# The Study of Elliptic Flow for PID Hadron at RHIC-PHENIX

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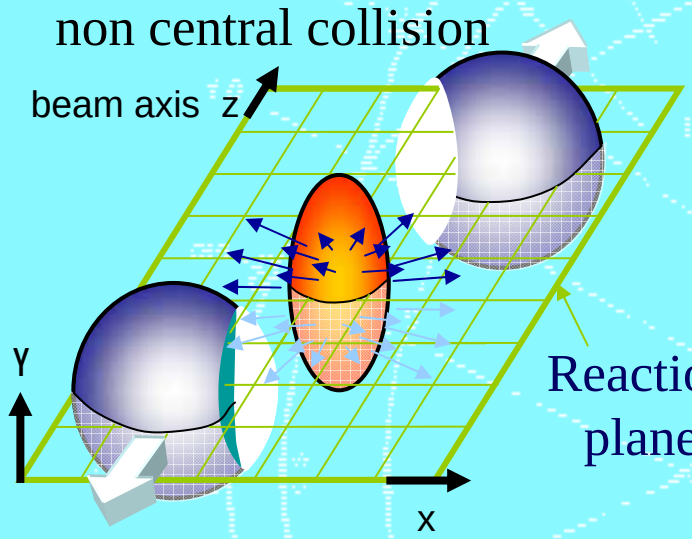
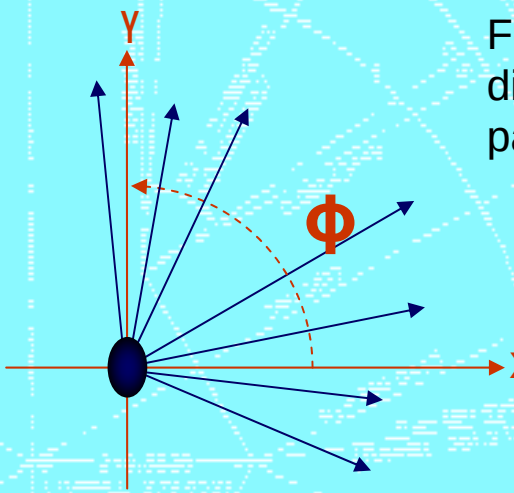
# About Elliptic Flow ($v_2$)

$v_2$ is the strength of the elliptic anisotropy of produced particles.

A sensitive probe for studying properties of the hot dense matter made by heavy ion collisions.




Fourier expansion of the distribution of produced particle angle, $\Phi$, to RP

$$\frac{dN}{d\varphi} = n\{1 + 2V_2\cos[2(\varphi - \Phi_{RP})]\}$$

$v_2$ is the coefficient of the second term
→ indicates ellipticity

If yield is (x direction)>(y direction), $v_2$ >0.

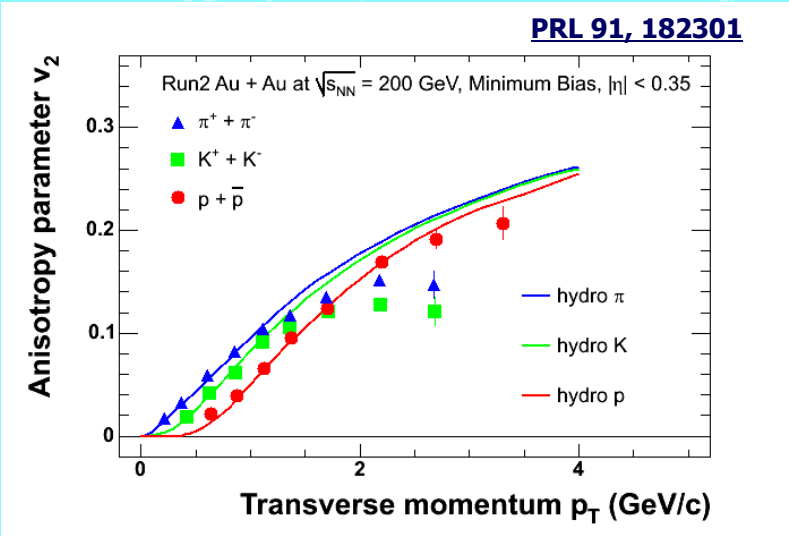
The initial geometrical anisotropy is transferred by the pressure gradients into a momentum space anisotropy → the measured $v_2$ reflects the dense matter produced in the collisions.

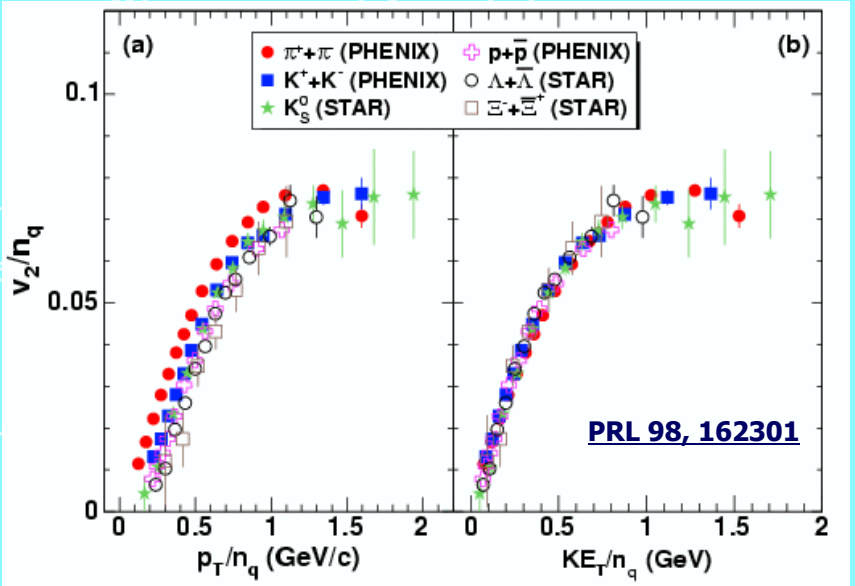
# Motivation

## 1. From the results at 200GeV

$v_2$ at low $p_T$ (< ~2 GeV/c) →can be explained by a hydro-dynamical model
$v_2$ at mid $p_T$ (<4~6 GeV/c) → is consistent with recombination model

The results are consistent with Quark number scaling.




