RECENT RESULTS ON BARYONS WITH STRANGENESS AND CHARM

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I will review recent experimental results on baryons with strangeness (i.e. hyperons), baryons with charm, and baryons with both strangeness and charm. The production of these particles will be discussed first and then some of their properties will be considered. In the first part I will restrict myself to hadron collisions (i.e. I will not consider the measurements in neutrino, photon or charged lepton beams). In the second part I will review the Ω^- decay properties, the measurements of the lifetimes and branching ratios of the charmed baryons Λ_c^+ and A^+ and the first observation of the double strange charmed baryon T^o. Because of lack of time and because S. Wojcicki nicely summarized the subject earlier in the conference, I will not cover the semileptonic decays of hyperons and the recent Cabibbo model fit by the WA2 Collaboration at CERN.[1)]

As an introduction, Fig.1 will remind us how the three-quark baryons of spin-parity $1/2^+$ and $3/2^+$ form multiplets, corresponding to charm quantum numbers C = 0 to C = 3. The only charmed baryons observed so far are contained in the family of C = 1, $J^P = 1/2^+$ baryons: Σ_c^+ (1 event observed), Σ_c^{++} (8 events), and Λ_c^+ reported in several experiments with various decay modes.[2)] The strange charmed baryons A^+ and T^o were recently observed in the SPS Hyperon Beam.[3-4)]

1. Production in high energy hadron interactions

1.1 Strange baryons and antibaryons

The experimental results consist essentially of inclusive measurements in the forward direction, i.e. reactions of the type *Hadron projectile + Target* $\rightarrow \overset{(-)}{B} + X$, where B is a baryon. The invariant cross section for this process is usually parametrized as

$$E\,\frac{d^3\sigma}{d\vec{p}^{\,3}} \;\alpha\; f(x)\ g(p_T)$$

with $f(x) = (1-x)^n$ for large values of x. This parametrization has been found to describe well the π^- and π^+ production by protons for $p_T \sim 0$ GeV/c with n = 4 and 3.5, respectively.

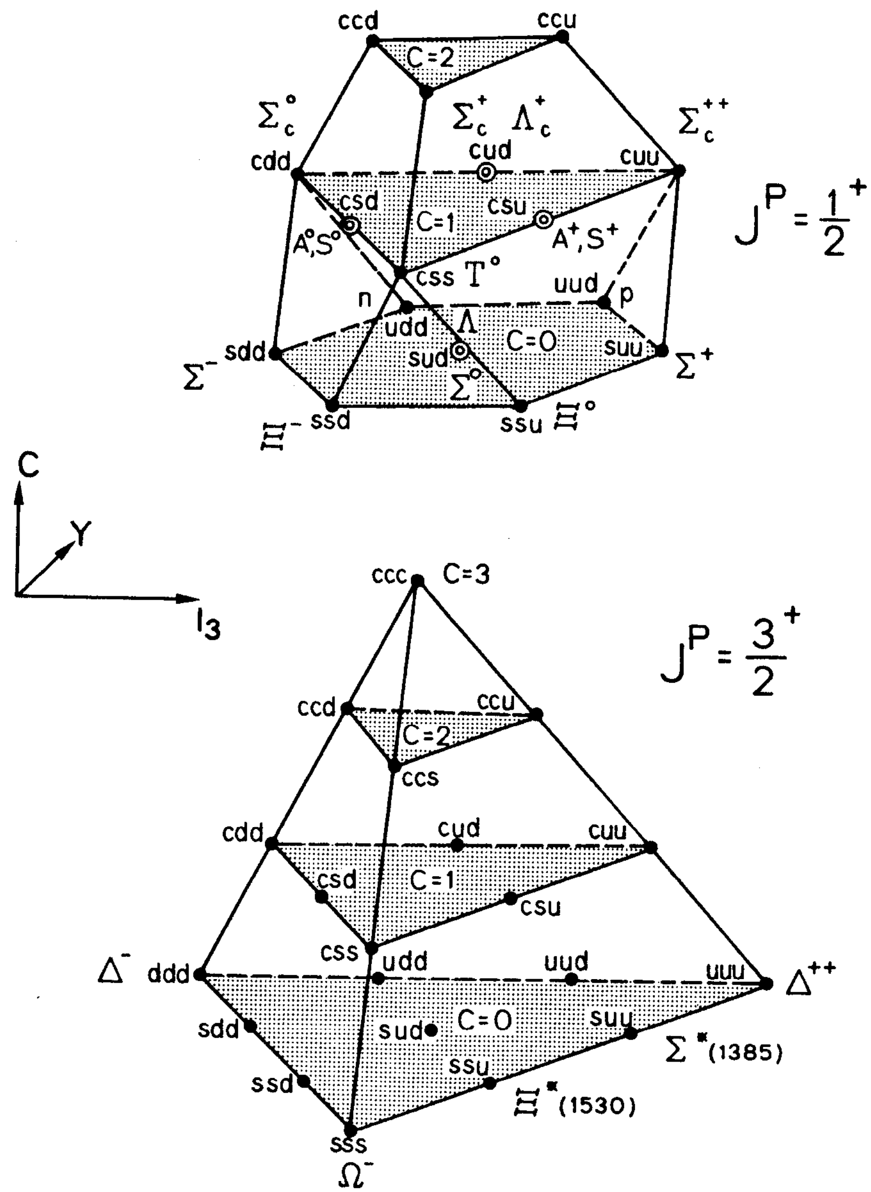

Fig. 1

Such measurements have been performed in the CERN SPS Hyperon Beam[5)] which operated between 1976 and 1982. The hyperons were produced by the interaction of a 200 to 250 GeV/c extracted proton beam in a Be target located in the West Area. Hyperons of 70 to 135 GeV/c were selected with a magnetic channel and tagged with a special DISC Cherenkov counter. An example of the DISC counting rate as a function of the gas pressure is shown in Fig.2 for a beam setting of - 100 GeV/c. This technique allowed the measurement of ratios of produced particles as well as the tagging of Σ^-, Σ^+ or Ξ^- hyperons for studying their interactions in targets which could be installed downstream of the DISC.

Rare particles were detected by reconstructing their decays into their main channels ($\Omega^- \to \Lambda K^-$, $\overline{\Xi^-} \to \bar{\Lambda}\pi^+$, $\overline{\Omega^-} \to \bar{\Lambda}K^+$). Examples of effective mass distributions are shown in Fig.3. The experimental resolutions were typically 5 MeV/c^2 for Ξ^- and 6 MeV/c^2 for Ω^- (FWHM).

We observe in Fig.4, where data from the PS to the ISR have been collected, that Feynman scaling applies to the data for $\sqrt{s} > 20$ GeV. The x dependence is well described by the function $(1 - x)^n$, where n depends on the nature of the particle. The values of n are small for the proton and the hyperons, indicating a leading particle effect in the production mechanism. In contrast the values of n are large (~ 7) for $\bar{p}$ and $\bar{\Lambda}$ (not shown), since they seem to be mainly produced in particle-antiparticle pairs.

Figure 5a shows the result of a recent analysis of the inclusive production of Λ^o by Σ^- in the SPS Hyperon Beam. The invariant cross section is flat w.r.t. to p_L^{cm}, giving $n = 0.0 \pm 0.5$.[6)] Particle production data by incident Ξ^- is presently being analysed by the WA42 Collaboration. The result of an earlier analysis of the reaction $\Xi^- + N \to \Xi^- + X$, displayed in Fig.5b, indicated a flat production between x = 0.4 and the onset of the diffraction peak at x = 0.85.

