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To cite this article: Jihye Song and ALICE Collaboration 2017 J. Phys.: Conf. Ser. 832 012060

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Production of $\Sigma(1385)^\pm$ and $\Xi(1530)^0$ in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV measured by ALICE at the LHC

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Abstract. In order to study the hot hadronic matter created in heavy-ion collisions, it is important to compare particle production in large systems to that in smaller systems, such as proton-proton (pp) and proton-lead (p–Pb) collisions. In particular, resonances with different lifetimes are good candidates to probe the interplay of particle re-scattering and regeneration in the hadronic phase. The yields of the strange and double-strange hyperon resonances $\Sigma(1385)^\pm$ and $\Xi(1530)^0$ are measured in the rapidity range $-0.5 < y_{CMS} < 0$ in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with the ALICE detector at the LHC. We report on the transverse momentum distributions and mean transverse momentum as a function of the charged-particle multiplicity. These results complement the information derived from the measurements of other resonances such as $K^*(892)^0$ and $\phi(1020)$. The multiplicity dependence of the integrated yield ratios of excited hyperons to longer-lived particles is discussed and compared to model predictions from pQCD-inspired models such as PYTHIA8 as well as statistical hadronization models.

1. Introduction

The measurement of resonances in ultra-relativistic heavy-ion collisions allows one to study the properties of the hadronic medium. Hyperon resonances with lifetimes comparable to the duration of the hadronic phase are good candidates to probe the interplay of particle re-scattering and regeneration which could result in a modification of their measured yield.

Mesonic resonances such as $\rho(770)^0$, $K^*(892)^0$ and $\phi(1020)$ have been measured in pp, p–Pb and Pb–Pb collisions at different energies. The results show that the production of particles with short lifetime (Table 1), e.g. $\rho(770)^0$ [1] and $K^*(892)^0$ [2], exhibits progressively larger suppression when going from pp to p–Pb and Pb–Pb collisions. Longer-lived particles such as $\phi(1020)$ do not appear to be significantly modified across these systems, suggesting that the short-lived particles are affected more by re-scattering in the larger collision systems. Measurements of baryonic resonances, $\Sigma(1385)^\pm$ and $\Xi(1530)^0$, complement the information obtained from mesonic resonances. Since the lifetime of $\Xi(1530)^0$ (Table 1) is between that of $K^*(892)^0$ and $\phi(1020)$ and lifetime of $\Sigma(1385)^\pm$ is comparable with $K^*(892)^0$, these results are expected to help to understand the properties of the hadronic medium.

The ratio of the $p_T$-integrated yields of resonances to ground-state hadrons are used along with model predictions to estimate the properties (temperature [3, 4] and lifetime [5, 6]) of the fireball produced in heavy-ion collisions. In addition, particle production mechanisms are studied by comparing the measurements of resonances with different mass and quark content. This paper present measurements from the ALICE experiment that are related to these topics.
Table 1. Lifetimes of the measured resonances with their quark contents and decay modes [9].

<table>
<thead>
<tr>
<th>Decay modes used</th>
<th>quark contents</th>
<th>$c\tau$ (fm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi^+ + \pi^-$</td>
<td>$(u\bar{u} + d\bar{d})/\sqrt{2}$</td>
<td>1.3</td>
</tr>
<tr>
<td>$K^+ + \pi^-$</td>
<td>$d\bar{s}$</td>
<td>4.2</td>
</tr>
<tr>
<td>$\Lambda^+ \rightarrow (p\pi^-)\pi^+$</td>
<td>$uus$</td>
<td>5.5</td>
</tr>
<tr>
<td>$\Sigma^+(1385)$</td>
<td>$dds$</td>
<td>5.0</td>
</tr>
<tr>
<td>$\Xi^+(1530)$</td>
<td>$uss$</td>
<td>21.7</td>
</tr>
<tr>
<td>$\phi(1020)$</td>
<td>$s\bar{s}$</td>
<td>44</td>
</tr>
</tbody>
</table>

2. Analysis and Results

The $\Sigma(1385)^\pm$ and $\Xi(1530)^0$ baryons are reconstructed by the daughters of their hadronic decays. The intermediate decay products, $\Lambda$ and $\Xi^-$, are identified through selections based on their decay topology. The signals were reconstructed by invariant mass analysis of candidates for the decay products pairs from same events for various $p_T$ and multiplicity intervals. Combinatorial backgrounds, constructed using event mixing technique, are subtracted from the invariant mass distributions. The invariant mass distributions are fitted using Breit-Wigner functions for backgrounds, constructed using event mixing technique, are subtracted from the invariant mass distributions. First- or second-order polynomials are used to describe the residual background; see [14] for further details. The $p_T$ spectra, which are corrected for efficiency, acceptance, and branching ratios, are fitted using Lévy-Tsallis functions to extract the total integrated yields and mean transverse momenta to describe the residual background; see [14] for further details. The $p_T$ spectra, which are corrected for efficiency, acceptance, and branching ratios, are fitted using Lévy-Tsallis functions to extract the total integrated yields and mean transverse momenta of $\Lambda$, $\Xi^-$, $\Sigma(1385)^\pm$, $\Xi(1530)^0$ and $\Omega^-$ in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV as a function of the mean charged-particle multiplicity density $\langle dN_{ch}/d\eta_{lab} \rangle_{|\eta_{lab}| < 0.5}$, measured in the pseudo-rapidity range $|\eta_{lab}| < 0.5$.

