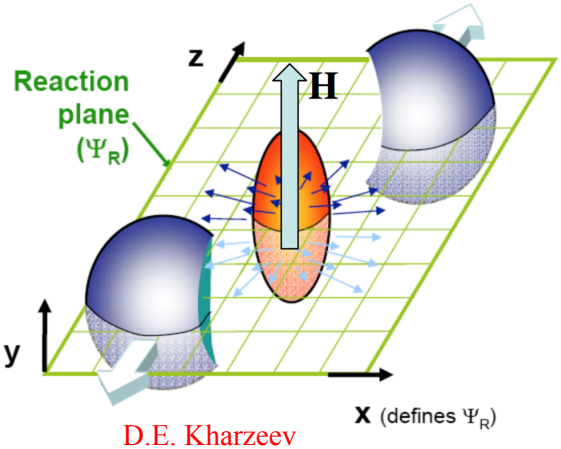
A New Correlator, $R_{\Psi_m}(\Delta S)$, to Detect and Characterize the Chiral Magnetic Effect

Niseem Magdy
Stony Brook University
niseemm@gmail.com

❖ Introduction

✓ Chiral Magnetic Effect (CME)

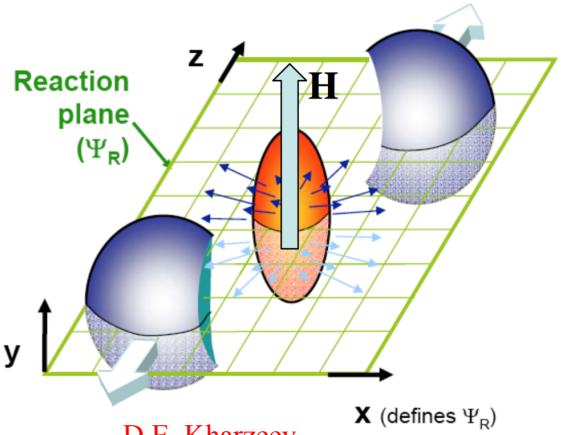


D.E. Kharzeev
Prog.Part.Nucl.Phys. 75 (2014) 133-151

- In non-central collisions a strong magnetic field is created ⊥ to Ψ_{RP}

❖ Introduction

✓ Chiral Magnetic Effect (CME)



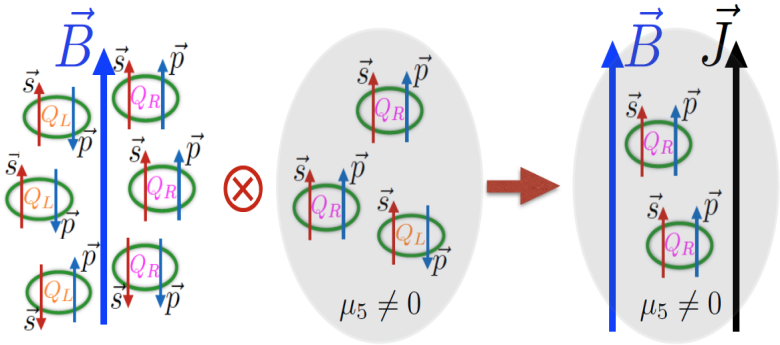
D.E. Kharzeev
Prog.Part.Nucl.Phys. 75 (2014) 133-151

Electric Current

$$\vec{J}_Q = \sigma_5 \vec{B}$$

$$\sigma_5 = C_A \mu_5$$ Kharzeev hep-ph/0406125

$$C_A = Q^2 / (4\pi^2)$$



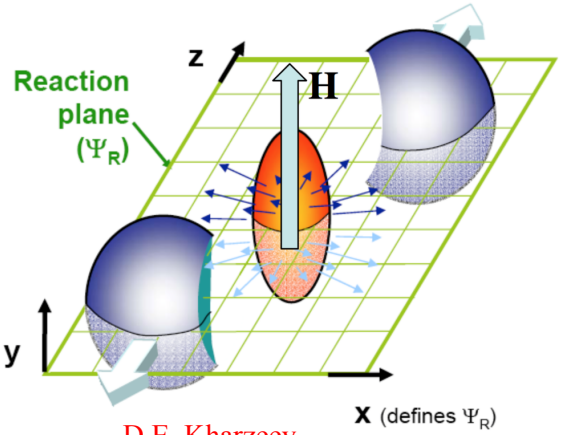
D.E. Kharzeev et al.
Prog.Part.Nucl.Phys. 88 (2016) 1-28

- In non-central collisions a strong magnetic field is created ⊥ to Ψ_{RP}

- Magnetic field acts on the chiral fermions with $\mu_5 \neq 0$ leads to an electric current along the magnetic field which leads to a charge separation

❖ Introduction

✓ Chiral Magnetic Effect (CME)



D.E. Kharzeev
Prog.Part.Nucl.Phys. 75 (2014) 133-151

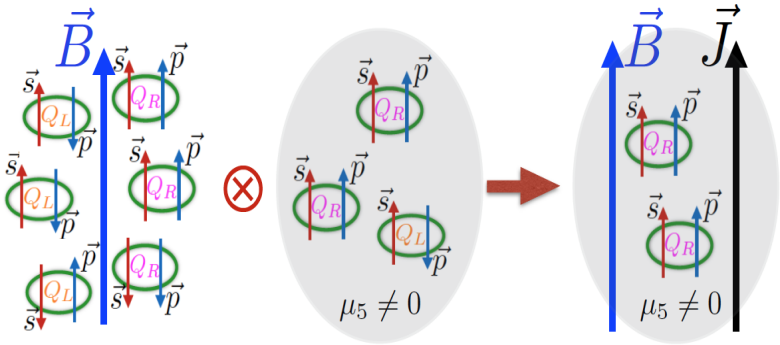
Electric Current

Chiral Magnetic Conductivity

$$\vec{J}_Q = \sigma_5 \vec{B}$$

$$\sigma_5 = C_A \mu_5$$ Kharzeev hep-ph/0406125

$$C_A = Q^2 / (4\pi^2)$$



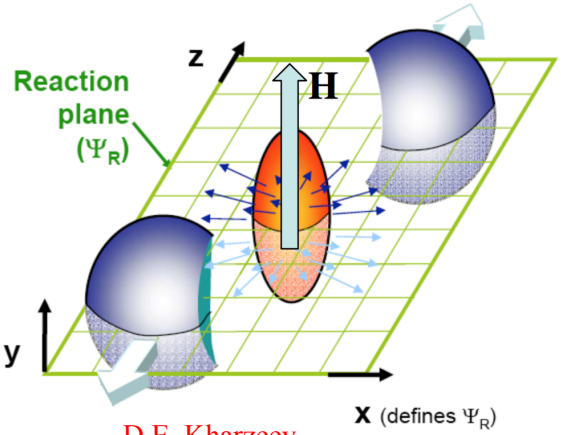
D.E. Kharzeev et al.
Prog.Part.Nucl.Phys. 88 (2016) 1-28

- In non-central collisions a strong magnetic field is created ⊥ to Ψ_{RP}

- Magnetic field acts on the chiral fermions with $\mu_5 \neq 0$ leads to an electric current along the magnetic field which leads to a charge separation

❖ Introduction

✓ Chiral Magnetic Effect (CME)



D.E. Kharzeev
Prog.Part.Nucl.Phys. 75 (2014) 133-151

Electric Current

Chiral Magnetic Conductivity

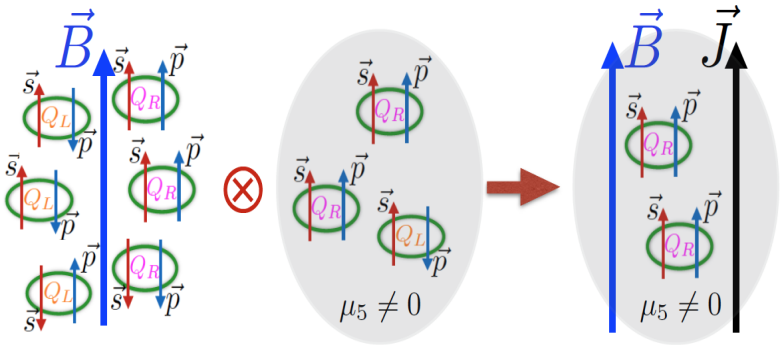
Chiral Chemical potential

$$\vec{J}_Q = \sigma_5 \vec{B}$$

$$\sigma_5 = C_A \mu_5$$

Kharzeev
hep-ph/0406125

$$C_A = Q^2 / (4\pi^2)$$



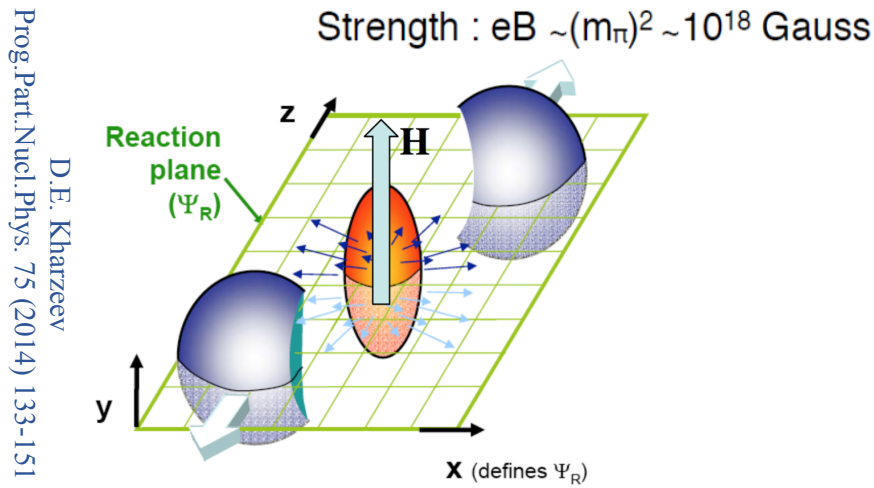
D.E. Kharzeev et al.
Prog.Part.Nucl.Phys. 88 (2016) 1-28

- In non-central collisions a strong magnetic field is created ⊥ to Ψ_{RP}

- Magnetic field acts on the chiral fermions with $\mu_5 \neq 0$ leads to an electric current along the magnetic field which leads to a charge separation

❖ Introduction

✓ Chiral Magnetic Effect (CME)



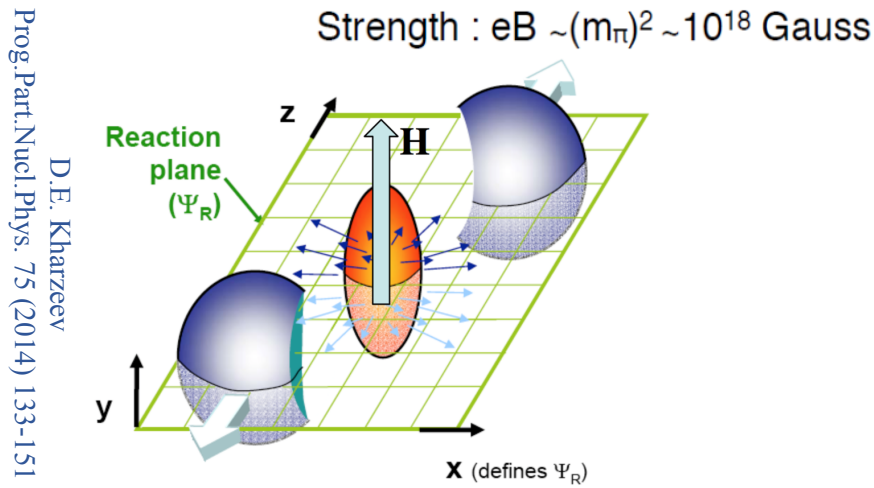
D.E. Kharzeev Prog.Part.Nucl.Phys. 75 (2014) 133-151

CME-driven charge separation leads to a dipole term in the azimuthal distribution of the produced charged hadrons:

$$\frac{dN^{ch}}{d\phi} \propto 1 \pm 2\, a_1^{ch} \sin(\phi) + \cdots \qquad a_1^{ch} \propto \mu_5 \vec{B}$$

❖ Introduction

✓ Chiral Magnetic Effect (CME)



D.E. Kharzeev Prog.Part.Nucl.Phys. 75 (2014) 133-151

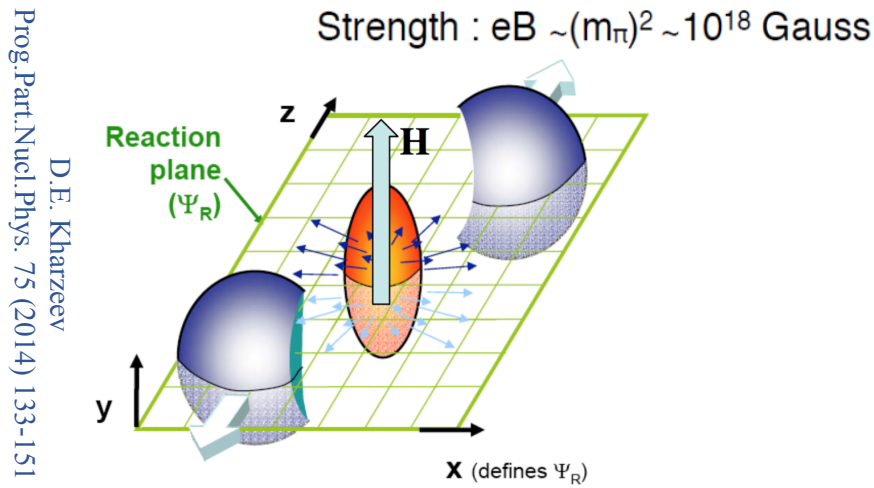
CME-driven charge separation leads to a dipole term in the azimuthal distribution of the produced charged hadrons:

$$\frac{dN^{ch}}{d\phi} \propto 1 \pm 2\, a_1^{ch} \sin(\phi) + \cdots \qquad a_1^{ch} \propto \mu_5 \vec{B}$$

Can we identify & characterize this dipole moment?

❖ Introduction

✓ Chiral Magnetic Effect (CME)



D.E. Kharzeev Prog.Part.Nucl.Phys. 75 (2014) 133-151

CME-driven charge separation leads to a dipole term in the azimuthal distribution of the produced charged hadrons:

$$\frac{dN^{ch}}{d\phi} \propto 1 \pm 2\, a_1^{ch} \sin(\phi) + \cdots \qquad a_1^{ch} \propto \mu_5 \vec{B}$$

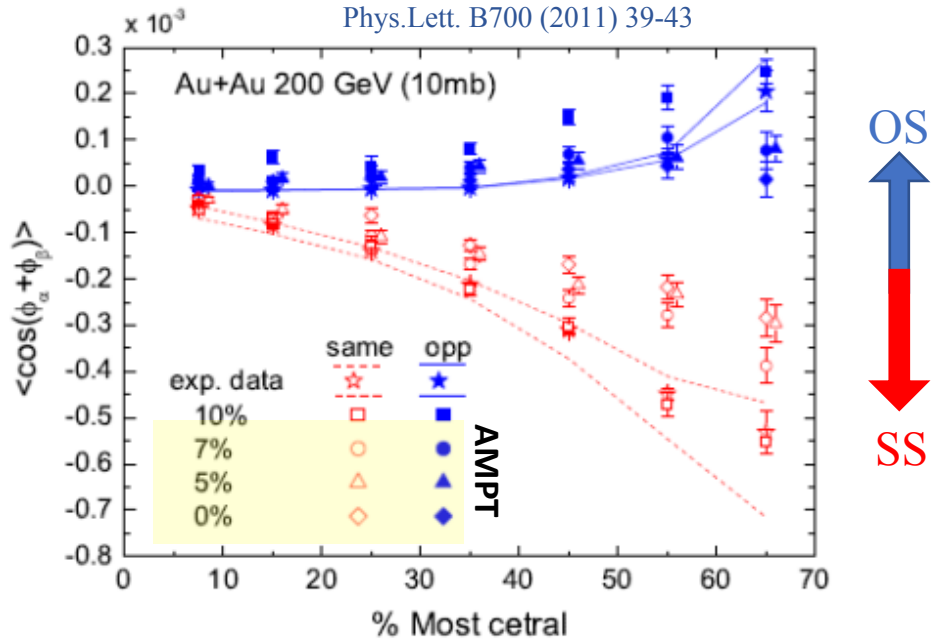
Can we identify & characterize this dipole moment?

The Gamma correlator and its variants, have been used extensively for experimental measurements.

