HBT and Collective Flow at Mid-Rapidity in d+Au and Au+Au collision systems

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for the PHENIX Collaboration

PHENIX

Stony Brook University

Outline

1. Motivation

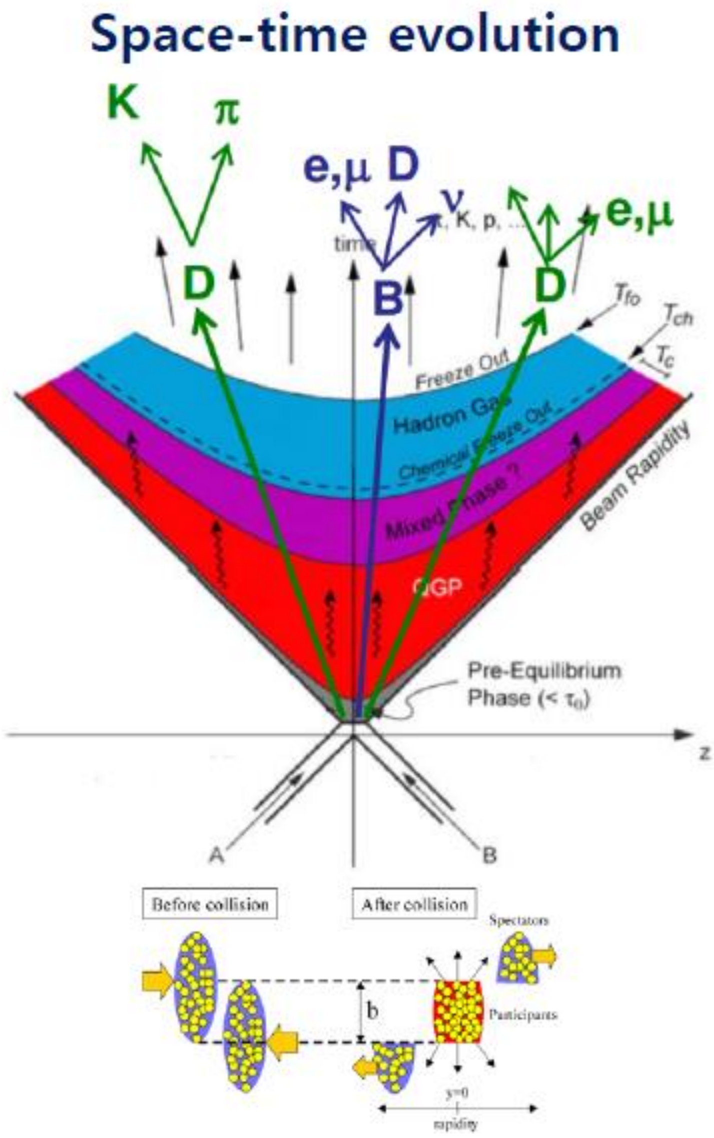
2. d+Au Flow

3. d+Au HBT

4. Scaling in HBT

5. Conclusions

Motivation



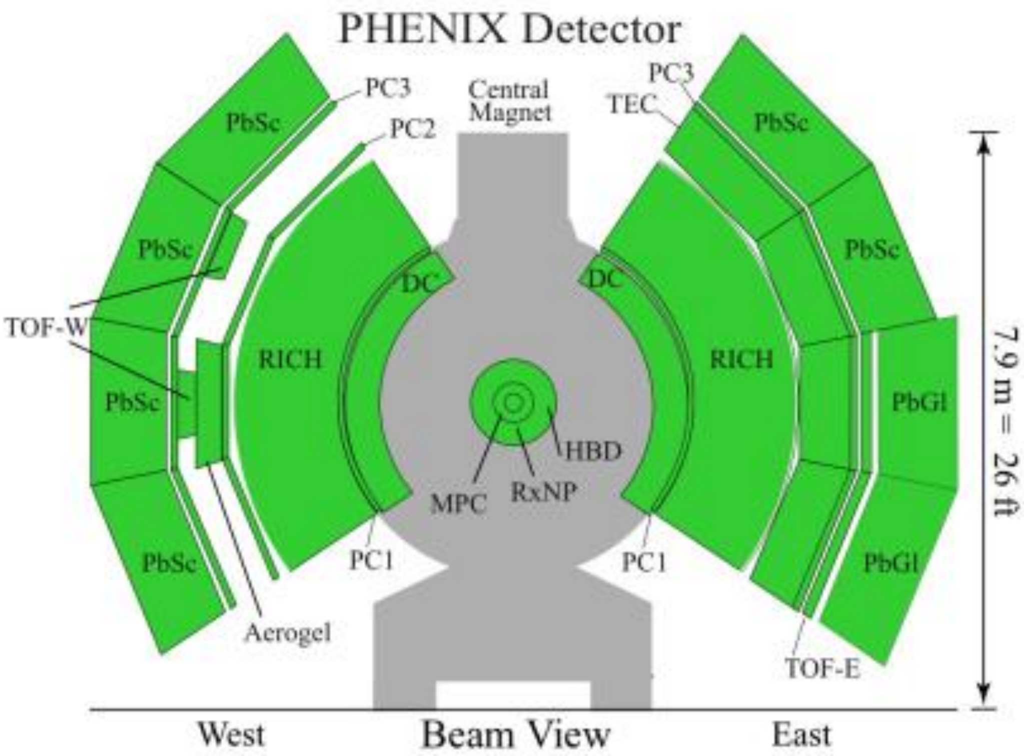
It is generally accepted that in relativistic A-A collisions a QGP medium is formed which signals its presence through long range correlations.

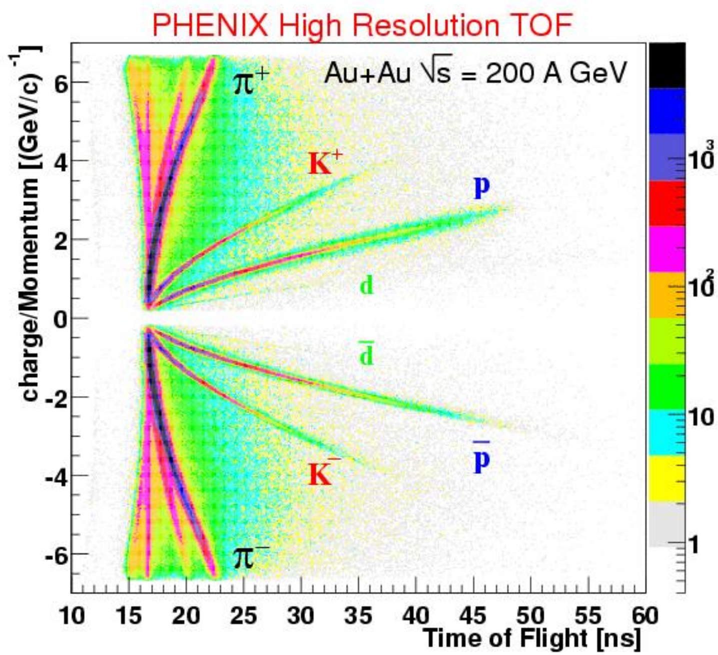
It was thought that p+p and p+A collisions are not capable of forming such a medium because of the small system size.

Recent experiments at the LHC have seen long range correlations in p+p and p+A systems in high multiplicity events
What about d+Au at RHIC ?

