Title
A NEW EXPERIMENTAL TEST OF THE DECAY RATE PREDICTION, 2 E- = /\ + /3 E+

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A NEW EXPERIMENTAL TEST OF THE DECAY RATE PREDICTION,
$2\Xi^-_- = \Lambda_- + \sqrt{3}\,\Sigma^+_0$

Berkeley, California

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Errata

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ERRATA

TO: All recipients of UCRL-11305

FROM: Technical Information Division

Subject: UCRL-11305, "New Experimental Test of the Decay-Rate Prediction, $2\Xi_-^- = \Lambda_- + \sqrt{3}\Sigma_0^+$," Physics Letters 9, 349 (1964).

M. L. Stevenson, J. P. Berge, J. R. Hubbard, G. R. Kalbfleisch, J. B. Shafer, F. T. Solmitz, S. G. Wojcicki, and P. G. Wohlmut

Please make the following corrections on subject report.

Page 349, authors reads: Wholmut. It should read: "Wohlmut."

Page 350, Eq. (12) reads: $\alpha_\Xi = \cdots$. It should read: "$\alpha_\Lambda = \cdots$."

Page 350, Top of second column reads: $\tau_{\Xi^+} = \cdots$. It should read: "$\tau_{\Sigma^+} = \cdots$."

Page 351, Table 1, next to last entry reads: $(10A \times 10^{-5}\ \text{sec}^{-1}\ m_{\pi^-}^{-1})$. It should read: "$(8\pi)^{-1/2}(10A) \times 10^{-5}\ (\text{sec}\ m_{\pi^-})^{-1/2}$."

Page 351, Table 1, last entry reads: $(10A \times 10^{-5}\ \text{sec}^{-1}\ m_{\pi^-}^{-1})$. It should read: "$(8\pi)^{-1/2}\ B \times 10^{-5}\ (\text{sec}\ m_{\pi^-})^{-1/2}$."

We wish to thank Dr. S. Y. Lo for pointing out the neglected factor of $(8\pi)^{-1/2}$ in the last two entries of the table. This does not affect any of the results.

submitted to Physics Letters

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February 19, 1964

A New Experimental Test of the Decay Rate Prediction,* $2\Xi^-_- = \Lambda_- + \sqrt{3}\,\Sigma^+_0$

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Predictions for a relationship between the amplitudes for the nonleptonic decay of $\Xi^- \rightarrow \Lambda + \pi^-$, $\Lambda \rightarrow p + \pi^-$, and $\Sigma^+ \rightarrow p + \pi^0$ have been made by B. Lee,[1] M. Gell-Mann,[2] H. Sugawara,[3] and S. Coleman and S. Glashow.[4] Lee, using SU_3 symmetry, octet dominance, and R invariance (i.e. inversion through the origin $T_z = 0$, $Y = 0$) predicts that the nonleptonic covariant decay amplitudes for both the S wave (A) and P wave (B) satisfy the relationship

$$2\Xi^-_- = \Lambda_- + \sqrt{3}\,\Sigma^+_0 , \tag{1}$$

and hence a triangular relationship exists. Gell-Mann finds that the relationship (1) holds for the parity-violating amplitude [i. e. the S-wave (A)] under the weaker assumption of CP invariance and SU_3 symmetry with "octet dominance." Coleman and Glashow, like Lee, predict the relationship to hold for both the S-wave (A) and P-wave (B) amplitudes (i. e., a triangular relationship), but without the strong assumption of R invariance which is not satisfied for the strong interactions. However, they require the existence of a presently unobserved octet of scalar mesons. The weak interactions proceeding virtually through these mesons violate combined CP and SU_3 invariance for the parity-conserving amplitude [i. e., the P-wave (B)] (M. Gell-Mann, private communication.) We wish to present experimental evidence from our Ξ^- data in the reaction $K^- + p \rightarrow \Xi^- + K^+$ that bears on this prediction.

A and B are related to the decay matrix, and the decay rate,[5] by

$$\mathcal{M} = \overline{U}(b')\,(A - B\,\gamma_5)\,U(b), \tag{2}$$

and

$$w = \frac{q}{8\pi M^2}\left\{ |A|^2 [(M+m)^2 - \mu^2] + |B|^2 [(M-m)^2 - \mu^2] \right\}. \qquad (3)$$

The U's are the baryon spinors and M, m, and μ are the rest masses of the parent baryon (b), the decay baryon (b') and decay pion, respectively. q is the pion momentum.

