A Polarized ^{6}Li Target to Study Parity Violation in ^{10}B

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It has been proposed that the $^{6}\vec{\mathrm{Li}}(\alpha,\gamma)^{10}\mathrm{B}$ (5.166 MeV) should provide a sensitive test for the presence of $\Delta T = 1$ neutral weak currents.[1] The total cross section is given by $\sigma = \sigma_0(1 + aP_Z + \frac{1}{2}P_{ZZ})$, where the parity-violating term a is expected to be $\sim 10^{-3}$, according to recent two-body calculations.[2] To measure such an effect, a system with large vector polarization is needed, that simultaneously has very small tensor polarization to reduce systematic effects. A polarized ^{6}Li target with these characteristics has been built for installation on the Argonne 4 MV Dynamitron.

Figure 1 shows a design of the apparatus for the ^{10}B experiment. The ^{6}Li atomic beam is produced by an oven similar to that used by the polarized electron source at SLAC.[3] It can hold 700 gm of ^{6}Li, which is enough for over 160 hours at full beam intensity. The beam is collimated by a pair of apertures that may be maintained at 300°C in order to inhibit clogging with residual Li. The beam is polarized by a pair of sextupole magnets, of total length 53.7 cm, with a 1.2 cm diameter and 10.5 kG pole tip field. The oven and magnet chambers are each pumped by a 1500 ℓ/sec turbomolecular pump. Typical pressures during normal operation are 2×10^{-6} torr in the oven chamber and 4×10^{-7} torr in the magnet chamber.

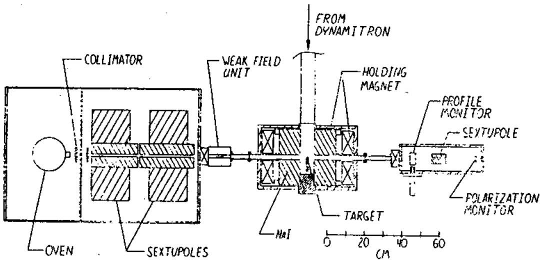

FIG. 1. ^{6}Li atomic beam source, polarized target and detector.

The atomic polarization is converted to nuclear polarization by using weak field adiabatic passage. A static field of 7 gauss with a gradient of +1.5 gauss/cm is used. The RF frequency is 6.0 MHz. Tests indicate that the efficiency of the transition unit is close to unity. Thus, we should be able to switch between $P_Z = 0$ and $P_Z \simeq -2/3$, while maintaining $P_{ZZ} \simeq 0$, by turning the RF off and on.

The ^{6}Li beam impinges on a hot, oxidized tungsten surface in a 1000 gauss holding field. The temperature of the surface is chosen so that the Li sitting time is well under 100 msec. This allows for an equilibrium Li thickness of approximately one monolayer. The strong field ($B/B_c \simeq 12$) maintains the polarization[4] while the ^{6}Li is on the surface. This field may be switched from parallel to anti-parallel to the α beam every 15 seconds. This helps reduce systematic effects by allowing for independent measurements for each polarization state, which may then be combined to cancel any effect due to remanent tensor polarization. The target is to be bombarded by an 80 μA α beam. It is located at the center of a 10" x 10" NaI detector to obtain a solid angle close to 4π.

In addition, the atomic beam apparatus includes two hot wire surface ionizers and an additional small sextupole. These allow us to monitor the atomic beam intensity and profile and, in conjunction with the RF unit, to measure relative beam polarizations as system parameters are changed.

The atomic beam apparatus has undergone several hundred hours of off-line tests. Beam intensities and profiles have been shown to be both stable and reproducible. Typical intensity variations over several hours have been <5% (due to long-term drifts in the oven temperature) and run-to-run variations have been <10%, well within the accuracy of the hot wires. The atomic beam flux at the target position is 2.3×10^{16} atoms/cm^2-sec, which compares favorably to the calculated flux of 2.5×10^{16} atoms/cm^2-sec.

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[2] D. Kurath, private communication.

[3] M.J. Alguard et al., Nucl. Instrum. Methods 163, 29 (1979).

[4] E. Steffens et al., Nucl. Instrum. Methods 143, 409 (1977) and J. Ulbricht et al., in Proceedings 4th International Symposium on Polarization Phenomena in Nuclear Reactions (Birkhauser, Basel, 1976), p. 875.

Search for Parity Violation in ^{6}Li

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Since our last report,[1] substantial changes in the experiment have taken place. Both the impending shutdown of the 50 MeV cyclotron and the need for more intense, higher resolution beams led us to move the experiment to Chalk River Nuclear Laboratories. Completely new apparatus has been constructed. The principle of the measurement is unchanged however, with $^6Li^{+++}$ recoils from capture of α particles by deuterium being detected at the focal plane of the QDDD spectrometer (Fig. 1).

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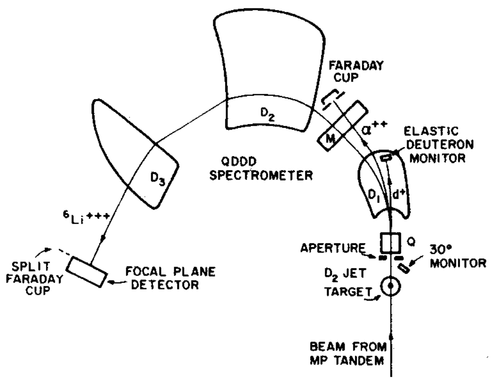

FIG. 1. Schematic diagram of $^2H(\alpha,\gamma)^6Li$ experiment.

