EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE-PUBLIC-2012-xxx
October 6, 2021

Supplement figures: Measurement of the production cross sections of Ξ_c^0 and Ξ_c^+ baryons and of the $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ ratio in pp collisions at $\sqrt{s}$ = 13 TeV

The ALICE Collaboration*

Abstract

The following public note presents supplemental figures for the paper "Measurement of the production cross sections of Ξ_c^0 and Ξ_c^+ baryons and of the $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ ratio in pp collisions at $\sqrt{s}$ = 13 TeV" [1]. The p_T-differential production cross sections of prompt charm-strange baryons Ξ_c^0 and Ξ_c^+ were measured at midrapidity in proton–proton (pp) collisions at $\sqrt{s}$ = 13 TeV with the ALICE detector at the LHC. The Ξ_c^0 baryon was reconstructed via both its semileptonic decay ($e^+\Xi^-\nu_e$) and, for the first time, also via its hadronic decay ($\Xi^-\pi^+$). The Ξ_c^+ baryon was also reconstructed for the first time via the hadronic decay ($\Xi^-\pi^+\pi^+$). The ratio $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ = 1.38 ± 0.14 (stat) ± 0.22 (syst) was measured.

*See Appendix A for the list of collaboration members

1 Invariant mass distributions

The Ξ_c^0 baryon, and its charge conjugate, was reconstructed via its decay into $e^+\Xi^-\nu_e$ (BR = $(1.8 \pm 1.2)\%$ [2]) and for the first time via its decay into $\Xi^-\pi^+$ (BR = $(1.43 \pm 0.32)\%$ [2]) in the interval $1 < p_T < 12$ GeV/c. The Ξ_c^+ baryon, and its charge conjugate, was also reconstructed for the first time via its decay into $\Xi^-\pi^+\pi^+$ (BR = $(2.86 \pm 1.21 \pm 0.38)\%$ [3]) in the interval $4 < p_T < 12$ GeV/c as reported in Ref. [1].

Examples of invariant-mass distributions of candidate Ξ_c baryons together with the result of the fits are reported in Fig. 1. For the semileptonic decay channel of the Ξ_c^0, the candidates are defined from $e^+\Xi^-$ pairs. Due to the undetected neutrino, the invariant-mass distribution of $e^+\Xi^-$ pairs does not show a peak at the Ξ_c^0 mass (shown in the left panel of Fig. 1). The background contributions are estimated exploiting the fact that Ξ_c^0 baryons and their antiparticles decay only into eΞ pairs with opposite charge sign ($e^+\Xi^-$ and $e^-\Xi^+$), denoted as right-sign (RS), and not into same-sign pairs ($e^-\Xi^-$ and $e^+\Xi^+$), denoted as wrong-sign (WS), while combinatorial background candidates contribute equally to both RS and WS pairs. The raw yield is obtained from the invariant-mass distribution of RS pairs after subtracting the WS contribution. For the two hadronic decay channels the invariant mass can be reconstructed and it is shown and the signal is extracted via fits (middle and right panel of Fig. 1). The fit function was composed of a Gaussian for the description of the signal and a linear function for the background. The widths of the signal peaks were fixed to the value obtained from simulations to make the fits more stable. The widths of the signal peaks were observed to be compatible within the uncertainties between data and simulations.

