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Sensitivity analysis of the chiral magnetic effect observables using the AMPT

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Based on arXiv: 1906.11631

Outline

- **Background & Motivation**
- **Method**
- **Preliminary Results**
- **Summary & Discussion**

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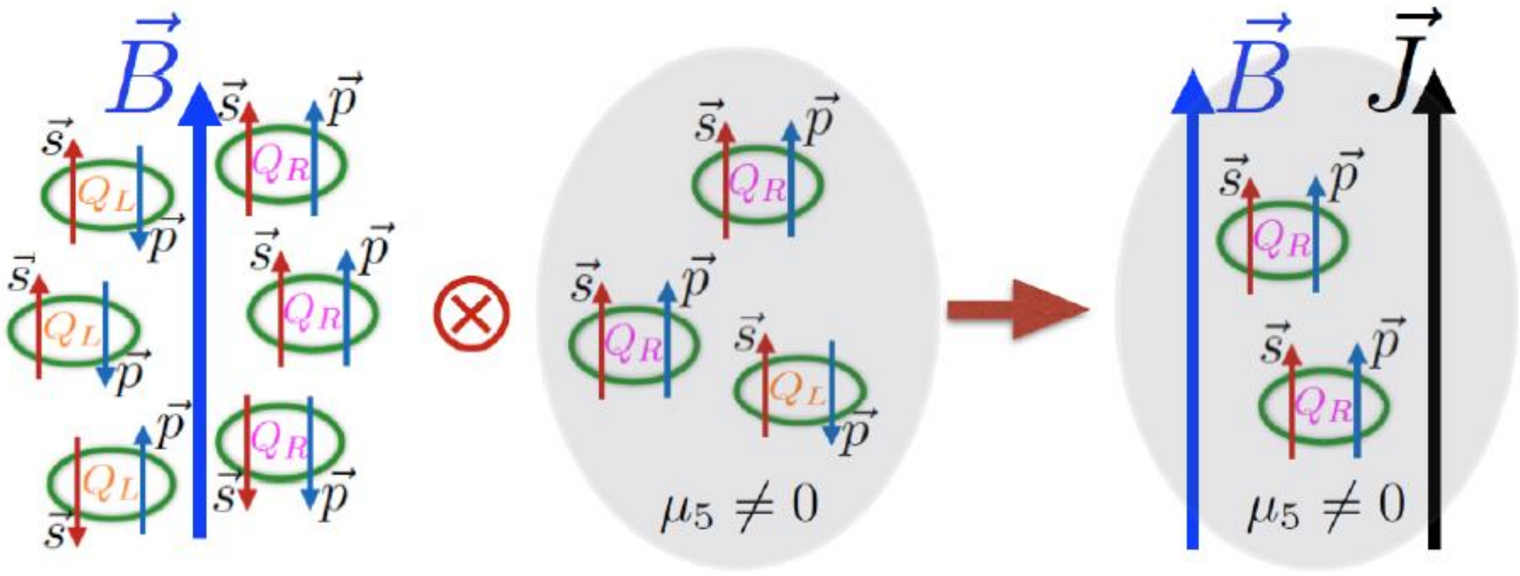
Chiral magnetic effect(CME)

D. E. Kharzeev, J.Liao, S. A.Voloshin, et. al.
Prog. Part. Nucl. Phys. 88 (2016)



CME: (Extremely large magnetic field) and (P or CP odd metastable domains)
➔ Charge current/separation in the direction of magnetic field

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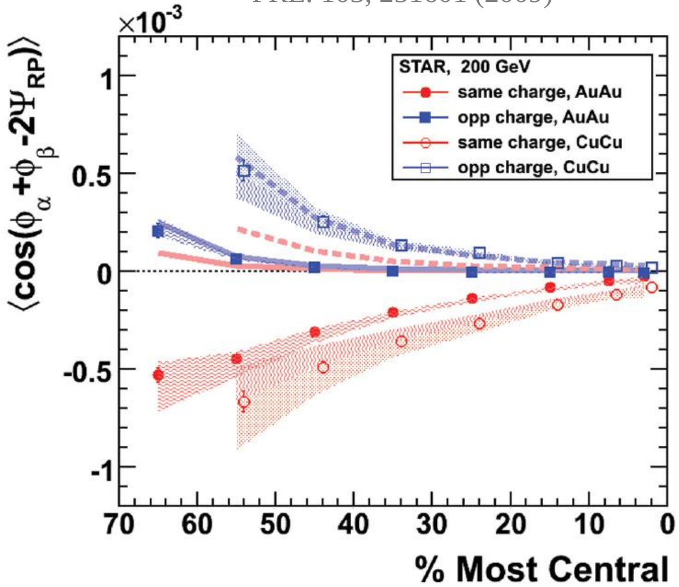
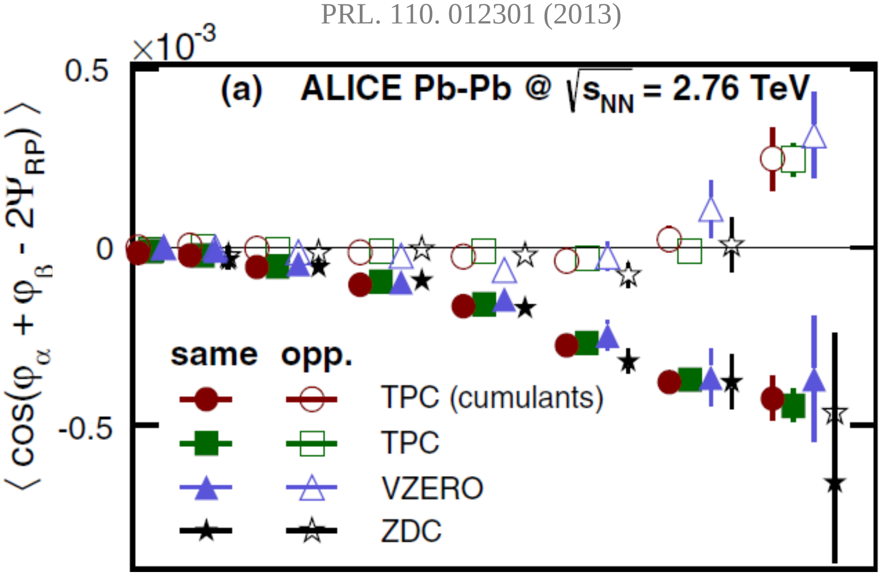
Background

B. I. Abelev et al. [STAR Collaboration], PRL. 103, 251601 (2009)



B. Abelev et al. [ALICE Collaboration], PRL. 110. 012301 (2013)



$$\gamma = \langle \cos(\phi_\alpha + \phi_\beta - 2\psi_{RP}) \rangle$$
$$= \langle \cos(\Delta\phi_\alpha)\cos(\Delta\phi_\beta) - \sin(\Delta\phi_\alpha)\sin(\Delta\phi_\beta) \rangle$$

ϕ_α / ϕ_β: "+" or "−" particles

ψ_{RP}: reaction plane

$\Delta\phi = \phi - \psi_{RP}$

- γ correlator not only includes CME-induced charge separation, but also background induced charge separation.

