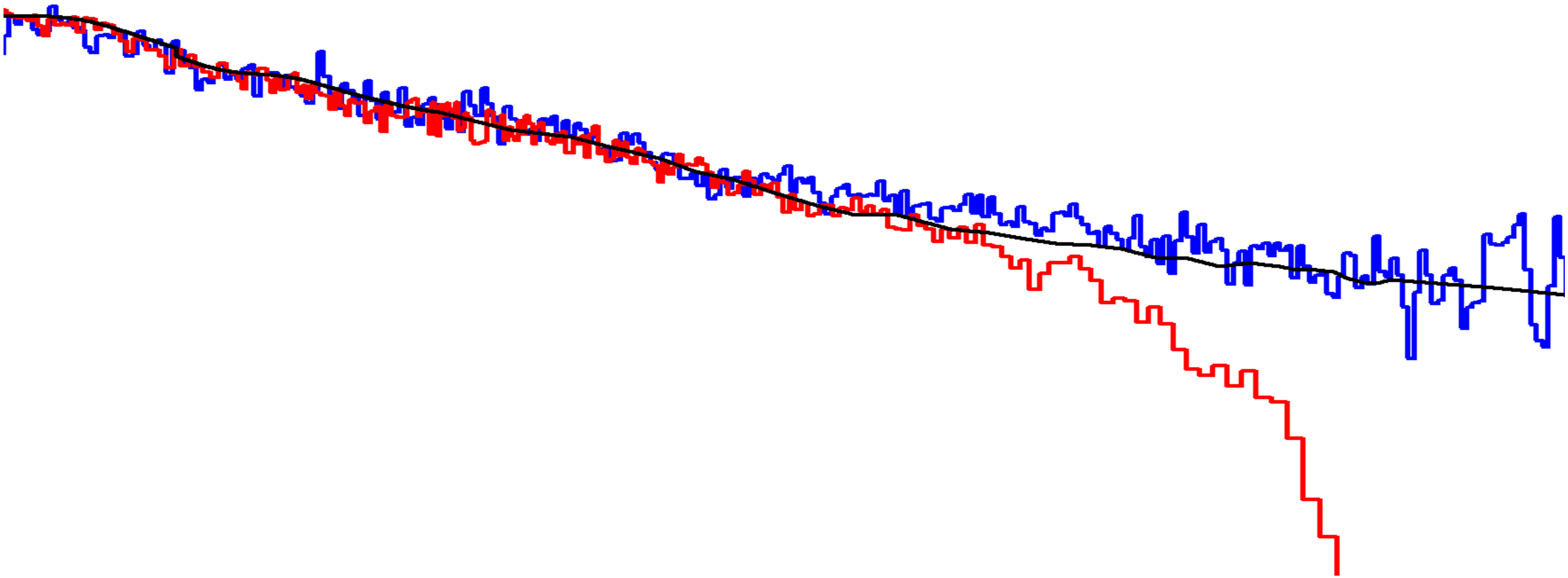
Digital Filtering Applications to the Lead Slowing-Down Spectrometer

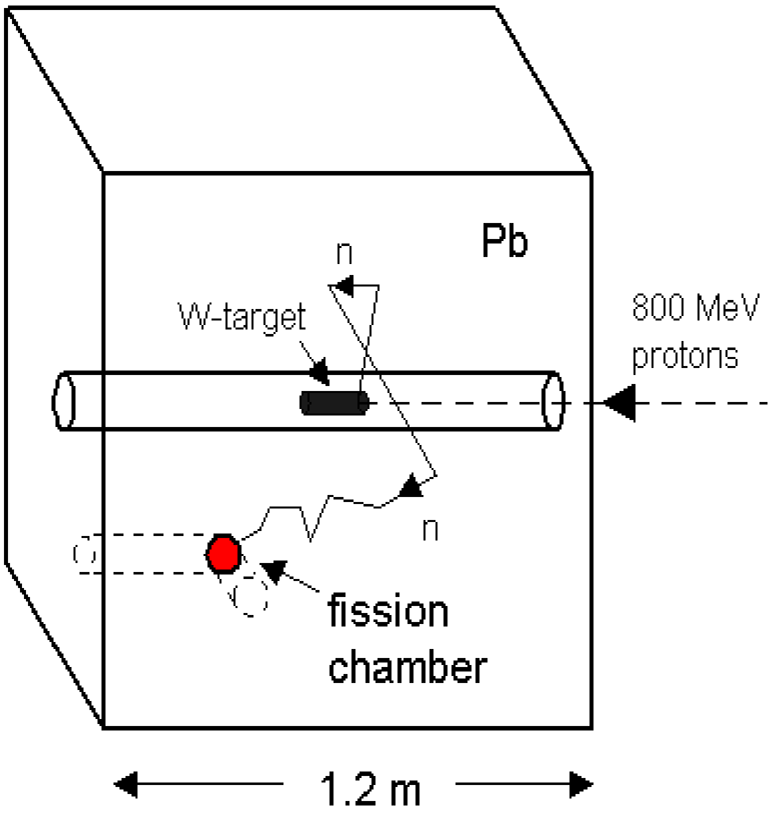
Kathryn D. Huff



The LSDS Works by "Recycling" Neutrons

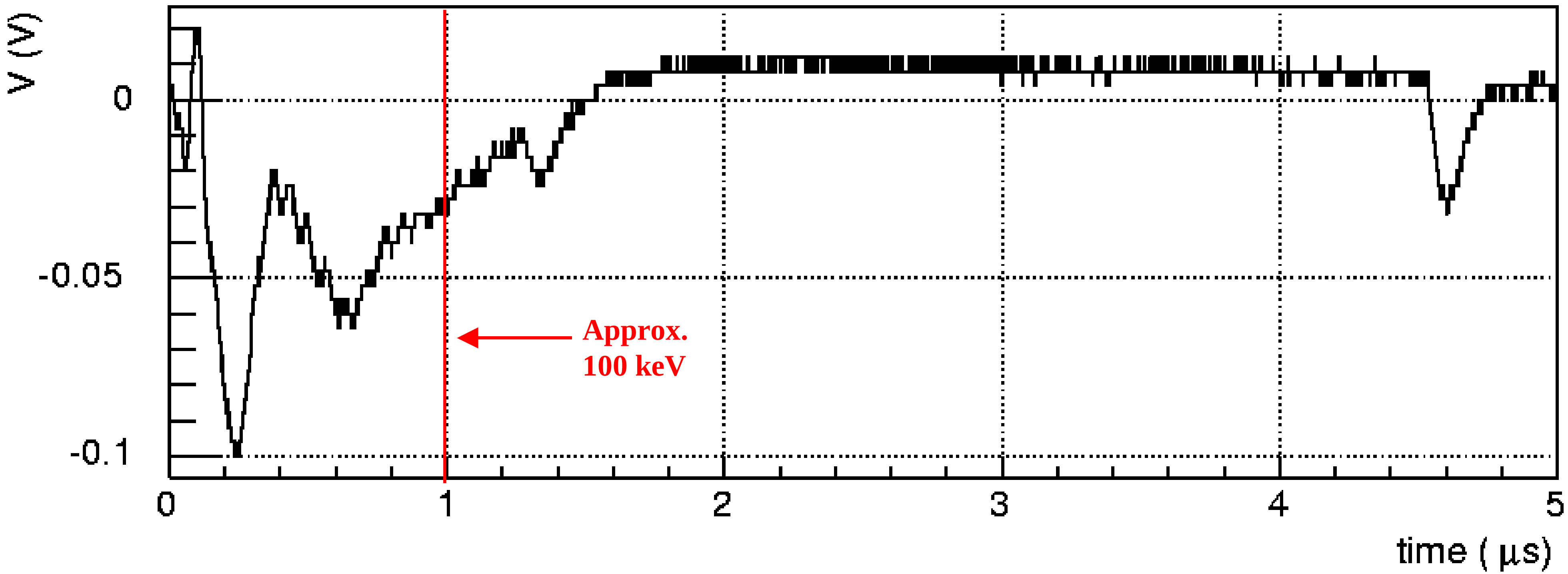
- The neutron source is pulsed.
- The neutrons are scattered through the lead, and elastically scattered neutrons suffer a small energy loss.
- The compensated fission chamber (red) measures fission as a function of time.
- For E_n < 100keV

