Nuclear recoils simulations with SRIM

CYGNO SIMULATION MEETING – 11/01/2021

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Ionization energy and QF

- $QF(E) = \frac{E_{ioniz}^{tot}}{E_{dep}} = \frac{E_{ioniz}^{tot}}{E}$ average fraction of ionization energy deposit for a particle of initial energy E
- QF(E) was computed from SRIM output files, from 100 ions sample in the energy range 1eV – 500keV
- If we want to estimate the ionization energy release at each step along the track of the ion, we must take into account its energy dependance
- Simple approach: $\Delta E^{ioniz} = QF(E_{initial}) \times \Delta E$ (what we did)
- We need a function $QF^{*}(E) = \frac{\Delta E^{ioniz}}{\Delta E}$ to be multiplied by the energy lost at each step, depending on the energy of the ion along the track

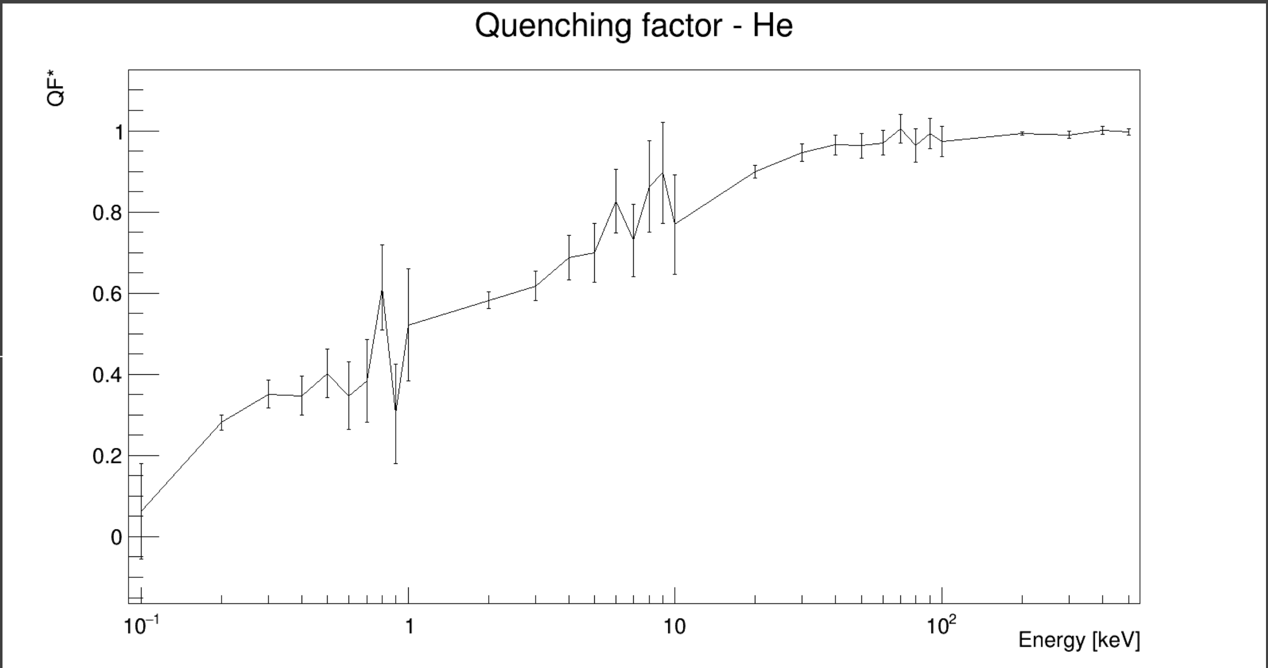
Ionization energy and QF

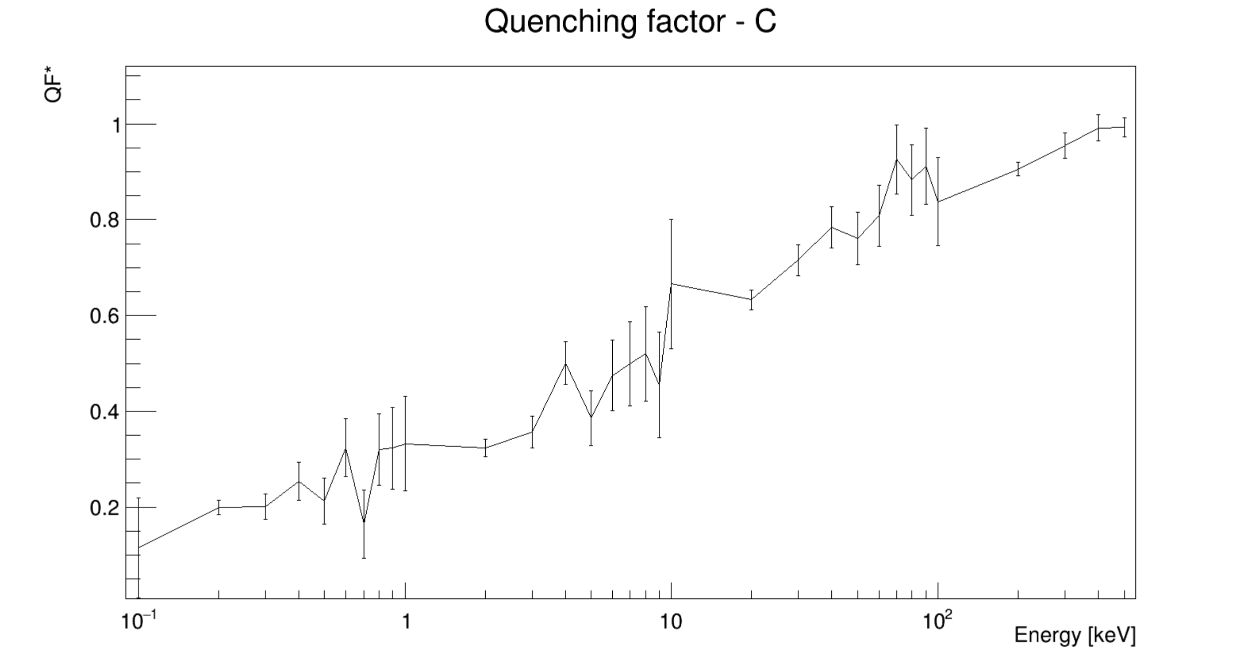
- The quenching factor can be written as $QF(E) = \frac{\sum_i E_i^{ioniz}}{E}$
- $QF(E_1) = \frac{\sum_i E_i^{ioniz}}{E_1}, \qquad QF(E_1 + \Delta E) = \frac{\sum_i E_i^{ioniz} + \Delta E^{ioniz}}{E_1 + \Delta E}$
- The ionization energy lost by an ion of energy $E_1 + \Delta E$ that deposited ΔE is

