Non-photonic Electron v2 and Heavy Quarkonia Measurements from STAR

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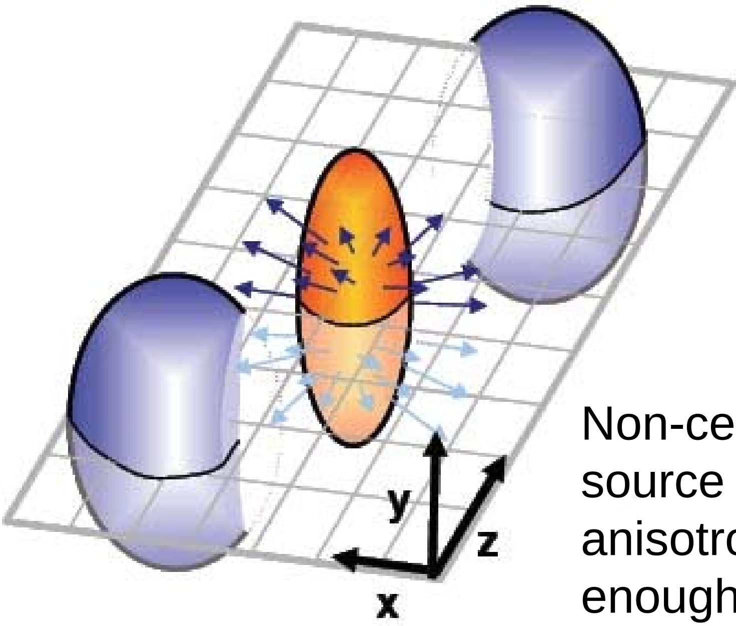
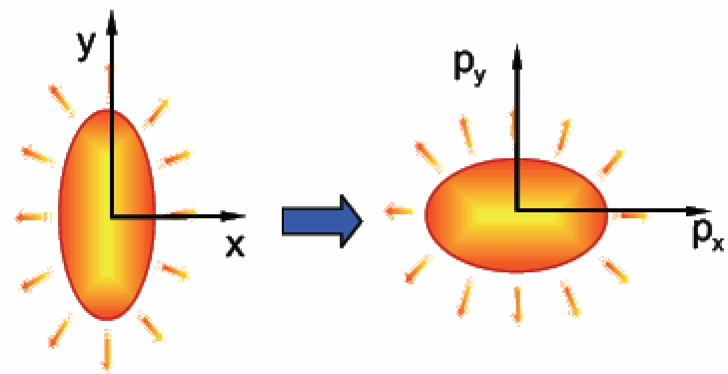
For STAR Collaboration

Outline

- V2 measurement: What is v2? What is a non-photonic electron and why do we measure its v2? Why is heavy quark v2 interesting? How do we measure it? What have we got?
- J/Psi measurement: What have we seen in STAR?

What is v2?





Non-central Au-Au collisions → azimuthally anisotropic source of matter in coordinate space → azimuthally anisotropic (isotropic) of particles in momentum space, given enough particle interactions → Non-zero (zero) v2

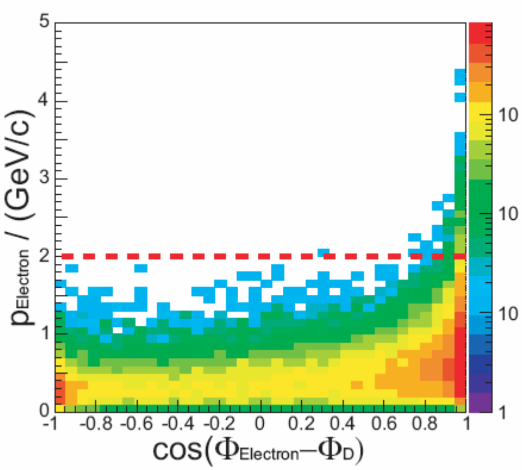
v2 is built up at the early stage of the collision so it is a nice probe of the hot and dense medium created at RHIC energy!

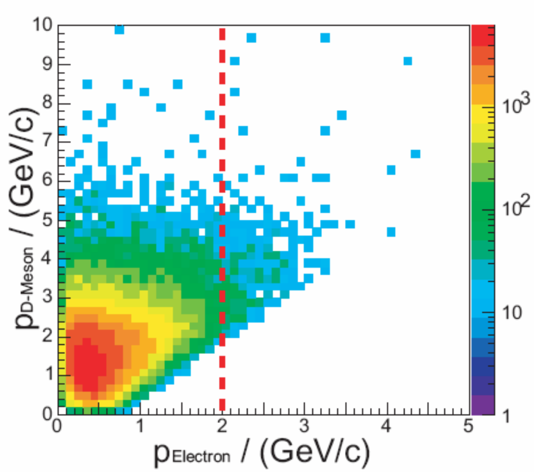
$$E\frac{d^3N}{dp^3} = \frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}\left(1+\sum_{n=1}^{\infty} 2v_n \cos[n(\phi-\psi_r)]\right)$$

$$v_2 = <\cos[2(\phi-\psi_r)]>$$

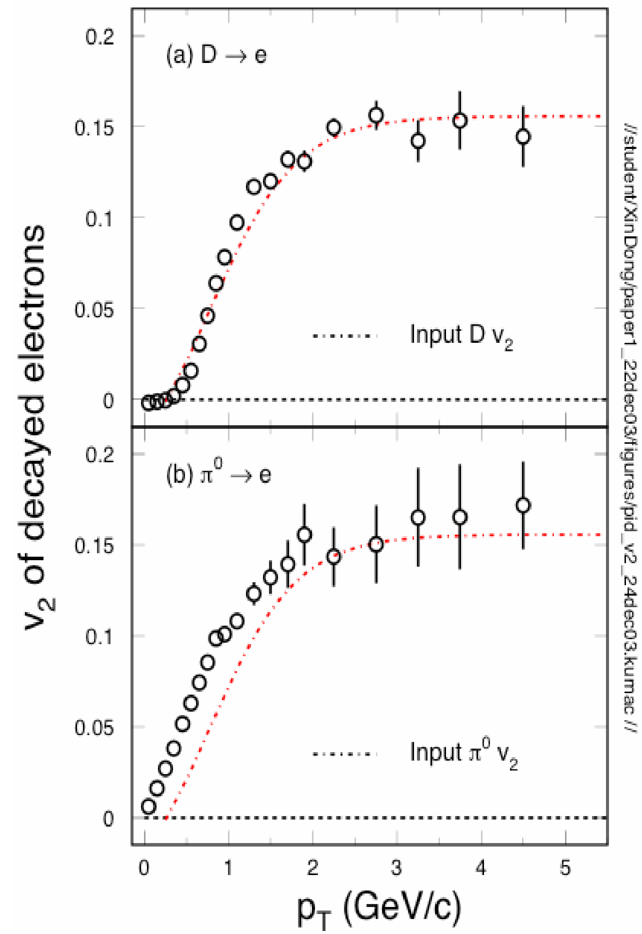
What Is a Non-photonic Electron and Why do we measure its v2?

- A Non-photonic electron is an electron from heavy quark decay. Charm semi-leptonic decay branch ratio~9.6%, Bottom semi-leptonic decay branch ratio~10.5%
- At high pt, the v2 of the daughter electron is correlated with the parent heavy quark v2: To measure the non-photonic electron v2 is to measure the heavy quark v2 indirectly





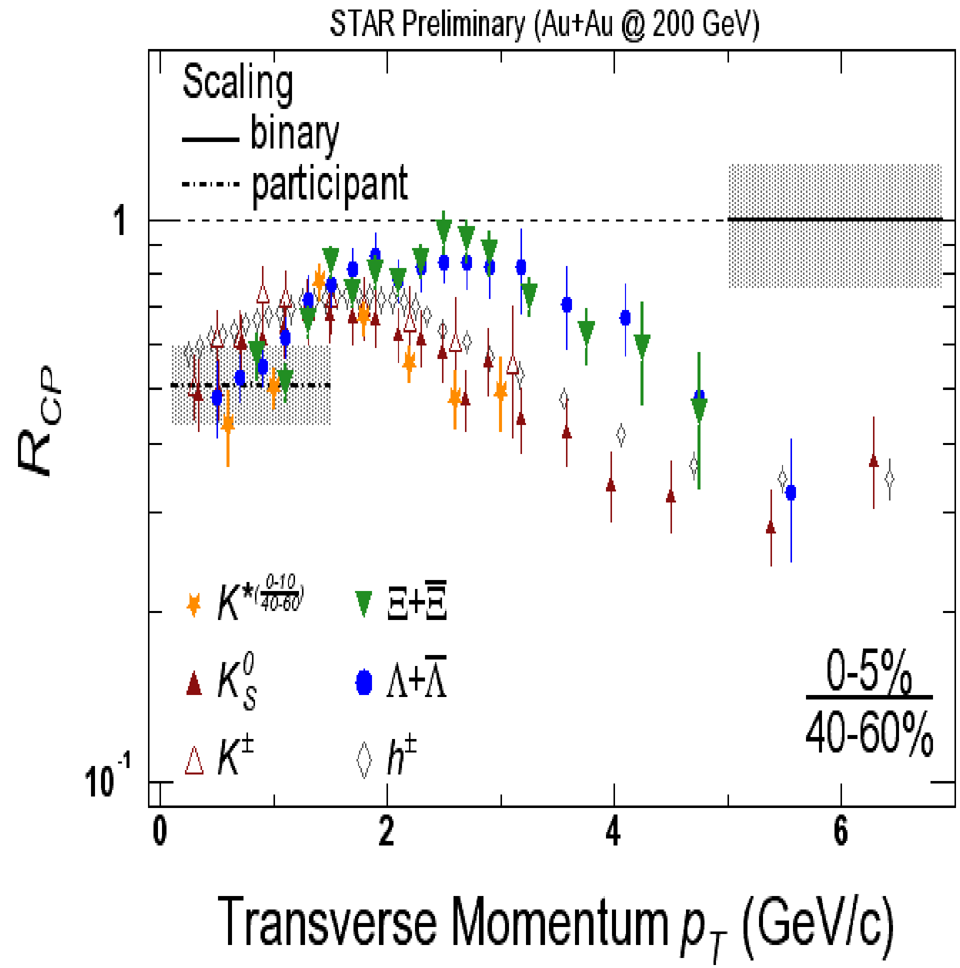
F. Laue



X. Dong et. al, *PLB597, 328(2004).*

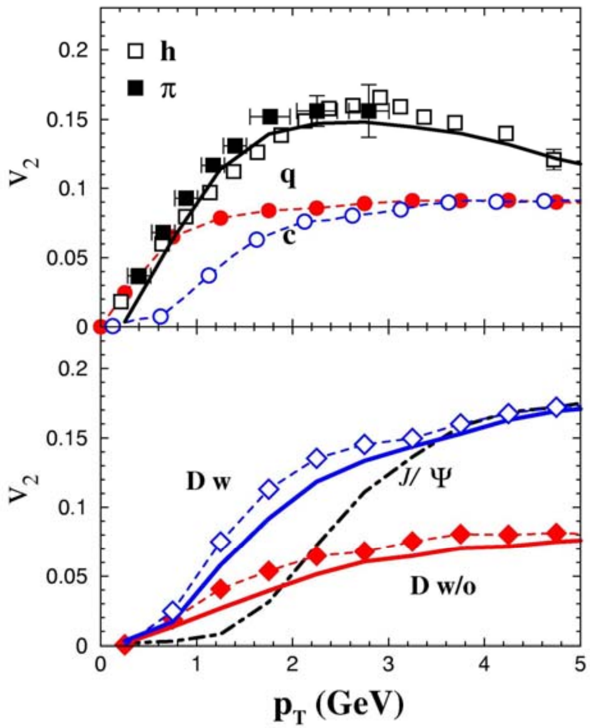
Why is heavy quark v2 interesting?

