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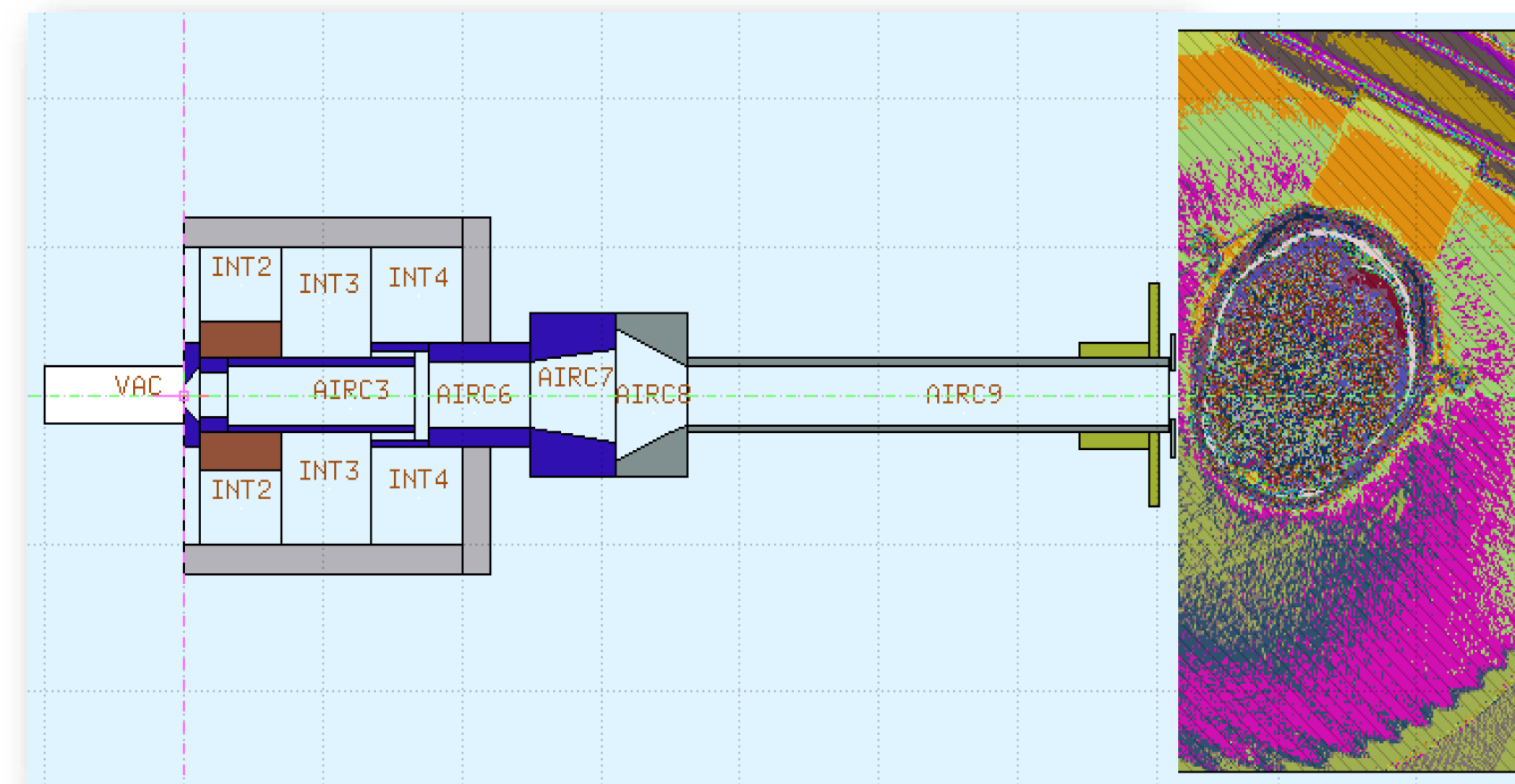
CENTRO RICERCHE
ENRICO FERMI



Development and Validation of a Monte Carlo-Based Treatment Planning System for FLASH IOeRT of Skin Cancer



soiort.com/flash-rt-technology/





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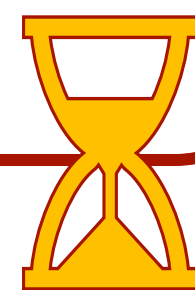
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Clinical trial @
CPFR for **FLASH**
radiotherapy
delivering **UHDR e⁻**
beams will address
the treatment of
skin cancer

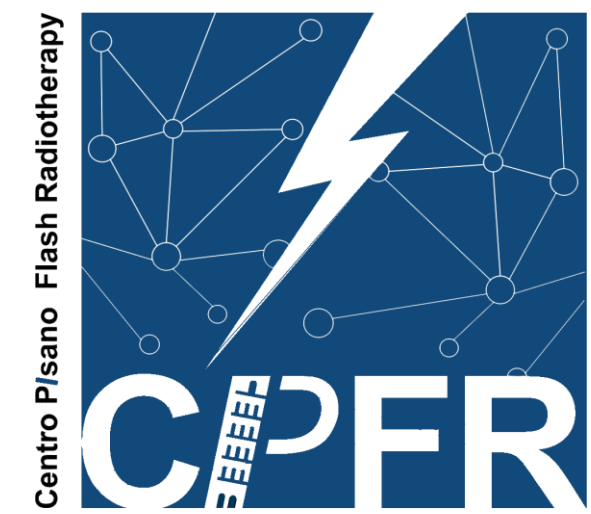
Waiting for approval
by the Italian Health
Ministry: **EBRT-like**
TPS needed!



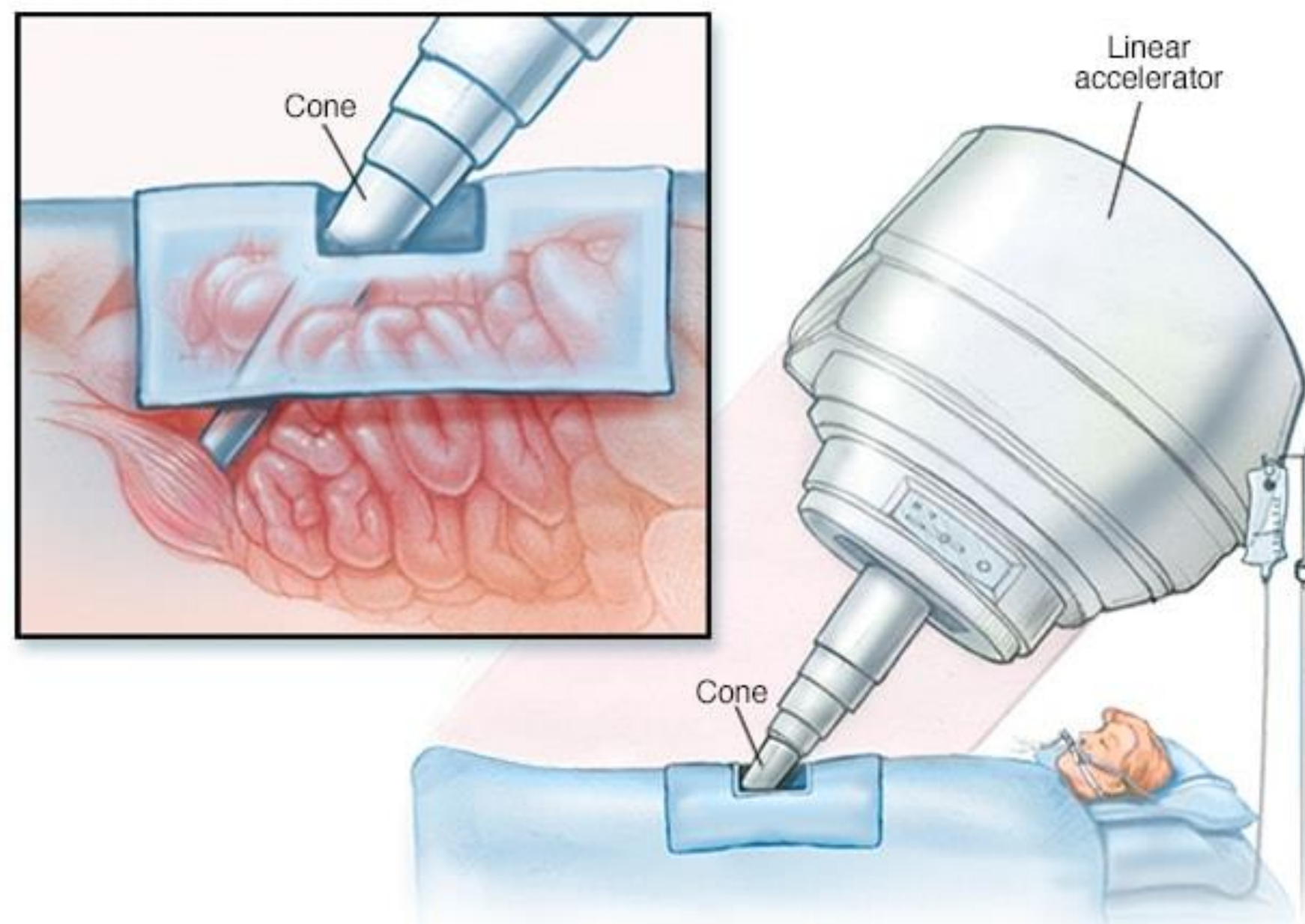
S.I.T. ElectronFlash @ CPFR



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Intra Operative electron Radiation Therapy (IOeRT)



Delivery of a **single high dose of radiation** (15-25 Gy) directly to the tumor bed **during surgery**, immediately after the macroscopic removal of the tumor, in order to minimize the risk of local recurrences.

In this clinical trial, the principles of IOeRT are extended to the treatment of **skin tumors** despite the absence of surgical resection.

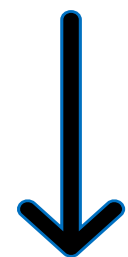
Principal applications:

- **Breast** cancer
- **Prostate** cancer
- **Pancreas** cancer

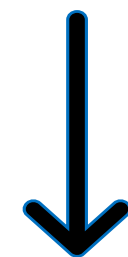


The FLASH effect

FLASH-RT involves delivery of the therapeutic dose at ultra high dose rates (**>40 Gy/s**), within a very short timeframe (**<200 ms**) compared to CONV-RT.



- **Tumor control** comparable to CONV-RT
- Significant reduction in **normal tissue toxicity**



The **biological mechanisms** underlying the FLASH effect are not yet fully understood, but there are some theories:

- **Oxygen consumption**
- **Immunological response**

So far, the **FLASH effect** has been **primarily studied using the electrons of IOeRT.**

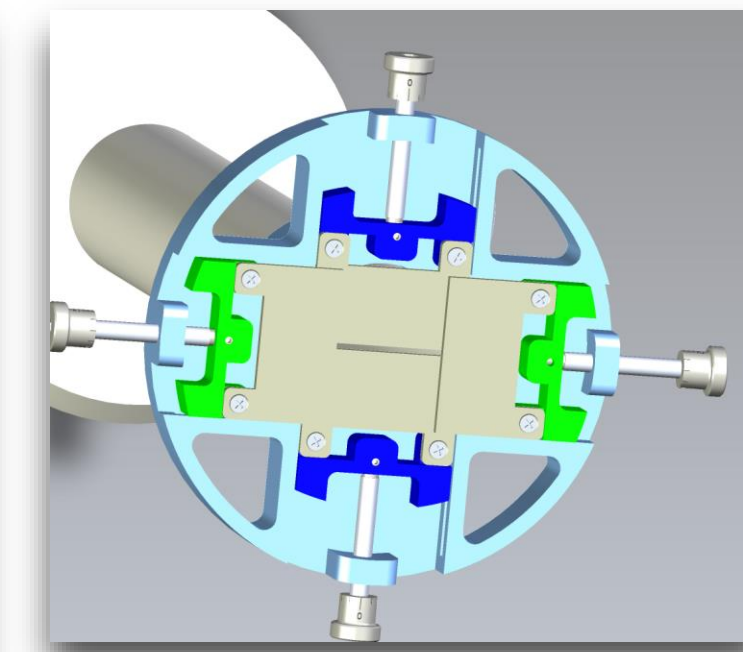
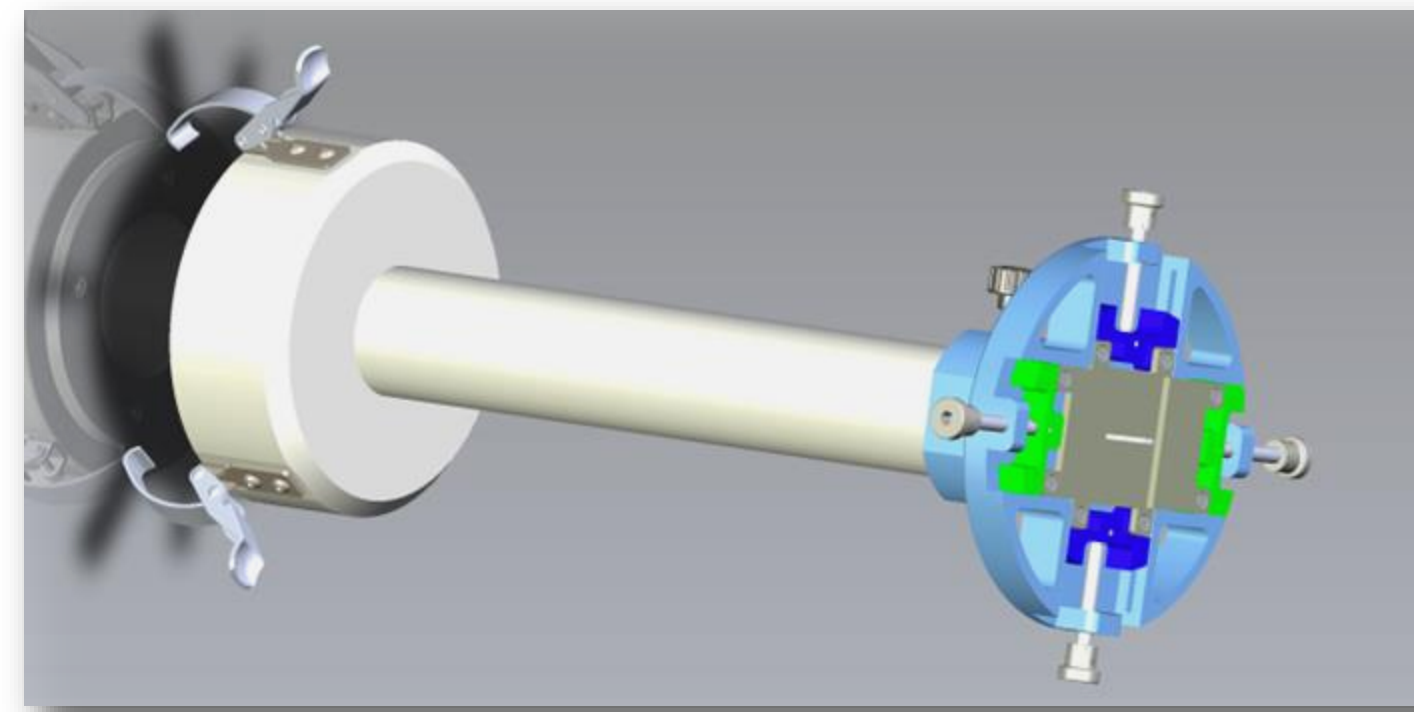
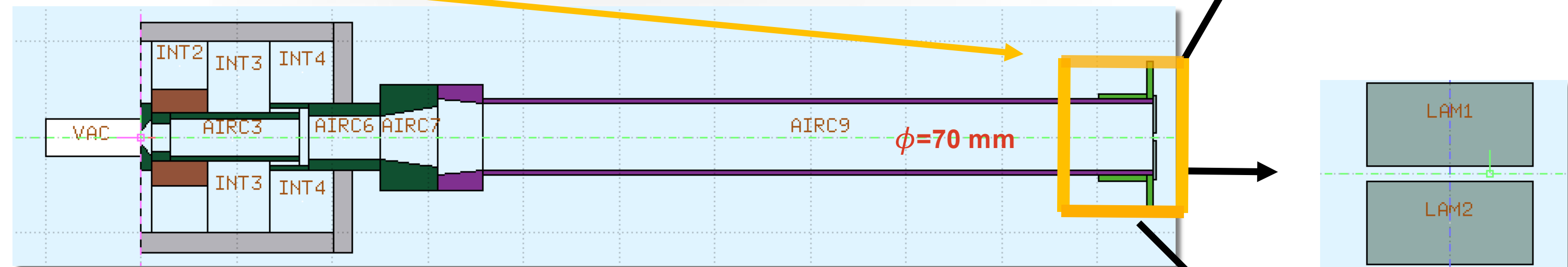
The ElectronFlash machine geometry has been reproduced in **FLUKA** to perform an accurate dose evaluation

