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Investigation of the Cumulative Proton Polarization in the Reaction $\gamma A \rightarrow pX$ on Various Nucleus

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Recently many experiments are carried out with different particle beams for measuring the polarization of cumulative protons, which is considered to be an independent source for important information on the mechanism of cumulative particle emission from nucleus-target.

The dependence of the polarization of cumulative protons on the mass number of nuclei, on the proton momentum and the angle of its emission has been investigated in pA, πA and γA-interactions in the works [1,2], [3] and [4], respectively.

In the present work we give data on the measurement of the cumulative proton polarization in $\gamma A \rightarrow pX$ reaction in the proton energy region (190 - 270) MeV for C, Cu, Sn, Pb targets. The measurements have been carried out at laboratory angle $\theta_{\gamma p}^{lab} = 95°\pm4°$ with the bremsstrahlung beam of Yerevan synchrotron with maximum energy of 4.5 GeV.

The layout of the experimental setup[5], by means of which the dependences of proton polarization on the energy and the atomic number of nucleus target have been measured, is shown in Fig. 1. The angles of proton emission from the target were determined with 4 two-coordinate multiwire proportional chambers MWPC 1-4, while the scattering angles of protons with MWPC 5-7. The accuracy of angular measurements was ±3 mrad, and the detection efficiency, constant over all the surface of chambers was 95%. The polarization was measured by the asymmetry of proton scattering, and a 25 mm thick carbon plate was used as a scatterer. The energy of protons was measured with a range spectrometer consisting of five scintillation counters R_{1-5} and absorbers ab_{1-5}. The energy spectra of protons, scattered in the carbon plate and stopped in the range spectrometer, were calculated by the Monte-Carlo method[6]. The accuracy in the determination of proton energy was ±8 MeV and ±11 MeV for the cases of proton stopping and scattering, respectively. To provide high homogeneity in the efficiency of detection, the scintillation counters R_i were made of two detached parts (counters) R_i^{up}, and R_i^{down} each of which detected the passage of particles with help of two photomultipliers. The detection efficiency of the counters R_i^{up}, R_i^{down} was practically 100% irrespective of the place of particle passage through the counter surface. The threshold Cerenkov counters ($\hat{C}$) served for the detection of charged pions, by means of which the false asymmetry of the experimental setup was determined. The solid angle of the setup, equal to 8.5×10^{-3} steradian, required to construct two similar threshold Cerenkov counters (TCC), each having 95% efficiency of $\pi^{\pm}$ meson detection, constant over all the radiator surface. These data for TCC were taken on the specially constructed pionic tract. The output signals from both the TCC fed to a unit of stroboscopic coincidences through an "OR" circuit for the simultaneous detection of $\pi^{\pm}$ mesons (for the determination of false asymmetry of the setup) and of cumulative protons. The amplitude analysis of signals from the dE/dx counter was made with the help of 8000 channel amplitude converter unit. The information from the converter unit as well as from stroboscopic coincidence unit and MWPC were fed to "Electronica - 60" computer with following transmission to "EC-1022" computer.

In Fig. 2 the dE/dx spectrum of protons is shown together with the dE/dx spectrum of pions detected as "false" protons taking into account the inefficiency of their detection by TCC equal to 5%. The polarization of protons was determined in the N>A region of dE/dx spectrum. The value of A was obtained coming out from the condition that the contribution of pions didn't exceed 5% of the number of protons. The polarization was determined by the formula

$$P_y = \Sigma_{LR}/[P_e(T_{p'},\theta_{pp'})\cdot\cos\phi_{pp'}]$$

where $P_c(T_{p'},\theta_{pp'})$ is the effective analyzing power of carbon; Σ_{LR} is the left-right asymmetry of proton scattering obtained by the formula

$$\Sigma_{LR} = \frac{N(180°\pm\Delta\phi_{pp'})-N(0°\pm\Delta\phi_{pp'})}{N(180°\pm\Delta\phi_{pp'})+N(0°\pm\Delta\phi_{pp'})} \quad .$$

