Measurements of Proton-Proton Correlation Function in 3 GeV Au+Au Collisions at RHIC-STAR
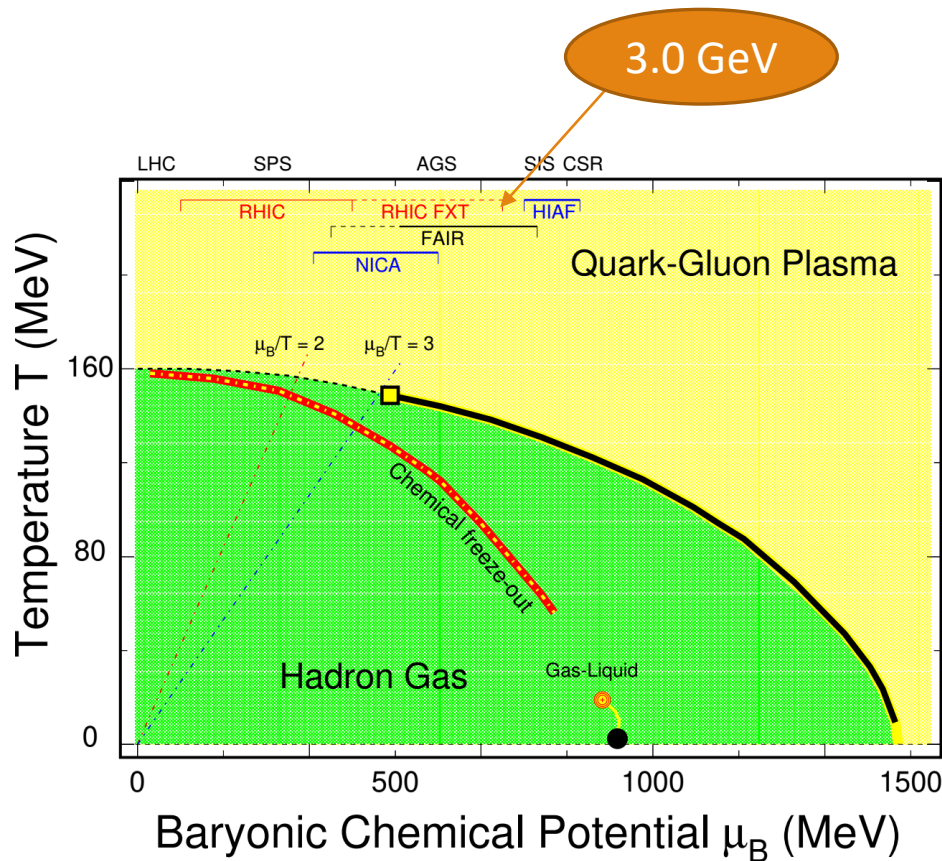
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Outline

➢Introduction

➢Experiment Setup

➢Correlation Function
  ✓Centrality Dependence
  ✓Rapidity Dependence
  ✓Energy Dependence

