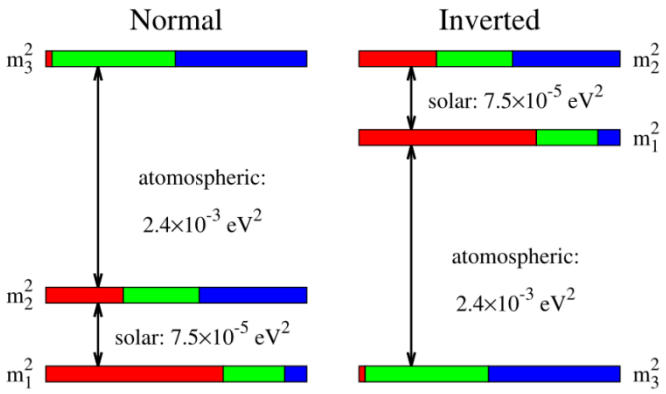
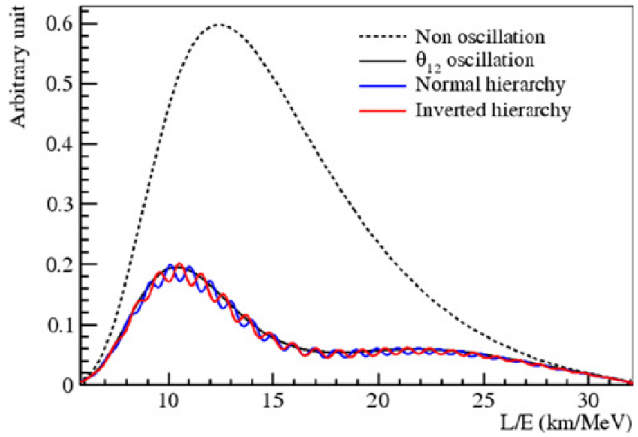
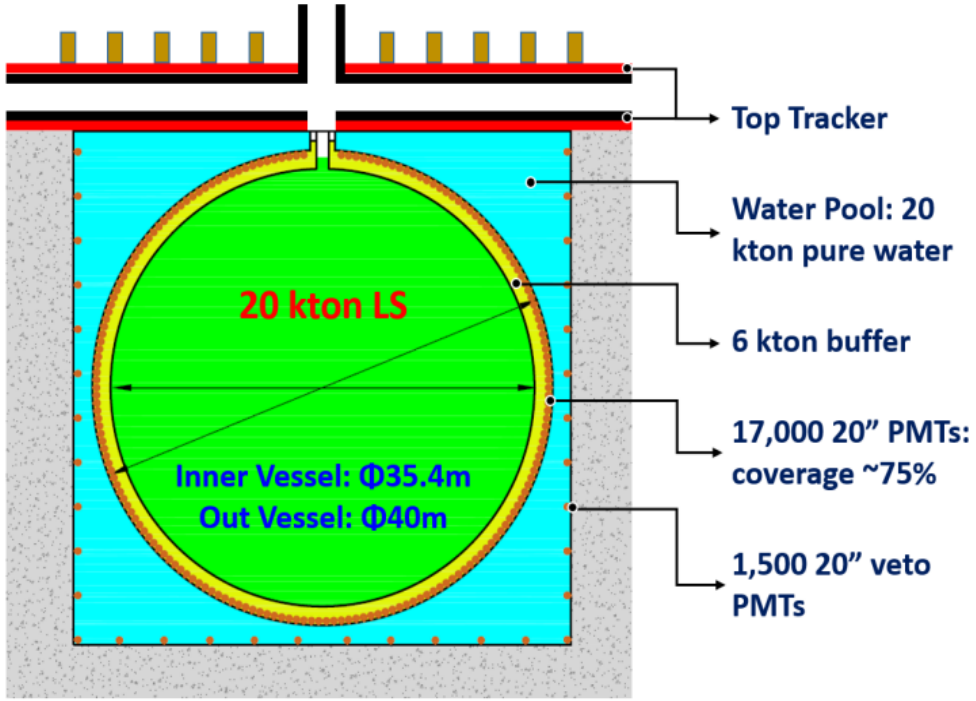
Measurement of scintillator light yield nonlinearity in the neutrino experiment JUNO

Tomáš Tměj

Motivation

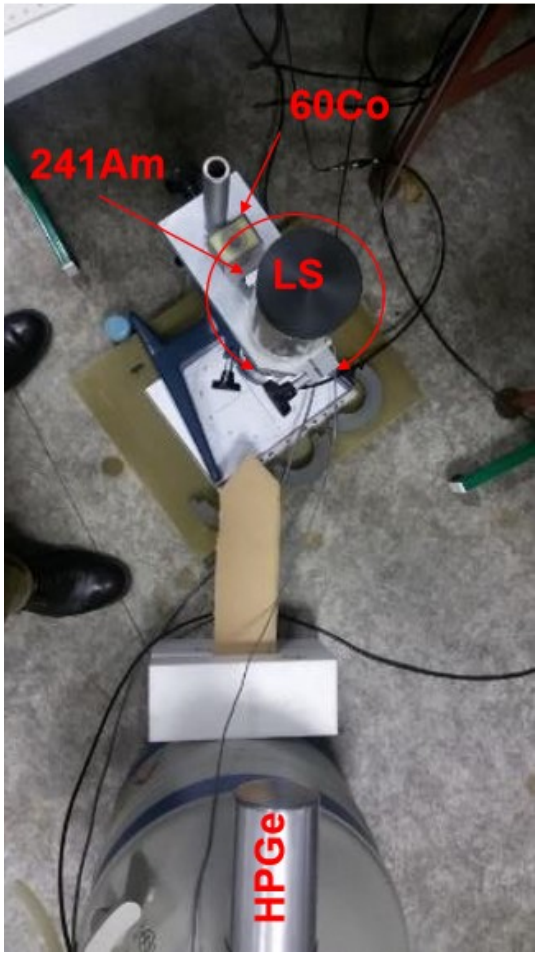






[arXiv:1507.05613]

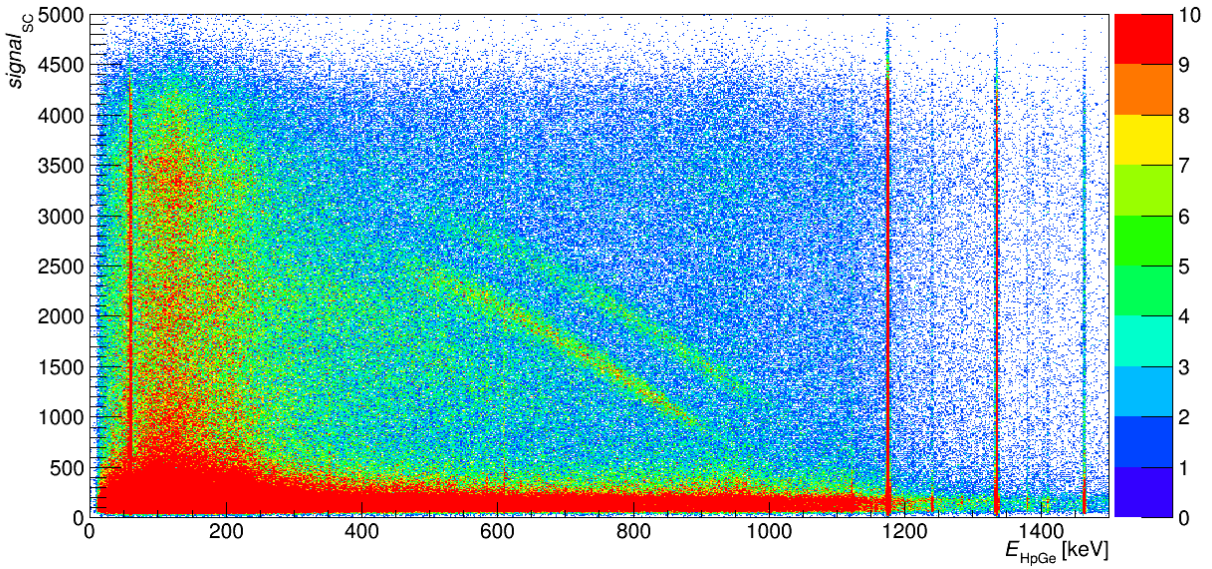
Princip of measurement



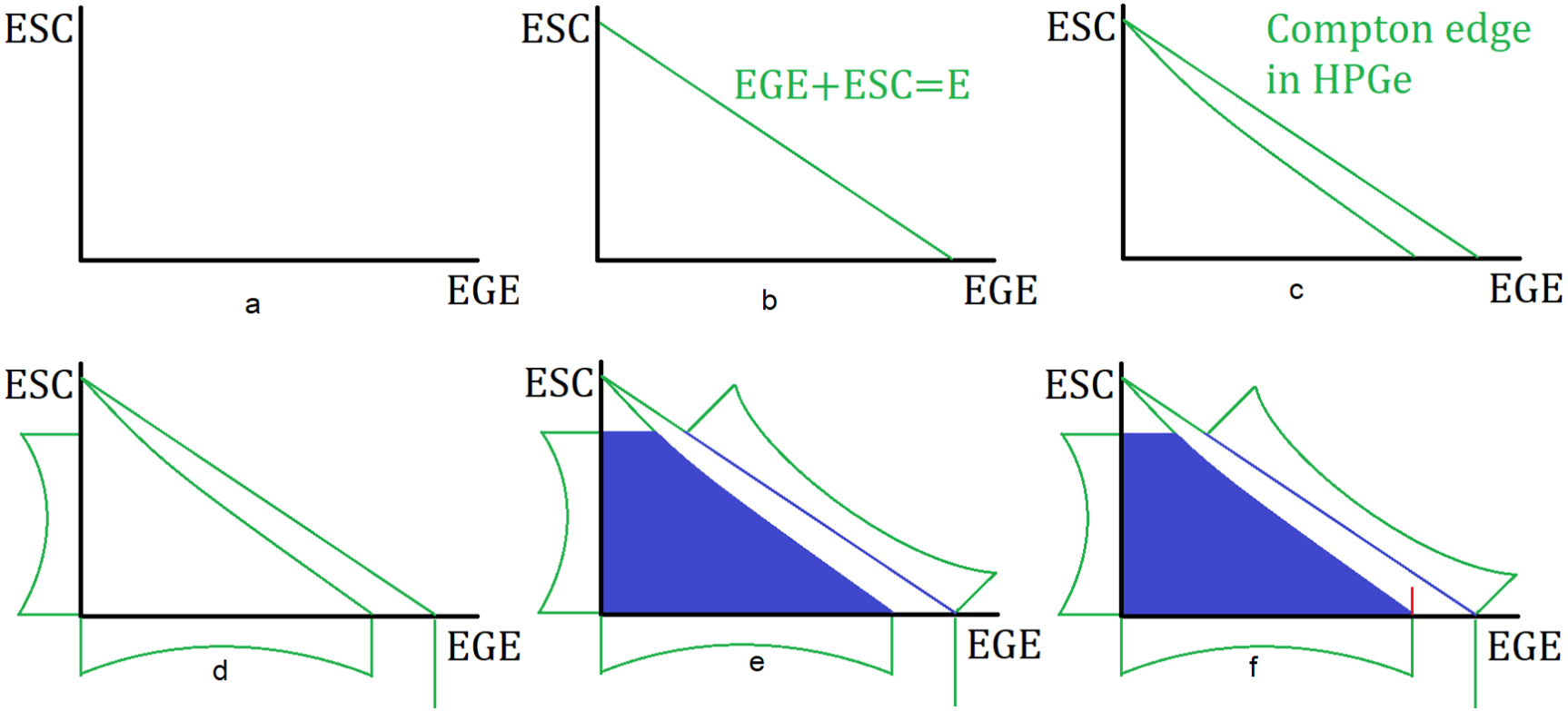
Birks quenching: $\frac{dL}{dx} = \frac{A}{1 + kB\frac{dE}{dx}}\frac{dE}{dx}$

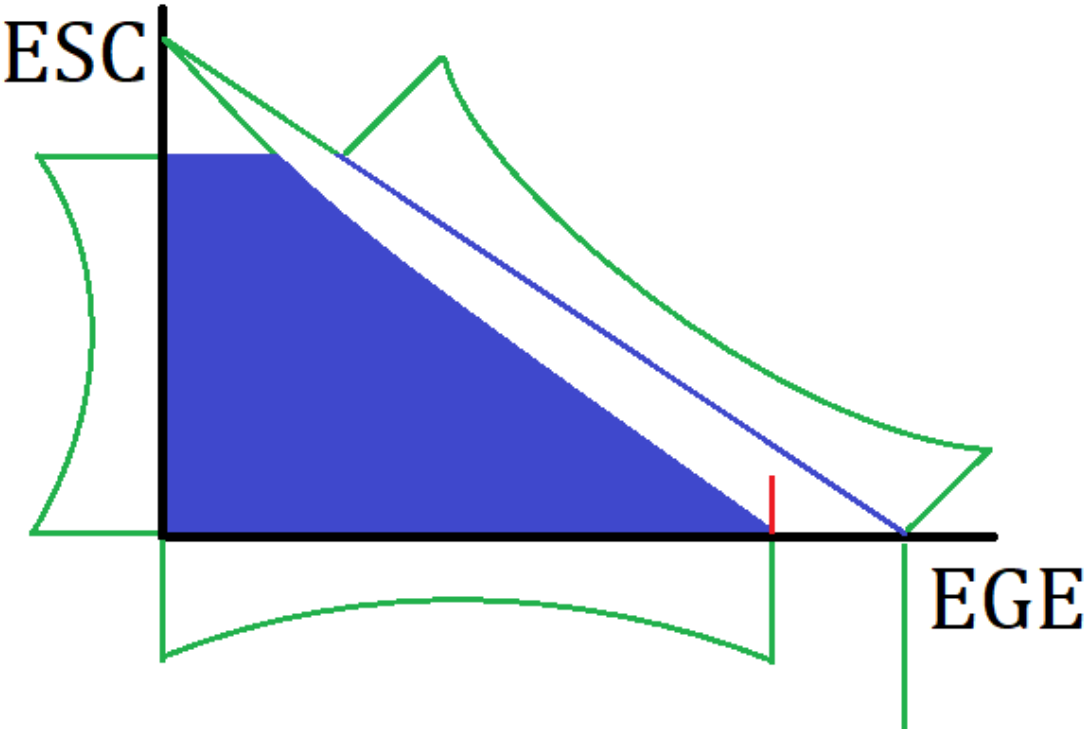
$$E_{\text{deposited}} = E - E' = E - E_{\text{HpGe}} = E - \frac{E}{1 + \frac{E}{m_e c^2}(1 - \cos\alpha)}$$

