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

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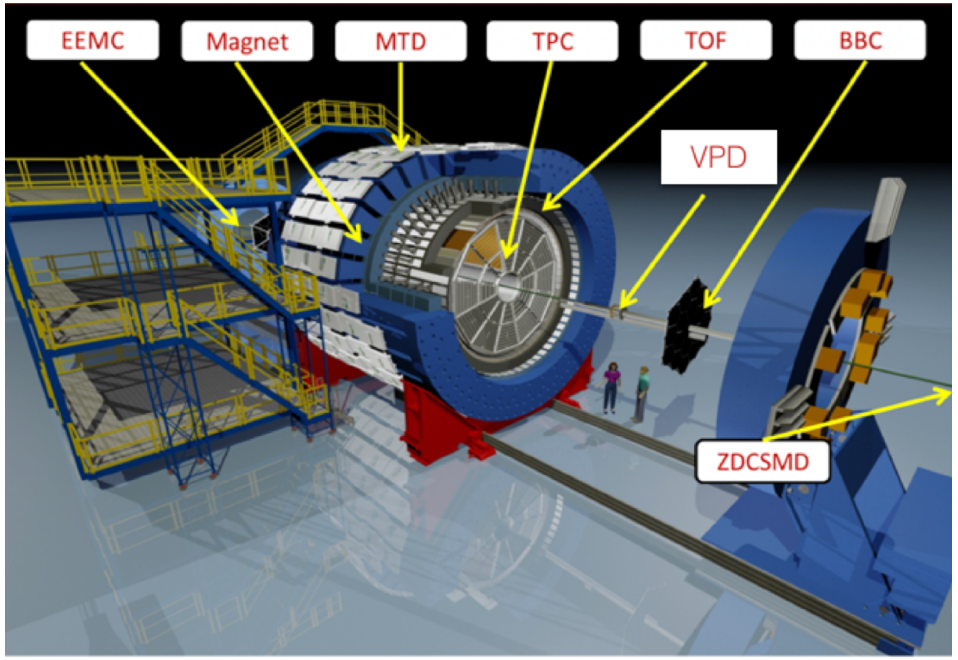


- Data set: Au +Au at $\sqrt{s_{NN}} = 200$ GeV
- Time Projection Chamber
  Tracking of charged particles with:
  - ✓ Full azimuthal coverage
  - ✓ $|\eta| < 1$ coverage
- In this analysis we used tracks with:
  $0.2 < p_T < 2$ GeV/c

ISMD2021 50th International Symposium on Multiparticle Dynamics (ISMD2021)

Motivation:

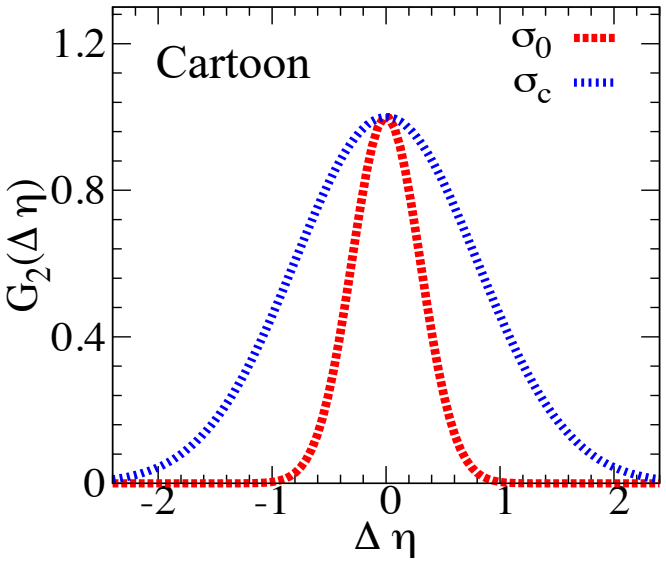
The Gavin ansatz: S. Gavin and M. Abdel-Aziz Phys.Rev.Lett. 97 (2006) 162302

- 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:

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

σ_c → Central

σ_0 → Peripheral



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

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

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

- $r_{1,2}$ 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

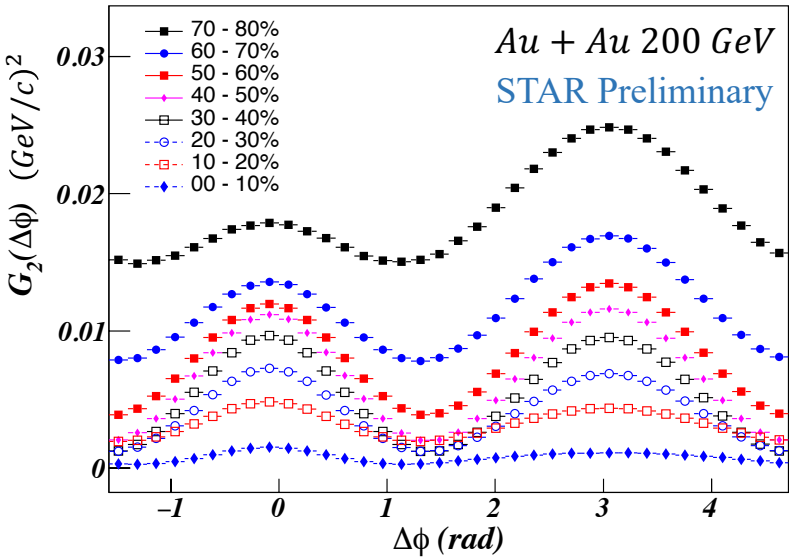
Excluding the POI from the collision centrality definition, helps reduce the possible self-correlations.

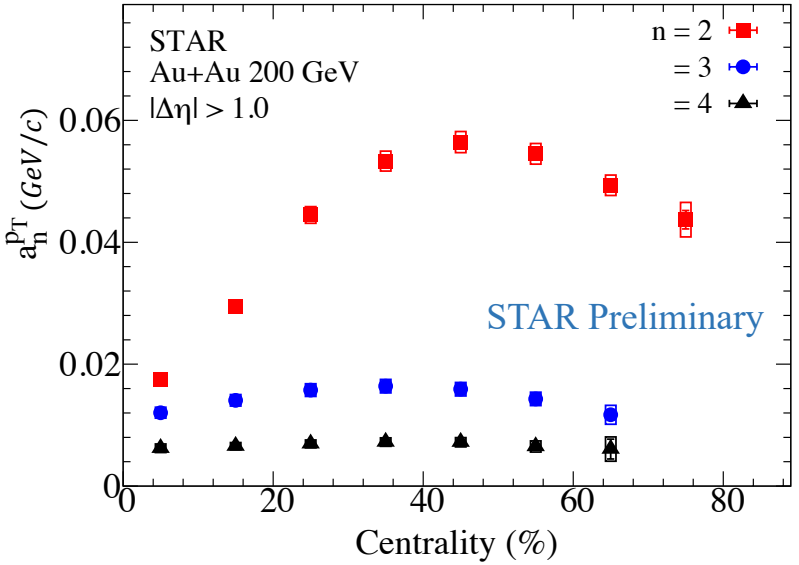
N. Magdy and R. Lacey arXiv: 2101.01555

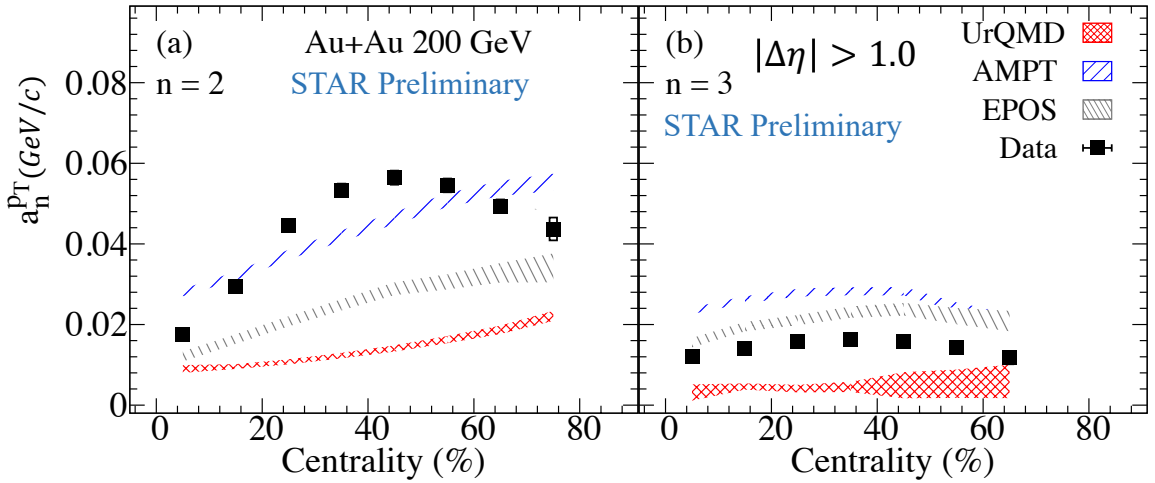
Investigations of the $p_T - p_T$ correlations from STAR

