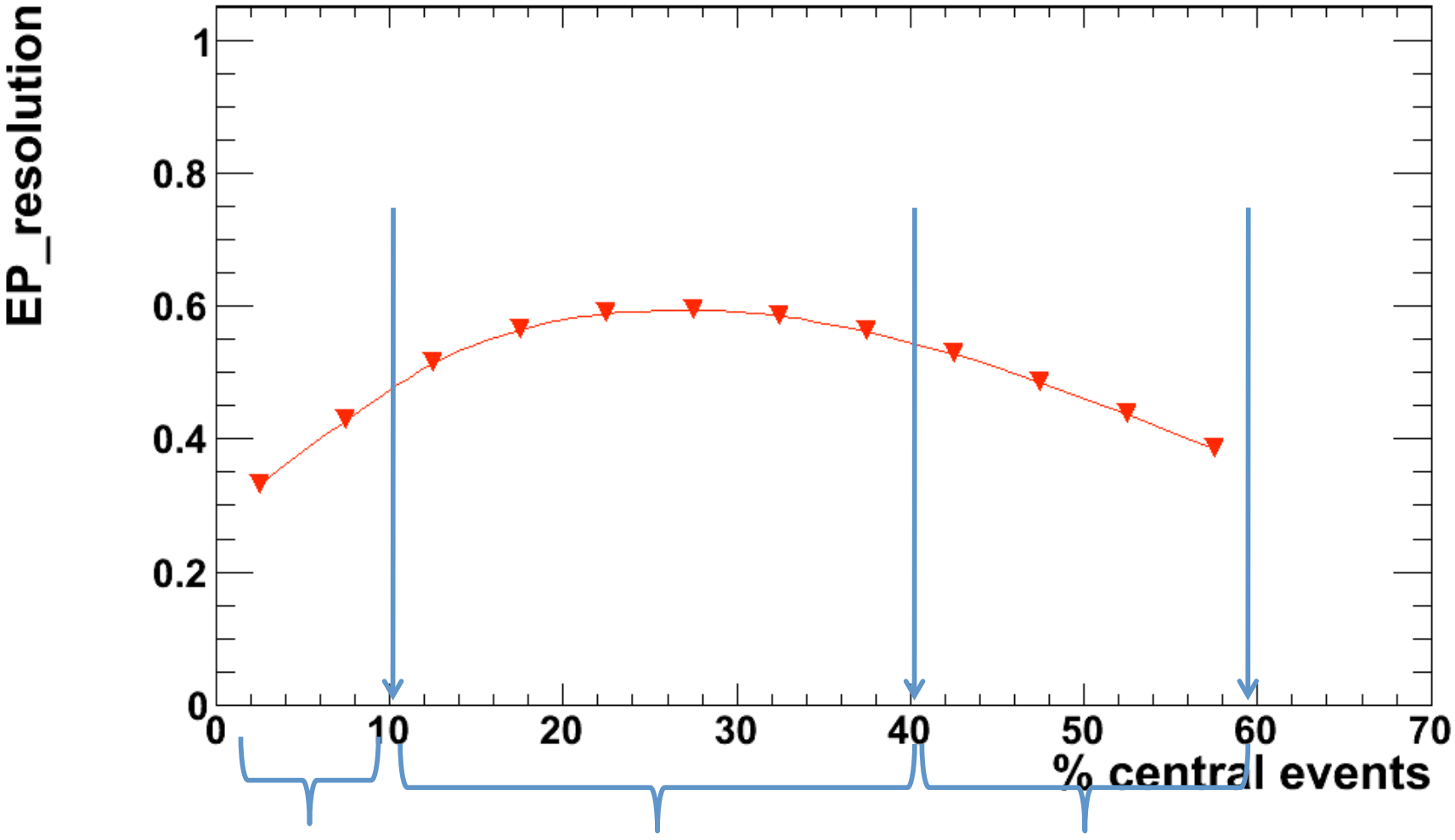


Nsigma electrons in Mini-Bias triggered events





Event plane resolution for sub-event plane method



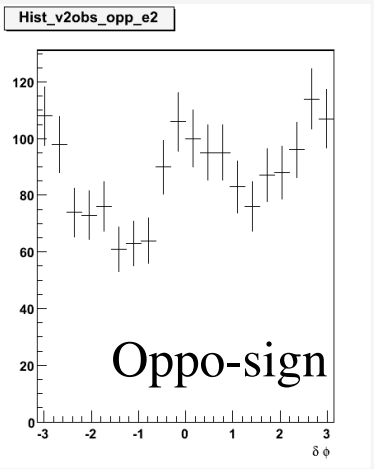
0.387
For 0~10%

0.568
For 10~40%

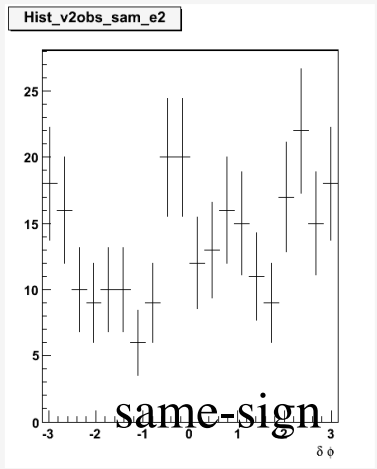
0.472
For 40~60%

3 centrality bins will be used for NPE v2.

