frequency of 1 cps will be approximately 2—3 per day when recording γ quanta with energies up to ω_3 = 500 MeV. We note that the cross section of the beams of colliding photons was chosen here to be 1 mm^2, which is necessary to separate the scattered photons from the photons of the primary beam with the same energy.

For a 40-BeV electron accelerator (Stanford) the number of electrons in the pulse (planned) is 6×10^{12}. Scattering of γ quanta with energies 33—40 BeV generated by these electrons by the photon beam of the laser considered above yields 10—15 separate photons with energies up to 500 MeV recorded in 1 hour.

The estimates show that the frequency of observing events in the two examples given above exceeds possible noise. One should also bear in mind that a number of possibilities exists for increasing the number of recorded events: increasing the intensity of the laser radiation or the frequency of laser operation, increasing the upper limit of the energy of recorded scattered γ quanta, etc.

Thus we arrive at the conclusion that the discovery and study of the very rare and extremely important process of scattering of light by light is possible when modern intensities of photons from laser radiation and of γ quanta from bremsstrahlung generated by high energy electron bemas are used.

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POLARIZATION IN pp *SCATTERING AT* 8.5 BeV

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WE report here the results of the first measurements of the polarization in pp scattering, carried out with the Joint Institute for Nuclear Research proton synchrotron.

The experimental setup has been placed directly underneath a straight section chamber of the accelerator (Fig. 1). Recoil protons of an energy E_1 scattered at an angle θ_1 on a polyethylene target (with dimensions 0.4 cm $\times$ 0.4 cm in the scattering plane) pass through a window (0.3 mm of steel) and are detected by a telescope S_{123} consisting of three scintillators (0.8 g/cm^2 each) with FU-33 photomultipliers. The scintillator S_3, shielded by graphite plates F_1, F_2 (5.4 g/cm^2) serves as a second target. After the second scattering the protons are slowed down in copper absorbers of varying thickness (F_3, F_3'). The thicknesses of F_3 and F_3' are chosen depending on the angle θ_1 and the beam energy E_0 in such a way that elastic protons, doubly scattered on the hydrogen nuclei in the target and on the C^{12} nuclei, would stop in the scintillators S_4, S_4' (1 g/cm^2) or in the thin copper absorbers F_4, F_4' (0.5 g/cm^2) behind them.

The selection of elastically scattered protons is assured on one hand by the requirement that the light pulses produced in S_4 and S_4' be roughly 15 times greater than the pulse from a relativistic

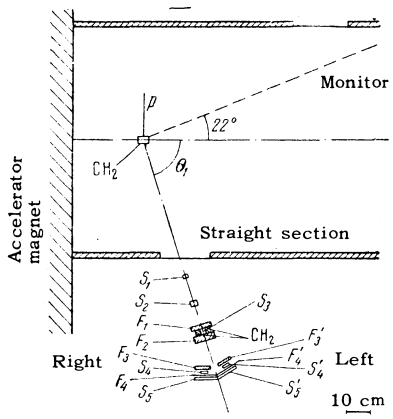

FIG. 1. Diagram of the array

particle and, on the other, by signals from the anticoincidence counters $\bar{S}_5$ and $\bar{S}'_5$ which are placed directly behind F_4 and F'_4. Thus, the ionization range serves as the selection criterion of elastically scattered protons. The array can be turned by 180° about the axis passing through the target and S_{123}, and the angle θ_1 can be continuously varied. The alignment of the telescope S_{123} on the target is better than $\pm 10'$. The measurements are monitored on the count M of a fixed scintillation telescope pointing at the target.

With an angular opening of the telescope S_{123} equal to $\Delta\theta_1 = 0.7°$ and a resolving time of the electronic circuitry equal to 1.7×10^{-9} sec, the arrangement records singly and doubly scattered protons with an effect-to-background ratio of 5:1 and 3:1 respectively. For 3×10^9 protons passing through the target in one acceleration cycle and a spill time of ~ 200 msec, about two doubly-scattered protons are detected, and chance coincidences are practically absent.

Curve a in Fig. 2 represents the variation of the singly-scattered proton counting rate with the angle θ for $E_0 = 8.5$ BeV and $E_1 = 150$ MeV. In taking these measurements, the counters $S_{1234\bar{5}}$, F_3, and F_4 were placed on a single axis. Curve b represents the counting rate of doubly scattered protons ($E_1 = 136$ MeV). The y axis in both cases represents the ratio $\eta = NS_{1234\bar{5}}/M$. It can be seen from Fig. 1b that the maximum of doubly scattered protons is not well defined from the side of small angles. This is due to the background from recoil protons whose energy degraded as a result of inelastic processes in the second scattering, in addition to the continuous spectrum of particles produced in inelastic processes in the target. From the side of large angles θ_1 the background contains only particles produced in inelastic processes in the target, since the recoil protons do not reach S_4 and are not detected by the array. Therefore, in subtracting the background, its level is determined on the side of larger angles θ_1.

A spurious asymmetry due to the presence of inhomogeneous magnetic field near the analyzer was lowered to $\sim 2\%$ by carefully shielding the photomultipliers and by incorporating a compensation of the photomultiplier gain when turning the array by 180°. In addition, control experiments were carried out regularly, in which lead was used instead of carbon as the second target. Using 25 g/cm^2 of lead, the angular distribution of protons with $E \sim 150$ MeV emitted from the target is in 96% due to multiple scattering processes, in which polarized protons are symmetrical with respect to the azimuth. A control experiment has shown that our array is symmetrical within 1–2%.