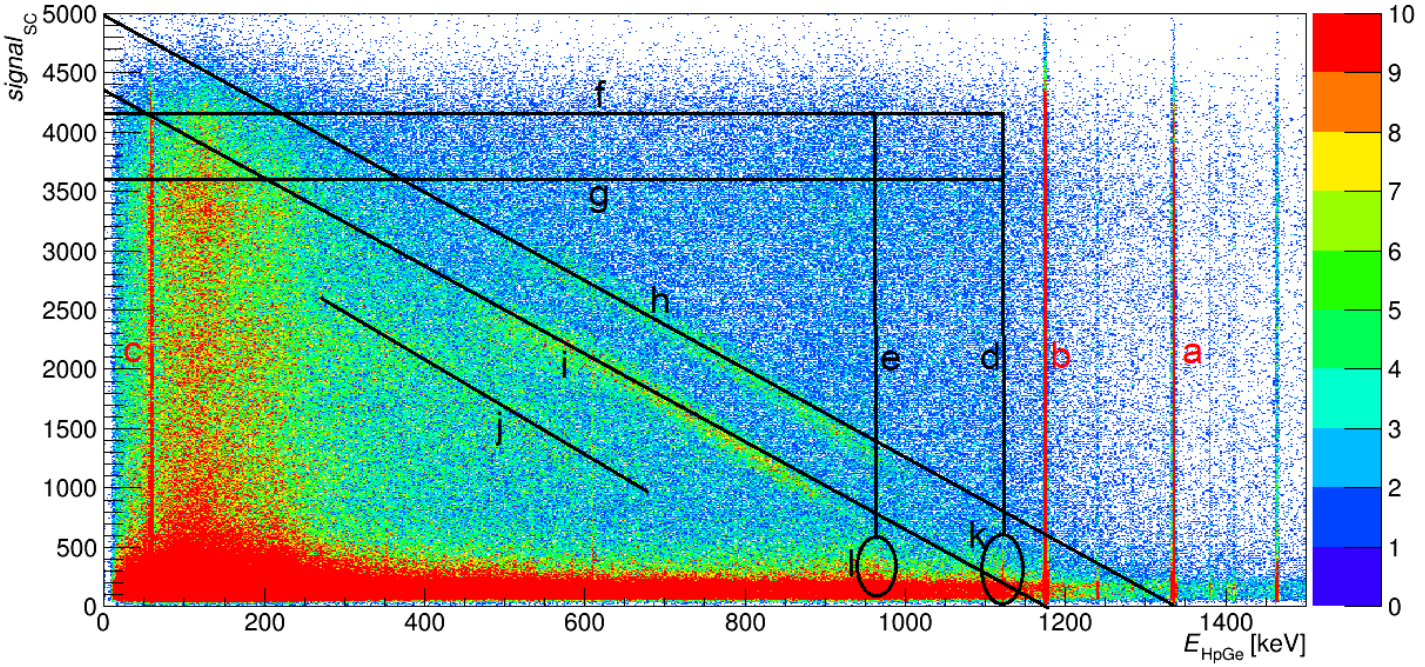
α = 50°



Simple picture

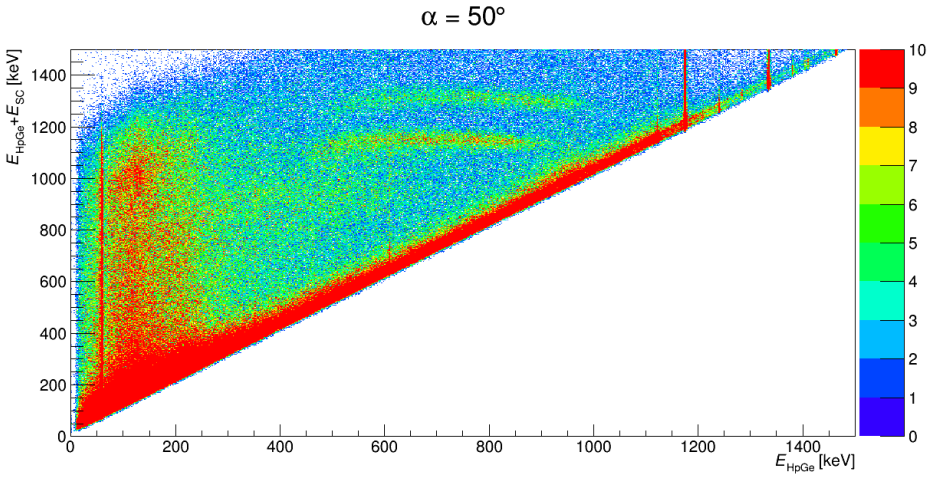


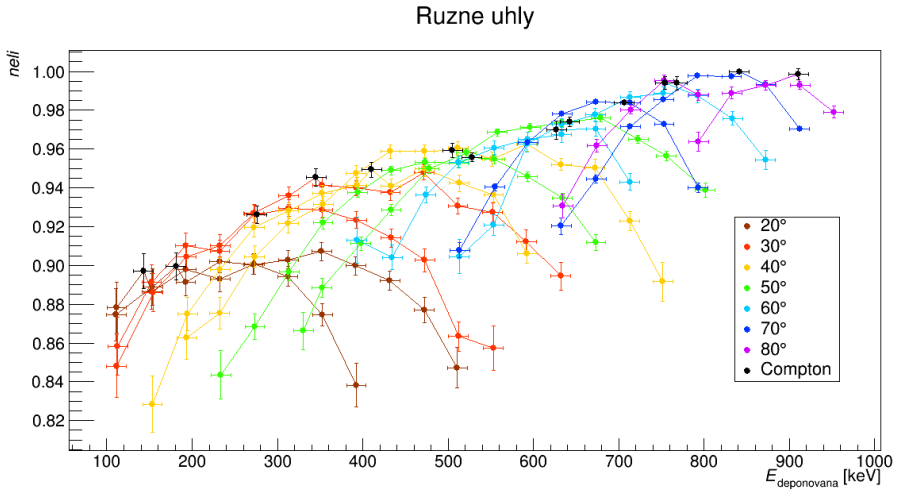

ESC
EGE

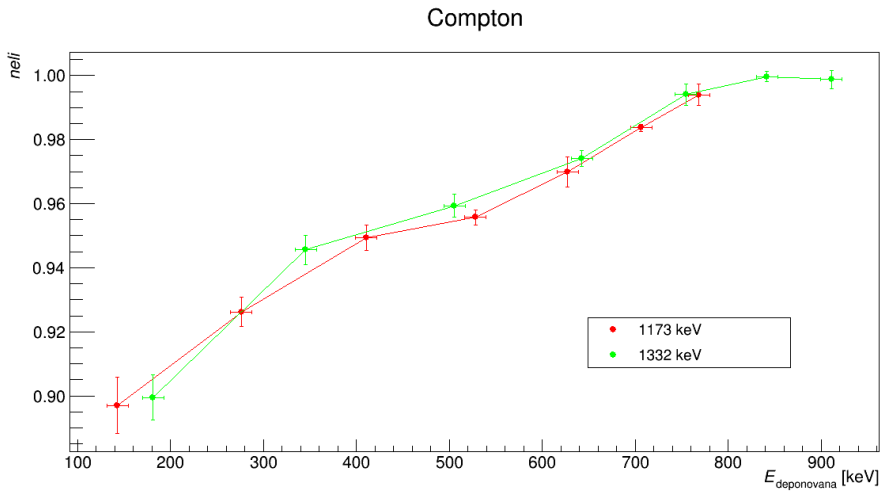

signal SC
E HpGe [keV]
a
b
c
d
e
f
g
h
i
j
k
l

Already processed

$$neli = \frac{\langle E_{\mathrm{HPGe}} + E_{\mathrm{SC}} \rangle - \langle E_{\mathrm{HPGe}} \rangle}{E - \langle E_{\mathrm{HPGe}} \rangle}$$

