WP4: IORT-FLASH PLANNING

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Our challenge

The Intra Operative Radio Therapy with electron (IOeRT) is a technique that, after the surgical tumor removal, delivers a dose of ionizing radiation (4-12 MeV) directly to the surgery bed. The typical prescribed dose is of few Gy, e.g. 20/21 Gy for the breast cancer treatment, delivered in ~ 1 minute (mean dose rate ~ 0.5 Gy/s).

Today the use of mono-energetic high intensity pulses of electrons makes IORT the current best candidate for the first implementation of the **FLASH effect** into the clinic.

The S.I.T company has already installed **3 IORT-FLASH accelerator** (Anversa, Orsay and Pavia soon) able to achieve mean dose rate > 100 Gy/s

To explore the IORT-FLASH potential, a TPS will be necessary. **To give a reasonable feedback to the operator we need to be capable to 'optimize' the treatment!**

IORT planning

Timing is an issue

1. **Quick imaging** after surgery;

2. **Quick planning:** an help for the radio-therapist to choose the position, angle of the applicator and beam energy and # electrons to deliver perceived dose, to ensure a proper OARs sparing

IORT planning

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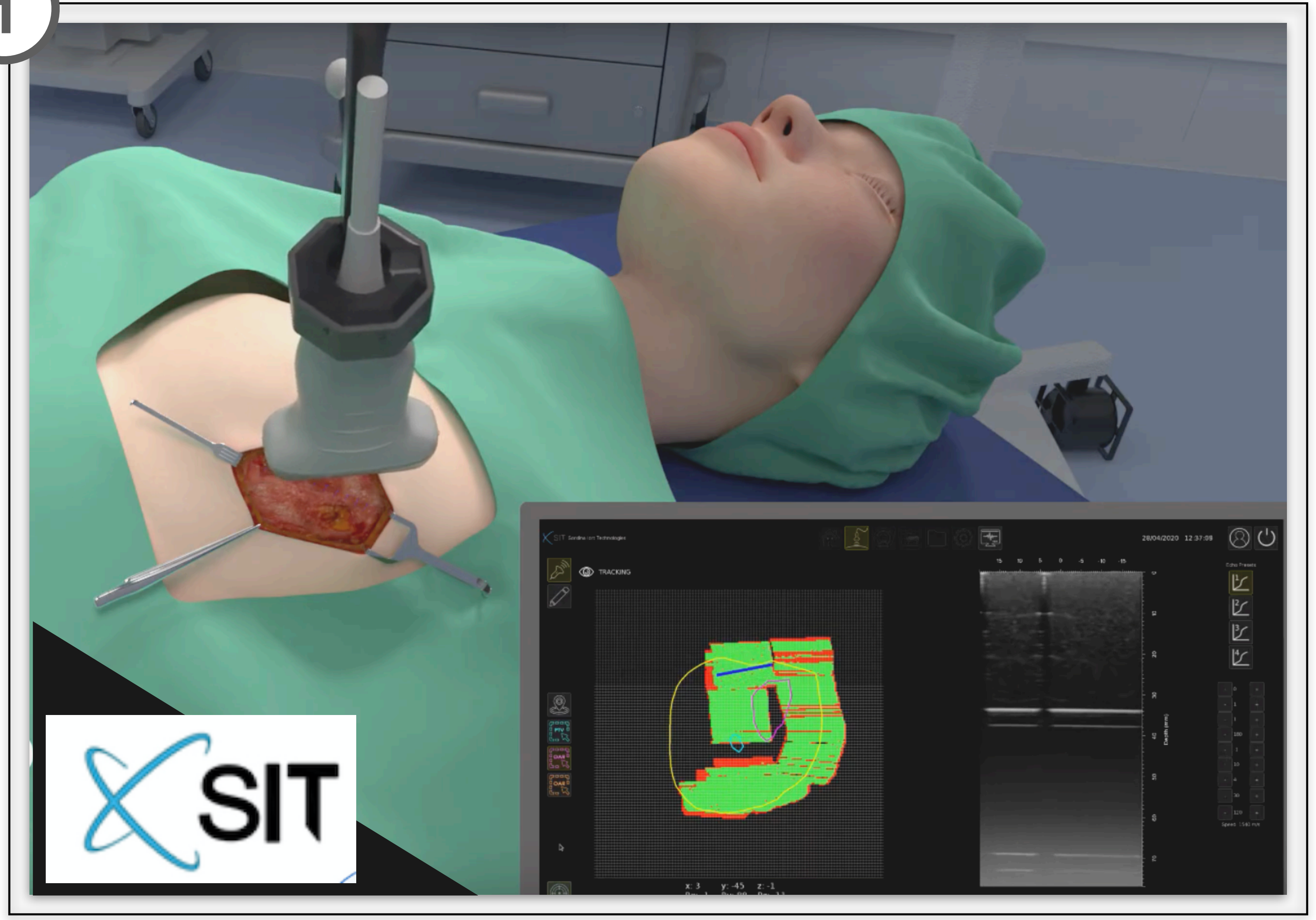
1

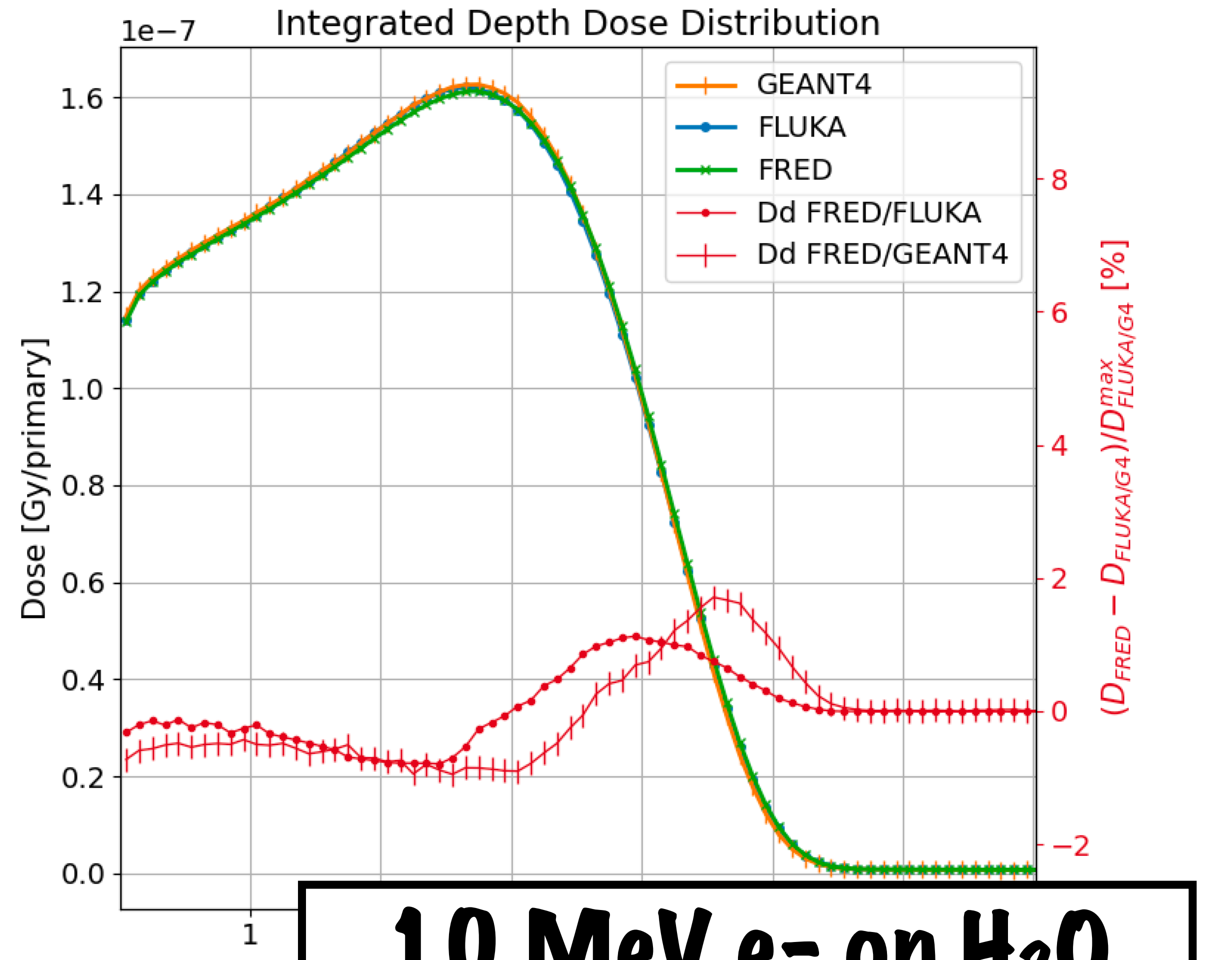


The SIT company (Aprilia, Italy) is exploiting a new **3D real-time echographic** imaging acquisition with limited precision (capable of discriminating only significant differences in density - air, water, metal)

2

A full MC is needed and the GPU architecture can be exploited to speed up the planning : **FRED MC**

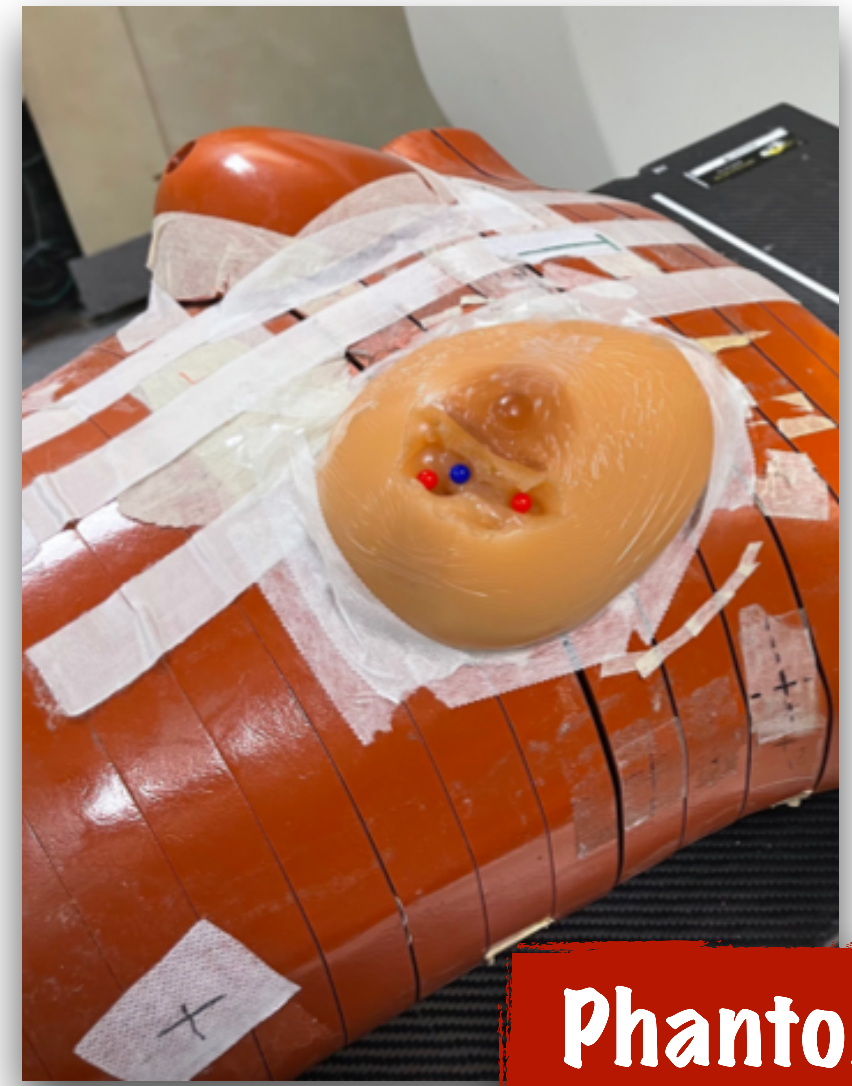
Timing Performance	FLUKA	FRED
e⁻ @ 1 MeV	5e3 prim/s	2e6 prim/s
e⁻ @ 10 MeV	1e3 prim/s	1.5e5 prim/s
e⁻ @ 100 MeV	4e2 prim/s	1.3e4 prim/s



