IV FOOT Collaboration Meeting

Radiobiological impact of proton target fragments and sensitivity analysis

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Proton RadioBiological effectiveness (RBE) is not constant. We all know it.

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So?

MoVe-IT Task1.1 Aim

Among the various models to consider RBE impact we propose an approach based on

1. considering the contribution of each single fragment produced by a proton in water
2. evaluate the total RBE by using a mixed field approach
3. test the difference in a treatment plan including the results in TRiP98 *Treatment Planning System* (TPS)

MoVe-IT Task1 Aim

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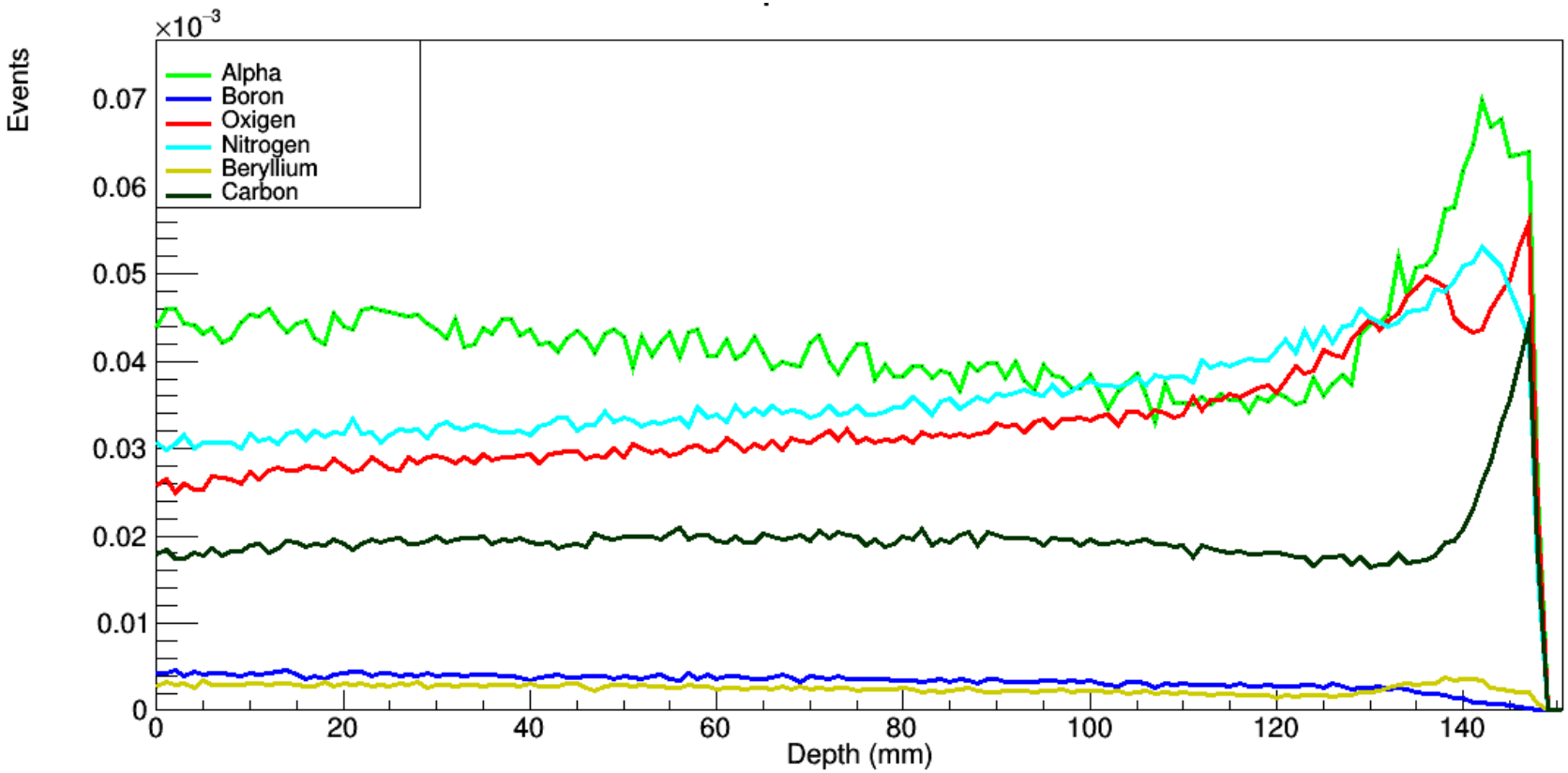
FOOT link Aim

Calculate the correlation between FOOT results uncertainty and biological dose uncertainty;

cross check Monte Carlo simulations with experimental data

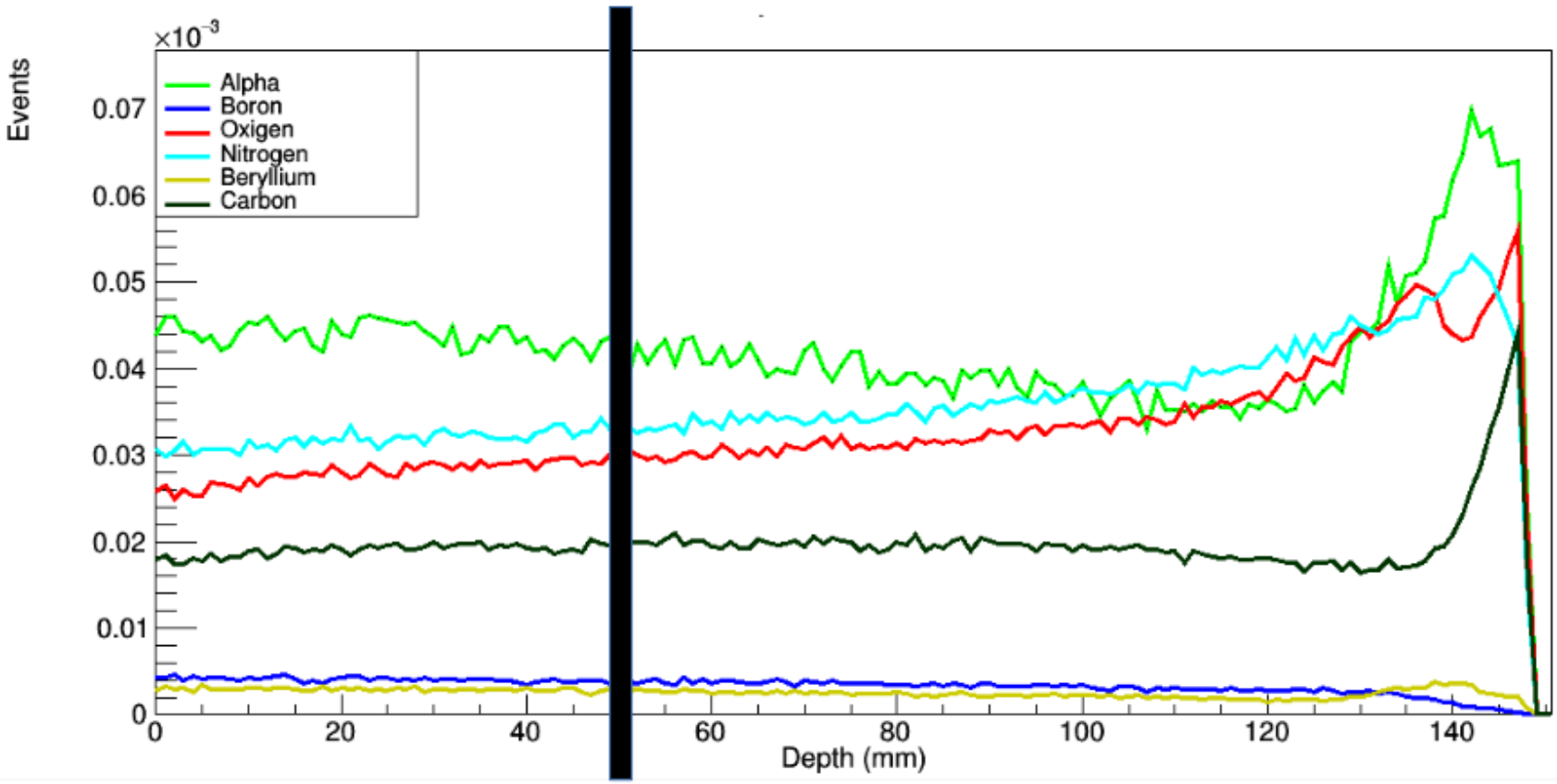
1. Preliminary energy deposition study
2. The mixed field model
3. Spectra data
4. Biological dose comparison
5. FOOT sensitivity analysis
6. Future perspectives

Energy deposition study: Fragments depth distribution, E_0=150MeV[1]

