Topas Project: Team protons and heavy ions

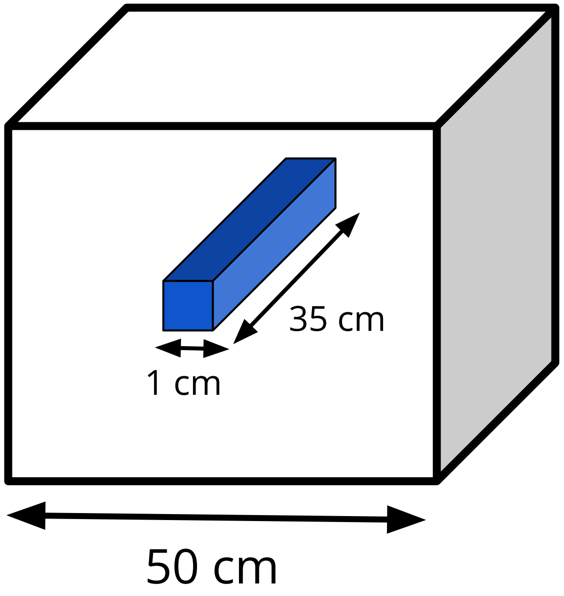
Gabrielle Germain, Hanieh Sadat Jozi, Philippe Dionne

Content

- General geometry
- Depth-dose relation
- Mean excitation value effect on Pragg peak position
- Beam modulation and SOBP (spread-out Bragg Peak)

General geometry

- Monde de (50x50x50) cm^3
- Détecteur de 35 cm
- 350 bins
- broad gaussian beam (10x10)cm^2



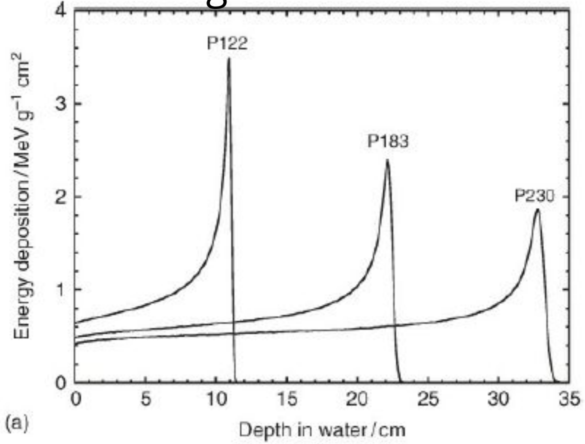
Depth-dose relation: methodology

4 combinations of physics lists:

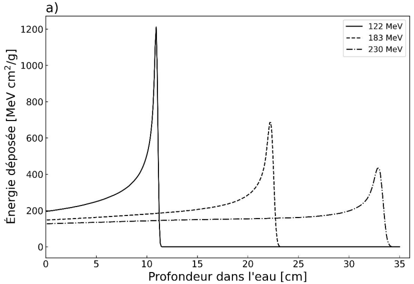
v1	g4em-standard_opt4					
v2	g4em-standard_opt4	g4h-phy_QGSP_BIC_HP	g4decay	g4ion-binarycascade	g4h-elastic_HP	g4stopping
v3	g4em-standard_opt4	g4h-phy_QGSP_BIC_HP				
v4	g4em-standard_opt4		g4decay	g4ion-binarycascade	g4h-elastic_HP	g4stopping

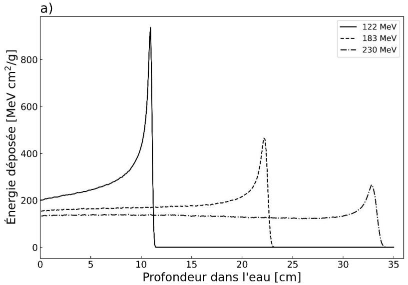
Depth-dose relation (proton beam)