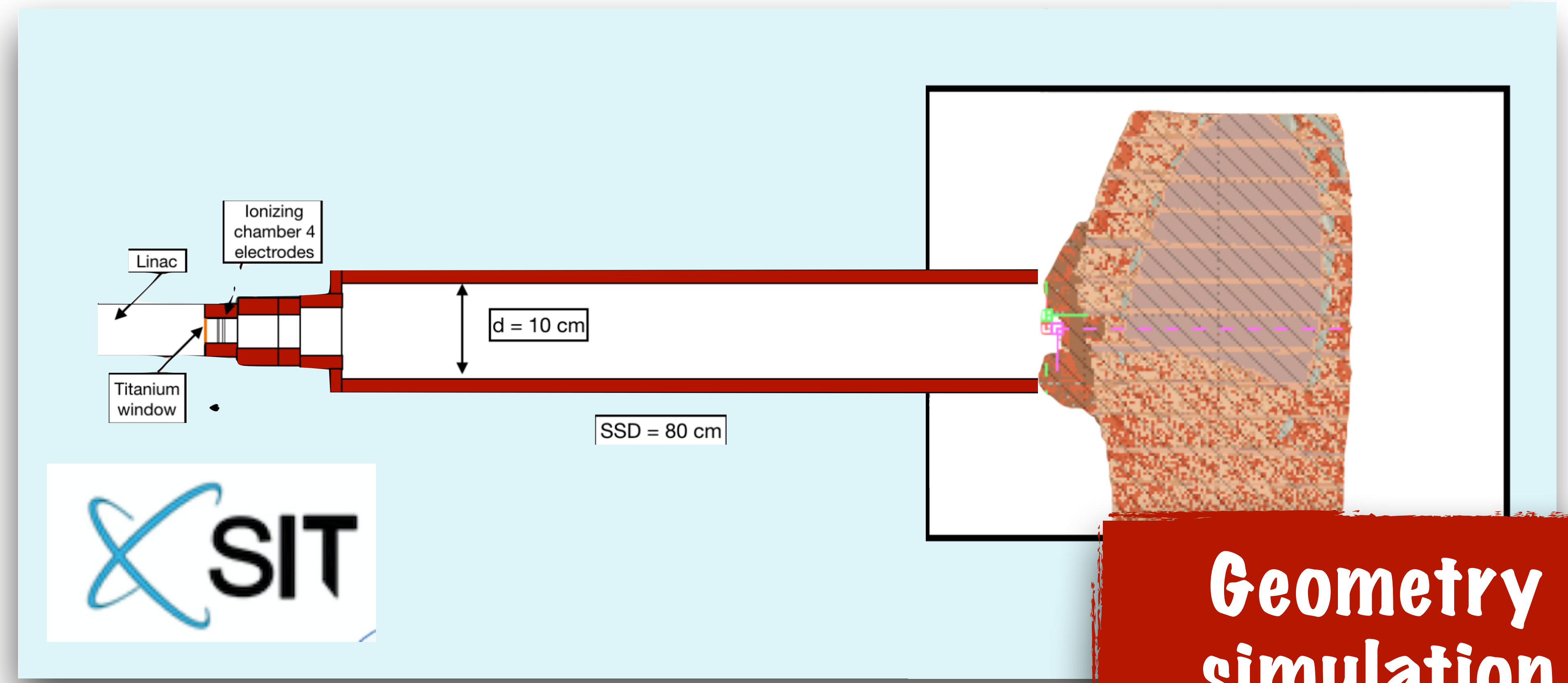
10 MeV e- on H_2O

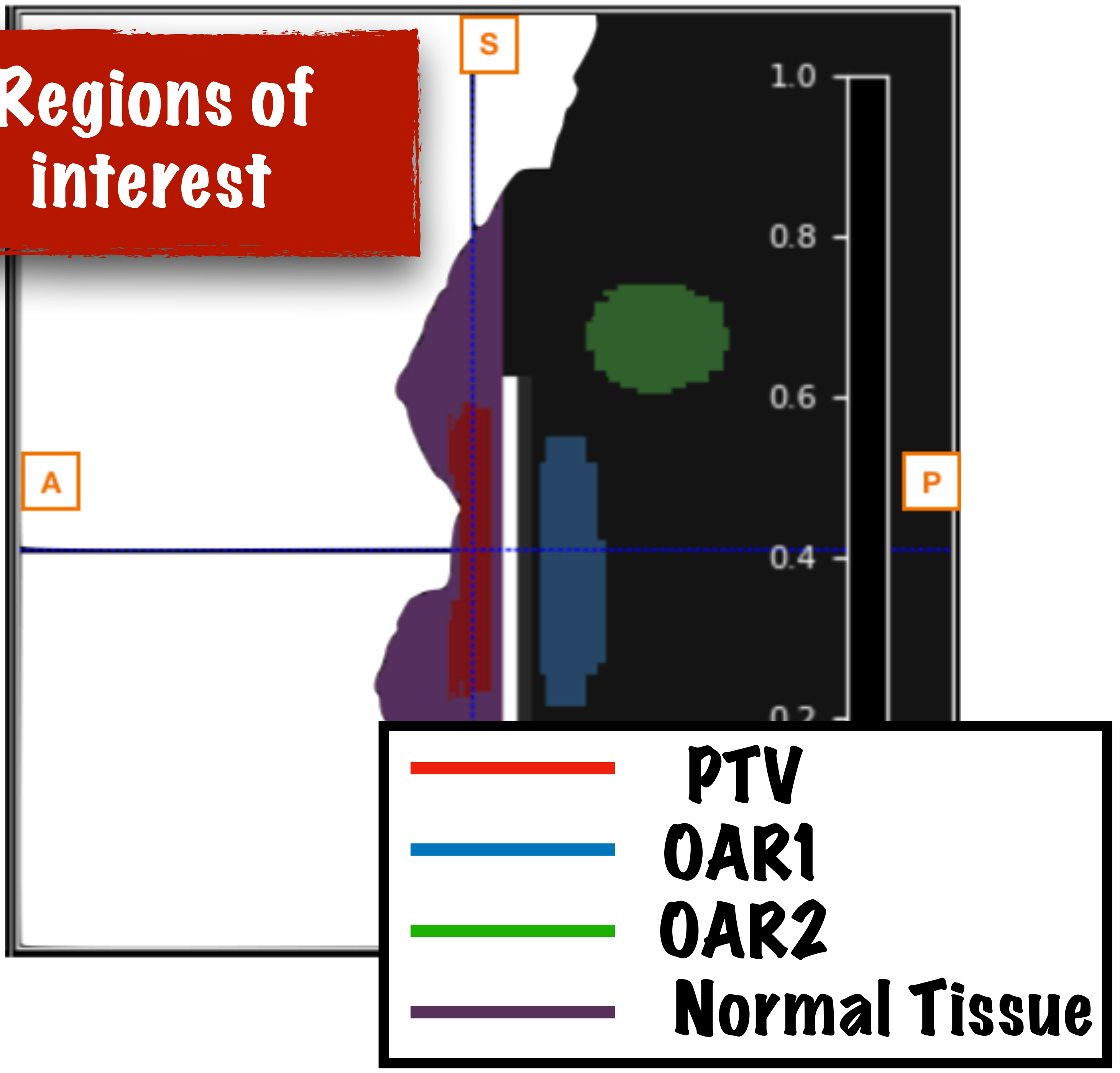
Breast cancer TPS

For the breast IORT treatment, we have used a CT of a phantom with a **breast prosthesis** used to simulate a breast surgery attached onto it and we have reproduced in detail the applicator structure of the NOVAC 11 accelerator, produced by the SIT company.



