Ξ^* Resonances in Ξ^- Be Interactions

I. Diffractive Production in the ΛK^- and $\Xi^- \pi^+ \pi^-$ Channels*

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Abstract. In an experiment carried out in the CERN SPS hyperon beam, the diffractive dissociation of incident Ξ^- hyperons into ΛK^- and $\Xi^- \pi^+ \pi^-$ final states has been observed. Several resonances are seen in the final states, including the well known $\Xi(1820)$ which appears in both channels, and the $\Xi(1680)$ which appears as a narrow state ($M = 1691.1 \pm 2.7$ MeV/c², $\Gamma < 8$ MeV/c²) in the ΛK^- channel and possibly also in the $\Xi \pi \pi$ channel.

1. Introduction

In spite of the considerable efforts that have been devoted to experimental searches for $S = -2$ baryon resonances (see [1] for references), the number of well established Ξ^* states is still far smaller than expected from quark models [2–3]. This situation is particularly unsatisfactory in view of the advances which have been made (for instance by the Toronto group, see [4] and references therein) in understanding the theoretical aspects of baryon spectroscopy by introducing into the quark model ingredients drawn from QCD.

We have carried out an experiment at the CERN SPS charged hyperon beam with incident Ξ^- , using an apparatus well suited to study various decay

modes of Ξ^* resonances. In this article we present the first results obtained, which consist of the observation of the diffractive dissociation of Ξ^- hyperons into the channels ΛK^- and $\Xi^- \pi^+ \pi^-$, and the production of Ξ^* resonances in these channels. The study of the inclusive production of Ξ^* resonances will be treated in later publications.

2. The Experimental Apparatus

The hyperon beam is described in detail elsewhere [5]. The incident Ξ^- hyperons of mean momentum 116 GeV/c were identified by a DISC Cherenkov counter and their trajectories measured in two clusters of multi-wire proportional chambers (MWPCs) [labelled A in Fig. 1] in two independent projections, x and y . The y axis is oriented vertically upwards, the z axis is in the beam direction, and the x - y - z system is right-handed. The origin of the z coordinate is at the centre of the last quadrupole of the hyperon beam.

The target consisted of a beryllium rod 83 mm long, representing 0.20 nuclear interaction lengths. Trajectories and momenta of outgoing charged particles were measured in a magnetic spectrometer consisting of two magnets [SM1, SM2] and clusters of MWPCs [B, C, D, E, F, G] and drift chambers [DC]. Upstream of SM1, three independent coordinates at 120° to each other were measured. In the region downstream of SM1, where topologies were less complicated, only two orthogonal coordinates were measured.

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Fig. 1. The experimental apparatus. See text for details

The threshold Cherenkov counter [Ch] was segmented into 24 cells and provided π/K separation with a nominal π threshold of 10 GeV/c. The lead glass array [LG] and the liquid argon detector [LAD] were not used in the present analysis.

Since the purpose of the experiment was to study Ξ^* resonances in many different channels, the trigger was chosen to be as universal as possible, demanding only an incident Ξ^- (defined by beam scintillators and the DISC), at least two charged particles through the multiplicity counter [M], and at least three charged particles in two different cells of the hodoscope H2 (downstream of SM1). The position of M was chosen to permit a 4 m decay region for secondary hyperons and a sufficient lever arm upstream of SM1 for an accurate momentum measurement of the decay products. A simple on-line algorithm was used in order to suppress triggers due to Ξ^- that did not interact in the target but decayed early in the apparatus.

In a typical SPS burst of 1.2 s effective spill time, $1.5 \cdot 10^6$ particles (mostly π^-) were counted, approximately $270 \Xi^-$ were identified by the DISC, and the trigger conditions were fulfilled by 60 events. Our total data sample consists of $1.8 \cdot 10^7$ triggers, corresponding to $8.2 \cdot 10^7$ incident Ξ^- .

3. Geometrical Reconstruction and Initial Event Selection

Tracks were reconstructed in projections separately in 4 regions, namely: the beam telescope (A chambers), the region upstream of SM1, the region between SM1 and SM2, and the region downstream of SM2.

