Azimuthal HBT measurements of charged pions and kaons in Au+Au 200GeV collisions at RHIC-PHENIX

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Outline

- Introduction
- Physics Motivation
- Analysis
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- Results
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    - Azimuthal dependence of HBT radii
    - Fourier components
  - Kaon
    - Azimuthal dependence of HBT radii
  - Eccentricity at freeze-out comparing between pion and kaon
- Summary & Outlook

Introduction

- What is HBT ?
  - Quantum interference between identical two particles
  - Powerful tool to explore space-time evolution in HI collisions
  - Correlation function c_2 is defined as :

$$\vec{q} = \vec{p}_1 - \vec{p}_2$$

$$\vec{k}_T = \frac{\vec{p}_1 + \vec{p}_2}{2}$$

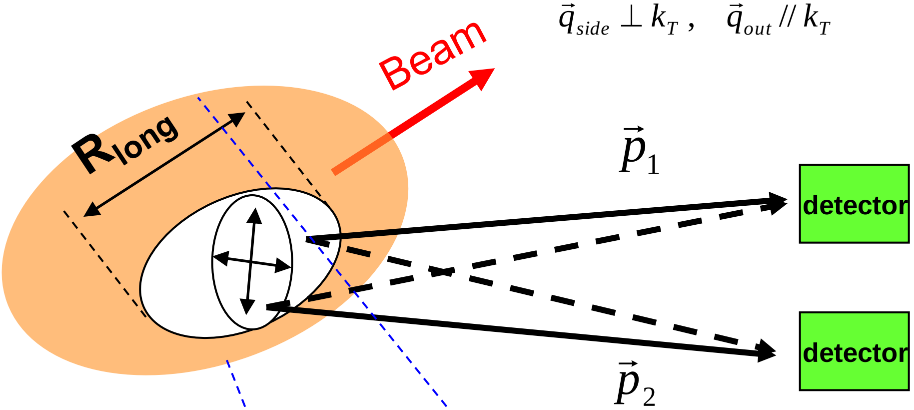
$$\vec{q}_{side} \perp \vec{k}_T \ , \quad \vec{q}_{out} \,//\, \vec{k}_T$$

$P(p_1)$: Probability of detecting a particle
$P(p_1,p_2)$: Probability of detecting pair particles

$$C_2 = \frac{P(\vec{p}_1, \vec{p}_2)}{P(\vec{p}_1)\cdot P(\vec{p}_2)}$$

$$= 1 + \left|\tilde{\rho}(q)\right|^2 = 1 + \exp(-R_{inv}^2 q_{inv}^2)$$

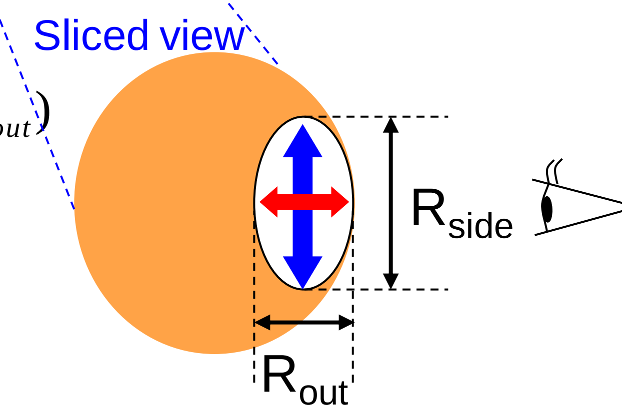
(If assuming gaussian source)



- Bertsch-Pratt parameterization at LCMS frame

$$C_2 = 1 + \lambda \exp(-R_{inv}^2 q_{inv}^2)$$

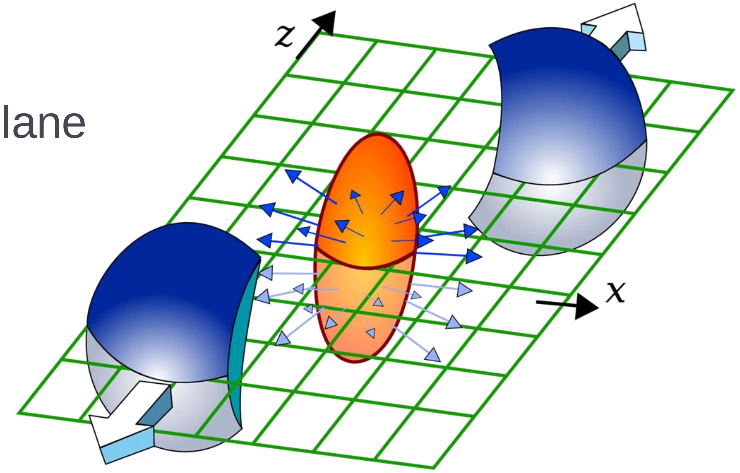
$$= 1 + \lambda \exp(-R_{side}^2 q_{side}^2 - R_{out}^2 q_{out}^2 - R_{long}^2 q_{long}^2 - 2R_{os}^2 q_{side} q_{out})$$



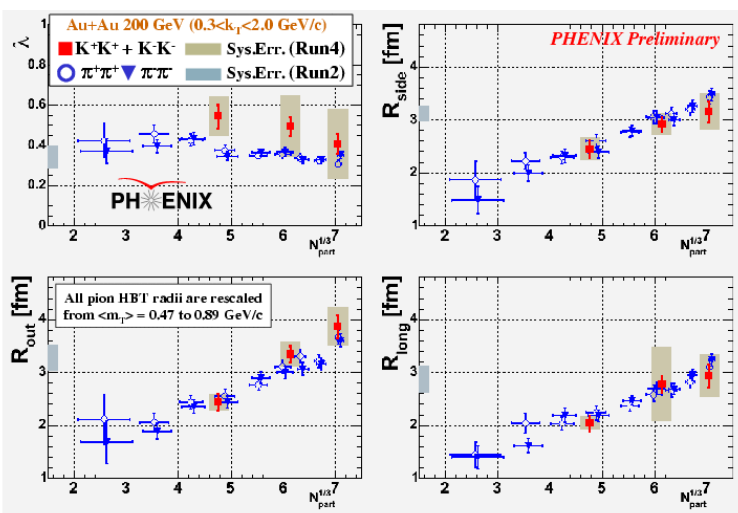
  - R_{side} : transverse size of source
  - R_{out} : transverse size of source + emission duration
  - R_{long} : longitudinal size of source
  - R_{os} : cross term between side and out

