Elliptic Flow of Φ Mesons at RHIC energy

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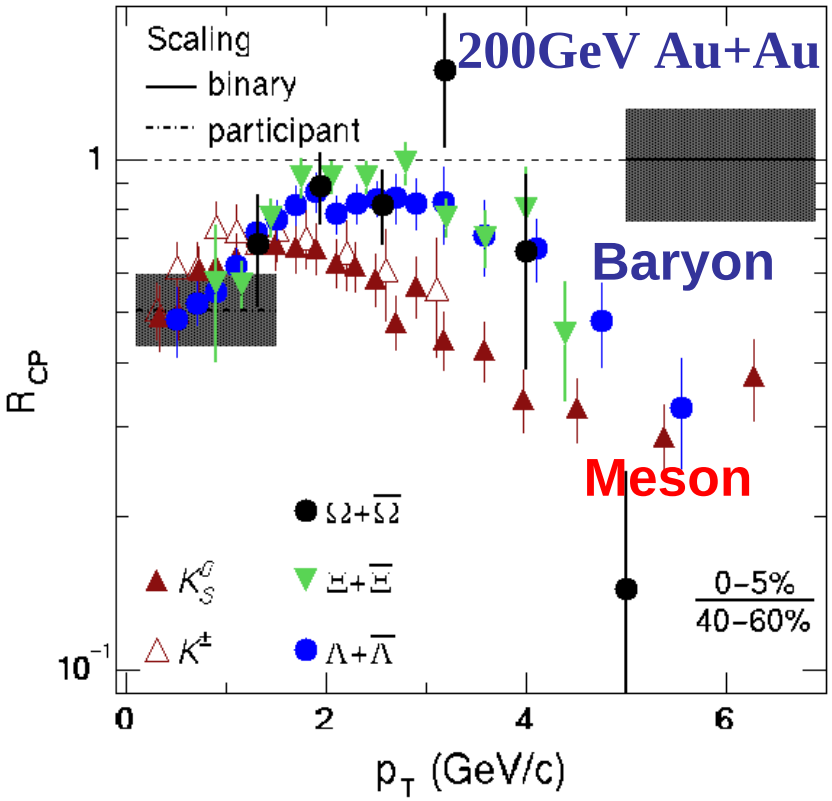
Outline

- Motivations
- R_{CP}: particle type or particle mass dependence
- Elliptic Flow of Φ Mesons in AuAu 200GeV collision
- AMPT Simulation
- Summary

Particle-type dependence of R_{CP} & v_2

*PHENIX: PRL**91**, 182301(03)*
*STAR: PRL**92**, 052302(04) nucl-ex/0306007*
*Models: Greco et al, PR**C68**, 034904(03)*



1) R_{CP} suppression of AuAu collisions at intermediate P_T.
2) Particle type dependence of R_{CP} from Au+Au collisions has been observed.
3) The particle type dependence of the R_{CP} at intermediate p_T in AuAu collisions can be explained by Recombination/Coalescence model.

R.C.Hwa et al. University of Oregon
C.M.Ko et al. Texas A&M
R. J. Fries et al. Duke/Minnesota
QB Xie et al., Univ. of ShanDong ……

$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_T dy}{\sigma_{in}^{pp} T_{AA}(b) * d^2N^{pp}/dp_T dy}$$

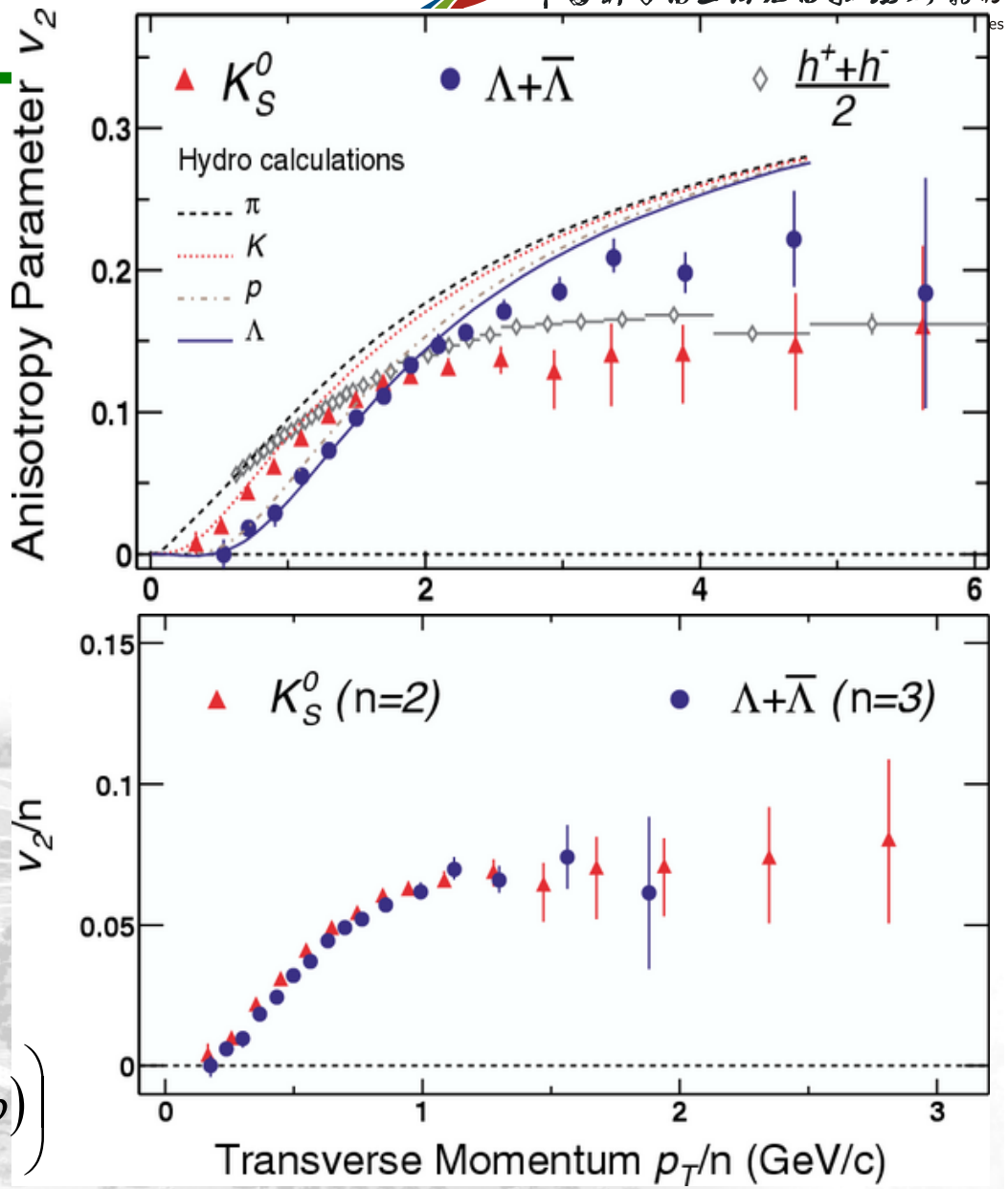
$$R_{CP}(p_T) = \frac{N_{coll}^{peripheral}}{N_{coll}^{central}} \frac{dN^2_{central}/dp_T dy}{dN^2_{peripheral}/dp_T dy}$$

Saturation at intermediate p_T

Baryon and meson difference -- Constituent Quark Number Scaling

Hydrodynamic model can describe data well at low p_T while the intermediate p_T range may be described by ReC/Coalescence model

$$E\frac{d^3N}{dp^3} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1+\sum_{n=1}^{\infty} 2v_n \cos(n\varphi)\right)$$



How about ϕ Meson?