$KE_T$ = mT-m0

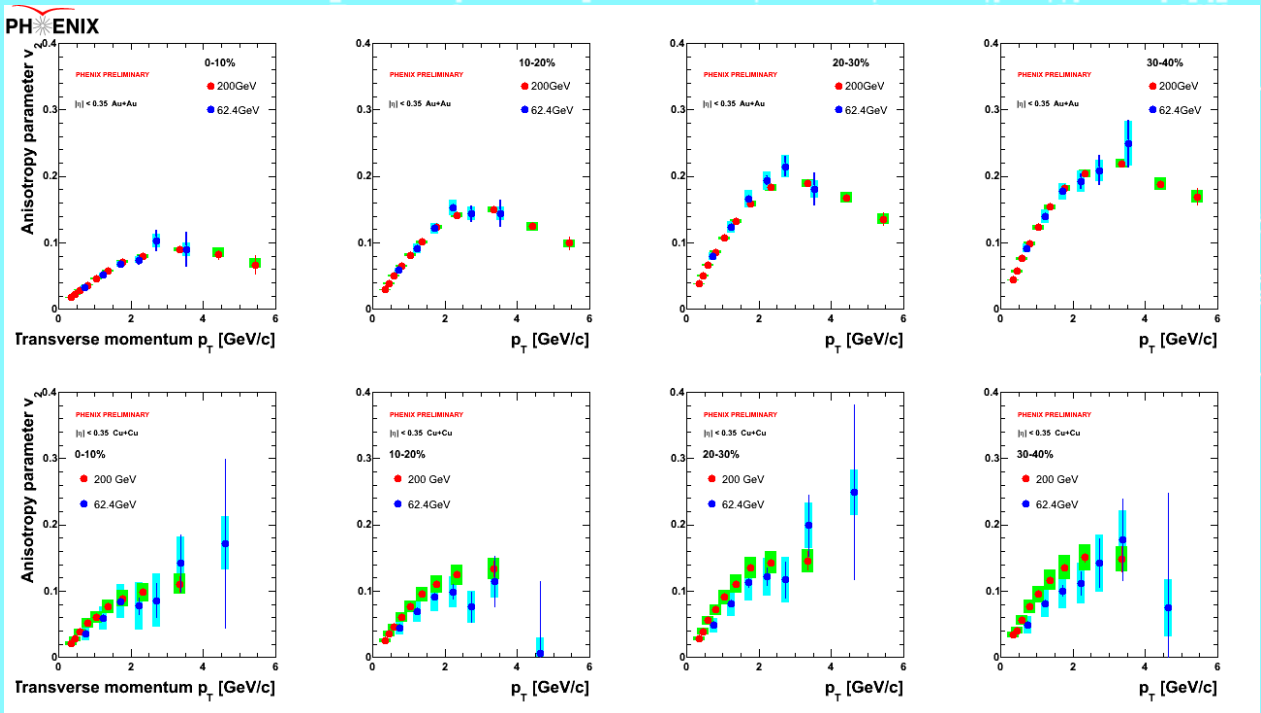
**How about $v_2$ at 62.4GeV !?**

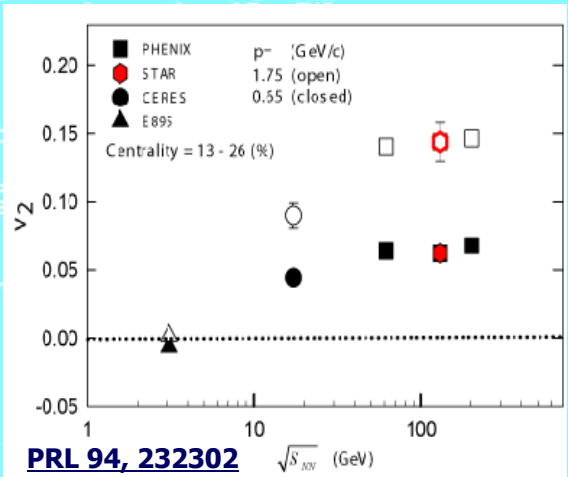
# Motivation

## 2. From the comparison between $v_2$s of charged hadron at 62.4GeV and 200GeV

$v_2(p_T)$ of inclusive charged hadrons agree well.

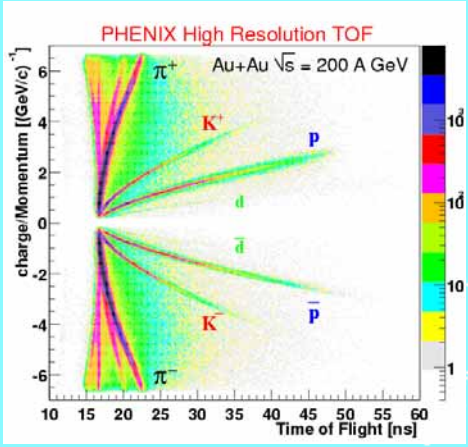
$V_2$ is saturated and doesn't depend on collision energy at RHIC.

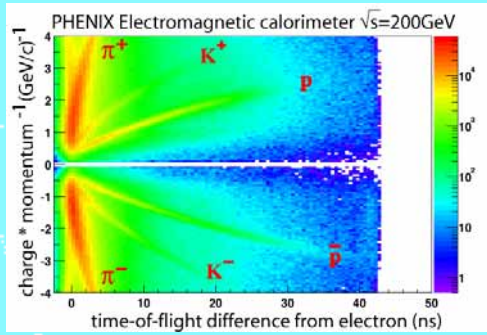



**How about PID $v_2$ at 62.4GeV !?**

# Analysis



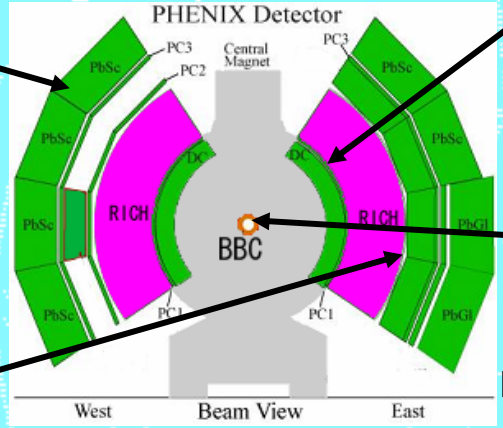

**<Data set for this analysis>**

- **Au+Au collision**
- **37.6 Million Events**
- **taken in 2003-2004 at RHIC-PHENIX**
- **Collision energy：62.4 GeV/2 nucleons**

## <PHENIX detectors>

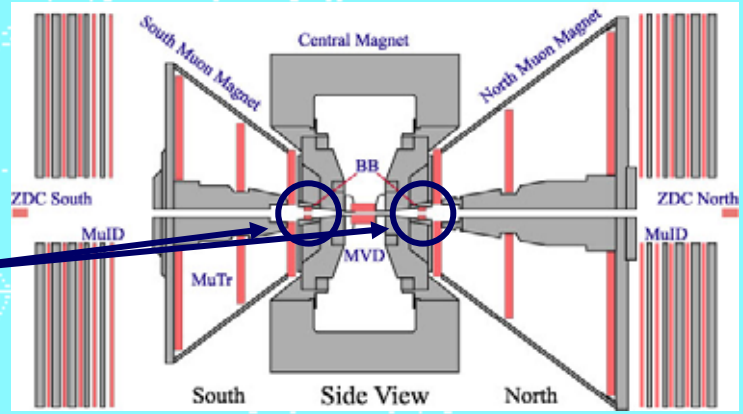
**EMCAL**
for Particle Identification
resolution=380ps

