Elliptic flow of J/ψ in U+U collisions performed at STAR experiment

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Outline of presentation

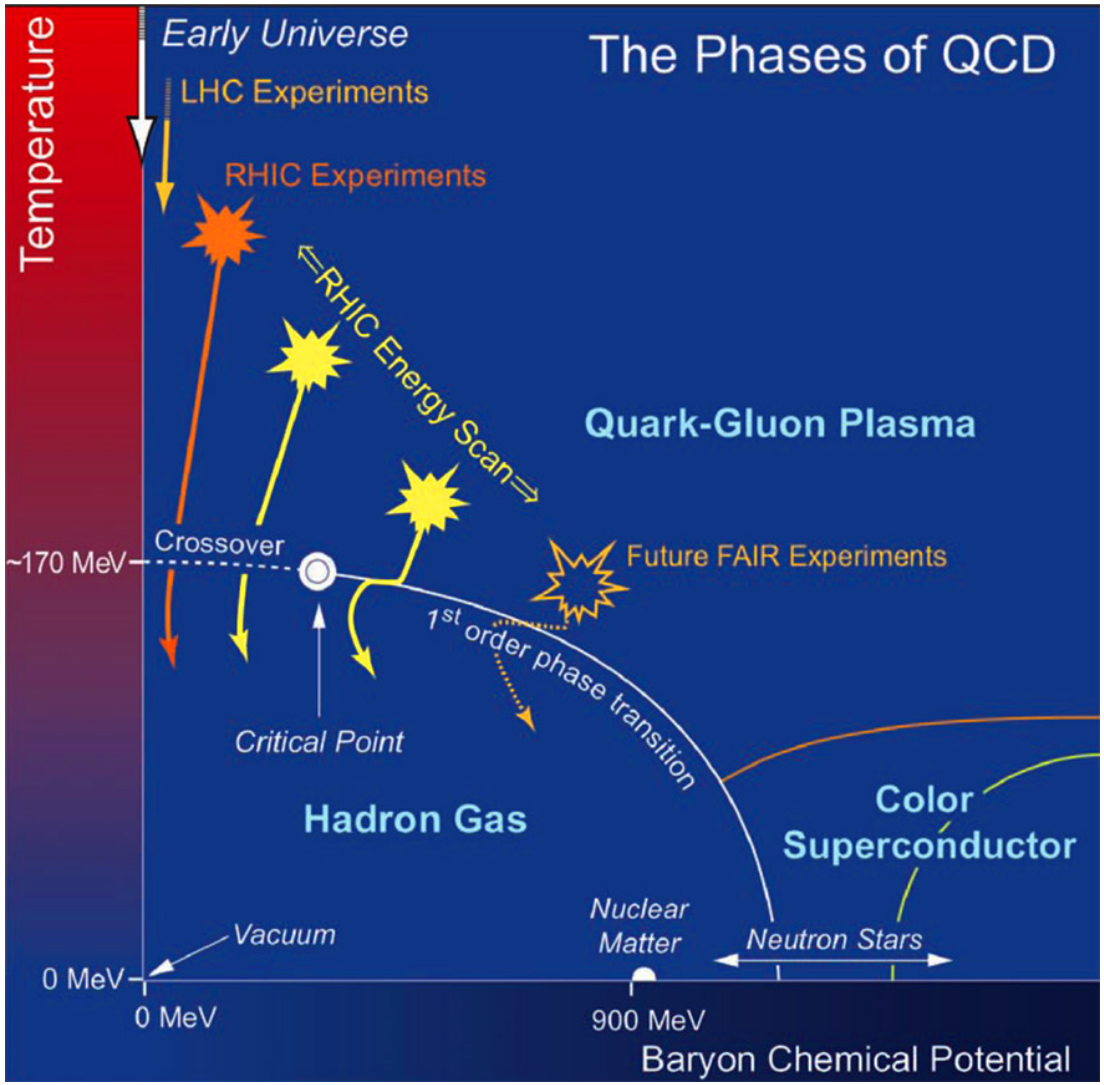
Quark-gluon plasma

Nuclear matter

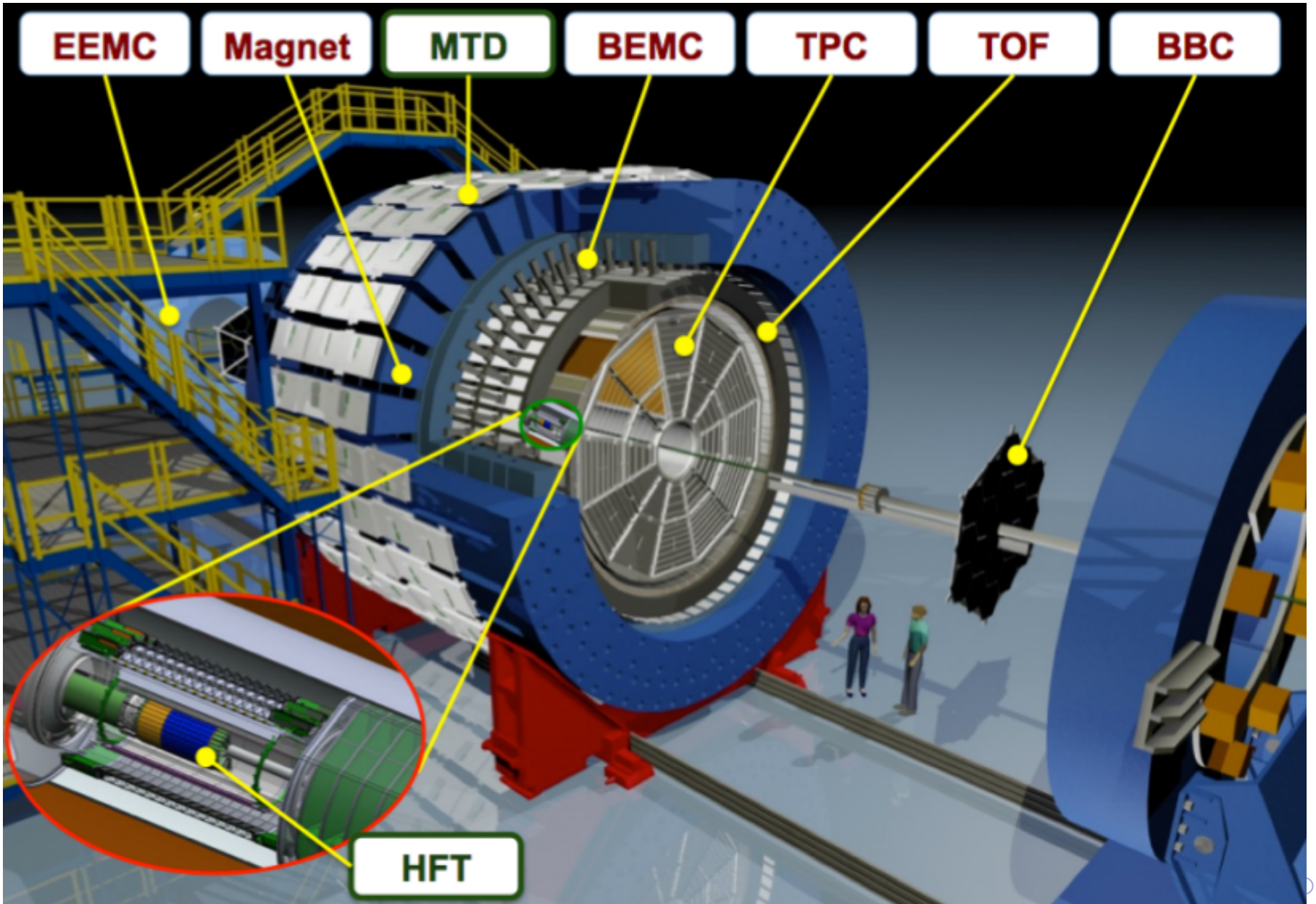
- quarks bounded in hadrons

Quark-gluon plasma