- The heavy quark v2 addresses two important physics issues
  - At RHIC we have observed partonic collectivity and jet quenching. The measurement of heavy quark v2 can test the thermalization of the medium created at RHIC energy
  - The energy loss of heavy quarks in the dense medium created in nucleus-nucleus collisions at RHIC

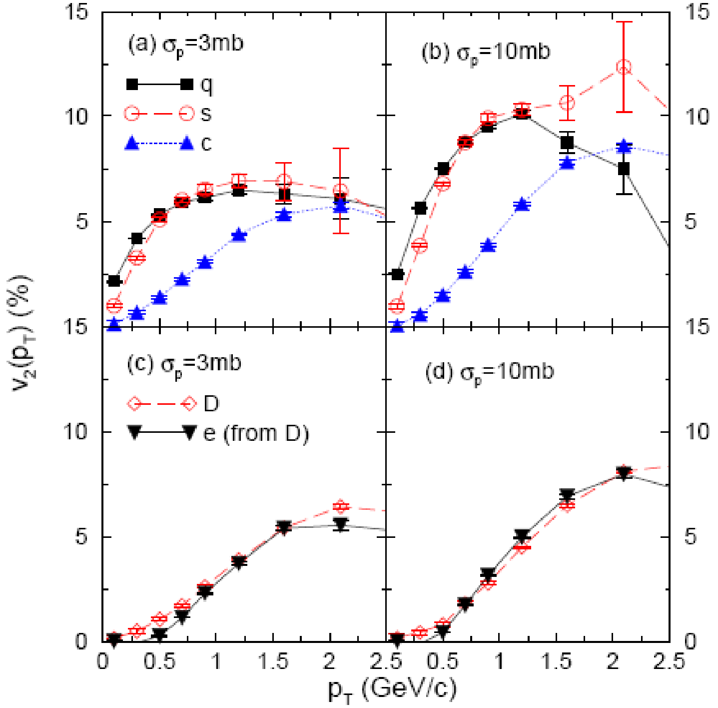


Does Heavy Quark Flow?

V. Greco et al., PLB 595(2004)202

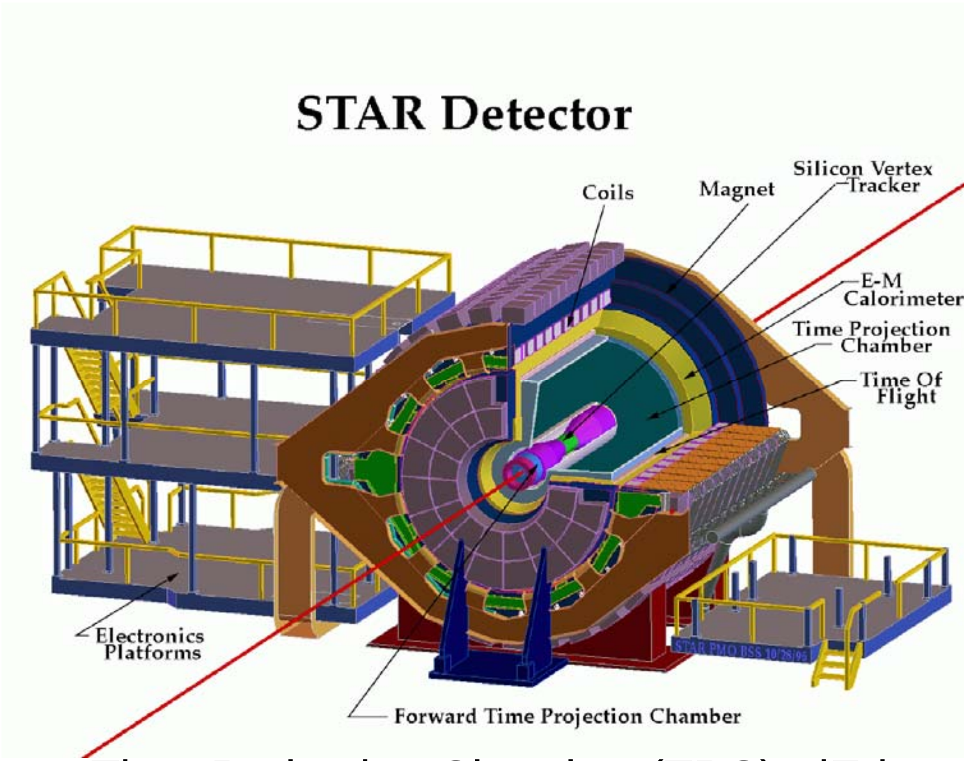


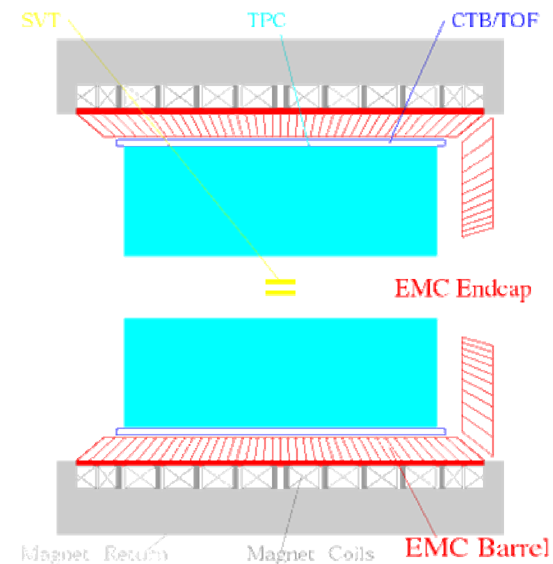
B. Zhang et al., nucl-th/0502056

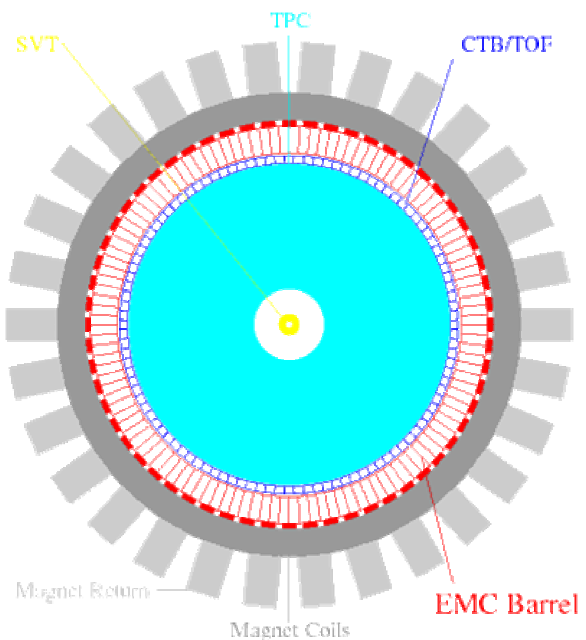


- Coalescence approach: charm has same v2 as light quark or zero v2
- AMPT transportation model: mass ordering, same saturation level, cross section dependence, correlation of electron v2 and D meson v2

Major Detectors Used







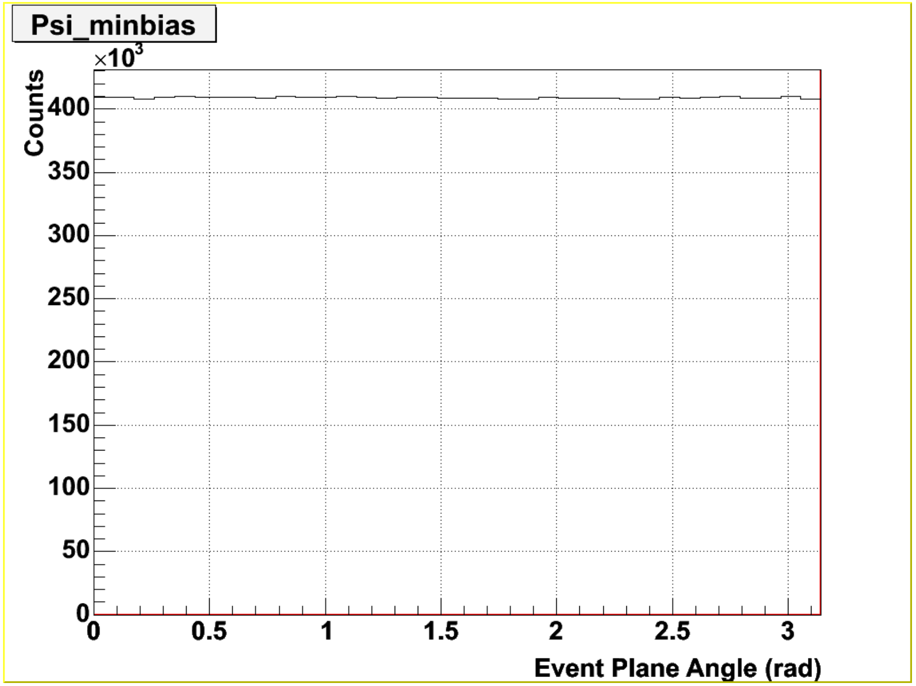
- Time Projection Chamber (TPC): dEdx v.s. P
- Electro-Magnetic Calorimeter (EMC): E
- Shower Maximum Detector (SMD): Shower size and shower position
- Signal: non-photonic electrons
- Background: hadrons and photonic electrons

Reaction Plane Angle

$$E\frac{d^3N}{dp^3} = \frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}\left(1+\sum_{n=1}^{\infty} 2v_n \cos[n(\phi-\psi_r)]\right)$$