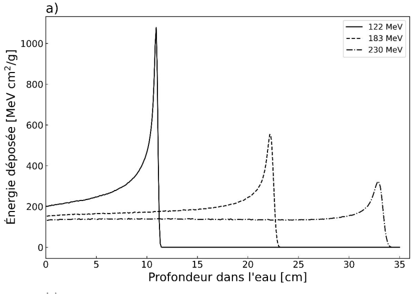
Attix figure 6.12a

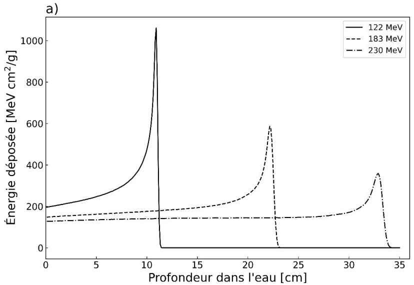


v1	v2	v3	v4



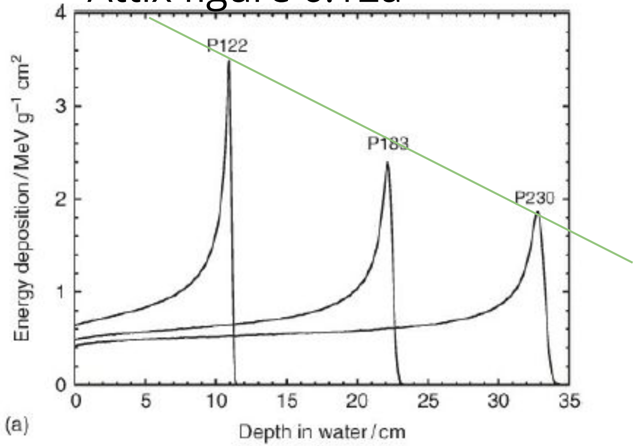




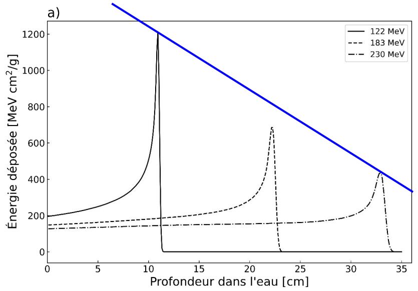


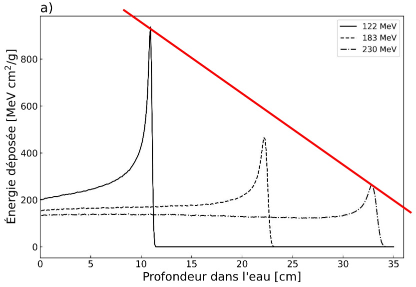
Depth-dose relation (proton beam)