**TOF**
for Particle Identification
resolution=120ps




**DC + PC1**
for good track selection and to determine p

**BBC**
to determine reaction plane and vertex




### <PID by TOF measurement>

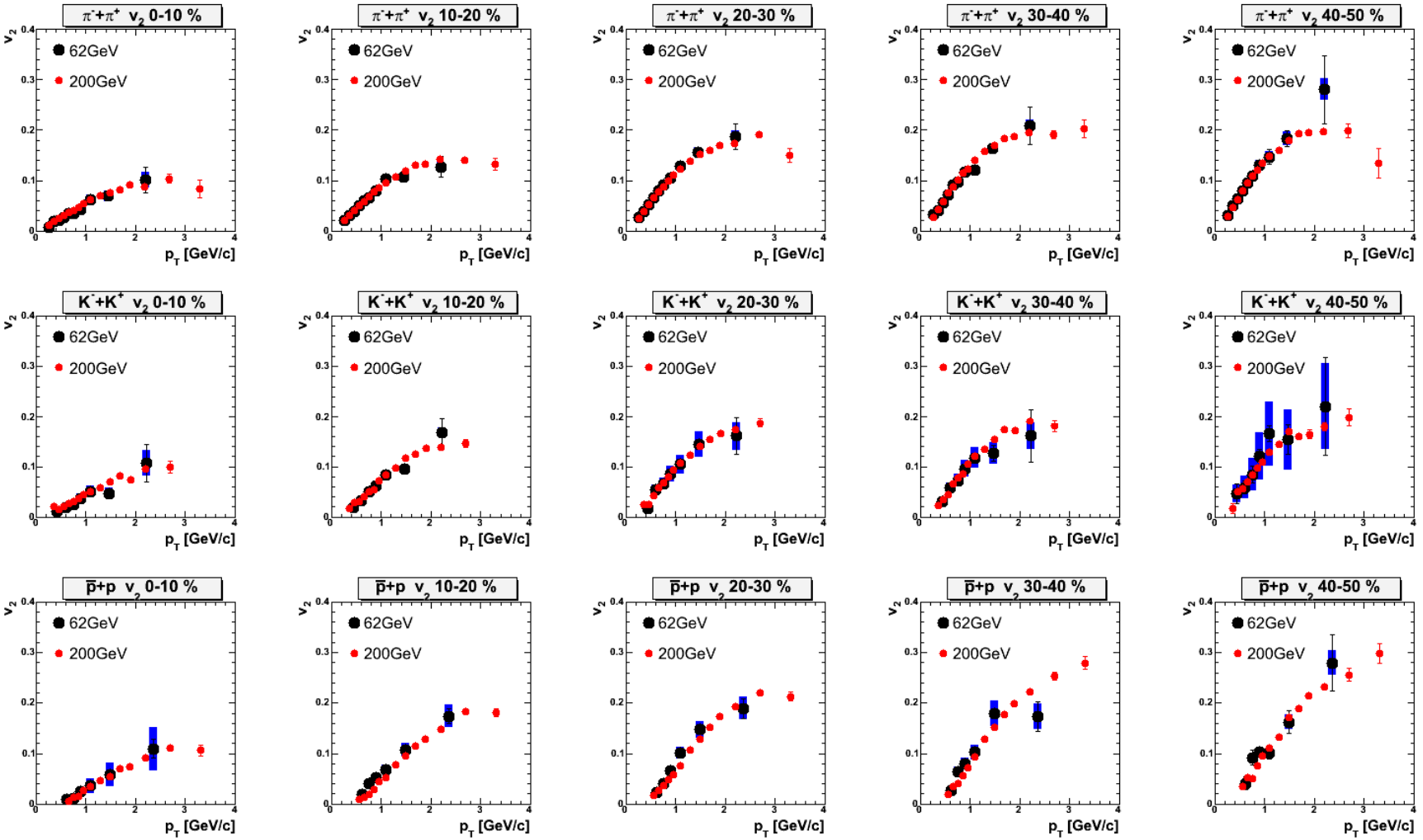
Using TOF or EMC with BBC, the flight time of the particles is obtained. Mass of the particle is calculated by the flight time and the momentum measured by DC.

### <Reaction Plane determination>

The reaction plane is obtained by measurement of the anisotropic distribution for the produced particles with north and south BBCs located at $|\eta| \sim 3 - 4$.