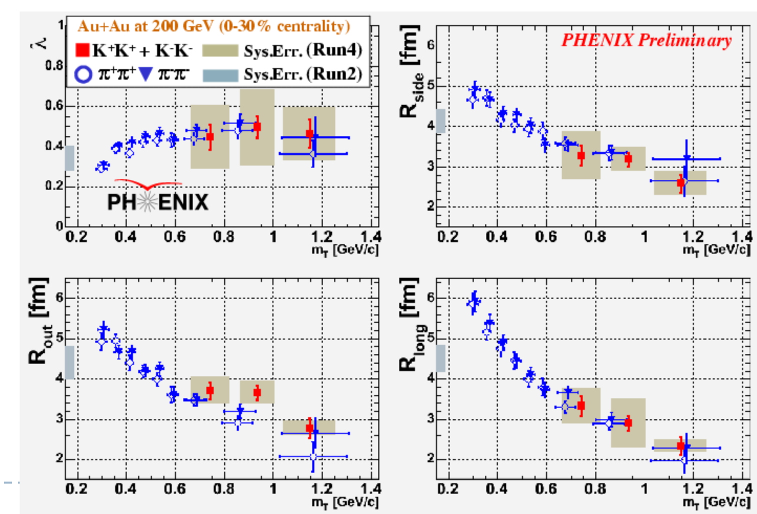
Physics Motivation

- Azimuthal HBT analysis
  - Measures the source shape w.r.t Reaction Plane
  - Source shape at freeze-out is
    - **Sensitive to "system lifetime"**
    - **Related to momentum anisotropy**



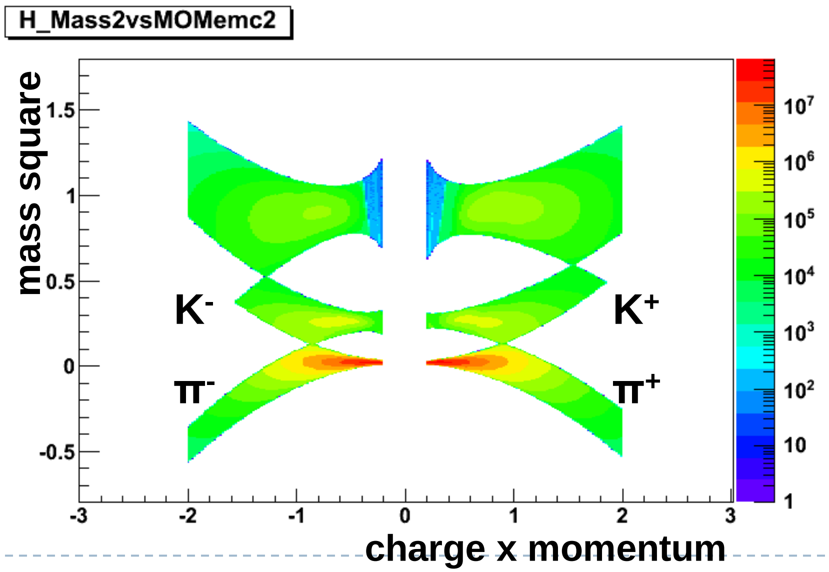
- HBT Results for charged pion and kaon
  - Centrality and m_T dependence were measured for pion and kaon
    →No significant difference between both species
  - **How about azimuthal dependence?**

