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Ξ^- PROPERTIES

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1. INTRODUCTION

An experiment has been performed in the Ecole Polytechnique heavy liquid bubble chamber to determine the properties of the negative cascade particle. More preliminary results have been given in (1). Results are given here for the Ξ^- mass (1321.4 ± 0.4 MeV), lifetime ($(1.86 {+0.15 \atop -0.14}) \times 10^{-10}$ sec), asymmetry parameters α (-0.44 ± 0.11), β ($-0.24 {+0.57 \atop -0.50}$) and γ ($0.87 {+0.05 \atop -0.28}$) and the Lee and Yang spin test functions. Our results are in agreement with other recent measurements (5). We have also measured the production cross section ratio $R = (K^- p \rightarrow \Xi^- K^+) / (K^- n \rightarrow \Xi^- K^0) = (1.05 \pm 0.18)$.

2. EXPERIMENTAL CONDITIONS

Our Ξ^- were produced mainly via the reactions $K^- + (p,n) \rightarrow \Xi^- + (K^+, K^0)$ in the Ecole Polytechnique 1 x 1/2 x 1/2 M^3 heavy liquid bubble chamber (2) running with Freon C_2F_5Cl (density 1.2 g cm^{-3}, radiation length 25 cm) in a magnetic field of 1.7 Weber m^{-2}. The chamber was in a 1.45 ± 0.03 GeV/c K^- beam (3) at the CERN PS. We have taken about 220'000 photos containing about 3 useful K^- interactions per photo and our results are based on 346 events where the Ξ^- is associated with a "signature" which is either a stopping K^+ or a K^0 giving $\pi^+ + \pi^-$, and 171 Ξ^- without signature. Rescanning is continuing. Data analysis systems and selection criteria for Ξ^- events and K^+ and K^0 signatures are given elsewhere (1), (4).

3. Ξ^- MASS

About 2/3 of the protons from the Λ and about 1/3 of the π^- from the Ξ^- stop in the chamber permitting a precise momentum determination from range measurement. We have calibrated our range momentum relation using μ^+ and π^+ secondaries from K^+ decays at rest obtained in the same run, assuming $M_{K^+} = 493.9$ MeV. As an overall check we have determined the Λ mass: 1115.67 ± 0.25 MeV, based on 75 events where both the p and the π^- stop. For 132 Ξ^- events with a stopping π^- we find for the mass

$$M_{\Xi^-} = 1321.4 \pm 0.4 \text{ MeV}$$

The error includes the uncertainties in the masses of the Λ (1115.4 $\pm$ 0.1 MeV) and the π^- (139.6 $\pm$ 0.05 MeV). Note that a systematic error in our magnetic field table would have negligible effect on our mass result, and that the beam momentum is irrelevant. We estimate any possible systematic errors to be less than 0.5 MeV. We have checked that masses and errors obtained with the several different analysis systems are compatible, and that the Ξ^- mass calculated using only the fitted Λ momentum and the measured π^- momentum agrees well with that calculated using in addition the measured Ξ^- direction.

4. Ξ^- MEAN LIFE

For our determination of τ_{Ξ^-} we have used only signed Ξ^-. Various cutoffs designed to eliminate possible biases and events with poor measurability have been applied. We have varied the cutoffs (Fig. 2) and chosen the final set (P_{Ξ^-} (at origin) $>$ 500 MeV/c, P_{Ξ^-} (at end of potential path) $>$ 400 MeV/c, 0.6 cm $< L_{\Xi^-} <$ 15 cm, 0.3 cm $< L_{\Lambda} <$ 20 cm) to give us the largest possible sample of unbiased Ξ^-. Further, the whole event has to be within the fiducial volume. The time of flight and the potential time of flight of the Ξ^- were calculated allowing for the slowing down of the Ξ^- in the chamber liquid. Fig. 1 shows the time distribution. The Ξ^- potential length was obtained by translating the event along the Ξ^- line of flight until either the Λ or the Ξ^- decay point would have left the fiducial volume, or until one of the cutoffs would have applied. A maximum likelihood estimate gives an apparent mean life τ_{Ξ^-} = $(1.78 {+0.15 \atop -0.13}) \times 10^{-10}$ sec for the 273 events which survive the cutoffs. This value has to be corrected for absorption of the Ξ^- in the liquid. Taking 35 $\pm$ 15 mb as a reasonable estimate for the total Ξ^- nucleon cross section we obtain as our best estimate

