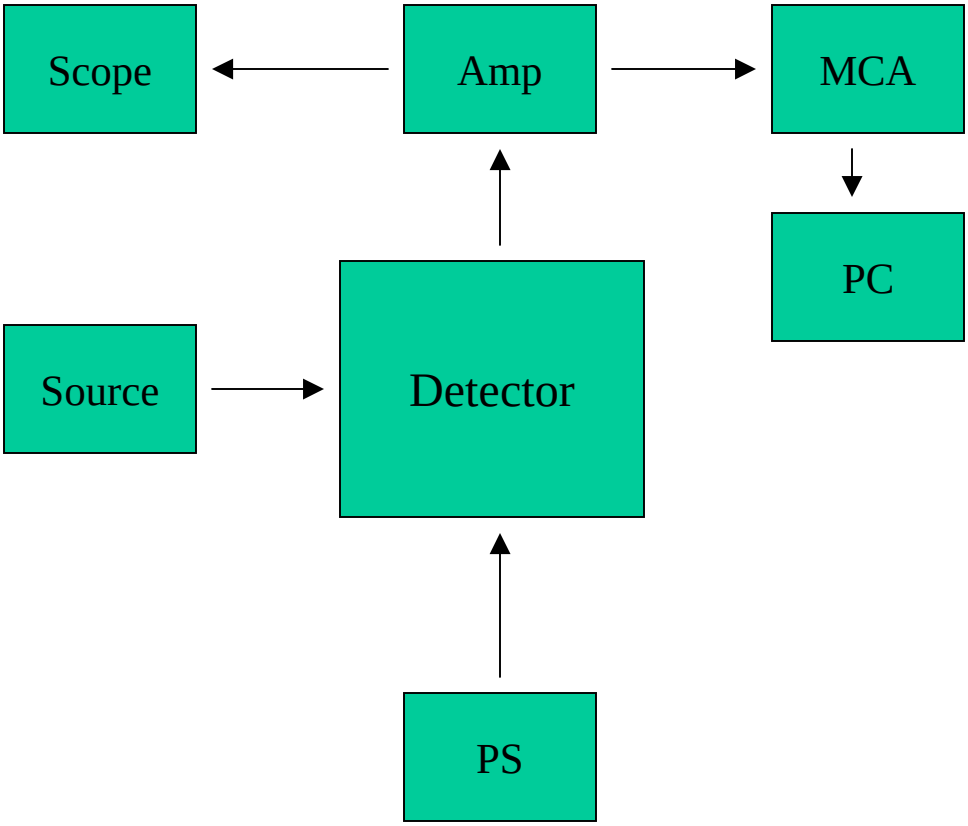
CsI Detectors Photoelectrons per MeV Relative Efficiency

Measured 49 Detectors For pe's/MeV:

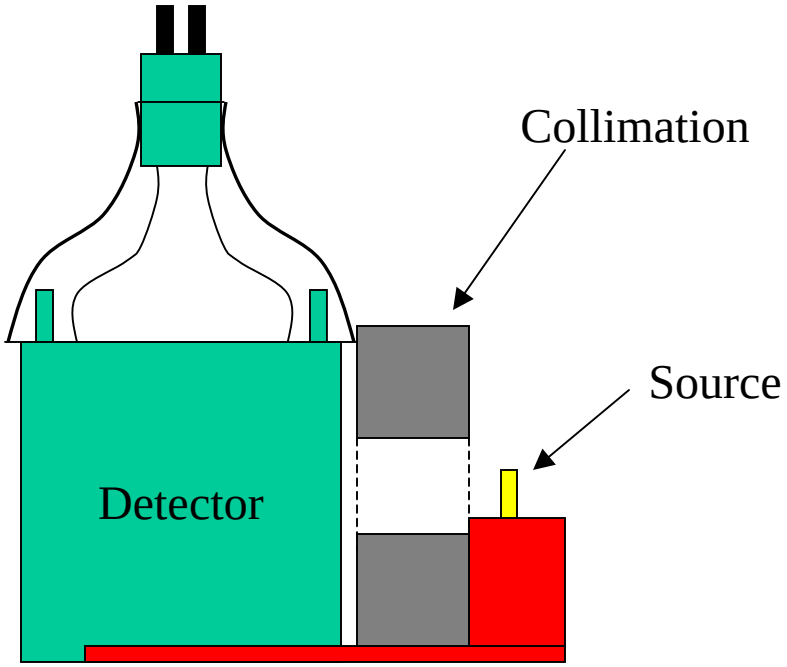
1. ^{137}Cs and ^{241}Am spectra peak widths