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- Phi production can be a good probe
  - OZI rule suppression
  - small cross section for scattering with nonstrange hadrons
    - Information from earlier time?
    - Sensitive to early flow?
- Production mechanism:
  - ggg -> ϕ
  - s sbar -> ϕ
  - K^+K^- -> ϕ
- May determine whether the particle dependence of the nuclear modification factor is dividing by the particle mass or particle type

  m_ϕ~1019 MeV/c^2 ; m_Λ~1116 MeV/c^2; m_{Ks}~498 MeV/c^2

- m ~ 1019 MeV/c^2 , Γ ~ 4.45 MeV/c^2, $c\tau$ ~ 41 fm
- Vector meson
- quark content : s, sbar
- Studied decay channel: $\phi \Rightarrow K^+ K^-$ (49.2%)

R_{CP} of ϕ

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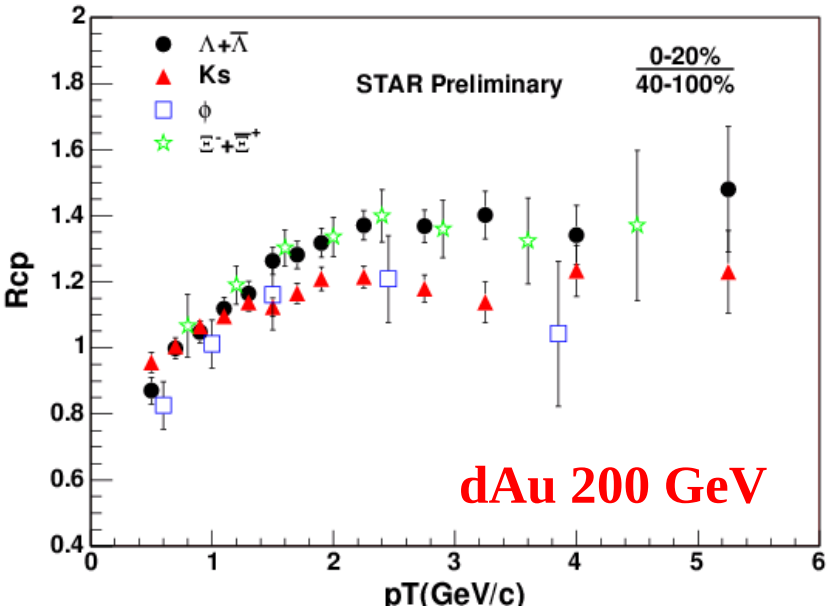
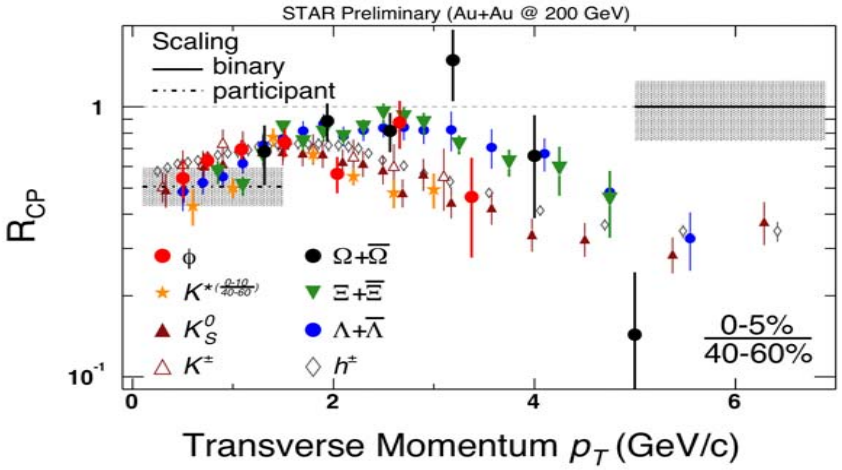
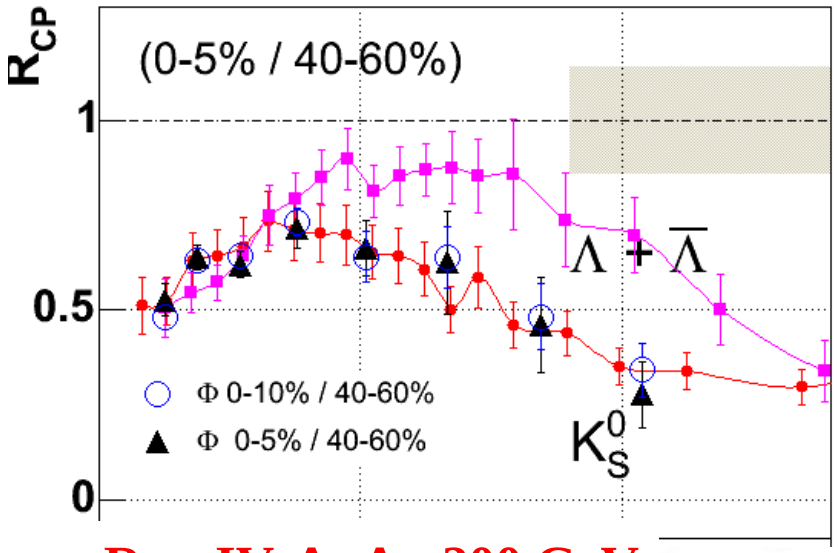


AuAu 200 GeV Run II





- **Mesons (Ks, K±, φ) have the similar R_{CP} for dAu & AuAu collisions at intermediate pT**
- **Baryons (Λ, Ξ) have the similar R_{CP} too, but higher than mesons.**

Particle production at intermediate p_T region is divided by the particle's types, not the masses

STAR: φ behaves like mesons, despite of its large mass

FAVOR: Recombination/Coalescence model

Run IV:AuAu 200 GeV

Φ V_2(use reaction plane method)

