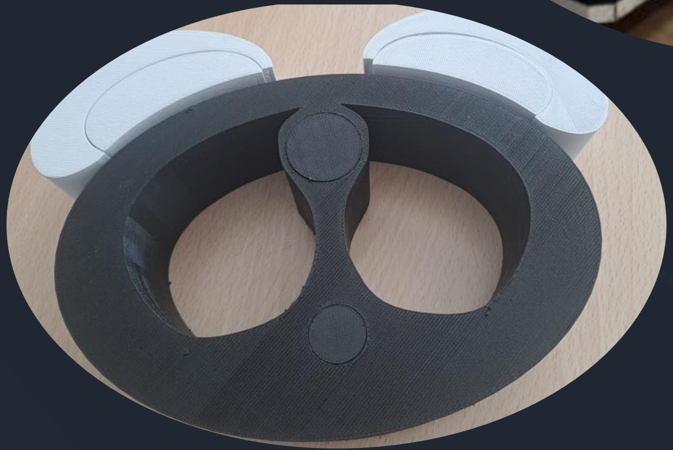
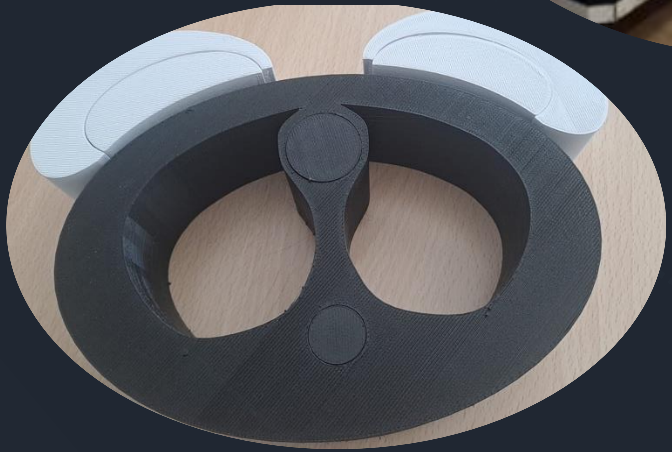
ARTEMIS



Overview

- Reminder of ARTEMIS (goals, group, organization)
- WP1:
  - Results for 2025
  - Summary
- WP2:
  - Results for 2025
  - Summary
- WP3:
  - Results for 2026
  - Summary
- Summary of funding for 2025
- Requests for funding for 2026
- Conclusions



ARTEMIS: sigla CSN5 INFN

Personale 2025

INFN Pisa

- Aafke Kraan (RN)
- Alessandra Retico
- Francesca Lizzi
- Silvia Arezzini
- Lorenzo Marini (dott.)
- Emmanuel Uwitonze (ass.)
- Rossana Lanzilotta (laur.)

INFN Firenze & Careggi University hospital

- Cinzia Talamonti
- Stefania Pallotta
- Carlotta Mozzi (ass.)

Totale: 5 FTE

Fondi 2025

INFN Pisa

- Missioni: 2k
- Consumo: 12.5k
- Pubblicazioni: 3k SJ

INFN Firenze & Careggi University hospital

- Missioni: 2k
- Consumo: 6k
- Pubblicazioni: 3k SJ

Totale: 22.5 k +6k SJ

Applicazioni **interdisciplinari** di tecnologie CSN5

Organizzazione

- Iniziato nel 2024, per 3 anni
- Circa 6 meeting all'anno (presenza)

Collaborazioni

- Sinergico con PRIN2022 INTREPID
- Collaborazione con Centro di Riferimento Oncologico (CRO)-Aviano

ARTEMIS: goal

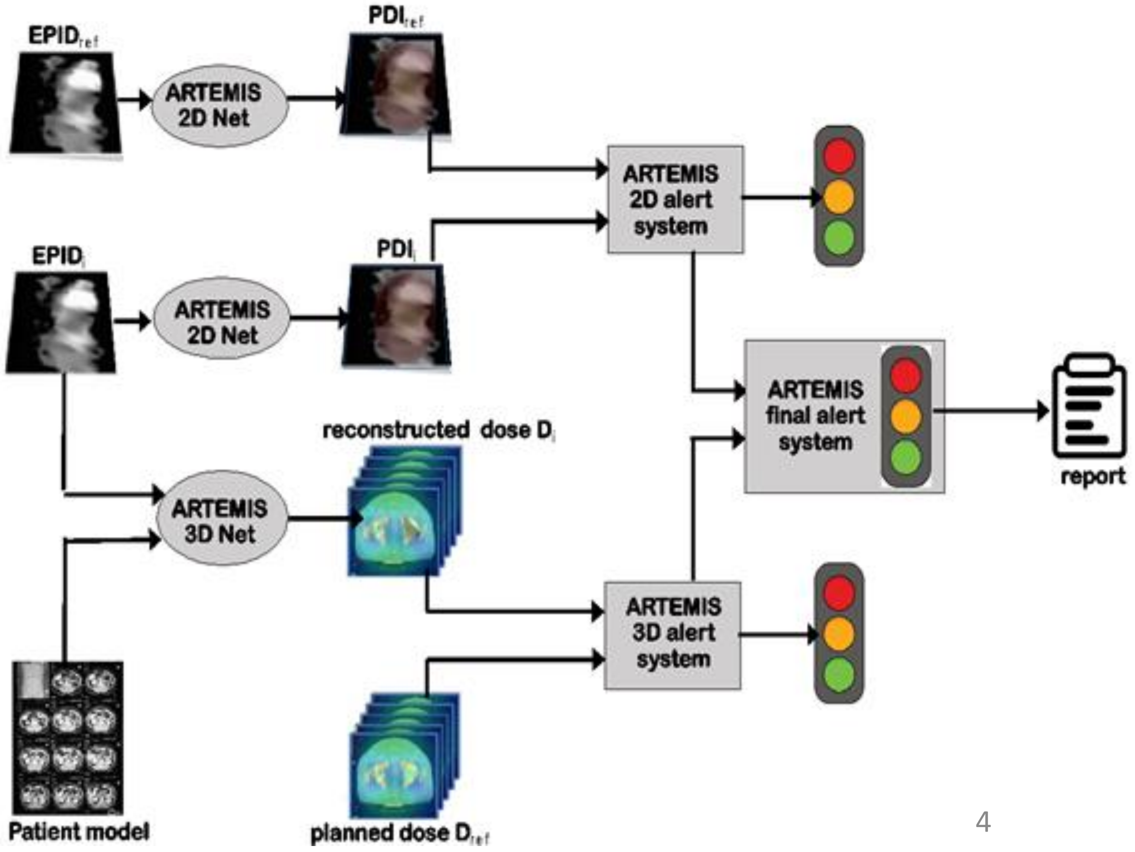
L'intelligenza artificiale può aiutare?

Artificial intelligence in RadioTherapy with EPID MonItoring System

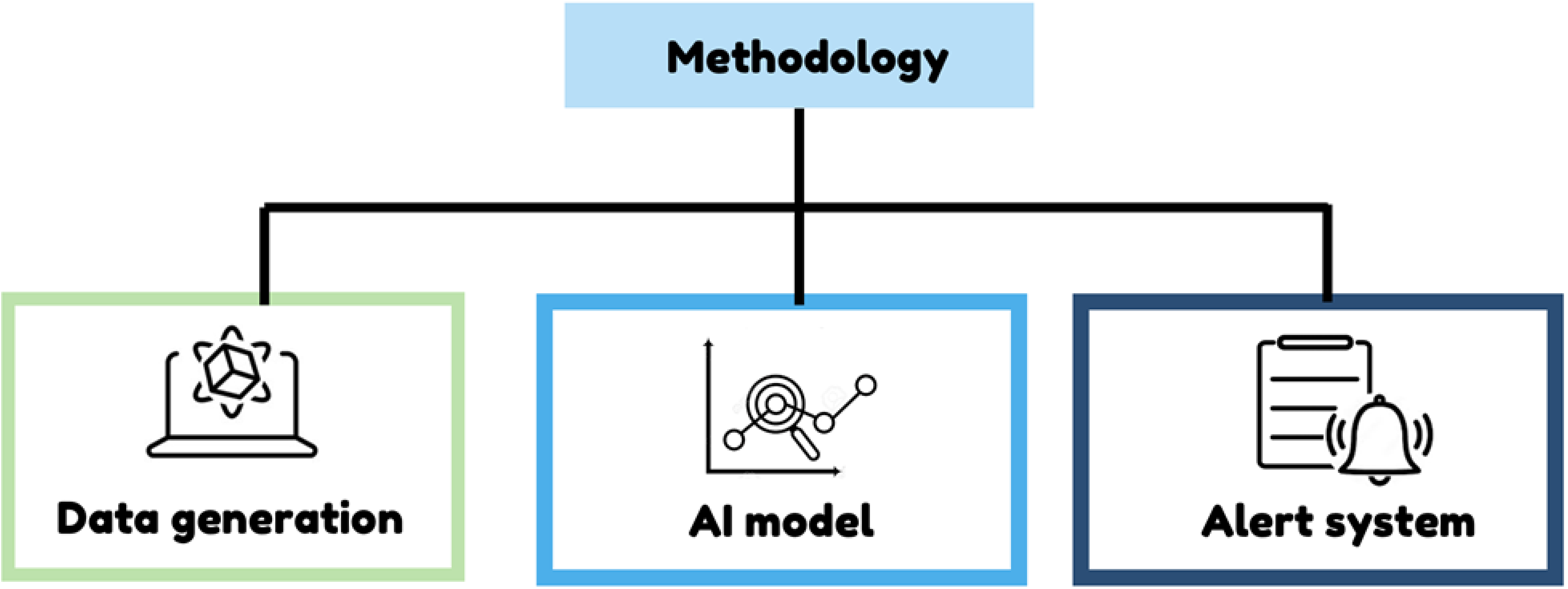
Scopo: sviluppare un **alert system** basato sull'intelligenza artificiale, che:

- verifica la correttezza della dose erogata su base giornaliera
- crea avvisi in caso di discrepanze significative

L'**alert system** deve essere veloce, facile da usare e preciso



ARTEMIS: Workpackages



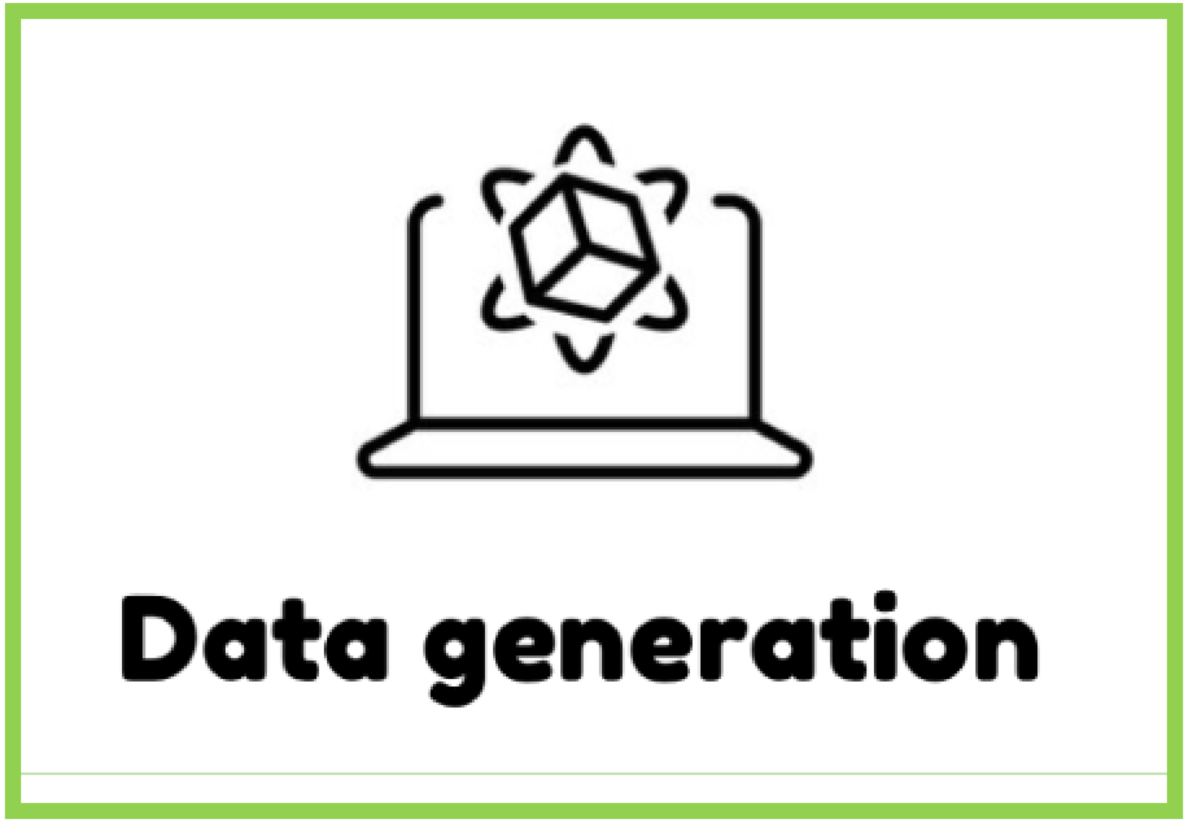
To develop, train and validate AI model (2D, 3D).

Design, creation, training, validation of AI models (2D, 3D)

Alert system to estimate whether to interfere (2D, 3D)

ARTEMIS: Workpackages

WP1



ARTEMIS: Workpackages

WP 1.1: Phantom data acquisition.