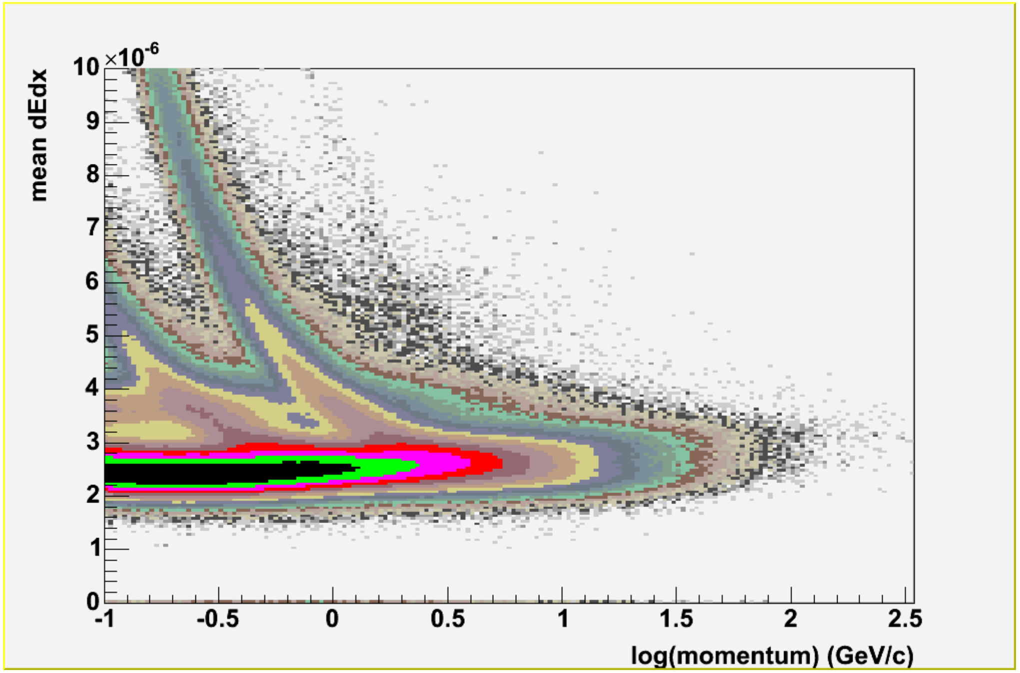
$$v_2 = <\cos[2(\phi-\psi_r)]>$$

$$\psi_{r(2)} = \left(\tan^{-1}\frac{\sum_i w_i \sin(2\phi_i)}{\sum_i w_i \cos(n\phi_i)}\right)/2$$



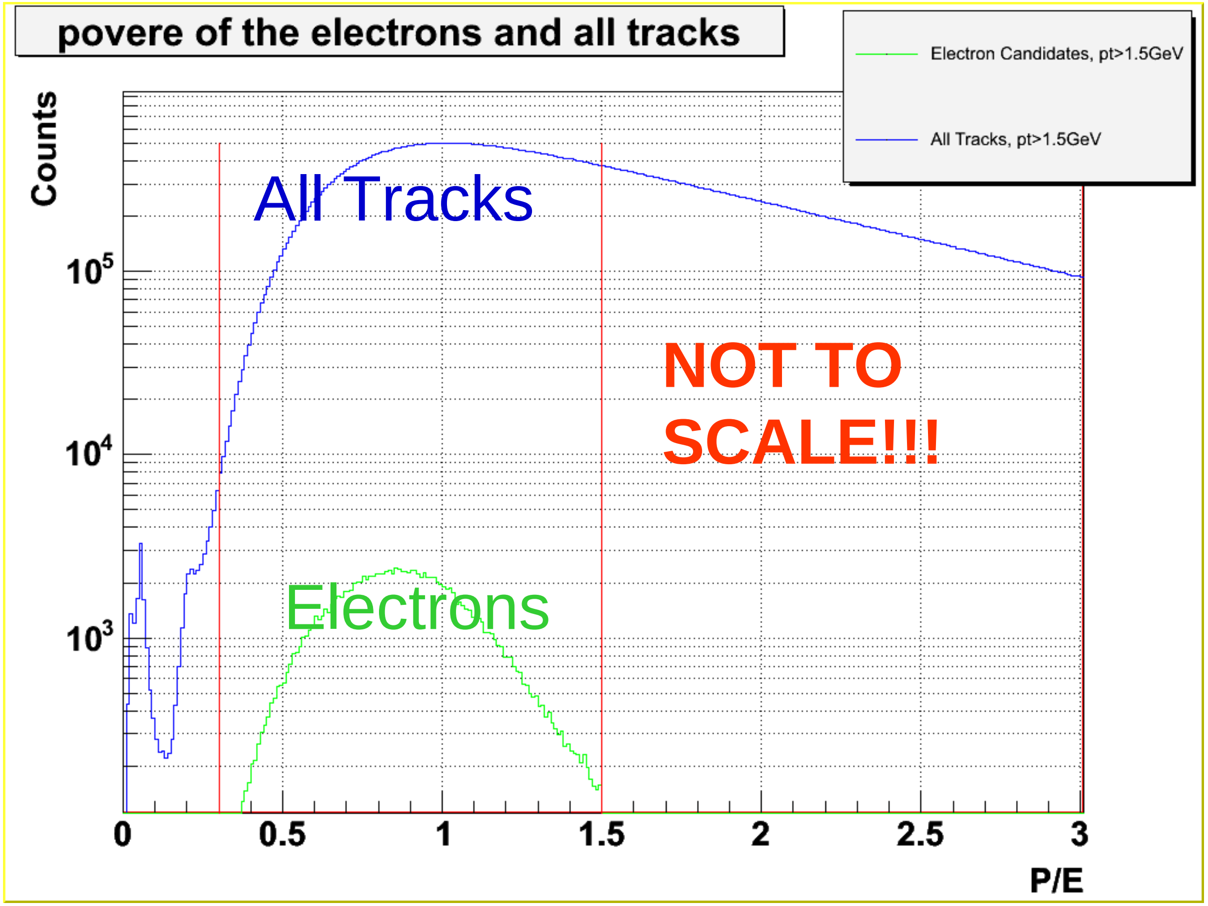
- Real reaction plane is unknown
- Event plane is the approximation of reaction plane
- Take tracks measured by TPC to get the event plane angle
- Limited resolution of event plane measurement dilutes the v2, this effect is corrected at the end

Electron ID: Cut on dEdx



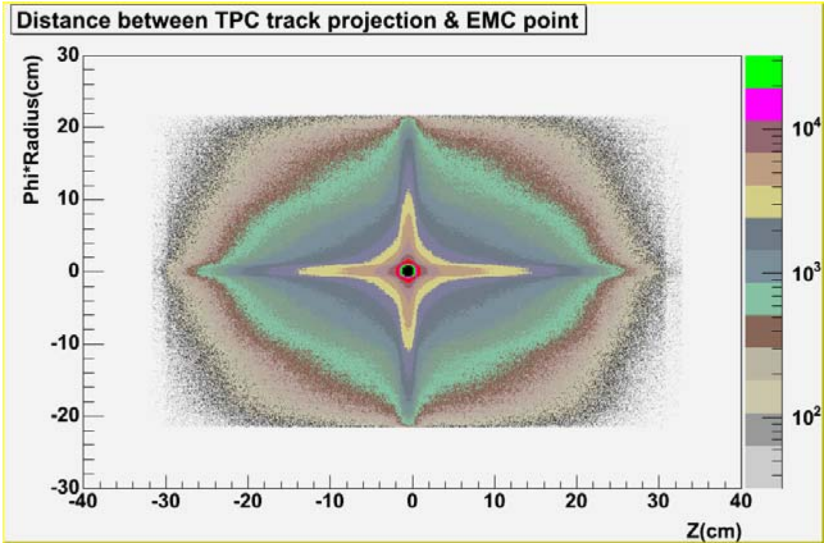
- TPC can identify charged particles to some extent
- Two orders of magnitude more hadrons than electrons
- Additional information needed to identify electrons

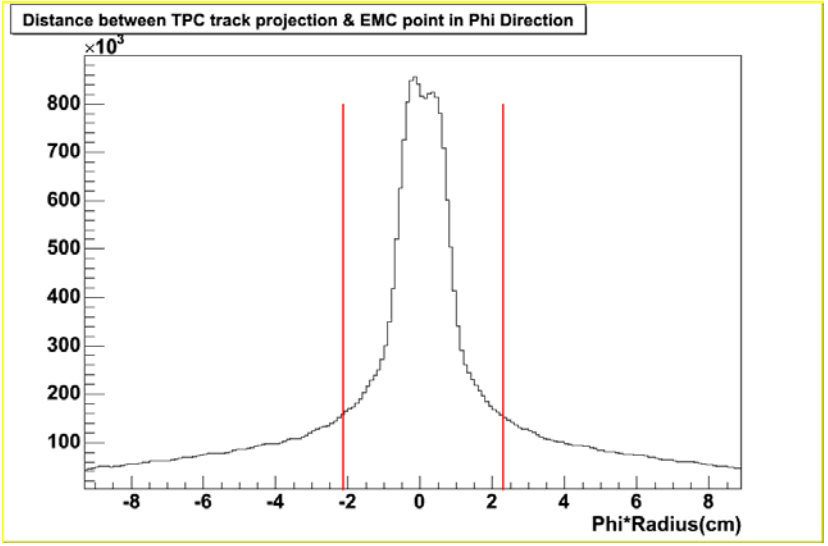
Electron ID: Cut on P/E

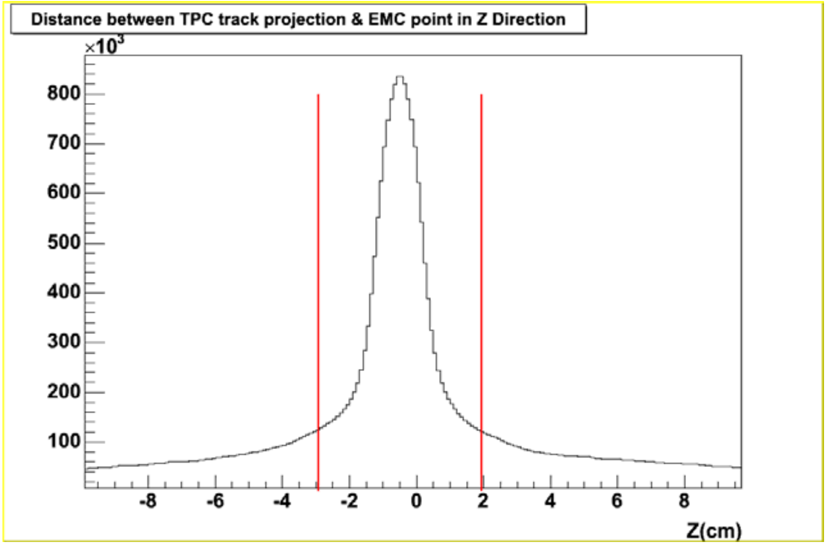


- P from TPC, E from Barrel EMC
- The P/E alone contributed hadron rejection power is not great at low pt, but becomes better at high pt

