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Abstract

Full Text

PHYSICS

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ENERGY AND ANGULAR DISTRIBUTION OF FAST PHOTOPROTONS FROM Ni AND Al

In experiments on the photodisintegration of nuclei by high-energy γ quanta, $\sim$ 200-300 MeV ($^{1-6}$), a sharp asymmetry has been established in the angular distribution of high-energy protons, with a maximum almost in the direction of the γ-quantum beam, and a sharp break in the energy distribution, plotted on a double-logarithmic scale, at proton energies near one-half of the maximum bremsstrahlung energy. These facts and the cross sections of the processes are qualitatively explained by the absorption of γ quanta by "quasideuterons" in the nucleus (^{7}). Recent experiments on the observation of n—p coincidences in the photodisintegration of nuclei ($^{8-10}$) are also in qualitative agreement with the "quasideuteron" model.

Of the works carried out up to the present time (^{11,12}), in which high-energy photoprotons were studied under irradiation of nuclei by γ quanta with maximum energy $\sim$ 65 MeV, no definite conclusions can be drawn about the mechanism of the (γ, p) reaction in this γ-quantum energy region.

In the present work, using the scintillation-telescope method, we studied the angular and energy distributions of fast photoprotons from Ni and the energy distribution of photoprotons from Al, irradiated with a bremsstrahlung spectrum of γ quanta with $E_{\gamma\,\max} = 85 \pm 5$ MeV. The telescope consisted of a front thin CsJ (Tl) crystal of thickness 0.026 cm and a rear NaJ (Tl) crystal of thickness 1.65 cm, mounted on FEU-19M photomultipliers. The pulses of the front counter, proportional to dE/dx of the particle, and of the rear counter, proportional to E, were analyzed respectively by five-channel integral and five-channel differential discriminators, the outputs of whose channels were connected to triple-coincidence circuits with resolving time $\tau \approx 1 \cdot 10^{-6}$ sec. To the third inputs of the circuits were fed pulses from a double-coincidence circuit for the pulses of the front and rear counters with $\tau \approx 1.5 \cdot 10^{-7}$ sec.; moreover, these double coincidences were opened by a gate circuit for counting and for feeding to the triple-coincidence circuits only during the time when electrons were dumped onto the internal target of the synchrotron. The front counter was calibrated

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Fig. 1. Energy distribution of photoprotons from Ni. Along the ordinate are plotted the numbers of protons per 1 MeV interval, reduced to unit monitor counts, in arbitrary units. Only statistical errors are indicated.

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Fig. 2

Figure 2: Fig. 2

with deuterons from the LFTI cyclotron, the rear one with photopeak from γ quanta of a Cs^{137} source. The linearity of the photomultipliers was checked from the ratio between the pulses from the Cs^{137} photopeak and from the lines of α particles of ThC' at different voltages

Fig. 1. Energy distribution of photoprotons from Ni. Along the ordinate are plotted the numbers of protons per 1 MeV interval, reduced to unit monitor counts, in arbitrary units. Only statistical errors are indicated.

on photomultipliers. The amplitude resolution of the counters for pulses from α-particles of ThC$'$ was 10–12%. To exclude the counting of pulses from superposed scattered electrons, the duration of the bremsstrahlung pulses was stretched to 1 msec. At the working biases on the discriminators, the numbers of coincidence counts per monitor count remained the same within the statistical error when the intensity was changed by a factor of 6. This indicated that the telescopes were insensitive to pulses from scattered electrons. The windows of the five-channel differential discriminator analyzing the pulses of the rear counter were set so that each channel counted protons in the interval $\Delta E/E \simeq 20\%$. The corresponding biases were set on the discriminator of the front counter. The proton energies were set both by the voltage on the photomultipliers and by copper absorbers. At a definite voltage on the photomultipliers, 5 numbers of proton counts were measured, which were reduced to unit energy interval and to unit monitor count. The next 5 numbers of counts were measured at another voltage on the photomultipliers; moreover, the reduced numbers of counts corresponding to the same mean proton energies in these two measurements agreed well. Good agreement of the corresponding reduced numbers of counts was also obtained when the proton energy was changed by means of absorbers, which testifies to the correct calibration and operation of the telescope.

Fig. 2. Energy distribution of photoprotons from Al. Along the ordinates are plotted the numbers of protons per interval of 1 MeV, reduced to unit monitor count, in arbitrary units. Only statistical errors are indicated.

The energy losses of protons in the absorbers and in the front crystal were calculated from the data of Ref. (13). The calculations of the energy losses of

Fig. 3

Figure 3: Fig. 3

protons in copper agree well with calculations from the range-energy curves for protons in copper given in Ref. (14).

In Figs. 1 and 2 are presented the curves of the energy distributions of protons emitted at 90° to the beam in the laboratory system from Ni and Al, plotted, as is customary, on a double logarithmic scale. Along the ordinates are plotted the numbers of proton counts per unit energy interval (1 MeV) per unit monitor count, in arbitrary relative units. It is seen that the energy distributions of protons from both elements have the same form: $f(E_p) \sim E_p^{-n}$, where the value of n for the part of the proton spectrum with energies above 33 MeV exceeds the value of n for the spectrum of protons with lower energies by more than a factor of 2. The positions of the breaks in the energy spectrum agree with those calculated according to the theory of photodisintegration of the statical deuteron. It should be noted that the energy spectrum of fast protons from Al obtained in (12) under irradiation by bremsstrahlung with $E_{\gamma\,\max} \simeq 65$ MeV shows a break that agrees poorly with this theory, and protons with energies near the break predicted by the theory were not measured at all.

Fig. 3. Angular distributions of photoprotons from Ni. Crosses—protons 20-33 MeV; light circles—protons 33-65 MeV. Errors are statistical.

Figure 3 presents the angular distributions of fast protons from Ni in the laboratory system, irradiated with bremsstrahlung with $E_{\gamma\,\max} = 85 \pm 5$ MeV, for two proton-energy intervals: 20-33 and 33-65 MeV. In constructing the graph, the points at 120° to the beam were set equal to one another. It is seen that the degree of asymmetry in the angular distribution increases with increasing proton energy.

The character of the obtained energy and angular distributions of fast photoprotons produced by bremsstrahlung with $E_{\gamma\,\max} \simeq 85$ MeV suggests the applicability of the "quasi-deuteron" model in this region of γ-quantum energies.

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