❖ Introduction

✓ The Gamma correlator

Ma, Zhang
Phys.Lett. B700 (2011) 39-43

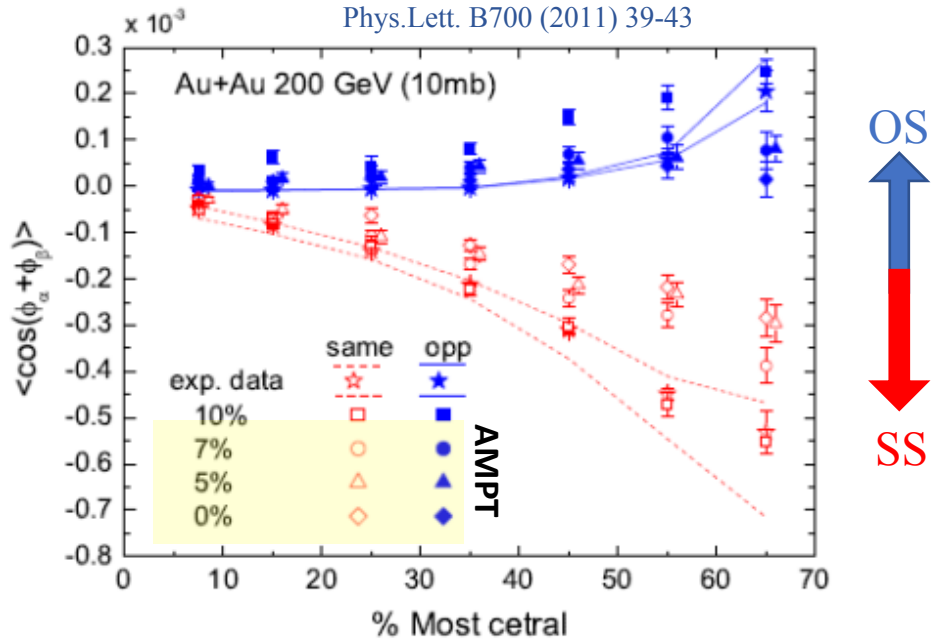


- The Gamma Correlator's response is similar for signal and background
  - ✓ Background-driven correlations complicate CME-driven signal extraction?

❖ Introduction

✓ The Gamma correlator

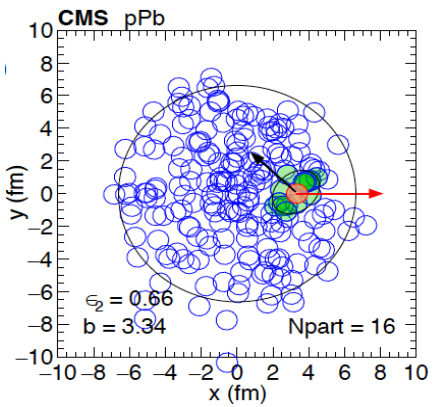
Ma, Zhang
Phys.Lett. B700 (2011) 39-43

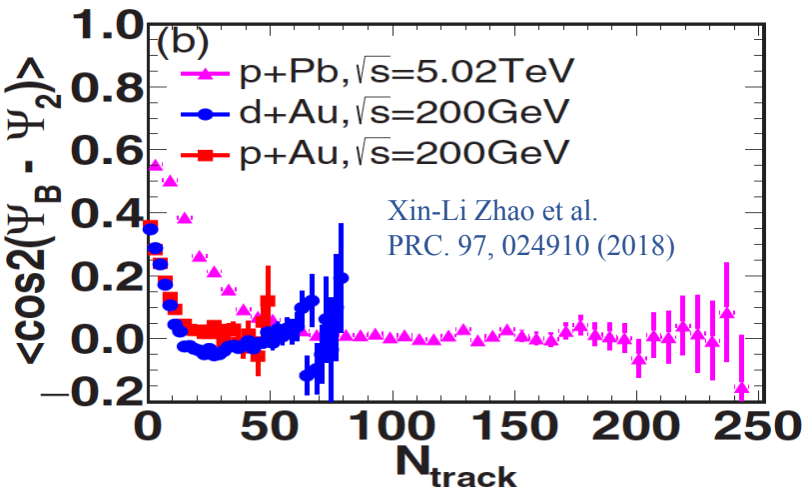


- The Gamma Correlator's response is similar for signal and background
  - ✓ Background-driven correlations complicate CME-driven signal extraction?
- Background can account for a part, or all of the observed charge separation signal?

❖ Introduction

✓ The Gamma correlator for small system



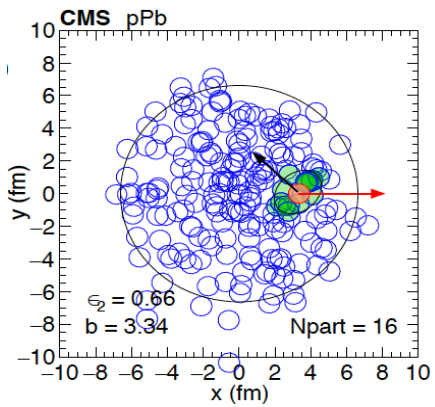


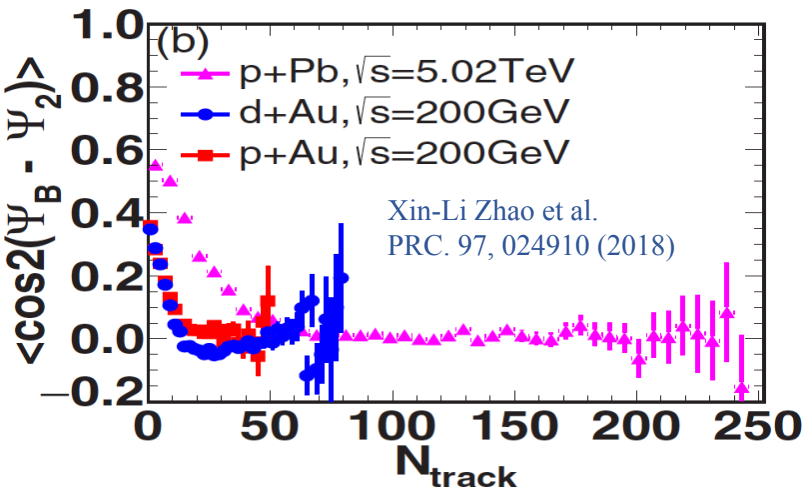
➢ p+A collisions:

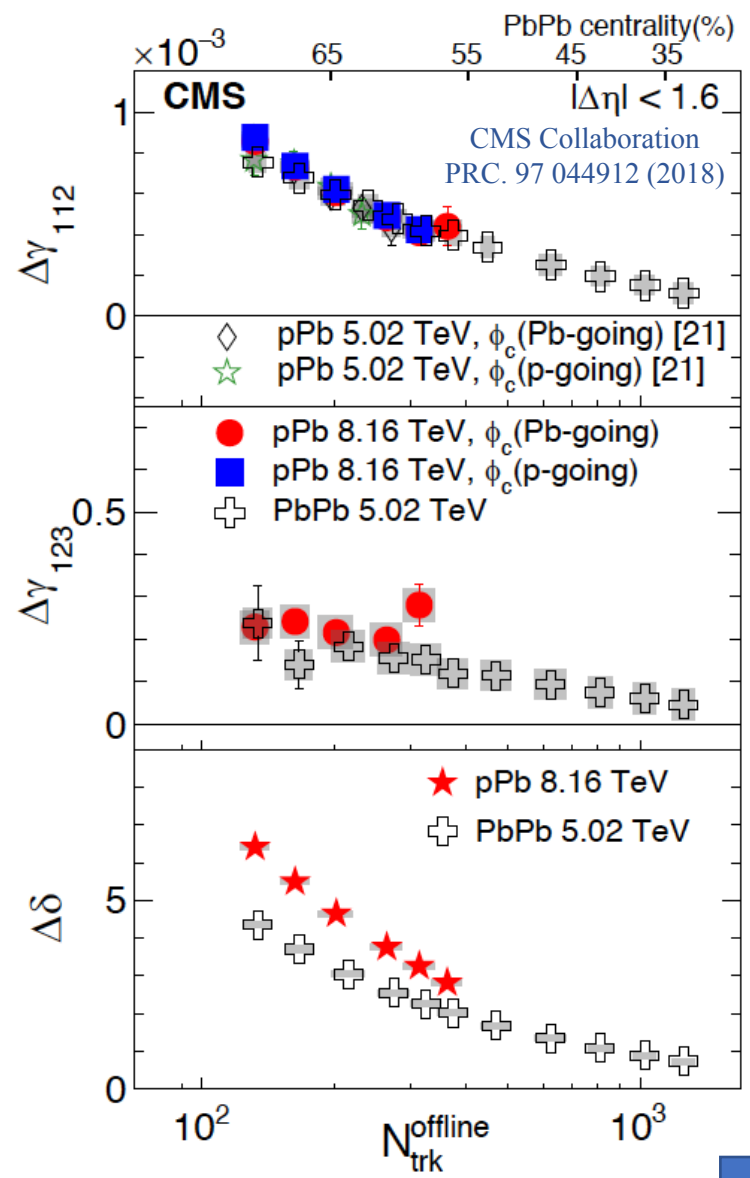
✓ $\langle \cos[2(\Psi_B - \Psi_{EP})] \rangle \sim 0$

❖ Introduction

✓ The Gamma correlator for small system







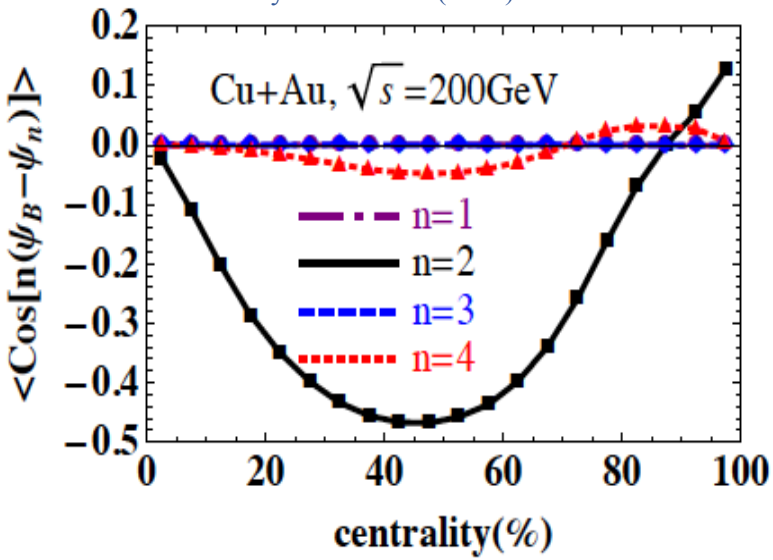
➢ p+A collisions:

- ✓ $\langle \cos[2(\Psi_B - \Psi_{EP})] \rangle \sim 0$
- ✓ Signal free system

❖ Introduction

✓ The Gamma correlator for Ψ_n

Wei-Tian Deng, Xu-Guang Huang
Phys.Lett. B742 (2015) 296-302

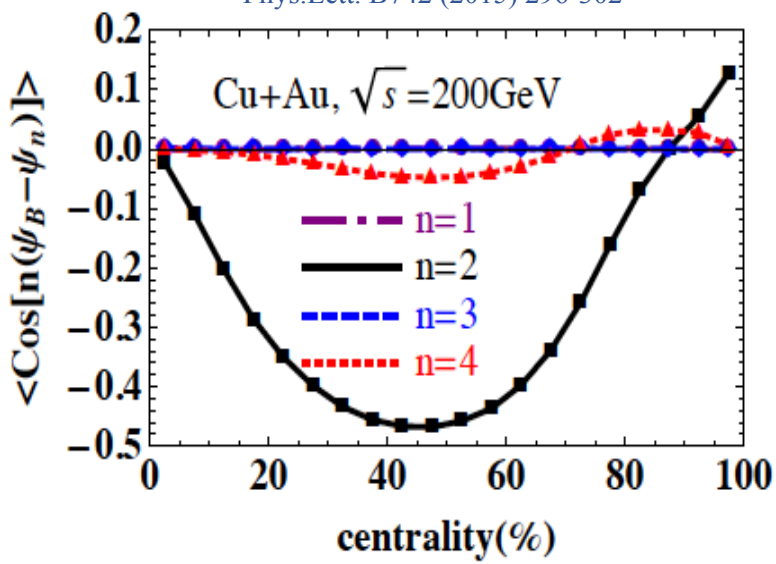


✓ $\langle \cos[3(\Psi_B - \Psi_3)] \rangle \sim 0$

❖ Introduction

✓ The Gamma correlator for Ψ_n

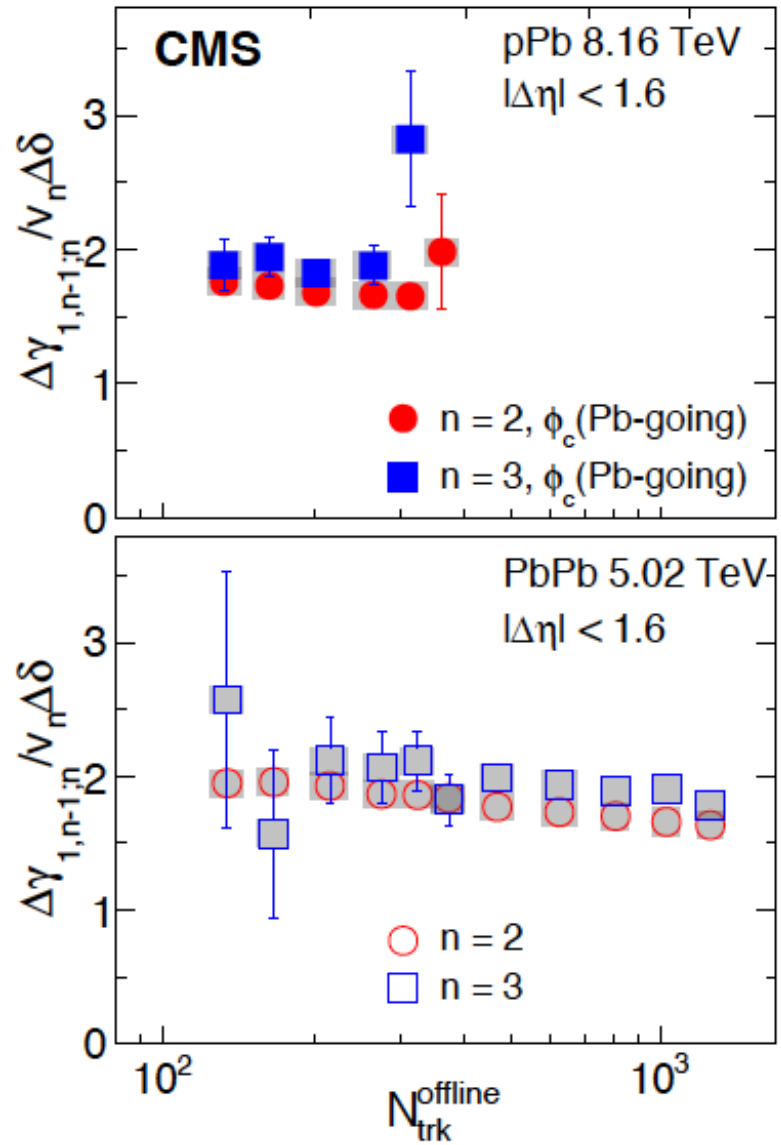
Wei-Tian Deng, Xu-Guang Huang
Phys.Lett. B742 (2015) 296-302



✓ $\langle\cos[3(\Psi_B - \Psi_3)]\rangle \sim 0$

$$\frac{\Delta\gamma_{112}}{v_2\Delta\delta} \approx \frac{\Delta\gamma_{123}}{v_3\Delta\delta}$$

CMS Collaboration
PRC. 97 044912 (2018)



➢ CMS at QM-18

✓ pPb consistent with 100% BKG

✓ Same for PbPb

❖ Introduction

✓ Why a new correlator?

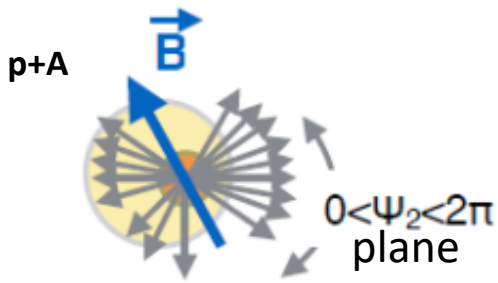
- We need better control over signal and background

❖ Introduction

✓ Why a new correlator?

➢ We need better control over signal and background

✓ Leverage Small systems



B and Ψ_2 ~ uncorrelated

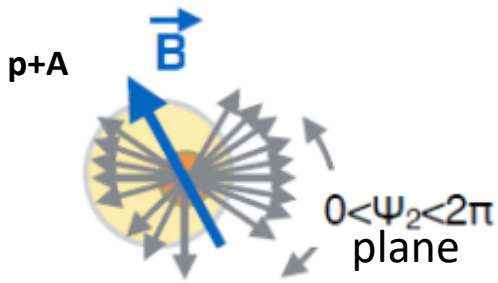
✓ Signal free

❖ Introduction

✓ Why a new correlator?