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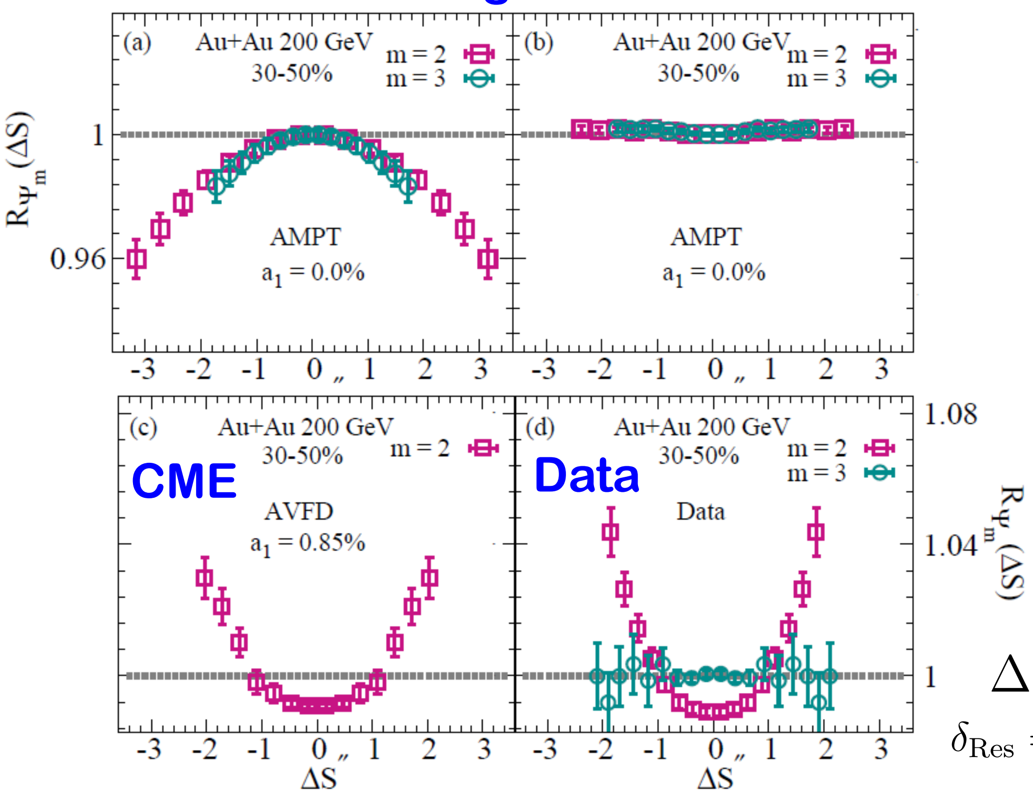
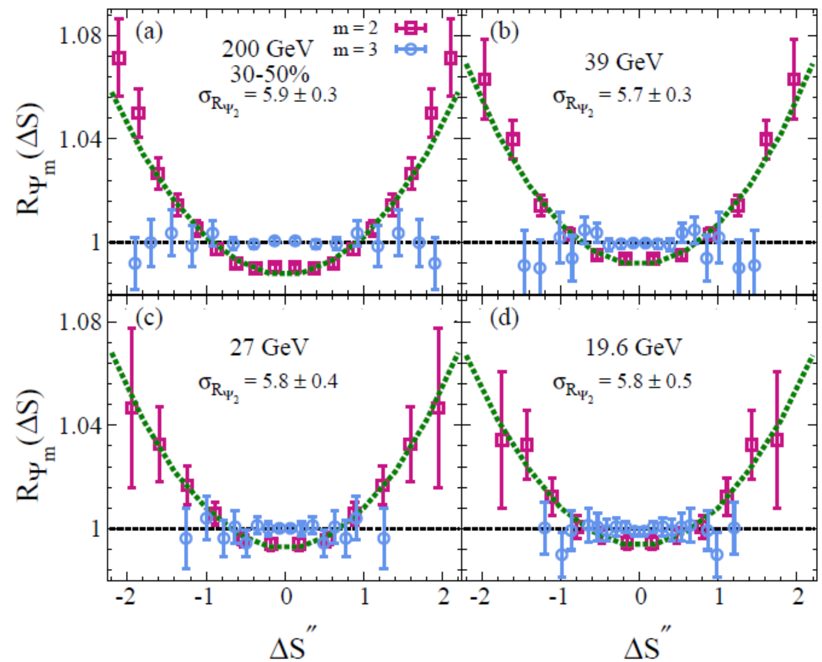
Background

N. Magdy et. al. PRC 97,061901 (2018)

Background





$$\Delta S'' = \Delta S' \times \delta_{\mathrm{Res}}, \quad \Delta S' = \Delta S / \sigma_{\Delta_{\mathrm{Sh}}},$$

