DISCOVERING PRIMORDIAL MOMENTUM ANISOTROPY IN HIGH-ENERGY NUCLEAR COLLISIONS

[Giacalone, Schenke, Shen, **2006.15721**]

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BACKGROUND

Elliptic flow (final-state momentum anisotropy) is a response to the initial ellipticity of the system.

$$\boxed{V_2} = \frac{1}{N}\int_{\mathbf{p}_t} \frac{dN}{d^2\mathbf{p}_t} e^{-i2\phi_p} \longrightarrow V_2 \propto \mathcal{E}$$

- scalar modes (initial energy density):

$$\boxed{\mathcal{E}_2} = \frac{\langle x^2 - y^2\rangle + i\langle 2xy\rangle}{\langle x^2 + y^2\rangle}$$

SPATIAL ELLIPTICITY

- tensor modes (initial stress tensor):

$$\boxed{\mathcal{E}_p} \equiv \frac{\langle T^{xx} - T^{yy}\rangle + i\langle 2T^{xy}\rangle}{\langle T^{xx} + T^{yy}\rangle}$$

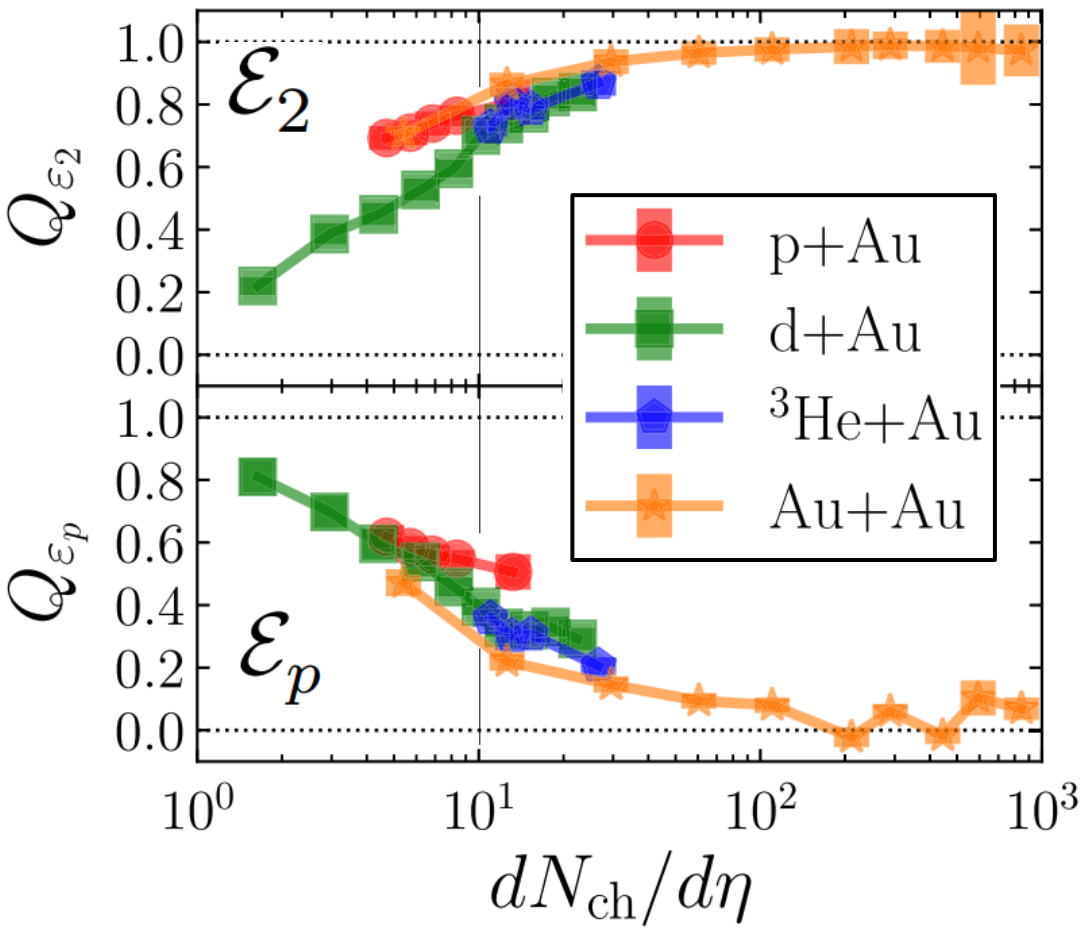
[Teaney, Yan, **1010.1876**]

