Quantifying the QGP shear viscosity using the two-particle transverse momentum correlations

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ALICE Collaboration
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Motivation:

- One of the main goals of heavy ions collisions is to understand the QGP transport properties (η/s).

- Several theoretical and experimental investigations have been devoted to the development of further constraints for more robust extractions of η/s

- Although these investigations have advanced the η/s extractions methods more constraints are still required to reduce the extractions uncertainty.

The Gavin ansatz:

- The p_T 2-P correlation function is sensitive to the dissipative viscous effects that ensue 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:

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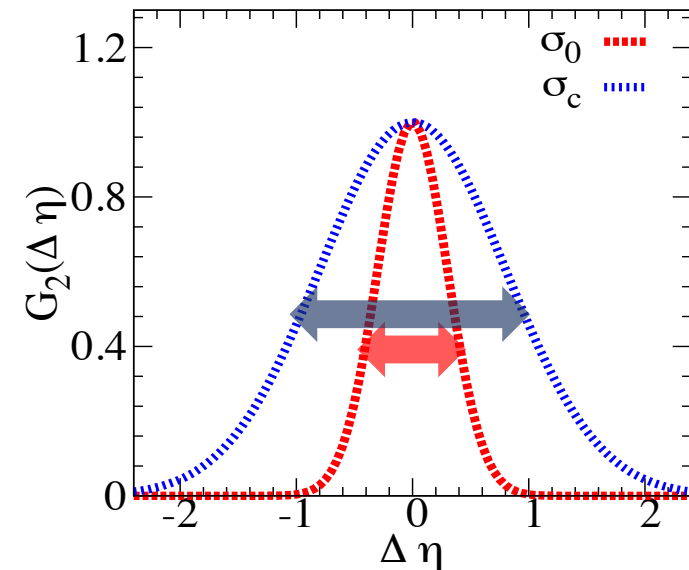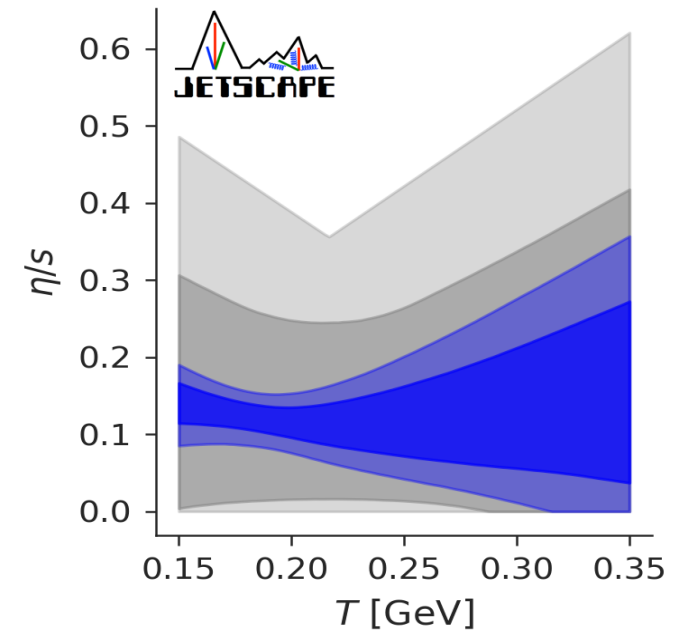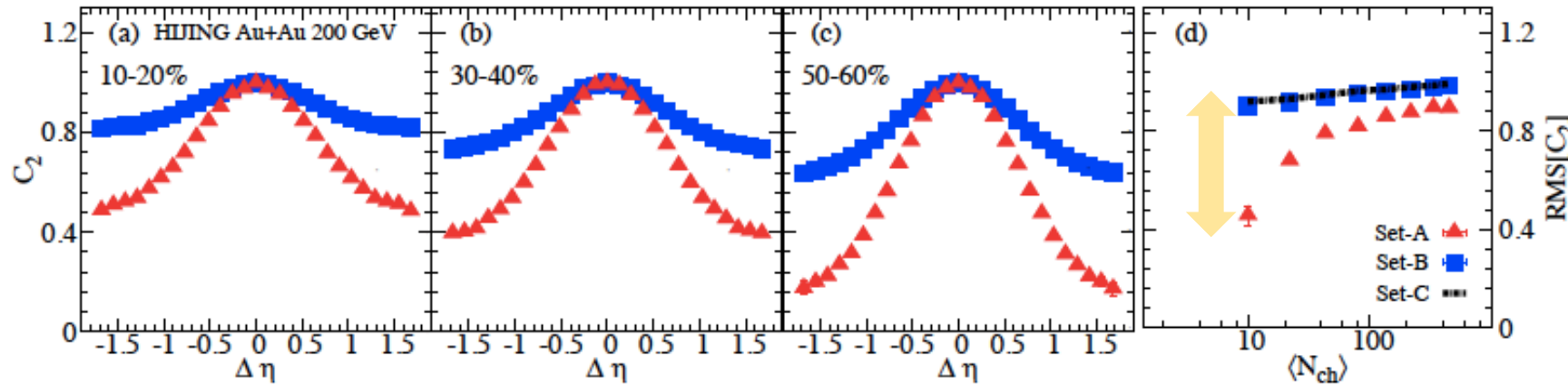
The p_T 2-P correlator:

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

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

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

➢ $r_{1,2}$ 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
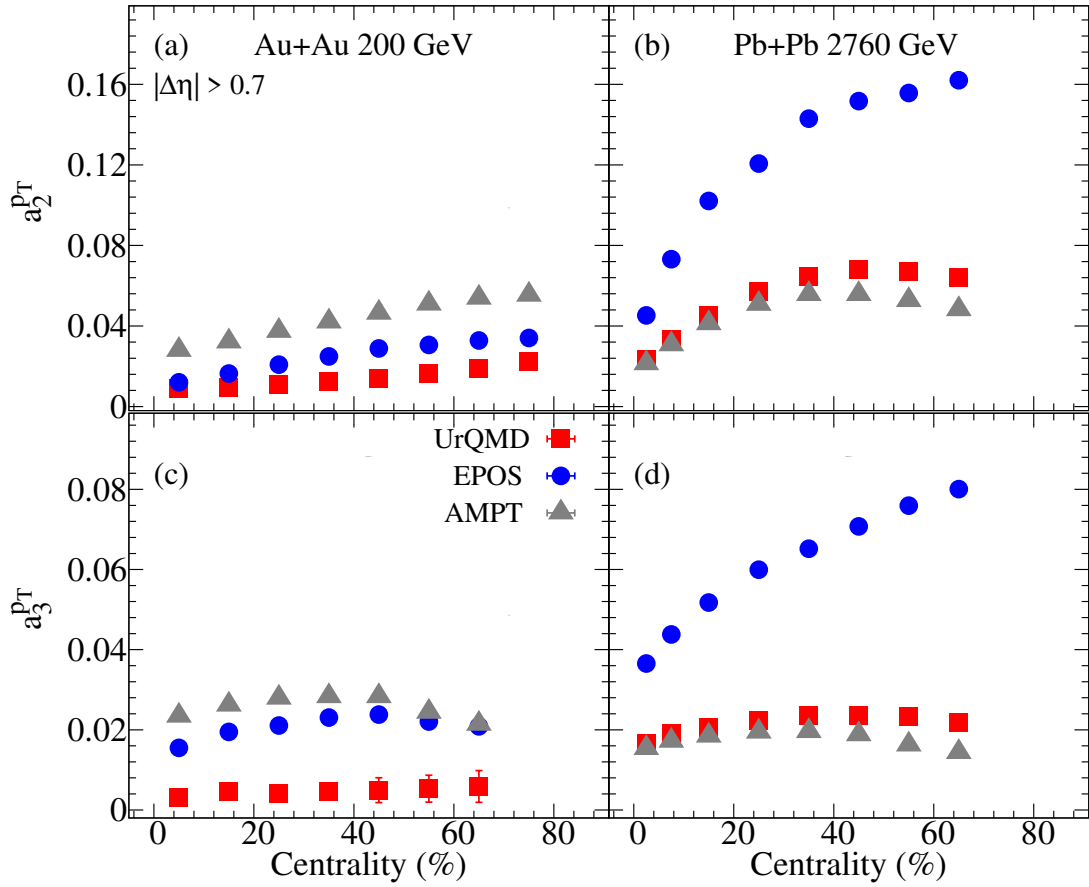(iii) Set-C: with centrality defined using the impact parameter distribution.

