Collision Energy Dependence of ϕ-Meson Spin Alignment at the STAR experiment

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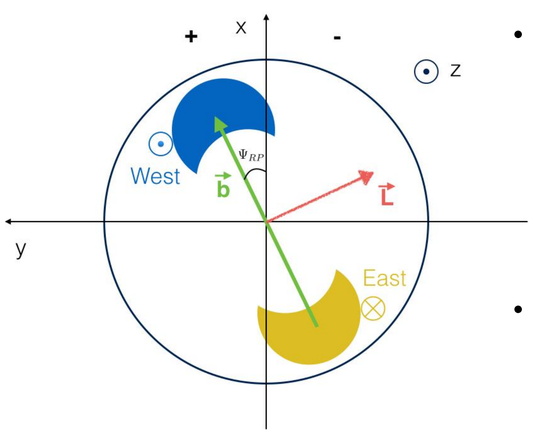
Abstract: Chirality is the only fundamental symmetry in the nuclear matter. The study of the vorticity and possible chiral vortical effect allows us to access this fundamental property of the hot and dense nuclear matter created in high-energy nuclear collisions, especially at the high baryon density region. Global polarization parameters of identified particles can be extracted from the azimuthal distribution of particles relative to the event plane. Recently, STAR has reported global polarization measurement of Λ-baryons (J=1/2).

The spin alignment of ϕ-meson (J=1) could be sensitive to hadronization scenarios and possible vorticity of the colliding system. In this poster, a systematic measurement of ϕ-meson spin alignment parameters from RHIC-STAR detector will be presented in Au+Au collisions at $\sqrt{s_{NN}}$ =19.6, 27, 39, 62.4 and 200 GeV. The beam energy dependence of spin alignment parameters will be discussed in association with the possible vorticity of the collision system.

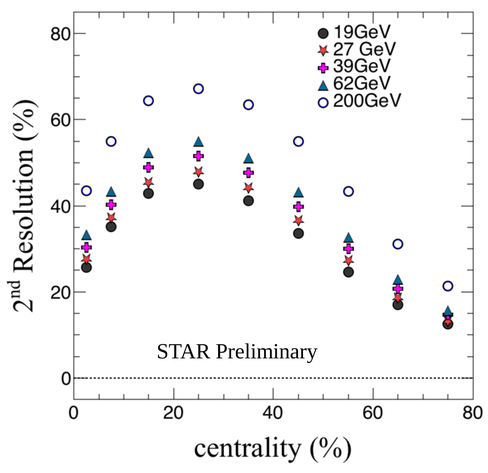
Motivation

- Non-central HICs have large angular momentum
- Baryon stopping may transfer angular momentum, in part, to the fireball
- Due to spin-orbit coupling, this orbital motion may result in net polarization of produced particles along the direction of the initial angular momentum (L) perpendicular to the reaction plane
- Vorticity, $\vec{\omega} = \vec{\nabla} \times \vec{v}$, may be measurable through net spins of emitted particles
- ϕ-meson is expected to originate predominantly from primordial production
- Sensitive to hadronization scenarios: recombination, fragmentation…[1][2]

