In-vivo Dose Reconstruction with EPID Detectors in radiotherapy

7 June 2024, Pisa - Workshop on AI-based in-vivo dosimetry with EPID

C. Mozzi, University of Florence

Overview

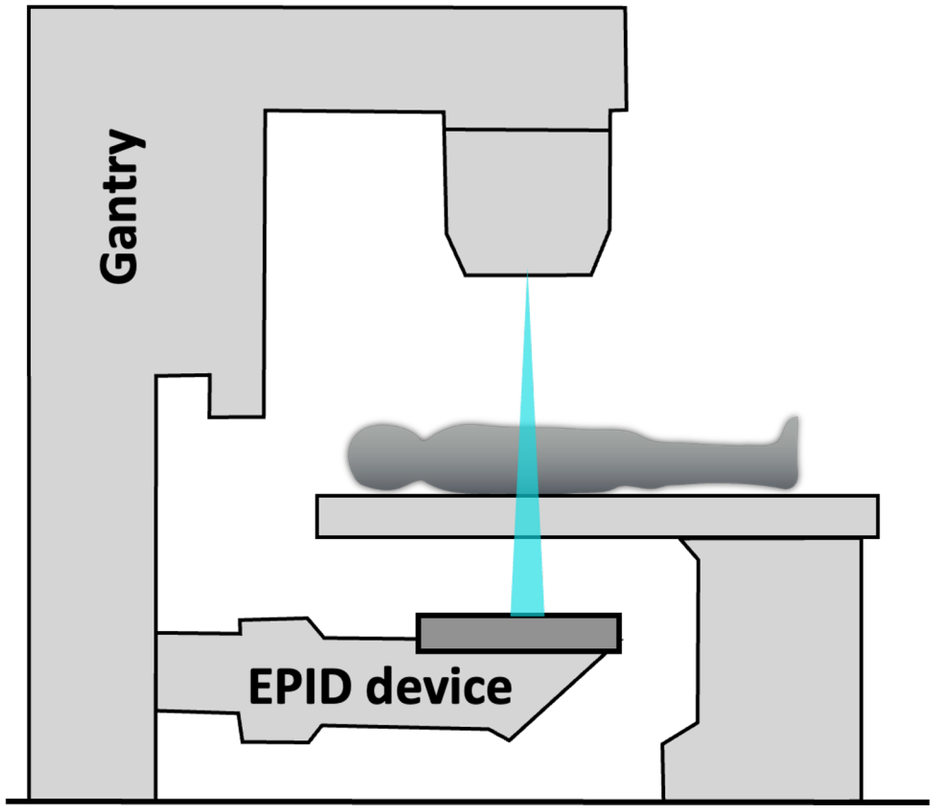
- **Introduction**
  - In vivo dosimetry with EPID
  - The InTrEPID project
- **Data collection**
  - EPID images
  - Portal Dose images
- **Database resume**

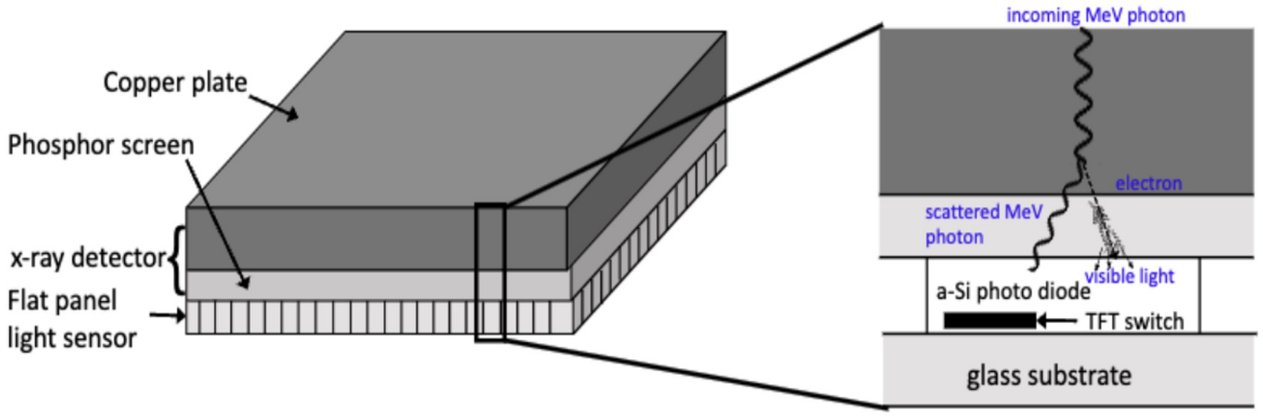
EPID for In-vivo dosimetry (IVD)

- **IVD** is an important quality assurance tool, measuring the dose during treatment and comparing it to the planned dose.

- **Electronic Portal Imaging Devices** (**EPID**) have gained prominence for **pre-treatment dose verification** and **real-time monitoring** in RT.

- However, **calibrating EPIDs is complex** due to their multi-layered structure, which differs from standard phantoms.





The InTrEPID project

The **In-vivo 3D dosimetry in radiotherapy Treatments with EPID** (**InTrEPID**) project born in October 2023 and lasting two years, is currently distributed across two locations (**University of Florence** and **INFN of Pisa**)

The InTrEPID project aims at developing a **Deep Learning**-based 3D in-vivo dose reconstruction framework based on EPID images acquired during dose delivery.

Unit 1: Data collection (UNIFI)

Cinzia Talamonti, Prof.

Icro Meattini, Prof.

Carlotta Mozzi, SSFM student

Michele Avanzo, CRO Aviano

Unit 2: AI model (INFN)

Alessandra Retico 1° Researcher

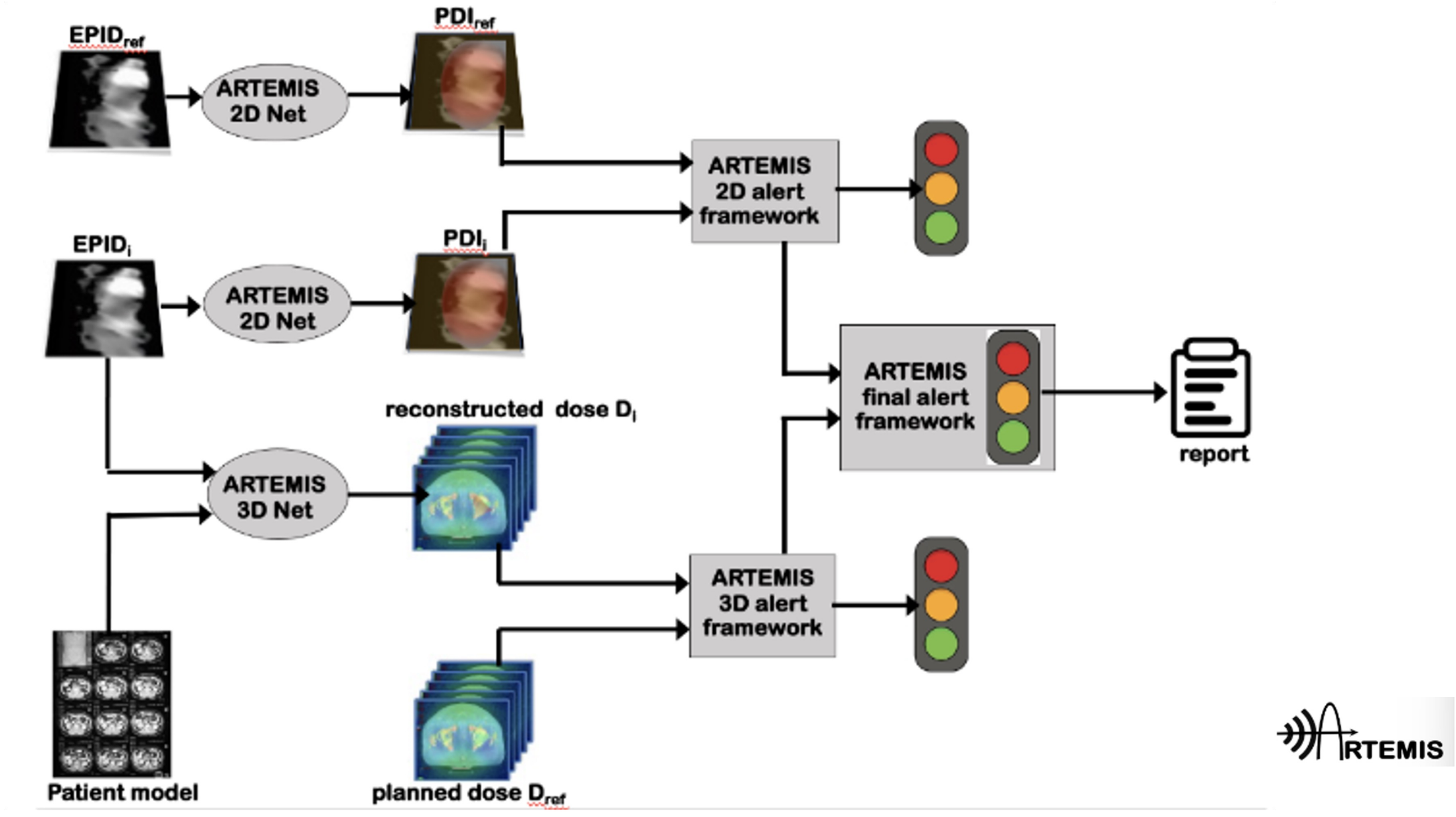
Aafke Kraan, Researcher

Silvia Arezzini, 1° Technologist

Lorenzo Marini, PhD student

The Artemis project

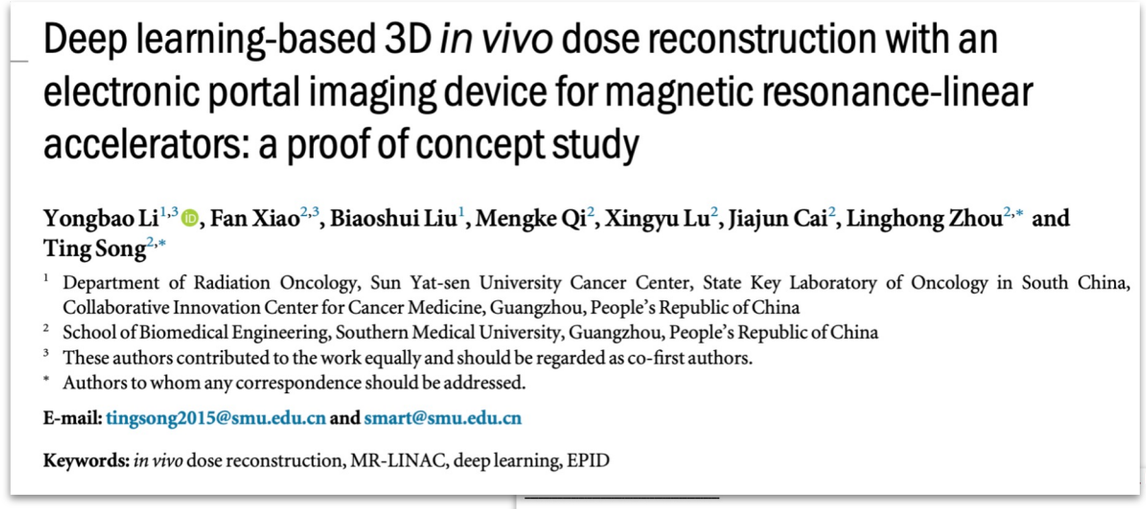
The **Artemis** project aims at developing also an alert framework to advise if the dose delivery is correct or not. Three years project, include patients treatments plans, funded by INFN.



