CME/CMW/… : what is next?

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Evolution of expectations:

2004-2009: the signal in Au+Au might be about 1/3 of $\Delta\gamma$.
We should be able to get "accuracy" of about 10% of $\Delta\gamma$

2017-2019: the signal is likely less than 10-15%.
We should be able to achieve 5% accuracy

2021 - isobars - no (?) signal at the level ~a few %, but it might be larger in AuAu and/or PbPb.

~2025(?) SP/PP and/or ESE < 0.5% in AuAu/ PbPb?

Isobars

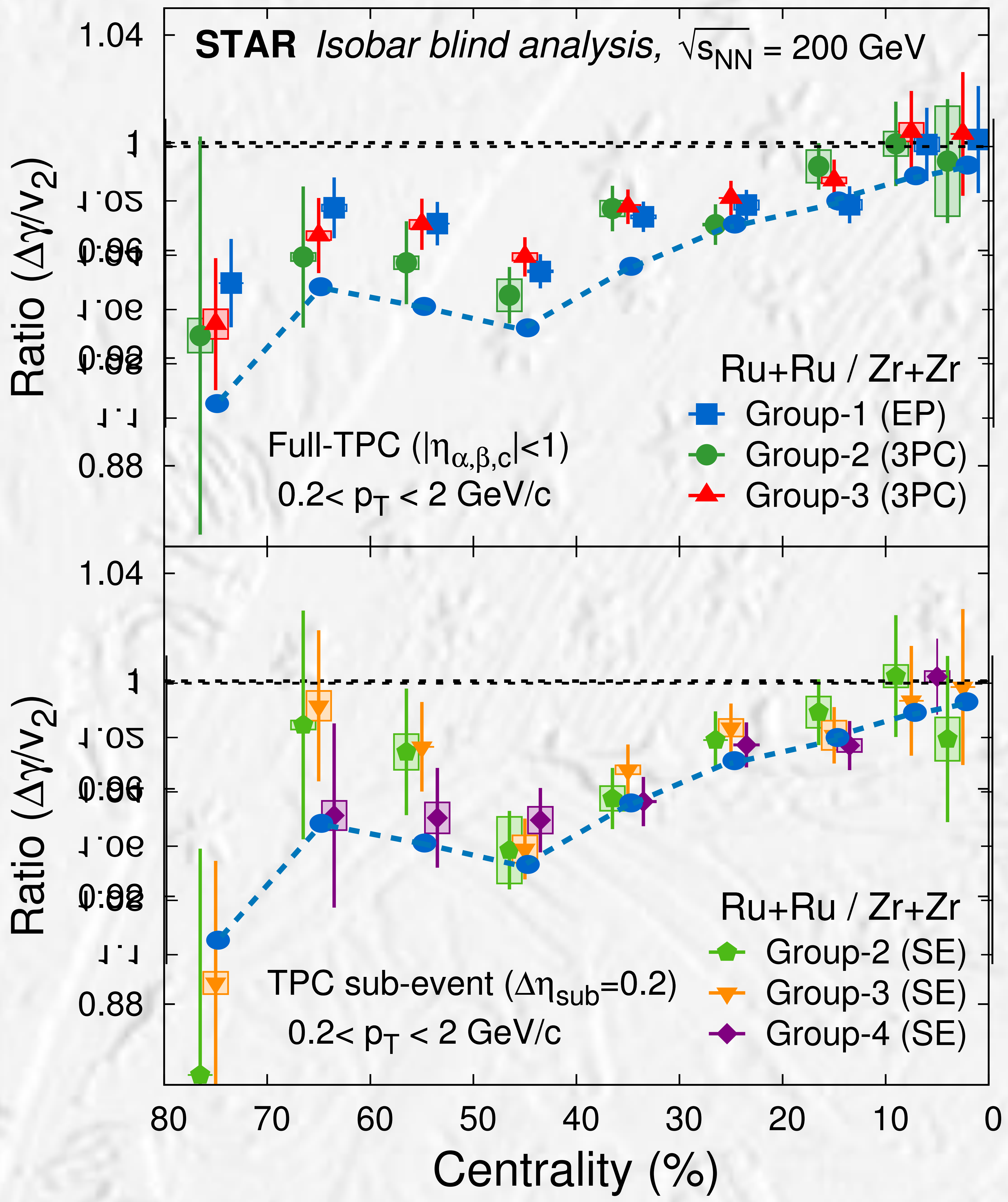
Playing on signal with system size

SP/PP

"Cross-observable-correlation"

U.S. DEPARTMENT OF ENERGY
Office of Science

Toward 1% precision



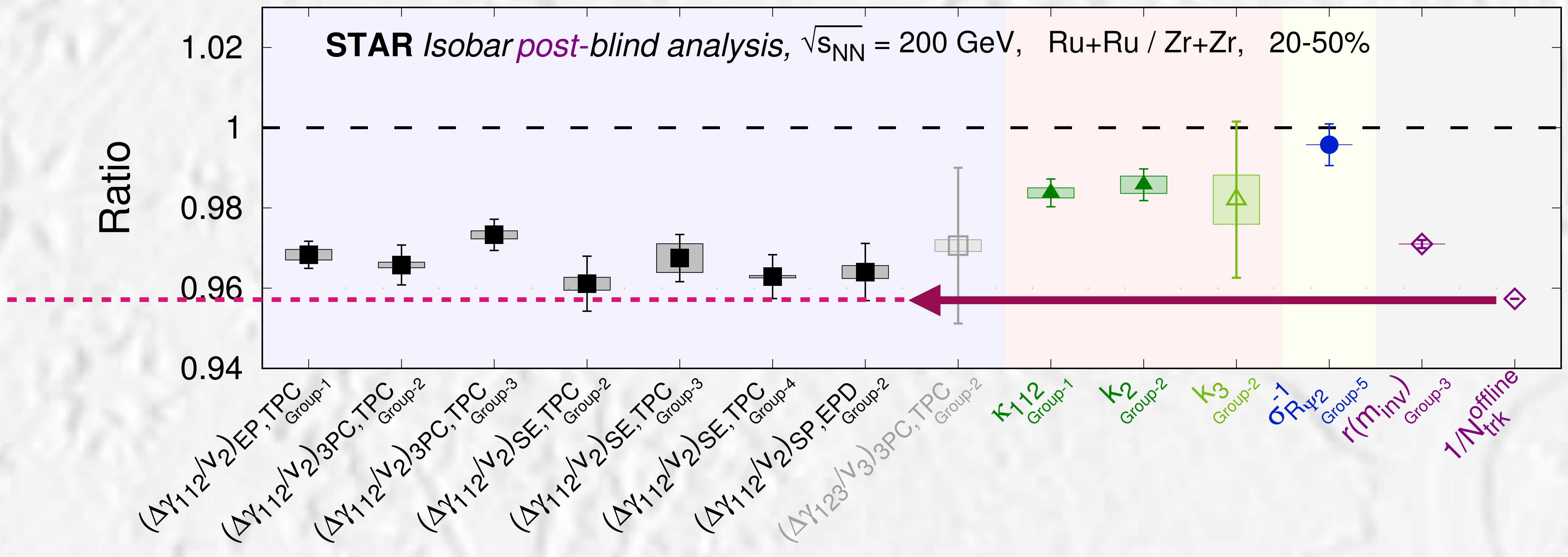


FIG. 27. Compilation of post-blinding results. This figure is largely the same as Fig. 26 with the following differences: numerical changes in the results from the new run-by-run QA algorithm are treated as an additional systematic uncertainty added in quadrature, and two data points (open markers) have been added on the right to indicate the ratio of inverse multiplicities ($N_{\rm trk}^{\rm offline}$) and the ratio of relative pair multiplicity difference (r) as explained in the text.

To establish exact limits, one need to resolve/understand systematics in the ratio

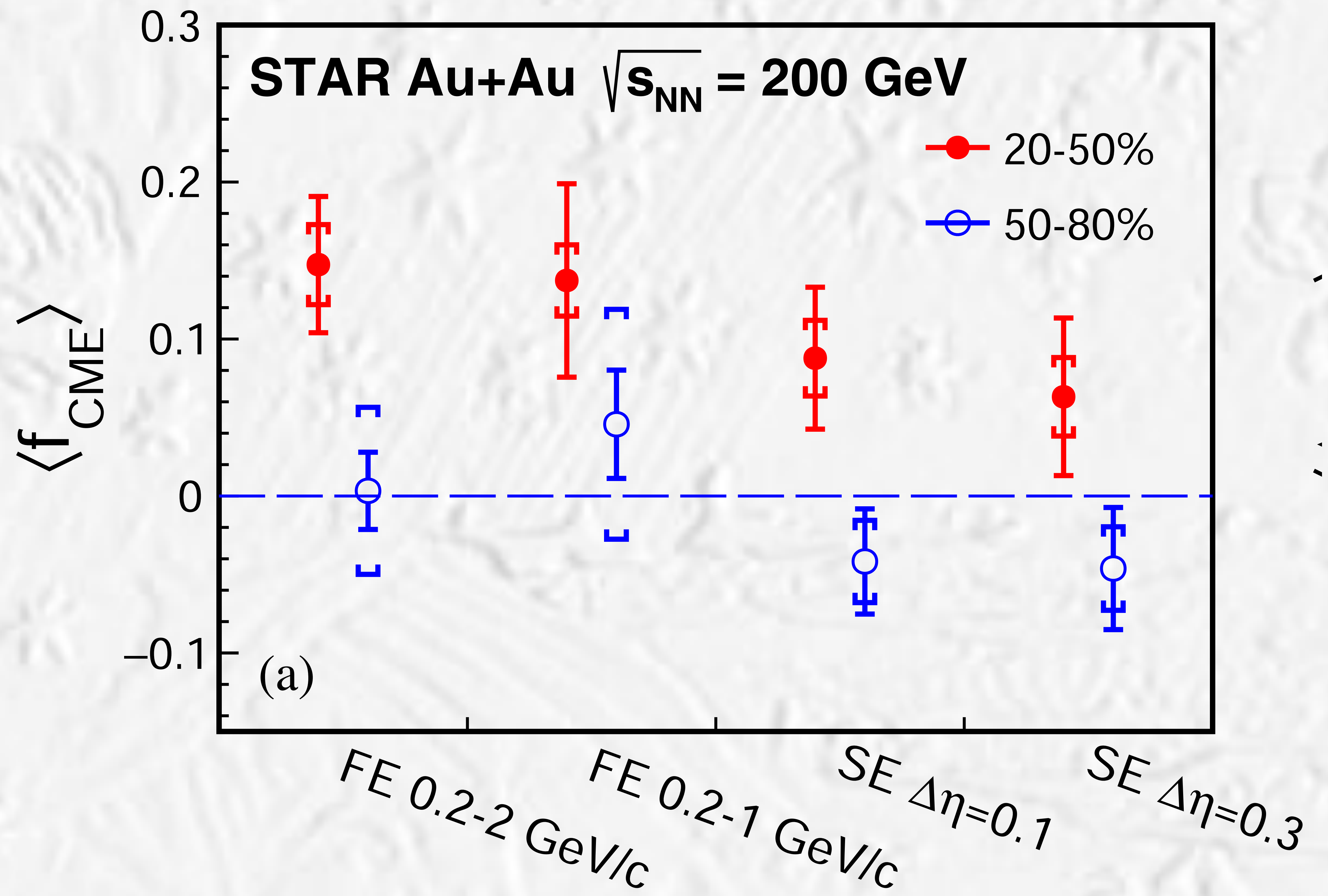
$$\frac{(\Delta\gamma/v_2)_{\rm Ru+Ru}}{(\Delta\gamma/v_2)_{\rm Zr+Zr}}$$

up to a (sub)percent level (note difference between results from different groups, “Full” vs “SE”).

STAR: f_{CME} from $\Delta\gamma$, SP/PP

Search for the chiral magnetic effect via charge-dependent azimuthal correlations relative to spectator and participant planes in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

STAR Collaboration   PHYSICAL REVIEW LETTERS **128,** 092301 (2022)



Error bars show statistical uncertainties; the caps indicate the systematic uncertainties.