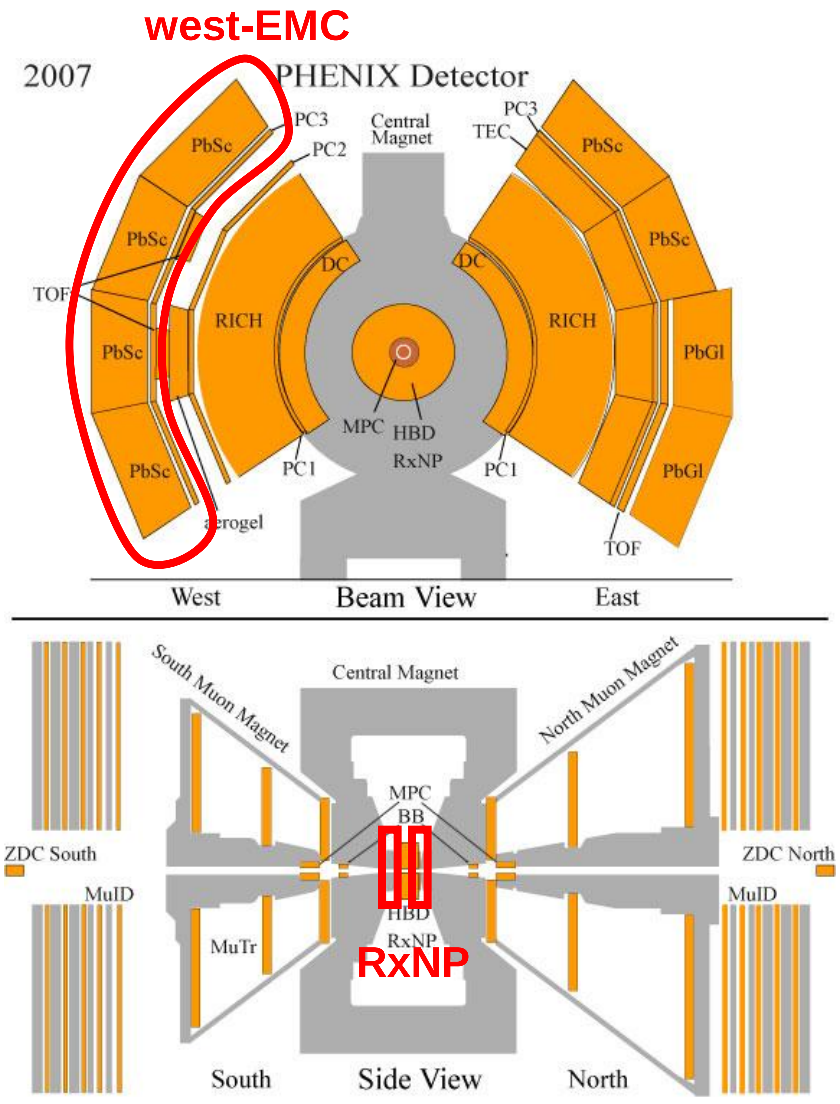




PHENIX Detector

- Vertex, Centrality
  - BBC, ZDC
- Event plane
  - Reaction Plane Detector(RxNP)
    - $1<|\eta|<2.8$
- Tracking
  - Drift Chamber, Pad Chamber
- PID
  - EMCal (all sectors in west arm)
    - $|\eta|<0.35$, $\Delta\varphi=90°$





Analysis flow

- Measure the experimental C_2
- Correct Event Plane resolution
  - Finite resolution reduce the oscillation amplitude of HBT radii
  - U.Heinz et al, PRC66, 044903 (2002)
- Fitting C_2
  - Sinyukov fitting method (includes coulomb correction and effect of long lived resonance decay)
- Get HBT radii(R_{side},R_{out},R_{long},…) as a fitting result

Analysis flow

- Measure the experimental C_2

$$C_2 = \frac{R(q)}{M(q)}$$

R(q): relative momentum dist. of Real pairs
M(q): that of mixed pairs

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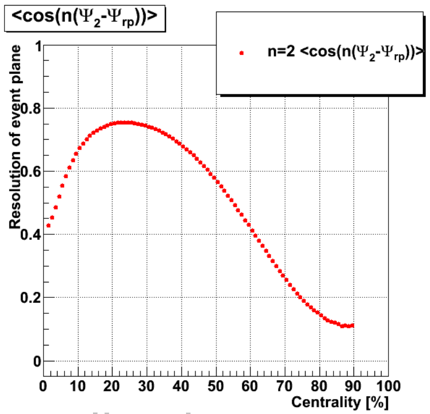

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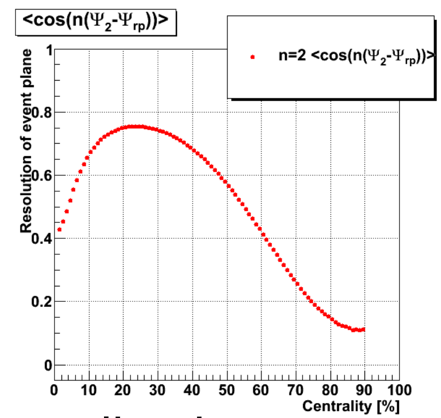

- Fitting C_2
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    (includes coulomb correction and effect of long lived resonance decay)

$$C_2 = C_2^{core} + C_2^{halo}$$

$$= [\lambda(1+G)F] + [1-\lambda]$$

$$G = \exp(-R_{side}^2 q_{side}^2 - R_{out}^2 q_{out}^2 - R_{long}^2 q_{long}^2 - 2R_{os}^2 q_{side} q_{out})$$

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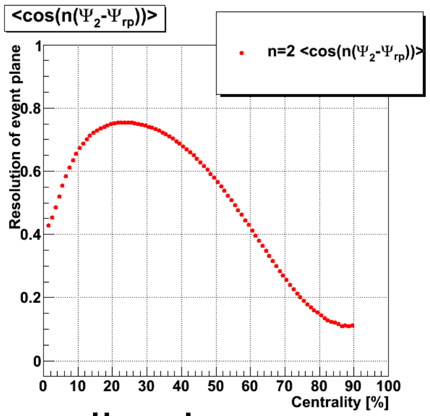