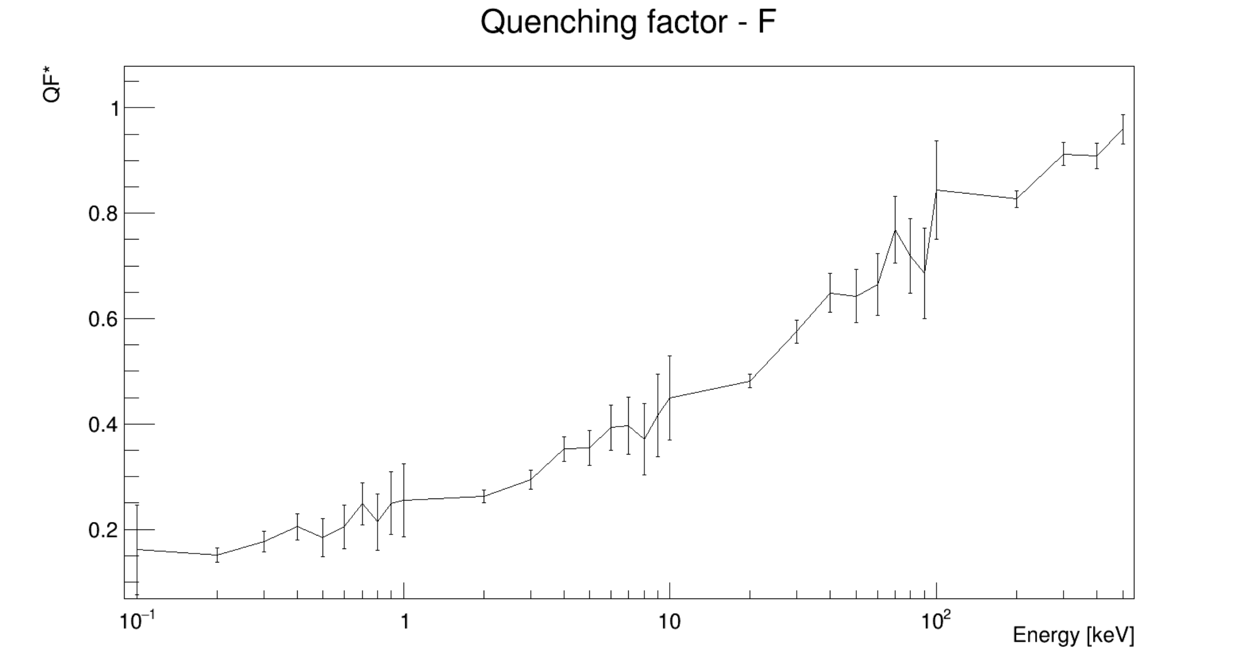
$$\Delta E^{ioniz} = (E_1 + \Delta E) \times QF(E_1 + \Delta E) - \sum_i E_i^{ioniz} = (E_1 + \Delta E) \times QF(E_1 + \Delta E) - E_1 \times QF(E_1)$$

- $QF^*(E) = \frac{\Delta E^{ioniz}}{\Delta E} = \frac{E \times QF(E) - (E - \Delta E) \times QF(E - \Delta E)}{\Delta E}$