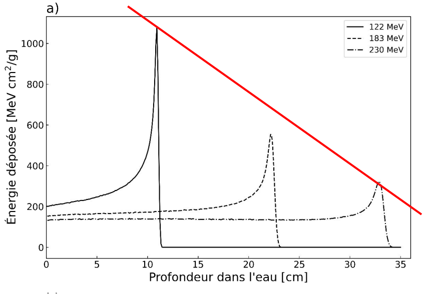
Attix figure 6.12a

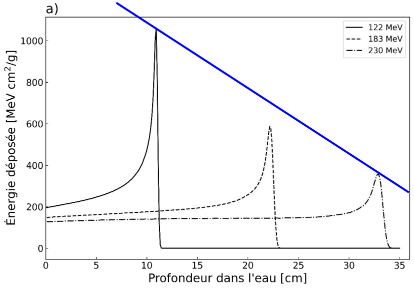


v1	v2	v3	v4



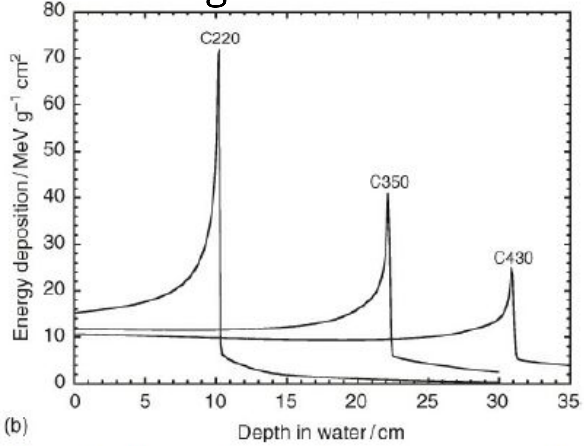




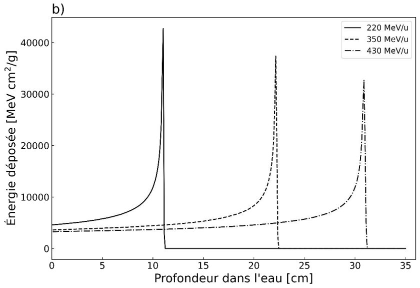


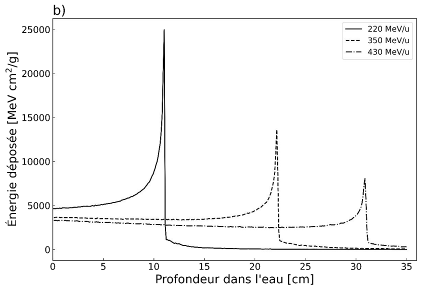
Depth-dose relation (carbon ions beam)