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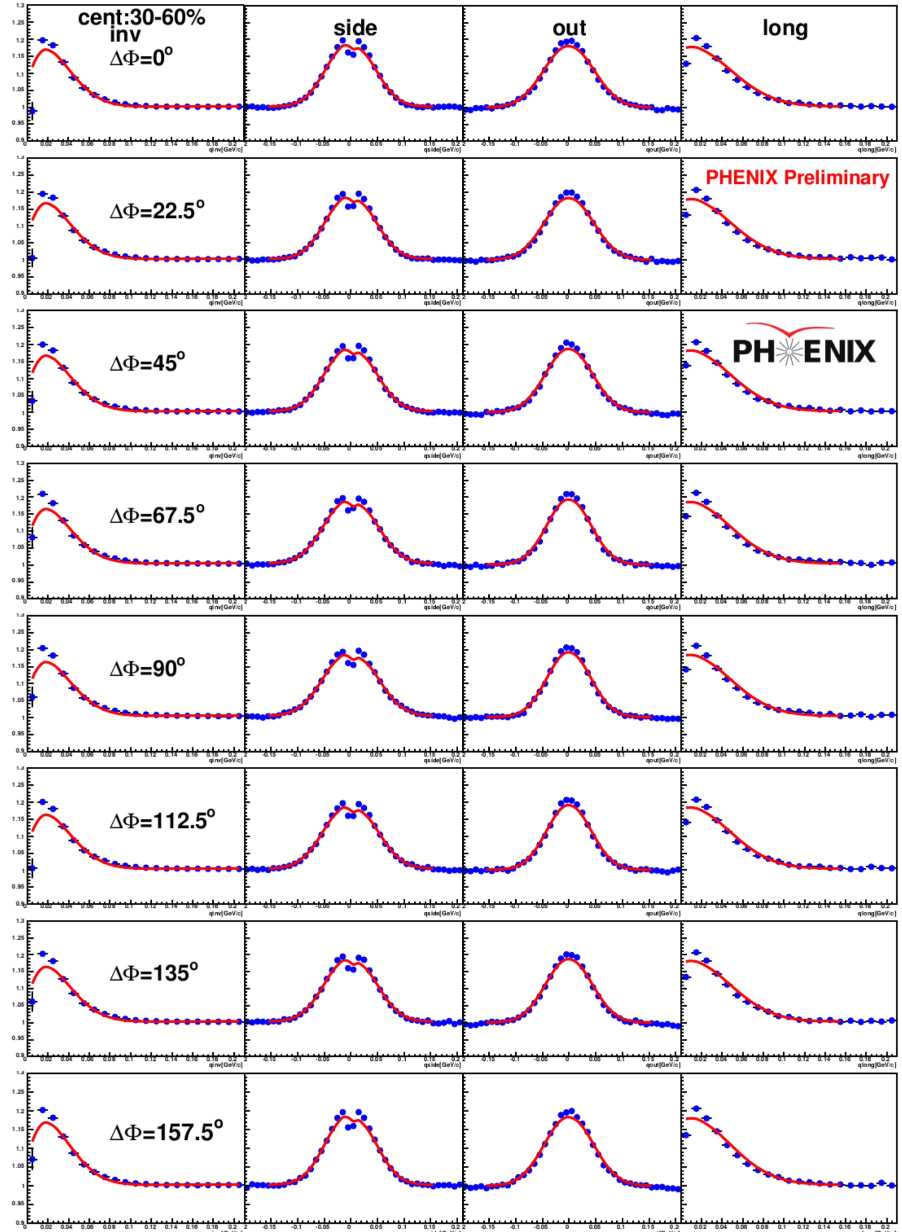
Correlation function for pion

- Raw c2
- With sinyukov' fitting function
- Centrality:30-60%



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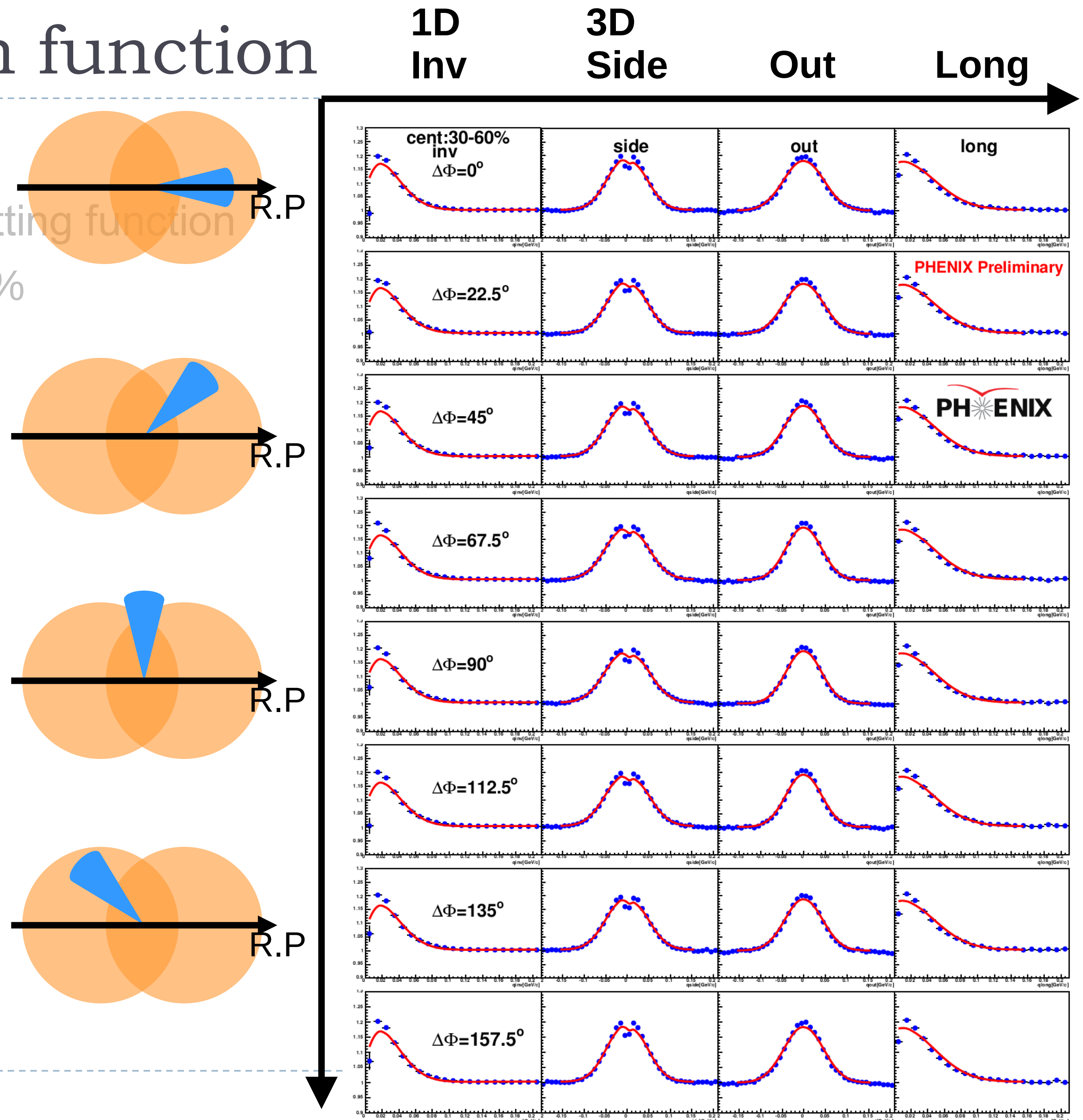
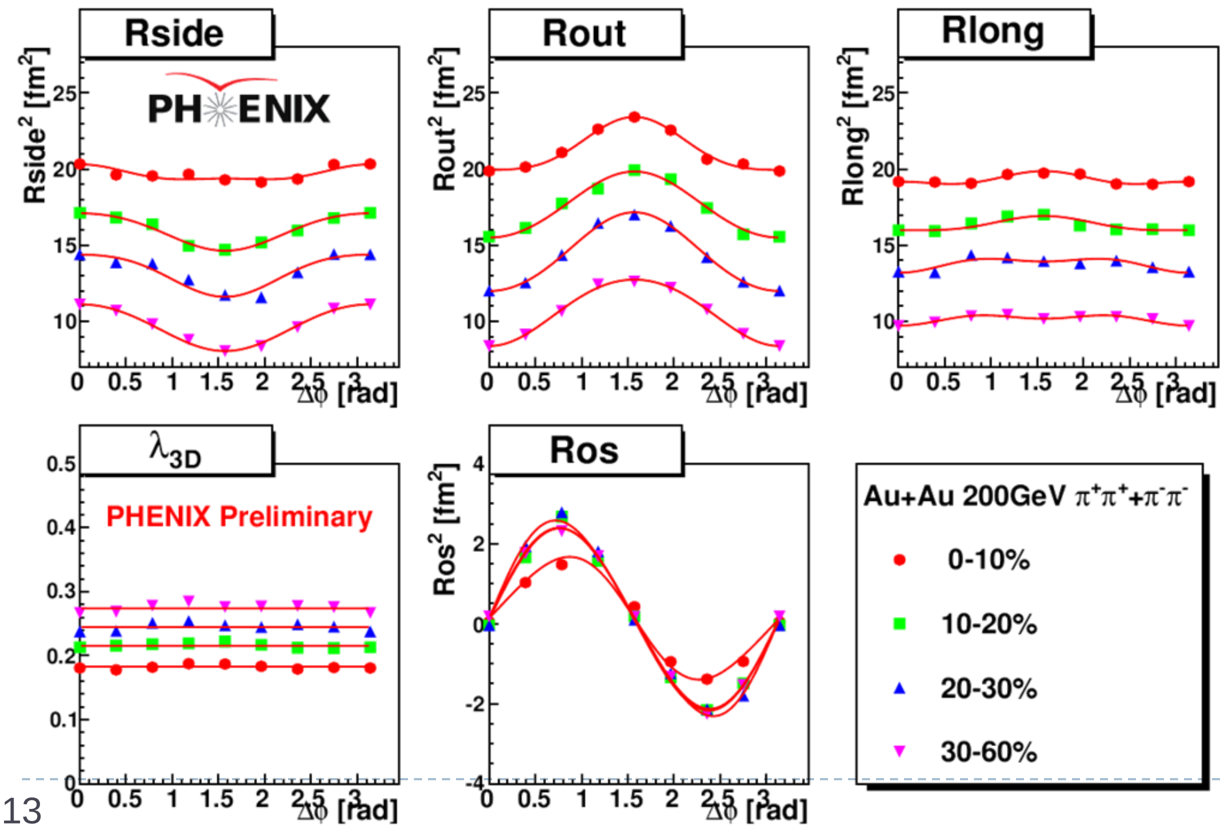