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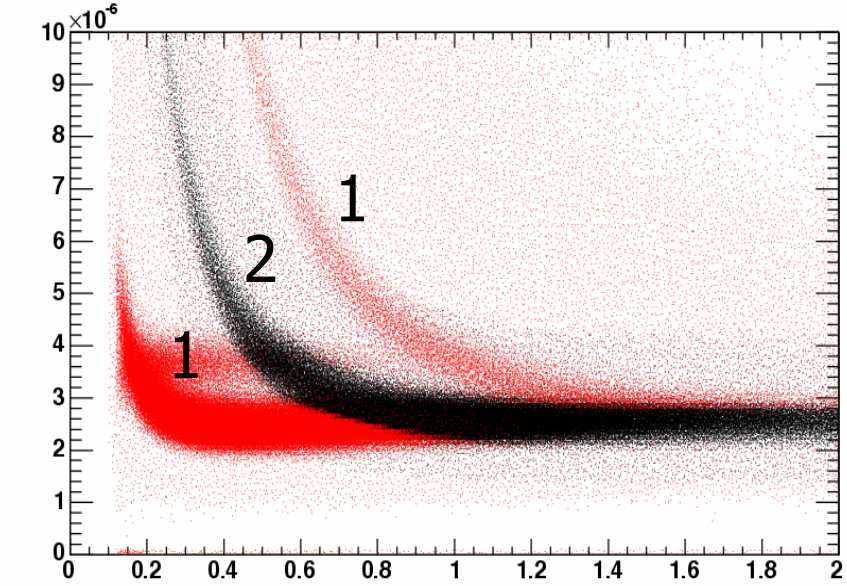

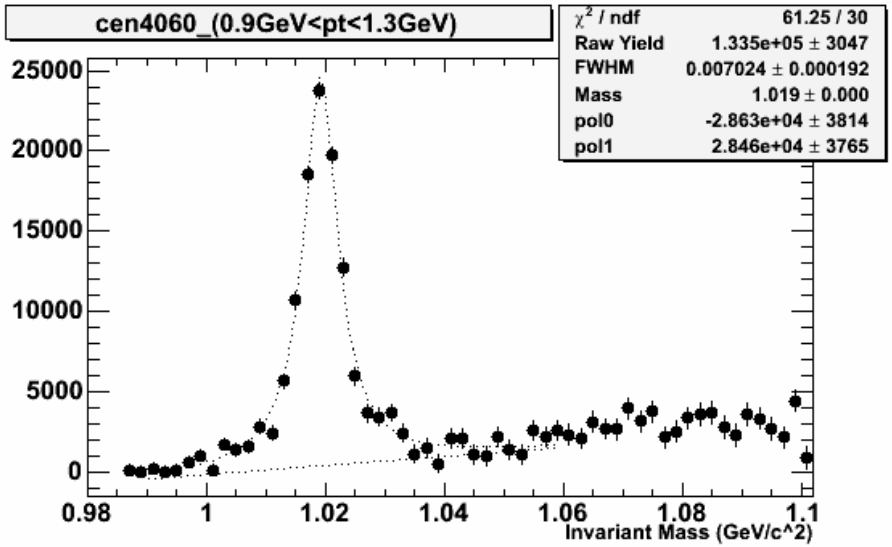

- Run IV AuAu200 (FullField+ReversedFullField)
- ~14M minibias events
- main cuts in the analysis:

| η |<1.0

NHits>15, NHits/NHitsPoss>0.52

|NSigmaKaon|<2.

DipAngle>0.04

|ReactionPlanecut|<Π/20 (event mixing)

|vertextZ|<30

ReactionPlane tracks: |NsigmaKaon|>2.0

Event-mixing techniques

Analysis details

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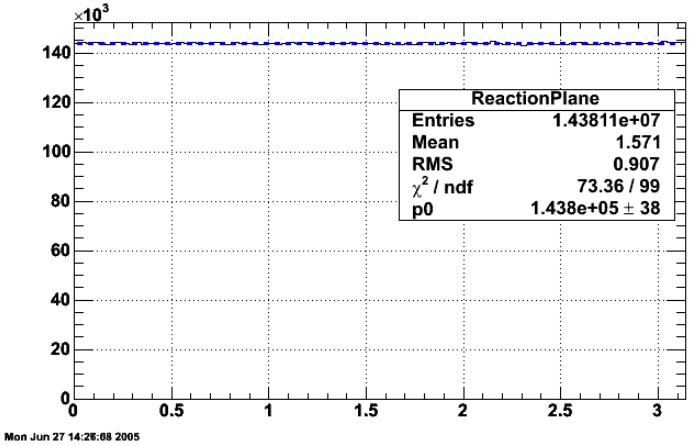
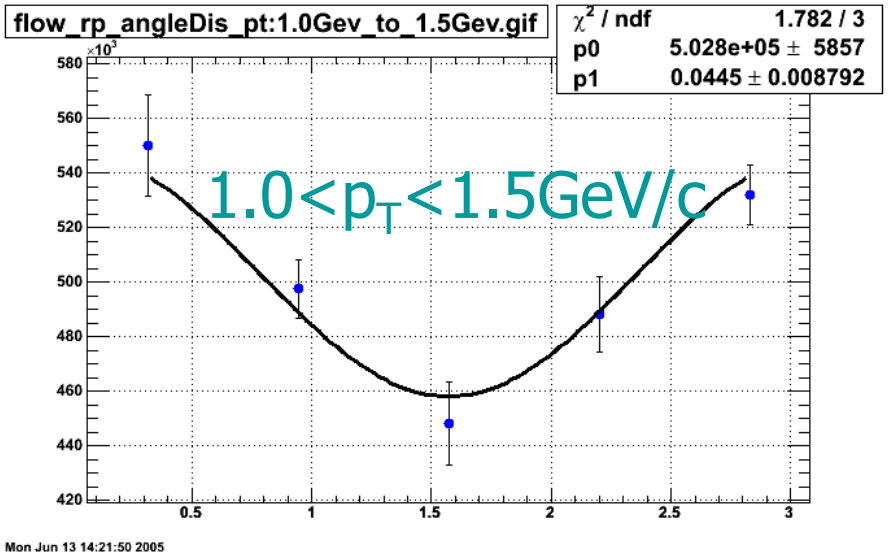
1.reaction-plane (Ψ)

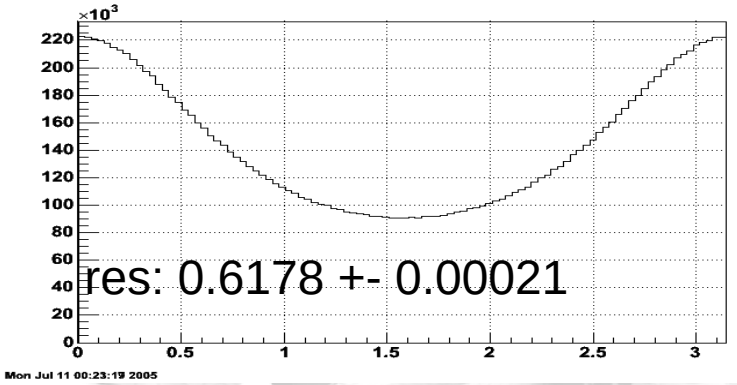
$$\psi_2 = (\tan^{-1} \frac{\sum_i \omega_i \sin(2\phi_i)}{\sum_i \omega_i \cos(2\phi_i)}) / 2 .$$



