TRINAT status – precision polarization and beta-asymmetry

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The TRINAT collaboration is utilizing magneto-optical trapping and optical pumping techniques to cool, confine and highly polarize ^{37}K atoms to provide an ideal source for precision β-decay experiments. Our goal is to measure parameters of the angular distribution to < 0.1% which would search for (or help constrain) physics beyond the standard model in a way that is competitive with and complementary to direct searches at high-energy colliders. Our particular focus at this point is a precision measurement of the β asymmetry parameter, A_β, which characterizes the correlation between the initial nuclear spin and the momentum of the daughter positron.

In order to be able to extract A_β from an asymmetry measurement (which goes like PA_β), we need to know the nuclear polarization of the atoms that are decaying. As described in last year's report [1], we use optical pumping to polarize the atoms along the same axis defined by the β detectors. We are able to reverse the direction of the polarization by simply reversing the polarization of the optical pumping laser light. Our result, recently published in Ref. [2], is $P_\uparrow = +0.9913(7)(5)$ and $P_\downarrow = -0.9912(6)(5)$ where the first uncertainty is statistical and the second systematic. The largest systematic uncertainty comes from an uncertainty in the initial distribution of the atoms amongst the possible sublevels. The overall uncertainty arising from our knowledge of the polarization is 0.08% which is precise enough to allow us to reach our goal of 0.1% in A_β.

Fig. 1 shows a drawing of the detection chamber. Two β telescopes, each consisting of a double-sided Si-strip (ΔE) and plastic scintillator (E) detectors, are positioned along the polarization axis. Electrostatic hoops generate an electric field which sweeps shake-off electrons and recoils to corresponding micro-channel plate detectors (MCPs); a coincidence with the shake-off MCP helps ensure that βs observed in the telescopes originated from decays that occurred within the trapping region and not, e.g., from untrapped atoms. On the right of Fig. 1, we show the observed asymmetry and the comparison

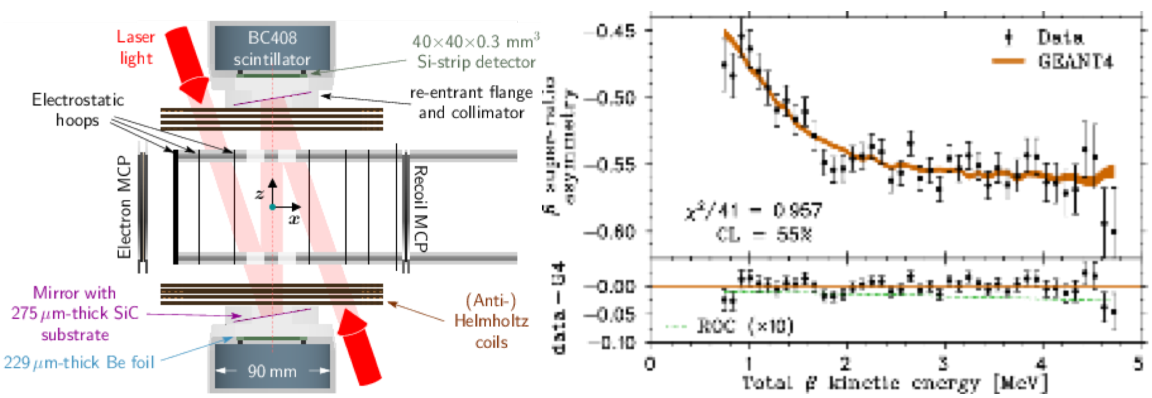

FIG. 1. The measurement chamber (left) and observed asymmetry (right) from part of the 2014 data set (filled circles). The super-ratio approach, which minimizes systematic effects, utilizes both β telescopes and both polarization states, and is compared to a GEANT4 simulation (filled band, with the width indicating it's statistical uncertainty) to extract A_β. Recoil-order effects introduce a very small correction, as shown by the dashed green line in the residual plot.

to our GEANT4 simulation. There is excellent agreement over the whole range of the β energies, requiring no background subtraction; the only free parameter of the fit was the value of $\rho = \frac{C_A M_{GT}}{C_V M_F}$ which determines the value of A_β.

$$A_\beta = -0.5707(12)_{\mathrm{syst}}(13)_{\mathrm{stat}}(5)_{\mathrm{pol}},$$

where the dominant systematic is due to a small background: we apply a correction of 0.14% and assign a $\pm 0.08\%$ uncertainty to this correction. All other systematics are at or below the 0.05% level. This result is in good agreement with the standard model prediction $A_\beta^{SM} = -0.5706(7)$.

In terms of constraining physics beyond the standard model, this 0.3% measurement – with the smallest fractional uncertainty of any β-asymmetry measurement in a nucleus or the neutron – has been interpreted in two ways: to search for right-handed currents, and to improve the measurement of V_{ud} from this mirror decay. These results are shown in Fig. 2. Our results alone improve the mass limits on a new right-handed boson to be >352 GeV, a 42 GeV improvement over the previous best limit from ^{12}N and ^{107}In. In terms of CKM unitarity, our result represents a nearly $5\times$ improvement to the value of V_{ud} for ^{37}K and brings the average value from all mirror nuclei slightly more precise than that of the neutron.

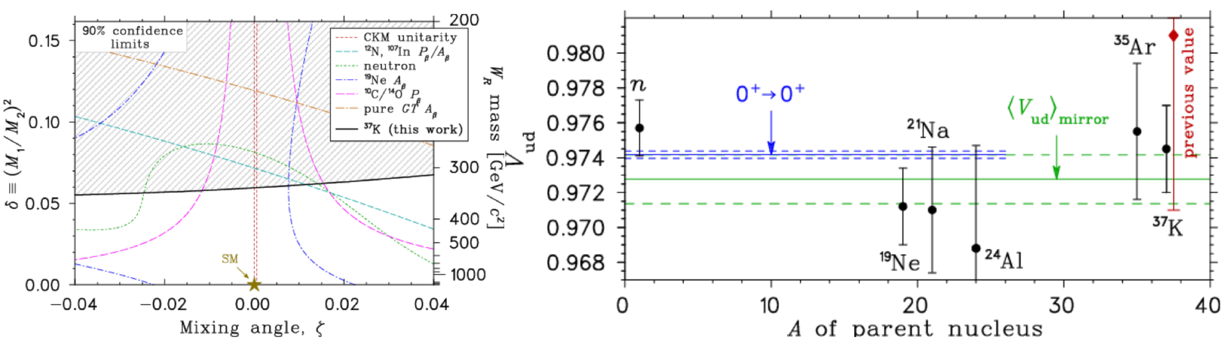

FIG. 2. Impact of the A_β measurement on physics beyond the standard model. On the left we compare our limit on right-handed current parameters to other nuclear experiments, where we provide the tightest constraint on the mass of a possible right-handed W boson, $M_W > 352\ GeV$ at 90% confidence level. On the right, we use our present result with the *ft* value [4] to dramatically improve the value of V_{ud} for ^{37}K which, as can be seen, is now about as precise at the neutron and ^{19}Ne.

The A_β result has been submitted for publication [3] as we continue analyzing the energy-dependence to search for 2nd-class currents and a non-zero Fierz interference parameter.

[1] D. Melconian *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2016-2017) p.I-65.

[2] B. Fenker *et al.*, New J. Physics **18**, 073028 (2016).

[3] B. Fenker *et al.*, arXiv:1706.00414; Phys. Rev. Lett. (Submitted).