bombarded by 10–40 kilovolt protons can withstand a beam of several micro amperes/cm^2 , and the degree of electron pick–up by the protons reaches tems of percent.

The possibility of using a pulsed technique for such a polarizer should be mentioned. This should be very practical for many accelerators. This method also makes possible the direct formation of negative ions of hydrogen with polarized muclei. For this, of course, one must use the negative ions emerging from the second foil.

A study of the polarization of the protons and its dependence on velocity may also be of interest in elucidating questions on the nature of ferromagnetism.

In conclusion it should be mentioned that, in principle, polarization of the protons should be achievable likewise using the polarized electrons of paramagnetic substances and metals.

Translated by A. Turkevich
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Inelastic Interaction of Protons with Energies Greater than 7 bev with Carbon and Hydrogen Nuclei

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(Submitted to JETP editor December 7,1956)
J. Exptl. Theoret. Phys.(U.S.S.R.) 32, 404–405
(February,1957)

WE have measured the cross section for inelastic interaction of high energy protons with carbon and hydrogen nuclei. The measurements were carried out in the stratosphere at an altitude of 20–25 km at a geomagnetic latitude of 31° N, where the minimum kinetic energy of the primary protons is 7 bev and 60% of all the protons have energies between 7 and 20 bev.

The apparatus for determining these inelastic interaction cross–sections was constructed as follows. The telescope defining the vertical beam of cosmic rays consisted of three rows of self quenching Geiger–Müller tubes connected in threefold coincidence (referred to as the counter telescope); some distance below these was a row of hodoscopic counters covering almost the complete solid angle of the apparatus. In between the middle and lower rows of telescopic counters there was placed an absorber made of 8 cm of lead and 0.9 cm aluminum. The absorbers being investigated, for example, of graphite (density $d = 1.0 - 1.1$ gm/cm^3 ; thickness per unit area of absorber $d = 16.0$ gm/cm^2), were placed on a trolley and every three minutes were interposed into the space between the top and middle rows of the telescopic counters in such a manner that the measurements with the graphite and without the graphite (and likewise the measurements with the paraffin and graphite) alternated. In order to register the products of the interaction of the protons with the material of the absorber, the telescope and absorbers were surrounded by a large number of counters. All the counters (including those in the telescope) were connected to a vacuum tube hodoscope. The apparatus was lifted into the stratosphere in September 1955 by sounding balloons. The results were sent to the ground by radio.

The cross section for inelastic interaction of protons with carbon nuclei was determined by two methods: (1) From the attenuation of the flux of single shower producing particles falling on the lead absorber by the graphite absorber in the telescope; this attenuation was governed by the inelastic interactions of the protons with the carbon nuclei (the measurements gave the decrease in the number of electron-nucleon showers from the Pb due to the insertion of the graphite into the telescope): (2) Through the direct measurement of the number of electron–nucleon showers arising in the graphite.

Using the attenuation method, we obtained the following values of the mean free path and the cross section for inelastic interaction of protons with carbon nuclei (corrections have been made for accidental coincidences, for the formation of δ-showers in the graphite and for interactions due to α particles in the primary cosmic rays):

$$L_p^C = 67^{+13}_{-9}\ g/\mathrm{cm}^2\ ;\ \sigma_p^C = 300 \pm 50\ \mathrm{mb}.$$

Direct measurements of the number of interactions in the graphite gave the following values for the mean free path and for the inelastic interaction cross section:

$$L_p^C = 73 \pm 7\ g/\mathrm{cm}^2\ ;\sigma_p^C = 270 \pm 30\ \mathrm{mb}.$$

All the values have indicated statistical errors.