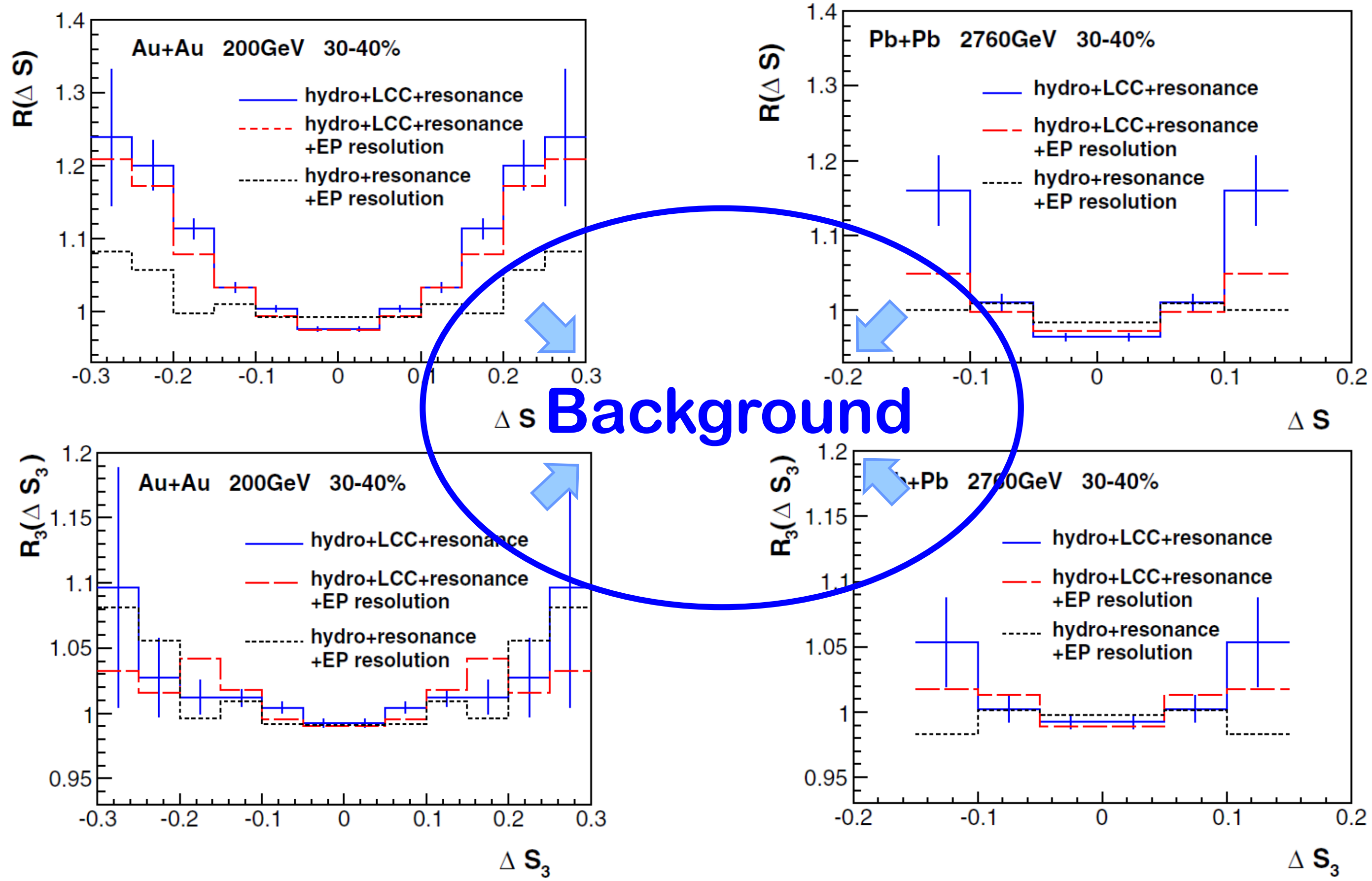
$$\delta_{\mathrm{Res}} = \sigma_{\mathrm{Res}} \times e^{(1-\sigma_{\mathrm{Res}})^2}, \quad \sigma_{\mathrm{Res}} = \langle \cos [n(\Psi_n - \Psi_{\mathrm{RP}})] \rangle .$$

- Results from the AMPT model and AVFD model show that R_{Ψ_2} is convex without CME, but concave with the CME.

$R_{\Psi 2}$: concave
$R_{\Psi 3}$: flat

Background

Piotr Bożek. PRC 97, 034907 (2018).



- Results from the hydrodynamic model with different background sources show that R_{Ψ_2} and R_{Ψ_3} are both concave no matter with or without the CME.

Method-Mix

$C_c(\Delta S)$ correlator:

$$C_c(\Delta S) = \frac{N(\Delta S_{\mathrm{csep}})}{N(\Delta S_{\mathrm{csmix}})}$$