Implications. Conclusions

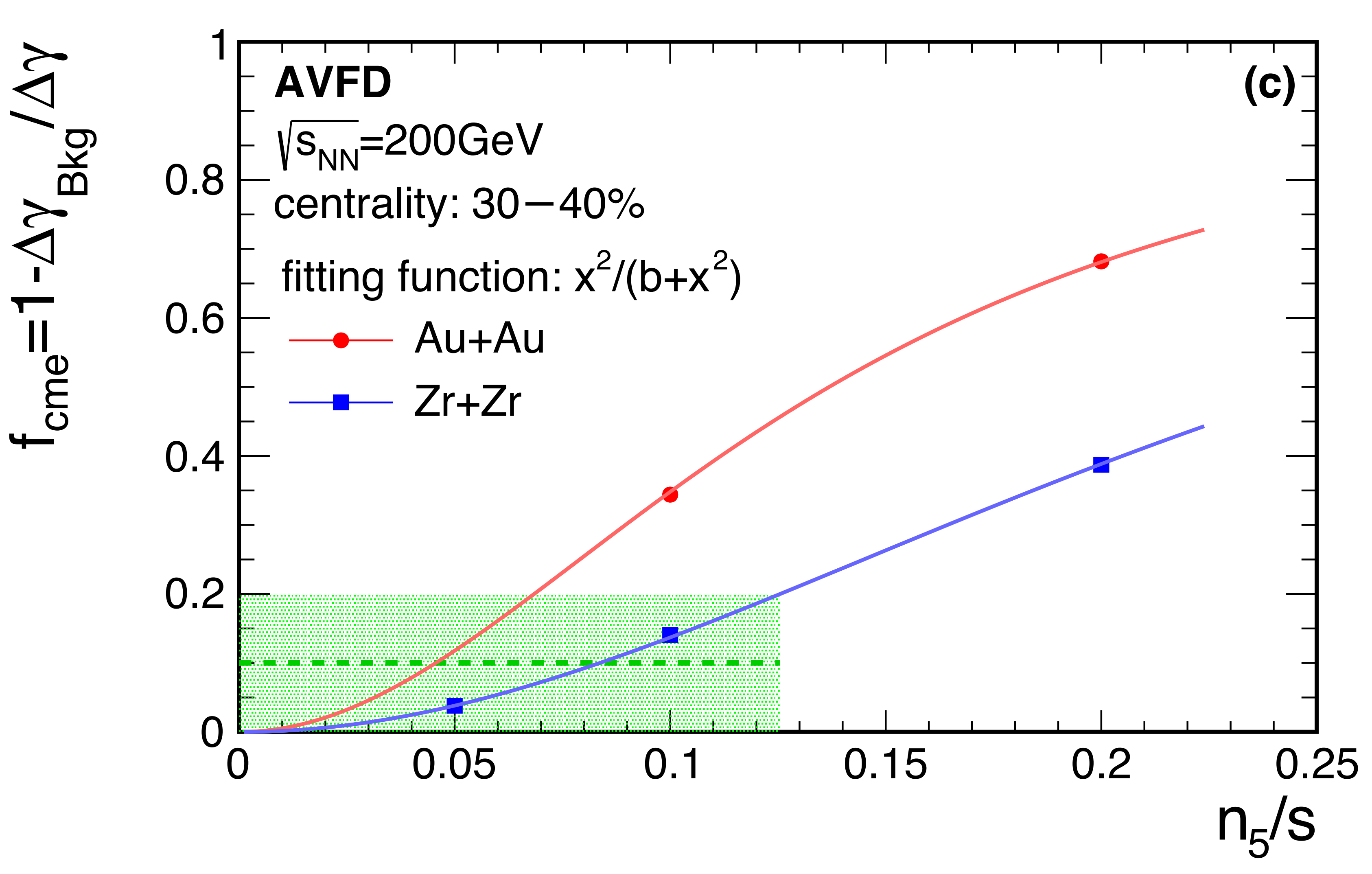
STAR isobars:

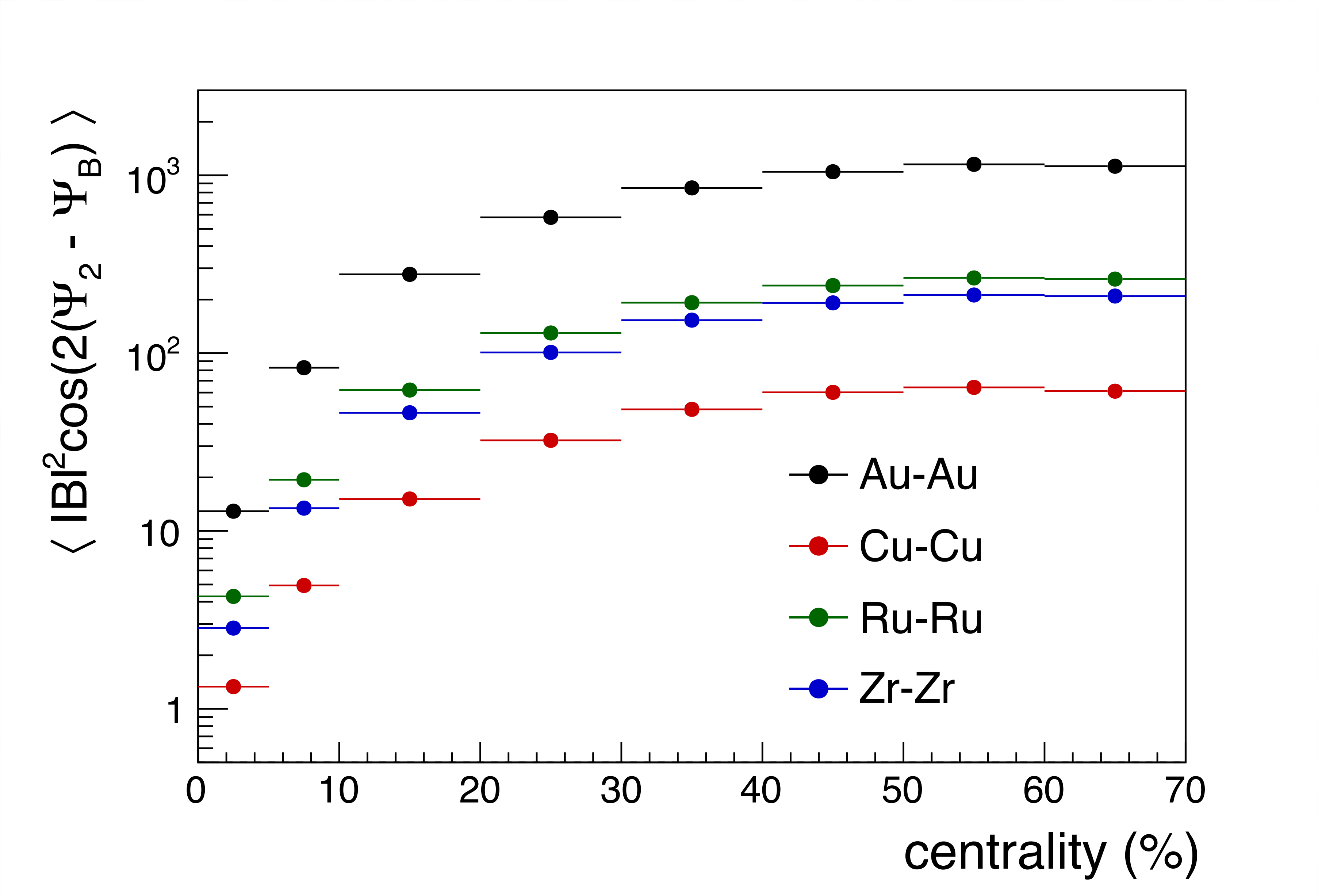
- No CME signature that satisfies the predefined criteria has been observed in isobar collisions in this blind analysis.
- Accurate upper limits for f_{CME} are being evaluated.

Isobar results do not exclude a bigger signal in AuAu.

The signal could be significantly smaller in such (relatively small nuclei) collisions

Y. Feng, Y. Lin, J. Zhao, and F. Wang, Phys. Lett. B **820**, 136549 (2021),





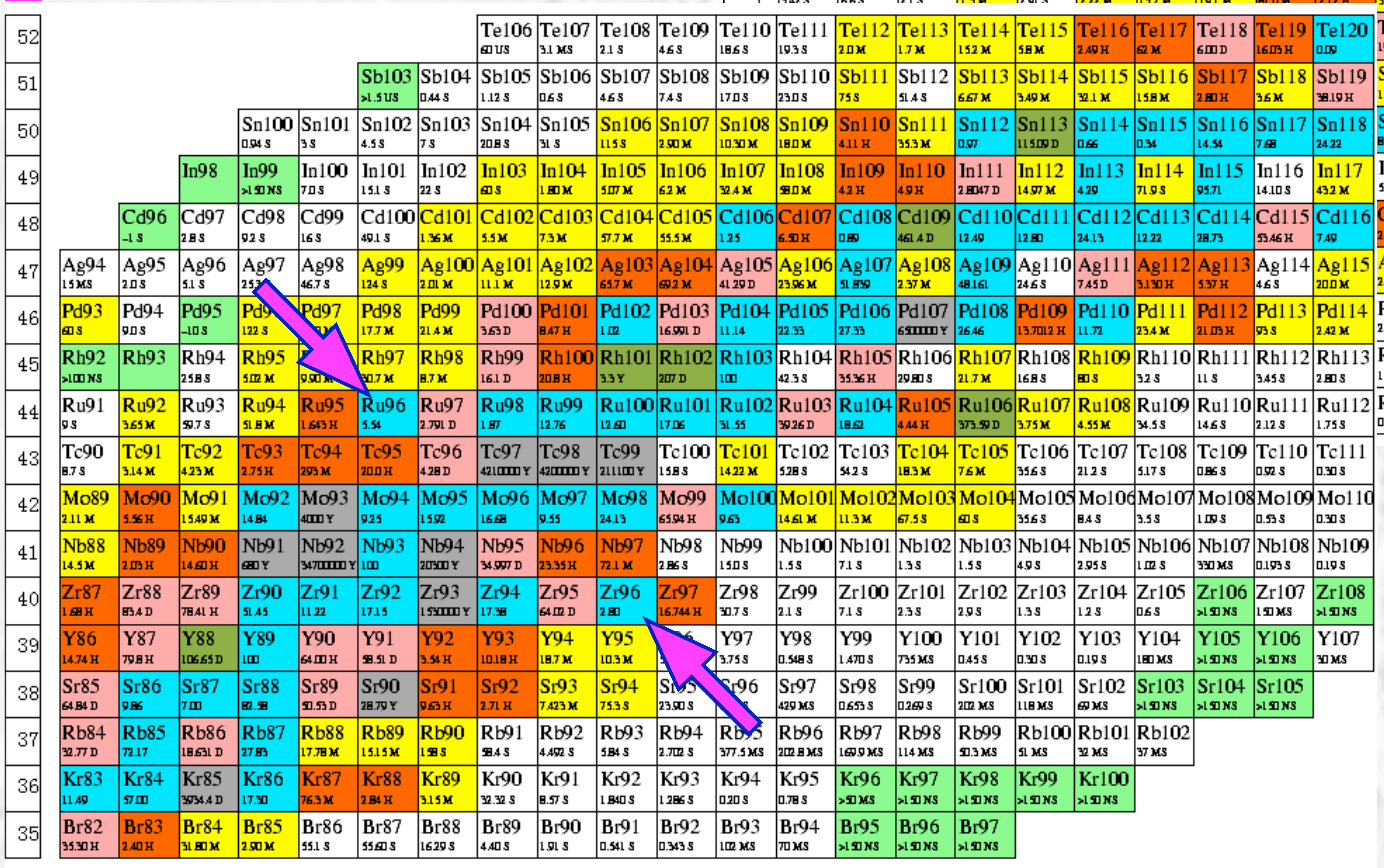
The signal could depend strongly on the system size.

Calculations by A. Dobrin (private communication)

Isobar run was a real success (not only for the CME search)

Should we request for more? $^{136}_{54}\mathrm{Ce}$, $^{136}_{50}\mathrm{Xe}$?