$$\tau_{\Xi^-} = (1.86 {+0.15 \atop -0.14}) \times 10^{-10} \text{ sec}$$

As a check we find the corrected value, using 35 $\pm$ 15 mb, of the mean life of the daughter Λ :

$$\tau_{\Lambda} = (2.44 {+0.21 \atop -0.18}) \times 10^{-10} \text{ sec}$$

and of the signature K_1^o : $\tau_{K^o} = (0.95 {+0.11 \atop -0.09}) \times 10^{-10}$ sec (using 25 $\pm$ 8 mb).

PS/4088

5. ASYMMETRY PARAMETERS

The determination of the α parameter [6] was based on 346 signed and 171 unsigned events. The distribution $I(\hat{p}\cdot\hat{\Lambda}) = 1 + \alpha_{\Xi^-}\alpha_{\Lambda}(\hat{p}\cdot\hat{\Lambda})$ (Fig. 3), where $\hat{p}$ is the direction of flight of the proton in the Λ rest system and $\hat{\Lambda}$ is the direction of flight of the Λ in the Ξ^- rest system, yields $\alpha_{\Xi^-}\alpha_{\Lambda} = -0.27 \pm 0.07$. Defining $\alpha = +2\,\mathrm{Re}\,(S^* P)$ and using $\alpha_{\Lambda} = 0.62 \pm 0.07$ [7], we find :

$$\alpha_{\Xi^-} = -0.44 \pm 0.11$$

For the determination of β and γ we need a sample of polarized Ξ^-. A polarization at production may be lost in events where the Ξ^- undergoes interaction in the parent nucleus. In an effort to eliminate such events we divide our sample of signed Ξ^- into two groups : "clean" events : characterized by a relatively good momentum balance between initial and final states, $|\vec{p}\,(\text{initial}) - \vec{p}\,(\text{final})|$ less than 450 MeV/c and no evaporation prongs longer than 3 cm ; and "dirty" events which are all other signed events. A measure of the polarization is the asymmetry coefficient in the distribution of the Λ direction in the Ξ^- rest system with respect to the production normal $\vec{n} = \vec{K}^{\mp}_{o} \times \vec{\Xi}^-$: $I(\hat{n}\cdot\hat{\Lambda}) = 1 + \alpha_{\Xi^-} P_{\Xi^-}(\hat{n}\cdot\hat{\Lambda})$. In fact for the clean events we find a larger polarization than for the dirty ones : for 182 clean events : $\alpha_{\Xi^-} P_{\Xi^-} = 0.21 \pm 0.13$

for 164 dirty events : $\alpha_{\Xi^-} P_{\Xi^-} = 0.06 \pm 0.13$.

The corresponding angular distribution for clean events is shown in Fig. 4. For the determination of β, γ and P we have used only the clean events. β and γ may be determined from the angular distributions (Fig. 4).

$$I(\cos\theta_\beta) = 1 + \frac{\pi}{4} P \beta \alpha_\Lambda \cos\theta_\beta \qquad \text{where } \cos\theta_\beta = p\cdot(\hat{n}\times\hat{\Lambda})/|\hat{n}\times\hat{\Lambda}|$$

$$I(\cos\theta_\gamma) = 1 + \frac{\pi}{4} P \gamma \alpha_\Lambda \cos\theta_\gamma \qquad \text{where } \cos\theta_\gamma = \hat{p}\cdot(\hat{\Lambda}\times(\hat{n}\times\hat{\Lambda}))/|\hat{\Lambda}\times(\hat{n}\times\hat{\Lambda})$$

