lower than ours but this could be due to the fact that the initial proton energy was somewhat higher (230 Mev). The sign of the polarization is, however, the same and is opposite to the sign obtained by them for free neutron proton scattering.

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Phenomenological Two-Nucleon Potential up to 150 Mev*

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THE large amount of experimental data bearing on the two-nucleon interaction in the energy region up to 150 Mev has thus far not been fitted by any type of meson-theoretic or even phenomenological potential. It is true that several meson-theoretic two-nucleon potentials give a reasonable fit of the low-energy parameters. However, all of these potentials (in particular, the Lévy[1] and Gartenhaus[2] potentials) fail conspicuously when an attempt is made to match the unpolarized and polarized scattering data at 100 and 150 Mev.[3] From this latest work one receives the distinct impression that no combination of central and tensor forces, making full allowance for an arbitrariness in the spin and isotopic spin dependence, will match the existing data up to 150 Mev.

On the other hand, from a purely phenomenological point of view, there is no reason why a spin-orbit two-nucleon interaction should not be added to the central and tensor forces. Case and Pais[4] first pointed out some of the virtues of the two-nucleon spin-orbit interaction but Goldfarb and Feldman[5] found that this interaction by itself (in triplet states) is incapable of explaining the experimental data. Recently, Ohnuma and Feldman[6] made a phase shift analysis of the experimental cross sections at 150 Mev and found that almost every set of acceptable phase shifts favors the inclusion of a spin-orbit potential. Other arguments for the existence of a spin-orbit component of the two-nucleon interaction can be adduced from the work of Wolfenstein[7] and Greene,[8] and of course from the success of the shell model for complex nuclei.

While none of the aforementioned arguments is conclusive, the contribution of a spin-orbit force to

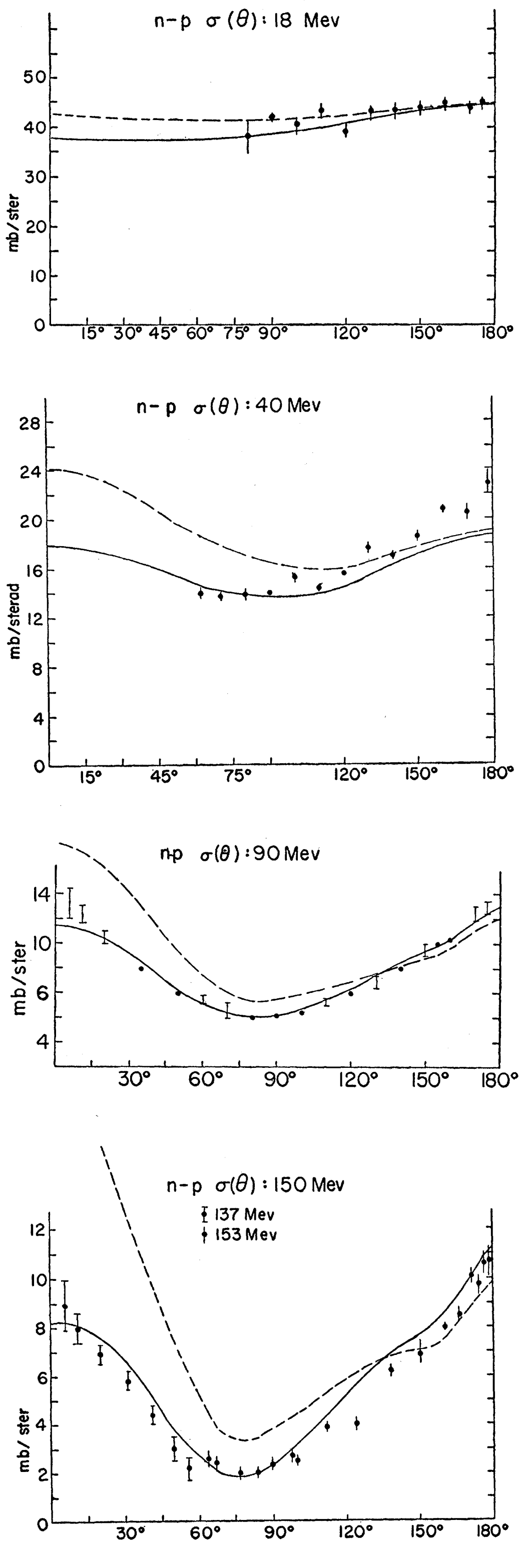

FIG. 1. Calculated $n-p$ scattering cross sections. The dashed lines represent the predictions of the Gartenhaus potential. Solid lines represent the cross sections calculated on the basis of Eq. (1). The points denote the best experimental data available.[10]

