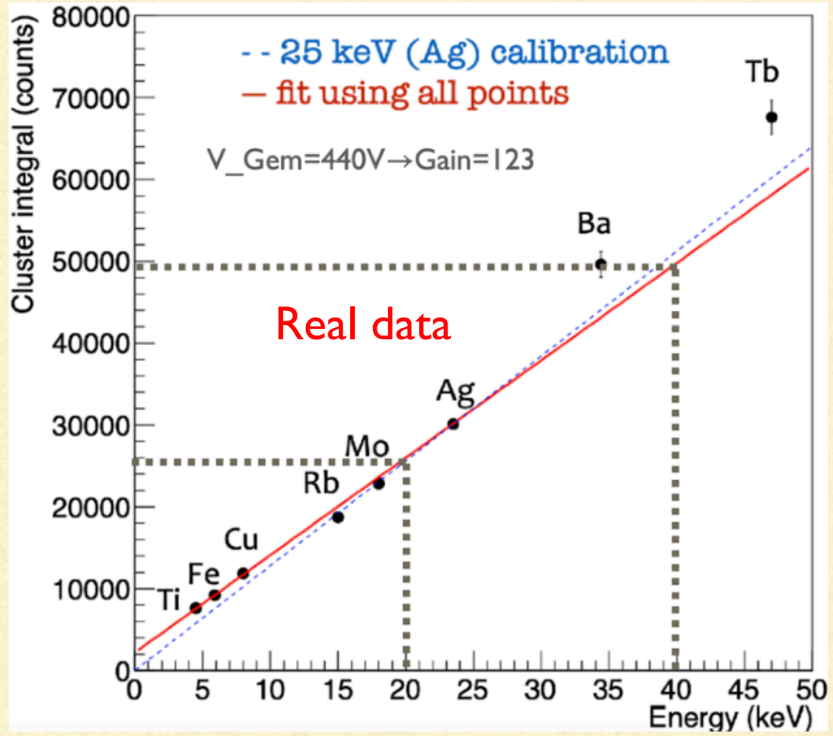
First results on data-MC comparison with low energy X-Ray in LIME

S.Torelli - E.Baracchini - E.Di Marco

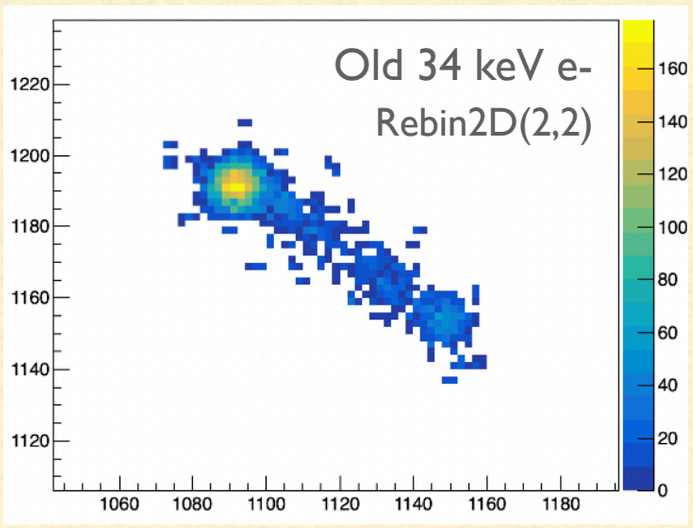
Preface

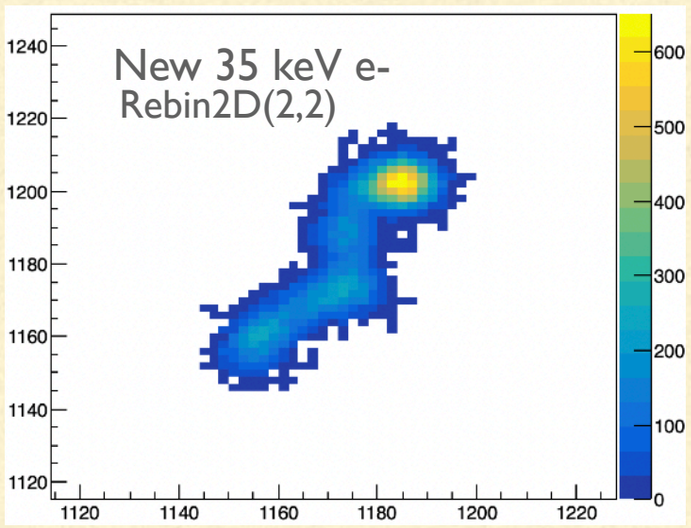
- To validate the directionality analysis we need to validate the Montecarlo

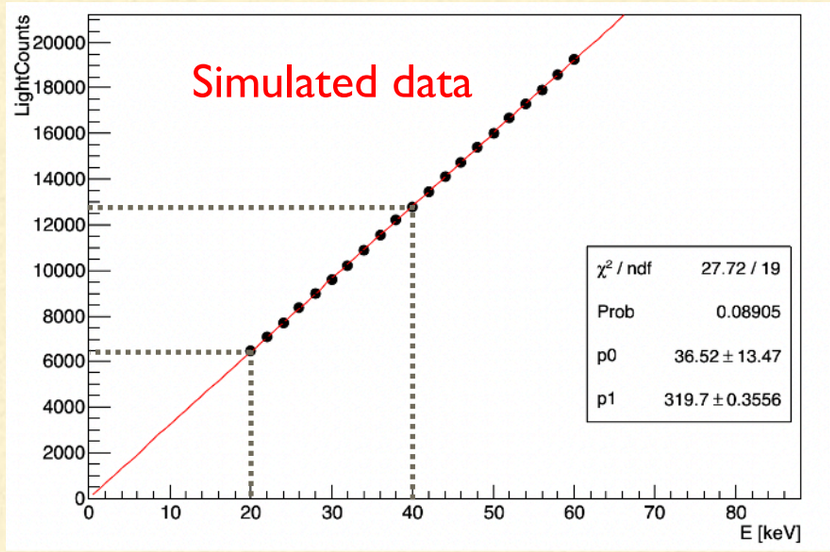
- In a first evaluation we noticed a factor ~4 of difference in light between data and MC



- Simulated data have been reproduced with the new code (which include the saturation effect)







The saturation effect

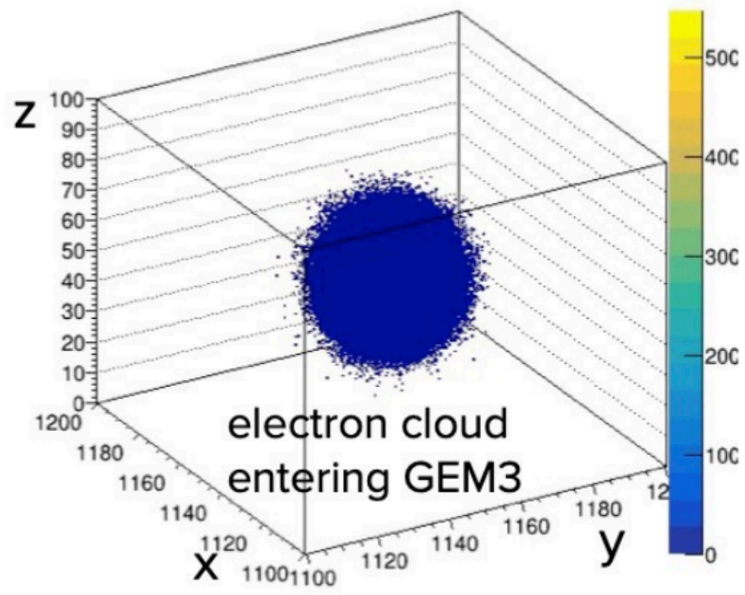
Simulation of the saturation

- The number of electrons entering GEM3 are calculated as before.
- The charge cloud have a 3D gaussian shape:

$\sigma_T = \sqrt{\sigma_{T_0}^2 + \sigma_{D,T}^2}$ in the plane of the GEM as before;

$\sigma_L = \sqrt{\sigma_{L_0}^2 + \sigma_{D,L}^2}$ along the z axis

- Clouds are divided in voxels (with the size of the pixels in the x-y plane and 2 x GEM thickness in z);



- Non saturated gain in GEM#1 and GEM#2 is assumed;
- the number n of electrons in each voxel is multiplied by a gain

$G = A\frac{g}{1+\frac{n}{n_h}(g-1)}$ where g is the no-saturated gain; A is an overall free parameter

- Total number of electrons is the sum of all voxels along z.
- The number of photons (in each x-y bin) is obtained as before (light yield, geometrical efficiency, …).

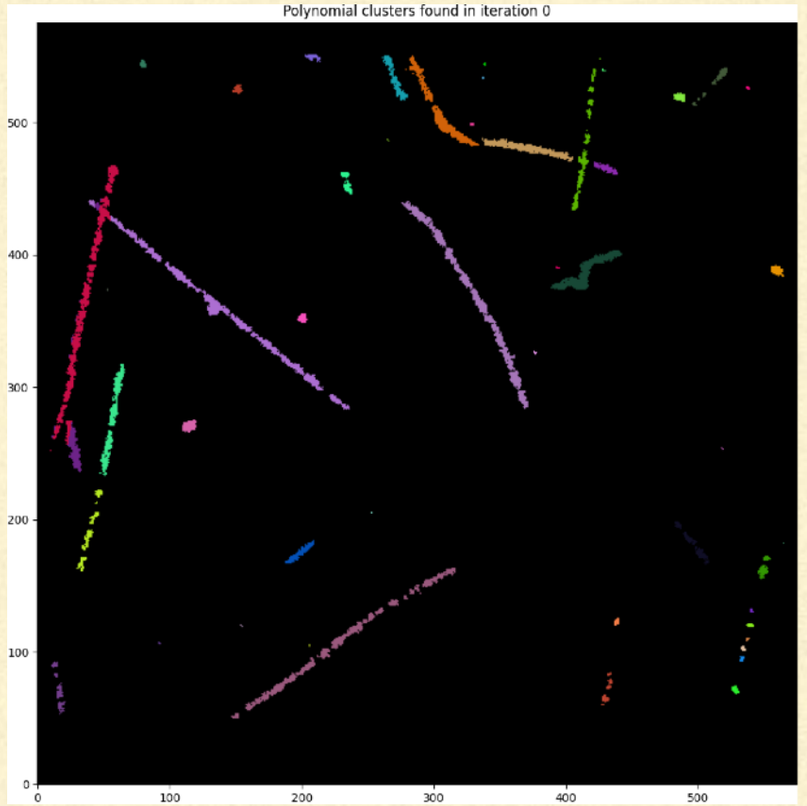
From a "simple" model:

$$G = \frac{Ae^{\alpha V_{GEM}}}{1 + \beta n_0 (e^{\alpha V_{GEM}} - 1)}$$

Comparison Between…

- High statistic data of x-Ray from different sources

5801	400	50	Xray source Cu 8.04/8.91 keV - 24cm distance from beginning of window
5806	400	50	Xray source Rb 13.4/15 keV - 24cm distance from beginning of window
5813	400	50	Xray source Mo 17.4/19.6 keV - 24cm distance from beginning of window
5825	400	50	Xray source Ag 22.1/25 keV - 24cm distance from beginning of window
5832	400	50	Xray source Ba 32.1/36.6 keV - 24cm distance from beginning of window
5848	400	50	Xray source Tb 44.2/50.6 keV - 24cm distance from beginning of window



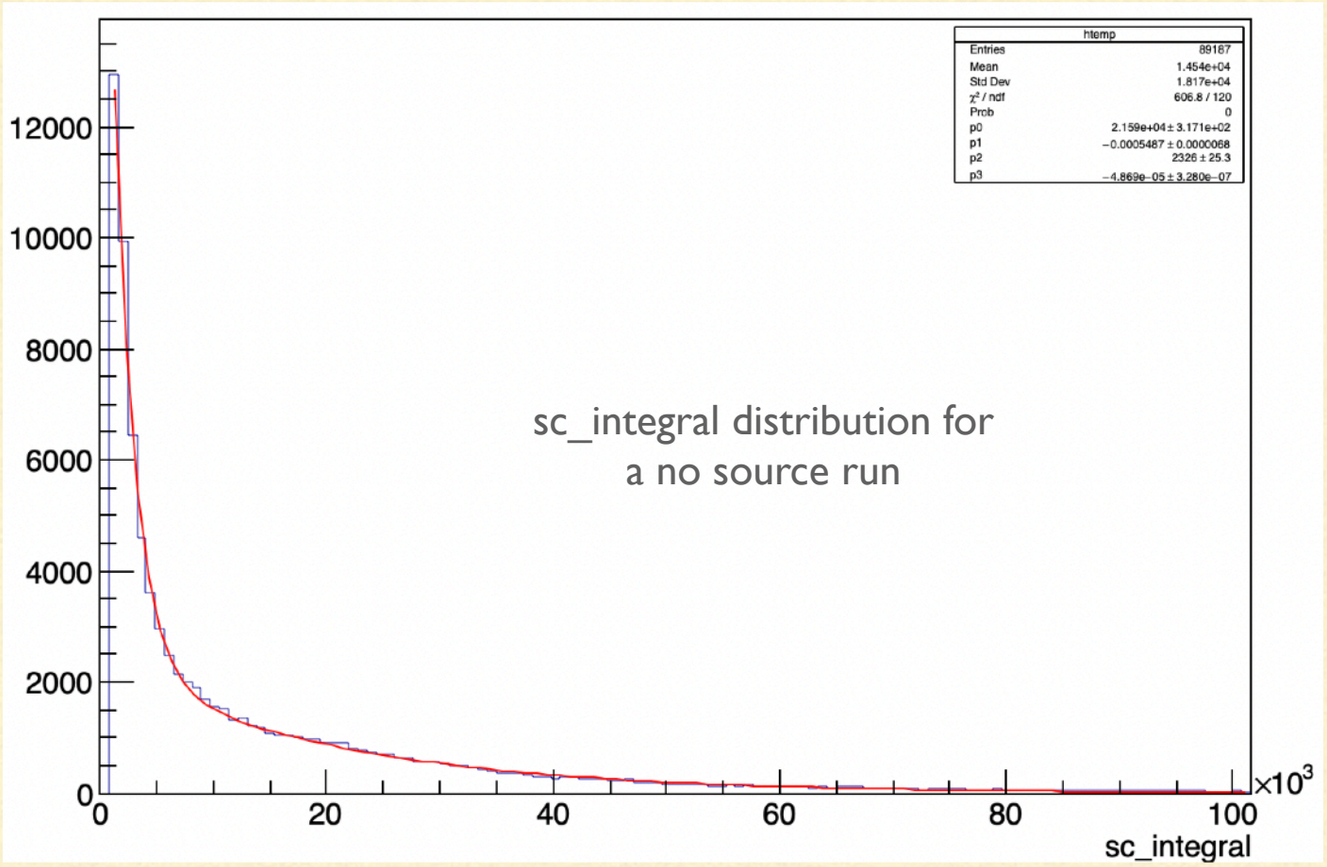
…and…

- Data digitized with the digitization code with saturation
- 500 tracks per energy
- Energies at: 8, 15, 18, 24, 35,45 keV
- Diffusion uniform within 5- 45 cm
- Reconstructed with same reconstruction code with same parameters of data
- Variables compared:
  - Integral
  - Lenght
  - Width
  - Slimness
  - Density (light/npixels)
  - dEdx (light/lenght)
  - TGaussMean
  - TGaussSigma
  - Cluster nhits
  - Cluster size

Study on linearity and energy resolution

Strategy and Background modeling

- Strategy: fit of signal component over the background component evaluated on the sidebands of the distribution
- RooFit used with unbind likelihood fit on the data
- First background studies from the no source run



sc_integral distribution for a no source run

- Cuts:
  - length<500 (remove cosmics)
  - integral>1000 (fake cluster remotion)

$$b(x) = By(c \cdot e^{(\alpha_1 \cdot x)} + (1 - c) \cdot e^{(\alpha_2 \cdot x)})$$

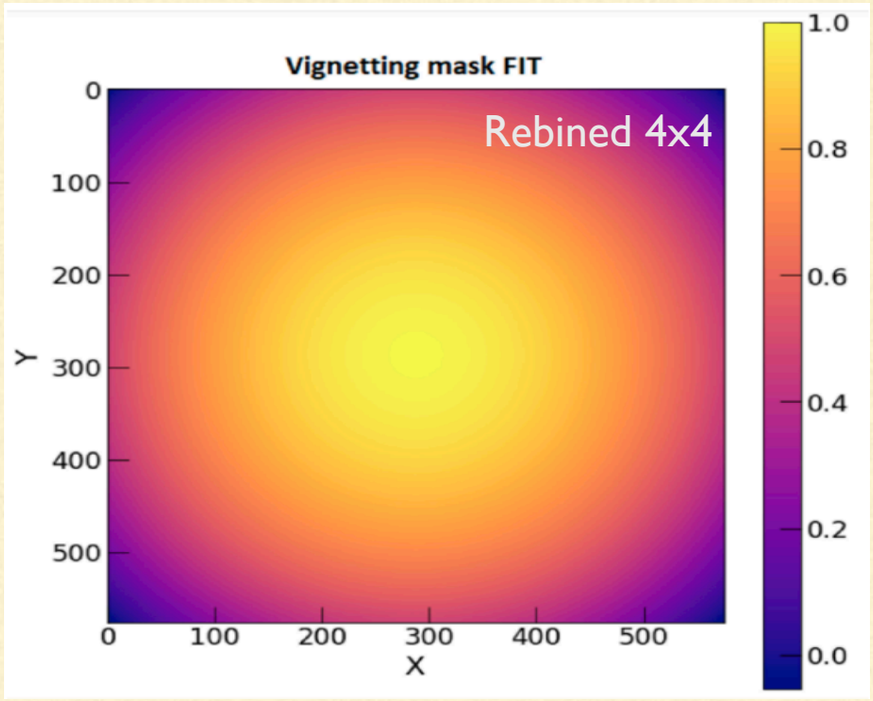
Coefficient to weight the two component

Fake cluster component

Physics component

Fit results

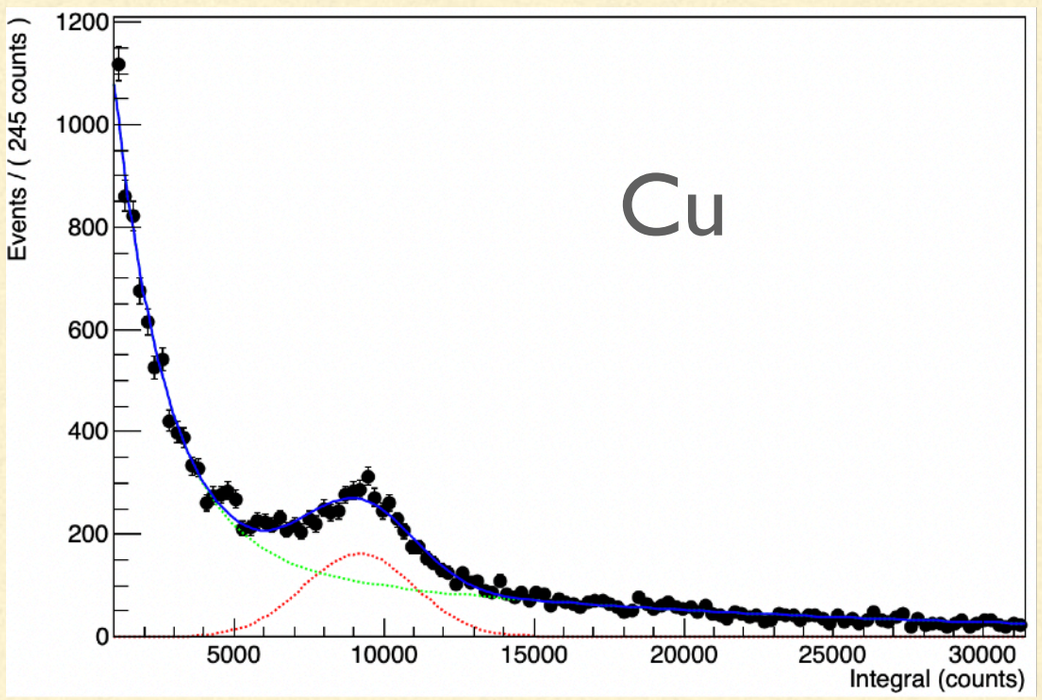
Selection length<500 integral>1000 and event in a radius of 1000 from the center of the picture (vignetting)

