Measurement of J/ψ Elliptic Flow in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV in STAR Experiment

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for the STAR Collaboration

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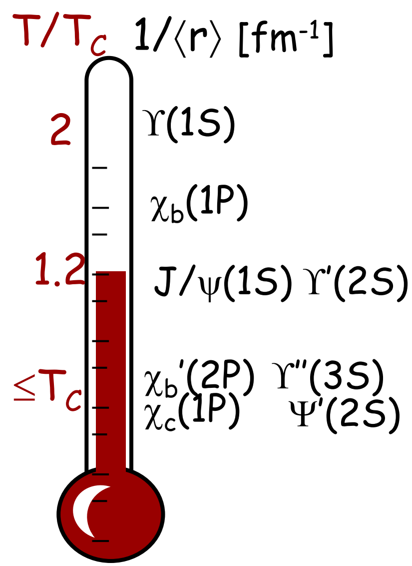
Outline

- Motivation
- J/ψ identification
- v_2 methods
- Results
- Summary and outlook

Motivation

- Charm quarks
  - large mass → produced in the early stage and less influenced by later evolution
  - excellent tool to study properties of the hot and dense matter created in A+A 200GeV collisions

Quarkonia's suppression patterns
➔ QGP thermometer



***A .Mocsy**, 417th WE-Heraeus-Seminar,2008*

c $\bar{c}$

Screening effect
J/ψ suppression → QGP formation

Matsui & Satz 1986

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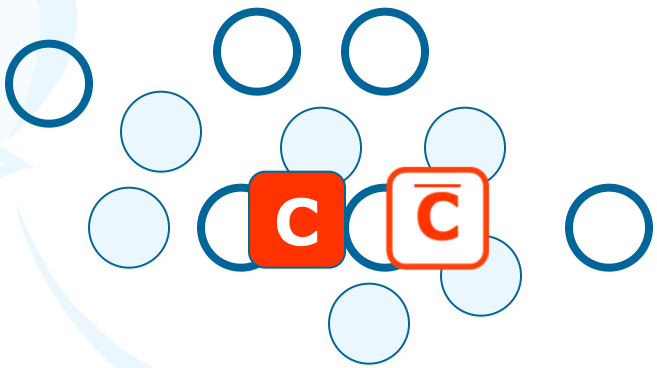

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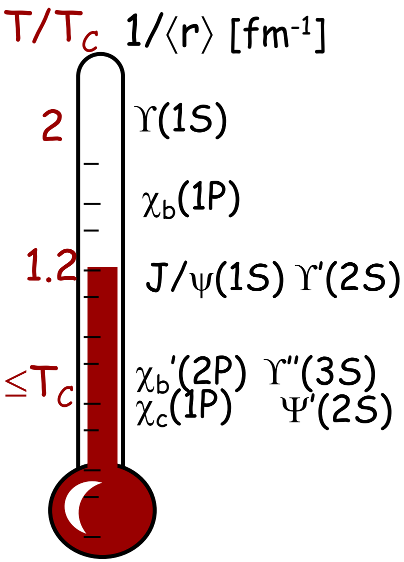

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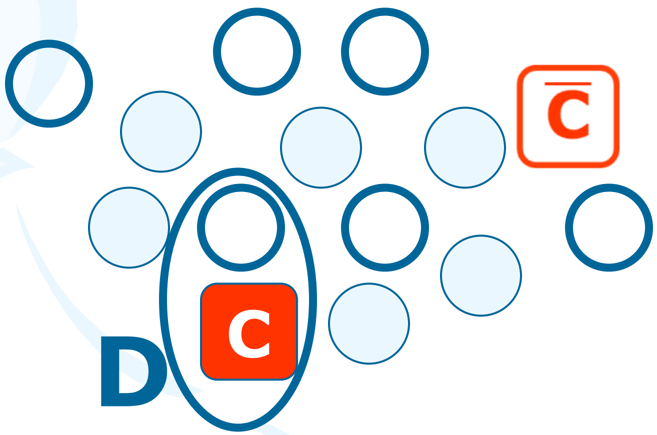

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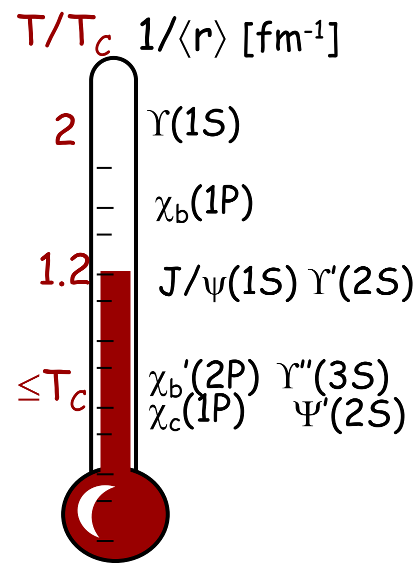

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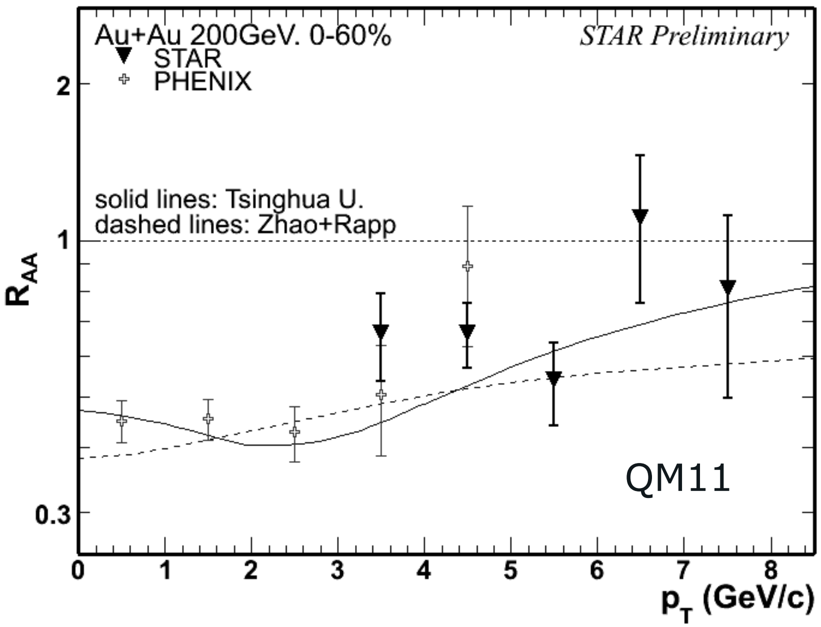
Motivation



