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Spin alignment measurements of K^{*0} vector mesons with ALICE at the LHC

Sourav Kundu (for the ALICE Collaboration)*
School of Physical Sciences, National Institute of Science Education and Research, HBNI, Jatni 752050, India
E-mail: sourav.kundu@cern.ch

We present the recent spin alignment measurements of K^{*0} vector mesons at mid-rapidity ($|y|<0.5$) in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV and 5.02 TeV and in pp collisions at $\sqrt{s}$ = 13 TeV, performed with the ALICE detector at the LHC. Spin alignment measurements of K^{*0} vector mesons are performed with respect to the production plane and second order event plane. The measured value of the spin density matrix element ρ_{00} is below 1/3 at low transverse momentum (p_T) ($p_T<1.8$ GeV/c) and consistent with 1/3 at high p_T in mid-central Pb-Pb collisions. The ρ_{00} values from both production plane and event plane are similar and no energy dependence is observed for measured ρ_{00} values at $\sqrt{s_{NN}}$ = 2.76 TeV and 5.02 TeV within the uncertainties. ρ_{00} also shows a centrality dependence with maximum deviation from 1/3 at mid-central collisions. ρ_{00} values for K^{*0} in pp collisions at $\sqrt{s}$ = 13 TeV and for K^0_S in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV in the 20-40% centrality are consistent with 1/3 in the whole measured p_T interval, which ranges from $0.0<p_T<10$ GeV/c and $0.0<p_T<5$ GeV/c respectively.

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*Speaker.

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1. Introduction

The system created in the initial stages of high energy heavy-ion collisions exhibits a large magnetic field [1] and angular momentum [2]. Vector mesons (spin 1) can be polarized due to these initial stage effects. Evidences of these effects can be studied by measuring the angular distribution of the decay daughters of vector mesons [3, 4] with respect to a quantization axis. This quantization axis can be perpendicular to the production plane (defined by the momentum direction of the vector meson and the beam axis direction) or perpendicular to the reaction plane (defined by the impact parameter direction and the beam axis direction) of the system. From the experimental point of view event plane [3] is used as a proxy of reaction plane. The angular distribution for vector mesons is expressed as [5],

$$\frac{dN}{d\cos\theta^*} = N_0[1-\rho_{00}+\frac{1}{R}\cos^2\theta^*(3\rho_{00}-1)], \tag{1.1}$$

The angle θ^* is defined as the angle formed by the momentum direction of one of the decay daughters in the rest frame of the vector meson and the quantization axis. N_0 is a normalization constant and R is the 2^{nd} order event plane resolution for event plane analysis. In case of production plane analysis coefficient $1/R$ in Eq.(1.1) becomes 1. ρ_{00} is the diagonal element of the spin density matrix. The polarization of vector mesons due to the initial conditions or the final hadronization process will translate in non uniform angular distributions, which will lead to a deviation from 1/3 of the density matrix element ρ_{00}. In this work we present the recent results related to the spin alignment of K^{*0} vector mesons from the ALICE experiment [6] at LHC energies obtained by determining the value of ρ_{00} with respect to both production plane and event plane in pp and Pb-Pb collisions.

2. Analysis details

The analysis is carried out by analyzing 14 M events collected in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV (2010 run) and the sample of 30 M events collected in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV (2015 data taking). In addition, 43 M minimum bias pp collision events at $\sqrt{s}$ = 13 TeV are also used to extract ρ_{00} value for K^{*0} in pp collisions. Measurements are performed at mid-rapidity (-0.5 $< y <$ 0.5) in different $p_{\rm T}$ regions. In order to perform a null hypothesis test, similar measurements with spin zero K^0_S hadrons are performed for 20-40% Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV. K^{*0} are reconstructed in each event via invariant mass technique by identifying K and π decay daughters with opposite charge, as discussed in [7] while the K^0_S is reconstructed via the identification of oppositely charged pion daughters with V0 decay topology, as reported in [8]. The charged kaons and pions are identified using two particle identification tecniques: the specific energy loss measured in the Time Projection Chamber (TPC) [6] and the β velocity measured by the Time Of Flight (TOF) [6] detector. Trigger, centrality and the $2^{\rm nd}$ order event plane estimation are determined by using the V0 detectors [6]. K^{*0} yields are extracted in each $p_{\rm T}$ and $\cos\theta^*$ bin. The final yields are obtained after the data are corrected for the acceptance and efficiency, determined by using a dedicated Monte Carlo production. The efficiency and acceptance corrected K^{0*} yields are studied as a function of $\cos\theta^*$ to extract ρ_{00} in each $p_{\rm T}$ interval. The left panel of Fig. 1 shows corrected $\cos\theta^*$ distribution at mid-rapidity in 10-30% Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ =

5.02 TeV for $0.8 \leq p_{\mathrm{T}} < 1.2$ GeV/c using the production plane and right panel shows corrected $\cos\theta^*$ distribution at mid-rapidity in 10-30% Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV for $0.8 \leq p_{\mathrm{T}} < 5.0$ GeV/c using the event plane. Corrected $\cos\theta^*$ distributions are fitted with Eq.(1.1) to extract ρ_{00} values in each p_{T} bin and centrality class.