The cross section for inelastic interaction of protons with protons was established from the difference of numbers of electron–nucleon showers registered with paraffin and with graphite using an apparatus of the same type (the paraffin absorber had a density $d = 0.90 - 0.95$ gms/cm^3

and a thickness of $d_1 = 18.8$ gms/cm^2 ; the pulverized graphite absorber had a density $d = 1.0 - 1.0$ gms/cm^3 ; $d_1 = 16.0$ gms/cm^2). The mean free path and inelastic scattering cross section for proton–proton interaction came out to be

$$L_p^{\mathrm{H}} = 47^{+37}_{-15} g/\mathrm{cm}^2 \, ; \sigma_p^{\mathrm{H}} = 35 \pm 16 \ \mathrm{mb}.$$

In getting this value of the cross–section we did not know sufficiently accurately the contribution of δ-showers produced in the hydrogen. However, on the basis of experimental data available, it can be said that the values of the cross–section will not change more than ± 10% after correcting for these δ-showers. At the present time we are carrying out measurements at sea level to determine the formation of delta showers in graphite and paraffin.

Translated by A. Turkevich
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On the Theory of Scattering of Particles by Nuclei

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(Submitted to JETP editor November 29,1956)
J. Exptl. Theoret. Phys. (U.S.S.R.) 32, 402–403
(February, 1957)

IN the study of the scattering of nucleons by nuclei, a model[1,2] has often been used which considers the nucleus as a Fermi gas of nucleons at a temperature $T = 0$. It seems reasonable to use this same model to study the nuclear scattering of particles having masses different from that of a nucleon. Such a study would allow one to start evaluating the effect of the Pauli principle in the scattering of π and K-mesons.

Let a particle 1 with mass m_1 and momentum $\mathbf{p}_1$ impinge on a Fermi gas of particles 2 of mass m_2 and momenta $\mathbf{p}_2$ $(0 \leq p_2 \leq p_F)$, at a temperature $T = 0$. Let the differential scattering cross section for the free particles 1 and 2 be isotropic, independent of energy, and equal to $\sigma_0 / 4\pi$. We will calculate the total cross section $\sigma = \sigma_0 F$ for the collision of particle 1 with one of the particles of the gas. It is obvious that the factor F must be less than 1 since, because of the Pauli principle, not all of the final states for particle 2 are allowed, but only those with $p_2' > p_F$. In order to calculate F let us consider the collision of two particles (Fig. 1). We will let $\mathbf{p}_1'$ and $\mathbf{p}_2'$ be the momenta of particles 1 and 2 in the laboratory system of coordinates after the collision; $\mathbf{p}$ and $\mathbf{p}'$ will be the momenta of particle 1 in the center of mass before and after the collision, respectively. Then

$$p_2' = |-\mathbf{p}' + m_2(\mathbf{p}_1 + \mathbf{p}_2)/(m_1 + m_2)| > p_F.$$

Keeping in mind that

$$p' = p = |m_2\mathbf{p}_1 - m_1\mathbf{p}_2|/(m_1 + m_2)$$

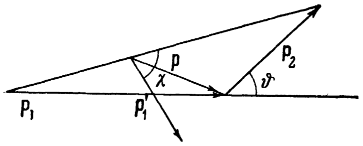

FIG. 1

and introducing the variables

$$\alpha = m_1/m_2, \ u = p_2/p_1,$$
$$w = p_F/p_1, \ x = \cos\vartheta, \ y = \cos\chi,$$

we obtain the equation for the surface S in the space u, y, x that determines the allowed region of the variables u, y, x:

$$\begin{aligned} S(\alpha, w; u, y, x) &= (1 + \alpha^2u^2 - 2\alpha ux) + (1 + u^2 + 2ux) \\ &-2\left[(1 + \alpha^2u^2 - 2\alpha ux)(1 + u^2 + 2ux)\right]^{1/2} y \\ &- w^2(1 + \alpha)^2 = 0. \end{aligned}$$

This surface depends on α and w parametrically. Schematically, the allowed region is presented in Fig. 2. It is bounded by the surface S and the planes $y = -1, x = +1, x = -1, u = 0, u = w$.

Calculating the number of collisions suffered by particle 1 in unit time, we obtain for the factor F the following expression:

$$F = (3/4w^3) \int\int\int u^2 \sqrt{1 + \alpha^2u^2 - 2\alpha ux} \, du \, dx \, dy.$$

Here the integration has to be carried out over the allowed region described above. Different