The PHENIX detector at RHIC

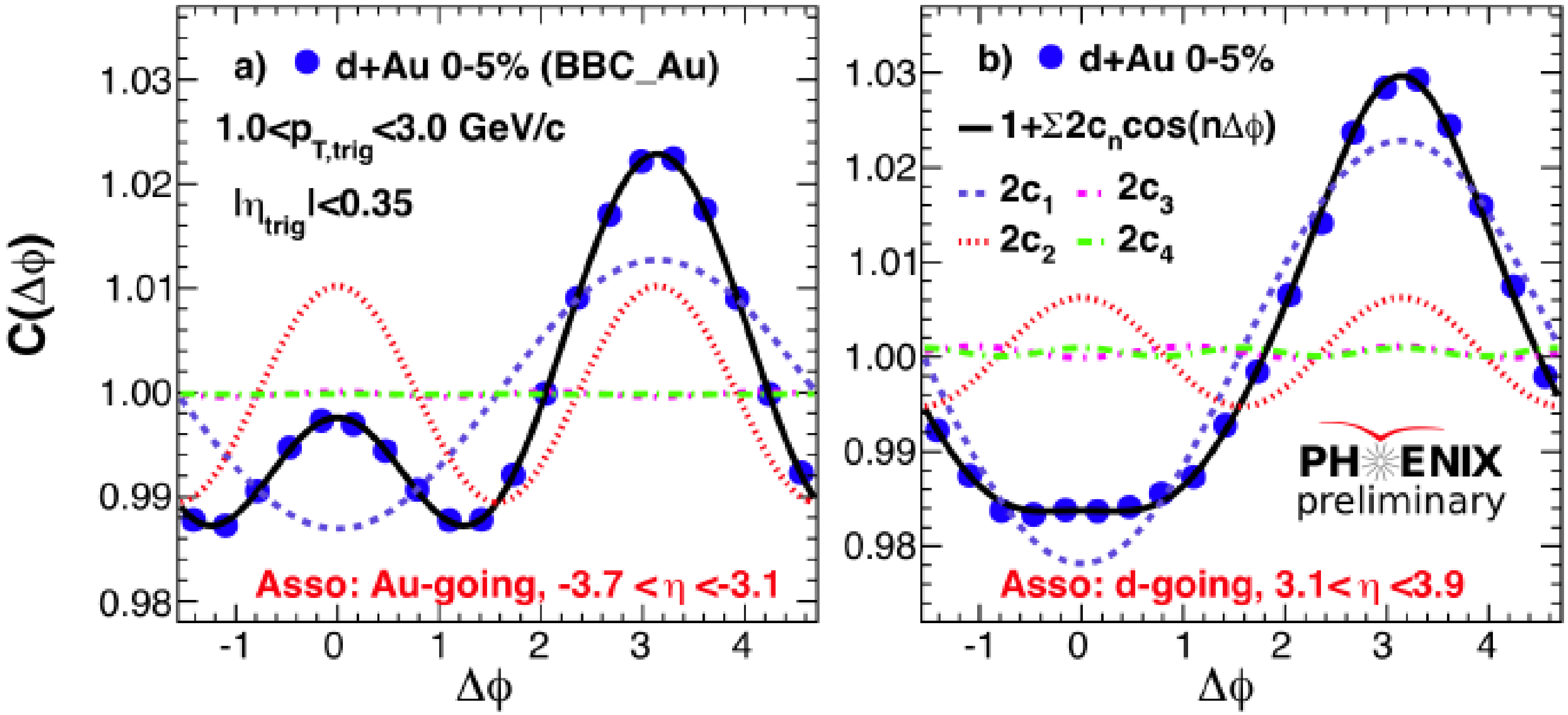
Zero Degree Calorimeter (ZDC) & Beam Beam Counter (BBC)
Vertex and centrality determination
Drift Chamber (DC) & Pad Chamber (PC) Tracking information
Electromagnetic Calorimeter (EMC) ,
Time-of-Flight Detector (TOF) PID information

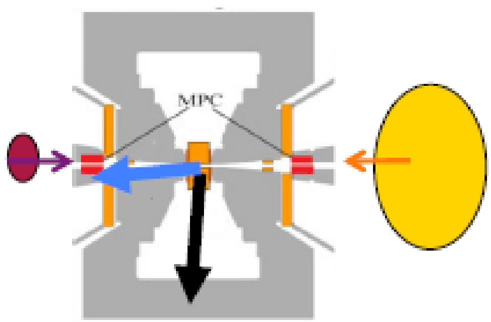


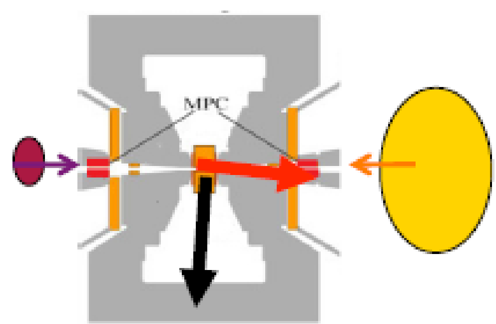


Good acceptance
Very good π-K separation

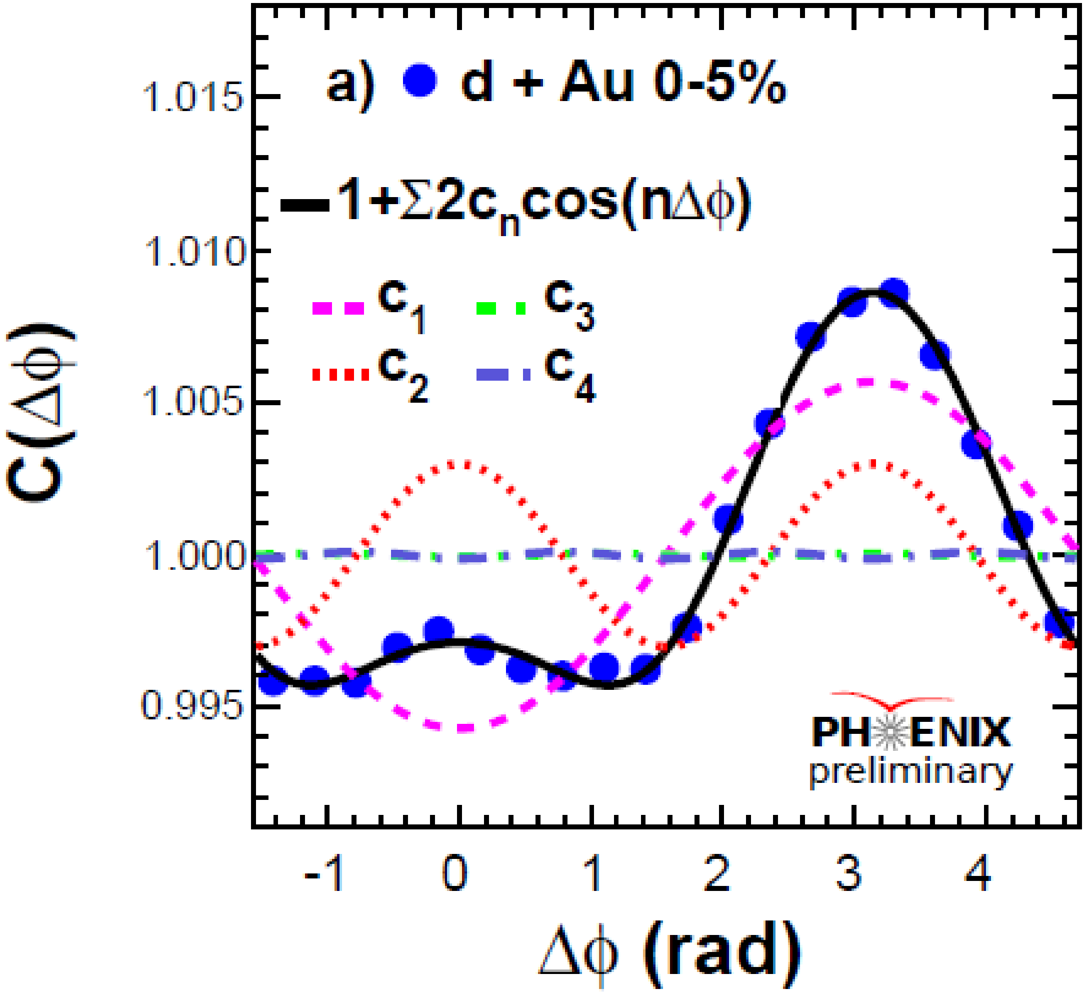
"Au-going" vs "d-going"

