Chiral magnetic effect search in p+Au, d+Au and Au+Au collisions at RHIC

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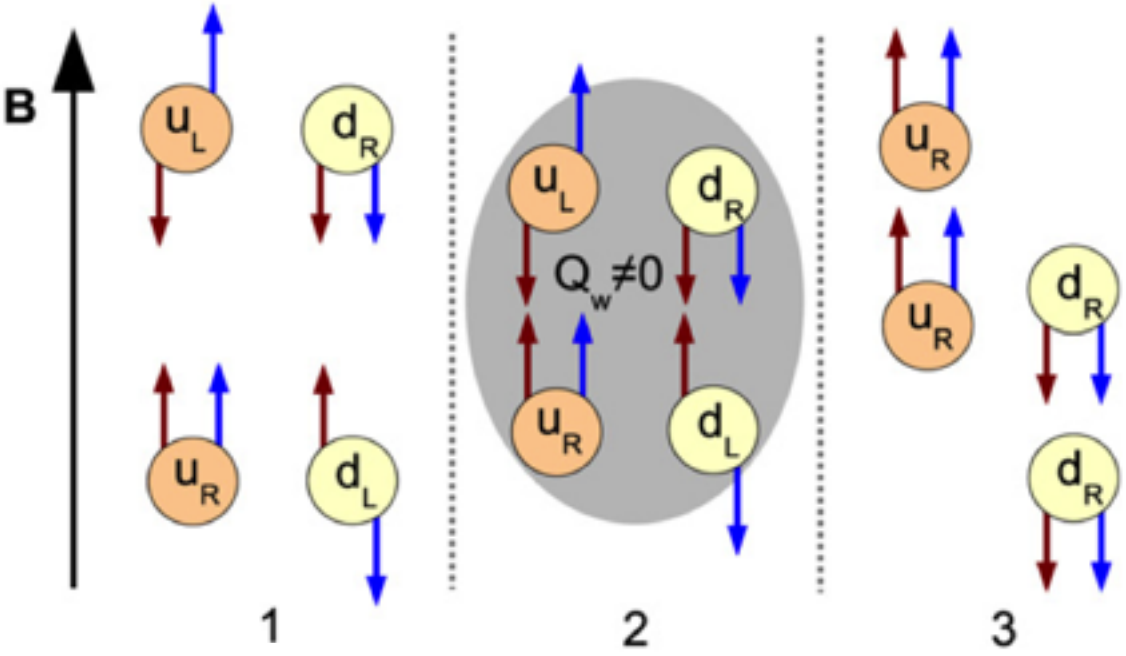
Outline

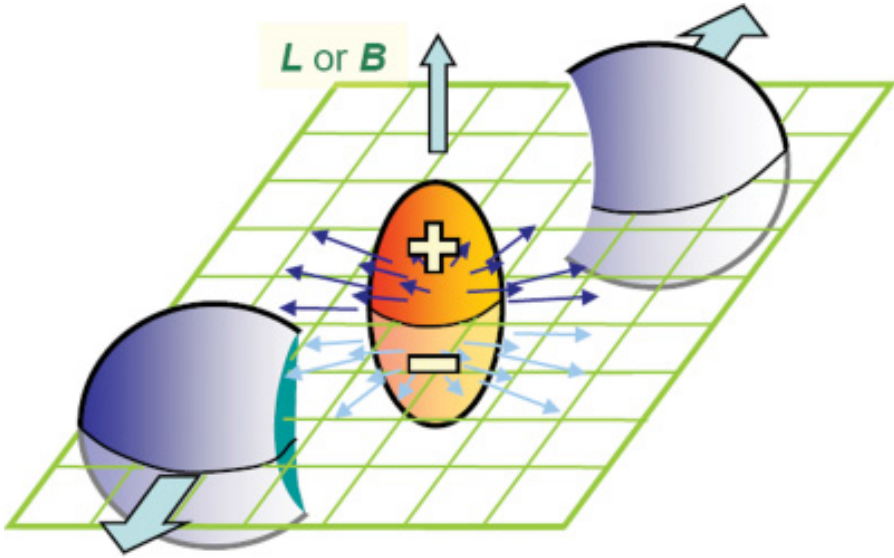
- Chiral Magnetic Effect (CME)
- CME in small systems
- RHIC-STAR experiment
- Results with respect to Ψ_2
- Results with respect to Ψ_1
- Summary

Ψ_2: second order eventplane; Ψ_1: first order eventplane

Chiral Magnetic Effect (CME)

D. Kharzeev, etc. NPA 803, 227(2008)





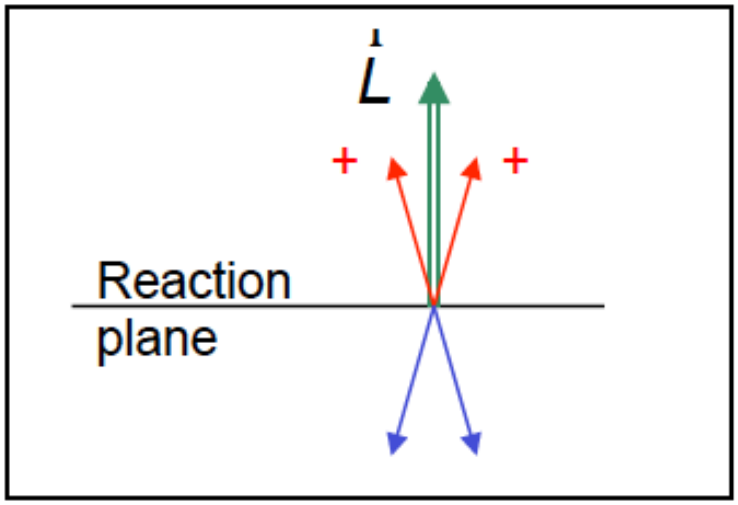
$$j_V = \frac{N_c e}{2\pi^2}\mu_A B, \Longrightarrow$$ electric charge separation alone the B field

Configuration with non-zero topological charge converts left(right)-handed fermions to right(left)-handed fermions, generating electric current along B direction and leading to electric charge separation

Azimuthal Charged-Particle Correlations

Particle distribution effectively can be described by:

$$\frac{dN_{\pm}}{d\phi} \propto (1 + 2v_1 \cos(\Delta\phi) + 2v_2 \cos(2\Delta\phi) + \ldots + + 2a_{\pm} \sin(\Delta\phi)), \quad (1)$$



slide from S. A. Voloshin

a > 0 preferential emission along the angular momentum, $a_+ = -a_-$.

