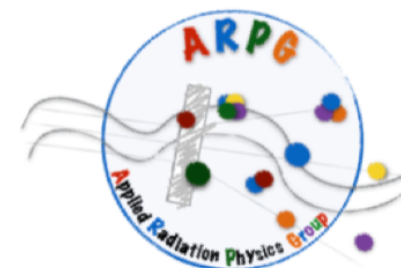




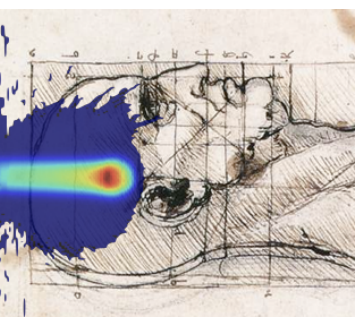
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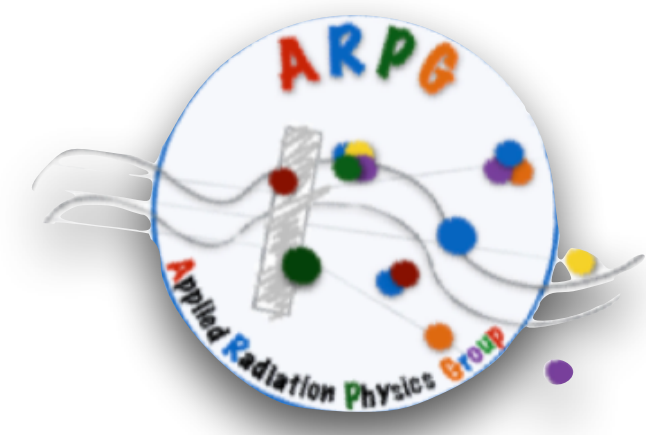
CENTRO RICERCHE
ENRICO FERMI



Fast paRticle thErapy Dose evaluator FRED



FRED (Fast paRticle thErapy Dose evaluator) is a fast **dose engine** based on Monte Carlo (MC) code for the transport of particles in heterogeneous media that allows for a quick recalculation of the **deposition of the dose**.



FRED has been developed to work on **GPU (Graphics Processing Unit)** and it reduces the simulation time by a factor of **1000** for proton treatments compared to a standard MC.



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Excellent results achieved in the context of Particle Therapy (**protons** and **carbon ions**) and conventional radiotherapy (**electrons** and **photons**) in terms of **tracking performance** and **dose accuracy**.

Physics in Medicine & Biology

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PAPER

Fred: a GPU-accelerated fast-Monte Carlo code for rapid treatment plan recalculation in ion beam therapy

To cite this article: A Schiavi *et al* 2017 *Phys. Med. Biol.* **62** 7482

View the [article online](#) for updates and enhancements.

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frontiers
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ORIGINAL RESEARCH
published: 25 March 2022
doi: 10.3389/fonc.2022.780784



A Data-Driven Fragmentation Model for Carbon Therapy GPU-Accelerated Monte-Carlo Dose Recalculation

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GPU-accelerated Monte Carlo simulation of electron and photon interactions for radiotherapy applications

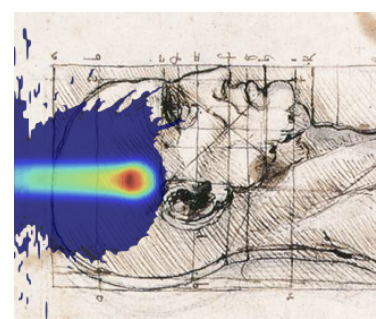
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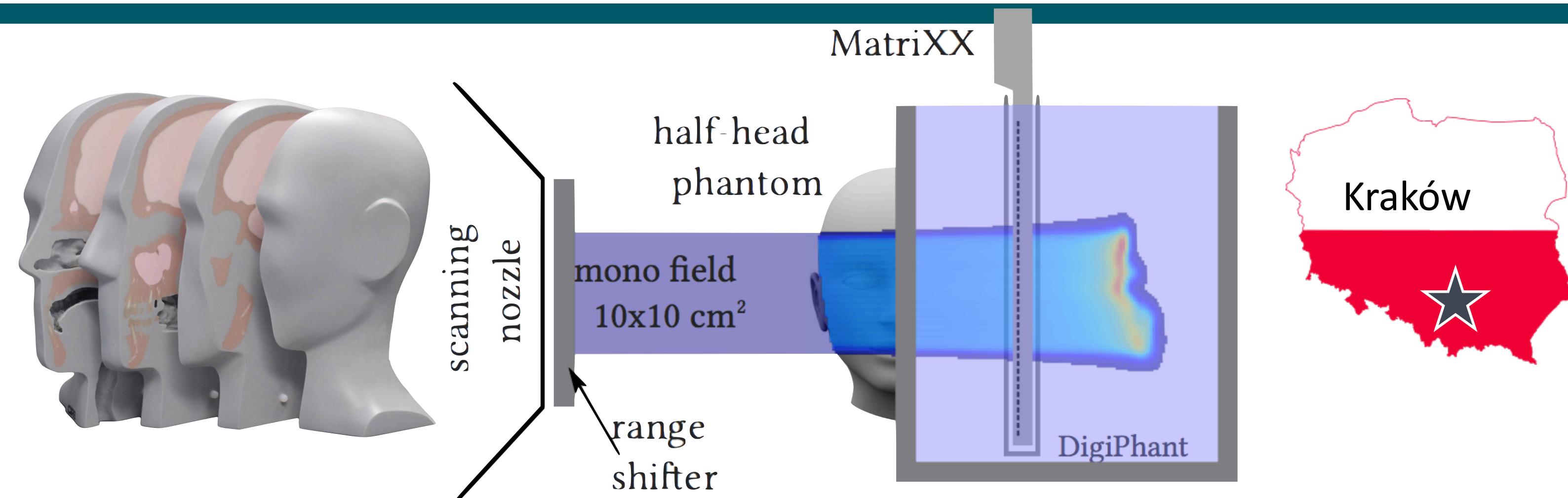
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Jon Hakkila

FRED-p



- Heterogeneous head phantom
- MatriXX measurement in water
- Single energy: 100, 150 and 200 MeV
- Range shifter



Today FRED-p is used in several research center, such as:

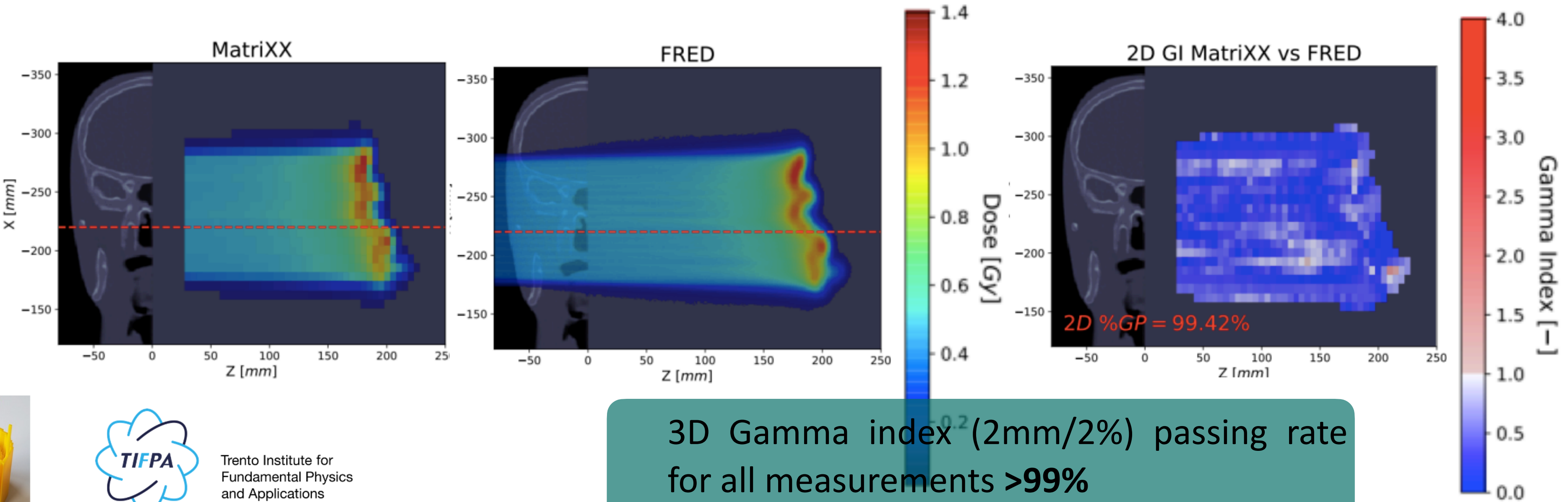
Range verification in PT



FLASH proton therapy using 3D Range Modulators

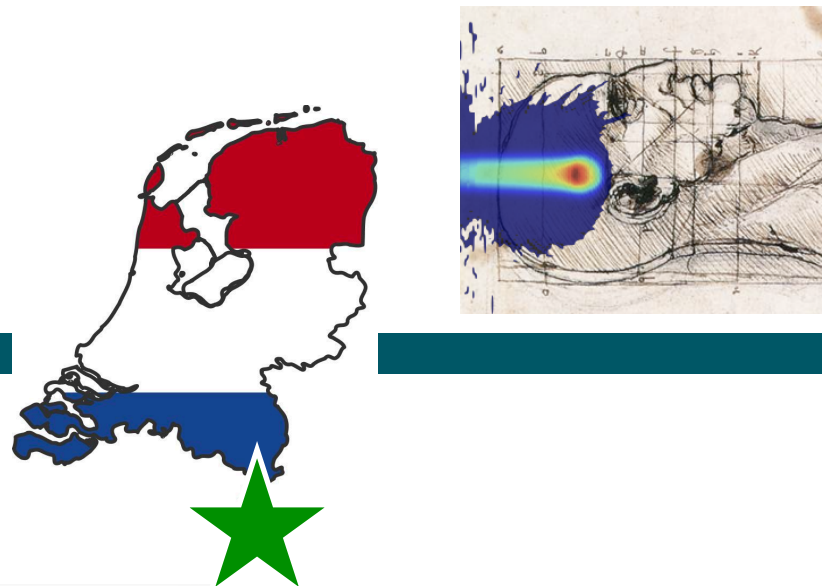


Trento Institute for Fundamental Physics and Applications



3D Gamma index (2mm/2%) passing rate for all measurements >99%

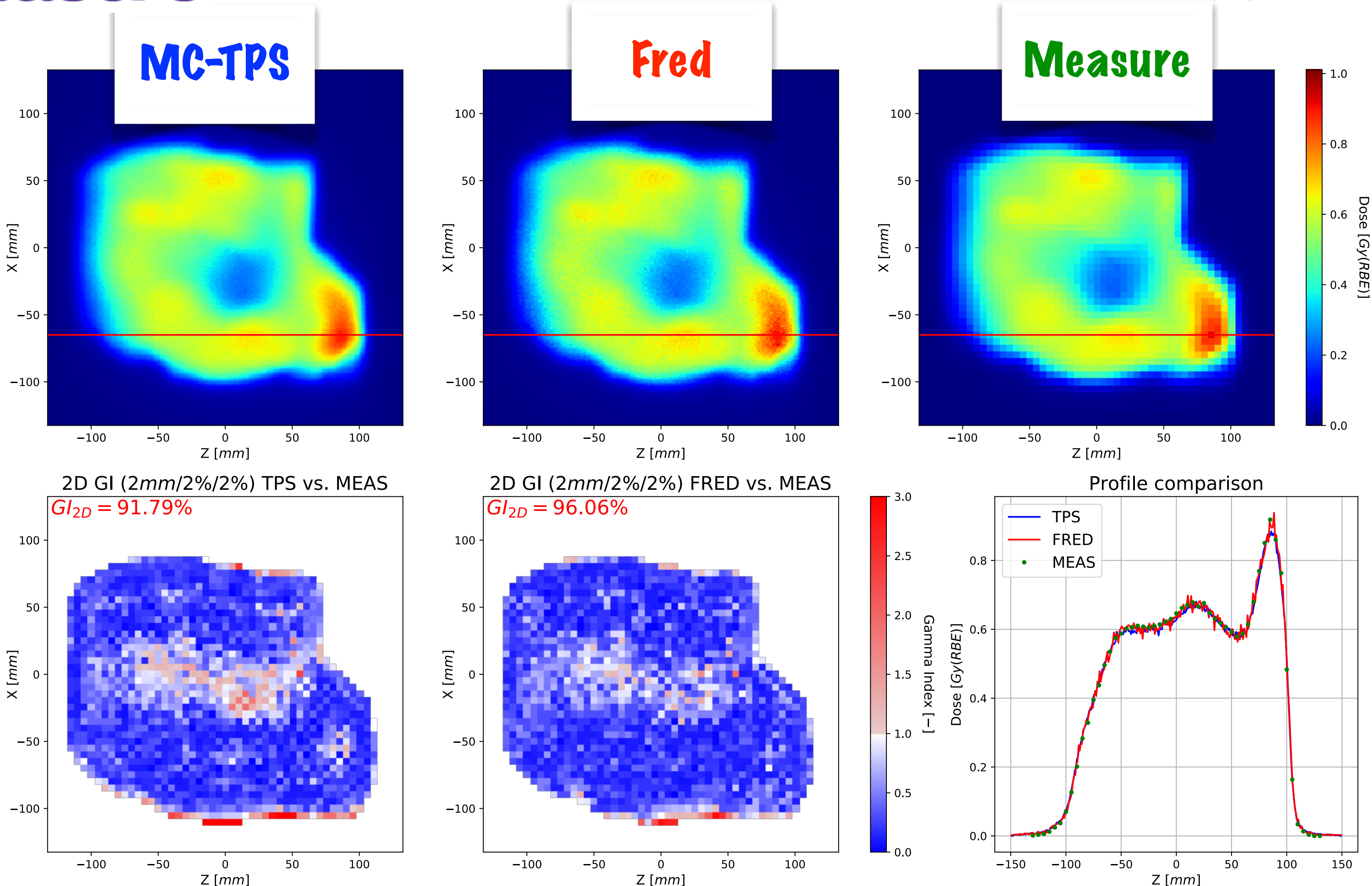
FRED-p: application

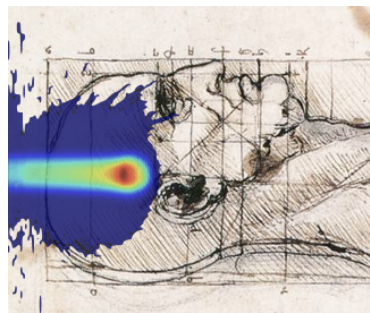


Maastricht

Patient Quality Assurance (QA) @ **Maastricht**

- 1. Automatic pipeline is fully operative and review of automatic verification reports has become part of daily clinical routine;