In Pauli spin space the decay matrix is written as

$$\mathcal{M} = \chi^{+}(b') \left\{ A_s + A_p \vec{\sigma} \cdot \hat{P}_{b'} \right\} \chi(b) , \qquad (4)$$

where $\hat{P}_{b'}$ is the unit vector in the decay baryon direction and the χ's are Pauli spinors. The decay parameters are defined in terms of A_s and A_p rather than A and B, thus

$$\begin{aligned} \alpha &= 2 \,\mathrm{Re}\, A_s A_p^* / (|A_s|^2 + |A_p|^2), \\ \beta &= 2 \,\mathrm{Im}\, A_s A_p^* / (|A_s|^2 + |A_p|^2), \\ \gamma &= (|A_s|^2 - |A_p|^2) / (|A_s|^2 + |A_p|^2) . \end{aligned} \qquad (5)$$

A and B are related to A_s and A_p by

$$x \equiv A_p/A_s = (B/A) \left[\frac{(M-m)^2 - \mu^2}{(M+m)^2 - \mu^2} \right]^{1/2} . \qquad (6)$$

Here we ignore final-state interaction and use the prediction of time-reversal invariance that all amplitudes are relatively real (i.e. $\beta = 0$). For a given α, x is a double-valued function,

$$x = \frac{1}{\alpha}(1 \pm \sqrt{1-\alpha^2}) \quad \text{or} \quad \alpha x = 1 - \gamma , \qquad (7)$$

where the sign of γ determines the correct root.

Following Lee,[1] we represent the decay amplitudes graphically with the value of B plotted as the ordinate and A as the abscissa. The tangent of the angle that a given decay amplitude makes with respect to the A axis is

$$\epsilon \equiv B/A = x \cdot \left[\frac{(M-m)^2 - \mu^2}{(M+m)^2 - \mu^2}\right]^{1/2} . \qquad (8)$$

We report here on the measurements of the decay rate, w, and the α, β, and γ for the $\Xi^- \rightarrow \Lambda + \pi^-$ decay and how they bear upon the above prediction. Our results are based upon a sample of 900 Ξ^- decays. Details of this analysis will appear elsewhere.[6,7] For the lifetime of the Ξ^- we obtain

$$\tau_{\Xi^-} = 1.69 \pm 0.07 \times 10^{-10} \text{ sec.} \qquad (9)$$

To relate the lifetime of the Ξ^- to the decay rate $\Xi^- \rightarrow \Lambda + \pi^-$ we have searched for other decay modes, such as leptonic decay, and found them to be negligible. Therefore,

$$w(\Xi^- \rightarrow \Lambda + \pi^-) = 0.592 \pm 0.025 \times 10^{10} \text{ sec}^{-1}. \qquad (10)$$

When we assume the Ξ^- spin to be 1/2 and use $\alpha_\Lambda = 0.62$[6] we obtain from our analysis

$$\alpha_{\Xi^-} = -0.41 \pm 0.08,$$

$$\beta_{\Xi^-} = \sqrt{1-\alpha_{\Xi^-}^2} \sin \phi_{\Xi^-} = +0.08 \pm 0.26, \qquad (11)$$

$$\gamma_{\Xi^-} = \sqrt{1-\alpha_{\Xi^-}^2} \cos \phi_{\Xi^-} = 0.91,$$

$$\phi_{\Xi^-} = 0.08 \pm 0.28 \text{ radian} .$$

From these values we obtain $\epsilon_{\Xi^-} = -3.45 \pm 0.66$.

In Fig. 1 we graph the amplitude $2\,\Xi_-^-$, whose magnitude is proportional to $\sqrt{A^2 + B^2}$.

The value of Λ_- is determined from

(a) $\tau_\Lambda = 2.55 \pm 0.07 \times 10^{-10}$ sec,[9]

(b) $w(\Lambda \rightarrow p + \pi^-)/[w(\Lambda \rightarrow p + \pi^-) + w(\Lambda \rightarrow n + \pi^0)] = 0.660 \pm 0.004$,[10] (12)

and (c) $\alpha_\Lambda = 0.62 \pm 0.07$.[8]

For Σ_0^+ we use

(a) the lifetime $\tau_{\Sigma^+} = 0.78 \pm 0.03 \times 10^{-10}$ sec,[11]

(b) the branching ratio $w(\Sigma^+ \rightarrow p + \pi^0)/[w(\Sigma^+ \rightarrow p + \pi^0) + w(\Sigma^+ \rightarrow n + \pi^+)]$
$= 0.507 \pm 0.023$,[11]

and (c) $\alpha_0 = -0.90 \pm 0.25$.[12] A value of α_0 has been published by Beall et al.,[13] but these authors are presently recalculating a new value of α_0 based upon more recent information on the analyzing power of the proton-carbon interactions. Therefore, until their new value is published we use only the data of Tripp et al.[12]

