~~To be submitted to~~ Physics Letters 5, 261, '63

CERN/TC/PHYSICS 63-10
21.6.1963

33/63

Ξ^- Properties

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PS/3875/jc

We have measured the mass, lifetime, and α parameter of the Ξ^-, on a sample of 320 Ξ^- produced in the Ecole Polytechnique 1 x 1/2 x 1/2 m^3 heavy liquid bubble chamber[1] by a beam[2] of $1.45 \pm .03$ GeV/c K^- at the CERN PS. The liquid was freon 115 ($C_2 F_5 Cl$ having a density of 1.2 gm/cm^3, radiation length 25 cm); the magnetic field of the chamber was 1.7 W/m^2. These events are from 210.000 scanned photos containing about 3 useful K^- interactions per photo. (The π^- contamination of the beam was less than 2 o/o).

Selection of Ξ^- Events

These Ξ^- were produced in the reactions

$K^- + p \longrightarrow \Xi^- + K^+ (\pi^0)$ or $\Xi^- + K^0 + \pi^+$

$K^- + n \longrightarrow \Xi^- + K^0 (\pi^0)$ or $\Xi^- + K^+ + \pi^-$

Two types of events were retained at the scanning stage:

1) "Signed Ξ^-": i.e. $\Xi^- \longrightarrow \Lambda + \pi^-$ followed by $\Lambda \longrightarrow p + \pi^-$ together with signature of $K^0 \longrightarrow \pi^+ + \pi^-$ or characteristic disintegration of stopped K^+, all visible in the chamber fiducial volume.

2) "Unsigned Ξ^-": as above but with no visible K^0 or K^+ decay.

We present here only results from 320 signed Ξ^-. The unsigned events are still being analysed.

The CERN events were passed through the THRESH-GRIND system[3] and Ξ^- events selected on the basis of the usual χ^2 criteria. Similarly events from U.C.L. and N.I.R.N.S. were passed through the N.I.R.N.S. analysis system[4]. Essentially equivalent criteria were adopted for the Paris and Bergen events which had to satisfy the obvious coplanarity, transverse momentum, and Q value tests to within two standard deviations.

Many of the secondaries (roughly 1/3 of the π^- from Ξ^-, and 2/3 of protons from Λ^0) stop in the chamber liquid permitting precise estimation of momentum by measuring the range. For this purpose we have calibrated our range momentum relations using the decays $K^+ \longrightarrow \mu^+ + \nu$ and $K^+ \longrightarrow \pi^+ + \pi^0$ (assuming $M_{K^+} = 0,4939$ GeV) from K^+ at rest obtained in the same run. Thus for stopping particles, the momentum precision is limited essentially by straggling and measurement error (totalling typically $\pm$ 2 o/o).

Ξ^- Mass

We have 82 events where the π^- from the Ξ^- stops in the BC liquid, permitting a particularly accurate Ξ^- mass determination. They give a weighted mean Ξ^- mass of:

$$M_{\Xi^-} = 1321.4 \pm 0.6 \text{ Mev}$$

which we consider to be our best estimate. Note that any possible systematic errors in the magnetic field table would have only a small effect on this value and that the exact value of the beam momentum is irrelevant. (M_Λ = 1115.5 Mev and M_{π^-} = 139.6 Mev were used).

If essentially all Ξ^- are included we have

$$M_{\Xi^-} = 1321.0 \pm 0.5 \text{ Mev}$$

These values are in good agreement with other recent determinations[5,6].

As a check we have calculated the Λ^o mass for those Λ's with stopping protons and π^-, and find

$$M_\Lambda = 1115.7 \pm 0.3 \text{ Mev}$$

and for essentially all Λ's

$$M_\Lambda = 1115.6 \pm 0.3 \text{ Mev.}$$

The agreement of this Λ mass with other recent measurements[(6)], gives further confidence that no significant bias is introduced by our various measurement and fitting proceedures and in particular by our range momentum relation. We find also that the analysis systems used by the various collaborating groups yield entirely compatible values and errors for the Ξ^- and Λ masses, and that Ξ^- masses calculated using only the fitted Λ and measured π^- variables (no constraint) agree well with those calculated using in addition the measured Ξ^- direction (two constraint fit).

