Improving the dose distribution in minibeam radiation therapy: protons vs helium ions

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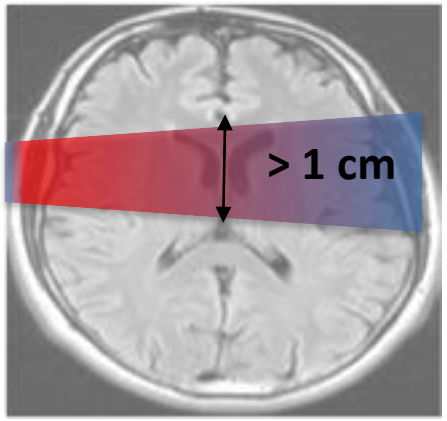
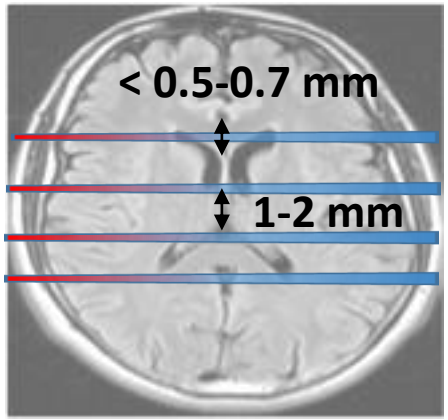
Background: minibeams

Standard RT

large beam sizes
(> 1 cm²)
+
homogeneous
dose distributions



Spatially fractionated RT



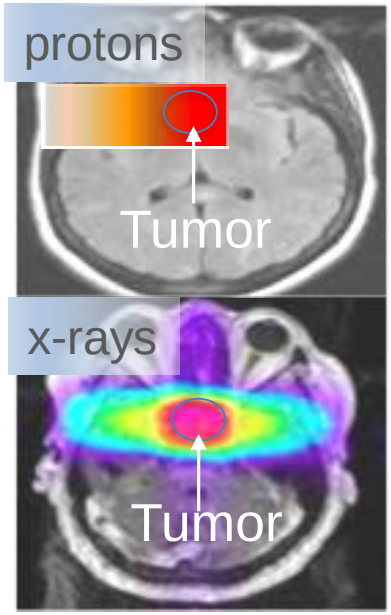
very narrow beam sizes
separated by
areas of low dose
+
heterogeneous
distributions

Proton minibeam RT (pMBRT)

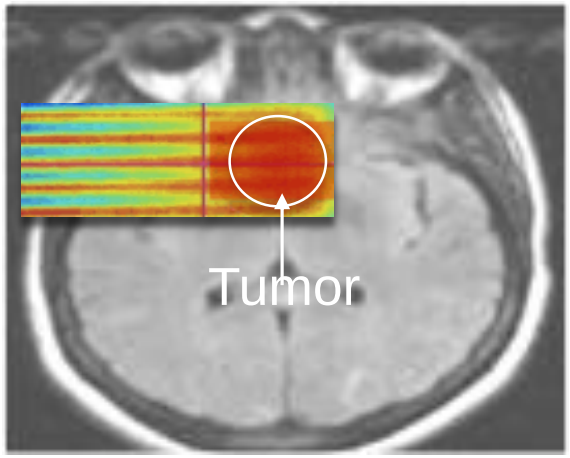
Our proposal: a novel approach in disruption with standard RT
(Prezado et al 2013)

spatial fractionation + **superior dose distribution of protons**

Standard



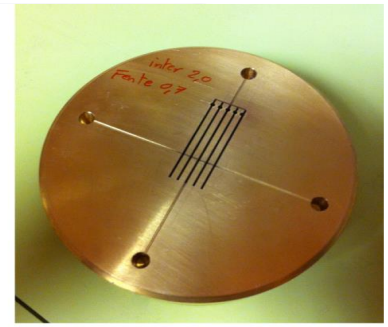
Proton minibeam radiation therapy (pMBRT)