WP 1.2 MC Simulations

WP 1.3 Ethical commission and patient treatment

Most work in WP1 is in WP 1.1+1.2:

- The development of 3D-printed phantoms → **Slide 8 to 16**
- The creation of a DataBase with data and simulations (that can be divided later on with other hospitals) → **slide 17-18**

Workflow for the development of the phantoms

An important part of WP1 is the development of 3D-printed phantoms

Developing phantom for breast treatments for:

- Increase data diversity for our AI model for 2D and 3D
- To study more realistic cases for the development of the ALERT system

Workflow in the development:

Design

→

Select suitable tissue equivalent materials

- INFN Pisa
- LNGS
- Bio3DModel
- MadeInAdd

→

Realization of assembly phantom ("incastro")

(~25x25x10 cm^3)

- INFN Pisa: ARTEMIS1
- LNGS
- Bio3DModel

→

Tests for full size realistic phantom

- INFN LNGS
- Bio3DModel?
- MadeInAdd?

→

Realization of full scale phantom

(~35x35x20cm^3)

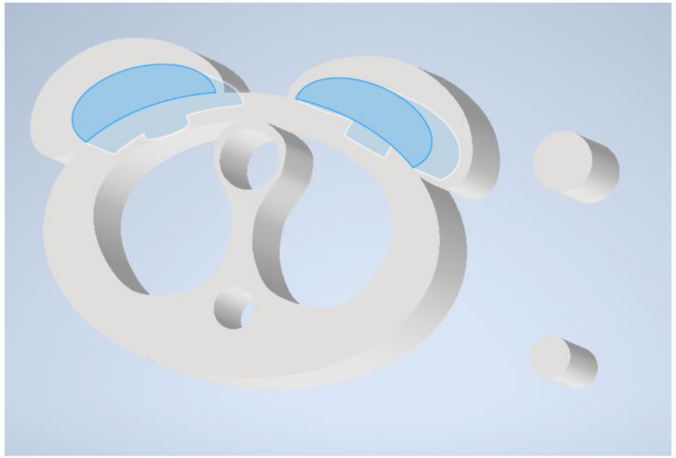
- INFN LNGS
- Bio3DModel?
- MadeInAdd?

Design (2024)

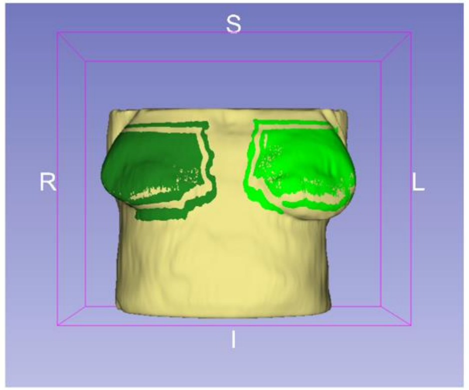
Two possibilities for design

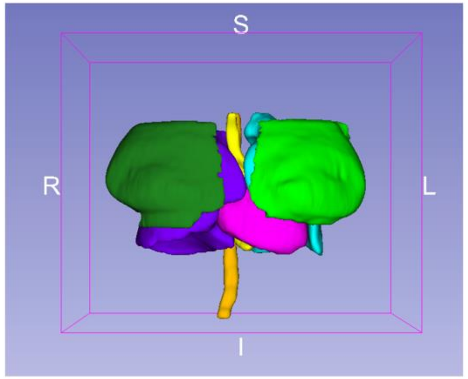
model

Design 1: incastro



Design 2: CT-based (realistic)





✓ mostly done in 2024

Design → **Select suitable tissue equivalent materials**
- INFN Pisa
- LNGS
- Bio3DModel
- MadeInAdd

→ **Realization of assembly phantom ("incastro")**

(~25x25x10 cm^3)
- INFN Pisa: ARTEMIS1
- LNGS
- Bio3DModel

→ **Tests for full size realistic phantom**
- INFN LNGS
- Bio3DModel?
- MadeInAdd?

→ **Realization of full scale phantom**

(~35x35x20cm^3)
- INFN LNGS
- Bio3DModel?
- MadeInAdd?

Selection of materials (2025)

- Proper radiological response…
  - Must closely match the volume, density and chemical composition characteristics of the represented tissue
  - Should match tissue attenuation characteristics at >MeV (radiotherapeutic X-rays) as well as X-rays with lower energies (CT scan)

It cannot be simply assumed that the response for X-rays from CT is automatically OK for radiotherapeutic energies!

- MUCH literature was studied about this problem, which is quite common for research into 3D phantoms for radiotherapy!!!
- Overview available in collaboration meeting, presentation on 5th May 2025, see **https://agenda.infn.it/event/47055/**

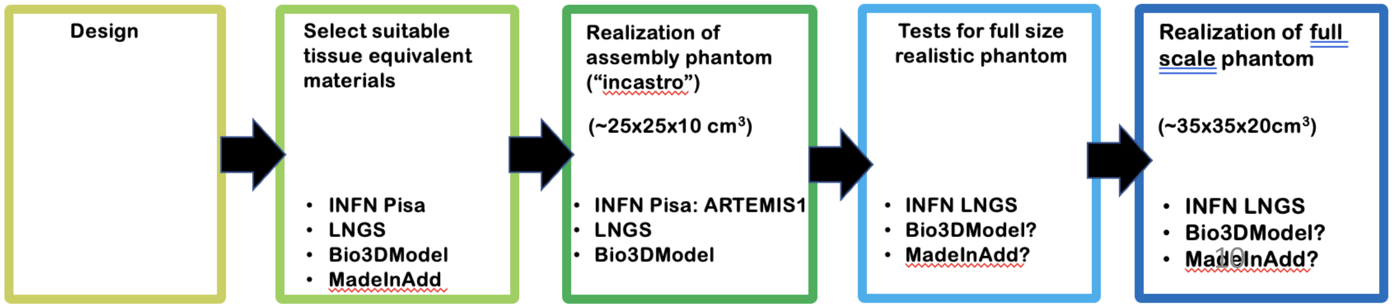
Good news!

- From Dancewitz et al, **it seems that when HU is equivalent, also the dose measurements with MeV photons match**
- Other papers about RT dosimetry and 3D filament printing seem to confirm this. Usual procedure is:
  - CT of 3D printed material
  - Make a treatment plan with TPS, base on this CT-scan
  - Check dose somewhere inside or behind material, using films or ionization chambers
  - Quote a Gamma Passing Rate→ it always matches OK, apart from metals!

(Dancewicz, Orrie & Sylvander, Steven & Markwell, Tim & Crowe, Scott & Trapp, J.V.. (2017). Radiological properties of 3D printed materials in kilovoltage and megavoltage photon beams. Physica Medica. 38. 111-118. 10.1016/j.ejmp.2017.05.051.

Solution for us:

- Try different materials (24 tested in 2025, more coming)
- Make selection based on HU (focus on soft tissue)
- Cross-check the MeV X-ray response
  - by taking EPID images and compare with solid water
  - by doing dose measurements



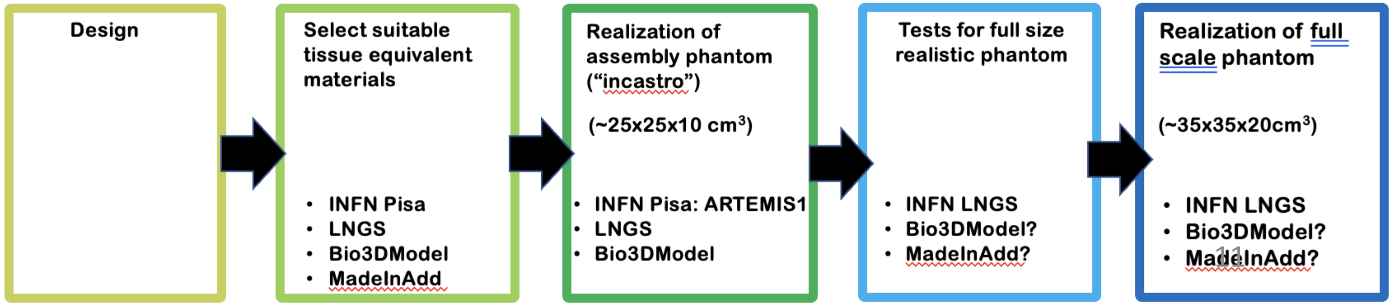
Selection of materials (2025)

In first half of 2025 we explored several options

- Servizi di officina e progettazione meccanica **dell'INFN di Pisa** (Sandro, Andrea, et al)
  - Form 3B → Form 4B (not yet)
  - Bambu Lab X1 → **5 cubes** printed
- Advantage: inhouse, fast. Disadvantage: only incasso-design possible!

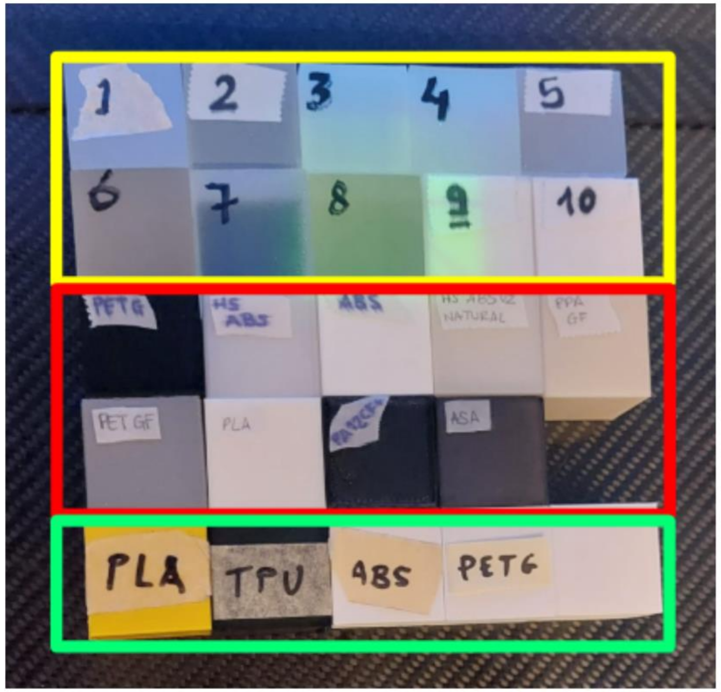
- Collaborazione con servizi Design e Additive Manufactoring dei **Laboratori Nazionali di Gran Sasso** (Daniele Cortis, Donato Orlandi et al)
  - **9 cubes** printed at LNGS (stampante 3D Raise3DPro): PLA, PET, TPU, … 100% filling density
  - Advantage: inhouse so cheap, compatible with Stonefill filament. Disadvantage: not local

- Bio3DModel company Toscana
  - **10 cubes** of different (unknown) materials with densities 0.9-1.2 g/cm^3
  - Advantage: Stratasys 3D printer: super advanced. Disadvantage: expensive, no bone

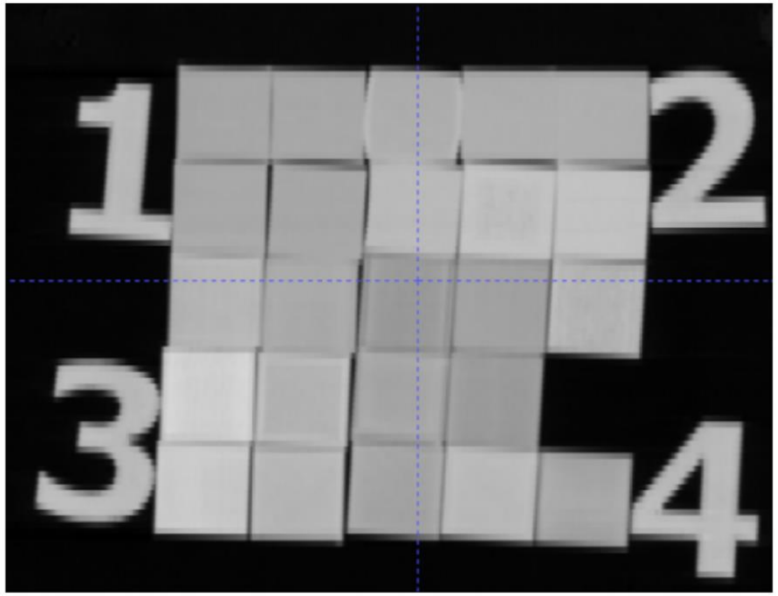


Selection of materials (2025)