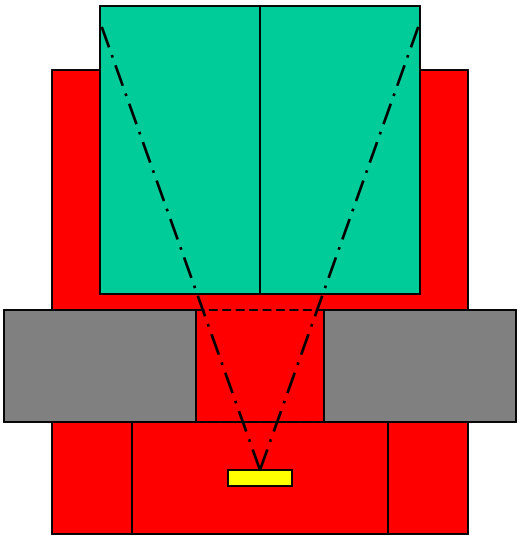
2. 5 inch S-20 PMT at 1.6 kV

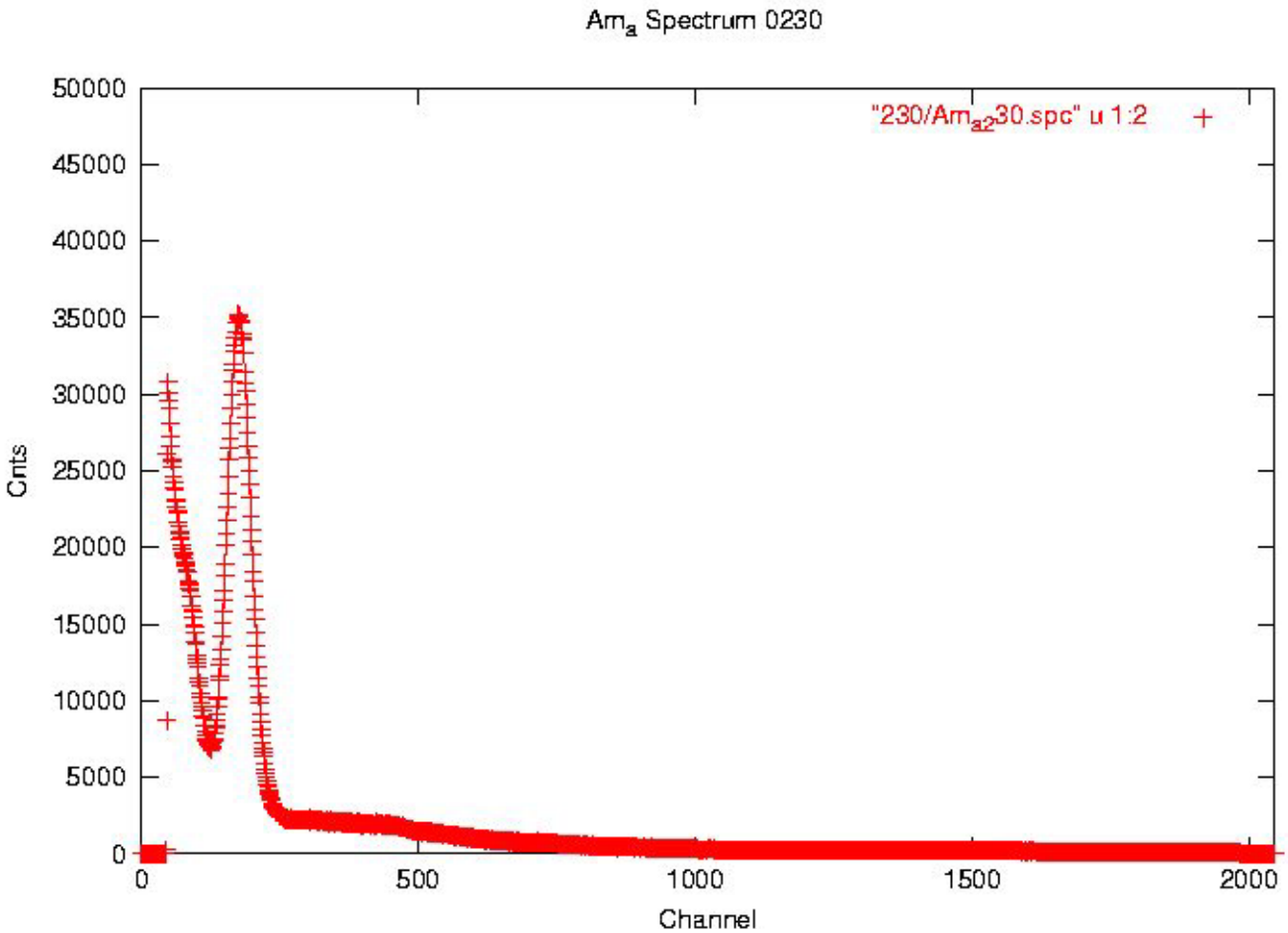
3. Computer Interfaced MCA (2048 channels)