- The azimuthal correlations for Au+Au at 200 GeV

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





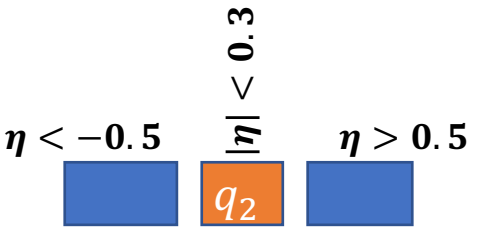


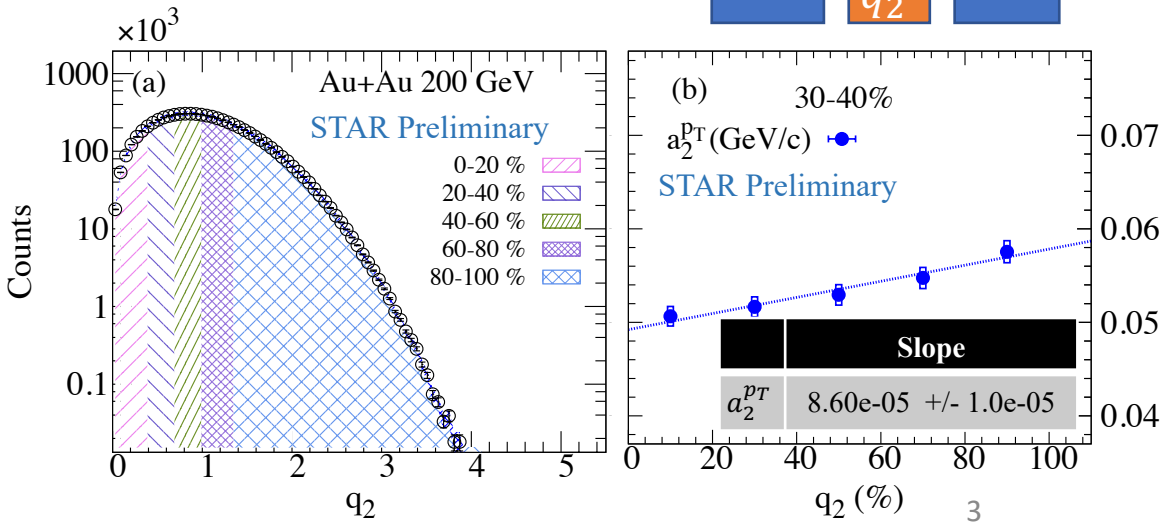
- The extracted $a_2^{p_T}$:
  - ✓ Decrease with harmonic order
  - ✓ Models do not describe the data
  - ✓ Event shape dependent

