A MEASUREMENT OF THE MAGNETIC MOMENT OF THE Λ^0 HYPERON

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A considerable effort has been applied in recent years toward the measurement of the magnetic moment of the Λ hyperon [1—3]. But the precision obtained until now is not yet sufficient to allow a meaningful comparison with the theoretical predictions based on the symmetries of the strong interactions [4, 5].

EXPERIMENTAL PROCEDURE

The present experiment was carried out at the CERN PS. It is based on the same principle as most magnetic moment measurements: one observes the change of direction of the

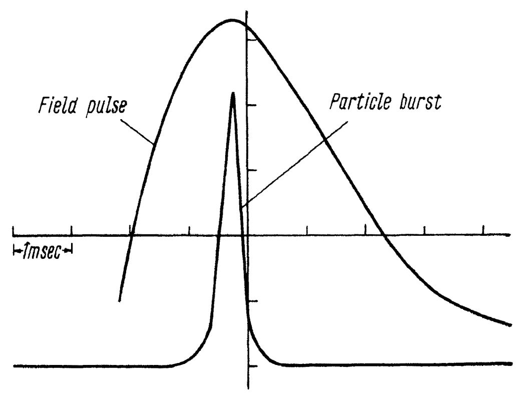

Fig. 1.

polarization vector as the particles go through a strong magnetic field. It differs from preceding experiments in the use of photographic emulsion as detector, and in the orientation of the field which is perpendicular to the Λ momentum. With this geometry, the precession of the Λ spin corresponds to a rotation of the decay pattern around the normal to the emulsion plane, by an amount proportional to the time spent by the particle in the field and to its magnetic moment.

The emulsion stacks were made up of 20 pellicles of stripped K5 emulsion each $7.5 \times \times 3$ cm^2 $\times$ 1200 μm thick, the orientation of the stacks being such that the emulsion plane was vertical. The initial direction of the spin polarization of the hyperon is then parallel to the emulsion plane and also roughly vertical for all decays detected in the stacks. The exposures were divided into two groups, called *A* and *B*, for which the sign of the magnetic field was reversed. Each stack was exposed to the secondary particles produced by $1.07 \pm \pm 0.02$ MeV/c π^--mesons incident on the polythene target, under conditions where the magnet pulse was synchronised with the P. S. burst to 200 μsec (Fig. 1 : 1 cm $\rightarrow$ 1 msec). No stack was considered usable if the field was less than 80% max. during particle burst. In addition, two stacks prepared of the same available emulsion were exposed to 70 MeV π^+-mesons from the S. C. at CERN. They were then treated in the same way as the material from the main exposures, and after processing used to establish for each scanner the relation between normalized grain density and velocity.

THE MAGNET

A special type of pulsed magnet has been built for this experiment, giving a uniform transverse field of 150 kG over a length of 17 cm, in a useful volume of about 500 cm^3 [6].

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The coil consists of 20 rectangular plates ($170 \times 280 \times 2.5$ mm^3) of copper — chromium. At this field, and with a repetition rate of 1 pulse every 15 seconds, such a coil has a life-time of the order of 4000 pulses. This low repetition rate is necessary to insure the cooling of the coil.

Due to the finite duration of the burst from the PS, the particles are submitted to a field smaller than the peak-value. Throughout the experiment a film was taken of the field signal displayed on an oscilloscope together with the machine burst (see Fig. 1). From the analysis of these pictures, we estimate the average effective field as $95 \pm 1\%$ of the peak-field.

Inside the coil, the field is uniform within 2%, except in the target where it varies in a known way. In evaluating the quantity (field $\times$ $\times$ flight distance) for each event, this variation was taken into account; the origin of all Λ's was taken at the effective center of the target (weighted by the field distribution) and their end at the actual decay point.

The absolute value of the peak-field is known within 2%. Fig. 2 shows the arrangement of the emulsion stack within the coil.