Geometry and Event Plane Reconstruction

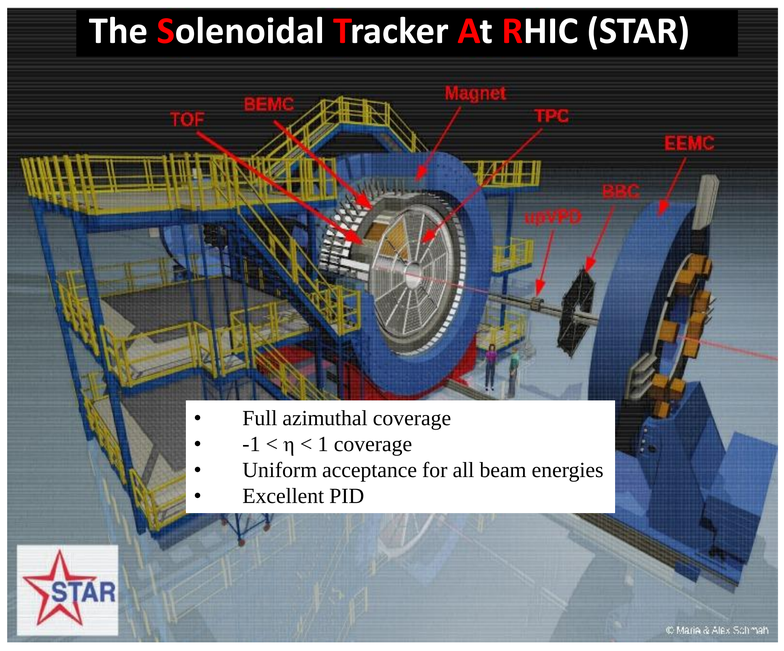


- 00-conponent of ϕ-meson spin density matrix (ρ_{00}) can be measured by angular distribution of decay daughter ϕ→K^++K^- using:
  $\frac{dN}{d(\cos\theta^*)} = \frac{3}{4}[(1-\rho_{00}) + (3\rho_{00}-1)\cos^2\theta^*]$,
  where θ* is the angle between K^+ and polarization direction of the collision system in the ϕ-meson rest frame
- A deviation of ρ_{00} from 1/3 indicates a spin alignment

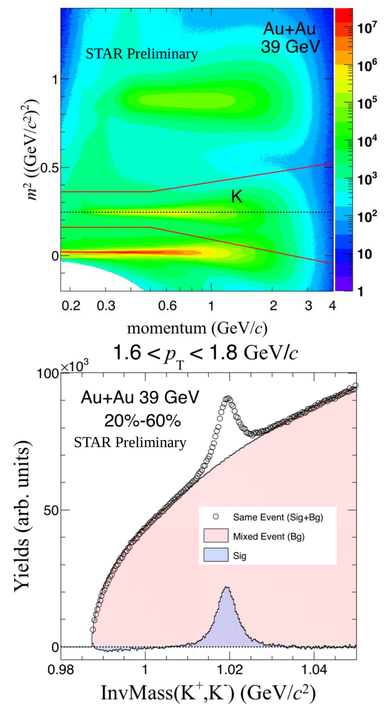


- Reaction Plane is defined by impact parameter and beam direction => can be estimated by the event plane[3]
- Finite event plane resolution need to be corrected

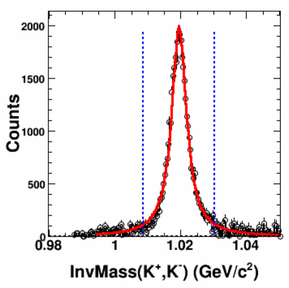
Particle Identification and ρ_{00} extraction at STAR



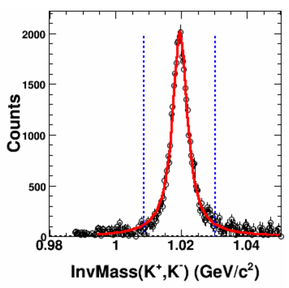
- Full azimuthal coverage
- -1 < η < 1 coverage
- Uniform acceptance for all beam energies
- Excellent PID



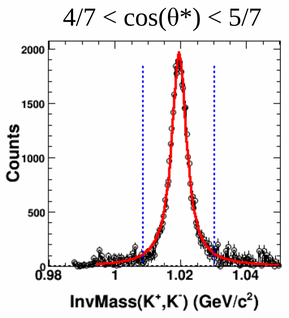
2/7 < cos(θ*) < 3/7

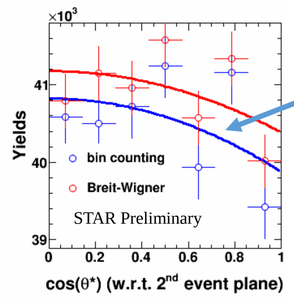


3/7 < cos(θ*) < 4/7



4/7 < cos(θ*) < 5/7



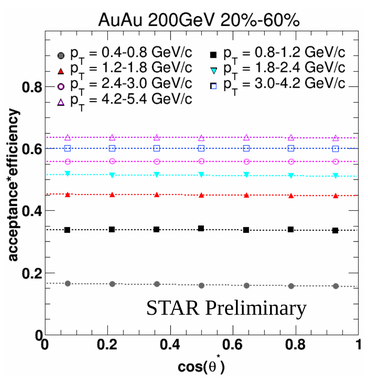


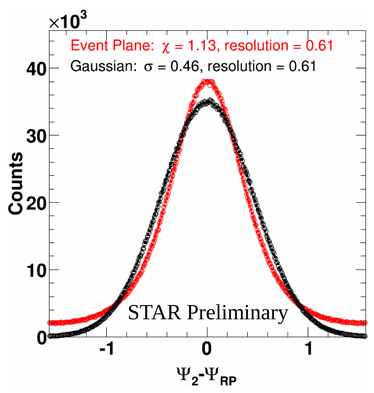
$\sqrt{s_{NN}}$ (GeV)	Num of Events (10^6)	z-vertex range (cm)
19.6	29.1	[-70.0,70.0]
27	58.1	[-70.0,70.0]
39	117.7	[-40.0,40.0]
62.4	54.6	[-40.0,40.0]
200	374.9	[-30.0,30.0]

