GEANT4 simulations of the TAMUTRAP facility

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The TAMUTRAP facility [1] has the primary goal of measuring the electroweak interaction's beta-neutrino correlation parameter, $a_{\beta\nu}$. This parameter is sensitive to scalar currents in the electroweak charged-current interaction which would be a sign of physics beyond the standard model. We will determine the parameter by measuring the proton spectrum of T=2 superallowed $0^+ \rightarrow 0^+$ beta-delayed proton emitters and separating the spectrum based on whether the proton is detected in the same or opposite hemisphere as the beta particle. In addition, we expect to be able to measure the β-p branching ratios in our system which, with the known lifetimes, would allow us to determine the ft value and perhaps contribute to the evaluation of V_{ud}, the up-down element of the Cabibbo-Kobayashi-Maskawa (CKM) matrix [2].

Circular double-sided silicon strip detectors with central holes will replace the end cap electrodes in the current configuration of the 180-mm diameter Penning trap [3]. Charged particles inside the trap are constrained to an axial position within one Larmor diameter ($D = \frac{2v}{\omega} = \frac{2\beta\gamma mc}{qB}$). With the betas being light and relatively low energy (T ~4 MeV) they are kept within a Larmor diameter of ~10 mm. Because of this, decays taking place on the trap's central axis have a high probability of the beta escaping detection through the central hole. To avoid these losses, we will excite the magnetron motion of the ions, moving them off-axis farther than the 6-mm holes in the end cap electrodes. Distributions of the radii where protons and betas from the superallowed p_0 proton emitting channel hit the detector in simulation are shown below in Fig. 1.

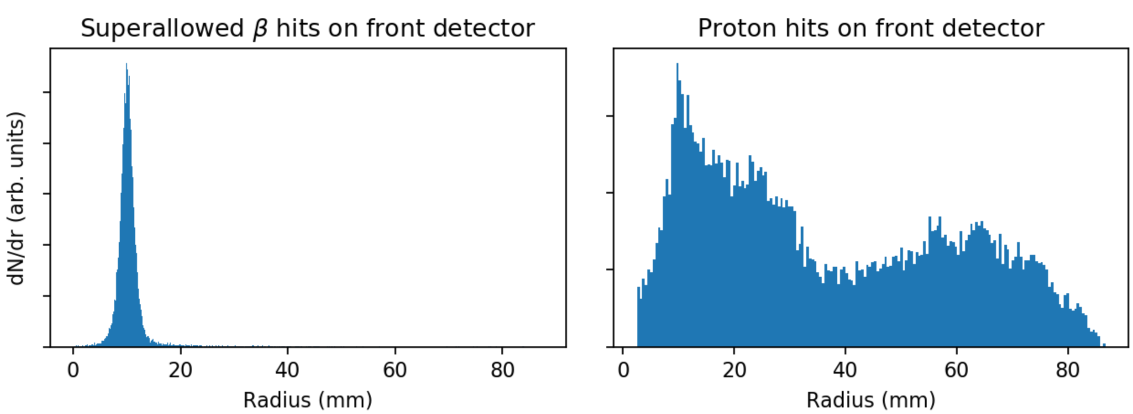

FIG. 1. Simulation of the radial position of the beta (left) and proton (right) in Si detectors following a β-p decay of ^{32}Ar. The βs have a small Larmor radius, so their distribution is essentially the initial radius (in this case, magnetron excitation move them to R=10mm). The protons may have a large helical path and so illuminate more of the detector.

Our simulations [4], which previously simulated only the main beta-delayed-proton branch in the ^{32}Ar decay scheme (with branching ratio 20.50% [5]), have been expanded to allow for a second beta to be produced by the radioactive daughter isotope. Ions are loaded into TAMUTRAP in the 1^{+} charge state, so ^{32}Cl ions will be neutral unless there are shake-off electrons. Because the ^{32}Cl ions are neutral in this case, they unaffected by both the electric and magnetic fields which trap the ^{32}Ar. Therefore, the geometric efficiency is effectively much smaller for the betas produced by ^{32}Cl decays than ^{32}Ar decays (approximately 12% efficiency).

Though this simulation does not implement the full decay scheme of ^{32}Ar, the energy spectrum of the ^{32}Cl daughters is not the focus of the study, as the TAMUTRAP detectors will not capture the full energy of the betas. Thus, we have selected samples of 80% decays through the ^{32}Cl (1.1 MeV) state producing two betas and 20% superallowed beta-delayed-proton events producing one beta and one proton.

We are currently analyzing the results of these simulations to determine the precision with which TAMUTRAP will be able to measure the *ft* values of the superallowed transitions, as well as the best strategy for time and spatial separation of the counts due to daughter decays.

[1] P.D. Shidling *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2018-2019), p. IV-47.
[2] J.C. Hardy and I.S. Towner, Phys. Rev. C **91**, 025501 (2015).
[3] V.S. Kolhinen *et al*., *Progress in Research*, Cyclotron Institute, Texas A&M University (2018-2019), p. IV-45.
[4] V.S. Kolhinen *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2017-2018), p. IV-44.
[5] M. Bhattacharya *et al.*, Phys. Rev. C **77**, 065503 (2008).