Nuclides



Summer 2016 — extensive discussion of possible isobar pairs:

In consideration:
- largest (relative) charge difference
- similarity in shape
- availability and price
- possibility to accelerate (Tandem, EBIS)

Vary signal, II

arXiv:2210.15383v1 [nucl-ex] 27 Oct 2022

Search for the Chiral Magnetic Effect with charge-dependent azimuthal correlations in Xe–Xe collisions at $\sqrt{s_{NN}} = 5.44$ TeV

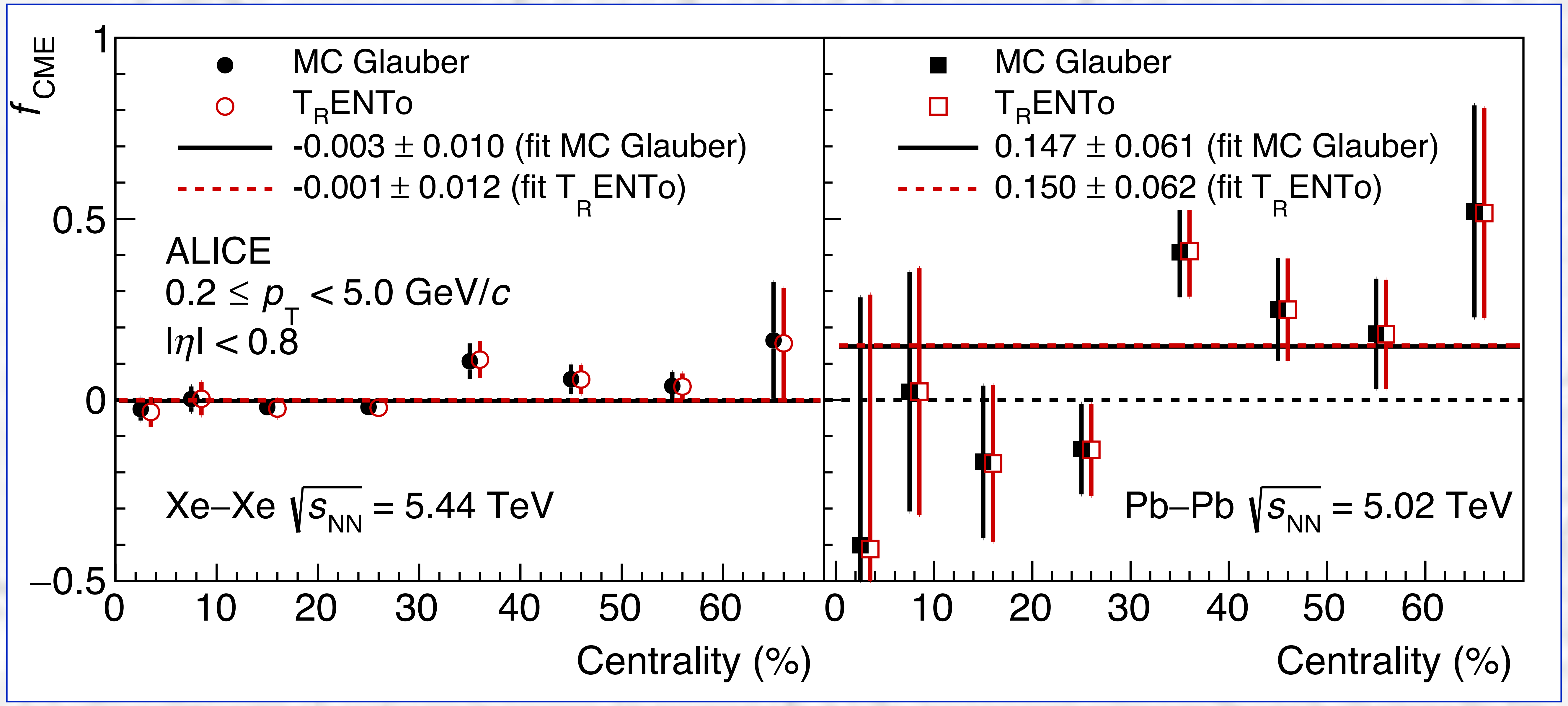
ALICE Collaboration

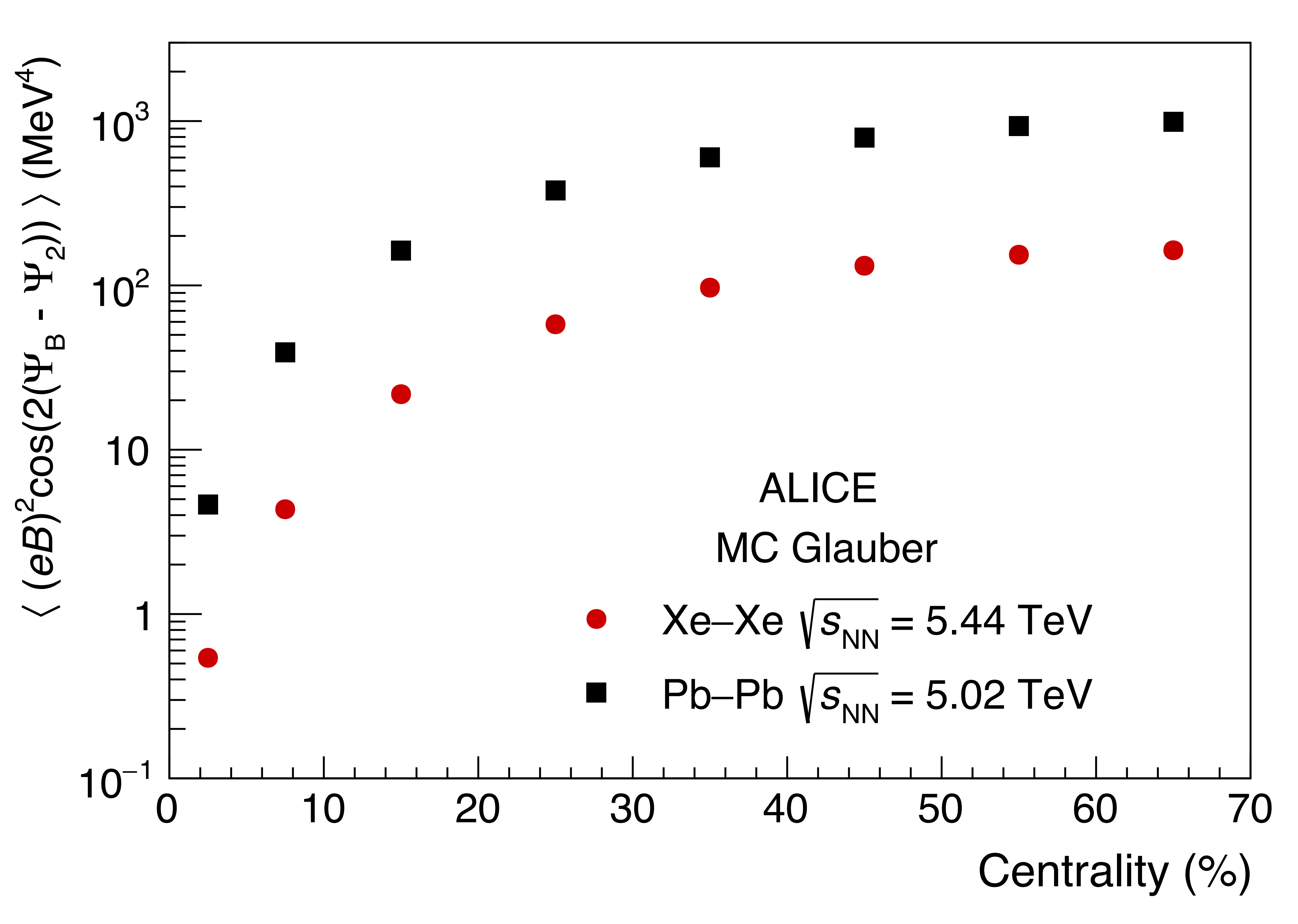
the ITS and TPC as described in Ref. [47]. Approximately 10^6 Xe–Xe events in the 0–70% centrality interval, with a primary vertex position within ± 10 cm from the nominal interaction point along the beam

$$\Gamma^{\text{Xe-Xe}} = sB^{\text{Xe-Xe}} + bv_2^{\text{Xe-Xe}}, \qquad (5)$$

$$\Gamma^{\text{Pb-Pb}} = sB^{\text{Pb-Pb}} + bv_2^{\text{Pb-Pb}}, \qquad (6)$$

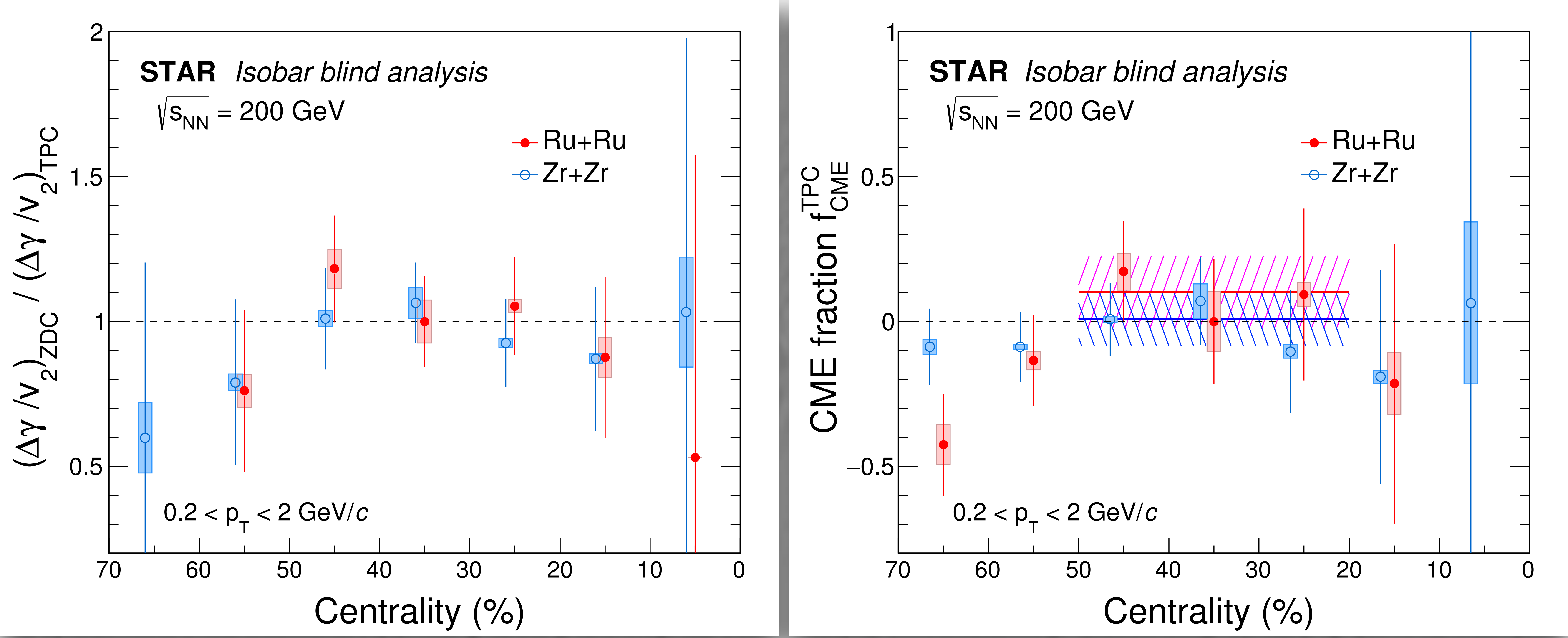
where $\Gamma \equiv \gamma_{\alpha\beta}\, dN_{ch}/d\eta$, $B \equiv \langle (eB)^2 \cos(2(\Psi_B - \Psi_2)) \rangle$, and v_2 is taken from Ref. [41] and $\gamma_{\alpha\beta}^{\text{Pb-Pb}}$ from Ref. [39]. The s and b parameters quantify the signal and background contributions, respectively, and do not depend on collision system as a result of the assumption that both scale with $dN_{ch}/d\eta$. While





$f_{\rm CME}$ from PP/SP measurements

Group 4 (also done by group 3)

