LIST OF REFERENCES AND NOTES

1. Garwin, R. L., Hutchinson, D. P., Penman, S. and Shapiro, G. Phys. Rev. **118**, p. 271 (1960).
2. Koslov, S., Fitch, V. and Rainwater, J. Phys. Rev. **95**, p. 291 (1954).
3. Lathrop, J., Lundy, R., Telegdi, V., Winston, R. and Yovanovitch, D. Nuovo Cimento (to be published).
4. Lathrop, J., Lundy, R., Telegdi, V., Winston, R., Yovanovitch, D., Penman, S. and Bearden, A. Nuovo Cimento (to be published).
5. Bearden, A. Phys. Rev. Letters **4**, p. 240 (1960).
6. Petermann, A. and Yamaguchi, Y. Phys. Rev. Letters **2**, p. 359 (1959).
7. Jones, M. T. Phys. Rev. **50**, p. 110 (1936).

GYROMAGNETIC RATIO OF FREE PROTONS AT 150 MeV

B. Rose

Atomic Energy Research Establishment, Harwell, Didcot, England

I wish to report on some work carried out at Harwell by Manning and myself. As part of our program of work on *p-p* scattering, we intend to measure the Wolfenstein A parameter for which a longitudinally polarized beam is required. This is obtained most conveniently by passing a horizontally and transversely polarized beam through a bending magnet with a vertical magnetic field. On passing through the magnet, the magnetic moment precesses more rapidly than the orbital motion turns, and the relation between the two originally given by Mendlowitz and Case and based on Dirac theory is $\omega_s/\omega_L = 1+a\gamma$. This was also derived classically by Bargman et al. This relationship has not been tested experimentally, and it is of importance not only in the measurement of certain triple scattering parameters but also in the study of anomalous magnetic moments.

The measurement was carried out as shown in Fig. 1 and is based on a suggestion of Cassels some years ago. A vertically polarized proton beam, produced by scattering from a carbon target inside the cyclotron, was passed through a solenoid of such magnetic length that it converted the polarization to the horizontal. The polarization was either to the left or to the right depending upon the direction of the solenoid current. Any small longitudinal component would be unaltered.

The beam was then passed through a bending magnet giving a deflection of $\sim 43\frac{1}{2}°$, sufficient to precess the spin through roughly 90° with respect to the orbital motion, say through $(90°-\phi)$. The transverse components of polarization for ϕ small would be $P_T+P_V\phi$ and $P_T-P_V\phi$ for the two directions of solenoid current, where P_V is the vertical component of polarization on entering the solenoid, and P_T is the longitudinal component of polarization.

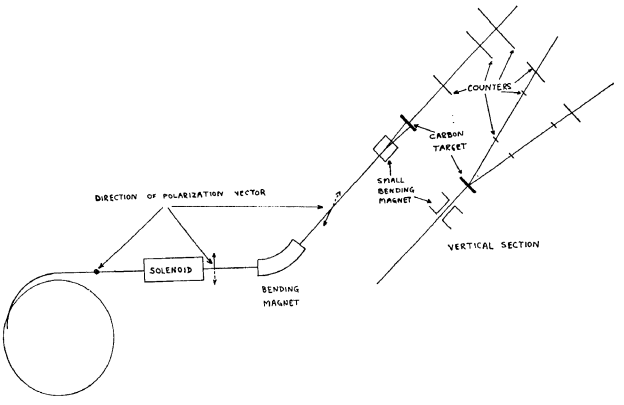

Fig. 1 Experimental apparatus for measuring the gyromagnetic ratio of the free proton at 151 MeV.

The beam was then focused by a quadrupole pair onto a scattering target of carbon, from which protons scattered up and down at $8\frac{1}{2}°$ were detected by two

three-counter telescopes. The solenoid asymmetry ε, defined as

$$\varepsilon = \frac{\left[\left(\frac{UN}{DN}\right)\left(\frac{DR}{UR}\right)\right]^{\frac{1}{2}} - 1}{\left[\left(\frac{UN}{DN}\right)\left(\frac{DR}{UR}\right)\right]^{\frac{1}{2}} + 1},$$

where UN is the counting rate in the up counter with the solenoid current normal, etc., may be shown to be equal to $PP_V\phi$ where P is the analyzing power of the counter telescopes.