➢Summary and Outlook

Beam Energy Scan Program

- BES program
  Search for critical point
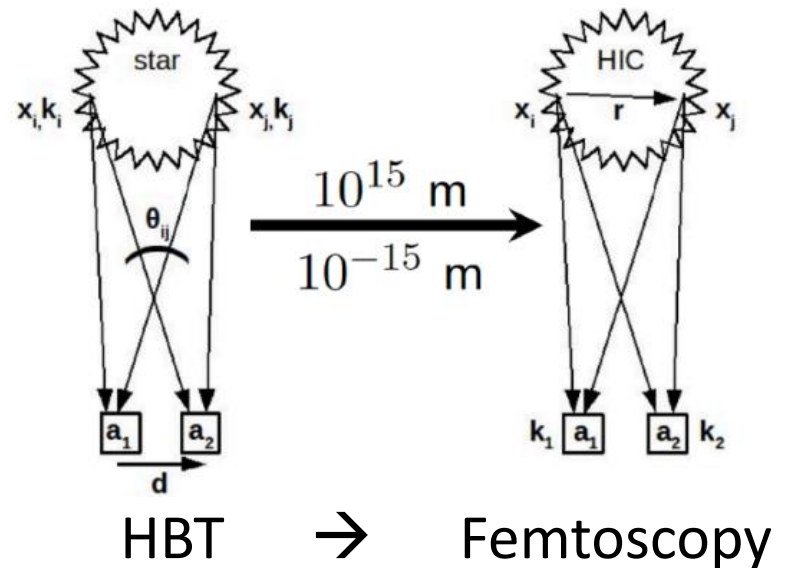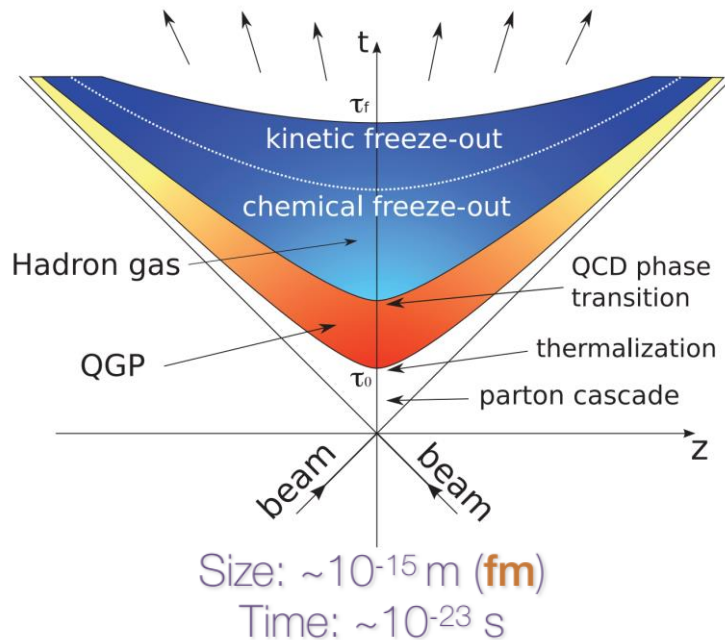 Search for phase boundary

- Collider mode
  Au+Au at $\sqrt{s_{NN}}$ = 7.7-62.4 GeV

- Fixed-Target Program
 Au+Au at $\sqrt{s_{NN}}$ = 3.0-7.7 GeV
  High Baryon Density Region
  with 420-750 MeV

X. Luo, S. Shi, N. Xu, Y. Zhang, Particles 2020, 3, 278-307

Femtoscopy in Heavy Ion Collisions

Size: ~10^{-15} m (**fm**)
Time: ~10^{-23} s

$$\frac{10^{15}\ \text{m}}{10^{-15}\ \text{m}}$$

HBT → Femtoscopy

➢ Femtoscopy method inspired by **H**anbury **B**rown and **T**wiss interferometry method in astronomy:
measurement of the source size of particle-emitting region in HIC.

R. Hanbury-Brown, R. Q. Twiss, Nature 178, 1046 (1956)

Correlation Function
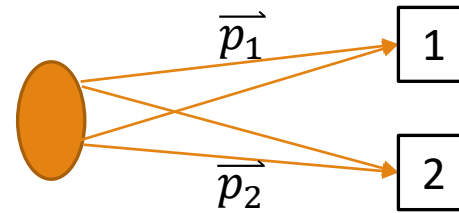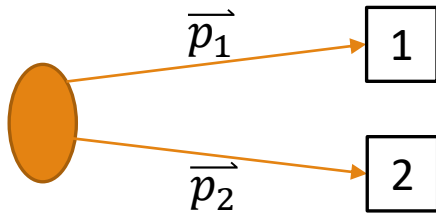
Interference correlation

$$C_{\text{Theory}}(\overrightarrow{p_1}, \overrightarrow{p_2}) = \frac{P_2(\overrightarrow{p_1}, \overrightarrow{p_2})}{P_1(\overrightarrow{p_1})P_1(\overrightarrow{p_2})}$$

$$C_{\text{Exp.}}(q_{\text{inv}}) = \frac{A(q_{\text{inv}})}{B(q_{\text{inv}})}$$