We find

$$\frac{\pi}{4} P \beta \alpha_\Lambda = 0.05 \pm 0.13 \qquad \frac{\pi}{4} P \gamma \alpha_\Lambda = -0.19 \pm 0.13$$

From the 4 experimentally observed asymmetry coefficients we can determine α, β, γ and P. As α, β and γ are subject to the constraint $\alpha^2 + \beta^2 + \gamma^2 = 1$, a best fit was carried out giving as result :

$\alpha_{\Xi^-} = -0.44 \pm 0.11$ $\beta_{\Xi^-} = -0.24 {+0.57 \atop -0.50}$

$\gamma_{\Xi^-} = 0.87 {+0.05 \atop -0.28}$ $P_{\Xi^-} = -0.47 {+0.23 \atop -0.20}$

For the angle $\phi = \text{Arctan}\ \beta/\gamma$ which is essentially uncorrelated with α we find $\phi = -16^\circ \pm 37^\circ$.

6. SPIN

Lee and Yang test functions (8) for the Ξ^- spin give for 182 clean events :

$$T_{1/2\ 1/2} = 0.21 \pm 0.13$$

$$T_{3/2\ 3/2} = 1.06 \pm 0.33$$

$$T_{5/2\ 5/2} = 1.83 \pm 0.56$$

$T_{j,m}$ must be less than 1 if the Ξ^- has spin j, projection m.

7. PRODUCTION CROSS SECTION RATIO

We have 195 events with stopping K^+ and 62 events with visible K_1^o decay where the K_1^o would have stopped within the chamber fiducial volume had it been a K^+. The momentum spectra of these K^+ and K_1^o show the same shape within the limits of statistics. We assume that the entire K^+ and K^o spectra have the same shape. From the numbers above, correcting for invisible K^o decay modes we find :

$$R = (K^- p \rightarrow \Xi^- K^+)/(K^- n \rightarrow \Xi^- K^o) = 1.05 \pm 0.18$$

for a mean momentum of $\sim$ 1.4 GeV/c.

