Sensitivity analysis of the chiral magnetic effect observables using the AMPT

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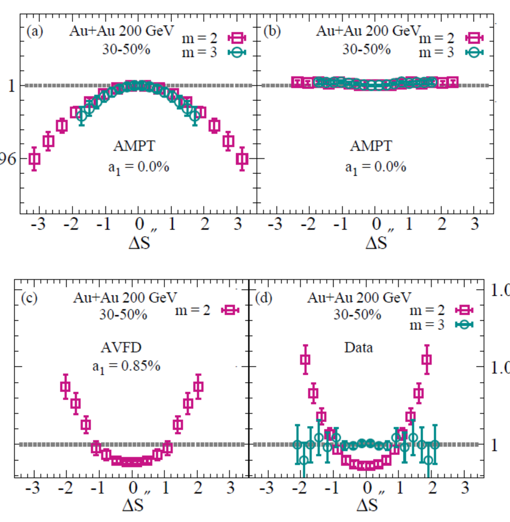
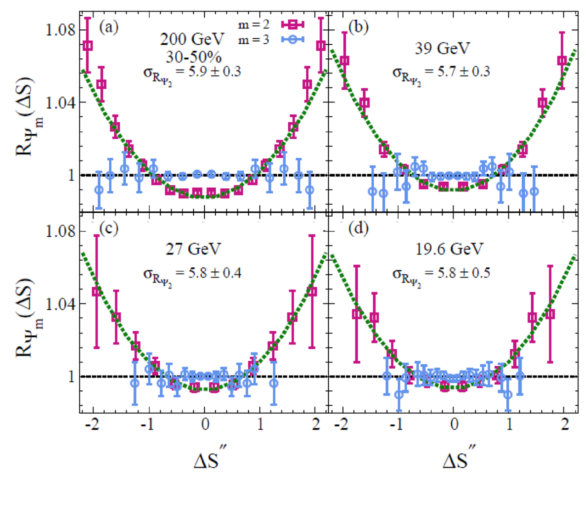
Motivation

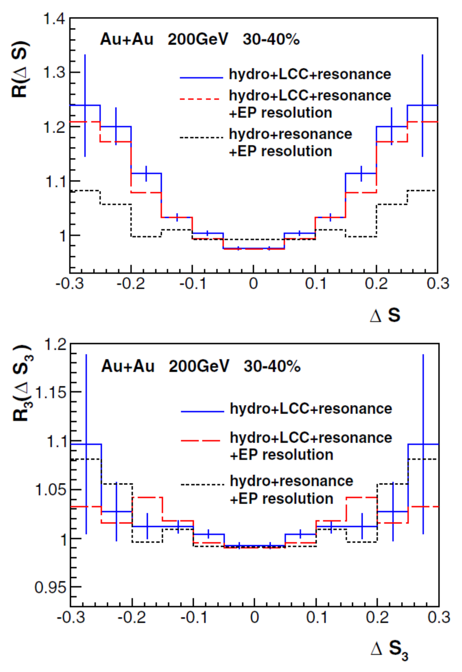
Results of R_{Ψ_m} from different sources:





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

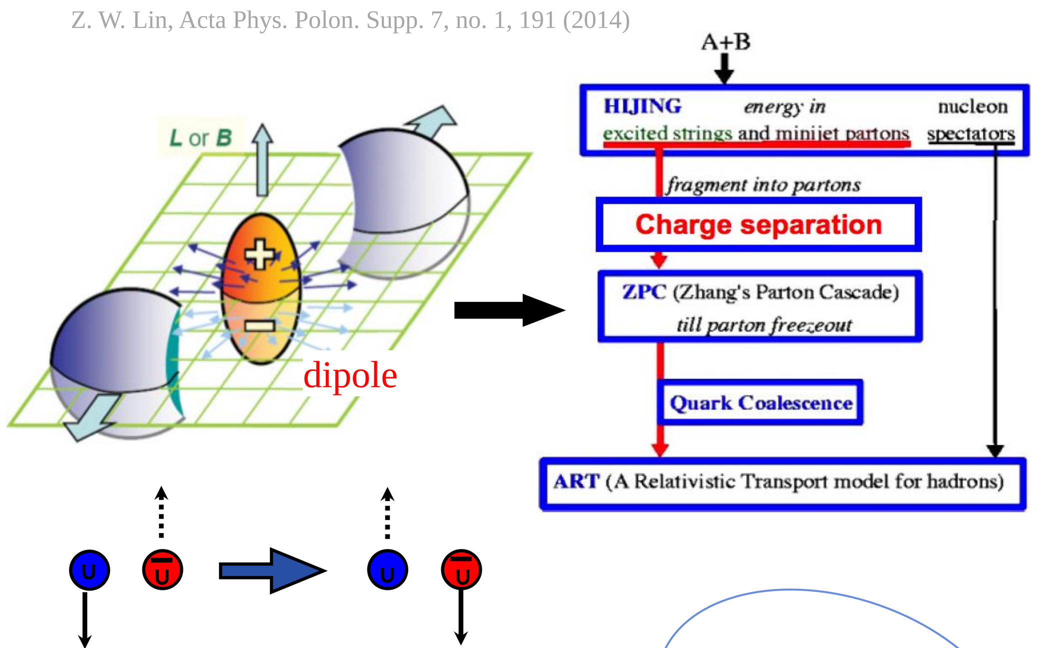
Piotr Bożek. PRC 97, 034907 (2018).



- Comparing to the γ, R correlator was proposed to distinguish the CME and its background.
- Some results show that R correlator is convex if only with background but concave with the CME. On the other hand, some results show that R correlator can be also concave only with background.
- It is interesting to study whether R correlator could distinguish the CME and its background with a transport model with both the CME and background.

The AMPT Model

Z. W. Lin, Acta Phys. Polon. Supp. 7, no. 1, 191 (2014)



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

percentage of initial charge separation is used to adjust strength of the CME

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

- The new version of AMPT with string meting mechanism is charge conserved.
- The string melting version consists of four main components:
  - The initial condition mainly simulates the spatial and momentum distributions of minijet partons by using HIJING model
  - The parton cascade describes strong interactions among partons through elastic partonic collisions
  - A quark coalescence model for hadronization
  - The ART model is used to simulate baryon-baryon, baryon-meson and meson-meson reactions in hadronic rescatterings
- The CME signal was been introduced into the AMPT model by exchanging the p_y values of a percentage of the downward moving $u(\bar{d})$ quarks with those of the upward moving $\bar{u}(d)$ quarks.

Methods

Method-Mix

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

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

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

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

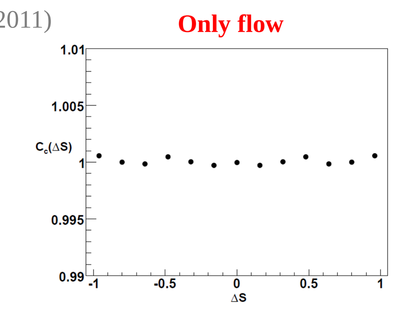
$C_c(\Delta S)$ correlator:

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

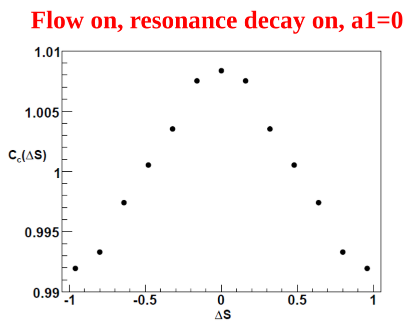
randomly chosen hadrons

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

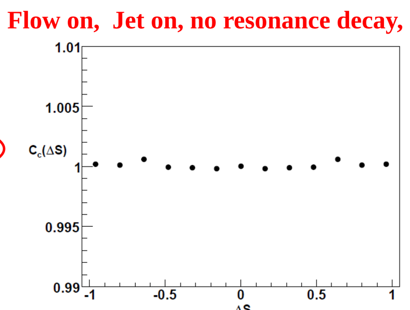
Only flow



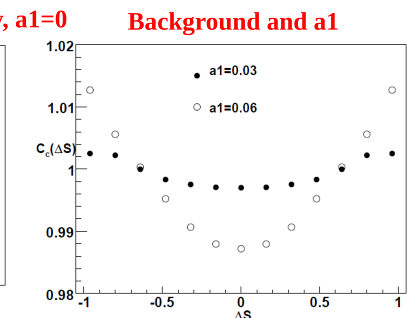
Flow on, resonance decay on, a1=0



Flow on, Jet on, no resonance decay, a1=0



Background and a1



Method-Shuffle

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

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

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

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

$C_c(\Delta S)$ correlator:

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

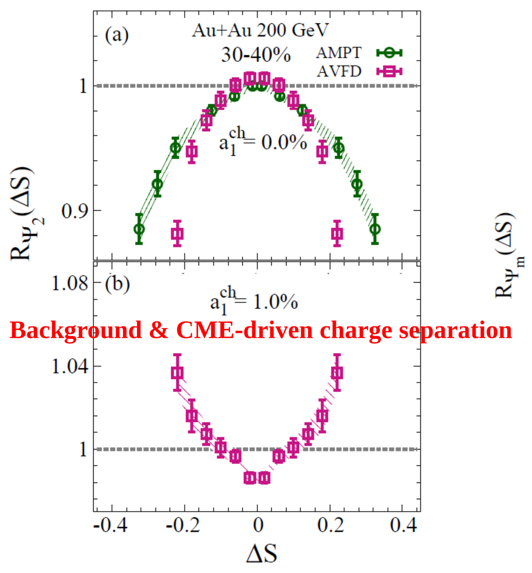
Only the charge of the positive /negative charged particles

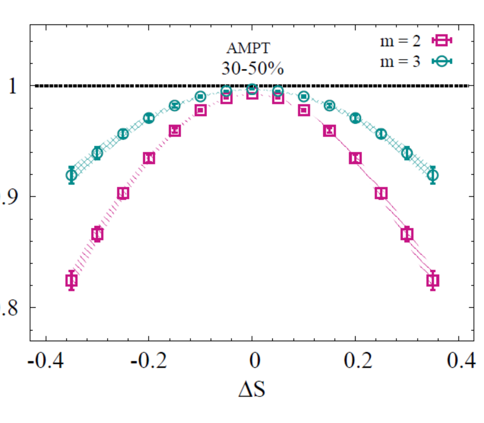
$R_{\Psi_m}(\Delta S)$ correlator:

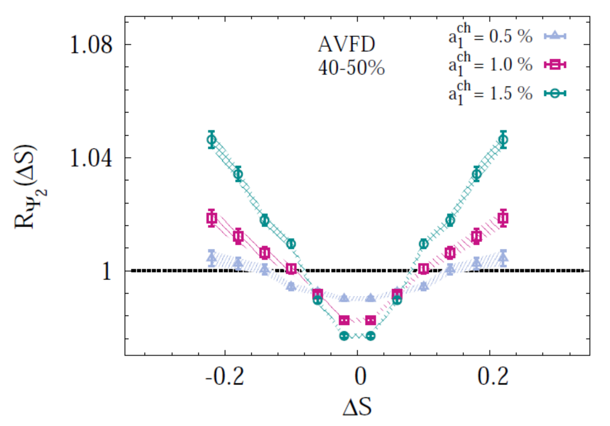
$$R_{\Psi_m}(\Delta S) = \frac{C_{\Psi_m}(\Delta S)}{C^{\perp}_{\Psi_m}(\Delta S)} \quad \text{m=2, 3}$$

