TRINAT Status – Precision polarization and beta-asymmetry

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The TRINAT collaboration seeks to make precision measurements angular correlations in the positron decay of ^{37}K which confine and cool with a magneto-optical trap. Measurements with a relative uncertainty of <1.0% can constrain physics beyond the standard model with complementary uncertainties to direct searches at high-energy colliders. Alternatively, correlation coefficient measurements at this level of precision can be used to derive a value of V_{ud}, the top-left element of the CKM matrix independent of the most precise determination using pure-Fermi super-allowed decays [1]. We expect our current data set, collected in 2014, to measure the beta-asymmetry, i.e. the correlation between the spin of the parent nucleus and the momentum of the outgoing positron, to $\Delta A/A \leq 0.5\%$. When complete, this will be the most precise measurement of this parameter in any nucleus and have comparable precision the measurements in the neutron.

Critical to this measurement is a precise determination of the degree of polarization of the parent nuclei. We use the technique of optical pumping to select the atomic sublevel with maximum projection of nuclear angular momentum along the quantization axis. We monitor the total population of unpolarized and partially polarized atoms by photoionizing atoms after excitation by the optical pumping light and detecting the resulting photoions by accelerating them onto a microchannel plate detector with an electric field. As atoms accumulate in the fully-polarized state, they are no longer available to be photoionized and the rate of photoionization decreases as shown in Fig. 1. The contribution to the average nuclear polarization from the atoms that are not fully polarized is modeled using the density matrix [2]. Our analysis makes a precise measurement of the degree of polarization of the optical pumping light [3] and fits a magnetic field transverse to the optical pumping axis to the experimental data, shown as the red curve. With coherent population trapping accounted for in the theoretical model and deliberately avoided in the experiment, this accounts for all of the possible mechanisms leading to less-than-perfect

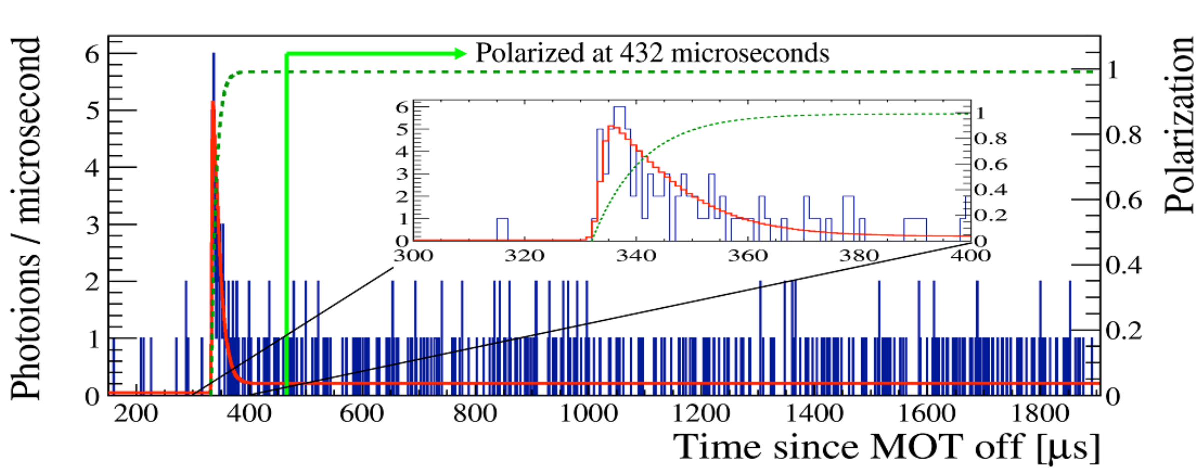

FIG. 1. Time spectrum of photoions used to determine the cloud polarization. The optical pumping light is turned on at 350μs, and are polarized in 82μs.

polarization. The final results we obtained with this method are $P = +0.9913(7)(5)$ and $P = -0.9912(6)(5)$

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. This result has been submitted for publication [4].

Furthermore, significant progress has been made towards the measurement of the asymmetry in the number of positrons detected along and against the nuclear polarization axis. At this point, all of the detectors have been characterized and the analysis cuts are in the process of being finalized. Although the data is still "blind" to prevent over- or under-fitting of the data, it agrees well with the experimental asymmetry predicted by a GEANT4 simulation that includes tracking the positron through the experimental geometry and ideally includes the effects of scattering off of the surrounding material.

Fig. 2 shows the energy spectrum from our plastic scintillator detectors which record the total energy deposited by the positron. Overlayed with the data is the GEANT4 simulation which is able to reproduce the spectrum. It is worth emphasizing that there is zero background included in this figure. This analysis, which is in its final stages, will make up Benjamin Fenker's Ph.D. thesis and will be complete this summer.

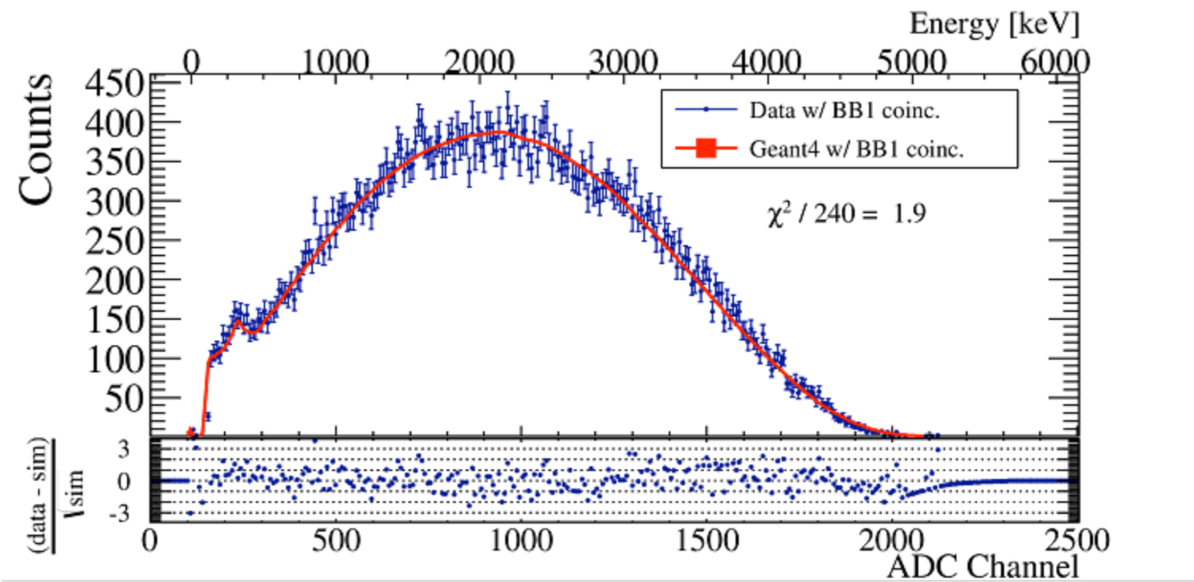

FIG. 2. Energy spectrum of the upper plastic scintillator and comparison to our Monte Carlo simulation (top). The residuals of the fit are shown below.

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