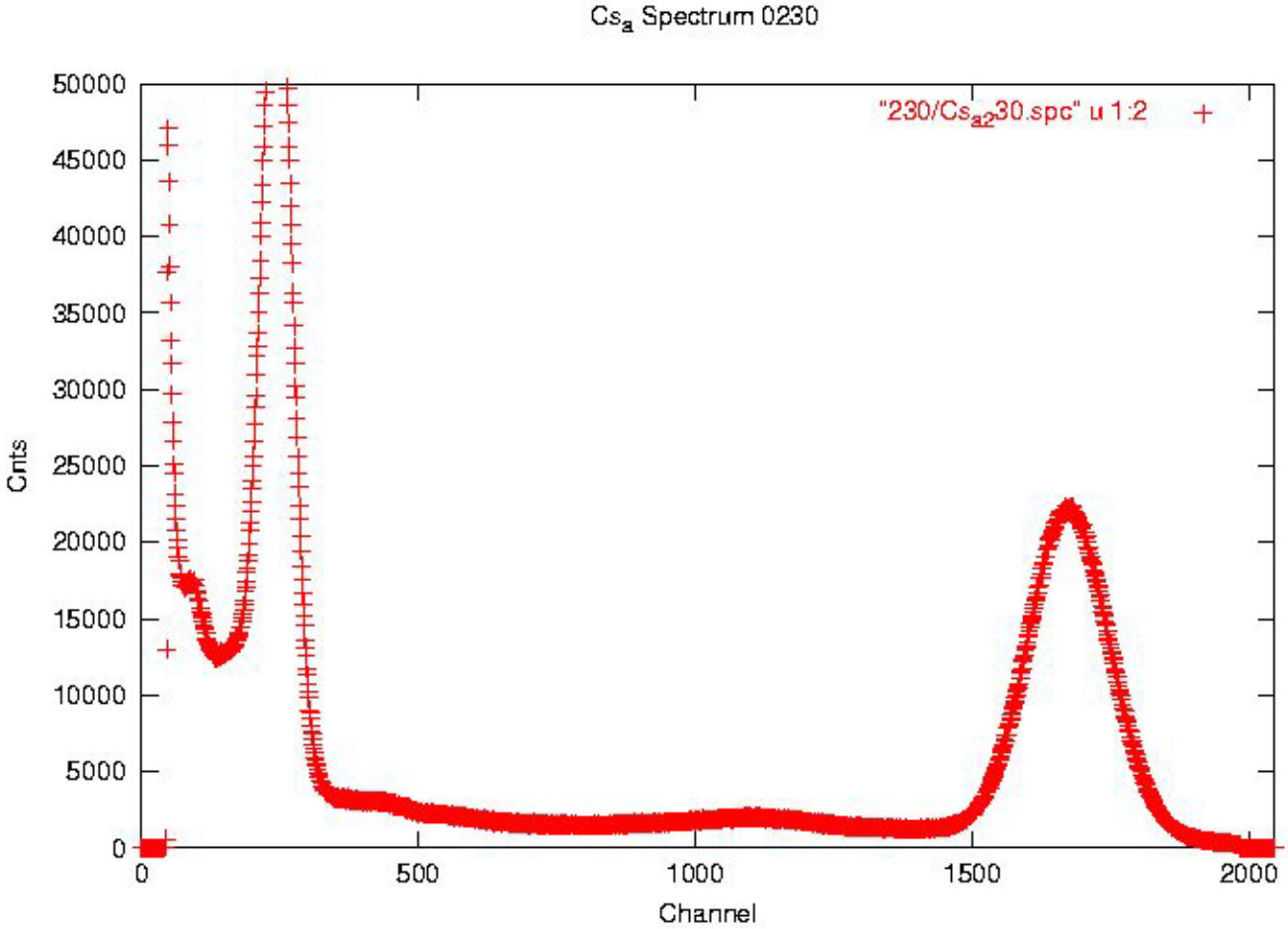


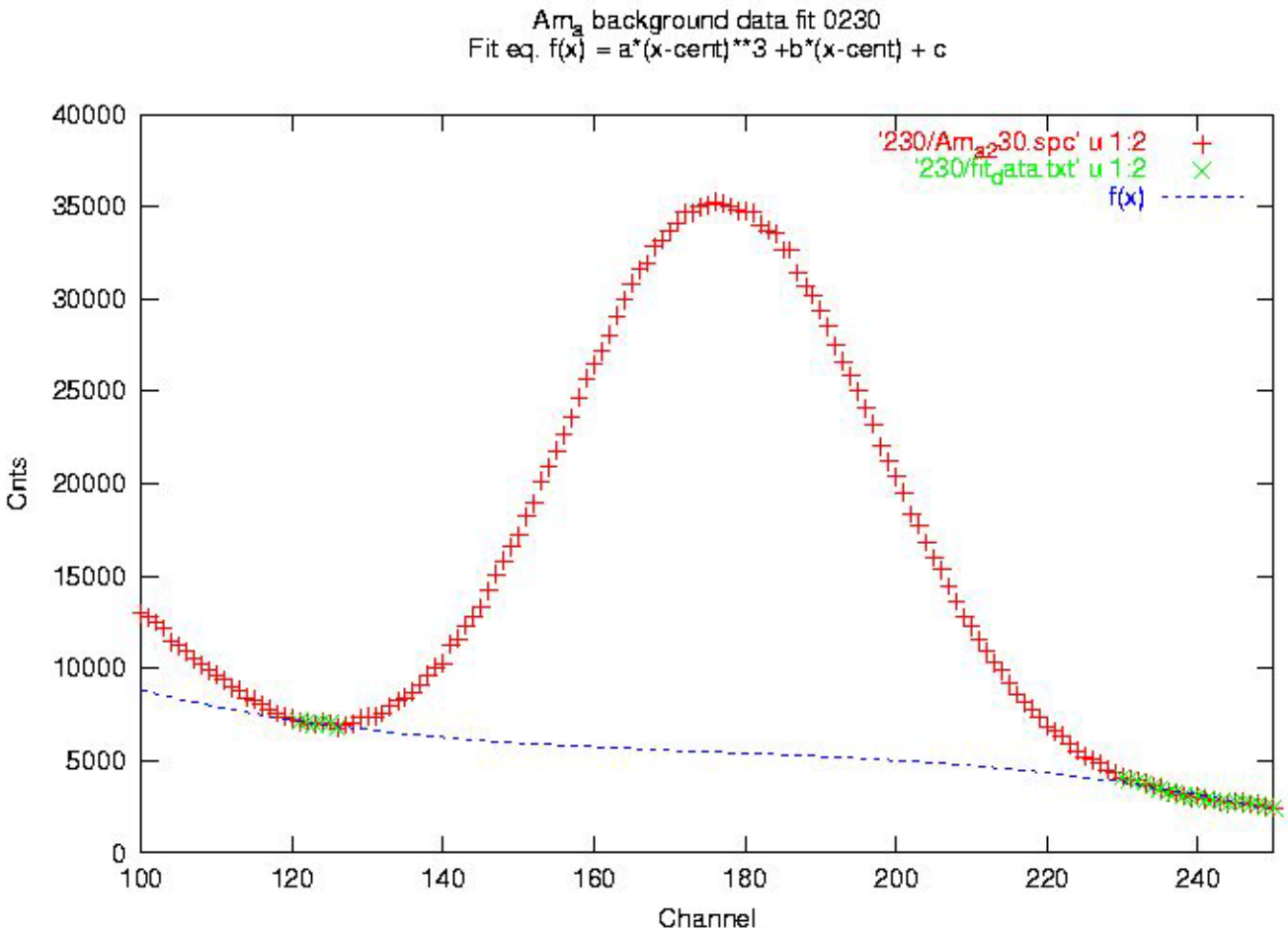
Physical Setup

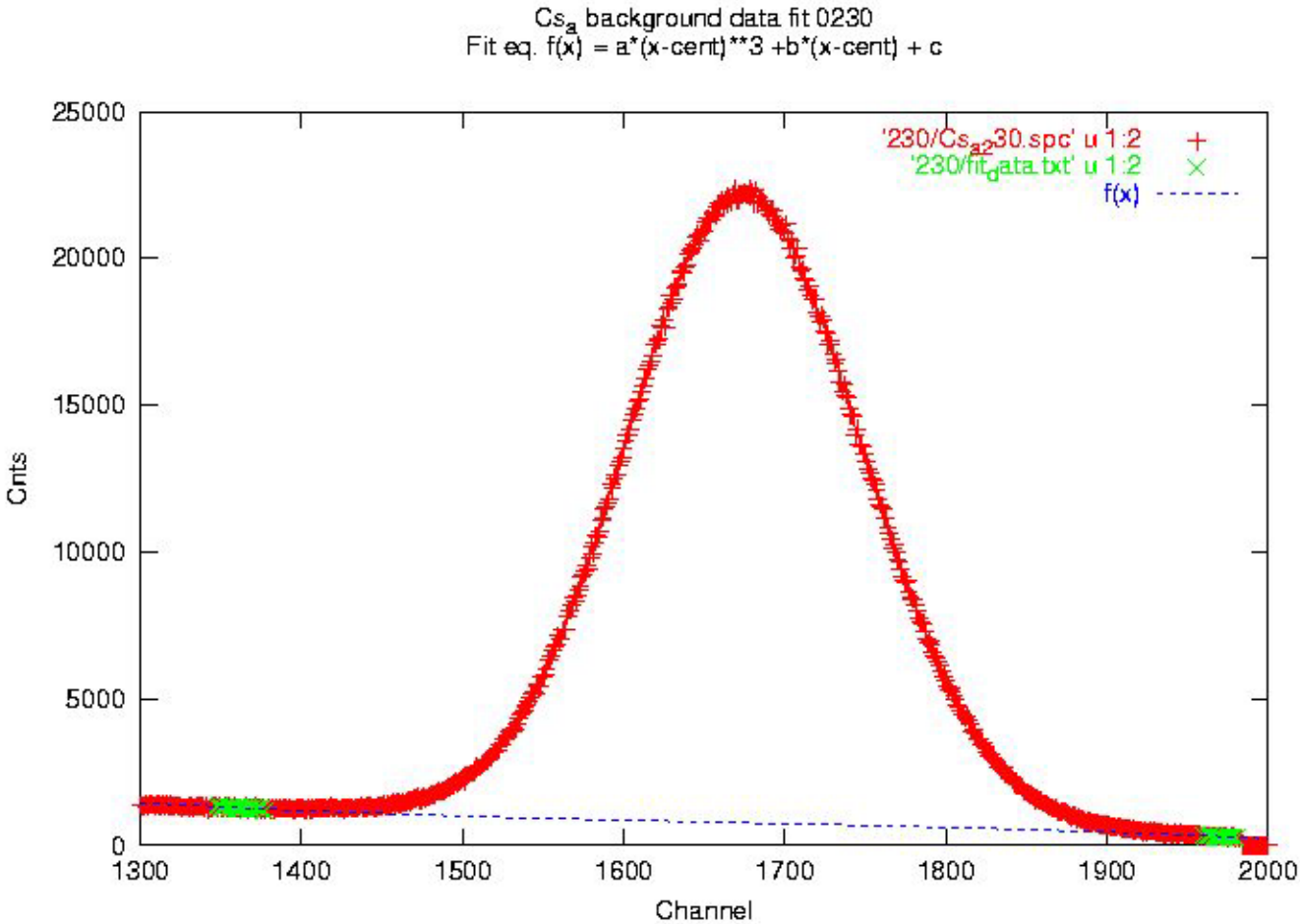


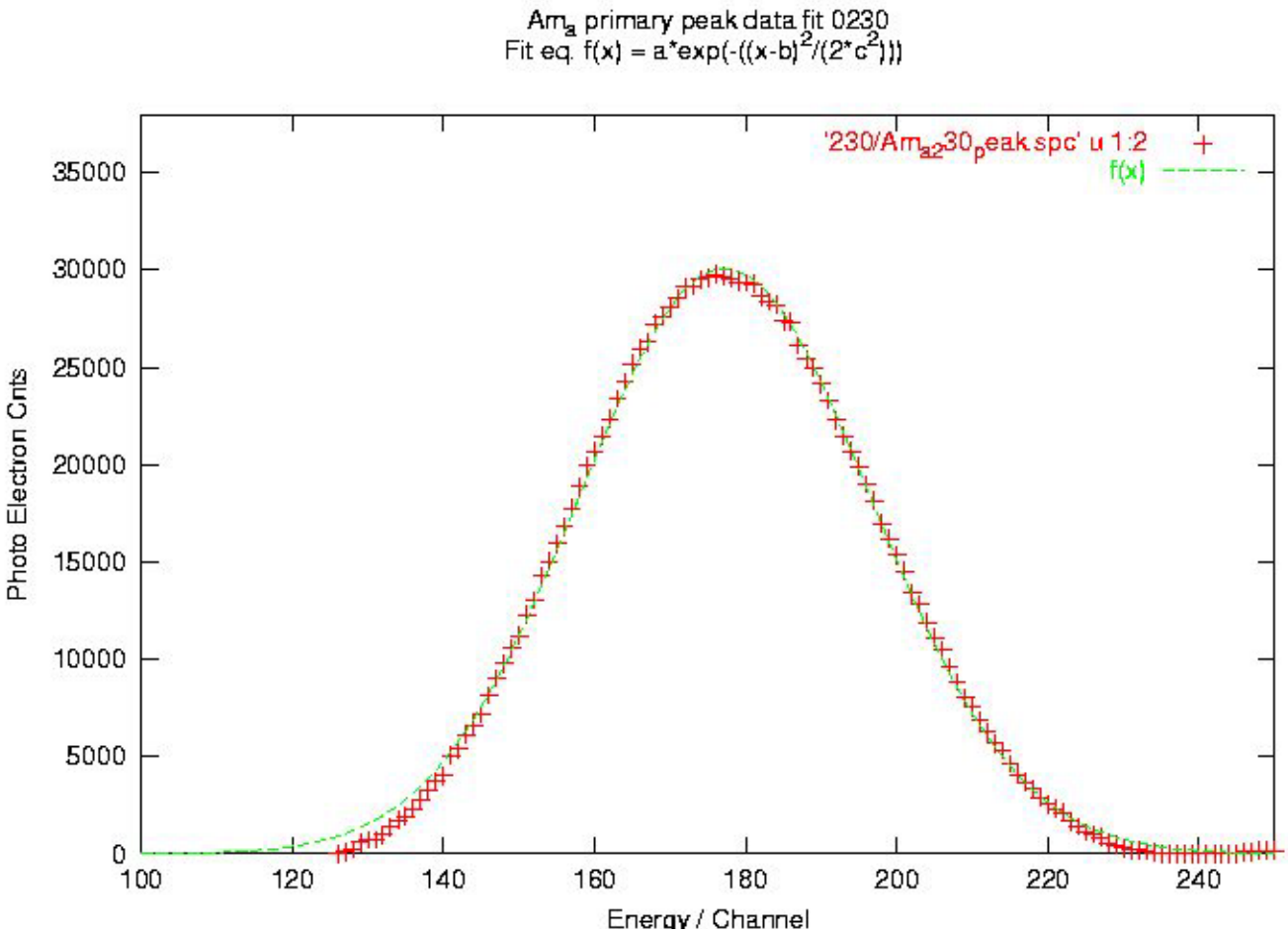


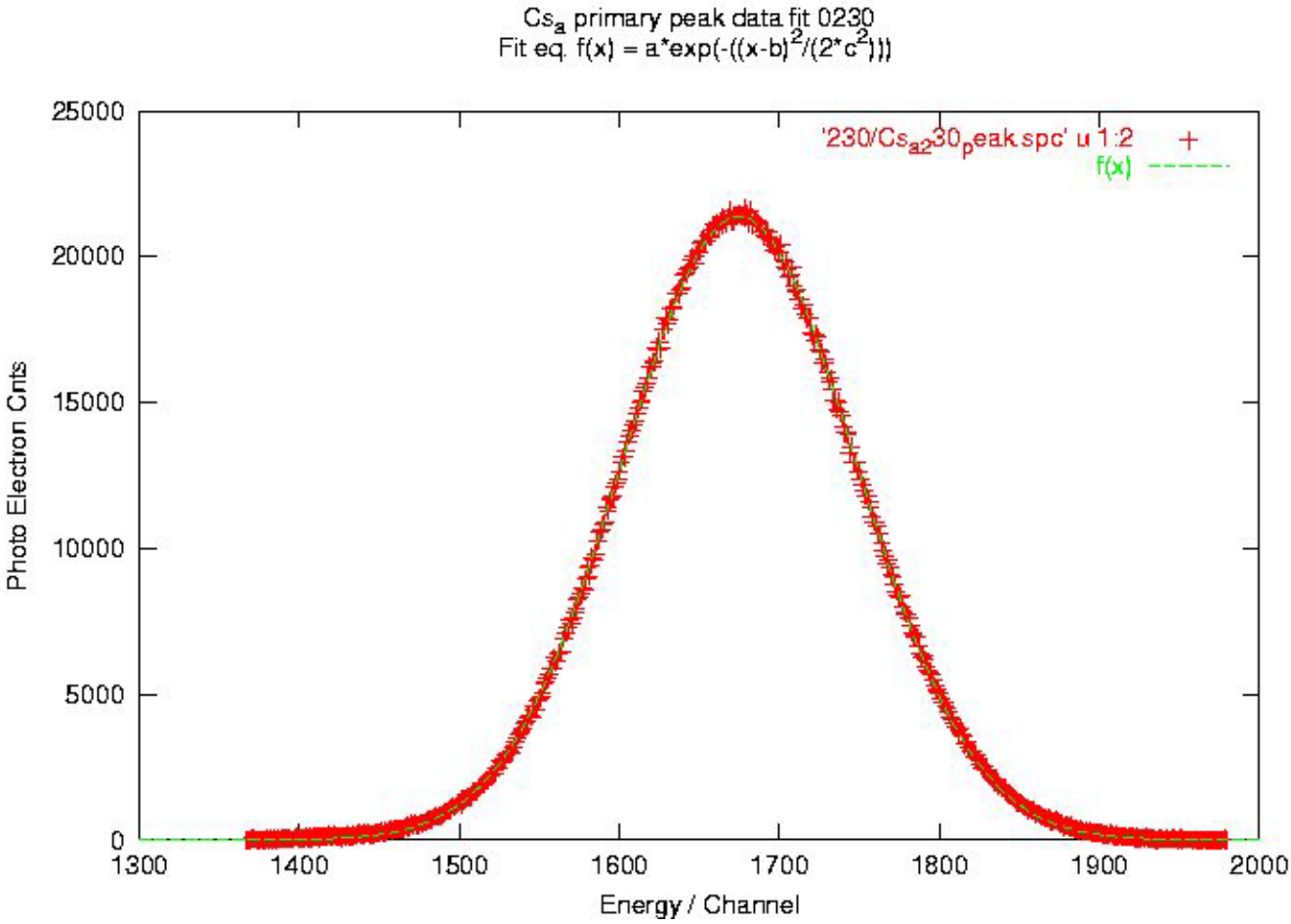

Am$_a$ Spectrum 0230
"230/Am$_{a2}$30.spc" u 1:2
Cnts
Channel
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
0
500
1000
1500
2000


Cs$_a$ Spectrum 0230
"230/Cs$_{a2}$30.spc" u 1:2
Cnts
Channel
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
0
500
1000
1500
2000


Am$_a$ background data fit 0230
Fit eq. f(x) = a*(x-cent)**3 +b*(x-cent) + c
'230/Am$_{a2}$30.spc' u 1:2
'230/fit$_d$ata.txt' u 1:2
f(x)
Cnts
Channel
0
5000
10000
15000
20000
25000
30000
35000