$<E_n>=K/(t+t)^2$



****Slide courtesy of Bob Haight****

The Lead Slowing-Down Spectrometer

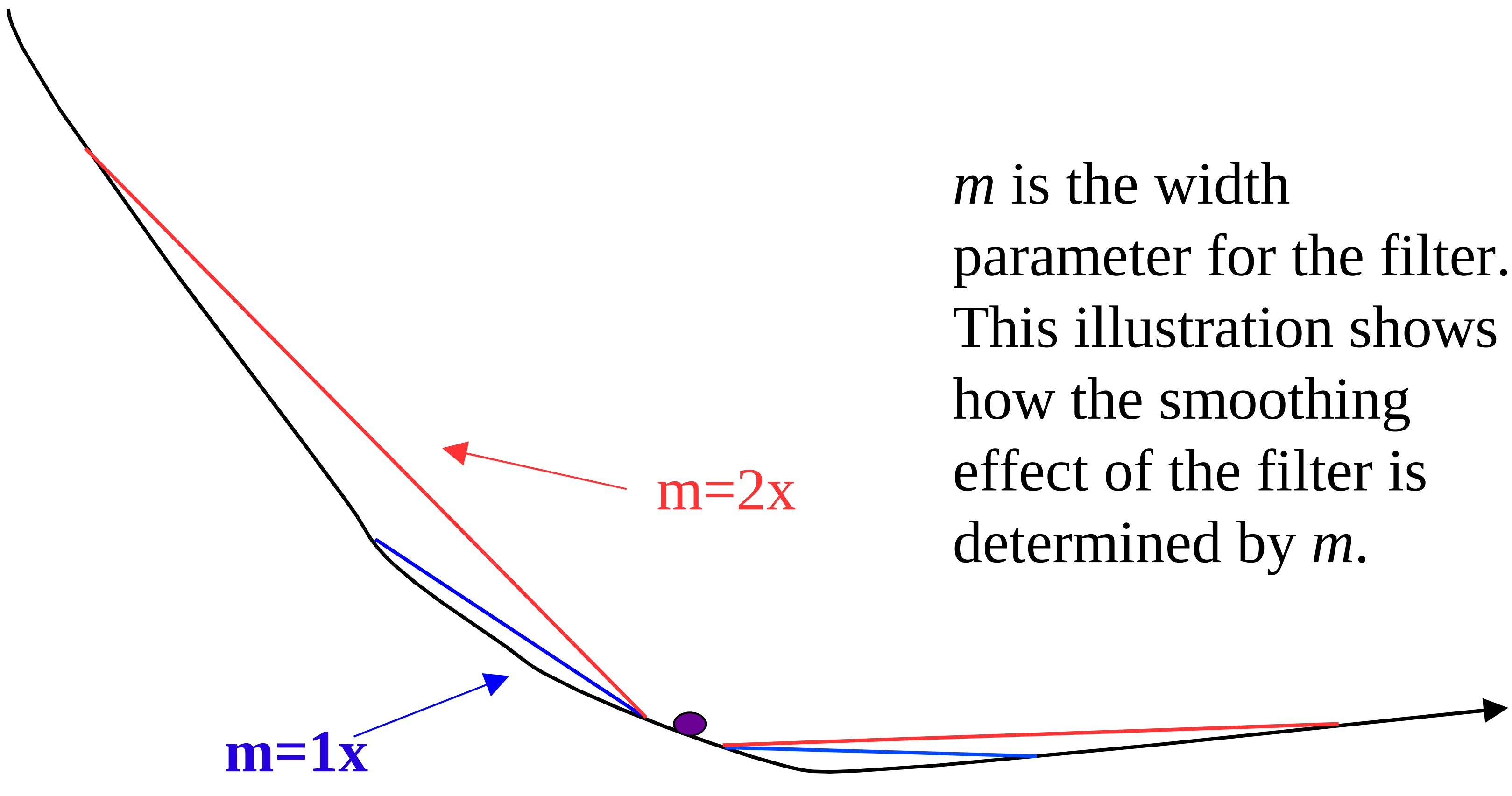


Used to measure neutron cross sections, the LSDS uses a compensated fission chamber, and produces an output signal in the form of a waveform of fission peaks on a complex background. That complex background makes analysis of those peaks difficult.

The **goal** is to extend the range of useful measurement to 100 keV or more.

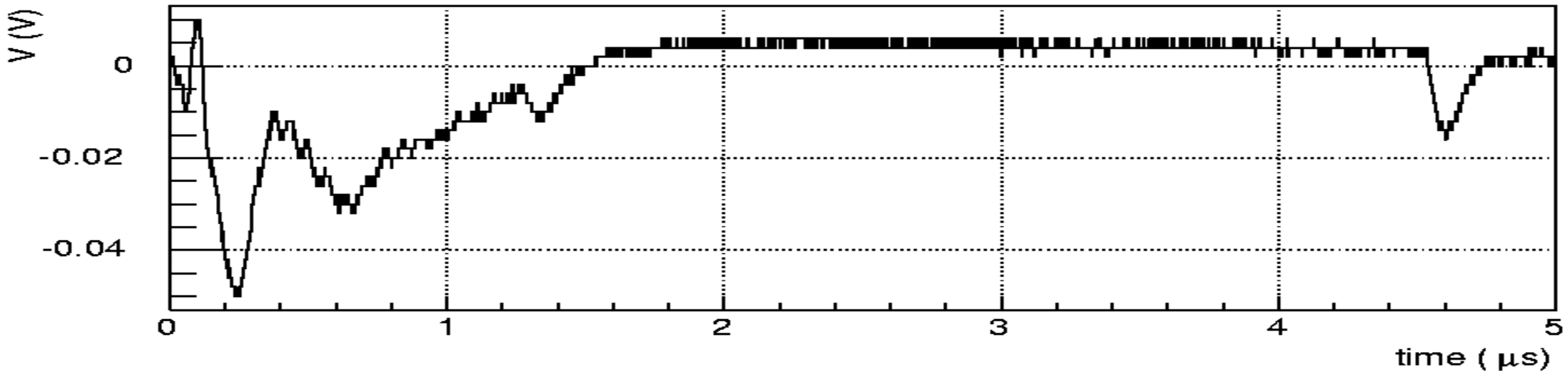
Our Digital Filter

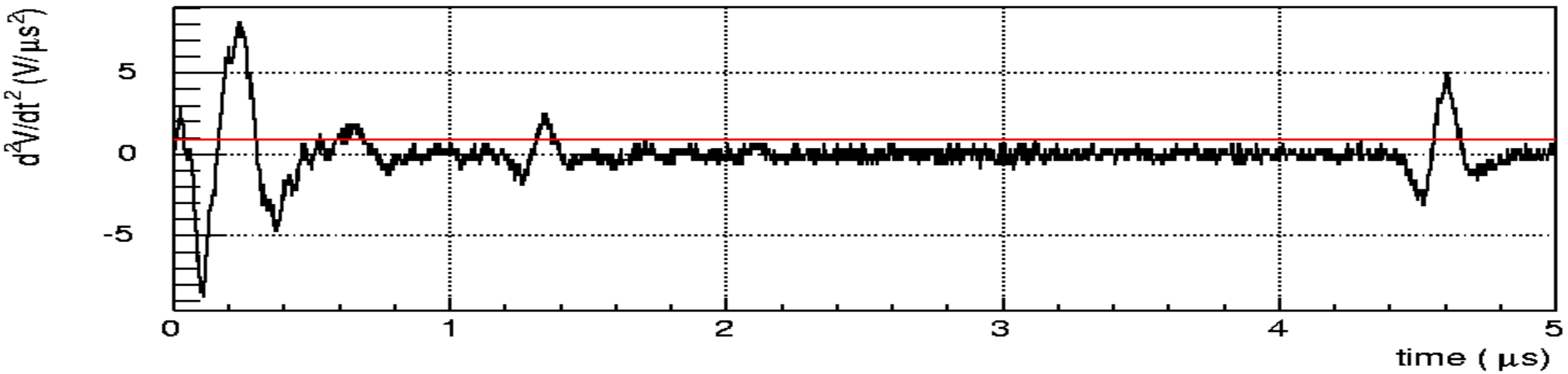
$$\frac{d^2y}{d^2x} = \frac{(V_{m+1+i} - V_{1+i} - V_{-1+i} + V_{-m-1+i})g}{(256\Delta_t^{2}m(m+2))}$$



m is the width parameter for the filter. This illustration shows how the smoothing effect of the filter is determined by *m*.

