Bottom Production at RHIC with the STAR Experiment

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Outline

- Motivation
- The STAR Detector
- Bottom Production in p+p Collisions
  - Non-prompt J/ψ
  - Non-Photonic Electron (NPE)
- Heavy Flavor Tracker in Future Analyses
- Summary and Outlook

Motivation

Bottom Quarks

- Large mass - Predominantly produced in initial hard parton scatterings.
- Long lifetime - Experience the full medium evolution in Au+Au collisions.
- Theory predicts bottom quarks will lose less energy than charm quarks in the Quark Gluon Plasma (QGP).
- Need to know the baseline of bottom quark production in p+p collisions to study the suppression in Au+Au collisions.

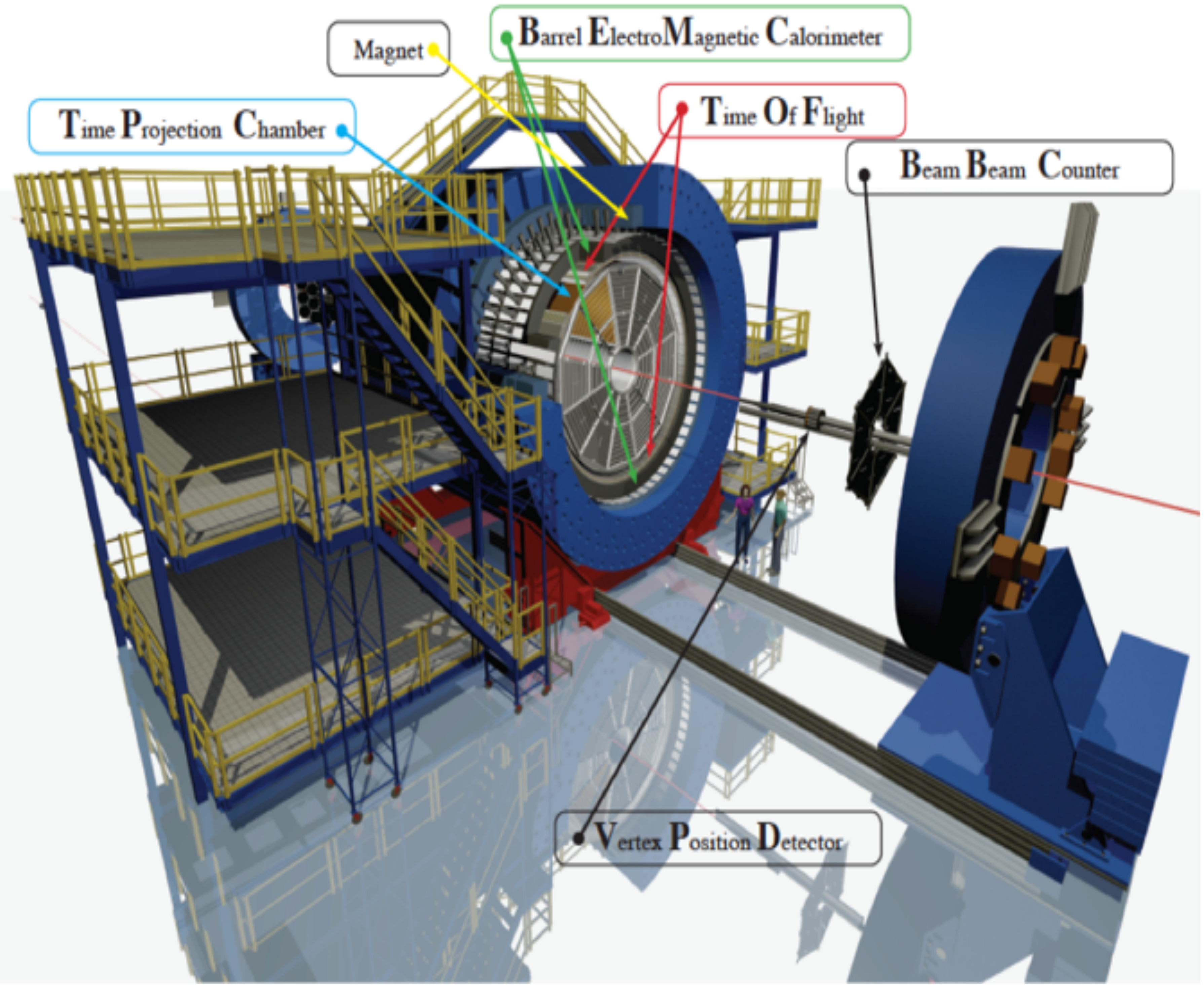
Non-prompt J/ψ

- Produced from B hadron decays.
- Can be reconstructed from dielectron channel (Branching Ratio: 5.9%).
- Closely resembles bottom hadron kinematics.

Non-Photonic Electrons

- Produced from open heavy flavor hadron decays ($B \rightarrow e$, $D \rightarrow e$)
- Good proxy for heavy flavor production.

STAR Detector (2012)



Time Projection Chamber
Charged Particle Tracking,
Momentum Reconstruction,
Electron ID through dE/dx.

Time Of Flight
Electron ID for $p_T < 1.5$ GeV/c.

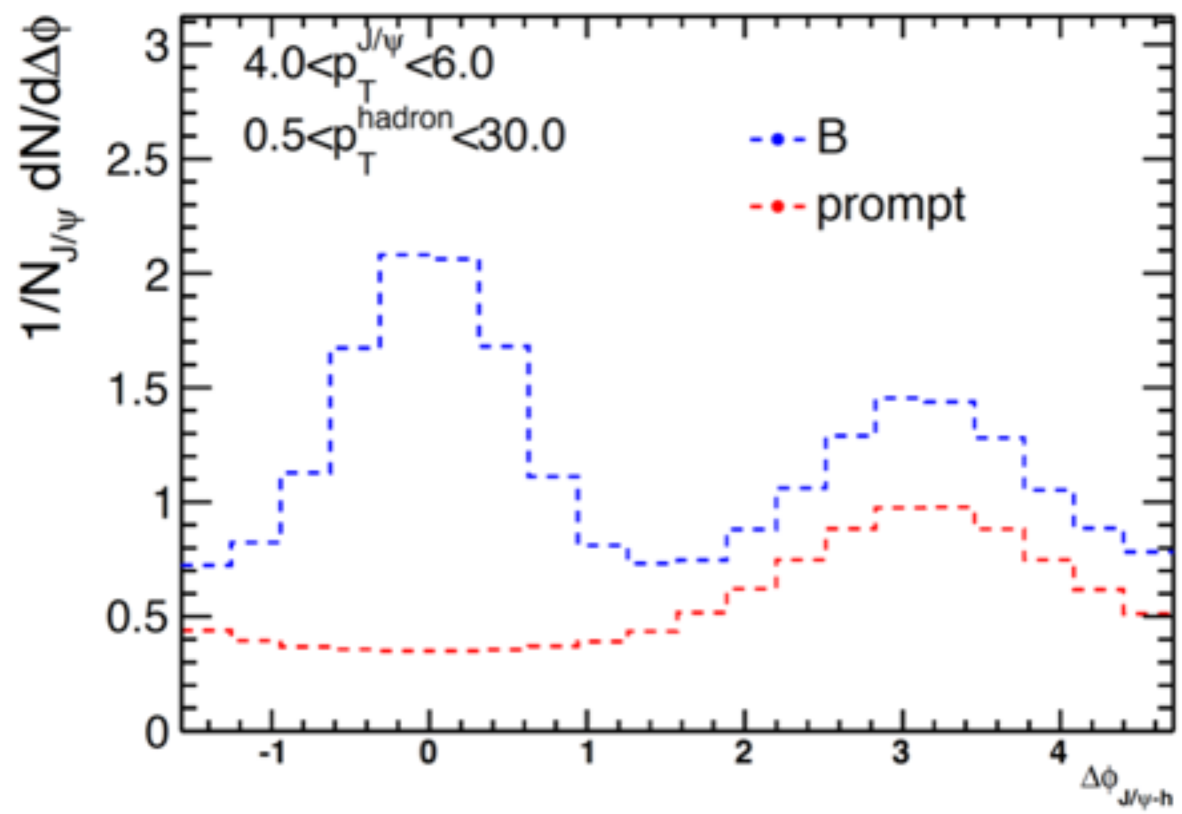
Barrel EM Calorimeter
Electron ID for $p_T > 1.5$ GeV/c;
High p_T electron online trigger

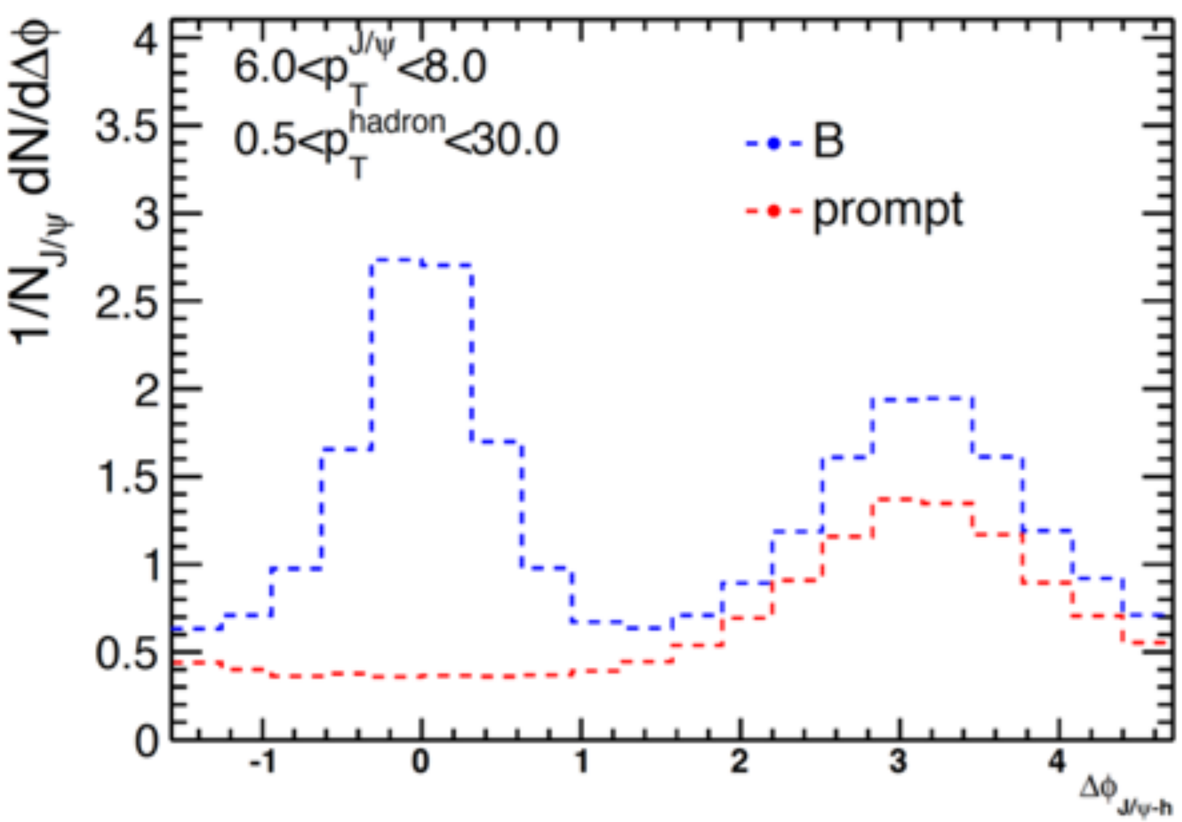
Vertex Position Detector
Minimum Bias Trigger

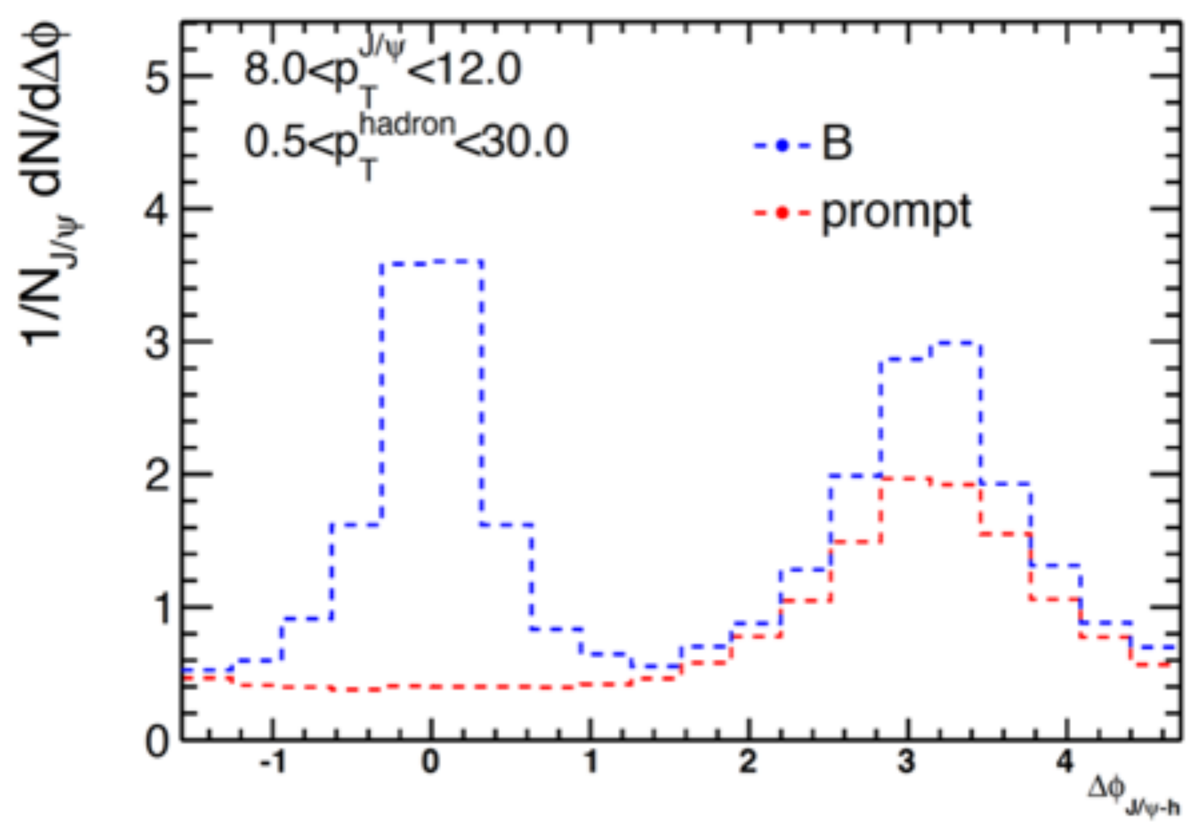
Analysis: Non-Prompt J/ψ

Pythia 8 Monte Carlo simulation

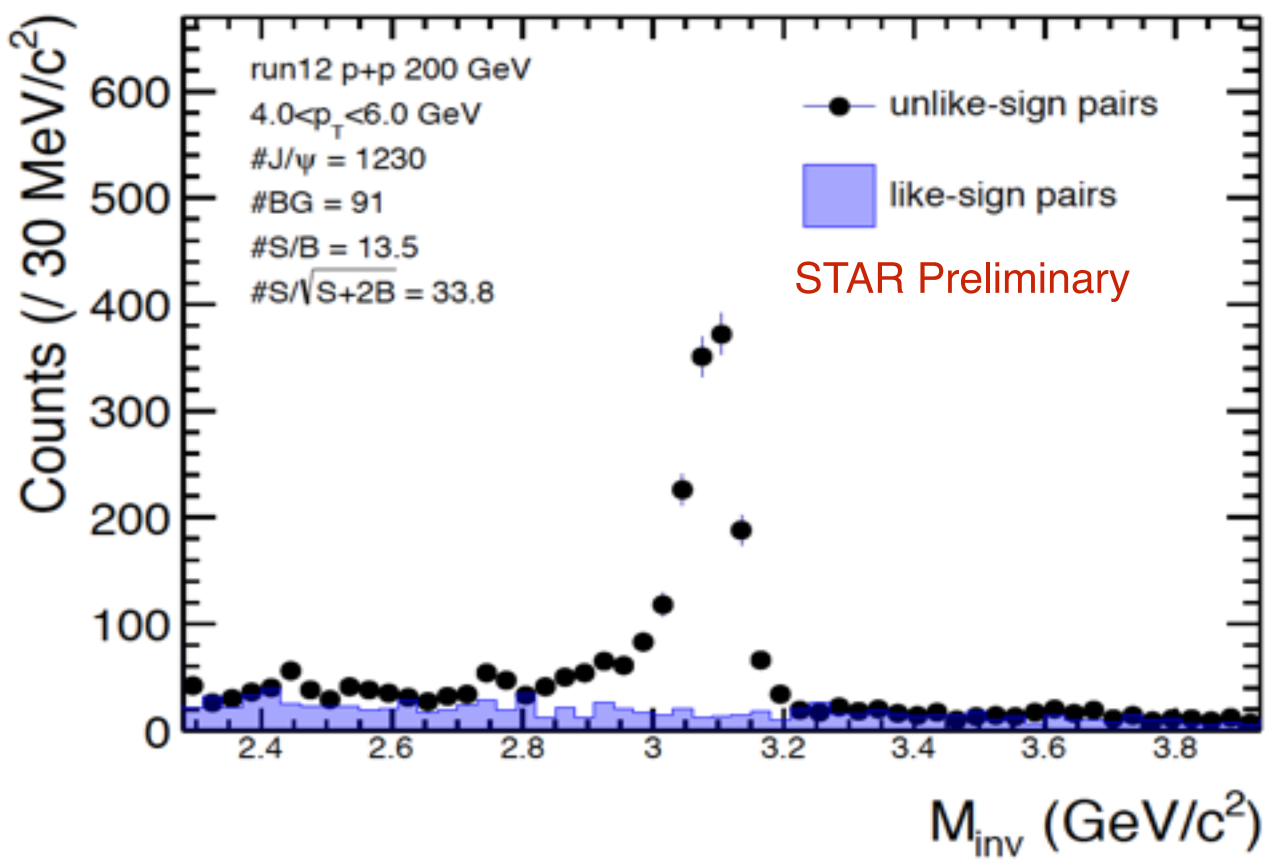
- Δϕ correlations: J/ψ's azimuthal angle and hadron's azimuthal angle.
- Simulated for prompt J/ψ and B → J/ψ.