2.Azimuth angle distribution

$a*(1+2*v_2*\cos(2(\Phi-\Psi)))$





3. reaction-plane resolution

$v_2 = v_2^{obs}/res$

Compared results on the different analysis methods

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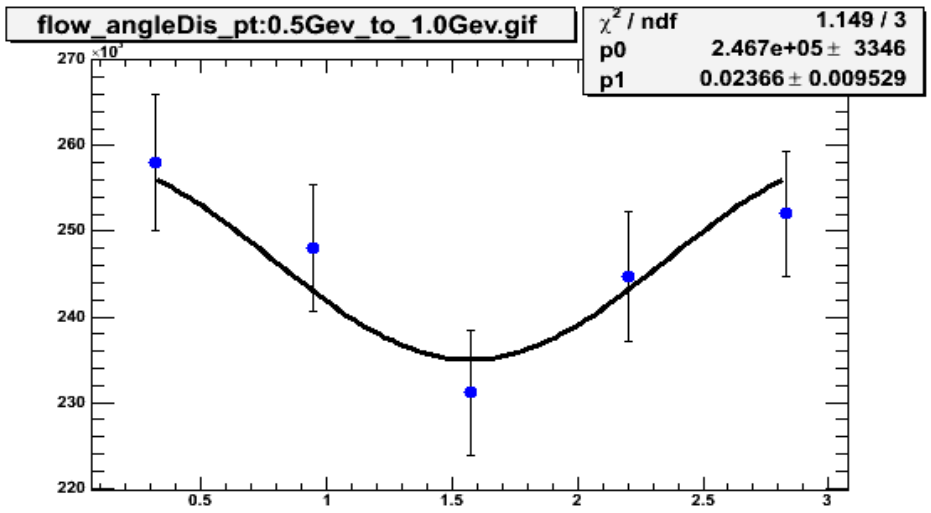