P_2: the probability of finding both particle 1 and 2
P_1: the probability of finding the particle 1 and 2 separately

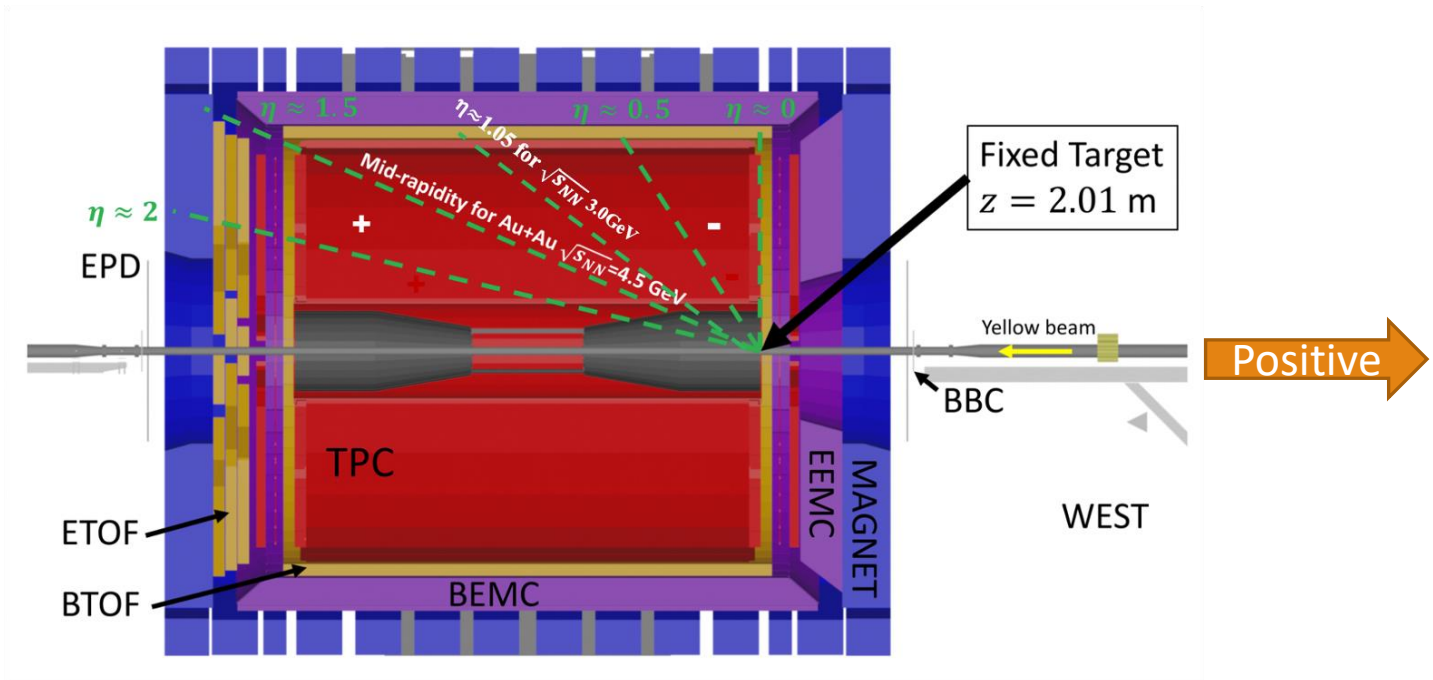$$Q_{\text{inv}} = \sqrt{-\Delta p^u \Delta p_u}$$