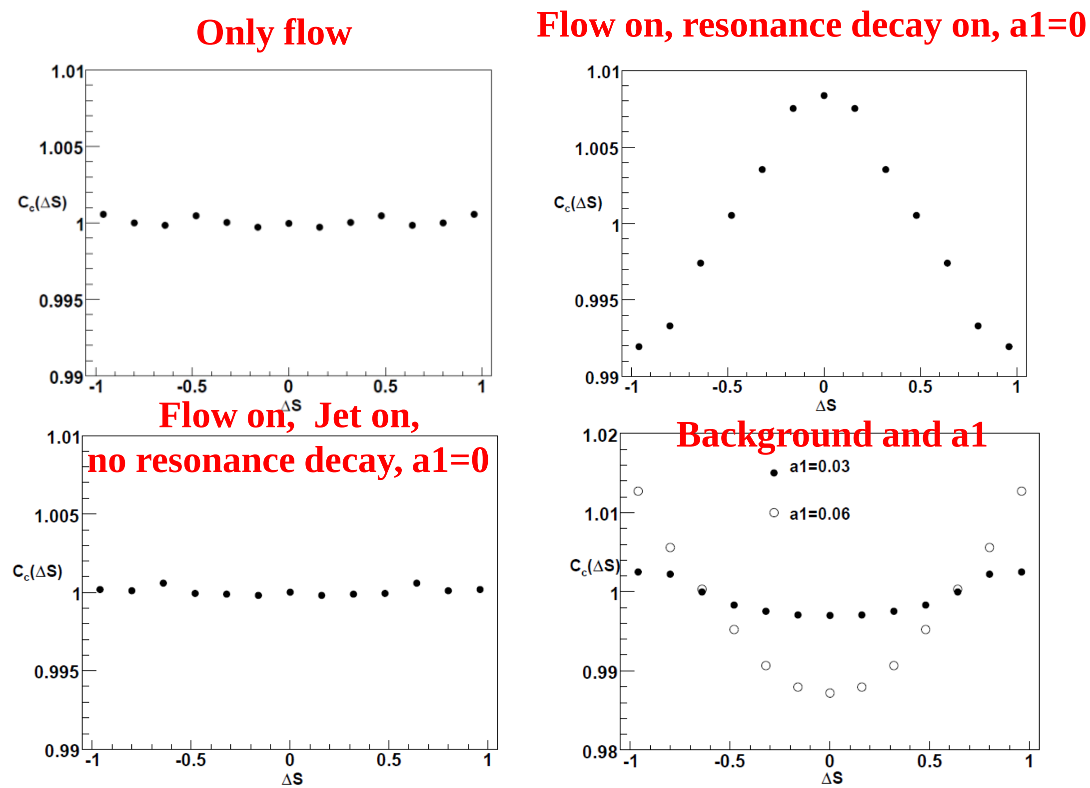
randomly chosen hadrons

$$\Delta S_{csep} = \langle S_p^{h+} \rangle - \langle S_n^{h-} \rangle$$

$$\langle S_p^{h+} \rangle = \frac{\sum_1^p \sin(\Delta\varphi_+)}{p},$$

$$\langle S_n^{h-} \rangle = \frac{\sum_1^n \sin(\Delta\varphi_-)}{n}.$$

p/n: number of "+/-" hadrons



N. N. Ajitanand. et. al, PRC 83, 011901 (2011)

- If there is some amount of CME, the distribution of $N(\Delta S)$ would be wider than that from only background. So the radio $C(\Delta S)$ would be concave.

Method-Shuffle

$R_{\Psi_m}(\Delta S)$ correlator:

$$R_{\Psi_m}(\Delta S) = \frac{C_{\Psi_m}(\Delta S)}{C^{\perp}_{\Psi_m}(\Delta S)}$$

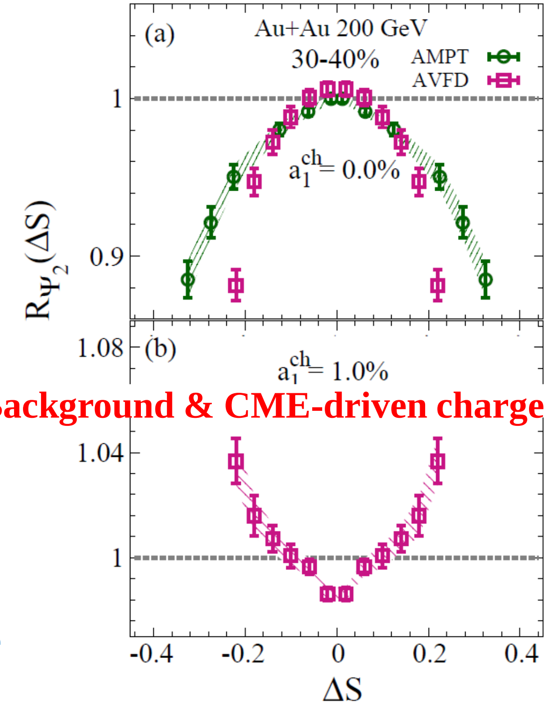
m=2, 3

$$C_{\Psi_m}(\Delta S) = \frac{N_{\text{real}}(\Delta S)}{N_{\text{shuffled}}(\Delta S)}$$

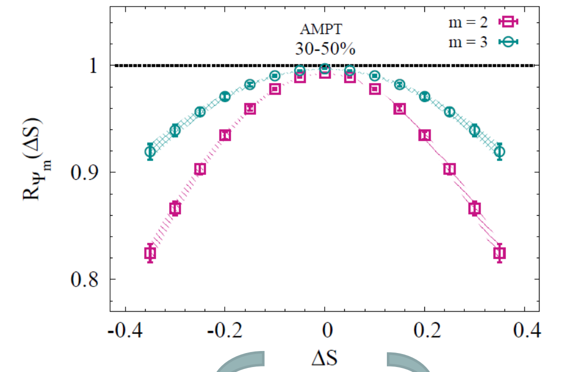
Only the charge of the positive/negative charged particles

Background-driven charge separation

N. Magdy, et. al. PRC 97, 061901 (2018)



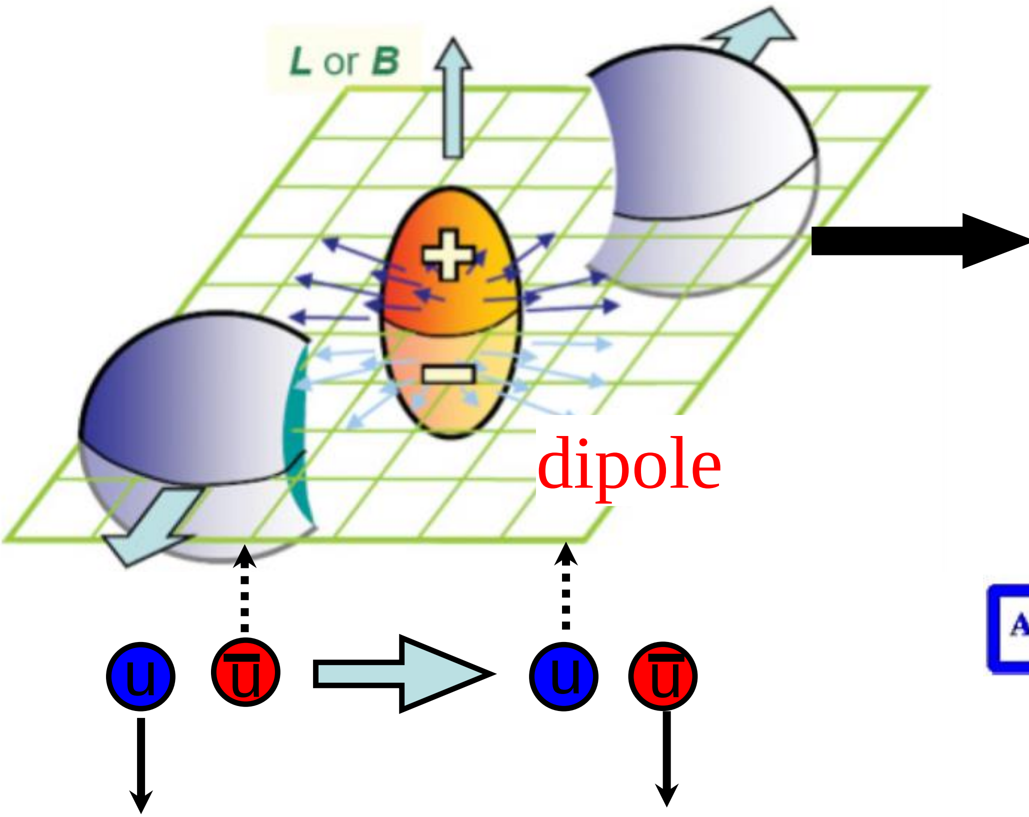
Background & CME-driven charge separation

