Measurements of Longitudinal Flow Decorrelation in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV from the STAR Collaboration

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For the STAR collaboration

Shanghai Institute of Applied Physics &

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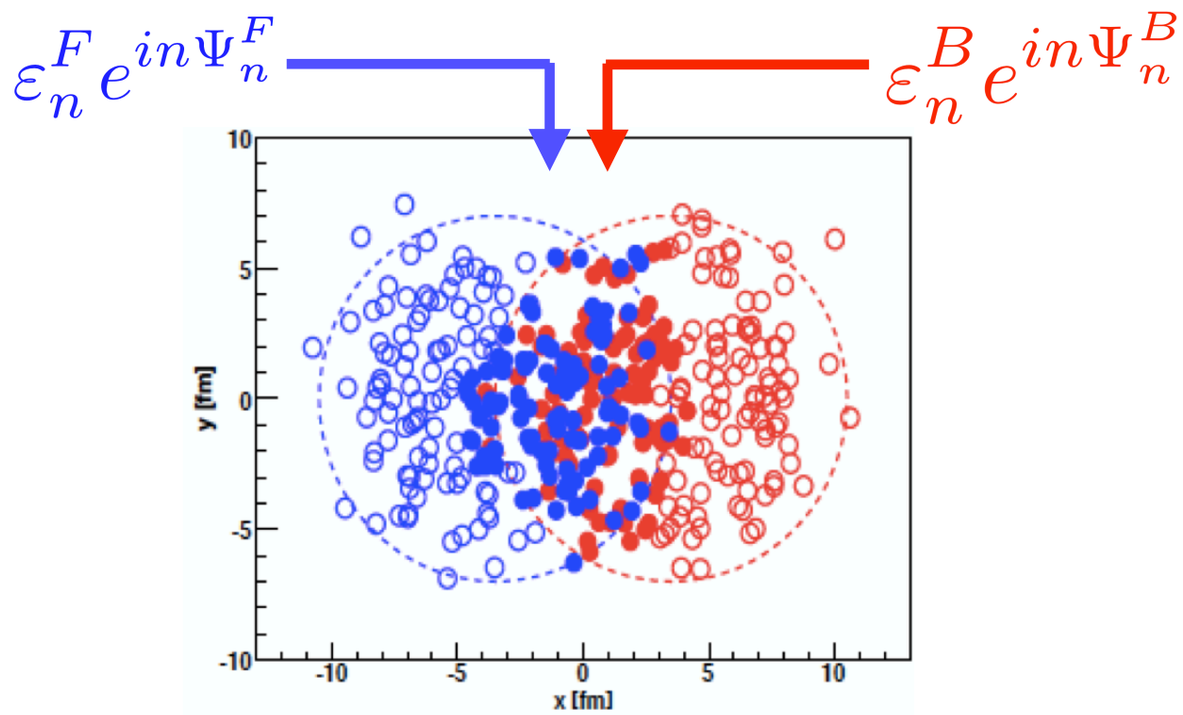
Initial Stages 2017

Polish Academy of Arts and Sciences

September 18-22, 2017, Cracow, Poland

Origin of the flow decorrelation

- Shape of an overlapping region is driven by eccentricities of Forward-going and Backward-going participants



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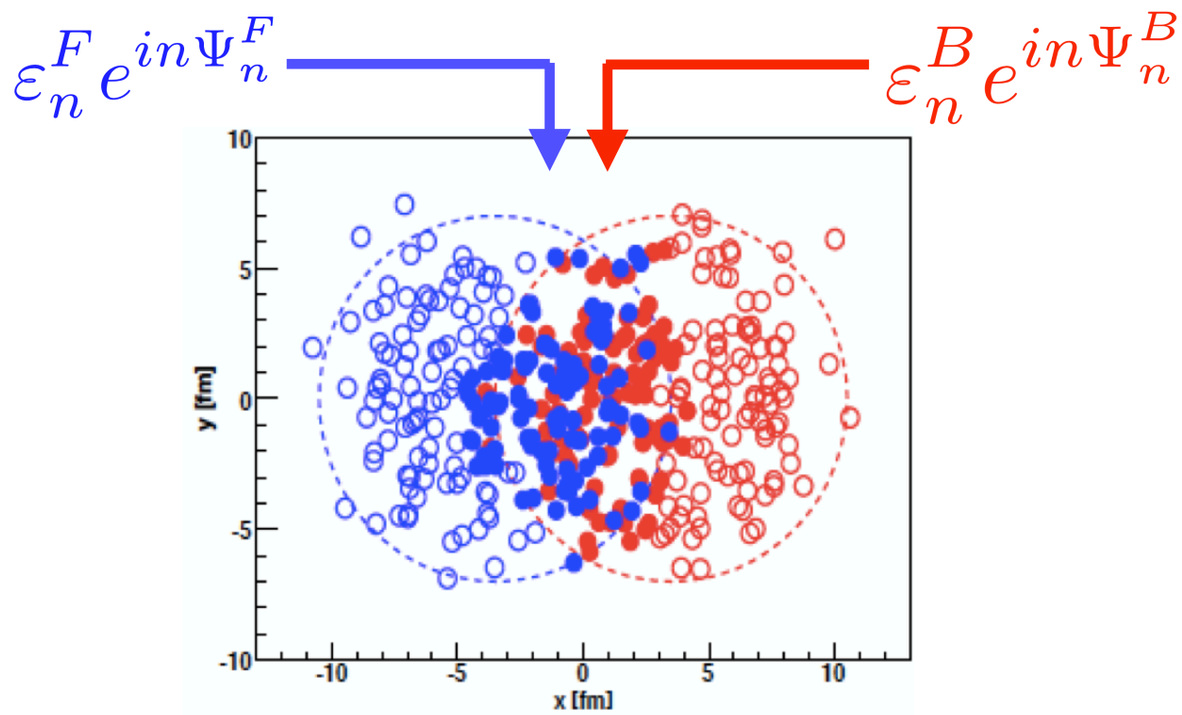
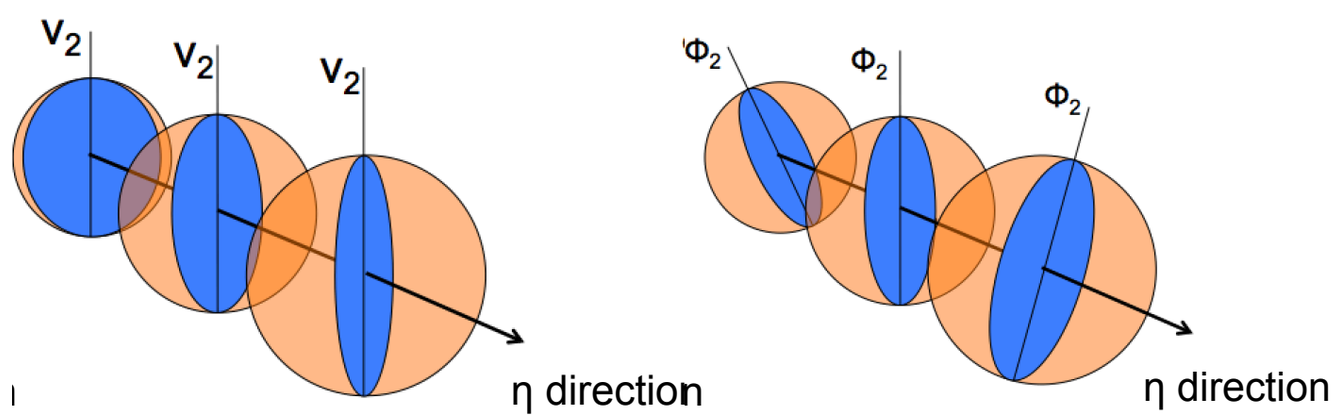


- Consequence: $V_n(\eta) = v_n(\eta) e^{in\Psi_n(\eta)}$

P. Huo QM2017 Flash talk

Asymmetry of a flow magnitude Torque/twist of an event plane



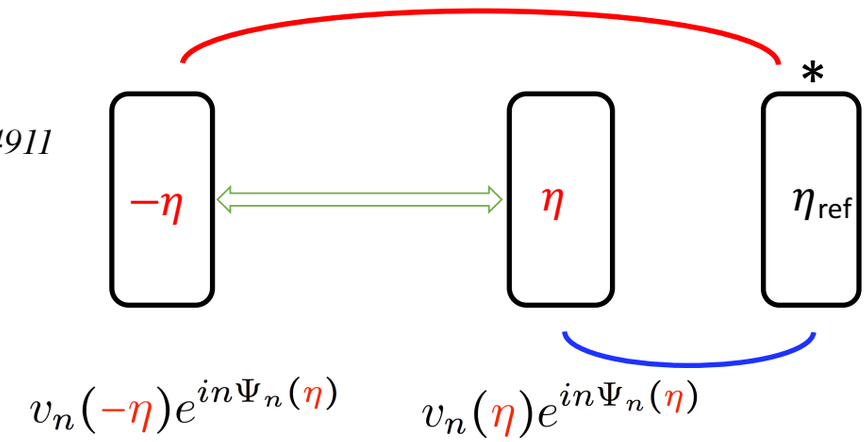
$v_n(\eta_1) \neq v_n(\eta_2)$ $\Psi_n(\eta_1) \neq \Psi_n(\eta_2)$

Method

- Factorization ratio r_n is constructed to measure of the flow decorrelation

$$r_n(\eta) = \frac{\langle V_n(-\eta) V_n^*(\eta_{\rm ref})\rangle}{\langle V_n(\ \eta) V_n^*(\eta_{\rm ref})\rangle} = \frac{\langle v_n(-\eta) v_n(\eta_{\rm ref}) \cos n(\Psi_n(-\eta) - \Psi_n(\eta_{ref}))\rangle}{\langle v_n(\ \eta) v_n(\eta_{\rm ref}) \cos n(\Psi_n(\ \eta) - \Psi_n(\eta_{ref}))\rangle}$$

CMS Collaboration, Phys. Rev. C 92 (2015) 034911



- r_n measures relative fluctuation between $\mathbf{v}_n(-\eta)$ and $\mathbf{v}_n(\eta)$

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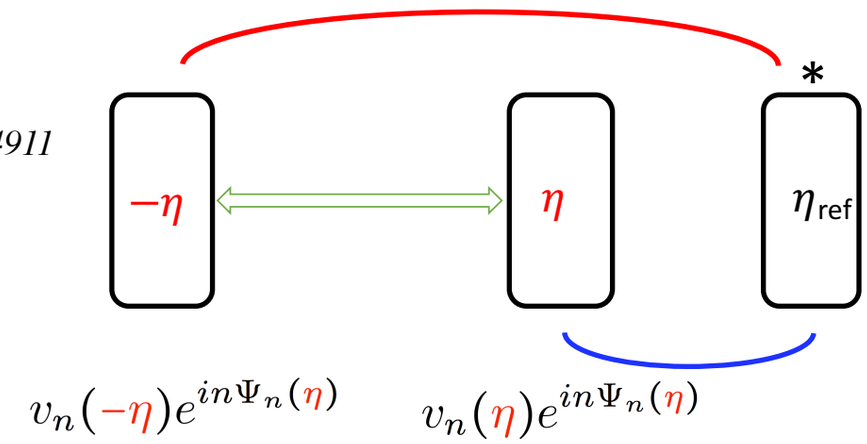