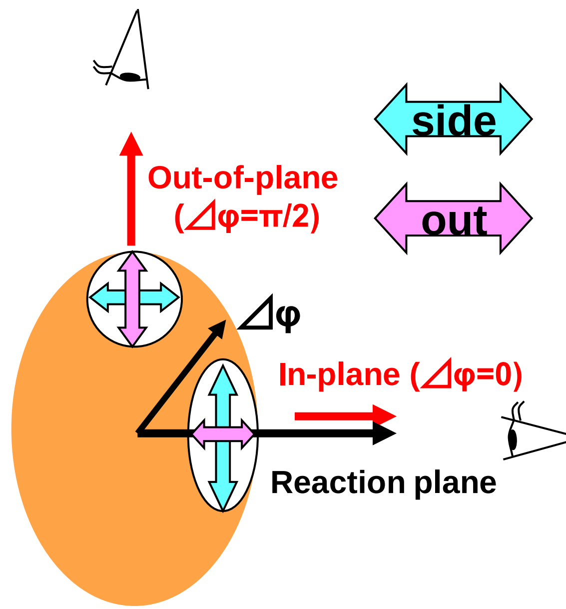
Azimuthal dependence of HBT radii for pion

- Observed the oscillation for R_{side}, R_{out}, R_{os}
- Different emission duration between in-plane and out-of-plane at 0-10%?
- Data points are fitted by cosine series function

$$R = R_{\mu,0}^2 + 2R_{\mu,2}^2 \cos(2\Delta\phi) + 2R_{\mu,4}^2 \cos(4\Delta\phi) \qquad \mu = s,o,l$$

$$R = R_{\mu,0}^2 + 2R_{\mu,2}^2 \sin(2\Delta\phi) + 2R_{\mu,4}^2 \sin(4\Delta\phi) \qquad \mu = os$$

