Status of Chiral Magnetic Wave Studies

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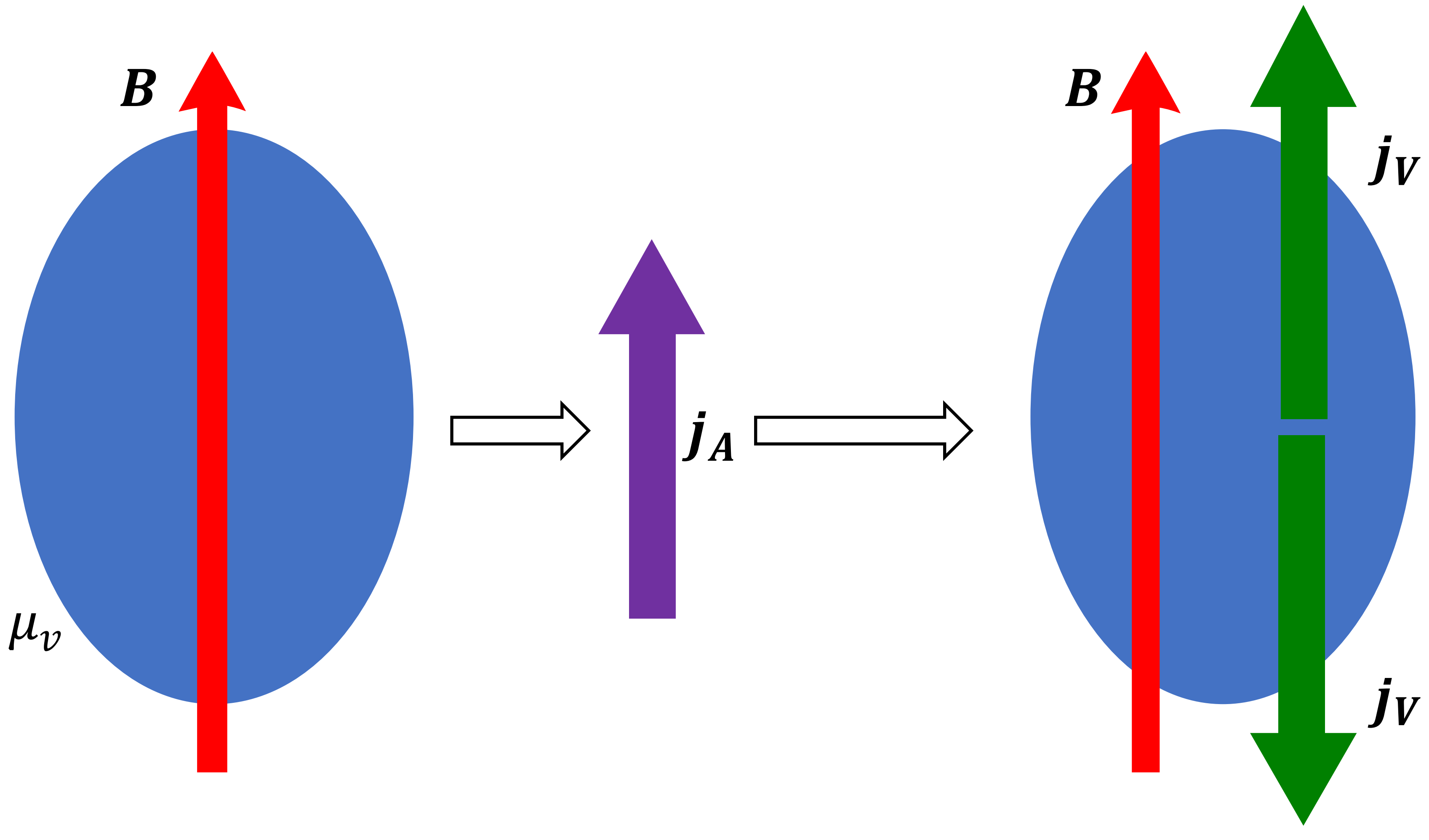
Chiral Magnetic Wave(CMW) and Observables



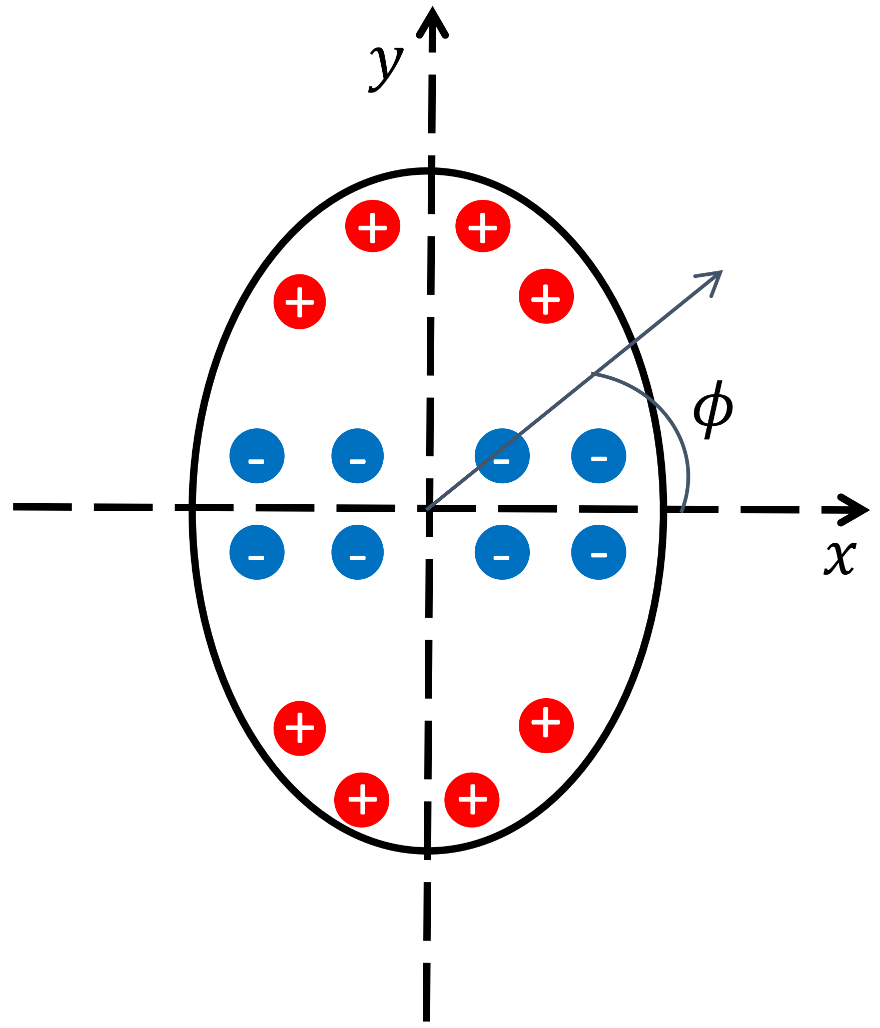
CSE

$$\boldsymbol{j_A} = \frac{N_c e}{2\pi^2}\mu_V \boldsymbol{B}$$

CME

$$\boldsymbol{j_V} = \frac{N_c e}{2\pi^2}\mu_A \boldsymbol{B}$$

Kharzeev, D. E. & Yee, H.-U. PRD 83, 085007 (2011).



Obv. I: Slope r of A_{ch} and Δv_2

$$\Delta v_2 = v_2^- - v_2^+ \approx r A_{ch}$$

Obv. II: 3-particle correlation(Covariance)

Integral Form $\langle v_n^{\pm} A_{ch} \rangle - \langle A_{ch} \rangle \langle v_n \rangle$

Differential Form $\langle v_n^{\pm} q_3 \rangle - \langle q_3 \rangle_1 \langle v_n \rangle$

Voloshin, S. A. & Belmont, NPA 931, 992–996 (2014).