The sign of Q_w **can vary** event to event and domain to domain -> one has to measure correlations, $\langle a_\alpha a_\beta \rangle$, P-even quantity (!) -- possibility of contribution from effects not related to P-violation

Predictions:

$a_+ = -a_-$

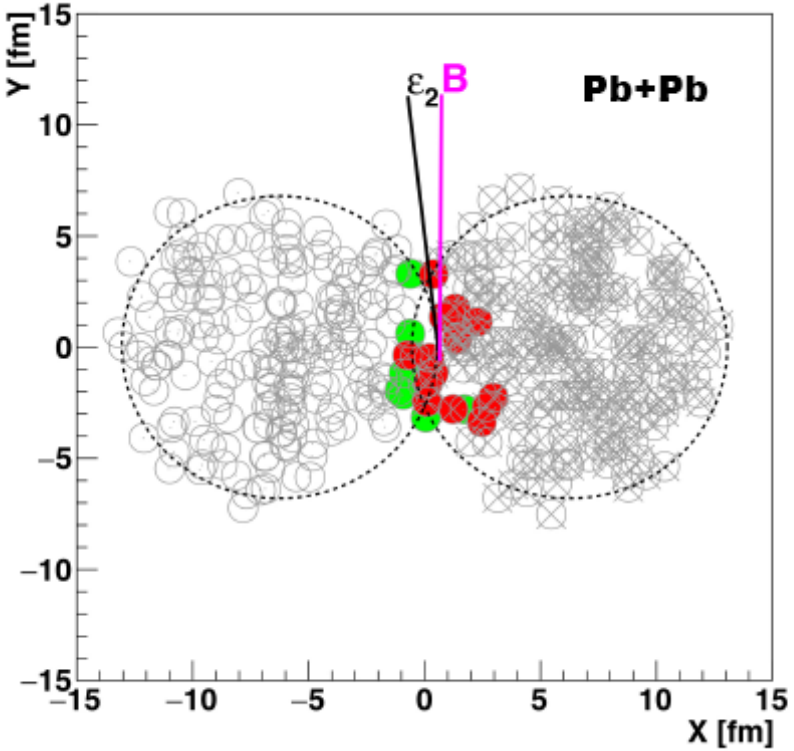
$a_+ a_+ = a_- a_- = -a_+ a_-$

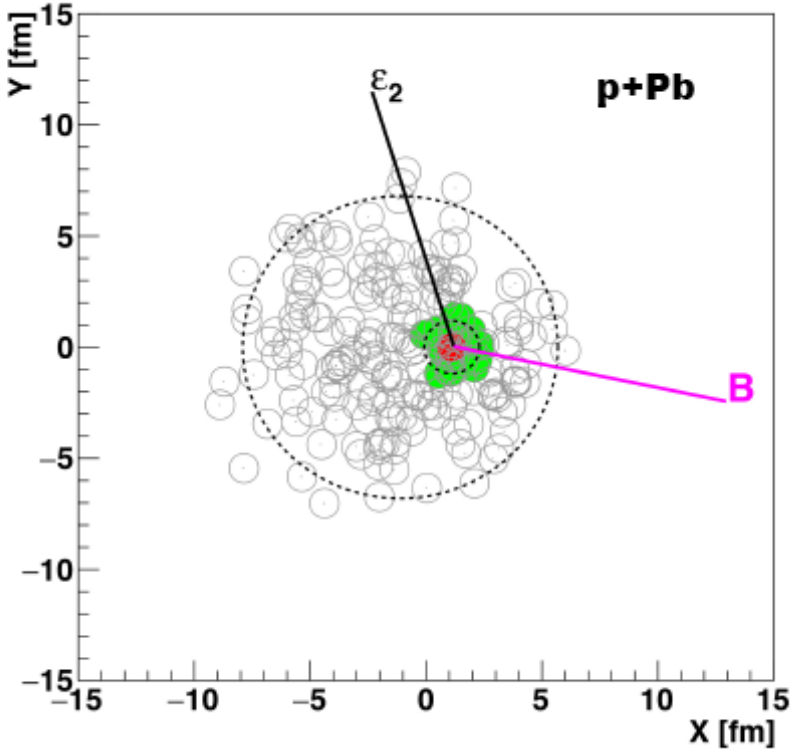
$a \sim 10^{-2}$ for midcentral coll-ns

$$\langle \cos(\phi_\alpha + \phi_\beta - 2\Psi_{RP}) \rangle =$$
$$= \langle \cos(\phi_\alpha - \Psi_{RP}) \cos(\phi_\beta - \Psi_{RP}) \rangle - \langle \sin(\phi_\alpha - \Psi_{RP}) \sin(\phi_\beta - \Psi_{RP}) \rangle$$
$$\approx (v_{1,\alpha} v_{1,\beta} - a_\alpha a_\beta)$$

Harmonic planes in small systems

CMS collaboration, arXiv:1610.00263; R. Belmont and J.L. Nagle, arXiv:1610.07964v1 [nucl-th]