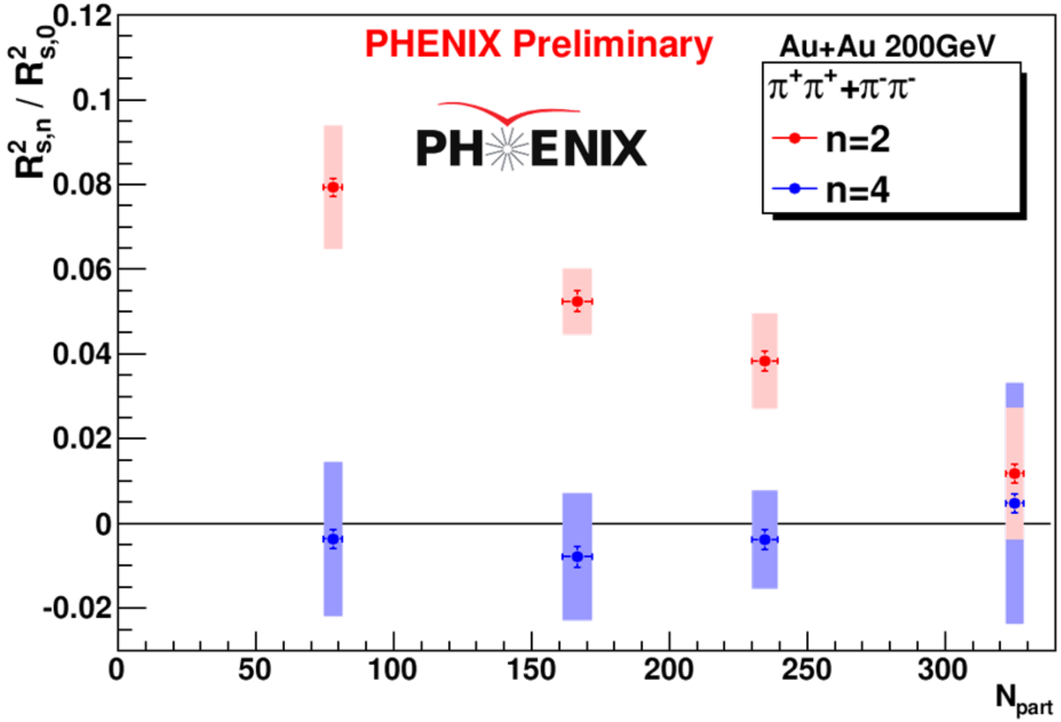


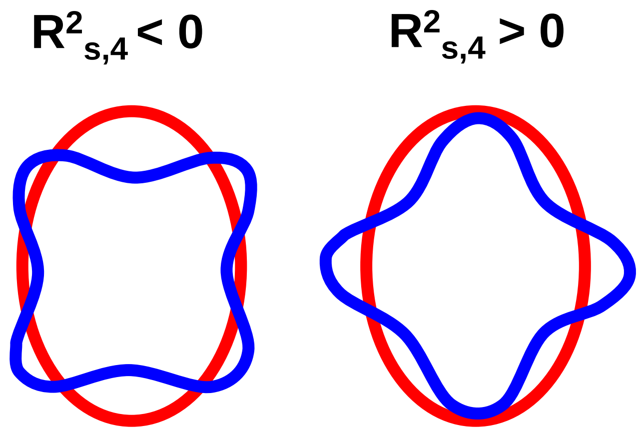


Fourier components of azimuthal HBT radii

- Fourier component for R_{side} is calculated by the following fit

$$R = R^2_{side,0} + 2\boxed{R^2_{side,2}}\cos(2\Delta\phi) + 2\boxed{R^2_{side,4}}\cos(4\Delta\phi)$$

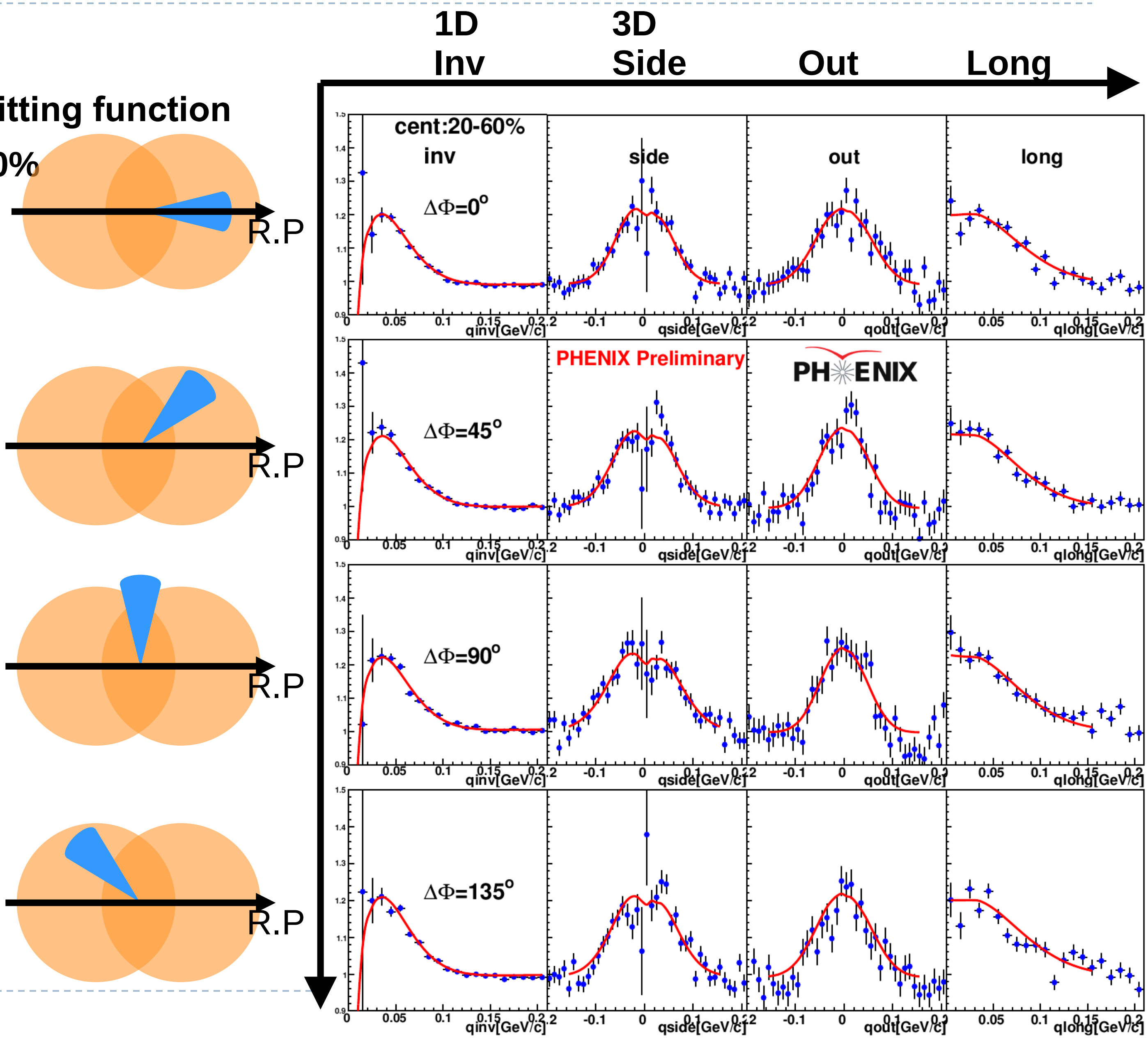




Relative 4th order radius seems to have negative value,
But it's zero within systematic error

