The Azimuthal Anisotropy of Electrons from Heavy Flavor Decays in $\sqrt{s_{NN}}$=200 GeV Au-Au Collisions at PHENIX

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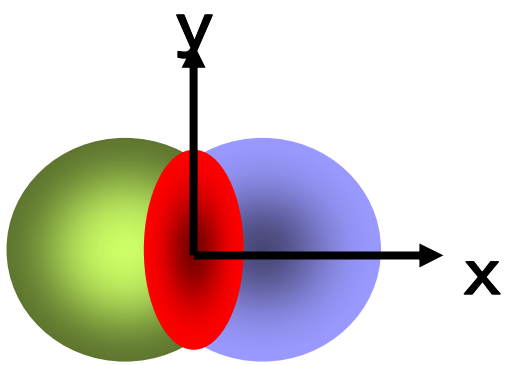
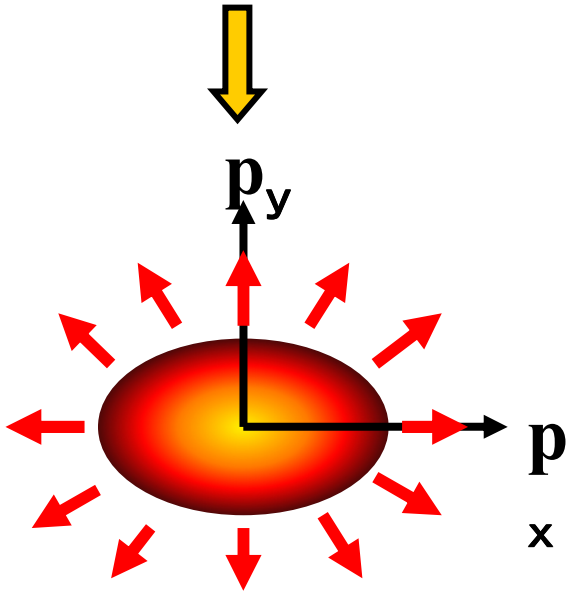
Azimuthal anisotropy

- **A powerful probe of the initial state of the high energy heavy ion collision**
- **transfer initial spatial anisotropy to momentum space anisotropy**
  - **macroscopic ; hydro model => pressure gradient**
  - **microscopic => scattering in the medium**

$$dN/d\varphi \propto N_0(1+2v_2\cos(2\varphi))$$



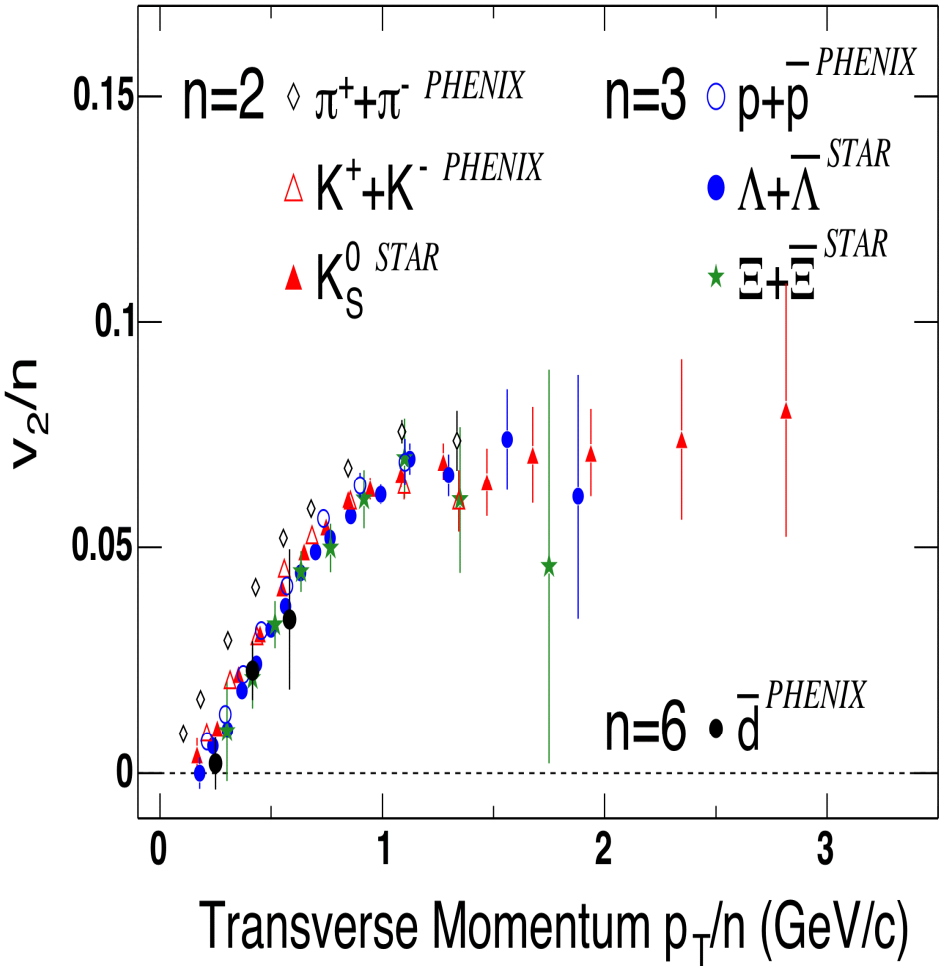
Initial spatial anisotropy



Momentum space anisotropy of particle emission

v_2 already developed in partonic phase ?