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/fv

Distribution : (open)
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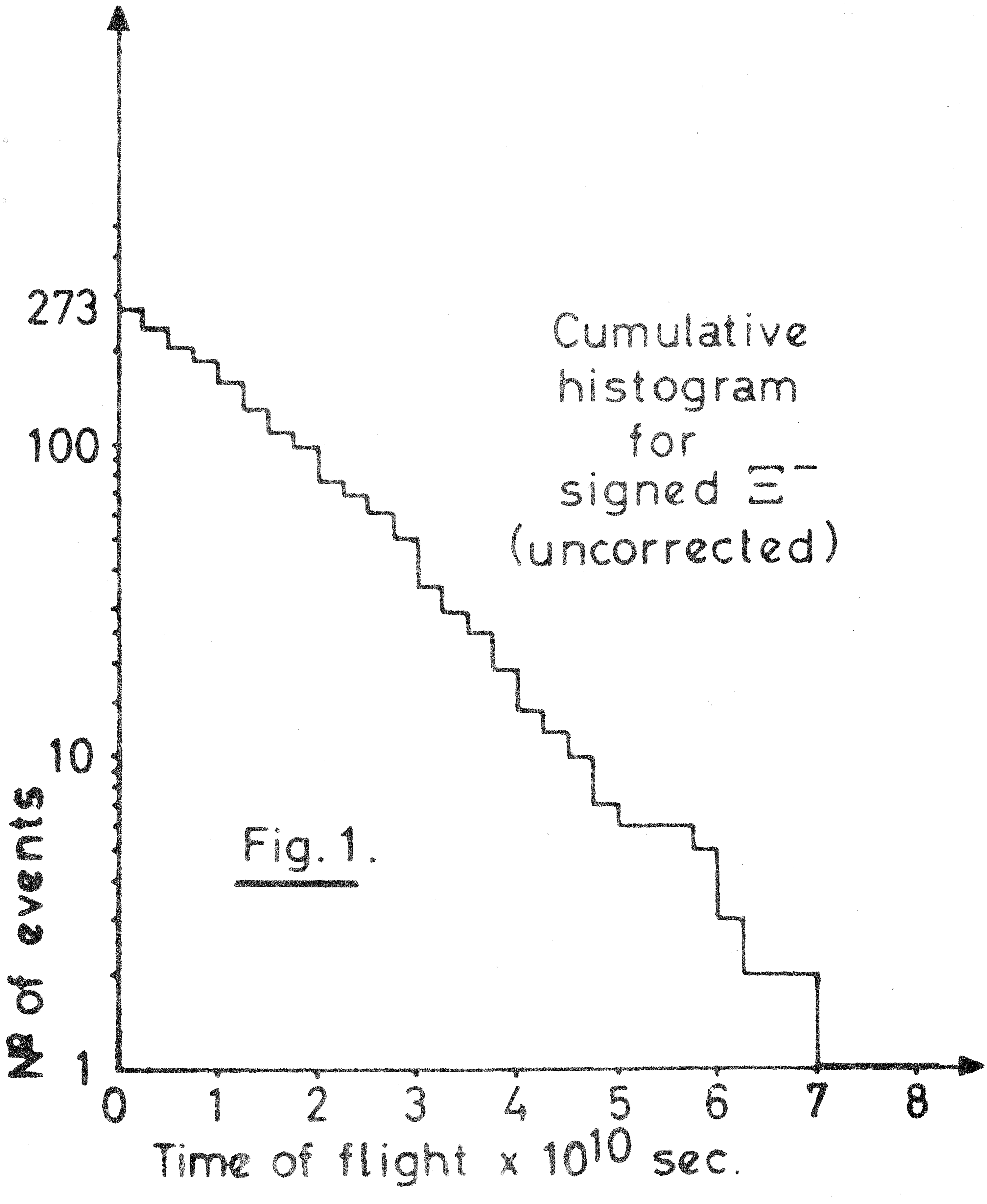
273
100
10
1
Nº of events
0
1
2
3
4
5
6
7
8
Time of flight x 10^10 sec.
Cumulative
histogram
for
signed Ξ⁻
(uncorrected)

Fig. 1.

