TABLE I. π^+ to π^- ratio as a function of the laboratory meson energy.

E_π, Mev	π^+/π^- ratio
42	5.8 ± 2.5
51	7.4 ± 1.7
60	21.6 ± 8.9
70	22.1 ± 3.5
79	20.8 ± 7.1
88	36.5 ± 6.2
98	$34\ \pm14$
108	—
126	—

indicated a less than 5 percent contamination of particles with ranges greater than the expected meson ranges.

The target used was a high pressure gas target 24 in. long, which contained deuterium at 1400 psi at liquid nitrogen temperature. This placed 3.3 grams per square centimeter of deuterium in the beam, and since the end windows of the target contained only 1.7 grams per square centimeter of stainless steel, the production from the deuterium was greater than that from the target windows. Magnetic shielding was placed around the target to prevent the fringe fields of the first magnet from effecting the paths of the mesons produced in the far end of the target.

The ratios observed were obtained by measuring the meson production from the container plus gas at a series of energies, reversing the fields in both magnets, and measuring the mesons produced at the same energies. The gas was then removed from the container and similar measurements were made for the production from the end windows of the target. The values of the field strengths corresponding to various meson energies were obtained by using a current carrying wire to give the trajectories of the mesons of various energies. The fields were adjusted so the trajectory for each energy was the same. Use of the wire showed that reversing the magnetic fields delivered particles of the same energy but of opposite sign to the same position on the rear counters.

Checks of the counter efficiency were made using a Co^{60} source, and reversal of the magnetic fields was found to effect the counting rate in counters 1 and 3 by less than one percent. Counters 2 and 4 could not be tested in this manner, but the measured magnetic field at these counters was less than that at the position of counters 1 and 3.

The values of the π^+ to π^- ratio obtained for deuterium are given in Table I. Errors shown are standard deviations. Values are not shown for 108 and 126 Mev because no negative mesons were found at these energies. The ratios shown are those obtained by simply reversing the magnetic fields at a particular meson energy. The production curves are being corrected at the present time for the energy resolution of the apparatus, and any changes in the results will be published in a forthcoming article which will also include the results obtained for He, Be, C, and Pb.

The results that were obtained agree with the previous work on deuterium[1] in that they show a value higher than expected. Previous theoretical work[2] indicated that a ratio of about 8 might be expected. Some theoretical implication of these results are discussed in the following letter.

[1] Passman, Block, and Havens, Phys. Rev. **85**, 370 (1952).
[2] H. P. Noyes, Phys. Rev. **81**, 924 (1951).

The π^+ to π^- Ratio from Proton Bombardment of Deuterium*

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NOYES[1] has calculated the expected ratio of negative to positive π-mesons in the forward direction when deuterium is bombarded by 345-Mev protons. Most of the mesons in collisions with free target nucleons have 60-Mev to 70-Mev energy in the laboratory system. To obtain π-mesons in this energy range from $p-d$ collisions, the production must come mostly when the internal momentum of the deuteron is small. For these cases, when the proton and neutron are far apart, the uncertainties in the deuteron wave function are minimized and Noyes' assumptions are most likely to be valid. He finds a π^+ to π^- ratio of 8.2 ± 0.8 at 60 Mev if the $p+p\rightarrow\pi^+$ cross section differs from $p+n\rightarrow\pi^-$ only in a factor of two for the two protons and in the different interactions between the final nucleons. The final proton and neutron after π^+ production are taken to be in a ^3S state. Any admixture of singlet lessens the ratio. The matrix elements are assumed to be energy independent. If they vary like the square root of the meson center of mass kinetic energy, the ratio is a few percent smaller.

The experimental[2] value of the forward π^+ to π^- ratio at 60 Mev is about three times larger than predicted, implying that the $p+n\rightarrow\pi^-$ matrix element is suppressed relative to $p+p\rightarrow\pi^+$. This also seems to be true at 90°.[3]

If isotopic spin is conserved in meson production and the π^- meson is emitted predominantly into a p-state, the initial $p-n$ system is ^3S or ^3D and therefore has isotopic spin zero. Then in the final state of a π^- meson and two protons, the π^- and either proton must be in a state of isotopic spin one-half. To the extent that the interaction is strong only when leading to π^--proton states of isotopic spin $\frac{3}{2}$, the π^- production will be forbidden.[4] It is interesting to note that while isotopic spin does not contribute a selection rule for $p+p\rightarrow\pi^+$, the angular distribution indicates that the final state is one in which the π^+ and either nucleon have angular momentum $\frac{3}{2}$.[5]

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[1] H. P. Noyes, Phys. Rev. **81**, 924 (1951).
[2] J. Carothers and C. G. Andrè, preceding Letter [Phys. Rev. **88**, 1426 (1952)].
[3] Passman, Block and Havens, Phys. Rev. **85**, 370 (1952).
[4] This would not necessarily imply that, at these energies, the scattering of π-mesons in hydrogen should be strong only in isotopic spin 3/2 states, since the scattering could involve matrix elements which cannot contribute to single meson production, viz., a meson pair coupling [J. V. Lepore, Phys. Rev. **88**, 750 (1952); G. Wentzel, Phys. Rev. **86**, 802 (1952)].
[5] K. Brueckner and K. M. Watson, Phys. Rev. **86**, 923 (1952).

Optical and Infrared Reflectivity of Metals at Low Temperatures

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THE theory of the anomalous skin effect in metals was developed by Reuter and Sondheimer[1] to cover the case, often encountered at low temperatures, in which the electron mean free path is comparable to, or larger than the skin depth, as computed from the conventional theory.[2] Under such conditions explicit account must be taken of the motion of electrons in a spatially inhomogeneous electric field, with the result that the standard relation,[3]

$$\mathbf{j}(\mathbf{r})=\sigma(\omega)\mathbf{E}(\mathbf{r})=(ne^2\tau/m)(1+i\omega\tau)^{-1}\mathbf{E}(\mathbf{r}), \tag{1}$$

between the current density and electric field must be replaced by a more general expression of the form:

$$\mathbf{j}(\mathbf{r})=\int G(\mathbf{r},\mathbf{r}')\mathbf{E}(\mathbf{r}')dV'. \tag{2}$$

With regard to the "relaxation" region $\omega\gg1/\tau$ with which we are primarily concerned here, Reuter and Sondheimer make the plausible statement that, when the skin depth

$$\delta\gg v/\omega, \tag{3}$$

i.e., when the skin depth is large compared to the distance traversed by an electron in a period of electromagnetic oscillation, the conventional theory based upon (1) should apply. Nevertheless, their results (reference 1, Fig. 4) on metallic absorptivity in the optical and near infrared regions, in which (3) is valid, are generally in disagreement with the prediction of this theory. In the