Open issues

- **Artificial Intelligence** techniques have been explored in RT to address some challenges, including image segmentation and predictive models.

- This project will focus on recent implementations of **Deep Learning** (DL) techniques for predicting **2D/3D dose maps** based on EPID measurements.



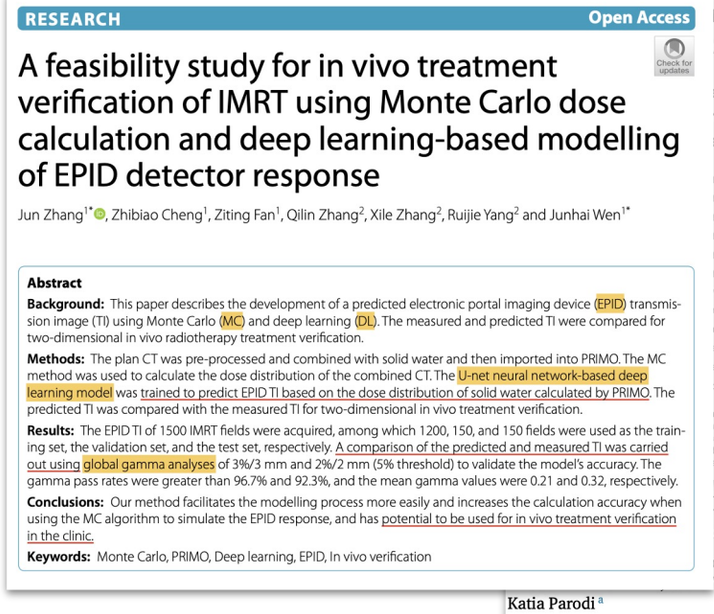
Deep learning-based 3D *in vivo* dose reconstruction with an electronic portal imaging device for magnetic resonance-linear accelerators: a proof of concept study

Yongbao Li[1,3], Fan Xiao[2,3], Biaoshui Liu[1], Mengke Qi[2], Xingyu Lu[2], Jiajun Cai[2], Linghong Zhou[2,*] and Ting Song[2,*]

[1] Department of Radiation Oncology, Sun Yat-sen University Cancer Center, State Key Laboratory of Oncology in South China, Collaborative Innovation Center for Cancer Medicine, Guangzhou, People's Republic of China
[2] School of Biomedical Engineering, Southern Medical University, Guangzhou, People's Republic of China
[3] These authors contributed to the work equally and should be regarded as co-first authors.
[*] Authors to whom any correspondence should be addressed.

E-mail: tingsong2015@smu.edu.cn and smart@smu.edu.cn

Keywords: *in vivo* dose reconstruction, MR-LINAC, deep learning, EPID



RESEARCH Open Access

A feasibility study for in vivo treatment verification of IMRT using Monte Carlo dose calculation and deep learning-based modelling of EPID detector response

Jun Zhang[1*], Zhibiao Cheng[1], Ziting Fan[1], Qilin Zhang[2], Xile Zhang[2], Ruijie Yang[2] and Junhai Wen[1*]

Abstract

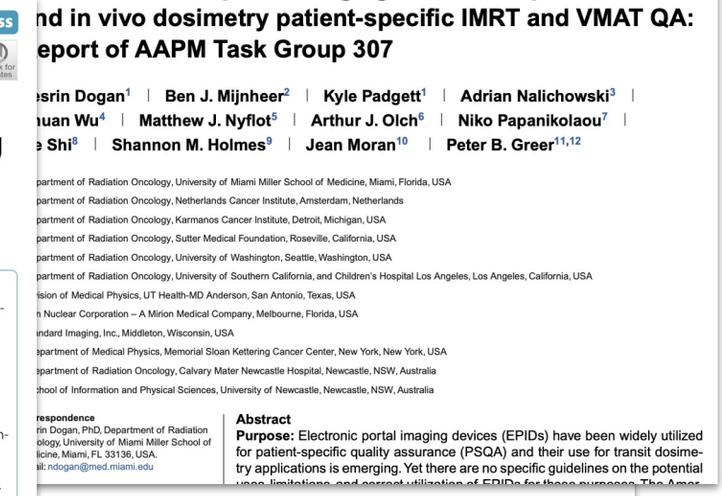
Background: This paper describes the development of a predicted electronic portal imaging device (EPID) transmission image (TI) using Monte Carlo (MC) and deep learning (DL). The measured and predicted TI were compared for two-dimensional in vivo radiotherapy treatment verification.

Methods: The plan CT was pre-processed and combined with solid water and then imported into PRIMO. The MC method was used to calculate the dose distribution of the combined CT. The U-net neural network-based deep learning model was trained to predict EPID TI based on the dose distribution of solid water calculated by PRIMO. The predicted TI was compared with the measured TI for two-dimensional in vivo treatment verification.

Results: The EPID TI of 1500 IMRT fields were acquired, among which 1200, 150, and 150 fields were used as the training set, the validation set, and the test set, respectively. A comparison of the predicted and measured TI was carried out using global gamma analyses of 3%/3 mm and 2%/2 mm (5% threshold) to validate the model's accuracy. The gamma pass rates were greater than 96.7% and 92.3%, and the mean gamma values were 0.21 and 0.32, respectively.

Conclusions: Our method facilitates the modelling process more easily and increases the calculation accuracy when using the MC algorithm to simulate the EPID response, and has potential to be used for in vivo treatment verification in the clinic.

Keywords: Monte Carlo, PRIMO, Deep learning, EPID, In vivo verification



PHYSICS

Use of electronic portal imaging devices for pre-treatment nd in vivo dosimetry patient-specific IMRT and VMAT QA: eport of AAPM Task Group 307

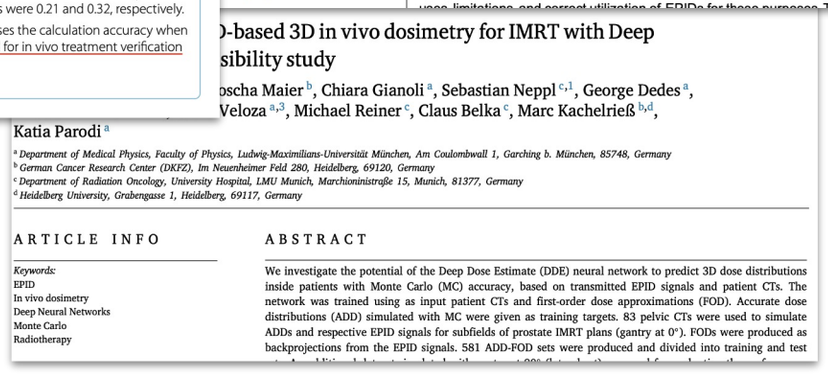
srin Dogan[1] | Ben J. Mijnheer[2] | Kyle Padgett[1] | Adrian Nalichowski[3] | uan Wu[4] | Matthew J. Nyflot[5] | Arthur J. Olch[6] | Niko Papanikolaou[7] | e Shi[8] | Shannon M. Holmes[9] | Jean Moran[10] | Peter B. Greer[11,12]

partment of Radiation Oncology, University of Miami Miller School of Medicine, Miami, Florida, USA
partment of Radiation Oncology, Netherlands Cancer Institute, Amsterdam, Netherlands
partment of Radiation Oncology, Karmanos Cancer Institute, Detroit, Michigan, USA
partment of Radiation Oncology, Sutter Medical Foundation, Roseville, California, USA
partment of Radiation Oncology, University of Washington, Seattle, Washington, USA
partment of Radiation Oncology, University of Southern California, and Children's Hospital Los Angeles, Los Angeles, California, USA
sion of Medical Physics, UT Health-MD Anderson, San Antonio, Texas, USA
n Nuclear Corporation – A Mirion Medical Company, Melbourne, Florida, USA
ndard Imaging, Inc., Middleton, Wisconsin, USA
partment of Medical Physics, Memorial Sloan Kettering Cancer Center, New York, New York, USA
partment of Radiation Oncology, Calvary Mater Newcastle Hospital, Newcastle, NSW, Australia
chool of Information and Physical Sciences, University of Newcastle, Newcastle, NSW, Australia

respondence
rin Dogan, PhD, Department of Radiation
ology, University of Miami Miller School of
icine, Miami, FL 33136, USA.
il: ndogan@med.miami.edu

Abstract

Purpose: Electronic portal imaging devices (EPIDs) have been widely utilized for patient-specific quality assurance (PSQA) and their use for transit dosimetry applications is emerging. Yet there are no specific guidelines on the potential



)-based 3D in vivo dosimetry for IMRT with Deep sibility study

oscha Maier [b], Chiara Gianoli [a], Sebastian Neppl [c,1], George Dedes [a], Veloza [a,3], Michael Reiner [c], Claus Belka [c], Marc Kachelrieß [b,d], Katia Parodi [a]

[a] Department of Medical Physics, Faculty of Physics, Ludwig-Maximilians-Universität München, Am Coulombwall 1, Garching b. München, 85748, Germany
[b] German Cancer Research Center (DKFZ), Im Neuenheimer Feld 280, Heidelberg, 69120, Germany
[c] Department of Radiation Oncology, University Hospital, LMU Munich, Marchioninistraße 15, Munich, 81377, Germany
[d] Heidelberg University, Grabengasse 1, Heidelberg, 69117, Germany

