The Compact Muon Solenoid Experiment

Conference Report

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Λ_c^+ production in pp and PbPb collisions at 5.02 TeV with the CMS detector

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Abstract

Due to their large masses, the interactions of heavy quarks with the quark-gluon plasma (QGP) may be different from those of light quarks. The lightest charm baryon is the Λ_c^+ , composed of a charm quark and two light quarks. Measurements of Λ_c^+ production in both pp and PbPb collisions can provide important inputs to the understanding of heavy quark transport in the QGP and the creation of heavy quark mesons and baryons via coalescence. Models involving quark coalescence predict a large enhancement of Λ_c^+ production in PbPb collisions compared to pp collisions. The high luminosity datasets collected at a nucleon-nucleon center-of-mass energy of 5.02 TeV using the CMS detector have been used to measure Λ_c^+ production in both pp and PbPb collisions via the $\Lambda_c^+ \rightarrow p^+ K^- \pi^+$ decay channel. Results for differential cross sections for Λ_c^+ and ratios of Λ_c^+ over D^0 yields in pp and PbPb collisions, as well as the nuclear modification factors for Λ_c^+ , are presented.

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Λ_c^+ production in pp and PbPb collisions at 5.02 TeV with the CMS detector

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Abstract. Due to their large masses, the interactions of heavy quarks with the quark-gluon plasma (QGP) may be different from those of light quarks. The lightest charm baryon is Λ_c^+ , composed of a charm quark and two light quarks. Measurements of Λ_c^+ production in both pp and PbPb collisions can provide important inputs to the understanding of heavy quark transport in the QGP and the creation of heavy quark mesons and baryons via coalescence. Models involving quark coalescence predict a large enhancement of Λ_c^+ production in PbPb collisions compared to pp collisions. The high luminosity datasets collected at a nucleon-nucleon center-of-mass energy of 5.02 TeV using the CMS detector have been used to measure Λ_c^+ production in both pp and PbPb collisions via the $\Lambda_c^+ \rightarrow pK^-\pi^+$ decay channel. Results for differential cross sections for Λ_c^+ and ratios of Λ_c^+ over D^0 yields in pp and PbPb collisions, as well as the nuclear modification factor for Λ_c^+ , are presented.

Keywords: CMS, physics, nuclear modification factor, heavy flavor, Λ_c^+

1 Introduction

Measurements of heavy-quark production provide unique inputs in understanding the properties of quark-gluon plasma (QGP) [1]. In relativistic heavy ion collisions, besides the fragmentation process present in proton-proton (pp) collisions, hadron production can also occur via coalescence. Due to the larger number of constituent quarks, the relative coalescence contribution to baryon production is expected to be more significant than for mesons. In particular, models involving coalescence of charm and light-flavor quarks predict a large enhancement in the Λ_c^+/D^0 production ratio in heavy ion collisions relative to pp collisions [2–4]. All discussions of Λ_c^+ and D^0 also include the corresponding charge conjugate states. In this report, we report a study of inclusive Λ_c^+ baryon production in pp and lead-lead (PbPb) collisions. The data were collected at $\sqrt{s_{NN}} = 5.02$ TeV in 2015 using the CMS detector [5]. The Λ_c^+/D^0 production ratios use the corresponding CMS measurements of prompt D^0 production [6].

2 Analysis procedure

The $\Lambda_c^+ \rightarrow pK^-\pi^+$ candidates are reconstructed by selecting three charged tracks with $|\eta| < 1.2$ and a net charge of +1. During the invariant mass re-

construction, both possibilities for the mass assignments of the same-sign tracks are considered, while the kaon mass is assigned to the opposite-signed track. The incorrect assignment results in a broad distribution in the invariant mass and is indistinguishable from the combinatorial background. The Λ_c^+ baryon yields in each transverse momentum (p_T) interval are obtained from unbinned maximum likelihood fits to the invariant mass distribution. The signal shape is modeled by the sum of two Gaussian functions. Representative invariant mass distributions in pp and PbPb collisions are shown in Fig. 1.

Fig. 1. Invariant mass distribution of Λ_c^+ candidates with $p_T = 5\text{--}6\text{ GeV}/c$ (left), $10\text{--}20\text{ GeV}/c$ (middle) in pp collisions, and $p_T = 10\text{--}20\text{ GeV}/c$ in PbPb collisions within the centrality range 0–100% (right). The solid line represents the full fit and the dashed line represents the background component [7].