We do see suppression, however other hot and cold nuclei effects can influence the yield:

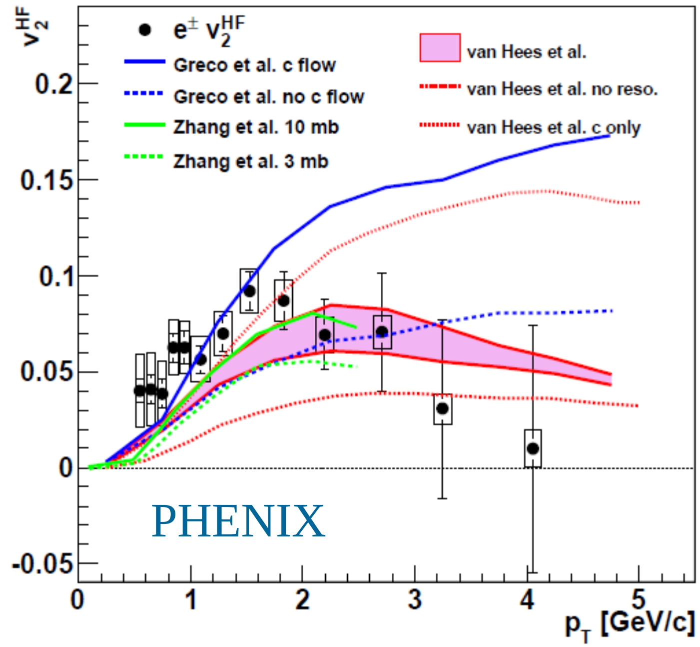
- Recombination
- "comovers"

- Modification of gluon distribution function
- nuclear absorption
- "Cronin effect"

Direct pQCD production + leakage effect	➡	Limited v_2
Produced by coalescence of thermalized charm quarks	➡	Large v_2

Motivation

- Charm quark is much heavier, thus much more difficult to thermalize than light quarks. So if charm flows, the system dominated by light quarks should be fully thermalized.
- v_2 of J/ψ from recombination carries the v_2 of charm.
- Precise comparison between model and data is needed to consider the contribution from both direct and recombined J/ψ.

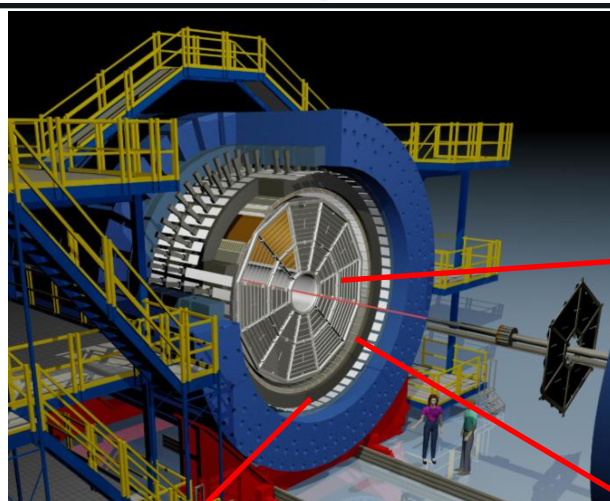


http://arxiv.org/abs/1005.1627v2

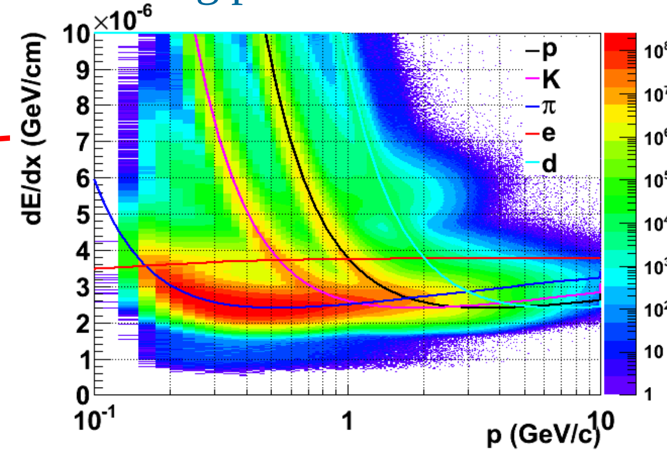
- Non-photonic electron v_2 measurement favors flowing charm.

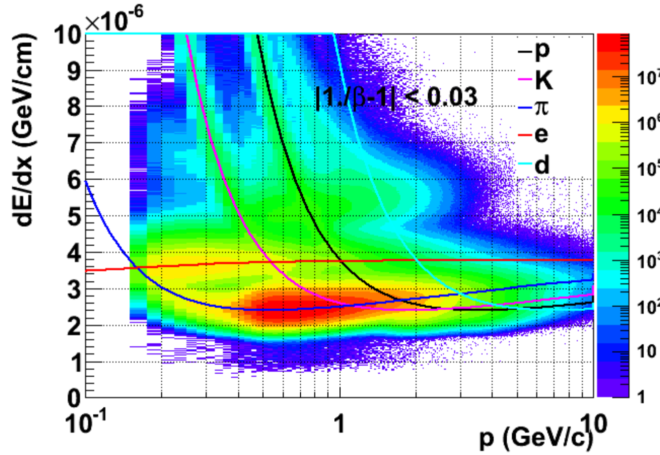
J/ψ Identification

$J/\psi \to e^+e^-$
Br 5.9 %



Time Projection Chamber - TPC
Measuring p and dE/dx

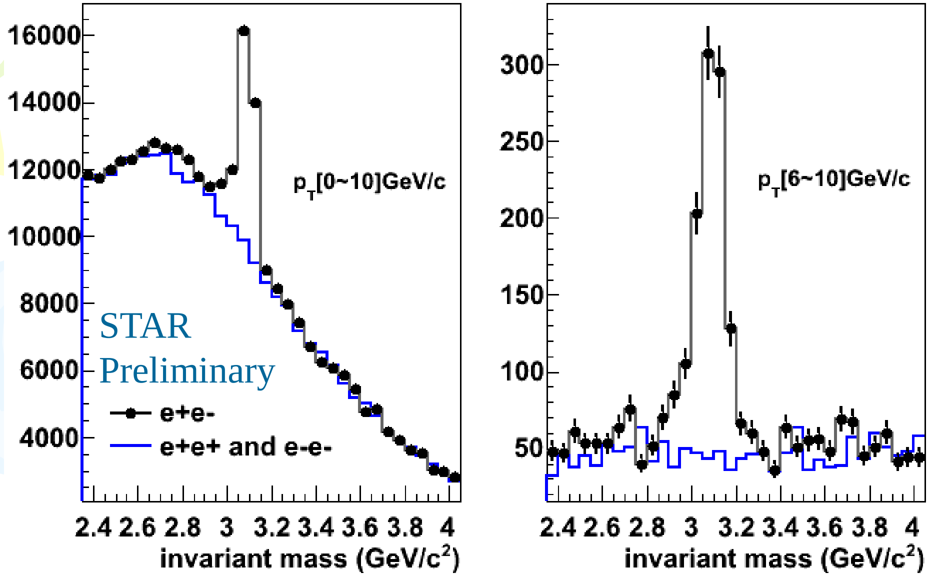




Barrel ElectroMagnetic Calorimeter - BEMC
p/E 0.3~1.5
Suppress hadrons at high p_T