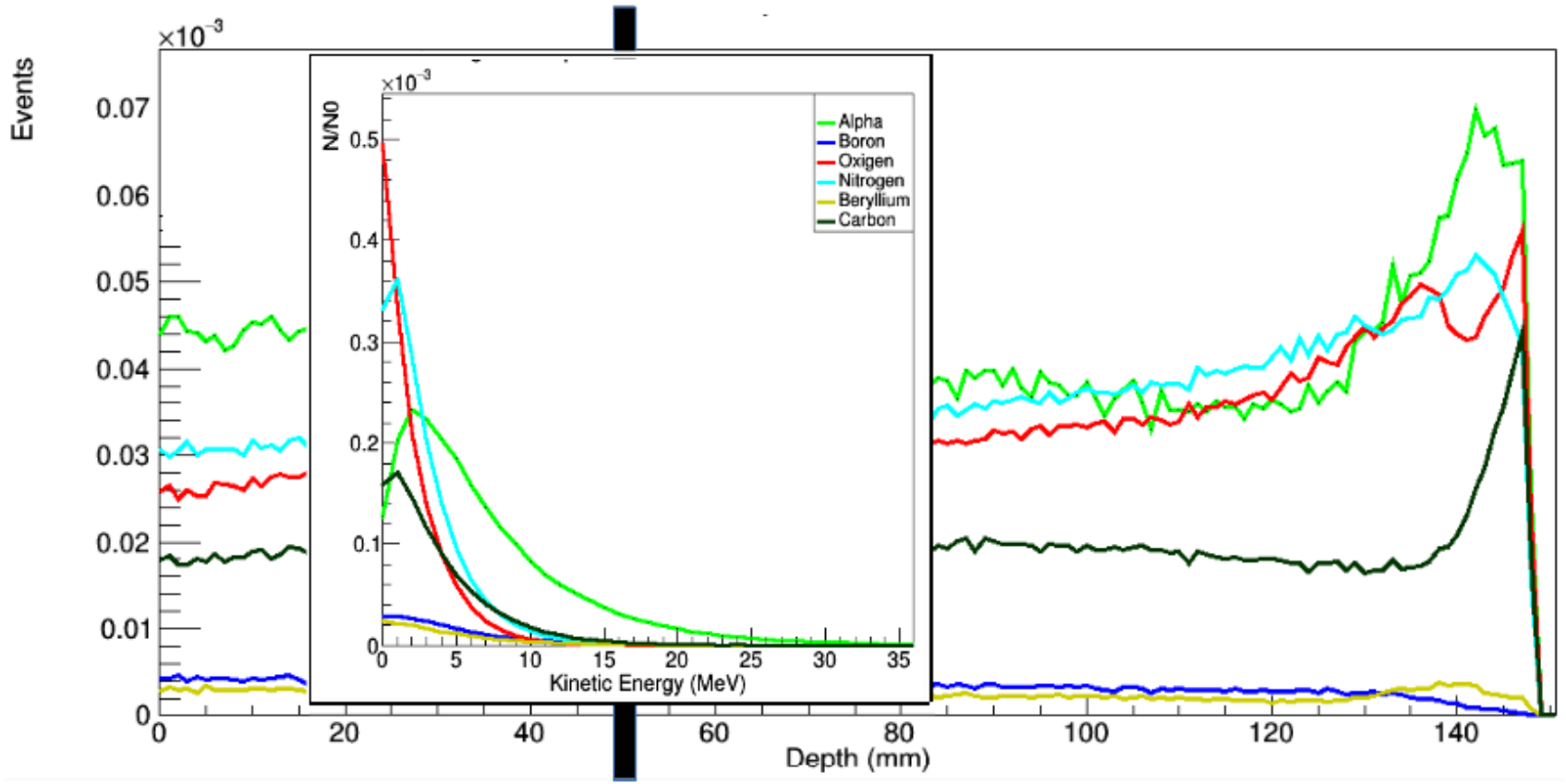


[1] INFN- LNS Catania

Energy deposition study: Fragments depth distribution, E_0=150MeV



Energy deposition study: Spectra analysis for each depth

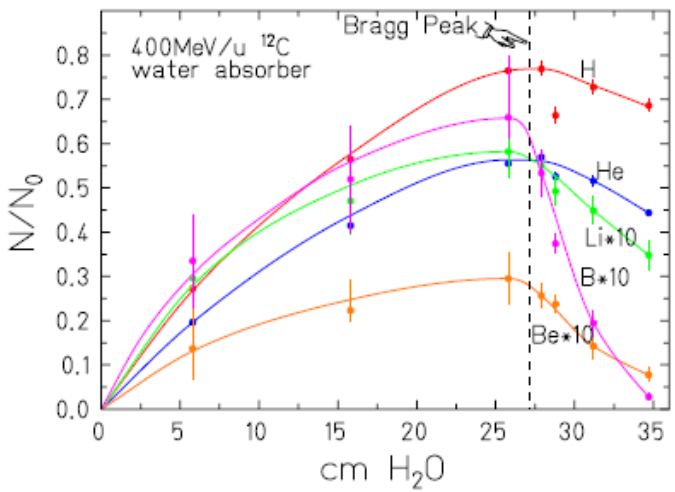


The mixed field model

Primary proton's fragments are considered as secondary particles; each single spectra of those fragments is evaluated separately, considering its impact on the RBE. The total RBE is evaluated by using mixed field algorithm[2] [3] and LEM IV model.

$$\bar{\alpha} = \left(\sum_l w_l \frac{\mathrm{d}E}{\mathrm{d}x}(l) \right)^{-1} \sum_l w_l \frac{\mathrm{d}E}{\mathrm{d}x}(l) \alpha_l$$

$$\sqrt{\bar{\beta}} = \left(\sum_l w_l \frac{\mathrm{d}E}{\mathrm{d}x}(l) \right)^{-1} \sum_l w_l \frac{\mathrm{d}E}{\mathrm{d}x}(l) \sqrt{\beta_l}$$



where w_l denotes the relative weight of the radiation component l and

α_l, β_l are the α_D, β_D values in low dose approximation

[2] M. Zaider and H.H. Rossi 1980 Rad. Res. 83:732–9

[3] M. Krämer and M. Scholz 2006 Phys. Med. Biol. 51:1959–1970

1 Preliminary energy deposition study

2 The mixed field model

3 Spectra data

4 Biological dose comparison

5 FOOT sensitivity analysis

6 Future perspectives

Spectra data

The initial fluence spectra have been obtained performing a Monte Carlo simulation with SHIELD-HIT12A[4][5] *v.7.0.3* as

- 150 MeV proton in water
- scoring the fluence of all the produced particles integrating all the isotopes (Z,A): (2,4); (3,7); (4,9); (5,11); (6,12); (7,14); (8,16)
- Ionization Potential $I = 75.321eV$
- $\Delta E_{protons} = 0.1MeV$, $\Delta E_{fragments} = 0.01MeV$
- $\Delta z = 0.5mm$

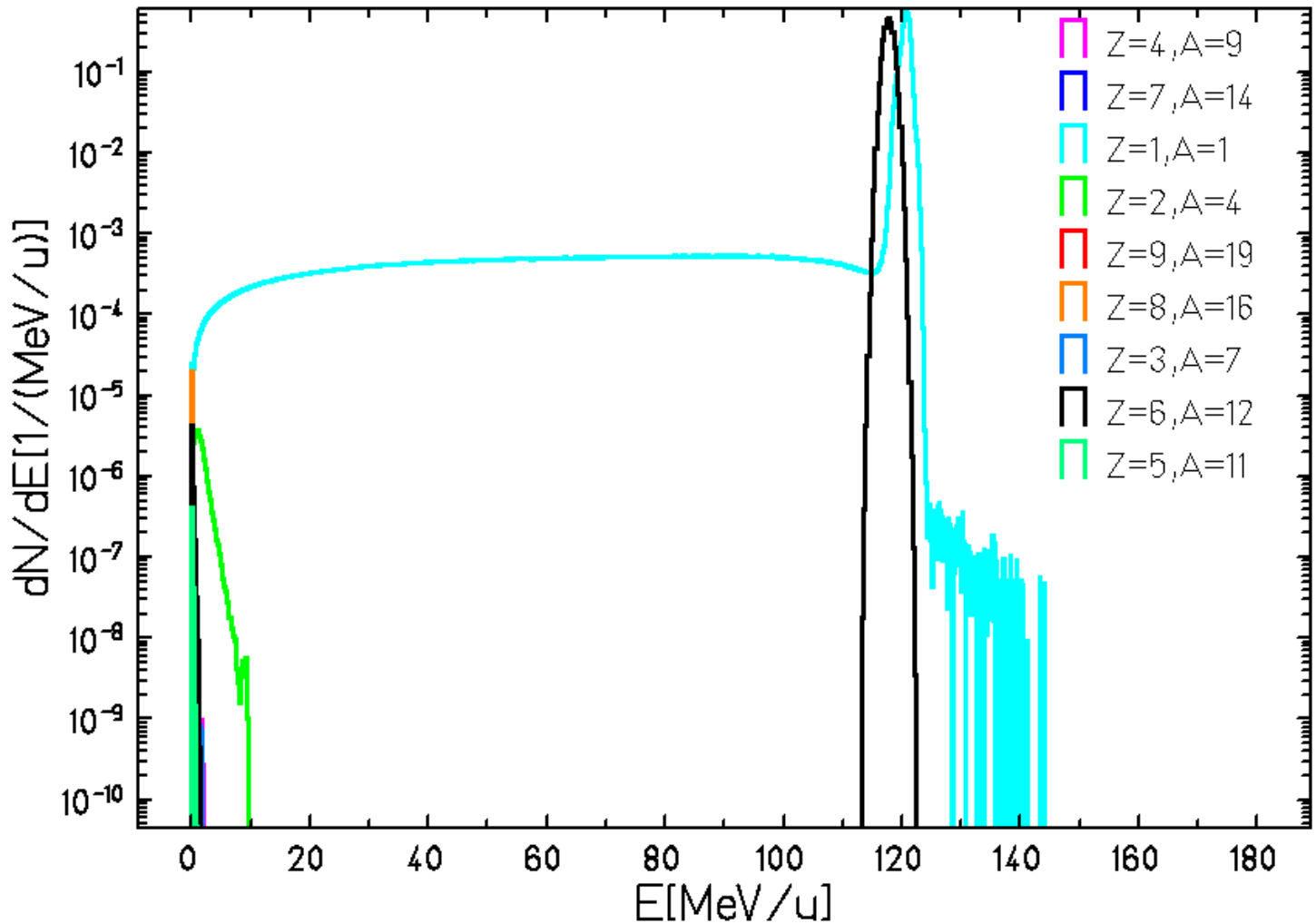
And these results have been compared with the default LUT[6] of TRiP98 TPS