The projections were associated in each region to give 3-dimensional lines. Lines in regions 2, 3 and

4 were then connected on the basis of their distance of approach at the middle plane of the magnets. Pairs of tracks of oppositely charged particles were identified as V^0 candidates if they intersected in the region extending from 75 mm downstream of the centre of the target to the multiplicity counter with a closest distance of approach (cda) less than 3.0 mm, the average cda of the selected events being 0.62 mm. These candidates were then identified as Λ hyperons if the effective mass of the two secondary particles, assumed to be a proton and a π^- , was within 20 MeV/c² of the known Λ mass. The Λ signal has a width (FWHM) of 4.7 MeV/c² with negligible background.

The initial event selection demanded that a Λ and at least one other charged particle be completely reconstructed (momentum measured in SM1); $1.36 \cdot 10^6$ events survived these cuts.

4. Selection of Diffractive Events

In the next step of our analysis, we searched for diffractive dissociation events, i.e. events in which the incident Ξ^- hyperon dissociates into a system consisting of a Λ and one or three charged particles, with a small loss of longitudinal momentum and a small transverse momentum transferred to the target nucleus.

4.1 The ΛK^- Sample

Events with exactly one negative particle completely reconstructed (henceforth referred to as X^-) in addition to the Λ decay products were selected. Furthermore, events containing tracks reconstructed upstream of SM1 but not downstream were rejected. These tracks were usually due to large-angle or low-momentum particles. The reconstructed beam trajec-

Fig. 2. ΛK^- sample: The X^- momentum after the geometric cuts and the $\Lambda\pi^-$ effective mass cut (full line) and after the Cherenkov cut (dashed line)

tory was required to be within 1.0 mrad of the mean beam angle in both xz and yz projections, the width of the observed distributions being 200 μ rad (FWHM). The total longitudinal momentum of the event was required to be between 100 and 135 GeV/c, roughly equal to the mean beam momentum. The total transverse momentum was required to be less than 1.0 GeV/c.

A consequence of the open trigger used in this experiment was the inclusion in the data sample of decays of non-interacting or elastically scattered Ξ^- when both decays $\Xi^- \rightarrow \Lambda\pi^-$ and $\Lambda \rightarrow p\pi^-$ occurred before M . These represent about 10% of the incoming Ξ^- , to be compared to 13% which interact in the target. Furthermore the diffractive dissociation of Ξ^- into ΛK^- represents only a small fraction of the total number of Ξ^- interactions. Thus the majority of the events with a Λ and an additional negative particle are non-interacting or elastically scattered Ξ^- ; various cuts are necessary to suppress this background.

First, a series of geometric cuts was applied in order to choose events where the Λ and X^- particles originated from the primary interaction vertex of the incident Ξ^- . The cda between the Λ trajectory and the X^- trajectory was required to be less than 2.5 mm (the average cda being 0.60 mm) and the longitudinal (z) coordinate of this intersection was required to be within ± 75 mm of the target centre, the resolution in z being typically 30 mm. A final geometric cut at ± 2.0 mm was applied on the transverse distance (in x and y separately) between the ΛX^- intersection and the beam trajectory extrapolated to the z coordinate of the intersection, the rms of this distance being 0.60 mm.

Fig. 3a-d. Total longitudinal momentum p_L of the outgoing particles ΛK^- for: a $p_T^2 < 0.03$ (GeV/c) 2 , b $0.03 < p_T^2 < 0.12$ (GeV/c) 2 , c $0.12 < p_T^2 < 0.50$ (GeV/c) 2 , d $p_T^2 > 0.50$ (GeV/c) 2

A significant number of $\Xi^- \rightarrow \Lambda\pi^-$ decays are still present, due to the decay in the target of non-interacting or elastically scattered Ξ^- . In order to suppress them, the $\Lambda\pi^-$ effective mass was required to be larger than 1350 MeV/c 2 . The distribution of the X^- momentum after this cut is shown in Fig. 2 (full line). Many Ξ^- remain as can be seen from the step at 30 GeV/c which is the kinematical limit for π^- from the decay of 116 GeV/c Ξ^- . These events are not removed by the cut on the $\Lambda\pi^-$ effective mass presumably because of large angle scattering of the π^- in the target.

