OBSERVATION OF A NARROW STATE AT 2.46 GeV/c^2 - A CANDIDATE FOR THE CHARMED STRANGE BARYON A^+

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ABSTRACT : In an experiment at the CERN SPS hyperon beam a narrow state has been observed in the reaction $\Sigma^- + \text{Be} \rightarrow (\Lambda K^- \pi^+ \pi^+) + X$. The effective mass distribution shows an excess of 82 ± 16 events at 2.46 GeV/c^2. The positive charge of the observed final state, which has strangeness -2, suggests the interpretation as a Cabibbo favoured decay of the charmed strange baryon, A^+ (quark content {csu}). The cross section times branching ratio is measured to be $\sigma \cdot B = (5.3 \pm 2.0)$ μb/(Be nucleus) for $x > 0.6$. The invariant production cross section is described by

$$E \frac{d^3\sigma}{d\vec{p}^3} \propto (1-x)^{(1.7 \pm 0.7)} \; e^{-(1.1^{+0.7}_{-0.4}) p_T^2}$$

The production of the charmed baryon Λ_c^+ in nucleon-nucleon interaction has been observed in several experiments at the CERN ISR1). The same mechanism should allow to produce charmed strange baryons in hyperon-nucleon interactions, i.e. using baryon projectiles which contain already a strange quark.

I will present first results of a search for charmed strange baryons produced by incident Σ^-. Such particles will have zero or positive charge and the Cabibbo favoured decay will result in final states with strangeness -2.

In the experiment described here, we have only studied final states which involved both a Λ and a K^-. This choice had the advantage that the K^- and the proton from the $\Lambda \to p\pi^-$ decay could be identified by Cerenkov counters and therefore selected on the trigger level.

A schematic view of the apparatus is shown in Fig. 1 . The hyperon beam was tuned to its maximum momentum of 135 GeV/c and at this setting the DISC selected 2×10^4 incident Σ^- in each beam pulse containing a total of $1.5 \times 10^6 \pi^-$. The experimental target was a 8 cm long beryllium rod, The incident Σ^-were tracked in multiwire proportional chambers (MWPC) and the charged reaction products were measures in a magnetic spectrometer equipped with MWPCs and drift chambers. Two multicell threshold gas Cerenkov counters C1 and C2 allowed to separate protons, kaons and pions. The cell structure of these Cerenkov counters was matched by two scintillator hodoscopes H4 and H5. The additional deflection of the second magnet SM2 separated positive and negative charged particles at the position of H4.

The trigger was designed to select final states of the type $(\Lambda K^-\pi^+)$ + anything, therefore at least two charged particles coming from the target were required in hodoscope H1. In addition the decay $\Lambda \to p\pi^-$ had to occur before H2, thus at least four particles were required in H2 and H3. A K^- candidate had to pass through the negative-particle region of H4 without being counted in the corresponding cell of C1, $(\overline{C1}_i \times H4_i)$. A proton candidate had to fulfill the condition $(\overline{C2}_j \times H5_j)$ in the positive-particle region of C2. About 1.5% of the Σ^- fulfilled these trigger requirements and in 20 days interactions corresponding to 10^9 incident Σ^- were recorded.

In this talk only the analysis of the $(\Lambda K^-\pi^+\pi^+)$ channel will be described. Other final states are still under study.

The Λ were identified through their $p\pi^-$ decays. The reconstructed decay vertex was required to be between the target and H2 and the $(p\pi^-)$ effective mass had to be within ±4 MeV/c^2 of the Λ mass.

The identification of the K^- was made by the combined use of C1 and C2. The Cerenkov counter C1 had a pion threshold of 14 GeV/c and reached its maximum efficiency of 97% at a pion momentum of 30 GeV/c. In order to reject pions a momentum cut at 17 GeV/c was applied to the K^- candidates. At this momentum, the efficiency of C1 for detecting pions was 68%. To reduce further the pion contamination the additional condition $(\overline{C2}_j \times H5_j)$ was imposed for tracks with momenta below the K^- threshold of 36 GeV/c.

