Chiral magnetic effect search in p+Au, d+Au and Au+Au collisions at RHIC

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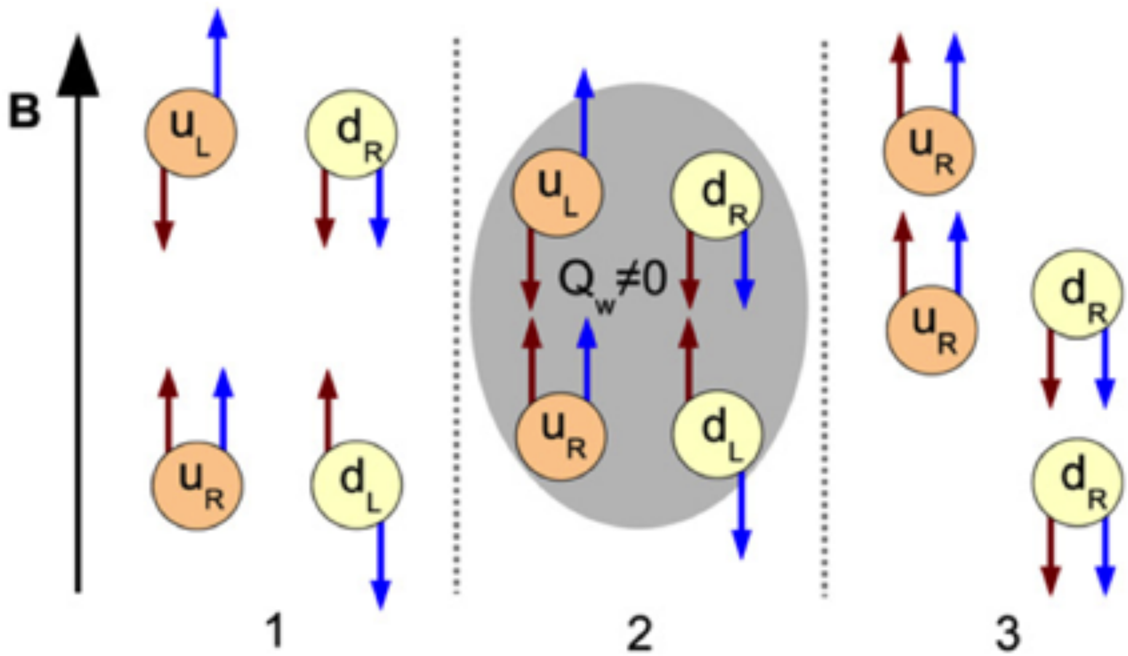
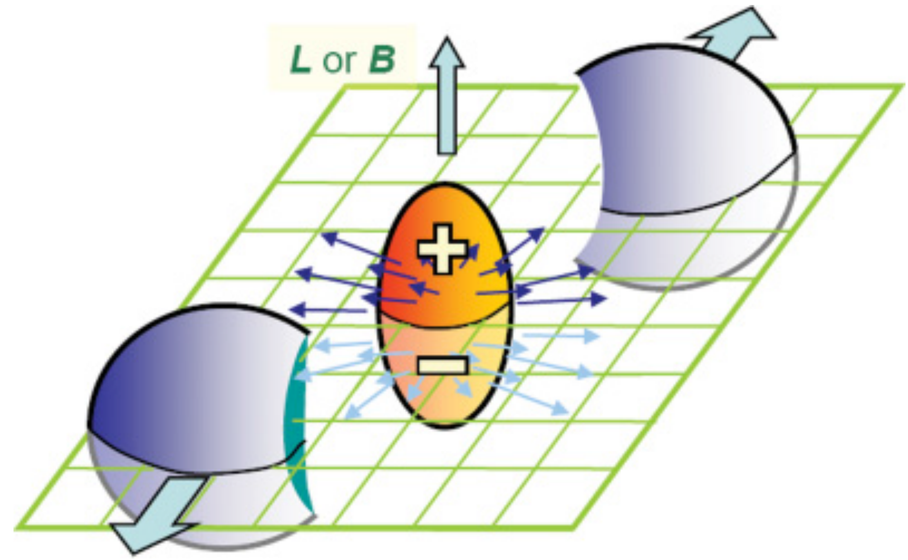
Outline

- Chiral Magnetic Effect (CME)
- CME in small systems
- Results in p/d+A and A+A collisions
- Identification of backgrounds and possible CME
- Summary

Chiral Magnetic Effect (CME)

