Λ_c analysis with the ALICE detector at the LHC

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Abstract. ALICE is the LHC experiment dedicated to the study of the Quark Gluon Plasma (QGP) in high-energy nuclear collisions. Due to their large mass and their production at the early collision stage, heavy quarks (charm and beauty) are well-suited probes to study the properties of the QGP. The open charm baryon Λ_c is reconstructed in ALICE in the decay channels ${\Lambda_c}^+ \rightarrow \pi^+ + K^- + p$ and ${\Lambda_c}^+ \rightarrow K^0_S + p$, exploiting both topological selections and particle identification. We report about the analysis strategy to observe the signal in pp collisions for both decay channels and then show the invariant mass plots where the Λ_c peak is clearly visible.

1. Introduction

Heavy quarks are sensitive probes of the QGP formed in heavy-ion collisions, since they are produced in the initial hard scattering processes and experience the full collision evolution. In particular, measurements of open charm and beauty production in Pb–Pb collisions, using the pp measurements as a reference, probe the energy loss experienced by partons traversing the hot and dense medium formed in high-energy nuclear collisions.

Measuring Λ_c production in Pb–Pb collisions would provide an answer to the question whether the baryon-over-meson enhancement at intermediate momentum, observed in the light-flavor sector at RHIC and LHC, also holds in the heavy-quark sector, suggesting charm hadron production via coalescence. The measurement of the Λ_c production cross section in pp collisions, not only provides the necessary baseline to understand the heavy ions results, but has also an interest per se, since it is needed to measure the total charm cross section. The golden decay channels are: $\Lambda_c^+ \rightarrow pK^-\pi^+$, with a branching ratio of BR=$5.0 \pm 1.3\%$, and ${\Lambda_c}^+ \rightarrow K^0_S + p$, with an overall branching ratio of approximately $0.8 \pm 0.2\%$. The Λ_c cross section has been measured previously in γ-p , e^+e^- and e-p collisions [1]. The fragmentation fraction $c \rightarrow \Lambda_c$ measured by different experiments in the different collision systems has large uncertainties and varies from 8 to 14%. In addition, the open charm baryon cross section has never been measured in hadronic collisions. LHCb has also measured Λ_c, but only the ones coming from Λ_b decays [2].

ALICE (A Large Ion Collider Experiment) [3] is the LHC experiment dedicated to the study of the properties of the QGP formed in heavy-ion collisions. Its subdetectors provide excellent tracking performance, secondary vertex reconstruction, and particle identification capability, making the measurement of Λ_c in pp collisions possible down to low momenta.

2. ALICE detector: setup and data sample

For the Λ_c analysis, the main detectors involved in the central barrel ($-0.9 < \eta < 0.9$) are: the Inner Tracking System (ITS), for vertices reconstruction and tracking), the Time Projection

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Chamber (TPC), for tracking, Particle Identification (PID) and recontruction of K^0_S decays and the Time Of Flight (TOF), for PID. The ITS plays a central role in the reconstruction of primary and secondary vertices. The primary interaction vertex is reconstructed event by event with a resolution better than 100 μm. Good primary vertex and impact parameter resolution are both important for discrimination of tracks from secondary vertices close to the interaction vertex. The main ALICE tracking device is the TPC [4]. It is the largest TPC ever built and it has been designed to reconstruct efficiently up to 15000 primary tracks in a single collision, with a momentum resolution better than 1% for tracks with $p_T < 1$ GeV/c. The TPC is also the tracking device used to reconstruct the $V0$ secondary vertices: they are defined as the weak decay of a neutral particle decaying into two charged tracks after typically few cm. In particular, the $K^0_S \to \pi^+\pi^-$ decay has a $c\tau$ of 2.68 cm and is reconstructed with approximately 40% efficiency.

The results shown here are obtained analysing 3×10^8 pp minimum bias events at 7 TeV (corresponding to an integrated luminosity of 5 nb^{-1}). The detectors used for issuing the minimum bias trigger are the Silicon Pixel Detector (SPD) and the VZERO scintillator arrays, covering the rapidity ranges 2.8< η <5.1 and -3.7< η <-1.7 and placed at 3.4 m and 0.9 m from the interaction point, respectively. The trigger requires at least one hit in the SPD, combined in logical or with one signal in the VZERO counters, triggering in this way on at least one track anywhere in the eight units of pseudorapidity covered by the two trigger detectors.

3. The Λ_c analysis

For the decay channel $\Lambda_c^+ \to pK^-\pi^+$, the candidates are triplets of tracks with correct charge combination. Single tracks are first selected for their quality and transverse momentum. A second track is attached to form a pair of opposite charged tracks. A third track is attached to the selected pairs and the secondary vertex is reconstructed.