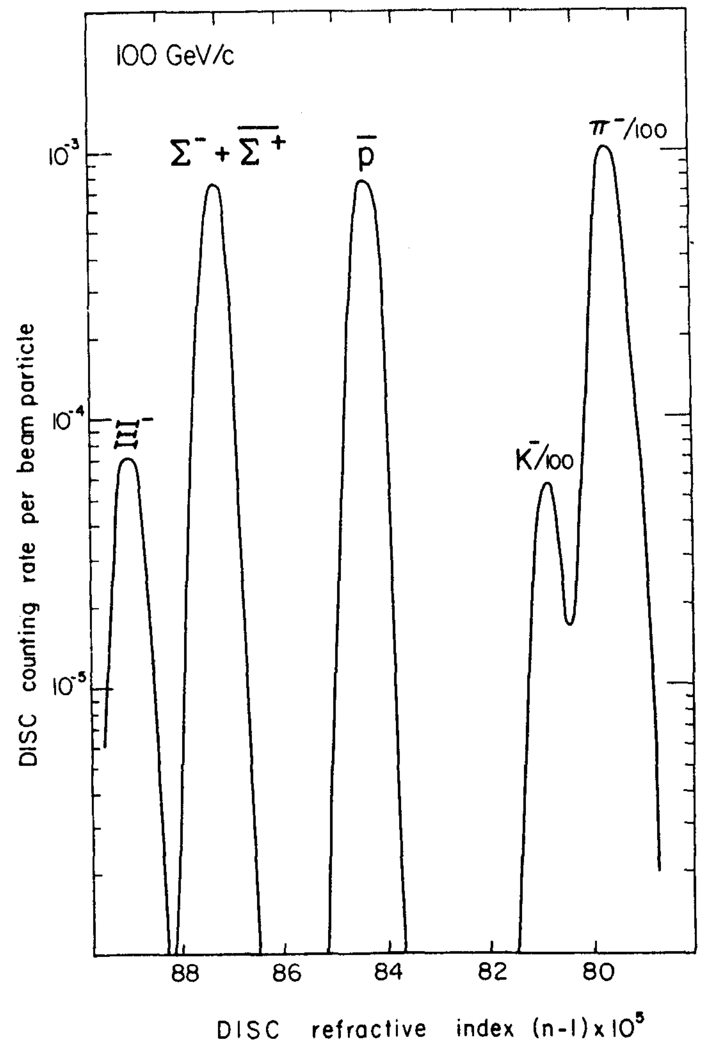

Fig. 2

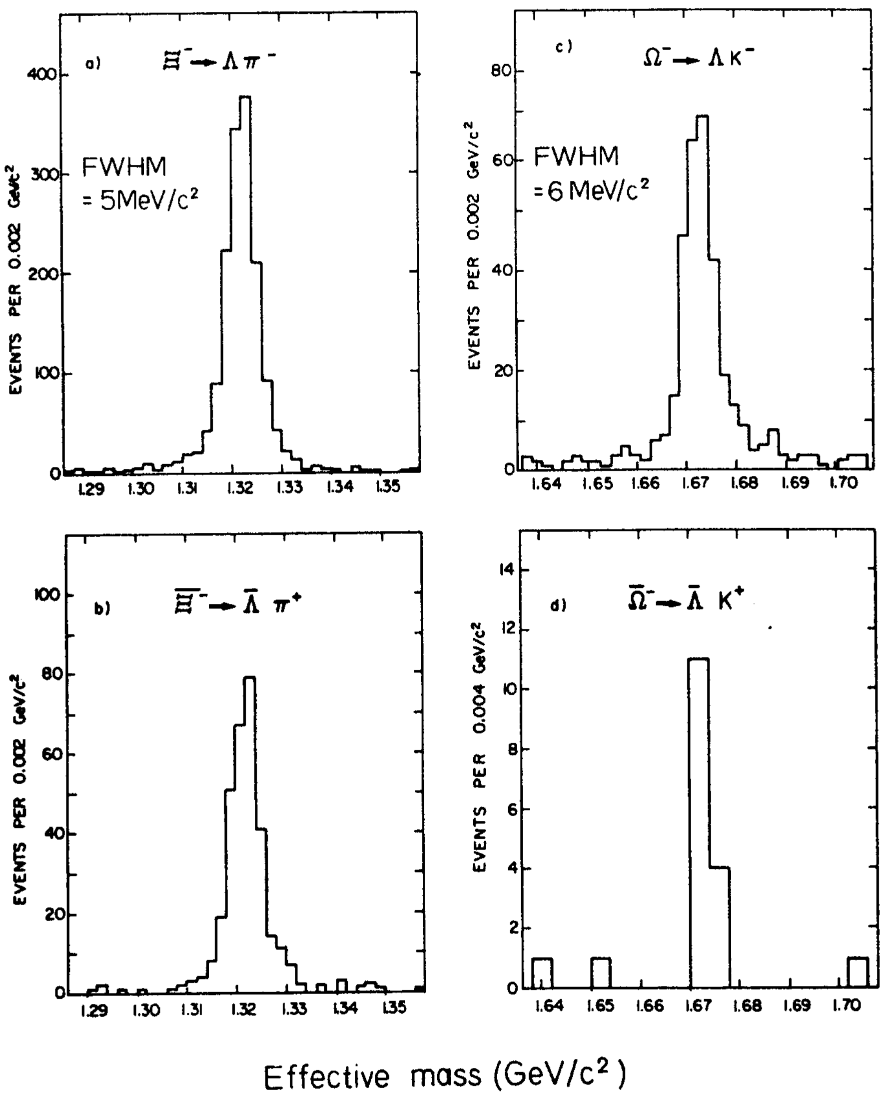

Fig. 3

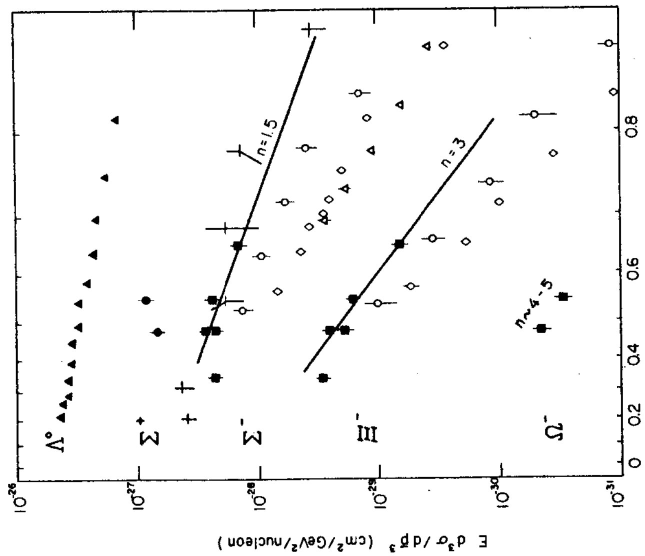

Fig. 4b

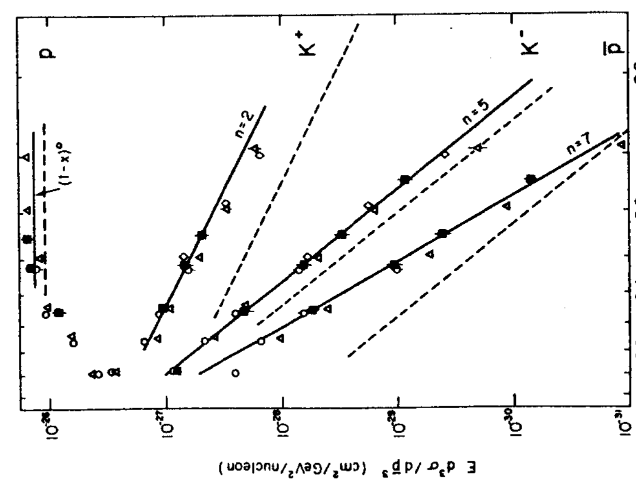

Fig. 4a

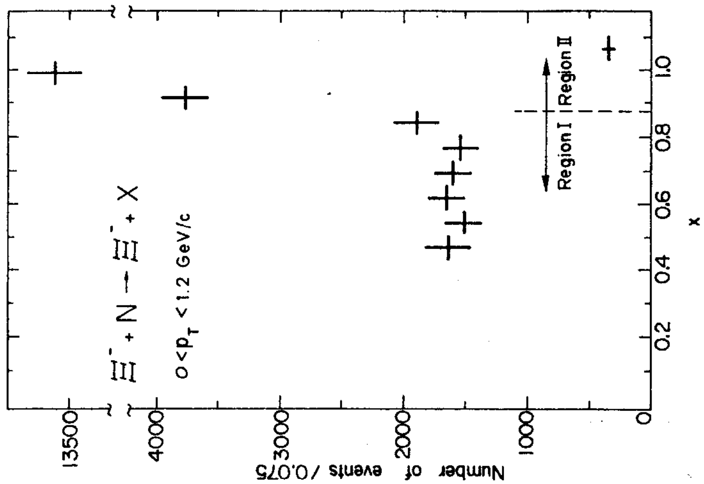

Fig. 5b

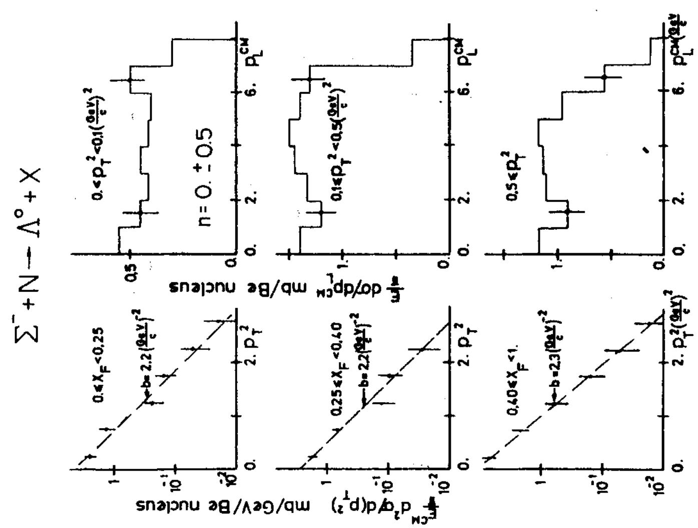

Fig. 5a

In Table 1, various measurements for $x \geq 0.5$ are summarized. One notices that they fall into four classes, according to the difference in quark composition between the incoming (first column) and the outgoing particles (second column). In the class of reactions where one valence quark of the projectile is replaced by another valence quark to form the new baryon, all the measurements, except $\Sigma^- \to \Lambda$, are consistent with $n \approx 1$. Where two valence quarks are replaced, a central value of about 2.25 indicates that a leading particle effect is still present in this class. This effect is an essential feature of hyperon beams, explaining the reasonably high rate of short-lived baryons with respect to the more stable pions. Even the value of n for Ω^-, which shares no common valence quark with the incident proton, is not larger than 4 to 5.