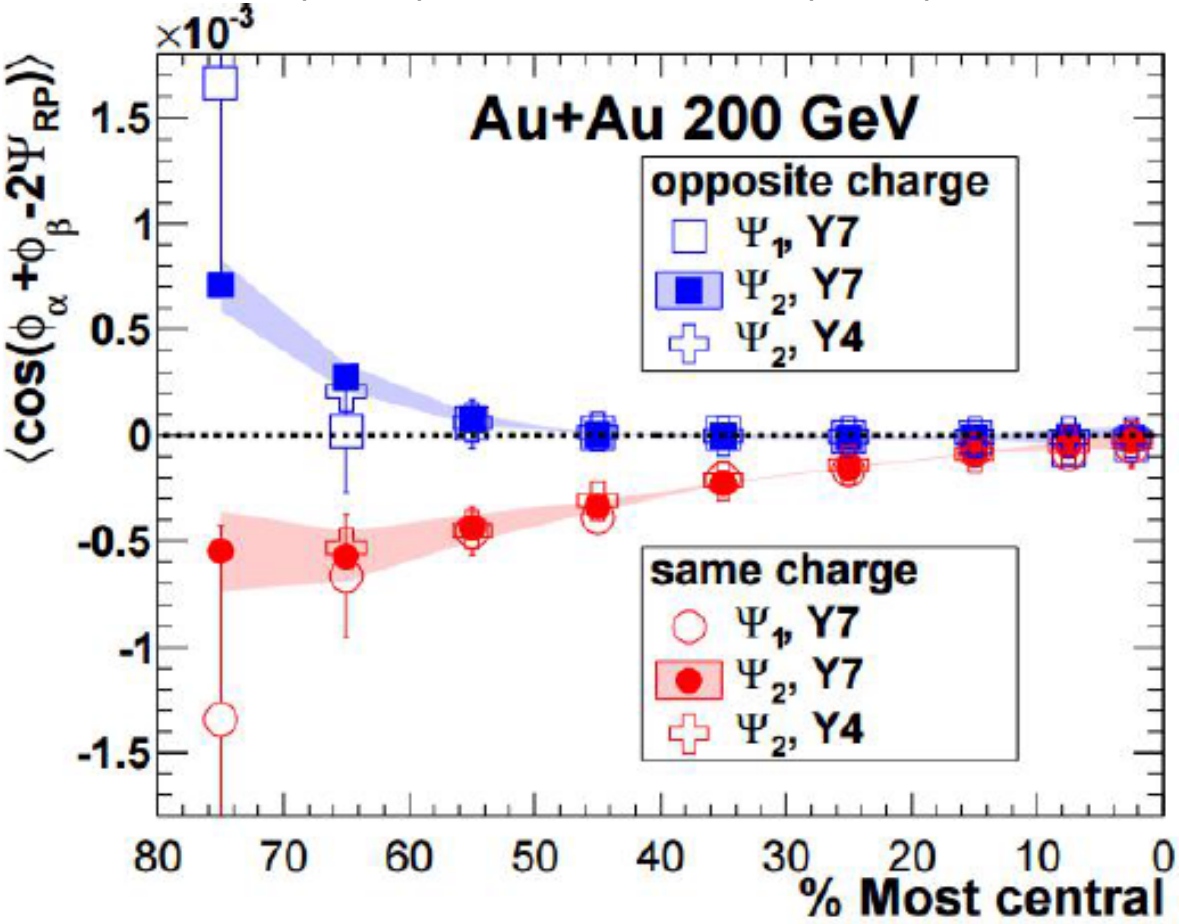




- Ψ_2 related to flow, related to -> flow background
- Ψ_1 related to the magnetic direction (B), useful for -> CME signal
- Ψ_1 and Ψ_2 correlated in A+A, signal and background entangled
- Ψ_1 and Ψ_2 not correlated in p+A, d+A, signal and background disentangled
- try p+Au, d+Au with ZDC-smd ψ_1 to measure CME w/o flow background contamination

Charge dependent correlation signal

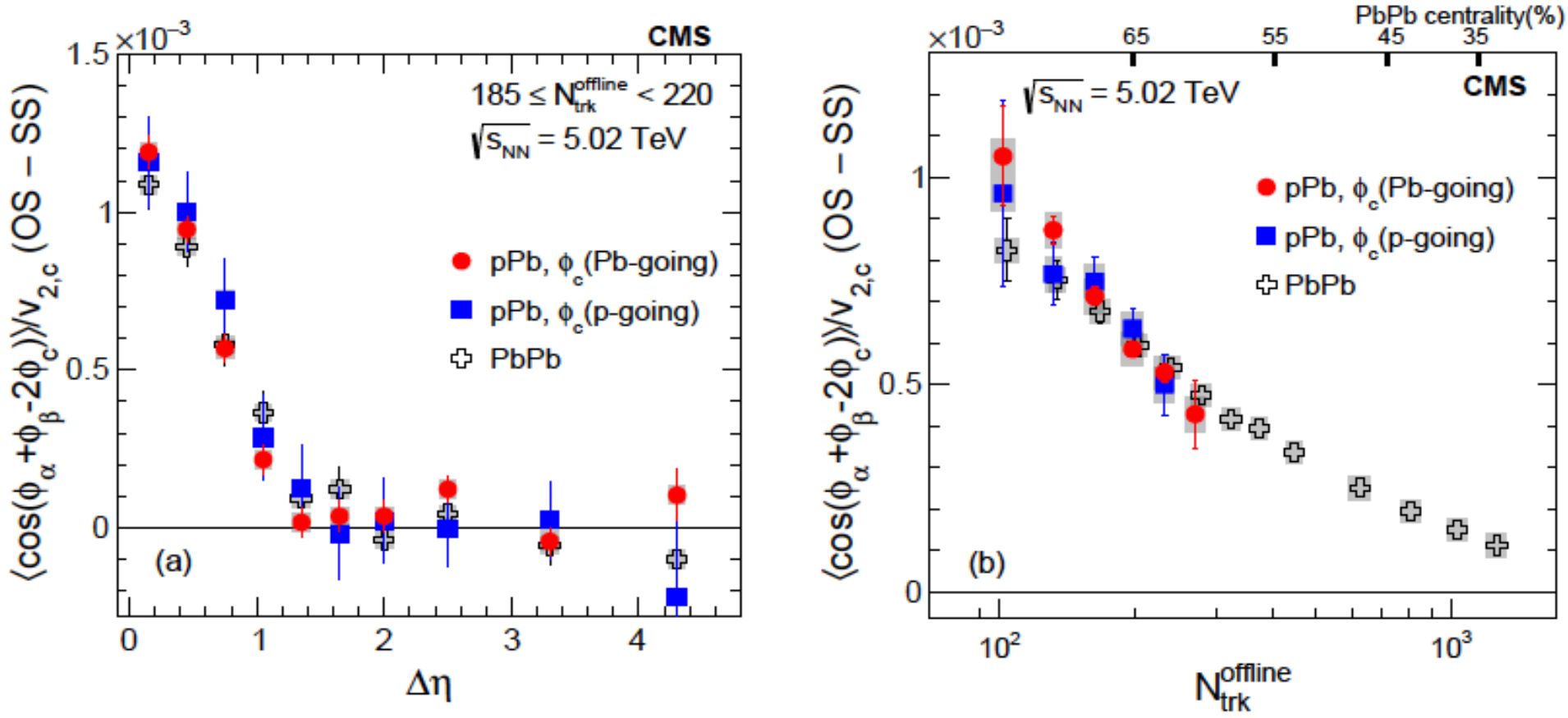
STAR collaboration, PRL 103(2009)251601; PRC 81(2010)54908; PRC 88 (2013) 64911