➢ We need better control over signal and background

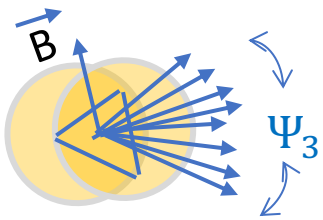
✓ Leverage Small systems



B and Ψ_2 ~ uncorrelated

✓ Signal free

✓ Leverage Ψ_3 measurements



B and Ψ_3 ~ uncorrelated

✓ Signal free

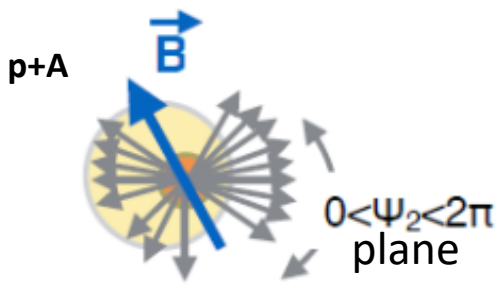
✓ Compare with Ψ_2 measurements

❖ Introduction

✓ Why a new correlator?

➢ We need better control over signal and background

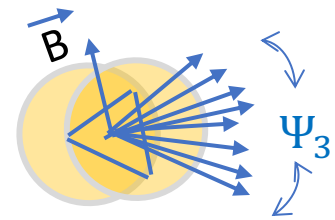
✓ Leverage Small systems



B and Ψ_2 ~ uncorrelated

✓ Signal free

✓ Leverage Ψ_3 measurements



B and Ψ_3 ~ uncorrelated

✓ Signal free

✓ Compare with Ψ_2 measurements

❖ Excellent bench mark

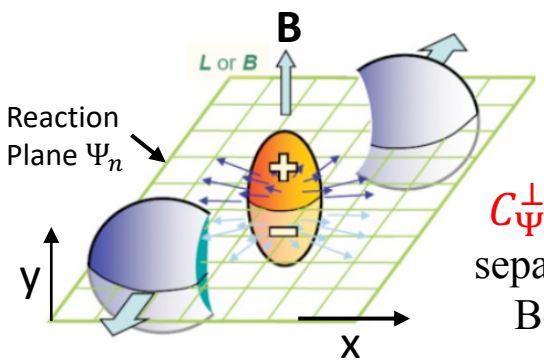
❖ The New Correlator

N. Magdy et al. arXiv: 1710.01717

- The correlator is constructed for a given event plane Ψ_m via a ratio of two correlation functions

$C_{\Psi m}(\Delta S)$ quantifies charge separation along the B-field

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



$C^{\perp}_{\Psi m}(\Delta S)$ quantifies charge separation perpendicular to the B-field (only background)

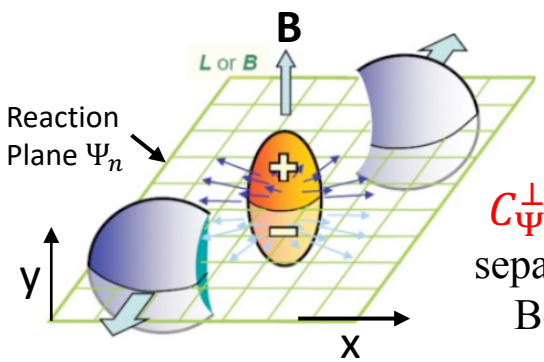
❖ The New Correlator

N. Magdy et al. arXiv: 1710.01717

- The correlator is constructed for a given event plane Ψ_m via a ratio of two correlation functions

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

$C_{\Psi_m}(\Delta S)$ quantifies charge separation along the B-field



$C^{\perp}_{\Psi_m}(\Delta S)$ quantifies charge separation perpendicular to the B-field (only background)

The $R_{\Psi_m}(\Delta S)$ correlator measures the magnitude of charge separation parallel to the B-field, relative to that for charge separation perpendicular to the B-field

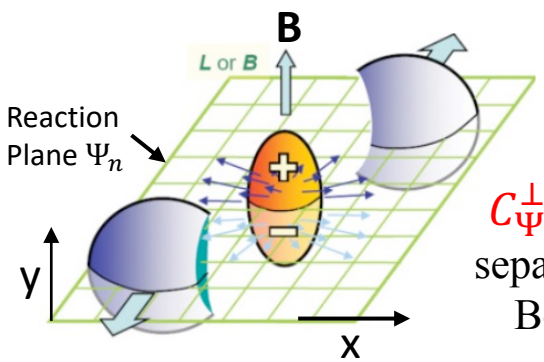
❖ The New Correlator

N. Magdy et al. arXiv: 1710.01717

➢ The correlator is constructed for a given event plane Ψ_m via a ratio of two correlation functions

$C_{\Psi_m}(\Delta S)$ quantifies charge separation along the B-field

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



$C^{\perp}_{\Psi_m}(\Delta S)$ quantifies charge separation perpendicular to the B-field (only background)

The $R_{\Psi_m}(\Delta S)$ correlator measures the magnitude of charge separation parallel to the B-field, relative to that for charge separation perpendicular to the B-field

Note that both $C_{\Psi_3}(\Delta S)$ and $C^{\perp}_{\Psi_3}(\Delta S)$ are insensitive to CME-driven charge separation (only background)

❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al. arXiv: 1710.01717

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

$$C_{\Psi_m}(\Delta S) = \frac{N(\Delta S\ \ )}{N(\Delta S_{sh})}$$

$$\Delta\varphi = \varphi - \Psi_{\mathrm{m}}$$

$$C^{\perp}_{\Psi_m}(\Delta S) = \frac{N(\Delta S_{\perp})}{N(\Delta S^{Sh}_{\perp})}$$

Sensitive to charge separation
(CME and Background)

$N(\Delta S)$

$$\Delta S = \frac{\sum_1^p \sin(\frac{m}{2}\ \Delta\varphi)}{p} - \frac{\sum_1^n \sin(\frac{m}{2}\ \Delta\varphi)}{n}$$

$N(\Delta S^{\perp})$

$$\Delta S_{\perp} = \frac{\sum_1^p \cos(\frac{m}{2}\ \Delta\varphi)}{p} - \frac{\sum_1^n \cos(\frac{m}{2}\ \Delta\varphi)}{n}$$

❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al. arXiv: 1710.01717

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

$$C_{\Psi_m}(\Delta S) = \frac{N(\Delta S\ \ )}{N(\Delta S_{sh})}$$

$$\Delta\varphi = \varphi - \Psi_{\mathrm{m}}$$

$$C^{\perp}_{\Psi_m}(\Delta S) = \frac{N(\Delta S_{\perp})}{N(\Delta S^{Sh}_{\perp})}$$

Sensitive to charge separation
(CME and Background)

$N(\Delta S)$

$$\Delta S = \frac{\sum_1^p \sin(\frac{m}{2}\,\Delta\varphi)}{p} - \frac{\sum_1^n \sin(\frac{m}{2}\,\Delta\varphi)}{n}$$

$N(\Delta S^{\perp})$

$$\Delta S_{\perp} = \frac{\sum_1^p \cos(\frac{m}{2}\,\Delta\varphi)}{p} - \frac{\sum_1^n \cos(\frac{m}{2}\,\Delta\varphi)}{n}$$

Shuffling of charges within an event breaks the charge separation sensitivity

$N(\Delta S_{Sh})$

$$\Delta S_{Sh} = \frac{\sum_1^p \sin(\frac{m}{2}\,\Delta\varphi)}{p} - \frac{\sum_1^n \sin(\frac{m}{2}\,\Delta\varphi)}{n}$$

$N(\Delta S^{Sh}_{\perp})$

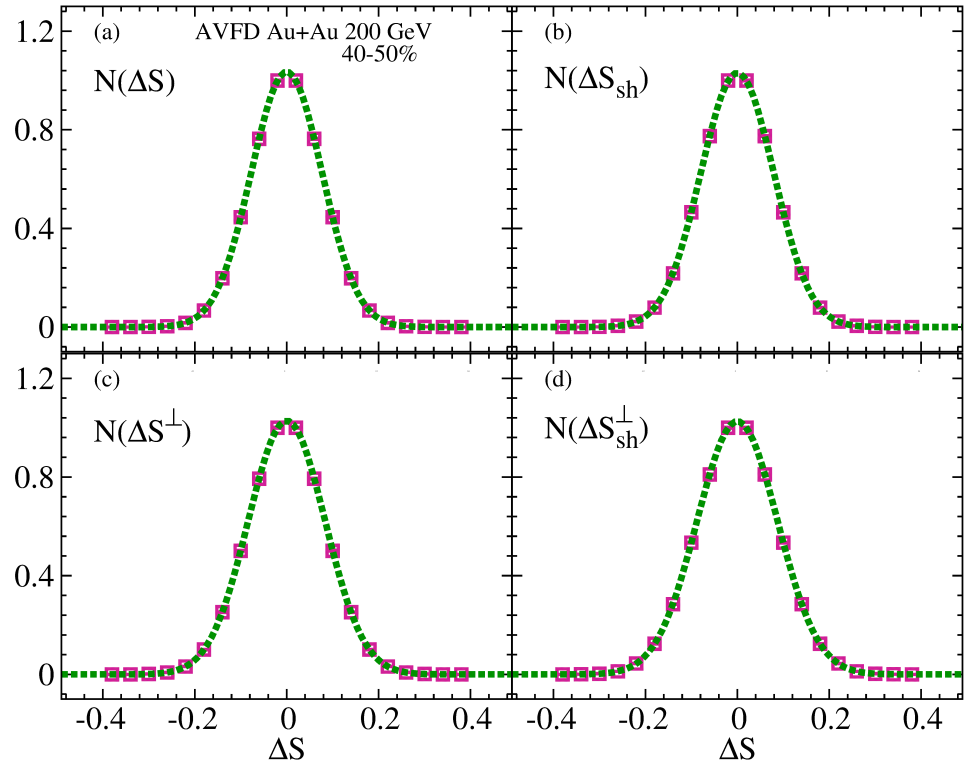
$$\Delta S^{Sh}_{\perp} = \frac{\sum_1^p \cos(\frac{m}{2}\,\Delta\varphi)}{p} - \frac{\sum_1^n \cos(\frac{m}{2}\,\Delta\varphi)}{n}$$

❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al. arXiv: 1710.01717

- ➢ $N(\mathrm{X})$ distributions:
  - ✓ Gaussian like distribution
- ➢ $N(\Delta S)$ distributions:
  - ✓ Carry charge separation information
- ➢ $N(\Delta S_{\mathrm{sh}})$ distributions:
  - ✓ Carry no charge separation information

$$Fit(x) = a\, e^{-0.5\left(\frac{x}{\sigma}\right)^2}$$

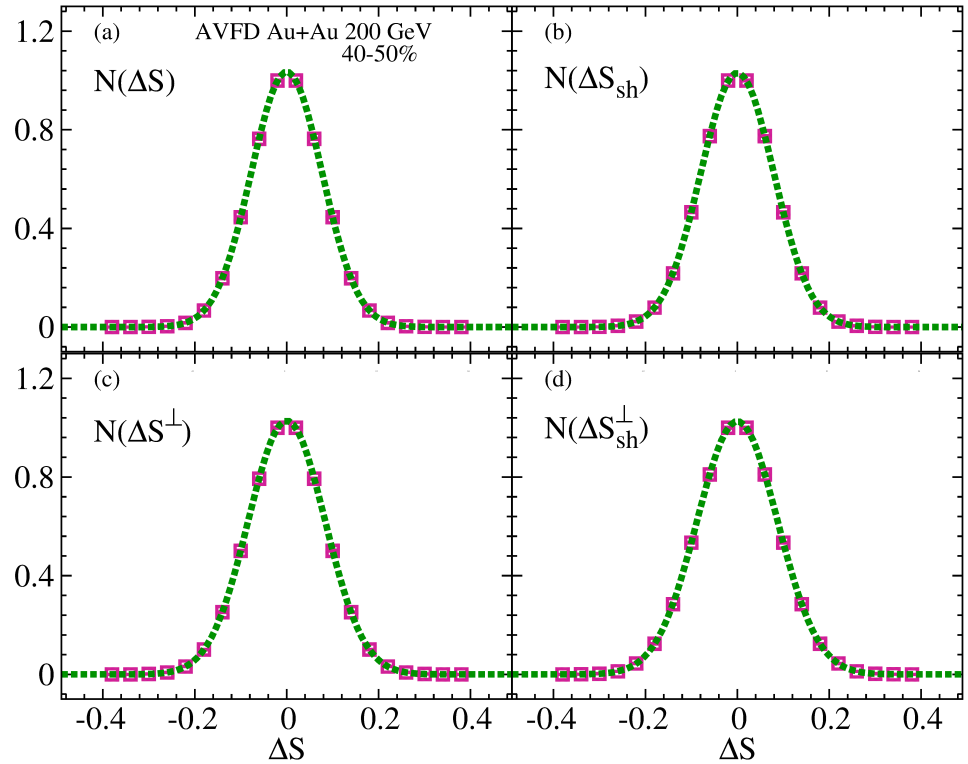


❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al. arXiv: 1710.01717

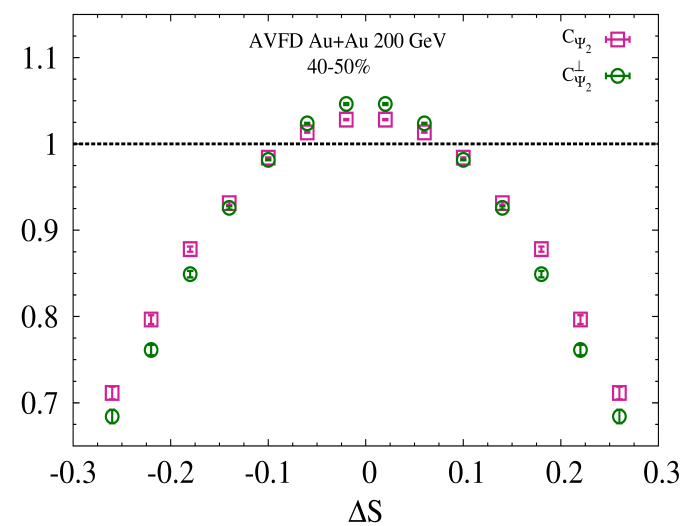
- ➢ $N(\mathrm{X})$ distributions:
  - ✓ Gaussian like distribution
- ➢ $N(\Delta S)$ distributions:
  - ✓ Carry charge separation information
- ➢ $N(\Delta S_{\mathrm{sh}})$ distributions:
  - ✓ Carry no charge separation information

$$Fit(x) = a\, e^{-0.5\left(\frac{x}{\sigma}\right)^2}$$



$$C^{\perp}_{\Psi_m}(\Delta S) = \frac{N(\Delta S_{\perp})}{N(\Delta S^{Sh}_{\perp})}$$

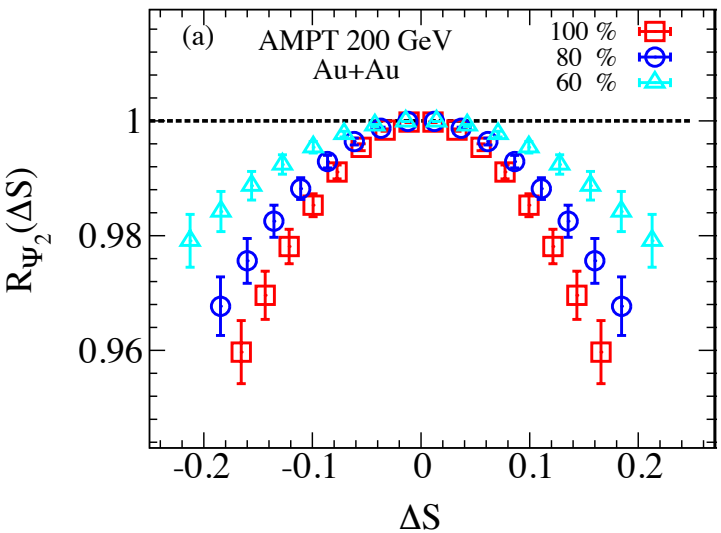
$$C_{\Psi_m}(\Delta S) = \frac{N(\Delta S\ \ )}{N(\Delta S_{sh})}$$



❖ $R_{\Psi_m}(\Delta S)$ Width

- Charge separation magnitude is reflected in the width of the $R_{\Psi_m}(\Delta S)$ distribution which is affected by:
  - ✓ Number fluctuations
  - ✓ EP-resolution