Electron ID: Cut on Projection Distance

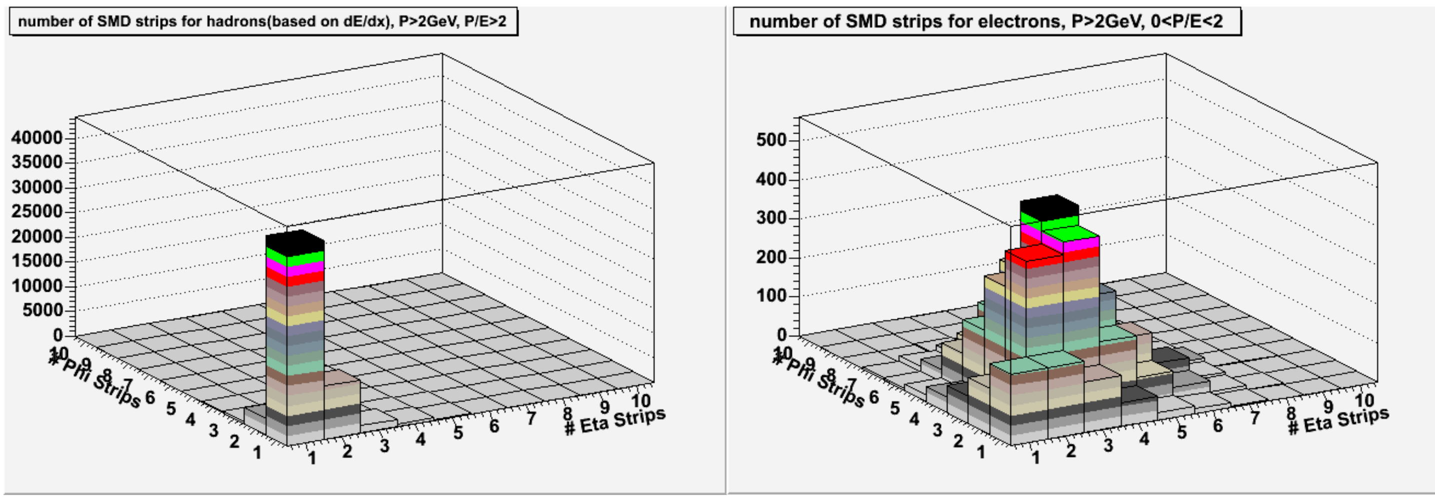






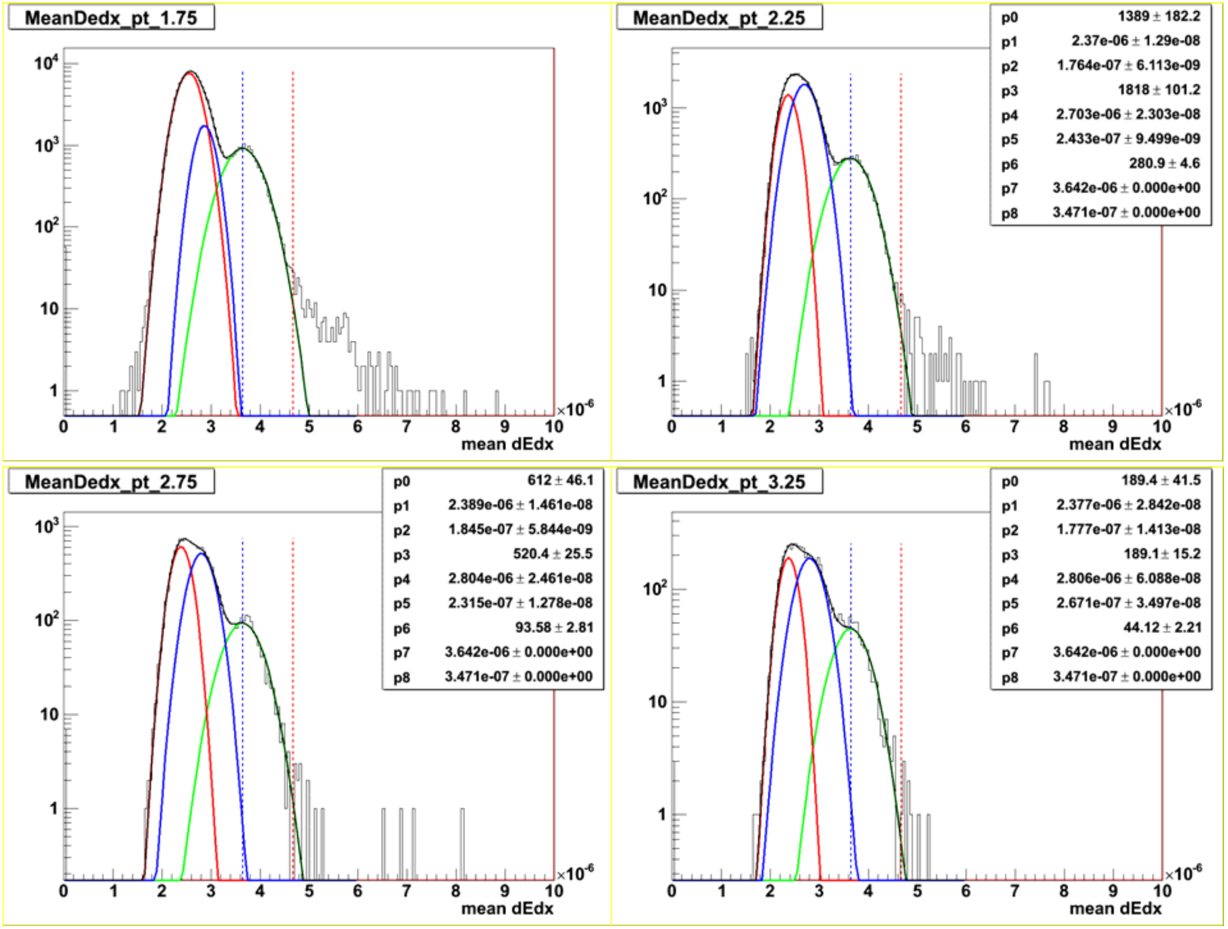
- Nice positional resolution from the help of SMD
- -3 σ <phi_dist< 3 σ
- -3 σ <z_dist< 3 σ

Electron ID: Cut on Shower Size



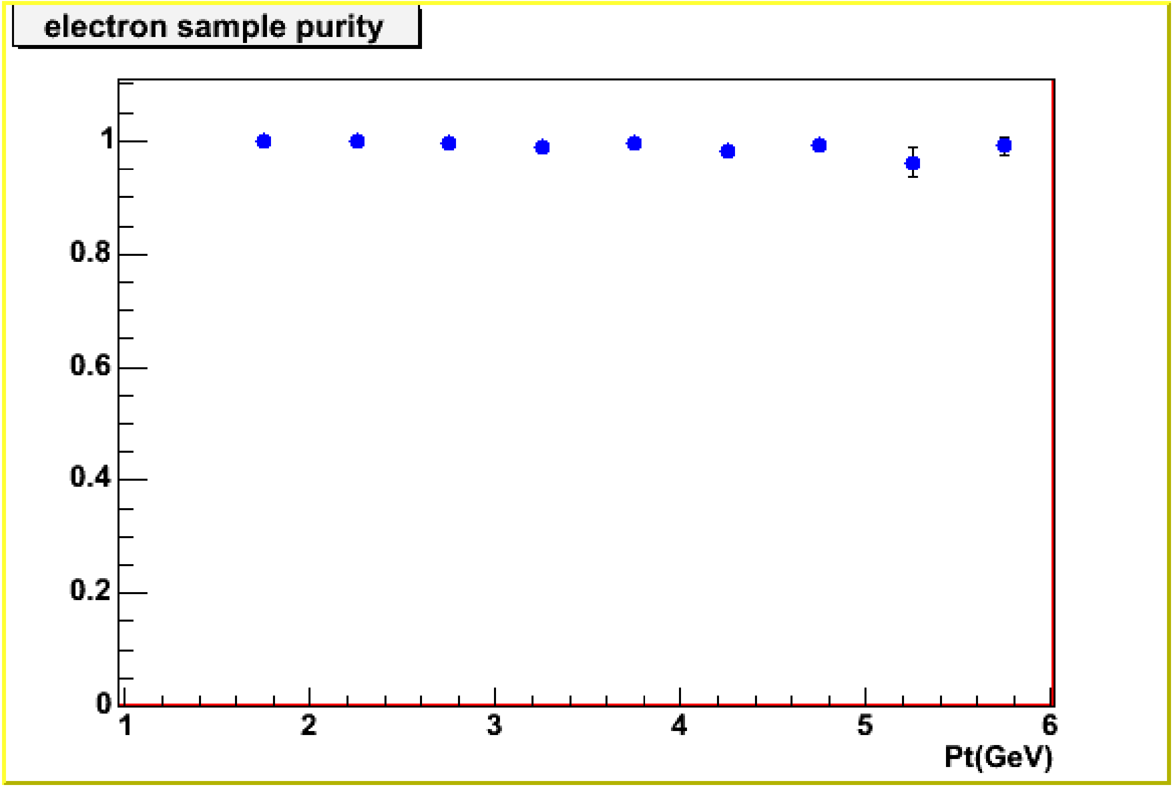
- Shower hadrons typically have small shower sizes
- Number of SMD hits per shower indicates shower size
- Number of hits on SMD larger than 1 for electrons

