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Discriminator Threshold Study for Scint 1

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1 Introduction

During electronics testing at NSRL, the fluence/spill is recorded from the QC1 chamber. This chamber, which is a permanent fixture on the NSRL beamline, requires calibration from an external radiation detector that can measure ion flux directly. A $1.0 \times 1.0 \times 0.5$ cm^3 scintillator is used at the testing location to calibrate all NSRL beams for electronic experiments. A calibration factor is derived by comparing the ions observed by the scintillator and QC1 during an exposure of at least 10^5 scintillator counts or total ions.

The analogue scintillator signal, or scint 1, is sent to a NIM crate where it is discriminated. The discriminator is used during beam calibration to convert the scintillator pulse to a logic pulse and filter noise. The purpose of this study is to measure the discriminator threshold curve, and justify the discriminator set point utilized during NSRL fluence-based beam calibrations. A generalized discriminator threshold curve is observed in Fig. 1. The figure shows the curve separated into three segments: tube noise (orange), "plateau" region (green) and threshold exceeded (red). In the orange section, the scintillator counts are high and the signal is dominated by tube noise. As the magnitude of the discriminator voltage setting is increased, the curve progresses into a plateau region where the scintillator exhibits 100% counting efficiency (primary ions trigger a single scintillator pulse). The slight difference in the normalized counts is caused by fragments counted by the scintillator. Finally, the red section has the highest discriminator settings and undercounts primary ions, since the scintillator output for the primary ion is below the discriminator threshold. During operation, it is ideal for discriminator threshold set point to be within the plateau region of the curve to avoid noise and undercounting.

This study investigates the discriminator threshold curve for three NSRL beams: (1) Au @ 196 MeV/n, (2) Fe @ 1000 MeV/n and (3) P @ 1000 MeV/n. The data from the Fe @ 1000 MeV/n and P @ 1000 MeV/n beam was collected in 2008 (I was a freshman in high school), while the data for the Au @ 196 MeV/n beam was collected on March 13, 2025.

Discriminator levels and mean peak height settings for calibration

The operational discriminator setting and mean peak pulse height has changed between the measurements collected in 2008 and 2025. In 2008, the discriminator threshold was set to -30 mV and the HV applied to scint 1 was adjusted to set the mean peak pulse height at -100 mV. These settings were optimal for the low linear energy transfer (LET) beams historically used at NSRL during NASA's biology work. Since 2008, NSRL capabilities were extended to higher LET beams utilized in electronic testing. High LET beams require a lower HV setting to achieve the 100 mV peak height. Operating the scintillator in these relatively low voltage regions causes irregular pulse shapes and miscounting of trigger events. For this reason, the settings

