Measurement of Non-Photonic Single Electron v_2 with STAR

Frank Laue (BNL)
for
the STAR Collaboration

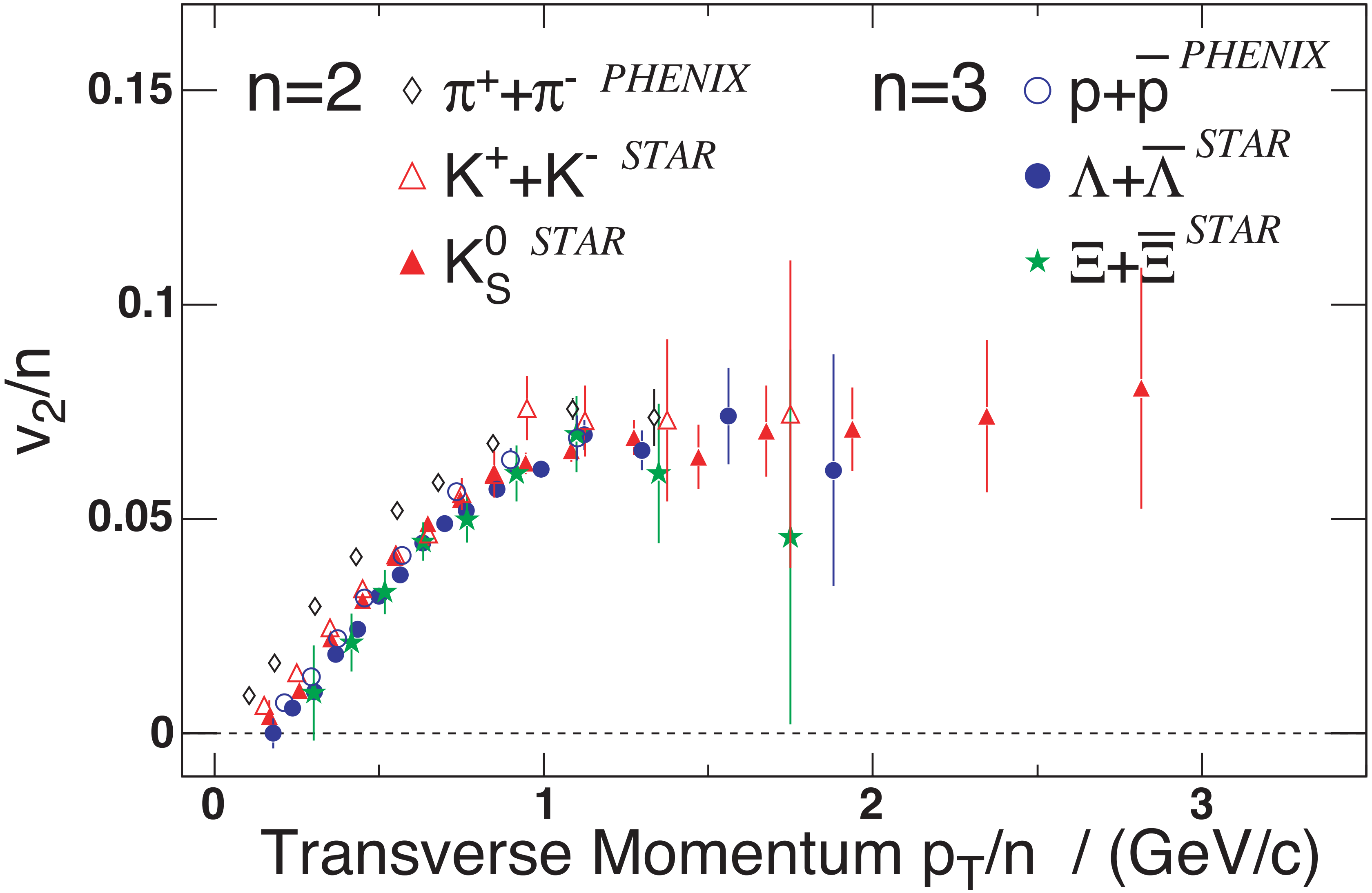
Outline:

- Motivation
- Analysis
- Result
- Outlook

Data Set:

Au+Au @ sqrt(s_{NN}) = 200 GeV
0-80% most central

Motivation I: Elliptic flow



✓ scaling with Number of Constituent Quarks (NCQ)

in NCQ region:

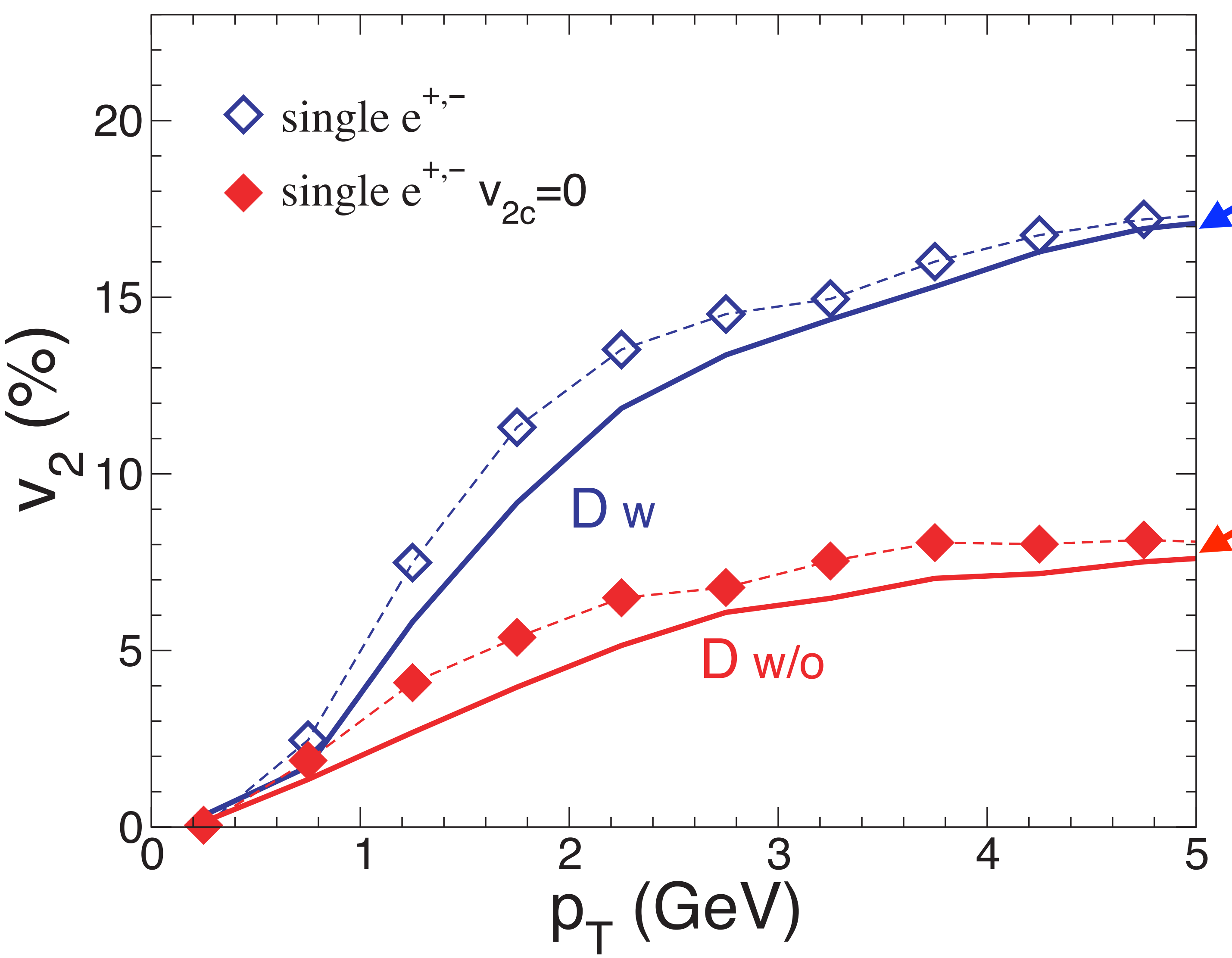
✗ no mass dependence

✗ no flavor dependence (p,Λ,Ξ,Ω)

M$Q : partonic degrees of freedom ?

Motivation II: Charm v2

V.Greco, C.M.Ko nucl-th/0405040



charm quarks flow just like light quarks (upper limit, no jets)

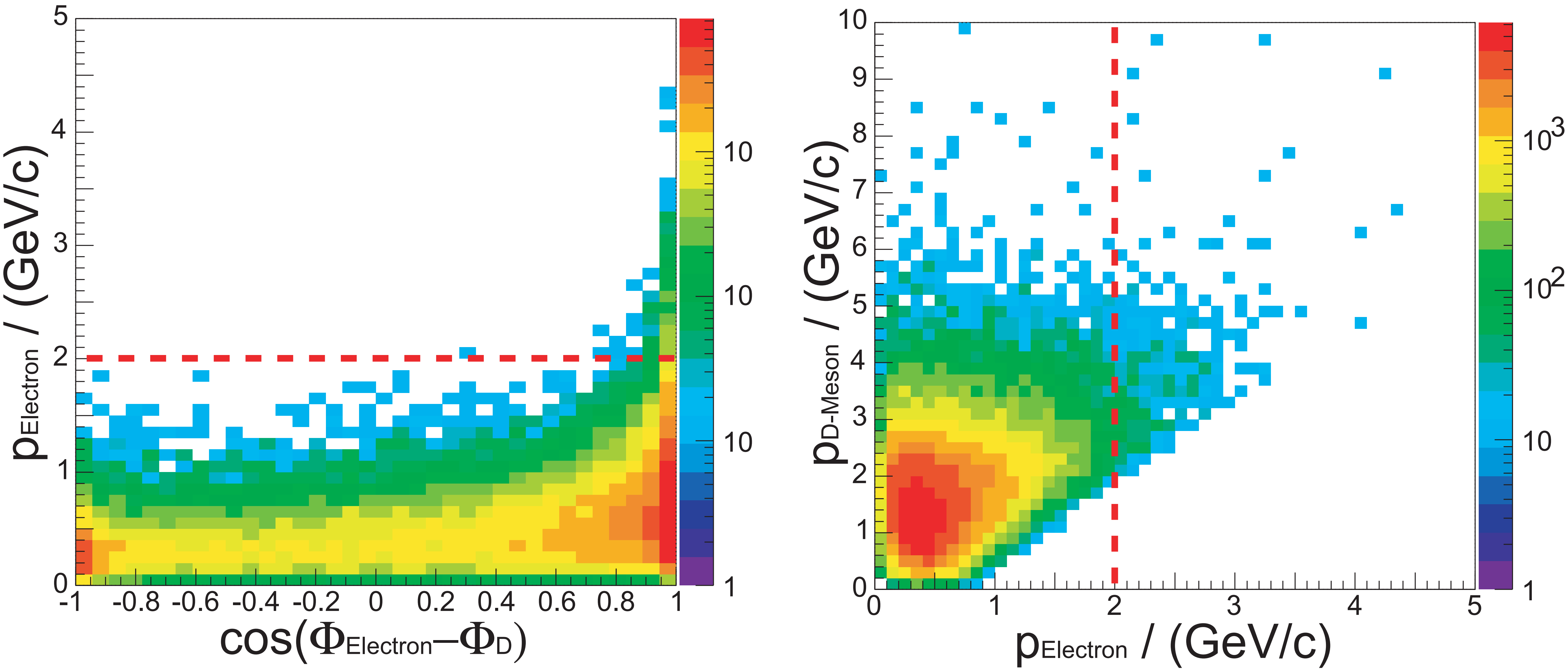
only light quarks flow (lower limit)

Charm flow interesting because:

Charm is produced almost exclusively in hard processes at first impact.