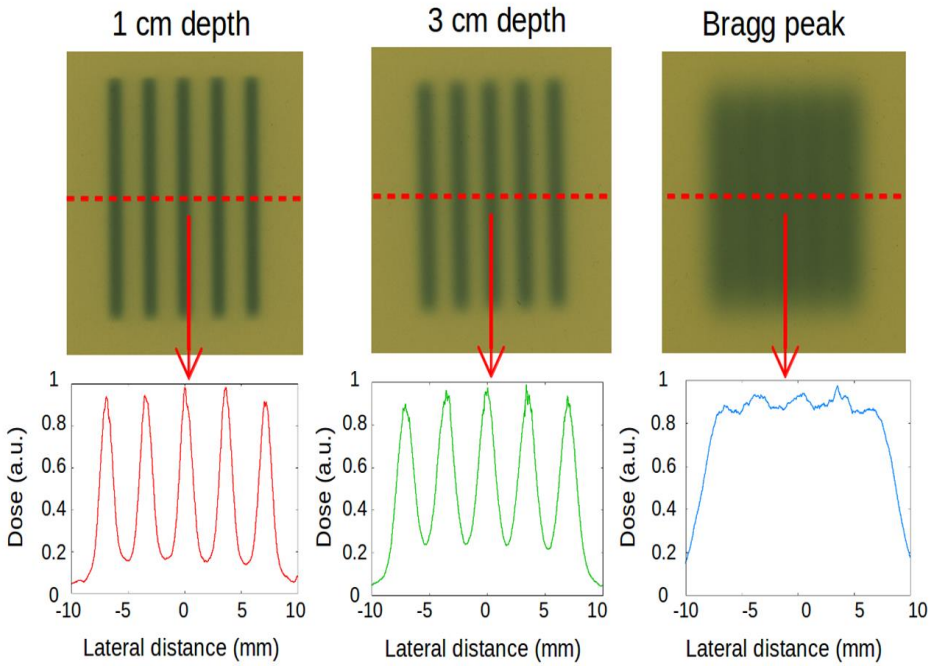


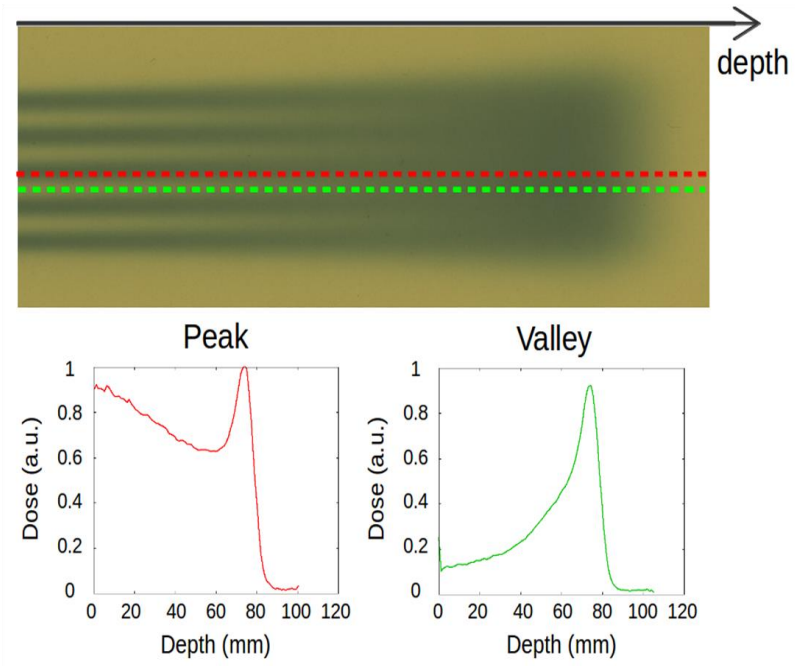
Homogeneous dose in the tumour
+
Spatial fractionation in normal tissue
+
Biological advantages of protons

Proton minibeam RT (pMBRT)

- experimental proof of concept: dose distributions assessed with gafchromic films (Peucelle et al, Med. Phys. 2015)
- minibeam generation: a first prototype with mechanical collimation



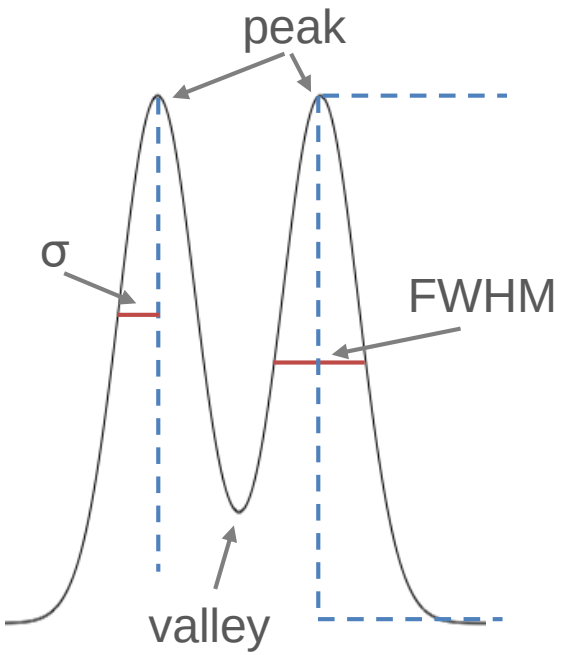


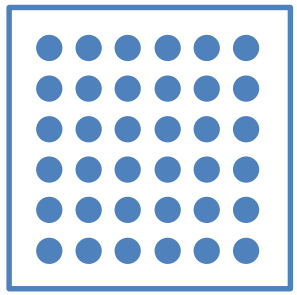


Source: Peucelle et al., Proton minibeam radiation therapy: Experimental dosimetry evaluation, Med Phys 2015