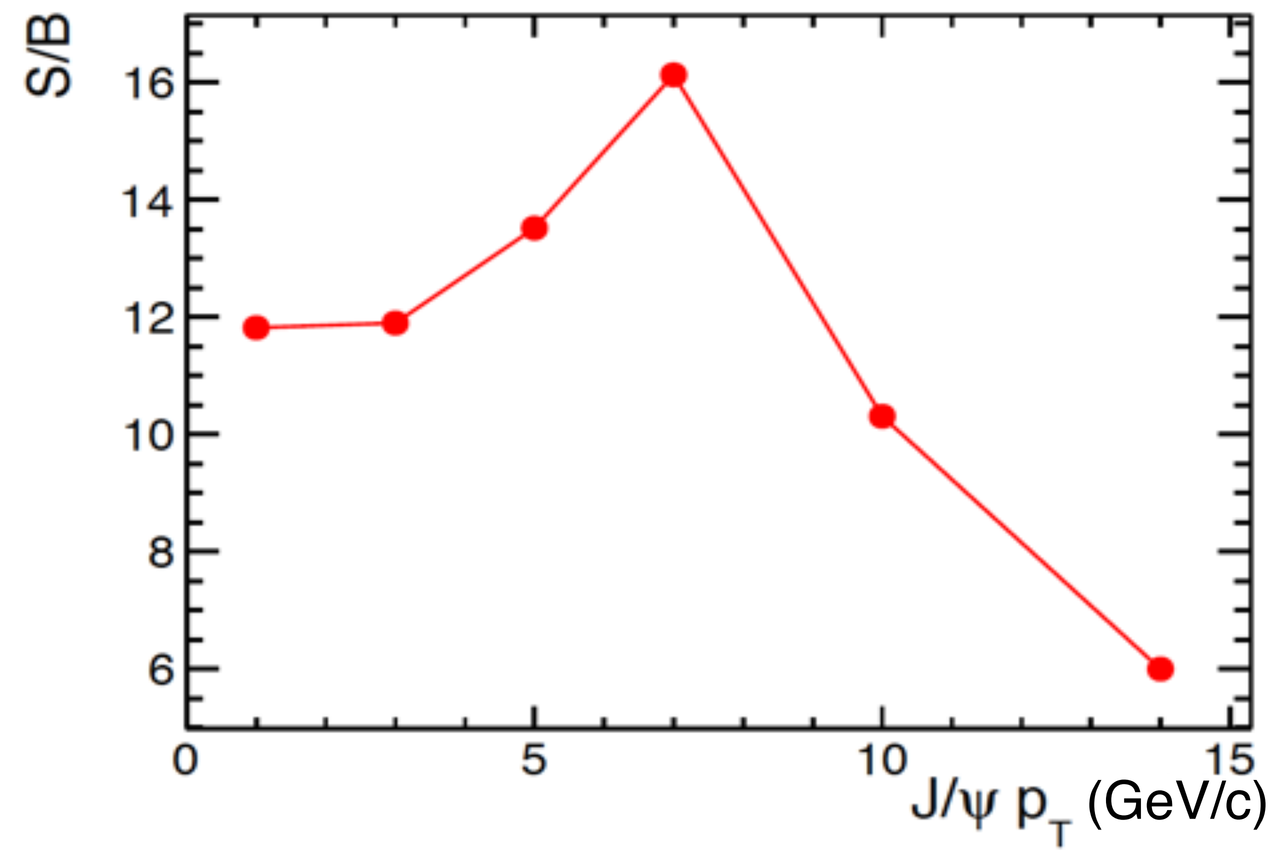




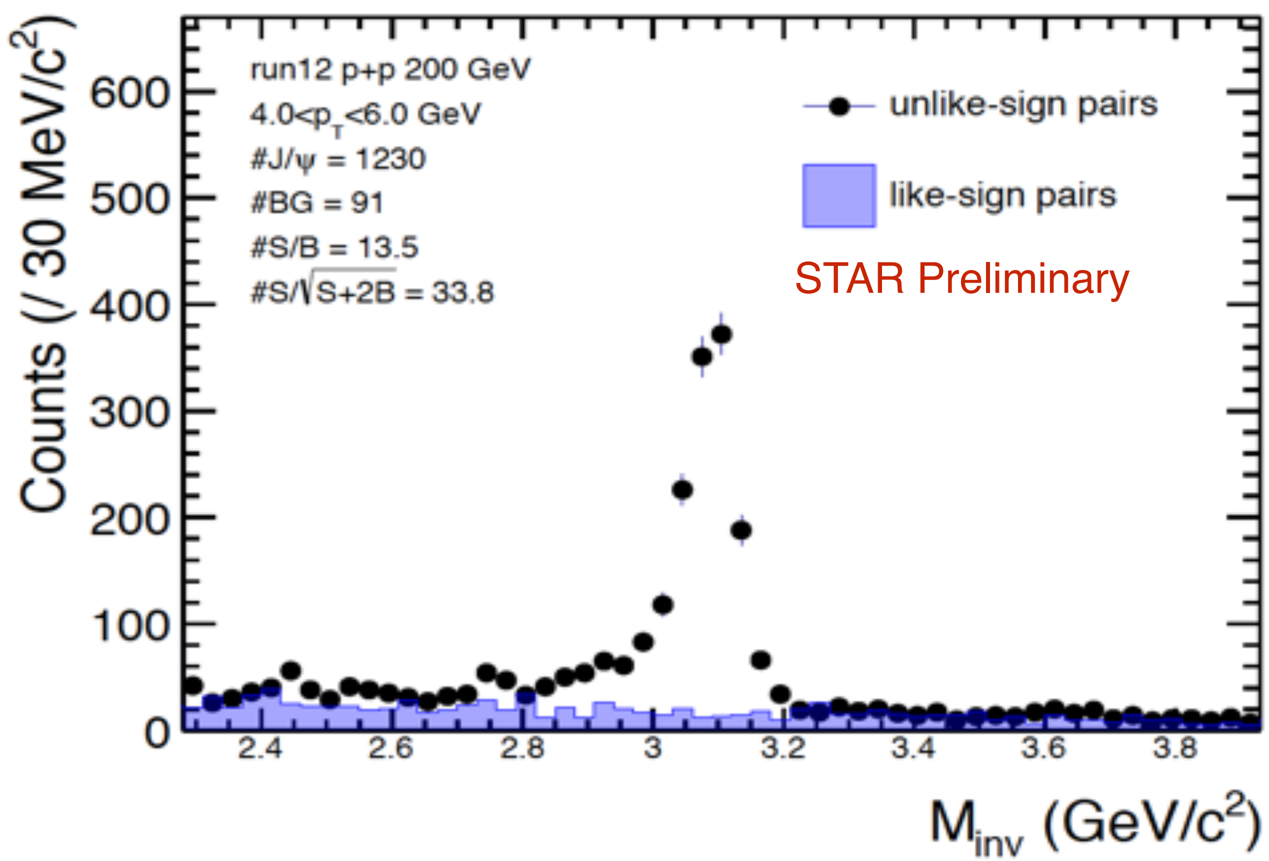


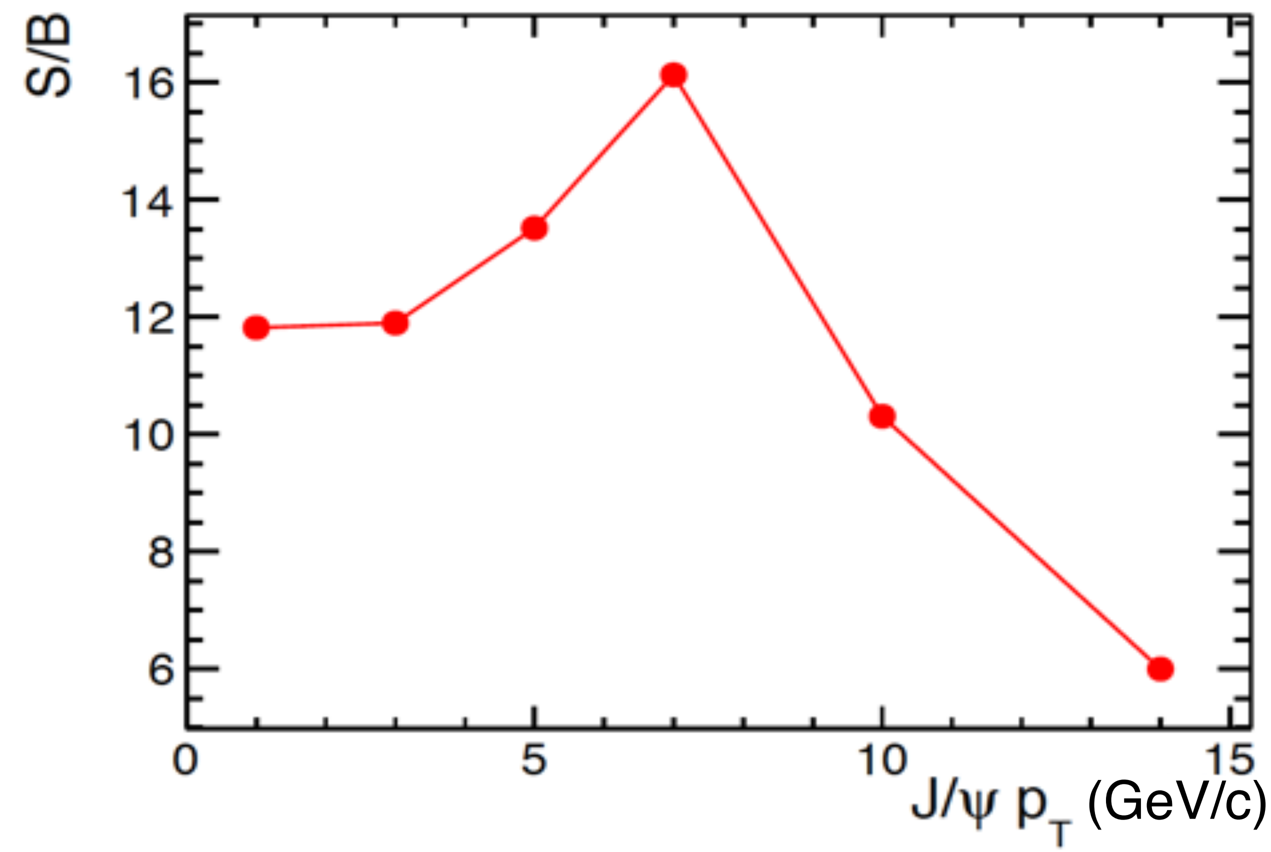
Analysis: Non-Prompt J/ψ

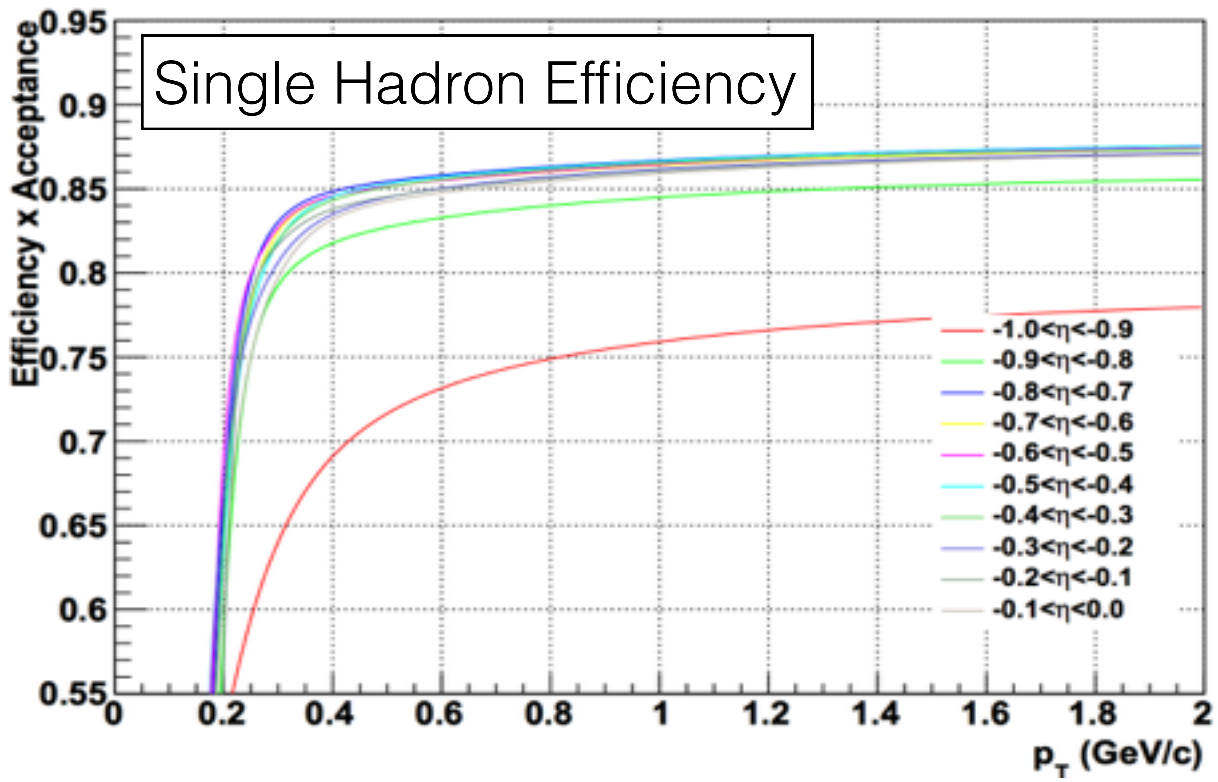




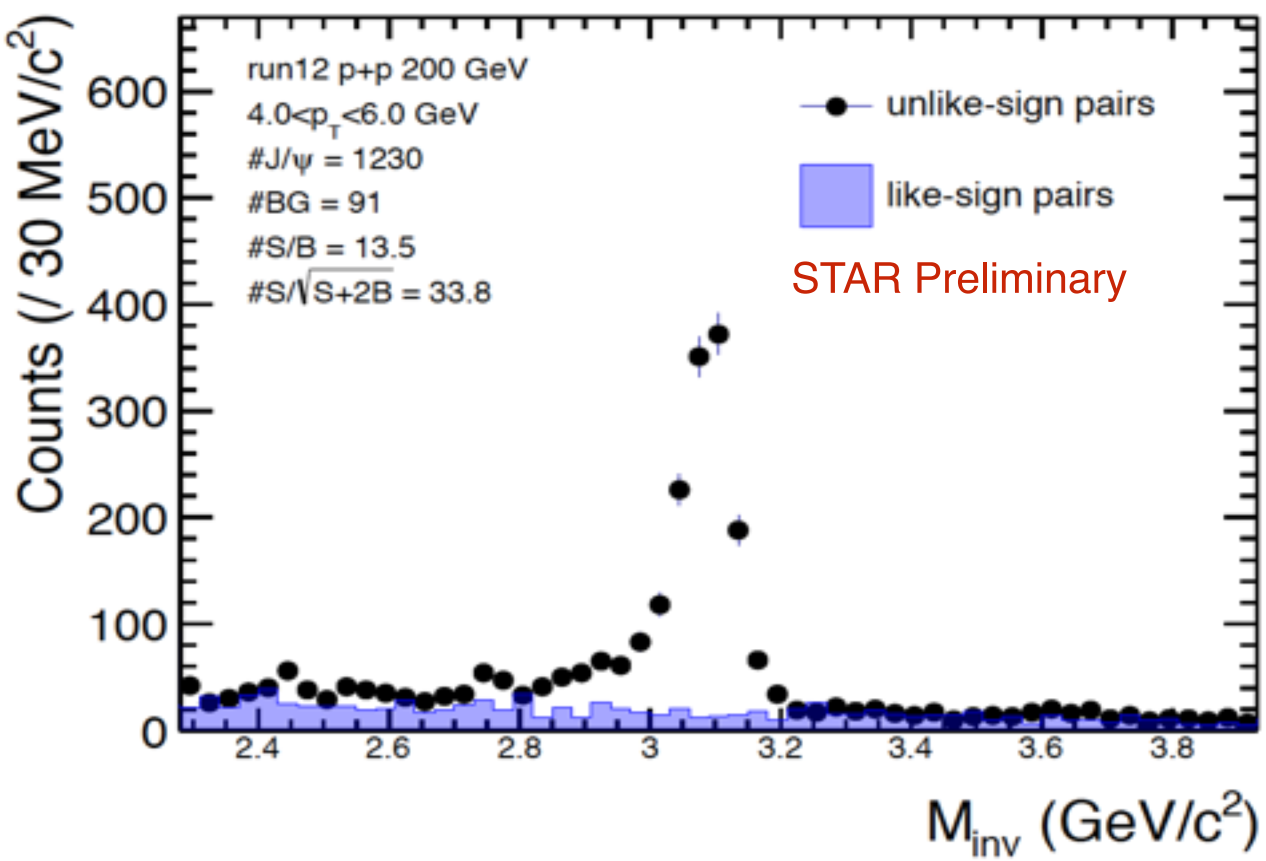
Analysis: Non-Prompt J/ψ

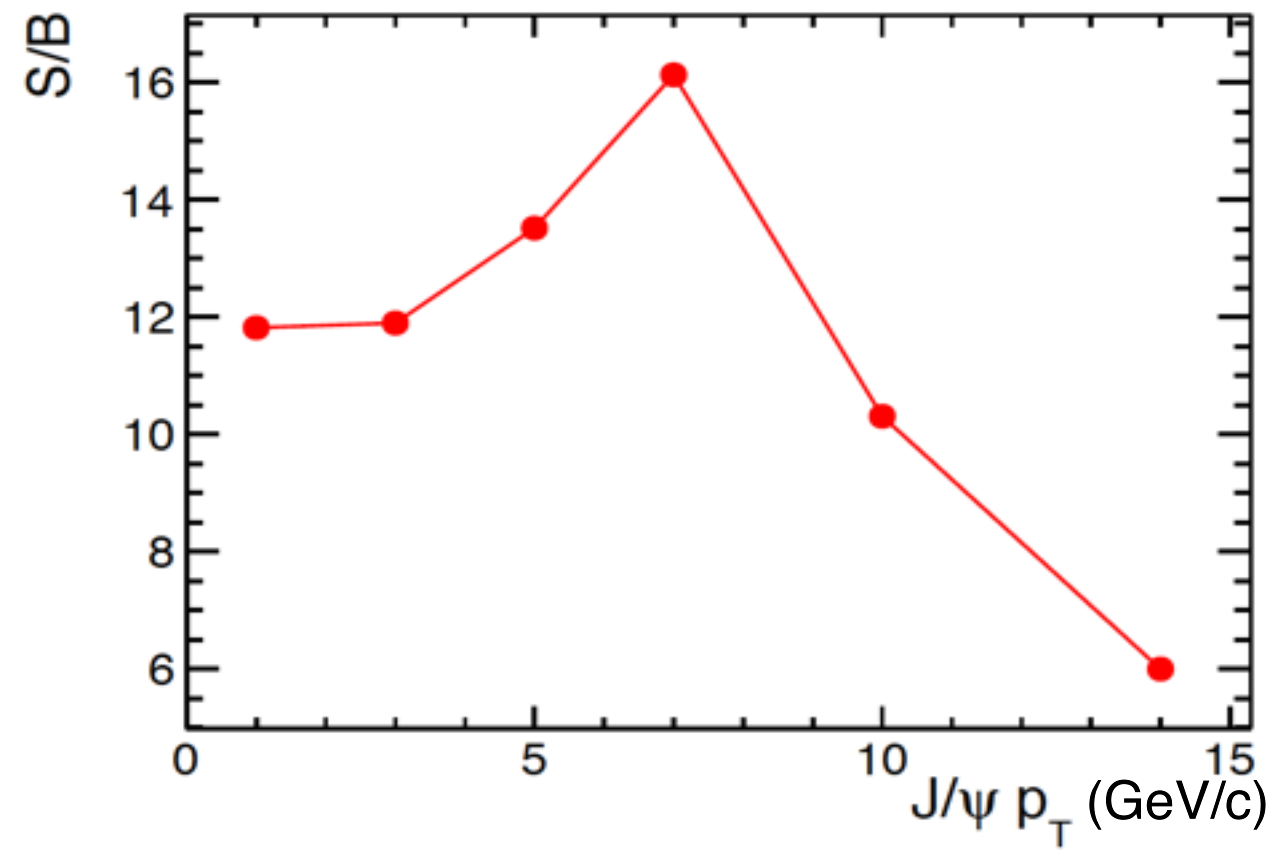


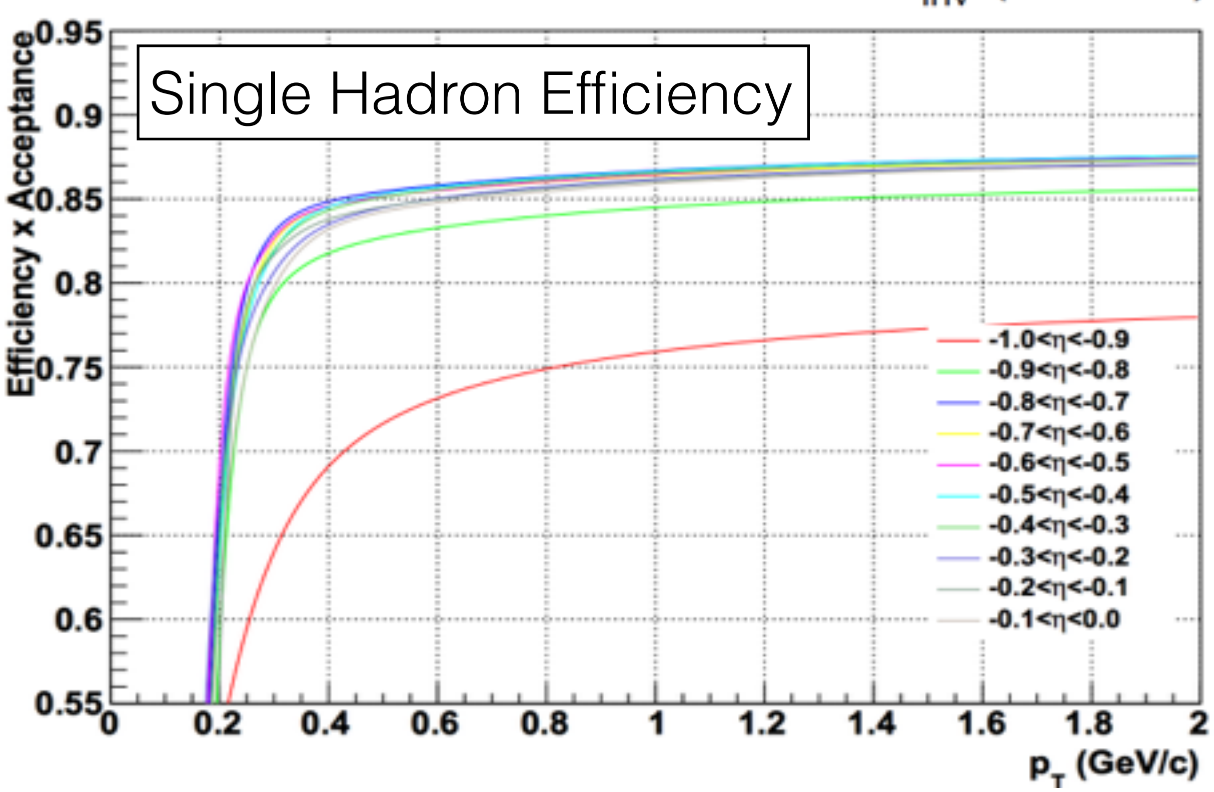


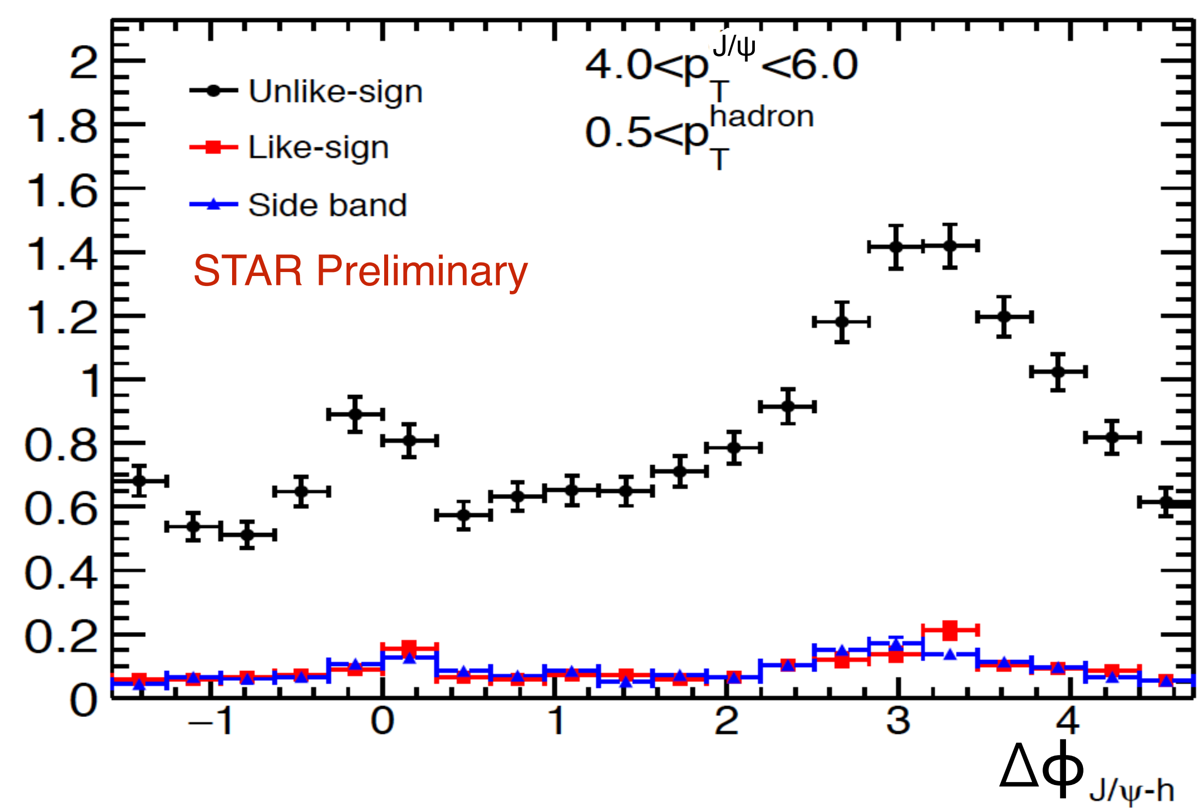


Analysis: Non-Prompt J/ψ



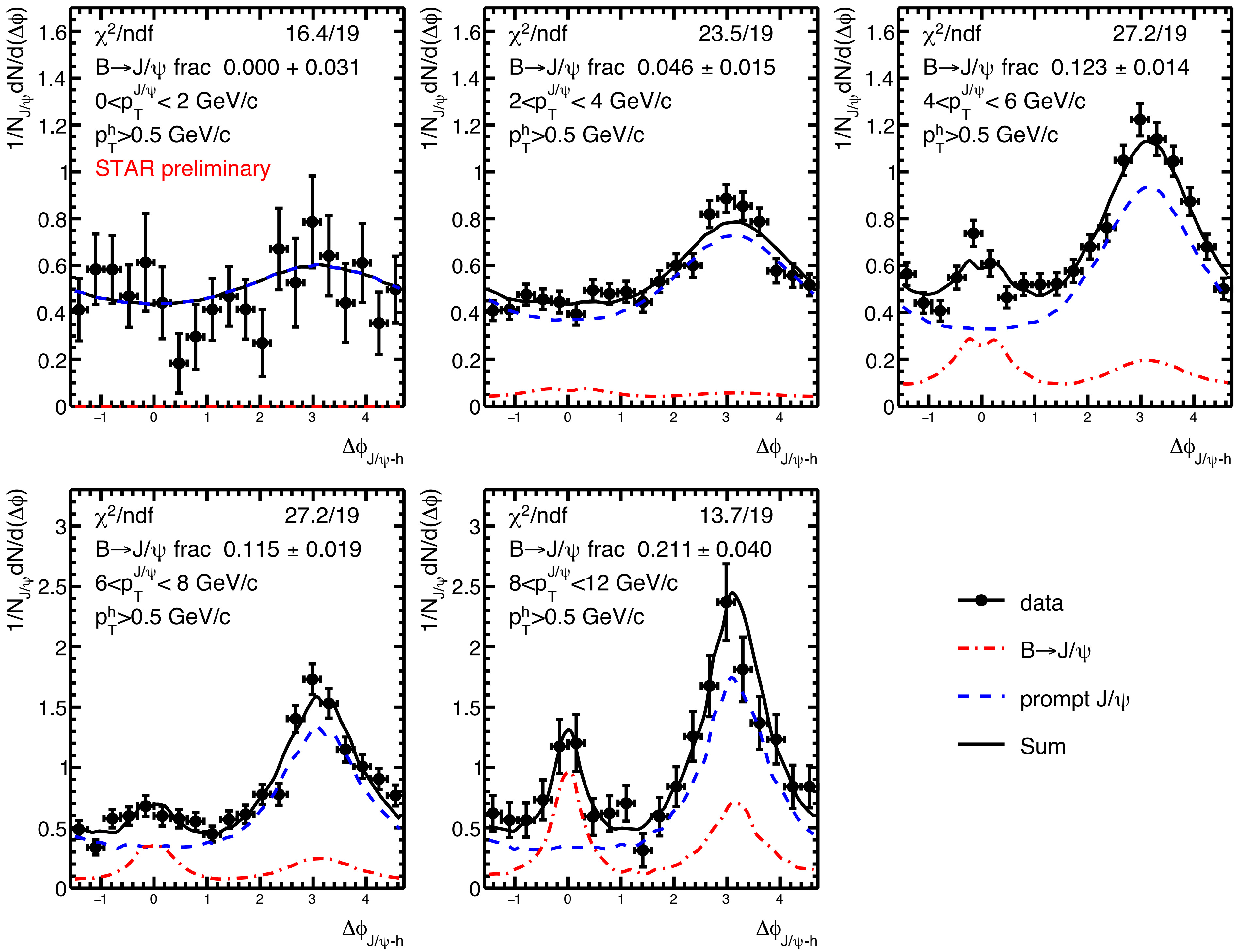




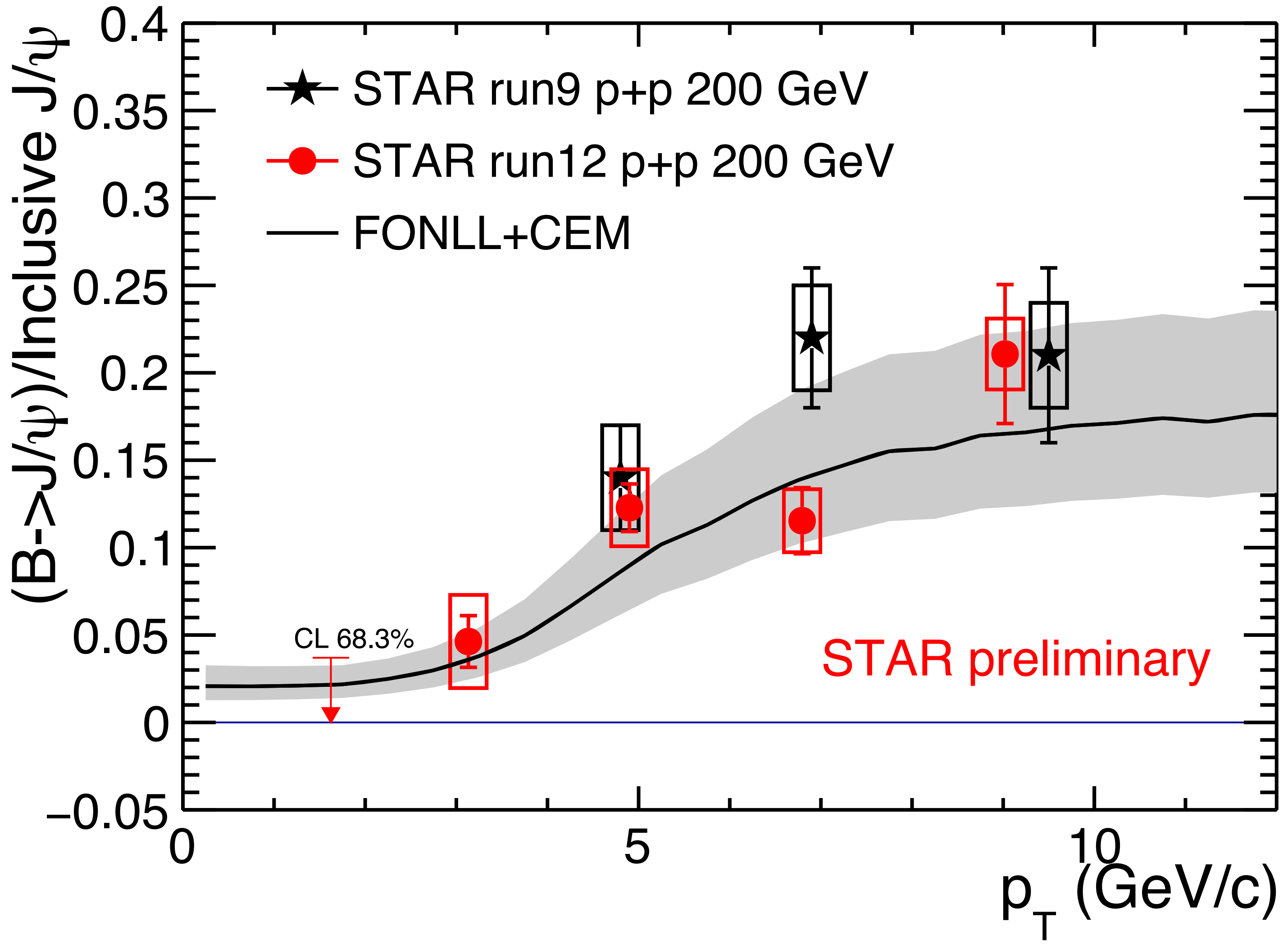


Analysis: Non-Prompt J/ψ

$$Data = p[1] * p[0] * B \rightarrow J/\Psi + p[1] * (1 - p[0]) * Prompt\ J/\Psi$$



Result: Non-Prompt J/ψ



- p[0] from the fit is the percentage contribution of B → J/ψ
- Results cover a larger p_T range and are more precise than the previous measurement.
- Experimental results confirm FONLL+CEM calculations.