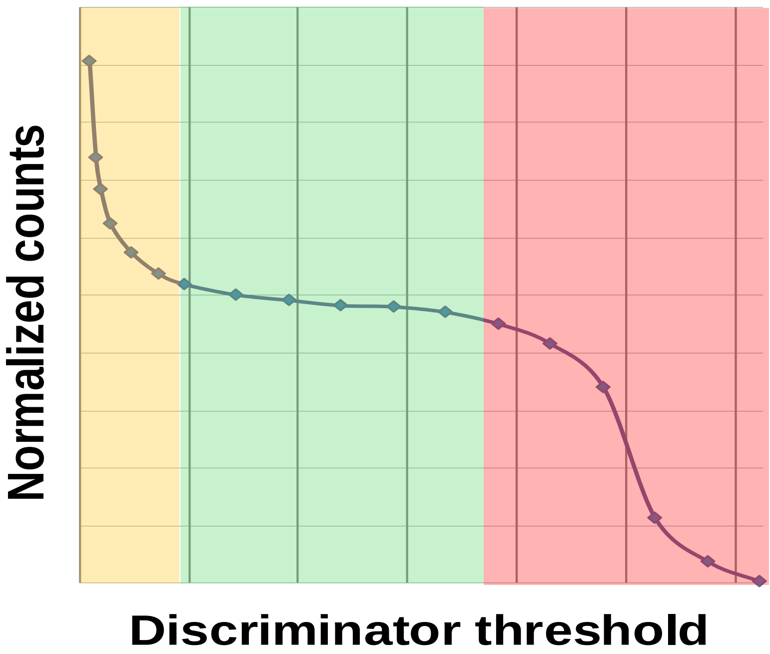

Figure 1: Generalized overview of a discriminator threshold curve and the referenced sections of the curve. The orange section encompasses the region of high scintillator noise. The green center section encompasses the plateau or flat region where scintillator counts are independent of set point. The final red section represents the region where the voltage set points are above the threshold for ion detection.

were established at an order of magnitude higher. The discriminator level was decreased to -300 mV with the mean discriminator pulse height now at -1 V. These settings accommodate both the low and high LET beam signals. This study will justify these set points for the discriminator and mean peak pulse heights.

2 Methods

Prior to collecting data, scint 1 was aligned to the center of the beam area at the testing position along the z-axis. QC1 is located upstream of scint 1 on the beamline. Next the scint 1 HV was adjusted so the mean pulse peak height is at the established set point (-100 mV for 2008 and -1 V for 2025). Data collection required adjusting the discriminator threshold to the approximate measurement value, then running an exposure of 10^5 total scintillator counts. The fluence (scintillator counts) and discriminator threshold is recorded and the threshold adjusted for the next measurement.

3 Results and measurement uncertainty

A plot showing the raw scintillator counts as a function of discriminator threshold is seen in Fig. 2. As the LET increases, the plateau region is extended to higher discriminator settings. The Fe @ 1000 MeV/n and the P @ 1000 MeV/n beams both show a clear tube noise, plateau, and threshold exceeded region in their curve. The Au @ 196 MeV/n beam does not extend beyond the plateau region. To synthesize the threshold exceeded region, an interpolation method was used by fitting the Au @ 196 MeV/n curve to a third order polynomial function, then applying that function to higher voltages. The resulting interpolated curve, and the raw data is seen in Fig. 3. Moving forward, this study will use the extrapolated curve for the Au @ 196 MeV/n analysis.

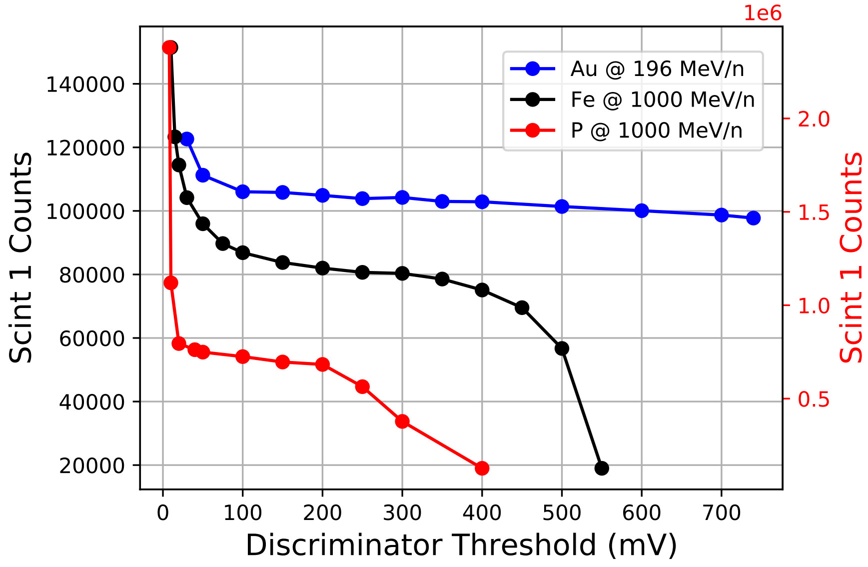

Figure 2: Raw scintillator counts as a function of discriminator threshold magnitude for beams considered in this study.