- QCD predicts also another stage of matter
- QGP – quark gluon plasma
- quarks not bounded in hadrons
- present at the beginning of universe

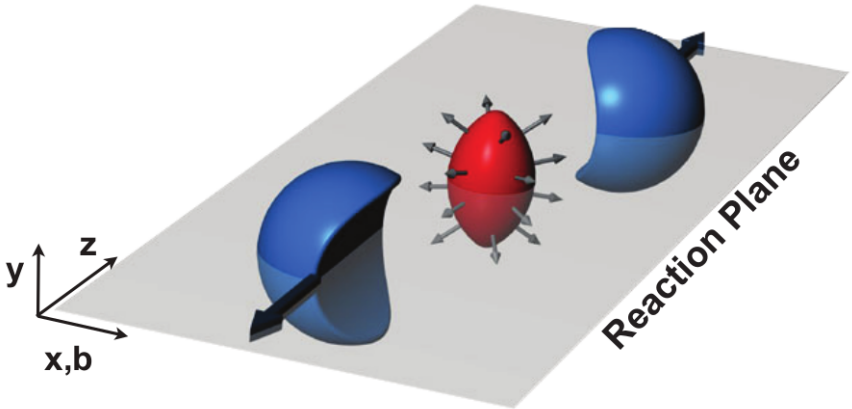


STAR detector



Azimutal distribution of particle momentum

- azimutal anisotrophy in spatial distribution of matter in non-central collisions