FONLL+CEM:
Bedjidian M, Blaschke D, Bodwin G T, Carrer N, Cole B et al. 2004 (Preprint hep-ph/0311048)
Cacciari M, Nason P and Vogt R 2005 Phys.Rev.Lett. 95 122001 (Preprint hep-ph/0502203)
STAR Run 9:
The STAR Collaboration, Phys. Lett. B 722 (2013) 55

Analysis Method: NPE

- Using $\Delta\phi$ correlations, we can also separate the B→e and D→e contributions to non-photonic electrons (NPE).

Inclusive electron

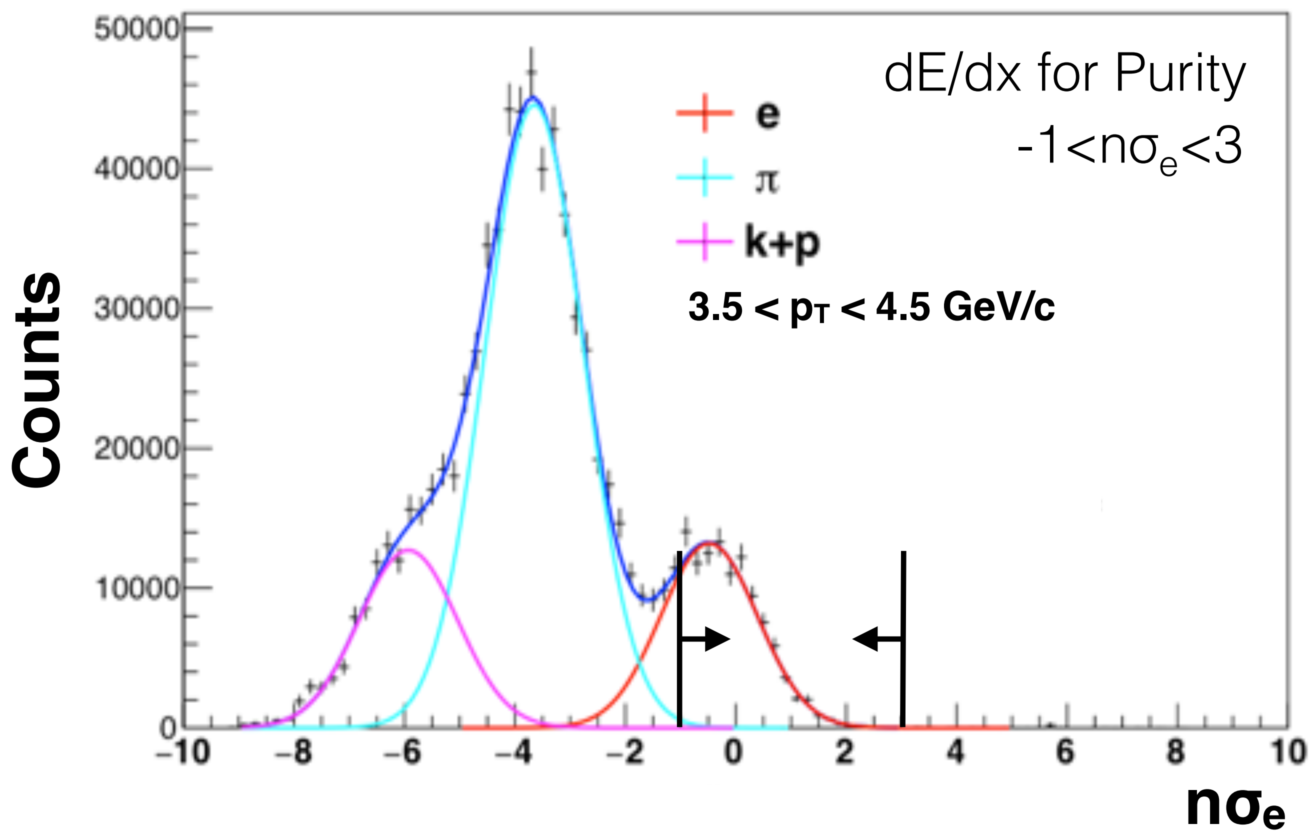
After all the ePID cuts:
Hadron contamination

- Non-photonic electron(from open heavy flavor decay)
  bottom and charm hadrons via semi-leptonic decay.
- PHE
  ePID and pair invariant mass cuts
  Not 100% reconstructed
  - Gamma conversion $\gamma \rightarrow e^+e^-$ (~54%)
  - π^0 Dalitz Decay $\pi^0 \rightarrow \gamma e^+e^-$ (~36%)
  - η Dalitz Decay $\eta \rightarrow \gamma e^+e^-$ (~10%)

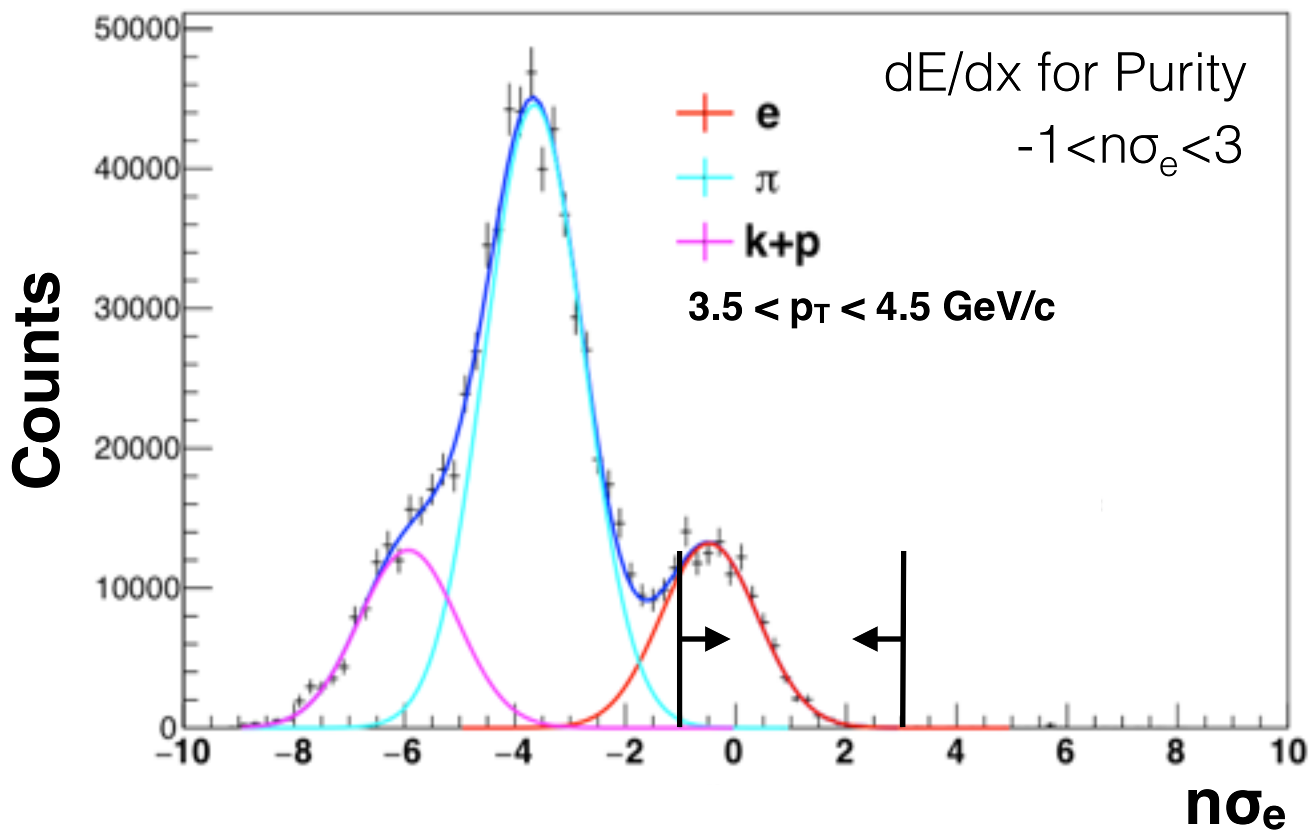
$$\Delta\phi_{NPE} = \Delta\phi_{Semi} - (\frac{1}{\epsilon} - 1)\Delta\phi_{US} + \frac{1}{\epsilon}\Delta\phi_{LS} - (1 - e_{pure})\Delta\phi_{HH}$$

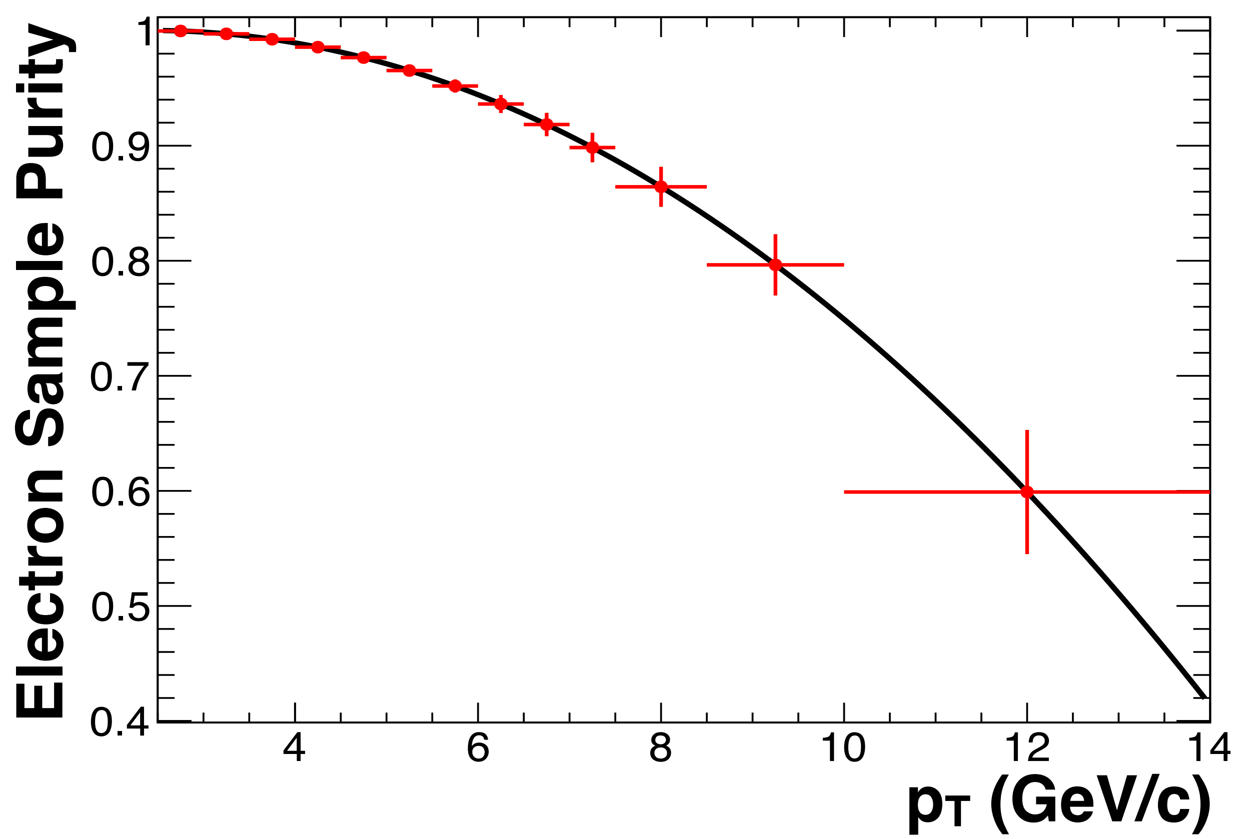
Semi-Inclusive (Semi): All non-paired trigger electrons
Unlike Sign (US): Paired trigger electrons, with unlike sign partner
Like Sign (LS): Paired trigger electrons, with like sign partner
Hadron-Hadron (HH): Pure trigger pion sample
e_{pure}: Purity of the trigger electron sample
ϵ: Photonic electron reconstruction efficiency