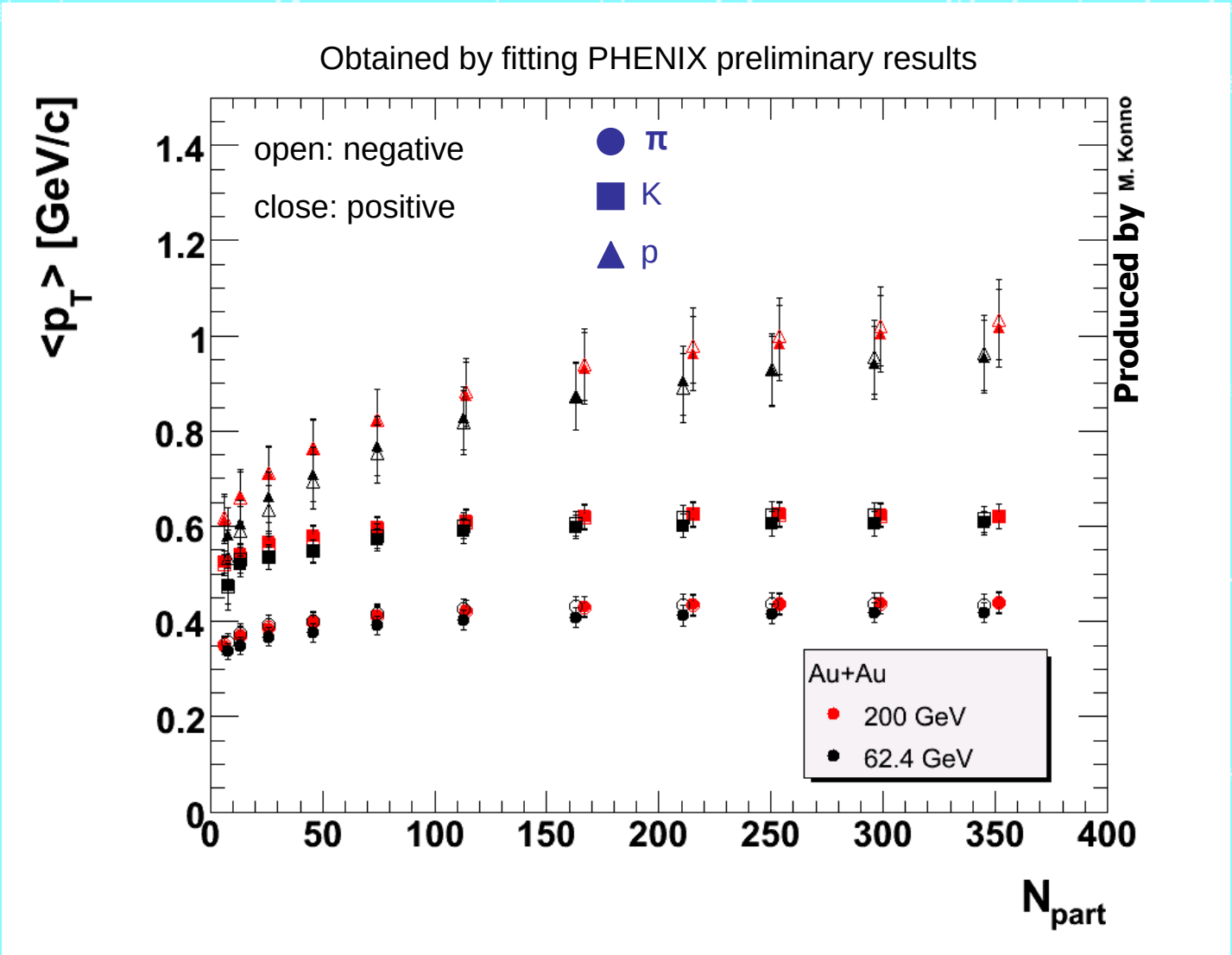
# Comparison of 62.4GeV to 200GeV

PHENIX PRELIMINARY




**Similar to 200 GeV results for any particles at any centrality.**

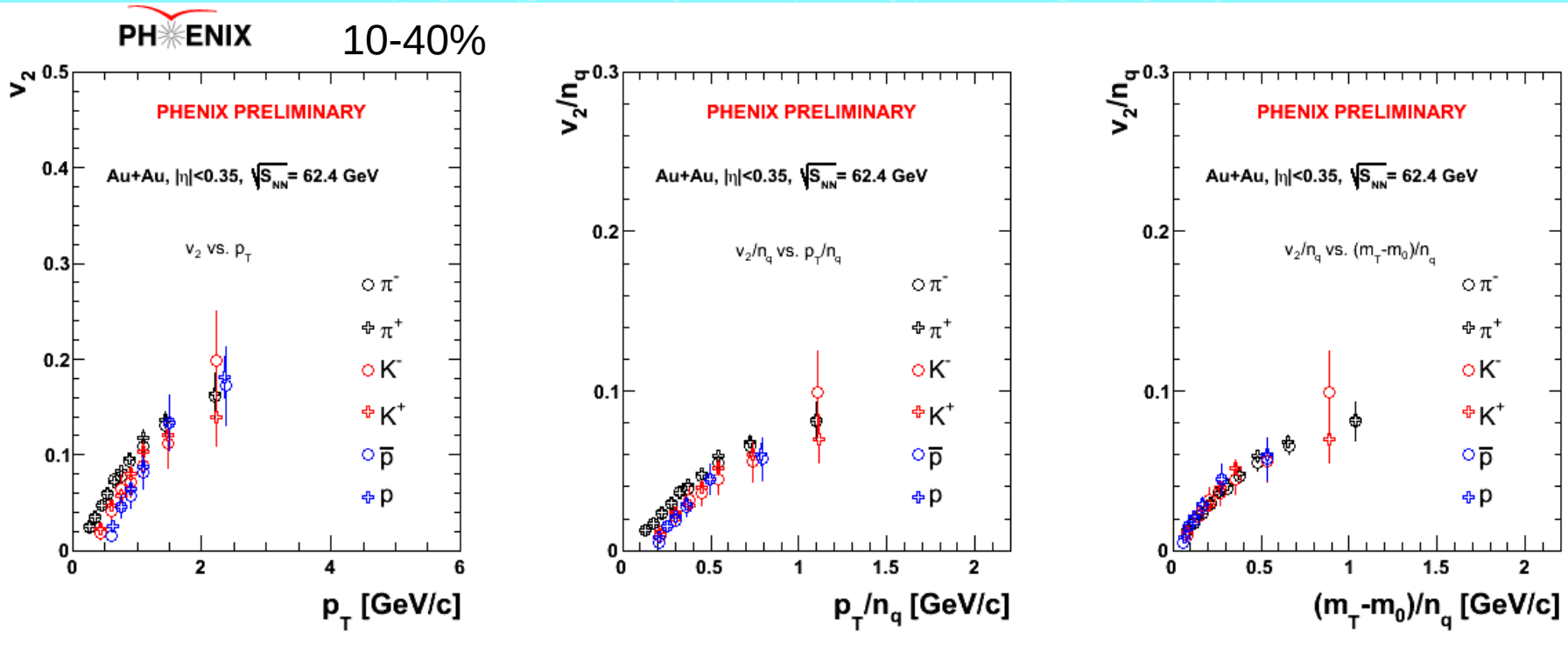
# Mean pT




Mean $p_T$ of 62.4 GeV and 200 GeV are consistent within errors.

# Quark number scaling

$K_{ET} = m_T - m_0$




Error bars include both statistical and systematic errors.

The result at 62.4GeV is consistent to quark number scaling.