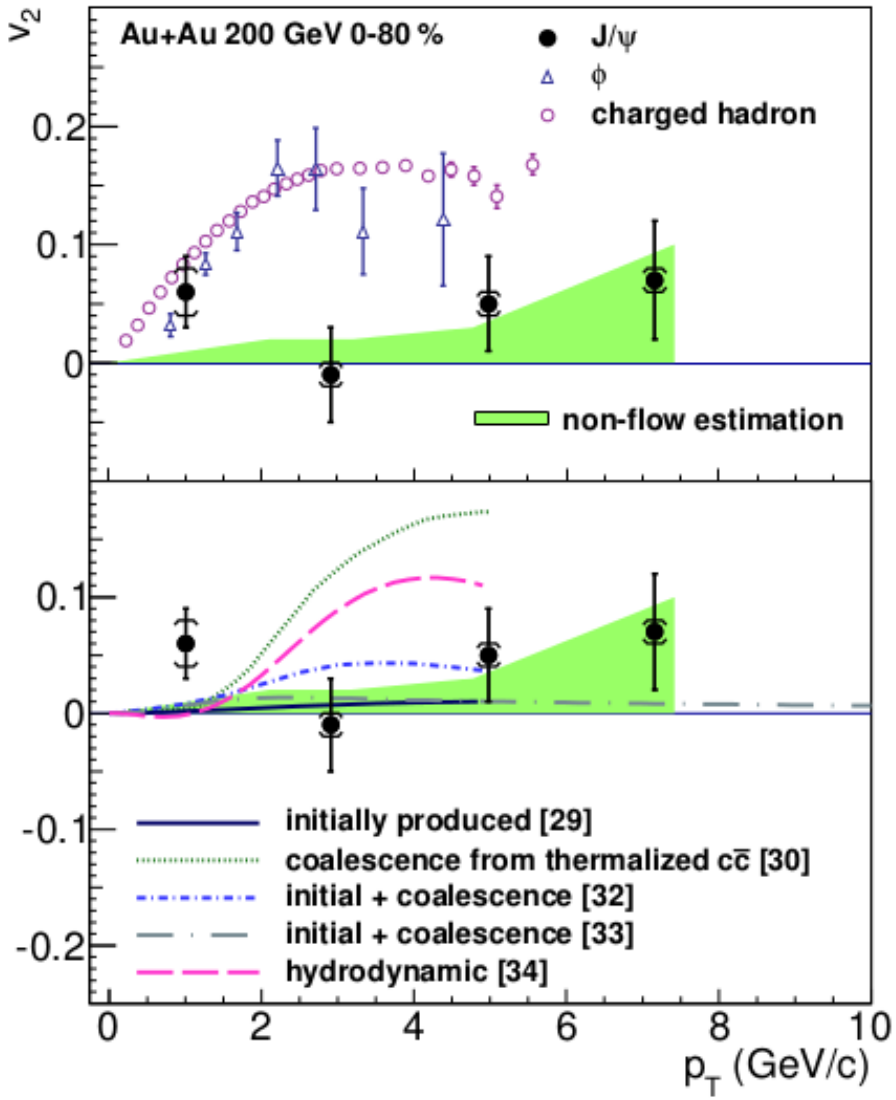


- medium thermalized briefly after the collision, expands anisotrophically
- preassure gradient - different magnitude at different places of the transverse plane
- azimutal distribution of particle momentum sensitive to early stages of the collision

arXiv:1102.3010

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1+\sum_{i=1}^{\infty} 2v_n \cos(n(\phi-\Phi_n^{RP}))\right)$$

