TOTAL CROSS SECTIONS OF PROTONS WITH MOMENTUM BETWEEN 10 AND 28 Gev/*c*

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A beam of protons elastically scattered by the internal aluminum target of the CERN proton synchrotron[1] (scattering angle ~25 mrad) has been used for counter measurements of proton cross sections on protons, neutrons, and complex nuclei.

The momentum of the proton beam was varied from 10 to 28 Gev/*c* by changing the operating energy of the accelerator and by isolating the elastic peak by means of magnetic selection. A typical momentum spectrum of the beam at 24-Gev operating energy is given in Fig. 1. It was obtained at ~80 m from the target, with a 1m magnet and four scintillators defining the incoming and outgoing beams (resolution of the system, $\Delta p/p \approx 5\%$). The spectra at other energies were similar to this one. No particles were found around the elastic peak when the field of the analyzing magnet was reversed, thus confirming that the particles detected at normal setting were indeed protons.

The cross-section measurements were made utilizing the protons around (± 2.5%) the elastic peak. At 80 m from the target their intensity was, at all energies, $\sim 5\times10^3$ cm^{-2} pulse^{-1}, when 2×10^{11} protons per pulse were circulating in the accelerator ($\frac{1}{5}$ pulse sec^{-1} at the highest energy, 1 sec^{-1} at the lowest; duration of each pulse ≈ 30 msec).

The total cross sections on protons and neutrons were measured with a "good geometry" setup. After magnetic selection, the incoming beam was defined by two scintillators, each 1 cm in diameter, 10 m apart, and the beam attenuation was measured by a row of 5 scintillators, 2 cm in diameter, aligned with the first two and subtending, at the absorber, angles ranging from 2 to 10 mrad. The choice of these angles was dictated by the divergence of the beam, the expected multiple Coulomb scattering of the protons in the absorber (~1 radiation length thick), and the expected distribution of the elastically scattered protons (the characteristic angle of the nucleon shadow scattering at 25 Gev is ~10 mrad).

For the *p*-*p* cross section, attenuation measurements were carried out alternatively with a carbon and a polyethylene absorber. For the *p*-*n* measurements H_2O and D_2O were used. Conventional coincidence circuits with resolving times of $\sim 2\times10^{-8}$ sec measured simultaneously real and chance coincidences.

The total cross section was obtained, at each energy, by extrapolating to zero solid angle the attenuations measured with the various apertures. For angles small in comparison with those expected for shadow scattering, this extrapolation should be linear in a solid angle plot, and in fact at all energies the experimental points after correction for multiple scattering[2] and beam di-

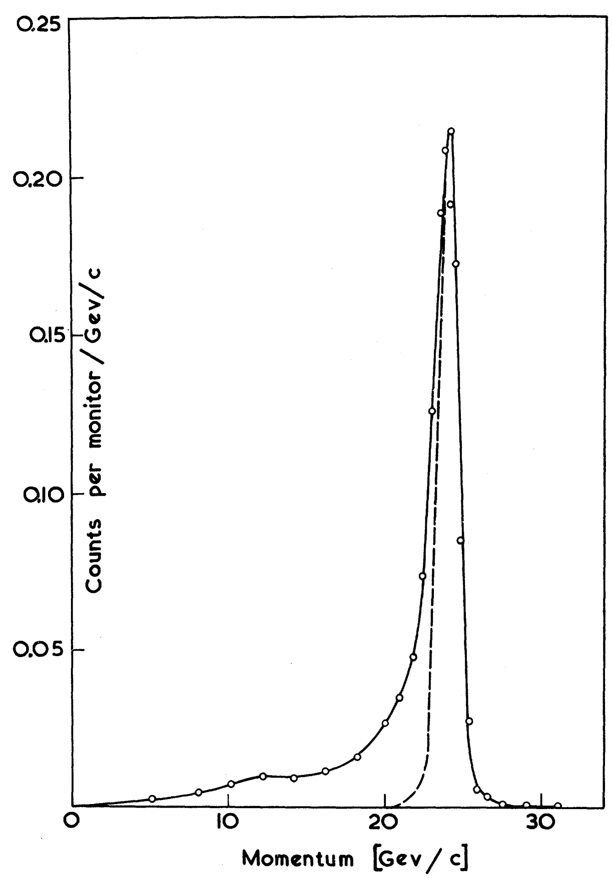
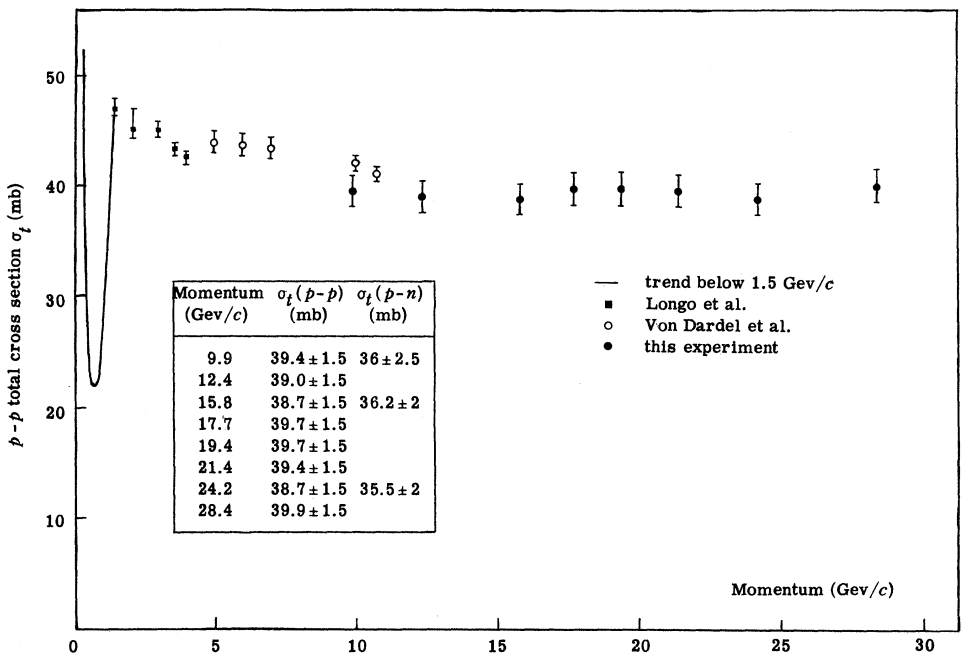