- 2. Recalculation of patient dose distributions normally takes **1 to 4 minutes**;
- 3. Since July 2020, we have used FRED to recalculate **2141 plans**;
- 4. **745 hours less** routine QA work (about 30 min per PSQA measurement).



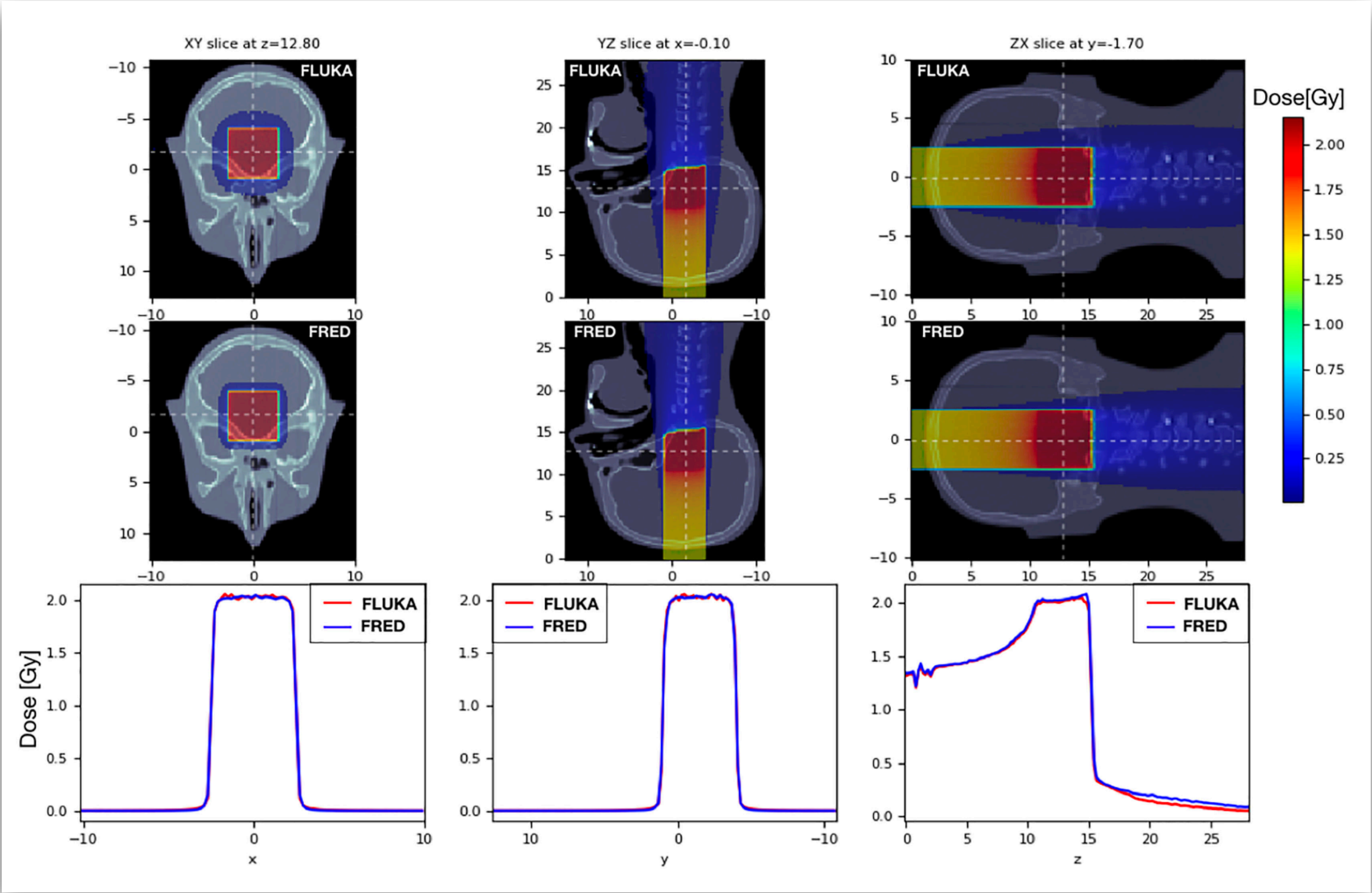


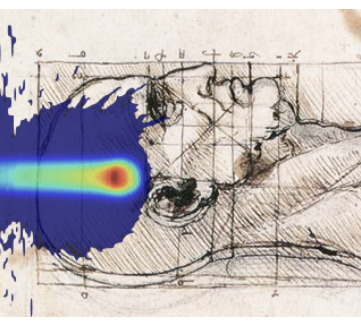
FRED accuracy was tested in homogenous and heterogeneous phantom

SOBP on Head&Neck CT scan

The 2mm/3% gamma-index between FRED and FLUKA dose distributions is 99.89% with threshold of 5%.