40000
100
120
140
160
180
200
220
240


Cs$_a$ background data fit 0230
Fit eq. f(x) = a*(x-cent)**3 +b*(x-cent) + c
'230/Cs$_{a2}$30.spc' u 1:2
'230/fit$_d$ata.txt' u 1:2
f(x)
Cnts
Channel
0
5000
10000
15000
20000
25000
1300
1400
1500
1600
1700
1800
1900
2000


Am$_a$ primary peak data fit 0230
Fit eq. f(x) = a*exp(-((x-b)^2/(2*c^2)))
'230/Am$_{a2}$30$_p$eak.spc' u 1:2
f(x)
Photo Electron Cnts
Energy / Channel
0
5000
10000
15000
20000
25000
30000
35000
100
120
140
160
180
200
220
240


Cs$_a$ primary peak data fit 0230
Fit eq. f(x) = a*exp(-((x-b)^2/(2*c^2)))
'230/Cs$_{a2}$30$_p$eak.spc' u 1:2
f(x)
Photo Electron Cnts
Energy / Channel
0
5000
10000
15000
20000
25000
1300
1400
1500
1600
1700
1800
1900
2000

Data Extraction

Get pe's/MeV from σ_p:
Assume σ_p is due to fluctuations in the number of pe's created at the photo-cathode and each successive dynode plus a contribution due to crystal properties σ_{int} .

Assume the two contributions are independent.

$$\Sigma^2 \equiv \left(\frac{\sigma_p}{m'}\right)^2 = \frac{1}{n}\left(1+\frac{1}{\delta-1}\right)\frac{1}{E} + \sigma_{\text{int}}^2$$

$$m' = \textbf{peak centroid} - \textbf{zero offset}$$

$$\delta = \textbf{Gain at each PMT stage}$$

So

$$\frac{\#\, pe's}{MeV}(\textbf{at 1 MeV}) = n = a^{-1}\frac{\delta}{\delta-1}$$

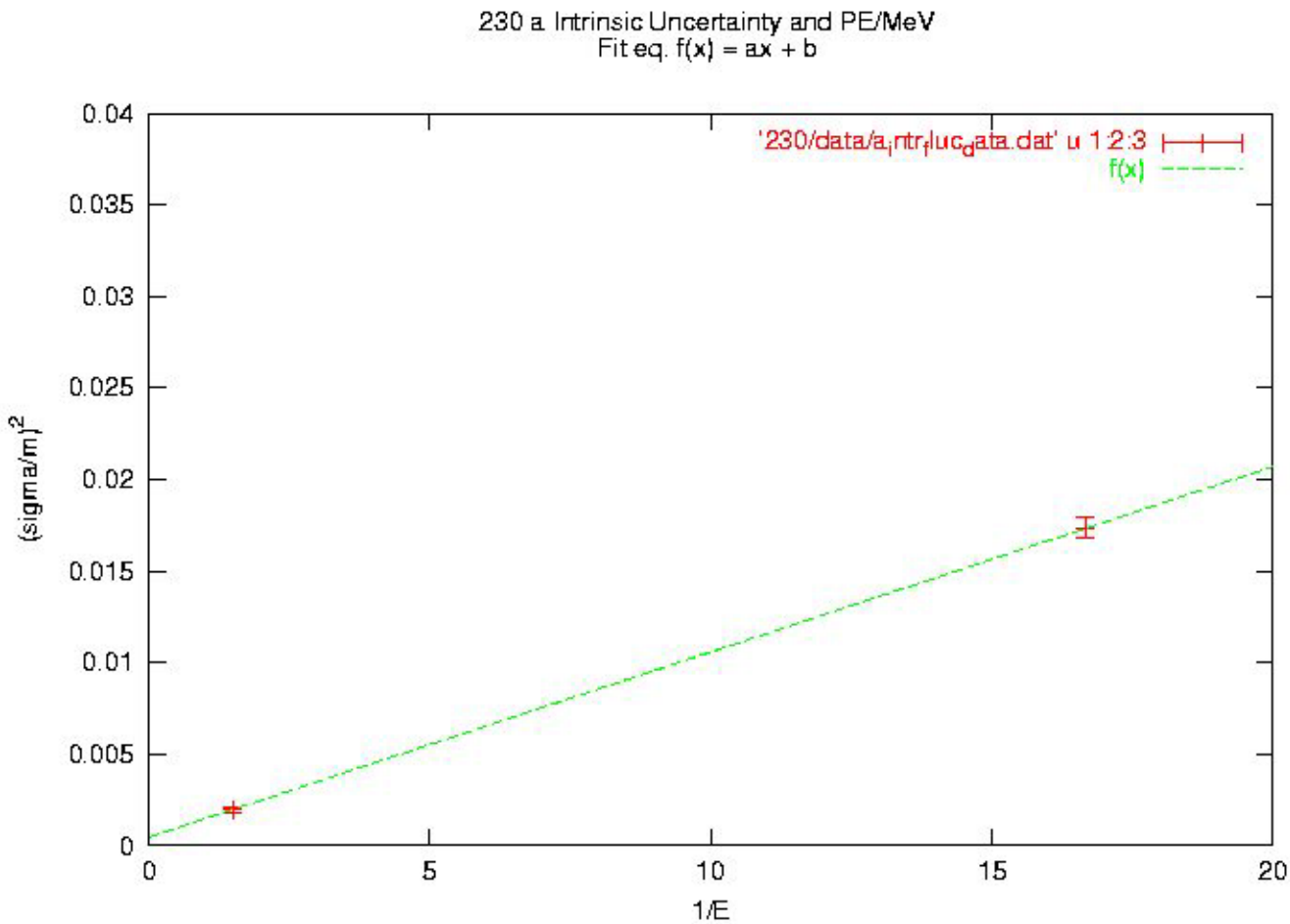
Where "a" is the slope of line Σ^2 **vs.** $\frac{1}{E}$