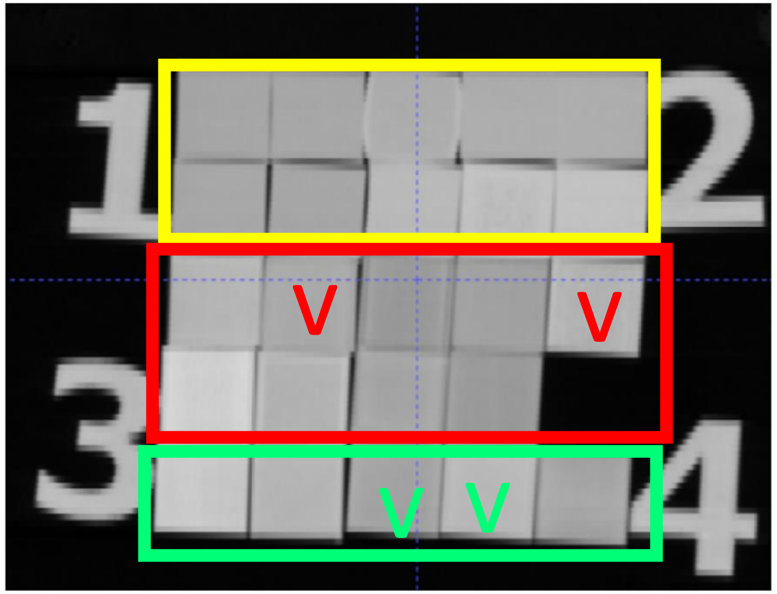
materiali



CT scan

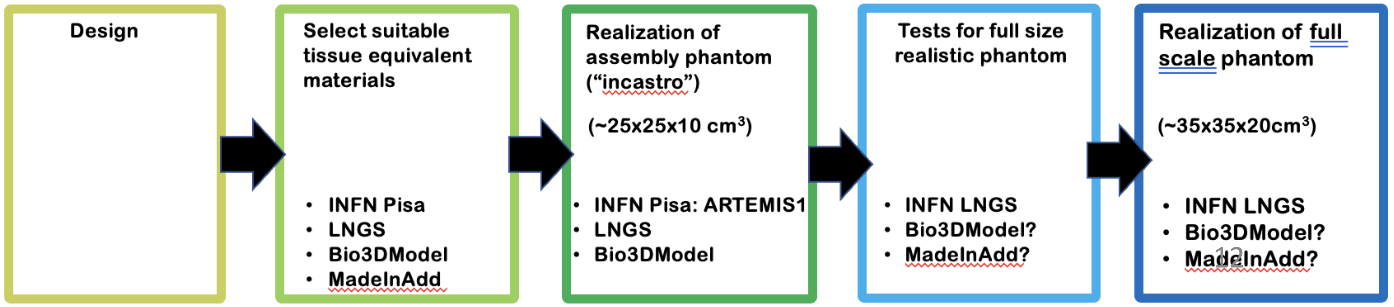


Selected



Bio3DModel
LNGS
INFN Pisa

- **Bio2D model**: should mix various materials
- **LNGS**
  - HS ABS (HU=-1.62) per il seno
  - PPA GF (HU=69.50) per i tessuti molli
- **INFN Pisa:**
  - ABS (HU=-29.04) per il seno
  - TPU (HU=64.94) per i tessuti molli



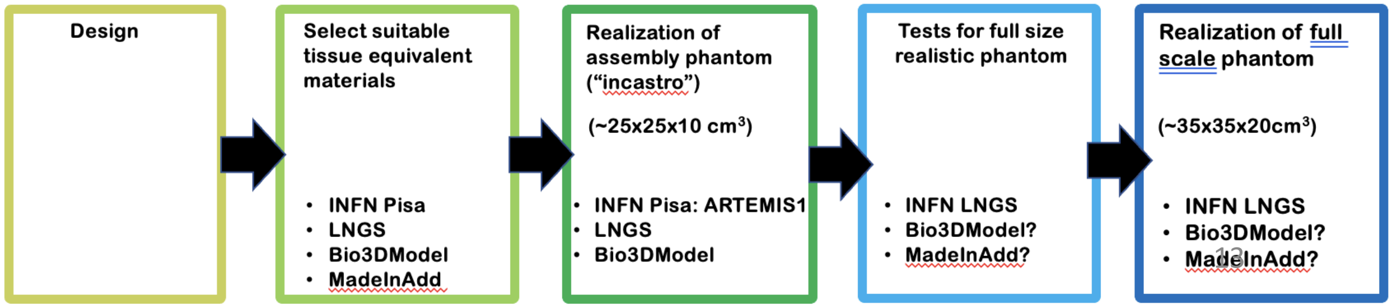
Selection of materials (2025)

- It turns out to be really challenging to find a material equivalent to bone!
- Especially since we want to print it as part of a whole body (**not** as incasso!)
- After studying many papers, found a few valid promising options:
  - Stonefil filaments (low Z, high density): 100% for bone, and then vary filling density or combine with PLA
  - Ceramics (low Z, high density): 100% for bone and then vary filling density (MadeInAdd)

→ will explore these options in rest of 2025!

For now:

- We have an option for breast and for soft tissue.
- We can print them only separately. So only good for incastro-phantom (see next)
  - For realistic phantom, we need to take a heavy material and vary in-fill density

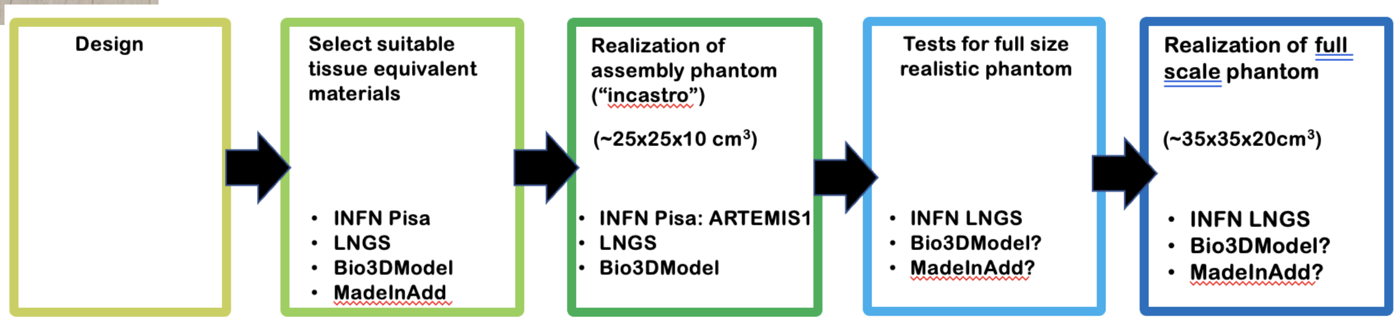


Realization of assembly phantom (2025)

Assembly phantom («incastro»)

- Printed in Pisa, May 2015 → ARTEMIS1
  - Critical points:
    - Material of breast (PLA) is curving
    - Needed to adjust it
    - ”Incastro” not good (it falls apart)
    - Dose measurements do not agree with PD predictions of the model (breast plan made)
- Print ARTEMIS2 with LNGS (fall 2025)
  - Small version (already paid)
  - 1 piece, 1 breast size (no assembly)
  - No bone
  - 1 material, different filling densities
- Print ARTEMIS3 with Bio3DModel (fall 2025)
  - Small version (already paid)
  - 1 piece, 1 breast size
  - No bone
  - Different materials printed in one print

7



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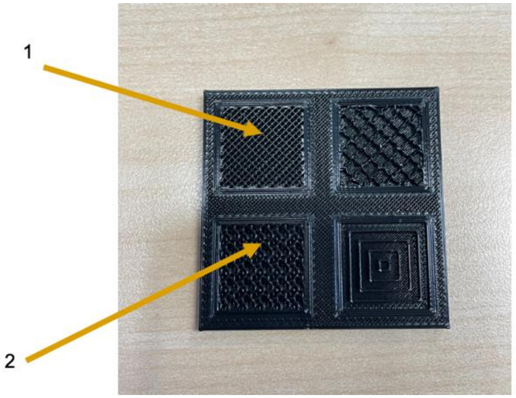
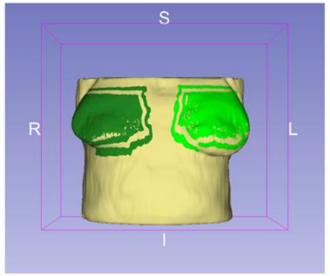
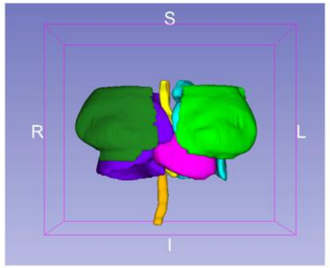
Tests for a full scale phantom (2025)

- Fall 2025:
  - Test 20 ceramic cubes of MadeInAdd (to buy)
  - Test 30 plastic cubes of LNGS → no-bone
  - Order Stonefill material, print at LNGS, and test this material → phantom with bone
  - Valid alternative for the search for our perfect materials….
    - Make an ICRU certified simple breast phantom from breast and solid water plates







Design → **Select suitable tissue equivalent materials**
- INFN Pisa
- LNGS
- Bio3DModel
- MadeInAdd

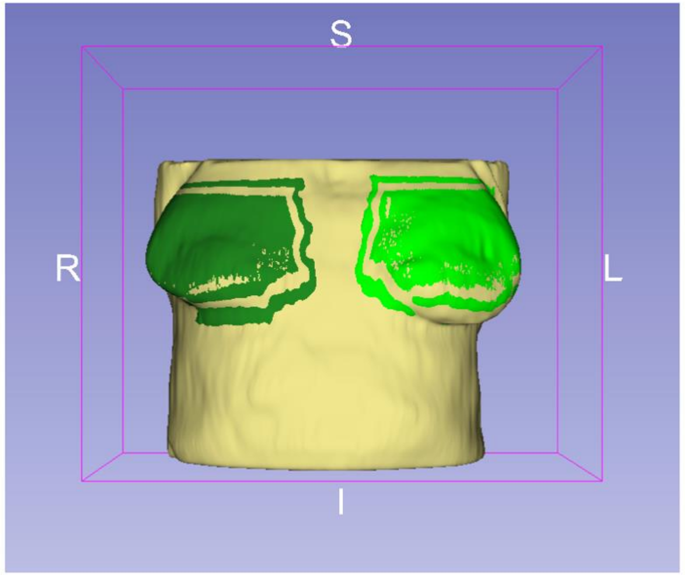
→ **Realization of assembly phantom ("incastro")** (~25x25x10 cm^3)
- INFN Pisa: ARTEMIS1
- LNGS
- Bio3DModel

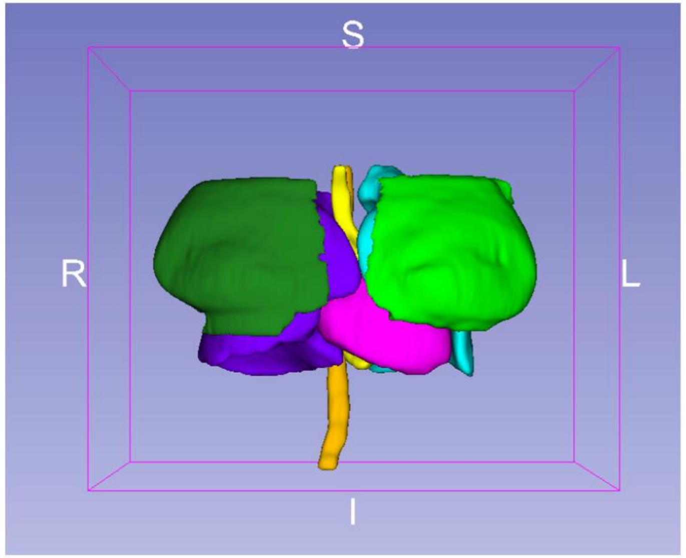
→ **Tests for full size realistic phantom**
- INFN LNGS
- Bio3DModel?
- MadeInAdd?

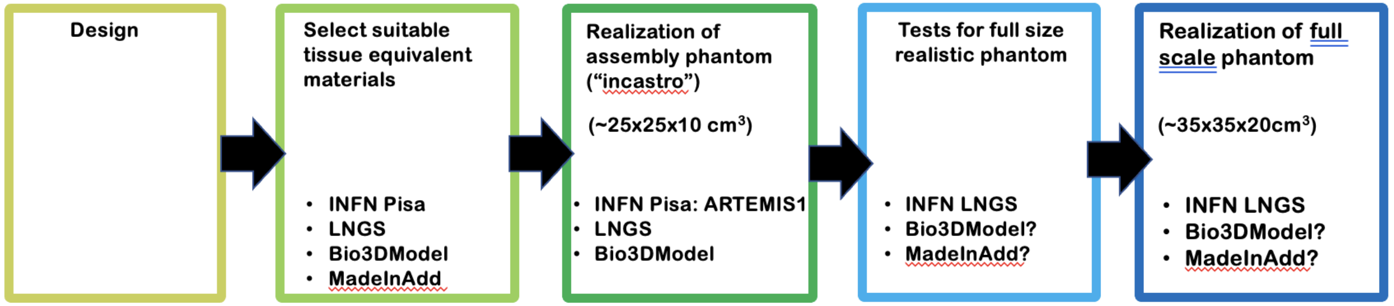
→ **Realization of full scale phantom** (~35x35x20cm^3)
- INFN LNGS
- Bio3DModel?
- MadeInAdd?