Analysis Method: NPE

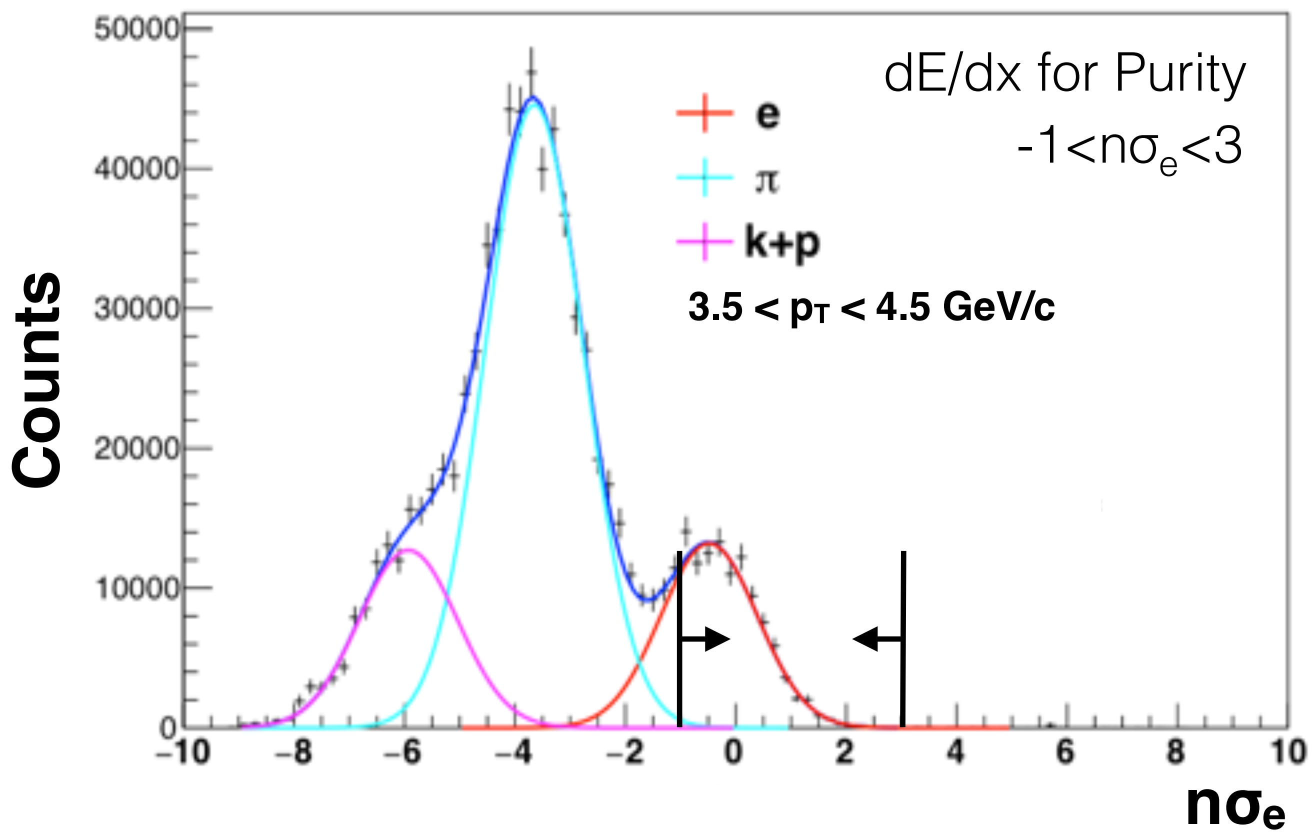


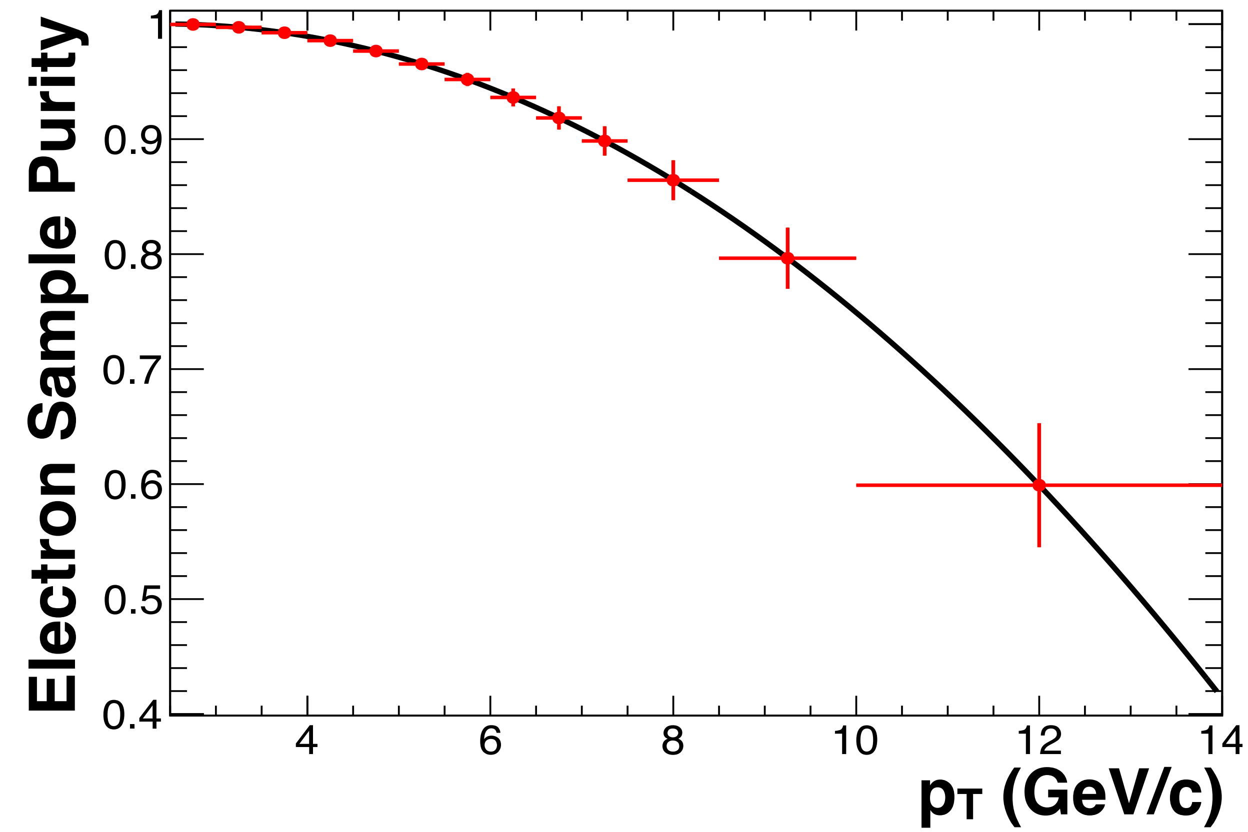
Analysis Method: NPE

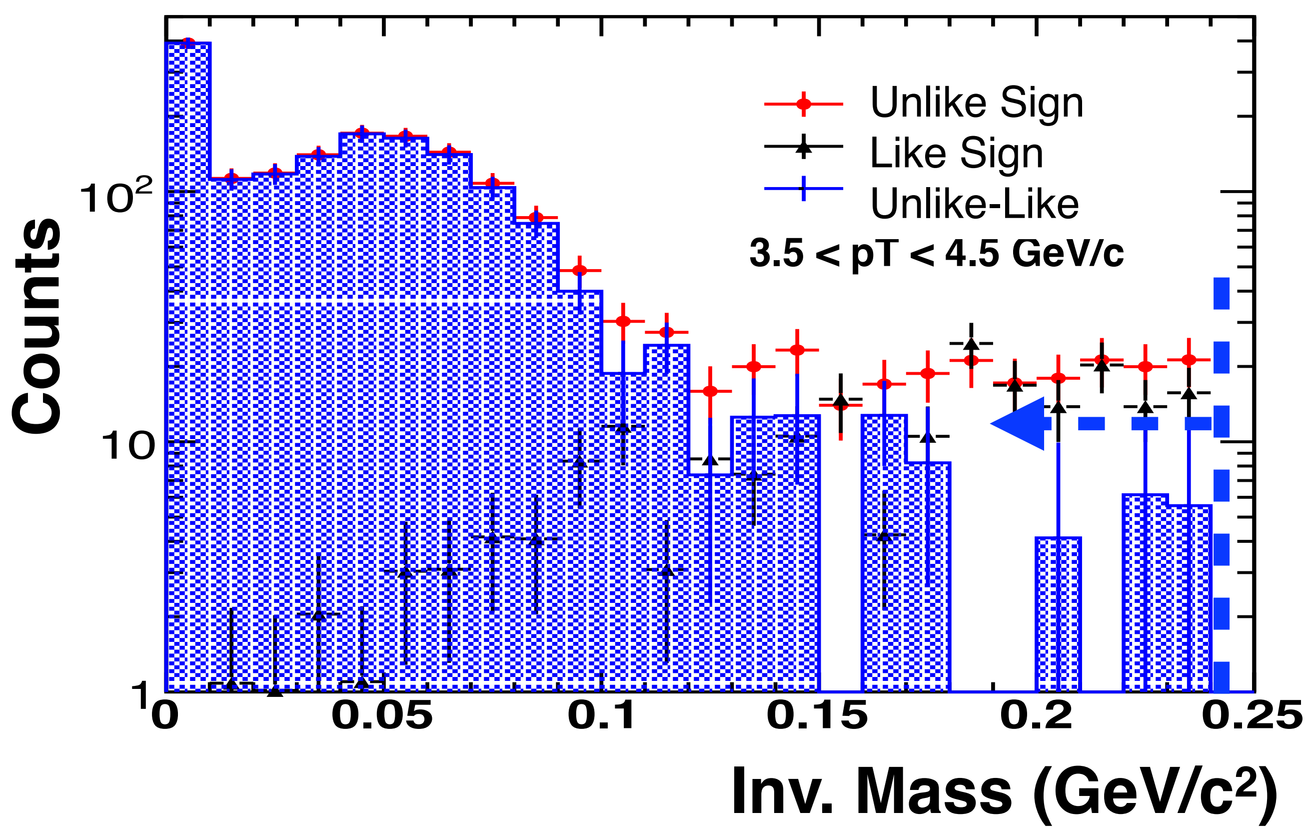




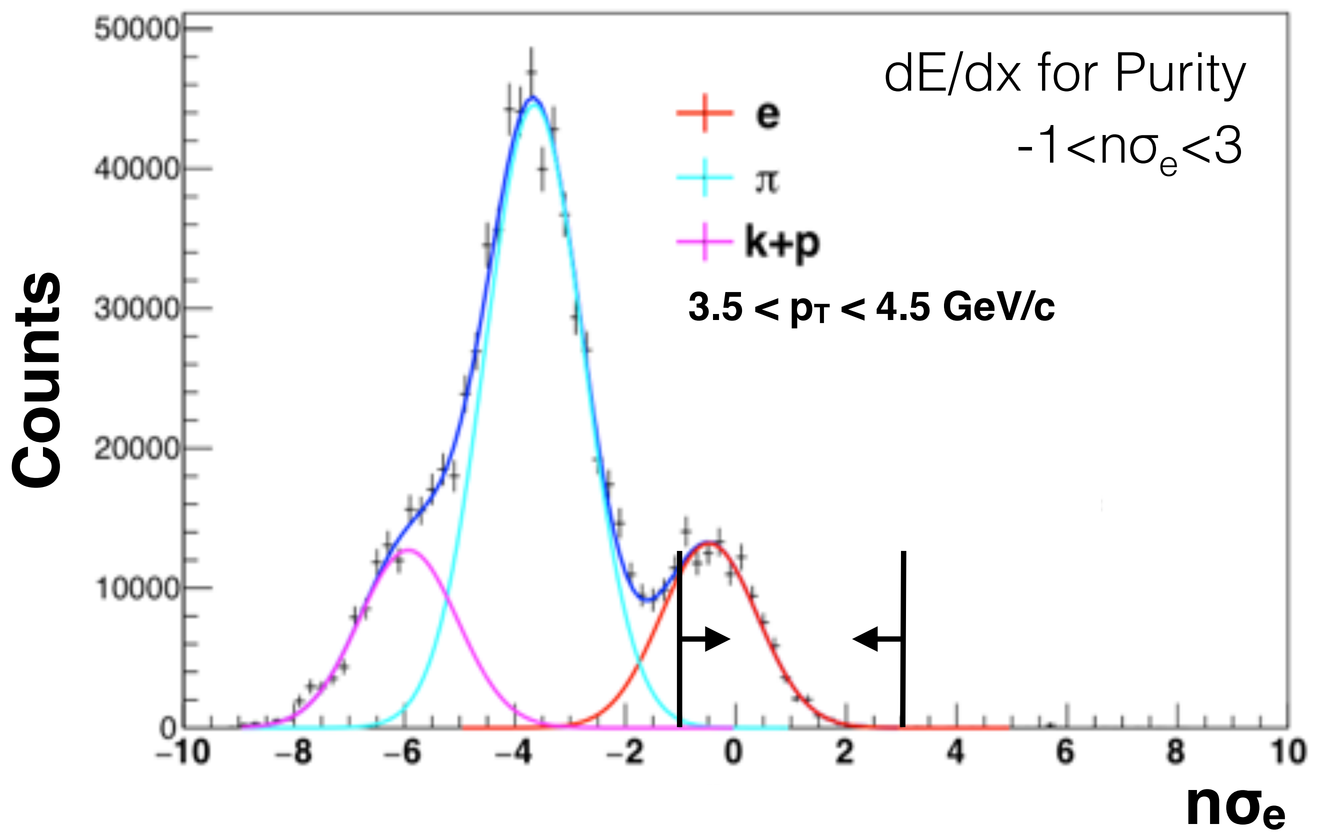
Analysis Method: NPE

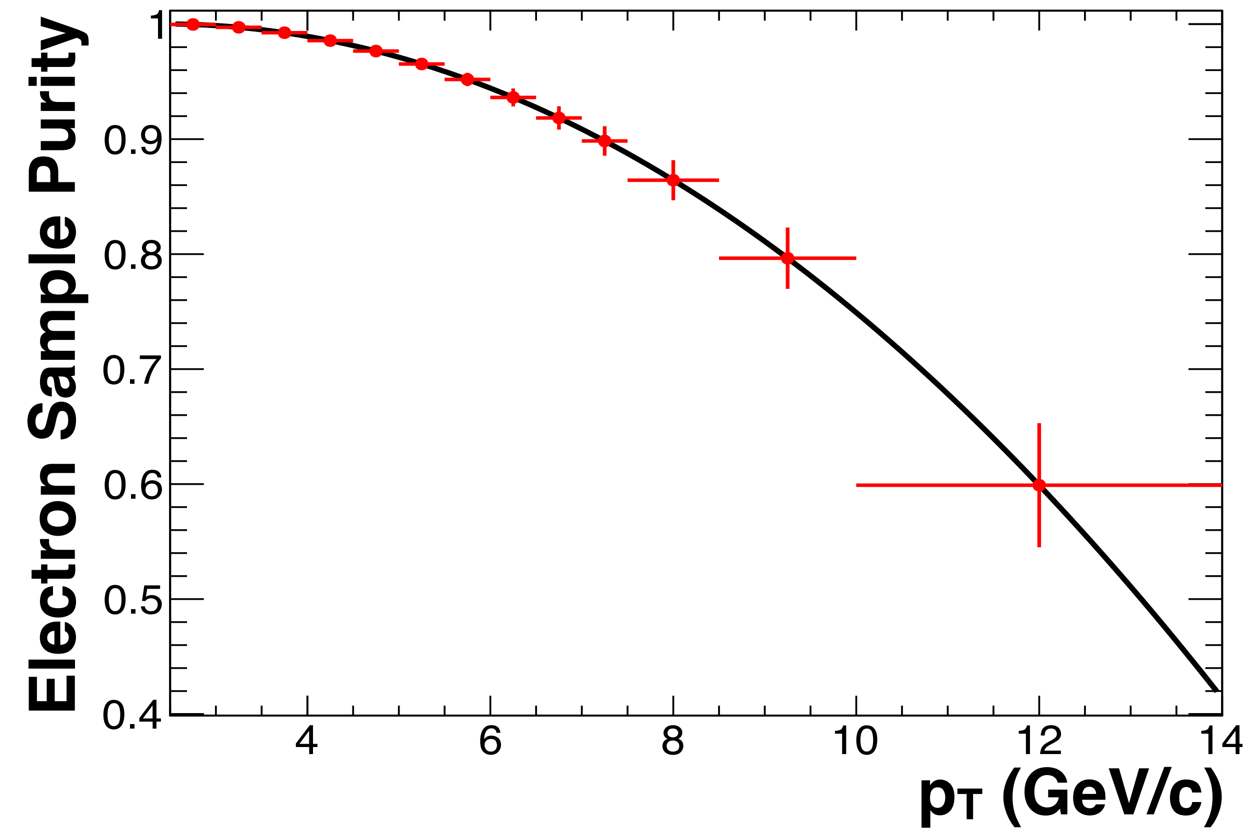


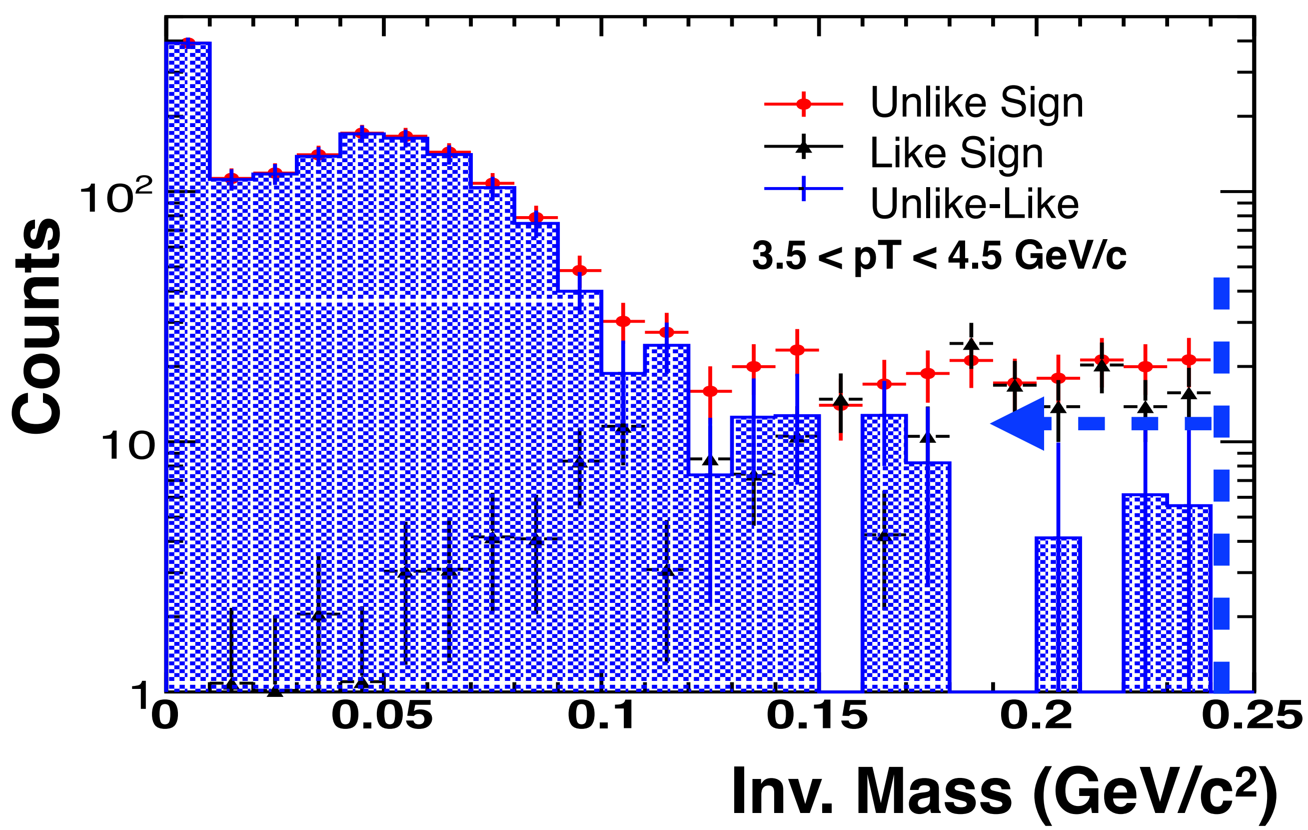


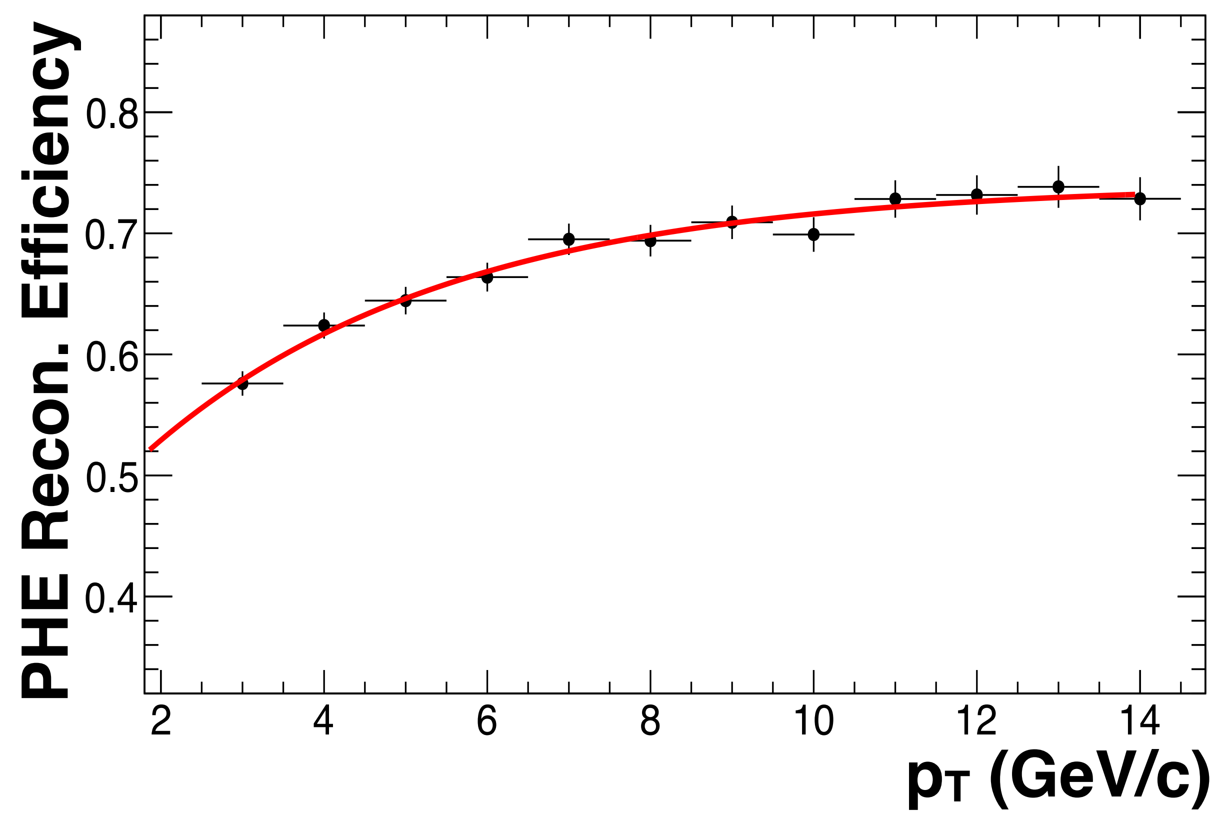


Analysis Method: NPE



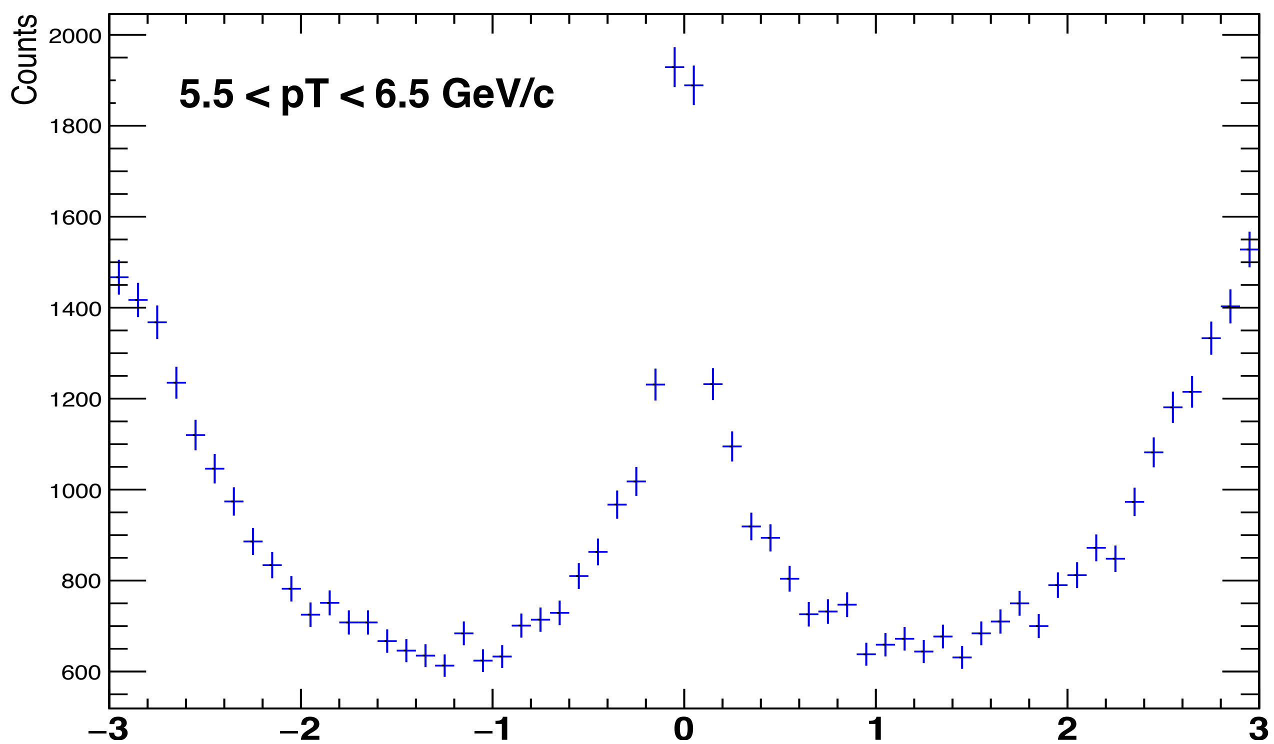




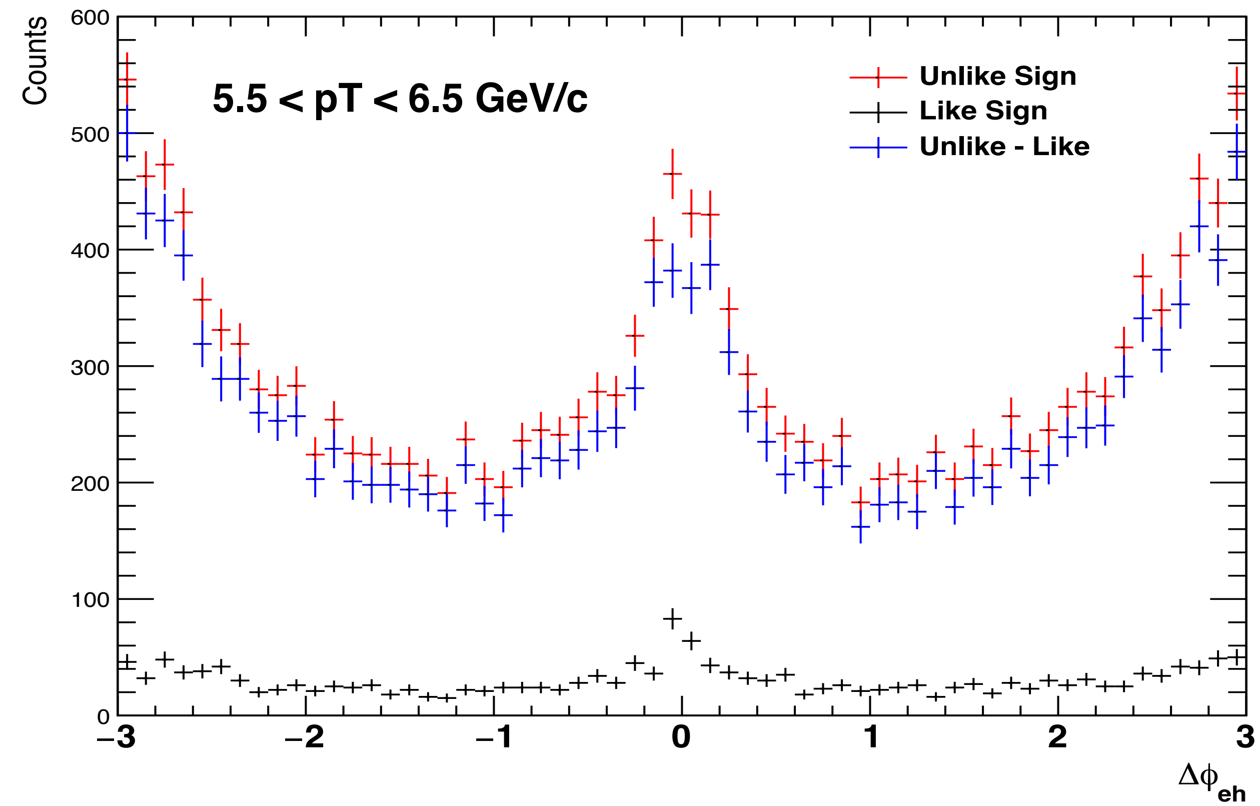


Analysis Method: NPE

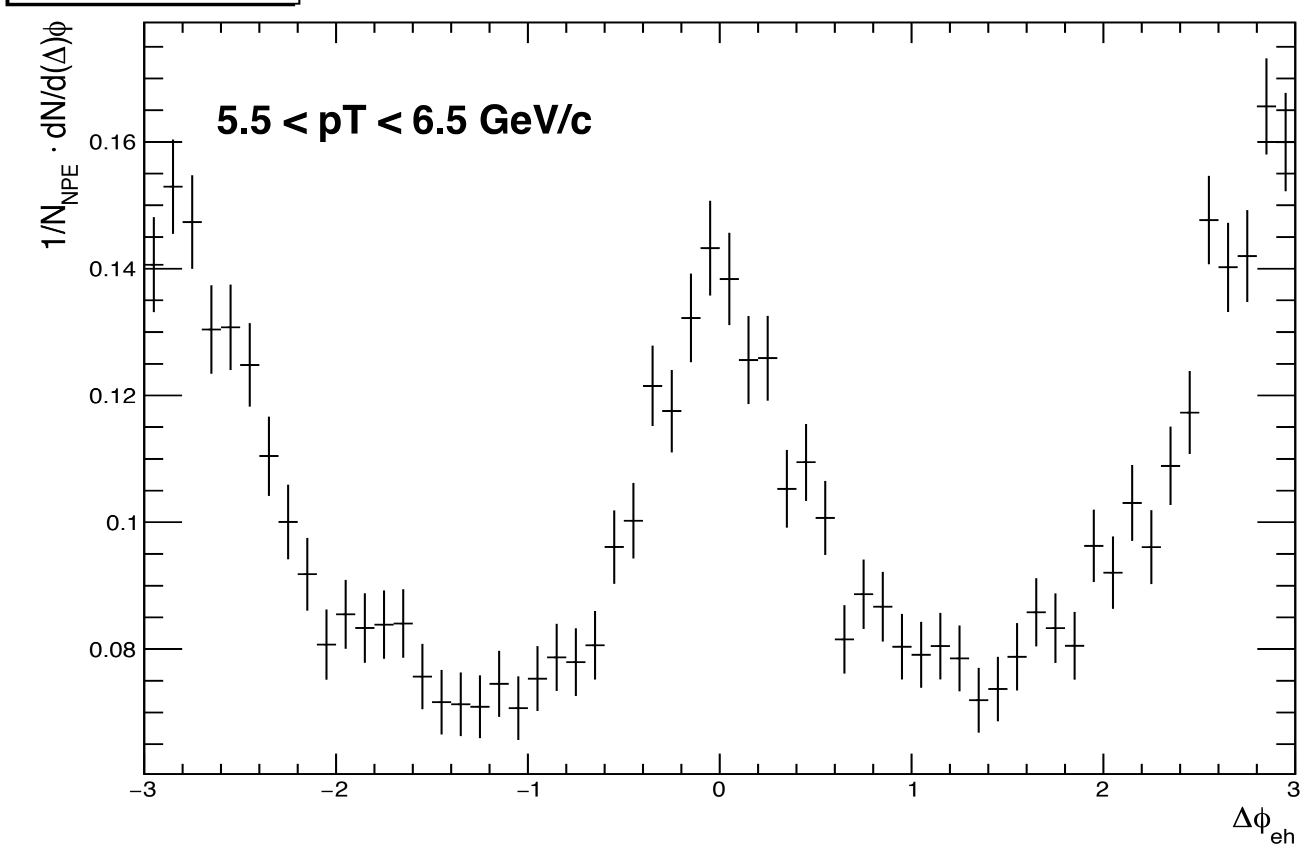
Inclusive Electron-Hadron Δϕ

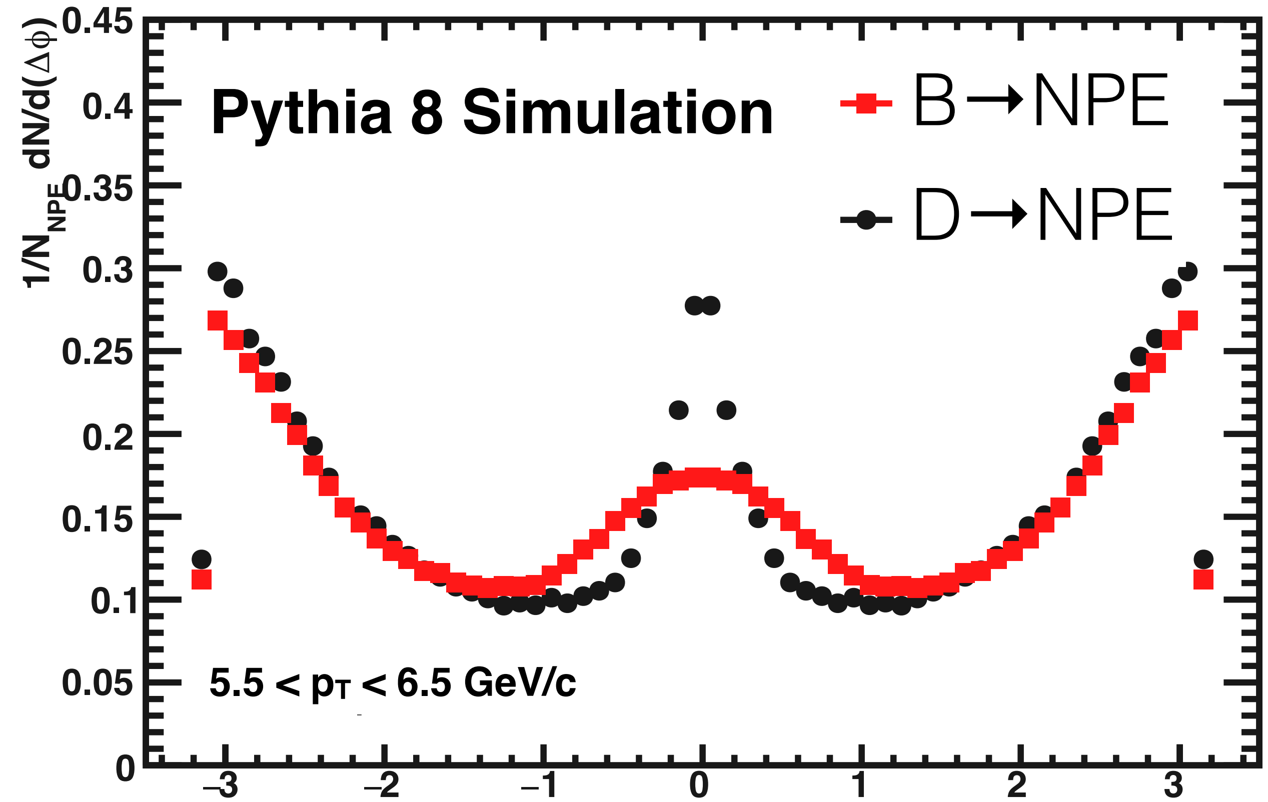


Photonic Electron Δϕ



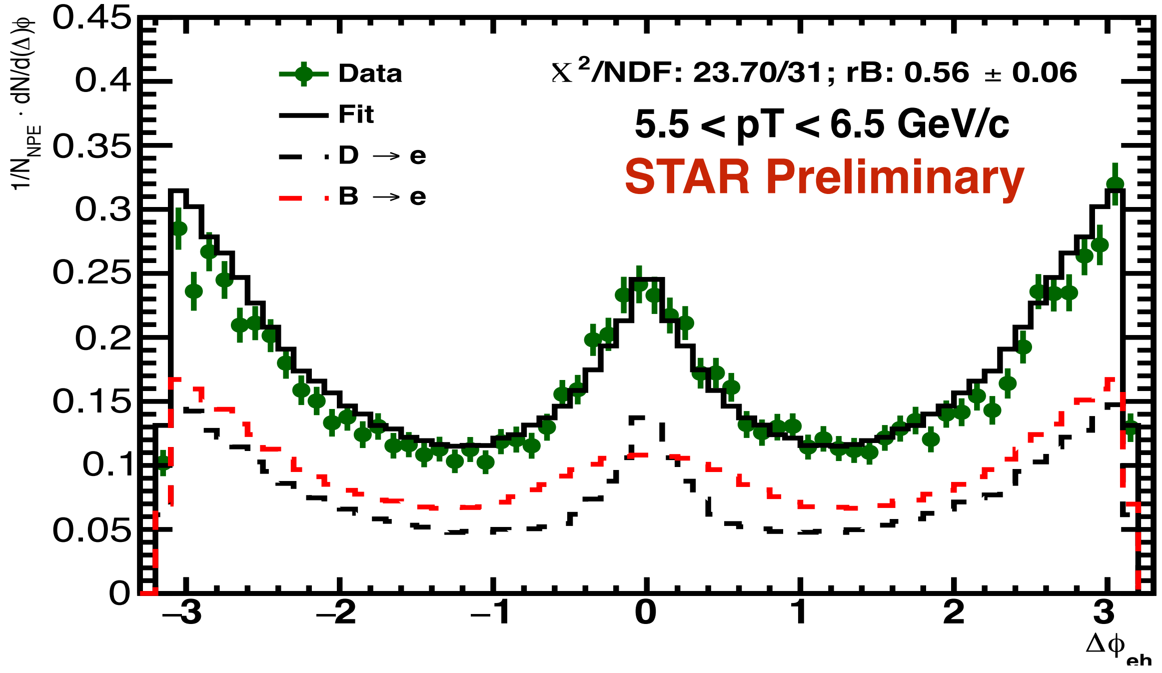
NPE-had Δϕ





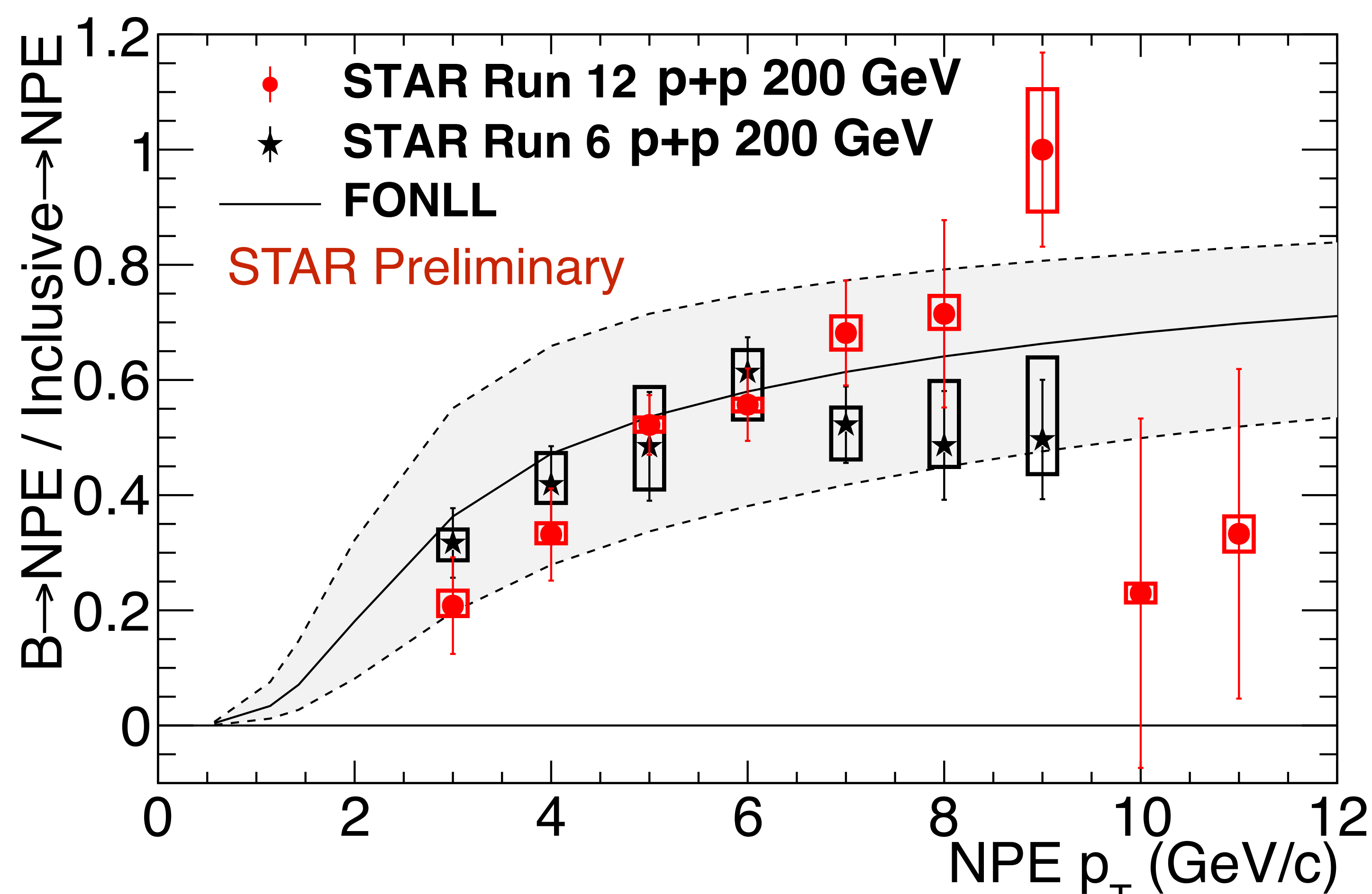
Result: NPE

$$Data = p[1] * p[0] * TemplateB + p[1] * (1 - p[0]) * TemplateC$$



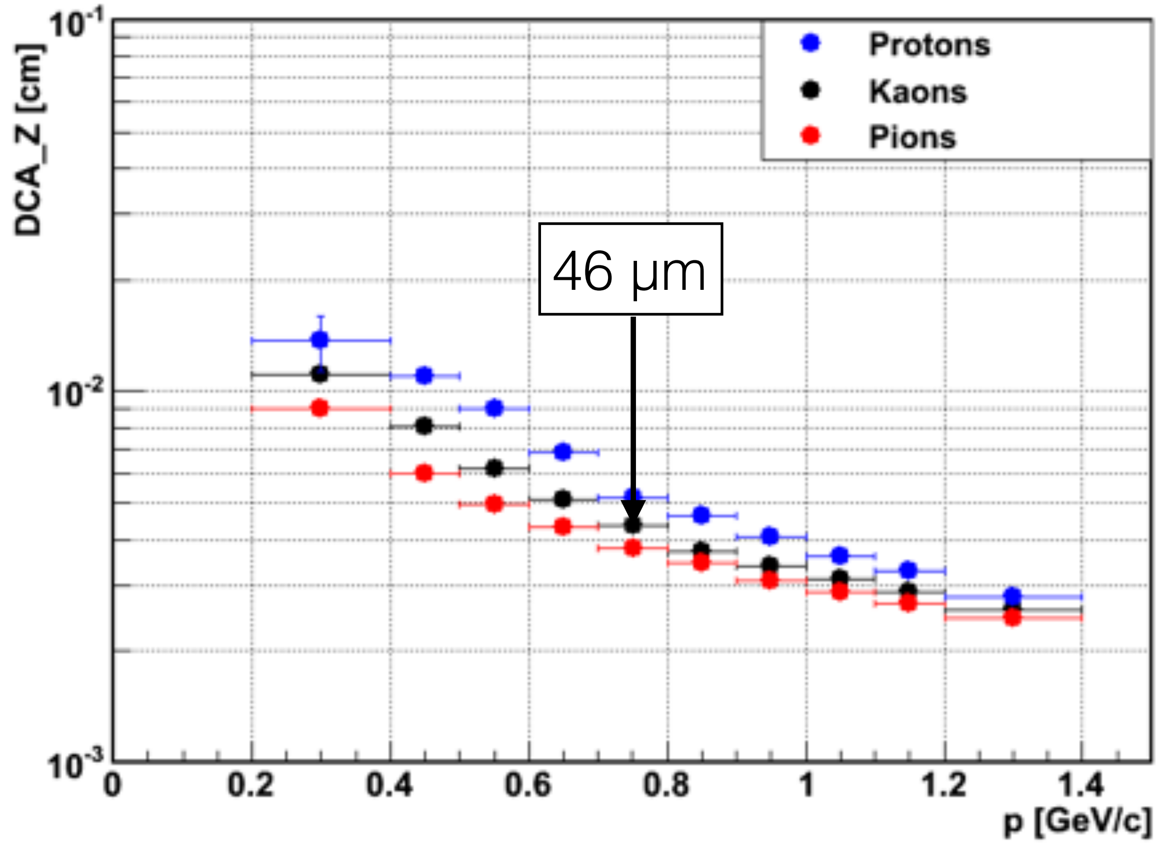
- p[0] is the B→e template contribution percentage