STAR results on v_2 J/ψ in Au+Au collisions

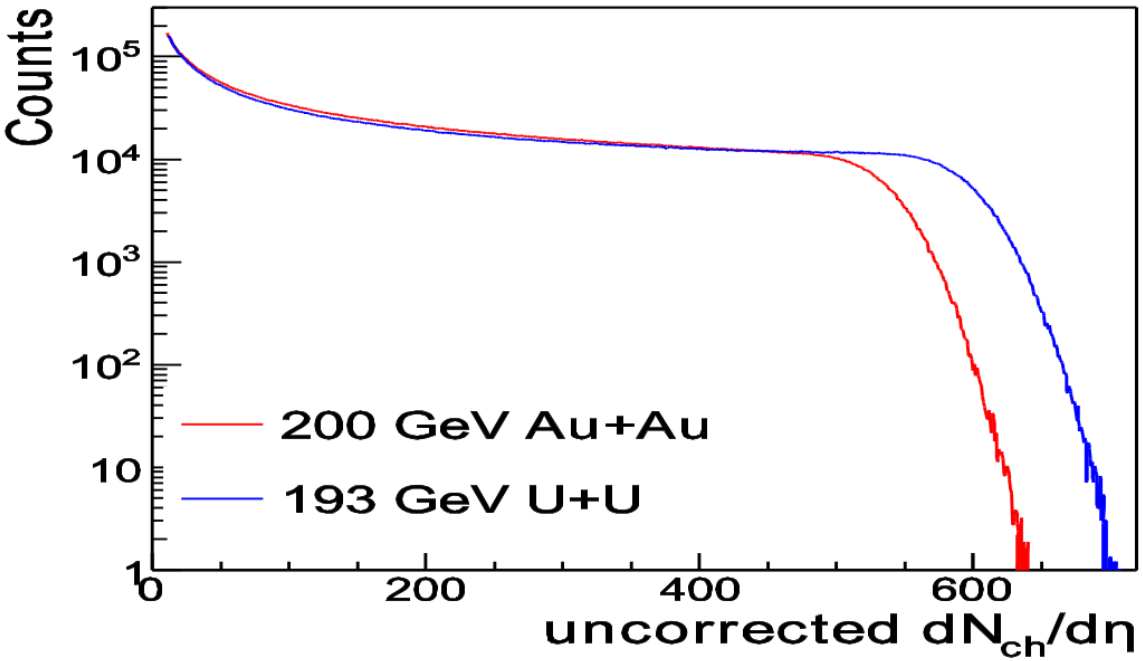


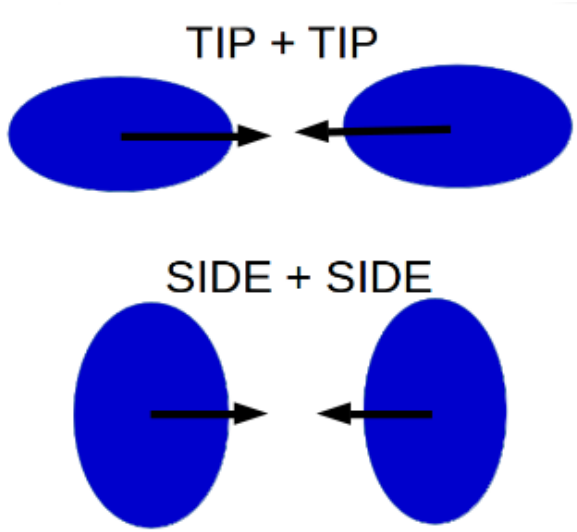
- the first results on v_2 J/ψ at STAR experiment
- v_2 J/ψ in Au+Au collisions
- J/ψ – colorless meson
- J/ψ has low v_2 in comparison to charged hadron and ϕ meson
- J/ψ with higher p_T probably are not produced predominantly by coalescence

arXiv:1212.3304

Used data

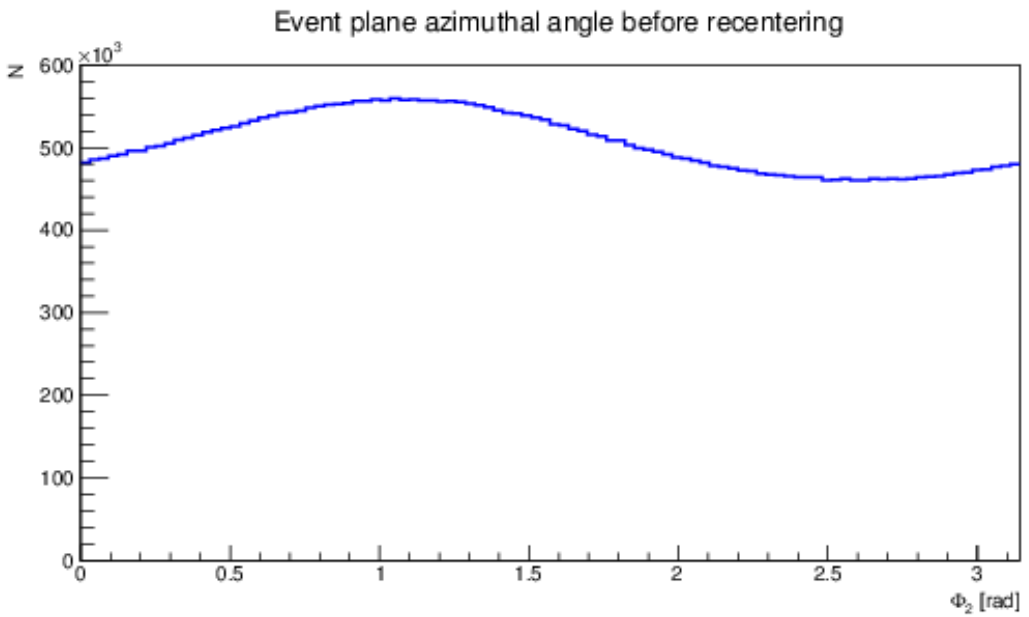
- U+U collisions at $\sqrt{s_{NN}} = 192.8\text{GeV}$
- high energy density
- non-spherical shape





Event plane

- distribution of angle of event plane Q-vector should be uniform
- TPC efficiency is not azimuthally uniform
- $Q_{x,2} = \sum_i w_i \cos(2\phi_i) = Q_2 \cos(2\Phi_2)$,
  $Q_{y,2} = \sum_i w_i \sin(2\phi_i) = Q_2 \sin(2\Phi_2)$



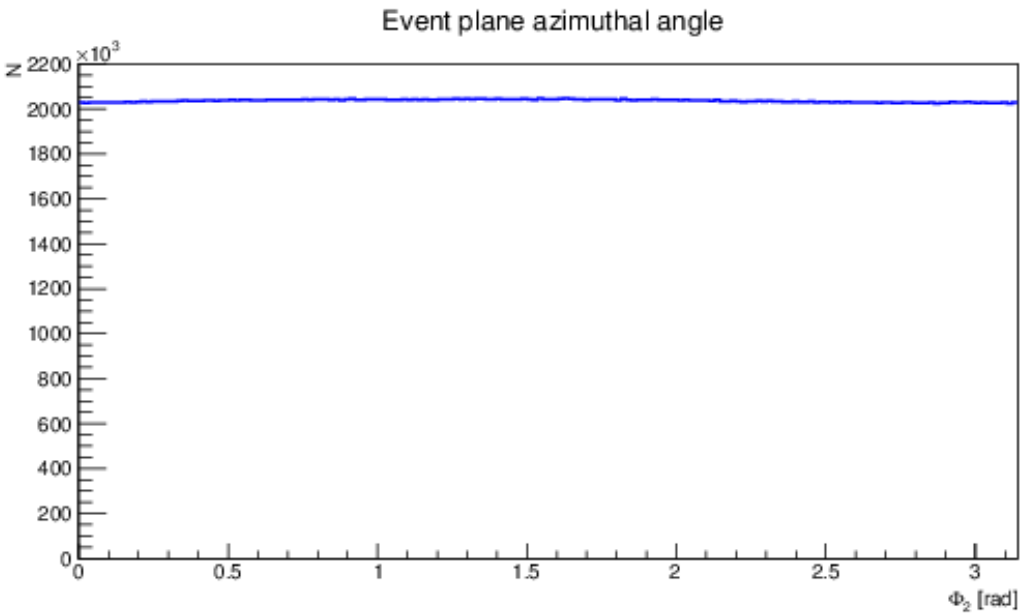
- minimum bias,
- $|v_z| < 30$cm,
- $|charge| = 1$,
- $15 < nHitsFit$,
- $0.52 < nHitsRatio$,
- global $DCA < 2$cm,
- $0.15 < p_T < 2$GeV,
- $|\eta| < 1$.