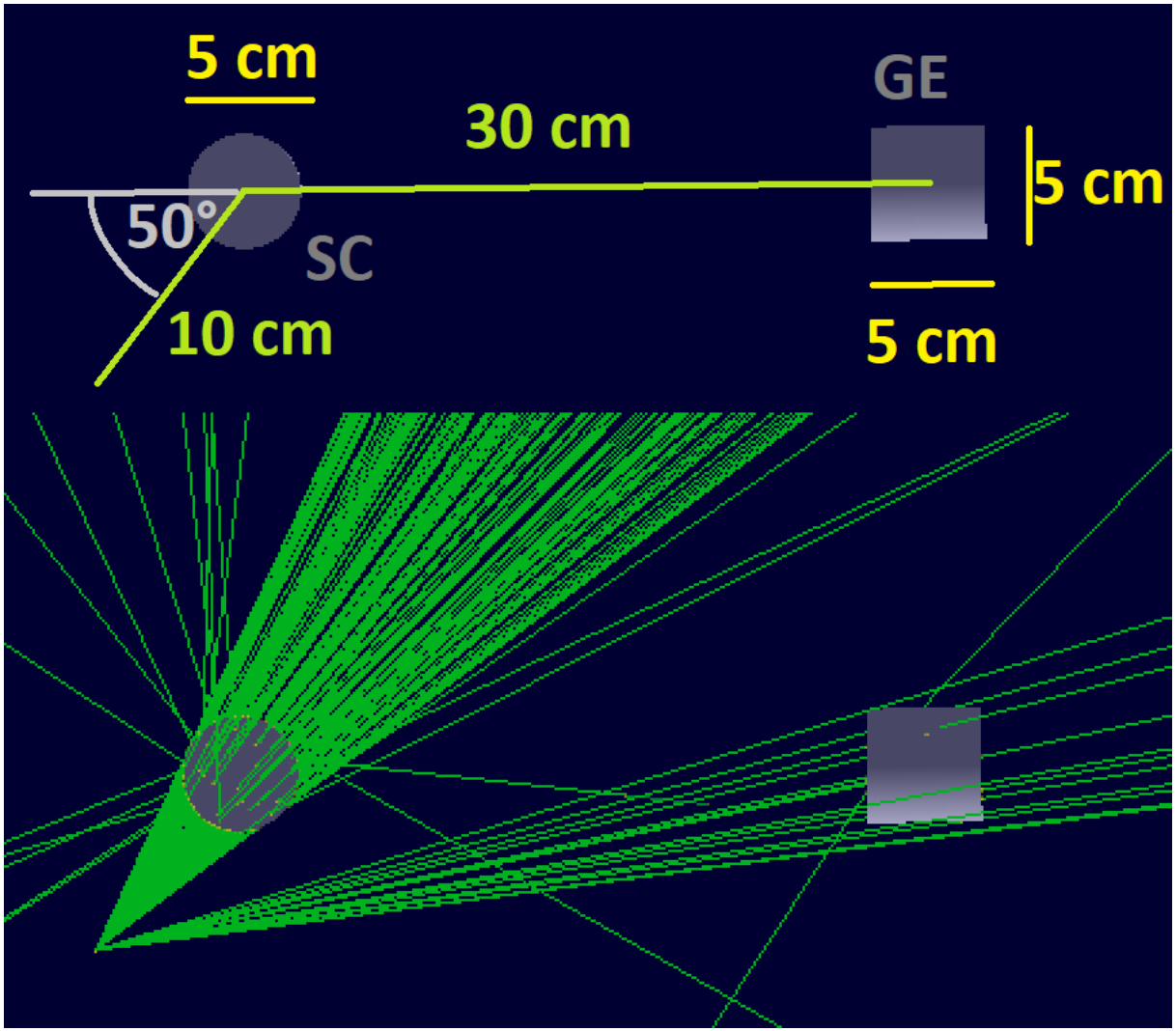




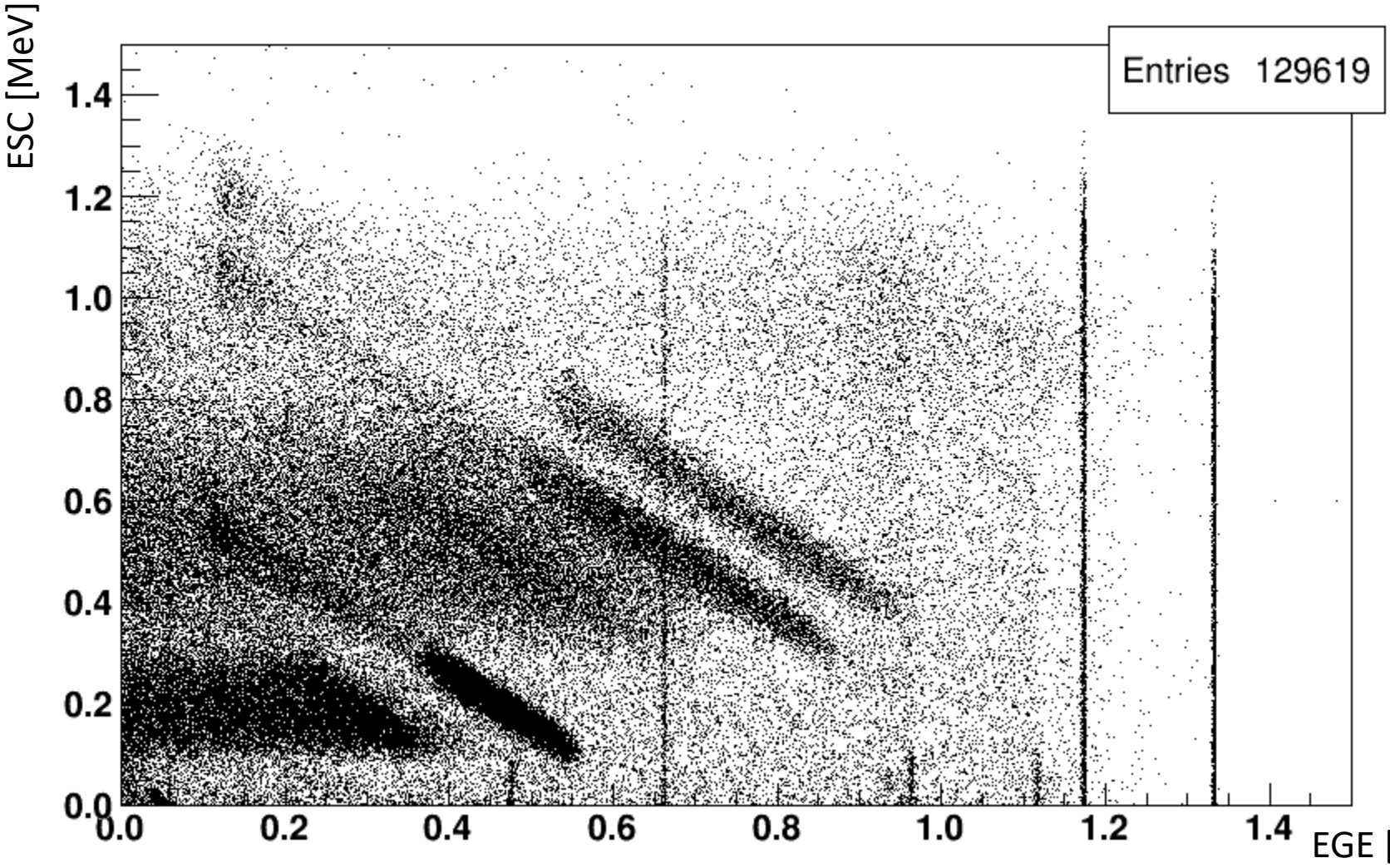


Simulation

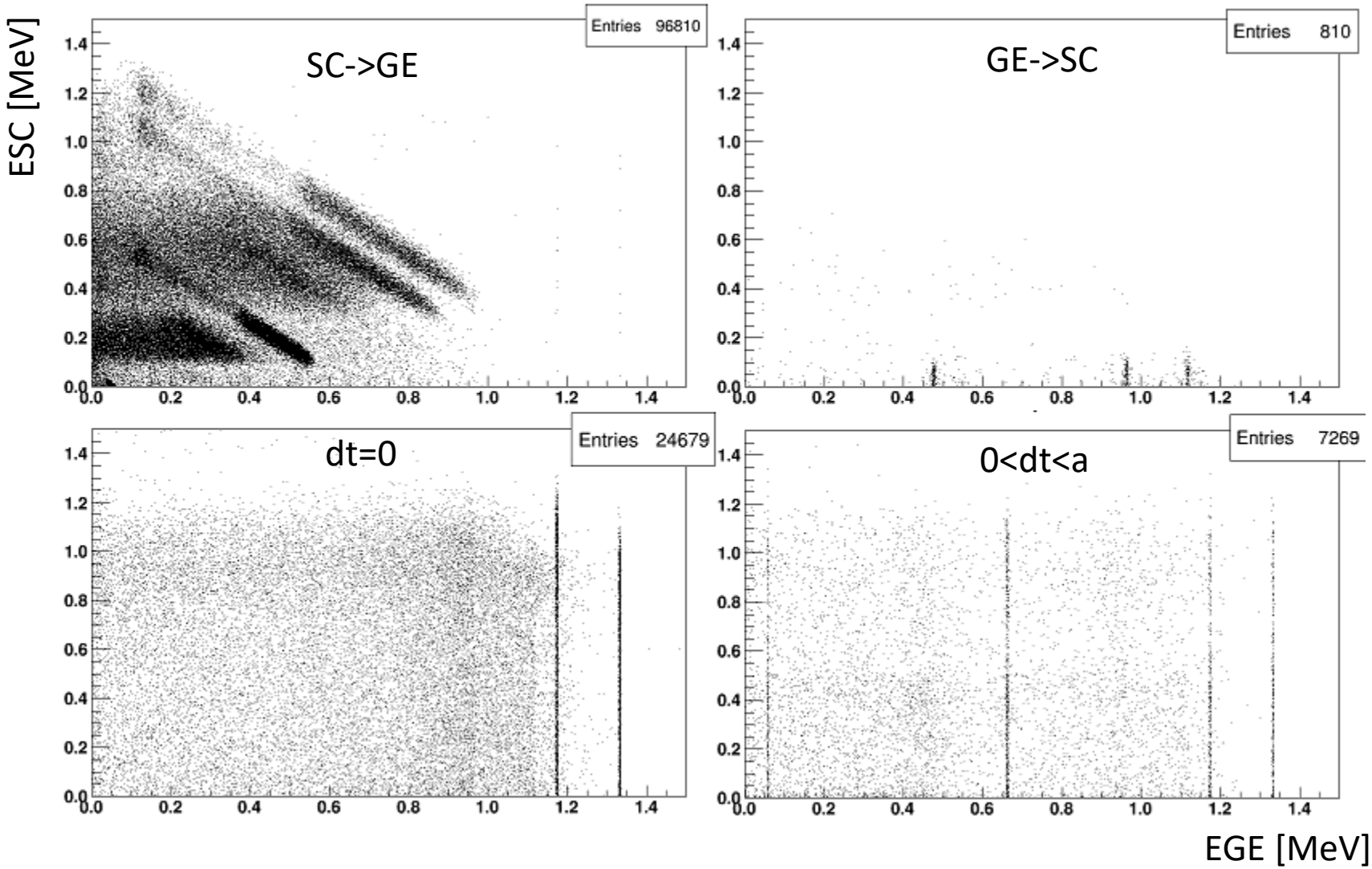
Geometry



Simple picture



Simple picture analysis



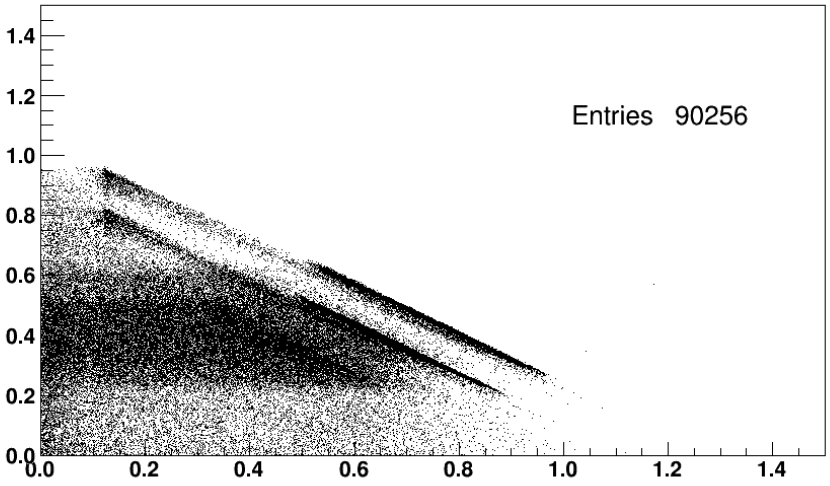
Simulation with kB

Introduction

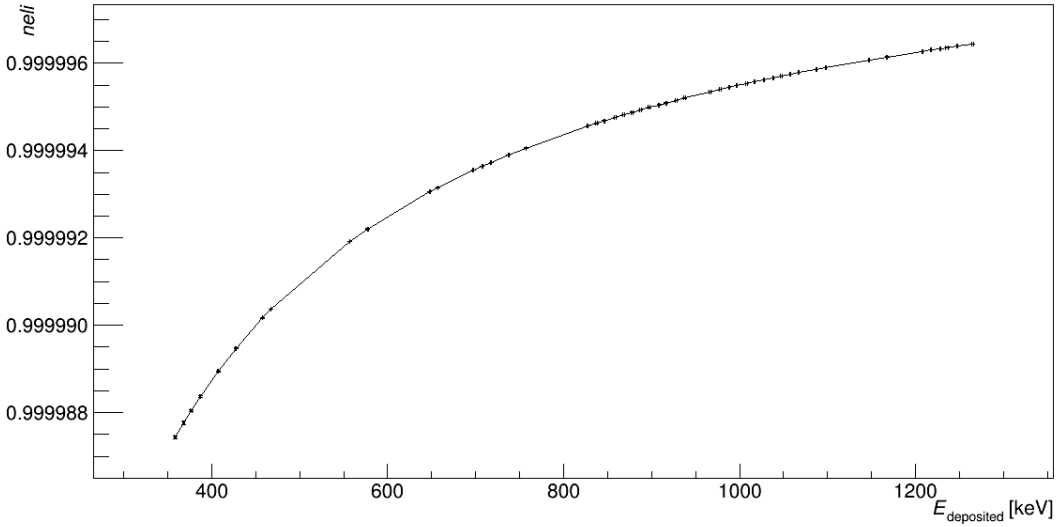
$$E = \mathrm{A}S = \mathrm{A}\sum \frac{dE}{1 + \mathrm{kB}\frac{dE}{dx}}$$

$$neli = \frac{\langle E_{\mathrm{HPGe}} + E_{\mathrm{SC}} \rangle - \langle E_{\mathrm{HPGe}} \rangle}{E - \langle E_{\mathrm{HPGe}} \rangle} \cong \frac{\mathrm{A}S}{E_{\mathrm{SC}}}$$

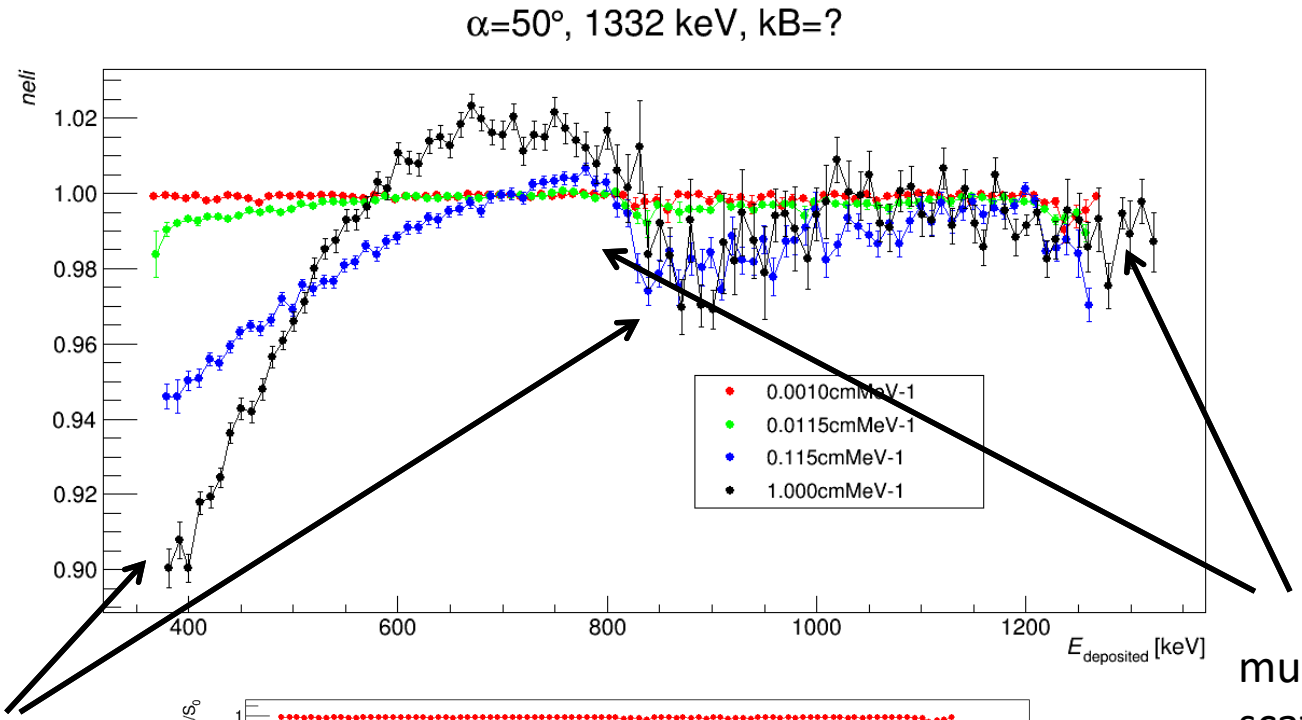
$$\frac{S}{S_0} \cong \frac{\frac{neli}{\mathrm{A}}}{\frac{neli_0}{\mathrm{A}_0}} \cong \frac{neli}{\mathrm{A}}$$