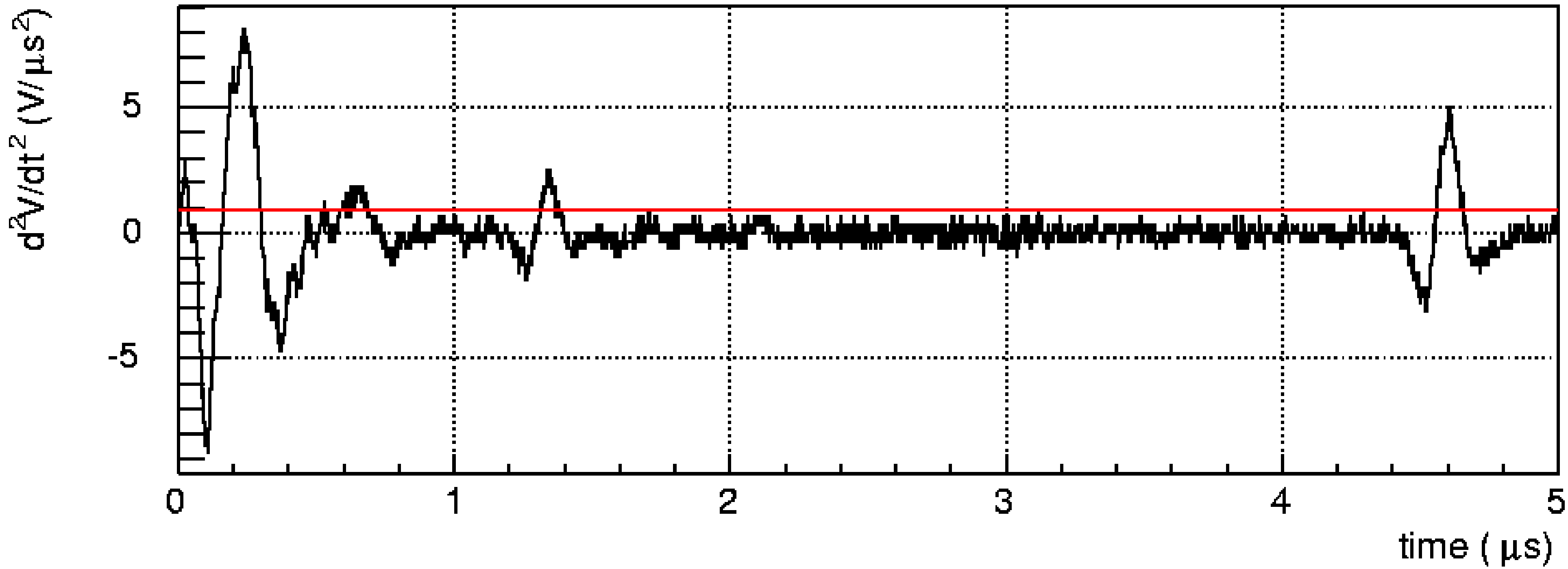
Digital Filtering





- Our filter was designed by John M. O'Donnell.
- With a digital filter, a signal can be mathematically smoothed and reorganized, producing a more easily analyzable data set.
- Using two steps of derivation to flatten background shapes and integration to smooth out noise, peaks can be filtered from a waveform with a complex background.

The Threshold



Once we have applied the filter, we are able to set a threshold line above which lie the peaks and below which lies noise. The value for the threshold depends on m. For digitization noise, the threshold can be found theoretically:

$$3 \cdot 2 \cdot g/(m \cdot (m+2) \cdot \Delta_t^2 \cdot \ddagger 12 \cdot 2^{7.2})$$

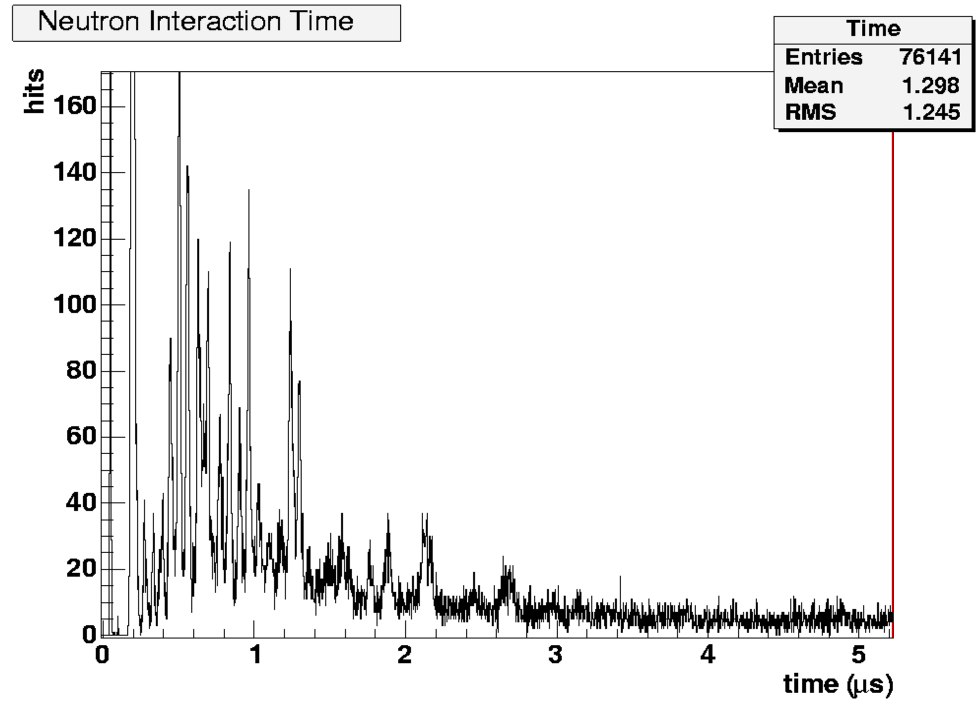
To avoid counting all the noise on the peaks, we cut out those occurrences with widths narrower than a certain width.

This allows us to lower the threshold slightly into the noise.