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

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

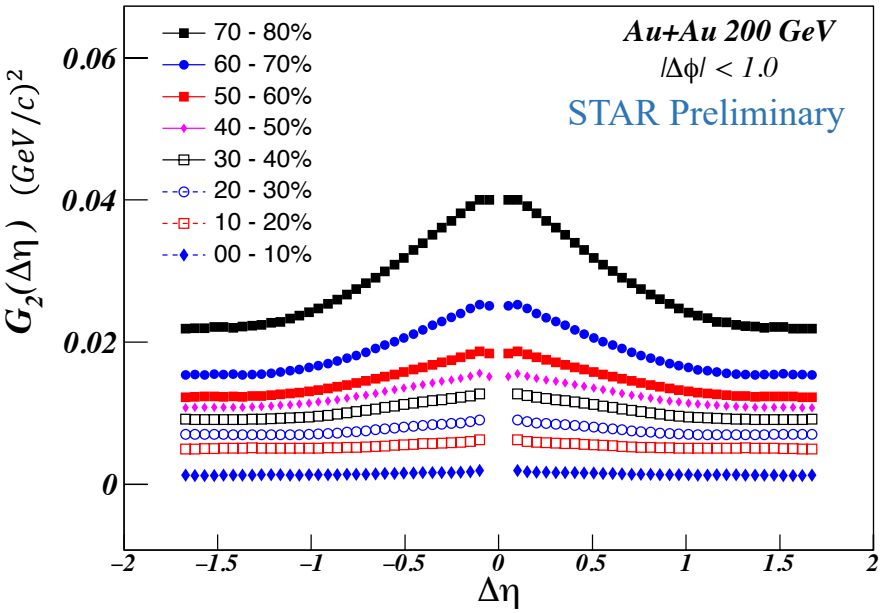
- q_2 is separated from particle of interest





Investigations of the $p_T - p_T$ correlations from STAR

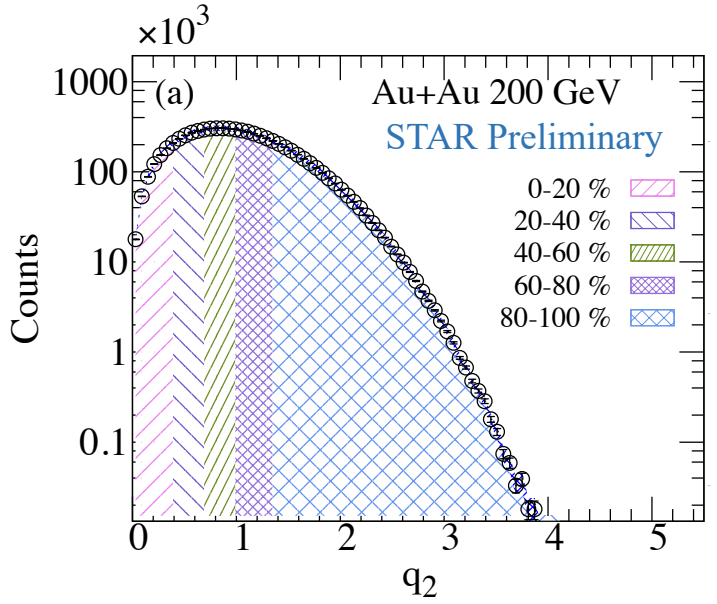
- The longitudinal correlations for Au+Au at 200 GeV

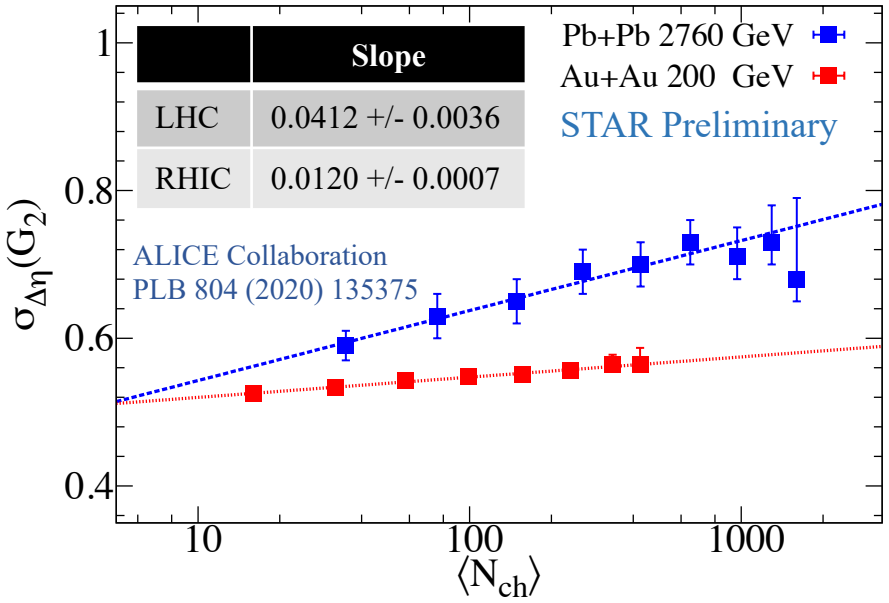


$$\sigma_{\Delta\eta}(G_2) = RMS[G_2(\Delta\eta)]$$

- The slope of $\sigma_{\Delta\eta}(G_2)$ is softer for RHIC
  - ✓ Smaller η/s for RHIC