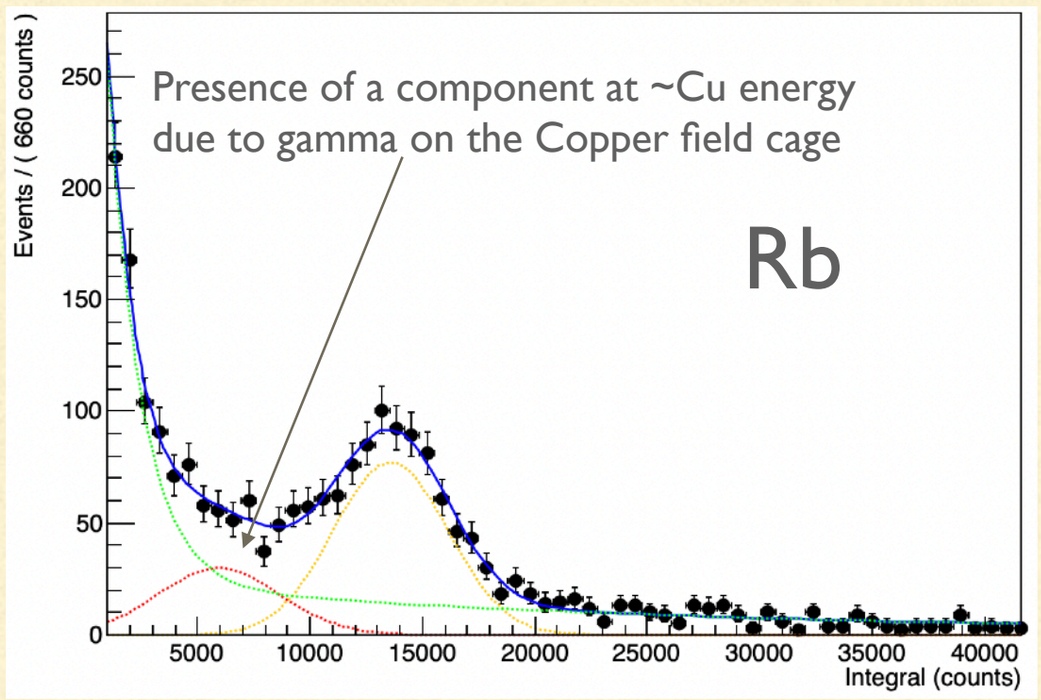


Parameters of the fit for 1 signal component

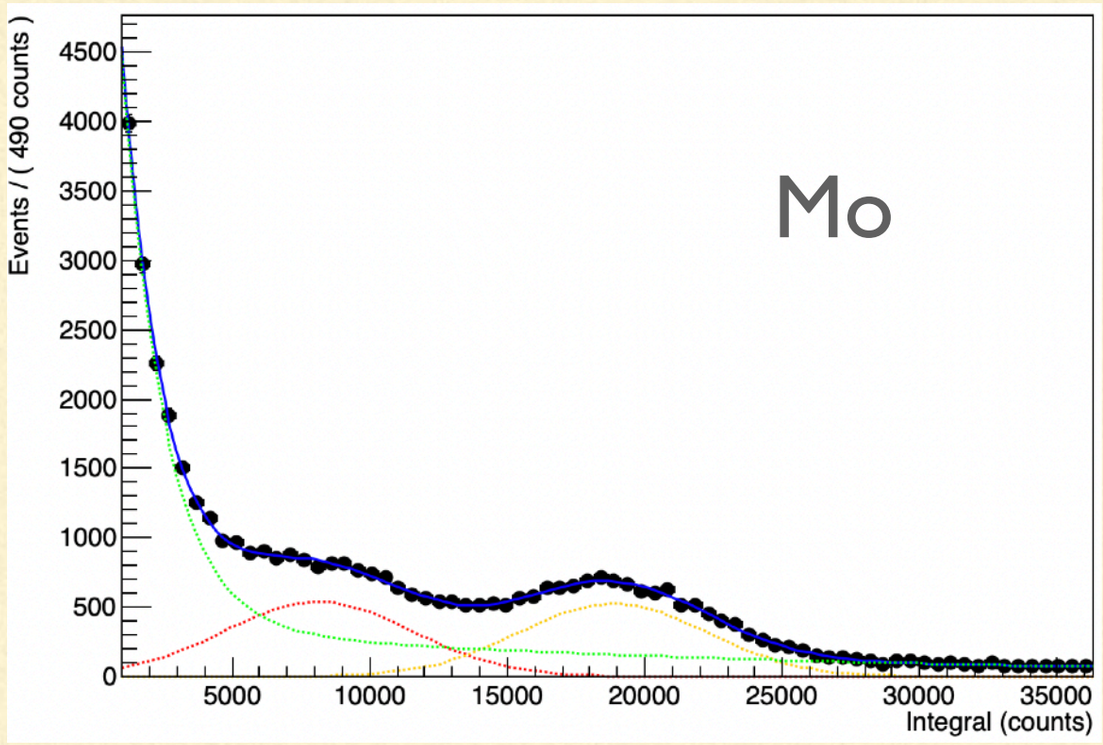
NO.	NAME	VALUE	ERROR	STEP SIZE	VALUE
1	alpha1	-5.81286e-04	1.97088e-05	1.18432e-04	1.05730e+00
2	alpha2	-6.05128e-05	1.77088e-06	5.42959e-06	1.40797e+00
3	bkgYield	1.69208e+04	2.07392e+02	2.65526e-05	-1.25859e+00
4	coeff	3.80460e-01	1.16467e-02	2.38017e-04	-2.41419e-01
5	mean	9.17576e+03	7.60068e+01	3.79573e-04	1.94293e-01
6	sigma	1.85037e+03	1.01406e+02	1.06464e-04	-3.17660e-01
7	signalYield	3.05915e+03	1.70743e+02	1.93020e-05	-1.21924e+00

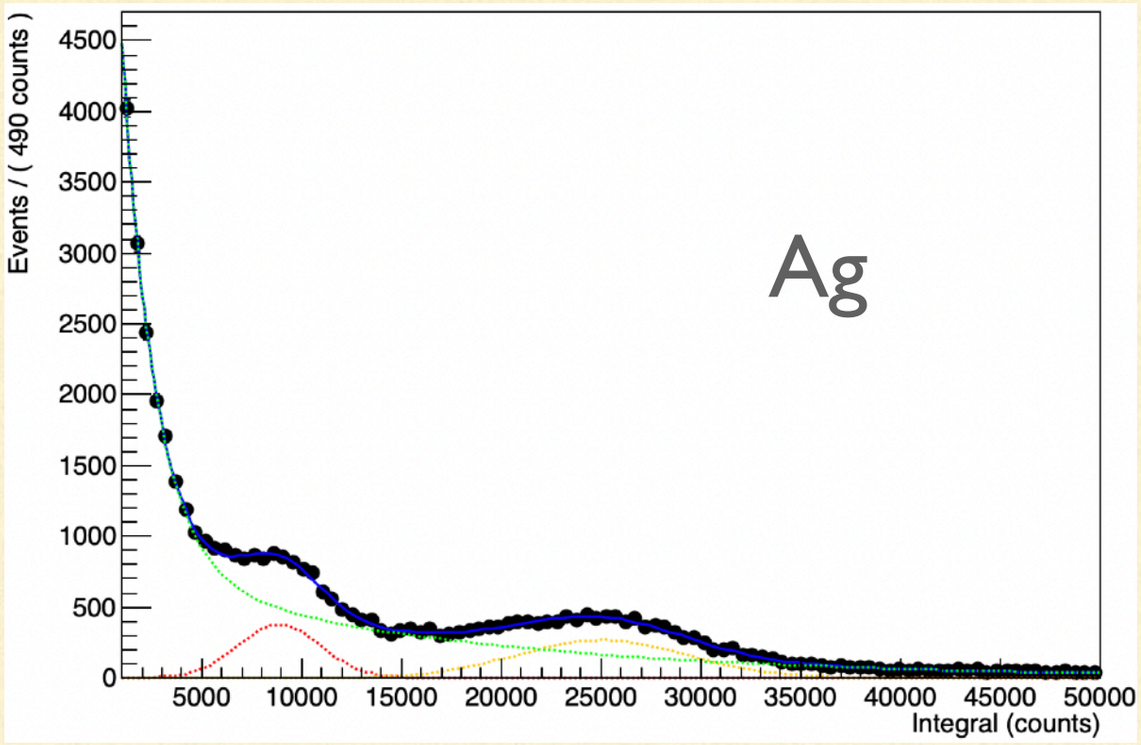
All the parameters let free to vary (a possible constrain of some parameter should be evaluated)

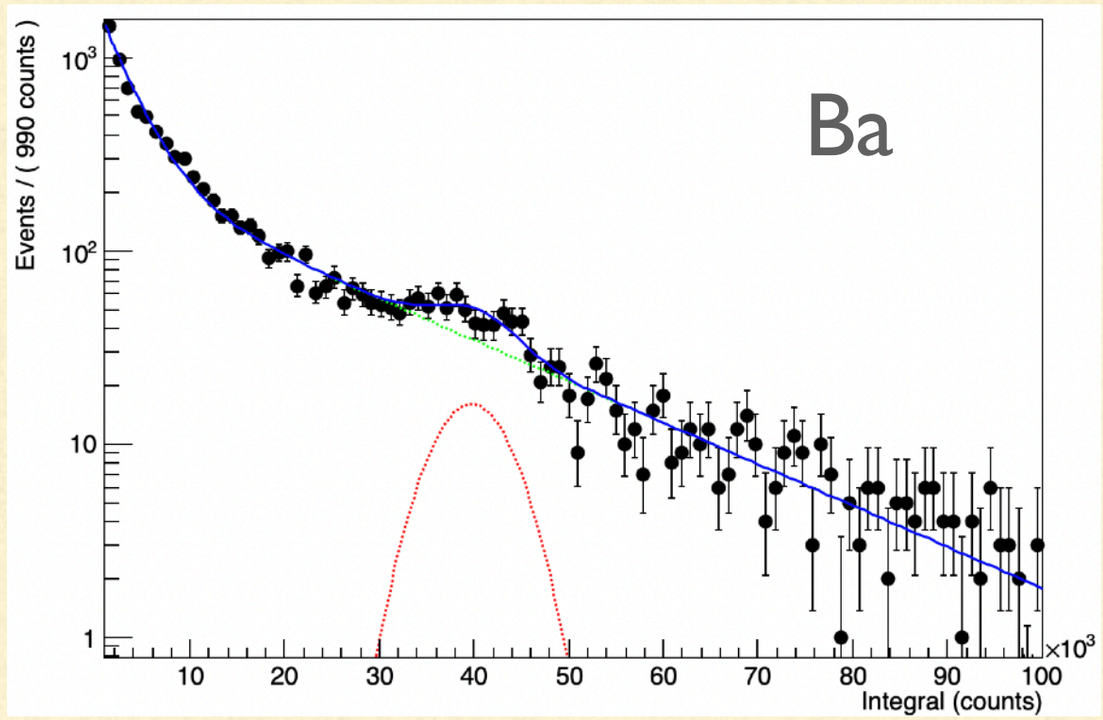


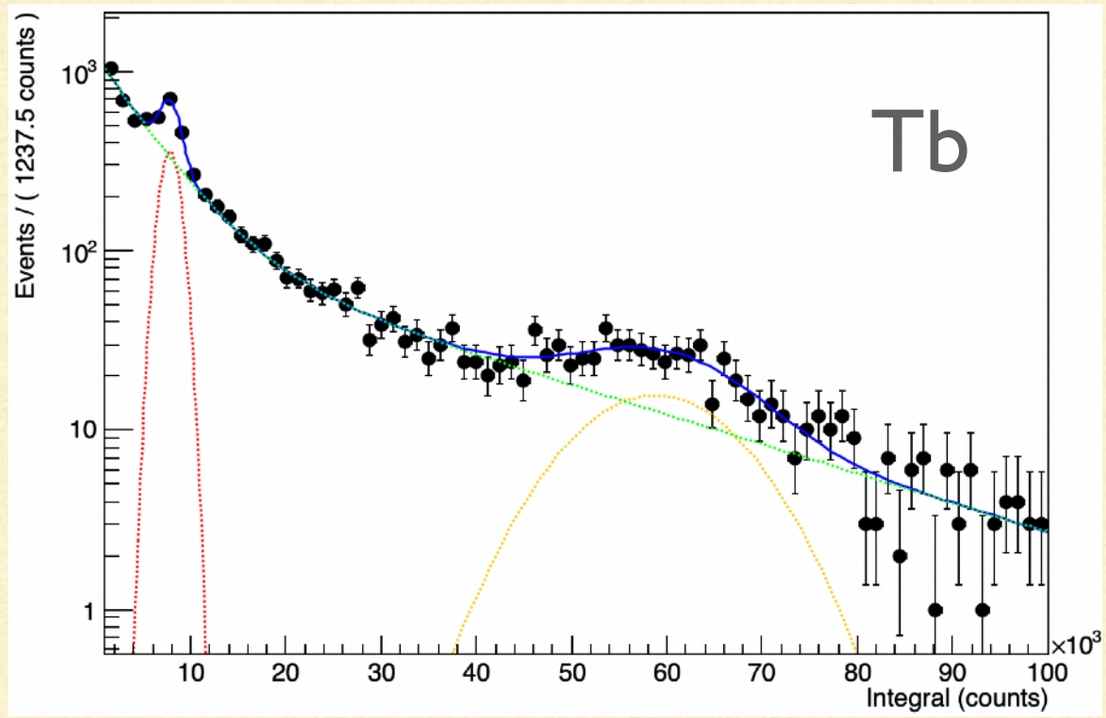


Fit results


Mo
Events / (490 counts)
Integral (counts)

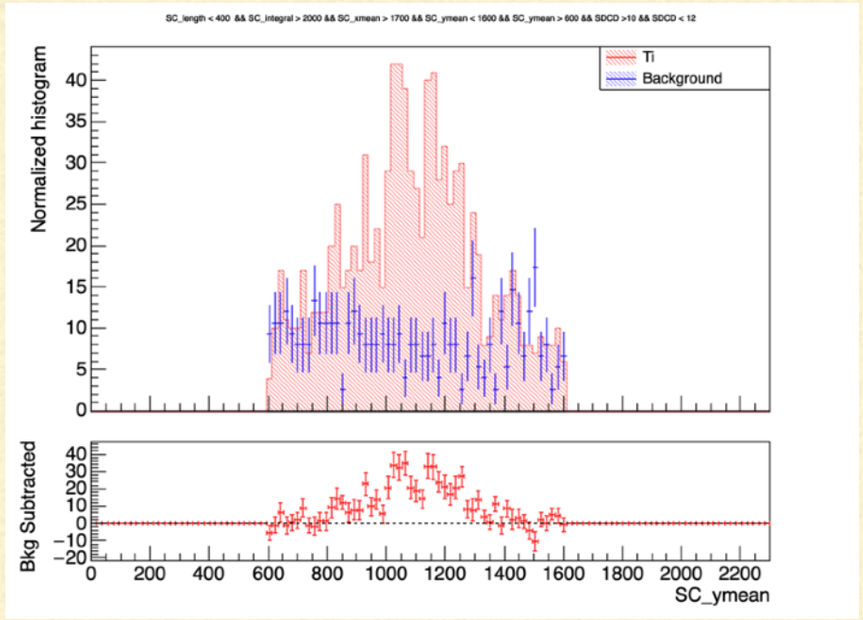

Ag
Events / (490 counts)
Integral (counts)

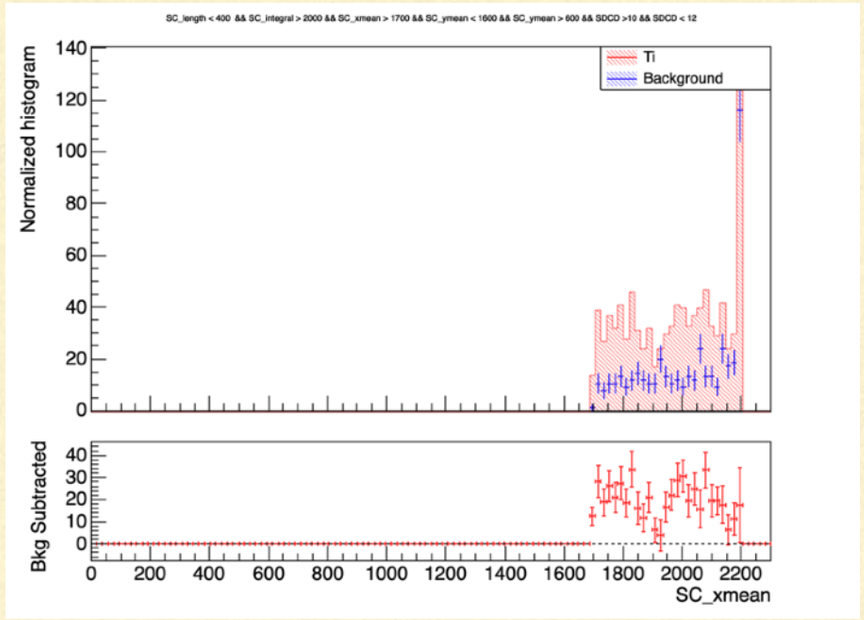

Ba
Events / (990 counts)
×10³
Integral (counts)


Tb
Events / (1237.5 counts)
×10³
Integral (counts)

