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MEASUREMENT OF CUMULATIVE PHOTOPROTONS POLARIZATION ON NUCLEI

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ИЗМЕРЕНИЕ ПОЛЯРИЗАЦИИ КУМУЛЯТИВНЫХ ФОТОПРОТОНОВ НА ЯДРАХ

Приводятся первые экспериментальные данные по измерению поляризации кумулятивных протонов в реакции $\gamma A \to pX$ при энергии E_γ^{max} = 4,5 ГэВ для угла 120° л.с. и ядер ^{12}C, ^{63}Cu, ^{118}Sn ^{208}Pb. Результаты показывают, что в случае легчайших ядер протоны поляризованы и величина поляризации убывает с ростом массового числа ядер.

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MEASUREMENT OF CUMULATIVE PHOTOPROTONS POLARIZATION ON NUCLEI

The first experimental data on the measurement of cumulative photoprotons polarization in the reaction $\gamma A \to pX$ at E_{γ}^{max} = 4.5 GeV for the angle 120° in l.s. and nuclei ^{12}C, ^{63}Cu, ^{118}Sn, ^{208}Pb are presented. The results show that in the case of light nuclei protons are polarized and the polarization value decreases with the increase of the mass number of nuclei.

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1. The production of cumulative protons on nuclei was so far investigated in the main in inclusive processes. When trying to interprete the data obtained, it has turned out [1,2], that the energy and angular spectra are satisfactorily described by model representations based on physical assumptions far from each other. One apparently needs such investigations which would reveal the differences between these models. Such investigations are already planned [3] mainly in two directions - polarization and correlation experiments.

The cumulative proton polarization at $E_o > 1$ GeV has been investigated only in one experiment [4] with primary hadrons. Protons produced at 162^o in l.s. are shown to be polarized. The polarization depends on all parameters of the reaction (on the primary particle energy, on the secondary proton emission angle and momentum, on the target-nucleus).

In photoproduction of cumulative protons there are not yet any data on polarization.

Below the first experimental (preliminary) results are given on the measurement of polarization of protons produced at 120^o in l.s. from C, Cu, Sn and Pb nuclei, irradiated with bremsstrahlung γ -quanta with a maximum energy 4.5 GeV.

2. The investigations were carried out on the beam Γ - 3 of the Yerevan electron synchrotron on the experimental setup "Deuteron" [5] . In fig. 1 the polarimeter design is presented. Cumulative protons were identified with a range detector [6] composed of counters $C_1 \div C_5$. The proton polarization was determined by means of measuring the left-right asymmetry in the process of detected particles scattering in the analyzer. As an analyzer the 30 mm thick scintillator of C_1 was used. In fact, the conditions of the experiment [4] were reproduced, so as to have the opportunity to make a comparison. To define the scattering angle, hodoscopic scintillation counters were used located before and after the analyzer. The hodoscope Γ_1 , together with the beam spot on the target, allows to define the input angle of protons in C_1 , and hodoscopes Γ_2 Γ_3 and Γ_4 - the trajectory after the analyzer. Hodoscopes Γ_1 and Γ_3 are arranged vertically, hodoscopes Γ_2 and Γ_4 - horizontally. Thus, in the analyzer area there exist $N_1 \times M_2$ "cells", and in Γ_3 Γ_4 area - $N_3 \times N_4$ cells, where N_i is the number of counters in the hodoscope Γ_i . The number of counters in hodoscopes was chosen as follows: N_1 = 3; N_2 = 3; N_3 = 7; N_4 = 7. The geometry of counters arrangement was chosen in such a way that the polar angle of scattering was limited by the interval up to 18° (the azimuthal angle is 0° - 360°).

Protons identified by the range telescope (coincidences $C_1 + C_2 + C_3 + C_4 + C_5$) produced a "master-pulse" which triggered an event recording system from hodoscopes to the computer "Elektronika - 60". By a simple geometrical program the computer accumulates all the data from the particles with already defined trajectories before and after the analyzer C_1 , i.e., with a measured scattering angle.

Provisions are made for turning the polarimeter around the horizontal axis passing via centres of the target and the whole range telescope. This allows to take into account the false asymmetry caused by various efficiencies of the counters used.

3. It is first of all necessary to define the boundaries of azimuthal angles for the events of "left-right" scattering in analyzer. For that purpose we have measured the dependence of the yield of scattering on the azimuthal angle for some interval of the scattering polar angle. These results are presented in fig. 2. As is seen, the whole effect is included in the range of azimuthal angles $\varphi = \frac{\pi}{2}, -\frac{\pi}{2}$. It should be noted that φ is an angle composed between the directions of axes z and z' , where $\vec{z}' = \vec{n}_1 \times \vec{n}_2$, $\vec{n}_1$ is the proton direction before scattering, $\vec{n}_2$ - after scattering. Thus, the cases with φ , lying in the interval $(\frac{\pi}{2}, -\frac{\pi}{2})$, were taken as events of the scattering to the left, and the events in the interval $(\frac{3}{2}\pi, -\frac{3}{2}\pi)$ - to the right. The dimensions of hodoscopic counters and the polarimeter geometry allow to carry out the measurements in the polar angle intervals $\vartheta_p = 4^\circ - 12^\circ$; $8^\circ - 16^\circ$ etc. In the present work the results only for the interval $\vartheta_p = 4^\circ - 12^\circ$ are given. The

