Measurement of charm and bottom contributions to electrons from heavy quark decay at RHIC-PHENIX experiment

Ryohji Akimoto (CNS, Univ. of Tokyo)
for the PHENIX Collaboration

Outline

- Introduction
- Heavy quark measurement
  - experimental setup
  - background evaluation
  - measurement of bottom fraction
- Result
- Summary

Heavy quark (charm, bottom)

- Heavy quark
  - created by initial hard collisions

    → Interaction between parton & QGP can be clearly extracted.

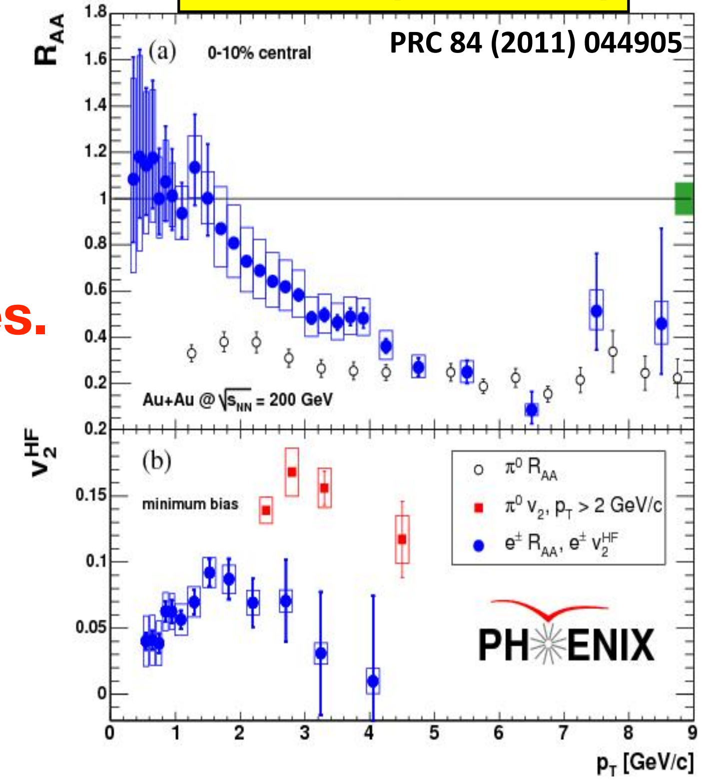
- The interaction depends on many factors.

    → Multiple information is necessary to test interaction models & to extract QGP properties.

- Experimental results
  - measurement of heavy quark electron : c+b→e
  - direct reconstruction of charm : D→Kπ, Kππ
  - high momentum bottom : B→J/ψ+X, b-jet

We measure both charm & bottom contributions in $e^{\pm}$ from heavy quark decay via direct measurement of c/b ratio.

c+b→e (PHENIX)



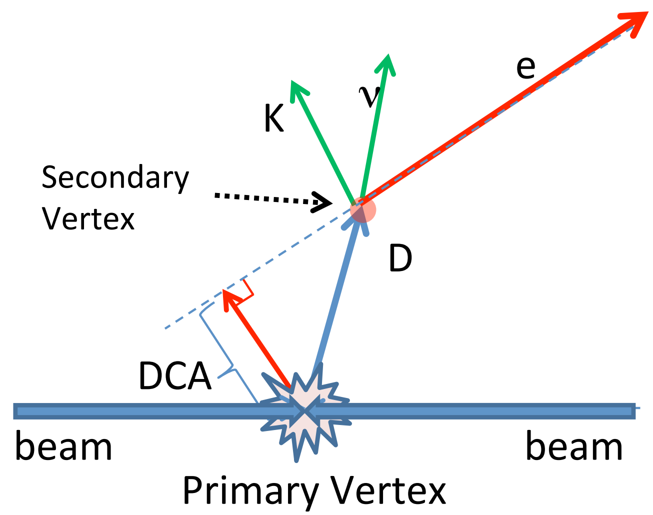
Measurement of charm & bottom

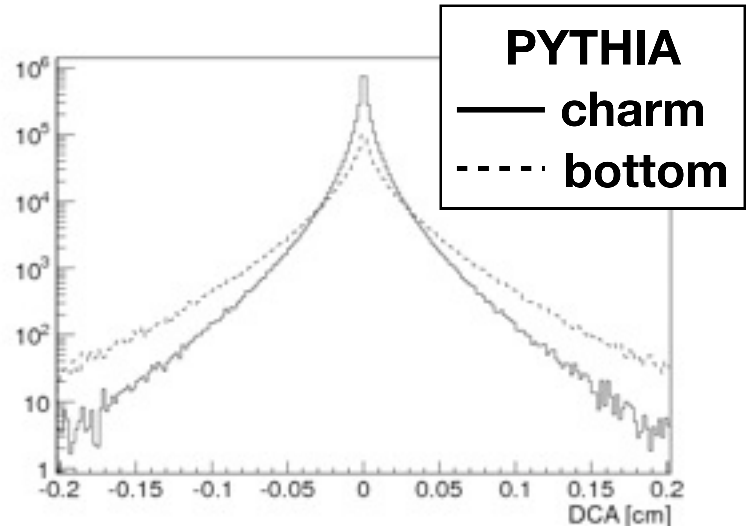
- **charm & bottom measurement** : measure **electron/positron** from semi-leptonic decay.
- **Distance of Closest Approach (DCA)**
  - c/b contributions are evaluated with DCA distribution.
  - depends on life-time and q-value of parent hadrons.

→ DCA can be used to distinguish charm & bottom

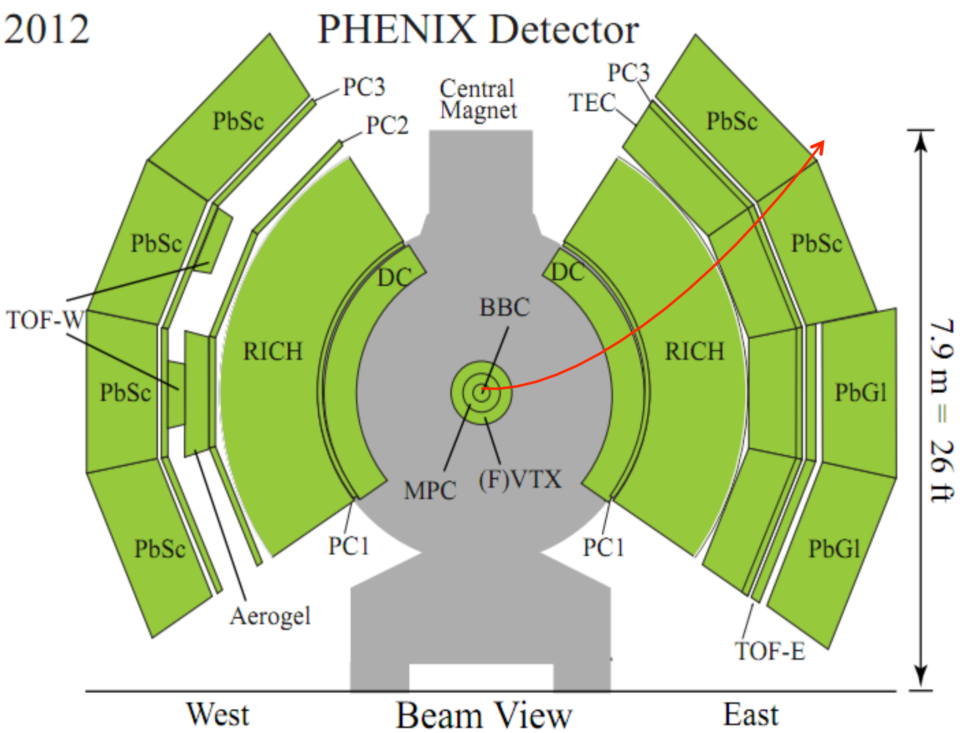
✓$D^{\pm}$: cτ=311.8μm, D^0: cτ=122.9μm

✓$B^{\pm}$: cτ=491.1μm, B^0: cτ=457.2μm





Experimental setup



PHENIX central arm

- coverage
  - $|\eta|<0.35$ & $\Delta\phi=90°\times2$
- track reco. & p_T measurement
  - Drift chamber
  - Pad chamber
- electron ID
  - EM calorimeter
  - RICH