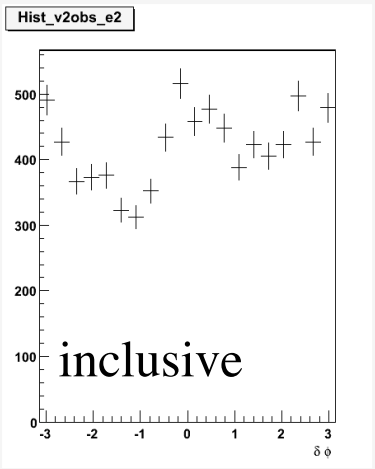
Break up of npe v2, 10~40%



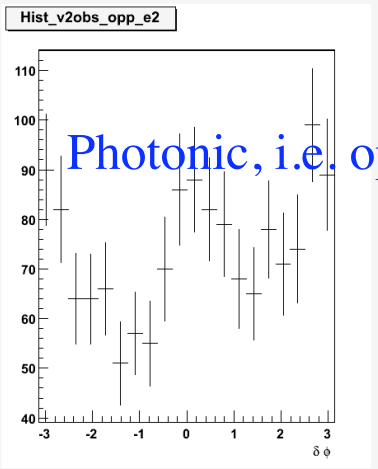
Oppo-sign

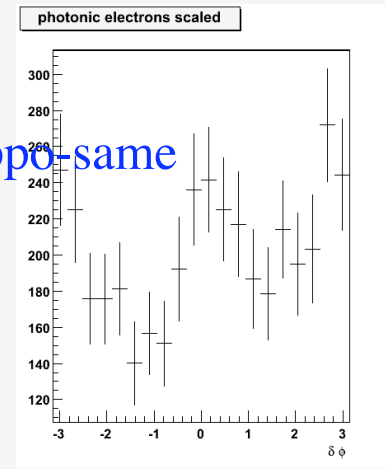


same-sign

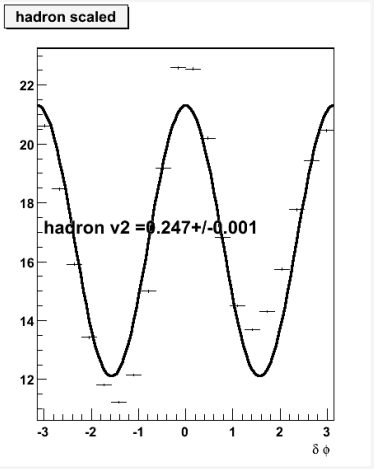


inclusive