With All EMC Cuts Applied



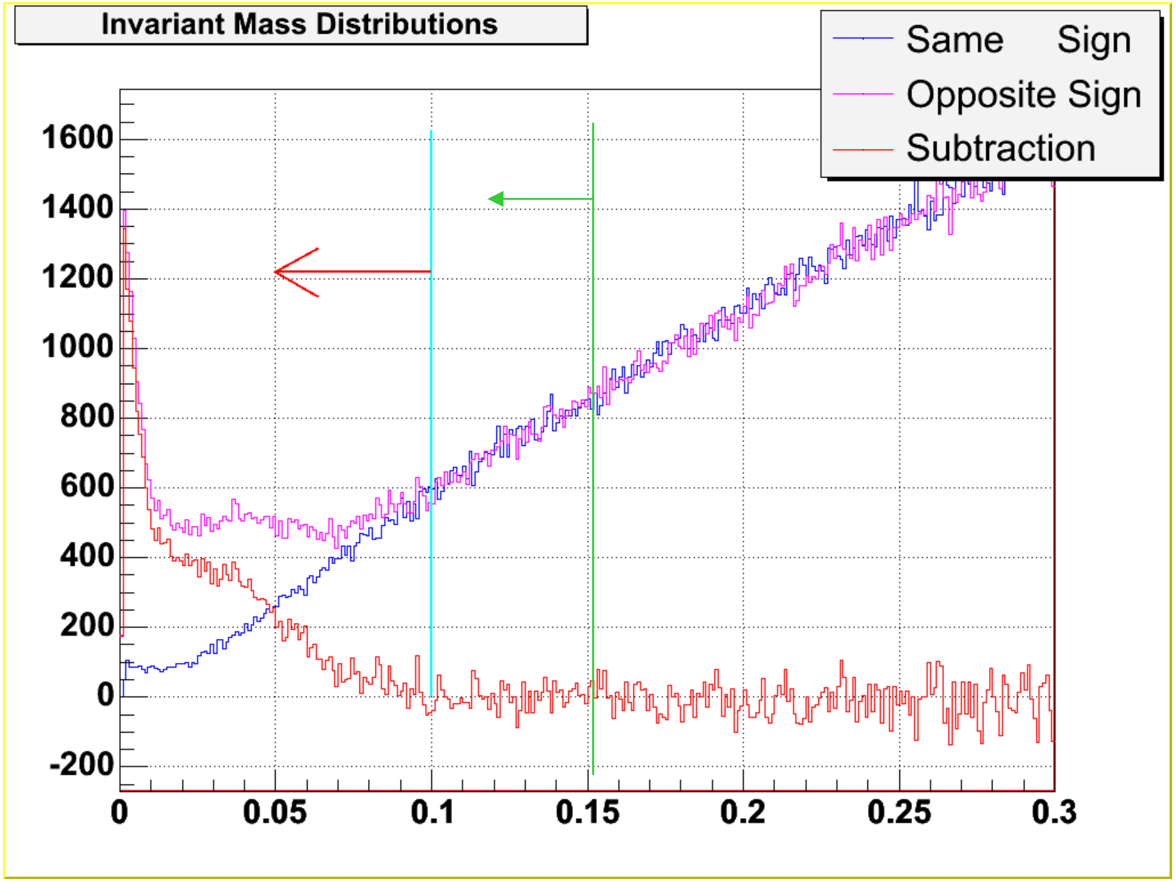
- dEdx cut: from 0 to 3 sigma on electron band

Electron Sample Purity



- Electron Purity>99% for measured pt range
- No worry about hadronic background

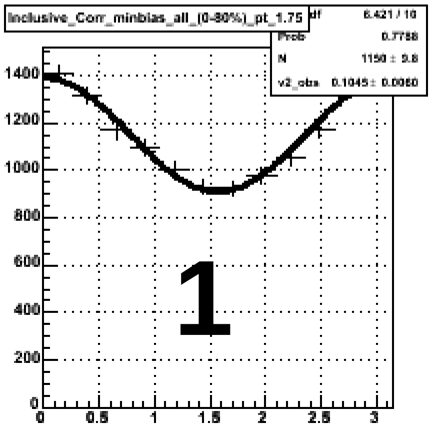
Photonic Background

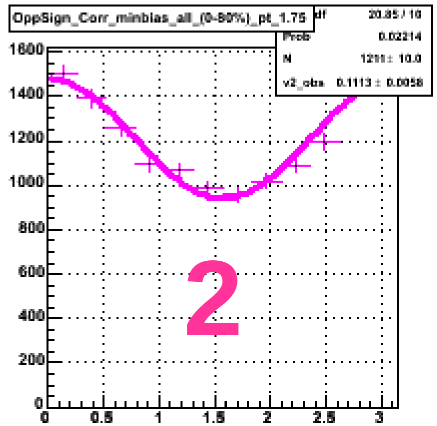


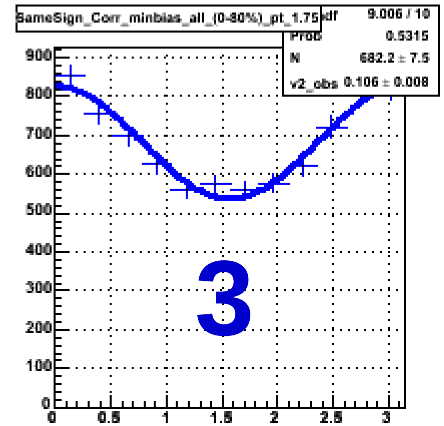
- Reconstructed photonic electron is the subtraction
- Real produced photonic electron is the subtraction/eff
- eff calculated from simulation

The Removal of Background Electrons

OSLM: Opposite Sign Low Invariant Mass; SSLM: Same Sign Low Invariant Mass







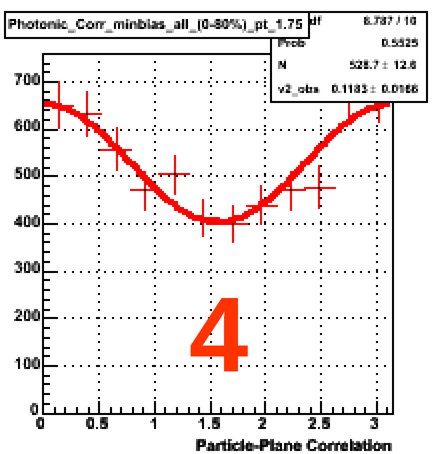
1: inclusive

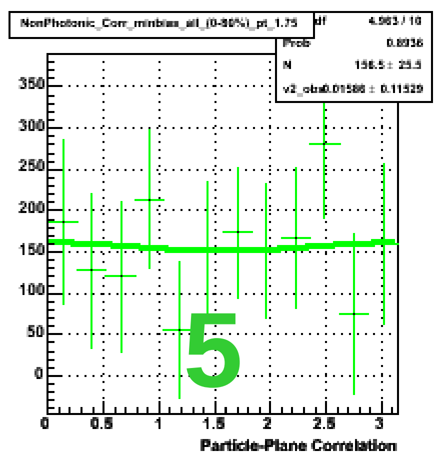
2: OSLM

3: SSLM

4: 2-3

5: 1-(2-3)/eff





OppSign: Electrons having invariant mass lower than 0.15GeV with opposite sign tracks in the same event

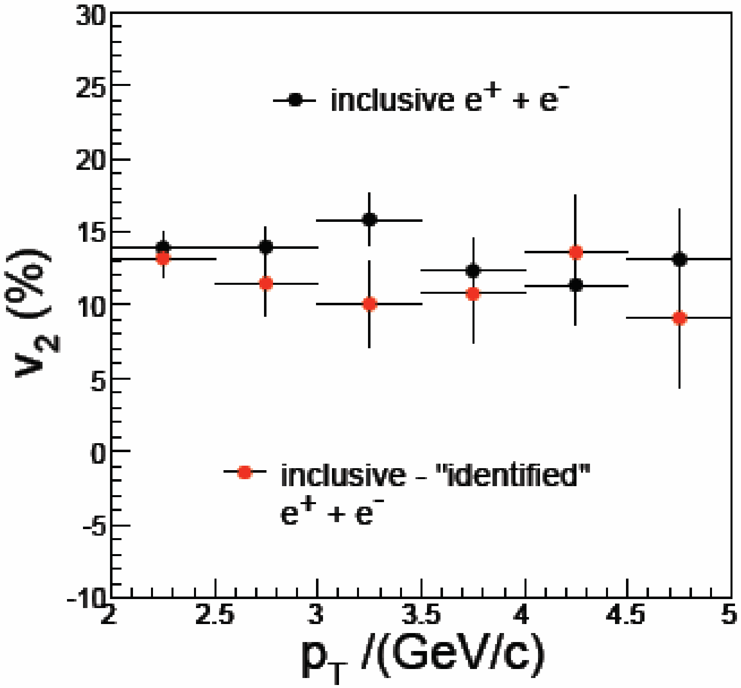
SameSign: Electrons having invariant mass lower than 0.15GeV with same sign tracks in the same event

Photonic=OppSign-SameSign

NonPhotonic=Inclusive-Photonic/Photonic_Eff

QM2005 Method

Calculating the non-photonic v_2



Assumption:

$$v_2^A = \frac{v_2^{sin} \cdot n^{sin,A} + v_2^{pho} \cdot n^{pho,A}}{n^{sin,A} + n^{pho,A}}$$

$$v_2^B = \frac{v_2^{sin} \cdot n^{sin,B} + v_2^{pho} \cdot n^{pho,B}}{n^{sin,B} + n^{pho,B}}$$

2 equation with 2 unknown can be solved analytically

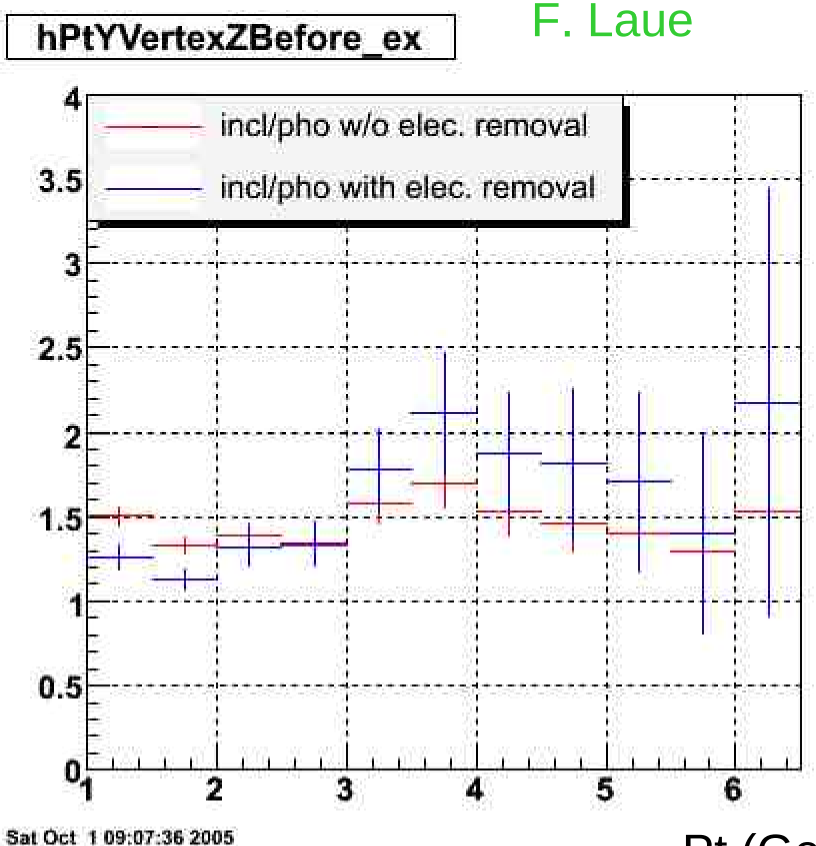
Measure the $e^{+/-}$ v_2 twice:

