Reaction $p+p\rightarrow\pi^{+}+d$ with Polarized Protons*†

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THE 45 percent polarized proton beam[1] of the Carnegie synchrocyclotron has been used to measure the azimuthal asymmetries of the above reaction at π^{+} c.m. angles of 90° and 50°. The polarized external beam of 415±5 Mev protons impinged upon liquid hydrogen, and the resulting pions were detected in fast coincidence with their associated deuterons. We define the asymmetry $\epsilon(\theta)$ to be $[I(\theta)-I(-\theta)]/[I(\theta)+I(-\theta)]$ with $I(\theta)$ the intensity at a c.m. angle of θ. θ is in the same plane as the first scattering which produces the polarized beam and positive θ is in the same sense as the first scattering. We find $\epsilon(90°)=-0.20\pm0.03$ and $\epsilon(50°)=-0.023\pm0.015$, where these refer to the asymmetries in the sense defined by the meson. These values are the average of four separate runs at 90° and three at 50°, with each run taken on a different day and of about 15 hours duration.

To exclude the reaction $p+p\rightarrow\pi^{+}+p+n$, which would otherwise constitute about 10 percent of the counting rate in the geometry we used, sufficient absorber was placed in front of the deuteron counter to absorb the slow protons resulting from this reaction. The beam direction was determined from a beam profile obtained by using the meson counter as the defining counter. The beam polarization and energy were checked before each run as described in reference 1. By using the normal unpolarized proton beam, degraded to 415 Mev, an asymmetry measurement at 90° c.m. yielded $\epsilon=-0.01\pm0.04$.

As shown by Marshak and Messiah,[2] an azimuthal asymmetry in the reaction $p+p\rightarrow\pi^{+}+d$ can arise through the interference of meson S and P states (but from neither alone), and the resulting asymmetry will be given by $\epsilon(\theta)=PQA\sin\theta/(A+\cos^{2}\theta)$, with P the beam polarization, Q a parameter of their theory, and $A+\cos^{2}\theta$ the unpolarized angular distribution. A recent experiment[3] by Crawford and Stevenson yields $Q=0.39\pm0.05$ at $(\mathrm{K.E.}_{\pi})_{\mathrm{c.m.}}=11.3$ Mev. The present experiment gives $Q=0.45\pm0.08$ for $(\mathrm{K.E.}_{\pi})_{\mathrm{c.m.}}=55$ Mev.

According to the above equation, $\epsilon(50°)$ should be given by[4] $\epsilon(90°)/(4.0\pm0.4)$, which is -0.050 ± 0.009. The difference between this and our experimental value is 0.027±0.018. In this connection, it should be stated that the quoted errors are statistical only; systematic errors are probably smaller than these. It was pointed out to us by Professor L. Wolfenstein that a $P-D$ interference term will make a maximal contribution to ϵ at 50°. The fact that this difference is scarcely nonzero outside of statistics and does not include the unknown systematic error means that it cannot be interpreted as more than a possible indication of such a D-state effect.

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2 R. E. Marshak and A. M. L. Messiah, Nuovo cimento **11**, 337 (1954).
3 F. S. Crawford, Jr., and M. L. Stevenson, Phys. Rev. **95**, 1112 (1954).
4 We have here used $A=0.20\pm0.02$ as measured at an incident proton energy of 437 Mev. Fields, Fox, Kane, Stallwood, and Sutton, Phys. Rev. **95**, 638 (1954).

Search for 15-Mev Gamma Radiation from $N^{14}+d$ and $Be^{9}+\alpha$†

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COHEN, Moyer, Shaw, and Waddell[1] have recently reported 15.2-Mev γ radiation from the bombardment of carbon with protons and of B^{11} with deuterons, but not from the bombardment of beryllium with alphas. They suggest that the state in C^{12} involved is the isotopic spin $T=1$ analog of the ground states of B^{12} and N^{12}. The isotopic spin selection rules would then forbid the production of this state in the $N^{14}(d,\alpha)$ reaction. We have attempted to verify this.

A 1-inch Harshaw canned NaI(Tl) crystal viewed by a DuMont 6291 photomultiplier was available for the detection of γ rays. The crystal was surrounded by $2\frac{1}{2}$ inches or more of lead except for a 0.52-inch diameter aperture filled with Lucite which was directed towards the target. A $\frac{3}{4}$-inch long Bakelite plug was placed between the front face of the crystal and the lead.

This arrangement was not, of course, the best possible for detecting 15-Mev γ radiation. Its most important defect was that lower-energy pulses from other γ rays required the use of very low ($\sim0.005\mu$a) deuteron beams to avoid excessive total counting rates. Figure 1 shows the pulse spectrum obtained when a thick B_4C target is bombarded with 10.8-Mev deuterons. Although no detailed analysis of the shape of the spectrum was made, its form is not unexpected because of the small crystal size. By taking the break point in the curve as equal to $(E_{\gamma}-1.02)$ Mev and using the pair peak of the 4.43-Mev γ ray from C^{12} for calibration we get 15.1±0.4 Mev for the highest-energy γ ray. If, as a very rough estimate, it is assumed that 15 percent of the 15-Mev quanta that enter the 0.52-inch aperture produce pulses >11.6 Mev, then our yield for this γ ray is $\sim3\times10^{-5}$ per deuteron.

With a thick Melmac 404 $(N_6C_3H_6)^2$ target, we obtained a small number of counts corresponding to γ