100 MeV/u		
MC	Hardware	Primary/s
FLUKA	single CPU core	0.7 k
FRED	single CPU core	4.2 k
FRED	single GPU card	2000 k
300 MeV/u		
MC	Hardware	Primary/s
FLUKA	single CPU core	0.3 k
FRED	single CPU core	3 k
FRED	single GPU card	2500 k

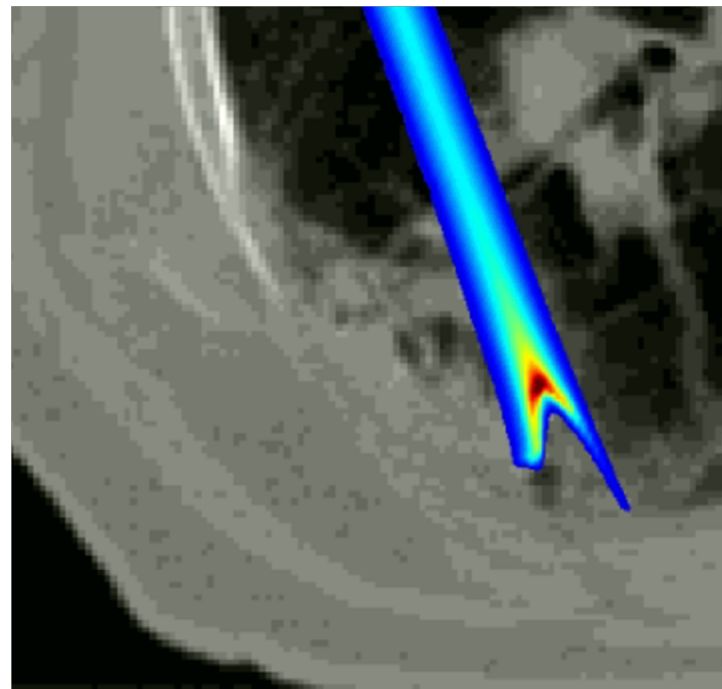




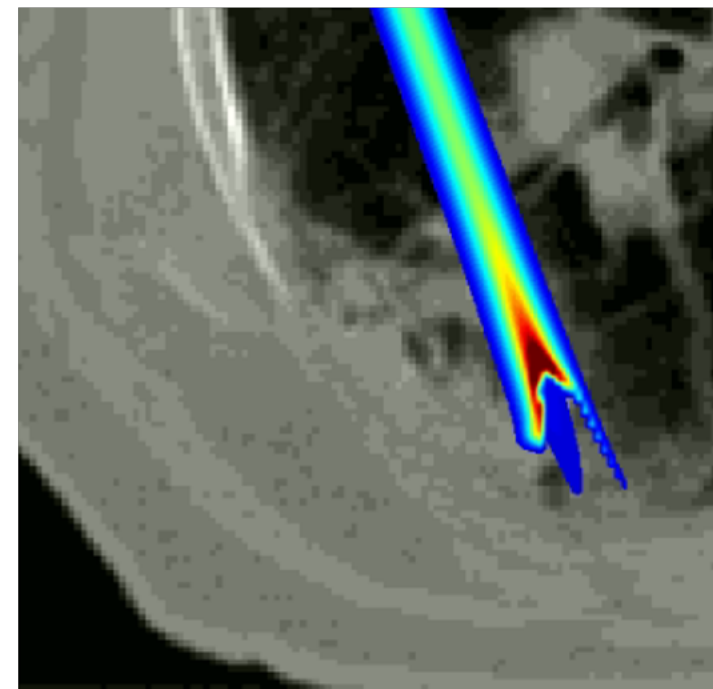
An AI dose engine for fast carbon ion treatment planning

- Online adaptive radiotherapy requires fast, precise and accurate dose calculation.
- Analytical pencil beam algorithms are fast but less accurate in comparison to Monte Carlo simulations, which are not fast enough for online therapy (FRED 10 s/10⁶ particles)