No initial v_2 at production → v_2 must come from interactions with the medium

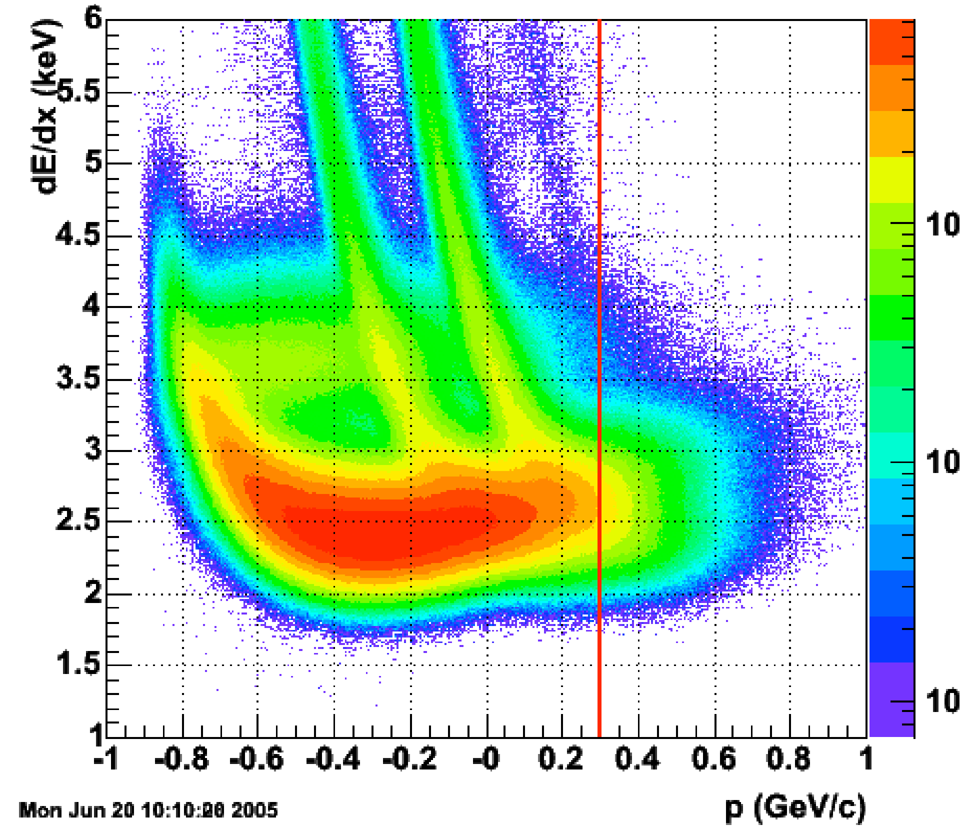
Electron v_2 as a proxy for D-meson v_2

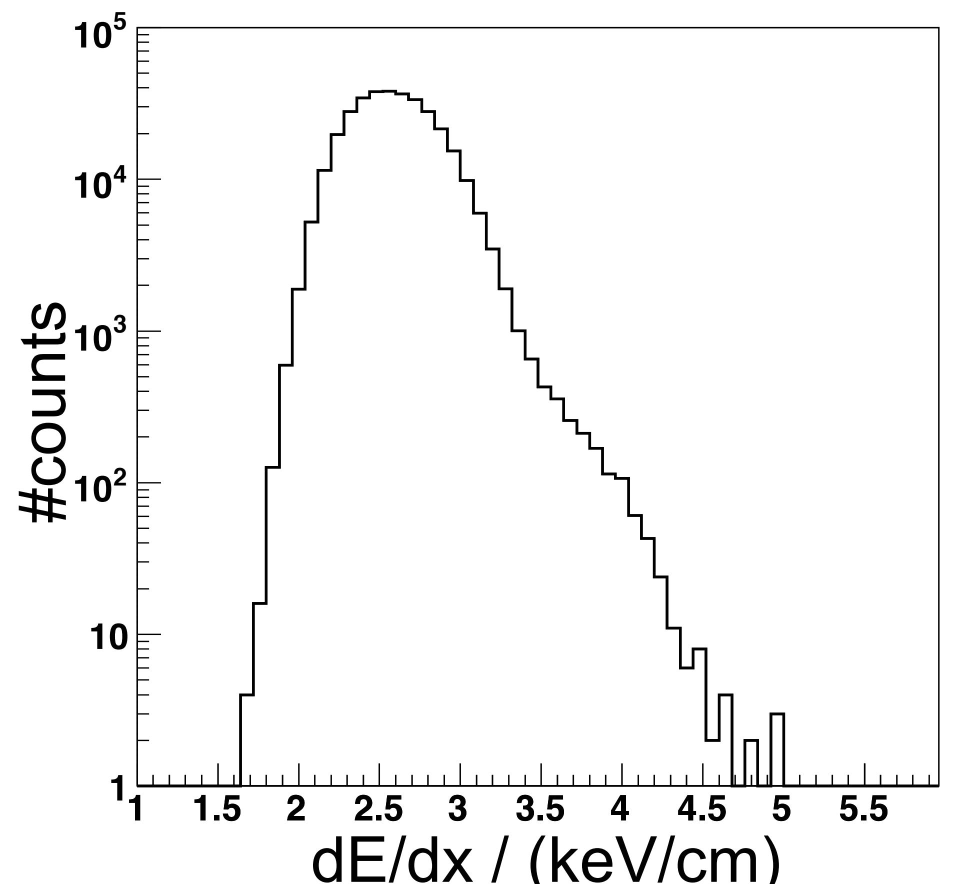


- Emission angles are well preserved above p = 2GeV/c
- 2-3 GeV Electrons correspond to ≈3.8GeV D-Mesons

Electron ID in STAR – EMC

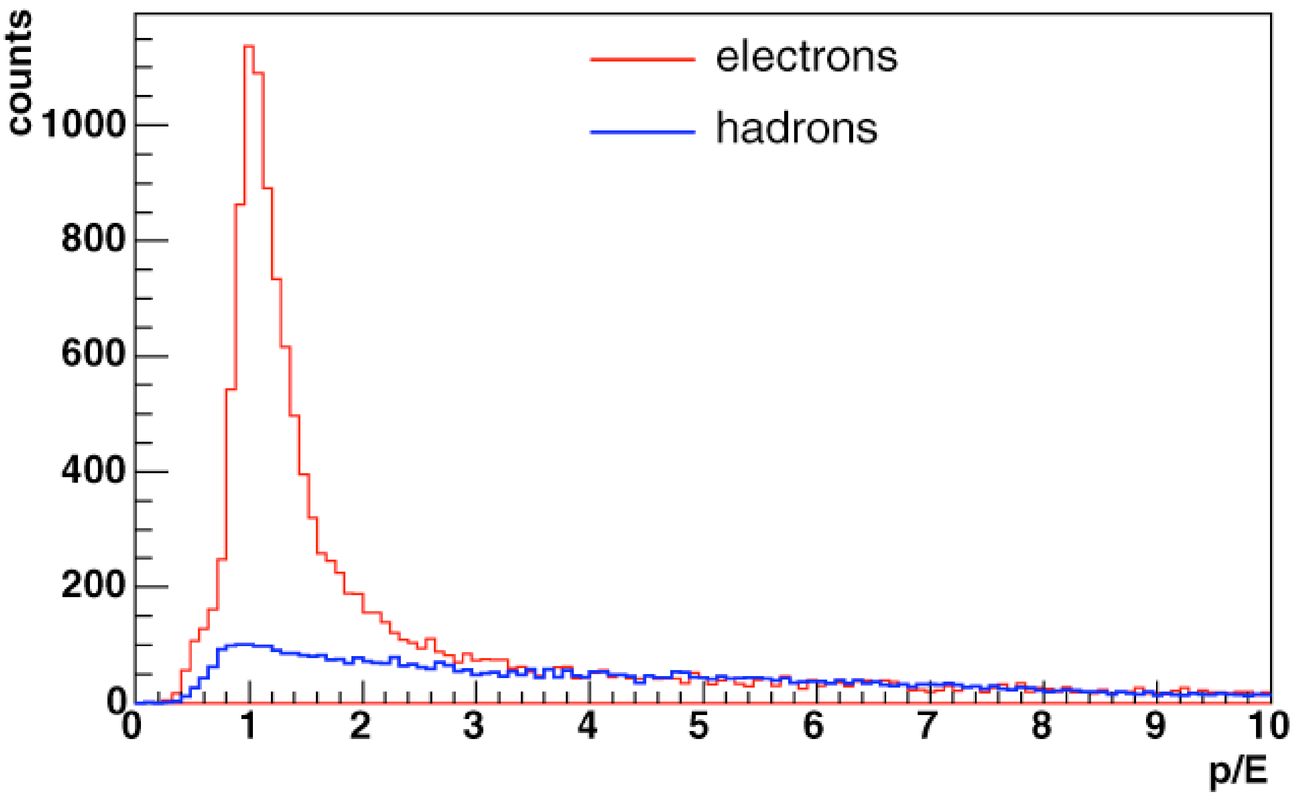
1. TPC: dE/dx vs p for p>2GeV
2. EMC: Tower E >1.5GeV
3. EMC: Tower E $\Rightarrow$ p/E
4. EMC: Shower Max Detector (SMD) shape to reject hadrons
5. TPC: dE/dx cut

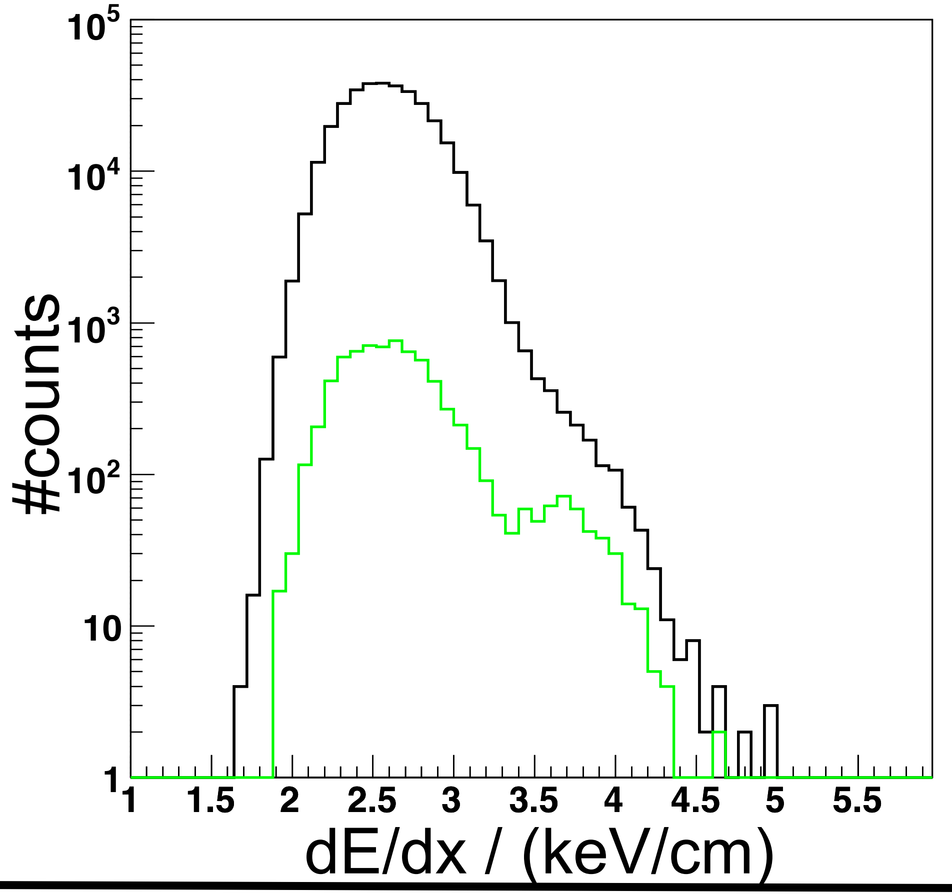




Electron ID in STAR – EMC

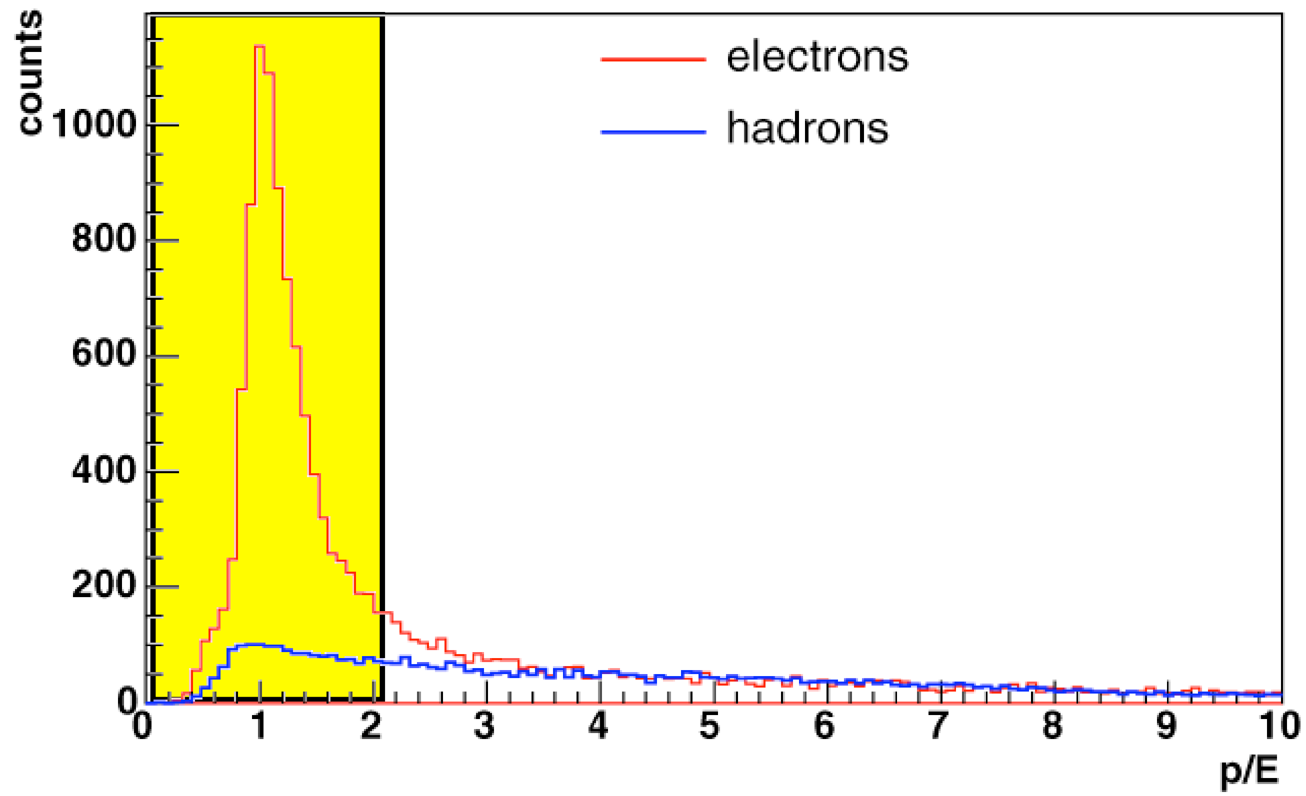
1. TPC: dE/dx vs p for p>2GeV
2. EMC: Tower E >1.5GeV
3. EMC: Tower E $\Rightarrow$ p/E
4. EMC: Shower Max Detector (SMD) shape to reject hadrons
5. TPC: dE/dx cut

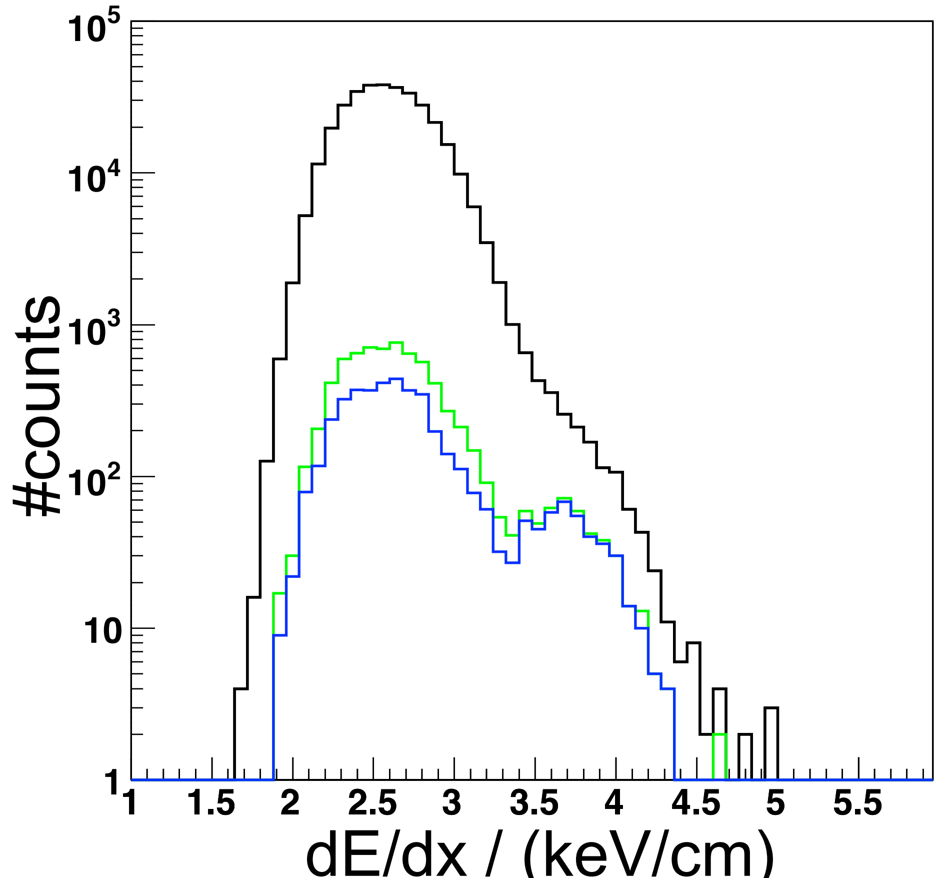




Electron ID in STAR – EMC

1. TPC: dE/dx vs p for p>2GeV
2. EMC: Tower E >1.5GeV
3. EMC: Tower E ⇒ p/E
4. EMC: Shower Max Detector (SMD) shape to reject hadrons
5. TPC: dE/dx cut