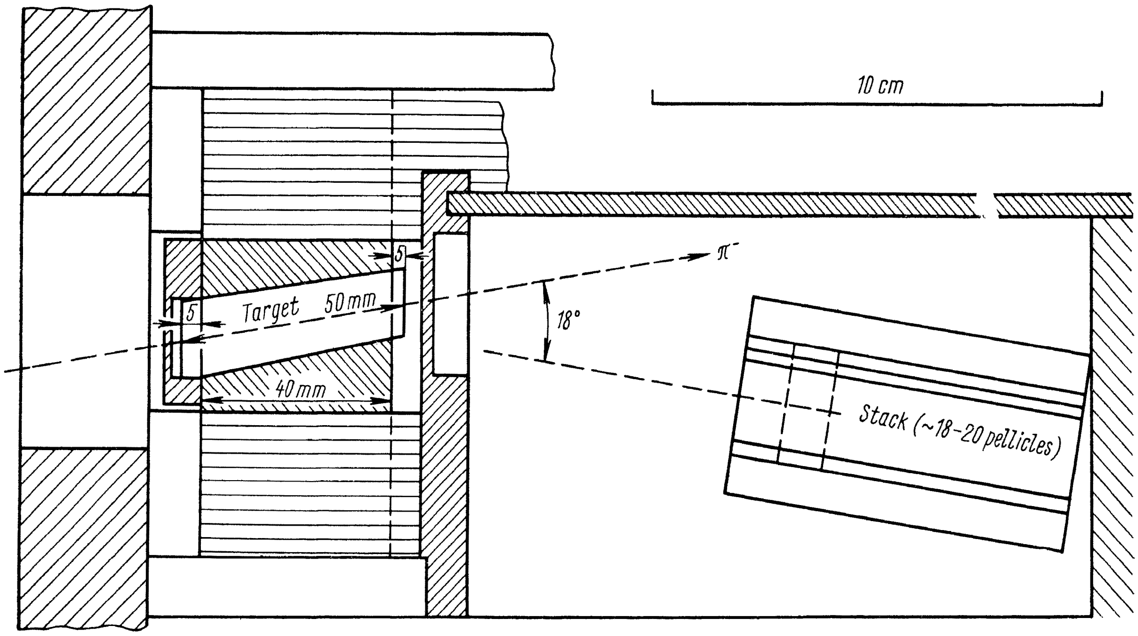

Fig. 2.

PROCESSING AND SCANNING

The exposure geometry of the main experiment was established by photographing onto the emulsions before processing, a grid, one set of lines of which radiated from a point equivalent to the centre of the polythene target. All angles in the emulsion plane were subsequently measured with respect to these radiating grid lines.

Fig. 3 shows the angular distribution of all tracks entering one of the plates. The effect of the magnetic field on the charged products of the interactions in the polythene target is clearly seen: the negative products which all have minimum ionization and are mainly the elastically scattered pions give a peak centred around $+16.5°$ which is clearly separated from another broader peak starting at about $-7°$ which is due to positively charged particles. Most of the tracks lying in angle between these two peaks (in the angular window) are electrons from the conversion of γ-rays in the emulsion, and when followed towards the entry edge of the plate, in a large number of cases were found to originate in a pair.

The scanning for V-events was done using an oil immersion $\times$ 53 Leitz or $\times$45 Cook objective giving a useful field of view of about 100 μm and at the beginning of the scan in each plate, all tracks crossing a line 1 cm from the entry edge were followed back towards that edge if they lay within $^{+13°}_{-4°}$ (the angular window) in projected angle with respect to the nearest reference grid line. The choice of such an angular window was dictated by the necessity to observe as large a phase space as possible for the Λ-decays without having to follow many of the charged products from the target. Taking account of the finite geometry of the experiment the 13° limit on one side enabled all hyperons above 650 MeV/c to be detected

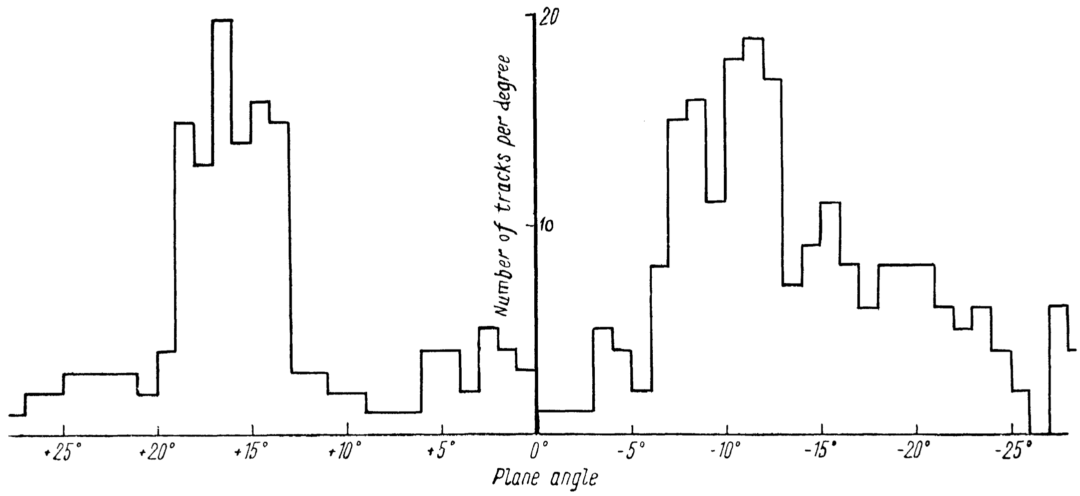

Fig. 3.