- identified hadrons v_2 after scaling number of quarks
- v2 after scaling fall on same curve
- partonic level v2
- v2 already formed in the partonic phase for hadrons made of light quarks (u,d,s)



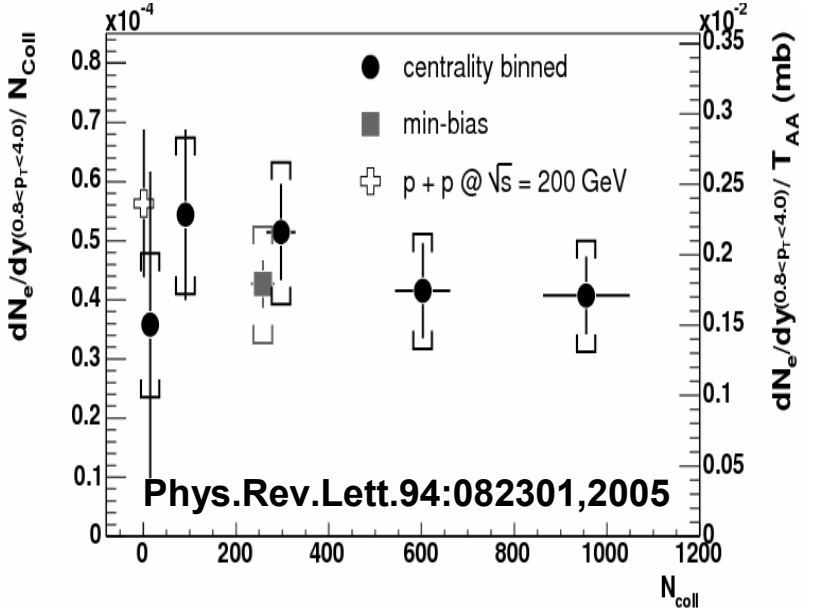
Charm quark

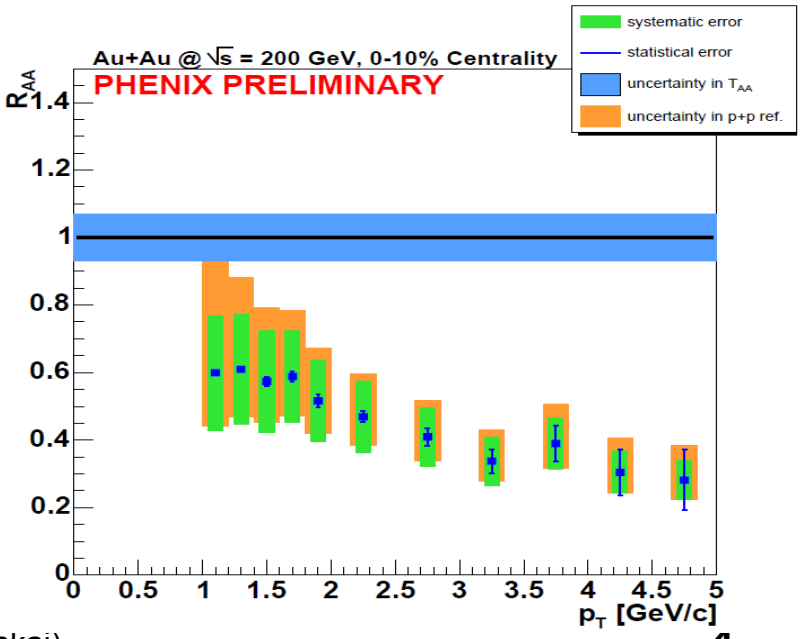
- Charm is believed to be produced in initial collisions via gluon fusion
  => total cross-section ; binary scaling

- Charm propagates through medium created in the collisions
  => good probe of medium

- R_{AA} --- suppression @ high pT

- initial charm v2 might be 0
  => charm quark v2 due to scattering in medium
  => non-zero charm v2 indicate very high dense medium created in the collision !



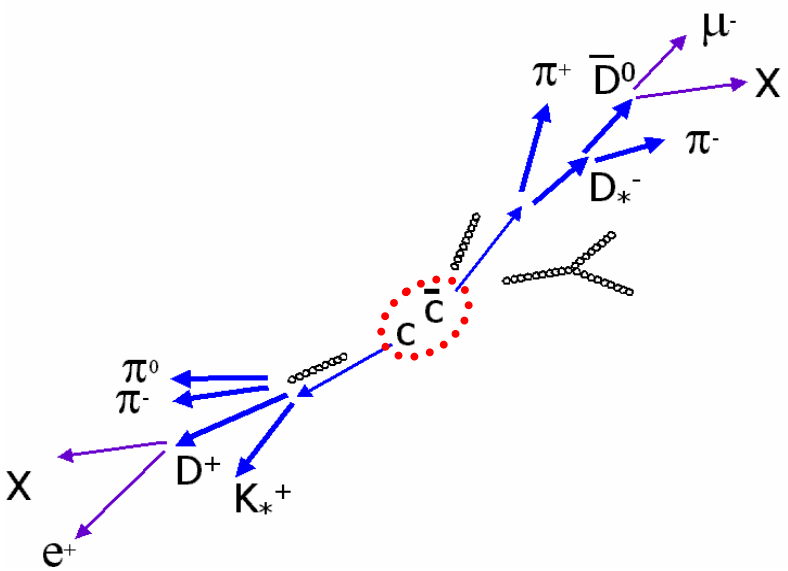


Charm quark study @ PHENIX

- Electron sources

  charm decay, beauty decay } non-photonic

  Dalitz decays
  Di-electron decays
  Photon conversions
  Kaon decays
  Thermal dileptons } photonic



- Subtract photonic electrons following methods
  - "Cocktail subtraction" – calculation of "photonic" electron background from all known sources
  - "Converter subtraction"– extraction of "photonic" electron background by special run with additional converter (brass, X = 1.7%)

Non-photonic electron v2 measurement

converter method

Measure inclusive electron v2 with/without converter

Then separate non-photonic & photonic e v2

Non-converter ; $N_{nc} = N_{\gamma} + N_{non\text{-}\gamma}$ => $(1+R_{NP})v2_{nc} = v2_{\gamma} + R_{NP} v2_{non\text{-}\gamma}$

Converter ; $N_c = R\gamma * N_{\gamma} + N_{non\text{-}\gamma}$ => $(R\gamma + R_{NP})\, v2_c = R\gamma\, v2_{\gamma} + R_{NP} v2_{non\text{-}\gamma}$