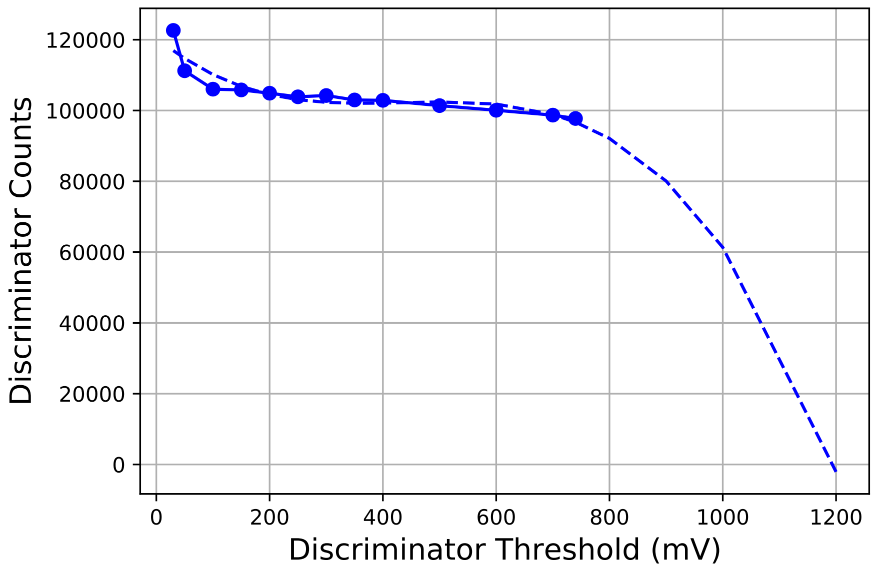

Figure 3: Raw scintillator counts and the extrapolated discriminator curve for Au @ 196 MeV/n.

To mitigate uncertainties associated with the scintillator, high statistics or high fluence was collected for each datapoint. The primary source of measurement uncertainty is the discriminator threshold setting. The set point for each measurement was within $\pm 0.2\,\text{mV}$ of the desired value. Another potential source of measurement uncertainty is the position of the scintillator downstream along the beamline. Materials of varying composition and thickness cause fragments and increase variance within the plateau region.

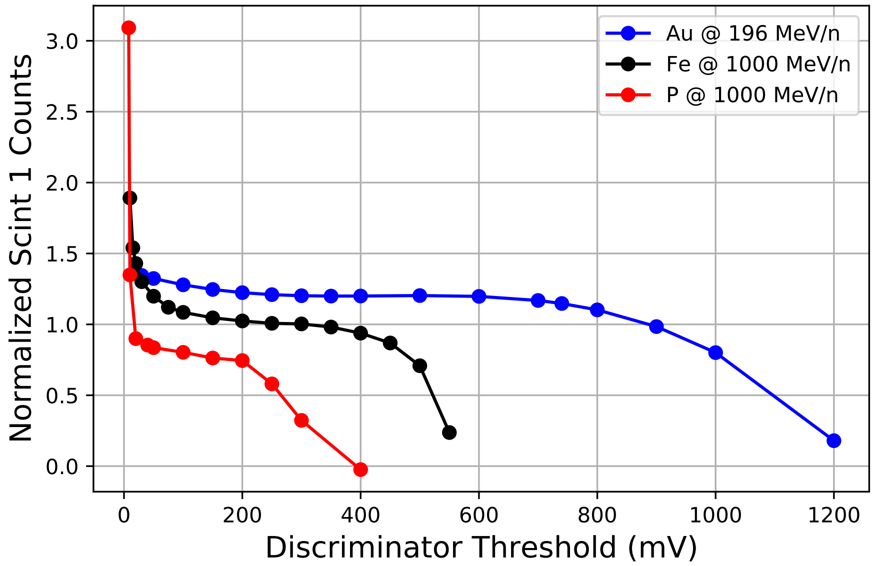

Figure 4: Discriminator counts as a function of discriminator threshold setting for each beam. The discriminator counts are normalized by the mean value of the "plateau" region of each curve. The P @ 1000 MeV/n and the Au @ 196 MeV/n curves are shifted vertically for visualization purposes.