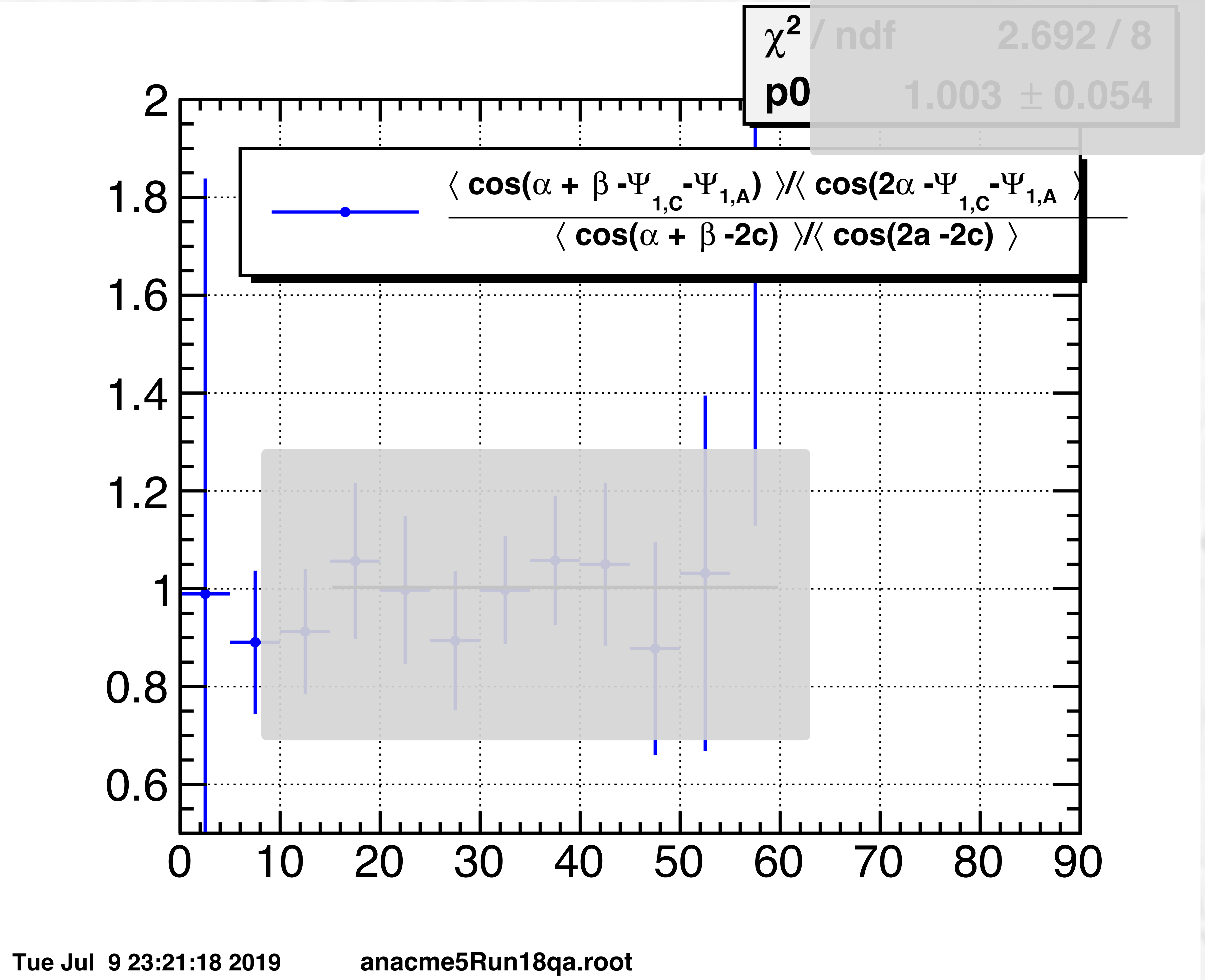


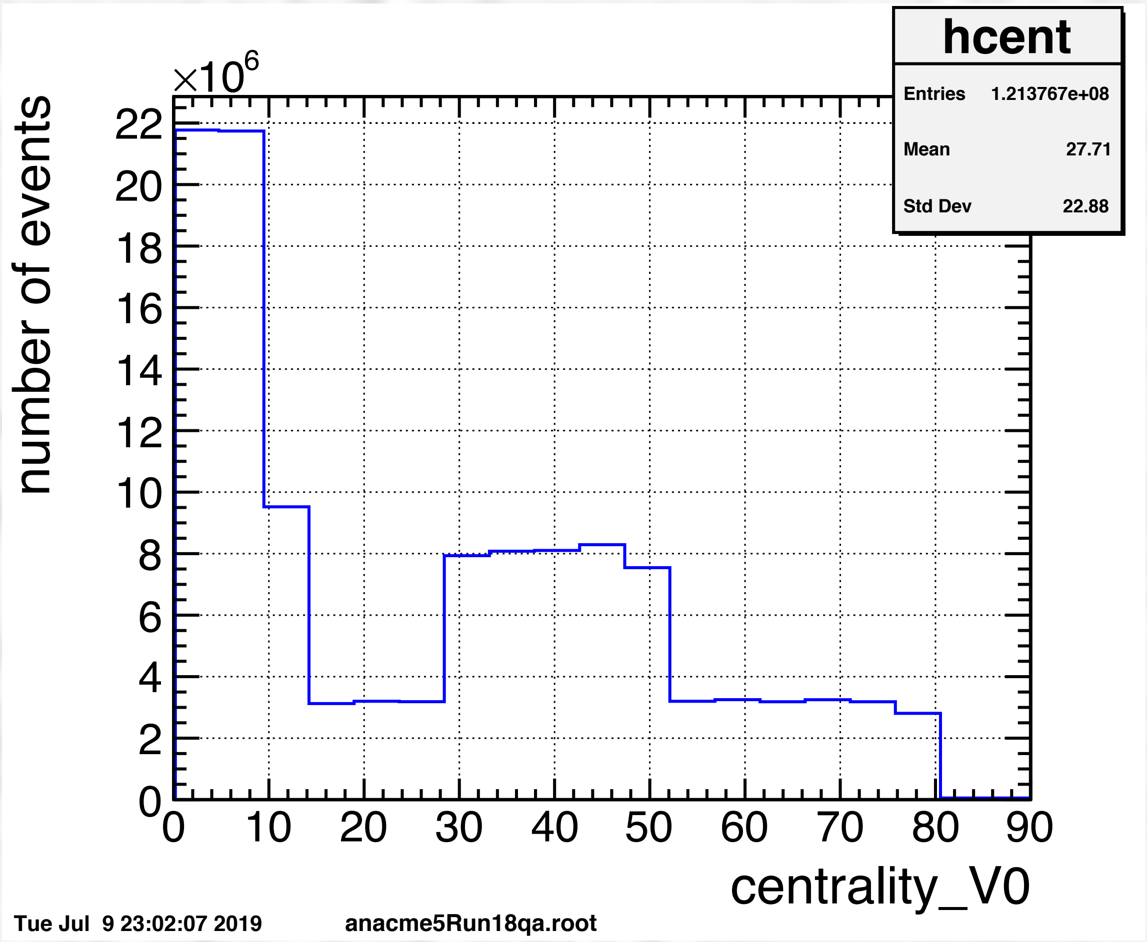
Ru:
$0.101 \pm 0.123\ (\mathrm{stat.}) \pm 0.023\ (\mathrm{syst.})$
Zr:
$0.009 \pm 0.088\ (\mathrm{stat.}) \pm 0.033\ (\mathrm{syst.})$

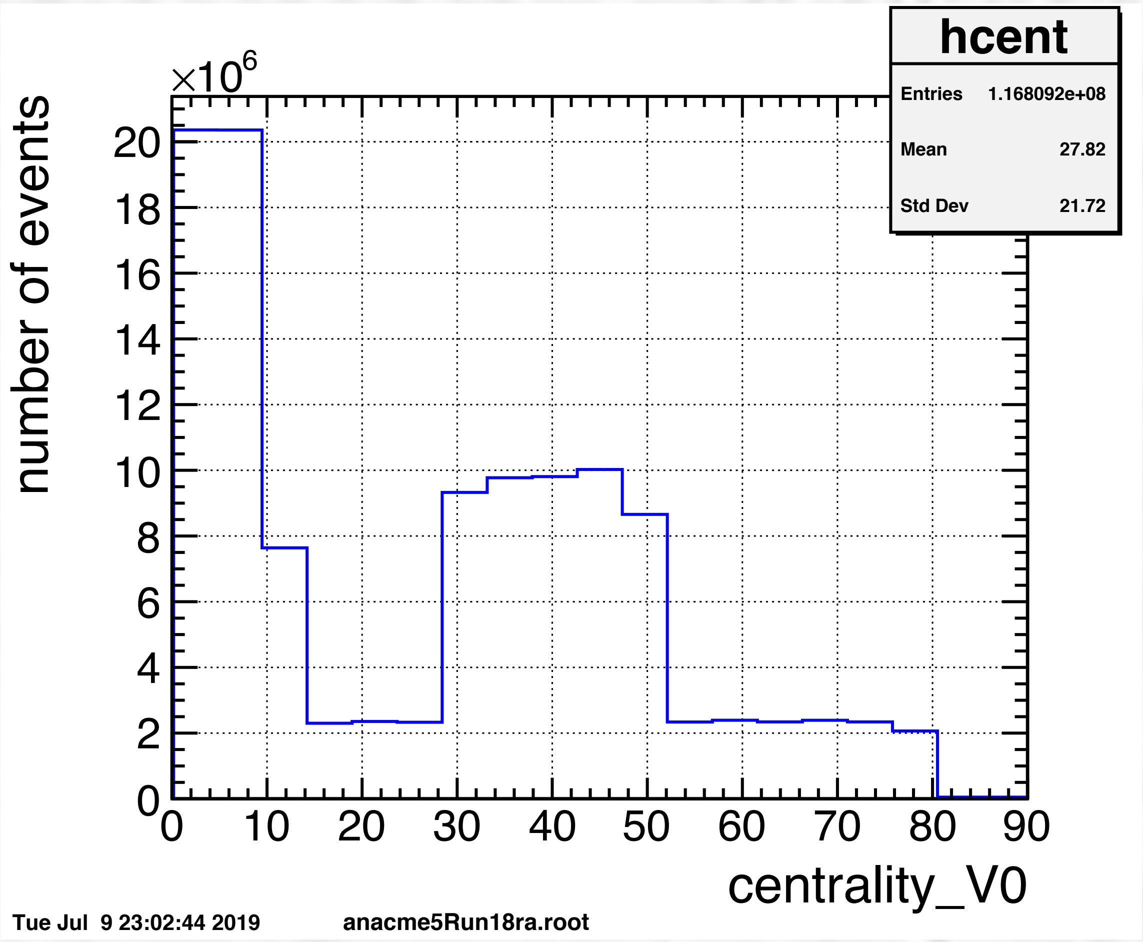
$$\frac{(\Delta\gamma/v_2)_{\rm spectator}}{(\Delta\gamma/v_2)_{\rm participant}} = \frac{(\Delta\gamma/v_2)_{\rm ZDC}}{(\Delta\gamma/v_2)_{\rm TPC}} = \frac{\Delta\langle\cos(\phi_\alpha+\phi_\beta-\Psi_1^{\rm W}-\Psi_1^{\rm E})\rangle/\langle\cos(2\phi-\Psi_1^{\rm W}-\Psi_1^{\rm E})\rangle}{\Delta\langle\cos(\phi_\alpha+\phi_\beta-2\phi_c)\rangle/\langle\cos(2\phi_\alpha-2\phi_c)\rangle}.$$

$$\frac{(\Delta\gamma/v_2)_{\rm ZDC}}{(\Delta\gamma/v_2)_{\rm TPC}} = 1 + f_{\rm CME}^{\rm TPC}\left(\frac{v_2^2\{\rm TPC\}}{v_2^2\{\rm ZDC\}} - 1\right)$$