$q_{\text{inv}} = 0.5* Q_{\text{inv}}$
$\Delta p^u = p_1^u - p_2^u$
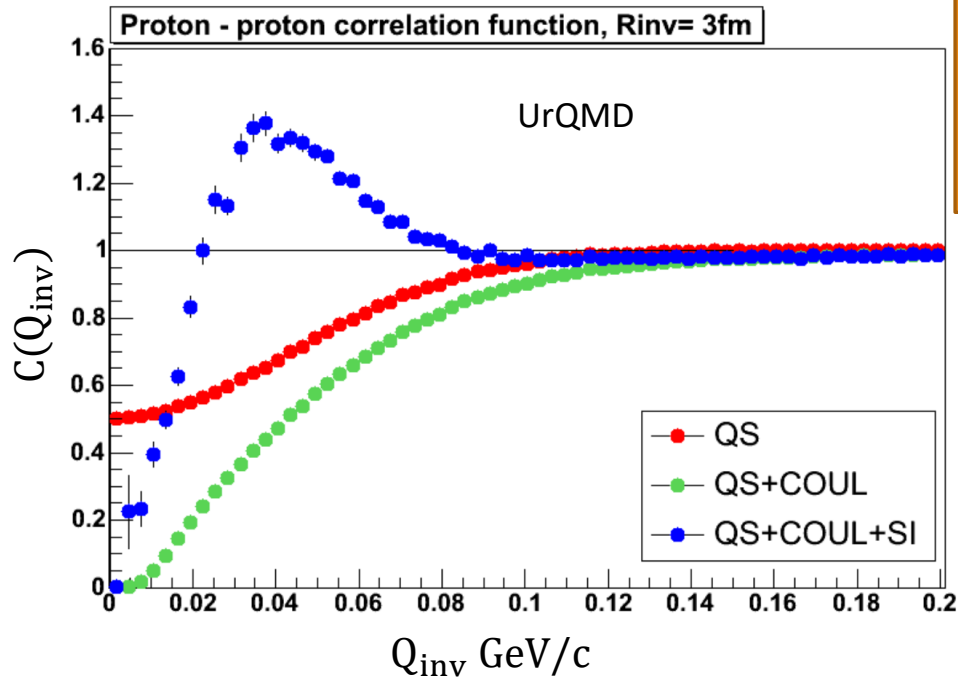$A(q_{\text{inv}})$: distribution from the same event
$B(q_{\text{inv}})$: normalized distribution from the mixed events