[Sousa, Luzum, Noronha, **2002.12735**]

PRIMORDIAL MOMENTUM ELLIPTICITY
PREDICTED BY THE CGC FRAMEWORK

WHAT IS THEIR ROLE? [Schenke, Shen, Tribedy, 1908.06212]

$$Q_\varepsilon = \frac{\mathrm{Re}\langle \mathcal{E} V_2^* \rangle}{\sqrt{\langle |\mathcal{E}|^2 \rangle \langle |V_2|^2 \rangle}}$$



- Q coefficient of linear correlation.

- E_2 is the dominant contribution to V_2 for $dN/d\eta \geq 20$.

THIS IS VERY WELL-KNOWN

- At low multiplicity, V_2 is instead in a stronger correlation with E_p.

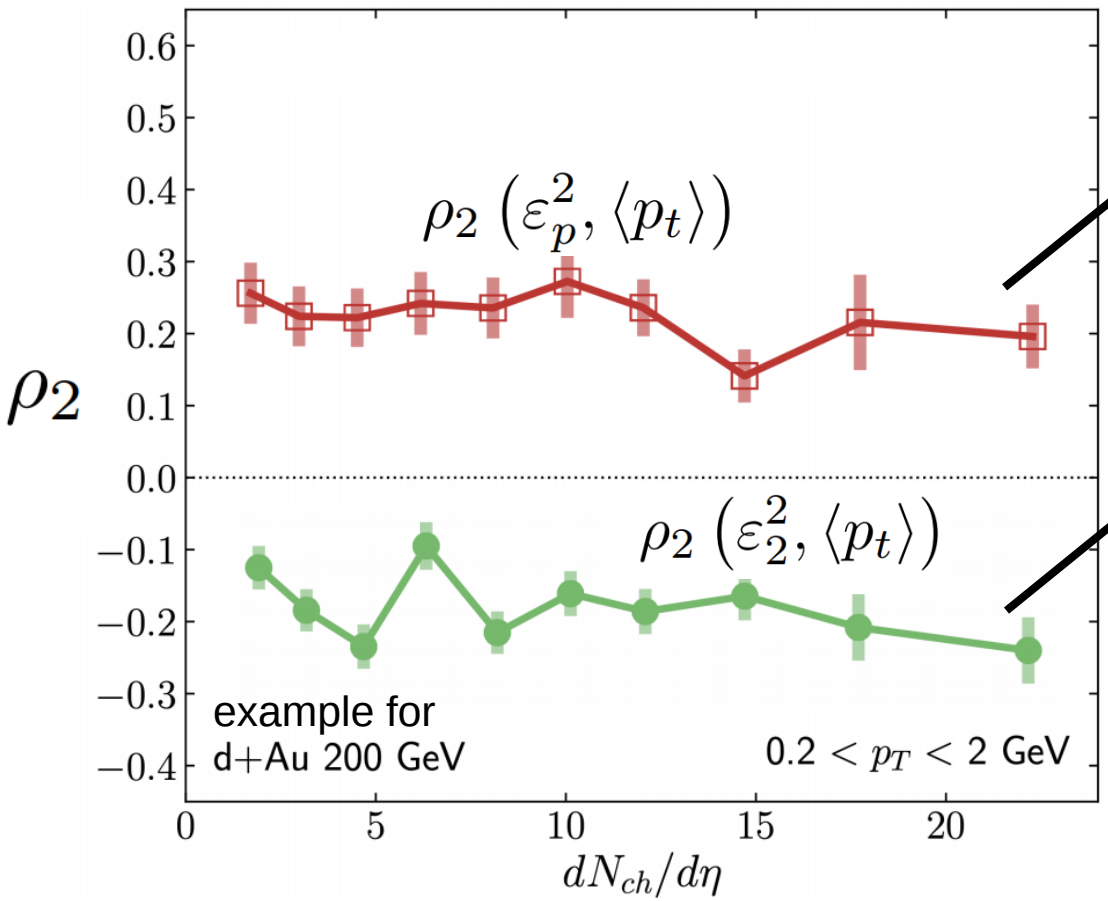
EXPERIMENTAL EVIDENCE STILL MISSING

What <u>observable</u> can reveal this transition and probe ε_p ?

