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RADIATIVE MUON CAPTURE ON ^{3}He

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The least well-known parameter of the weak hadronic current is the induced pseudoscalar coupling, g_p. Several measurements of ordinary muon capture (OMC) on hydrogen yield values of g_p/g_a , where g_a is the axial-vector coupling. The world average of these data is [1]

$$g_p/g_a = 6.9 \pm 1.5 \tag{1}$$

with the best single measurement having an error of 40%. A value of g_p/g_a is predicted by the Goldberger-Treiman relationship between the axial-vector and pseudoscalar couplings for the nucleon

$$\frac{g_p}{g_a} = \left.\frac{2Mm_\mu}{m_\pi^2 + q^2}\right|_{q^2=0.88m_\mu^2} = 6.9\ . \tag{2}$$

where the condition $q^2 = 0.88m_\mu^2$ constrains the momentum transfer to its OMC value. In order to obtain greater precision, Radiative Muon Capture (RMC) can be performed on ^{3}He. In RMC the emitted photon has an energy between 0 and 100 MeV. Thus the value of q^2 can approach the pion pole of equation 2, yielding a sensitivity to g_p much greater than that for OMC. ^{3}He is a desirable target because g_p can be extracted in a model-independent way from the measured RMC rate. For a three-body nucleus, reliable wave functions from nucleon-nucleon potentials exist. The initial and final states for RMC in ^{3}He

$$\mu^- +^3 He \rightarrow t + \nu_\mu + \gamma \tag{3}$$

$$\mu^- +^3 He \rightarrow d + n + \nu_\mu + \gamma \tag{4}$$

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$$\mu^- +^3 He \rightarrow p + n + n + \nu_\mu + \gamma \tag{5}$$

can therefore be calculated, thus allowing a straightforward prediction of the photon spectrum for a given value of g_p. Interest in ^{3}He arises from its simplicity and its similarity to hydrogen. The $^3He \rightarrow^3 H$ transition has the same spin, isospin and parity as the $p \rightarrow n$ transition. ^{3}He is also interesting because it is expected that such a light nucleus will have important meson exchange corrections. According to equation 2, one pion exchange dominates the pseudoscalar part of the semi-leptonic current. If meson exchange effects are important and in fact modify the pion pole behavior, they could show up as a measured value of g_p much different from that predicted by the Goldberger-Treiman estimate. Deviations of the extracted value of g_p as a function of A may be present in carbon, oxygen and calcium [3], suggesting a renormalization of g_p in the nuclear medium. An experiment to measure RMC on the proton is already underway at TRIUMF [2]. Thus there will be values of g_p at A=1,12,16 and 40. A value of g_p at A=3 is therefore of strategic importance in determining the onset of possible nuclear medium effects.

Although the predicted branching ratio for RMC on ^{3}He is $\sim$ 16 times that of RMC on hydrogen, it is still small (1.6×10^{-6}). The experiment must therefore contend with low signal rates and large backgrounds. For this reason a large acceptance pair spectrometer [4] will be used to detect high energy photons from RMC. The target will consist of 2 liters of liquid ^{3}He. Negative muons of 55 MeV/c from TRIUMF channel M9 will be stopped in the target at a typical rate of 2×10^5/sec. The few muons that undergo radiative capture will produce a photon spectrum which is the sum of the individual spectra from reactions 4,5 and 6. The measurement of the photon rate in the exclusive channel (equation 4) is very interesting because its interpretation is most straightforward. To measure it the scintillation light in ^{3}He from the recoil of the residual tritium nucleus will be collected and put into coincidence with the RMC photon. Nearly all the rest of the stopping muons either undergo Michel decay which can be followed by bremsstrahlung of the decay electron, or radiative decay in which a high energy photon is produced directly. Since the muon stopping rate is so large compared to the RMC rate, any measurement of RMC photons below the Michel decay endpoint (53 MeV) is impossible. Thus only the top 30% of the photon rate is observable. Using the above values for the branching ratio and beam rate along with a value of 1% for the spectrometer acceptance, the predicted rate for photons of energy greater than 60 MeV is 9.6×10^{-4}/sec. At this rate 30 days of running will deliver about 2500 good events.

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