CERN Summer Studentship 2021 – Report

August 2021

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Project title: —Measurement of the Ξ_c^0 mass—

Abstract: I report on my activities at CERN during the course of my Summer Studentship. My project focused on the Measurement of the Ξ_c^0 mass, and was concluded by the observation of the best precision of the measurement of the mass of the Ξ_c^0.

Introduction

Baryons are heavy subatomic particles that are made up of three quarks. Both protons and neutrons, as well as other particles, are baryons. (The other class of hadronic particle is built from a quark and an antiquark and is called a meson). The final states that we are studying are a protons, two kaons and a pion. And there are two baryons which decay into the same final states. The two baryons are called Ξ_c^0 which is made of a charm quark, strange quark and a down quark while the Ω_c^0 is made of charm quark and two strange quark.

But my project will focus on the measurement of the mass of Ξ_c^0 which has a decay mode of $\Xi_c^0 \to pK^-K^-\pi^+$ and a quark content of csd and have a $J^P = \frac{1}{2}^+$. The latest value of this mass is known to be $m_{\Xi_c} = 2470.44 \pm 0.28 MeV$.

Theorical aspects

Charmed baryons are a category of composite particles comprising all baryons with at least one unit of charm (quantum number). In quark model terms, charmed baryons consist of three quarks, one or more of which is a charm quark. These particles were first observed in the 1970s; since then, a large number of distinct charmed bayron states have been identified. The important parameters of charmed baryons, to be studied, consist of three properties. They are firstly the mass, secondly the lifetime for those with a measurable lifetime, and lastly their decay modes.

The discovery of hidden charm in 1974 and naked charm in 1976 opened a new era in hadron spectroscopy [1, 2]. All new heavy mesons and baryons [3] have been described simply by adding a new quark, c, to the series of the constituents d, u and s, thus reinforcing the quark model. Just as for the light mesons and baryons, approximate flavor $SU(3)$ symmetry of the light quarks–the u, d, and s – is expected to relate matrix elements of charmed baryons belonging to the same multiplet, up to corrections of order $(m_s - m_d)\,\Lambda_{QCD}$ 20%. The charmed Ξ_c^0 baryon was discovered in 1989 by the CLEO collaboration[2], who measured a peak in the decay mode of $\Xi^-\pi^+$ with a mass of $2471 \pm 5 MeV/c^2$. And the observation of the $pK^-K^-\pi^+$ final state was made in 1990 by the ACCMOR Collaboration[4], who observed four $\Xi_c^0 \to pK^-\bar{K}^*(892)^0$ decays; but there was no information on their rate.

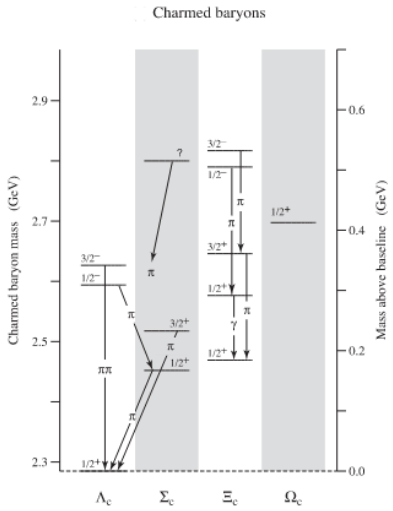

Figure 1: Charmed baryons and some of their orbital excitations [5]

A measurement of the lifetimes of the Ξ_c^0 baryons is reported using proton-proton collision data at a centre-of-mass energy of $13TeV$, corresponding to an integrated luminosity of $5.4fb^{-1}$ collected by the LHCb experiment. The Ξ_c^0 baryons are produced directly from proton interactions and reconstructed in the $pK^-K^-\pi^+$ final state. The Ξ_c^0 lifetime is measured to be $148.0 \pm 2.3 \pm 2.2 \pm 0.2fs$, where the first uncertainty is statistical, the second systematic, and the third due to the uncertainty on the D^0 lifetime. These results confirm previous LHCb measurements based on semileptonic beauty-hadron decays.

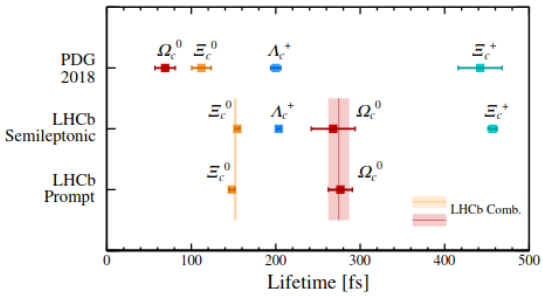

Figure 2: llustration of the LHCb measurements of the Ω_c^0 and Ξ_c^0 lifetimes obtained from semileptonic beauty-hadron decays and prompt signals, and the previous 2018 world average. The combined LHCb results are shown in coloured bands.