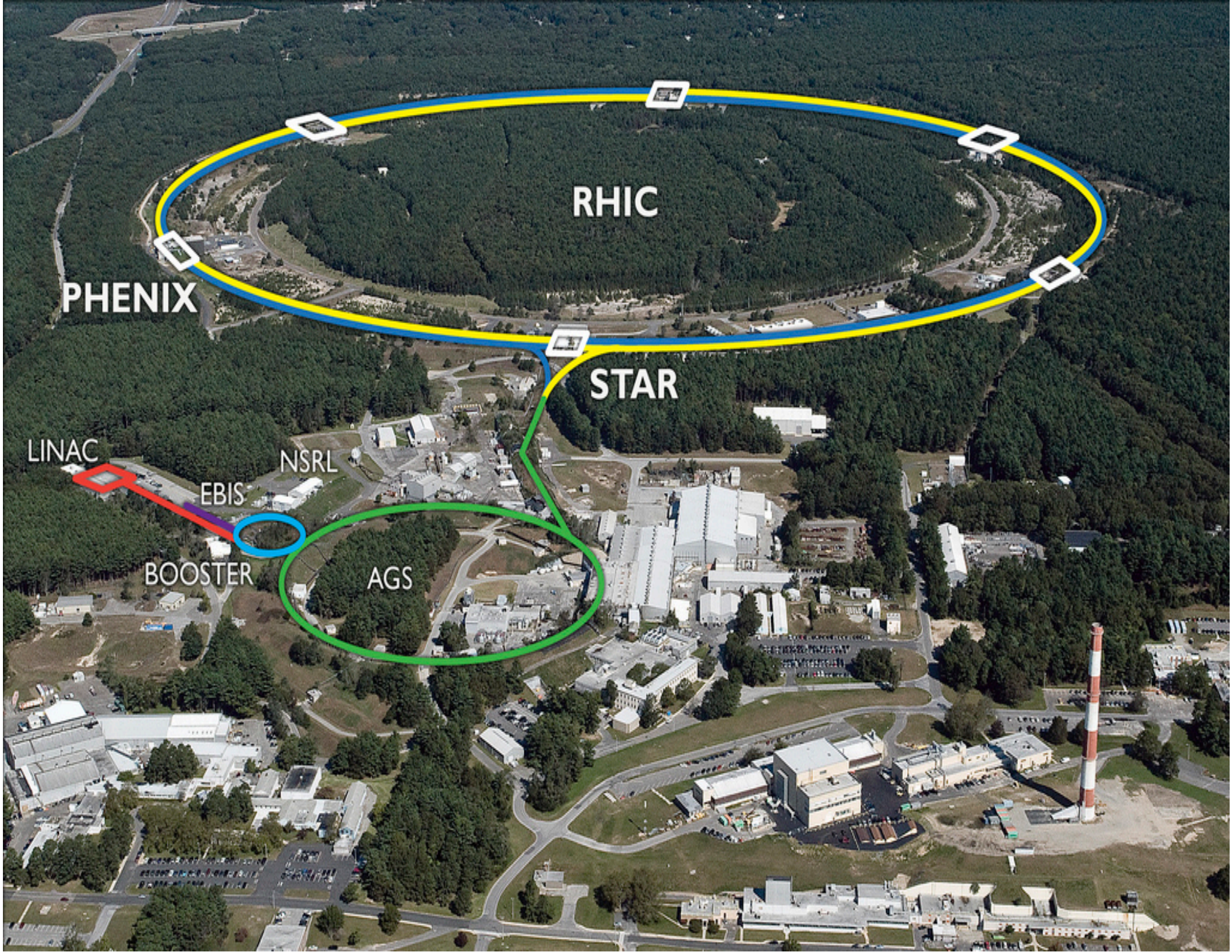
- Correlator indicates charge dependent signal
- Consistent between different years (2004 and 2007)
- Consistent with 1st-order EP (from spectator neutron v_1)