Monte Carlo TOPAS

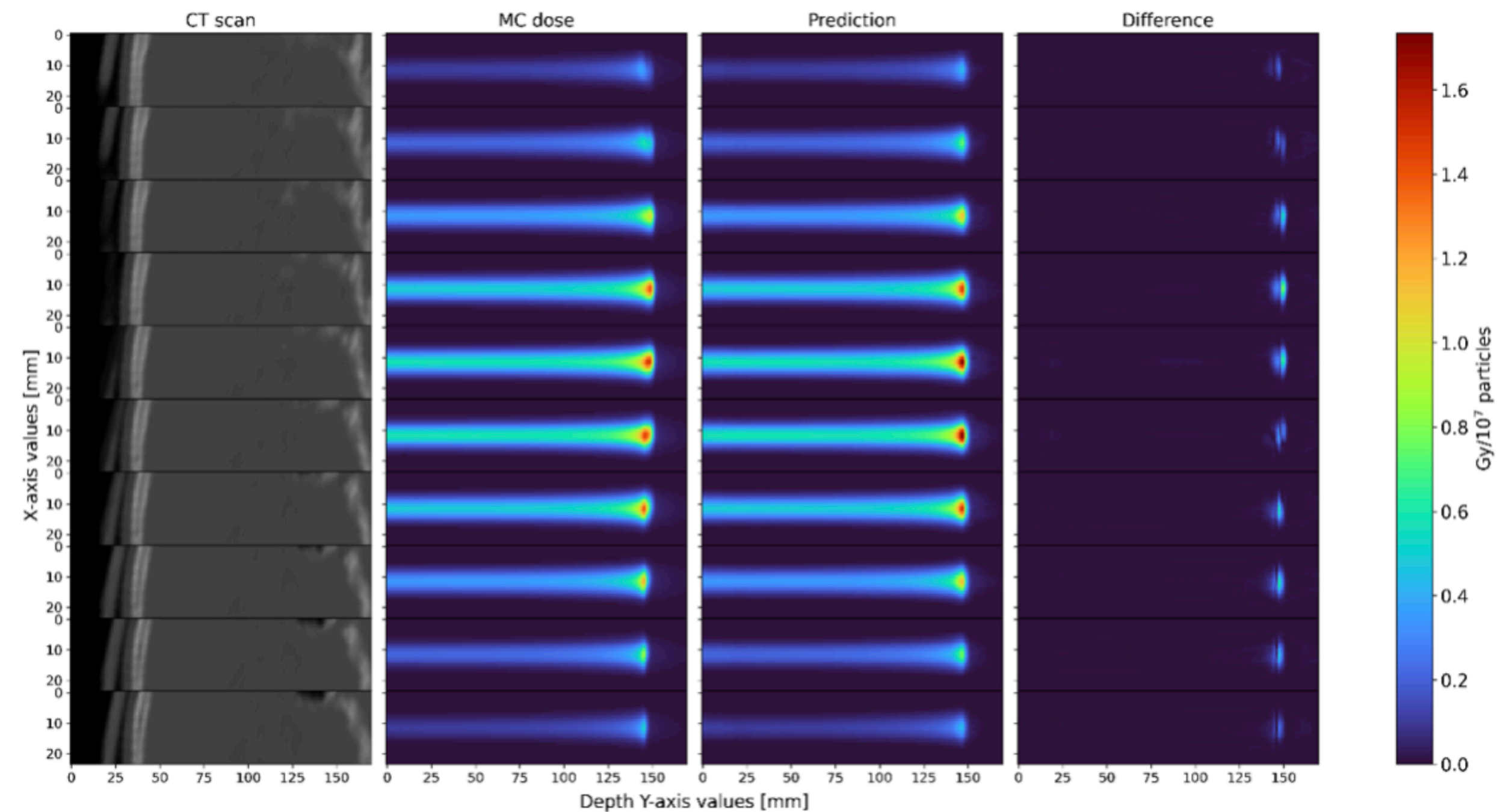


Analytical dose calculation



Given its accuracy in dose prediction, the FRED code can be also used to provide the training and validation dataset to dose engines based on deep-neural network.

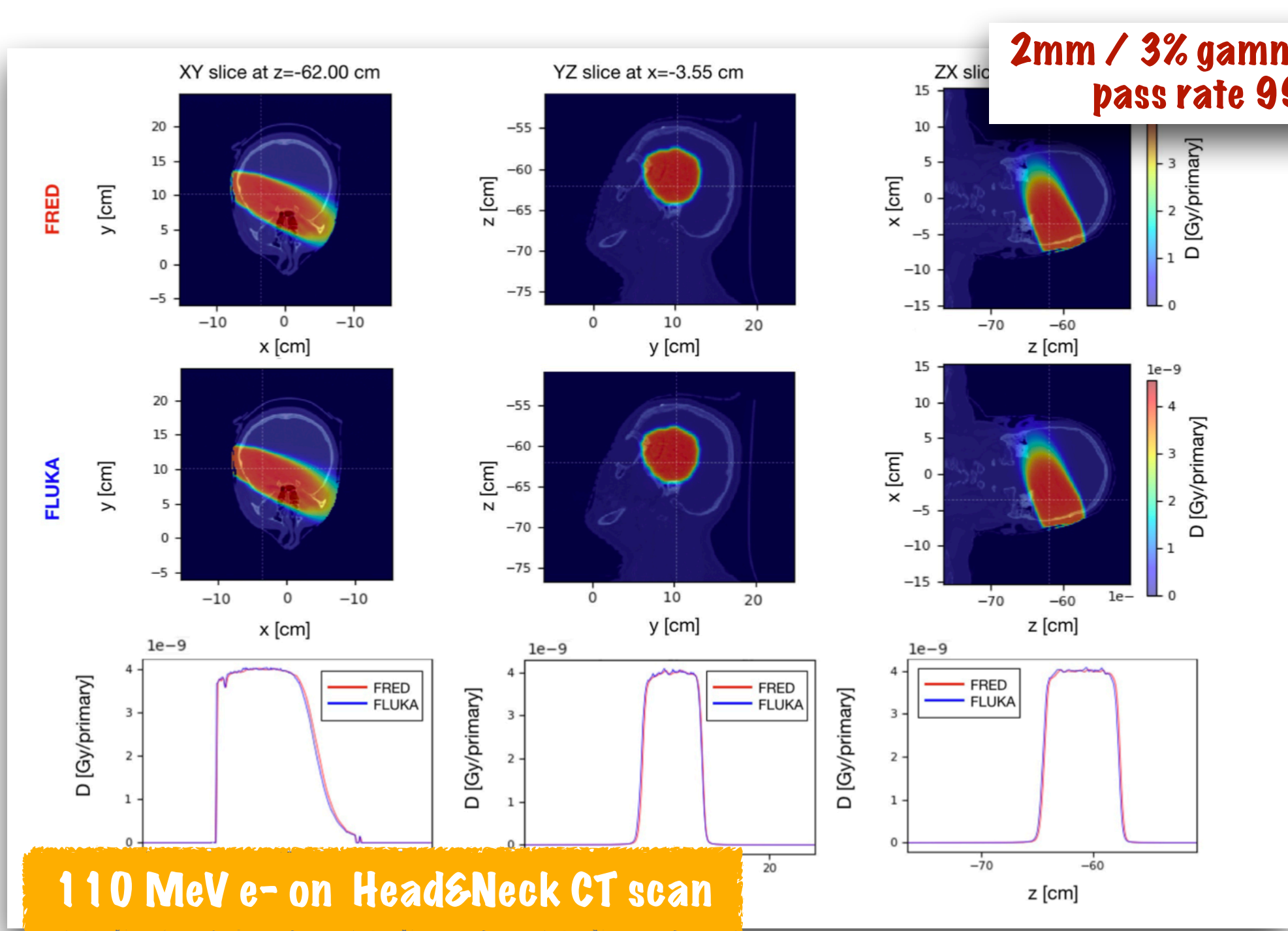
The physical dose prediction agreed with the FRED at an average gamma of 99.4 % (1 %/ 3 mm acceptance criteria)



