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STAR

Investigations of the longitudinal broadening of two-particle transverse momentum correlations from STAR

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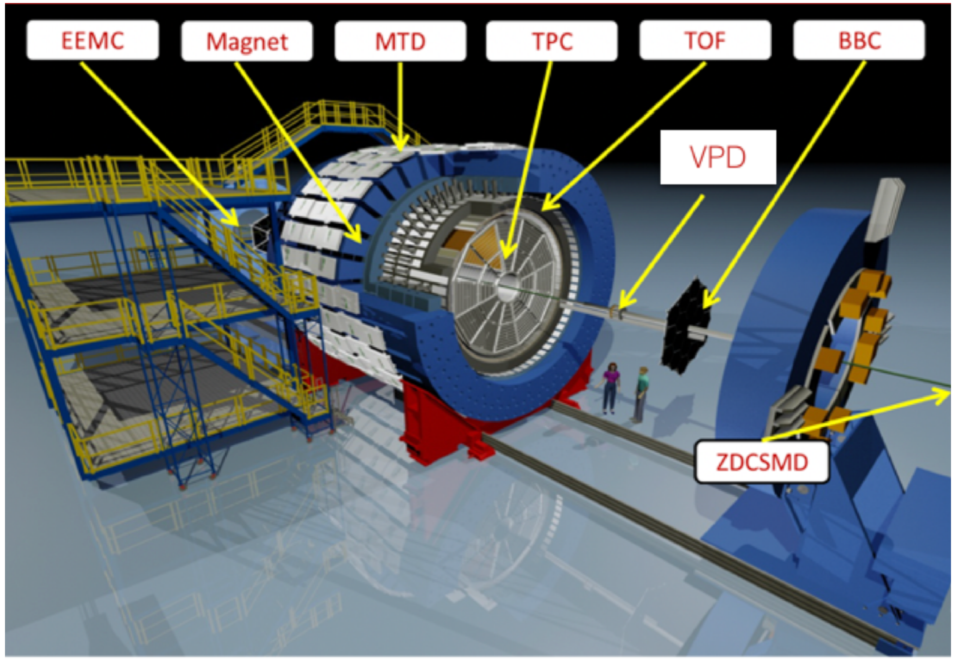


- Data set: Au +Au at $\sqrt{s_{NN}} = 200$ GeV
- Time Projection Chamber
  Tracking of charged particles with:
  - ✓ Full azimuthal coverage
  - ✓ $|\eta| < 1$ coverage
- In this analysis we used tracks with:
  $0.2 < p_T < 2$ GeV/c

ISMD2021 50th International Symposium on Multiparticle Dynamics (ISMD2021)

Motivation:

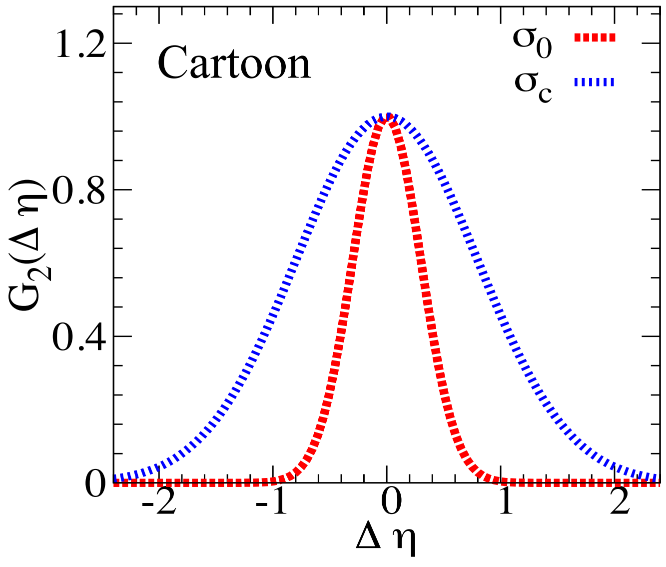
The Gavin ansatz: S. Gavin and M. Abdel-Aziz Phys.Rev.Lett. 97 (2006) 162302

- The p_T 2-P correlation function is sensitive to the dissipative viscous effects that are ensured during the transverse and longitudinal expansion of the collisions' medium.
- Because such dissipative effects are more prominent for long-lived systems, they lead to longitudinal broadening of p_T 2-P correlation function as collisions become more central.
- A proposed estimate of this broadening, $\Delta\sigma^2$, can be linked to η/s as:

$$\Delta\sigma^2 = \sigma_c^2 - \sigma_0^2 = \frac{4}{T_c}\frac{\eta}{s}\left(\frac{1}{\tau_0} - \frac{1}{\tau_{c,f}}\right)$$