This classification is approximately described by the short distance counting rules for low p_T fragmentation.[7] It will be quite instructive to test these ideas further when the results of the WA42 Collaboration on Σ^*, Ξ^* and Ω^- production by Ξ^- become available.

The baryon (antibaryon) - to - pion ratios for the reactions $p + Be \to (\bar{B}$ or $B) + X$ are given in Fig.6 as a function of strangeness, for $x = 0.48$, $p_T = 0.6$ GeV/c and $\sqrt{s} = 21.2$ GeV. The full line, guiding the eye, illustrates the rapid increase of the antibaryon - to - baryon ratio, rising from 0.001 for $\bar{p}/p$ to 0.3 for $\overline{\Omega^-}/\Omega^-$. This can be interpreted as a decrease with strangeness of a process where the baryons are produced in the decay of excited states of the incoming proton relative to a process of baryon-antibaryon pair production. It is important nevertheless to notice that the ratio $\overline{\Omega^-}/\Omega^-$ is less than unity, indicating that a leading particle mechanism still contributes to the production by protons of strangeness - 3 baryons.

1.2 Charmed Baryons

We can now attempt to compare inclusive hyperon production with charmed and strange charmed baryons. The relevant direct observations

projectile	outgoing baryon	n
p (uud)	p (uud)	0
Ξ^- (ssd)	Ξ^- (ssd)	~ 0
p (uud)	n (udd)	~ 1
	Λ (uds)	~ 1
	Σ^+ (uus)	0.7 ± 0.3
	Λ_c^+ (udc)	~ 1
n (udd)	Λ^0 (uds)	0.9 ± 0.3
	Σ^- (1385)(sdd)	1.1 ± 0.4
	Λ_c^+ (udc)	1.5 ± 0.5
Σ^- (sdd)	Λ^0 (uds)	0 ± 0.5
p (uud)	Σ^- (sdd)	1.5
	Ξ^- (ssd)	3
n (udd)	Ξ^- (ssd)	1.9 ± 0.4
	Σ^+ (1385)(uus)	2.9 ± 0.5
Σ^- (sdd)	Λ^+ (csu)	1.7 ± 0.7
p (uud)	Ω^- (sss)	$\sim 4-5$
p (uud)	$\bar{p}$ ($\bar{u}\bar{u}\bar{d}$)	7

Table 1 - Inclusive invariant baryon production cross section for $x \geq 0.5$ expressed as $(1-x)^n$.

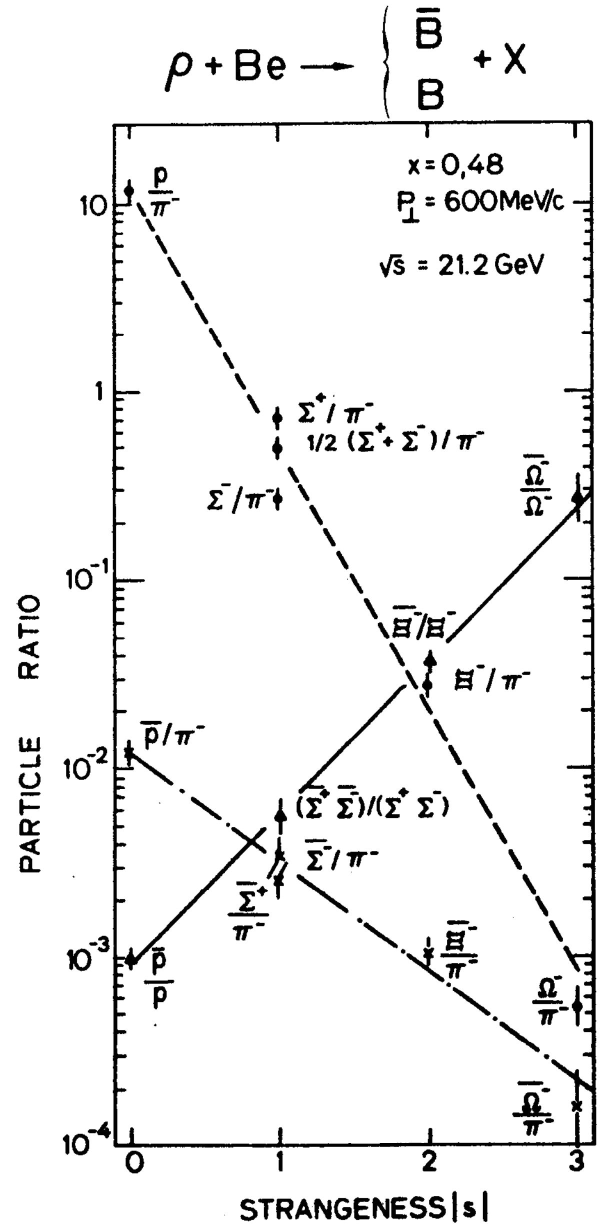

Fig. 6

of these particles in hadron interactions come from three sources: the CERN ISR and Serpukhov for Λ_c^+ and the SPS Hyperon Beam for A^+.

At the ISR ($58 < \sqrt{s} < 63$ GeV) the observation in pp collisions was made by several experiments[8] in the modes $K^- p\, \pi^+$, $\Lambda\pi^+\pi^-\pi^+$, K^*p and $K^-\Delta^{++}$. A diffractive production is suggested with $n \sim 1$, although the effect of the trigger and analysis cuts is a little uncertain.

The BIS-2 Collaboration[9] has detected Λ_c^+ decays via the two modes $K^o p\pi^+\pi^-$ and $\Lambda^o\pi^+\pi^+\pi^-$, in interactions on a carbon target of 40 to 70 GeV neutrons. The events in the peaks correspond to ~ 10 and ~ 5 standard deviations above background, respectively. The invariant cross section has been parametrized with $\exp(-\, bp_T)(1-x)^n$, where $b = 2.5\ (\mathrm{GeV}/c)^{-1}$. The best estimate of n is 1.5 ± 0.5.

One can see from Table 1 that the observed x dependence of Λ_c^+ produced by protons and neutrons is comparable to that of other baryons when one of the incident quark is replaced by another one.

The Bristol-Geneva-Heidelberg-Lausanne-Queen Mary College-Rutherford Appleton Lab Collaboration undertook in 1980 a search for strange charmed baryons at the SPS. In the Cabibbo-allowed decay modes of A^o (csd) and A^+ (csu), the charmed quark decays into a $(su\bar{d})$ quark combination. Thus the search concentrated in the final states of strangeness − 2 and electric charge 0 or + 1. This configuration of quantum numbers is naturally lower in background as the incoming beam consisted of Σ^- hyperons. The beam was tuned to its maximum momentum available of 135 GeV/c. The DISC was adjusted to tag about $2 \times 10^4\ \Sigma^-$ per burst. Figure 7 shows the layout of the apparatus. In addition to the eightfold DISC coincidence, the trigger logic was designed to select final states of the type $(\Lambda K^-\pi^+)$ + anything. For this purpose at least two charged particles were required in the hodoscope H1 near the target, at least four charged particles in H2 and H3, a K^- candidate in H4 and the Cherenkov C1, and a proton

