Error Analysis III

Monte Carlo Technique

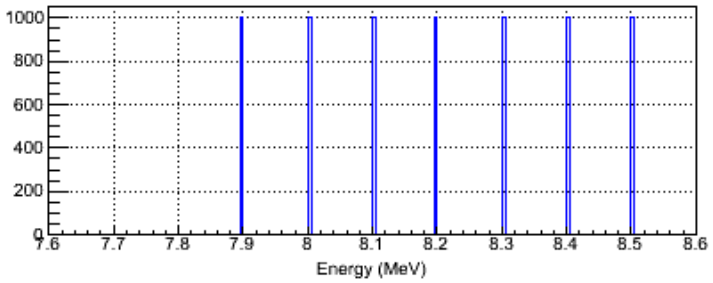
02 October 2013

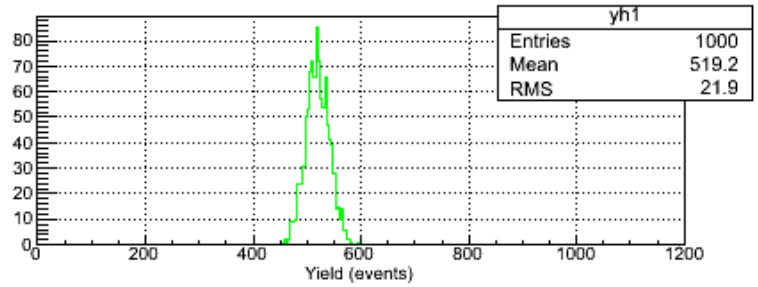
Statistical Error – No Background

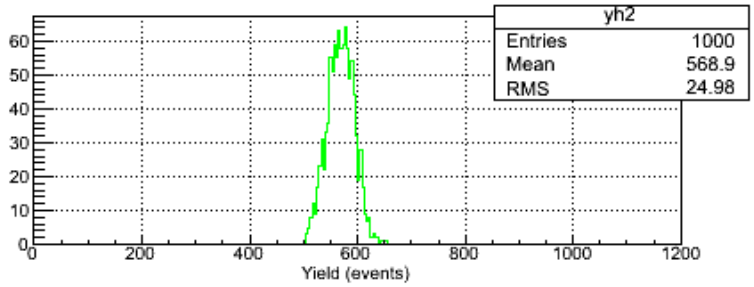
I. Calculate the yield
II. Allow for statistical fluctuations:

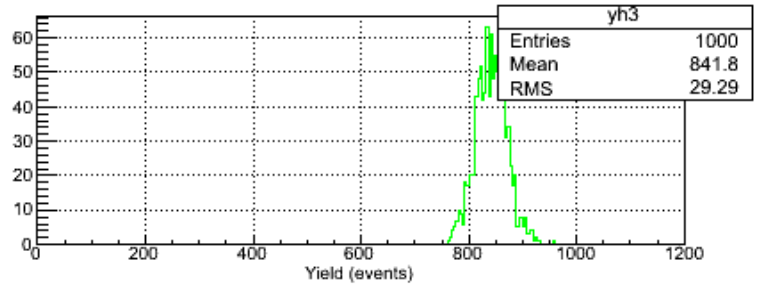
$$y_i = gRandom\text{->}Gaus(y_i, Sqrt(y_i))$$

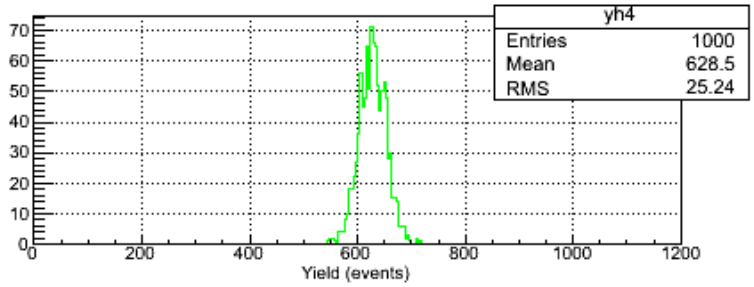
III. Unfold cross section
IV. Repeat for 1000 tries

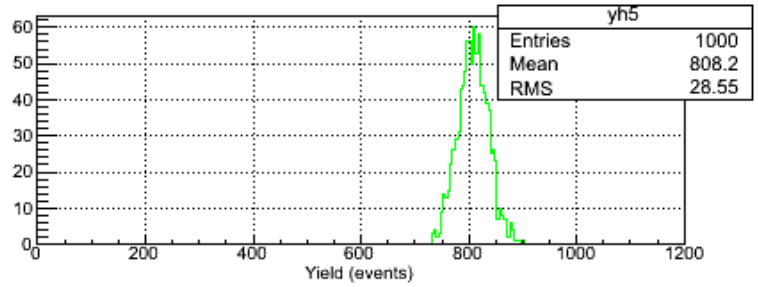

Energy (MeV)

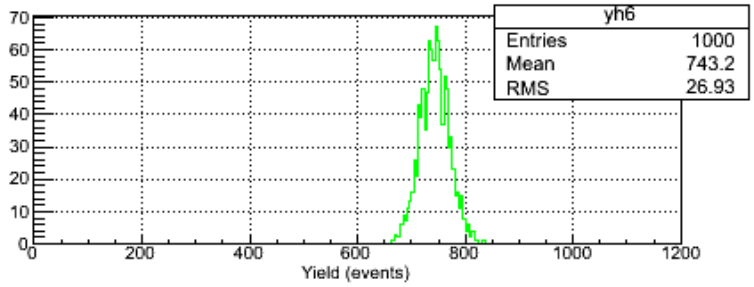

yh1
Entries 1000
Mean 519.2
RMS 21.9
Yield (events)

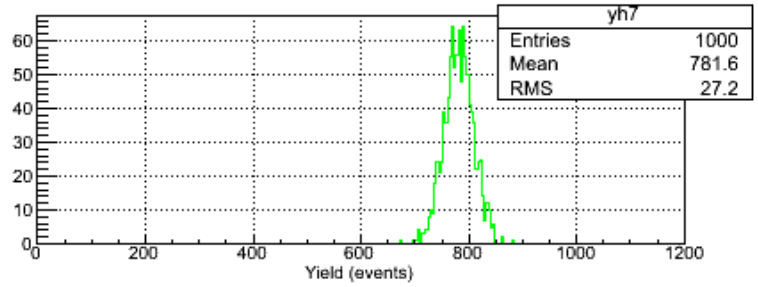

yh2
Entries 1000
Mean 568.9
RMS 24.98
Yield (events)

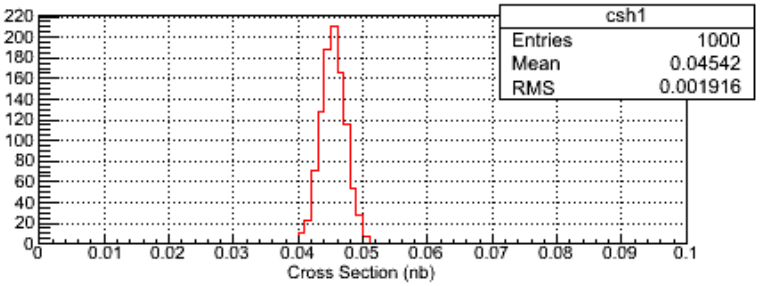

yh3
Entries 1000
Mean 841.8
RMS 29.29
Yield (events)

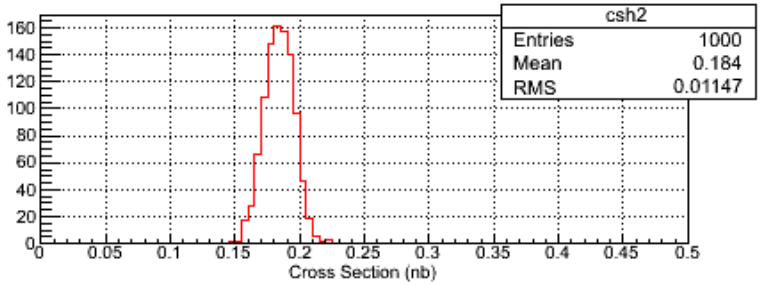

yh4
Entries 1000
Mean 628.5
RMS 25.24
Yield (events)

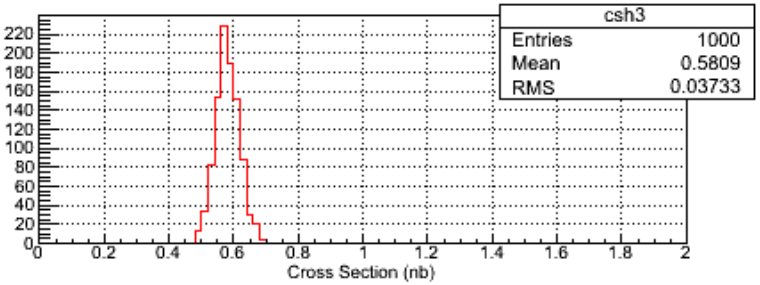

yh5
Entries 1000
Mean 808.2
RMS 28.55
Yield (events)

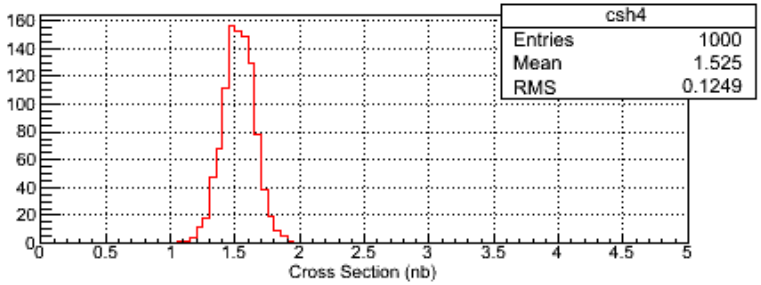

yh6
Entries 1000
Mean 743.2
RMS 26.93
Yield (events)

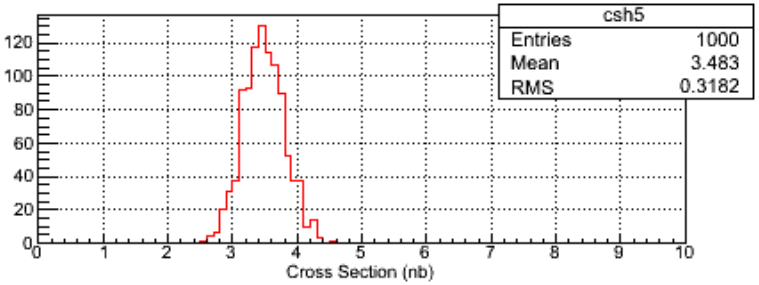

yh7
Entries 1000
Mean 781.6
RMS 27.2
Yield (events)