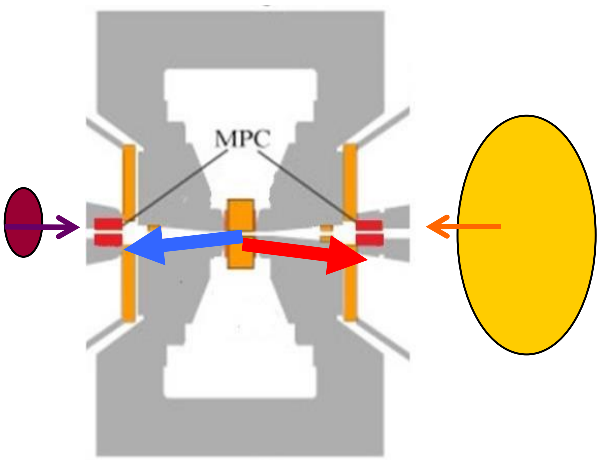






A ridge is observed with $|\Delta\eta| > 6.0$



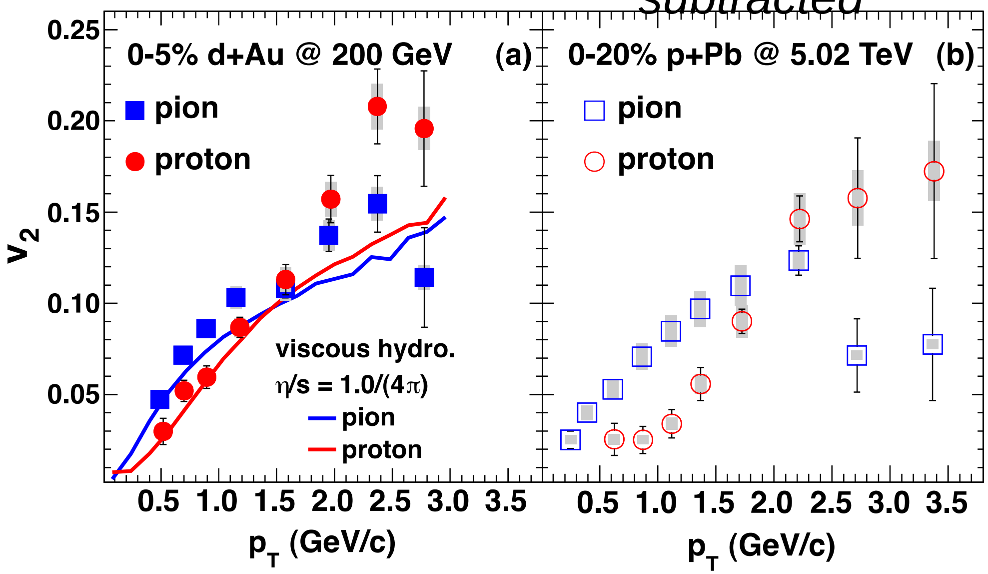


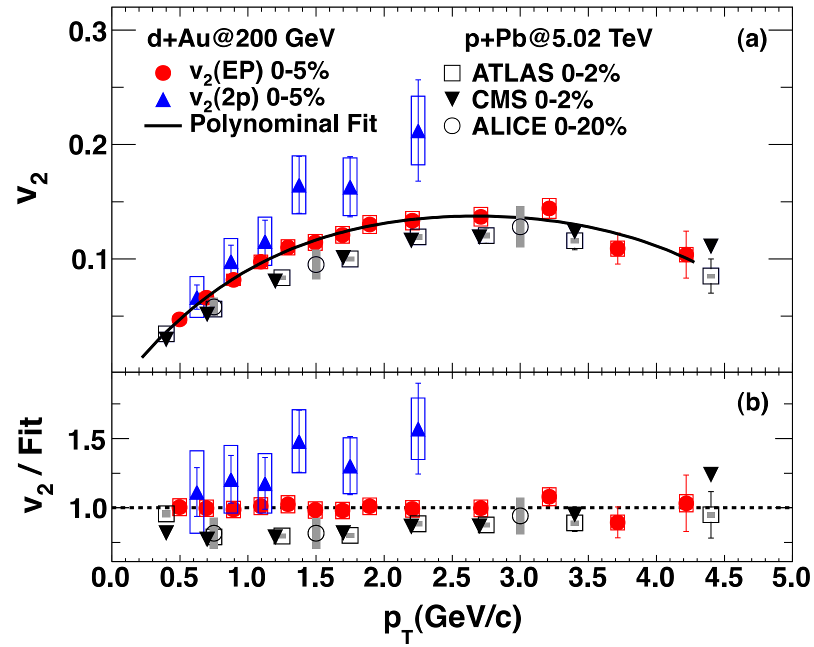
- ❑ Correlation between Au-going and d-going MPC towers

d+Au flow

arXiv:1404.7461

peripheral subtracted





Mass ordering of v2

mass splitting for d+Au at RHIC is less than that for p+Pb at LHC

Maybe due to lower radial flow at RHIC

pT dependence of v2

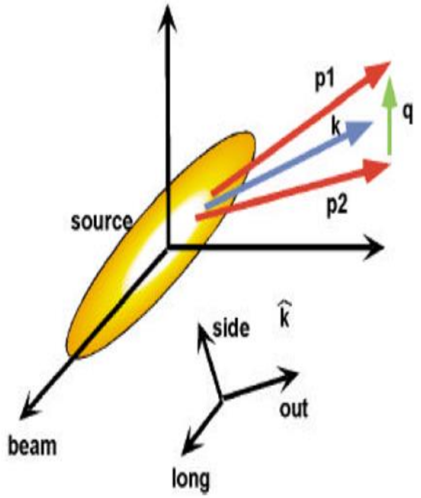
d+Au results at RHIC ~ than for p+Pb at LHC

Both CGC and hydrodynamic expansion models describe certain features of the large angle correlations

Next we look at small angle (HBT) correlations which carry information specifically about the space-time extent of the system at freeze-out

Common trends in A+A and p+A systems in HBT measurements would be a strong indication of a commonality of the underlying physics

