RESONANCE RESULTS FROM THE ALICE DETECTOR IN 7 TeV $pp$ COLLISIONS AT THE LHC*

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The study of resonances in $\sqrt{s} = 7$ TeV $pp$ collisions provides a test of QCD in a new energy domain as well as a baseline for heavy-ion collisions. The resonances $K^*(892)^0$, $\phi(1020)$, $\Lambda(1520)$, $\Sigma(1385)^\pm$, and $\Xi(1530)^0$ are reconstructed at mid-rapidity from their hadronic decay using data collected by the ALICE detector. We compare the $\phi(1020)$ and $\Sigma(1385)^\pm$ $p_T$ spectra to perturbative QCD models such as PHOJET and different PYTHIA tunes. We also search for the $\Phi(1860)$ pentaquark for which we find no evidence.

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1. Introduction

The study of resonance production in $pp$ collisions is important in two noteworthy ways. By comparing the measured spectra of resonances to PYTHIA predictions we can improve our understanding of hadronization. Also, the measured spectra in $pp$ provide a baseline for particle production enhancement/suppression studies in Pb–Pb, $R_{AA}$.

2. Results

Data for the results presented here were taken during the 2010 $\sqrt{s} = 7$ TeV $pp$ run at the LHC using minimum bias collisions with the ALICE detector. The number of events used ranged from 24 to 150 M events depending on the resonance. The resonances were reconstructed using their main hadronic decay channels:

\[ K^*(892)^0 \rightarrow K^- + \pi^+ (+cc), \]
\[ \phi(1020) \rightarrow K^{+-} + K^{--}, \]
\[ \Sigma(1385)^{+-} \rightarrow \Lambda + \pi^{+-}, \]
\[ \Lambda(1520) \rightarrow p^+ + K^- (+cc), \]
\[ \Xi(1530)^0 \rightarrow \Xi^- + \pi^+ (+cc), \]

where the weak decays of the $\Xi^{+-}$ and $\Lambda$ were reconstructed through their main charged hadronic decay channels, $\Xi^{+-} \rightarrow \Lambda + \pi^{+-}$ and $\Lambda \rightarrow p^+ + \pi^-$, respectively. Particle tracking was done using the Inner Tracking System (ITS) and the Time Projection Chamber (TPC) [1]. Particle identification was done via the measured energy loss in the TPC as well as the timing information from the Time-of-Flight (TOF) detector. Identical track quality assurance cuts were applied to the decay daughters of all resonances. These include cuts on: number of TPC clusters used for tracking, and $p_T > 0.15$ GeV/$c$ for instance. The chosen rapidity range was $|y| < 0.5$ for the $K^*(892)^0$, $\phi(1020)$, and $\Xi(1530)^0$. While for the $\Sigma(1385)^{+-}$ and $\Lambda(1520)$ it was $|y| < 0.8$ and $|y| < 0.9$, respectively.

All resonances for which we present a $p_T$ spectrum are compared to two QCD inspired models: PHOJET [2] and PYTHIA [3]. For PYTHIA we use three different tunes: D6T, ATLAS-CSC, and Perugia 2011. It is worth mentioning that the latest PYTHIA tune, Perugia 2011, already contains some input from the LHC experiments for the measured multiplicity distributions and strangeness production.

Fig. 1. $K^*(892)^0$ invariant mass distribution in $\sqrt{s} = 7$ TeV pp collisions. The same charge pion–kaon invariant mass distribution is used to subtract the background. The resulting distribution is fit with a Breit–Wigner + 1st degree polynomial.
The $K^*(892)^0$ invariant mass distribution is shown in Fig. 1. The same charge background estimation is subtracted from the opposite charge signal distribution and the resulting peak is fitted with a Breit–Wigner function. The $p_T$ spectrum for the $K^*(892)^0$ is underway.

The $\phi(1020)$ $p_T$ spectrum compared to the various models is shown in Fig. 2. Here, we observe that the D6T tune of PYTHIA provides very good agreement for $p_T < 2.0$ GeV/$c$ while for higher $p_T$ PHOJET seems to give a better description of the data. The latest tune, Perugia 2011, does not provide a good description of the data.

The $\Sigma(1385)^-\pi^+$ and $\Sigma(1385)^+\pi^-$ spectra compared to the various models are shown in Fig. 3 and Fig. 4, respectively. For these two baryon resonances we see that all models underpredict the data with PHOJET being the furthest off.

The $\Xi^\pm + \pi^\mp$ invariant mass distribution is shown in Fig. 5. Clearly visible is the $\Xi(1530)^0$ peak for opposite charge combinations in black (blue). Also shown is the same charge combination in grey (red). Both combinations may contain the decay of the hypothetical doubly-charged and neutral $\Phi(1860)$ pentaquark. Evidence for this particle was found by the NA49 Collaboration in $\sqrt{s} = 17.2$ GeV $pp$ collisions at the SPS [4]. Here we do not see any visible peak. To further quantify this observation we took the ratio of the $\Xi(1530)^0$ yield to the maximum possible excess yield in the $\Phi(1860)$ (the same-charge) mass range above the background while accounting for $3\sigma$ (99% confidence level) statistical fluctuations. An identical procedure was
done by the COMPASS Collaboration [5]. The ratio for NA49 is 4.2 while for ALICE it is greater than 31 indicating stronger evidence against this hypothetical particle at the LHC.

**Fig. 3.** $\Sigma(1385)^-$ $p_T$ spectrum compared to various PYTHIA tunes and PHOJET in $\sqrt{s} = 7$ TeV $pp$ collisions. The bottom panel displays the ratio to the models.

**Fig. 4.** $\Sigma(1385)^+$ $p_T$ spectrum compared to various PYTHIA tunes and PHOJET in $\sqrt{s} = 7$ TeV $pp$ collisions. The bottom panel displays the ratio to the models.
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Fig. 5. Charged $\Xi + \pi$ invariant mass distribution in $\sqrt{s} = 7$ TeV pp collisions. Black (blue) points are opposite charge combinations and grey (red) are the same charge combinations. The $\Xi(1530)^0$ peak is clearly visible while the hypothetical $\Phi(1860)$ pentaquark is not visible.

The $\Lambda(1520)$ as well as the doubly charged $\Delta(1232)$ can be reconstructed with the ALICE detector as well. Figure 6 shows the $\Lambda(1520) \rightarrow p^{+-} + K^{-+}$ invariant mass distribution for candidates with $1.25 < p_T < 1.50$ GeV/c and $|\eta| < 0.9$. The peak is fit with a Breit–Wigner function and the combinatoric background with a polynomial. The $p_T$ spectra for these particles are underway.

Fig. 6. $\Lambda(1520)$ invariant mass distribution for $1.25 < p_T < 1.50$ GeV/c and $|\eta| < 0.9$ in $\sqrt{s} = 7$ TeV pp collisions.
3. Conclusions

We find that none of the QCD inspired models simultaneously describe all of the resonance spectra presented here. In particular, the latest PYTHIA tune, Perugia 2011, does not generally provide a good description of resonance production despite its input from the early LHC results. We also observe quite a significant $K^*(892)^0$, $\Xi(1530)^0$, and $\Lambda(1520)$ invariant mass peak for which $p_T$ spectra are underway. Finally, we see no evidence for the hypothetical $\Phi(1860)$ pentaquark.

REFERENCES