$R\gamma$ -- ratio of electrons with & without converter

$v2_{nc}$ --- inclusive e v2 measured with non-converter run

$v2_c$ --- inclusive e v2 measured with converter run

$v2_{\gamma}$ --- photonic e v2,

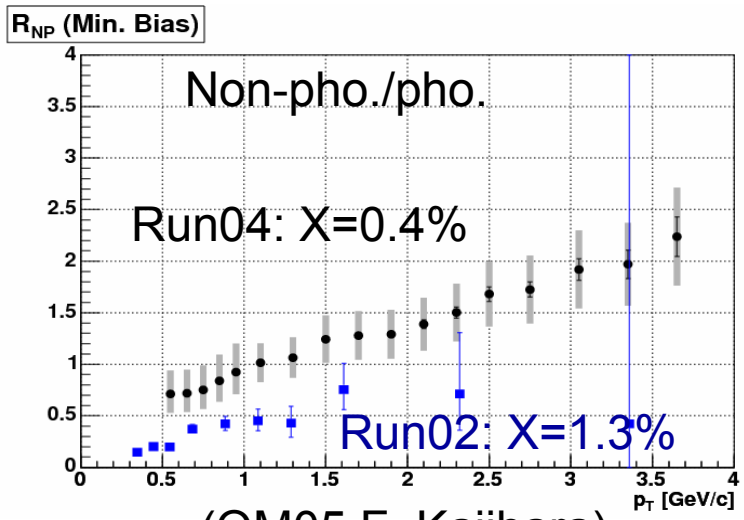
$v2_{non\text{-}\gamma}$ --- non photonic e v2

cocktail method

Determined photonic electron v2 with simulation

Then subtract it from electron v2 measured with non-converter run

$$v2_{non\text{-}\gamma} = \{(1+R_{NP})v2_{nc} - v2_{\gamma}\}\}/R_{NP}$$



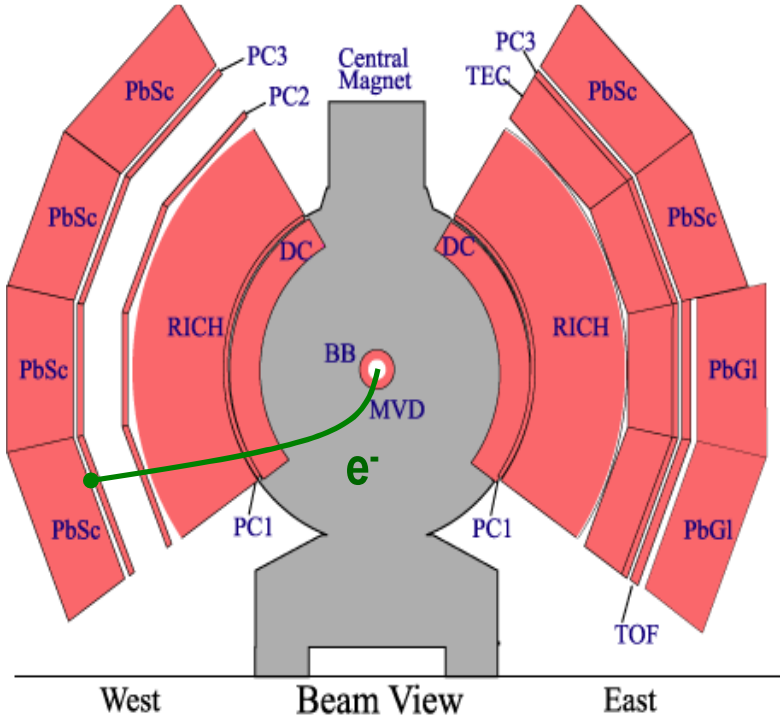
(QM05 F. Kajihara)

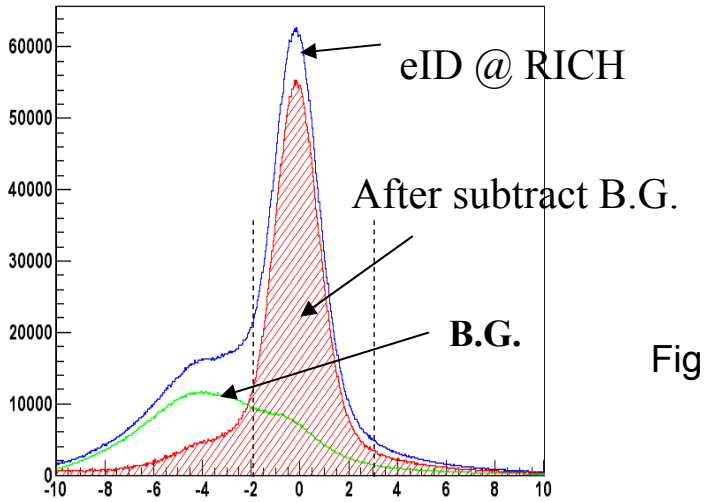
Electron v2 measurement @ PHENIX

- Electron v_2 is measured by R.P. method

$$dN/d(\phi-\Phi) = N\,(1 + 2v_2^{obs}\cos(2(\phi-\Phi)))$$

- R.P. --- determined with BBC
- Tracking (pT, ϕ) --- DC + PC
- electron ID --- RICH & EMCal