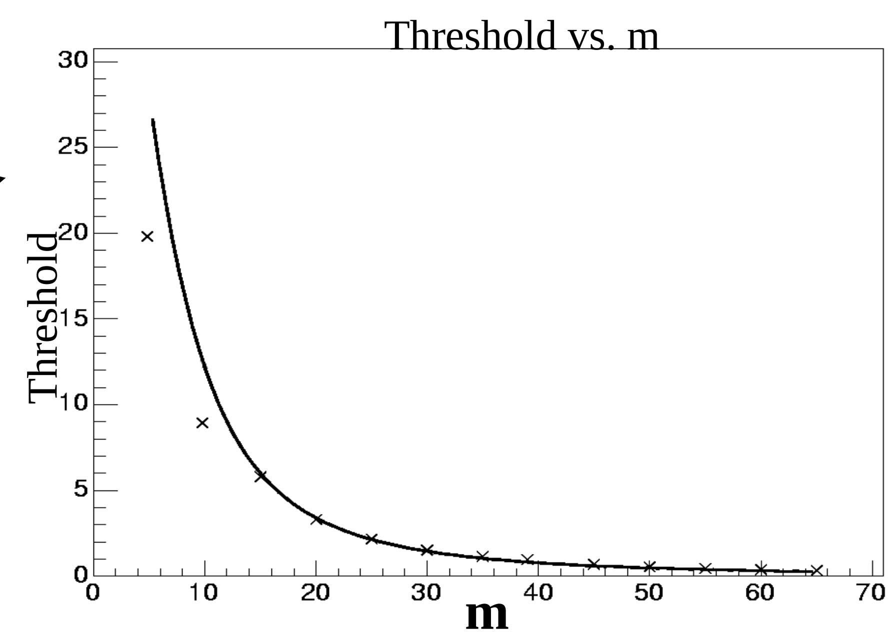
Determining The Threshold

Subjective examination of the Time and Width histograms

- Shape of the time histogram:
  - Clearly oscillating shape -> threshold too low
  - Low counts -> threshold too high
- Quantity of narrow counts : total number of counts
  - Large ratio -> threshold too low
  - Small ratio -> threshold too high

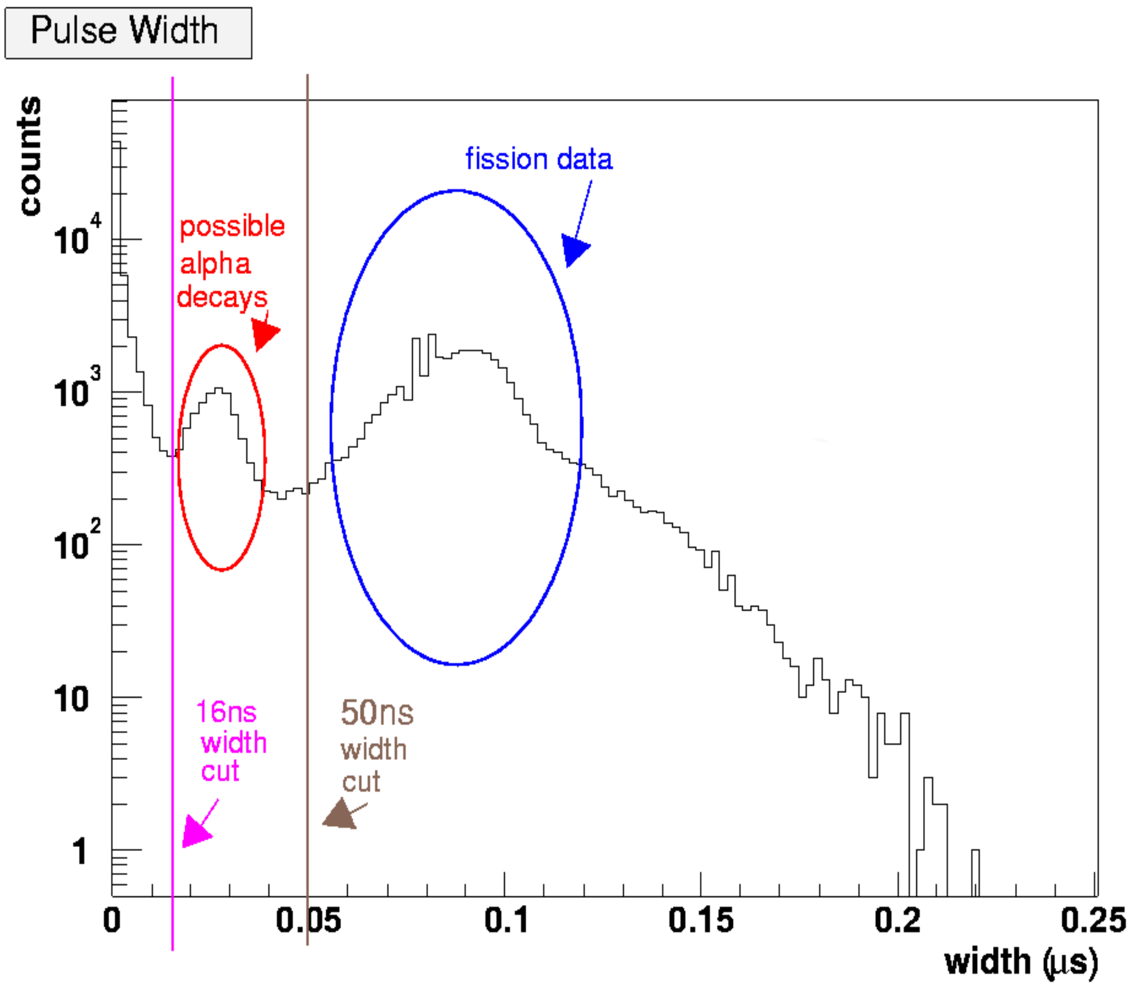


This graph shows that there was a real correlation with the theoretical estimation: $3 \cdot 2 \cdot g/m \cdot (m+2) \cdot \Delta_t^2 \cdot /12 \cdot 2^{7.2}$