HBT Methodology



Space-momentum correlation function

$$C(q,k) - 1 = \int \left(d^3 r S_k(r) \left[|\left(\psi(k,r)\right)|^2 - 1 \right] \right)$$

S : 3D Gaussian Source distribution
ψ : final state interactions

$$S(\vec{r}) \sim \exp\left(-\frac{r_{out}^2}{R_{out}^2} - \frac{r_{side}^2}{R_{side}^2} - \frac{r_{long}^2}{R_{long}^2} \right)$$

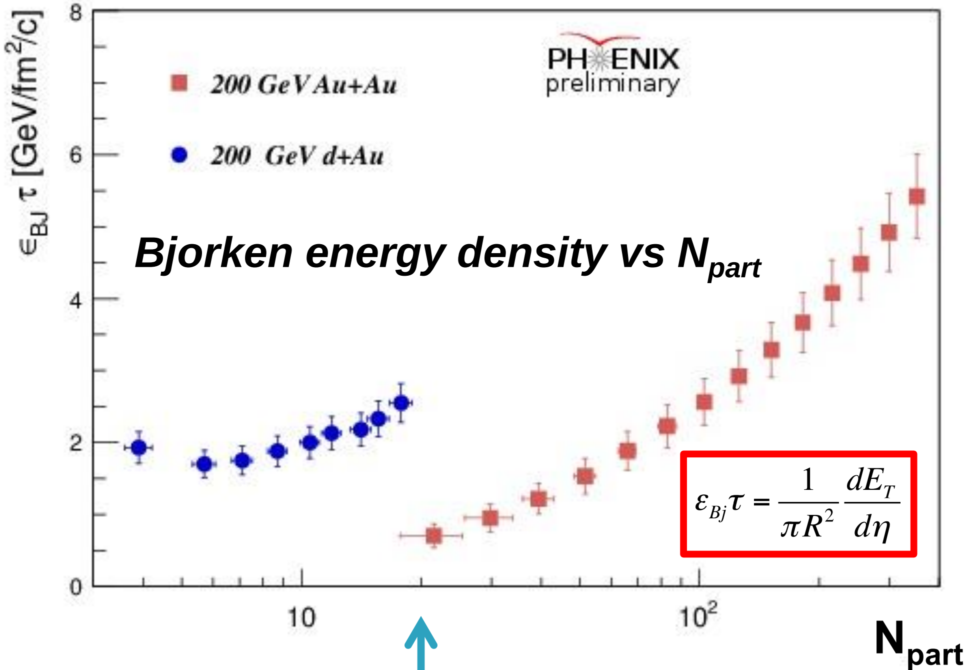
In longitudinally co-moving frame correlation can be written as :

$$C\left(q_{side}, q_{out}, q_{long}\right) = (1-\lambda) + \lambda(1+\mathrm{G})\mathrm{F}c\ ,$$

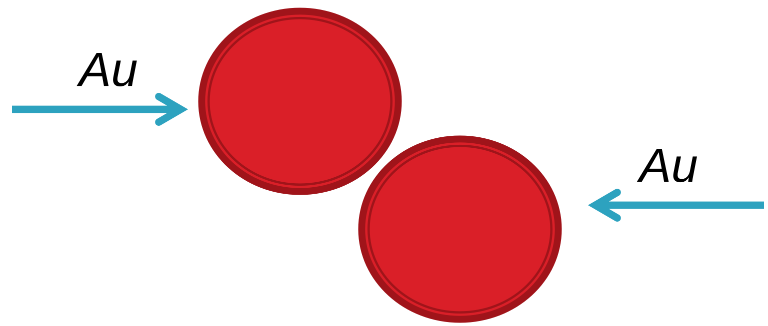
Fc=Coulomb Correction

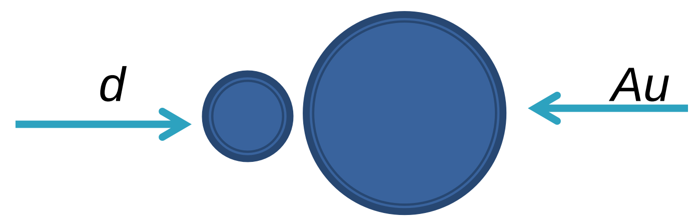
$$G = \exp\left(-R_{side}^2 q_{side}^2 - R_{out}^2 q_{out}^2 - R_{long}^2 q_{long}^2\right)$$

q_{side} perpendicular to beam,
q_{out} parallel to $\vec{k}$,
q_{long} along beam



Initial Parameters for peripheral Au+Au and central d+Au

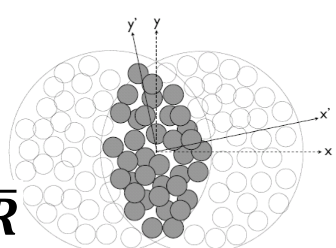




	N_{part}	$dE_T\,/\,d\eta$	$\bar{R}$	ε
Au+Au	16.7±1.1	19±.1.5	0.71	0.5
d+Au	15.7±1.6	22±1.5	0.44	2.5

Glauber Model initial size

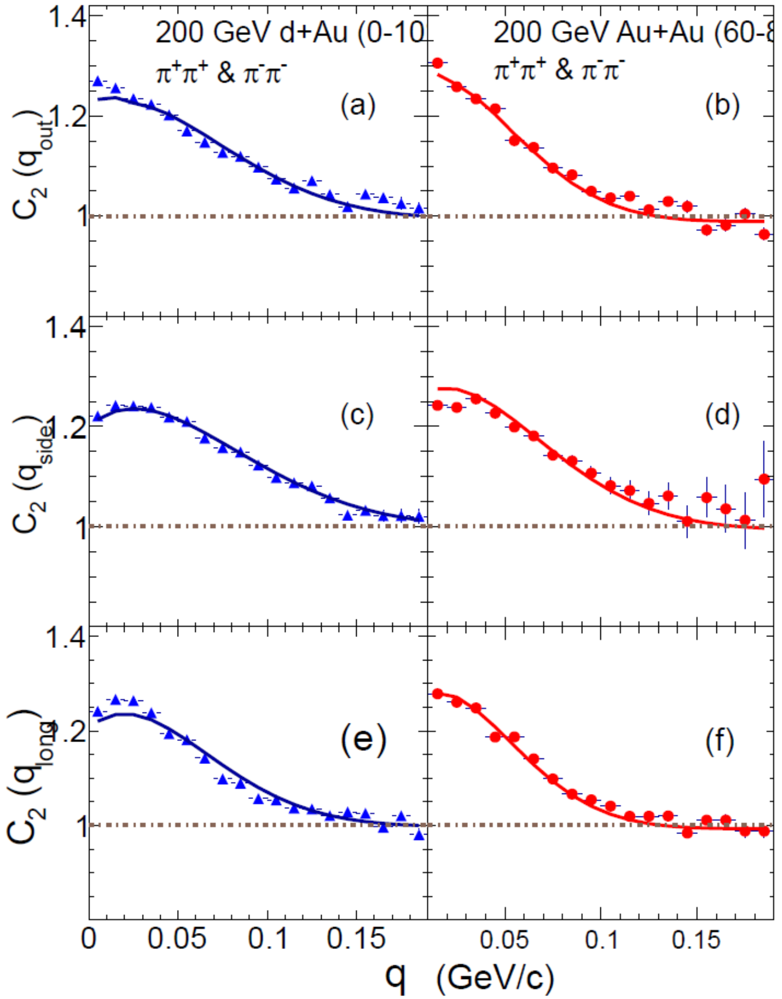
$\bar{R}$



$$\frac{1}{\bar{R}} = \sqrt{\left(\frac{1}{\sigma_x^2} + \frac{1}{\sigma_y^2}\right)}$$