Sample A: without photonic electron rejection (inclusive)

Sample B: after photonic electron rejection

QM2005 Method: Problems

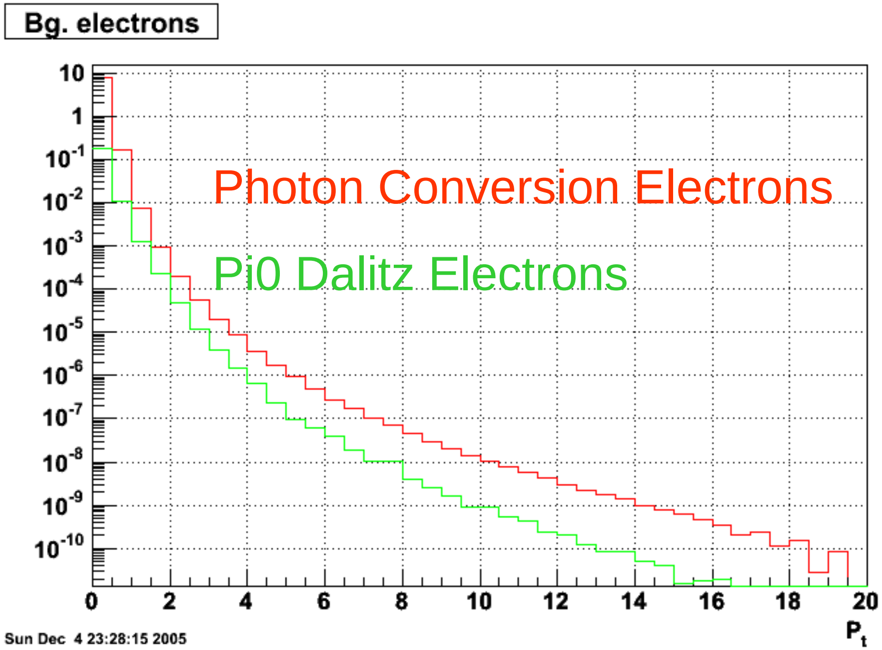
F. Laue

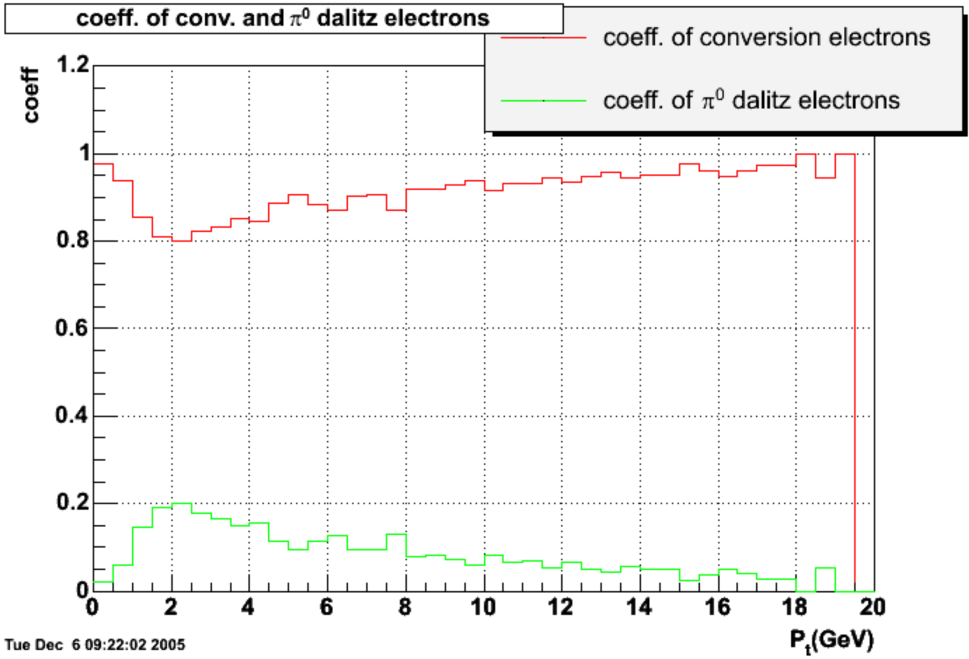


Pt (GeV)

1. **Two equations are almost the same experimentally**
2. **Low invariant mass cut is essentially low opening angle cut, but v2 is just about opening angle: the v2 of non-photonic electron are not the same in two equations!**
3. **Non-flow effect**
4. **Error calculation incomplete**

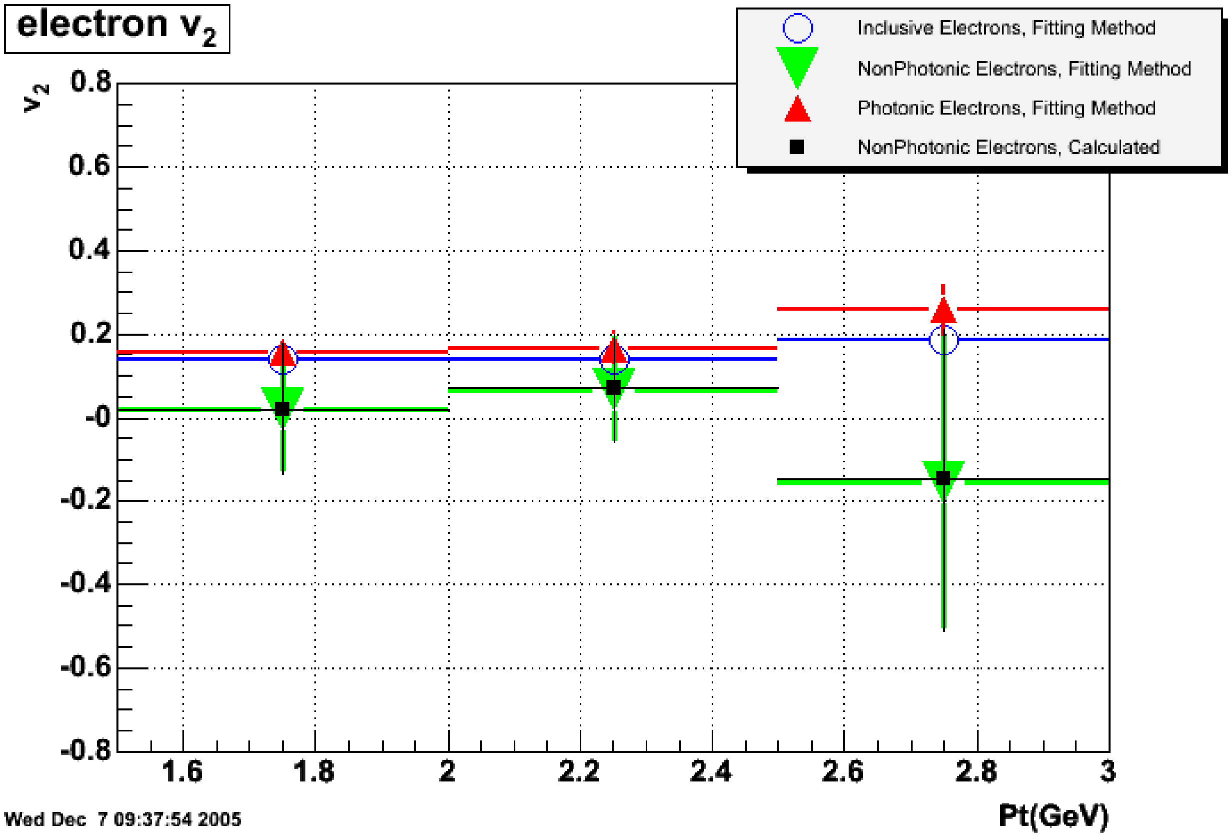
Too much photon conversion electrons!





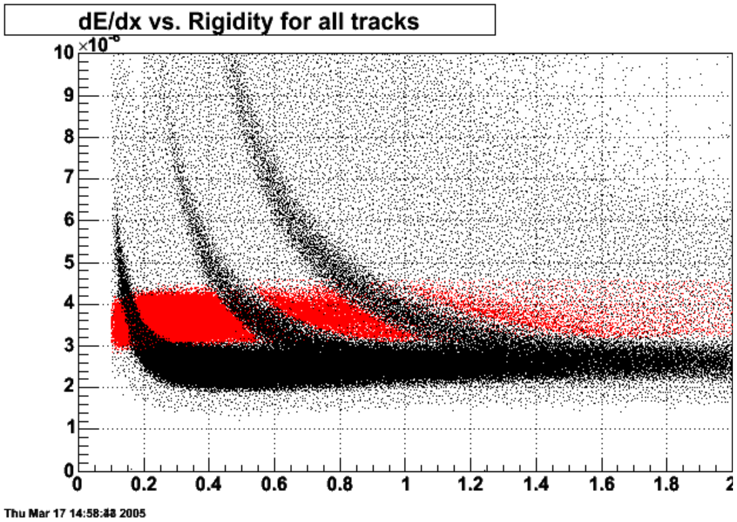
Both methods suffer from photon conversion electrons!!!

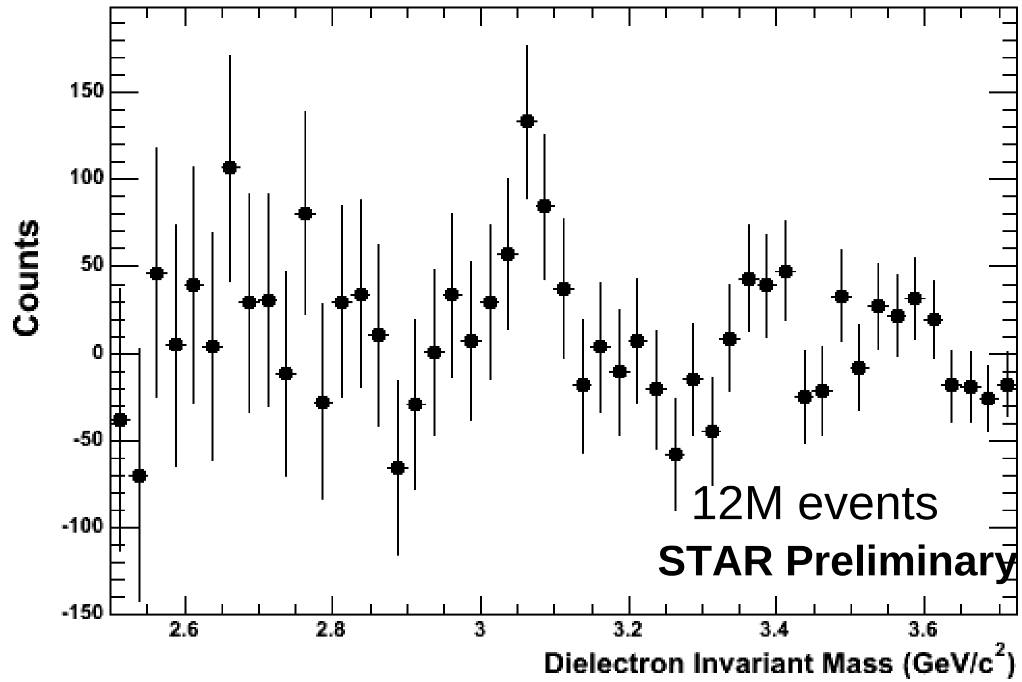
V2 results with new method



The detector material in STAR caused too much photonic background, which caused huge systematic and statistical uncertainties. Our result is not sensitive enough to make any conclusion about heavy quark v2 so far. More work ahead!