- 70 mm(ϕ) **applicator** for beam uniformity
- **Nylon shaper** with two pairs of 40x80x3 mm **tungsten slits**

Optimisable degrees of freedom:

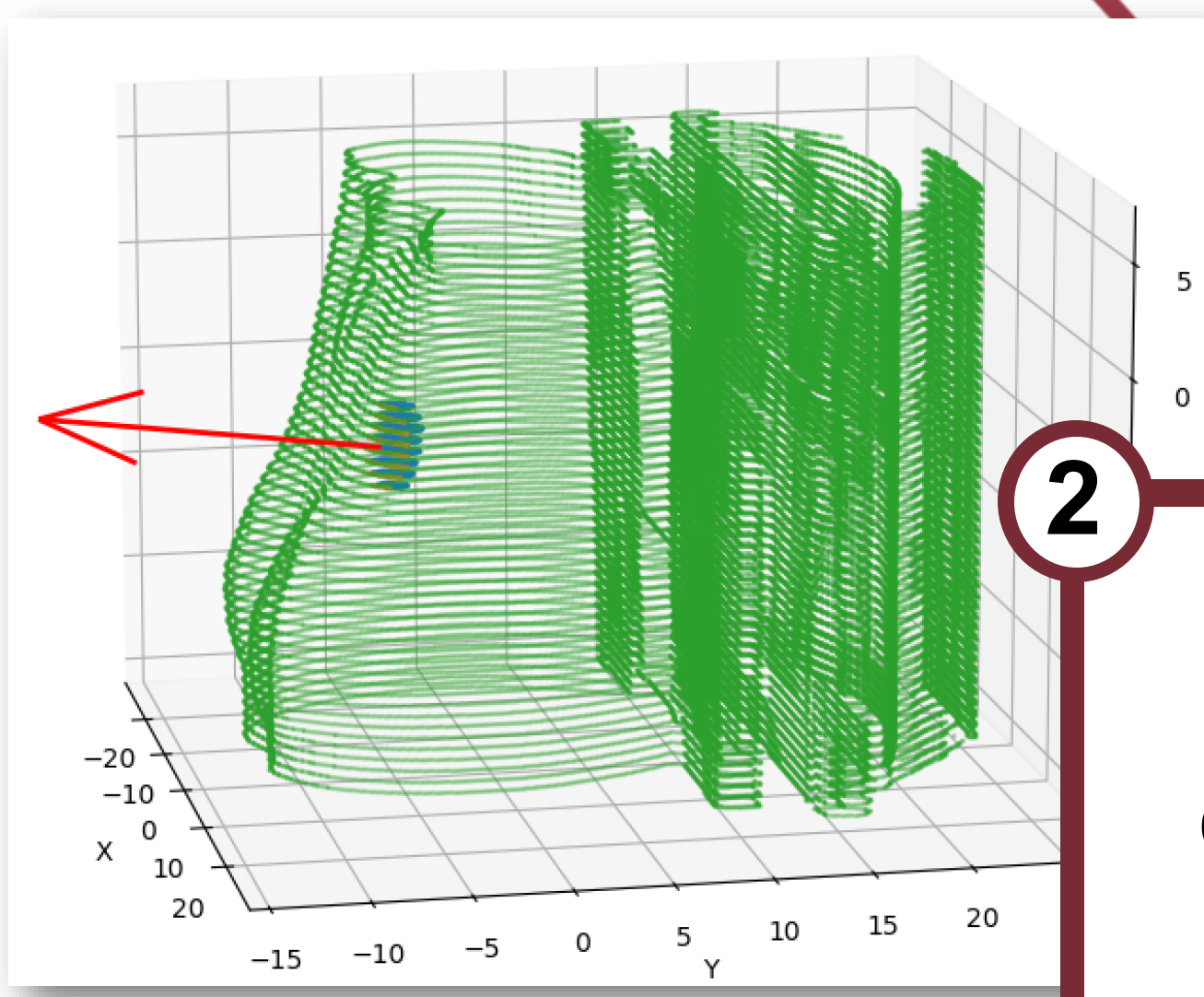
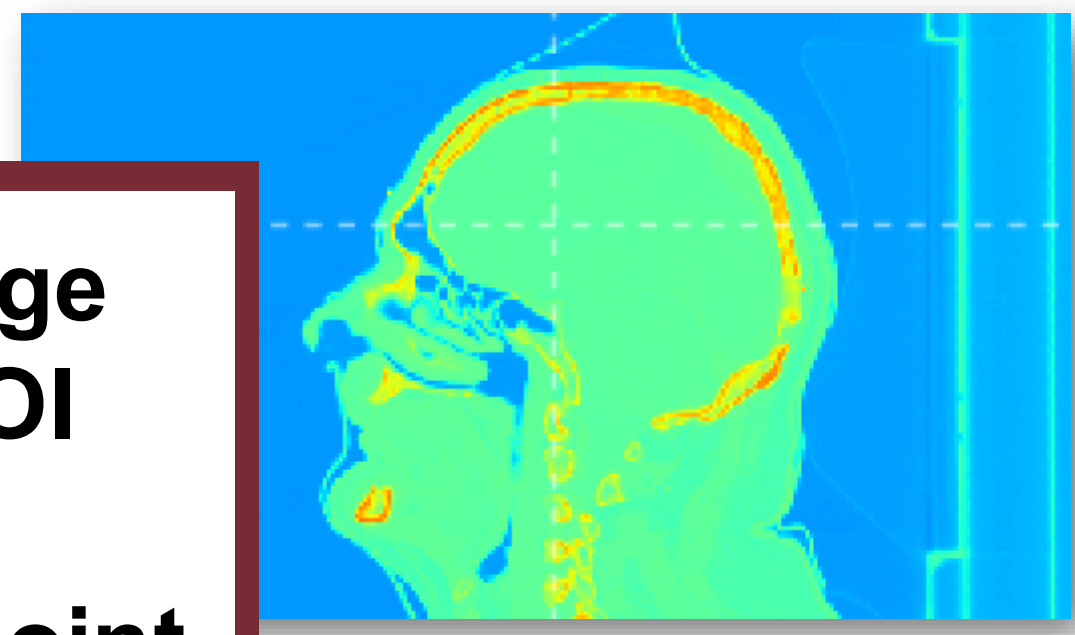
- 1) Different size of the **rectangular field**
- 2) Different **angles** due to the rotation of the shaper around the beam axis

