System-size & beam energy dependence of the space-time extent of the pion emission source in HI collisions

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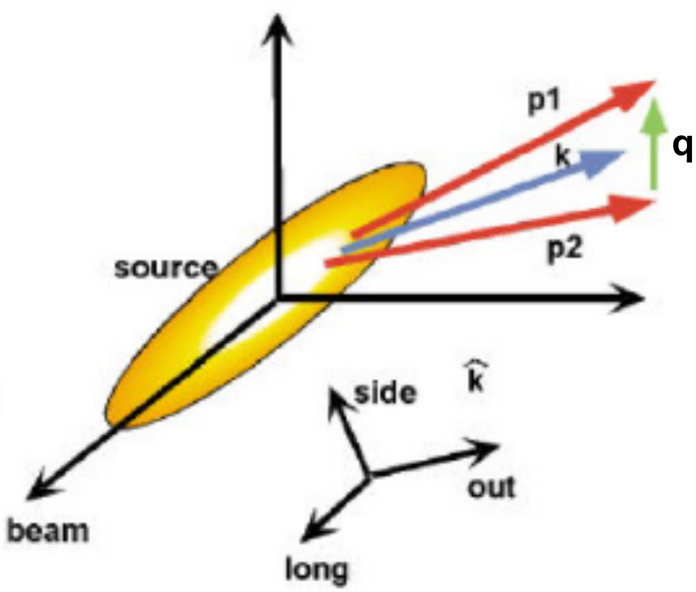
HBT methodology

- Construct 2 pion correlation function: $C_2(\mathbf{q}) = A(\mathbf{q})/B(\mathbf{q})$
  - $A(\mathbf{q})$: measured distribution of relative momentum difference $\mathbf{q}$
  - $B(\mathbf{q})$: uncorrelated distribution for pairs from mixed events
- Measured $\mathbf{q}$'s determine HBT Gaussian radii, R's

$\mathbf{q} = \mathbf{p_2} - \mathbf{p_1}$ is relative momentum difference between pion pairs
$k_T = |\mathbf{p_{T2}} + \mathbf{p_{T1}}|/2$ is pion-pair transverse momentum