$\sigma_c \rightarrow$ Central

$\sigma_0 \rightarrow$ Peripheral



The p_T 2-P correlator: STAR Collaboration PLB 704 (2011) 467–473

$$G_2(\eta_1,\varphi_1,\eta_2,\varphi_2) = \frac{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} p_{T,i}p_{T,j}\right\rangle}{\langle n_1\rangle\langle n_2\rangle} - \langle p_{T,1}\rangle_{\eta_1,\varphi_1}\langle p_{T,2}\rangle_{\eta_2,\varphi_2}$$

$$\frac{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} p_{T,i}\, p_{T,j}\right\rangle}{\langle n_1\rangle\langle n_2\rangle} = \frac{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} p_{T,i}\, p_{T,j}\right\rangle}{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} n_i\, n_j\right\rangle} r_{1,2}$$

$$r_{1,2} = \frac{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} n_i\, n_j\right\rangle}{\langle n_1\rangle\langle n_2\rangle}$$

- $r_{1,2}$ is a number correlation, it will be unity when the particle pairs are independent
- The $r_{1,2}$ correlations can be impacted by the centrality definition

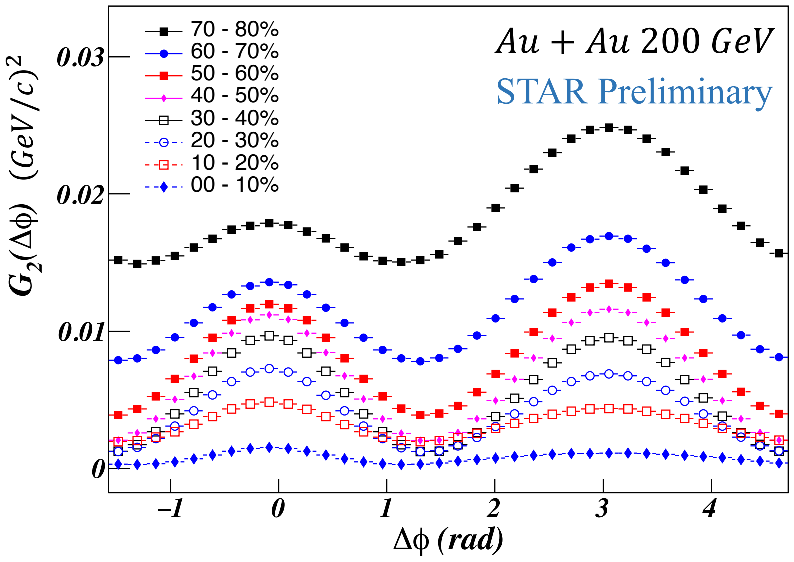
Excluding the POI from the collision centrality definition, helps reduce the possible self-correlations.

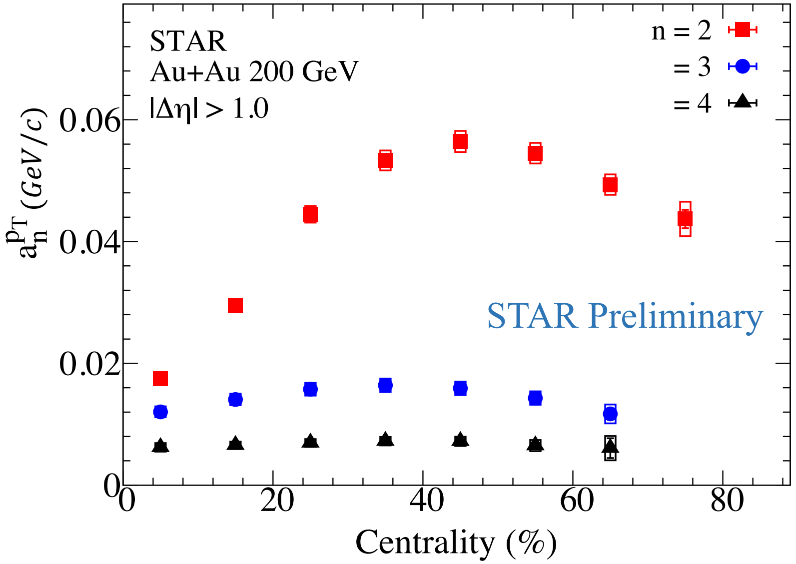
N. Magdy and R. Lacey e-Print: 2101.01555