[4] This research was supported in part by *PL-Grid infrastructure*

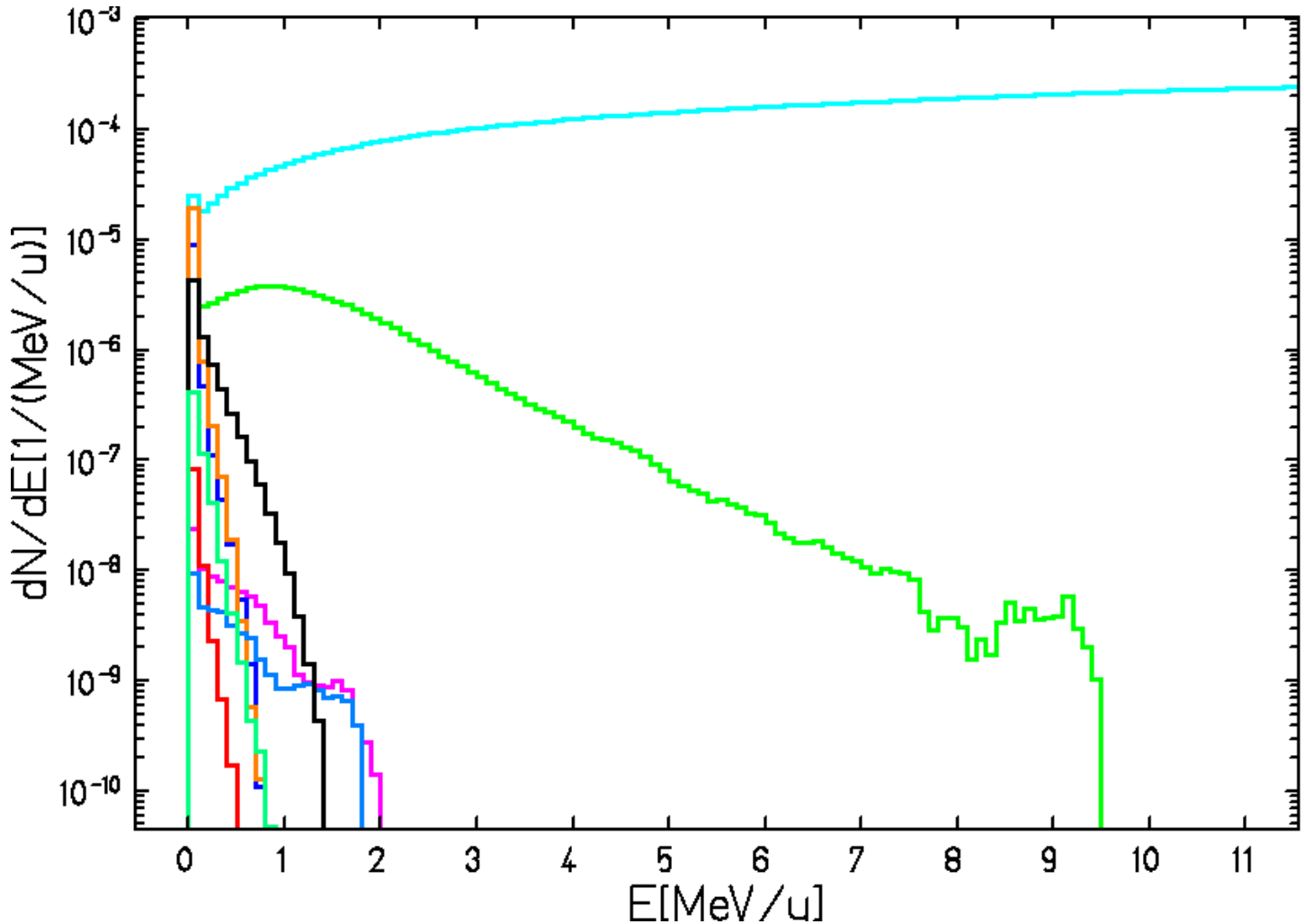
[5] Bassler N, Hansen DC, Lühr A, et al. SHIELD-HIT12A – a Monte Carlo particle transport program for ion therapy research. J Phys Conf Ser. 2014;489:12004.