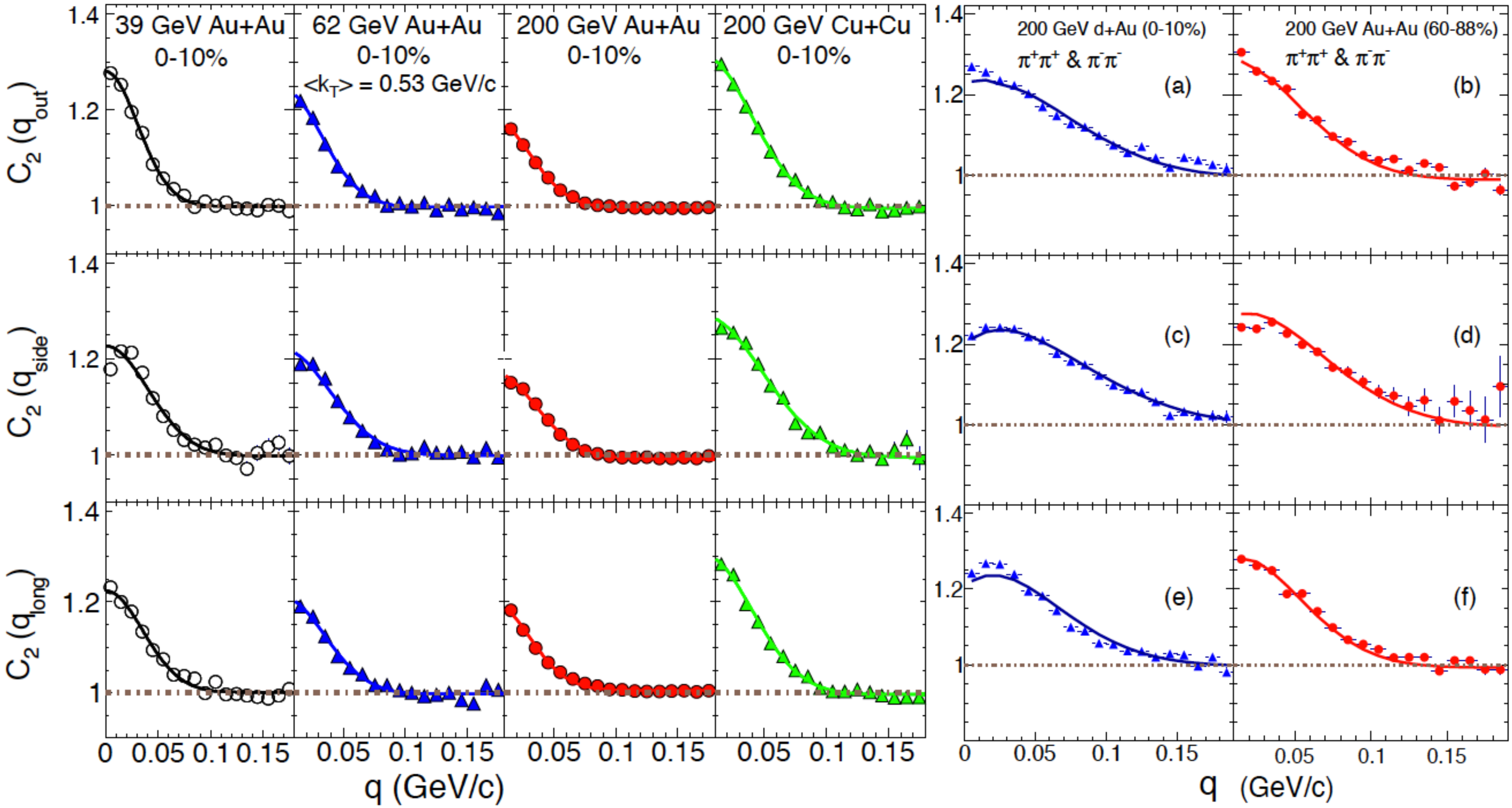


Calculated in longitudinally co-moving frame

Bertsch-Pratt convention:

- q_{out} parallel to k_T
- q_{long} parallel to beam direction
- q_{side} perpendicular to beam & k_T

3D 2 pion HBT correlation functions



Coulomb corrected fits as in PLB **432**, 248 (1998):

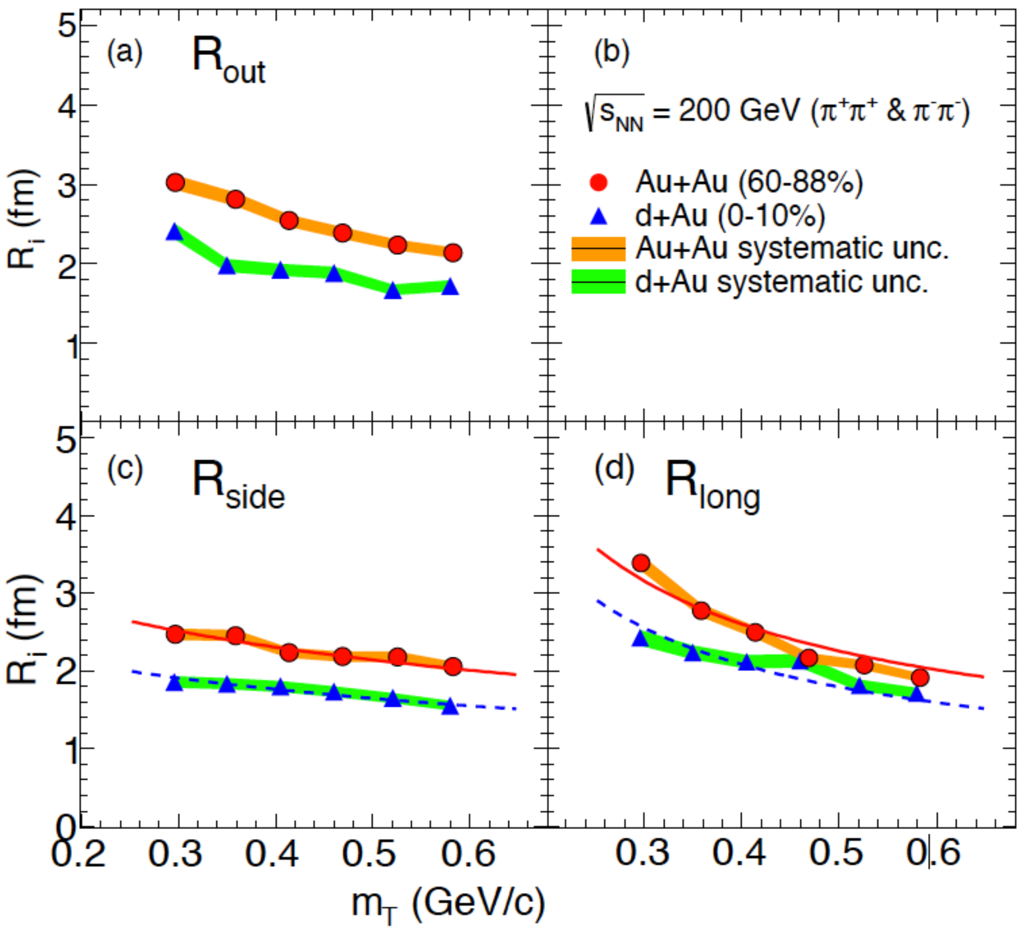
$$C_2(\mathbf{q}) = N[(\lambda(1 + G(\mathbf{q})))F_c + (1 - \lambda)]$$

