Reaction Plane Dependence of Neutral Pion Production in Center-of-Mass Energy of 200 GeV Au+Au Collisions at RHIC-PHENIX

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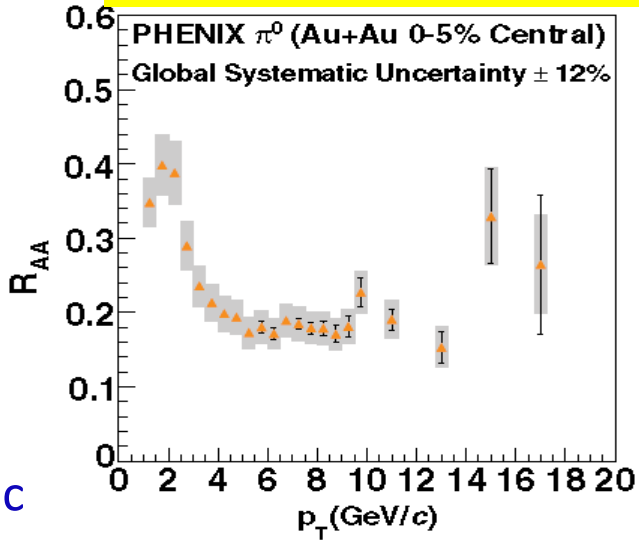
Physics Motivation

- **Jet Quenching**
  - Suppression of π^0 yields in central collision
  - *Energy loss* due to gluon radiation in the medium

Nuclear Modification Factor

$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_T d\eta}{T_{AA} d^2\sigma^{NN}/dp_T d\eta}$$



PRC **77**, 064907 (2008)

- **Parton Energy Loss vs. Path length (L)**

Collisional Process	$E_{loss} \propto L$
Radiative Process	$E_{loss} \propto L^2$

If medium has static density,

GLV method

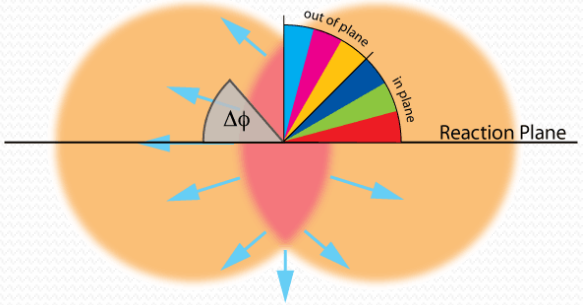
$$\Delta E = \frac{9\pi C_R \alpha_s^3}{4} \int_0^L d\tau \, \rho_{eff}(\tau, x(\tau)) \, \tau \ln\left(\frac{1}{x_c}\right), \quad x_c = \frac{\mu^2 L}{2E}$$

- Approach to path length dependence of R_{AA}

Measurement of R_{AA} for each azimuthal angle

Measurement of $R_{AA}(p_T, L)$

- **Relation between Path length (L) and azimuthal angle ($\Delta\phi$)**



$R_{AA}(p_T, L) \leftrightarrow R_{AA}(p_T, \text{centrality}, \Delta\phi)$

- **Extraction of $R_{AA}(p_T,\Delta\phi)$**

$$R_{AA}(p_T,\Delta\phi) \cong R_{AA}(p_T) \times \frac{N(p_T,\Delta\phi_i)}{\sum_{\phi_i} N(p_T,\Delta\phi_i)}$$

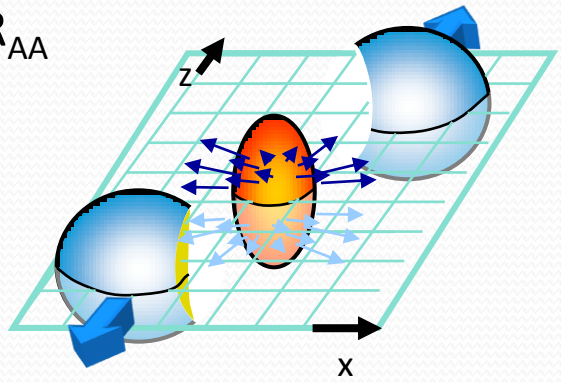
$$N(p_T,\Delta\phi_i) \cong N(1+2v_2\cos(2\Delta\phi_i))$$

