Testing the "Halo counter" FSD and setting the threshold

immediate

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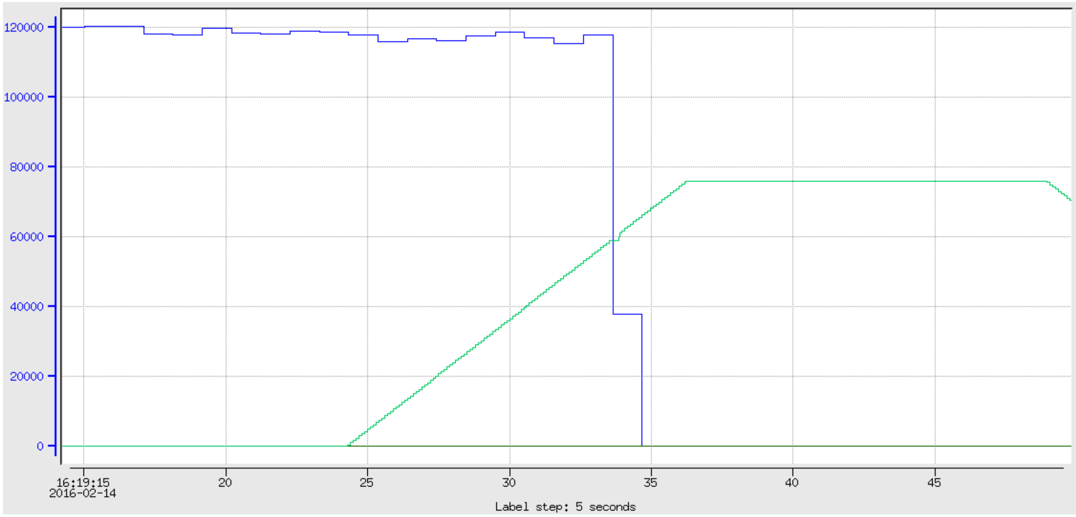
This document describes the testing of the Hall-B "Halo-counter" component of CEBAF Fast Shut Down (FSD) system. The CEBFAF FSD system has many components. If any one of them triggers, then it takes about 31.2 μs for the signal to propagate to FSD and beam to be comepletly OFF For the HPS experiment the most important component is the "Hall B Halo counters". The input signal to the FSD card is a sum of 4 HPS halo counters "HPS_Left", "HPS_Right", "HPS_t" and "HPS_SC". "Halo counter" FSD will trigger, if the number of counts within certain time window (called integration time) exceeds the given threshold value. The threshold value and the integration time MCC operator can set by request of Hall B.

The Struck scaler application was used to test whether FSD triggers within correct integration time if the signal passes the set threshold value. One buffer of the Struck scaler has 60000 elements which represents integrated rate of the input signal within the set dwell time. For FSD testing purposes we used 300 μs dwell time, which is lower than the FSD integration time, and is large enough to get reasonable rates on halo counters with the presence of 4 μm target in the beam.

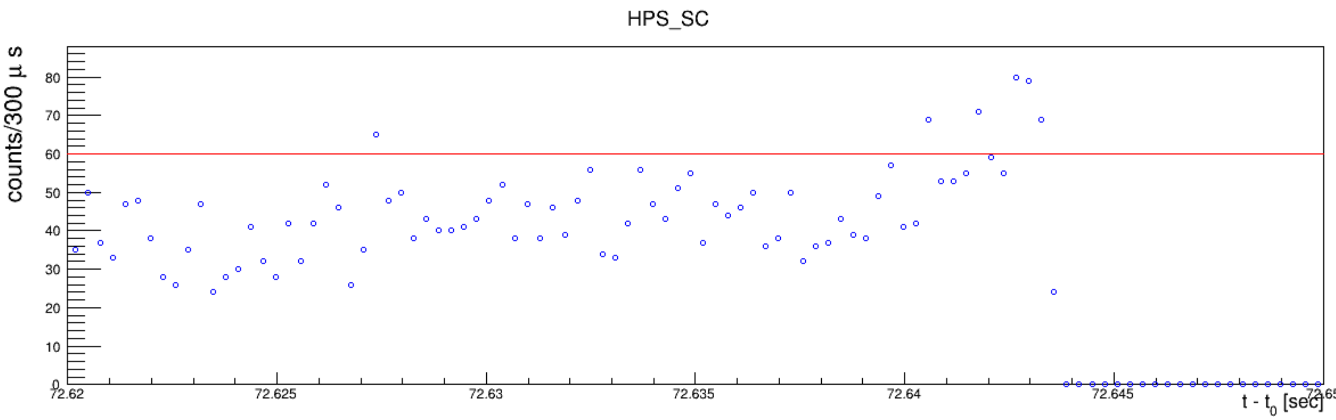
To have an identical signals into Struck and FSD, high voltage of "HPS_SC" was kept "ON", while it was turned "Off" for other HPS halo counters. The way to test the FSD, is to set a large enough threshold value that it will not trip immediately, and then drive the harp wire to the beam which will enforce rates to pass the threshold and (if the FSD works properly) will trip the beam. Fig.1 shows rates on HPS_SC counter as a function of time. The top figure represents rates on HPS_SC in Hz (blue line) and 2H02A harp motor position (green line) from MYA archiver. As one can see at sompe position of the harp the beam tripped. The average rate of HPS_SC before trip was between 115 $KHz - 120$ KHz. The FSD threshold value was set to be 200 KHz and the integration time was 1 ms. In 300 μs time window, 200 KHz rate correspond to 60 counts. The bottom graph of Fig.1 represents rates on Struck scaler in a 30 ms time interval, which includes the FSD trip. Red horizontal line shows the threshold limit for 300 μs time window. The 1 ms time corresponds to 3.3 Struck points. We can see from Fig.1b that at $t - t_0 \approx 72.6425$ three consecutive points getting above the threshold, and after that counts rapidly go to 0. There were several tests with 1 ms and 5 ms integration times, and all showed consistent results. This studies shows that the halo counter FSD works properly.