Investigations of the $p_T - p_T$ correlations from STAR

- The azimuthal correlations for Au+Au at 200 GeV

$$G_2(\Delta\varphi) = A_0^{p_T} + 2\sum_{n=1}^{6} A_n^{p_T}\cos(n\,\Delta\varphi) \qquad a_n^{p_T} = \sqrt{A_n^{p_T}}$$



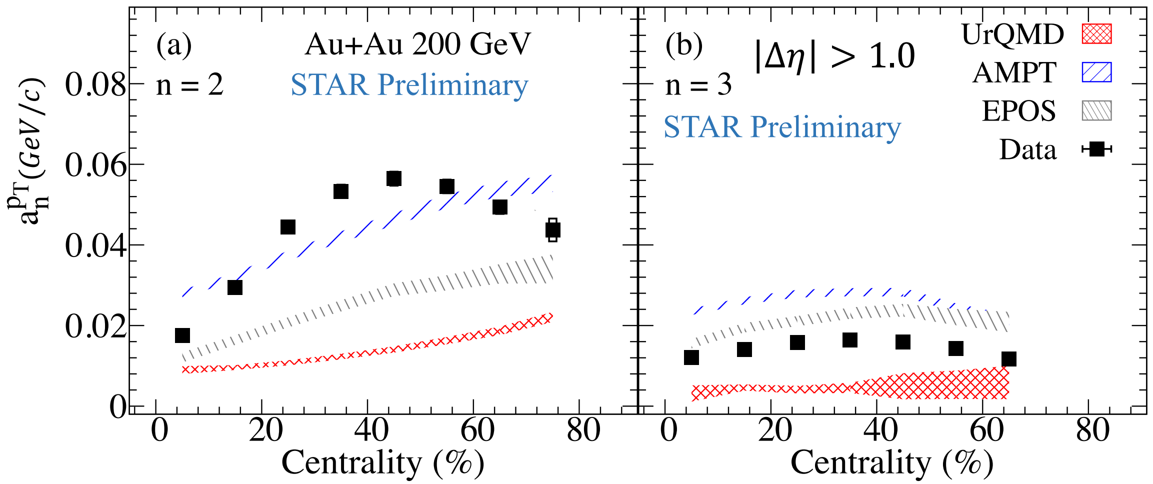


- The extracted $a_2^{p_T}$:
  - ✓ Decrease with harmonic order
  - ✓ Models do not describe the data
  - ✓ Event shape dependent

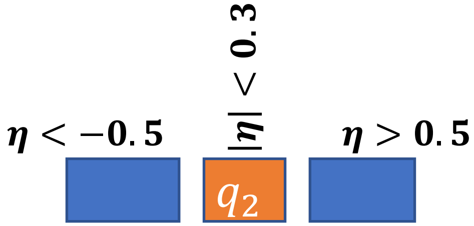
$$Q_{2,x} = \sum_{i=1}^{M}\cos(2\,\varphi_i)$$

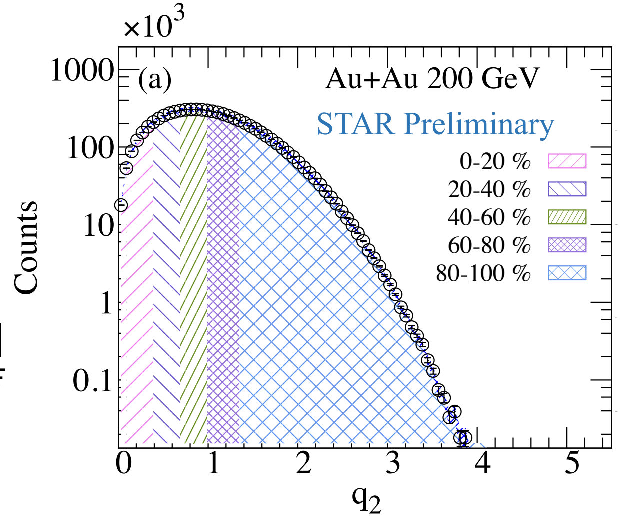
$$Q_{2,y} = \sum_{i=1}^{M}\sin(2\,\varphi_i)$$