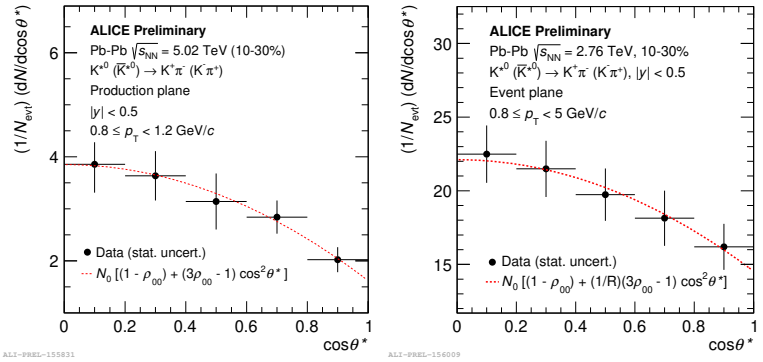

Figure 1: (Color online) $dN/d\cos\theta^*$ vs. $\cos\theta^*$ distribution at mid-rapidity in 10-30% Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV using production plane (left panel) and at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV using event plane (right panel).

3. Results

The left panel of Fig. 2 shows the ρ_{00} values as a function of p_{T} for K^{*0} vector mesons in pp collisions at $\sqrt{s} = 13$ TeV and in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV and 5.02 TeV for 10-50% centrality class. The ρ_{00} values of K^{*0} are consistent with 1/3 both in pp collisions for the whole studied p_{T} range and in Pb-Pb collisions at high p_{T} ($1.8 \leq p_{\mathrm{T}} < 5.0$ GeV/c) whereas a deviation is observed at low p_{T} in Pb-Pb collisions. ρ_{00} values in Pb-Pb collisions are consistent with each other for both collision energies within statistical and systematic uncertainties. The measurements are also compared with the ρ_{00} values of $\mathrm{K}^0_{\mathrm{S}}$ in Pb-Pb collisions, which are consistent with 1/3 in the whole p_{T} interval. Right panel of Fig. 2 shows a comparison of K^{*0} results using the production and event planes in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV. The ρ_{00} values of K^{*0} using production plane in 10-50% Pb-Pb collisions are 2.5 σ below from 1/3 at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV for $0.4 \leq p_{\mathrm{T}} < 1.2$ GeV/c and 2.3 σ below from 1/3 at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV for $0.8 \leq p_{\mathrm{T}} < 1.2$ GeV/c. The ρ_{00} value of K^{*0} using event plane for $0.8 \leq p_{\mathrm{T}} < 1.2$ GeV/c in 10-50% Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV is 1.7 σ below from 1/3. Figure 3 shows the ρ_{00} values as a function of $\langle N_{\mathrm{part}} \rangle$ in Pb-Pb collisions for the lowest p_{T} bin (left panel) and integrated over measured p_{T} region (right panel). The ρ_{00} values show a clear centrality dependence and maximum deviation from 1/3 occurs in mid-central collisions where the angular momentum is expected to be large.

4. Summary

We have presented results on the spin alignment of K^{*0} vector mesons in pp collisions at $\sqrt{s}$ = 13 TeV and in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV and 5.02 TeV. The ρ_{00} values are consistent with 1/3 in pp collisions for the whole measured p_{T} region. In Pb-Pb collisions the ρ_{00} values are consistent with 1/3 at high p_{T} and below from 1/3 at low p_{T} for both production and event plane

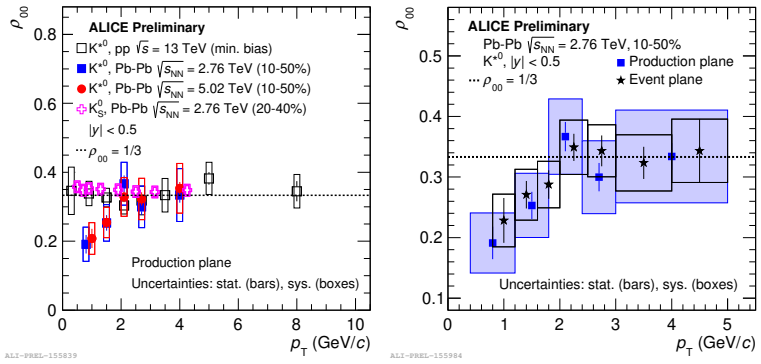

Figure 2: (Color online) Left Panel: ρ_{00} values as a function of p_{T} at mid-rapidity for K^{*0} using production plane, in pp collisions at $\sqrt{s}$ = 13 TeV and in 10-50% Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV and 5.02 TeV along with the measurements for $\mathrm{K}^0_{\mathrm{S}}$ in 20-40% Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV. Right Panel: Comparison of ρ_{00} w.r.t. production plane and event plane analysis in 10-50% Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV.

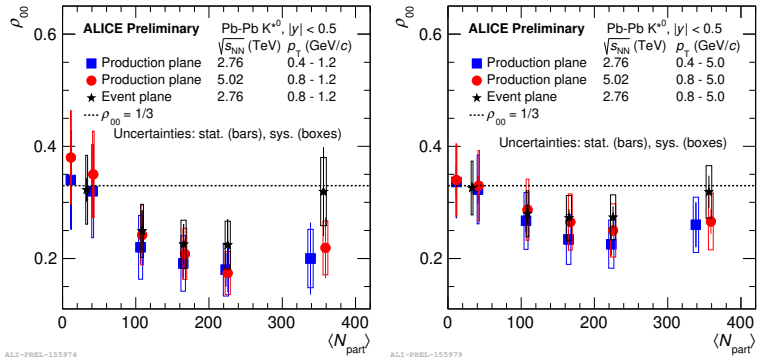

Figure 3: (Color online) Left panel: ρ_{00} vs. $\langle N_{\mathrm{part}} \rangle$ at mid-rapidity for lowest p_{T} bin in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV and 5.02 TeV for both production plane and event plane analysis. Right panel: Same as in the left panel but integrated over p_{T} bin.

analysis. No energy dependence is observed for the extracted ρ_{00} values and measurements using event plane and production plane are consistent with each other within uncertainties.

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