Results of treating the Λ° particles

Decay event number	Q[1] Mev	Kinetic energy[1] of Λ° Mev	$\Delta\varphi$,[2] degrees	$\Delta\alpha$,[2] degrees	parent event
1	38,3	3,0	0,8±5,5	2,0±2,9	σ_K
2[3]	42,0	20,9	1,0±2,6	0,5±2,8	σ_K
3	36,0	13,1	1,6±2,3	1,5±1,9	σ_K
4	36,4	10,1	0,2±1,5	0,5±2,1	σ_K
5	38,2	14,5	0,9±1,5	0,0±2,7	ρ_K[6]
6[4]	40,0	48	0,1±2,0	1,5±2,2	σ_K
			1,2±2,0	2,2±2,2	ρ_K[6]
7	38,3	4,9	1±5	0,0±2,1	σ_K
8	37,5	12	1±2,0	0,5±2,1	σ_K
9	38,9	8,8	0,5±1,9	1,5±2,3	ρ_K[6]
10[5]	37,5	3,4	—	—	—
11[5]	36,8	0,9	—	—	—
12[5]	36,5	10,1	—	—	—
13	36,6	6,0	0 4±1,5	0,8±4,5	σ_K
14[5]	37,1	18,4	—	—	—
15	38,2	35,5	2±2,4	2,5±2	ρ_K[6]
16	38,7	23,2	1,7±2,0	2±1,7	σ_K
17	38,3	7,3	2,1±2,5	2,5±2,6	σ_K
18[5]	38,1	10,13	—	—	—

[1]The errors in the energies are 1 to 2 Mev.

[2]Emulsion shrinkage was not considered in estimating the errors for events 1, 2, and 17, since the Λ^0 decay and the parent event were observed in the same pellicle.

[3]The energy of the π^- meson was estimated from the ionization.

[4]This event has two possible parent events. The energy of the π^- meson was estimated from the ionization.

[5]The parent event (σ_K, ρ_K) was not found.

[6]The mass was determined from multiple scattering and ionization.

One may expect that a juxtaposition of the Λ^0 decays with the parent events will be helpful in the investigation of the diverse types of nuclear interactions associated with the production Λ^0 particles and in the study of the properties of the Λ^0 particles themselves.

The authors express deep gratitude to E. Gerul, Prof. M. Danysz and M. I. Podgoretskii for the statement of the problem and for valuable advice in the course of the work.

*Institute of Nuclear Studies, Warsaw.

†The authors take this opportunity to express gratitude to Prof. Segré for assistance in obtaining the emulsion stack, and to S. Goldhaber for processing the emulsions.

[1]M. Teucher, Suppl. Nuovo cimento **4**, 482 (1956).

[2]George, Herz, Noon, and Solntseff, Nuovo cimento **3**, 94 (1956).

[3]Apparao et al., Suppl. Nuovo cimento **4**, 474 (1956).

[4]Fay, Gottstein and Hain, Suppl. Nuovo cimento **11**, 234 (1954).

Translated by J. Heberle
214

MEASUREMENT OF THE POLARIZATION OF (D + T) — NEUTRONS AT DEUTERON ENERGIES OF 1800 kev

I. I. LEVINTOV, A. V. MILLER and V. N. SHAMSHEV

Academy of Sciences, U.S.S.R.

Submitted to JETP editor January 18, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **34**, 1030-1032 (April, 1958)

THE reaction $T(d, n)He^4$ at energy of the deuterons of $E_d = 107$ kev passes through the $3/2^+$ level of the He^5 nucleus, formed by s-deuterons. Consequently, the neutrons obtained at this energy cannot be polarized. At $E_d = 2$ Mev, a significant contribution (about 50%) of the higher states is observed. This is confirmed by the deviation of the total cross section from the Breit-Wigner formula for a single level, and also by the appearance of anisotropy in the angular distribution of reaction products.[1] It is of interest to explain the degree of polarization of the neutrons in this very important reaction.

Measurement of the polarization of (D + T) neutrons was carried out with the help of a method described previously.[1] In view of the large energy of the neutrons, the pressure of the helium flowing through the proportional counter was raised to 8 — 12.5 atmospheres (depending on the angle of emission of the neutrons from the target). The angular range of the counters was 22°; the cutoff of the discriminator in working measurements amounted to 80% of the cutoff corresponding to the cutoff of pulses from arbitrary collisions of n — He^4.