- r_n measures relative fluctuation between $\mathbf{v}_n(-\eta)$ and $\mathbf{v}_n(\eta)$

A large η gap is required to avoid short-range correlation

If no decorrelation

$$\langle v_n(-\eta)v_n(\eta_{\rm ref})\rangle = \langle v_n(\eta)v_n(\eta_{\rm ref})\rangle$$

$$\Rightarrow \quad r_n(\eta) = 1$$

If decorrelation

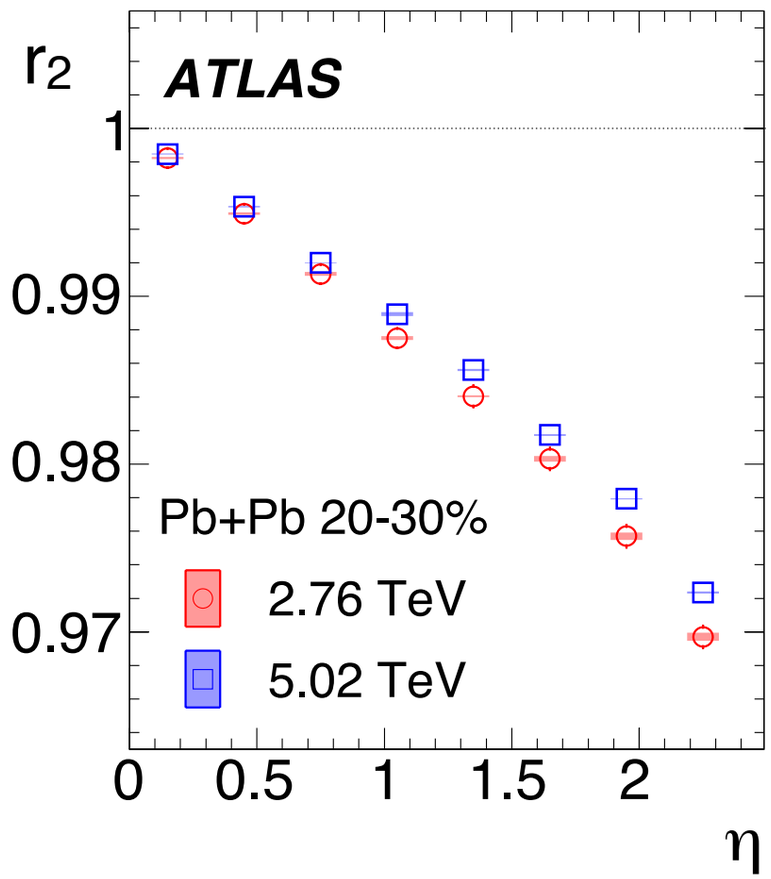
$$\langle V_n(\eta)V_n^*(\eta_{\rm ref})\rangle = \langle v_n(\eta)v_n(\eta_{ref})\cos n(\Psi_n(\eta)-\Psi_n(\eta_{ref}))\rangle$$

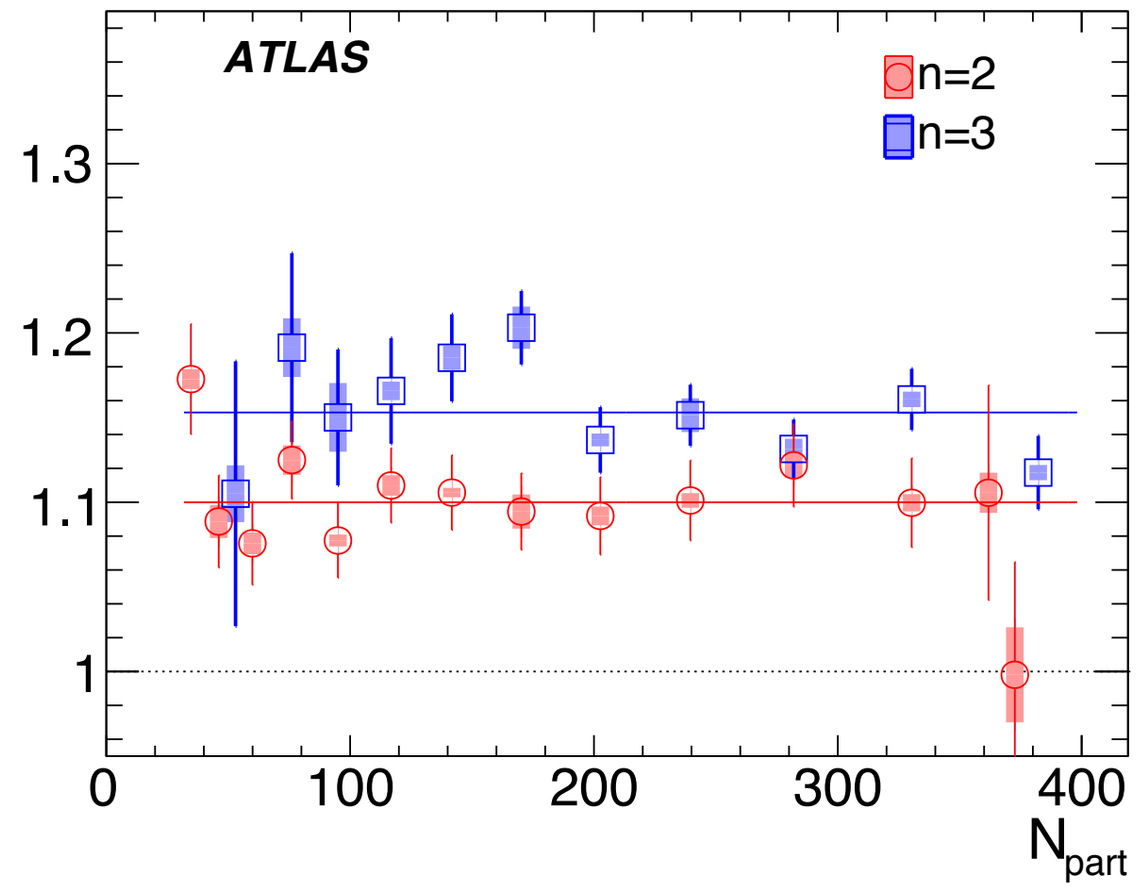
$$\Rightarrow \quad r_n(\eta) \neq 1$$

The current longitudinal dynamics study in the experiment

$$r_n = 1 - 2F_n\eta \qquad \frac{F_n(2.76\ \text{TeV})}{F_n(5.02\ \text{TeV})}$$

ATLAS Collaboration, arXiv:1709.02301





- Evidence of flow decorrelation has been observed at LHC.
- From 5.02 TeV to 2.76 TeV, stronger decorrelation is observed.

~10% / 16% higher for v2/ v3

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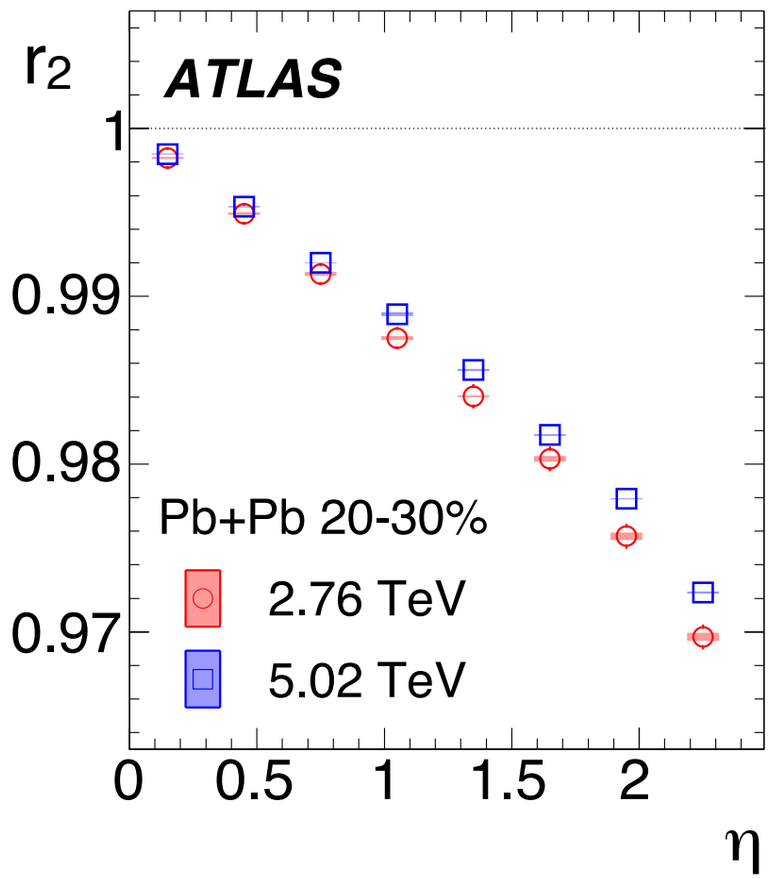