The Hamamatsu S20 PMT has 10 dynode stages producing a gain of 5×10^5 at 1.6 kV.

So

$$\delta^{10} = \mathbf{5 \times 10^5} \Rightarrow \delta \approx \mathbf{3.7}$$

$$\Rightarrow \boldsymbol{n} \approx \boldsymbol{a}^{-1} \times \mathbf{1.37}$$



Error Analysis

$$\textbf{Counting Statistics}: \frac{1}{\sqrt{n}} = 0.0007 - 0.001$$

$$\textbf{Peak centroid}: \; m = ch \pm \frac{\sigma_p}{\sqrt{n}}$$

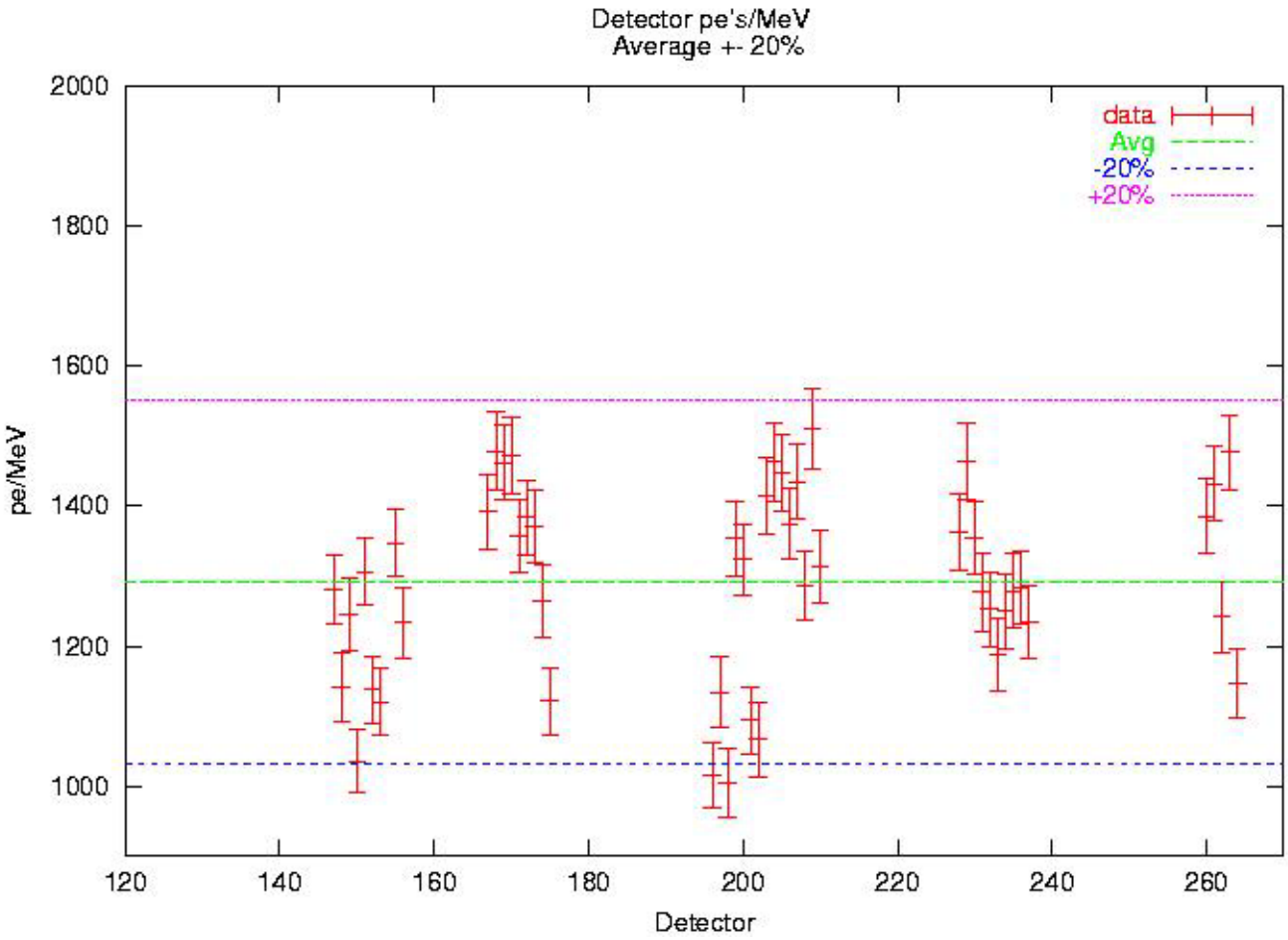
$$\textbf{Total variance}: \Sigma^2 = \left(\frac{\sigma_p}{m'}\right)^2 \pm \left(\frac{\sigma_p}{m'}\right)^2 \times \frac{\sqrt{2\left(\sigma_p / m'\right)m'^2 + 2}}{m'}$$

The errors from the least squares fit contribute most:

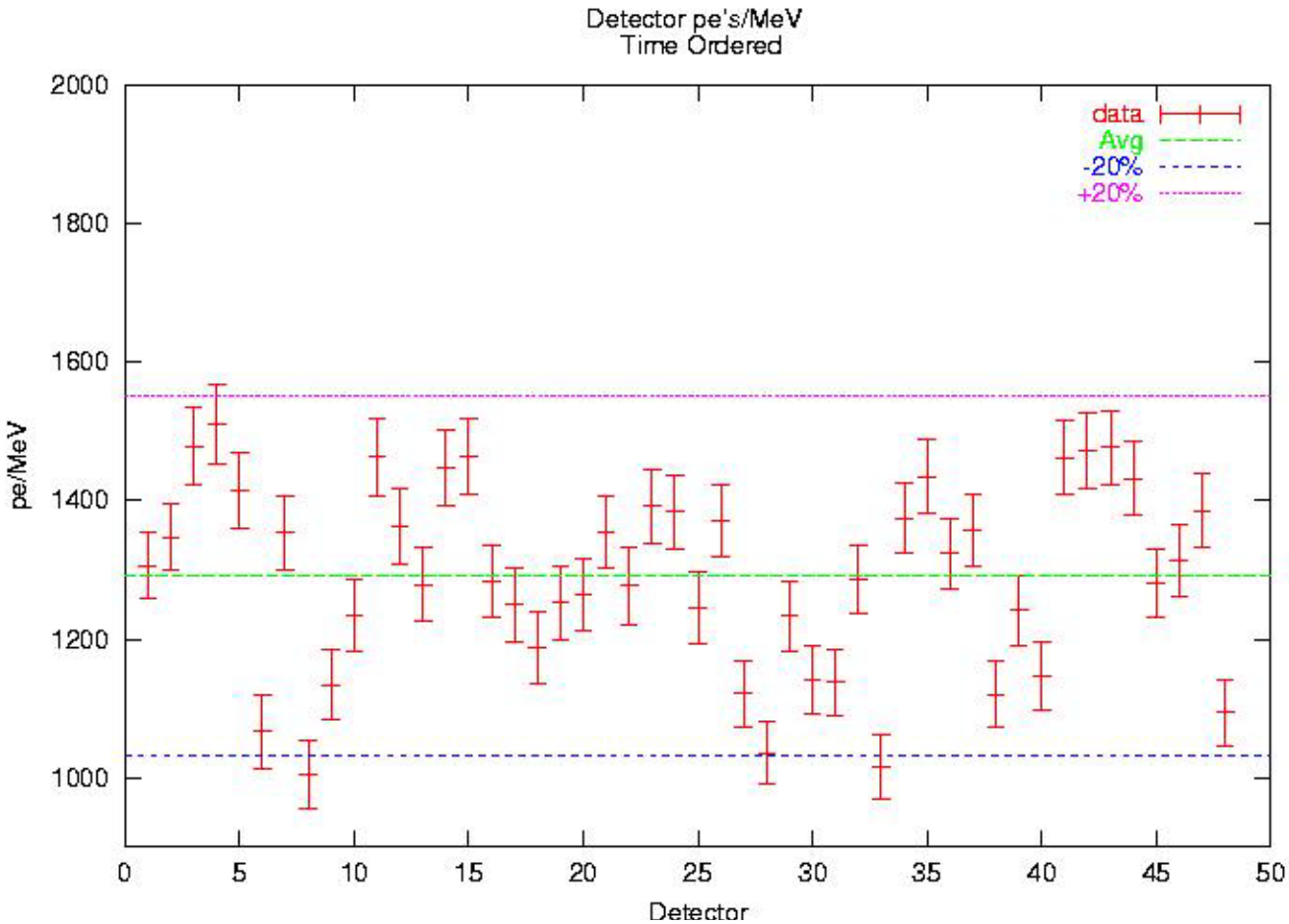
$$\sigma^2(n) = \frac{\sum_i \frac{1}{\hat{\sigma}_i}}{\left(\sum_i \frac{1}{\hat{\sigma}_i^2}\right)\sum_i \left(\frac{1}{E\hat{\sigma}_i}\right)^2 - \left(\sum_i \frac{1}{E\hat{\sigma}_i^2}\right)^2}$$

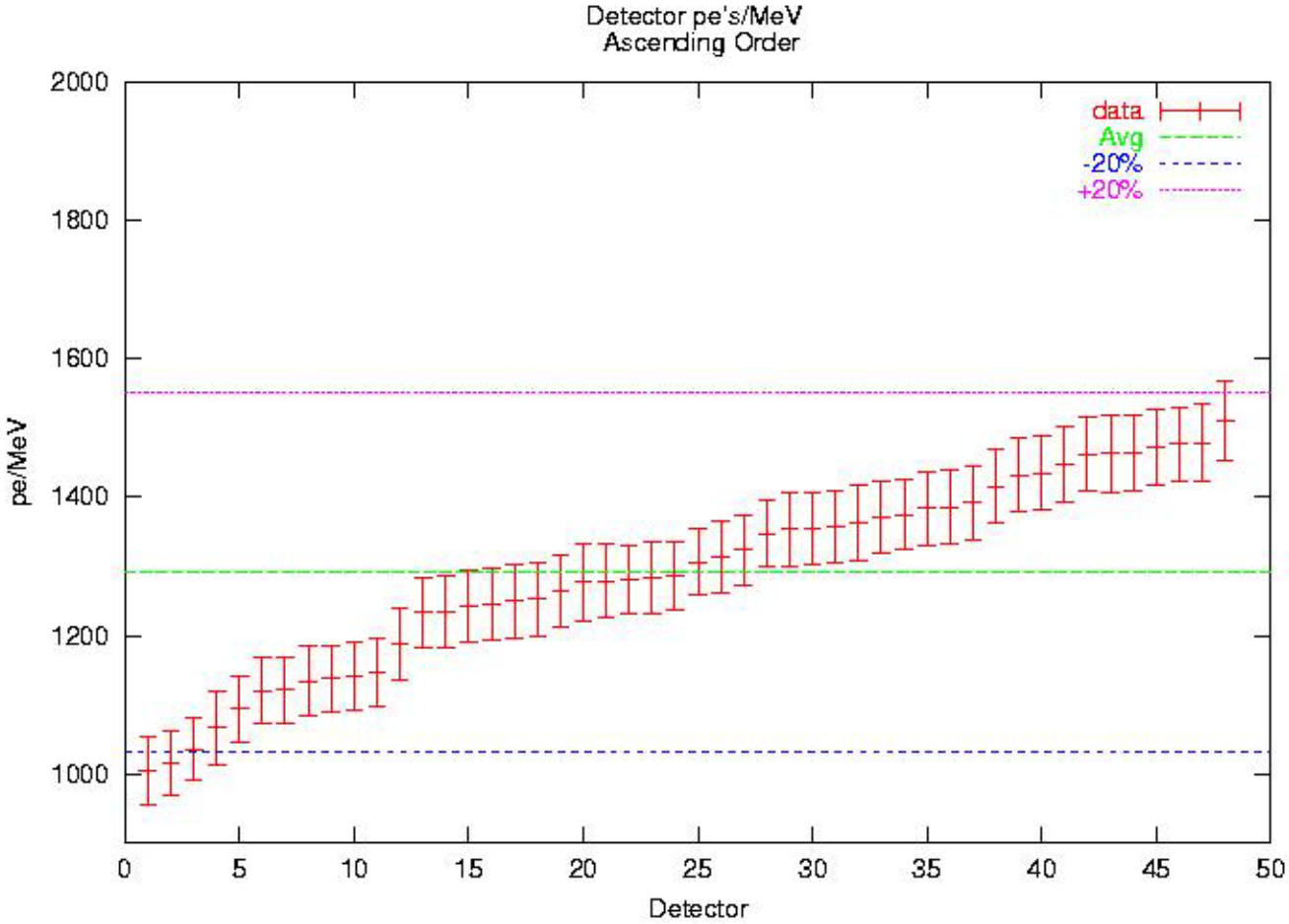
$$\sigma^2\left(\sigma_{\text{int}}^2\right) = \frac{\sum_i \left(\frac{1}{E\hat{\sigma}_i}\right)^2}{\left(\sum_i \frac{1}{\hat{\sigma}_i^2}\right)\left(\sum_i \frac{1}{E^2\hat{\sigma}_i^2}\right) - \left(\sum_i \frac{1}{E\hat{\sigma}_i^2}\right)^2}$$