ARTICLE INFO

Keywords:
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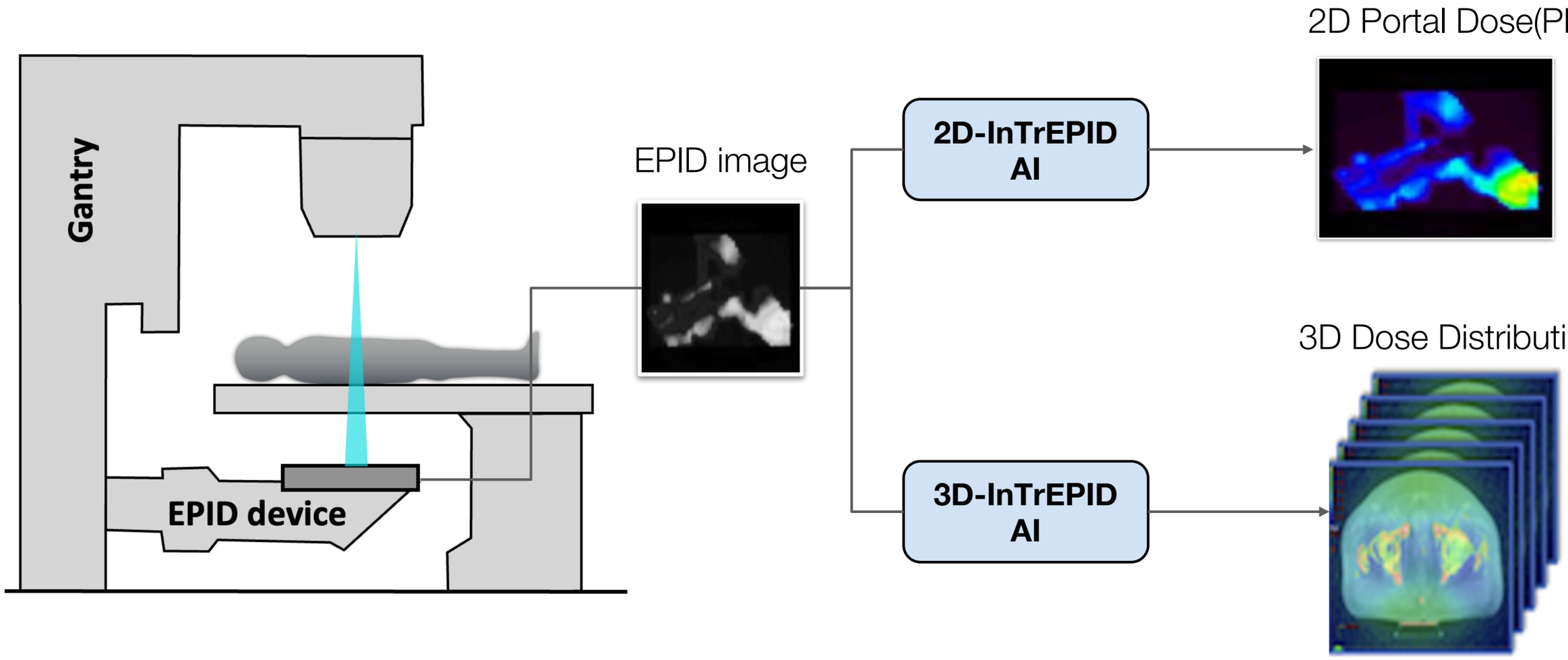
In vivo dosimetry
Deep Neural Networks
Monte Carlo
Radiotherapy

ABSTRACT

We investigate the potential of the Deep Dose Estimate (DDE) neural network to predict 3D dose distributions inside patients with Monte Carlo (MC) accuracy, based on transmitted EPID signals and patient CTs. The network was trained using as input patient CTs and first-order dose approximations (FOD). Accurate dose distributions (ADD) simulated with MC were given as training targets. 83 pelvic CTs were used to simulate ADDs and respective EPID signals for subfields of prostate IMRT plans (gantry at 0°). FODs were produced as backprojections from the EPID signals. 581 ADD-FOD sets were produced and divided into training and test

The InTrEPID project: the goal

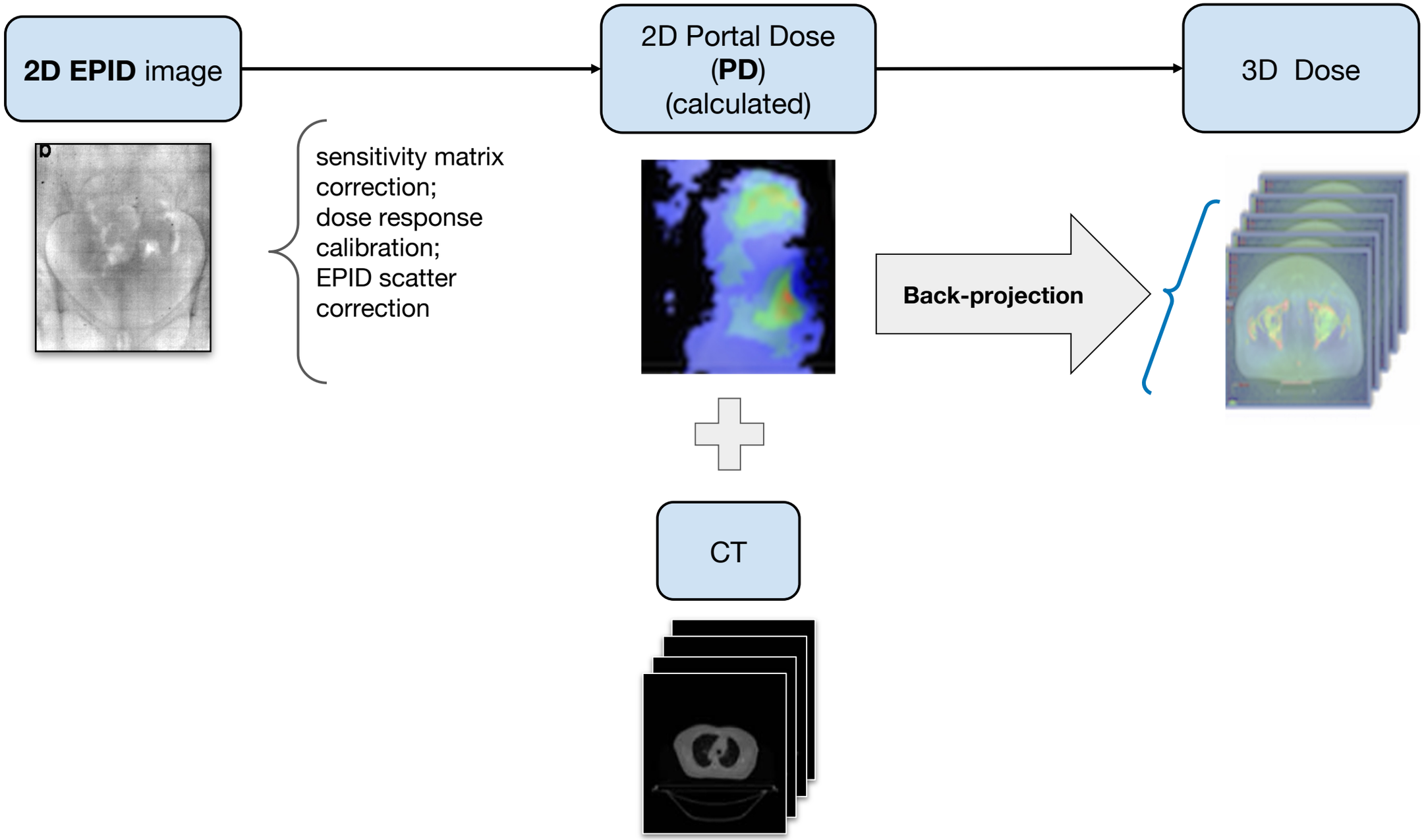


1. The **EPID** image is acquired during the treatment and then transformed in **PD** by the **2D-InTrEPID** AI system.

2. **EPID** + **CT** slices as input of the **3D-InTrEPID** → prediction of the 3D dose distribution