PP/SP,





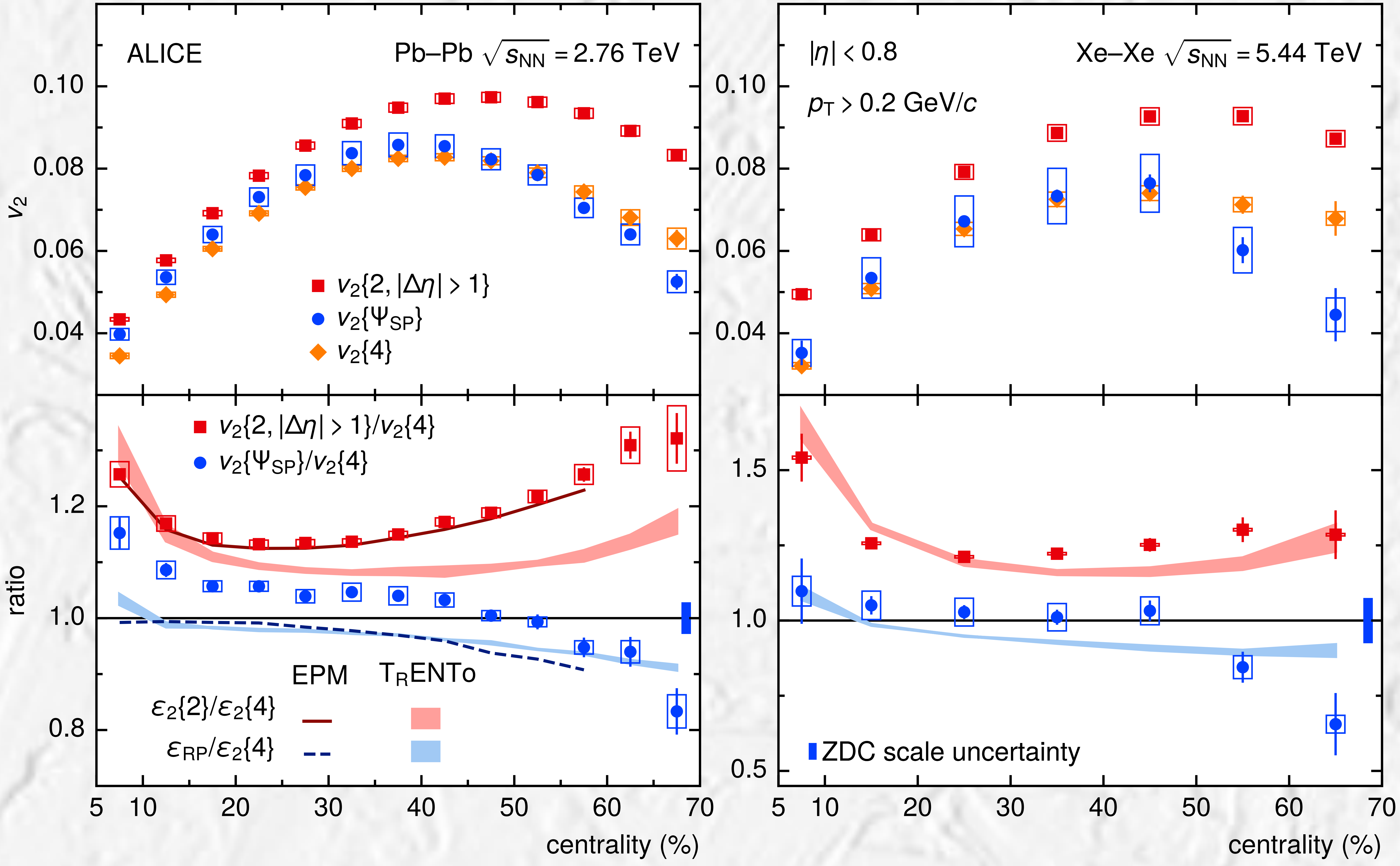


IN PROGRESS

$v_2\{ZDC\}$

Elliptic Flow Fluctuations at Midrapidity using Spectator Neutrons — ALICE Collaboration

arXiv:2204.10240v1 [nucl-ex] 21 Apr 2022



Cross-correlations, LCC as BG to CME/CMW

Global constraint on the magnitude of anomalous chiral effects in heavy-ion collisions

Wen-Ya Wu[a,b], Qi-Ye Shou[a,b], Panos Christakoglou[c], Prottay Das[d], Md. Rihan Haque[e], Guo-Liang Ma[a,b], Yu-Gang Ma[a,b], Bedangadas Mohanty[d], Chun-Zheng Wang[a,b], Song Zhang[a,b], and Jie Zhao[a,b]

arXiv:2211.15446v1 [nucl-th] 28 Nov 2022

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S.A. Voloshin, R. Belmont / Nuclear Physics A 931 (2014) 992–996 995

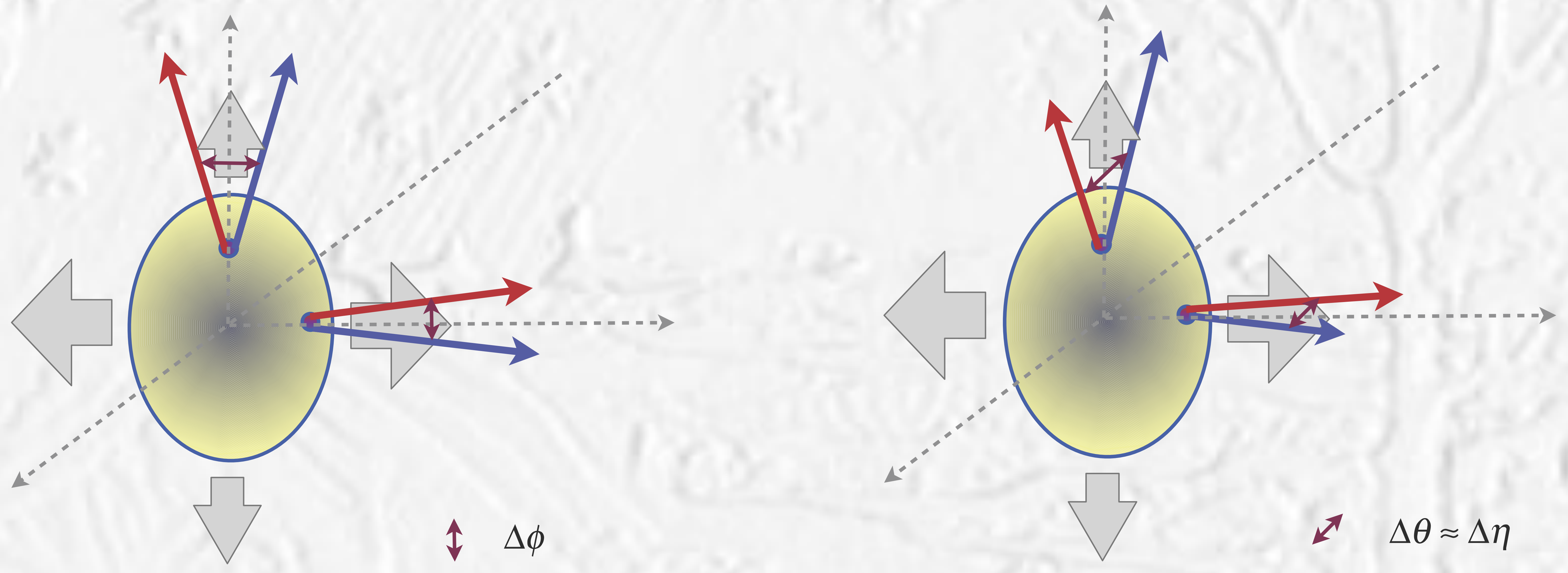
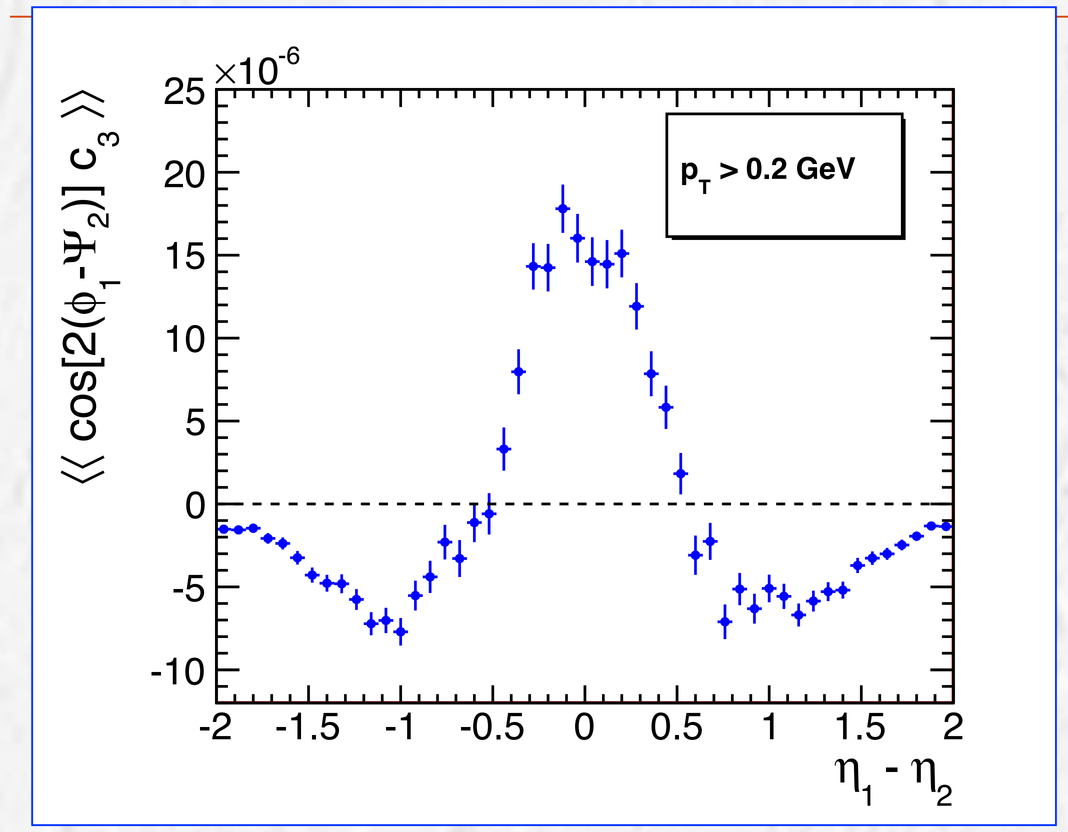
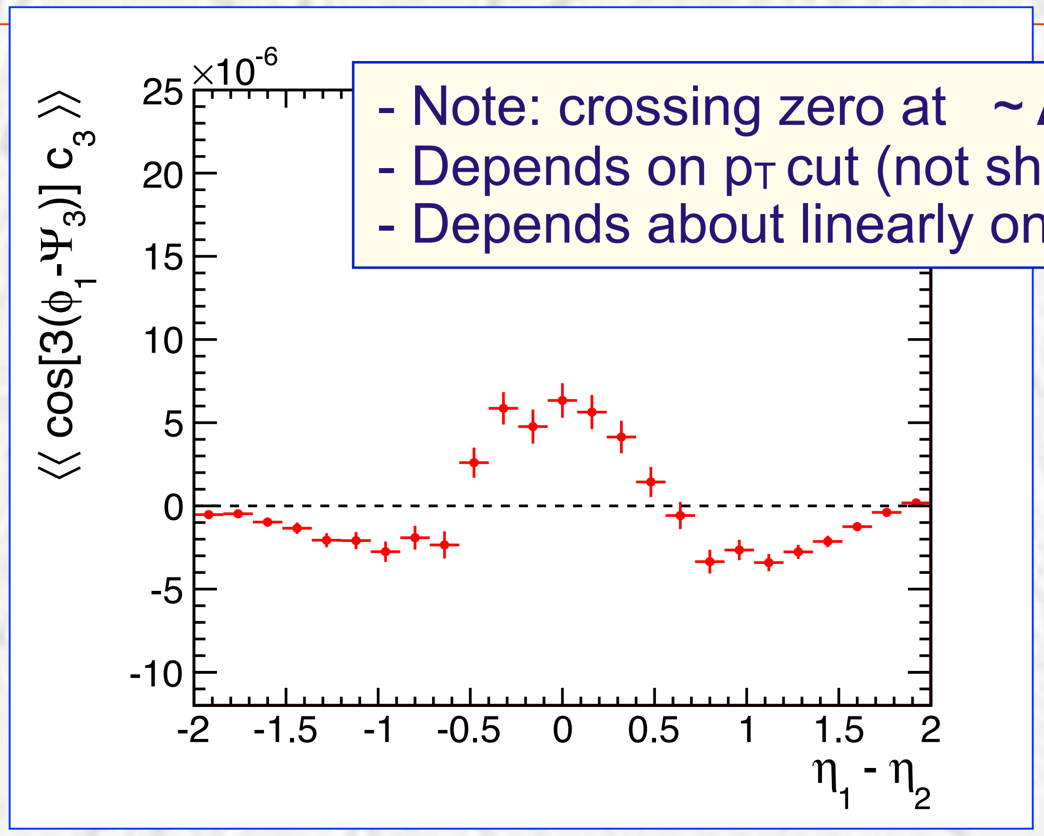