Table I summarizes the experimental values used in obtaining the triangle plot of Fig. 1. Three vectors are displayed for $\sqrt{3}\ \Sigma_0^+$, one for $\alpha_0 = -1$ (the value that very nearly closes the $\Sigma_-^- = \Sigma_+^+ + \sqrt{2}\ \Sigma_0^+$ triangle), and two with associated error ellipses, for the two roots of $x(\Sigma_0^+)$. Since the sign of $\gamma_{\Sigma_0^+}$ is unknown, one of the roots cannot be ruled out. For either root the experimental agreement is good. Chi-squared tests indicate that the probabilities of getting fits worse than the ones displayed are 66% for $\gamma_{\Sigma_0^+} > 0$ and 26% for $\gamma_{\Sigma_0^+} < 0$, respectively. From the figure one sees that the main uncertainty in the experimental validity of the triangular relationship comes from the uncertainty in $\alpha_{\Sigma_0^+}$ (and $\gamma_{\Sigma_0^+}$) not from the values of the lifetimes and branching ratios. Nothing that we have measured so far tells us whether the individual vectors point in the directions that we have shown or 180 degrees opposite to them. We have simply chosen the directions that would best satisfy the rule.

The $\Delta T = 1/2$ rule for nonleptonic decay, which is also a consequence of these theories, predicts $w(\Xi^0 \rightarrow \Lambda + \pi^0)/w(\Xi^- \rightarrow \Lambda + \pi^-) = 1/2$. From our value of the Ξ^0 lifetime,[7] $\tau_{\Xi^0} = 2.5^{+0.4}_{-0.3} \times 10^{-10}$ sec, we find the ratio of the Ξ^0 decay rate to the Ξ^- decay rate to be 0.68 ± 0.10, within two standard deviations of the predicted value.

REFERENCES

*This work done under the auspices of the U. S. Atomic Energy Commission.

1. B. W. Lee, Phys. Rev. Letters 12, 83 (1964).

2. M. Gell-Mann, Phys. Rev. Letters 12, 155 (1964).

3. Hirotaka Sugawara (to be published).

4. S. Coleman and S. L. Glashow, Departures from the Eightfoldway: The Theory of Strong-Interaction Symmetry Breakdown, Lyman Laboratory of Physics, Harvard University, Cambridge, Mass. PR 134, B671 (1964)

5. See, for example, S. B. Treiman, in Proceedings of the 1958 Annual International Conference on High Energy Physics at CERN (CERN, Geneva, 1958), page 276.

6. J. Cronin and O. Overseth, Phys. Rev. 129, 1795 (1963).

7. J. R. Hubbard, J. P. Berge, G. R. Kalbfleisch, J. B. Shafer, F. T. Solmitz, M. L. Stevenson, S. G. Wojcicki, and P. G. Wohlmut, The Lifetimes of the Ξ^- and Ξ^0 Hyperons, submitted to Phys. Rev.

8. J. P. Berge, P. E. Eberhard, J. R. Hubbard, G. R. Kalbfleisch, J. B. Shafer, F. T. Solmitz, M. L. Stevenson, S. G. Wojcicki, and P. G. Wohlmut, Production and Decay of Cascade Hyperons by K^-+p Interactions Between 1.2 and 1.7 BeV/c, to be submitted to the Physical Review.

9. This value is the average of our value of $\tau_\Lambda = 2.59 \pm 0.09 \times 10^{-10}$ sec and the compiled average of $\tau_\Lambda = 2.51 \pm 0.09 \times 10^{-10}$ sec found in Barkas and Rosenfeld, UCRL-8030 Rev., April 1963.

10. We combine the data of (a) W. Humphrey and R. Ross, Phys. Rev. 127, 1305 (1962), with the data of the following authors as summarized by reference 10:

(b) M. Chrétien, V. K. Fischer, H. R. Crouch, Jr., R. E. Lanou, Jr., J. T. Massimo, A. M. Shapiro, J. P. Averell, A. E. Brenner, D. R. Firth, L. G. Hyman, M. E. Law, R. H. Milburn, E. E. Ronat, K. Strauch, J. C. Street, J. J. Szymanski, L. Guerriero, I. A. Pless, L. Rosenson, and G. A. Salandin, Phys. Rev. 131, 2208 (1963);

(c) J. L. Brown, H. C. Bryant, R. A. Burnstein, D. A. Glaser, R. Hartung, J. A. Kadyk, J. D. Van Putten, D. Sinclair, G. H. Trilling, and J. C. Van der Velde, Nuovo Cimento 19, 1155 (1961);

(d) C. Baglin, M. Bloch, V. Brisson, J. Hennessy, A. Lagarrigue, P. Mittner, P. Musset, A. Orkin-Lecoutois, P. Rancon, A. Rousset, A. M. Sarius, X. Sauteron, and J. Six, Nuovo Cimento 18, 1043 (1960);

