MEASUREMENT OF $\Lambda^0 - \overline{\Lambda^0}$ MASS DIFFERENCE

K. RYBICKI

Institute of Nuclear Physics
Kawiory 26a, PL-30 055 Cracow, Poland

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We measure the masses of of Λ^0 and $\overline{\Lambda^0}$ hyperons using a very clean sample of 30844 hyperons produced in 230 GeV/c π^-– Cu interactions and decaying in a silicon vertex detector. Systematic errors were estimated by using K_s^0 decays registered in the same vertex detector. For the average $\Lambda^0/\overline{\Lambda^0}$ mass we obtain $(1115.766 \pm 0.006 \pm 0.042)$ MeV/c^2. The mass difference $M_\Lambda - M_{\overline{\Lambda}} = (0.015 \pm 0.013)$ MeV/c^2 averaged with the E766 result of (-0.012 ± 0.010) MeV/c^2 yields (-0.002 ± 0.008) MeV/c^2. This confirms the CPT invariance within the accuracy of 7×10^{-6}.

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1. Introduction

In a recent paper [1] the E766 collaboration at the Brookhaven AGS reported the most precise mass measurement of the Λ^0 and $\overline{\Lambda^0}$ hyperons, namely $M_\Lambda = (1115.678 \pm 0.006 \pm 0.006)$ MeV/c^2 and $M_{\overline{\Lambda}} = (1115.690 \pm 0.008 \pm 0.006)$ MeV/c^2. These values, based on 20138 Λ^0's and 18309 $\overline{\Lambda^0}$'s, yield the mass difference $M_\Lambda - M_{\overline{\Lambda}} = (-0.012 \pm 0.010)$ MeV/c^2. This result, representing an improvement by a factor of more than 10 over the previous world average [2], confirmed the CPT invariance to 1 part in 10^5 as far as the $\Lambda^0 - \overline{\Lambda^0}$ system is concerned.

Under the impact of these results we have performed a similar analysis in our old data. We mean here a somewhat smaller sample of 17786 Λ^0's and 13058 $\overline{\Lambda^0}$'s collected by the ACCMOR collaboration in the NA32 experiment as a byproduct of the charm search. This sample of decays in the silicon vertex detector was used for a study of the $\Lambda^0/\overline{\Lambda^0}$ polarization [3] in π^--induced reactions. Here we use it for the "second best" result on the masses.

The paper is organized as follows: In Section 2 we briefly review the ACCMOR experiment and data processing. The results on mass fits are shown in Section 3 and discussed in Section 4.

2. The experiment and data analysis

The data used in this study come from the second phase of the NA32 experiment, dedicated to the charm search, which was performed at the CERN SPS using a negative 230 GeV/c beam (96% pions and 4% kaons) and a 2.5 mm Cu target. Charm decays were reconstructed with a silicon vertex detector and a large-acceptance spectrometer. The latter consisted of two magnets, 48 planes of drift chambers and three multicellular Cherenkov counters allowing pion, kaon and proton identification in the momentum range $(4 \div 80)$ GeV/c. The vertex detector consisted of a beam telescope with seven microstrip planes and a vertex telescope with two charge-coupled devices (CCDs) and eight microstrip planes. The overall precision of our vertex detector allowed a purely topological charm search, which was restricted neither to a limited number of decay modes nor to any mass window.

Event reconstruction is done in several steps (see Ref. [4] for more details). First, all tracks are reconstructed in the drift chambers and particle identification is performed. Independently, the beam track and the secondary tracks are reconstructed in the beam and vertex telescopes, respectively. Then, tracks found in the drift chambers and in the vertex telescope are matched. Finally, the reconstruction of the primary vertex is performed. We only accept events with the primary vertex inside the target and at least two tracks not originating from the vertex. These tracks are then used as a seed for the search for one or more secondary vertices. The vertices should be between the target and the first microstrip plane (65mm from the target). In addition we require the vector sum of the momenta of all particles originating from the secondary vertex to pass through the primary one. This procedure has yielded about 1200 fully reconstructed decays of charmed particles (see *e.g.* Ref. [5]) and tens of thousands of decays of neutral strange particles. Namely, we have found 31147 $\Lambda^0/\overline{\Lambda^0}$ ($p-\pi$ effective mass between 1110.5 MeV/c^2 and 1120.5 MeV/c^2) decay vertices in the silicon detector. There are more $\Lambda^0/\overline{\Lambda^0}$'s decaying downstream in the remaining part of the apparatus but our V^0 reconstruction program in the large-angle spectrometer was found to have a rather large (∼25%) and badly known inefficiency. Consequently, we restrict our study to $\Lambda^0/\overline{\Lambda^0}$ decaying in the vertex detector, which was thoroughly tested in the charm search and for which the reconstruction efficiency is well under control. In addition, the angles of decay products are measured with high precision in the vertex detector. This is very important for the hyperon mass measurement.