Correlation function for kaon

- **Raw c2**
- **with sinyukov' fitting function**
- **Centrality: 20-60%**

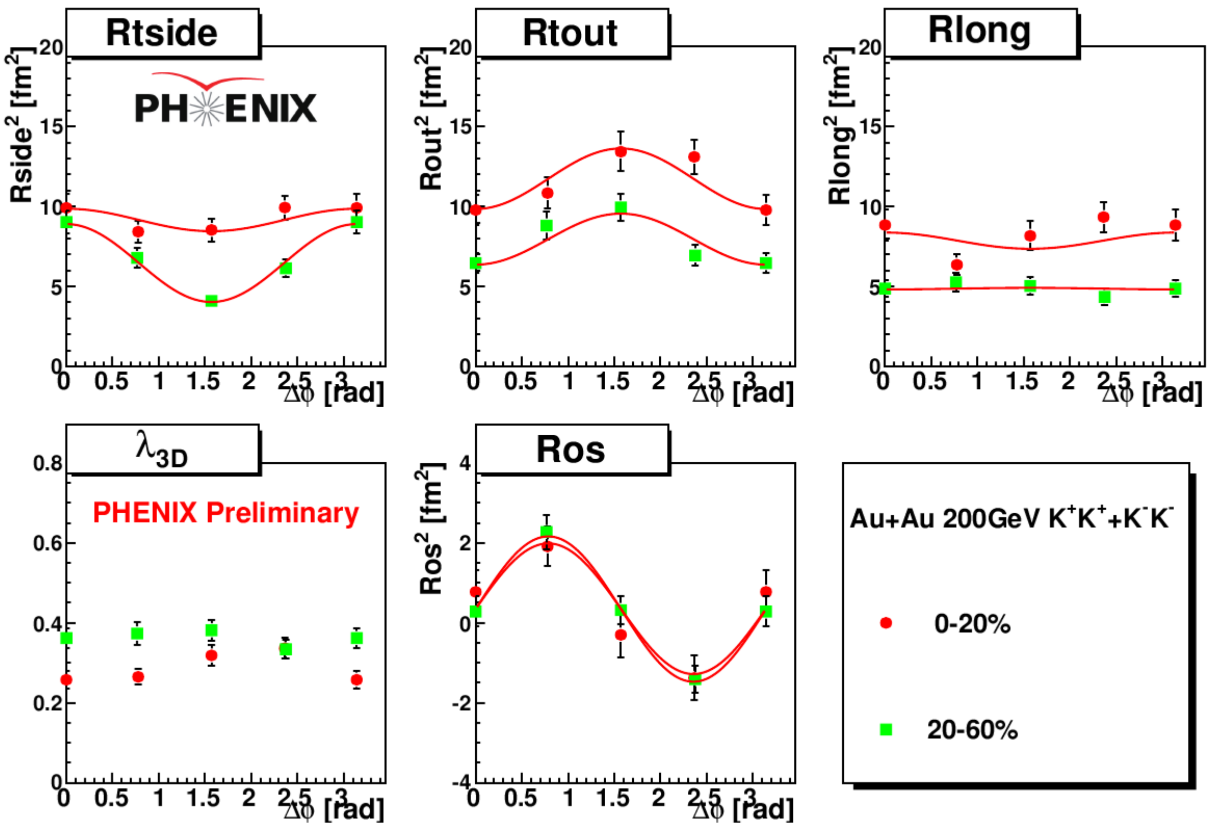


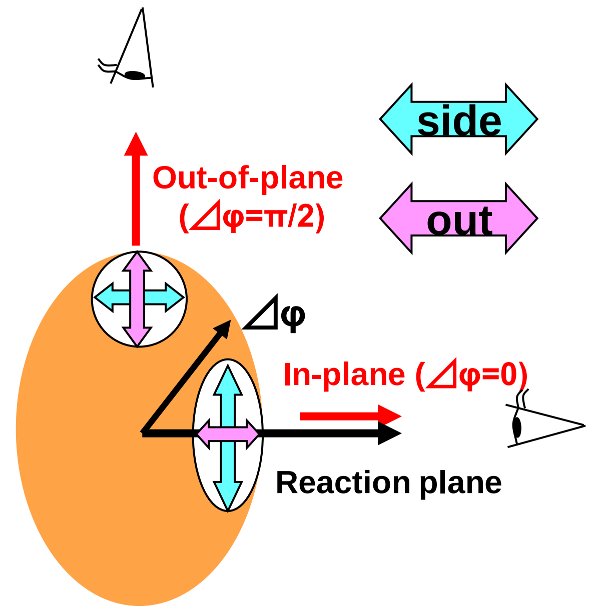
Azimuthal dependence of HBT radii for kaon