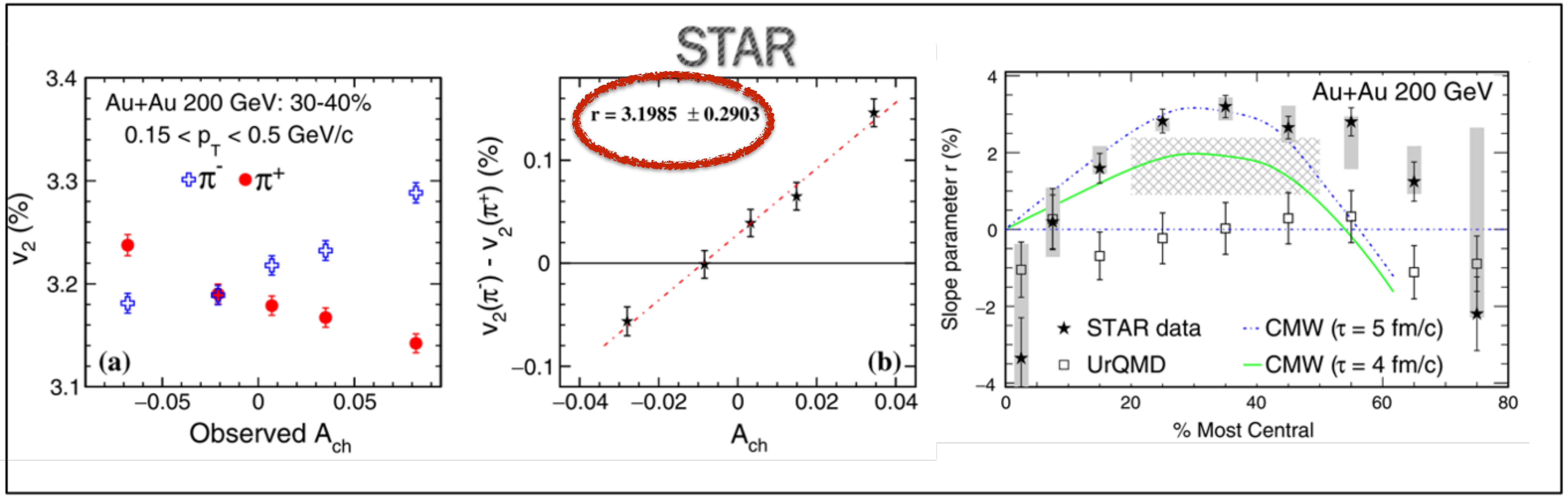
$$A_{ch} = < N^+ - N^- > / < N^+ + N^- >$$

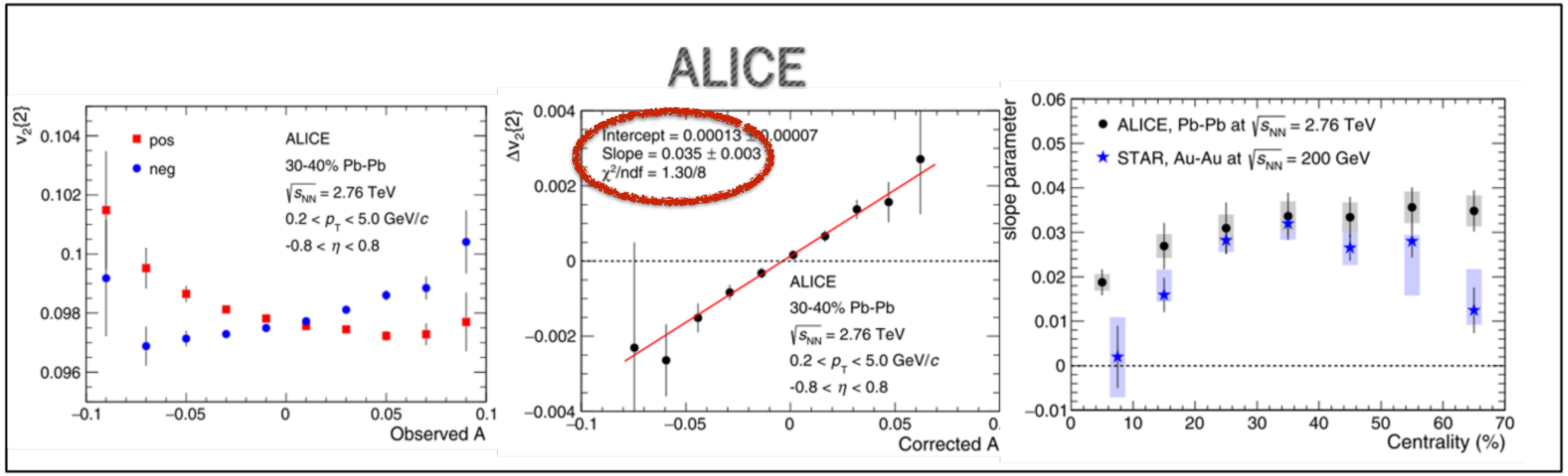
Charge asymmetry

- Chiral Separation Effect and Chiral Magnetic Effect are coupled to produce Chiral Magnetic Wave;
- CMW causes an electric quadrupole along the reaction plane—Charge-dependent elliptic flow.

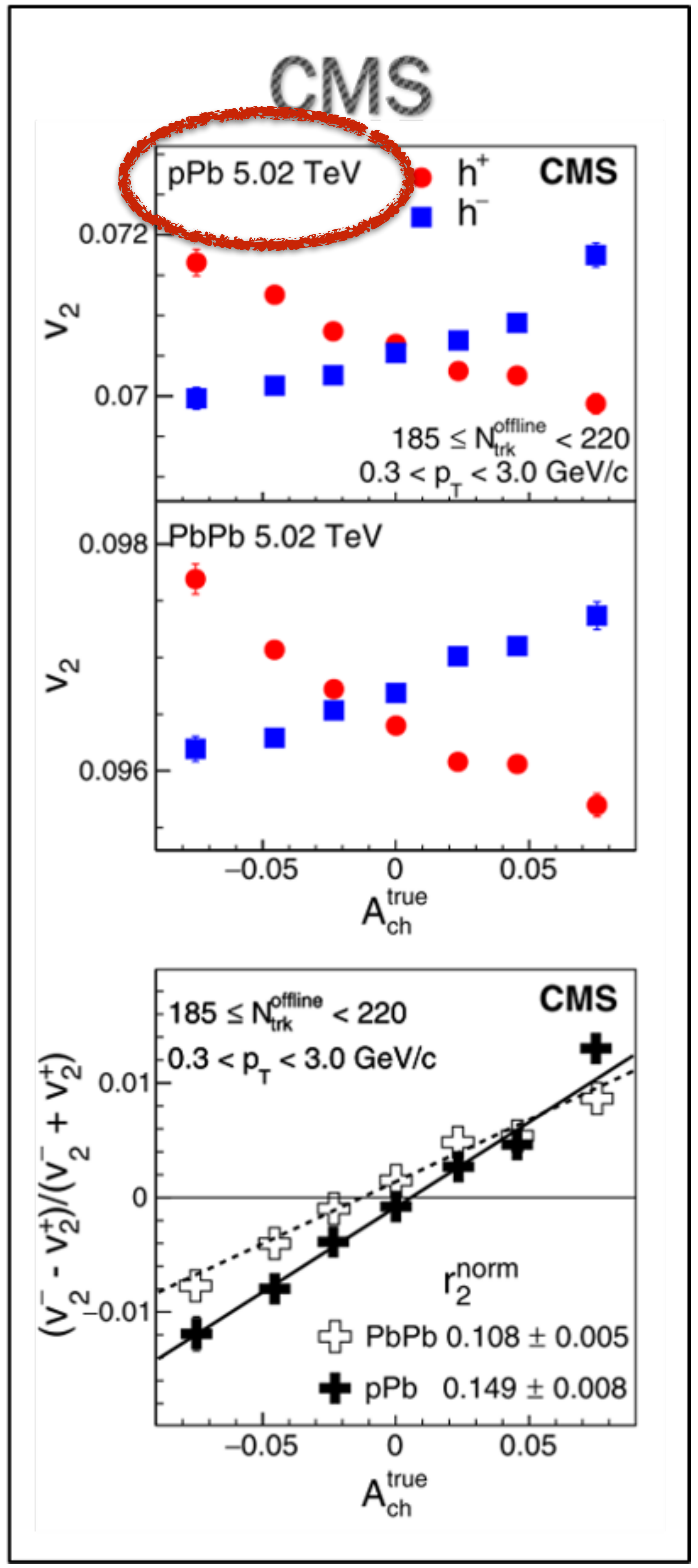
Experimental Result

STAR Collaboration, PRL 114, 252302 (2015).