- p[1] acts as an overall normalization

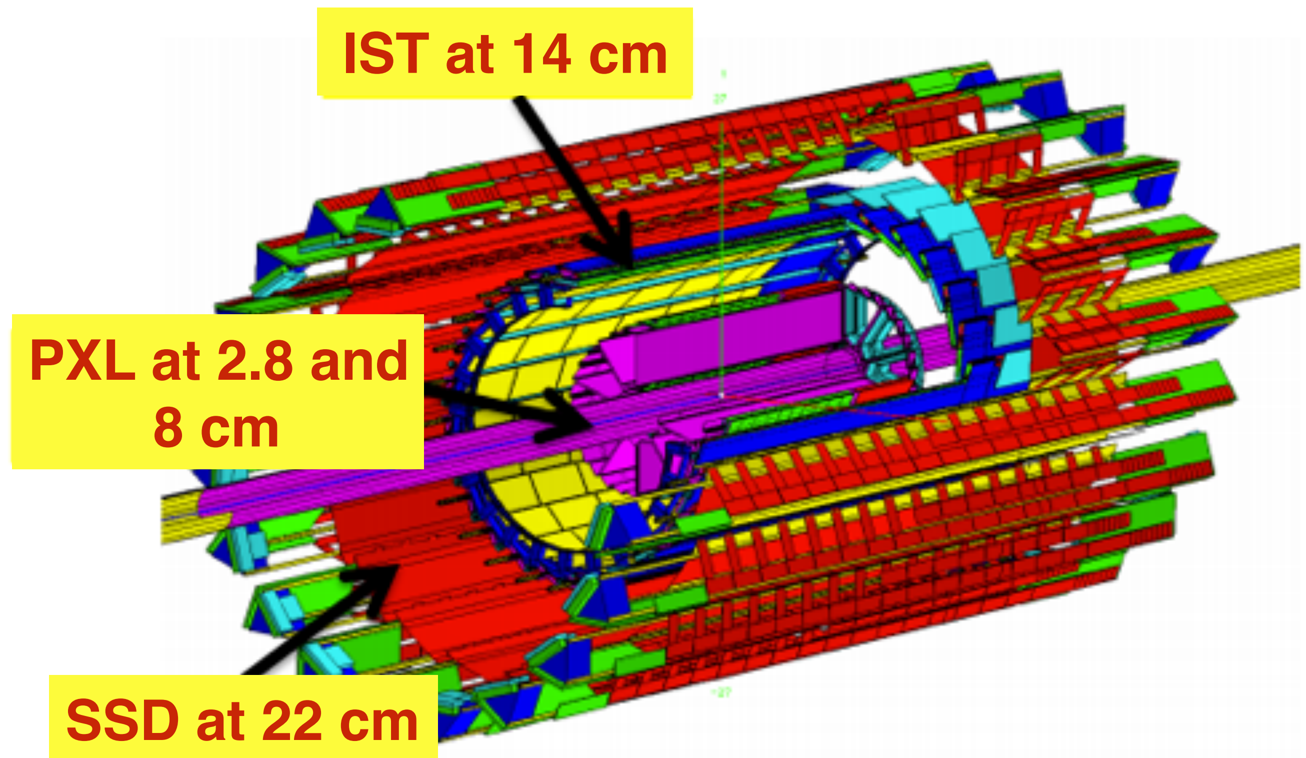
- Preliminary result agrees with previous STAR analysis for $p_T < 8.5$ GeV/c
- First Order Next to Leading Logarithm (FONLL) is a pQCD prediction for the ratio of B→NPE to total NPE cross section.
- Improvement is expected for the high p_T bins in NPE analysis.

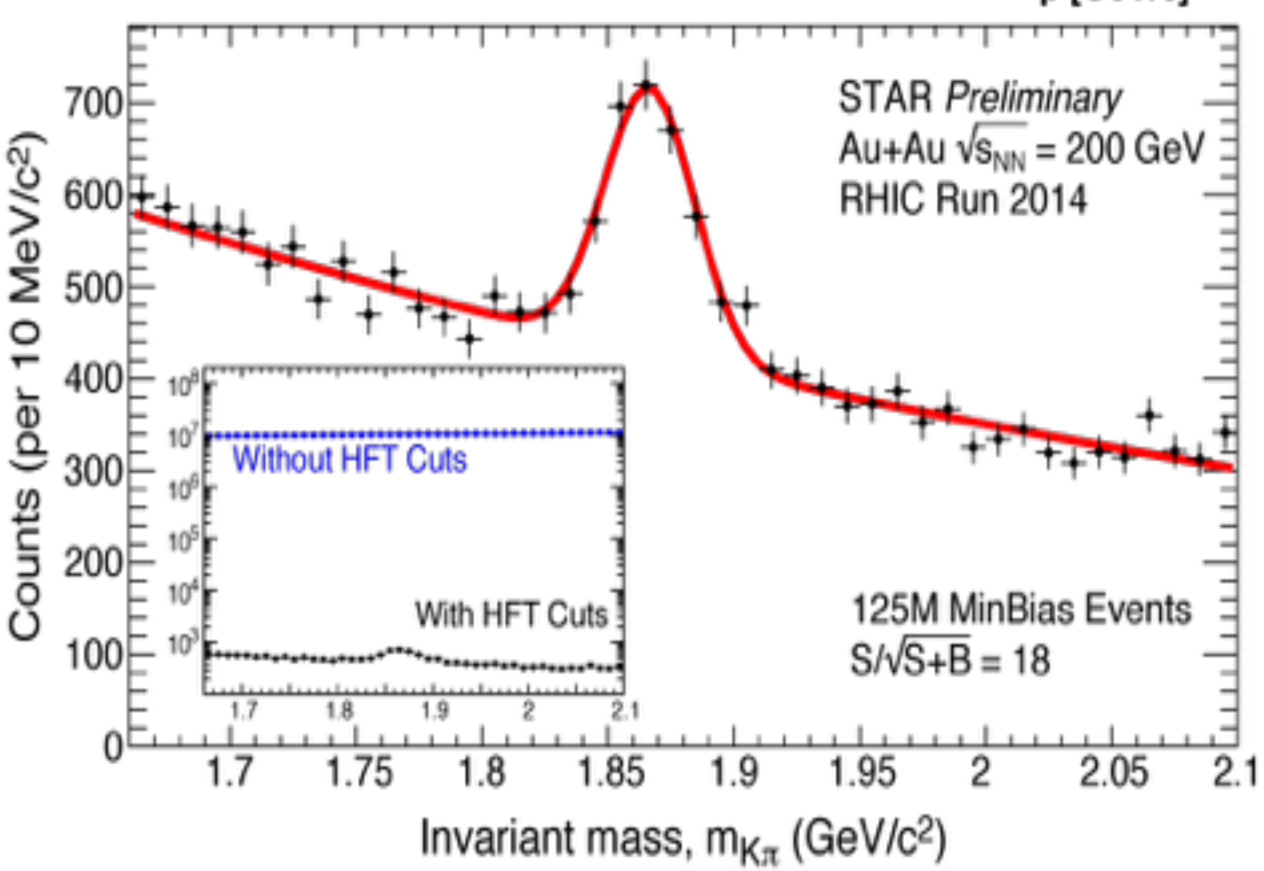


STAR Run 6: Phys.Rev.Lett. 105, 202301 (2010)
FONLL: Phys.Rev.Lett. 95 122001 (Preprint hep-ph/0502203)

Heavy Flavor Tracker

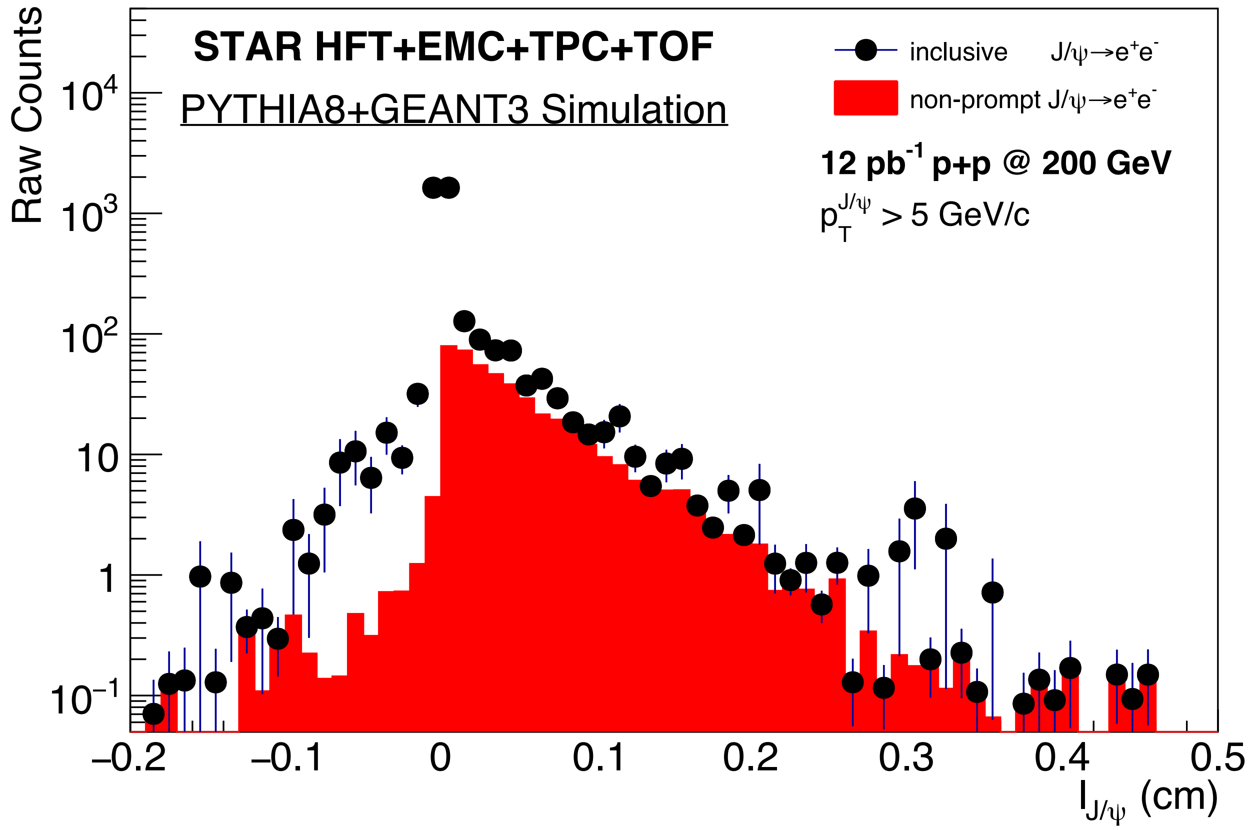


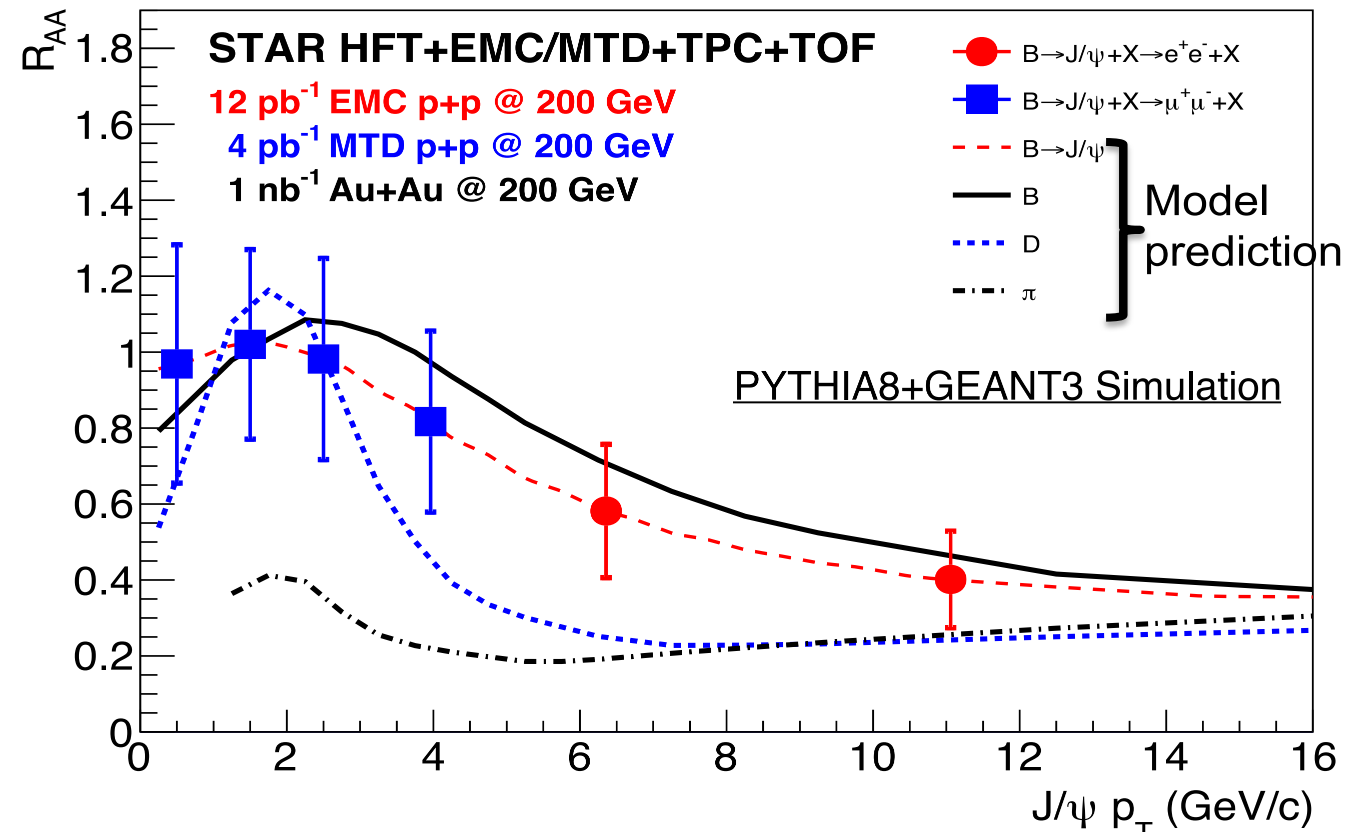




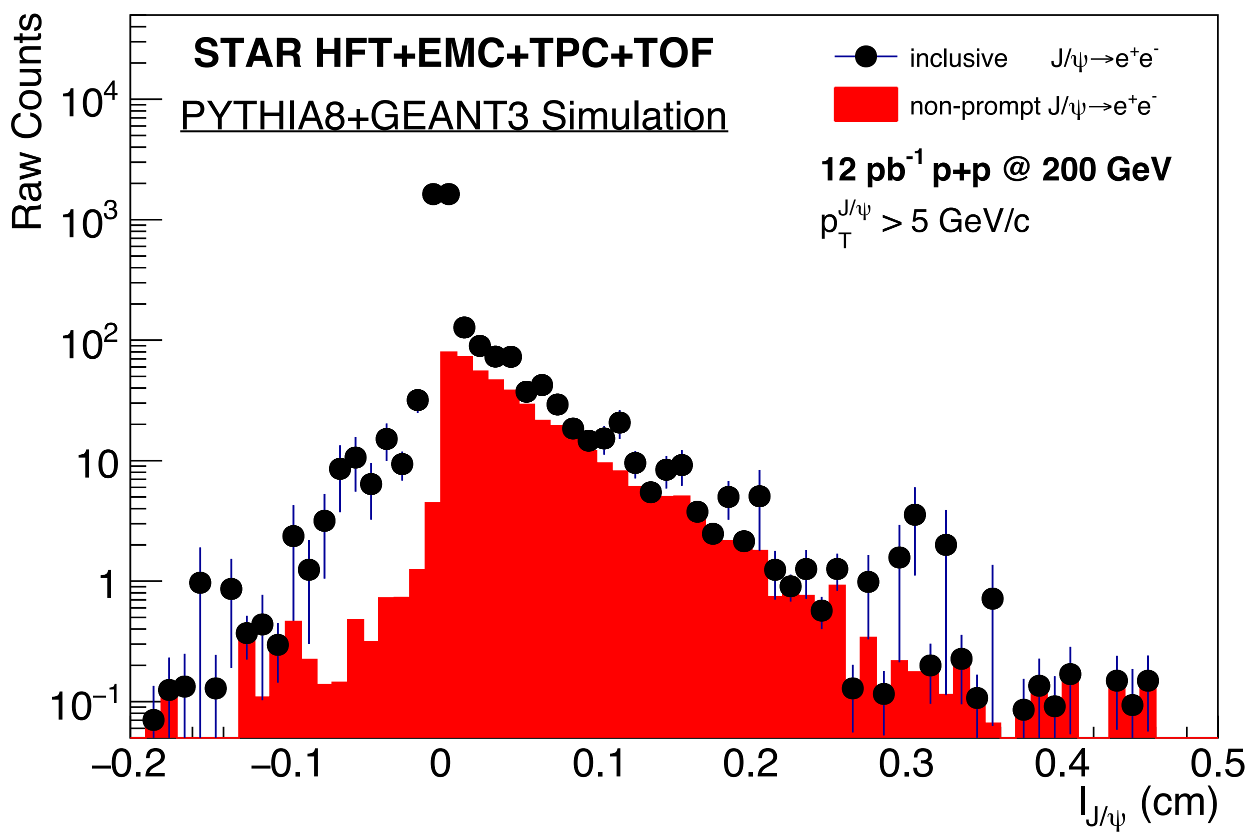
- The HFT exceeded the goal for pointing resolution.
- Use this pointing resolution to identify particles from secondary vertexes, greatly reduces the backgrounds.
- D^0 mesons can be identified via reconstruction of the $D^0 \rightarrow K\pi$ channel with excellent significance.