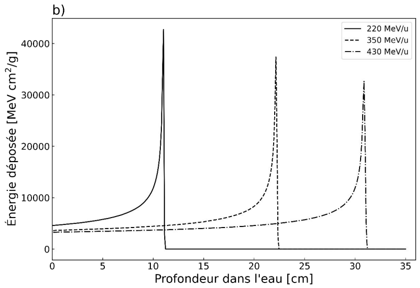
Attix figure 6.12b

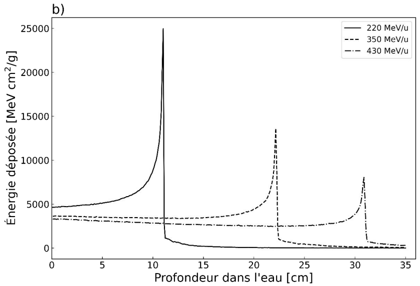


v1	v2	v3	v4

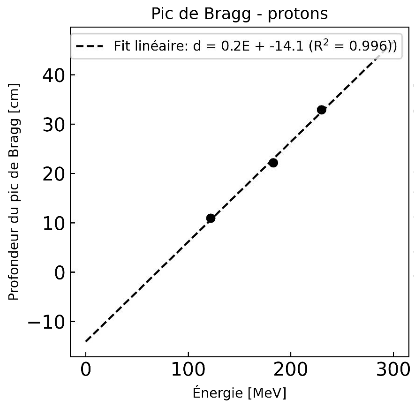


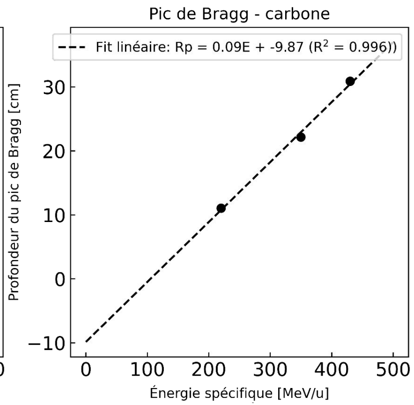


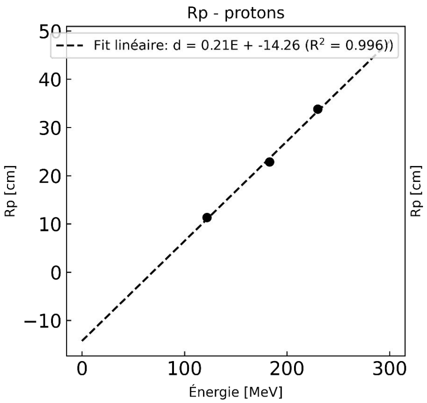


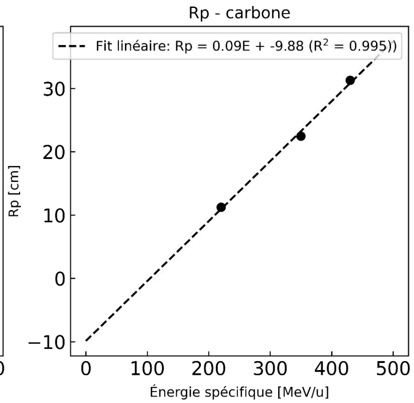


Depth-dose relation: linear regression



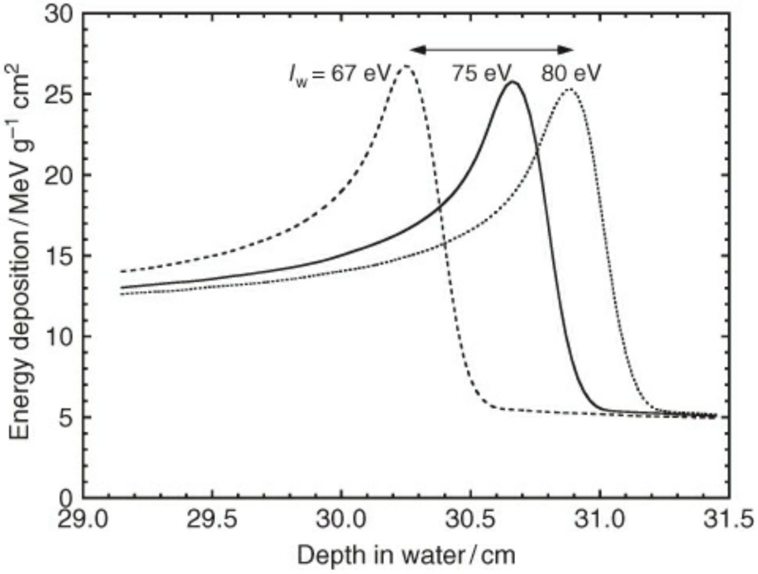






Mean excitation value effect on Bragg peak position

- Carbon Gaussian beam, 430 MeV/u.
- Mean excitation energy of water of 67, 75 and 80 eV.
- Extension of the Bragg peak depth over a region of 6mm.



Attix - Fig. 6.13

Mean excitation value: TOPAS simulation

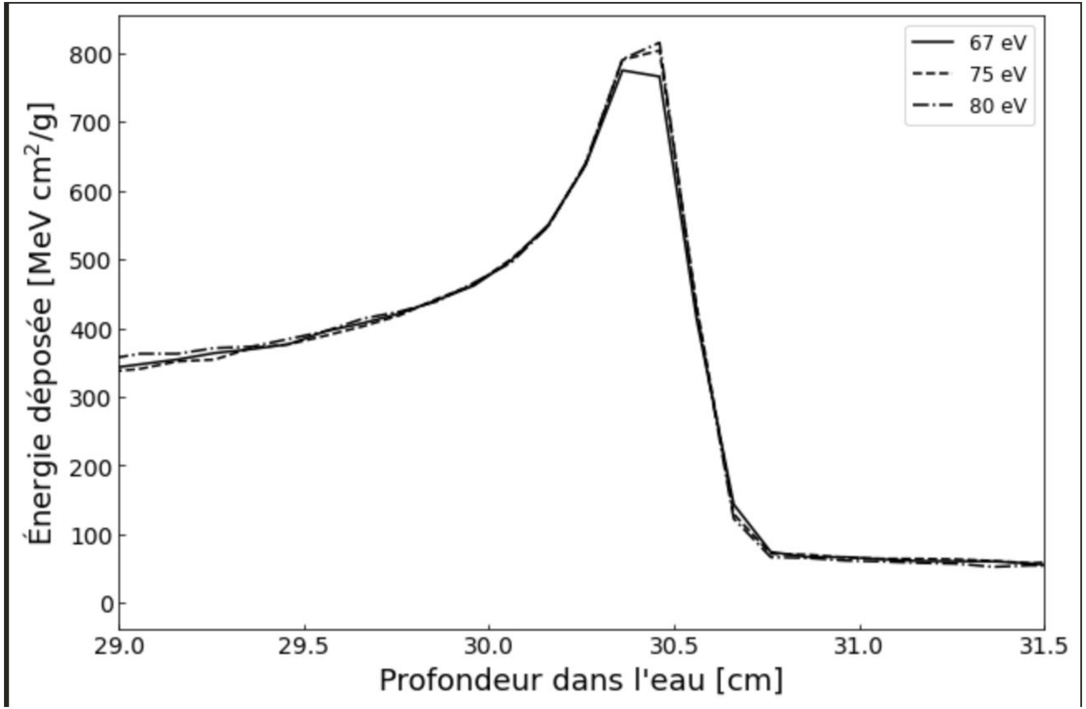
- First attempt: Create a custom “water” world with specified mean excitation value.

```
# 50 cm side water cube
d:Ge/World/HLX = 25 cm
d:Ge/World/HLY = 25 cm
d:Ge/World/HLZ = 25 cm
sv:Ma/Water_67eV/Components = 2 "Hydrogen" "Oxygen"
uv:Ma/Water_67eV/Fractions = 2 0.111894000 0.888106000
d:Ma/Water_67eV/Density = 1.0 g/cm3
d:Ma/Water_67eV/MeanExcitationEnergy = 67 eV
s:Ma/Water_67eV/DefaultColor = "blue"
s:Ge/World/Material = "Water_67eV"
```