A new supersonic jet target has been built in which D_2 gas at 150° K expands from a glass nozzle. The gas flow is removed directly by a 60 cfm mechanical pump, and by 3 stages of differential pumping provided by 2 130 cfm and one 400 cfm Roots blowers. Each section is isolated from the next by a pair of highly-polished 5 mm diameter aluminum apertures. The QDDD scattering chamber itself is pumped by a 1500 l/sec turbo-molecular pump backed by the 400 cfm Roots blower. Under normal operating conditions a target thickness of 1.7 $\mu g/cm^2$ is achieved with a chamber pressure of 6×10^{-4} mm Hg (indicated, uncorrected). Pumping restrictions give satisfactory pressures in the QDDD and the beam line (5×10^{-6} and 1×10^{-6} mm respectively). Deuterium is recirculated through an oil vapor trap and one of two interchangeable molecular sieve cryo-traps. Gas purity is monitored via elastic scattering at 30°, and has remained extremely high throughout long runs. The cryo-trap must be isolated and baked approximately every two days to maintain gas flow.

The high dispersion of the QDDD magnet necessitated construction of a new focal plane detector with an aperture of 1.6 x 30 cm. The design is essentially the same as the shorter one previously used in the Enge spectrograph. The increased size of the detector and the large acceptance of the QDDD have significantly improved the rejection of background. With beam currents of 2μA($^4He^{++}$), the background count rate is in the vicinity of 2500 counts/sec.

The beam energy is calibrated by the momentum-matching technique using a 31 keV Tl^+ beam as described previously.[2] The beam energy is scanned over a 9 keV search range by sweeping the analyzing magnet field appropriately. The MP Tandem terminal voltage is locked to the analyzing magnet slits in a feedback loop. The analyzing magnet field is measured by a tracking NMR sensor whose output is digitized and recorded on magnetic tape with each event. To prevent any modulation due to motion of the beam spot at the target, the switching magnet field is also swept. Further compensation (e.g. sweeping the quadrupole fields) is unnecessary inasmuch as the ^{6}Li ratios are normalized to deuteron elastic scattering.

A ten-day run during which all the components performed very reliably yielded some 25,000 ^{6}Li captures. The focal plane position spectrum is shown in Fig. 2. The general shape of the angular distribution corresponds to the strong

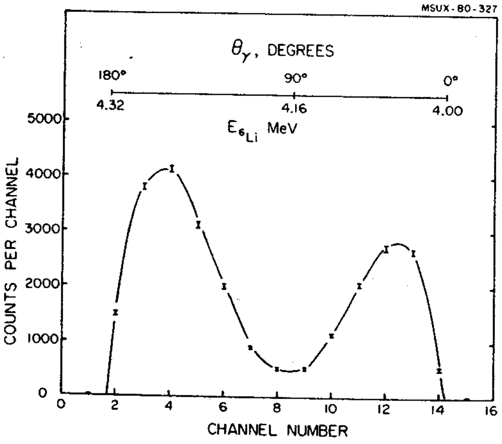

FIG. 2. Focal plane position spectrum of ^{6}Li recoils. The scale is almost exactly proportional to cosθ, where θ is the γ-ray emission angle.

a_4 component of E2 capture, and the asymmetry between the forward and backward lobes is believed to be due to E1-E2 interference, although detailed theoretical analysis has not been completed. The deep minimum at 0° somewhat enhances sensitivity to capture through the 0^{+} T=1 state, which must, of course, be isotropic. Therefore, rather than examine the total cross section excitation function, we have analyzed the isotropic component. Constraining the higher-order terms (a_1 through a_4) to be non-resonant improves the statistical accuracy in $\Gamma_{\alpha d}$ by about 20%. The excitation function of the a_0 term is shown in Fig. 3. From these data (80% of the total taken to date) we conclude that $\Gamma_{\alpha d} = (0.6 \pm 0.8) \times 10^{-6}$ eV, and $\Gamma_{\alpha d} < 2.0 \times 10^{-6}$ eV (90% C.L.). This value is almost three orders of magnitude below the best previous limit,[3] 8×10^{-4} eV (68% C.L.). The theoretical calculations are in relatively rough form at present, but a decay width of about $3.4\ f_{\pi}^{2} \times 10^{-10}$ eV is expected, where f_{π} is the πNN coupling constant in units of 3.8×10^{-8}. Thus the present data correspond to a neutral current enhancement limit of 80.

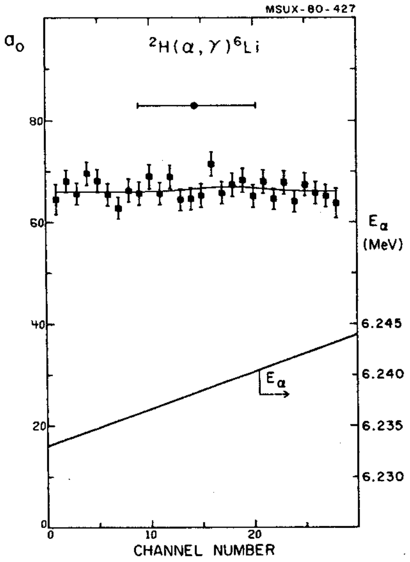

FIG. 3. Excitation function of the a_0 term in the angular distribution. The expected resonance position is indicated by the bar above the spectrum, and the best fit of a Gaussian (of predetermined width) plus a constant background is the solid curve.

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1. R.G.H. Robertson, et al., MSU Annual Report 1977-78, p. 62.
2. P. Dyer and R.G.H. Robertson, MSU Annual Report 1978-79 p. 93.
3. E. Bellotti et al., Nuovo, Cim. 29A (1975) 106.