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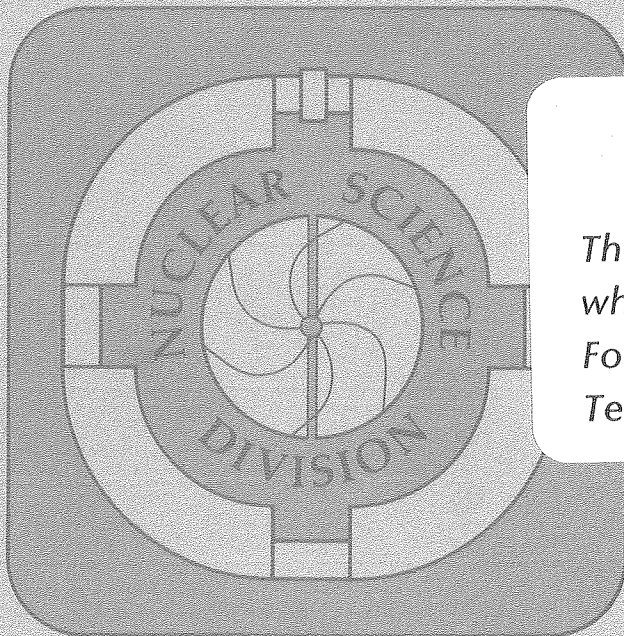
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CONCERNING TESTS OF TIME REVERSAL INVARIANCE VIA
THE POLARIZATION-ANALYZING POWER EQUALITY

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ABSTRACT

It is shown that one of the more recent tests of time reversal invariance, via measurements of the polarization and the analyzing power in $p + {}^{13}\text{C}$ elastic scattering, does not, in fact, provide a significant test of time reversal invariance. This follows from the fact that the polarization-analyzing power equality depends on the equality of the two possible spin-flip probabilities. A possible non-zero difference between the spin-flip probabilities was beyond the precision of the experiment simply because the individual spin-flip probabilities are so small. It is immediately clear that tests of time reversal invariance should be made through measurements of the polarization and analyzing power in a reaction (and its inverse) where the spin-flip probability is expected or known to be large.

It has long been established that time reversal invariance (TRI) is a necessary and sufficient condition for the general polarization-analyzing power equality.¹ That is, the polarization (P) of an outgoing particle from a (binary) nuclear reaction is equal to the analyzing-power (A) for those polarized particles incident in the inverse reaction. Since elastic scattering is its own inverse process, it has been used in essentially all of the tests of TRI that use the polarization-analyzing power equality.

In particular, the most sensitive test by this method was made on $p + {}^{13}\text{C}$ elastic scattering.² It is necessary to scatter from a nucleus with a non-zero spin value, because otherwise parity conservation alone ensures that $P = A$. By making the measurements for ${}^{13}\text{C}$ relative to ${}^{12}\text{C}$, it was not necessary to measure either the absolute beam polarization or the absolute analyzing power, and the result that $P = A$ to $\pm 2.5\%$ was achieved.

As is shown in reference 2, the P-A difference is given by

$$P(\theta) - A(\theta) = (\sigma^{-+}(\theta) - \sigma^{+-}(\theta)) / \sigma(\theta) \quad (1)$$

where

$$\sigma(\theta) = (\sigma^{++}(\theta) + \sigma^{+-}(\theta) + \sigma^{-+}(\theta) + \sigma^{--}(\theta)) / 2$$

and $\sigma^{-+}(\theta)$ is the cross section for the scattering of a proton from

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an initial negative spin state to a final positive spin state. Using the Madison convention,³ the positive (+y) direction is up for a proton scattered to the left in the horizontal plane. Since the time-reversed process of $\sigma^{-+}(\theta)$ is $\sigma(\theta)^{+-}$, eqn. (1) becomes $P(\theta)-A(\theta) = 0$ if the strong interaction is invariant under time reversal. Thus, the reference 2 result for the elastic scattering of 32.9-MeV protons from ^{13}C at $\theta_L=60^\circ$ was interpreted as satisfying TRI within the $\pm 2.5\%$ accuracy of the experiment.

It is clear, however, from eqn. (1) that another reason for $P(\theta)-A(\theta)\approx 0$ could be the very small values of the individual spin-flip probabilities, even if they were not equal as required by TRI. And, it is now known from measurements of the depolarization in elastic p-nucleus scattering that this is, indeed, the case.⁴ Since the depolarization parameter is given by

$$D(\theta) = 1-2S(\theta) \quad (2)$$

with the (total) spin-flip probability

$$S(\theta) = (\sigma^{+-}(\theta)+\sigma^{-+}(\theta))/2\sigma(\theta), \quad (3)$$

measurements of $D(\theta)$ provide determinations of $S(\theta)$. It is now possible to estimate a value of $S(\theta)$ in p- ^{13}C scattering at 32.9-MeV and $\theta_L=60^\circ$ from determinations of $D(\theta)$ in p- ^9Be scattering at 25 MeV.⁵ That is, for the same qR , with q the momentum transfer and $R=r_0A^{1/3}$, the nuclear radius, one has $D = 0.94\pm 0.02$.⁶ I take this to be the lower limit of $D(32.9 \text{ MeV}, \theta_L=60^\circ)$ for p- ^{13}C scattering, since the quadrupole spin-slip mechanism⁷ is not available here because of the spin-1/2 value of ^{13}C . Thus,

$$2S \leq 0.06. \quad (4)$$

Assume now that

$$\sigma^{+-} = 2\sigma^{-+}, \quad (5)$$

which would be a clear and substantial breaking of TRI. From eqns. (1), (3), (4), and (5) it follows that even then

$$|P-A| \leq 0.02, \quad (6)$$

which is smaller than the experimental error. Hence, the experiment did not provide a test of time reversal invariance.

It is immediately obvious from this discussion that tests of TRI using the polarization-analyzing power equality should be made through measurements in a reaction and its inverse where the spin-flip probability is expected or known to be large. Such measurements are presently underway in a Laval-Berkeley collaboration.⁸

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REFERENCES

1. R. J. Blin-Stoyle, Proc. Phys. Soc. A65, 452 (1952);
G. R. Satchler, Nucl. Phys. 8, 65 (1958).
2. E. E. Gross, J. J. Malanify, A. van der Woude, and A. Zucker,
Phys. Rev. Lett. 21, 1476 (1968).
3. Polarization Phenomena in Nuclear Reactions, eds. H. H. Barschall
and W. Haeberli (Univ. of Wisconsin Press, Madison, 1971), p. xxv.
4. See, for example, H. S. Sherif, Proc. Fourth Int'l. Symposium
on Polarization Phenomena in Nuclear Reactions, eds. W. Gruebler
and V. König (Birkhäuser Verlag, Basel, 1976), p. 189.
5. J. Birchall, H. E. Conzett, J. Arvieux, W. Dahme, and
R. M. Larimer, Phys. Lett. 53B, 165 (1974).
6. From a linear interpolation, using the three data points of
ref. 5 between $\theta_c = 60^\circ - 100^\circ$.
7. J. S. Blair, M. P. Baker, and H. S. Sherif, Phys. Lett. 60B,
25 (1975).
8. R. J. Slobodrian, C. Rioux, R. Roy, H. E. Conzett, P. von Ressen,
and F. Hinterberger, to be published.