σ_x & σ_y → RMS widths of density distribution

	N_{part}	$<k_T>$
Au+Au	16.7±1.1	0.39
d+Au	15.7±1.6	0.39



HBT Correlation functions at similar N_{part} and k_T

d+Au broader than Au+Au

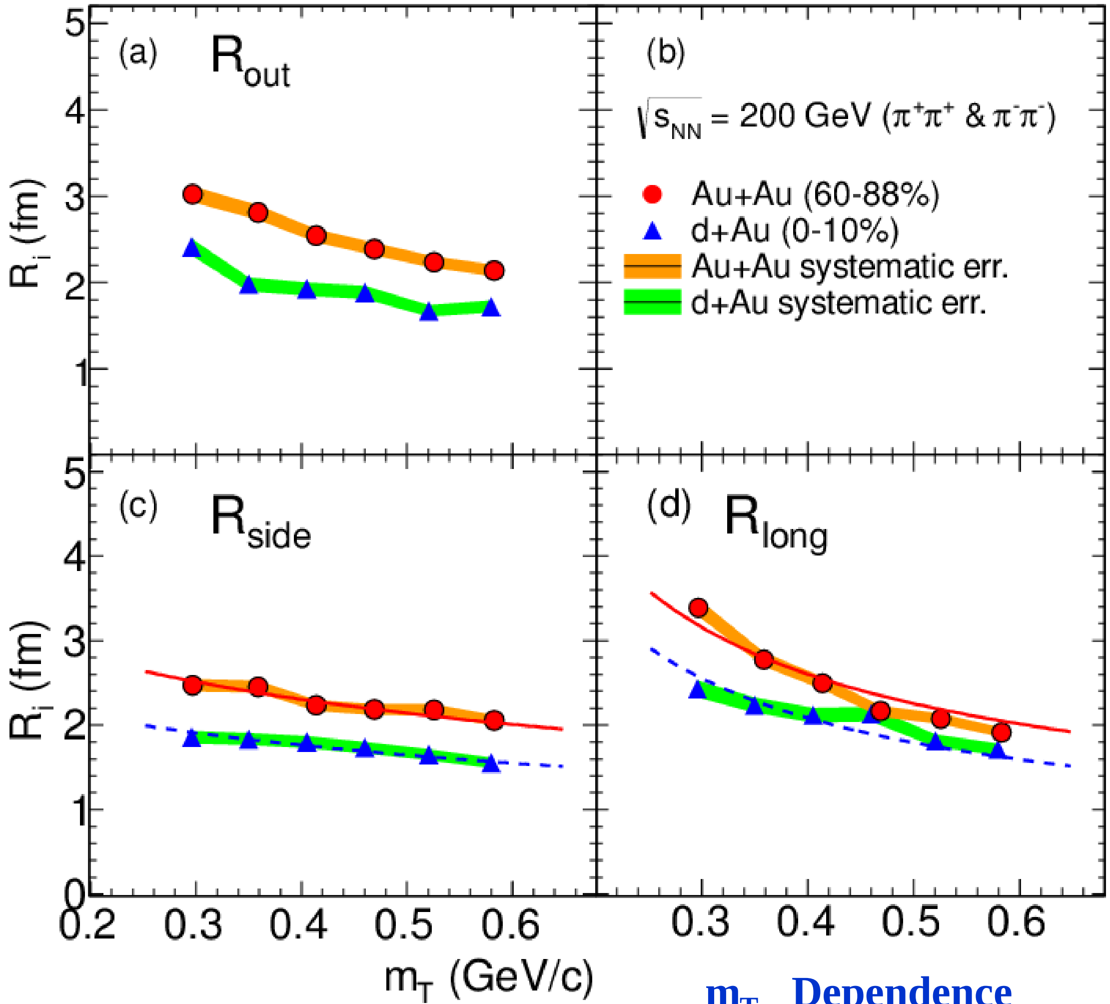
implying a smaller Rside

dAu HBT

arXiv:1404.4946

Similar m_T dependence observed in d+Au and Au+Au

As expected from space momentum correlations Introduced by hydrodynamic expansion



m_T Dependence

Blast Wave Fit defined by expansion velocity and temperature at freeze-out

Smaller size for d+Au

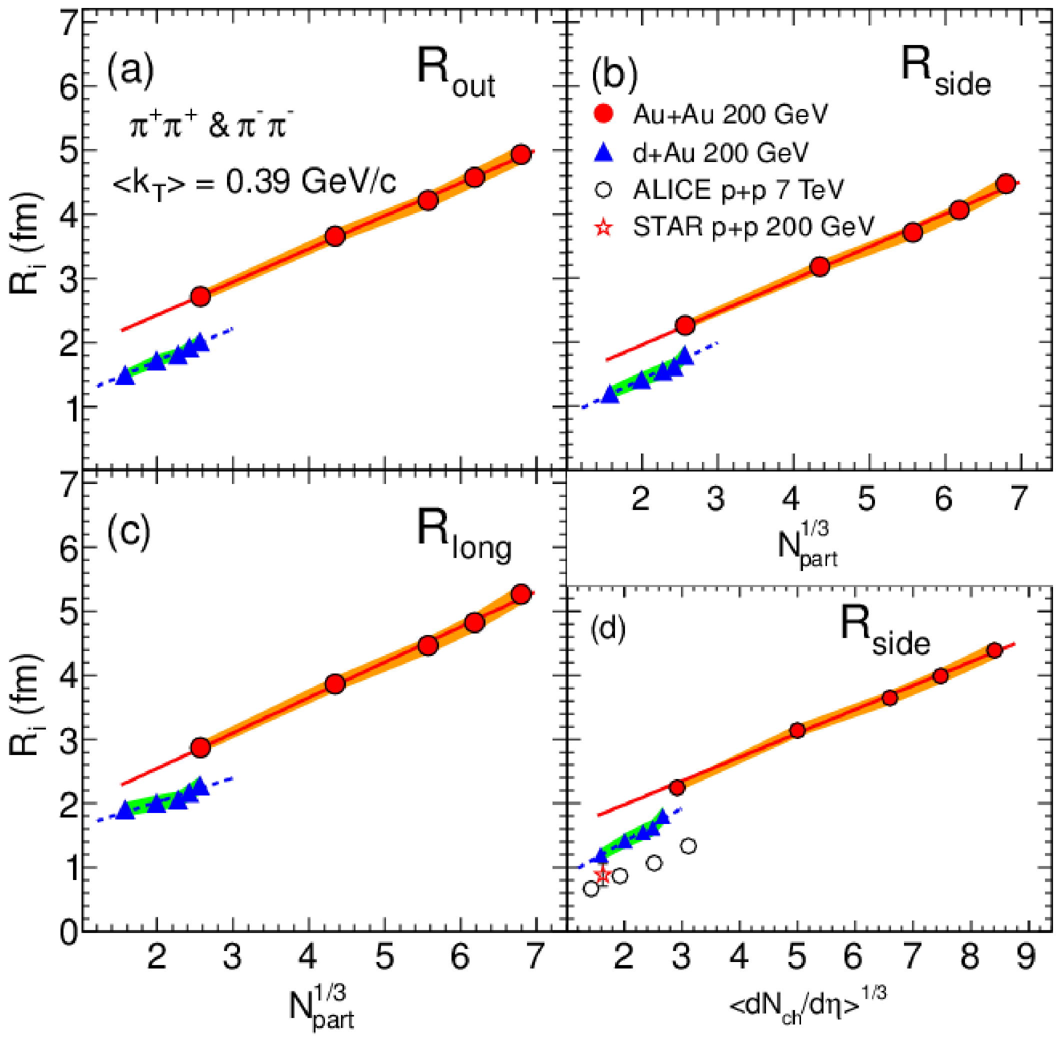
$$R_{side} = R_{geom} / \sqrt{(1 + \beta^2 (m_T / T))},$$