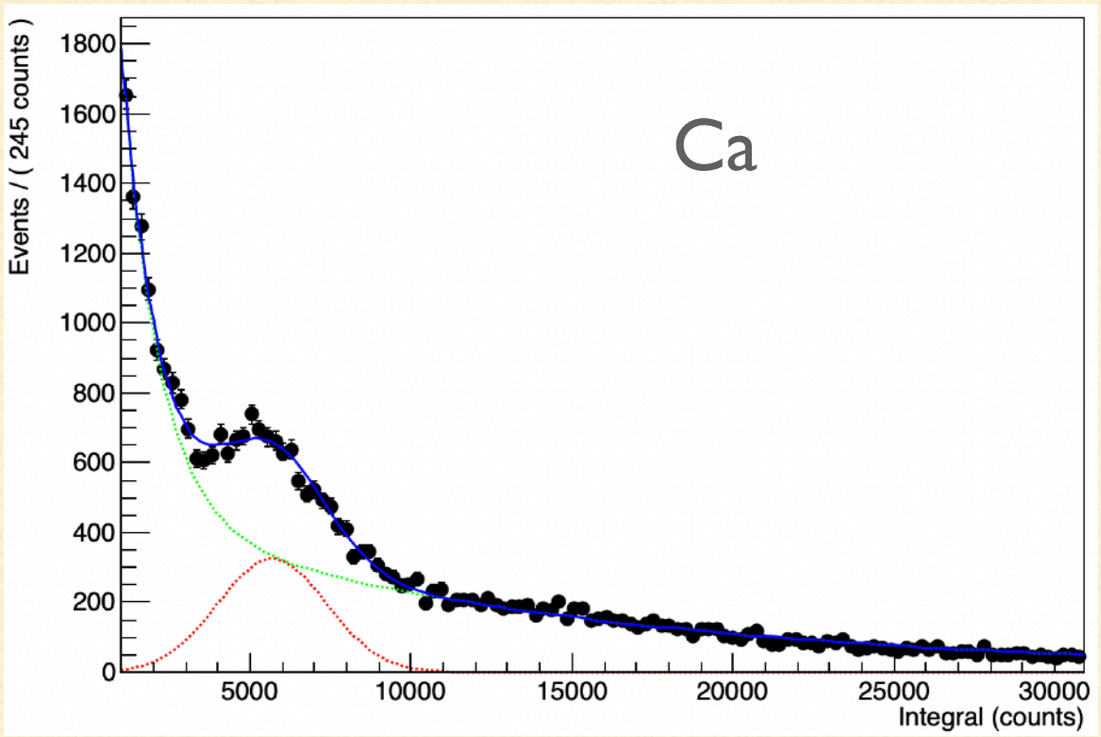
Fit results

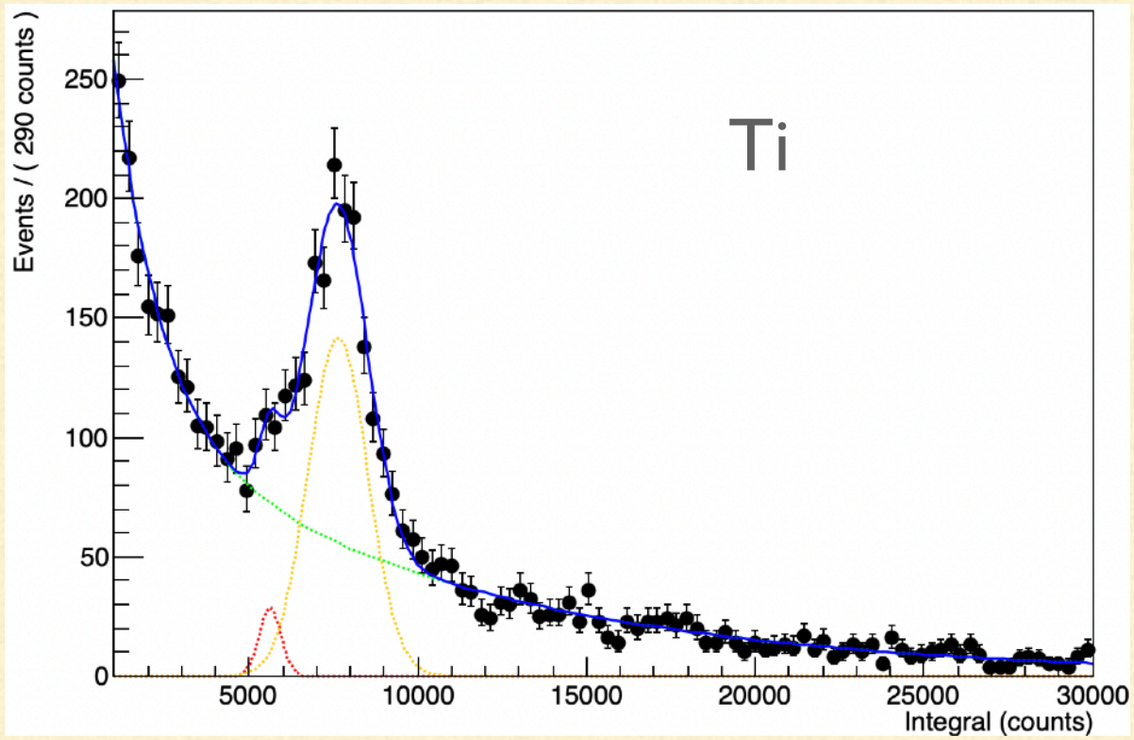
- Data taken impinging 6 keV X-Rays from ^{55}Fe source on Ti foil and piece of chalk



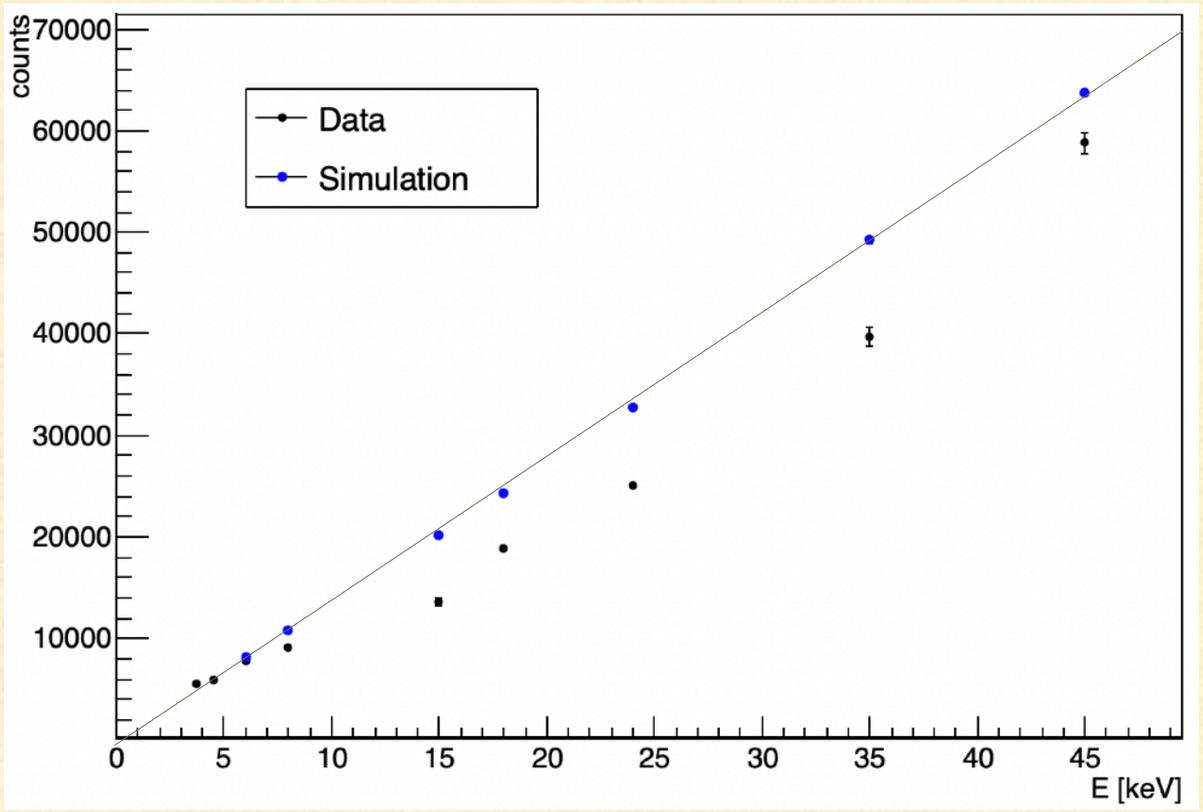


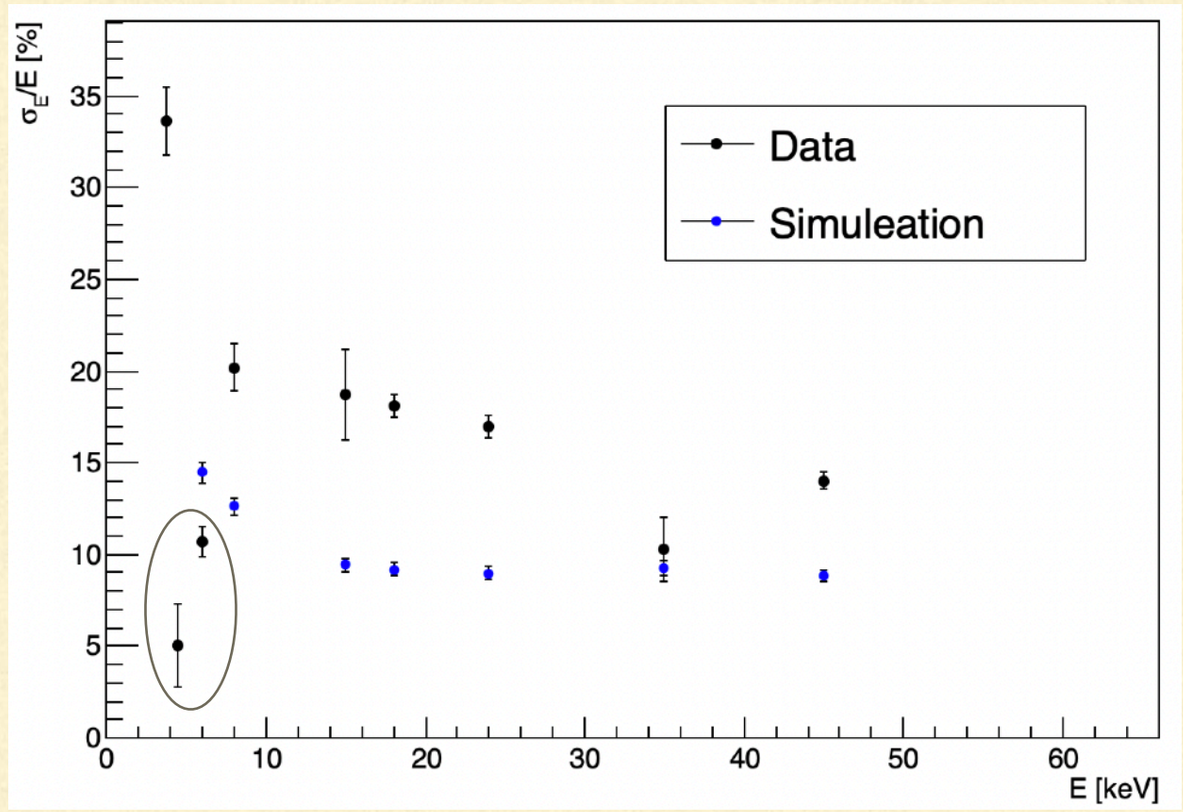
- Selection length<500 integral>1000 and constrain in 1700<xmean<2100 and 900<ymean<1400 (signal to noise ratio improvement, small path of such low energy X-Ray)





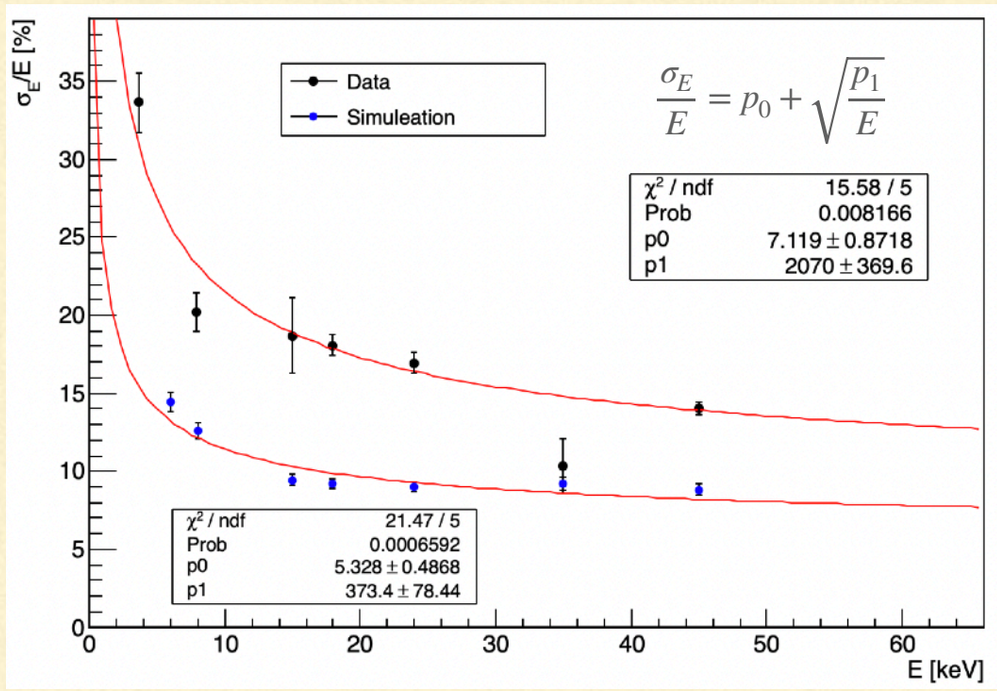
Linearity and Energy Resolution





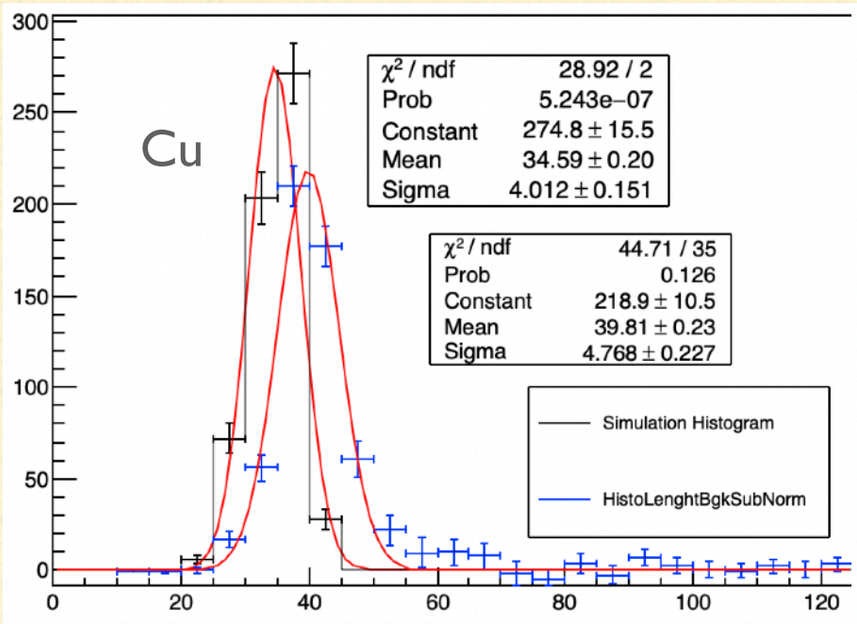
- Linear behaviour on simulation while not on data
- Too small EReso on Fe and Ti (effect of the selection?)