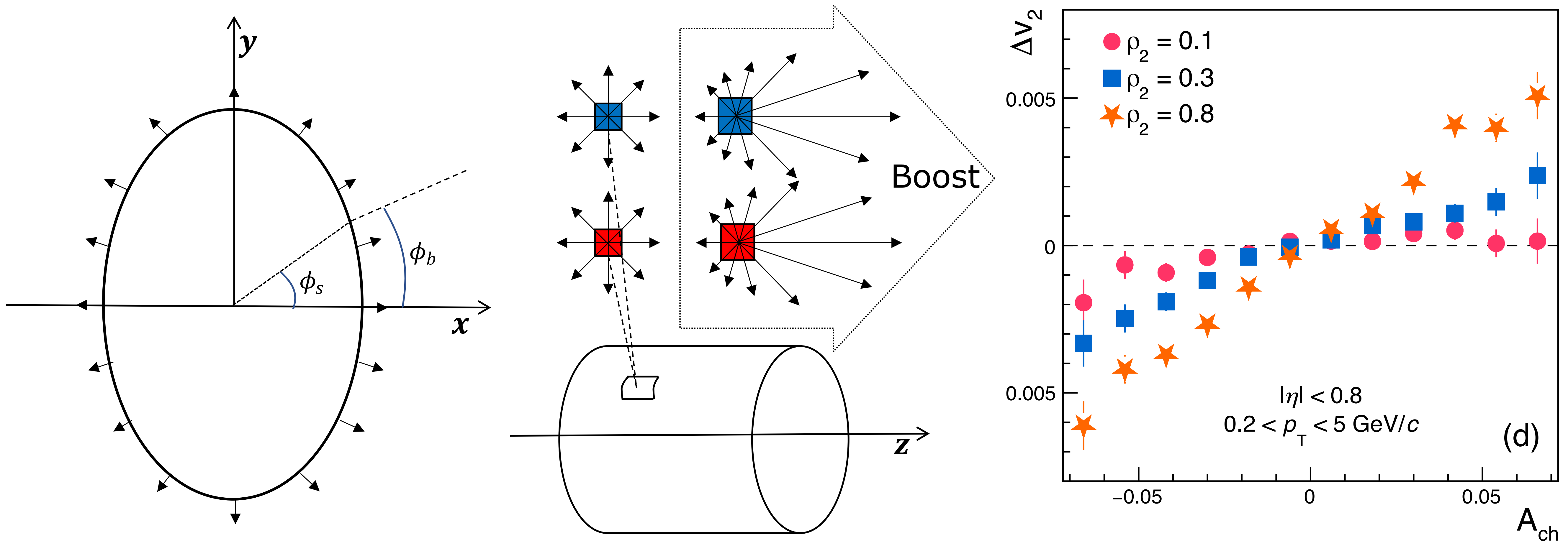
ALICE Collaboration PRC 93, 044903 (2016).



CMS Collaboration PRC 100, 064908 (2019).

Local Charge Conservation(LCC)

Build a model that only includes the LCC effect

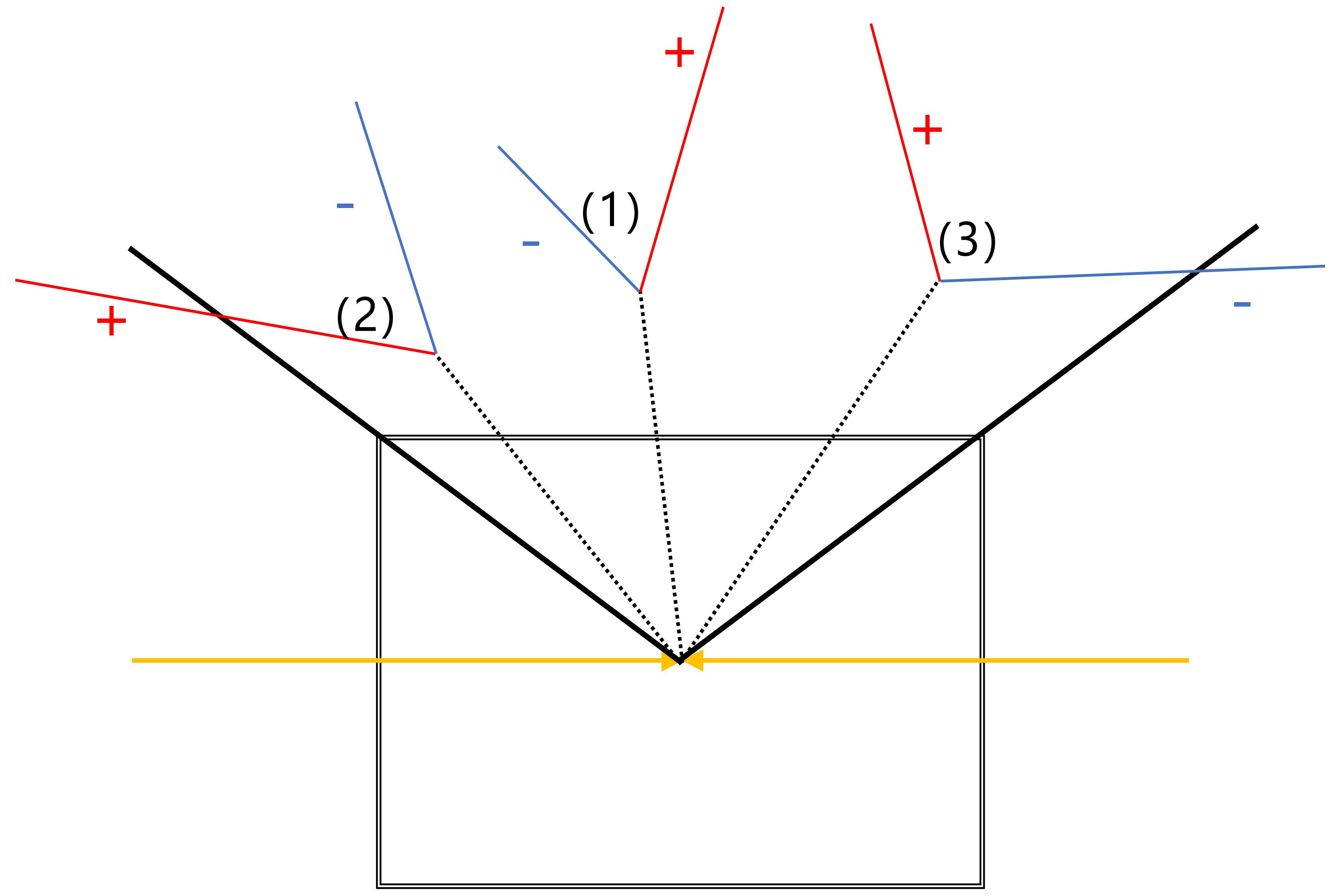


CZ.Wang et al. PLB 820, 136580 (2021).

Blast Wave + Pair Production

- The BW Model can describes the collective flow.
- The particles with positive and negative charges are emitted at the same position, and their kinematics is related by the four-speed boost of the emission point;
- Only includes the LCC. No CMW at all.