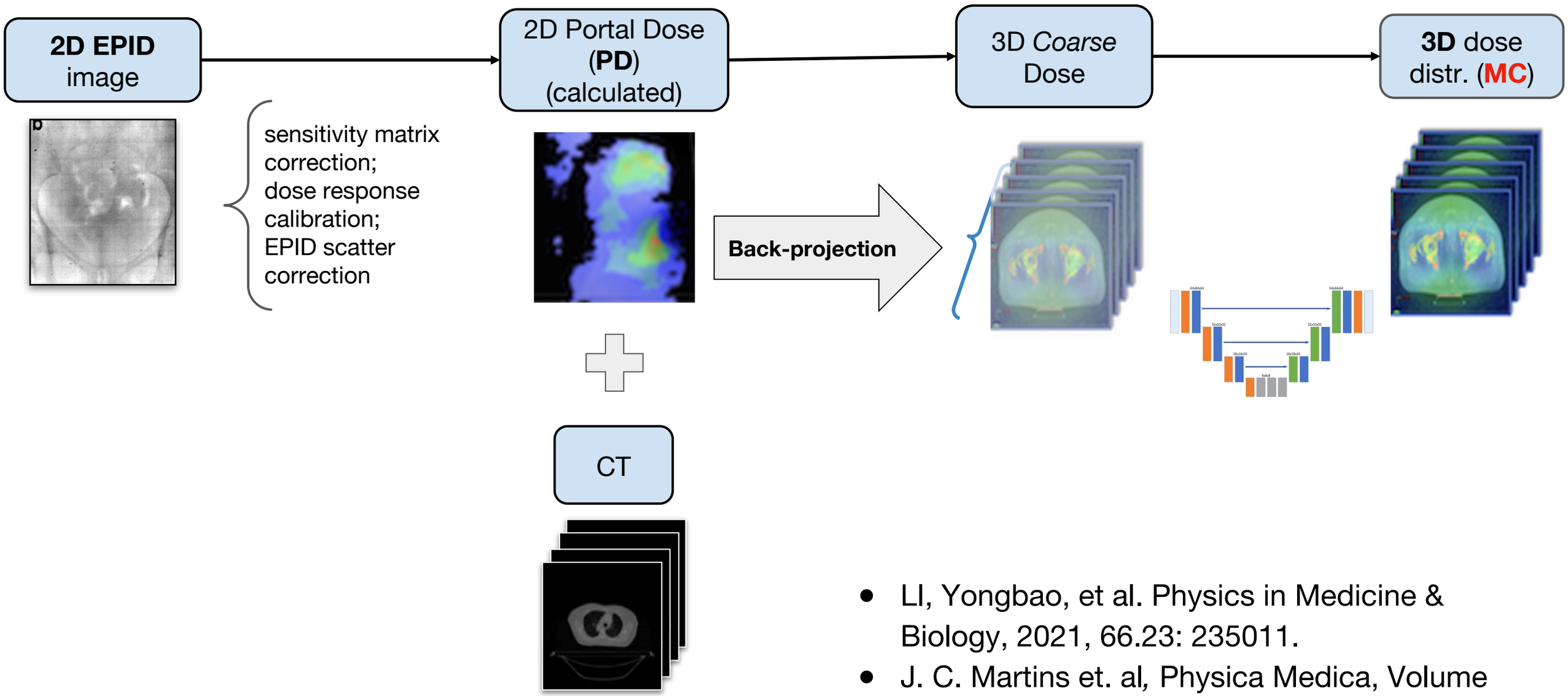
Traditional and Deep Learning approach

Traditional approach



Traditional and Deep Learning approach

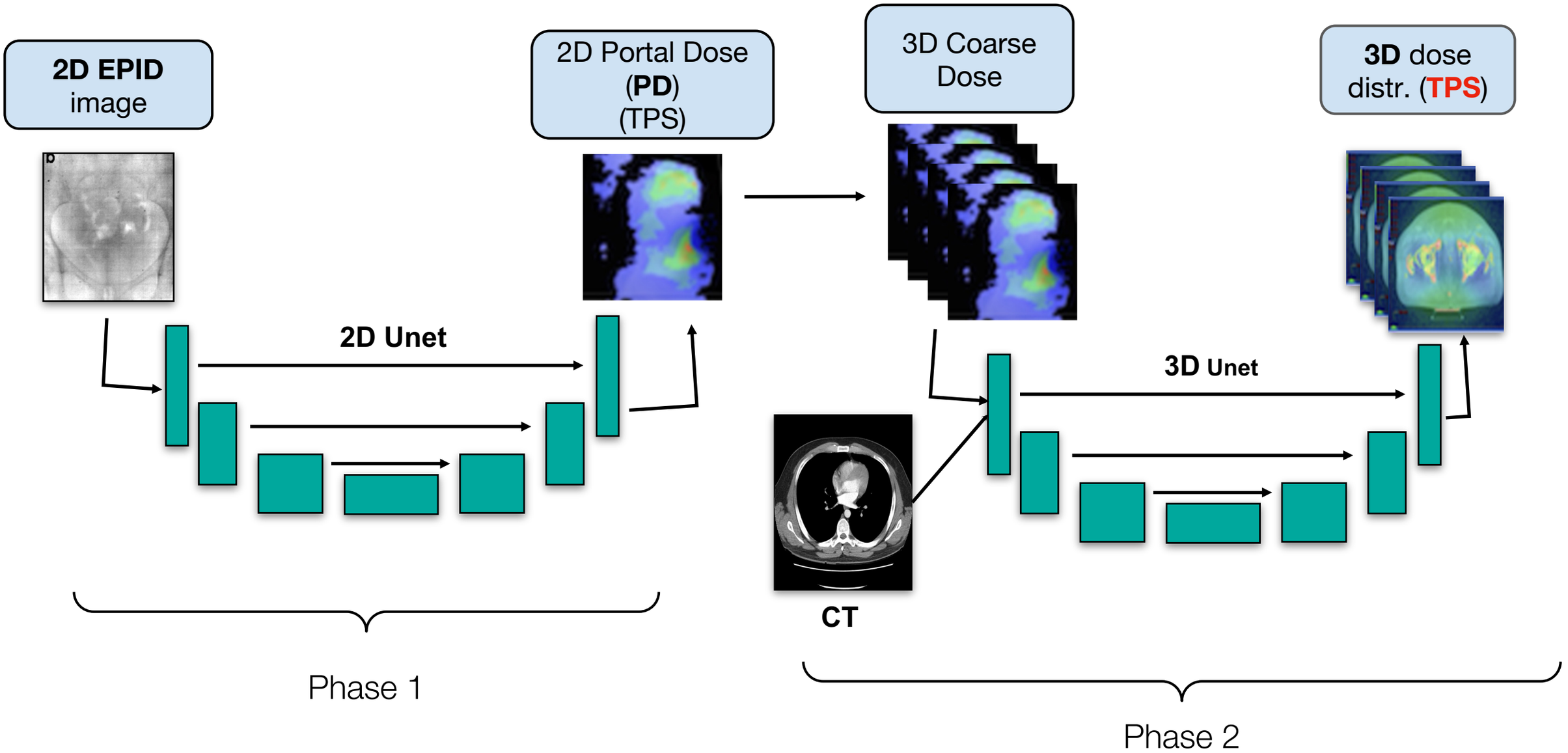
Deep Learning: state-of-arts



- LI, Yongbao, et al. Physics in Medicine & Biology, 2021, 66.23: 235011.
- J. C. Martins et. al, Physica Medica, Volume 114, October 2023, 103148