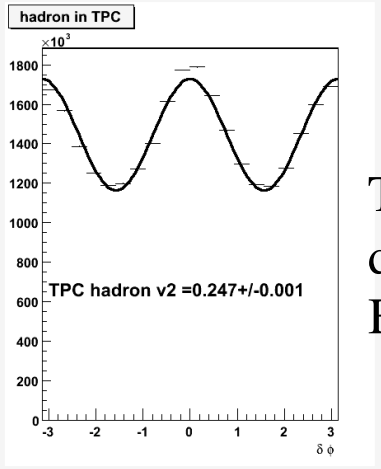




Photonic, i.e. oppo-same

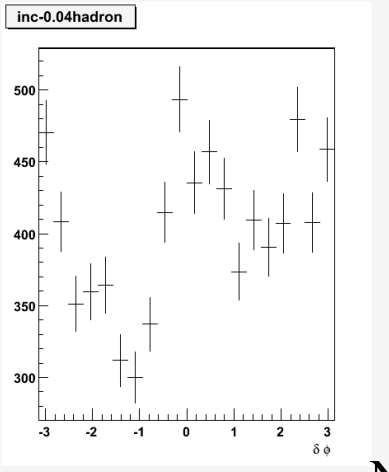


Hadrons
With BEMC
matching

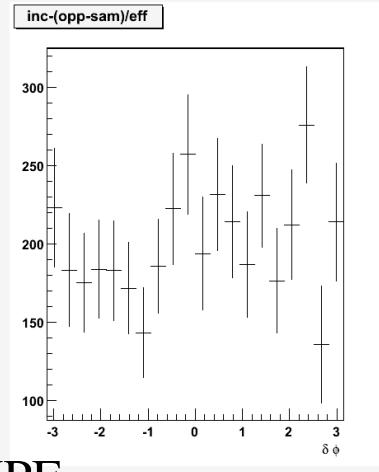


TPC hadrons

TPC hadrons
don't care about
BEMC matching