A thin (~30 kev) tantalum target, saturated with tritium was employed. The apparatus about the target were lightened as much as possible, so that the neutrons in their path to the counter traversed not more than 1 gm/cm^2 of matter. The construction of the target also permitted intense cooling of the target, which made it possible to raise the ion current to 60 μa.

As was shown previously,[2] the worth of this method consists of the complete absence of noise of parasitic pulses from neutrons which do not undergo scattering on the analyzer (helium). In the measurements taken for the reaction D(d, n)He^3,[3] no extraneous pulses were observed. However, in research with neutrons of much higher energy, there arises the danger of the appearance of pulses from α-particles which appear as products of the reaction (n, α) on the walls of the counters. Protons from various (n, p) reactions cannot be registered by the apparatus, since the energy allotted to them in the counters is not sufficient that their pulses be recorded by the amplifier.

A control experiment making evident the extraneous pulses consisted of a rotation of the counters perpendicular to the incident neutron flux. In this case the pulses from nuclei far distant from the helium were absent, since the largest energies from these nuclei, which are recorded in the small angle of rotation of the counter now traversed the counter transversely and entered into its wall, not succeeding in releasing sufficient energy in the gas. The experiment showed that under operation the apparatus registered about 3 — 5% of the extraneous pulses. According to our assumption, these pulses were produced by α-particles from the reaction O^{16}(n, α)C^{13} in the oxygen of the quartz disc which covered the end window of the counter. The presence of this small noise was taken into consideration in the subsequent experiments.

We also verified the possibility of exciting parasitic asymmetry, connected with the non-symmetric location of various pieces of apparatus. This attempt consisted in the measurement of the velocity of counting of the pulses at the upper and lower positions of the counters, and was carried out on a thick tritium target with deuteron energies of 400 kev. In this case the incident part of the neutron flux consisted of neutrons connected with $3/2^+$ level of the He^5 nucleus. Such neutrons are unpolarized and, consequently cannot give an azimuthal asymmetry for scattering on helium. As a result of these measurements, it was established that the counting rate in both positions was the same within 0.5%.

It was shown earlier that a strong anisotropy in the angular distribution of the products of the reaction under study for poor geometry of our apparatus noticeably distorts the true azimuthal asymmetry. However, the asymmetry of the angular distribution of neutrons of the reaction D(T, n)He^4 for E_d = 1800 kev does not exceed 30%,[1] and therefore, for calculation purposes the polarization of neutrons was not considered. Computation of the angular distribution can increase the value of the asymmetry several times, and our results must be considered as the lower bound for the polarization of neutrons.

The following data were obtained for the azinuthal asymmetry of scattering R at various angles ϑ_n of emission of the neutrons from the target.

In the Table, we have given only the statistical errors of measurement. The effectiveness of our analyzing apparatus is equal to 0.8 to 0.9. Therefore, the values of R in the Table correspond to the following values of the polarization of the neutrons P_n:

$$\vartheta_n = 45;\quad 67.5;\quad 90;\quad 112.5;\quad 135°$$
$$P_n(\%) = 7\pm3;\quad 12\pm3;\quad 10\pm3;\quad 2\pm3;\quad 0\pm5.$$

Thus, for E_d = 1800 kev, we observed a noticeable polarization of the (D + T) neutrons. It should be expected that the polarization would increase with increase in the energy of the deuterons. It is especially interesting to determine the

ϑ_n	45°	67.5°	90°	112.5°	135°
Helium pressure (atmos)	12.5	11.3	10.1	8.8	7.1
R	1.12±0.06	1.22±0.08	1.18±0.06	1.03±0.05	1.00±0.08

degree of polarization of the neutrons for deuteron energies of the order of 8 Mev where, according to the data of Galonsky and Johnston,[1] the existence of resonance is assumed, which corresponds to the level of the He^5 nucleus at 22 Mev (probably $D_{5/2}$).

At the present time we are continuing measurements of the polarization of neutrons of the reaction $D(T, n)He^4$ for high energy deuterons.

---

[1] A. Galonsky and C. H. Johnson, Phys. Rev. **104**, 421 (1957).

