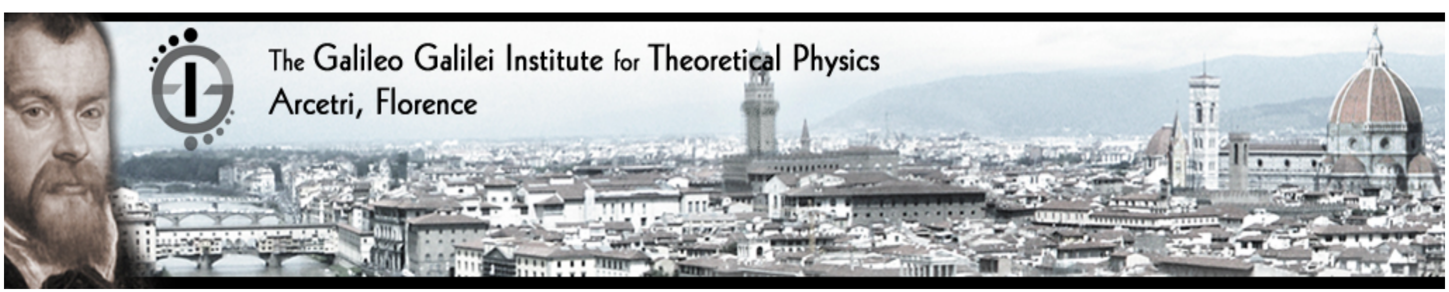
Beam energy and collision system dependence of charge separation using the $R_{\Psi_m}(\Delta S)$ correlator

Niseem Magdy
STAR Collaboration
Stony Brook University

niseem.abdelrahman@stonybrook.edu



Outline

- Introduction
  - ✓ Chiral Magnetic Effect (CME)
  - ✓ CME-charge separation vs Background-charge separation

Outline

- Introduction
  - ✓ Chiral Magnetic Effect (CME)
  - ✓ CME-charge separation vs Background-charge separation

- $R_{\Psi_m}(\Delta S)$ Correlator

Outline

- Introduction
  - ✓ Chiral Magnetic Effect (CME)
  - ✓ CME-charge separation vs Background-charge separation

- $R_{\Psi_m}(\Delta S)$ Correlator

- Results
  - ✓ Event plane and small systems dependence
  - ✓ $R_{\Psi_2}(\Delta S)$ vs $\langle p_T \rangle$
  - ✓ $R_{\Psi_\mathrm{m}}(\Delta S)$ vs $\sqrt{s_{NN}}$
  - ✓ $R_{\Psi_\mathrm{m}}(\Delta S)$ vs centrality

Outline

- Introduction
  - ✓ Chiral Magnetic Effect (CME)
  - ✓ CME-charge separation vs Background-charge separation

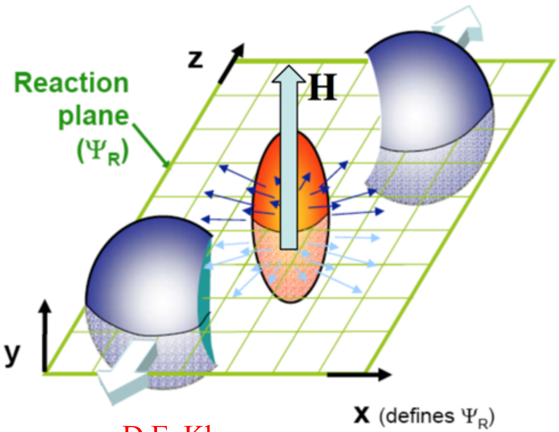
- $R_{\Psi_m}(\Delta S)$ Correlator

- Results
  - ✓ Event plane and small systems dependence
  - ✓ $R_{\Psi_2}(\Delta S)$ vs $\langle p_T \rangle$
  - ✓ $R_{\Psi_\mathrm{m}}(\Delta S)$ vs $\sqrt{s_{NN}}$
  - ✓ $R_{\Psi_\mathrm{m}}(\Delta S)$ vs centrality

- Conclusion

❖ Introduction

✓ Chiral Magnetic Effect (CME)

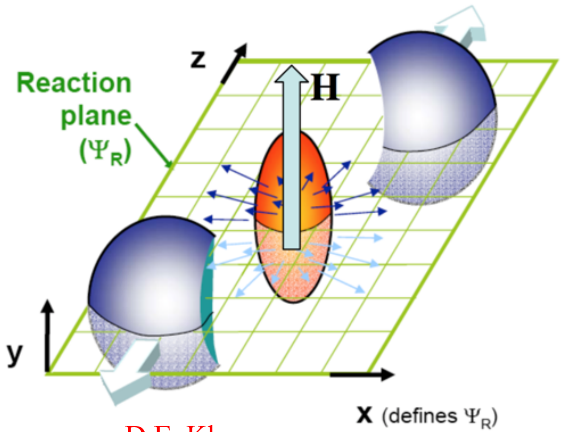


D.E. Kharzeev
Prog.Part.Nucl.Phys. 75 (2014) 133-151

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

❖ Introduction

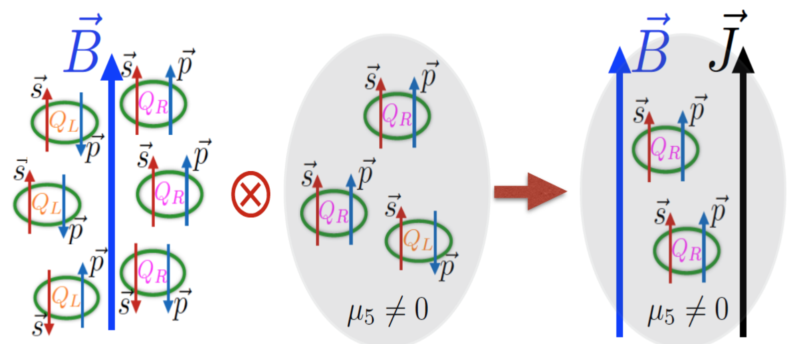
✓ Chiral Magnetic Effect (CME)



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

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

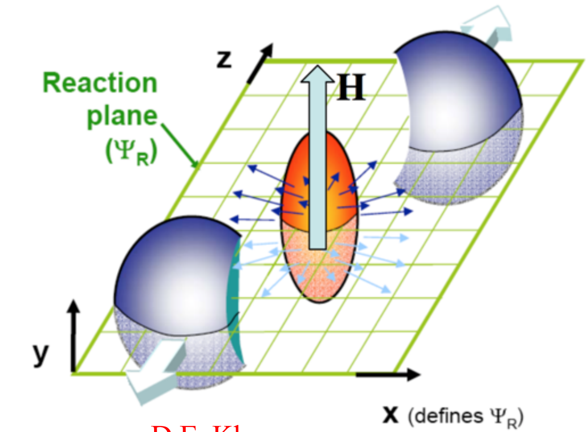
D.E. Kharzeev et al.
Prog.Part.Nucl.Phys. 88 (2016) 1-28



- 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

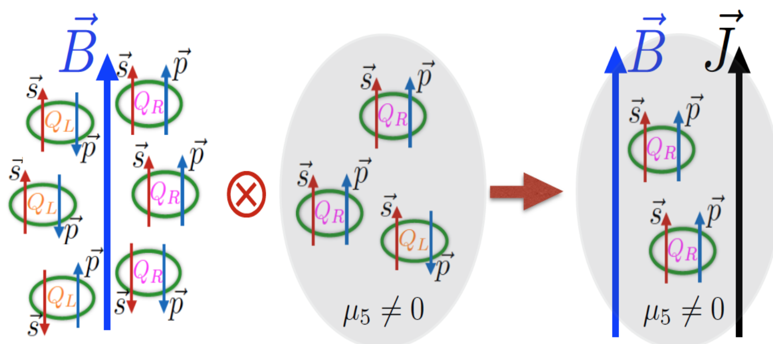
✓ Chiral Magnetic Effect (CME)



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

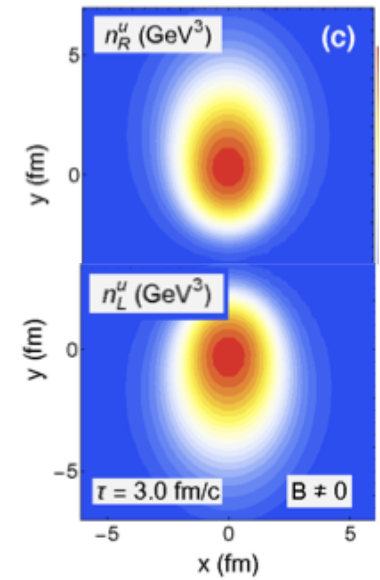
- In non-central collisions a strong magnetic field is created $\perp$ to Ψ_{RP}

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



- 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

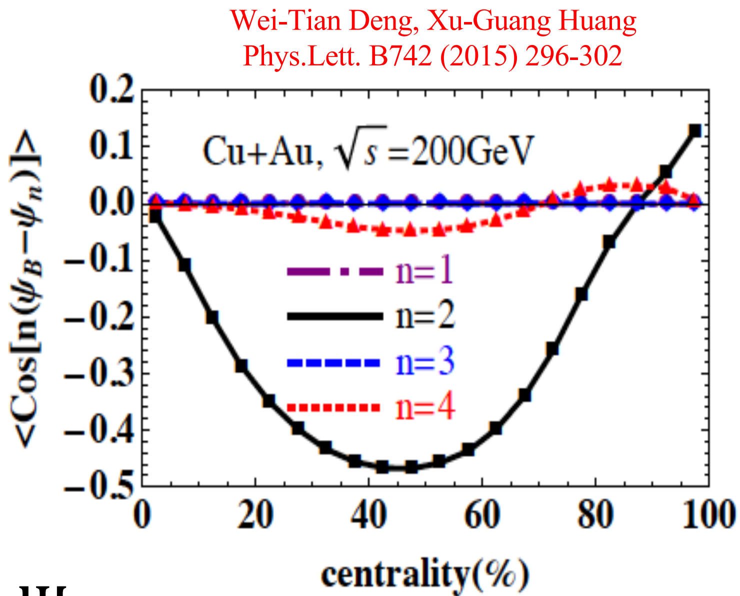
Yin Jiang et al.
arXiv:1611.04586



- This charge separation leads to a "dipole moment"

❖ Introduction

✓ CME-charge separation vs Background-charge separation

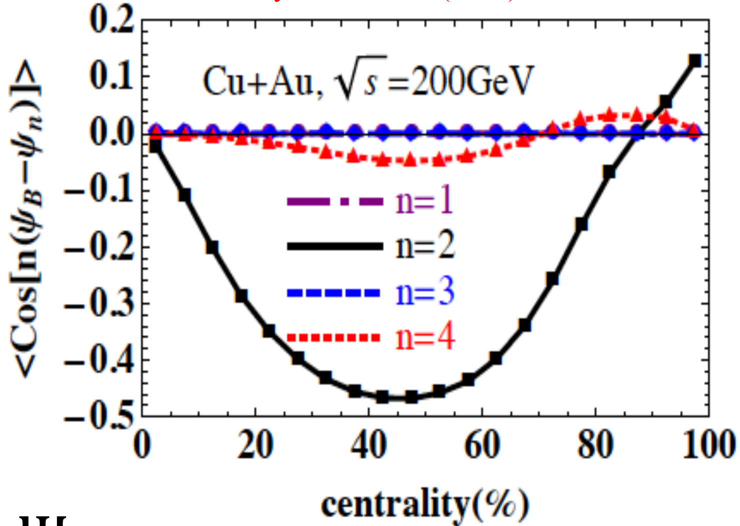


- Ψ_B
  - ✓ Strong correlated with Ψ_2

❖ Introduction

✓ CME-charge separation vs Background-charge separation

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

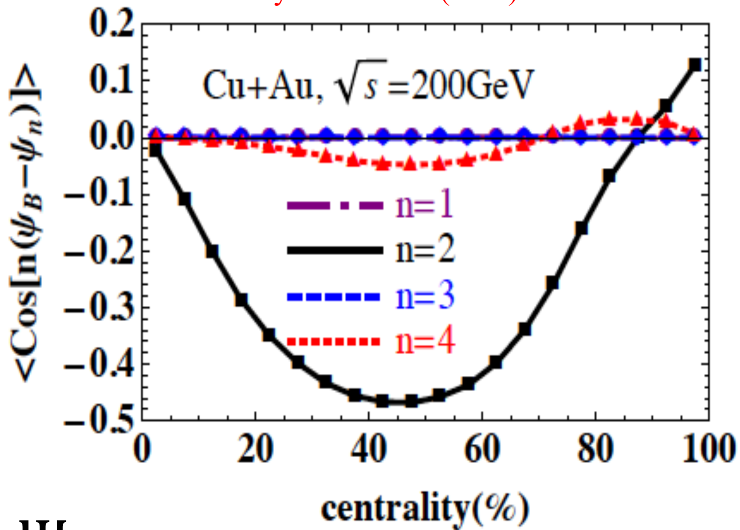


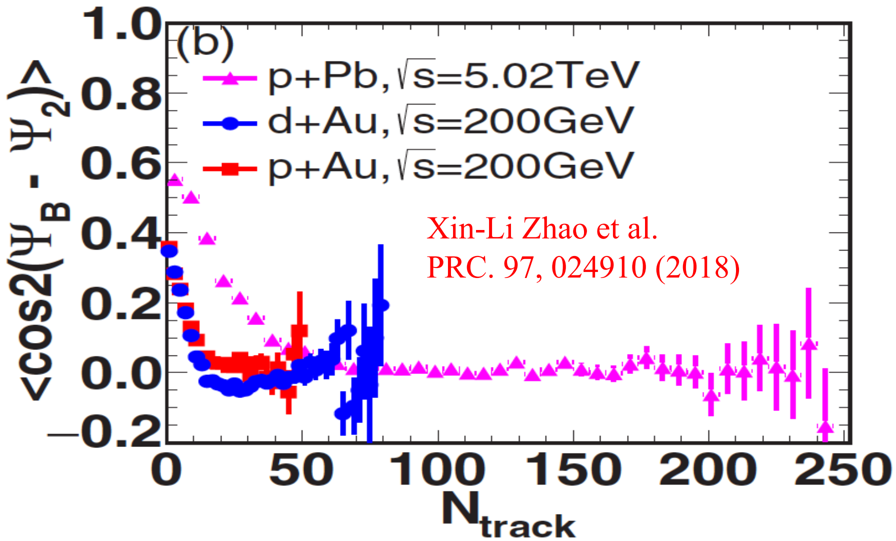
- Ψ_B
  - ✓ Strong correlated with Ψ_2
  - ✓ No correlation with Ψ_3

❖ Introduction

✓ CME-charge separation vs Background-charge separation

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



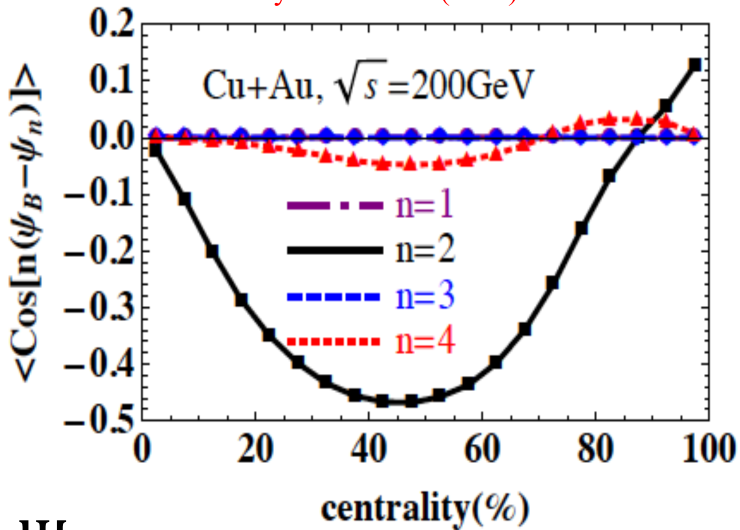


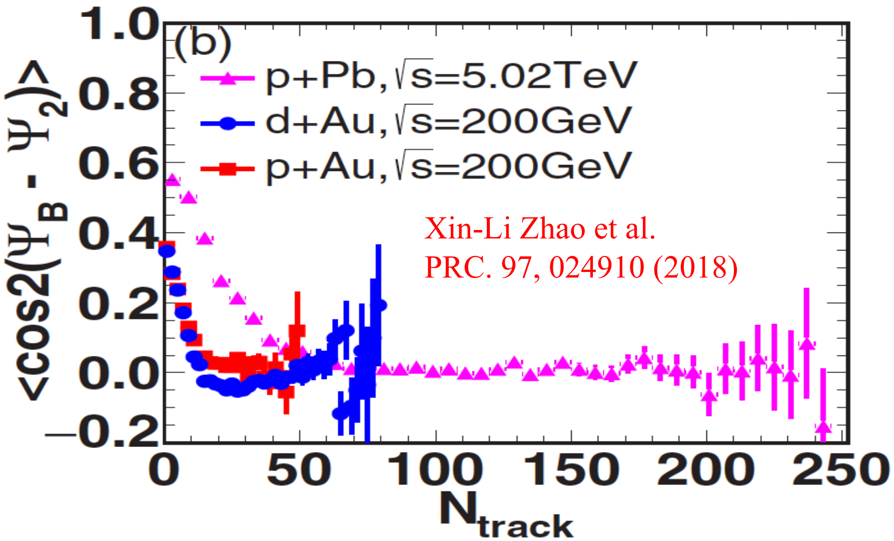
- Ψ_B
  - ✓ Strong correlated with Ψ_2
  - ✓ No correlation with Ψ_3
  - ✓ Weak correlated with Ψ_2 in small systems