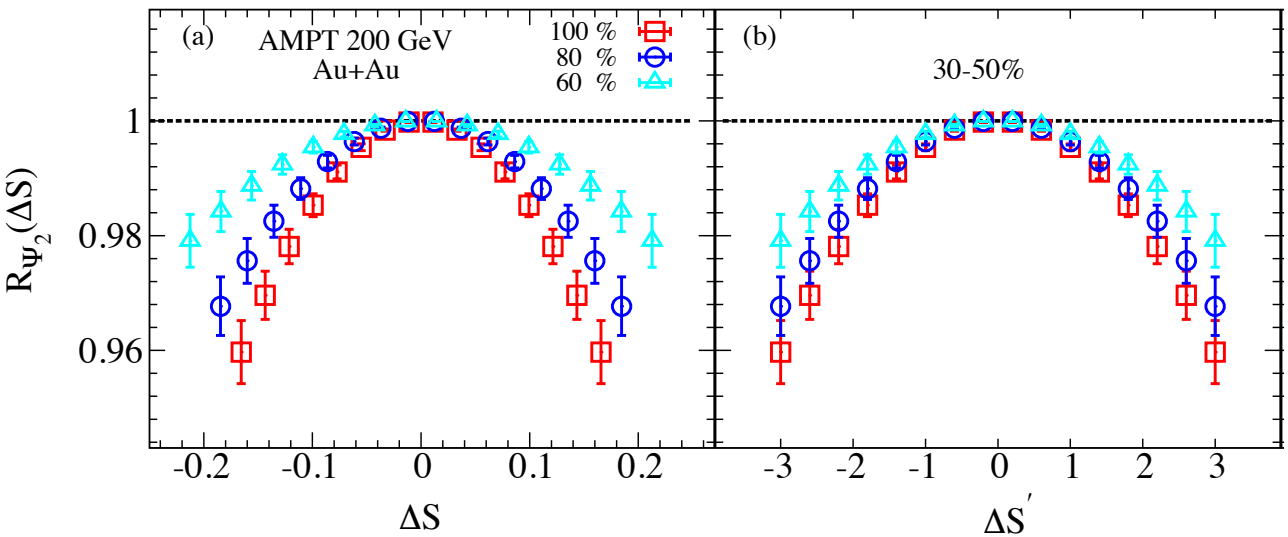
Subdivide the event multiplicity into different percentage



❖ $R_{\Psi_m}(\Delta S)$ Width

- Charge separation magnitude is reflected in the width of the $R_{\Psi_m}(\Delta S)$ distribution which is affected by:
  - ✓ Number fluctuations
  - ✓ EP-resolution

Subdivide the event multiplicity into different percentage



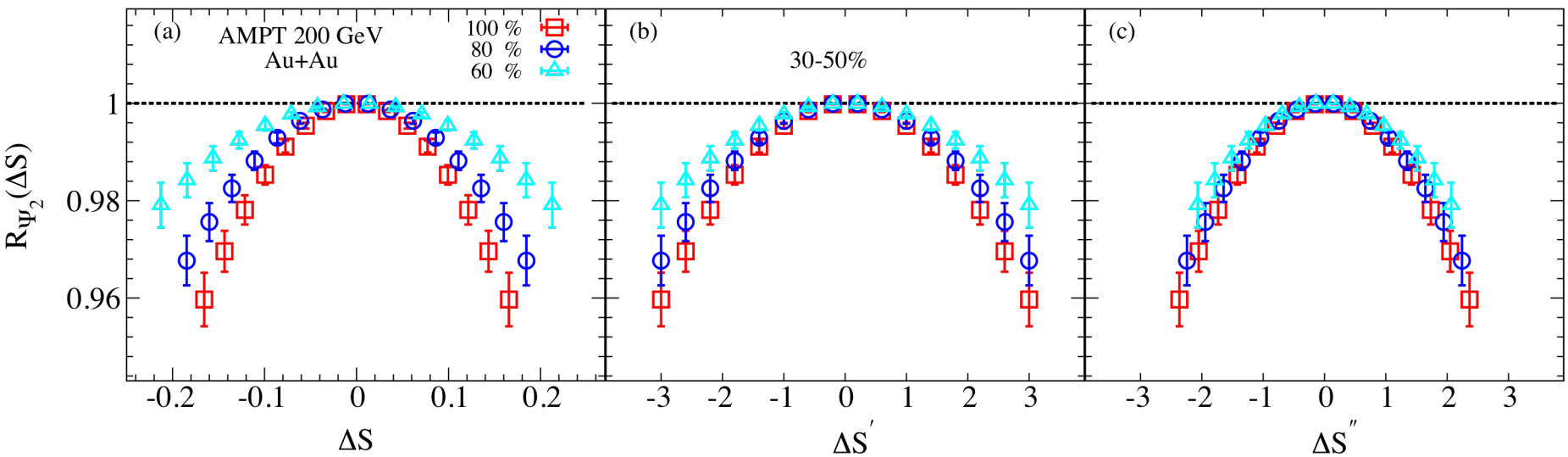
$$\Delta S' = \Delta S / \sigma_{\Delta S^{sh}}$$

- We can account for both number fluctuations and EP-resolution effect on the width of the $R_{\Psi_m}(\Delta S)$

❖ $R_{\Psi_m}(\Delta S)$ Width

- Charge separation magnitude is reflected in the width of the $R_{\Psi_m}(\Delta S)$ distribution which is affected by:
  - ✓ Number fluctuations
  - ✓ EP-resolution

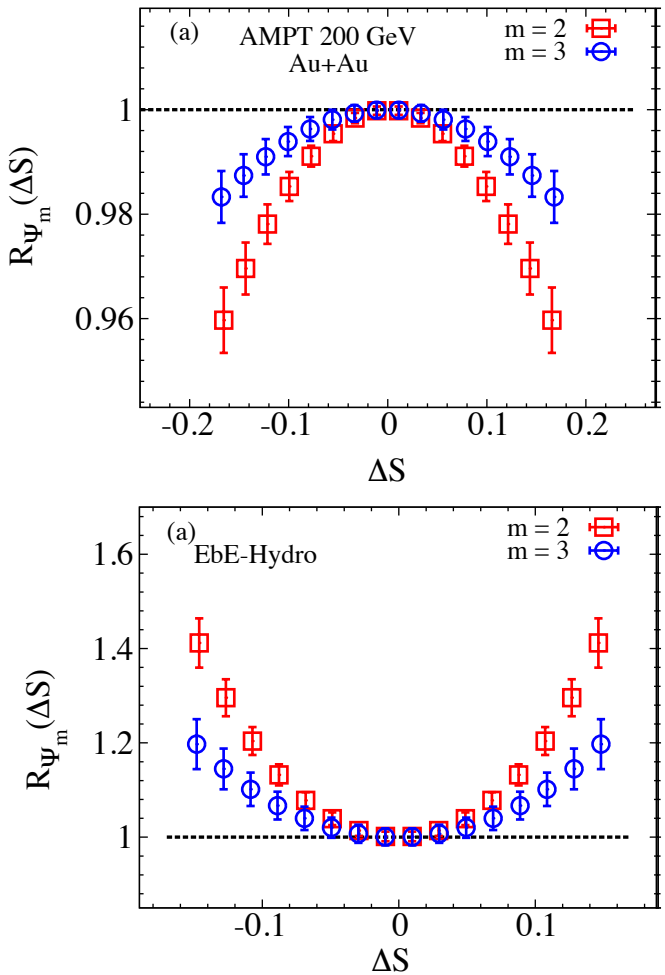
Subdivide the event multiplicity into different percentage



$$\Delta S' = \Delta S / \sigma_{\Delta S^{sh}} \qquad \Delta S'' = \Delta S' . Res$$

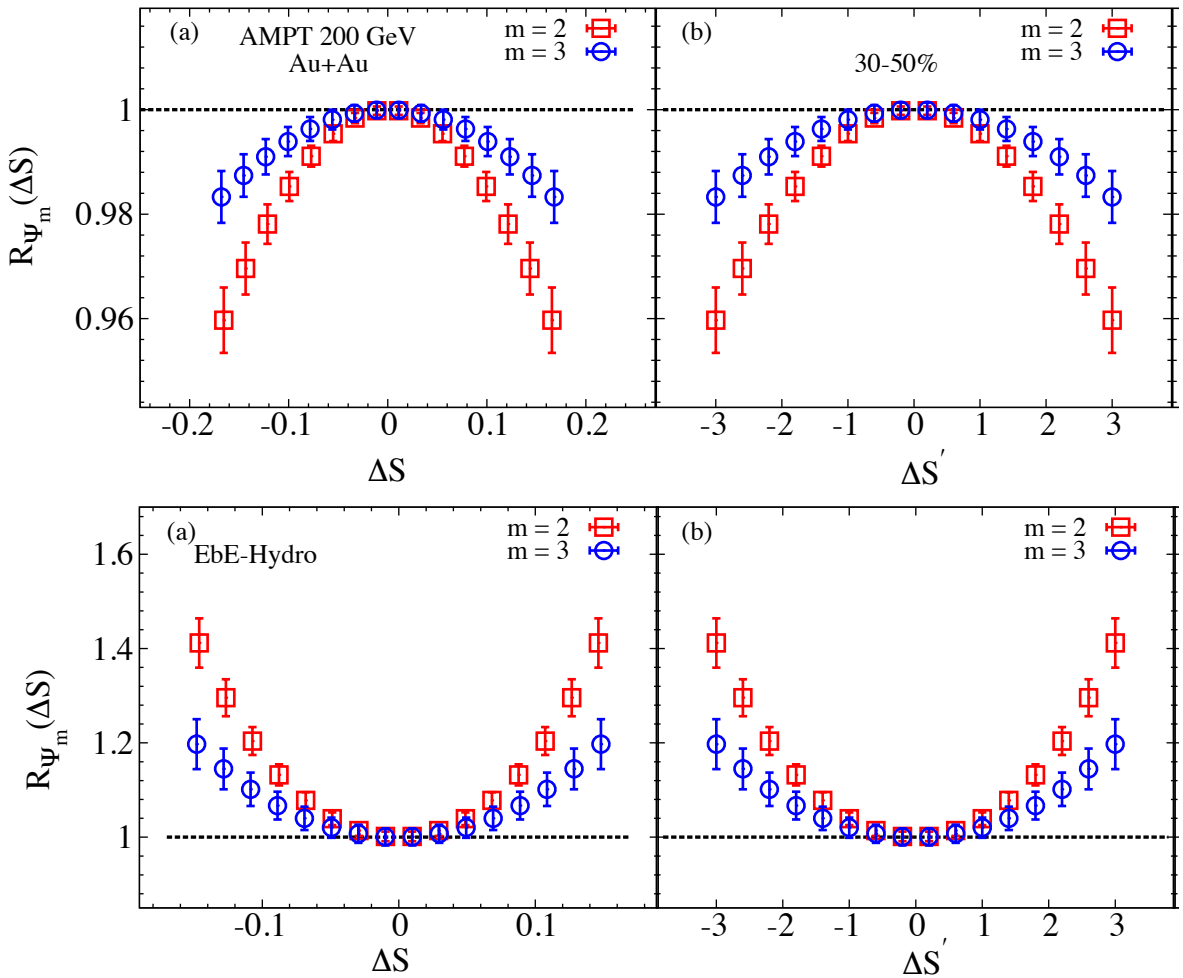
- We can account for both number fluctuations and EP-resolution effect on the width of the $R_{\Psi_m}(\Delta S)$

❖ $R_{\Psi_m}(\Delta S)$ In Background Models



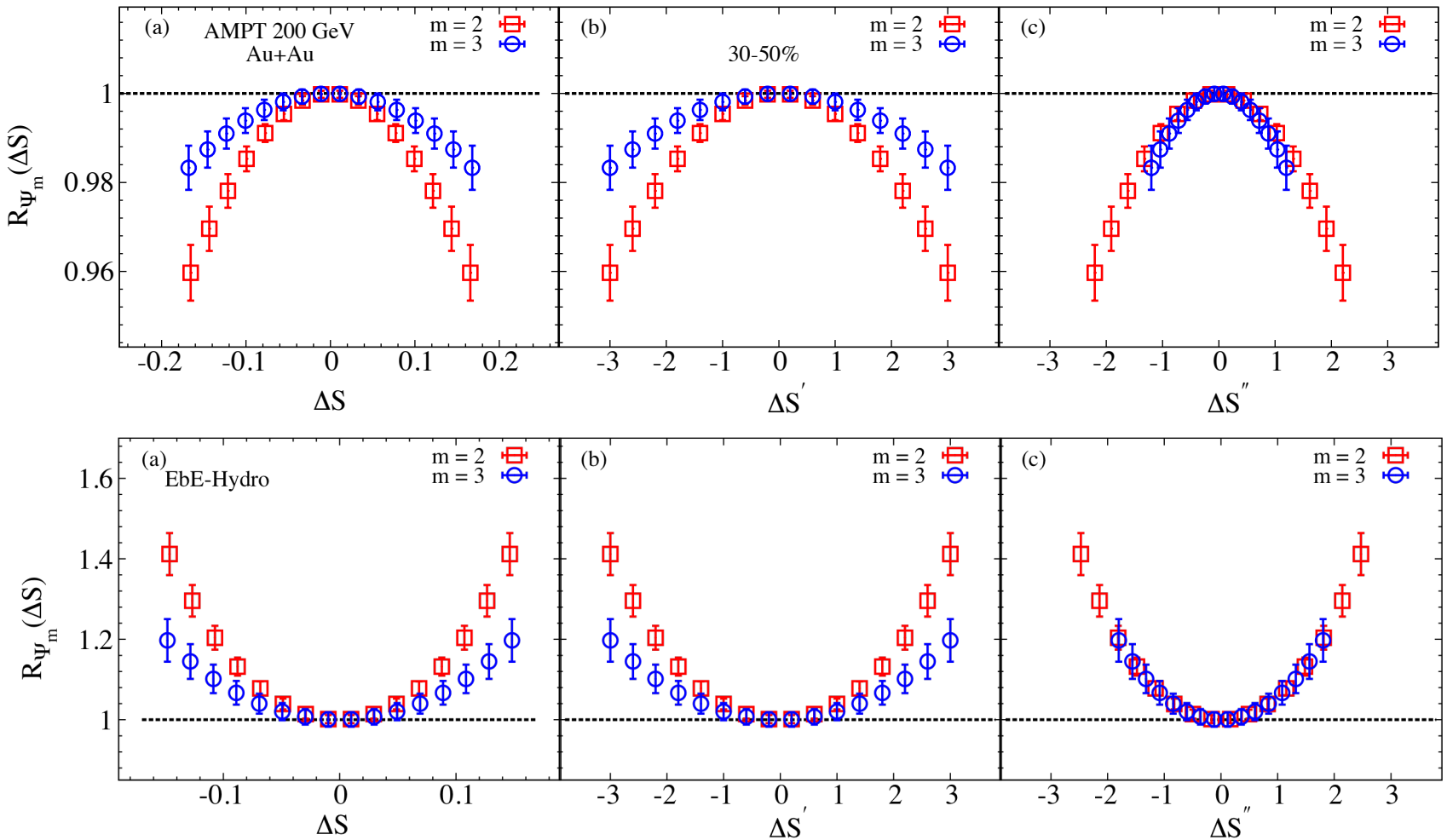
➢ Validation of the expected similarity between the patterns for $R_{\Psi_2}(\Delta S)$ and $R_{\Psi_3}(\Delta S)$ for background-driven charge separation

❖ $R_{\Psi_m}(\Delta S)$ In Background Models



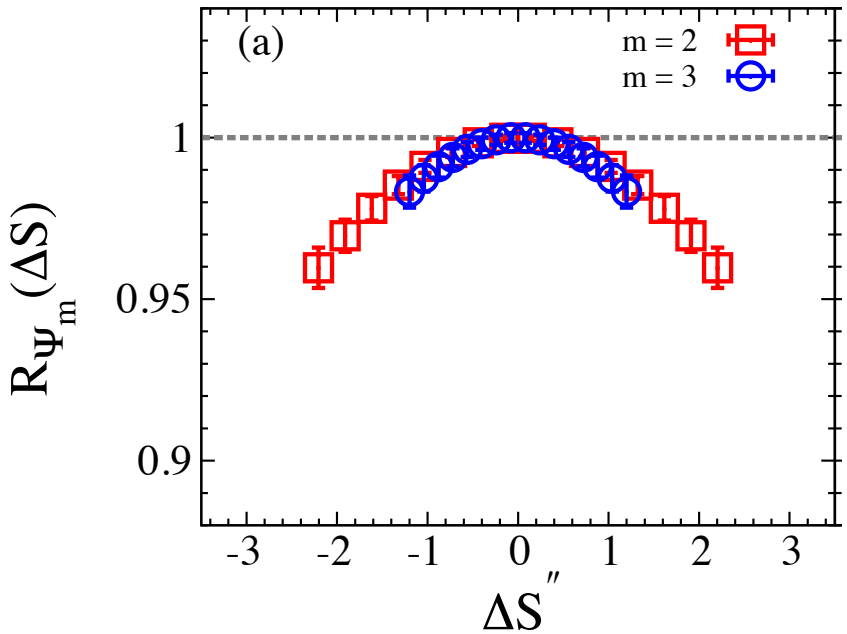
➢ Validation of the expected similarity between the patterns for $R_{\Psi_2}(\Delta S)$ and $R_{\Psi_3}(\Delta S)$ for background-driven charge separation