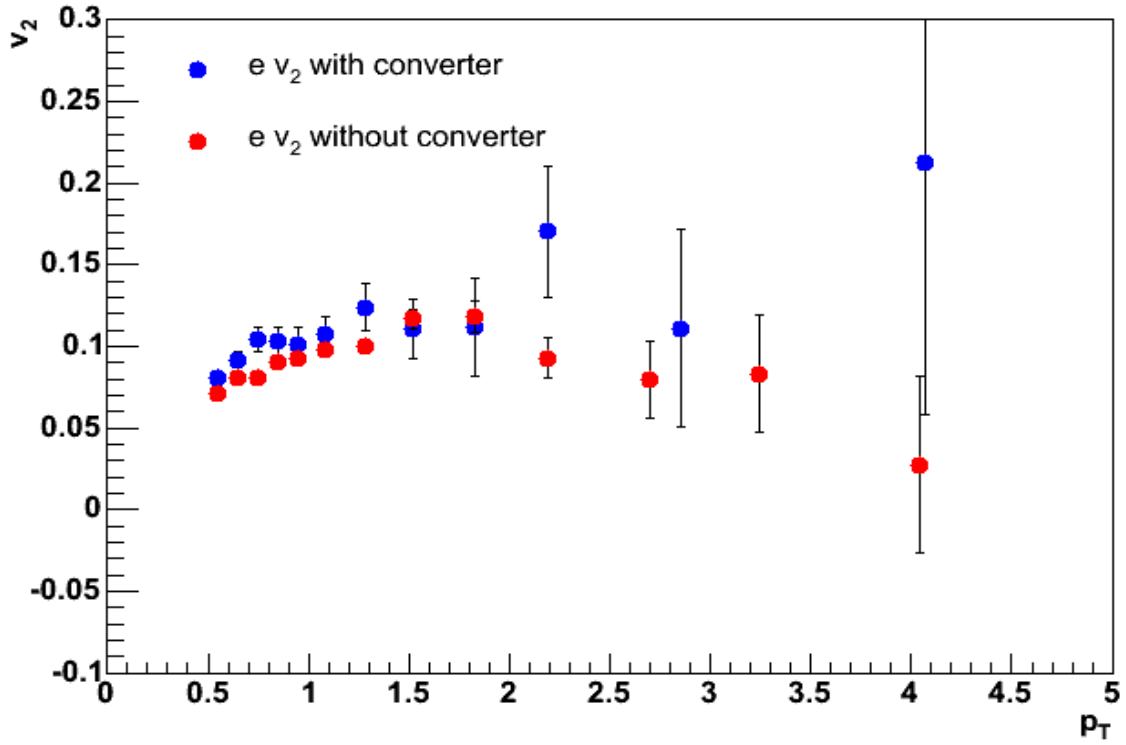




(E-p/p/sigma) distribution

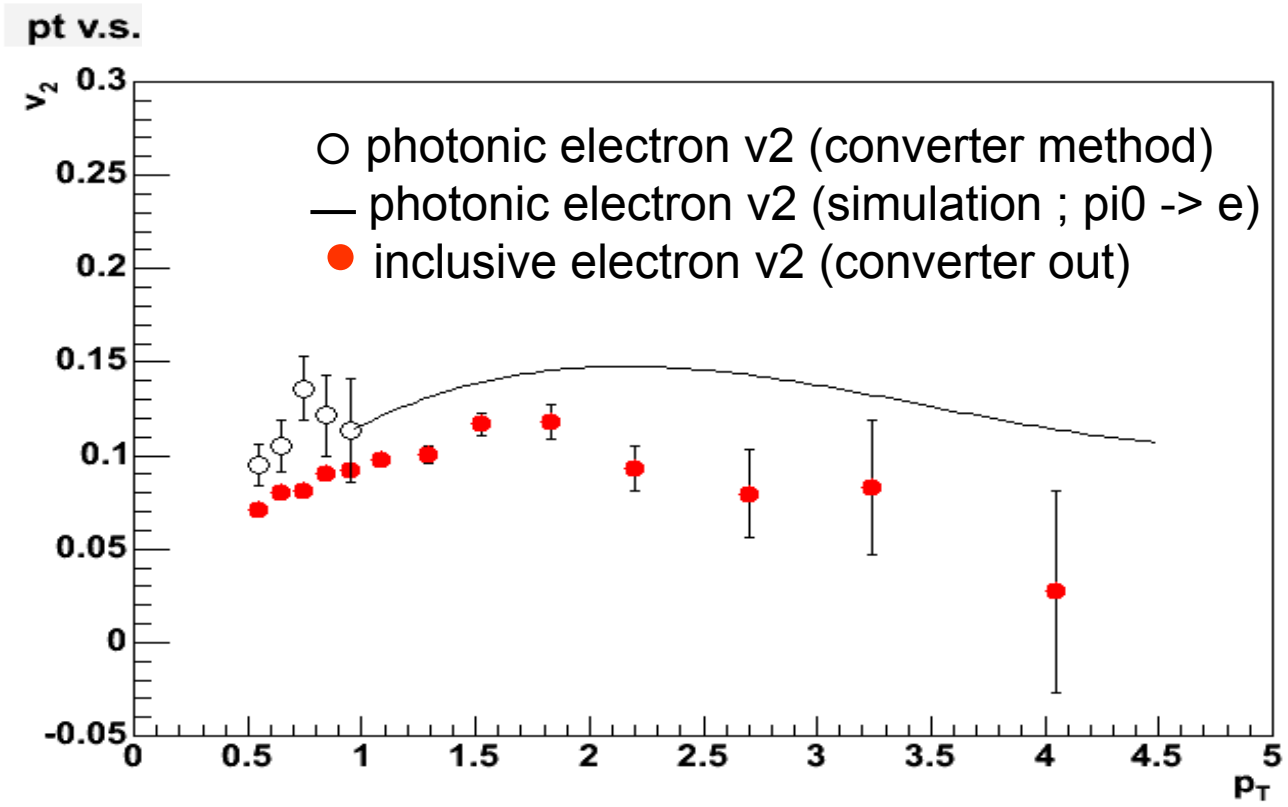
Fig : Energy (EMcal) & momentum matching of electrons identified by RICH.
Clear electron signals around E-p/p = 0

Inclusive electron v2 (in/out converter)



