The science case for a small system scan at RHIC

arXiv: 1901.10415

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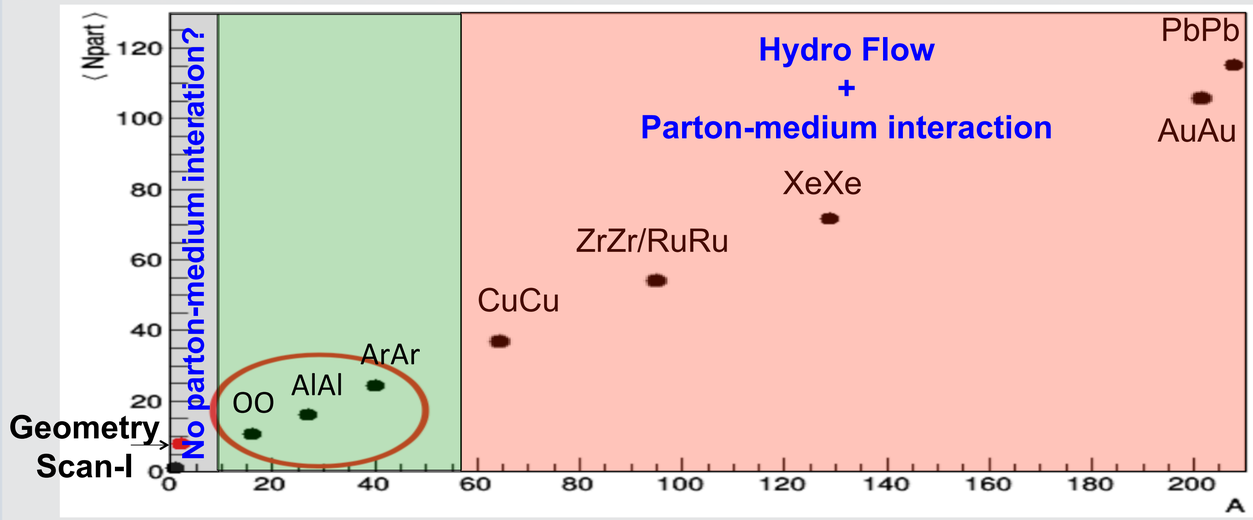
Abstract

The observation of multi-particle azimuthal correlations in high-energy small-system collisions has led to intense debate on its physical origin between two competing theoretical scenarios: one based on initial-state intrinsic momentum anisotropy (ISM), the other based on final-state collective response to the collision geometry (FSM). To complement the previous scan of asymmetric collision systems (p+Au, d+Au and He+Au), we propose a scan of small symmetric collision systems at RHIC, such as C+C, O+O, Al+Al and Ar+Ar at 0.2 TeV, to further disentangle contributions from these two scenarios.

