Validation of the Pulse Shape Simulation Tools

C.M. O'Shaughnessy and J. Rager

University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
Triangle Universities Nuclear Laboratory, Durham, NC, USA

(Dated: December 2, 2016)

The waveform generation for MAJORANA uses the fieldgen and siggen tools. While these are fairly throughly validated by both the use in GRETINA and by the WF-fitting routines that have also been developed. We must be certain that no systematic effects enter an analysis that utilizes these simulations for estimation of the systematic effects of PSAs.

CONTENTS

I. INTRODUCTION

In the evaluation of the various Pulse Shape Analysis (PSA) routines developed by MAJORANA we intend to utilize Pulse Shape Simulations (PSS) to estimate the systematic uncertainties incurred. To do this with confidence we must be sure there is no systematic difference between the simulated waveforms and waveforms with data within the measure being addressed.

To perform the validation a number of datasets are used. We use a source of collimated ^{133}Ba as a clean source of surface events with 81 keV. These data are expected to generate waveforms with a very characteristic pulse shape distribution. The distribution of single site events in the single-escape peak (SEP) and double-escape peak (DEP) are also known to have unique distributions and therefore calibration data from a ^{228}Th source is also utilized.

II. VALIDATION TECHNIQUES

A. Collimated ^{133}Ba

A series of scans were taken using a collimated ^{133}Ba button source. The lead collimation was XXX mm in diameter by XXX mm long and was situated XX mm from the surface of the STC, resulting in a distance of XX-XX mm from the detector. To clean the dataset from backgrounds a coincidence cut is applied. This is a coincidence between 81 keV gammas in the detector vs 356 keV gammas in the NaI detector. Since these gammas occur in coincidence X%, this results in a XX% reduction in background events.

Gammas with an energy of 81 keV have a mean free path of XX mm in germanium. This results in a spot size of roughy XX by XX by XX on the surface of the detector. Given this very specific position distribution of events on the detector, the distribution of waveforms shapes are also specific to the collimation geometry. Waveform risetime is one of the more sensitive parameters to the position. By parameterizing the risetime distribution, peak position, width, etc. we can compare simulation to a z-scan of a detector.

Additionally we can make use of the superpulse classes to characterize the distributions of pulse shapes from collimated data. By generating a library of superulses with a variety of chi-square thresholds we expect the distribution of shapes to be similar and therefore the frequency of similar waveforms to also be similar. Adding waveforms from simulation to the superpulse library generated by data should only scale in magnitude if the distributions are similar.

Another way to utilize superpulses is to create a single superpulse of all events from a run after A/E cut for single site events. This will average the waveform shape in non-physical ways, however if the distribution of events are similar the averaging should be similar for data and simulation.

B. Calibration Data

Other data samples that have a specific position distribution depending on the detector geometry include the DEP and SEP events from pair production. These are more likely to occur at the detector surfaces and corners. By fitting the simulated wavforms to data we can estimate the most likely position of the event. This should lead to the distribution of events that are similar to those simulated for calibrations of the same detectors.

C. ^{60}Co Data

Since fitting the low energy collimated data that have fairly well known position distributions does not yield high precision fits, one can also consider using ^{60}Codata from a characterization scan. Collimation of the ^{60}Cosource does not yield precision information about the position due to the increased mean free path of higher energy gammas, it also leads to events with degraded energy and produces an energy spectrum with linewidths washed out. We will first simulate the collimation and design an optimized collimator to minimize these effects. An alternative could be to use a gross collimation and an NaI detector to measure compton scattered events. At high angles most of the energies are deposited and one can utilize the kinematics to reconstruct the vertex position.

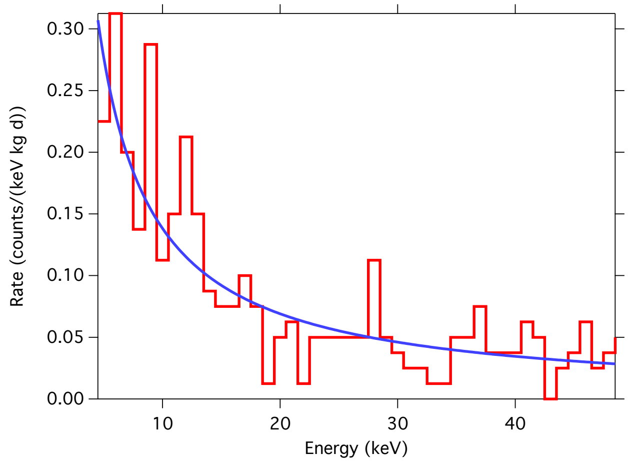

FIG. 1 The energy spectrum from IGEX (?) with a fit to the function R_0/E with the result $R_0 = 1.38$ counts/(kg d).

D. Hi$\gamma\gamma$s scans

Similar to collimated ^{60}Co it is possible that we could operated the detector at the Hi$\gamma\gamma$s facility where we can select the energy and collimate the beam to perform high energy scans of the detector. This will provide data that can be fit using the WF fitting tools and given the specific geometry we would be able to use these data to determine the systematics uncertainty in the fir positions by comparing with a simulated model of the Hi$\gamma\gamma$s source.

III. A TEST OF OUR METHODS

Validate your techniques. Since this is a unidoc we want lots of detail here. What did you do to convince yourself the analysis is correct? Did you benchmark your analysis? How did you do this? How does it compare to previous analyses?

$$\frac{d\Gamma(E)}{dE} = \frac{\alpha\lambda}{\pi a^2 m_e^2 E}, \tag{1}$$

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

$$\lambda < \frac{R_0}{k_T N_{Ge} N_e \gamma}. \tag{2}$$

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

The result of our R_0/E fit is shown in Fig. 1 and the resulting value for $R_0 = 1.38$ /(kg k) agrees very will with the previous work.

To convert R_0 into a limit on λ,

$$\begin{aligned}\lambda &< \frac{1.38/\text{kg d}}{(86400\ \text{s/d})(7.96\times10^{24}/\text{kg})(22)(3.46\times10^{-14})}\\ &< 2.6\times10^{-18}\ /\text{s}.\end{aligned} \tag{3}$$

This result agrees with the previous work.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

IV. MAJORANA ANALYSIS

This is the results, you applied the methods described previously to the data described previously and these are the results you get. First what are they with no interpretation. Next do you have an interpretation of these results? Is future work required? What worked? What didn't?

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

V. JOURNAL THOUGHTS

How were previous results published? What journals make sense to present these results in?