The central arm does not have enough capability for c/b separation from DCA measurement

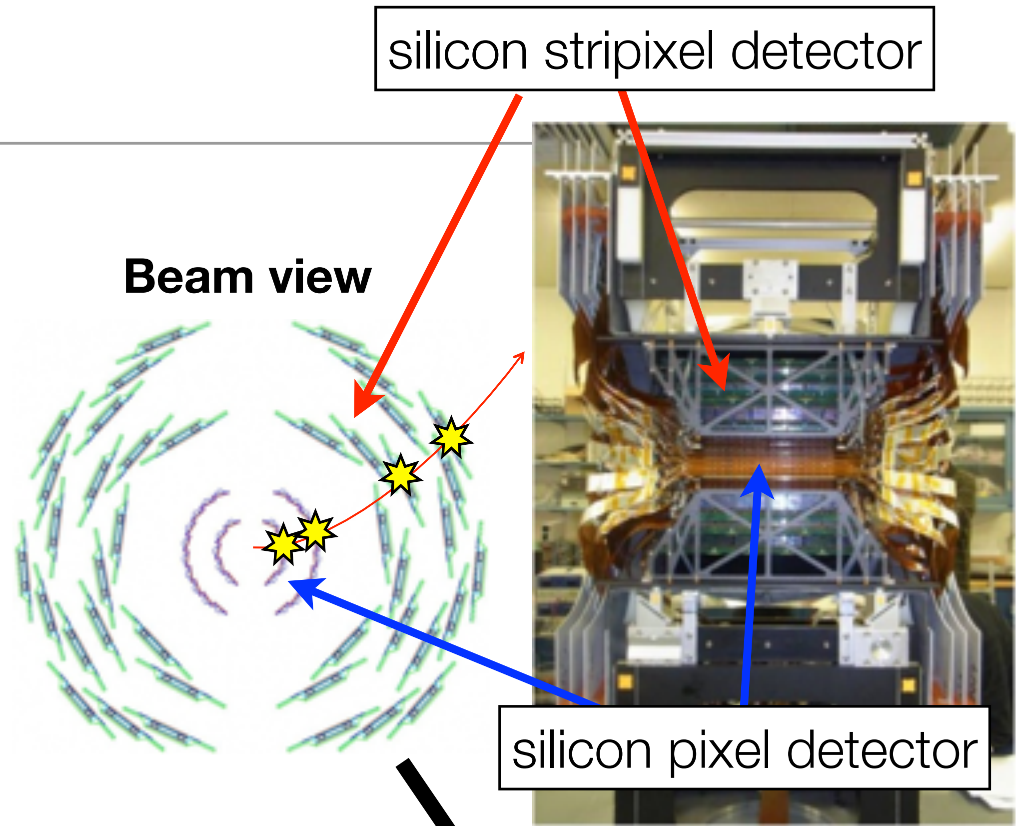
- detectors are located far from the collision vertex.

→ newly install silicon vertex tracker (VTX) around collision vertex point

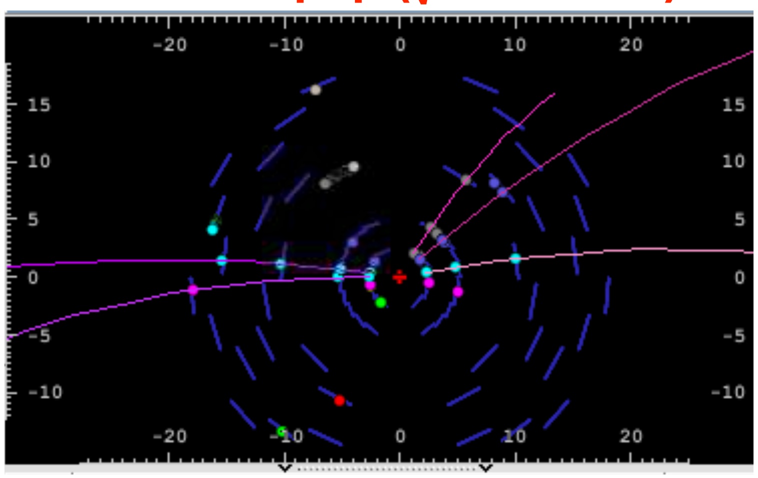
Silicon vertex tracker (VTX)

Silicon Vertex Tracker (VTX)

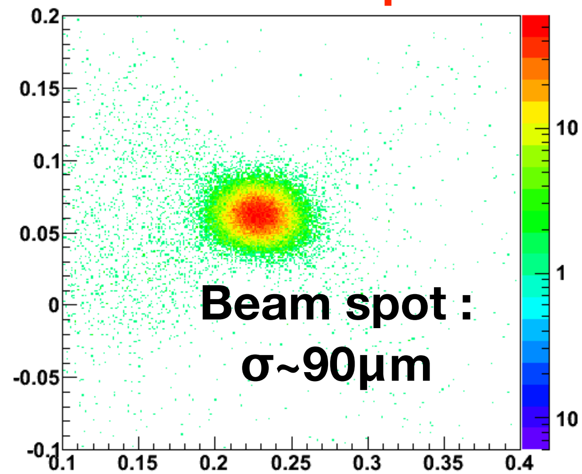
- silicon detector with 4 layers
  - pixel detector (inner 2 layers)
  - stripixel detector (outer 2 layers)
- precise tracking & collision vertex reconstruction are done by VTX.

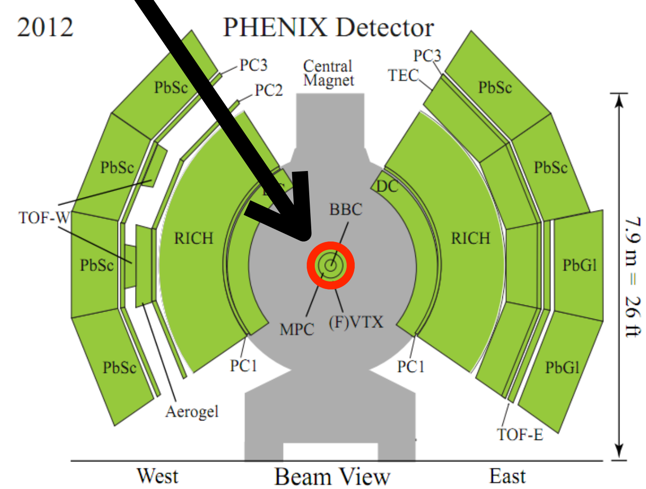


Run2012 p+p ($\sqrt{s}$=200GeV)