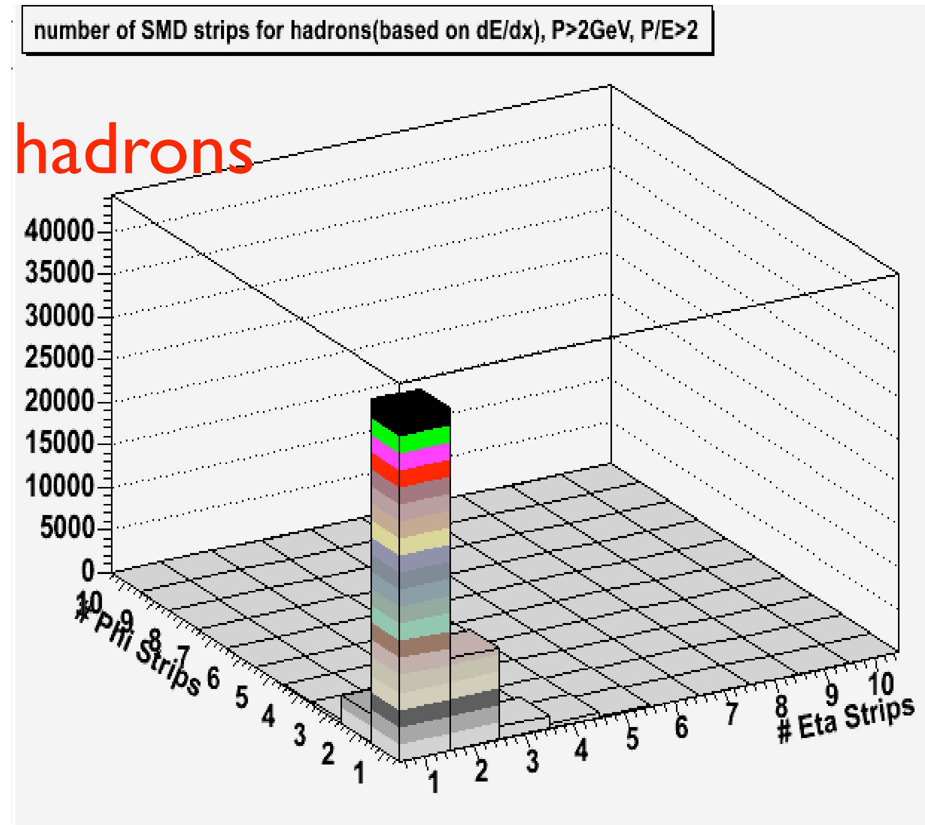


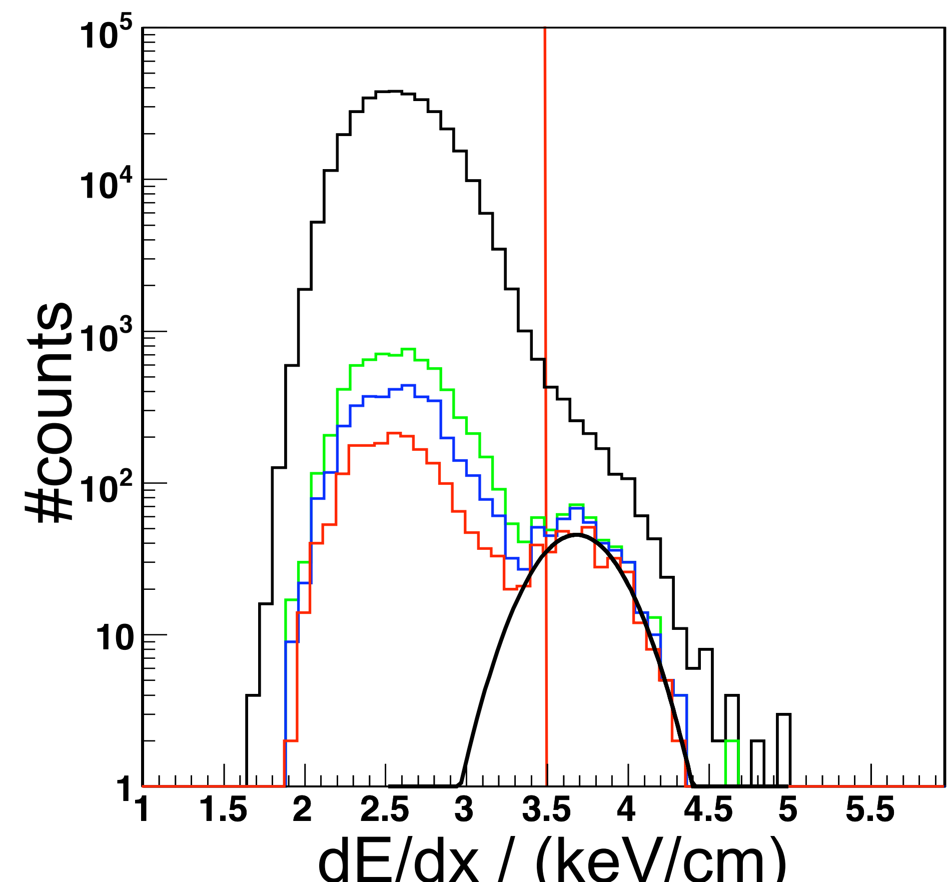


Electron ID in STAR – EMC

1. TPC: dE/dx vs p for p>2GeV
2. EMC: Tower E >1.5GeV
3. EMC: Tower E $\Rightarrow$ p/E
4. EMC: Shower Max Detector (SMD) shape to reject hadrons
5. TPC: dE/dx cut

✔ *e* purity 98-94%
✔ *h* discrimination power ~10^4
✔ Works best for p > 1.5 GeV/c, perfect complement to the ToF

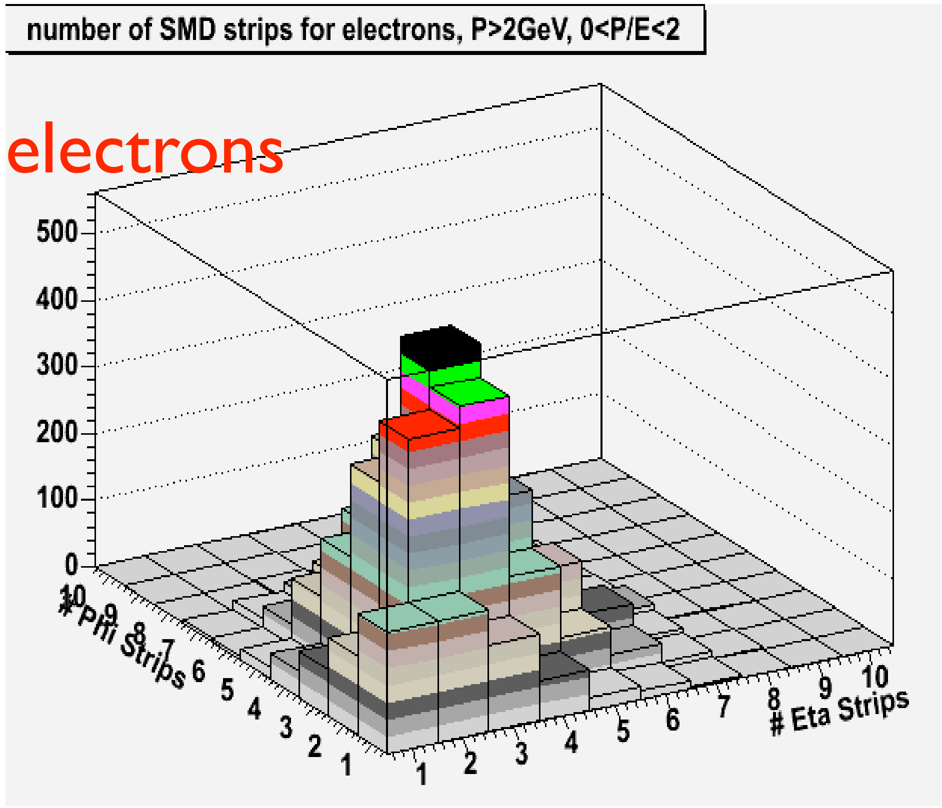


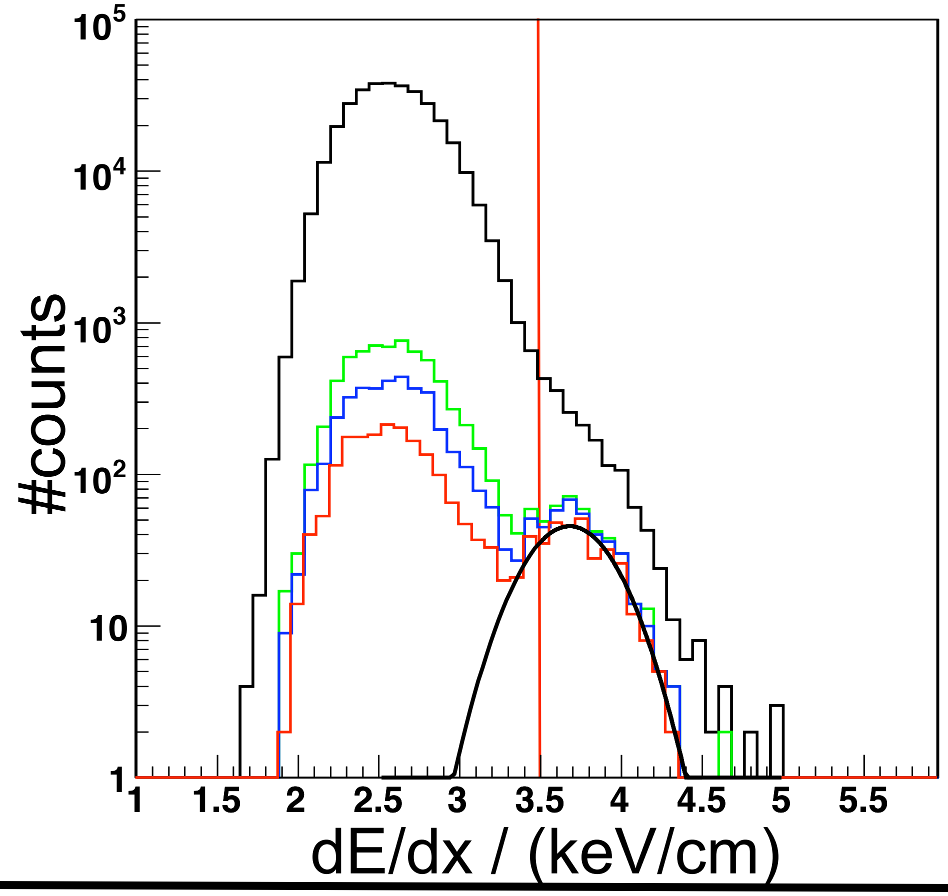


Electron ID in STAR – EMC

1. TPC: dE/dx vs p for p>2GeV
2. EMC: Tower E >1.5GeV
3. EMC: Tower E $\Rightarrow$ p/E
4. EMC: Shower Max Detector (SMD) shape to reject hadrons
5. TPC: dE/dx cut

✔ e purity 98-94%
✔ h discrimination power ~10^4
✔ Works best for p > 1.5 GeV/c, perfect complement to the ToF