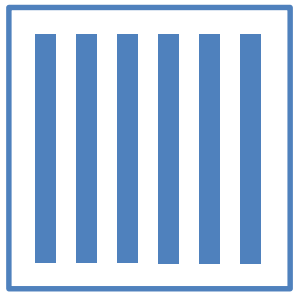
Some vocabulary for SFRT/minibeams

- peaks and valleys: peak-to-valley dose ratio (**PVDR**)
  - ➢ important for tissue sparing
- beam width: σ, full width at half maximum (**FWHM**)
- GRID therapy (x-rays)
  - 2D “grid” of beams
  - beam width 1 cm
- microbeam RT (MRT)
  - 1D “array” of beams
  - beam width 25 – 75 µm
- **minibeam RT (MBRT)**
  - 1D “array” of beams
  - beam width 300 µm – 1 mm





2D grid



1D array

Hadron minibeam RT (hMBRT)

Can we improve MBRT with other particle types?

- carbon and oxygen ions → González et al., Med. Phys. 44 (5), 2017
- C, O, Ne, Si, Ar and Fe ions → González and Prezado, Med. Phys. 45(6), 2018

➢ nuclear fragmentation of ions can increase valley doses

➢ heavy ions are much more expensive to produce and accelerate

Lighter ion as compromise?

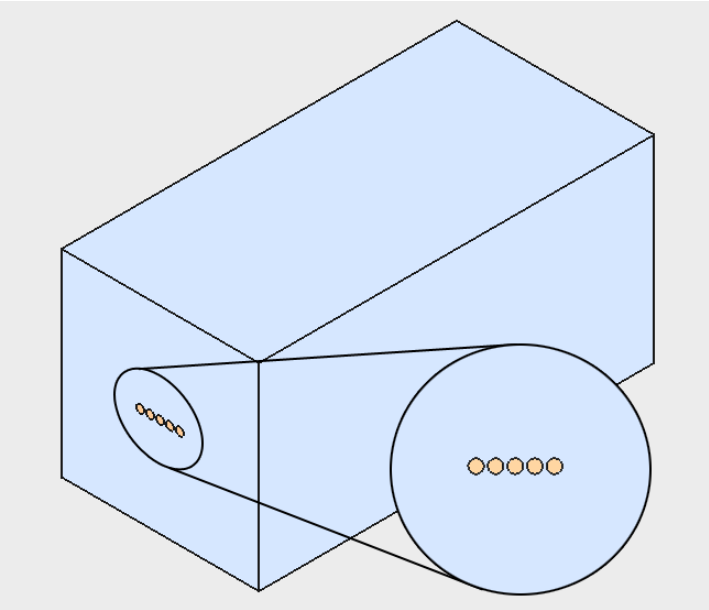
➢ He ions

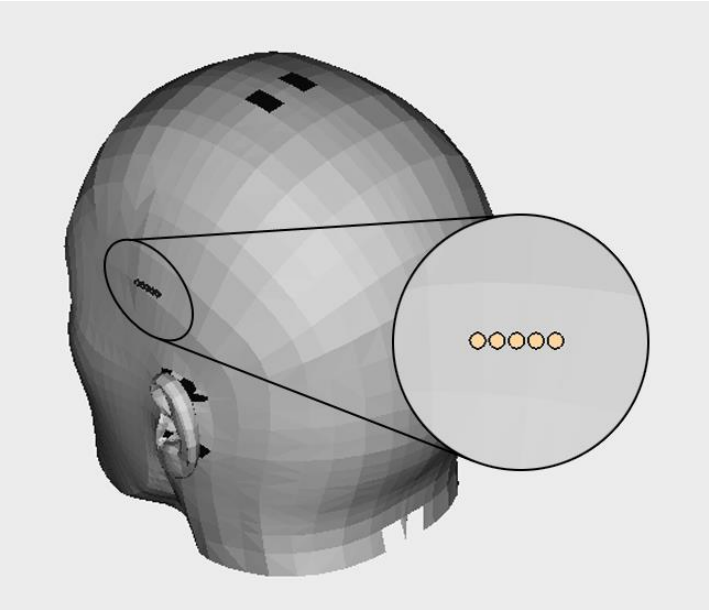
➢ thorough dosimetric comparison with protons

pMBRT vs HeMBRT

Comparative study with GATE

- GATE v8.0
- horizontal array of 5 minibeams (circular)
- theoretical point source (no beam optics elements) placed directly at the target
- two targets: water phantom and CT of human head
- comparison of dose distribution and LET
- simple example of treatment plan (SOBP in CT target)