Computed from the «new» definition



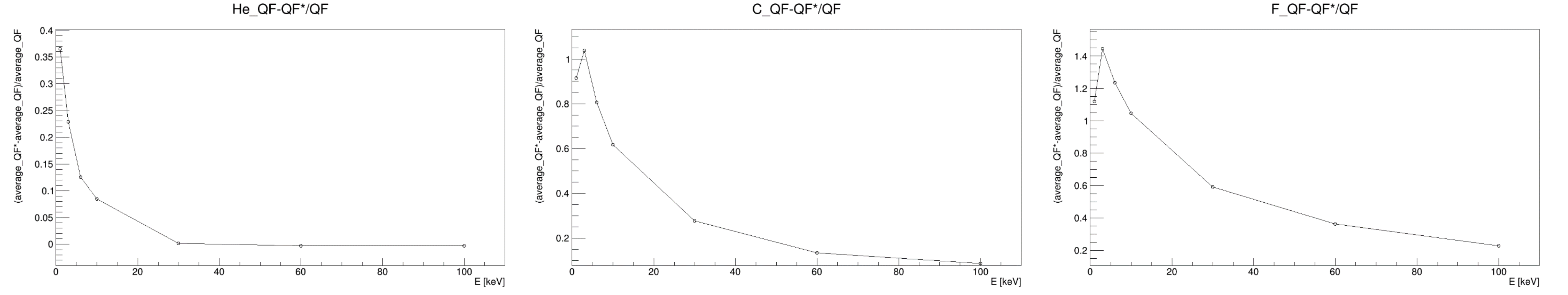




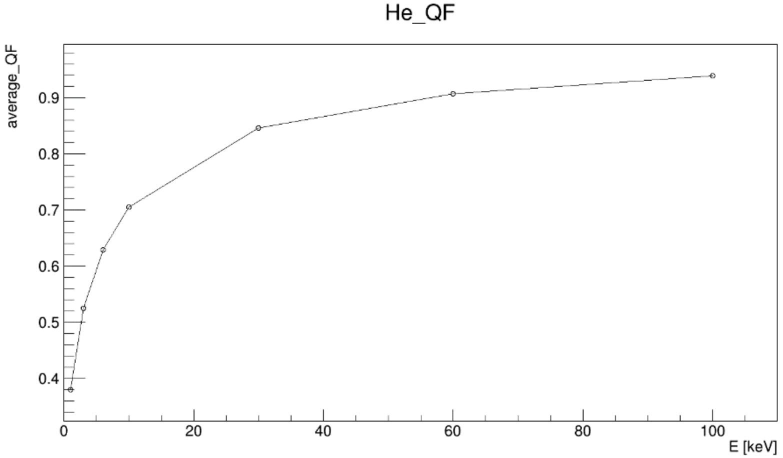
Retrieving average QF

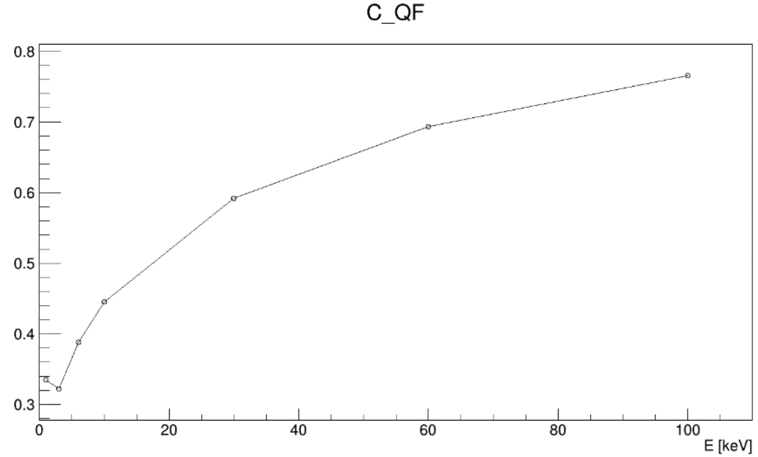
This function was multiplied by the deposited energy at each step of the simulated tracks, to obtain the ΔE^{ioniz} values

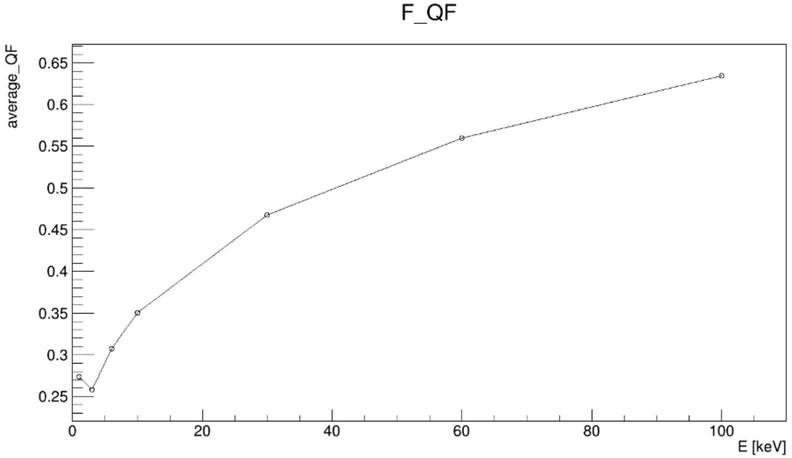
The sum of all these contributions divided by the initial energy of each simulated ion should result in the average QF (by definition)