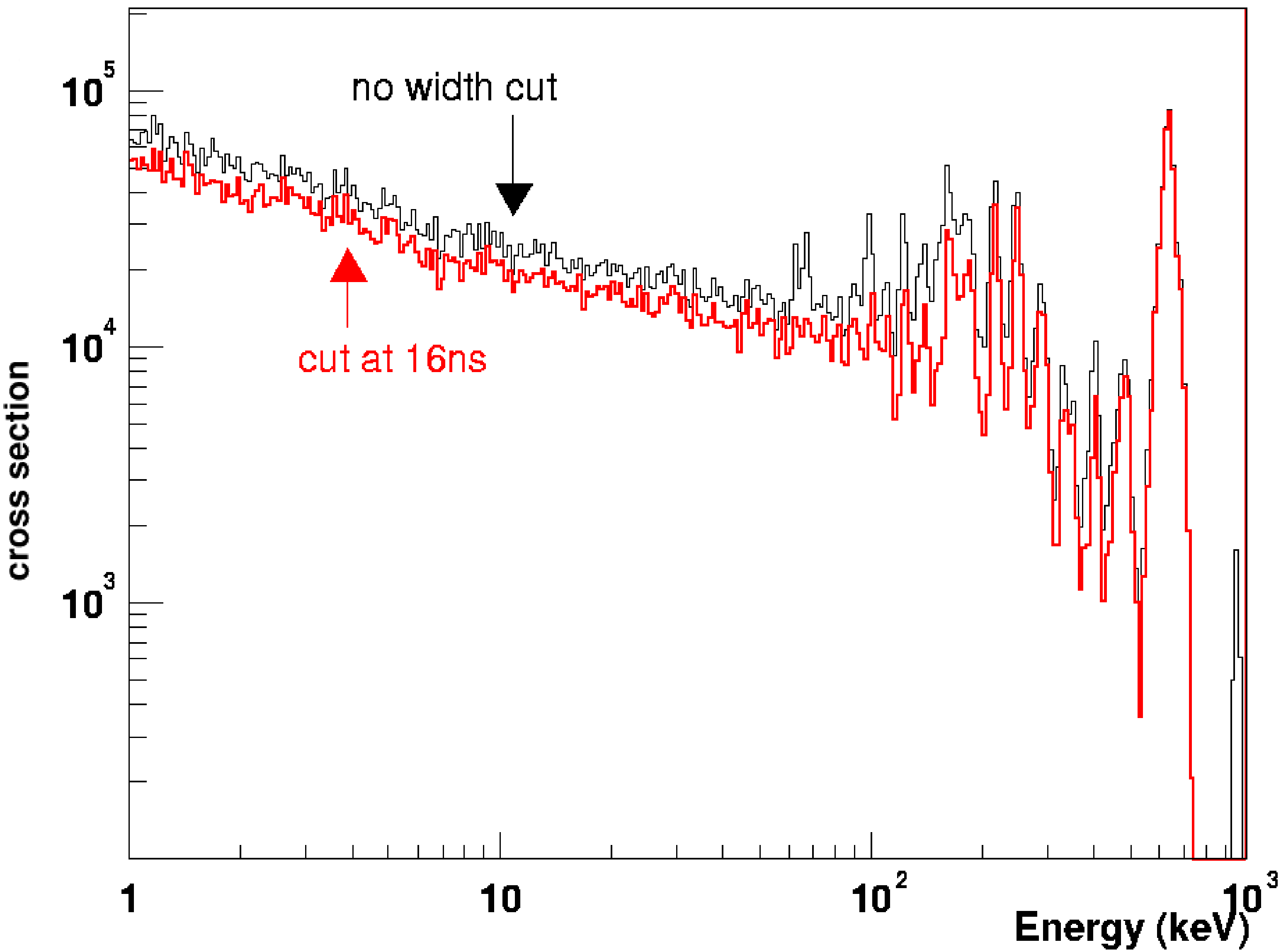
The Width Histogram

- The width histogram inspires more study:
  - Two peaks : what is the first peak?
    - Try a width cut at 16 ns to cut out very narrow peaks.
    - Test suspected alpha decays (red) with width vs. time histogram.
      - If these are not alphas, they are noise, and we can cut the tail of narrow widths from the data with a width cut between 40 and 60 ns.



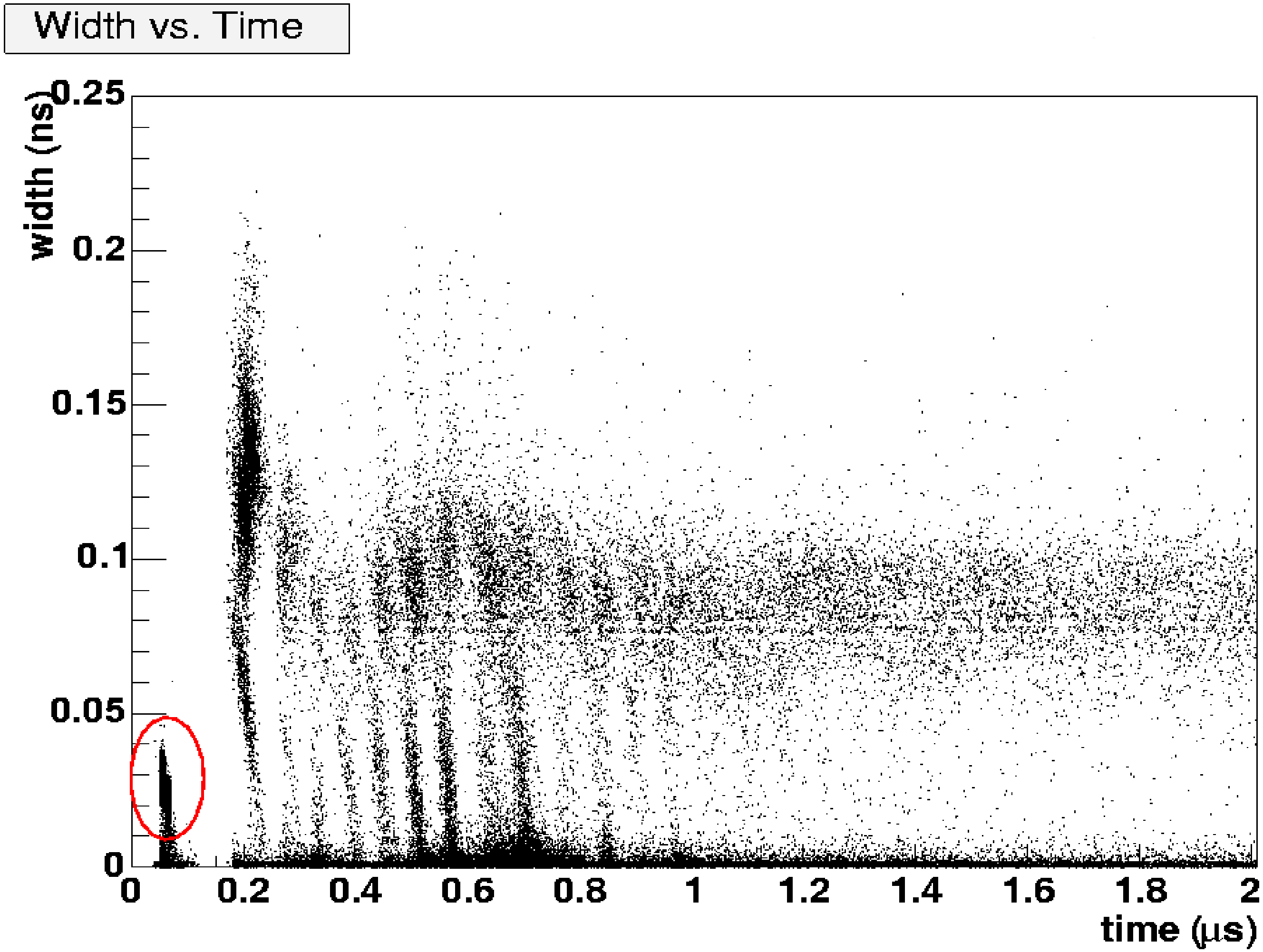
Testing the 16 ns Width Cut

- Note the disappearance of the 60 keV bump with the 16 ns width cut.