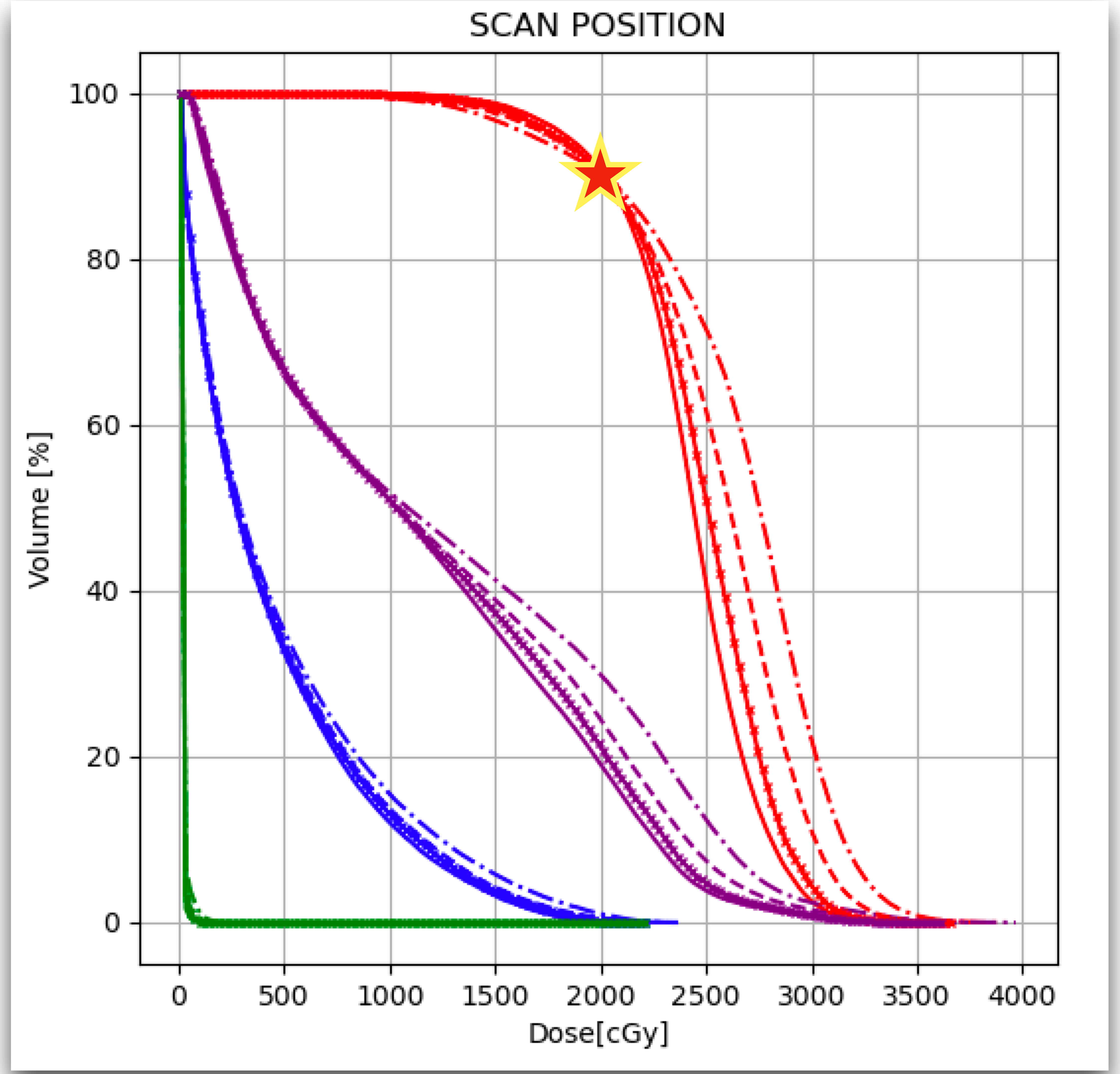
CT

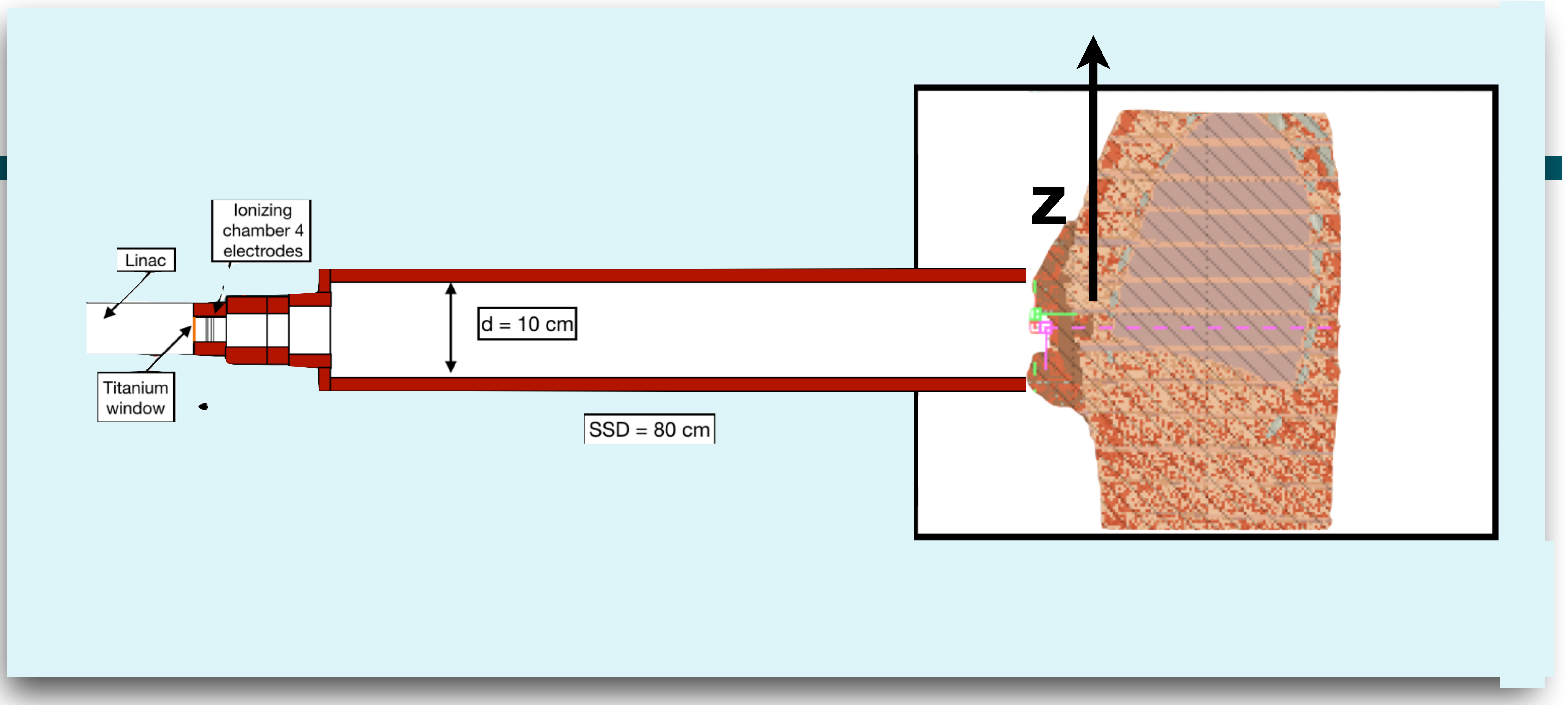




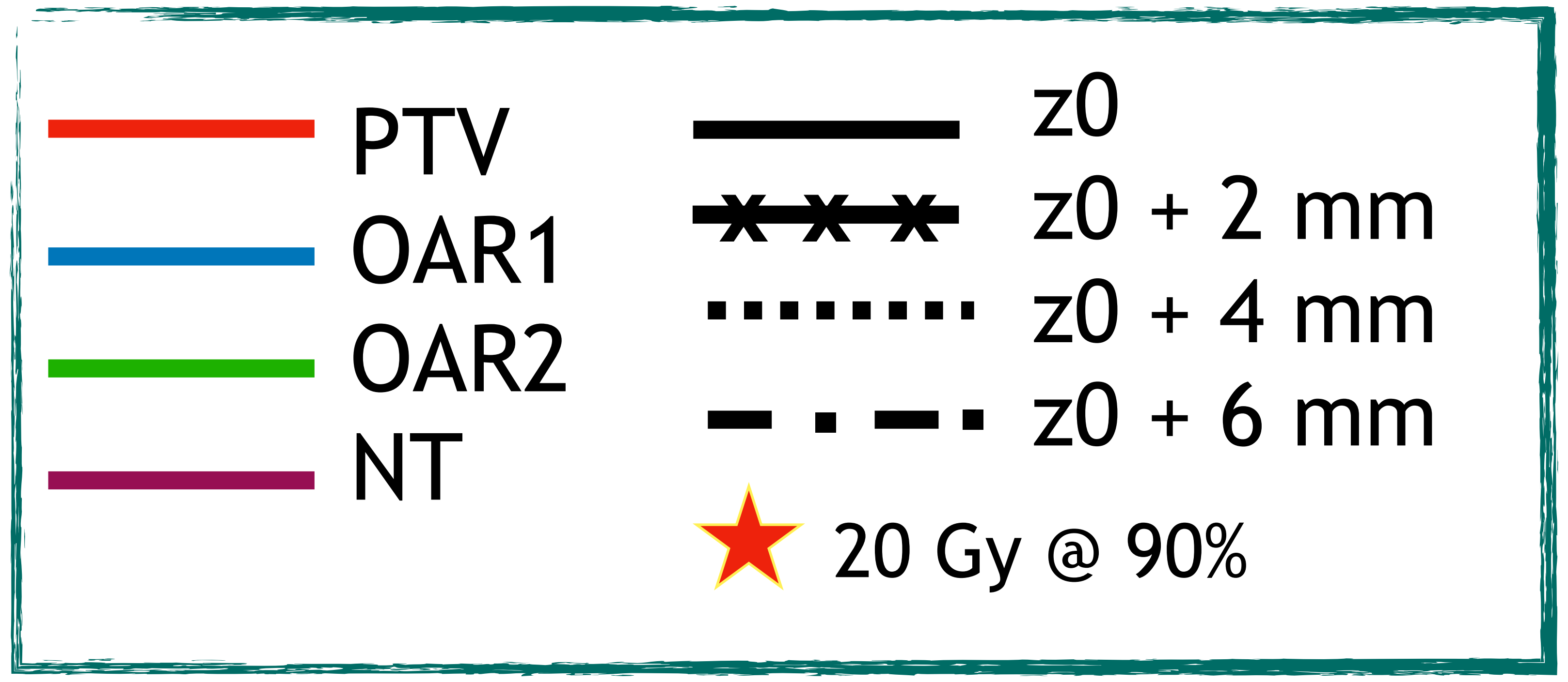
- We have inserted the **radioprotection disk**;
- We have identified a reasonable **PTV** (d ~ 6÷7 cm, 1 cm thick), two **OARs** and the **normal tissue**.
- For the optimization studies: we have shot **10^6 electrons** (several orders of magnitude below a full treatment), of different energies and with different applicator geometries and we have analysed the **resulting Dose Volume Histograms (DVHs)**.

Results: Position scan





With an 8 MeV electrons beam and a d=70 mm applicator, we have performed a position scan, moving the applicator with 2 mm steps along the z-axis



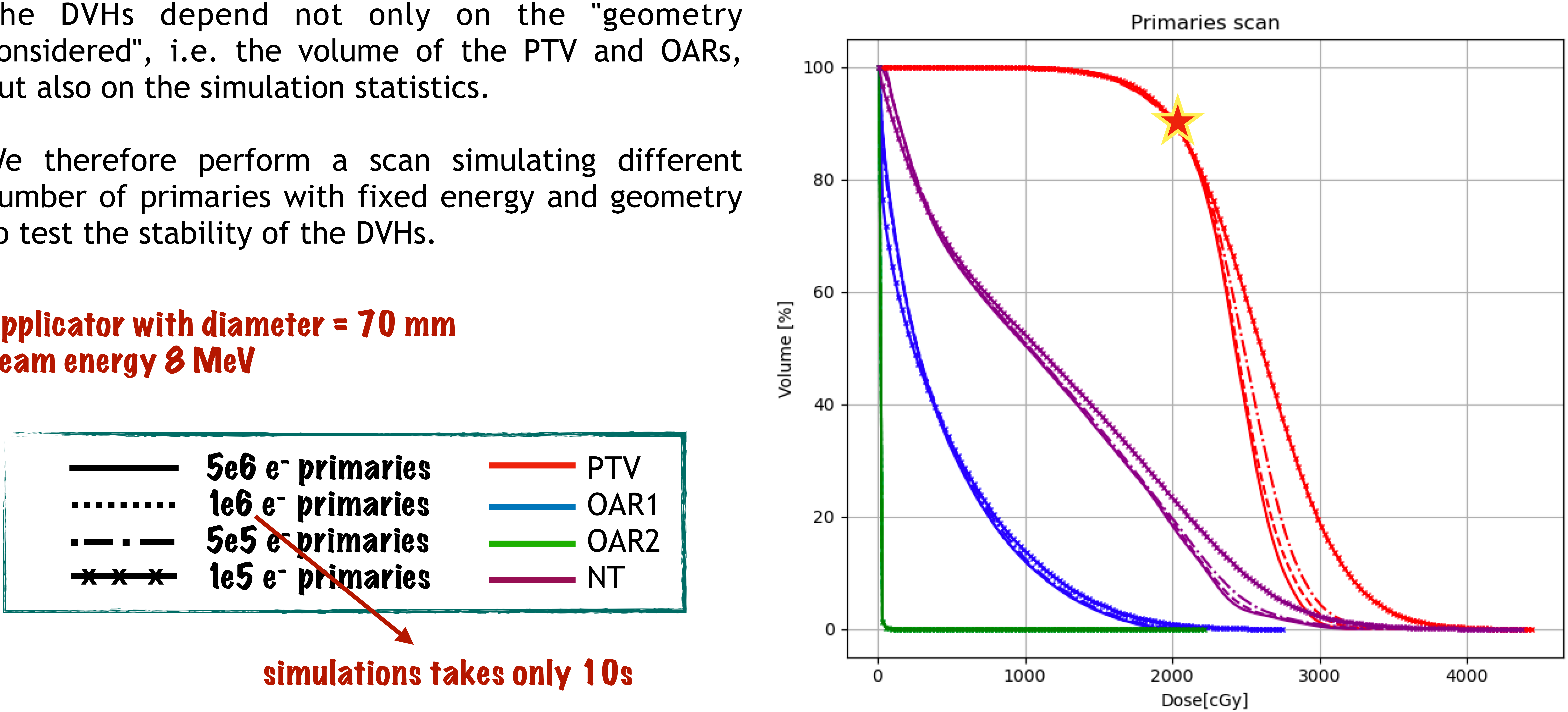
The impact of a 2mm position scan is clear both on the PTV and on the NT.