Charge dependent signal by CMS

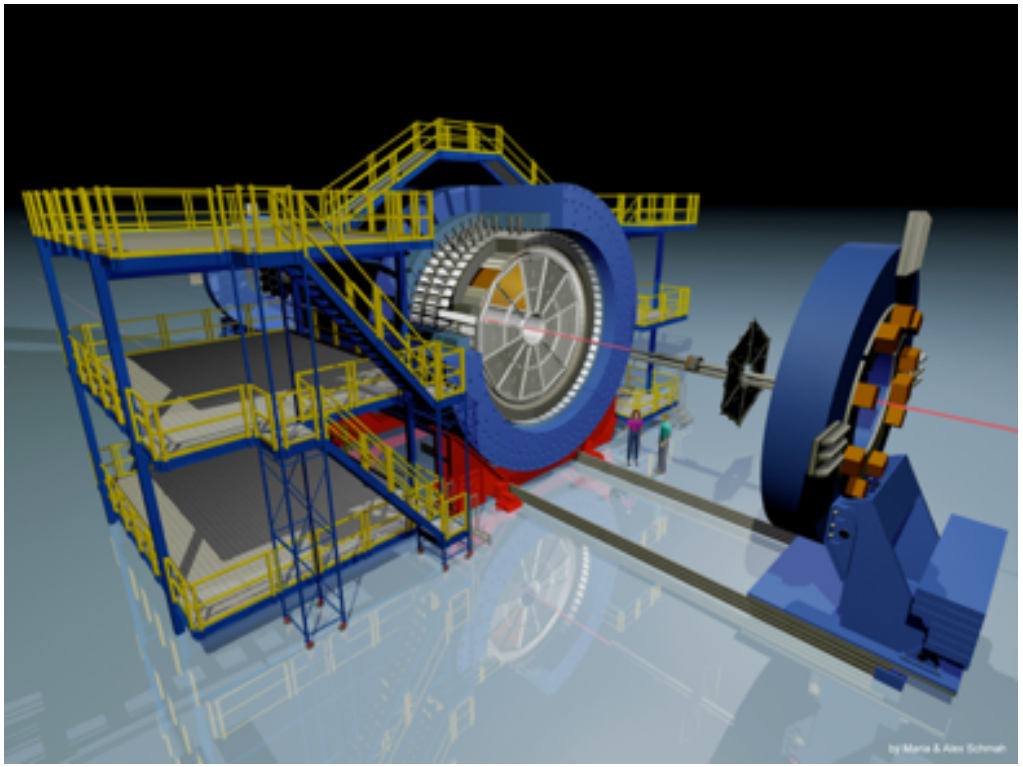
CMS collaboration, arXiv:1610.00263

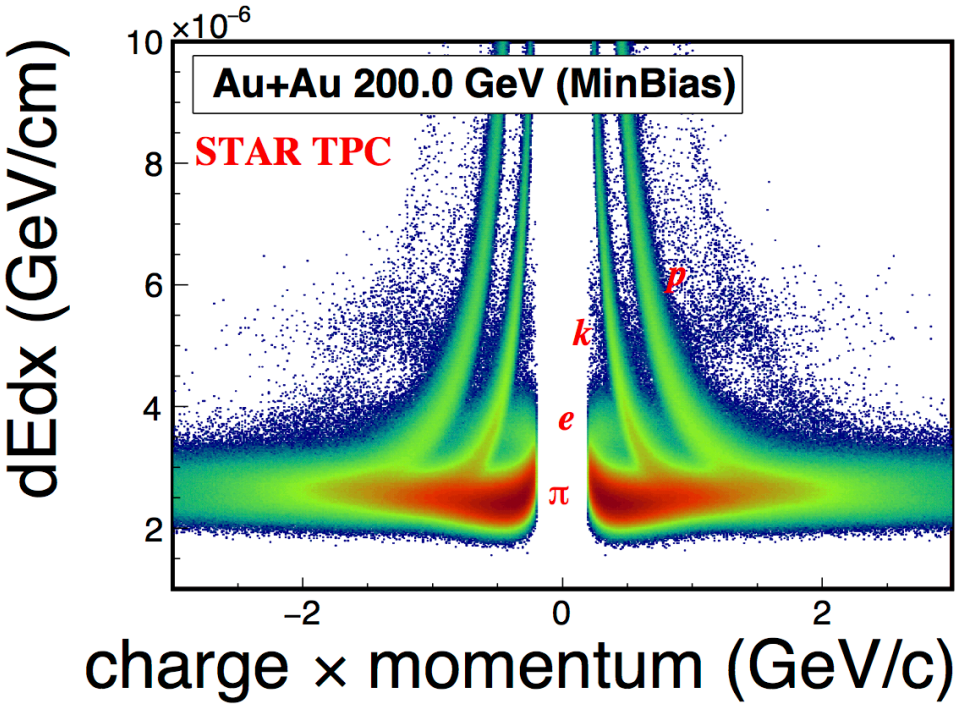


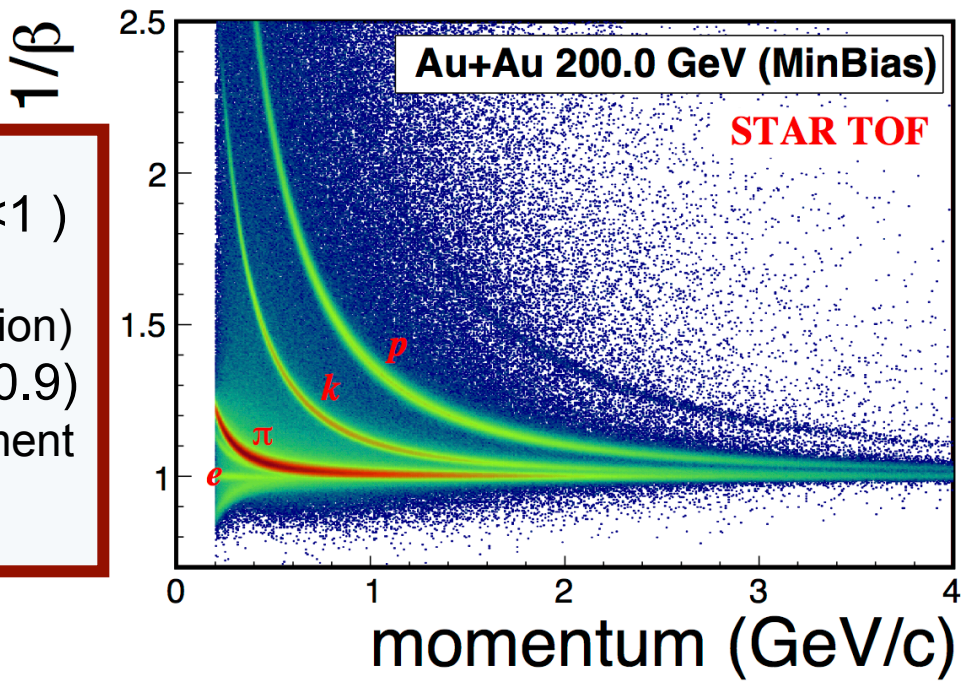
- The observed signal as functions of multiplicity and eta gap, are of similar magnitude in p+Pb and Pb+Pb collisions at the same multiplicities
- The results pose a challenge for the interpretation of charge-dependent azimuthal correlations in heavy ion collisions in terms of the CME