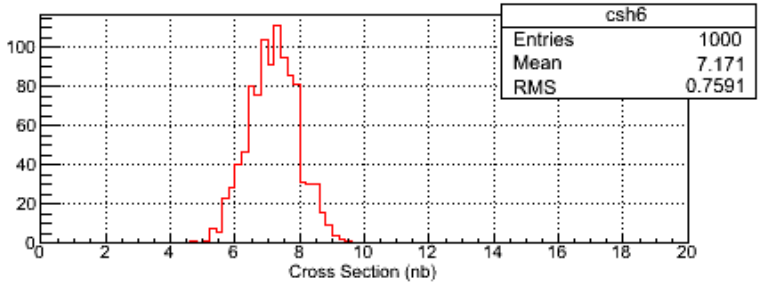

csh1
Entries 1000
Mean 0.04542
RMS 0.001916
Cross Section (nb)

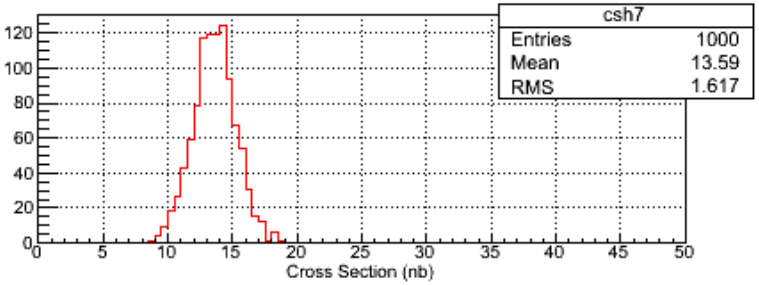

csh2
Entries 1000
Mean 0.184
RMS 0.01147
Cross Section (nb)


csh3
Entries 1000
Mean 0.5809
RMS 0.03733
Cross Section (nb)


csh4
Entries 1000
Mean 1.525
RMS 0.1249
Cross Section (nb)


csh5
Entries 1000
Mean 3.483
RMS 0.3182
Cross Section (nb)


csh6
Entries 1000
Mean 7.171
RMS 0.7591
Cross Section (nb)


csh7
Entries 1000
Mean 13.59
RMS 1.617
Cross Section (nb)

Electron Beam K. E.	Beam Current (μA)	Time (hour)	y_i	dy_i (no bg)	dy_i/y_i (no bg, %)
7.9	100	100	519	22	4.2
8.0	100	20	569	25	4.4
8.1	80	10	842	29	3.5
8.2	20	10	629	25	4.0
8.3	10	10	808	29	3.5
8.4	4	10	743	27	3.6
8.5	2	10	782	27	3.5

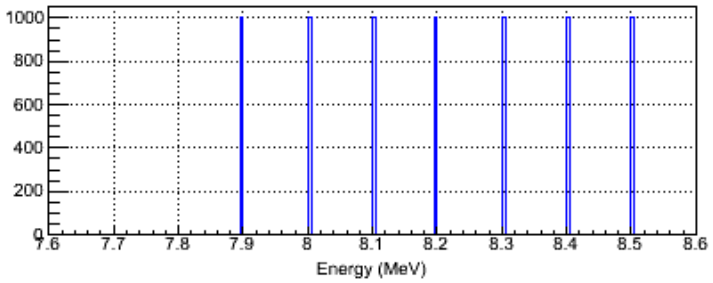
Electron Beam K. E.	Cross Section (nb)	Stat Error (no bg, %)
7.9	0.045	4.2
8.0	0.184	6.2
8.1	0.58	6.4
8.2	1.53	8.2
8.3	3.48	9.1
8.4	7.2	10.6
8.5	13.6	11.9

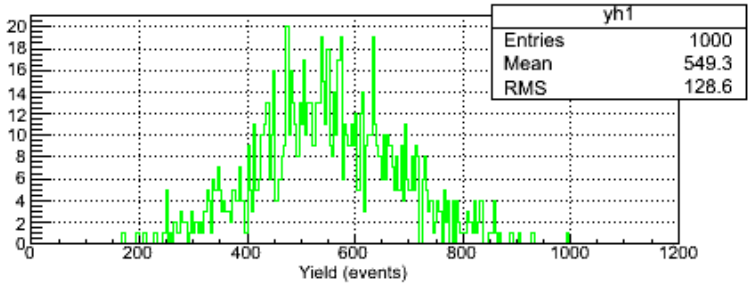
Statistical Error – With Background

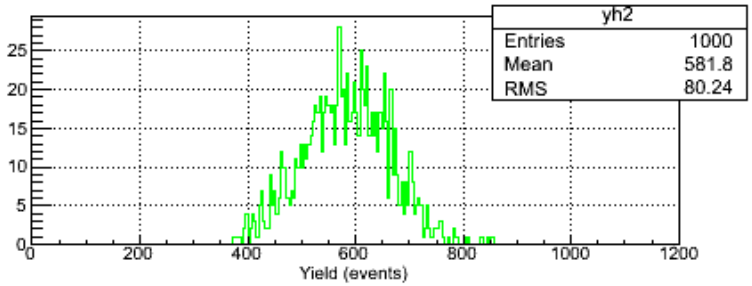
I. Calculate the yield
II. Calculate the background yield from ^{18}O
III. Allow for statistical fluctuations:

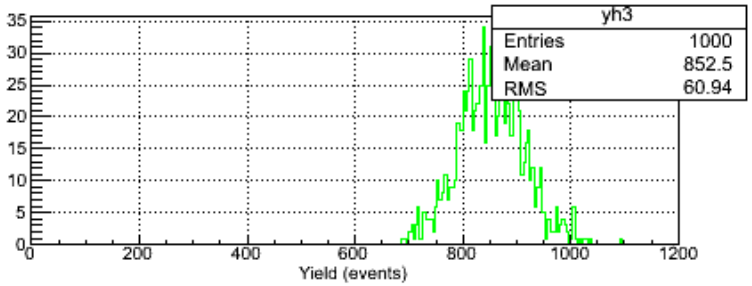
$$y_i = gRandom->Gaus(y_i, Sqrt(y_i+2y_i^{bg}))$$

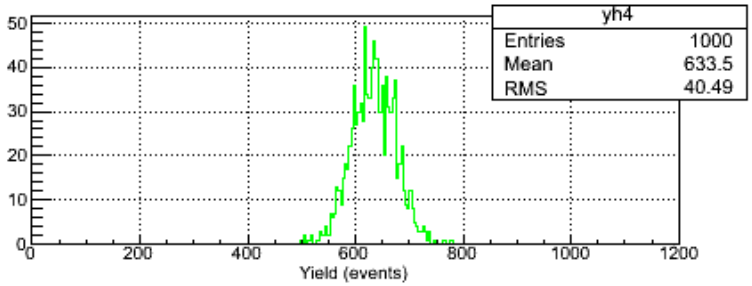
IV. Unfold cross section
V. Repeat for 1000 tries

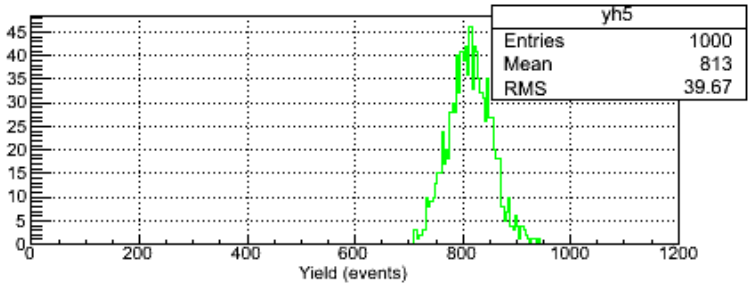

Energy (MeV)

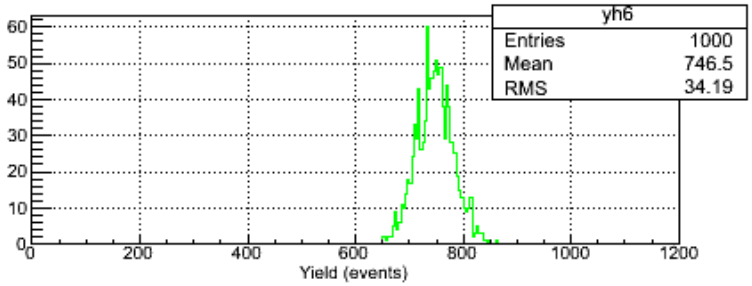

yh1
Entries 1000
Mean 549.3
RMS 128.6
Yield (events)

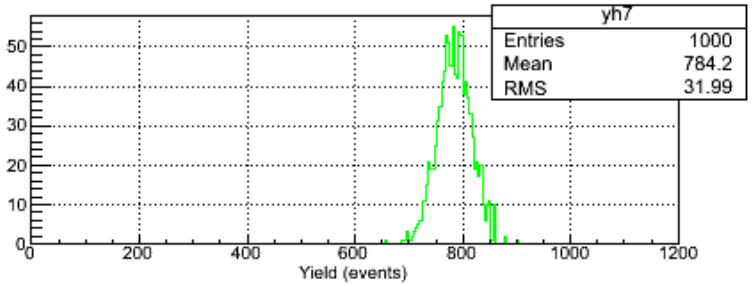

yh2
Entries 1000
Mean 581.8
RMS 80.24
Yield (events)

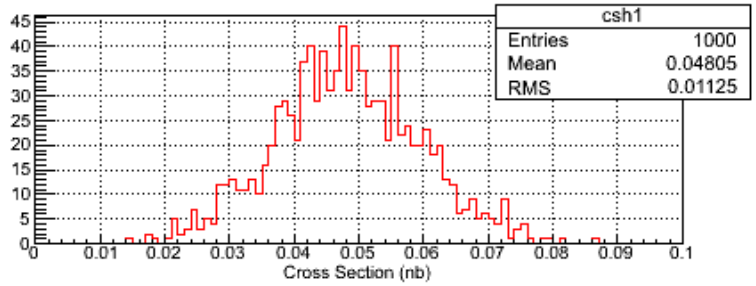

yh3
Entries 1000
Mean 852.5
RMS 60.94
Yield (events)