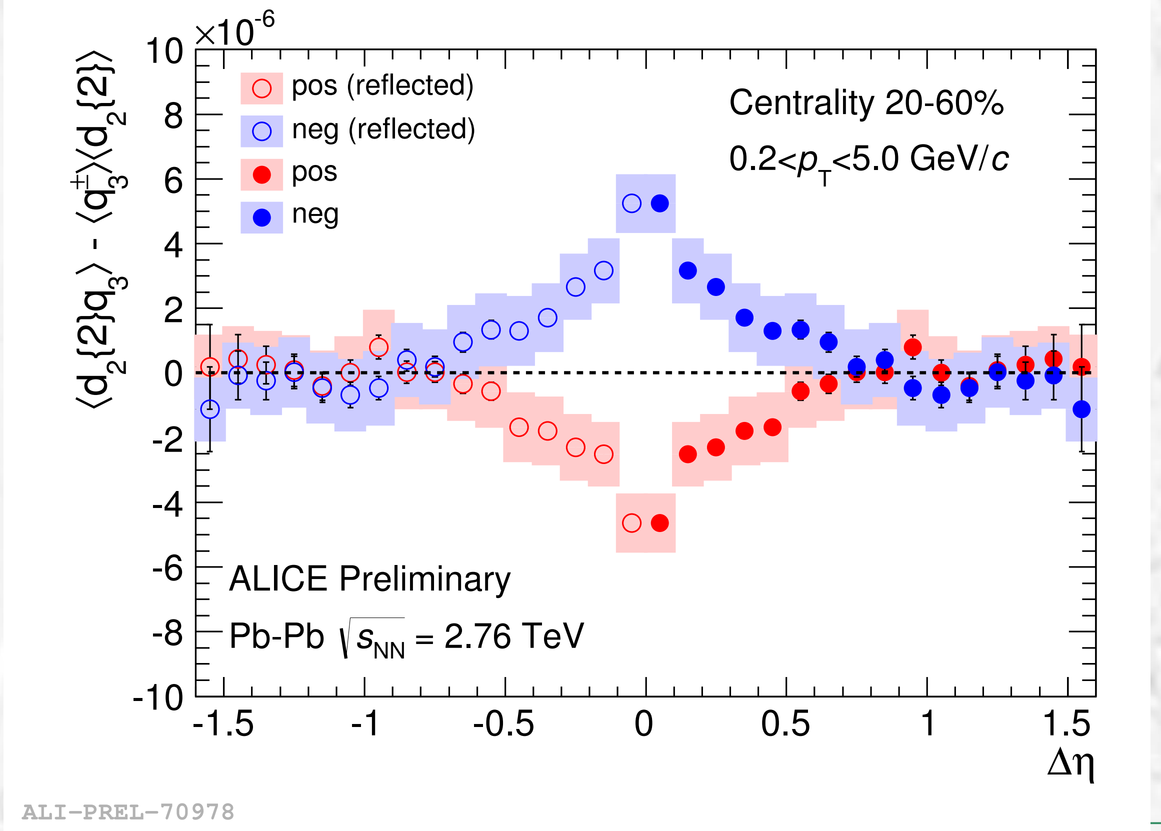
Fig. 2. Effect of the radial boost on two particle angular difference in azimuth (left panel) and pseudorapidity (right panel).

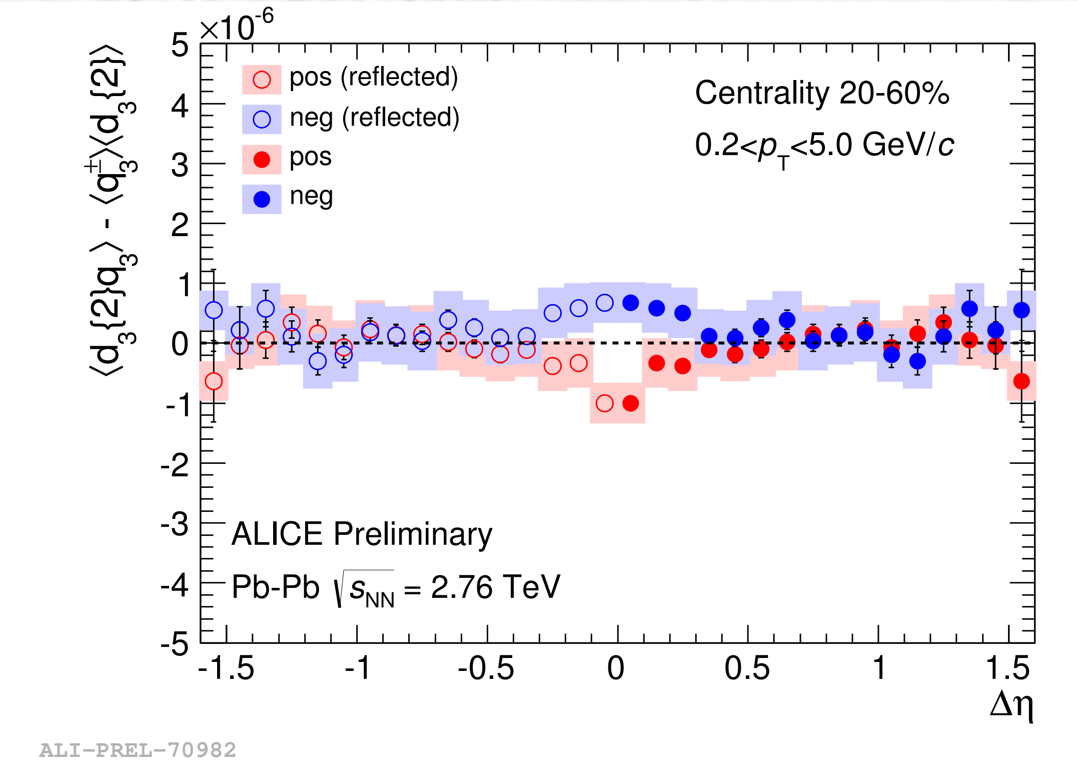
... + 《cos[n(ϕ₁ - Ψₙ] c3》





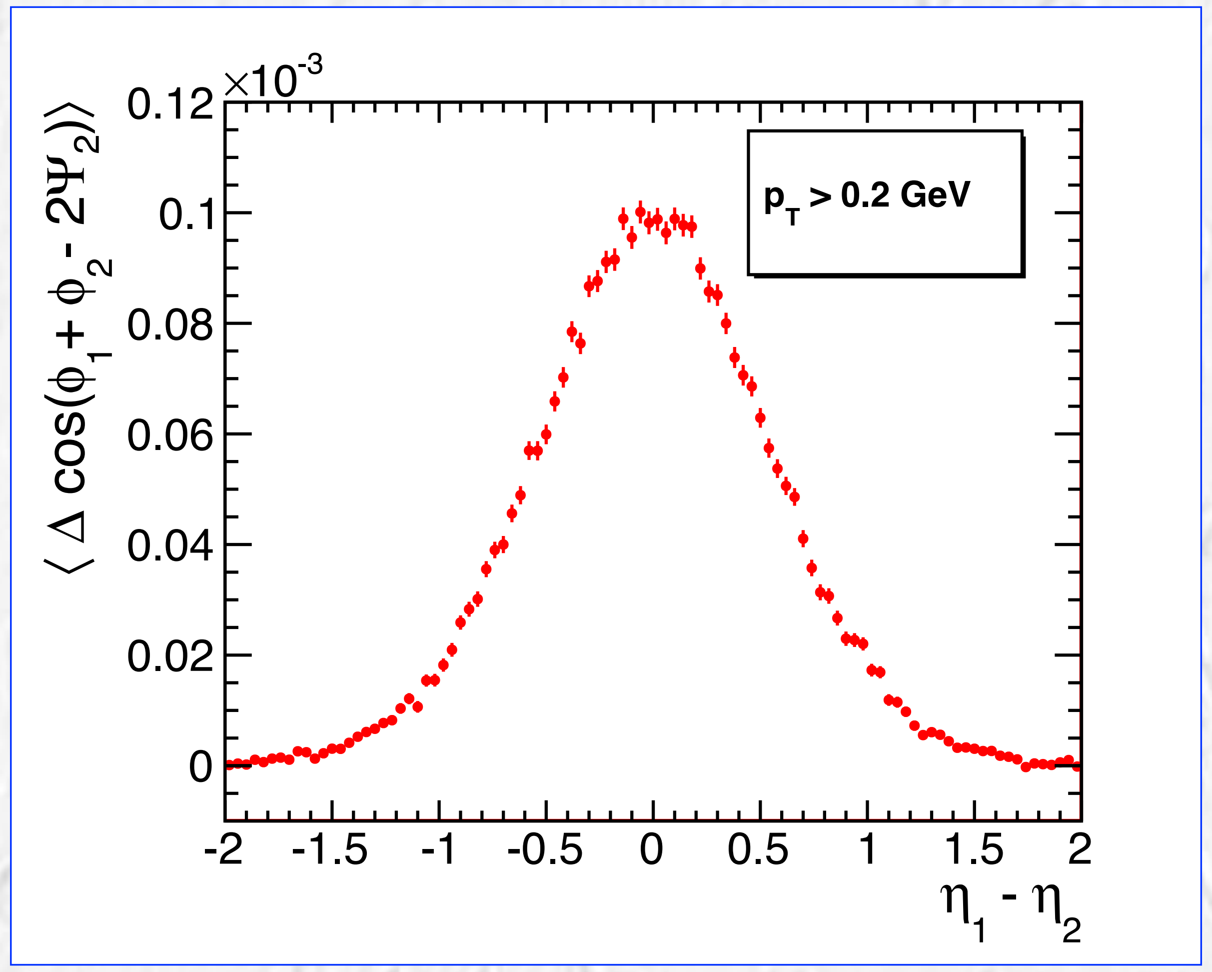
- Note: crossing zero at ~ $\Delta\eta$ = 0.7
- Depends on p_T cut (not shown)
- Depends about linearly on v_n