Time Of Flight - TOF
$|1-1/\beta|<0.03$

J/ψ Identification



- ~14000 J/ψ identified
- prominent signal for $p_T > 6$ GeV/c region
- Data taken in RHIC 200 GeV Au+Au run in 2010

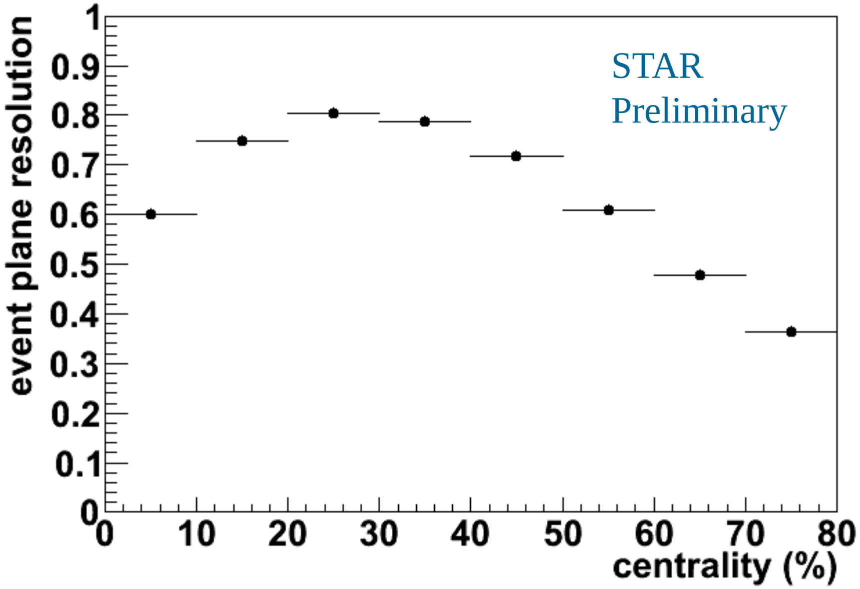
- 350 million minimum bias events
- 270 million central events
- BEMC high tower triggered events equivalent to ~ 7 billion minimum bias in the relatively higher p_T region.

Event Plane

$$v_2 = <\cos[2(\phi - \Psi_{rp})]>$$

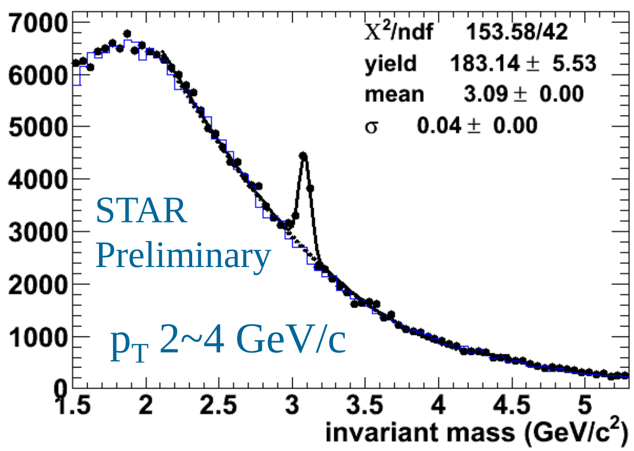
$$v_{2\_obs} = <\cos[2(\phi - \Psi)]>$$

$$v_2 = v_{2\_obs} / R$$

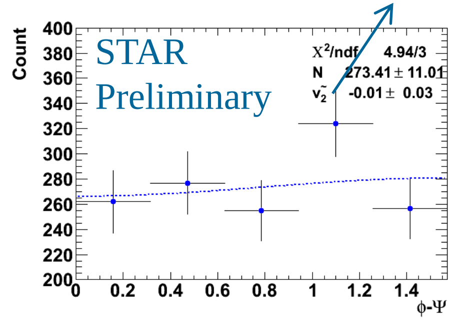


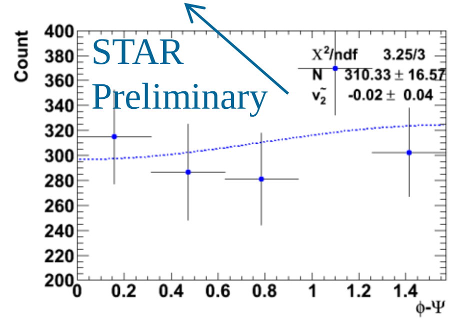
- Event plane resolution is calculated from random sub-event.