- **Anisotropy v_2 at high p_T**

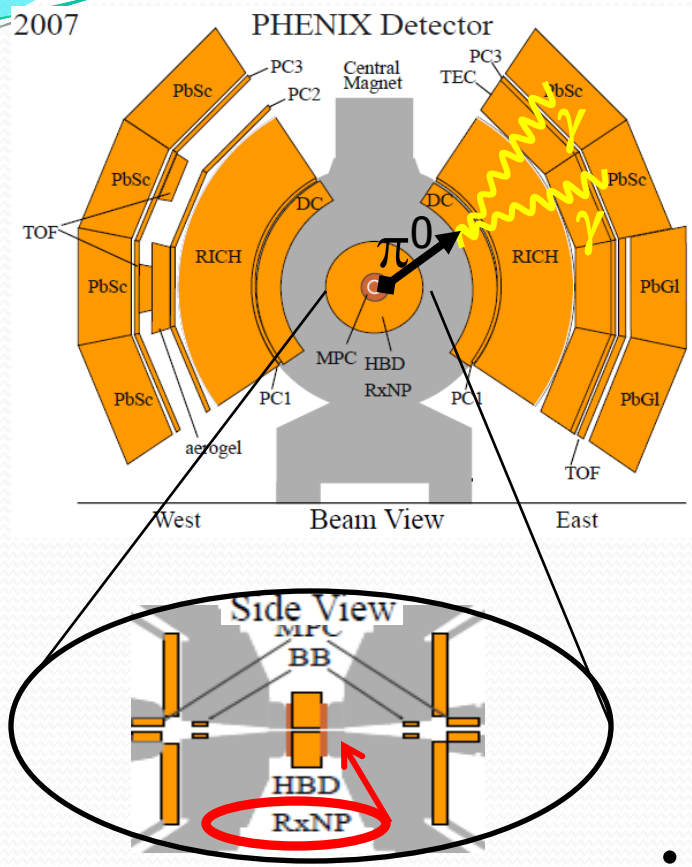
Spatial anisotropy in non-central collisions influence R_{AA} for each azimuthal angle

$$\frac{dN}{d(\phi-\Psi)} = N[1+\Sigma 2v_n\cos(n(\phi-\Psi))]$$

ϕ : Azimuthal angle of emitted particles
Ψ : Azimuthal angle from reaction plane



Measurement of $R_{AA}(\pi^0, \Delta\phi)$ in PHENIX



EMCal (PbSc and PbGl)

- π^0 ($\rightarrow 2\gamma$) measurement

Beam Beam Counter (BBC)

- Trigger and determination of centralities
- Determination of reaction plane (until 2006)

  $3.0 < |\eta| < 3.9$

Reaction plane Detector (RxNP)

- Determination of reaction plane (from 2007)

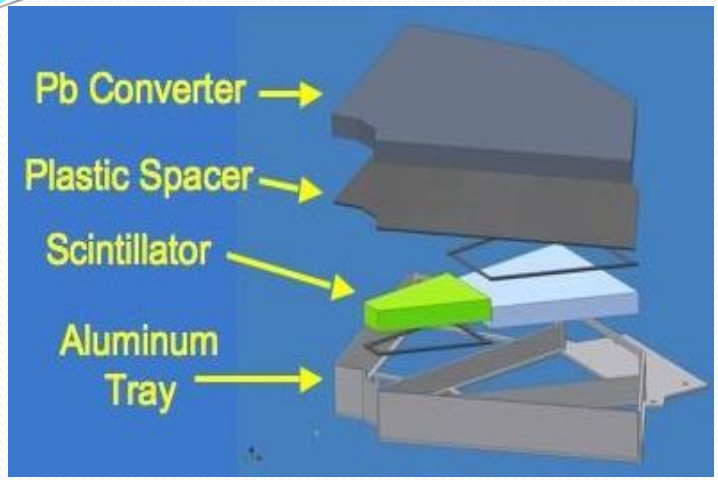
  $1.0 < |\eta| < 1.5$ && $1.5 < |\eta| < 2.8$