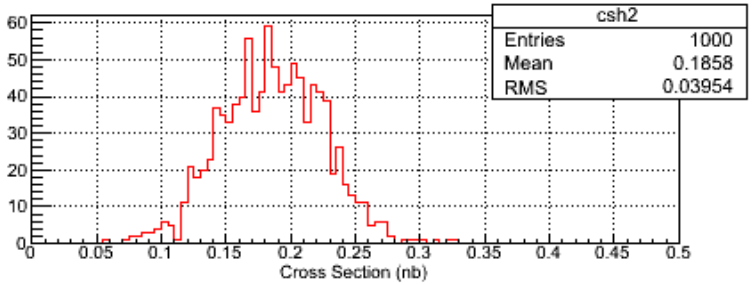

yh4
Entries 1000
Mean 633.5
RMS 40.49
Yield (events)

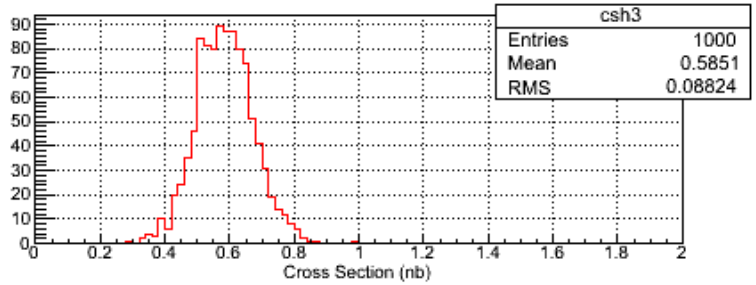

yh5
Entries 1000
Mean 813
RMS 39.67
Yield (events)

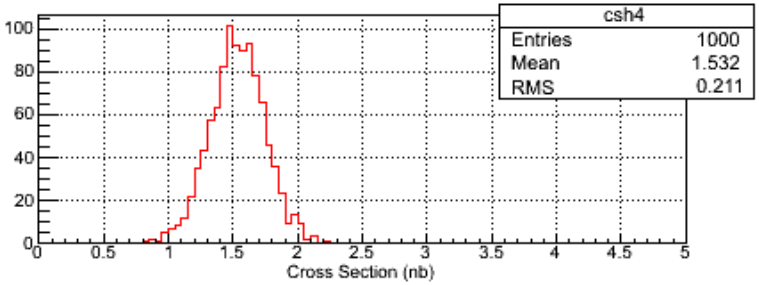

yh6
Entries 1000
Mean 746.5
RMS 34.19
Yield (events)

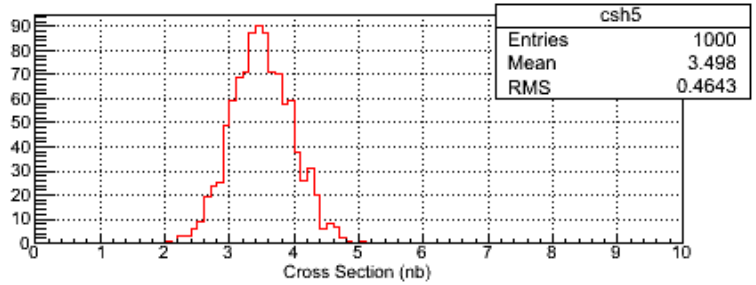

yh7
Entries 1000
Mean 784.2
RMS 31.99
Yield (events)

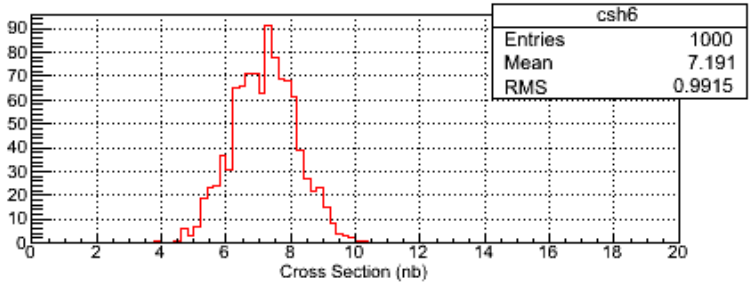

csh1
Entries 1000
Mean 0.04805
RMS 0.01125
Cross Section (nb)

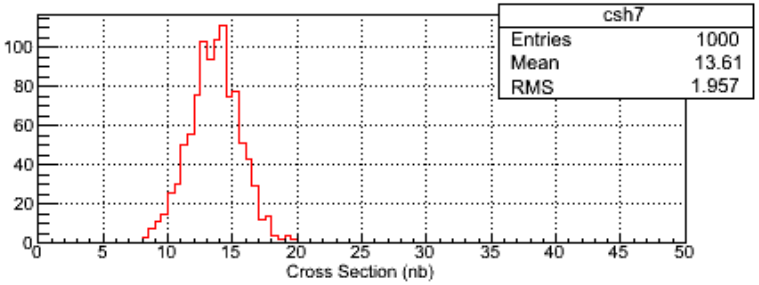

csh2
Entries 1000
Mean 0.1858
RMS 0.03954
Cross Section (nb)


csh3
Entries 1000
Mean 0.5851
RMS 0.08824
Cross Section (nb)


csh4
Entries 1000
Mean 1.532
RMS 0.211
Cross Section (nb)


csh5
Entries 1000
Mean 3.498
RMS 0.4643
Cross Section (nb)


csh6
Entries 1000
Mean 7.191
RMS 0.9915
Cross Section (nb)


csh7
Entries 1000
Mean 13.61
RMS 1.957
Cross Section (nb)

Electron Beam K. E.	Beam Current (μA)	Time (hour)	y_i	dy_i (with bg)	dy_i/y_i (with bg, %)
7.9	100	100	549	129	23.4
8.0	100	20	582	80	13.8
8.1	80	10	852	61	7.1
8.2	20	10	633	40	6.4
8.3	10	10	813	40	4.9
8.4	4	10	747	34	4.6
8.5	2	10	784	32	4.1

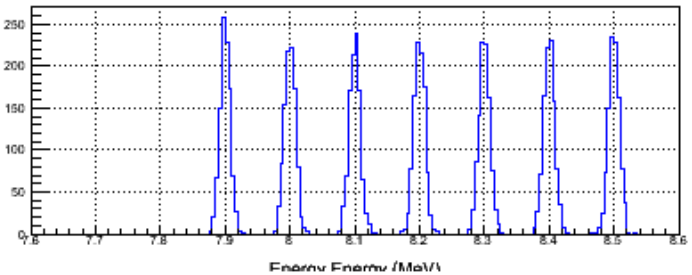
Electron Beam K. E.	Cross Section (nb)	Stat Error (with bg, %)
7.9	0.048	23.4
8.0	0.186	21.3
8.1	0.59	15.1
8.2	1.53	13.8
8.3	3.50	13.3
8.4	7.2	13.8
8.5	13.6	14.4

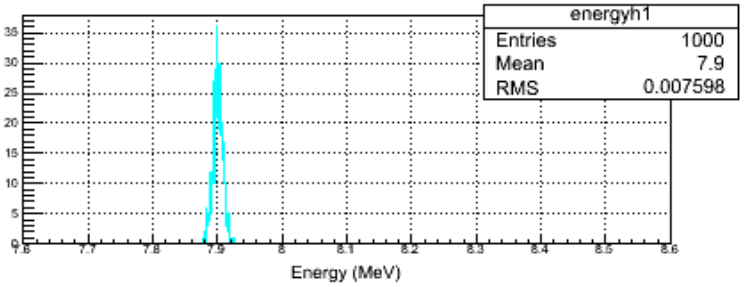
Systematic Error – Beam Energy

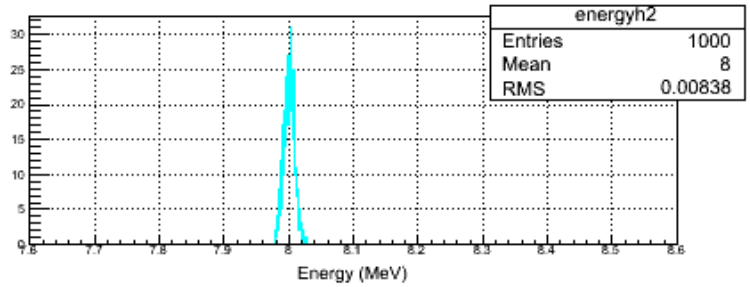
I. Calculate the N_{ij} for each nominal beam energy, E_i (since we will use GEANT4)
II. Allow for absolute beam energy to change by:

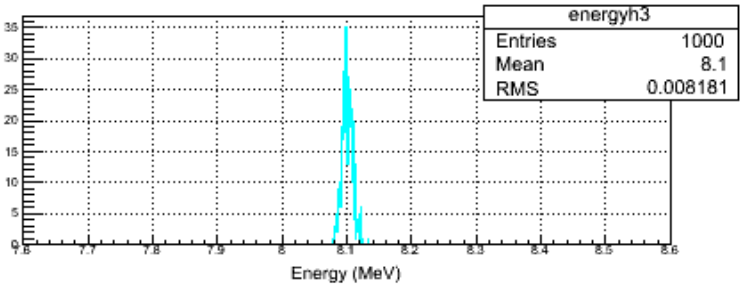
$$E_i = E_i * gRandom->Gaus(1, 0.001)$$

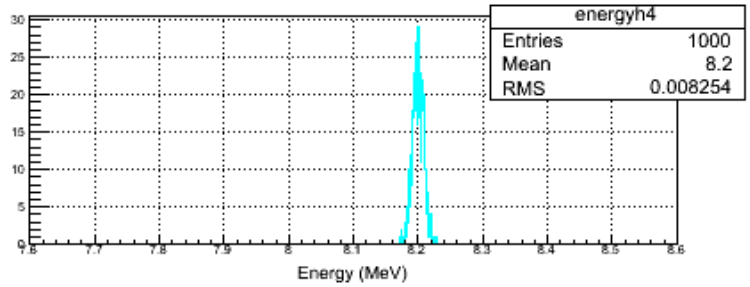
III. Calculate the yield
IV. Unfold cross section
V. Repeat for 1000 tries