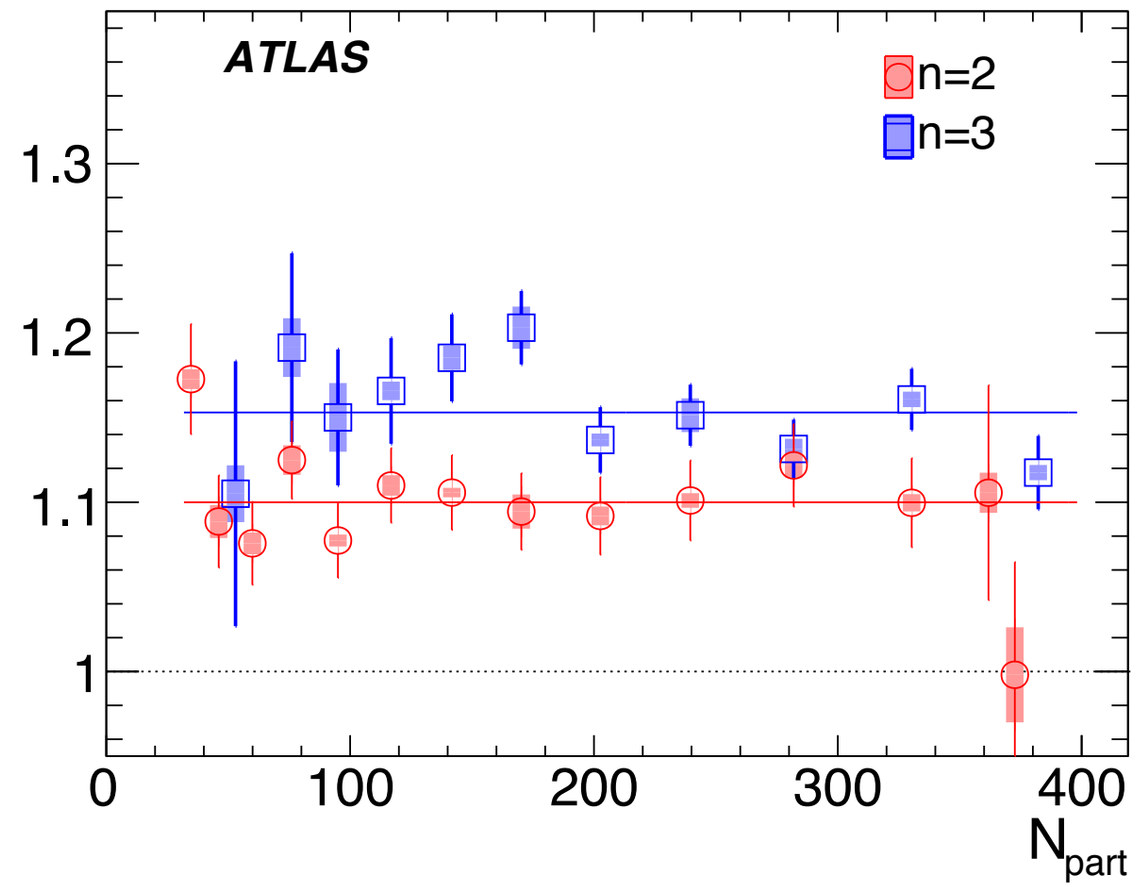

- Evidence of flow decorrelation has been observed at LHC.
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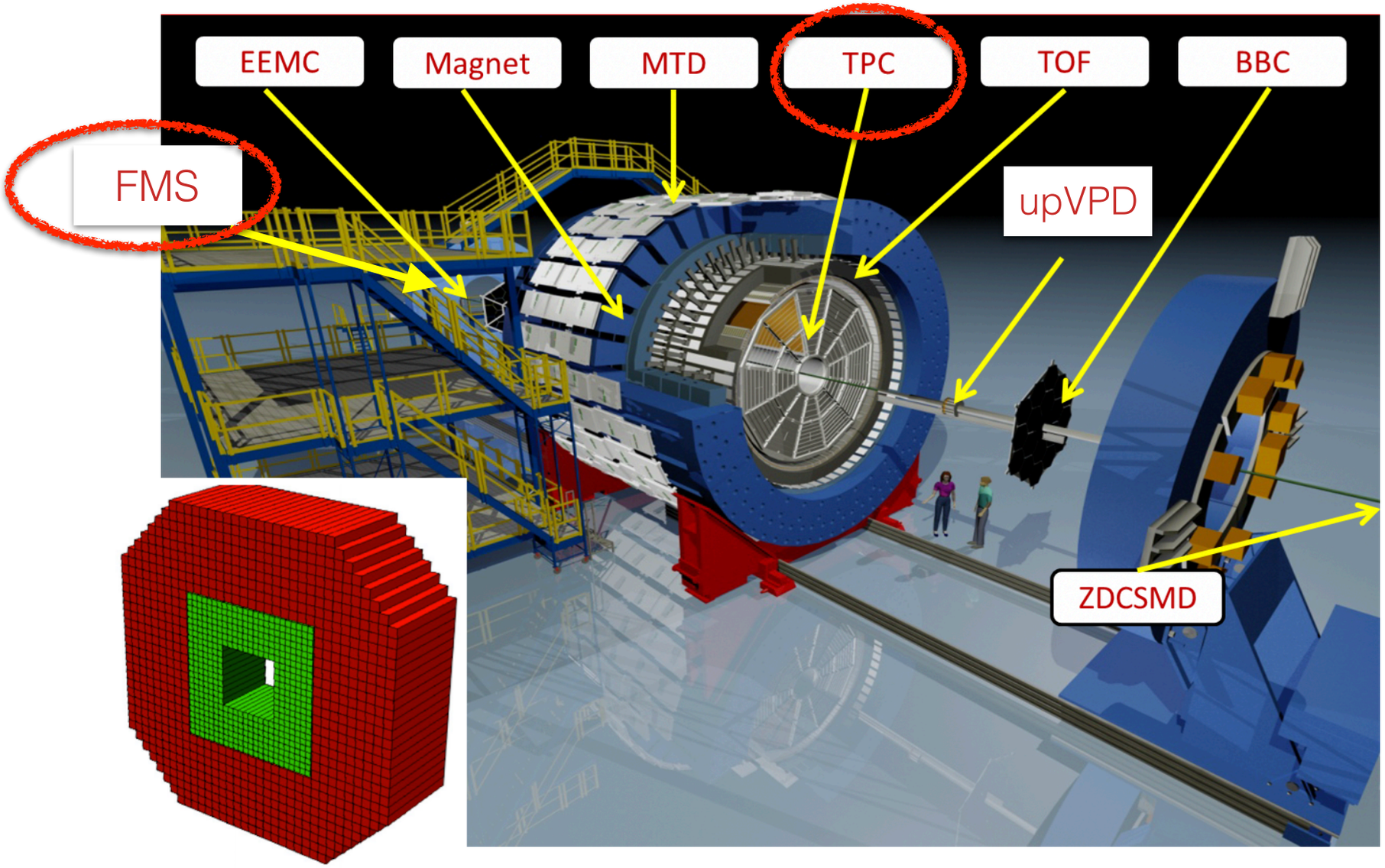
- How about the flow decorrelation at the RHIC energy?

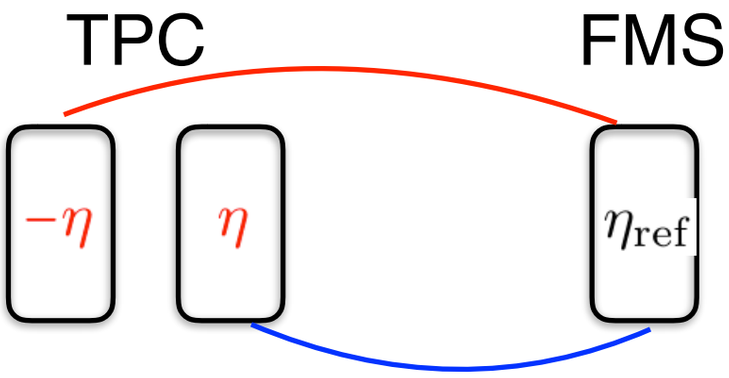
The STAR detector

Forward Meson Spectrometer (FMS)