Ξ^- Mean Life

Using for each event the fitted Ξ^- momentum (for $M_{\Xi^-} = 1321$ Mev) we calculate the Ξ^- flight time and potential flight time for each event, allowing for slowing down of the Ξ^- in the chamber liquid. A maximum likelihood estimate of the apparent mean life of the Ξ^- gives the value: $\tau_{\Xi^-} = 1.82 {}^{+0.16}_{-0.14} \times 10^{-10}$ sec. Fig. 1 shows the time distribution without corrections for Ξ^- escape or absorption. The maximum likelihood estimate includes the escape correction, of course, but we must correct this value for loss of Ξ^- due to absorption in the liquid (see below).

We have taken as potential path length for each event, the shortest of the following 3 distances obtained by translating the event along the Ξ^- line of flight:

1) to the point where either the Λ^o or the Ξ^- decay point would leave the chamber fiducial volume;

2) until the potential path length of the Ξ^- exceeds 15 cms (greater than 3 mean lives for the highest momentum Ξ^- obtained). (This avoids a possible scanning bias for long Ξ^-);

3) to the point where the Ξ^- would have slowed down to 400 MeV/c. (This cut-off avoids an uncertain correction for absorption of slow Ξ^-. The choice of 400 MeV/c is arbitrary in so far as the absorption cross section is unknown, but we have verified that the choice is not critical (fig.2)).

To avoid further possible scanning bias and large measurement errors we have also rejected those Ξ^- whose path length was less than 0,6 cms, or where the Λ^o path length from the Ξ^- decay point was less than 0,3 cms or greater than 20 cms. We have verified that these cut offs do not influence our result significantly (provided that the first one is 0,6 cms or greater (fig.2)).

We must correct the above apparent mean life for absorption of Ξ^- in the bubble chamber liquid. This correction is about 5 o/o if we take 35 $\pm$ 15 mb as a reasonable estimate of the total Ξ^- - nucleon cross section (this figure is consistent with some 14 Ξ^- interactions we have actually observed in the liquid).

With this correction, our estimate of the Ξ^- mean life becomes:

$$\tau_{\Xi^-} = 1.91^{+0.17}_{-0.15} \times 10^{-10} \text{ sec}$$

As a check we find the corrected value of the mean life of the daughter Λ^0's from the Ξ^- to be

$$\tau_{\Lambda} = 2.44^{+0.20}_{-0.17} \times 10^{-10} \text{ sec}$$

These values are consistent with our more preliminary results[7] and with other recent determinations[5,6,8]. Thus our ratio[7]: $\tau_{\Xi^0}/\tau_{\Xi^-} = 2.0^{+0.7}_{-0.5}$ remains in good agreement with the $\Delta I = 1/2$ rule prediction.

α_{Ξ}

It is well known[9] that the probability distribution of the angle Θ between the direction of motion of the proton (of the Λ^0) in the rest frame of the Λ^0 and the direction of the Λ^0 in the rest frame of the Ξ^- is of the form:

$$I(\Theta) = 1 + \alpha_{\Lambda}\, \alpha_{\Xi} \cos\Theta$$

irrespective of the spin of the Ξ.

Fig. 3 shows our distribution of cos Θ. A maximum likelihood method gives:

$$\alpha_{\Lambda}\, \alpha_{\Xi^-} = -\,0.33 \pm 0.09$$

Taking[10] $\alpha_{\Lambda} = -\,0.62 \pm 0.07$

we have

$$\alpha_{\Xi} = +\,0.53 \pm 0.16$$

compatible with other recent measurements[5,6,12].

Our sample of 320 signed Ξ^-, taken as a whole, shows no significant polarization. Thus we are at present unable to make any straightforward estimate of the Ξ^- spin or of β and γ.

Ξ^- Leptonic Decays

Electrons are directly recognized at the scanning stage by their rapid spiralization due to bremsstrahlung in the heavy liquid (and occasionally by large δ rays or by materialization of a bremsstrahlung quantum). The detection probability of a Ξ^- electron secondary is about 80 o/o. We have found no candidate $\Xi^- \rightarrow \Lambda + e^- + \nu$ among the 320 Ξ^- with signature. As one such event would correspond to the branching ratio $\dfrac{\Xi^- \rightarrow \Lambda + e^- + \nu}{\Xi^- \rightarrow \Lambda + \pi^-} = \dfrac{1}{250}$ we conclude that this branching ratio is less than 1 o/o with 90 o/o confidence.