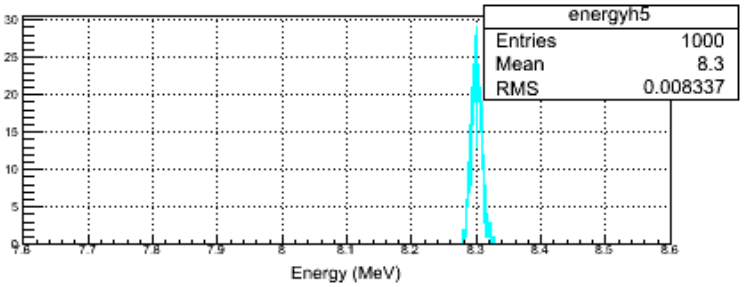


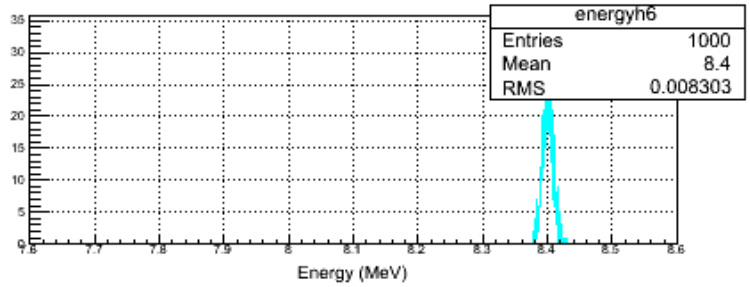

energyh1
Entries 1000
Mean 7.9
RMS 0.007598
Energy (MeV)

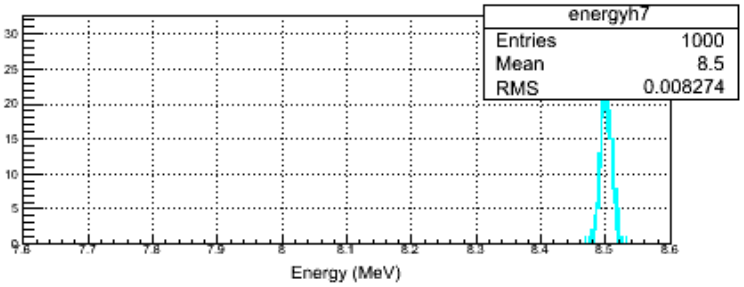

energyh2
Entries 1000
Mean 8
RMS 0.00838
Energy (MeV)

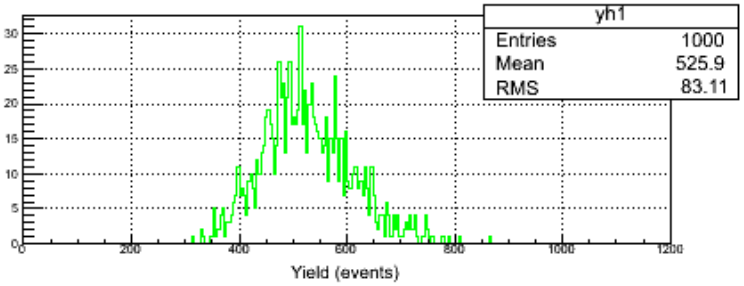

energyh3
Entries 1000
Mean 8.1
RMS 0.008181
Energy (MeV)

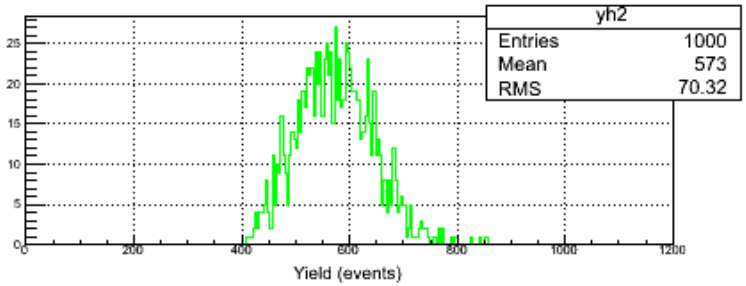

energyh4
Entries 1000
Mean 8.2
RMS 0.008254
Energy (MeV)

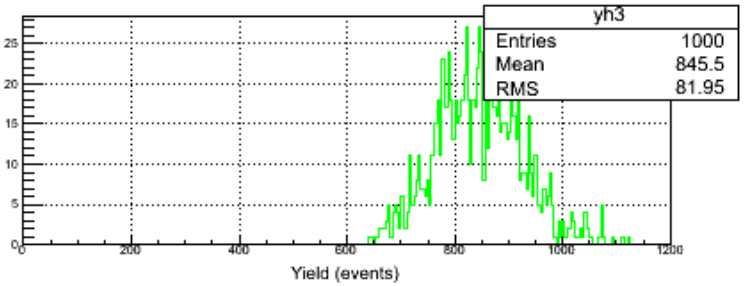

energyh5
Entries 1000
Mean 8.3
RMS 0.008337
Energy (MeV)

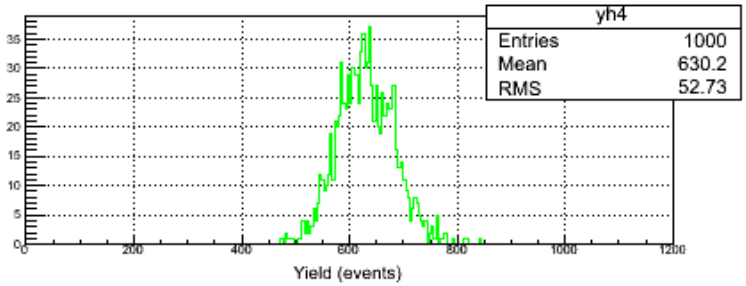

energyh6
Entries 1000
Mean 8.4
RMS 0.008303
Energy (MeV)

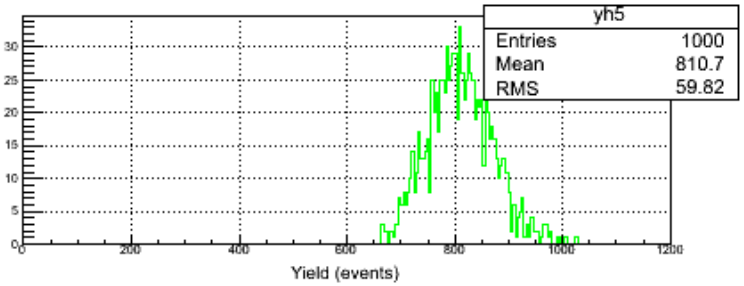

energyh7
Entries 1000
Mean 8.5
RMS 0.008274
Energy (MeV)

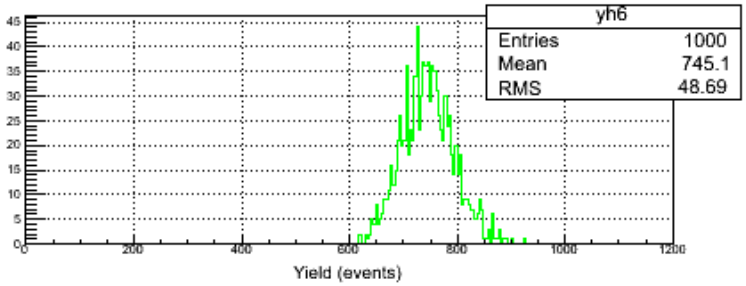

yh1
Entries 1000
Mean 525.9
RMS 83.11
Yield (events)

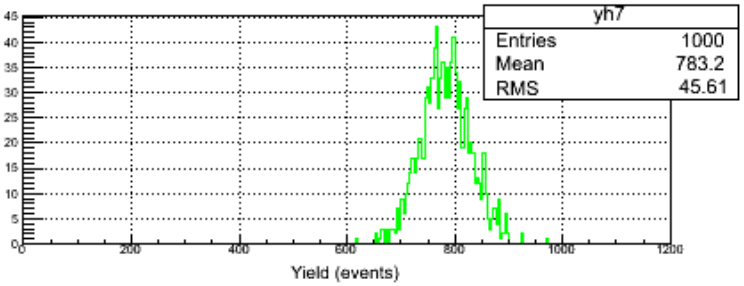

yh2
Entries 1000
Mean 573
RMS 70.32
Yield (events)

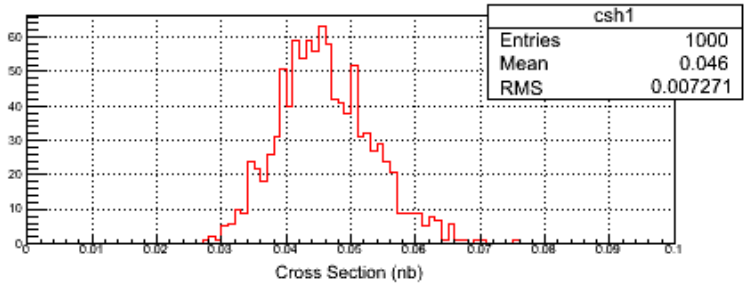

yh3
Entries 1000
Mean 845.5
RMS 81.95
Yield (events)

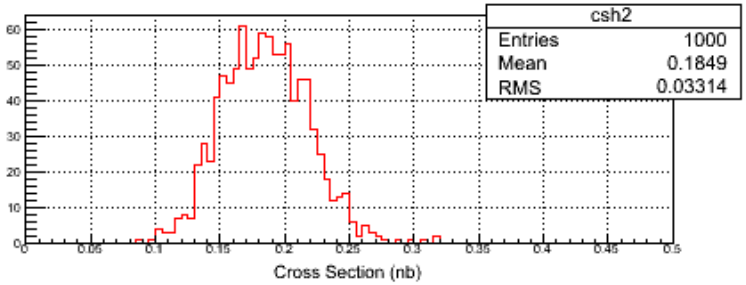

yh4
Entries 1000
Mean 630.2
RMS 52.73
Yield (events)

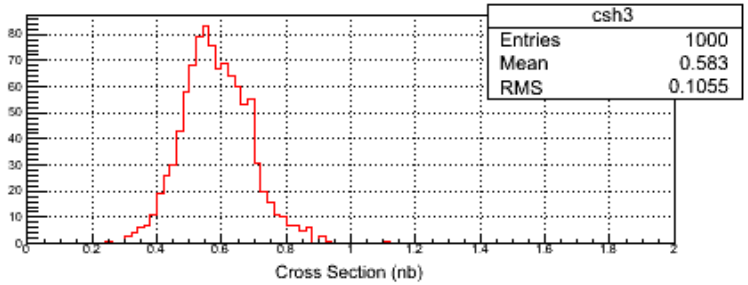

yh5
Entries 1000
Mean 810.7
RMS 59.82
Yield (events)

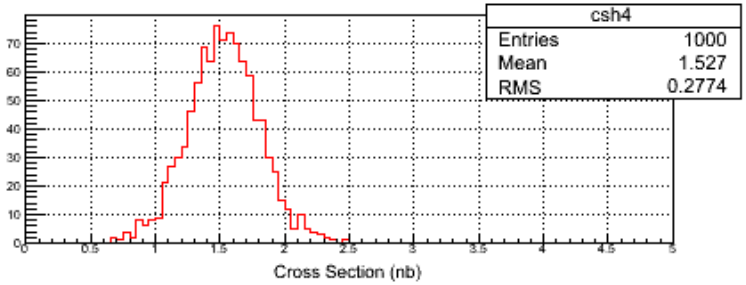

yh6
Entries 1000
Mean 745.1
RMS 48.69
Yield (events)