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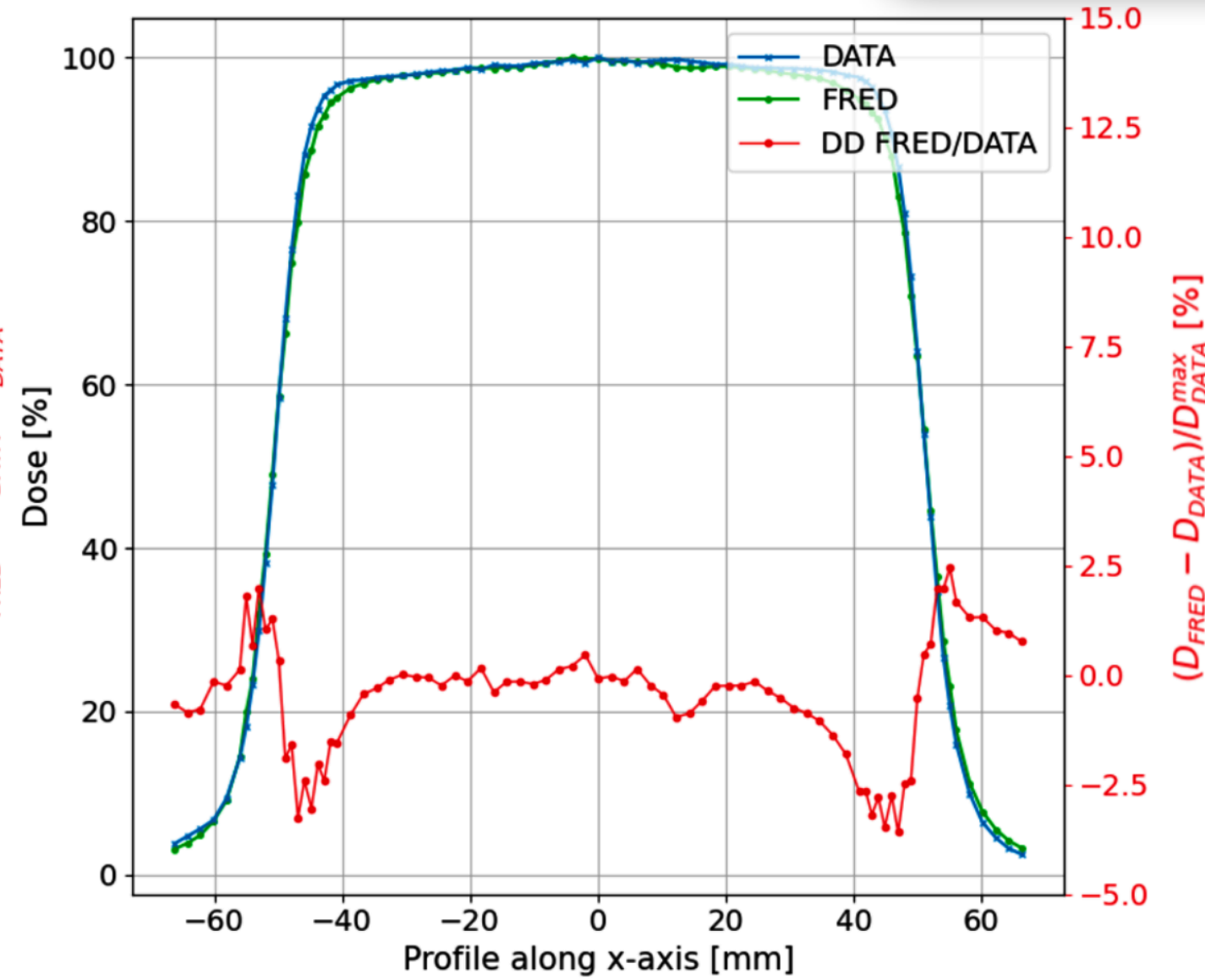
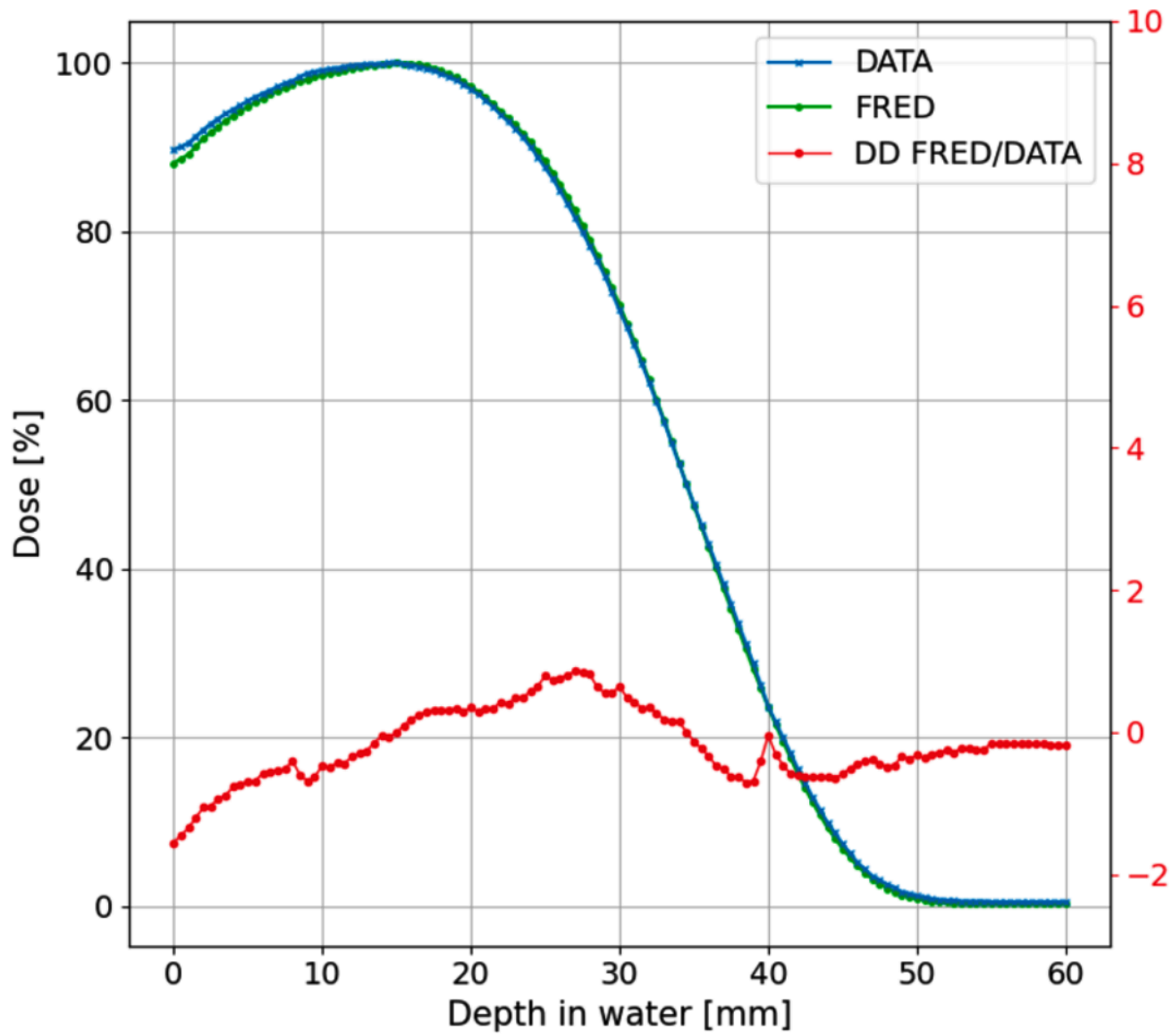
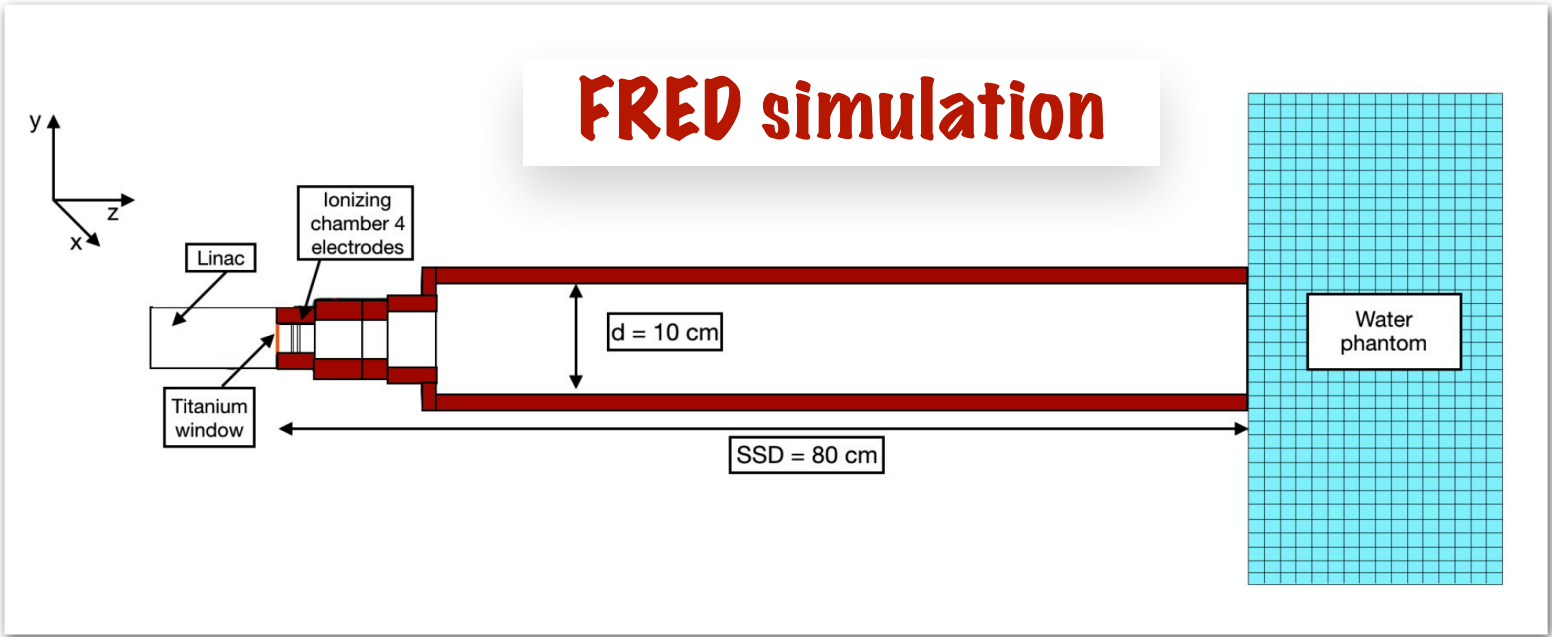
FRED-em