[6] Look Up Table

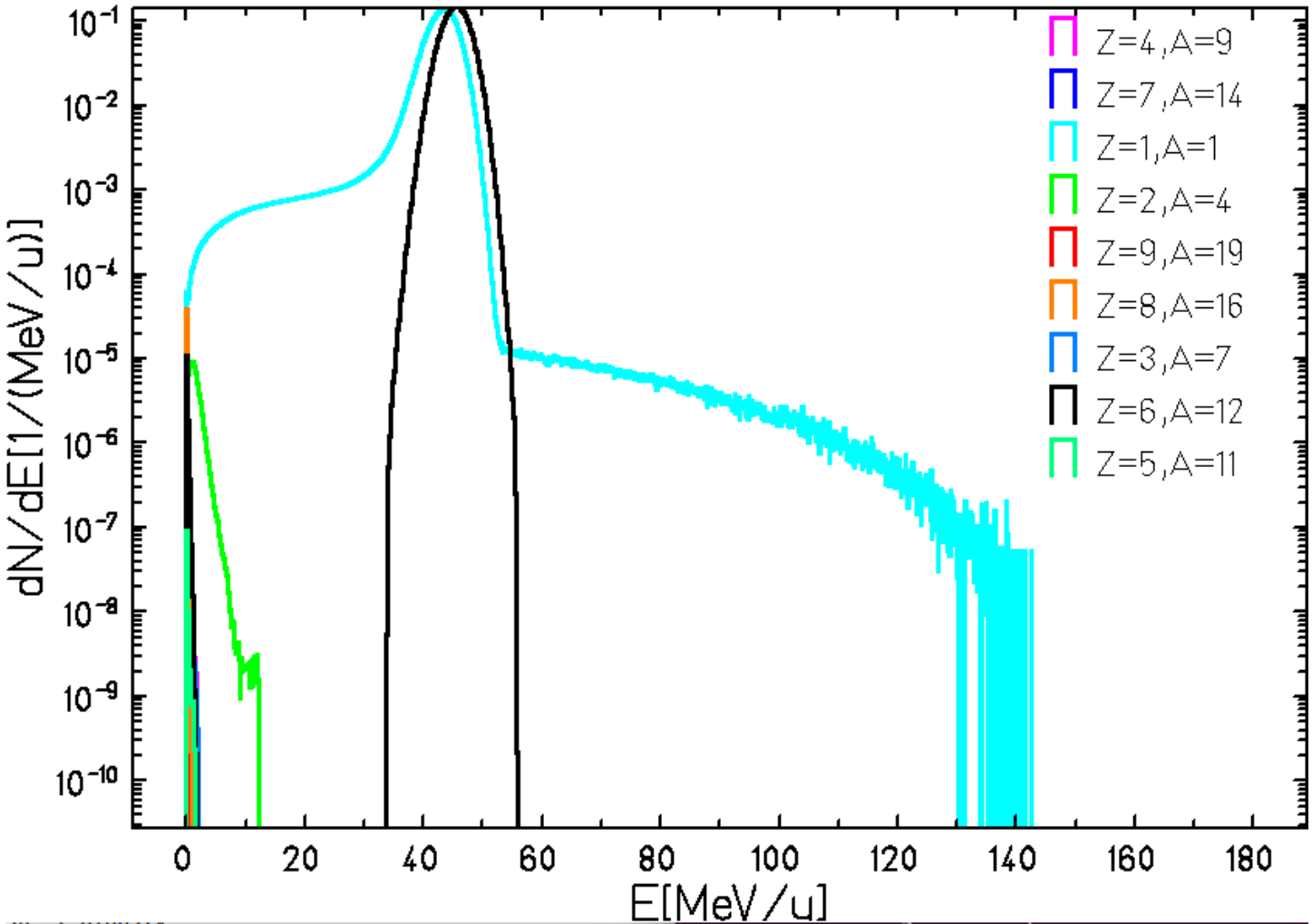
Spectra data: 5cm



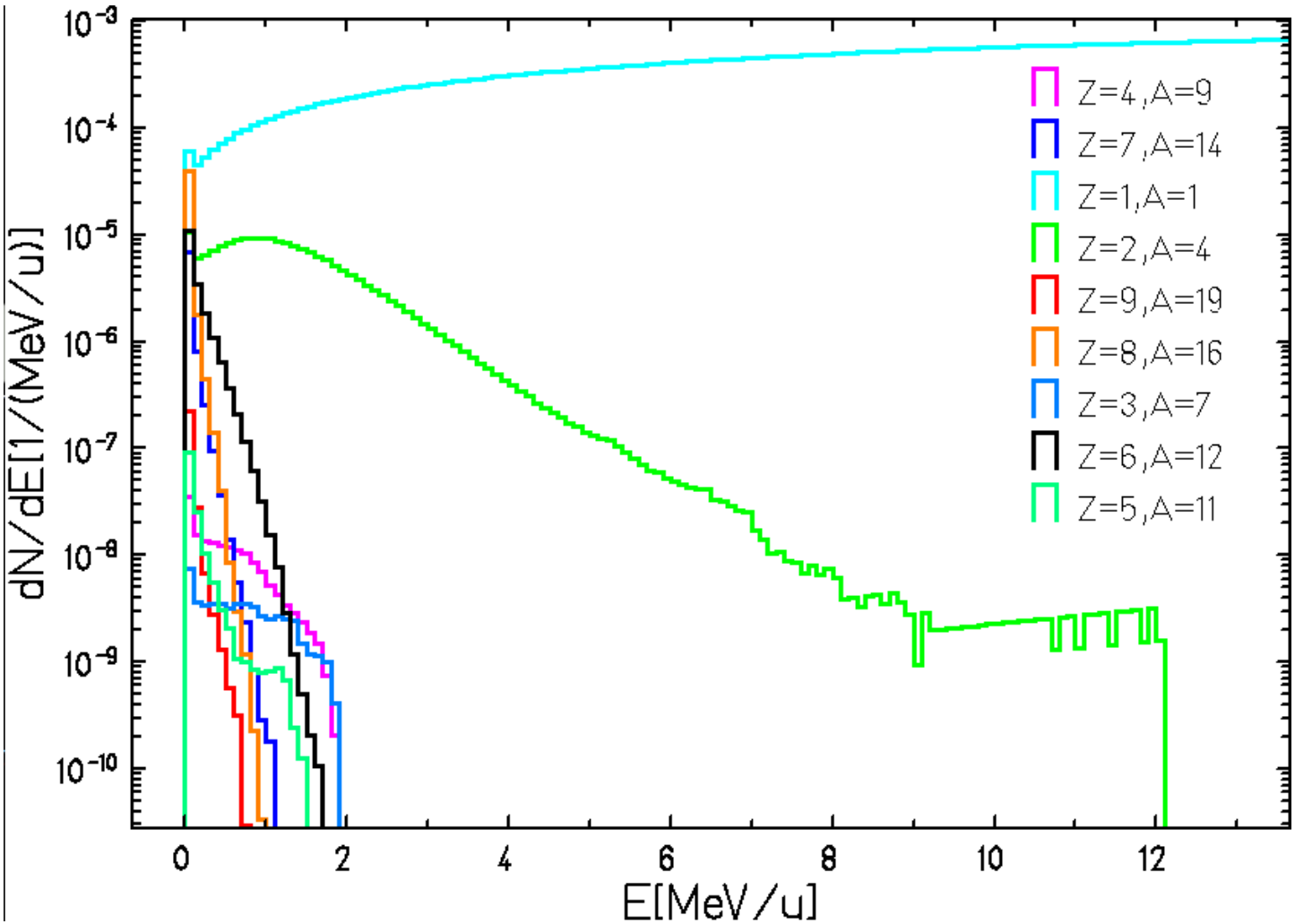
Spectra data: 5cm Zoom



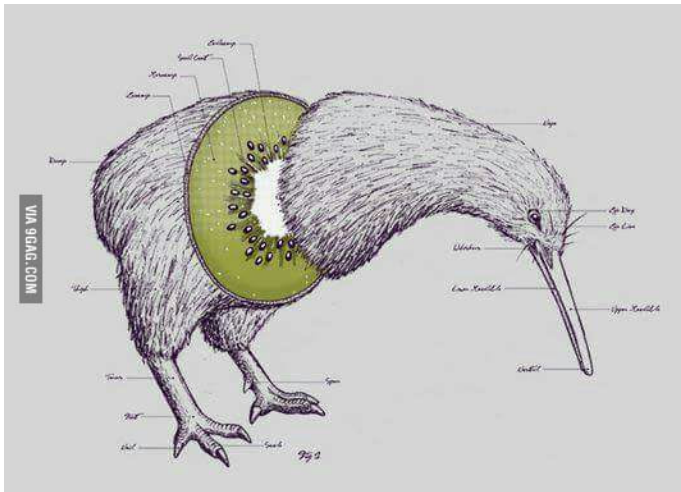
Spectra data: 14cm



Spectra data: 14cm Zoom

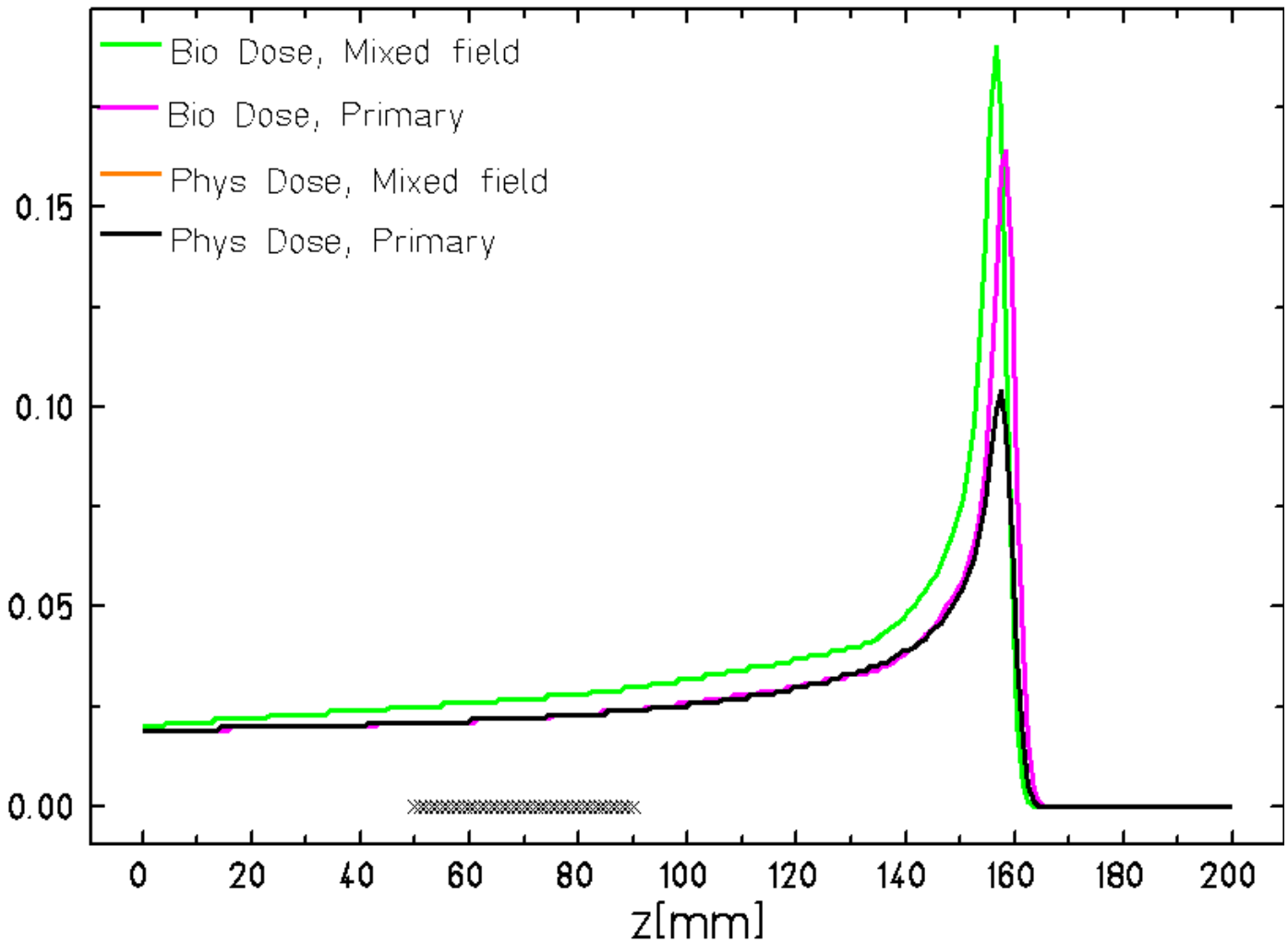


Biological dose comparison:

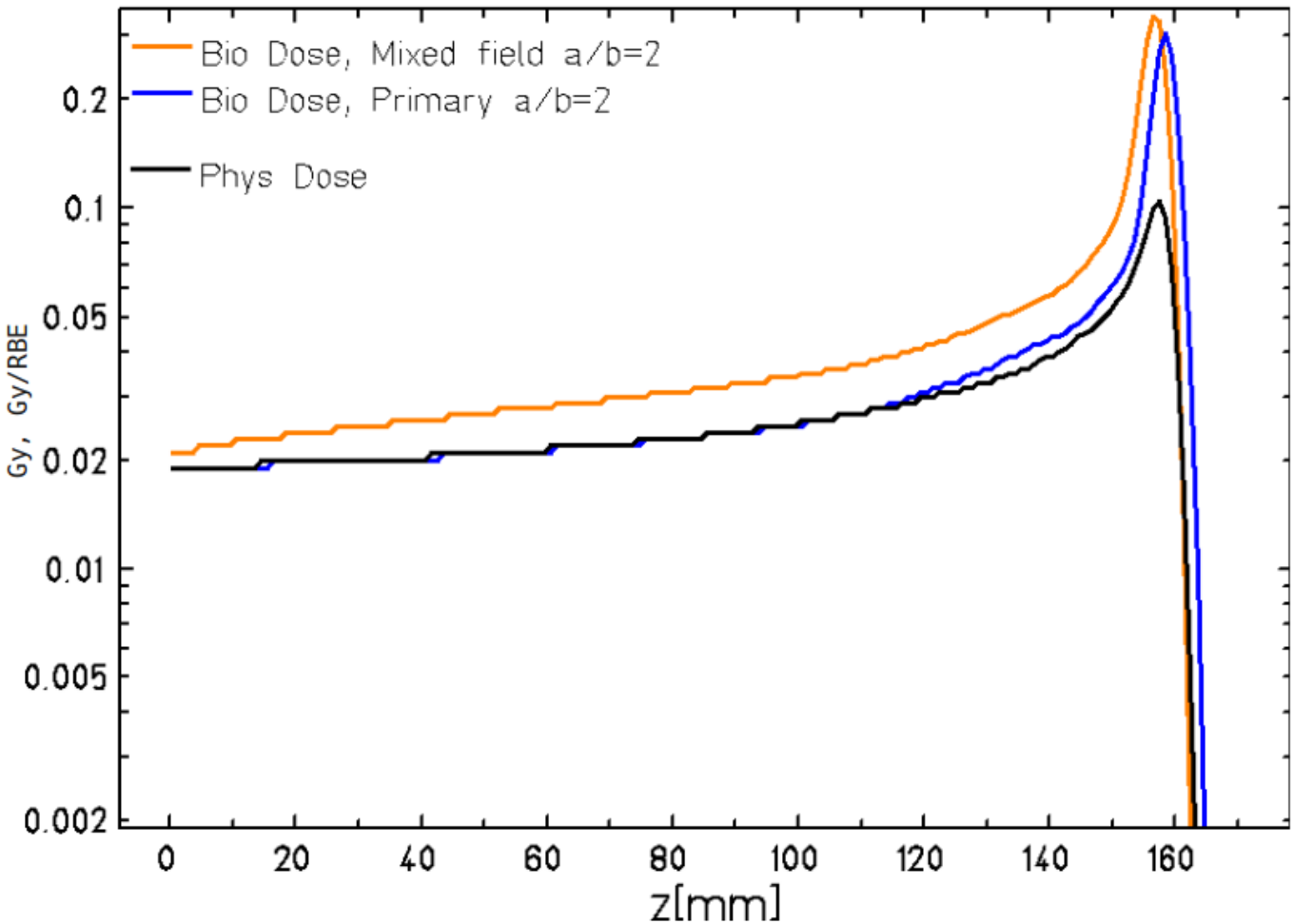


The following results show the biological dose evaluated by the TPS based on the spectra including all fragments.
All the plots refer to the central line of the CT