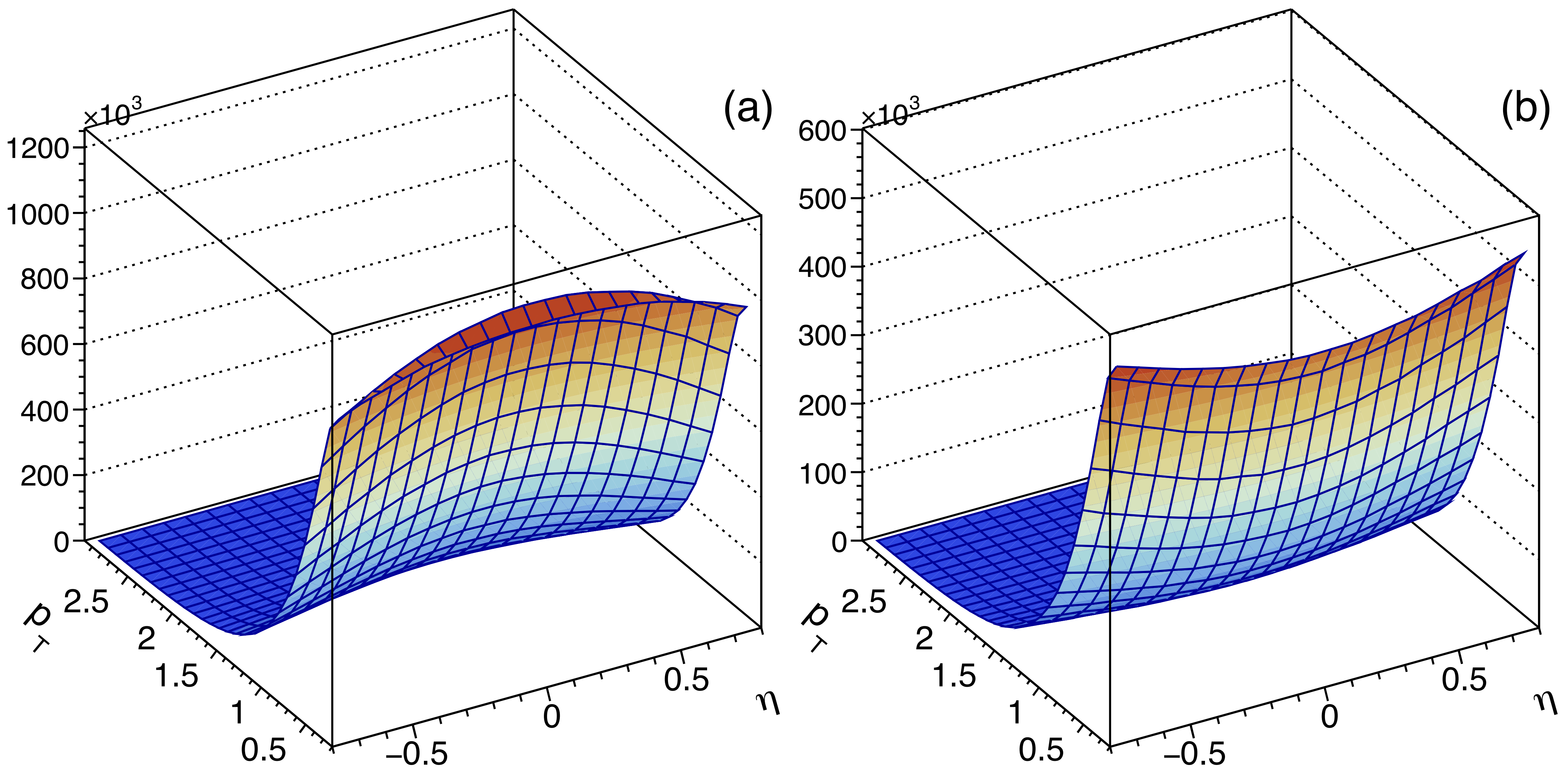
Detector acceptance limit



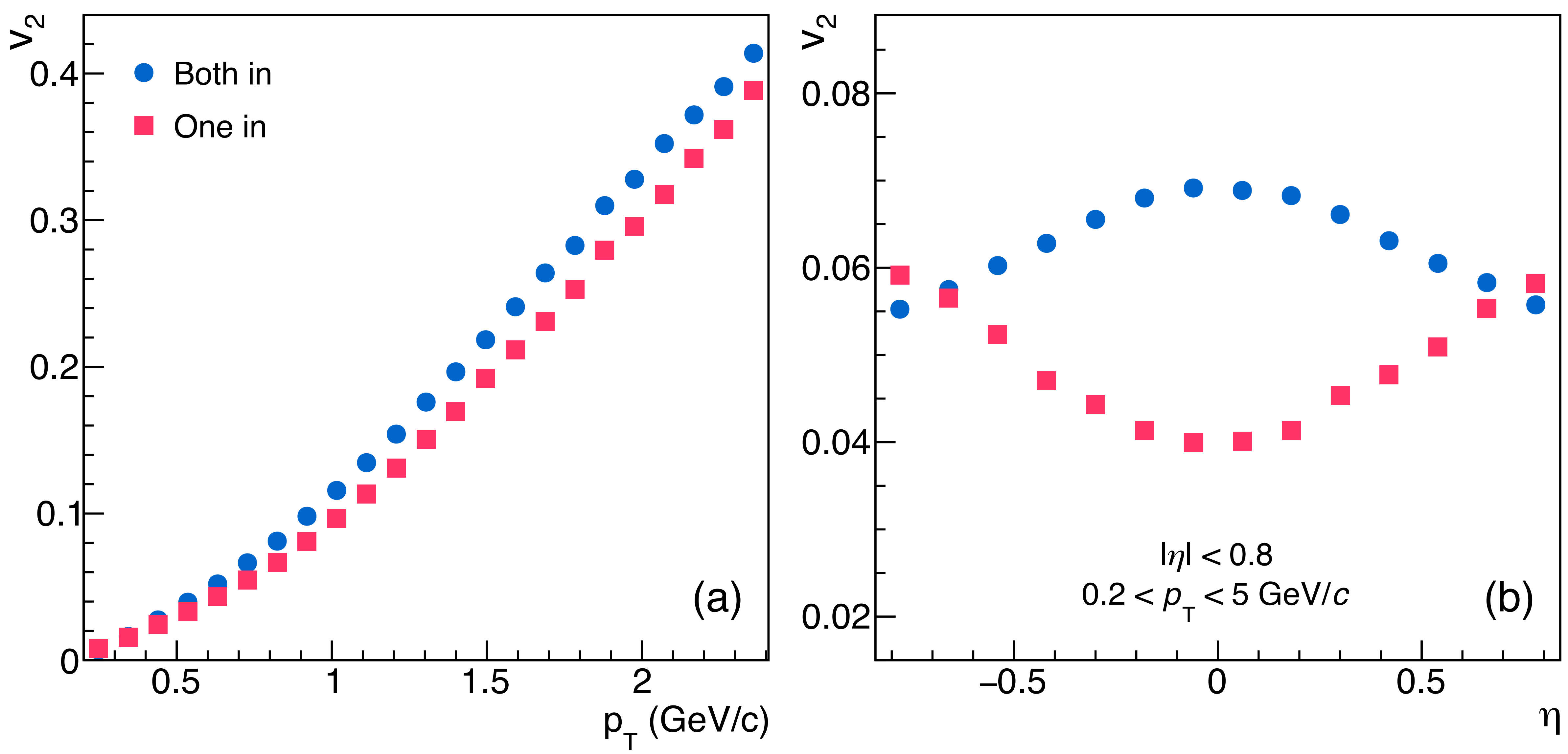
A. **Both in(2,3)：** Both pos & neg particles from the zero-charge local area are received;

B. **One in(1)：** Only one type of particle from the area is within the acceptance.

Local Charge Conservation(LCC)



Case(a)/(b) $p_T - \eta$ Joint distribution



Case (a)/(b) v_2 *vs.* $p_T - \eta$

Different acceptance of particles of Case(a)/(b)

- Same trend p_T, opposite trend η;
- $v_2^{Bothin} > v_2^{Onein}$.