Mean excitation value: TOPAS simulation

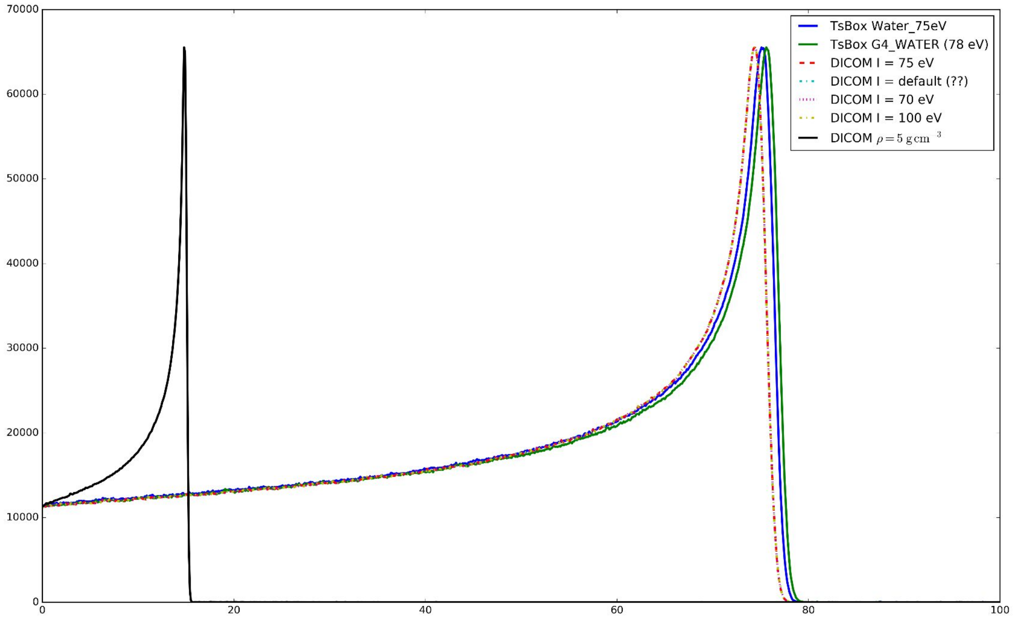
Results...

- Not what was expected...
- No spread in depth even for different I value.
- Energy deposed in the medium is also incorrect.