Beam source

- *PencilBeam* source
- beam energies: 100 MeV for protons / 400 MeV for He ions
- circular beam cross section
- FWHM 1 mm and 3 mm
- divergence 3 mrad
- array of 5 minibeams
  - ➢ multiple copies of source
  - ➢ varying spacing (*center-to-center distance*)

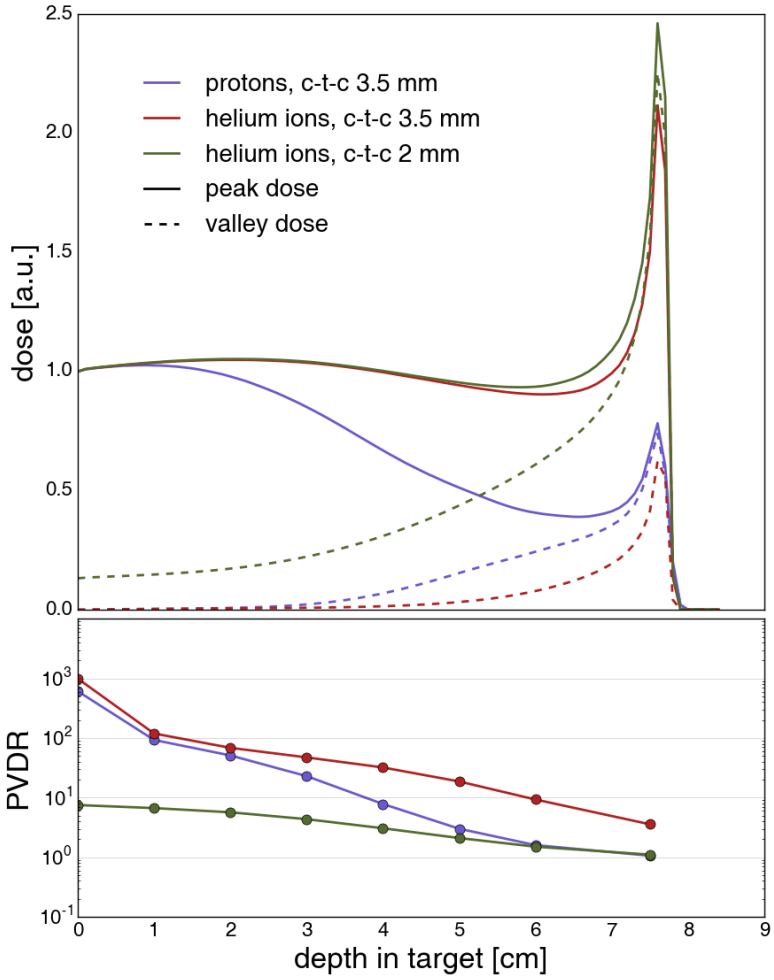
Targets

- target 1: water phantom (10 cm × 10 cm × 10 cm)
- target 2: *ImageNestedParametrisedVolume* with CT images of human head
- dose actor (0.1 mm × 1 mm × 1 mm voxels)
- LET actor (0.1 mm × 1 mm × 1 mm voxels)
- phase space actors for analysis of secondaries