Needed statistics/GPU time

The DVHs depend not only on the "geometry considered", i.e. the volume of the PTV and OARs, but also on the simulation statistics.

We therefore perform a scan simulating different number of primaries with fixed energy and geometry to test the stability of the DVHs.

Applicator with diameter = 70 mm
Beam energy 8 MeV



Conclusion

- We have developed an optimization tool using **FRED** which is able to produce with 10^6 primary electrons **robust and accurate dose distributions** in about **10 seconds** that can be used for the treatment optimization. Ex: The simulation time for a preliminary TPS, i.e. 3 different beam energy and for each energy 3 different applicator position, is ~ 1 minute;

- At the moment we need the **breast cancer specialists input** in order to progress with our study:

1. The results here presented heavily depend on the specific case analysed and therefore on how we have defined PTV and OAR. We need a more **realistic case**, i.e. a real ecographic input, a real PTV and real OARs.

2. Currently we don't have specified **dosimetric constraints. We need to understand, from the clinical practice, which are the constraints that have to be implemented: which organ, what dose, etc etc….**

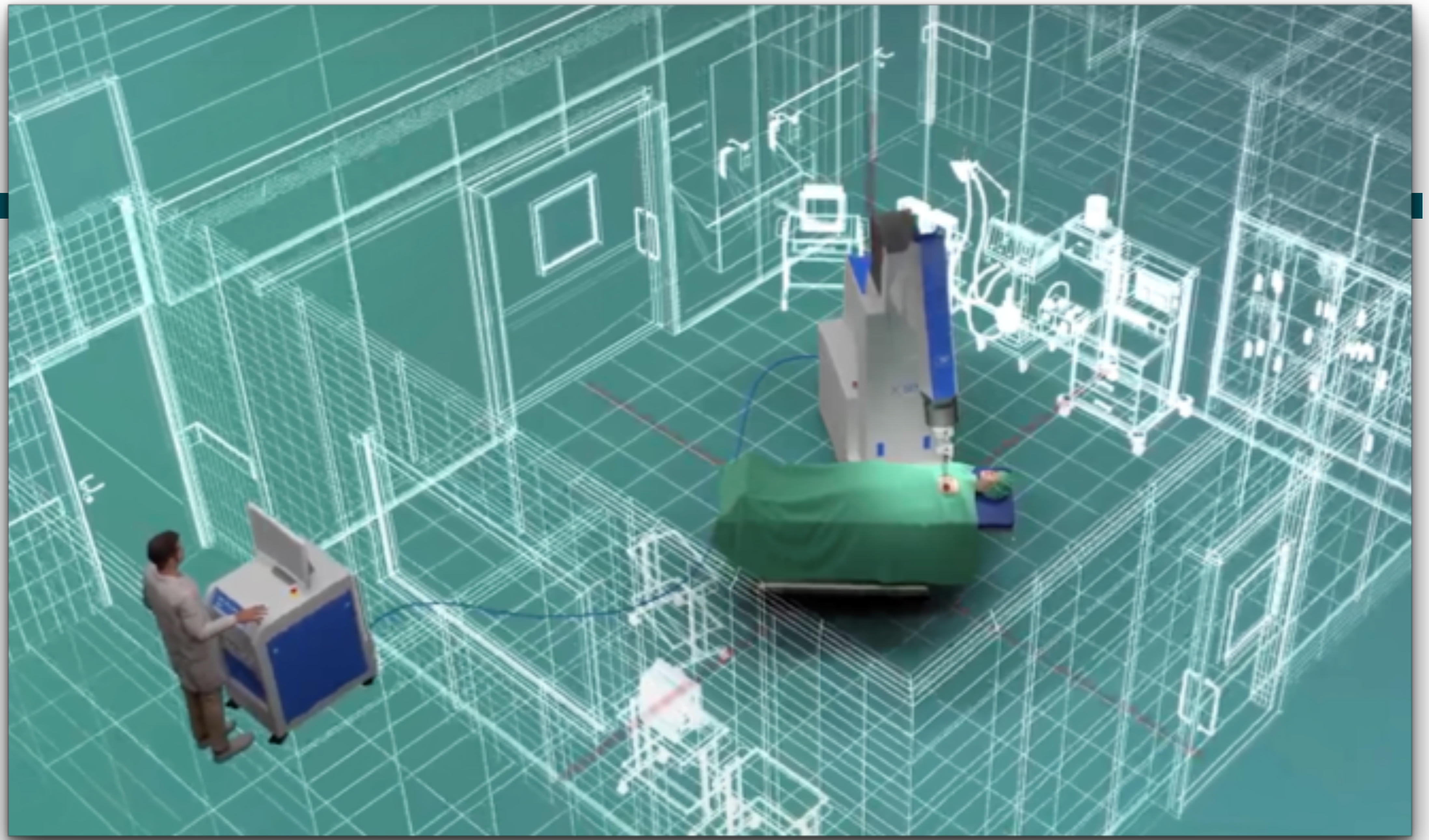
- Results shown so far have been obtained displaying the **physical dose**. However, the implementation of the biological dose, including the **flash effect**, will be straightforward once the DMF model will be available. We will explore the impact on the skin and in some internal organs (e.g. heart and lungs for breast cancer);

SPARE SLIDES

The current status

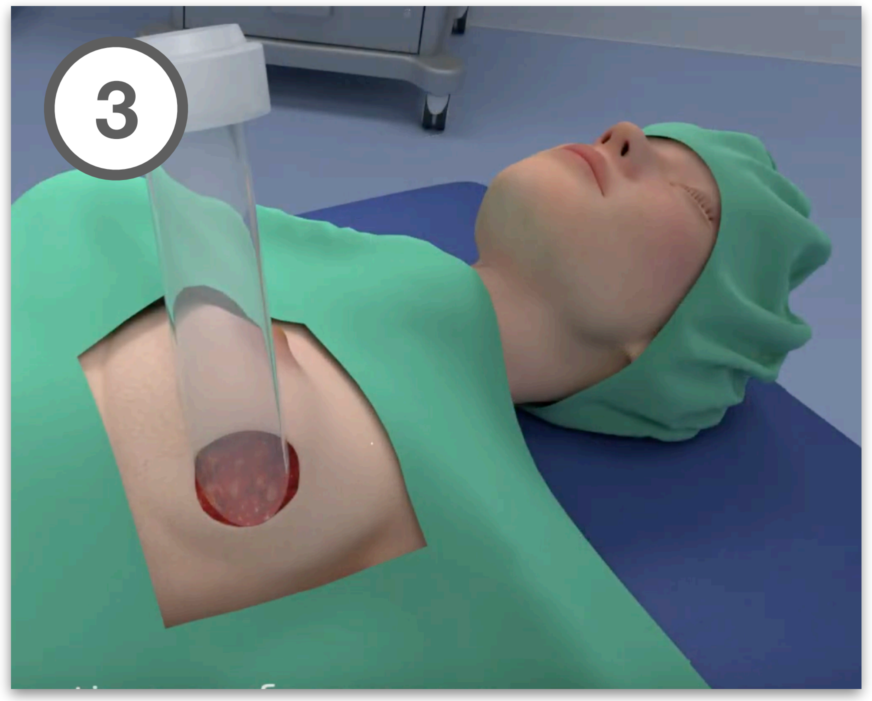
So far IORT treatments goes as:

The patient is surgically treated. The surgeon identifies and prepares the **PTV** that has to be treated.

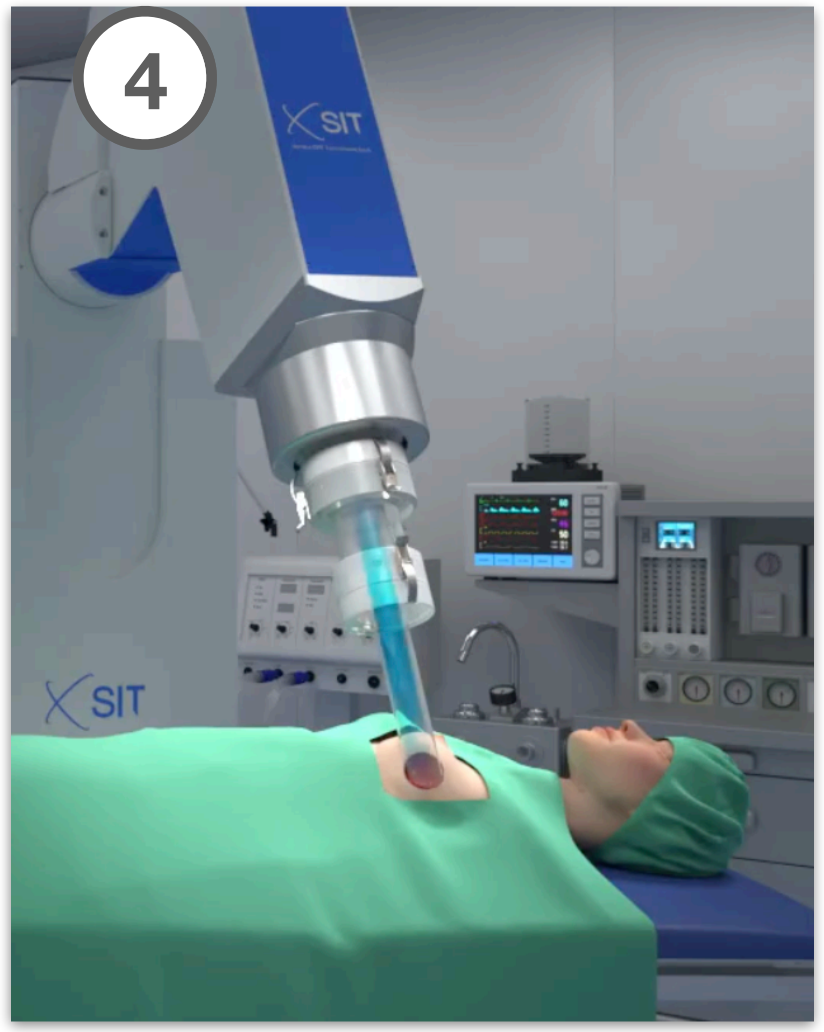


A **protective disk** is applied in order to preserve the organs from the undesired dose.