φ–Ψ Method



Scale then with average 1/resolution



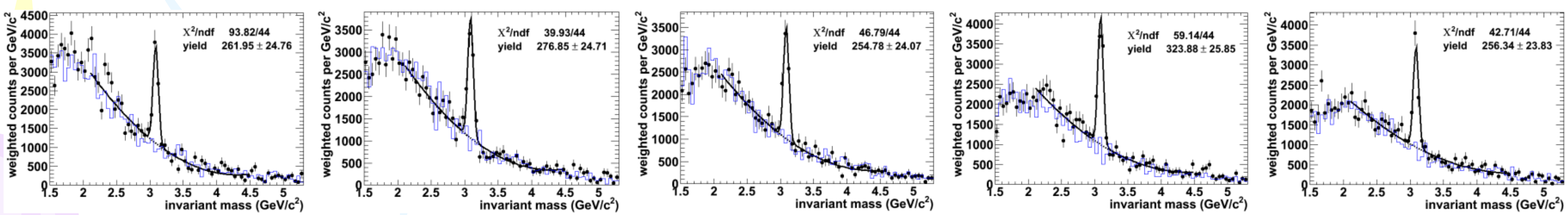


yield from fit

yield from raw counts

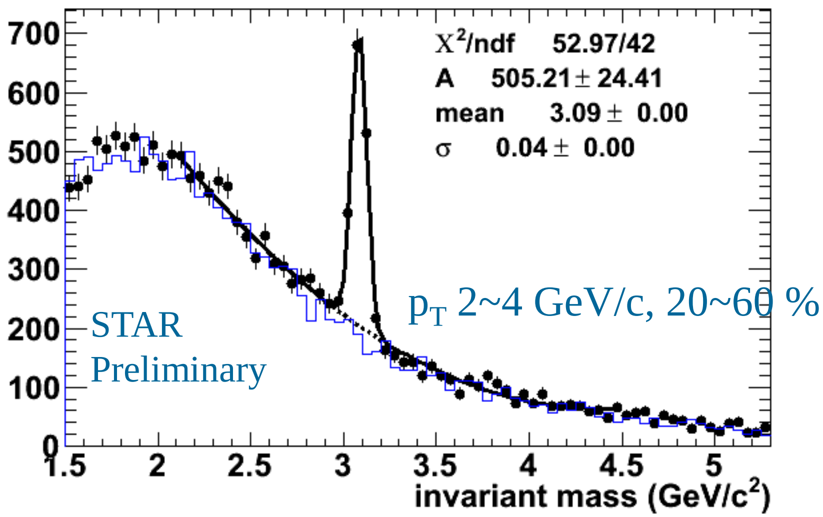
unlike – like sign

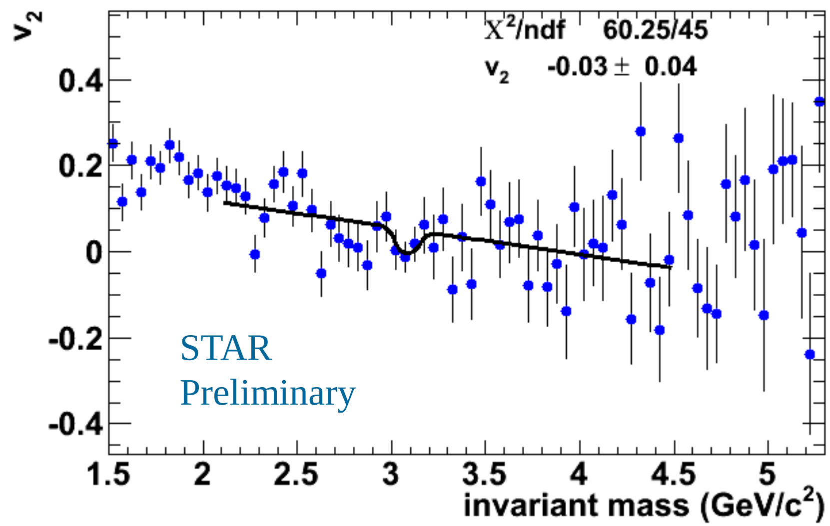
p_T 2~4 GeV/c, 20~60 %



- 10 φ–Ψ bins and combine every two bins symmetrical to π/2
- Fix the Gaussian shape, fit only the amplitude and the background.

Invariant Mass Method





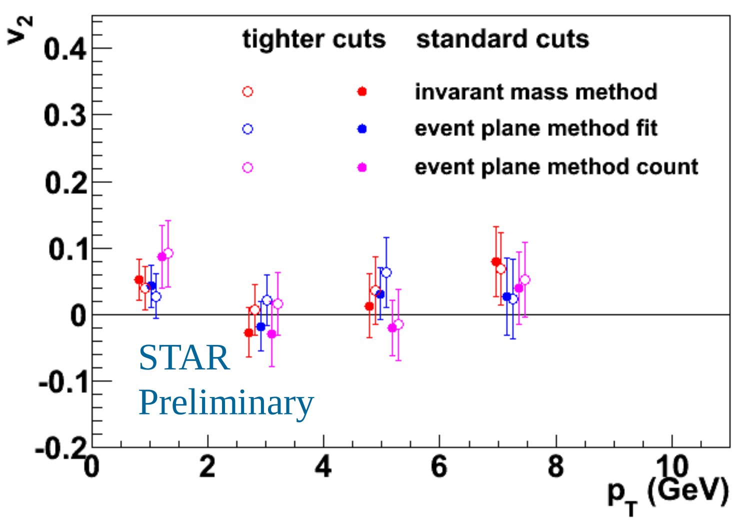
- Polynomial: background
- Gaussian: signal

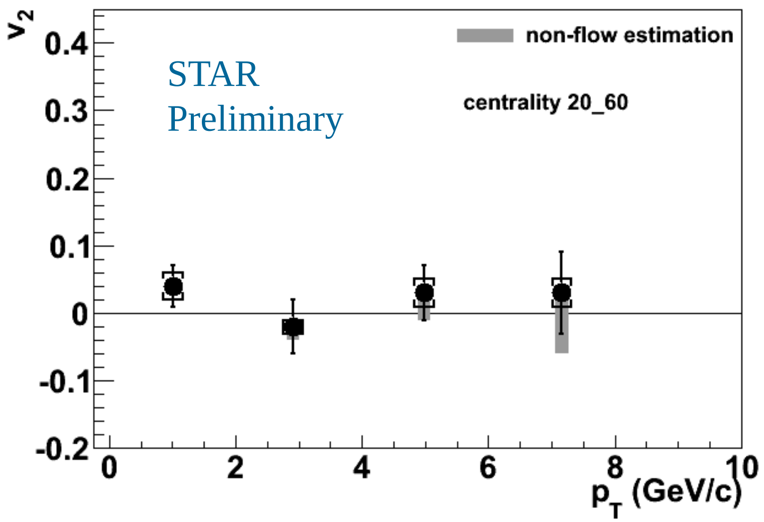
weighted with 1./resolution

centrality by centrality

$$v_{2\_overall}(m) = (v_{2\_J/\psi} * s(m) + v_{2\_background}(m) * b(m)) / (s(m) + b(m))$$

Systematic Errors





event plane method fit, standard cuts as central value

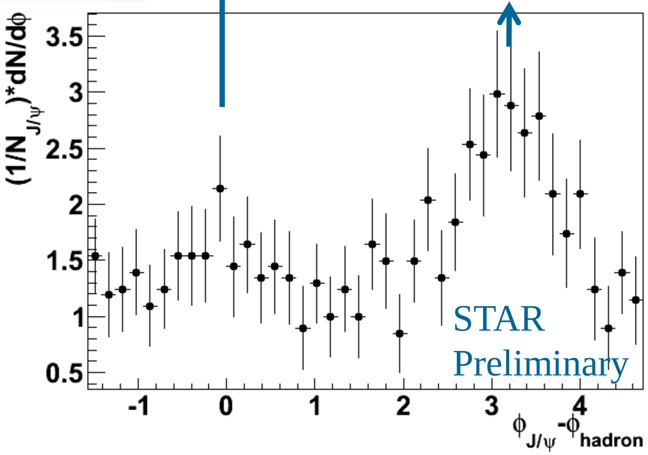
Assuming uniform distribution,

1 σ systematic error = (max-min)/√12.

