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DECAY OF A BERYLLIUM HYPERFRAGMENT

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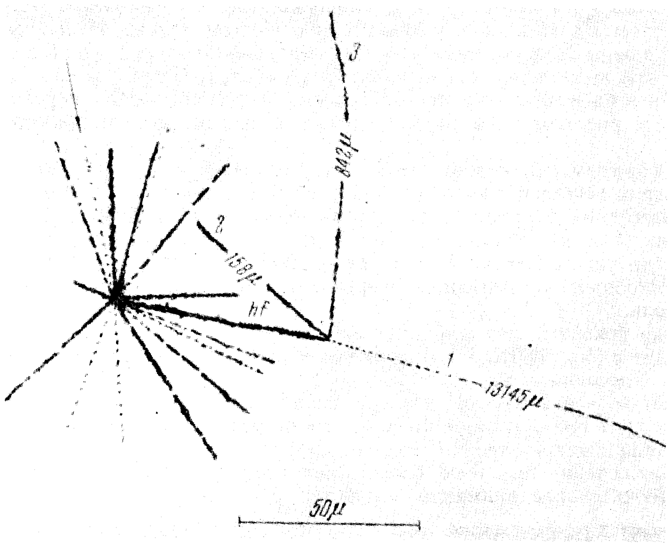
A systematic scanning of Ilford G-5 emulsions[1] irradiated at an approximate altitude of 25 km we observed a non-mesonic decay of a beryllium hyperfragments, which permits a relatively accurate measurement of the binding energy of the Λ^0 particle.

A primary star of the 12 + 4p type (see microphotograph) emits a slow particle hf. It is stopped in the same layer and forms a secondary three-prong star. The hf range is 60 microns. An estimate of the charge, made by comparing the thickness of hf track with the thicknesses of the tracks of the Be^8 fragments and the alpha particles from the Be^8 decay yields $Z \approx 4$. An analogous estimate was made for tracks 1, 2, and 3. The measurement details are listed in the table.



Track of Hyperfragment

Primary star	12 + 4p
Connected phenomena	None observed
Length, μ	60 ± 2
Angle with undeveloped emulsion	28° + 30′
Proof of stopping	Thinning
Charge hf	4
Energy of nucleon, Mev	≈ 3.9, if Be^8

Secondary Star

Track	1	2	3
Nature of particle	p	He^4	d
Range	13145	158	842
Experimental error	± 120	± 2	± 10
Measured mass, $m_e(\alpha, R)$	1820 ± 250	–	3400 ± 1300
Energy, Mev	61.4 ±0.8	19.1±0.2	17.6±0.3
Angle of inclination, θ	−1°10′	41°50′	−15°50′
Error Δθ	± 10′	± 30′	± 30′
Polar angle φ	182° 40′	17°4p′	64°
Error Δφ	± 0.50	± 1°	± 1°

The total momentum of particles 1, 2, and 3 is 345.7 ± 2 Mev. Assuming that an equal and opposite momentum has been carried away by the neutron, we arrive at the following decay scheme:

$$^{*}_{\Lambda^0}Be^8 \to He^4 + d + p + n + Q, \quad Q = (160.0 \pm 1.3) \text{ Mev}.$$

We obtain for the binding energy of Λ^0 in the Be^8 nucleus $B_{\Lambda^0} = 9.2 \pm 1.6$ Mev.

The measured values of B_{Λ^0} for the known decays of $_{\Lambda^0}Be^8$ are 3.7 ± 3 (reference 2), 0 ± 5 (reference 3), 9.3 or 6.6 (depending on the decay scheme, reference 4), and 5.9 ± 0.5 (mesonic decay, reference 5).

The three decay schemes

$$^{*}_{\Lambda^0}Be^9 \to He^5 + d + p + n + Q;$$
$$^{*}_{\Lambda^0}Be^8 \to He^3 + H^3 + p + n + Q;$$
$$^{*}_{\Lambda^0}Be^9 \to He^4 + H^3 + p + n + Q$$

can be eliminated, for they lead to large negative values of B_{Λ^0}, equal respectively to 13.6 ± 1.8, −18.3 ± 1.8, and −27.5 ± 2.2 Mev.