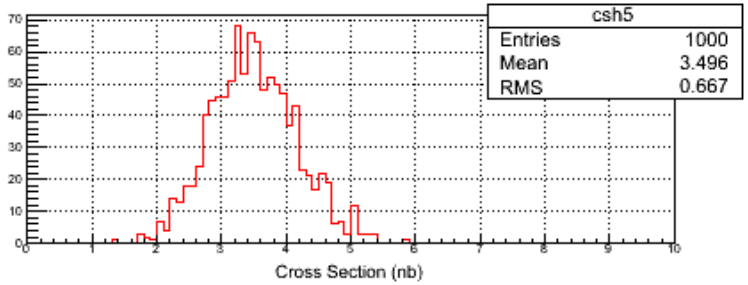

yh7
Entries 1000
Mean 783.2
RMS 45.61
Yield (events)

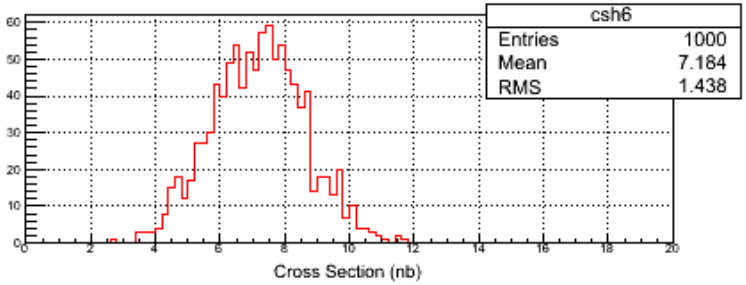

csh1
Entries 1000
Mean 0.046
RMS 0.007271
Cross Section (nb)

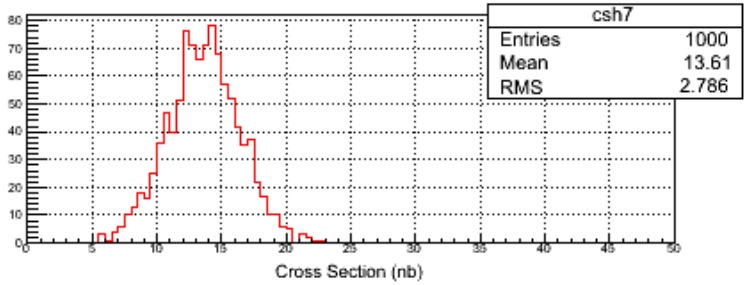

csh2
Entries 1000
Mean 0.1849
RMS 0.03314
Cross Section (nb)


csh3
Entries 1000
Mean 0.583
RMS 0.1055
Cross Section (nb)


csh4
Entries 1000
Mean 1.527
RMS 0.2774
Cross Section (nb)


csh5
Entries 1000
Mean 3.496
RMS 0.667
Cross Section (nb)


csh6
Entries 1000
Mean 7.184
RMS 1.438
Cross Section (nb)


csh7
Entries 1000
Mean 13.61
RMS 2.786
Cross Section (nb)

Systematic Errors

I. Calculate the N_{ij} for each nominal beam energy, E_i (since we will use GEANT4)

II. Allow for absolute beam energy to change by:

$$E_i = E_i * gRandom->Gaus(1, 0.001)$$

III. Calculate the yield

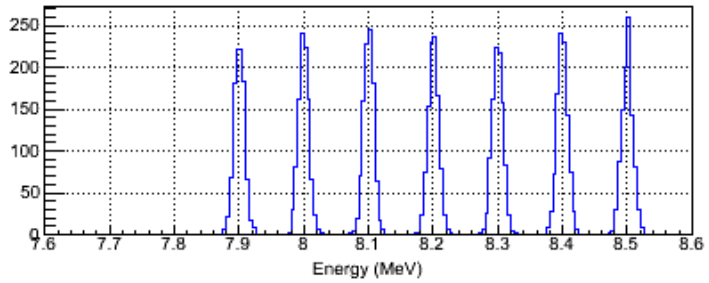
IV. Include other systematic errors:

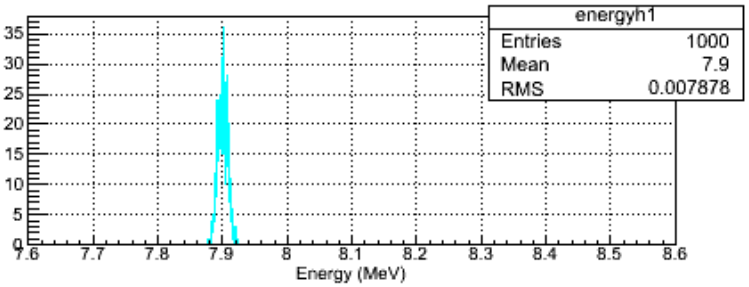
$$N_{ij} = N_{ij} * gRandom->Gaus(1, \delta\varphi/\varphi)$$

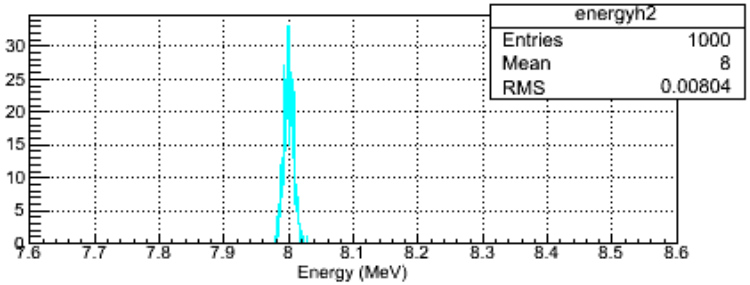
$$y_i = y_i * gRandom->Gaus(1, Sqrt(\delta I/I^2 + \delta R/R^2 + \delta T/T^2 + \varepsilon^2)$$

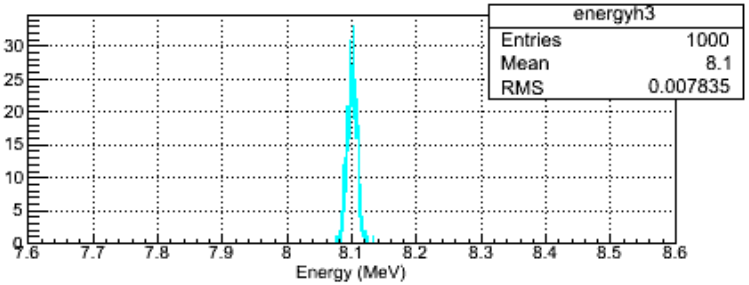
V. Unfold cross section

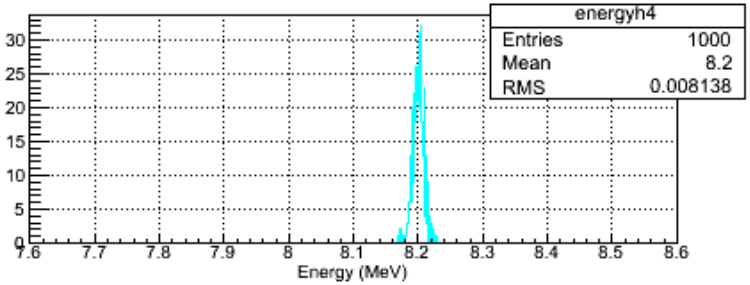
VI. Repeat for 1000 tries

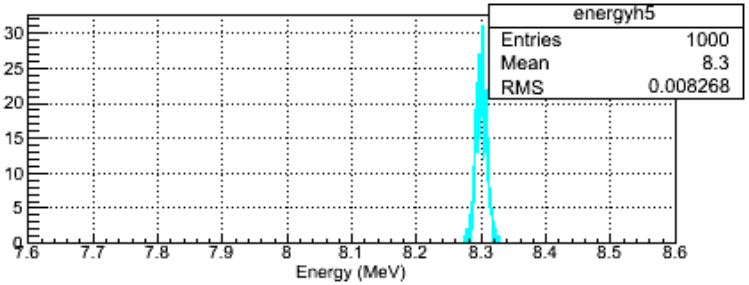

Energy (MeV)

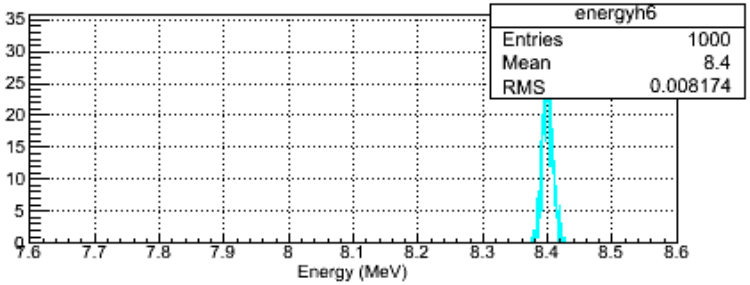

energyh1
Entries 1000
Mean 7.9
RMS 0.007878
Energy (MeV)

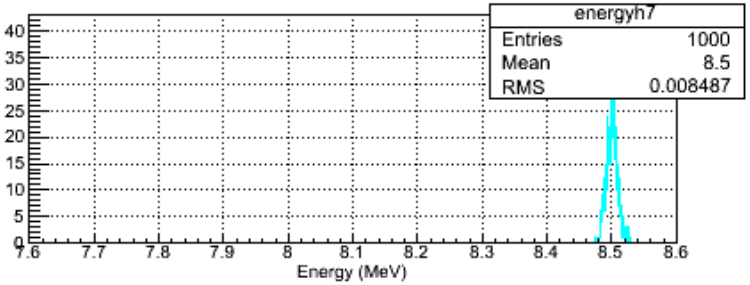

energyh2
Entries 1000
Mean 8
RMS 0.00804
Energy (MeV)

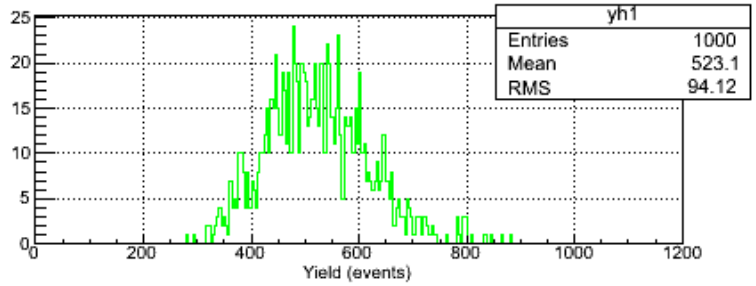

energyh3
Entries 1000
Mean 8.1
RMS 0.007835
Energy (MeV)

