Exploring the magnetic field in heavy-ion collisions through spin alignment measurements at ALICE

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Outline:

- Motivation
- Experimental observable
- Signal extraction
- Results
- Summary and outlook
Heavy-ion collisions and initial state

Reaction plane: Impact parameter and beam axis
L and B perpendicular to reaction plane

Impact parameter dependence

Large magnetic field
Large angular momentum (Conserved quantity)

Focus of the study is to see the effect of large angular momentum (L) and magnetic field (B) in heavy-ion collisions

Goal: How can we probe these observables in experiments

M_{2\pi}^2 \sim 2 \times 10^4 \text{ MeV}^2 \sim 3 \times 10^{14} \text{ Tesla} \sim 3 \times 10^{18} \text{ Gauss}
Angular distribution of vector mesons

$K^0$ Vector meson
- Mass – 896 MeV/c²
- Lifetime – 4 fm/c
- Spin 1
- Decays to $K^+$ and $\pi^-$ (B.R – 66%)
- Quark content $(d,\bar{s})$

$\phi$ Vector meson
- Mass – 1019 MeV/c²
- Lifetime – 42 fm/c
- Spin 1
- Decays to $K^+$ and $K^-$ (B.R – 49%)
- Quark content $(s,\bar{s})$

Quantisation axis:
- Normal to the production plane (Momentum of vector meson and beam axis)
- Normal to the reaction plane (Impact parameter and beam axis)


$$\frac{dN}{dcos\theta^*} = N_0[1 - \rho_{0,0} + \cos^2\theta^*(3\rho_{0,0} - 1)]$$

$\rho_{0,0}$: Probability that vector meson is in spin state = 0, Spin density matrix element

$\rho_{0,0} = 1/3 \Rightarrow$ No spin alignment

Angular distribution of decay daughters of vector (spin=1) meson gets modified in presence of large angular momentum
Here $N_0 = \text{normalisation constant and } \rho_{00} \text{ is spin density matrix element}$

The $\rho_{00}$ values are obtained for different $p_T$ bins and centrality bins
Spin alignment of vector mesons

**$p_T$ dependence**

- Spin Alignment ($\rho_{00} < 1/3$) observed for spin 1 particle at low momentum
- No spin alignment ($\rho_{00} \sim 1/3$) observed for spin 0 particle and pp collisions

**Centrality dependence**

- Maximum spin alignment observed for mid-central collisions in low $p_T$ ($3\sigma$ for $K^{*0}$ and $2\sigma$ for $\phi$)
- $\rho_{00} \sim 1/3$ for high $p_T$ vector mesons

**Graphs**

- Graph showing $p_T$ dependence with $K^0$, Pb–Pb $\sqrt{s_{NN}} = 2.76$ TeV (10–50%) and $K^{*0}$, pp $\sqrt{s} = 13$ TeV
- Graph showing centrality dependence with $\rho_{00}$ vs. $N_{part}$ for production plane and event plane with $K^0$, Pb–Pb $\sqrt{s_{NN}} = 2.76$ TeV and $\phi$, Pb–Pb $\sqrt{s_{NN}} = 2.76$ TeV
First evidence of spin alignment in vector mesons in high energy heavy-ion collisions with ALICE at the LHC

Spin alignment not observed in proton-proton collisions

Spin alignment not observed for spin 0 particles in heavy-ion collisions

Measurement with high statistics Pb-Pb data at 5.02 TeV in progress

Measurement of spin alignment with charged K* (magnetic moment larger than neutral K*) to probe initial magnetic field effects in progress

THANK YOU