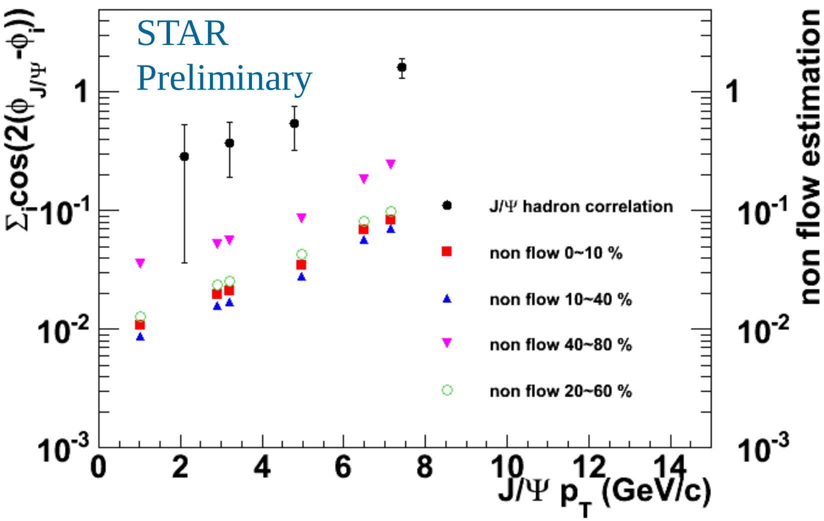
Non-flow Estimation

Near side:
Decay like
B-> J/ψ +X

Away side: Jet,
will be greatly
modified by the
medium in Au+Au
collisions



J/ψ-hadron azimuthal correlation
in pp 200 GeV collisions
J/ψ p_T: 6~10 GeV/c
Hadron p_T: 0.15~2 GeV/c

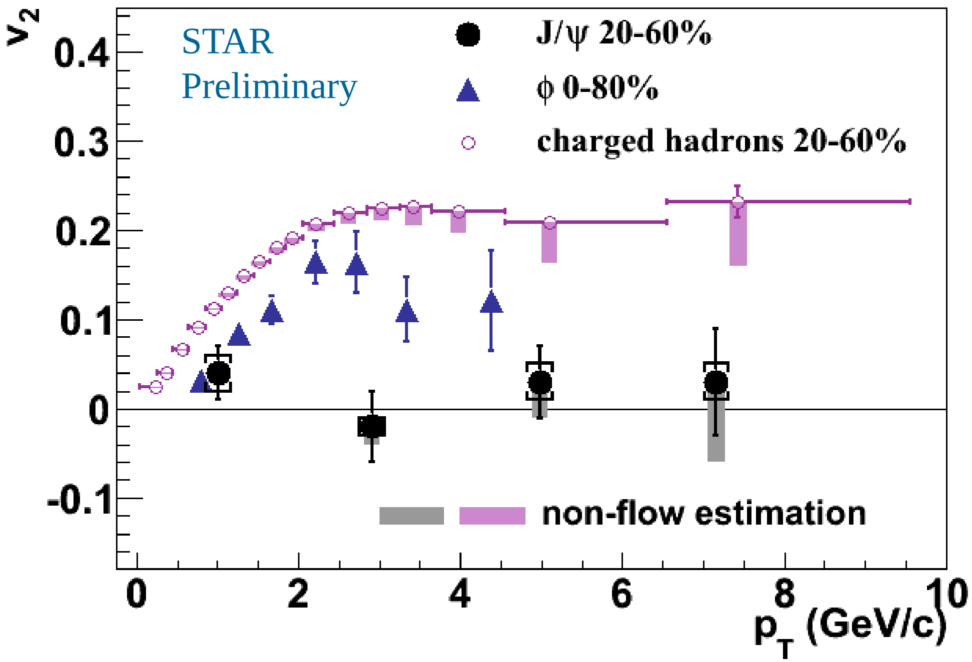


$<\Sigma_i \cos 2(\varphi_{pT}-\varphi_i)> = M v_2(p_T) v_2 + \{\text{non-flow}\}$

Phys. Rev. Lett. 93, 252301 (2004)

Assuming J/ψ-hadron correlation in pp survive intactly in AuAu,
non-flow effect on calculated J/ψ v_2 = $<\Sigma_i \cos 2(\varphi_{pT}-\varphi_i)>_{pp}/Mv_2$.
A very conservative estimation
Further study by looking at J/ψ-hadron correlation in AuAu

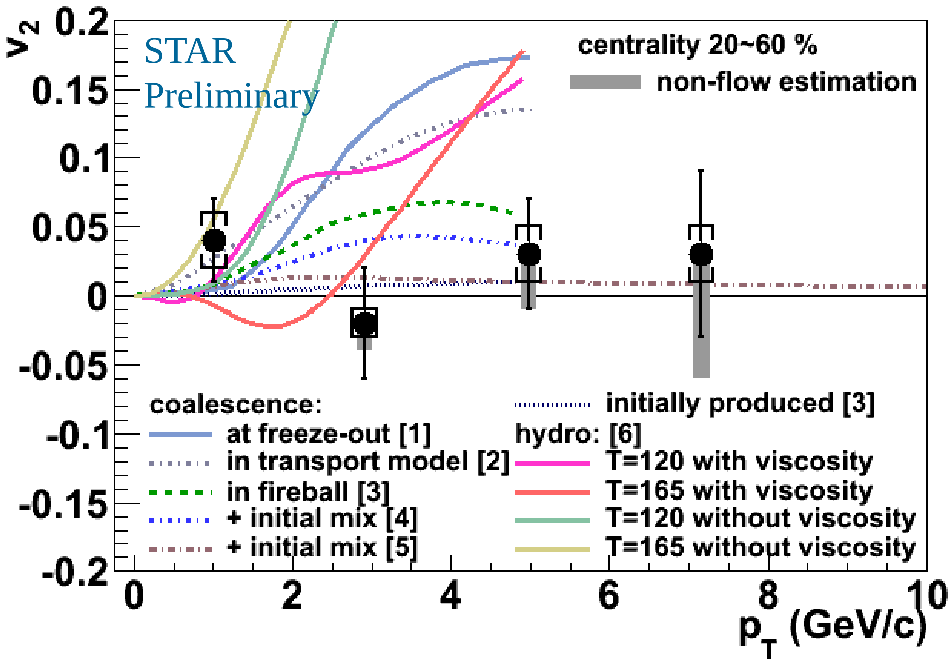
Results



Phys. Rev. Lett. 99 (2007) 112301
Phys. Rev. Lett. 93, 252301 (2004)

- Unlike charged hadrons and φ, J/ψ v_2 at higher p_T is found consistent with zero considering errors of the measurement.