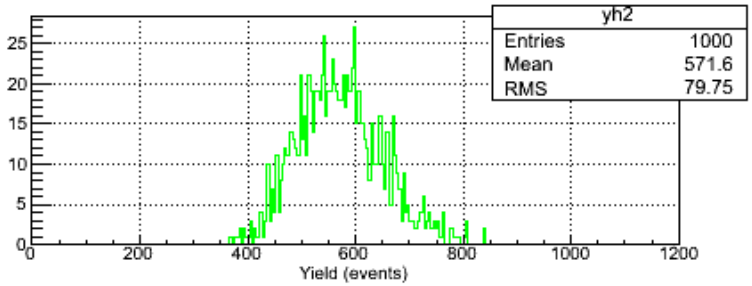

energyh4
Entries 1000
Mean 8.2
RMS 0.008138
Energy (MeV)

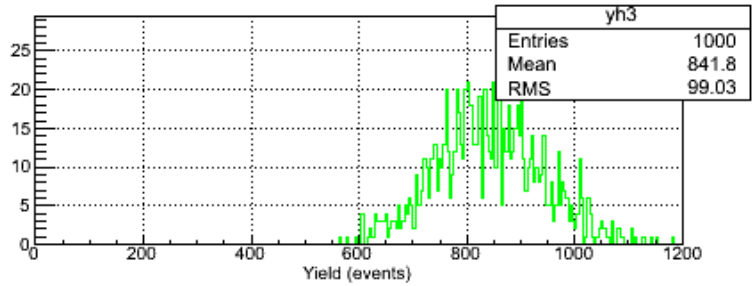

energyh5
Entries 1000
Mean 8.3
RMS 0.008268
Energy (MeV)

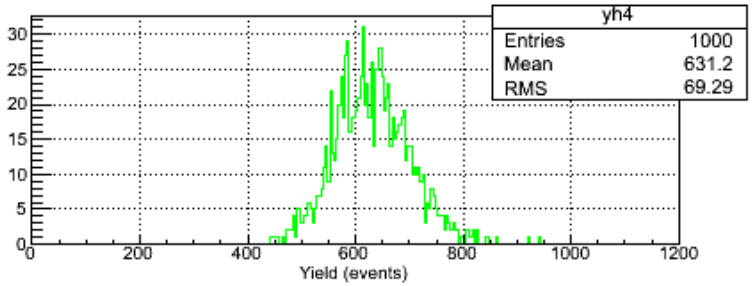

energyh6
Entries 1000
Mean 8.4
RMS 0.008174
Energy (MeV)

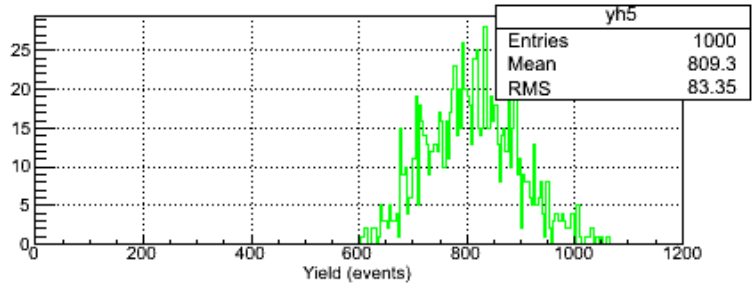

energyh7
Entries 1000
Mean 8.5
RMS 0.008487
Energy (MeV)

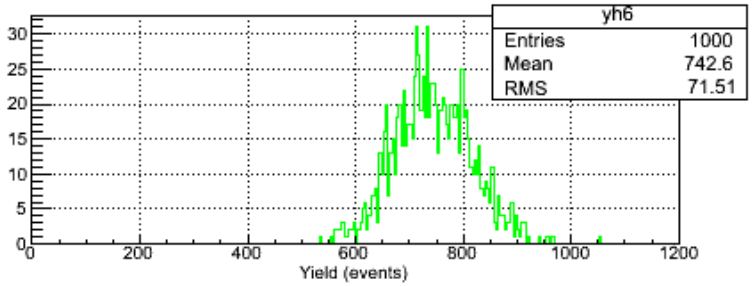

yh1
Entries 1000
Mean 523.1
RMS 94.12
Yield (events)

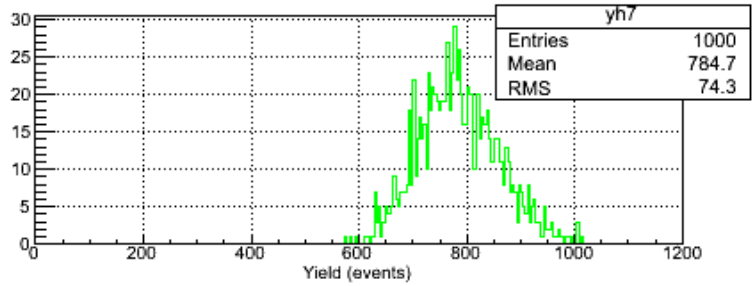

yh2
Entries 1000
Mean 571.6
RMS 79.75
Yield (events)

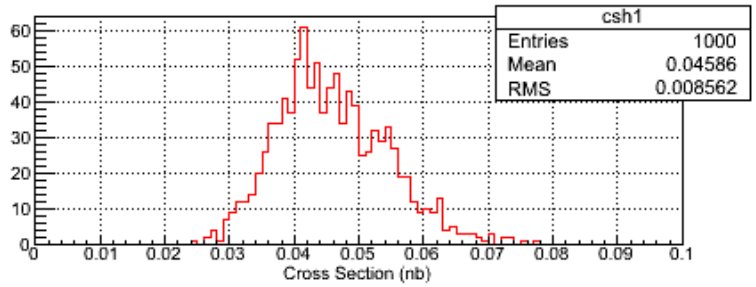

yh3
Entries 1000
Mean 841.8
RMS 99.03
Yield (events)

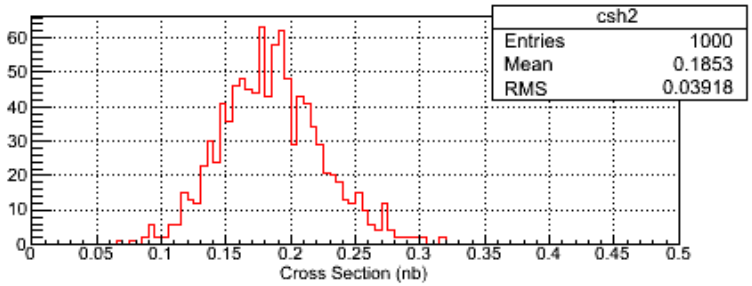

yh4
Entries 1000
Mean 631.2
RMS 69.29
Yield (events)

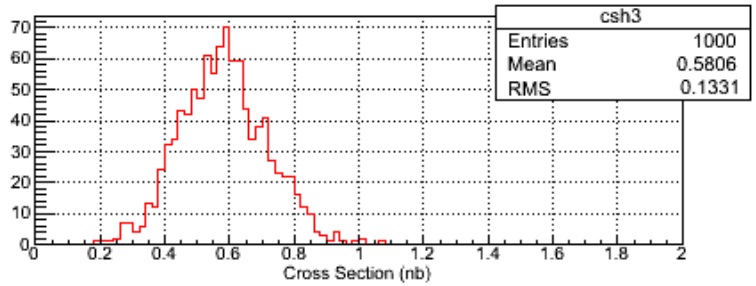

yh5
Entries 1000
Mean 809.3
RMS 83.35
Yield (events)

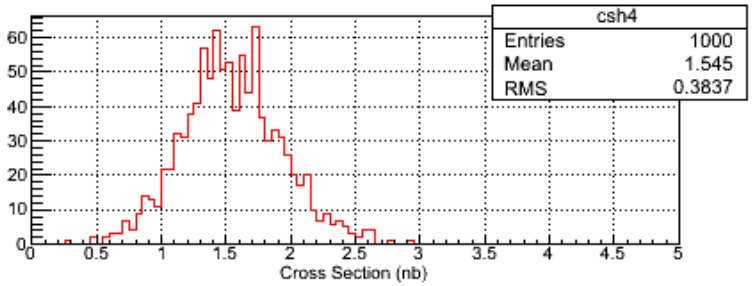

yh6
Entries 1000
Mean 742.6
RMS 71.51
Yield (events)

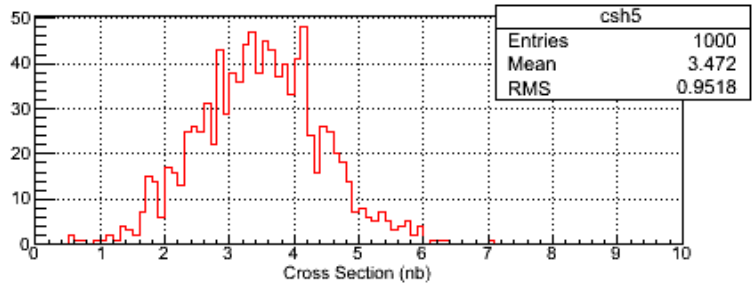

yh7
Entries 1000
Mean 784.7
RMS 74.3
Yield (events)

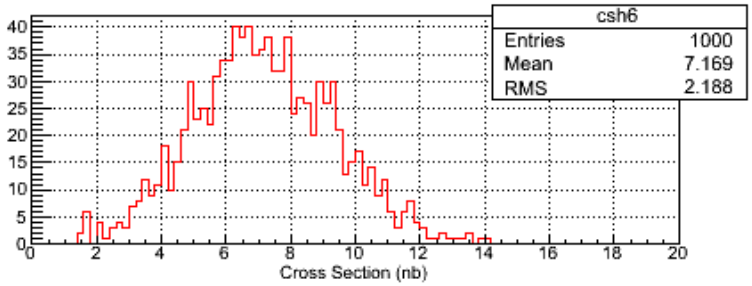

csh1
Entries 1000
Mean 0.04586
RMS 0.008562
Cross Section (nb)