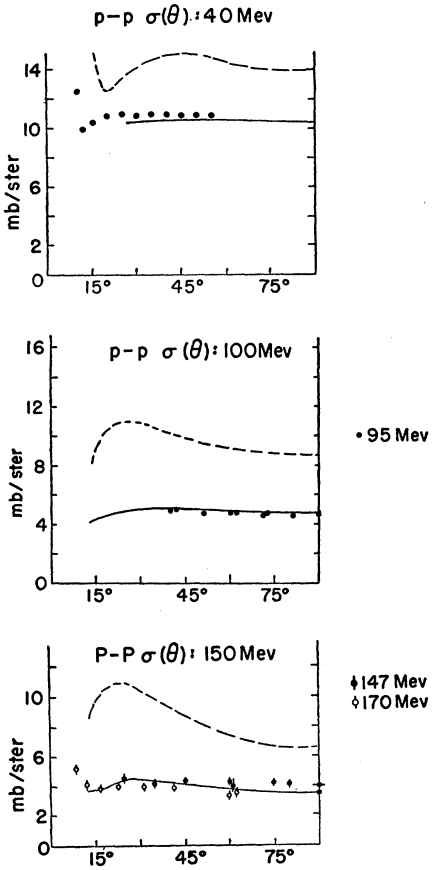

FIG. 2. Calculated $p-p$ scattering cross sections. See caption of Fig. 1.

the two-nucleon interaction deserves further study. We have therefore investigated the consequences of adding a spin-orbit term to the Gartenhaus potential, as follows:

$$V=V_G+\mathbf{L}\cdot\mathbf{S}\frac{V_0}{x_c}\frac{d}{dx}\frac{e^{-x}}{x}\bigg|_{r=r_c}, \qquad r\leq r_c$$

$$V=V_G+\mathbf{L}\cdot\mathbf{S}\frac{V_0}{x}\frac{d}{dx}\frac{e^{-x}}{x}, \qquad r>r_c \tag{1}$$

$$x=r/r_0, \quad x_c=r_c/r_0,$$

where V_G is the Gartenhaus potential[9] and V_0, r_c, and r_0 are parameters characterizing the spin-orbit potential. We have chosen V_G ($f^2=0.089$ and $\omega_m=6\mu$) as the central + tensor part of the two-nucleon force because it appears to have the most plausible meson-theoretic basis and because it fits the low-energy data so well.[2] The choice of the spin-orbit term is essentially that of Goldfarb and Feldman,[5] namely $V_0=+30$ Mev, $r_c=0.21\times10^{-13}$ cm, $r_0=1.07\times10^{-13}$ cm, except that their "zero" cutoff is replaced by a "straight" cutoff.

The results of exact calculations of the p-p and n-p scattering cross sections and polarizations on the basis of Eq. (1), using the IBM 650 located at the University of Rochester, are plotted as solid lines (G+TY1) in Figs. 1–4 for several energies up to 150 Mev. The Coulomb amplitude is taken into account in the p-p calculations. The dashed lines (G) in Figs. 1–4 represent the predictions of the Gartenhaus potential and the points denote the best experimental data available.[10] It is clear that Gartenhaus plus spin-orbit force with the sign needed for the shell model (the opposite sign, i.e., $V_0=-30$ Mev, gives complete

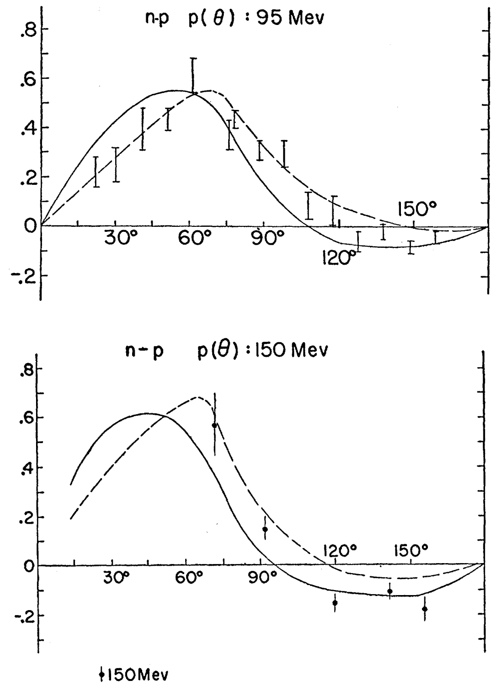

FIG. 3. Calculated $n-p$ polarizations. See caption of Fig. 1.