Setting the FSD threshold

From the safety perspectives it is desirable to keep the FSD threshold value and the integration time as low as possible. However rates on halo counters are not constant as a function of time. The variation of rates can be caused by statistical fluctuations or by the change of the beam condition (beam current



(a)

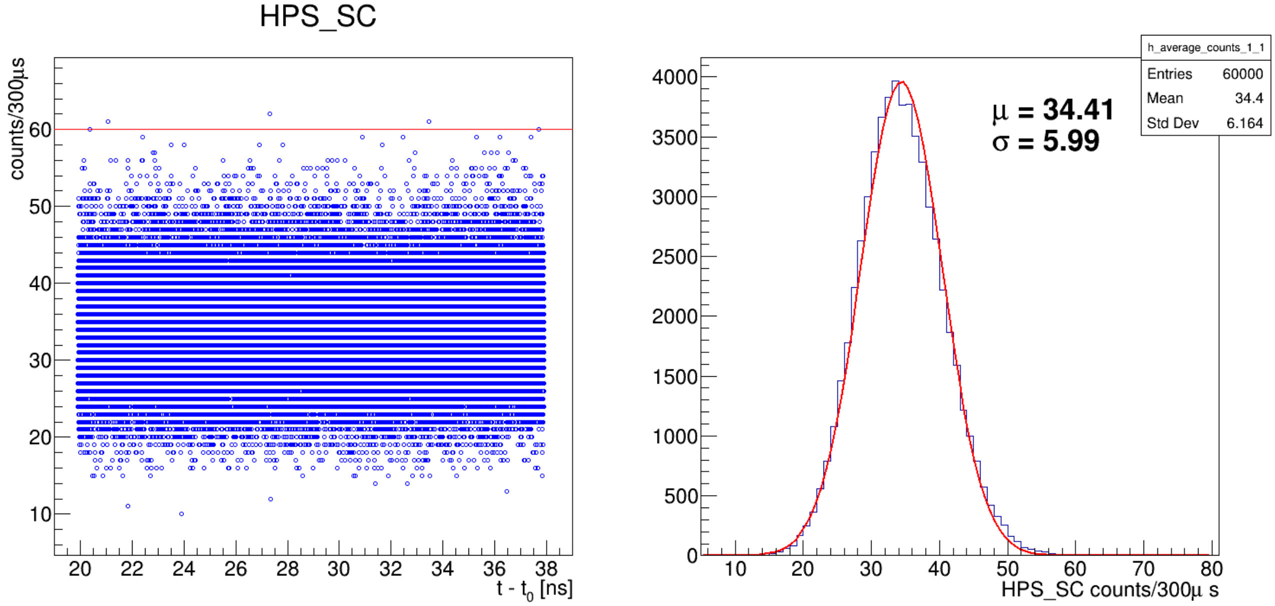


(b)

Figure 1: Rates on HPS_SC counter as a function of time. Top figure: Blue line represents rates in Hz as a function of time, while green line shows 2H02A harp motor position. At around 16:19:25 sec. wire got close enough to the beam that caused FSD trip. Bottom Figure represents rates on Struck scaler in a 30 ms time interval, which includes the FSD trip. Red horizontal line shows the threshold limit for 300 μs time window.