$$R_{long} = \tau_0 \sqrt{(T / m_T)[(K_2(m_T/T))/(K_1(m_T/T))]},$$

TABLE I. Fit parameters

	d+Au	Au+Au
τ_0 (fm/c)	3.2 ± 0.04 ± 0.4 (syst)	3.8 ± 0.04 ± 0.3 (syst)
χ^2/ndf	26/5	24/5
R_{geom} (fm)	2.2 ± 0.03 ± 0.2 (syst)	2.8 ± 0.03 ± 0.2 (syst)
χ^2/ndf	6/5	4/5

arXiv:1404.4946



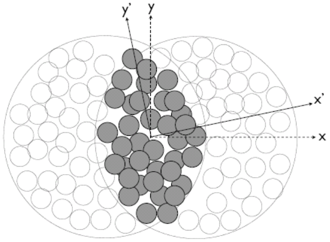
Pion HBT radii as a function of $N_{part}^{1/3}$

d+Au and Au+Au do NOT scale together

Hydro models associate a larger expansion time with a larger initial size
Does it make $\bar{R}$ a good scaling parameter ?

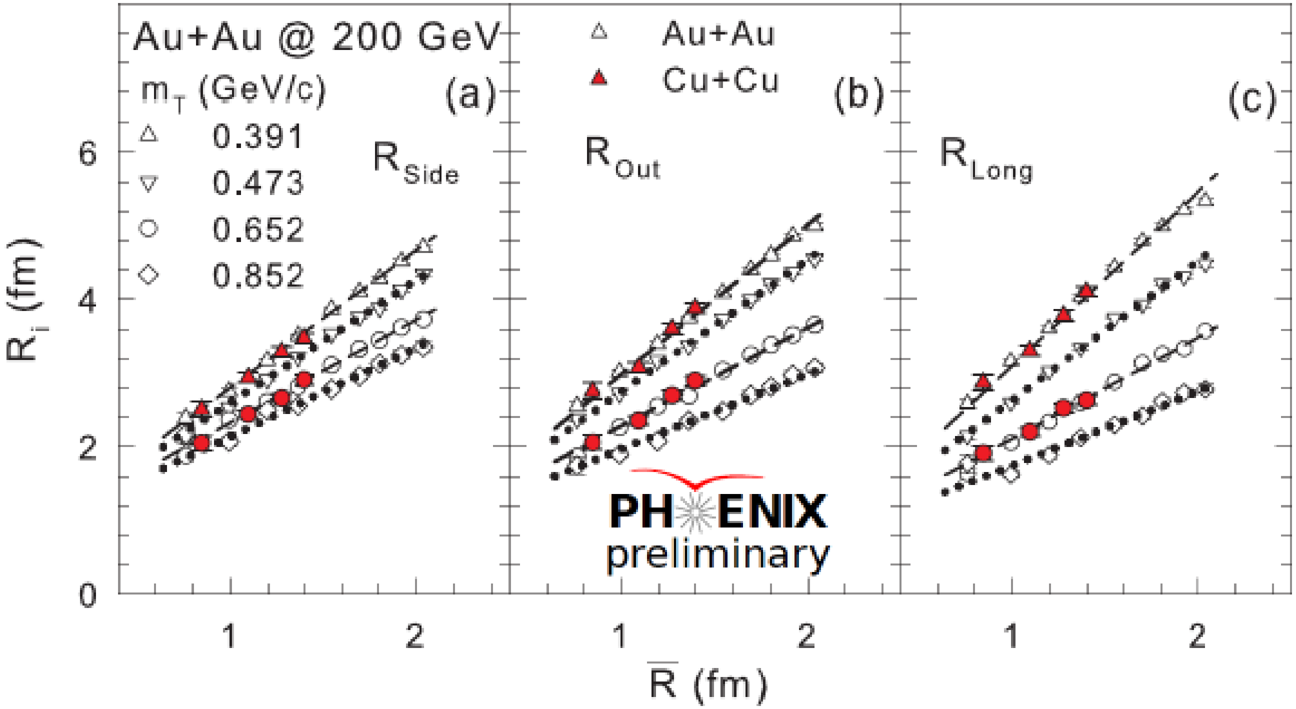
Use Glauber model to get

$N_{part}^{1/3}$ *vs* *initial size* $\bar{R}$



$$\frac{1}{\bar{R}} = \sqrt{\left(\frac{1}{\sigma_x^2} + \frac{1}{\sigma_y^2}\right)}$$