Advantage for Run7 (2007)

- **Higher Statistics than that in Run4 (2004)**

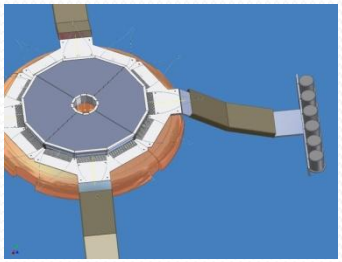
  4 times higher → ½ of statistical error (Run4)
- **Improve the determination of reaction plane**

Structure and performance of RxNP



Beam Side View

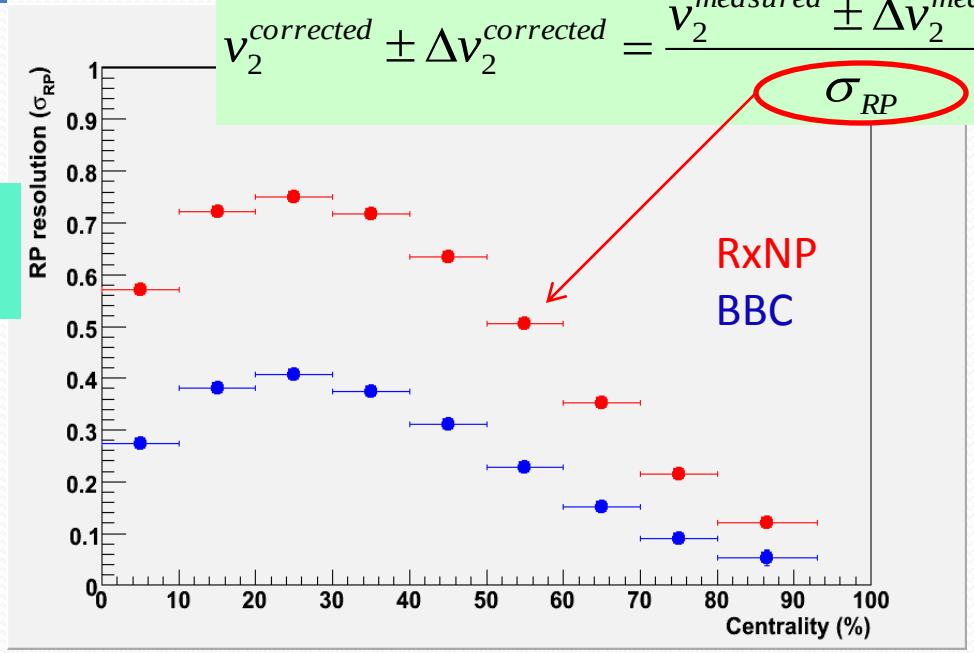
- **Each quadrant contains**
  - 1 Pb convertor
  - 3 inner & 3 outer scintillation
  - 6 fine mesh PMT's