kB=0, α=50°, 1332 keV

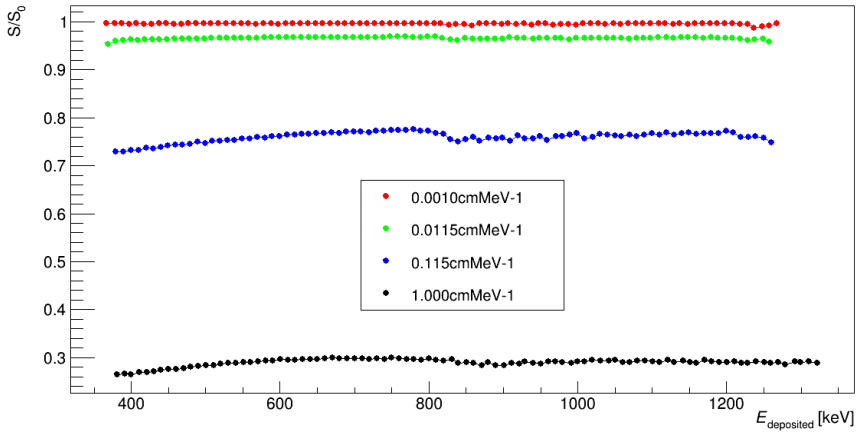


Different kB

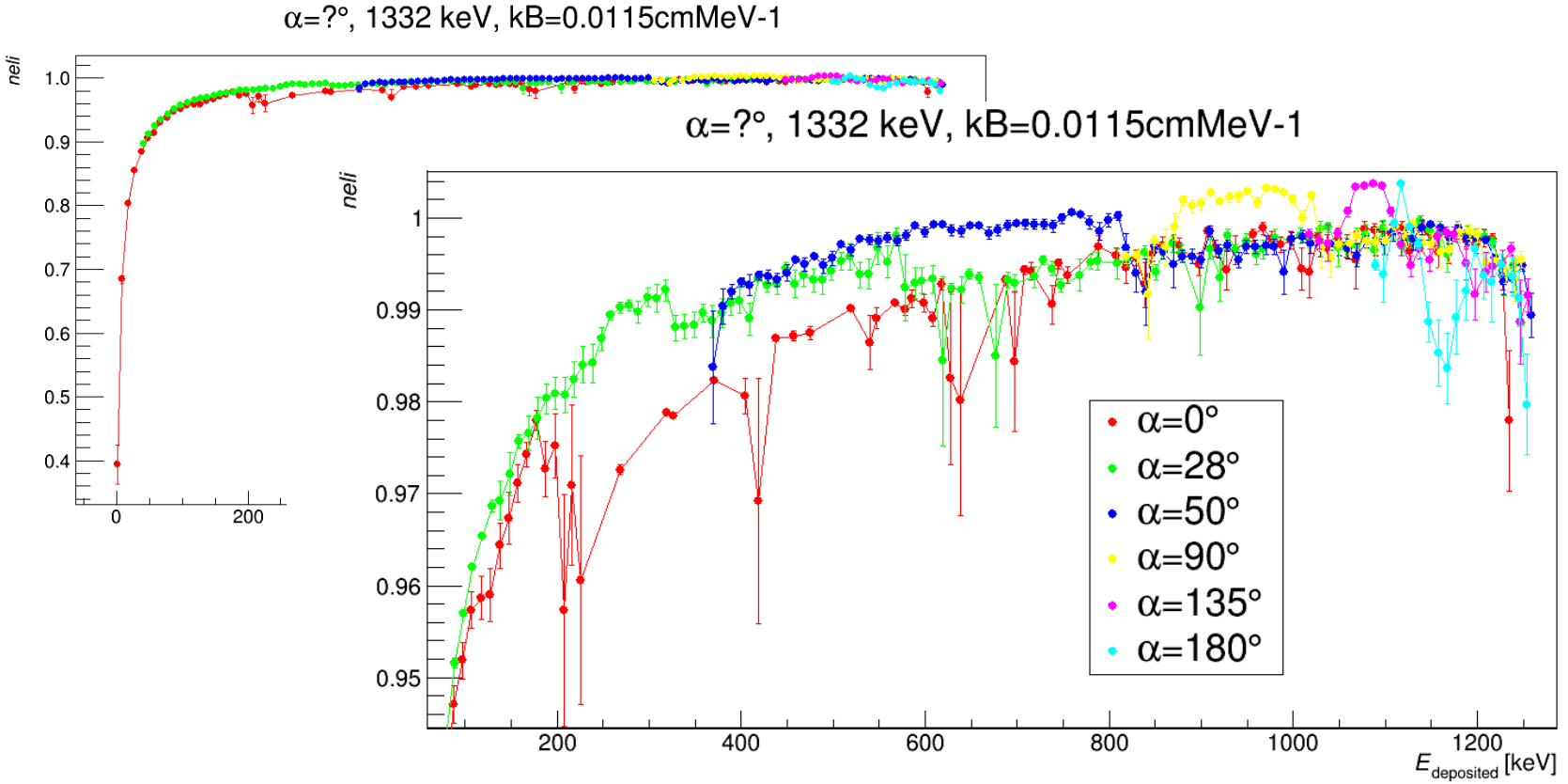


1 Compton scattering

multiple Compon scattering

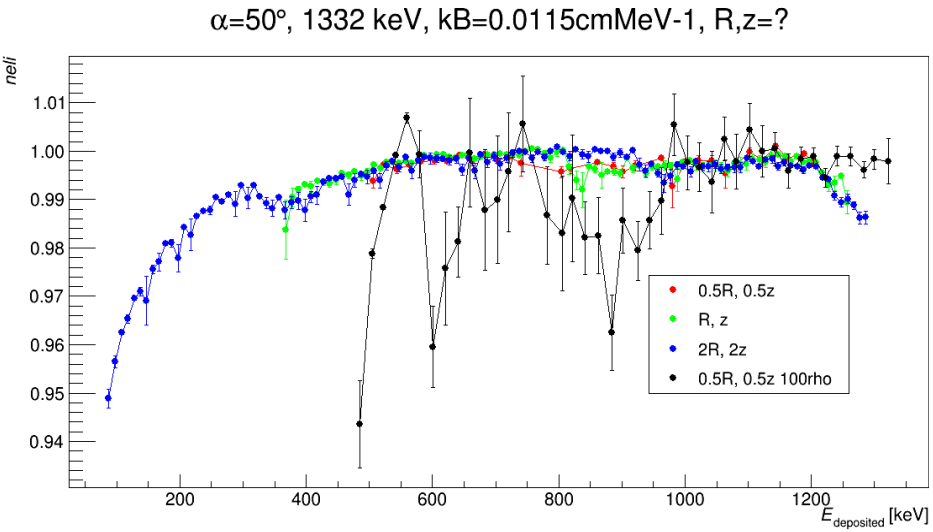


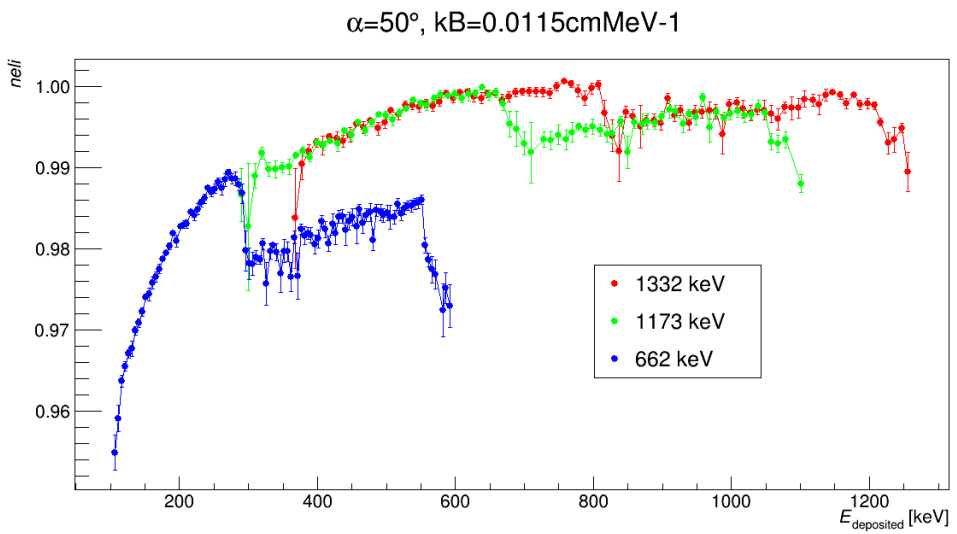
Different α



α	2 scattering min (keV)	1 scattering min (keV)	Compton (keV)	1 scattering max (keV)	2 scattering max (keV)
0°	0	0	0	121.7	1215.9
28°	37.3	72.3	311.6	562.5	1215.6
50°	247.8	411.5	642.6	809.0	1213.5
90°	682.9	871.5	963.1	1024.4	1204.1
135°	959.2	1059.1	1088.1	1106.2	1182.1
180°	1089.8	1114.6	1118.1	1118.1	1140.5

Volume and initial energy

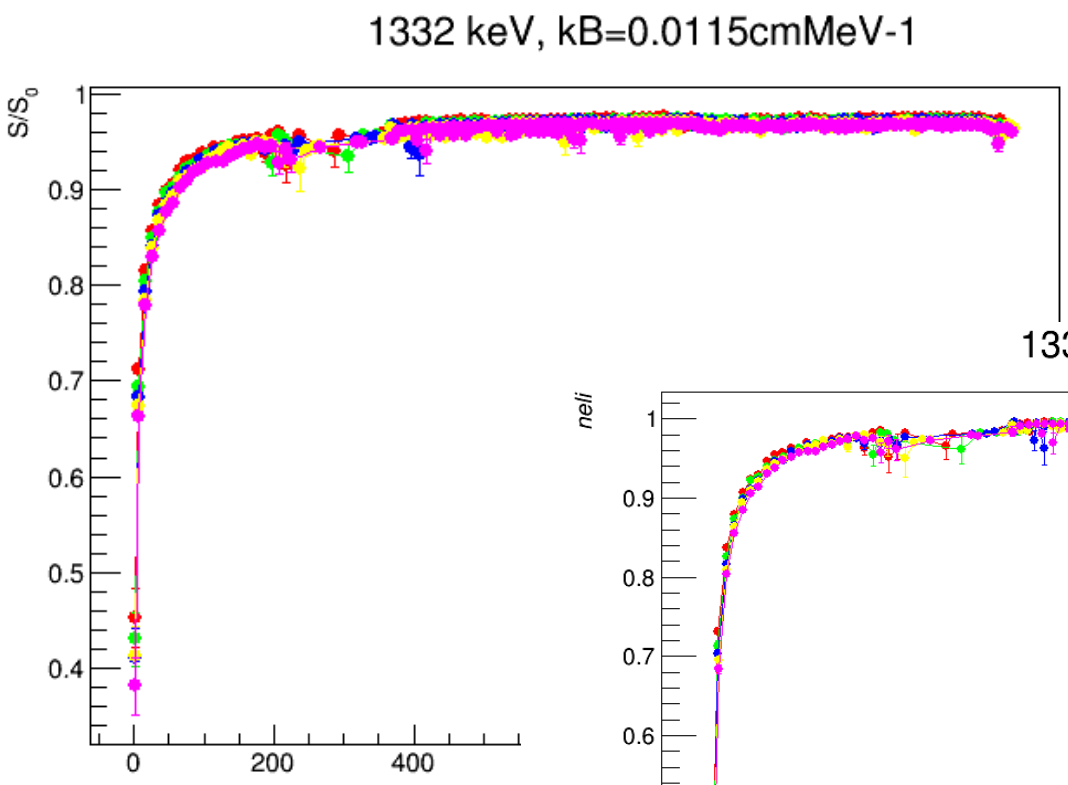




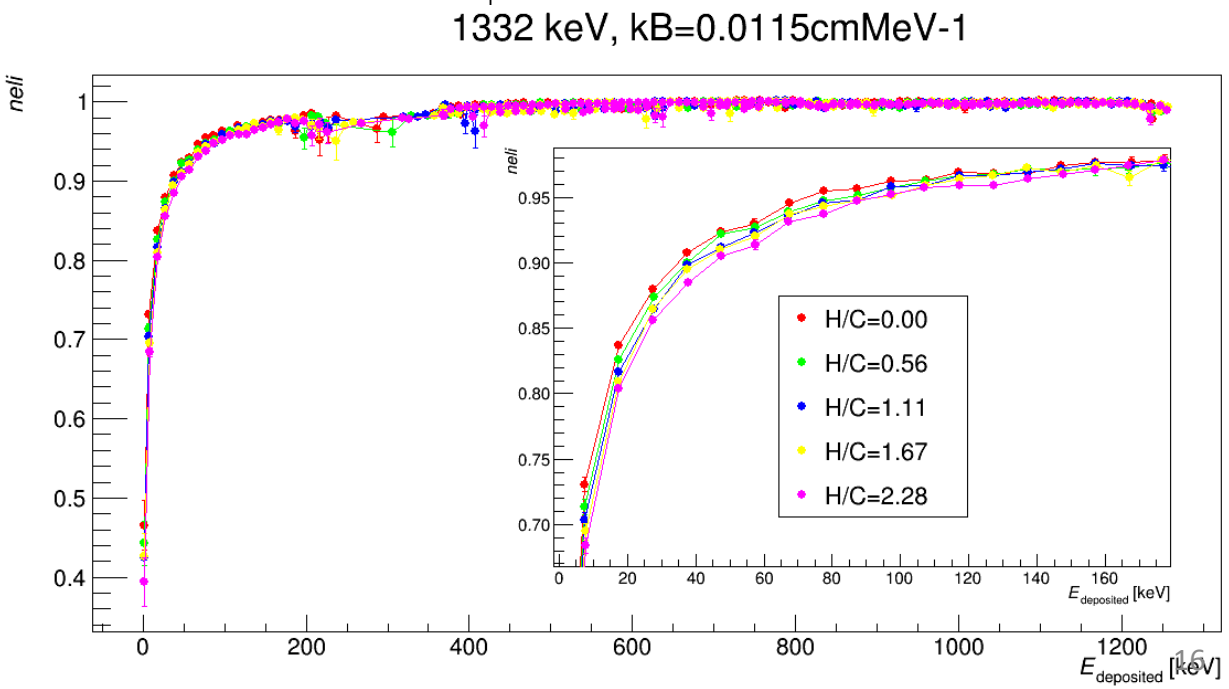
geometry	2 scattering min (keV)	1 scattering min (keV)	Compton (keV)	1 scattering max (keV)	2 scattering max (keV)
0.5R, 0.5z	344.0	535.9	642.6	732.8	1212.3
1.0R, 1.0z	247.8	411.5	642.6	809.0	1213.5
2.0R, 2.0z	69.3	131.0	642.6	929.5	1215.4

Initial energy	2 scattering min (keV)	1 scattering min (keV)	Compton (keV)	1 scattering max (keV)	2 scattering max (keV)
1173 keV	196.4	331.2	528.6	676.2	1055.7
1332 keV	247.8	411.5	642.6	809.0	1213.5
662 keV	67.4	120.1	209.3	287.3	552.6