❖ $R_{\Psi_m}(\Delta S)$ In Background Models



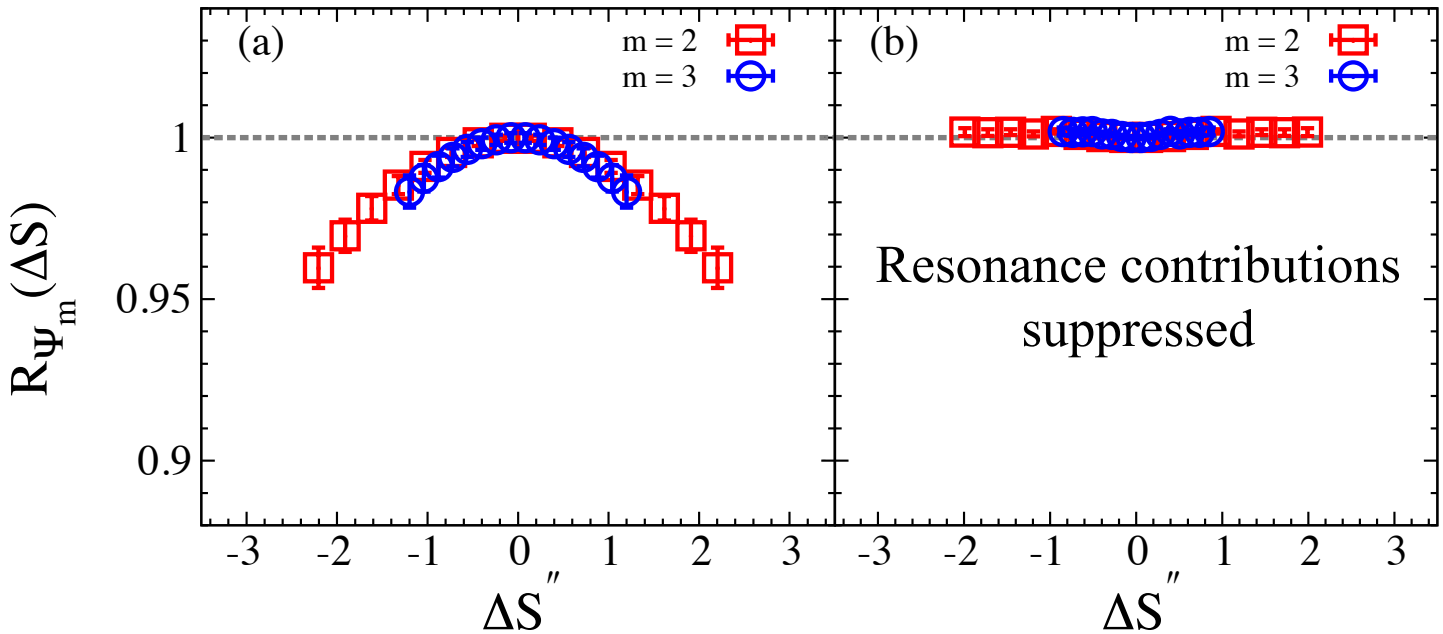
➢ Validation of the expected similarity between the patterns for $R_{\Psi_2}(\Delta S)$ and $R_{\Psi_3}(\Delta S)$ for background-driven charge separation

❖ $R_{\Psi_m}(\Delta S)$ In Background Models



- Validation of the expected similarity between the patterns for $R_{\Psi_2}(\Delta S)$ and $R_{\Psi_3}(\Delta S)$ for background-driven charge separation

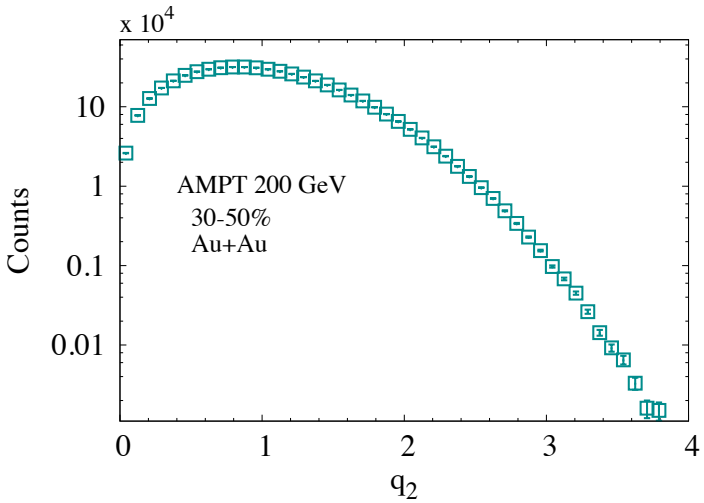
❖ $R_{\Psi_m}(\Delta S)$ In Background Models

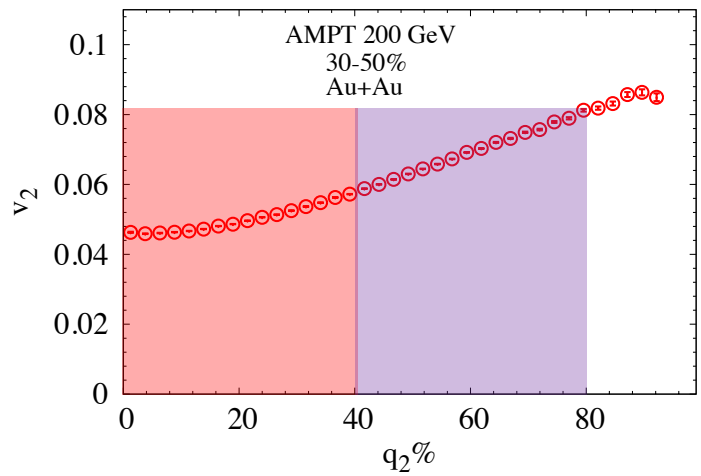


- Validation of the expected similarity between the patterns for $R_{\Psi_2}(\Delta S)$ and $R_{\Psi_3}(\Delta S)$ for background-driven charge separation

- Suppressing the resonance contributions leads to a flat shape for $R_{\Psi_2}(\Delta S)$ and $R_{\Psi_3}(\Delta S)$ for background-driven charge separation

❖ $R_{\Psi_m}(\Delta S)$ In Background Models



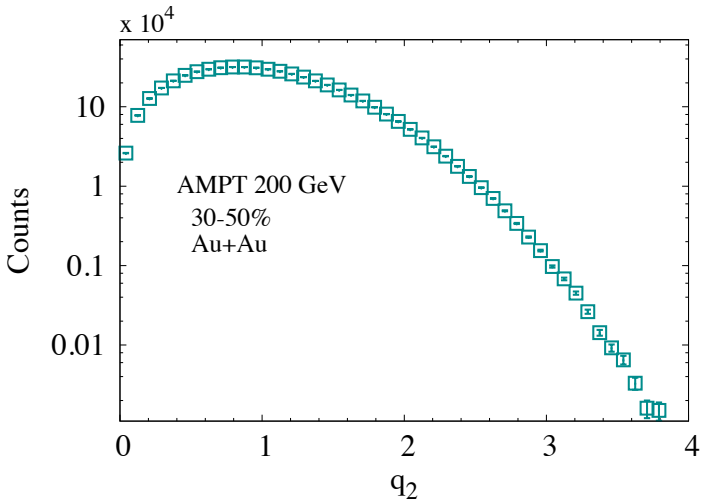


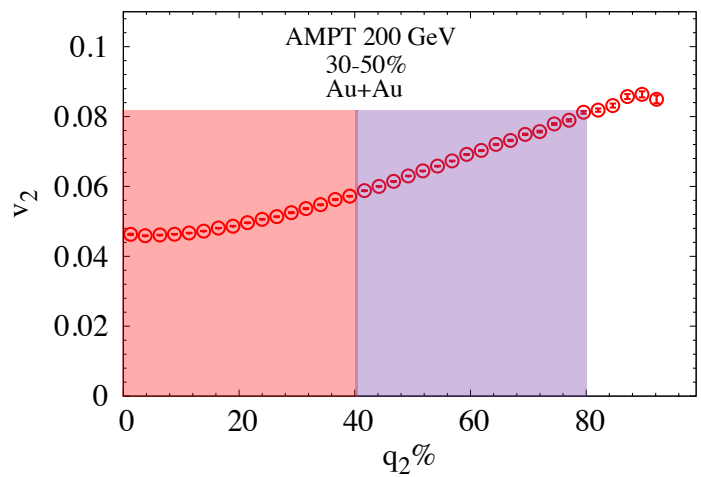
- Events are further subdivided into groups with different q_2 magnitude:

$$Q_{2,x} = \sum_{i=1}^{M} \cos(2\,\varphi_i) \qquad Q_{2,y} = \sum_{i=1}^{M} sin(2\,\varphi_i)$$

$$|Q_2| = \sqrt{Q_{2,x}^2 + Q_{2,y}^2} \qquad q_2 = \frac{|Q_2|}{\sqrt{M}}$$

❖ $R_{\Psi_m}(\Delta S)$ In Background Models

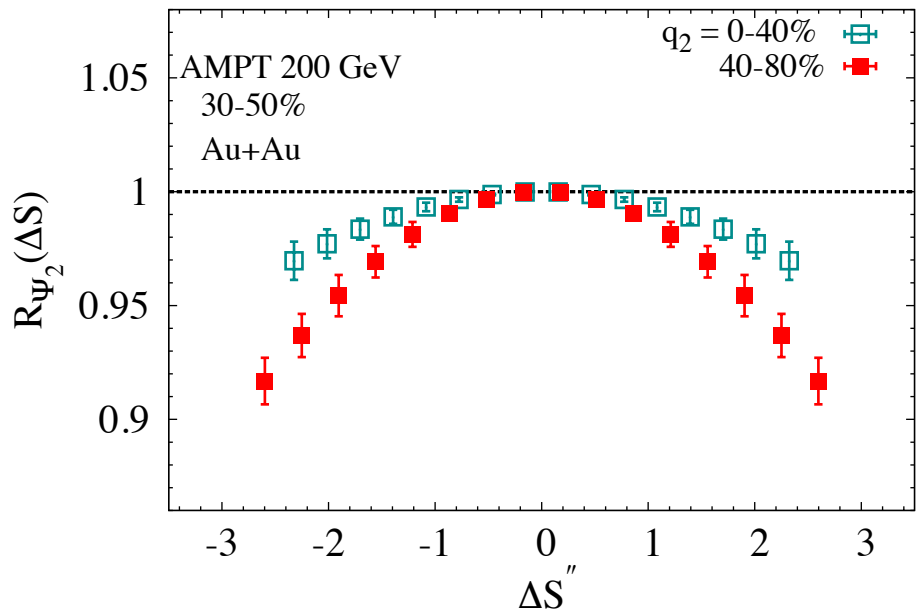




➢ Events are further subdivided into groups with different q_2 magnitude:

$$Q_{2,x} = \sum_{i=1}^{M} \cos(2\,\varphi_i) \qquad Q_{2,y} = \sum_{i=1}^{M} sin(2\,\varphi_i)$$

$$|Q_2| = \sqrt{Q_{2,x}^2 + Q_{2,y}^2} \qquad q_2 = \frac{|Q_2|}{\sqrt{M}}$$

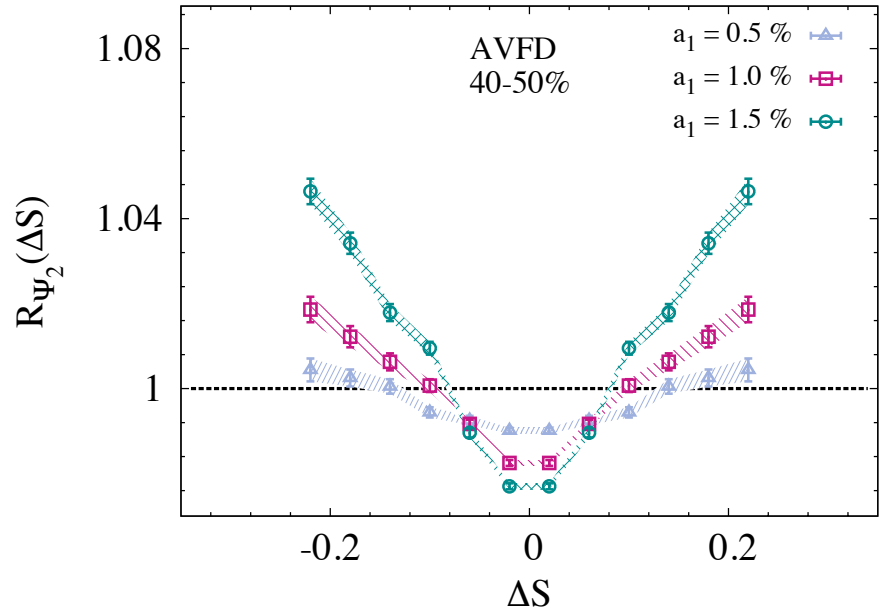


➢ The events-shape selections validation the expected resonance contributions to the $R_{\Psi_2}(\Delta S)$

❖ $R_{\Psi_m}(\Delta S)$ Response

N. Magdy et al. arXiv: 1710.01717

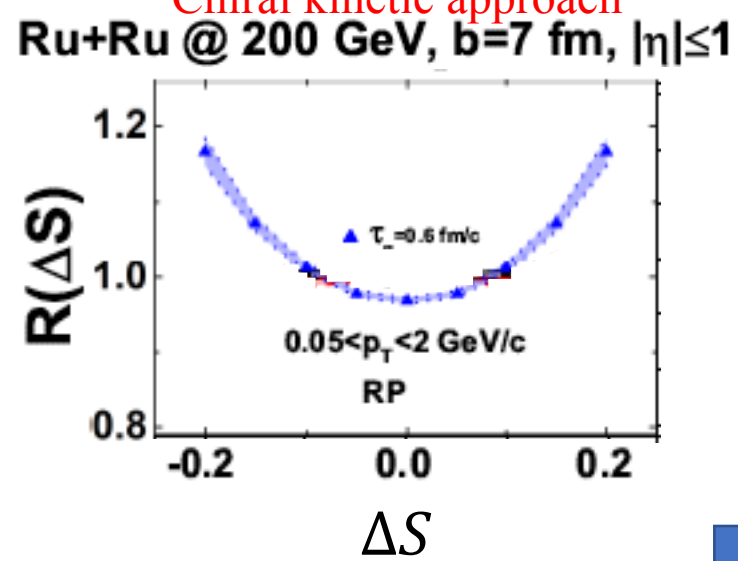
- Validation of the expected concave-shaped response of $R_{\Psi_2}(\Delta S)$ to CME-driven charge separation input in CME-events.