D. Kharzeev, etc. NPA 803, 227(2008)



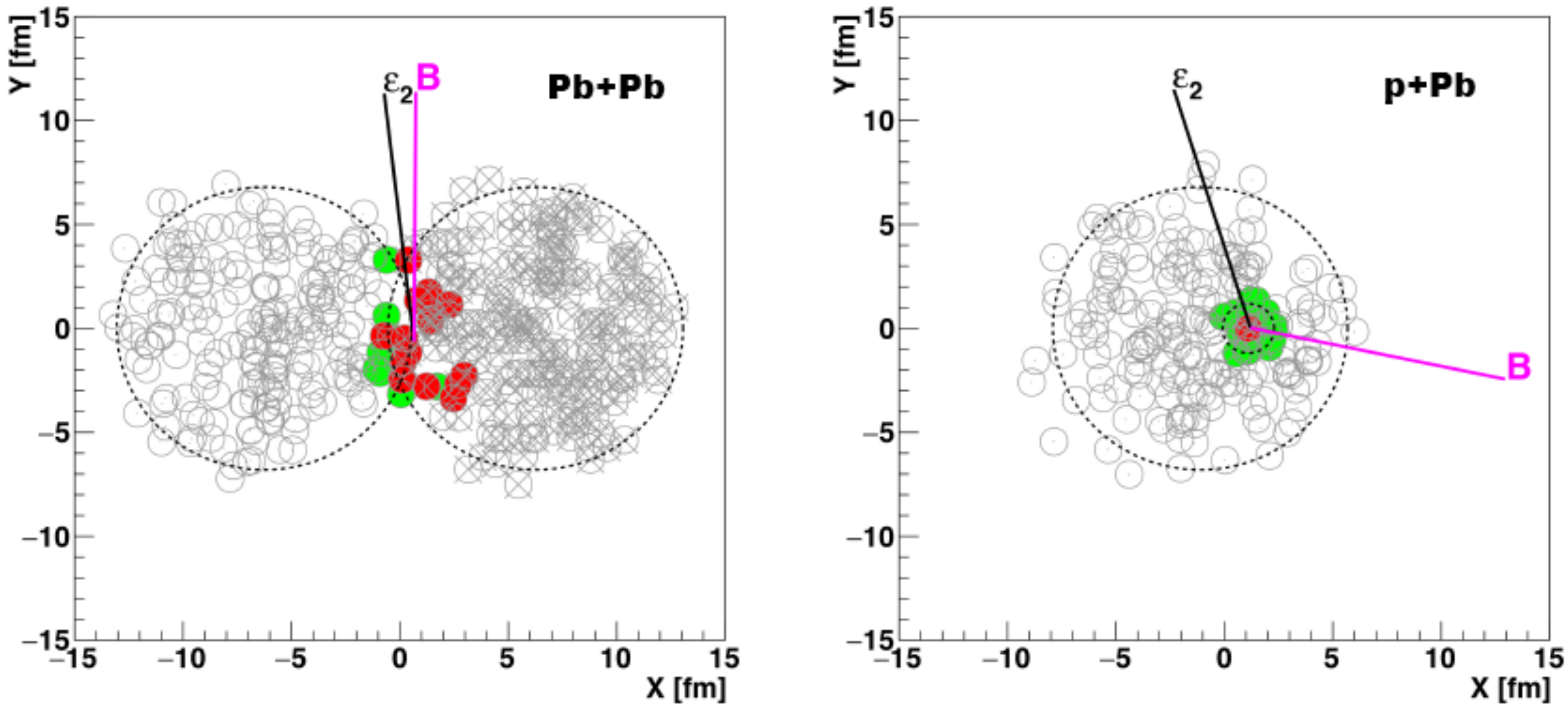


$$j_V = \frac{N_c e}{2\pi^2}\mu_A B,$$ ⇨ electric charge separation alone the B field

Configuration with non-zero topological charge (Q_w) converts left (right)-handed fermions to right (left)-handed fermions, generating electric current along B direction and leading to electric charge separation

Harmonic planes in small systems

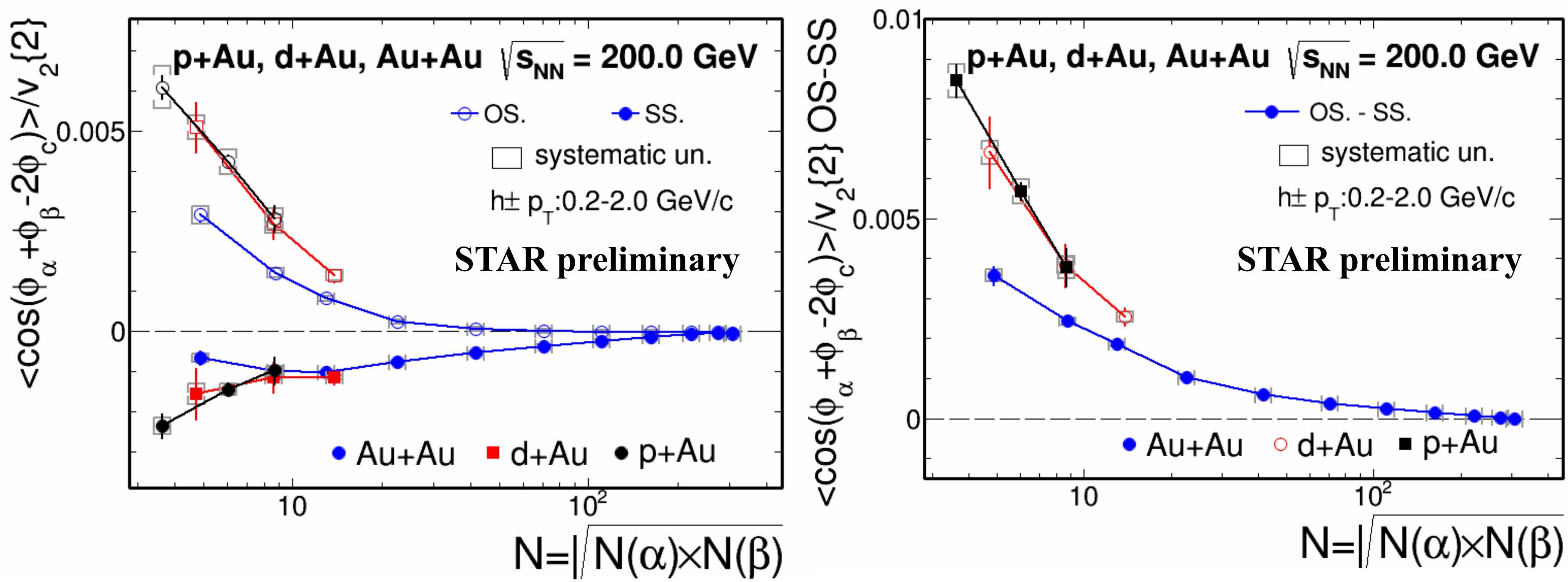
CMS collaboration, PRL 118(2017)122301; R. Belmont and J.L. Nagle, arXiv:1610.07964v1