The azimuthal angle $\phi_{pp'}$ was taken from the positive direction of x axis; the axes y and z of the right coordinate frame xyz were directed along the proton momentum $\vec{p}$ and vector $\vec{n} = [\vec{p},\vec{p}\,']/\left|[\vec{p},\vec{p}\,']\right|$, respectively. The processing of measurement data was made for ranges of polar angles of proton (pion) scattering in carbon plate $\Delta\theta_{pp'} = 5° - 20°$ and of azimuthal angles $\Delta\phi_{pp'} = \pm 45°$ relative to $\phi_{pp'} = 0°$ and $180°$ with the selection of those scattering events which remained within the solid angle of setup at the mirror reflection (i.e., the replacement of $\phi_{pp'}$, by $\phi_{pp'}+\pi$). The left-right asymmetry of the setup was determined by measuring the asymmetry of $\pi^{\pm}$ meson scattering; for the energies of detected pions it was in average 0.045 within the statistical accuracy of ±(1.52)%. In Fig. 3 we give measurement data for Cu. To increase the statistical accuracy of the data two latter energy range were joined. In Fig. 3a we give the up-down asymmetry for pions. In Fig. 3b - the left-right asymmetry for pions, in Fig. 3c - the up down asymmetry for protons, in Fig. 3d - the left-right asymmetry for protons and in Fig. 3e - the polarization of protons. The errors in the polarization of protons include both the statistical errors and the error due to the determination of $P_C \cdot \cos\phi_{pp'}$ amounting to ~7%.

Similar results were obtained for remaining C, Sn, and Pb targets. The compilation of the data for all the targets is given in the Table, and in Fig. 4. One can see that the measured polarization of cumulative protons is almost independent of their energy in the (190 - 270) MeV and of the atomic number of nuclei in the (12 - 207) MeV region and its average value if (0.55 - 0.60).

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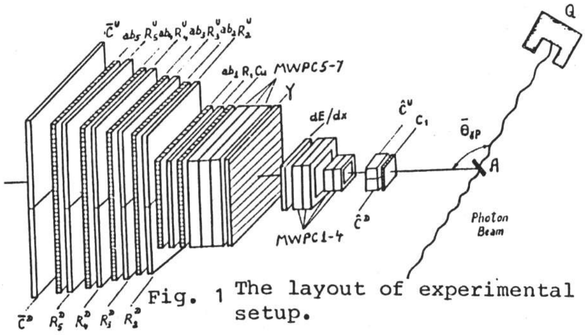

Fig. 1 The layout of experimental setup.

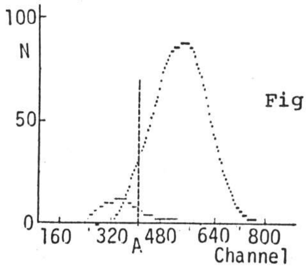

Fig. 2 The dE/dx spectrum of protons.

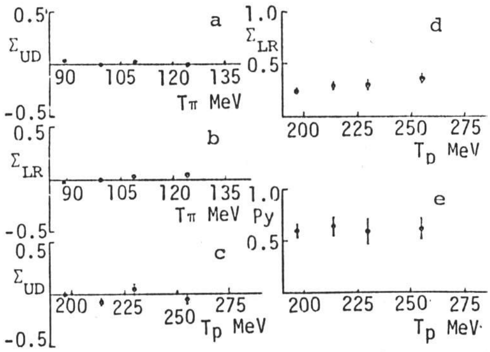

Fig. 3 The energy dependences of asymmetry and polarization for Cu.

Table 1 $P_y \pm \sigma(P_y)$

$T_p \pm \sigma(T_p)$ MeV	C	Cu	Sn	Pb
196.8±7.7	0.467±0.048	0.594±0.069	0.355±0.051	0.463±0.056
213.7±8.4	0.700±0.076	0.635±0.087	0.585±0.079	0.503±0.086
230.4±9.4	0.582±0.087	0.594±0.119	0.657±0.096	0.489±0.109
255.0±17.5	0.592±0.085	0.611±0.103	0.601±0.089	0.643±0.099

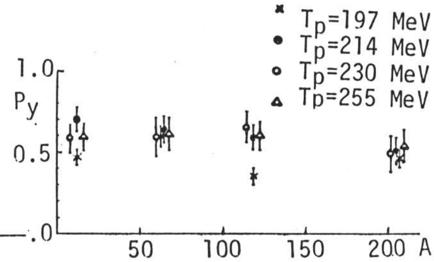

Fig. 4
The dependence of cumulative protons polarization on the atomic number of nucleus.