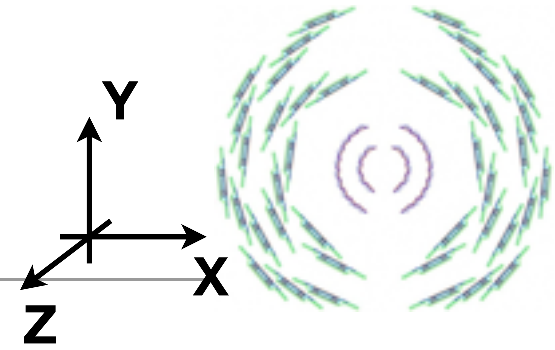


collision vertex position



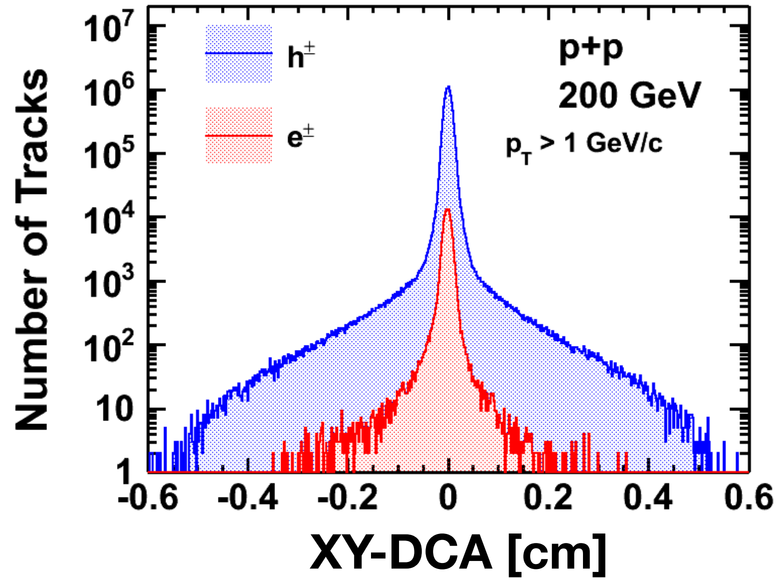


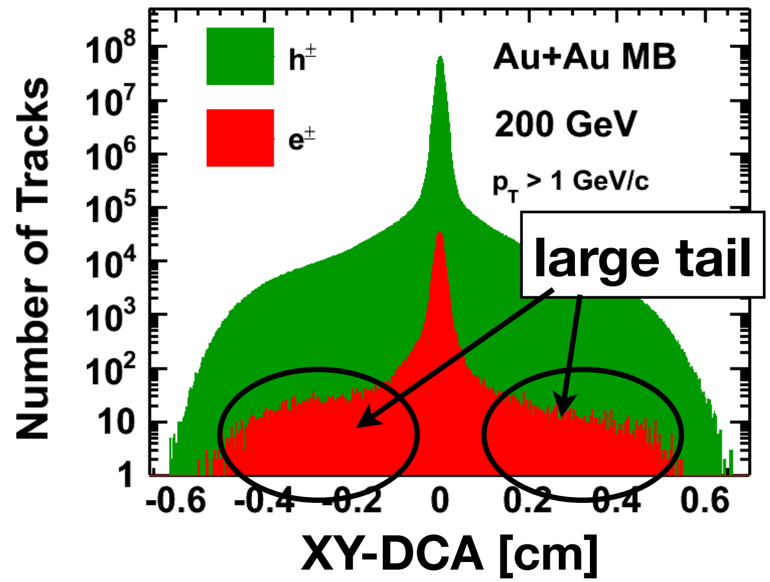
Background evaluation



- **background**
  - photon conversion
  - Dalitz decay of pseudo-scalar mesons
  - Ke3
  - mis-association hits created by other track.
- **XY-DCA distribution of inclusive electron**
  - XY-plane : perpendicular to beam axis
  - background tail in large XY-DCA region in Au+Au collision
    - ✓main source : photon conversion
    - ✓Large XY-DCA region is important especially for bottom yield evaluation.

    → need rejection for e± from photon conversion

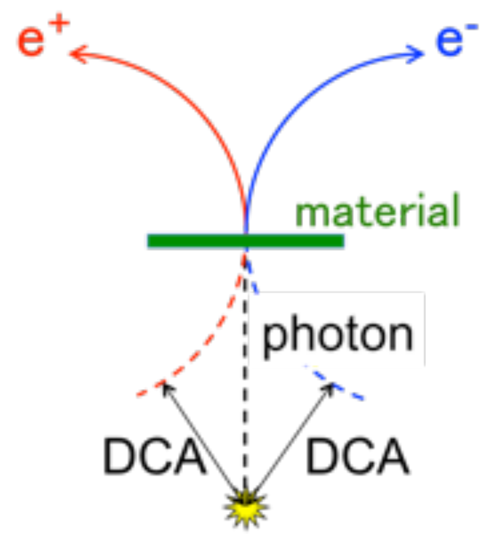




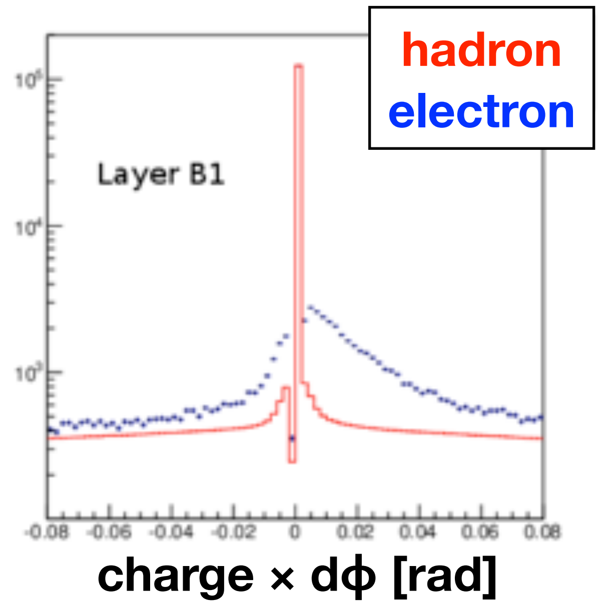
photon conversion rejection

- **photon conversion : isolation cut is effective**
  - isolation cut : require no hit near associated hits
  - photon conversion creates e^+e^- pair & opening angle ~0

    → hits created by e^+ & e^- tracks locate very near.