$$G(\mathbf{q}) \cong \exp(-R^2_{\rm side}q^2_{\rm side} - R^2_{\rm out}q^2_{\rm out} - R^2_{\rm long}q^2_{\rm long})$$

broader width ⟶ smaller HBT radius

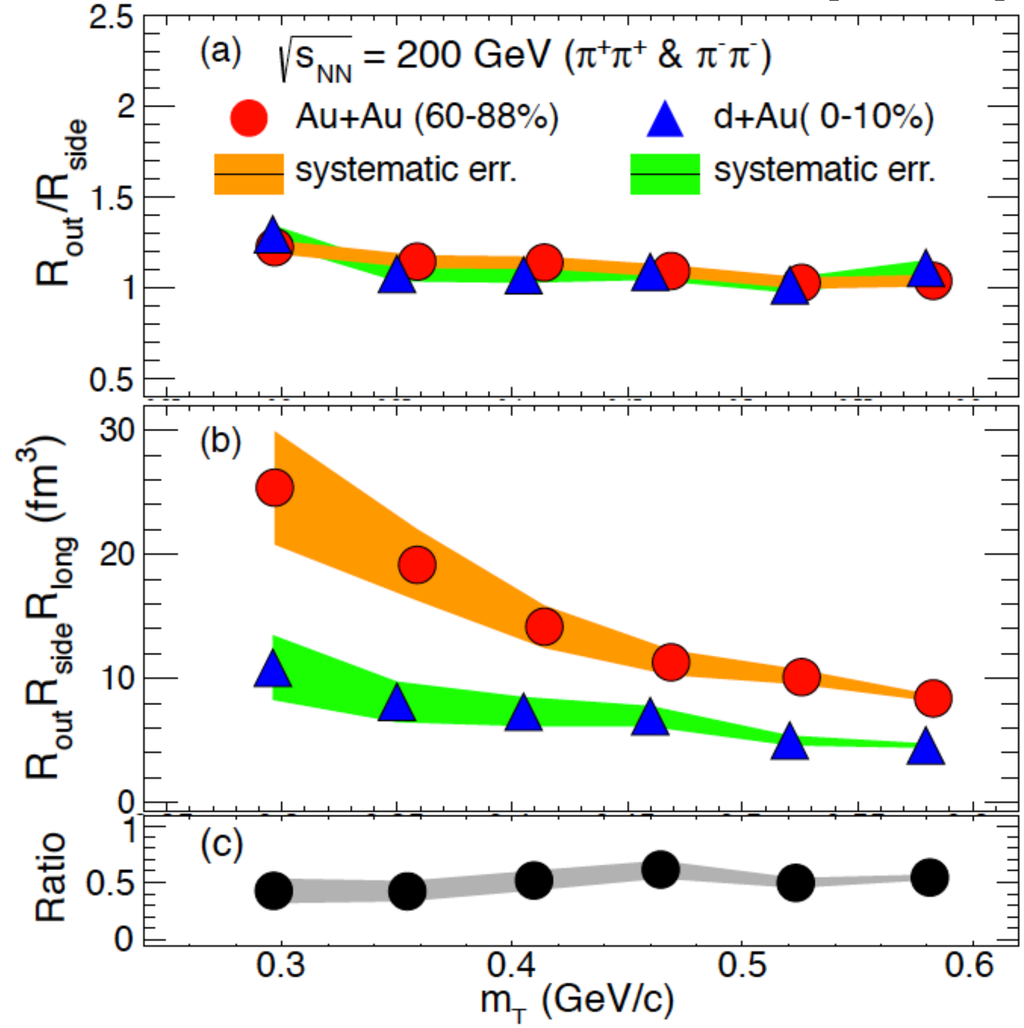
m_T dependence of HBT radii

position-momentum correlations reduce R's as in PRC **70**, 044907 (2004):



$$m_T = \sqrt{(k_T^2 + m_\pi^2)}$$

arXiv:1404.5291 [nucl-ex]