Ψ_2: second-order event plane; Ψ_1: first-order event plane

- Ψ_2 related to flow, related to flow background
- Ψ_1 related to the magnetic direction (B), useful for CME signal
- Ψ_1 and Ψ_2 correlated in A+A, signal and background entangled
- Ψ_1 and Ψ_2 not correlated in p+A, d+A, signal and background disentangled

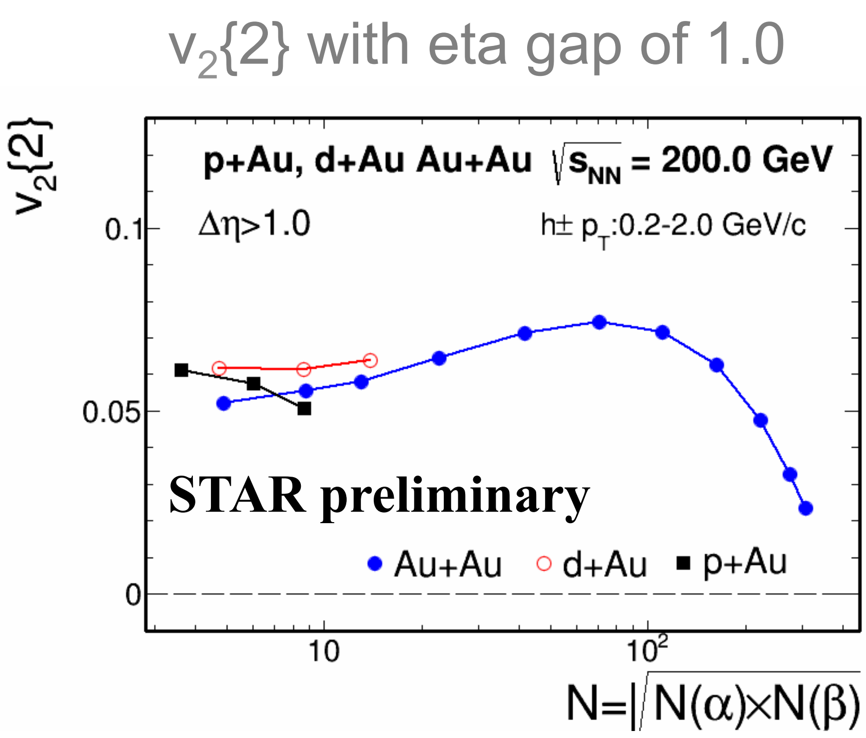
Multiplicity dependence in small systems