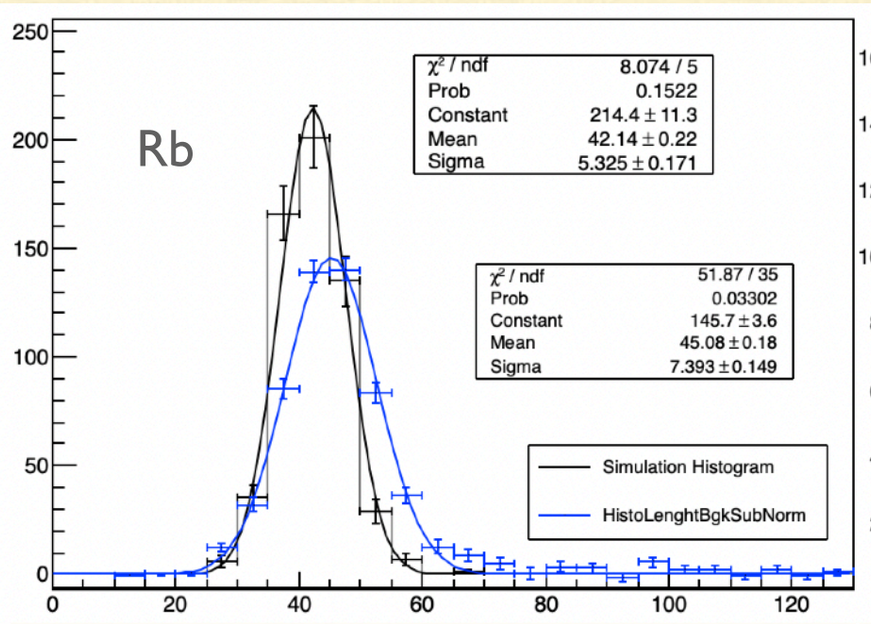
Data without Ti and Fe

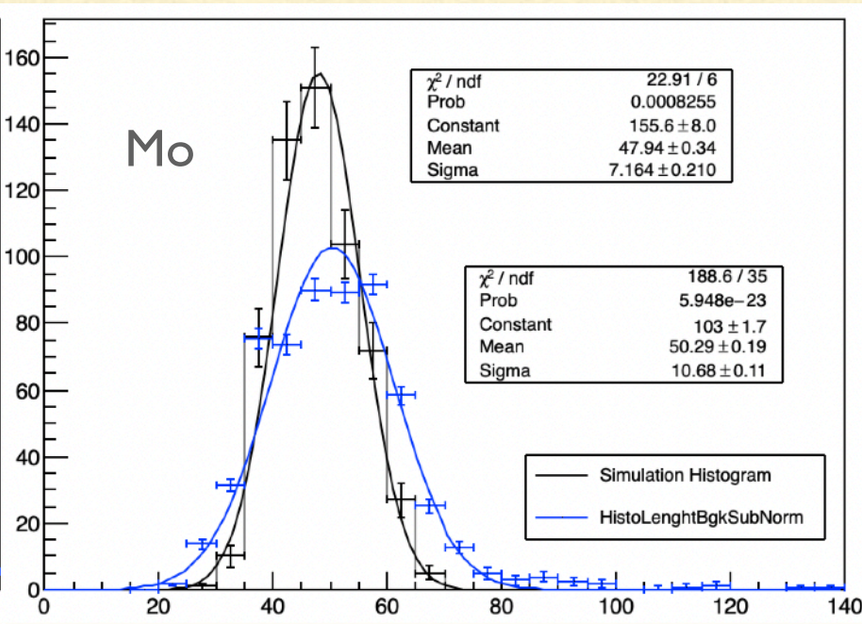


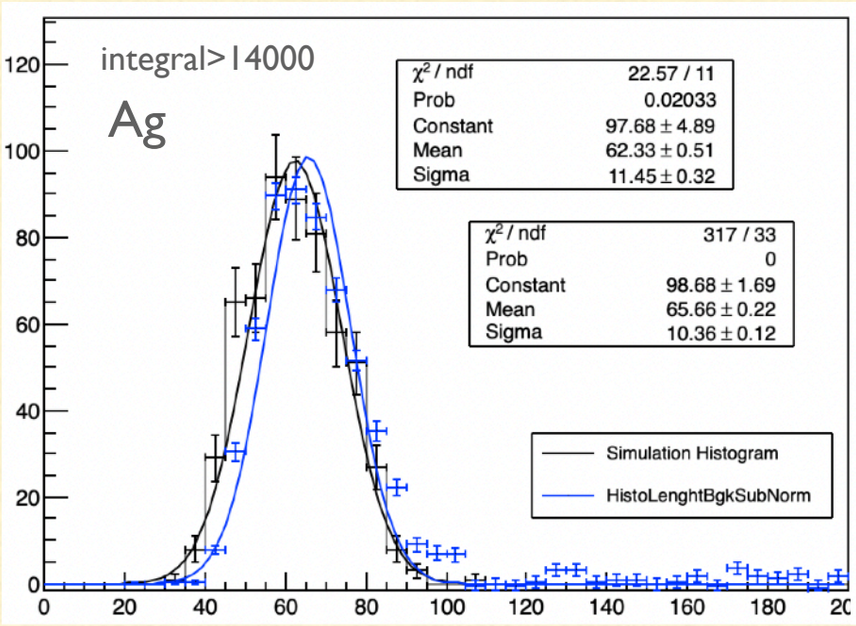
Shape variables comparison

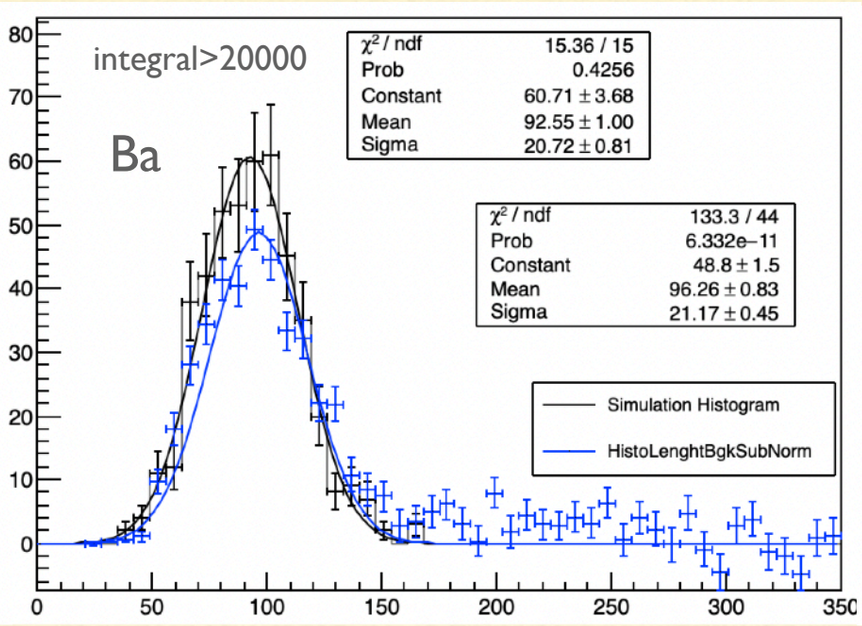
Length

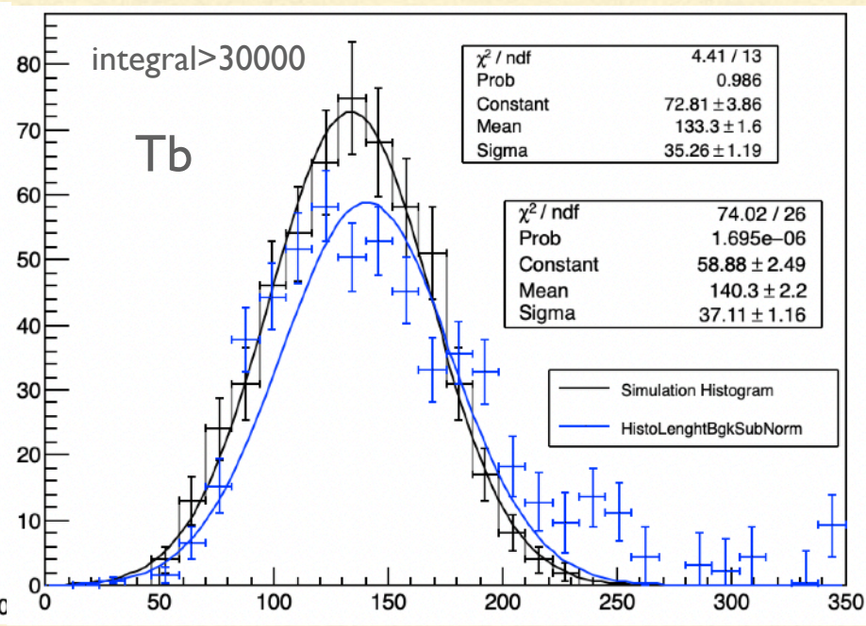

Cu
χ² / ndf 28.92 / 2
Prob 5.243e−07
Constant 274.8 ± 15.5
Mean 34.59 ± 0.20
Sigma 4.012 ± 0.151
χ² / ndf 44.71 / 35
Prob 0.126
Constant 218.9 ± 10.5
Mean 39.81 ± 0.23
Sigma 4.768 ± 0.227
Simulation Histogram
HistoLenghtBgkSubNorm


Rb
χ² / ndf 8.074 / 5
Prob 0.1522
Constant 214.4 ± 11.3
Mean 42.14 ± 0.22
Sigma 5.325 ± 0.171
χ² / ndf 51.87 / 35
Prob 0.03302
Constant 145.7 ± 3.6
Mean 45.08 ± 0.18
Sigma 7.393 ± 0.149
Simulation Histogram
HistoLenghtBgkSubNorm

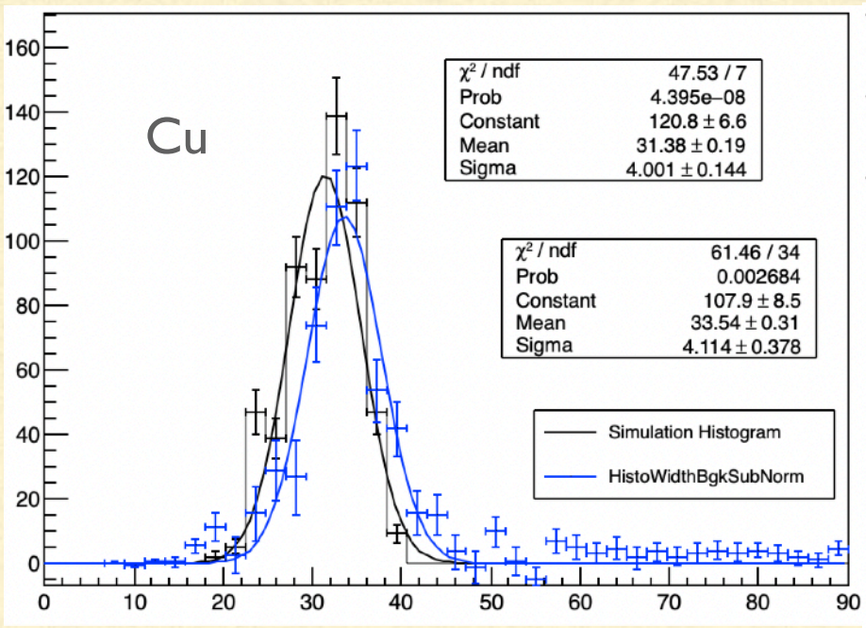

Mo
χ² / ndf 22.91 / 6
Prob 0.0008255
Constant 155.6 ± 8.0
Mean 47.94 ± 0.34
Sigma 7.164 ± 0.210
χ² / ndf 188.6 / 35
Prob 5.948e−23
Constant 103 ± 1.7
Mean 50.29 ± 0.19
Sigma 10.68 ± 0.11
Simulation Histogram
HistoLenghtBgkSubNorm

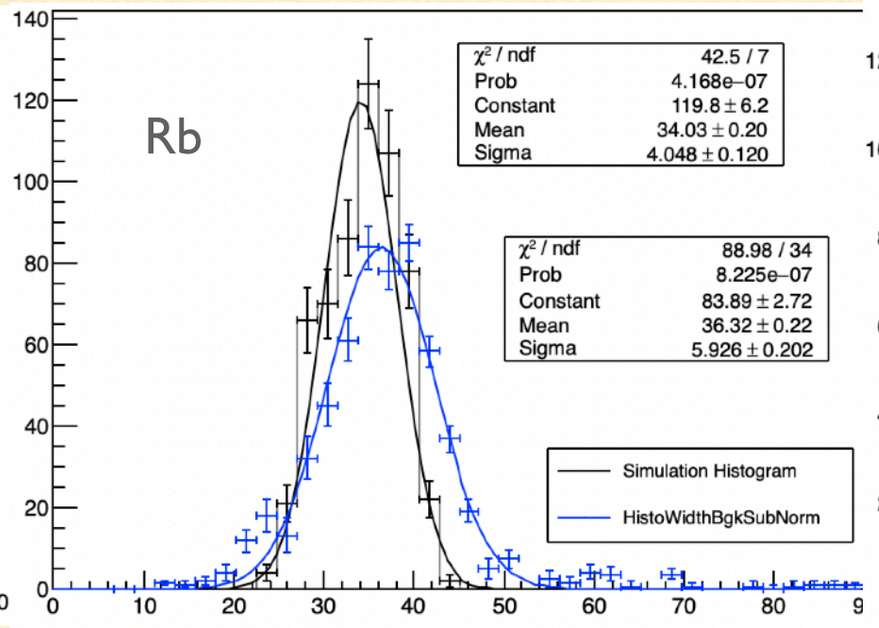

integral>14000
Ag
χ² / ndf 22.57 / 11
Prob 0.02033
Constant 97.68 ± 4.89
Mean 62.33 ± 0.51
Sigma 11.45 ± 0.32
χ² / ndf 317 / 33
Prob 0
Constant 98.68 ± 1.69
Mean 65.66 ± 0.22
Sigma 10.36 ± 0.12
Simulation Histogram
HistoLenghtBgkSubNorm

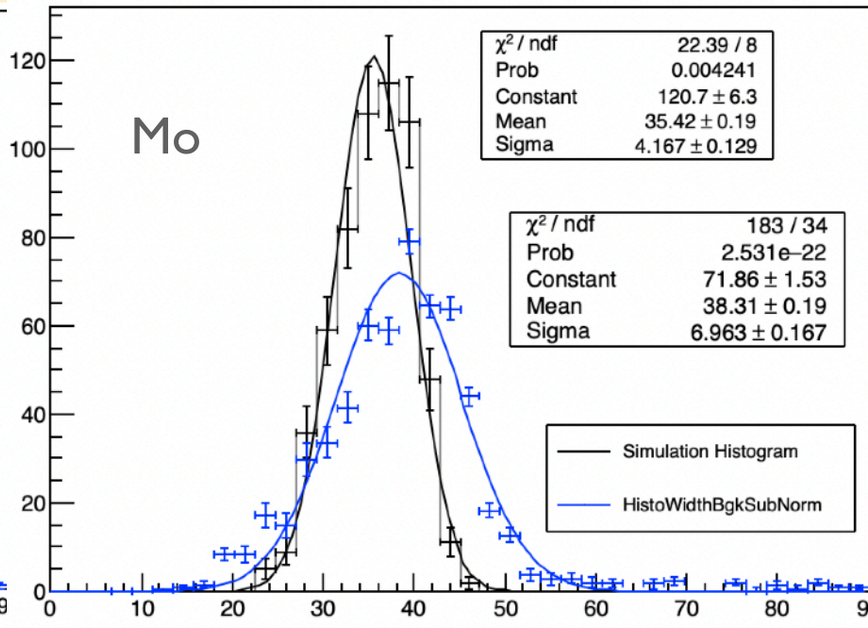

integral>20000
Ba
χ² / ndf 15.36 / 15
Prob 0.4256
Constant 60.71 ± 3.68
Mean 92.55 ± 1.00
Sigma 20.72 ± 0.81
χ² / ndf 133.3 / 44
Prob 6.332e−11
Constant 48.8 ± 1.5
Mean 96.26 ± 0.83
Sigma 21.17 ± 0.45
Simulation Histogram
HistoLenghtBgkSubNorm

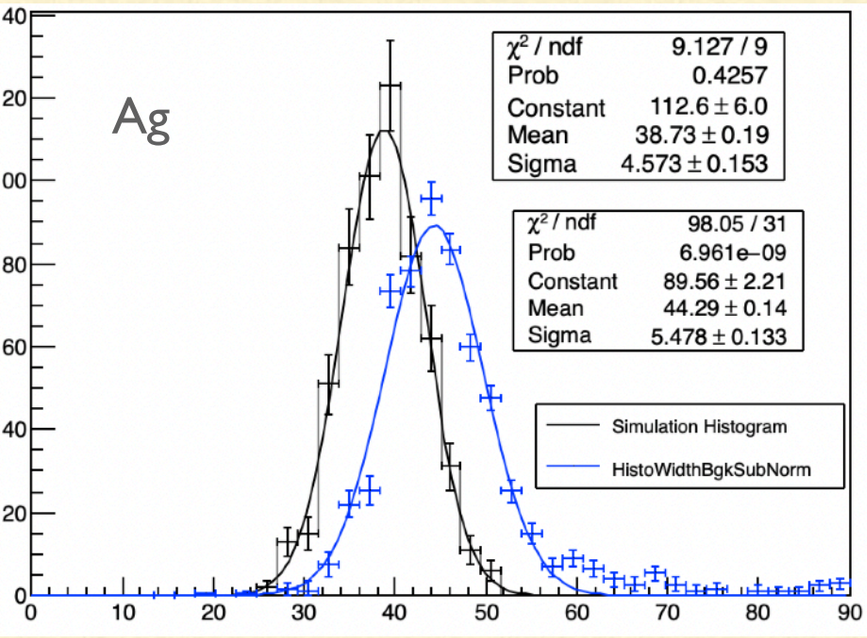

integral>30000
Tb
χ² / ndf 4.41 / 13
Prob 0.986
Constant 72.81 ± 3.86
Mean 133.3 ± 1.6
Sigma 35.26 ± 1.19
χ² / ndf 74.02 / 26
Prob 1.695e−06
Constant 58.88 ± 2.49
Mean 140.3 ± 2.2
Sigma 37.11 ± 1.16
Simulation Histogram
HistoLenghtBgkSubNorm

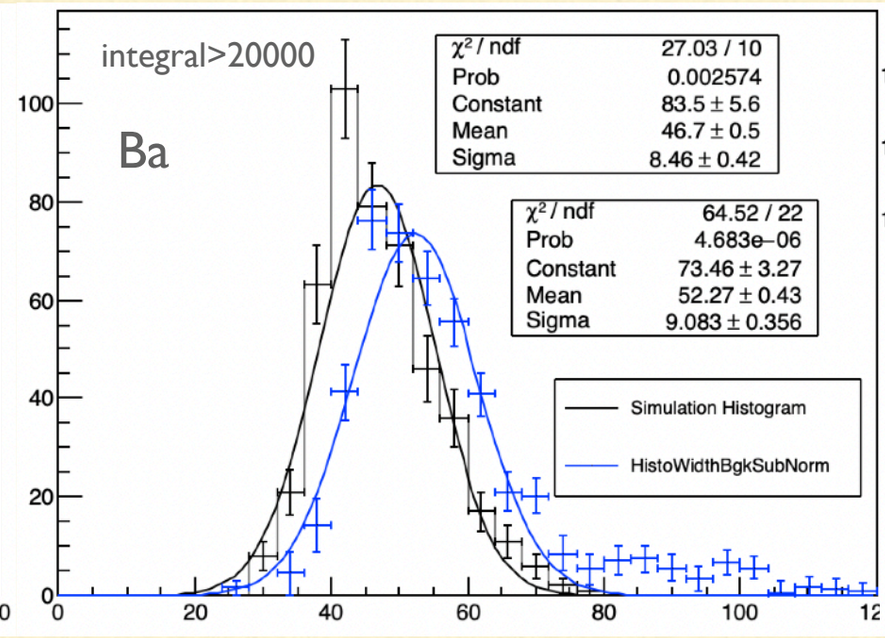
Width

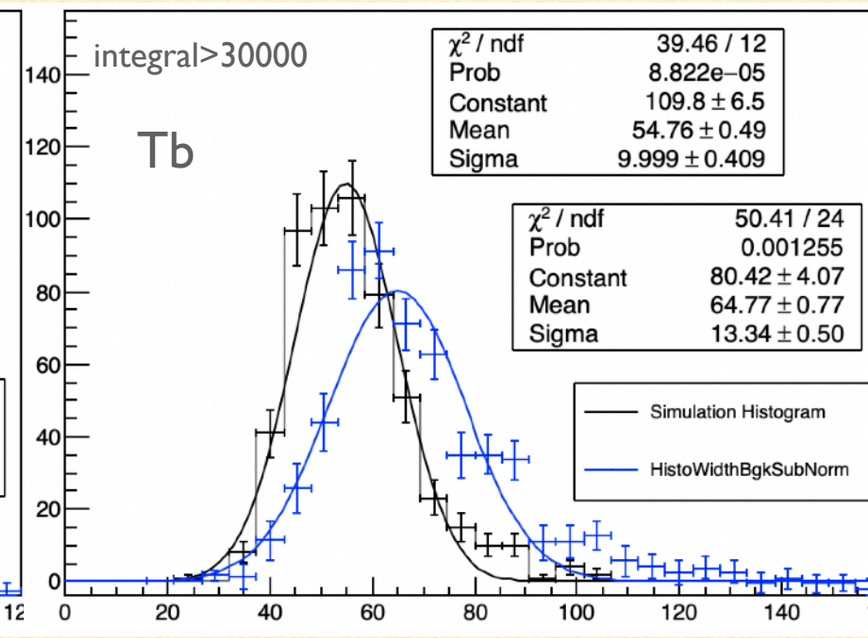

Cu
χ² / ndf 47.53 / 7
Prob 4.395e−08
Constant 120.8 ± 6.6
Mean 31.38 ± 0.19
Sigma 4.001 ± 0.144
χ² / ndf 61.46 / 34
Prob 0.002684
Constant 107.9 ± 8.5
Mean 33.54 ± 0.31
Sigma 4.114 ± 0.378
Simulation Histogram
HistoWidthBgkSubNorm


Rb
χ² / ndf 42.5 / 7
Prob 4.168e−07
Constant 119.8 ± 6.2
Mean 34.03 ± 0.20
Sigma 4.048 ± 0.120
χ² / ndf 88.98 / 34
Prob 8.225e−07
Constant 83.89 ± 2.72
Mean 36.32 ± 0.22
Sigma 5.926 ± 0.202
Simulation Histogram
HistoWidthBgkSubNorm