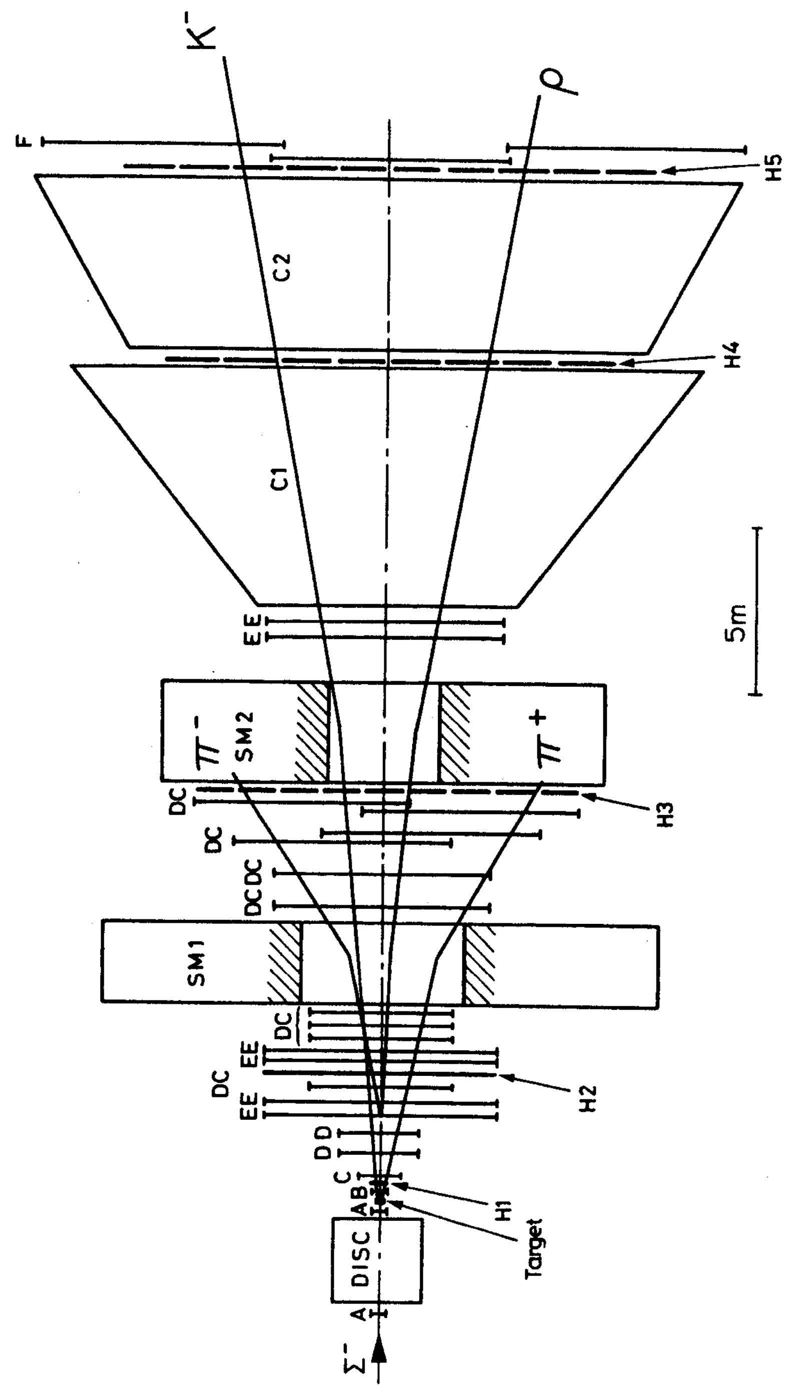

Fig 7

candidate in the positive-particle region of H5 and the Cherenkov C2. In 20 days of beam time, a total of 15 million triggers corresponding to 10^9 incident Σ^- were recorded.

The search for the $(\Lambda K^-\pi^+\pi^+)$ channel retained all events which had a combination of tracks giving a $(p\pi^-)$ effective mass within $\pm$ 4 MeV/c^2 of the Λ mass, a K^- candidate identified in the Cherenkov counters, which implied a momentum in excess of 17 GeV/c, and two positive particles which were assumed to be pions. The tracks of these last three particles had to intersect with the reconstructed Σ^- trajectory in the target.

With these rather straightforward criteria the $(\Lambda K^-\pi^+\pi^+)$ effective mass distribution shown in Fig.8 presents a prominent narrow peak at a mass of (2460 $\pm$ 15) MeV/c^2 with a width of 9 MeV/c^2 (r.m.s.) which is compatible with the experimental resolution. The statistical significance of the signal of (82 $\pm$ 16) events over the background is more than six standard deviations. If one considers events with only one $(\Lambda K^-\pi^+\pi^+)$ combination, the signal to background ratio is even increased from 1/1.8 to 1/1.5. The absolute value of the mass scale and its linearity have been checked with reconstructed known particles from the K^o to the Ω^-.

The longitudinal and transverse momentum distributions of the signal, background subtracted, yielded values of n = 1.7 $\pm$ 0.7 and $b = (1.1 {}^{+0.7}_{-0.4})(\mathrm{GeV/c})^{-2}$ for the invariant cross section parametrized as

$$E\,\frac{d^3\sigma}{d\vec{p}^{\,3}} \propto (1-x)^n\, e^{-bp_T^2}\,.$$

This result has been corrected for the effect of the apparatus acceptance, which is a steeply rising function of x starting at $x \sim 0.6$. The value of n is consistent with values found in this class of reactions where two valence quarks are replaced (see Table 1).

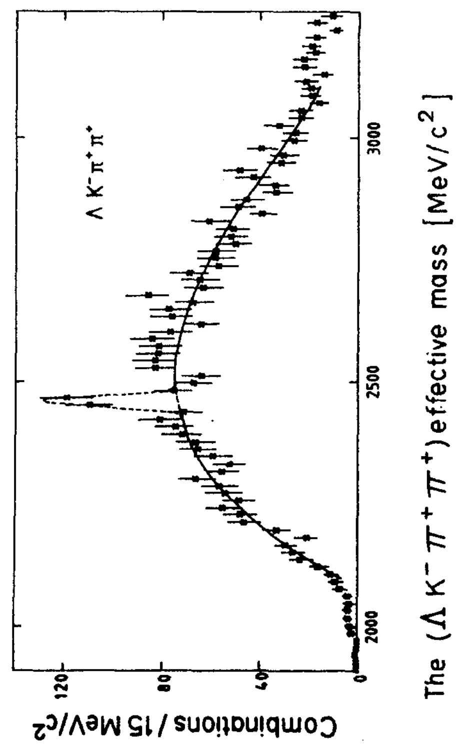

Fig. 8

The $\Lambda K^- \pi^+ \pi^+$ final state has baryon number +1, charge +1 and strangeness -1. It was checked that the peak is not a reflection of a misidentified strangeness -2 state. In view of its width which is narrower than 20 MeV/c^2 it can be the product of the decay of either a charmed strange baryon (csu) or an exotic state (ssuu$\bar{d}$). Its identification as the A^+ would be strenthened by anyone of the following observations.

a) Detection of associated anticharm ($\bar{D}$) production. This search was negative, however, due to the small apparatus acceptance for this requirement, coupled to the relatively small branching ratios.

b) Observation of the A^+ mother particle. No signal was observed, but the acceptance was again very small and the experiment had no photon detectors to be sensitive to the expected radiative decays.

c) Measurement of a lifetime typical of charmed particle decays: a lifetime of a few 10^{-13}s would result in a decay length of a few mm. This measurement is described in the second part of this talk.

It would be useful to calculate the total inclusive production cross sections to compare the various reactions producing charmed baryons between themselves and with QCD inspired models. Unfortunately the experimental results summarized in Table 2 are not sufficient to obtain reliable estimates of total cross sections per nucleon.

The main problems are:

a) *Extrapolation to unmeasured regions of x;*
b) Extrapolation from a cross section per nucleus to a cross section per nucleon with an unknown A dependence; this function is usually parametrized as A^α, where α has been shown[10] to vary with x for non-charmed particles (Fig.9);
c) Unknown or uncertain branching ratios (see Section 2.3); and
d) Unknown particle correlations when the experiment requires a signature from the associated anti-charmed particle.

	Reaction	$\sqrt{s}$	x	σ.B [μb/nucleus]
BIS-2	$n + C \to \Lambda_c^+ + X$ $\hookrightarrow p\ \overline{K^0}\ \pi^+\ \pi^-$ $\hookrightarrow \Lambda\ \pi^+\ \pi^+\ \pi^-$	∿ 10	> 0.5	 10 ± 4 2.3 ± 1.1
NA11/32	$p + Be \to \Lambda_c^+ + X + \bar{D}$ $\hookrightarrow p\ K^-\pi^+$	17	> 0.1	≤ 1.6*
WA62	$\Sigma^- + Be \to A^+ + X$ $\hookrightarrow \Lambda\ K^-\pi^+\ \pi^+$	16	> 0.6	5.3 ± 2.0
ISR	$p + p \to \Lambda_c^+ + X + \bar{D}$	∿ 60	Δx ∿ 0.2	2 - 3

* dependent on production dynamics

Table 2 - Total cross section for charmed baryon production.

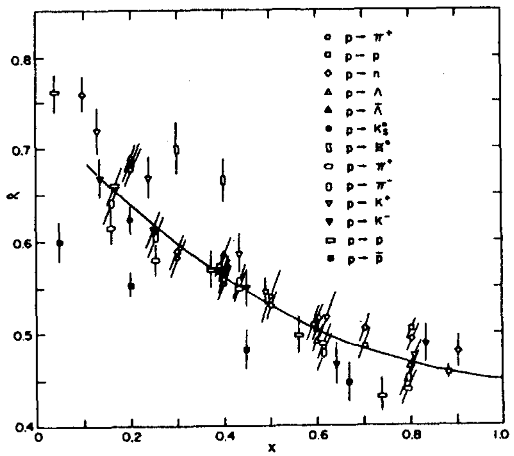

Fig. 9

One is forced to conclude that a substantial experimental effort is still required. This need is emphasized by the ongoing theoretical work on heavy quark production mechanisms, which is reviewed by S. Brodsky in the following talk.