- Signal magnitude reflected in the widths of the distributions
  - Smaller widths for larger input signal

Chiral kinetic approach

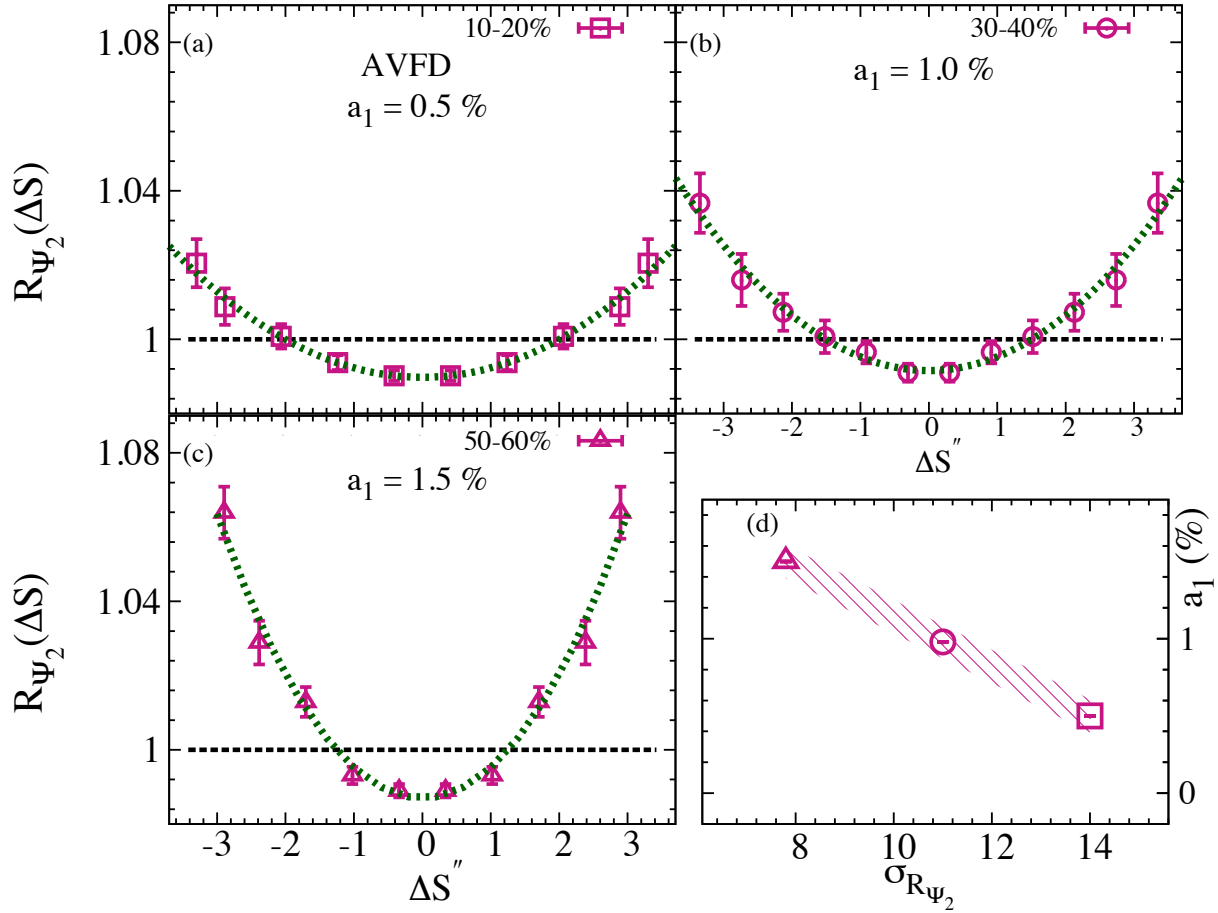
Y. Sun et al. arXiv: 1803.06043



Concaved-shape distribution for input charge separation

❖ $R_{\Psi_m}(\Delta S)$ vs Centrality AVFD (bkg&CME)

N. Magdy et al. arXiv: 1710.01717

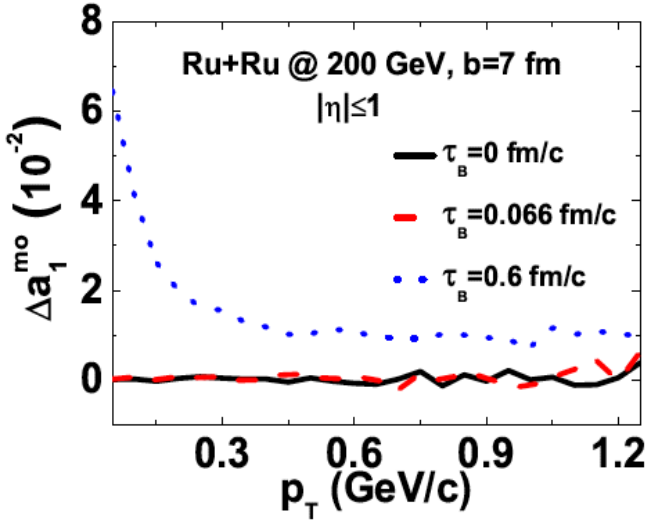


➢ Validation of the expected centrality dependence of $R_{\Psi_2}(\Delta S)$ to CME-driven charge separation input in AVFD events.

❖ $R_{\Psi_m}(\Delta S)$ vs (τ_B)

Y. Sun et al.
arXiv: 1803.06043

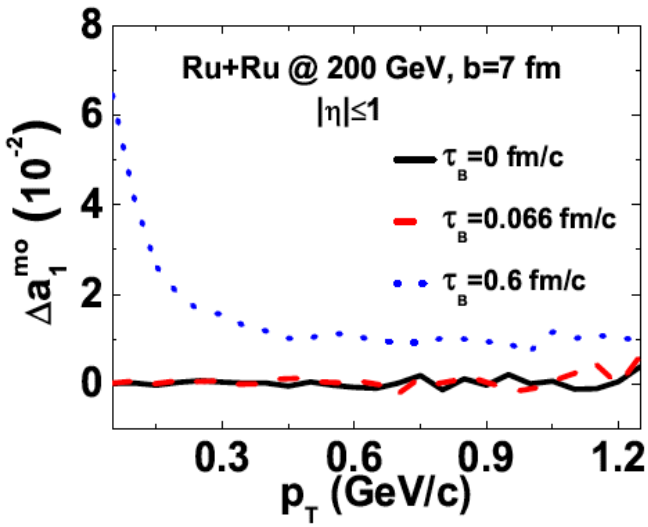
Chiral kinetic approach

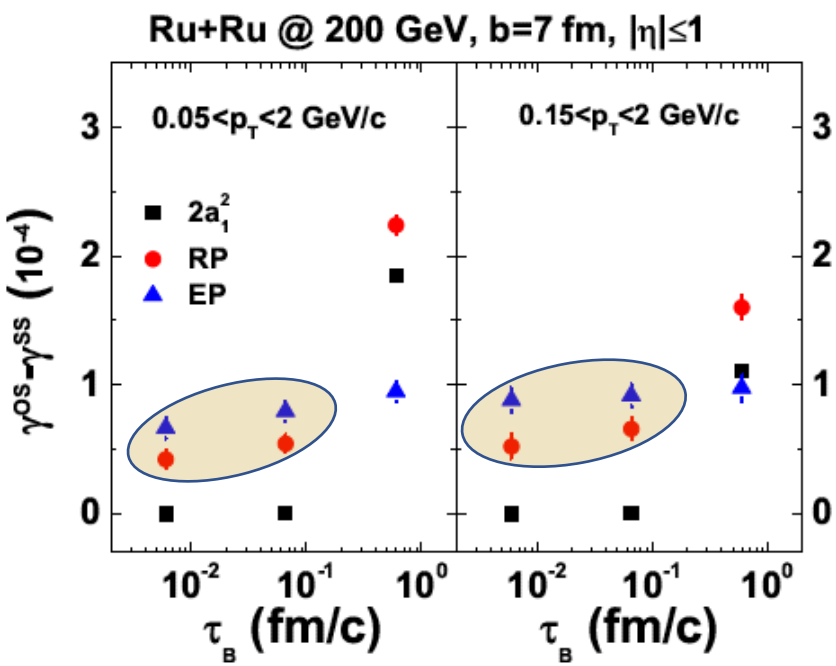


❖ $R_{\Psi_m}(\Delta S)$ vs (τ_B)

Chiral kinetic approach

Y. Sun et al.
arXiv: 1803.06043



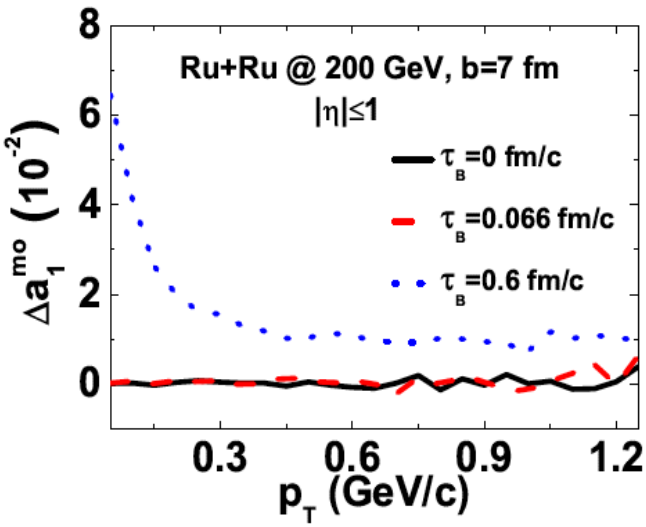


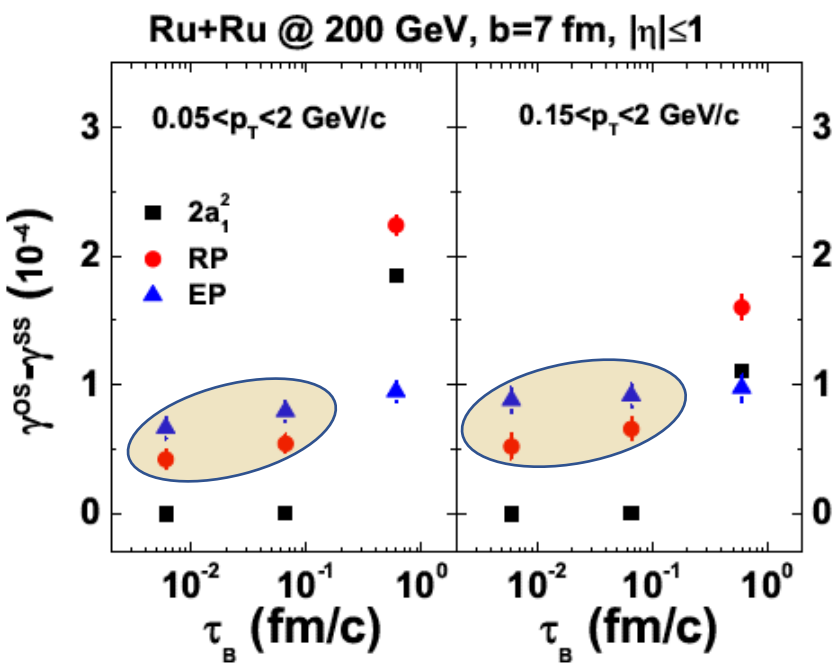
- $a_1 \sim 0$ for $\tau_B < 0.6$ fm/c
  - ✓ $\Delta\gamma$ shows non zero value

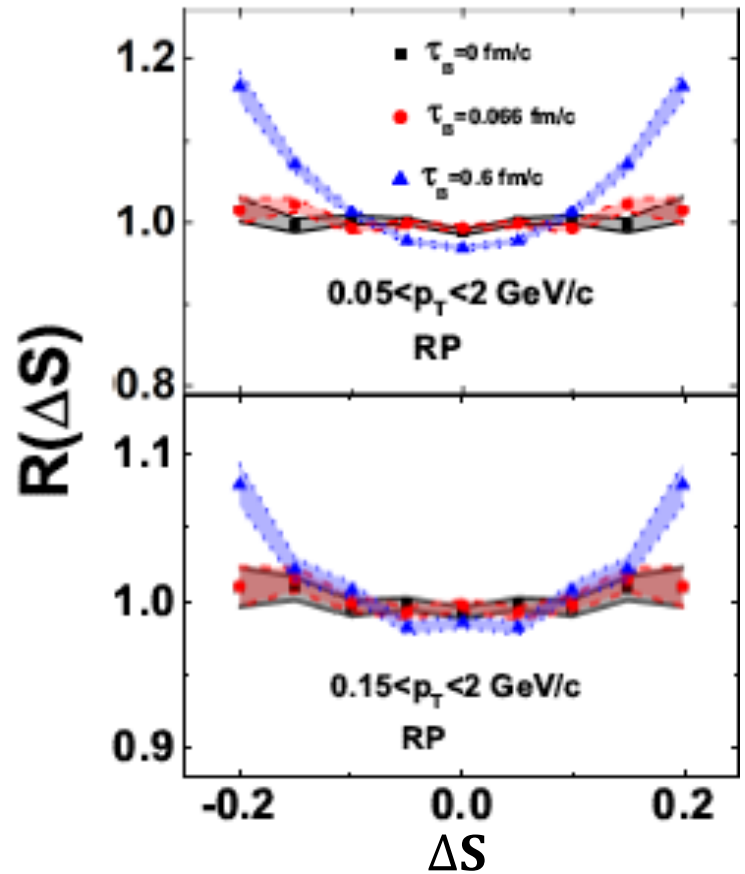
❖ $R_{\Psi_m}(\Delta S)$ vs (τ_B)

Chiral kinetic approach

Y. Sun et al.
arXiv: 1803.06043

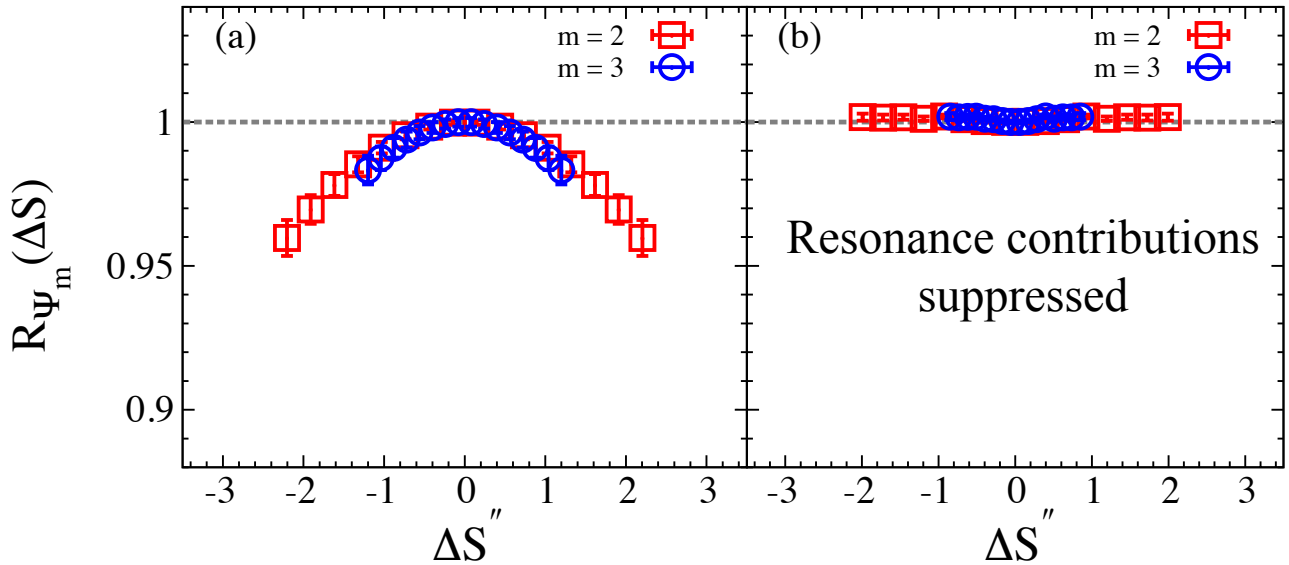


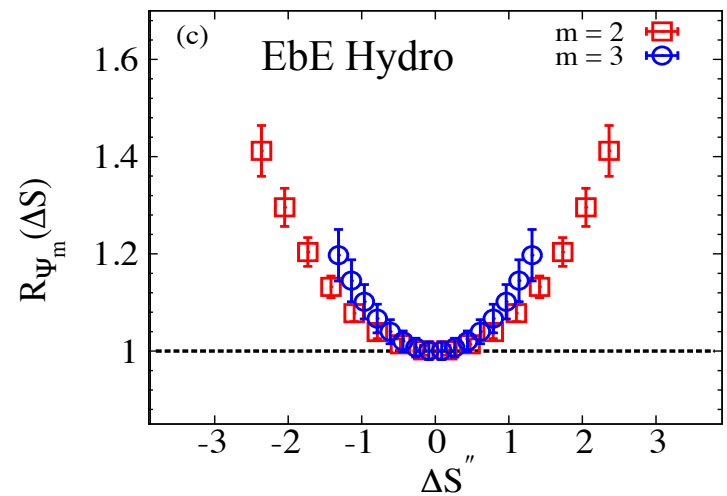




- $a_1 \sim 0$ for $\tau_B < 0.6$ fm/c
  - ✓ $\Delta\gamma$ shows non zero value
  - ✓ $R_{\Psi_2}(\Delta S)$ shows flat shape

❖ $R_{\Psi_m}(\Delta S)$vs Background





- Expected similarity between $R_{\Psi_2}(\Delta S)$ and $R_{\Psi_3}(\Delta S)$ for background-driven charge separation

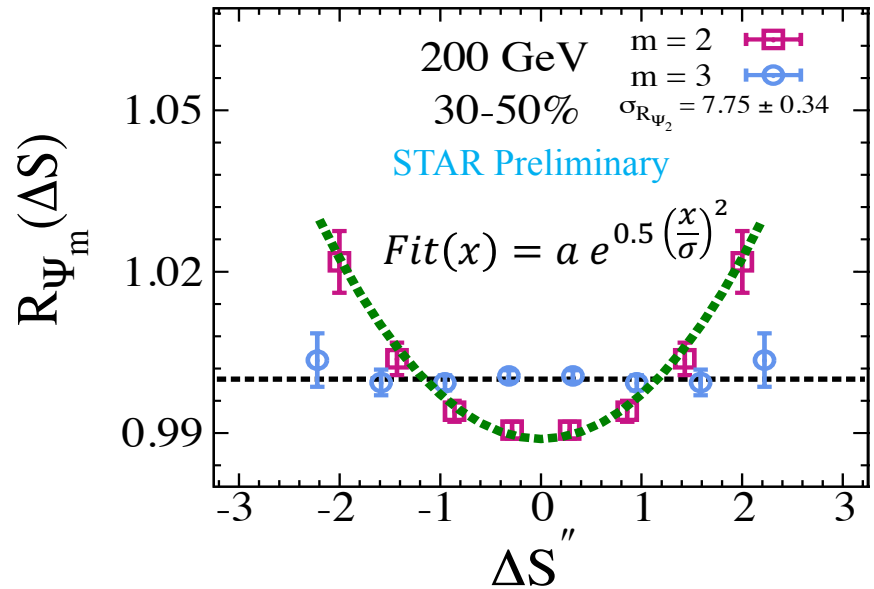
❖ $R_{\Psi m}(\Delta S)$ Measurements at RHIC

