GEANT4 simulations of the TAMUTRAP facility

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The TAMUTRAP facility has been built for β decay studies of superallowed T = 2 β-delayed proton transitions. The goal is to deduce the β-ν correlation parameter, $a_{\beta\nu}$, which is sensitive to possible scalar currents contributing to the dominant vector interaction of the standard model. By doubling [1] the world's largest Penning trap [2] to an inner diameter of 180 mm, the 7 T uniform field will fully contain delayed protons emitted with $E_p \leq 4.8$ MeV, and direct them to detectors regardless of the direction they are emitted. The program will start with 32Ar, and continue with a number of other similar T=2 β-delayed proton emitters: ^{20}Mg, ^{24}Si, ^{28}S and ^{36}Ca.

The protons are emitted isotropically in the intermediate nucleus's frame, but the intermediate nucleus recoils from the initial β decay and causes a Doppler broadening of the proton's energy spectrum. If the interaction is purely vector the β and ν tend to be emitted the same direction, whereas if it is scalar they tend to be emitted in opposite directions. The effect on the proton energy is shown in the left panel of Fig. 1 for the two interactions. Essentially, a measurement of the shape of the proton's energy spectrum can be used to test for scalar contributions, as has been demonstrated in Ref. [3] where they reached 0.5% precision. To reach our goal of 0.1% precision, we will measure the β as well, and whether it went in the same hemisphere as the proton or the opposite, thus breaking up the spectrum into the two shown in the right panel of Fig. 1. In this way, we will obtain a cleaner spectrum (due to the coincidence condition with the β) as well as increase our sensitivity by measuring the means (1st moments) of the two distributions instead of the shape (2nd moment) to deduce $a_{\beta\nu}$.

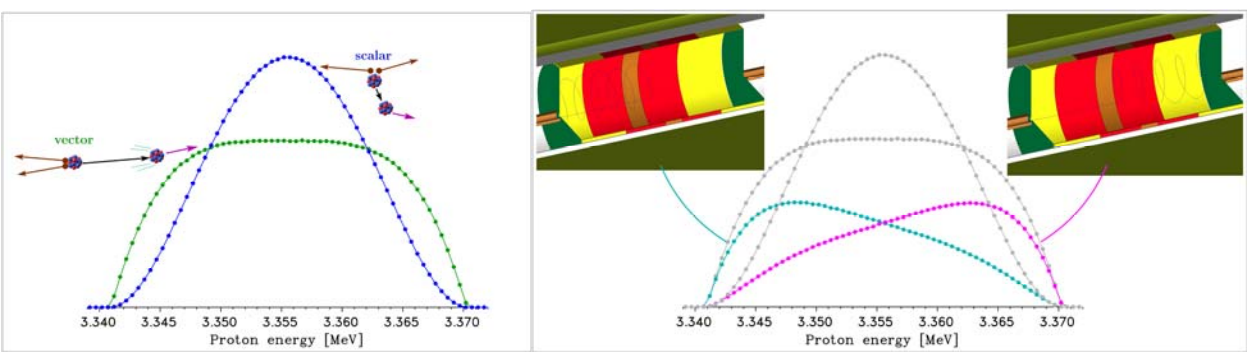

FIG. 1. Simulated energy spectrum from the decay of ^{32}Ar assuming a vector interaction compared to a scalar (left plot). Using a Penning trap to confine the ions and observing both the proton and β, we can break up the spectrum into two: one where the β went in the same hemisphere as the proton, and another where it was emitted in opposite hemisphere (right panel).

The design of the full-sized trap is completed and we have included the new geometry in our GEANT4 simulations. We are using these simulations to guide us towards an optimal detection system as we consider the specific geometry of the position-sensitive Si detectors we will use at either end of the Penning trap. SRIM simulations have determined the minimum thickness of the silicon detectors to capture the full energy of even the highest energy protons from the T = 2 β -delayed proton transitions.

While already useful for checking geometric efficiencies, the slight non-uniformities of our *B* field (far from the center of the bore), and effects arising from β backscattering, trap size, etc., there are many improvements yet to be implemented. These include: incorporating recoil-order corrections in the decay generator, adding branches to excited states other than the superallowed transition, and including a more realistic geometry once the design of the detectors is finalized. We will also use these simulations to optimize the analysis so we maximize our sensitivity to non-standard model physics.

[1] V.S. Kolhinen, *et al*., Progress in Research, Cyclotron Institute, Texas A&M University (2017-2018) p. IV-42.

[2] M.Mehlman, *et al*., Nucl. Instrum. Methods Phys. Res. **A712**, 11 (2010).

[3] E.G. Adelberger, *et al.*, Phys. Rev. Lett. **83**, 1299 (1999).