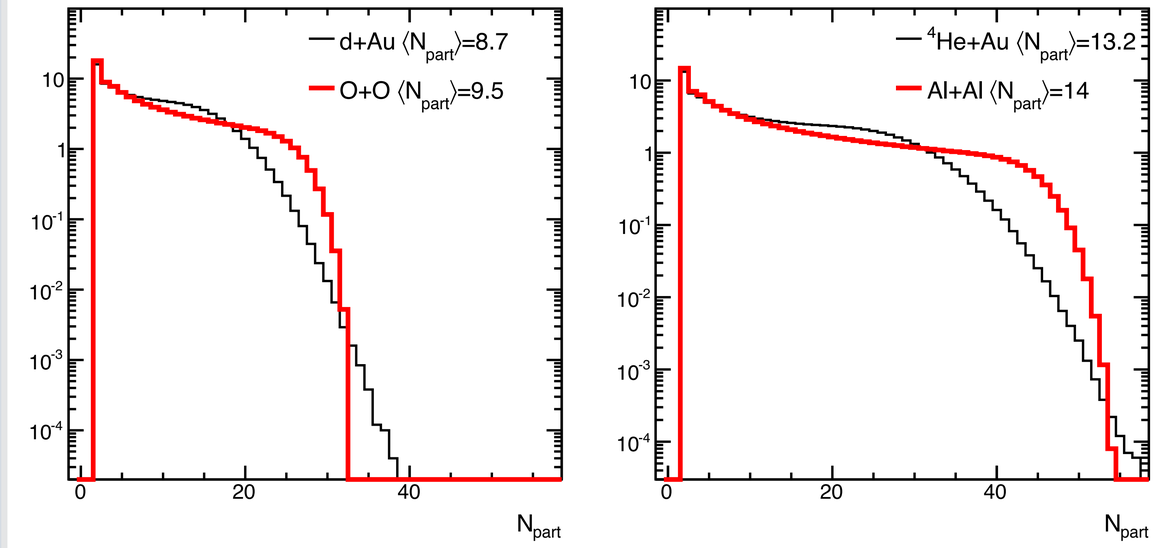
Motivation



System scan of intermediate AA collision systems provides unique insights on

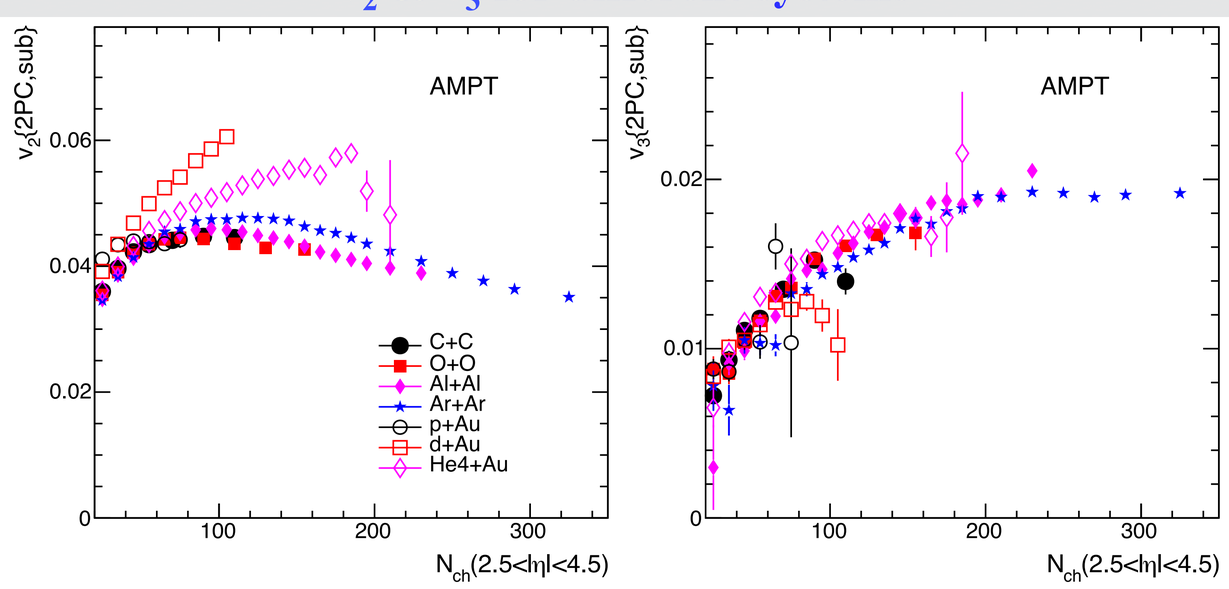
- Whether flow harmonics reflect initial geometry from small to large systems
- At what system size the initial-state effects become sub-dominant
- Turn-on of jet-quenching and Heavy Flavor "thermalization" with system size

Symmetric vs Asymmetric systems



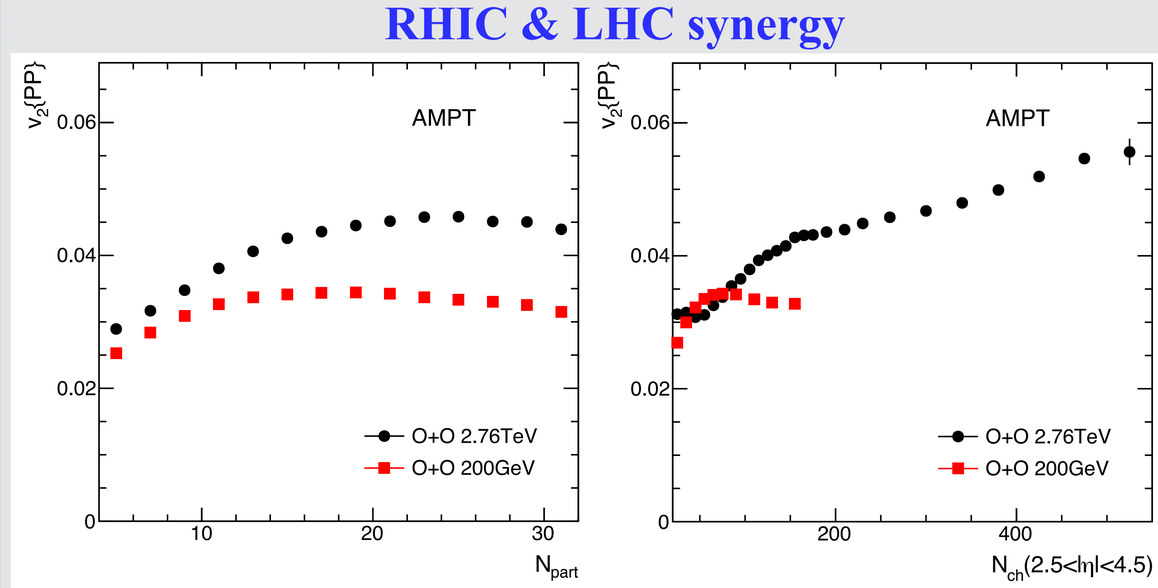
For systems with approximately same <N_{part}>, the symmetric system has a flatter shoulder than that for the asymmetric system, which thus is expected to be less sensitive to experimental centrality resolution effects.

v_2 & v_3 for different systems



- Symmetric systems: v_2 increases and then decrease with increasing <N_{ch}>, the peak positions also increase slightly for larger systems.
- Asymmetric systems: v_2 increase with increasing <N_{ch}>.
- v_3 for all systems follow common increasing trend as function of <N_{ch}>.