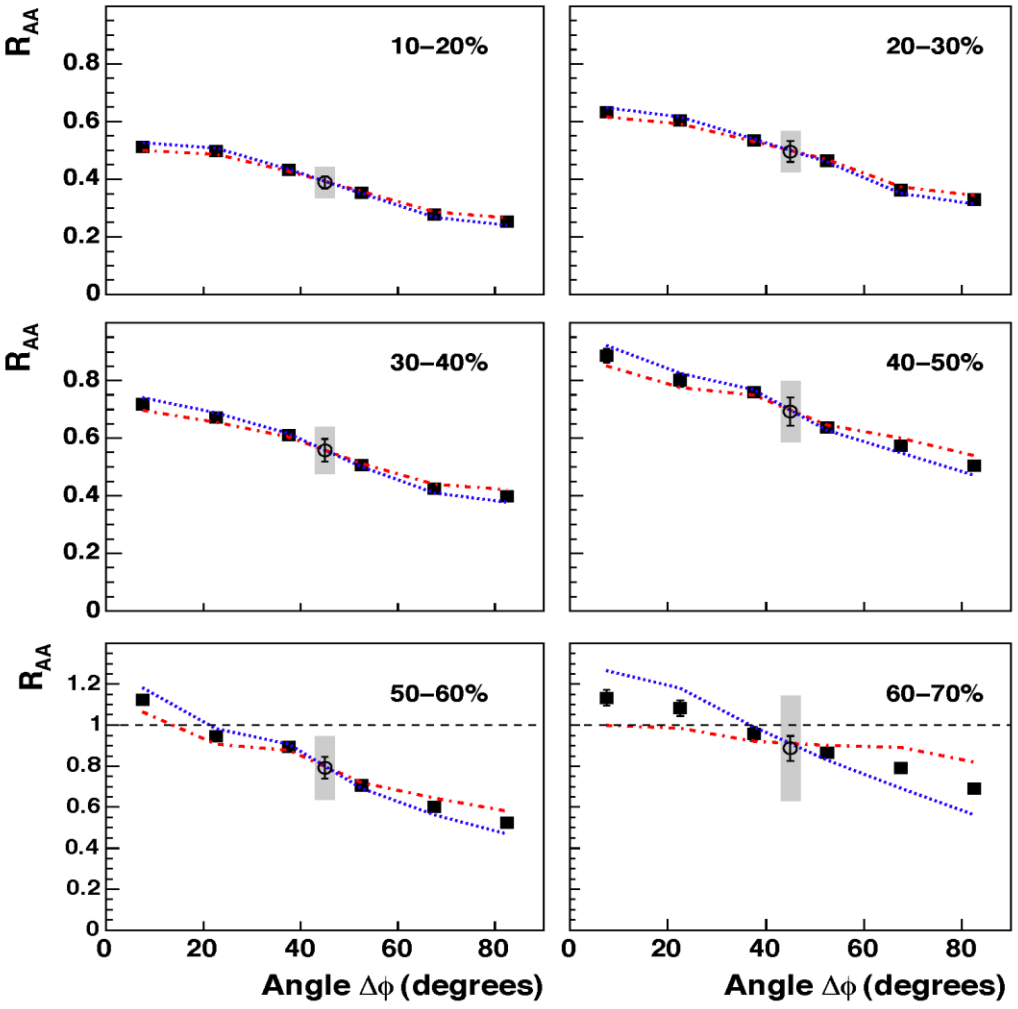
- **Determination of reaction plane**
  - Direction where many particles are emitted.

$$v_2^{corrected} \pm \Delta v_2^{corrected} = \frac{v_2^{measured} \pm \Delta v_2^{measured}}{\sigma_{RP}}$$

2 times better →
½ of statistical error of v_2(Run4)



Current results (Azimuthal angle dependence of R_{AA})



$3 < p_T < 5$ GeV/*c*

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Phys Rev C 76, 034904 (2007)

For all centrality,

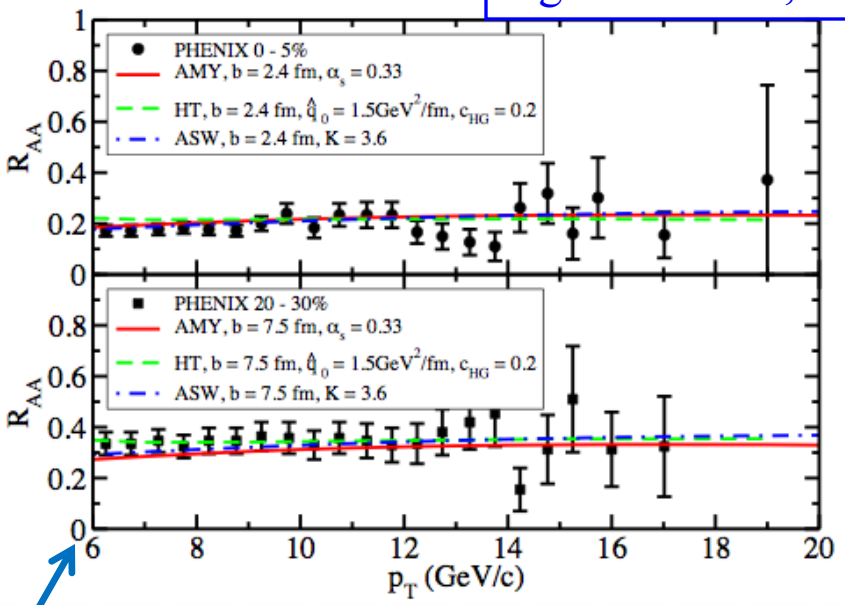
$$\frac{R_{AA}(\Delta\phi = 0)}{R_{AA}(\Delta\phi = \pi/2)} \sim 2$$

