Abstract: In order to study the QCD phase structure, Relativistic Heavy Ion Collider (RHIC) has conducted the beam energy scan program since 2010. In this presentation, we report our analysis on the energy dependence of \( \phi \)-meson and proton \( v_2 \) from minimum bias (MB) Au+Au collisions at \( \sqrt{s}_{NN} = 7.7 \text{ GeV} \) - 200 GeV. The \( p_T \) integrated \( v_2 \) of \( \phi \)-meson values for both \( \phi \)-meson and proton are found to be proportional to the collision energy and at \( \sqrt{s}_{NN} < 19.6 \text{ GeV} \), the \( \phi \)-meson \( v_2 \) values become less than that of protons. Since \( \phi \)-mesons do not participate in the hadronic re-scatterings, this observation indicates that the hadronic interactions become dominant at the lower energy collisions. In addition, the comparison of \( p_T \) dependent of \( v_2 \) for \( \phi \) meson and proton, from MB 200GeV Au+Au collisions, we have shown the effect of the later stage hadronic re-scatterings on protons \( v_2(p_T) \) distribution. Transport model such as AMPT provides consistent predictions.

Introduction
The Quantum Chromodynamics (QCD) predicts:
- At low temperature and low density, quarks and gluons are confined within the hadrons.
- However, at very high temperature and/or at very high energy density the quarks and gluons will be no longer confined within the hadrons.

Such de-confined states is known as Quark-Gluon-Plasma (QGP)

Motivation:
- What will happen if we decrease the centre-of-mass energy?

Effect of Hadronic Re-scattering

\( \phi \)-meson \( v_2 \): Not affected by hadronic re-scattering due to small hadronic interaction cross section.

Energy dependence of \( p_T \) integrated \( v_2 \)

\[ v_2(\phi) \text{ for } \sqrt{s}_{NN} \geq 19.6 \text{ GeV can be described by AMPT SM by varying parton-parton cross section from 3 mb to 10 mb.} \]

AMPT default (hadronic model) over-predicts the data at \( \sqrt{s}_{NN} = 11.5 \text{ GeV} \):

\[ v_2(\phi) > 19.6 \text{ GeV} / v_2(p_T) \]

\[ v_2(\phi) \leq 19.6 \text{ GeV} / v_2(p_T) \]

Difference between \( v_2(\phi) \) and \( v_2(p_T) \) is

\[ > 1.5 \text{ at } 11.5 \text{ GeV} \]

In addition, contribution in \( v_2 \) between particle and antiparticle was observed at low beam energy.

Summary
Partonic Collectivity:
- At high collision energy (\( \sqrt{s}_{NN} \geq 27 \text{ GeV} \)), we observed similar magnitude of \( v_2 \) for both \( \phi \)-meson and proton.
- At lower energy (\( \sqrt{s}_{NN} \leq 19.6 \text{ GeV} \)), the magnitude of \( \phi \)-meson \( v_2 \) is much smaller than proton, indicating that the hadronic interaction become dominant in the low energy region.

AMPT model with string melting scenario quantitatively explains the data at \( \sqrt{s}_{NN} \geq 19.6 \text{ GeV} \) by varying the parton-parton interaction cross-section from 3 mb to 10 mb. For lower beam energies data is below calculations from AMPT-default model. Indicates collectivity for \( \phi \)-meson is difficult to generate without partonic interactions.

Hadrronic Re-scattering:
- STAR preliminary data shows \( v_2(\phi) / v_2(p_T) > 1.0 \) at low \( p_T \). Both Hydro+Cascade and AMPT model qualitatively explains the data by considering effect late stage hadronic interaction on proton \( v_2 \).

Partonic interactions dominant for \( \sqrt{s}_{NN} \geq 19.6 \text{ GeV} \) (\( \mu_s \leq 210 \text{ MeV} \))
Hadrronic interactions dominant for \( \sqrt{s}_{NN} \leq 11.5 \text{ GeV} \) (\( \mu_s \geq 315 \text{ MeV} \))

Acknowledgements:
Funding support from XXIV Quark Matter organiser committee and Department of Physics and Astronomy, UCLA are gratefully acknowledged. This work is supported by DST Swarnajayanti fellowship of Govt. of India.