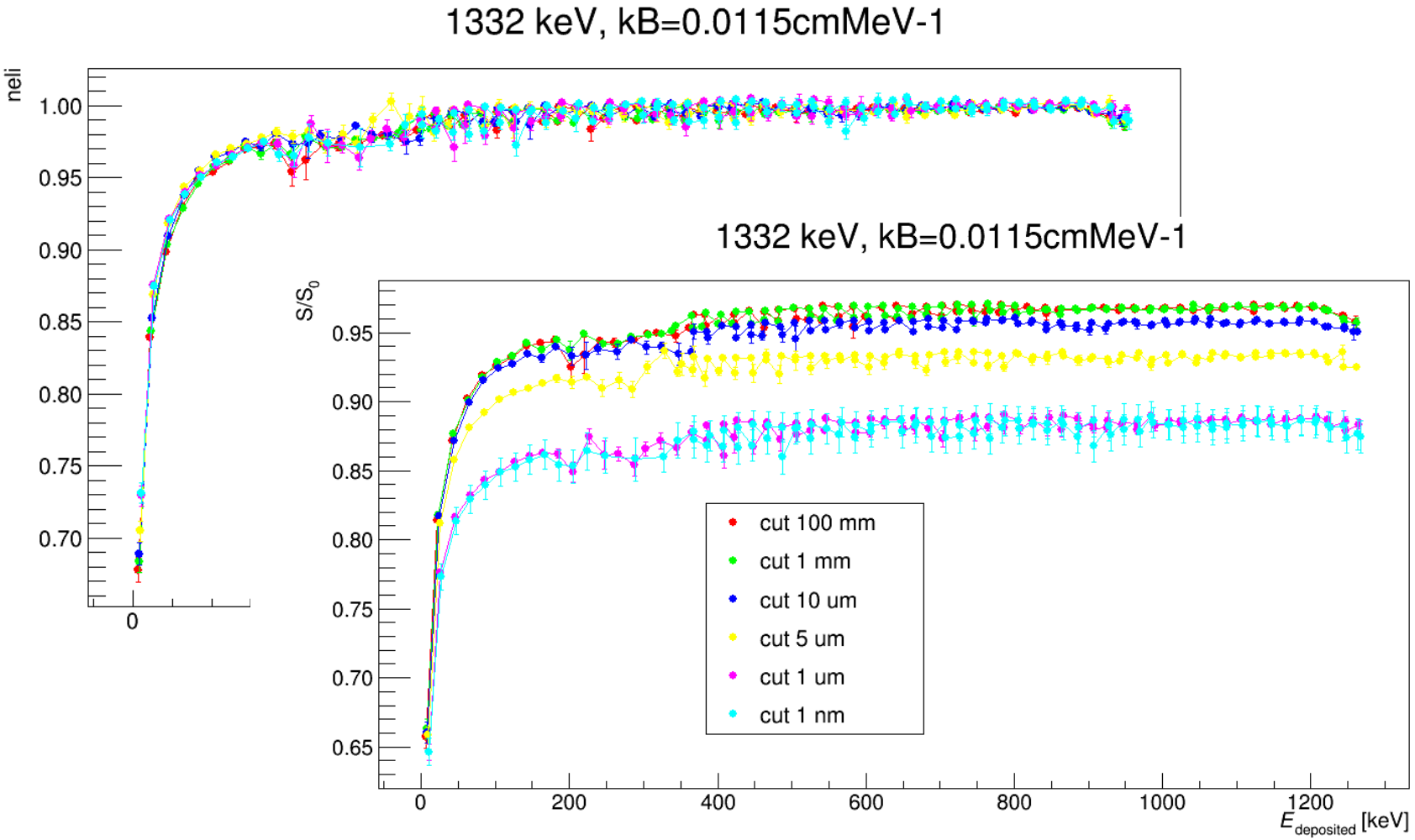
Different composition



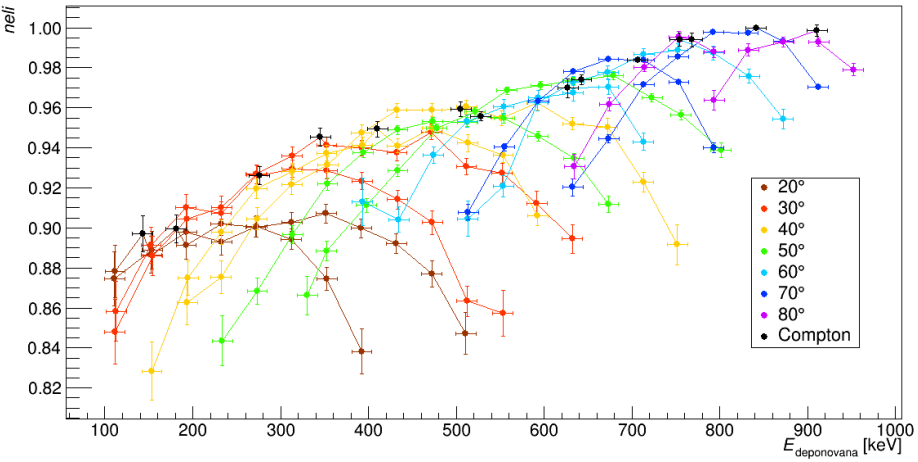
H/C	ρ [cm-3]
0.00	2.62e23
0.56	2.73e23
1.11	2.84e23
1.67	2.93e23
2.28	3.03e23
Ge	14.12e23



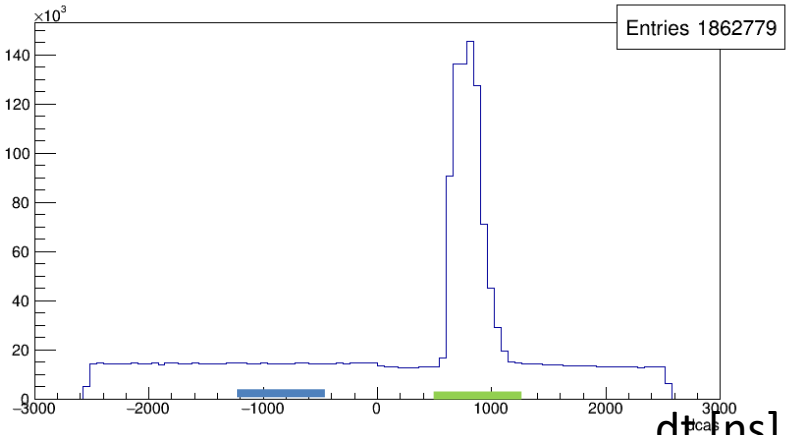
Different cut



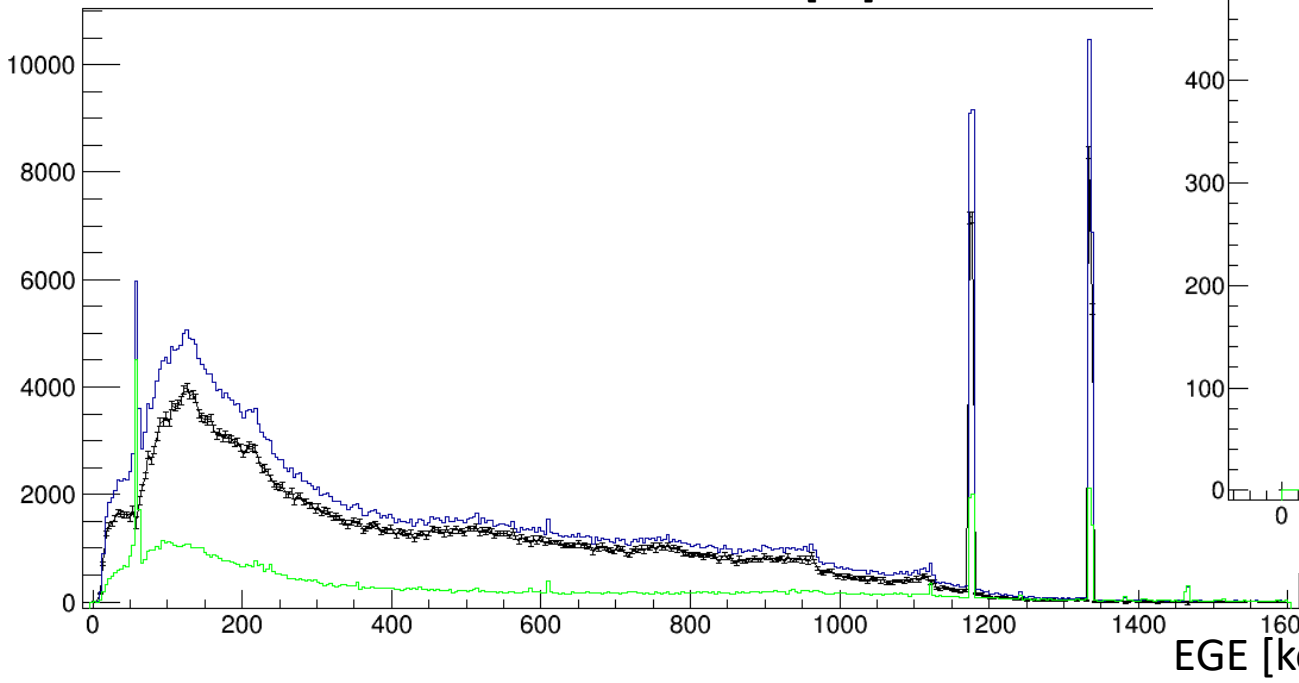
Measured data

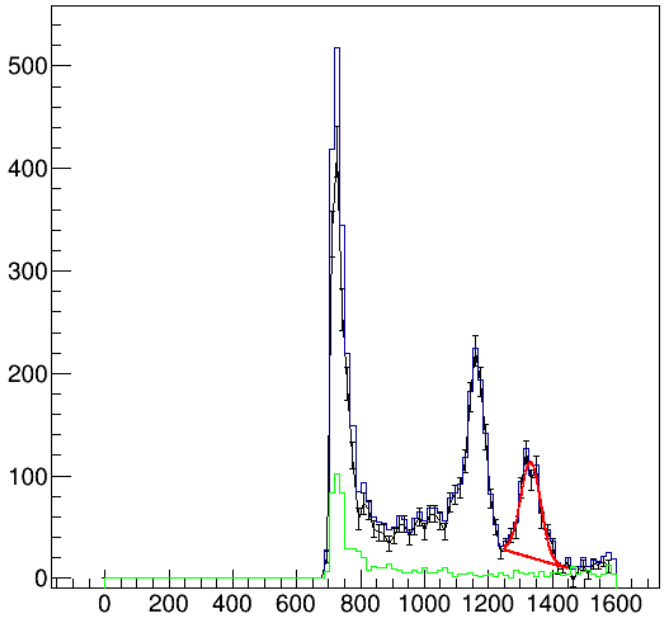

neli
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
100
200
300
400
500
600
700
800
900
1000
$E_{\text{deponovana}}$ [keV]
20°
30°
40°
50°
60°
70°
80°
Compton

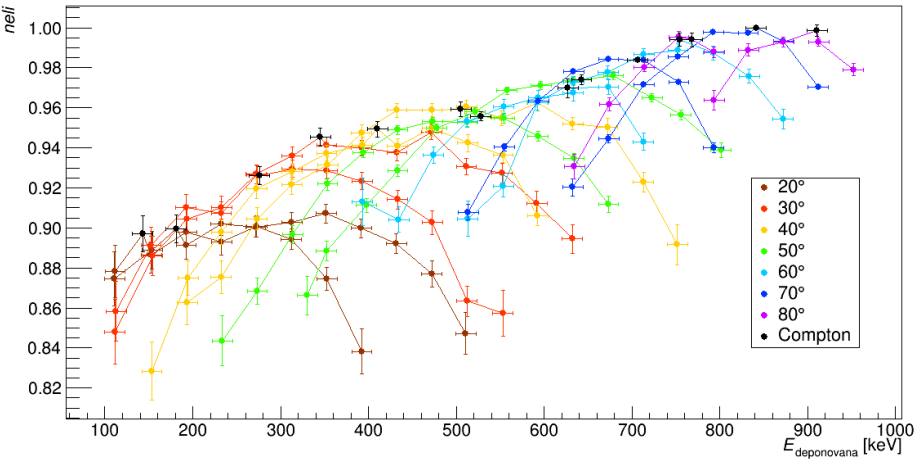
Background



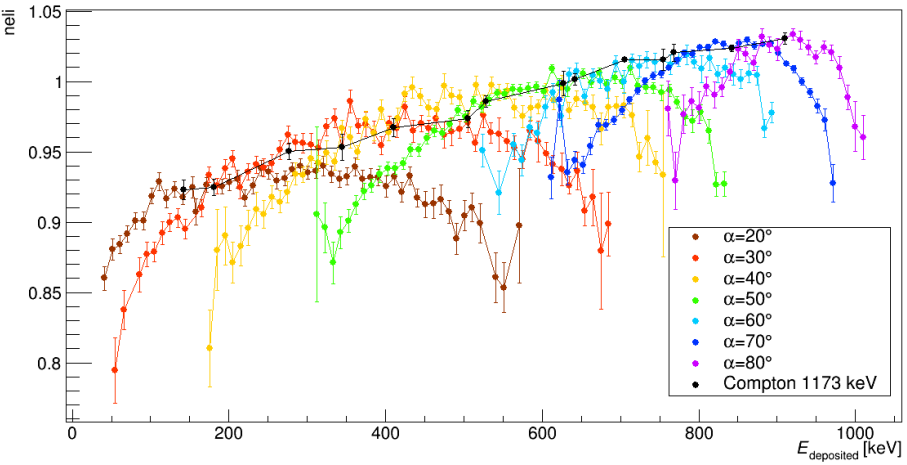
$$\langle EGE_{nob} \rangle = \frac{N_{all}\langle EGE \rangle - N_b \langle EGE_b \rangle}{N_{all} - N_b}$$