RHIC
PHENIX
STAR
LINAC
NSRL
EBIS
BOOSTER
AGS

STAR detector

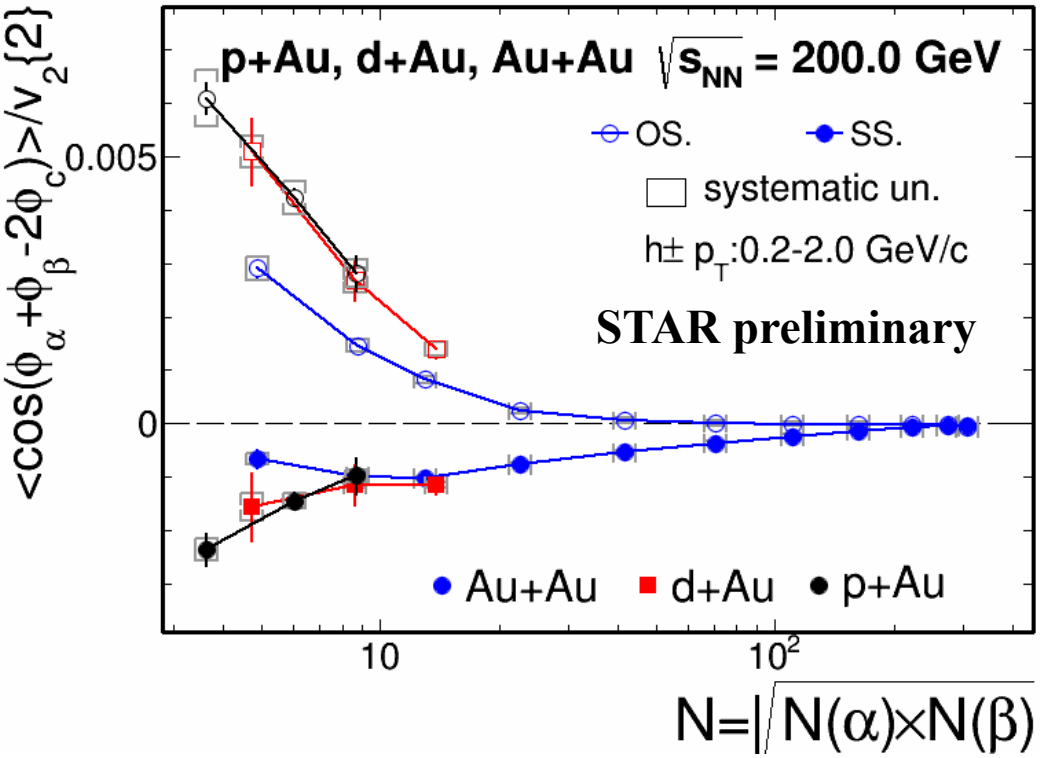


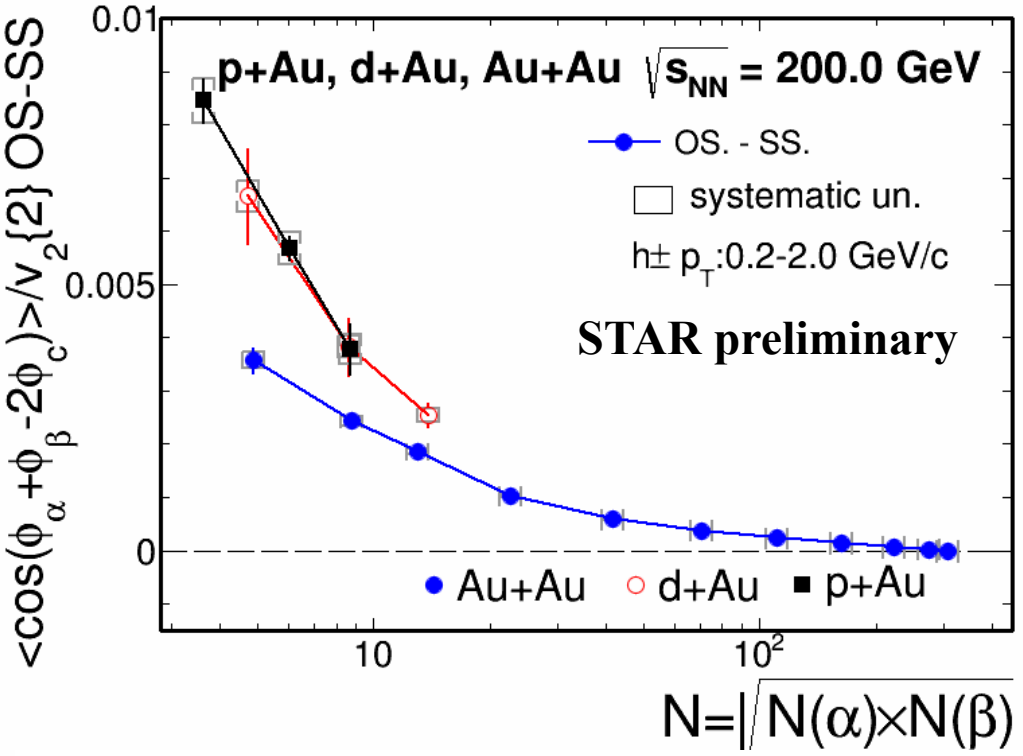




- **Time Projection Chamber** (0<ϕ<2π, |η|<1)
  Tracking – momentum
  Ionization energy loss – dE/dx(particle identification)
- **Time Of Flight detector** (0<ϕ<2π, |η|<0.9)
  Timing resolution <100ps - significant improvement for PID