OUR FINDING

[Giacalone, Schenke, Shen, **2006.15721**]

Introduce ρ_2 , statistical correlation between event-by-event <p_t> and event-by-event anisotropy at fixed multiplicity.



Correlation with momentum anisotropy, ε_p, is positive. (expected in CGC picture)

Correlation with spatial anisotropy, ε_2, is negative. (expected in a small system)

Correlation with v_2 will thus reveal the transition!

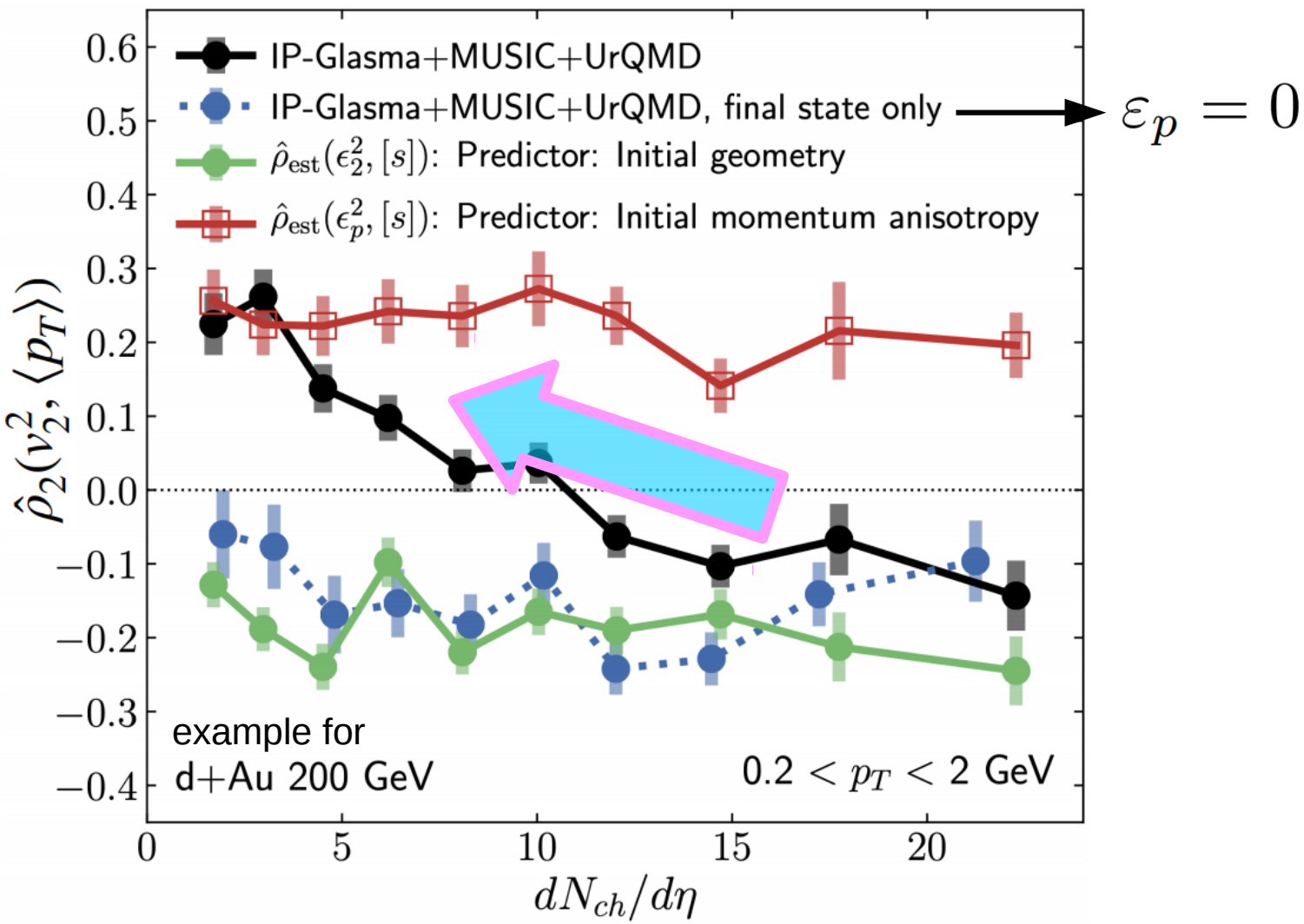
[Bozek, **1601.04513**]