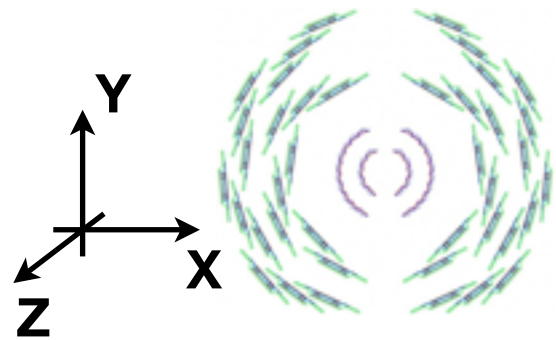


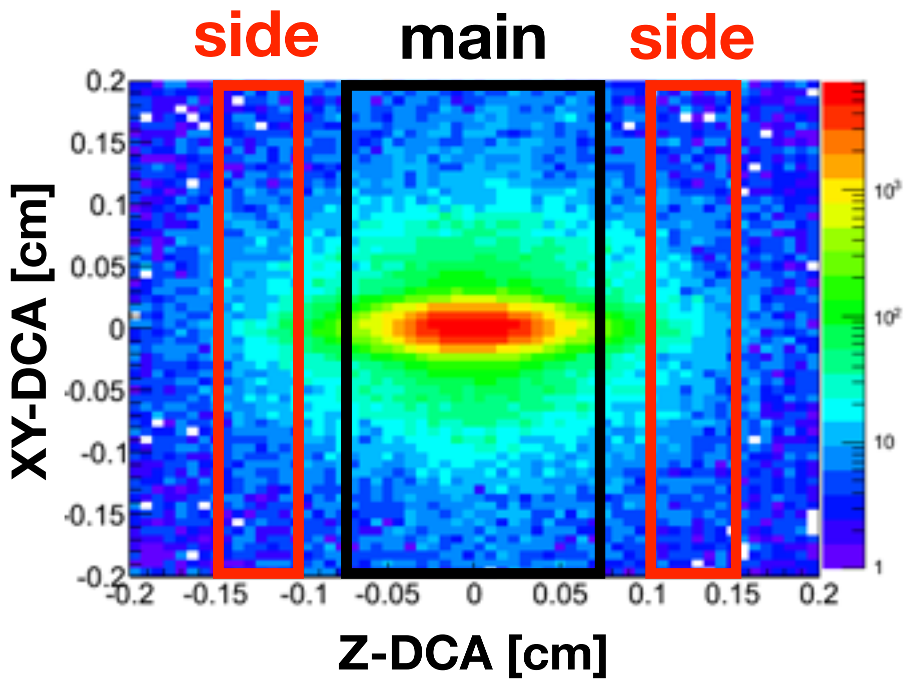
- **Rejection fraction**
  - **75%** of conversion electron is rejected.
  - Only **20%** is rejected by random matching at Au+Au MB.

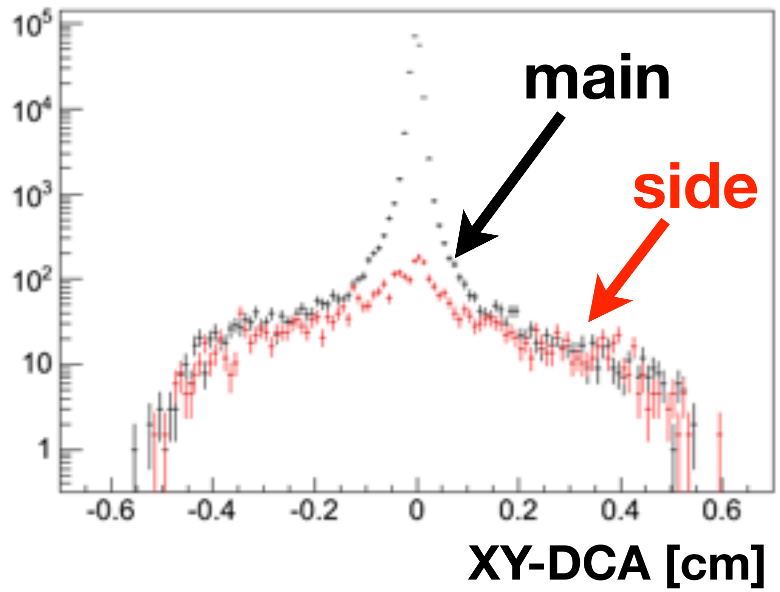


mis-association BG

- evaluated by XY-DCA distribution with large Z-DCA (normalized by z-range)
  - XY-DCA distribution at side-band well reproduces XY-DCA tail of main region.
- charm, bottom : side/main~0.1%
  - signal contamination is very small.

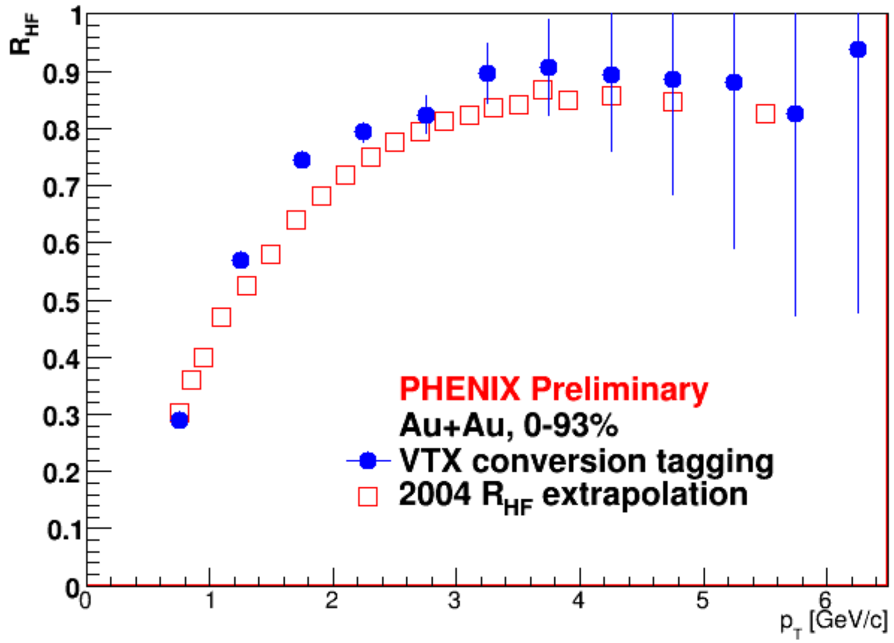






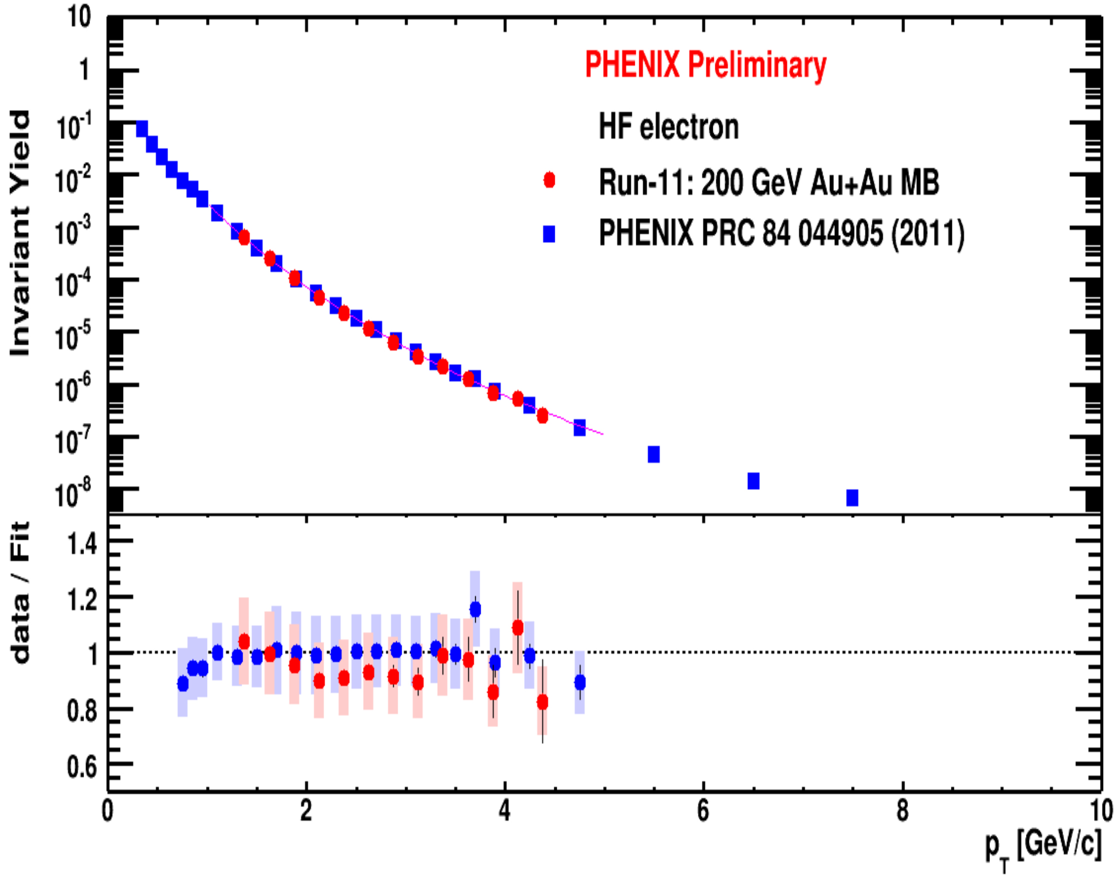
Signal v.s. Background

- R_{HF} (= e^{HF} / $e^{inclusive}$) is evaluated.
  - fraction of $e^{\pm}$ from heavy quark decay in inclusive electron.
  - R_{HF}>80% at p_T>2GeV/c
  - **consistent with expectation** (red square)
    - ✓expectation : previous result + increase of material