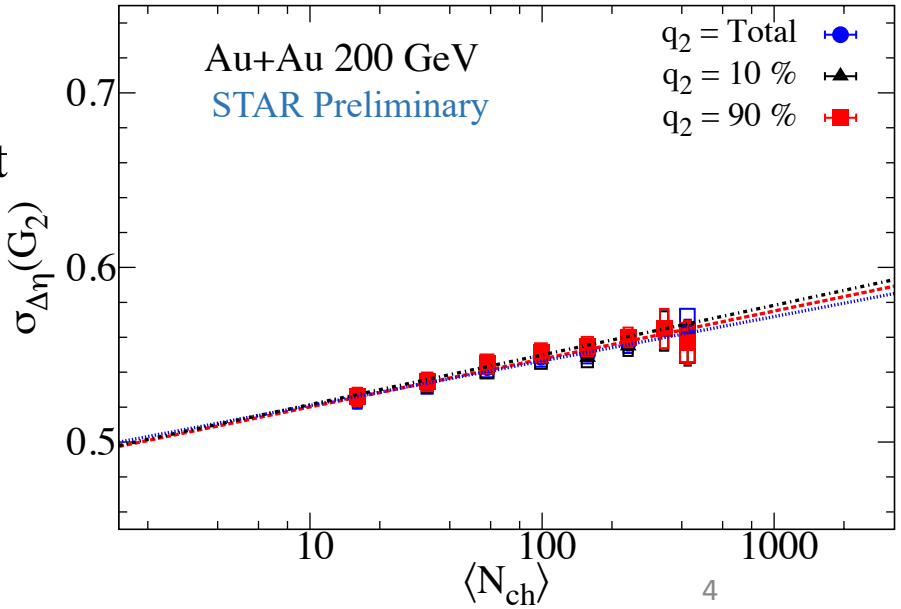
P. Alba et al.
PRC 98, 034909 (2018)





- 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 $p_T - p_T$ 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