$\Xi^0 + n \rightarrow \Xi^- + p$ event

We have found an event which we interpret as a Ξ^0 charge exchange. (Fig. 4). The Ξ^- and the K^0 signature fit well ($Q_{\Xi^-} = 79.4 \pm 8$ Mev) and the Ξ^-, p and supposed Ξ^0 lines of flight are nearly coplanar ($< 1^0$, which is well within the deviation possible due to Fermi momentum).

Ξ^- Inelastic Interactions

We have found 2 events which could be examples of the reaction

$$\Xi^- + Z \longrightarrow \Xi^o_\delta + Z' \text{ followed by } \Xi^o_\delta \longrightarrow \Xi^- + \pi^+$$

on a nucleus in the chamber liquid. (The notation is that of Glashow + Rosenfeld[11]). These two events give

$M_{\Xi^- \pi^+}$ = (1533 $\pm$ 7 Mev) and (1515 $\pm$ 20 Mev). Fig. 5 shows one of them.

Acknowlegements

We are very grateful to Professors L. Leprince-Ringuet, Ch. Peyrou, B. Trumpy, C.A. Ramm, R.G.P. Voss and J. Prentki for their sustained interest.

We thank especially Professor A. Lagarrigue who has headed our collaboration.

The K^- beam was due to the CERN TC, NPA and MPS divisions. We thank especially Drs. H. Filthuth and A. Segar.

