Central European Journal of Physics

Multi-strange baryon elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV measured with the ALICE detector

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Abstract: We present the results on elliptic flow with multi-strange baryons produced in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. The analysis is performed with the ALICE detector at LHC. Multi-strange baryons are reconstructed via their decay topologies and the $v_2$ values are analyzed with the two-particle scalar product method. The $p_T$ differential $v_2$ values are compared to the VISH2+1 model calculation and to the STAR measurements at 200 GeV in Au+Au collisions. We found that the model describes $\Xi$ and $\Omega$ $v_2$ measurements within experimental uncertainties. The differential flow of $\Xi$ and $\Omega$ is similar to the STAR measurements at 200 GeV in Au+Au collisions.

PACS (2008): 25.75.Dw, 25.75.Gz, 21.65.Qr

Keywords: multi-strange baryon • elliptic flow • heavy-ion collisions

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1. Introduction

In heavy-ion collisions the elliptic flow ($v_2$) is one of the most informative observables used to understand the dynamics of the collisions and the fundamental properties of the created quark matter [1]. The first measurement by ALICE at 2.76 TeV [2] shows that, compared to flow measured at 200 GeV, the integrated elliptic flow of charged particles increases by about 30% but the $p_T$ differential flow doesn’t change within uncertainties at low $p_T$. This can be explained by hydrodynamical models [3] as being due to a larger radial flow velocity at higher energies, which results in an increase of the mean $p_T$ of charged particles and a more pronounced mass dependence of the elliptic flow. Indeed, measurements of identified particle $v_2$ at 2.76 TeV [4] indicate a larger mass splitting between pions and anti-protons at low $p_T < 2$ GeV/$c$ than that seen by STAR at 200 GeV [5]. However, to describe the anti-proton flow it is required to introduce a hadronic rescattering stage to the hydrodynamical

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model calculations [6]. To estimate the relative contributions to the elliptic flow from early deconfined partonic interactions and later hadronic rescatterings in the system evolution, it is desired to measure the elliptic flow of multi-strange baryons, as it is argued that they have small hadronic cross-sections [7, 8] and therefore are expected to be more sensitive to the quark-gluon-plasma phase than to the hadronic one.

In this contribution, we present the $p_T$ differential $v_2$ measurements of multi-strange baryons in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV measured with the ALICE detector. The data are then compared to hydrodynamical model calculations and to RHIC measurements at 200 GeV [9].

2. Data Analysis

This analysis is based on data taken during the 2010 Pb-Pb run. The standard physics selection criteria [10] for Pb-Pb collisions were applied to select minimum bias events. Cuts on ZDC timing, SPD vertex quality and TPC track multiplicity compared to the global track multiplicity were enforced at event selection level. Only events with a reconstructed vertex at $|v_z| < 7$ cm along the beam axis were used. In total, about 8 million selected events were used for this analysis. The event centrality was determined based on the sum of the amplitudes measured in the VZERO detectors [11]. Multi-strange baryons were reconstructed via their weak decay topology: $\Xi^- \rightarrow \Lambda + \pi^-$ and $\Omega^- \rightarrow \Lambda + K^-$, with the subsequent decay of $\Lambda \rightarrow p + \pi^-$. Charged tracks were reconstructed in the ITS and TPC detectors. Track candidates were selected in $|\eta| < 0.8$. Cuts on geometry, kinematics and particle identification on the daughter tracks via specific ionization energy loss in TPC were applied to reduce the combinatorial background. Elliptic flow was measured using the two-particle scalar product method [12] with particles in $|\eta| < 0.5$ excluded from the flow vector determination. Only multi-strange baryon candidates in $|\eta| < 0.5$ were selected to analyze the elliptic flow. The $v_2$ signal was extracted by using $v_2 = \frac{N_T v_T^2 - N_B v_B^2}{N_S}$, where $v_T^2$ and $v_B^2$ are determined from the signal mass band and two mass side-bands of the signal region, respectively. $N_T = N_S + N_B$, where $N_S$ and $N_B$ are the signal and background yields in the signal mass band.

3. Results

Figure 1 shows $v_2(p_T)$ of $\Xi^- + \Xi^+$ (left) and $\Omega^- + \Omega^+$ (right) for 0-20%, 20-40%, 40-80% and 0-80% centrality classes in 2.76 TeV Pb-Pb collisions. The error bars show the statistical uncertainties. The brackets indicate the systematic errors. Figure 2 shows elliptic flow of identified particles measured for 20-40% central collisions compared with VISH2+1 hydrodynamical model calculations [6]. The error bars in this figure (and also in the following ones) indicate systematic and statistical uncertainties added in quadrature. As can be seen, the VISH2+1 model describes the measured $v_2$ for pions and kaons, but deviates up to 20% for anti-protons. Within experimental uncertainties the model calculations are compatible with the measured $\Xi$ and $\Omega$ elliptic flow.

To test whether the transverse kinetic energy scaling observed at RHIC energies [13] holds at LHC energies, we plot in Fig. 3 $v_2/n_q$ versus $(m_T - m_0)/n_q$ for identified particles in 20-40% centrality Pb-Pb collisions at 2.76 TeV.
$v_2(p_T)$ of $\Xi^- + \bar{\Xi}^+$ (left) and $\Omega^- + \bar{\Omega}^+$ (right) for 0-20%, 20-40%, 40-80% and 0-80% centralities in 2.76 TeV Pb-Pb collisions. The error bars show the statistical uncertainties. The brackets indicate the systematic errors.

Figure 2. $v_2(p_T)$ of identified particles in 20-40% centrality Pb-Pb collisions at 2.76 TeV compared to VISH2+1 hydrodynamical model calculations.

The transverse kinetic energy $n_q$ scaling of elliptic flow is not observed, but within errors mesons and baryons separately seem to scale.

Figure 3. $v_2/n_q$ versus $(m_T - m_0)/n_q$ for identified particles in 20-40% centrality Pb-Pb collisions at 2.76 TeV.

Figure 4. Comparison of $\Xi^- + \bar{\Xi}^+ v_2$ (left) for 40-80% centrality and $\Omega^- + \bar{\Omega}^+ v_2$ (right) for 0-20% centrality in 2.76 TeV Pb-Pb collisions to the STAR measurements in 200 GeV Au-Au collisions.
Figure 4 shows a comparison of $\Xi^- + \Xi^+ v_2$ (left) for 40-80% centrality and $\Omega^- + \Omega^+ v_2$ (right) for 0-20% centrality in 2.76 TeV Pb-Pb collisions to results from 200 GeV Au-Au collisions at the same centralities measured by the STAR experiment [9]. As can be seen, the differential flow does not change within uncertainties.

4. Summary

We presented the $p_T$ differential elliptic flow of multi-strange baryons in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV measured with the ALICE detector at the LHC. We showed the $p_T$ differential elliptic flow of identified particles for 20-40% centrality and compared it to the VISH2+1 model calculations. The viscous-hydro prediction describes $\Xi$ and $\Omega$ $v_2$ measurements within experimental uncertainties. We also showed that the number of constituent quark transverse kinetic energy scaling does not work as well as at RHIC. Mesons and baryons seem to follow two different trends when the $v_2/n_q$ is plotted as a function of $(m_T - m_0)/n_q$. In addition, we observed that the differential flow of $\Xi$ for 40-80% centrality and $\Omega$ for 0-20% centrality is similar to the STAR measurements at 200 GeV in Au-Au collisions.

Acknowledgments

We thank the ALICE collaboration and the ALICE funding agencies (the same as the acknowledgments in [10]). This work is supported partly by the NSFC under grants No. 10975061, 10875051 and 11020101060.

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