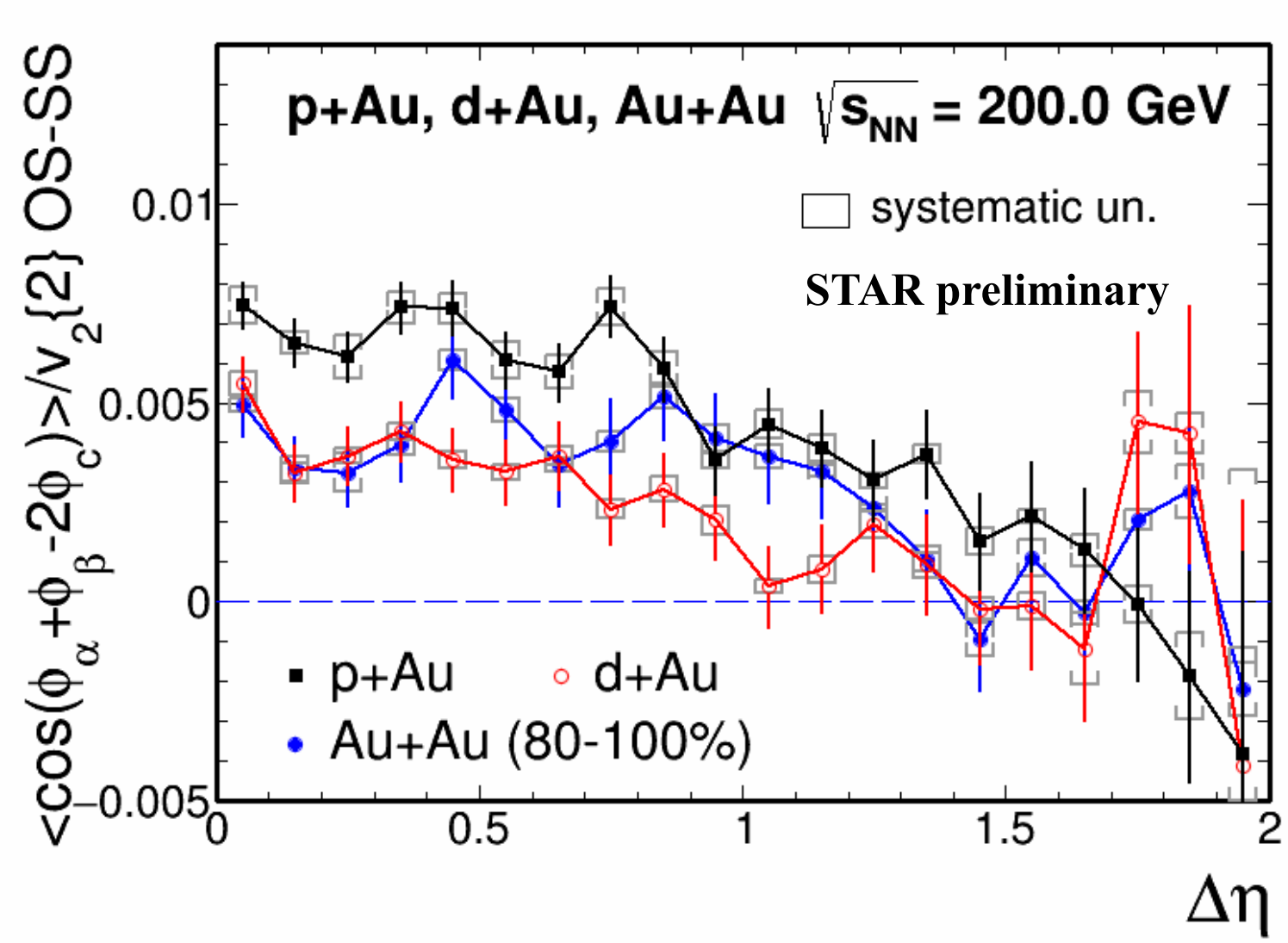
Results with respect to Ψ_2





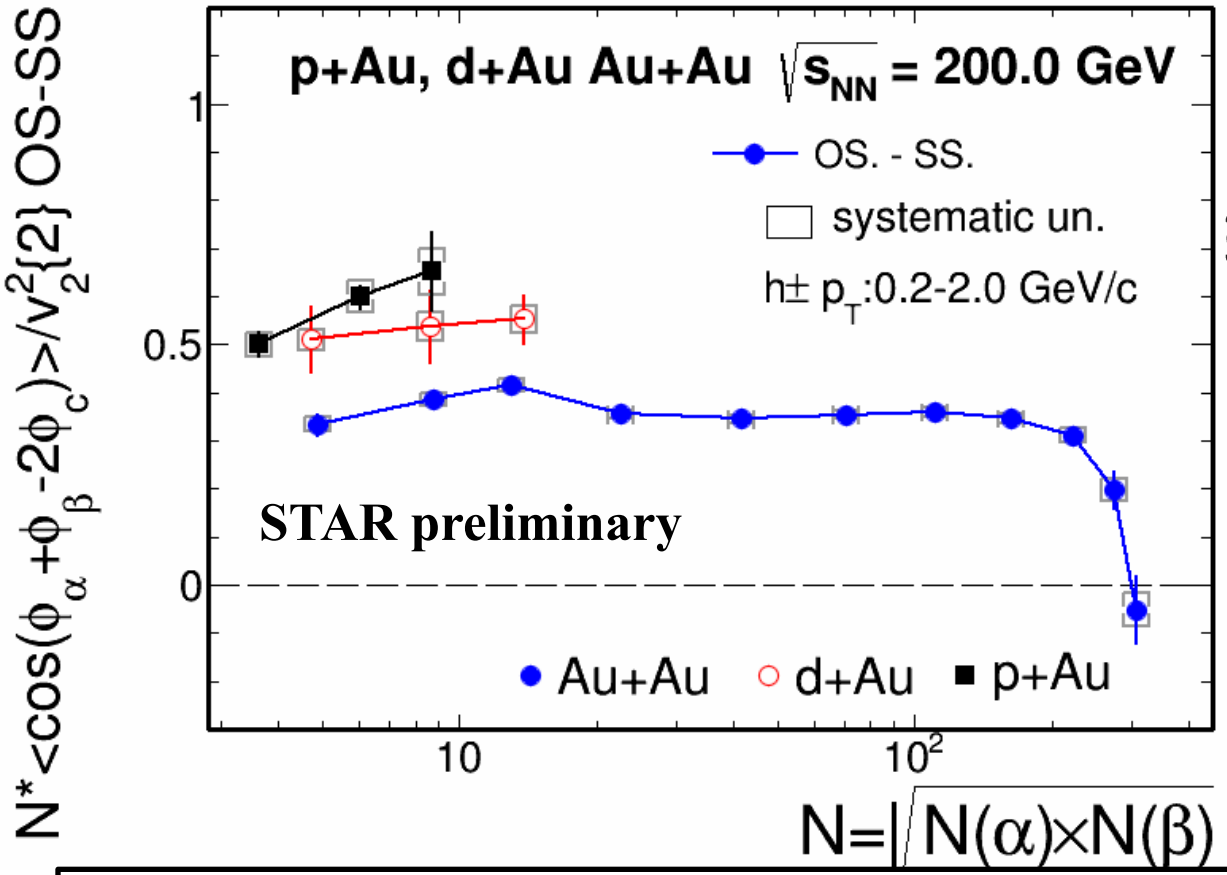
- Sizeable charge dependent signal in small system p+Au and d+Au collisions with respect to second order eventplane Ψ_2
- $v_2\{2\}$ with eta gap of 1.0

Results with respect to Ψ_2

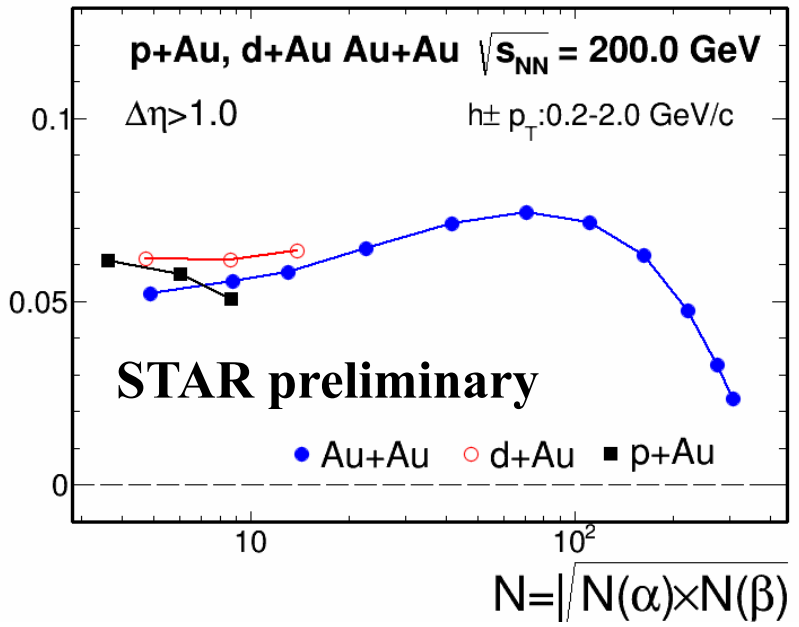


- Correlator as function of the eta gap between the two charged particles in p+Au, d+Au and peripheral Au+Au collisions