Background-driven charge separation

Background & CME-driven charge separation







N. Magdy, S. Shi, J. Liao, N. Ajitanand and R. A. Lacey, Phys. Rev. C 97, 6, 061901 (2018)

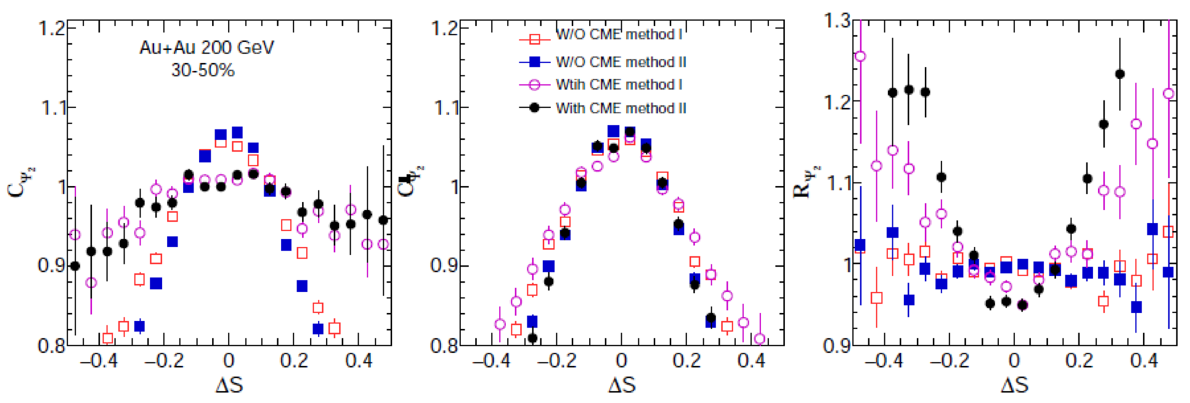
Results

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

method I: mixing particles method

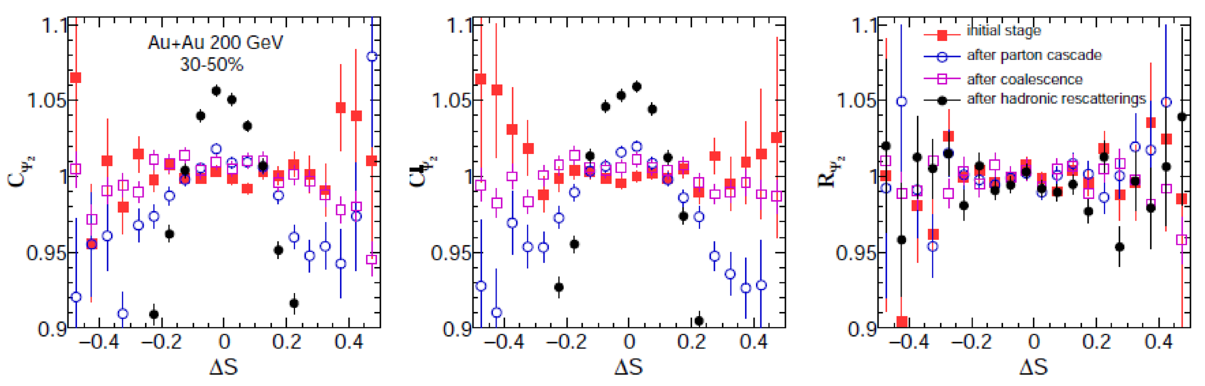
method II: shuffling particles method

① Method comparison



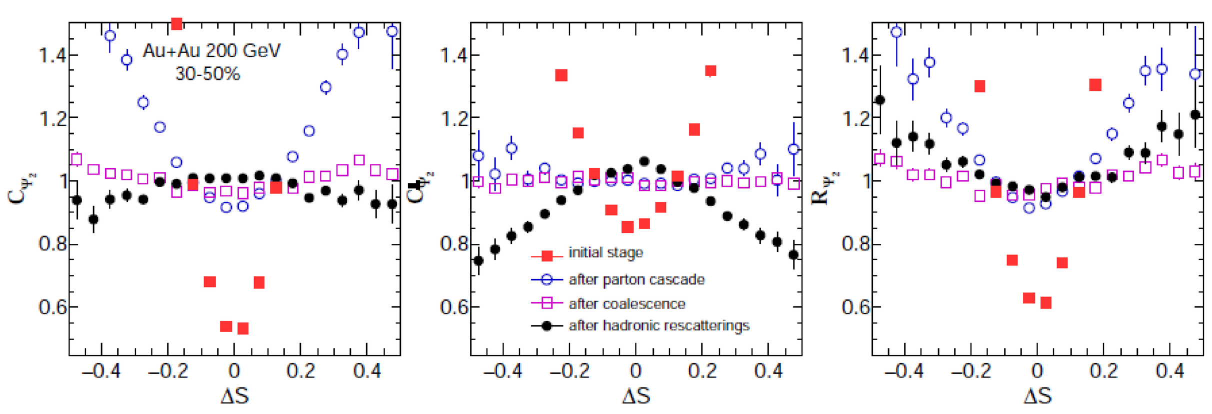
- R_{Ψ_2} of mixing particles method is consistent with the result of shuffling particles method.
- R_{Ψ_2} from original AMPT is flat, while concave from the AMPT with CME. It can distinguish the CME and its background.