Beam energy: **7** or **9 MeV**



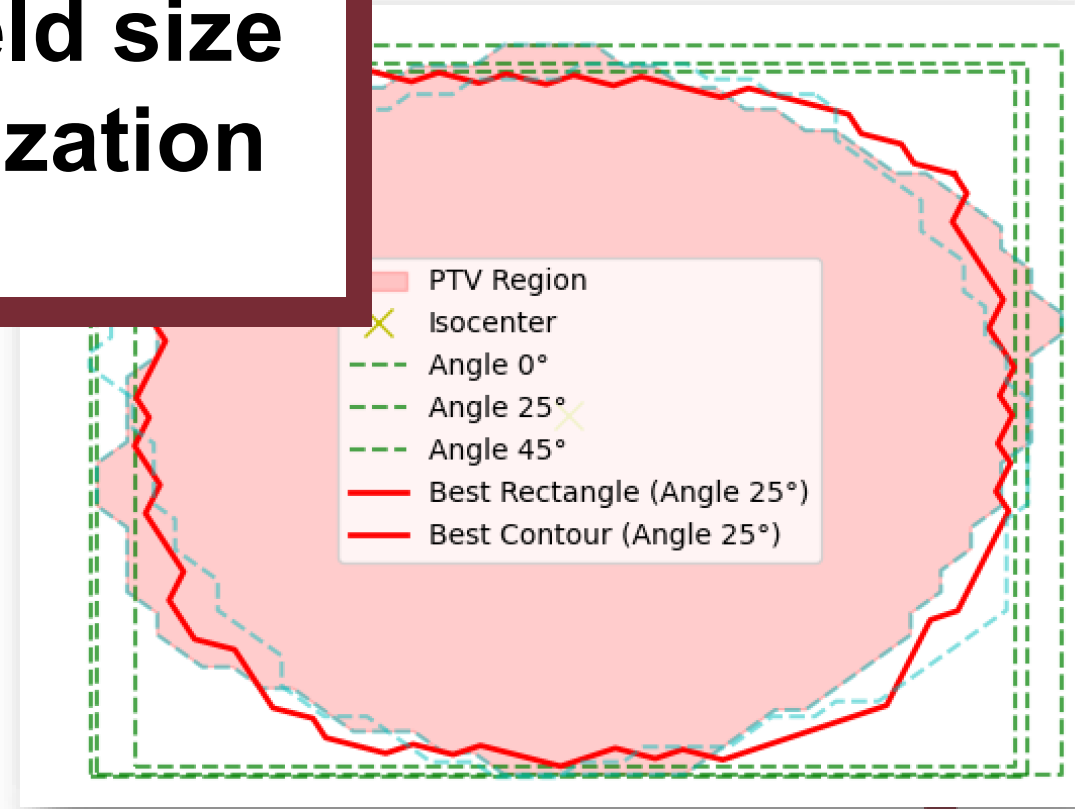


1
CT image
and ROI
+
marker point

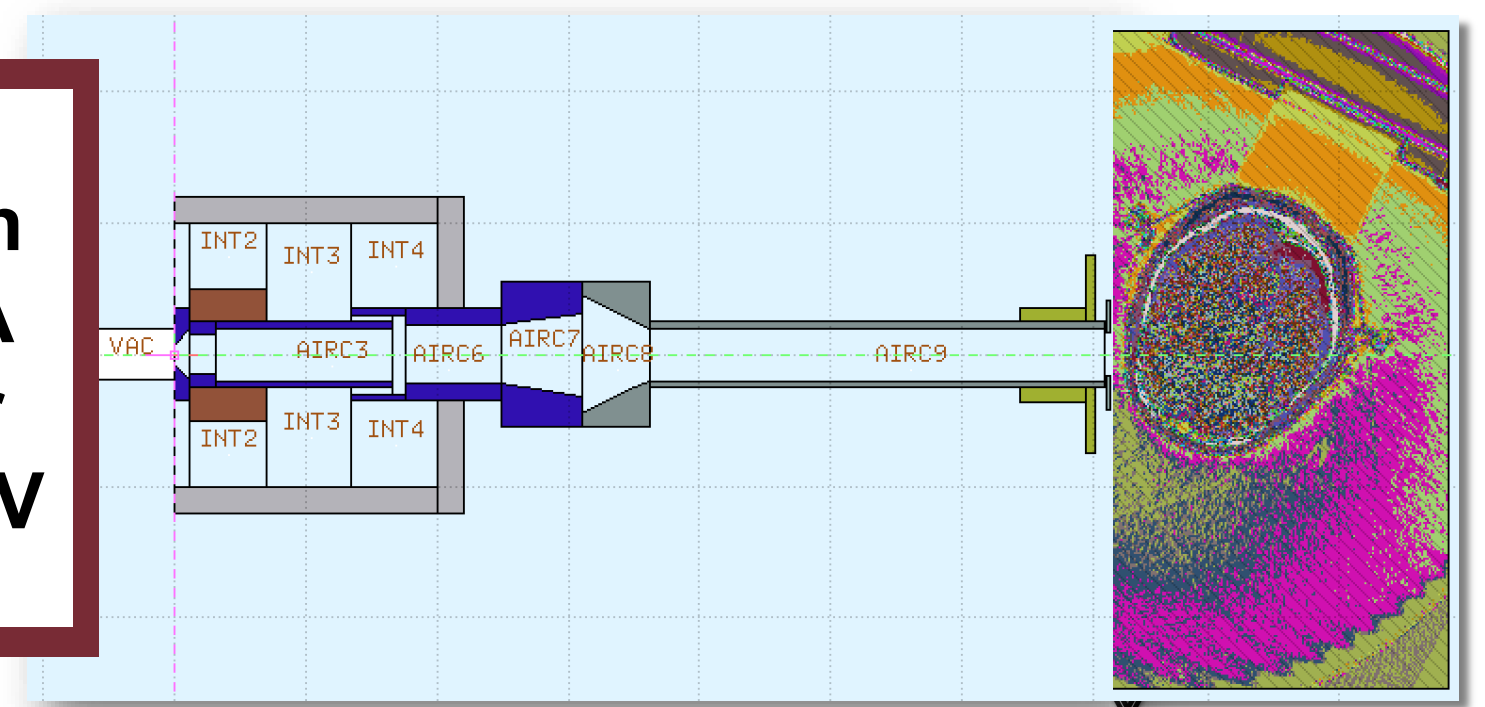


2
Beam
direction

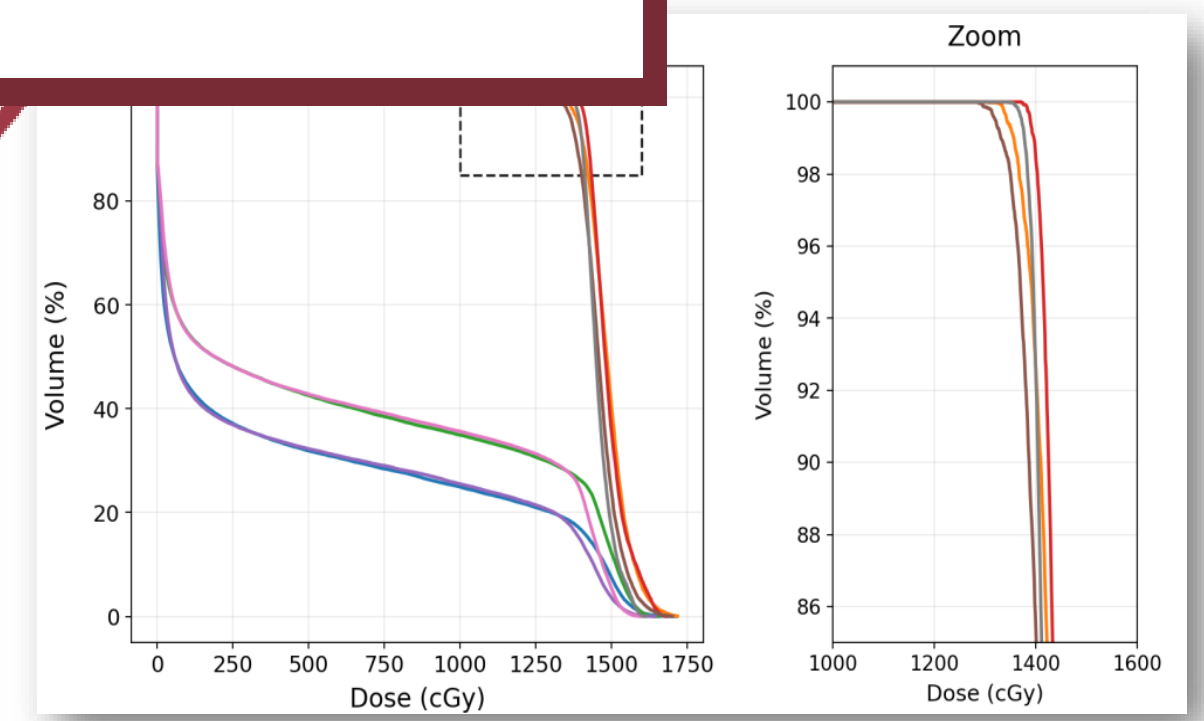
3
Shaper angle
and field size
optimization



4
Dose evaluation
through FLUKA
simulations for
both 7 and 9 MeV



5
Dose maps
and DVHs





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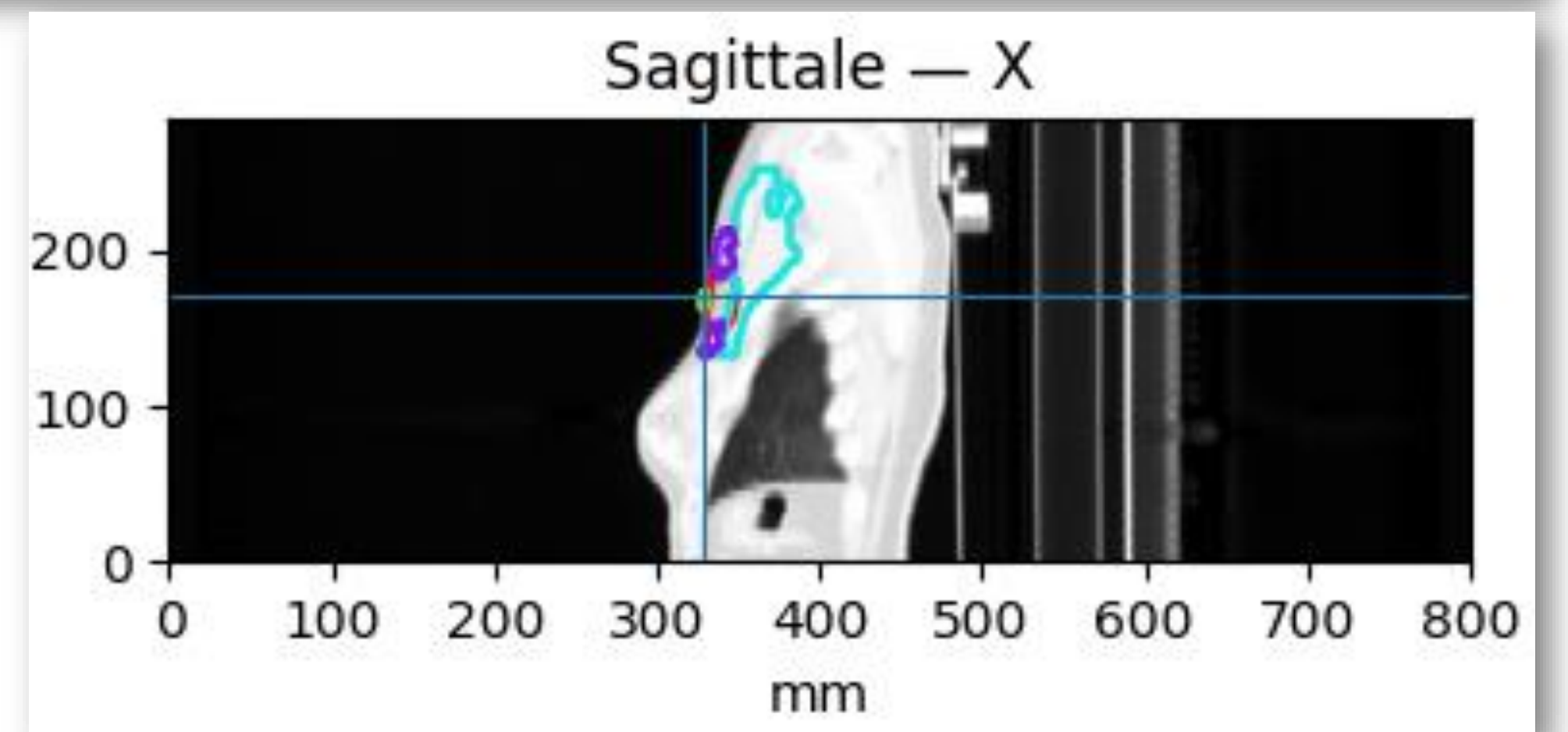
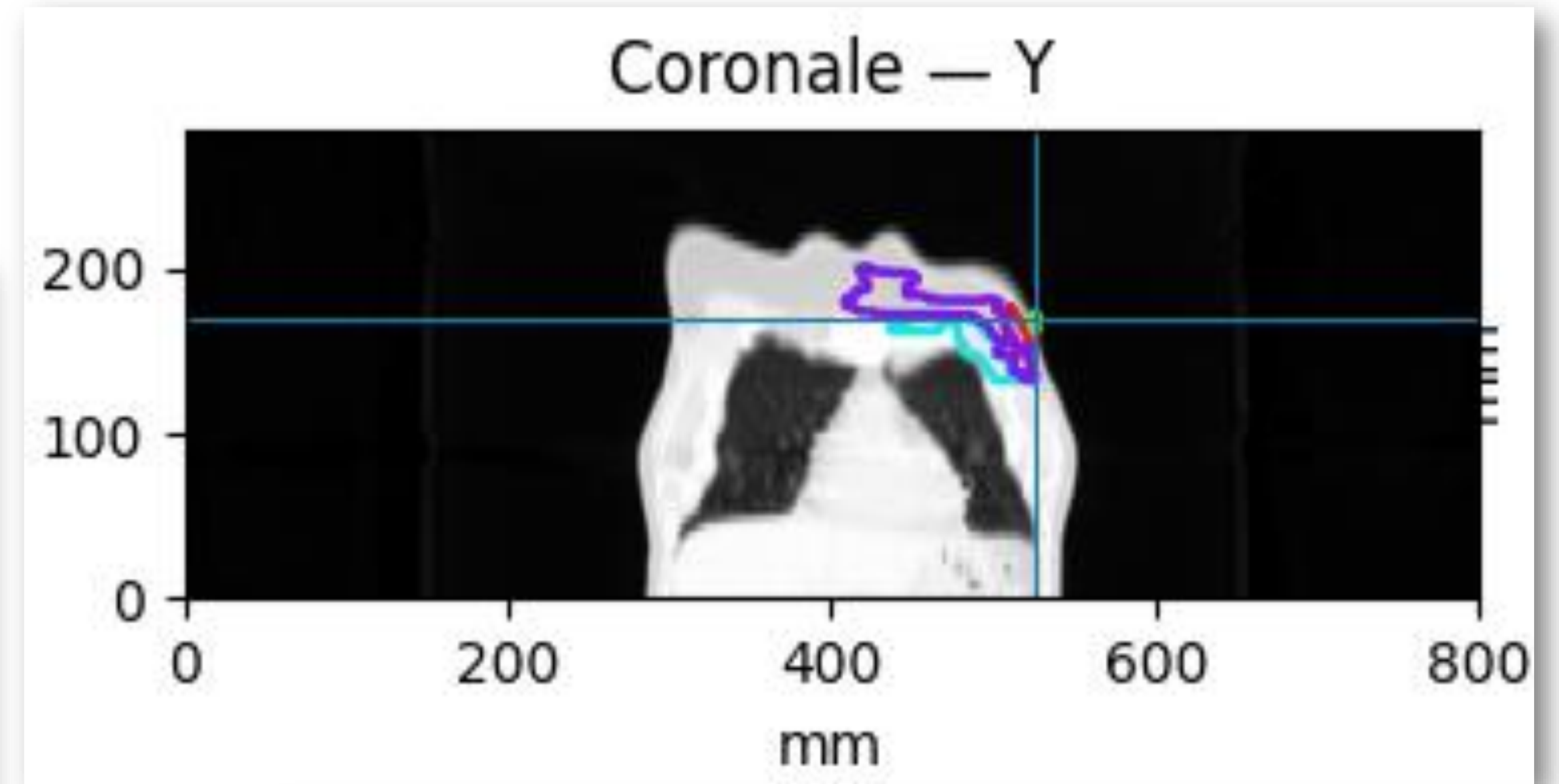
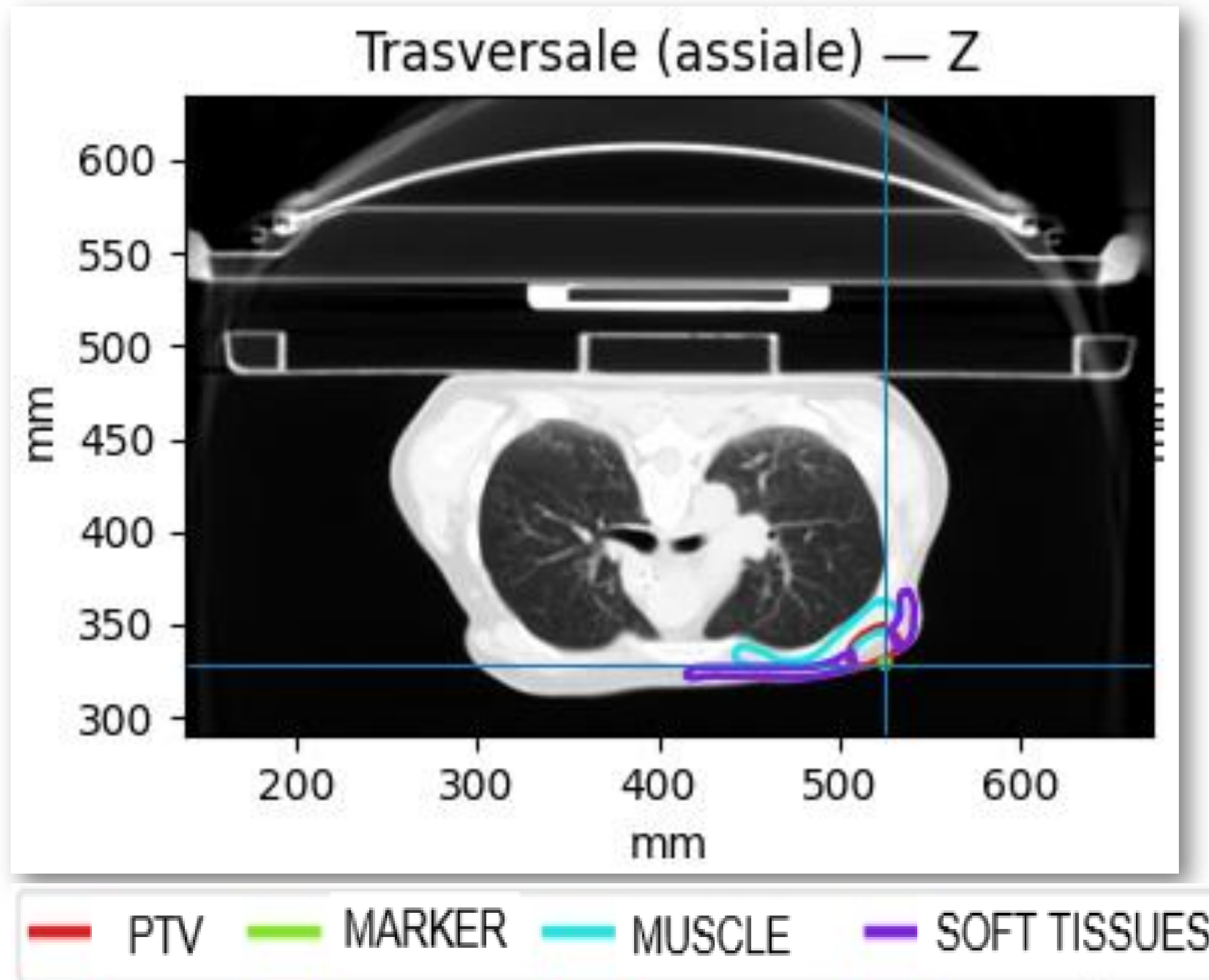
Development of a TPS for the Pisan Clinical Trial