❖ Introduction

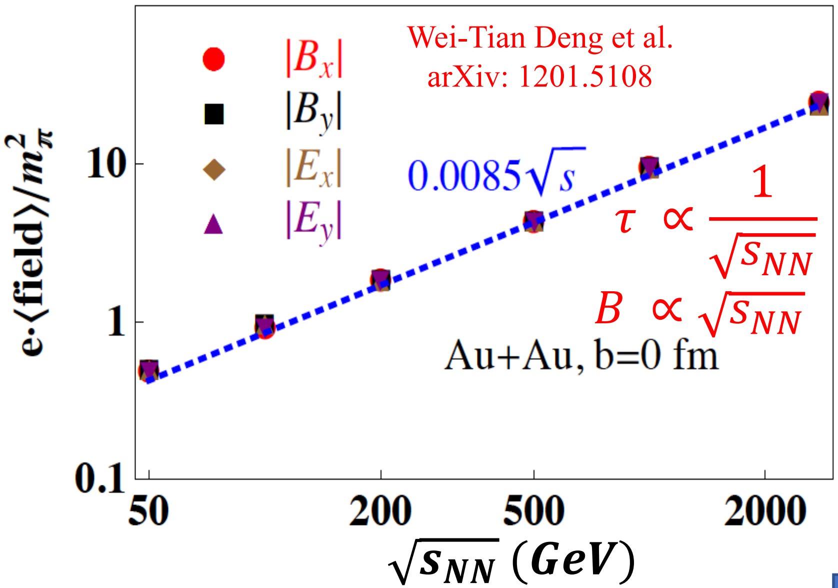
✓ CME-charge separation vs Background-charge separation

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





- ➢ Ψ_B
  - ✓ Strong correlated with Ψ_2
  - ✓ No correlation with Ψ_3
  - ✓ Weak correlated with Ψ_2 in small systems



- ➢ Weak $B(\tau)$ $\sqrt{s_{NN}}$ dependence

❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al.
arXiv: 1710.01717

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

❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al.
arXiv: 1710.01717

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

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

$N(\Delta S)$ $\quad \Delta\varphi = \varphi - \Psi_{\mathrm{m}}$

$$\langle S^{+}_{\Psi_m}\rangle = \frac{\sum_1^p \sin(\frac{m}{2}\,\Delta\varphi)}{p}$$

$$\langle S^{-}_{\Psi_m}\rangle = \frac{\sum_1^n \sin(\frac{m}{2}\,\Delta\varphi)}{n}$$

$$\Delta S = \langle S^{+}_{\Psi_m}\rangle - \langle S^{-}_{\Psi_m}\rangle$$

Sensitive to charge separation
(CME and Background)

❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al.
arXiv: 1710.01717

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

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

$N(\Delta S)$ $\quad \Delta\varphi = \varphi - \Psi_{\mathrm{m}}$

$$\langle S^{+}_{\Psi_m}\rangle = \frac{\sum_1^p \sin(\frac{m}{2}\,\Delta\varphi)}{p}$$

$$\langle S^{-}_{\Psi_m}\rangle = \frac{\sum_1^n \sin(\frac{m}{2}\,\Delta\varphi)}{n}$$

$$\Delta S = \langle S^{+}_{\Psi_m}\rangle - \langle S^{-}_{\Psi_m}\rangle$$

Sensitive to charge separation
(CME and Background)

$N(\Delta S_{Sh})$

$$\langle S^{+}_{\Psi_m}\rangle^{Sh} = \frac{\sum_1^p \sin(\frac{m}{2}\,\Delta\varphi)}{p^{Sh}}$$

$$\langle S^{-}_{\Psi_m}\rangle^{Sh} = \frac{\sum_1^n \sin(\frac{m}{2}\,\Delta\varphi)}{n^{Sh}}$$

$$\Delta S_{Sh} = \langle S^{+}_{\Psi_m}\rangle^{Sh} - \langle S^{-}_{\Psi_m}\rangle^{Sh}$$

Shuffling of charges within
an event breaks the charge
separation sensitivity

❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al.
arXiv: 1710.01717

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

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

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

$N(\Delta S)$ $\quad \Delta\varphi = \varphi - \Psi_{\mathrm{m}}$

$$\langle S^{+}_{\Psi_m} \rangle = \frac{\sum_1^p \sin(\frac{m}{2}\,\Delta\varphi)}{p}$$

$$\langle S^{-}_{\Psi_m} \rangle = \frac{\sum_1^n \sin(\frac{m}{2}\,\Delta\varphi)}{n}$$

$$\Delta S = \langle S^{+}_{\Psi_m} \rangle - \langle S^{-}_{\Psi_m} \rangle$$

$N(\Delta S_{Sh})$

$$\langle S^{+}_{\Psi_m} \rangle^{Sh} = \frac{\sum_1^p \sin(\frac{m}{2}\,\Delta\varphi)}{p^{Sh}}$$

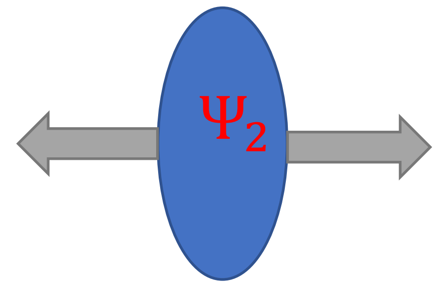
$$\langle S^{-}_{\Psi_m} \rangle^{Sh} = \frac{\sum_1^n \sin(\frac{m}{2}\,\Delta\varphi)}{n^{Sh}}$$

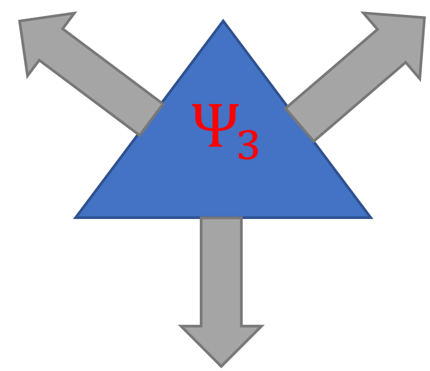
$$\Delta S_{Sh} = \langle S^{+}_{\Psi_m} \rangle^{Sh} - \langle S^{-}_{\Psi_m} \rangle^{Sh}$$

Sensitive to charge separation
(CME and Background)

$$\Psi_{\mathrm{m}} \rightarrow \Psi_{\mathrm{m}} + \frac{\pi}{m}$$

Shuffling of charges within an event breaks the charge separation sensitivity



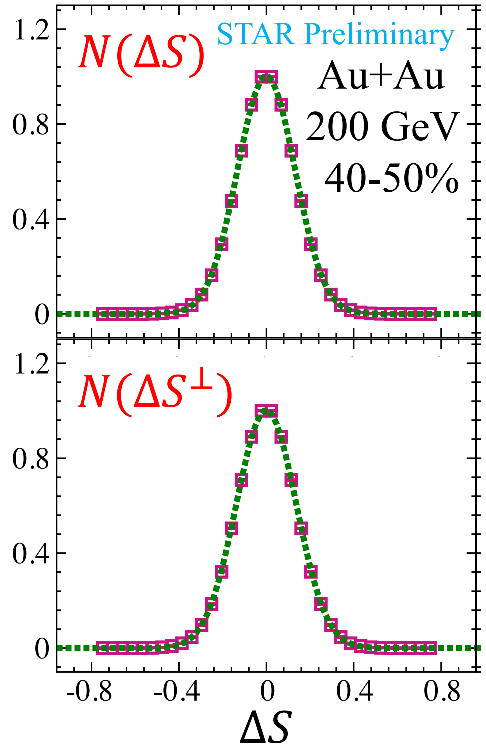


❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al.
arXiv: 1710.01717

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

- $N(\Delta S)$ distributions:
  - ✓ Gaussian like distribution
- $N(\Delta S)$ distributions:
  - ✓ Carry charge separation information

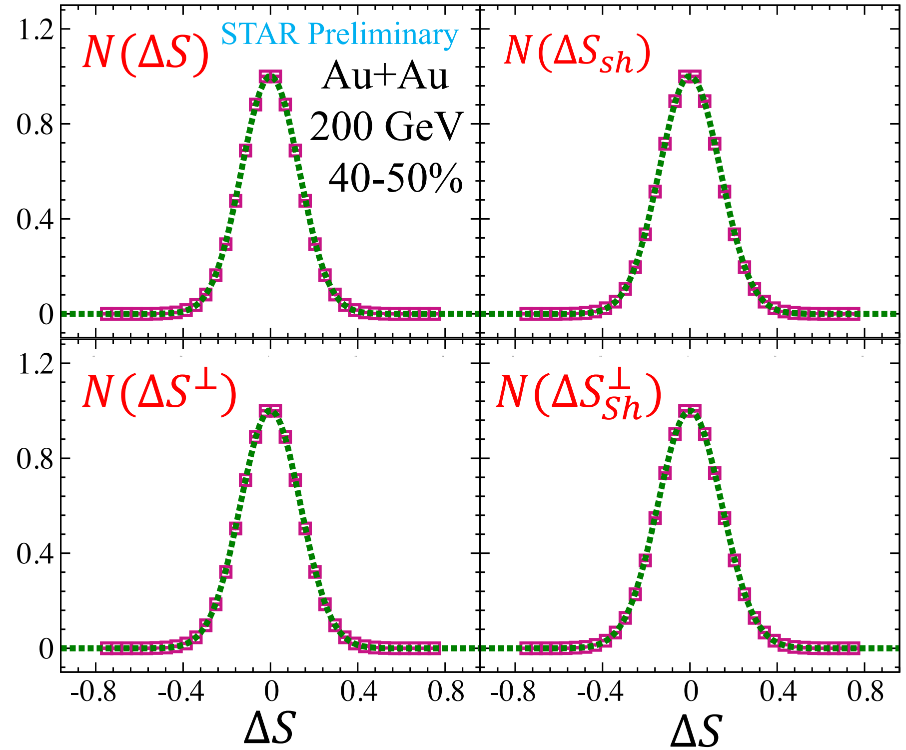


❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al.
arXiv: 1710.01717

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

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

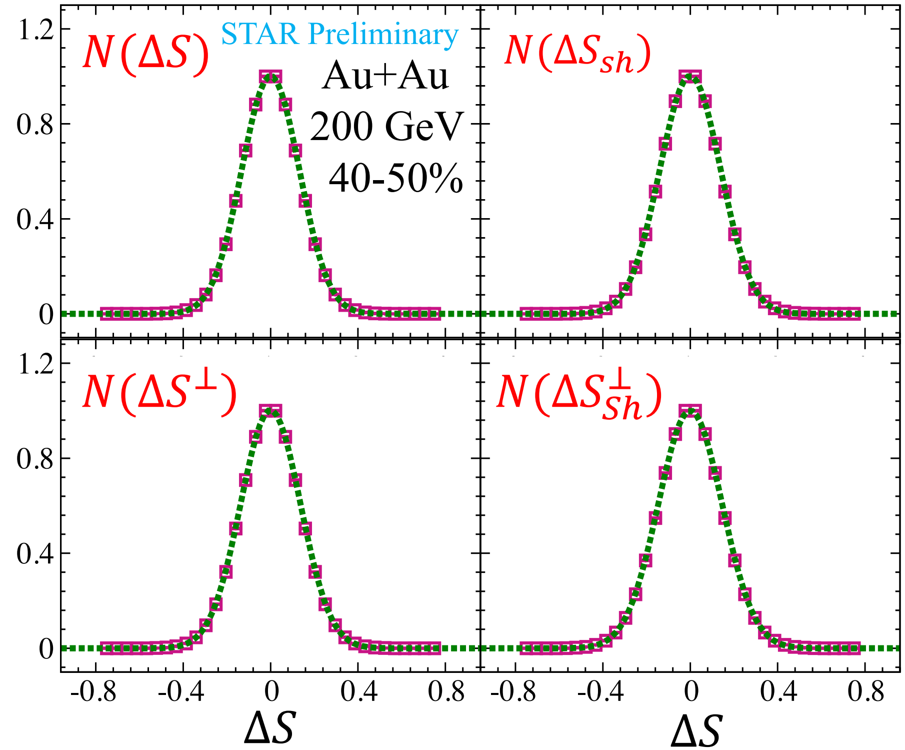


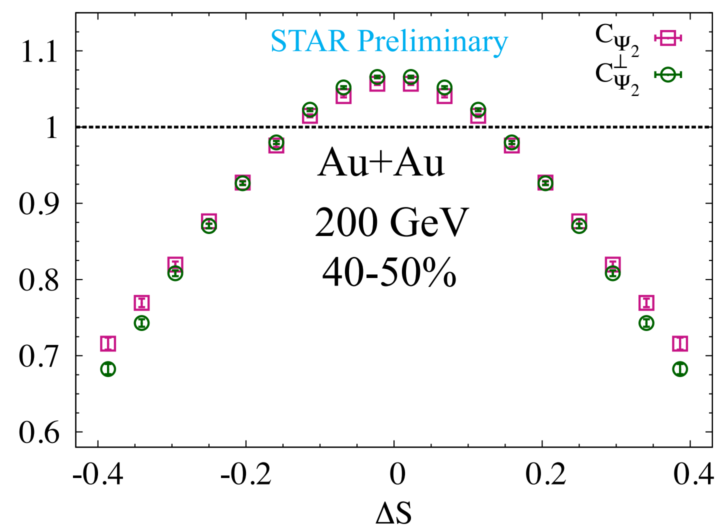
❖ $R_{\Psi_m}(\Delta S)$ Correlator

N. Magdy et al.
arXiv: 1710.01717

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

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

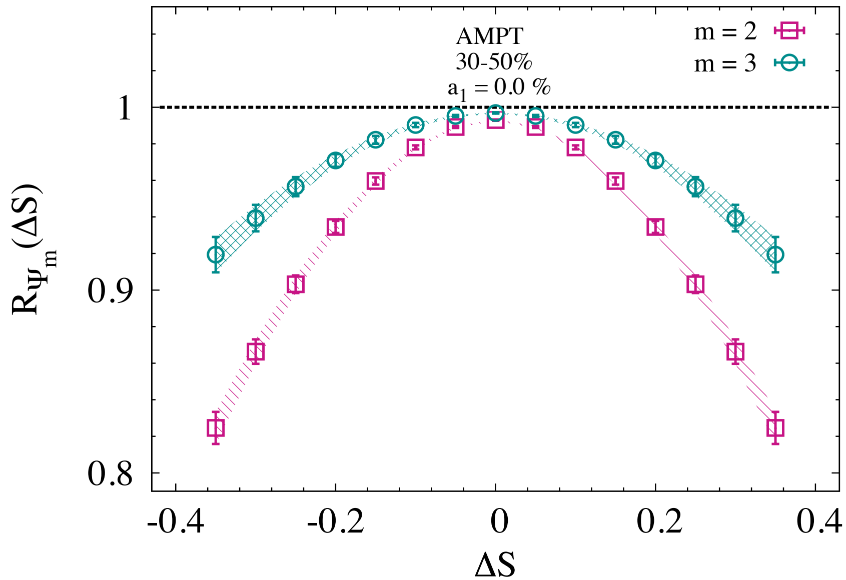




❖ $R_{\Psi_m}(\Delta S)$ Correlator

Background

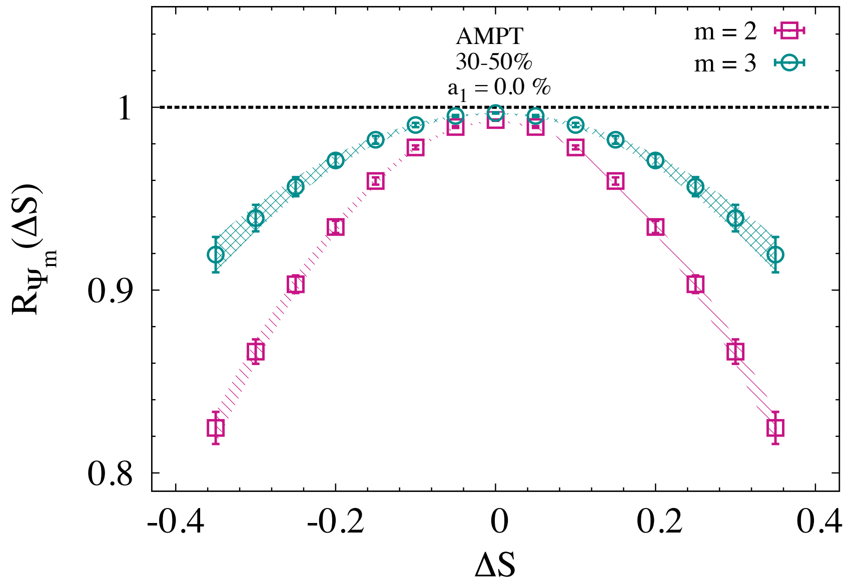
N. Magdy et al.
arXiv: 1710.01717



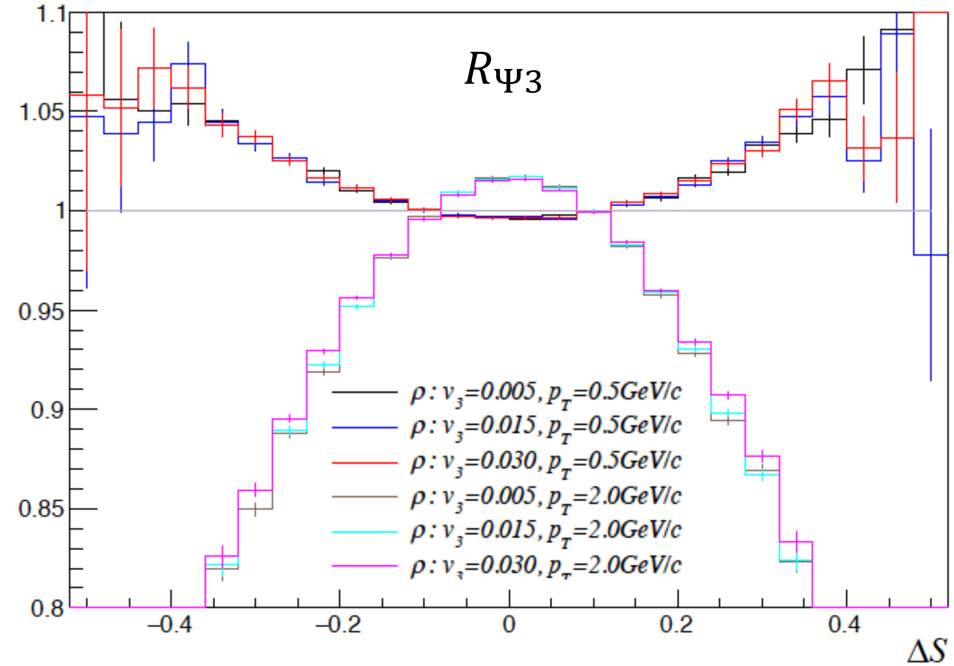
- R_{Ψ_m} in background models:
  - ✓ Similar response for Ψ_2 and Ψ_3

