Title

DECAY PARAMETERS FOR 2~^=>nTT

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In this paper we present measurements of the decay parameters $\beta_{\pm}$ and $\gamma_{\pm}$ for $\Sigma^{\pm} \rightarrow n\pi^{\pm}$. We confirm that the $\Sigma^{+} \rightarrow n\pi^{+}$ decay takes place predominantly in the P wave, and find $\Sigma^{-} \rightarrow n\pi^{-}$ is dominated by S-wave decay, in agreement with the $\Delta I = \frac{1}{2}$ rule.

The experiment was performed at the Bevatron, with the LRL 25-inch hydrogen bubble chamber. More than 10^5 charged Σ hyperons produced by K^-p interactions at an average momentum of 385 MeV/c have been analyzed.

The nonleptonic Σ decays $\Sigma^{\pm} \rightarrow n\pi^{\pm}$ and $\Sigma^{+} \rightarrow p\pi^{0}$ are conventionally parameterized in terms of their decay rates and the three parameters α, β, and γ, defined as

$$\alpha = \frac{2\,\mathrm{Re}\,S^{*}P}{|S|^2 + |P|^2}, \tag{1}$$

$$\beta = \frac{2\,\mathrm{Im}\,S^{*}P}{|S|^2 + |P|^2}, \tag{2}$$

$$\gamma = \frac{|S|^2 - |P|^2}{|S|^2 + |P|^2}, \tag{3}$$

where S and P are respectively the S-wave and P-wave decay amplitudes. Subscript +, -, or 0 indicates the charge of the decay pion.

Previous experiments[1,2] indicate that α_+ and α_- are very nearly equal to zero, while α_0 is very nearly equal to -1. The sign convention is such that α has the same sign as the helicity of the decay nucleon. If time-reversal invariance holds, the phases of S and P are given by the πN scattering phase shifts evaluated at the decay energy. Since these phase shifts are very small, S and P are both predominantly real. Thus β is predicted to be close to zero.

If α and β are equal to zero, then $\gamma = \pm 1$, and the decay proceeds entirely through the S-wave or the P-wave channel. In addition, the $\Delta I = \frac{1}{2}$ rule requires that if $\gamma_+ = \pm 1$, then $\gamma_- = \mp 1$.[1] Results derived from current algebra, with the assumption of partial conservation of the axial-vector current, predict that $\gamma_+ = -1$.[3] This sign has already been shown to be correct by the results of Berley et al.[2]

In the Σ rest frame the polarization of the neutron in $\Sigma^\pm \rightarrow n\pi^\pm$ is given by

$$\mathbf{P}_n = \left\{[\alpha + \mathbf{P}_\Sigma \cdot \hat{n}(1-\gamma)]\, \hat{n} + \gamma \mathbf{P}_\Sigma + \beta\, (\mathbf{P}_\Sigma \times \hat{n})\right\}/(1 + \alpha \mathbf{P}_\Sigma \cdot \hat{n}), \quad (4)$$

where $\hat{n}$ is along the momentum of the neutron and $\mathbf{P}_\Sigma$ is the polarization of the Σ. Since α has been measured for both decays, and since $\alpha^2 + \beta^2 + \gamma^2 = 1$, it is convenient to express β and γ in terms of the parameter φ so that $\beta = (1 - \alpha^2)^{\frac{1}{2}} \sin \varphi$ and $\gamma = (1 - \alpha^2)^{\frac{1}{2}} \cos \varphi$. From (4) we note that if $\mathbf{P}_\Sigma$ is known, then $\mathbf{P}_n$ is a function of the single unknown parameter φ.