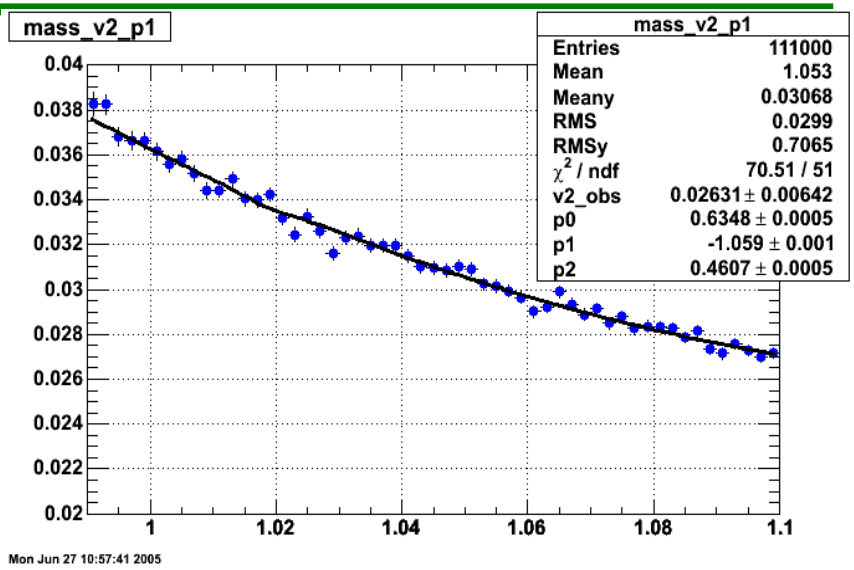

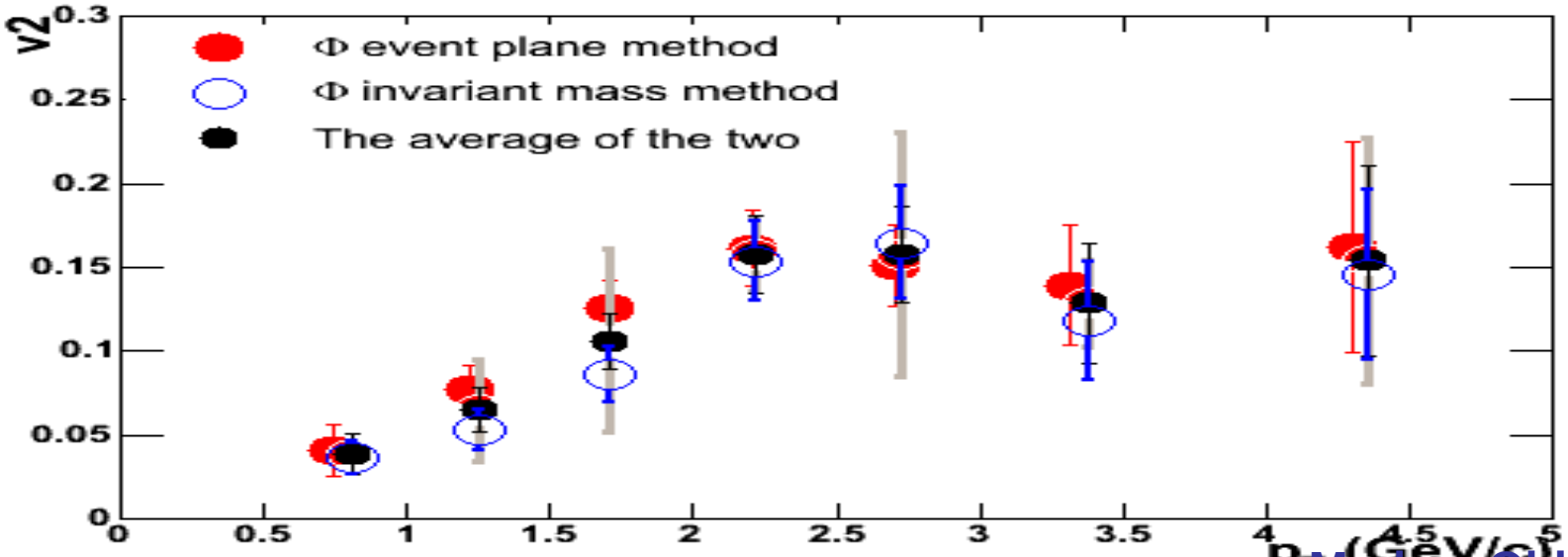

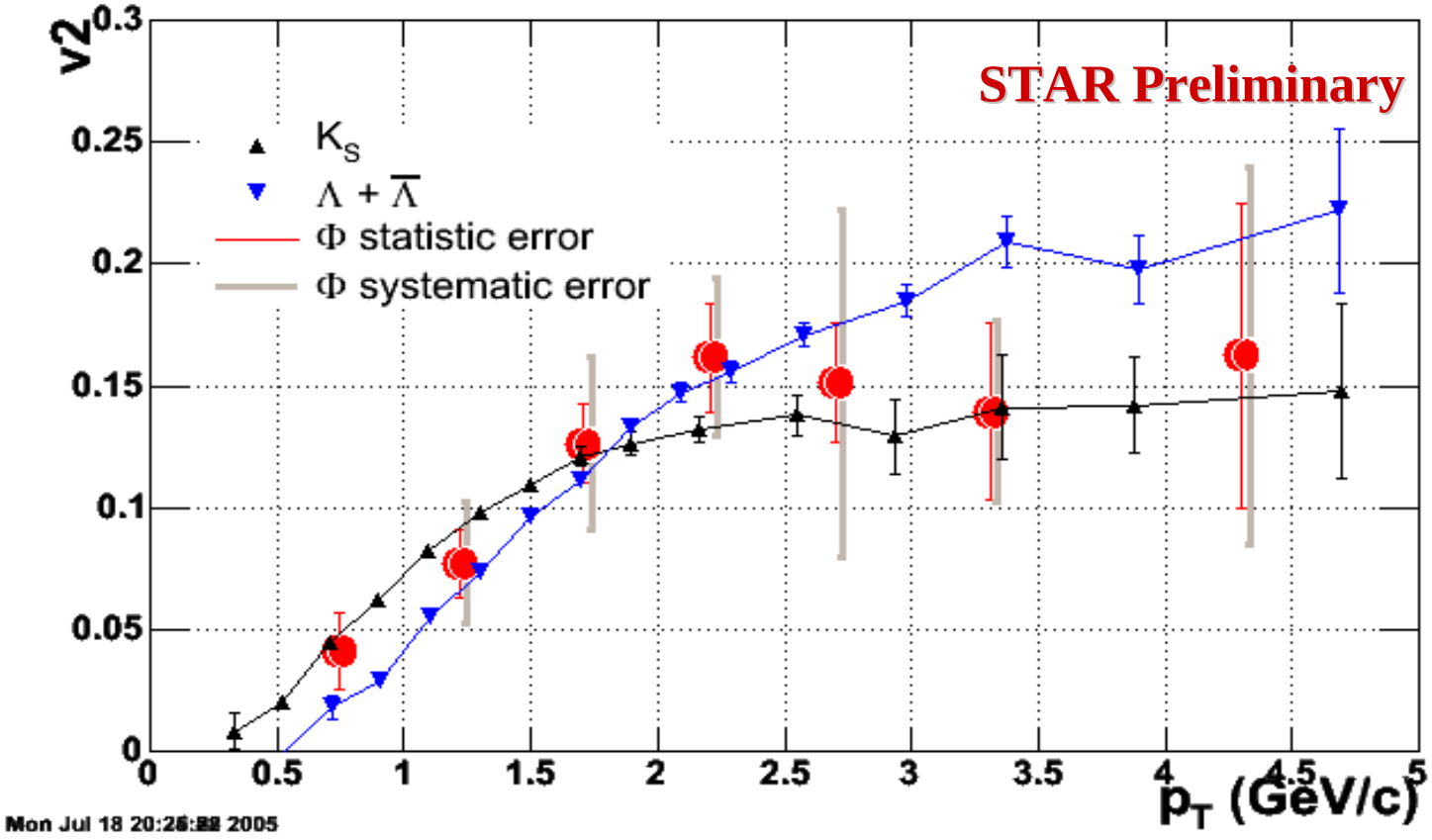

1. the elliptic flow of Φ-meson is close to Ks

2. error bars in high pt range (2.5GeV,5.0GeV) are still large

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A multiphase transport model

Default: Lin, PaL, Zhang, Li &Ko, PRC 61, 067901 (00);
64, 041901 (01); nucl-th/0411110

- Initial conditions: HIJING (soft strings and hard minijets)
- Parton evolution: ZPC
- Hadronization: Lund string model for default AMPT
  Coalescence model for string melting scenario
- Hadronic scattering: ART

String melting: PRC 65, 034904 (02); PRL 89, 152301 (02)

- Convert hadrons from string fragmentation into quarks and antiquarks
- Evolve quarks and antiquarks in ZPC
- When stop interacting, combine nearest quark and antiquark to meson, and nearest three quarks to baryon,
- Hadron flavors are determined by quarks' invariant mass