The **thickness** of the target volume is identified by means of a **needle** and thus the electron **beam energy** is chosen.



The beam is passively collimated by means of a **PMMA applicator**, whose **dimension** is chosen according to the volume of the surgical breach.



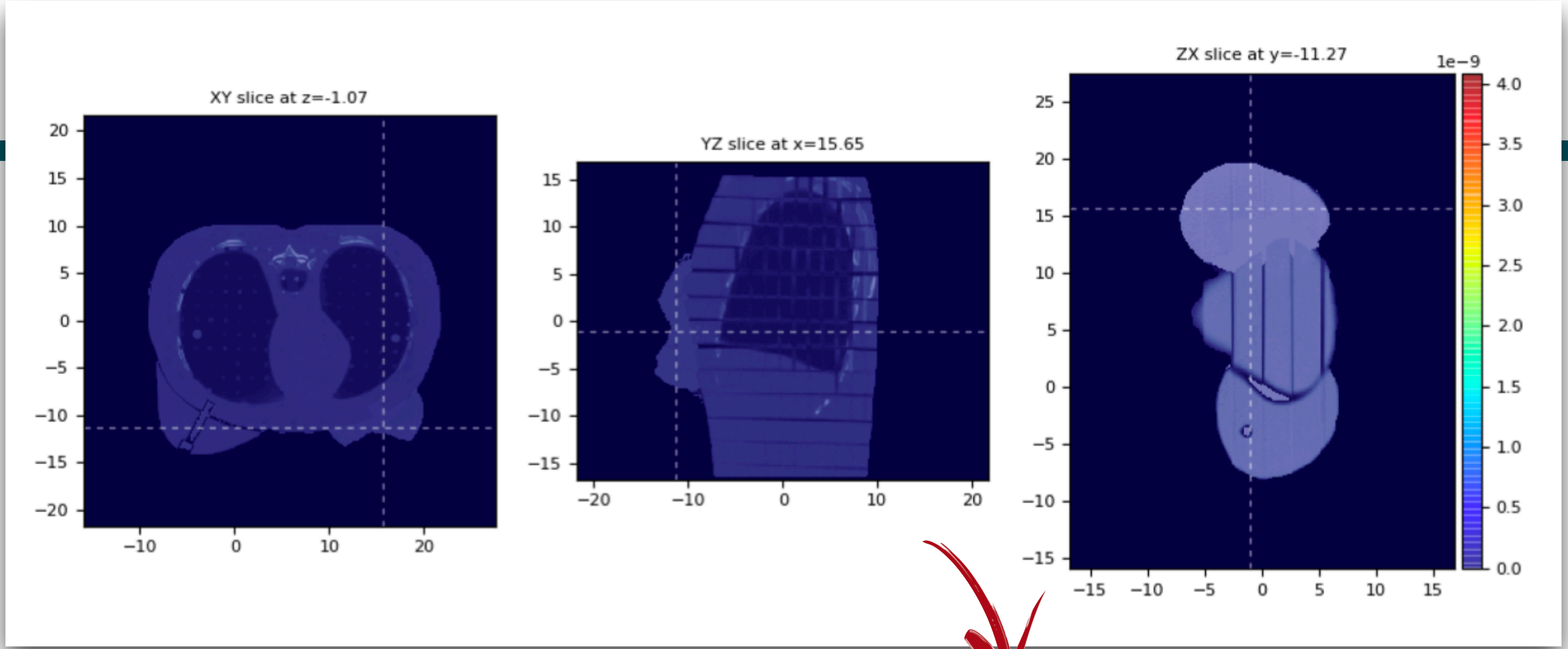
The dose is provided by a **uniform electron beam** produced by the SIT LINAC accelerator with energy between 4 and 12 MeV.

No TPS

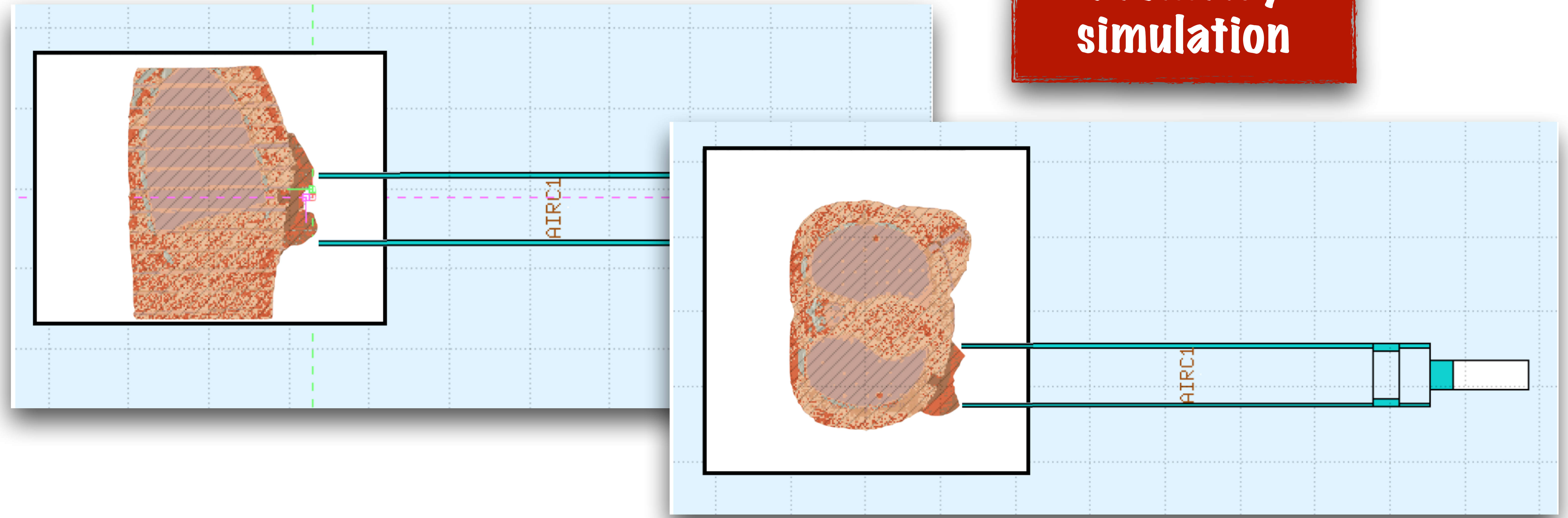
The inputs

For the breast IORT treatment, we have used a CT of a phantom with a **breast prosthesis** used to simulate a breast surgery attached onto it (Rando).

CT



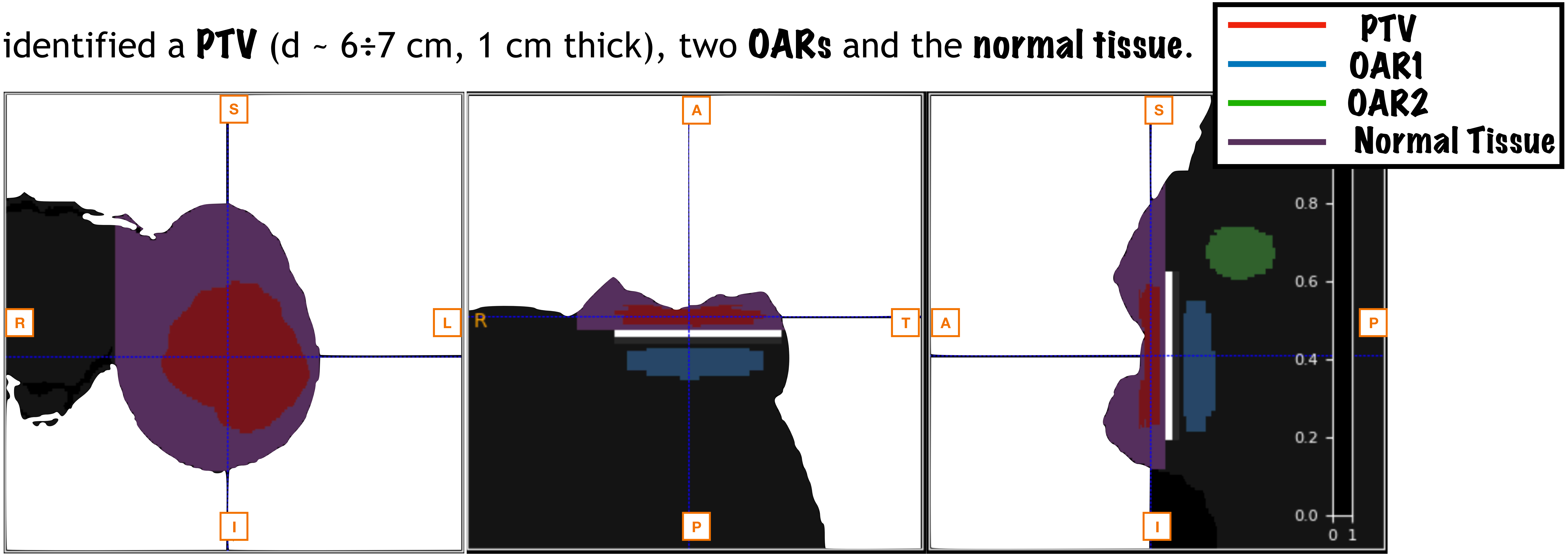
Geometry simulation



The inputs

The prosthesis has been modified to show the effect of a surgical breach, so no cut is needed to put the applicator.

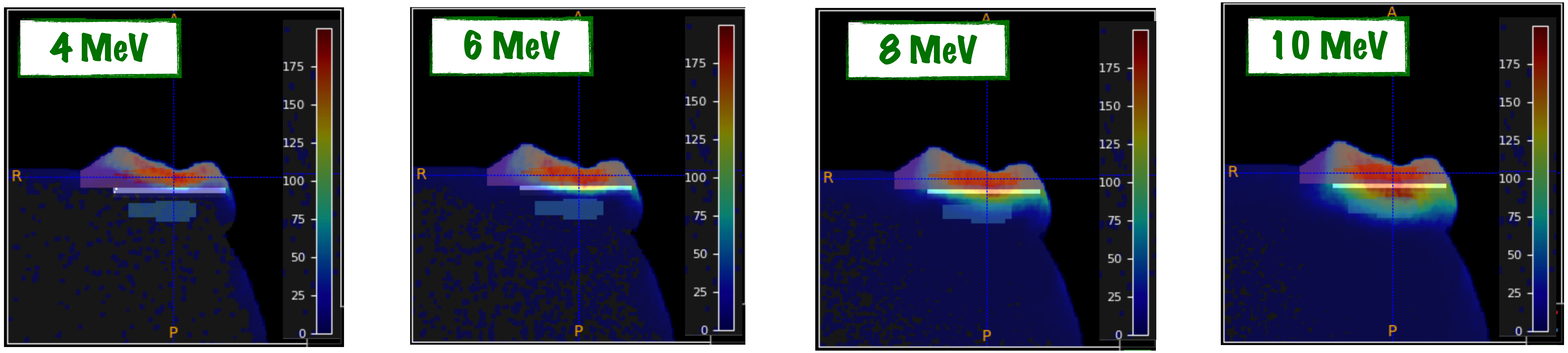
- We have inserted the radio **protection disk**;
- We have identified a **PTV** (d ~ 6÷7 cm, 1 cm thick), two **OARs** and the **normal tissue**.