We have an auxiliary deflecting magnet just in front of the scatterer which allows a further deflection of the proton beam of $\pm 1\frac{1}{2}°$. The experiment consisted therefore of measuring the solenoid asymmetry as a function of the total deflection angle of the proton beam, and determining that angle for which this asymmetry vanishes—for then $\phi = 0$, which means that the precession angle is just 90° more than the deflection angle.

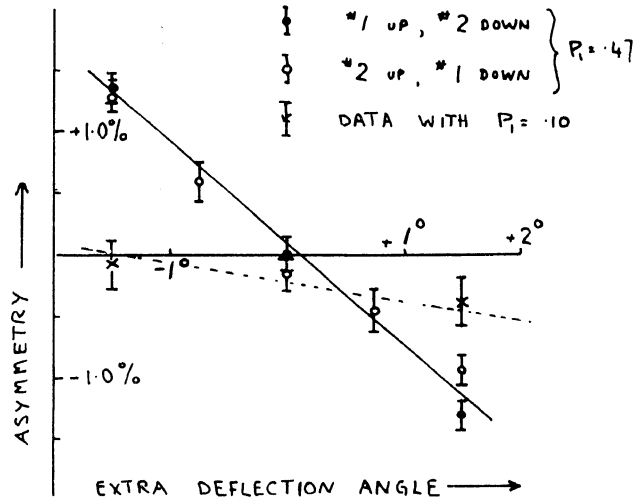

Fig. 2 Measured asymmetries.

The results are shown in Fig. 2. The straight line through the experimental points has the slope calculated from the known product PP_V. The solid circles were taken with counter 1 up and 2 down, and the open circles with them the other way. The crosses were points taken with a beam of 10% polarization and indicate that the observed variation of asymmetry was not due to spurious side effects, such as an effect on the photomultipliers of the magnetic field of the small deflection magnet.

From the intercept and the measured deflection angles of the beam between the input to the solenoid and the scattering target we determine the value of $\omega_s/\omega_L = 3.076 \pm 0.008$ to be compared with the theoretical value of 3.0810 ± 0.0005. If one were to use this as a measurement of the anomalous magnetic moment of the proton one would find the value 1.788 ± 0.007 compared with the expected value 1.793.

From certain measurements made in connection with this experiment, one may derive an improved upper limit to the electric dipole moment of the proton. The counter telescopes were set to detect horizontal scattering from the carbon target, and the usual solenoid asymmetry. This would detect any vertical component of polarization at the scatterer. The vertical component could arise in two ways: the first is from any horizontal transverse component of the beam at the entrance to the solenoid; this would be converted into a vertical component by the solenoid, and remain vertical while passing through the bending magnet. The second possible origin of a vertical component would be from the magnetic field of the bending magnet acting of any EDM of the proton. This would produce a precession about the radius of curvature and hence a vertical component.

The vertical component was found to be 0.036 ± 0.019 of the major component of polarization of the beam. The horizontal transverse component of polarization was determined from a study of the undeflected proton beam and found to be 0.01 ± 0.01 of the major component. The contribution of the EDM to the vertical component of the polarization of the beam after deflection was accordingly 0.046 ± 0.022 of the major component. From this we derive the value of f, the electric dipole moment in natural units eh/mc, to be 0.08 ± 0.04. The precision is insufficient at present to use this other than as an upper limit measurement, and we accordingly say that $f < 0.16$ or $\mathrm{EDM}/e < 3.2 \times 10^{-13}$ cm. This is to be compared with the previous upper limit, determined by Sternheimer, from the levels of the hydrogen atom, of 1.3×10^{-15} cm. The above upper limit could certainly be reduced by a more careful experiment along these lines.