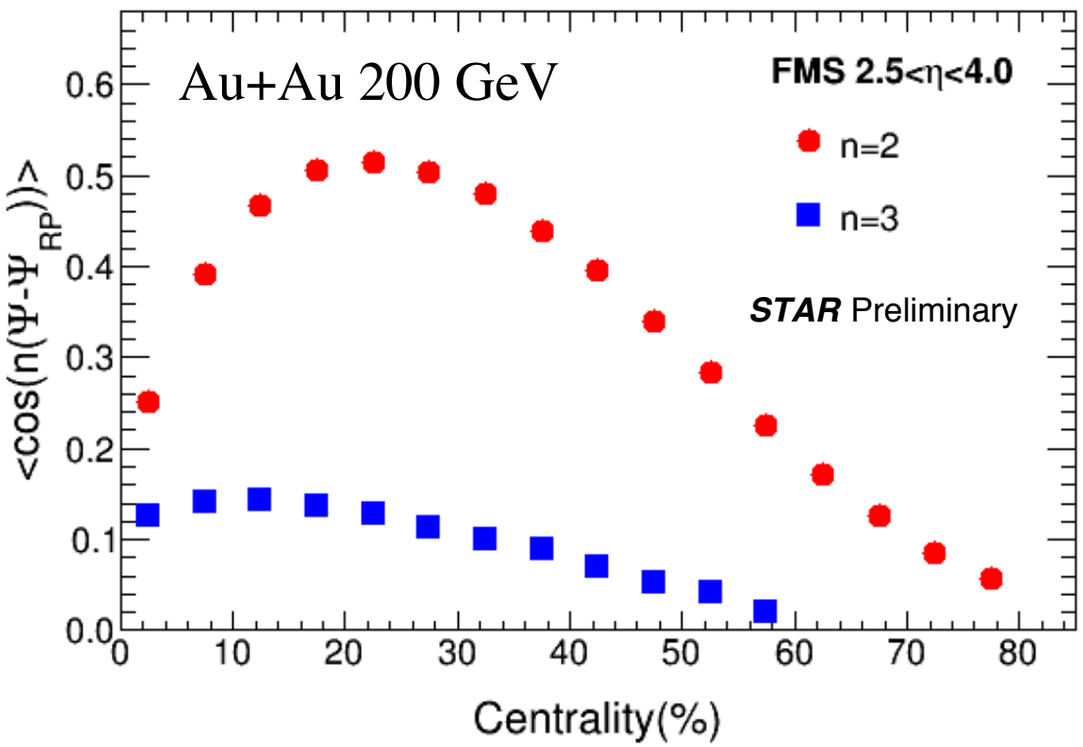
TPC acceptance -1< η <1

FMS acceptance 2.5< η <4

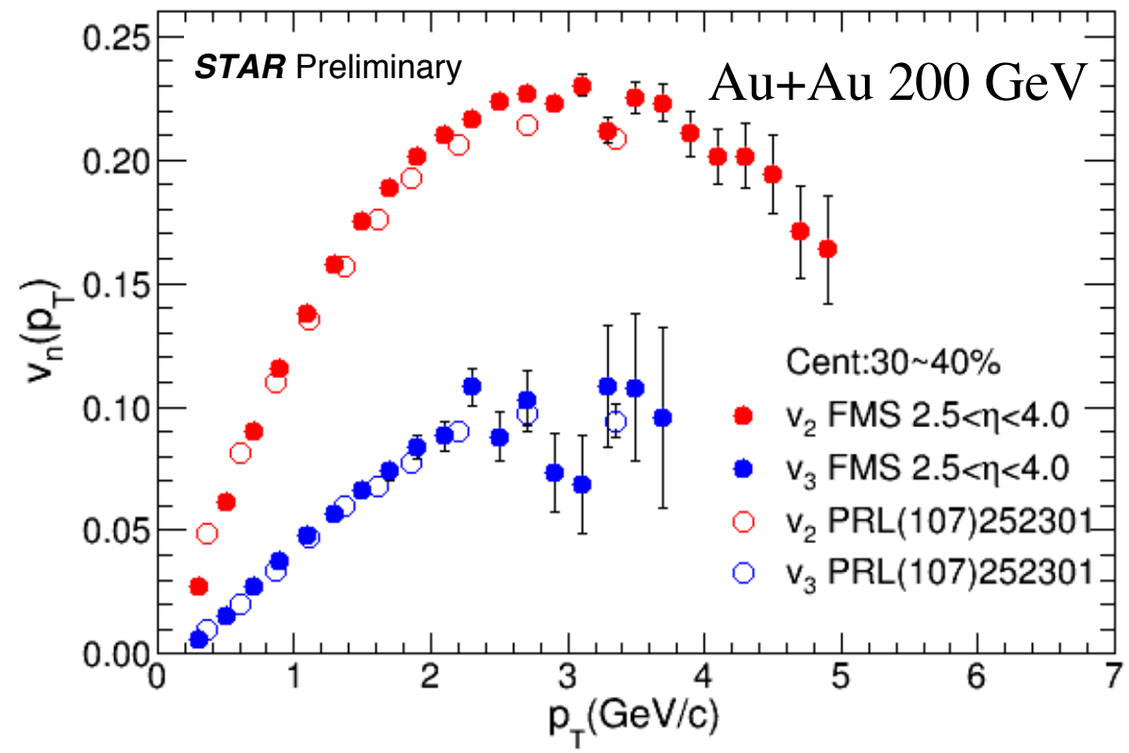


Performance of the FMS detector

FMS event plane resolution



A comparison with published results

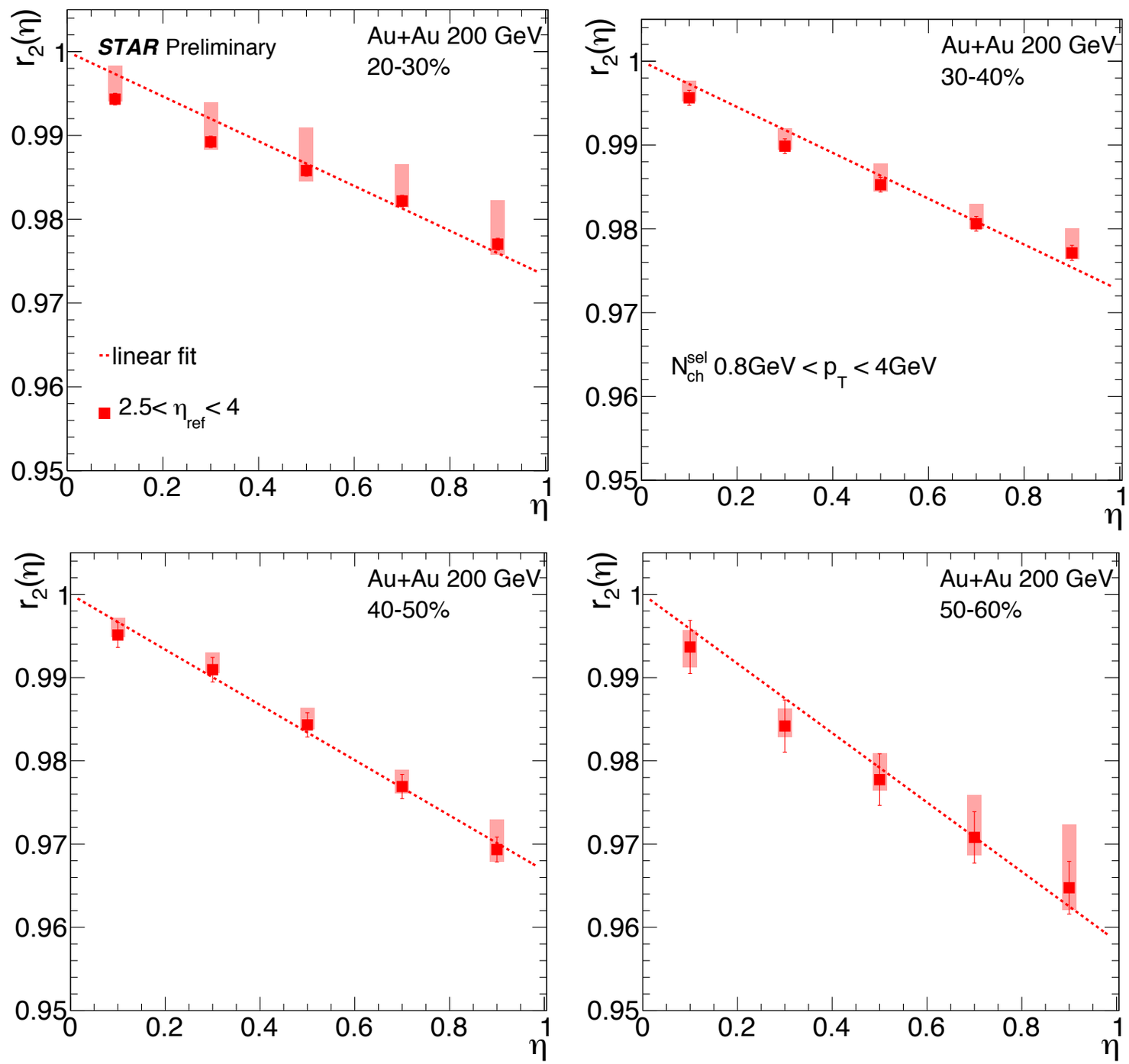


- The maximum event plane resolution from FMS can reach 50% (15%) for v_2(v_3).
- Both v_2 and v_3 are consistent with the published results from 200 GeV Au+Au collisions.
- FMS can be used as an event-plane detector.

Longitudinal decorrelation of v_2 in Au+Au

✦ Decorrelation of $v_2(\eta)$

$$r_2(\eta) = \frac{\langle V_2(-\eta)V_2^*(\eta_{\rm ref})\rangle}{\langle V_2(\ \eta)V_2^*(\eta_{\rm ref})\rangle}$$

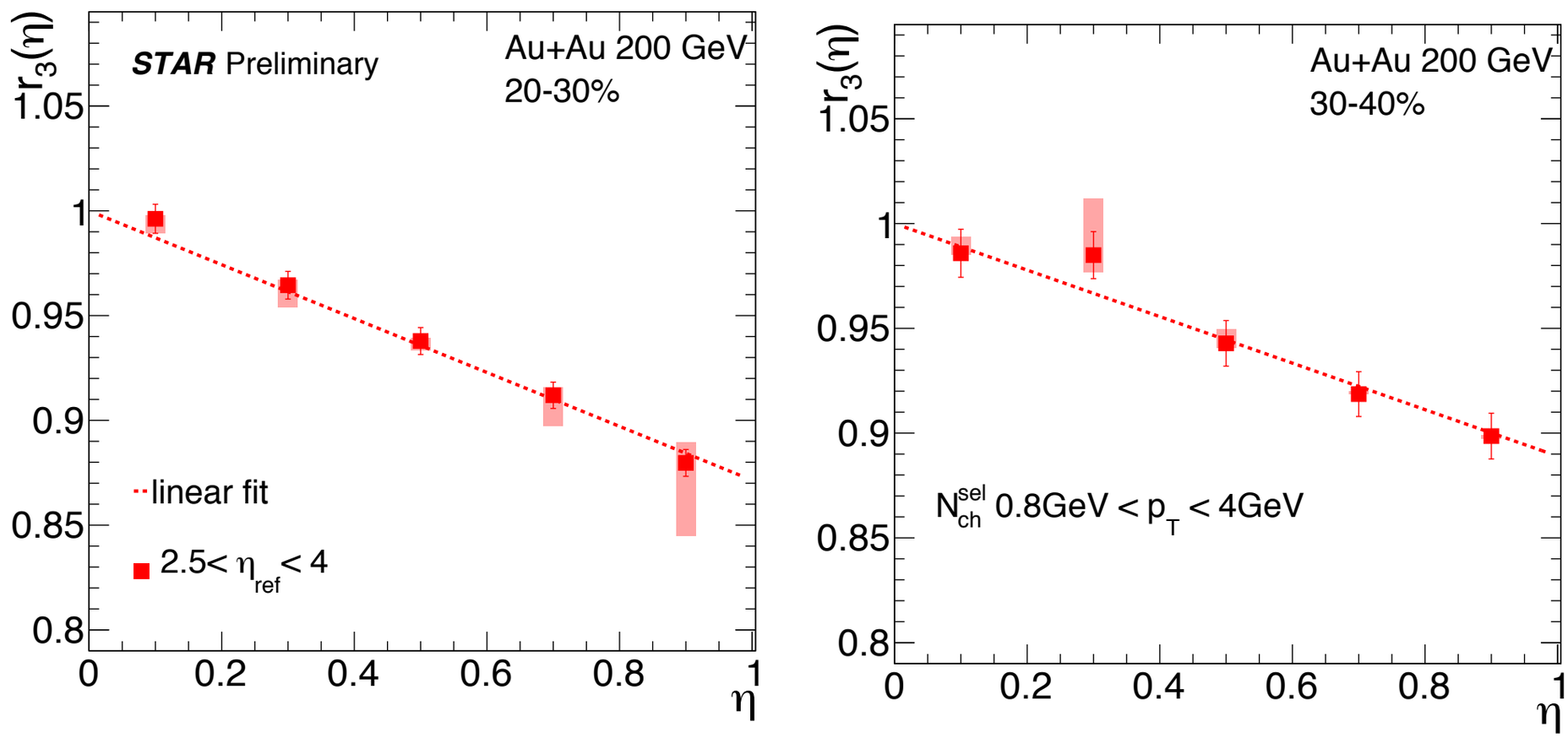


- $r_2(\eta)$ decreases linearly for different centralities.
- Stronger decorrelation effect in more peripheral collisions.