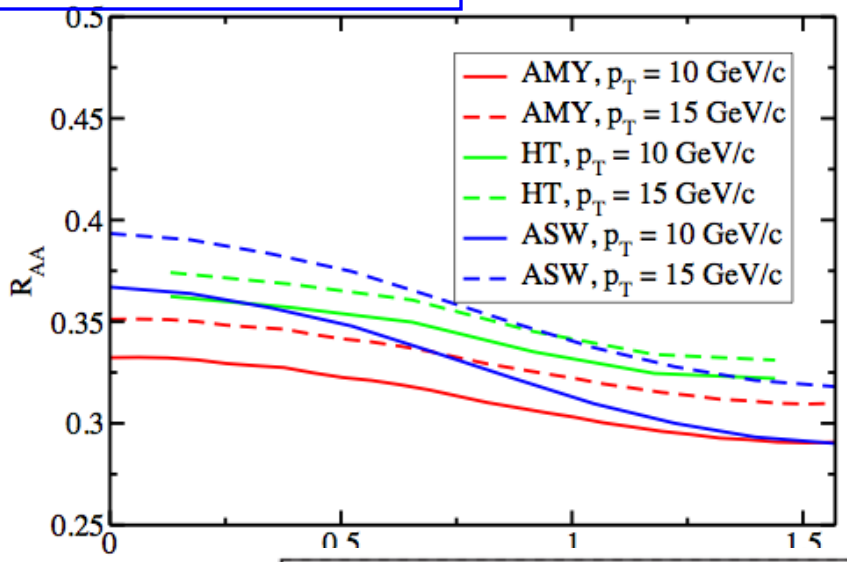
But suppressions in peripheral event should be smaller than that of most central for parton energy loss.

→ Collective flow effect?
→ v_2 at high p_T should be small !
→ Measure $R_{AA}(p_T, \Delta\phi)$ at higher pT

Theorist's approach to $R_{AA}(p_T, \Delta\phi)$

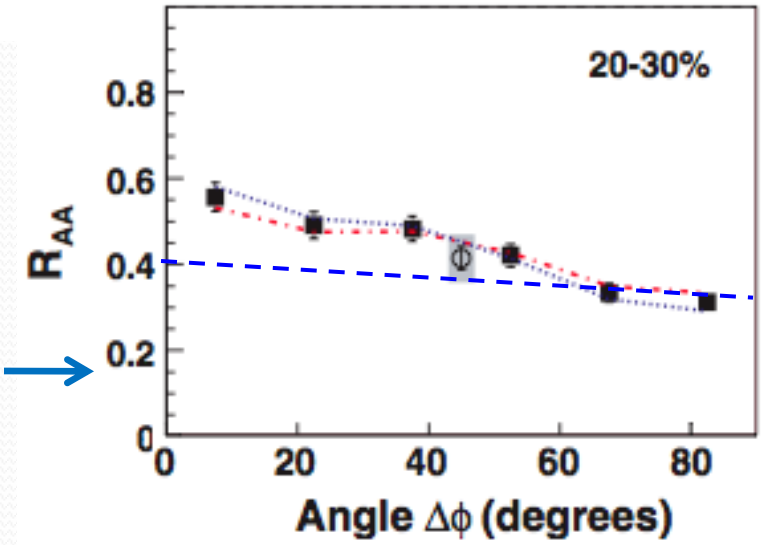
e.g. S. A. Bass, et al., arXiv:0805.3271





RAA (pT)vs. pT is **GOOD AGREEMENT !**

Even with ASW model for high-pT ,
the data can not be reproduced.



Also, other work by many of the co-authors, e.g.
PRC 76 (2007) 064907, PRL 100 (2008) 072301

Current status for theory and experiment (PHENIX)

- Theory

→ Theorists start to tackle $R_{AA}(p_T, \Delta\phi)$ sequentially.