The CERN group in particular are very grateful to many people in the DD Division, and especially Dr. R. Böck and Mlle. A. Cnops, for their indispensible aid in setting up and in using our data analysis system. The N.I.R.N.S. and U.C.L. groups would like similarly to thank A.G. Wilson and J.M. Sparrow.

We would like also to thank the CERN PS Division, our linkman Dr. F. Bonaudi, the many people who operated the chamber and beam, and the scanning, measuring and computing staffs of the several laboratories.

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Figure Captions

Fig. 1 Cumulative distribution of observed Ξ^- flight times (uncorrected). Bartlett method gives apparent Ξ^- mean life of $1.82^{+0.16}_{-0.14} \times 10^{-10}$ sec. After correction for Ξ^- absorption in liquid, best estimate is $\tau_{\Xi^-} = 1.91^{+0.17}_{-0.14} \times 10^{-10}$ sec.

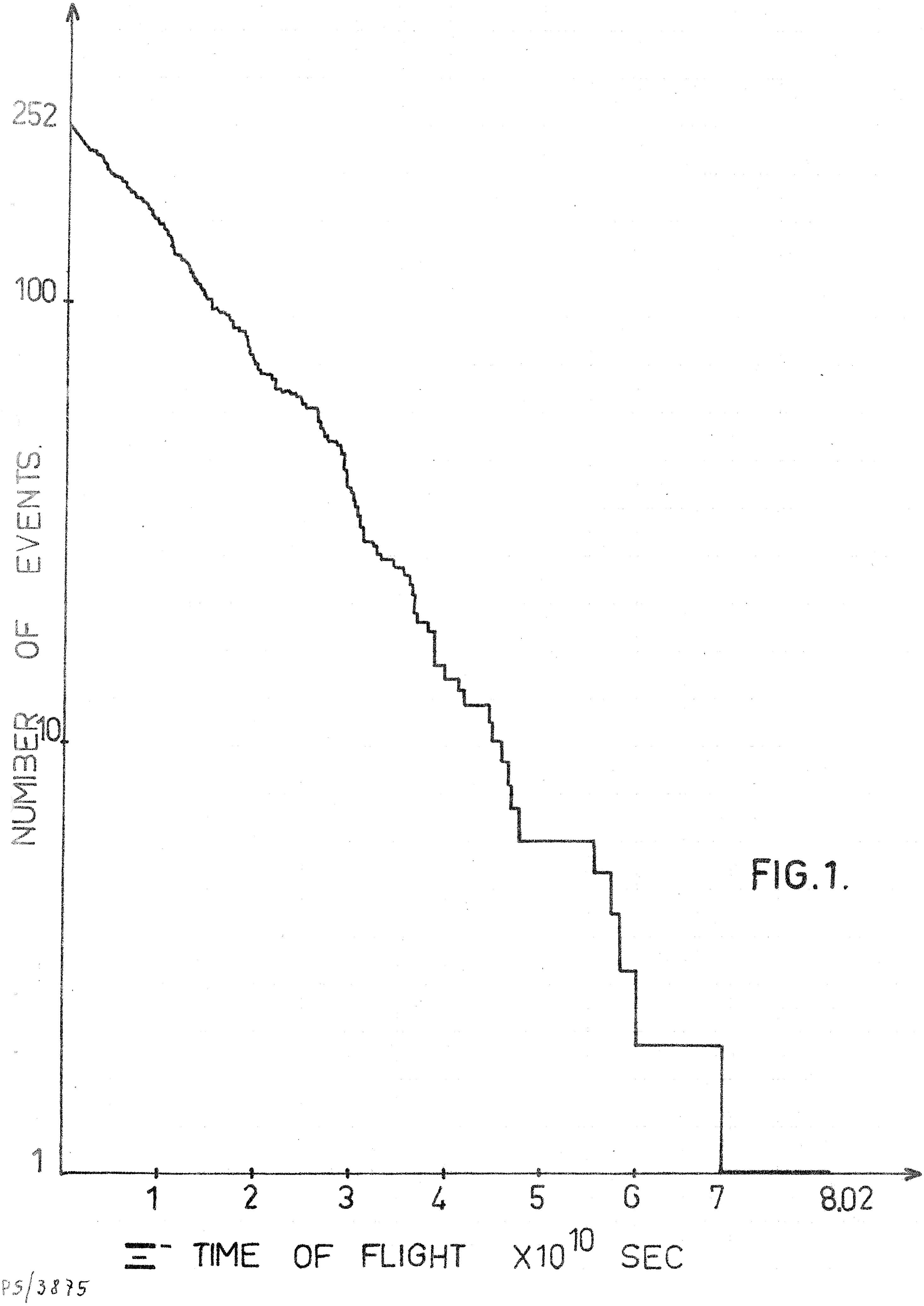
Fig. 2 Curves showing insensitivity of observed Ξ^- mean life with respect to various selection criteria ("cut-offs")