- ✓ Event plane and
- ✓ Systems dependence

➢ Measurements for R_{Ψ_m} show:

- ✓ Different response for $R_{\Psi 2}$ and $R_{\Psi 3}$

Presented at Workshop on Chirality 2018



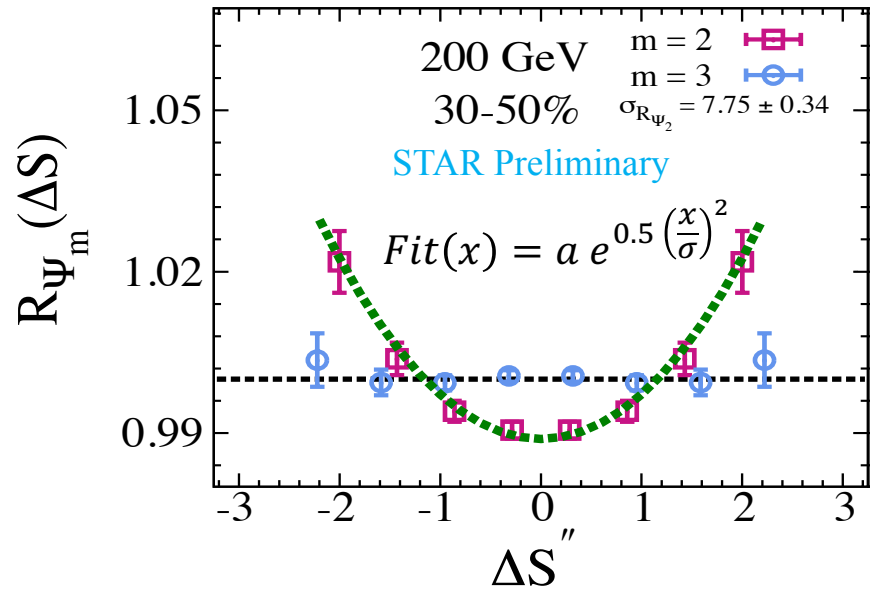
❖ $R_{\Psi m}(\Delta S)$ Measurements at RHIC

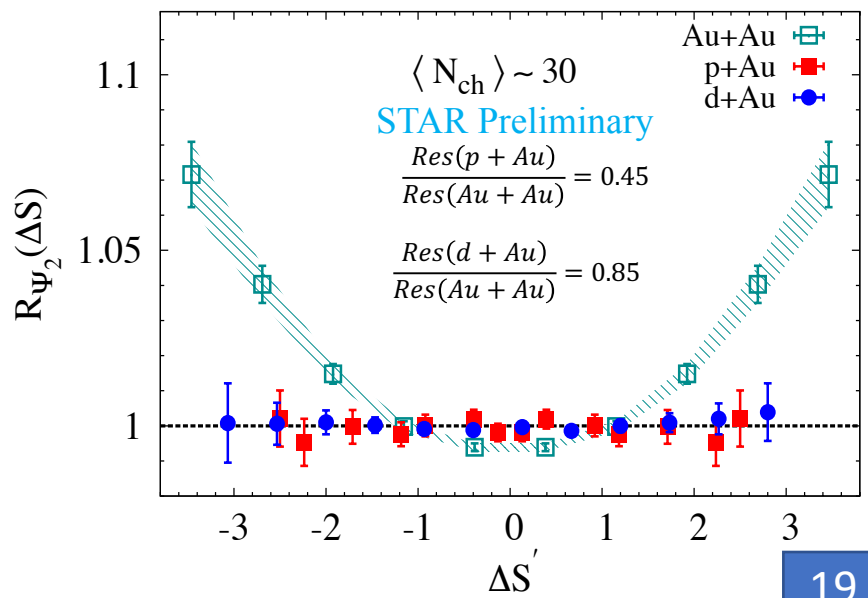
- ✓ Event plane and
- ✓ Systems dependence

➢ Measurements for R_{Ψ_m} show:

- ✓ Different response for $R_{\Psi 2}$ and $R_{\Psi 3}$
- ✓ Different response for small (p(d)+Au) and large (Au+Au) systems

Presented at Workshop on Chirality 2018





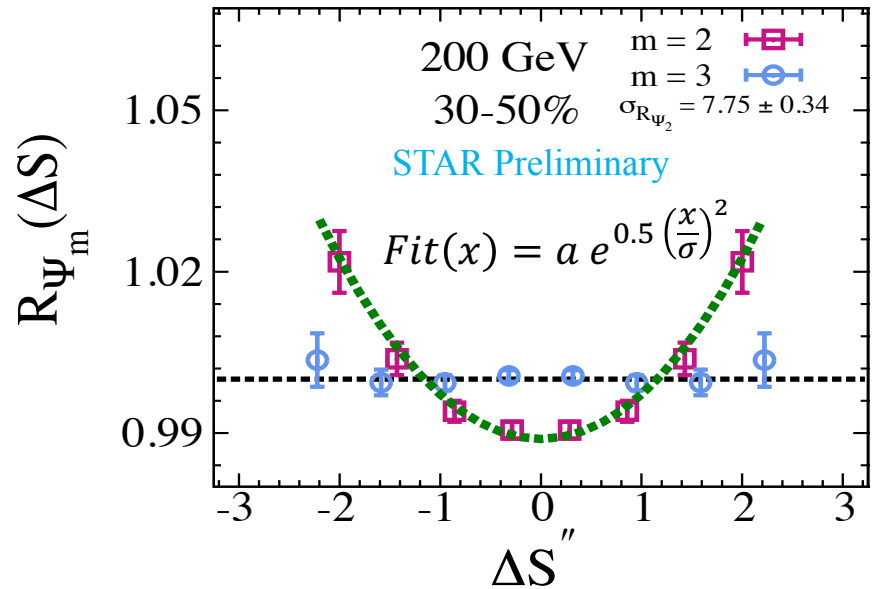
❖ $R_{\Psi m}(\Delta S)$ Measurements at RHIC

- ✓ Event plane and
- ✓ Systems dependence

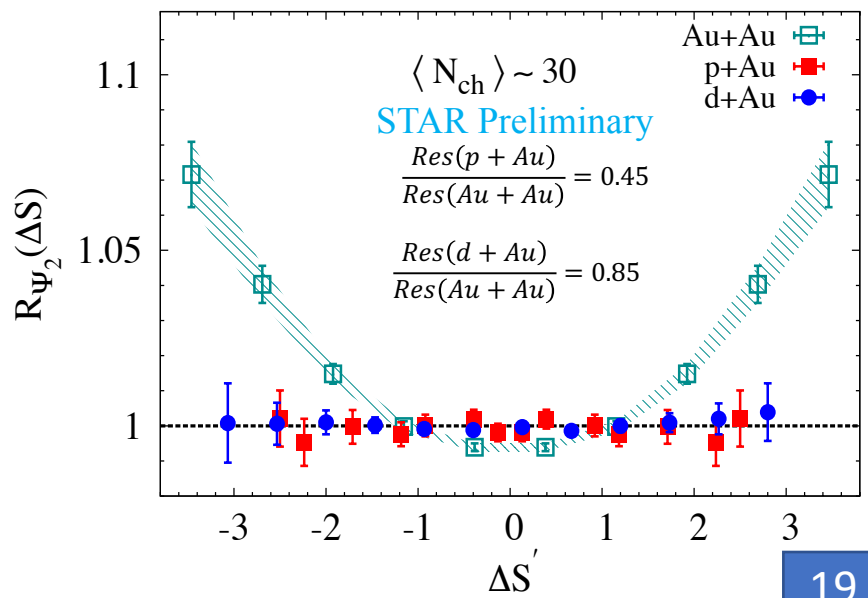
Presented at Workshop on Chirality 2018

➢ Measurements for R_{Ψ_m} show:

- ✓ Different response for $R_{\Psi 2}$ and $R_{\Psi 3}$
- ✓ Different response for small (p(d)+Au) and large (Au+Au) systems



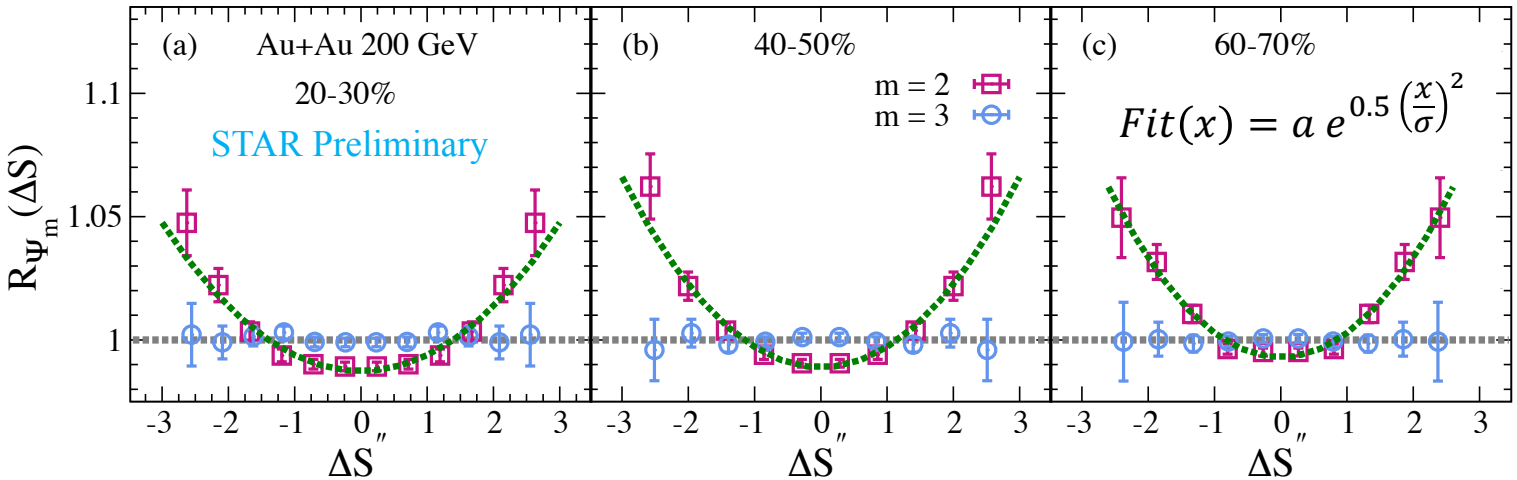
➢ R_{Ψ_m} results are consistent with the expectation for CME-driven charge separation.



❖ $R_{\Psi m}(\Delta S)$ Measurements at RHIC

✓ $R_{\Psi m}(\Delta S)$ vs centrality

Presented at Workshop on Chirality 2018



➢ Measurements show:

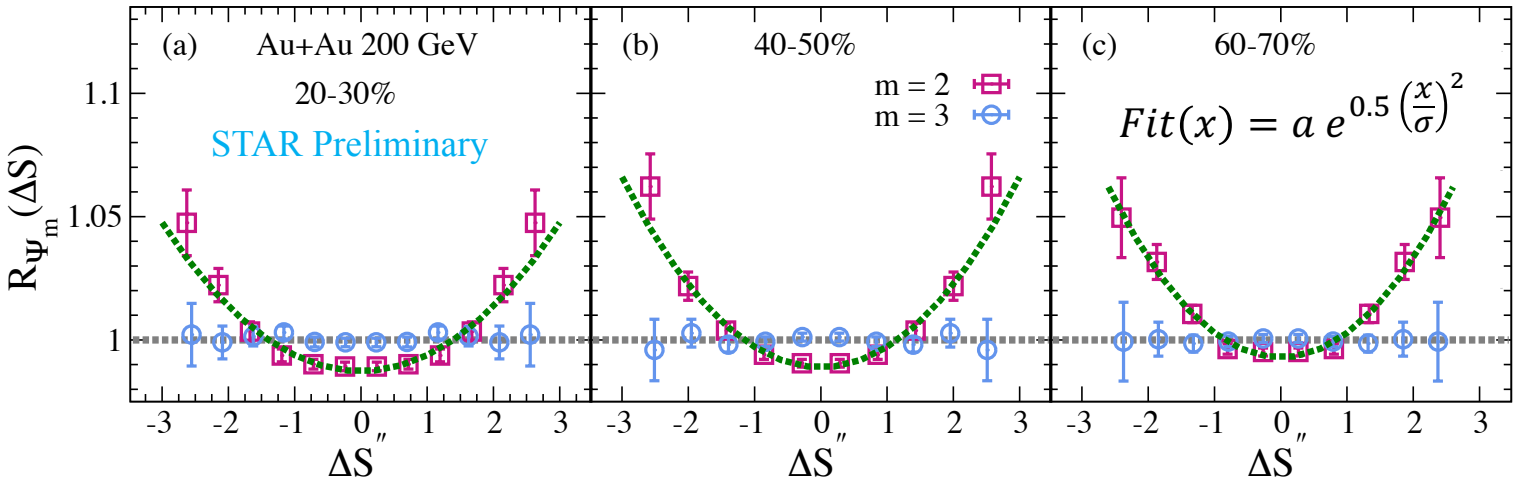
✓ Different response for Ψ_2 and Ψ_3

✓ $R_{\Psi 2}$ width is centrality dependent

❖ $R_{\Psi m}(\Delta S)$ Measurements at RHIC

✓ $R_{\Psi m}(\Delta S)$ vs centrality

Presented at Workshop on Chirality 2018

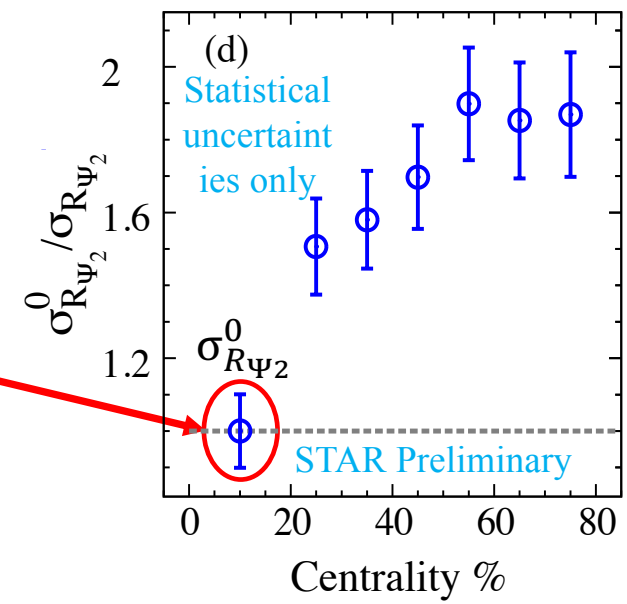


➢ Measurements show:

✓ Different response for Ψ_2 and Ψ_3

✓ $R_{\Psi 2}$ width is centrality dependent

All widths are normalized to the width of 0-20% (smallest a_1)

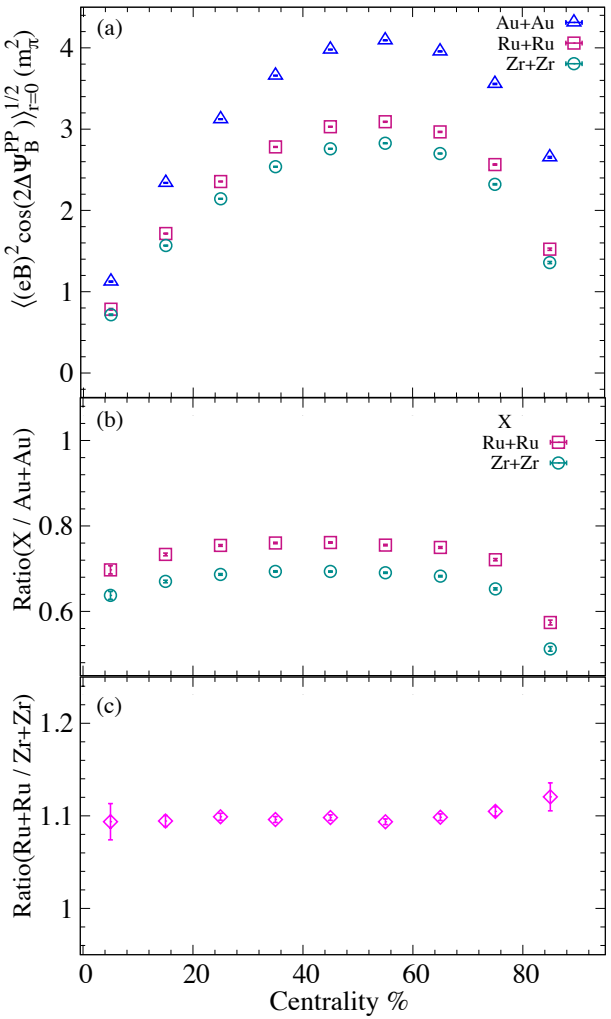


➢ $R_{\Psi m}$ results are consistent with the expectation for CME-driven charge separation.