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

N. Magdy et al.
arXiv: 1710.01717



Y. Feng et al.
arXiv:1803.02860



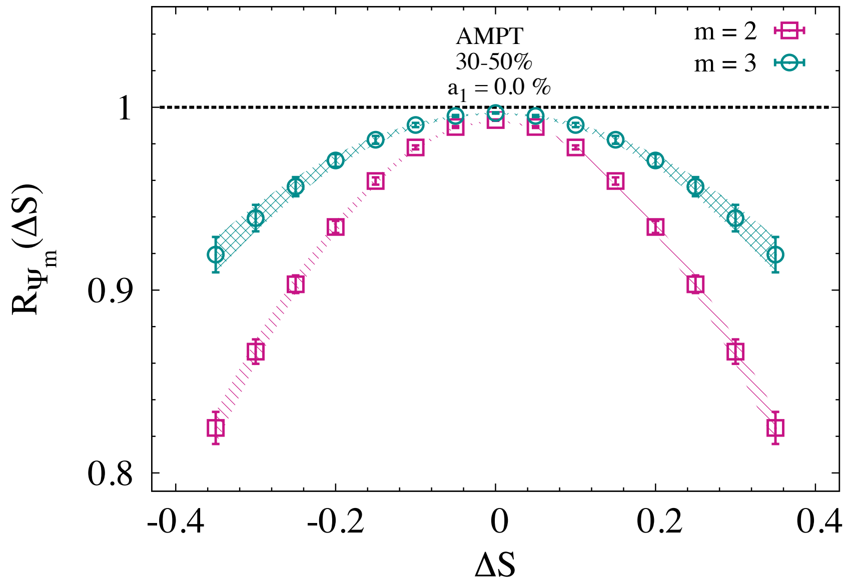
➢ R_{Ψ_m} in background models:

✓ Similar response for Ψ_2 and Ψ_3

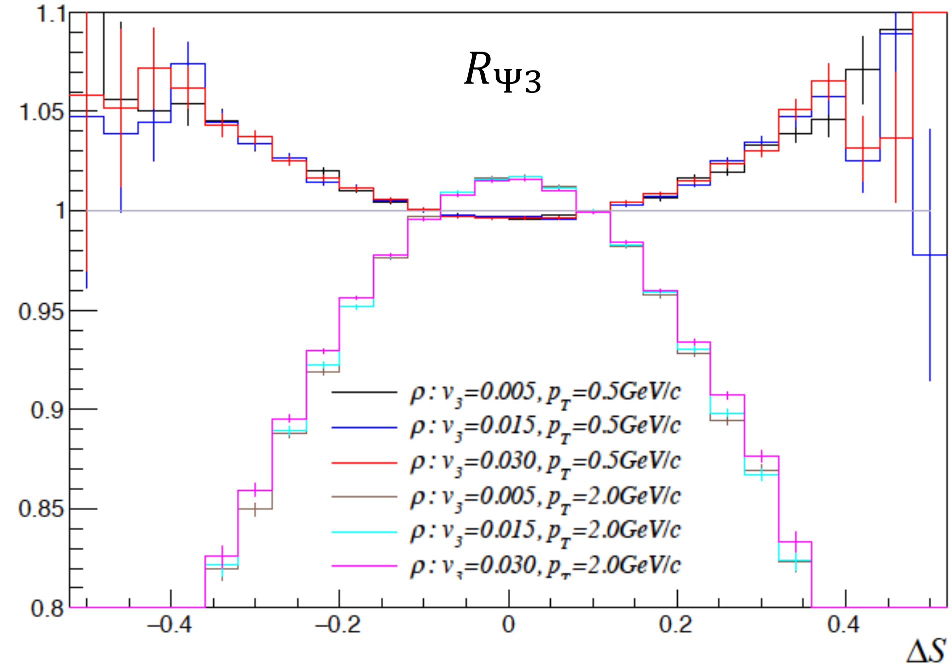
✓ The R_{Ψ_m} width change with $\langle p_T \rangle$

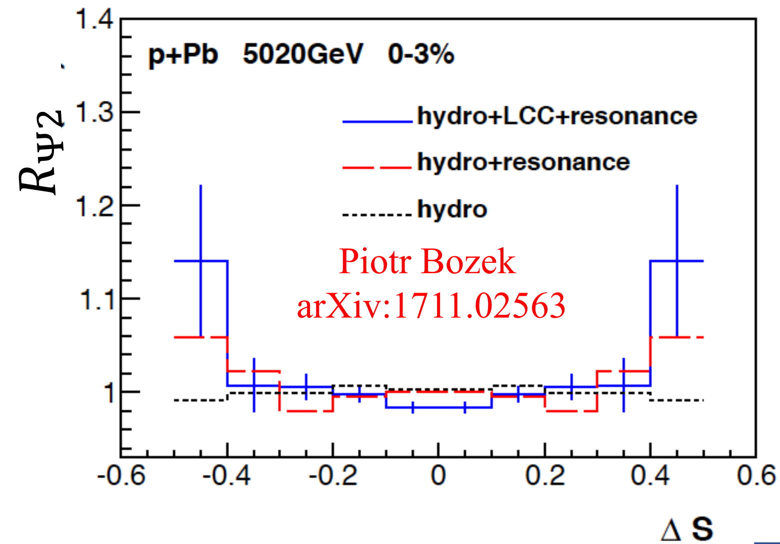
❖ $R_{\Psi_m}(\Delta S)$ Correlator
Background

N. Magdy et al.
arXiv: 1710.01717



Y. Feng et al.
arXiv:1803.02860





- R_{Ψ_m} in background models:
  - ✓ Similar response for Ψ_2 and Ψ_3
  - ✓ The R_{Ψ_m} width change with $\langle p_T \rangle$
  - ✓ Similar response for small and large systems

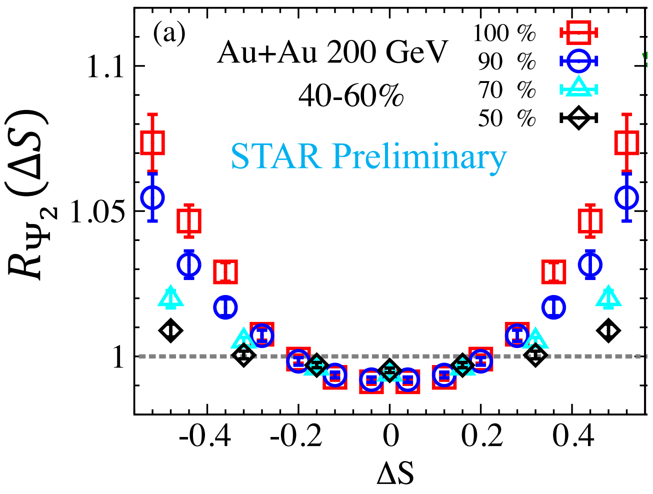
❖ $R_{\Psi_m}(\Delta S)$ Correlator

- **Charge separation magnitude is reflected in the width of the $R_{\Psi_m}(\Delta S)$ distribution**

❖ $R_{\Psi_m}(\Delta S)$ Correlator

- **Charge separation magnitude is reflected in the width of the $R_{\Psi_m}(\Delta S)$ distribution**

- $R_{\Psi_m}(\Delta S)$ width affected by:
  - ✓ Number fluctuations



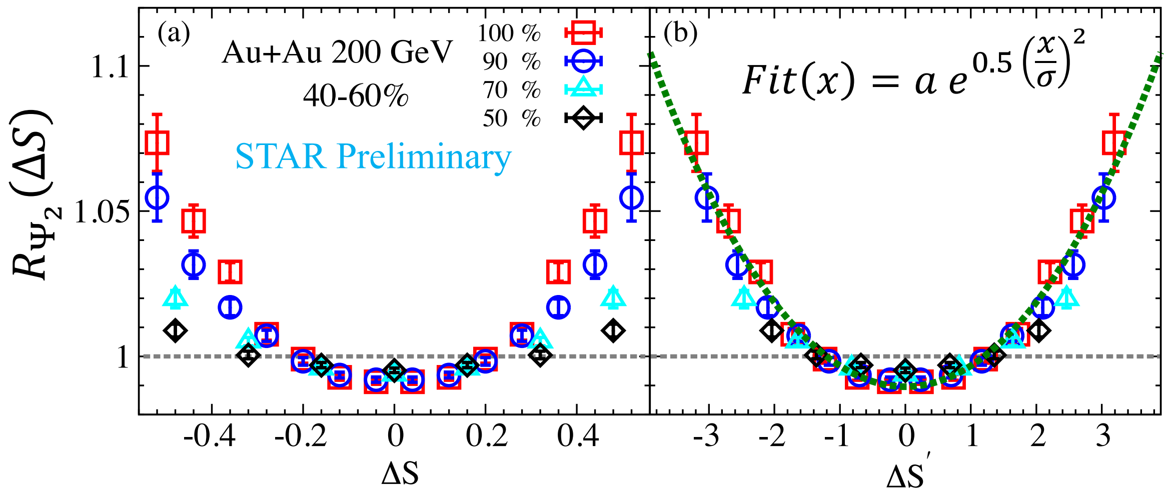
❖ $R_{\Psi_m}(\Delta S)$ Correlator

➢ **Charge separation magnitude is reflected in the width of the $R_{\Psi_m}(\Delta S)$ distribution**

➢ $R_{\Psi_m}(\Delta S)$ width affected by:

- ✓ Number fluctuations

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



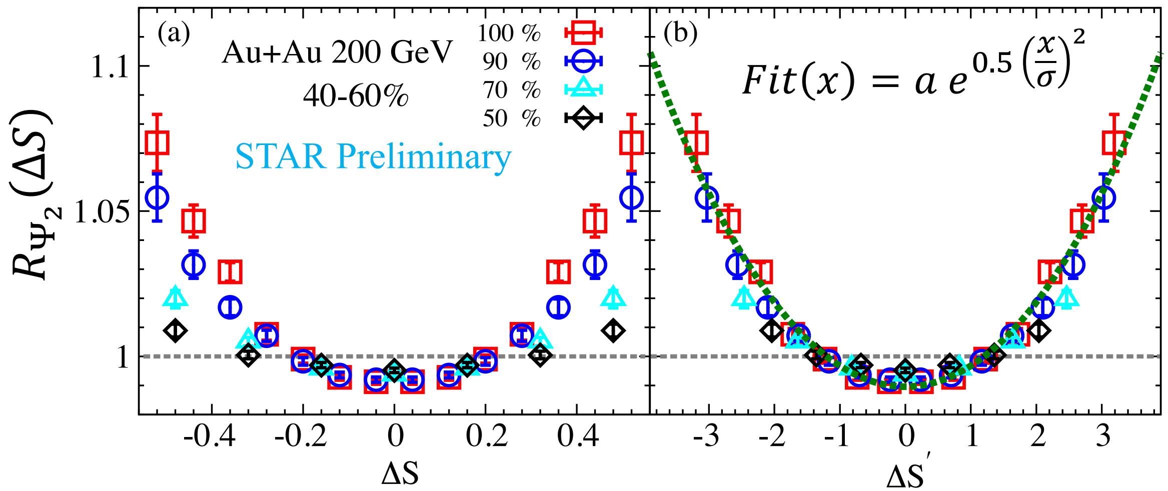
$R_{\Psi_m}(\Delta S)$ Correlator

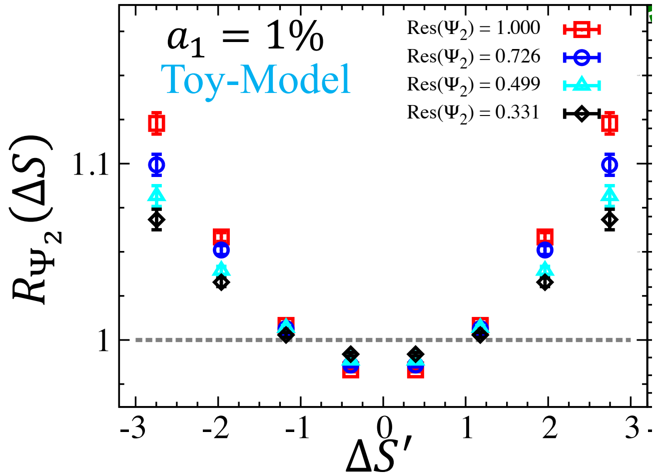
- **Charge separation magnitude is reflected in the width of the $R_{\Psi_m}(\Delta S)$ distribution**

- $R_{\Psi_m}(\Delta S)$ width affected by:
  - ✓ Number fluctuations

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

  - ✓ EP-resolution





❖ $R_{\Psi_m}(\Delta S)$ Correlator

➢ **Charge separation magnitude is reflected in the width of the $R_{\Psi_m}(\Delta S)$ distribution**

➢ $R_{\Psi_m}(\Delta S)$ width affected by:

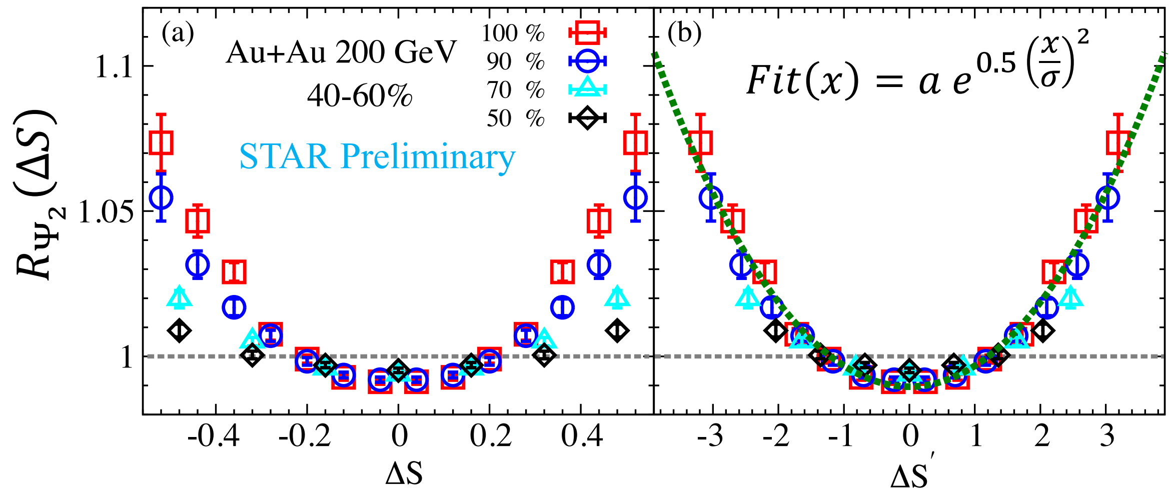
- ✓ Number fluctuations

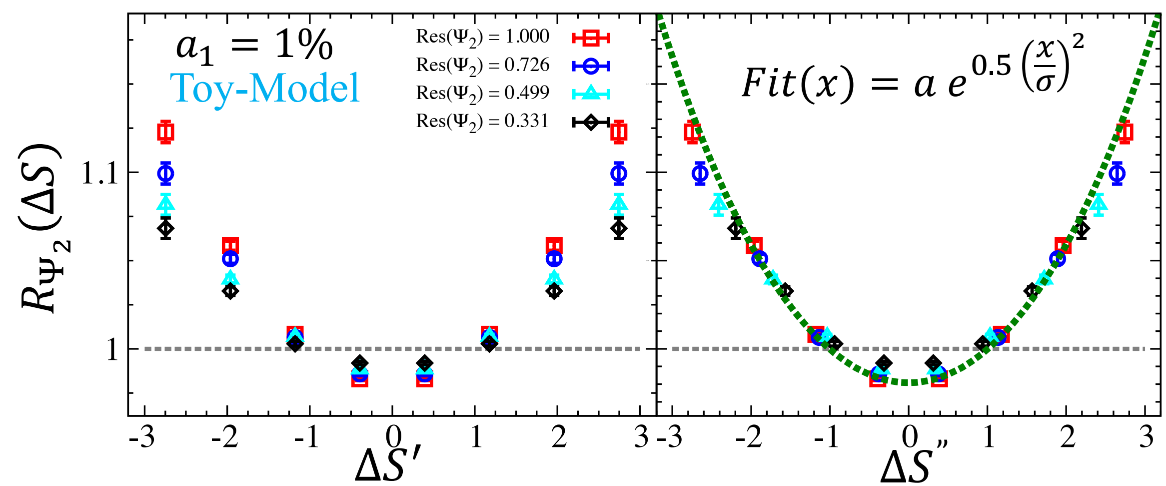
$$\Delta S' = \Delta S / \sigma_{\Delta S^{sh}}$$