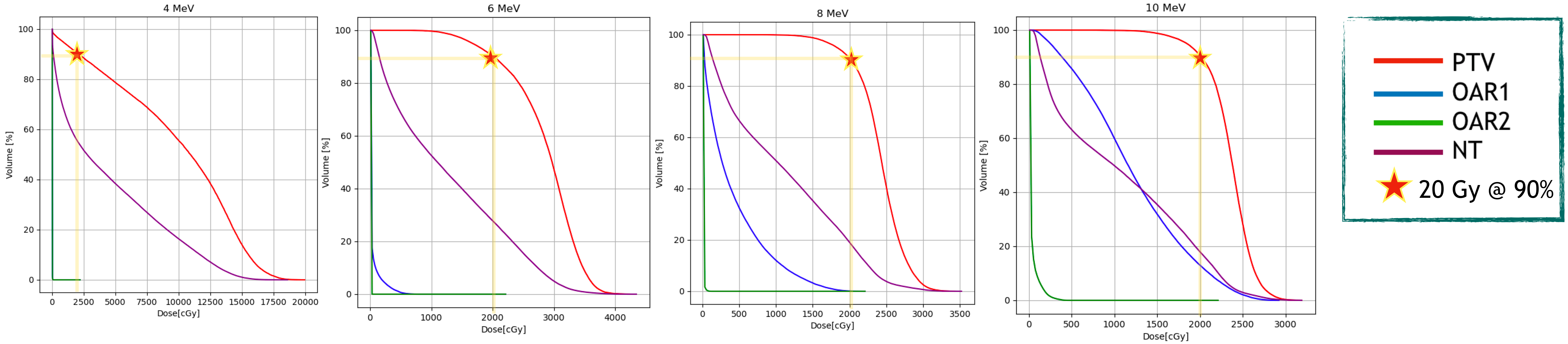


- Then we tried to optimize: we have shot **10^6 electrons** (several order of magnitude below a full treatment), of whatever energy, inside whatever applicator and we have analysed the **resulting DVHs**.

Energy scan

With a fixed applicator with diameter equal to 70 mm, we have simulated electron beams @ 4, 6, 8 and 10 MeV and we have analyzed the resulting DVHs.

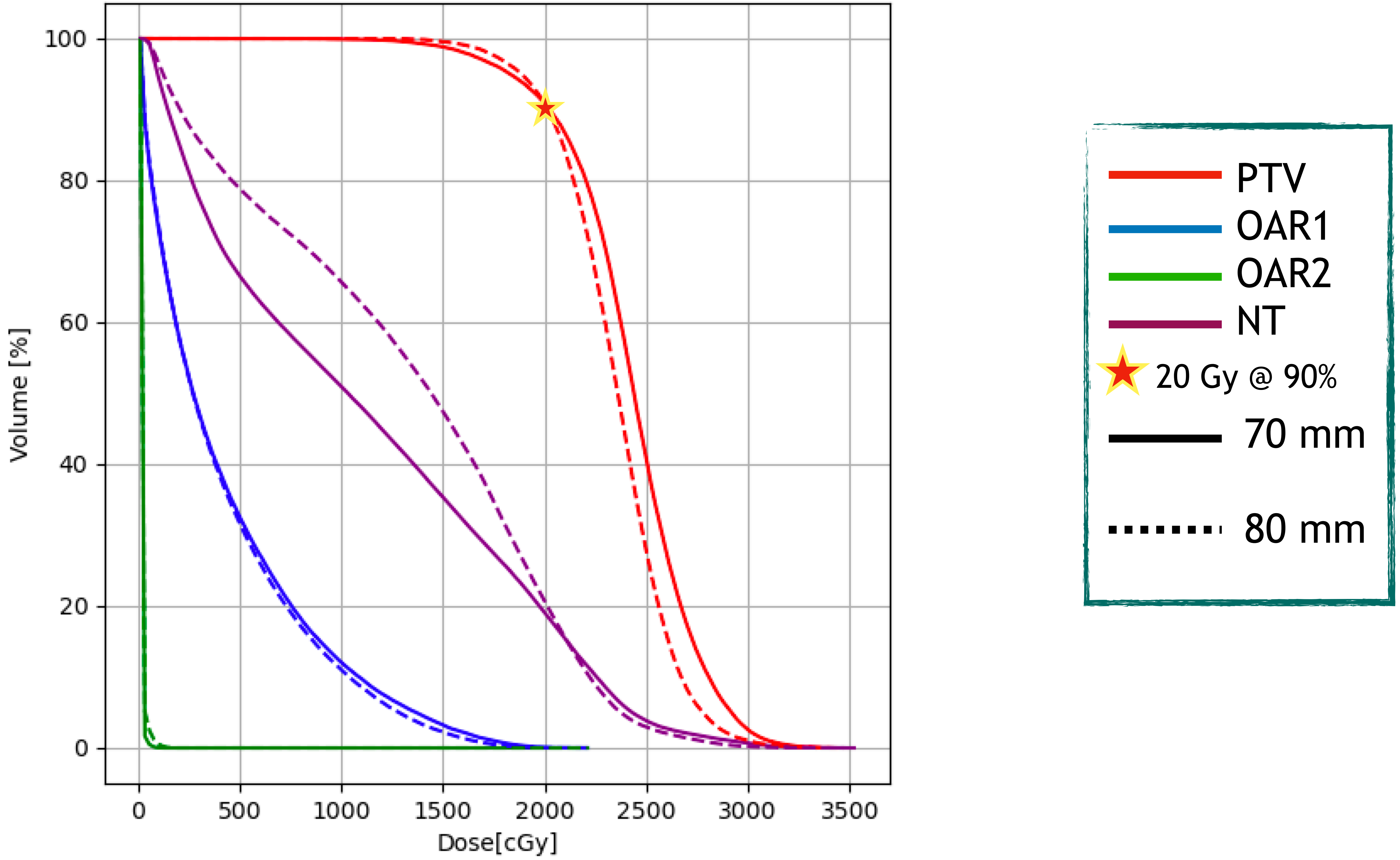




Which applicator?

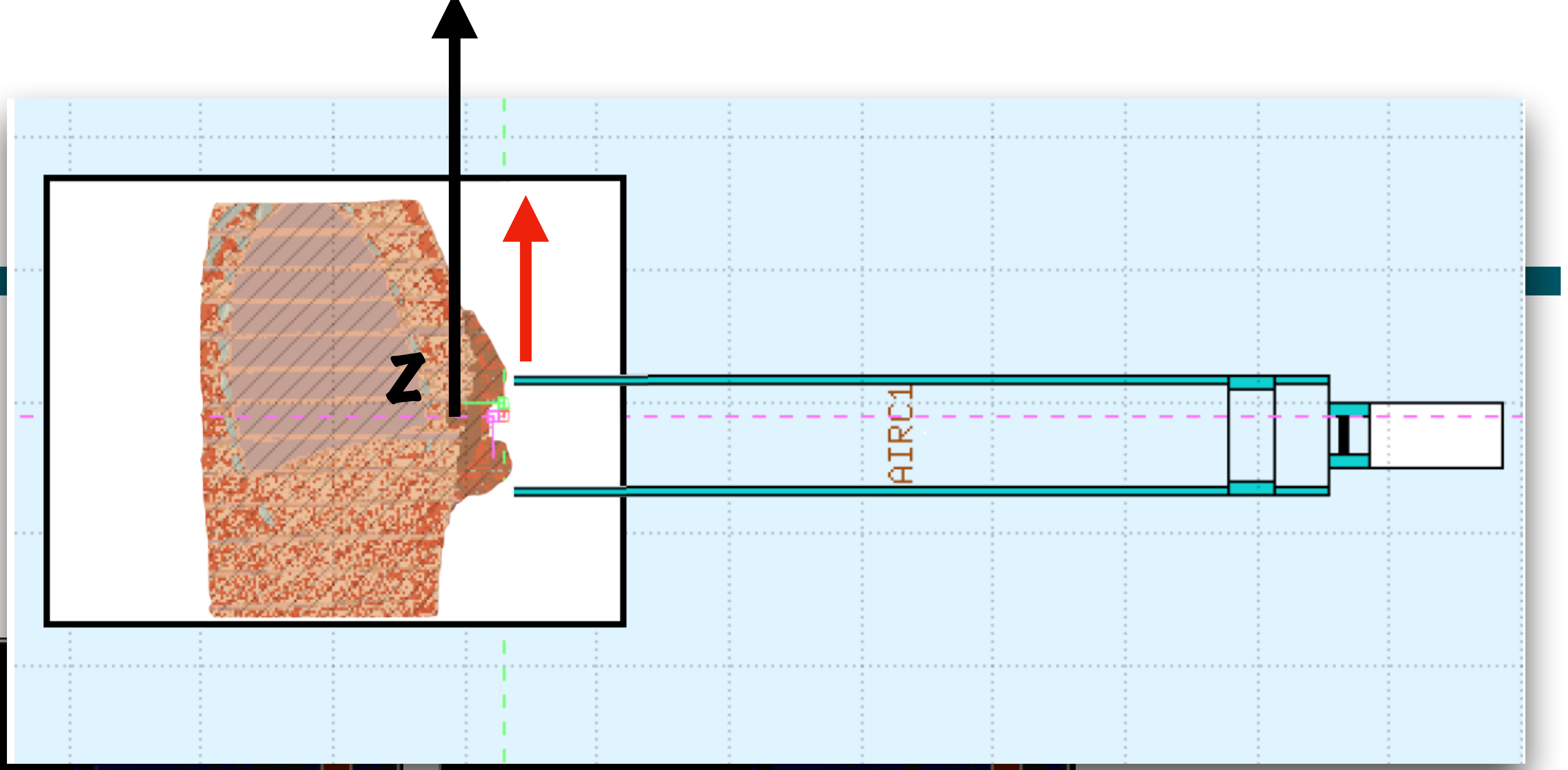
With fixed energy, 8 MeV, we have analyzed the DVHs obtained using the d=70 mm and d=80 mm applicator