Results

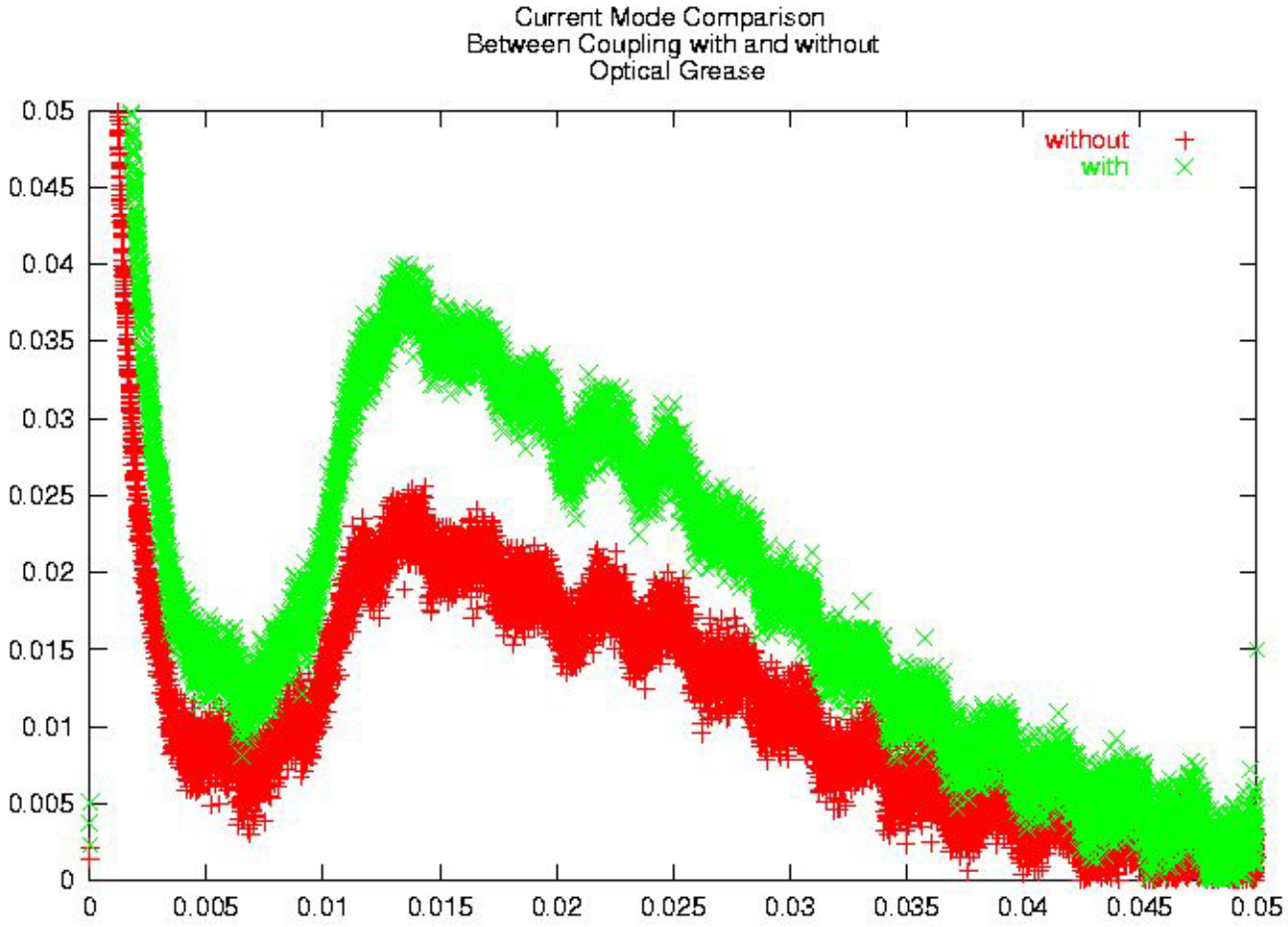


1. Distribution is not gaussian
2. Values vary by up to 40%
3. Errors are ~ +/-5%
4. Average number of pe's/MeV is 1292


Detector pe's/MeV
Time Ordered
data
Avg
-20%
+20%
pe/MeV
Detector
2000
1800
1600
1400
1200
1000
0
5
10
15
20
25
30
35
40
45
50


Detector pe's/MeV
Ascending Order
data
Avg
-20%
+20%
pe/MeV
Detector
2000
1800
1600
1400
1200
1000
0
5
10
15
20
25
30
35
40
45
50

With Optical Coupling vs. Without



1. 1998 test run data
2. Verified by measuring two detectors
3. Optical coupling is necessary – windows not smooth
4. Determined 3 detectors have non-protruding / slanted windows (one of them critical)

Schedule

1. VPD efficiency measurements
2. CsI VPD matching
3. Check VPD’s with one LED / Check LED’s
4. Collect hardware to mount pre-amplifiers
5. Feedback resistors arrive in November
6. Assembly of pre-amplifiers
7. Testing with DAQ
8. Gain temperature dependence test
9. ?