Azimuthally-sensitive two-pion interferometry in U+U collisions at STAR

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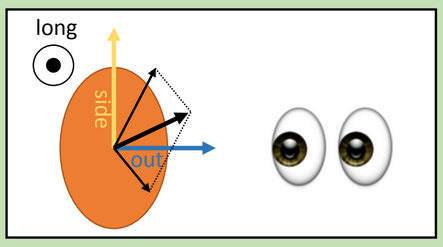
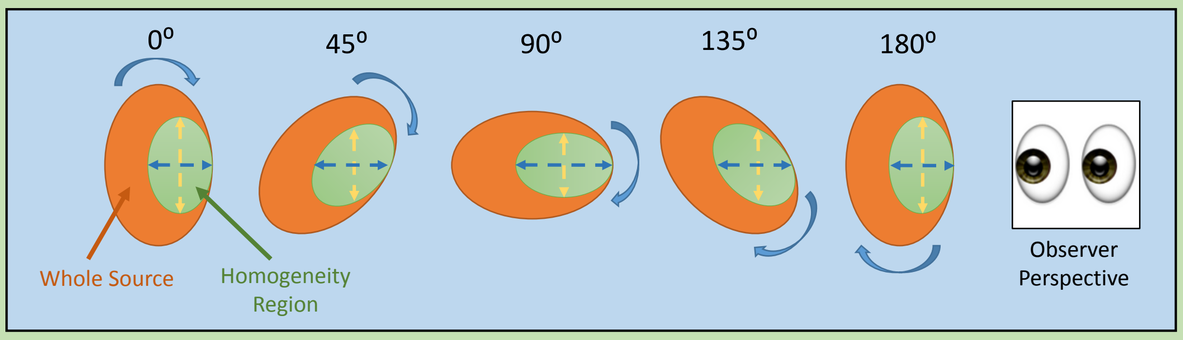
Collisions between uranium nuclei have been produced in the Relativistic Heavy Ion Collider and measured in the STAR detector. Due to the prolate deformation of the nuclei, fully overlapping U+U collisions offer the opportunity to produce highly anisotropic participant zones similar in shape to mid-central Au+Au collisions, but with twice the size. The larger fireball should be characterized by a long time over which it collectively evolves from its non-trivial initial shape to its final one. The final-state anisotropy of zero-spectator collisions in momentum space (v_n) is under active study. We will present a preliminary analysis of the coordinate-space anisotropy, measured via azimuthally-sensitive two-pion interferometry ("HBT") of full-overlap collisions, performed differentially in the reduced flow parameter q_2 in U+U collisions at $\sqrt{s_{NN}}$ = 193 GeV.

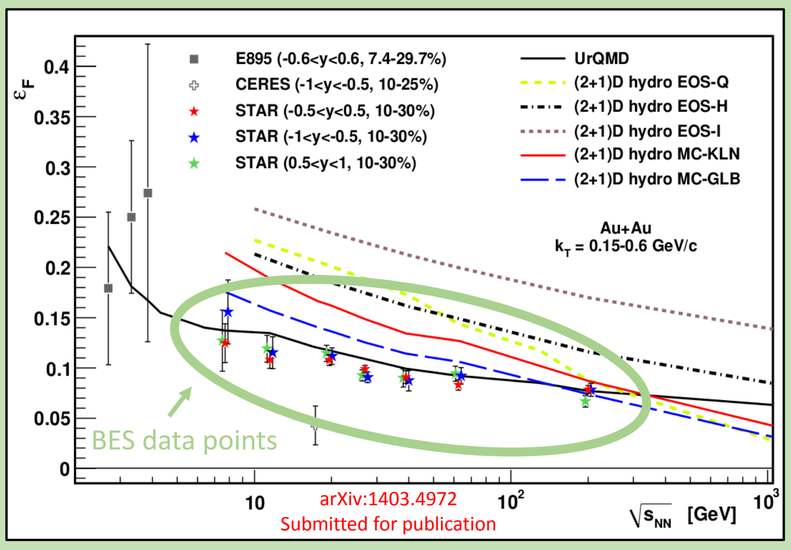
2nd Order Azimuthal Femtoscopy



- The pair momentum vector is represented in the 'out-side-long' coordinate system. This reference frame rotates around the source with the observer.
- As we rotate perspective around the pion emitting source we "see" different parts of it.