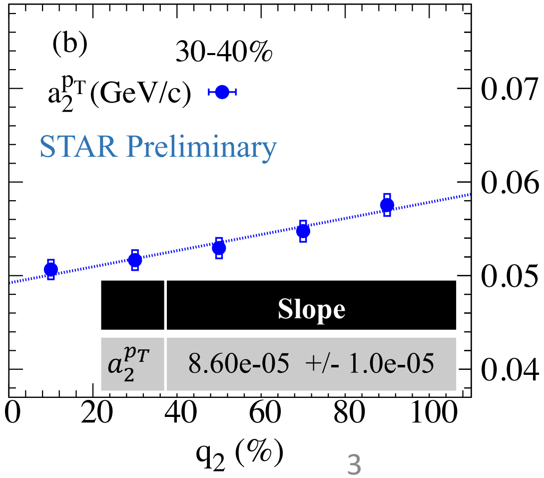
$$|Q_2| = \sqrt{Q_{2,x}^2 + Q_{2,y}^2} \qquad q_2 = \frac{|Q_2|}{\sqrt{M}}$$



- q_2 is separated from particle of interest

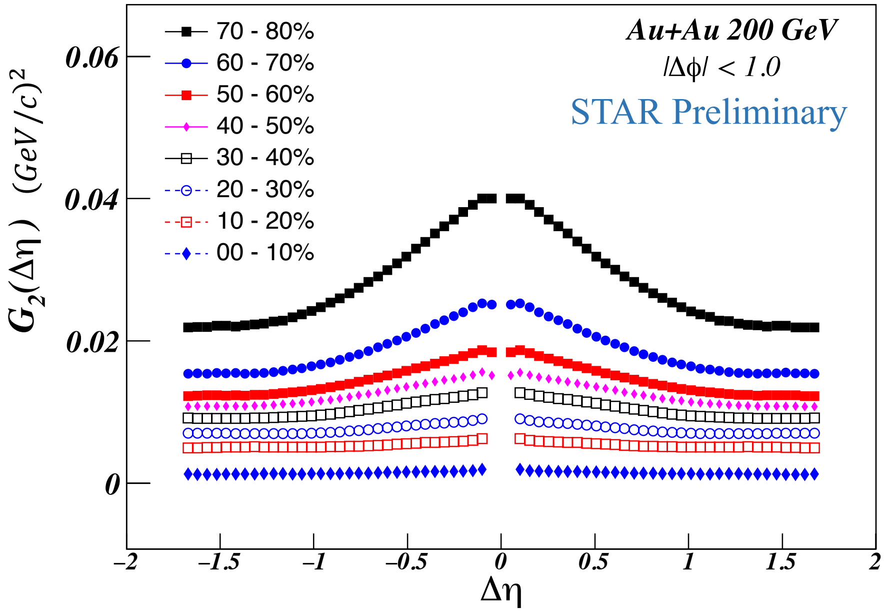






Investigations of the $p_T - p_T$ correlations from STAR

➢ The longitudinal correlations for Au+Au at 200 GeV

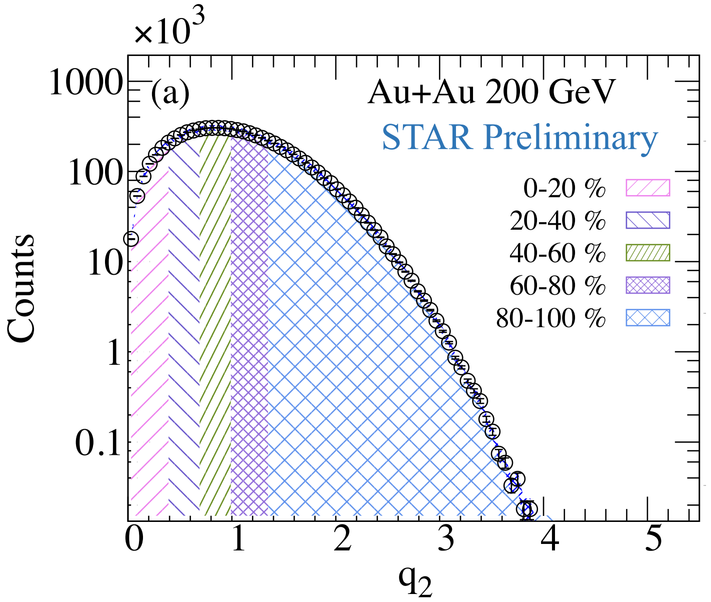


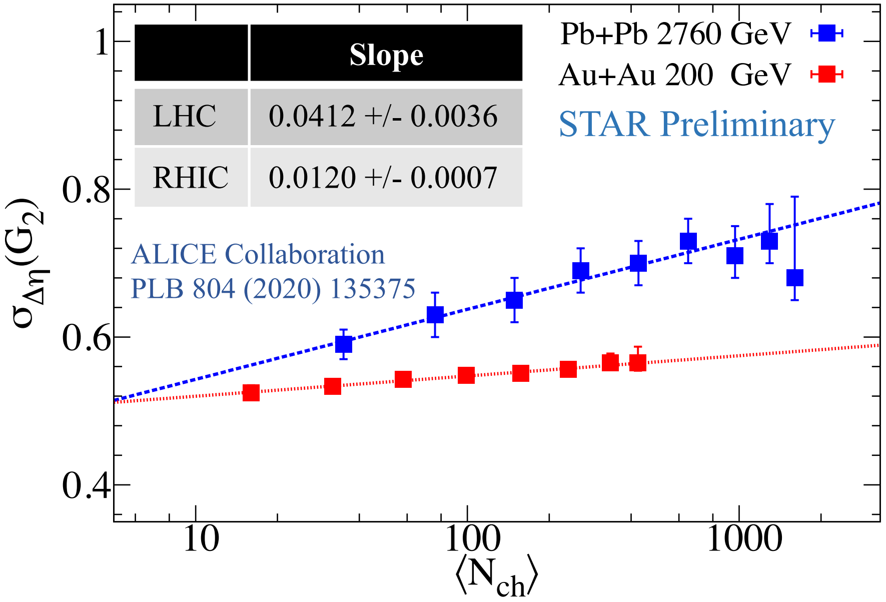
$$\sigma_{\Delta\eta}(G_2) = RMS[G_2(\Delta\eta)]$$

➢ The slope of $\sigma_{\Delta\eta}(G_2)$ is softer for RHIC