Particles which were not identified as K^- or as Λ decay products were taken to be pions. A positive Cerenkov identification for these particles was not possible, as more than 90% of them had momenta less than 17 GeV/c or did not pass through SM2.

The $(\Lambda K^-\pi^+\pi^+)$ effective mass distribution is shown in Fig. 2a. There is a prominent narrow peak which is contained in two bins of 15 MeV/c^2 centred at 2460 MeV/c^2. The smooth curve in Fig. 2a shows the background under the peak obtained by fitting a polynomial of the order 3 to the mass range from 2100 to 3090 MeV/c^2 excluding the two channels of the signal. Other background shapes have been studied, for example those obtained by mixing Λ, K^-, π^+ from different events, or by requiring a negative charged pion in place of one of the positive ones. All methods gave compatible results of 147 ± 5 events. Thus the signal contains 82 ± 16 events.

We have checked that the signal is not a reflection of a misidentified strangeness -1 state by assigning the π^- mass to the K^- candidate (Fig. 2b) and also by assigning the K^+ mass to one of the positive pions (Fig. 2c). In both cases no significant peak is seen.

The invariant cross section was parametrized as

$$E \frac{d^3\sigma}{d\vec{p}^{\,3}} \propto (1-x)^n \cdot e^{-bp_T^2}, \text{ where } x = p_L^{cm} / p_{max}^{cm}$$

and Monte Carlo (MC) simulations for several values for n and b were performed. From the comparison of data and the MC we conclude $n = 1.7 \pm 0.7$ and $b = (1.1^{+0.7}_{-0.4})$ $(\mathrm{GeV}/c)^{-2}$. Due to the very small acceptance at low values of p_L we have calculated the cross section times branching ratio $(\sigma \cdot B)$ only for $p_L > 82$ GeV/c, i.e. $x > 0.6$. On the basis of 63 events above this limit we get

$$\sigma \cdot B = (5.3 \pm 2.0)\ \mu\mathrm{b/Be\ nucleus}\ (x > 0.6)$$

The extrapolation of this value over the region $x > 0$ and for a single nucleon will depend very much on the assumptions made. As an example we calculated $\sigma \cdot B$ for $x > 0$ under the hypothesis that the $(1 - x)^{1.7}$ description is valid over the whole range $x > 0$ and the dependence on the atomic number A is linear. We then get $\sigma \cdot B = 12.7$ μb/nucleon. If instead we assume an $A^{2/3}$ dependence the result is $\sigma \cdot B = 26.4$ μb/nucleon. As also the x behaviour is unknown for $x < 0.6$ these numbers can only indicate an order of magnitude.

The observed final state has baryon number +1, charge + 1 and strangeness

−2. Such a state cannot be produced in the strong decay of a particle constructed from 3 quarks of the flavours up, down and strange. Only multiquark baryons composed of at least five quarks could decay strongly into a channel with these quantum numbers. In view of the narrow width of the observed signal we therefore suggest its interpretation as the Cabibbo favoured weak decay of the charmed strange baryon A^+, which contains an up, a strange and a charmed quark. The mass of this particle is expected to be approximately 200 MeV/c^2 above that of the Λ_c, leading to a mass of approximately 2.5 GeV/c^2 which is compatible with the observed mass of 2.46 GeV/c^2.

For more details see [2,3])