PATIENTS ANALYSIS

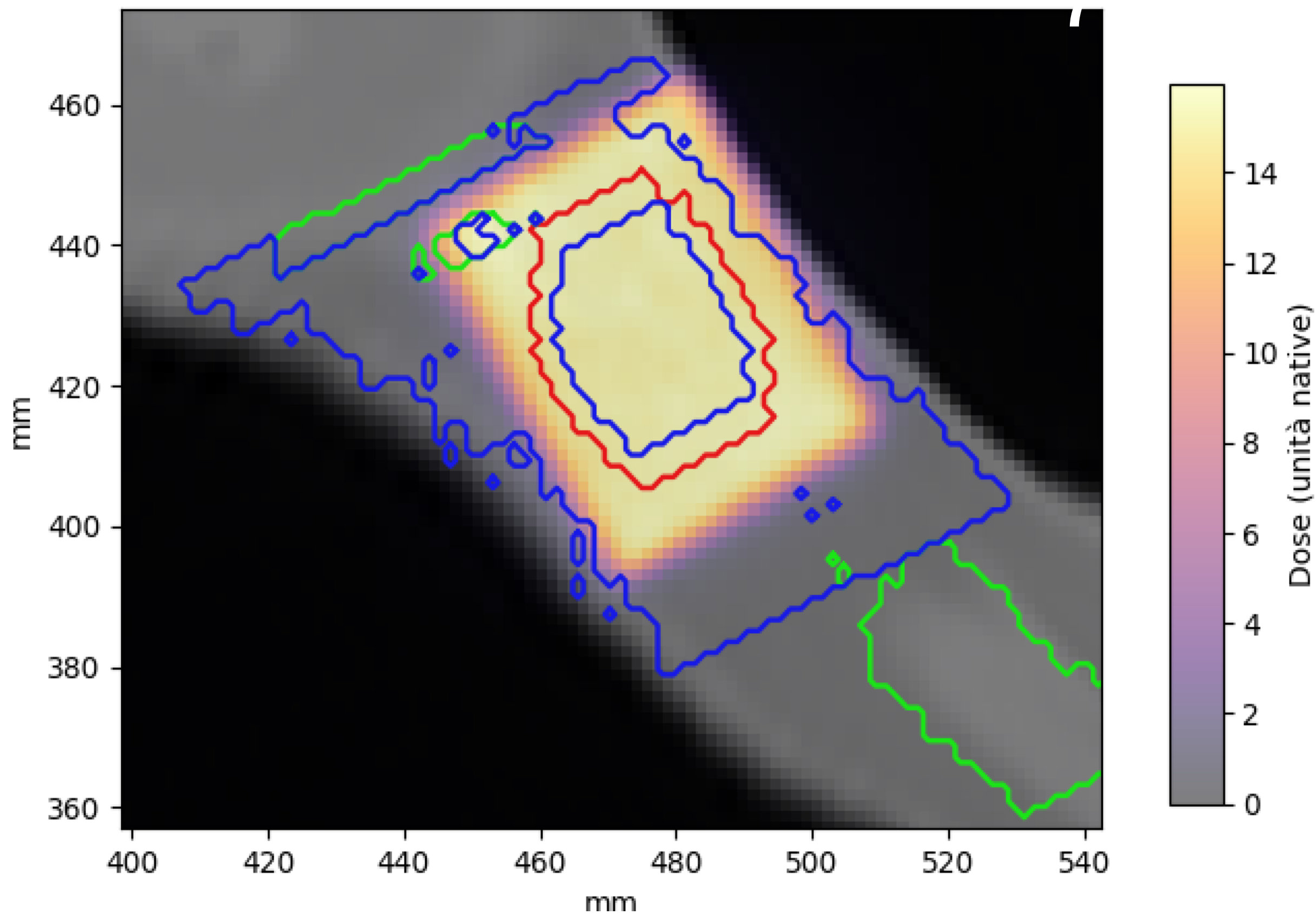
Development and Validation of a Monte Carlo-Based Treatment Planning System for FLASH Electron Radiotherapy of Skin Cancer