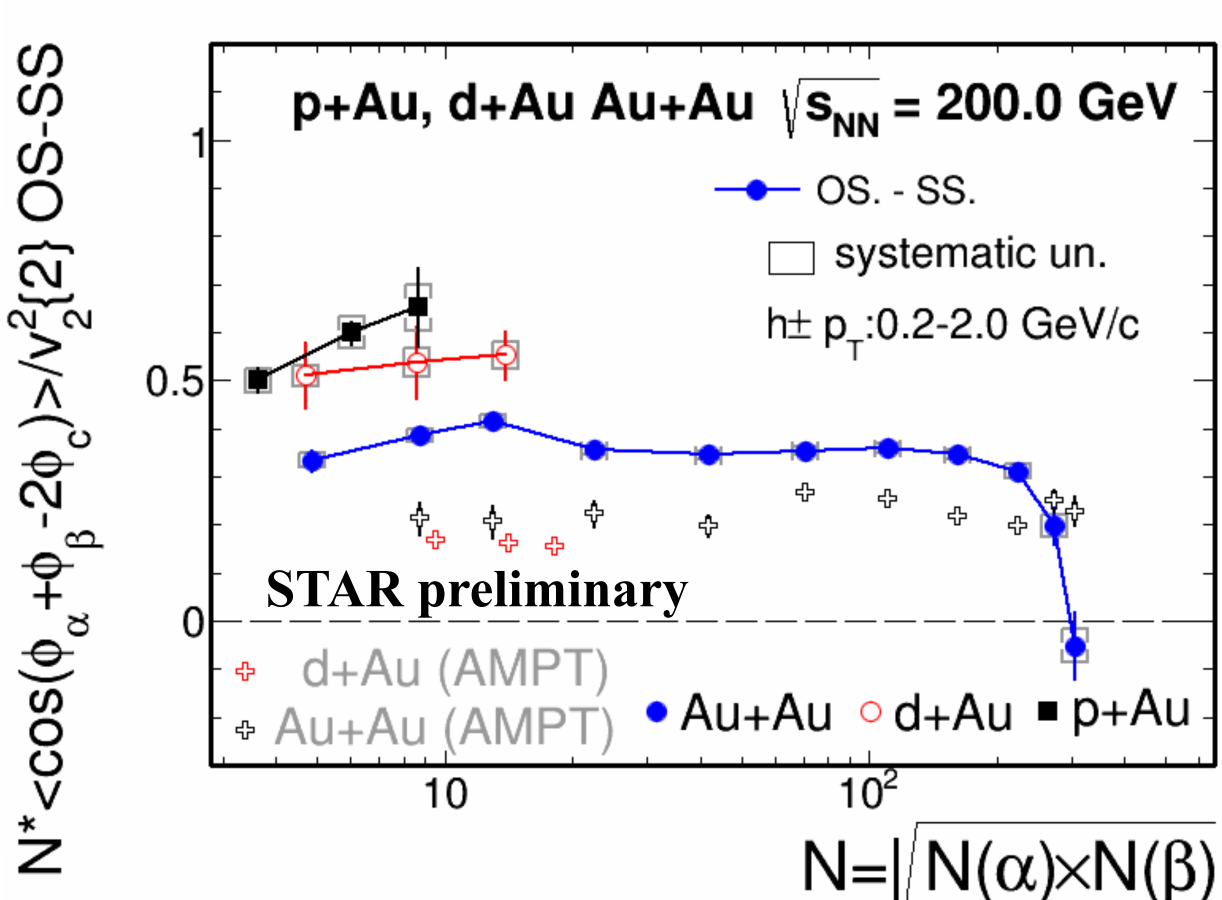


N(α/β) represents the charged (+/-) particle multiplicity used for the correlator

- Sizeable charge dependent signal in small system p+Au and d+Au collisions with respect to second-order event plane Ψ_2
- $v_2\{2\}$ with η gap of 1.0