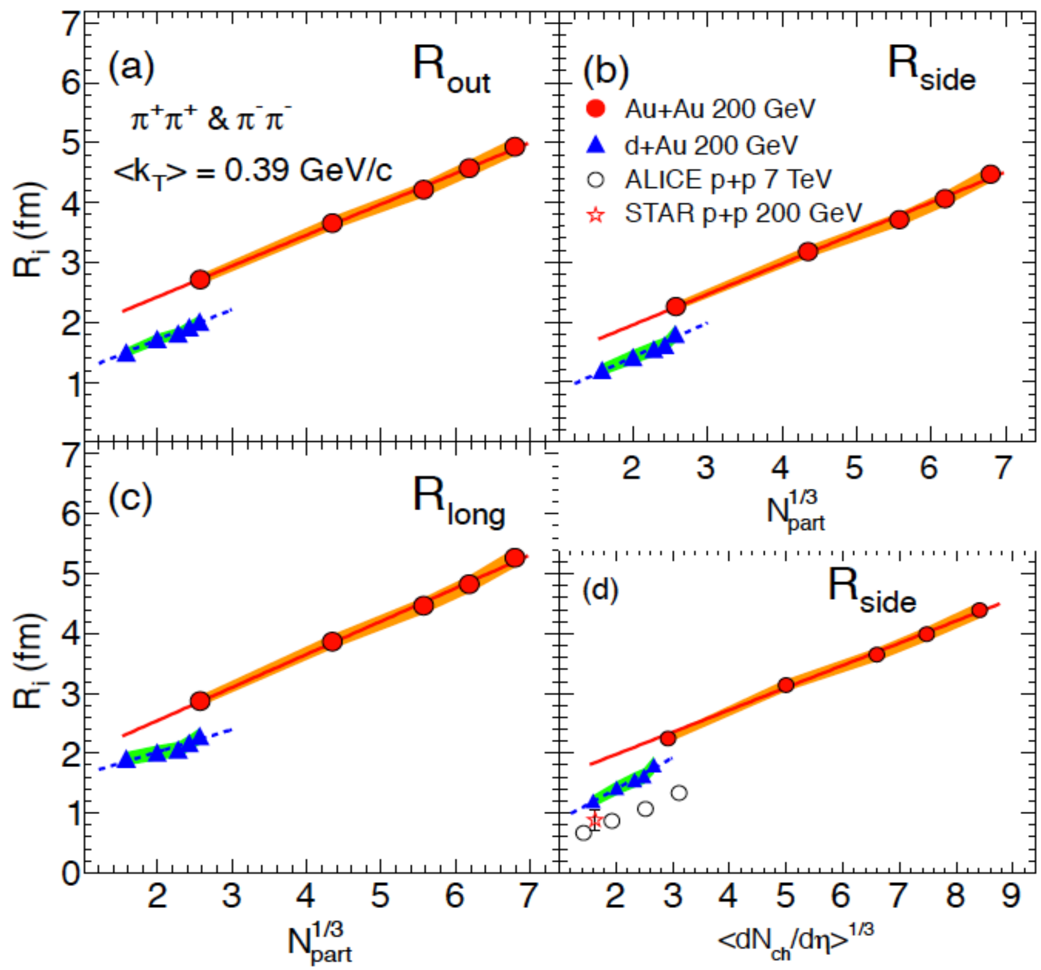


- characteristic signature for expansion of emitting source of short emission duration
- indication for final-state rescattering effects in reaction dynamics for *d*+Au

centrality (N_{part}) dependence of HBT radii

smaller transverse freeze-out size for *d*+Au emission source from blast wave fits as in PRC **52**, 2694 (1995):

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



blast wave fit functions:

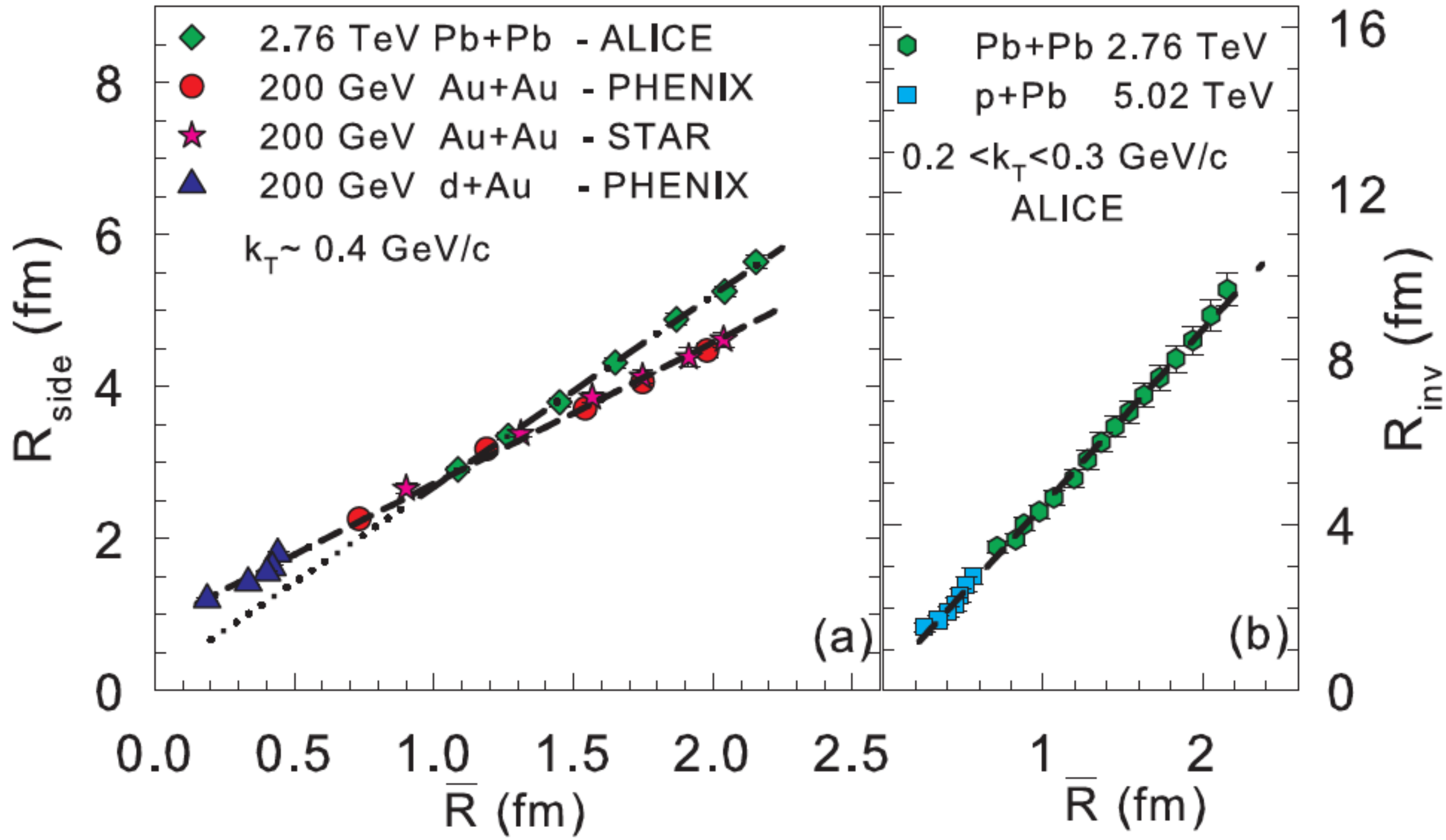
$$R_{\mathrm{side}} = R_{\mathrm{geom}}/\sqrt{(1 + \beta^2(m_T/T))}$$

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

suggests correlation between transverse freeze-out size and initial geometric size

geometric scaling of HBT radii

arXiv:1404.5291 [nucl-ex]



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

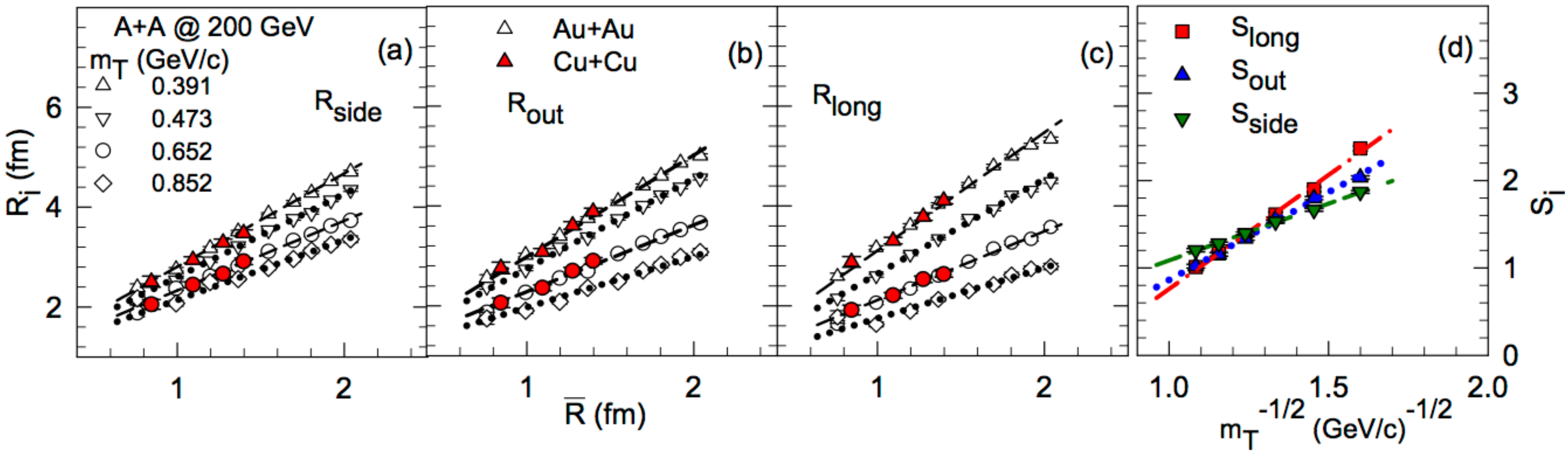
σ_x and σ_y are RMS widths of density distributions