Chest Patient

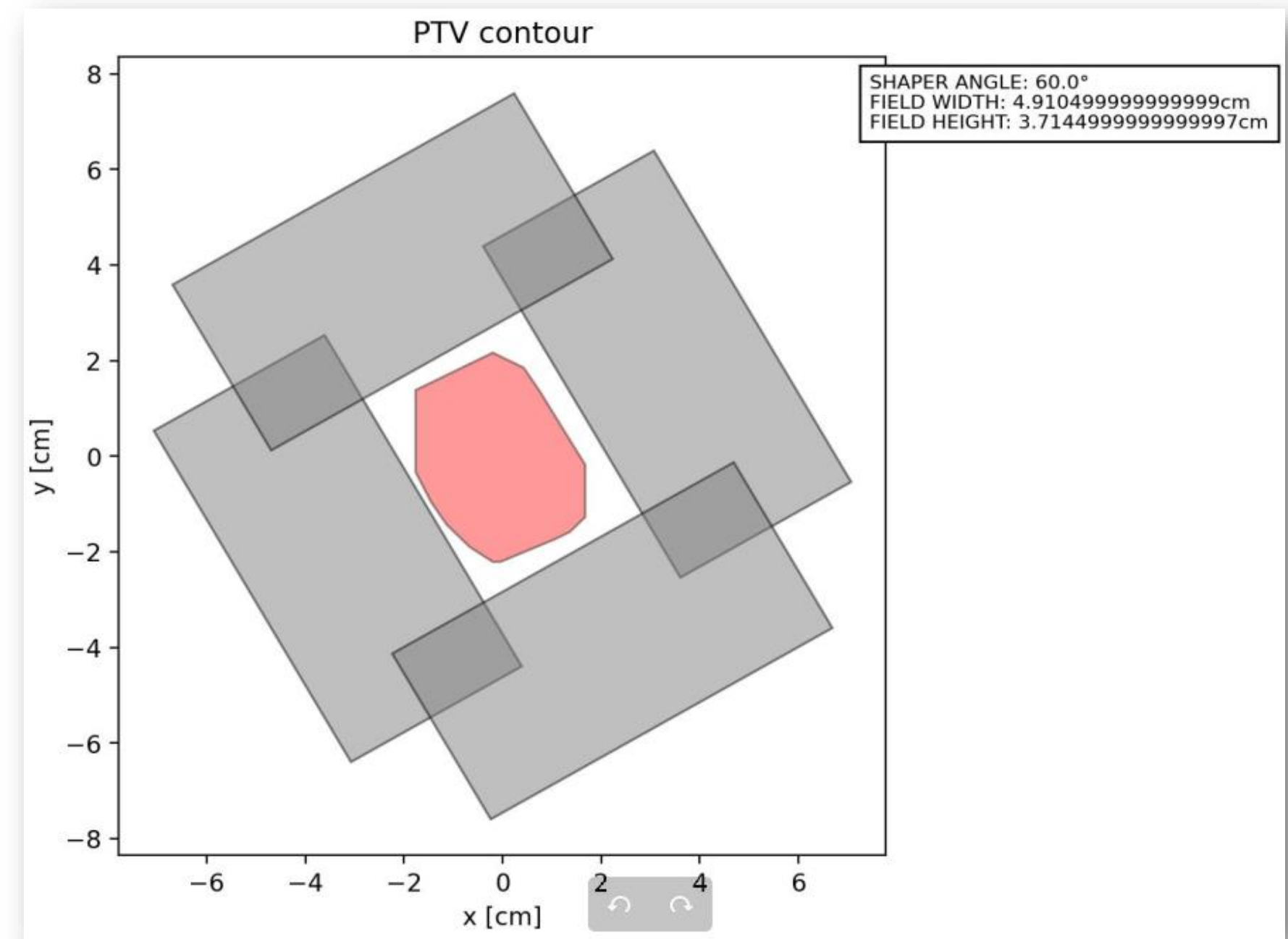
Chest skin cancer - 2 cm depth



Chest Patient



— PTV
 — MUSCOLO
 — TESSUTI_MOLLI



Best rectangle
 - Width: 4.27 cm
 - Height: 3.23 cm

Best angle:
 - 60°

Additional slits aperture 15%

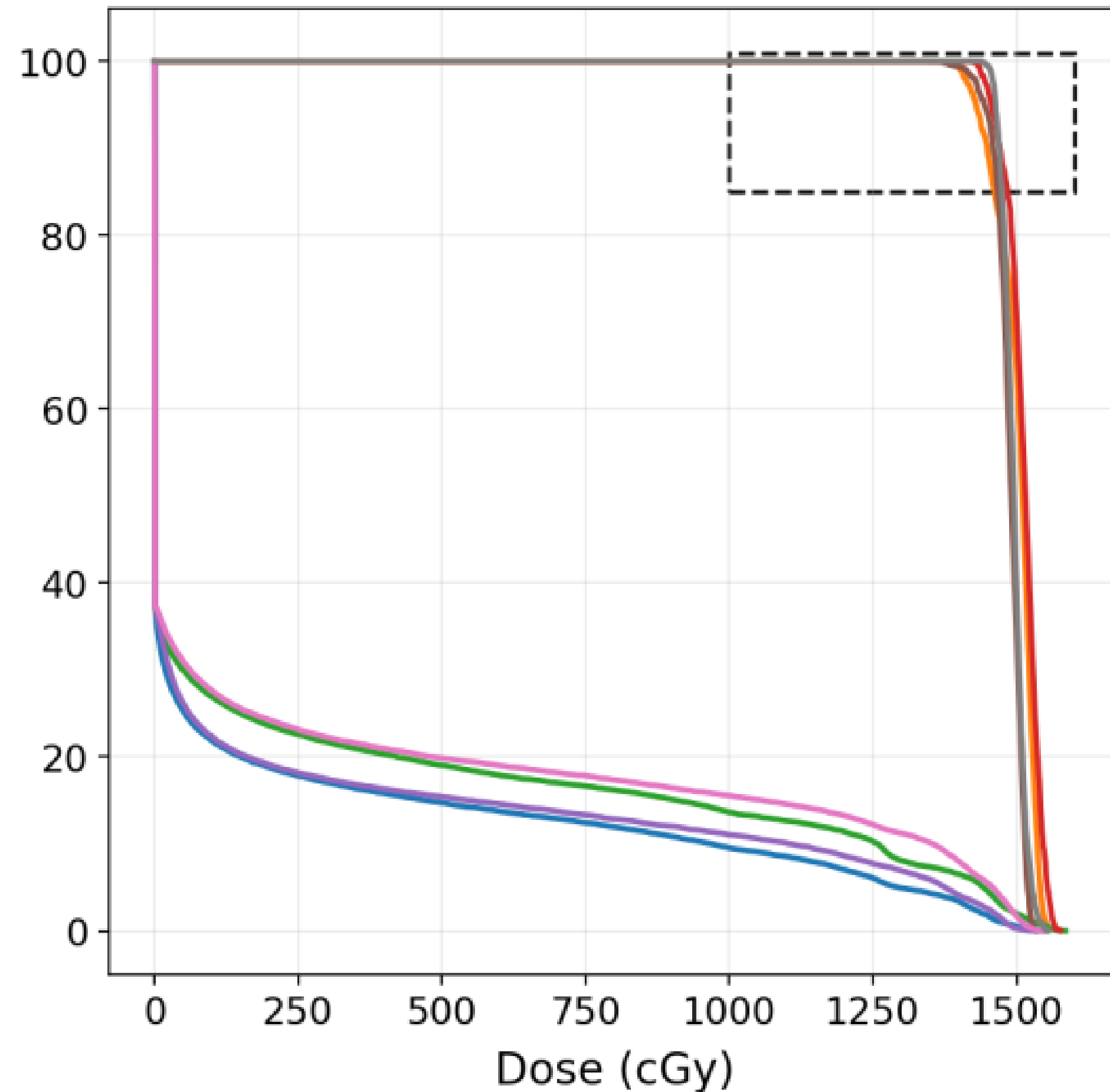
- Width: 4.91 cm
 - Height: 3.71 cm

Additional slits aperture 35%

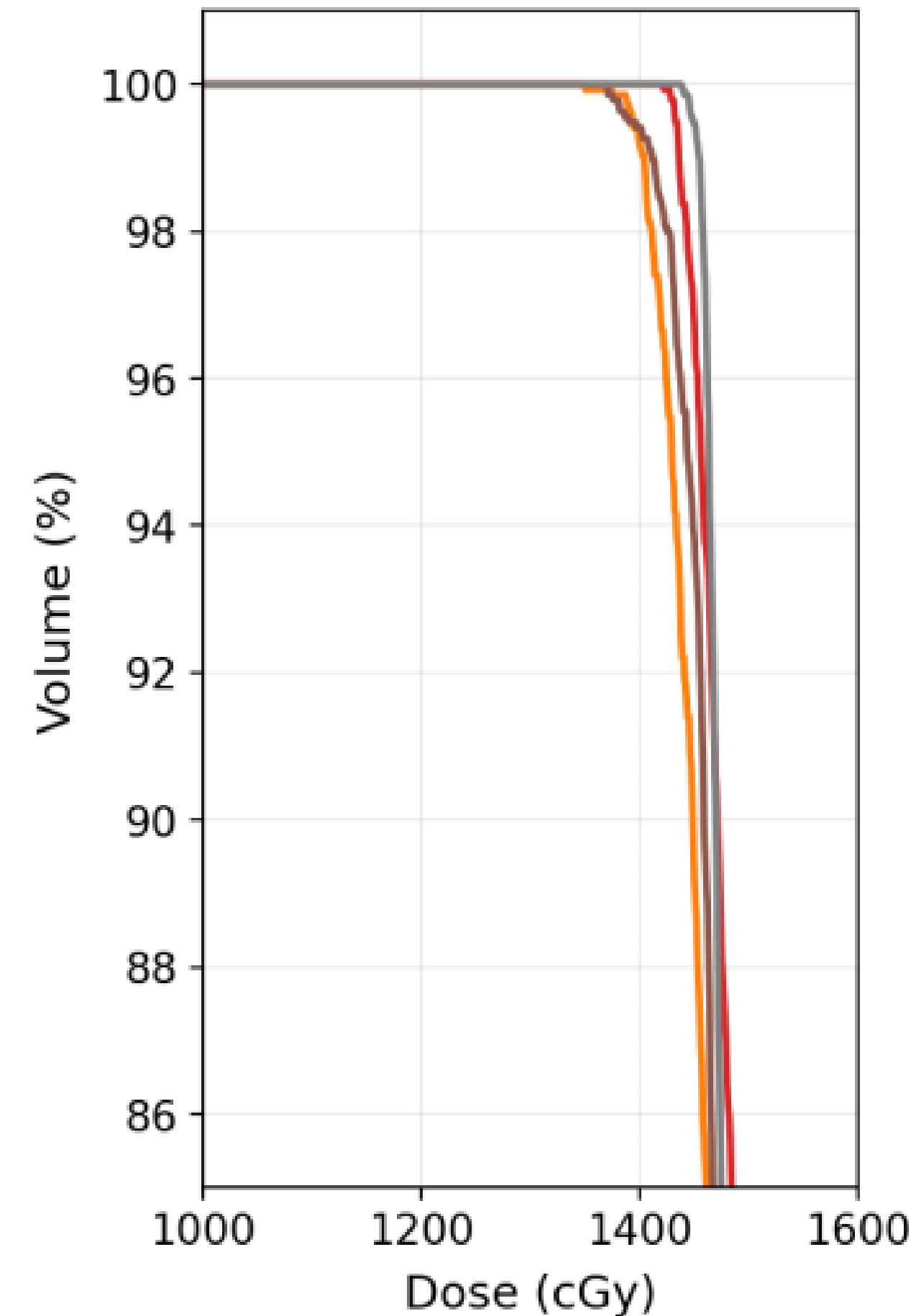
- Width: 5.76 cm
 - Height: 4.36 cm

DVH - PTV coverage

DVH PZ1_Torace

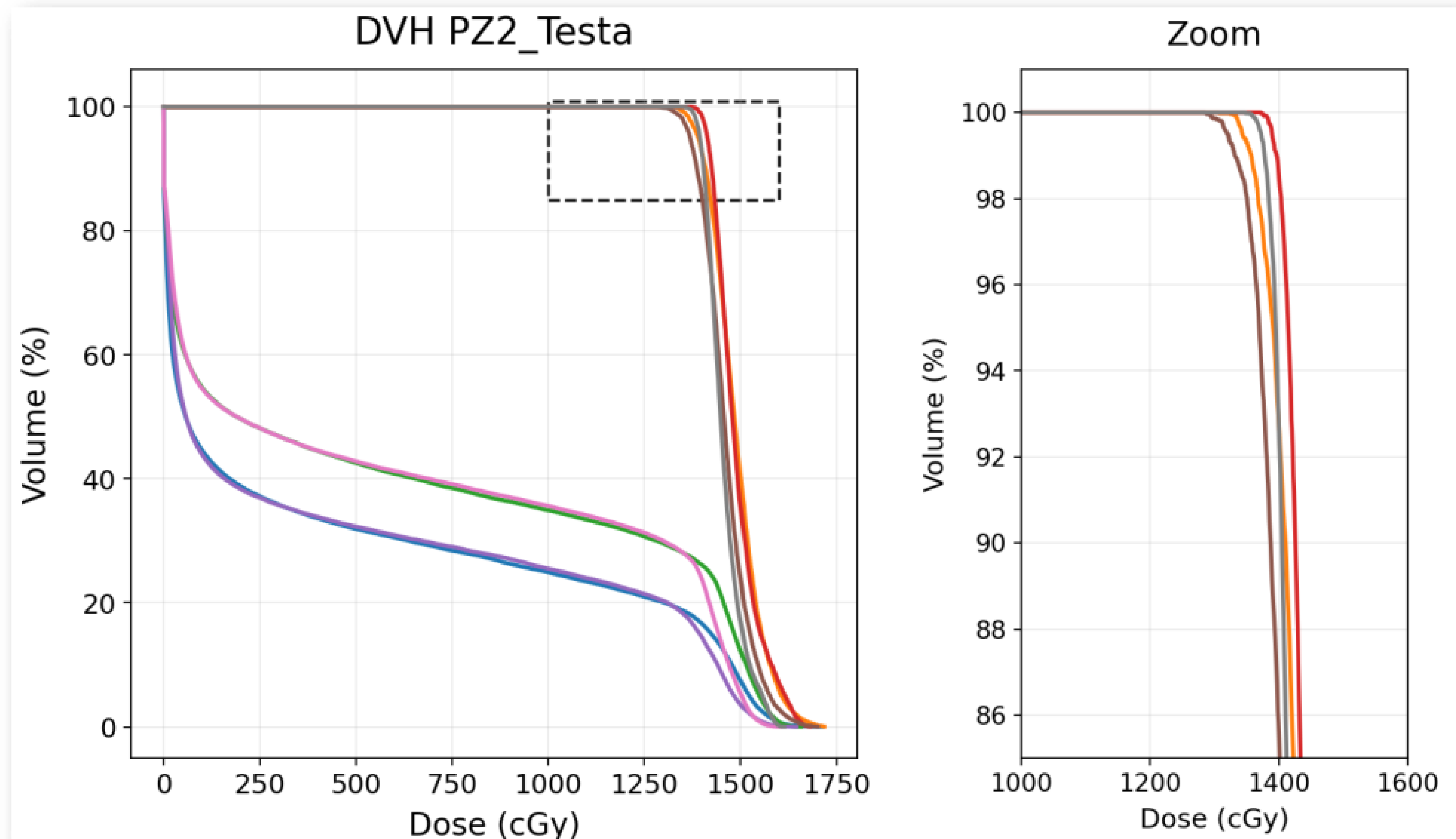


Zoom

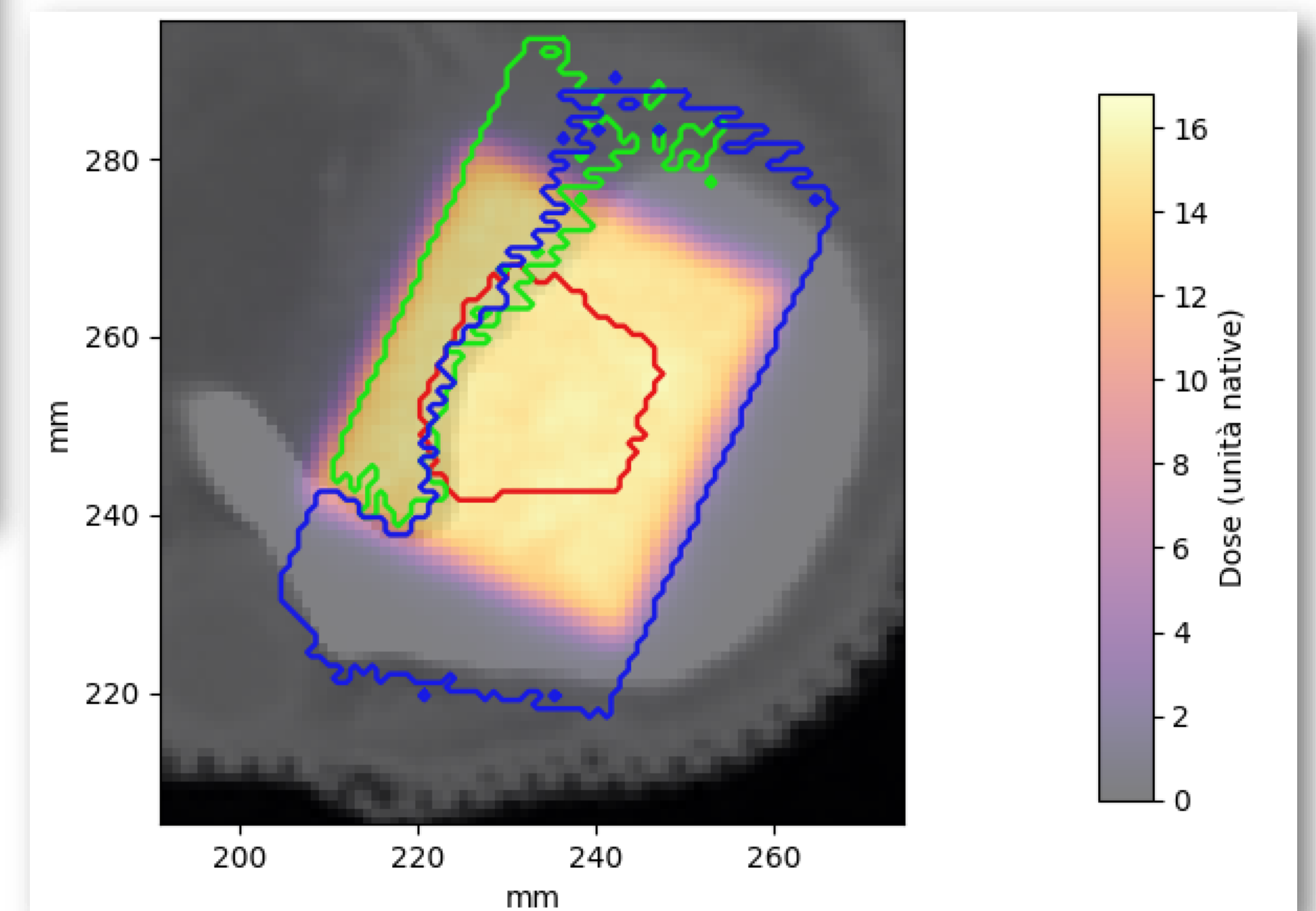


- Typically, the prescription is given in terms of dose delivered to a certain volume of the PTV; in this case we set an arbitrary number of pulses, proportional to the delivered dose.
- **PTV coverage improves as the field aperture increases.**
- The procedure does not include energy optimization, both 7 and 9 MeV are simulated.

DVH – OARs sparing



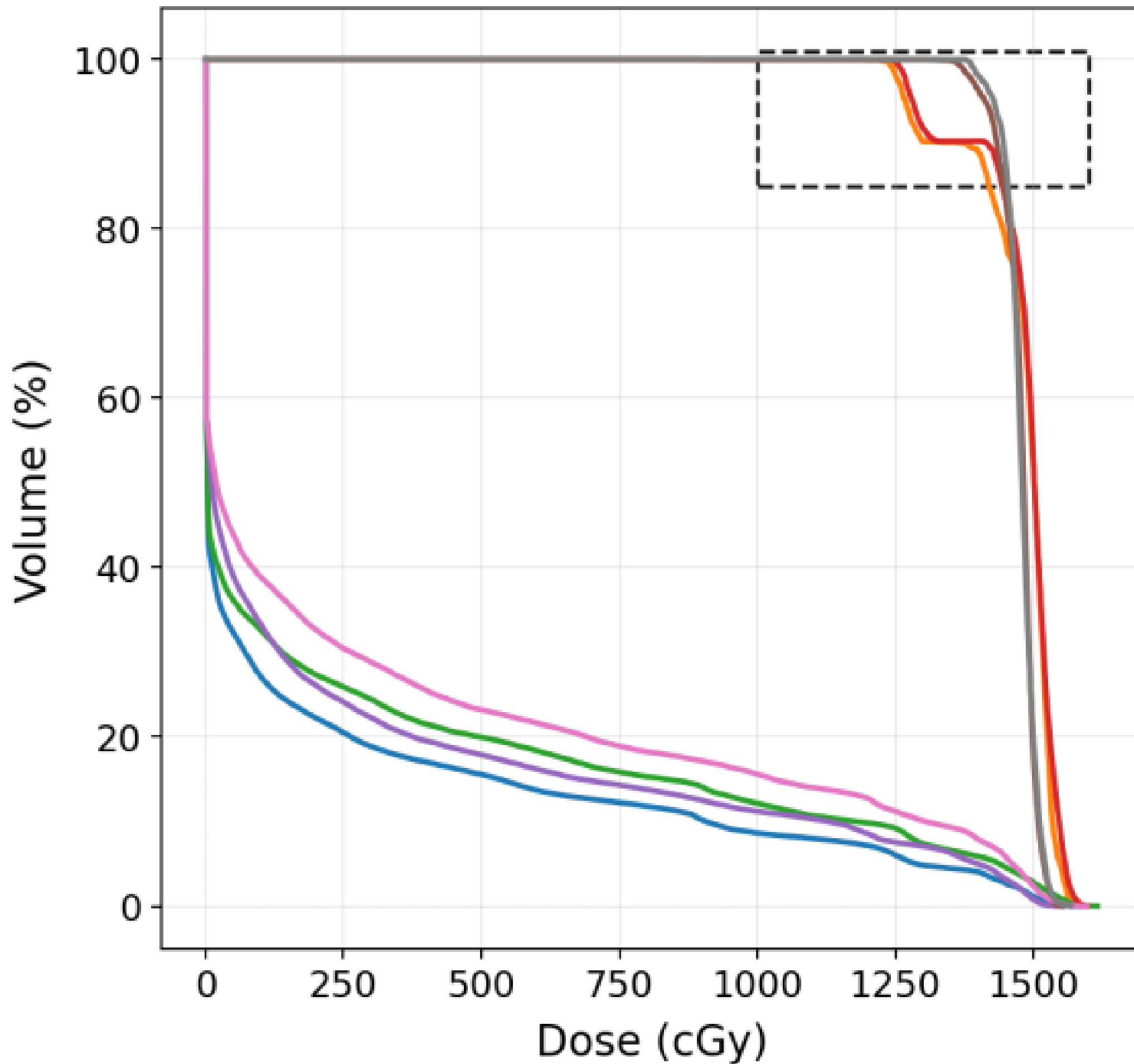
- DVH7MeV_15p/Osso_plan7MeV15p
- DVH7MeV_15p/PTV_plan7MeV15p
- DVH7MeV_35p/Osso_plan7MeV35p
- DVH7MeV_35p/PTV_plan7MeV35p
- DVH9MeV_15p/Osso_plan9MeV15p
- DVH9MeV_15p/PTV_plan9MeV15p
- DVH9MeV_35p/Osso_plan9MeV35p
- DVH9MeV_35p/PTV_plan9MeV35p