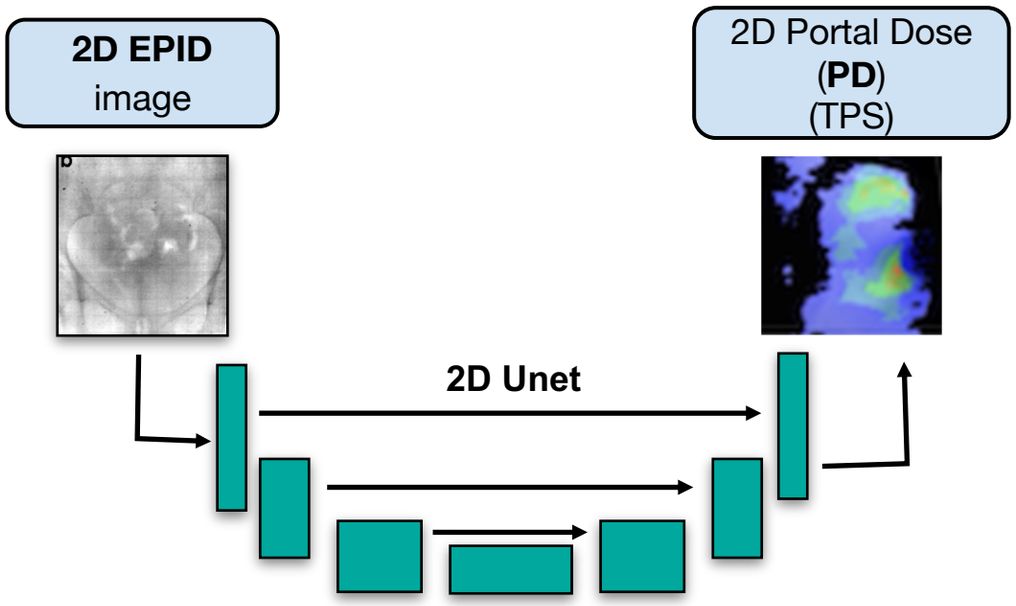
InTrEpid Deep Learning approach

DL approach



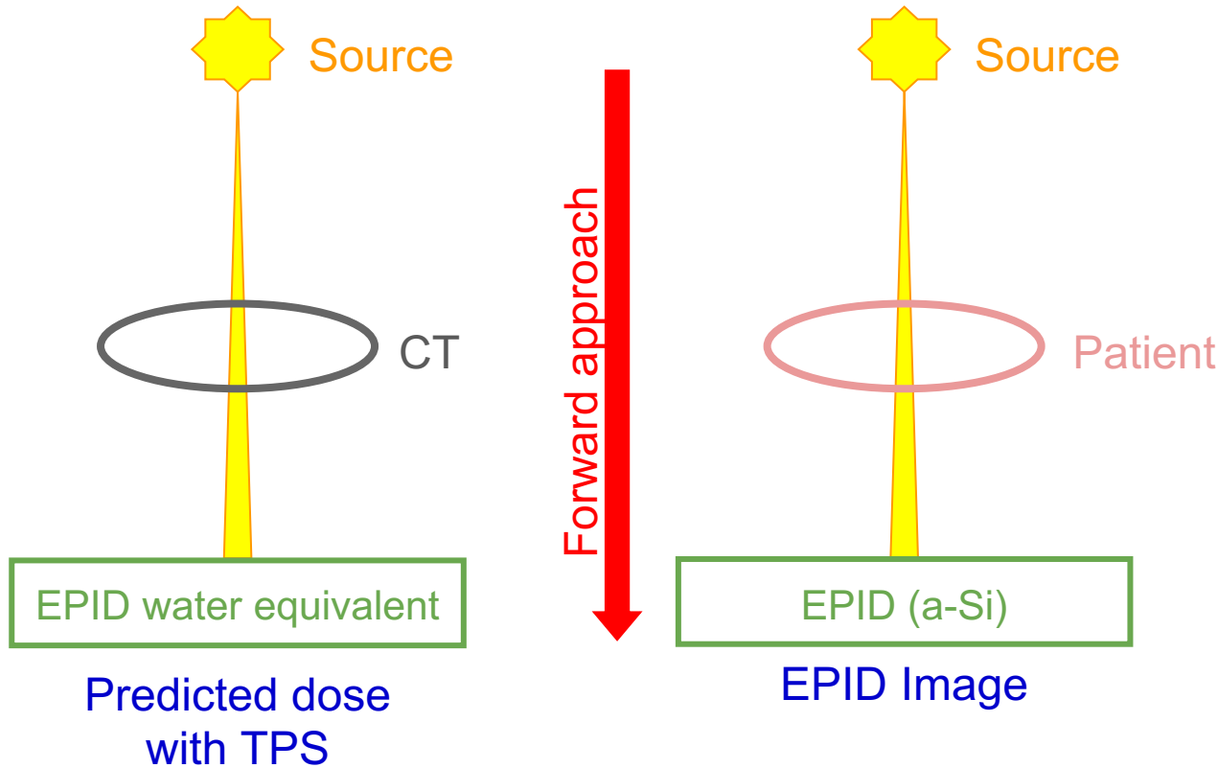
Data collection: Dataset

Phase 1



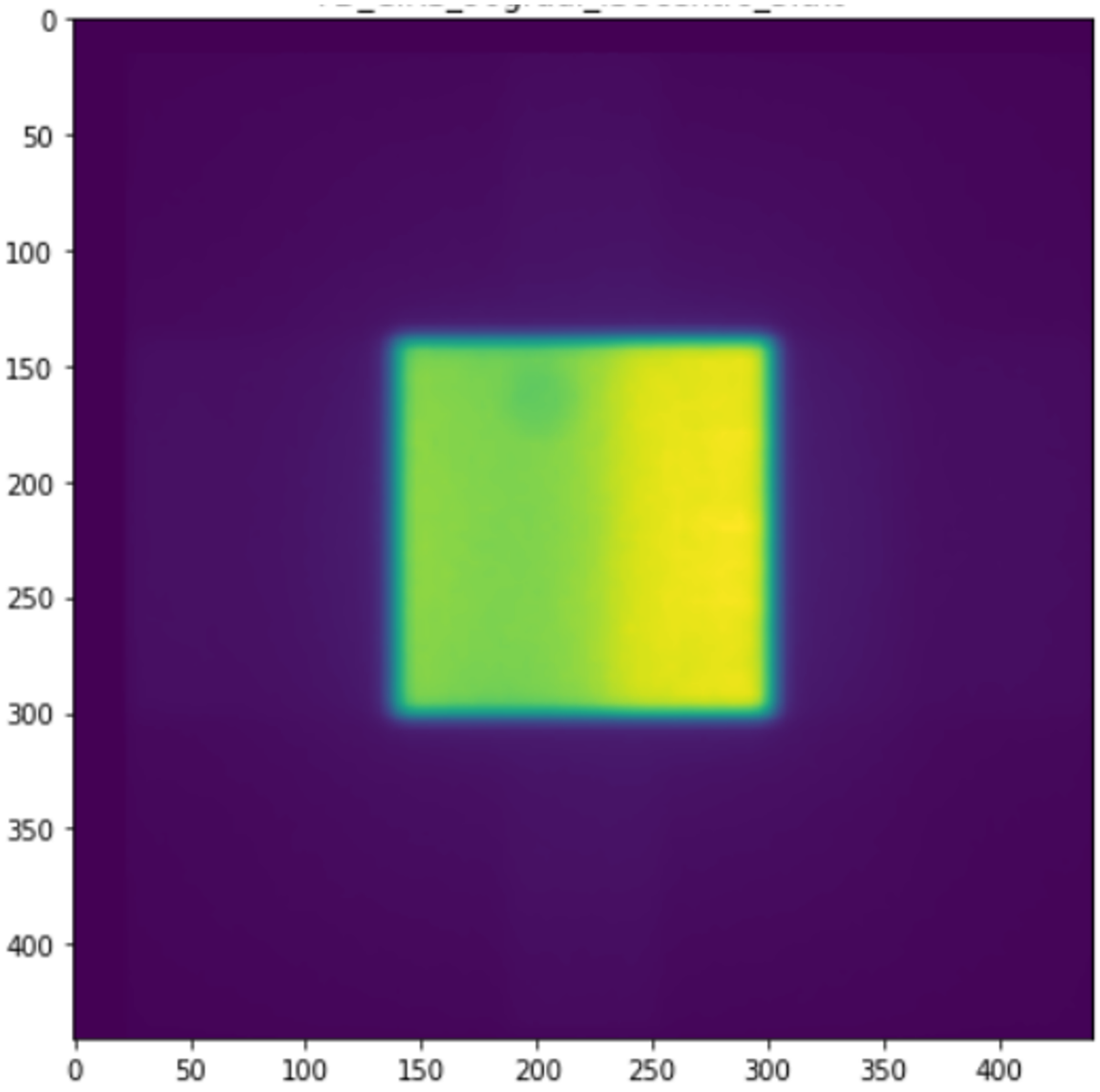
How to train the **U-net architecture**?

We need a set of data composed by pairs of EPID data and calculated PD image.

