PHYSICS

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Abstract

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RELATIVE YIELD AND ENERGY DISTRIBUTION OF PHOTODEUTERONS FROM COPPER

The ratio of the yield of photodeuterons to the yield of photoprotons from copper and the energy distribution of these particles were measured at a maximum energy of the bremsstrahlung spectrum of γ rays of 70 MeV. The target of copper foil had dimensions 1.3×0.4 cm^2. The foil thickness was 25.5 mg/cm^2. Irradiation was carried out in a specially constructed vacuum chamber with photographic plates. The chamber had the form of a cylinder with inlet and outlet tubes for the beam of γ quanta and a tube for pumping. Trapezoidal photographic plates were arranged around the target in such a way as to make it possible to record a continuous angular distribution of the products of photodisintegration of nuclei in the interval of angles θ from 20 to 160° with respect to the direction of the photon beam. In the present experiment particles were recorded at values of θ from 20 to 50°. The distance L from the center of the chamber to the front edge of each plate was 10.4 cm. The mean angle of entry of the particles into the emulsion ξ was 15°. The chamber was placed in a homogeneous magnetic field ($H = 11\,500$ oersted), perpendicular to the direction of flight of the photoparticles recorded by the nuclear emulsions. Nuclear emulsions of the NIKFI-Ya2 type, 400 μ thick, were used.

Fig. 1. Diagram of the arrangement of the target and one of the photographic plates in the chamber. The geometrical constructions necessary for deriving dependences (2) and (3) are shown.

For identification of the particles, a range-momentum analysis was developed. The radius of the circle along which a particle moves in the magnetic field before entering the emulsion is

$$\rho = \frac{c}{ZeH}\sqrt{2mE(R)}, \tag{1}$$

where c is the speed of light; Ze is the particle charge; m is the particle mass; H is the magnetic-field strength; E is the kinetic energy of the particle, determined from the range R in the emulsion. According to formula (1) and the known range-energy curves for protons, deuterons, α particles, and tritons at $H = 11\,500$ oersted, graphs were constructed of the dependence of the radii of curvature on the ranges in the emulsion (see Fig. 2). The ranges of the particles

Fig. 2. Dependences of the radii of curvature on the ranges of particles in the emulsion and the "error zones." The points show the measurement results.

Figure 1: Fig. 2. Dependences of the radii of curvature on the ranges of particles in the emulsion and the "error zones." The points show the measurement results.

were measured in the usual way. To determine the radii of curvature, separate measurements were required. On entering the emulsion, the particle moves practically tangent to the segment of the circle described by it in vacuum. It then follows from the geometry of the arrangement of the photographic plates and the target that

$$\rho = \frac{L + y\cos\xi}{2\cos\varphi \cdot \cos(\alpha \pm \varphi)}, \tag{2}$$

and the angle of emission of the particle with respect to the direction of the γ-ray beam

$$\theta = (90^\circ + \varphi_0) - (\alpha \pm 2\varphi). \tag{3}$$

The meaning of all the quantities entering into (2) and (3) is clear from Fig. 1, which shows the arrangement of the target and one of the photographic plates in the chamber and depicts the geometrical constructions needed in deriving these relations. In particular,

$$\varphi = \operatorname{arc\,tg} \frac{x}{L + y\cos\xi}.$$

For tracks located in different parts of the plate (with respect to the axial dash-dotted line), the angle φ has different signs. For each particle the range in the emulsion, the distances x, y, and the angle α were measured. The remaining quantities were specified during construction or were calculated. Taking reasonable values of the errors for all the quantities entering into (2), "error zones" were calculated for the measurements of ρ. The most substantial errors in determining the radii of curvature are introduced by inaccuracies in the measurements of the angles α and φ. In calculating the "error zones," $\Delta\alpha$ was taken equal to $\pm 1^\circ$.

Fig. 2. Dependences of the radii of curvature on the ranges of particles in the emulsion and the "error zones." The points show the measurement results.

The results of the range-momentum analysis are presented in Fig. 2. The calculated dependences $\rho(R)$ and the corresponding "error zones" for α-particles and tritons practically coincide. For these particles, only the dependence $\rho(R)$ is shown in Fig. 2. For protons and deuterons, in addition to $\rho(R)$, the "error zones" are also indicated. The error zone for deuterons is determined by the

Fig. 3. Energy distribution of photodeuterons

Figure 2: Fig. 3. Energy distribution of photodeuterons

dashed curves with crosses, and for protons by the dashed curves. For these particles, in the range interval $0\div300\,\mu$, according to the calculation, one obtains

there is complete distinguishability. The real distinguishability can be judged from the positions of the experimental points. In comparison with the method of counting grains on particle tracks in a nuclear emulsion, the developed method of particle separation is considerably less laborious and more reliable.

The energy distribution obtained for the identified protons agrees well with the data of other works and is not given in the article. The energy spectrum of "pure" deuterons is shown in Fig. 3. Some fraction of the photodeuterons with energies from 3 to 4 MeV could have been absorbed in the target; this was not taken into account in the spectrum presented. However, even without allowing for absorption in the target, it turned out that the energy interval from 3 to 4 MeV contains $^{2}/_{5}$ of the total number of photodeuterons with energies $4\div19$ MeV. Hence one may conclude that the maximum in the energy distribution lies at an energy $\leqslant 4$ MeV. The energy spectrum of photodeuterons from copper, obtained by Byerly and Stephens ([1]), has a maximum near 3.5 MeV.

The measured ratio of the yield of deuterons with energies $4\div10$ MeV to the yield of protons of the same energies is

$$\frac{Y(\gamma,\mathrm{d})}{Y(\gamma,\mathrm{p})} = 0.07_8 \pm 0.04_1.$$

For the energy interval $3\div10$ MeV,

$$\frac{Y(\gamma,\mathrm{d})}{Y(\gamma,\mathrm{p})} \geqslant 0.08_6 \pm 0.04_5.$$

The maximum errors are indicated. The values of the relative yield of photodeuterons from copper obtained when particles are identified by the grain-counting method ([1-3]) are somewhat higher than the value obtained by us.

Fig. 3. Energy distribution of photodeuterons

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CITED LITERATURE

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Note: Figure translations are in progress. See original paper for figures.