a) Minimum Ξ^- momentum;

b) Minimum Ξ^- flight path length from production point to decay point;

c) Minimum Λ flight path length from Ξ^- decay point to Λ decay point.

Fig. 3 Distribution of angle Θ between proton direction in Λ rest system and Λ direction in Ξ^- rest system. Maximum likelihood estimate gives $\alpha_{\Lambda}\, \alpha_{\Xi^-} = -0.33 \pm 0.09$.



252
100
10
1
NUMBER OF EVENTS
1
2
3
4
5
6
7
8.02
Ξ⁻ TIME OF FLIGHT X10^10 SEC

FIG.1.

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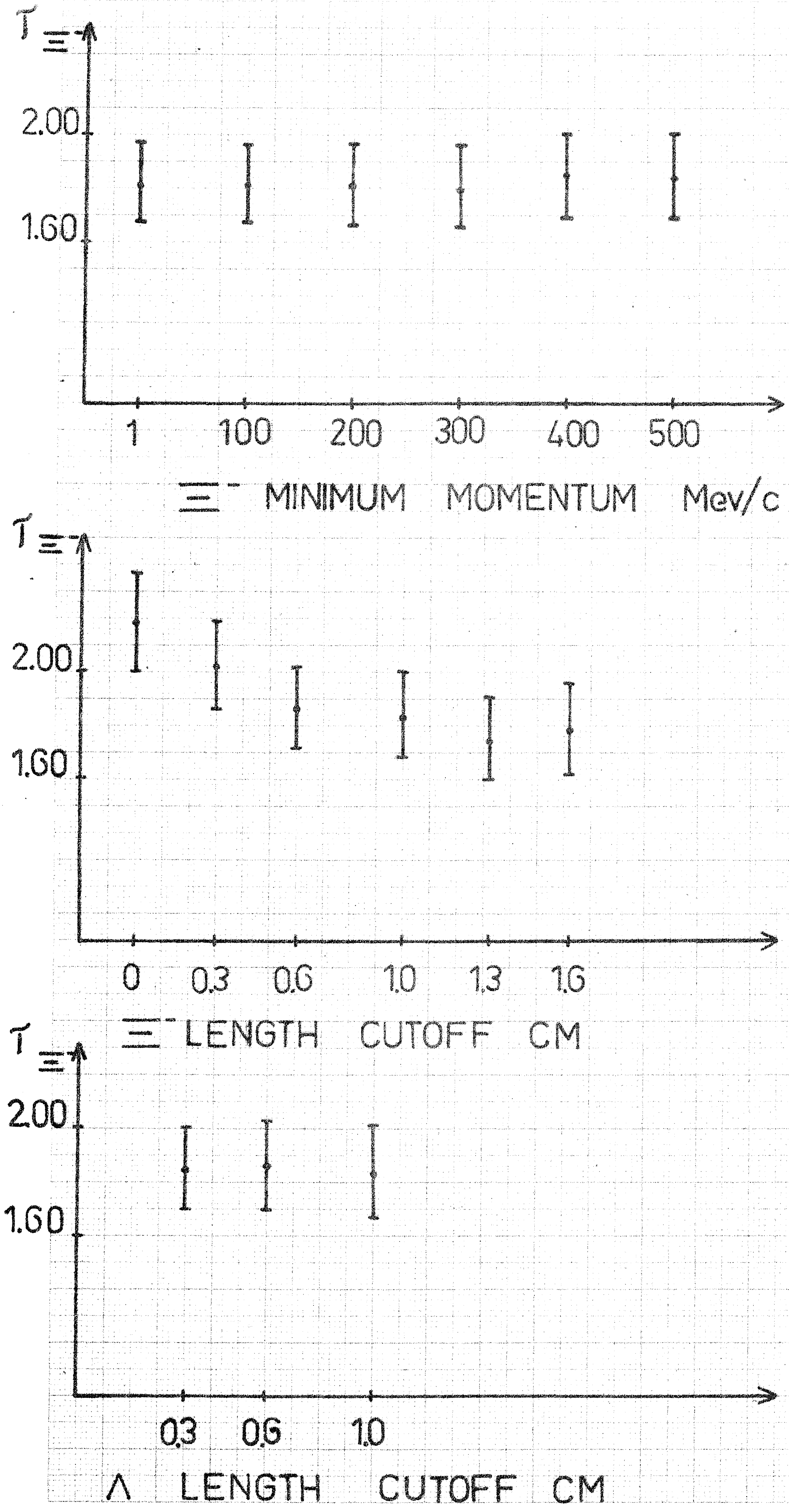

τ_{Ξ}
2.00
1.60
1
100
200
300
400
500
Ξ^- MINIMUM MOMENTUM Mev/c
τ_{Ξ}
2.00
1.60
0
0.3
0.6
1.0
1.3
1.6
Ξ^- LENGTH CUTOFF CM
τ_{Ξ}
2.00
1.60
0.3
0.6
1.0
Λ LENGTH CUTOFF CM

FIG. 2.