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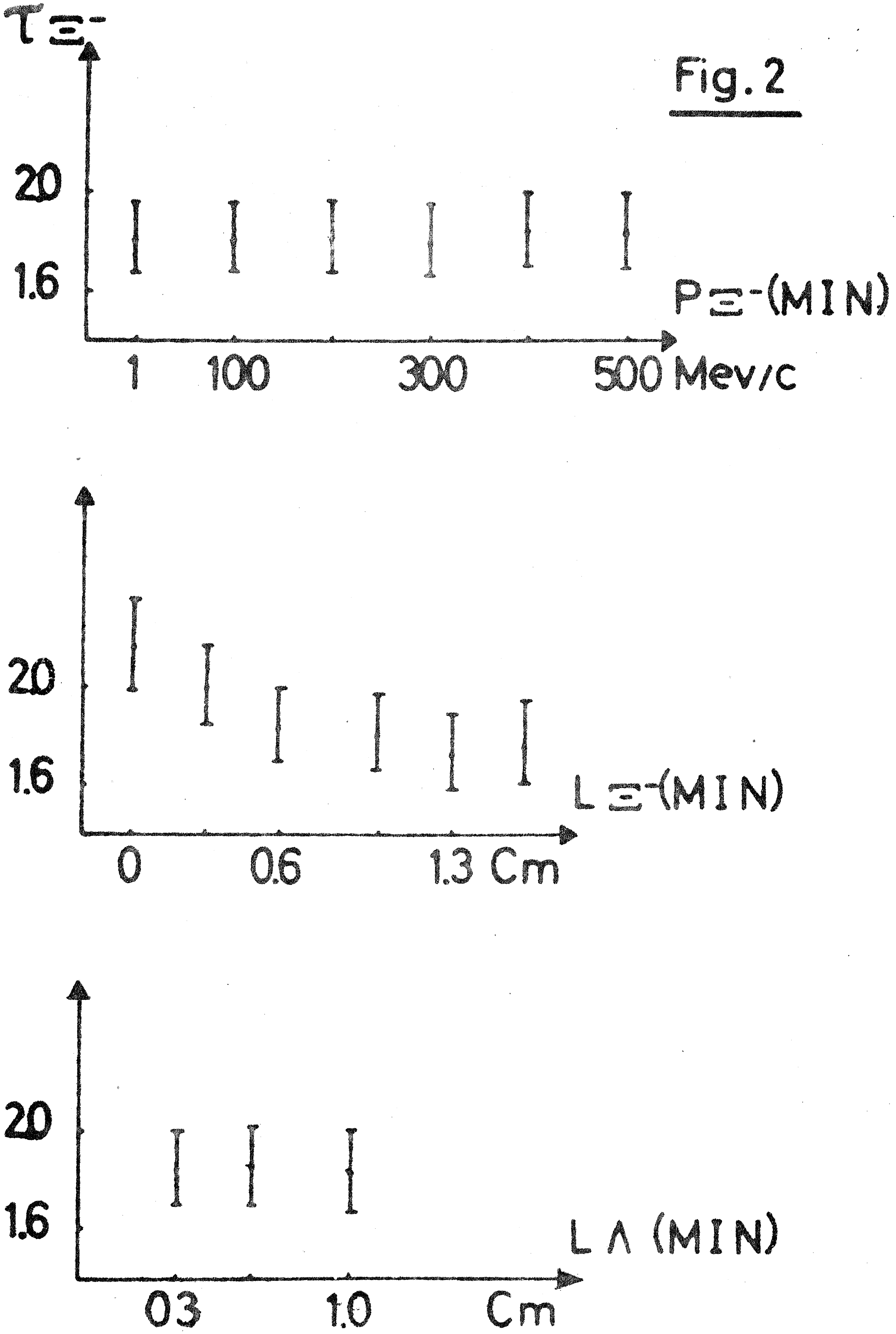
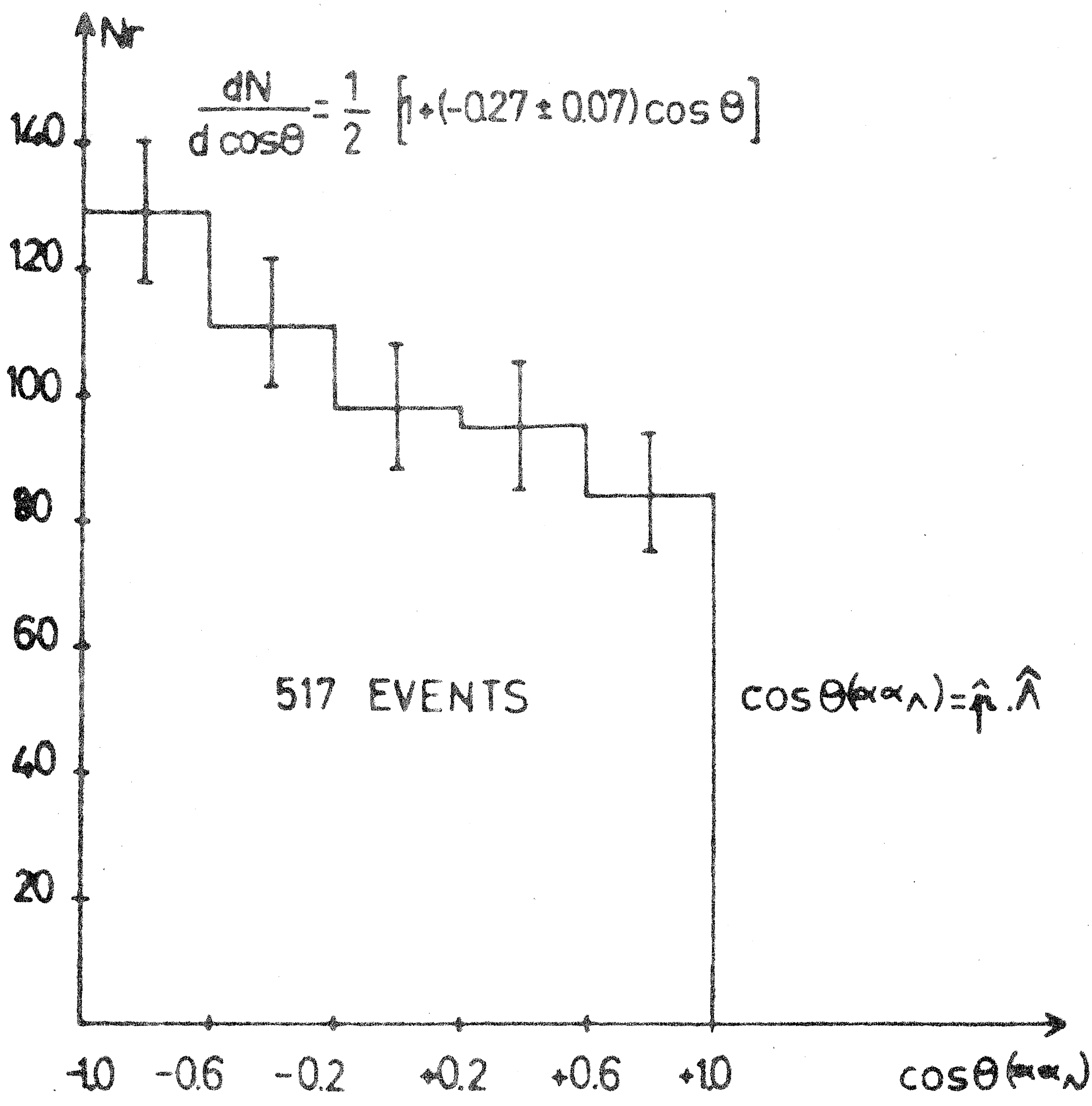
Fig. 2