Results



- [1] V. Greco, C.M. Ko, R. Rapp, PLB 595, 202. (minbias)
- [2] L. Ravagli, R. Rapp, PLB 655, 126. (minbias)
- [3] L. Yan, P. Zhuang, N. Xu, PRL 97, 232301. (b=7.8 fm)
- [4] X. Zhao, R. Rapp, 24th WWND, 2008. (20~40 %)
- [5] Y. Liu, N. Xu, P. Zhuang, Nucl. Phy. A, 834, 317. (b=7.8 fm)
- [6] U. Heinz, C. Shen, priviate communication. (20~60 %)

- Considering errors, J/ψ v_2 at higher p_T is found consistent with zero, which disfavors the case that J/ψ is produced dominantly by coalescence of thermalized charm quarks at higher p_T.

Summary and Outlook

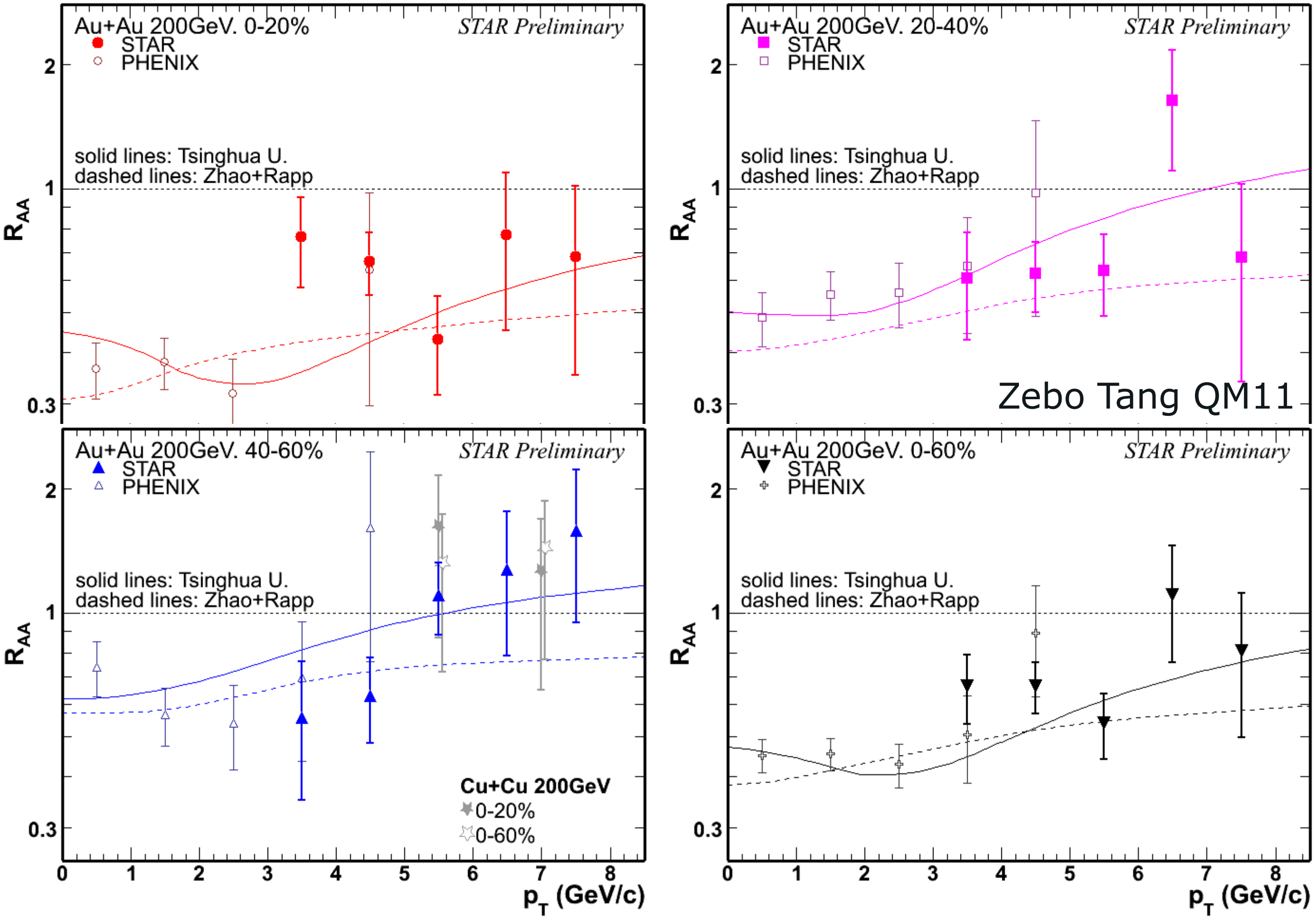
- Considering errors, J/ψ v_2 measured by STAR is found to be consistent with zero, which disfavors the case that J/ψ is produced dominantly by coalescence of thermalized charm quarks at higher p_T region.

- Finalize systematic uncertainty evaluation.
- J/ψ-hadron correlation in AuAu to help understand the non-flow effect..
- More statistics in Au+Au 200 GeV collisions are expected from data taken in 2011. This measurement can be also extended to different collision energies and collision species like U+U.

Thank you!