→ Good S/N is achieved & background is evaluated well.

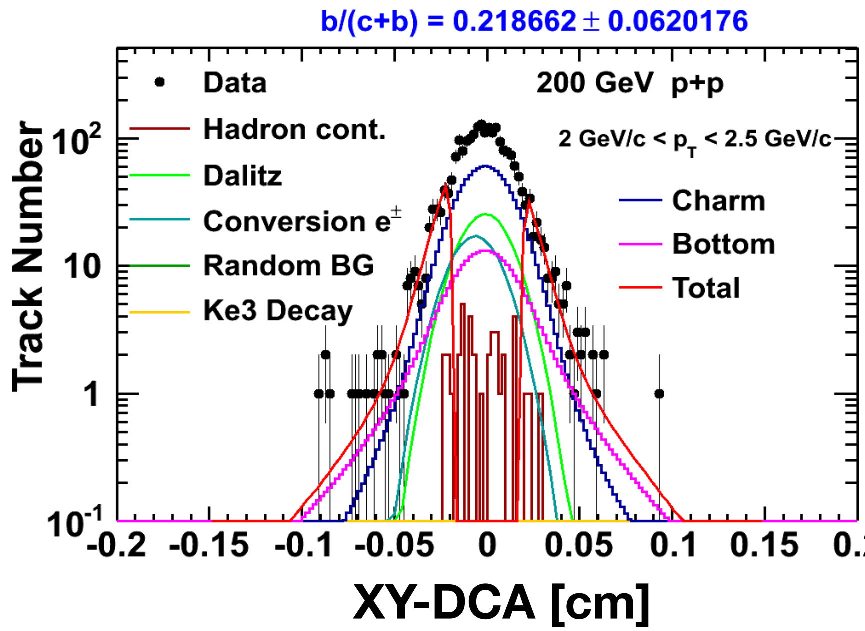
Invariant yield of heavy quark electron in Au+Au



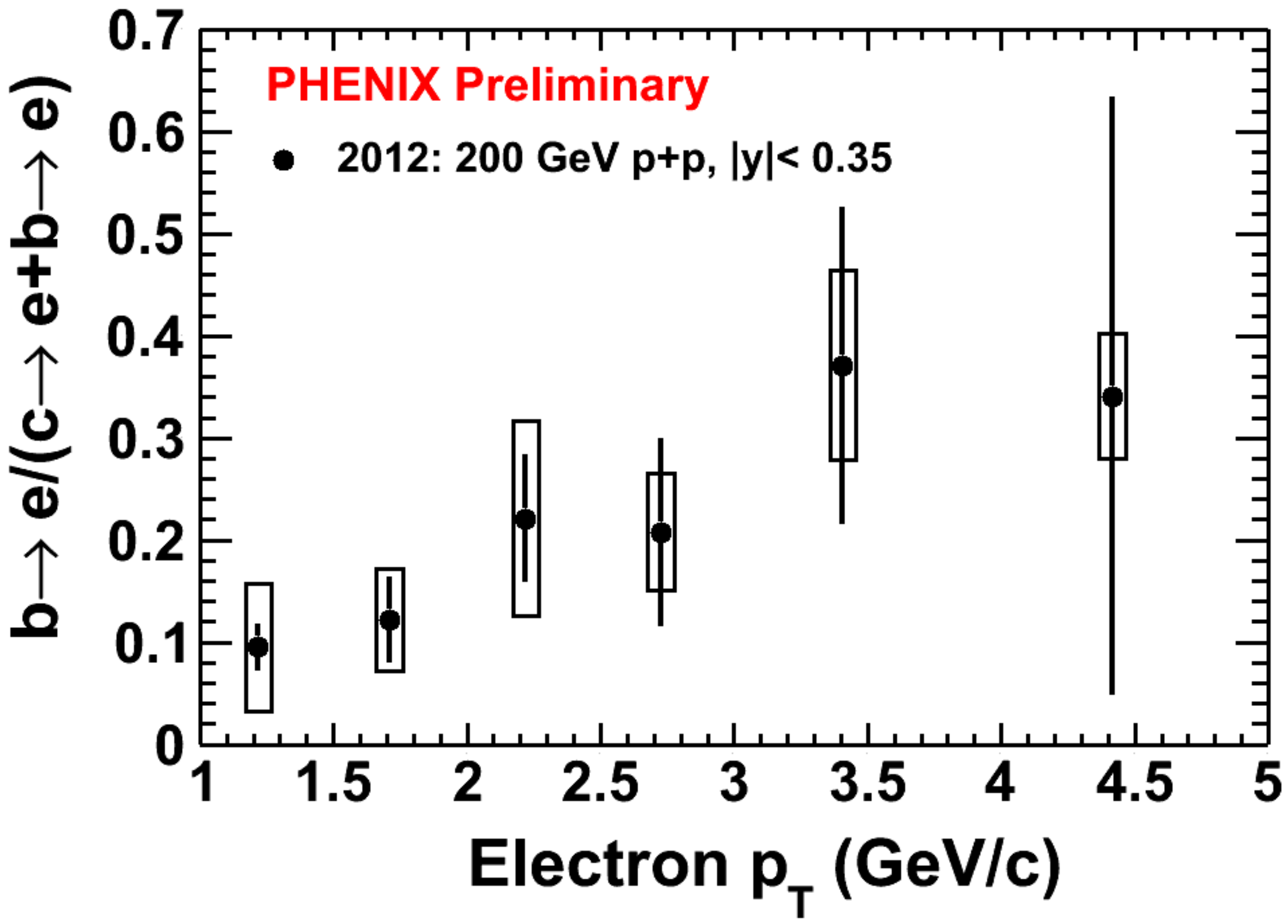
- Invariant yield of heavy quark electron is evaluated with R_{HF}.
  - **consistent with published result (by PHENIX).**

Bottom fraction measurement : DCA decomposition

- $b \rightarrow e/(c \rightarrow e + b \rightarrow e)$ is evaluated by decomposing XY-DCA distribution.
  - DCA decomposition is done by fitting with templates evaluated by simulation and data.
- **non-photonic electron** : HF, Kaon
  - PYTHIA simulation + Gaussian convolution
    - ✓Gaussian mean is evaluated by GEANT simulation and sigma is DCA resolution.
- **photonic electron** : conversion, Dalitz
  - GEANT simulation + Gaussian fit