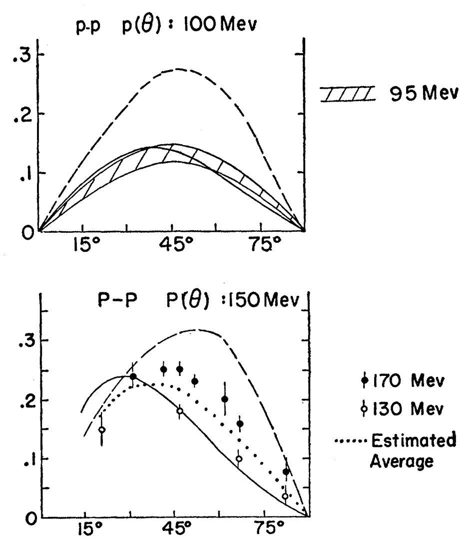

FIG. 4. Calculated $p-p$ polarizations. See caption of Fig. 1.

disagreement with experiment) is a tremendous improvement over the Gartenhaus potential alone. Indeed, the over-all agreement between the predictions based on Eq. (1) and the wide range of available scattering data is sufficiently encouraging to justify the hope that a potential description of the two-nucleon interaction, at least up to 150 Mev, is attainable and that the essential features of such a potential model are contained in Eq. (1).

Work now in progress includes pushing the calculations down below 40 Mev for the p-p scattering (taking more accurate account of the Coulomb force) and above 150 Mev. An attempt is also being made to examine the effects of varying the five parameters in the potential defined by Eq. (1). There is no reason why a potential model should continue to hold at higher energies,[11] say at 300 Mev, and it is hoped to ascertain the character of the additional velocity dependence (if any) of the two-nucleon interaction at the higher energies.

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Evidence Against Spin 1 for the τ Meson*

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NOW that a large number of τ^+ mesons with low-energy π^- mesons have been found, it is possible to devise a fairly sensitive and model-independent test for odd spin. Because of conservation of angular momentum, the low-energy negative pions must have the momentum dependence p^n where $n \geq 2$ for τ^+ mesons of odd spin. For small p, this is independent of the energy dependence and "interaction radius" of the decay interaction.[1] For an even-spin τ meson, n can be zero. In this letter the present world data will be shown to be consistent with $n=0$ and strongly inconsistent with $n=2$. A test somewhat similar to the one used here was made by Orear, Harris, and Taylor[2] using their 71 τ^+ mesons. They obtained odds of 10^3 to 1 against (1+) compared to (0−).

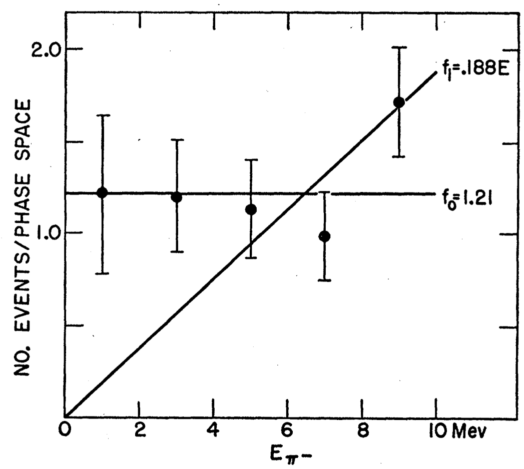

FIG. 1. The number of events per unit phase space in 2-Mev intervals is plotted *vs* π^- energy. The two lines f_1 and f_0 are least-squares fits using the momentum dependence p^2 and p^0 respectively.

In the present analysis only the τ^+ mesons with π^- energies less than 10 Mev are used. In this region $kR<0.1$ for $R=\hbar/M_\tau c$. Systematic scanning in K^+ beams from the Bevatron and Cosmotron has yielded a total of 835 analyzed τ^+, 92 of which have π^- under 10 Mev.[2–9] These 92 events are divided into 2-Mev intervals and plotted in Fig. 1. As a preliminary test, least-squares fits are made to the two momentum dependences $n=0$ and $n=2$. It is seen that the fit to the $n=0$ curve is much better than that to the $n=2$ curve. The true curve should give a least-squares sum of 4.0 on the average. The least-squares sum is 2.7 for the $n=0$ curve and 12.1 for the $n=1$ curve. The χ^2 probability of getting a fit no better than that of the $n=0$ curve is 0.60, and the probability of getting a fit no better than the $n=2$ curve is 0.015. In this particular application, the χ^2 type of test is weak because it doesn't make use of some valuable information. For example, it is quite improbable to obtain a π^- of 0.36 Mev if the τ has spin 1. By lumping this event in a group of 7 others from 0 to 2 Mev, one is throwing away valuable information. For this problem the general statistical procedure would be to form the likelihood ratio of spin 1 to spin zero using the energy values of each individual event.[10] Let $f_0(\epsilon)$ be the spin-zero distribution function and $f_1(\epsilon)$ be the spin-one