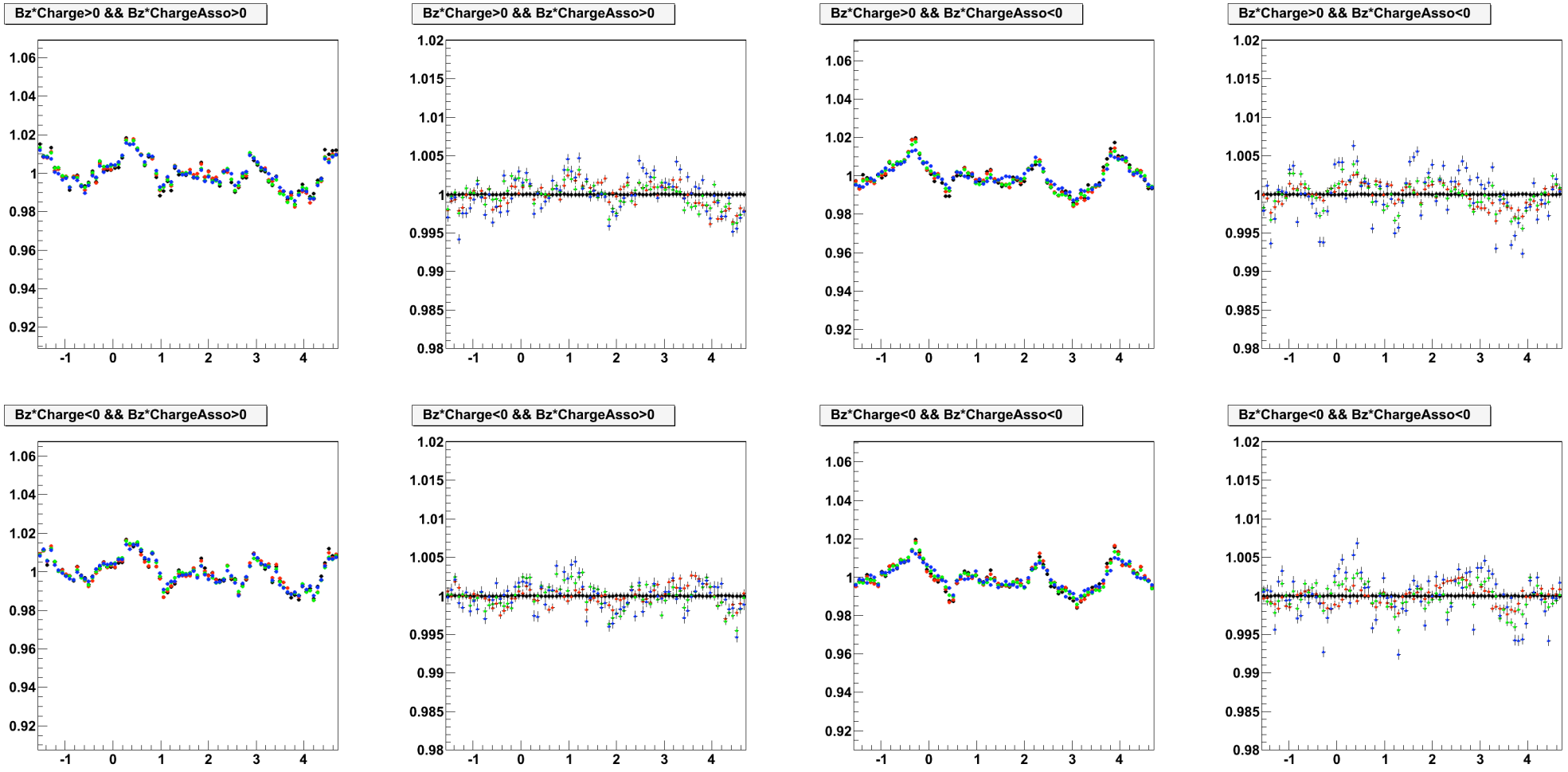


Inclusive -
scaled hadron



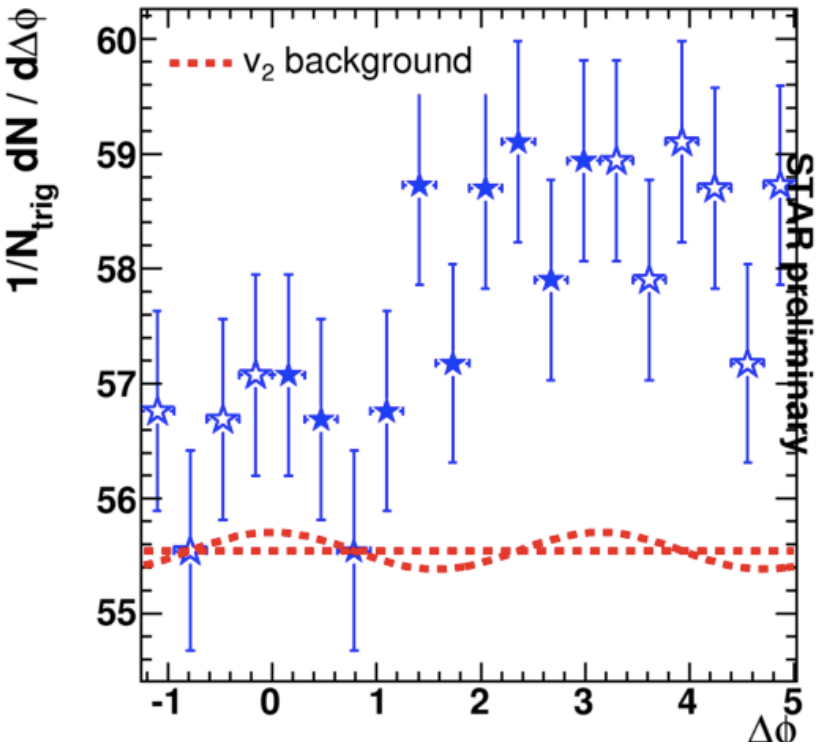
NPE,
before folding

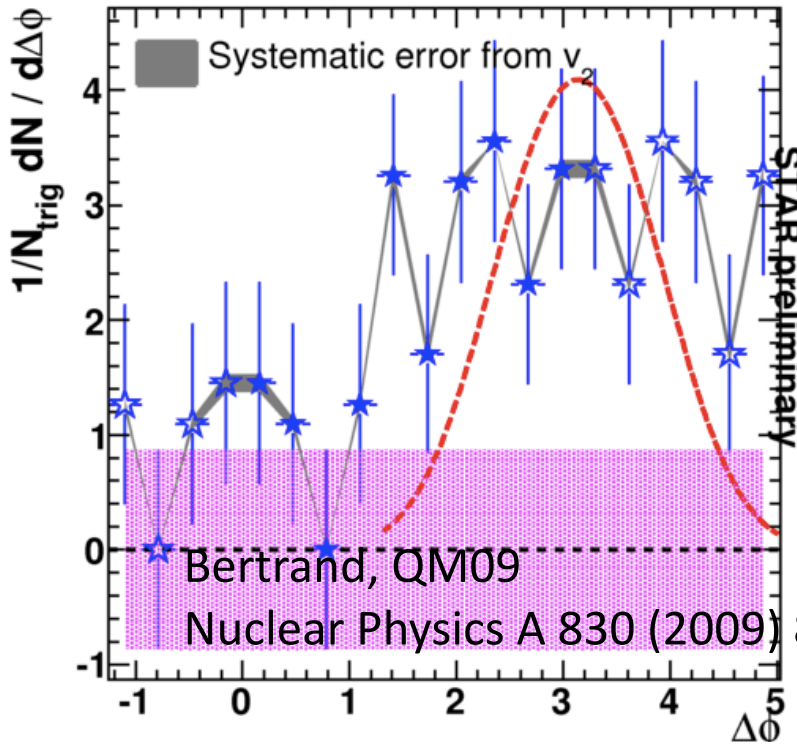
STAR NPE-h correlation mixing event backgrounds