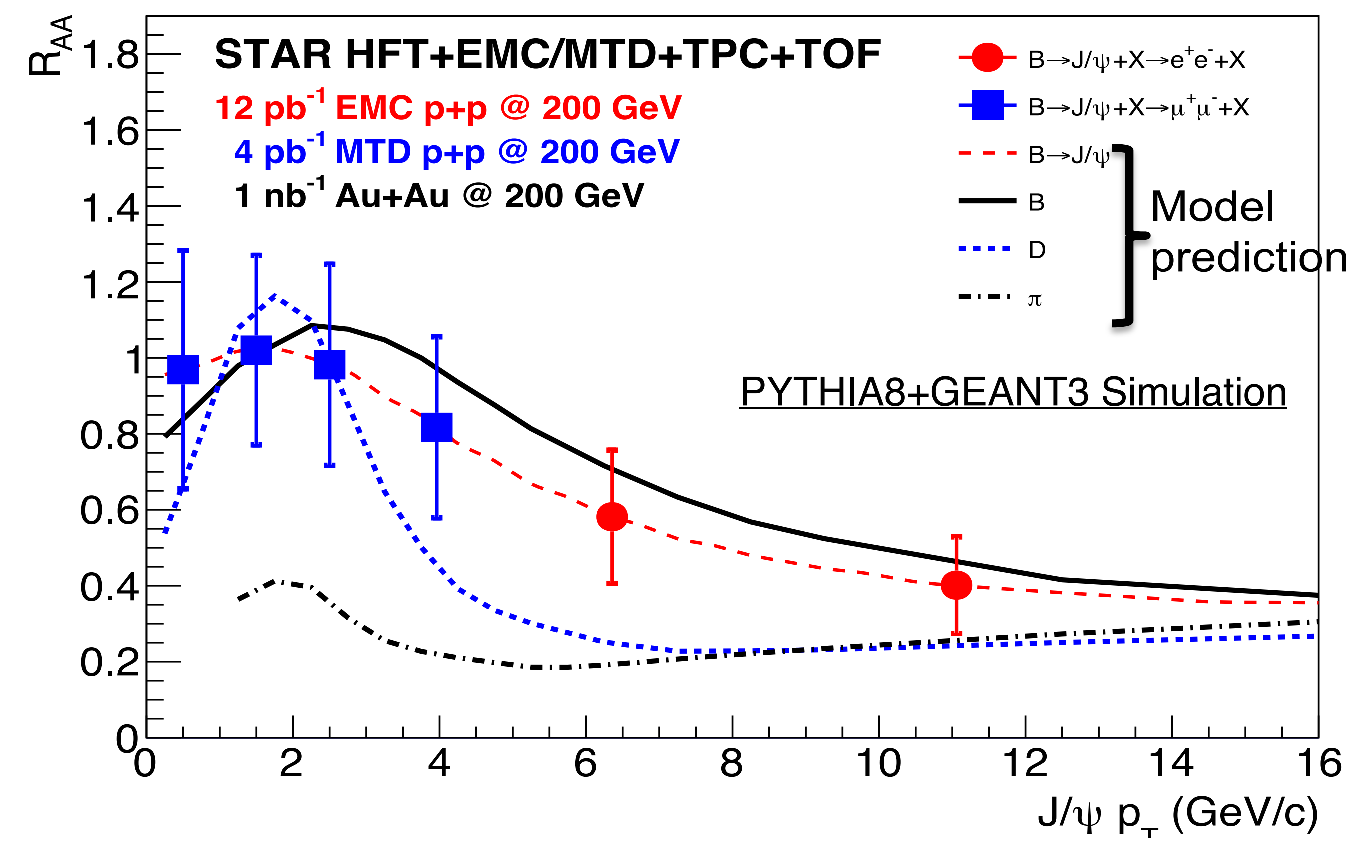
Projected Results: HFT

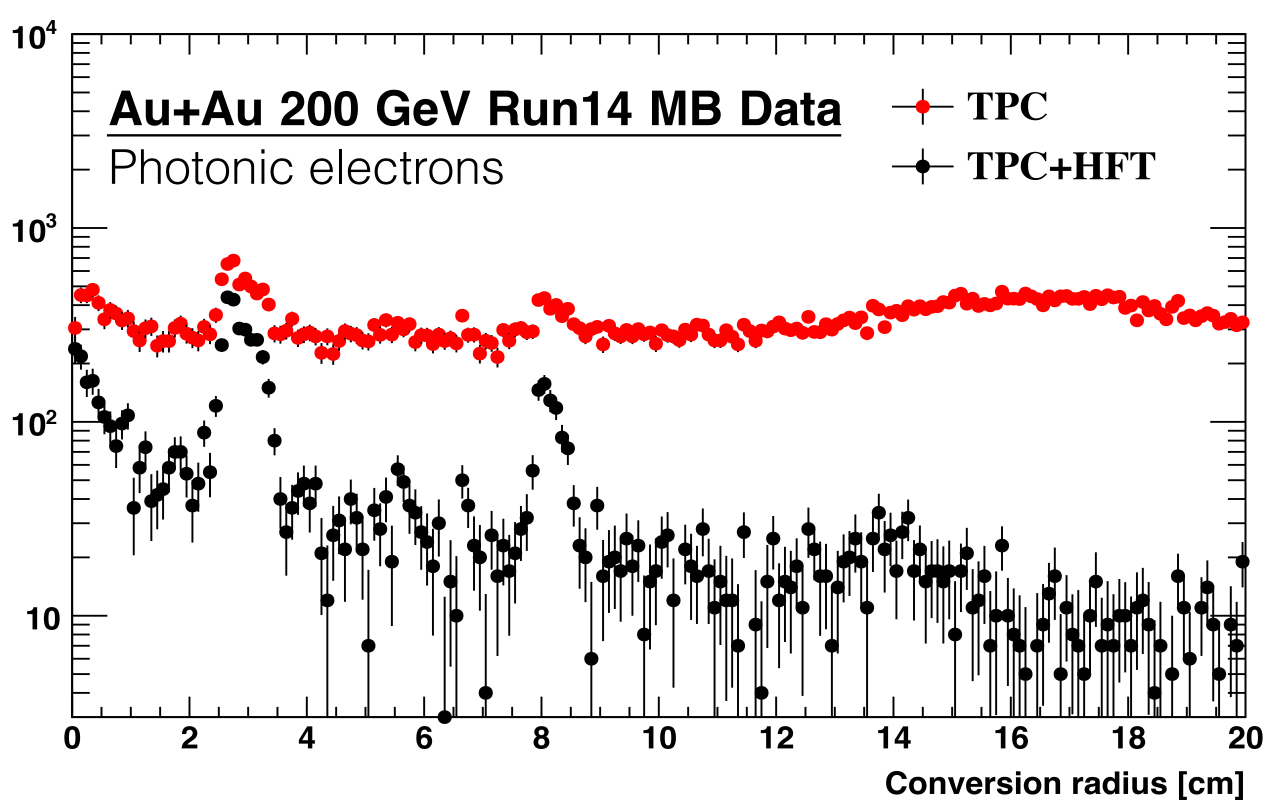


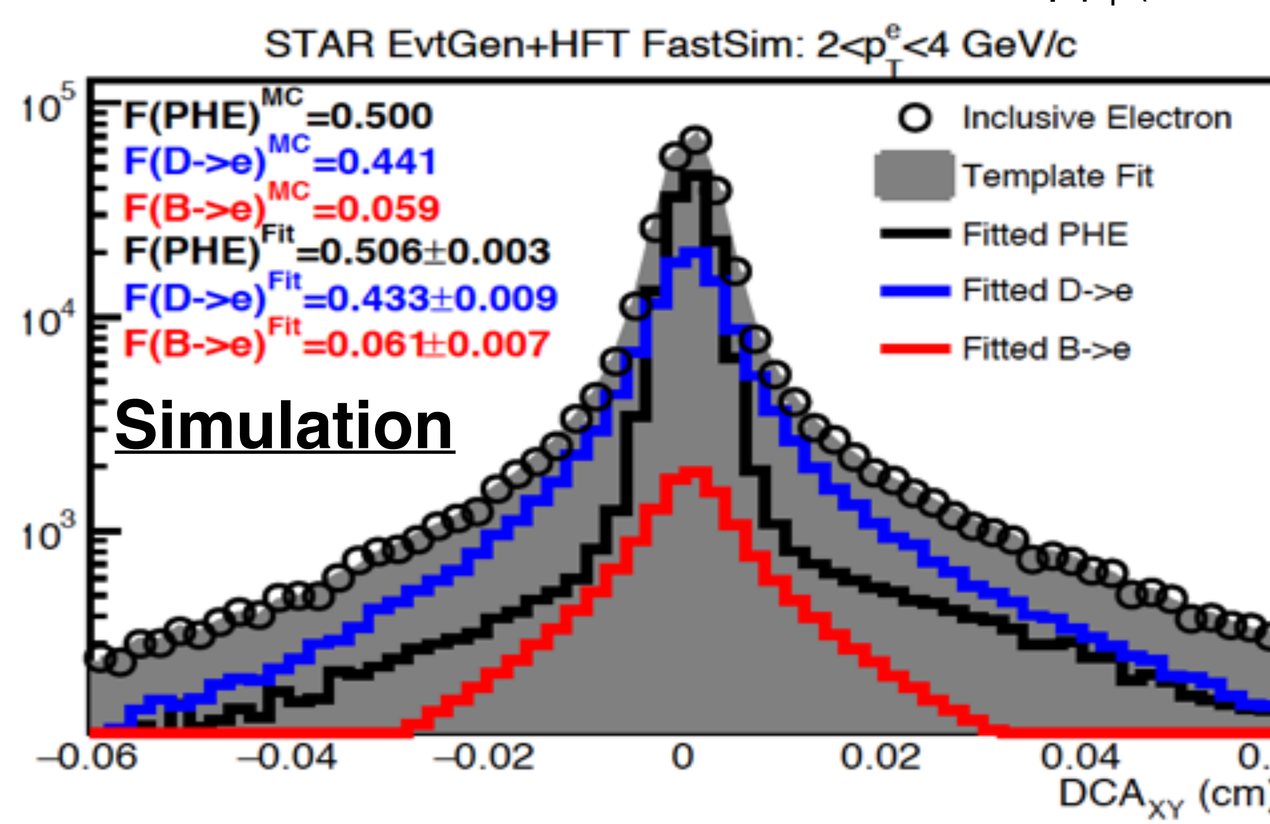


Projected Results: HFT

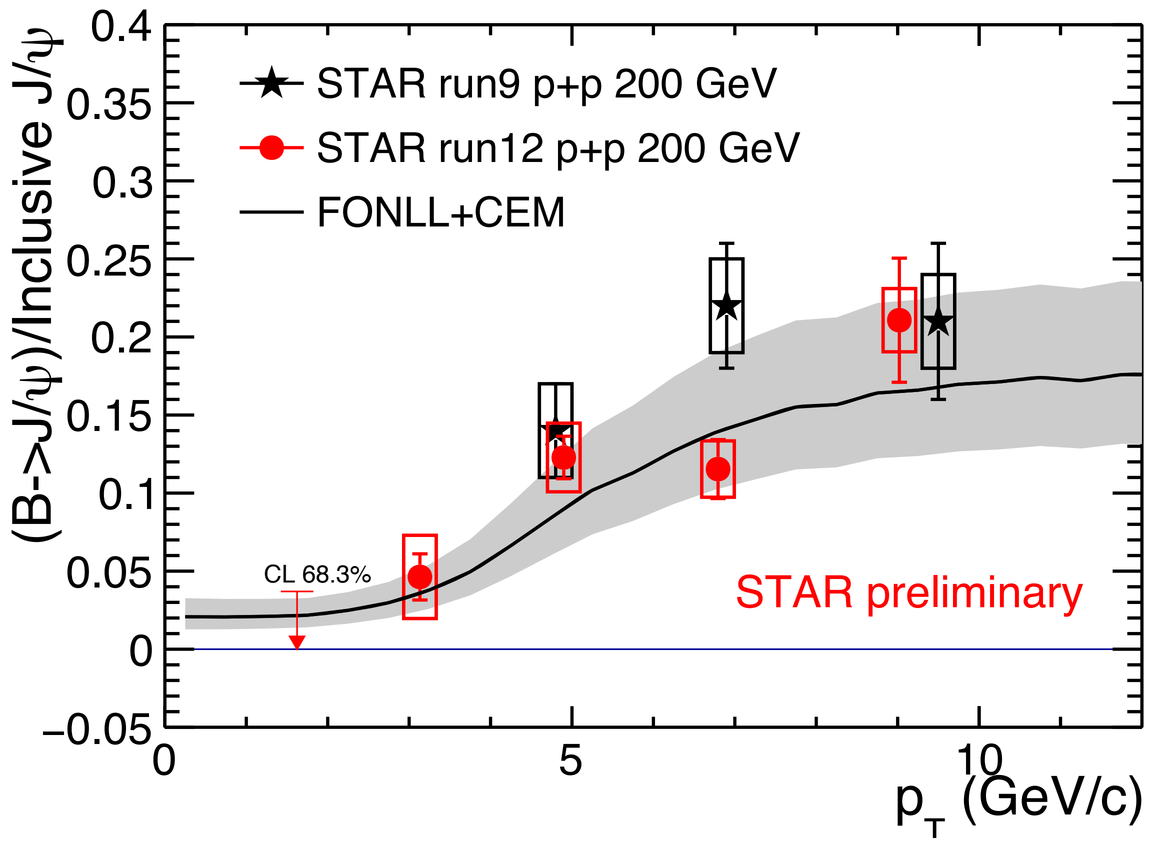


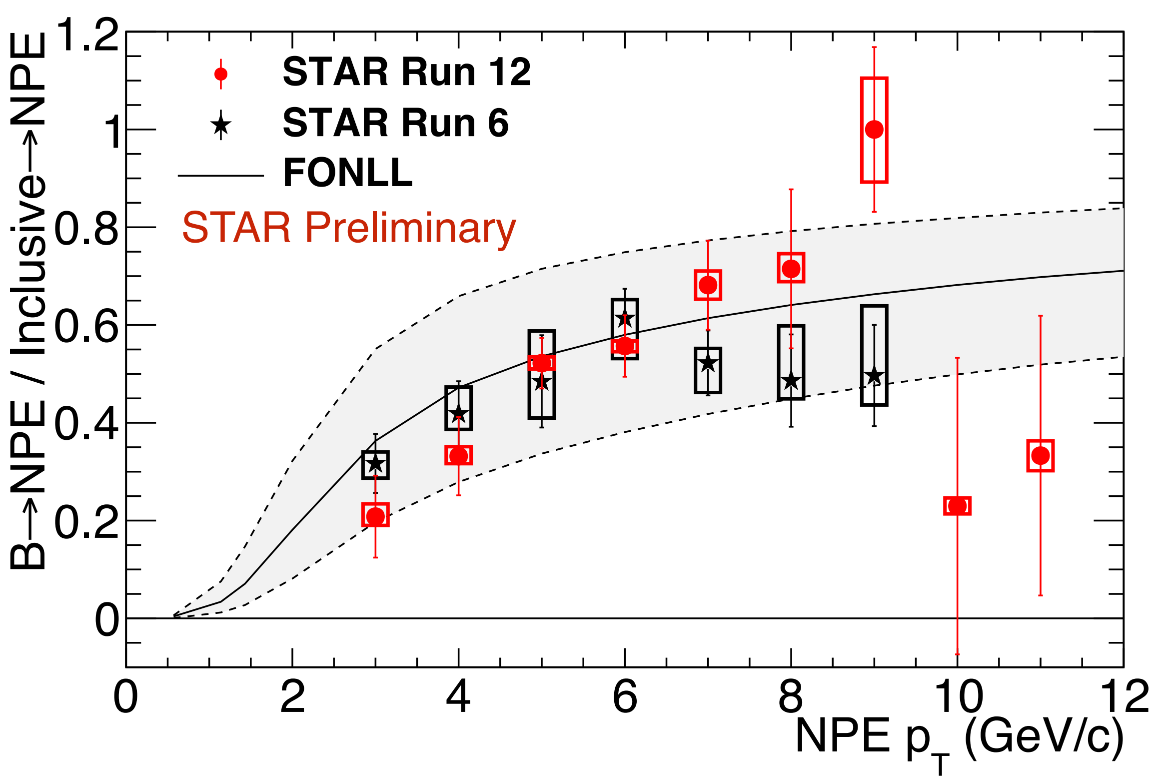






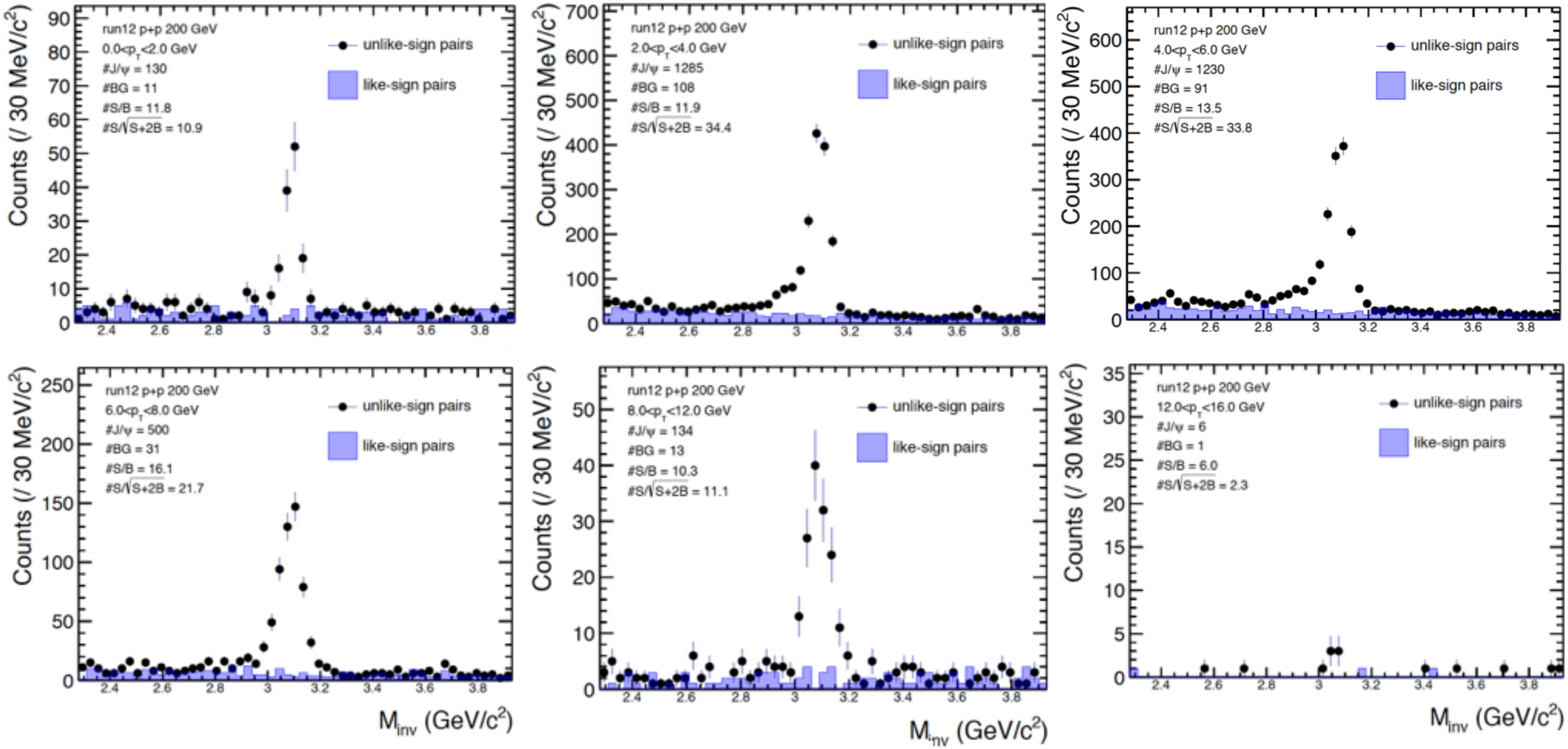
Summary and Outlook

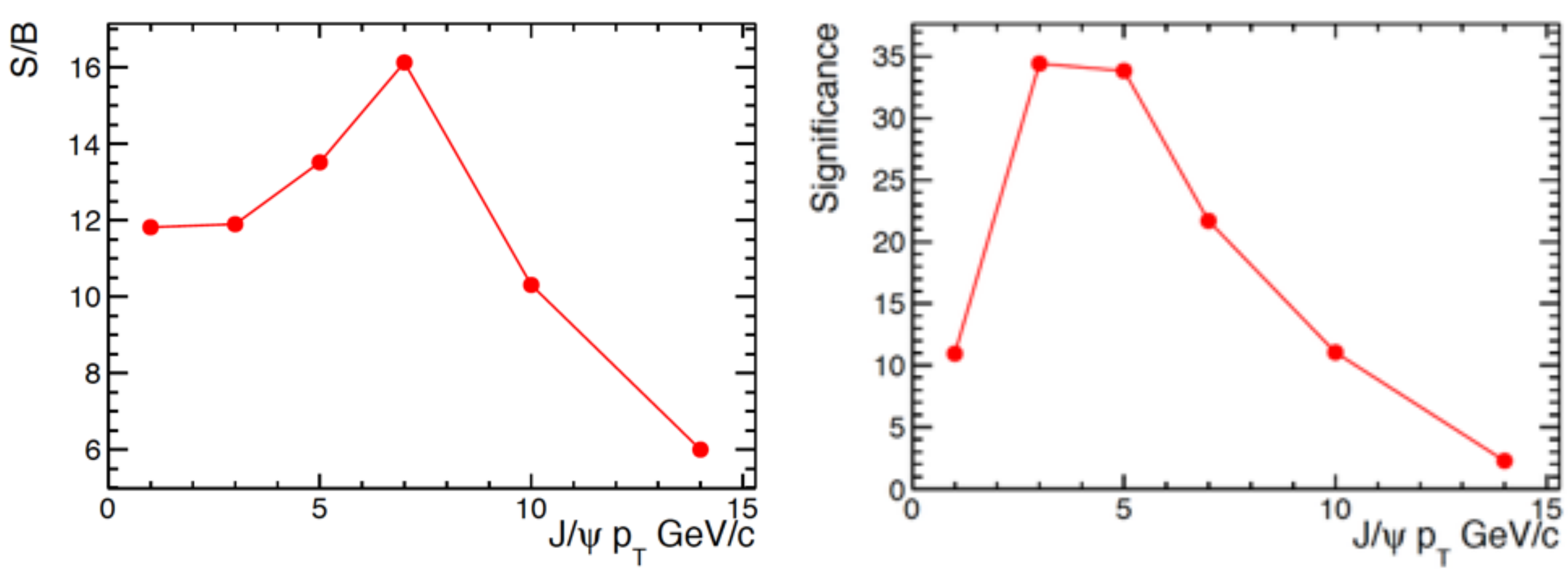




- New results have been extracted for bottom contribution in the J/ψ and NPE channels in p+p collisions at 200 GeV.
- The 200 GeV p+p results have an expanded range and better precision than previous measurements. They also confirm theory calculations.
- The first set of Au+Au data with HFT is being analyzed.
- The HFT allows access to B contributions in Au+Au collisions via recorded geometric data.