For the decay channel $\Lambda_c^+ \to K^0_S p$, the $V0$s are selected in the invariant mass window of the K^0_S. Then a track is selected for its global reconstruction quality, identified and attached to the K^0_S to form a Λ_c.

The Λ_c has a $c\tau$ of only 60 μm, so it is not easy to distinguish the secondary displaced vertices of the low momentum charmed baryon candidates. Therefore, the topological selection is less effective than for D meson decays ($c\tau >= 120$ μm).

The PID is very important for the analysis, for both decay channels under study. For this analysis the TPC and TOF detectors are used for PID. The TPC can be used to identify particles with intermediate momenta (up to $p = 1$ GeV/c for the separation of proton from K and π) thanks to the information on the specific energy deposit dE/dx in its volume. The TOF can be used to separate, for example, protons from pions up to 3 GeV/c and provide p/K separation up to 1.5 GeV/c. The two detectors cover the p_T range relevant for the identification of tracks coming from charmed baryon decays.

For the decay channel $\Lambda_c^+ \to pK^-\pi^+$, the Bayesian approach is used to combine the response of the two detectors. The probability W for a track to be of a specie i is the combination of the detectors response (s_{TPC}, s_{TOF}) and the initial value of the composition of the sample (the so called "priors", C):

$$W(i) = \frac{C_i \prod_{j=1}^{N} r(s_j|i)}{\sum_{k=e,\mu,\pi,..} C_k \prod_{j=1}^{N} r(s_j|k)}$$

To identify a track uniquely, the maximum probability criterion is applied: a track is identified as specie i if the probability $W(i)$ is the highest.

In the upper side of Fig. 1, the effect of the PID on the pKπ invariant mass distribution is shown for four different p_T ranges: the background is reduced by a factor hundred when PID is applied. The proton of the $\Lambda_c^+ \to K^0_S p$ is identified by the specific ionization energy loss in the TPC, combined in logical OR with the time of flight measured by TOF. In addition, the track is rejected if it is compatible with the kaon or pion hypothesis. In the lower side of Fig. 1, the effect of the PID on the decay channel K^0_Sp invariant mass distribution, p_T integrated, is shown: also in this case, the background is dramatically reduced.

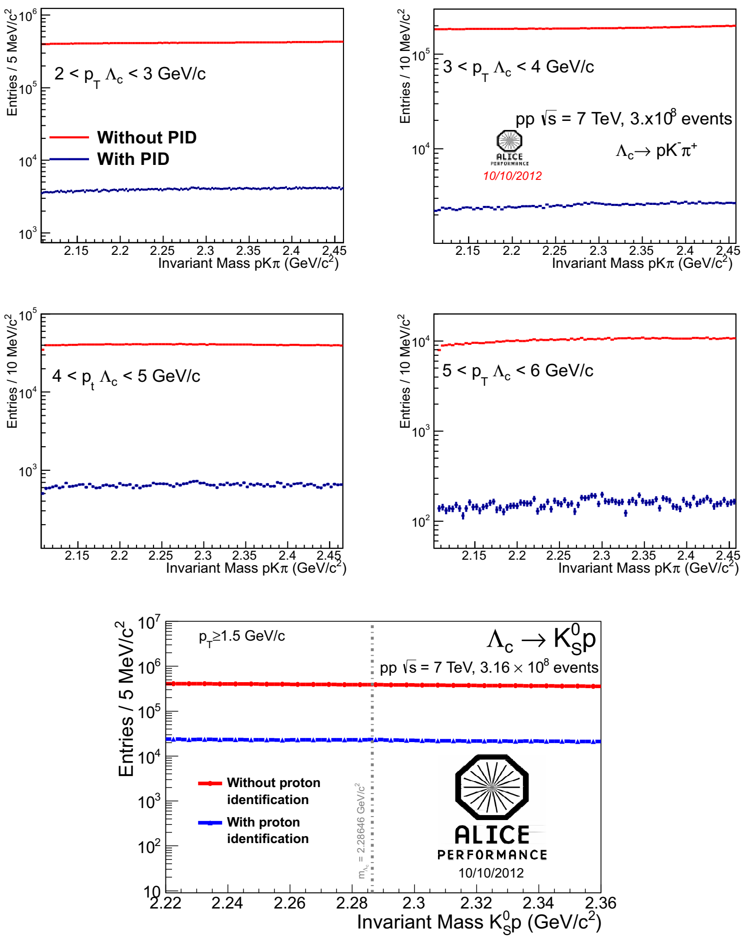

Figure 1. Invariant mass distributions for Λ_c candidates with PID (in blue) and without PID (in red), for the decay channels pKπ in the upper side and K^0_Sp in the lower side.