Multiplicity dependence



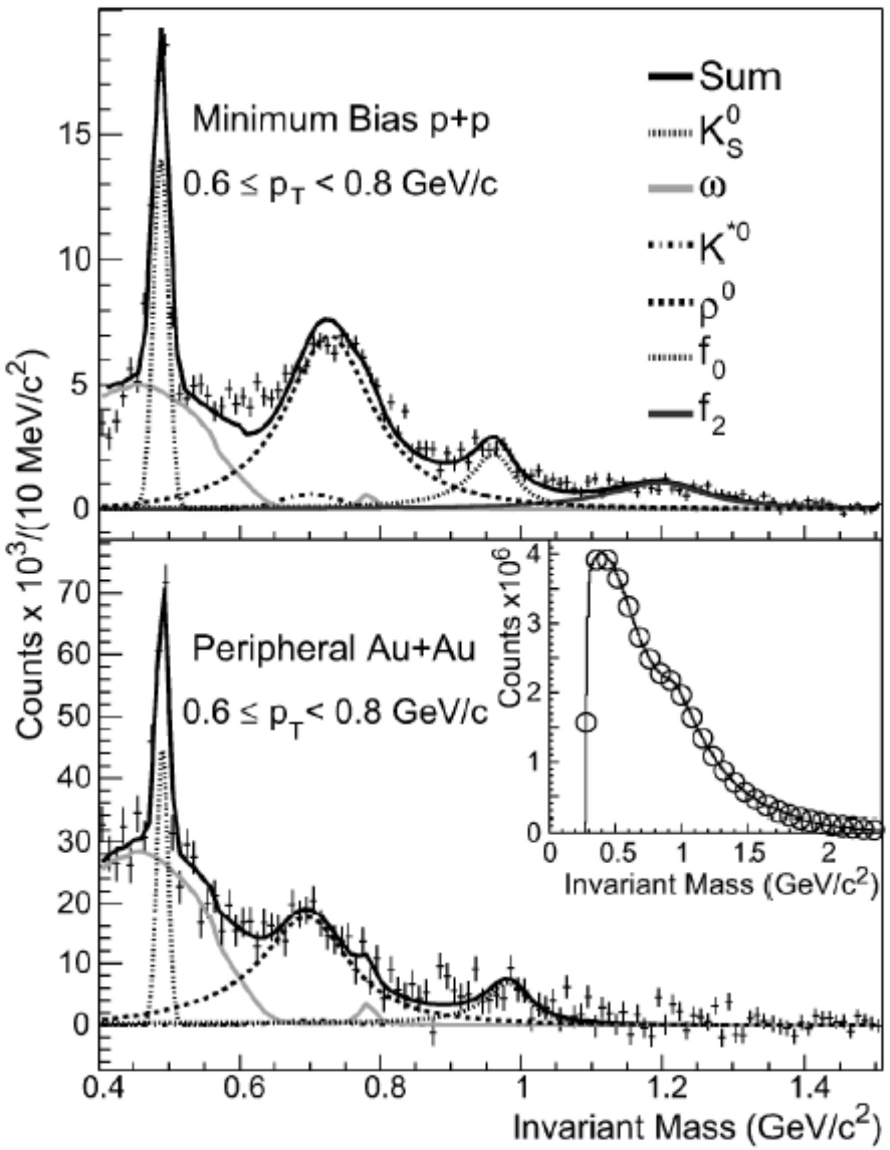


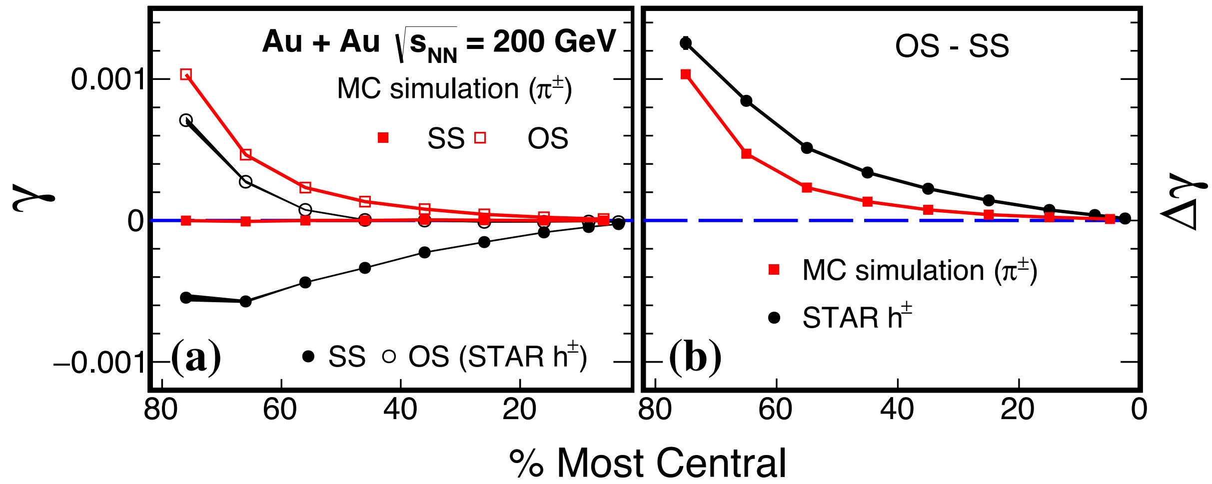
- Background expectation: N dilution, proportional to flow $v_2\{2\}$
- Right plot: if intrinsic particle pair-wise correlation is independent of N, background scenario would yield a constant as a function of N
- With topological charge sign fluctuations and magnetic field direction fluctuations, CME might yield different multiplicity dependence

Resonance decay background

Fuqiang Wang, Jie Zhao, Phys.Rev.C 95,051901(R) (2017)

STAR, Phys.Rev.Lett.92,092301 (2004)

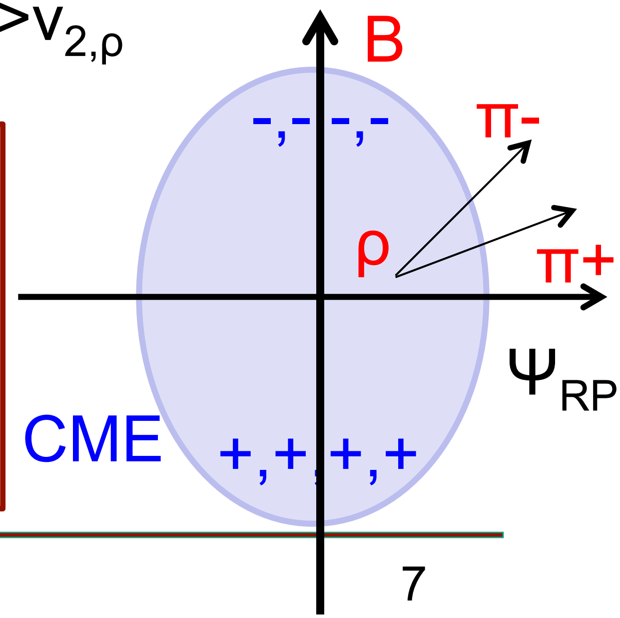




Resonance decay:

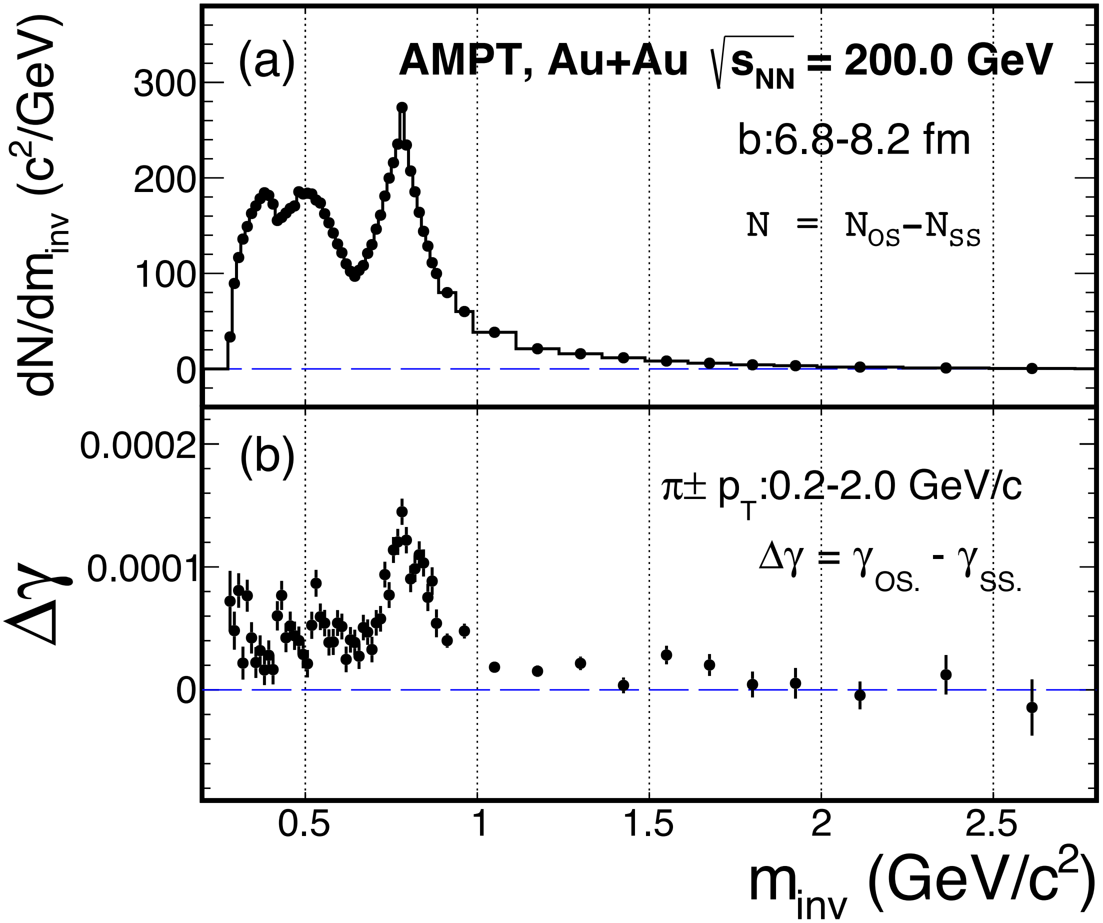
$$\Delta\gamma = \cos(\alpha+\beta-2\Psi_{RP})$$
$$\propto \langle\cos(\alpha+\beta-2\phi_\rho)\rangle\cos 2(\phi_\rho-\psi_{RP})$$
$$\approx \langle\cos(\alpha+\beta-2\phi_\rho)\rangle v_{2,\rho}$$

