High Precision half-life measurement of $^{21}$Na

R.S. Behling, B. Fenker, J.C. Hardy, V.E. Iacob, M. Mehlman, D. Melconian, H.I. Park, P.D. Shidling, and B.T. Roeder

A review of all $T=1/2$ mirror $\beta$ decays [1] indicates that $^{21}$Na is one of the best candidates from this group for testing the standard model. The total uncertainty in the $ft$ value of $^{21}$Na was dominated by the half-life. So, half-life measurements were carried out recently by two different groups [2,3] unfortunately with inconsistent results. We have performed a precise half-life measurement for $^{21}$Na aimed at resolving this discrepancy.

$^{21}$Na was produced via the $p(^{22}$Ne, $2n)^{21}$Na reaction in inverse kinematic at a primary beam energy of 25 MeV/u. The Momentum Achromat Recoil Spectrometer (MARS) was used to produce a secondary beam of $^{21}$Na with a purity of 99.9%. Fig. 1a shows typical two-dimensional plot of energy-loss vs position as obtained with the 16-strip position-sensitive silicon detector (PSSD) in the MARS focal plane. The secondary beam exited the vacuum system through a Kapton foil and then passed through a thin plastic scintillator, a series of Al degraders and eventually implanted in the center of an Aluminized Mylar tape. In repeated cycles, the fast-tape transport system quickly transported the sample to a well shielded location, placing it in the center of a $4\pi$ proportional gas counter where $\beta$ activity was recorded for about 20 half-lives. The total data set was divided into 21 runs with different settings of the experimental parameters: bias voltage, discriminator threshold and dominant dead-times. Each cycle was dead-time corrected and the cycles from a given run were summed and fit using the Levenberg-Marquardt $\chi^2$ minimization algorithm. The fit function consisted of one exponential corresponding to the decay of $^{21}$Na plus a constant background. The decay curve observed with the summed fit overlayed is shown in Fig. 1b.

![FIG. 1. (a) On the left, two dimensional plot of energy-loss versus position in the PSSD at the MARS focal plane. (b) On the right, typical dead-time corrected summed decay curve obtained from a single run with residuals. The reduced chi-square of the fit is 1.10.](image)

Our final result for the $^{21}$Na half-life is $t_{1/2} = 22.4615 \pm 0.0039 \text{ (stat)} \pm 0.00015 \text{ (syst)} \text{ s}$ [4]. Our result strongly disfavors the half-life measured by Grinyer et al. [2] but does not fully agree with Finlay et
al. [3] either. It should be noted that the uncertainty in our measurement is dominated by statistics, whereas the total uncertainty in the two recent measurements [2,3] is dominated by systematics. In any case, the new world average of the $^{21}\text{Na}$ half-life is increased by 0.0048 s and has an uncertainty reduced by a factor of 1.5. The new $f_t$ value is now limited in precision by the 95.235(69)% ground state branching ratio. More important still, the uncertainty in $V_{ud}$ is dominated by the ±1% uncertainty associated with the value of $\rho$, which derives from a correlation measurement [5].