- Femtoscopy probes the 3D shape of 'homogeneity regions', the space over which particle pairs are correlated.
- Three length scales are recovered, one for each direction in the out-side-long system: R_{out}, R_{side}, and R_{long}.
- We can also recover *correlations between directions*: R_{os}, R_{ol}, *and* R_{sl}.



Can find the *freeze out eccentricity* with Fourier moments of R_{side}

$$\varepsilon_f \approx 2\frac{R^2_{side,2}}{R^2_{side,0}}$$

This has already been done in Au+Au collisions in the Beam Energy Scan

Construct experimentally measured *correlation functions* in terms of relative momentum q of *pairs of particles*

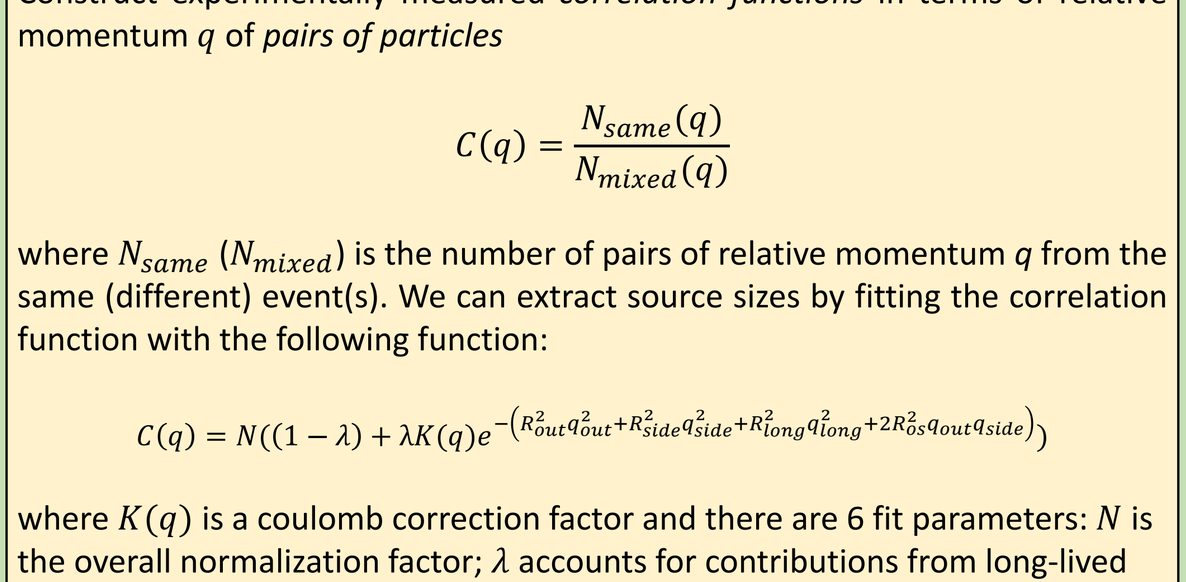
$$C(q) = \frac{N_{same}(q)}{N_{mixed}(q)}$$

where N_{same} (N_{mixed}) is the number of pairs of relative momentum q from the same (different) event(s). We can extract source sizes by fitting the correlation function with the following function:

$$C(q) = N((1-\lambda) + \lambda K(q) e^{-\left(R^2_{out}q^2_{out} + R^2_{side}q^2_{side} + R^2_{long}q^2_{long} + 2R^2_{os}q_{out}q_{side}\right)})$$

where $K(q)$ is a coulomb correction factor and there are 6 fit parameters: N is the overall normalization factor; λ accounts for contributions from long-lived decays; and the R_{out}, R_{side}, R_{long}, R_{os} terms describe the size and orientation of the emitting source.