② Stage evolution from AMPT (w/o CME)



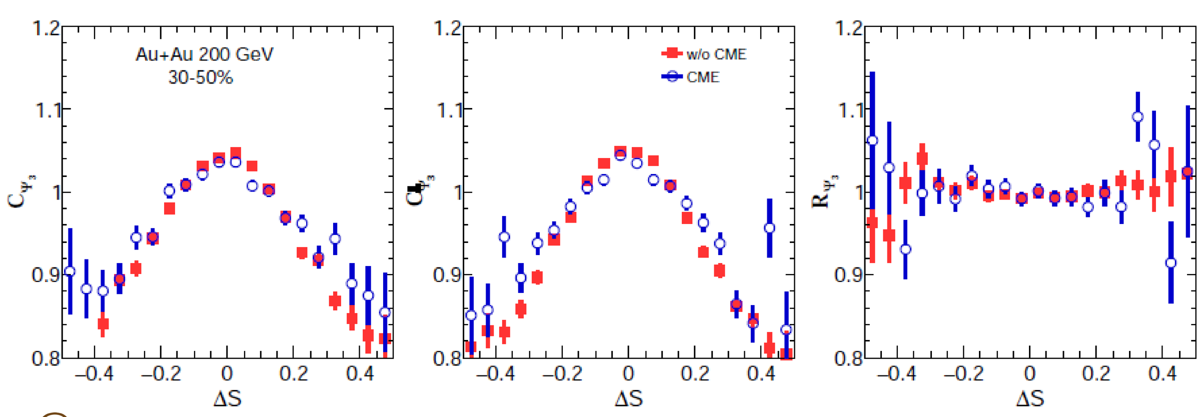
- C_{Ψ_2} and $C^{\perp}_{\Psi_2}$ of mixing particles method are flat at the initial stage, and then convex at the stage of after parton cascade. After the coalescence, they are both trend to be flat, but they become more convex after hadronic rescatterings.
- R_{Ψ_2} is always flat from initial stage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

③ Stage evolution from AMPT (with CME)



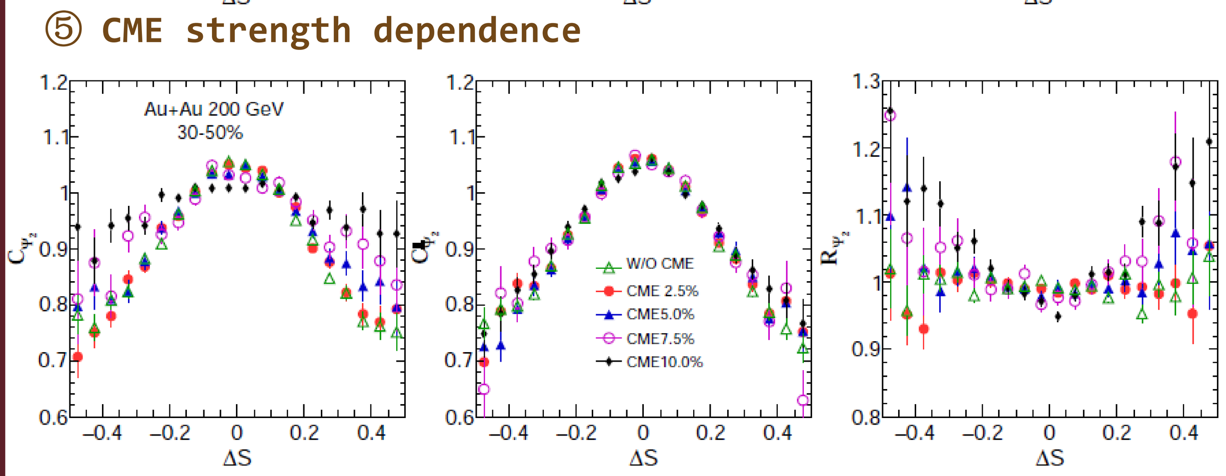
- C_{Ψ_2} and $C^{\perp}_{\Psi_2}$ of mixing particles method are concave at the initial stage, and then still concave at the stage of after parton cascade. After the coalescence, they are both trend to be flat, but they become convex after hadronic rescatterings.
- R_{Ψ_2} is concave from initial stage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