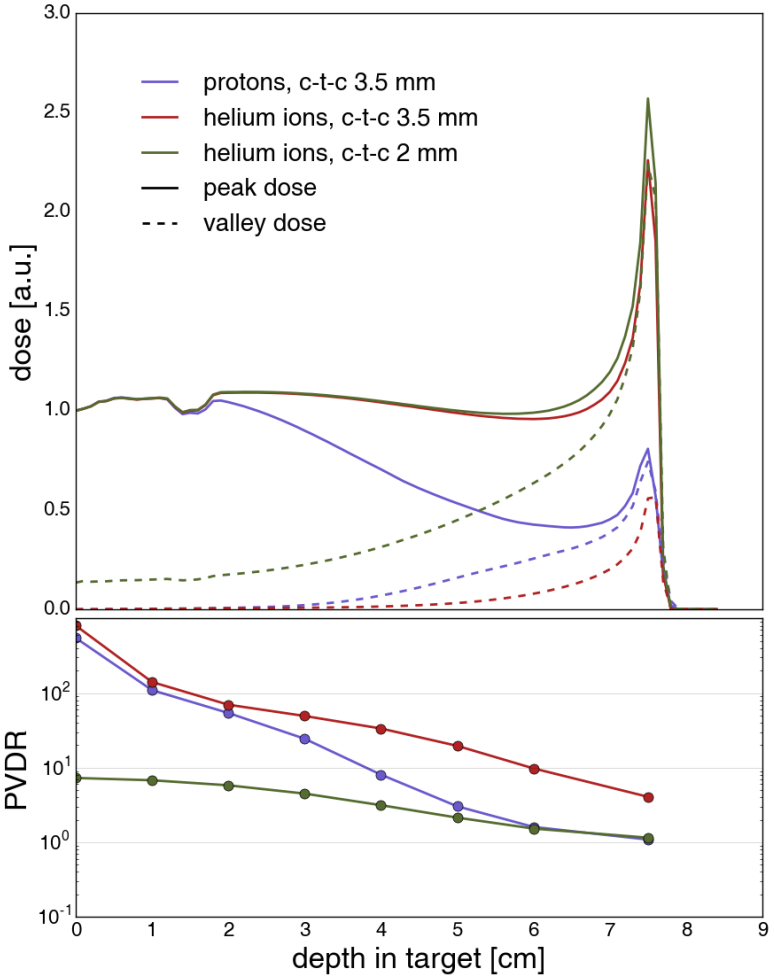
Results – dose

Example for 1 mm FWHM

water phantom



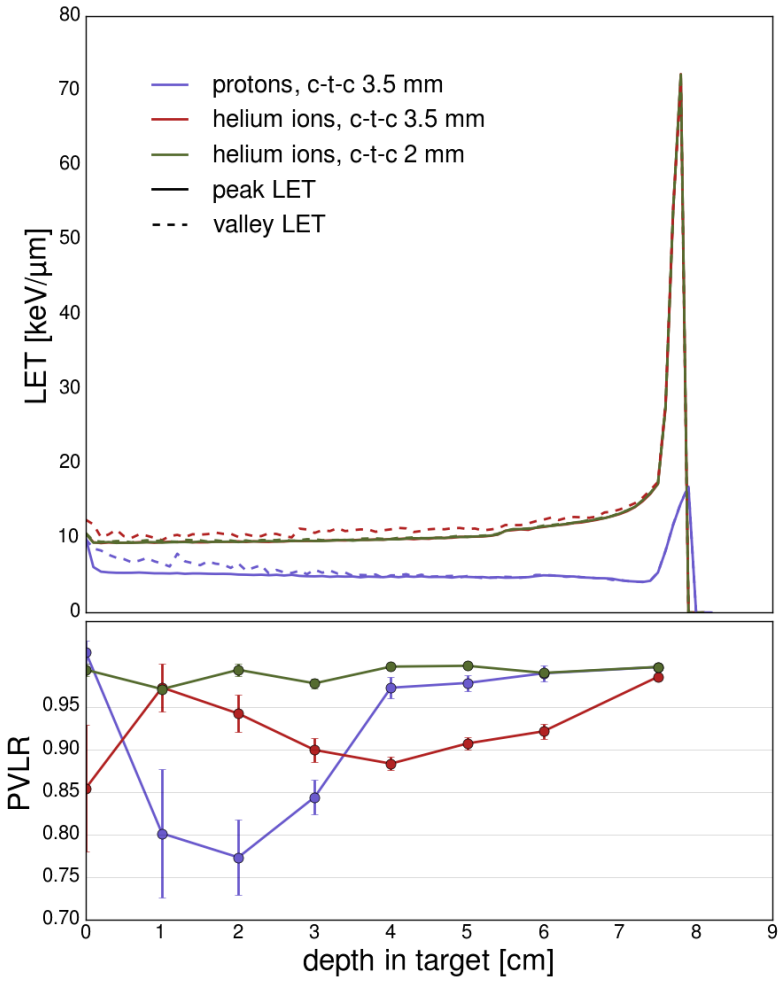
CT target