Rev. Mod. Phys. 62, 553 (1990).

Experiment Setup

- ➢ TPC: track reconstruction of charged particles with acceptance: $-2 < \eta < 0$
- ➢ Particle identification: particle's energy loss: Time Projection Chamber (TPC) + particle's flight time: Time of Flight (TOF)
- ➢ $\sqrt{s_{\mathrm{NN}}}$ = 3 GeV : the lowest collision energy at RHIC

Proton-proton Correlations

Proton - proton correlation function, Rinv= 3fm

UrQMD

- QS
- QS+COUL
- QS+COUL+SI

$C(Q_{inv})$

Q_{inv} GeV/c

Correlation After Burner (CRAB):
- Quantum Statistical effects (QS)
- Coulomb Interaction (COUL)
- Strong Interaction (SI)

Transport model (UrQMD):
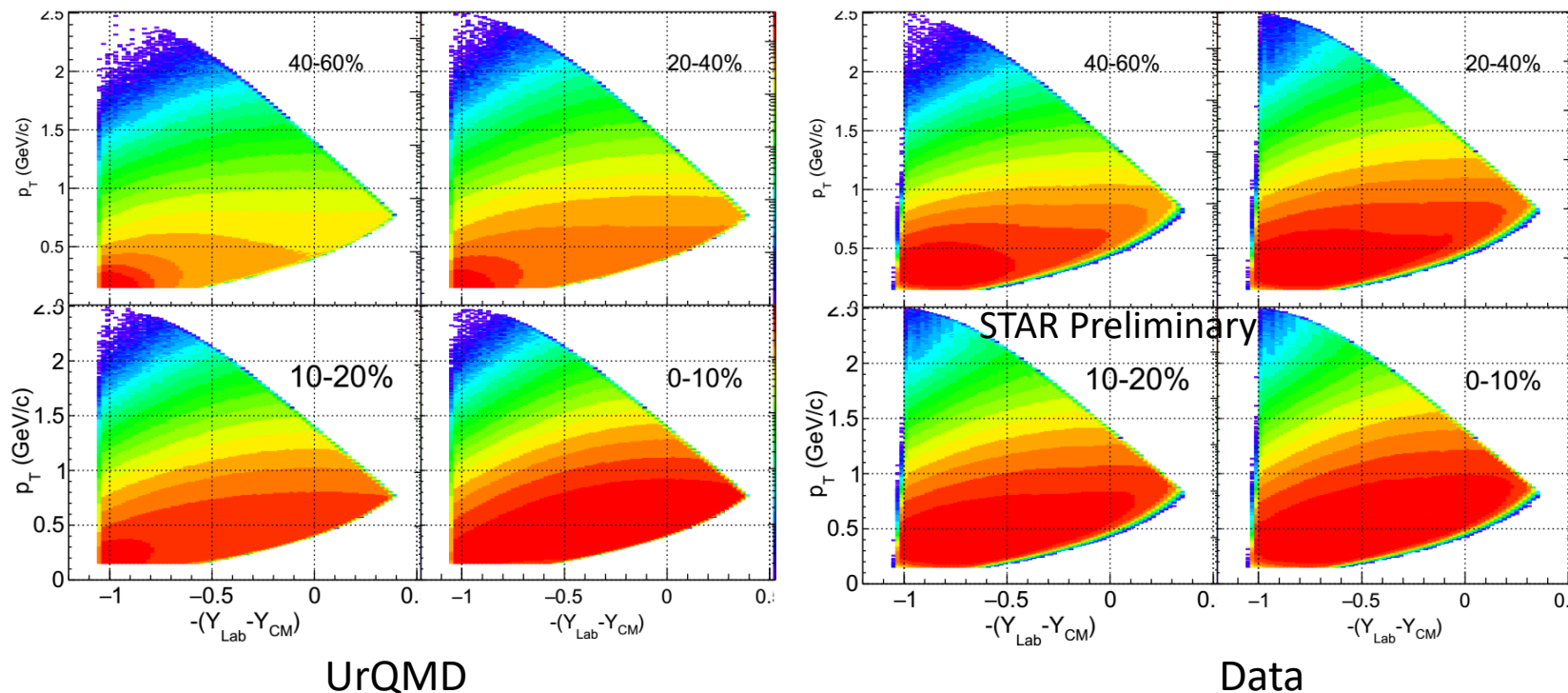(px, py, pz, E, x, y, z, t)