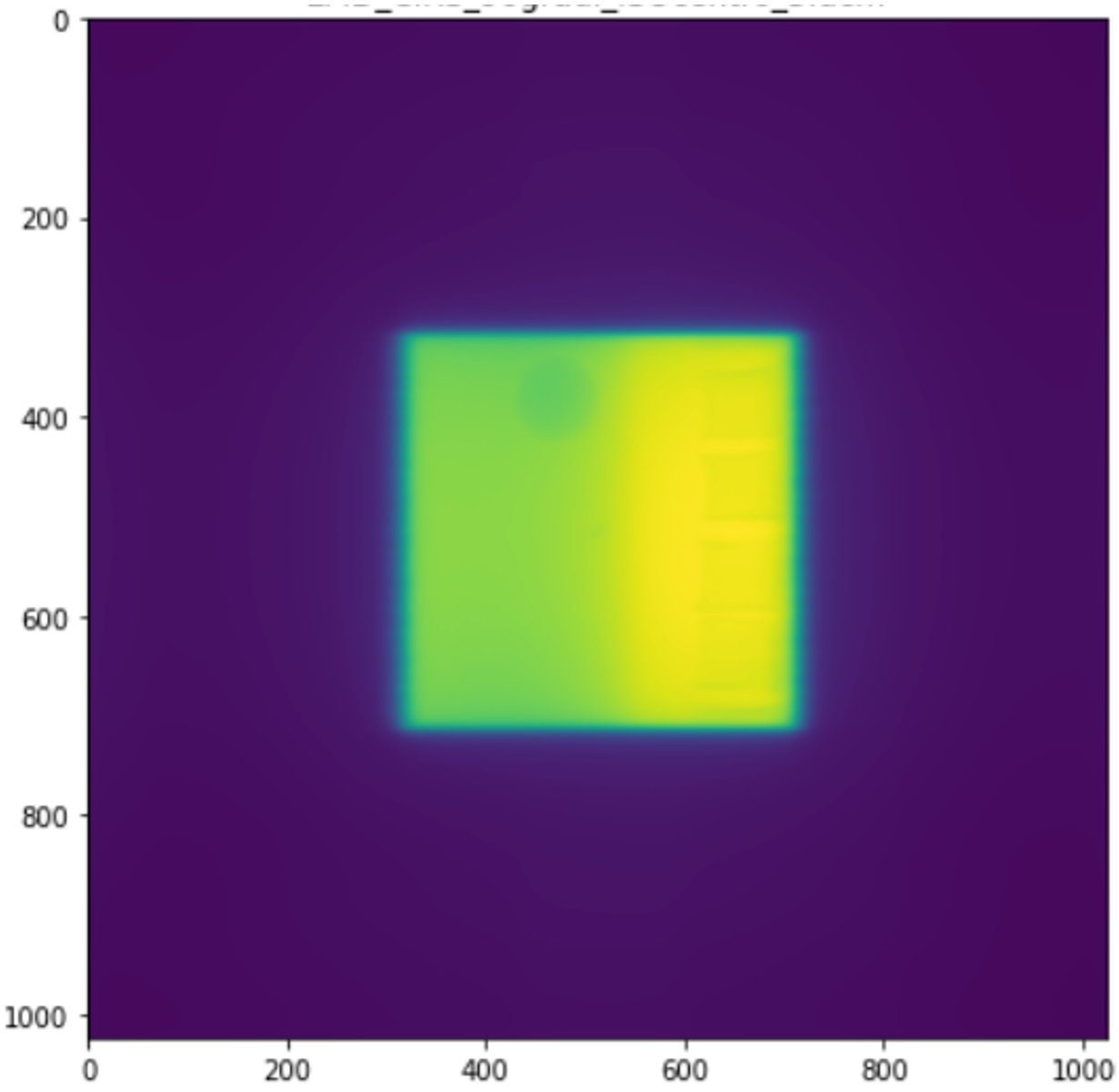


Data collection: Dataset

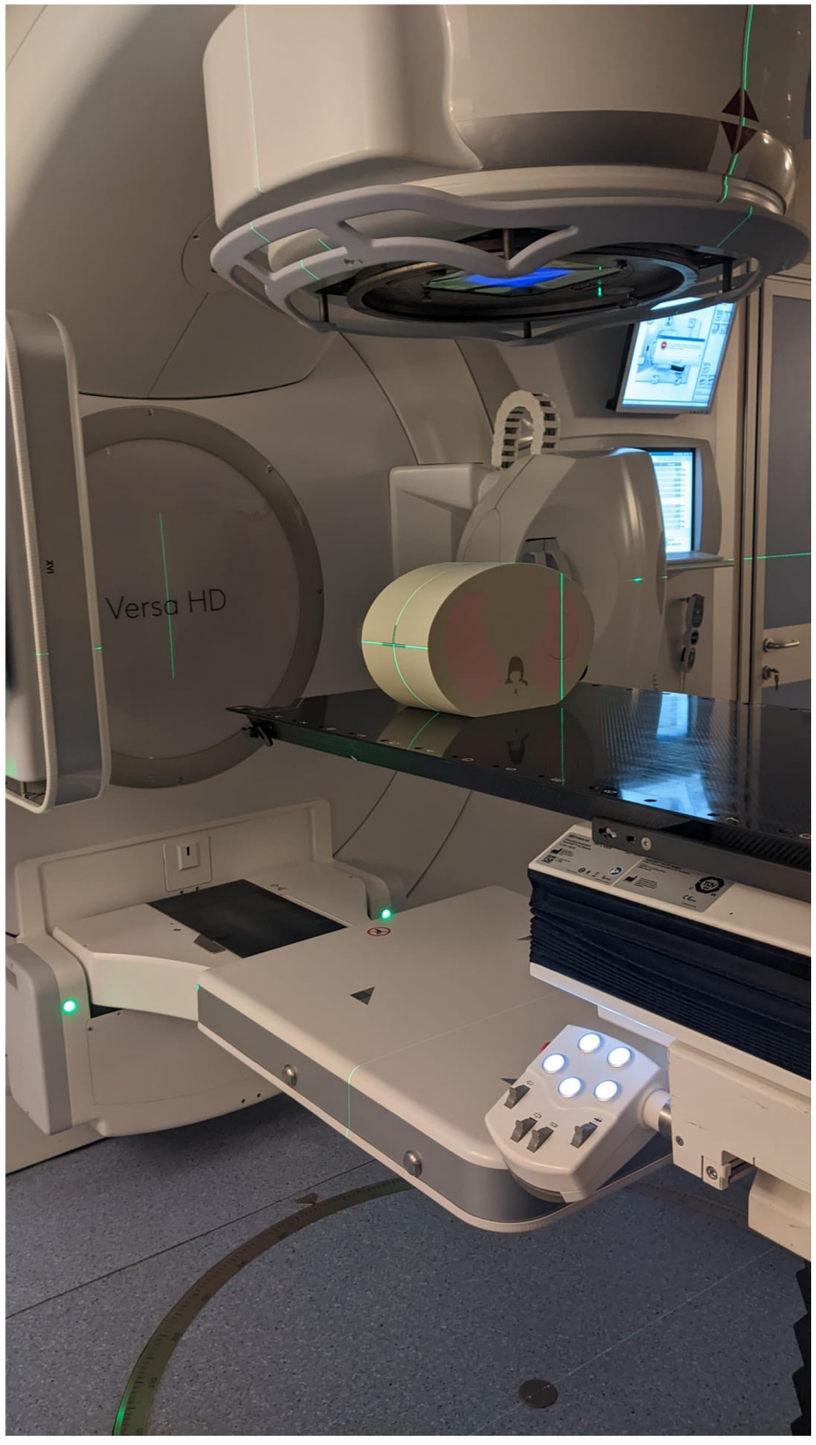
TPS



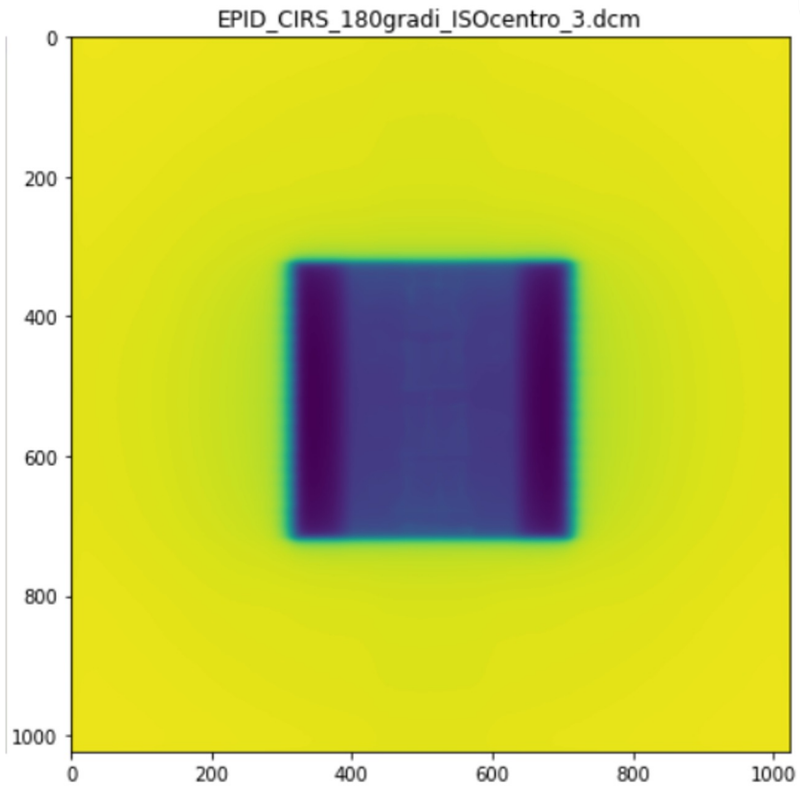
EPID

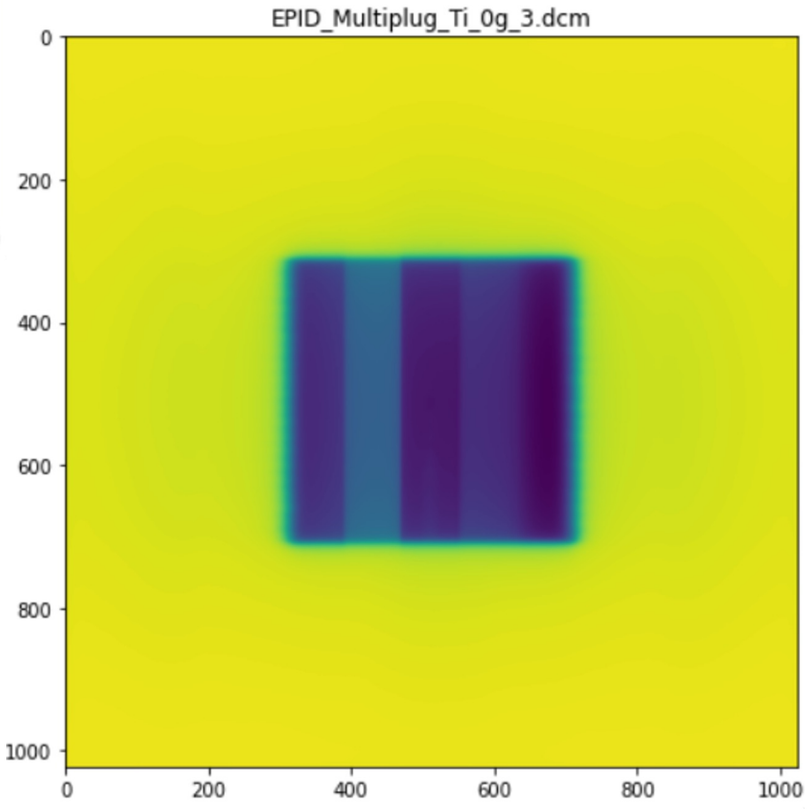


Data collection: EPID images



2D EPID
Examples





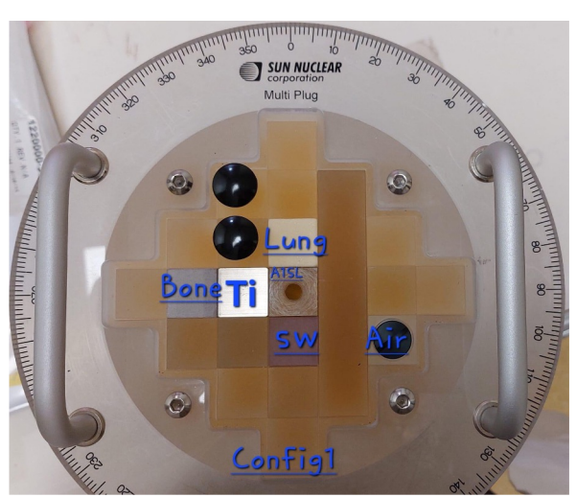
Data collection: EPID images

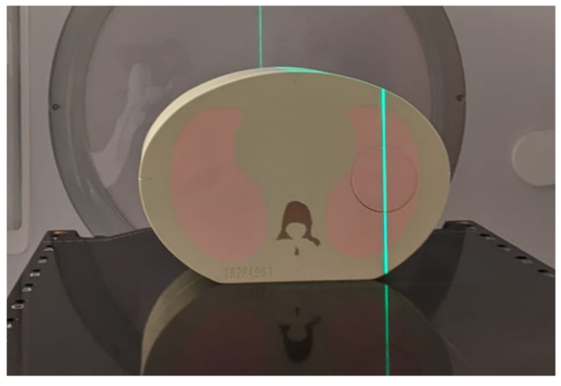
We have delivered 32 treatment plans using 6 MV X-ray beams at VersaHD Elekta Linac (Careggi Hospital)

Each plan consist of 4 beams with different size (2x2, 5x5,10x10,20x20 cm2) and 100 MU each.

Phantom used:

- anthropomorphic
- homogeneous SLAB
- SLAB with inhomogeneities
- Multiplug with different insert (Ti, Bone, Lung)





Data collection: PD images (TPS)

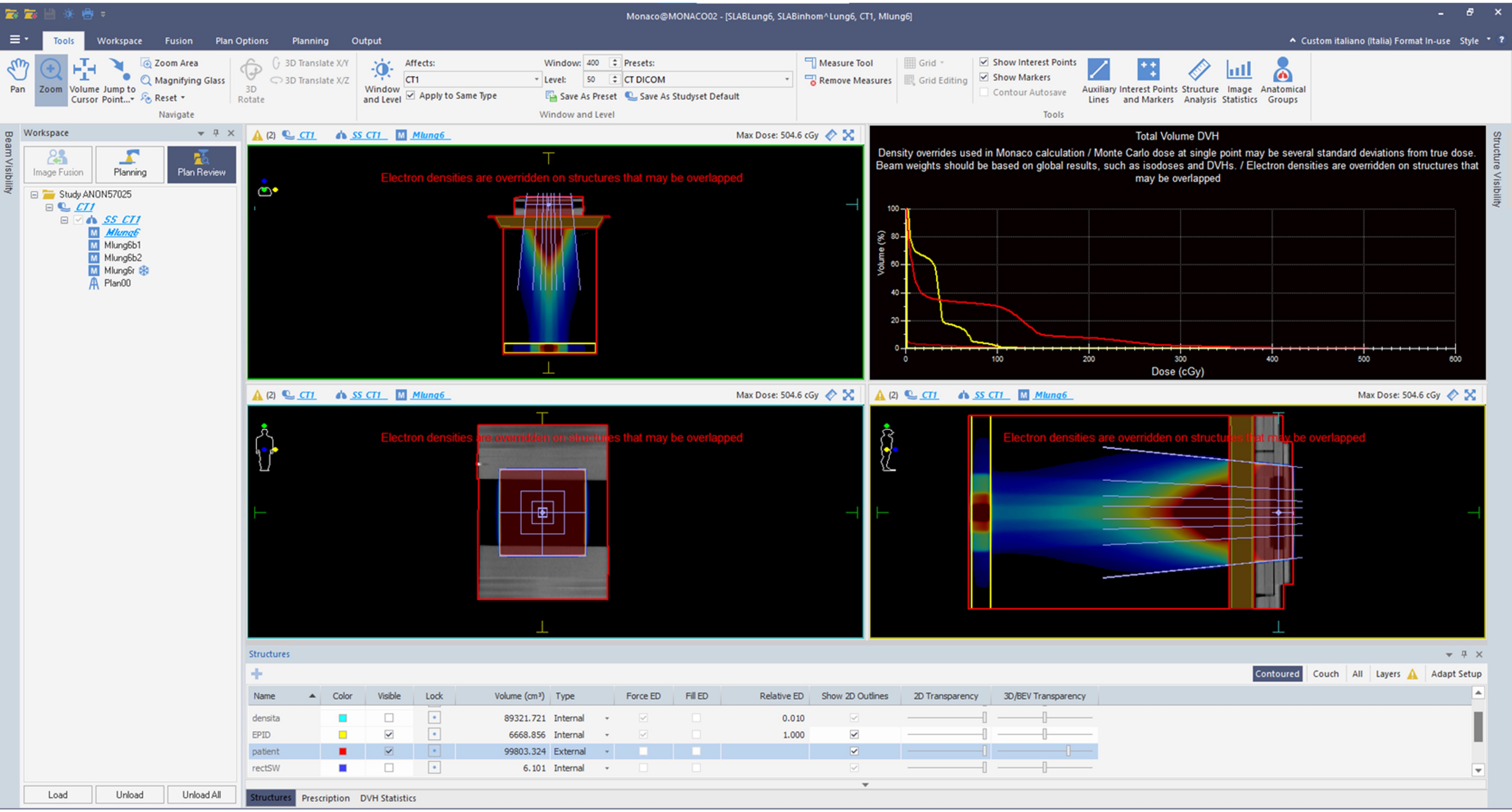
How to obtain **PD image**?