Longitudinal decorrelation of v_3 in Au+Au

- Decorrelation of $v_3(\eta)$

$$r_3(\eta) = \frac{\langle V_3(-\eta) V_3^*(\eta_{\rm ref})\rangle}{\langle V_3(\ \eta) V_3^*(\eta_{\rm ref})\rangle}$$

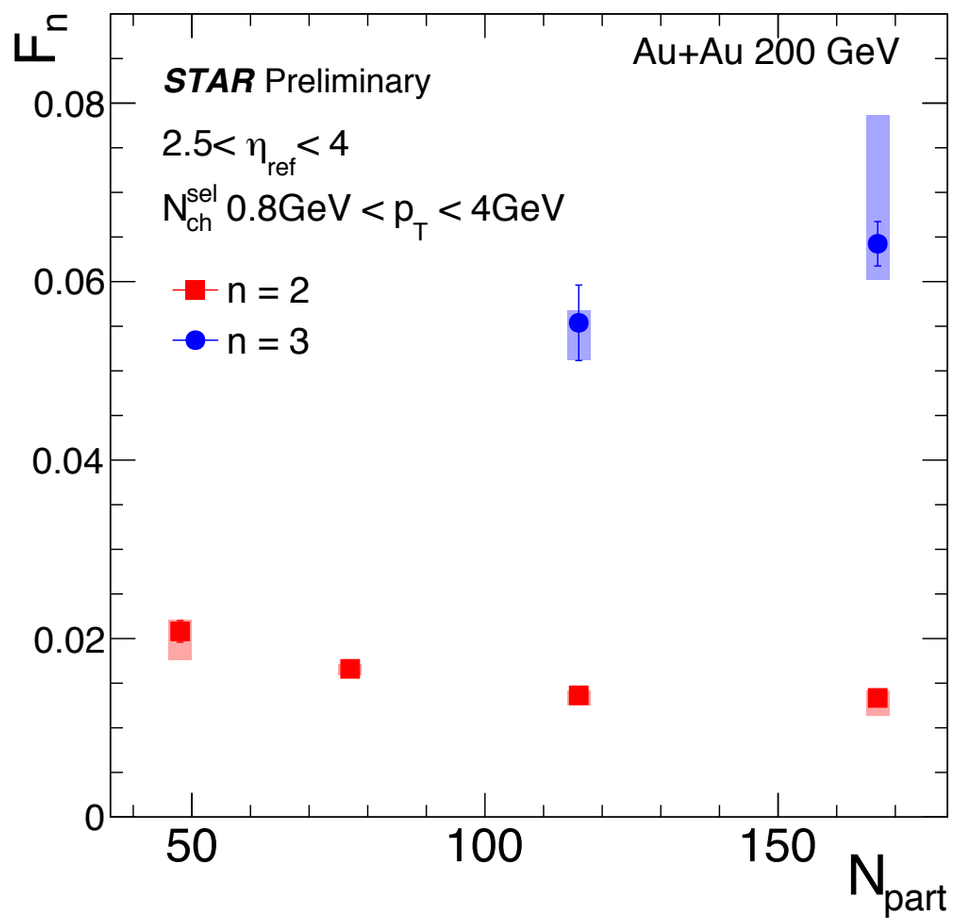


- $r_3(\eta)$ roughly linear decreasing along with η.
- v_3 shows relatively stronger decorrelation than v_2.

Centrality dependence of r_n

- r_n is parameterized with a linear function

$$r_n = 1 - 2F_n\eta$$

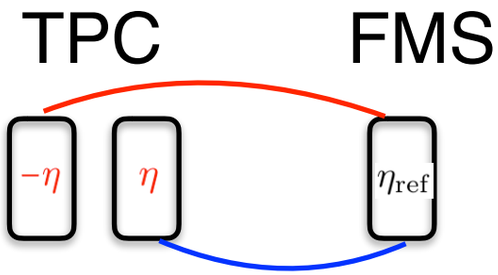


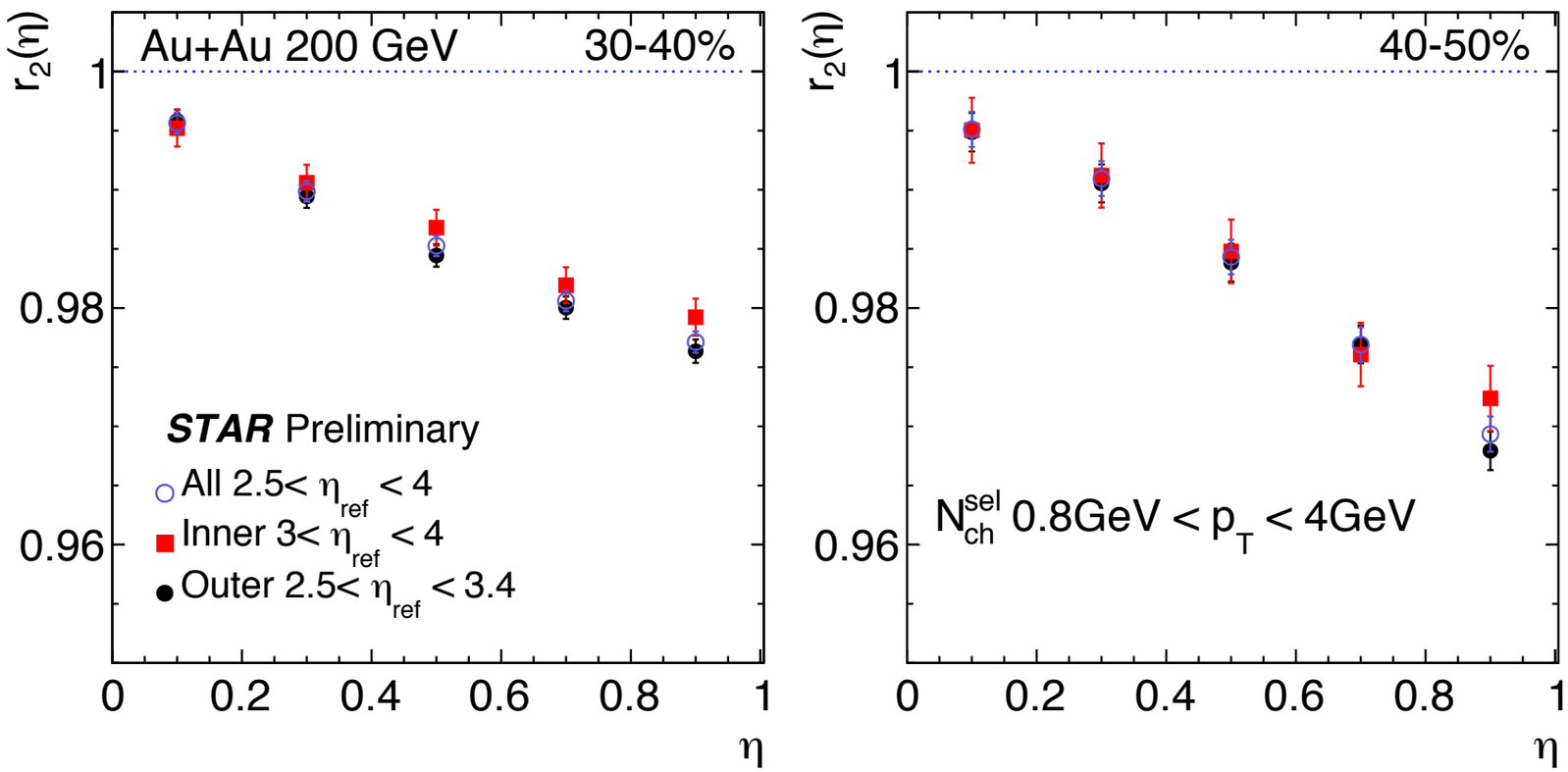
- Slope parameter F_n is extracted to quantify the decorrelation effect.
- For v_2, from mid-central to peripheral, the decorrelation effect gets stronger.

η_{ref} dependence of r_n

- r_n for different η_{ref} range

check for short-range correlation





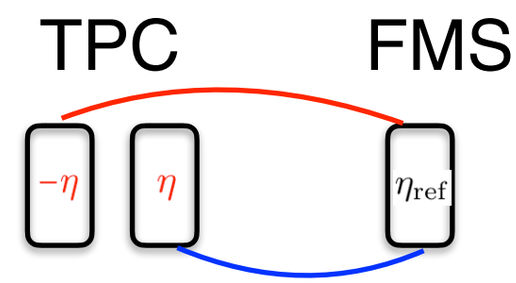
r_2 is consistent for different η_{ref}

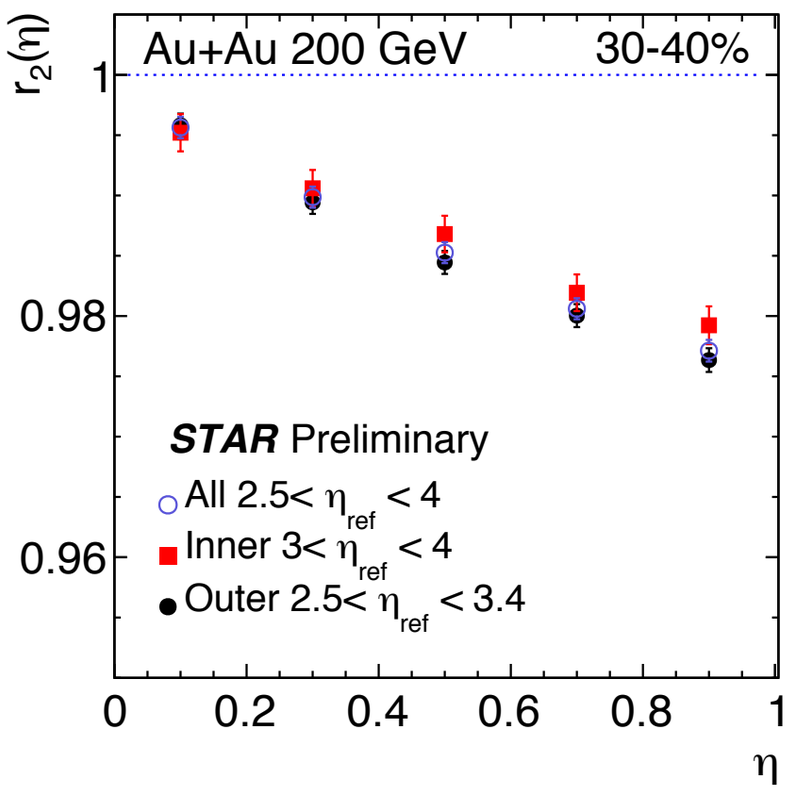
- Large $\Delta\eta$ → suppress short-range correlation (SRC).