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%

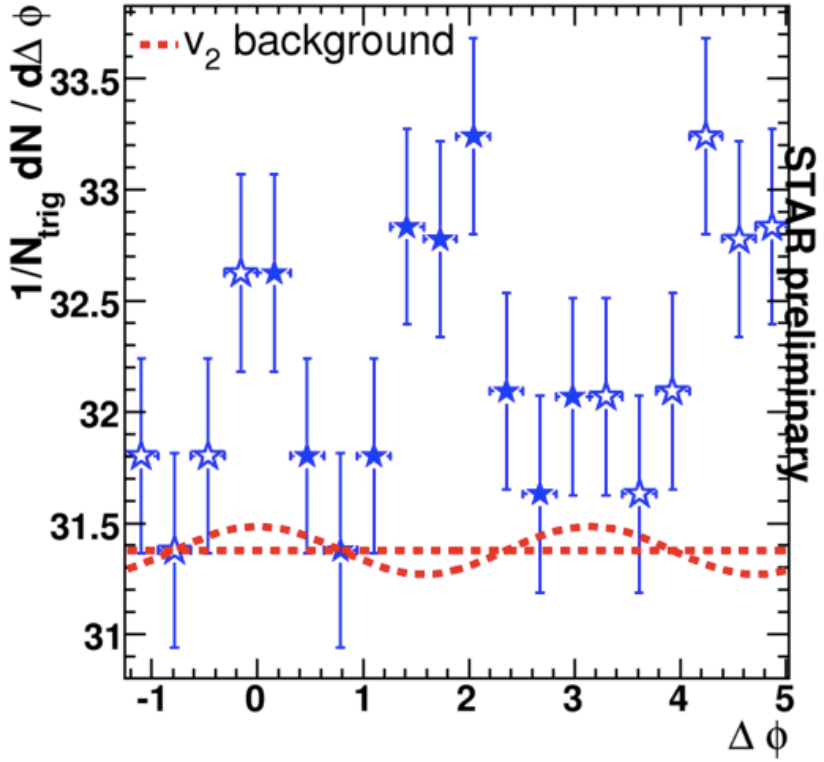


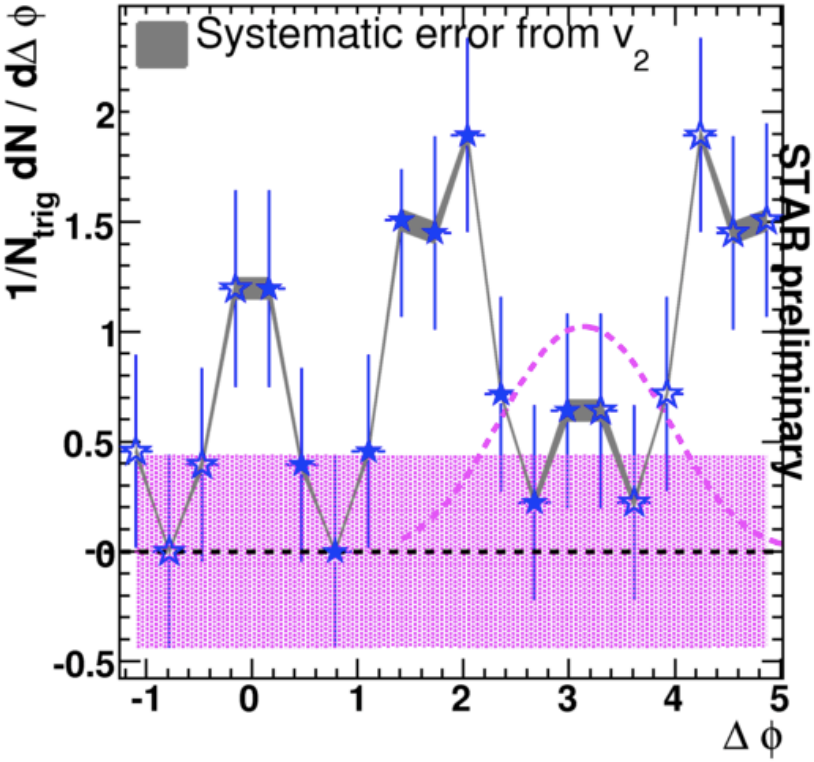


AuAu at 200 GeV

Bertrand, QM09

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





CuCu at 200 GeV