Complex calibration for EPID in dose → After conversion in **water equivalent** thickness, we use **TPS Monaco** to calculate dose at plane of EPID (forward approach)

About Monaco TPS:

- Monte Carlo based
- developed by Elekta
- research software version

Data collection: PD images (TPS)

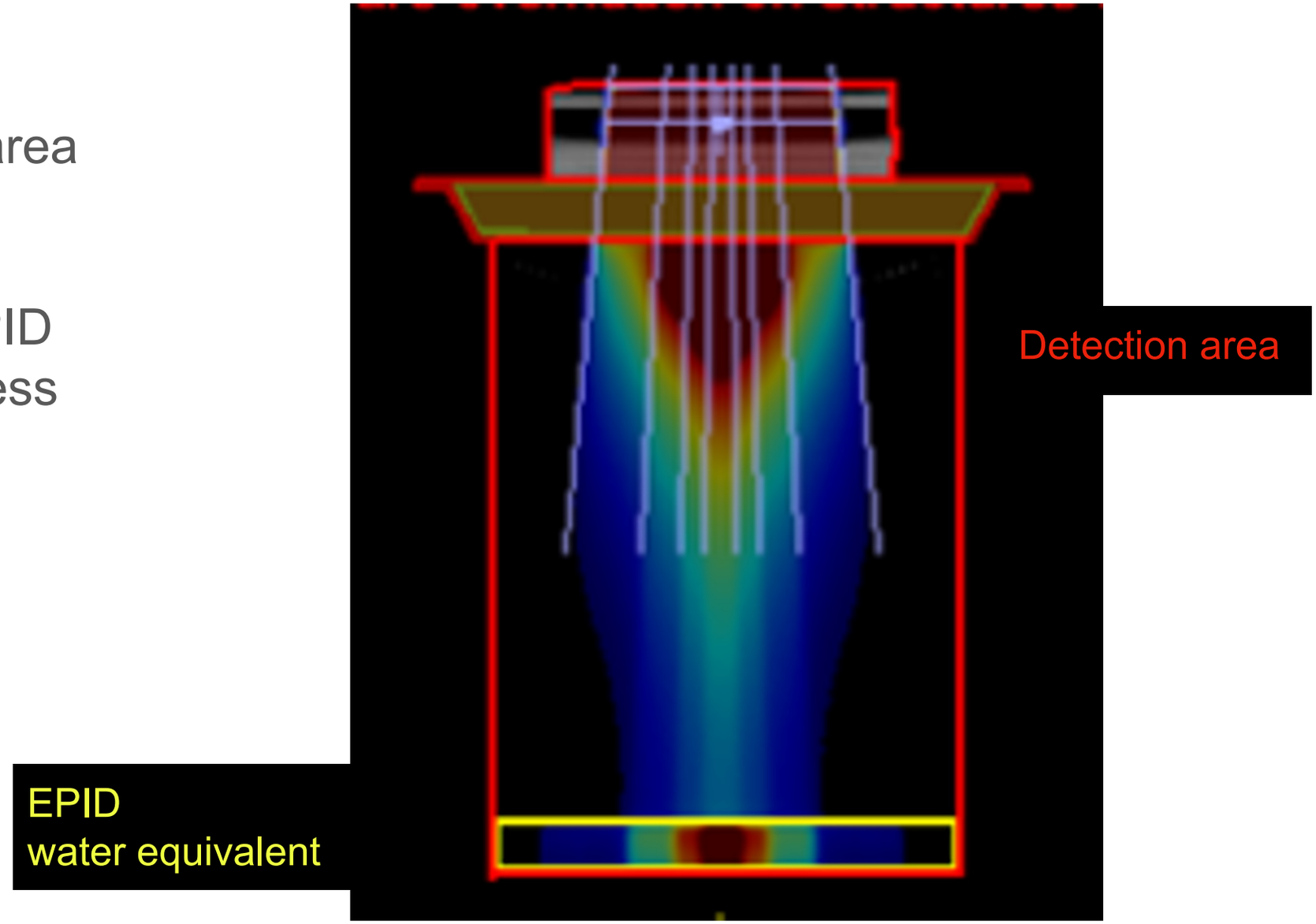


Data collection: PD images (TPS)

1. Extension of detection area beyond CT

2. Positinate the virtual EPID water equivalent thickness (4 cm of thickness)

3. Dose calculation

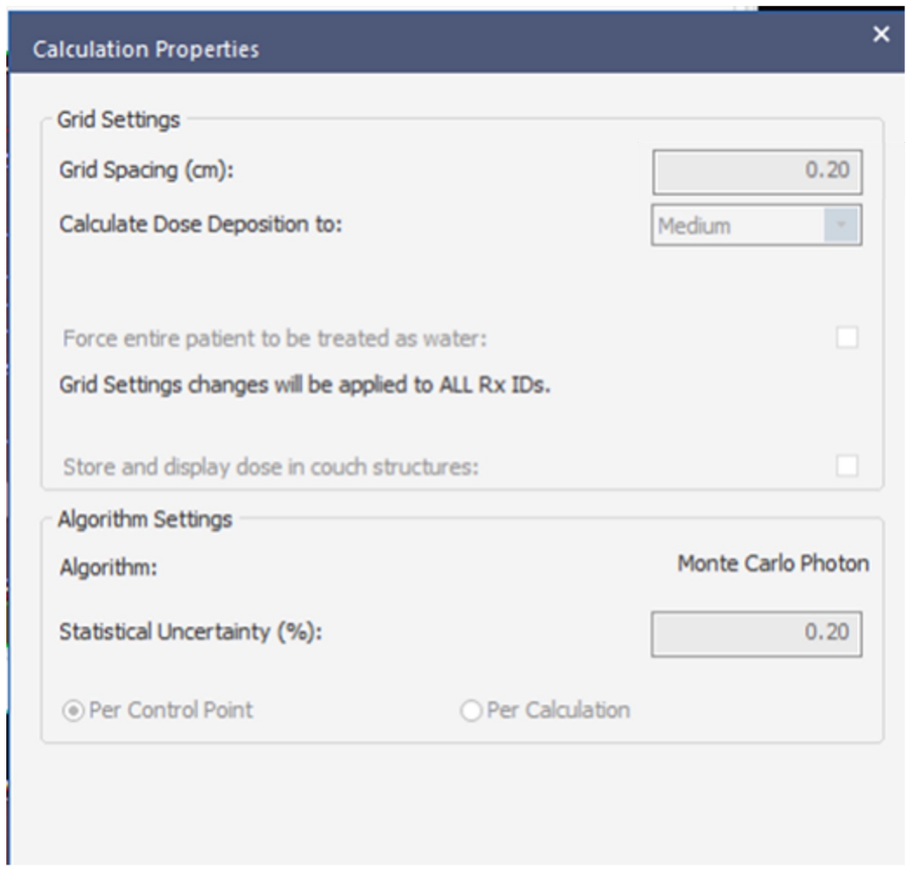


Data collection: PD images (TPS)

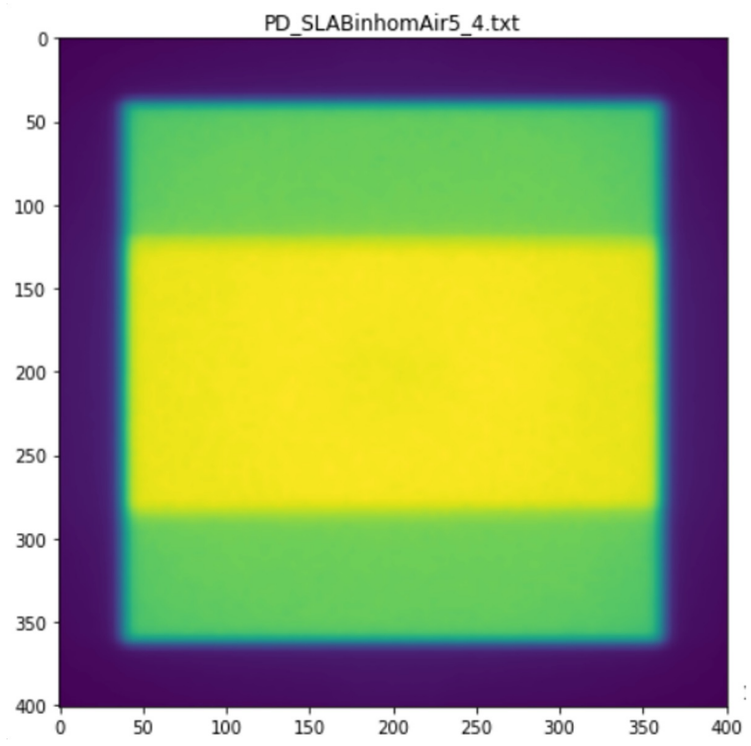
File.txt as output:

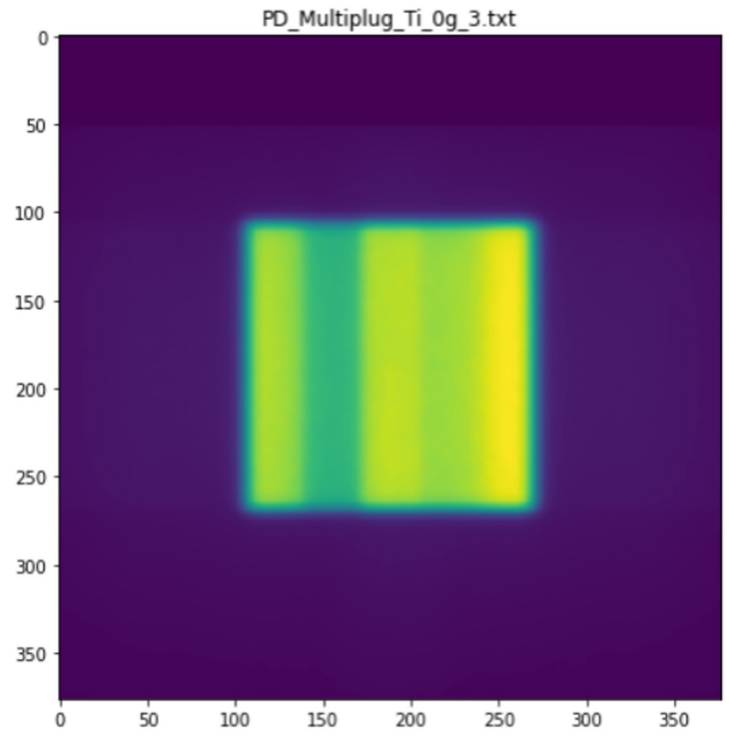
Calculation Grid Resolution
(x,y,z) 2.0,2.0,2.0 mm