Watson, Ferro-Luzzi, and Tripp[4] have shown that Σ's produced by the K^-p interaction in the vicinity of the $Y_0^*(1520)$ are highly polarized (as a result of the interference of the resonant $D_{3/2}$ amplitude with the S-wave background). This was corroborated by our later analysis of roughly 15 000 Σ events. In contrast to α_0, which is nearly -1, α_- is very small, so that it is impractical to measure well the Σ^- polarization by observing the decay asymmetry, and one must rely on the values obtained from the production amplitudes. In order to establish these amplitudes more precisely we have recently analyzed more than 10^5 Σ events. The incident K^- momentum ranged from 290 to 430 MeV/c. Our preliminary results are in substantial agreement with the previous work, and we conclude that there is no gross error in the Σ^- polarization. In the following analysis we use the values of Ref. 1.

The polarization $\underset{\sim}{P}_n$, and hence φ, can be measured by observing the left-right asymmetry in the np interactions of those decay neutrons which subsequently scatter on the hydrogen in the bubble chamber. The distribution function for these np scatterings is

$$W(\underset{\sim}{P}_n \cdot \hat{n}) = \tfrac{1}{2}(1 + A\,\underset{\sim}{P}_n \cdot \hat{S}), \tag{5}$$

where $\hat{S}$ is the normal to the np scattering plane and A is the np scattering asymmetry. We use the values of A determined by Arndt and MacGregor.[5]

The background flux of fast neutrons in the bubble chamber is high, producing roughly 25 np scatterings per frame. In order to select those scatterings resulting from Σ decay, we first measured and analyzed about 20 000 events of the type $\Sigma^+ \to \pi^+ n$ and 52 000 events of the type $\Sigma^- \to \pi^- n$. The results of this analysis were used to predict the direction of the neutron on the scanning table in three different views. We then scanned for np scatterings that occurred within $\pm 3^0$ of the predicted direction in all three views.

Only those events were recorded in which the projected length of the proton (on the scanning table with a magnification of 2/3) was at least 2 mm in one view and not less than 1 mm in any view. In addition, only those frames were scanned in which the neutron momentum was greater than 275 MeV/c. At lower momenta A is very small and the events would not significantly contribute to our results. Nearly 4100 candidates were found. The recoil proton was measured and the results of that measurement were merged with the original measurements of the event. The resulting data were subjected to a seven-constraint, three-vertex fit. In some cases the momentum of the recoil proton cannot be measured with sufficient accuracy to warrant the seven-constraint fit. In these cases, which constitute 4% of the fitted data, a six-constraint fit was imposed. At present we have a sample of 497 Σ_+^+ and 1256 Σ_-^- containing negligible background. These represent respectively about 40% and 80% of our eventual number of events.

To evaluate φ we form the likelihood function

$$\mathcal{L}(\varphi) = \prod_{i=1}^{N} (1 + A\,\underset{\sim}{P}_n(\varphi)\cdot\hat{S}). \tag{6}$$

The value of $\underset{\sim}{P}_n$ used in this function is obtained from the value given by (4) by applying the appropriate relativistic transformations and by taking into account the precession of the polarization in the magnetic field of the bubble chamber. The logarithms of the resulting likelihood functions, $\ln\mathcal{L}(\varphi)$, are shown in Fig. 1. From these curves we obtain

$$\varphi_+ = 139^\circ \pm 32^\circ,$$

$$\varphi_- = 3^\circ \pm 21^\circ.$$

For Σ_+^+, $\gamma_+ = -1$ is 890 times as likely as $\gamma_+ = +1$, and for Σ_-^-, $\gamma_- = -1$

is 1.25 x 10^8 times as likely as $\gamma_- = +1$. These results are consistent with the $\Delta I = \frac{1}{2}$ rule, the current algebra predictions, and the previous measurement of γ_+.

This experiment provides essentially no test of time-reversal invariance. The relative phase Δ of S and P is given by $\Delta = \tan^{-1}(\beta/\alpha)$. The large fractional uncertainties in α and β leave Δ practically undetermined.

We are appreciative of the diligent efforts of the 25-inch bubble chamber crew and our scanning and measuring personnel. We also acknowledge the continuing support and encouragement of Professor Luis W. Alvarez. This work was done under auspices of the U.S. Atomic Energy Commission.