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

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Investigations of the $p_T - \mathrm{p_T}$ correlations

➢ The azimuthal correlations for Au+Au at 200 GeV

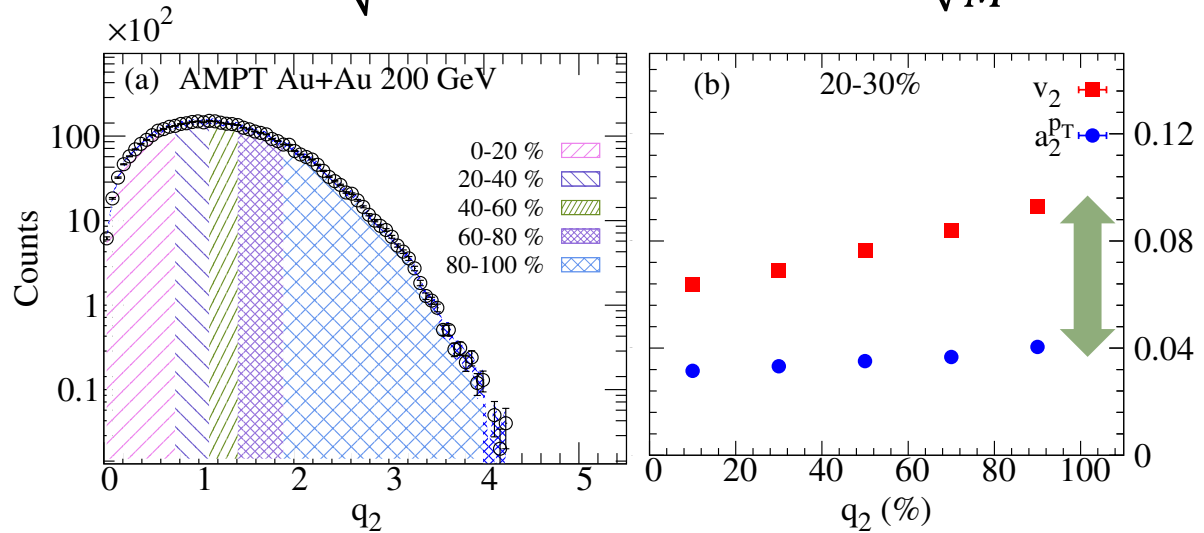$$f(\Delta\varphi) = a_0^{p_T} + 2 \sum_{n=1}^{6} \left(a_n^{p_T}\right)^2 \cos(n\,\Delta\varphi)$$