❖ $R_{\Psi_m}(\Delta S)$ In Isobaric Collisions

N. Magdy et al. arXiv: 1803.02416

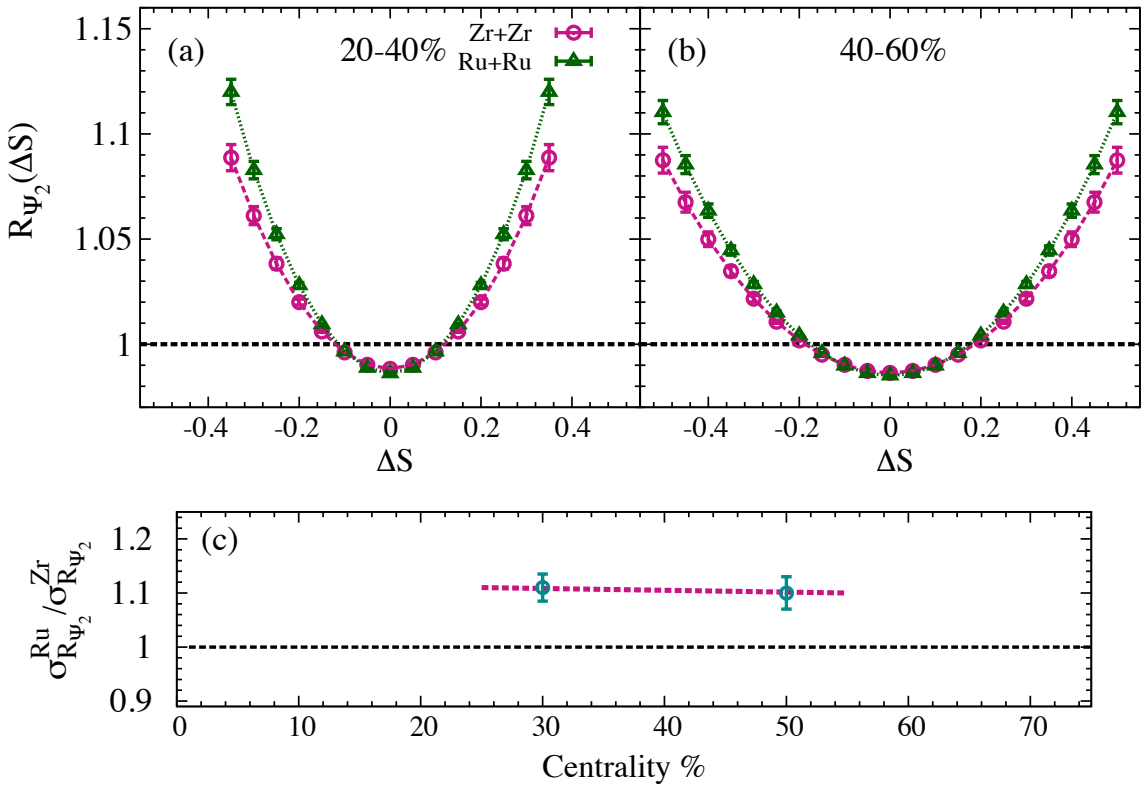
➢ AVFD predictions for the Ru+Ru and Zr+Zr isobaric systems

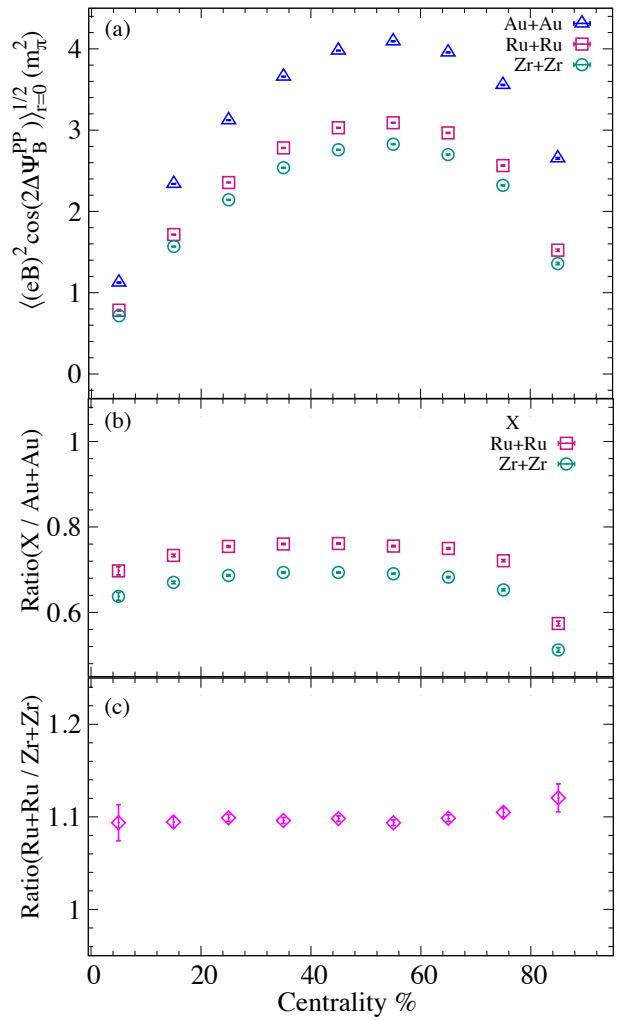


❖ $R_{\Psi_m}(\Delta S)$ In Isobaric Collisions

N. Magdy et al. arXiv: 1803.02416

➢ AVFD predictions for the Ru+Ru and Zr+Zr isobaric systems



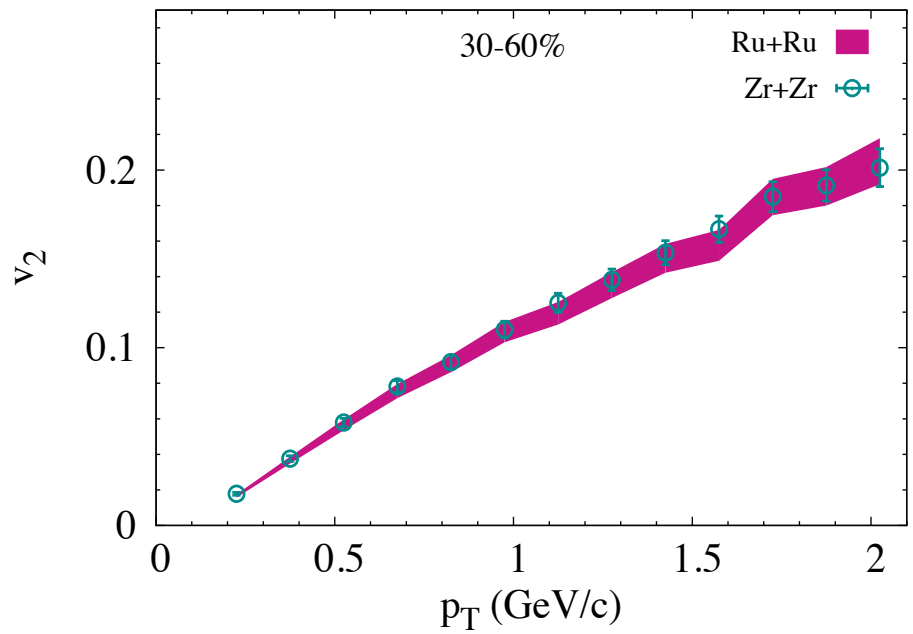


➢ Validation of the expected isobaric dependence of $R_{\Psi_2}(\Delta S)$ to CME-driven charge separation input in AVFD events.

❖ $R_{\Psi_m}(\Delta S)$ In Isobaric Collisions

N. Magdy et al. arXiv: 1803.02416

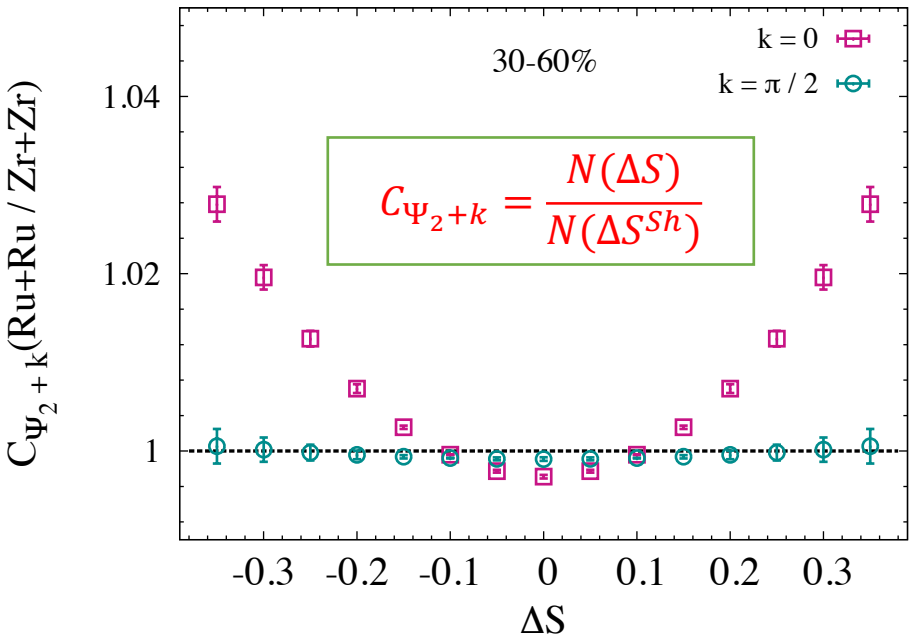
➢ AVFD predictions for the Ru+Ru and Zr+Zr isobaric systems

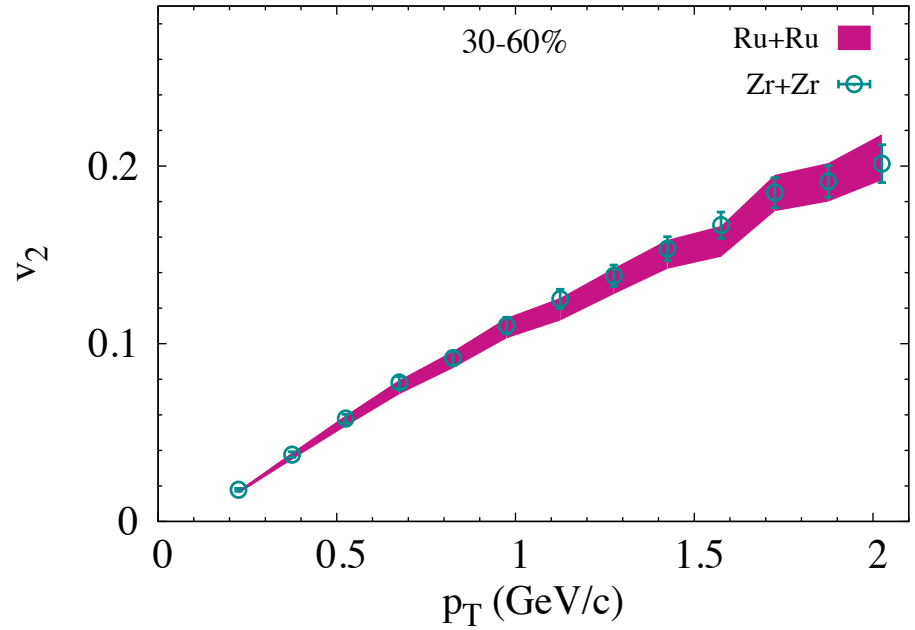


❖ $R_{\Psi_m}(\Delta S)$ In Isobaric Collisions

N. Magdy et al. arXiv: 1803.02416

➢ AVFD predictions for the Ru+Ru and Zr+Zr isobaric systems





➢ Isobaric ratios of the correlation function can be used to characterize both signal and background

✓ Crucial for isobar run!

❖ Conclusion

The charge separation correlators $R_{\Psi_m}(\Delta S)$, are investigated in different models and for STAR data.

- R_{Ψ_m} In Background models:

- R_{Ψ_m} In Data:

- R_{Ψ_2} In Isobaric Collisions:

❖ Conclusion

The charge separation correlators $R_{\Psi_m}(\Delta S)$, are investigated in different models and for STAR data.

- R_{Ψ_m} In Background models:
  - ✓ Expected similarity in the response for R_{Ψ_2} and R_{Ψ_3}

- R_{Ψ_m} In Data:

- R_{Ψ_2} In Isobaric Collisions:

❖ Conclusion

The charge separation correlators $R_{\Psi_m}(\Delta S)$, are investigated in different models and for STAR data.

- R_{Ψ_m} In Background models:
  - ✓ Expected similarity in the response for R_{Ψ_2} and R_{Ψ_3}
  - ✓ Expected response with and without resonances

- R_{Ψ_m} In Data:

- $R_{\Psi 2}$ In Isobaric Collisions:

❖ Conclusion

The charge separation correlators $R_{\Psi_m}(\Delta S)$, are investigated in different models and for STAR data.

- R_{Ψ_m} In Background models:
  - ✓ Expected similarity in the response for R_{Ψ_2} and R_{Ψ_3}
  - ✓ Expected response with and without resonances
  - ✓ Expected response for event-shape selections (q_2) on R_{Ψ_2}
- R_{Ψ_m} In Data:
- $R_{\Psi 2}$ In Isobaric Collisions:

❖ Conclusion

The charge separation correlators $R_{\Psi_m}(\Delta S)$, are investigated in different models and for STAR data.

- R_{Ψ_m} In Background models:
  - ✓ Expected similarity in the response for R_{Ψ_2} and R_{Ψ_3}
  - ✓ Expected response with and without resonances
  - ✓ Expected response for event-shape selections (q_2) on R_{Ψ_2}
- R_{Ψ_m} In Data:
  - ✓ Expected difference in the response for Ψ_2 and Ψ_3
- $R_{\Psi 2}$ In Isobaric Collisions:

❖ Conclusion

The charge separation correlators $R_{\Psi_m}(\Delta S)$, are investigated in different models and for STAR data.

- R_{Ψ_m} In Background models:
  - ✓ Expected similarity in the response for R_{Ψ_2} and R_{Ψ_3}
  - ✓ Expected response with and without resonances
  - ✓ Expected response for event-shape selections (q_2) on R_{Ψ_2}
- R_{Ψ_m} In Data:
  - ✓ Expected difference in the response for Ψ_2 and Ψ_3
  - ✓ Expected difference in the response for small (p(d)+Au) and large systems
    - Consistent with random $\vec{B}$ field orientations
- $R_{\Psi 2}$ In Isobaric Collisions:

❖ Conclusion

The charge separation correlators $R_{\Psi_m}(\Delta S)$, are investigated in different models and for STAR data.

- R_{Ψ_m} In Background models:
  - ✓ Expected similarity in the response for R_{Ψ_2} and R_{Ψ_3}
  - ✓ Expected response with and without resonances
  - ✓ Expected response for event-shape selections (q_2) on R_{Ψ_2}
- R_{Ψ_m} In Data:
  - ✓ Expected difference in the response for Ψ_2 and Ψ_3
  - ✓ Expected difference in the response for small (p(d)+Au) and large systems
    - Consistent with random $\vec{B}$ field orientations
  - ✓ R_{Ψ_2} width is decreasing with centrality
    - Consistent with the the $\vec{B}$-field increase with centrality
- R_{Ψ_2} In Isobaric Collisions:

❖ Conclusion

The charge separation correlators $R_{\Psi_m}(\Delta S)$, are investigated in different models and for STAR data.

- R_{Ψ_m} In Background models:
  - ✓ Expected similarity in the response for R_{Ψ_2} and R_{Ψ_3}
  - ✓ Expected response with and without resonances
  - ✓ Expected response for event-shape selections (q_2) on R_{Ψ_2}
- R_{Ψ_m} In Data:
  - ✓ Expected difference in the response for Ψ_2 and Ψ_3
  - ✓ Expected difference in the response for small (p(d)+Au) and large systems
    - Consistent with random $\vec{B}$ field orientations
  - ✓ R_{Ψ_2} width is decreasing with centrality
    - Consistent with the the $\vec{B}$-field increase with centrality
- R_{Ψ_2} In Isobaric Collisions:
  - ✓ Isobaric ratios of the correlation function can be used to characterize both signal and background