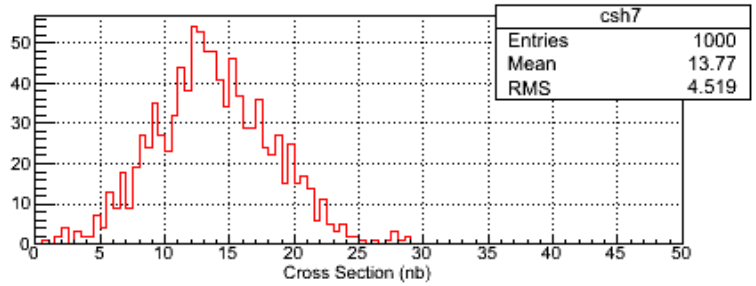

csh2
Entries 1000
Mean 0.1853
RMS 0.03918
Cross Section (nb)


csh3
Entries 1000
Mean 0.5806
RMS 0.1331
Cross Section (nb)


csh4
Entries 1000
Mean 1.545
RMS 0.3837
Cross Section (nb)


csh5
Entries 1000
Mean 3.472
RMS 0.9518
Cross Section (nb)


csh6
Entries 1000
Mean 7.169
RMS 2.188
Cross Section (nb)


csh7
Entries 1000
Mean 13.77
RMS 4.519
Cross Section (nb)

Electron Beam K. E.	Beam Current (μA)	Time (hour)	y_i	dy_i/y_i (%)
7.9	100	100	523	18.0
8.0	100	20	572	14.0
8.1	80	10	842	11.8
8.2	20	10	631	11.0
8.3	10	10	809	10.3
8.4	4	10	743	9.6
8.5	2	10	785	9.5

Electron Beam K. E.	Cross Section (nb)	Sys Error (Total, %)
7.9	0.046	18.7
8.0	0.185	21.1
8.1	0.58	22.9
8.2	1.54	24.8
8.3	3.48	27.4
8.4	7.2	30.5
8.5	13.8	32.8

Systematic Error – Relative Beam Energy

I. Calculate the N_{ij} for each nominal beam energy, E_i (since we will use GEANT4)

II. Allow for absolute beam energy 7.8 MeV to change by:

$$E_0 = 7.8 * gRandom->Gaus(1, 0.001)$$

III. Higher energies has zero relative error,

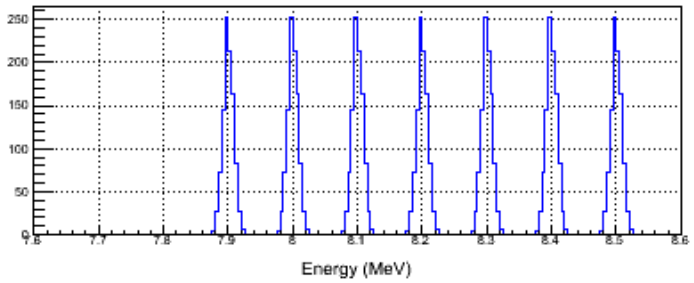
$$E_i = E_0 + i\Delta$$

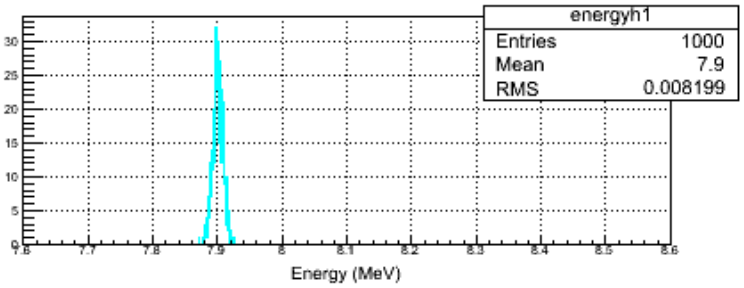
IV. Calculate the yield

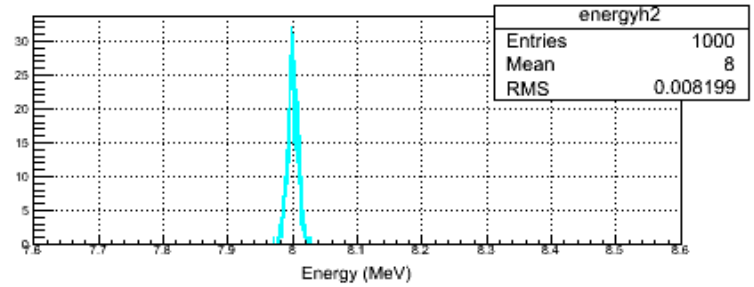
V. Unfold cross section

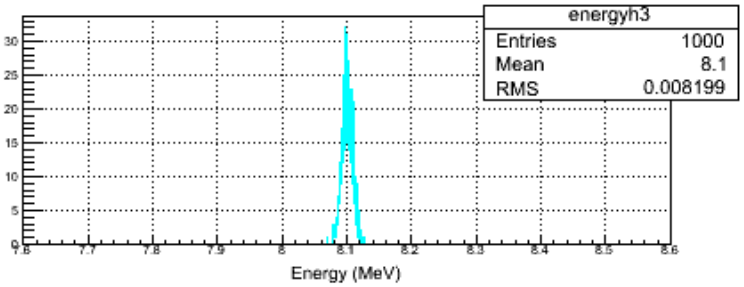
VI. Repeat for 1000 tries

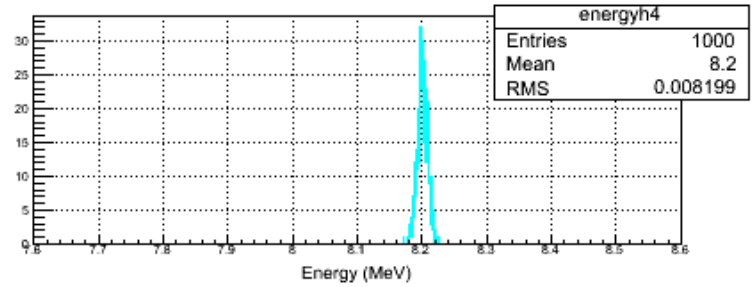
Now, we have to worry about beam stability (RF stability). Need injector FFB system to maintain relative beam stability

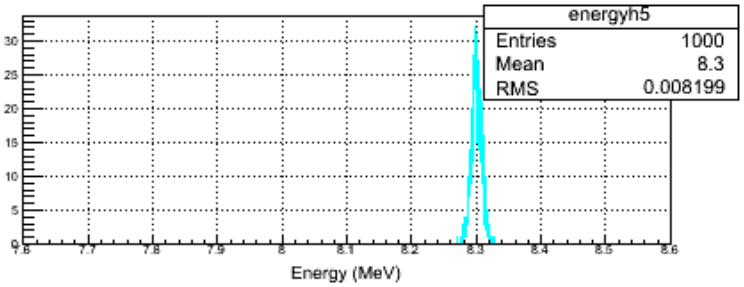

Energy (MeV)

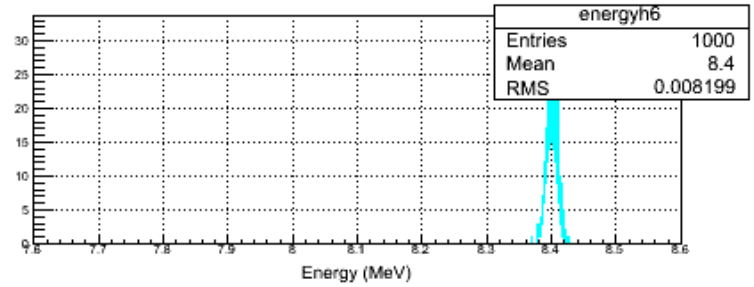

energyh1
Entries 1000
Mean 7.9
RMS 0.008199
Energy (MeV)

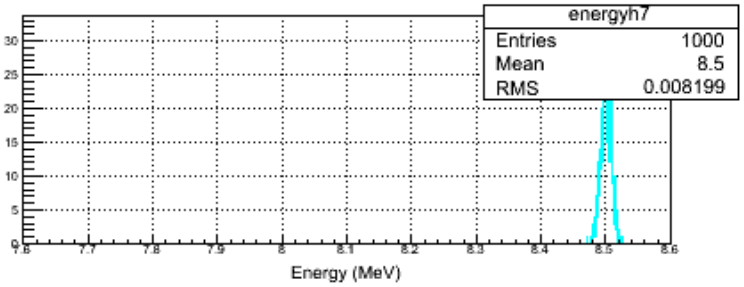

energyh2
Entries 1000
Mean 8
RMS 0.008199
Energy (MeV)

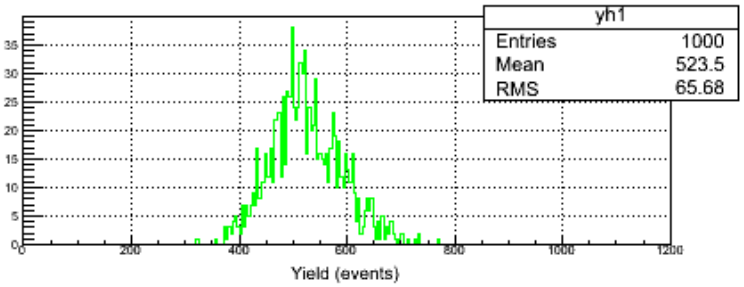

energyh3
Entries 1000
Mean 8.1
RMS 0.008199
Energy (MeV)

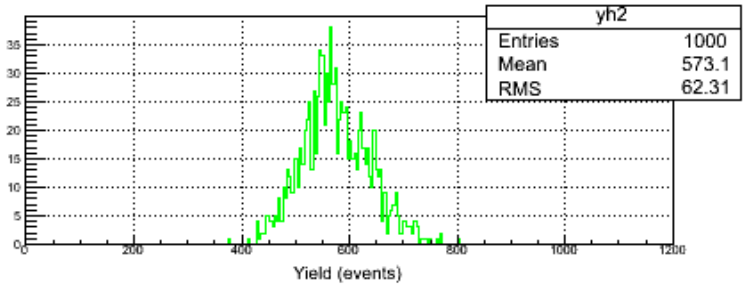

energyh4
Entries 1000
Mean 8.2
RMS 0.008199
Energy (MeV)

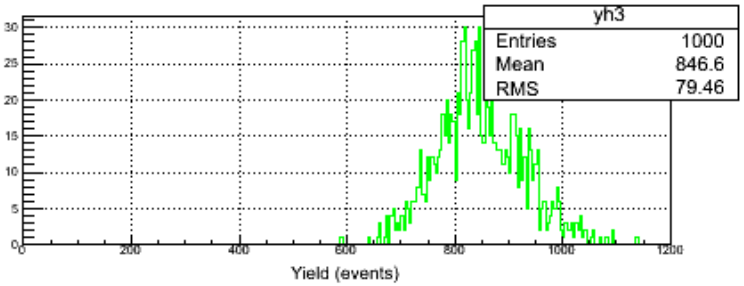

energyh5
Entries 1000
Mean 8.3
RMS 0.008199
Energy (MeV)