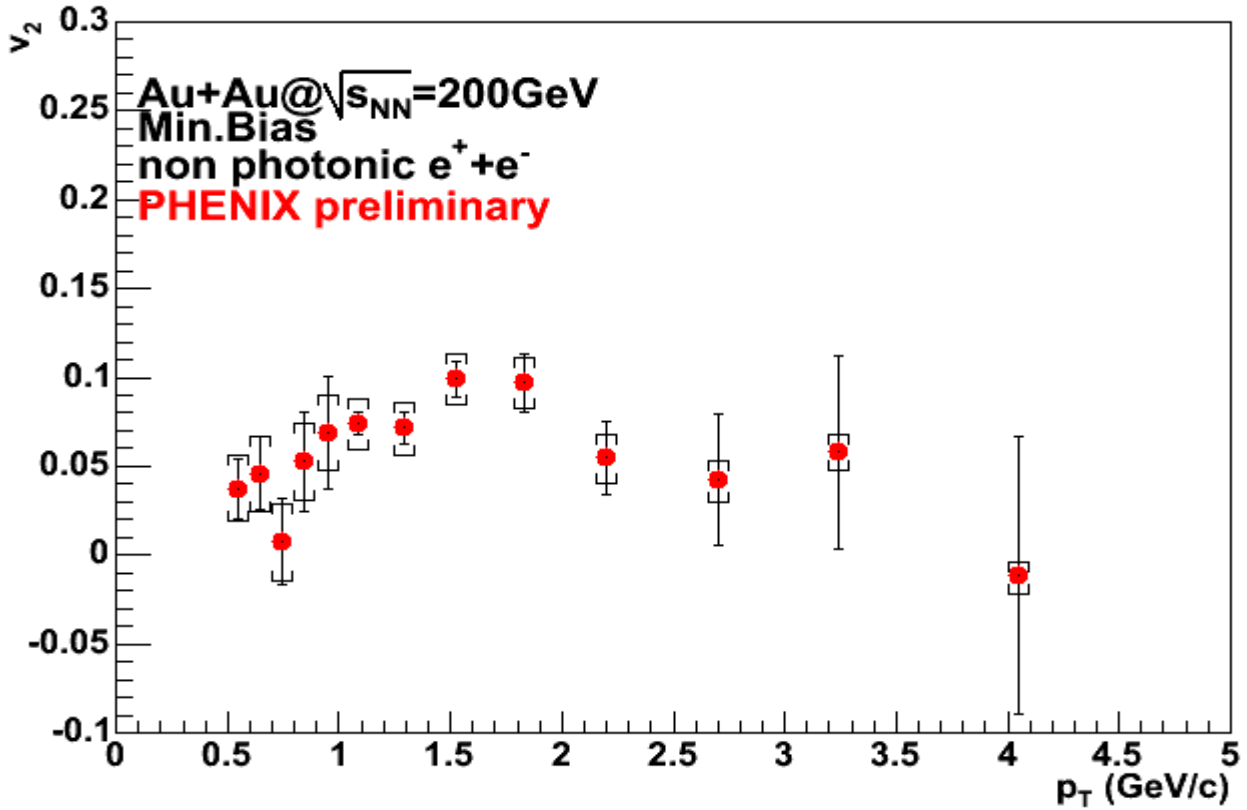
- **inclusive electron v2 in / out converter**
- **clear difference between converter in / out**
  => photonic & non-photonic e v2 is different

Inclusive electron & photonic electron v2



- **compare with inclusive & photonic electron v2**
- **photonic e v2 ; pT < 1.0 (conv.) & pT > 1.0 (cock.)**
- **inclusive electron v2 is smaller than photonic electron v2**

Non-photonic electron v_2



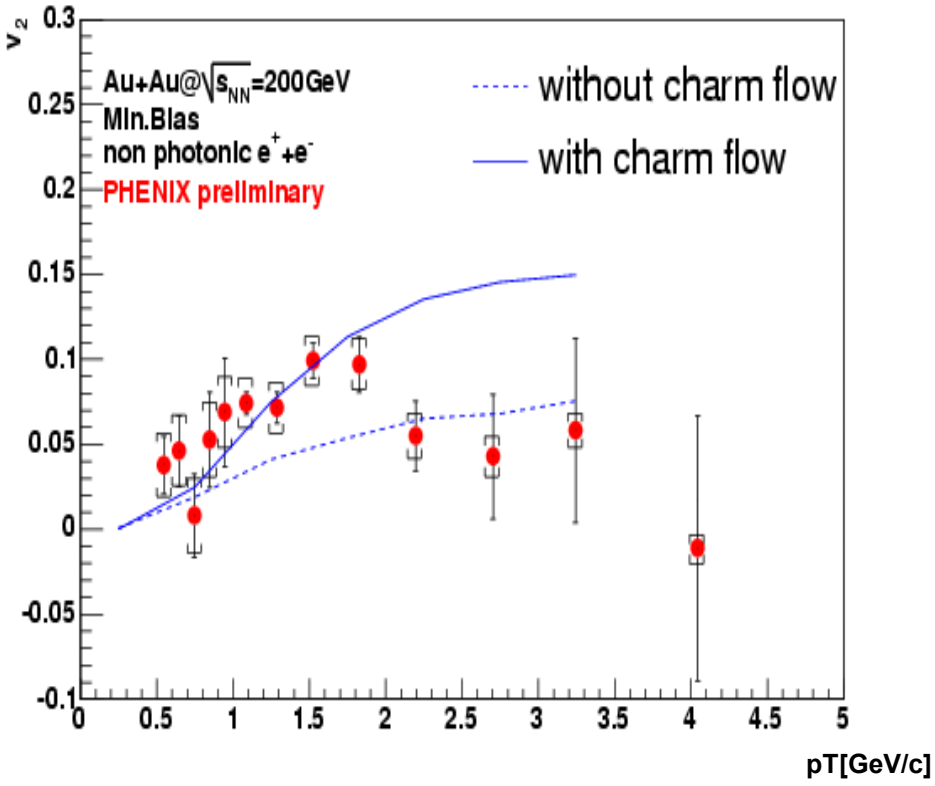
- Non-photonic electron v2 : pT < 1.0 (conv.) & pT>1.0 (cock.)
- Non-photonic electron v2 has non-zero v2
  => indicate non-zero D meson v2

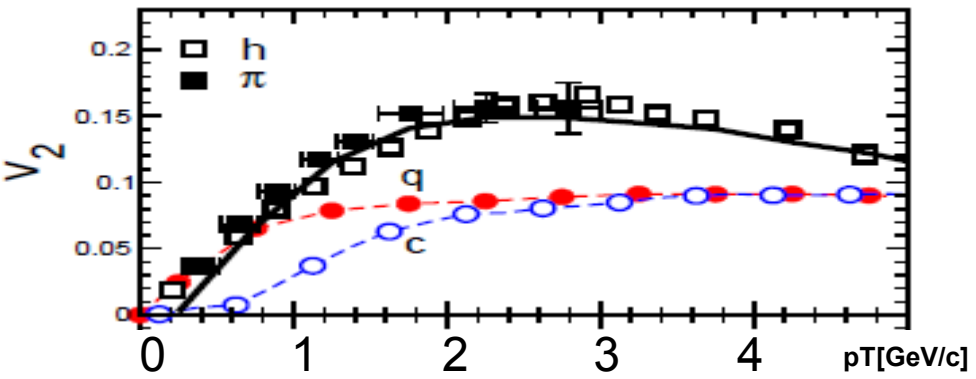
Charm quark flow ?