2. Properties of strange and charmed baryons

2.1 Ω^- decay properties

Twenty years ago the discovery of the Ω^- [11] with the mass and strangeness expected for the tenth member of the $3/2^+$ decuplet supplied clear evidence for the SU(3) classification scheme proposed by Gell-Mann and Ne'eman. This year the WA2 collaboration has achieved the analysis of 16,000 decays collected in the SPS Hyperon Beam at 131 GeV/c.[12] A large number of new results have been obtained. The clean identification of the three main decay modes is illustrated in Fig.10 which presents: a) the ΛK^- vs $\Lambda\pi^-$ effective masses for the $\Omega^- \to \Lambda K^-$ sample, b) the $(\Omega^- - \pi^-)$ missing mass for the $\Omega^- \to \Xi^0\pi^-$ sample, and c) the $(\Omega^- - \Xi^-)$ missing mass squared for the $\Omega^- \to \Xi^-\pi^0$ sample. In b) and c) the shaded areas correspond to the events where one photon has been detected in a Pb-Glass array.

From the measurements of the angular distribution of the protons from the Λ decays or of the Λ from Ξ decays, the weak decay asymmetry parameters have been determined. They are all consistent with zero, indicating that each mode is nominated by a single partial wave, D or P:

$$\alpha(\Omega^- \to \Lambda K^-) = -\,0.025 \pm 0.028,$$
$$\alpha(\Omega^- \to \Xi^0\pi^-) = 0.09 \pm 0.14, \text{ and}$$
$$\alpha(\Omega^- \to \Xi^-\pi^0) = 0.05 \pm 0.21.$$

Combining the branching ratio and lifetime measurements of this experiment with a previous lower statistic one in the same SPS hyperon beam gives

$$\Gamma(\Omega^- \to \Lambda K^-)/\Gamma(\Omega^- \to \text{all}) = 0.678 \pm 0.007,$$
$$\Gamma(\Omega^- \to \Xi^0\pi^-)/\Gamma(\Omega^- \to \text{all}) = 0.236 \pm 0.007,$$
$$\Gamma(\Omega^- \to \Xi^-\pi^0)/\Gamma(\Omega^- \to \text{all}) = 0.086 \pm 0.004, \text{ and}$$

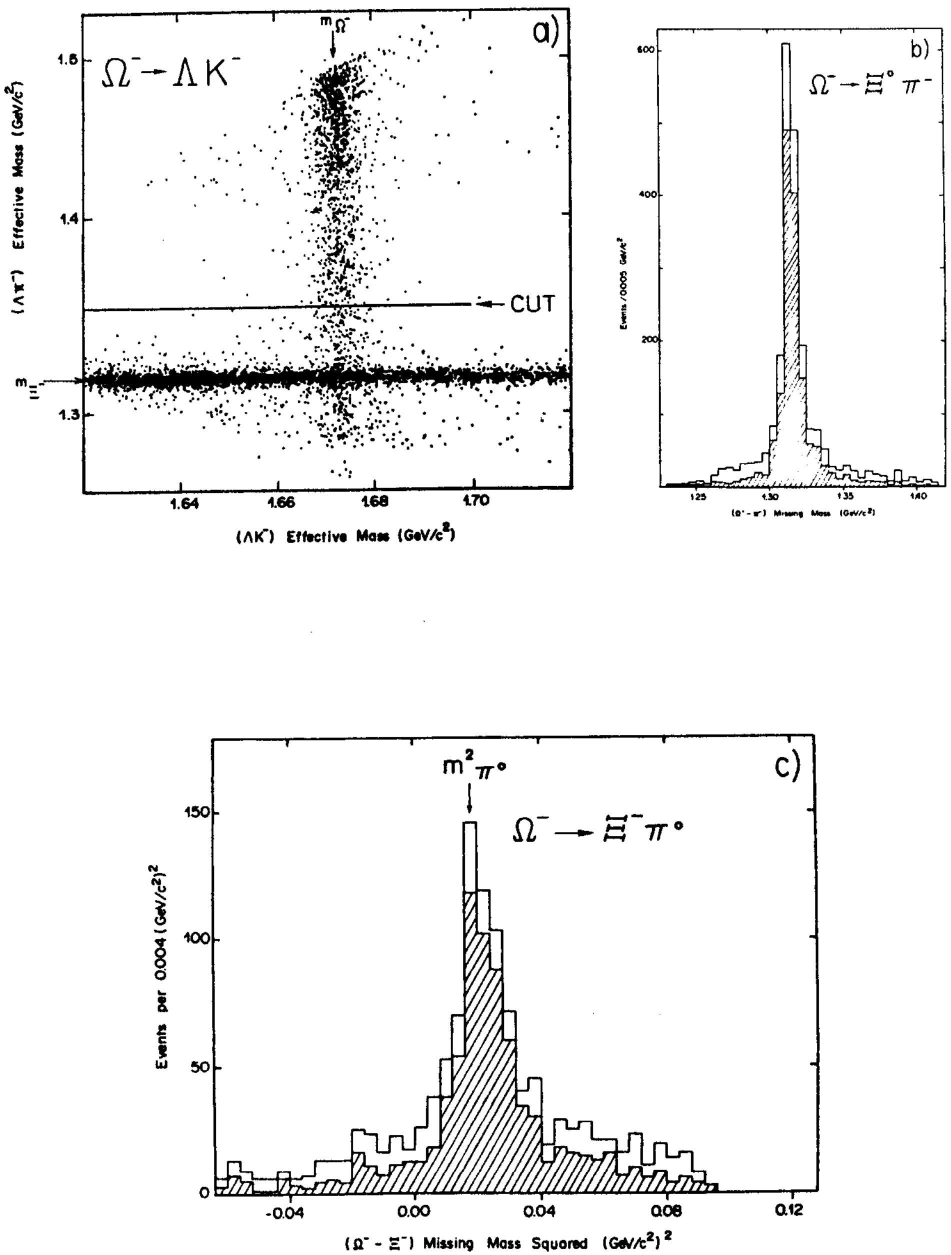

Fig. 10

$$\tau_{\Omega^-} = (0.823 \pm 0.013) \times 10^{-10} s.$$

Of particular interest is the ratio $\Gamma(\Xi^0\pi^-)/\Gamma(\Xi^-\pi^0)$ which is found to be 2.72 ± 0.17 (for the 131 GeV/c sample). Pure $|\Delta\vec{I}| = 1/2$ transitions would lead to a value of 2.07, including phase space corrections. A coherent description of the non-leptonic decays of kaons and octet hyperons has been developed,[13] using the QCD framework. The elementary process for such decays is the scattering $s+u \rightarrow u+d$. As the Ω^- contains only strange valence quarks, several diagrams corresponding to $|\Delta\vec{I}| = 1/2$ transitions are suppressed so that the $|\Delta\vec{I}| = 3/2$ contribution is enhanced, explaining the above ratio.[14,15] In this model the weak Hamiltonian can be decomposed into six operators O_1 to O_6. The observed rates of the $\Xi\pi$ decay modes allow the calculation of the contributions from the last three operators, the first ones being fixed from other decays. The value of the O_4 term which corresponds to $|\Delta\vec{I}| = 3/2$ amplitudes is in agreement with values obtained from the pure $|\Delta\vec{I}| = 3/2$ $K^+ \rightarrow \pi^+\pi^0$ decay amplitude.

A prediction of the model is that the three main decay modes are dominated by P-wave amplitudes, in agreement with the asymmetry parameter measurements.

Four events of the type $\Xi^-\pi^+\pi^-$ have been found, giving an estimate of the branching ratio

$$\Gamma(\Omega^- \rightarrow \Xi^-\pi^+\pi^-)/\Gamma(\text{all}) = (4.3 {}^{+3.4}_{-1.3}) * 10^{-4}.$$

The four events are compatible with an intermediate $\Xi^*(1350)\pi^-$ state. This branching ratio is, however, notably smaller than the QCD prediction, calculated using the terms obtained with the other decays.

Seventeen decays candidates $\Xi^0 e^- \bar{\nu}$ have been isolated. This is the first observation of the semileptonic decay of a member of the baryon decuplet. The branching ratio is

$$\Gamma(\Omega^- \rightarrow \Xi^o e^- \bar{\nu})/\Gamma(\mathrm{all}) = (0.55 \pm 0.28) \times 10^{-2}$$

in agreement with the prediction of Finjord and Gaillard.[15)] Finally a search for the radiative mode $\Xi^-\gamma$ has led to an upper limit of the branching ratio

$$\Gamma(\Xi^-\gamma)/\Gamma(\mathrm{all}) < 2.2 \times 10^{-3} \text{ (at 90 \% C.L.)},$$

and a search for the $\Delta S = 2$ mode $\Lambda\pi^-$ has set an upper limit

$$\Gamma(\Lambda\pi^-)/\Gamma(\mathrm{all}) < 3.2 \times 10^{-4} \text{ (at 90 \% C.L.)}.$$

2.2 Measurement of the A^+ lifetime

The apparatus of experiment WA62 did not include any high-resolution vertex detector. The 8 cm long Be target was preceeded and followed by MWPC's with 0.5 mm wire spacing (denoted A and B on Fig.7). It was thus not possible to measure a transverse displacement of the A^+ with respect to the incident Σ^-. Only the longitudinal difference, named Δz, between the A^+ production and decay vertices could be determined. It is illustrated in Fig.11 which shows also the decay vertex of the associated anticharmed particle, named $\bar{D}^-$, although no evidence for it could be obtained.

