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APPENDIX

Consider the following expansion of $g(\alpha)$ about $\alpha=\beta$, where α and β depend upon a common parameter:

$$g(\alpha)=\sum_{m=0}^{\infty}\frac{1}{m!}\frac{d^m}{d\alpha^m}\left[(\alpha-\beta)^m\frac{d\beta}{d\alpha}g(\beta)\right]. \quad \text{(A.1)}$$

To see that this series generates a Taylor series, first substitute $\alpha-\beta=\phi$, and hence $d\beta/d\alpha=1-d\phi/d\alpha$, into Eq. (A.1). Then, using the relation

$$\phi^m\frac{d\phi}{d\alpha}g(\beta)=(m+1)^{-1}\frac{d}{d\alpha}[\phi^{m+1}g(\beta)] - (m+1)^{-1}\phi^{m+1}\frac{d\beta}{d\alpha}\frac{dg(\beta)}{d\beta}, \quad \text{(A.2)}$$

obtained from differentiating the product $\phi^{m+1}g(\beta)$, and rearranging terms, gives

$$g(\alpha)=\sum_{m=0}^{\infty}\frac{1}{m!}\frac{d^m}{d\alpha^m}[\phi^m g(\beta)] - \sum_{m=0}^{\infty}\frac{1}{(m+1)!}\frac{d^{m+1}}{d\alpha^{m+1}}[\phi^{m+1}g(\beta)] + \sum_{m=0}^{\infty}\frac{1}{(m+1)!}\frac{d^m}{d\alpha^m}\left[\phi^{m+1}\frac{d\beta}{d\alpha}\frac{dg(\beta)}{d\beta}\right]. \quad \text{(A.3)}$$

The second sum in Eq. (A.3) cancels all but the first term of the first sum. The surviving term is the zeroth derivative, $g(\beta)$, which is the first term of the Taylor series with the third sum in Eq. (A.3) as remainder.

Applying the above procedure m times to the series remaining at each step and making the replacement $\phi=\alpha-\beta$ generates the first m terms of the Taylor series with a series remainder.

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π^+-Mesonic Decay of a Hyperfragment*

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The π^+-mesonic decay of a hyperfragment has been observed. The hyperfragment was produced in a negative K-meson star in emulsion, and it decayed into two visible particles, a π^+-meson and a recoil. It can be interpreted as ${}_{\Lambda}Li^7\rightarrow n+\pi+He^6$, or ${}_{\Lambda}Be^7\rightarrow n+\pi^++Li^6$. Since the Λ particle decays only into $p+\pi^-$ and $n+\pi^0$, the appearance of a π^+-meson from this hyperfragment is explained as due to the charge exchange of a π^0-meson from the Λ decay with the residual nucleus of the hyperfragment.

HYPERFRAGMENTS are known to decay by three modes: nonmesonic, π^--mesonic corresponding to the decay mode $\Lambda\rightarrow p+\pi^-$, and π^0-mesonic corresponding to the decay mode $\Lambda\rightarrow n+\pi^0$.[1]

An event (No. L4-54) has been found in this laboratory which is interpreted as the π^+-mesonic decay of a hyperfragment. It occurred in a stack of Ilford L4 emulsions which was exposed to a beam of negative K mesons at the Bevatron. One prong (track F) of a three-pronged K^--meson star which was produced at rest, decayed into two particles: a recoil particle (track 1), and a π^+ meson (track 2). Track F is completely black. The π^+ meson is identified by the fact that after coming to rest it underwent the characteristic π-μ decay. The range of the μ meson was 600 microns. This compares to the mean range of μ mesons from π-μ decay of 602 microns. The measurements on tracks F, 1, and 2 are given in Table I.

In considering this event, we ask which of the particles produced in K-meson capture (Σ^+, Σ^0, Σ^-, and Λ) can decay into a π^+ meson. Clearly only the Σ^+ can do this, i.e., $\Sigma^+\rightarrow\pi^++n$. Since the particle making track F decays into two charged particles, if the Σ^+ were involved it would have to be a bound Σ^+. There

Table I. Measurements on tracks F, 1, 2.