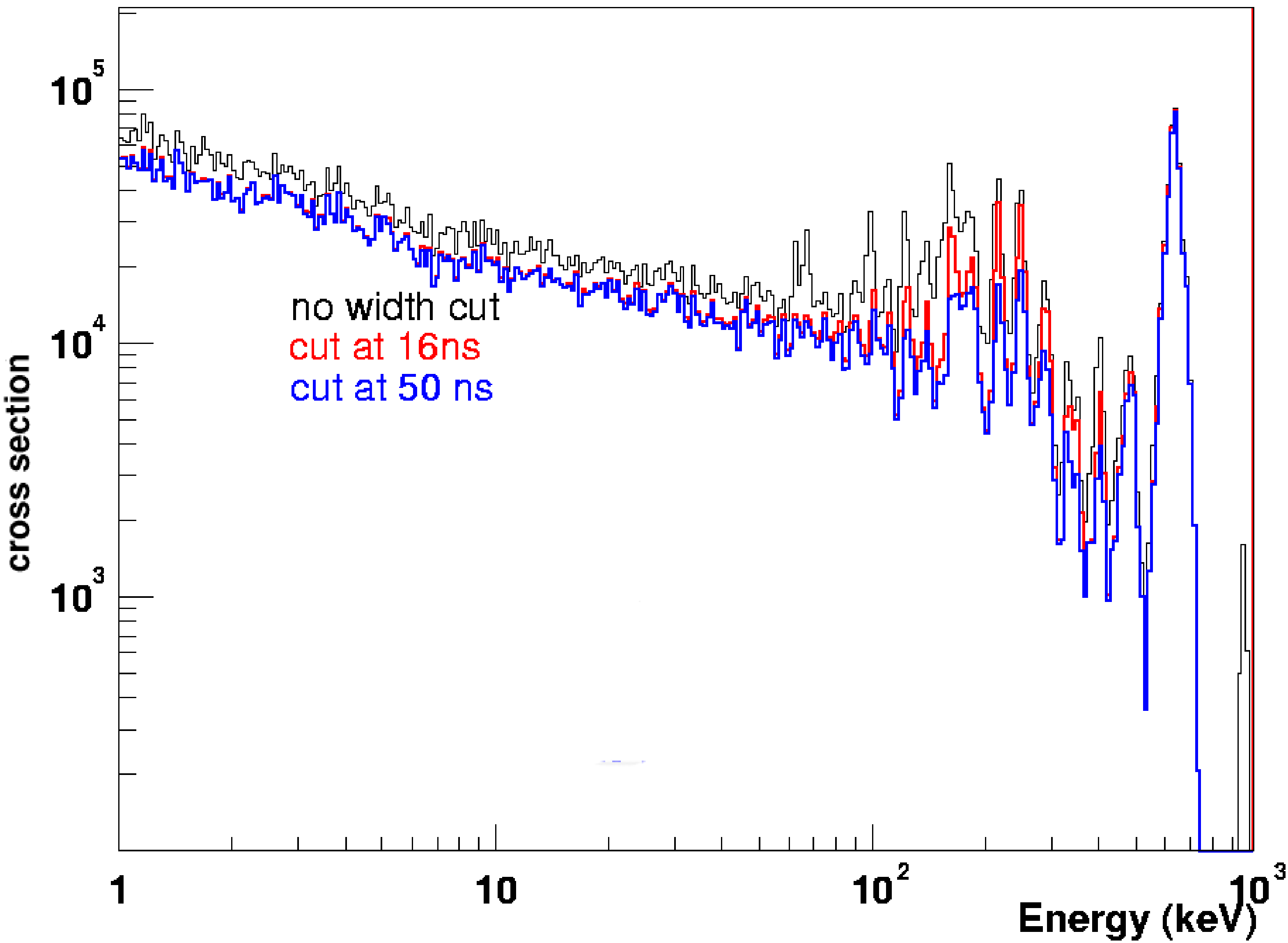
Testing for an Alpha Band

- In this width vs. time plot, there is no horizontal band of widths anywhere from 16 to 40 ns, which would be the case if the first peak had resulted from alpha decay.



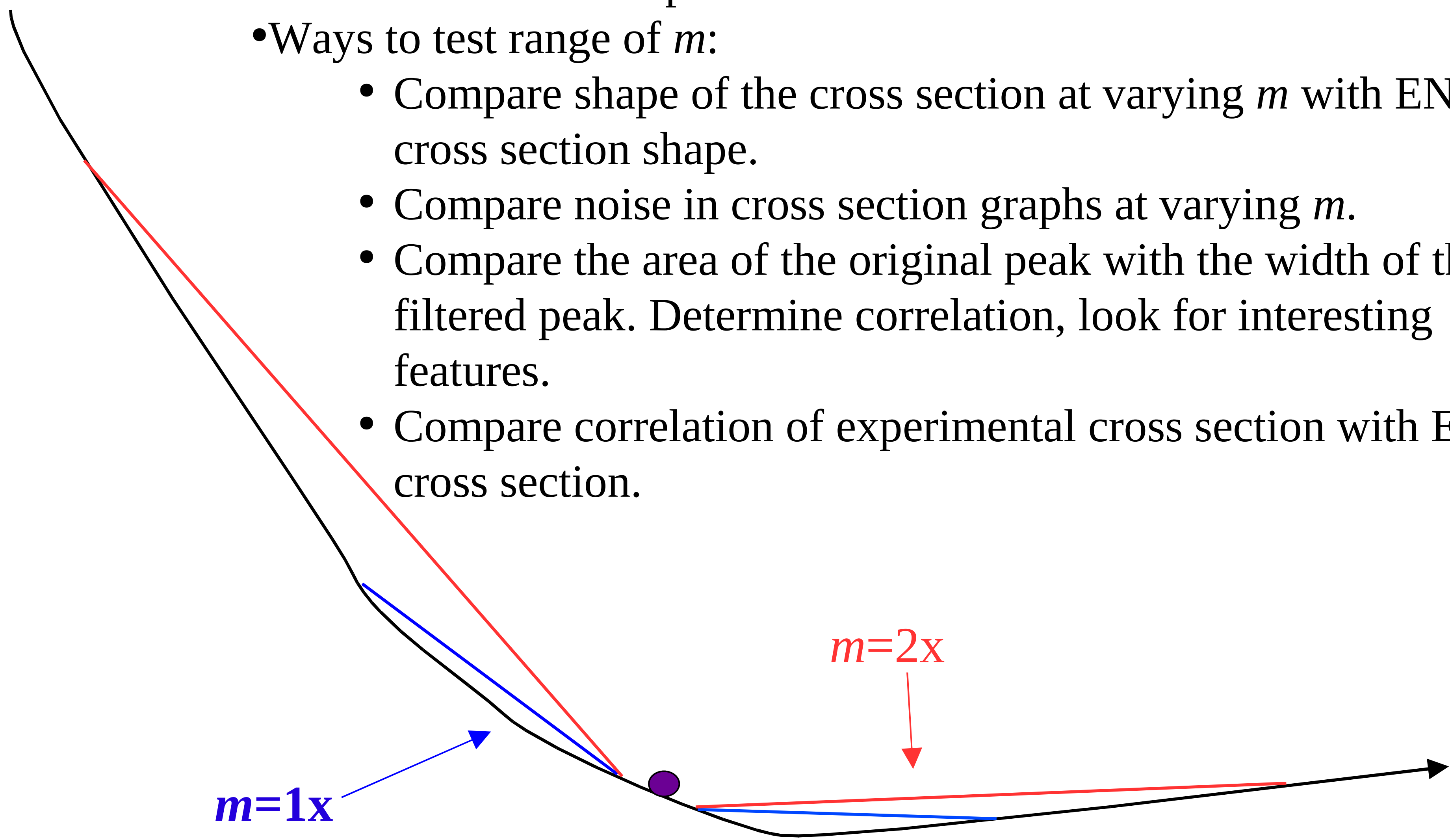
50 ns Width Cut

- Now that it has been shown that even the first peak in the width histogram is just noise, we should extend our width cut to no longer include the narrow peaks in our data.



Exploring 'm'

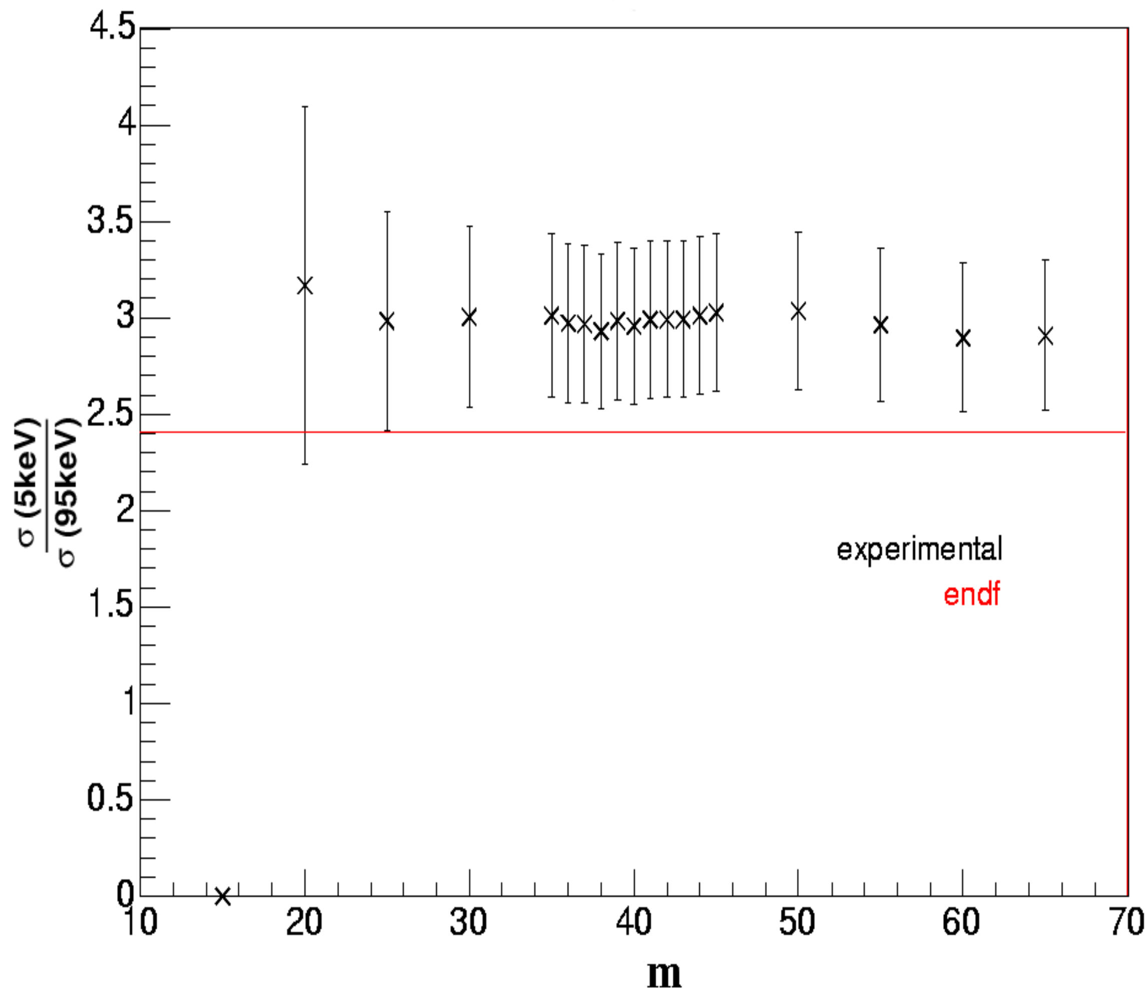
- Original simple estimate for *m* is 39.
- The value of *m* determines smoothness in the filter.
- The threshold also depends on *m*.
- Ways to test range of *m*:
    - Compare shape of the cross section at varying *m* with ENDF cross section shape.
    - Compare noise in cross section graphs at varying *m*.
    - Compare the area of the original peak with the width of the filtered peak. Determine correlation, look for interesting features.
    - Compare correlation of experimental cross section with ENDF cross section.