④ With respect to Ψ_3



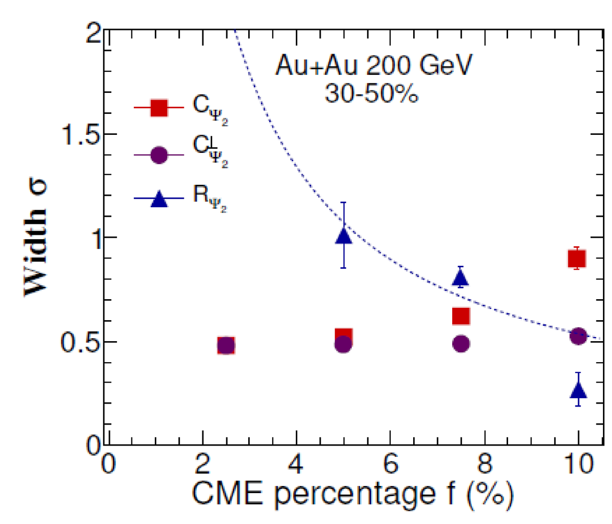
- R_{Ψ_3} are both flat no matter whether there is the CME or not.
- R_{Ψ_3} is not a sensitive observable to detect CME.

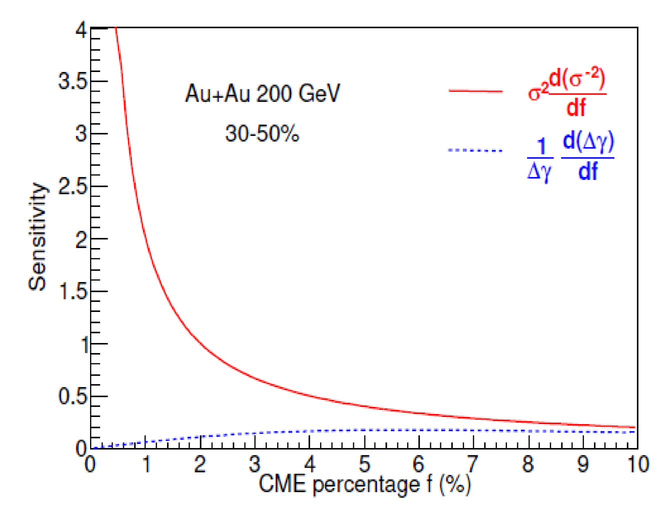
⑤ CME strength dependence



- 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.
- With the initial charge separation percentage increase, C_{Ψ_2} become wider and wider, R_{Ψ_2} become narrower and narrower.

⑥ Sensitivity comparison





- R_{Ψ_2} from 2.5% initial charge separation percentage and original AMPT are both flat within our current statistics, its width is infinity.
- 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

- In Au+Au 200 GeV collisions, R_{Ψ_2} is flat if only with background, but concave with the CME from the AMPT model.
- 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.

more details see: arXiv:1906.11631

References

[1] N. N. Ajitanand, R. A. Lacey, A. Taranenko and J. M. Alexander, Phys. Rev. C 83, 011901 (2011) [arXiv:1009.5624[nucl-ex]].
[2] N. Magdy, S. Shi, J. Liao, N. Ajitanand and R. A. Lacey, Phys. Rev. C 97, no. 6, 061901 (2018) [arXiv:1710.01717[physics.data-an]].
[3] Y. Feng, J. Zhao and F. Wang, Phys. Rev. C 98, no. 3, 034904 (2018) [arXiv:1803.02860 [nucl-th]].
[4] G. L. Ma, B. Zhang, Phys. Lett. B 700 39 (2011), [arXiv:1101.1701 [nucl-th]].
[5] Z. W. Lin, Acta Phys. Polon. Supp. 7, no. 1, 191 (2014) [arXiv:1403.1854 [nucl-th]].

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