Results with respect to Ψ_2

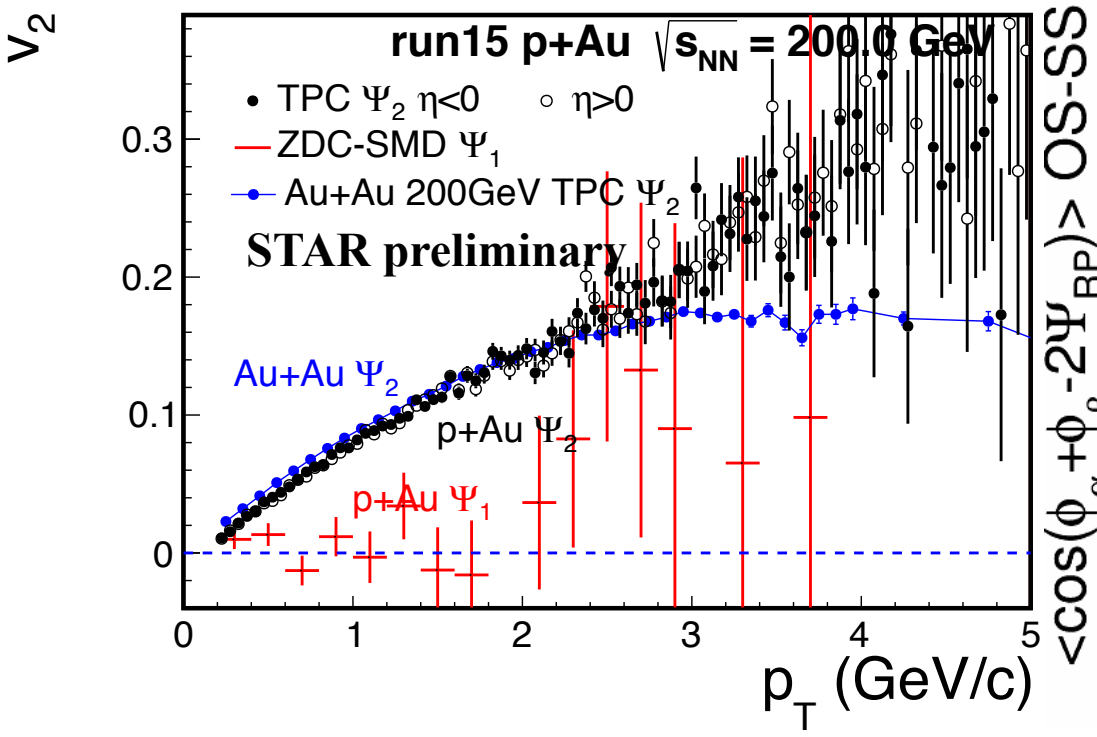


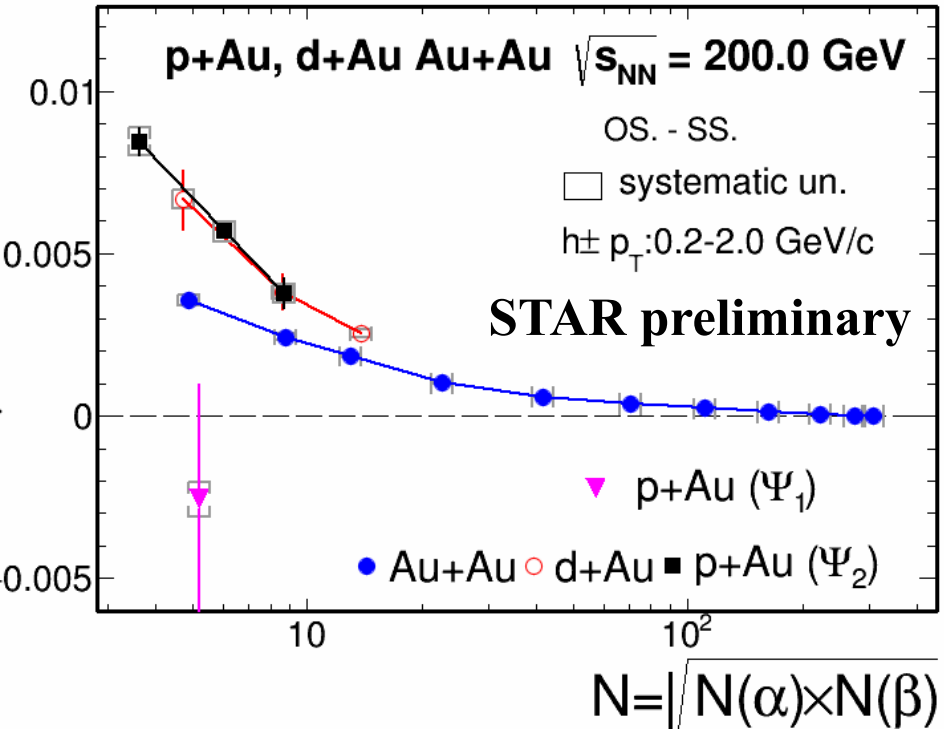
$v_2\{2\}$ with eta gap of 1.0



- background expectation: N dilution, proportional to flow $v_2\{2\}$
- Left plot: if intrinsic particle pair-wise correlation is independent of N, background scenario would yield a constant for the coordinate variable
- With topological charge sign fluctuations and magnetic field direction fluctuations, CME might yield different multiplicity dependence

Results in p+Au with Ψ_1





- With respect to ZDC-smd Ψ_1, within present large uncertainty in p+Au collisions the charge dependent signal is consistent with zero

Summary

- In small systems, anisotropy-related background and possible CME signal may be decoupled
- With respect to Ψ_2: p+Au and d+Au charge-dependent correlations are background. Peripheral Au+Au data are comparable to that of p+Au and d+Au. The scaled correlators from peripheral to mid-central Au+Au collisions are consistent with background scenario
- With respect to Ψ_1: charge dependent signal in p+Au and d+Au is free of anisotropic background. Within the present large uncertainty the signal is consistent with zero