Decay schemes with several neutral particles cannot be excluded, but are less probable. In the processing of the data we used the values of the constants from Shapiro's review[6] and the range-energy relations from the paper by Fry, Gottstein, and Hain.[7]

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ON THE PROBABILITY OF DOUBLE BETA DECAY

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As is well known, the experimental searches for double β decay undertaken up to now have not met with success, although the accuracy of the experiments has increased so greatly that one of the latest papers[1] gives for the lower limit on the half-life $T_{1/2}$ a value of 0.7×10^{19} years. On the other hand theoretical calculations give for $T_{1/2}$ (in the Majorana scheme, $\nu \equiv \tilde{\nu}$) a quantity of the order of 10^{12} to 10^{19} years.[2-6] Therefore the negative results of searches for double decay can be interpreted as an indication that the neutrino is not a Majorana particle. At present, however, the accuracy of the experiments is still not great enough for the discovery of double β decay with Dirac neutrinos ($\nu \neq \tilde{\nu}$).

In view of the new situation in the theory of β decay it is useful to make a theoretical reexamination of the problem of the probability of double β decay, with due regard to effects of parity nonconservation and nonconservation of the leptonic charge (the latter possibility is evidently not very probable, but cannot as yet be finally rejected). The Hamiltonian of the β interaction with nonconservation of parity and leptonic charge has been discussed by Pauli.[7] Enz,[8] starting from Pauli's results, obtained the expression in general form for the probability of double β decay. We note the fact that the probability of double β decay is proportional to a combination of the squares of the quantities

$$I_{ij} = C_iC_j - C_i'C_j', \quad J_{ij} = C_iC_j' - C_jC_i'. \tag{1}$$

where C and C′ are the coupling constants for the terms conserving parity and not conserving it, and the indices i, j take the values S, V, T, A, P.

It can be seen from Eq. (1) that (for $i = j$) even in the case of the Majorana neutrino the probability of double β decay can be much smaller than the value previously given if $|C| \approx |C'|$, or can even be exactly zero if $|C| = |C'|$. One can get an idea of the ratio of the constants C and C′ from the data of experiments to measure the longitudinal polarization of β-ray electrons or the circular polarization of γ-ray quanta. At present the precision of these experiments is such that the equality $|C| = |C'|$ is established with an accuracy of 10 to 20 percent. In this scheme the theoretical value of the half-value period of double β decay can be written as follows ($i = j = V$; the order of magnitude of $T_{1/2}$ is practically independent of the choice of type of interaction):

$$T_{1/2} \leqslant 1 \cdot 10^{19} \frac{(ft)^2}{|I|^2 K(\varepsilon)} \frac{A^{2/3}}{Z^2} \text{ sec}, \tag{2}$$

where ft is the well known quantity characteristic of β decay, Z and A are the atomic number and mass number, and $K(\epsilon)$ is a function depending on the energy ϵ of the transition (its values* for several nuclei are given in the table).† Setting $|C| = 0.8\,|C'|$, we get for Ca^{48} the result $T_{1/2} \leq 2 \cdot 10^{19}$ years.

As can be seen from Eq. (1), in the case of equality of the constants, $|C| = |C'|$, double β decay can occur only for the following choice of the signs of the constants: $C_i = -C_i'$, $C_j = C_j'$, or $C_i = C_i'$, $C_j = -C_j'$. But the very latest data on the polarization of β-ray electrons evidently agree with $C_S/C_S' = C_T/C_T' = 1$ and $C_V/C_V' = C_A/C_A' = -1$.[9] Using also the fact that the Fierz interference terms vanish, we get only the following two possible combinations of interaction types with which double β decay can occur: $i = S$, $j = A$, and $i = V$, $j = T$. It is well known, however, that double β decay occurs mainly between nuclei in 0^+ states. The probability of double β decay will be proportional to the product of the squares of the Fermi (M_F) and Gamow-Teller (M_{GT}) matrix elements. For allowed transitions M_F gives the selection rules $\Delta J = 0$ (no), whereas the allowed M_{GT} give the rules $\Delta J = 0, \pm 1$ (no), with $0 \to 0$ forbidden. Therefore double β decay can occur only through the level 1^- (or through levels with higher angular momentum), but then both the first transition ($Z \to Z + 1$) and the second transition ($Z + 1 \to Z + 2$) will be singly forbidden. The