Study of short-lived resonances with the ALICE Experiment at the LHC

Ayben Karasu Uysal

Department of Physics, Yildiz Technical University, Istanbul, Turkey

E-mail: akarasu@cern.ch

Abstract. The study of short-lived resonances allows the investigation of the collision dynamics and of the properties of the hot and dense medium created in high energy collisions. Moreover it is interesting to address the topics of the strangeness production by the analysis of strange resonances. First measurements of the \(\phi(1020), \Lambda^*(1520), K^*(892), \Xi^*(1530)\) and doubly charged \(\Delta(1232)\) resonances in pp collisions at a center of mass energy of 7 TeV with the ALICE apparatus at the LHC are presented. Thermal model predictions of particle ratios in proton-proton collisions are shown.

1. Introduction

Resonances have unique characteristics to probe various properties of the hot and dense matter produced in relativistic heavy-ion collisions. The in-medium effects related to the high density and/or high temperature of the medium can modify various resonance properties, such as masses, widths and yields [1].

Since resonances may decay between chemical and thermal freeze-outs of the fireball, they can also provide information on hadronization and the time span between chemical and thermal freeze-out [2]. Comparison of the properties of the resonances obtained from heavy-ion collisions with the same obtained from elementary pp collisions is expected to provide evidences for possible in-medium effects.

In view of this, ALICE has attempted to detect and analyze resonances. Measurement of their properties such as mass, width, yield as a function of the transverse momentum can provide insight for understanding the dynamics of the medium created in the collision.

ALICE [3] is the LHC experiment mainly devoted to the study of ultrarelativistic heavy-ion collisions, in order to investigate the properties of the Quark-Gluon Plasma (QGP). Its excellent capabilities for particle identification in a wide transverse momentum \((p_t)\) range (from \(\sim 0.1\) to \(\sim 10\) GeV/c), make it a very well suited device for resonances study.

In this contribution, results are presented for \(K^*(892)^0\) (identified by charged \(K\pi\) decay channel), \(\phi(1020)\) (\(K^*K\) decay channel), \(\Xi(1530)^0\) (\(\Xi\pi\) decay channel), \(\Lambda^*(1520)\) (pK decay channel) and doubly charged \(\Delta(1232)\) (p\(\pi\) decay channel) measurements done with a sample of data collected by ALICE in 2010. Section 2 shortly describes the analysis procedure and Section 3 shows some results. Section 4 presents the conclusions and an outlook.

\footnote{For the ALICE Collaboration}

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2. Analysis

The Time Projection Chamber (TPC) and the Time-of-Flight (TOF) detectors are used to measure the resonance production through the detection of its hadronic decay products. The TPC provides identification and momentum information of the charged particles by measuring their ionization energy loss (dE/dx). Charged particles in the intermediate momentum range are identified in ALICE by the Time Of Flight (TOF) detector. The time measurement with the TOF, in conjunction with the momentum and track length measured by the tracking detectors is used to calculate the particle mass. The combination of these methods provides particle identification over the large transverse momentum range.

The online trigger selection requires a signal in either of the VZERO scintillator counters or at least one hit in either of the silicon pixel detector (SPD) layers. The primary vertex is reconstructed using either SPD tracklets or global tracks. Events are selected by requiring that the distance between the position of primary vertex and the geometrical centre of the apparatus along the beam axis be less than 10 cm.

The dataset corresponding to pp collisions at $\sqrt{s} = 7$ TeV consisted of 25 to 385 millions of minimum-bias (MB) events, for the different resonances analyzed.

2.1. Reconstruction of resonances

Resonance signals are reconstructed by calculating the invariant mass of the pair of decay daughters. However, the pair invariant mass spectra have large underlying backgrounds due to many random combinatorial pairs, which have no correlation at all. Therefore, to get the real resonance invariant spectra one needs to subtract out the huge combinatorial background. This is done using event-mixing [4] or like-sign [5] techniques if the resonance signals are not clearly visible.

The result of the subtraction is fitted with a Breit-Wigner or a Voigtian (= convolution of Gaussian and Breit-Wigner) to describe the signal function plus a polynomial function to account for the remaining residual background. Background identification methods and fit functions used for each resonance species are summarized in the Table 1.

| Resonance | Background Technique | Signal Function | Residual Background Function |
|-----------|----------------------|----------------|-----------------------------|
| $K'(892)^0$ | Like-Sign | Breit-Wigner | Straight Line |
| $\phi(1020)$ | Fit Function | Voigtian | 2nd Order Polynomial |
| $\Xi(1530)^0$ | Fit Function | Voigtian | 2nd Order Polynomial |
| $\Lambda'(1520)$ | Event-Mixing | Breit-Wigner | 2nd Order Polynomial |
| $\Delta(1232)$ | Event-Mixing | p-wave Breit-Wigner | Straight Line |