☺

R_{AA}


Au+Au 200GeV. 0-20%
STAR
PHENIX
STAR Preliminary
solid lines: Tsinghua U.
dashed lines: Zhao+Rapp
Au+Au 200GeV. 20-40%
Zebo Tang QM11
Au+Au 200GeV. 40-60%
Cu+Cu 200GeV
0-20%
0-60%
Au+Au 200GeV. 0-60%
R_AA
p_T (GeV/c)

Standard Cuts

- Event cut:
  - abs(vertexZ) < 30. cm
  - vertexR > 0.
  - refMult >= 0
- Track quality cuts:
  - nHitsFit > 20
  - nHitsDedx > 15
  - nHitsFit / nHitsPossible > 0.52
  - Global DCA < 1. cm
- Electron identification cuts:

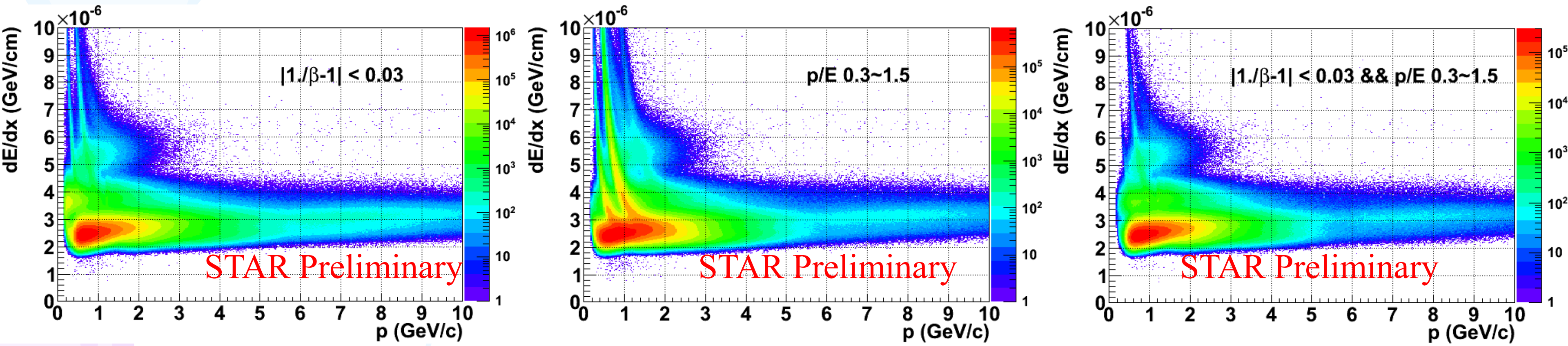
  (abs(1./beta-1.)<0.03 && p>1.2 GeV && nSigmaDedx: -0.3~3.)

  || (bemc energy>0.5 GeV && p/E: 0.3~1.5 && p>1.5 GeV && nSigmaDedx: -0.6~3.)

  || (abs(1./beta-1.)<0.03 && bemc energy>0.5 GeV && p/E: 0.3~1.5 && p>1.2 GeV && nSigmaDedx: -1.~3.)
- Daughter momentum cuts:
  - P1>1.4 GeV
  - P2>1.2 GeV

Tighter Cuts

- Electron identification cuts:
  (abs(1./beta-1.)<0.03 && p>1.2 GeV && nSigmaDedx: -0.~3.)
  || (bemc energy>0.5 GeV && p/E: 0.3~1.5 && p>1.5 GeV && nSigmaDedx: -0.5~3.)
  || (abs(1./beta-1.)<0.03 && bemc energy>0.5 GeV && p/E: 0.3~1.5 && p>1.2 GeV && nSigmaDedx: -0.8~3.)

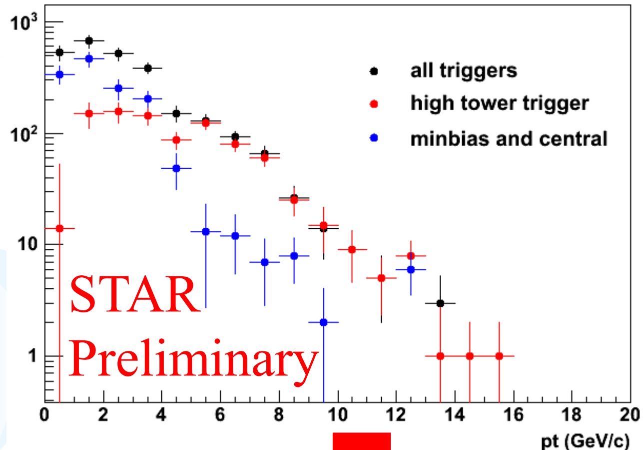


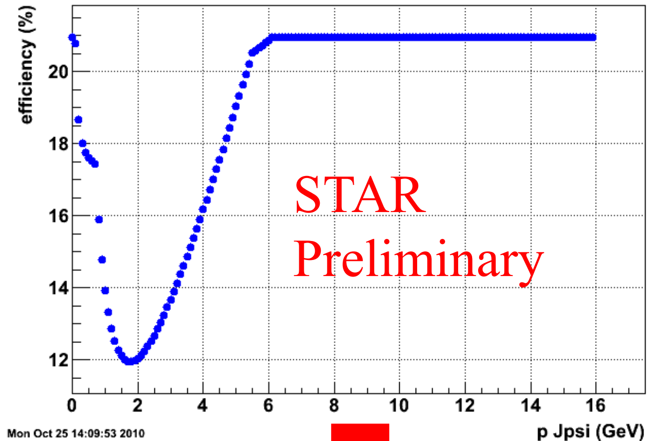
Systematic Errors

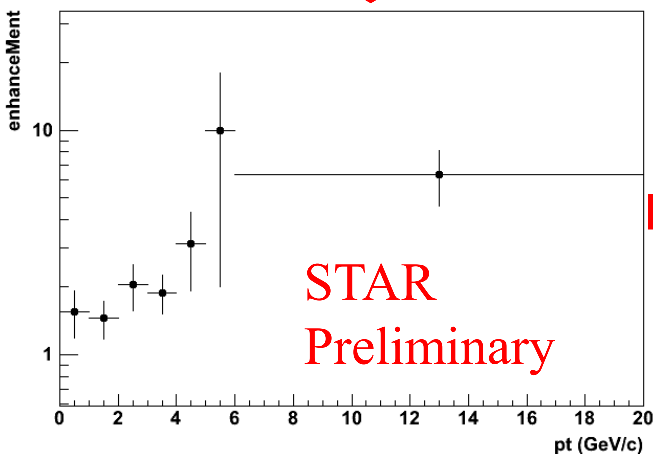
- Different methods, Different cuts
- Non-flow