- HBT radii scale with initial transverse size for both *p*(*d*)+A and A+A collisions
- larger slope corresponds to larger expansion rate for LHC data
- final state rescattering effects are important in *p*(*d*)+A collisions also

geometric scaling of HBT radii in HI collisions

arXiv: 1408.1343 [nucl-ex]

S_i are slopes from linear fits

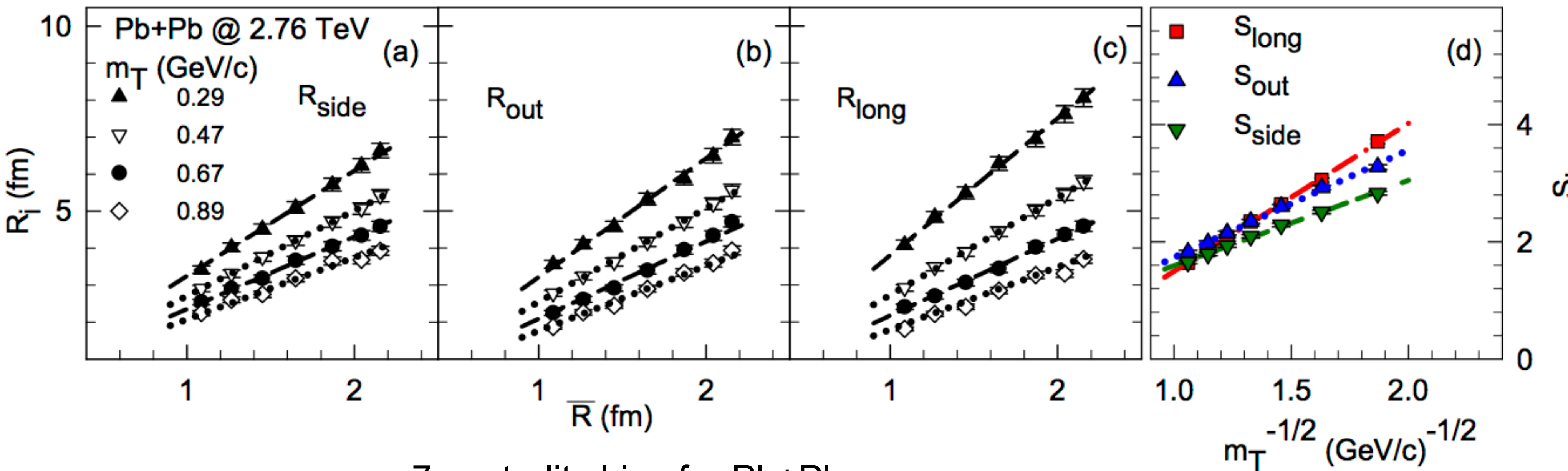


9 centrality bins for Au+Au & 4 centrality bins for Cu+Cu

Decrease in slope with m_T confirms influence of position-momentum correlations resulting from collective expansion in HI collisions.