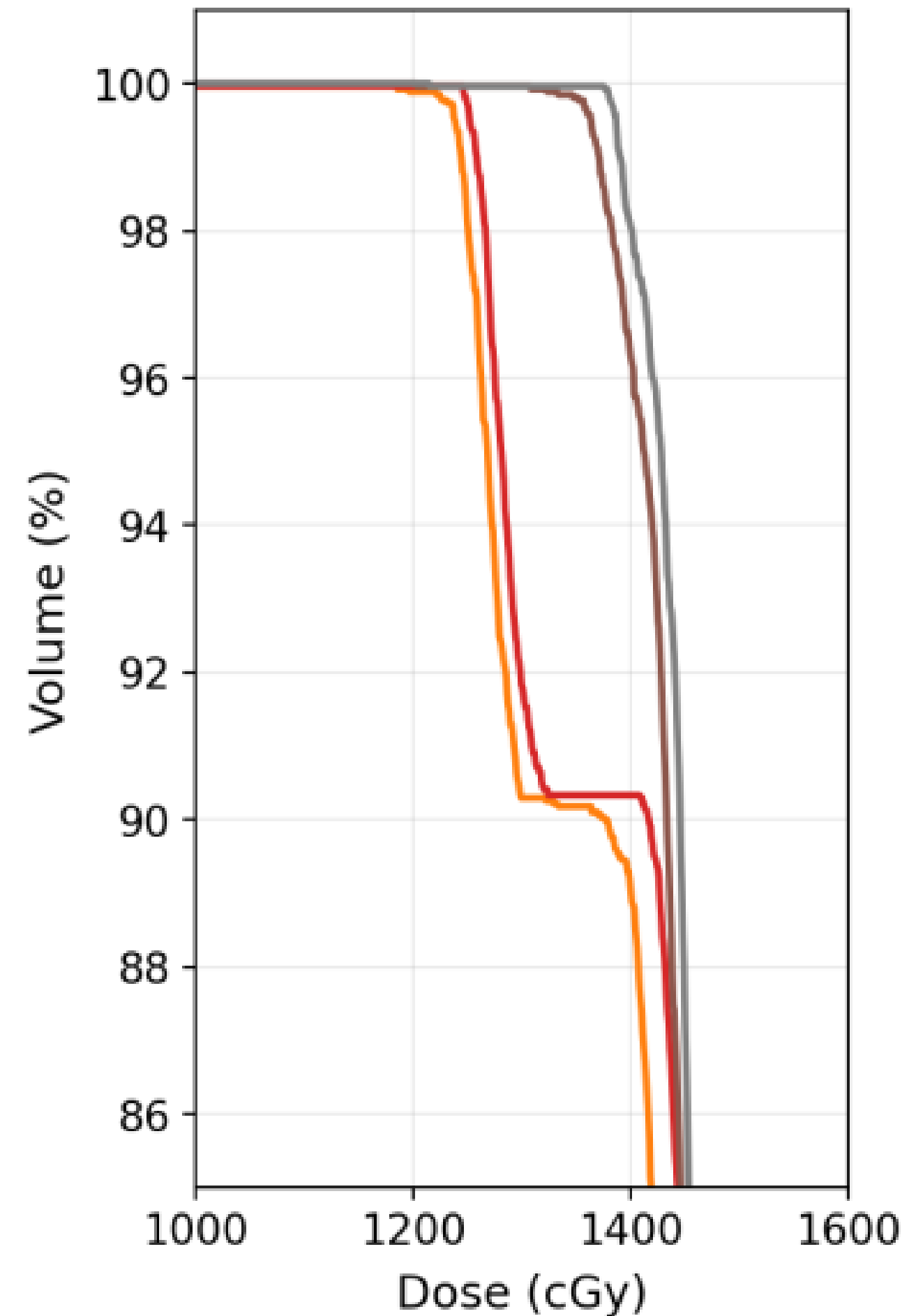
- **Dose delivered to OARs rises as the field aperture increases**
- According to the DVH, radiotherapist has the option to move the slits manually, in order to protect normal tissues.

Leg_ant_2 Patient

DVH PZ5_Gamba_ant_2_PTV1



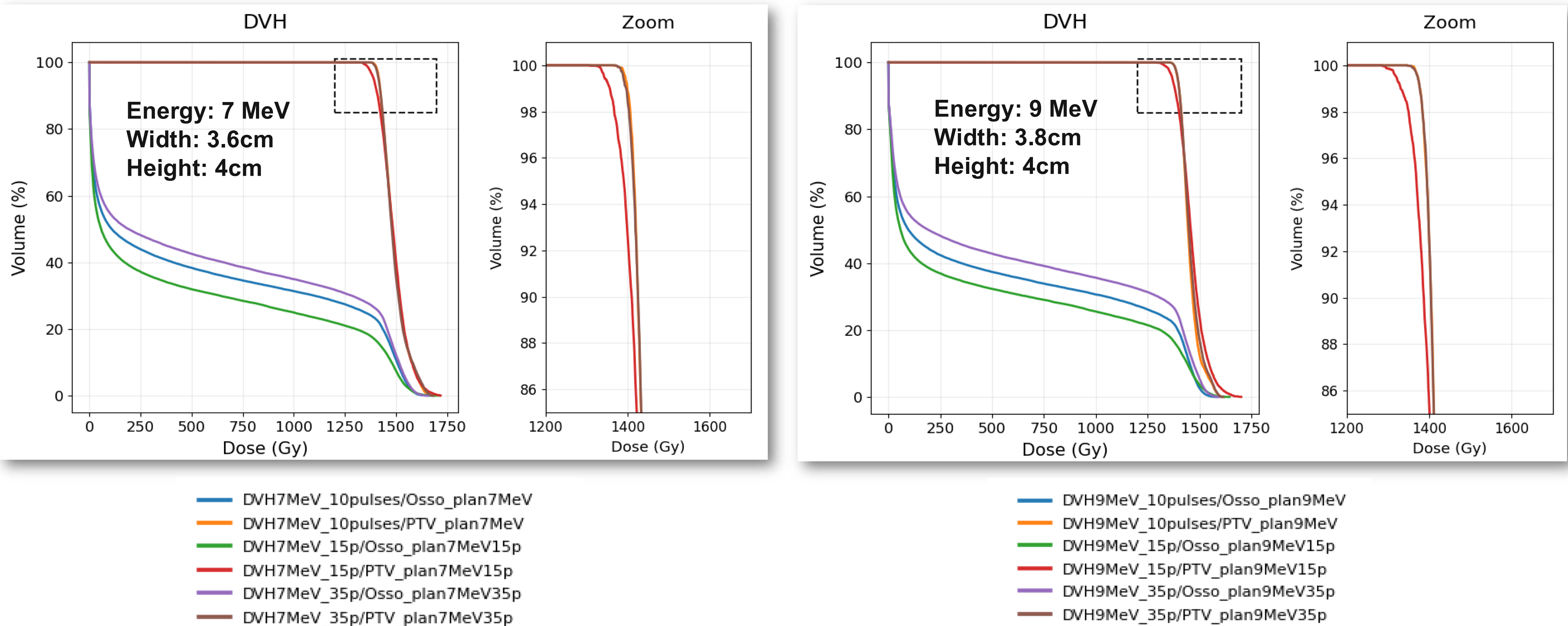
Zoom



- DVH7MeV_15p/Muscolo1_plan7MeV15p
- DVH7MeV_15p/PTV_plan7MeV15p
- DVH7MeV_35p/Muscolo1_plan7MeV35p
- DVH7MeV_35p/PTV_plan7MeV35p
- DVH9MeV_15p/Muscolo1_plan9MeV15p
- DVH9MeV_15p/PTV_plan9MeV15p
- DVH9MeV_35p/Muscolo1_plan9MeV35p
- DVH9MeV_35p/PTV_plan9MeV35p

Since the trasversal axis resolution is quite large (wrt PTV size), significant **differences between the two energies** can be appreciated. These differences might be attenuated resampling the CT map and hence the dose grid.

Automatic optimization



The procedure is able to perform the complete optimization automatically. The optimised field aperture is a bit smaller compared to the 35%-increased one and the DVH shows see that the it maintains the **same PTV coverage** but also **improving OARs sparing!**

Next steps

- The study of these six patients has been crucial to verify the proper functioning of the optimization procedure, although they represent cases that are not exactly the ones that will be treated during the clinical trial.
- An additional step will be to counter-rotate the dose map from the beam-eye view to the standard clinical reference system and overlay it onto the original CT orientation.
- It will be crucial to successfully validate this procedure under the same conditions required during the trial in terms of data structures and dose prescription.