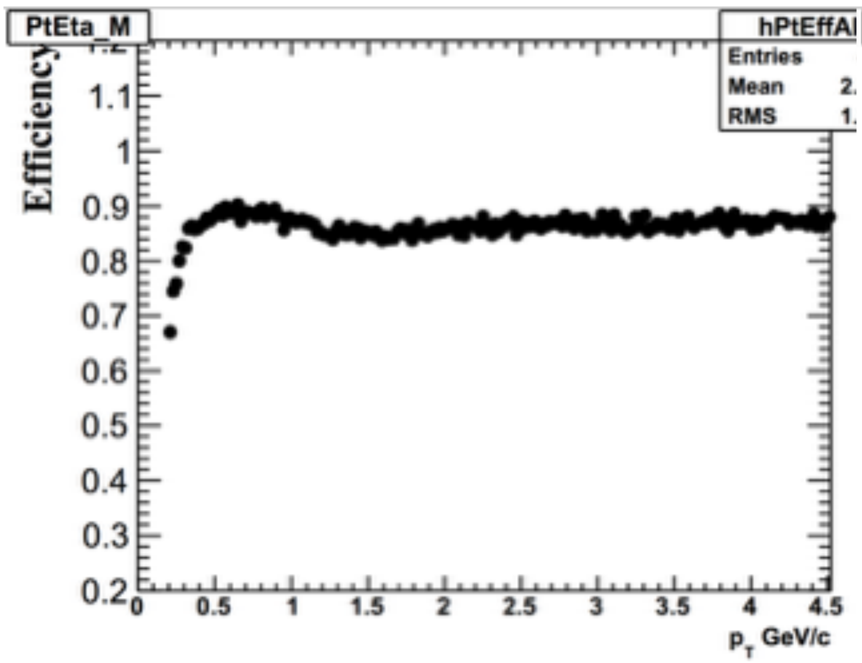
Extra Slides

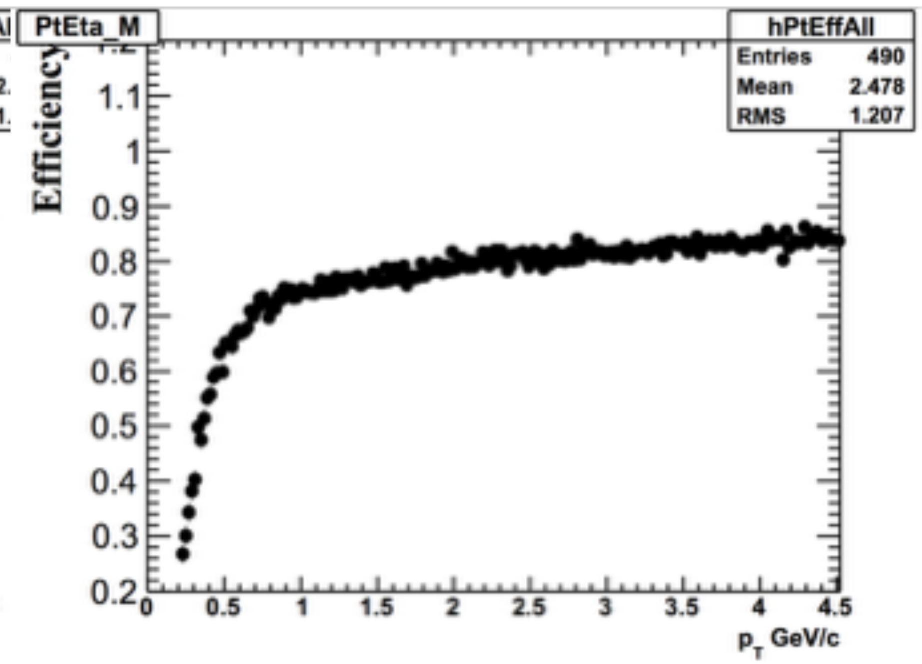

run12 p+p 200 GeV
0.0<p_T<2.0 GeV
#J/ψ = 130
#BG = 11
#S/B = 11.8
#S/√S+2B = 10.9
run12 p+p 200 GeV
2.0<p_T<4.0 GeV
#J/ψ = 1285
#BG = 108
#S/B = 11.9
#S/√S+2B = 34.4
run12 p+p 200 GeV
4.0<p_T<6.0 GeV
#J/ψ = 1230
#BG = 91
#S/B = 13.5
#S/√S+2B = 33.8
run12 p+p 200 GeV
6.0<p_T<8.0 GeV
#J/ψ = 500
#BG = 31
#S/B = 16.1
#S/√S+2B = 21.7
run12 p+p 200 GeV
8.0<p_T<12.0 GeV
#J/ψ = 134
#BG = 13
#S/B = 10.3
#S/√S+2B = 11.1
run12 p+p 200 GeV
12.0<p_T<16.0 GeV
#J/ψ = 6
#BG = 1
#S/B = 6.0
#S/√S+2B = 2.3
unlike-sign pairs
like-sign pairs
Counts (/ 30 MeV/c²)
M_inv (GeV/c²)

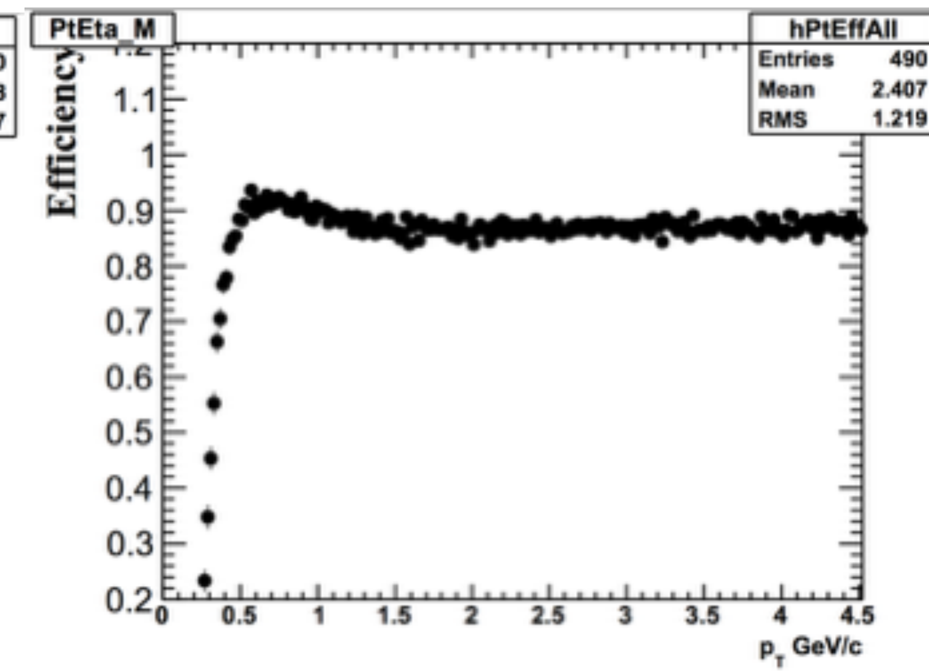

S/B
Significance
J/ψ p_T GeV/c

Efficiency correction

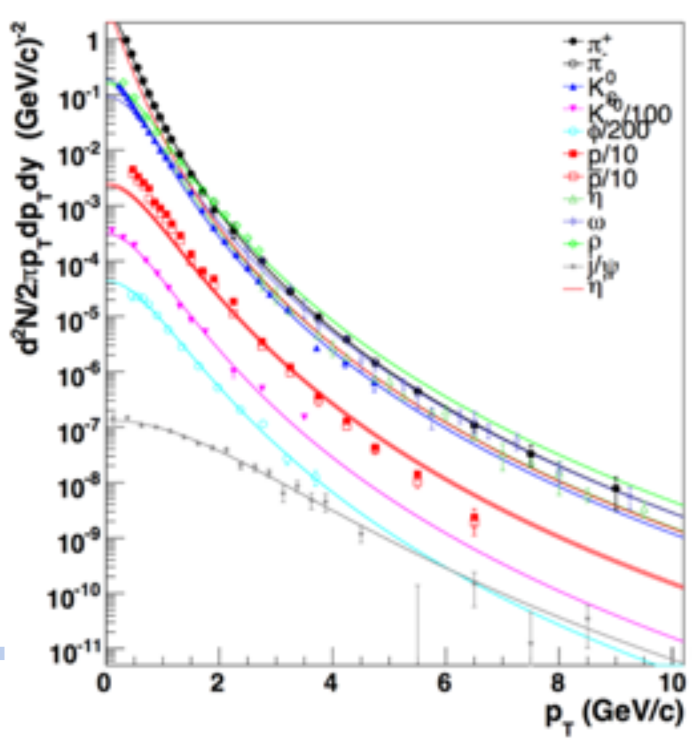
Use pi/k/p embedding in run12.

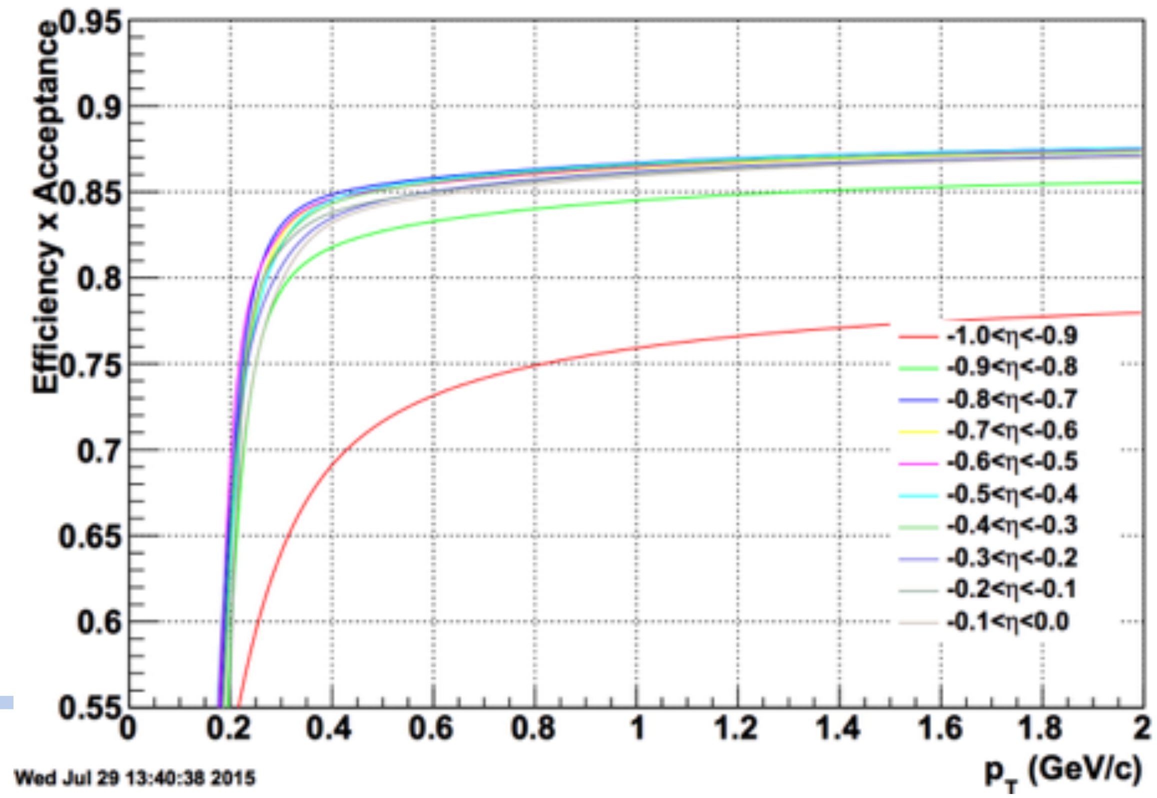






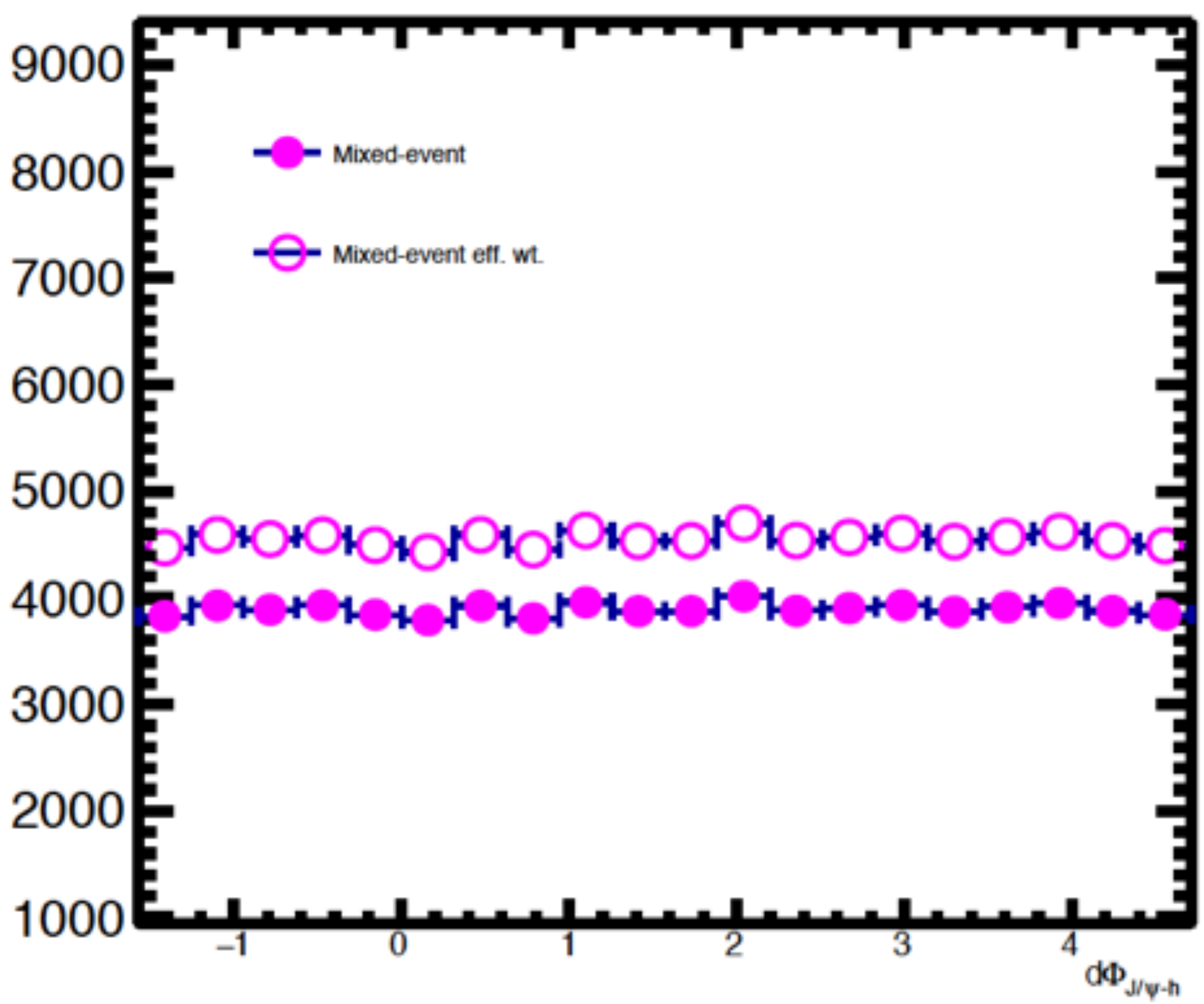
Fold pi/k/p to hadron efficiency by their yields.

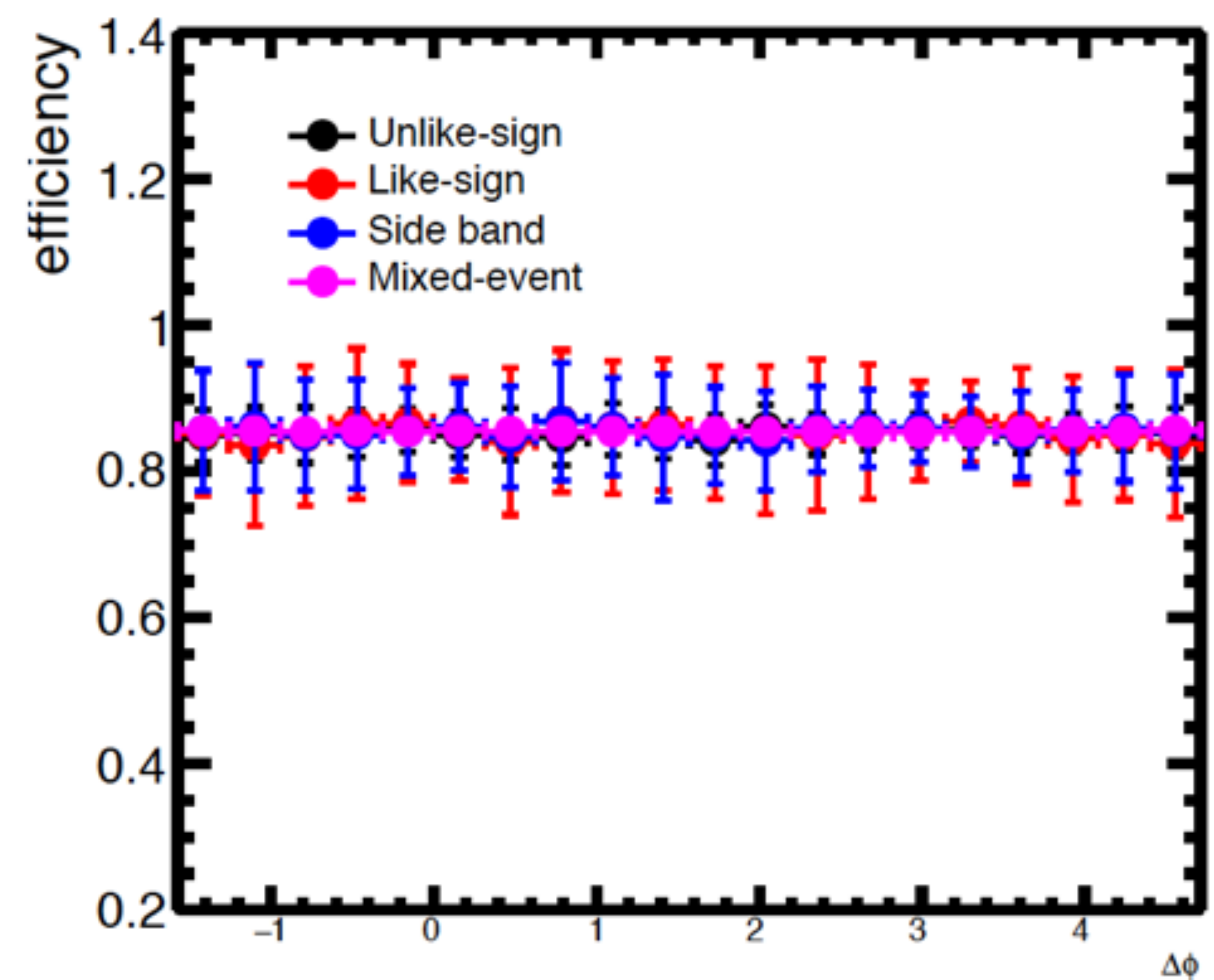




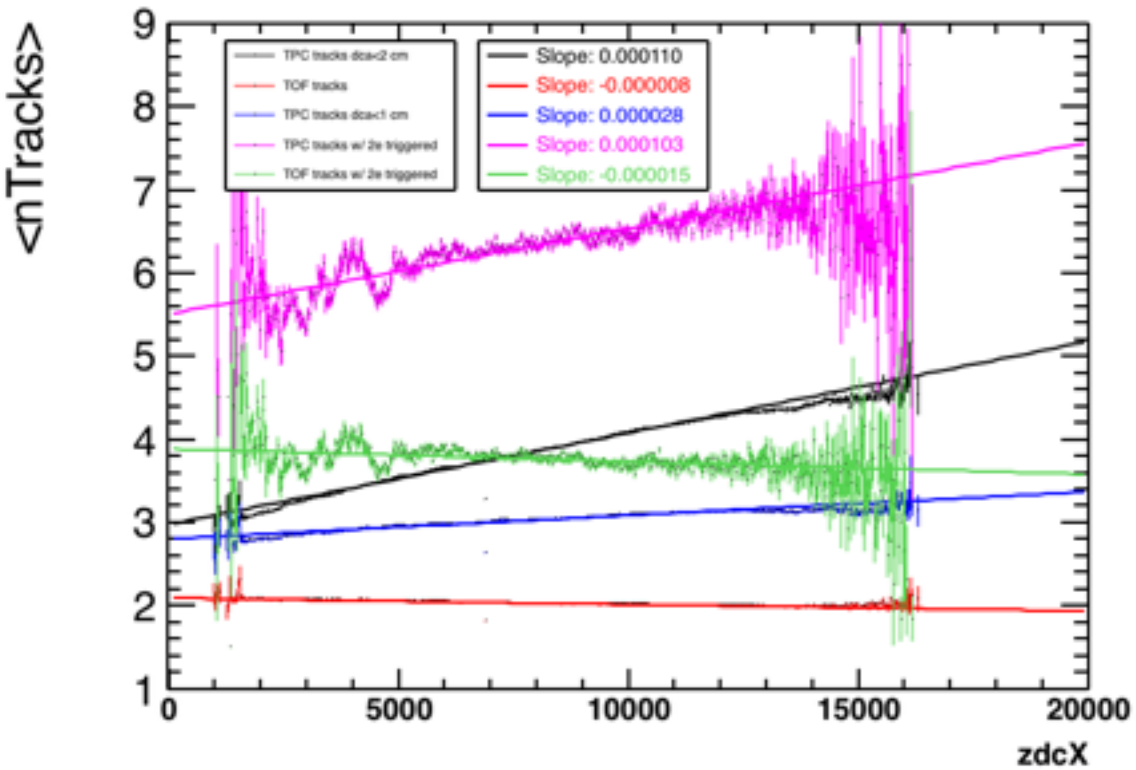
Efficiency folding

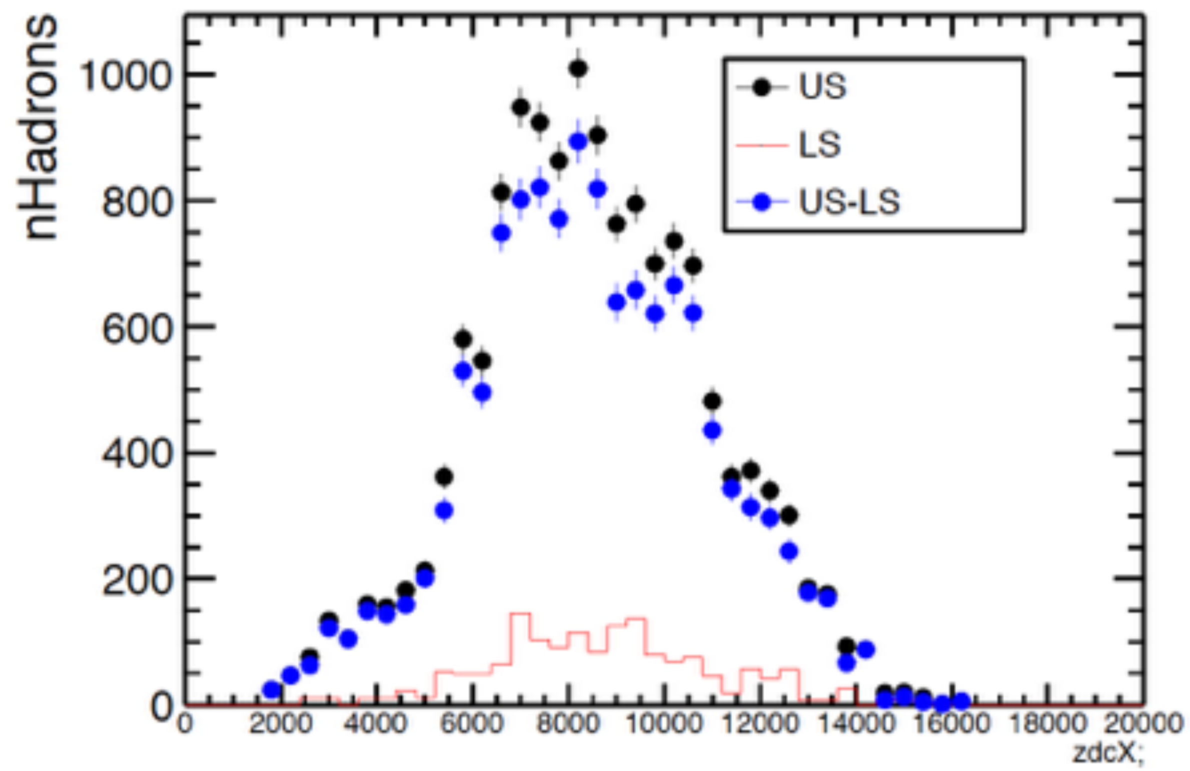
Hist1: hMix->Fill(jpsi.Pt(), pt_h, dphi);
Hist2: hMixEffWt->Fill(jpsi.Pt(), pt_h, dphi, wt);
wt = 1./eff(pT, eta).

