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# DETERMINATION OF THE SEMI-LEPTONIC WEAK INTERACTION PSEUDOSCALAR COUPLING CONSTANT, $g_P$, USING THE REACTION $\mu^-\mathbf{p} \rightarrow \nu_\mu \mathbf{n}\gamma$

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The basic leptonic weak interaction is V-A in nature. However, in the case of a weak semi-leptonic interaction, there are 4 additional couplings induced by the strong interaction. Two of these induced couplings ( scalar, tensor ) are expected to vanish due to G-parity invariance. The weak magnetism coupling constant, $g_M$, has been accurately measured in ordinary muon decay and this value agrees with the Conserved Vector Current ( CVC ) prediction. The pseudoscalar coupling constant, $g_P$, is very difficult to determine in neutron $\beta^-$ decay because of the small momentum transfers involved. Ordinary Muon Capture ( OMC ) can provide much larger momentum transfers but this reaction is dominated by the Vector and Axial-Vector amplitudes and the 4% accuracy in the OMC rate [1] yields a 40% uncertainty in the pseudoscalar coupling constant, $g_P$ for the $\mu^- p \rightarrow \nu_\mu n \gamma$ reaction.

Using general field theory principles and assuming the Partial Conservation of the Axial-Vector Current ( PCAC ) along with the dominance of the pion pole, Goldberger and Treiman [2] were able to relate $g_P$ to $g_A$

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

(9220)

where the value $q^2 = 0.88m_\mu^2$ constrains the momentum transfer to its OMC value. In the Radiative Muon Capture (RMC) reaction, $\mu^- + p \rightarrow n + \nu_\mu + \gamma$, the momentum transfer, $q^2$, varies from $0.88m_\mu^2$ to $-m_\mu^2$. At the largest photon energies, the momentum transfer becomes negative ( *time – like region* ) and the amplitude for the pseudoscalar term is enhanced by $\sim 3$ over its OMC value.

The most recent calculation [3] indicates that the RMC rate for photon energies $E_\gamma > 56$ MeV changes by $\sim 20\%$ for a 20% change in $g_P$ while the OMC rate changes by less than 3%. This increased sensitivity of RMC to $g_P$ is offset by the extremely low rate ( $10^{-5}$ ) when compared to OMC. Therefore, such RMC measurements have, in the past, been limited to nuclear targets where the capture rates are much larger ( $\Lambda \sim Z^4$ ). However, the interpretation of these results is subject to uncertainties in the nuclear response function. RMC on hydrogen is completely free of such theoretical uncertainties but the extremely low branching ratio ( $\sim 10^{-8}$ per stopped $\mu^-$ ) makes the reduction of the experimental backgrounds a formidable problem. All pions in the muon beam must be identified at the level of $1 : 10^9$ since each pion produces a high energy gamma-ray when it stops in liquid hydrogen. Contaminants in the hydrogen, cosmic-ray events, multiple single tracks, and neutron events must all be eliminated in order to extract a clean RMC signal for hydrogen.

In order to reject these backgrounds and observe this weak signal we have constructed [4] a large volume pair spectrometer which utilizes a cylindrical drift chamber ( DC ) in an axial magnetic field ( 0.24 T ). Veto scintillators surround the target to reject the copious flux of Michel decay $e^-$. A thin Pb converter ( 1.08 mm ) is used to create $e^+e_-$ tracks which are measured to $\sim 140\mu$m in the 4 layer drift chamber. The 6 sense wires in each cell are each equiped with a multi-hit TDC which is essential to eliminate events in which multiple single tracks form an apparent gamma vertex.

The expected event rate in our $\sim 3\pi$ solid-angle detector is only about 5 events/day so that even cosmic-ray backgrounds must be subtracted from our final spectrum. The experiment has been in a data-taking mode since July 1990. To date, we have stopped $\sim 2 \times 10^{12}\mu^-$ and have accumulated $\sim 200$ good RMC events on tape. The final goal of 400 RMC events should be achieved about mid-1992. The 5% statistical error for the RMC rate will be increased by the systematic errors, in particular by the 4% uncertainty of the ortho-para transition rate, $\Lambda_{OP}$. This should allow a final accuracy of 10% for the value of $g_P$ which will serve as a benchmark when looking for any possible renormalization of $g_P$ in the nuclear medium.

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