Realization of full size phantom (2026)

- 2026:
  - Print at MadeInAdd (10 k)
  - Print at Bio3DModel? (13k)
  - (Print at LNGS, but then no bone… which is less innovative and less complete)



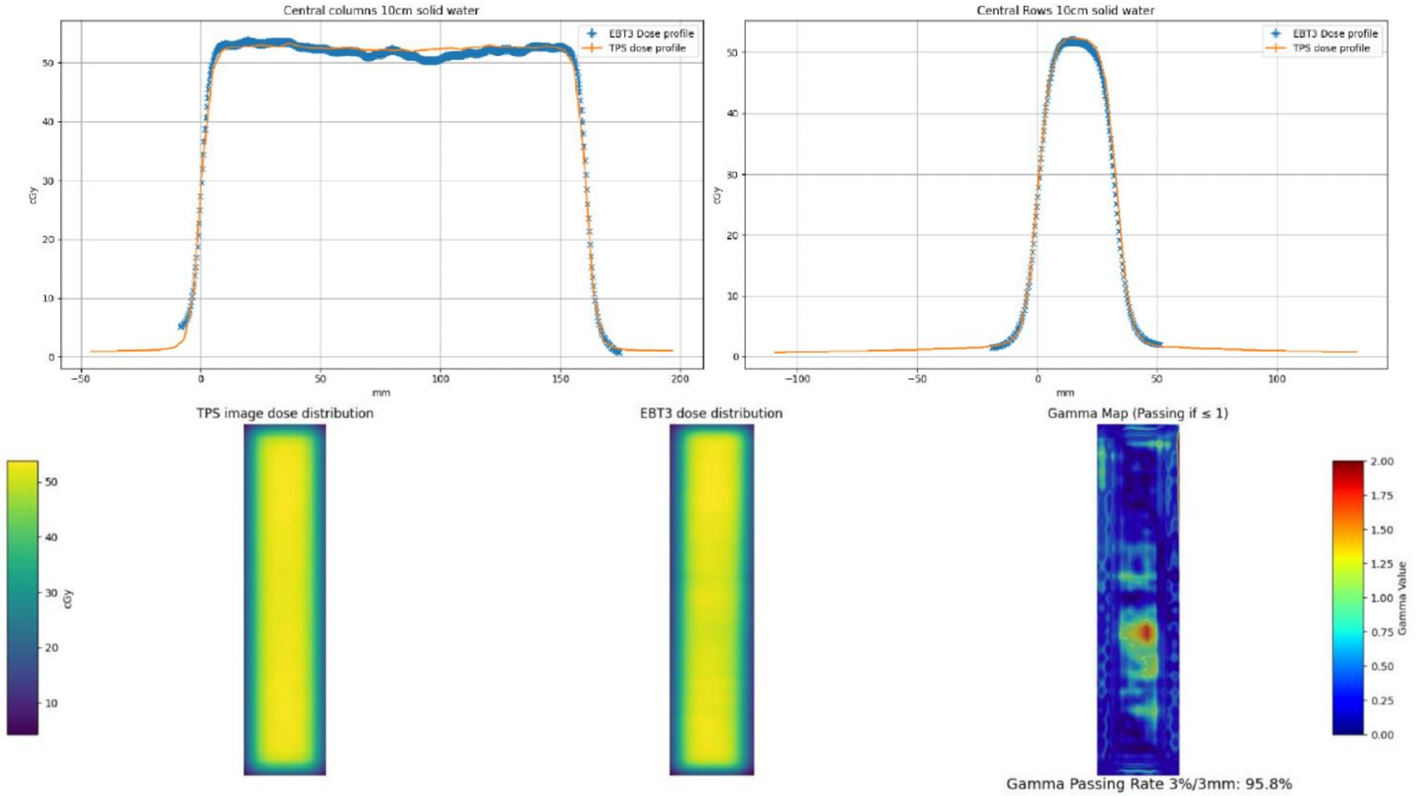




Example of TPS verification measurements

Another part of our funding goes to GafChromic films…

Goal: verify that the Monaco TPS accurately predicts the portal dose→ create a DataBase! (measurements and simulations)



PD of TPS

GafChromic

gamma

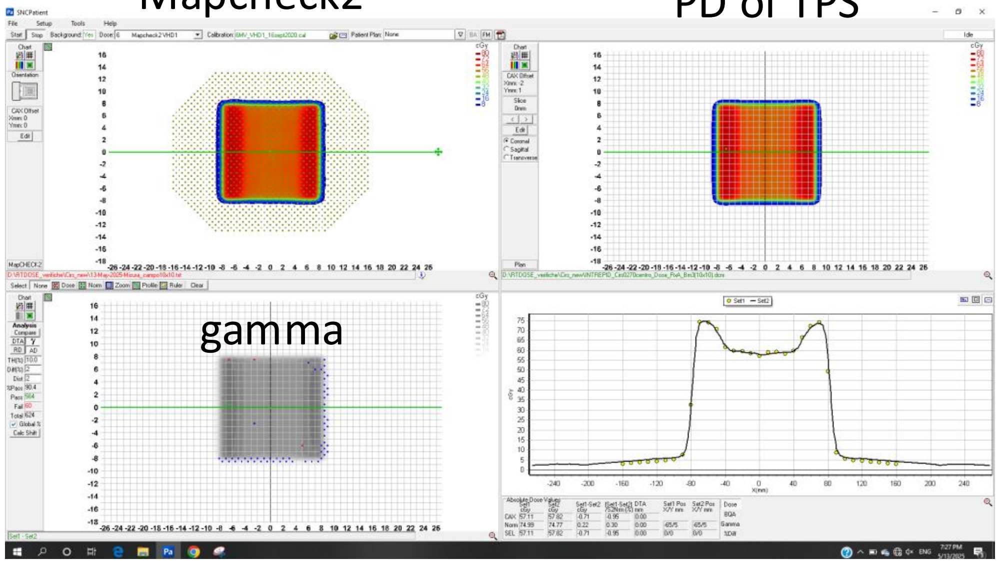
Example (of of the MANY of measurements done)

Generally TPS agrees reasonably well with measurements, some exceptions

Example of TPS verification measurements

Goal: verify that the Monaco TPS accurately predicts the portal dose → create a DataBase! (measurements and simulations)

Mapcheck2 PD of TPS



Example (of of the MANY of measurements done)

Fantocci	Campi	Gamma 5%/5mm loc Relativa	Gamma 5%/5mm loc Assoluta	Gamma 3%/3mm loc Relativa	Gamma 3%/3mm loc Assoluta	2%2mm globale relativa	2%2mm globale assoluta	2%2mm locale assoluta	Scarto con farmer %
Cirs iso in centro	2x2	100	100	100	100		97.3	97.3	-0.8
Cirs iso in centro	2x10	100	100	100	99.3	93.5	92.8	92.8	-0.8
Cirs iso in centro	10x10	100	100	98.6	98.9	90.6	90.4	88.6	3.0

Generally TPS agrees reasonably well with measurements, some exceptions

WP1: Summary

Jan-Sept 2025

WP1

Data generation

EPID measurements and PDI simulations with standard and in-house developed 3D phantoms, dose distributions, CT scans

WP1.1: Phantom data acquisition.

For model development:
- Acquisition of EPID images at Careggi (simple+complex) commercial geometries
- Dose measurements using GafChromics and MapCheck2 (for comparisons with simulations)

For development of 3D-printed phantom:
- Realization of 24 cubes of several materials: 10 by Bio3DModel (company, Stratasys), 9 by LNGS (Raise3DPro), and 5 by INFN Pisa (Bambulab). Bought glue and tray (**0.15kE**)
- For material selection:
  - CT data acquisition (120 keV X-ray) for all
  - 6 MeV EPID data for all (24 together in 1 acquisition, 30 x 30 cm2 field)
  - Analysis: mean HU, mean 6keV signal for the 24 cubes → 2 materials selected
  - Studied literature regarding materials for 3D printed radiotherapeutic phantoms
- Realization of ARTEMIS1 prototype (incasso) at INFN Pisa → some critical points seen
- 30 LNGS cubes ordered

For development of 2D ALERT system:
- Data acquisition done with commercial phantoms we introduced controlled errors and measured EPIDs (about 50 measurements). Data analysis started.

WP1.2 MC Simulations
- For model development: for each measured EPID, created Portal Dose (PD) image, using MONACO TPS
- Compared the TPS calculated PD with measurements (GafChromics+Mapcheck2)
- For ARTEMIS1 INFN phantom: created a treatment plan and simulated dose in patient and at EPID level.
- Bought new pc (fixed work station for analysis, **2kEuro**) and external disks (**0.5 kEuro**)

WP1.3 Ethical commission and patient treatment
- waiting

WP1: Summary

WP1

Data generation

EPID measurements and PDI simulations with standard and in-house developed 3D phantoms, dose distributions, CT scans

WP1.1: Phantom data acquisition.

Rest of 2025

For model development:

- Acquisition of more EPID images at Careggi (simple+complex) commercial geometries
- More dose measurements using GafChromics and MapCheck2 (for comparisons with simulations)
- Buy more materials that we know are OK (certified ICRU, **6.5 kEuro)** for new data

For development of realistic 3D-printed phantom:

- 24 cubes (10 by Bio3DModel, 9 by LNGS, 5 by INFN Pisa):
  - Analyze: density vs HU
  - Take MeV EPID data for all, but separately (same position) and analyze again
- New 30 LNGS cubes arrived in July:
  - Perform CT data acquisition (120 keV X-rays), acquire 6 MeV data, density → analyze
- Buy 20 more cubes based on ceramics (MadeInAdd) → **2.1 kEuro**
- Print small 3D phantom ARTEMIS2 (incasso) with Bio3Dmodel (already paid, no bone-like material)
- Bio3Dmodel: bone like material? No answer yet.
- Buy Stonefill filament (3DJake) and assessories → **0,5kEuro**

For development of ALERT system:

- Data acquisition done with with commercial phantoms: more data with controlled errors and measured EPIDs
- Take more data with ARTEMIS1 and ARTEMIS2 prototype printed at INFN Pisa

WP1.2 MC Simulations

- See 2025 points. For ARTEMIS1+ARTEMIS2 INFN phantom: new treatment plan

WP1.3 Ethical commission and patient treatment

- hope for answer

WP1: Summary

WP1

Data generation

EPID measurements and PDI simulations with standard and in-house developed 3D phantoms, dose distributions, CT scans

WP1.1: Phantom data acquisition.

2026

For model development:

- Acquisition of more EPID images at Careggi (simple+complex) commercial geometries, focus 3D
- Corresponding dose measurements using GafChromics and MapCheck2 (for comparisons with simulations)
- Take more data with new inhomogeneous slab phantoms including breast, bone (**3.6 k**)

For development of realistic 3D-printed phantom:

- Analyse all cubes, select 5-6 materials and print full 3D phantom (CT-like!)
    - We want a phantom in 2026 including bone, and have 2 options:
        - Stonefill → LNGS
        - Commercial: Bio3DModel (**13k**) and/or MadeInAdd (**10k**)

For development of ALERT system:

- Data acquisitions to be done with with commercial phantoms and ARTEMIS1, ARTEMIS 2, and newly printed phantoms: introduce controlled errors and measured EPIDs

WP1.2 MC Simulations

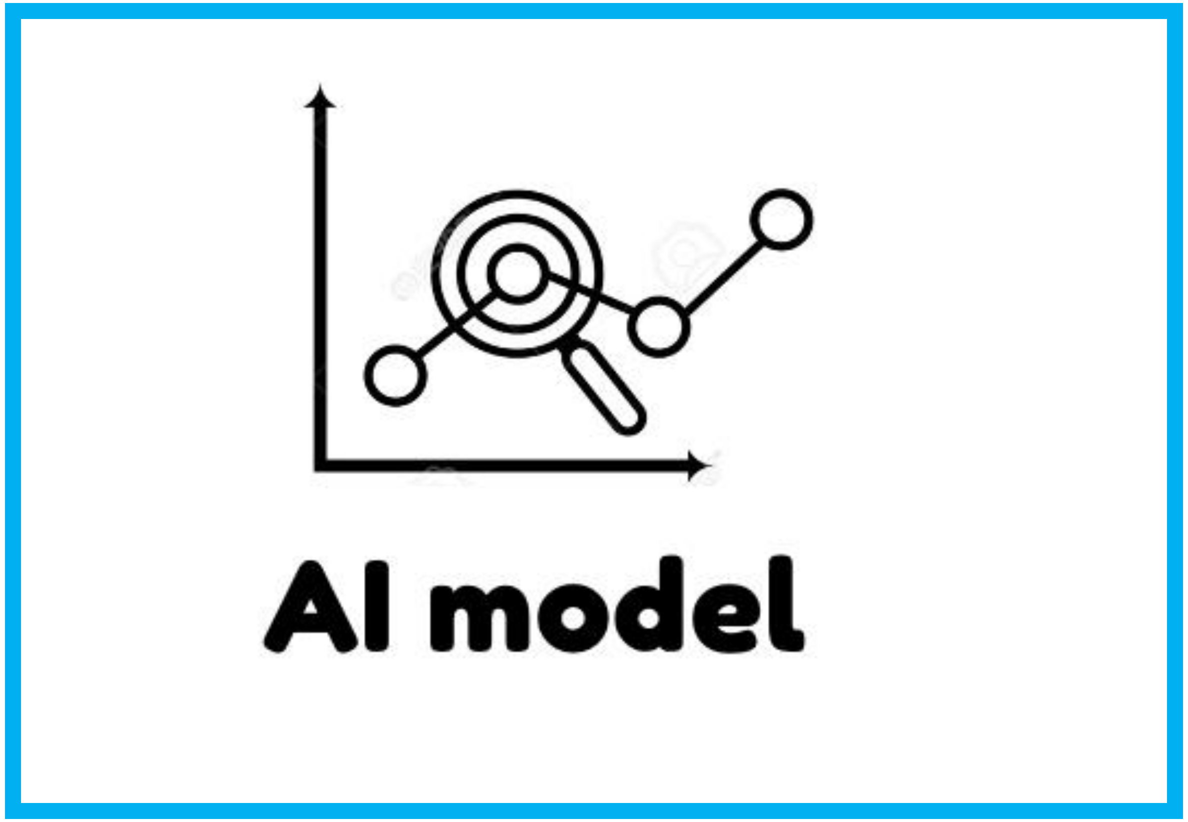
- For model development: for each measured new EPID, created Portal Dose (PD) image, using MONACO TPS
- Compared the TPS calculated PD with measurements (GafChromics+Mapcheck2)
- For new phantoms: irradiate and simulated dose in patient and at EPID level.