- Observed the oscillation for R_{side}, R_{out}, R_{os} as well as pion
- Data points are fitted by cosine series function

$$R = R_{\mu,0}^2 + 2R_{\mu,2}^2 \cos(2\Delta\phi) \qquad \mu = s, o, l$$

$$R = R_{\mu,0}^2 + 2R_{\mu,2}^2 \sin(2\Delta\phi) \qquad \mu = os$$





Eccentricity at freeze-out

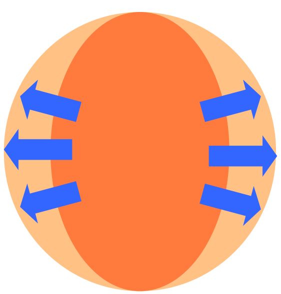
- Final eccentricity is defined as $\varepsilon_{final} = 2\frac{R_{s,2}^2}{R_{s,0}^2}$ by Blast-wave model

<u>if $\varepsilon_{final} = \varepsilon_{initial}$</u>

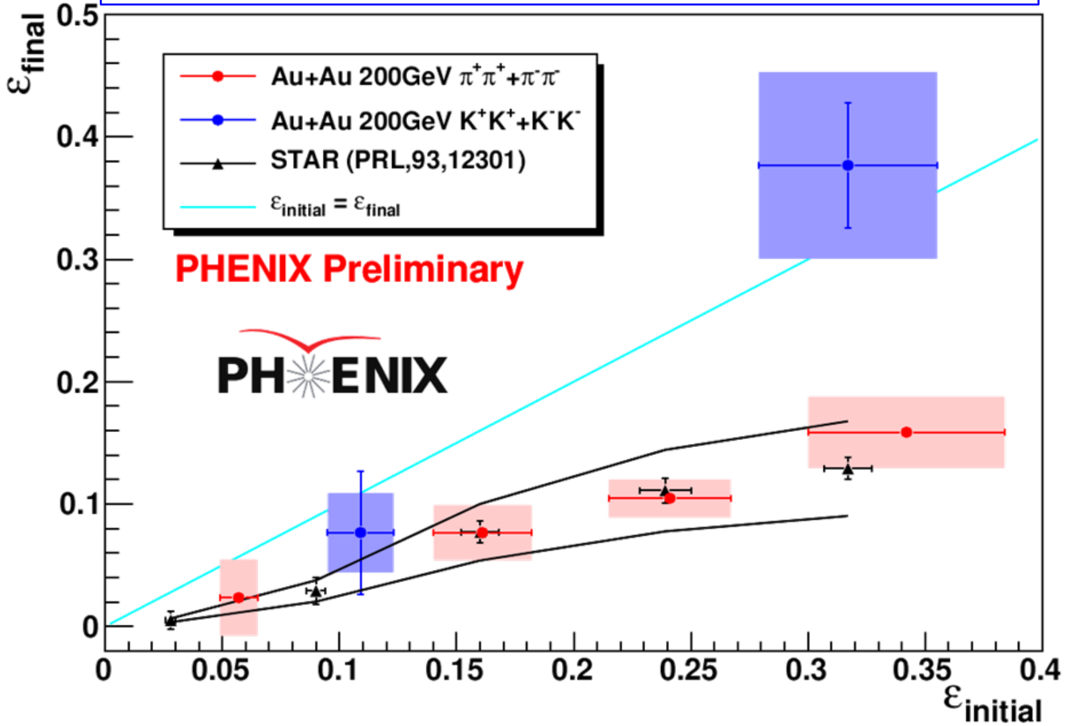
Same source shape between
Initial state and freeze-out

<u>if $\varepsilon_{final} < \varepsilon_{initial}$</u>

Source expands to In-plane direction



$\varepsilon_{initial}$: initial eccentricity calculated by Glauber model
ε_{final} : final eccentricity calculated by above

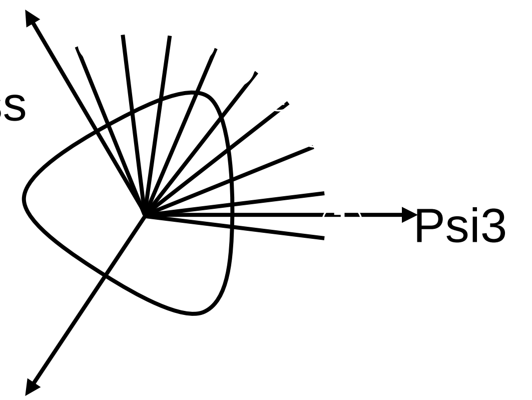


- **PHENIX result is consistent with STAR result for pion**
- **ε_{final} of kaon is larger than that of pion and close to $\varepsilon_{initial}$**
  - **Due to different average m_T? or different cross section?**

Summary & Outlook

- Measurements of azimuthal dependence of HBT radii for pion and kaon in Au+Au 200GeV collisions
  - Observed the oscillation of R_{side} and R_{out} for kaon as well as for pion
  - 4^{th} order in oscillation of R_{side} for pion is zero within systematic error
  - Final eccentricity of pion is consistent with STAR result
  - Final eccentricity of kaon is larger than that of pion

- Outlook
  - Need to check m_T dependence of final eccentricity
    - Possible to understand the difference of pion and kaon?
  - Comparison with model (ex. blast wave model)
  - Azimuthal HBT w.r.t higher order event plane
    - Analysis using 3^{rd} order event plane is in progress
    - Provides information about relation between v_3 and source shape?



Thank you!

Back up

Data selection

- Data
  - Run7 Au+Au 200GeV
- Track Cut
  - quality: 63 or 31
  - pion : pt > 0.2[GeV/c] && mom<2.0[GeV/c]
  - kaon : pt > 0.3[GeV/c] && mom<2.0[GeV/c]
  - temc < 50[nsec]
  - 3σ matching cut @ PC3
  - 3σ matching cut @ EMC
  - ecent > 0.1[GeV]
  - EMC–west(all sectors)

- PID
  - pion: Pi<2σ && K>2σ && P>2σ
  - kaon: Pi>2σ && K<2σ && P>2σ

- Event mixing
  - Zvertex: 30[bins]
  - Centrality: 20[bins] (10[bins] for kaon)
  - Reaction plane by RxP: 30[bins] (20[bins] for kaon)