lower limit is chosen by analogy with ref. [4] in accord with the fact that multiple scattering dominates in the region $\vartheta_p \leq 4^\circ$ [7]. The upper limit $\vartheta_p = 12^\circ$ is conditioned by the fact that in this interval is well known the analyzing power of carbon for the energy region of protons detected in the present work. As is known [7,8], the analyzing power depends both on scattering angle and protons energy. In literature the analyzing power A is commonly referred as a function of the product of these two parameters, or rather of $\eta = \vartheta\sqrt{E}$, where E is the kinetic energy. Fig. 3 shows the adopted from ref. [7] dependence of the analyzing power A_o on η for a number of proton energies (in fact, it is the dependence on the angle ϑ). Since in the present work the proton energy is chosen $E_p = 110 \pm 5$ MeV, the interval A_o lying between the data [7] $E_p = 95$ MeV and 135 MeV should be used. According to fig. 3 the interval $\vartheta_p = 4^\circ - 12^\circ$ ($\eta = 42 \div 136$) doesn't cover the analyzing power maximum but in this interval the contribution of inelastic scatterings is negligible and for $\vartheta_p = 20^\circ - 30^\circ$ ($\eta = 200\text{-}300$), where $A_o = A_o^{max}$, the cross sections of these two scatterings are compared (see figs. 2 and 3 of ref. [7]); (it should be noted that the contribution determining the asymmetry from inelastic scatterings is negligible too, since in this case the analyzing power is at least not more than that of elastic scattering).

4. In polarization measurements the consideration of false asymmetry is quite essential. As has been already mentioned,

we have taken into account the false asymmetry component connected with various efficiencies of counters, by carrying out measurements for two values of azimuthal angles differing by 180°. However, due to the system adjustment errors, the setup rotation around the horizontal axis as well as virtual displacements of the target centre during its change may lead to geometrical asymmetry. In order to take into account such errors, measurements where the investigated effect is absent should be carried out. As such check measurements we have carried out for all nuclei measurements of the asymmetry arising at scattering of π -mesons detected in the same conditions. As is known [6], the range detector allows to pick out with 100% efficiency the protons and π -mesons which have stopped in the scintillator C_4. In fig, 4 the spectra dE/dx (in fact, they are mass spectra, since $R=const$) of detected particles are presented. At measurements with detection of protons by a simple discrimination we have used particles filling the right peak, and at π -mesons - the left one.

5. As an asymmetry we have taken the difference between the "proton" and " π -meson" asymmetries. The results obtained are presented in fig. 5, which shows the asymmetry of protons versus the mass number A of target nuclei. As is seen the asymmetry depends on A. For ^{12}C it is different from zero, whereas for ^{208}Pb it already vanishes. This comes to confirm the data of ref. [4] obtained with hadron beams at $\vartheta_p = 162^{\circ}$ and at higher energies of protons.

The transition from asymmetry to polarization is accomplished by the ratio

$$P = \frac{\varepsilon}{A_0} \qquad (1)$$

where A_0 is the analyzing power of the scatterer. For this case we cannot use the value A_0 (by fig. 3) for energies E_p = 110 MeV, since the ionization loss in the analyzer is rather great (some 15 MeV). For a correct consideration of this, one should construct a function $A_0 = A_0(E_p)$ and contract it with the function of change of proton energy within the scatterer. In this work we have made an assumption about the uniform distribution of ionization loss all over the depth of the analyzer C_1 (of a 30 mm scintillator) in the energy interval 85 - 115 MeV (this is the maximum possible interval of proton energy in scintillator). It was then found that A_0 = 0.25. In fig. 6 the value P from (1) is given. Though errors are large, nevertheless the results show that at the cumulative photoprotons detection angle $\vartheta_p = 120^\circ$ and with energy (110 ± 5) MeV (P_p = 476 ± 11 MeV/c) a nearly 100% polarization is possible on the light nuclei.

In conclusion it should be noted that the presented results are preliminary and, therefore, we shall continue measurements in wider energy ranges and angles of cumulative protons.

