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AN EXPERIMENT TO INVESTIGATE TIME REVERSAL INVARIANCE IN THE DECAY OF ^8Li

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Résumé -

Le paramètre R de violation du renversement du temps a été mesuré pour la décroissance du ^8Li et donne $R = -0.024 \pm 0.044$. Cette quantité est sensible à la partie imaginaire de la constante de couplage tensorielle qui devrait être présente dans les modèles non standards de l'interaction faible.

Abstract - The Time Reversal Violating R-parameter in the decay of ^8Li has been measured with the result $R = -0.024 \pm 0.044$. This quantity is sensitive to imaginary parts of the tensor coupling constants that might be present in the non-standard models of the weak interaction.

The unresolved problem of CP Violation in kaon decay has motivated experimenters to look for Time Reversal Violation in other systems. Polarized β -unstable nuclei provide a good testing ground for such investigations. In this contribution we present a measurement of the T-odd triple correlation $\vec{R} \cdot \vec{J} \cdot (\vec{p} \times \vec{e})$ where $\vec{J}$ is the nuclear spin, $\vec{p}$ the momentum, and $\vec{e}$ the spin of the electron emitted in the decay of ^8Li . We discuss a new electron polarimeter of unique design which has been developed at PSI /1/ for the study of this decay. The R-parameter in this decay is sensitive to imaginary parts of the tensor coupling constants which might be present in non standard models of the weak interactions.

There has been one prior measurement of the R-parameter. An experiment performed at Princeton University /2/ yielded the value $R = -0.079 \pm 0.053$ for the decay of ^{19}Ne . In this case the interference with the scalar part of the interaction was investigated.

The most suitable process to analyze the polarization of electrons of a few MeV energy is large angle Mott scattering from a thin foil of high Z nuclei. A schematic drawing of a double ring polarimeter /1/ with rotational symmetry about the nuclear spin axis is presented in Fig. 1.

Fig. 1. Schematic view of the polarimeter. A polarized sample of decaying nuclei is placed in the center of the apparatus. The rates measured by up/down symmetric ring detectors are sensitive to the transverse polarization of the emitted electrons, allowing thereby a measurement of the triple correlation $\vec{J} \cdot (\vec{p} \times \vec{e})$.

Such a polarimeter has large solid angles both for electrons emitted by the source and those scattered from the analyzer foil toward the ring detector. High symmetry of the apparatus may reduce possible systematic errors. According to our calculations /1/, the effective analyzing power of such a polarimeter for electrons with energies above 3 MeV from the ^8Li decay amounts to -0.14 .

Our investigations show that ^8Li nuclei can be polarized to approx. 10% by using the reaction $^7\text{Li}(d,p)^8\text{Li}$ at 10 MeV energy of the deuteron beam. A source strength of 10^8 decays/s was achieved and no contaminant reaction products were observed. Polarization relaxation times exceeding 3 lifetimes of ^8Li (0.84 s) were obtained by placing an isotopically pure ^7Li target in a weak magnetic field (≈ 3 mT). In order to retain the long relaxation time the ^7Li target is cooled with liquid nitrogen /3/.

The decay of ^8Li is characterized by an energy release of 13 MeV. Therefore the shielding of the detectors from the intense primary radiation emitted from the activated target requires careful design. We constructed apparatus /4/ consisting of two 90 degree segments of $\Delta E/E$ telescope scintillator ring shown in Fig. 1. With this arrangement we observe an order of magnitude more signal events than associated with the decay background leaking through the shielding. Fig. 2. shows the spectrum of the scattered electrons (with a 27 mg/cm² thick Pb scattering foil in place) compared to the background obtained when the analyzer foil is removed.

Fig.2. Signal (scattering foil in place) and background (foil removed) observed with the apparatus described in the text.

We have studied the following systematic effects:

- Nonuniform illumination of the scattering foil due to the beta asymmetry coupled to a variation of the efficiency of the detector as the function of the vertical position on the foil. We performed measurements with a narrow ribbon foil which test this false asymmetry effect. The resulting systematic uncertainty in R-parameter is less than 0.005.
- Gain shift of the photomultipliers. We installed a system of LED/PIN diodes which monitor the gain of the detectors in every time window after activation, when the electrons are counted. The gain variations for two spin states of the target are very similar, and the resulting effect is negligible.
- Depolarization of the ^8Li nuclei in the production target. Small detector telescopes continuously monitor the polarization of the ^8Li sample. The mean polarization of the target (averaged over the counting period) is approx. 0.09.
- Scattering in the air surrounding the detectors. Tests with a Helium bag replacing the air in the vicinity of the detectors show that this effect is negligible.
- Cosmic ray and room background. These sources amount to 0.01 of the good events and, therefore, can be neglected.
- Accidental coincidences, which amount to 0.001 of the good events are negligible.
- Multiple scattering in the foil. Our calculations based on /5/ predict that this effect reduces the effective analyzing power of the polarimeter from -0.14 to -0.10.

Data for the R-parameter were accumulated during two days using two 90 degree segments of the detector rings. An analysis of these preliminary runs gives a value $R = -0.024 \pm 0.044$ for the time reversal violating triple correlation in the decay of polarized ^8Li .

A measurement of the R-parameter for this decay with a precision of 0.01, is planned to improve present limits on the tensorial couplings (C_T, C_T') in the weak interaction. In particular, the imaginary part $\text{Im}(C_T + C_T')$ will be restricted to ≈ 0.03 . We note that the only limits on such couplings were obtained in an indirect way by observing final state interaction (FSI) effects in the decay of ^{153}Sm /6/. Such FSI effects can also mimic the genuine time reversal violating observable in our experiment. However, due to small nuclear charge and high decay energy (13.1 MeV) in the case of ^8Li , they are expected to be in the order of 10^{-3} , which is much below the aimed for experimental accuracy /7,8/.

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