Comparing q_2

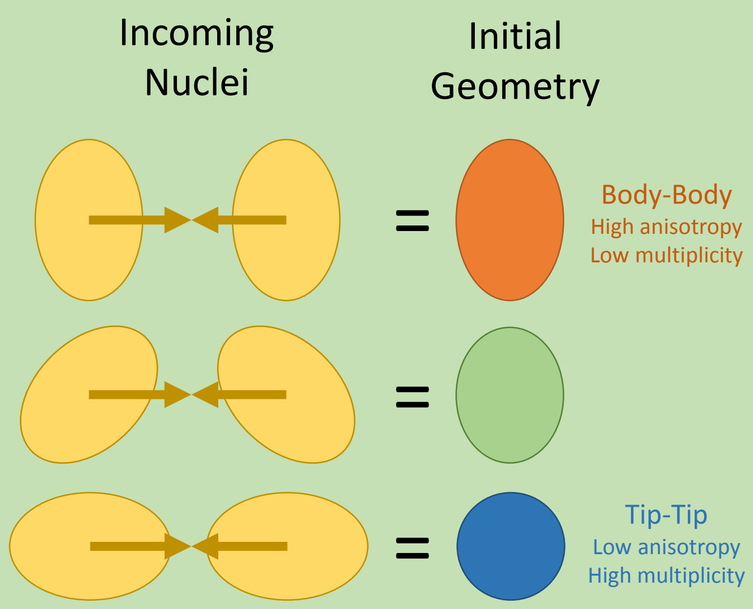


Shown are the 2nd-order oscillation amplitudes (Fourier moments) for the four radii studied here and the measured freeze out eccentricity, ε_f. Data are shown as a function of q_2 from lowest (0-10%) to highest (80-90%). Error bars are statistical only.

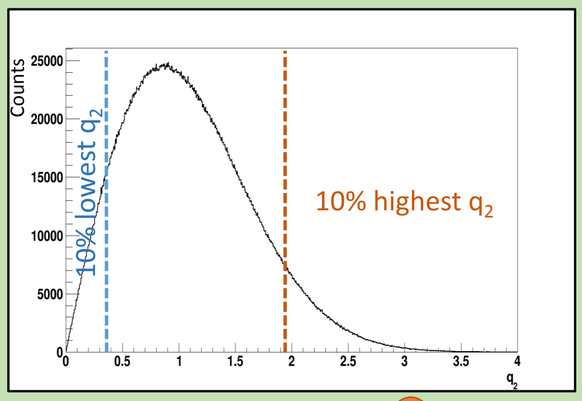
- Clear non-zero oscillation signal, especially for the 3 'transverse radii': R_{out}, R_{side}, and R_{os}.
- No obvious trend as a function of q_2: ε_f is roughly flat, no evidence for shape selection in q_2

Shape Selection in U+U collisions

- Gold/lead nuclei are approximately *spherical*. Can access different initial geometries by varying *impact parameter.*
- Uranium nuclei are *prolate*. Can access different initial geometries with *full overlap* by varying *orientation* of incoming nuclei
- Full overlap U+U collisions create a *large system* that will evolve over a *long time*.
- Body-Body collisions should have a higher *freeze out eccentricity* than Tip-Tip collisions.



Data Set and Experimental Cuts



- U+U collisions at $\sqrt{s_{NN}} = 193\ GeV$
- Use 1% Zero Degree Calorimeter (ZDC) to select events that are *almost fully overlapping*
- ~7 Million events survive cuts
- Analysis is performed differentially in the *reduced flow parameter* q_2