σ_x & σ_y → RMS widths of density distribution

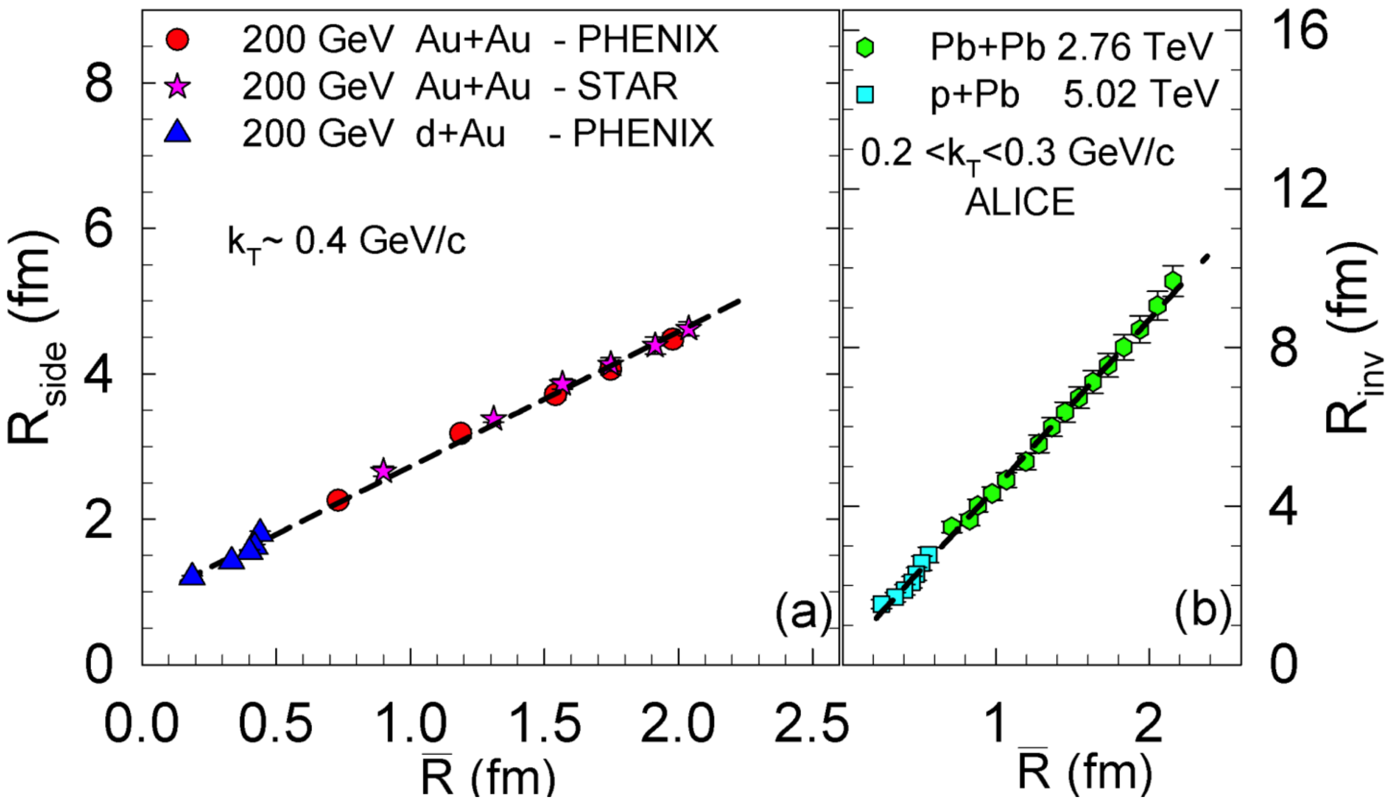


Pion HBT radii scale with $\bar{R}$

Linear dependence of transverse expansion on initial geometry

Application of $\overline{R}$ scaling to d+Au and p+Pb

arXiv:1404.4946



Linear dependence and good scaling seen between p/d+A and A+A systems Implies radial expansion in d+Au collisions