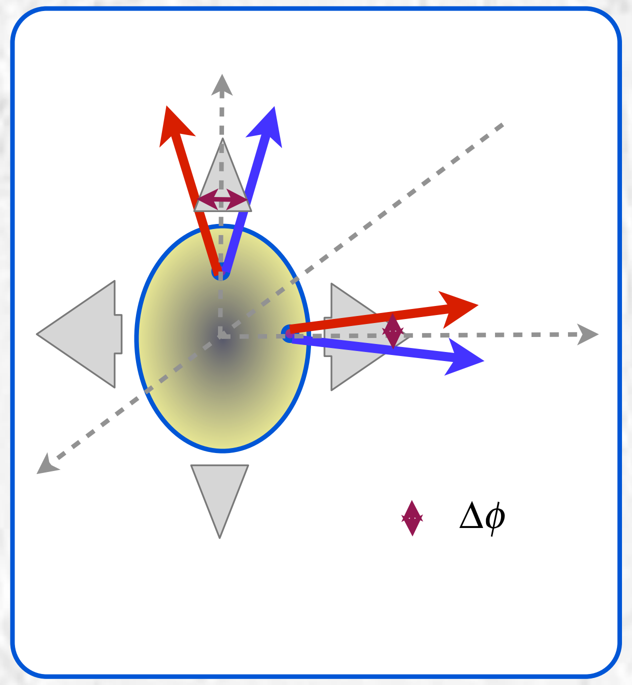




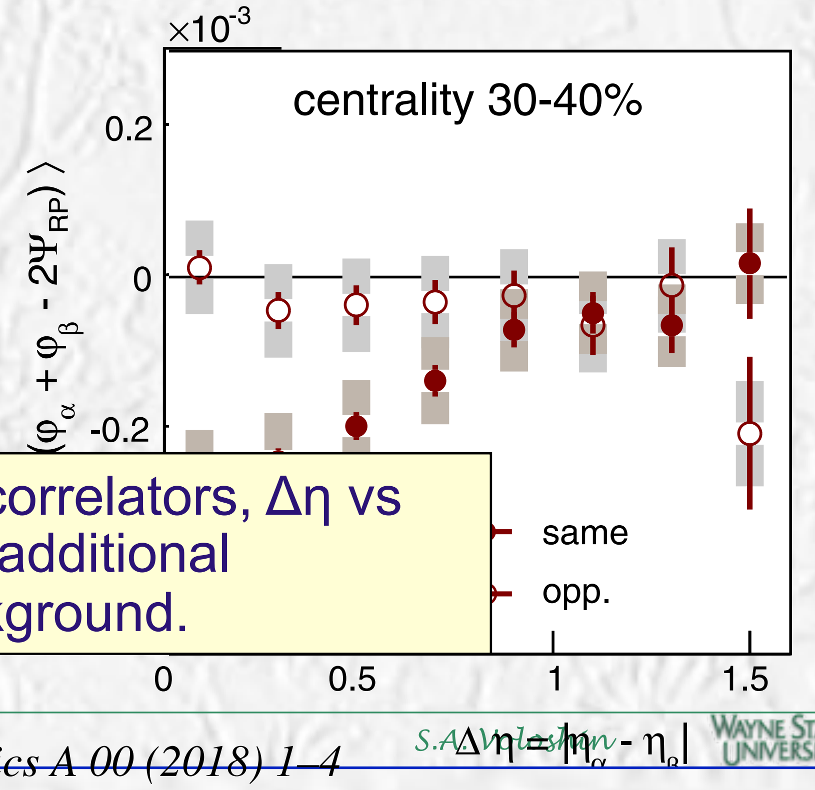
Relation to 3-particle "CME correlator"

$$\Delta(\ldots) \equiv (\ldots)_{opposite} - (\ldots)_{same}$$





The correlations are "diluted" according to $dN_{ch}/d\eta$



Cross-comparison of the results, e.g. "CMW" vs "CME" correlators, $\Delta\eta$ vs p_T dependence, 2-particle correlations, etc., will provide additional constraints in identifying mechanisms for the signal/background.

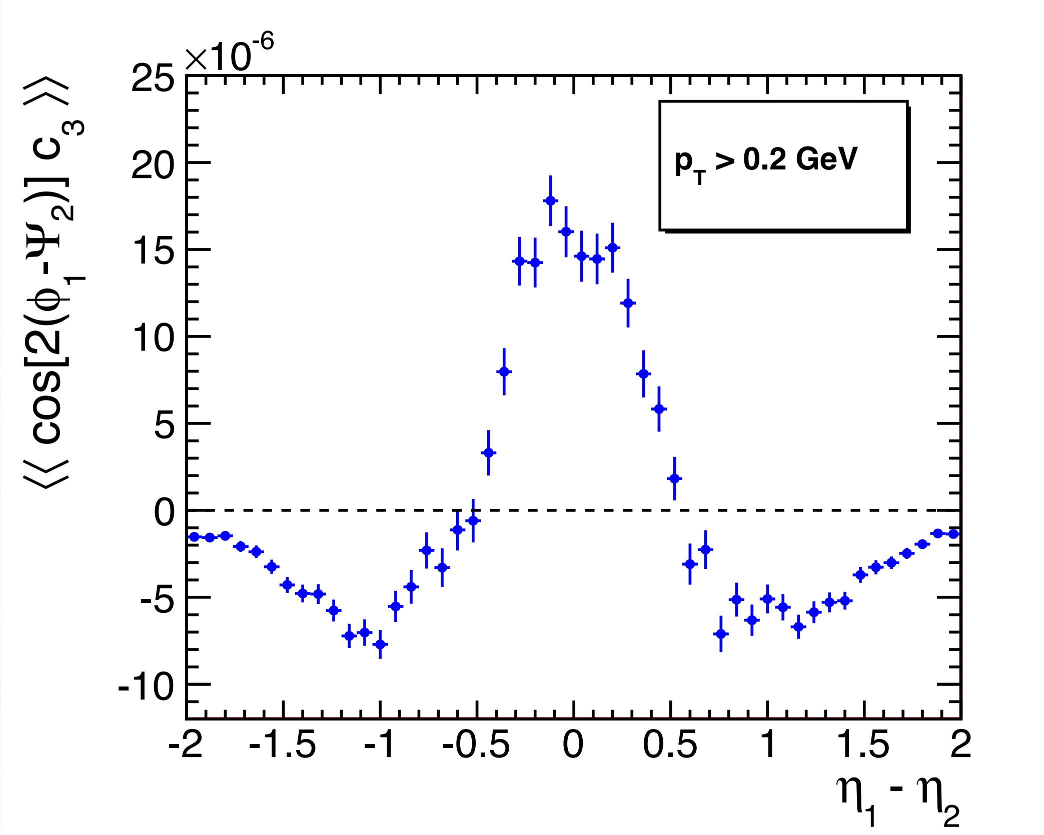
S.A. Voloshin and R. Belmont / Nuclear Physics A 00 (2018) 1–4

PHYSICAL REVIEW C **93**, 044903 (2016)

Charge-dependent flow and the search for the chiral magnetic wave in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

J. Adam *et al.**
(ALICE Collaboration)

p_T dependence might be important to explore



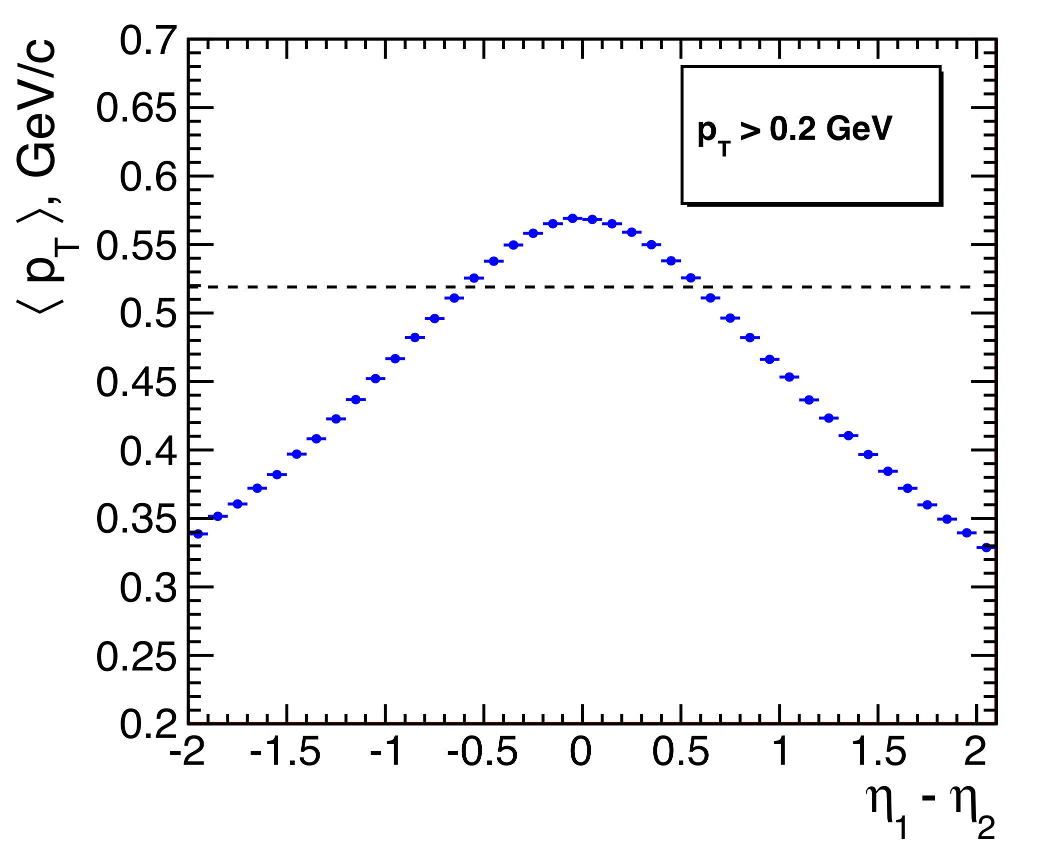


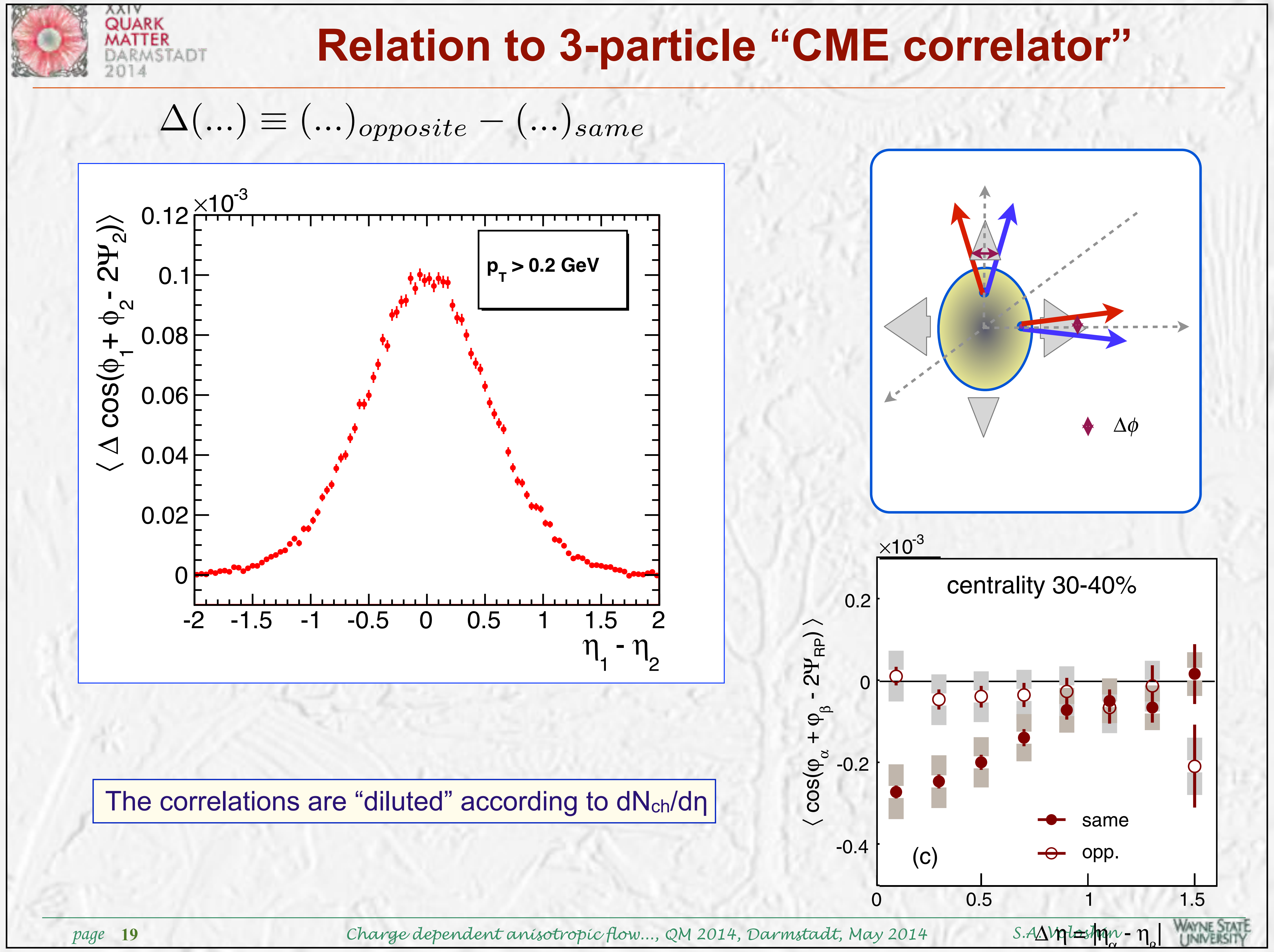
Figure 3. Left: The correlator $\langle\langle \cos[n(\phi_1 - \Psi_n)]\, c_3 \rangle\rangle$ as a function of $\Delta\eta$. Right: Mean p_T of the balancing charge particle.

