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 β 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 $p(^{22}\text{Ne}, 2n)^{21}\text{Na}$ 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 4π proportional gas counter where β 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 χ^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.

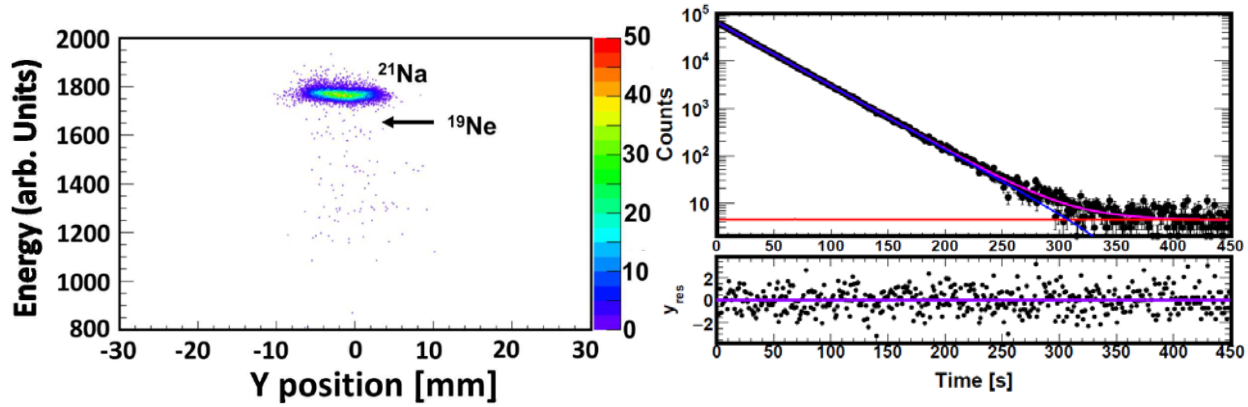

FIG. 1. (a) On the left, two dimensional plot of energy-loss versus position in the PSSD at the MARS focal plane. (b) On the right, typical dead-time corrected summed decay curve obtained from a single run with residuals. The reduced chi-square of the fit is 1.10.

Our final result for the ^{21}Na half-life is $t_{1/2}$ = 22.4615 ± 0.0039 (stat) ± 0.00015 (syst) 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}Na half-life is increased by 0.0048 s and has an uncetainty reduced by a factor of 1.5. The new *ft* 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 ρ, which derives from a correlation measurment [5].

[1] O. Naviliat-Cuncic and N. Severijns, Phys. Rev. Lett. **102**, 142302 (2009).
[2] J. Grinyer *et al.*, Phys. Rev. C **91**, 032501(R) (2015).
[3] P. Finlay *et al.*, Phys. Rev. C **96**, 025501 (2017).
[4] P.D. Shidling *et al.*, Phys. Rev. C (submitted).
[5] P.A. Vetter *et. al.*, Phys. Rev. C **77**, 035502 (2008).