WP1.3 Ethical commission and patient treatment

- approval

ARTEMIS: Workpackages

WP2



ARTEMIS: Workpackages

WP 2.1: Development of 2D AI model

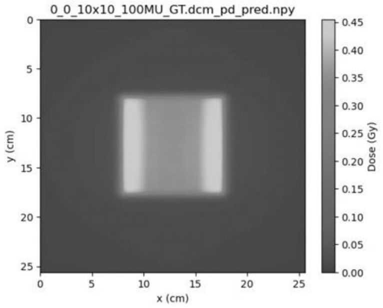
WP 2.2: Development of 3D AI model

Here only results from WP 2.1 → slide 26-30

Sviluppo modello AI in 2D (WP2)

- **Primo passo:** sviluppo modello AI che verifica la dose sul piano EPID **dietro** il paziente: 2D
- Sviluppato modello AI per convertire immagini 2D EPID (toni di grigio) in Dose Portale (PD, dose in Gy)
- 250 immagini EPID acquisite su diversi fantocci, angoli e campi di irraggiamento e accoppiate con immagini simulate di Dose Portale

Dati: EPID



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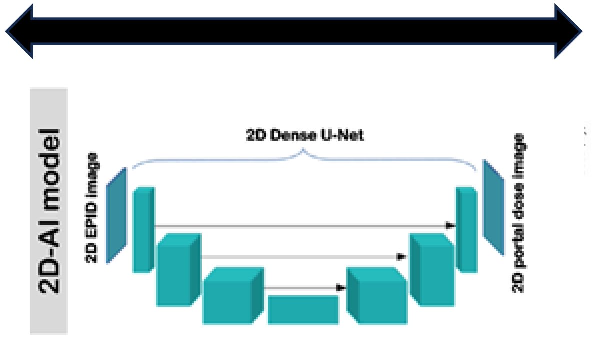
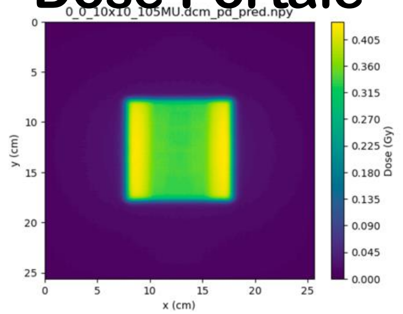
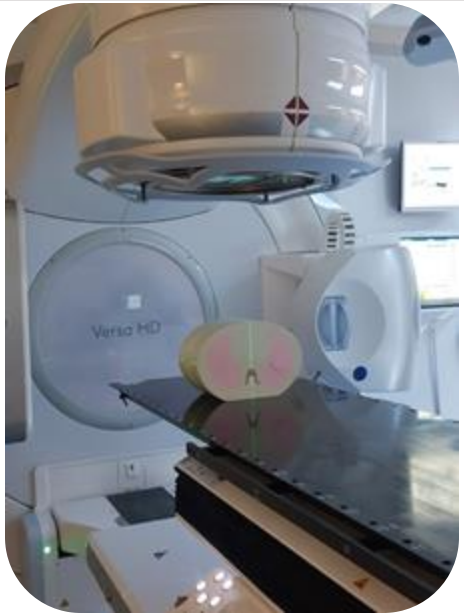


Simulazioni: Dose Portale



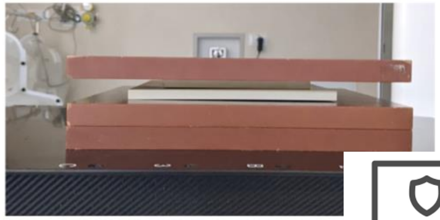
DATI

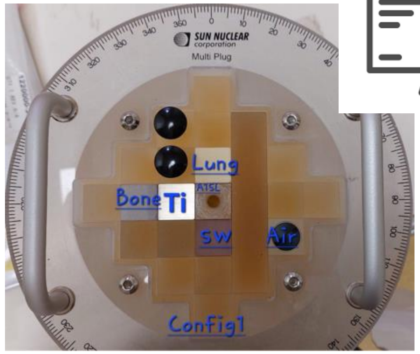
Sala di trattamento Careggi Firenze

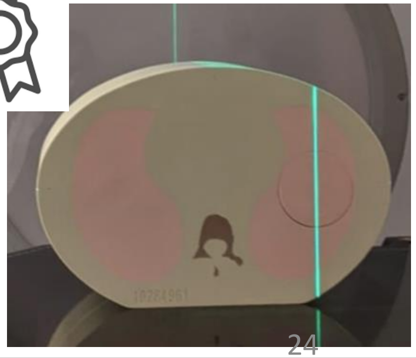


- Dati attuali per modello presi su fantocci convenzionali (tessuto equivalente)
  - Acqua solida (**contributo INFN**)
  - Bone
  - CIRS phantom
  - multi-plug phantom

PRIN2022 INTREPID



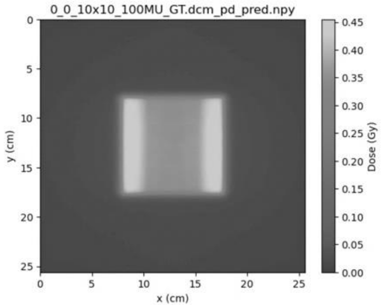




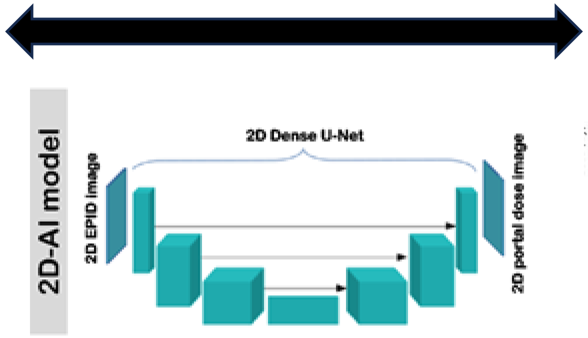
Sviluppo modello AI in 2D (WP2)

- **Primo passo:** sviluppo modello AI che verifica la dose sul piano EPID **dietro** il paziente: 2D
- Sviluppato modello AI per convertire immagini 2D EPID (grey values)in Dose Portale (PD, dose in Gy)
- 250 immagini EPID acquisite su diversi fantocci, angoli e campi di irraggiamento e accoppiate con immagini simulate di Dose Portale

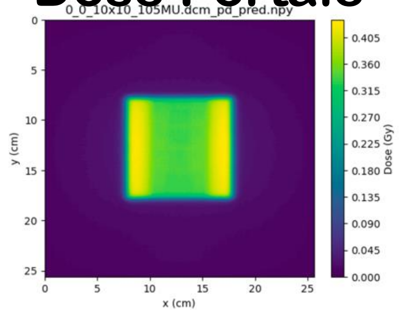
Dati: EPID



UNet

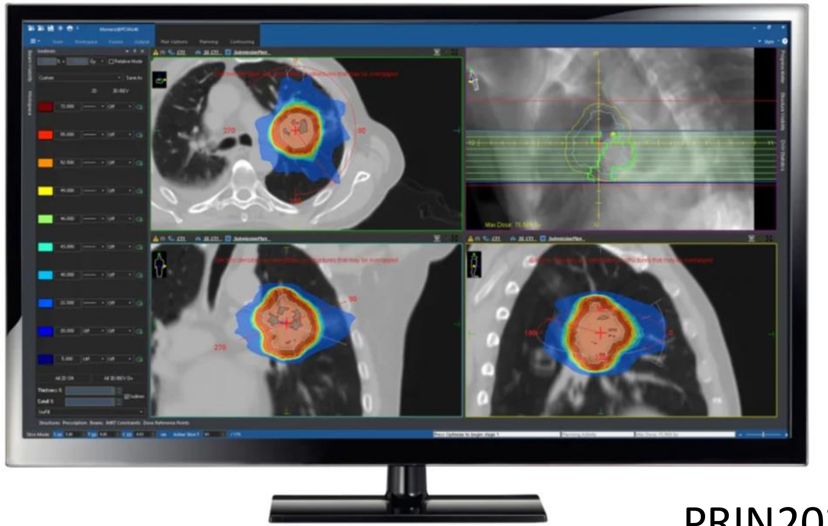


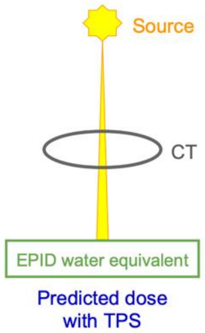
Simulazioni: Dose Portale



SIMULAZIONI

- Simulazioni attualmente fatti con un treatment planning system (TPS) commerciale Monaco (Elekta)
- Geometria di calcolo esteso a dietro il paziente
- Validato con misure
  - Film
  - matrice 2D di diodi Mapcheck2
  - misure puntiformi con la camera a ionizzazione Farmer.

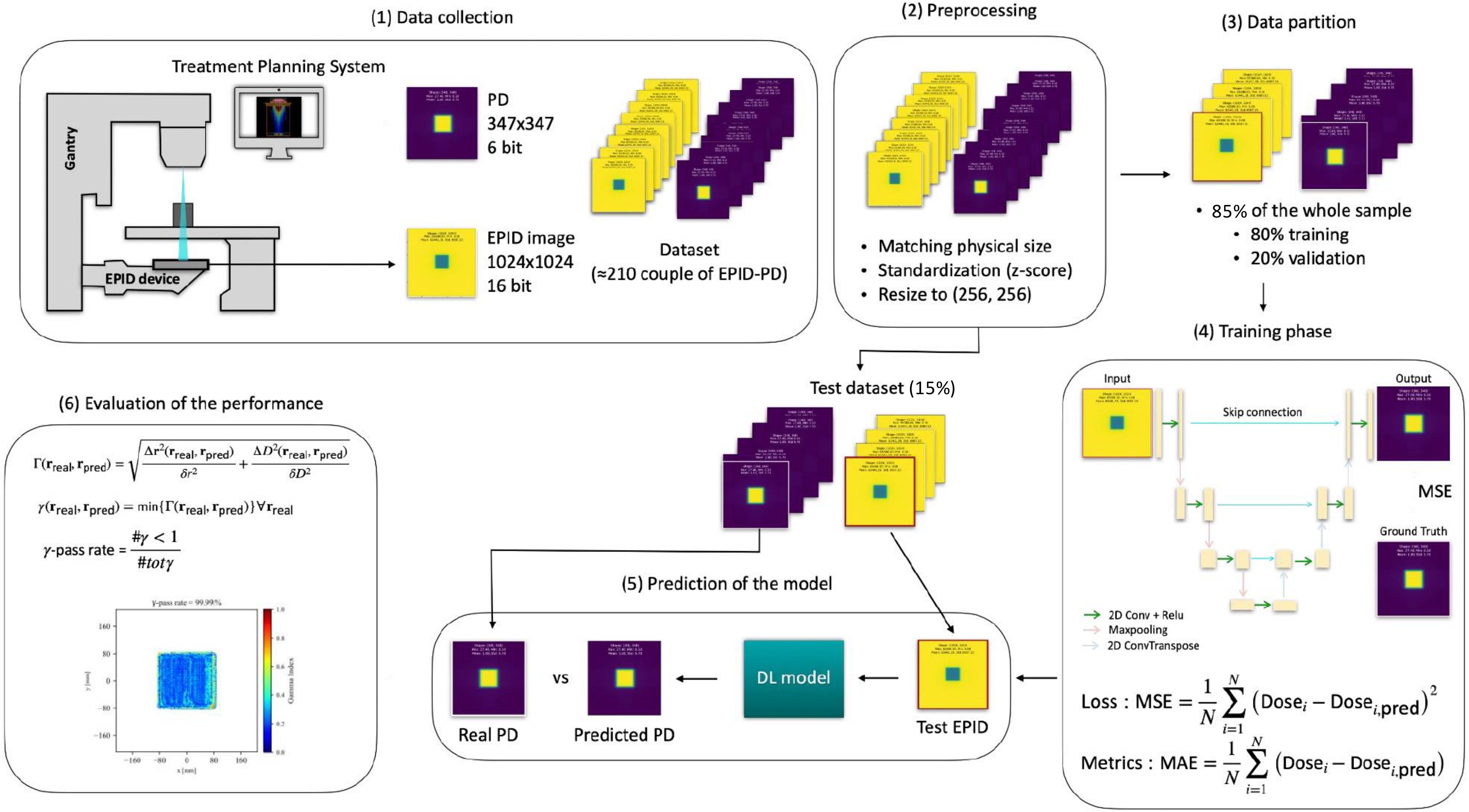




PRIN2022
INTREPID

Sviluppo modello AI in 2D (WP2)