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

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

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

N. Magdy and R. Lacey
arXiv: 2101.01555

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

N. Magdy et al.
arXiv: 2105.07912

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

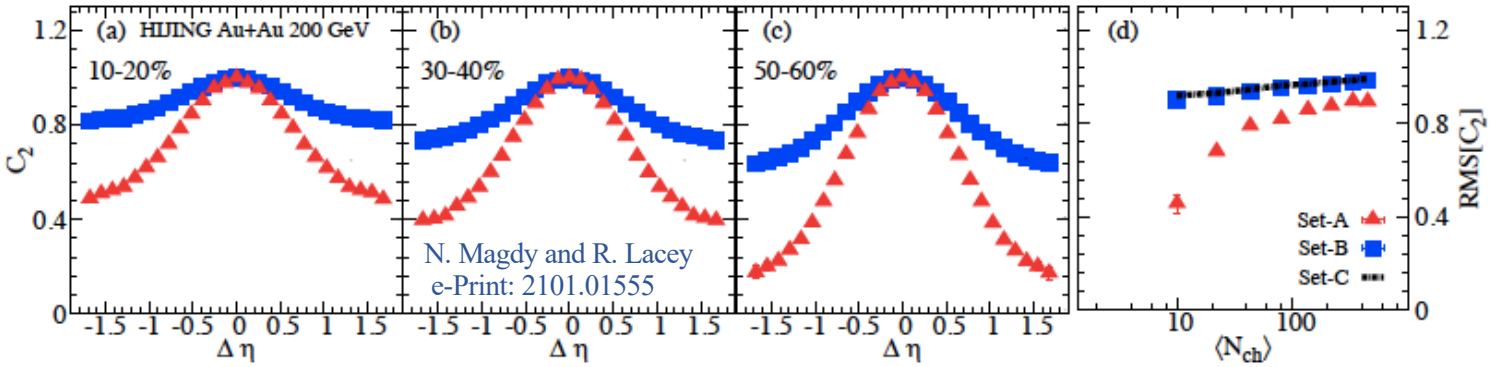
Thank You

N. Magdy and R. Lacey
arXiv: 2101.01555

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

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

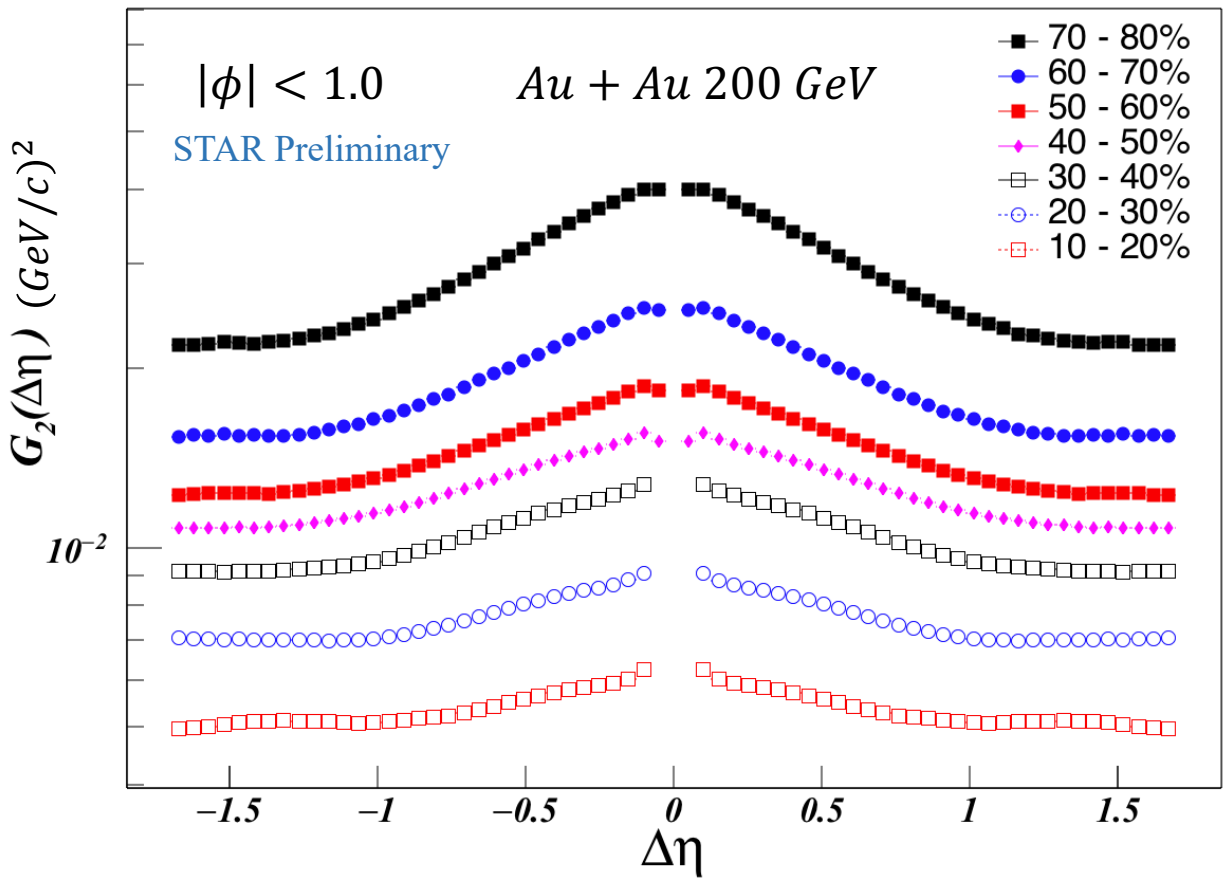
- $r_{1,2}$ is a number correlation, it will be 1 when the particle pairs are independent.
- The $r_{1,2}$ correlations can be impacted by the centrality definition.



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.


$|\phi| < 1.0$
$Au + Au$ 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