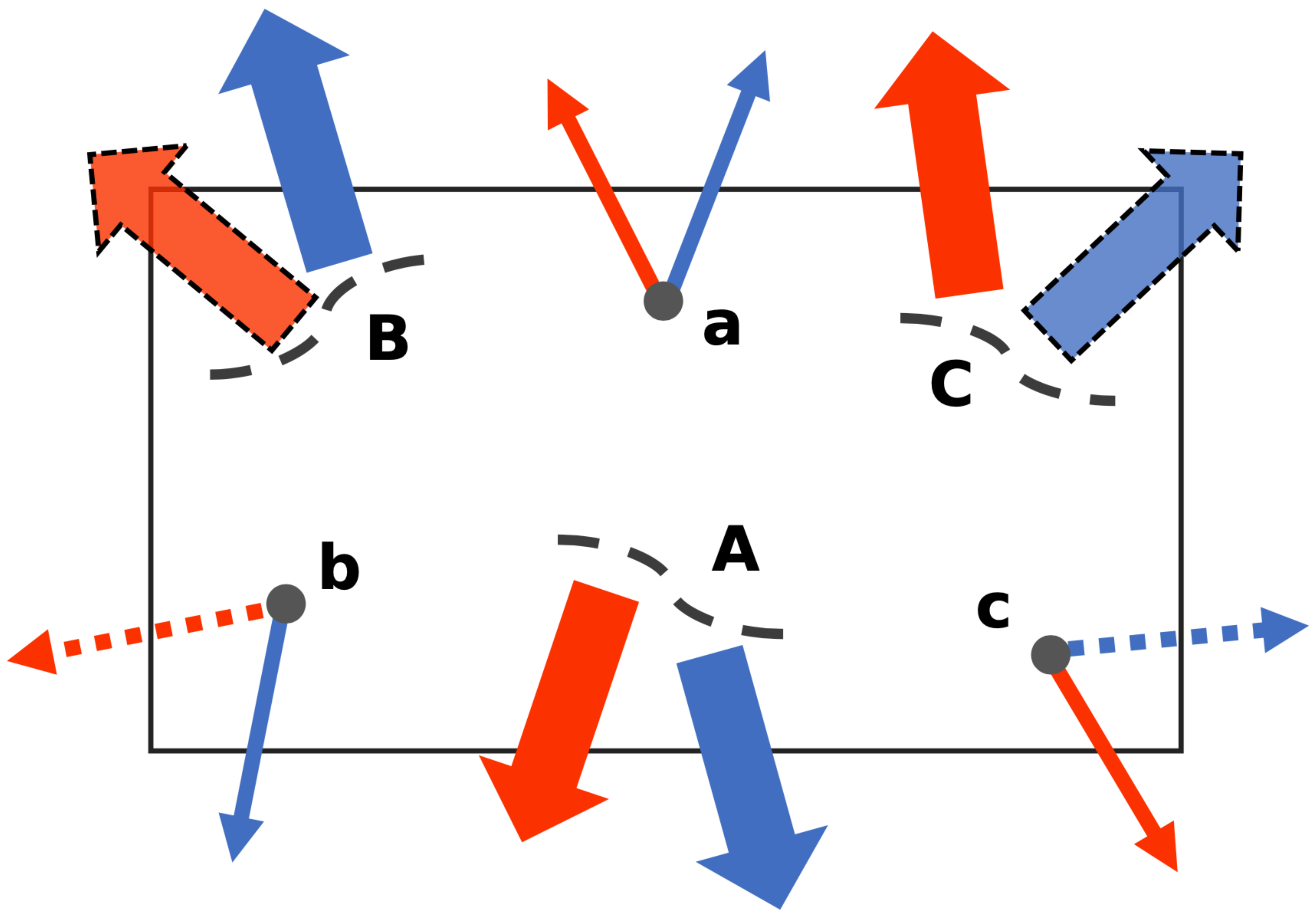
More "One in" positive particles

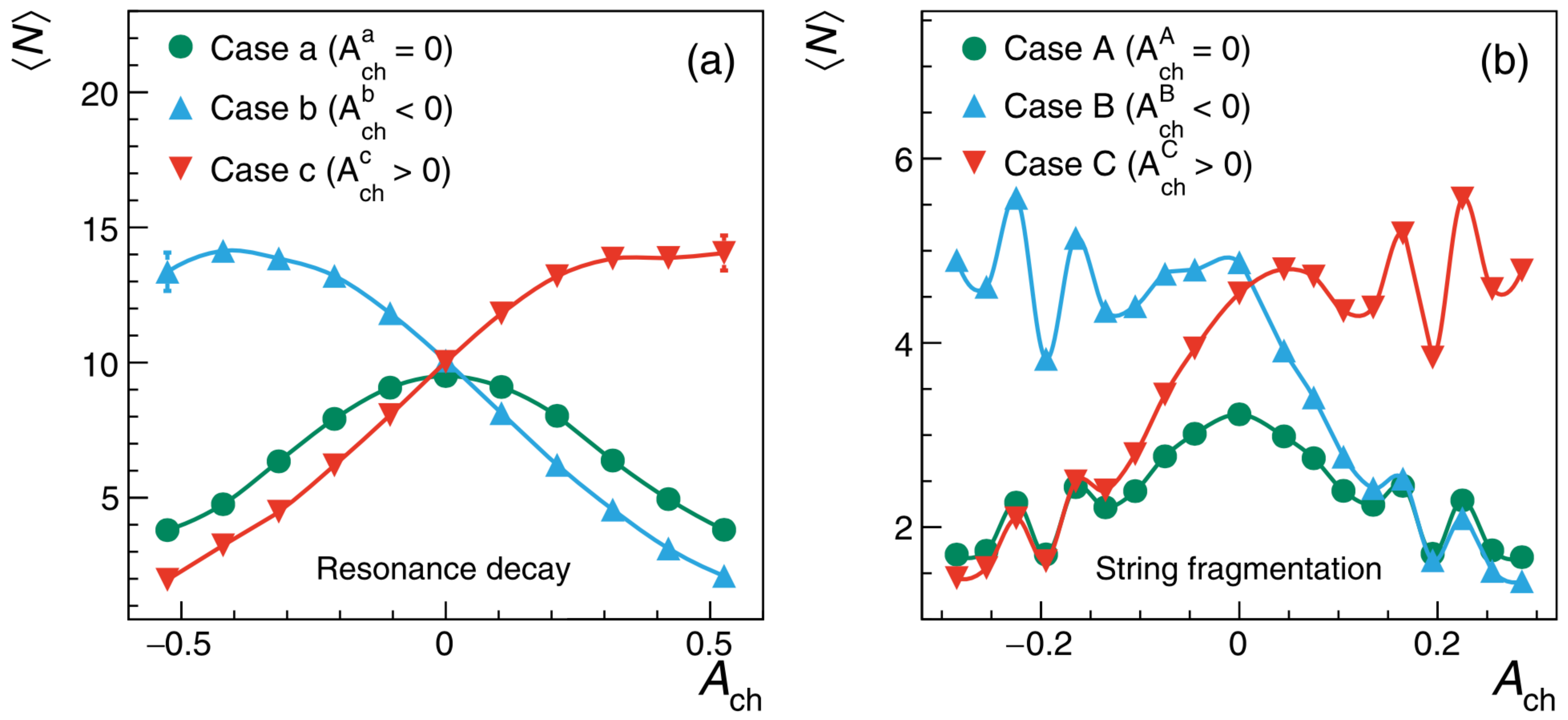
$A_{ch} > 0 : v_2^{onein} < v_2^{+} < v_2^{-} < v_2^{bothin}$