3 Results

Figure 2 shows the p_T -differential cross section of Λ_c^+ baryon in pp and PbPb collisions. The shape of the p_T distribution in pp collisions is consistent with the PYTHIA8 calculation [8], while the data are systematically higher than PYTHIA8. The nuclear modification factor R_{AA} for Λ_c^+ baryons is shown in Fig. 3 as a function of the number of participating nucleons $\langle N_{part} \rangle$ for PbPb collisions. There is a hint that the production of Λ_c^+ is suppressed in PbPb collisions for $p_T > 10\text{ GeV}/c$, but no conclusion can be drawn due to the large uncertainty in the pp differential cross section. However, the ratio of the R_{AA} values for the 0–30% and 30–100% centrality ranges shows evidence for more suppression in the more central PbPb collisions.

Figure 4 shows the Λ_c^+/D^0 production ratio as a function of p_T for pp and 0–100% centrality PbPb collisions. The production ratio from pp collisions, is similar in shape versus p_T but systematically higher than the calculation from PYTHIA8.212 tune CUETP8M1. The calculations of PYTHIA8 adding a color reconnection (CR) mechanism [9], shown in Fig. 4, are consistent with the Λ_c^+/D^0 production ratio results in pp collisions. The Λ_c^+/D^0 production ratio in pp collisions is also compared to two models. The black solid line shows calculations using a model

Fig. 2. The p_T -differential cross sections for Λ_c^+ baryon in pp collisions and in three centrality regions of PbPb collisions, along with the PYTHIA8 calculation for pp collisions [7]. The boxes and error bars represent the systematic and statistical uncertainties, respectively. The PbPb data points are shifted in the horizontal axis for clarity. The bottom panel shows the ratio of the measured p_T -differential cross section in pp data to the PYTHIA8 calculation. The box at unity indicates the 5.8% normalization uncertainty for pp collision arising from the integrated luminosity and branching fraction.

Fig. 3. The nuclear modification factor R_{AA} versus $\langle N_{part} \rangle$ [7]. The boxes and error bars on the data points represent the systematic uncertainties, which also contain the track reconstruction efficiency and T_{AA} uncertainties, and statistical uncertainties in the PbPb invariant yield, respectively. The box at unity indicates the total uncertainty in the pp differential cross section, which is common to all three R_{AA} values.

Fig. 4. The Λ_c^+ / D^0 production cross section ratio versus p_T from pp collisions as well as 0–100% centrality PbPb collisions [7]. The PbPb data point is shifted in the horizontal axis for clarity. The open crosses and open stars represent the predictions of PYTHIA8 with the CUETP8M1 tune and with color reconnection [9], respectively. The solid and dashed lines are the calculations from Ref. [10] and Ref. [11], respectively.

that includes both coalescence and fragmentation in pp collisions [10]. Compared to the data, this model predicts a stronger dependence on p_T . Another model includes enhanced contributions from the decay of excited charm baryon states not included in PYTHIA [11] also shown in Fig. 4 by the dashed line. This model provides a reasonable description of the data in the range where it is available. The PbPb measurement in the p_T range 10–20 GeV/ c is consistent with the pp result. This lack of an enhancement may suggest that there is no significant contribution from the coalescence process for $p_T > 10$ GeV/ c in PbPb collisions.

4 Summary

In summary, this report presents the Λ_c^+ spectra in pp and PbPb collisions at 5.02 TeV with the CMS detector. A hint of suppression of Λ_c^+ production for $10 < p_T < 20$ GeV/ c is observed in PbPb when compared to pp data, with central PbPb events showing stronger suppression. The Λ_c^+/D^0 production ratios in pp collisions are consistent with the predictions of PYTHIA8 adding color reconnection in hadronization, and also with a model that includes enhanced contributions from the decay of excited charm baryons. The Λ_c^+/D^0 production ratios in pp and PbPb collisions for $p_T = 10$ –20 GeV/ c are found to be consistent with each other. This may suggest that the coalescence process does not play a significant role in Λ_c^+ baryon production in this p_T range.

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