Mean excitation value: TOPAS simulation

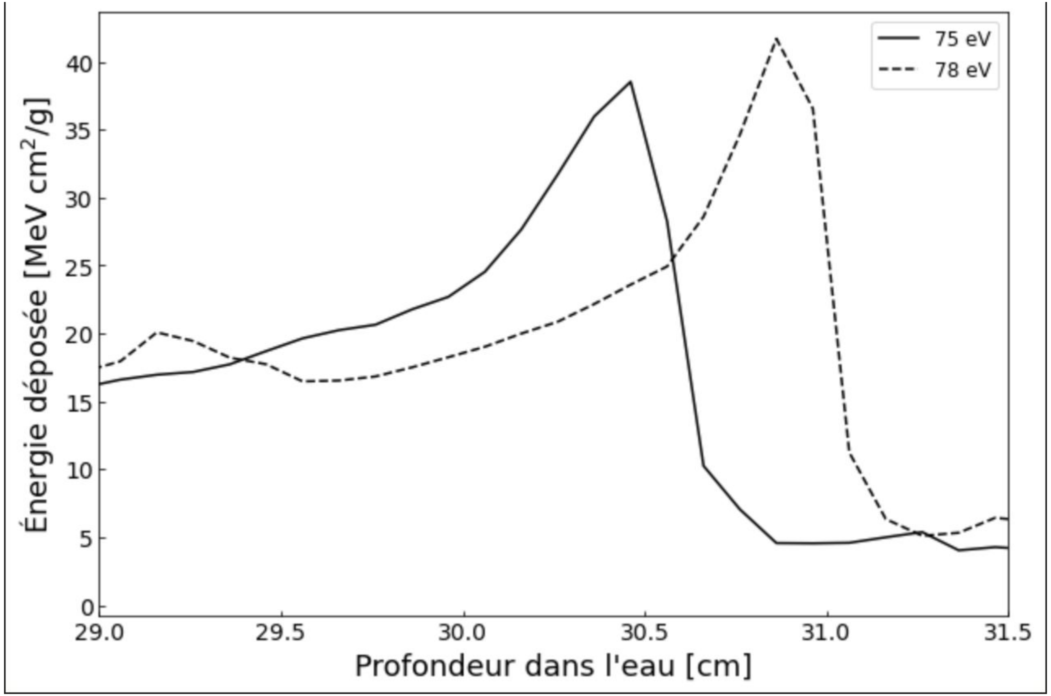
- Troubleshooting, TOPAS google forum…
- Material: “Water_75eV” and “G4_WATER”



https://groups.google.com/g/topas-mc-users/c/bUbgXVz2Dmw/m/QCb9FndgAQAJ

Mean excitation value: TOPAS simulation

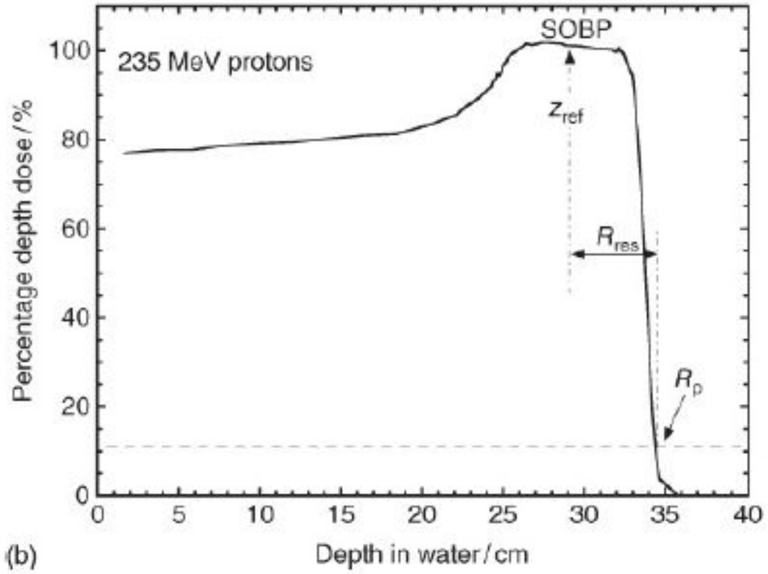
- Comparison between G4_WATER and Water_75eV