- Compared with quark coalescence model prediction.
  with/without charm quark flow
  (Greco, Ko, Rapp: PLB 595 (2004) 202)
  - No Bottom contribution
  - c v2 small u v2 @ low pT
  - quark v2 flat @ high p_T

- Below 2.0 GeV/c ;
  consistent with charm quark flow model.

- non-photonic electron v2
  favor charm quark flow model





D v2 estimate from non-γ e v2 (1)

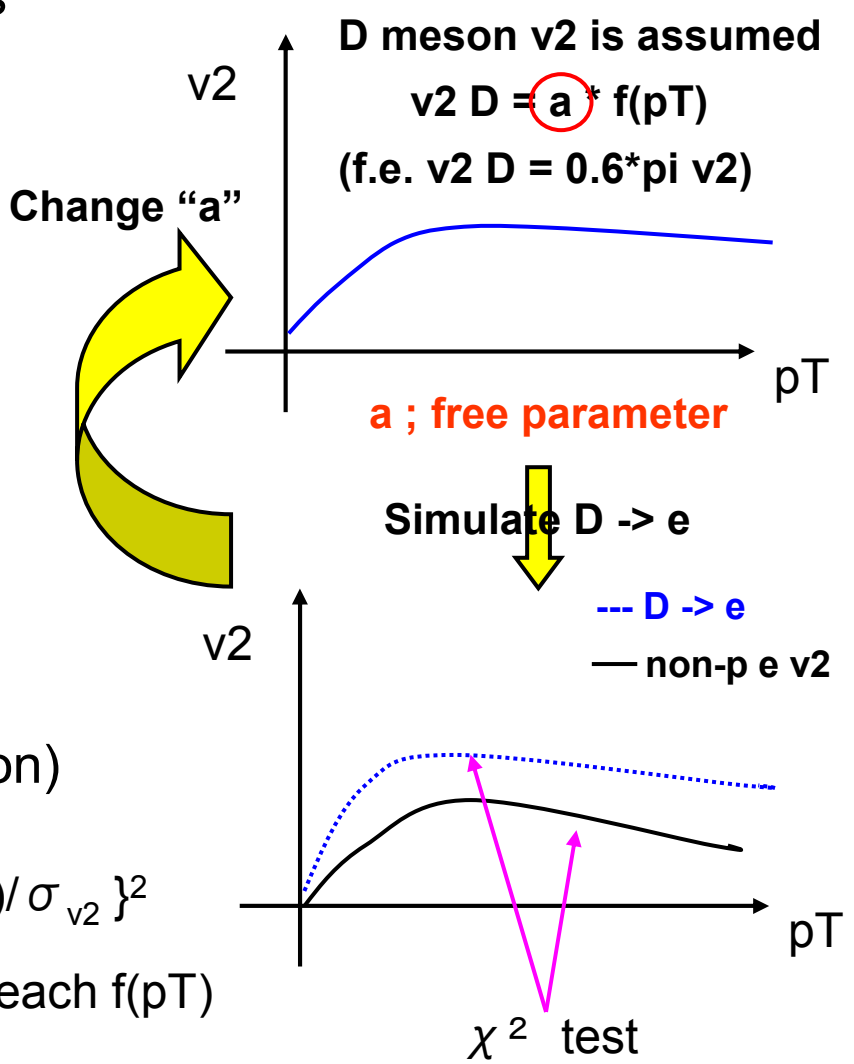
(1) different v_2(pt) shape assumptions
for D meson ;
D v2 = a * f(pT)
f(pT) = pi v2 / k v2 / p v2
a ; free parameter

(2) Simulate D -> e
* p_T distribution tuned
to reproduce electron spectra
shape at Au+Au

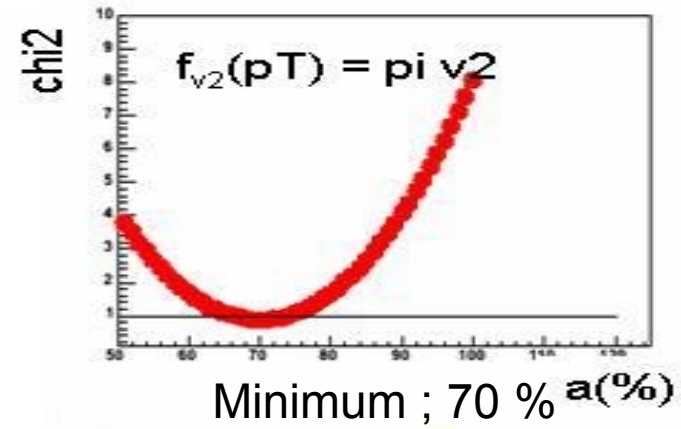
(3) χ^2 restricted up to p_T<2GeV/c
(due to uncertainty of B contribution)

$$\chi^2 = \Sigma_{pT}\{(v2_{non\text{-}\gamma\ e}(pT) - v2_{D\text{->}e}(pT))/\sigma_{v2}\}^2$$