In order to eliminate these events, we used the information from the Cherenkov counter. This counter had a nominal π threshold of 10 GeV/c (corresponding to a K threshold of 35 GeV/c) and its efficiency, measured with π^- from kinematically identified $\Lambda \rightarrow p\pi^-$ decays, was 85% at 12 GeV/c (peak efficiency was 97%). Events with X^- momentum smaller than 12 GeV/c were rejected. The absence of a Cherenkov signal in the appropriate cell for events with X^- momentum smaller than 30 GeV/c was also required. In Fig. 2 (dashed line) we show the distribution of the Ξ^- momentum after these cuts which define the ΛK^- sample.

Figure 3 shows the distribution of the total longitudinal momentum p_L for subsamples corresponding to four intervals of p_T^2 defined by the limits 0.03, 0.12 and 0.50 (GeV/c) 2 . A peak is visible near 115 GeV/c in the p_L distribution for the samples with p_T^2 smaller than 0.50 (GeV/c) 2 , which becomes more prominent with decreasing p_T^2 . That this peak is not due to $\Lambda\pi^-$ decay of incident or elastically scattered Ξ^- , surviving the cuts, has been checked by considering only events

Fig. 4a–d. Total longitudinal momentum p_L of the outgoing particles $\Xi^- \pi^+ \pi^-$ for: **a** $p_T^2 < 0.03$ (GeV/c)², **b** $0.03 < p_T^2 < 0.12$ (GeV/c)², **c** $0.12 < p_T^2 < 0.50$ (GeV/c)², **d** $p_T^2 > 0.50$ (GeV/c)²

with an X^- momentum above 30 GeV/c . The peak subsisted in the proportion expected.

The presence of a peak at 115 GeV/c in p_L for small p_T^2 is evidence for the diffractive dissociation of the incident Ξ^- into the channel ΛK^- .

4.2 The $\Xi^- \pi^+ \pi^-$ Sample

In this case, events were chosen with exactly two negative and one positive reconstructed charged particles (in addition to the Λ decay products). The same initial cuts on the total longitudinal momentum, the transverse momentum, and on the beam trajectory angle were applied.

Due to the 5-track requirement, there is no background from non-interacting Ξ^- in this subsample. We therefore selected Ξ^- decaying downstream of the target using the following geometric cuts: We demanded that the cda between the Λ trajectory and a negative particle be less than 3.0 mm, and the z coordinate of this intersection had to be more than 75 mm downstream of the target centre but upstream of the Λ decay point. Events where both additional negative particles passed these cuts were rejected. The Ξ^- signal is now nearly background free, and a cut at $\pm 20 \text{ MeV}/c^2$ around the mass of the Ξ^- was applied. Finally the two additional secondary particles and the trajectory of the Ξ^- were required to intersect the beam with a cda less than 3.0 mm, at a z coordinate within 40 mm of the centre of the target and more than 80 mm upstream of the Ξ^- decay vertex.

The Cherenkov counter was not used in the selection of the $\Xi^- \pi^+ \pi^-$ sample because in 65% of the

Fig. 5a, b. Transverse momentum squared p_T^2 of the outgoing particles **a** ΛK^- and **b** $\Xi^- \pi^+ \pi^-$. The curves represent the fits with an interference term included

events at least one of the two additional particles is below 12 GeV/c , where no π/K discrimination is possible. We have checked that above 12 GeV/c the number of secondaries having a Cherenkov signal is compatible with the efficiency quoted above for pions.

Figure 4 shows the distribution of the total longitudinal momentum of the $\Xi^- \pi^+ \pi^-$ system, for subsamples defined by the same limits as above in p_T^2 . A peak is seen near 115 GeV/c for the samples with p_T^2 smaller than 0.12 (GeV/c)²; for the sample with $0.12 < p_T^2 < 0.50$ (GeV/c)², there is an excess of events in the region of p_L near 115 GeV/c . This provides evidence for the diffractive dissociation of the incident Ξ^- into $\Xi^- \pi^+ \pi^-$.