Track	Dip angle (degrees)	Angle in the plane of the emulsion (degrees)	Range (in microns)	Identity	Energy (Mev)
F	0	···	4.0	${}_{\Lambda}Li^7$ or ${}_{\Lambda}Be^7$	1.4 or 3.4
1	−44.0	0	9.0	He^6 or Li^6	2.6 or 4.1
2	+66.5	91.9	4050	π^+	13.8

* Supported by the U. S. Atomic Energy Commission.
[1] Schneps, Fry, and Swami, Phys. Rev. **106**, 1062 (1957); R. Levi Setti and W. E. Slater, Phys. Rev. **111**, 1395 (1958).

is some evidence[2] that the Σ^+p system is bound. If we assume that F is the track of a bound Σ^+p, then the decay would be

$$(\Sigma^+p)_{\text{bound}}\rightarrow p+n+\pi^+. \tag{1}$$

Assuming that track 1 is that of a proton and giving the residual momentum of the π^+ and proton to a single neutron, we find that the Q value of reaction (1) is 15.8 Mev. However, the Q-value for the Σ^+ decay is about 110 Mev. Hence we can rule out this interpretation.

A reasonable assumption is that the event was the decay of a hyperfragment in which the Λ decayed by the π^0-mesonic mode, the π^0 meson subsequently charge exchanging with the core of the hyperfragment, into a π^+ meson. If we assume that only one neutron was emitted, then this event can be fitted to the following two decay schemes:

$$_{\Lambda}\text{Li}^7\rightarrow n+\pi^++\text{He}^6, \tag{2}$$

$$_{\Lambda}\text{Be}^7\rightarrow n+\pi^++\text{Li}^6. \tag{3}$$

The Q value in reaction (2) is 26.5 Mev and the binding energy of the Λ is 5.7 Mev. The Q value in reaction (3) is 34.9 Mev and the binding of the Λ is 5.4 Mev. These are excellent fits.

Because of the low sensitivity of Ilford L4 emulsion to minimum-ionizing tracks, we are not able to examine track 1 for the electron from the β decay of He^6. Also, we point out that more than one neutron may have been emitted in the decay.

Since track F is flat we have measured its thickness by the method of Alvial *et al.*,[3] using cells of 0.2 micron. The ratio of its mean thickness to that of the K meson which produced it is 1.14 ± 0.03. The ratio of the thickness of helium particles to K mesons we find to be 1.09 ± 0.04. For Li^8 we find this ratio to be 1.20 ± 0.07. These values were determined from seven helium tracks and five Li^8 tracks, all of dip angle less than 20 degrees. The errors quoted are rms deviations. This suggests the charge of the particle which made track F is 2 or 3. Since the range of F is small and we do not know the thickness of Be tracks, we cannot rule out a charge of 4. These thickness measurements are consistent with the above interpretation of the event.

[2] W. F. Fry, Proceedings of the Padua-Venice Conference on Elementary Particles, 1957 [Suppl. Nuovo cimento (to be published)].

[3] Alvial, Bonetti, Dilworth, Ladu, Morgan, and Occhialini, Suppl. Nuovo cimento 4, 244 (1956).

The possibility that this event could be the inelastic scattering of a π^+ meson is extremely unlikely for the following reason: In Ilford L4 emulsion the grain density of a 20–30 Mev π meson is only 30–40 grains per 100 microns, and the grain size is small, about $\frac{1}{3}$ of a micron. It is very unlikely that such a π meson could produce a completely black track of length 4 microns. For example, in a sample of 1000 microns of track corresponding to a 15 Mev π meson, we found that all blobs had a length less than one micron. Also the thickness measurement suggests a charge of two or greater, which tends to rule out a π meson.

We conclude then that this event is the charge exchange of the π^0 from a hyperfragment decay and is most likely represented by the two-step process

$$_{\Lambda}\text{Li}^7\rightarrow n+\pi^0+\text{Li}^6\rightarrow n+\pi^++\text{He}^6, \tag{4}$$

or

$$_{\Lambda}\text{Be}^7\rightarrow n+\pi^0+\text{Be}^6\rightarrow n+\pi^++\text{Li}^6. \tag{5}$$

It is also possible that the π^0 meson was virtual. That is, the event would represent the stimulated decay of the Λ by the process

$$\Lambda+p\rightarrow(n+\pi^0)+p\rightarrow n+\pi^++n.$$

Note added in proof.—Another interesting hypothesis for the explanation of this event is the following. If, as has been suggested by Dallaporta and Ferrari, and Ross and Lichtenberg, the virtual process $\Lambda\rightarrow\Sigma+\pi$ is important in the Λ-n interaction, then the Λ-n system can exist in a virtual Σ-n state. Then we would expect hyperfragments to occasionally decay from the virtual state, and hence a π^+-mesonic decay would be possible. The frequency with which such decays can be expected to occur has not been estimated.

It should also be pointed out that the probability for a negative π meson to decay from rest into a μ meson of the normal range is about one in five thousand, as observed by Fry and White.

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