The **FRED** accuracy and timing performance were tested against state-of-art full MCs, such as **FLUKA** and **GEANT4**, in homogenous and **heterogenous** phantom and against **experimental data (IOeRT LINAC)**.



Timing Performance in water	FLUKA	GEANT4	FRED
e- @ 1 MeV	1.6e4 prim/s	1.3e3 prim/s	3.0e6 prim/s
e- @ 10 MeV	4.4e3 prim/s	2.2e2 prim/s	4.0e5 prim/s
e- @ 100 MeV	1.1e3 prim/s	4.8e1 prim/s	7.2e4 nrim/s

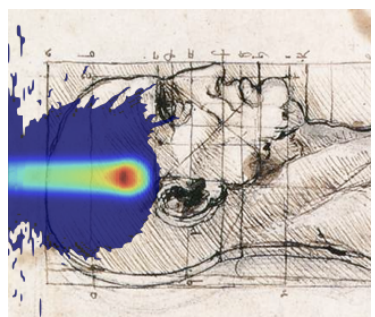
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IOeRT



FRED-em : IOeRT application



Collaborating with the S.I.T. company we have developed an online IOeRT TPS solving the lack of such software to date and opening the door to the clinical translation of IOeRT-FLASH treatments with pre-clinical and clinical trials.