FIG. 1. Momentum spectrum of the external beam of protons elastically scattered in the target of the accelerator. Operating energy 24 Gev; Al target; scattering angle 25 mrad. The dashed line shows the shape expected for a monochromatic line of 24.2 Gev/*c*.



Momentum (Gev/c)	$\sigma_t(p\text{-}p)$ (mb)	$\sigma_t(p\text{-}n)$ (mb)
9.9	39.4±1.5	36±2.5
12.4	39.0±1.5	
15.8	38.7±1.5	36.2±2
17.7	39.7±1.5	
19.4	39.7±1.5	
21.4	39.4±1.5	
24.2	38.7±1.5	35.5±2
28.4	39.9±1.5	

FIG. 2. p-p and p-n total cross sections (diffraction scattering included) as a function of proton momentum. (Von Dardel et al., reference 4; Longo et al., reference 6.)

vergence did not deviate too much from a straight line. The slopes of these lines were, as expected, inversely proportional to the square of the proton momentum.[3]

The final results for the cross sections are given in Fig. 2, together with those of other authors. The correction for multiple Coulomb scattering and beam divergence was $\leq 4\%$, that for chance coincidence $\leq 4\%$. The errors quoted for our points are ~3 times larger than the purely statistical ones because of the contribution of the systematic errors introduced by these corrections and the extrapolation to zero solid angle. The relative values at different momenta should thus have errors smaller than those given in Fig. 2. Our values for the p-p cross sections are in good agreement, around 10 Gev/c, with those obtained by Von Dardel et al.[4] using a liquid hydrogen absorber, and at 24 Gev/c with that obtained with the CERN 30-cm hydrogen bubble chamber.[5] The striking feature of the data contained in Fig. 2 is the constancy, at around 40 mb, of the p-p cross section from 5 to 28 Gev/c.

Taking into account the shadowing of the neutron by the accompanying proton in the deuteron, it seems that the p-n cross section is essentially the same as the p-p cross section at the three momenta where measurements were performed.

At 24 Gev a "bad geometry" measurement of the cross section of protons on nuclei was performed. In this case only three scintillators were used after the absorber and subtended angles of 15, 20, and 30 mrad. At these angles the effect of the shadow scattering was small and the other corrections were negligible. A linear extrapolation to zero solid angle based on these three measurements was taken as an estimate of the absorption (total minus diffraction scattering) cross section. The results of this measurement are displayed in Fig. 3. It is remarkable how well an $A^{2/3}$ law fits the data, though for the

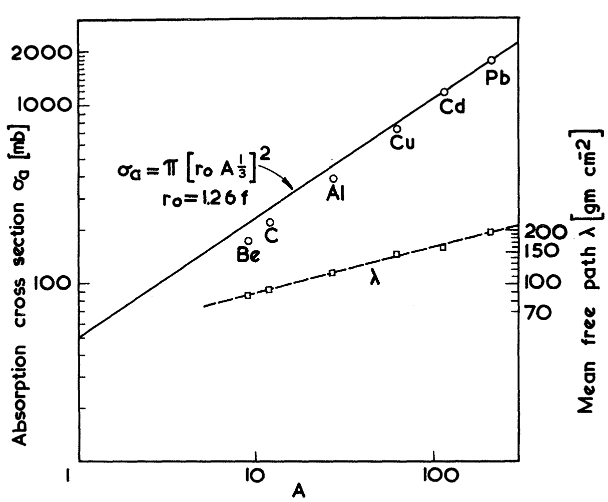


FIG. 3. Nuclear absorption cross sections and mean free paths of 24.2-Gev/c protons in various elements.

lightest elements a good deal of transparency could be expected.