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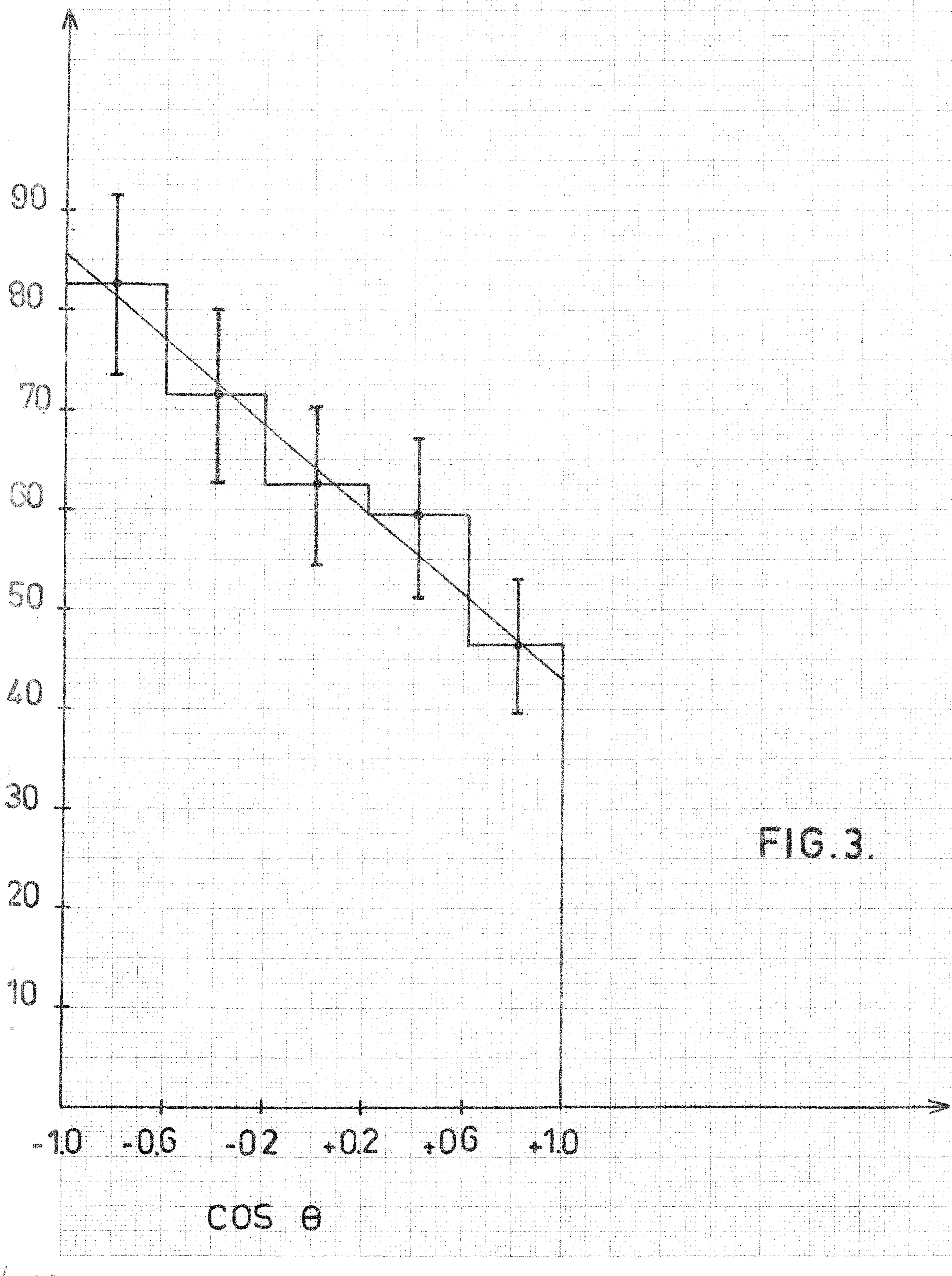
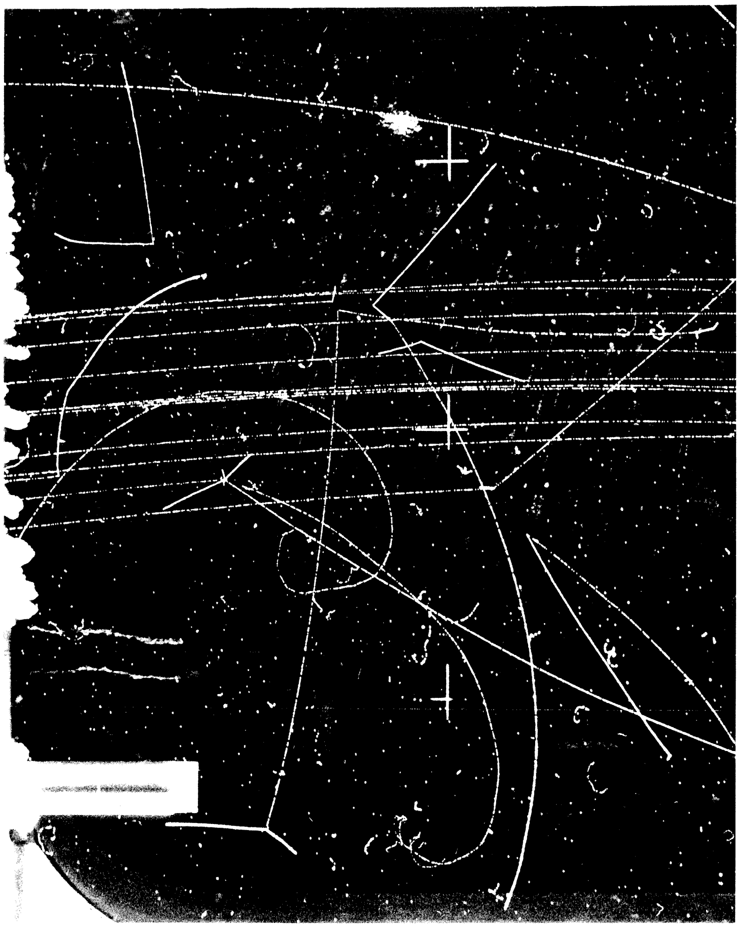


FIG.3.