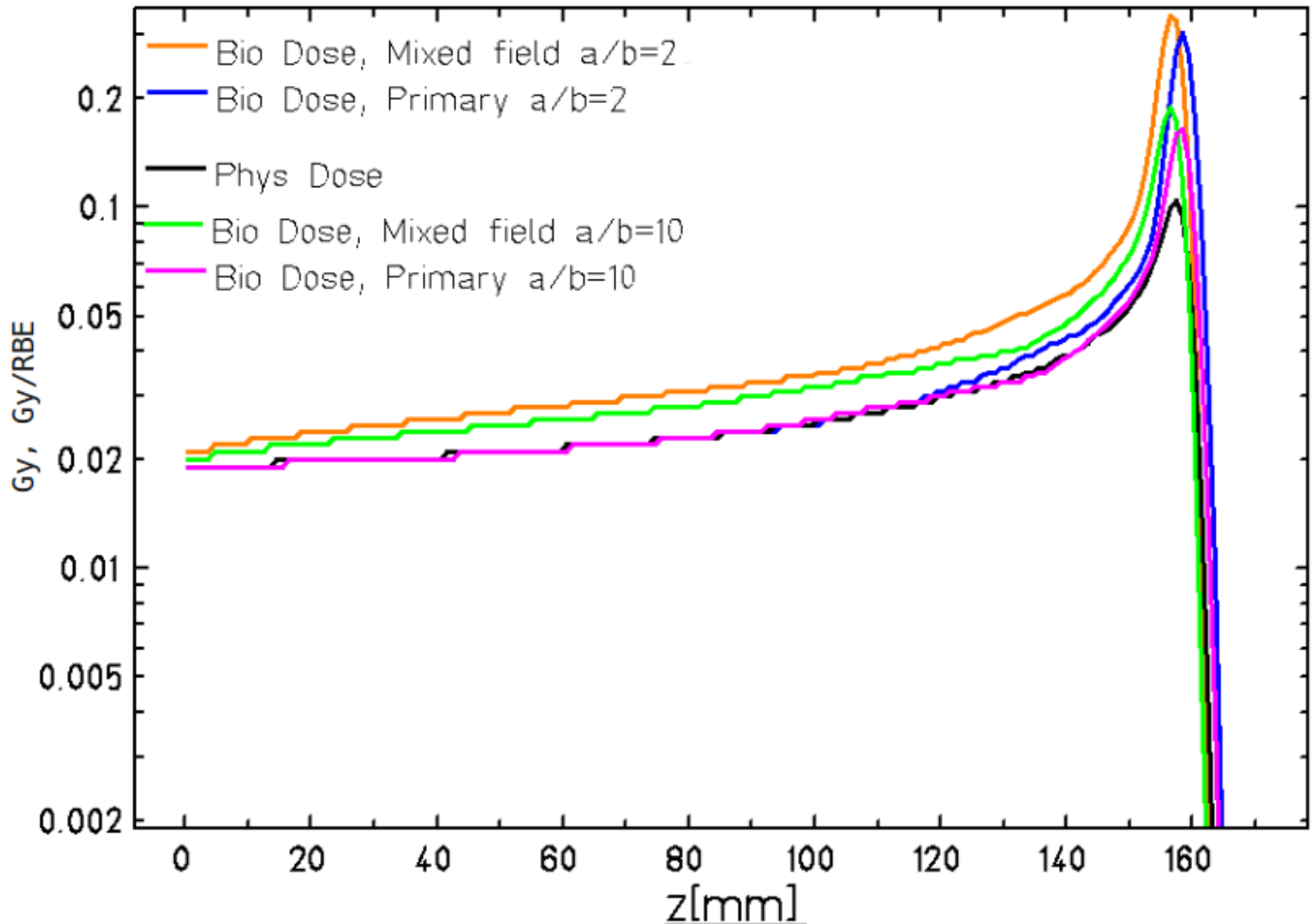
Biological dose comparison:



Dose comparison: Tissue dependence



Dose comparison: Tissue dependence



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FOOT sensitivity analysis: Work-flow

- Input: row Monte Carlo spectra ($E_0 = 150MeV$, $\Delta E = 0.1mm$, scoring E_{kin})

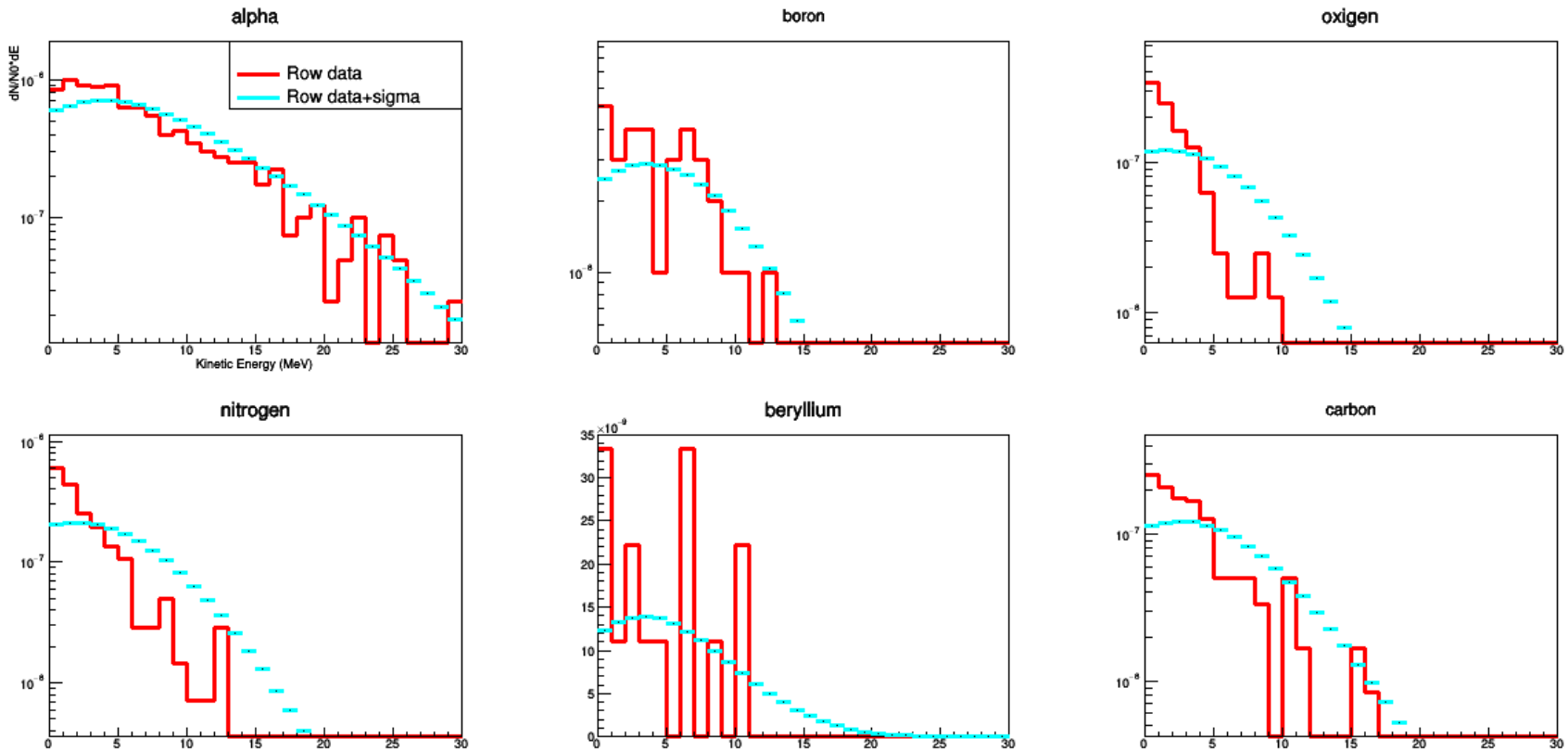
$\downarrow$

- Application of gaussian-like error of μ =bin center, $(0.1 \leq \sigma \leq 10)MeV$ with $\Delta\sigma = 0.1MeV$