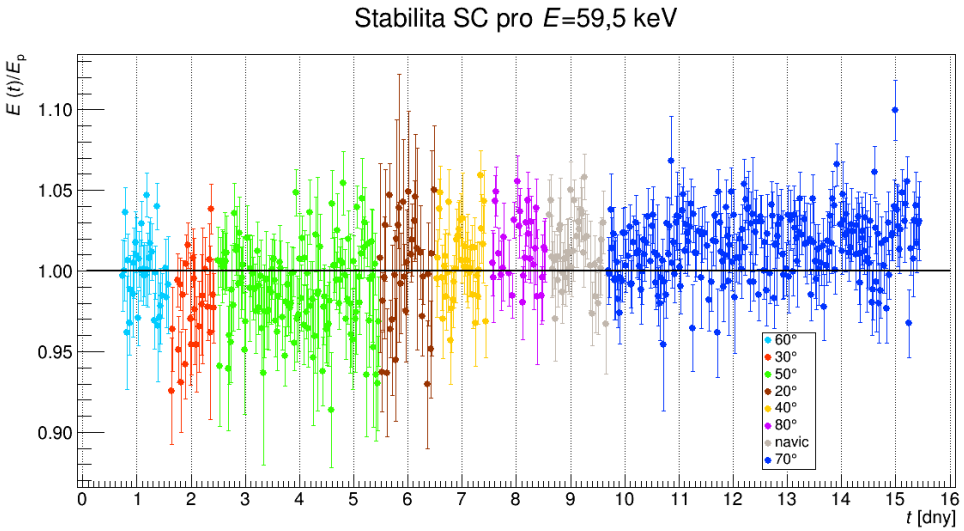


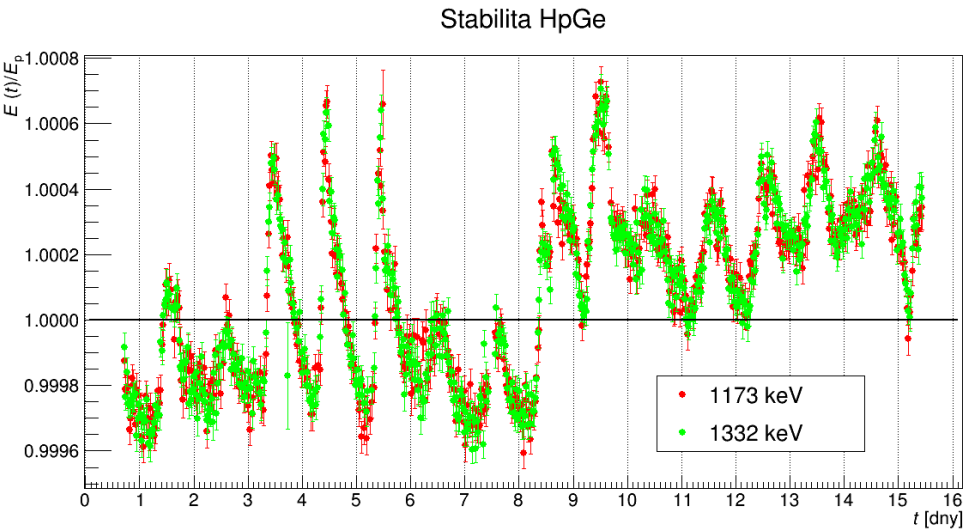


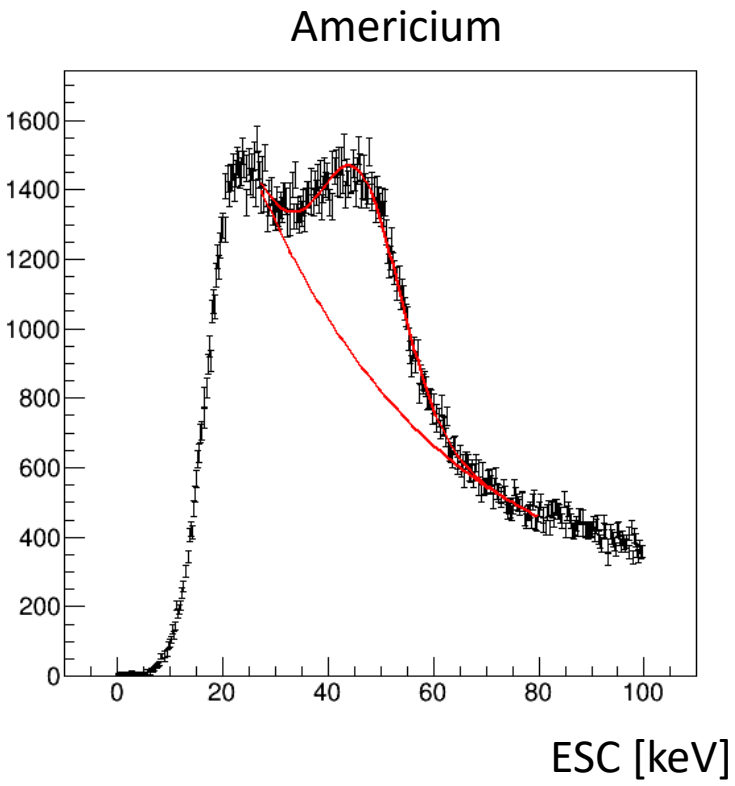
less background

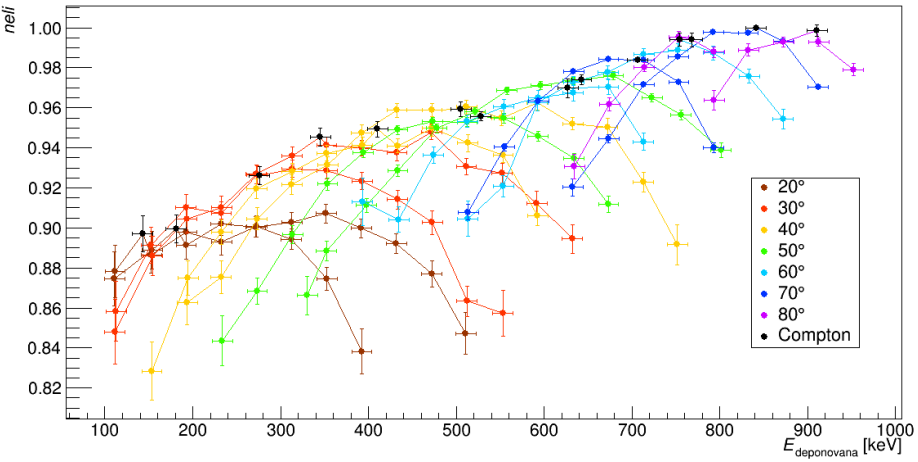


Temperature

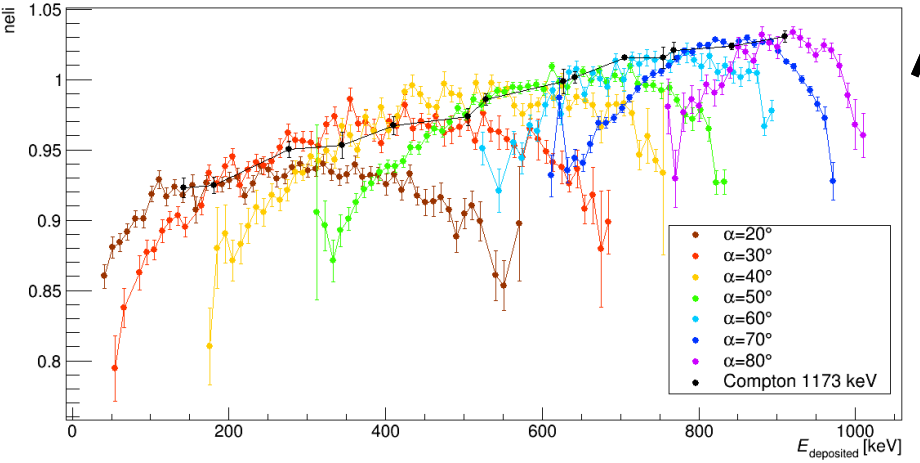




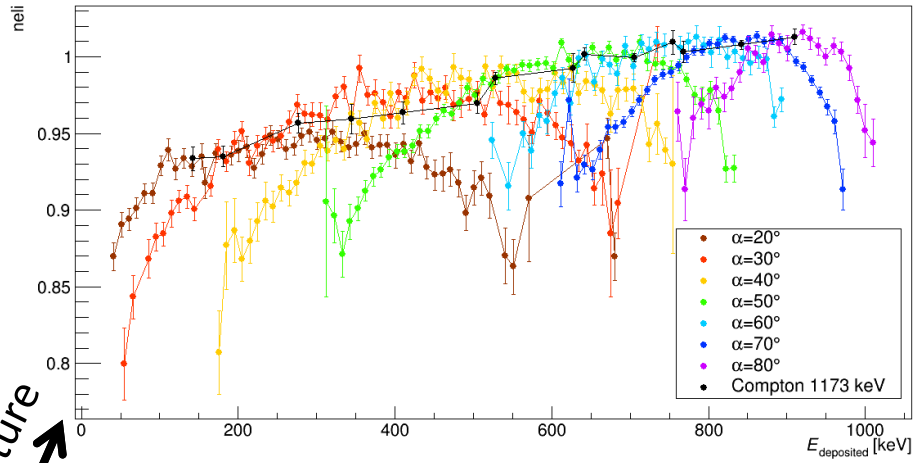




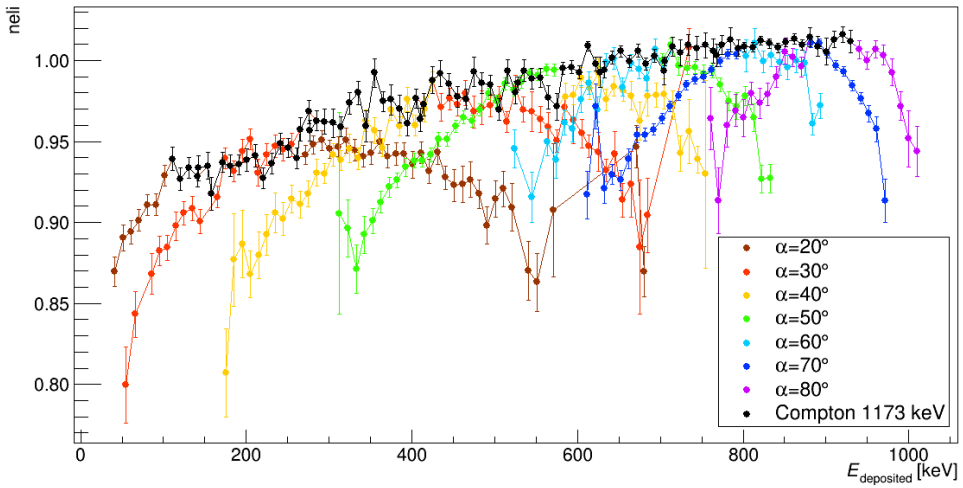
less background

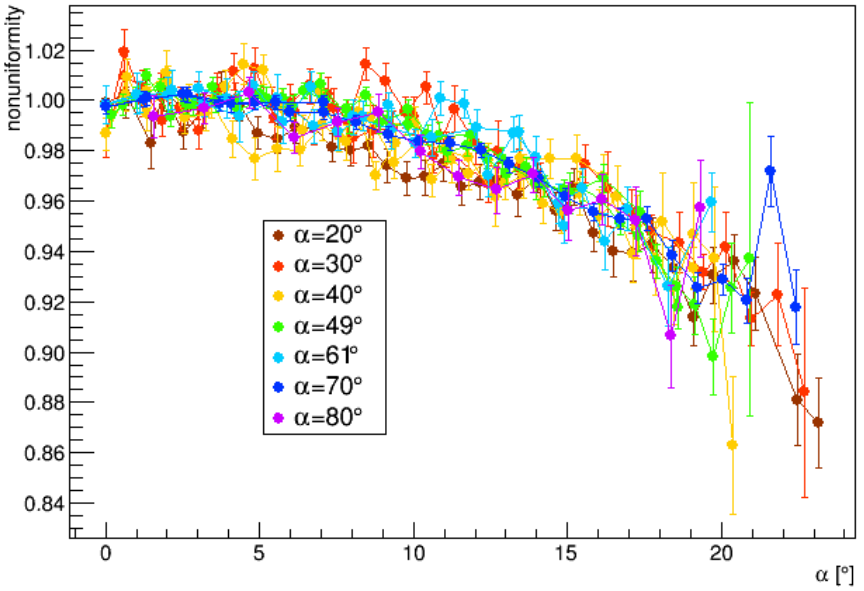


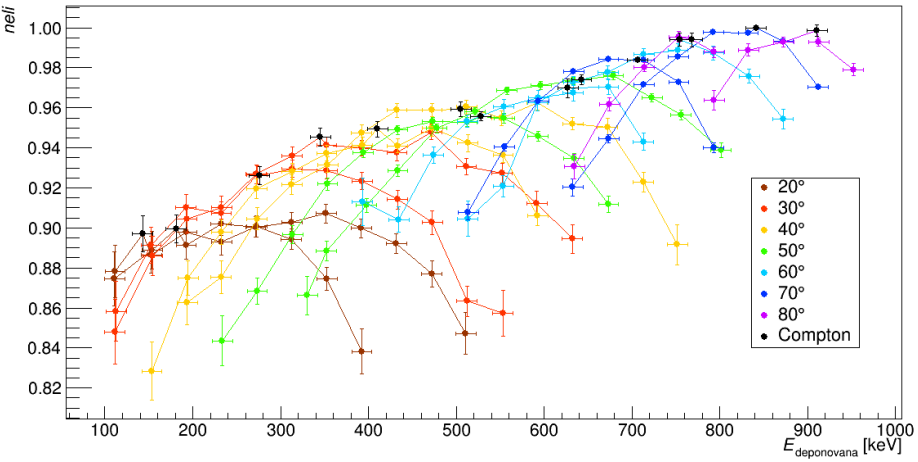
temperature



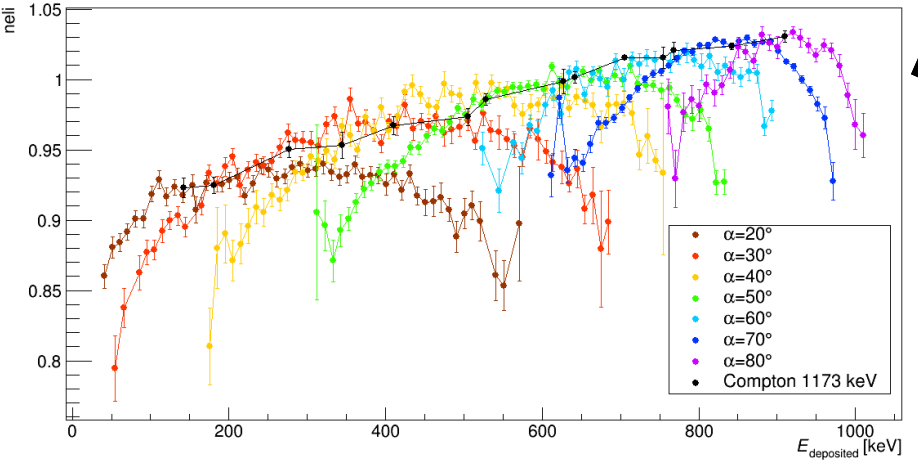