3. Results

$K'(892)^0$, $\phi(1020)$ and $\Xi(1530)^0$ raw counts in pp collisions are corrected for reconstruction efficiency, acceptance and branching ratio. The obtained $p_T$ spectra are compared with the PHOJET [6] and some widely used PYTHIA [7] Atlas-csc [8], Perugia-0 [9] and D6T [10] tunes. For $K'(892)^0$, the best agreement is obtained for D6T, while PHOJET and Atlas-csc overestimate low $p_T$ yields and underestimate high $p_T$ ones. The $\phi(1020)$ is well reproduced by D6T below 2.5 GeV/c and by PHOJET and Atlas-csc above this limit. Both mesons are underestimated by Perugia-0. In the case of $\Xi(1530)^0$, none of the above Monte-Carlo (MC) models succeeds in describing the measured $p_T$ spectrum. Figure 1 shows the comparison between corrected spectra and MC models.
Figure 1. Transverse momentum spectra of (upper) $K^*(892)^0$, (middle) $\phi(1020)$ and (lower) $\Xi^*(1530)^0$ compared with different MC Models. Lower part of each plot shows the ratio between MC and data for each measured bin. The shadow band is the systematic error on data.

Figure 2 and Figure 3 show the extracted mass values for the doubly charged $\Delta(1232)$ and $\Lambda^*(1520)$ resonances as a function of $p_t$. The values are in agreement with the Particle Data Group.
values within errors for Λ*(1520), while 30-50 MeV/c² mass shift is observed for doubly charged Δ(1232).

![Figure 2](image_url1)

**Figure 2.** Extracted mass of Λ*(1520) + anti-Λ*(1520) as a function of p_t. Solid line is the PDG mass (1.5195 GeV/c²) and the dashed lines are the PDG errors. Statistical errors are estimated from the fit function while systematical errors are calculated from the difference when Λ*(1520) and anti-Λ*(1520) are analyzed separately.

![Figure 3](image_url2)

**Figure 3.** Extracted mass of (full symbols) Δ^+ and (open symbols) Δ^- as a function of p_t. Solid line is the PDG mass (1.232 GeV/c²). Errors are statistical only.

4. Conclusions

The resonance measurements have been performed using the dE/dx in the gas of the TPC and time-of-flight information from TOF. The combinations of these techniques allow us to cover a broad range of momentum.

d²N/dydp_t has been determined for K*(892)^0, φ(1020) and Ξ(1530)^0 resonances through their hadronic decay channels. Spectra show different levels of agreement with various MC event generators: mesons are reasonably well reproduced by PYTHIA D6T, while PHOJET and PYTHIA Atlas-csc match φ(1020) above 2.5 GeV/c and Perugia-0 underestimates all spectra. The Ξ(1530)^0 is underestimated in all cases. The study of other resonances will complete the picture on pp collisions at √s = 7 TeV. The presented analysis in pp is done as a baseline and will be continued for the Pb-Pb data.
The $\Delta^{++}$ and $\Delta^{--}$ masses are shifted found to be shifted by 30-50 MeV/$c^2$ and no $p_t$ dependence of this shift is observed. Width values, except for the high momentum range, are in agreement within the error bars with the PDG value. The mass shift can be explained as a kinematical shift inside a thermal medium which is coupled to the $N\pi\leftrightarrow\Delta(1232)$ interaction [12].

In order to estimate the particle yield ratios, the statistical thermal model used. Ratios for pp collisions at $\sqrt{s} = 7$ TeV for different temperature values have been calculated within strangeness canonical approach using the THERMUS code [13] and the results are presented in Figure 4. This shows that the particle ratios are very sensitive to the freeze-out temperature and they are inversely proportional to the mass difference.

![Figure 4](image_url)  
*Figure 4.* Ratios of particles with different temperatures predicted using the strangeness canonical THERMUS model. $\Delta M$ values show the mass differences between the two particles.

References

[1] Rapp R and Wambach J 2000 Adv. Nucl. Phys. 25 1
[2] Torrieri G and Rafelski 2001 J Phys. Lett. B 509 239
[3] Aamodt K et al. (ALICE Collaboration) 2008 JINST 3 S08001
[4] L'Hôte D 1994 Nucl. Inst. Meth. in Phys. Res. Sec. A 337 544
[5] Adams J et al. 2003 Phys. Rev. Lett. 92 092301
[6] Engel R et al. 1995 Z. Phys. C 66 203
[7] Sjöstrand T, Mrenna S and Skands P 2006 J. High Energy Phys. 05 026
[8] Field R 2008 Acta Phys. Pol. B 39 2611
[9] Buttar C, Clements D, Dawson I and Moraes A 2004 Acta Phys. Pol. B 35 433
[10] Skands P Z 2009 Preprint hep-ph/0905.3418 [arXiv]
[11] Nakamura K et al. (Particle Data Group) 2010 J. Phys. G. 37 075021
[12] Weinhold W, Friman B and Nörenberg W 1998 Phys. Lett. B 433 236
[13] Wheaton S and Cleymans J 2009 Comput. Phys. Commun. 180 84