67° Course of the advanced radiation protection school“Carlo Polvani”

Milano

25 giugno 2025

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IRPA Airp Associazione Italiana di Radioprotezione

Digital twins for personal dosimetry

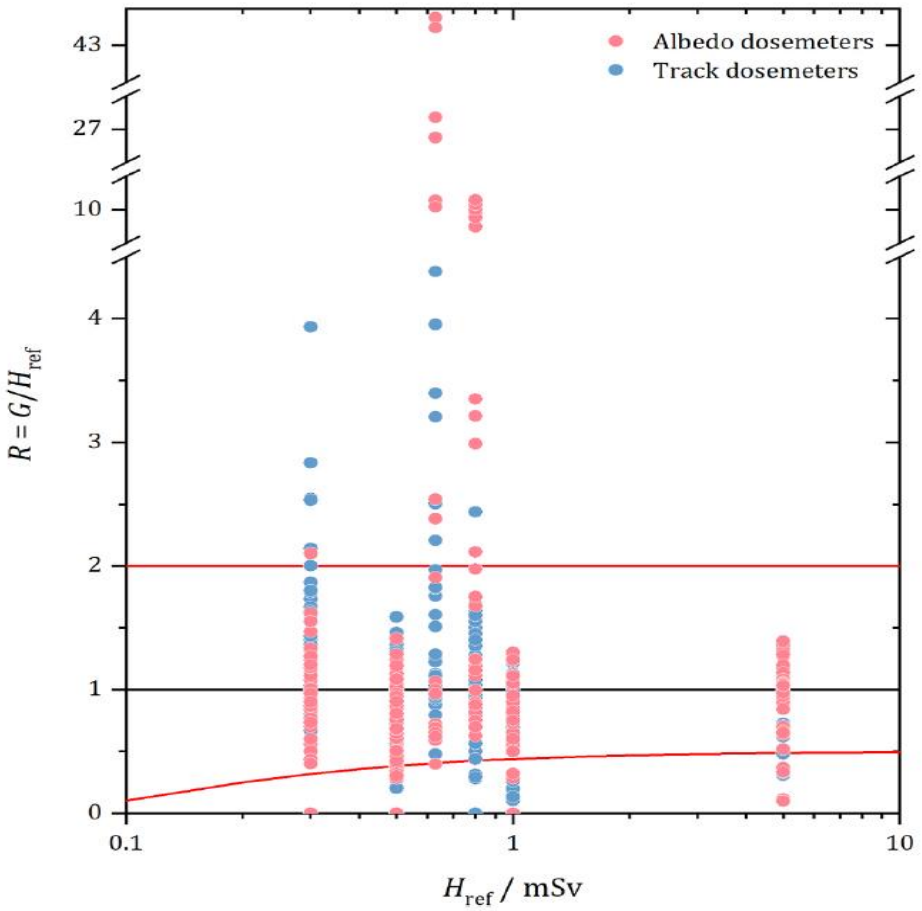
Marco Caresana

Motivation

Personal dosimetry can be not reliable in several situations

1) Extremely inhomogeneous radiation fields, where the dosimeter position cannot be representative of the whole body irradiation

2) Intrinsic difficulty in performing personal dosimetry, like in neutron fields



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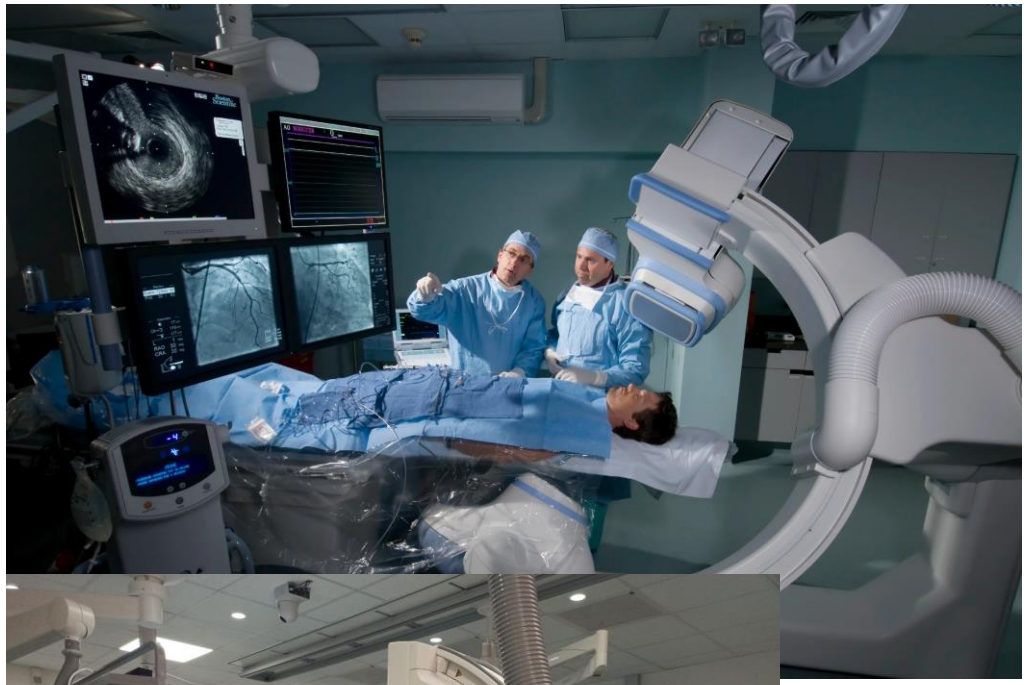
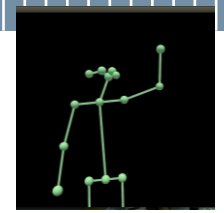
Interventional cardiology/radiology