5. Production Characteristics

For both the ΛK^- and the $\Xi^- \pi^+ \pi^-$ channels, the production angular distributions are strongly peaked in the forward direction, with a mean transverse momentum p_T of 320 MeV/c . The distributions of $-t = p_T^2$ are shown in Figs. 5a, b, for $110 < p_L < 122 \text{ GeV}/c$; the vertical scale is logarithmic. The numbers of events are 4480 and 1292, respectively. For both reactions, the t distribution is fairly well represented by an exponential over the larger part of the t range, from 0.15 to 1.0 (GeV/c)². However, a sharper peak is noticeable at low t . This suggests the presence of two effects: the coherent production of the final state particles off single nucleons (shallower slope) and off Be nuclei (steeper slope).

A fit of the t distribution as a sum of two exponentials:

Table 1. Parameters of the fitted distributions of $-t = p_T^2$ (The slopes B_1, B_2 are in $(\text{GeV}/c)^{-2}$)

Final-state	Parameters	No interference	Interference
AK^-	A_1	1663 ± 86	1129 ± 263
	B_1	48.7 ± 3.1	66.4 ± 8.6
	A_2	222 ± 11	214 ± 11
	B_2	3.91 ± 0.12	3.83 ± 0.12
	$\cos \phi$	0.0	0.66 ± 0.36
	χ^2	59.54	51.01
	dof	46	45
$\Xi\pi\pi$	A_1	483 ± 42	325 ± 100
	B_1	41.9 ± 4.8	56.4 ± 9.4
	A_2	94.4 ± 5.3	46.1 ± 5.3
	B_2	3.24 ± 0.23	3.12 ± 0.24
	$\cos \phi$	0.0	0.76 ± 0.54
	χ^2	46.94	41.58
	dof	46	45

$$dN/dt = A_1 \exp(B_1 t) + A_2 \exp(B_2 t)$$

even if acceptable in terms of χ^2 , gives systematically too few events in the first bin, too many in the next two bins. This situation is improved if one allows for an interference term between the two exponentials:

$$dN/dt = A_1 \exp(B_1 t) + A_2 \exp(B_2 t) + 2\sqrt{A_1 A_2} \cos \phi \exp(0.5(B_1 + B_2)t)$$

even though the overall effect of this term may not be statistically significant.

The parameters of the fits are given in Table 1 for both reactions, with and without interference. The errors quoted take into account the strong correlation between the various parameters. One notices that the slopes measured for the two reactions are similar, but not strictly compatible. The same is true of the relative fractions of events corresponding to the two slopes.

6. Diffractive Production of Resonances

In both channels, the diffractive samples of events have been defined somewhat arbitrarily by the cuts:

$$110 < p_L < 122 \text{ GeV}/c,$$

$$0 < p_T^2 < 0.50 (\text{GeV}/c)^2.$$

To improve the resolution on the mass of the final state, the $A \rightarrow p\pi^-$ and $\Xi^- \rightarrow A\pi^-$ decays have been kinematically fitted (1C-fits), and cuts applied at a χ^2 probability of 1%. This leaves 4036 events in the AK^- channel and 1157 events in the $\Xi^- \pi^+ \pi^-$ channel.

Fig. 6. The AK^- effective mass

6.1 The AK^- Channel

In Fig. 6 we show the AK^- effective mass distribution for the diffractive sample. A narrow enhancement is seen at $1690 \text{ MeV}/c^2$ and a broader one at $1830 \text{ MeV}/c^2$.

A Ξ^* resonance with a mass close to $1830 \text{ MeV}/c^2$ has been observed in several experiments. The experiment with the largest statistics and the best resolution, that of Gay et al. [6] which used a hydrogen bubble chamber and incident K^- mesons of $4.2 \text{ GeV}/c$, found for this state a mass of $1823 \text{ MeV}/c^2$ and a width of $21 \text{ MeV}/c^2$. In the same experiment, an enhancement at $1694 \text{ MeV}/c^2$ was observed [7] in the $\Sigma\bar{K}$ channel and less convincingly in $A\bar{K}$. This state is called $\Xi(1680)$ and attributed a two-star status in the Particle Data Group tables. In an earlier experiment in the CERN SPS hyperon beam with incident Ξ^- of 100 and $135 \text{ GeV}/c^2$, and liquid hydrogen and deuterium targets, we observed two broad enhancements in the AK^- channel at 1700 and $1830 \text{ MeV}/c^2$ [8]; this experiment had a smaller acceptance and a poorer mass resolution than the present one.