To reconstruct accurately the production (V_p) and decay (V_A) vertices, tracks were fitted using only the information from the first 3 chamber modules (20 planes) downstream of the target. The decay vertex was reconstructed from the K^- and the two π^+ tracks only, which had to be closer than 700 μm (r.m.s.). Only events with a single $K^-\pi^+\pi^+$ combination were retained. There remained 61 A^+ events above a background of 91 (Fig.12a). The production vertex was reconstructed from the tracks of the incoming Σ^- and of additional particles, if any, emerging from the target

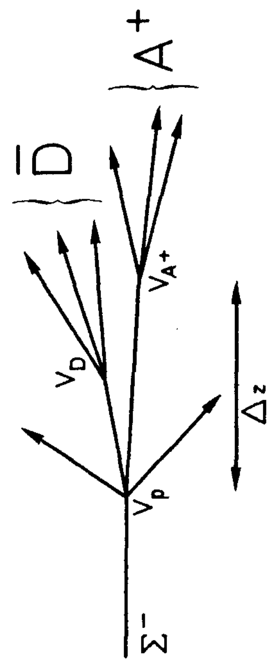

Fig. 11

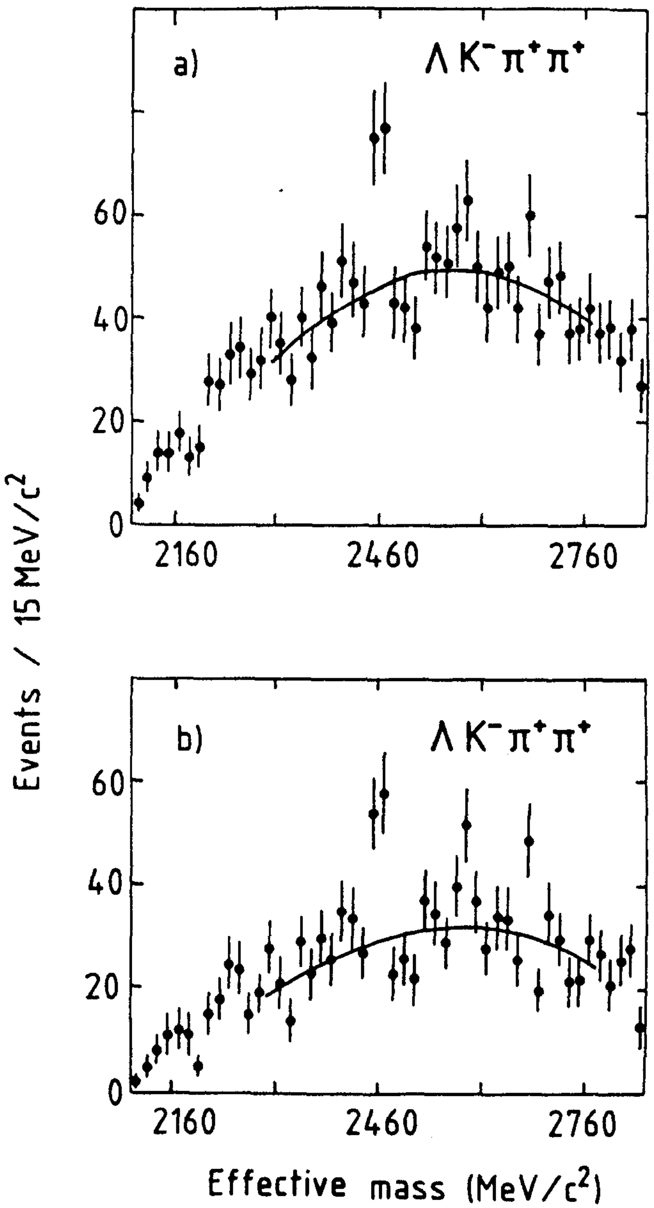

Fig. 12

(Fig.11). The angle of those additional particles with that of the Σ^- had to be larger than 20 mrad. These particles were not required to pass though SM1, thereby increasing the maximum accepted angle. The vertex position had to be inside the target and the r.m.s. distance between all tracks used for its reconstruction had to be less than 700 μm. There remained 53 A^+ events over a background of 59 (Fig.12b).

The distribution of Δz is shown in Fig.13 for various event samples. A positive value means that the A^+ decay vertex is downstream of the production vertex. The sample in Fig.13a consists of the "far background", i.e. all the events with $m(\Lambda K^-\pi^+\pi^+) <$ 2370 MeV/c^2 or $m(\Lambda K^-\pi^+\pi^+) >$ 2550 MeV/c^2. One notices that the mean of this distribution is at zero and its width is 6 mm(r.m.s.). Figure 13b *contains the events in the* A^+ *signal bins and it is shifted* to positive values. Figure 13c shows the "near background," which, like the "far background," is centered at zero. Subtracting the Δz spectrum of the normalized "near background" from that of the A^+ signal bins, one obtains the distribution of Fig.13d for the A^+ signal. This last distribution shows a clear shift to positive values, which can be fitted with A^+ decaying with a lifetime

$$\tau_{A^+} = (4.8 \begin{smallmatrix} +\ 2.9 \\ -\ 1.8 \end{smallmatrix}) \times 10^{-13}\ \text{s}.$$

The quoted error contains systematic uncertainties on

a) background subtraction (1×10^{-13} s) and
b) possible use of tracks from $\bar{D}$ decay, which tends to shorten the A^+ lifetime measurement (1.7×10^{-13} s on the positive side only).

This result can be compared with the only other measured charmed baryon lifetime

$$\tau_{\Lambda_c^+} = (2.2 \begin{smallmatrix} +\ 0.7 \\ -\ 0.4 \end{smallmatrix}) \times 10^{-13}\ \text{s}.$$

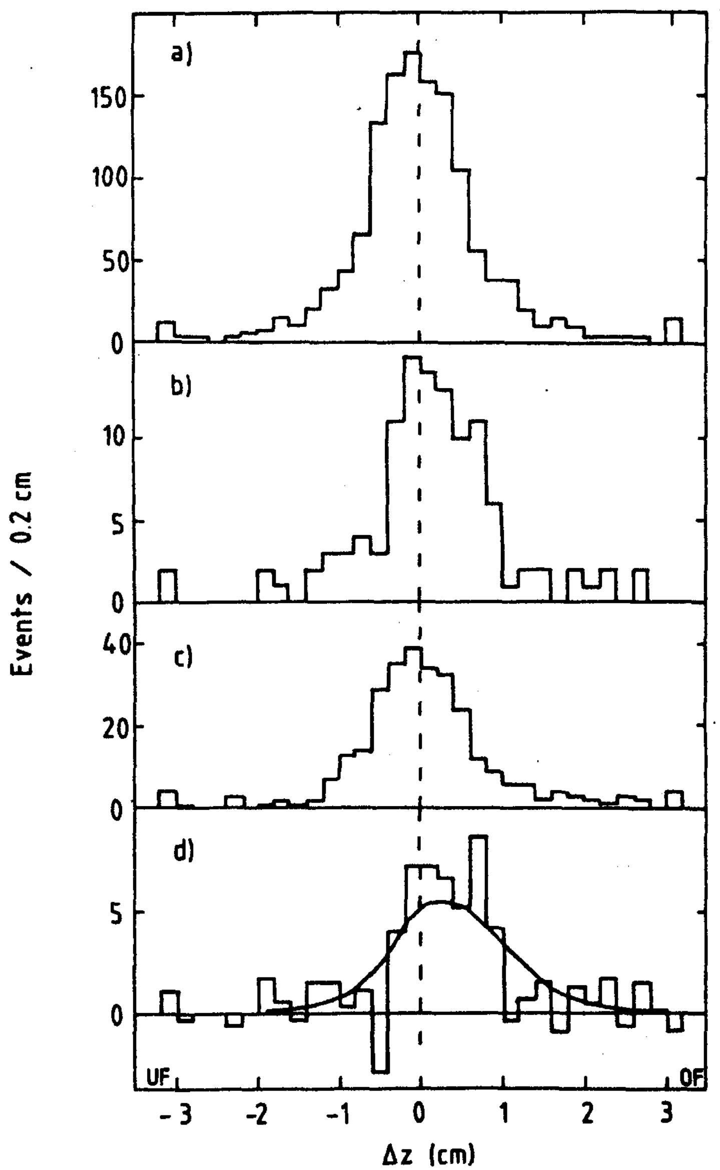

Fig. 13

This value is a world average from 19 events detected in 3 different experiments.[16] One notices that τ_{A^+} is about twice $\tau_{\Lambda_c^+}$ (but the difference is only 2 standard deviations). If charmed baryons decay by spectator and exchange diagrams, such an effect is expected: exchange processes $c+d \rightarrow s+u$ can contribute to Λ_c^+ (cdu) decays but not to A^+ (csu) decays. This effect is also supported by the difference between the lifetimes of the charged and neutral D mesons.