DoseUnits, cGy



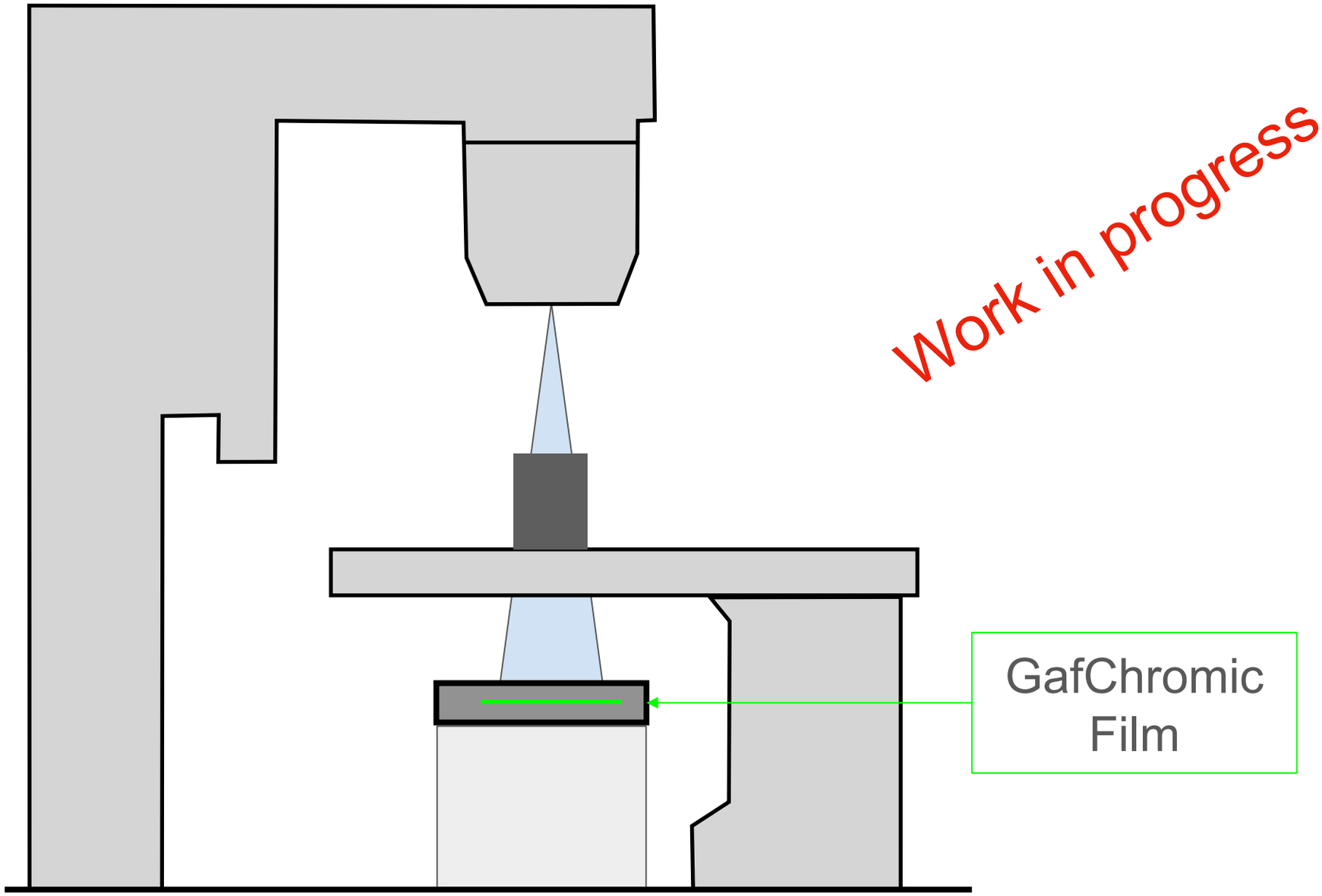
2D Dose Portale (**PD**)
Examples





TPS Portal dose verification

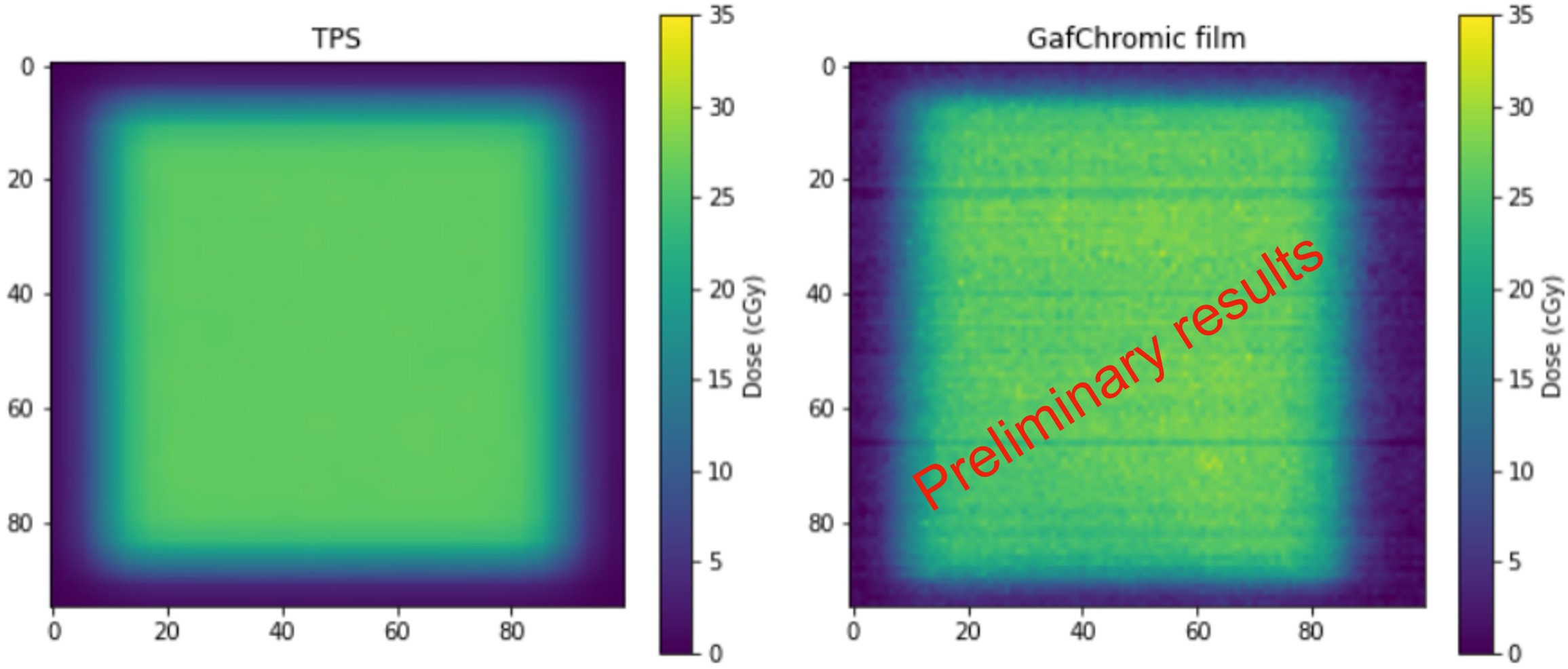
Acquired some Portal Dose with Gafchromic to be compared with Portal Dose computed by TPS.



Work in progress…

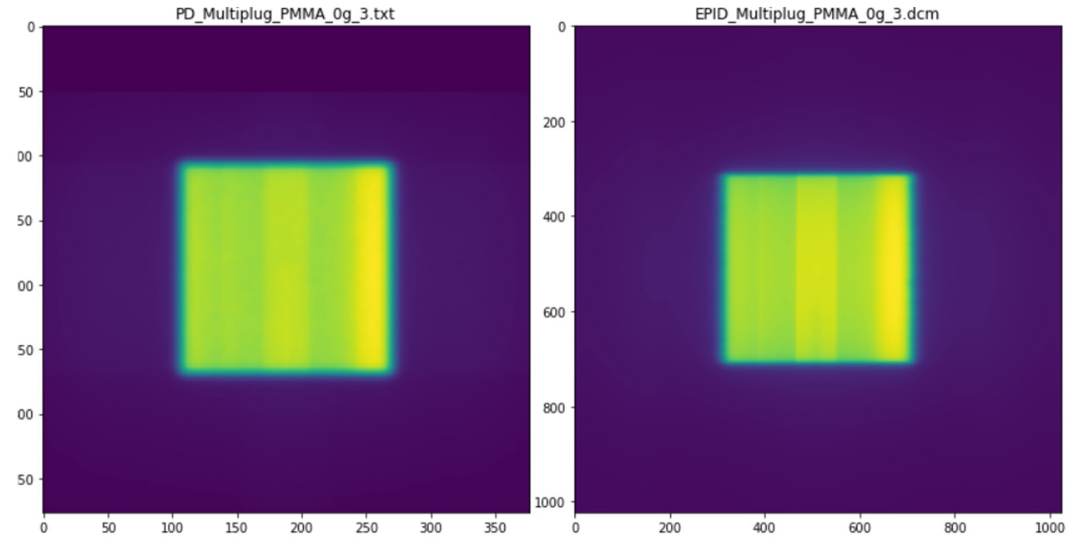
TPS Portal dose verification

Examples:



Dataset

Collection of 128 pair of EPID and TPS portal dose images used for train 2D InTrEpid U-net.



Future plan:

- Increase the dataset
- Changing shape of beams
- Changing Energy (10MV, 6FFF)
- New phantoms
- Vmat treatments

Thank you for your attention