[2] Levintov, Miller and Shamshev, J. Exptl. Theoret. Phys. (U.S.S.R.) **32**, 274 (1957); Soviet Phys. JETP **5**, 258 (1957).

[3] Levintov, Miller, Shamshev and Tarumov, J. Exptl. Theoret. Phys. (U.S.S.R.) **32**, 375 (1957); Soviet Phys. JETP **5**, 310 (1957).

Translated by R. T. Beyer
215

SPONTANEOUS RADIATION OF A PARAMAGNETIC IN A MAGNETIC FIELD

V. M. FAIN

Gor'kii Radiophysics Institute

Submitted to JETP editor January 24, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **34**, 1032-1033 (April, 1958).

THE problem of spontaneous emission in the radioband was considered in the papers by Dicke[1] and the author.[2,3] It was shown there that if a system of identical quantum objects* that possess two energy levels E_1 and E_2 ($E_1 < E_2$), are situated in a volume, the linear dimensions of which are much smaller than the wavelength, such a system can radiate coherently. The intensity of the radiation of the system may be proportional not to the number of objects, n, but to its square, n^2. States in which the system radiates in proportion to n^2 were called "superradiant." If originally all objects were in the upper energy state then after a time[3]

$$\tau_{r,0} = \ln n / n\gamma_0 \qquad (1)$$

the system goes over into the "superradiant" state. Here γ_0 is the natural line width of one object. After a time $2\tau_{r,0}$ the system goes over into the lower energy state. Here $\tau_{r,0}$ may be sufficiently small.

Using the theory referred to, the following method of exciting electromagnetic radiation by means of a paramagnetic in a magnetic field is proposed.

We place the paramagnetic in a magnetic field. The electrons† of the paramagnetic will then have two energy levels with an energy difference equal to $E_2 - E_1 = \hbar\omega = g\beta H$, where β is the Bohr magneton, g a factor on the order of unity, and H the magnetic field strength. Let the temperature of the paramagnetic be nearly zero (the generalization to the case of finite temperatures is obvious); the magnetic moments of all the electrons are then arranged along the magnetic field. This will be the lowest energy state of the systems. Let us now reverse the direction of the magnetic field. Such a reversal must be sufficiently fast compared to the thermal relaxation time τ and the time $\tau_{r,0}$ of the radiation, and sufficiently slow compared to the period of radiation, $\tau_{rad} = 2\pi/\omega$, i.e., the reversal time τ_H must satisfy the inequalities

$$\tau_H \lesssim 2\tau_{r,0}; \quad \tau_H \ll \tau, \quad \tau_H \gg \tau_{rad}. \qquad (2)$$

After such a reversal, all electrons are in the upper energy state. Let us assume now that the dimensions of the paramagnetic are much smaller than the wavelength of the radiation $\lambda = 2\pi c/\omega$. After a time $\tau_{r,0}$ the system will then go over into the superradiant state. The intensity of the radiation will be equal to

$$I = \omega^4 |\mu_{12}|^2 n^2 / 3c^3, \qquad (3)$$

where μ_{12} is the dipole moment of the transition $1 \to 2$. It is equal to the Bohr magneton β as far as order of magnitude is concerned.

After the system has radiated, over a period $2\tau_{r,0}$, all the energy, which is equal to $A = n\hbar\omega$, and has gone over into the lower energy state, the magnetic field is reversed anew and the system again starts to radiate.

If we reverse the magnetic field with a frequency $f \approx \frac{1}{2}(\tau_H + 2\tau_{r,0})$ the system will in this way emit an average power on the order of

$$W = n\hbar\omega / (\tau_H + 2\tau_{r,0}). \qquad (4)$$

The peak power must be determined here by Eq. (3).

Let us make some estimates. Let $\omega = 6.3 \times 10^{10}\,sec^{-1}$ (wavelength $\lambda = 3$ cm) and $n = 10^{17}$ (this is a fully attainable number of electrons in a volume of order $(0.7)^3 \approx 0.35\,cm^3$). We have then $\gamma_0 \approx |\mu_{12}|^2\omega^3/\hbar c^3 \approx 0.9 \times 10^{-12}$, $2\tau_{r,0} \approx 0.9 \times 10^{-3} \approx \tau_H$, while the average power is equal to $W = 0.7 \times 10^{-3}$ w and the peak power $I \approx 2 \times 10^{-2}$ w.