✓ Smaller η/s for RHIC

P. Alba et al.
PRC 98, 034909 (2018)

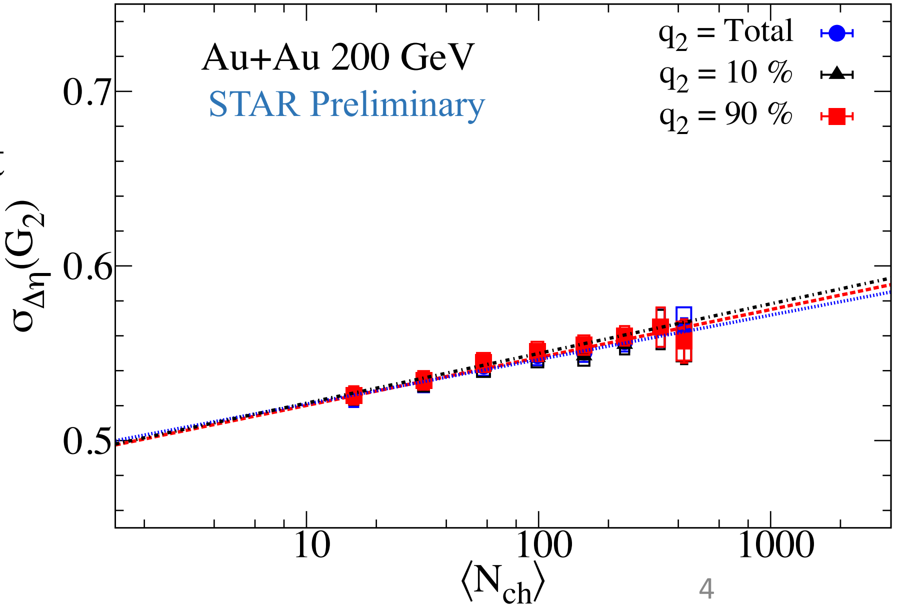




	Slope
LHC	0.0412 +/- 0.0036
RHIC	0.0120 +/- 0.0007

➢ The $\sigma_{\Delta\eta}(G_2)$ is event shape independent

	Slope
Total	0.0120 +/- 0.0007
10 %	0.0119 +/- 0.0009
90 %	0.0110 +/- 0.0012



Conclusions

We revisited the $\mathrm{p_T} - p_T$ 2-P correlation analysis for Au+Au at 200 GeV using a new approach by excluding self-correlations and we found that;