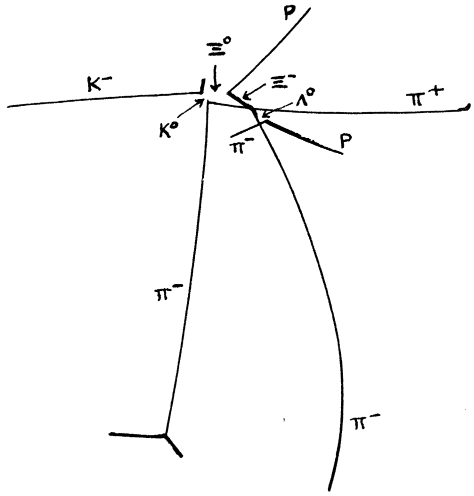
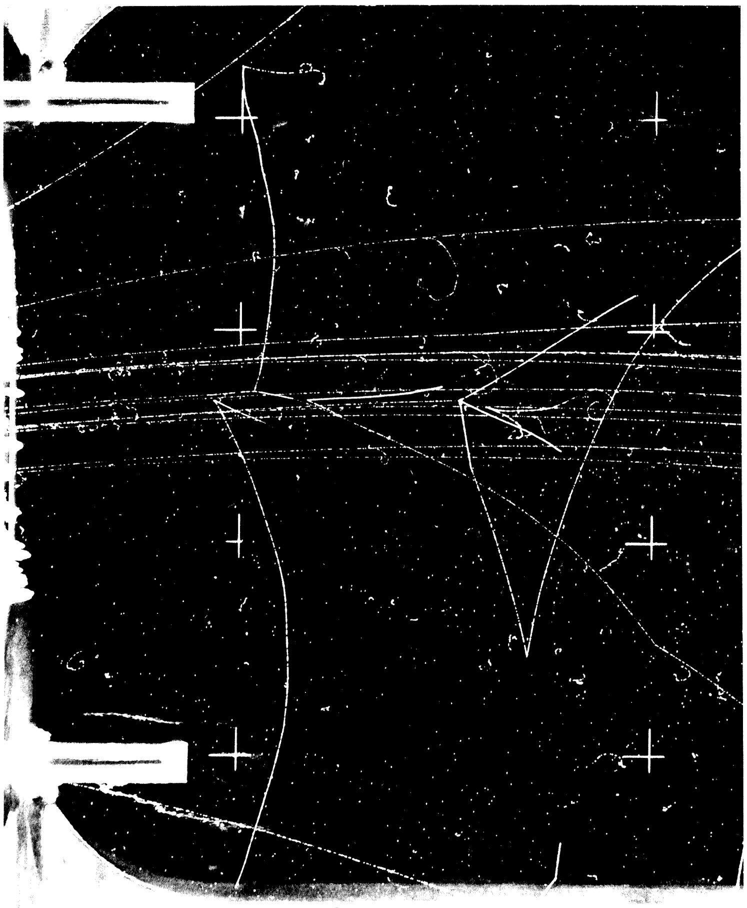


Fig. 4. Ξ^0 charge exchange
$\Xi^0 + n \rightarrow \Xi^- + p$



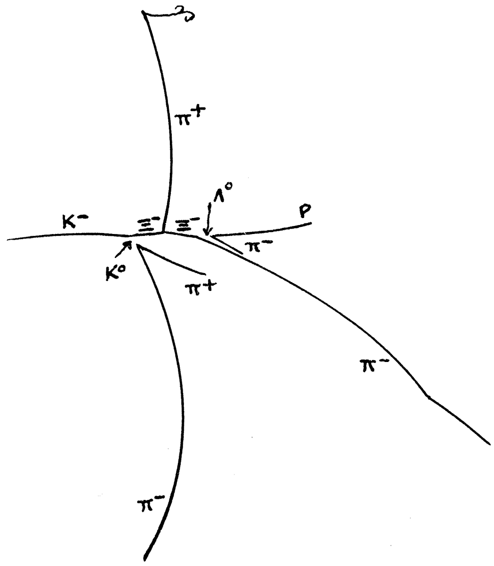


Fig. 5. Ξ^- inelastic interaction giving $(\Xi^- \pi^+)$ with a mass 1533 ± 7 Mev