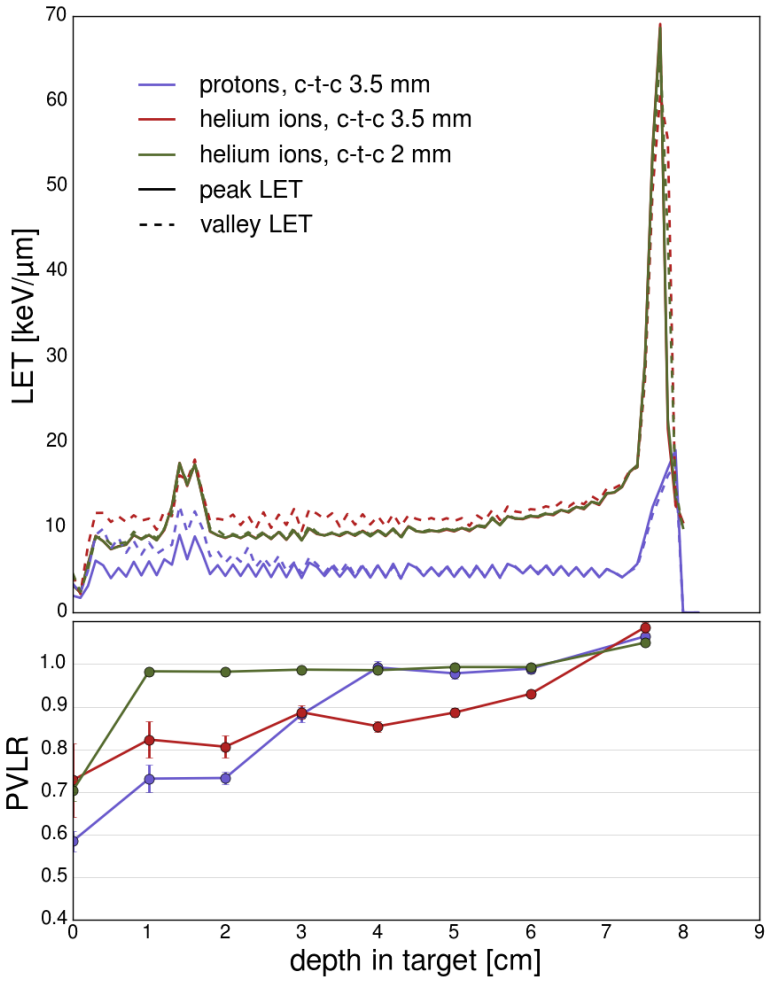
Results – LET

Example for 1 mm FWHM

water phantom

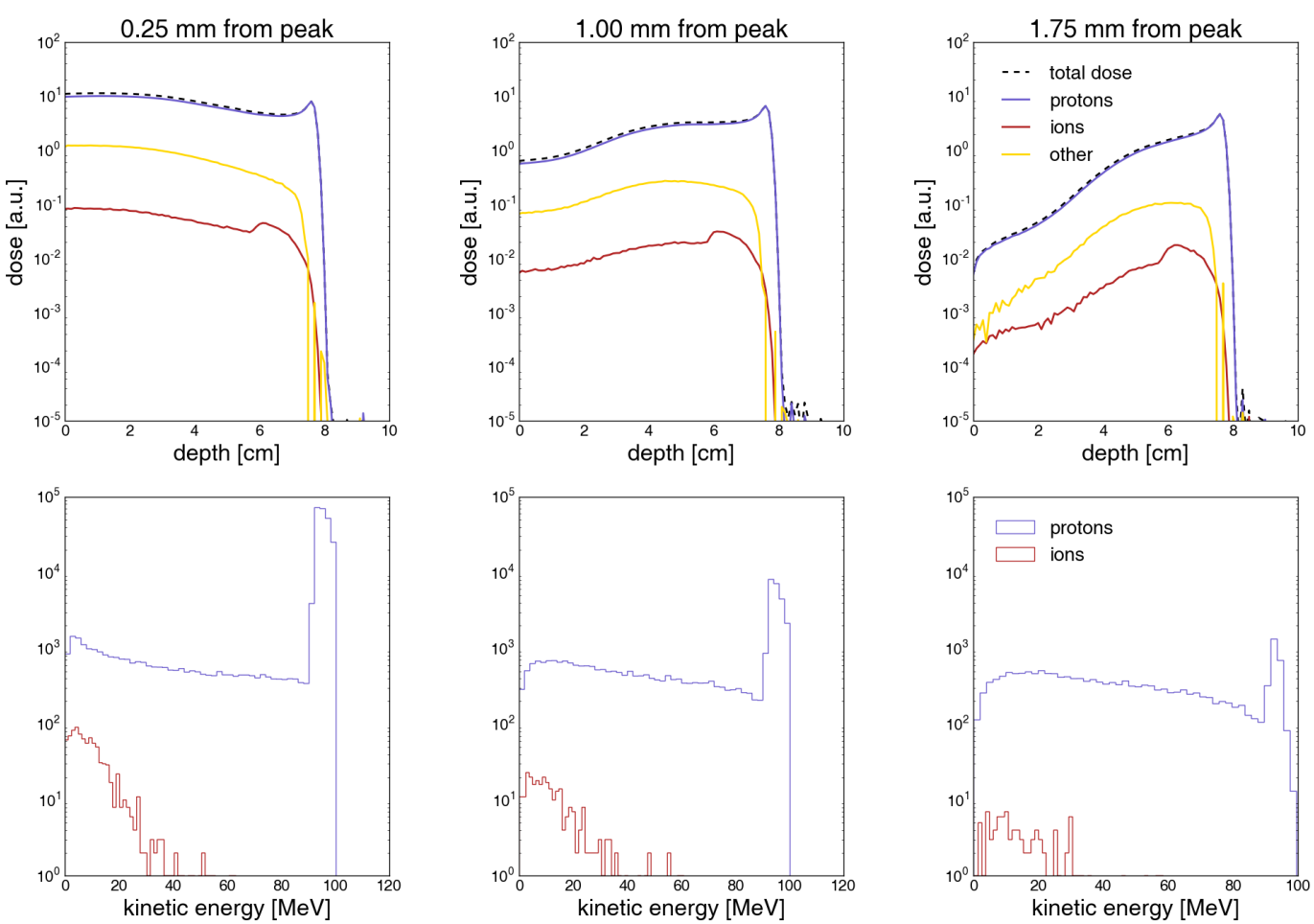