MODELLO AI 2D

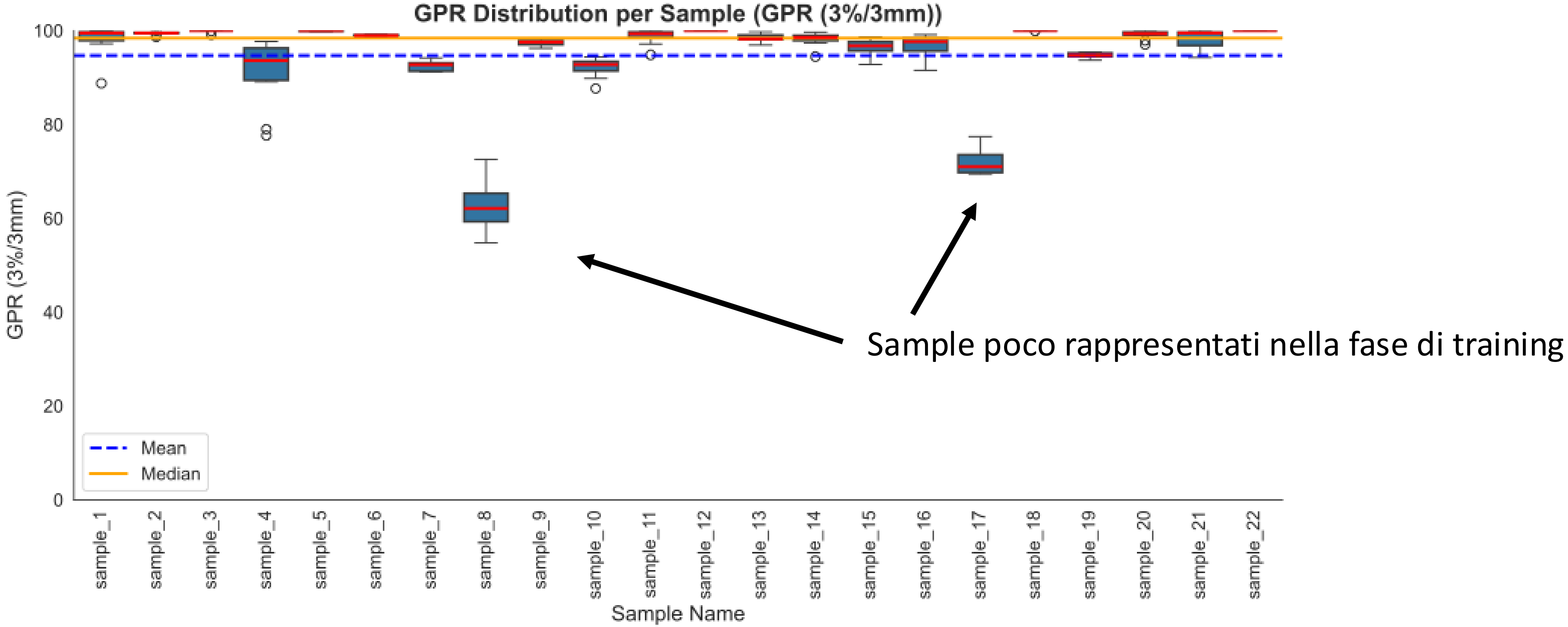


Centro di calcolo
INFN Pisa

PRIN2022
INTREPID

Sviluppo modello AI in 2D (WP2)

MODELLO AI 2D: performance



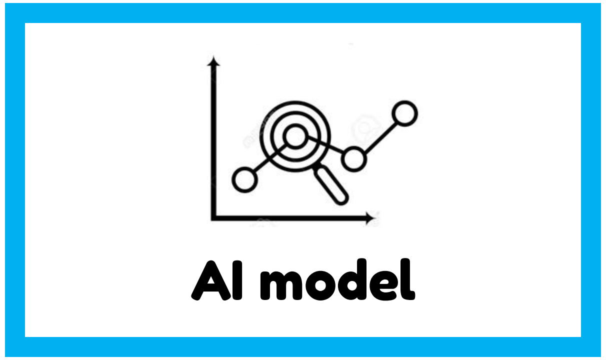
- Mediana modello 2D: gamma passing rate circa 95%
- Sottomesso a Physics and Imaging in Radiation Oncology

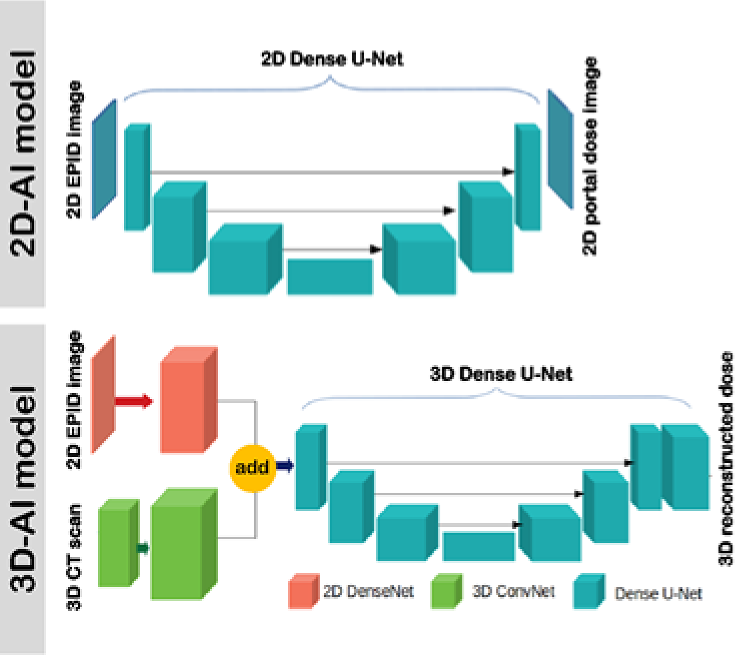
PRIN2022
INTREPID

WP2: Summary

WP2

Jan-Sept 2025





WP2.1 Development of 2D AI models

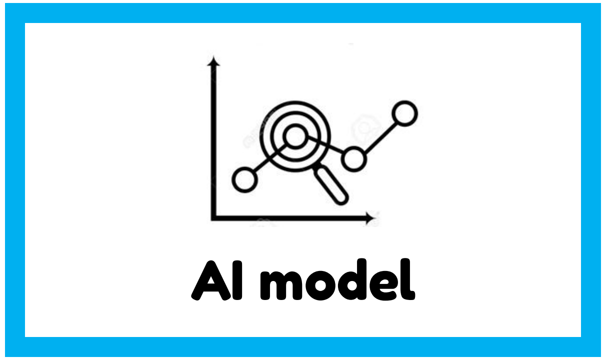
- The implementation of the 2D Unet mapping EPID into PD images was finalized, based on the current nr of acquisitions.
- A paper draft was written and submitted to Green Journal → rejected (out of journal scope)
- Paper was submitted to Physics and Imaging in Radiation Oncology (PHIRO) on September 6.

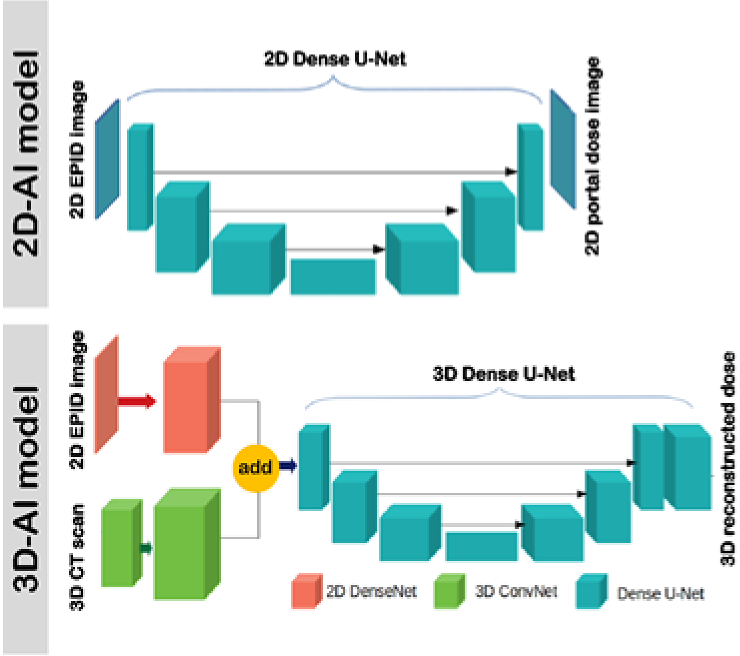
WP 2.2 Development of 3D AI models

- Work on design and implementation of a 3D AI model.
- Resolve critical points in preprocessing…

WP2: Summary

WP2





Rest of 2025

WP2.1 Development of 2D AI models

Eventually:

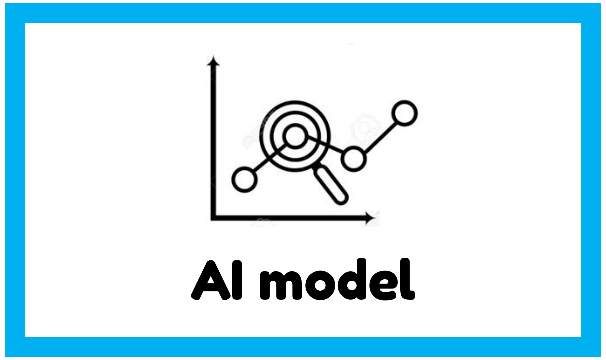
- Re-train the model when more images become available.
- Include ARTEMIS1 phantom in the model
- Include ARTEMIS2 phantom in the model

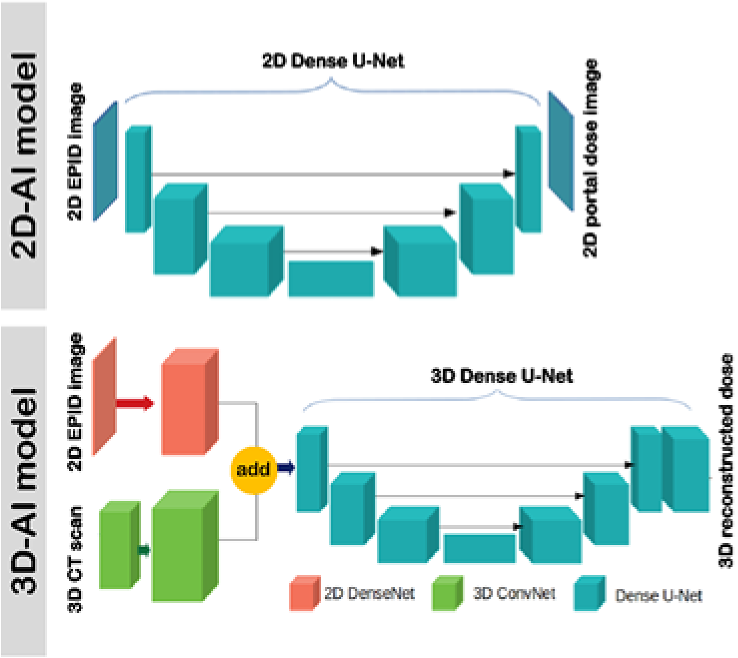
WP 2.2 Development of 3D AI models

- Resolve some critical points: preprocessing!!! Turned out to be complex, regarding factors like alignment of the EPID images with the TAC and dose in patient distribution
- Finalize the preprocessing, the design and implementation of a 3D AI model.

WP2: Summary

WP2





2026

WP2.1 Development of 2D AI models

- Include ARTEMIS-N phantom in the model

WP 2.2 Development of 3D AI models

- Finalize the 3D AI model

ARTEMIS: Workpackages

WP3

ARTEMIS: Workpackages

WP 3.1: Development of 2D alert system

WP 3.2: Development of 3D alert system

WP 3.3: Combined

Here only results from WP 3.1 → slide 33-39

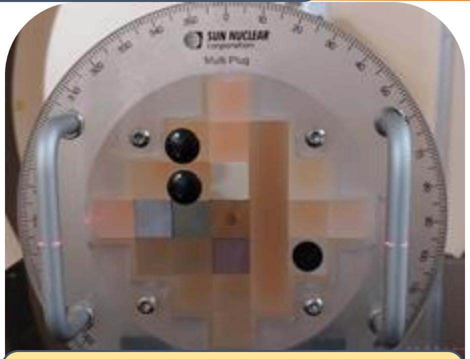
WP3: Alert system

Many measurements done at Carreggi… both using standard phantoms and the new phantom

LINAC Versa HD Elekta

Fantocci commerciali

CIRS E2E Thorax SBRT



Multiplug phantom

Lastre di acqua solida

Fantoccio ARTEMIS

WP3: Alert system

Errors in MU
- Reference: gantry at 0°, 100 MU
- Errors: Monitor Units varied between **100 MU** and **110 MU**, with steps of 2 MU

Errors in gantry angle
- Reference: gantry at 0°, 100 MU
- Errors: Rotations introduced of the gantry from **0°** a **10°**, with steps of 2°

Errors in patient positioning
- Reference: gantry at 0°, 100 MU
- Errors: Horizontal dispacements of the bed from **0 mm** to **6 mm**, with steps of 1 mm

Errors in patient anatomy
- Reference: gantry at 0°, 200 MU
- Errors: Add material: 1, e and 3 cm