q_{inv} distributions from same event and mixed events

S. Pratt et al., Nucl. Phys. A 566, 103c (1994)
H. Zbroszczyk, "Studies of baryon-baryon correlations in relativistic nuclear collisions registered at the STAR experiment"
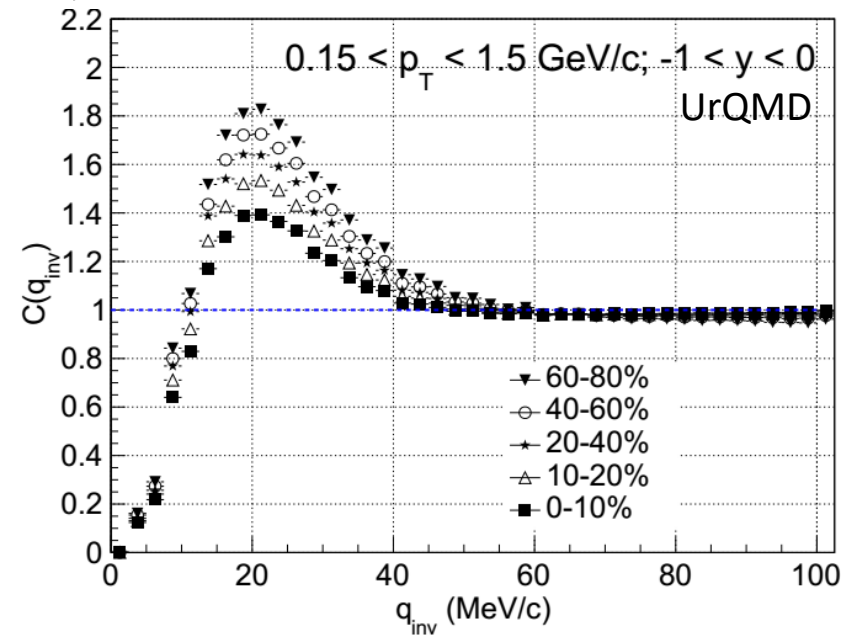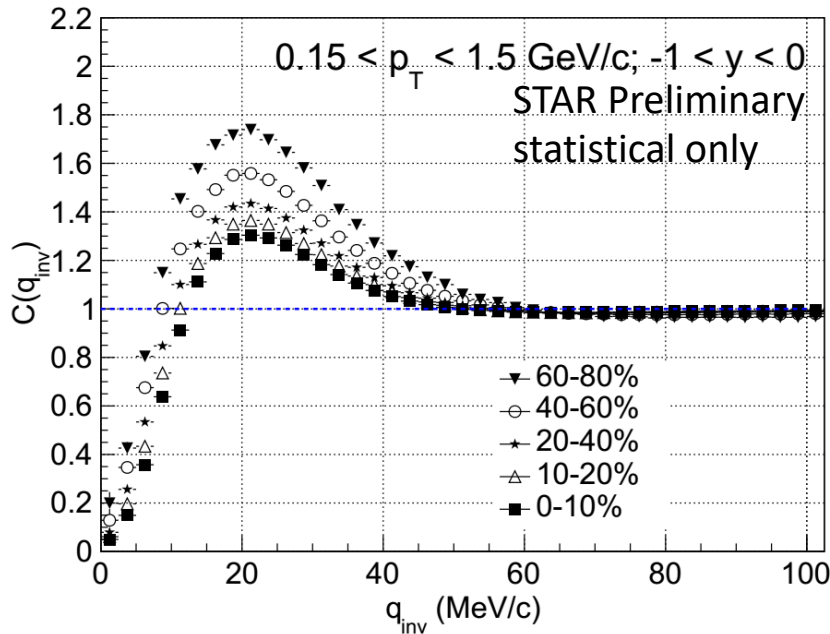
Distribution in Phase Space

Au+Au collisions at $\sqrt{s_{NN}}$ = 3 GeV

UrQMD   Data

➢ $Y_{Beam} = \cosh^{-1}(E/m_0) = -2.09$, $Y_{CM} = 0.5*(Y_{Target} + Y_{Beam}) = -1.045$
 Under the center of mass frame: $Y = Y_{Lab} - Y_{CM}$