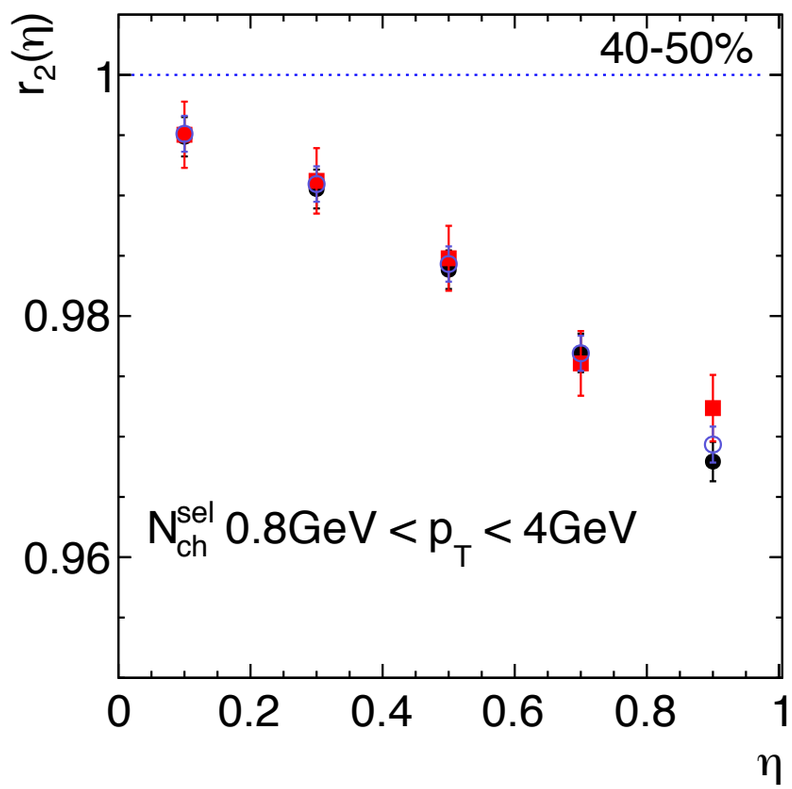
η_{ref} dependence of r_n

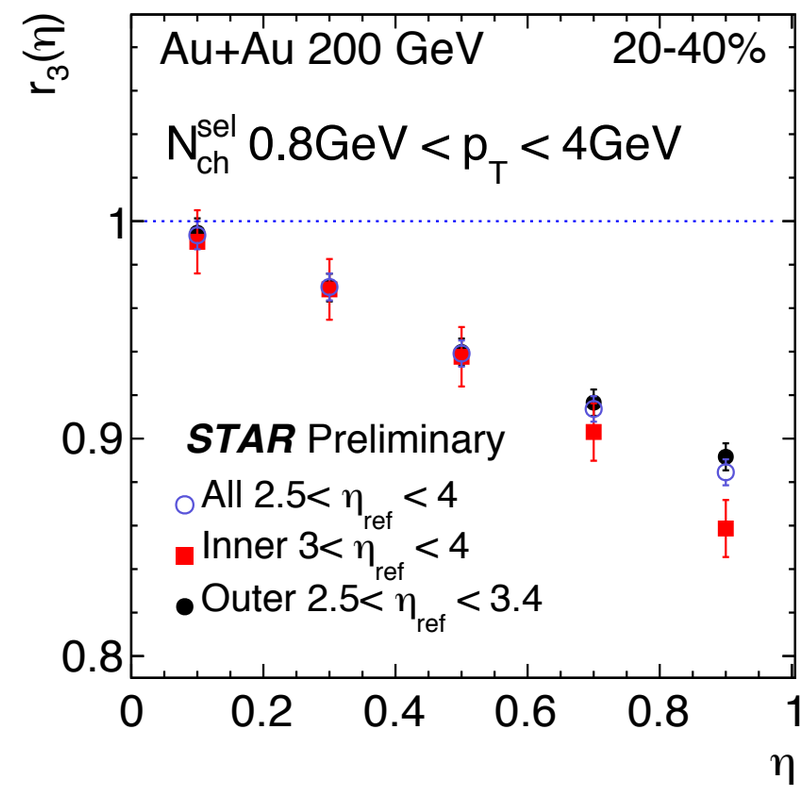
- r_n for different η_{ref} range

check for short-range correlation









r_2 is consistent for different η_{ref}

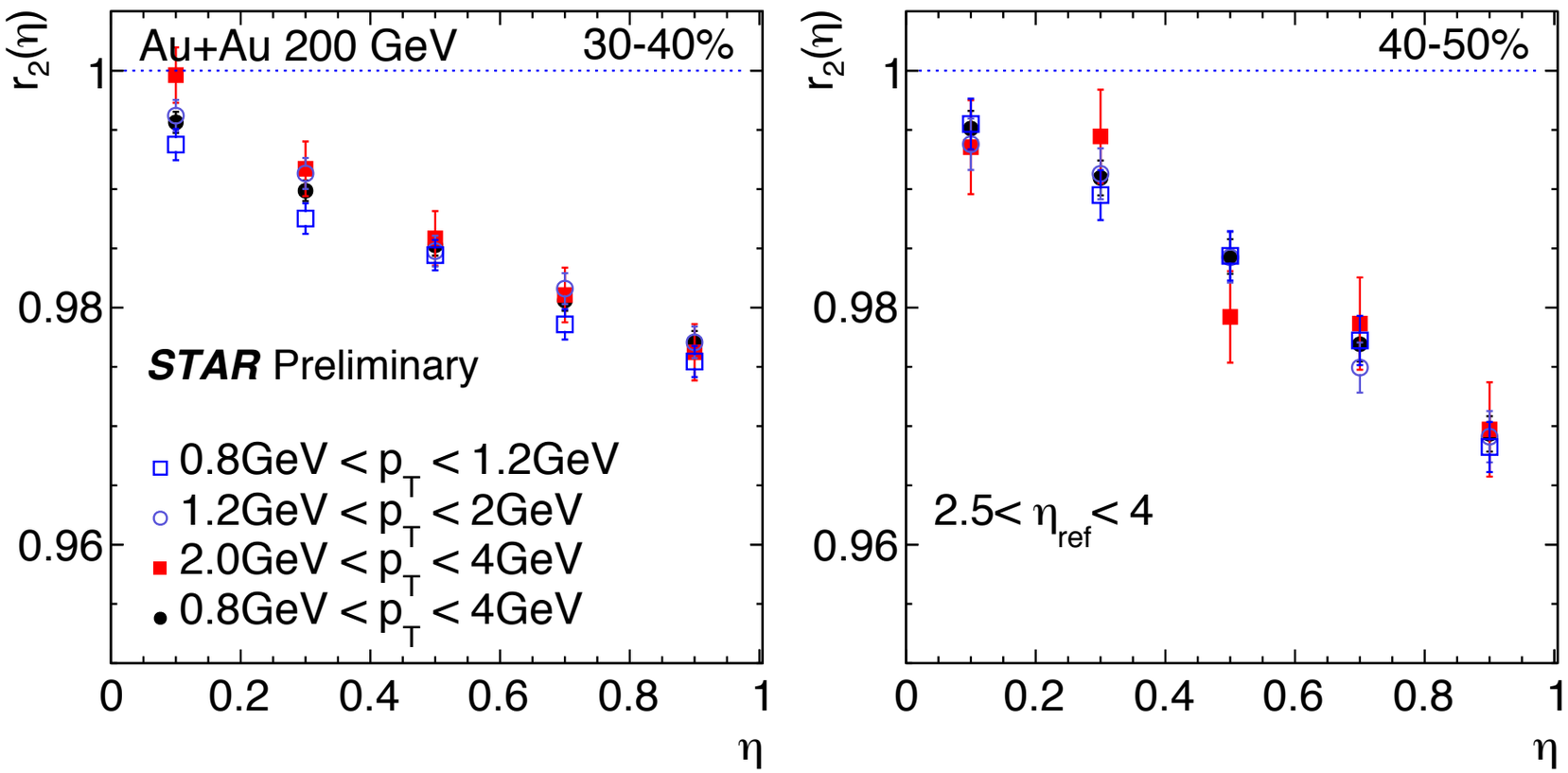
r_3 is consistent for different η_{ref}

- Large $\Delta\eta$ → suppress short-range correlation (SRC).
- SRC is significantly suppressed.
- For longitudinal correlations, r_n shows weak η_{ref} dependence.

p_T dependence of r_n

- r_n for different p_T range

$$r_2(\eta)$$



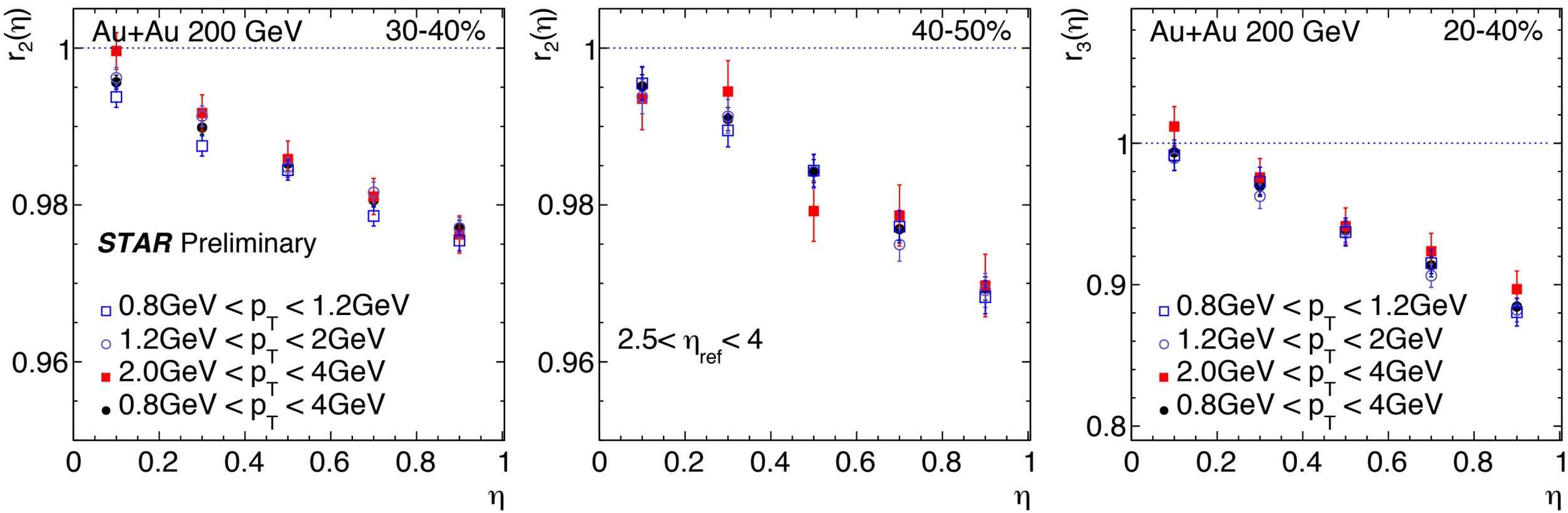
r_2 shows weak p_T dependence

- For longitudinal correlations, r_n almost independent of p_T within error.

p_T dependence of r_n

- r_n for different p_T range

$r_2(\eta)$ $r_3(\eta)$



r_2 shows weak p_T dependence

r_3 shows weak p_T dependence

- For longitudinal correlations, r_n almost independent of p_T within error.
- The independence of p_T → Indicates of an initial-state effect.