- ✓ EP-resolution

$$\Delta S'' = \Delta S' / \delta_{Res}$$

$$\delta_{Res} = e^{0.5(1-Res)^2}$$

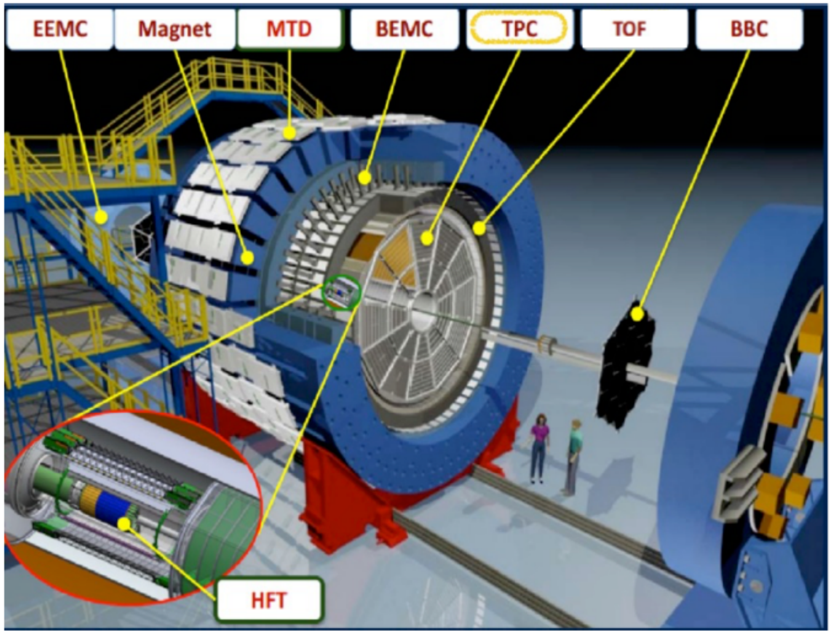




Data Analyses

STAR Experiment at RHIC

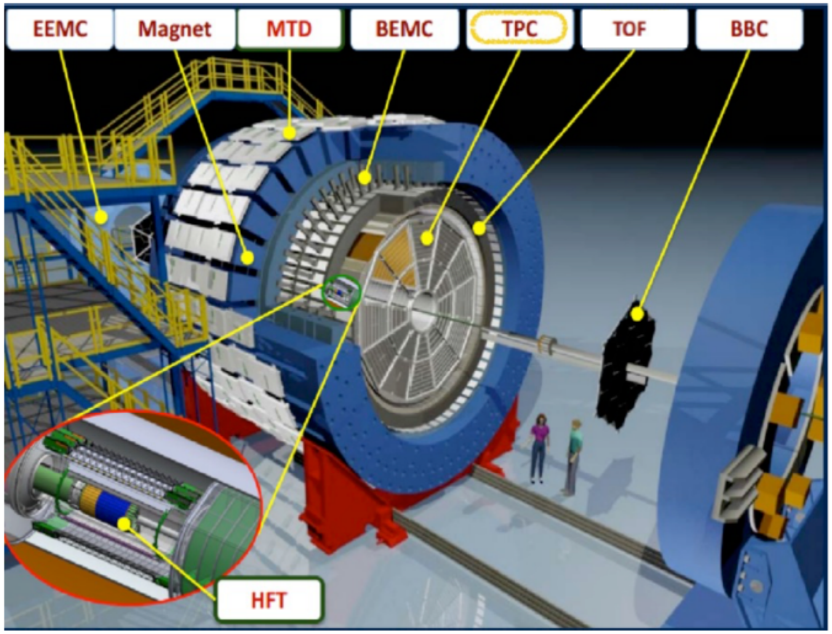
- The TPC detector is used in the current analysis



Data Analyses

STAR Experiment at RHIC

- ➢ The TPC detector is used in the current analysis
- ➢ Charged hadrons with $0.2 < pT < 2.0$ GeV/c are used to construct $\Psi_2^{\eta>0.1}$ & $\Psi_2^{\eta<-0.1}$

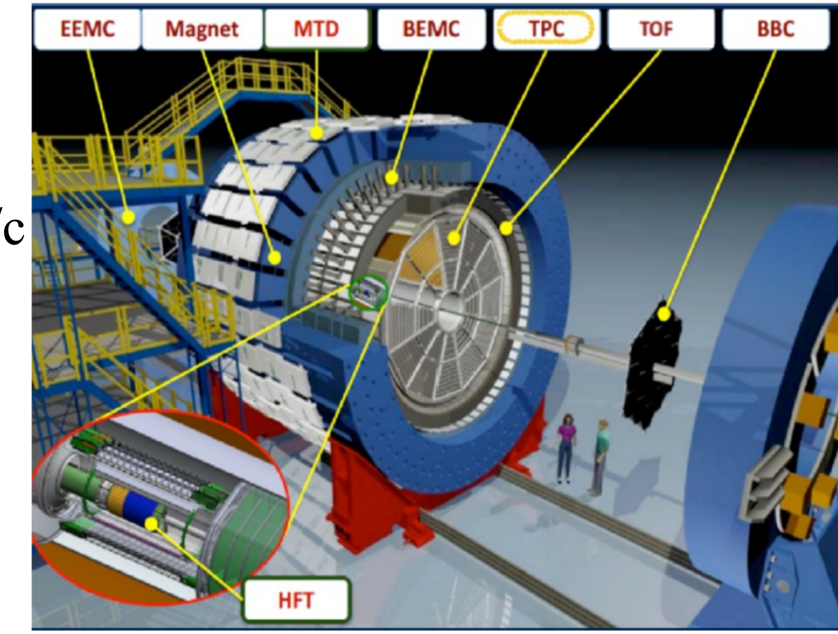


$\Psi_2^{\eta<-0.1}$ $\Psi_2^{\eta>0.1}$

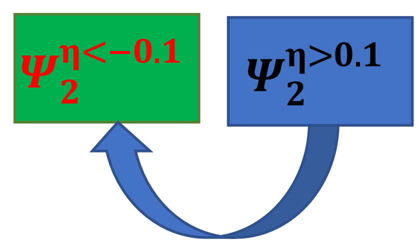
Data Analyses

STAR Experiment at RHIC

- The TPC detector is used in the current analysis
- Charged hadrons with $0.2 < pT < 2.0$ GeV/c are used to construct $\Psi_2^{\eta>0.1}$ & $\Psi_2^{\eta<-0.1}$



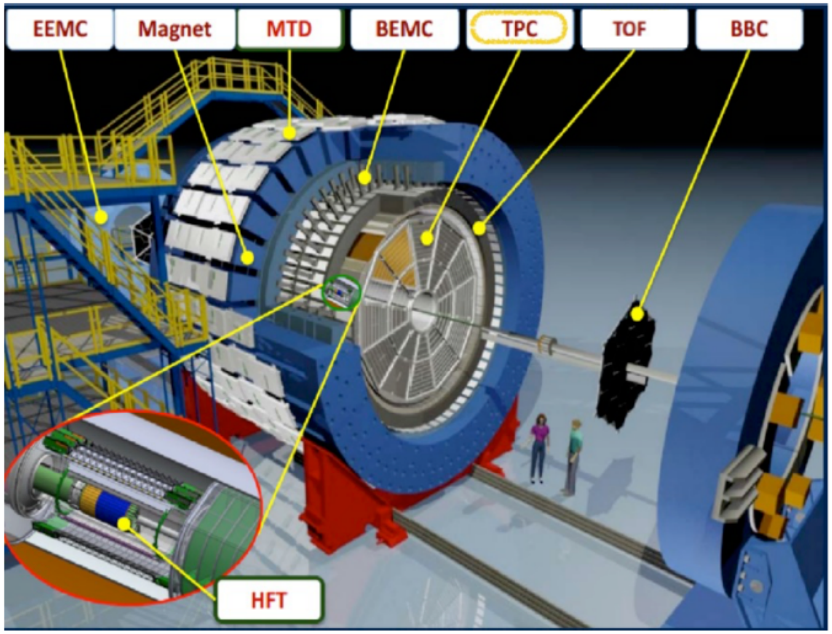
- Particles with $0.35 < pT < 2.0$ GeV/c and $\eta < 0$ are analyzed using $\Psi_2^{\eta>0.1}$



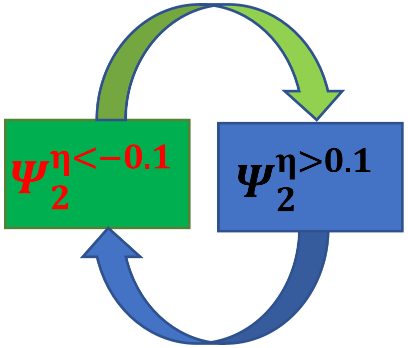
Data Analyses

STAR Experiment at RHIC

- The TPC detector is used in the current analysis
- Charged hadrons with 0.2 < pT < 2.0 GeV/c are used to construct $\Psi_2^{\eta>0.1}$ & $\Psi_2^{\eta<-0.1}$



- Particles with 0.35 < pT < 2.0 GeV/c and $\eta < 0$ are analyzed using $\Psi_2^{\eta>0.1}$
- Particles with 0.35 < pT < 2.0 GeV/c and $\eta > 0$ are analyzed using $\Psi_2^{\eta<-0.1}$



❖ Results

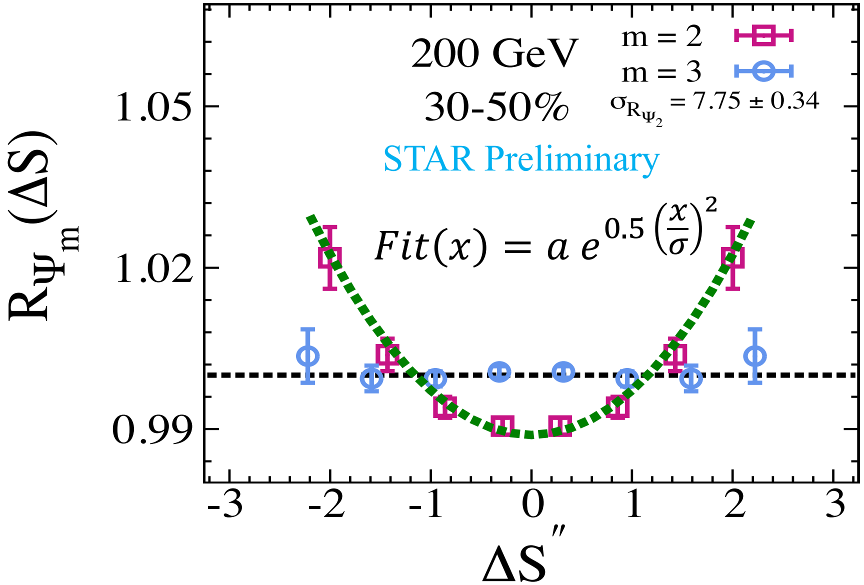
✓ Event plane and small systems dependence

❖ Results

✓ Event plane and small systems dependence

➢ Measurements for R_{Ψ_m} show:

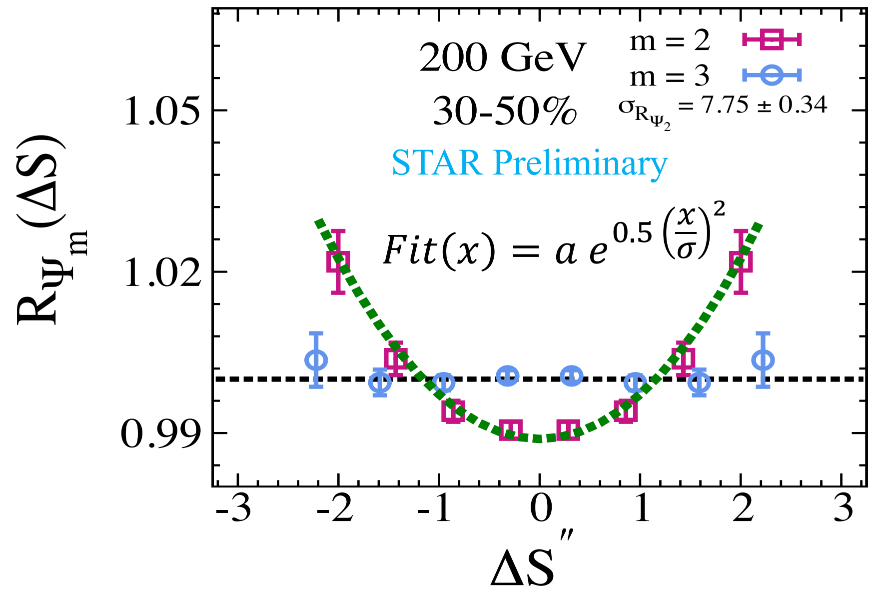
- ✓ Different response for R_{Ψ_2} and R_{Ψ_3}

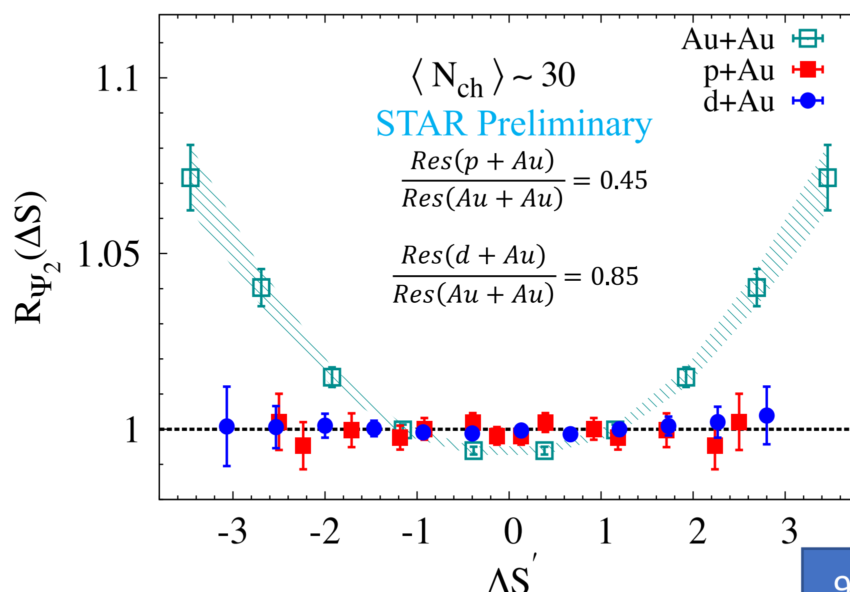


❖ Results

✓ Event plane and small systems dependence

- Measurements for R_{Ψ_m} show:
  - ✓ Different response for R_{Ψ_2} and R_{Ψ_3}
  - ✓ Different response for small (p(d)+Au) and large (Au+Au) systems



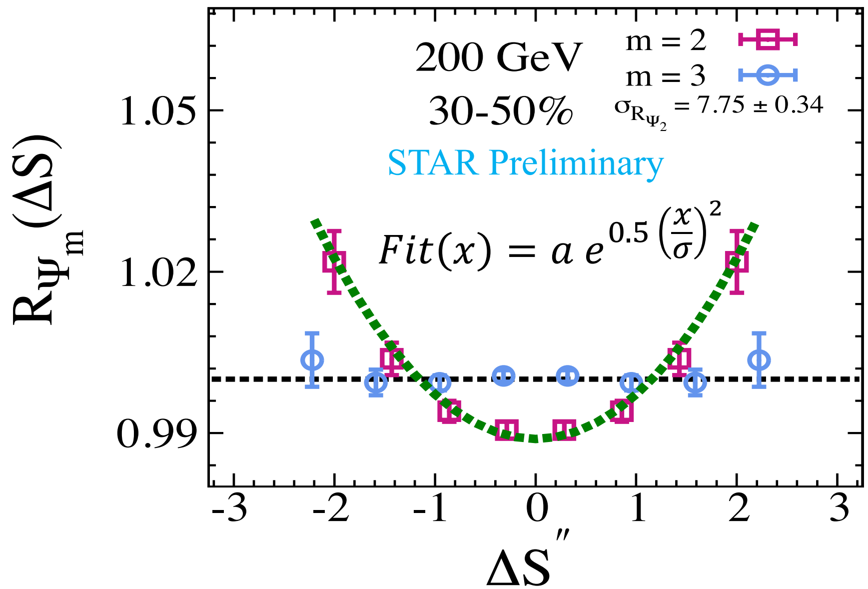


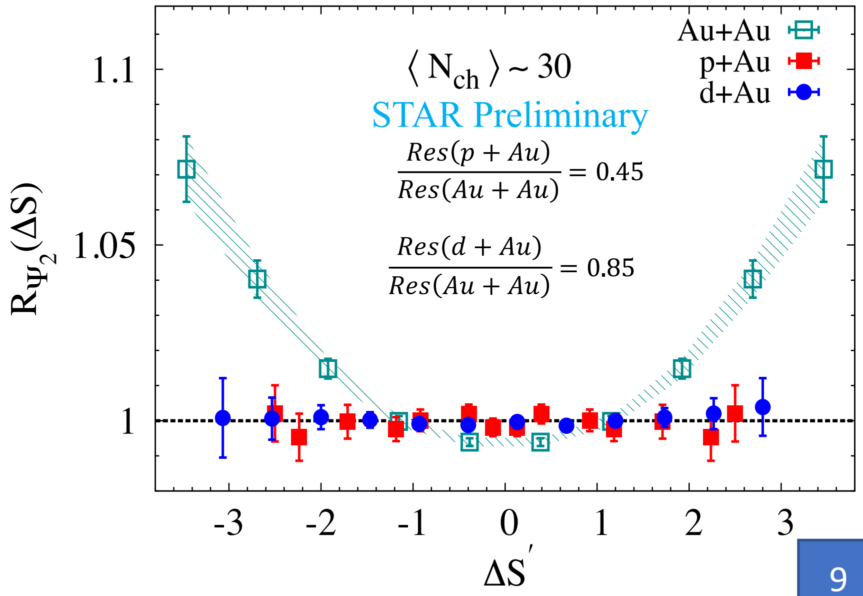
❖ Results

✓ Event plane and small systems dependence

- Measurements for R_{Ψ_m} show:
  - ✓ Different response for R_{Ψ_2} and R_{Ψ_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.