- The extracted $a_2^{p_T}$:
  - ✓ Decrease with harmonic order
  - ✓ Models don't describe the $a_2^{p_T}$ data
  - ✓ Event shape dependent

- The slope of $\sigma_{\Delta\eta}(G_2)$ vs multiplicity is:
  - ✓ Softer for RHIC (indicating smaller η/s for RHIC) than LHC
  - ✓ Event shape independent

ALICE Collaboration
PLB 804 (2020) 135375

V. Gonzalez et al.
Eur.Phys.J.C 81 5, 465 (2021)

N. Magdy and R. Lacey
arXiv: 2101.01555

N. Magdy et al.
arXiv: 2105.07912

S. Gavin and M. Abdel-Aziz
Phys.Rev.Lett. 97 (2006) 162302

Sean Gavin et al.
PRC 94 (2016) 2, 024921

M. Sharma et al.
PRC 84 (2011) 054915

STAR Collaboration
PLB 704 (2011) 467–473

These comparisons are reflecting the efficacy of the $G2(\Delta\eta,\Delta\varphi)$ correlator to differentiate among theoretical models as well as to constrain the η/s.

Thank You

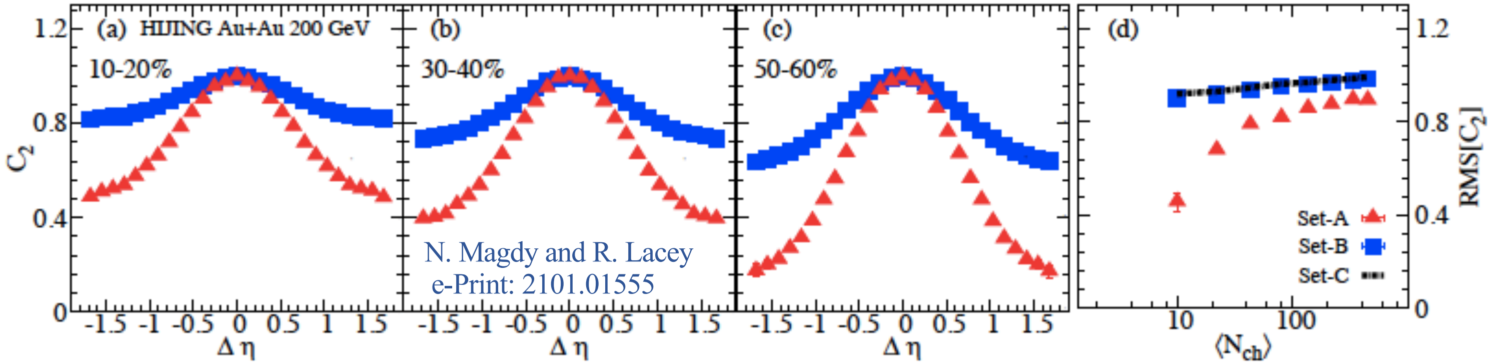
Thank You

N. Magdy and R. Lacey
arXiv: 2101.01555

- The p_T 2-P correlator is given as: $$G_2(\eta_1,\varphi_1,\eta_2,\varphi_2) = \frac{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} p_{T,i}p_{T,j} \right\rangle}{\langle n_1\rangle\langle n_2\rangle} - \langle p_{T,1}\rangle_{\eta_1,\varphi_1} \langle p_{T,2}\rangle_{\eta_2,\varphi_2}$$
- The first term can be given as:

$$\frac{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} p_{T,i}\, p_{T,j} \right\rangle}{\langle n_1\rangle\langle n_2\rangle} = \frac{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} p_{T,i}\, p_{T,j} \right\rangle}{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} n_i\, n_j \right\rangle} r_{1,2}, \quad \rightarrow \quad r_{1,2} = \frac{\left\langle \sum_{i}^{n_1}\sum_{j\neq i}^{n_2} n_i\, n_j \right\rangle}{\langle n_1\rangle\langle n_2\rangle}.$$