Nonuniformity



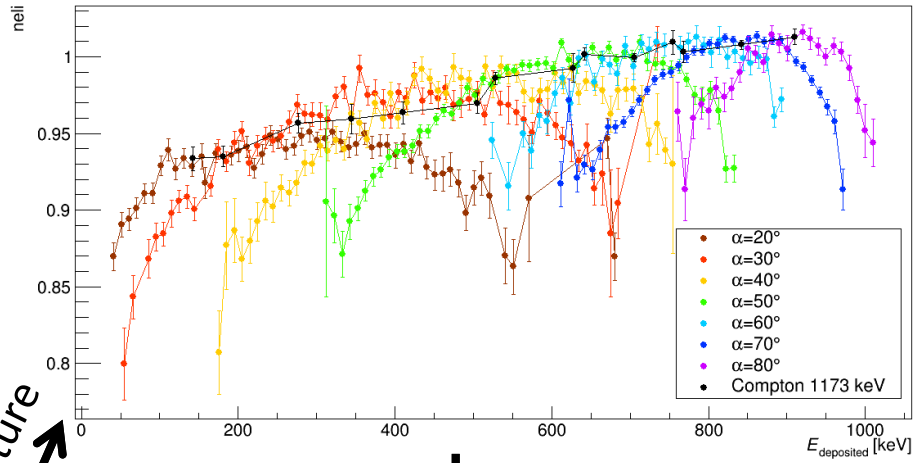




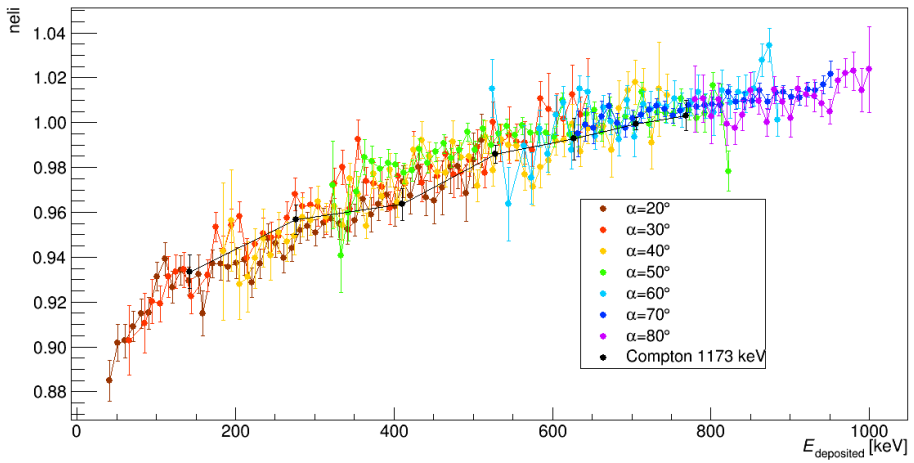
less background



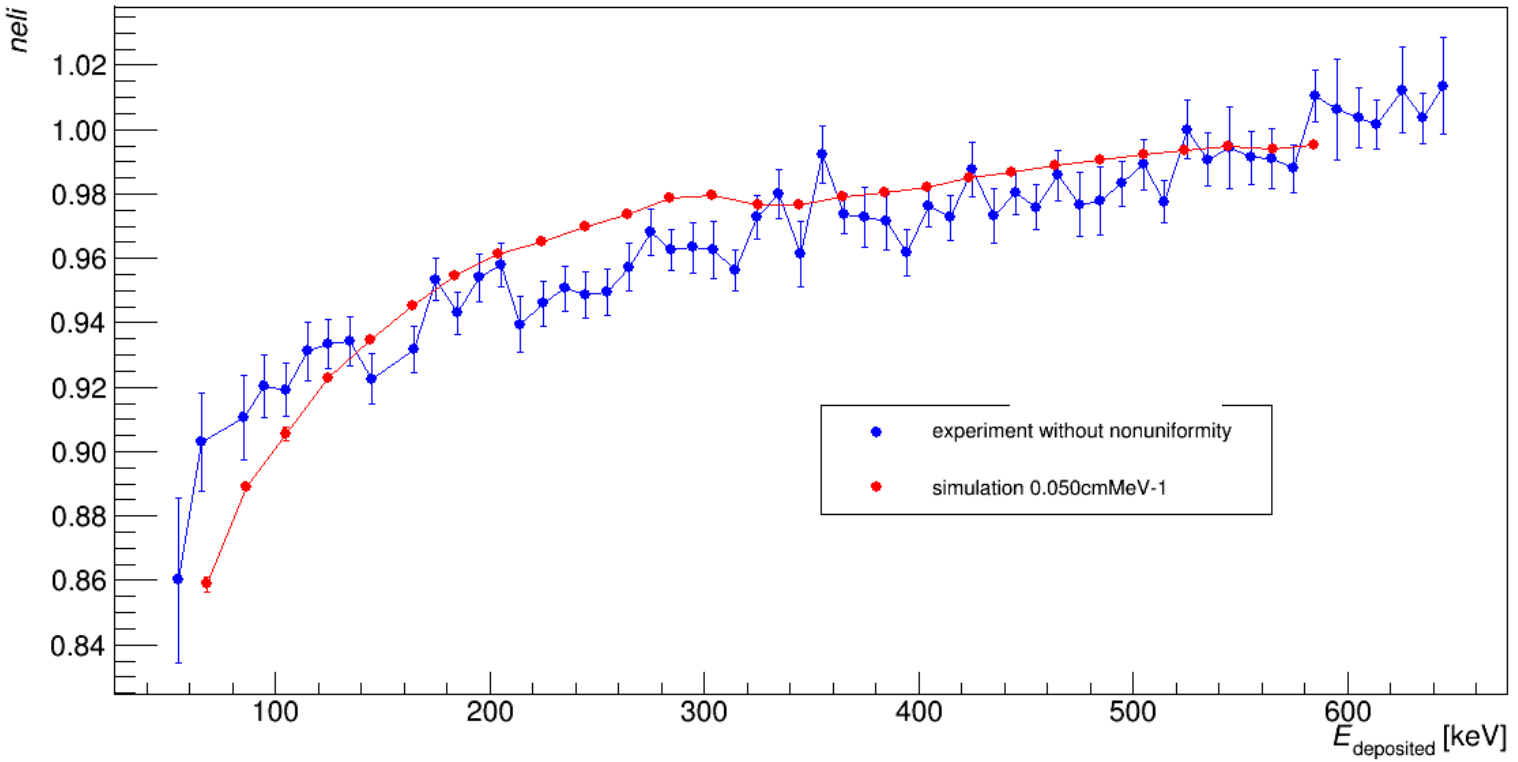
temperature



without nonuniformity



Result?

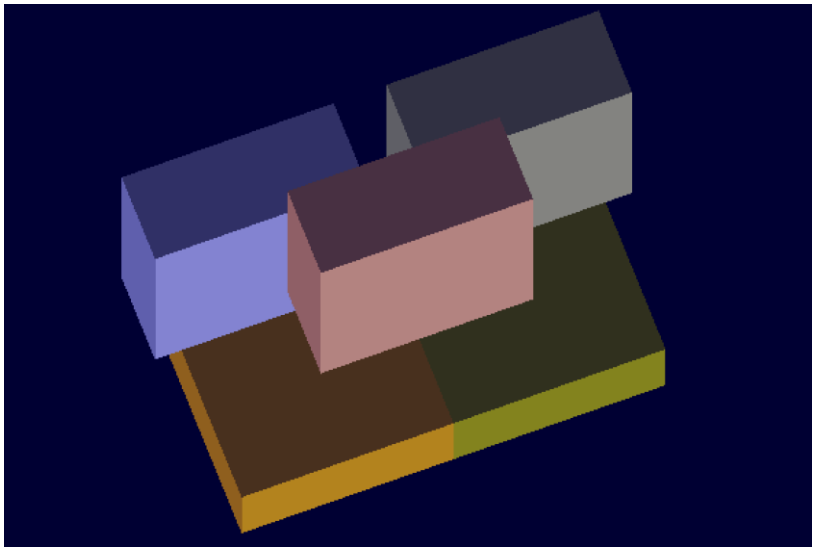


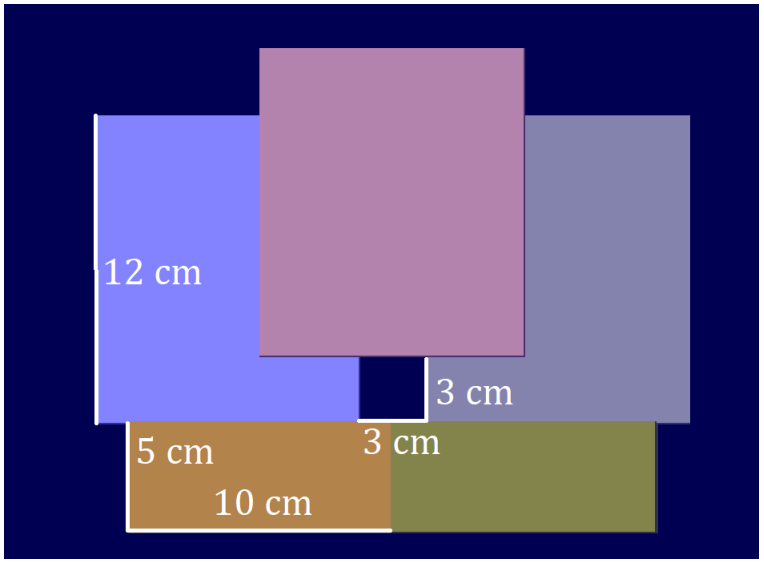
here $kB = (3.0 \pm 1.3) \times 10^{-2}\ \mathrm{g\,cm^{-2}MeV^{-1}}$

What it should be $kB = (0.728 \pm 0.023) \times 10^{-2}\ \mathrm{g\,cm^{-2}MeV^{-1}}$

