ALICE charming take on strangeness enhancement in pp collisions

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Abstract. Understanding strangeness enhancement in proton–proton (pp) collisions at the LHC is a challenge for hadronization models. Recent observations indicate that a substantial fraction of the detected Ω^- baryons may originate from the decay of charm baryons, e.g. from $\Omega_c^0 \to \Omega^- + \pi^+$. However, the Ω_c^0 production cross section, as well as branching ratios in different Ω_c^0 decay channels, are unknown, preventing an exact estimation of the contribution of baryons coming from charm-hadron decays. In this work, the first measurement of the fraction of Ω^- baryons originating from heavy hadron decays in pp collisions at $\sqrt{s}$ = 13.6 TeV, performed by the ALICE collaboration, is presented. This result is enabled by the new ALICE Inner Tracking System, which allows for the tracking of the Ω^- baryon prior to its decay. By studying the evolution of the fraction of Ω^- coming from heavy hadron decays and by comparing it with the existing models, the role of heavy hadron production as a driver of strangeness enhancement is explored.

1 Introduction

The enhanced strange-hadron production in heavy-ion collisions compared to pp collisions is historically linked to the formation of the Quark–Gluon Plasma (QGP) [1] and is characteristic of large collision systems such as lead–lead (Pb–Pb) collisions. More recently, it has also been observed in smaller, high-multiplicity systems, such as proton–lead (p–Pb) and proton–proton (pp) collisions, within the ALICE experiment [2, 3]. The measurement of the p_T-differential production cross section of inclusive Ω_c^0 baryons in pp collision [4] suggests that the enhanced production of Ω^- baryons originates from the decay of charmed hadrons, e.g. $\Omega_c^0 \to \Omega^- + X$. However, the lack of a measured absolute branching ratio for the Ω_c^0 prevents us from knowing with precision the production cross section of Ω_c^0, which is measured exclusively via the $\Omega_c^0 \to \Omega^-\pi^+$ channel, and extrapolated by employing the theoretical branching ratio of the decay, $BR(\Omega_c^0 \to \Omega^-\pi^+) = 0.51\%^{+2.19\%}_{-0.31\%}$ [4]. From these observations, it can be expected that the feed-down of Ω_c^0 into Ω^- is not negligible. The purpose of the work presented in this proceeding is to give a quantitative estimate of the feed-down of heavier baryons to the Ω^- production, in order to shed light on the phenomenon of the strangeness enhancement observed in high-multiplicity pp collisions. This study aims to distinguish the prompt Ω^- from the Ω^- originating from charm or beauty feed-down, analyzing data collected by ALICE in pp collisions at $\sqrt{s}$ =13.6 TeV during the LHC Run 3. The observable used to distinguish these fractions is the Distance of Closest Approach (*DCA*) of the strange

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baryon to the primary vertex. The upgraded ALICE Inner Tracking System (ITS2) for Run 3 of the LHC features three inner layers within the first four centimeters from the interaction point [5]. This enables the detection of weakly decaying baryons before their decay, by means of the novel strangeness tracking algorithm.

2 The strangeness tracking algorithm

The strangeness tracking algorithm is a novel method introduced during the LHC Run 3, which exploits the proximity of the first ITS2 layers to the interaction point to directly track charged strange particles before their decay. The Ω^- baryons have a mean proper decay length $c\tau$ of approximately 2.5 cm, and due to the relativistic boost, they can traverse multiple ITS2 layers before decaying. Therefore, the Ω^- track (mother track) in the innermost layers of the ITS2 can be reconstructed from the hits left by the incident particle. The charged decay daughters of the Ω^- are tracked and identified by using the ITS2 and the Time Projection Chamber (TPC). Finally, a matching algorithm connects the mother track with the reconstructed topology of the daughters. Thanks to this algorithm, the *DCA* resolution of the Ω^- baryon is improved by one order of magnitude with respect to the measurement performed by only reconstructing the Ω^- daughters, reaching values comparable to those obtained for the charm baryons $c\tau$, which is on the order of 50-100 μm. The difference in resolution obtained with and without the application of the strangeness tracking algorithm can be observed in Fig. 1. Moreover, a substantial reduction of the combinatorial background under the Ω^- signal is observed. The data purity (signal over signal plus background) exceeds 99% at low transverse momentum and 97% at high transverse momentum.

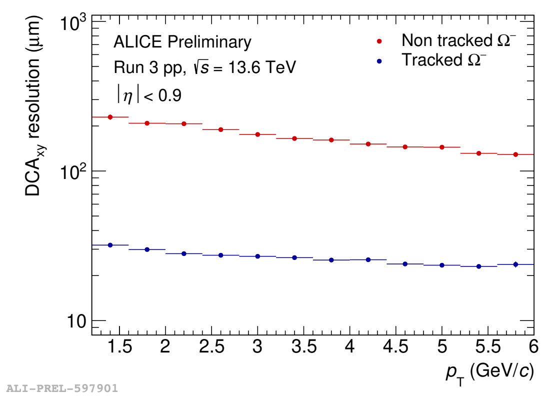

Figure 1. DCA_{xy} resolution of Ω^- baryons with (blue) and without (red) the application of the strangeness tracking algorithm. The resolution is obtained as σ of the Gaussian fit to the central region of the *DCA* distribution, between -0.02 and 0.02 cm.

