Exploring Electromagnetic-field Effects using Charge-Dependent Directed Flow from BES-II Data at STAR

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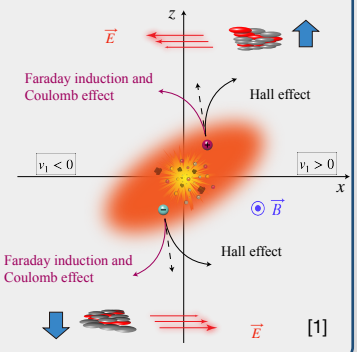
Abstract

Charge-dependent directed flow can reveal the influence of electromagnetic fields in heavy-ion collisions. For instance, Faraday induction is predicted to contribute negatively to $\Delta(dv_1/dy)$ defined as the difference in the slope of rapidity-odd directed flow (dv_1/dy), between positively and negatively charged particles. Recent STAR data from peripheral Au+Au collisions at 200 and 27 GeV supported this scenario. In this poster, we present the STAR BES-II results of $v_1$and Δv_1 for $\pi^{\pm}$, $K^{\pm}$, $p(\bar{p})$ and $\Lambda(\bar{\Lambda})$ as functions of rapidity, transverse momentum (p_T), and centrality at mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$= 19.6, 17.3, 14.6, 11.5, 9.2 and 7.7 GeV.

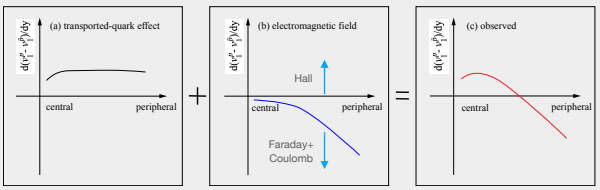
Motivation

- Ultra strong magnetic fields ~10^{18} Gauss are expected in Heavy Ion Collisions[1,2].
- Sensitive to early stages ~formation time of quarks.
- New measurements to understand beam energy dependence of EM fields: crucial to understand the conductivity of QGP and its evolution



[1]

Observable



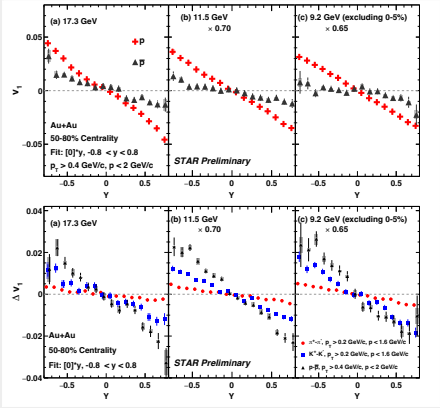
[1]

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1+\sum_{n=1}^{\infty} 2v_n \cos n(\phi-\Psi)\right)$$ [PRC 58 1671]

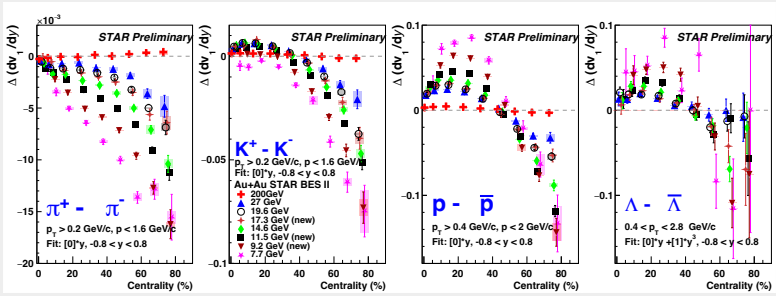
- v_1 reflects asymmetric emission preference along the x axis.
- **$\Delta(dv_1/dy) = dv_1(h^+)/dy - dv_1(h^-)/dy$ could reveal a sign change due to electromagnetic effects in QGP.**
- Active research ongoing to understand interplay of other contributions to Δv_1 such as baryon inhomogeneity [2].

$v_1(y)$ and $\Delta v_1(y)$

- In peripheral collisions (50-80%), Δv_1 slope turns negative
- Significantly negative slopes for all considered particles at BES-II energies



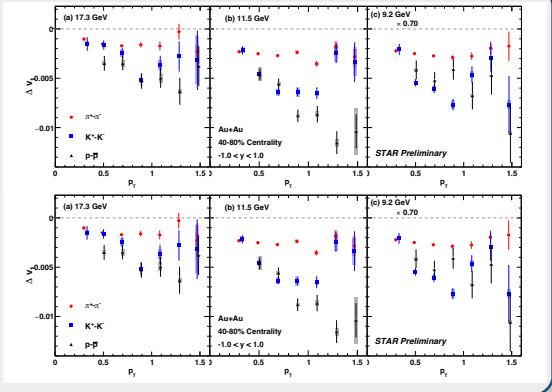
$\Delta(dv_1/dy)$ as a function of centrality



- $\Delta(dv_1/dy)$ is negative in peripheral collisions, consistent with domination of (Faraday + Coulomb) effect over (Hall + Transported quark) effect. It becomes more negative at lower collision energies.
- At lower energies, the lifetime of the fireball should be shorter and as the passage time (2R/γ) is larger, the lifetime of EM field should be longer.
- Similarity of $\Delta(dv_1/dy)$ between $p(\bar{p})$ and $\Lambda(\bar{\Lambda})$ motivates further investigation into both EM and non-EM effects that may be at play.

$\Delta v_1(p_T)$

- Negative Δv_1 in peripheral collisions (40-80% centrality) across the measured p_T range
- Indication of more negative Δv_1 at higher p_T as naively expected from EM effects



Conclusion

In peripheral collisions, $\Delta(dv_1/dy)$ becomes more negative at lower beam energies for all species studied, consistent with expectation from electromagnetic field effects. Detailed investigations of other possible contributions (e.g., baryon inhomogeneity) are needed to understand the beam energy dependence of Δv_1 and behavior for $\Lambda(\bar{\Lambda})$.

Acknowledgement

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References

1. STAR Collaboration, Phys. Rev. X 14, 011028 (2024); A.P. Dash(for the STAR Collaboration) EPJ Web of Conferences 296, 10007 (2024)
2. U. Gursoy et al., PRC 98, 055201 (2018), PRC, 89, 054905 (2014); D.E. Kharzeev, et al., Nucl.Phys.A803,227 (2008); T. Parida et al., arXiv:2503.04660 (2025)

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