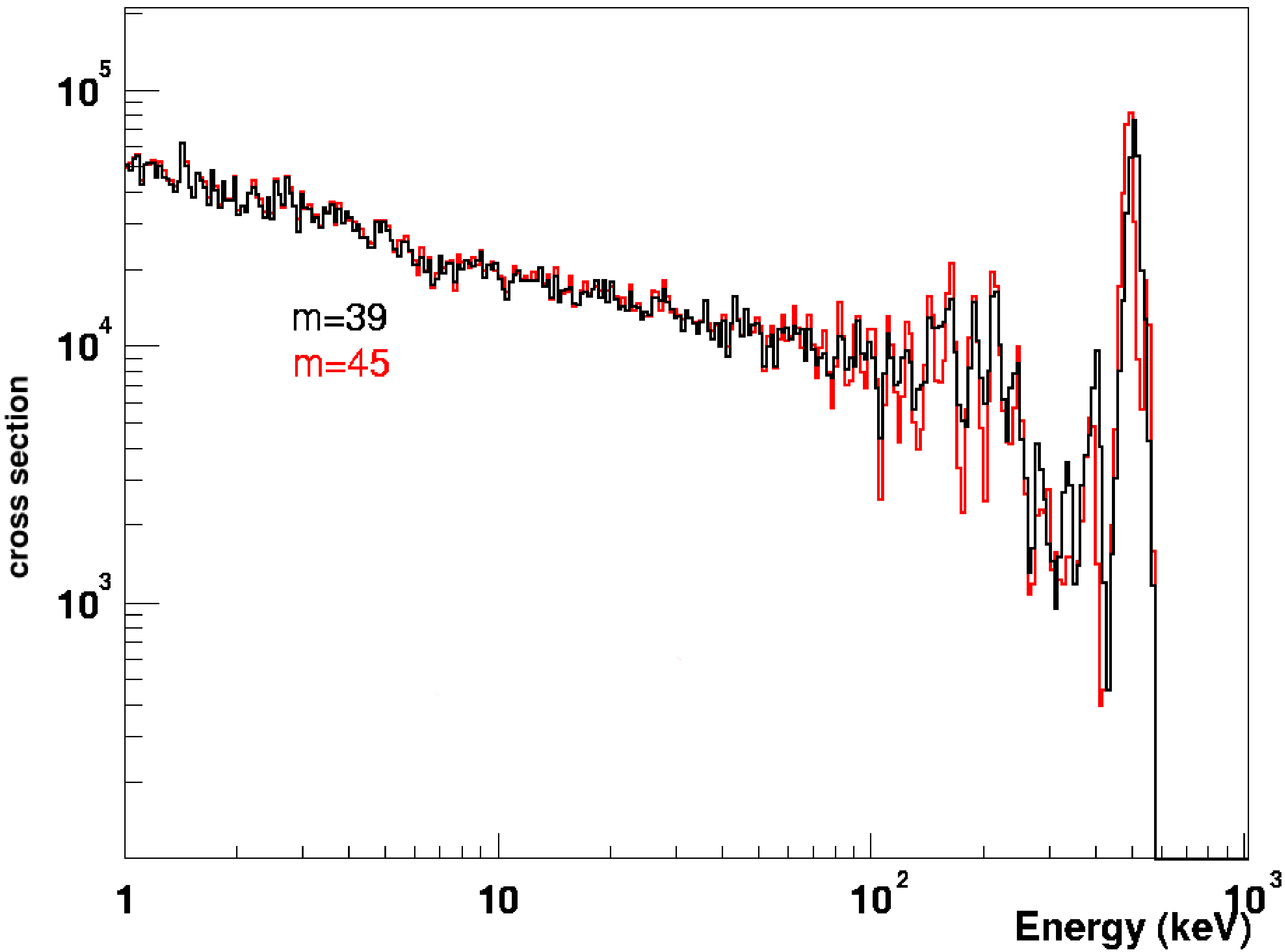
Using Cross Section Ratio to Explore Range of *m*

m is a width parameter for the filter being used. The value of *m* should effect the accuracy of the smoothing filter. Therefore, many tests were conducted to determine the best value for *m*.

- The ratios of the cross sections at 5 and 95 keV for different values of *m* were taken and compared with the same ratio of the ENDF cross section data.
- The error bars for *m*<30 are significantly larger than those for *m*>30.
- The values remain basically constant throughout the range of *m*, indicating that perhaps *m* has no upper limit where shape is concerned.