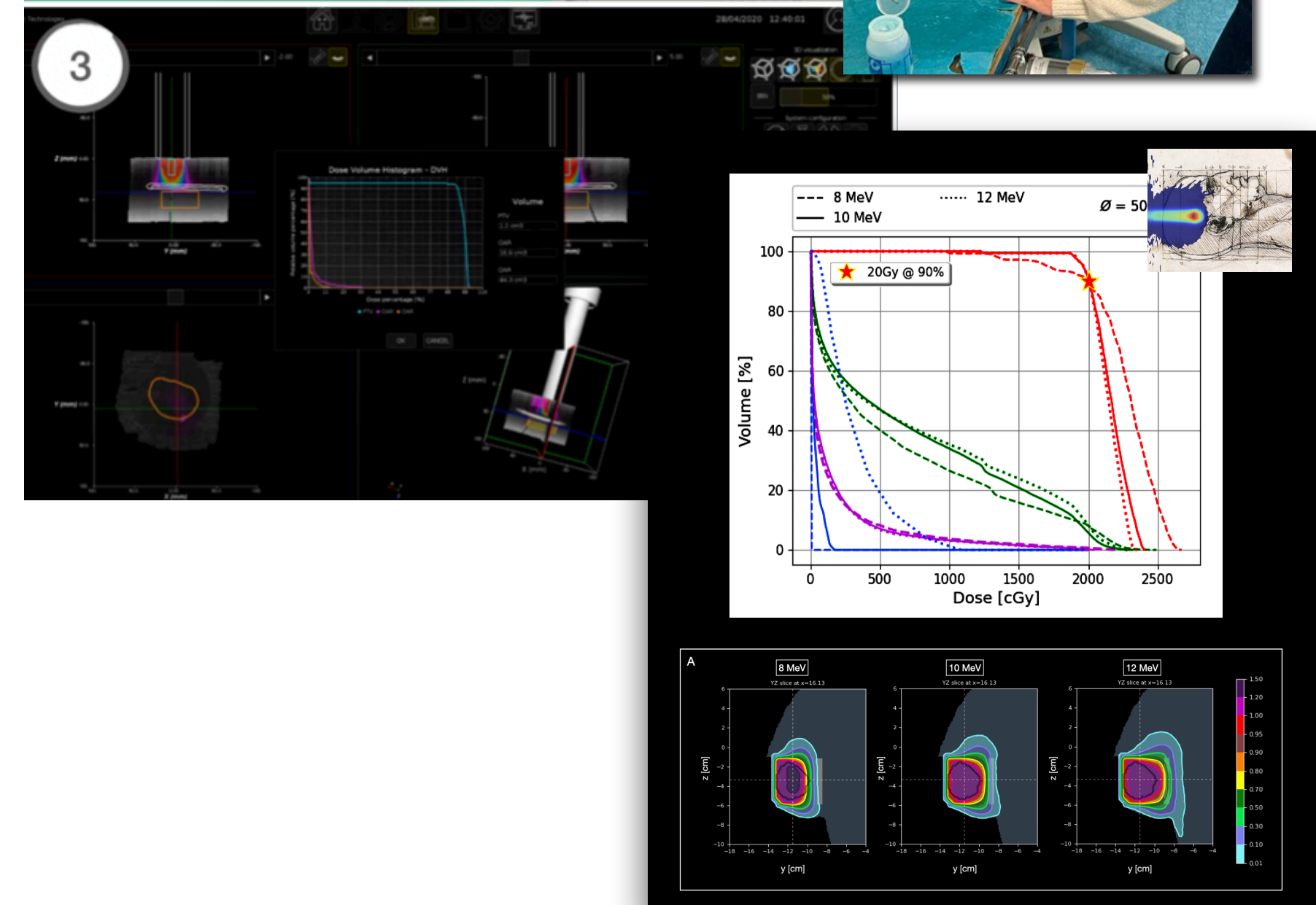
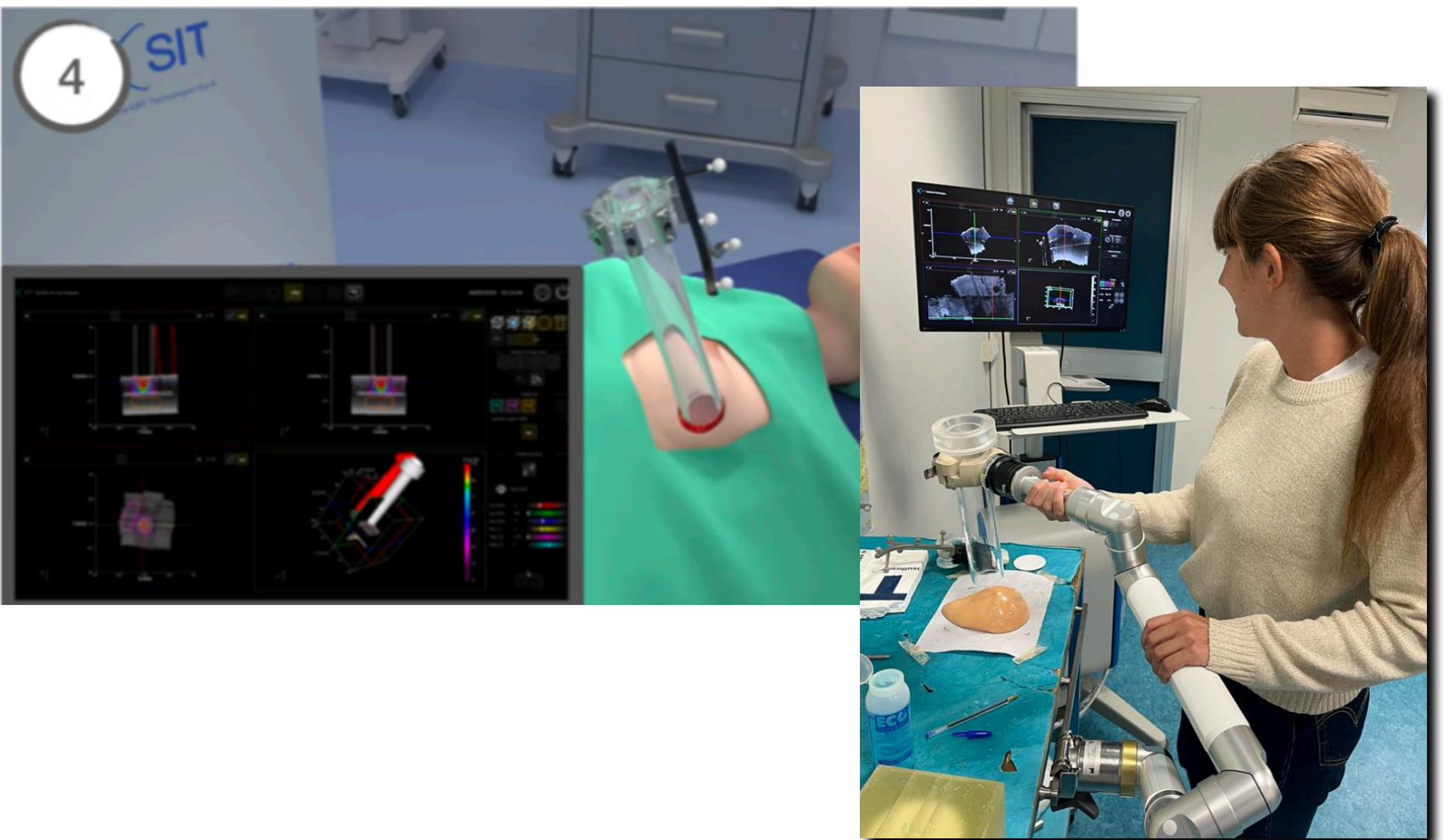
1 Identification of the regions of interest (**PTV** and **OARs**);

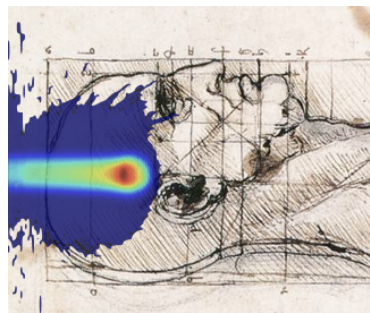
2 US imaging acquisition with the SIT online intra-operative image by means of the ECHO imaging system



3 Treatment **simulation** and optimization

4 Image guided docking to deliver the treatment exactly as it was planned in point 3.





Treatment Planning System VHEE FLASH