J/psi production

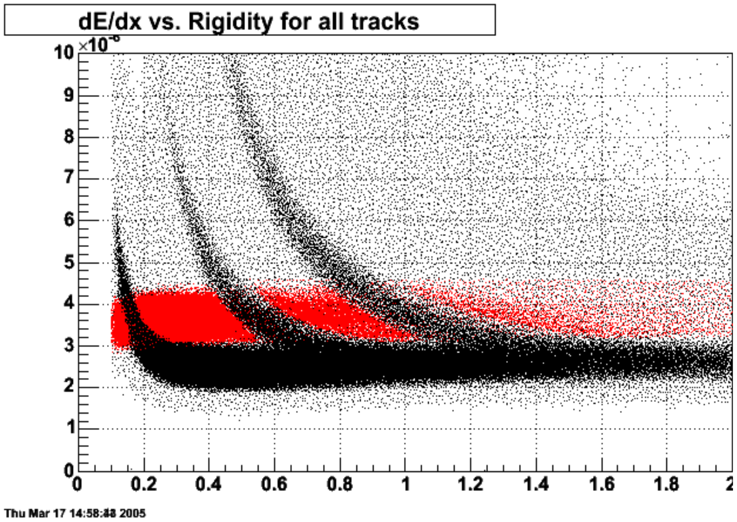




J. Gonzalez

- Select all possible electrons above 0.1 GeV/c, provided they don't impinge any of the hadron bands
- The di-electron invariant mass distribution is generated using the event-mixing
- Our J/psi yields are lower than statistical hadronization model predictions (red-dashed curve) $\Rightarrow$ Extreme enhancement scenarios ruled out

J/psi production



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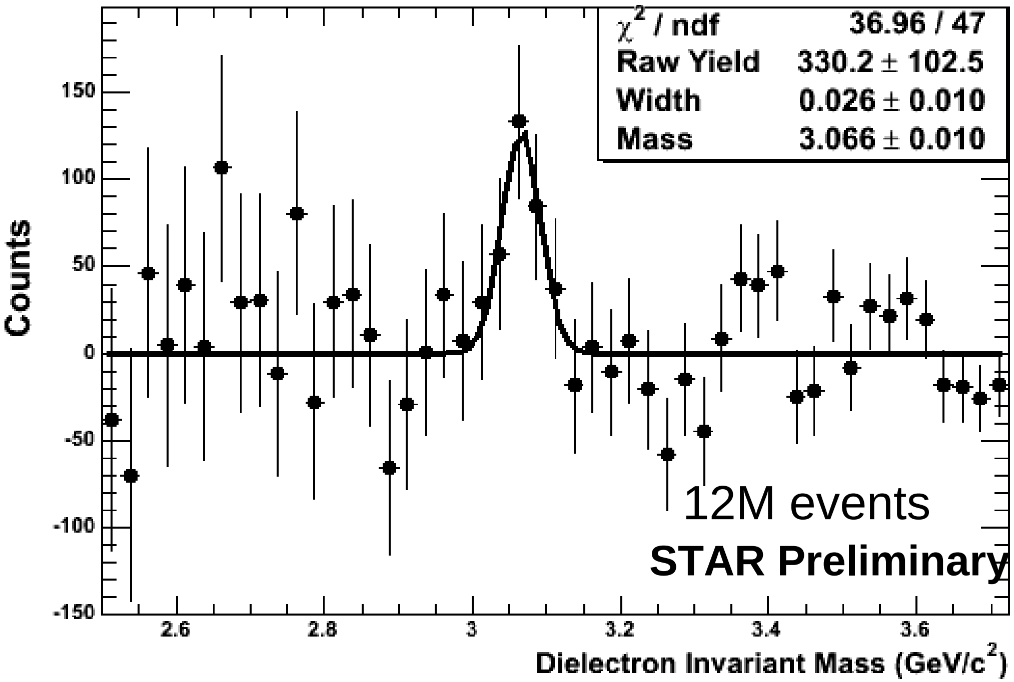

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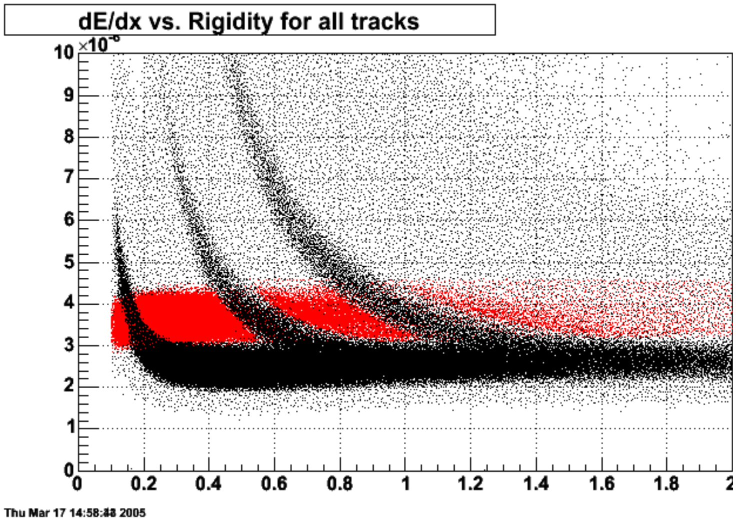

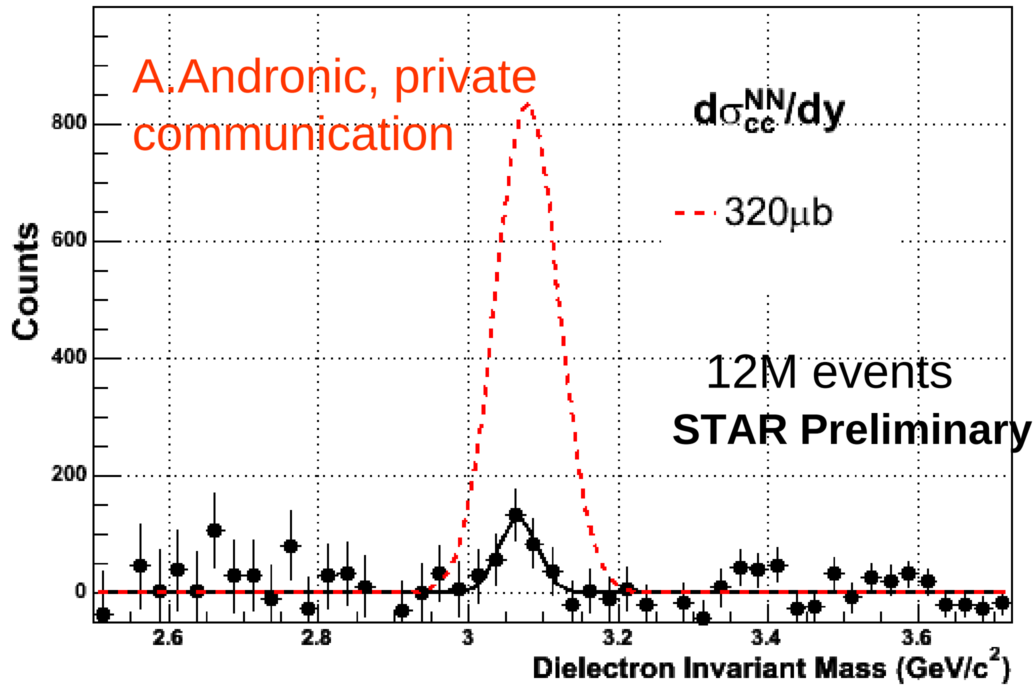

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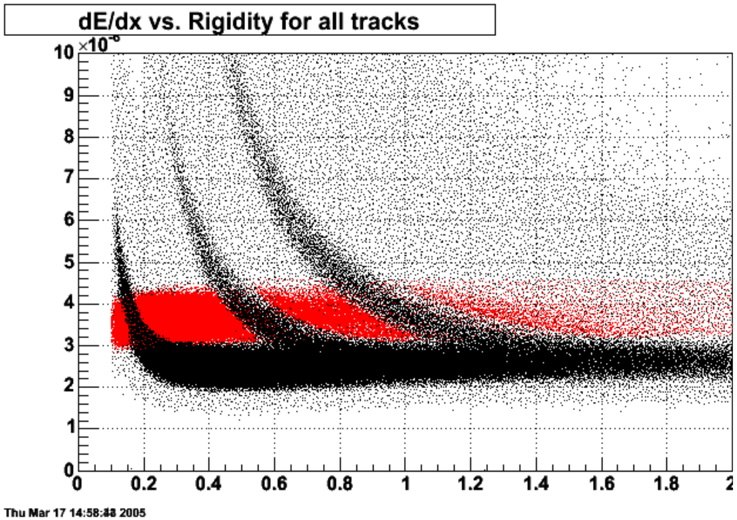