3 Measurement of the prompt Ω^- fraction

The goal of this analysis is to separate the prompt Ω^- component from the ones originating from feed-down of charm and beauty heavier baryons, by looking at the *DCA* of the Ω^- tracks to the primary vertex, both in the longitudinal direction (z) and in the transverse plane (xy). Data are fitted with a Monte Carlo (MC) model, built taking into account all components contributing to Ω^- production, as well as the combinatorial background. The templates for each component are derived from dedicated MC simulations, and their characteristic shapes are studied in different transverse momentum (p_T) intervals. An additional smearing is applied to the MC distributions to account for possible residual imperfections in the resolution description in the MC simulations. The probability density functions (PDFs) for the different MC components have been combined to build the total MC model as summarized in Eq. 1:

$$g(DCA) = n_{BG} \cdot g_{BG}(DCA) + n_P \cdot g_P(DCA) + n_c \cdot g_c(DCA) + n_b \cdot g_b(DCA) \tag{1}$$

where $g(DCA)$ represents the PDF of the total MC model, g_{BG}, g_p, g_c, g_b represent respectively the PDFs for the background, the primary component, the component from charm decays, and the component from beauty decays, and n_{BG}, n_p, n_c, n_b represent the scaling factors for the respective PDFs. The MC model has been built for each p_T interval used for the data, from 1.2 GeV/c to 6 GeV/c, in steps of 400 MeV/c.
The model built in Eq. 1 is used to fit DCA_{xy} and DCA_z data. The fit is done simultaneously in both the xy plane and the z direction, to directly obtain the fraction of prompt Ω^-. Figure 2 shows the fits of the model to data, for both the DCA_{xy} and the DCA_z, for a p_T interval between 1.6 GeV/c and 2.0 GeV/c.

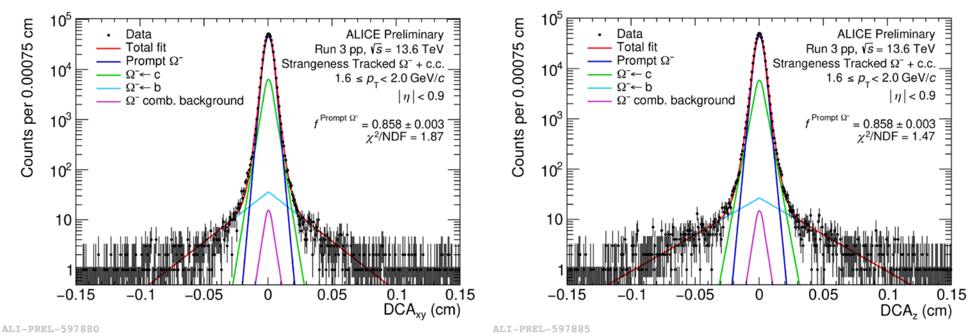

Figure 2. Fit of the MC model to data, for the DCA_{xy} (left) and for the DCA_z (right) in the p_T interval between 1.6 GeV/c and 2.0 GeV/c. The colored lines correspond to the different components composing the MC model, as indicated in the legend. The red line represents the total MC model, which is fitted to the data. The fraction of prompt Ω^- ($f^{\text{Prompt }\Omega^-}$) is directly obtained from the fit.

Figure 3 shows the prompt Ω^- fraction extrapolated with this method, as a function of p_T. The systematic uncertainties have been evaluated by considering several different sources. The most significant contribution comes from the modified templates for $\Omega^- \leftarrow c$, accounting for possible variations of the branching ratios and decay modes of the decay channels involving the Ω^- production. This uncertainty was included due to the unknown absolute branching ratios of the Ω_c^0. Additional minor contributions come from modifications to the MC template function, variations in the DCA resolution assumed in MC, and the fitting procedure. Despite the large systematic uncertainties, from this figure emerges that there might be a non-negligible fraction of Ω^- originating from feed-down at low p_T. The results are compared with two different PYTHIA 8 models. The Monash tune [6] (orange band) exhibits almost no feed-down, while the Colour Ropes model [7] (red band) predicts a significant feed-down but with a different trend with respect to what is observed with this study.

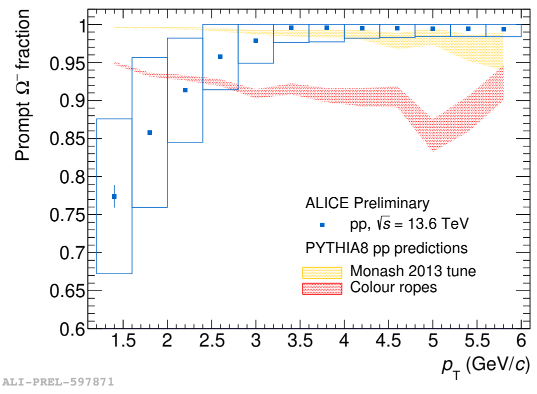

Figure 3. Fraction of prompt Ω^- baryons as a function of p_{T}. The blue vertical lines at each point represent the statistical errors, while the blue square represents the systematic uncertainty. The result is compared with the PYTHIA8 pp predictions derived using the Monash 2013 tune [6] and Colour ropes [7] models.

4 Conclusions

The investigation of the feed-down from charm and beauty hadrons to the Ω^- production is a key element for understanding the phenomenon of strangeness enhancement in high-multiplicity pp collisions. The approach used in this work was to distinguish the different contributions to the Ω^- production by studying its *DCA* to the primary vertex. The measurement suggests that the fraction of the Ω^- from heavy-flavor baryon decays might be of the order of about 20% at low p_{T}. This indicates that feed-down from heavy hadrons may represent a non-negligible contribution to the observed strangeness enhancement. However, the unknown decay modes of the Ω_c^0 prevent us from establishing this fraction with a small uncertainty. Further efforts are ongoing to perform this study as a function of the multiplicity, to investigate the role of feed-down from charm decays in the strangeness enhancement observed in high-multiplicity pp collisions.

References

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