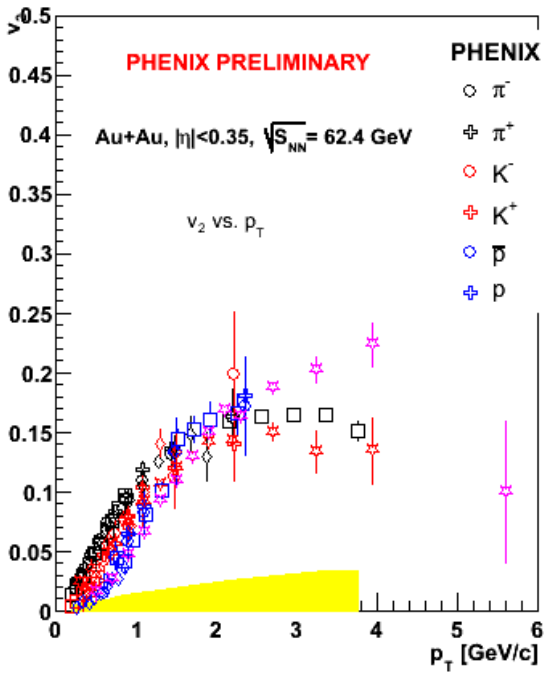
# Quark number scaling

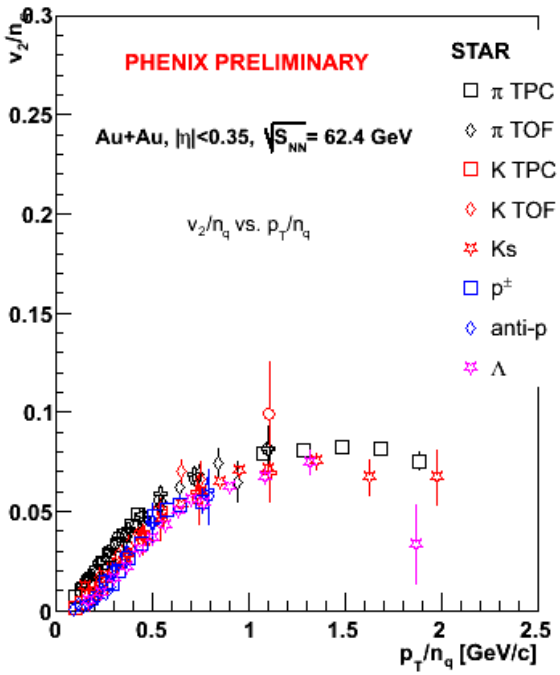
**PHENIX: Error bars include both statistical and systematic errors.**

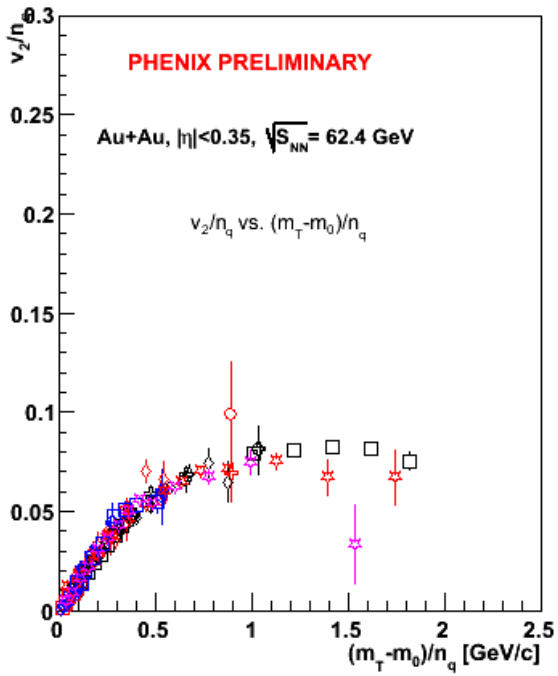
**STAR: Error bars include statistical errors. Yellow band indicates systematic errors.**

