Measurement of Collective Flow in Charm Strange Meson

CMS Collaboration[1]

The transverse momentum (p_T) spectra of inclusively produced Λ_c^+ baryons are measured via the exclusive decay channel $\Lambda_c^+ \longrightarrow pK^-\pi^+$, utilizing the CMS detector at the LHC. These measurements are performed as a function of p_T in both proton-proton (pp) and lead-lead (PbPb) collisions at a nucleon-nucleon center-of-mass energy of 5.02 TeV. The study is carried out in the rapidity interval $|y| < 1$, covering the p_T range of 5–20 GeV/c for pp collisions and 10–20 GeV/c for PbPb collisions. In the p_T region of 10–20 GeV/c, the Λ_c^+ baryon yield is found to be suppressed in central PbPb collisions compared to scaled pp collisions, based on the number of nucleon-nucleon (NN) interactions. Additionally, the Λ_c^+/D^0 production ratio in pp collisions is compared to theoretical predictions. In PbPb collisions, this ratio remains consistent with the pp results within the shared p_T range, highlighting a key similarity between the two collision systems.

1. Introduction

Heavy-quark production is essential for understanding parton energy loss and thermalization in the quark-gluon plasma (QGP) produced in heavy-ion collisions. Due to their larger mass, heavy quarks undergo distinct energy loss mechanisms, influencing their interactions with the QGP [1]. Hadronization occurs through both fragmentation, as in proton-proton (pp) collisions, and coalescence, where partons recombine within the QGP or at the phase boundary [2]. Fragmentation dominates at high transverse momentum ($p_T > 6$ GeV/c), while in the intermediate range ($2 < p_T < 6$ GeV/c), an enhanced baryon-to-meson ratio suggests increased coalescence in central collisions [3].

Elliptic flow studies at RHIC show that the second Fourier component of the azimuthal distribution scales with the number of constituent quarks for 2–5 GeV/c, consistent with coalescence. Charmonium and open charm measurements at RHIC and LHC confirm coalescence's role in charm quark hadronization [4]. The nuclear modification factor (R_{AA}) compares heavy-ion and pp collision yields. At RHIC, R_{AA} for J/ψ mesons ($p_T \leq 7$ GeV/c) decreases in central AuAu collisions, while at the LHC, weaker centrality dependence indicates more coalescence in PbPb collisions.

For D^0 mesons in AuAu collisions, R_{AA} rises up to 1.5 GeV/c and decreases from 2–6 GeV/c, consistent with coalescence models. At the LHC, D^0 R_{AA} and anisotropy agree with coalescence predictions, suggesting more baryon production via coalescence than for mesons, with enhanced Λ_c^+/D^0 ratios at higher p_T [5].

Recent Λ_c^+ measurements by ALICE and LHCb at $\sqrt{s} = 7$ TeV align with theoretical models, with ALICE reporting higher Λ_c^+/D^0 ratios, especially in PbPb collisions.

This letter presents inclusive Λ_c^+ production in pp and PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV from CMS data (2015). Λ_c^+ baryons are reconstructed in the central region ($|y| < 1$) via $\Lambda_c^+ \to pK^-\pi^+$. The Λ_c^+/D^0 ratio is measured in pp (5–20 GeV/c) and PbPb (10–20 GeV/c), with R_{AA} shown for three centrality intervals: 0–100%, 0–30%, and 30–100%.

2. Analysis Details

The candidates for the decay $\Lambda_c^+ \to pK^-\pi^+$ are reconstructed by selecting three charged tracks that satisfy the following criteria: pseudorapidity within $|\eta| < 1.2$ and a net charge of +1. The transverse momentum p_T of each track must exceed $0.7\,\mathrm{GeV}/c$ for proton-proton events, and $1.0\,\mathrm{GeV}/c$ for lead-lead events. During the invariant mass reconstruction, both mass assignments for the same-sign tracks are considered, with the kaon mass assigned to the opposite-sign track.

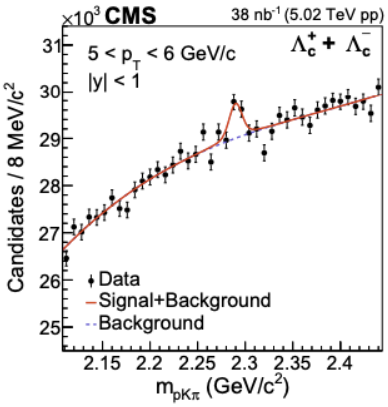

FIG. 1: Invariant mass distribution of Λ_c^+ candidates with a transverse momentum of $p_T = 5\,\mathrm{GeV}/c$ to $6\,\mathrm{GeV}/c$. This distribution is analyzed to identify the signal and understand the background contributions. It is constructed by selecting events that meet the necessary criteria for the reconstruction of the decay channel $\Lambda_c^+ \to pK^-\pi^+$.

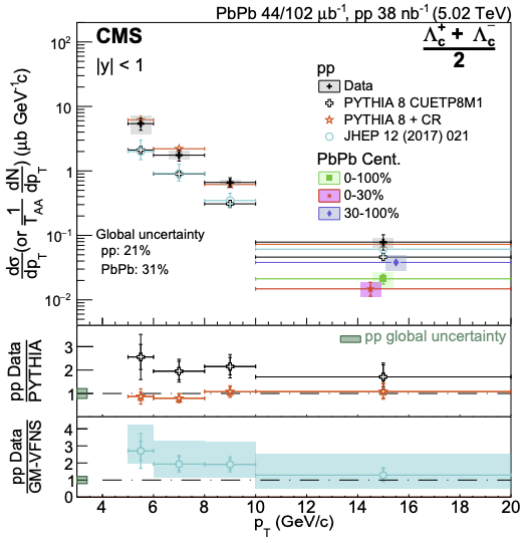

FIG. 2: The p_T-differential cross sections for inclusive Λ_c^+ production in collisions and the T_{AA}-scaled yields for three centrality regions of collisions. The boxes and error bars represent systematic and statistical uncertainties, respectively. Image adapted from Ref.[6].

3. Result and Discussion

The p_T-differential cross sections for Λ_c^+ in pp collisions are observed to be significantly lower in central PbPb collisions, reflecting the effect of the dense medium produced in heavy-ion collisions. The nuclear modification factor R_{AA} provides insight into the suppression of heavy flavor production in the QGP, highlighting the competition between energy loss mechanisms and the initial charm quark distribution in heavy-ion collisions.

As shown in Fig.2, the p_T-differential cross sections exhibit a clear dependence on centrality, with more significant suppression in the most central collisions. Furthermore, the Λ_c^+/D^0 production ratio remains consistent with the trend observed in previous studies, reinforcing the understanding of heavy quark dynamics in the context of heavy-ion collisions.

4. Conclusion

In summary, the measurement of Λ_c^+ baryons provides valuable insights into heavy flavor production in heavy-ion collisions. The observed suppression in central PbPb collisions supports coalescence models and highlights the QGP's role in altering heavy quark hadronization. These results improve our understanding of charm quark dynamics and their interactions with the medium, offering a foundation for future studies on heavy flavor production in the context of QGP formation.

References

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