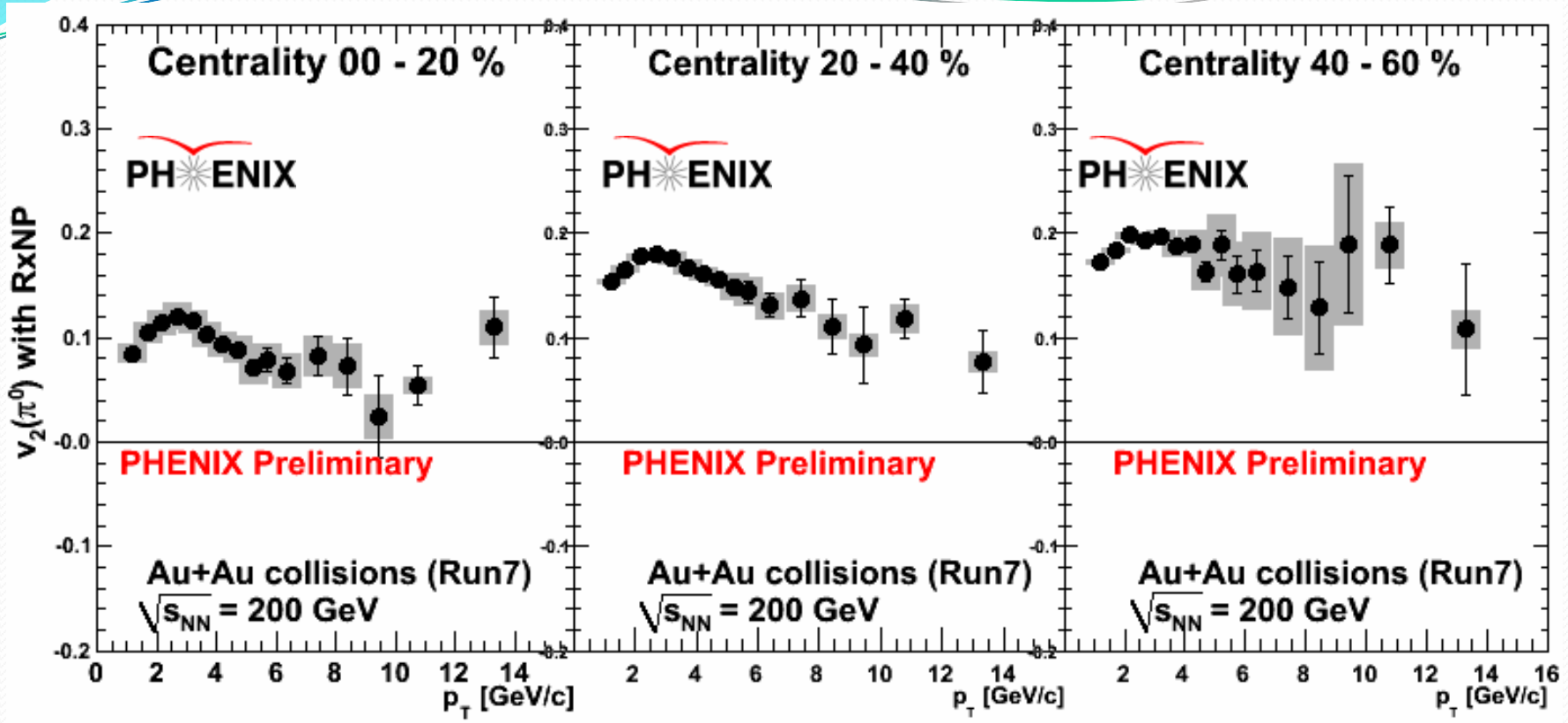
→ Challenge to the difference between the data and models

- Experiment

→ $v_2(\pi^0)$ at high pT can be measured by RxNP

→ How far does $R_{AA}(p_T, \Delta\phi)$ at high pT extend ?