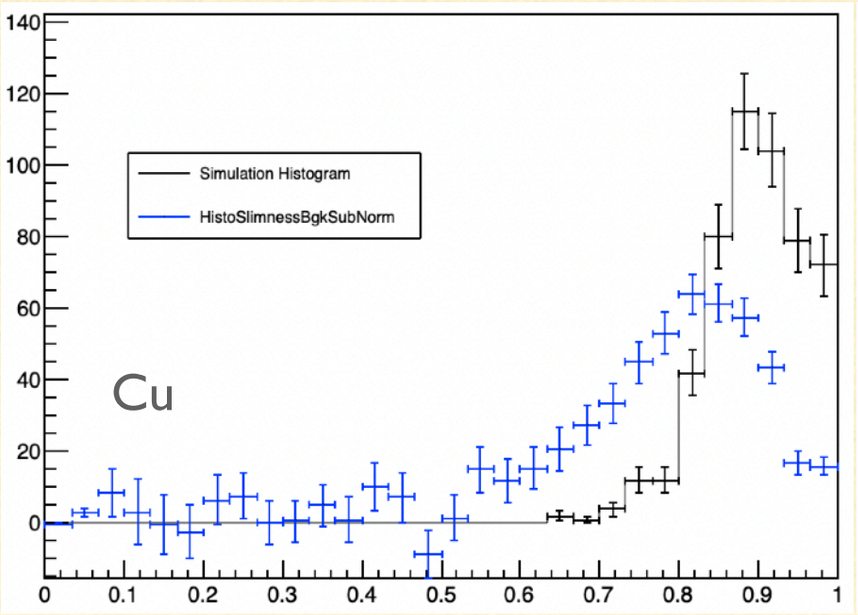

Mo
χ² / ndf 22.39 / 8
Prob 0.004241
Constant 120.7 ± 6.3
Mean 35.42 ± 0.19
Sigma 4.167 ± 0.129
χ² / ndf 183 / 34
Prob 2.531e−22
Constant 71.86 ± 1.53
Mean 38.31 ± 0.19
Sigma 6.963 ± 0.167
Simulation Histogram
HistoWidthBgkSubNorm

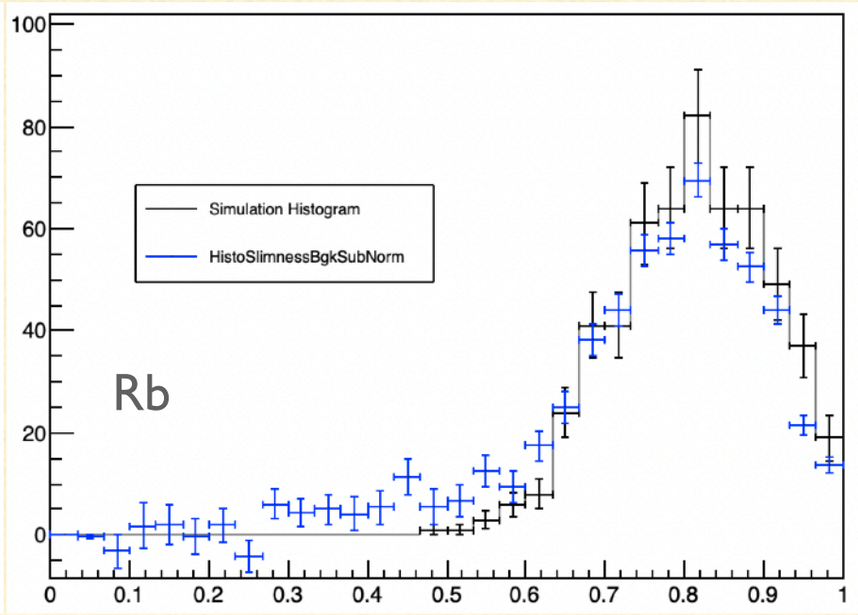

Ag
χ² / ndf 9.127 / 9
Prob 0.4257
Constant 112.6 ± 6.0
Mean 38.73 ± 0.19
Sigma 4.573 ± 0.153
χ² / ndf 98.05 / 31
Prob 6.961e−09
Constant 89.56 ± 2.21
Mean 44.29 ± 0.14
Sigma 5.478 ± 0.133
Simulation Histogram
HistoWidthBgkSubNorm

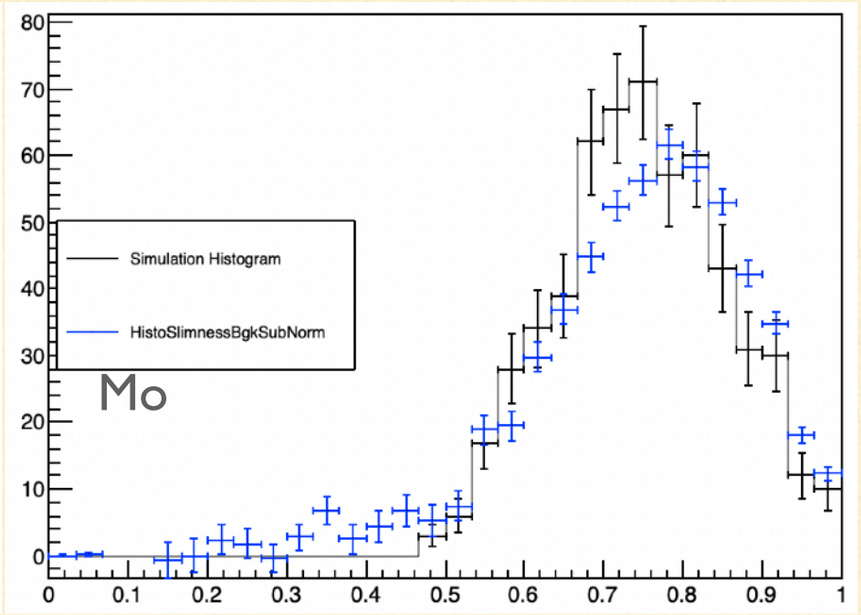

integral>20000
Ba
χ² / ndf 27.03 / 10
Prob 0.002574
Constant 83.5 ± 5.6
Mean 46.7 ± 0.5
Sigma 8.46 ± 0.42
χ² / ndf 64.52 / 22
Prob 4.683e−06
Constant 73.46 ± 3.27
Mean 52.27 ± 0.43
Sigma 9.083 ± 0.356
Simulation Histogram
HistoWidthBgkSubNorm

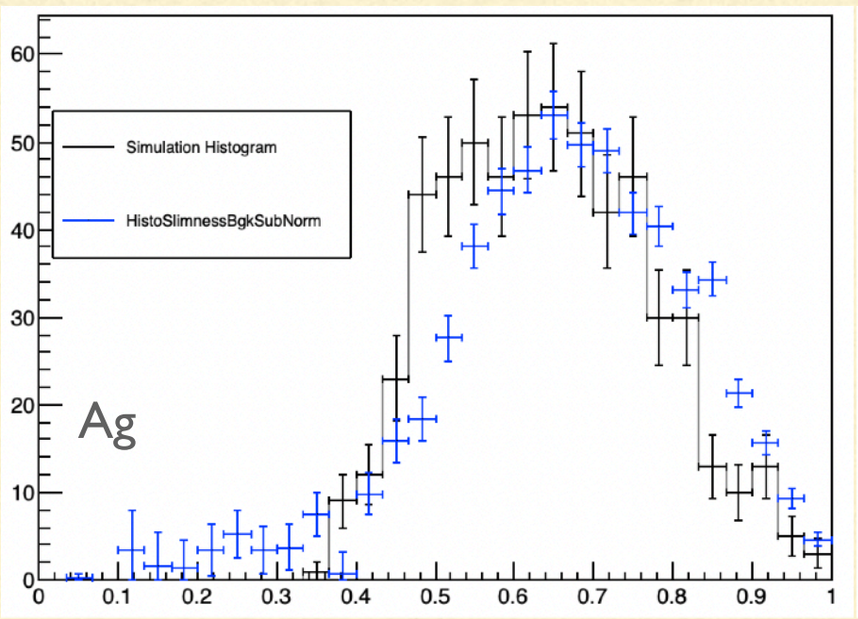

integral>30000
Tb
χ² / ndf 39.46 / 12
Prob 8.822e−05
Constant 109.8 ± 6.5
Mean 54.76 ± 0.49
Sigma 9.999 ± 0.409
χ² / ndf 50.41 / 24
Prob 0.001255
Constant 80.42 ± 4.07
Mean 64.77 ± 0.77
Sigma 13.34 ± 0.50
Simulation Histogram
HistoWidthBgkSubNorm