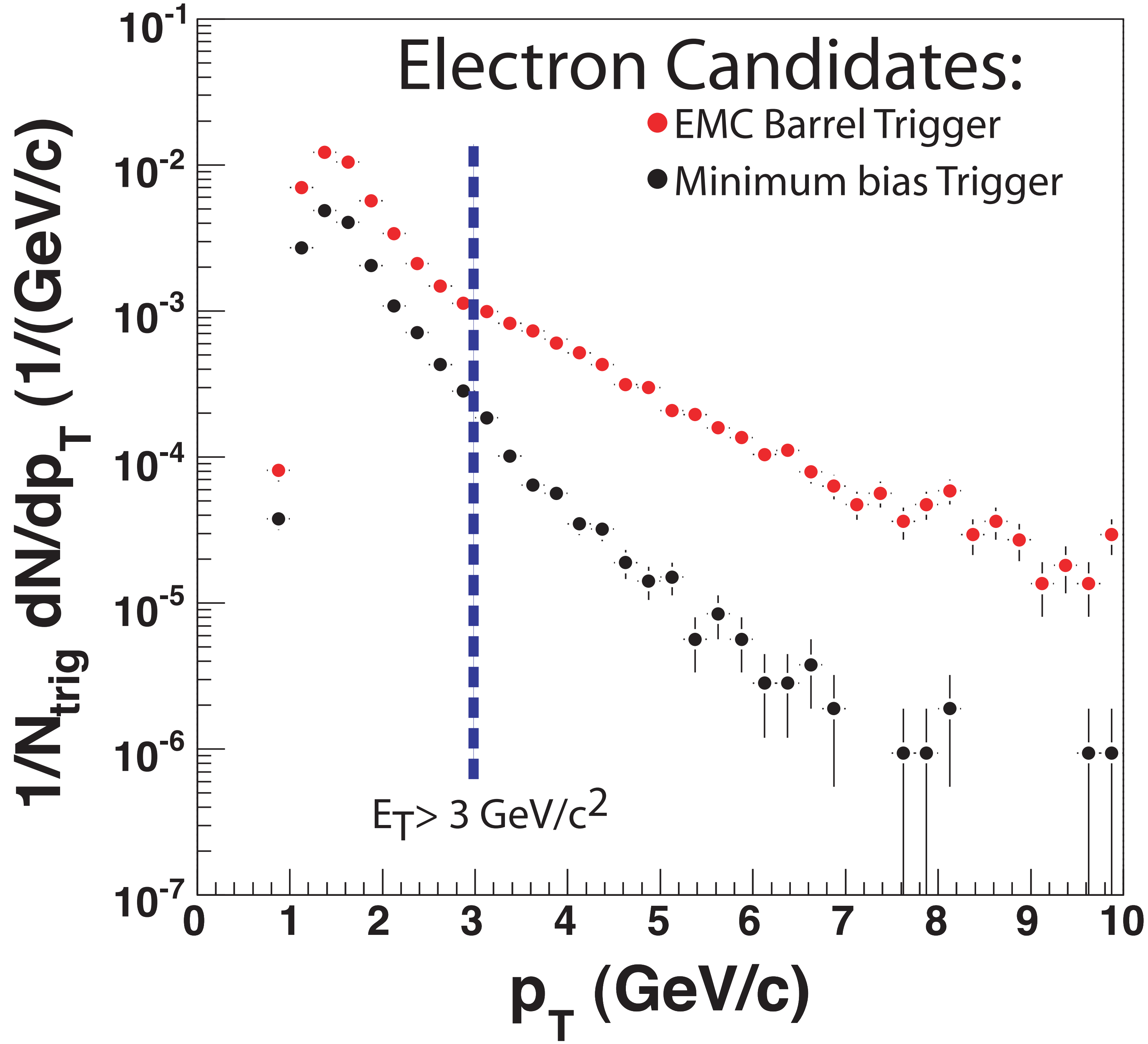




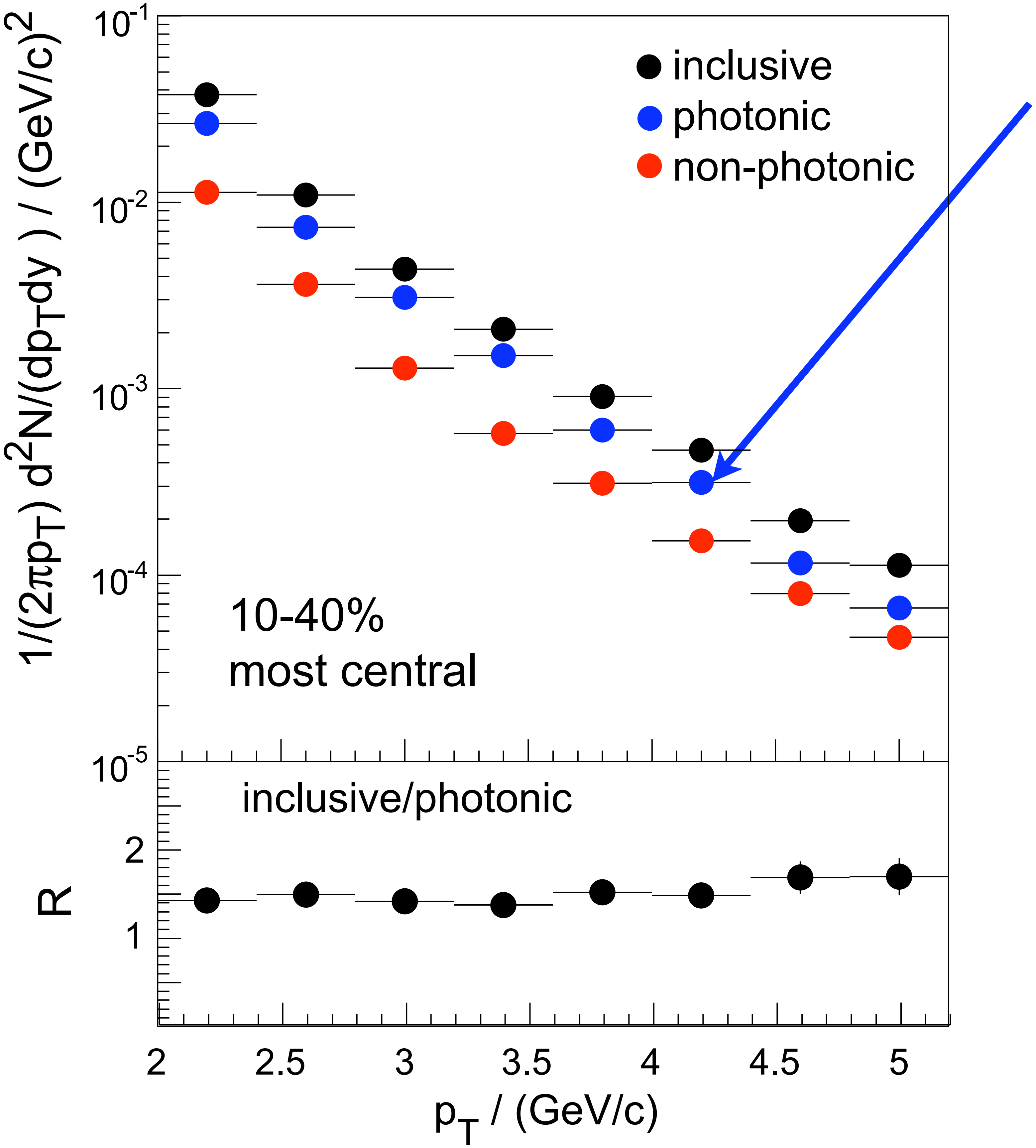
Triggering capabilities of the EMC

EMC provides a Level 0 high-pT electron trigger

- Runs for every RHIC crossing (10 MHz)
- More sophisticated triggers already working
  - J/Ψ (in p+p)
  - Jet



Electron sources



Dominating photonic $e^{+/-}$ sources:

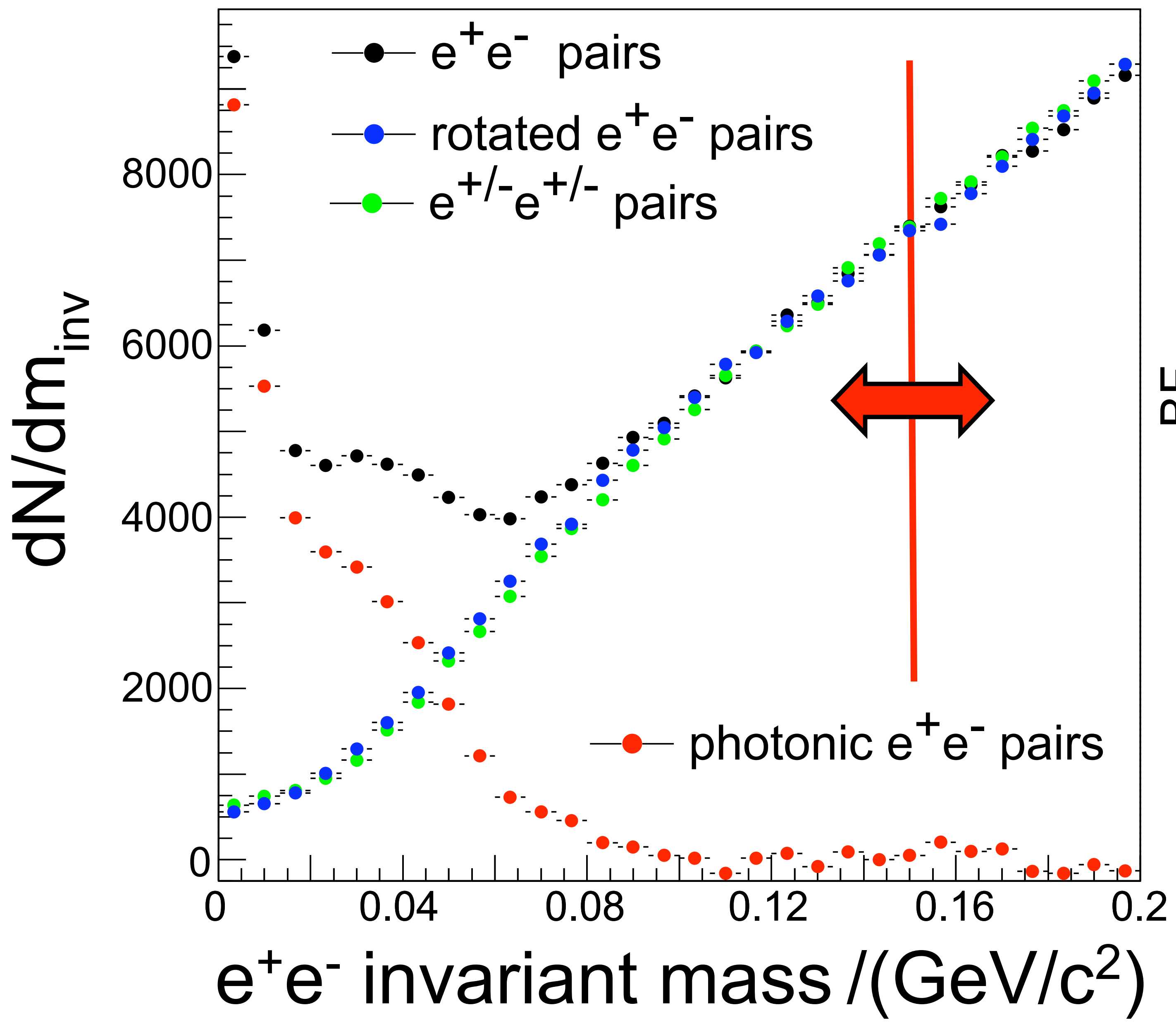
γ-conversion

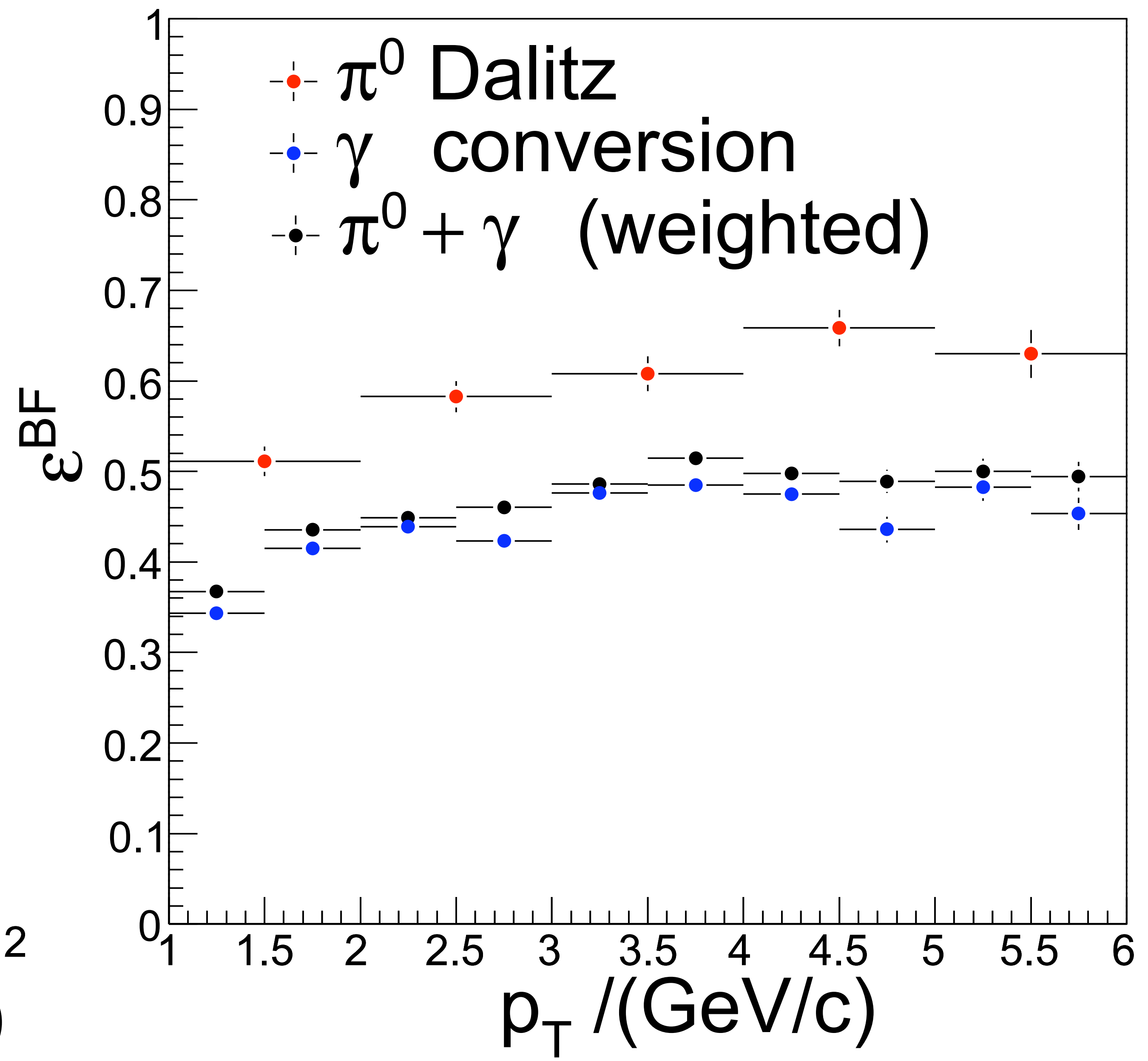
π^0,η-Dalitz

Please see Jaro Bielcik's talk (5c) on Monday for more non-photonic electron data

The amount of photonic/non-photonic $e^{+/-}$ can be determined without the help of models.