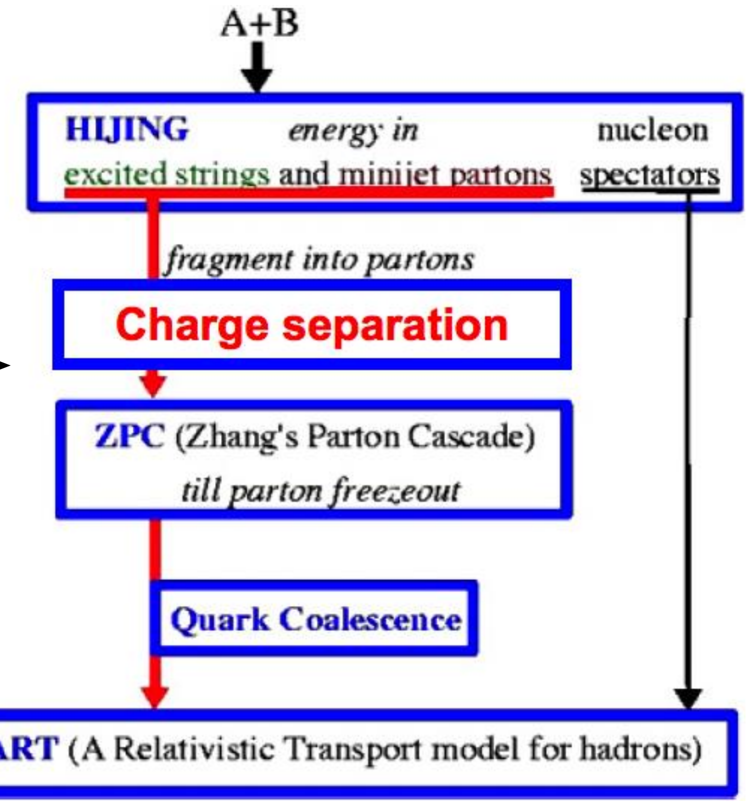


$R_{\Psi m}$ correlator for background-driven charge separation in 30%-50% Au+Au 200GeV collisions

- The shuffling particles method has a similar response to the CME and its background.

Model-AMPT





G. L. Ma, B. Zhang, PLB 700 (2011) 39

$$f\% = \frac{N^{+}_{\text{upward}} - N^{+}_{\text{downward}}}{N^{+}_{\text{upward}} + N^{+}_{\text{downward}}}$$

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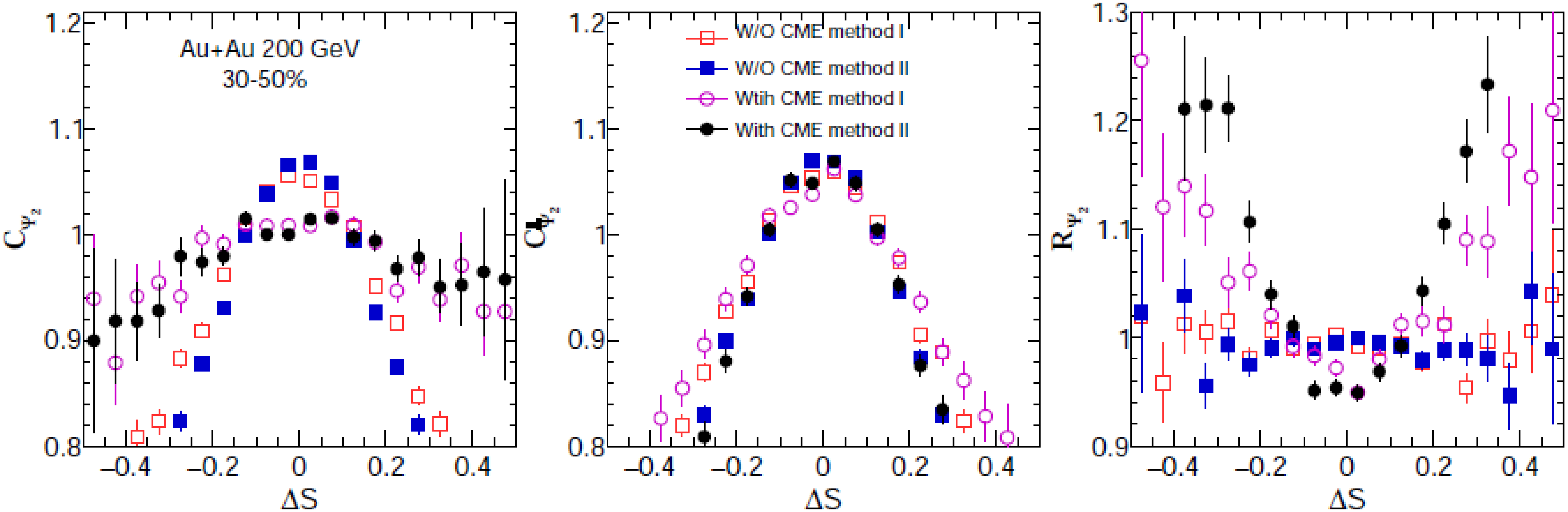
Preliminary Results