More "One in" negetive particles

$A_{ch} < 0 : v_2^{onein} < v_2^{-} < v_2^{+} < v_2^{bothin}$

Two Sources of LCC

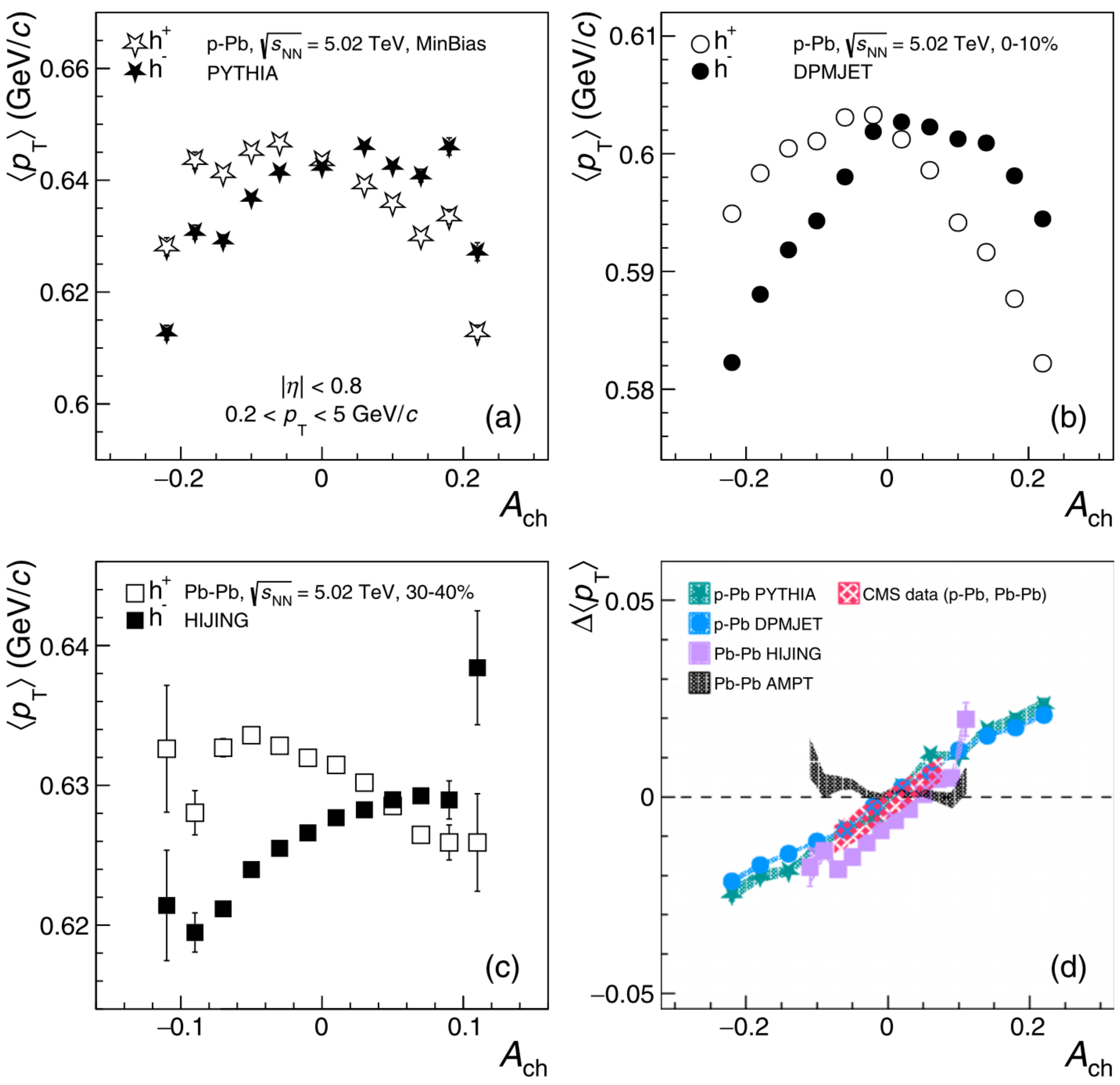


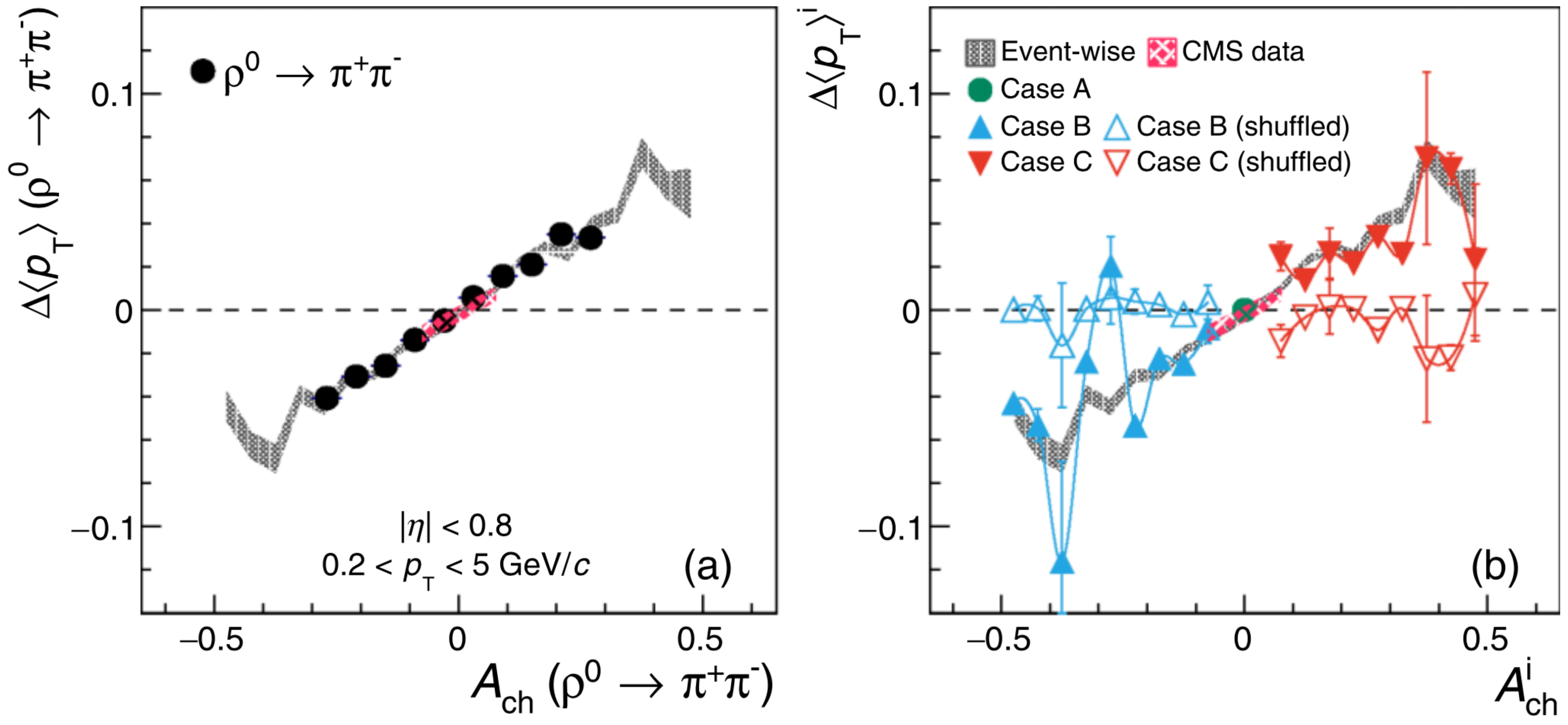


WY Wu et al. PRC 103, 034906 (2021).

- **Resonance decay(a, b, c):** Daughter Particles are emitted at the same space-time position;
- **String fragmentation (A, B, C):** Particles come from both ends of the string.

Study LCC by charge-dependent transverse momentum





Linear dependence $\Delta\langle p_T \rangle - A_{ch}$. Positive slope r.

r from string fragmentation model and resonance decay are close to the results of CMS.