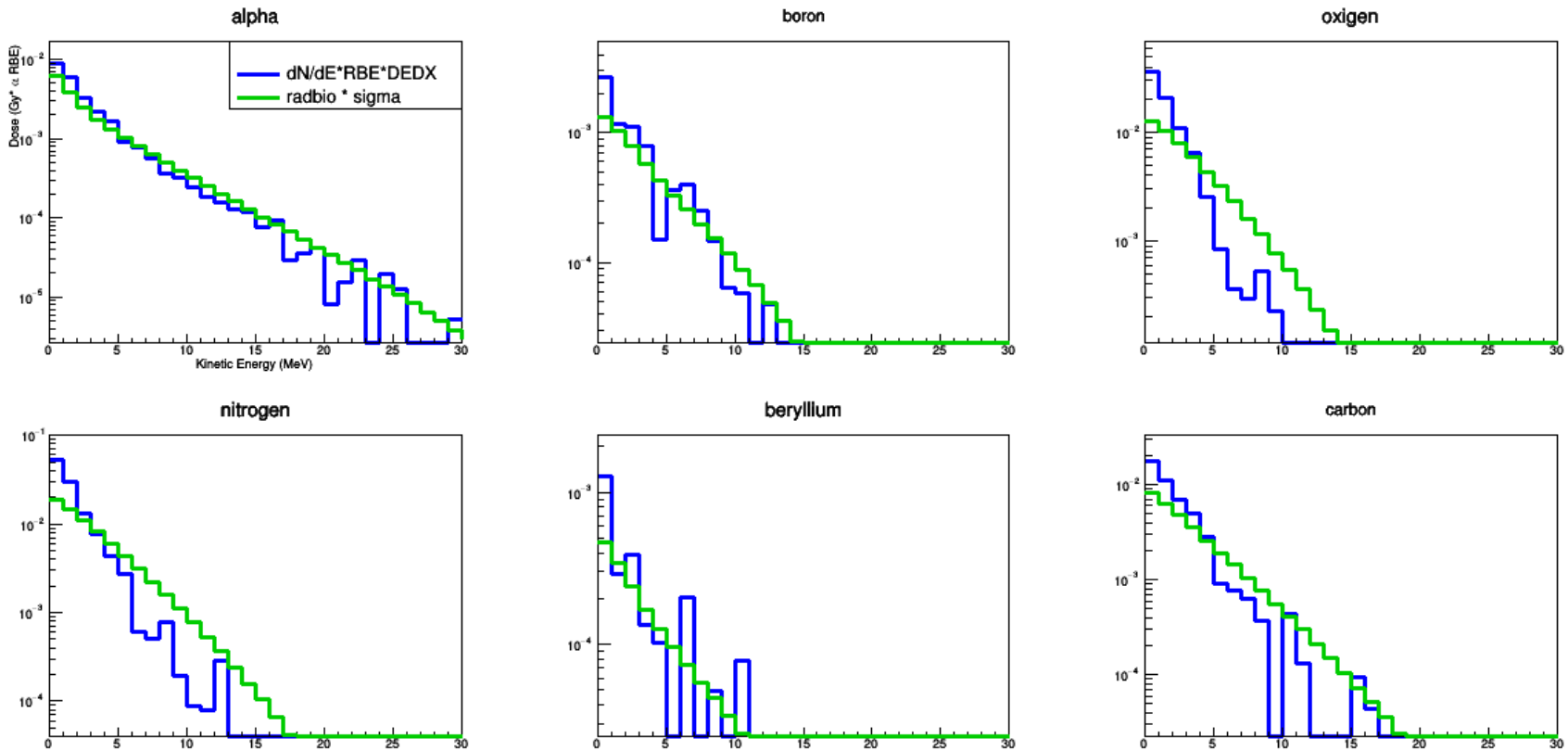
$\downarrow$

- Evaluation of the impact of this error on the biological dose error for various tissues (different α/β ratio) and various depths, for each ion and for total dose

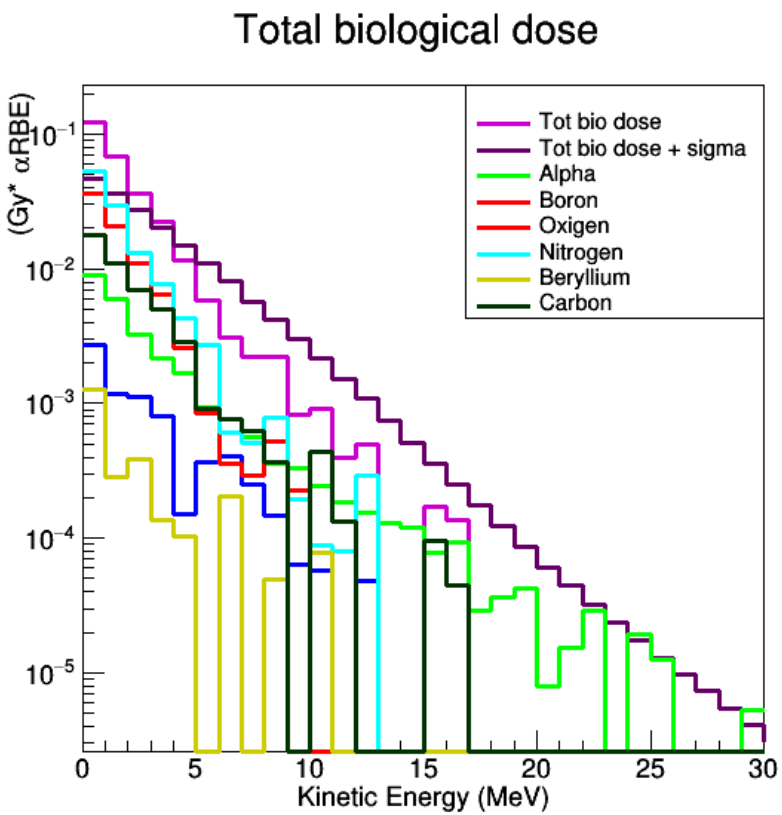
FOOT sensitivity analysis: Physical dose, $\sigma = 5MeV$, $Z = 0,5cm$, cho cells

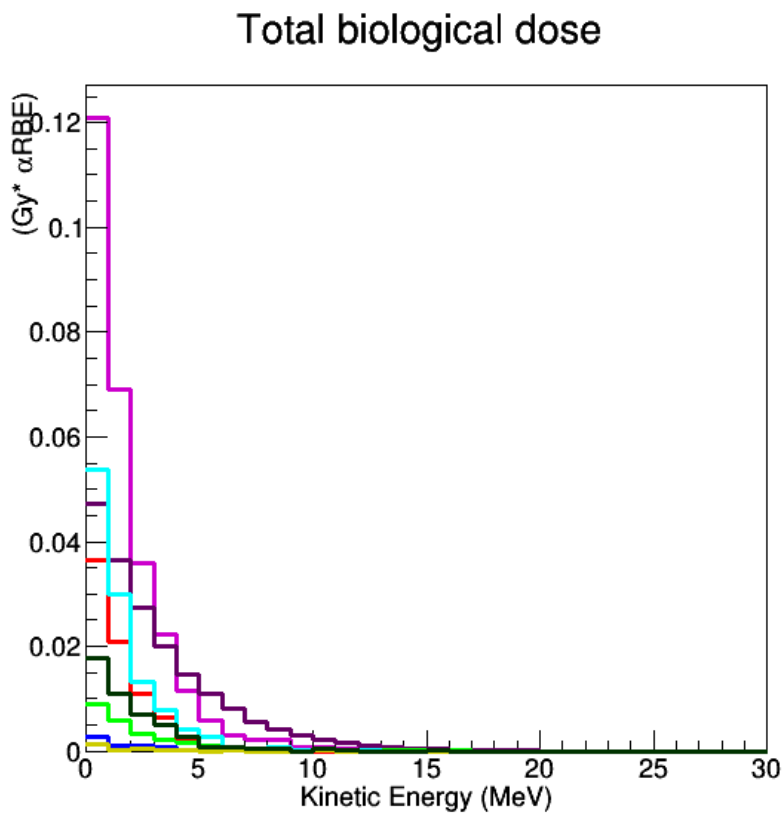


FOOT sensitivity analysis: Biological dose, $\sigma = 5MeV$, $Z = 0,5cm$, cho cells

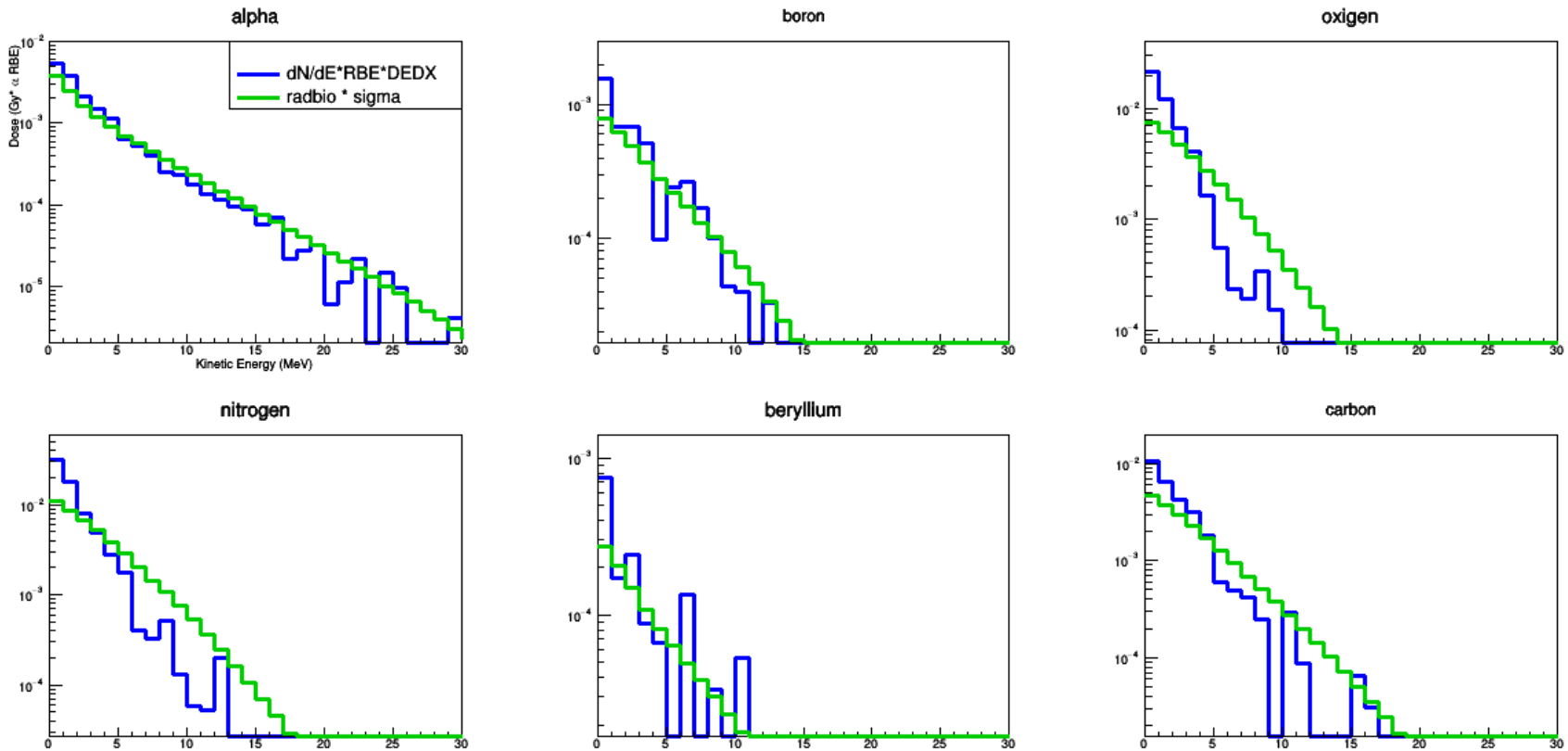


FOOT sensitivity analysis: Total Bio dose, $\sigma = 5MeV$, $Z = 0,5cm$, cho cells