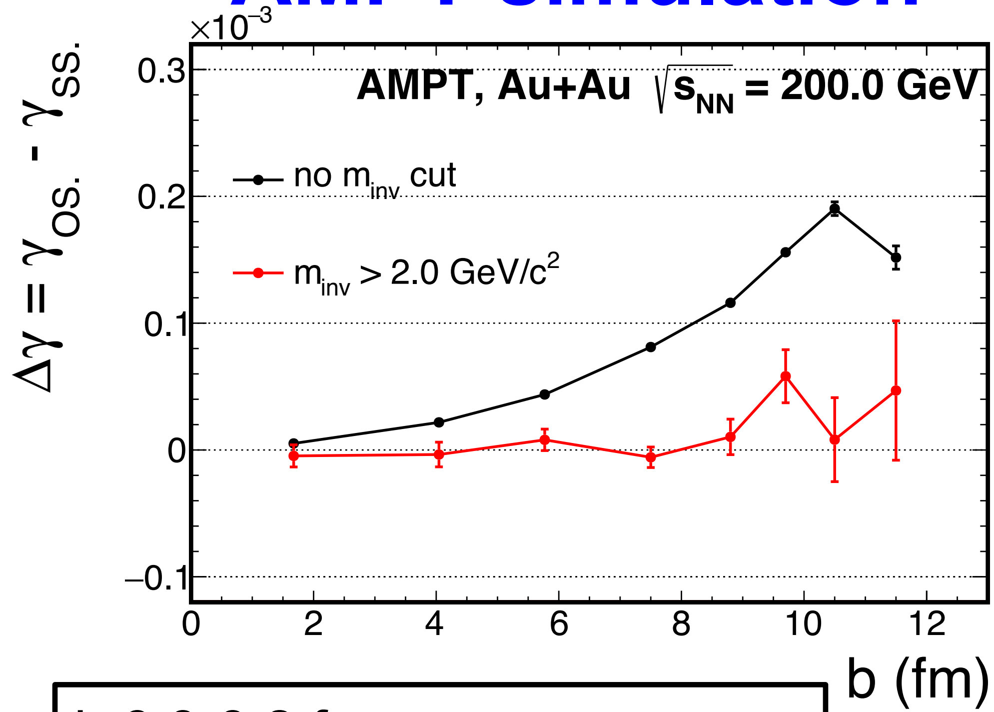
Resonance bkg.:
resonance decay coupled with v_2, will give a CME -like $\Delta\gamma$ signal