Using the maximum likelihood method, we have fitted two Breit-Wigner functions with adjustable parameters, added to a polynomial background of fourth order over the interval $1620\text{--}2100 \text{ MeV}/c^2$ of the AK^- mass spectrum. The values obtained for the parameters of the two peaks are the following:

$$M = 1691.1 \pm 1.9 \text{ MeV}/c^2, \\ \Gamma = 10.7 \pm 3.6 \text{ MeV}/c^2, \quad 104 \pm 24 \text{ events},$$

$$M = 1819.4 \pm 3.1 \text{ MeV}/c^2, \\ \Gamma = 24.6 \pm 5.3 \text{ MeV}/c^2, \quad 280 \pm 50 \text{ events}.$$

The statistical significance of the two peaks corresponds to 6.7 and 8.7 standard deviations, respective-

Fig. 7. The $\Xi^- \pi^+$ effective mass

ly. These values are deduced from the variation of the likelihood function when the amplitude of the corresponding signal is changed to zero. Unfolding the mass resolution, we obtain for the physical width of the $\Xi(1680)$ an upper limit of $8 \text{ MeV}/c^2$ at the 90% confidence level.

In order to check the mass scale in the region of the $1690 \text{ MeV}/c^2$ peak, we have compared the mass of our observed $\Omega^- \rightarrow \Lambda K^-$ signal (not shown) with the accepted value of $1672.45 \pm 0.29 \text{ MeV}/c^2$ [1]. For Ω^- momenta between $30 \text{ GeV}/c$ and $80 \text{ GeV}/c$, our measured Ω^- mass is $1671.7 \pm 0.2 \text{ MeV}/c^2$ (statistical error only). Furthermore, we notice no systematic trend in the value of the Ω^- mass as a function of the Ω^- momentum, and variations are smaller than $1 \text{ MeV}/c^2$ between different samples of Ω^- momentum. We estimate that the systematic error on the mass of the ΛK^- system at a total momentum of $116 \text{ GeV}/c$ is about $2 \text{ MeV}/c^2$, and the combined error on the mass of the $\Xi(1680)$ is $2.7 \text{ MeV}/c^2$.

The value of the mass resolution: $7 \text{ MeV}/c^2$ (rms) at a ΛK^- mass of $1690 \text{ MeV}/c^2$ and a total momentum of $116 \text{ GeV}/c$, was obtained using a Monte Carlo simulation program which took into account multiple scattering and the spatial resolution of the chambers. The same program reproduces very well the observed width of the Ω^- signal and its dependence in terms of the Ω^- momentum.

6.2 The $\Xi^- \pi^+ \pi^-$ Channel

In Fig. 7 we show the distribution of the $\Xi^- \pi^+$ effective mass, which is dominated by the $\Xi(1530)$ signal. A maximum likelihood fit of a Breit-Wigner function folded with a Gaussian, added to a linear background,

Fig. 8. The $\Xi^- \pi^+ \pi^-$ effective mass

over the $1500\text{--}1565 \text{ MeV}/c^2$ region of the mass spectrum, gives the following values for the resonance parameters (statistical errors only):

$$M = 1532.7 \pm 0.5 \text{ MeV}/c^2, \quad \Gamma = 11.6 \pm 1.4 \text{ MeV}/c^2.$$

The signal contains 650 events, i.e. 56% of the total $\Xi^- \pi^+ \pi^-$ diffractive sample.

In the same mass spectrum, a broad bump near $1950 \text{ MeV}/c^2$ is also visible (see inset of Fig. 7). Fitting a Breit-Wigner function added to a second order polynomial over the $\Xi^- \pi^+$ mass histogram in the interval $1700\text{--}2400 \text{ MeV}/c^2$ yields the following parameters:

$$M = 1944 \pm 9 \text{ MeV}/c^2, \quad \Gamma = 100 \pm 31 \text{ MeV}/c^2, \\ 129 \pm 35 \text{ events.}$$

In our earlier experiment [8] we have already observed a bump at the same mass and with a similar width in the same channel. It is not clear whether this effect can be related with the so-called $\Xi(1940)$ that has appeared for many years in the Particle Data Group compilations with a two-star status and which probably consists of several overlapping resonances. Indeed, in the same mass region, we have observed [9, 10] a fairly narrow state of mass $1963 \text{ MeV}/c^2$ in the inclusive $\Lambda \bar{K}^0$ channel.