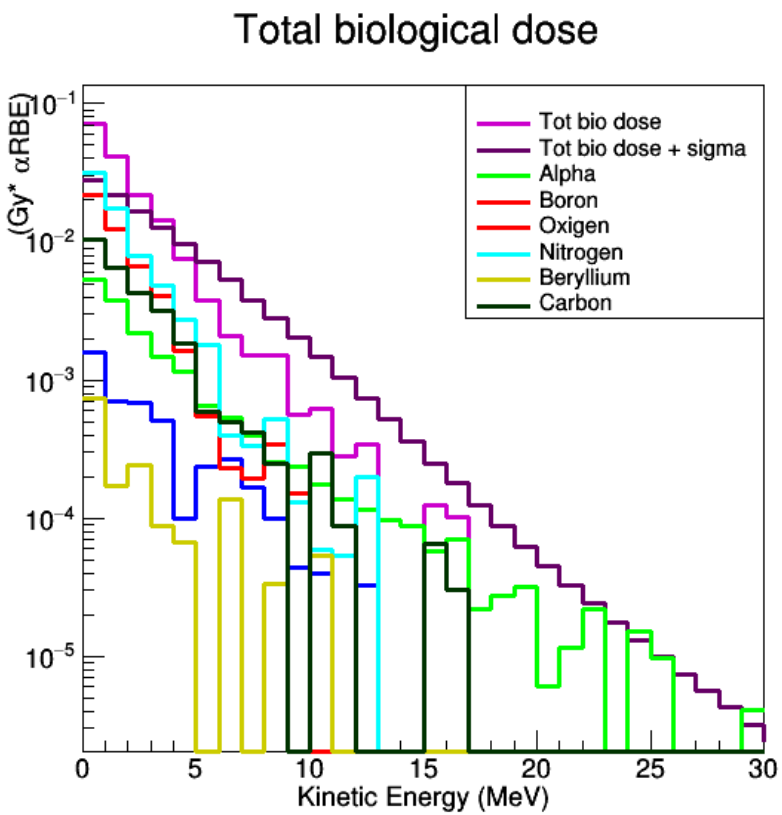


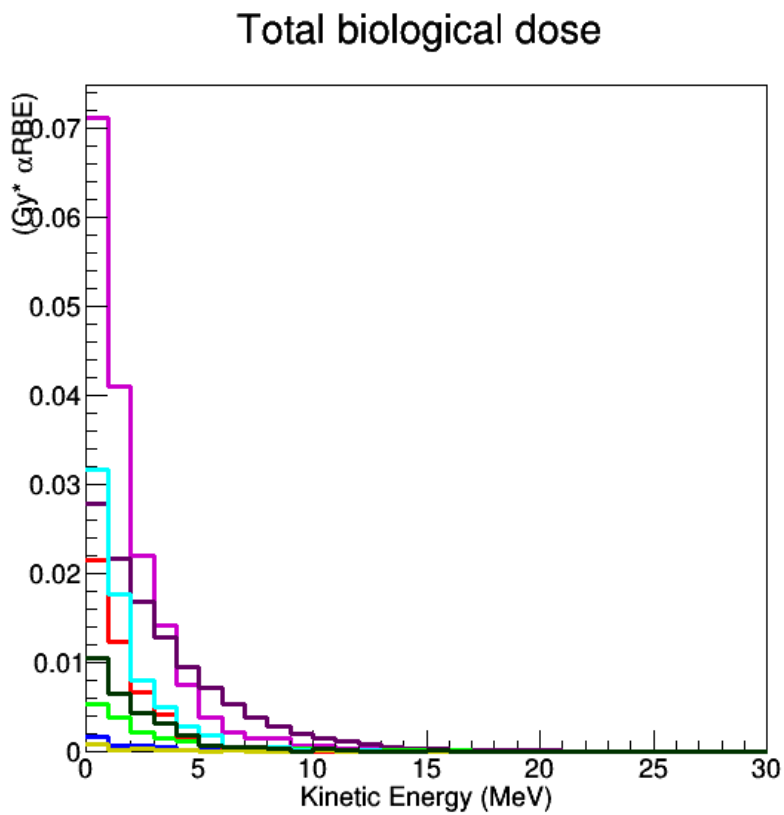


FOOT sensitivity analysis: Biological dose, $\sigma = 5MeV$, $Z = 0,5cm$, skin cells



FOOT sensitivity analysis: Total Bio dose, $\sigma = 5MeV$, $Z = 0,5cm$, skin cells



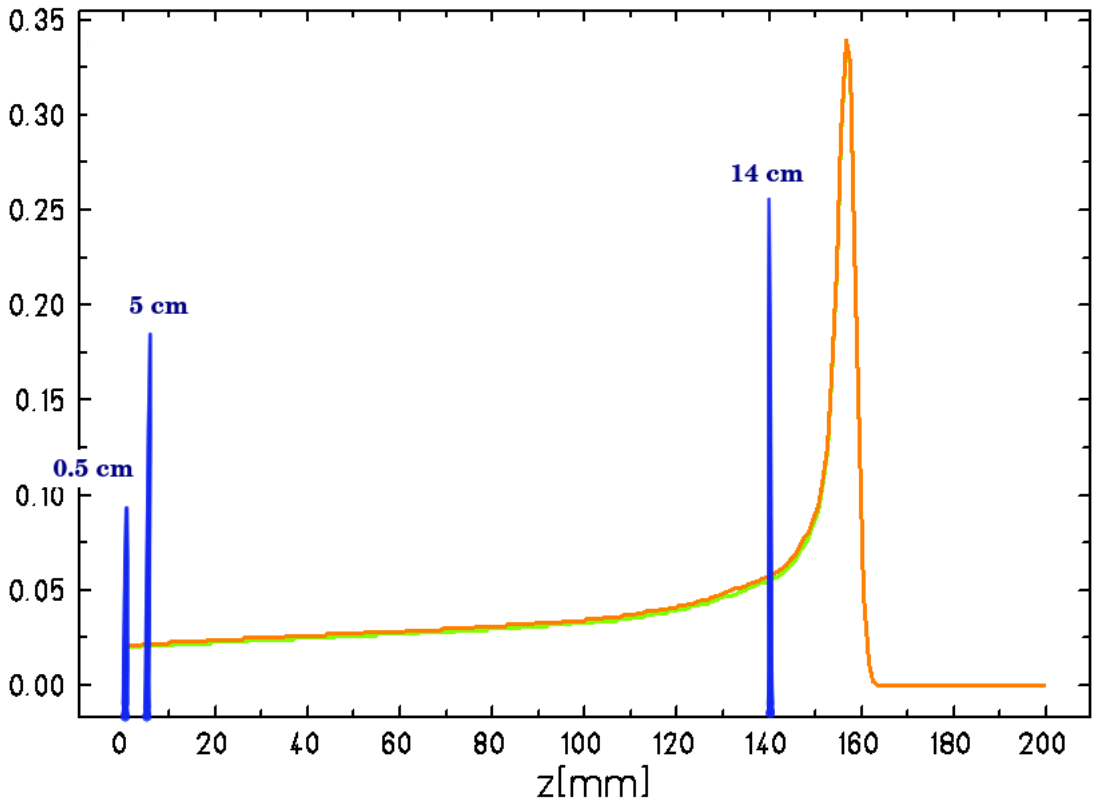


FOOT sensitivity analysis: Total Biological dose error vs σ_{Error}

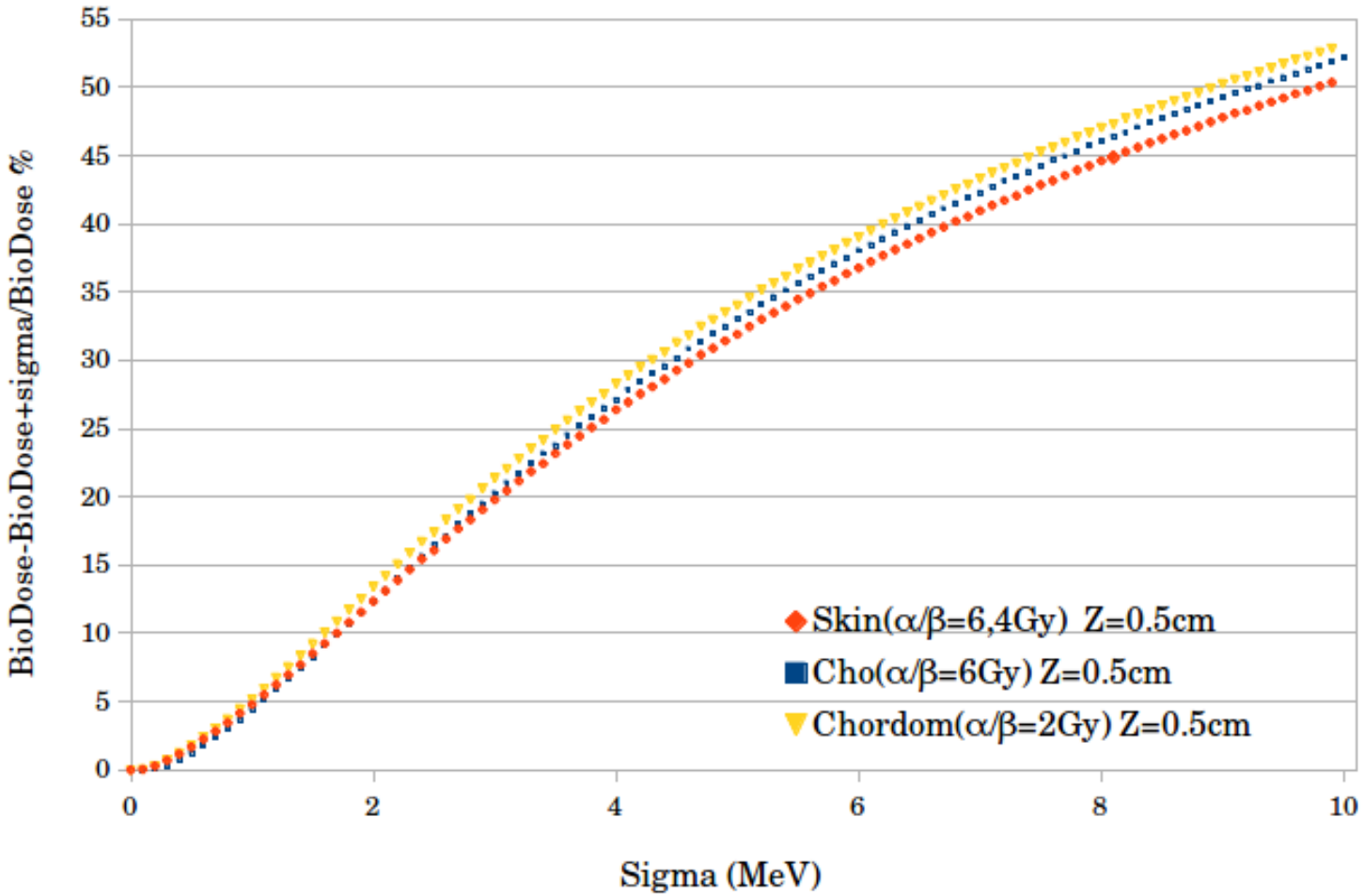
$$\frac{BioDose - BioDose_{+\sigma}}{BioDose}\% \ vs \ \text{Applied } \sigma(MeV)$$