dAu HBT

arXiv:1404.4946

R_{out} / R_{side} ~ 1

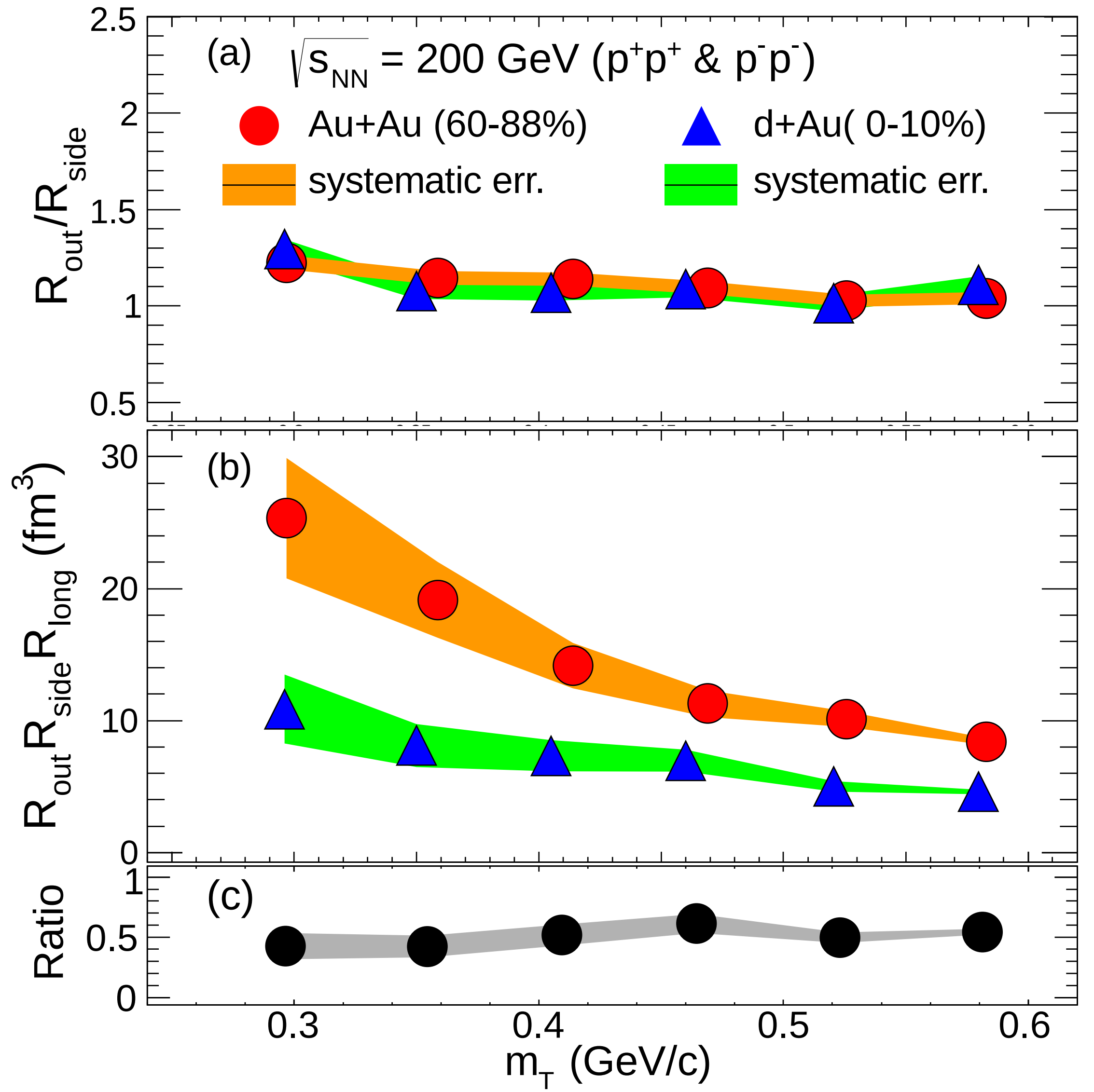
short emission duration

Freeze-out volume

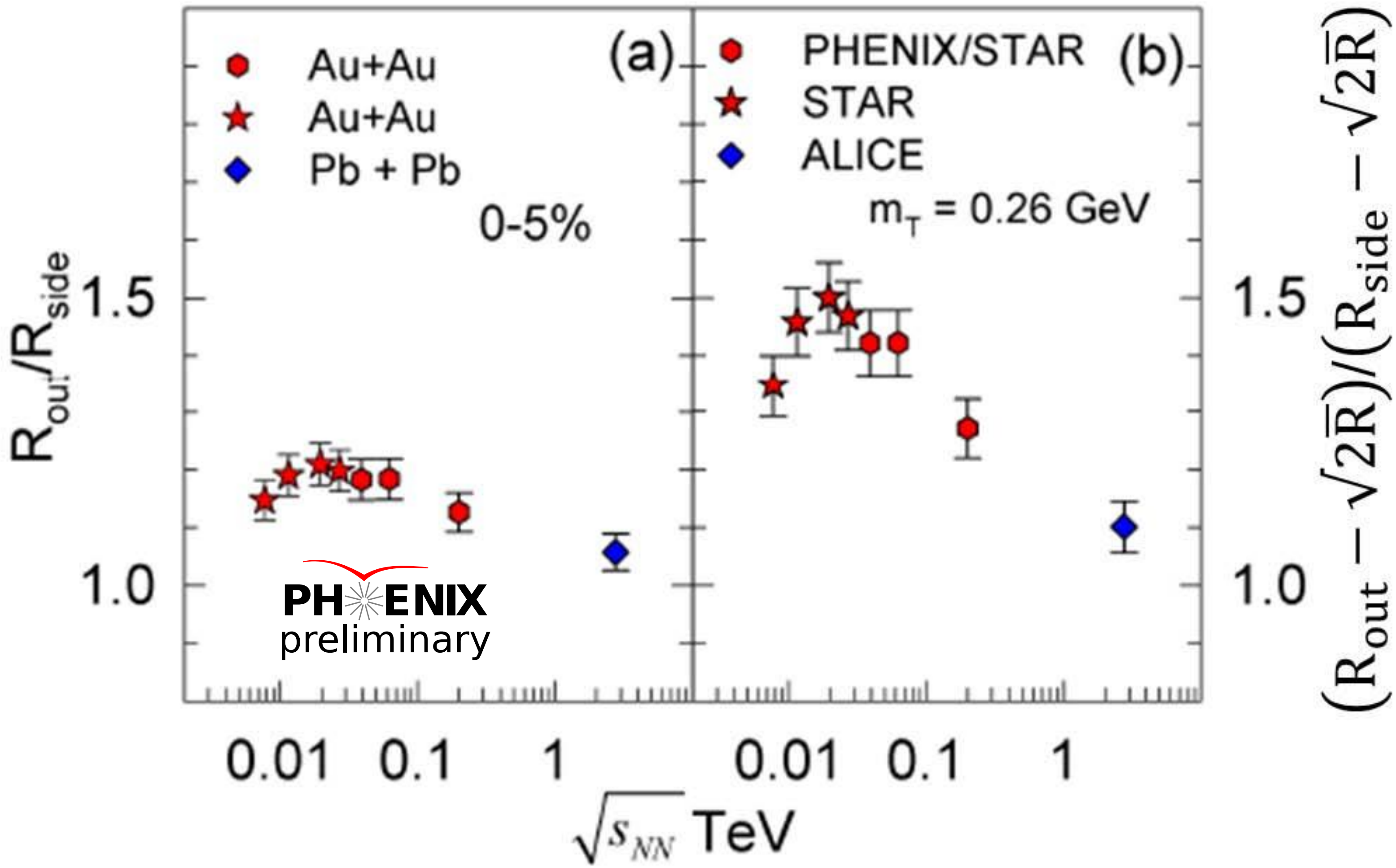
V ~ R_{out} x R_{side} x R_{long}

V(d+Au) < V(Au+Au)

mT dependence of V is similar

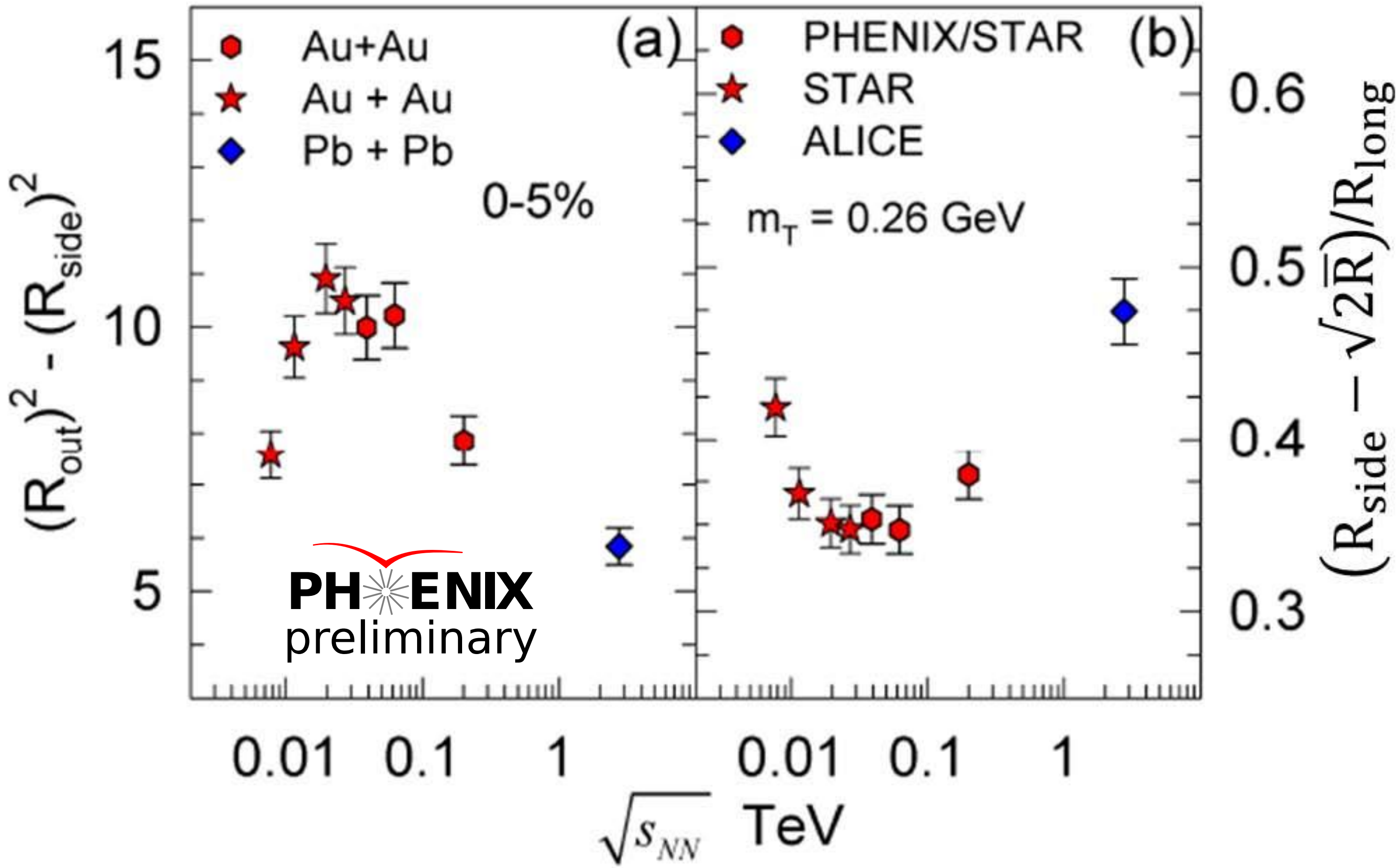


Measures of emission duration



- Non-monotonicity in R_{out}/R_{side}
- Subtract $\sqrt{2}\bar{R}$ to (over) estimate expansion

Emission duration and expansion/lifetime



- Non-monotonicity magnified with $(R_{out})^2$ – $(R_{side})^2$
- R_{side}/R_{long} indicative of expansion/lifetime

Summary and Conclusions

v2 in d+Au at RHIC is comparable to that in p+Pb at LHC

Mass splitting of v2 at RHIC is smaller than in p+Pb at LHC

Smaller Radial flow at RHIC

m_T dependence of HBT radii are similar for d+Au and Au+Au

Implies similar expansion dynamics

HBT radii scale with $\bar{R}$ across systems

Results suggest radial expansion in d+Au collisions as seen in hydro-dynamic evolution with final state scattering

A CGC calculation of the HBT results presented here would be quite useful

Non-monotonic $\sqrt{s_{NN}}$ behavior of HBT signals observed