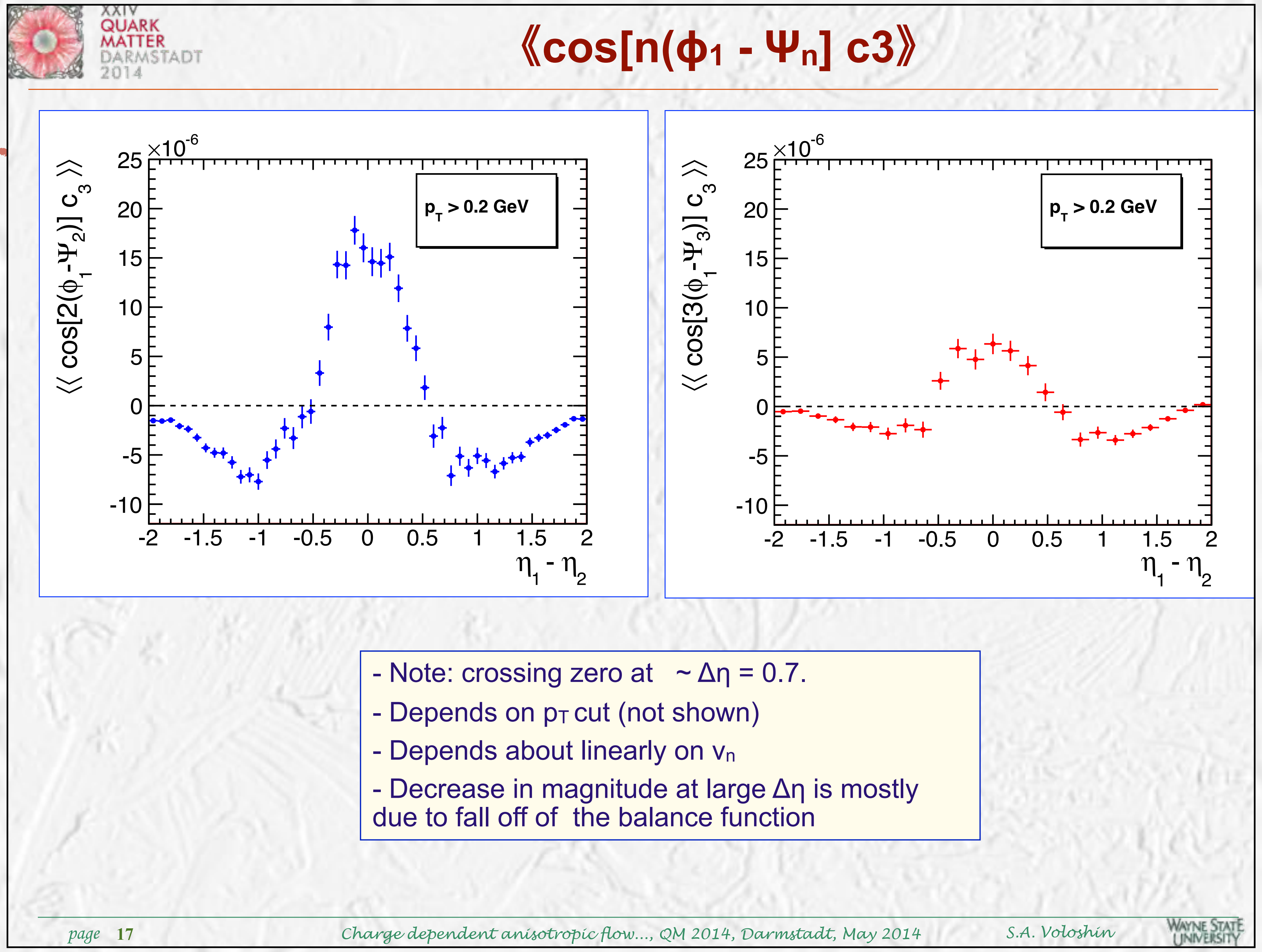
Summary

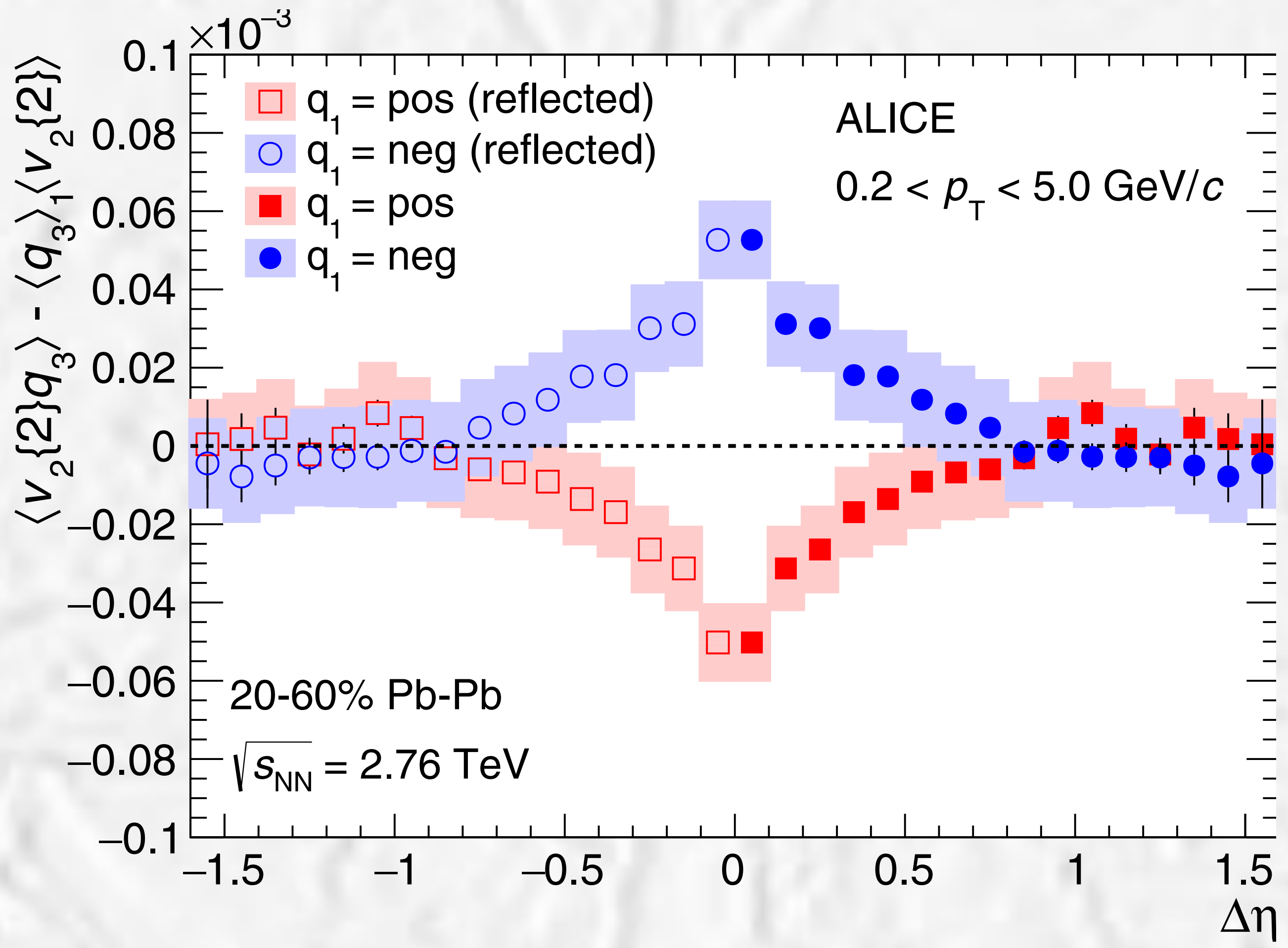
- siCME (si - shear induced)
  A smaller effect but
  with larger signal/background ratio
- Future highs statistics data:
  SP/PP and, probably ESE → 0.5% level
  in AuAu PbPb collisions
- all other approaches seems to have
  too large “systematic” uncertainty
- larger isobars?

EXTRA SLIDES

LCC ⇒ CME, CMW observables







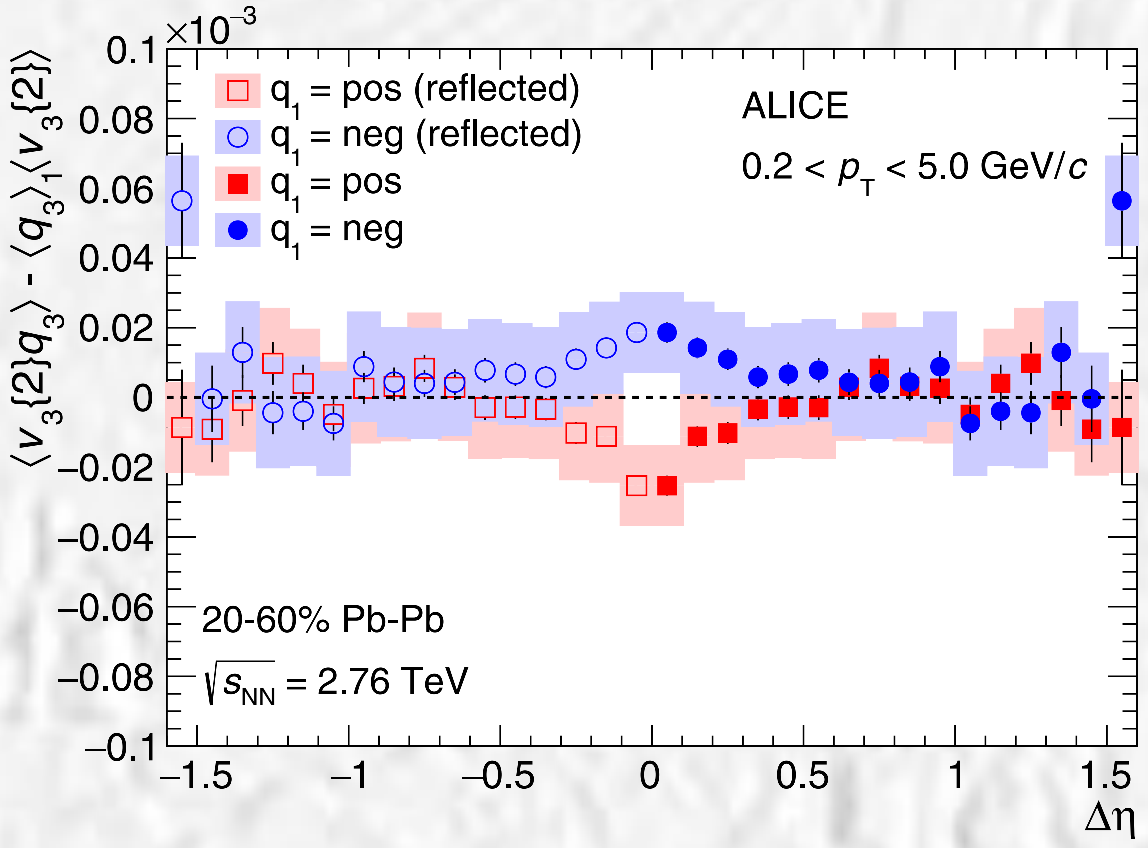


FIG. 9. Three-particle correlator for the second harmonic, fo positive (red squares) and negative (blue circles) particles. Statistica (systematic) uncertainties are indicated by vertical bars (shade boxes).

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