Figure 1. Mean transverse momenta $\langle p_T \rangle$ of $\Lambda$, $\Xi^-$, $\Sigma(1385)^\pm$, $\Xi(1530)^0$ and $\Omega^-$ in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV as a function of the mean charged-particle multiplicity density $\langle dN_{ch}/d\eta_{lab} \rangle_{|\eta_{lab}| < 0.5}$, measured in the pseudo-rapidity range $|\eta_{lab}| < 0.5$.

Figure 2. Mass dependence of the mean transverse momenta of identified particles for the $0 - 20\%$, 0-100% for $D^0$ and $J/\psi$, multiplicity class defined by scintillator detector, V0A, and with $-0.5 < y < 0$ in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [10,11] ([12], [13]) and minimum-bias pp collisions at $\sqrt{s} = 7$ TeV [14],[15] with $|y| < 0.5$. 

Uncertainties: stat.(bars), sys.(boxes)
Figure 1 shows the mean transverse momentum as a function of the mean charged-particle multiplicity density at midrapidity \(<dN_{ch}/d\eta_{lab}>\). The results for \(\Sigma(1385)^{\pm}\) and \(\Xi(1530)^{0}\) are compared with those for other hyperons measured by the ALICE collaboration in p–Pb collisions at \(\sqrt{s_{NN}} = 5.02\) TeV [10, 11]. For both \(\Sigma(1385)^{\pm}\) and \(\Xi(1530)^{0}\) the mean transverse momenta increase as the collision system size grows, similar to the other hyperons.

In all multiplicity classes, the \((p_T)\) follows mass ordering: \((p_T)_\Lambda < (p_T)_\Xi- \approx (p_T)\Sigma^{(1385)} < (p_T)\Xi(1530)^0 < (p_T)\Omega^-\). This hierarchy of mass-ordering, including \(D^0\) and \(J/\psi\), is presented in Figure 2. A similar mass dependence is observed in p–Pb and pp collisions.

The integrated yield ratios of excited to ground-state hyperons [10, 11, 14, 16] with the same strangeness content are shown in Figure 3 as a function of the mean charged particle multiplicity \(dN_{ch}/d\eta_{lab}\) at midrapidity. A few model predictions are also shown as lines at the appropriate abscissa.

The results are compared with model predictions, PYTHIA8 [8] for pp and DPMJET [7] for p–Pb collisions. The \(\Sigma^{\pm}/\Lambda\) ratios (left panel in Figure 3) are consistent with the values predicted by PYTHIA8 in pp, whereas the DPMJET prediction for p–Pb collisions is lower than the experimental data. The measured \(\Xi(1530)^0/\Xi\) ratios (right panel in Figure 3) appear higher than the corresponding event generator predictions for both systems.

The integrated yield ratios of excited hyperons to pions are shown in Figure 4 to study the evolution of relative strangeness production with the increase of the collision system size. Both \(\Sigma(1385)^{\pm}/\pi^{\pm}\) (left panel in Figure 4) and \(\Xi(1530)^{0}/\pi^{\pm}\) (right panel in Figure 4) show a gradual increase with multiplicity and approach (grand canonical) thermal model prediction [3, 4] in the highest multiplicity event class. The measured particle ratios indicate that the enhancement of hyperons, both resonances and ground-state, is due to their strangeness content and not their masses.

3. Summary

The baryonic resonances \(\Sigma(1385)^{\pm}\) and \(\Xi(1530)^{0}\) have been measured in p–Pb collisions at \(\sqrt{s_{NN}} = 5.02\) TeV as a function of multiplicity. The \((p_T)\) of these resonances increases with multiplicity and exhibits mass ordering. The \(\Sigma(1385)^{\pm}/\Lambda\) and \(\Xi(1530)^0/\Xi\) ratios do not vary with system in pp and p–Pb collisions. Integrated particle ratios of excited hyperon yields \((\Sigma(1385)^{\pm}/\pi^{\pm}\) and \(\Xi(1530)^{0}/\pi^{\pm}\)) increase with the multiplicity density and strangeness content.
Figure 4. Ratio of \(\Sigma(1385)^\pm\) to \(\pi^\pm\) (Left) and ratio of \(\Xi(1530)^0\) to \(\pi^\pm\) (Right) measured in pp [19], d–Au [17] and p–Pb [10, 14] collisions, as a function of the average charged particle density \((dN_{ch}/d\eta_{lab})\) measured at midrapidity. A few model predictions are also shown as lines at the appropriate abscissa.

The ALICE Collaboration is currently extending these measurements to higher energies, other resonances and other collision systems. Especially, the measurements of \(\Sigma(1385)^\pm\), \(\Xi(1530)^0\) and \(\Lambda(1520)\) in Pb–Pb collisions are being carried out and these will provide important information to further constrain the properties of the hadronic phase.

References