Recenered event plane

- average $\bar{Q}$-vector of one particle in one day for certain centrality subtracted from Q-vector of every particle

$$Q_{x,2} = \sum_{i=1}^{N_{ev}} (w_i \cos(2\phi_i) - \bar{Q}_{x,2,d,c}),$$

$$Q_{y,2} = \sum_{i=1}^{N_{ev}} (w_i \sin(2\phi_i) - \bar{Q}_{y,2,d,c}),$$



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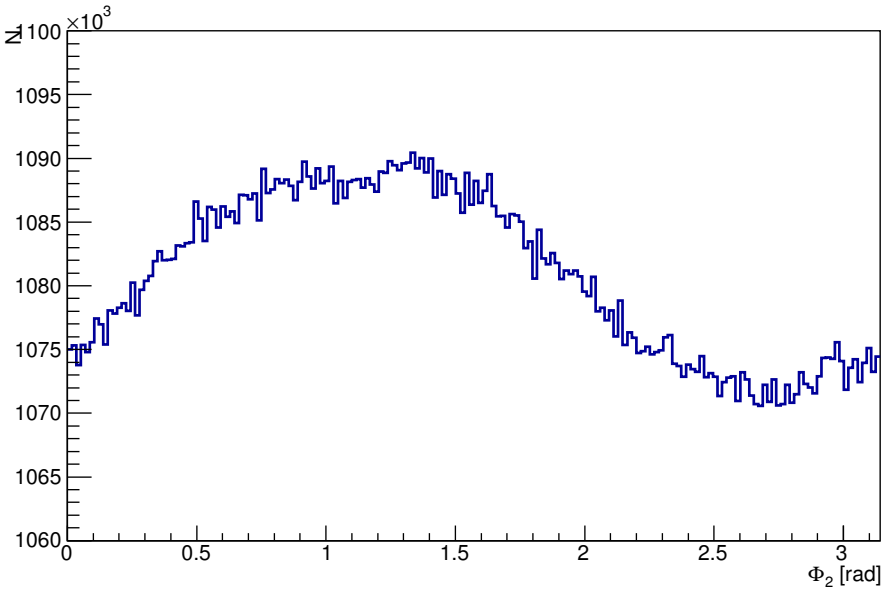
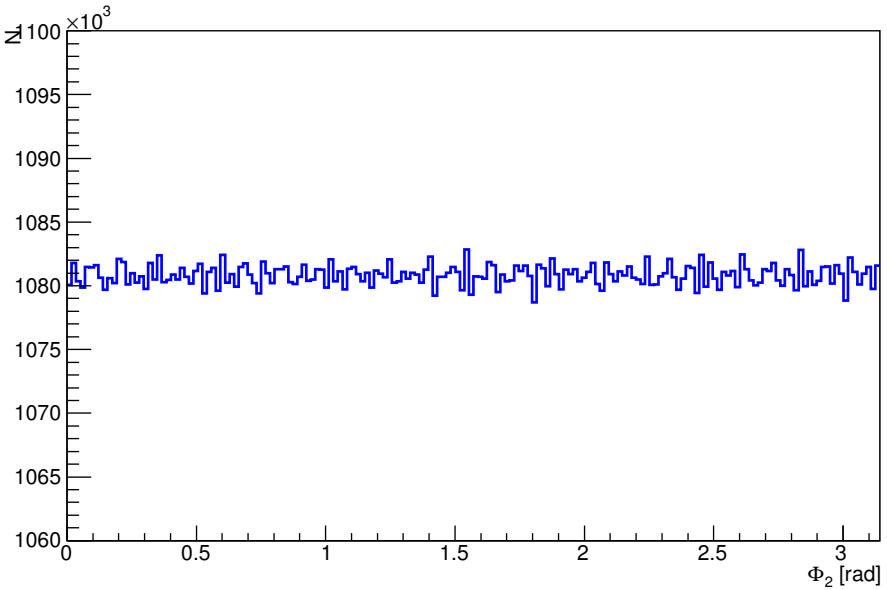
Shifting method