oscillations, beam position movement, change of the beam profile etc). Fig.2 shows counts on HPS_SC as a function of time (left) and the distribution of counts during that time (right) from Struck scaler single buffer. The total rate was about 115 KHz, this translates into about 34.5 counts per 300 μs time interval. As one can see from Fig.2b the distribution of counts is quite close to Gaussian, and for larger mean values it will be even closer to Gaussian, and the $\sigma \approx \sqrt{N_{MPV}}$ where N_{MPV} is the most probable value. Assuming the total number of counts in the FSD integration time interval will be distributed according to Gaussian distribution, we can calculate the probability if counts in one particular time interval will cause a trip or not, for the given threshold value.

$$P = 0.5 \cdot Erfc\left(\frac{threshold - MPV}{\sigma\sqrt{2}}\right) \tag{1}$$



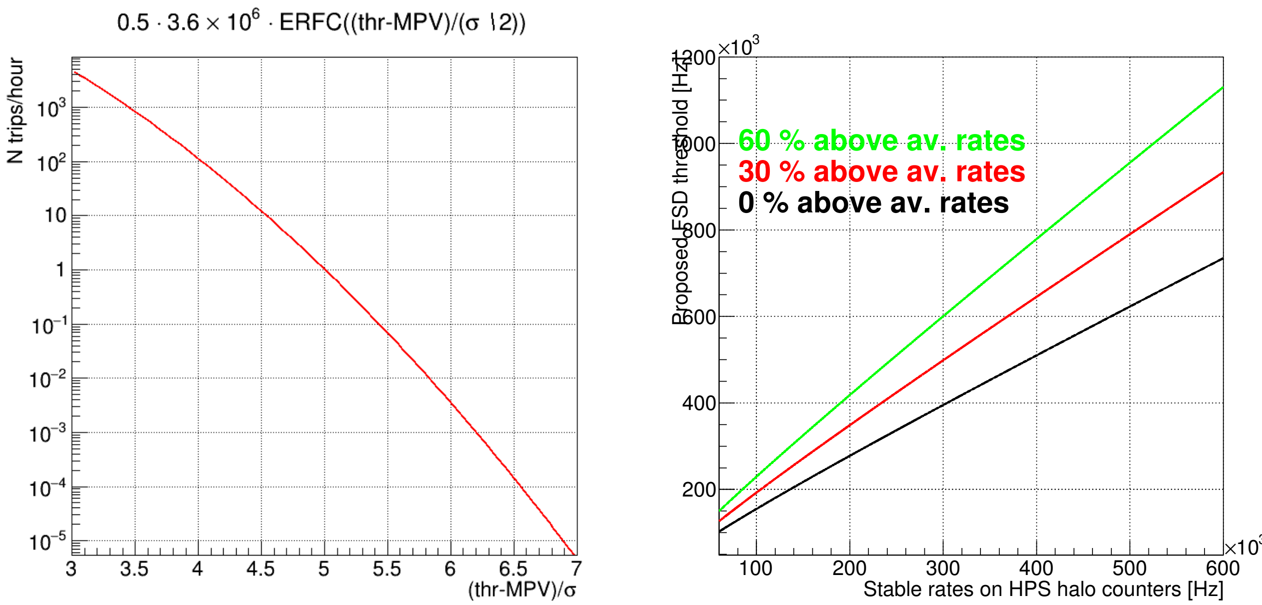
(a) (b)

Figure 2: 1 buffer form Struck scaler. Left shows counts on HPS_SC as a function of time. Right shows distribution of counts from one buffer.

where the *threshold* is the FSD threshold and $Erfc$ is the complementary Error function and is defines as:

$$Erfc(x) = 1 - Erf(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-t^2} dt \tag{2}$$

Assuming an ideal beam (condition doesn't change over the time), from the above discussion one can calculate number of trips in one hour as a function of the threshold value. Fig.3a shows the number of trips due to the statistical fluctuations, as a function of $(threshold - MPV)/\sigma$. In the graphic we assumed the integration time is 1 ms and the beam condition doesn't change over the time. This graphic suggests that in order to keep the trip rate less than $0.1/hour$ we should use $\mu + 5.5\sigma$ threshold. In reality beam conditions will change over a long time (order of hours), therefore we should take into account beam condition change also. Fig.3 shows proposed FSD thresholds for different Hallo rate drifts. In this figure we assumed 1 ms integration time, and $\mu + 5.5\ \sigma$ threshold value. Black curve assumes no beam condition change over the time, red assumes that over the time the average rate on halo counters can be changed by 30% i.e. threshold is determined as $\mu + 0.3\mu + 5\sigma$, and the green curve represents threshold, when rates can exceed the average value by 60%. This document doesn't give an estimate on what is the tolerable rates on halo counters for SVT, but it just proposes an FSD threshold value, which is large enough to not trip the beam quite often, and small enough for the rates to not exceed the tolerance level.



(a) (b)

Figure 3: Left: Number of statistical trips in one hour as a function of $(threshold - MPV)/\sigma$ (assuming an ideal beam). Right: Proposed FSD threshold for different halo fluctuations, as a function of average rates.