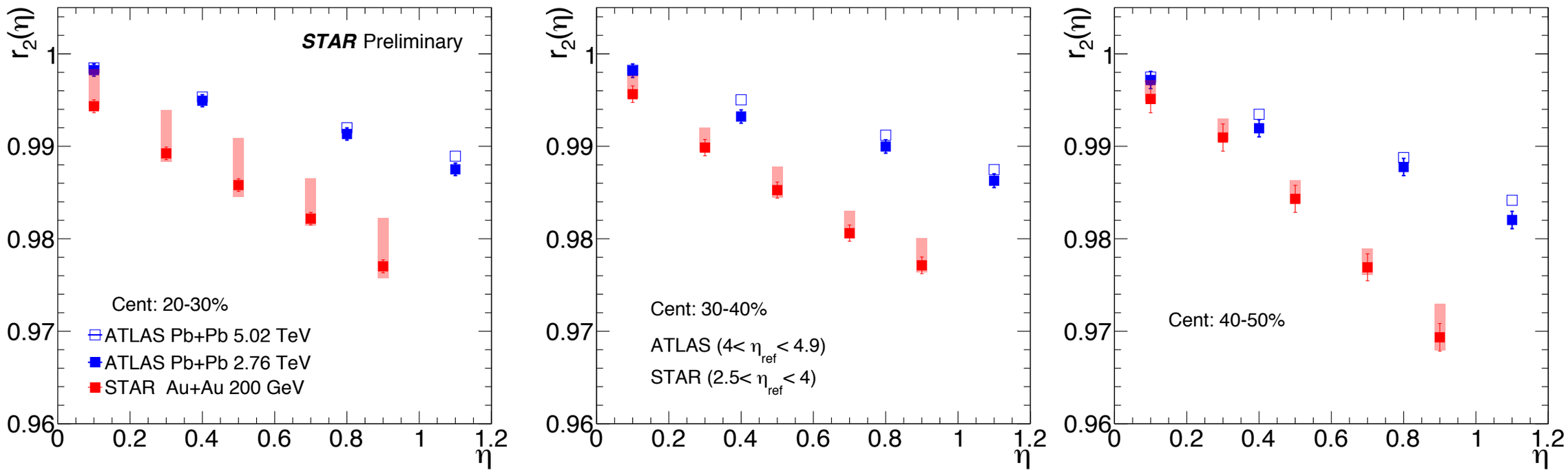
Comparison to the LHC results

- Decorrelation of $v_2(\eta)$

Comparison to the LHC results

✦ Decorrelation of $v_2(\eta)$

ATLAS Collaboration, arXiv:1709.02301

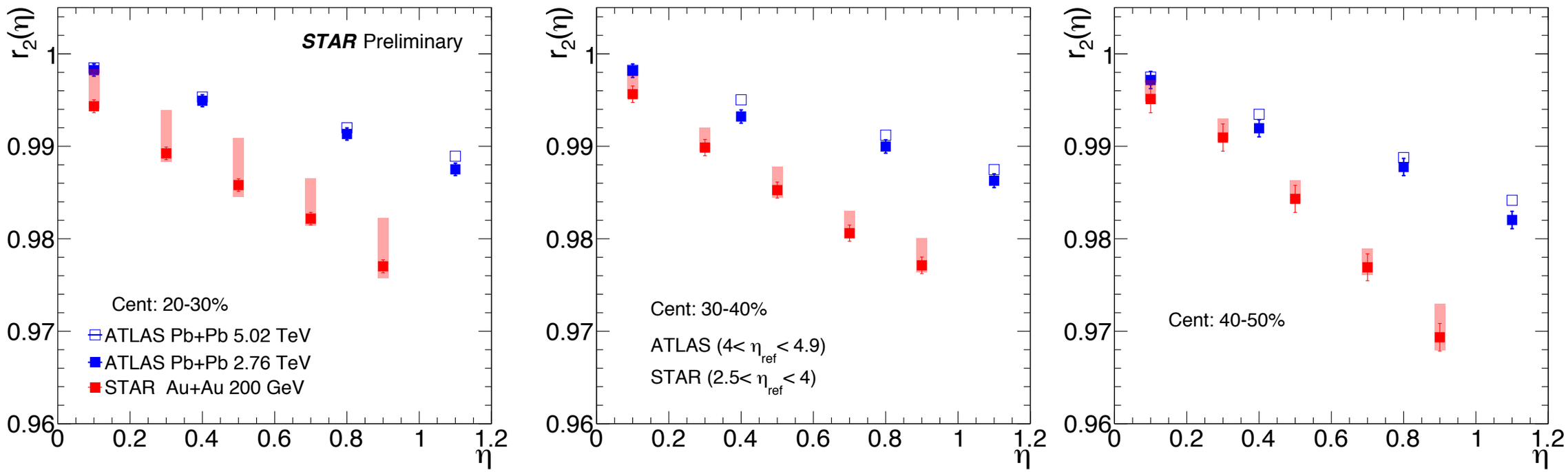


- A clear energy dependence is observed.
- 5.02TeV → 2.76TeV → 200GeV, decorrelation for v_2 gets stronger.

Comparison to the LHC results

✦ Decorrelation of $v_2(\eta)$

ATLAS Collaboration, arXiv:1709.02301



$$r_n = 1 - 2F_n\eta$$

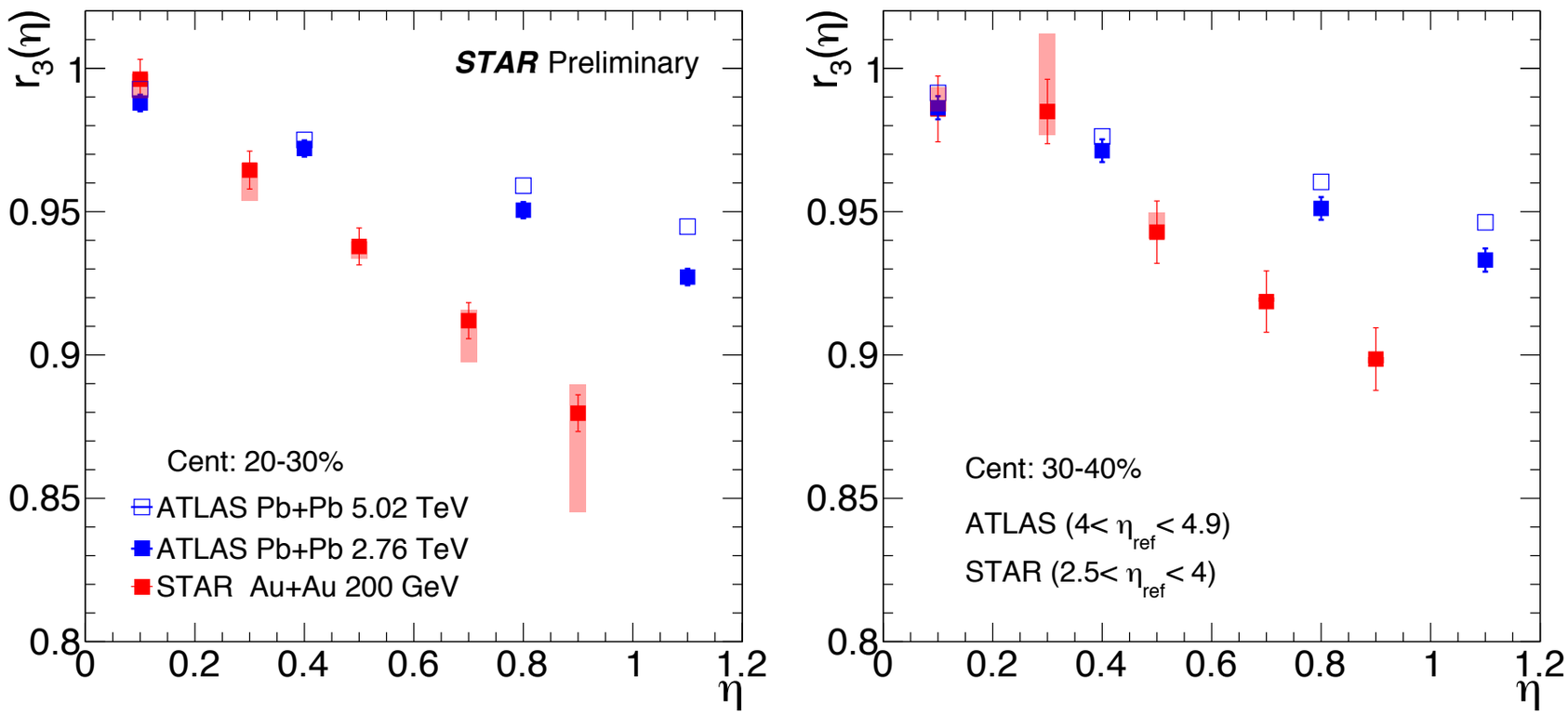
	20-30%	30-40%	40-50%
$F_2(Au+Au\ 200GeV)$	0.013 ±0.00027	0.014 ±0.00035	0.017 ±0.000575
$F_2(Pb+Pb\ 2.76TeV)$	0.0061 ±0.0002	0.0071 ±0.0002	0.0090 ±0.0002
$\frac{F_2(Au+Au)}{F_2(Pb+Pb)}$	2.2 ±0.084	1.9 ±0.073	1.9 ±0.076

- A clear energy dependence is observed.
- 5.02TeV → 2.76TeV → 200GeV, decorrelation for v_2 gets stronger.
- ~2 times stronger decorrelation effect than at the LHC energy 2.76 TeV.

Comparison to the LHC results

✦ Decorrelation of $v_3(\eta)$

ATLAS Collaboration, arXiv:1709.02301



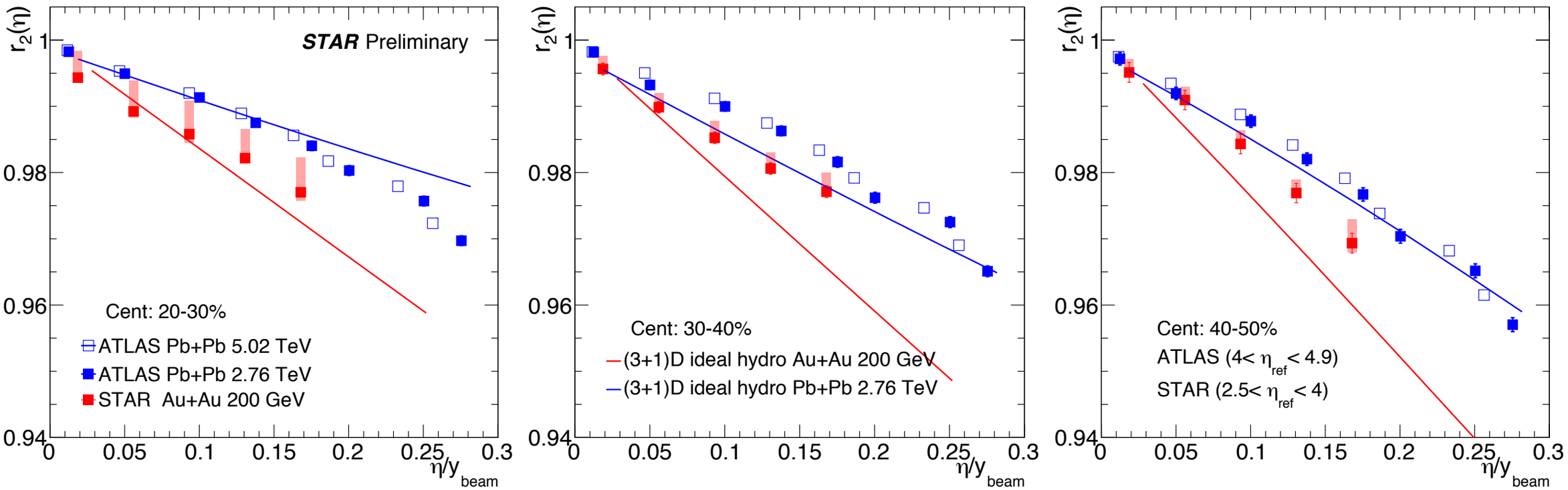
- r_3 show similar energy dependence.
- 5.02TeV → 2.76TeV → 200GeV, decorrelation gets stronger.