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FIGURE CAPTION

Fig. 1. $\ln\zeta(\varphi)$ as a function of φ.

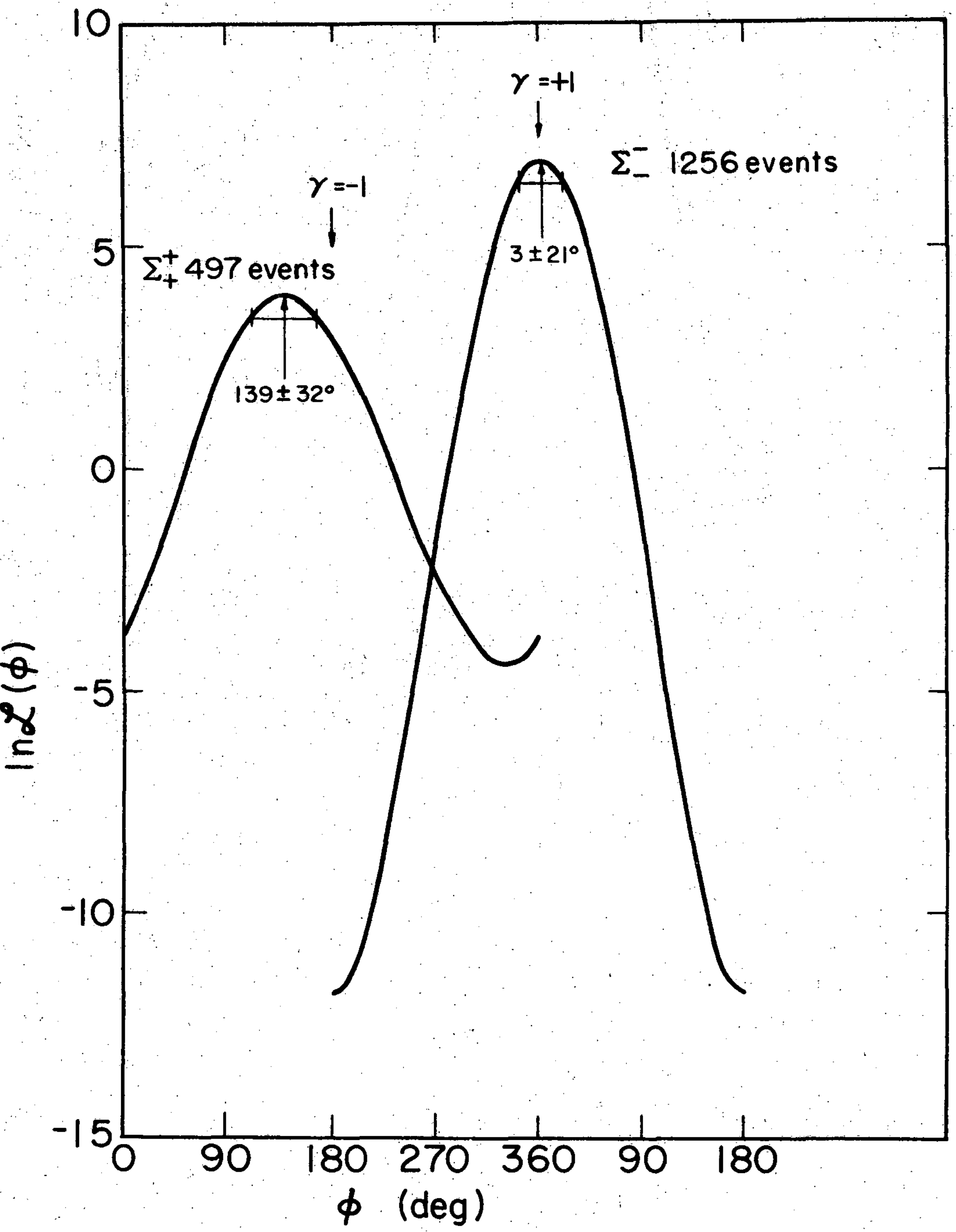

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Fig. 1