τ Ξ⁻
2.0
1.6
P Ξ⁻(MIN)
1
100
300
500 Mev/c
2.0
1.6
L Ξ⁻(MIN)
0
0.6
1.3 Cm
2.0
1.6
L Λ (MIN)
0.3
1.0
Cm

PS/4088

Fig. 3.


Nr
dN/d cosθ = 1/2 [1+(-0.27 ± 0.07) cos θ]
140
120
100
80
60
40
20
517 EVENTS
cos θ(p̂ α_Λ) = p̂ . Λ̂
-1.0
-0.6
-0.2
+0.2
+0.6
+1.0
cos θ

PS/4088.

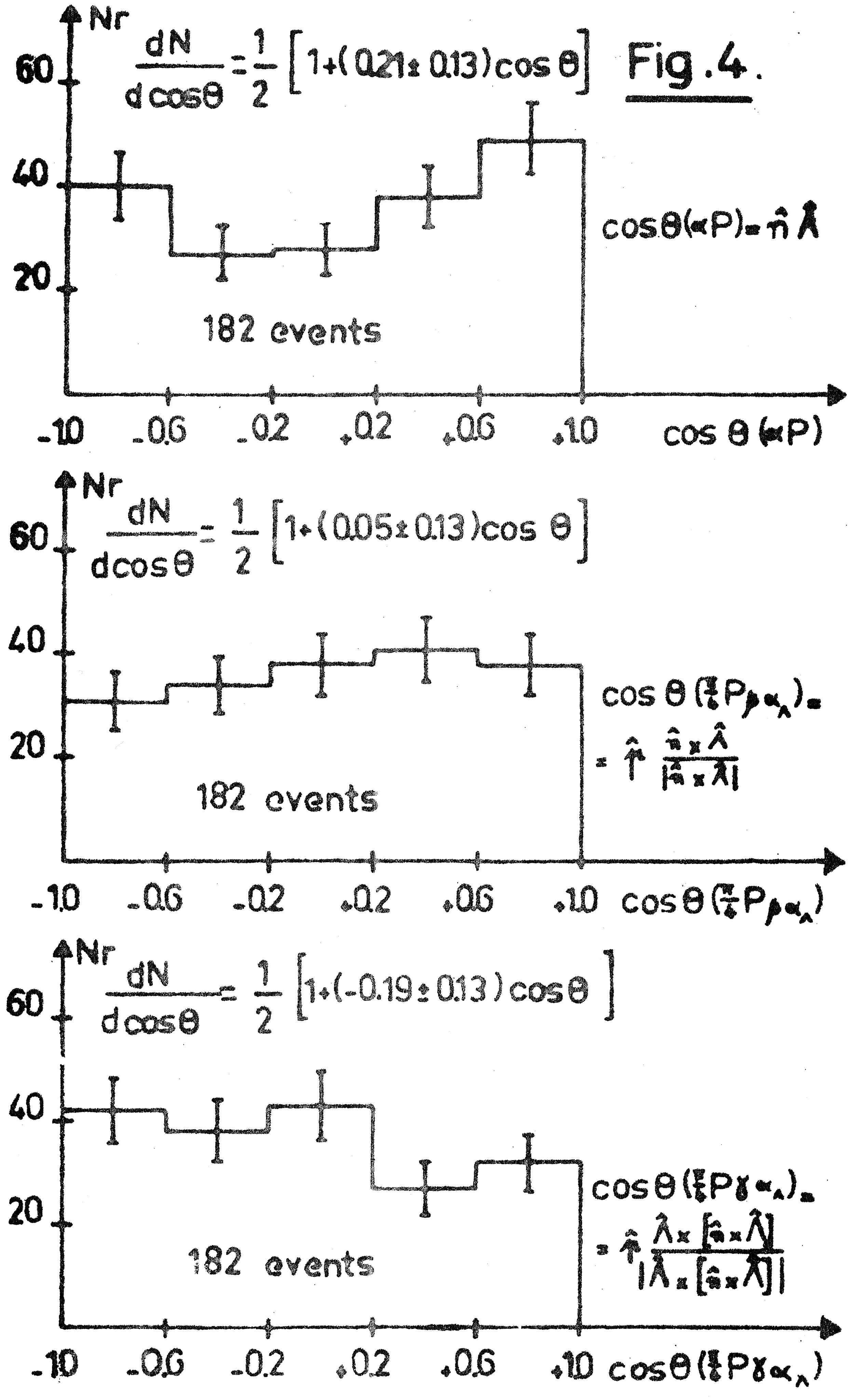

Nr
dN/dcosθ = 1/2 [1+(0.21±0.13) cos θ]
60
40
20
182 events
cosθ(αP) = n̂ Λ̂
-1.0 -0.6 -0.2 +0.2 +0.6 +1.0
cos θ (αP)
Nr
dN/dcosθ = 1/2 [1+(0.05±0.13) cos θ]
60
40
20
182 events
-1.0 -0.6 -0.2 +0.2 +0.6 +1.0
Nr
dN/dcosθ = 1/2 [1+(-0.19±0.13) cosθ]
60
40
20
182 events
-1.0 -0.6 -0.2 +0.2 +0.6 +1.0

Fig. 4.

FS/4088.