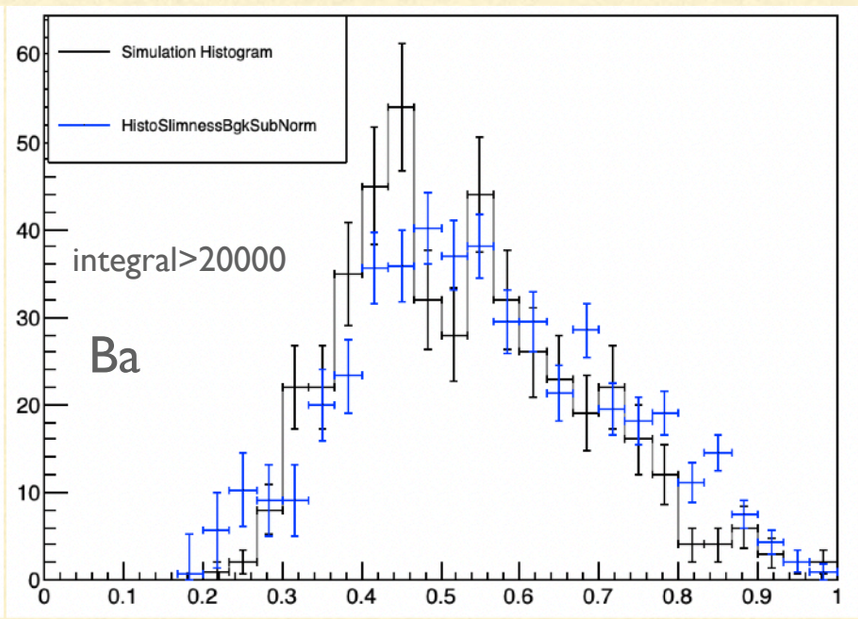
Slimness: ratio width/length

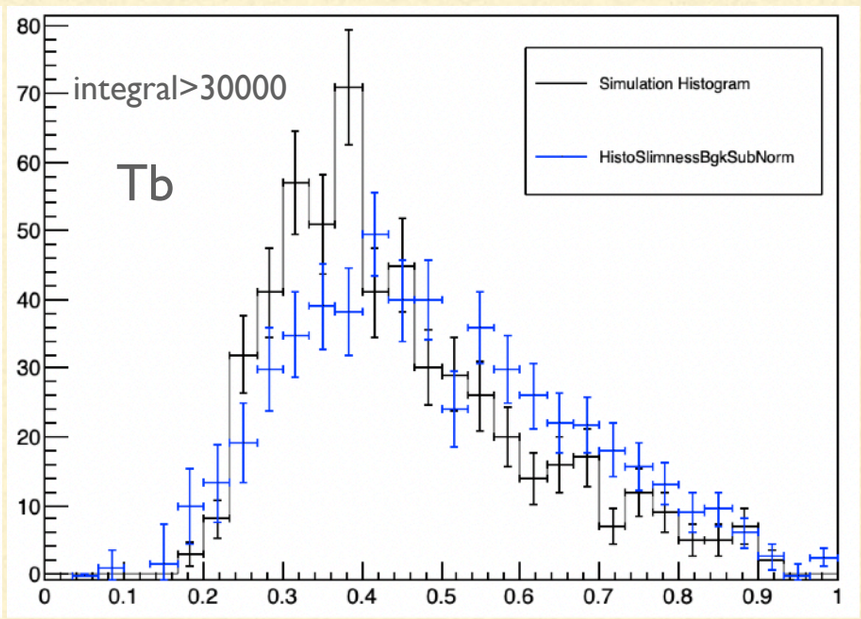




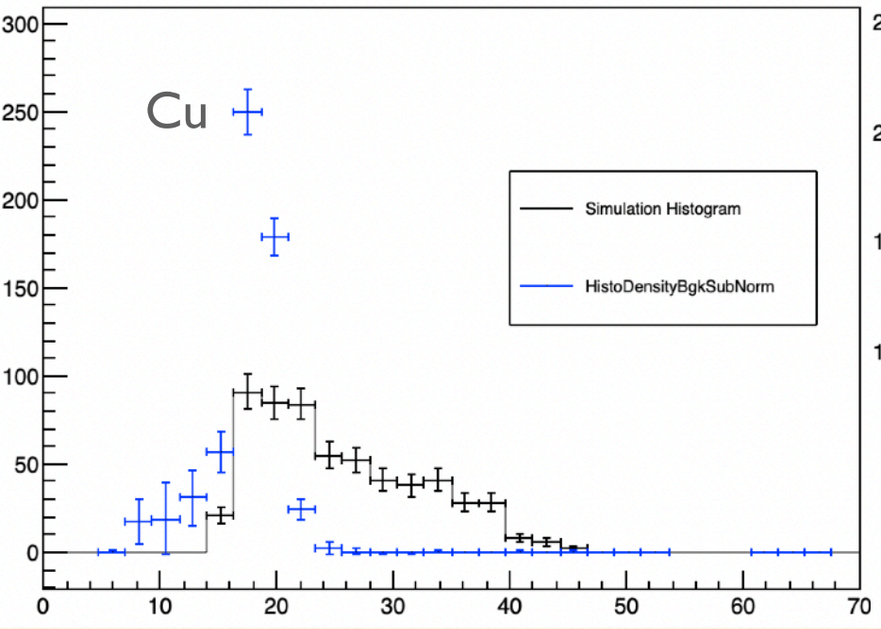


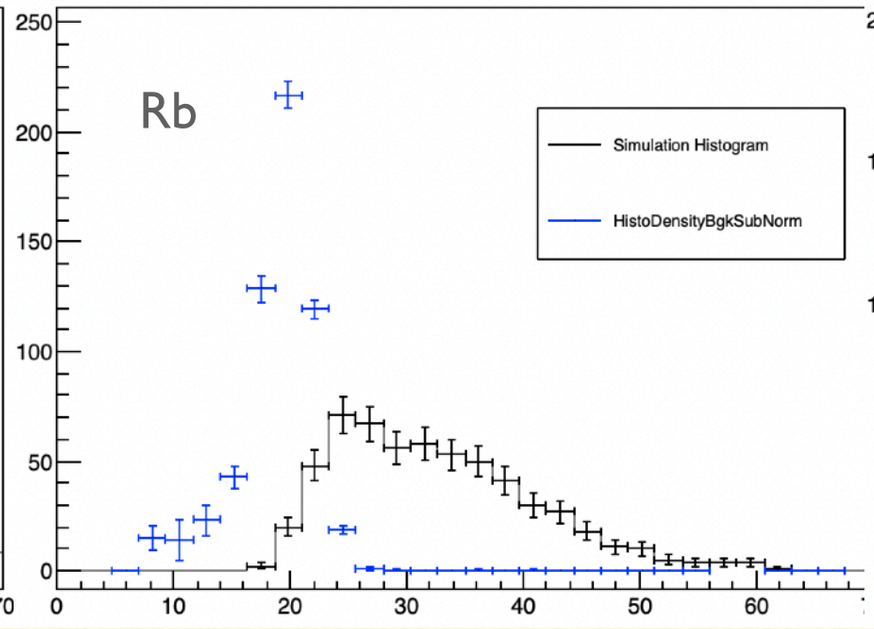


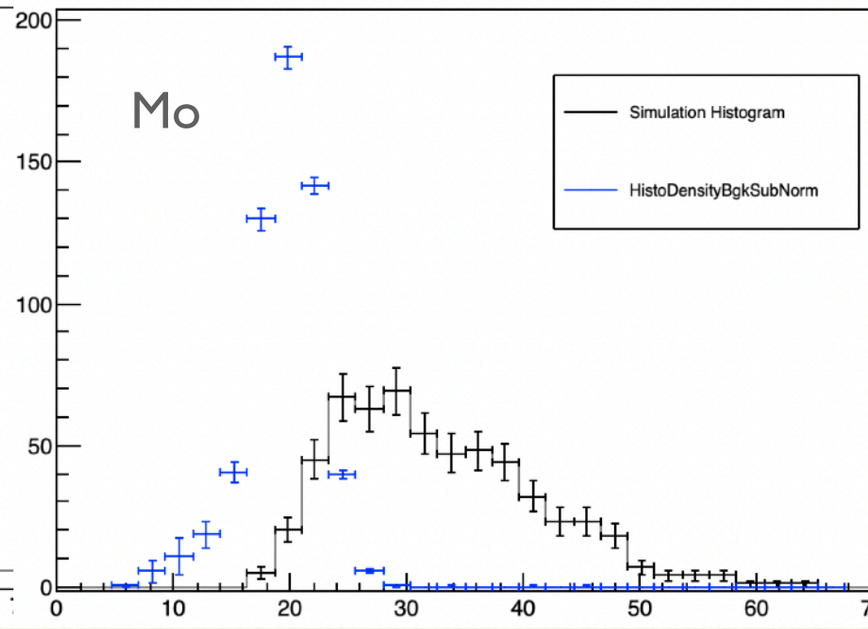


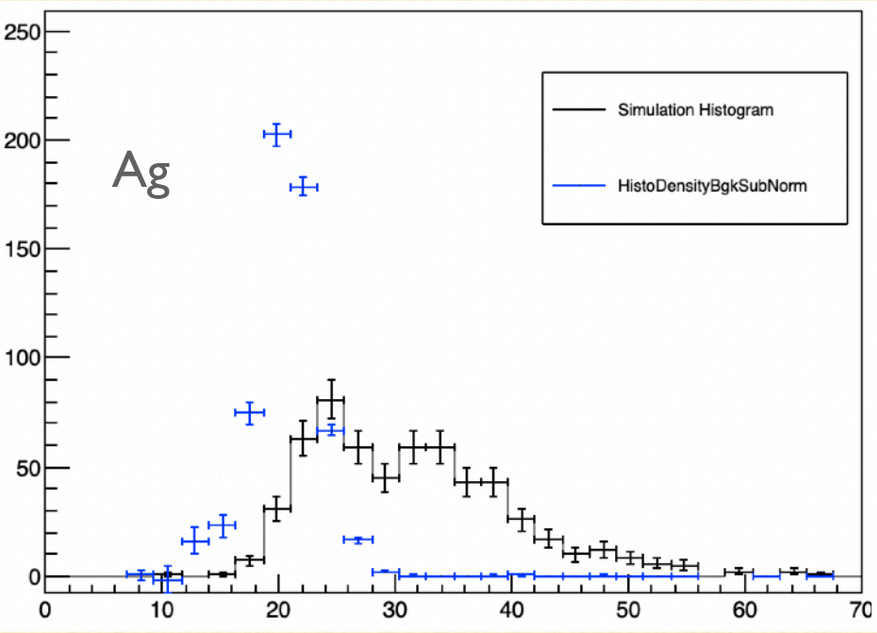


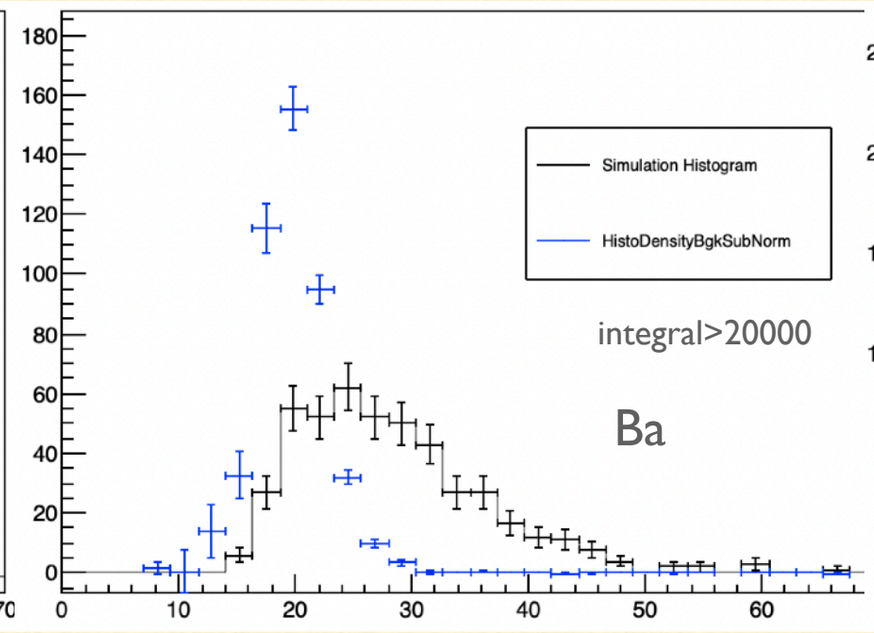
Density: integral/npixels

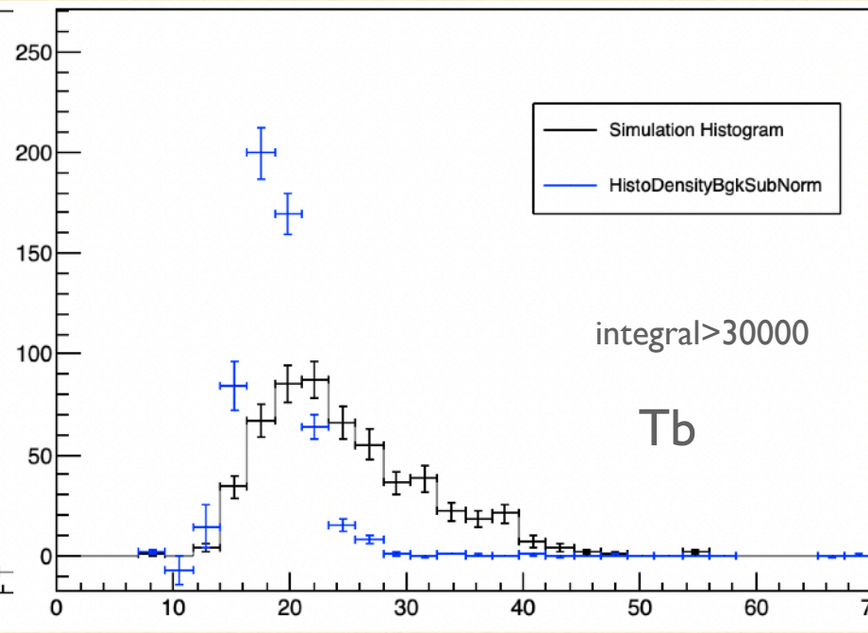




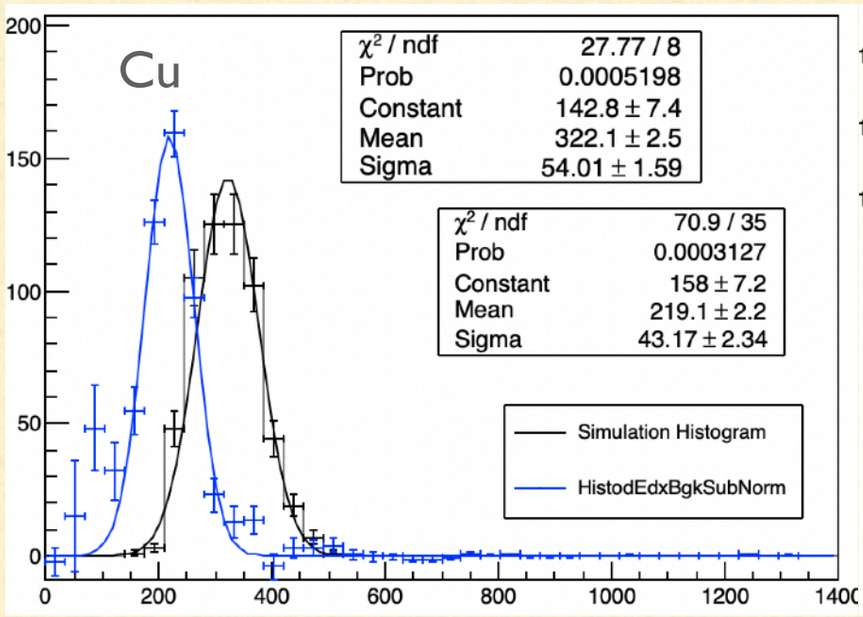


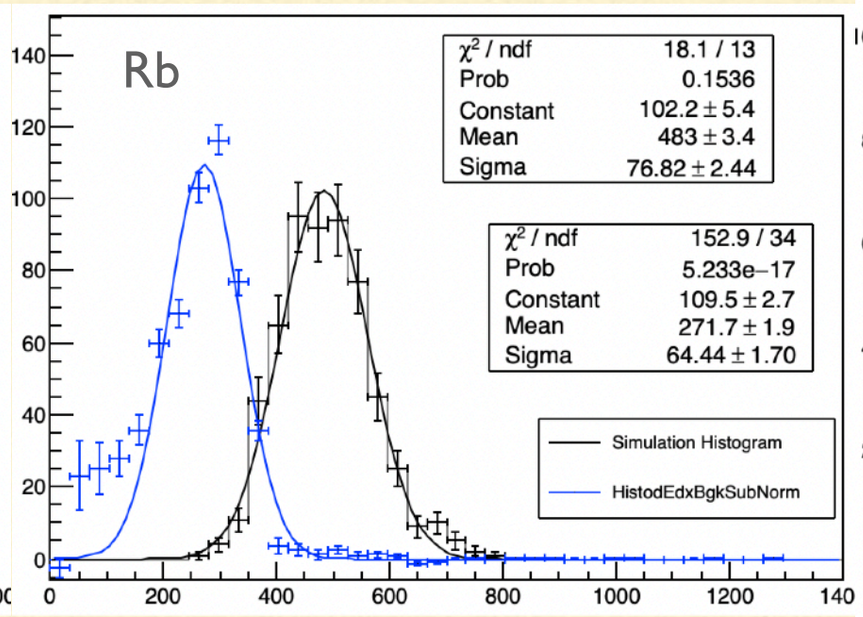


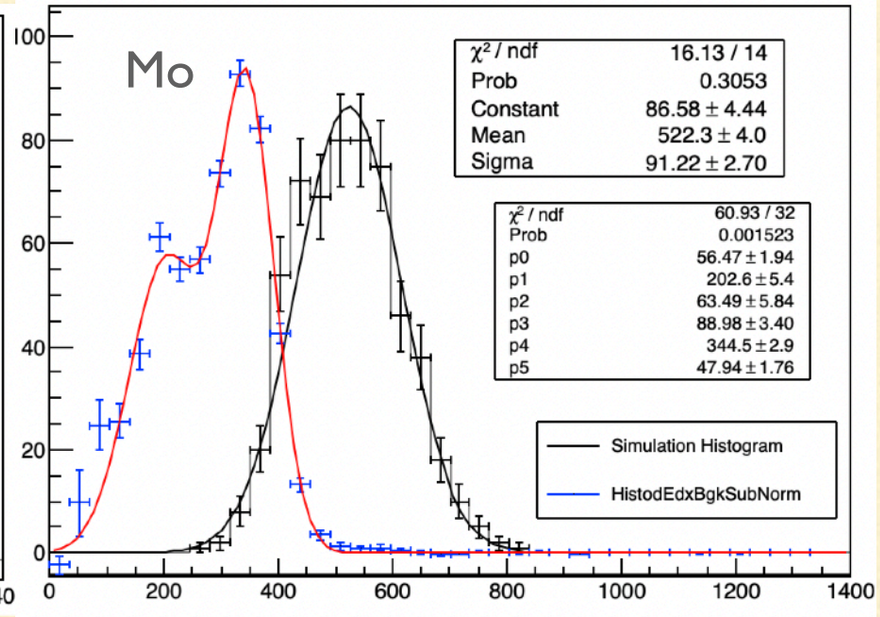


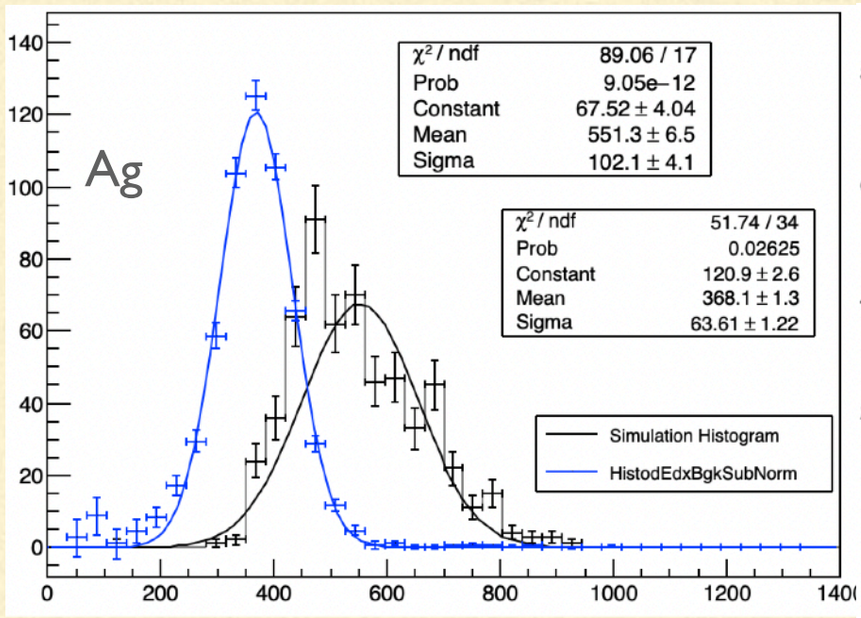


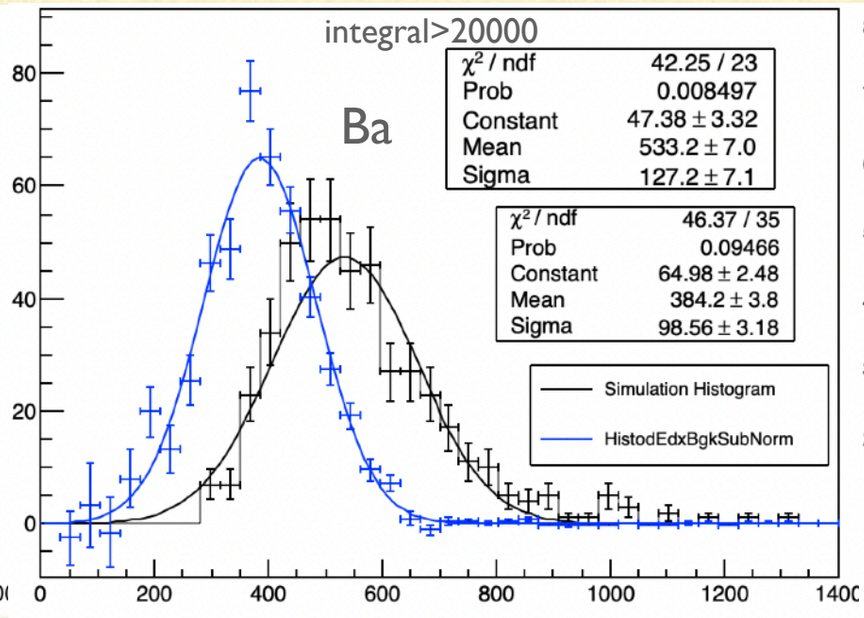
$\Delta E/\Delta l$

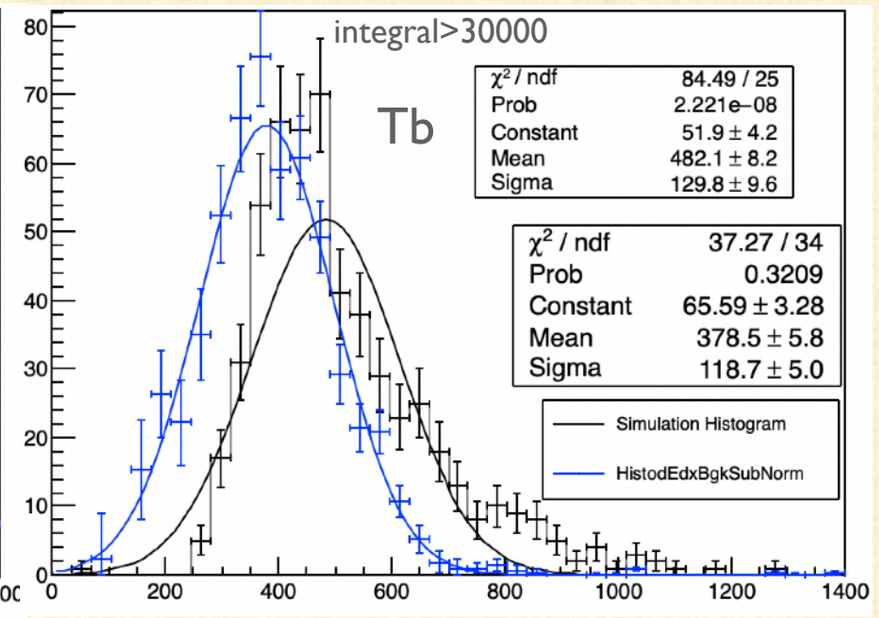




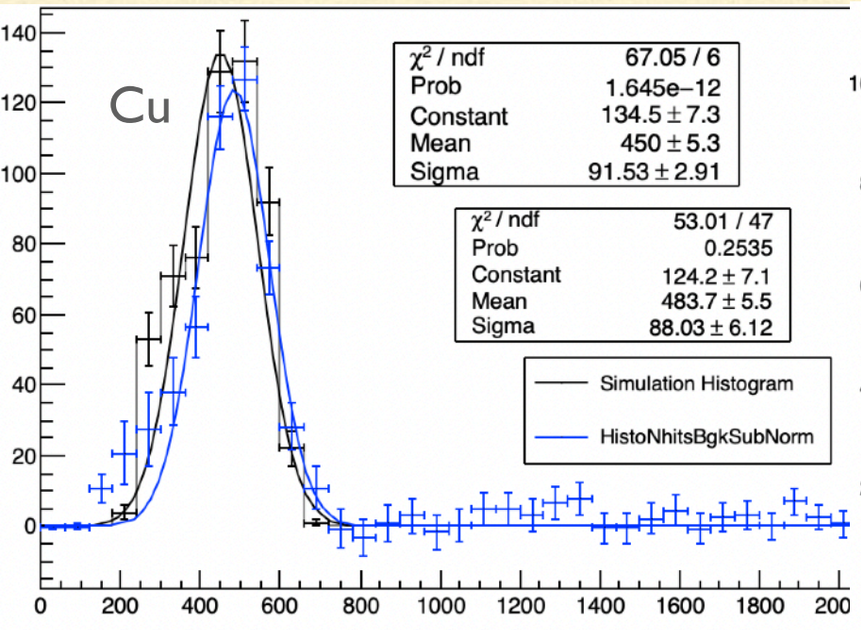


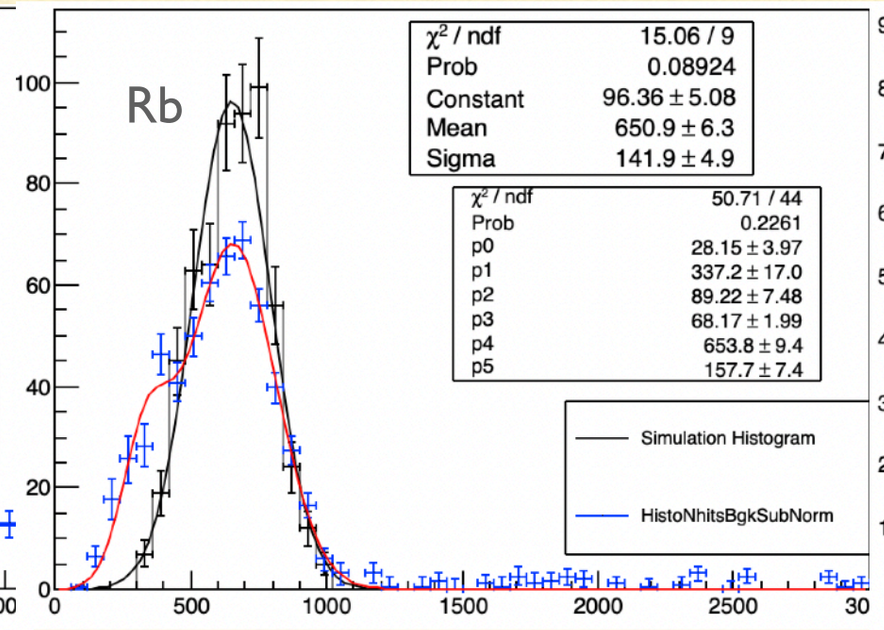


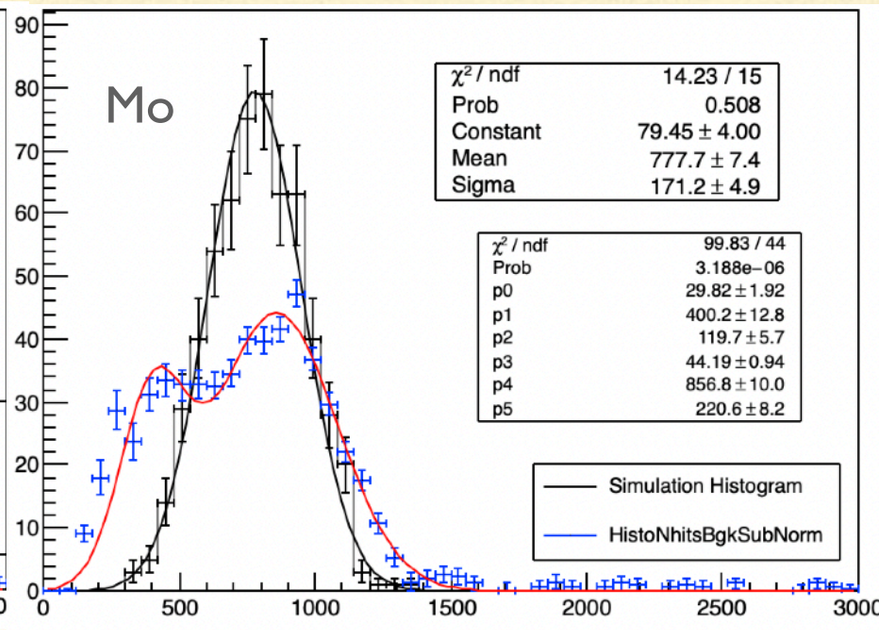


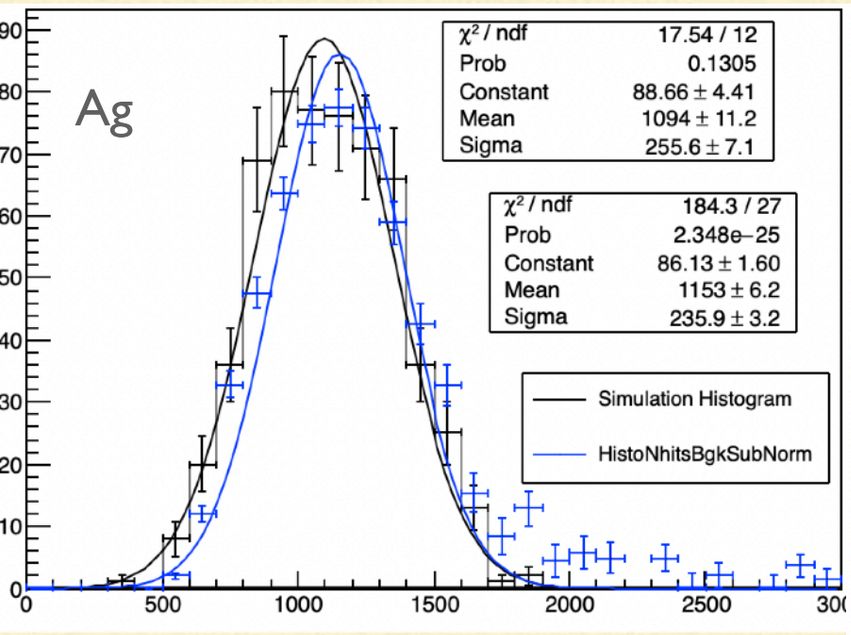


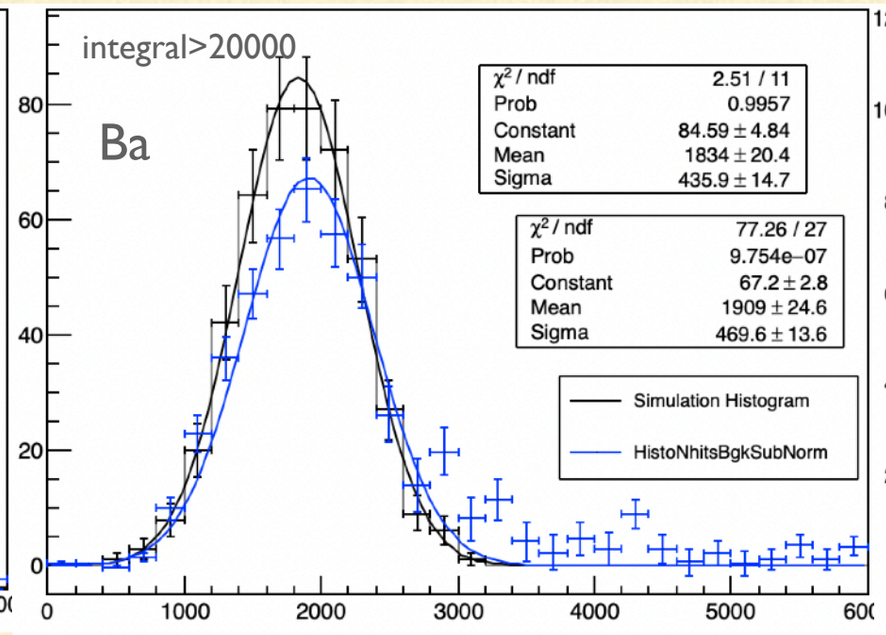
Nhits

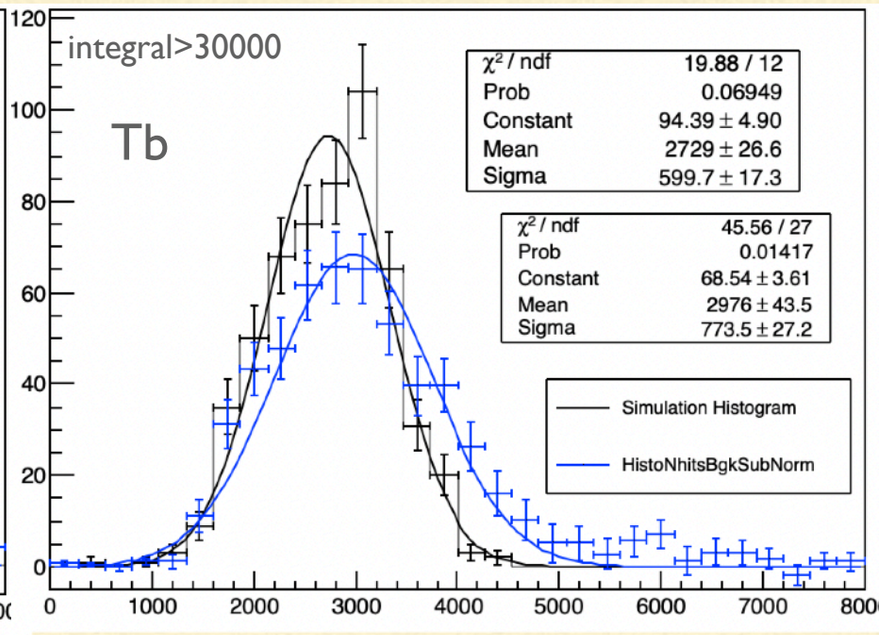

Cu
χ² / ndf 67.05 / 6
Prob 1.645e−12
Constant 134.5 ± 7.3
Mean 450 ± 5.3
Sigma 91.53 ± 2.91
χ² / ndf 53.01 / 47
Prob 0.2535
Constant 124.2 ± 7.1
Mean 483.7 ± 5.5
Sigma 88.03 ± 6.12
Simulation Histogram
HistoNhitsBgkSubNorm


Rb
χ² / ndf 15.06 / 9
Prob 0.08924
Constant 96.36 ± 5.08
Mean 650.9 ± 6.3
Sigma 141.9 ± 4.9
χ² / ndf 50.71 / 44
Prob 0.2261
p0 28.15 ± 3.97
p1 337.2 ± 17.0
p2 89.22 ± 7.48
p3 68.17 ± 1.99
p4 653.8 ± 9.4
p5 157.7 ± 7.4
Simulation Histogram
HistoNhitsBgkSubNorm

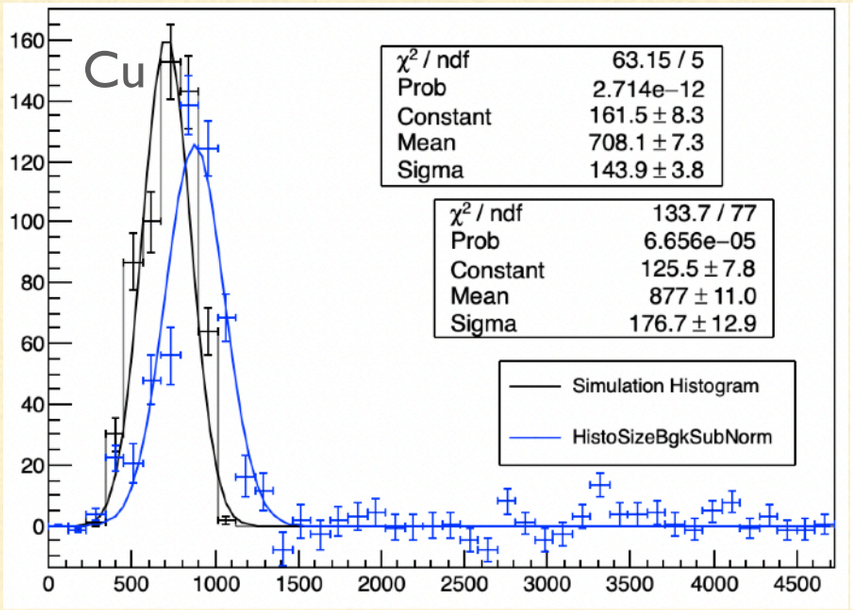

Mo
χ² / ndf 14.23 / 15
Prob 0.508
Constant 79.45 ± 4.00
Mean 777.7 ± 7.4
Sigma 171.2 ± 4.9
χ² / ndf 99.83 / 44
Prob 3.188e−06
p0 29.82 ± 1.92
p1 400.2 ± 12.8
p2 119.7 ± 5.7
p3 44.19 ± 0.94
p4 856.8 ± 10.0
p5 220.6 ± 8.2
Simulation Histogram
HistoNhitsBgkSubNorm

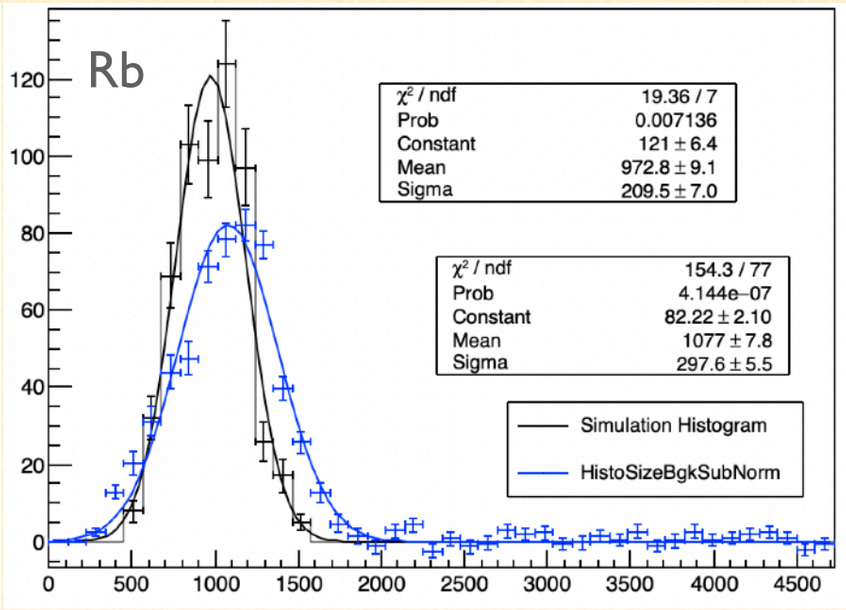

Ag
χ² / ndf 17.54 / 12
Prob 0.1305
Constant 88.66 ± 4.41
Mean 1094 ± 11.2
Sigma 255.6 ± 7.1
χ² / ndf 184.3 / 27
Prob 2.348e−25
Constant 86.13 ± 1.60
Mean 1153 ± 6.2
Sigma 235.9 ± 3.2
Simulation Histogram
HistoNhitsBgkSubNorm

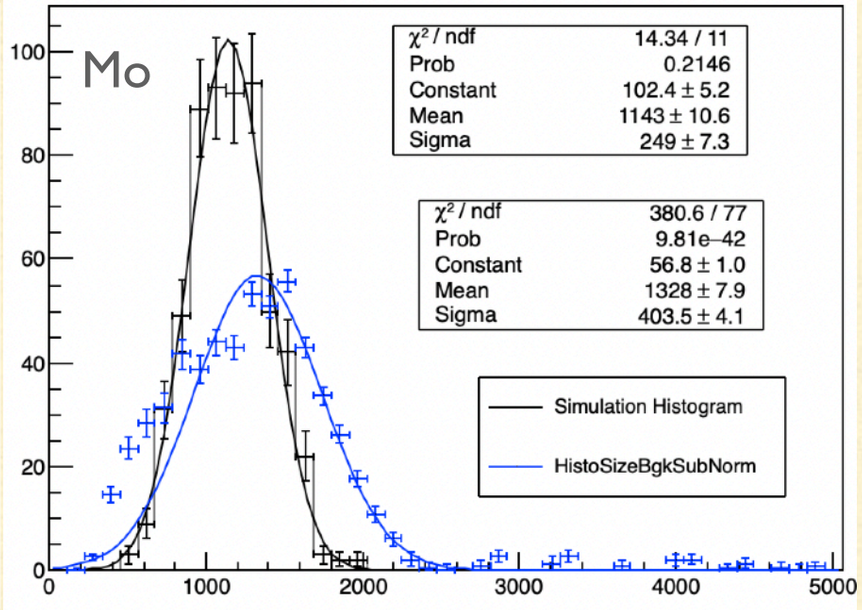