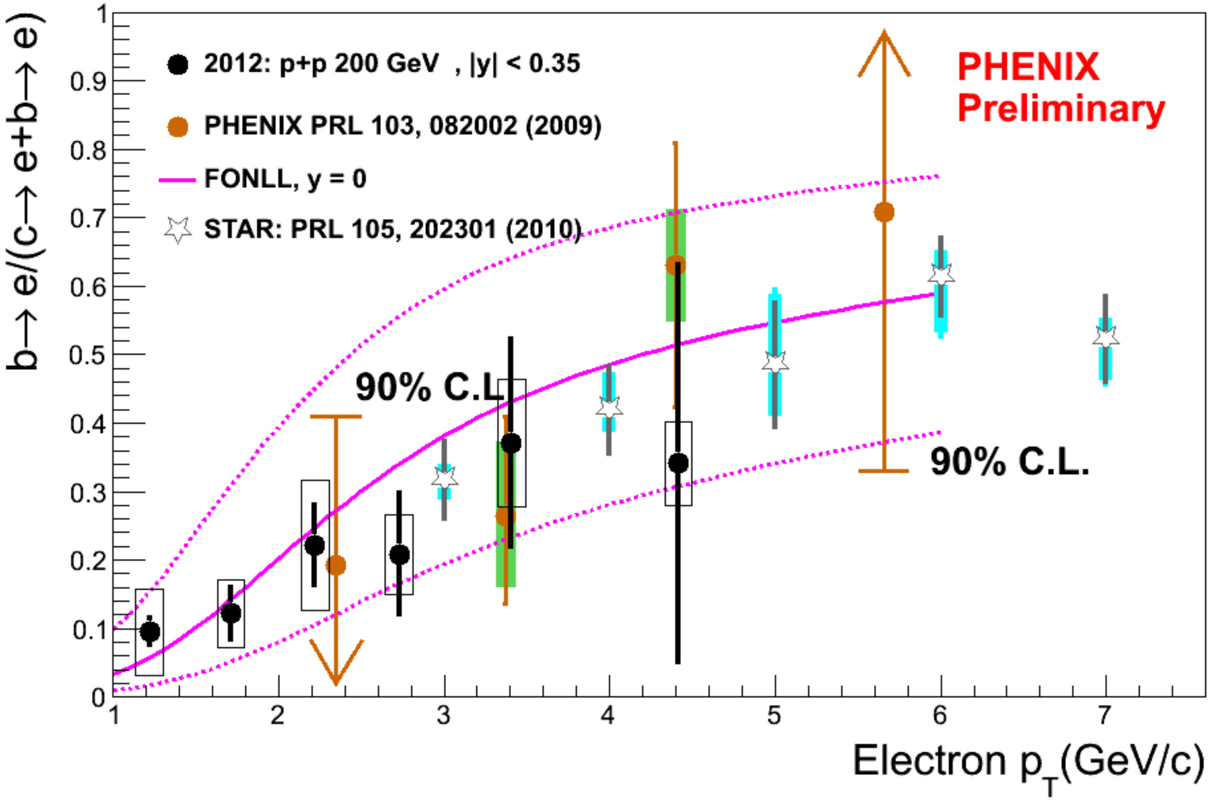


bottom fraction in p+p



First result of bottom fraction from DCA analysis

Comparison of result



- **The result is consistent with published data.** (by PHENIX & STAR)
  - published data : evaluated by e-h correlation analysis.
- FONLL calculation is consistent with the result.

bottom fraction in Au+Au

- Bottom fraction in Au+Au data is also evaluated.
  - But a missing item is found to be evaluated as a systematic error.
- missing item
  - If p_T distributions of heavy flavor hadrons are significantly modified, DCA templates are also modified.
    - ✓ p_T distribution in PYTHIA with default setup is used in the decomposition analysis.
  - For p+p data, p_T distribution is not so different from PYTHIA.
  - But for Au+Au data, p_T distribution can be changed from PYTHIA.

Evaluation of this item is ongoing !!!

Summary

Charm & bottom contributions in electron from heavy quark decay is measured directly from electron DCA distribution.

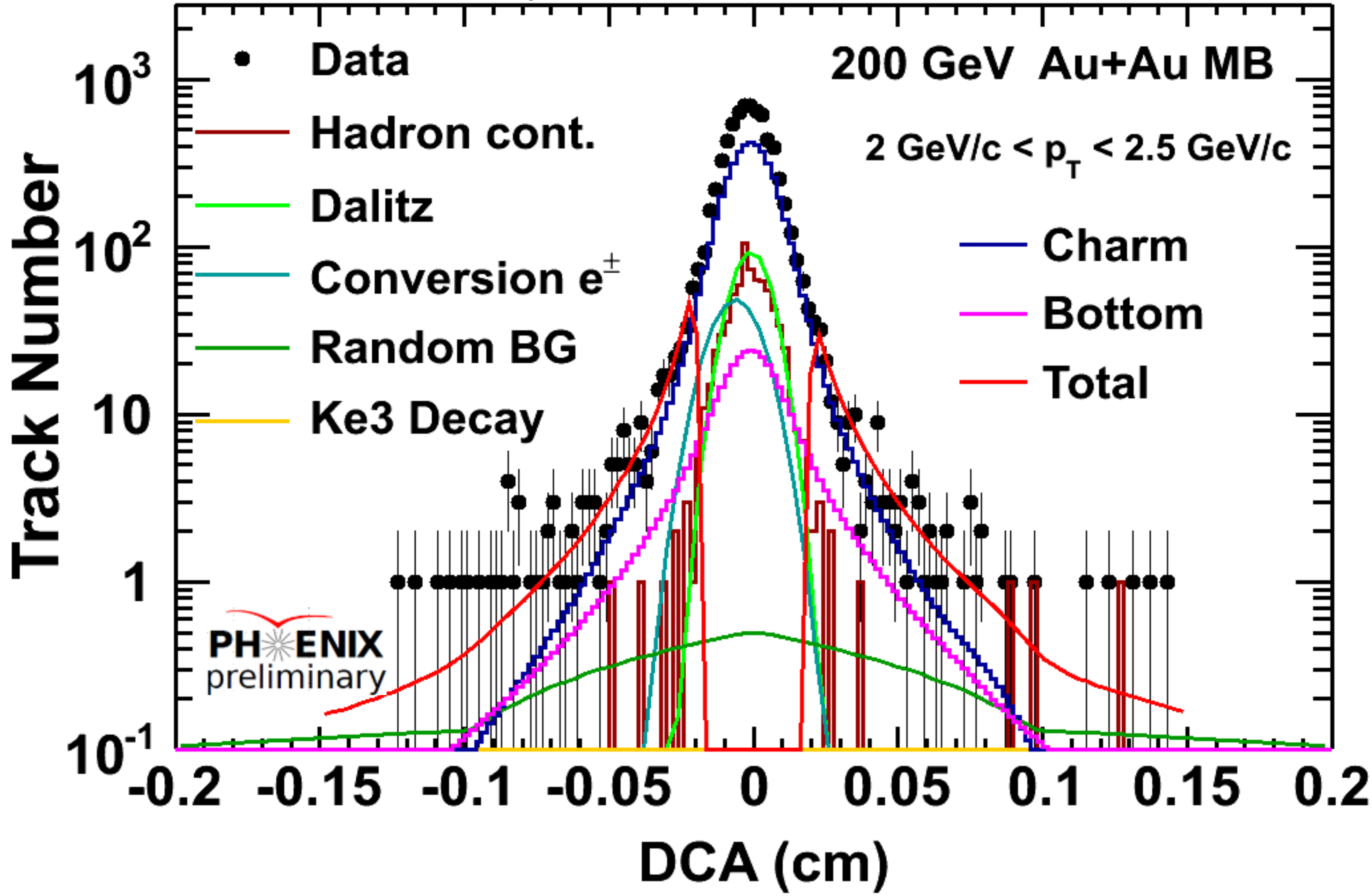
- **p+p**
  - The result of bottom fraction is consistent with the published result by PHENIX & STAR.
  - FONLL calculation is consistent with the result.
- **Au+Au**
  - Effect of modification of heavy flavor hadron p_T distribution is being evaluated.