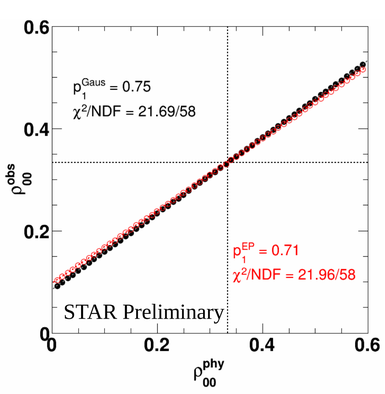
$$\frac{dN}{d(\cos\theta^*)} = N_0 \times [(1-\rho_{00}) + (3\rho_{00}-1)\cos^2\theta^*]$$

- Residual background subtracted
- Use 7 cosθ* bins
- Use Breit-Wigner fits and bin counting to extract raw yields
- Use angular distribution of K^+ to extract ρ_{00}

Efficiency and Event Plane Resolution Corrections

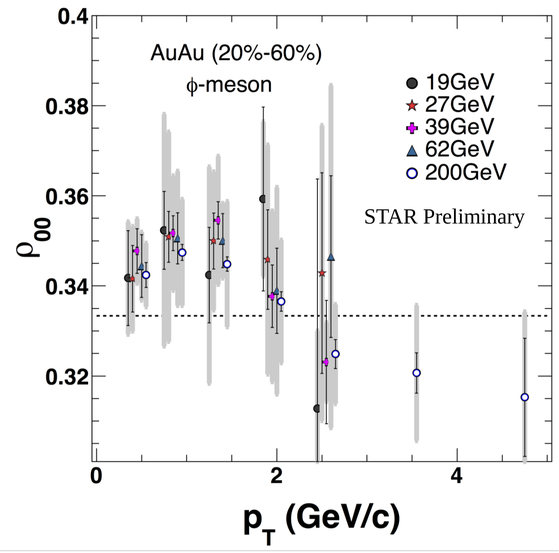


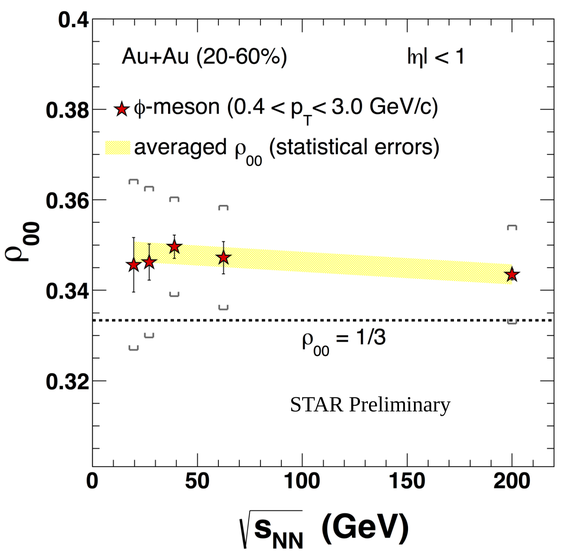




- ϕ-meson efficiency is calculated with K^+ and K^- embedding data and shows very weak cos(θ*) dependence
- Generated Monte Carlo ϕ-meson events with different ρ_{00} by using STAR published ϕ-meson spectra and elliptic flow[4,5] and smeared event plane with two different event plane distributions[6] based on event plane resolution measured by STAR
- Resolution correction factor can be extracted with a linear fit

Beam Energy Dependent ρ_{00}





- First measurement of ϕ-meson spin alignment at BES energies
- Weak beam energy dependence

References

[1] Z.T. Liang and X. N. Wang, Phys. Lett. B629,20 (2005)
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[3] A.M.Poskanzer and S.A.Voloshin, Phys. Rev. C58, 1671 (1998)
[4] L. Adamczyk et al (STAR Collaboration), Phys. Rev. C93, 021903(R) (2016)
[5] L. Adamczyk et al (STAR Collaboration), Phys. Rev. C93, 014907 (2016)
[6] S.A.Voloshi and Y. Zhang, Z. Phys. C70, 665 (1996)

Summary and Outlook

- ϕ-meson spin alignment signal shows weak beam energy dependence
- The future new EPD, providing independent event plane determination and better resolution, will help to keep the systematic uncertainties under control

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The STAR Collaboration
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