❖ Results

✓ Event plane and small systems dependence

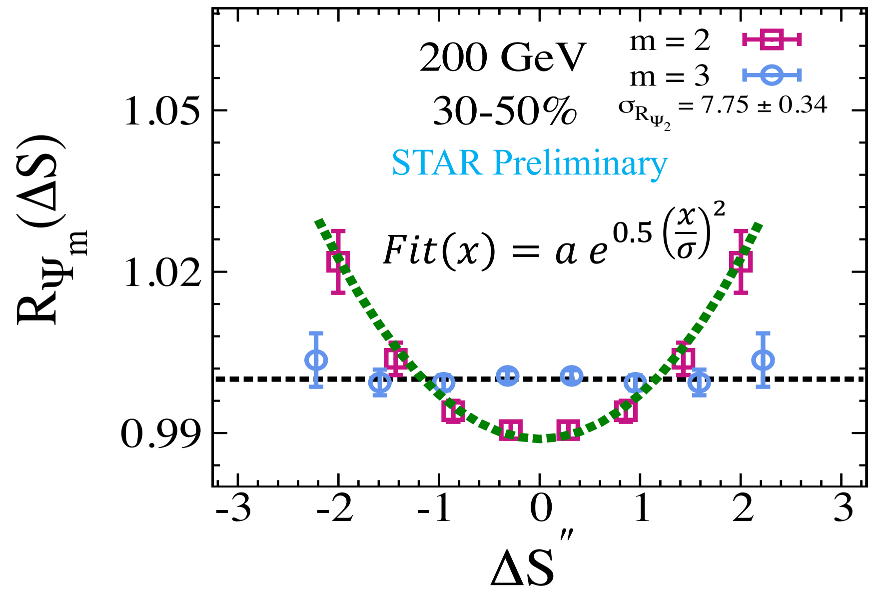
➢ Measurements for R_{Ψ_m} show:

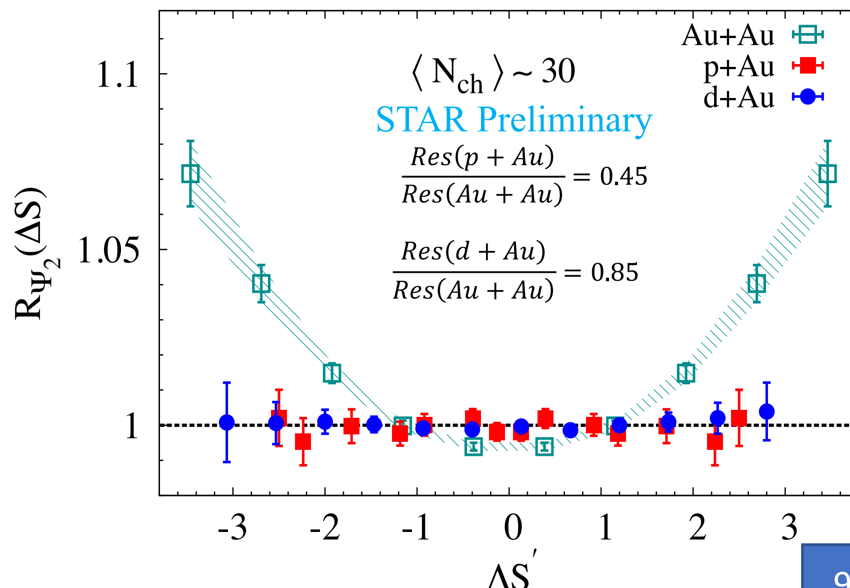
- ✓ Different response for R_{Ψ_2} and R_{Ψ_3}
- ✓ Different response for small (p(d)+Au) and large (Au+Au) systems

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

✓ Note that these observations contrast with those from the γ correlator.

[CMS Collaboration arXiv:1610.00263]



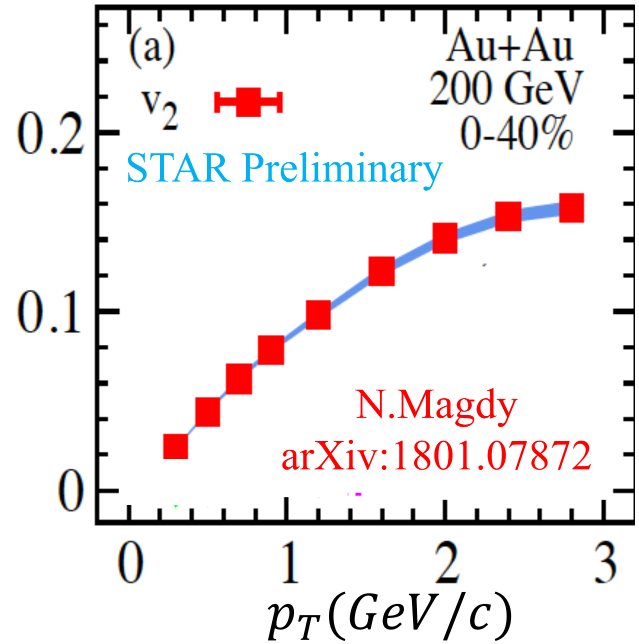


❖ Results

✓ $R_{\Psi_2}(\Delta S)$ vs $\langle p_T \rangle$

➢ Measurements show:

✓ v_2 (background) increases with $\langle p_T \rangle$



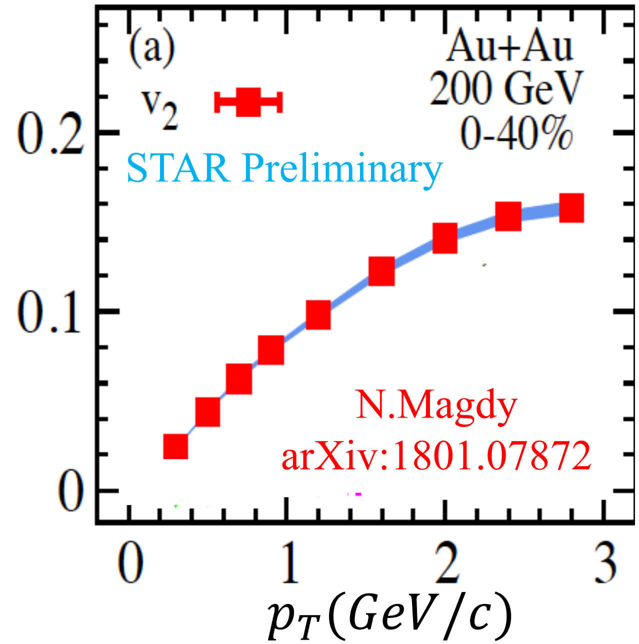
❖ Results

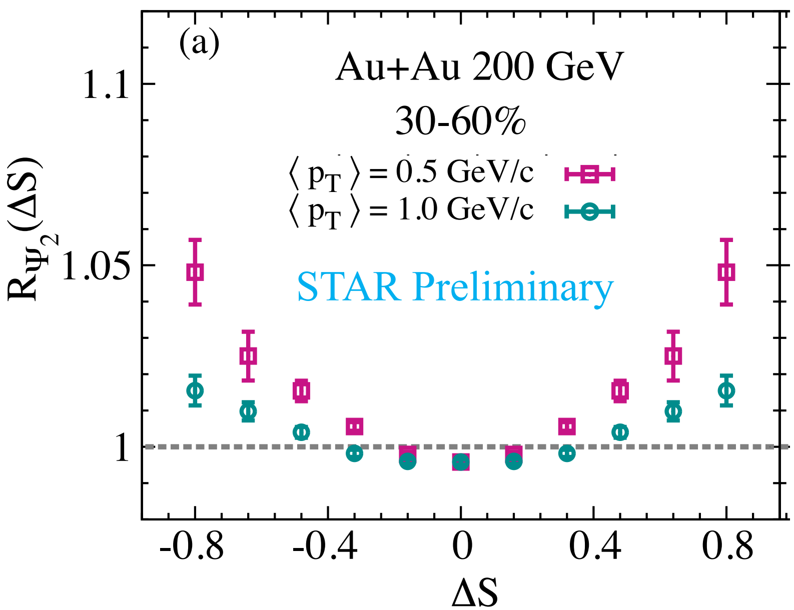
✓ $R_{\Psi_2}(\Delta S)$ vs $\langle p_T \rangle$

➢ Measurements show:

✓ v_2 (background) increases with $\langle p_T \rangle$

✓ But R_{Ψ_2} width increases with $\langle p_T \rangle$
-Number fluctuations?





$\langle p_T \rangle = 0.5$ GeV/c
$[0.35 < p_T < 0.7$ GeV/c$]$

$\langle p_T \rangle = 1.0$ GeV/c
$[0.7 < p_T < 2.0$ GeV/c$]$

❖ Results

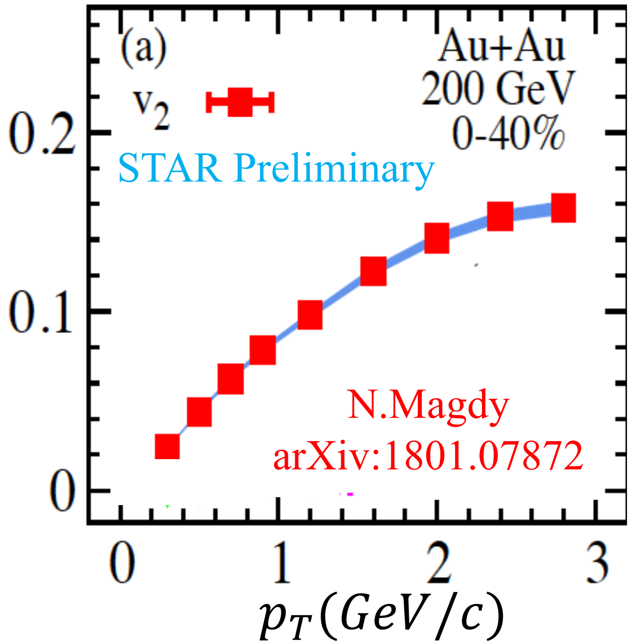
✓ $R_{\Psi_2}(\Delta S)$ vs $\langle p_T \rangle$

➢ Measurements show:

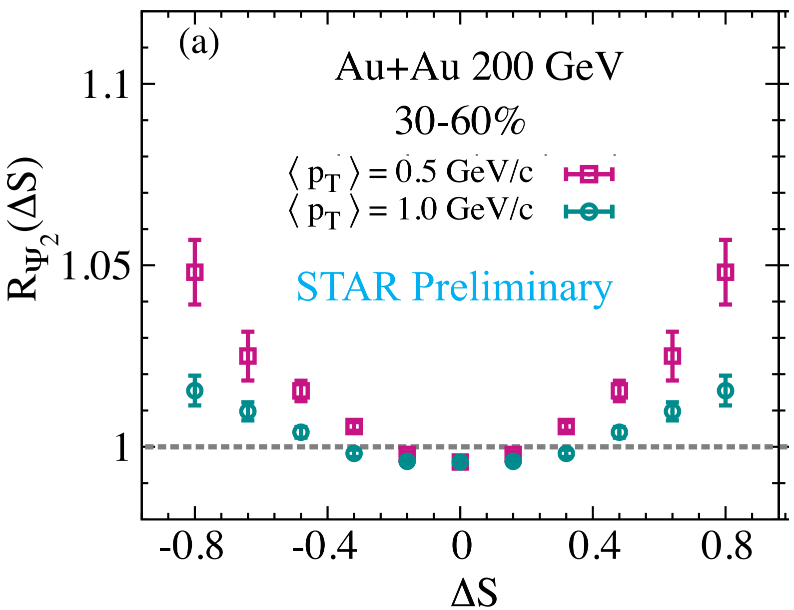
✓ v_2 (background) increases with $\langle p_T \rangle$

✓ But R_{Ψ_2} width increases with $\langle p_T \rangle$

-Number fluctuations?



➢ Scaling out the number fluctuations:



$\langle p_T \rangle = 0.5$ GeV/c
$[0.35 < p_T < 0.7$ GeV/c$]$

$\langle p_T \rangle = 1.0$ GeV/c
$[0.7 < p_T < 2.0$ GeV/c$]$

❖ Results

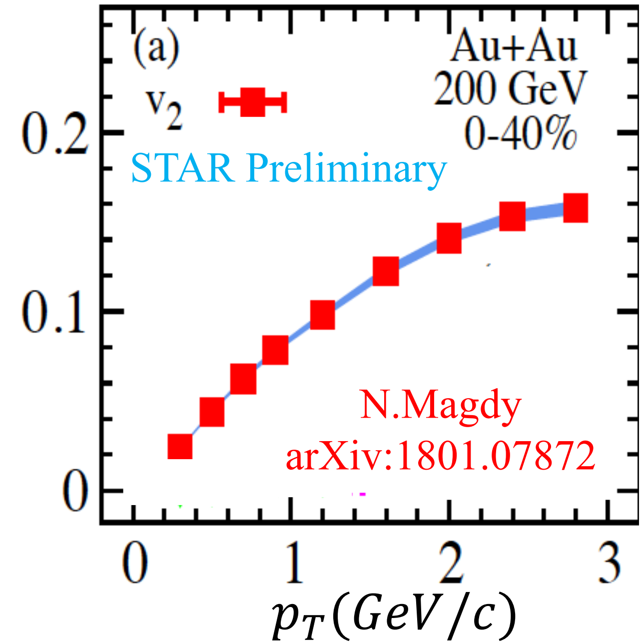
✓ $R_{\Psi_2}(\Delta S)$ vs $\langle p_T \rangle$

➢ Measurements show:

✓ v_2 (background) increases with $\langle p_T \rangle$

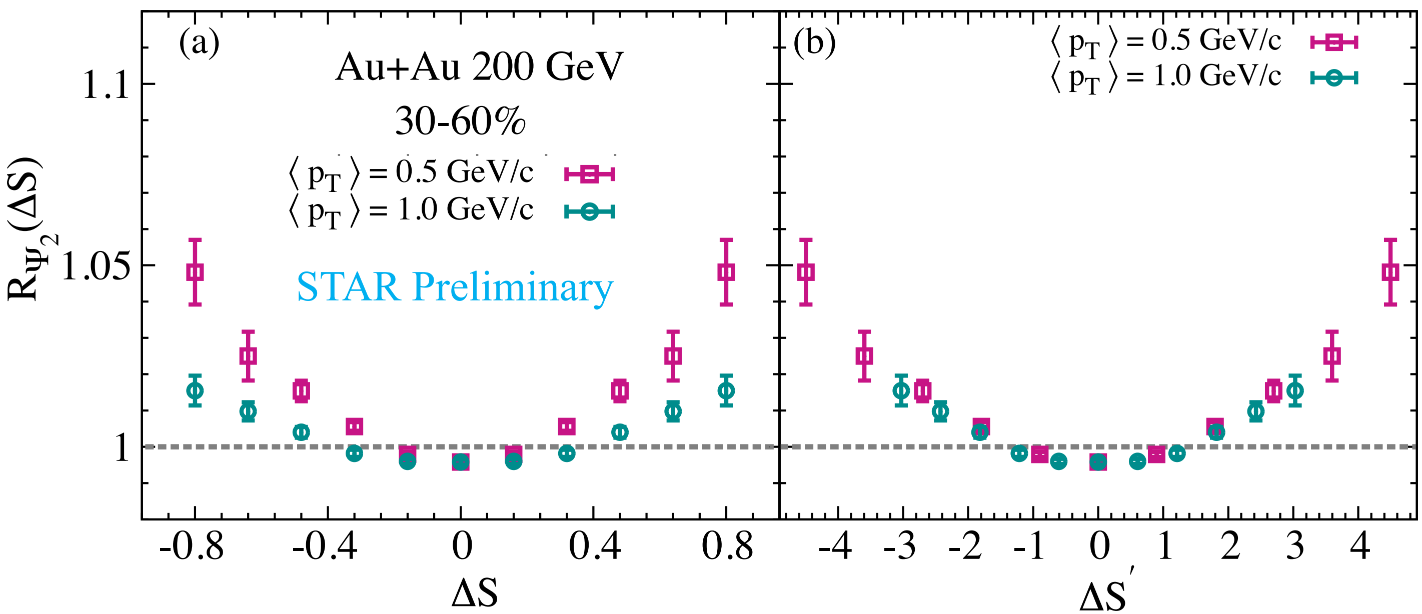
✓ But R_{Ψ_2} width increases with $\langle p_T \rangle$

-Number fluctuations?