Event Shape Engineering(ESE)

$$Q_{n,x} = \sum_{i}^{M} \cos\left(n\phi_i\right),$$

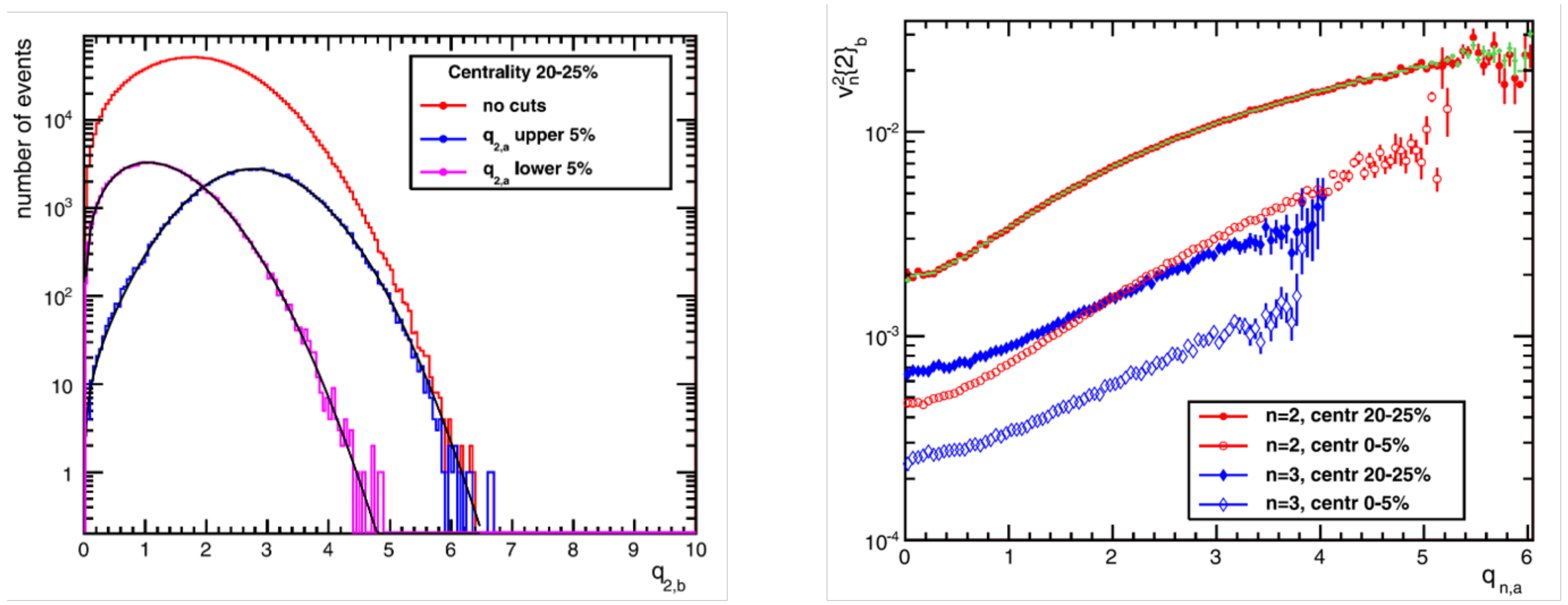
$$Q_{n,y} = \sum_{i}^{M} \sin\left(n\phi_i\right)$$

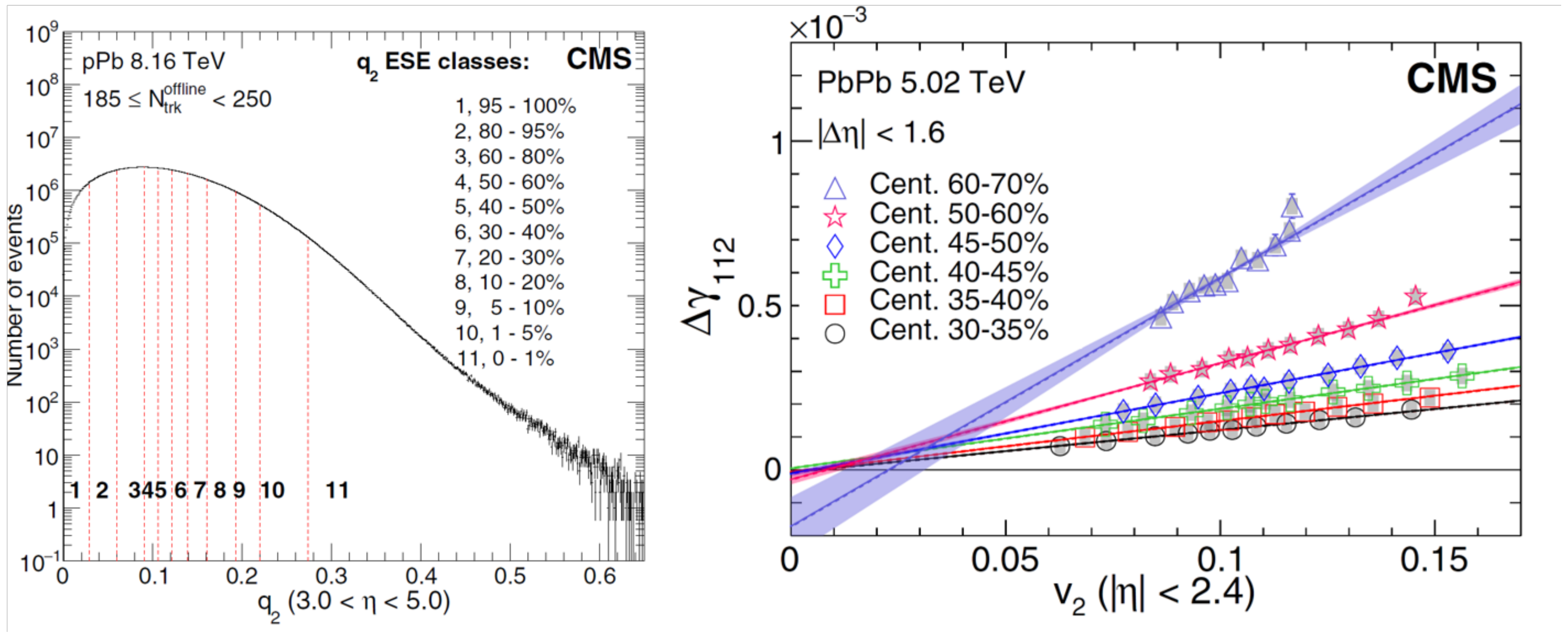
$$q_n = Q_n/\sqrt{M}$$

q_2 has the following relationship with v_2

$$\left\langle q_2^2 \right\rangle \simeq 1 + \langle (M-1) \rangle \left\langle \left(v_2^2 + \delta_2 \right) \right\rangle$$

J.Schukraft et al. PLB 719, 394–398 (2013).