- for three different cells type (different α/β): Skin, Cho, Chordoma
- and these depths: (0.5, 5, 14)cm

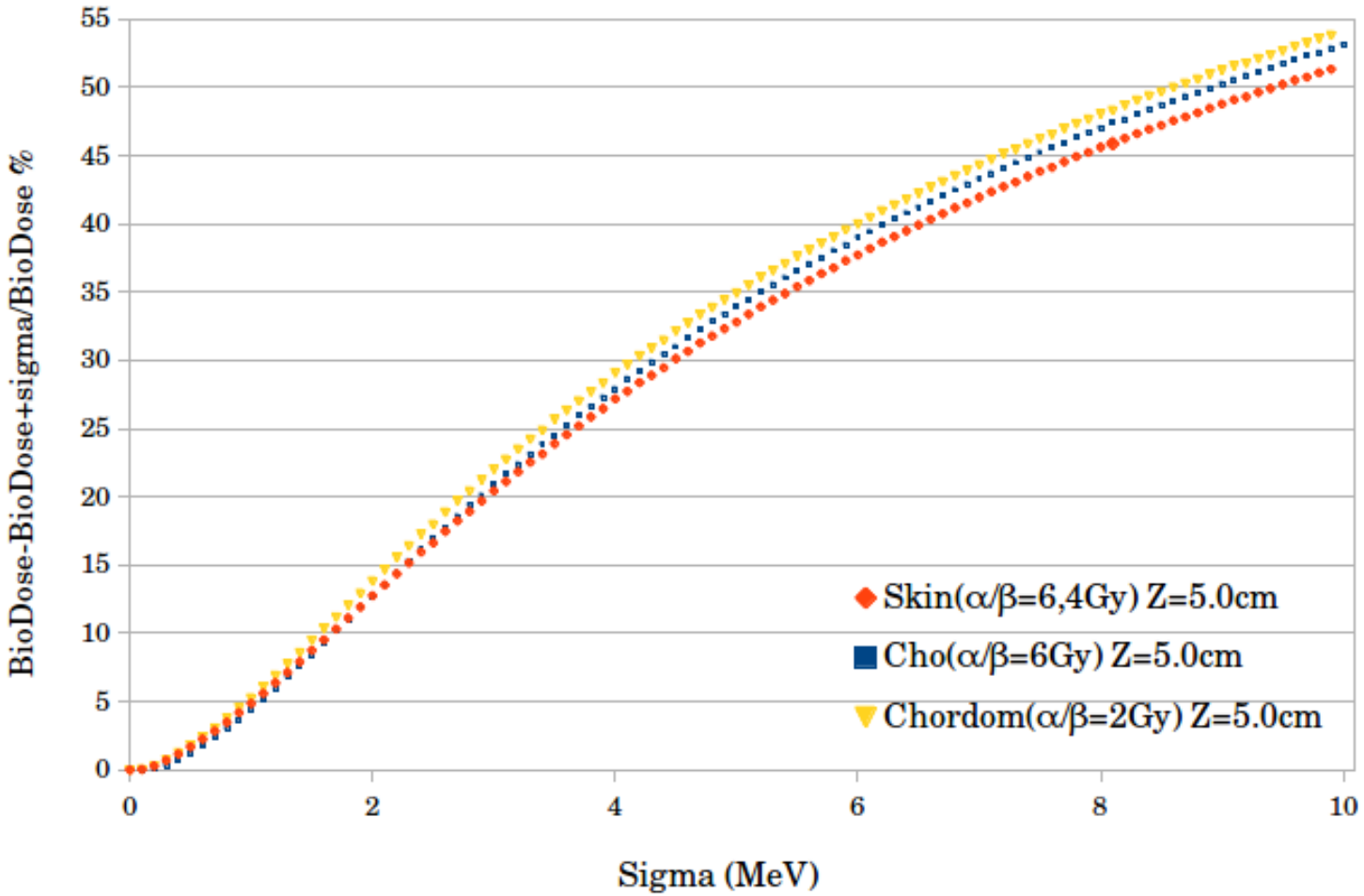
$\rightarrow$



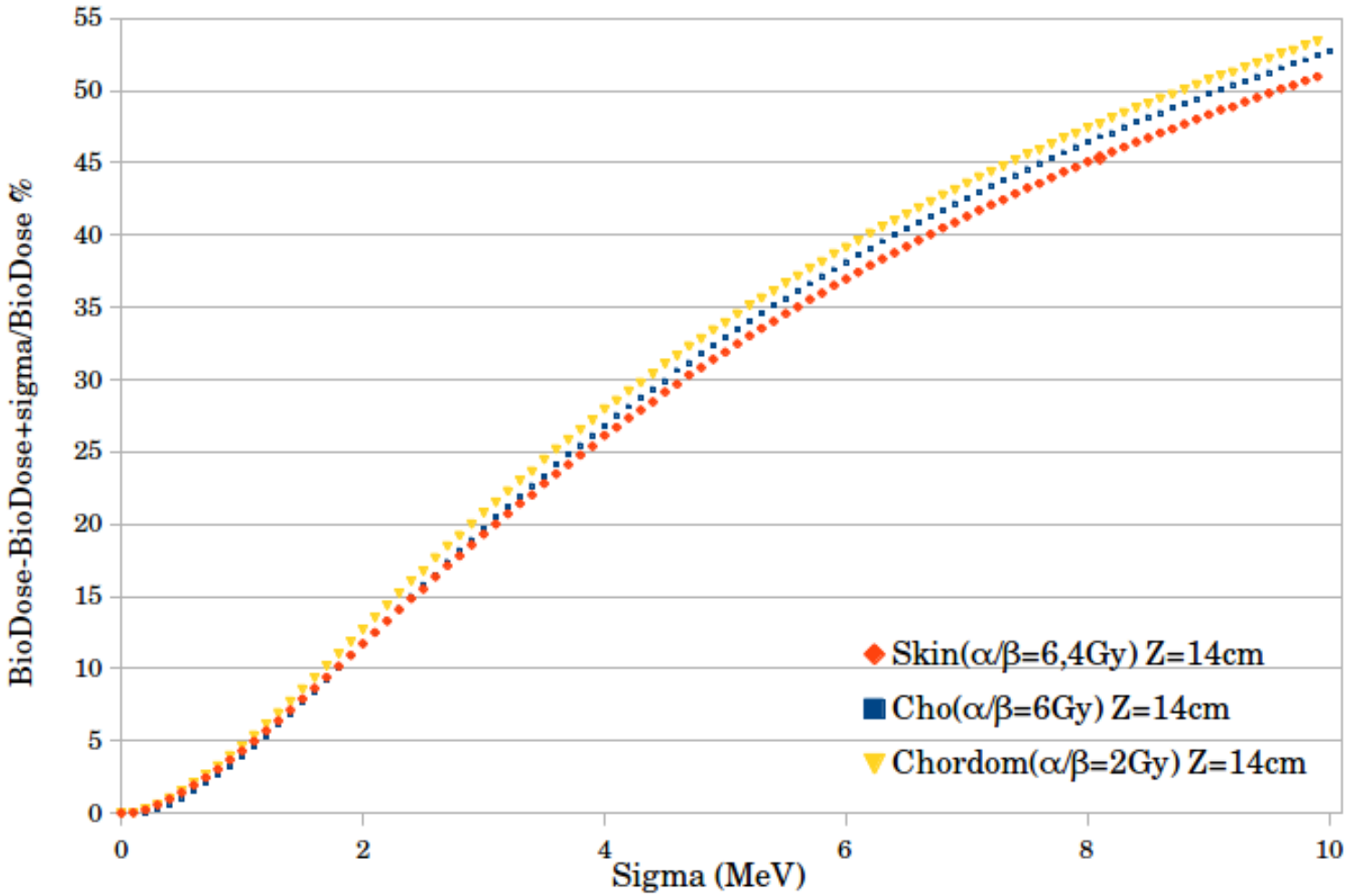
FOOT sensitivity analysis: Total Biological dose error vs σ_{Error} Z=0.5cm



FOOT sensitivity analysis: Total Biological dose error vs σ_{Error} Z=5cm



FOOT sensitivity analysis: Total Biological dose error vs σ_{Error} Z=14cm



Future perspectives

- Cross check with new FLUKA MC results
- RBE $\propto$ Dose analysis
- Systematic study on energies
- LET comparison
- Full treatment evaluation with TRiP98 TPS
- Computed spectra validation with FOOT experimental data

Thanks

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