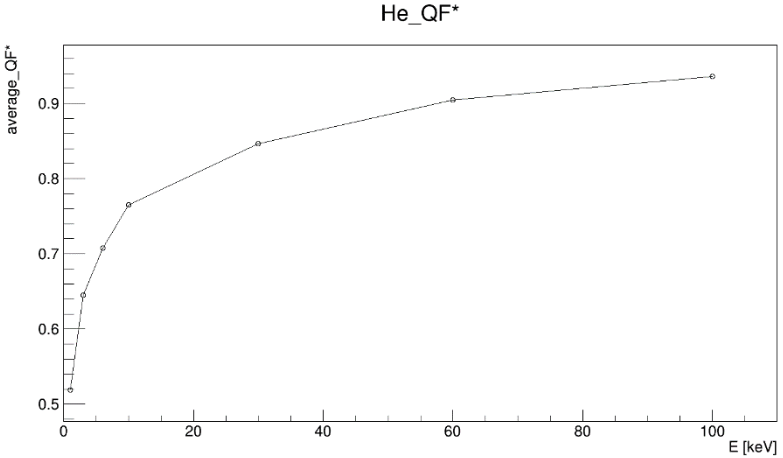


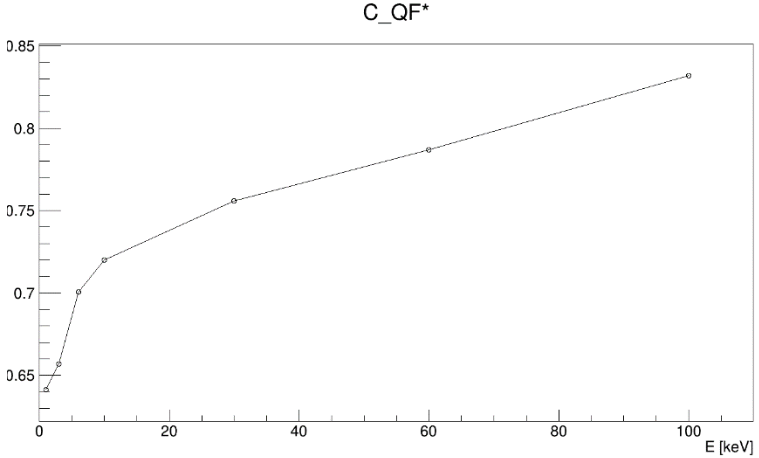
Average QF

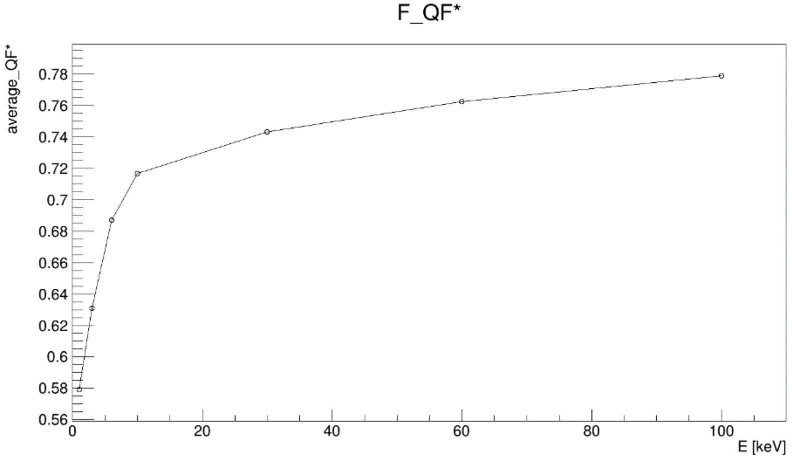

He_QF
average_QF
0.4
0.5
0.6
0.7
0.8
0.9
0
20
40
60
80
100
E [keV]


C_QF
0.3
0.4
0.5
0.6
0.7
0.8
0
20
40
60
80
100
E [keV]


F_QF
average_QF
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0
20
40
60
80
100
E [keV]


He_QF*
average_QF*
0.5
0.6
0.7
0.8
0.9
0
20
40
60
80
100
E [keV]


C_QF*
0.65
0.7
0.75
0.8
0.85
0
20
40
60
80
100
E [keV]


F_QF*
average_QF*
0.56
0.58
0.6
0.62
0.64
0.66
0.68
0.7
0.72
0.74
0.76
0.78
0
20
40
60
80
100
E [keV]

Conclusions

- A new calculation of the quenching factor for He, C and F was performed
- We defined a new function (QF*) to retrieve the ionization energy deposited at each step of the simulated tracks
- The resulting average quenching factors obtained from all the simulated tracks with the two approaches are not consistent with each other (why?)
- Do we need the ionization energy lost along the track even if we can use the w value?