The raw data was normalized by the mean of the plateau region as seen in Fig. 4. To determine the bounds of the plateau region, the derivative of each curve was calculated. Fig. 5 shows an example derivation curve for the Au @ 196 MeV/n beam. The region where the slope is at or close to zero is determined to be the plateau region of the curve. This is somewhat arbitrarily defined by a threshold slope value of 10 counts/ mV, 100 counts/mV and 1700 counts/mV for the Au @ 196 MeV/n, Fe @ 1000 MeV/n and P @ 1000 MeV/n beams, respectively. The region where each curve "flattens out" is determined by eye. The values of the discriminator counts within this plateau region are averaged and used as the normalization factor for their respective curves.

Returning to Fig. 4, an operational discriminator threshold of -300 mV, for a peak pulse height of -1V, is an appropriate setting for high LET beams to measure the primary ions and mitigate the fragments detected. This set point falls within the plateau region for both the heavy ion beams (Fe @ 1000 MeV/n and Au @ 196 MeV/n). The P @ 1000 MeV/n curve is entering the threshold exceeded region. Note the mean scintillator peak height was established at 100 mV for the Fe @ 1000 MeV/n and P @ 1000 MeV/n measurements.

4 Future work

To further understand the discriminator threshold curves for varying ions and energies, data should be collected for more NSRL beams with a consistent mean scintillator peak height across datasets. The normalization technique can be evaluated for future studies.

This variation observed in the plateau region is caused by a difference in the number of fragments measured by the scintillator at the different discriminator threshold settings. The standard deviations within the established plateau region are 210, 2 728 and 30 099 counts for the

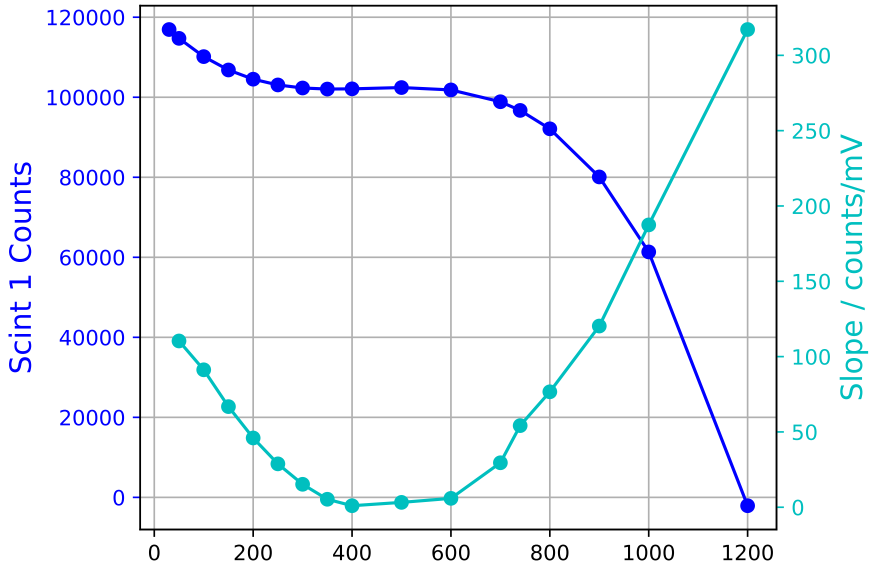

Figure 5: Derivative of the discriminator threshold curve for the Au @ 196 MeV/n beam.

Au @ 196 MeV/n, Fe @ 1000 MeV/n and P @ 1000 MeV/n curves, respectively. The relationship between the fragments measured in this region and the discriminator threshold can be simulated using FLUKA, a general-purpose Monte Carlo code for simulating particle acceleration and response to beamline optics and components. These simulations can be validated with the data collected from this study. This furthers the need for more experimental data.