End

Backup

How were the DCA measurement used?

- DCA data are fit by background components (left column) and c→e **and b→e "expected DCA"** (right column)
- The fit produces relative c→e to b→e fractions
- Where did the "expected DCA" distributions come from?



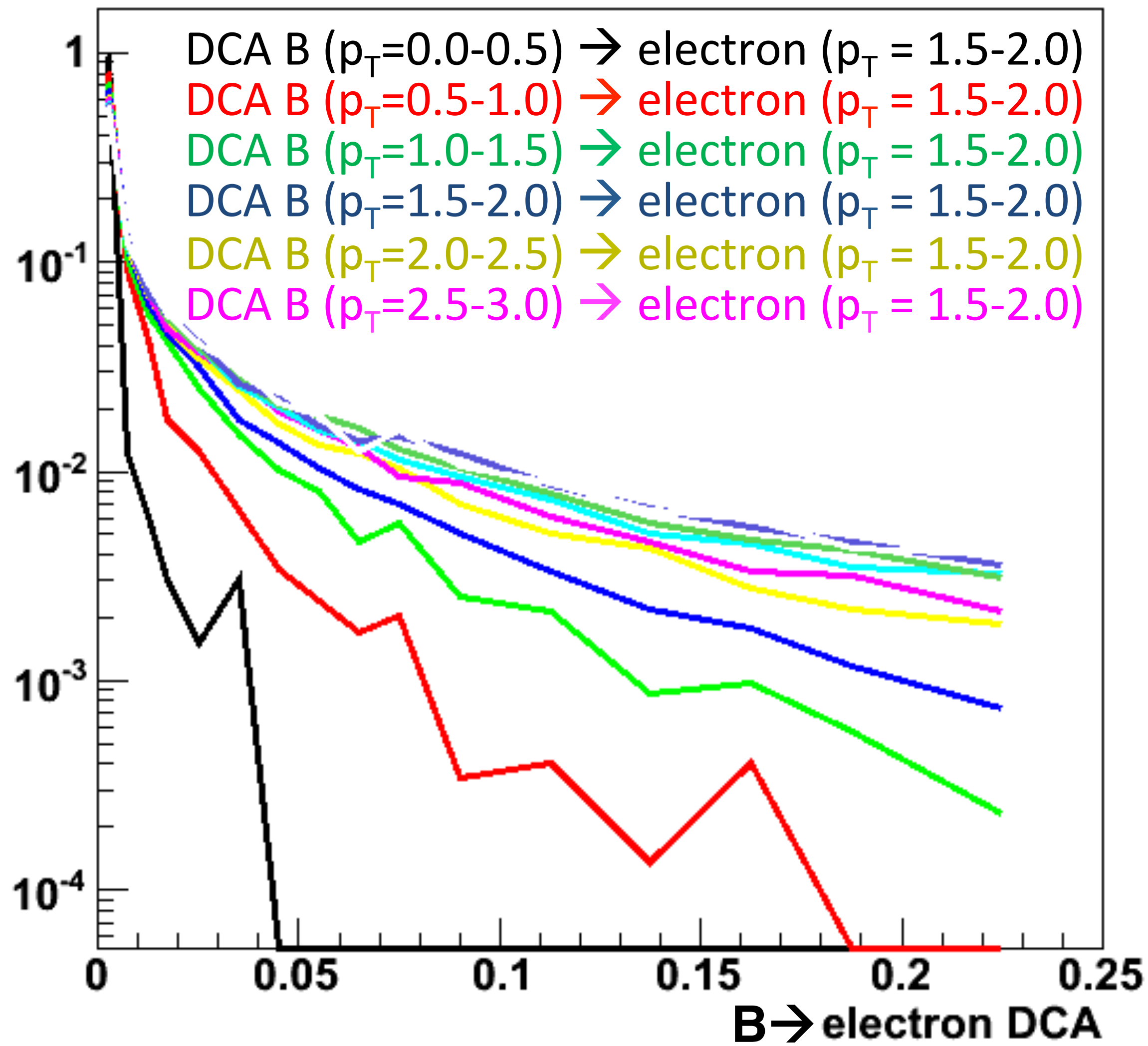
Where did the "expected DCA" distributions come from?

Simple Answer: For the QM Preliminary result, the analysis just used the PYTHIA output. That assumes the **PYTHIA** parent (e.g. D, B) p_T distribution and decay kinematics

The "expected DCA" b→e is a convolution of the B meson parent p_T spectrum with the electron decay kinematics and corresponding DCA

For these p_T electrons, if the parent B meson p_T distribution is significantly modified from PYTHIA, the "expected DCA" from PYTHIA will be wrong

All curves normalized to same integral for shape comparison

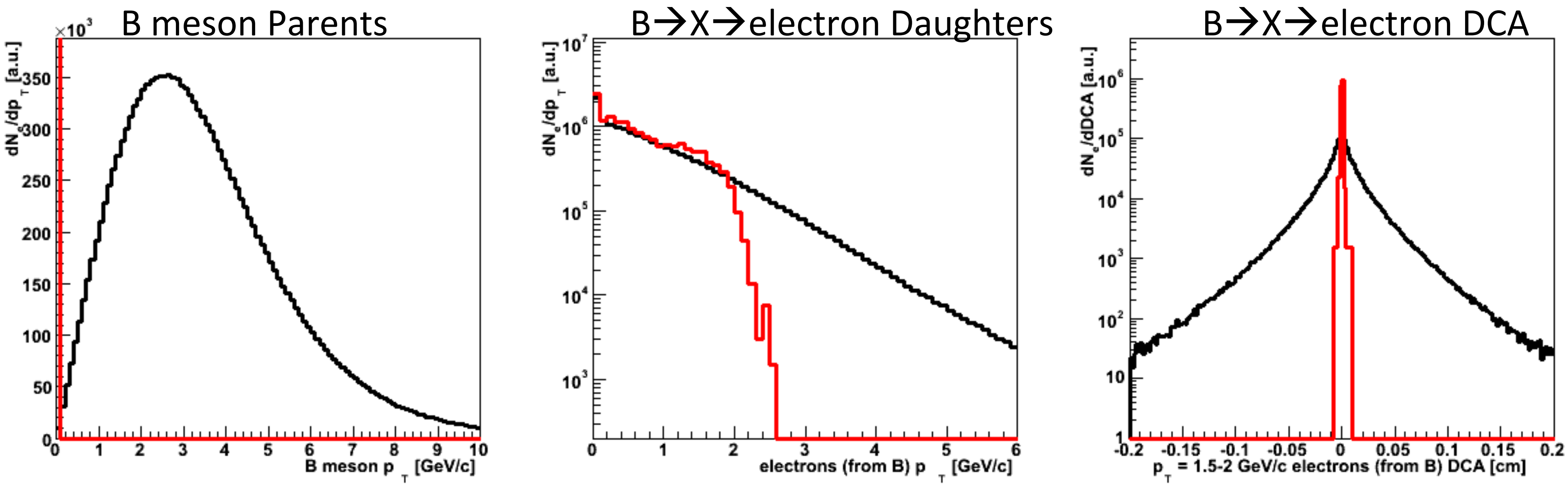


An Extreme Example Just to Demonstrate the Point

Compare **PYTHIA B meson p_T distribution (Black)** and a

Scenario with all B mesons at p_T = 0 (Red)