We are extremely grateful to the Machine Group of the proton synchrotron for their very efficient operation of the accelerator at all energies, and at all times. We thank Mr. C. A. Stahlbrandt for his assistance with the electronics. One of us (A.A.) wishes to thank CERN for making his visit possible.

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[1]This beam was initially proposed and studied by B. Dayton and H. Winzeler [B. Dayton, W. Koch, M. Nikolic, H. Winzeler, J. C. Combe, W. M. Gibson, W. O. Lock, M. Schneeberger, and G. Vanderhaeghe, Helv. Phys. Acta 33, 544 (1960)].

[2]R. M. Sternheimer, Rev. Sci. Instr. 25, 1070, 1954.

[3]Also the contribution of the secondaries generated by the interactions occurring in the absorber should be proportional to the solid angle. At our angles, however, this contribution was estimated to be small in comparison with the elastic scattering.

[4]G. Von Dardel, D. H. Frisch, R. Mermod, R. H. Milburn, P. A. Piroué, M. Vivargent, G. Weber, and K. Winter, Phys. Rev. Letters 5, 333 (1960).

[5]Private communication from the CERN bubble chamber and I.E.P. (Instrumentation for the Evaluation of Photographs) groups.

[6]M. J. Longo, J. A. Helland, W. N. Hess, B. J. Moyer, and V. Perez-Mendez, Phys. Rev. Letters 3, 568 (1959).

$\Lambda\pi$ RESONANCE AND POSSIBLE DETERMINATION OF THE KYN PARITIES*

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Experiments by Alston et al.[1] and Ferro-Luzzi et al.[2] at Berkeley, observing the reaction

$$K^- + p \to \Lambda + \pi^- + \pi^+, \qquad (1)$$

have recently been reported which indicate a resonance in the $\Lambda + \pi$ system at about 1380-Mev total energy, i.e., 50 Mev below the threshold for $\bar{K}+N$. We propose that this resonance be described in terms of a quasi-bound state of the isotopic spin $I=1$, s-wave $\bar{K}N$ system. (The angular distribution indicates $J=\frac{1}{2}$ for the resonant system, in agreement with this proposal.) Using our effective-range formalism[3] we will first establish the compatibility of this description with present data. Then we suggest how better data will permit fuller use of the effective-range theory to make detailed tests of this association of the $\Lambda\pi$ resonance with the $\bar{K}N$ s state. Determination of the orbital angular momentum of the resonant $\Lambda\pi$ state (or the resonant $\Sigma\pi$ state that will also be present), and thus determination of the $K\Lambda N$ (or $K\Sigma N$) parity, is discussed.

This description can be decided by reference to the observed $K^- + p$ reactions. Let us consider process (1) at a fixed high energy and examine those events where the π^+, say, has sufficiently high momentum so that it is definitely not associated with the Λ in this resonance. Such conditions were obtained in the experiment of Alston et al. We will speak in terms of the energy of the $\Lambda\pi^-$ system. We assume that the main production process near 1380 Mev involves two-body production of the π^+ and the resonant state, with the subsequent decay of the latter. Call the amplitude for this entire process $T_{\rm res}$. In this picture, the quasi-bound $\bar{K}N$ system decays into $\Lambda+\pi$ (or $\Sigma+\pi$), the rapid energy dependence in $T_{\rm res}$ being associated with this decay. This dependence is characterized essentially by the two-body amplitude[4]

$$|k_N^{-1/2}T(\bar{K}+N \to \Lambda+\pi)| = \left[\mathrm{Im}\,\frac{1}{a_1}\Big/(1+|\alpha|^2)\right]^{1/2}\left|\frac{1}{a_1}+ik_N\right|^{-1}, \qquad (2)$$

with $a_1(k_N)$ the $I=1$ $\bar{K}N$ complex scattering length, k_N the $\bar{K}N$ momentum, extended below threshold where $k\to i\kappa$ ($\kappa>0$) and $|\alpha|^2 = |T_1(N\Sigma)|^2/|T(N\Lambda)|^2$.