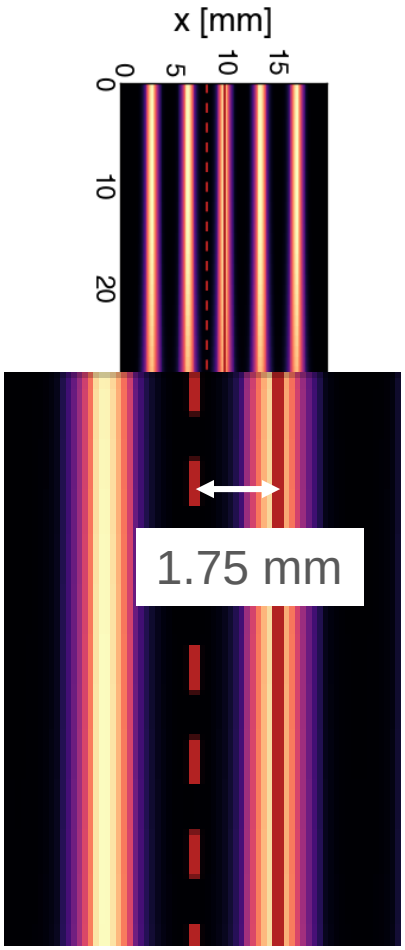
CT target



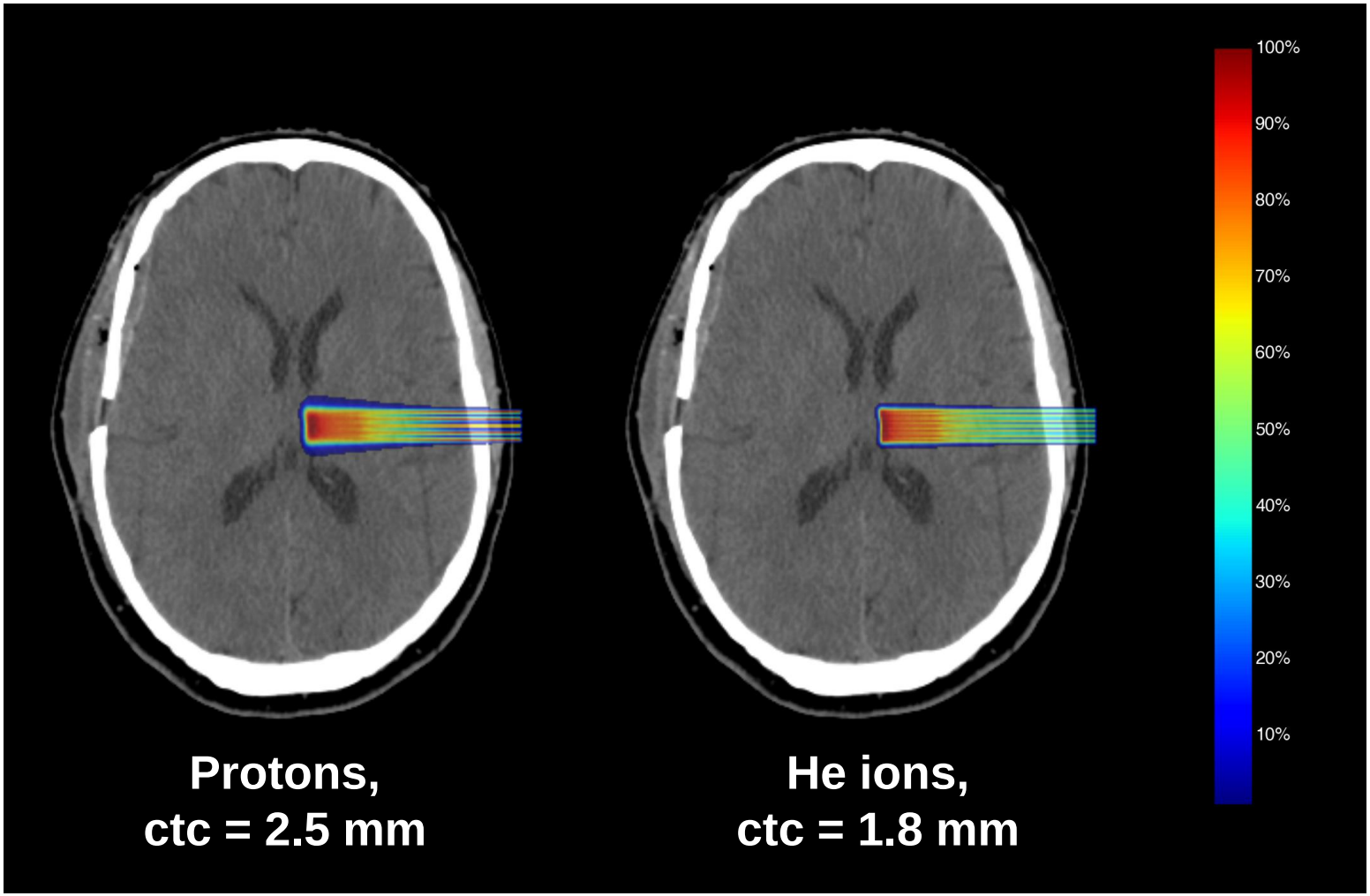
Results – secondaries

Example for protons

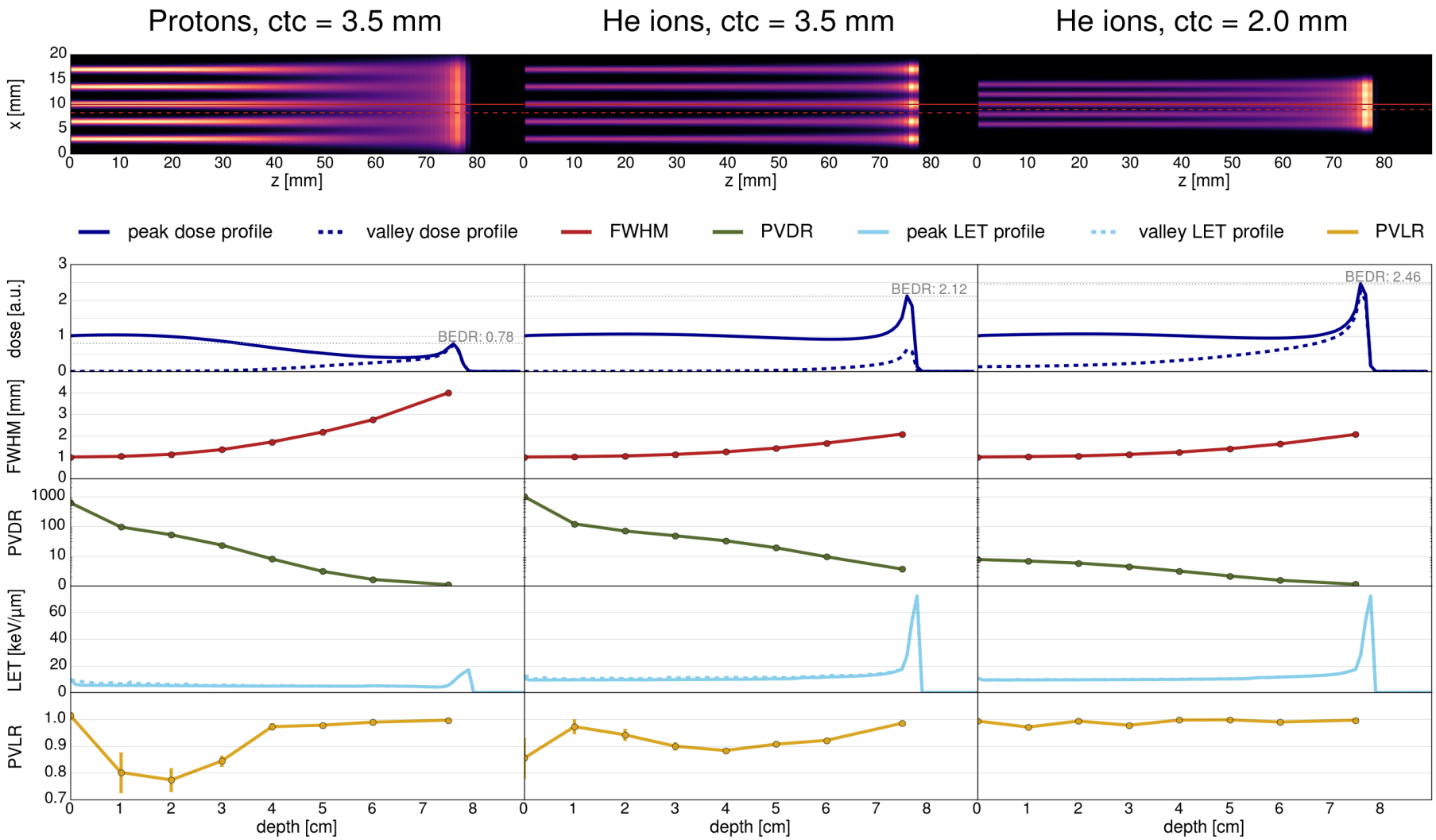




Results – example treatment plan



Results – summary



imagerie et modelisation en neurobiologie et cancerologie

Thank you for your attention!