Identify resonance bkg. by invariant mass

AMPT simulation

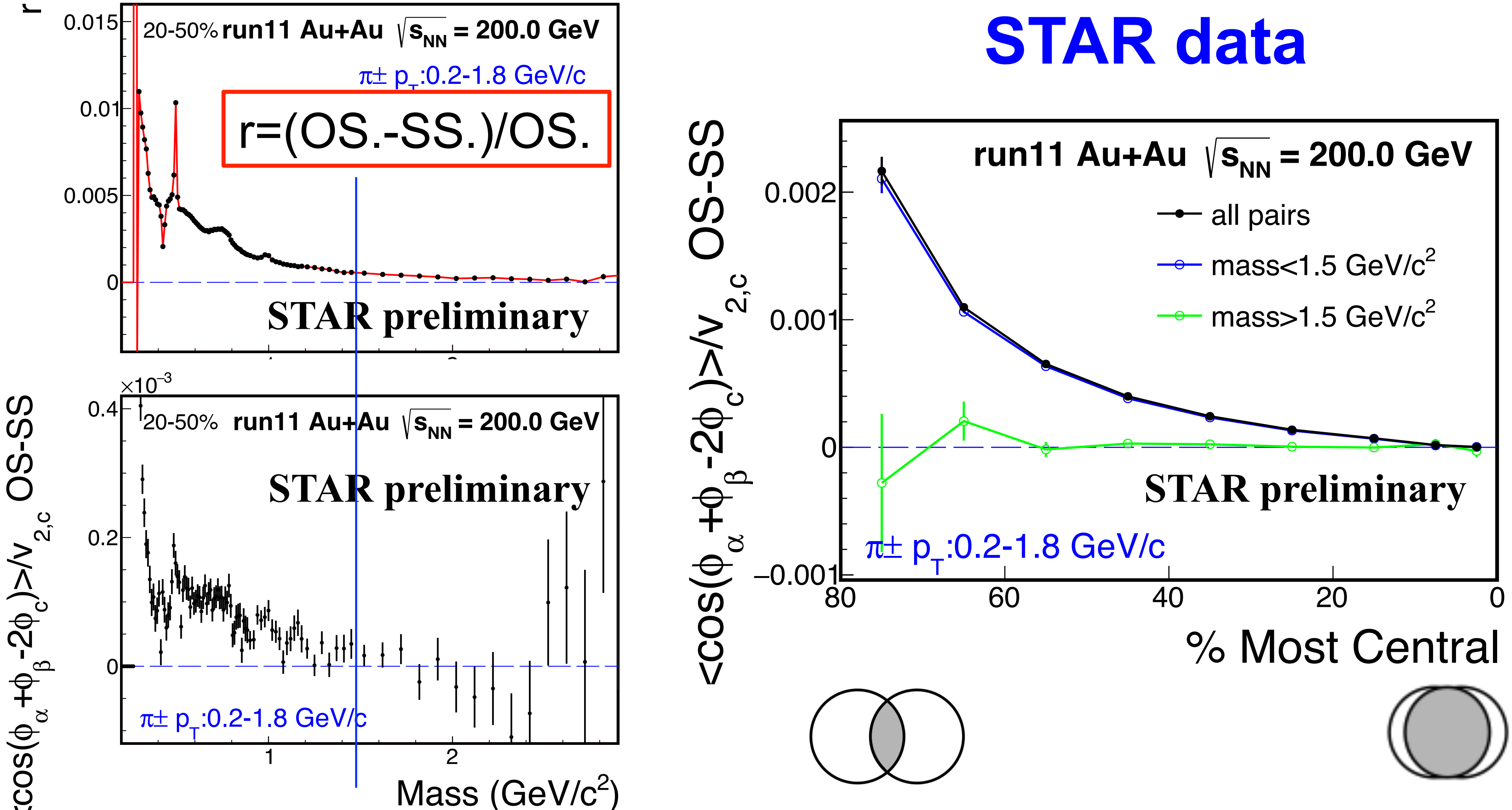




b:6.8-8.2 fm
Δγ: (81.2±1.2)E-6
m>2GeV/c^2: (-5.8±8.1)E-6

- AMPT has no CME, only background
- AMPT show resonance structure in Δγ as function of mass
- At large mass with smaller abundance difference between the unlike-sign and like-sign pairs, Δγ is consistent with zero

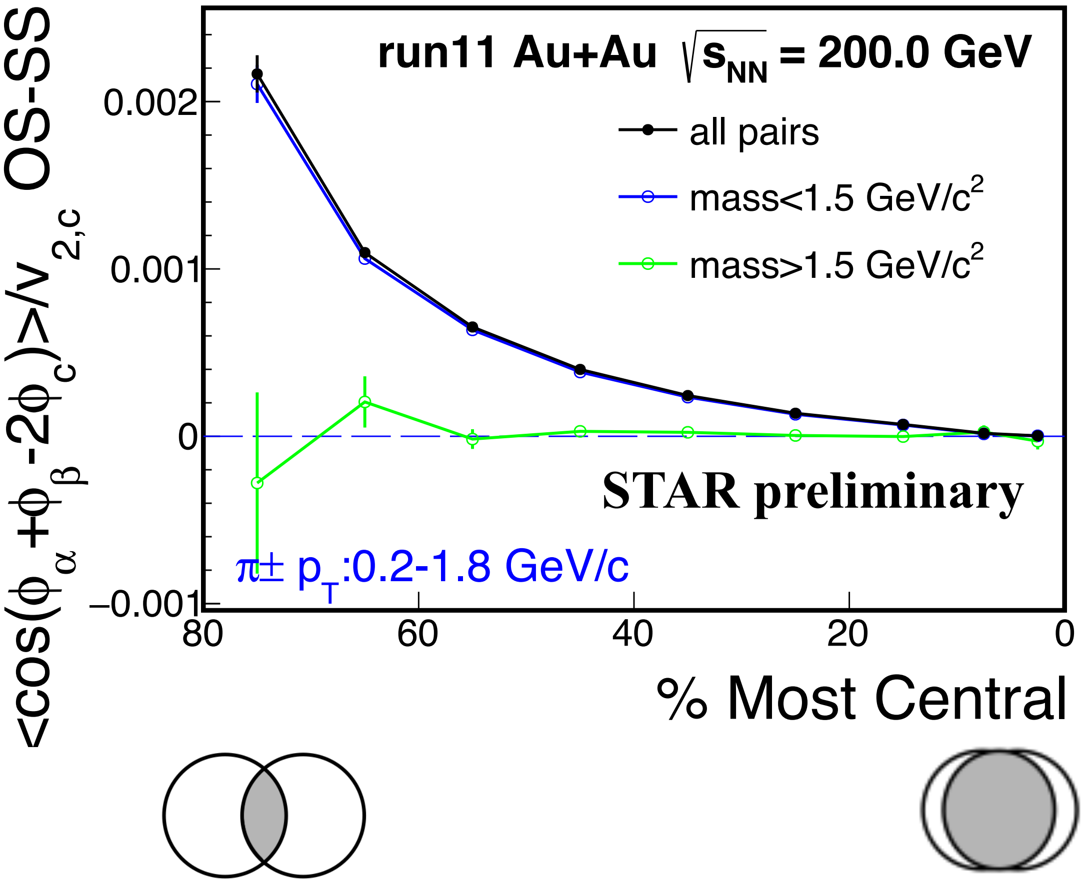
Identify resonance bkg. by invariant mass



- Identify resonance background by the invariant mass
- Data show resonance structure in Δγ as function of mass
- Δγ decrease as r decrease with m increase, larger r -> larger res. contribution -> larger Δγ