where the proton was emitted in that half cone irrespective of its angle in the c. m. s. of the decay. The 4° limit on the other side allowed for the curvature of the protons between the decay point and the traverse at which they were picked up. The dip angles of tracks to be followed were roughly required to be less than 13° (unprocessed). The scan of the traverse was then completed by only following those tracks inside the angular window if on a count in one field the grain density was greater than 1.2 g_p. Since the most energetic proton from a Λ^0 decay within the momentum range accepted has an ionization of 1.4 g_p, no effective bias was expected from this additional scanning criterion.

MEASUREMENT AND IDENTIFICATION OF EVENTS

For all 2-prong stars found in the scanning, the dip angles of both tracks and their plane angles with respect to the closest grid-line were measured, and the space angle computed. Events with opening angles smaller than 2° or larger than 170° were not accepted. The first criterion effectively eliminates electron pairs. (Electron pairs with opening angles larger than 2° were detectable from the strong curvature of at least one of the tracks in the magnetic field, and were then also eliminated). The second criterion excludes events due to elastic scattering of a particle.

The moments of the 2 particles were determined by counting of the order of 400 grains on each track, always assuming that the track followed in the scanning was a proton and the other a π-meson. Some of the pions which appeared to have chance to stop in the stack were followed, and if they did stop, their range was measured.

The measured quantities were then adjusted by a computer programme to fit the Λ decay kinematics. The Λ momentum and its direction were determined, as well as the characteristic angles of the decay in the Λ c. m. system, and a value of χ^2 characterizing the goodness of the fit. In the fitting procedure, the errors on the angles were considered negligible compared to the errors on the momenta. For the present sample only those events were accepted which satisfied all of the following conditions:

(a) $\chi^2 < 4$ (corresponding to a Q-value of the Λ^0 within two standard deviations of the established one);

(b) Λ^0-momentum > 700 MeV/c (this means that the decay angle of the proton is bound to lie in all cases within the interval specified by our scanning criteria);

(c) Flight direction of Λ^0 points within two standard deviations towards the effective centre of the target.

Out of a total of 646 V-events 109 events satisfied these conditions.

ANALYSIS

The analysis was done using a maximum likelihood method.

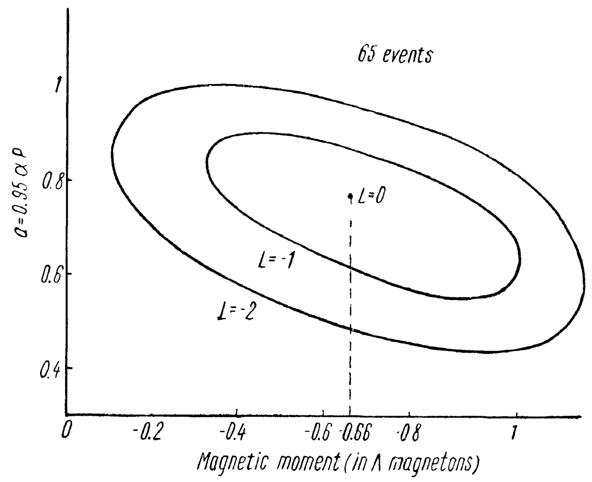

Fig. 4.

The probability to observe a given sample of n decay angles is a function of α_P (α: decay parameter, P: polarization) and of the magnetic moment μ. We have maximized this likelihood function with respect to the parameters αP and μ.

Fig. 4 shows the results of the likelihood function calculation. The ellipses show different contours of constant likelihood separated by factors of $1/e$ and $1/e^2$ respestively from the maximum likelihood point.

The maximum in μ occurs at -0.66, in αP at 0.75 which is compatible within the statistical errors with the value $\alpha = -0.62 \pm \pm 0.07$ found by Cronin and Overseth [7].

We conclude that our experiment gives the following value for the magnetic moment of the Λ^0:

$$\mu_\Lambda = -0.66 \pm 0.35 \text{ intrinsic magnetons;}$$

$$\mu_\Lambda = -0.5 \pm 0.3 \text{ nuclear magnetons.}$$

It is hoped to multiply our statistics by a factor 2 to 3 in the near future.

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