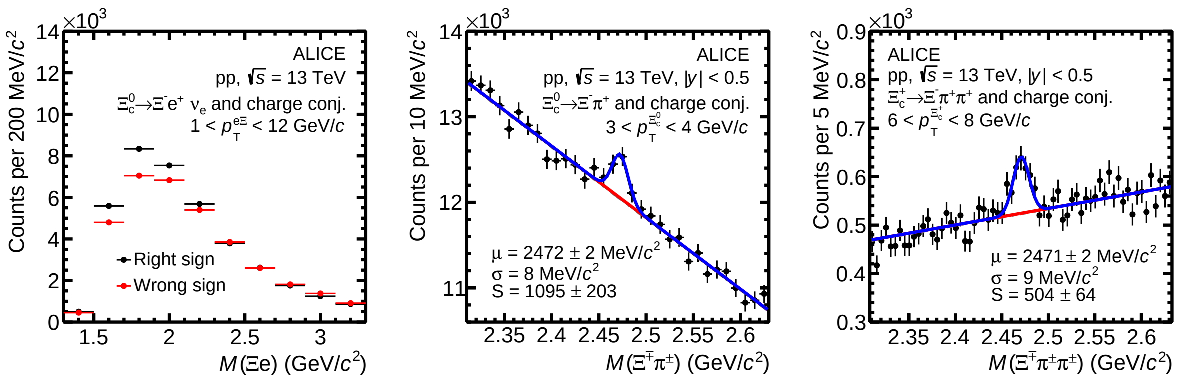

Fig. 1: Left panel: invariant-mass distributions of right-sign ($e^{\pm}\Xi^{\mp}$) and wrong-sign ($e^{\pm}\Xi^{\pm}$) pairs with $1 < p_T < 12$ GeV/c for the analysis of $\Xi_c^0 \to e^+\Xi^-\nu_e$. Middle and right panels: invariant-mass distributions of $\Xi_c^0 \to \pi^+\Xi^-$ and $\Xi_c^+ \to \pi^+\pi^+\Xi^-$ candidates and charge conjugates in $3 < p_T < 4$ GeV/c and $4 < p_T < 6$ GeV/c, respectively. The blue lines show the total fit functions and the red lines represent the combinatorial background.

The $p_T^{e\Xi}$-differential raw yield is corrected for the missing neutrino momentum to obtain the Ξ_c^0 raw yield in intervals of Ξ_c^0 p_T. The correction for the missing momentum of the neutrino is performed by using an unfolding technique with a response matrix which represents the correlation between the p_T of the Ξ_c^0 baryon and that of the reconstructed $e^+\Xi^-$ pair. The response matrix is determined through a simulation with the PYTHIA 8.2 event generator and the GEANT 3 transport code, including a realistic description of the detector conditions and alignment during the data taking period. The response matrix needs to be determined using a realistic Ξ_c^0-baryon p_T distribution which is not known a priori. Therefore, a two-step iterative procedure is adopted. In the first step, the response matrix is obtained with the p_T distribution generated with PYTHIA 8.2. This matrix is used to calculate a first estimate of the Ξ_c^0 p_T-differential spectrum from the measured p_T distribution of $e^+\Xi^-$ pairs. The Ξ_c^0 p_T distribution from this first iteration is used to reweight the response matrix, which is then used for the second iteration. The response matrix obtained from this procedure is shown in the left panel of Fig. 2, while the raw yield before and after the unfolding is applied is shown in the right panel of Fig. 2. The Bayesian unfolding technique implemented in the RooUnfold package is used. In this analysis the Bayesian procedure required three iterations to converge.

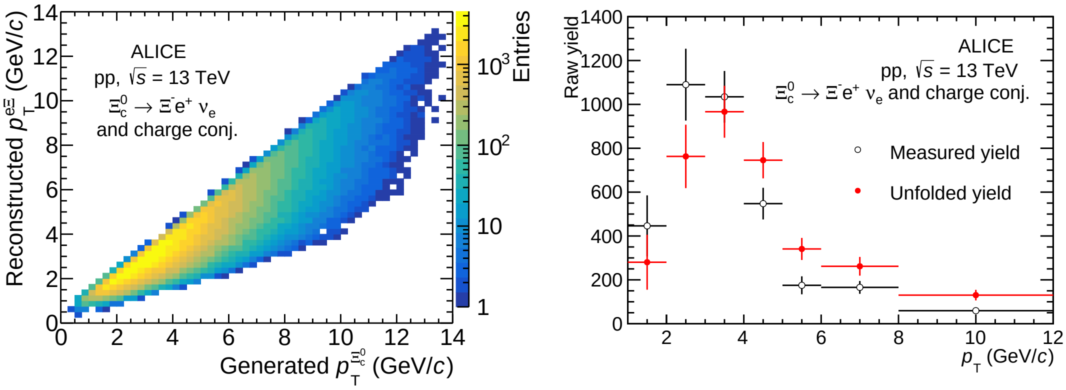

Fig. 2: Left panel: correlation matrix between the generated Ξ_c^0-baryon p_T and the reconstructed $e^+\Xi^-$ pair p_T. Right panel: The $p_T^{e\Xi}$-differential raw yield before (black open markers) and after (red solid markers) the unfolding is applied.

2 Prompt Ξ_c^0-baryon production cross section comparison

The measurement of the production cross section of prompt Ξ_c^0 baryons not corrected by the BRs in both the semileptonic and hadronic decays channels are shown in the upper panel of Fig. 3. The error bars and empty boxes represent the statistical and systematic uncertainties, respectively. The lower panel of Fig. 3 shows the p_T-dependent ratio of the two measurements and, as explained in [1], its weighted average was used to calculate the ratio $BR(\Xi_c^0 \to \Xi^- e^+ \nu_e)/BR(\Xi_c^0 \to \Xi^- \pi^+)$ with an improved precision by a factor of 3 with respect to the global average value reported by the PDG [2]. The average was calculated using as weights the sum in quadrature of the relative statistical and the p_T-uncorrelated part of the systematic uncertainties. The p_T-correlated systematic uncertainties were propagated by recomputing the average ratio after shifting up and down the p_T-dependent ratios by the corresponding p_T-correlated systematic uncertainty. The final systematic uncertainty on the ratio was obtained by summing in quadrature the p_T-correlated and uncorrelated systematic uncertainties.