Removal of γ-conversions and π^0-Dalitz decays

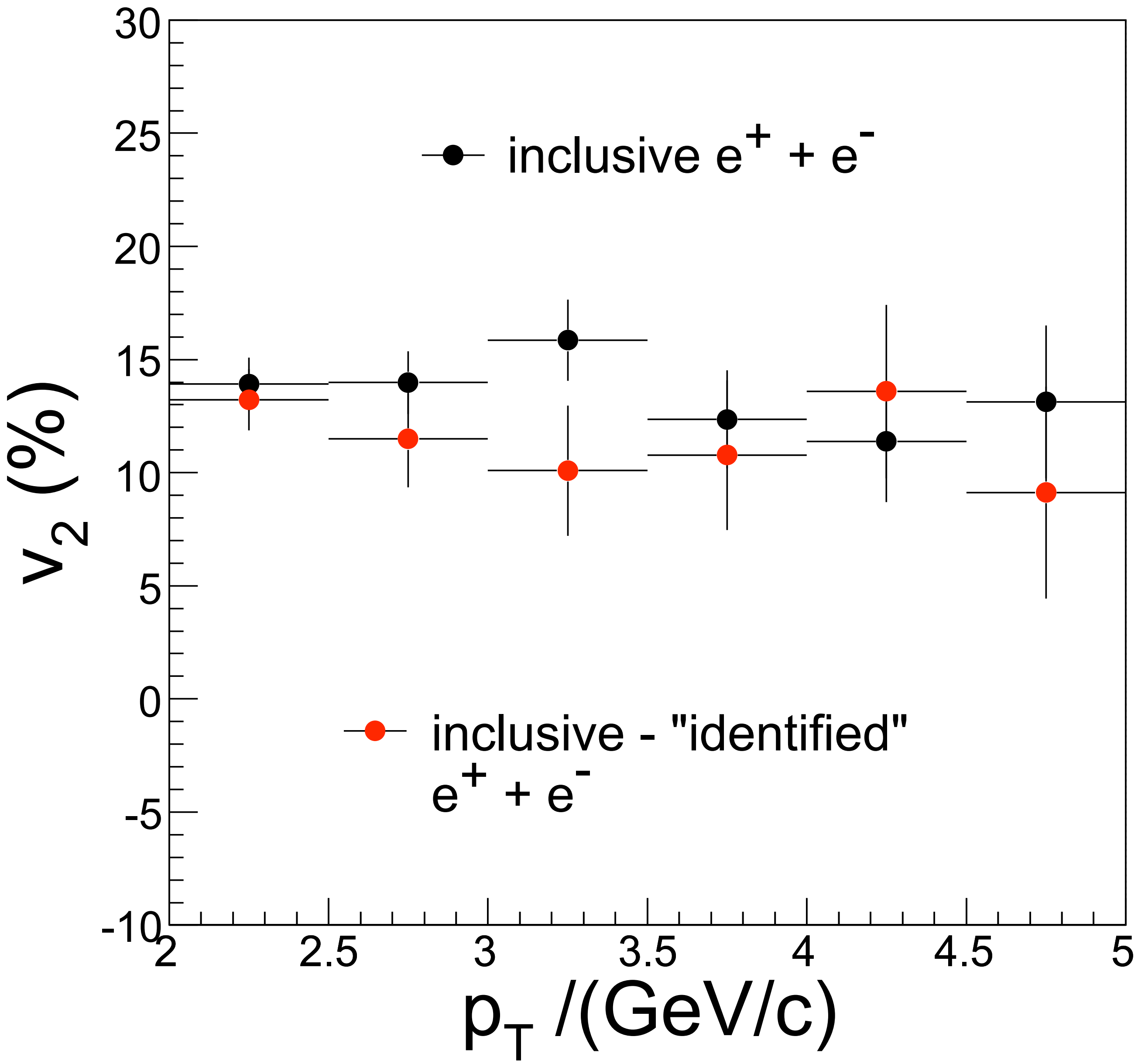




$$n^{removed} - n^{rotated} = n^{photonic\ removed}$$

$$\frac{n^{photonic\ removed}}{\epsilon^{BF}} = n^{photonic}$$

Calculating the non-photonic v_2



Assumption:

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

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

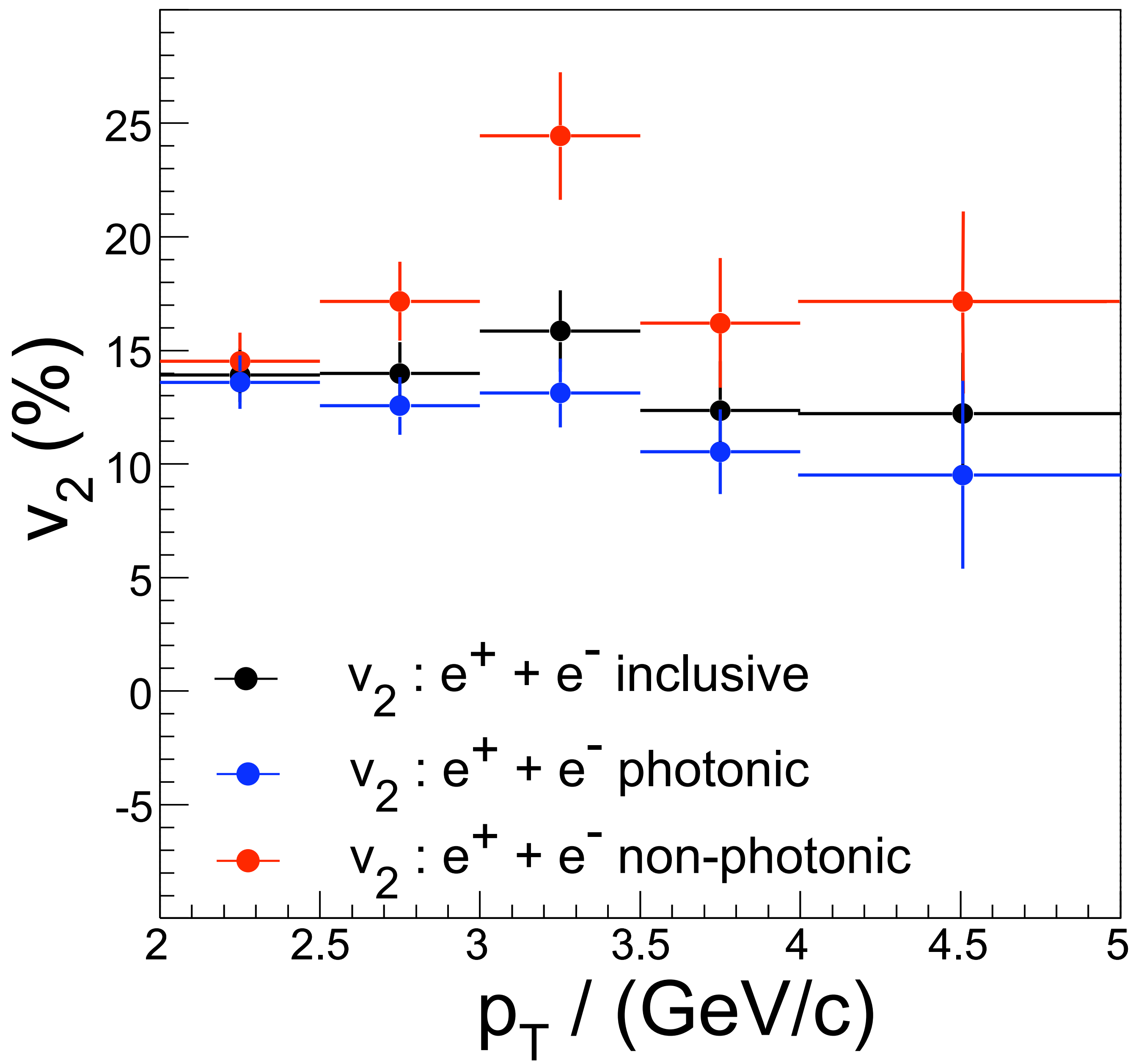
2 equation with 2 unknown can be solved analytically

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

Sample A: without photonic electron rejection (inclusive)

Sample B: after photonic electron rejection

Calculating the non-photonic v_2



Assumption:

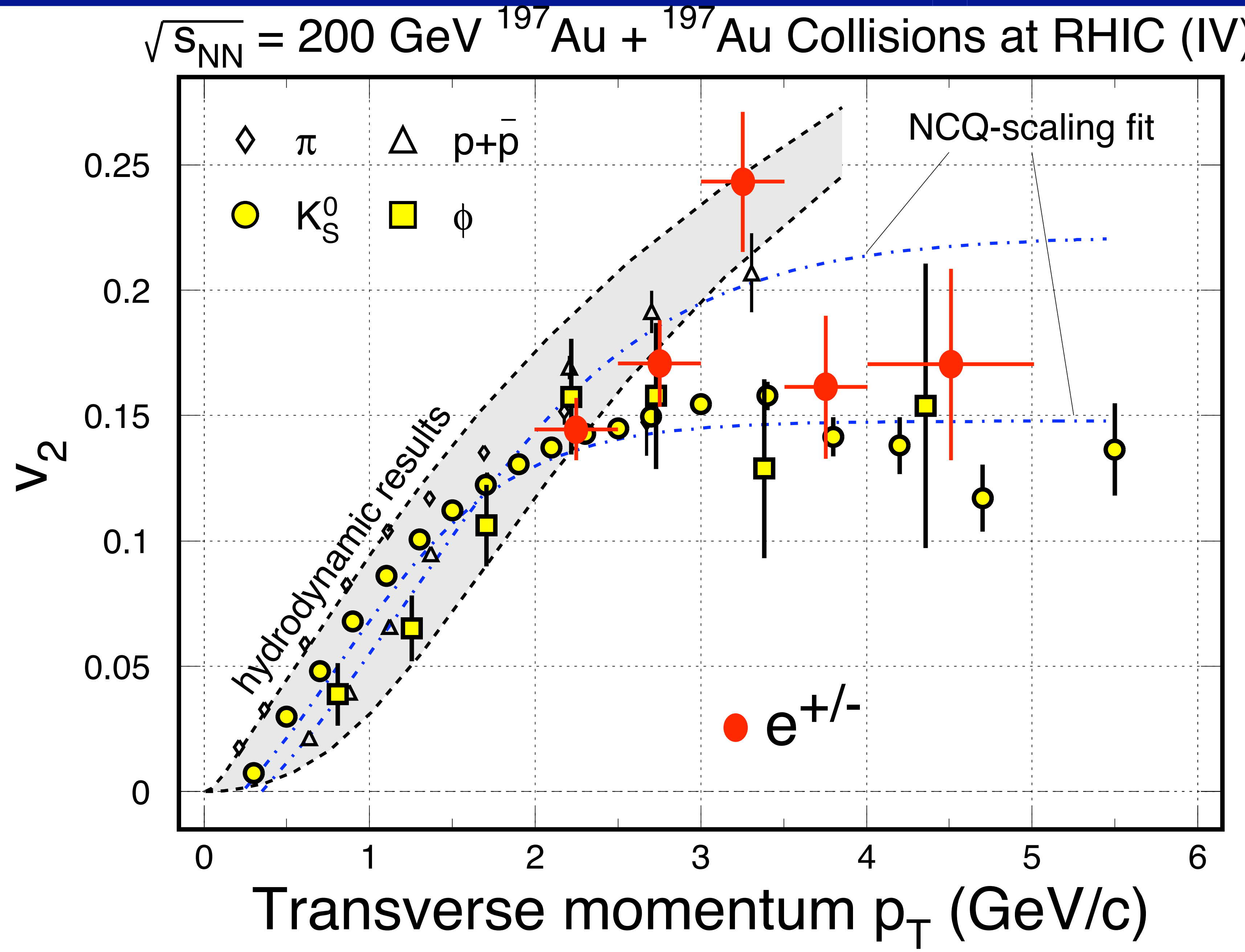
$$v_2^A = \frac{v_2^{sin} \cdot n^{sin,A} + v_2^{pho} \cdot n^{pho,A}}{n^{sin,A} + n^{pho,A}}$$

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

2 equation with 2 unknown can be solved analytically

v_2: inclusive photonic non-photonic

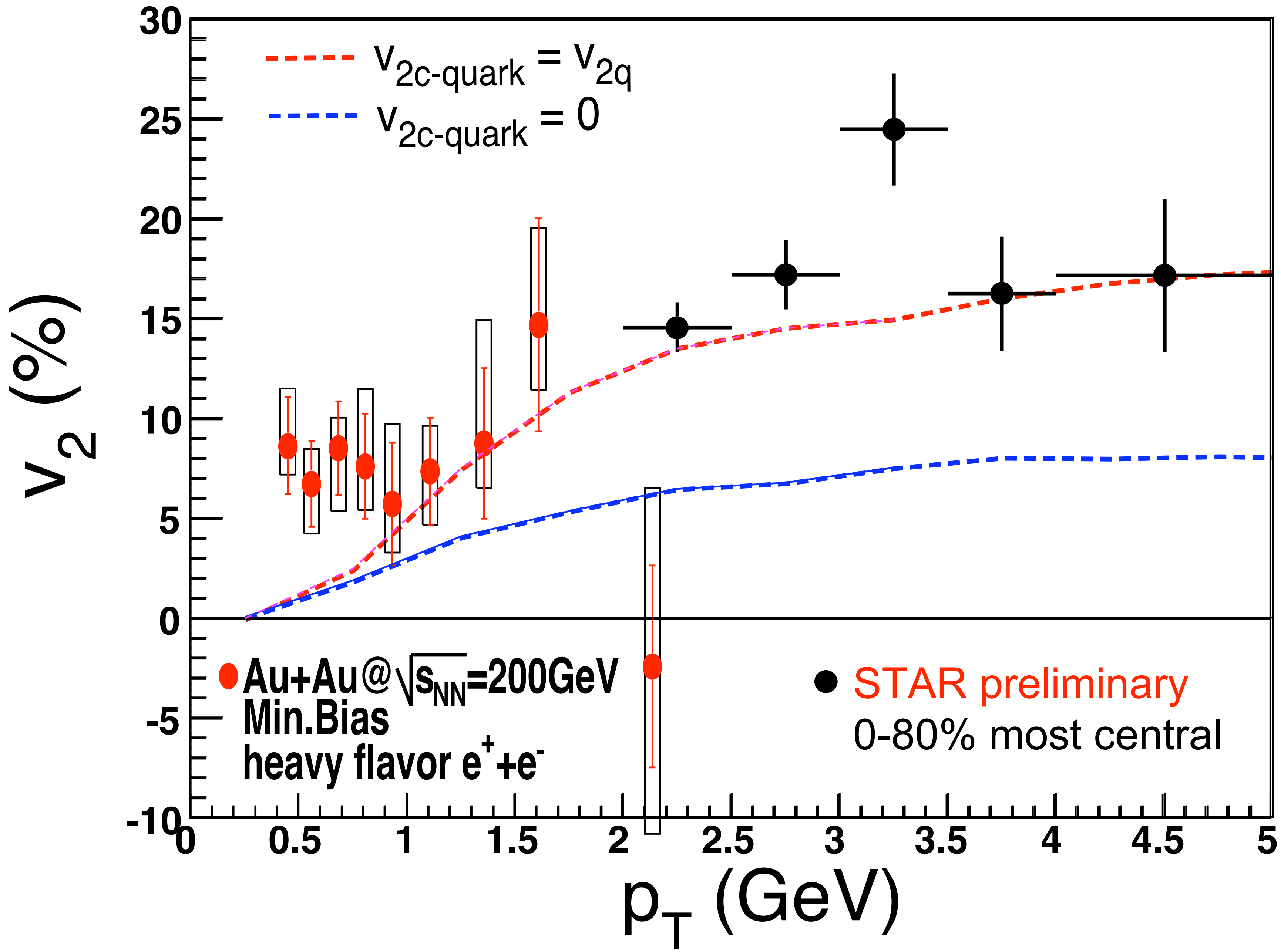
Non-photonic electron v_2 from STAR



0-80% most central events

- ✔ non-photonic $e^{+/-}$ v_2 similar to meson v_2
- ✘ However uncertainties are still large
  - ✘ Systematic uncertainties estimated to be ~30-40%