WP3: Alert system

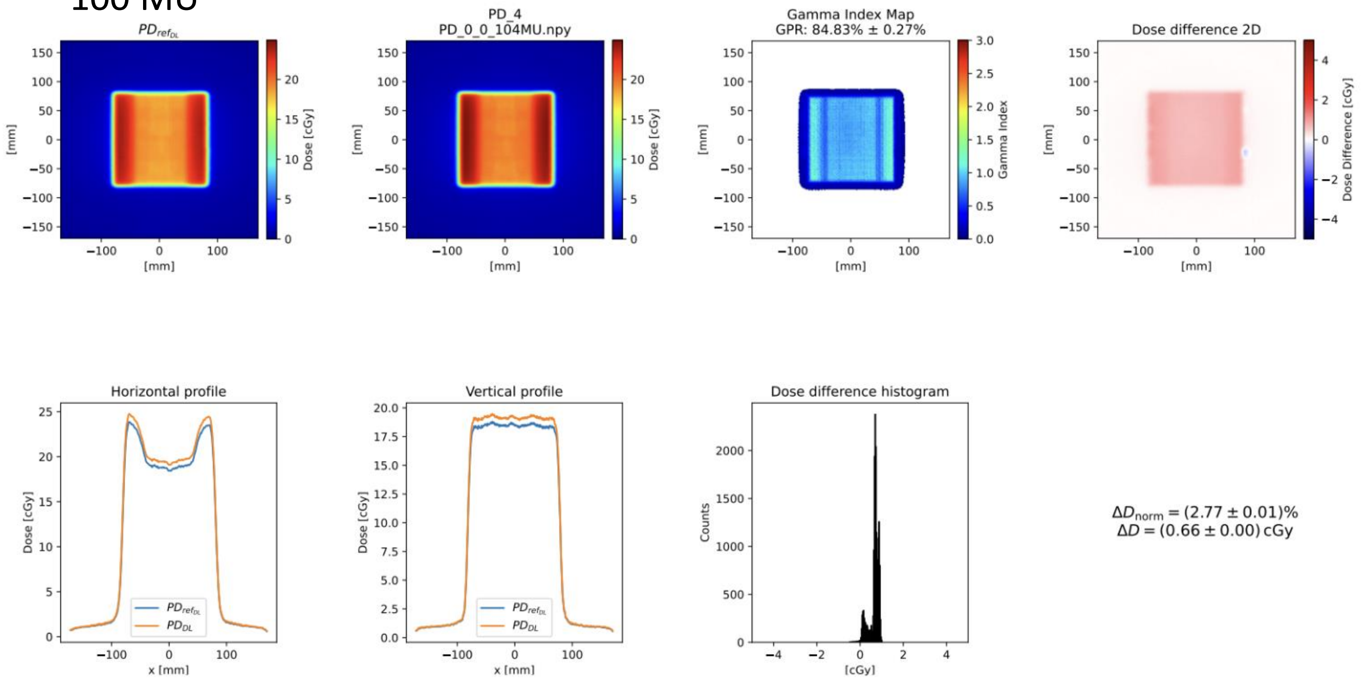
A possible layout

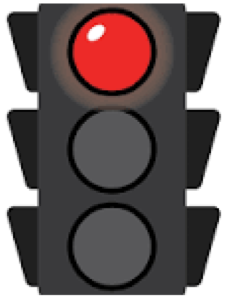
2025

- Alert system based on a 2D model in development
    - First tests done
    - Challenges:
        - Decide on metrics…
        - Gamma index
        - Dose difference
        - Central profiles
        - Global dose difference values

Reference
100 MU

Misura con errore: 104 MU





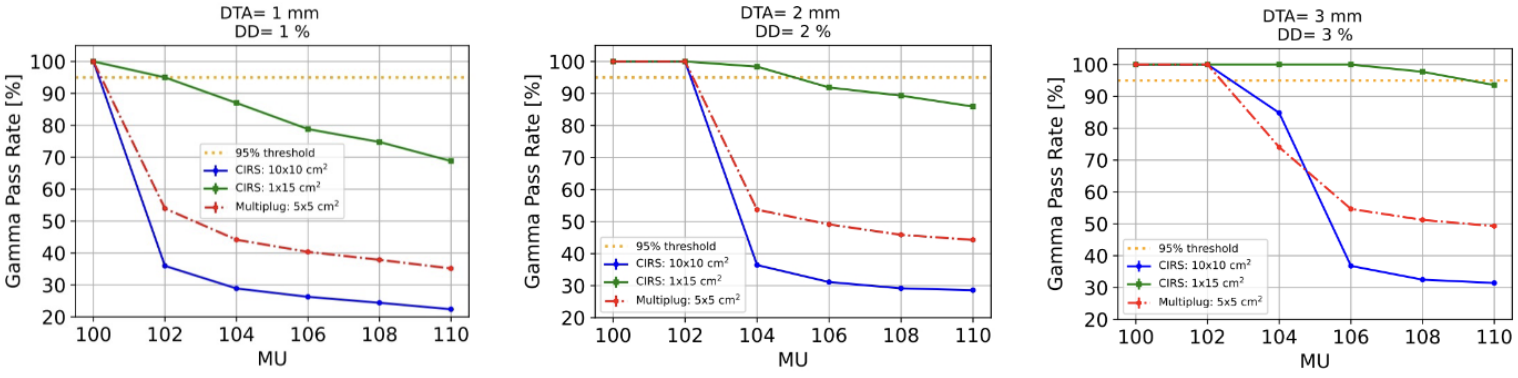
WP3: Alert system

2025

- Quantified the sensitivity of the AI-based system to to reveal Errors
  - MU (mostrato qua)
  - Shifts
  - Gantry angle
  - Material added

- Example of the passing rate range as a function of Monitoring Units for 3 commercial phantoms

- Alert level GPR=0.95--> Strong dependency on the type of phantom and field

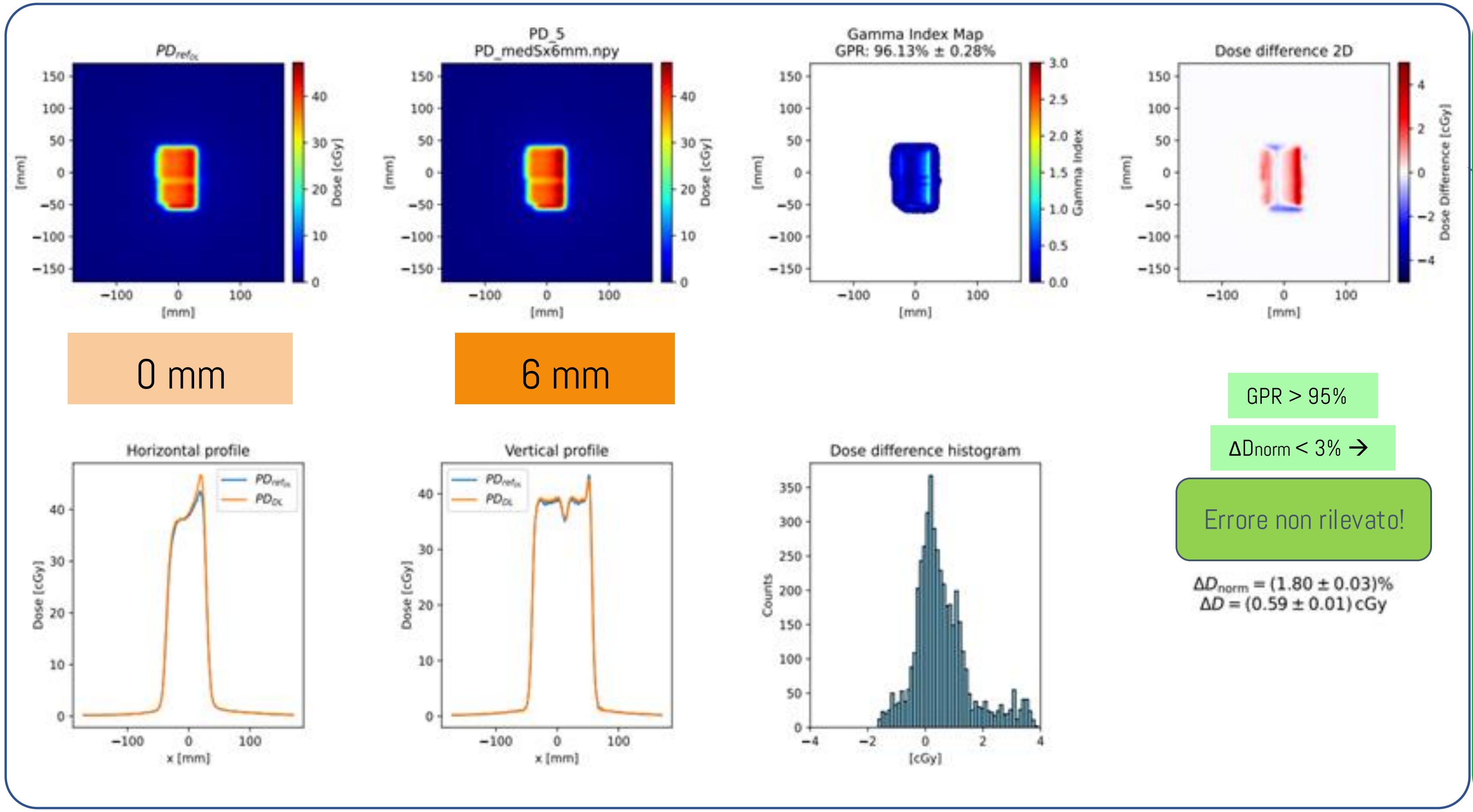


((a)) $1\%, 1mm$ ((b)) $2\%, 2mm$ ((c)) $3\%, 3mm$

WP3: Alert system

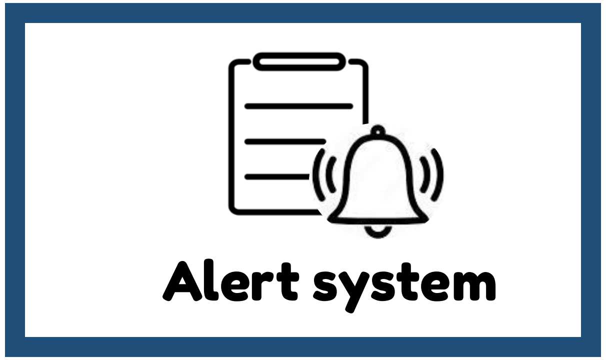
2025

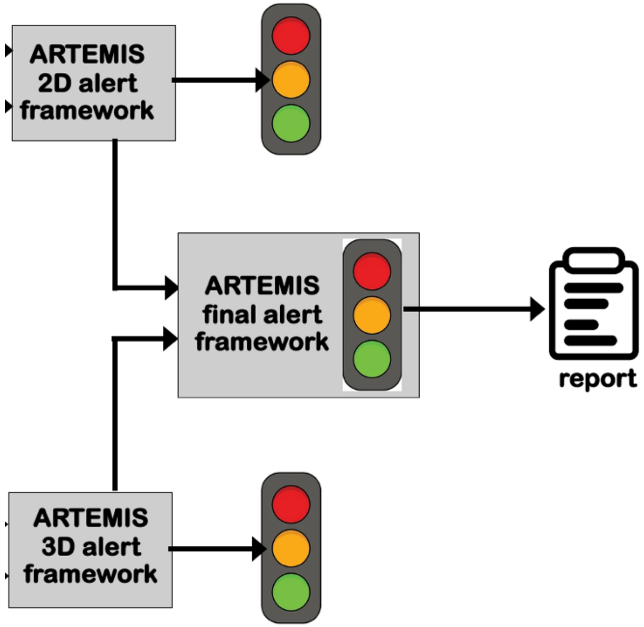
- Quantified the sensitivity of the AI-based system to to reveal Errors for breast phantom
  - MU
  - Shifts (example here)
  - Gantry angle



WP3: Summary

WP3





Jan-Sept 2025

WP 3.1 Development of 2D Alert system.

We made a preliminary layout for an alert system:

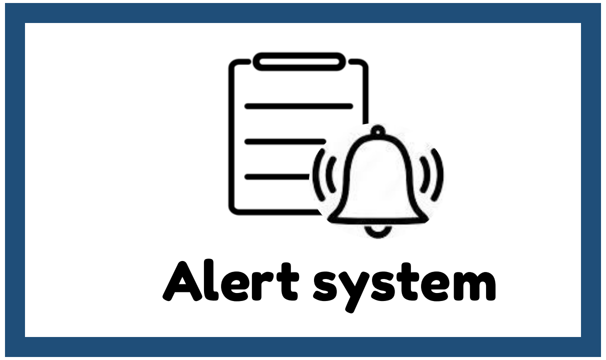
- Investigated a number of metrics, and quantified their sensitivity different thresholds
- Implemented them in a python software framework
- Identified 'difficult' cases (narrow fields)
- Quantified the dependence of sensitivity of the alert system to error size (monitoring units, setup errors, gantry rotations and material changes), done for
  - commercial phantoms
  - INFN printed phantom ARTEMIS 2
- Found some issues regarding the reproducibility of the EPID images/DL model over months
- Wrote a summary that can serve as draft for an eventual paper

.WP 3.2 Development of 3D Alert system.

We investigated literature regarding alert systems in radiotherapy and studied a few commercial systems. In-patient dose estimations from EPID are mostly done in a plane or point in the patient.

WP3: Summary

WP3



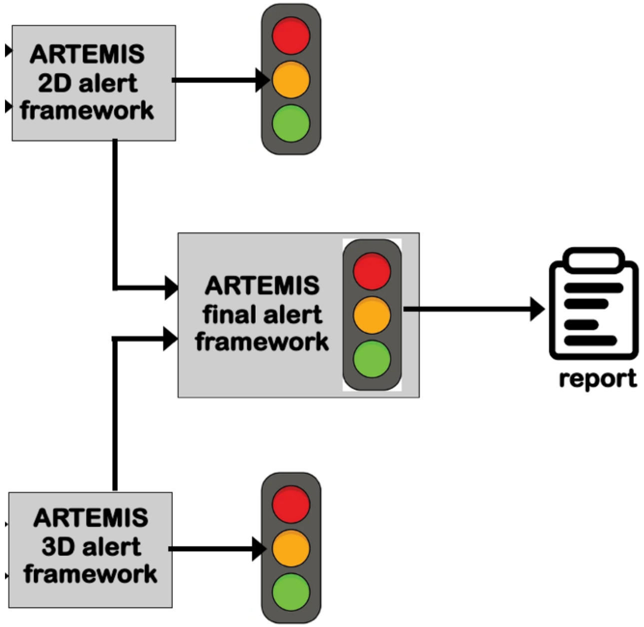
Rest of 2025

WP 3.1 Development of 2D Alert system.