Project work

Candidates for the $\Xi_c^0 \to pK^-K^-\pi^+$ decay are reconstructed by combining one proton candidate, two kaon candidates, and a pion candidate. We have used the Particle IDentification(PID) variable corresponding to the particles, to find the candidates.

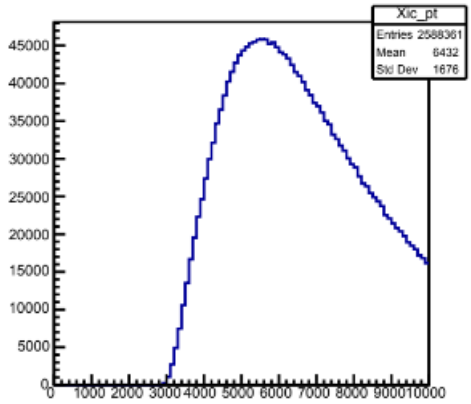

Figure 3: The cascade baryon transverse momemtum

I have removed the background from the signal using the data of the baryon Ξ_c^0. The $m\left(pK^-K^-\pi^+\right)$ is the invariant mass of the decay products of the baryon cascade, which is defined by the portion of the total mass which is independent of the overall motion of the system.

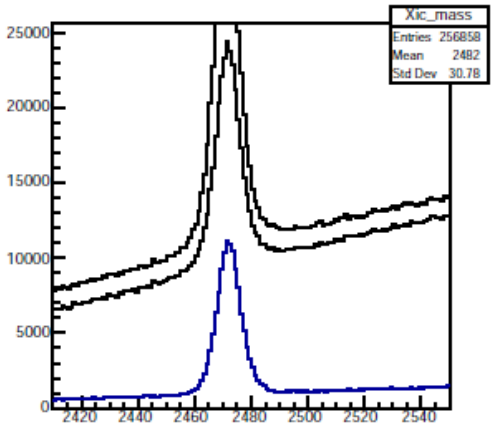

Figure 4: The Ξ_c^0 mass with the PID (blue) and the mass with the probabilities of the candidates less than 0.9 (black)

The data are fit to the polynomial for the background and the double-gaussian for the signal.

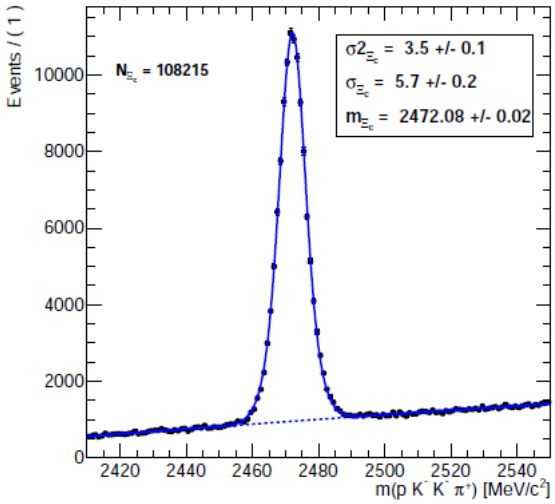

Figure 5: The baryon Ξ_c^0 mass with a gaussian mean of $\sigma = \pm 0.02$ after applying the PID cuts and fitting with a gaussian function and a flat background

Conclusion

I was able to reconstruct the $N_{\Xi_c} = 108215$ candidates and I was able to provide a measurement of the Ξ_c^0 mass with a gaussian mean of $\sigma = \pm 0.02 MeV$, which is the resolution of the value. We have noticed that the precision of the measurement of the Ξ_c^0 mass is much better than the latest value of this mass. We have obtained a more precised measurement : $m_{\Xi_c} = 2472.08 \pm 0.02 MeV$ compared to $m_{\Xi_c} = 2470.44 \pm 0.28 MeV$.

Skills
This project required reading theoretical, basis of the quark model and the baryons, and analyzing data. The ROOT and C++ were extensively used.

The CERN Summer Studentship

Even though this CERN summer student 2021 is fully online due to the COVID-19 pandemic, I have had the opportunity to attend a series of lec-

tures given by world-leading researchers, in both theoretical and experimental particle physics. I also have the chance to better recognize the lhcb experiment.

Acknowledgments

I would like to warmly thank my supervisor, Marco Pappagallo, I owe him all my gratitude for his patience, his availability and especially his help. I would also like to express my gratitude to the LHCb collaboration for accepting my application for this scholarship.

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