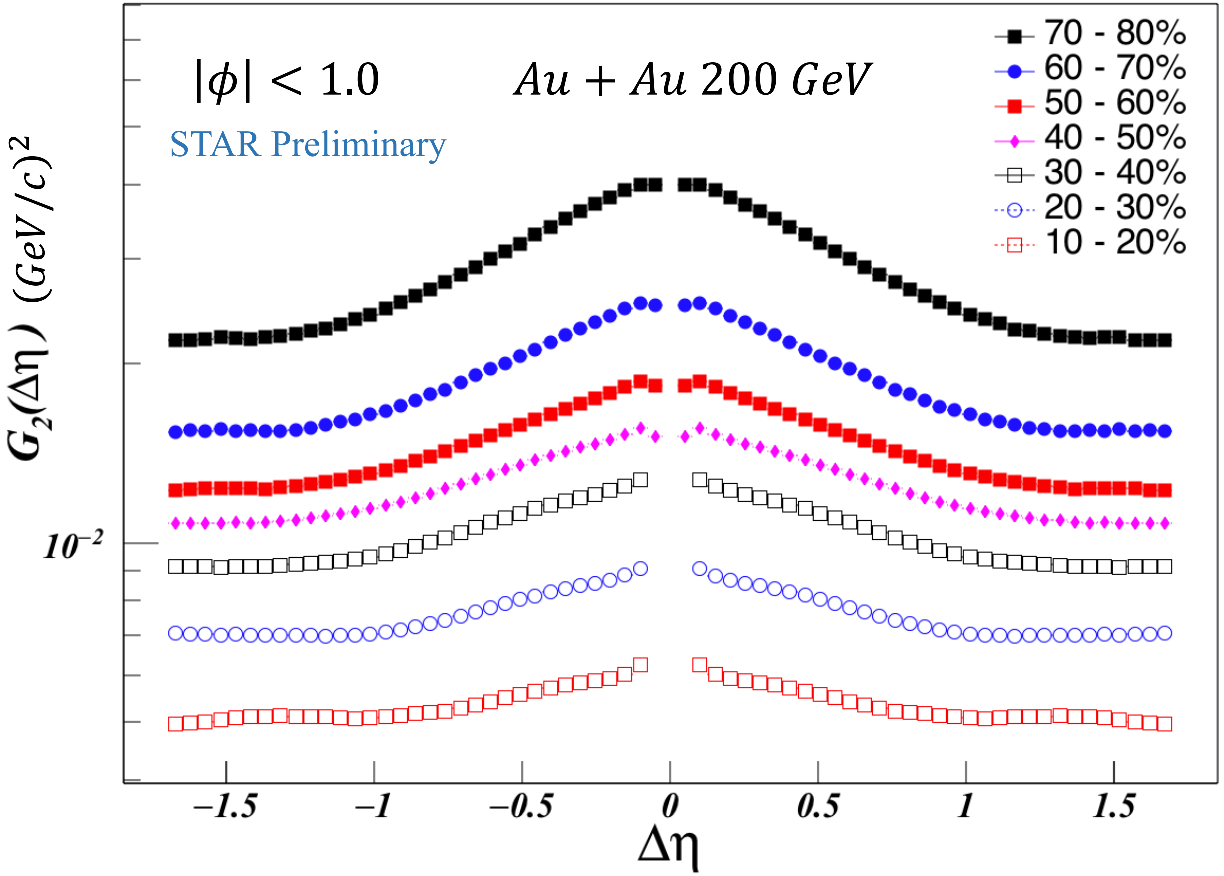
- $r_{1,2}$ is a number correlation, it will be 1 when the particle pairs are independent.
- The $r_{1,2}$ correlations can be impacted by the centrality definition.



Comparison of the $C_2(\Delta\eta)$ correlators ($|\Delta\varphi| < 1$) obtained from 10-20%, 30-40% and 50-60% central HIJING events for Au+Au collisions at 200 GeV.

(i) Set-A: with centrality defined using all charged particles in an event,
(ii) Set-B: with centrality defined using random sampling of charged particles in an event
(iii) Set-C: with centrality defined using the impact parameter distribution.

- Excluding the POI from the collision centrality definition, serves to reduce the possible self-correlations.



|ϕ| < 1.0
Au + Au 200 GeV
STAR Preliminary
70 - 80%
60 - 70%
50 - 60%
40 - 50%
30 - 40%
20 - 30%
10 - 20%
$G_2(\Delta\eta)\ (GeV/c)^2$
10^{-2}
−1.5
−1
−0.5
0
0.5
1
1.5
Δη