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

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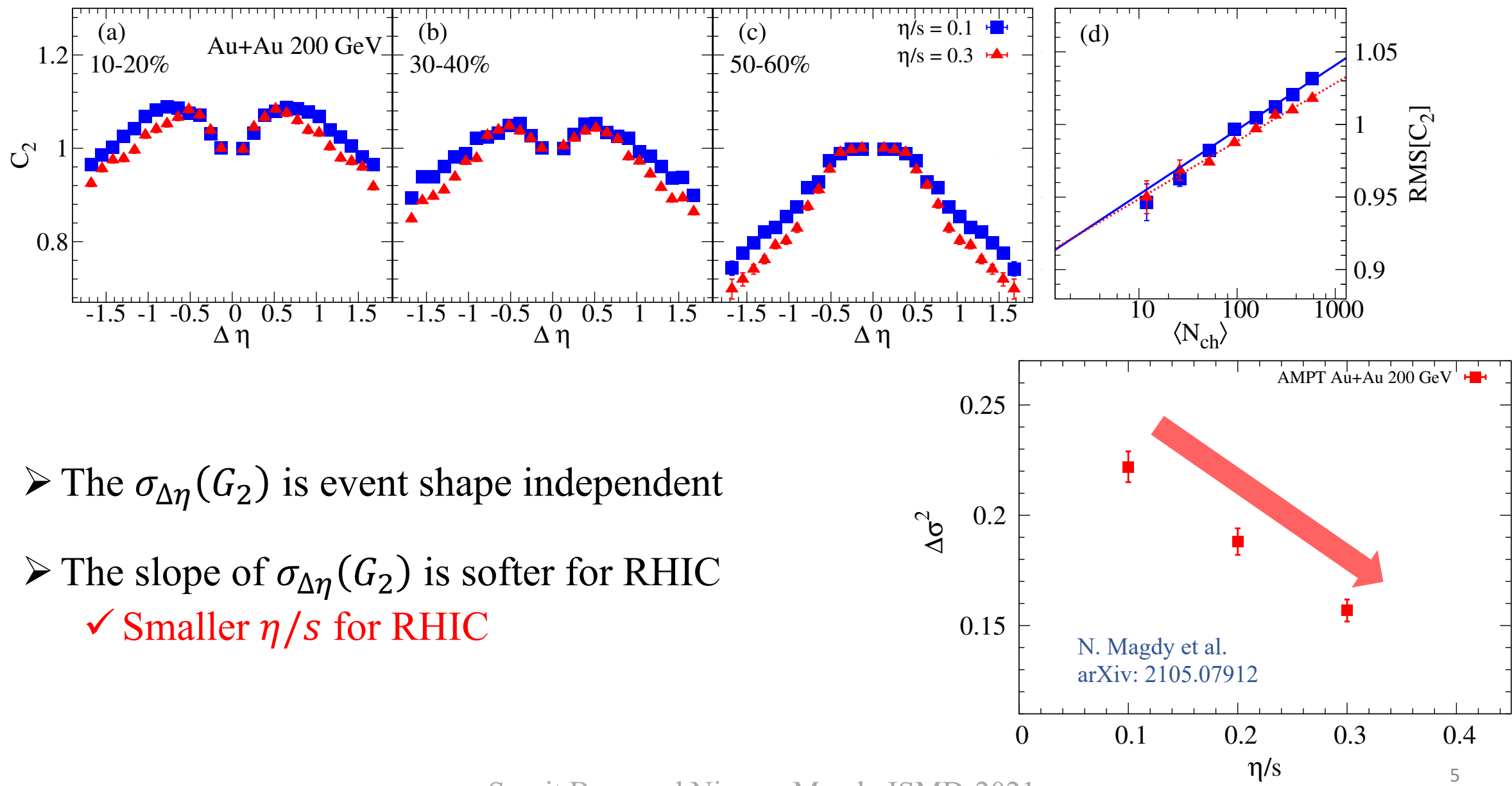

➢ The extracted $a_2^{p_T}$:

✓ Decrease with harmonic order

✓ Models don't agree with each other

✓ Event shape dependent

Investigations of the $p_T - p_T$ correlations

➤ The longitudinal correlations for Au+Au at 200 GeV

(a) Au+Au 200 GeV
10-20%

(b) 30-40%

(c) 50-60%

$\eta/s = 0.1$ ■
$\eta/s = 0.3$ ▲

(d)

C_2

$\Delta\eta$

$\langle N_{ch} \rangle$

RMS[C_2]

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

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

AMPT Au+Au 200 GeV ■

$\Delta\sigma^2$

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η/s

Investigations of the $p_T - p_T$ correlations

> ➤ Conclusions

We investigated the $p_T - p_T$ 2-P correlation function for Au+Au at 200 GeV in different models and we found that;

➤ The extracted $a_2^{p_T}$:

    ✓ Decrease with harmonic order

    ✓ Models don't agree with each other

    ✓ Event shape dependent

➤ The slope of $\sigma_{\Delta\eta}(G_2)$ is η/s dependance

Our results 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.

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Thank You

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