2.3 A^+ and Λ_c^+ branching ratios

The A^+ decay channels which could be investigated in experiment WA62 were restricted by the absence of a photon or neutron detector and by the trigger requirements. No other decay mode but $A^+ \rightarrow \Lambda K^- \pi^+ \pi^+$ was observed and several upper limits have been set with respect to the observed channel:

$A^+ \rightarrow p\, K^-\, \bar{K}^0\, \pi^+$	< 0.08,
$p\, K^-\, K^-\, \pi^+\, \pi^+$	< 0.03, and
$\Omega^-\, K^+\, \pi^+$	not seen.

The fraction of the Λ_c^+ *decays observed in other experiments is still* very small ($\sim$ 10 %). From Reference 2 one has the following branch*ing ratios (in %):*

$\Lambda_c^+ \rightarrow p\, K^- \pi^+$	2.2 ± 1.0,
$p\, \bar{K}^0$	1.1 ± 0.7,
$\Lambda\, \pi^+$	0.6 ± 0.5,
$\Sigma^0 \pi^+$	seen,
e^+ + anything	4.5 ± 1.7,
$p\, K^*$ (890)	seen, and
$\Delta^{++}\, K^-$	seen.

2.4 Evidence for T^0 decays

The Cabibbo allowed decays of the double strange charmed baryon T^0 (css) would result in final states of charge zero and strangeness

– 3, e.g. $\Xi^- K^- \pi^+ \pi^+$, with $\Xi^- \to \Lambda\pi^-$. Using the same sample of events that yielded the A^+ signal, i.e. $\Lambda K^- \pi^+ \pi^+$ combinations, a search was made for additional negative pions intersecting the Λ line of flight. Figure 14 shows the resulting $\Lambda\pi^-$ effective mass distribution with a clear peak of 20 events at the Ξ^- mass, none of them contained in the A^+ signal bins. The $\Xi^- K^- \pi^+ \pi^+$ effective mass distribution (Fig.15a) yields 26 combinations. The following figures show attempts at better identification of the final state by only using events with a production vertex V_p as defined in 2.2 (Fig.15b), with a $K^- \pi^+$ combination near the K^* (890) mass (Fig.15c), or with a $\Xi^- \pi^+$ combination near the Ξ^* (1530) mass (Fig.15d).

The requirement of both a reconstructed production vertex and a K^* (890) gave the distribution of Fig.16 with six combinations from four events, three of them grouped around (2740 ± 25) MeV/c^2.

This value is expected for the T^o (as discussed below). Further evidence is obtained from the calculation of the Δz values: in particular the three combinations at 2740 MeV/c^2 have positive Δz, compatible with the distribution obtained with A^+ events (Fig.17).

A calculation of the T^o production cross section times branching ratio is not possible as the acceptance is a strong function of the unknown T^o momentum spectrum. However, if one makes the rough assumption that the A^+ and T^o spectra are equal, then the acceptance of T^o would be about half that of A^+. We can see in Fig.4 that the ratio of Σ^- over Ξ^- production in pN collisions is 20 at $x \sim 0.7$. The observation of three T^o decays, as compared to 53 A^+ decays, is therefore of the expected order of magnitude.

2.5 Charmed baryons masses

Several authors[17)] have calculated the charmed baryon mass spectrum. Table 3 lists predicted mass differences between Λ_c^+, A^+ and T^o. The world average of 2282 MeV/c^2 is used for the Λ_c^+ mass,

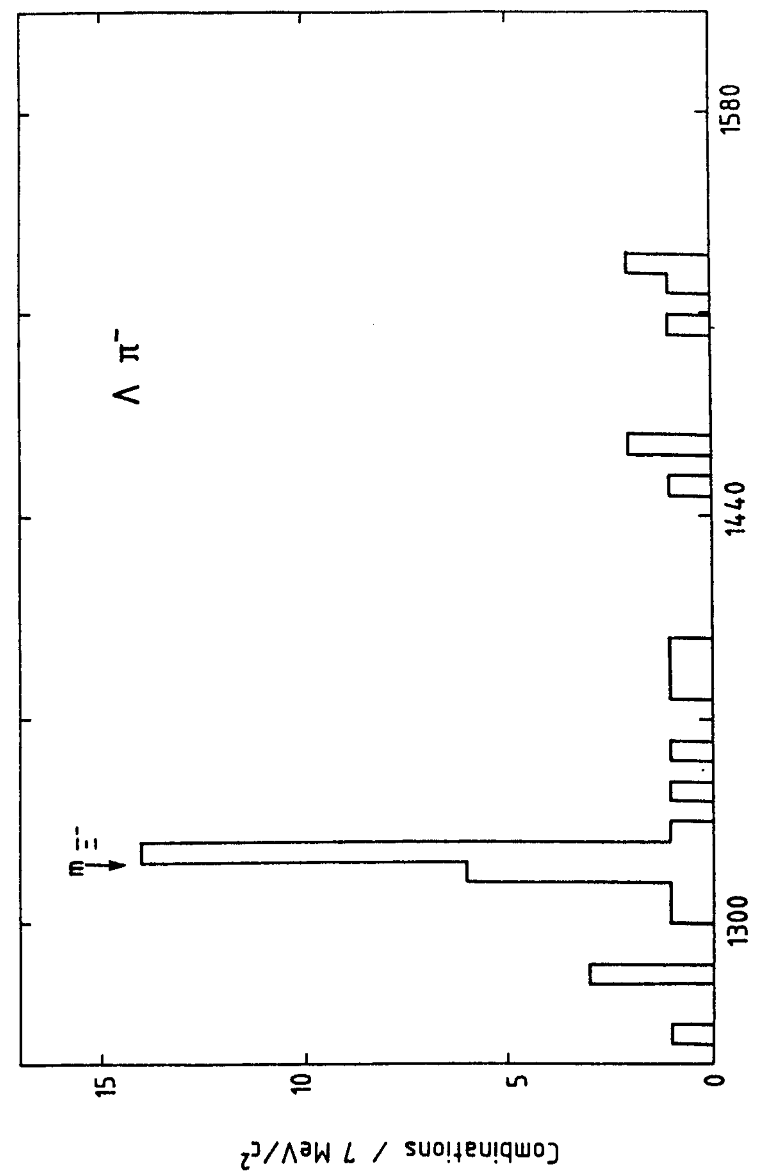

Fig. 14

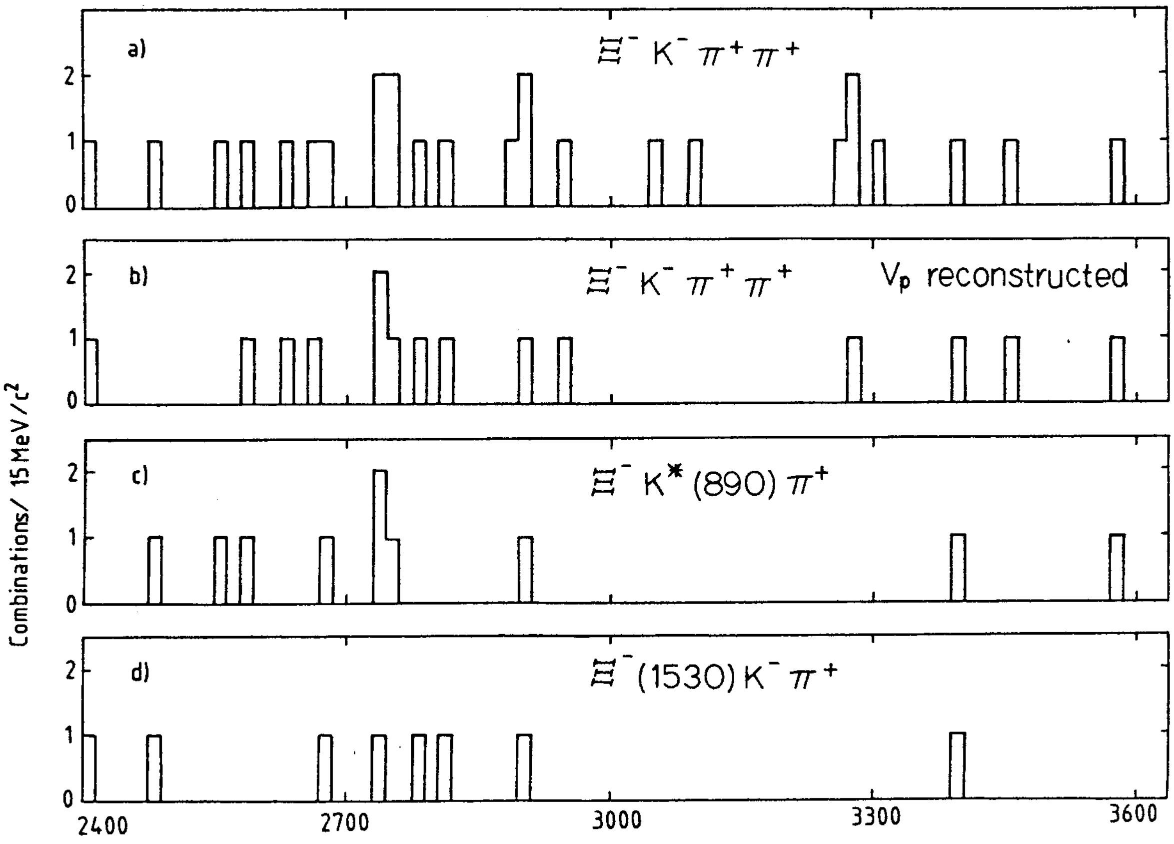
a)
$\Xi^- K^- \pi^+ \pi^+$
b)
$\Xi^- K^- \pi^+ \pi^+$
V_p reconstructed
c)
$\Xi^- K^*(890)\, \pi^+$
d)
$\Xi^-(1530)\, K^- \pi^+$
Combinations/ 15 MeV/c^2
0
1
2
2400
2700
3000
3300
3600
Effective mass (MeV/c^2)