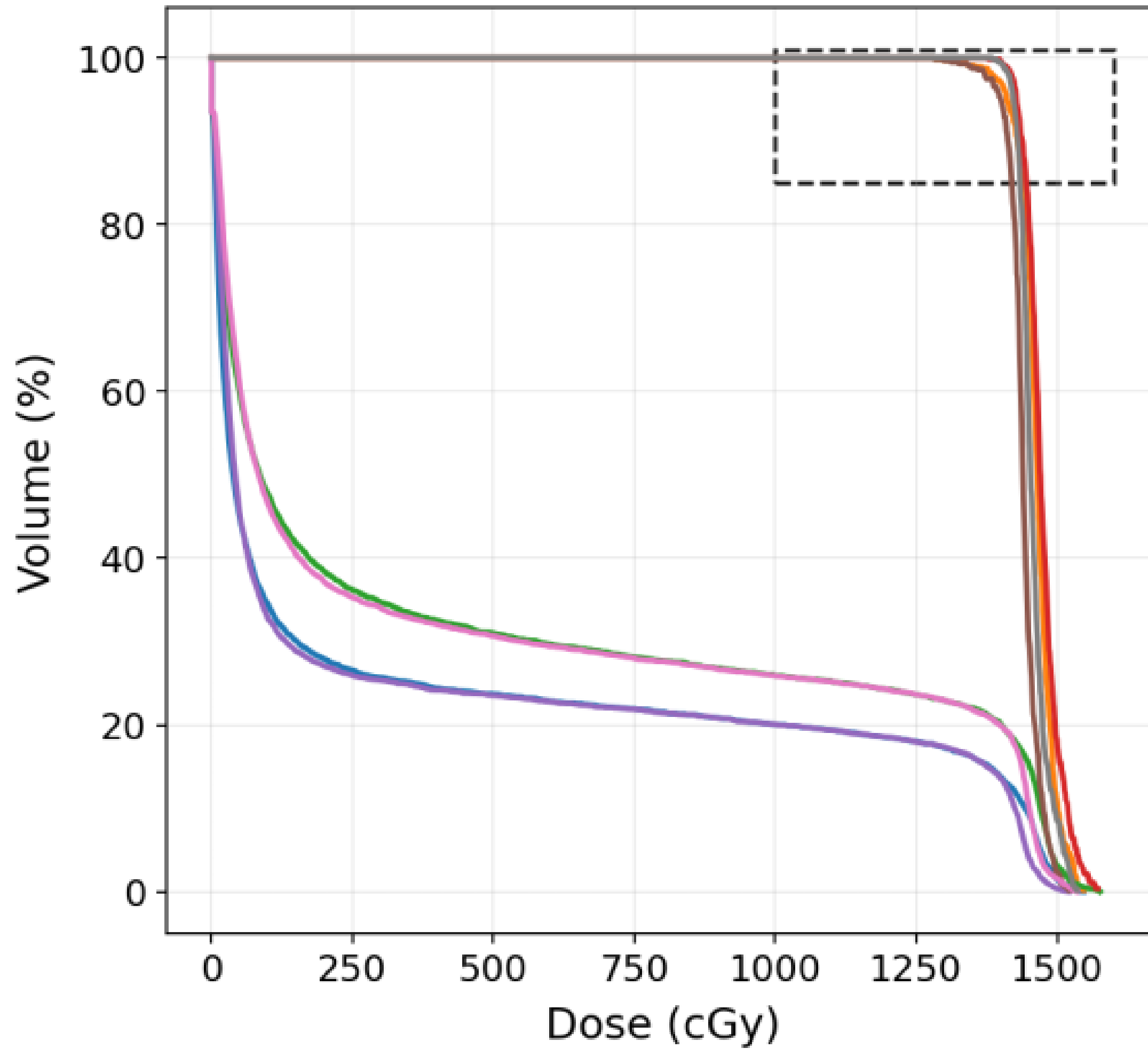




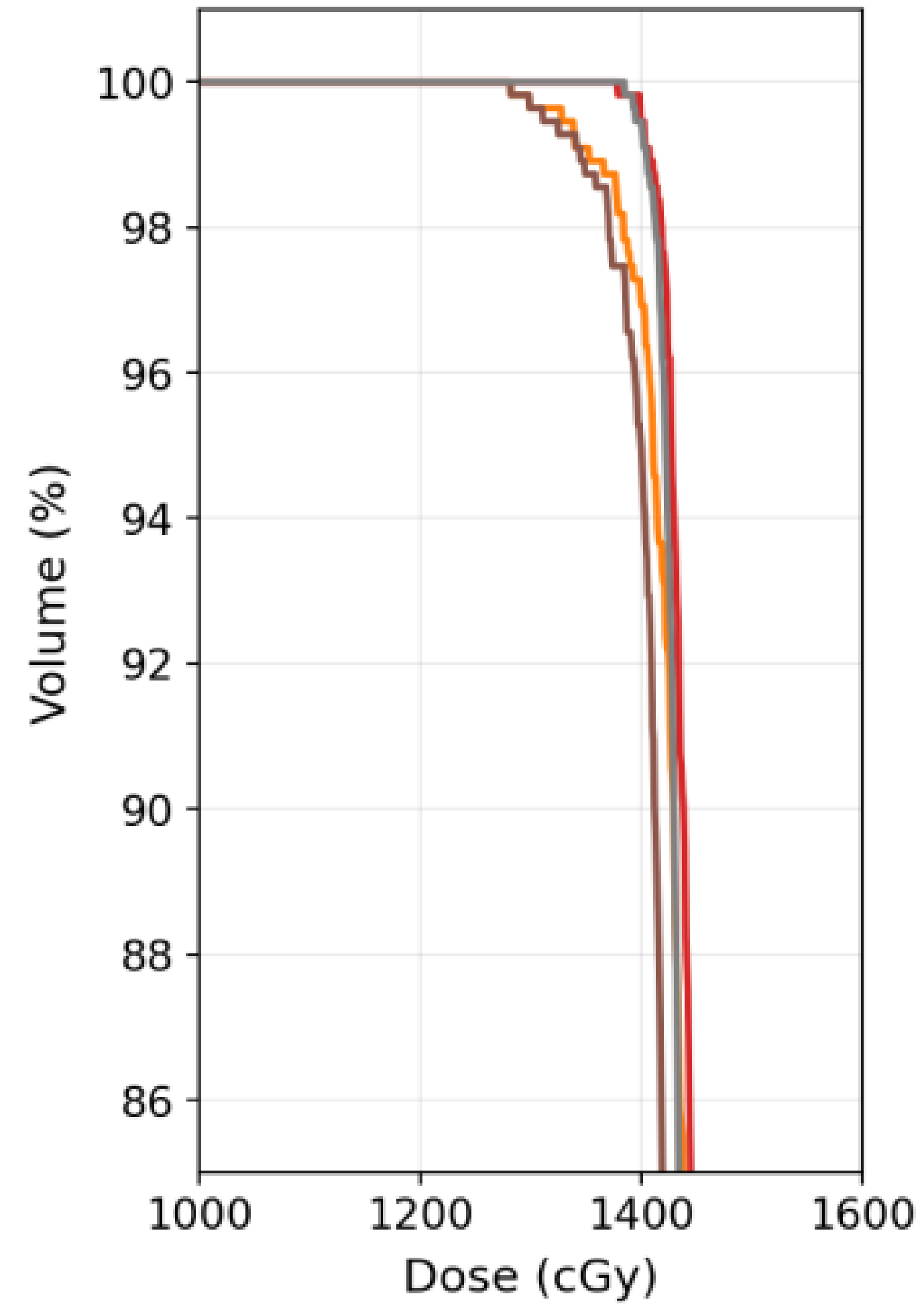
03/02/2026

DVH - Arm Patient (7MeV - 9MeV)

DVH PZ3_Braccio



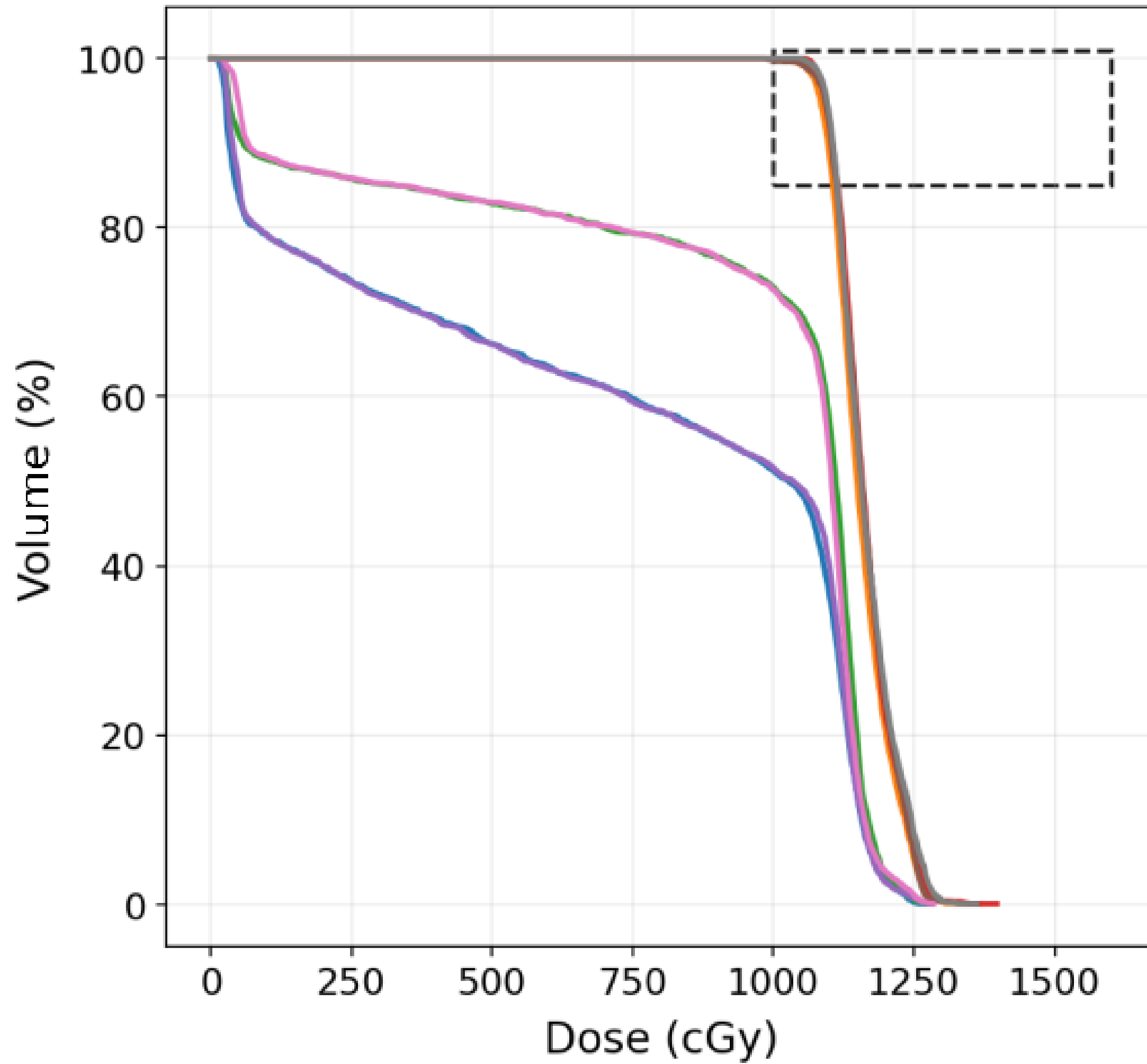
Zoom



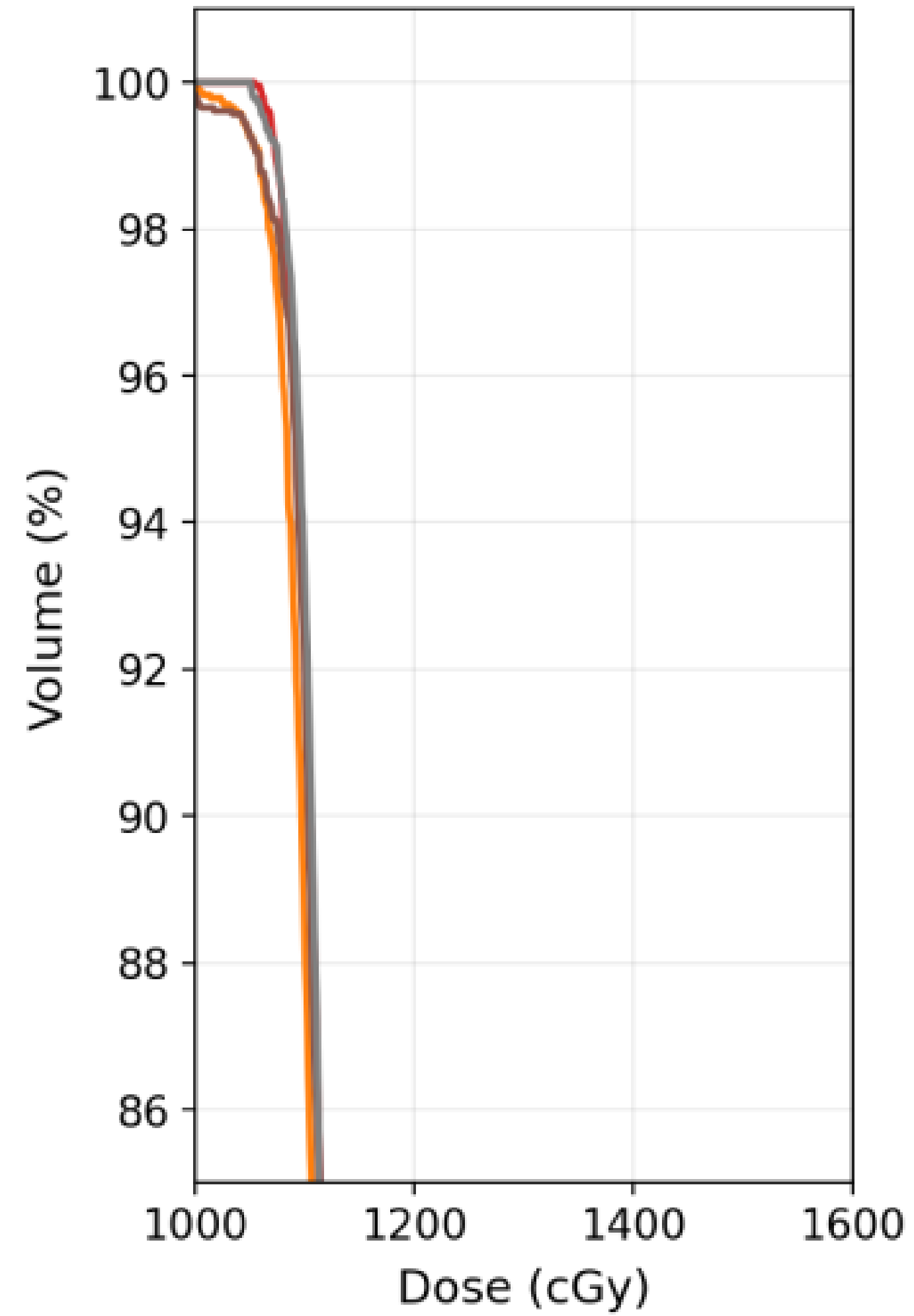
- DVH7MeV_15p/Muscolo2_plan7MeV15p
- DVH7MeV_15p/PTV_plan7MeV15p
- DVH7MeV_35p/Muscolo2_plan7MeV35p
- DVH7MeV_35p/PTV_plan7MeV35p
- DVH9MeV_15p/Muscolo2_plan9MeV15p
- DVH9MeV_15p/PTV_plan9MeV15p
- DVH9MeV_35p/Muscolo2_plan9MeV35p
- DVH9MeV_35p/PTV_plan9MeV35p

DVH - Leg Patient (7MeV - 9MeV)