Δγ traces r

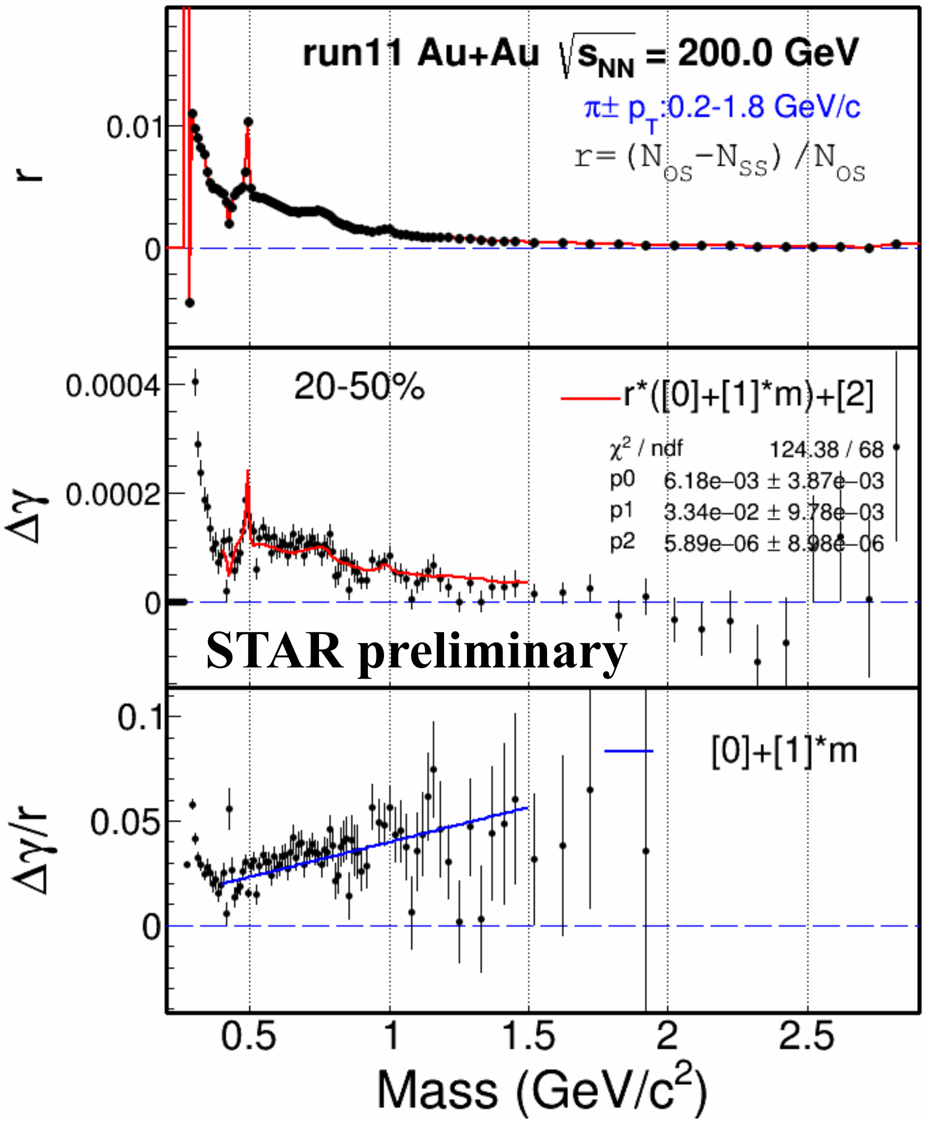
Go to high mass region



Centrality	All (A)	M>1.5 (B)	B/A
50-80%	(7.45±0.21)E-4	(1.3±5.7)E-5	(1.8±7.6)%
20-50%	(1.82±0.03)E-4	(7.7±9.0)E-6	(4.3±4.9)%
0-20%	(3.70±0.67)E-5	(-0.1±1.8)E-5	(-3.8±49)%

- Resonance contribution of unlike minus like sign pairs decreases with increasing mass
- At m>1.5 GeV/c², Δγ is consistent with zero

Identify resonance bkg. and possible CME



- **Resonance bkg.:**

$\Delta\gamma = \cos(\alpha+\beta-2\Psi_{RP})$

$\propto \langle\cos(\alpha+\beta-2\phi_{res.})\rangle \cos2(\phi_{res.}-\Psi_{RP})$

$\approx \langle\cos(\alpha+\beta-2\phi_{res.})\rangle v_{2res.}$

- **Resonance bkg. + CME**

$\Delta\gamma(m) = r(m)*\cos(\alpha+\beta-2\phi_{res.})*v_{2res.} + CME$

$= r(m)*f(m)*v_{2res.} \quad + CME$

peaky smooth

different dep. on mass,
viable way to distinguish the sig. and bkg.

Δγ (Inclusive)	(1.82±0.03)E-4	
	constant CME	exponential CME
Δγ (Fit)	(5.9±9.0)E-6	(3.0±2.0)E-5
Fit/Inclusive:	3.2±4.9%	16±11%

- Data are fitted with constant and exponential CME assumptions in mass
- In the current approach, the statistical uncertainty is dominant

Summary

- With respect to Ψ_2: p+Au and d+Au charge dependent correlations are background. Peripheral Au+Au data are similar to that of p+Au and d+Au
- The scaled correlators from peripheral to mid-central Au+Au collisions are approximately constant over multiplicity. These data do not currently allow conclusive statements to be made regarding the presence of the CME
- Identify resonance bkg. by the **invariant mass**
- At $m>1.5$ GeV/c^2, $\Delta\gamma$ is consistent with zero within uncertainty
- Observation of resonance structure in $\Delta\gamma$ at $m<1.5$ GeV/c^2. Two component fit is used to isolate the possible CME from bkg.