4. The Λ_c signal

The Λ_c signal can then be observed in both decay channels, in four p_T bins, as shown in Fig. 2, with a significance larger than 3. The signal is observed in the $\Lambda_c^+ \to pK^-\pi^+$ decay channel (zoom in of the case "With PID" in Fig.1) in the p_T range $2 < p_T < 6$ GeV/c, while the decay channel $\Lambda_c^+ \to K^0_S p$ covers the range $1 < p_T < 5$ GeV/c.

5. Conclusions

We have presented the analysis strategy that leads to the observation of the Λ_c signal in 3×10^8 minimum bias pp collisions at $\sqrt{s} = 7$ TeV, in the decay channels $\Lambda_c^+ \to pK^-\pi^+$ and $\Lambda_c \to K^0_S p$. The two decay channels allow us to cover a broad p_T range, with a wide overlap: not only they provide a complementary measurement, but also a good consistency check. The next step in the

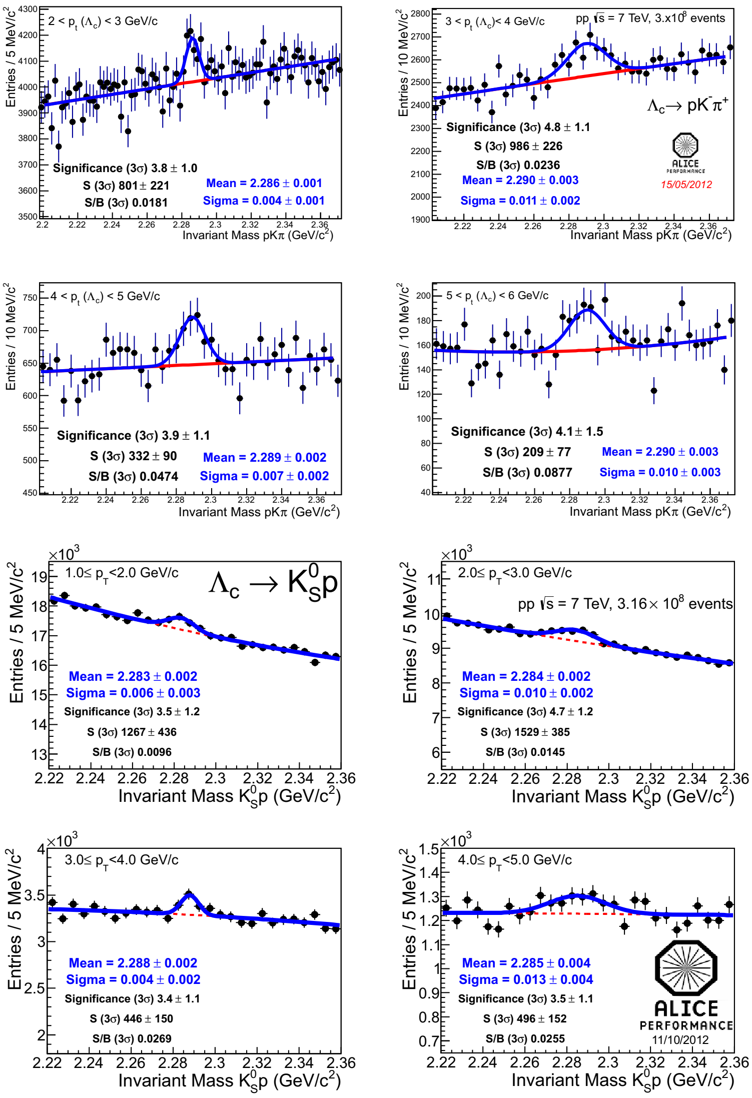

Figure 2. Invariant mass distributions for Λ_c candidates, for the decay channel $pK\pi$ in the upper side, for the decay channel $K^0_S p$ in the lower side. The background is fitted with a second order polynomial function, while the signal is fitted with a Gaussian term. The resolution in the invariant mass of the Λ_c is extracted from the fit and is determined from the width of the gaussian. It varies with the p_T of the Λ_c candidate because the momenta of the daughter particles increases with increasing momentum of the Λ_c. This leads to an increase in mass resolution.

analysis chain is to compute the efficiencies from dedicated MC simulations and estimate the feed down from beauty. Finally, the systematics errors will be evaluated.

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