➢ Scaling out the number fluctuations:

✓ R_{Ψ_2} is $\langle p_T \rangle$ independent



$\langle p_T \rangle = 0.5$ GeV/c
[$0.35 < p_T < 0.7$ GeV/c]

$\langle p_T \rangle = 1.0$ GeV/c
[$0.7 < p_T < 2.0$ GeV/c]

❖ Results

✓ $R_{\Psi_{\mathrm{m}}}(\Delta S)$ vs $\sqrt{s_{NN}}$

❖ Results

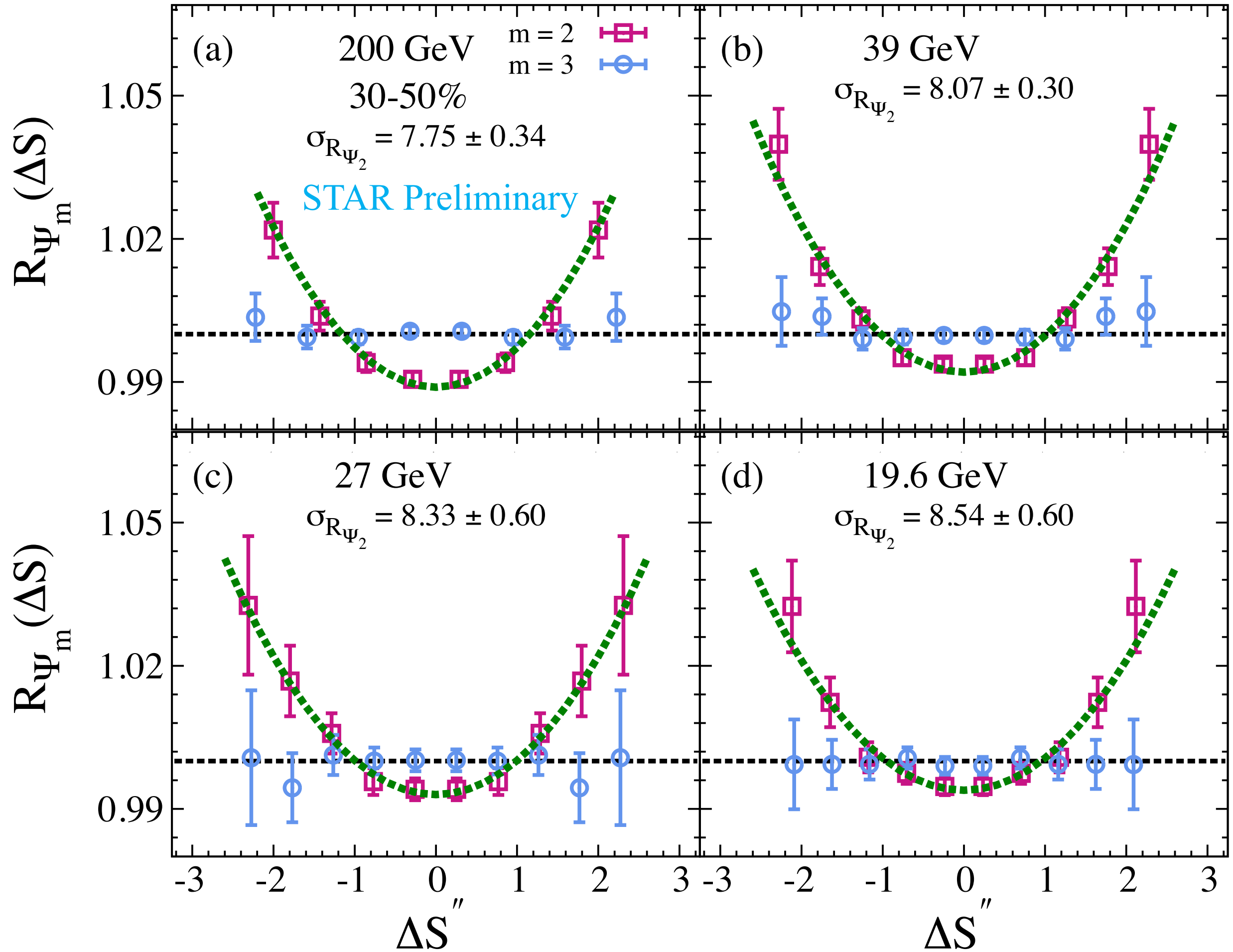
✓ $R_{\Psi_m}(\Delta S)$ vs $\sqrt{s_{NN}}$

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

$$\tau \propto \frac{1}{\sqrt{s_{NN}}}$$

$$B \propto \sqrt{s_{NN}}$$

- Measurements show:
  - ✓ Different response for Ψ_2 and Ψ_3



❖ Results

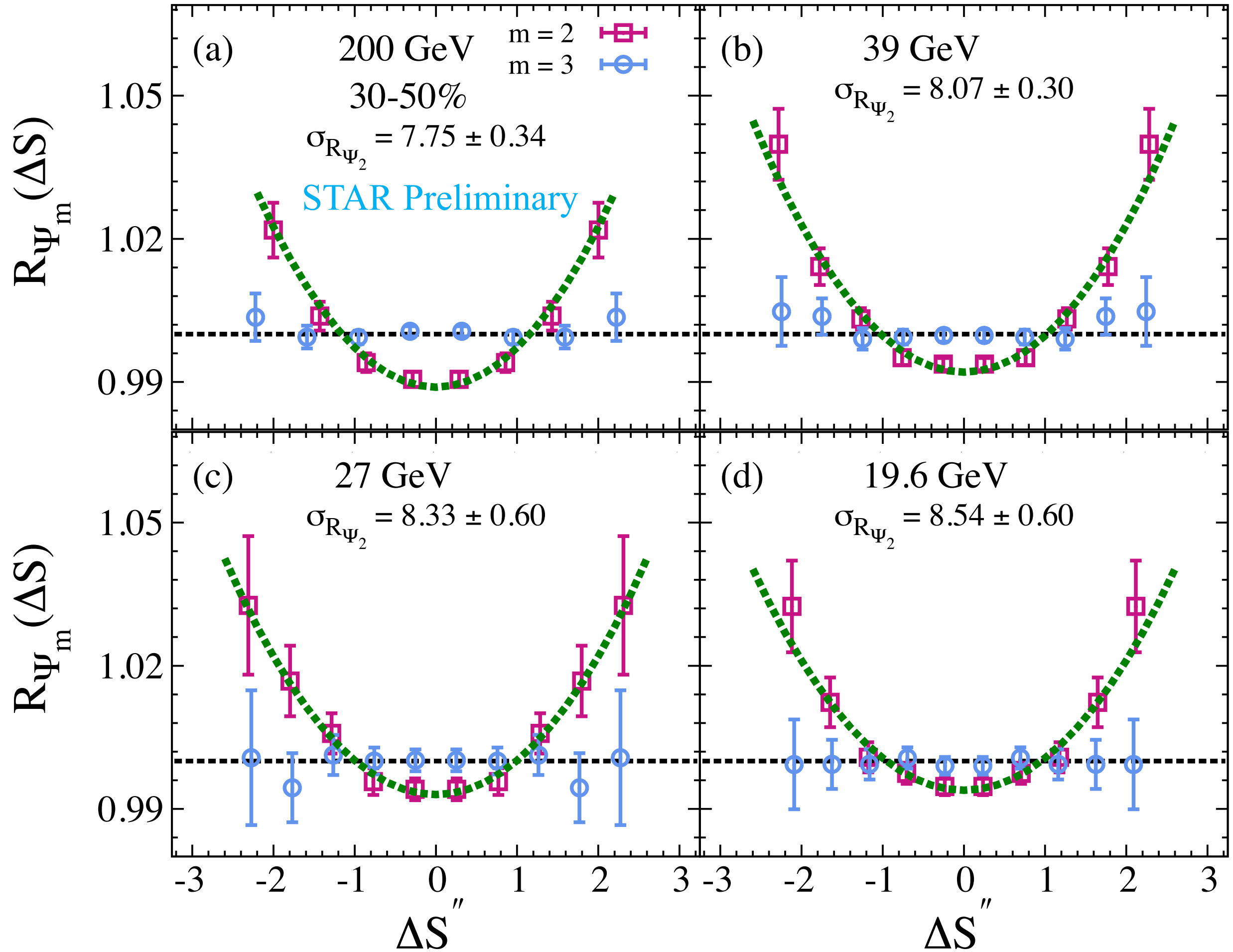
✓ $R_{\Psi_m}(\Delta S)$ vs $\sqrt{s_{NN}}$

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

$\tau \propto \frac{1}{\sqrt{s_{NN}}}$

$B \propto \sqrt{s_{NN}}$

- Measurements show:
  - ✓ Different response for Ψ_2 and Ψ_3
  - ✓ R_{Ψ_2} width is $\sqrt{s_{NN}}$ independent



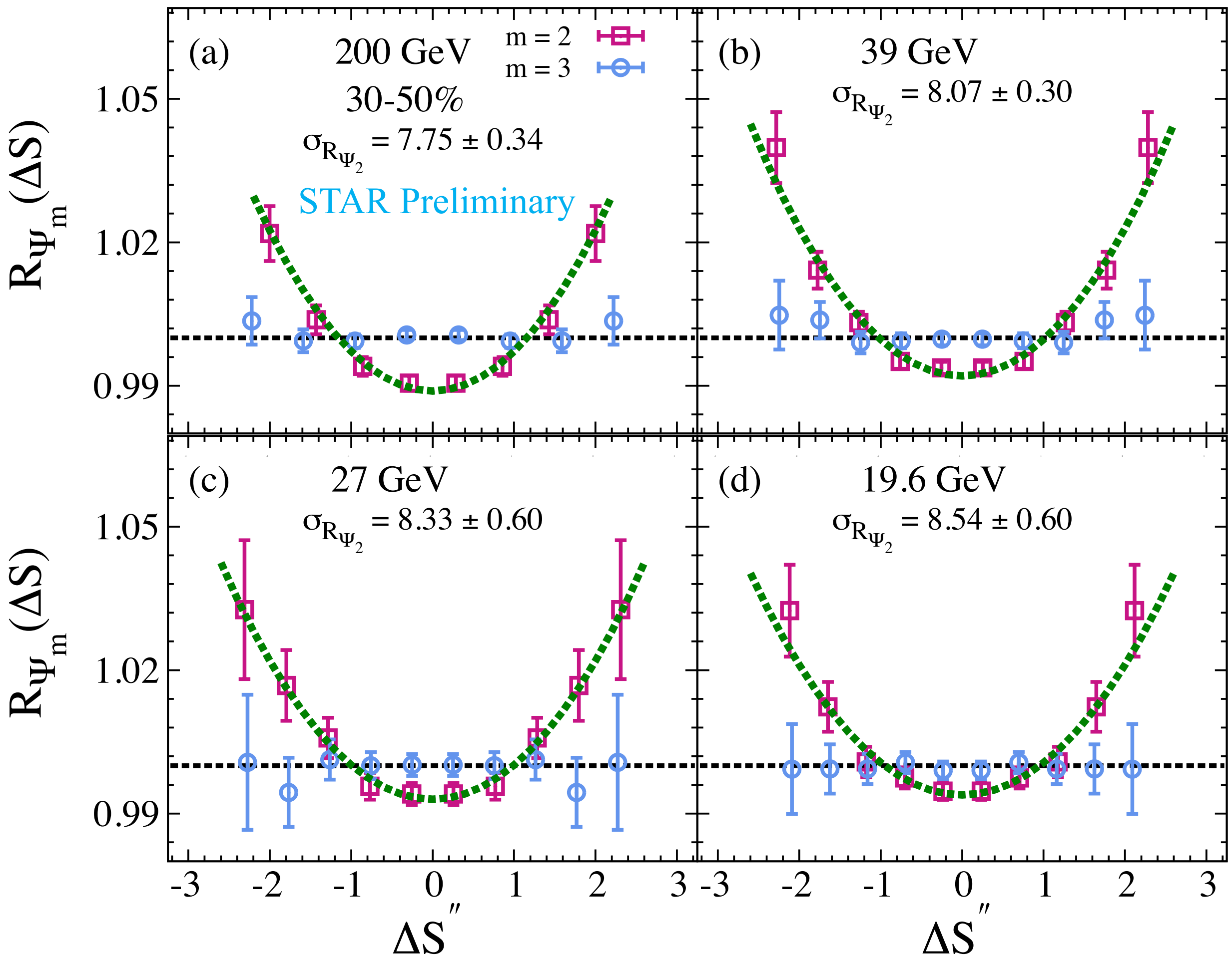
❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs $\sqrt{s_{NN}}$

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

$\tau \propto \frac{1}{\sqrt{s_{NN}}}$

$B \propto \sqrt{s_{NN}}$



➢ Measurements show:

✓ Different response for Ψ_2 and Ψ_3

✓ R_{Ψ_2} width is $\sqrt{s_{NN}}$ independent

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

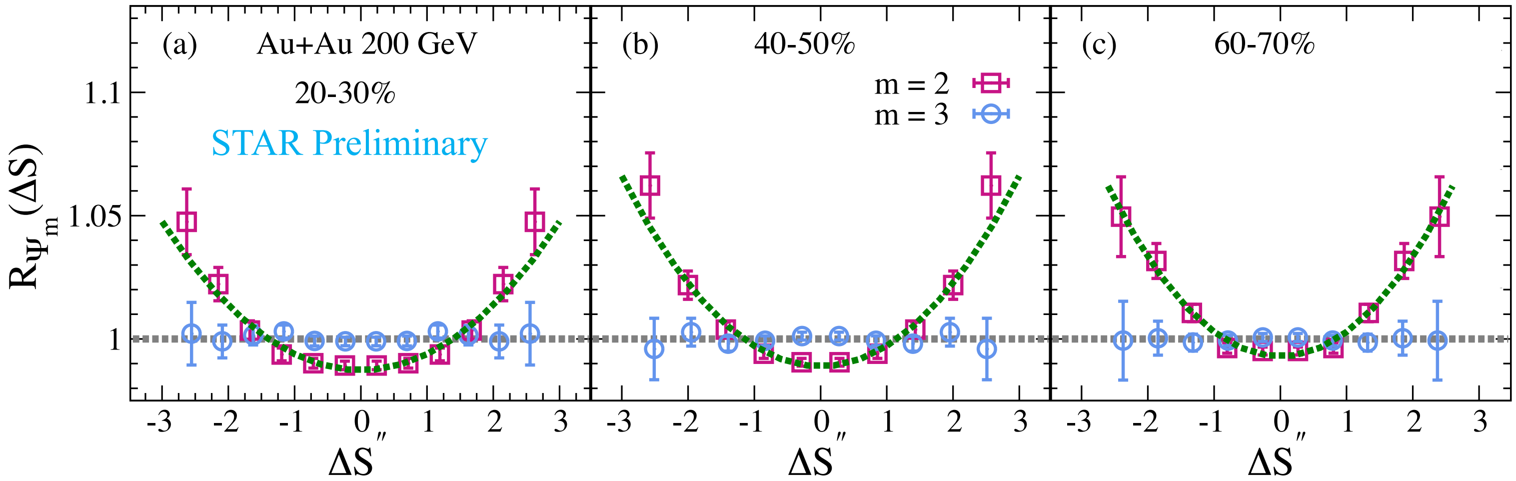
❖ Results

✓ $R_{\Psi_{\mathrm{m}}}(\Delta S)$ vs centrality (Au+Au)

❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs centrality (Au+Au)

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



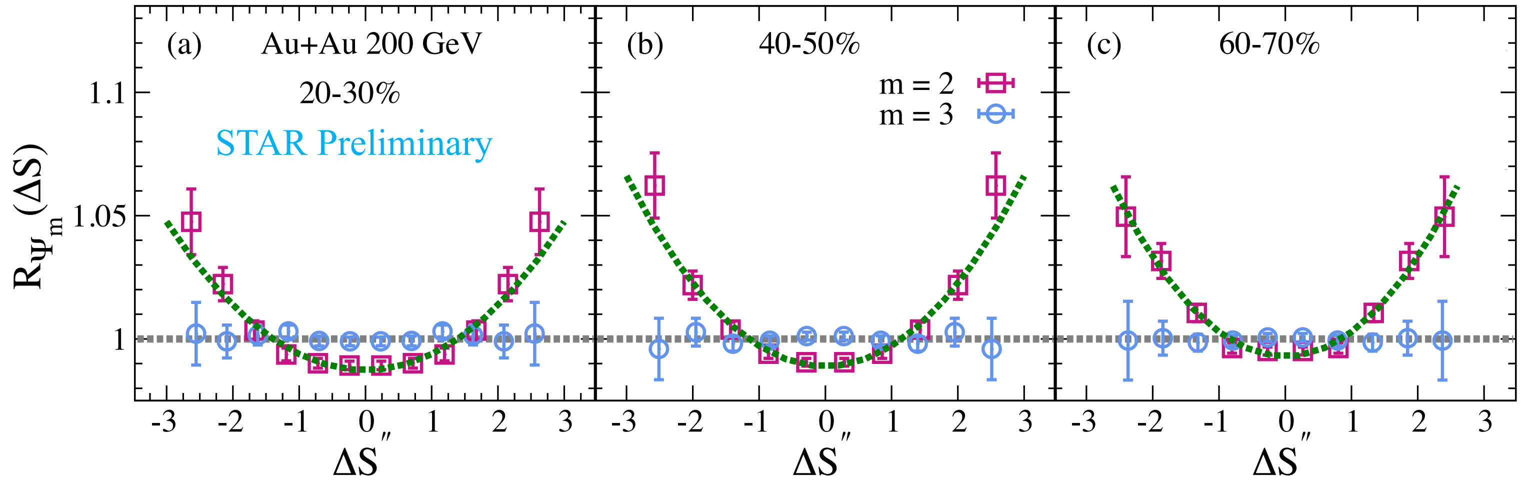
➢ Measurements show:

✓ Different response for Ψ_2 and Ψ_3

❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs centrality (Au+Au)

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

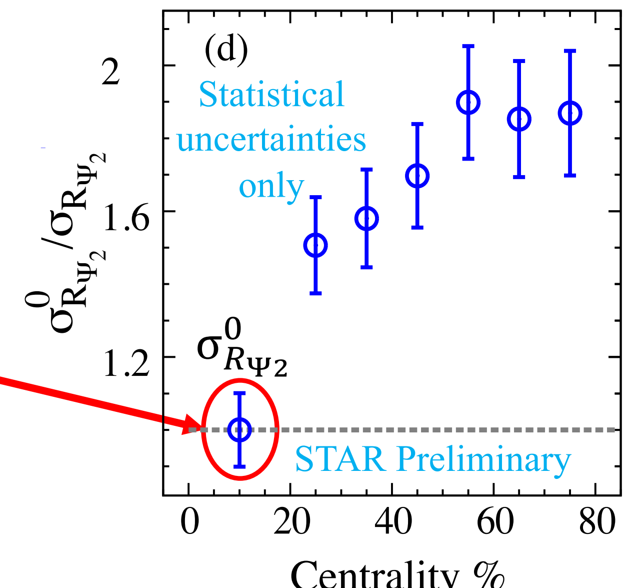


➢ Measurements show:

✓ Different response for Ψ_2 and Ψ_3

✓ R_{Ψ_2} width is centrality dependent

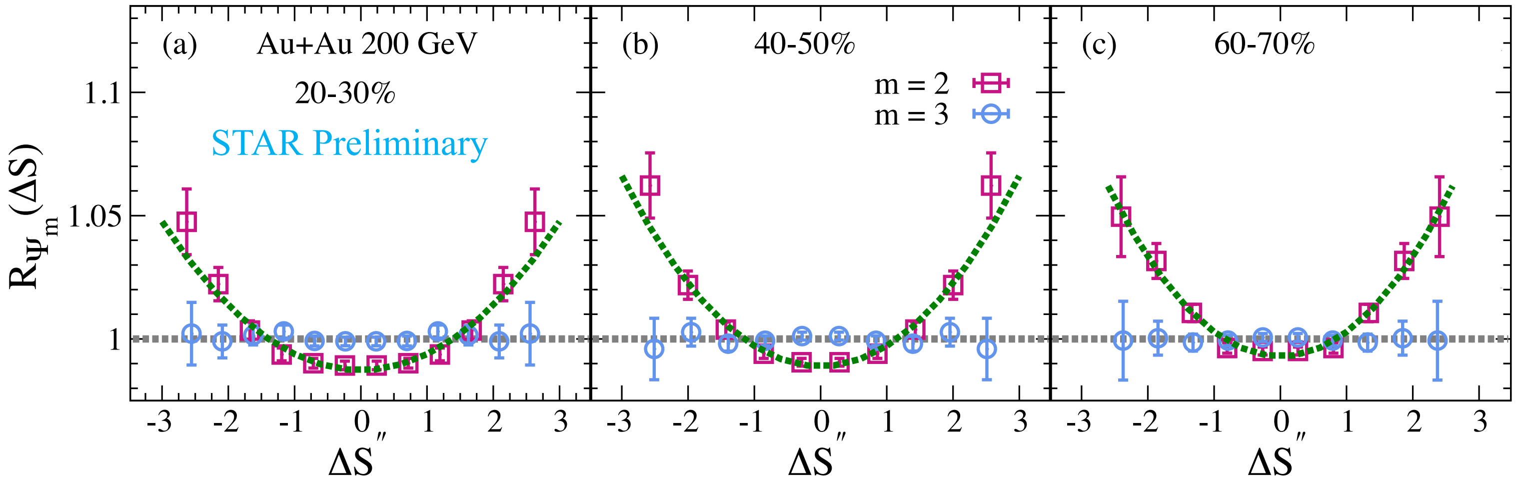
All widths are normalized to the width of 0-20% (smallest a_1)



❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs centrality (Au+Au)

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

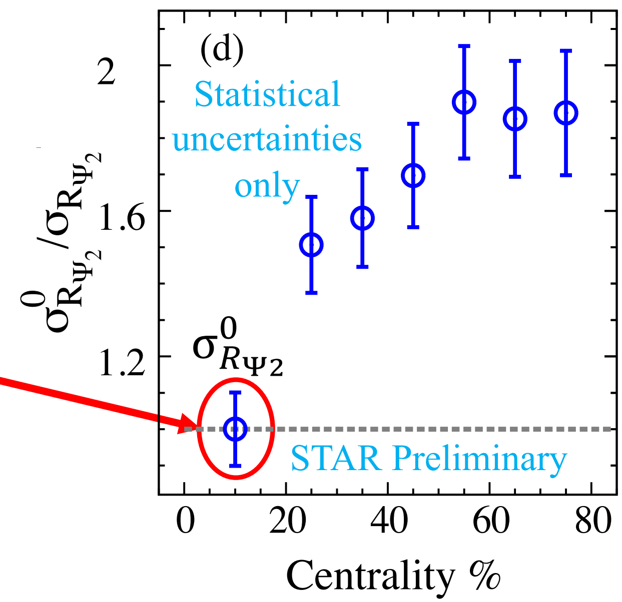


➢ Measurements show:

✓ Different response for Ψ_2 and Ψ_3

✓ R_{Ψ_2} width is centrality dependent

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



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

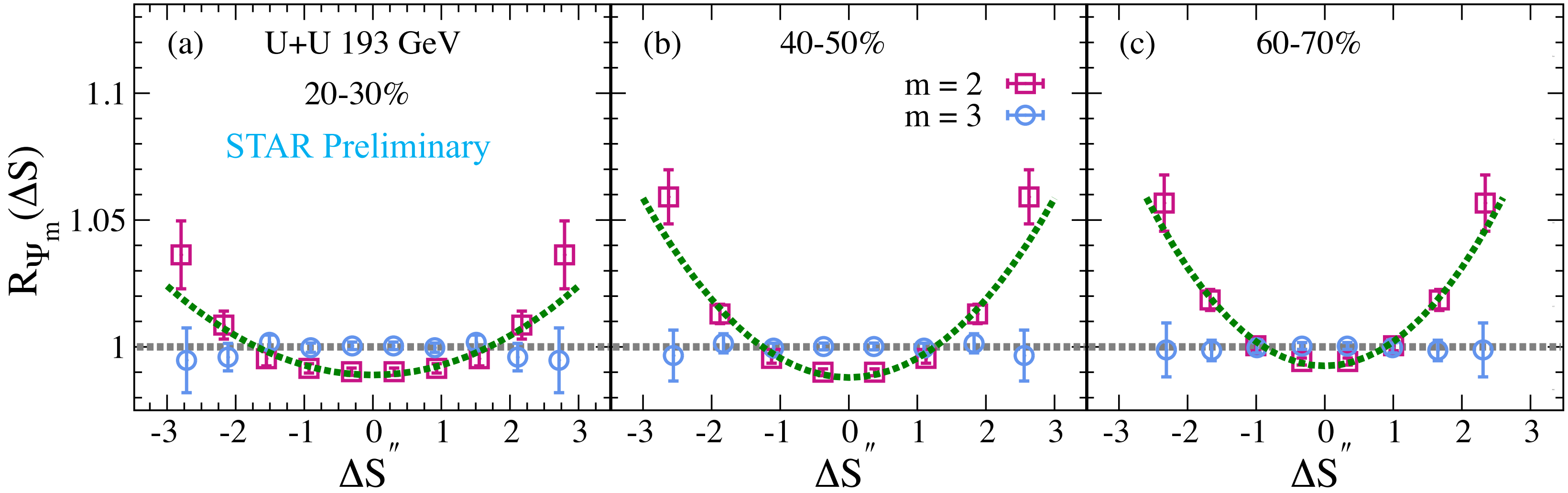
Results

- ✓ $R_{\Psi_{\mathrm{m}}}(\Delta S)$ vs centrality (U+U)

❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs centrality (U+U)

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

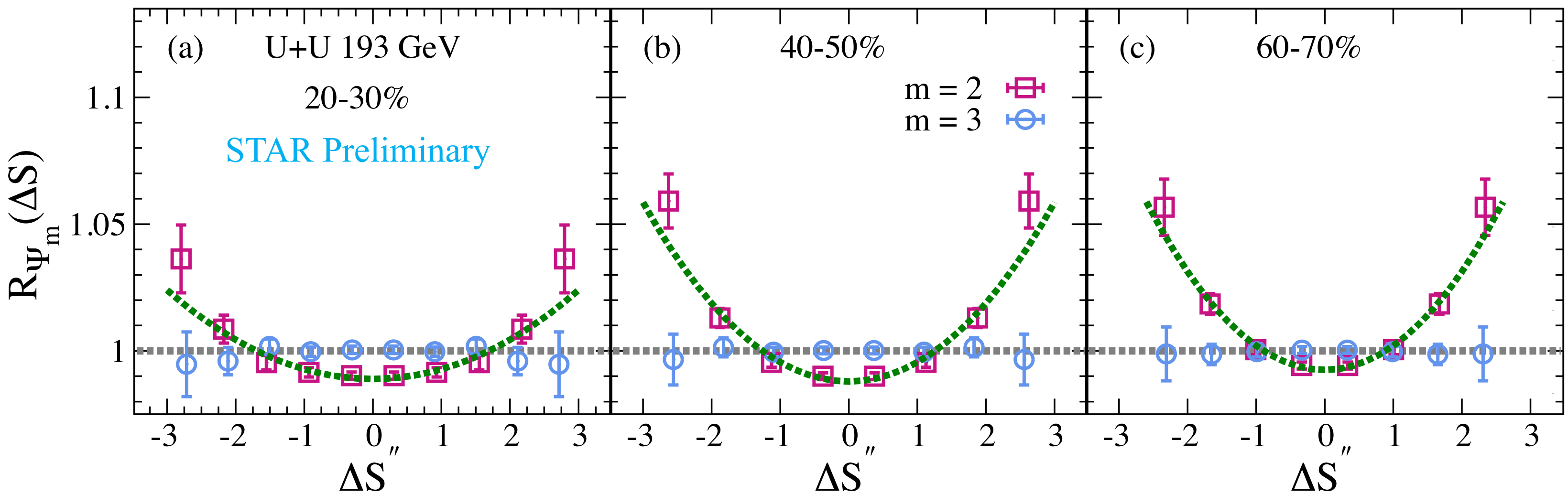


- Measurements show:
  - ✓ Different response for Ψ_2 and Ψ_3

❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs centrality (U+U)

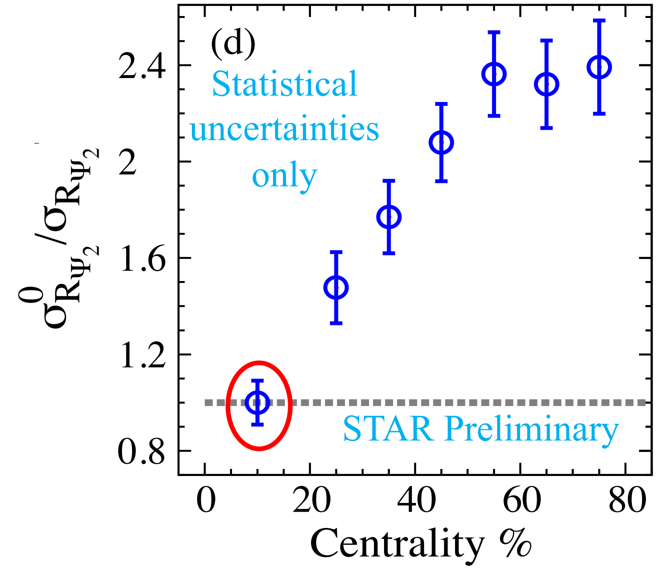
$$Fit(x) = a\, e^{0.5\left(\frac{x}{\sigma}\right)^2}$$



➢ Measurements show:

✓ Different response for Ψ_2 and Ψ_3

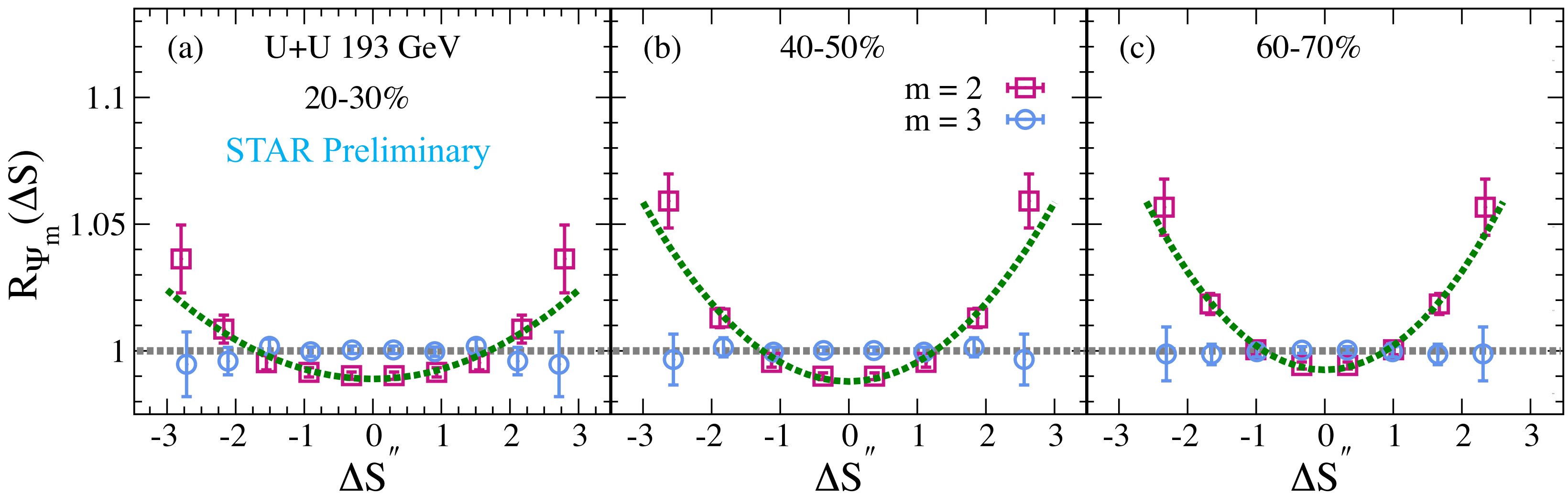
✓ R_{Ψ_2} width is centrality dependent



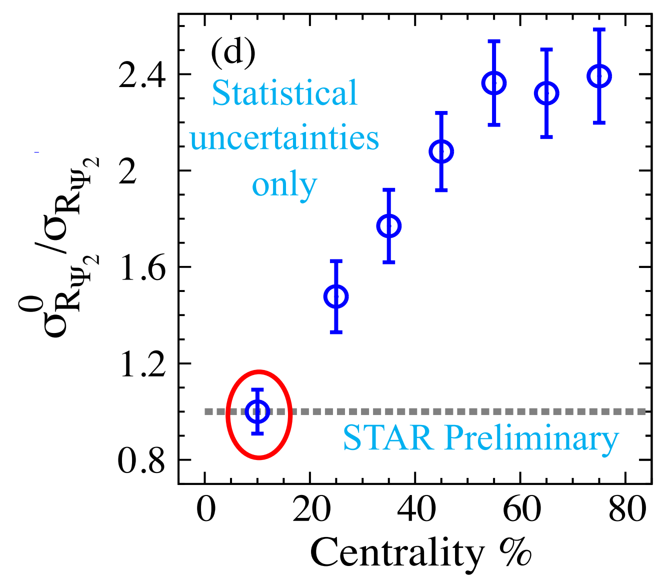
❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs centrality (U+U)

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



- Measurements show:
  - ✓ Different response for Ψ_2 and Ψ_3
  - ✓ R_{Ψ_2} width is centrality dependent