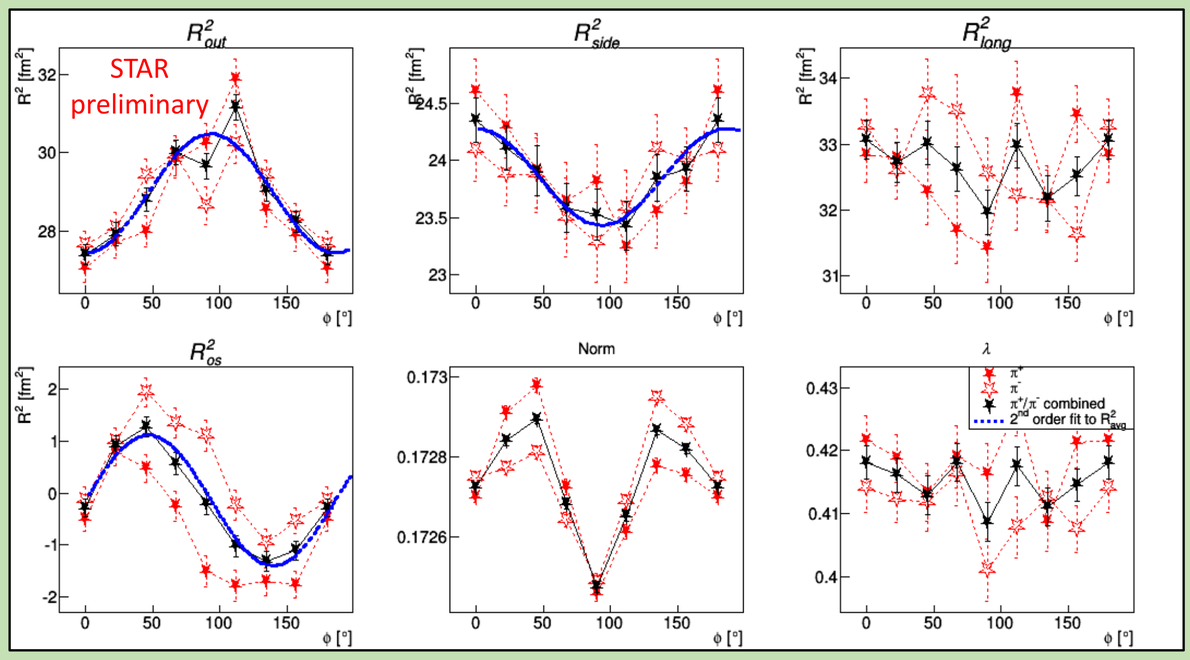
Can we see evidence of Tip-Tip or Body-Body enhanced collisions by performing this analysis differentially in q_2?

$$q_{2,x} = \frac{1}{\sqrt{M}}\sum_{i=1}^{M}\cos 2\phi_i$$

$$q_{2,y} = \frac{1}{\sqrt{M}}\sum_{i=1}^{M}\sin 2\phi_i$$

Event Cuts		Track Cuts		Pair Cuts + Binning	
$\|V_z\|$	< 30 cm	$\|\eta\|$	< 0.5	k_T	(0.15 GeV, 0.6 GeV)
V_r	< 2 cm	p_T	(0.15 GeV, 0.8 GeV)	ϕ	8 bins
$N_{ch,TPC}$	< 1000	$\|n\sigma_{pion}\|$	< 2	ψ_{EP}	16 mixing bins
		$\|n\sigma_{other}\|$	> 2	V_z	12 mixing bins
		N_{hits}	> 15		
		DCA	< 3cm		

Oscillating Radii



The 6 fit parameters, reconstructed for each of 8 azimuthal bins. Data shown here are for 80-90% q_2 *bin*.

- Results are presented for π^+ (π^-) shown in filled (empty) red symbols, and their average in black symbols. 2nd order harmonic fits are shown for R^2_{out}, R^2_{side}, and R^2_{os}
- 2nd order oscillation is seen for the 3 'transverse radii': R_{out}, R_{side}, and R_{os}

Summary

- First femtoscopic analysis of U+U collisions is presented
- Clear evidence for 2nd-order azimuthal signal
- No systematic variation of ε_f with q_2 ➔ no evidence for shape selection in q_2