Fig. 15

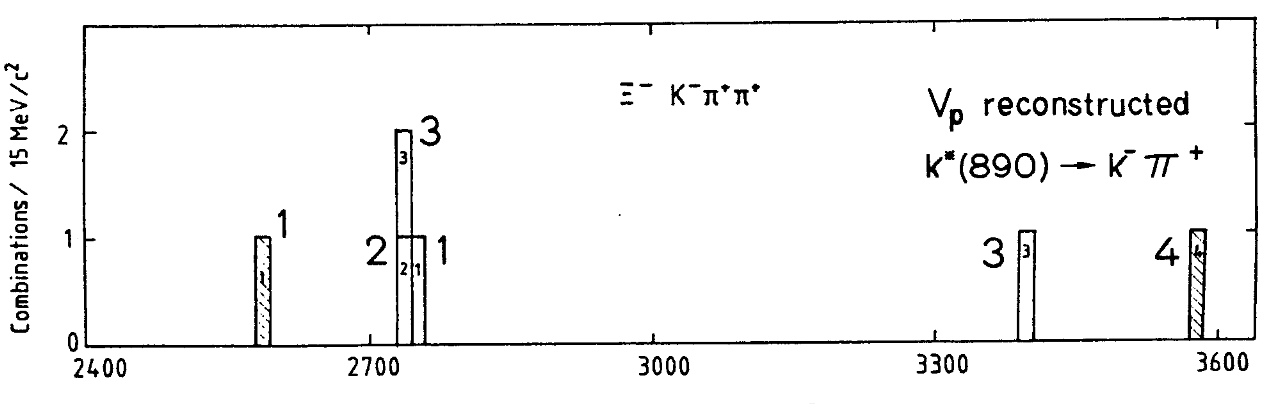
$\Xi^- K^- \pi^+ \pi^+$
V_p reconstructed
$K^*(890) \rightarrow K^- \pi^+$
1
3
2
1
3
4
Combinations/ 15 MeV/c^2
0
1
2
2400
2700
3000
3300
3600
Effective Mass (MeV/c^2)

Fig. 16

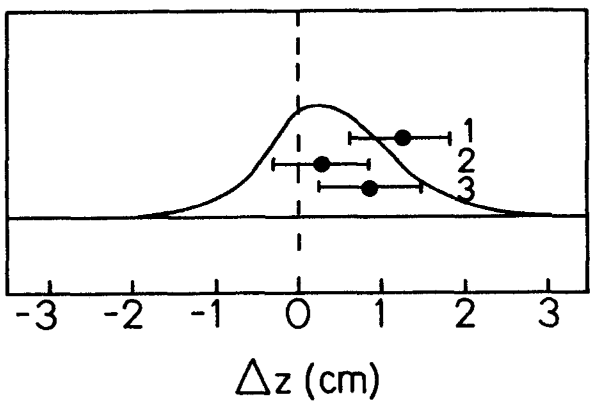

Fig. 17

	$A^+ - \Lambda_c^+$	$T^o - \Lambda_c^+$	$T^o - A^+$
De Rujula et al.	220	480	260
Fuchs and Scadron	110	550	440
Körner et al.	210	470	260
Maltman and Isgur	220	470	250
Sakharov	235	500	265
Vaisenberg	110	470	360
Richard and Taxil	180	380	200
WA62 Experiment	180 ± 15	460 ± 20	280 ± 20

Table 3 - Charmed Baryon Mass Differences in MeV/c^2.

but it should be kept in mind that there are large variations between experiments. One notices the excellent agreement with the experimental values for the quark model of De Rujula, Georgi, Glashow, for its version using different inputs by Körner et al., and for the quark model with QCD of Maltman and Isgur.

2.6 Search for A^o decays

The A^o decay mode which would be most similar to the observed decay $A^+ \to \Lambda K^- \pi^+ \pi^+$ would be $A^o \to \Lambda K^- \pi^+ \pi^o$. However, this mode could not be detected in the WA62 experiment, due to the absence of photon detectors. Thus, the $\Lambda K^- \pi^+$ effective mass was calculated (Fig.18); it contains about 20 thousand events. No signal is apparent at the expected mass (the A^+ mass within a few MeV/c^2). An upper limit of 40 events (90 % CL) can be set corresponding to a limit on the production cross section times branching ratio for $A^o \to \Lambda K^- \pi^+$ of about 3.1 μb/nucleus (depending somewhat on the production mechanism).

3. Summary

Our knowledge of the Ω^- lifetime and branching ratios is now of the same quality as for the other hyperons.

There is still little known on the production of charmed baryons in hadron interactions. For the Λ_c^+ and A^+, the x dependence shows that they are produced like "leading particles," as the hyperons. The estimate and comparison of integrated cross sections still requires more data on the x dependence over the complete x range, on the A dependence, and on branching ratios.

The usefulness of a Σ^- beam to produce strange charmed particles has been demonstrated. In the SPS hyperon beam the following properties have been measured:

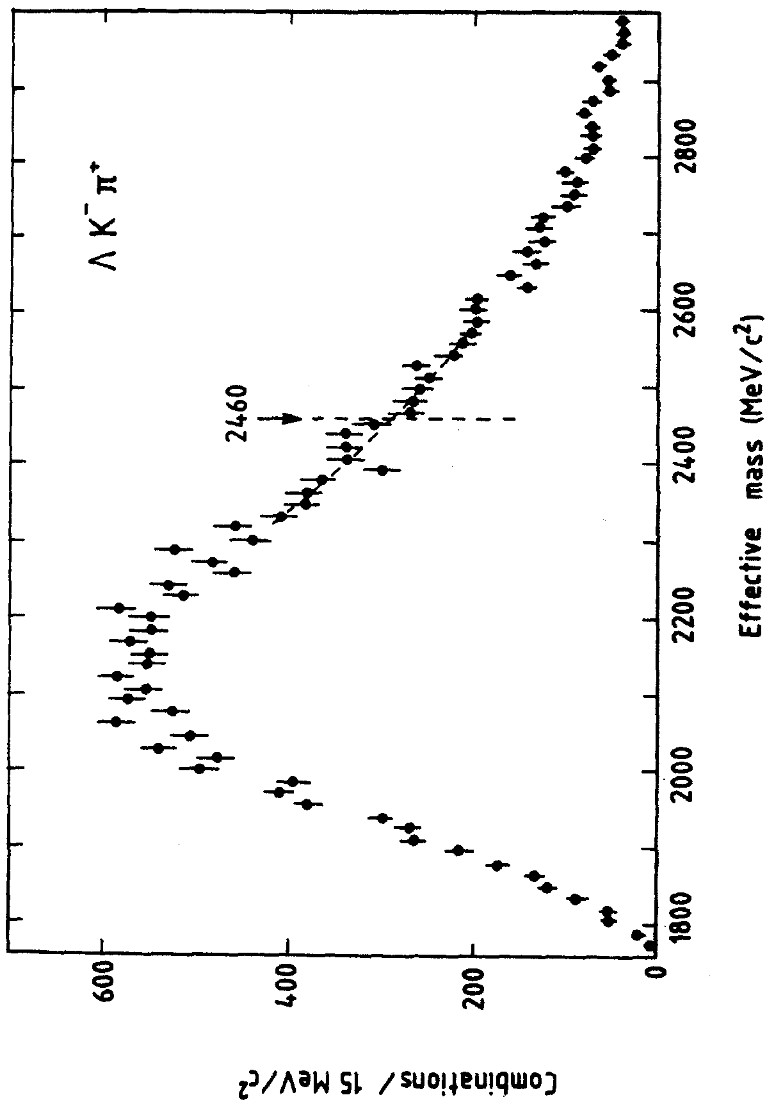

Fig. 18

$$m_{A^+} = (2460 \pm 15)\ \mathrm{MeV}/c^2 ,$$
$$\tau_{A^+} = (4.8 {+2.9 \atop -1.8}) \times 10^{-13}\ \mathrm{s} , \text{ and}$$
$$m_{T^o} = (2740 \pm 25)\ \mathrm{MeV}/c^2 .$$

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