geometric scaling of HBT radii in HI collisions

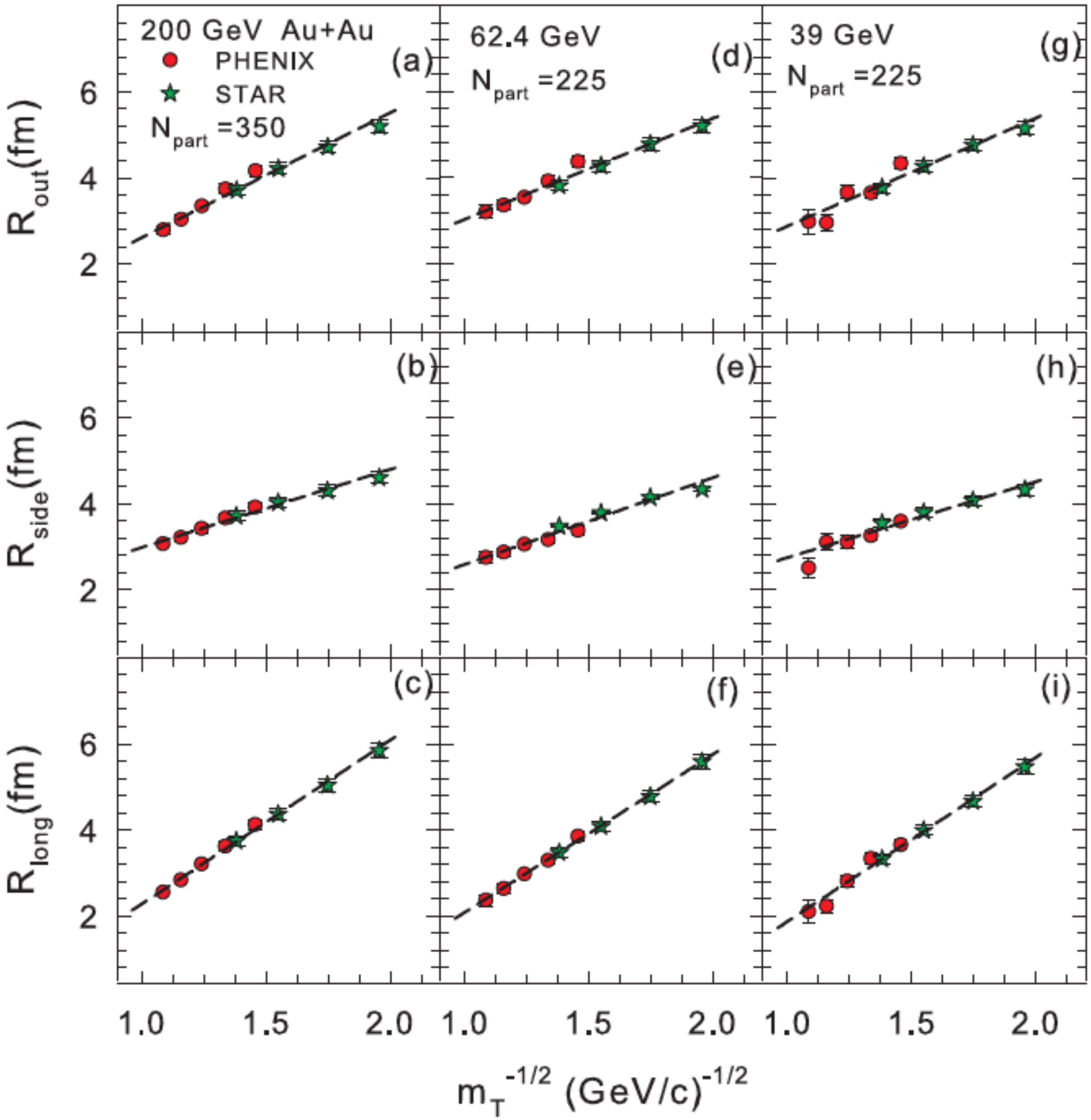
S_i are slopes from linear fits



7 centrality bins for Pb+Pb

- larger radii at LHC due to larger emission lifetime and expansion rate
- same scaling pattern at RHIC and LHC

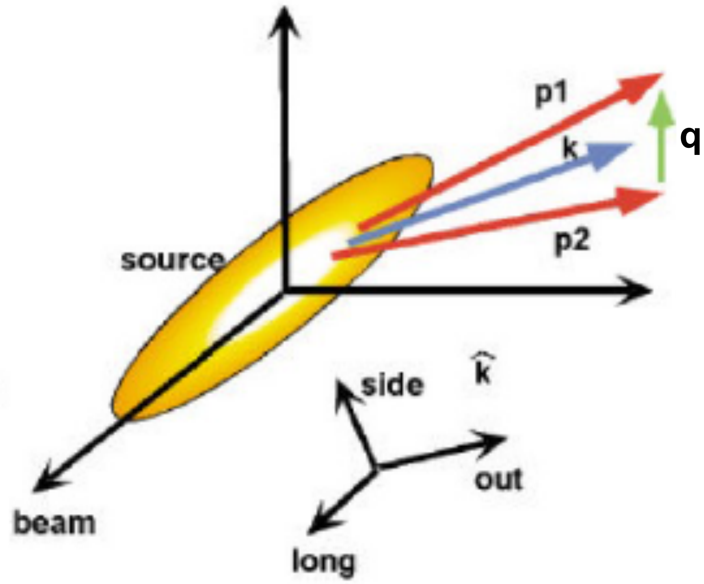
comparison of PHENIX & STAR HBT radii



STAR data from arXiv:1403.4972 [nucl-ex]

- agreement between PHENIX and STAR datasets
- PHENIX data provide sizable extension in m_T

expansion dynamics from HBT radii



From the literature:

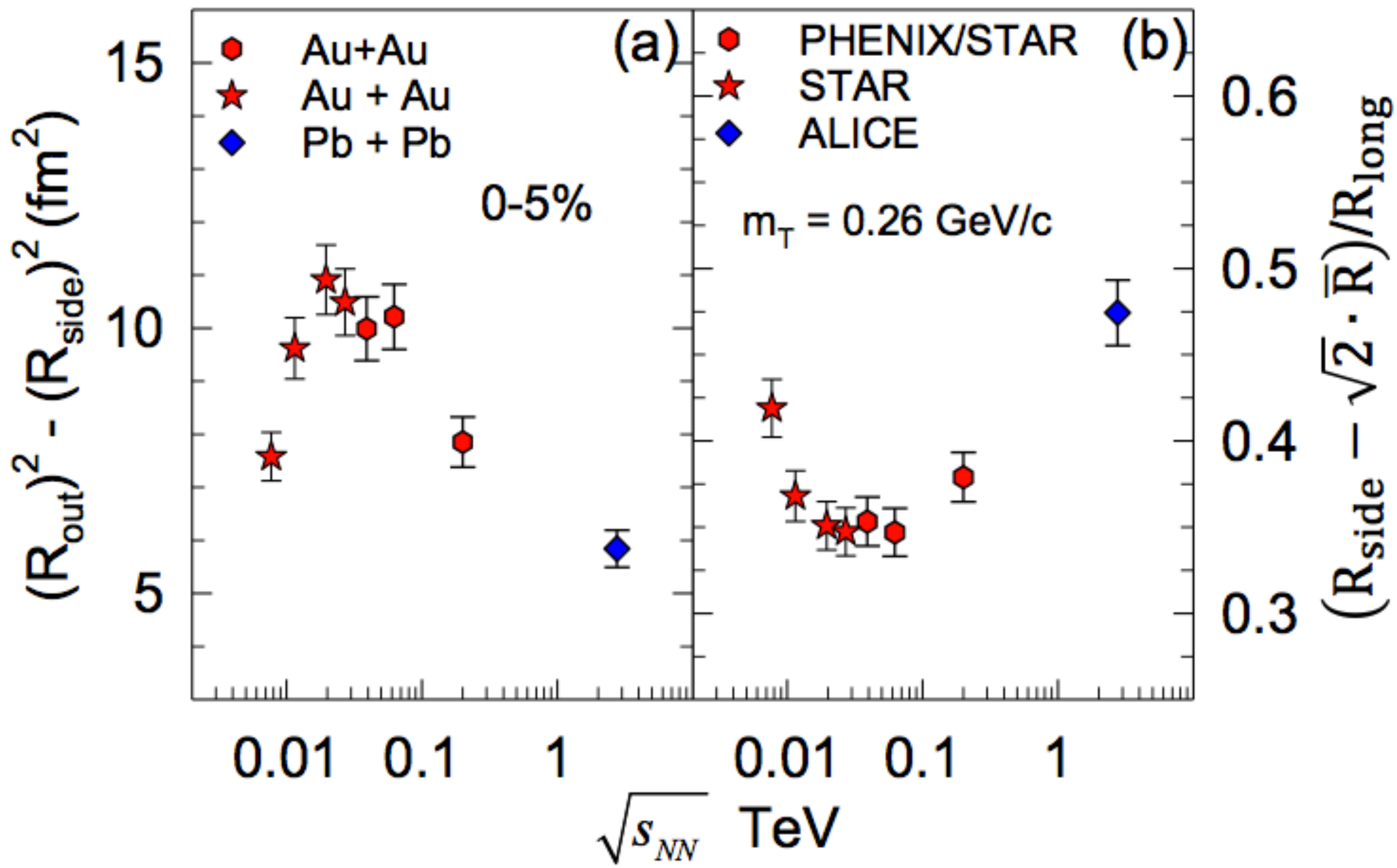
- ZPC **39**, 69 (1988)
- PRL **74**, 4400 (1995)
- PRL **75**, 4003 (1995)
- NPA **608**, 479 (1996)
- PRC **53**, 918 (1996)

$R_{\mathrm{long}} \propto \tau$	emission lifetime
$(R_{\mathrm{side}} - \sqrt{2}\bar{R})$	expansion radius for small m_T
$(R^2_{\mathrm{out}} - R^2_{\mathrm{side}}) \propto \Delta\tau^2$	emission duration
$(R_{\mathrm{side}} - \sqrt{2}\bar{R})/R_{\mathrm{long}}$	expansion rate

An emitting system produced in the vicinity of a 1[st] order transition of the phase diagram for nuclear matter could show a stalling of the mean expansion speed and a longer emission duration due to a "softening" of the equation of state (resulting in R_{out} > R_{side}).

beam energy dependence

arXiv: 1408.1343 [nucl-ex]



Nonmonotonic behavior with a maximum in emission duration $\Delta\tau$ and corresponding minimum in expansion rate in this beam energy range

Summary, Outlook and Acknowledgement

- From HBT radii in *d*+Au collisions:
  - linear dependence of R_{side} on initial transverse size
  - smaller freeze-out size compared to Au+Au
  - final state rescattering effects are important
- From HBT radii in HI collisions:
  - nonmonotonic behavior in this beam energy range of emission duration and expansion rate
  - change in expansion dynamics in this energy range
- Improved measurement of HBT radii w.r.t. event plane during BES II at RHIC in store
- Special thanks to Alex Mwai, Ajit & Roy @ SBU