Polarization by optical pumping – the β-asymmetry of ^{37}K

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As described in Ref. [1], we have collected data for a $\lesssim 0.5\%$ measurement of the polarized beta-asymmetry parameter in ^{37}K. The observed positron asymmetry is equal to the physics parameter of interest multiplied by the nuclear polarization. Therefore, a precise beta-asymmetry measurement requires a precise polarization measurement. To achieve the high polarization, we use a technique called optical pumping. In this process, we illuminate the atoms with circularly polarized laser light to select a particular Zeeman sublevel, called the "stretched state," which corresponds to complete atomic and nuclear polarization. However, not all of the atoms accumulate in the desired state, leaving the polarization slightly imperfect.

We can monitor the total population of non-stretched states by photoionizing and detecting a small fraction of atoms that have been excited by the laser light. The frequency of the photoionization laser is chosen such that it can only photoionize atoms after they have been excited by the optical pumping laser. Since atoms in the stretched state cannot be excited by the optical pumping light, they cannot be photoionized. Therefore, this technique produces a signal proportional to the total population of all the non-stretched states. As atoms accumulate in the stretched state they are no longer available to be photoionized and the time evolution of the photoionization rate, shown in Fig. 1, provides a clean measurement of the polarization.
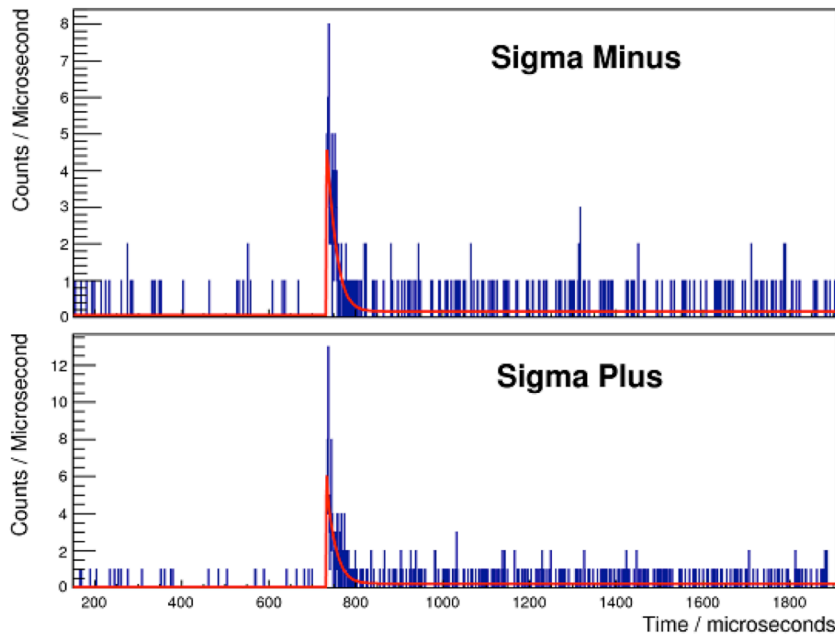

FIG. 1. Photoionization signal as a function of time. The photoionization signal is proportional to the total non-stretched population. Therefore, if the photoionization were completely extinguished the polarization would be 100% as all the atoms would be stretched. The degree to which the photoionization is not completely extinquished can be used to infer the nuclear polarization.

However, because it only measures the total non-stretched population and not the distribution among these states, the photoionization signal is an indirect measurement of the polarization. We have used a numerical model of optical pumping to infer this distribution and calculate the polarization. It includes two mechanisms by which the polarization can be imperfect: imperfect polarization of the laser light and a magnetic field transverse to the polarization axis. These two depolarizing mechanisms are completely indistinguishable in the data and so represent a systematic uncertainty in the polarization. To reduce this uncertainty, we have used off-line measurements of the light ellipticity and transverse magnetic field to constrain these parameters. While not eliminating the effect, this has allowed us to reduce the uncertainty to acceptable values, similar to the statistical uncertianty.

The polarization analysis is nearly complete with the result expected to have $P \approx 99.1\%$ and $< 0.3\%$ total uncertainty. This is a factor of 3 more precise than previous analyses by our group and represents significant progress towards the most precise determination of the beta-asymmetry in a nucleus.

[1] B. Fenker, M. Mehlman, D. Melconian, and P.D. Shidling, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015), p. I-5.