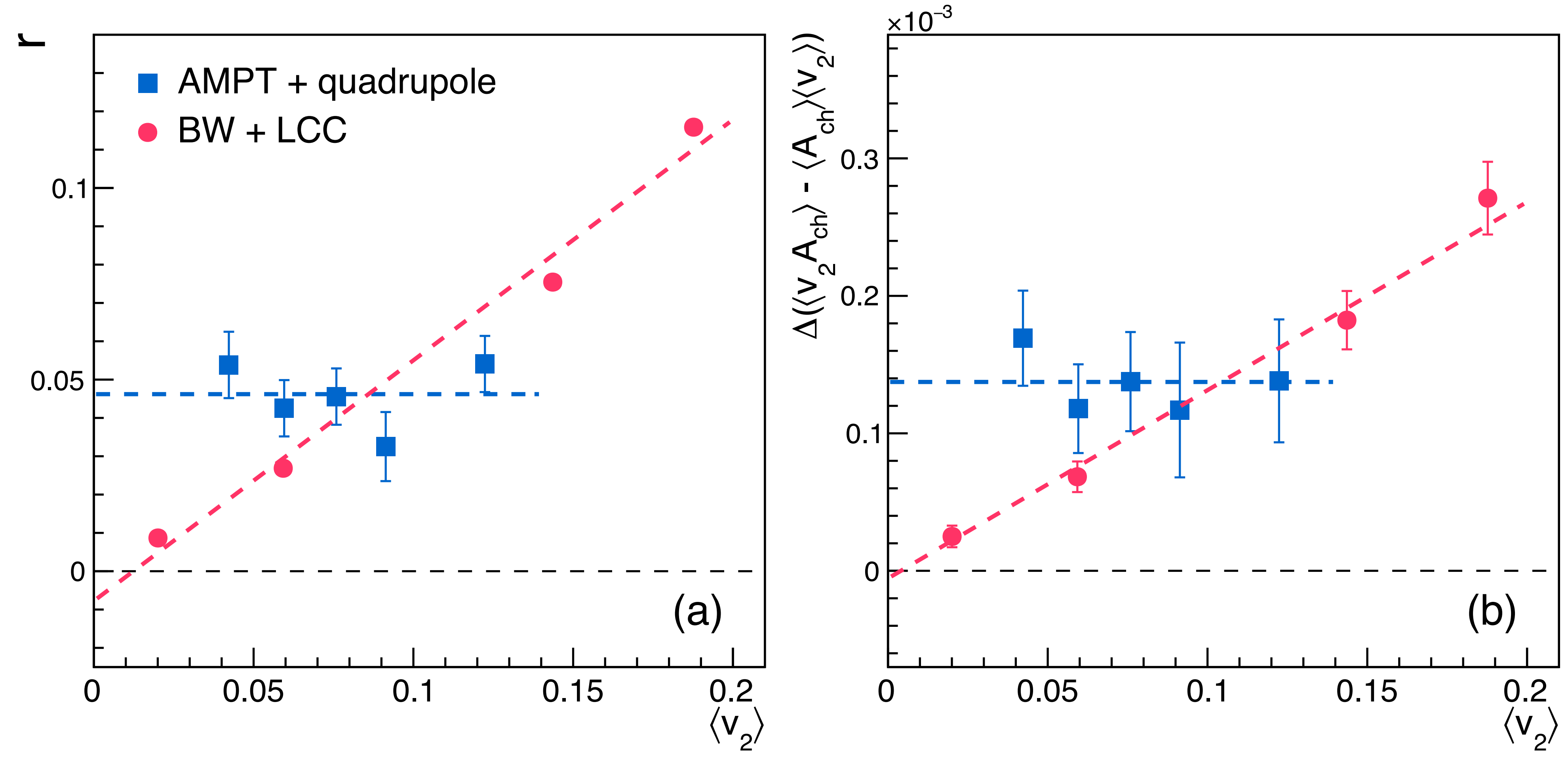




ESE in the study of CME

Select events via q_2: Events in the **neighborhood of q_2** have the same initial collision geometry.

Constraining the CMW with ESE



CMW-only events generated by AMPT
LCC-only events generated by BW

	CMW	LCC
r vs .v2	Independent	Proportional
cov vs.v2	Independent	Proportional

Leading a method which can extract the fraction of CMW in the experiment.

Analysis Process

Use ESE method to get events with different v_2

↓

Calculate $r\ \langle v_2^{\pm} A_{ch}\rangle - \langle A_{ch}\rangle\langle v_2\rangle$ in different q_n bins

↓

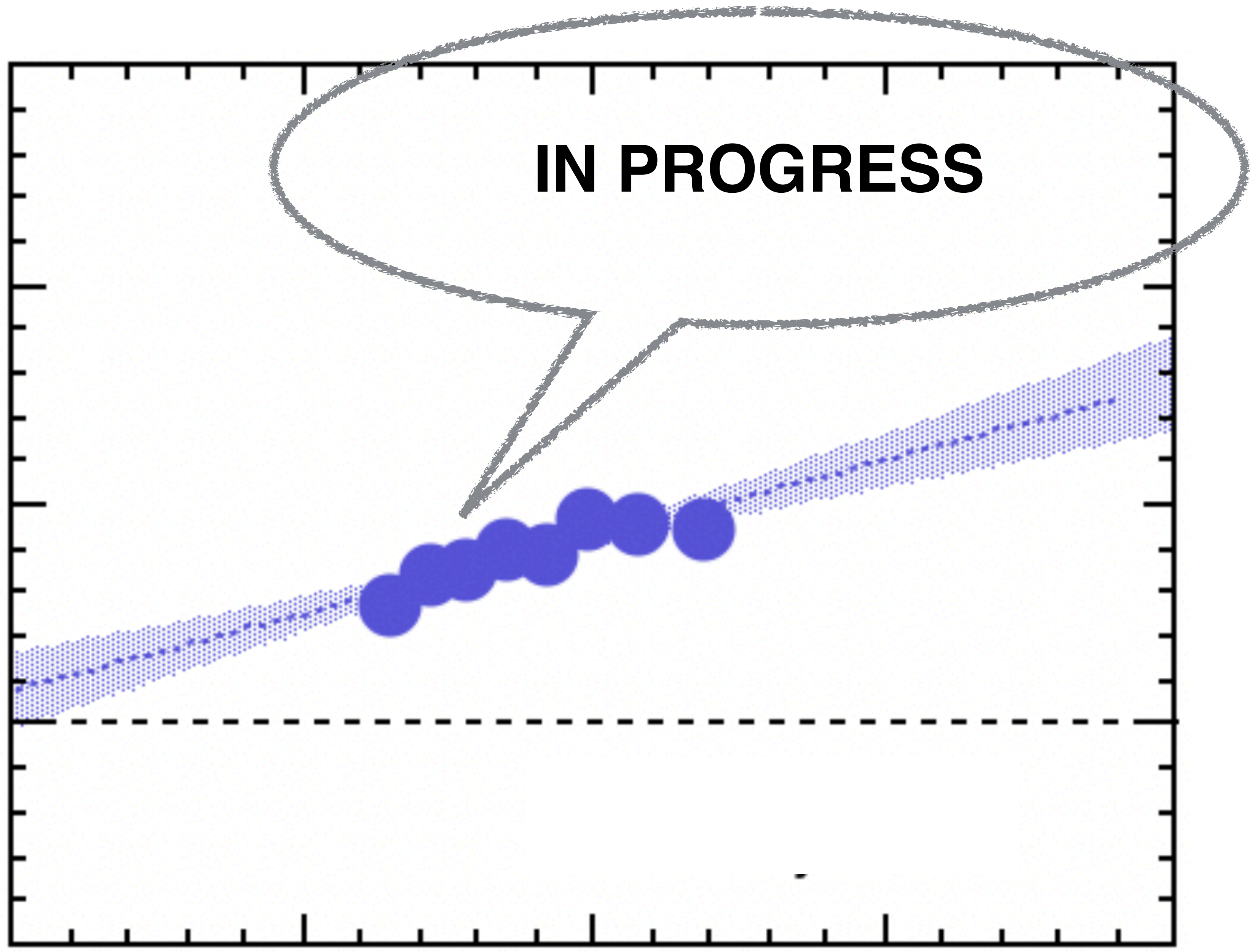
Linear fit $v_2 - r$ or $v_2 - \langle v_n^{\pm} A_{ch}\rangle - \langle A_{ch}\rangle\langle v_n\rangle$

↓

Extract the fraction of CMW $f_{\mathrm{CMW}} = \dfrac{b}{a\langle v_2\rangle + b}$

a and b are the slope and intercept of the fitting,
$\langle v_2\rangle$ is the elliptic flow in a event

Searching for CMW by ESE in the ALICE Experiment



- ALICE data analysis by ESE is in progress;

Summary

- Two observables for CMW — the slope r and the covariance of v_2 and A_{ch}.
- LCC is the main background of CMW. The non-uniform cutting of the particle kinematics by the limited acceptance of the detector leads to the LCC contribute to the observables.
- LCC can be studied by charge-dependent transverse momentum. The LCC process—String fragmentation and resonance decay contribute comparable $\Delta\langle p_T\rangle - A_{ch}$ to the Experiment.
- The ESE method can constrain the CMW measurement results and give the fraction of CMW.

Thanks for your attention

Back Up

Models in CMW research（For Experimenters）

Model	Feature or Imitation
PYTHIA, DPMJET, HIJING, …	Flow ×, LCC √, CMW x
AMPT	Flow √, LCC ×, CMW √
Blast Wave	Flow √, LCC √, CMW x