method I: mixing particles method
method II: shuffling particles method

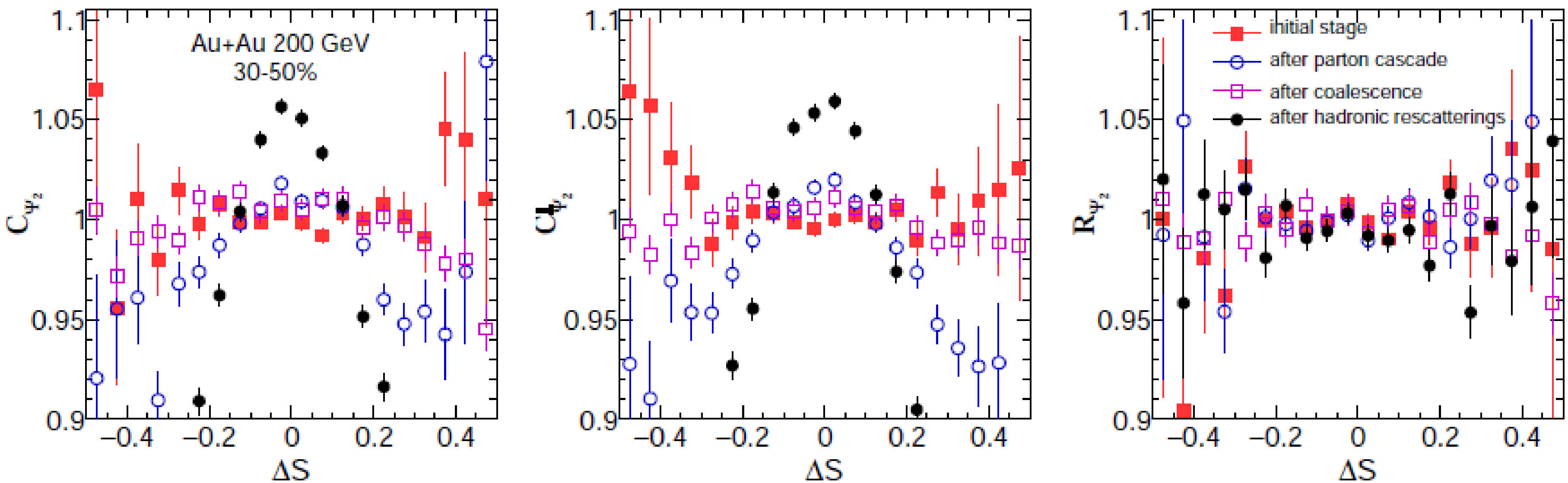
$0.35\text{GeV} < p_T < 2.0\text{GeV}, \quad -1 < \eta < 1$

arXiv:1906.11631



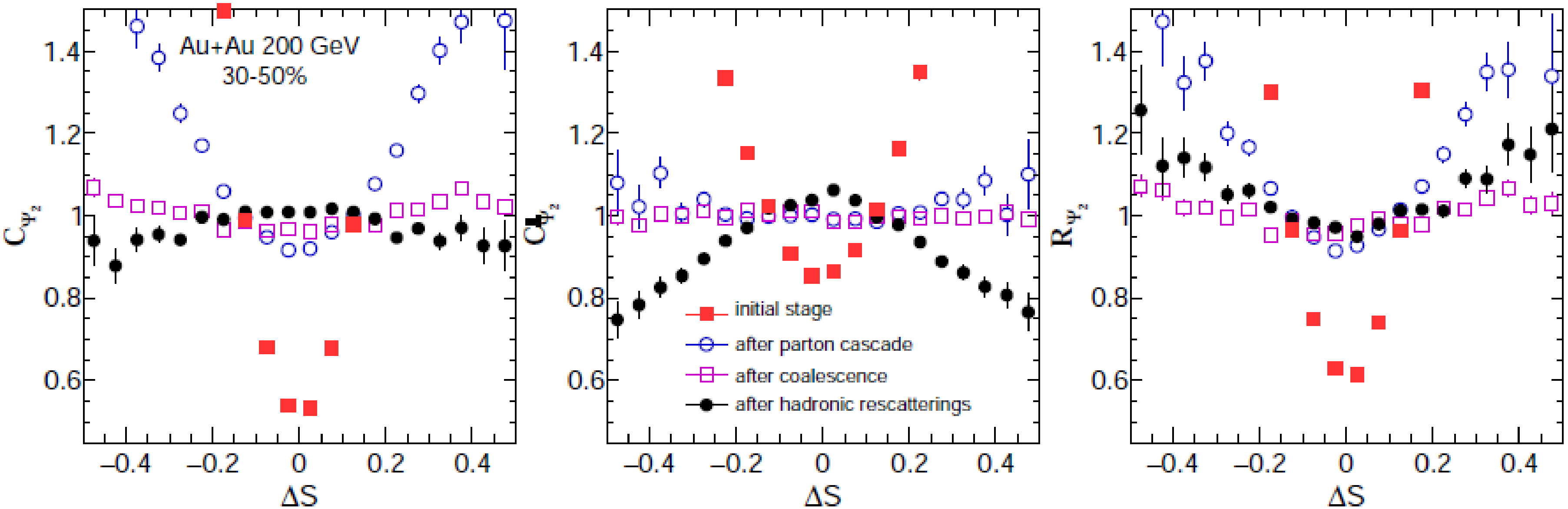
- R_{Ψ_2} of mixing particles method is consistent with the result of shuffling particles method.
- R_{Ψ_2} from original AMPT is flat, while concave from the AMPT with CME. It can distinguish the CME and its background.

Preliminary Results



- C_{Ψ_2} and $C^{\perp}_{\Psi_2}$ of mixing particles method are flat at the initial stage, and then convex at the stage of after parton cascade. After the coalescence, they are both trend to be flat, but they become more convex after hadronic rescatterings.
- R_{Ψ_2} is always flat from initial stage to after hadronic rescatterings.

Preliminary Results



- C_{Ψ_2} and $C^{\perp}_{\Psi_2}$ of mixing particles method are concave at the initial stage, and then still concave at the stage of after parton cascade. After the coalescence, they are both trend to be flat, but they become convex after hadronic rescatterings.
- R_{Ψ_2} is concave from initial stage to after parton cascade, but trend to flat after coalescence, then after hadronic rescatterings, it's concave.