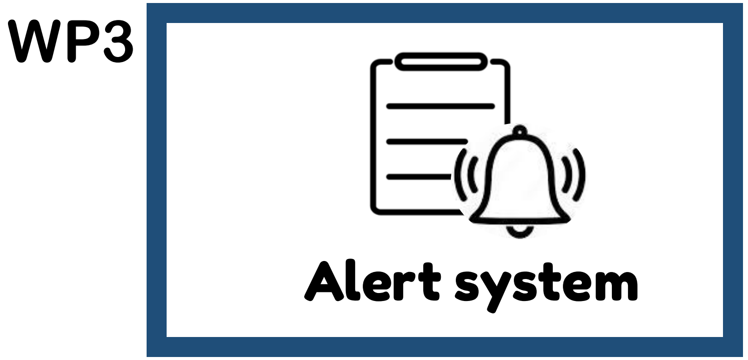
- Decide what metrics to use
- Take more data to test them, with inhomogeneous and homogeneous phantoms
- Write proceeding (Acta Physica Polonica A) and start drafting a real paper

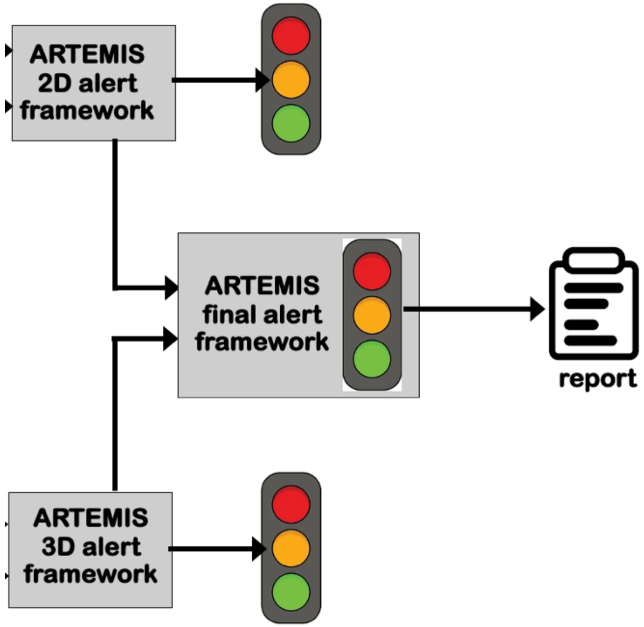
.WP 3.2 Development of 3D Alert system.

Start to analyze 3D dose analysis.



WP3: Summary





2026

WP 3.1 Development of 2D Alert system.

Finalize the system, test it and publish a paper.

.WP 3.1 Development of 3D Alert system.

- select possible alert metrics for 3D AI model
- first comparison with 2D model
- implement and test 3D metrics

Results 2024

Presentations

- ✓ Poster presentation by Lorenzo Marini (PhD student University of Pisa, 100% ARTEMIS): Deep Learning Methods for 2D In-vivo Dose Reconstruction with EPID Detector, 26 Mag - 01 Giu 2024, 16th Pisa Meeting on Advanced Detectors, La Biodola, Isola d'Elba, Italia.
- ✓ Oral presentation (Lorenzo Marini): Deep Learning Methods for 2D In-vivo Dose Reconstruction with EPID Detector, 7 Giu 2024, at Workshop on AI-based In-vivo Dosimetry with EPID, INFN, Sezione di Pisa, Italy.
- ✓ Oral presentation (Lorenzo Marini): Deep Learning Methods for 2D In-vivo Dose Reconstruction with EPID Detector, 9-15 Set 2024 110o Congresso della Societ`a Italiana di Fisica (SIF), University of Bologna, Italy.
- ✓ Poster with oral highlight (Lorenzo Marini): In-vivo Dose Reconstruction with EPID Detectors by Deep Learning, 11-14 Nov 2024 5th European Congress of Medical Physics (ECMP), Monaco di Baviera, Germania. The submitted abstract is available in https://doi.org/10.1016/j.ejmp. 2024.103684
- ✓ Oral presentation by Carlotta Mozzi: Development and validation of dataset using commercial TPS and radiochromic films for transit dosimetry with EPIDs, 9-15 Set 2024 110o Congresso della Societ`a Italiana di Fisica (SIF), University of Bologna, Italy. **Award for best communications with pubblication**
- ✓ Oral presentation by Carlotta Mozzi: In-vivo Dose Reconstruction with EPID Detectors in radiotherapy, 7 June 2024, at Workshop on AI-based In-vivo Dosimetry with EPID, INFN Pisa, Italy.
- ✓ Oral presentation Aafke Kraan: In-beam PET treatment monitoring of carbon therapy patients: results of a clinical trial, 10-15 June 2024, Singapore.

Publications

- ✓ Nuc. Instr. Meth. Phys. Res. A, 1069, 2024, 169908 (L. Marini, M. Avanzo, A.C. Kraan, F. Lizzi, C. Mozzi, A. Retico, C. Talamonti). (proceeding of PISA-meeting)
- ✓ Il Nuovo Cimento , 2025, Carlotta Mozzi, Development and validation of dataset using commercial TPS and radiochromic films for transit dosimetry with EPIDs

Results 2025

Presentations

End of 2025: 4 orals and 5 posters

Done:

- ✓ **Poster** with mini-oral: C. Mozzi et al, Mag 2025, Development and validation of a robust dataset using commercial TPS and radiochromic films for deep learning in transit dosimetry, C. Mozzi, L. Marini, M. Avanzo, A.C. Kraan, F. Lizzi, I. Meattini, L. Marrazzo, A. Retico, C. Talamonti, Radiotherapy and Oncology
- ✓ **Poster**: L.. Marini et al, 02-06 Mag 2025 European Society for Radiotherapy and Oncology (ESTRO), Vienna, Austria, Poster: Artificial intelligence for in-vivo dosimetry using EPID in external beam photon radiotherapy
- ✓ **Oral** presentation AAMP Trieste, Carlotta Mozzi
- ✓ **Poster** Emmanuel Uwitonze: Detection of treatment delivery errors in Radiotherapy with EPID imaging systems through 2D deep learning approach-based in-vivo dosimetry, School on Medical Physics for Radiation Therapy, ICTP Trieste, September 2025

Future:

- **Oral** presentation Rossana Lanzilotta, Detection of dosimetric deviations in conventional radiotherapy using a deep learning framework., SIF 2025
- **Poster** E. Uwitonze, Usage of DL-based portal dose images for treatment error detection with transit dosimetry, Krwakow, 2° Symposium on New Trends in Nuclear and Medical Physics, Krakow, September 24-26 2025.
- **Oral** presentation L Marini: In-vivo Dose reconstructor with EPID detector by deep learning, L. Marini, C. Mozzi, A.C. Kraan, M. Avanzo, F. Lizzi, A. Retico, C. Talamonti, Physica Medica, 202416-18 Ott 2025 Congresso Nazionale AIFM, Verona, Italia, Talk: Deep leaning model for transit dosimtry with EPID images
- **Oral** presentation Carlotta Mozzi, UPESM Adelaide Australia, September 2025
- **Poster** Carlotta Mozzi AIFM Verona, October 2025

Publications (written documents)

- ✓ Proceeding (published): Mag 2025, Development and validation of a robust dataset using commercial TPS and radiochromic films for deep learning in transit dosimetry, C. Mozzi, L. Marini, M. Avanzo, A.C. Kraan, F. Lizzi, I. Meattini, L. Marrazzo, A. Retico, C. Talamonti, Radiotherapy and Oncology, ESTRO
- ✓ Abstract (published): Artificial intelligence for in-vivo dosimetry using EPID in external beam photon radiotherapy, L. Marini, M. Avanzo, A.C. Kraan, F. Lizzi, C. Mozzi, A. Retico, C. Talamonti, ESTRO 2025 Abstract book, Radiotherapy and Oncology, S3406, 2025
- ✓ Master thesis Rossana Lanzilotta: Sviluppo di un sistema di verifica della dose in vivo in radioterapia basato su Deep Learning e immagini EPID, July 2025
- Acta Physica Polinica A proceeding ?
- Submitted Paper PHIRO??? «Improving patient treatment accuracy using transit dosimetry with EPID images and deep learning»

ARTEMIS: 2025 funding

Pisa

- ✓ Missioni: 2k: FINISHED!
- Consumo: 12k:
  - ✓ 2.1 k fixed PC (broke down)
  - ✓ 0.6 k external disks
  - ✓ 0.25 k tray and glue for Raise3Dprinter
  - 0.2 k: StoneFill filaments
  - 0.3 k: metal nozzles (ugelli) and trays
  - 2.1 k: 20 ceramic cubes with MadeInAdd, different densities
  - 6.5 k: 1 plate of breast (fibroglandular, 2x 30 x 30 cm3), 1 plate of breast (50/50, 1x 30 x 30 cm3), 1 plate of solid water. ICRU certified for radiotherapy and CT imaging, so we are 100% certain that they are useful for the model!!
- Pubblicazioni: 3k: maybe use something for Acta Fisica Polonica A if accepted (0.4k)?

Firenze

- ✓ Missioni: 2k: FINISHED!
- Consumo: 6 k:
  - 2.0 workstation for analysis
  - 3.0: 2 boxes of Gafchromics
  - 1.0: hard disk esterni per archiviati le immagini da tps e portali
- Pubblicazioni: 3k: we hope to use it for the submission to Physics and Imaging in Radiation Oncology

ARTEMIS: 2026 funding requests

Pisa

- Missioni: 2k
- Consumo: 16.5k:
  - full scale phantom
    - 10 k: MadeInAdd 3D print (offer received August 1)
    - 13 k: Bio3DModel print
  - Bone: 3.5 k for a 3 cm slab
- Pubblicazioni: 3k: will try to publish our work (2D alert system?)

Firenze

- Missioni: 2k
- Consumo: 10 k:
  - 6 boxes of Gafchromics
- Pubblicazioni: 3k: will try to publish work (3D model?)

Personale 2026

INFN Pisa

- Aafke Kraan (RN)
- Alessandra Retico
- Francesca Lizzi
- Silvia Arezzini
- Lorenzo Marini (dott.)
- Emmanuel Uwitonze (ass.)

- Cinzia Talamonti
- Stefania Pallotta
- Carlotta Mozzi
- Livia Marazzo

ARTEMIS: 2025 milestones

Data	Descrizione
31 dic 2025	Complete data set for phantoms with EPID measurements, treatment plans and TACs created.
31 dic 2025	First acquisitions of data of first patients performed
31 dic 2025	First validation tests on 2D AI-model
31 dic 2025	Design and initial setup of 2D alert system.

- ✓ We are on schedule to reach the milestones for 2025!

ARTEMIS: 2026 milestones

Data	Descrizione
31 dic 2026	MC simulations finalized
31 dic 2026	First patient acquisitions performed
31 dic 2026	Validation of 2D-DL model
31 dic 2026	Design and initial setup of 3D alert framework
31 dic 2026	Design and initial setup of combined 2D and 3D alert framework

Conclusioni

ARTEMIS 2025

- Modello AI 2D sviluppato, da consolidare
- Modello AI 3D in sviluppo
- Varie prese dati con errori controllati
- Sistema di alert in sviluppo
- Vari risultati presentati in conferenze: 5 posters and 4 orali alla fine del 2025!!

ARTEMIS 2026

- Più prese dati con errori controllati per sistema alert 2D
- Iniziare misure e implementazione sistema alert 3D
- Realizzazione fantoccio realistico!

MadeInAdd offer not in DB

FIELD_INFN - PISA - Parti finali_Series

INFN - PISA
56127 Pisa
Toscana Italy

Aafke Christine Kraan
aafke@pi.infn.it
+393484708409

Riferimento: 20250801-110309462
Preventivo creato: 1 agosto 2025
Scadenza preventivo: 11 agosto 2025
Preventivo creato da: Martina D'Anna
Customer Development Specialist
martina.danna@madeinadd.com
+393757799746

Commenti da Martina

Gentile Aafke,
di seguito trova la nostra quotazione relativa alla fornitura richiesta.

Precisiamo che la conferma circa la possibilità di mantenere una distanza massima di 1 mm tra le pareti interne potrà essere verificata solo in fase di modellazione della struttura trabecolare interna.

Prodotti e servizi

Customer Part/N	Oggetto e Descrizione	Quantità	Prezzo unitario	Totale
	assieme - Engineering Attività di design / modellazione 3D	1	€ 2.400,00	€ 2.400,00
	assieme - Manufacturing Tecnologia: DLP Materiale: Resina ceramica densità 1.73 g/cm3	1	€ 6.000,00	€ 6.000,00

Subtotale Una tantum	€ 8.400,00
Spedizione	€ 50,00
IVA	€ 1.859,00 22% di imposta
Totale	**€ 10.309,00**
Valore totale del contratto	**€ 10.309,00**

Lead Time (Giorni Lavorativi): 23

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