10-40%

**Star results were taken from Phys. Rev. C 75**

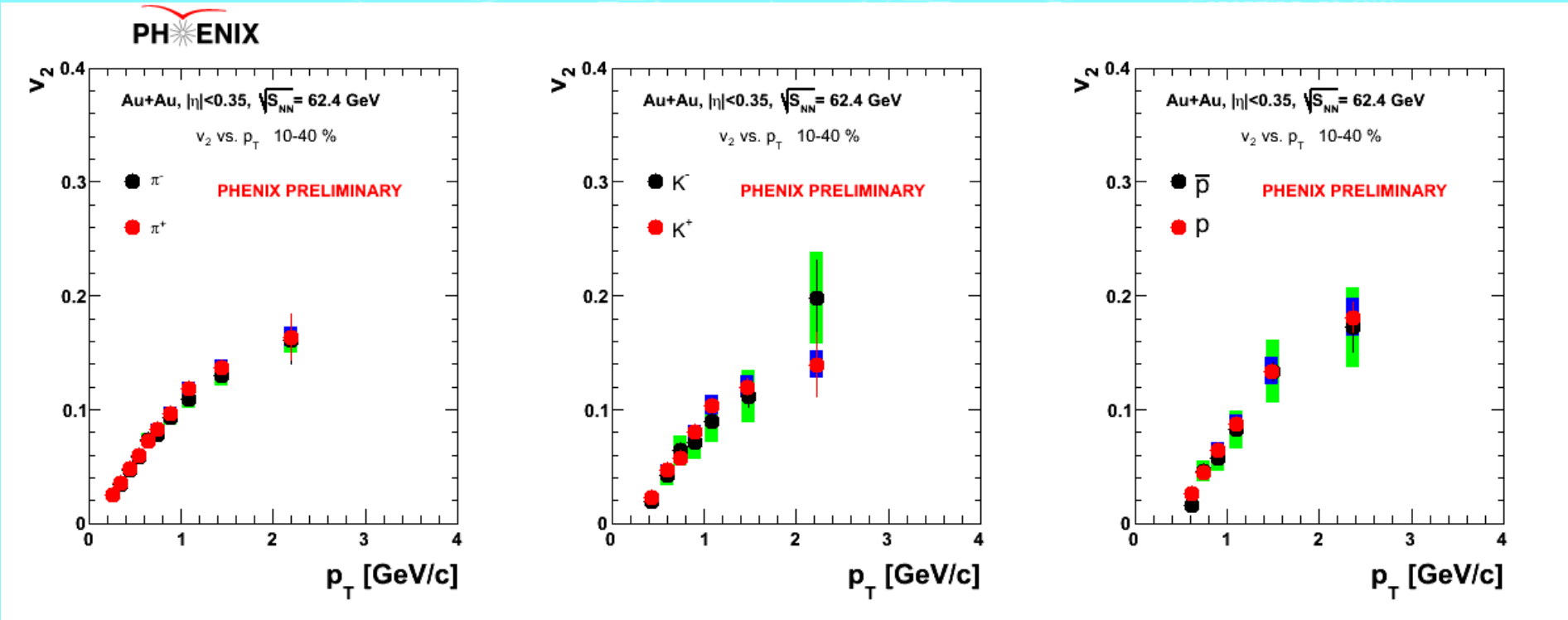


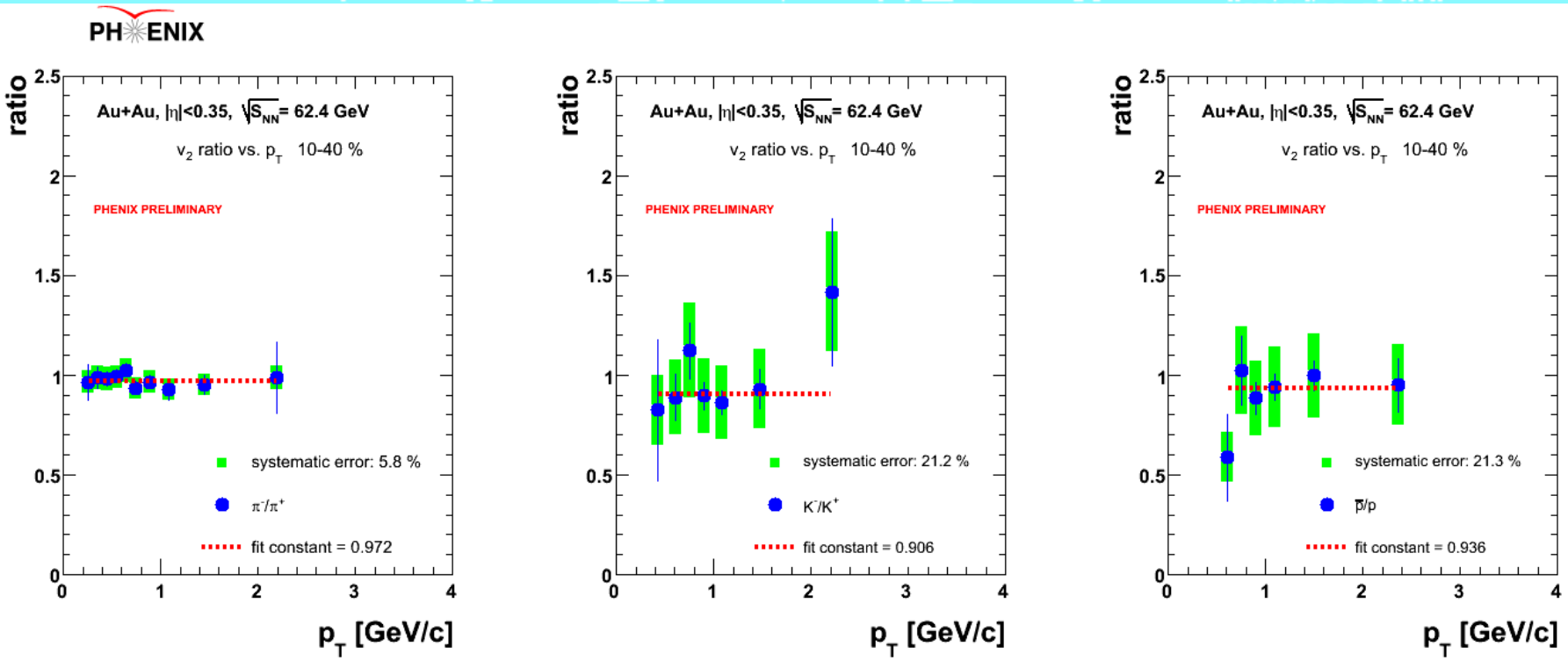

The result at 62.4 GeV is consistent to quark number scaling.

# Particles and Anti-particles




$v_2$ of $K^-$ and anti-proton look smaller than $K^+$ and proton, but errors are too big to conclude.

# Particles and Anti-particles




$v_2$ of $K^-$ and anti-proton look smaller than $K^+$ and proton, but errors are too big to conclude.

# Summary

- We measured PID ($\pi$, K, p) $v_2$ at 62.4 GeV in Au Au collisions and observed the dependence on $p_T$, centrality, and charge.
- $v_2$ of 62.4 GeV is similar to that of 200 GeV.
- $v_2$ of 62.4 GeV is consistent to quark number scaling.
- There could be the difference for $v_2$ of 62.4 GeV depending on the charge, however, the errors are to big to conclude.

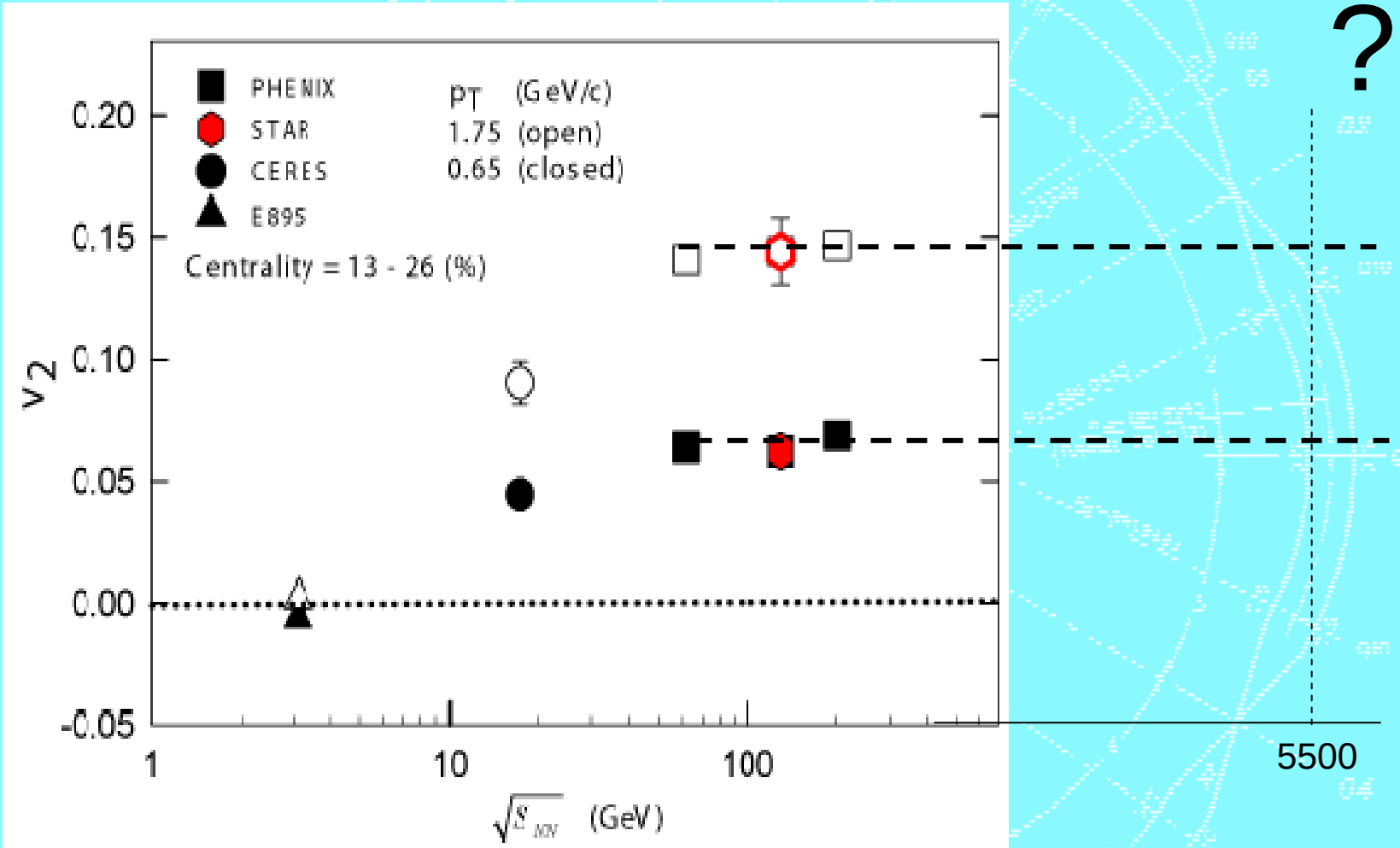
# Next Step

- Detail study for charge dependence.
- Close look into the difference of 200 GeV and 62.4 GeV
- Comparison with PID $v_2$ at Cu Cu 200 GeV

*and,,,,,, how about at LHC ? Stay ? Or Going Up ?*

One more interesting topic is of course ….