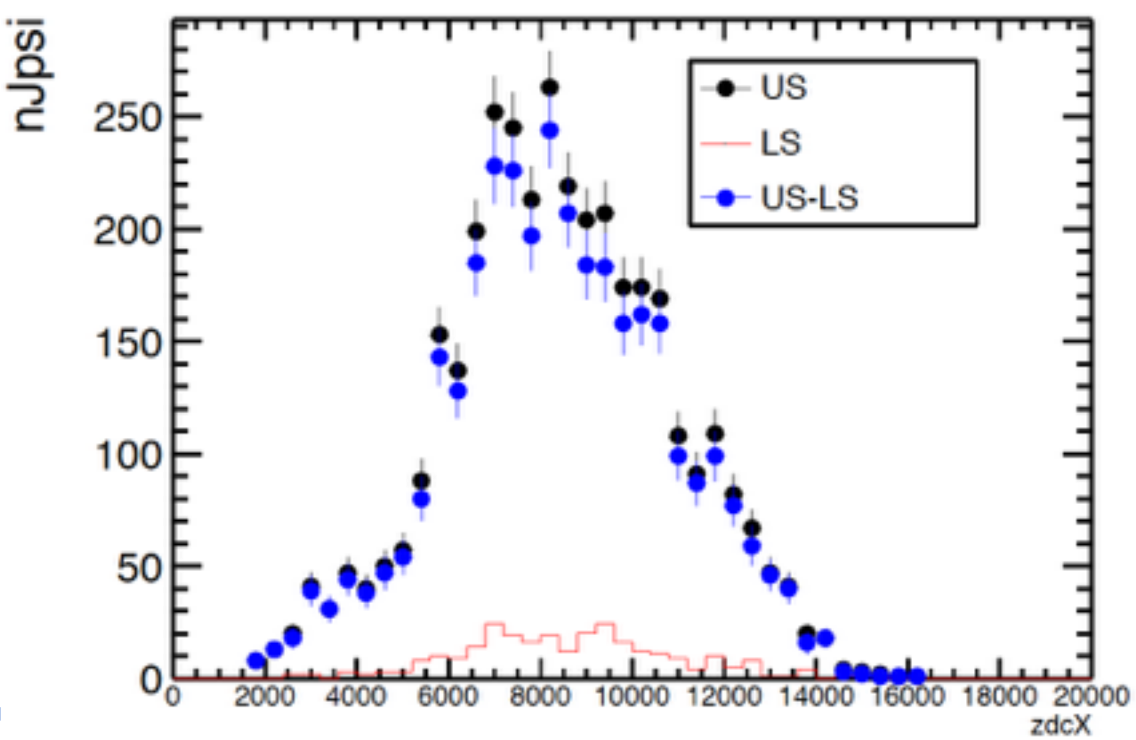


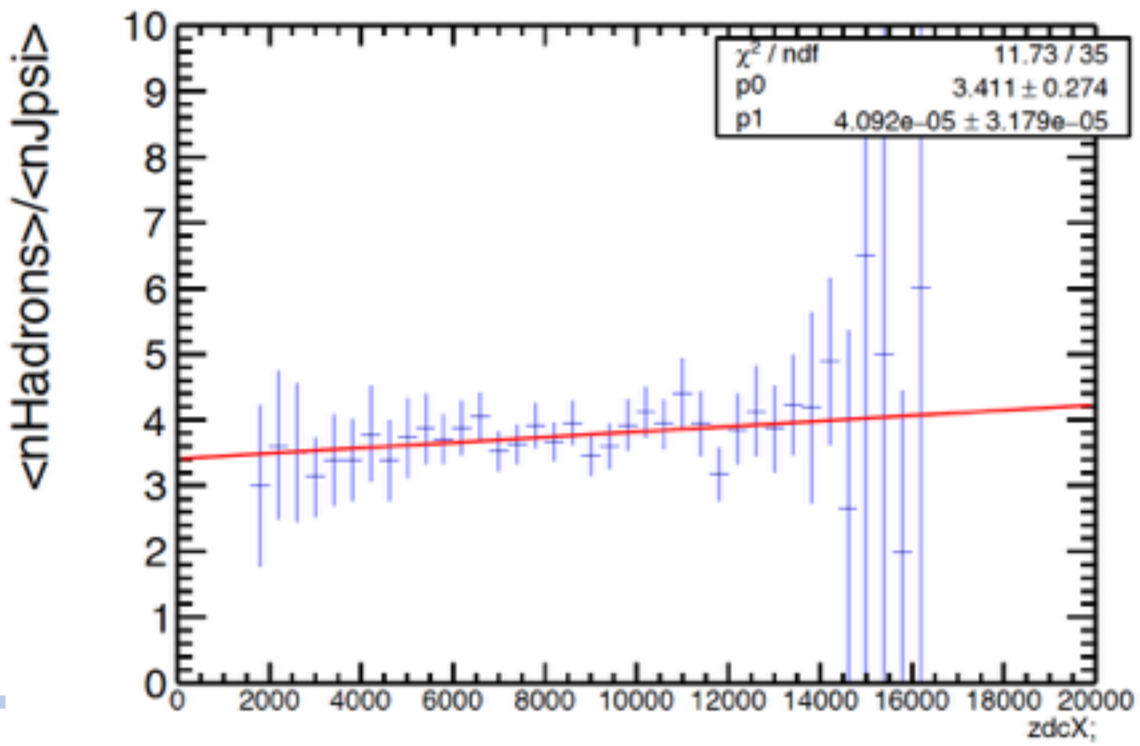


Pile-up correction

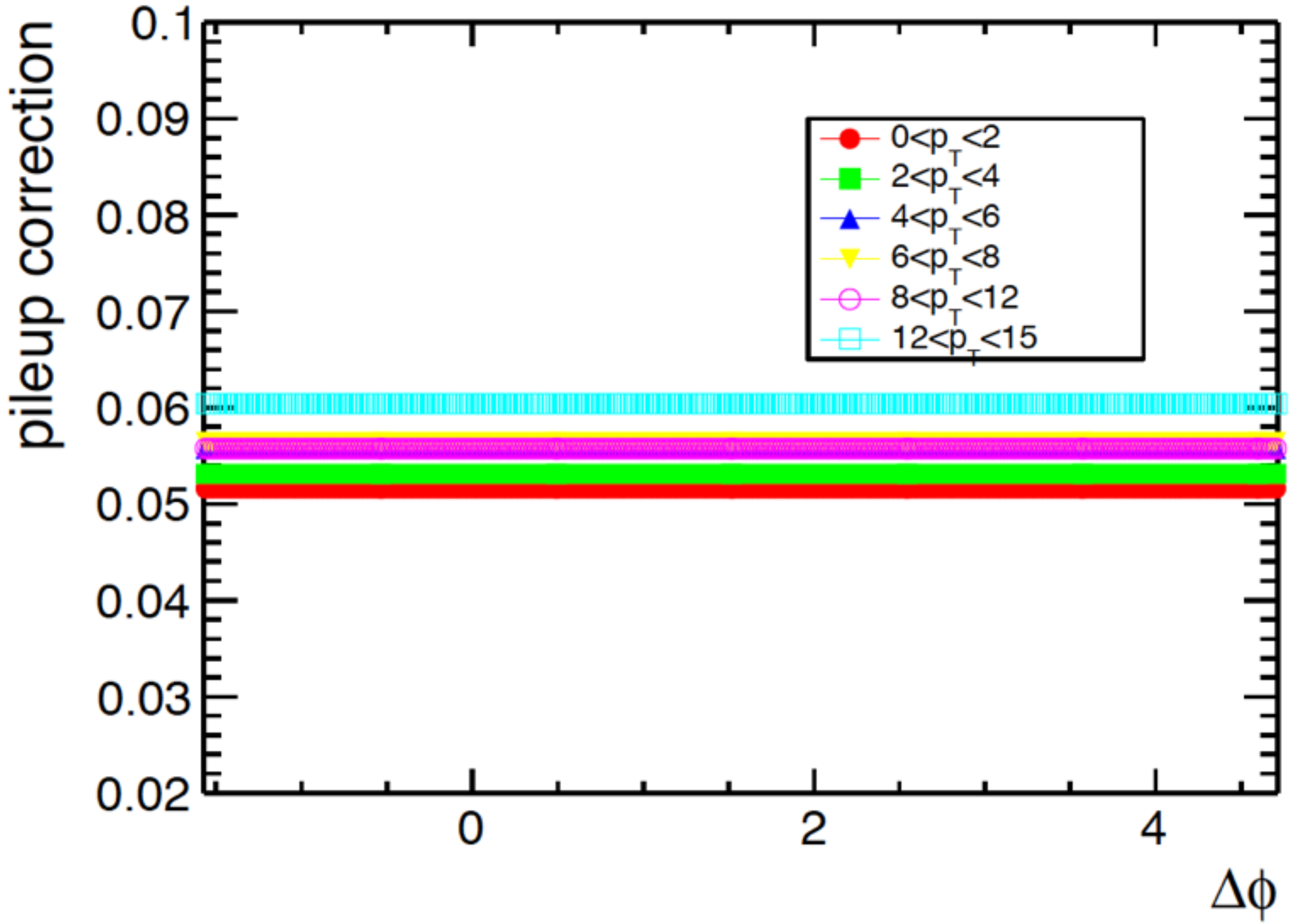




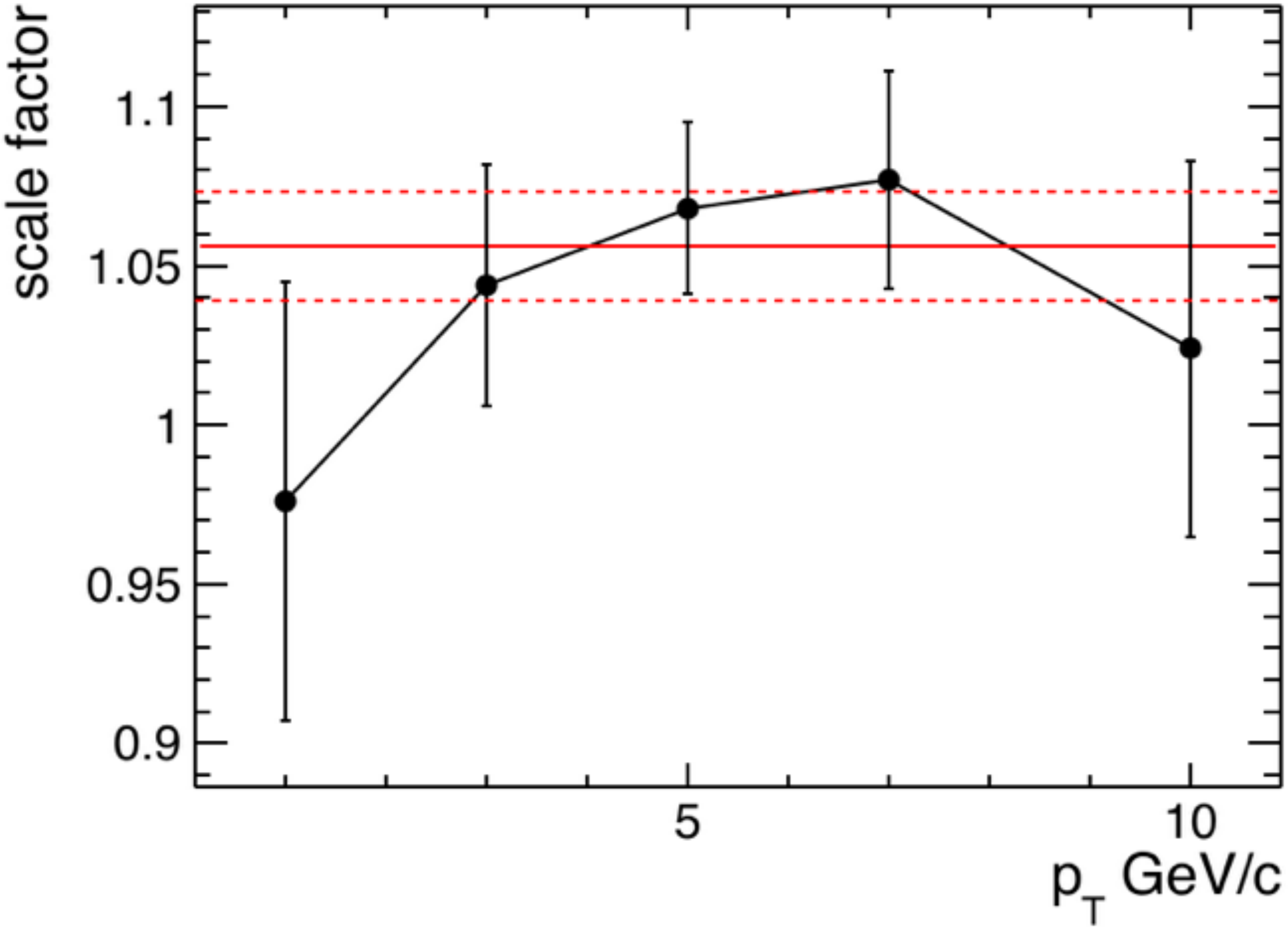




Pile-up correction

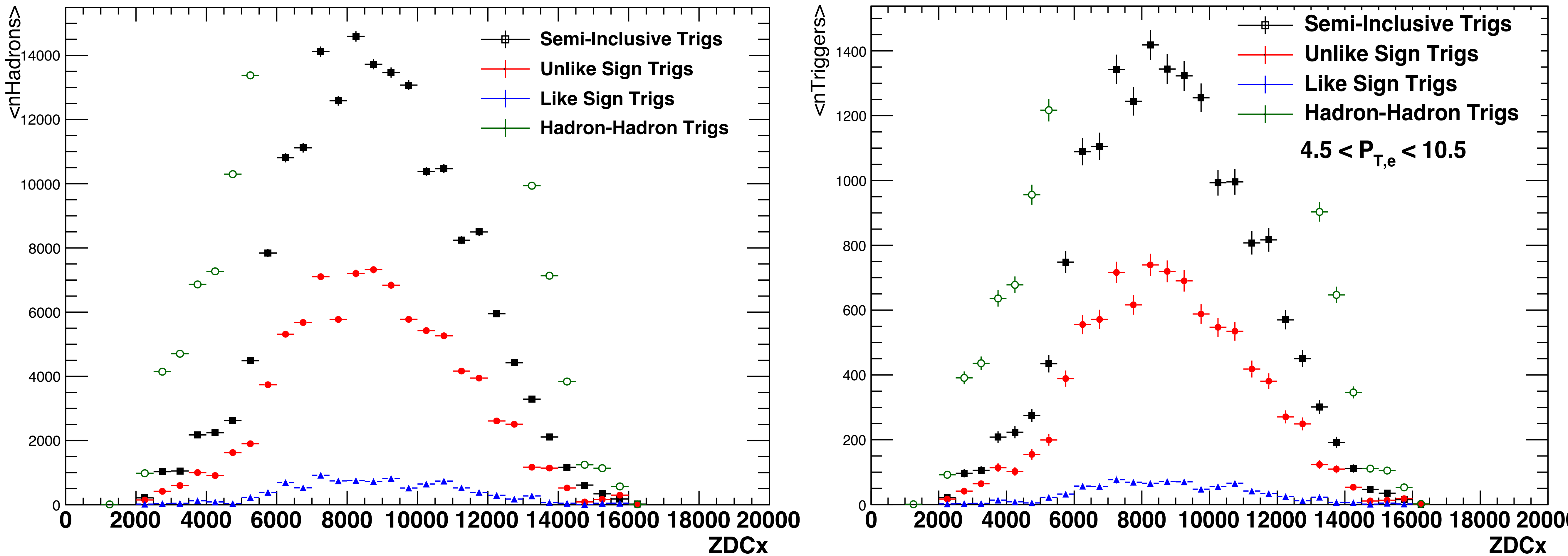


Scale factor



Overall scale factor is 1.056 +/- 0.017. Fix the scale factor to 1.056 to get the nominal B->Jpsi fraction value, and change it by +/-0.017 to obtain the uncertainty from it.

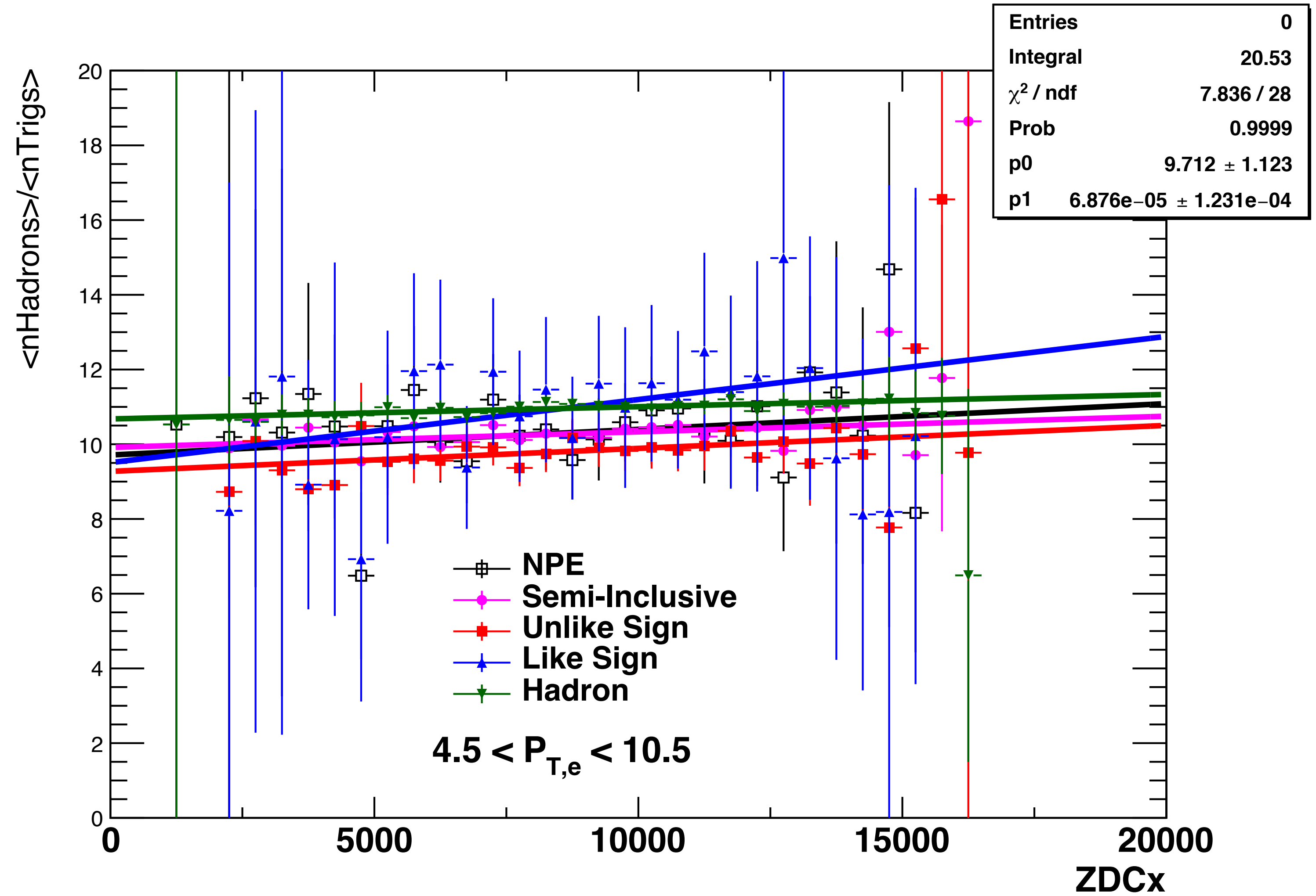
Pileup in NPE Data

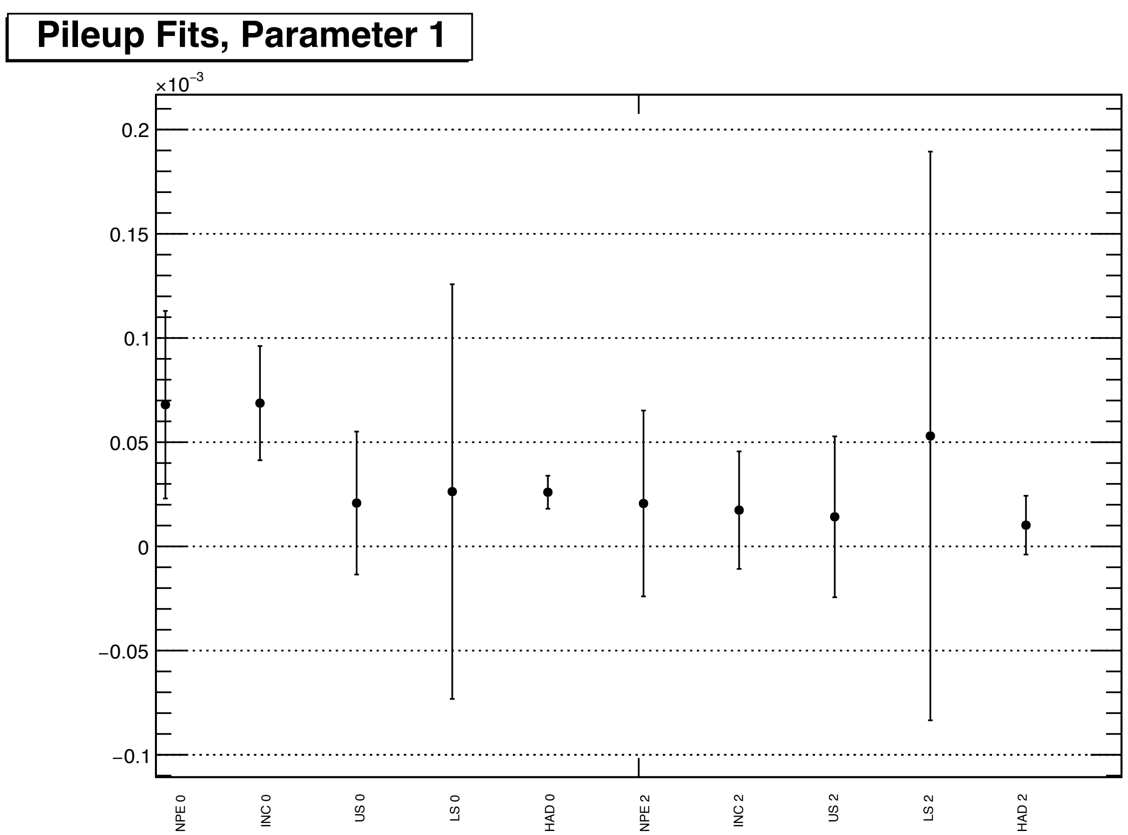


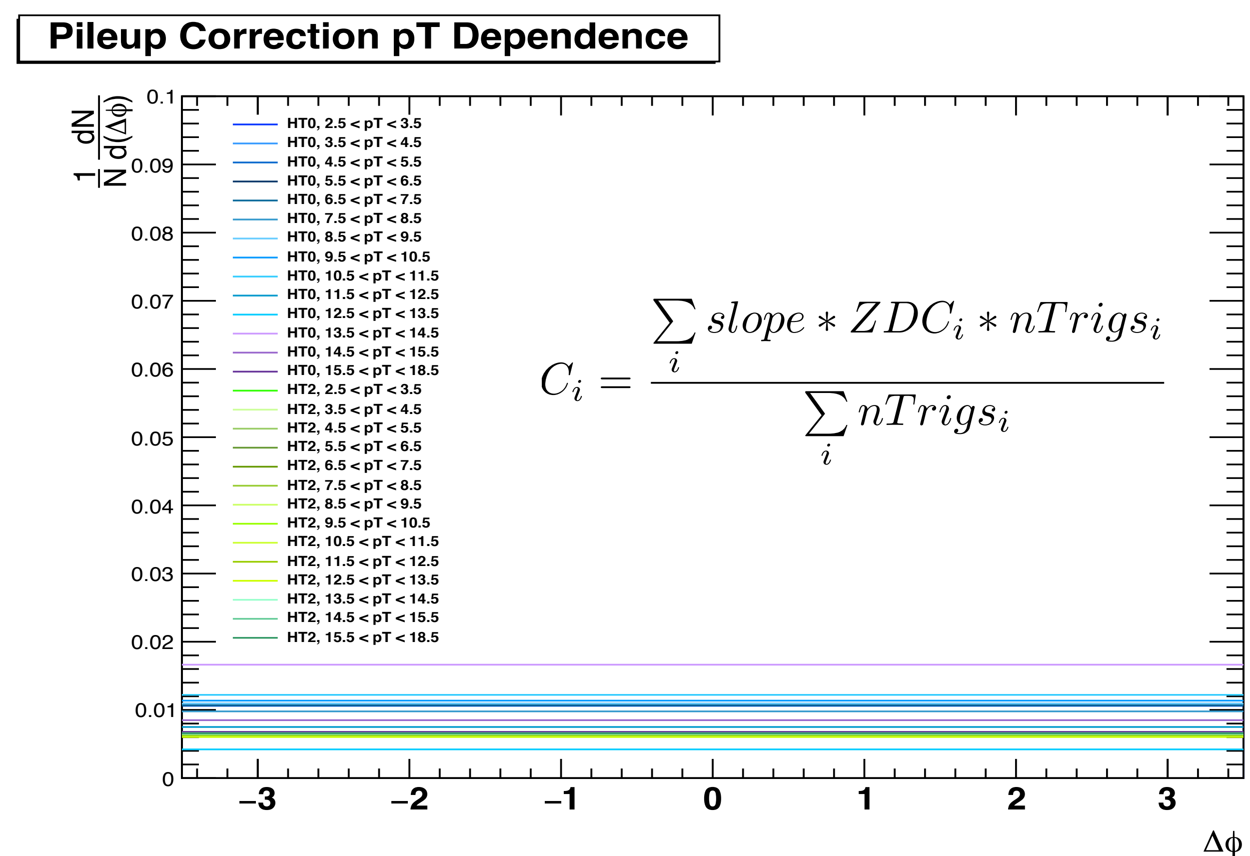
Measure average number of hadrons and triggers as a function of ZDCx. A bin by bin division gives the average number of hadrons per trigger, in terms of the luminosity (ZDCx).

Pileup in NPE Data

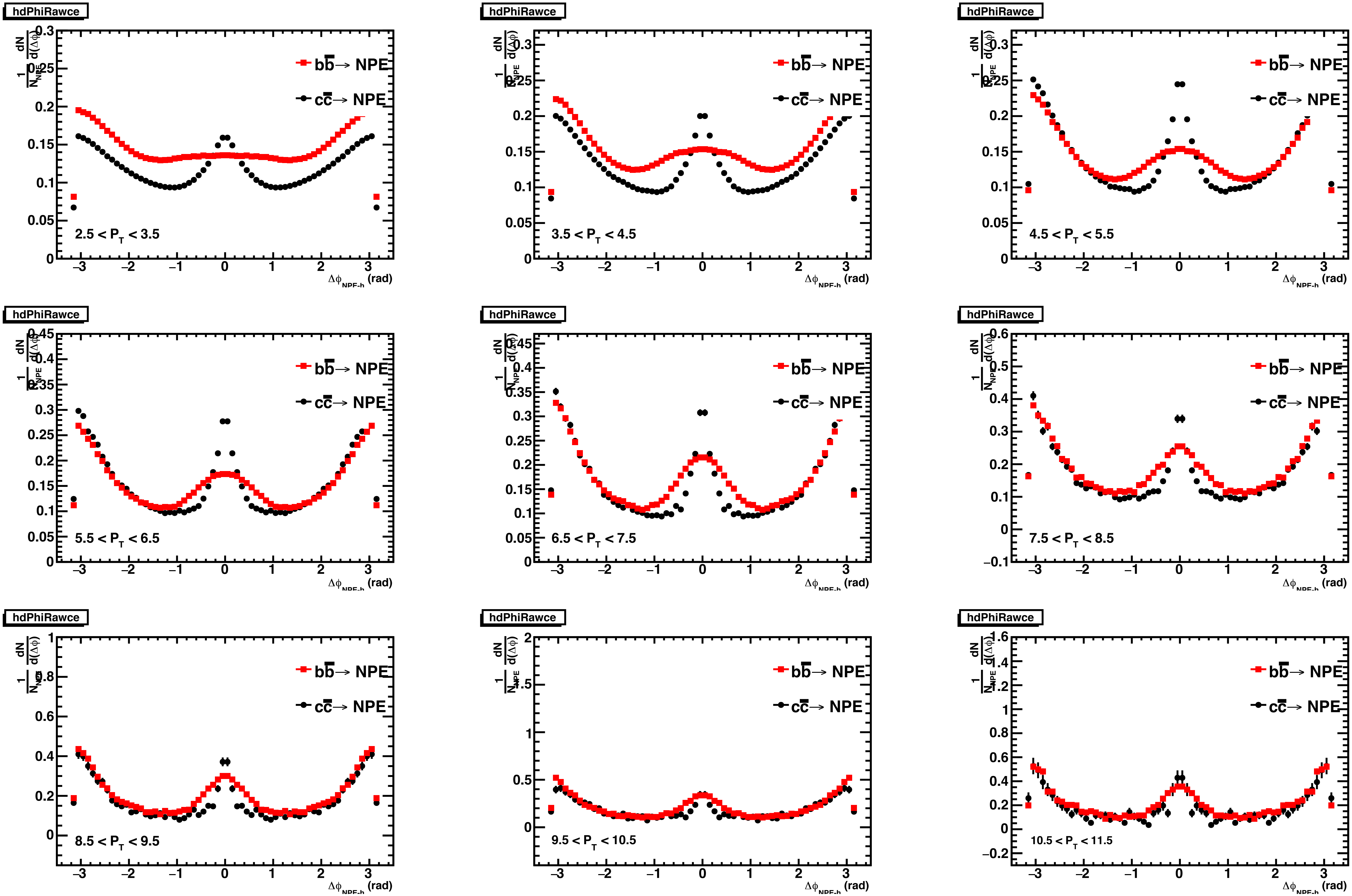
Fit this value to get the base rate, then use the slope of the fit to predict how much pileup contributes in each pT bin. This is divided evenly into ΔΦ, and subtracted from the final NPE ΔΦ distributions.







NPE Pythia Templates



NPE Fits • High Tower 0 • High Tower 2 o Fit Result