Reconstruct Φ in final state via K^+K^-

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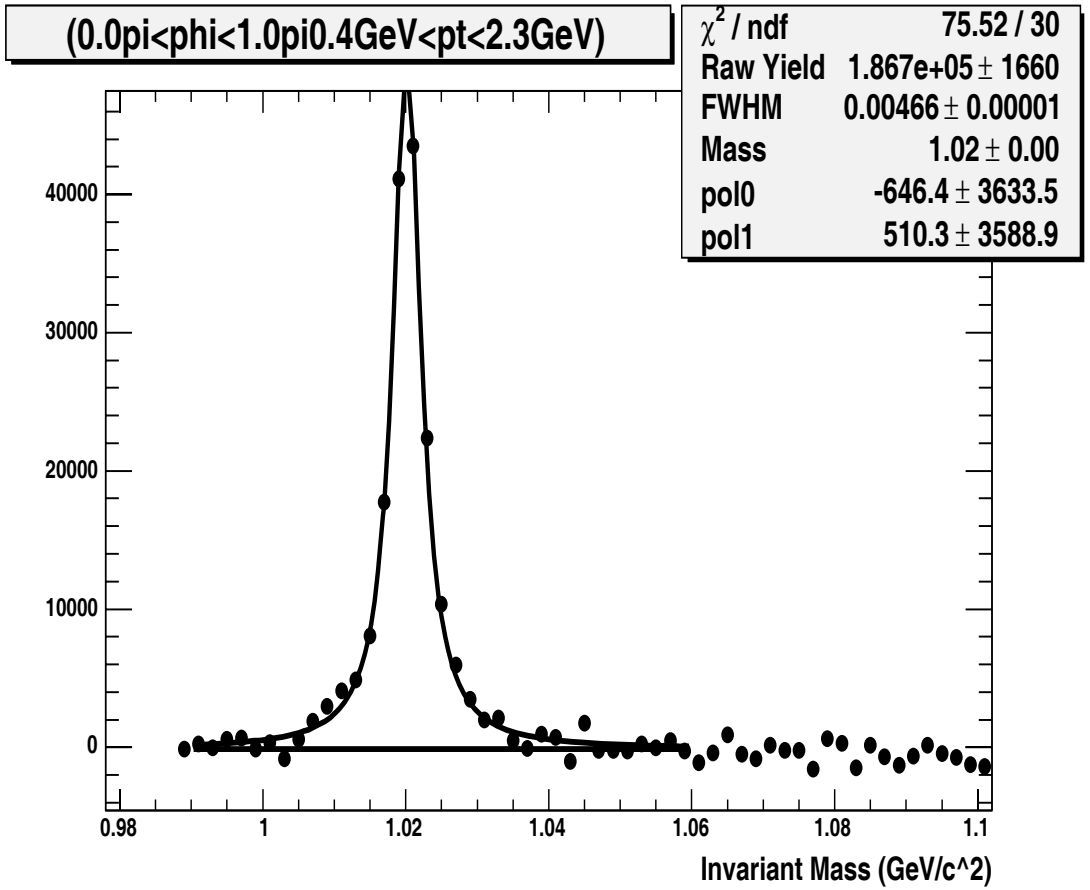
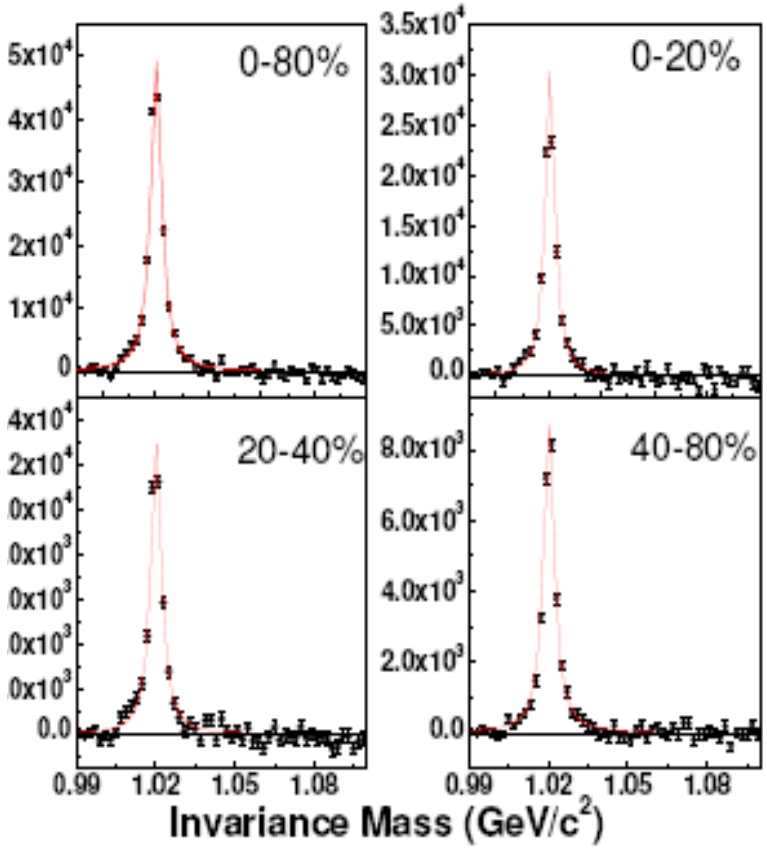
Simulation: 200GeV/c Au+Au





Azimuthal distribution with respect to True Reaction Plane or Event Plane

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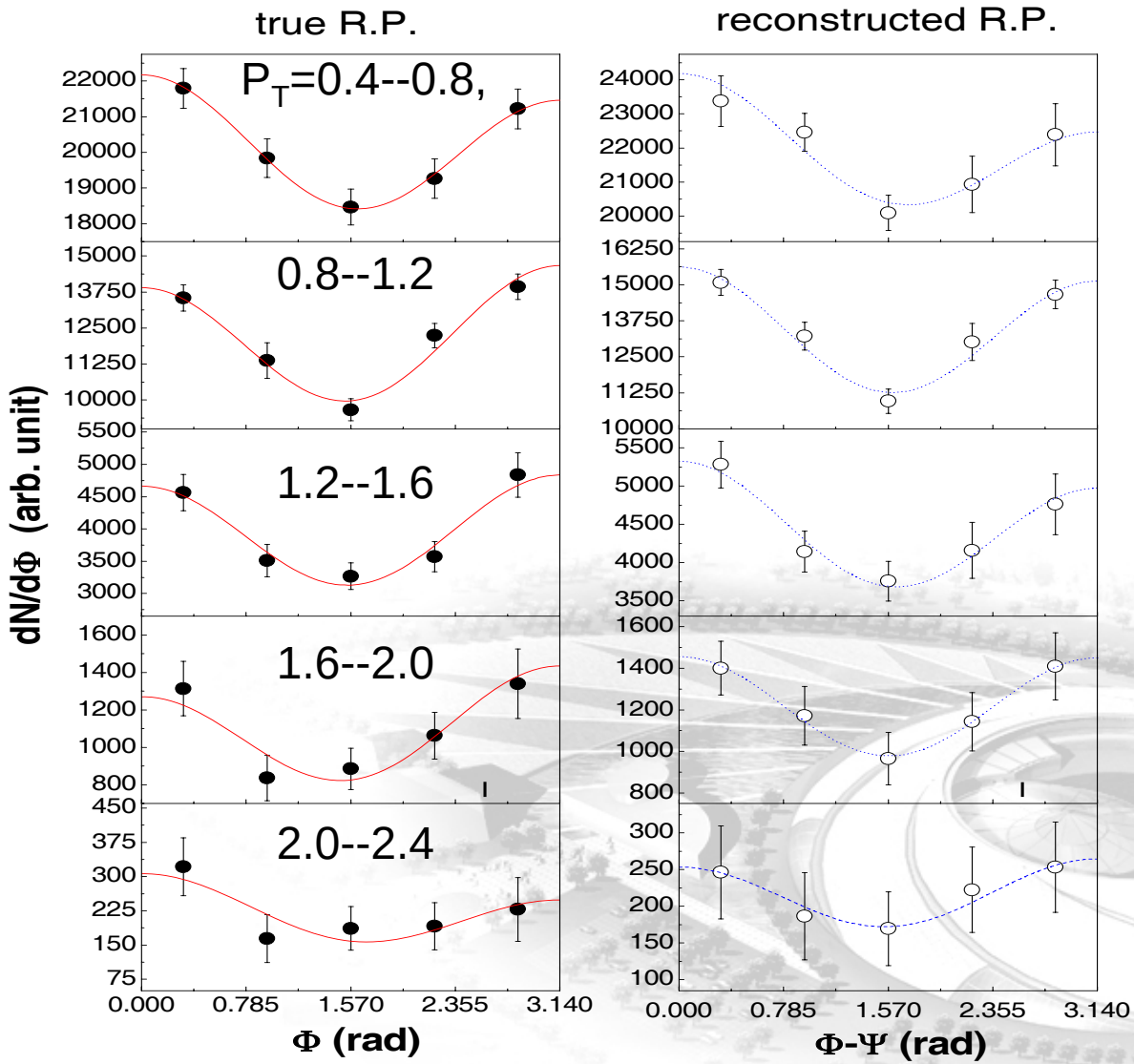
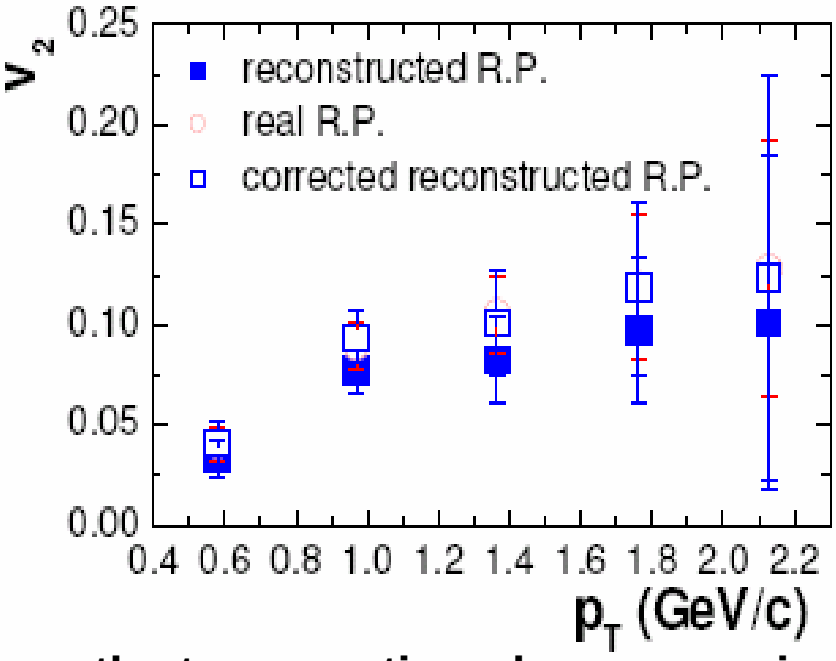