Non-photonic electron v_2 from STAR



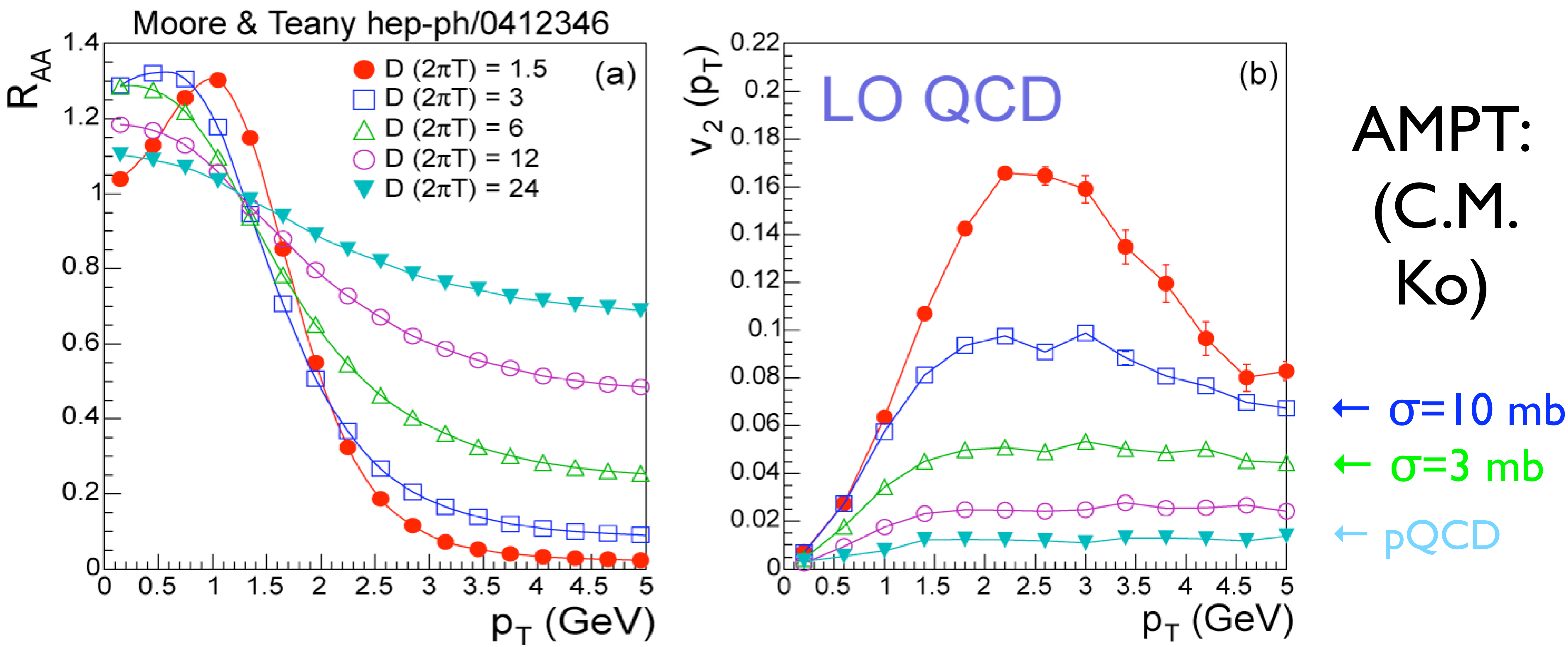
Phenix : Min. Bias
Star: 0-80%

Phenix:
nucl-ex/0502009

V.Greco, C.M.Ko
nucl-th/0405040

- ✔ Data favors the $v_{2,c} = v_{2light\text{-}q}$ hypothesis
  - ✘ Systematic uncertainties estimated to be ~30-40%
  - ✘ Can not rule out the v_{2c}=0 hypothesis

Charm elliptic flow from the Langevin Model



- Diffusion coefficient in QGP: D = T/Mη (η momentum drag coefficient)
- Langevin model for evolution of heavy quark spectrum in hot matter
- Numerical solution from hydrodynamic simulations
- pQCD gives D×(2πT) ≈ 6(0.5/αs)2

Summary

- ✓ We have measured the v_2 of non-photonic single electrons between p_T =2-5 GeV/c in minimum bias Au+Au collisions as sqrt (s)=200 GeV.
- ✓ Preliminary results indicate strong non-photonic electron v_2
  - ✓ favor the $v_{2c} = v_{2light-q}$ hypothesis
  - ✓ suggesting charm collectivity
  - ✳ Statistic and systematic uncertainties are too large to conclusively rule out the v_{2c}=0 hypothesis.
  - ✳ Non flow effects have to be addressed.
- ✓ Non-photonic electron (charm) v_2 and and non-photonic(charm) R_{AA} go hand in hand.
  - ✳ Novel processes to boost up charm x-sections are needed to explain v_2 and R_{AA}.
    - ✳ Ideas are out there, but quantitative calculations not yet.

STAR Collaboration

545 Collaborators from 51 Institutions in 12 countries

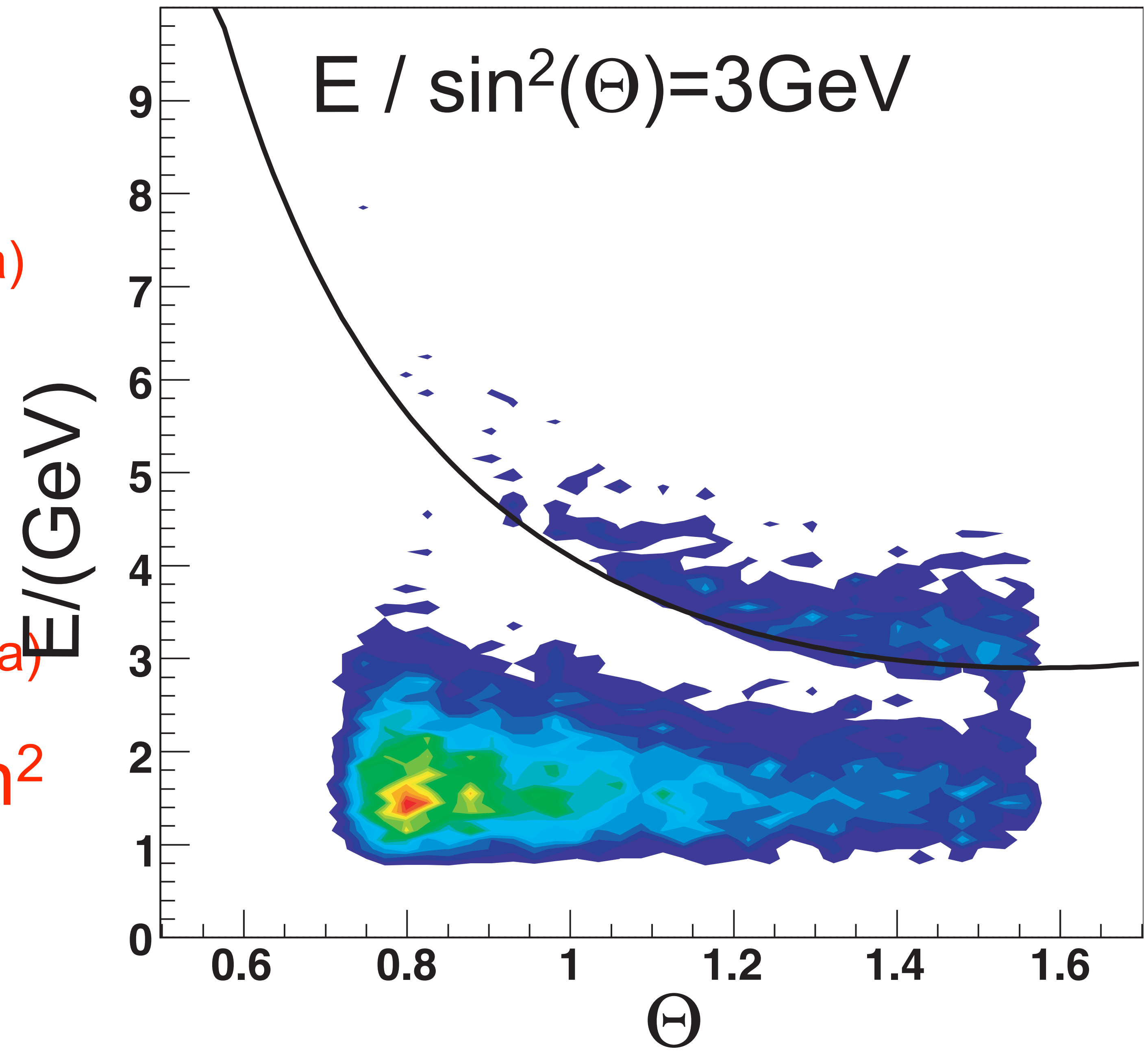
Argonne National Laboratory
Institute of High Energy Physics - Beijing
University of Bern
University of Birmingham
Brookhaven National Laboratory
California Institute of Technology
University of California, Berkeley
University of California - Davis
University of California - Los Angeles
Carnegie Mellon University
Creighton University
Nuclear Physics Inst., Academy of Sciences
Laboratory of High Energy Physics - Dubna
Particle Physics Laboratory - Dubna
University of Frankfurt
Institute of Physics. Bhubaneswar
Indian Institute of Technology. Mumbai
Indiana University Cyclotron Facility
Institut de Recherches Subatomiques de Strasbourg
University of Jammu
Kent State University
Institute of Modern Physics. Lanzhou
Lawrence Berkeley National Laboratory
Massachusetts Institute of Technology
Max-Planck-Institut fuer Physics
Michigan State University
Moscow Engineering Physics Institute

City College of New York NIKHEF
Ohio State University
Panjab University
Pennsylvania State University
Institute of High Energy Physics - Protvino
Purdue University
Pusan University
University of Rajasthan
Rice University
Instituto de Fisica da
Universidade de Sao Paulo
University of Science and Technology of China - USTC
Shanghai Institue of Applied Physics - SINAP
SUBATECH
Texas A&M University
University of Texas - Austin
Tsinghua University
Valparaiso University
Variable Energy Cyclotron Centre. Kolkata
Warsaw University of Technology
University of Washington
Wayne State University
Institute of Particle Physics
Yale University
University of Zagreb