Comparison to the LHC and model calculations

✦ Decorrelation of $v_2(\eta)$

ATLAS Collaboration, arXiv:1709.02301

L.-G. Pang et al, Eur. Phys. J. A 52 (2016) 97

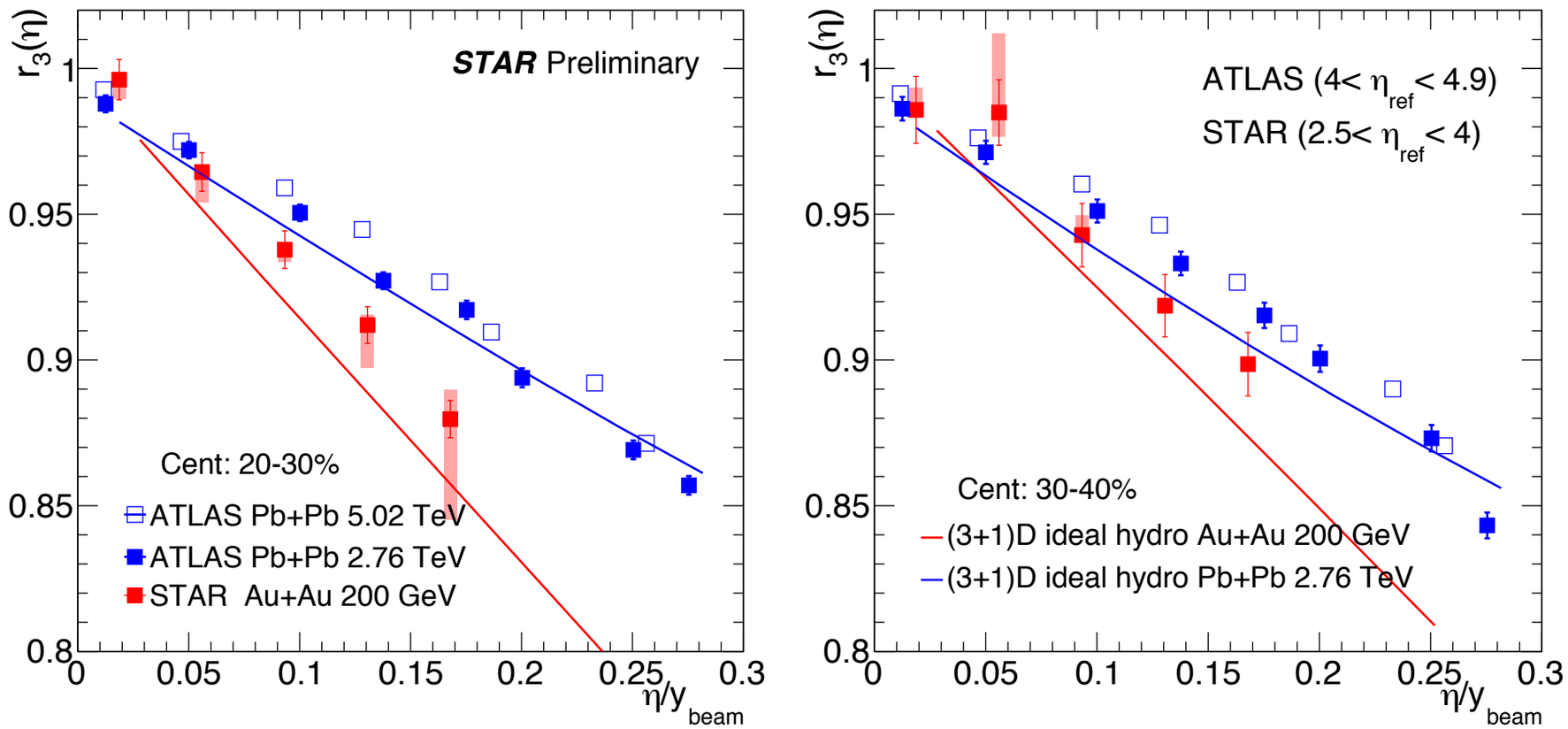


- After the rapidity normalization, energy dependence is still observed.
- Model calculation can roughly describe the LHC energy, but overestimate the decorrelation effect at RHIC.

Comparison to the LHC and model calculations

✦ Decorrelation of $v_3(\eta)$

ATLAS Collaboration, arXiv:1709.02301



- After the rapidity normalization, energy dependence is still observed.
- Model calculation can roughly describe the LHC energy, but overestimate the decorrelation effect at RHIC.
- A test for the model ➡ describe both the LHC and RHIC data.

Summary

- The first direct measurement of longitudinal flow decorrelation at RHIC.
- Longitudinal correlation of anisotropy flow:

  For v_2, centrality dependence is observed.

  longitudinal flow decorrelation reflects global property of the event.

- Compared to LHC, ~2 times stronger decorrelation effect at RHIC energy.
- The results will help to constrain the initial state of the models.

Backup

Systematics

Default

FMS All

All $2.5 < \eta_{ref} < 4$
Inner $3 < \eta_{ref} < 4$
Outter $2.5 < \eta_{ref} < 3.4$

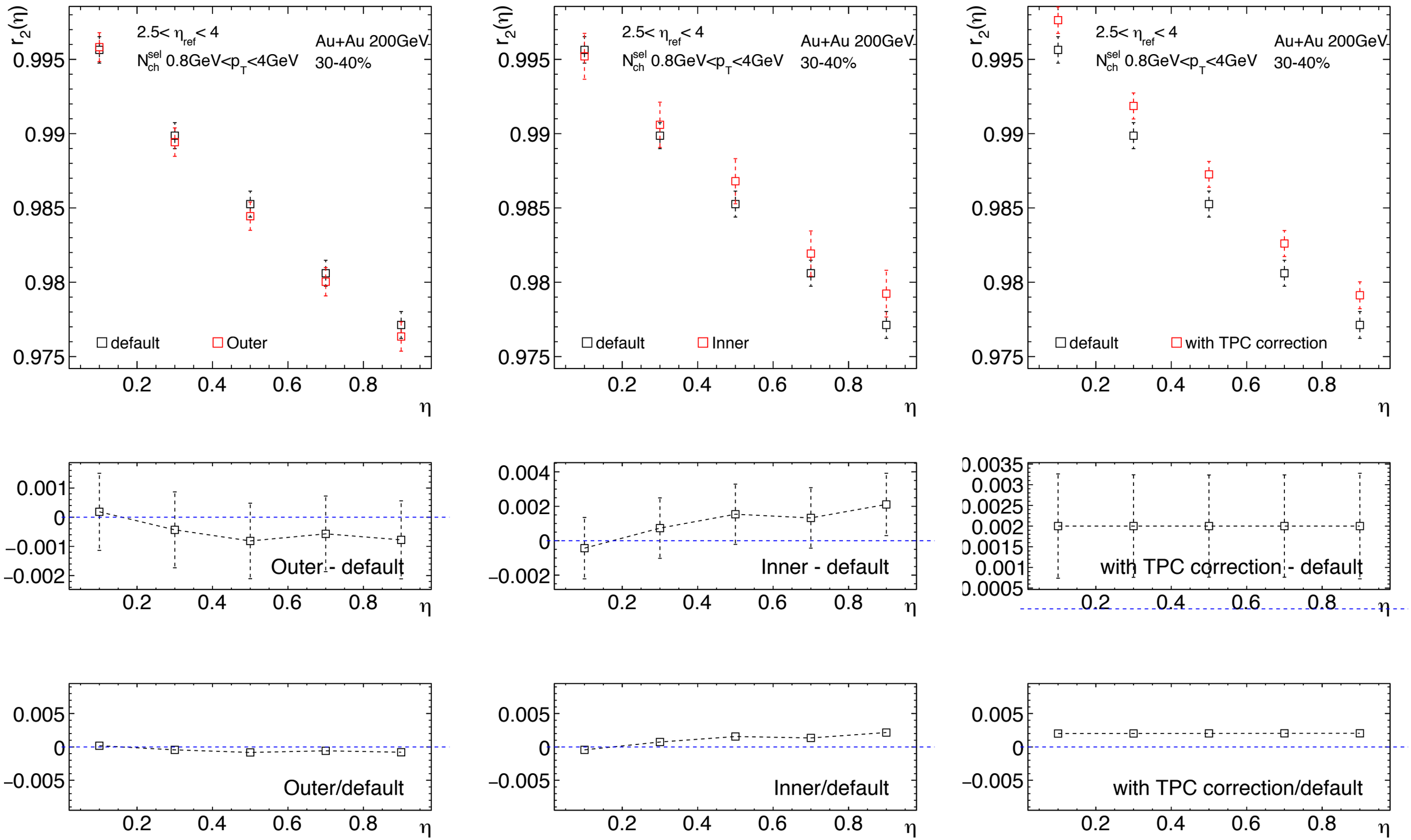
Systematics

1. FMS Outer
2. FMS Inner
3. FMS default with TPC correction

Quantify the systematics:

$$r_n(\eta)_{change} - r_n(\eta)_{default}$$

$$\frac{r_n(\eta)_{change} - r_n(\eta)_{default}}{r_n(\eta)_{default}}$$


$r_2(\eta)$
2.5< η_{ref} < 4
N_{ch}^{sel} 0.8GeV<p_T<4GeV
Au+Au 200GeV
30-40%
default
Outer
Inner
with TPC correction
Outer - default
Inner - default
with TPC correction - default
Outer/default
Inner/default
with TPC correction/default
η