The $\Xi^- \pi^+ \pi^-$ effective mass distribution is shown in Fig. 8 and the $\Xi(1530) \pi^-$ effective mass in Fig. 9, with the $\Xi(1530)$ being defined by the cut $1500 < M(\Xi^- \pi^+) < 1565 \text{ MeV}/c^2$. The main features of these mass spectra are two broad bumps in the regions $1800\text{--}2000 \text{ MeV}/c^2$ and $2150\text{--}2250 \text{ MeV}/c^2$.

The shape of the low-mass region of the $\Xi \pi \pi$ mass spectrum is such that it cannot be satisfactorily repro-

Fig. 9. The $\Xi(1530)\pi^-$ effective mass

duced by a polynomial of reasonable order. Typical values of χ^2 are 80 to 90 for 50 bins over the mass interval between 1700 and 2100 MeV/c^2 . On the other hand, if one adds to this polynomial a Breit-Wigner function centred near 1780 or 1830 MeV/c^2 , one can estimate a statistical significance of 3.3 and 2.0 standard deviations for the signals seen at these masses. If interpreted as resonances, these signals have the following characteristics, from a fit with two Breit-Wigner functions (χ^2 of 18.2 for 20 degrees of freedom):

$$M = 1782.6 \pm 1.4 \text{ MeV}/c^2, \quad \Gamma = 6.0 \pm 1.5 \text{ MeV}/c^2, \\ 27 \pm 10 \text{ events},$$

$$M = 1831.9 \pm 2.8 \text{ MeV}/c^2, \quad \Gamma = 9.6 \pm 9.9 \text{ MeV}/c^2, \\ 21 \pm 15 \text{ events}.$$

This fit is represented by the curve in Fig. 8. This curve is clearly not intended to reproduce the shape of the background above 2000 MeV/c^2 ; the sharp drop in the mass spectrum here, which is not due to a variation of the acceptance, indicates a resonant behaviour in the region 1900–2000 MeV/c^2 .

The peak near 2200 MeV/c^2 is much less apparent in the $\Xi(1530)\pi^-$ mass spectrum than in the $\Xi\pi\pi$ mass spectrum. Indeed, if one considers the two-dimensional plot of $M(\Xi\pi\pi)$ vs $M(\Xi\pi)$ (not shown here) one notices that the bump near 2200 MeV/c^2 is to a large extent associated with the 1950 MeV/c^2 peak in $\Xi\pi$. We have fitted a Breit-Wigner function added to a linear background to the mass spectrum (histogram) over the interval between 2050 and 2450 MeV/c^2 . We obtain the following parameters for the 2200 MeV/c^2 bump:

$$M = 2189 \pm 7 \text{ MeV}/c^2, \quad \Gamma = 46 \pm 27 \text{ MeV}/c^2, \\ 66 \pm 32 \text{ events}.$$

Fig. 10. Ideogram of the AK^- and $\Xi^- \pi^+ \pi^-$ effective masses

6.3 Comparison Between the AK^- and $\Xi^- \pi^+ \pi^-$ Channels

For a systematic comparison of the two channels, we have plotted each mass spectrum as an ideogram. In such a plot, each event is represented by a normalized Gaussian function centred at the measured mass and with a width equal to the expected resolution at that mass value. This representation has the advantage of freeing one from any particular choice of binning (origin as well as bin width) although care must be exercised in estimating the significance of any effect which may emerge. The two ideograms are represented in Figs. 10a, b with the same horizontal (mass) and vertical (number of events) scales.

The two peaks at 1690 and 1820 MeV/c^2 that dominate the AK^- mass spectrum (Fig. 6) appear conspicuously in the corresponding ideogram (Fig. 10a). In the $\Xi\pi\pi$ mass ideogram (Fig. 10b) the two narrow peaks at 1780 and 1832 MeV/c^2 are clearly visible, and there is evidence for a third one at 1740 MeV/c^2 ; a broad bump at about 1940 MeV/c^2 and a peak at 2185 MeV/c^2 are also seen. In what follows, we shall use the ideograms to consider successively the various structures which appear in the two channels.