THE OBSERVABLE →

$$\rho_2\left(v_2^2, \langle p_t \rangle\right) = \frac{\langle v_2^2 \langle p_t \rangle \rangle - \langle v_2^2 \rangle \langle \langle p_t \rangle \rangle}{\sigma(v_2^2)\sigma(\langle p_t \rangle)}$$

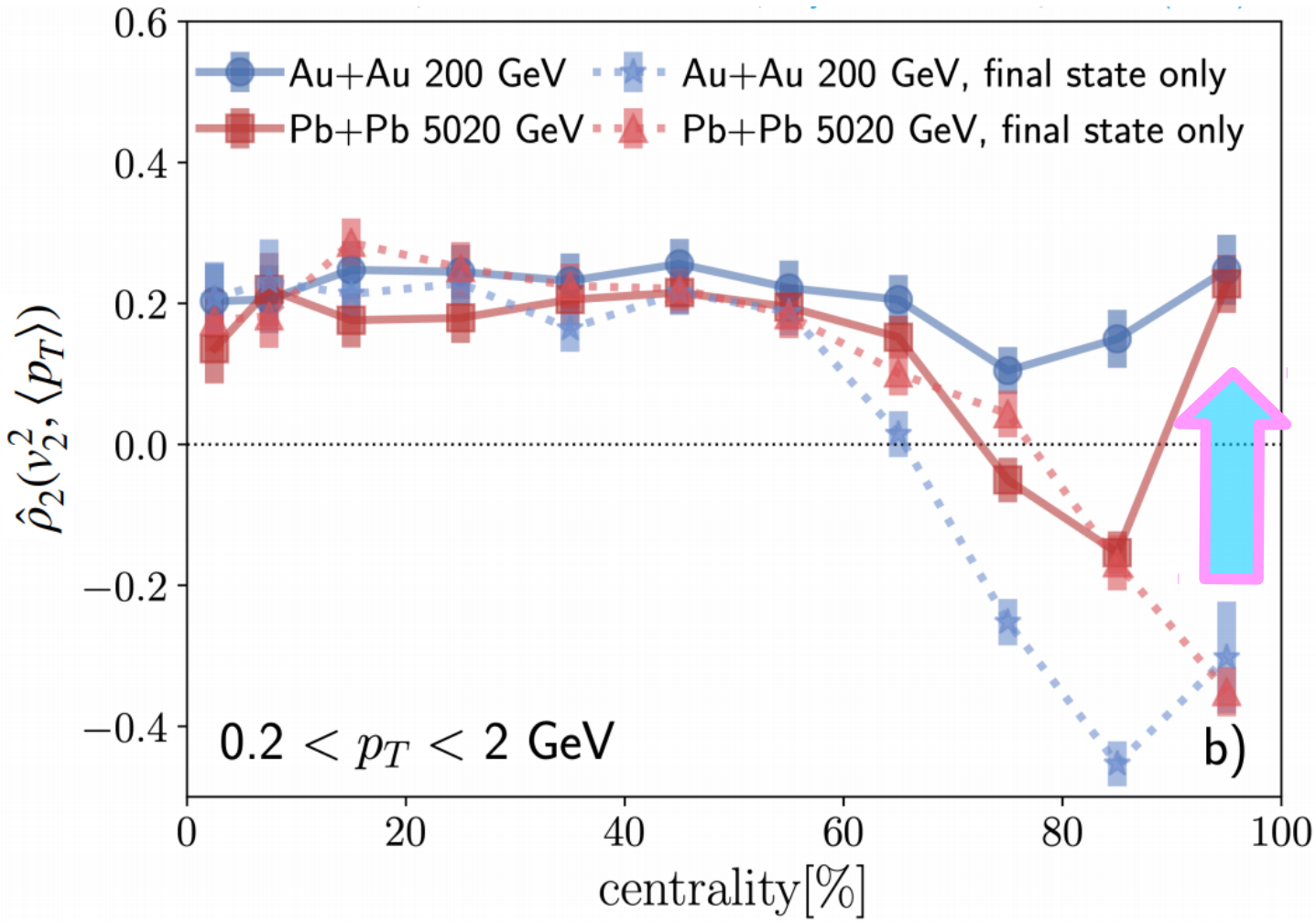
RESULTS & PREDICTIONS

GENERIC PREDICTIONS FOR SMALL SYSTEMS (p-Au, d-Au, p-Pb)



Correlator goes from negative to positive as we decrease dN/dη.