# *how about at LHC ?*



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*as of March 2005

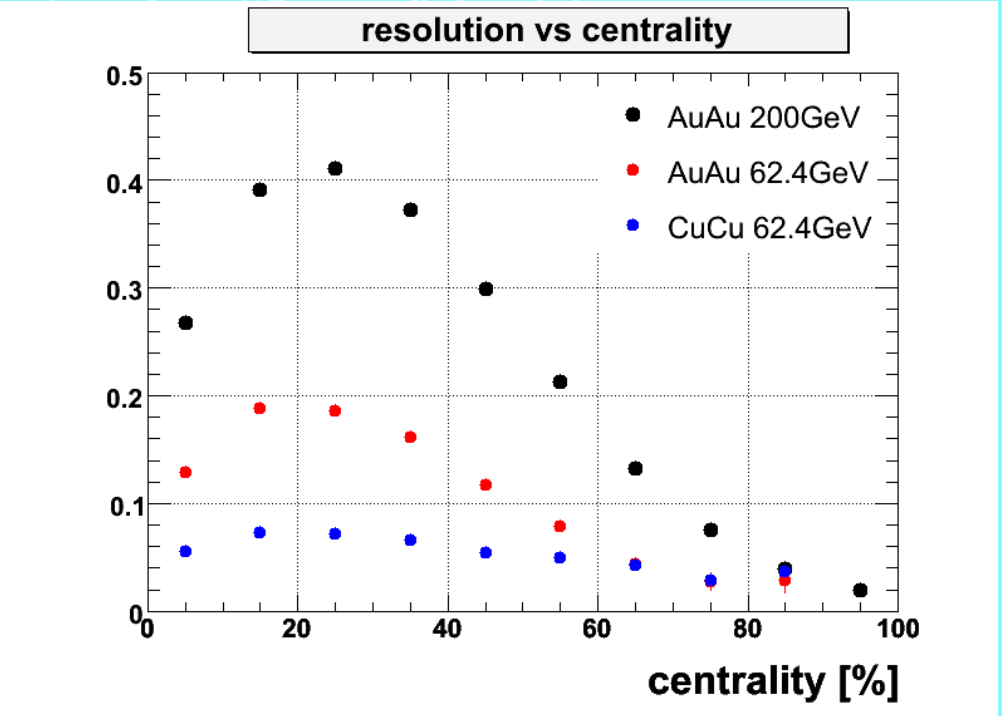

Back up

# Resolution Calculation of Reaction Plane

$$resolution = <\cos[2(\Psi_{measured} - \Psi_{true})]> \sim \sqrt{<\cos[2(\Psi_A - \Psi_B)]>}$$

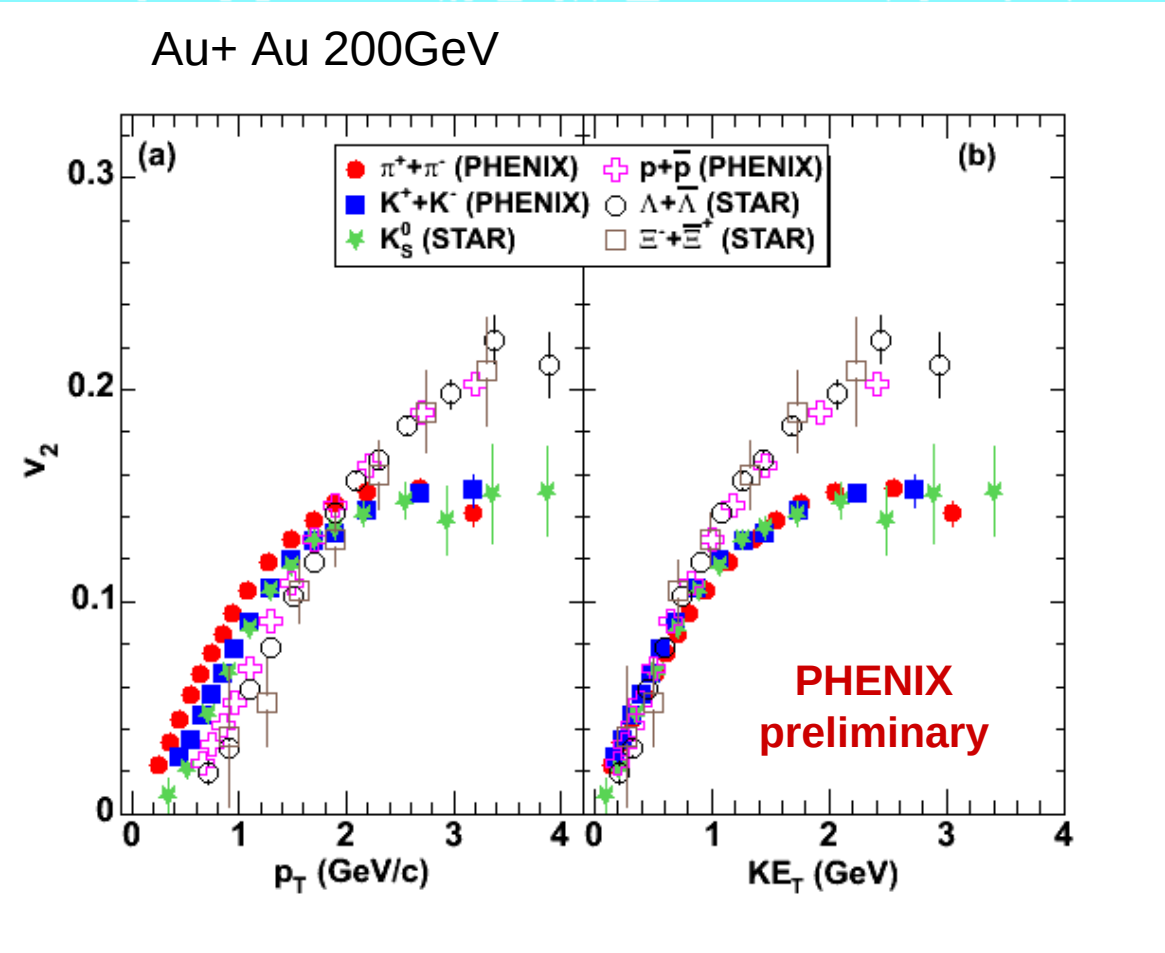
ΨA,B : reaction plane determined for each sub sample.