RHIC & LHC synergy



An O+O run at RHIC right after BES-II would provide a timely collision comparison of small system at very different collision energies to study systems with nearly identical nucleon geometry but different sub-nucleon fluctuations and particle production mechanism with different saturation scale and min-jet production in the initial state.

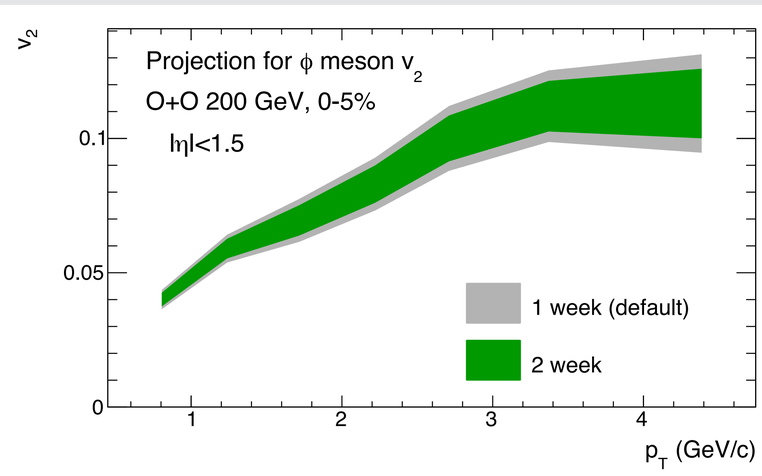
STAR Beam User Request Proposal

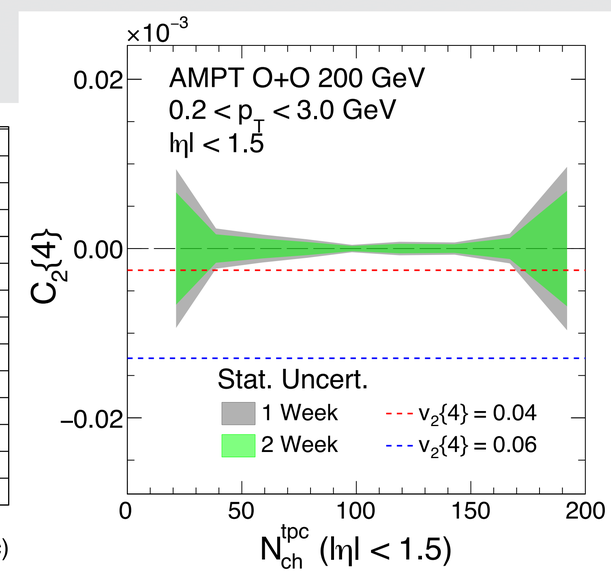
2020

Single-Beam Energy (GeV/n)	$\sqrt{s_{NN}}$ (GeV)	Run Time	Species	Events (MinBias)	Priority	Sequence
5.75	11.5	9.5 weeks	Au+Au	230M	1	1
4.55	9.1	9.5 weeks	Au+Au	160M	1	3
19.5	6.2 (FXT)	2 days	Au+Au	100M	2	5
13.5	5.2 (FXT)	2 days	Au+Au	100M	2	6
5.75	3.5 (FXT)	2 days	Au+Au	100M	2	2
4.55	3.2 (FXT)	2 days	Au+Au	100M	2	4
3.85	3.0 (FXT)	2 days	Au+Au	100M	2	7
100	200	1 week[2]	O+O	400M 200M (central)	3	8

2021

Single-Beam Energy (GeV/n)	$\sqrt{s_{NN}}$ (GeV)	Run Time	Species	Events (MinBias)	Priority	Sequence
3.85	7.7	12 weeks	Au+Au	100M	1	1
8.35	16.7	5 weeks	Au+Au	250M	2	2
100	200	1 week[4]	O+O	400M 200M (central)	2	3





Precise measurements of key observables can be made with proposed statistics

- Phi meson v_2 in central collisions
- v_2 from multi-particle correlations

Summary

A scan of small A+A systems at RHIC top energy 200 GeV has been proposed to understand the timescale for the emergence of collectivity and early thermalization mechanisms in nucleus-nucleus collisions. Comparing to asymmetric systems with similar N_{part}, the symmetric systems have different initial geometry fluctuations and less bias on the centrality selection. A scan of both symmetric and asymmetric systems provide an opportunity to disentangle contributions to collectivity from initial momentum anisotropy, pre-equilibrium and late-time dynamics.