The rapidity range is chosen to be (-1,1).

V2 can be extracted from the Foruier fit

Reaction Plane vs Event Plane



$$v_n = \frac{v_n^{obs}}{\langle cos(n(\Phi_n - \Psi_R)) \rangle}.$$

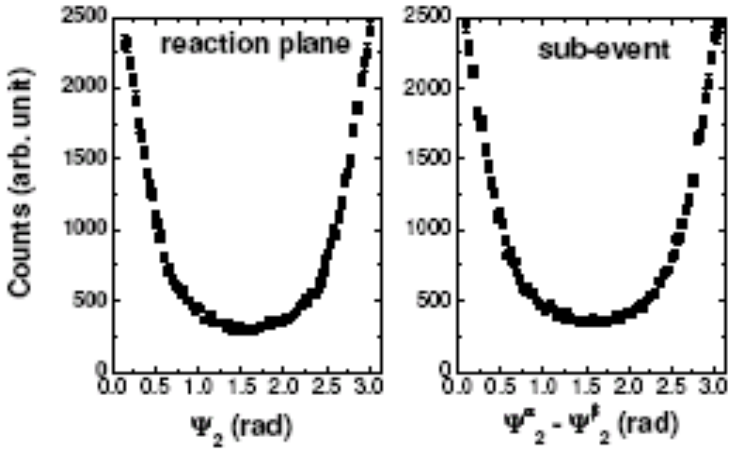


Fig. 2. The reconstructed reaction plane distribution (Ψ_2) and the subevent distribution (Ψ_2^a-Ψ_2^b).

the true reaction plane scenario is in good agreement with the corrected reconstructed event plane one, which illustrates that the method of flow analysis in experiments can actually give true evaluation of the magnitude of the flow.

V_2 vs P_T and NCQ scaling

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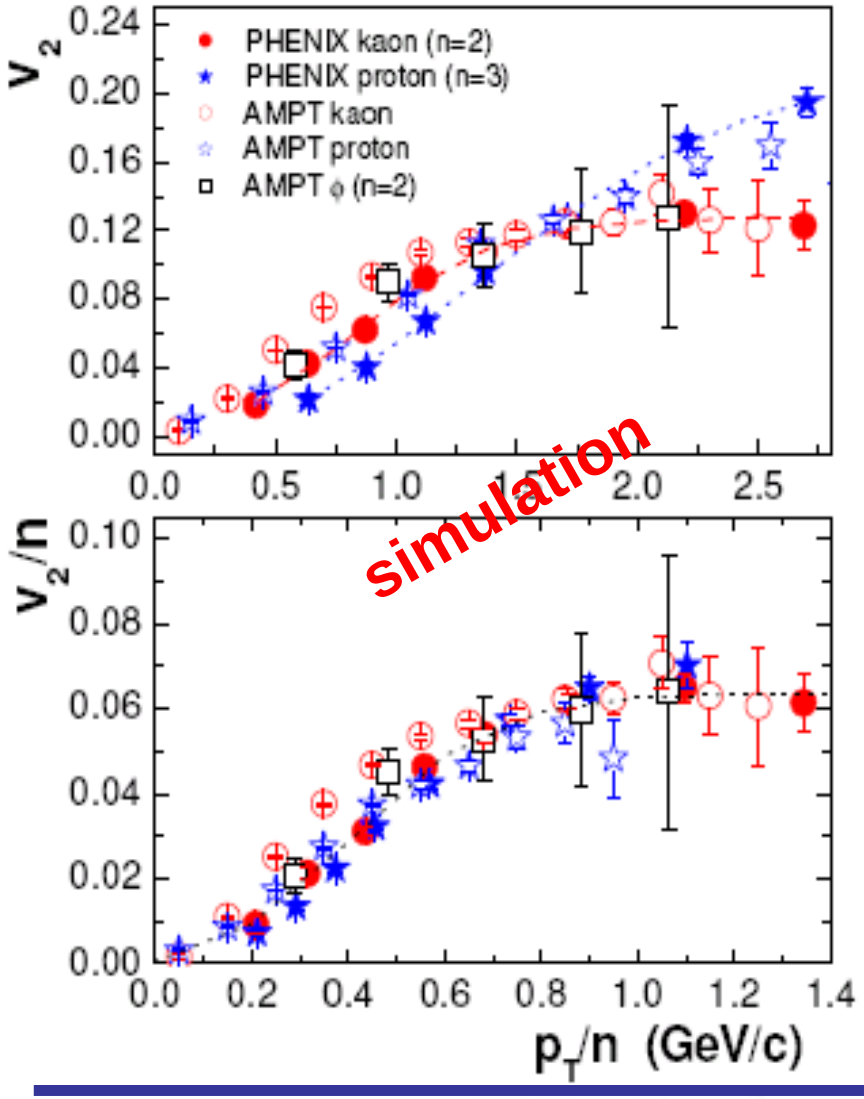