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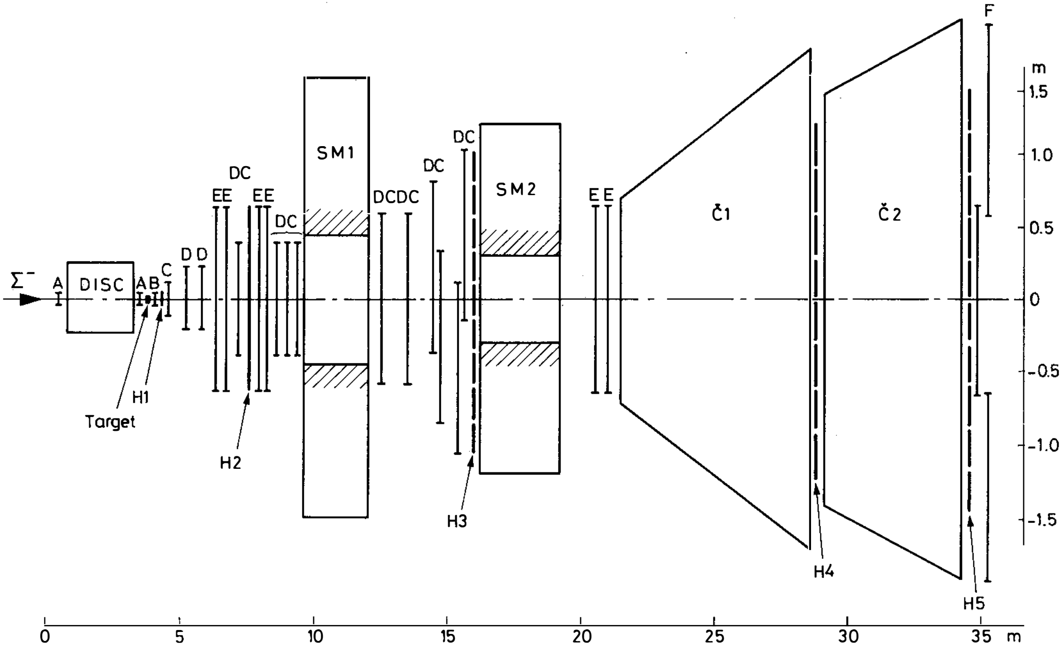

Fig. 1 Schematic layout of the apparatus. A, B, C, D, E, F = MWPCs, DC = drift chambers, SM1, SM2 = magnets, C1, C2 = gas Cerenkov counters, DISC = DISC Cerenkov counter, H1-H5 = scintillator hodoscopes, Σ^- = incident hyperon beam.

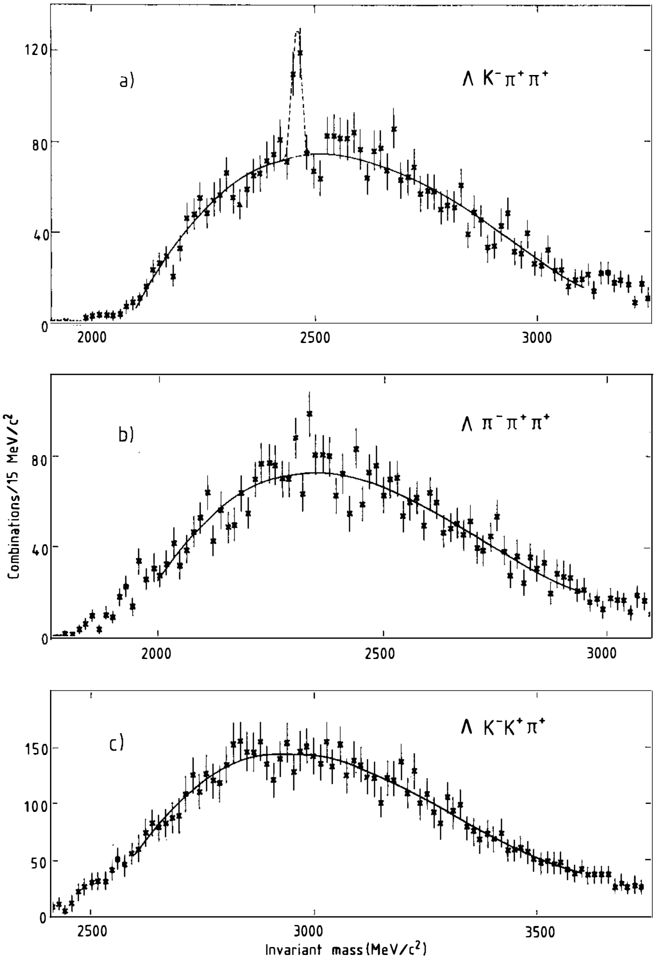

Fig. 2 Effective mass distributions, points with error bars are data, lines are fits of a polynomial of order 3.