Among the events selected there were 303 decays interpreted as reflections from the $K^0_s \to \pi^+\pi^-$ decay because:

- for the "proton" track the Cherenkov information yields the pion probability equal to at least half of the proton probability,

- the $\pi^+\pi^-$ mass was within the interval of $(492.7 \div 504.7)$ MeV/c^2.

Removing this reflection we are left with 30844 events. For the $\Lambda^0/\overline{\Lambda^0}$ polarization study [3] we have performed fairly elaborated acceptance calculations but we do not describe them here since they are not needed for the purpose of this investigation .

3. Results

It should be noted that calculating the effective mass M we have used the latest values of proton ($M_p = 938.27231$ MeV/c^2) and of charged pion ($M_{\pi^\pm} = 139.56995$ MeV/c^2) masses from the Review of Particle Properties [6].

In order to determine the hyperon masses we have fitted the Λ^0, $\overline{\Lambda^0}$ and the combined $\Lambda^0/\overline{\Lambda^0}$ mass distributions assuming a Gaussian plus a polynomial background in $(M - M_{\text{thr}})$, where $M_{\text{thr}} = M_p + M_{\pi^-}$. We have found that:

- the fits are generally good with a χ^2 close to 100 for 100 degrees of freedom,
- the results on hyperon masses are hardly sensitive to the exact form of the background; in fact an inspection of the error matrix shows the correlations between the mass and the remaining fit parameters are very weak,
- the results are practically independent of the bin size in the range between 0.05 MeV/c^2 and 0.15 MeV/c^2; we have finally used the value of $\Delta M = 0.10$ MeV/c^2, which yielded the smallest errors,
- the width of mass distribution is about 0.9 MeV/c^2, consistent with our resolution,
- our $\Lambda^0/\overline{\Lambda^0}$ mass of (1115.856 ± 0.006) MeV/c^2 is significantly higher than (1115.684 ± 0.006) MeV/c^2 measured by the E766 collaboration.

We attribute this difference to a slight overestimation of our magnetic field. This is confirmed by an observation that a similar fit to K_s^0 decays observed in the same detector yields $M_{K^0} = (497.97 \pm 0.06)$ MeV/c^2, significantly above the RPP [6] value of $M_{K^0} = (497.67 \pm 0.03)$ MeV/c^2. Following the E766 [1] procedure we have used our K_s^0 sample for calibration. After a reduction of our magnetic field by 0.18% the K_s^0 mass is brought down to $M_{K^0} = (497.66 \pm 0.11)$ MeV/c^2. The values of hyperon masses calculated before and after this correction are shown in Table I. A systematic error of 0.042 MeV/c^2 of all the masses in the second column of Table I is dominated by the statistical error of our K_s^0 sample.

TABLE I

Results of fits to hyperon masses

Mass [MeV/c^2]	This work (raw)	This work (corrected)	E766 [1]
Λ^0	1115.857 ± 0.008	$1115.773 \pm 0.008 \pm 0.042$	$1115.678 \pm 0.006 \pm 0.006$
$\overline{\Lambda^0}$	1115.846 ± 0.010	$1115.758 \pm 0.010 \pm 0.042$	$1115.690 \pm 0.008 \pm 0.006$
$\Lambda^0/\overline{\Lambda^0}$	1115.853 ± 0.006	$1115.766 \pm 0.006 \pm 0.042$	1115.684 ± 0.006 [6]
$\Lambda - \overline{\Lambda}$	0.011 ± 0.013	0.015 ± 0.013	-0.012 ± 0.010

4. Discussion of results

It is seen that even after the correction based on the "K^0_s calibration" our average mass of $\Lambda^0/\overline{\Lambda^0}$ hyperons *i.e.* $(1115.766 \pm 0.006 \pm 0.042)$ MeV/c^2 remains slightly higher than the value of $M_{\Lambda/\overline{\Lambda}} = (1115.684 \pm 0.006)$ MeV/c^2 calculated by the PDG [6] from the E766 results. However the difference is less than two standard deviations. The reason for the greater systematic error in our case is the much smaller sample of the K^0_s's.

The mass difference $M_\Lambda - M_{\overline{\Lambda}}$ suffers much less from the above uncertainty and is of comparable accuracy to the E766 result. It is interesting to note that the fluctuations went in opposite directions in the two experiments. The difference is again less than two standard deviations. The average value of $M_\Lambda - M_{\overline{\Lambda}} = (-0.002 \pm 0.008)$ MeV/c^2 confirms the CPT invariance within the accuracy of 7×10^{-6}.

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