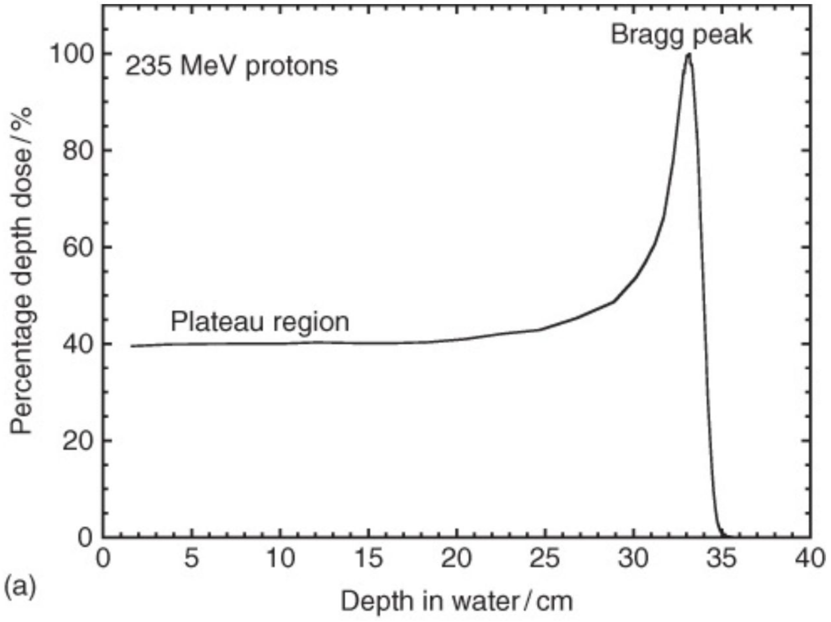
Beam modulation and SOBP

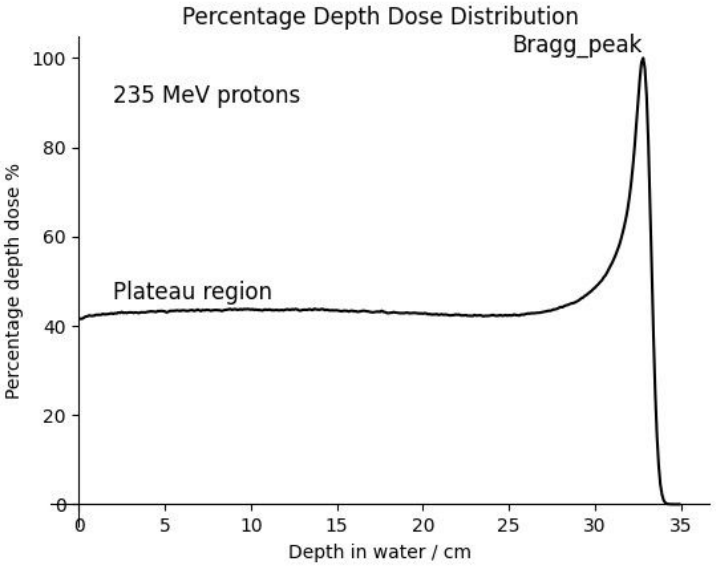
- Spread-Out Bragg Peak (SOBP) in MC simulations requires precise control over the energy and intensity of individual beams. It is not only about superimposing dose distributions from different energies but also about carefully adjusting the weights of each energy peak to achieve a flat dose distribution over the desired depth range.

- The aim is to produce a uniform dose region over the desired treatment depth.



Beam modulation and SOBP





simulated image

Beam modulation and SOBP

Fig 7.13.b

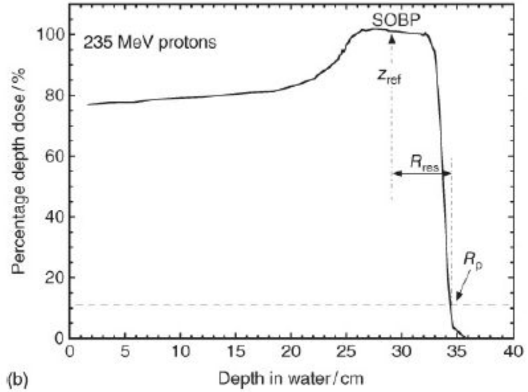
There are several methods to achieve an SOBP:

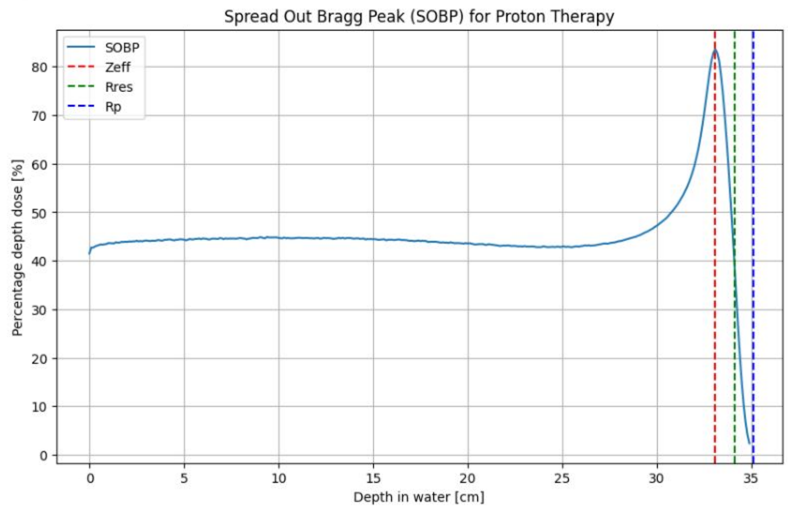
- **Modulating Wheel:** A modulating wheel with varying thicknesses can be used to physically degrade the beam energy, creating multiple Bragg peaks at different depths which combine to form an SOBP.

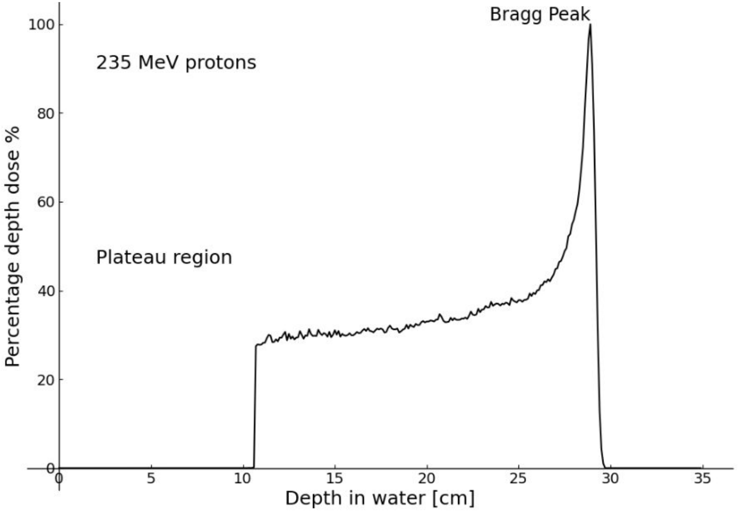
- **Energy Modulation:** Directly varying the energy of the proton beam in successive simulations (230, 231, 232, 233, 234, 235 MeV), and then superimposing the dose distributions.

Beam modulation and SOBP

Fig 7.13.b







s:Tf/BeamEnergy/Function = "Step"
dv:Tf/BeamEnergy/Times = 159
dv:Tf/BeamEnergy/Values = 159

References

P. Andreo, “On the clinical spatial resolution achievable with protons and heavier charged particle radiotherapy beams,” *Phys. Med. Biol.*, vol. 54, no. 11, p. N205, May 2009, doi: 10.1088/0031-9155/54/11/N01.

P. Andreo, D. T. Burns, A. E. Nahum, J. Seuntjens, and F. H. Attix, *Fundamentals of Ionizing Radiation Dosimetry*, 1er édition. Wiley-VCH, 2017.

M. Testa *et al.*, “Experimental validation of the TOPAS Monte Carlo system for passive scattering proton therapy,” *Med Phys*, vol. 40, no. 12, p. 121719, Dec. 2013, doi: 10.1118/1.4828781.