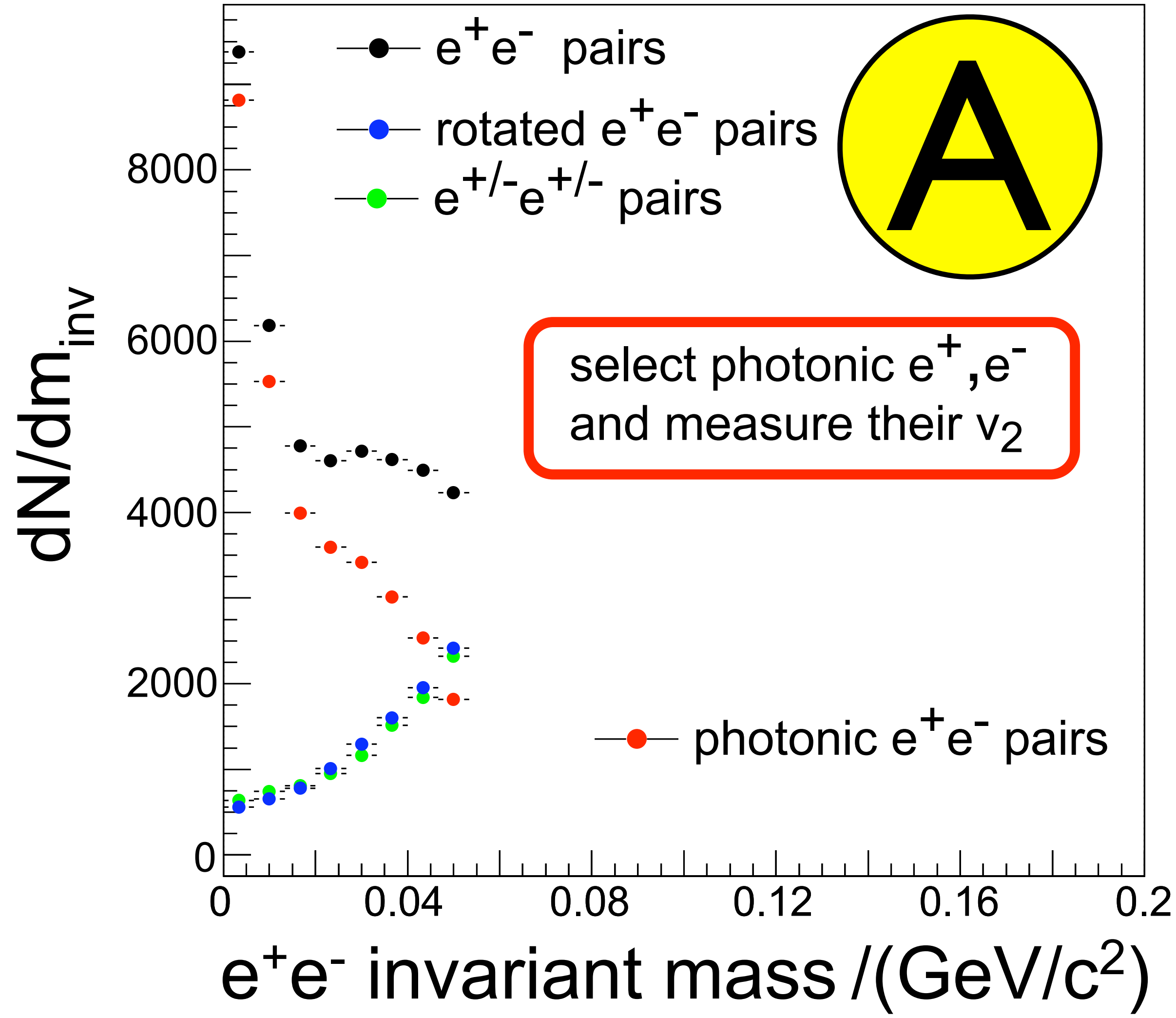
Backup Slides

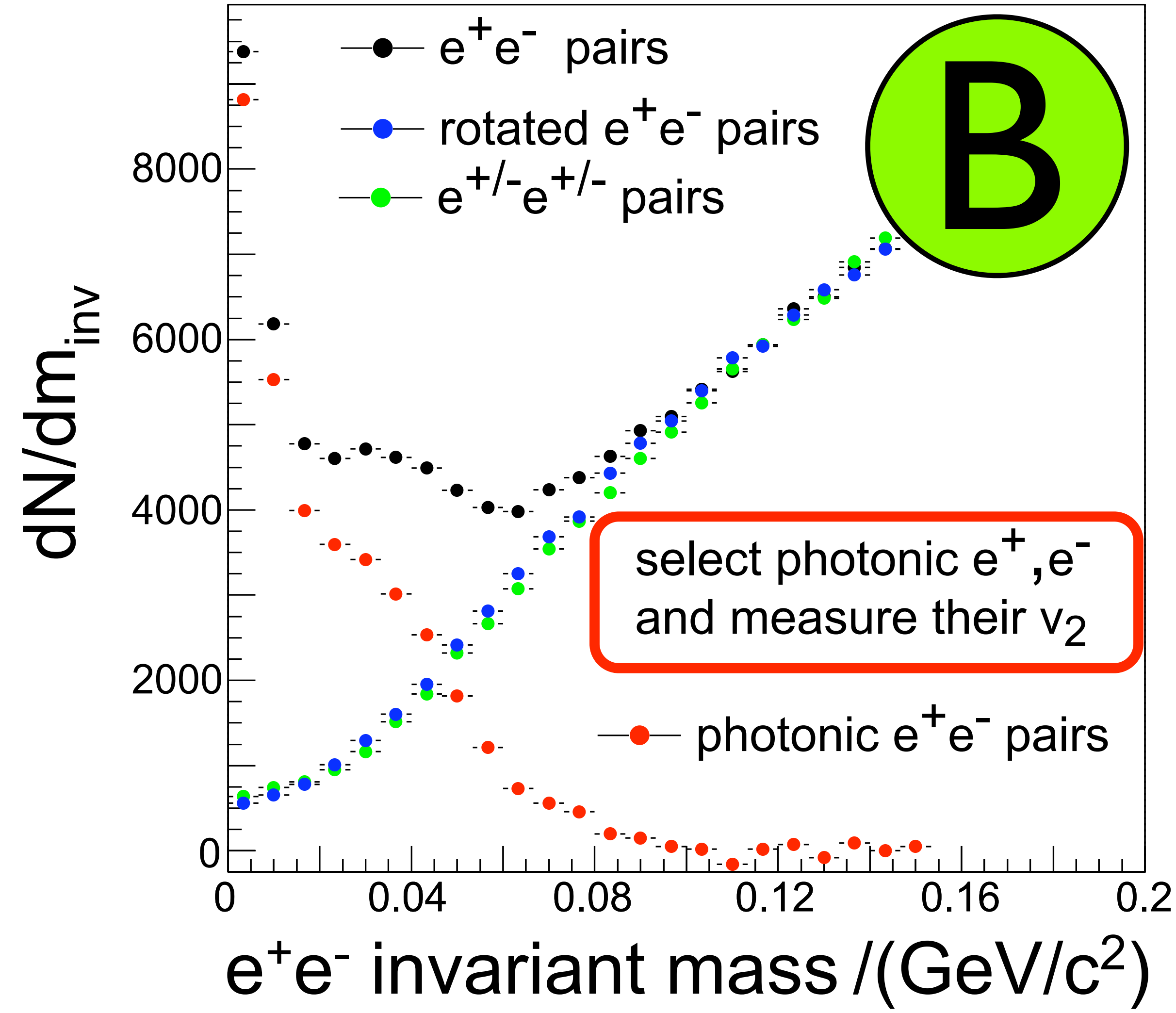
Trigger Issues

- E_T = E * sin(theta)
- ADC_thres_corr = ADC*Ecal *sin(theta)
  - For this plot, 3 GeV
- ADC_thres_used = ADC*Ecal /sin(theta)
  - For this plot, 3GeV *sin^2 (theta)
- Factor 5 loss in efficiency



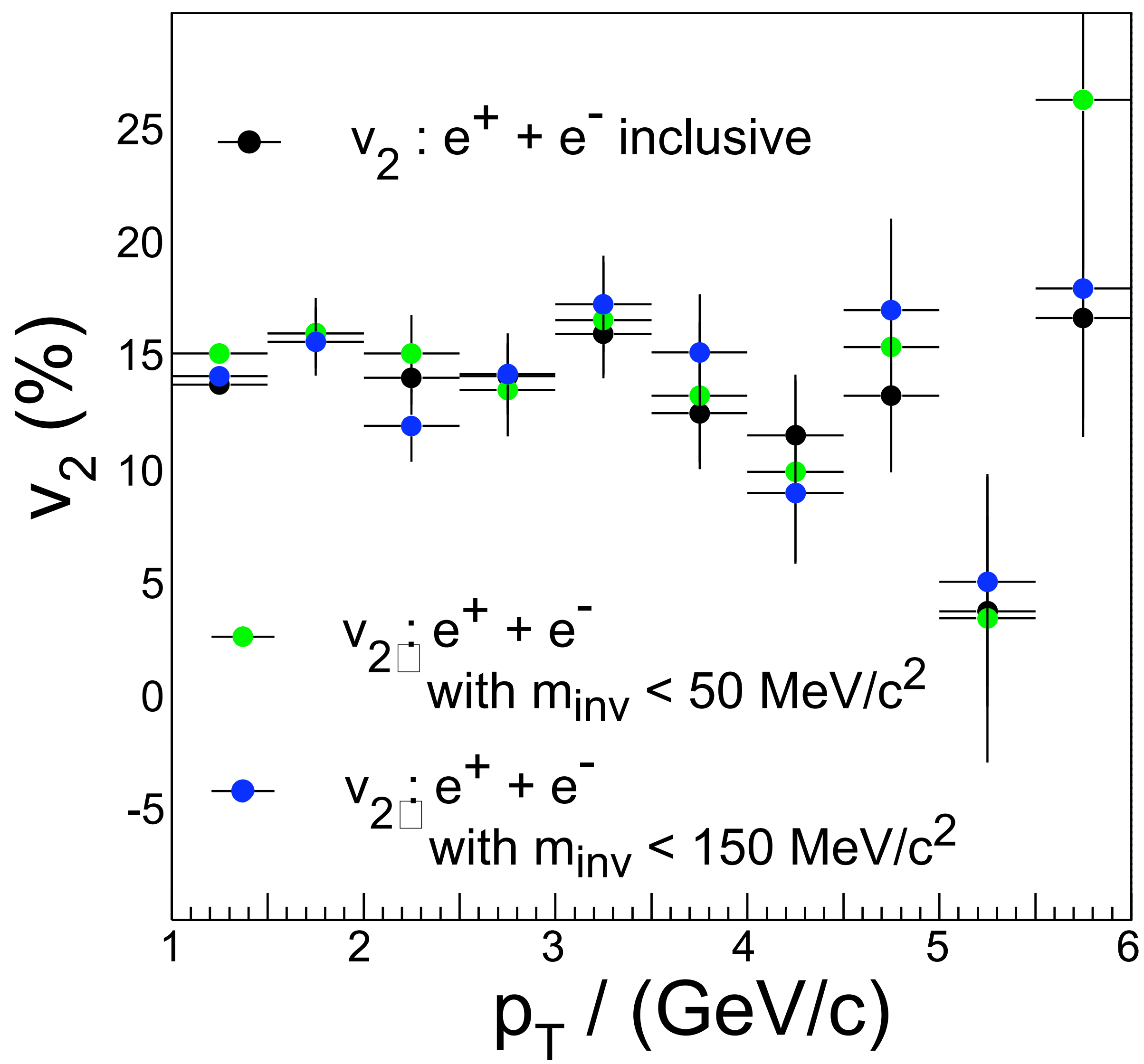
Cross-check: Meauring the photonic v_2 directly





- Sample A : selected photonic electrons with mass<50 MeV/c2 (almost pure photonic)
- Sample B: selected photonic electrons with mass<150 MeV/c2
- exact amount of photonic / non-photonic in each sample known

Cross-check: Meauring the photonic v_2 directly

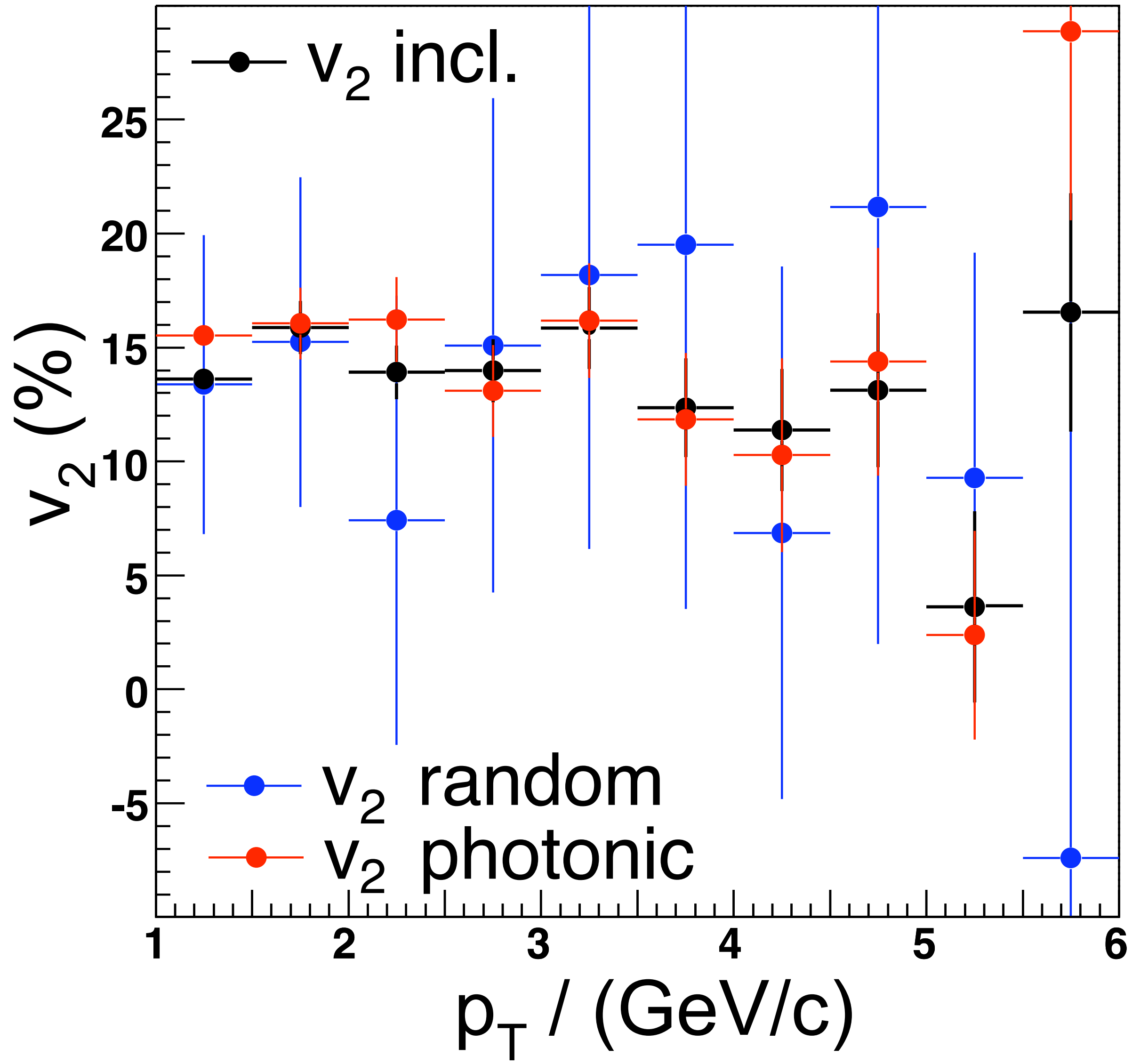


$$v_2^A = \frac{v_2^{ran} \cdot n^{ran,A} + v_2^{pho} \cdot n^{pho,A}}{n^{ran,A} + n^{pho,A}}$$

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

- use same Ansatz as in Method 1 to calculate the photonic and random v_2
- since it is an very pure sample of the photonic electrons, photonic v_2 is well constrained using this method

Calculating the non-photonic v_2 : Method 2 (checking the photonic v_2)

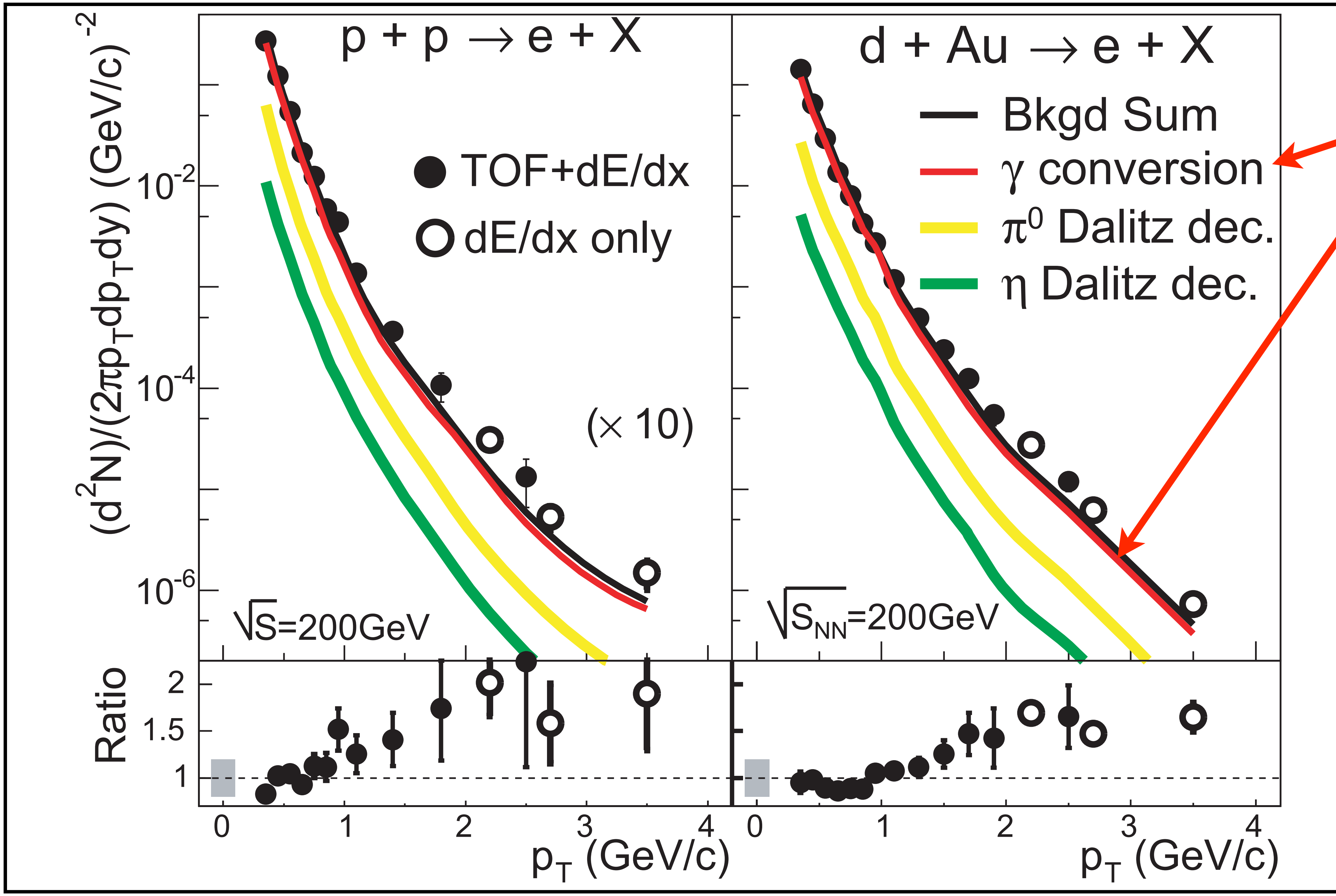


$$v_2^A = \frac{v_2^{ran} \cdot n^{ran,A} + v_2^{pho} \cdot n^{pho,A}}{n^{ran,A} + n^{pho,A}}$$