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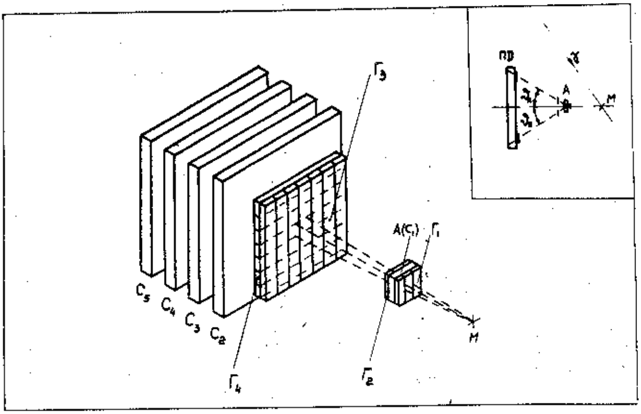

Fig. 1 Polarimeter design: M - target; $\Gamma_1 \div \Gamma_4$ - hodoscopes; A - analyzer; $C_1 \div C_5$ - scintillation range detector.

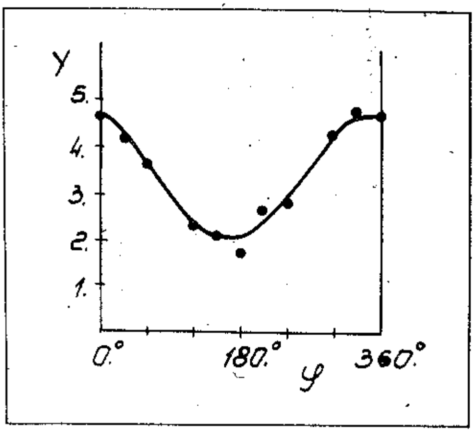

Fig. 2 Dependence of (110 ± 8) MeV protons scattering yield in analyzer on the azimuthal angle φ .

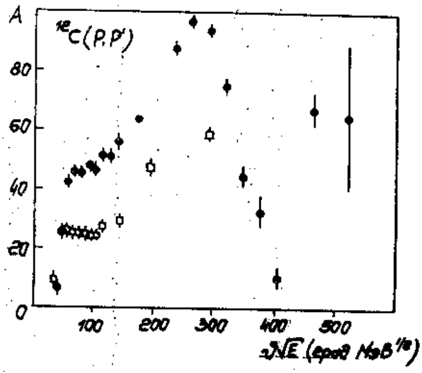

Fig. 3 Dependence of the carbon analyzing power on energy and elastic scattering angle of protons: ● - proton energy 95 MeV, ▫ - 135 MeV [7] .

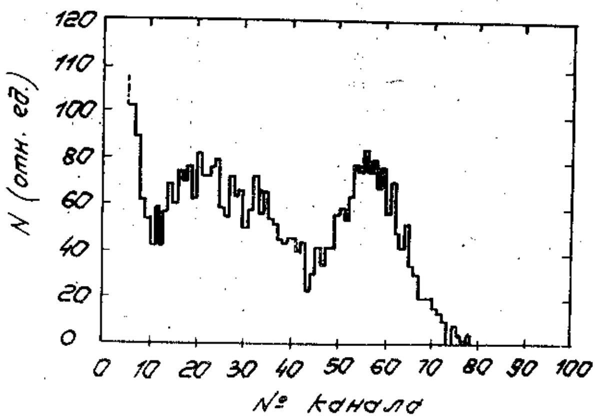

Fig. 4 Distribtuion of particles energy loss in counters of Γ_2 . .

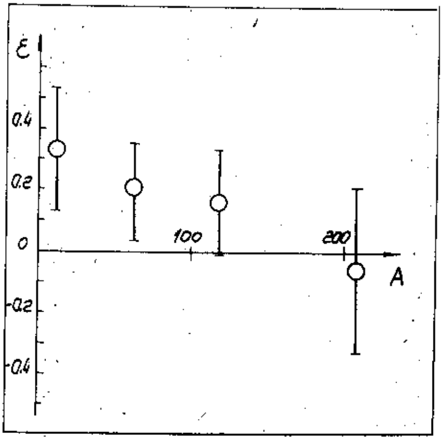

Fig. 5 Dependence of asymmetry on the mass number of nuclei for the protons from the reaction $\gamma A \rightarrow \vec{p} X$ at $\vartheta_p = 120^\circ$ and $E_p = (110 \pm 5)$ MeV.

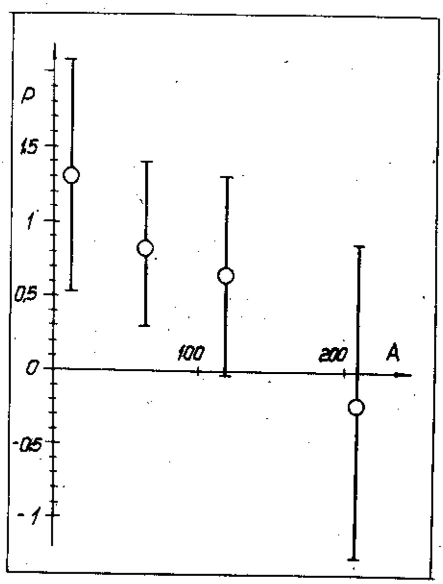

Fig. 6 The same dependence as in Fig. 5, only for polarization (by the ratio (1)).

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