Anisotropy $v_2(\pi^0)$ with RxNP

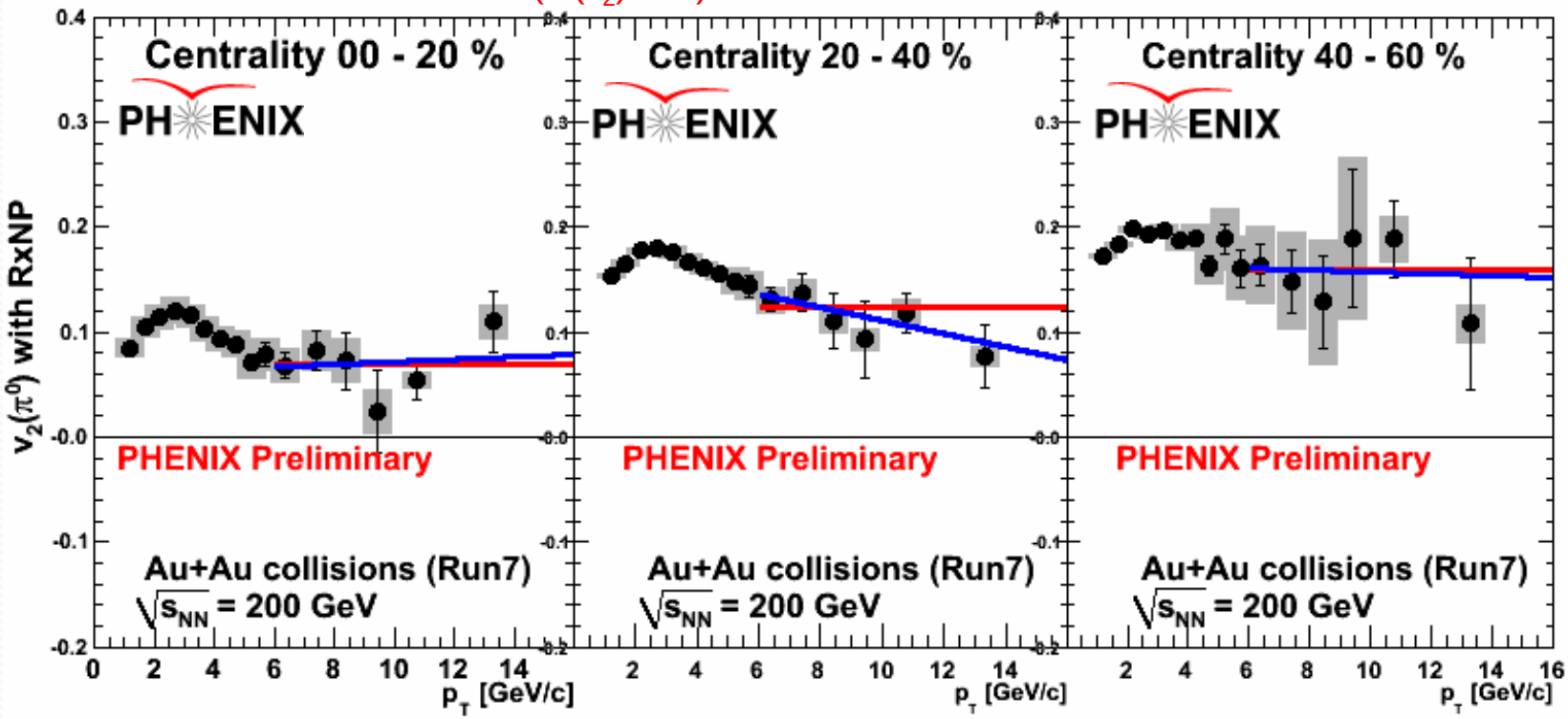


$v_2(\pi^0)$ at pT > 10 GeV/c is analyze with all the data.
$v_2(\pi^0)$ at pT < 10 GeV/c is analyzed with a part of all the data.

$v_2(\pi^0)$ for all centralities up to high p_T has **NON-ZERO** value.