- eventplane distribution after recentereng - not comletely flat
- other correction: shifting
- $2\Phi_2^{shift} \equiv 2\Phi_2 + 2\Delta\Phi_2^{rec}$
- $2\Delta\Phi_2 \equiv \sum_{k=1}[A_k \cos kn\Phi_2^{rec} + B_k \sin kn\Phi_2^{rec}]$
- $A_k = -\frac{2}{k}\langle \sin kn\Phi_2^{rec}, \rangle B_k = \frac{2}{k}\langle \cos kn\Phi_2^{rec} \rangle$
- coefficients – collisions minimumbias and central triggers

Zoomed eventplane after recentering

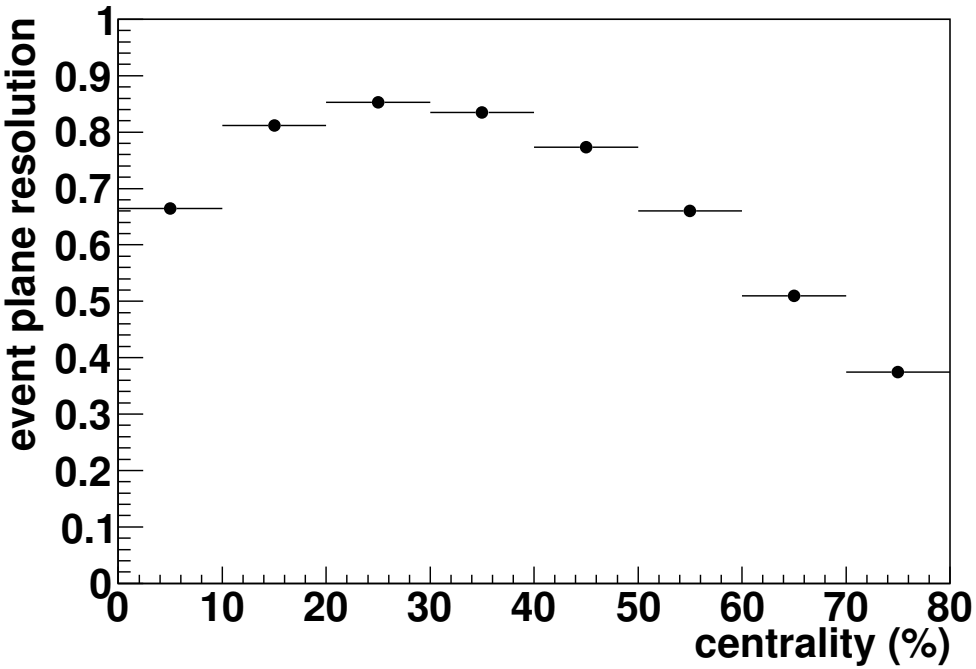


Zoomed eventplane after shifting



Event plane resolution

- not infinite multiplicity
- limited estimation of reaction plane angle
- event plane resolution: $R_2 = \langle \cos(2(\Phi_2 - \Phi_{RP})) \rangle$
- not known Φ_{RP}
- estimation R_2 using random subevents



Event plane method - J/ψ signal

Used triggers

- minimum bias, NPE, central

Cuts for J/ψ identification

- momentum cuts: $p_1 > 1.4\text{GeVc}^{-1}$, $p_2 > 1.2\text{GeVc}^{-1}$

- $1.5\ \text{GeVc}^{-1} < p$
- $0.3 < pc/E < 1.5$
- $-0.6 < n\sigma_e < 3$

or

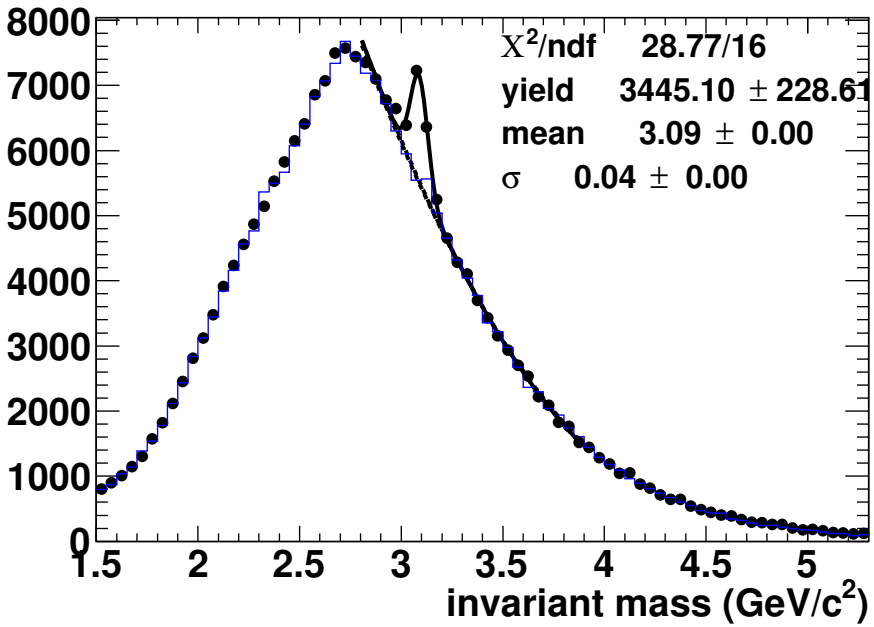
- $|1/\beta - 1| < 0.03$
- $-0.3 < n\sigma_e < 3$