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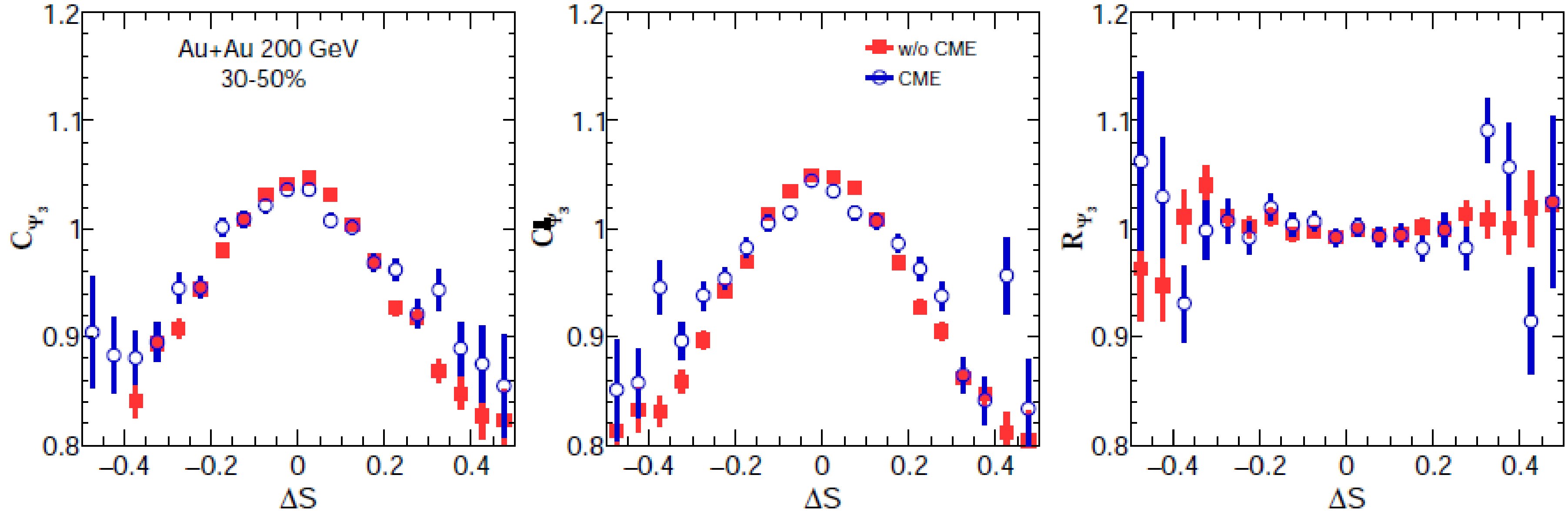
Preliminary Results



- R_{Ψ_3} are both flat no matter whether there is the CME or not.
- R_{Ψ_3} is not a sensitive observable to detect CME.

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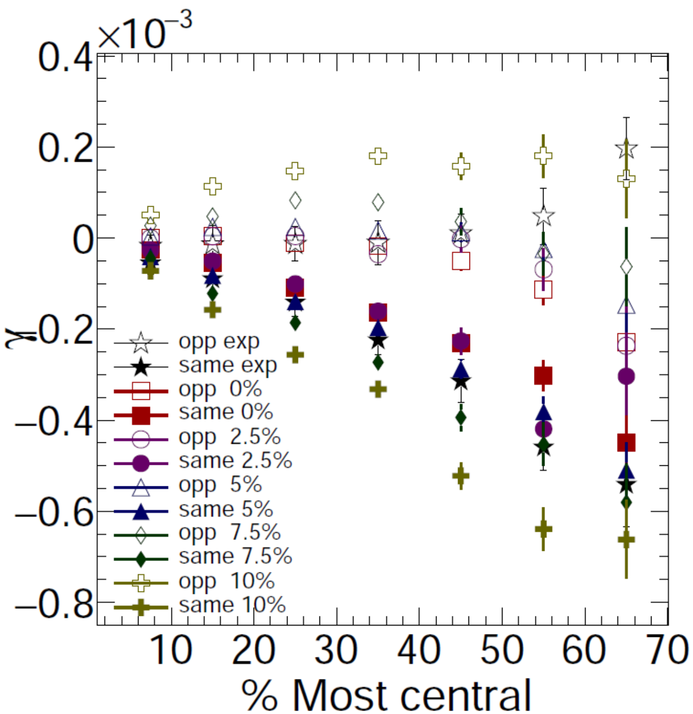
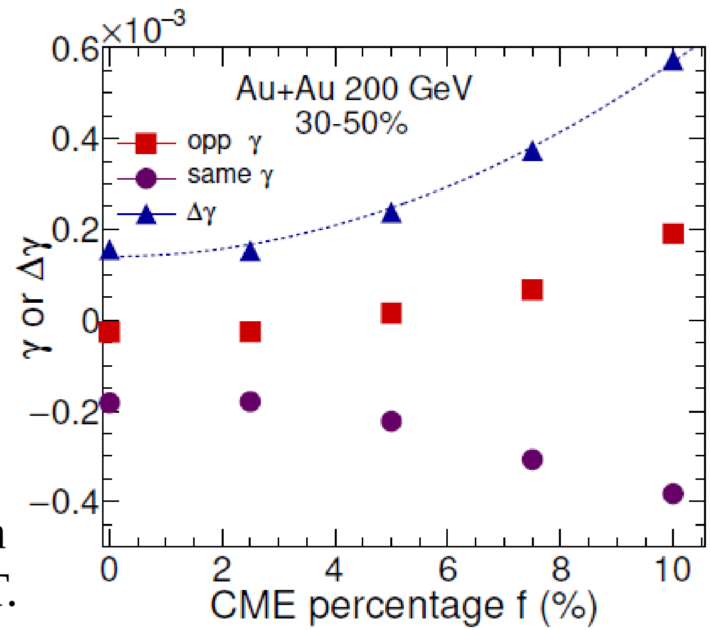
$\gamma/\Delta\gamma$ correlator



- γ correlator with 2.5% initial charge separation parameter is similar to that from the original AMPT.
- Only when the charge separation parameter is large enough, e.g. more than 5%, γ can become visible.



- $\Delta\gamma$ correlator with 2.5% initial charge separation parameter is similar to that from the original AMPT.