DVH PZ4_Gamba



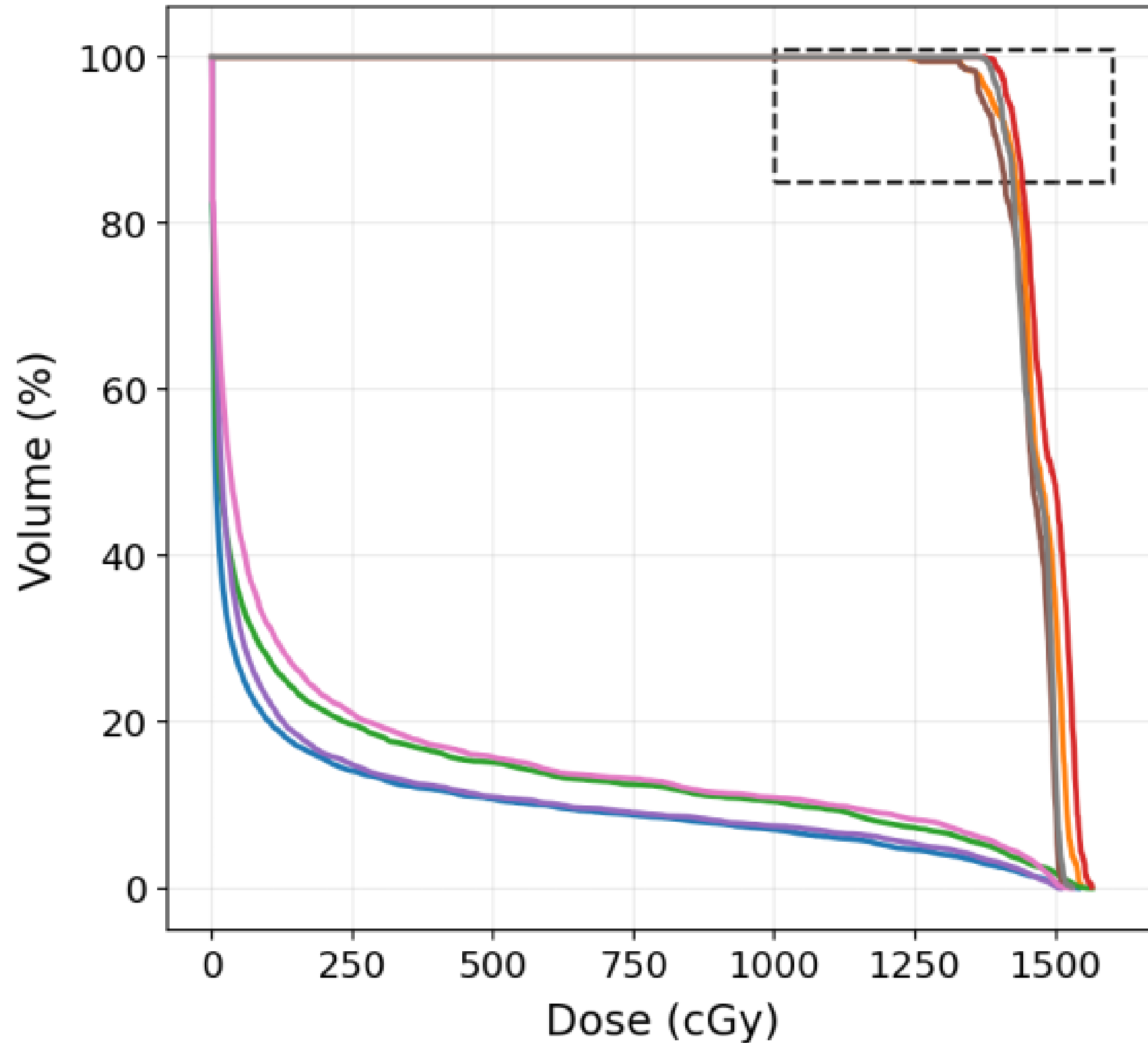
Zoom



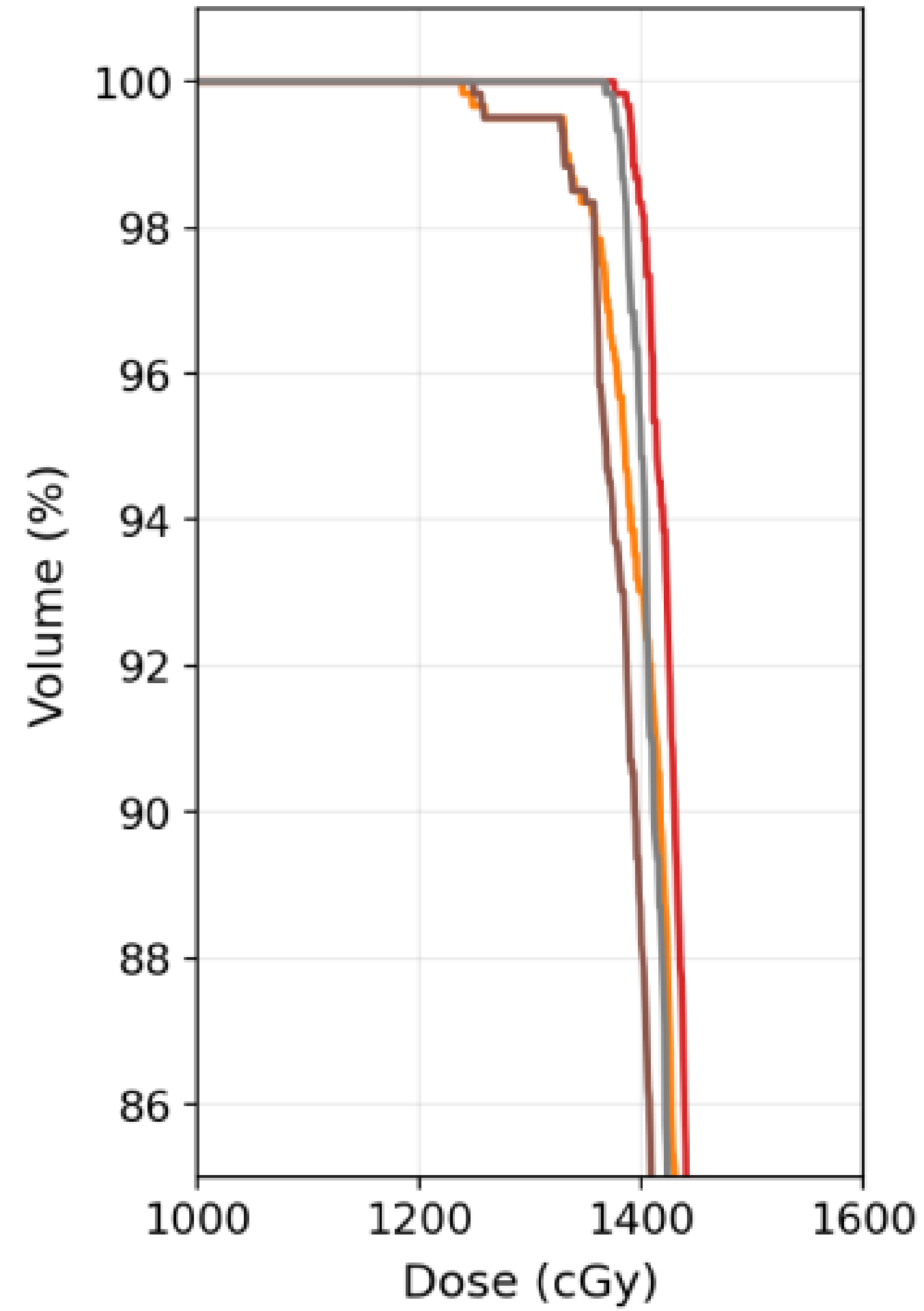
- DVH7MeV_15p/Muscolo_plan7MeV15p
- DVH7MeV_15p/PTV_plan7MeV15p
- DVH7MeV_35p/Muscolo_plan7MeV35p
- DVH7MeV_35p/PTV_plan7MeV35p
- DVH9MeV_15p/Muscolo_plan9MeV15p
- DVH9MeV_15p/PTV_plan9MeV15p
- DVH9MeV_35p/Muscolo_plan9MeV35p
- DVH9MeV_35p/PTV_plan9MeV35p

DVH tot (Leg_ant_2 Patient) (PTV2) (7MeV - 9MeV)

DVH PZ5_Gamba_ant_2_PTV2



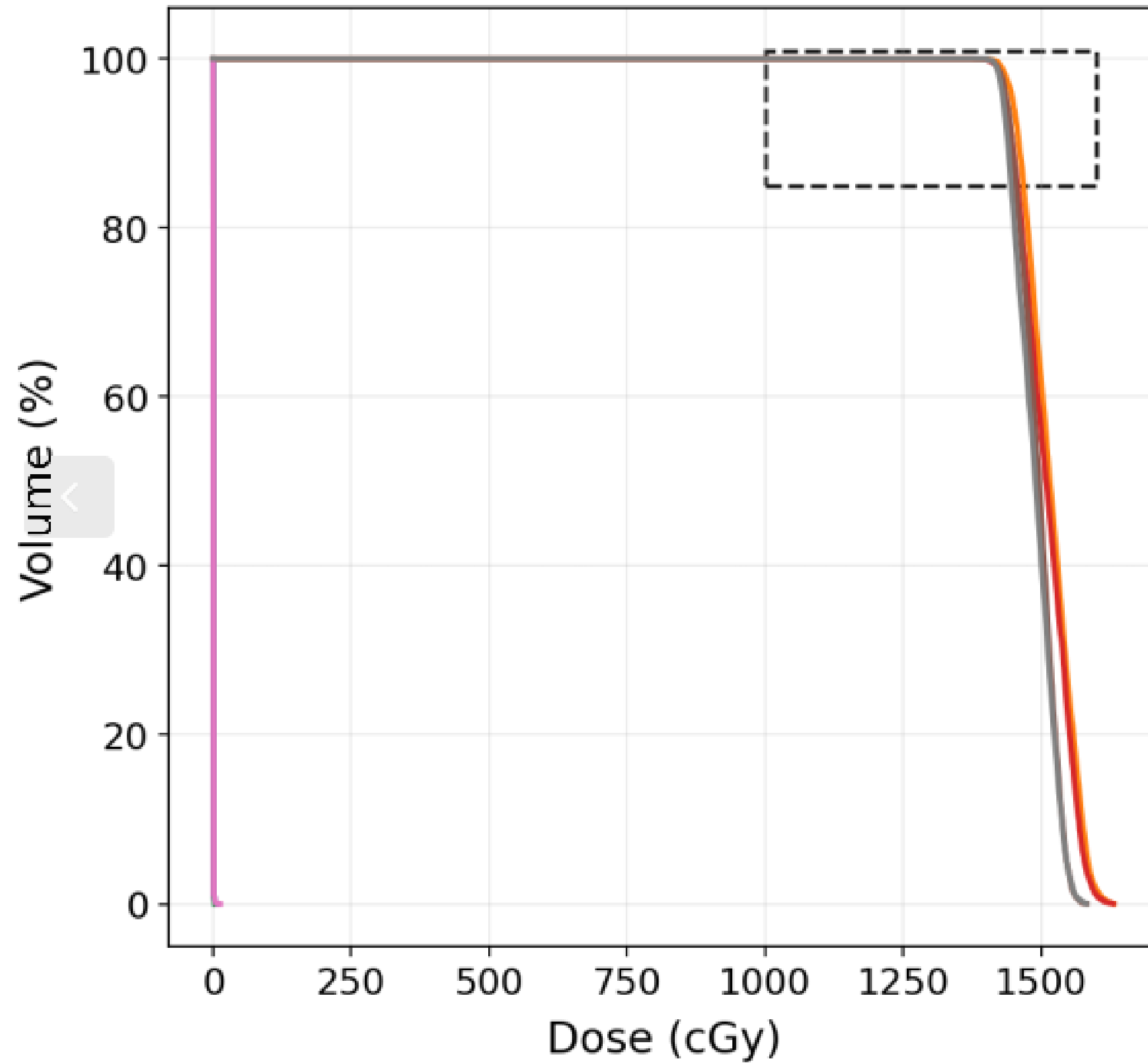
Zoom



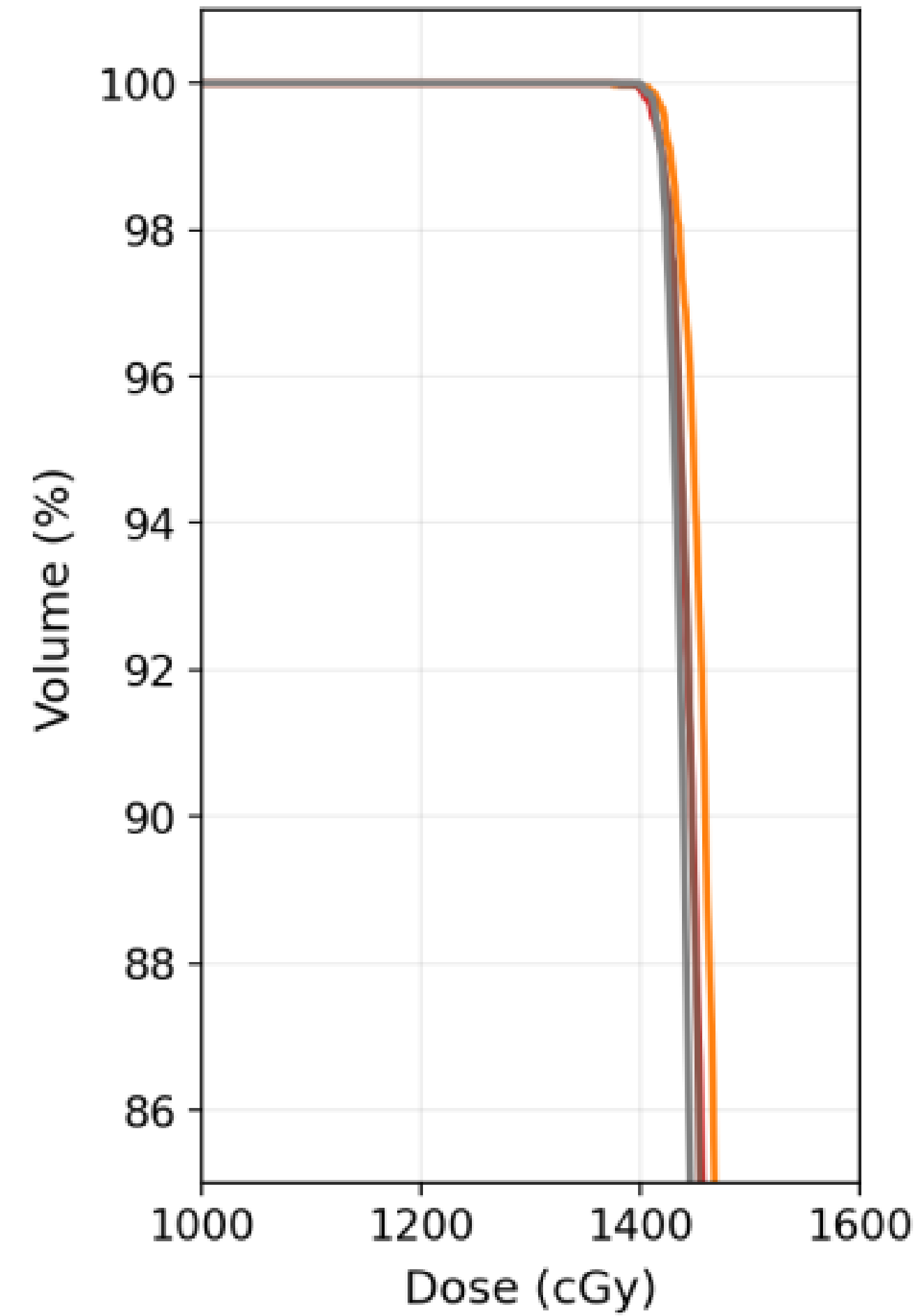
- DVH7MeV_15p/Muscolo2_plan7MeV15p
- DVH7MeV_15p/PTV_plan7MeV15p
- DVH7MeV_35p/Muscolo2_plan7MeV35p
- DVH7MeV_35p/PTV_plan7MeV35p
- DVH9MeV_15p/Muscolo2_plan9MeV15p
- DVH9MeV_15p/PTV_plan9MeV15p
- DVH9MeV_35p/Muscolo2_plan9MeV35p
- DVH9MeV_35p/PTV_plan9MeV35p

DVH tot (Gluteus Patient) (7MeV - 9MeV)

DVH PZ6_Gluteo



Zoom



- DVH7MeV_15p/Muscolo_plan7MeV15p
- DVH7MeV_15p/PTV_plan7MeV15p
- DVH7MeV_35p/Muscolo_plan7MeV35p
- DVH7MeV_35p/PTV_plan7MeV35p
- DVH9MeV_15p/Muscolo_plan9MeV15p
- DVH9MeV_15p/PTV_plan9MeV15p
- DVH9MeV_35p/Muscolo_plan9MeV35p
- DVH9MeV_35p/PTV_plan9MeV35p

Arm Patient