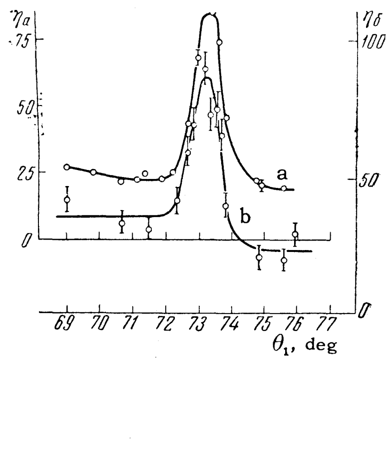

FIG. 2. Variation of the counting rate of singly scattered protons (curve a, $F_3 = 8.1$ g/cm^2 Cu) and doubly scattered protons (curve b, $F_3 = 9.5$ g/cm^2 Cu) with the angle θ_1.

The function $\eta(\theta_1)$ for doubly scattered protons with lead (25 g/cm^2) as the second target (the curve with the maximum), and the function $\eta(\theta_1)$ for the case where the polyethylene target was exchanged for a graphite one are shown in Fig. 3.

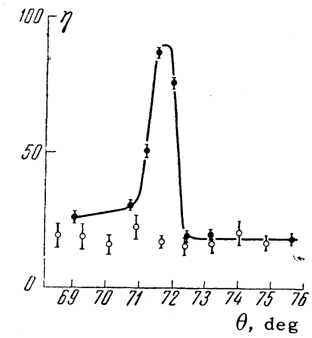

FIG. 3. Variation of the counting rate of doubly scattered protons (○ – carbon target, ● – polyethylene target; second target – lead, 25 g/cm^2) with angle θ_1.

In the latter case there is no maximum.

The magnitude of the polarization of the recoil protons $P_p(E_1)$ is given by the equation

$$P_p(E_1) = (R - 1)/(R + 1)\,\bar{P}_C(E_1),$$

where $R = I_{right}/I_{left}$ is the experimentally measured asymmetry taking the background into account, and $\bar{P}_C(E_1)$ is the efficiency of the carbon analyzer. A calculation of $\bar{P}_C(E_1)$, carried out using the polarization data and cross sections for proton scattering on carbon at 120–180 MeV[1-3] for the geometry of our array gives the value $\bar{P}_C(140) = 0.42 \pm 0.03$, $\bar{P}_C(160) = 0.55 \pm 0.03$. A resume of the results of our measurements is given in the table.

The mean value of the polarization for $E_0 = 8.5$ BeV and $t = -0.28$ (BeV/c)^2 (where t is the square of the four-momentum transfer) (c.m.s. = 15°30′) is

$$\bar{P}_p = +\,0.02 \pm 0.06\%.$$

Figure 4 shows the available data on the polarization in pp scattering at high energies and $t \sim -0.3$ (BeV/c)^2 for protons moving forward in the c.m.s.

	NS_{123}	I_{right}	I_{left}	R
Carbon target, measurement at the maximum; $\theta_1=72°15'$, $E_1=160$MeV, $E_1'=156$ MeV	6 280 000	2 087	2 110	0.99 ± 0.03
Carbon target, background measurement; $\theta_1=75°40'$, $E_1'=100$ MeV	4 080 000	681	741	0.92 ± 0.05
Carbon target, measurements at the maximum; $\theta_1=73°15'$, $E_1=140$ MeV, $E'_1=135$ MeV	9 600 000	4 301	4 216	1.02 ± 0.02
Carbon target, background measurements; $\theta_1=74°55'$, $E_1'=110$ MeV	7 720 000	1 601	1 517	1.06 ± 0.036
Lead target, measurement at the maximum; $\theta_1=71°35'$, $E_1'=167$ MeV	4 920 000	21 125	20 832	1.01 ± 0.01
Lead target, background measurements; $\theta_1=74°55'$	3 500 000	3 724	3 624	1.025 ± 0.023

E_1 is the kinetic energy of the recoil proton, determined from its range; E_1' is the kinetic energy of the recoil protons determined from the angle θ_1.

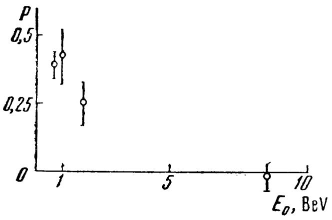

FIG. 4. Polarization of protons moving forwards in the c.m.s. in pp scattering at $t = -0.28$ (BeV/c)^2 and E_0 equal to 0.66,[4] 0.97,[5] 1.74,[6] and 8.5 BeV.

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DETERMINATION OF THE REAL PART OF THE SCATTERING AMPLITUDE FOR AN ASYMPTOTIC POWER LAW BEHAVIOR OF THE IMAGINARY PART

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THE experimental data on the total cross sections in the scattering of particles and antiparticles at high energies can evidently be well approximated by power series in the energy. In this connection the problem arises of calculating the real part of the forward scattering amplitude for large energy by means of the dispersion relations (d.r.) with a power-law approach of $\sigma_t(E)$ to its limiting values. In such an investigation one usually employs the Sommerfeld-Watson-Regge representation which yields for the asymptotic behavior of the real parts of the amplitude $D^\pm(E)$ (D^+ is symmetric and D^- is antisymmetric in the total laboratory energy E of the incoming particles) the relations

$$D^+(E) = D(E) + \tilde{D}(E) = -\sum \beta_i^+ E^{\alpha_i^+} \operatorname{ctg}(\pi\alpha_i^+/2),$$

$$D^-(E) = D(E) - \tilde{D}(E) = \sum \beta_i^- E^{\alpha_i^-} \operatorname{tg}(\pi\alpha_i^-/2), \qquad (1)*$$

respectively for the asymptotic sum and the difference of the cross sections for particles and for antiparticles [5]

$$A^\pm(E) = [\sigma_t(E) \pm \tilde{\sigma}_t(E)]\, E/4\pi = \sum \beta_i^\pm E^{\alpha_i^\pm}. \qquad (2^\pm)$$