Measurement of the $\beta - \nu$ Correlation in Laser Trapped ^{21}Na

N.D. Scielzo, S.J. Freedman, B.K. Fujikawa, and P.A. Vetter
Lawrence Berkeley National Laboratory and Department of Physics,
University of California at Berkeley, Berkeley, California 94720

Trapped radioactive atoms are an appealing source for precise measurements of the $\beta - \nu$ correlation coefficient, $a_{\beta\nu}$, since the momentum of the neutrino can be inferred from the detection of the low-energy recoil daughter nucleus. ^{21}Na is produced on-line at the 88-Inch Cyclotron and 800,000 atoms have been maintained in a magneto-optical trap. A static electric field draws daughter ^{21}Ne ions to a microchannel plate (MCP) detector and β^+s are detected in coincidence with a plastic scintillator (ΔE-E) β detector telescope. The time-of-flight distribution of recoil-ions determines $a_{\beta\nu}$.

The charge-state distribution following β^+ decay was measured and compared to a simple model based on the sudden approximation. The results are shown in Figure 1. The calculation also suggests a small contribution to ionization from nuclear recoil, which would cause a shift in the measurement of $a_{\beta\nu}$. No dependence on either the β^+ or the recoil nucleus energy was observed in the data.

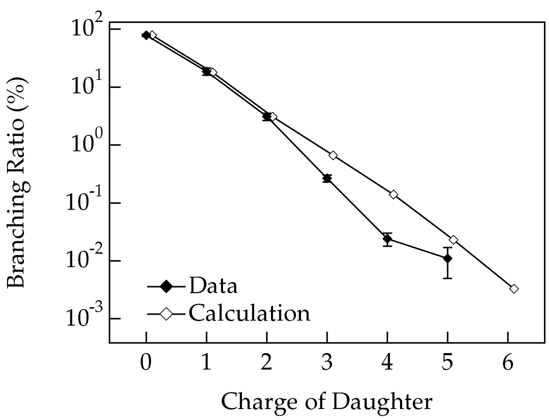

FIG. 1: Comparison of ^{21}Ne charge-state distribution with calculation. Points are connected for clarity.

We have investigated systematic effects at the <0.005 level for the $\beta - \nu$ correlation analysis. We now accept β^+ events that deposit more than 50 keV in the detector and 97.3% of the spectrum is detected. A correction for coincidences induced by annihilation γ-rays is made.

The MCP detector was calibrated off-line using an electron cyclotron resonance ion source (IRIS ECR)[1]. Using a monoenergetic beam of $^{20}Ne^+$, we found that the average pulse height decreases as the ions strike the MCP further from the center. By empirically modeling the MCP output, we determine 94–97% of the pulse height distribution for 10 keV ions is above the 25 mV electronic threshold. The position dependence leads to a correction of -0.0038 ± 0.0016 to $a_{\beta\nu}$.

We performed an optical rotation measurement to determine if the trapped sodium nuclei, with a nuclear spin of 3/2, develop a net polarizaton or tensor alignment. Since optical rotation signals required $> 2 \times 10^6$ atoms, we trapped stable ^{23}Na using the identical trap configuration. A 40 μW probe beam was passed through the trap 45° to the detector axis and was detected using photodiodes. Its polarization was oscillated from σ^+ to linear to σ^- to linear at $\omega = 50$ kHz using a photo-elastic modulator. The absorptivity was demodulated at 1ω and 2ω using a lock-in amplifier and the optical depth determined by the DC absorption of the probe beam. The probe beam frequency was swept through the atomic transitions. Comparing the resulting lineshapes to calculated lineshapes for various hyperfine sublevel population distributions, we determined the net nuclear polarization and tensor alignment must both be $<0.2\%$. This result was independent of electric/magnetic field settings, trap laser beam alignment and power, trap population, and region of the trap probed.

TABLE I: Corrections and systematic uncertainties for $a_{\beta\nu}$.

Source	Correction	Uncertainty
Recoil Order Corrections	-0.0010	
Order-α Radiative Corrections	$+0.0041$	
Recoil Ionization	-0.0033	0.0017
Polarization and Alignment		0.0006
β Detection		0.0024
Ion Detection	-0.0038	0.0016
Electric Field and Simulation		0.0027
Annihilation γ-rays	$+0.0085$	0.0018
β^+ Scattering	$+0.0039$	0.0016
Total	$+0.0083$	0.0049

We find $a_{\beta\nu} = 0.5243 \pm 0.0092$ from the recoil-ion spectrum, which is in 3.6 σ disagreement with the Standard Model prediction of $a_{\beta\nu} = 0.558 \pm 0.003$. Table I is a summary of systematic uncertainties.

[1] D. Wutte *et al*. Proceedings of the 1999 Particle Accelerator Conference (Cat. No.99CH36366). IEEE **3**, 1952 (1999).