➢ Same cuts for data and UrQMD: $p_T > 0.15$ GeV and $p < 2.5$ GeV/c and $-1.85 < \eta < 0$
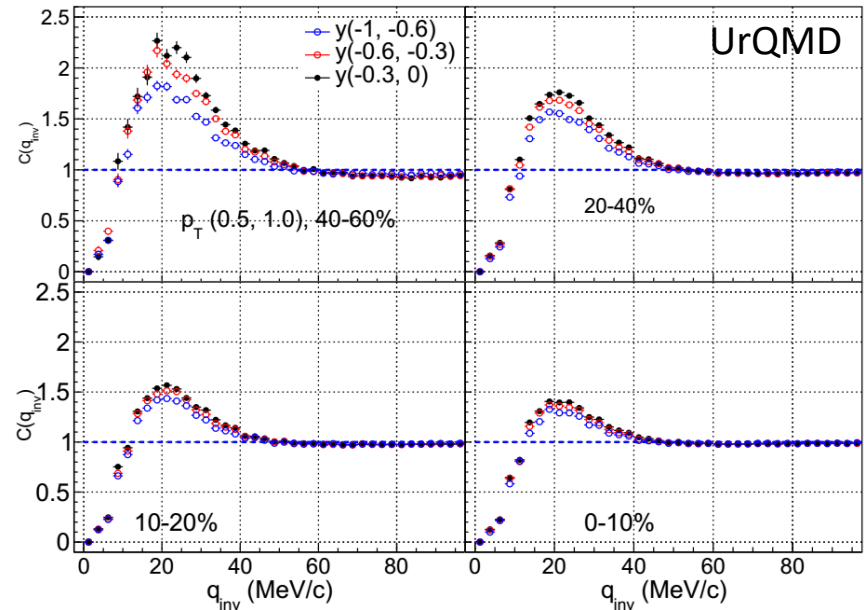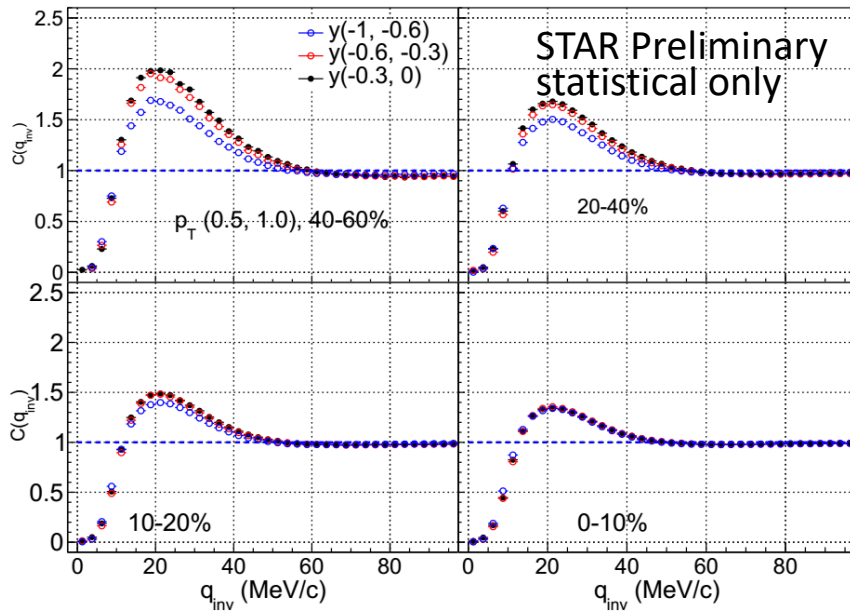
Centrality Dependence of CF