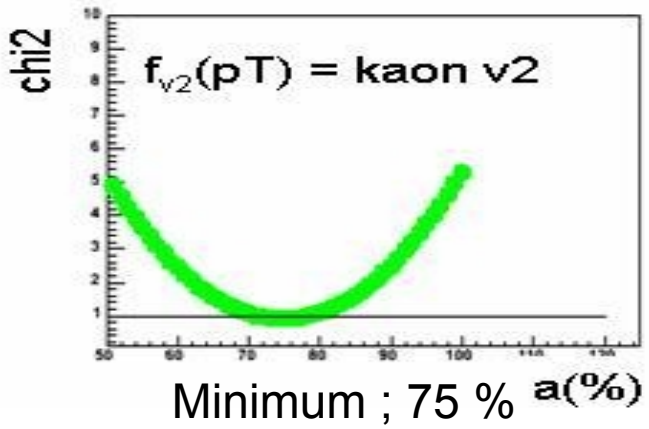
(4) Change “a” and find χ^2 minimum for each f(pT)



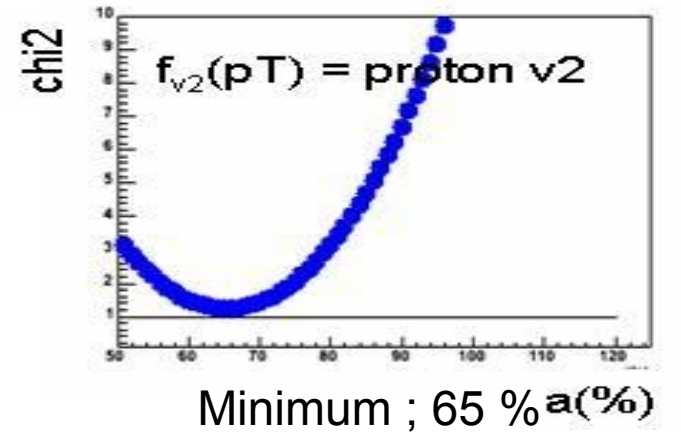
D v2 estimate from non-γ e v2 (2)



Minimum ; 70 %



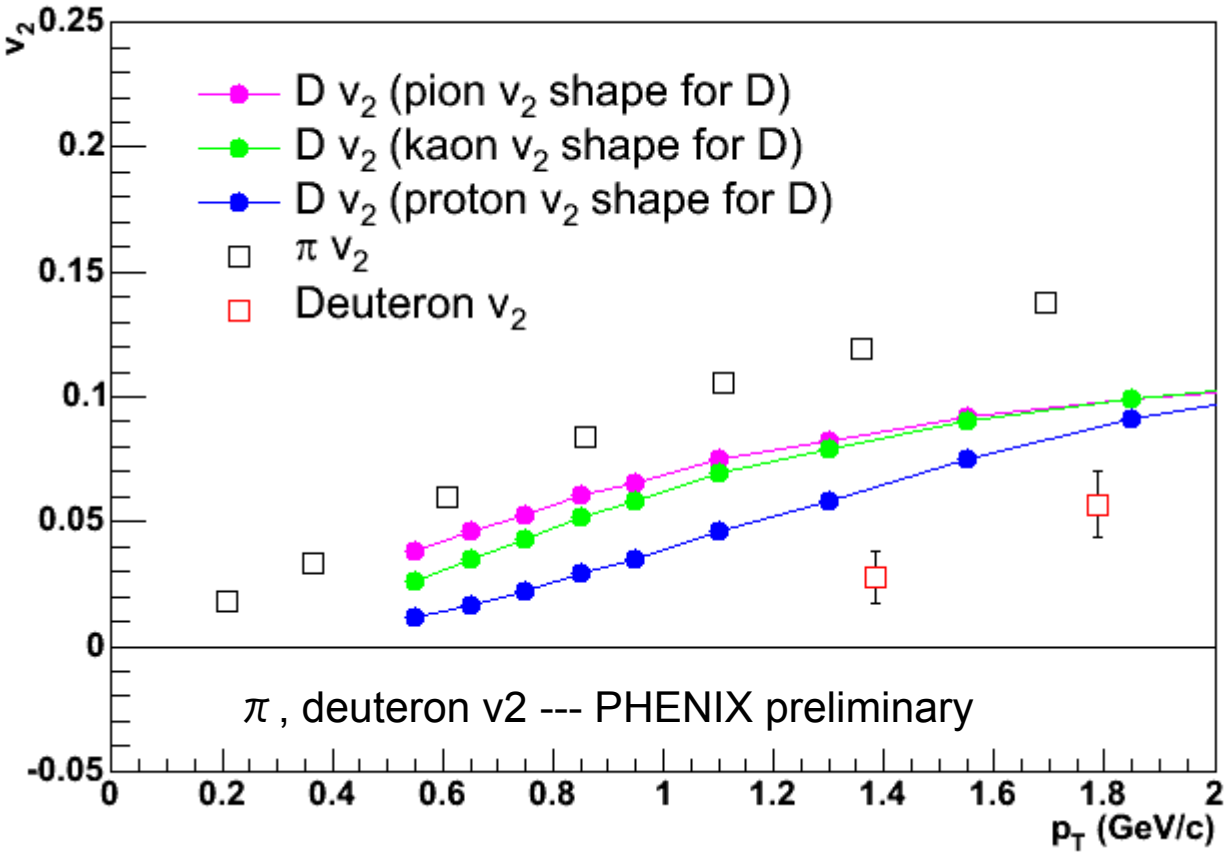
Minimum ; 75 %



Minimum ; 65 %

- χ^2/ndf v.s. scale factor (a)
- D meson v2 might be smaller than pi, K, p v2

Compare D v2 with other hadron v2



- expected D meson v2 from non-photonic electron v2 (p_T < 2.0 GeV/c)
  - smaller than pi v2
  - larger than Deuteron v2 if D v2 shape same as pi, k, p (Mass D meson~ Mass Deuteron)

Summary

- Non-photonic electron v_2 from heavy flavor decays has been measured with RHIC-PHENIX
- Non-photonic electron v2 has non-zero v2
  => indicate non-zero D meson v2
- Compare with model calculations assuming charm flow or not
  Our result consistent with charm flow model below 2.0 GeV/c
- Estimate D meson v2 from non-photonic electron v2 assuming D meson v2 shape as pion, Kaon, proton.