The $\Xi(1680)$, convincingly seen in AK^- with a mass of 1691 MeV/c^2 , can be put in correspondance with a cluster of four events at the same mass in the $\Xi\pi\pi$ mass spectrum; this suggests an alternate decay mode of this resonance, the four events corresponding to a branching ratio $\Gamma(\Xi(1680) \rightarrow \Xi\pi\pi)/\Gamma(\Xi(1680) \rightarrow AK^-)$ of 0.12 when the relative acceptances are taken into account.

To the narrow peak at 1740 MeV/c^2 in $\Xi\pi\pi$ corresponds a weak signal in the AK^- channel. The $\Xi\pi\pi$ peak at 1780 MeV/c^2 has no clear partner in AK^- .

The well known $\Xi(1820)$ appears in both channels, but with lower statistical significance in $\Xi\pi\pi$. The difference in mass, 12.5 ± 4.2 MeV/c², seems to be larger than can be explained from statistics; systematic errors in the mass scale would affect both masses in the same direction. The difference could be due to the fact that both peaks sit on a background whose shape is more complicated than assumed in the fits. The width is also poorly determined in the $\Xi\pi\pi$ channel. The numbers of events would correspond to a branching ratio $\Gamma(\Xi(1820) \rightarrow \Xi\pi\pi)/\Gamma(\Xi(1820) \rightarrow AK^-)$ of 0.30 ± 0.20 , in agreement with the value of 0.34 ± 0.18 quoted by the Particle Data Group [1] in their Baryon Full Listings (but not in the Baryon Summary Table).

In the $\Xi^- \pi^+ \pi^-$ channel, the mass region 1900–2000 MeV/c² is dominated by a broad bump which could correspond to several resonances. Nothing convincing is seen in the AK^- mass spectrum in this region. The bump in the same mass region in the $\Xi^- \pi^+$ channel is produced under completely different kinematical conditions (not diffractively) and is therefore not directly comparable.

Finally, there is some evidence for a peak at 2170 MeV/c² in the AK^- mass spectrum, which could be associated with the clear signal at 2189 MeV/c² in $\Xi\pi\pi$.

7. Discussion

We have observed the dissociation of incident Ξ^- hyperons in the final states AK^- and $\Xi^- \pi^+ \pi^-$ with a p_T^2 distribution expected for diffraction phenomena on targets of nucleon or nuclear size. Resonances are observed in both final states, in particular the well known $\Xi(1820)$. The $\Xi(1680)$ is clearly seen as a narrow peak in AK^- , which confirms definitely the existence of this resonance, and there is a hint of its presence in $\Xi\pi\pi$.

In total, we observe 6 Ξ^* enhancements of varying

statistical significance produced diffractively, four of which are in the mass region between 1600 and 2000 MeV/c². The quark model predicts 12 [4] to 15 [2] Ξ^* states in this mass range, from the $N=1$ and $N=2$ levels of the harmonic oscillator quark model. However, if one relies on the Gribov-Morrison selection rule according to which diffractively produced resonances must belong to the natural parity series $1/2^+$, $3/2^-$, etc ..., one only expects to observe 6 or 7 resonances in the mass range considered. It is no doubt premature to try to associate the experimental peaks and the predicted resonances, without a spin-parity determination, especially since the precision on the predicted masses is not expected to be better than ± 20 to 30 MeV/c². Nevertheless, the $\Xi(1680)$ is a good candidate for the doubly strange analogue of the Roper resonance $N(1440)$, of spin-parity $1/2^+$. The mass predicted by Chao et al. [4] for this state is 1695 MeV/c² and its total width 1.6 MeV/c²; the branching ratio $\Gamma(\Xi^* \rightarrow \Xi\pi\pi)/\Gamma(\Xi^* \rightarrow AK^-)$ is expected to be 0.08, to compare with our estimate of 0.12. The same authors predict a $3/2^-$ state with a mass of 1800 MeV/c², a total width of 34 MeV/c² and a branching ratio $\Gamma(\Xi^* \rightarrow \Xi\pi\pi)/\Gamma(\Xi^* \rightarrow AK^-)$ of 0.25, consistent with the values found for the $\Xi(1820)$.

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