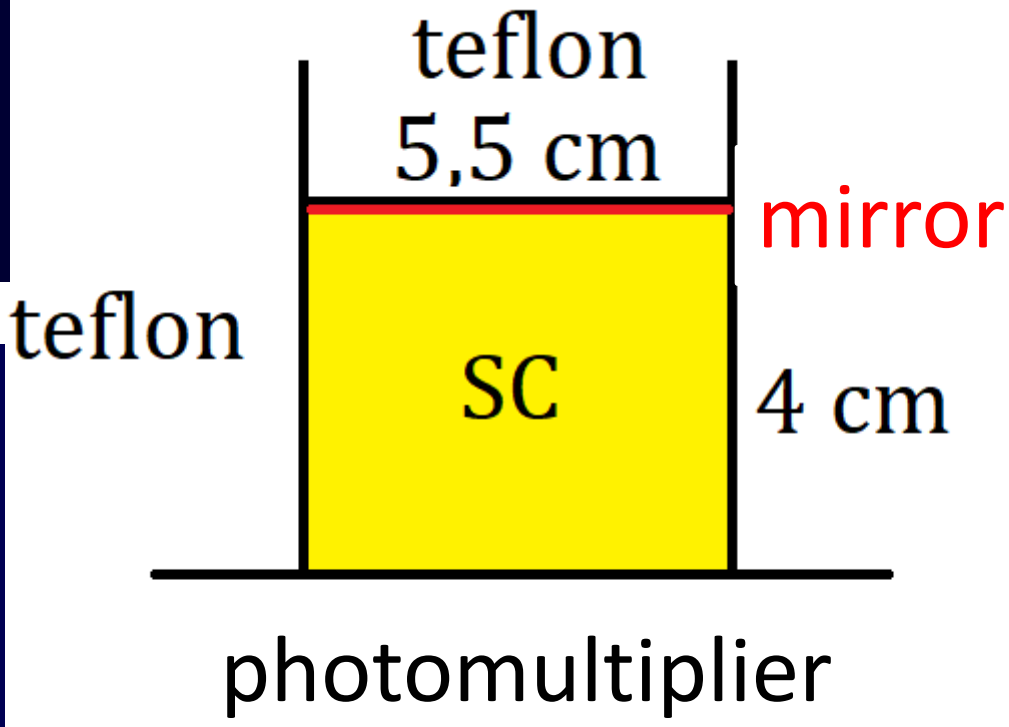
Experiment with Cs

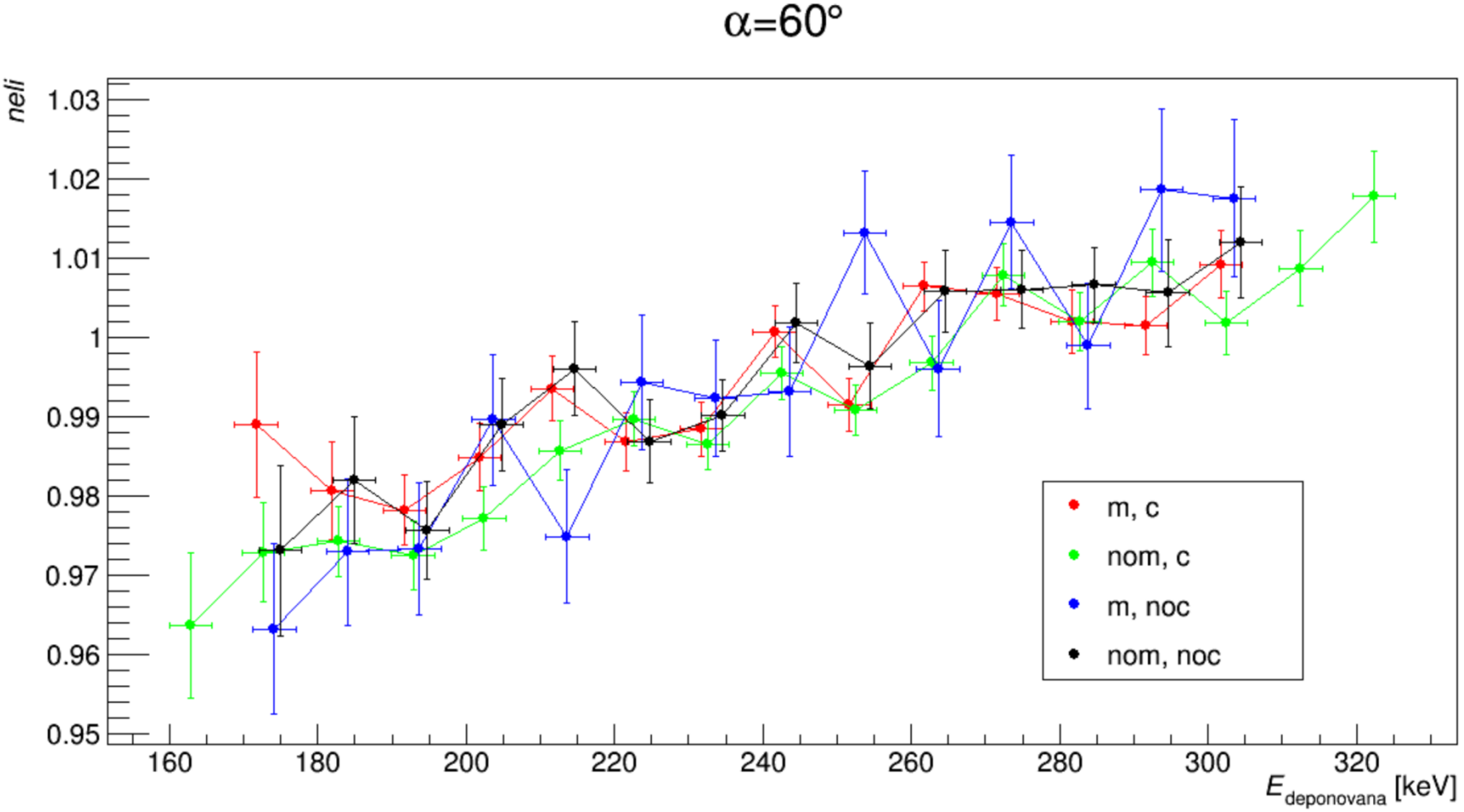
Collimator





Scintillator

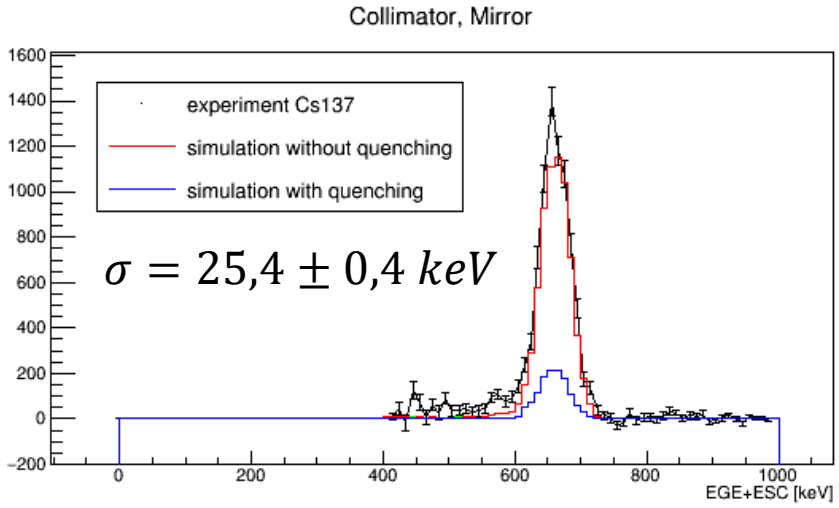


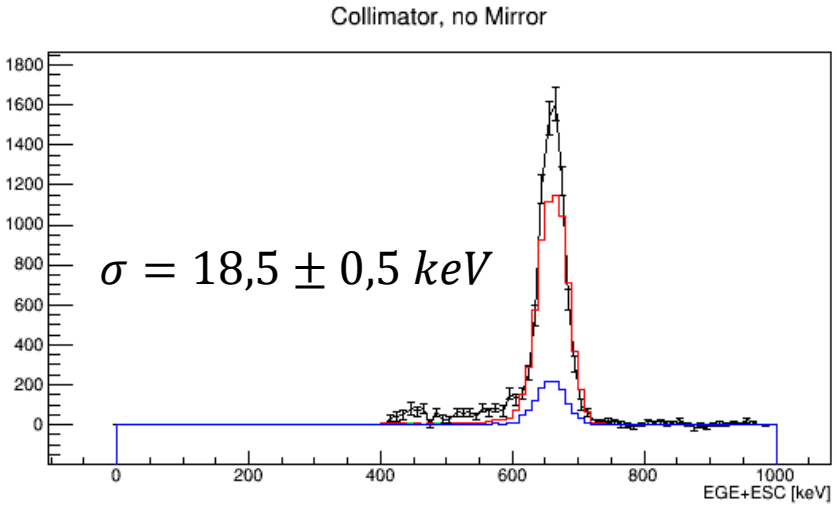


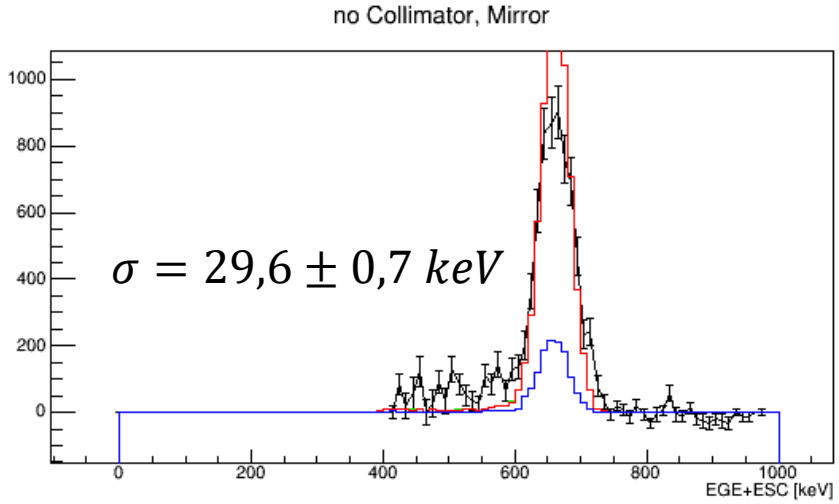
m – with mirror
nom – without mirror
c – with collimator
noc – without collimator

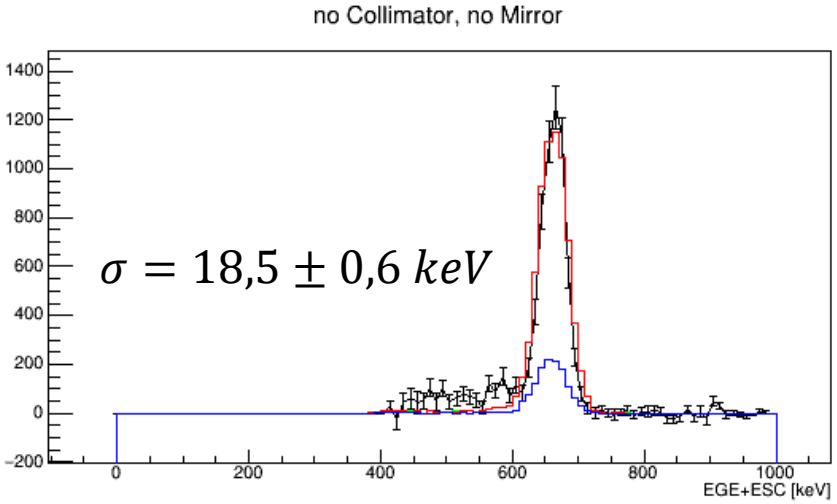
		events	time [h]	events in one hour	k [keV/bin]
m, c	Cs, Am, Ra	~~297000~~	~~23,3~~	~~13000~~	0,180
nom, c	Cs	87200	15,2	5700	0,160
m, noc	Cs	76200	5,8	13000	0,181
nom, noc	Cs	83000	6,0	14000	0,163

Cs EGE 400keV

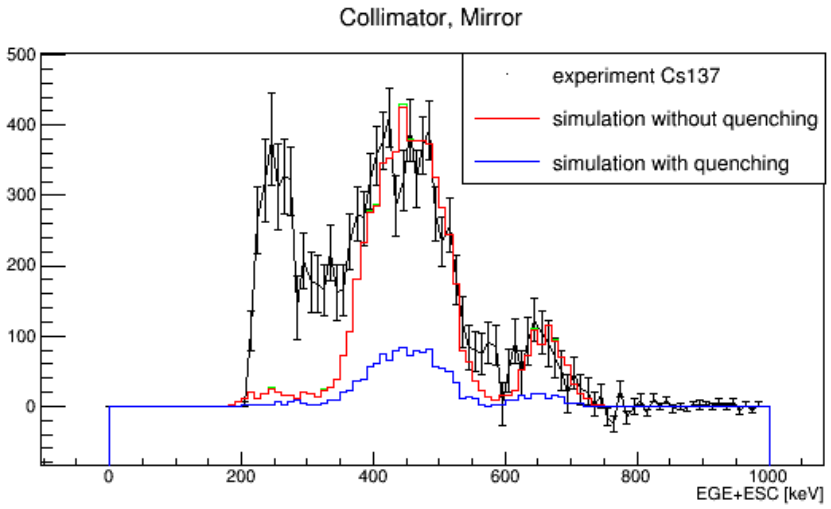


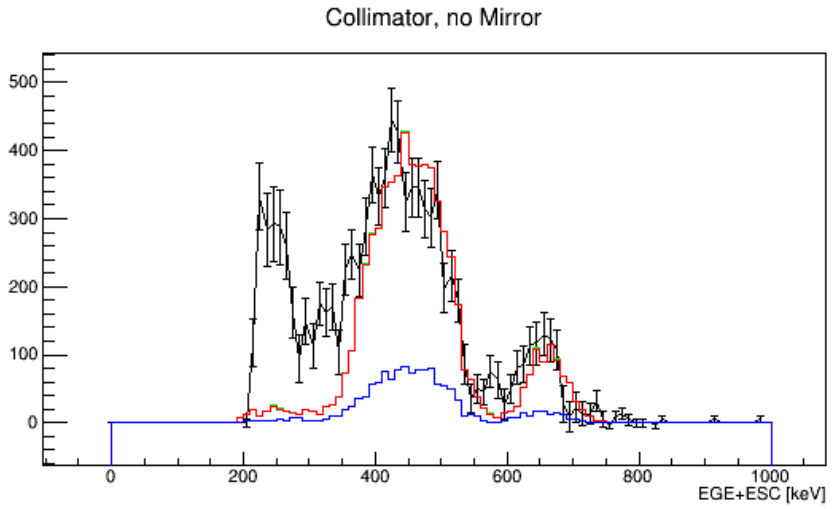


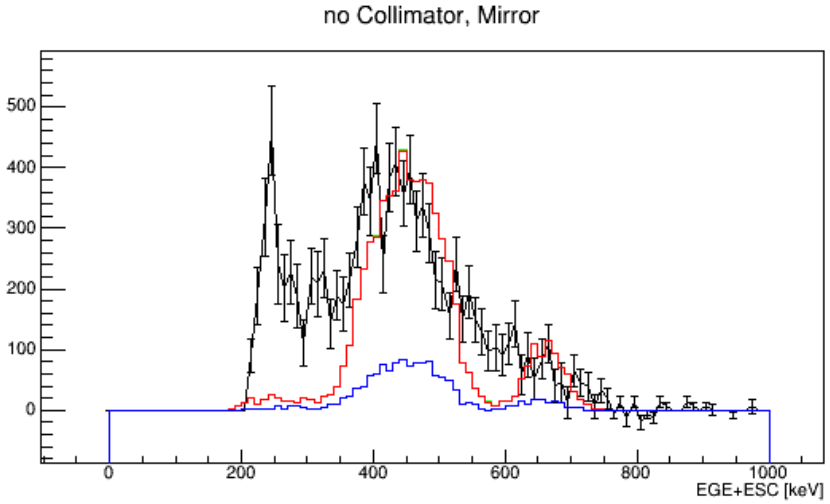


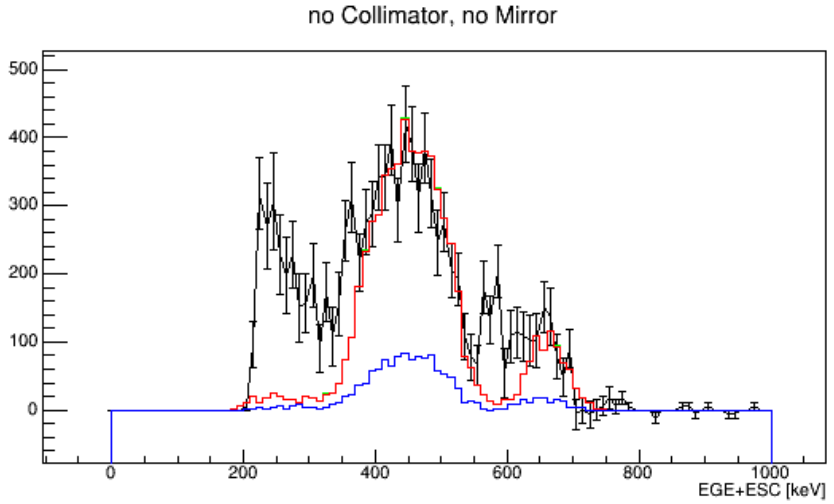


Cs EGE 200keV









Thank you for your attention