PREDICTIONS FOR PERIPHERAL A-A SYSTEMS.



Sign change around ~70% is generic in geometry-driven systems.

[Schenke, Shen, Teaney, **2004.00690**]

Initial momentum anisotropy yields:

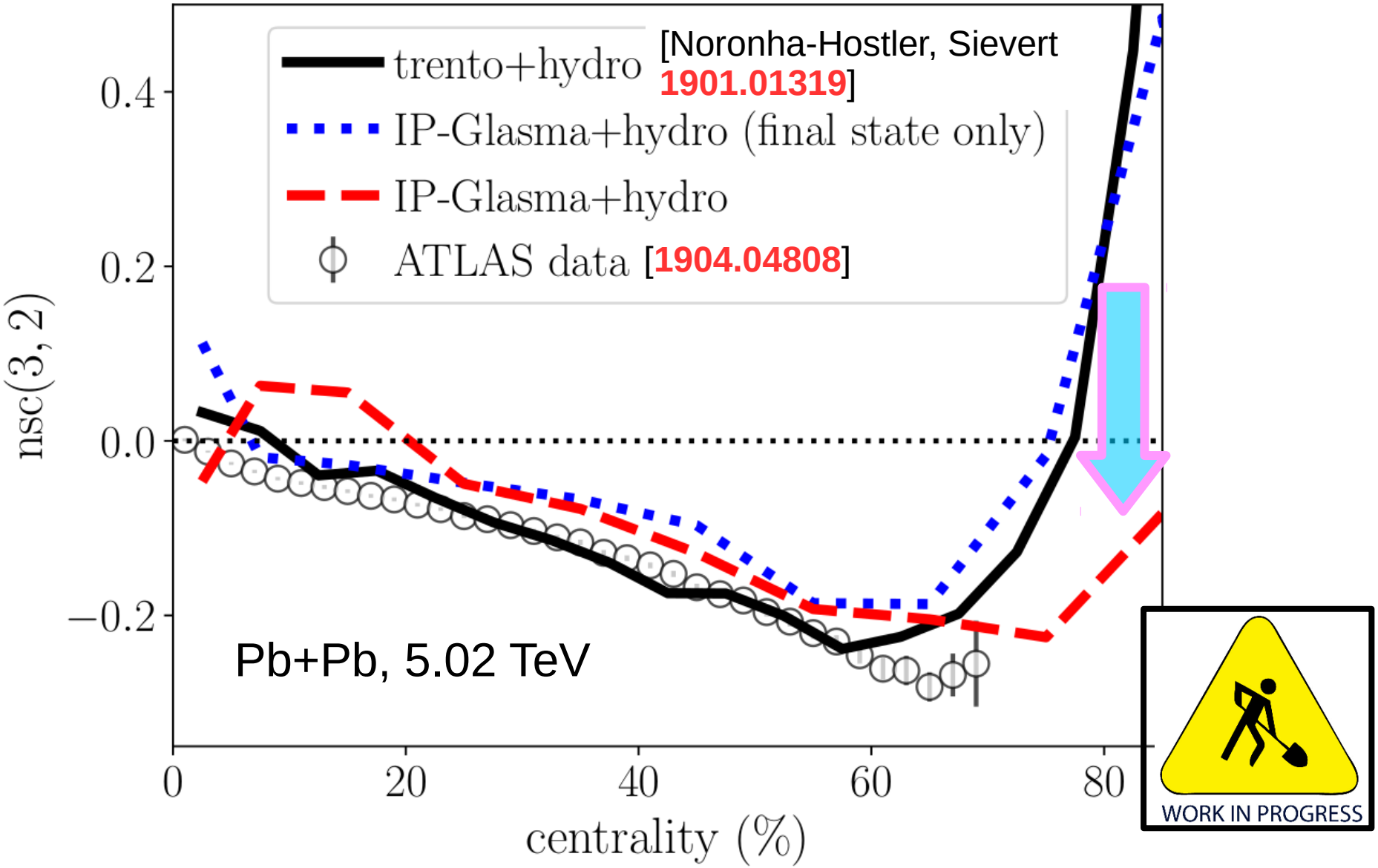
– Double sign change in Pb-Pb collisions @ LHC.