➤ The centrality dependence in UrQMD is similar to data.
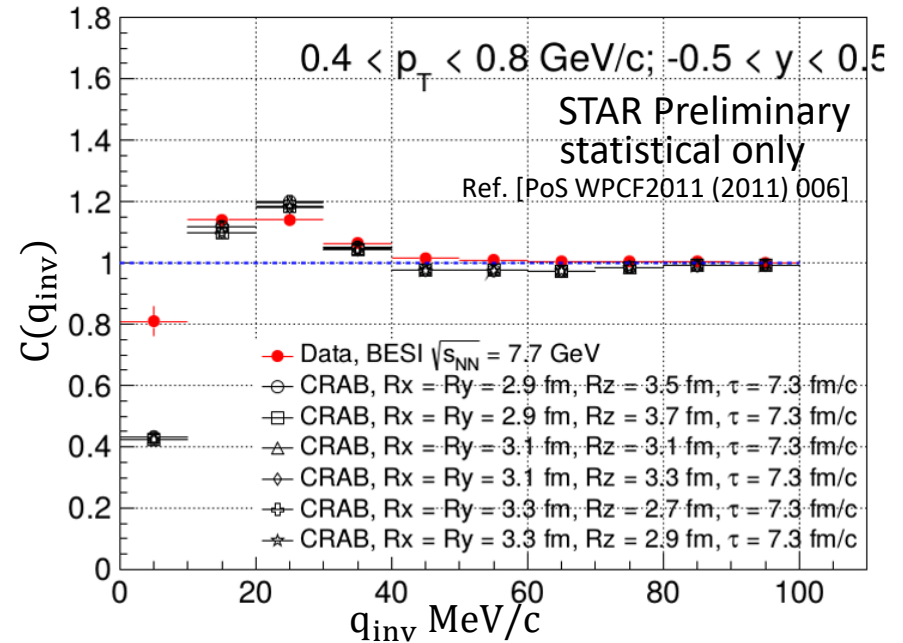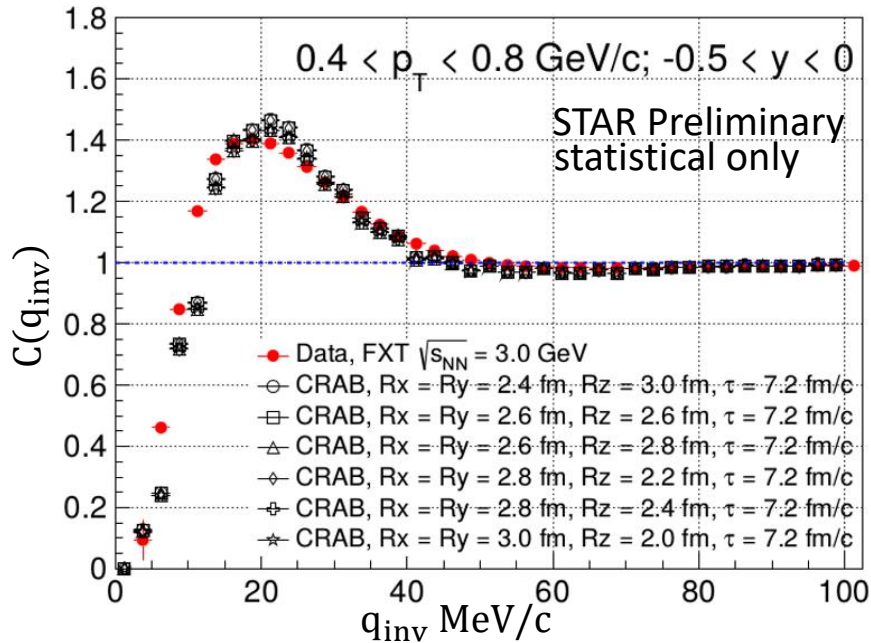➤ The centrality dependence is more significant in data than UrQMD when q_{inv} < 20 MeV/c.

Rapidity Dependence of CF

Au+Au collisions at $\sqrt{s_{NN}}$ = 3 GeV

p_T (0.5, 1.0) GeV/c

➤ The rapidity dependence in UrQMD is similar to data.

Energy Dependence of CF

➤ The energy dependence of CF is observed.
➤ The proton-source volume will be extracted from CFs and the energy dependence of the volume will be studied.

Summary and Outlook

➢ First measurements of the proton-proton correlation function in Au+Au collisions at $\sqrt{s_{NN}}$ = 3 GeV.

➢ Centrality/rapidity dependence of CF is observed.

➢ The energy dependence of CF is observed.

Outlook:
The energy dependence of system volume extracted from pp CFs will be studied.