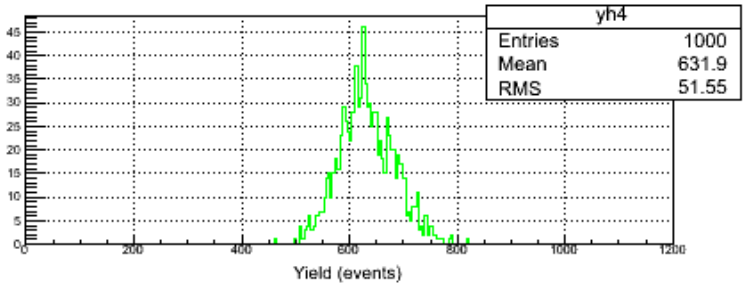

energyh6
Entries 1000
Mean 8.4
RMS 0.008199
Energy (MeV)

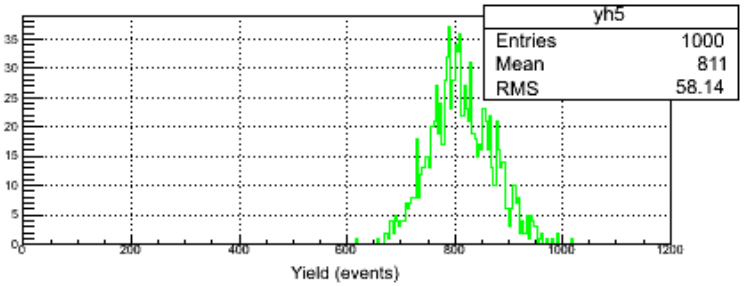

energyh7
Entries 1000
Mean 8.5
RMS 0.008199
Energy (MeV)

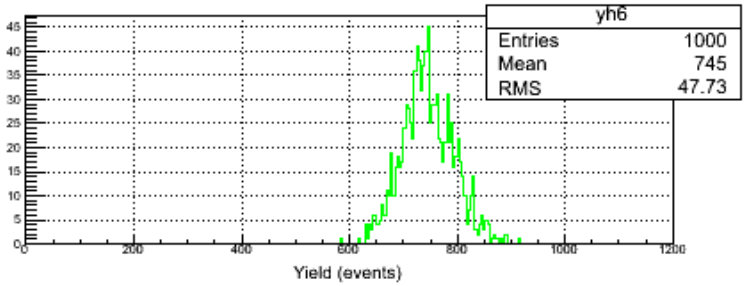

yh1
Entries 1000
Mean 523.5
RMS 65.68
Yield (events)

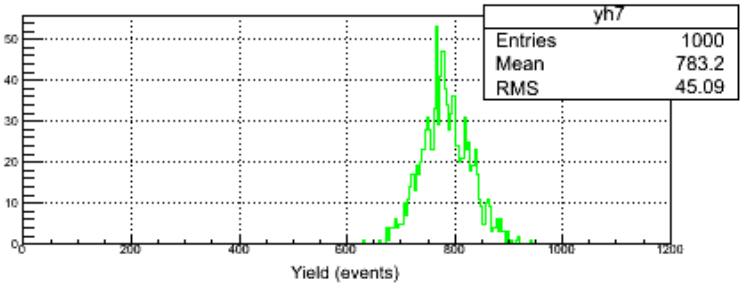

yh2
Entries 1000
Mean 573.1
RMS 62.31
Yield (events)

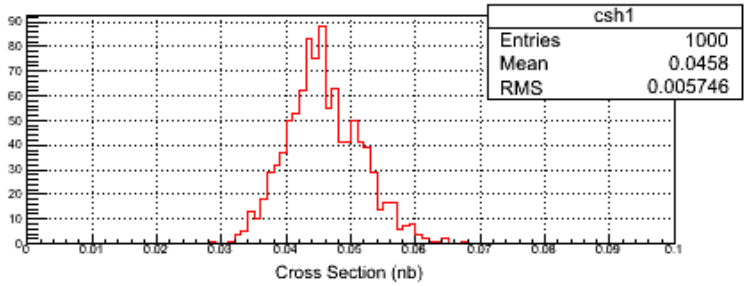

yh3
Entries 1000
Mean 846.6
RMS 79.46
Yield (events)

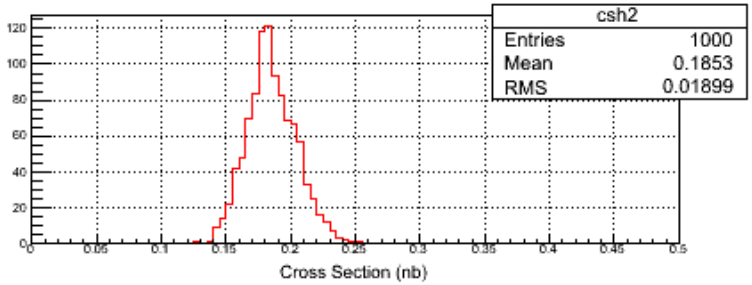

yh4
Entries 1000
Mean 631.9
RMS 51.55
Yield (events)

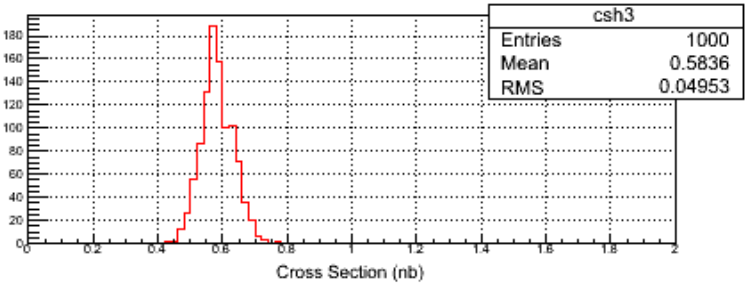

yh5
Entries 1000
Mean 811
RMS 58.14
Yield (events)

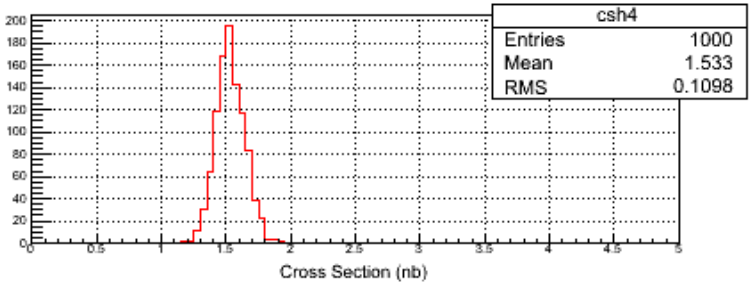

yh6
Entries 1000
Mean 745
RMS 47.73
Yield (events)

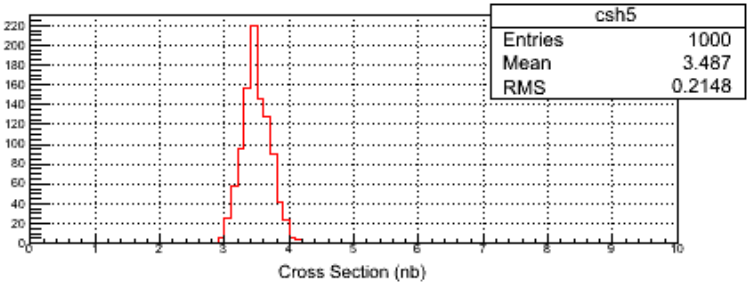

yh7
Entries 1000
Mean 783.2
RMS 45.09
Yield (events)

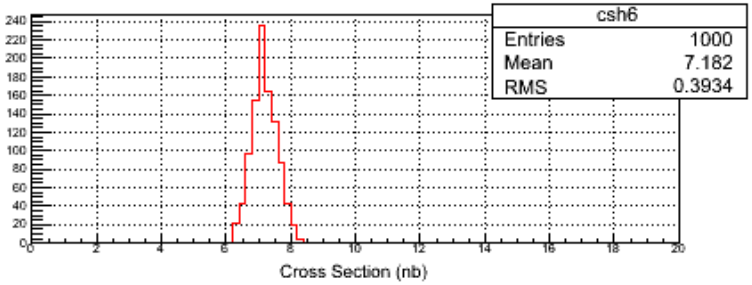

csh1
Entries 1000
Mean 0.0458
RMS 0.005746
Cross Section (nb)

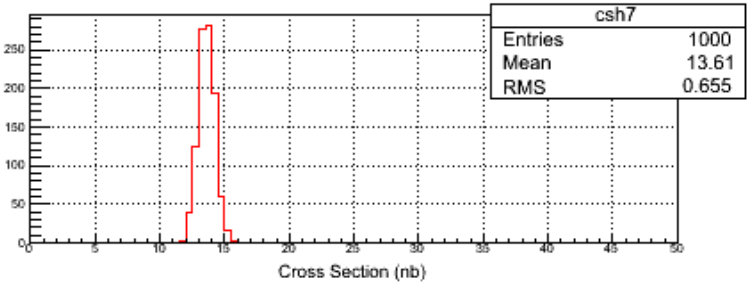

csh2
Entries 1000
Mean 0.1853
RMS 0.01899
Cross Section (nb)


csh3
Entries 1000
Mean 0.5836
RMS 0.04953
Cross Section (nb)


csh4
Entries 1000
Mean 1.533
RMS 0.1098
Cross Section (nb)


csh5
Entries 1000
Mean 3.487
RMS 0.2148
Cross Section (nb)


csh6
Entries 1000
Mean 7.182
RMS 0.3934
Cross Section (nb)


csh7
Entries 1000
Mean 13.61
RMS 0.655
Cross Section (nb)

Electron Beam K. E.	Beam Current (μA)	Time (hour)	y_i	dy_i/y_i (%)
7.9	100	100	524	12.5
8.0	100	20	573	10.9
8.1	80	10	846	9.4
8.2	20	10	632	8.2
8.3	10	10	811	7.2
8.4	4	10	745	6.4
8.5	2	10	783	5.8

Electron Beam K. E.	Cross Section (nb)	Sys Error (Energy, %)
7.9	0.046	12.5
8.0	0.185	10.2
8.1	0.58	8.5
8.2	1.53	7.2
8.3	3.49	6.2
8.4	7.2	5.5
8.5	13.6	4.8