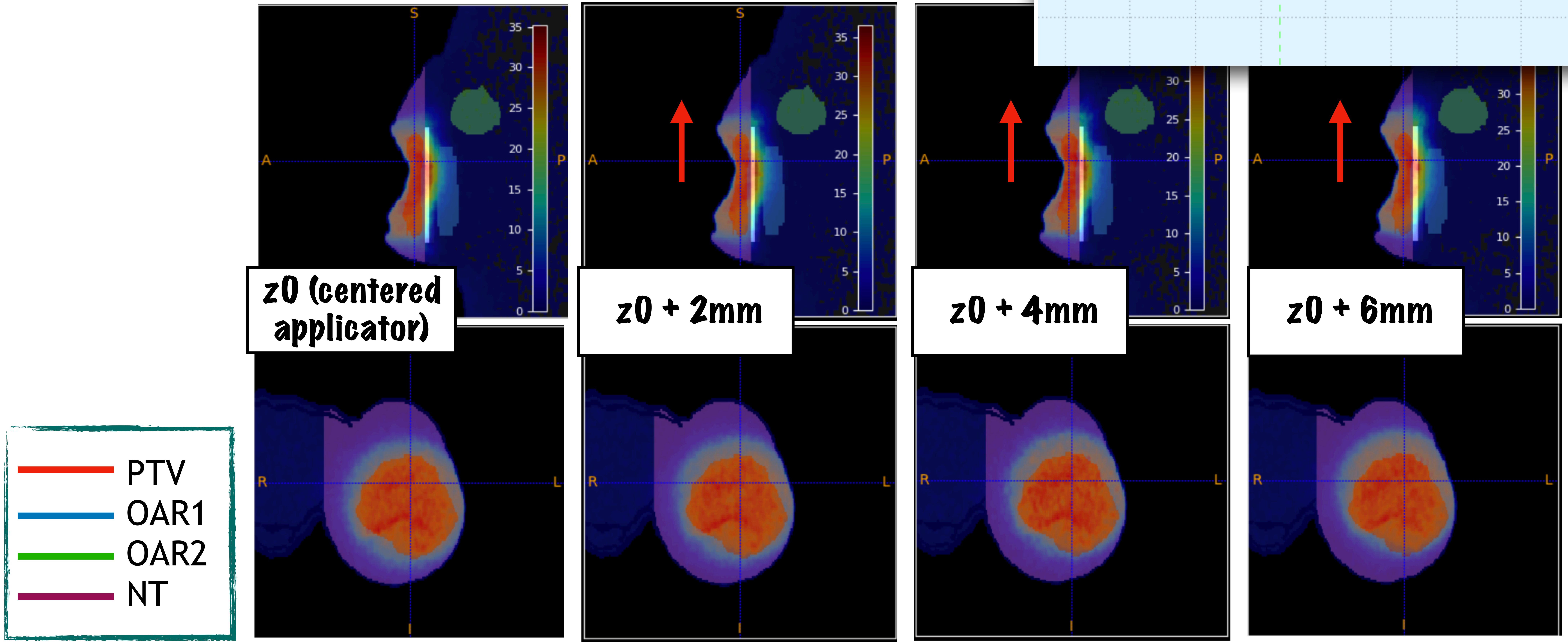
With d= 70 mm we obtain nearly the same **PTV** coverage but a slightly better **Normal tissue** sparing



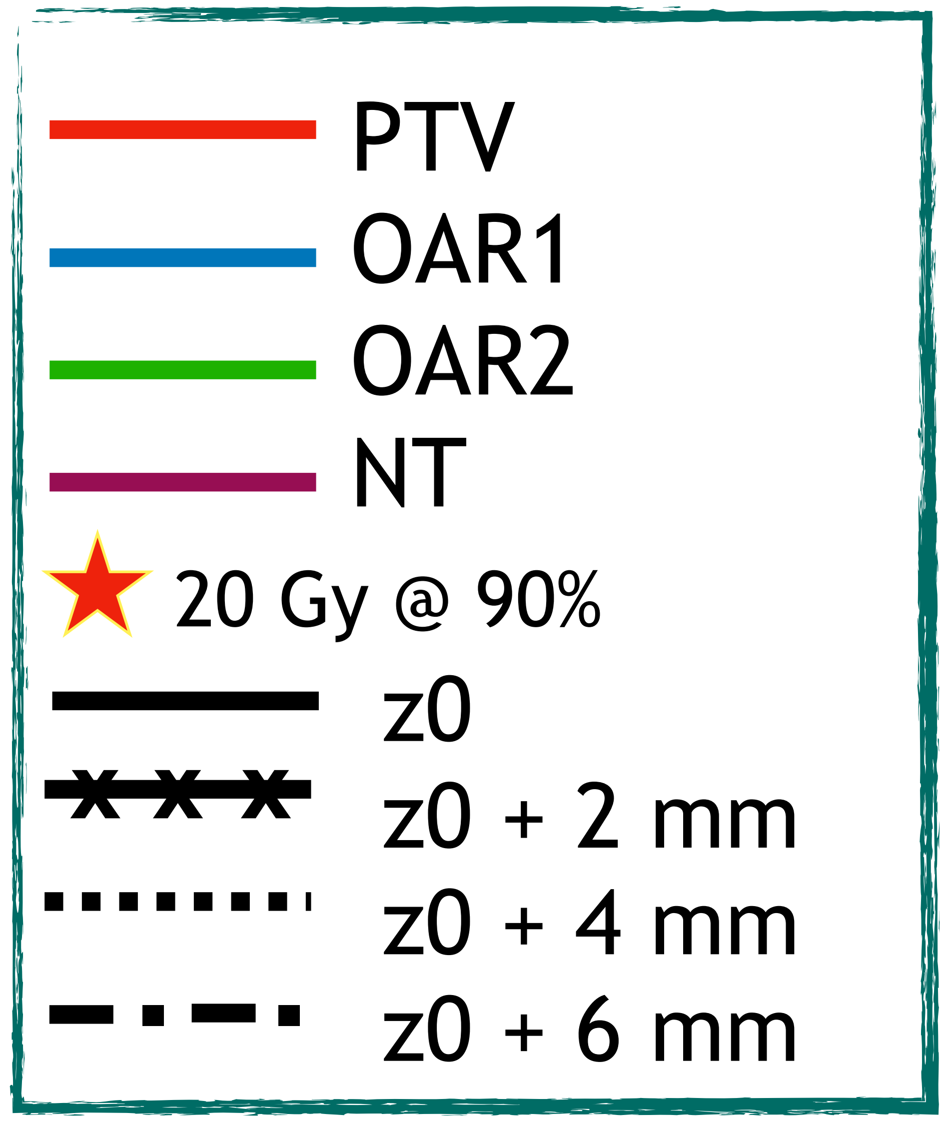
Position scan

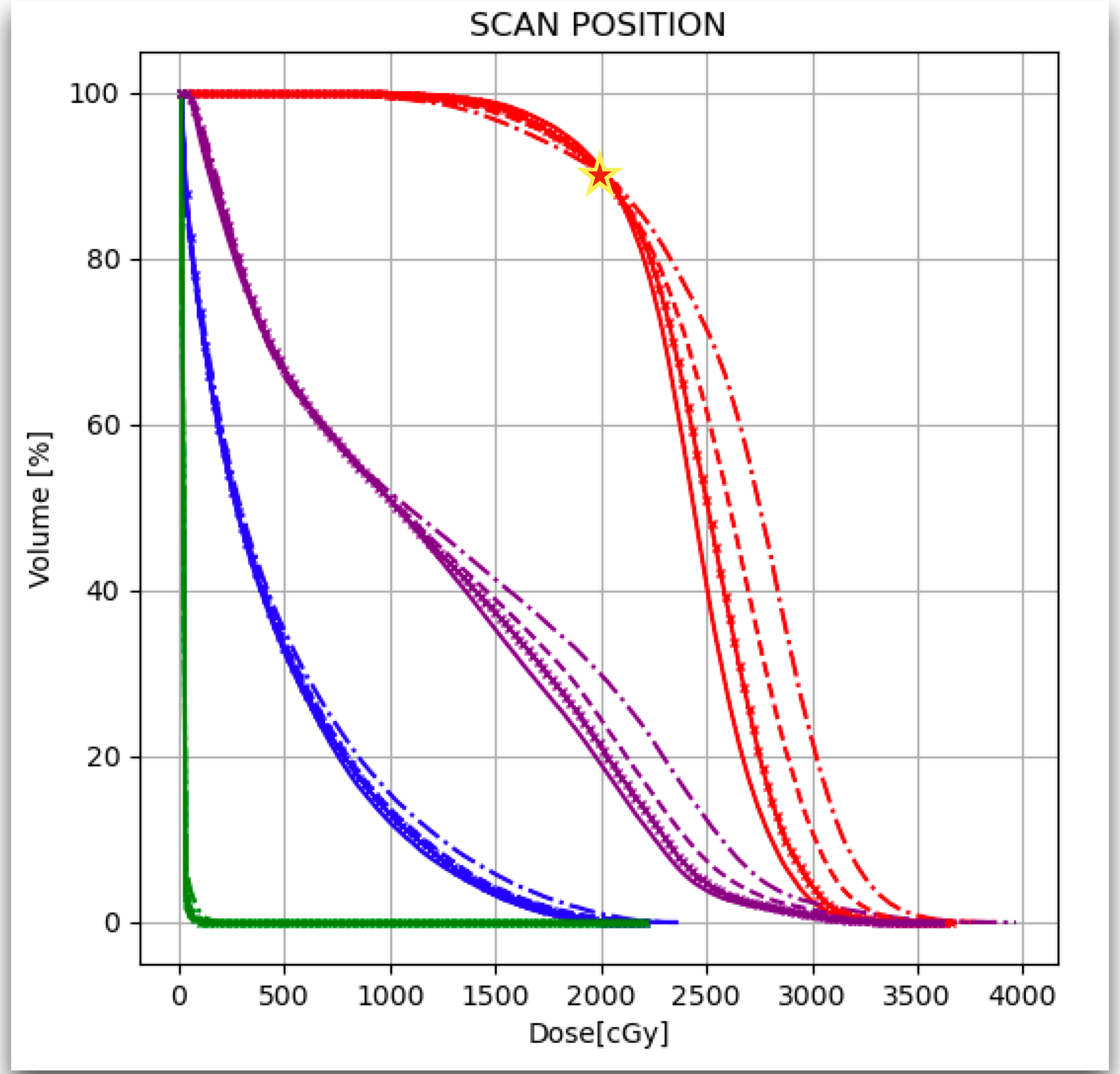
With 8 MeV electrons beam and d=70 mm applicator, we have performed a position scan, moving the applicator with 2 mm steps along the z-axis