or

- $-1 < n\sigma_e < 3$
- $0.3 < pc/E < 1.5$
- $|1/\beta - 1| < 0.03$

Event plane method - J/ψ signal

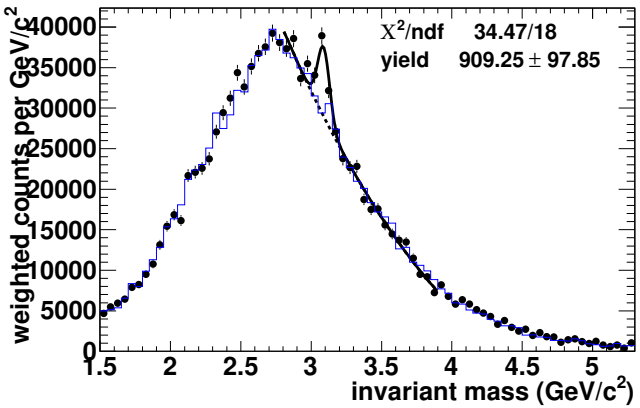
- all centralities
- definite p_T bin
- fit like-sign background invariant mass distribution with 2nd order polynomial
- fit unlike-sign invariant mass distribution with 2nd order polynomial (defined by background fit) + gaussian



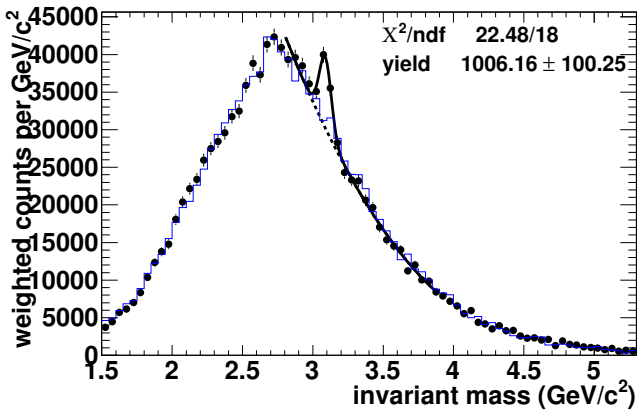
All centralities, $0 < p_T < 2\text{GeVc}^{-1}$

Event plane method

- fix mean and sigma of the gaussian (from previous fit)
- devide signal (background) into 10 bins according to $\phi_i - \Phi_2$
- combine 2 bins symmetricaly to $\pi/2$ - resulting 5 bins
- weight invatiant mass distribution with inverse of event plane resolution for each centrality bin
- fit invariant mass distribution for each $\phi - \Phi_2$ bin



p_T $0 - 2\text{GeVc}^{-1}$, cent 0-80%
1st bin

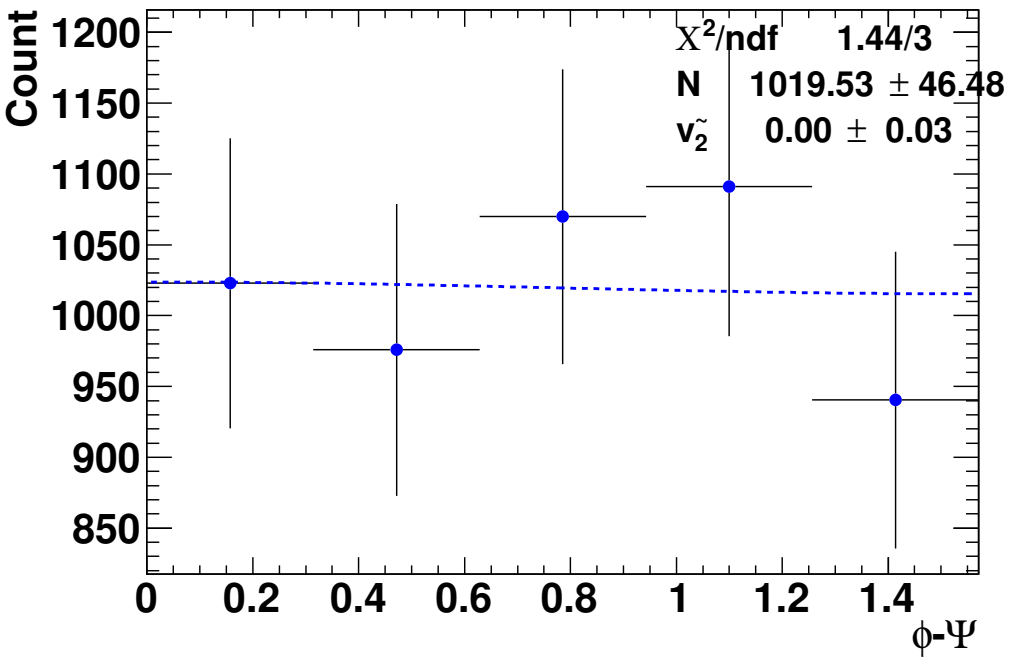


p_T $0 - 2\text{GeVc}^{-1}$, cent 0-80%
3rd bin

Event plane method

- extract yiels with help of fits of signal and background
- fit yields by function $N \cdot (1 + v_{2,obs} \cdot \cos(2 \cdot (\phi - \Phi_2)))$