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

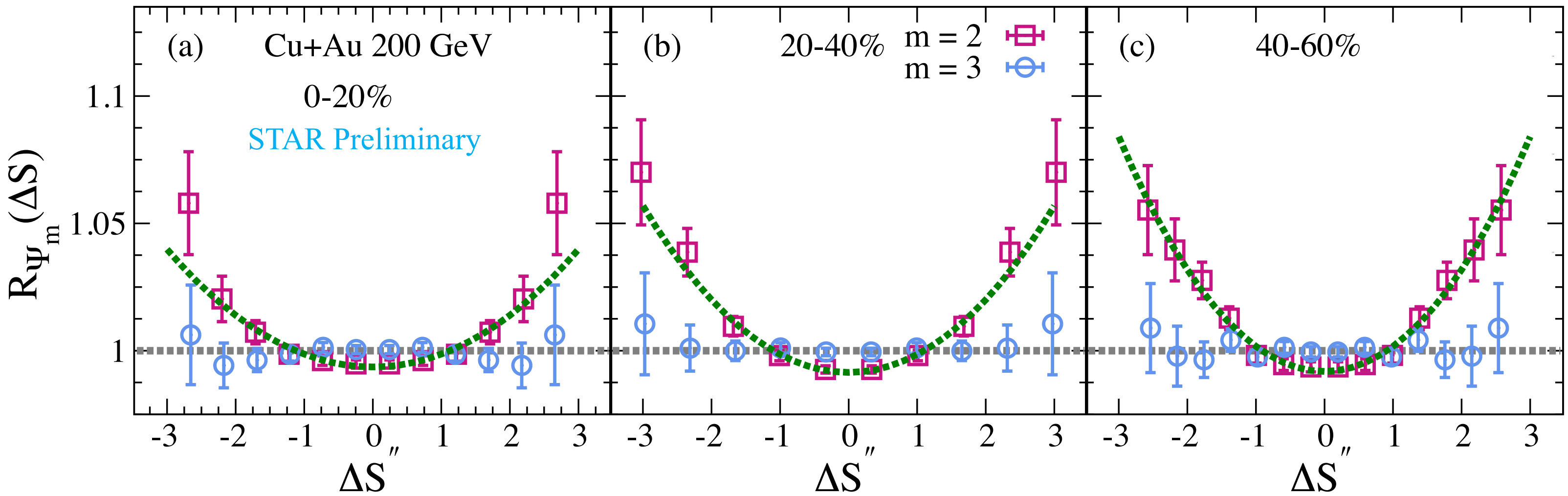
❖ Results

✓ $R_{\Psi_{\mathrm{m}}}(\Delta S)$ vs centrality (Cu+Au)

❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs centrality (Cu+Au)

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

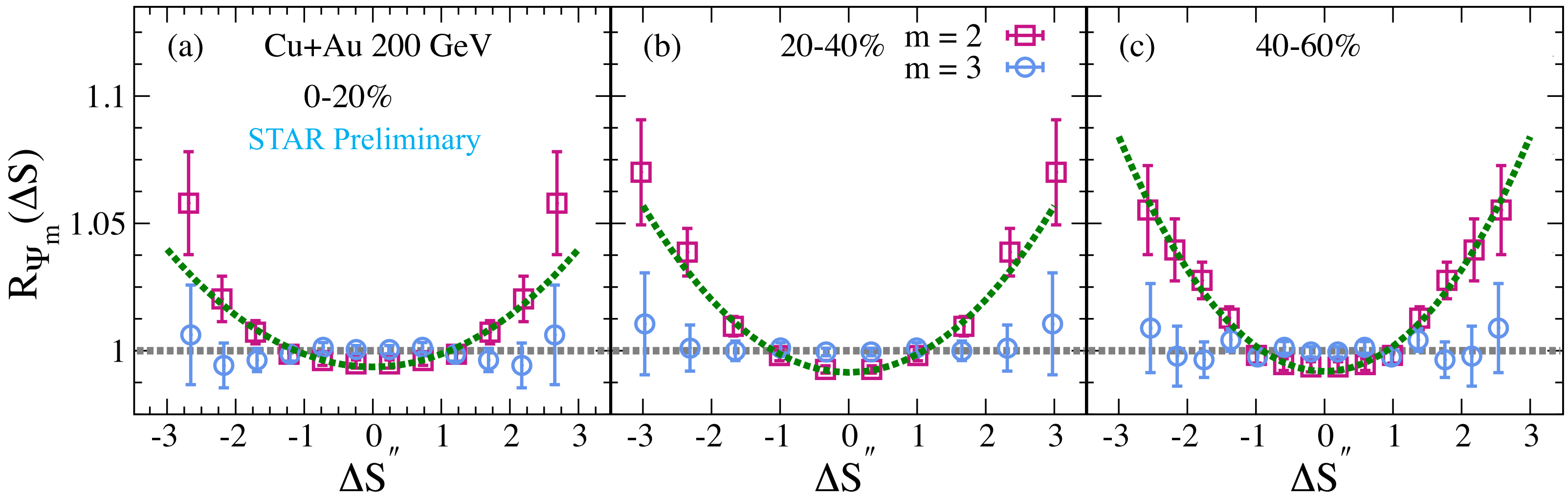


- ➢ Measurements show:
  - ✓ Different response for Ψ_2 and Ψ_3

❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs centrality (Cu+Au)

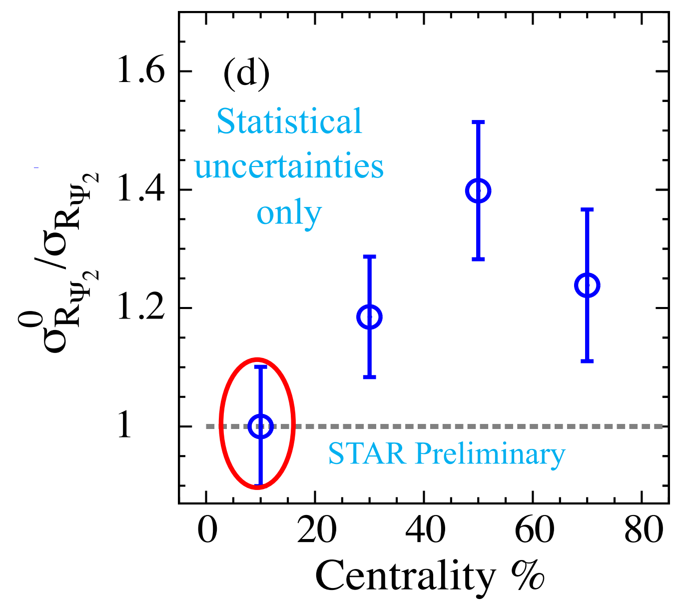
$$Fit(x) = a\, e^{0.5\left(\frac{x}{\sigma}\right)^2}$$



➢ Measurements show:

✓ Different response for Ψ_2 and Ψ_3

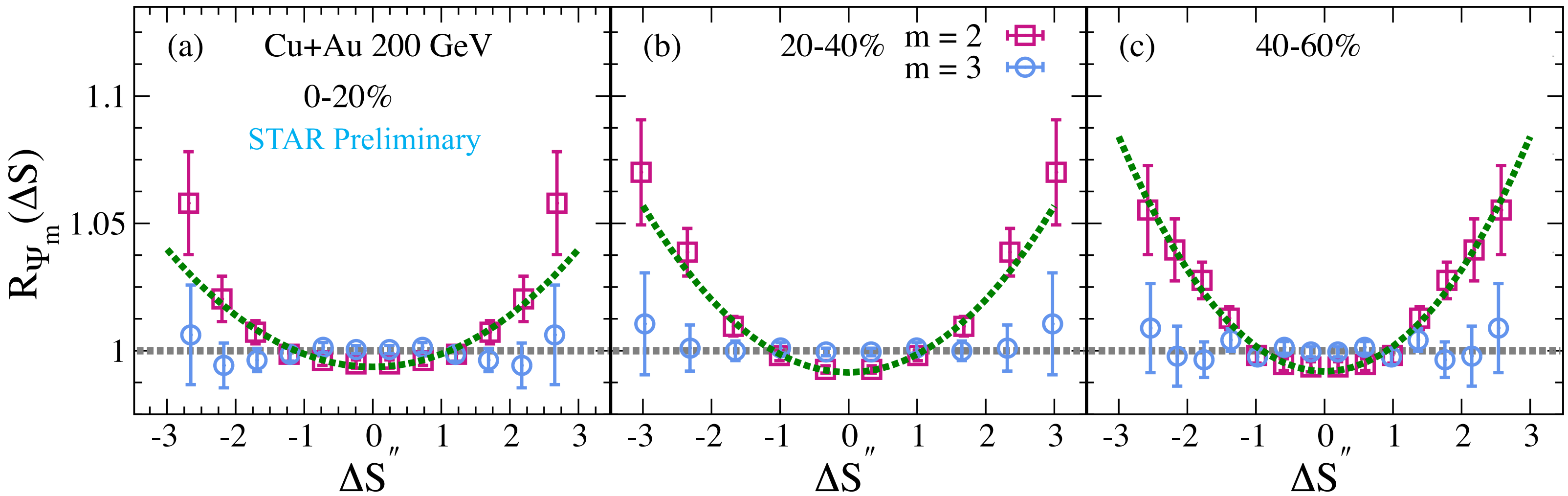
✓ R_{Ψ_2} width is centrality dependent



❖ Results

✓ $R_{\Psi_m}(\Delta S)$ vs centrality (Cu+Au)

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

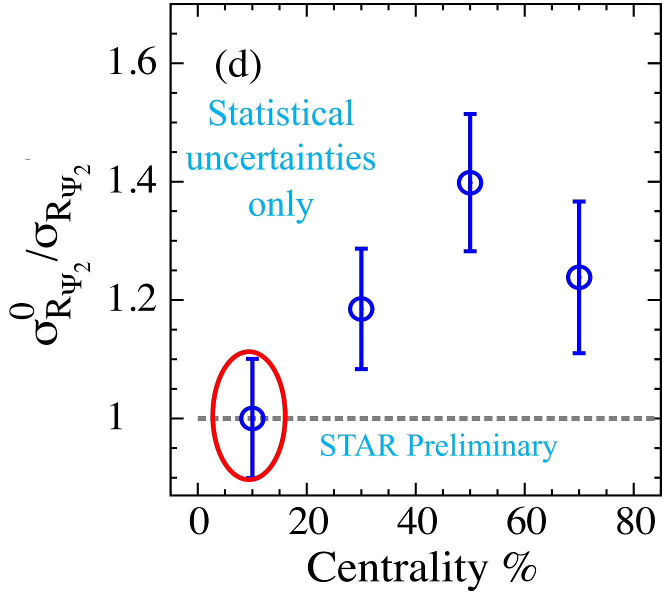


➢ Measurements show:

✓ Different response for Ψ_2 and Ψ_3

✓ R_{Ψ_2} width is centrality dependent

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



❖ Conclusion

Charge separation correlators R_{Ψ_m}, are investigated in p(d)+Au, Cu+Au (200 GeV), U+U (193 GeV) and Au+Au collisions (19.6 - 200 GeV) in the STAR experiment.

❖ Conclusion

Charge separation correlators R_{Ψ_m}, are investigated in p(d)+Au, Cu+Au (200 GeV), U+U (193 GeV) and Au+Au collisions (19.6 - 200 GeV) in the STAR experiment.

- R_{Ψ_m} measurements show:
  - ✓ Expected difference in the response for Ψ_2 and Ψ_3

❖ Conclusion

Charge separation correlators R_{Ψ_m}, are investigated in p(d)+Au, Cu+Au (200 GeV), U+U (193 GeV) and Au+Au collisions (19.6 - 200 GeV) in the STAR experiment.

- R_{Ψ_m} measurements show:
  - ✓ Expected difference in the response for Ψ_2 and Ψ_3
  - ✓ Expected difference in the response for small (p(d)+Au) and large systems

❖ Conclusion

Charge separation correlators R_{Ψ_m}, are investigated in p(d)+Au, Cu+Au (200 GeV), U+U (193 GeV) and Au+Au collisions (19.6 - 200 GeV) in the STAR experiment.

- R_{Ψ_m} measurements show:
  - ✓ 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

❖ Conclusion

Charge separation correlators R_{Ψ_m}, are investigated in p(d)+Au, Cu+Au (200 GeV), U+U (193 GeV) and Au+Au collisions (19.6 - 200 GeV) in the STAR experiment.

- R_{Ψ_m} measurements show:
  - ✓ 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:
  - ✓ $R_{\Psi_2}(\Delta S')$ width is $\langle p_T \rangle$ independent

    (Inconsistent with flow-driven background)

❖ Conclusion

Charge separation correlators R_{Ψ_m}, are investigated in p(d)+Au, Cu+Au (200 GeV), U+U (193 GeV) and Au+Au collisions (19.6 - 200 GeV) in the STAR experiment.

- R_{Ψ_m} measurements show:
  - ✓ 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:
  - ✓ $R_{\Psi_2}(\Delta S')$ width is $\langle p_T \rangle$ independent

    (Inconsistent with flow-driven background)
  - ✓ $R_{\Psi_2}(\Delta S'')$ width is $\sqrt{s_{NN}}$ independent

    (Consistent with $\vec{B}(\tau)$ $\sqrt{s_{NN}}$ dependence)

❖ Conclusion

Charge separation correlators R_{Ψ_m}, are investigated in p(d)+Au, Cu+Au (200 GeV), U+U (193 GeV) and Au+Au collisions (19.6 - 200 GeV) in the STAR experiment.

- R_{Ψ_m} measurements show:
  - ✓ 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:
  - ✓ $R_{\Psi_2}(\Delta S')$ width is $\langle p_T \rangle$ independent

    (Inconsistent with flow-driven background)
  - ✓ $R_{\Psi_2}(\Delta S'')$ width is $\sqrt{s_{NN}}$ independent

    (Consistent with $\vec{B}(\tau)$ $\sqrt{s_{NN}}$ dependence)
  - ✓ $R_{\Psi_2}(\Delta S'')$ width is decreasing with centrality

    (Consistent with the the $\vec{B}$-field increase with centrality)

❖ Conclusion

Charge separation correlators R_{Ψ_m}, are investigated in p(d)+Au, Cu+Au (200 GeV), U+U (193 GeV) and Au+Au collisions (19.6 - 200 GeV) in the STAR experiment.

- R_{Ψ_m} measurements show:
  - ✓ 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:
  - ✓ $R_{\Psi_2}(\Delta S')$ width is $\langle p_T \rangle$ independent

    (Inconsistent with flow-driven background)
  - ✓ $R_{\Psi_2}(\Delta S'')$ width is $\sqrt{s_{NN}}$ independent

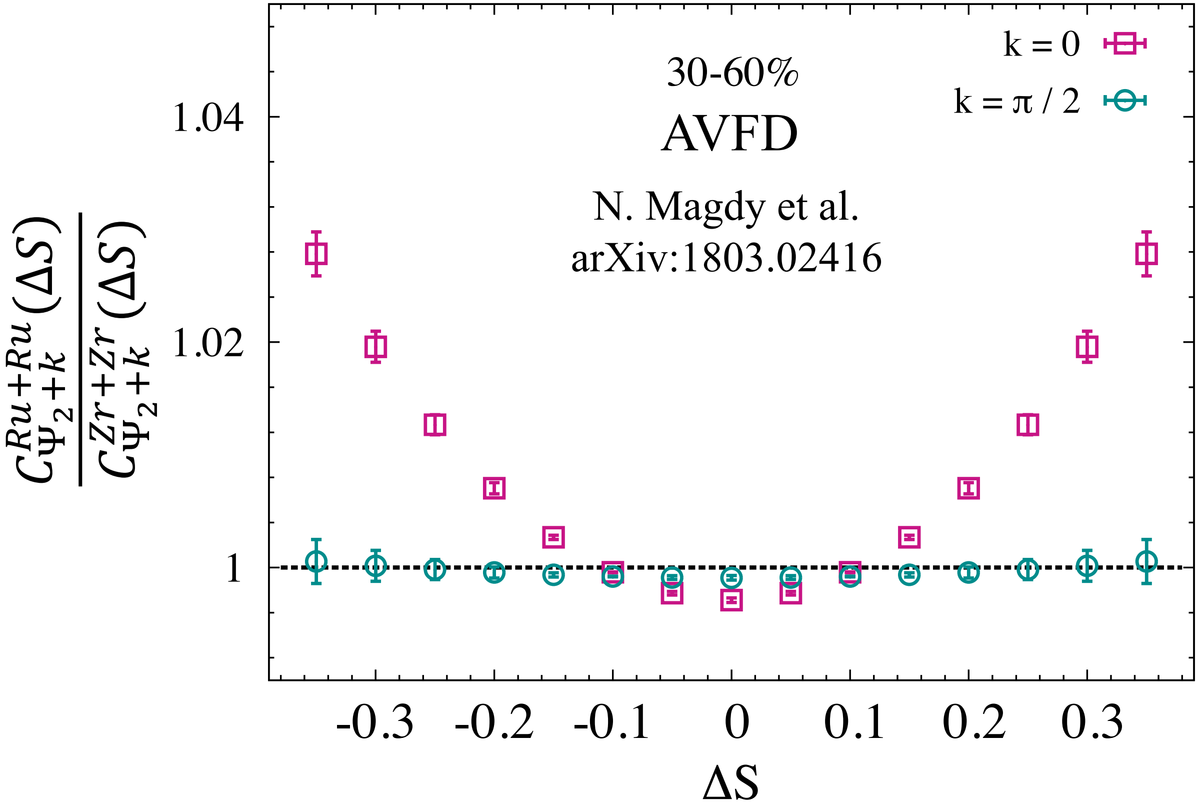
    (Consistent with $\vec{B}(\tau)$ $\sqrt{s_{NN}}$ dependence)
  - ✓ $R_{\Psi_2}(\Delta S'')$ width is decreasing with centrality

    (Consistent with the the $\vec{B}$-field increase with centrality)

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

❖ Outlook

$$C_{\Psi_2+k} = \frac{N(\Delta S^{\Psi_2+k})}{N(\Delta S_{sh}^{\Psi_2+k})}$$



➢ AVFD implies that the use of the R_{Ψ_m} correlators in the isobar data will provide useful information to characterize both signal and background

THANK YOU