integral>20000
Ba
χ² / ndf 2.51 / 11
Prob 0.9957
Constant 84.59 ± 4.84
Mean 1834 ± 20.4
Sigma 435.9 ± 14.7
χ² / ndf 77.26 / 27
Prob 9.754e−07
Constant 67.2 ± 2.8
Mean 1909 ± 24.6
Sigma 469.6 ± 13.6
Simulation Histogram
HistoNhitsBgkSubNorm

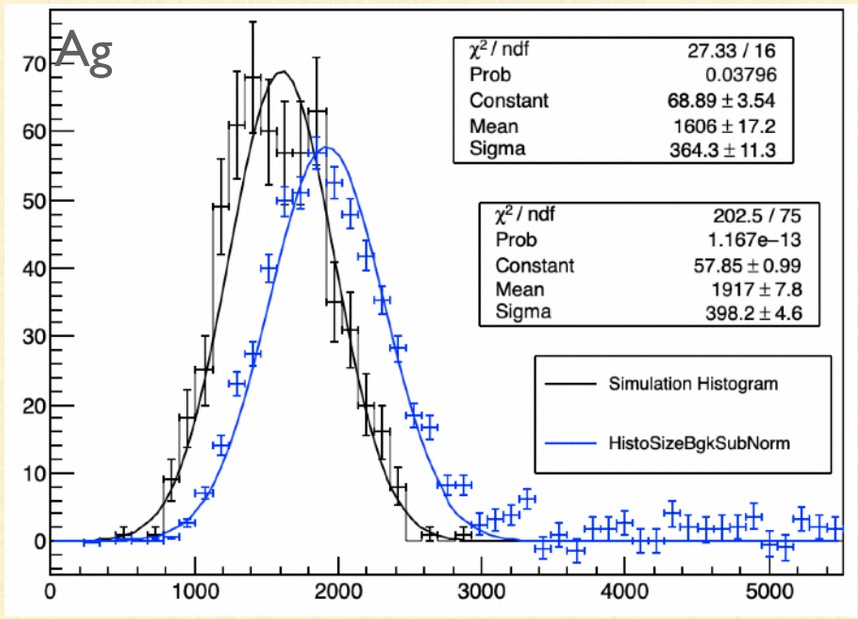

integral>30000
Tb
χ² / ndf 19.88 / 12
Prob 0.06949
Constant 94.39 ± 4.90
Mean 2729 ± 26.6
Sigma 599.7 ± 17.3
χ² / ndf 45.56 / 27
Prob 0.01417
Constant 68.54 ± 3.61
Mean 2976 ± 43.5
Sigma 773.5 ± 27.2
Simulation Histogram
HistoNhitsBgkSubNorm

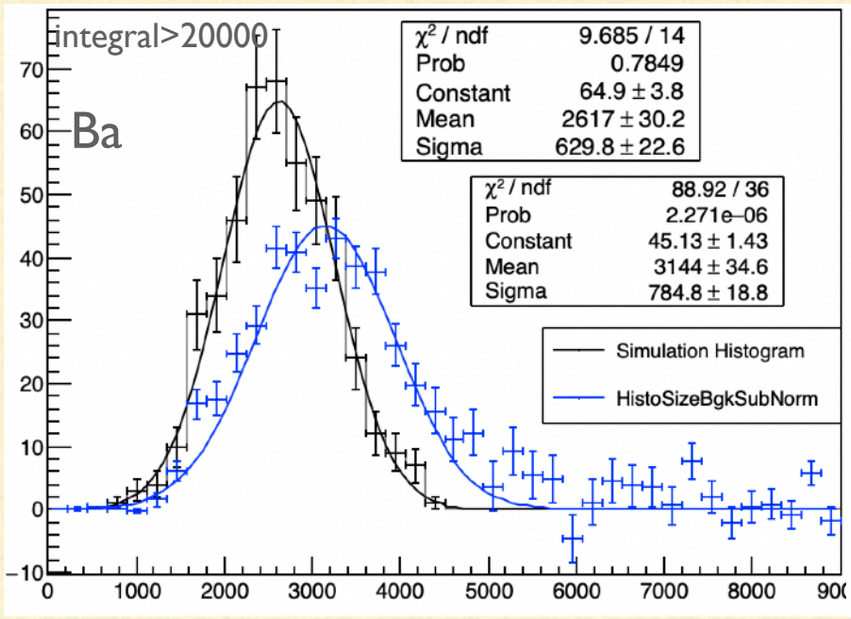
Size

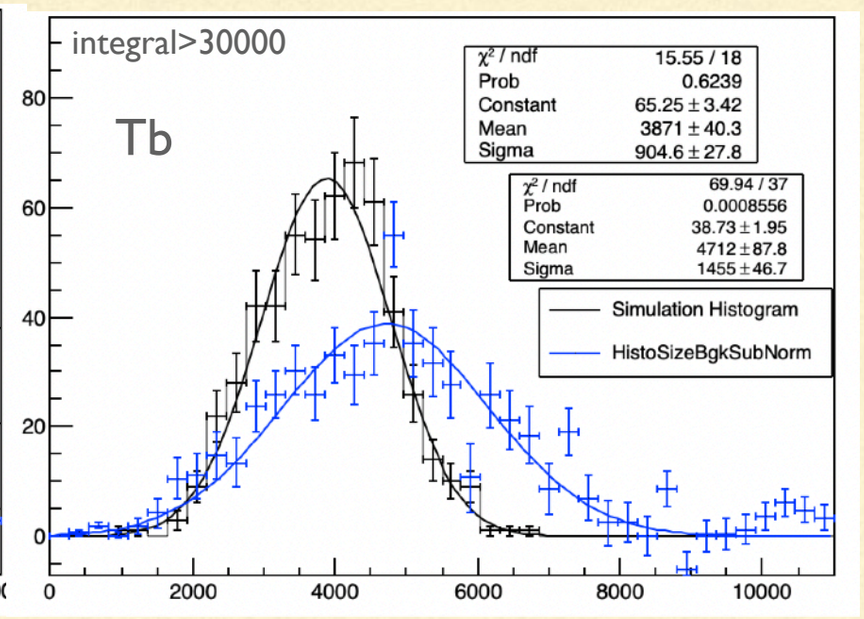

Cu
χ² / ndf 63.15 / 5
Prob 2.714e−12
Constant 161.5 ± 8.3
Mean 708.1 ± 7.3
Sigma 143.9 ± 3.8
χ² / ndf 133.7 / 77
Prob 6.656e−05
Constant 125.5 ± 7.8
Mean 877 ± 11.0
Sigma 176.7 ± 12.9
Simulation Histogram
HistoSizeBgkSubNorm


Rb
χ² / ndf 19.36 / 7
Prob 0.007136
Constant 121 ± 6.4
Mean 972.8 ± 9.1
Sigma 209.5 ± 7.0
χ² / ndf 154.3 / 77
Prob 4.144e−07
Constant 82.22 ± 2.10
Mean 1077 ± 7.8
Sigma 297.6 ± 5.5
Simulation Histogram
HistoSizeBgkSubNorm


Mo
χ² / ndf 14.34 / 11
Prob 0.2146
Constant 102.4 ± 5.2
Mean 1143 ± 10.6
Sigma 249 ± 7.3
χ² / ndf 380.6 / 77
Prob 9.81e−42
Constant 56.8 ± 1.0
Mean 1328 ± 7.9
Sigma 403.5 ± 4.1
Simulation Histogram
HistoSizeBgkSubNorm


Ag
χ² / ndf 27.33 / 16
Prob 0.03796
Constant 68.89 ± 3.54
Mean 1606 ± 17.2
Sigma 364.3 ± 11.3
χ² / ndf 202.5 / 75
Prob 1.167e−13
Constant 57.85 ± 0.99
Mean 1917 ± 7.8
Sigma 398.2 ± 4.6
Simulation Histogram
HistoSizeBgkSubNorm


integral>20000
Ba
χ² / ndf 9.685 / 14
Prob 0.7849
Constant 64.9 ± 3.8
Mean 2617 ± 30.2
Sigma 629.8 ± 22.6
χ² / ndf 88.92 / 36
Prob 2.271e−06
Constant 45.13 ± 1.43
Mean 3144 ± 34.6
Sigma 784.8 ± 18.8
Simulation Histogram
HistoSizeBgkSubNorm


integral>30000
Tb
χ² / ndf 15.55 / 18
Prob 0.6239
Constant 65.25 ± 3.42
Mean 3871 ± 40.3
Sigma 904.6 ± 27.8
χ² / ndf 69.94 / 37
Prob 0.0008556
Constant 38.73 ± 1.95
Mean 4712 ± 87.8
Sigma 1455 ± 46.7
Simulation Histogram
HistoSizeBgkSubNorm

Recap.