(e) F. S. Crawford, Jr., M. Cresti, R. L. Douglass, M. L. Good, G. R. Kalbfleisch, M. L. Stevenson, and H. K. Ticho, Phys. Rev. Letters 2, 266 (1959);

(f) F. Eisler, R. Plano, N. Samios, M. Schwartz, and J. Steinberger, Nuovo Cimento 5, 1700 (1957);

(g) Frank S. Crawford, Jr., in Proceedings of the 1962 International Conference on High Energy Physics at CERN (CERN, Geneva, 1962), pp. 832-836;

(h) M. Schwartz, in Proceedings of the 1960 International Conference on High Energy Physics at Rochester (Interscience Publishers, Inc., New York, 1960), p. 726.

11. Compilation by Matts Roos, Rev. Mod. Phys. 35, 314 (1963) which includes

(a) Berkeley and Michigan groups, 1958 International Conference on High Energy Physics at CERN, page 271;

(b) Evans et al., Nuovo Cimento 15, 873 (1960);

(c) Freden, Komblurn, and White, Nuovo Cimento 16, 611 (1960);

(d) Dyer, Barkas, Heckman, Mason, Nickols, and Smith (unpublished value of $0.82^{+0.10}_{-0.08} \times 10^{-10}$ sec);

(e) W. Humphrey and R. Ross, Phys. Rev. 127, 1305 (1962).

12. R. D. Tripp, M. B. Watson, and M. Ferro-Luzzi, Phys. Rev. Letters 9, 66 (1962).

13. E. F. Beall, B. Cork, D. Keefe, W. C. Murphy, and W. A. Wenzel, Phys. Rev. Letters 8, 75 (1962), and private communication.

Table I. Summary of experimental data.

	Ξ^-_-	Σ^+_0	Λ_-
$(\tau\times10^{10})$ sec	1.69±0.07	0.78±0.03	2.55±0.07
Branching ratio	1.000	0.507±0.023	0.660±0.004
$[w(b\to b'+\pi)\times10^{-10}]\sec^{-1}$	0.592±0.025	0.650±0.045	0.259±0.008
α	-0.41±0.08	-0.90±0.25	0.62±0.07
β	0.08±0.26		0.18±0.24
γ	0.91		0.78±0.06
M(MeV)	1321.0	1189.40	1115.36
m(MeV)	1115.36	938.21	938.21
μ(MeV)	139.59	135.00	139.59
$\frac{(M+m)^2-\mu^2}{(M-m)^2-\mu^2}$	259.46	101.87	352.88
$(10A\times10^{-5})\sec^{-1} m_{\pi^-}^{-1}$	4.09±0.18	3.39±0.59($\gamma_\Sigma>0$) 2.0±0.9($\gamma_\Sigma<0$)	3.09±0.10
$(B\times10^{-5})\sec^{-1} m_{\pi^-}^{-1}$	-1.41±0.12	-2.1±0.9($\gamma_\Sigma>0$) -3.5±0.5($\gamma_\Sigma<0$)	2.02±0.26

FIGURE LEGEND

Fig. 1. Test of rule $2\ \Xi^{-}_{-} = \sqrt{3}\ \Sigma^{+}_{0} + \Lambda_{-}$.

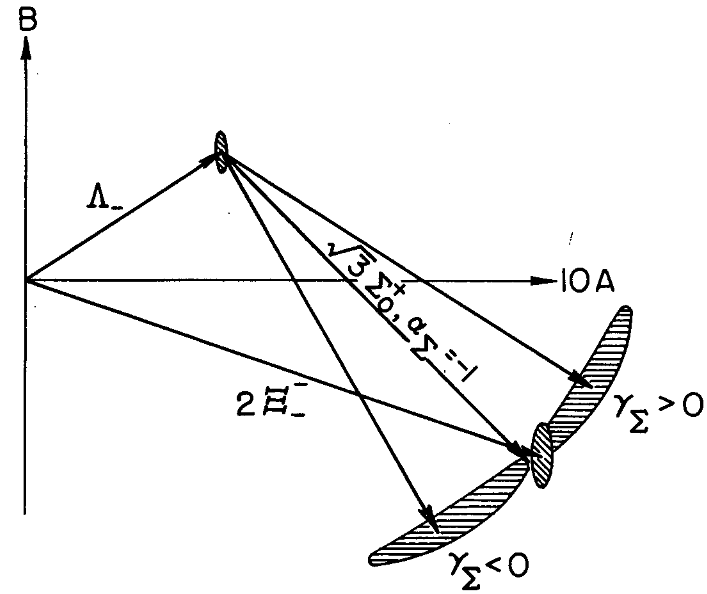

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Fig. 1.