The prompt Ξ_c^0-baryon cross section measurements in the two decay channels corrected with BR are shown in Fig. 4 and agree within the statistical uncertainties in the common p_T interval of the measurement. The results from the two decay channels were combined to obtain a more precise measurement of the prompt p_T-differential Ξ_c^0-baryon production cross section. The error bars and empty boxes represent the statistical and systematic uncertainties, respectively. The systematic uncertainties on the BRs and on the luminosity are not included in the boxes but their values are listed in the figures.

3 Acknowledgements

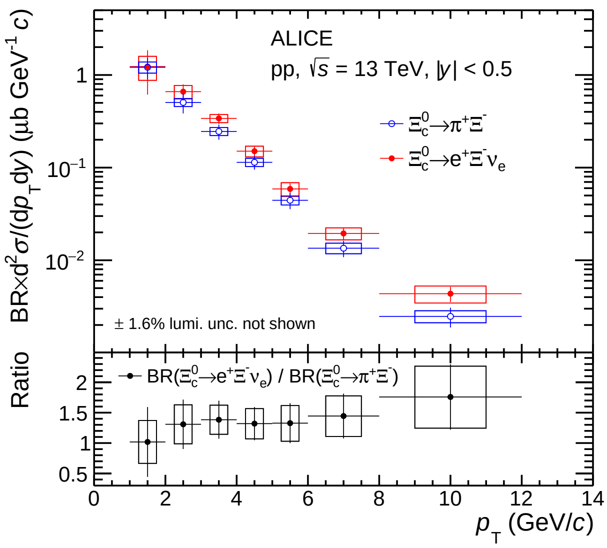

Fig. 3: Upper panel: BR $\times$ cross sections of prompt $\Xi_c^0 \to e^+\Xi^-\nu_e$ (full red circles) and $\Xi_c^0 \to \pi^+\Xi^-$ (open blue circles) as a function of the transverse momentum p_T. Lower panel: ratio of BR $\times$ cross sections of prompt $\Xi_c^0 \to e^+\Xi^-\nu_e$ and $\Xi_c^0 \to \pi^+\Xi^-$ as a function of p_T.

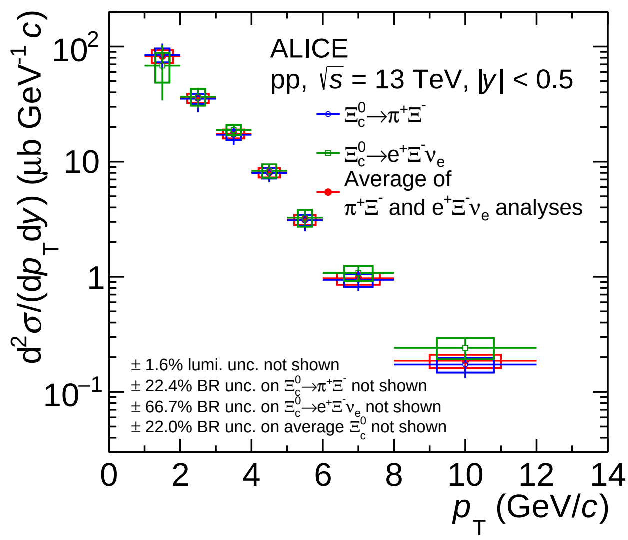

Fig. 4: Cross sections of prompt $\Xi_c^0 \to e^+\Xi^-\nu_e$ (empty green squares) and $\Xi_c^0 \to \pi^+\Xi^-$ (open blue circles) and the average of the cross section values (full red markers) as a function of the transverse momentum p_T.

A The ALICE Collaboration

References

[1] **ALICE** Collaboration, S. Acharya *et al.*, "Measurement of the production cross sections of Ξ_c^0 and Ξ_c^+ baryons and of the $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ ratio in pp collisions at $\sqrt{s}$ = 13 TeV", *in preparation,* **to be updated when submitted to the journal** .

[2] **Particle Data Group** Collaboration, P. Zyla *et al.*, "Review of Particle Physics", *PTEP* **2020** no. 8, (2020) 083C01.

[3] **Belle** Collaboration, Y. Li *et al.*, "First measurements of absolute branching fractions of the Ξ_c^+

baryon at Belle", *Phys. Rev. D* **100** (2019) 031101.