- Backup slides

Converter method

Separate non-photonic & photonic e v2 by using Non-converter run & converter run

$$\begin{cases} \text{Non-converter} ; \ N_{nc} = N_{\gamma} + N_{non\text{-}\gamma} \\ \text{Converter} \ ; N_{c} = R\gamma * N_{\gamma} + N_{non\text{-}\gamma} \end{cases}$$

$$\Rightarrow \begin{cases} (1+R_{NP})v2_{nc} = v2_{\gamma} + R_{NP} v2_{non\text{-}\gamma} \\ (R\gamma + R_{NP})\, v2_{c} = R\gamma\, v2_{\gamma} + R_{NP} v2_{non\text{-}\gamma} \end{cases}$$

$R\gamma$ --- ratio of electrons with & without converter (measured)
R_{NP} --- non-photonic/photonic ratio (measured)
$v2_{nc}$ --- inclusive e v2 measured with non-converter run (measured)
$v2_{c}$ --- inclusive e v2 measured with converter run (measured)

$v2_{non\text{-}\gamma}$ (non-photonic) & $v2_{\gamma}$ (photonic) is "*experimentally*" determined !

Cocktail method

Determined photonic electron v2 with simulation
Then subtract it from electron v2 measured
with non-converter run

$$dN_e/d\Phi = dN_{pho.e}/d\Phi + dN_{non\text{-}pho.e}/d\Phi$$

$$v2_{non\text{-}\gamma} = \{(1+R_{NP})\, v2 - v2_{\gamma}\} \} / R_{NP}$$

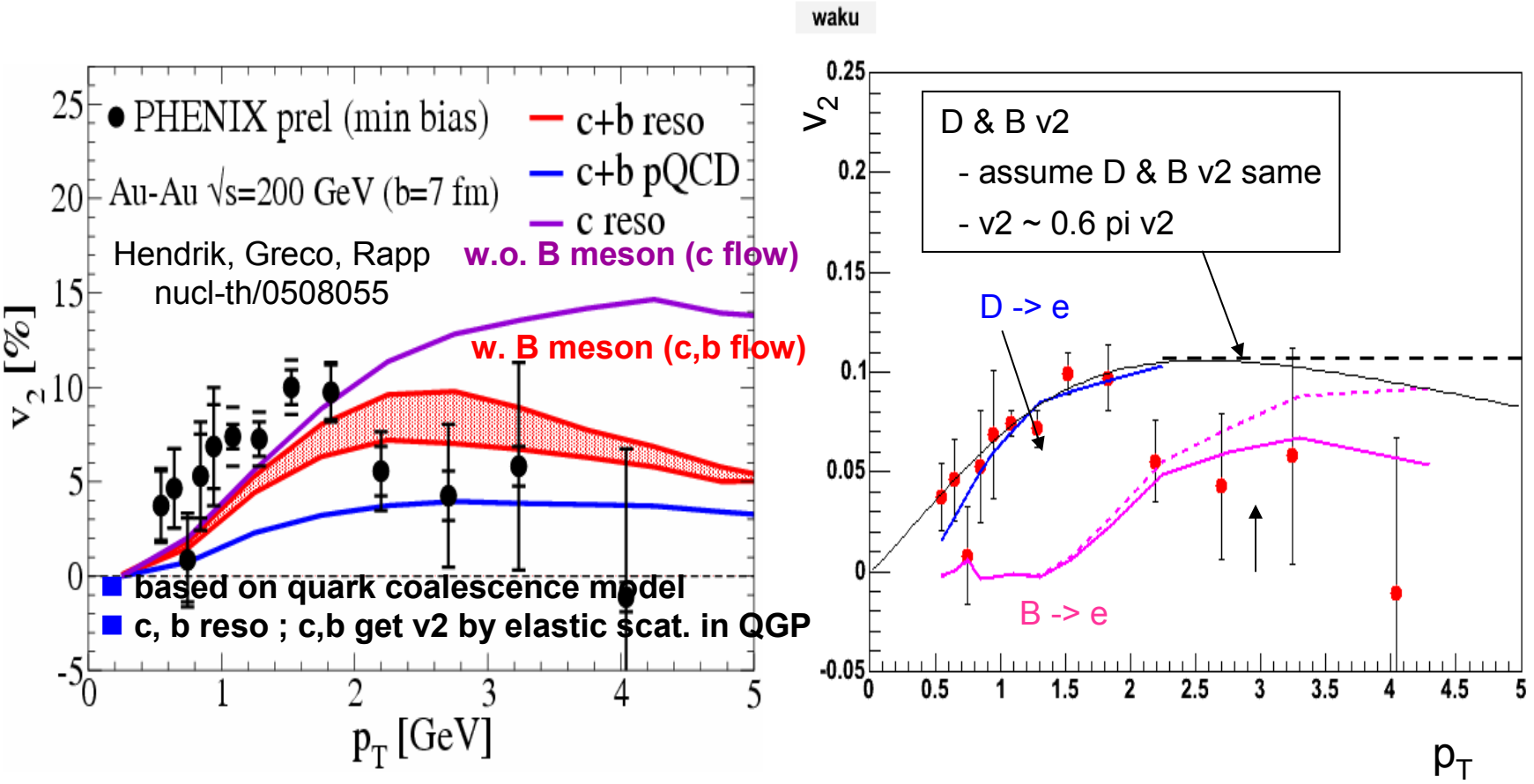
$v2_{non\text{-}\gamma}$: measured

$(1+R_{NP})\, v2$: measured

$v2_{\gamma}$: calculate

R_{NP} --- non-photonic/photonic ratio
experimentally determined
v2 --- inclusive electron v2 (without converter)
$v2_{\gamma}$ --- photonic electron v2
calculated from pi0 (pion) v2

B meson contribution to non- γ.e. v2



- Model predict B -> e v2 reduce non-photonic electron v2 @ high pT
- if B meson v2 saturate @ high pT, non-photonic electron v2 reduce due to smearing of electron v2 from B meson.