Linear and constant function fitting

Blue : Liner function (f (v_2) = ax + b)
Red : Constant (f (v_2) = c)



Centrality 00 - 20 %	Centrality 20 - 40 %	Centrality 40 - 60 %
Chi2/NDF (Linear) : 4.44913/5	Chi2/NDF (Linear) : 4.38504/5	Chi2/NDF (Linear) : 2.2259/5
Chi2/NDF (Const.): 4.34353/4	Chi2/NDF (Const.) : 1.48925/4	Chi2/NDF (Const.) : 2.2095/4

- Both of Chi2/NDF for flat and linear fit are almost same. (Centrality 00-20% , 40-60%)
- Chi2/NDF for linear fit is better than flat fit. (Centrality 20-40 %)
  v_2 in most central and peripheral is trend to have a constant value.
  v_2 in mid-central is trend to decrease.

Summary and Outlook

- Measurement of **path length/azimuthal angle** dependence of R_{AA} has been started.
- R_{AA} for p_T~3-5 GeV/*c* as a function of azimuthal angle has been started to compare with models.
- Measurement of $v_2(\pi^0)$ can be **extend to p_T~14GeV/*c*.**
  $v_2(\pi^0)$ in most central and peripheral is trend to be flat than monotonic decrease.
  $v_2(\pi^0)$ in mid-central is trend to monotonic decrease than flat.

- Angular and path length dependence of R_{AA} using RxNP
  Ongoing

Backups

$R_{AA}(p_T, \Delta\phi)$ vs. $\Delta\phi$ ($5<p_T<8$ GeV/c)

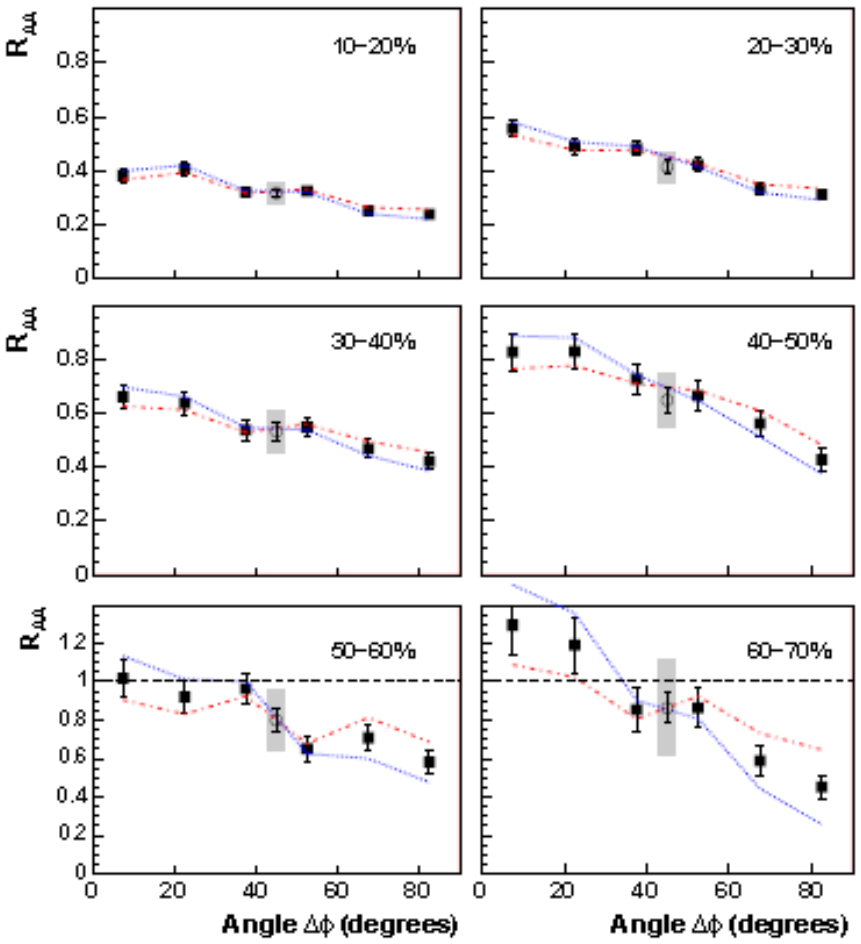


FIG. 13: (color online) R_{AA} vs. $\Delta\phi$ for π^0 yields integrated over $5 < p_T < 8$ GeV/c. The error lines and band are the same as in Fig. 12.

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