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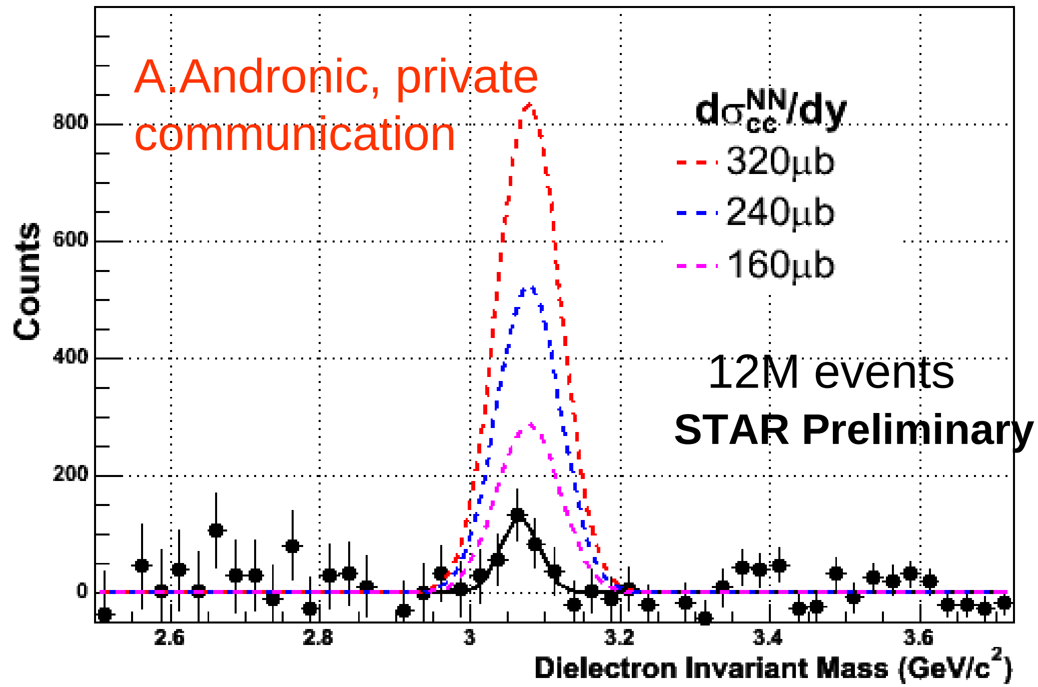

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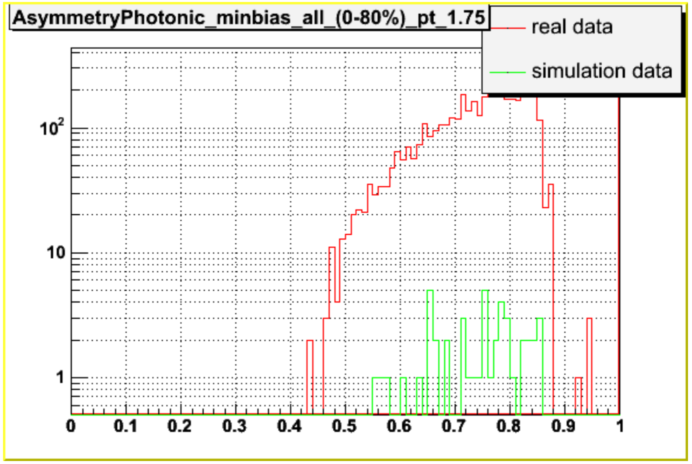
- Our J/psi yields are lower than statistical hadronization model predictions (red-dashed curve) ⇒ Extreme enhancement scenarios ruled out

Summary

- We have developed a new method to measure the non-photonic electron v2 in heavy ion collisions. The material in STAR detector caused too much photon conversion electrons, which make the v2 measurement very difficult. Our result is not sensitive enough to make any conclusion about heavy quark v2 so far. More work ahead!
- We have observed a J/Psi peak in our data. The magnitude of the peak seems to rule out the extreme enhancement scenarios

Other plots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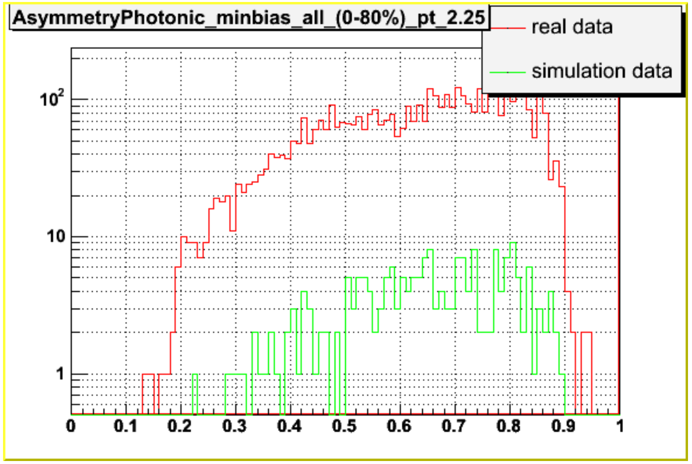
real data
simulation data
10^2
10
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1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simulation data
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0.1
0.2
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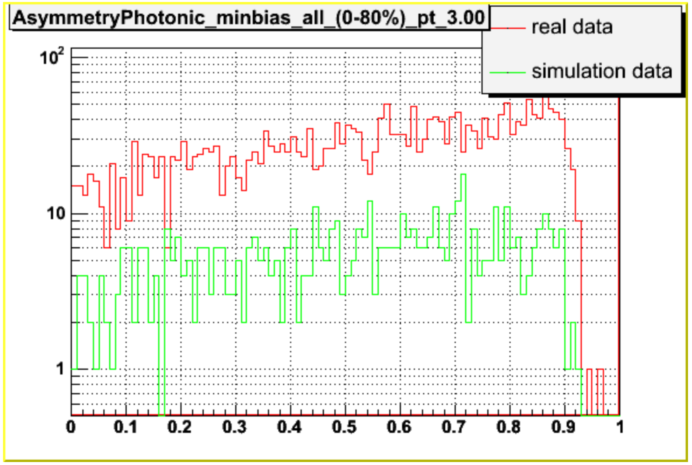
0.4
0.5
0.6
0.7
0.8
0.9
1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simulation data
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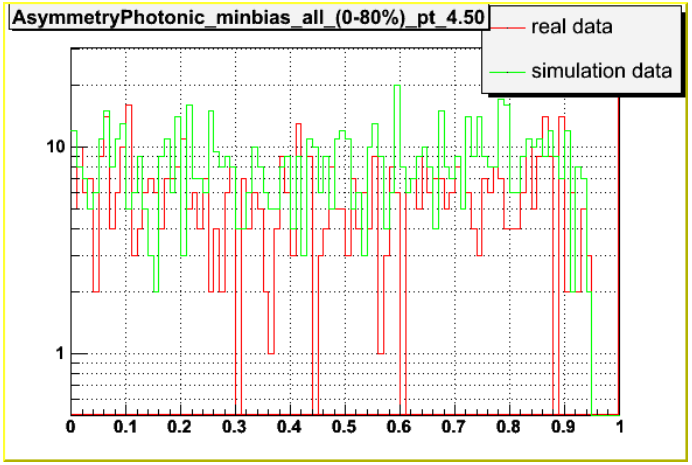
0.5
0.6
0.7
0.8
0.9
1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simulation data
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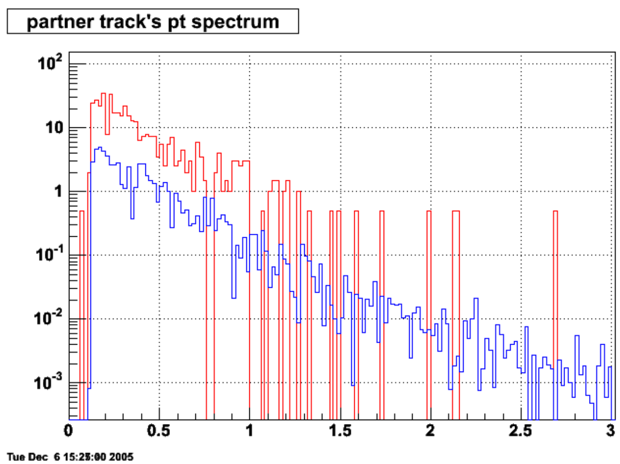
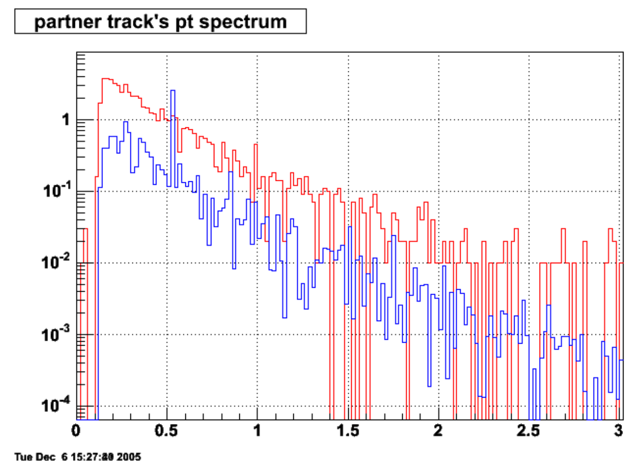
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

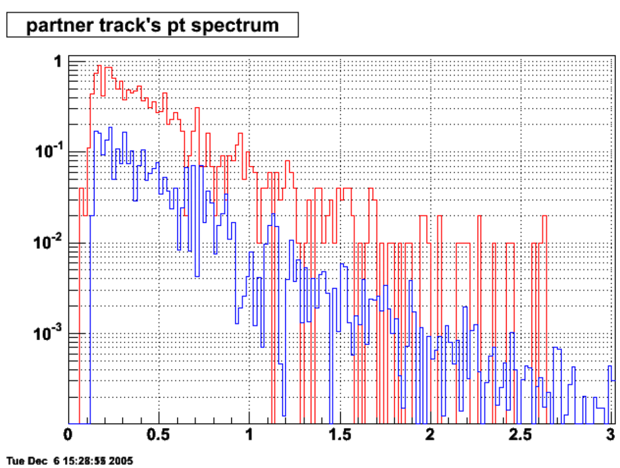
Partner pt



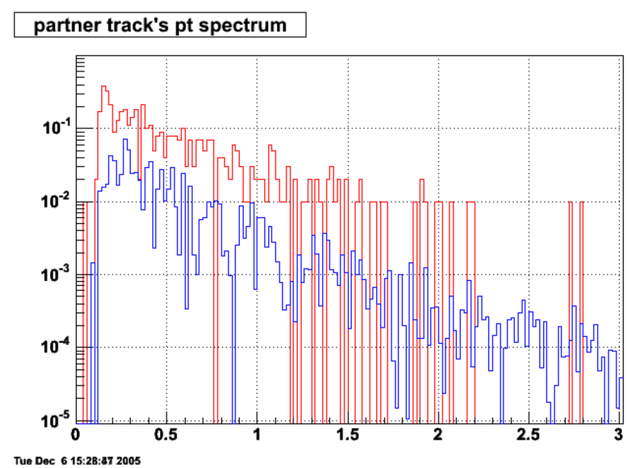
partner track's pt spectrum
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
0 0.5 1 1.5 2 2.5 3



partner track's pt spectrum
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0 0.5 1 1.5 2 2.5 3



partner track's pt spectrum
1
10^{-1}
10^{-2}
10^{-3}
0 0.5 1 1.5 2 2.5 3



partner track's pt spectrum
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0 0.5 1 1.5 2 2.5 3

Inv Mass Distr.