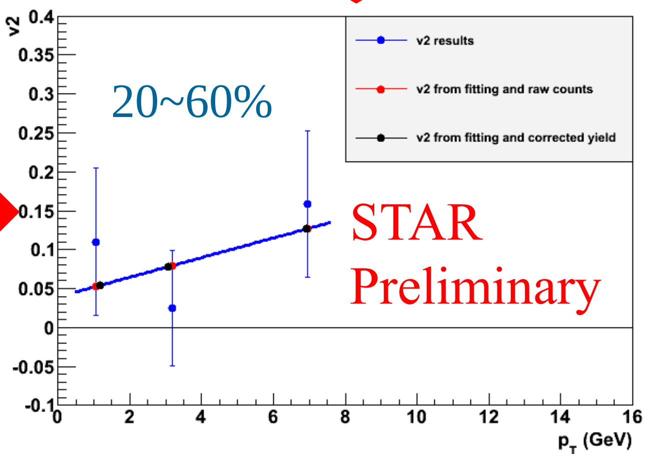
- Items that are neglected (back-up slides)
  - v_2 vs. Pt + efficiency and trigger effects vs. Pt
  - v_2 vs. centrality + trigger effects vs. centrality
  - v_2 vs. rapidity + efficiency vs. rapidity

v_2 vs. Pt + Efficiency and Trigger Effects vs. Pt Neglected

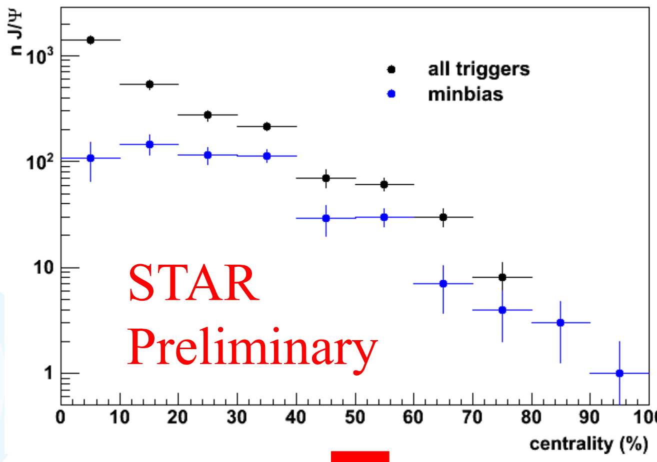


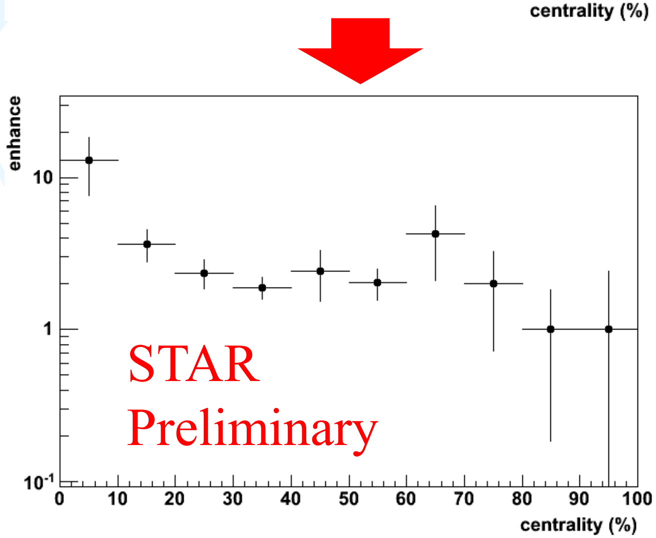


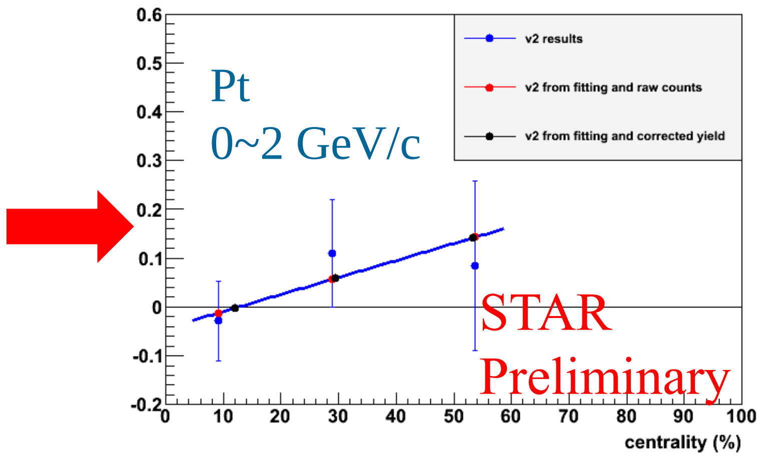




v_2 vs. Centrality + Trigger Effects vs. Centrality Neglected

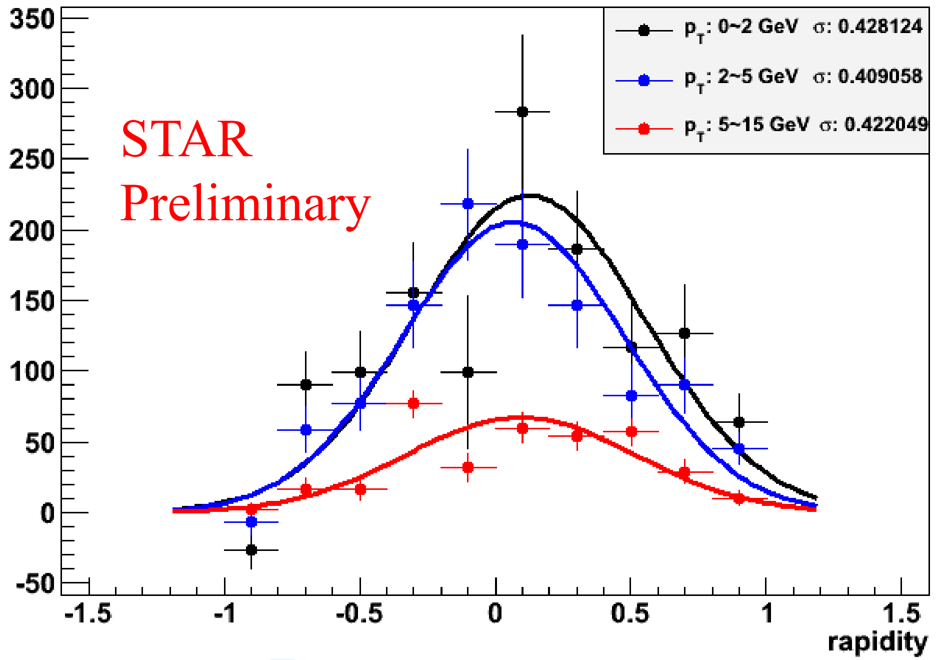






- Efficiency vs. centrality effect is even smaller

v_2 vs. Rapidity + Efficiency vs. Rapidity Neglected



- The rapidity distribution is mainly caused by daughter eta acceptance.
- Assume v_2 is independent of rapidity within the range of [-1,1].