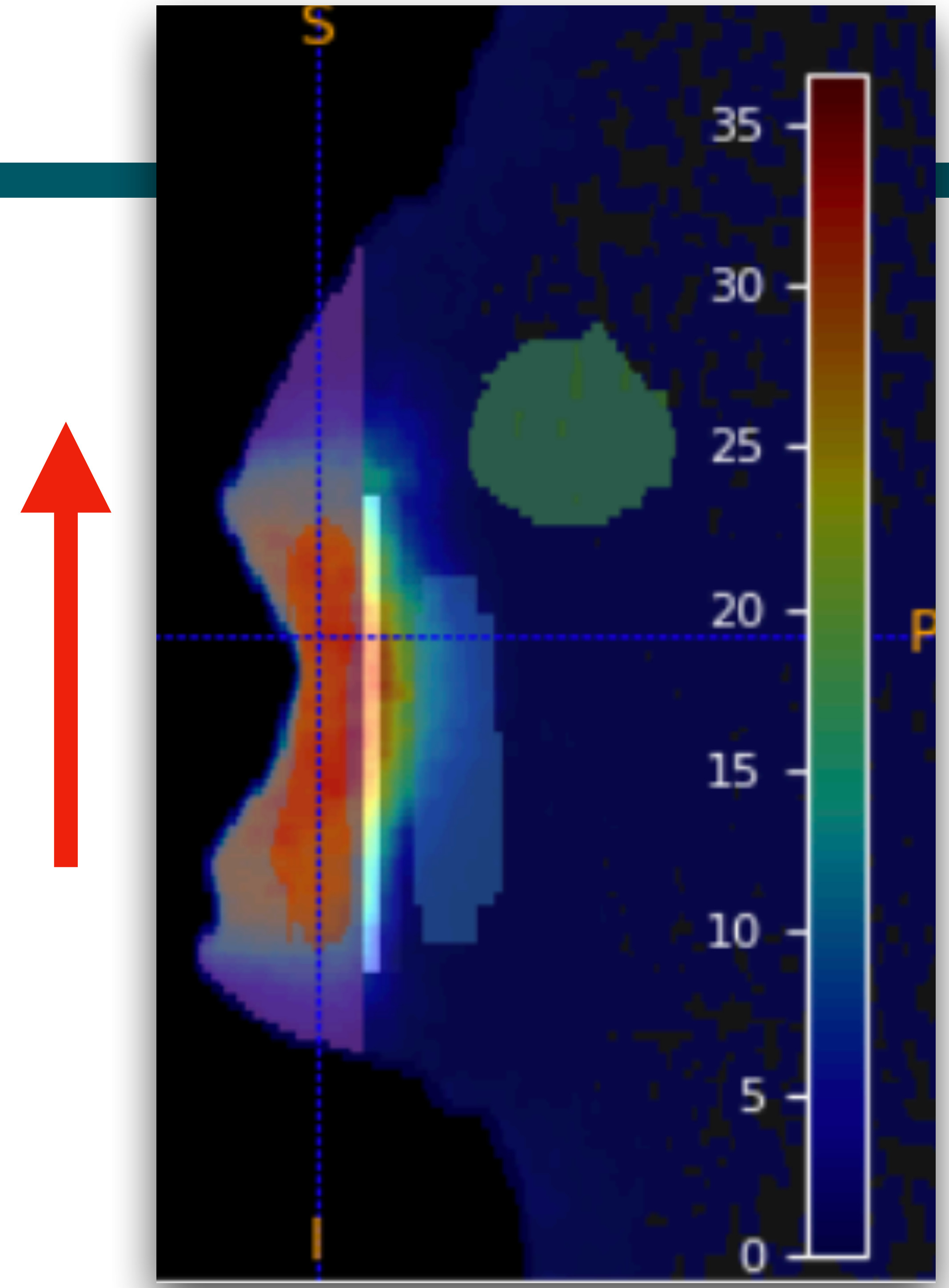




Position scan







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Primaries scan

The DVHs depend not only on the "geometry considered", i.e. the volume of the PTV and OARs, but also on the simulation statistics.

We therefore perform a statistics scan simulating different number of primaries with fixed energy and geometry to test the stability of the DVHs.

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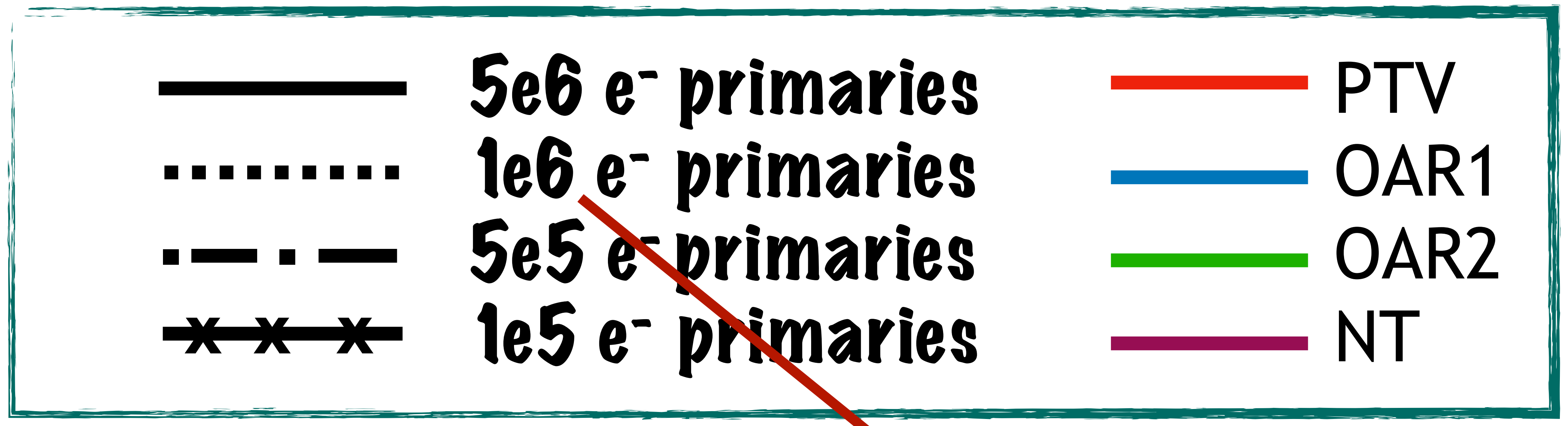
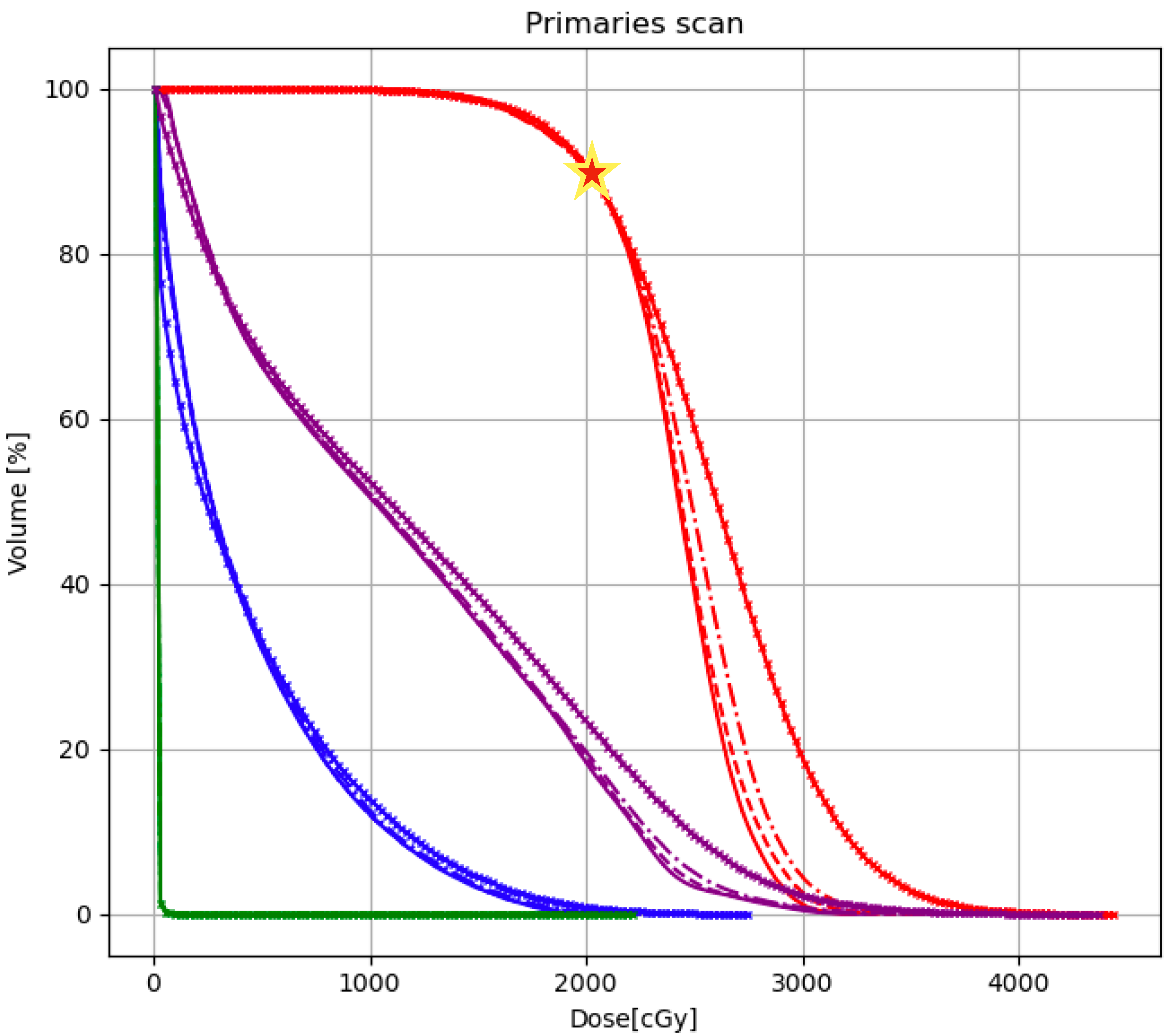
Energy beam 8 MeV



only ~10 s of simulation!



Flash effect

At the moment in all DVHs here presented, we have worked with the **physical dose**.

No problem!!!

Once we have optimized the breast cancer study (i.e. defined a real PTV, a real OAR and worked with real dosimetric constraints), our tool is ready to introduce the **flash effect** and study the **biological dose**.

The FLASH effect could help:
-> Sparing the OARs that receive a significant % of the total dose
-> Spare the skin, reducing the surgical breach

Question:

In the context of breast cancer, what kind of **sparing** should we test/explore first? Should we concentrate on the impact on the Skin? Or imagine that some gain can be achieved in the most internal organs (like heart or lungs)?

What's next?

- We have a **machinery** that is **ready** and in place:

With 10^6 primary electrons we already obtained **robust dose distributions** in about **10 seconds** that can be used for the optimization

- At the moment we need the **breast cancer specialists input** in order to progress with our study:

1. The results here presented heavily depend on the specific case analysed and therefore on how we have defined PTV and OAR. We need a more **realistic case**, i.e. a real ecographic input, a real PTV and real OARs. In addition we also need to understand how the treatment is delivered (i.e. one single fraction or multiple fractions with the implementation of 'boost' sessions)

2. Currently we don't have specified **dosimetric constraints. We need to understand, from the clinical practice, which are the constraints that have to be implemented: which organ, what dose, etc etc….**

All this is useful to finalize the work in view of a paper on '**Breast cancer IORT TPS**'

Thanks for your attention!

The needed inputs

1. Can we agree on a r**easonable modeling of the PTV** in breast cancer? **Shape** (cylindrical/cuboid) **Dimension**, **thickness**, **radius.**

2. Can we stick with the **20 Gy at 90%** prescription for breast cancer on the PTV? We have assumed that the treatment is delivered in a **single fraction**, it is reasonable?

3. Can we agree on how to define **normal tissue** and **OARs** and their respective prescription in the case of breast cancer (lungs, heart, column, ribs) ?

4. In the context of **flash application**: should we concentrate on the impact on the **Skin**? Or imagine that some gain can be achieved in the most **internal organs** (like heart or lungs)?

Position scan with 1e5 primaries