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

- use same Ansatz as in Method 1 to calculate the photonic and random v_2
- since it is an very pure sample of the photonic electrons, photonic v_2 is well constrained using this method

Electron sources

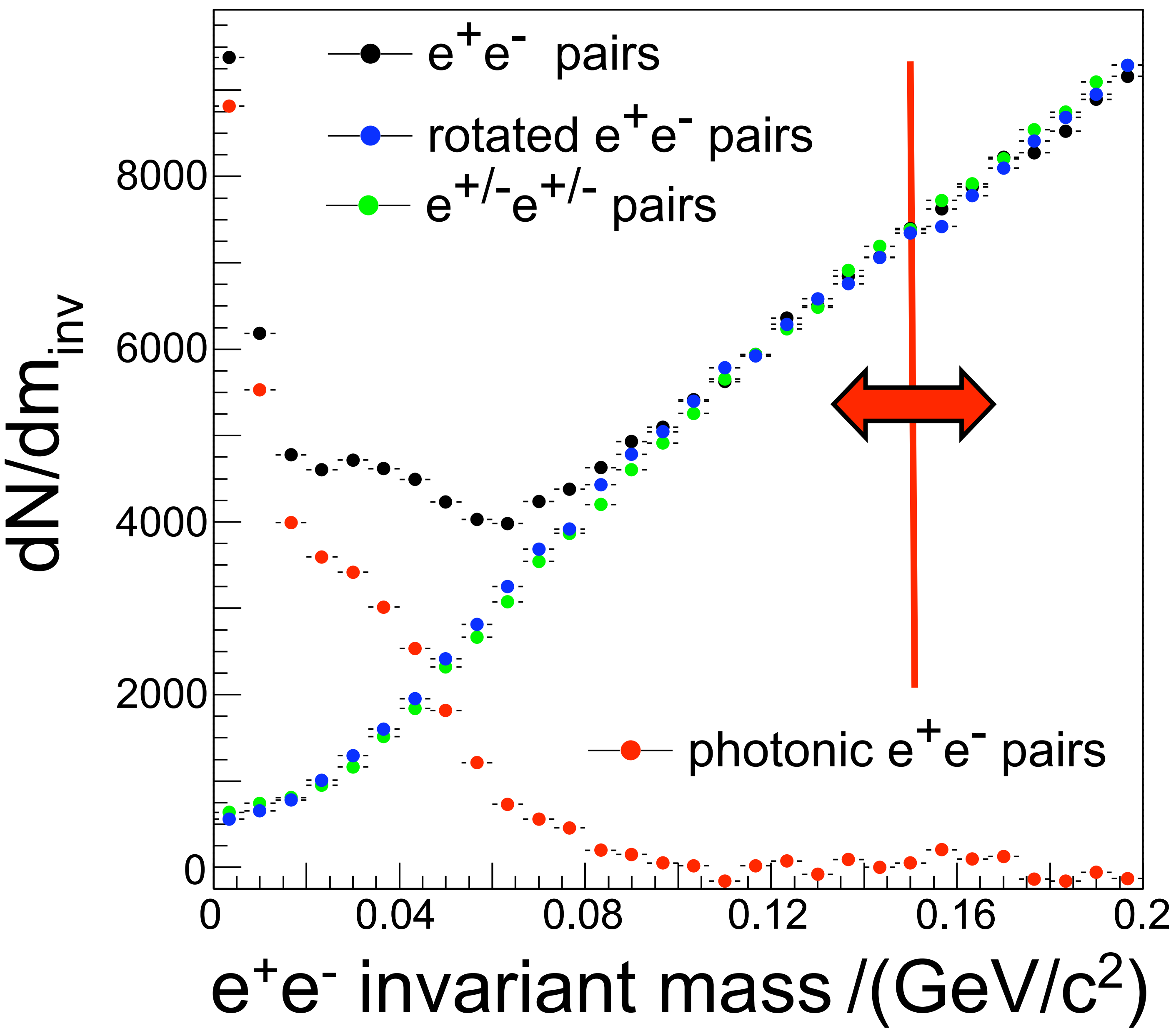


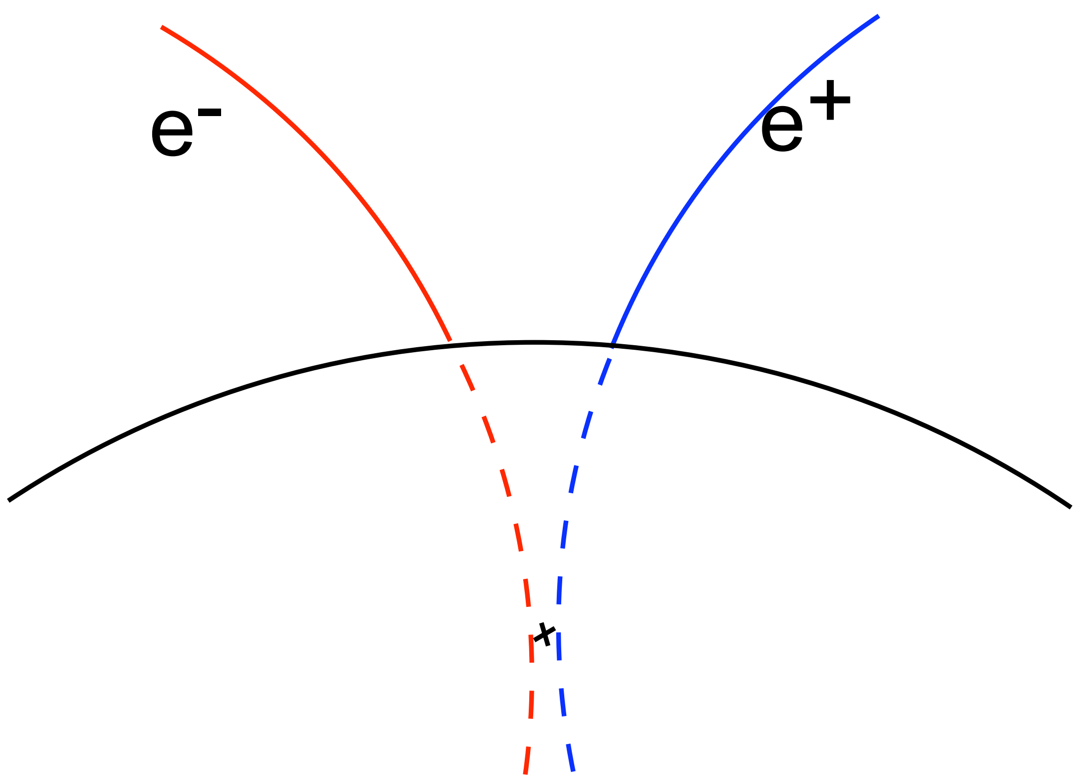
STAR: nucl-ex/0407006

Pythia tuned to STAR data

$e^{+/-}$ from γ's and π^0 Dalitz can be reduced by factor 2 via invariant mass method

Removal of γ-conversions and π^0-Dalitz Decays

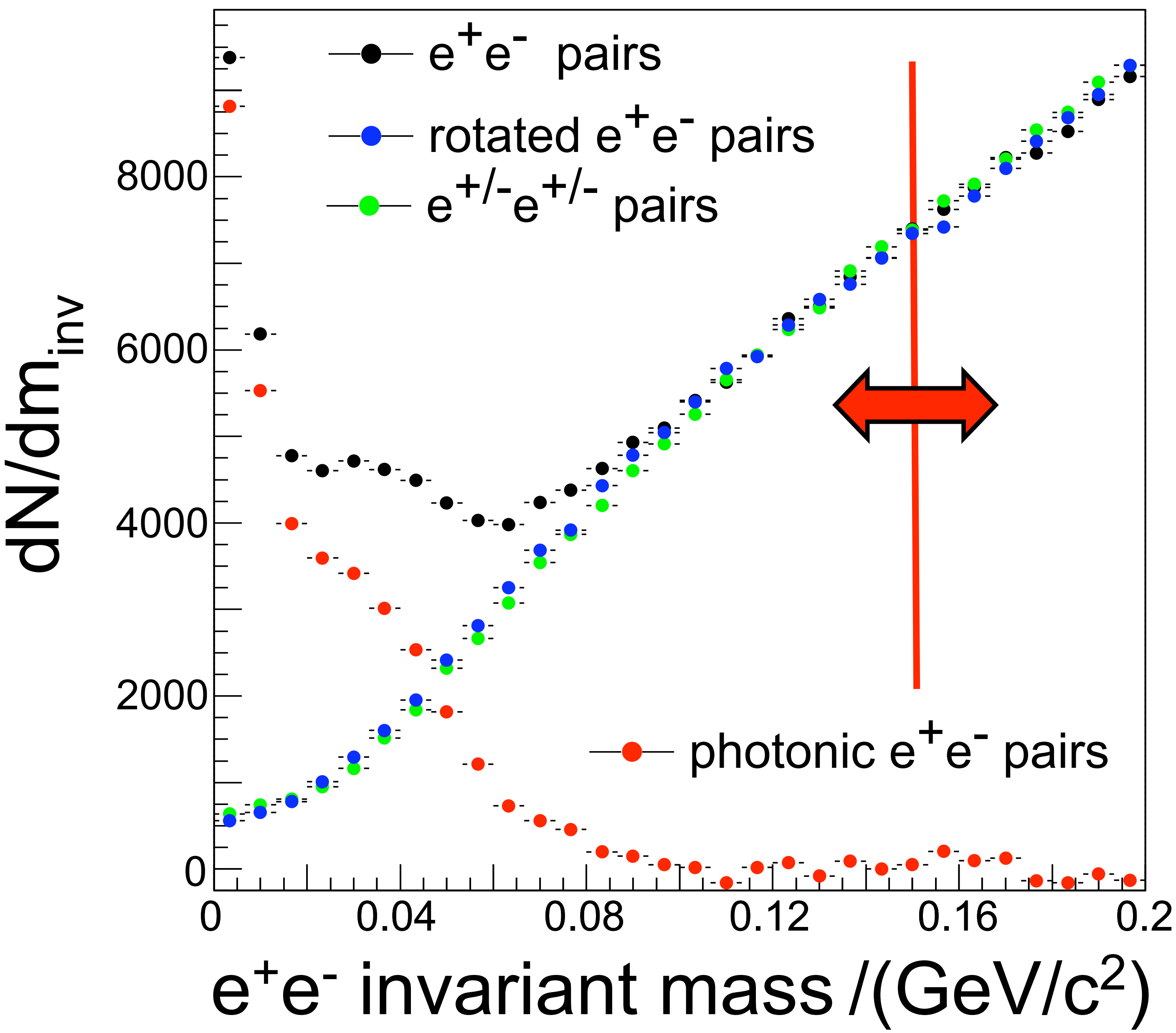


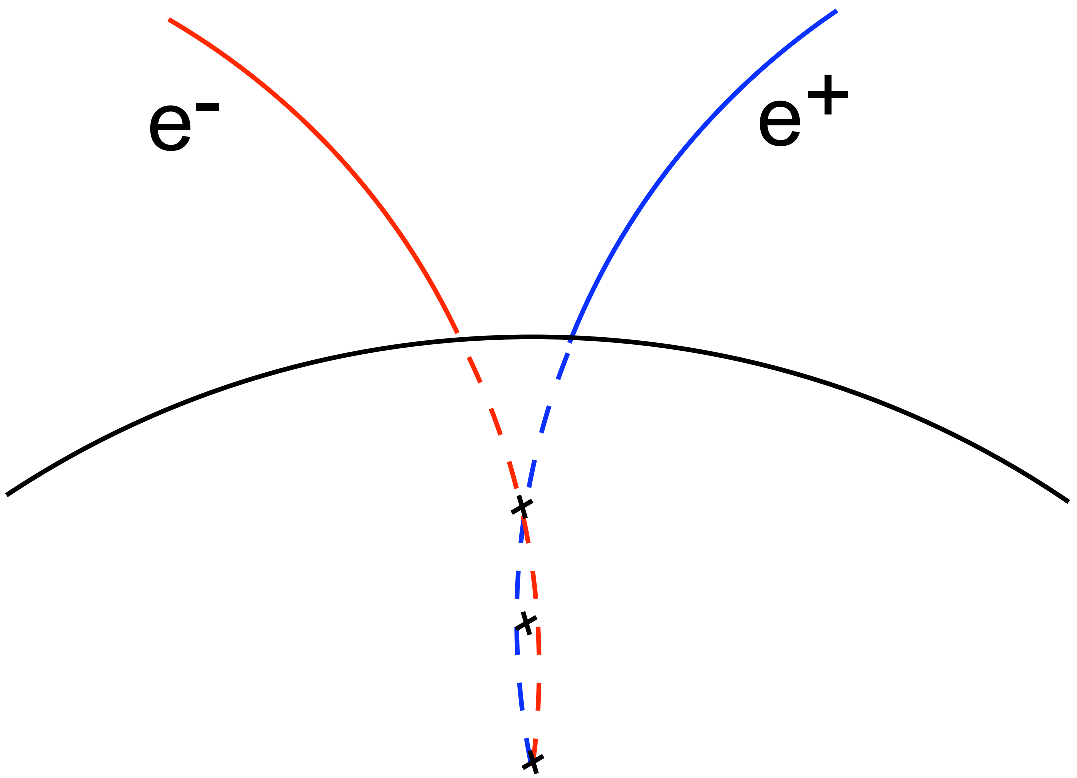


Conversion point and mass well reconstructed

~50% of electrons originating from γ-conversions and π^0-Dalitz decays can be removed with invariant mass method

Removal of γ-conversions and π^0-Dalitz Decays





Two fake conversion points reconstructed (picking one closer to primary vertex)

~50% of electrons originating from γ-conversions and π^0-Dalitz decays can be removed with invariant mass method