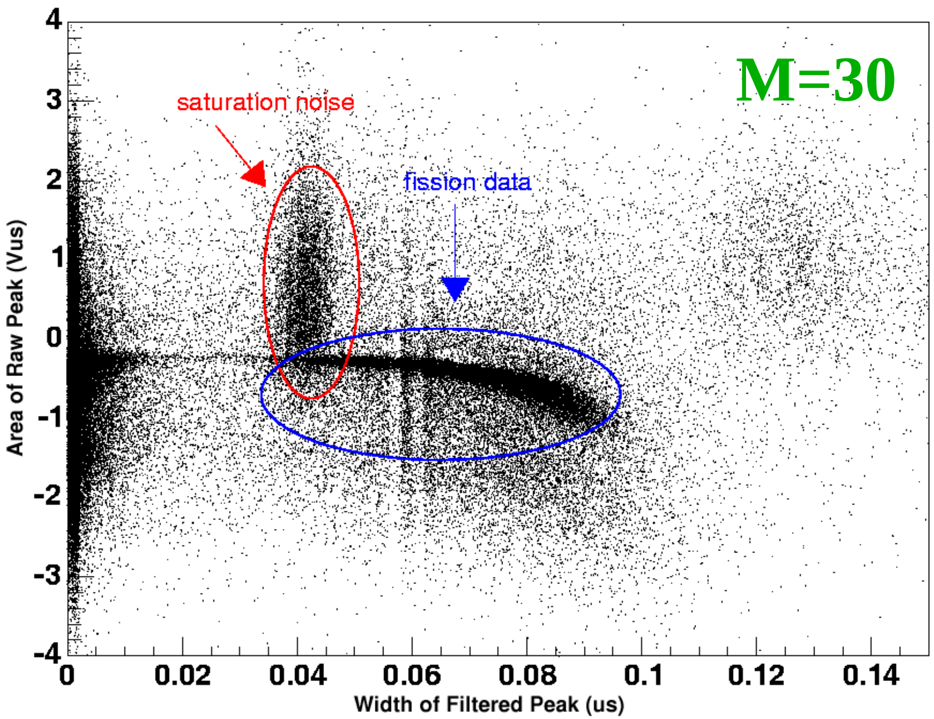


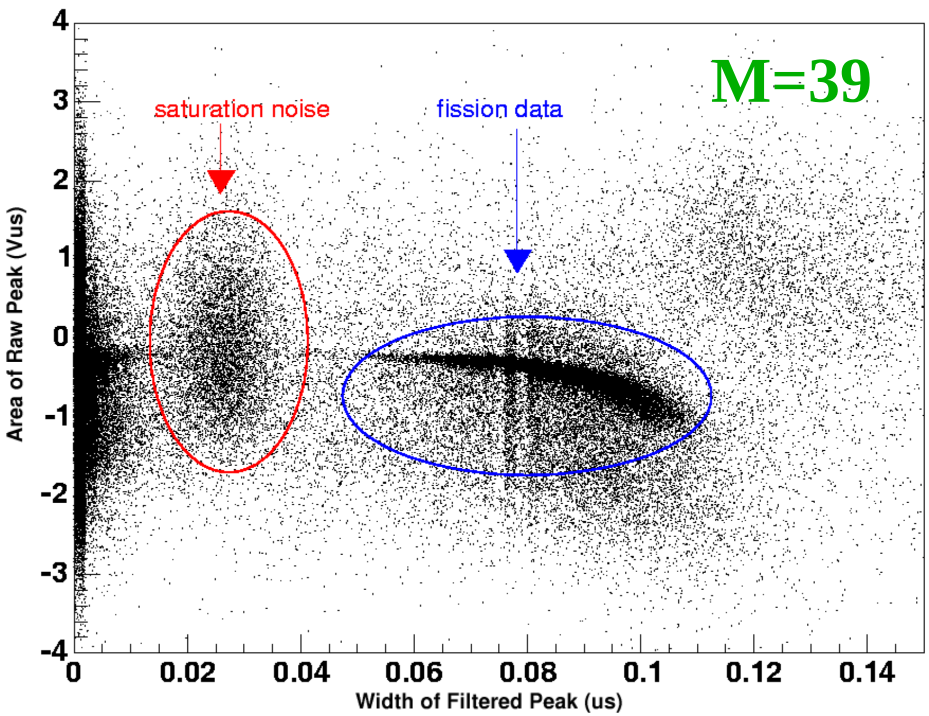
Using Cross Section vs. Energy to Determine 'm'



- Note the deviation in *m*=45

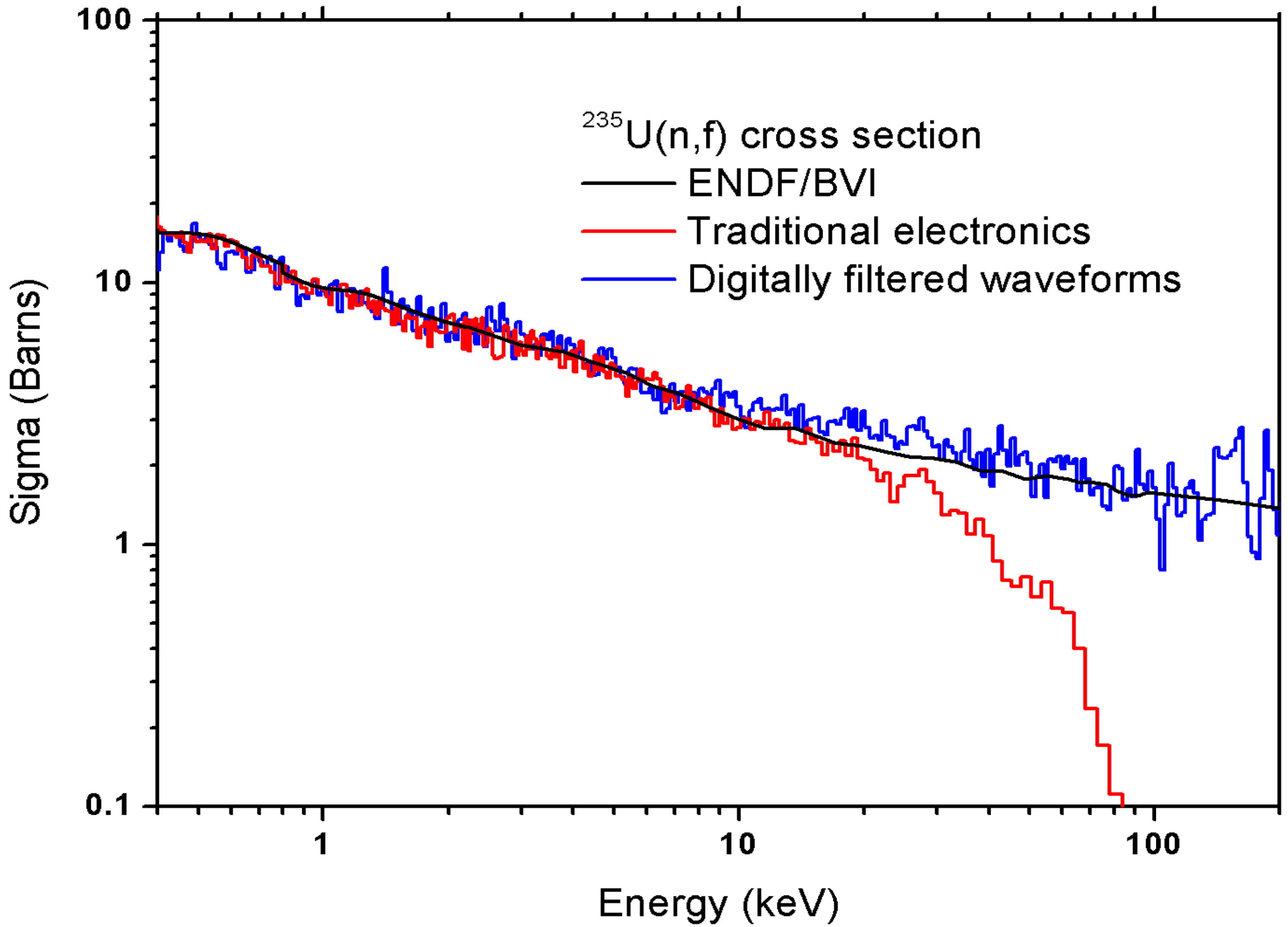
Using Peak Height Comparison to Explore 'm'





- **Here, we compare the area of the original peak with the width of the filtered peak.**
- **When m grows smaller, noise (red) begins to overlap the fission data (blue) and therefore becomes more difficult to filter out.**
- **When m grows larger, the fission data begins to inch toward the noisier region.**
- **Upper Limit** ≈ 40.

Using ENDF Comparison to Explore 'm'



- It appears that with *m*=39 we are able to extend the analyzable data range of the measurements to over 100 keV, whereas traditional electronics could only reach 20 keV without a dead time correction.

How Fast **is** This Program?

We ran a set of about 2000 waveforms with 50,000 samples each, and found that the replay time was about 15 times faster than real time.

Since
$15(50,000)=750,000$
and
$1.5ms/5ns=300,000$:

If we were to run up to 1.5ms and have an interval of 5ns, perhaps we will have over a factor of two to spare, which should cover the readout time by far.

Conclusions

- Digital filtering is applicable and preferable for Lead Slowing-Down Spectrometer data.
- A width cut should be made at 40 to 60 ns.
- The search for alpha decay information was inconclusive.
- *m*=39 has been proven to be an acceptable value for our filter's width parameter.
- The program is expected to be fast enough for a 5 ns interval up to 1.5ms.