– No sign change in Au-Au collisions @ RHIC.

[consistent with preliminary STAR data]

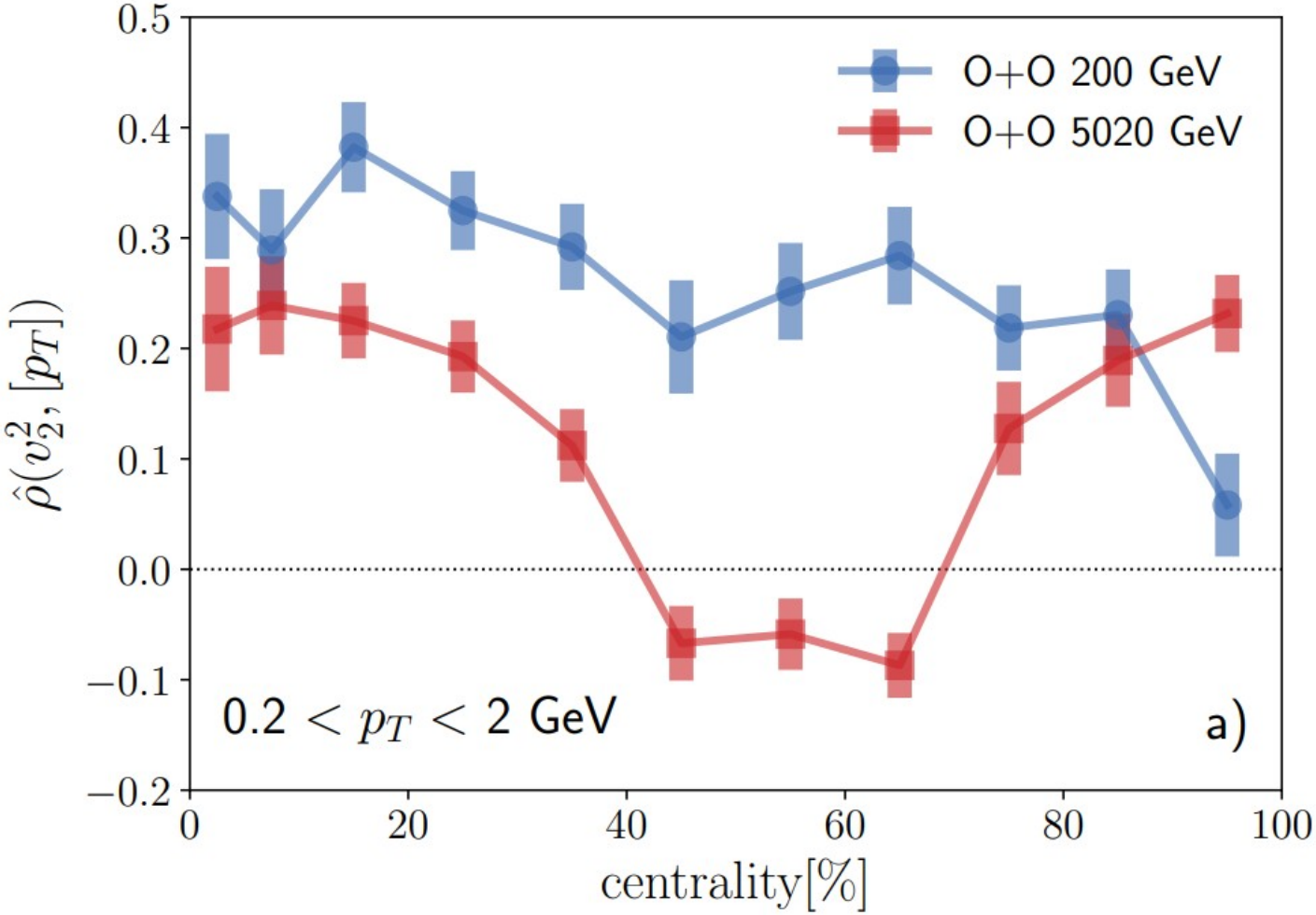
NEW

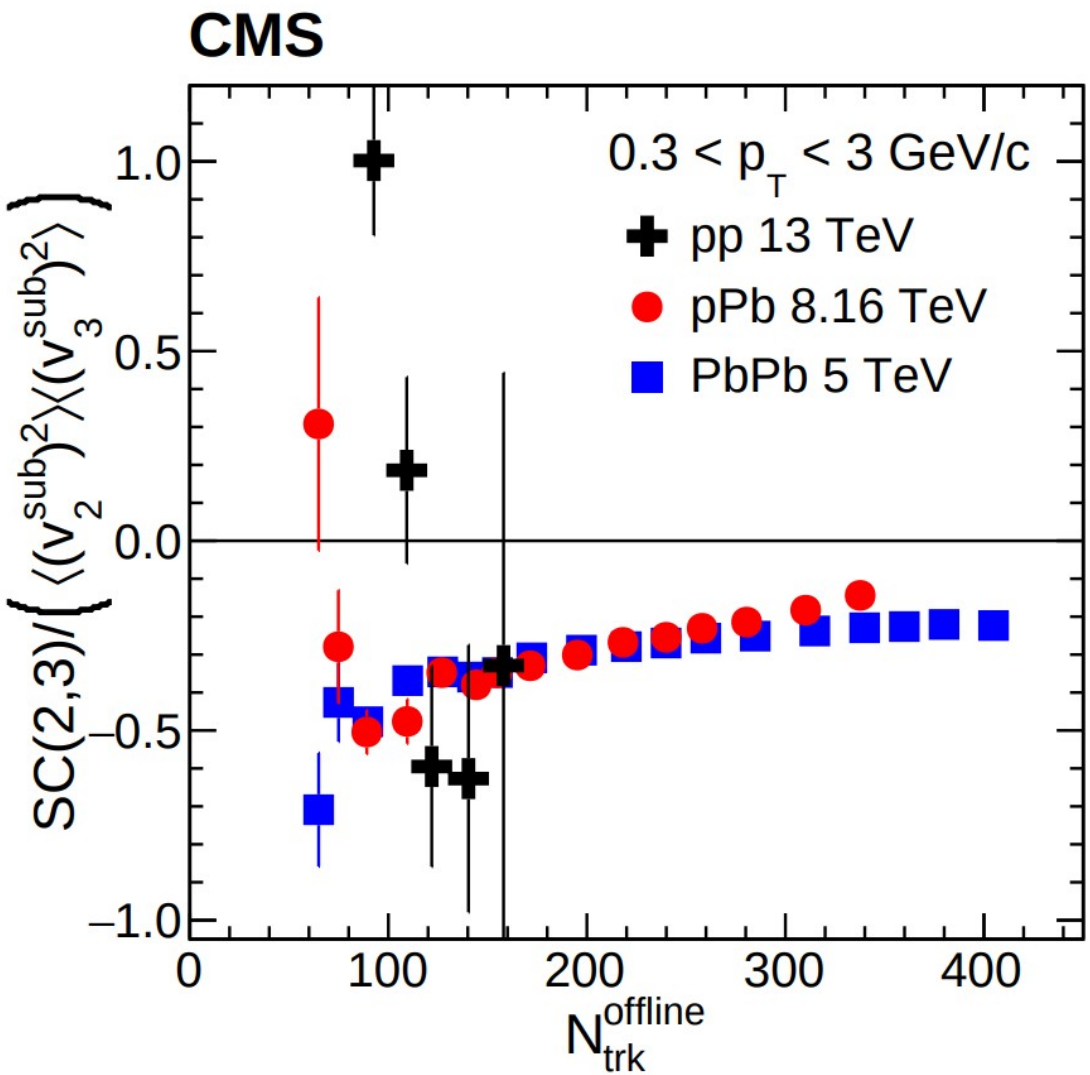
Normalized symmetric cumulant. Candidate observable signature.



With initial momentum anisotropy the cumulant stays negative!

BACKUP


O+O 200 GeV
O+O 5020 GeV
$0.2 < p_T < 2$ GeV
a)
$\hat{\rho}(v_2^2, [p_T])$
centrality[%]
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
0
20
40
60
80
100


CMS
0.3 < p_T < 3 GeV/c
pp 13 TeV
pPb 8.16 TeV
PbPb 5 TeV
SC(2,3)/{⟨(v_2^sub2)²⟩⟨(v_3^sub2)²⟩}
1.0
0.5
0.0
−0.5
−1.0
0
100
200
300
400
N_trk^offline