

Study of direct photon polarization to shed on strong magnetic field in heavy ion collisions at PHENIX[†]

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A strong magnetic field is expected to be created in non-central heavy-ion collisions. This field is created by the effect of both of the collision participants and spectators. The field direction is perpendicular to the collision reaction plane. The magnitude of the field created in the collisions at BNL-RHIC top energy is estimated to reach as high as 10^{14} teslas. If the magnitude of the magnetic field in heavy-ion collisions is compared with the QED critical magnetic field ($B_c = m_e^2/e = 4 \times 10^9$ teslas) and the surface of magnets (10^{11} teslas), the field magnitude is much higher in heavy ion collisions. The field magnitude is decreased rapidly but keeps the magnitude above the critical field of an electron for about $3 \text{ fm}/c$.

Creation of a strong magnetic field in heavy ion collisions was first expected in 1976¹⁾. The strong magnetic field in heavy ion collisions has recently attracted the interest of researchers in theories and experiments in recent years for the following reasons. First, the magnetic field can reach beyond the critical field and interesting phenomena such as Chiral magnetic effects and non-linear QED effects can appear in such a strong field. Second, quark-gluon plasma (QGP) is expected to be created in a strong magnetic field thus the evolution of the plasma may have an effect by the strong magnetic field. The state of the initial stage is another topic of recent interest. Measuring the effect of the field should be the key to understanding the initial stage.

Chiral magnetic effect is measured by experiments using charged particle asymmetry with respect to the reaction plane which is reported by STAR and ALICE experiments²⁾³⁾. However the field has not yet been directly detected by experiments. If the effects of the magnetic field can be detected, we can directly access to the initial stage of collisions. Electro-magnetic particles are a clean probe for accessing the initial stage because they are not affected by the strong interaction.

Dilepton production rate in an external magnetic field is calculated using a photon vacuum polarization tensor, and the production rate depends on the direction of the field. The production rate is higher in perpendicular direction to the field than that parallel to the field.

Dilepton polarization is also measured to understand the production mechanism of quarkonia. The PHENIX experiment measured J/ψ polarization with dielectron⁴⁾. While the physics motivation and mechanism are different between the measurement of quarkonia and

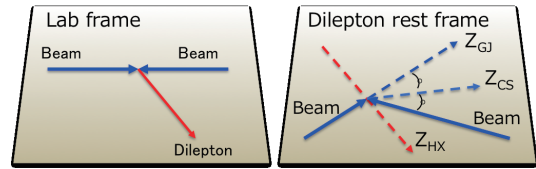


Fig. 1. Definitions of polarization axis

virtual photon polarization, we are now using the same parametrization with that analysis.

$$\frac{dN}{d\cos(\theta)} \propto 1 + \lambda \cos(\theta) \quad (1)$$

where θ is the angle between the positive lepton in a dilepton rest frame and a certain polarization axis, and λ is the polarization parameter; if λ is positive (negative), polarization is transverse (longitudinal).

Three definitions of polarization frames are usually used. In the helicity (HX) frame, the axis is the dilepton momentum in the laboratory frame. In the Collins-Soper (CS) frame, the axis is the bisector between two beams in the dilepton rest frame. In the Gottfried-Jackson (GJ) frame, the axis is the direction of the beam in the dilepton rest frame.

We use the data set of Au+Au and $p+p$ at 200 GeV/nucleon pair collected in 2004 and 2006, respectively. The PHENIX experiment has excellent electron identification capabilities and has succeeded in measurement of direct virtual photons.

The direct virtual photon is the probe and π^0 and η Dalitz decay electrons are candidates of control probes because they are from a later stage of the collisions. Polarization measurement in $p+p$ collisions can also act as a control probe since a field is not created in the collisions.

We are measuring polarization with the following mass regions, $0.12 < M_{ee} < 0.3$ (containing virtual photon) and $M_{ee} < 0.12 \text{ GeV}/c^2$ (π^0 Dalitz decay dominant). The acceptance effect is included in the $\cos(\theta)$ distribution. Thus we need to correct the effect with simulation. Since the simulation does not contain the effect of the magnetic field, we can estimate the effect. We are now estimating the acceptance effect with single particle simulations.

References

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