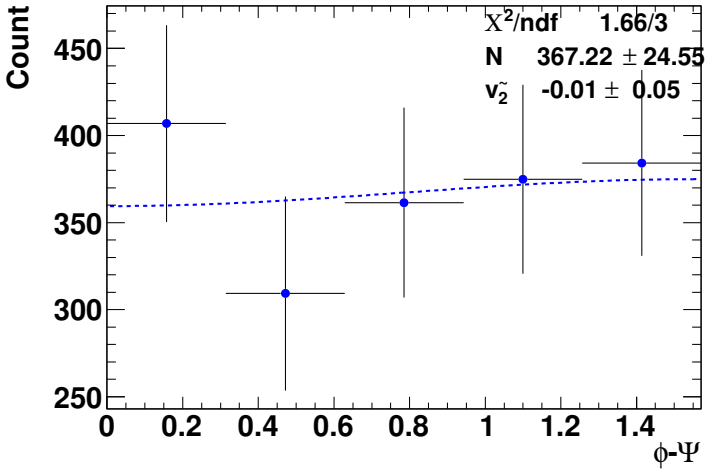
p_T $0 - 2\mathrm{GeVc}^{-1}$, cent 0-80%



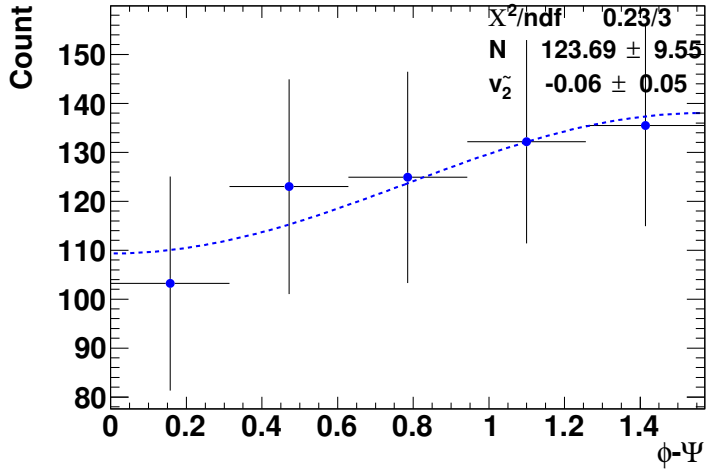
- observed v_2 consistent with zero

Event plane method

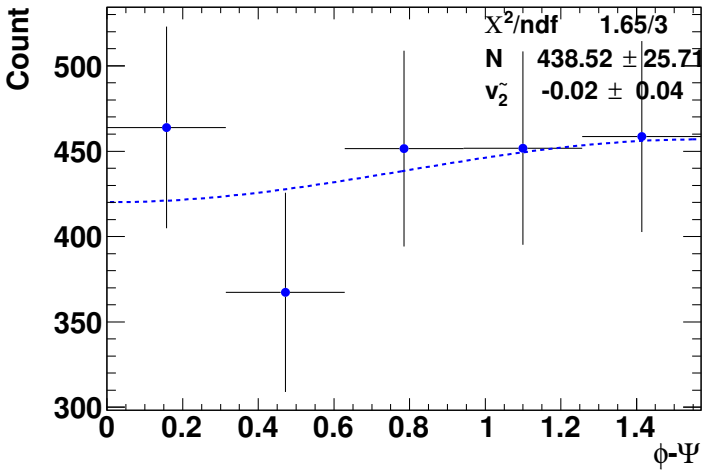
p_T $2-4\mathrm{GeVc}^{-1}$, cent 0-80%



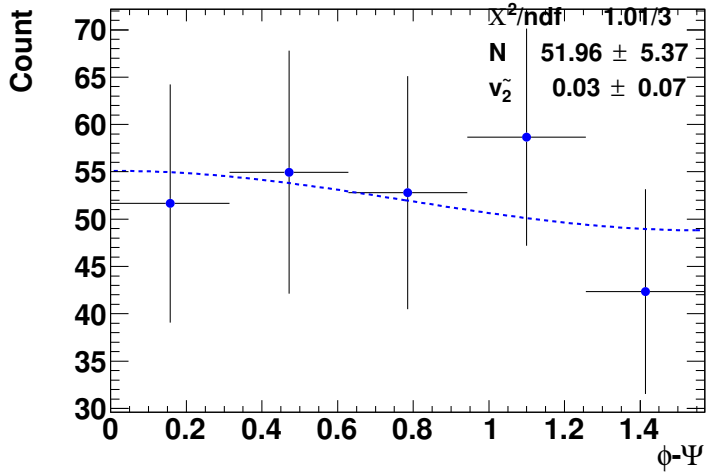
p_T $4-6\mathrm{GeVc}^{-1}$, cent 0-80%



p_T $2-5\mathrm{GeVc}^{-1}$, cent 0-80%



p_T $5-10\mathrm{GeVc}^{-1}$, cent 0-80 %



Conclusion

- azimuthal distribution of particle momentum sensitive to early stage of collision
- elliptic flow
- J/ψ – colorless meson
- Au+Au – v_2 consistent with zero (with exception of first p_T bin)
- U+U – v_2 calculated by event plane method consistent with zero

Thank you for attention