- Data and MC comparison shows:

- Agreement in:
  - Nhits
  - TGausMean

Diffusion is well simulated?

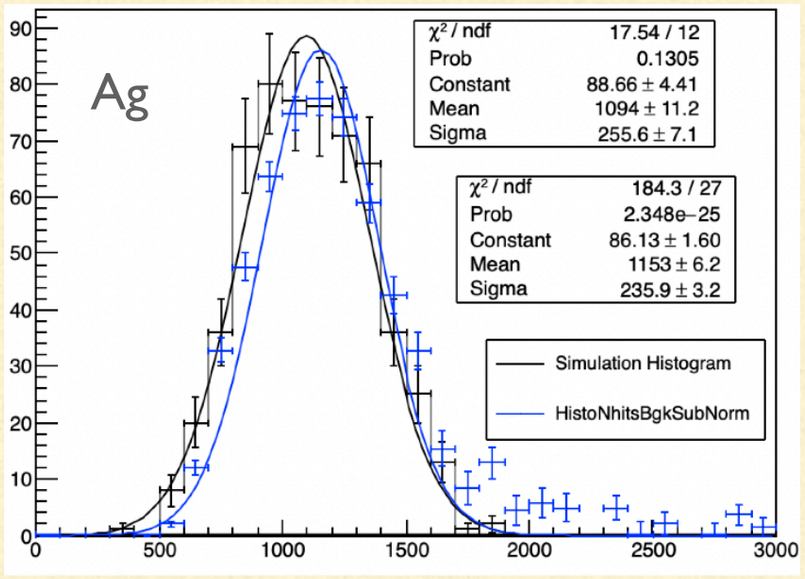
- Fine-tune needed in:
  - Lenght
  - Width
  - TGaussSigma
  - Size

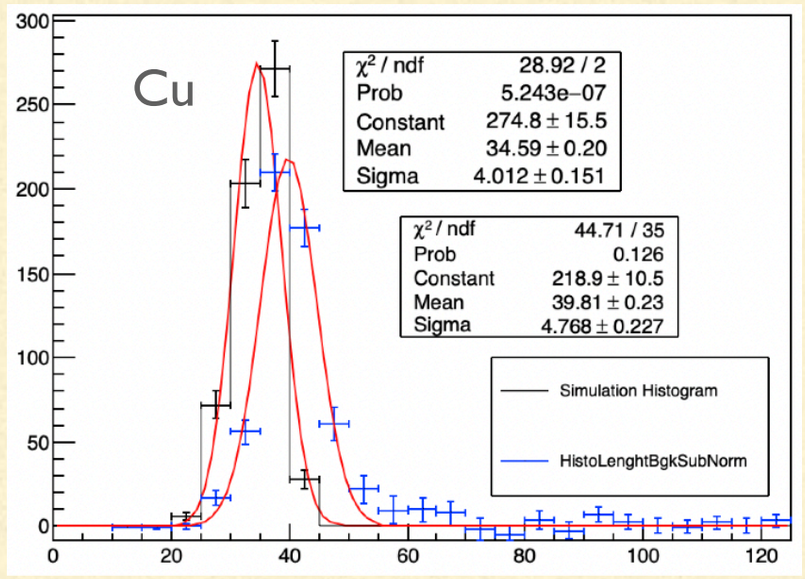
Possible relation with a different pedestal in simulation?

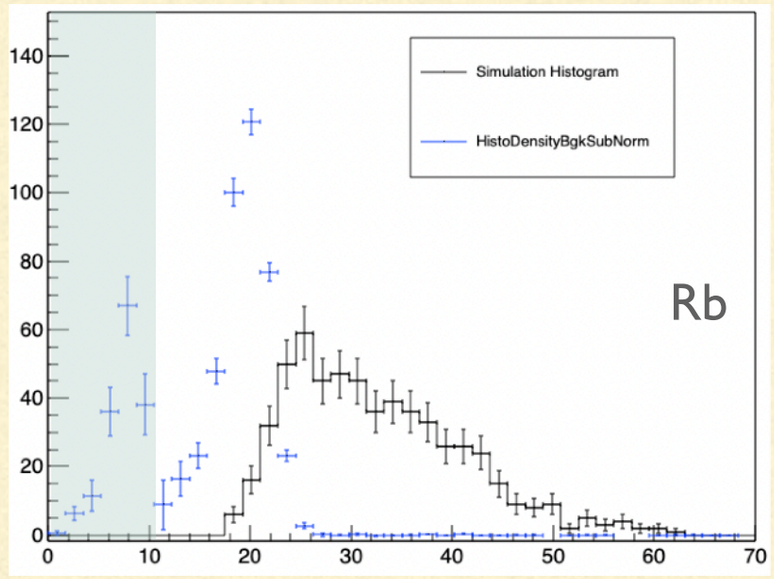
Non uniform z distribution?

- To improve:
  - Linearity
  - EResolution
  - Light density
  - Specific ionization

Connected with the saturation?

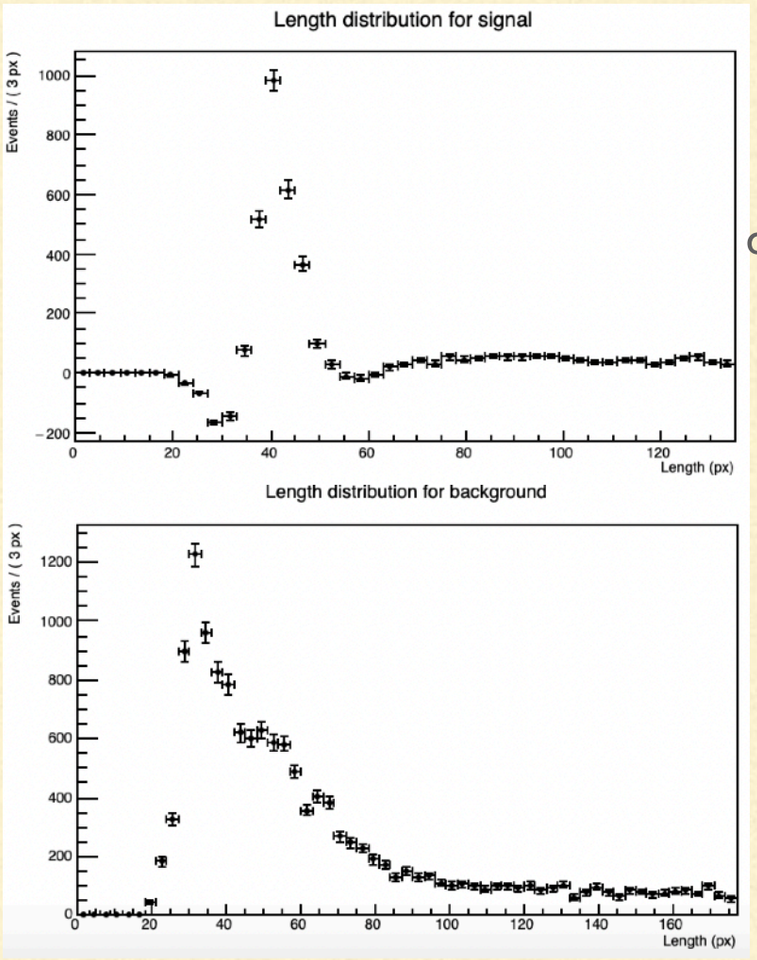






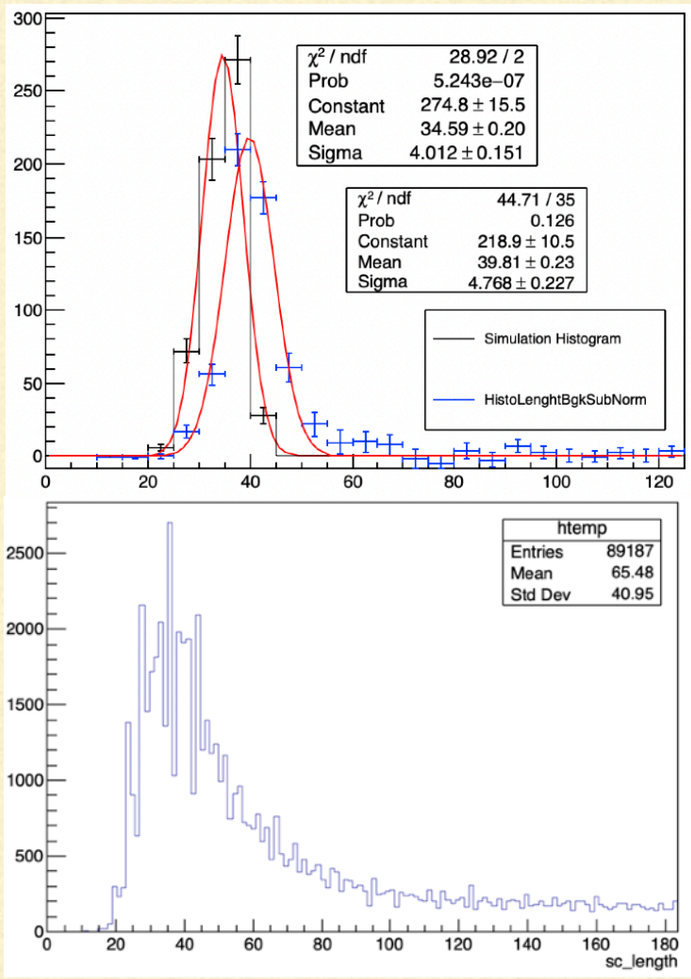
Conclusions and next steps

- The strategy of the background modeling on the sideband of the signal is giving promising results
- The Data-MC comparison shows that the main discrepancy is in the light production, and this discrepancy propagates in some other variables energy related
- All the geometrical variables seems quite in agreement within data and simulation
- The framework to work with *sPlot* is now ready for a better Data-MC comparison



S-weighted length distribution for signal

S-weighted length distribution for bgk



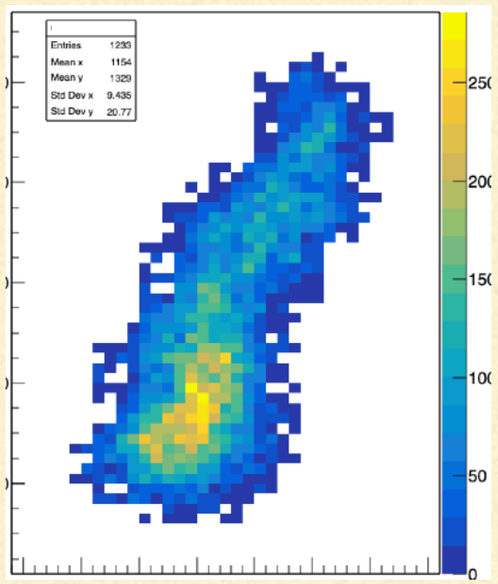
Length distribution for copper bkg subtracted (blue)

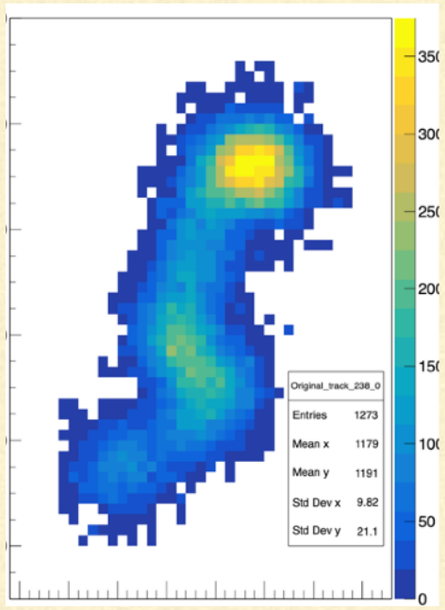
Length distribution for a cosmic run

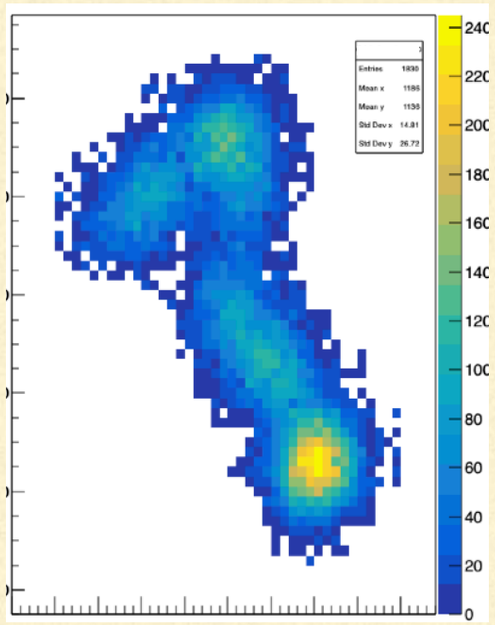
From: Nucl.Instrum.Meth.A 555 (2005) 356-369

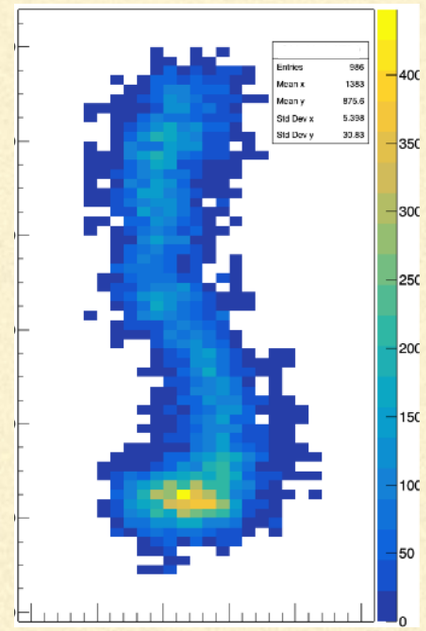
Data or simulation?

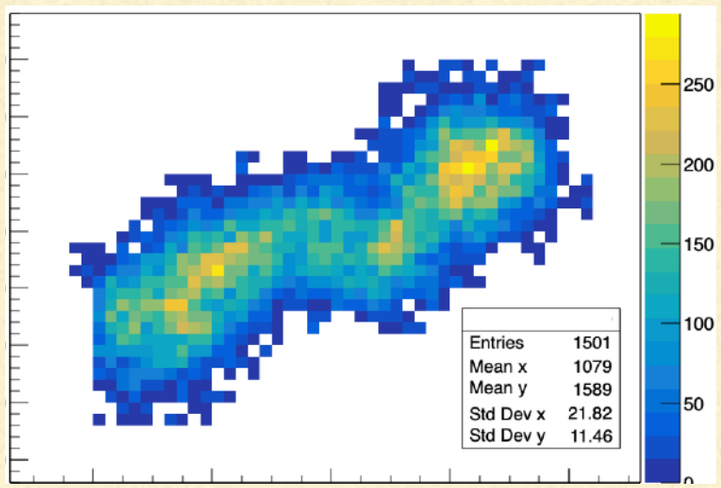
Find the difference: 4 real electrons and 4 simulated electrons at ~30 keV

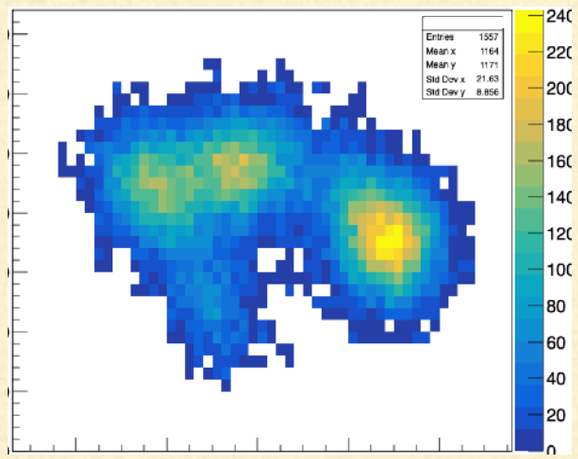


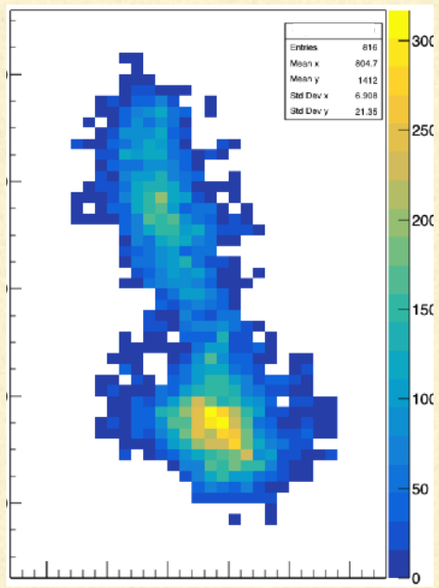


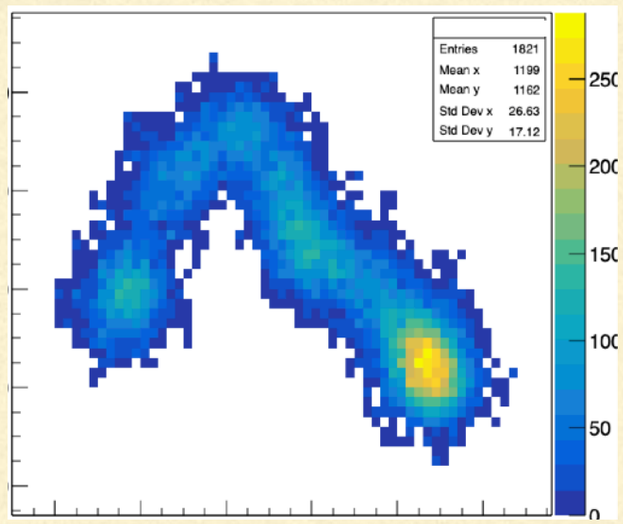












Data or smulation?