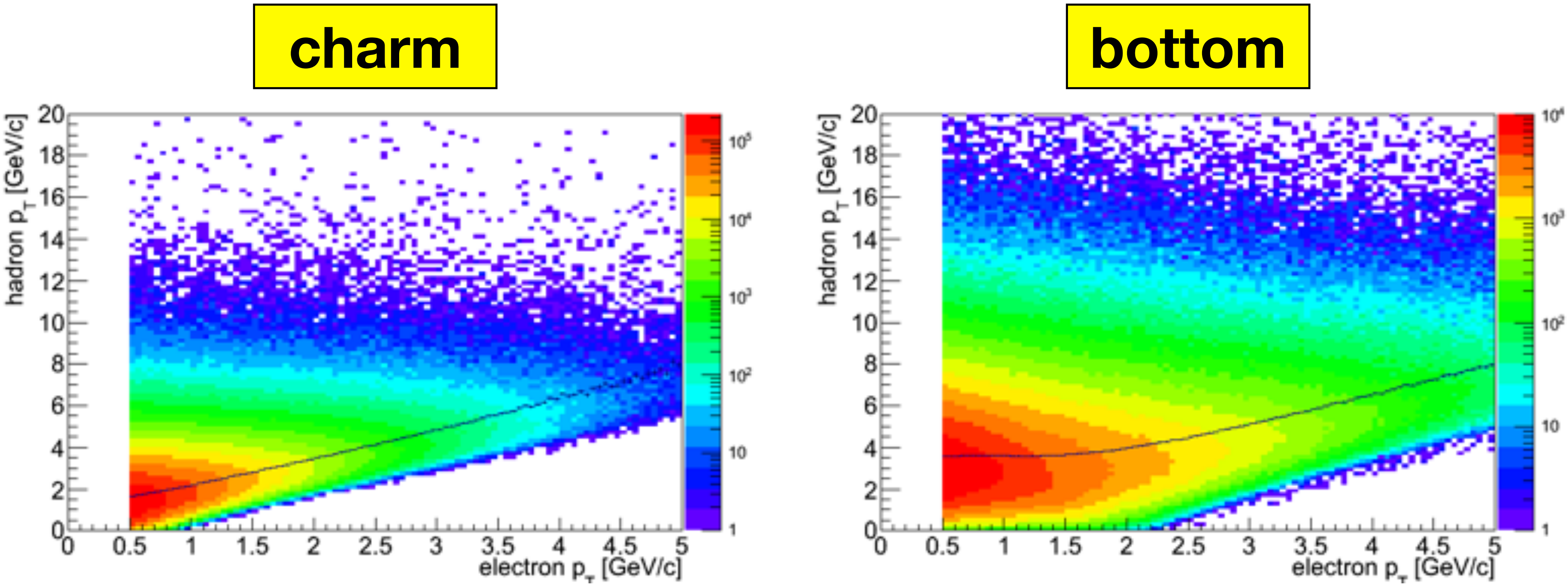
We said it was extreme…



Because of decay kinematics, even in the Red Scenario, one will have B→X→e all the way out beyond electron $p_T \approx$ 2 GeV/c.

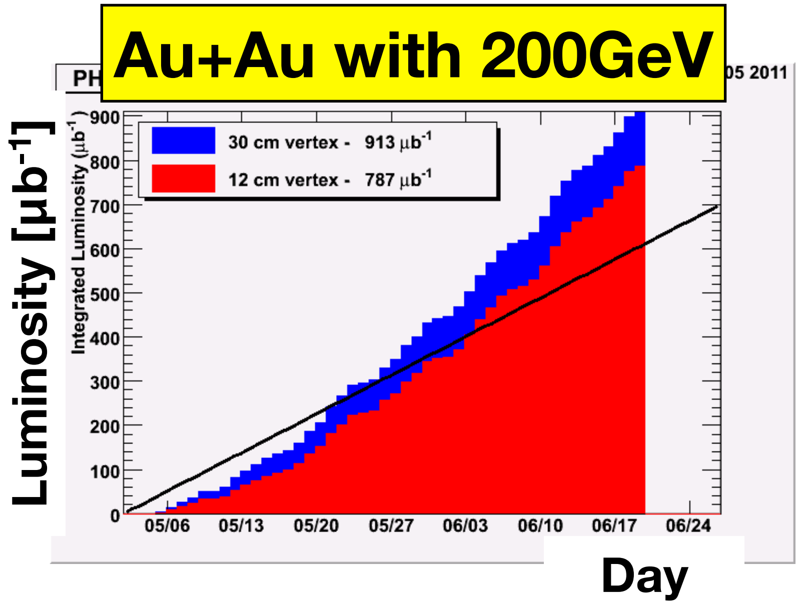
However, these electrons will all have DCA = 0 (since the B is at rest) and thus would **not** be properly extracted using the PYTHIA DCA template.

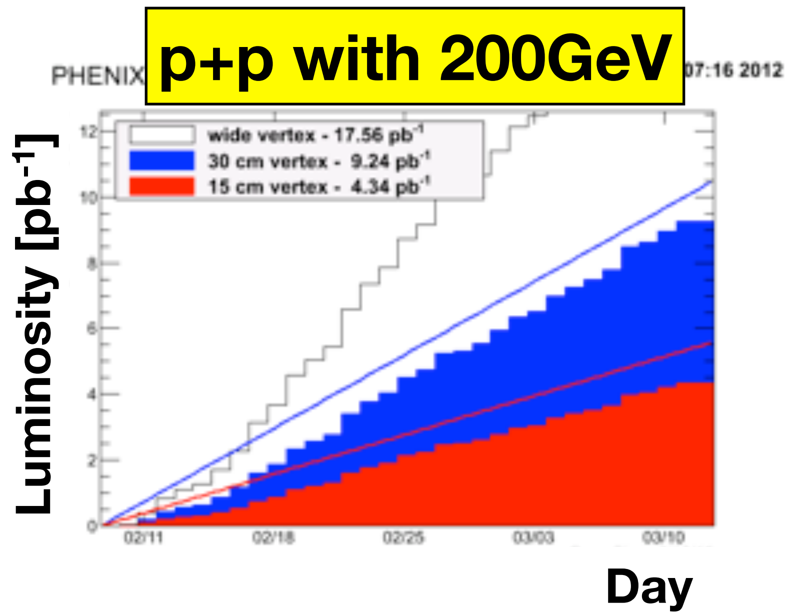
Correlation of parent p_T & electron p_T



Statistics

- FY2011
  - Au+Au ($\sqrt{s_{NN}}$=200GeV) : 1.5 months
    - ✓ $\int L dt$=**~800μb^{-1}** ($\int L^{NN} dt$=**~31pb^{-1}**)
  - Au+Au ($\sqrt{s_{NN}}$=19.6GeV) : 1 week
  - Au+Au ($\sqrt{s_{NN}}$=27.0GeV) : 1 week
  - p+p ($\sqrt{s}$=500GeV) : 1 week
- FY2012
  - p+p ($\sqrt{s}$=200GeV) : 1 month
    - ✓ $\int L dt$=**~3.8pb^{-1}**





conversion rejection