$$v_2^{real} = \frac{v_2^{measured}}{resolution}$$




- BBC North + South combined
- $\sqrt{}$(2*<cos(2*($\Psi_S - \Psi_N$))>) =1/correction factor

# $KE_T$ Scaling

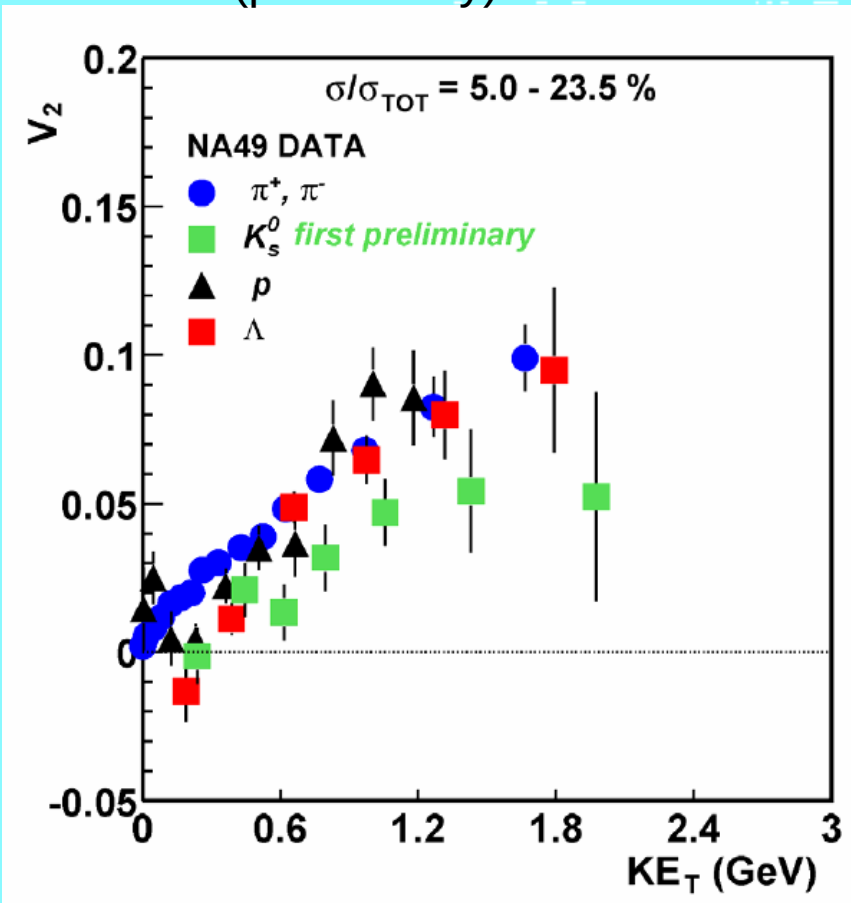

Au+ Au 200GeV
(a)
(b)
$\pi^+ + \pi^-$ (PHENIX)
$K^+ + K^-$ (PHENIX)
$K^0_S$ (STAR)
$p + \bar{p}$ (PHENIX)
$\Lambda + \bar{\Lambda}$ (STAR)
$\Xi^- + \bar{\Xi}^+$ (STAR)
$v_2$
$p_T$ (GeV/c)
$KE_T$ (GeV)
PHENIX
preliminary

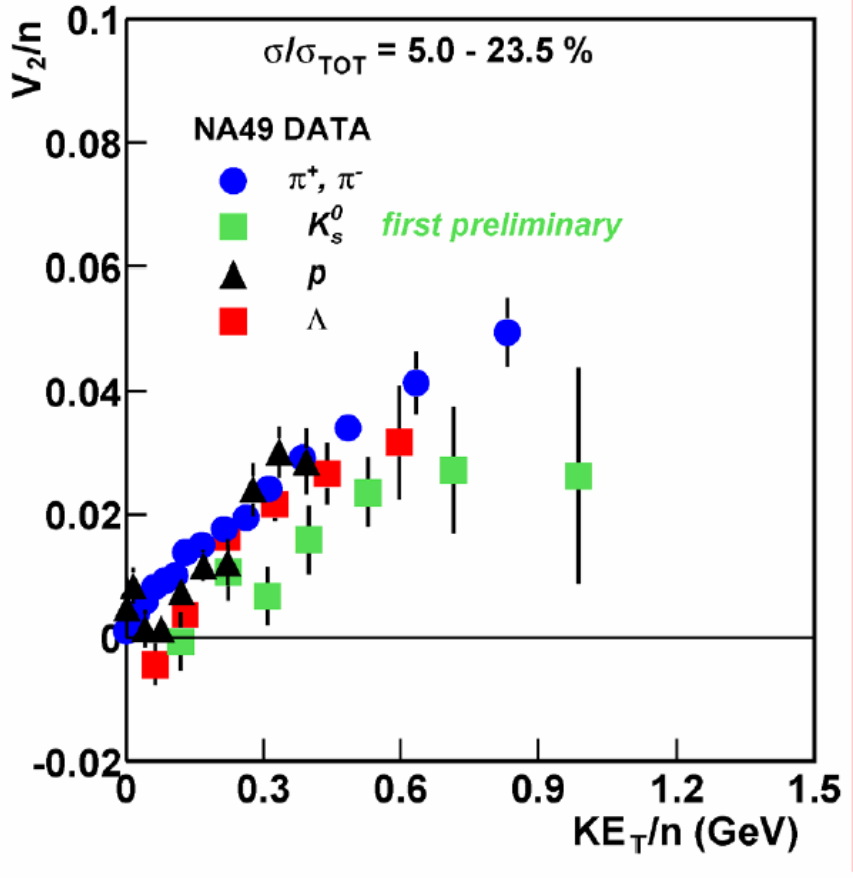
This slide is taken from A. Tranenko's talk at QM 2006.

# Elliptic Flow at SPS (Pb+Pb at 158 GeV, NA49)

v2 of p, **π**, **Λ** - C. Alt et al (NA49 collaboration) nucl-ex/0606026 submitted to PRL

V2 of K0 (preliminary) - G. Stefanek for NA49 collaboration (nucl-ex/0611003)




**The statistical errors are too large to make any statement about the scaling of elliptic flow at SPS energies**