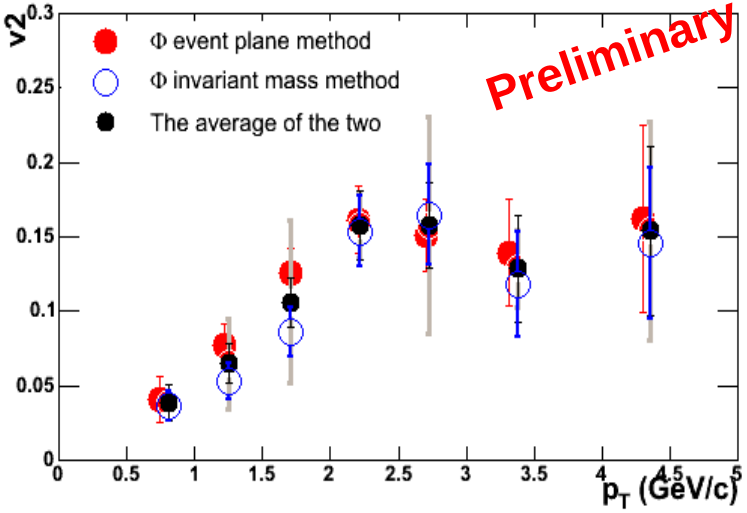

Particle-type dependence of Flow.

protons and Phi mesons are the same for pT up to 1.5-1.7 GeV, which finds a "natural" explanation in terms of a mass-dependence of v2 in this region. It shows that mass-ordering is not only a property of hydro models, but appears also in AMPT.

Constituent NCQ scaling looks satisfied for phi-meson. It represents a constituent quark momentum-space anisotropy v_{2}^{q} that may indicate a consequence of collectivity in a partonic stage which includes strange quarks. The reconstructed results give an implication that a new stage of partonic matter may be created with v_{2}^{q} characterizing the property of the matter.

Centrality dependence & rescattering effect in hadronic phase

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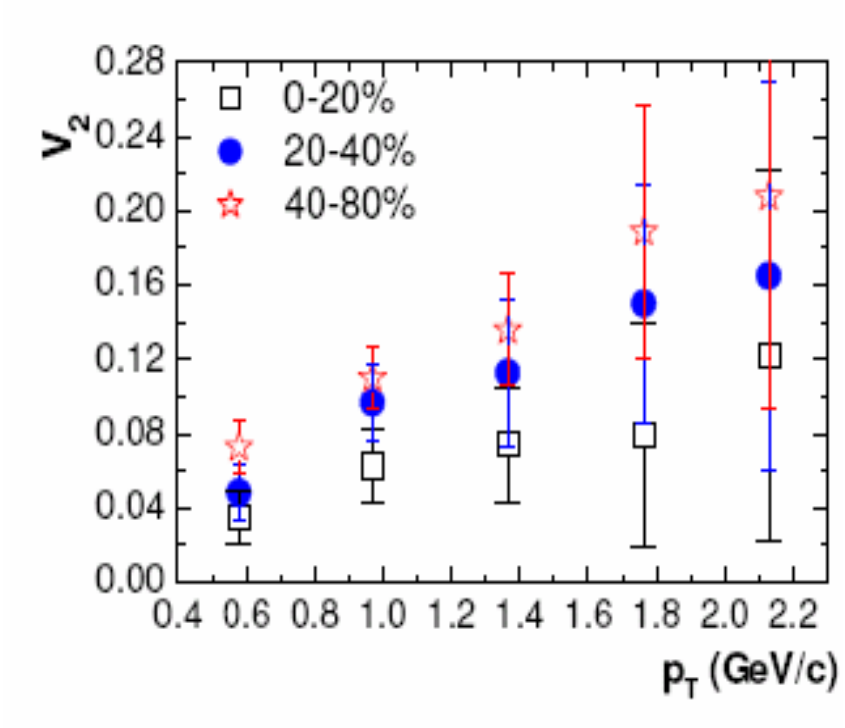

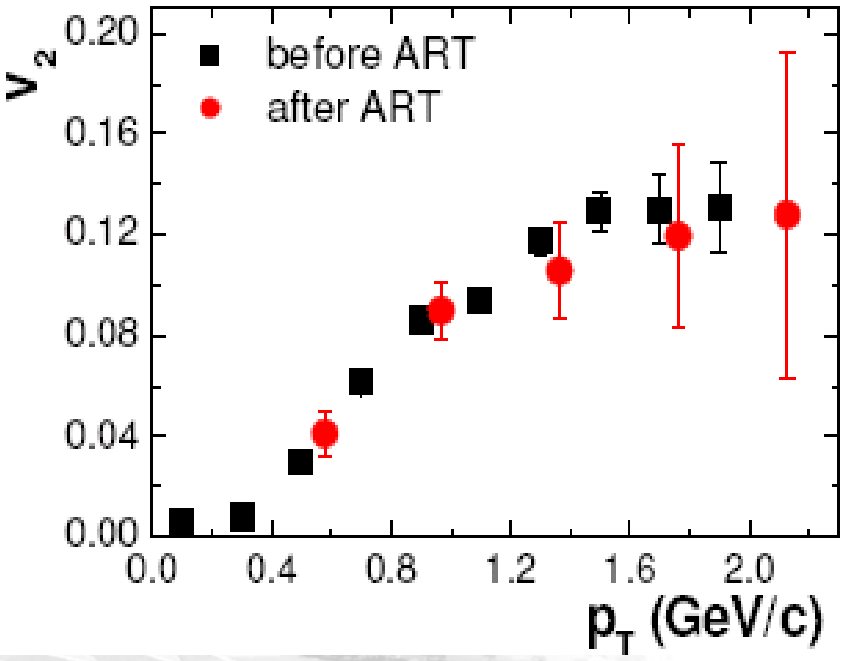

The value of v_{2}(p_T) rises from central collision to semi-peripheral collision, which is consistent with the geometric picture of the collision where the overlap zone of the system tends to become more anisotropic from central collision to semi-peripheral one.

v_{2} values before ART is subtracted directly from AMPT model without ART process. v_2 after ART is reconstructed from $K^{+}+K^{-}$ pair from AMPT model with ART process.
Two scenarios are consistent with each other. It indicates that the in-medium hadronic re-scattering effect on the final ϕ elliptic flow can be ignored within the errors.

Summary

1) The elliptic flow v2 have been measured in run IV Au+Au 200GeV collisions. Since phi cannot be made via K^+K^- fusion, this implies partonic collective at RHIC! See talks of X.Z. Cai, Markus Oldenburg and Pal in QM2006.

2) Before the experimental results come out, AMPT predicted that phi v2 has the same NCQ scaling as other hadrons. It indicates that Collectivity develops early among partons, ➔ Partonic Collectivity at RHIC.