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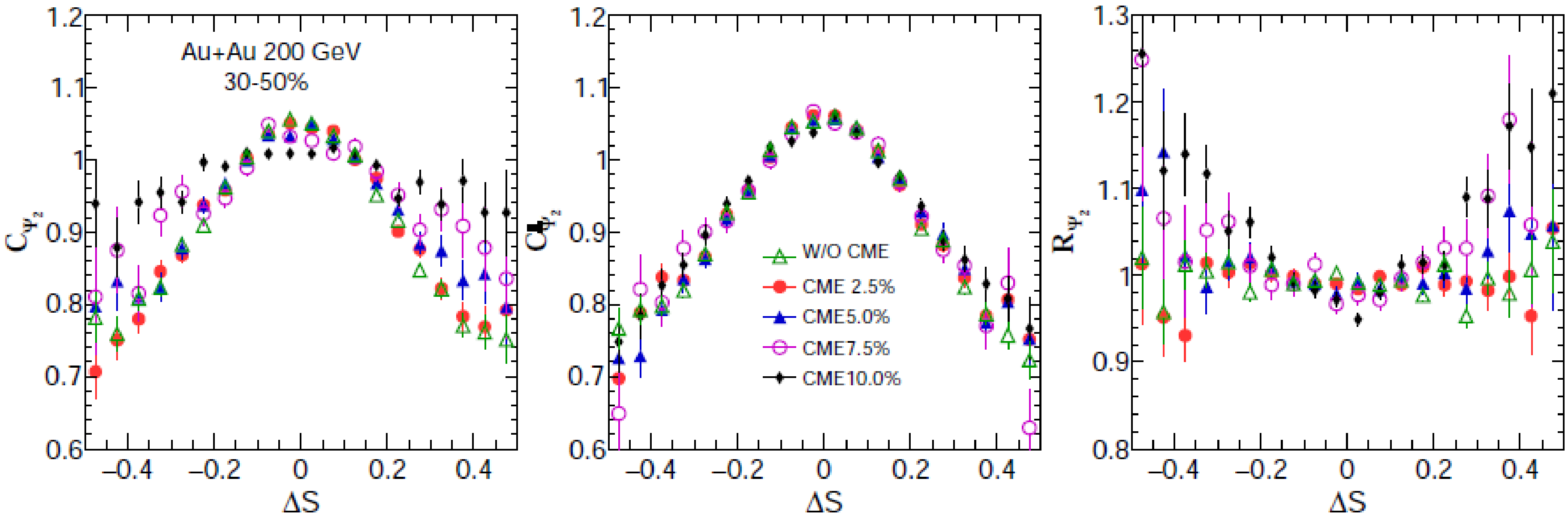
R_{Ψ_2} correlator through different initial charge separation parameters:



- R_{Ψ_2} with 2.5% initial charge separation parameter is similar to R_{Ψ_2} with the original AMPT within error bars, they are both flat.
- When added 5% initial charge separation parameter, R_{Ψ_2} become concave.
- With the initial charge separation percentage increase, C_{Ψ_2} become wider and wider, R_{Ψ_2} become narrower and narrower.

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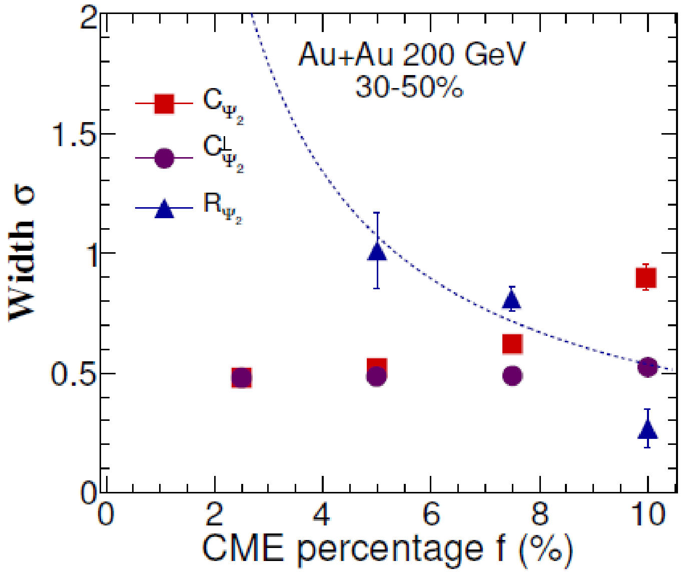
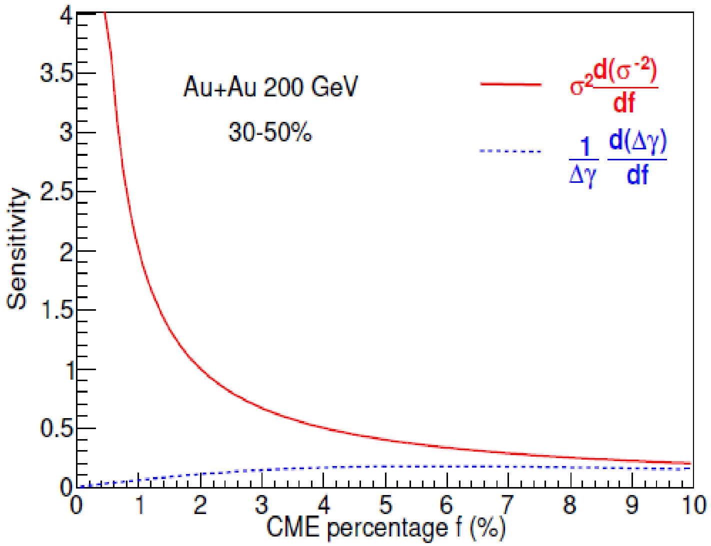
R_{Ψ_2} correlator



- R_{Ψ_2} from 2.5% initial charge separation percentage and original AMPT are both flat within our current statistics, its width is infinity.
- With the initial charge separation increases, the width of C_{Ψ_2} is bigger and bigger. Which means C_{Ψ_2} will become more and more concave.



- Comparing the sensitivity to the CME between γ and R_{Ψ_2}, R_{Ψ_2} is more sensitive to the CME than γ when the initial charge separation parameter is very small.

Summary & Discussion

- In Au+Au 200 GeV collisions, R_{Ψ_2} is flat if only with background, but concave with the CME.
- R_{Ψ_3} is not a sensitive observable to the CME.
- The initial CME signal will be weaken by strong final state interactions.
- R correlator is more sensitive to the CME than γ correlator when the initial charge percentage is very small.

Thank you for your attention!

Backup

For $\Delta\gamma$: assume it's proportional to f^2

$$\Delta\gamma = Af^2 + B$$

A and B is parameters

For σ : assume it's proportional to f

$$\sigma = Cf$$

C is parameter