Huge **uncertainties** on delivered dose to clinical staff:

- **Time variation** of scattered field during procedure, due to **variation of:**
  - **X-ray source positioning**
  - **Shielding objects positioning** (ceiling-suspended shield, detector)
  - **Patient positioning** (rotation/translation of patient bed)

Concept



Body tracking of clinical staff

input

on-line data

input

on-line data

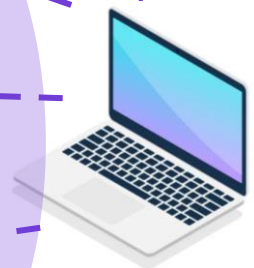
Position tracking of shields

off-line data

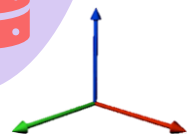
Irradiation data

SUPER USER

Phantom animation



MC dose simulations



Object modelling

- **Organ dose**
- **Effective dose**

to clinical staff

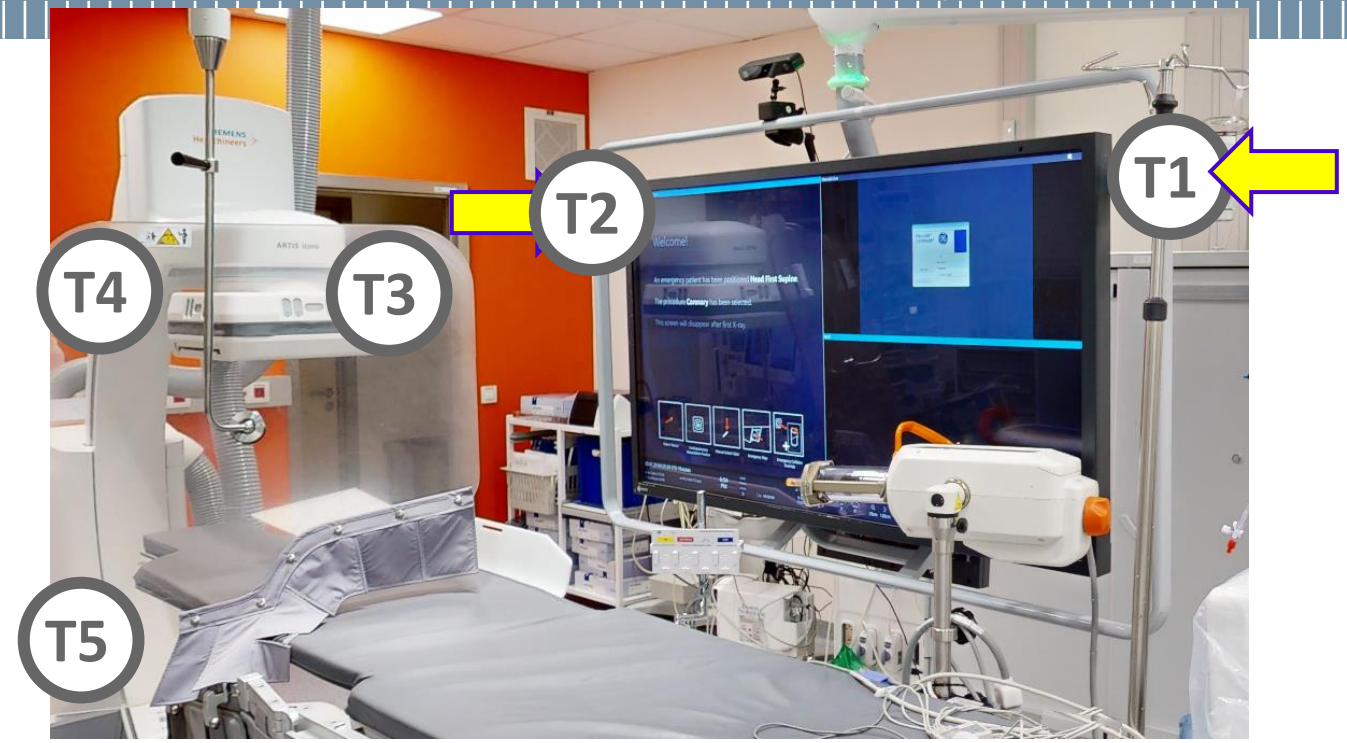
+

Validation of data-stream system and results

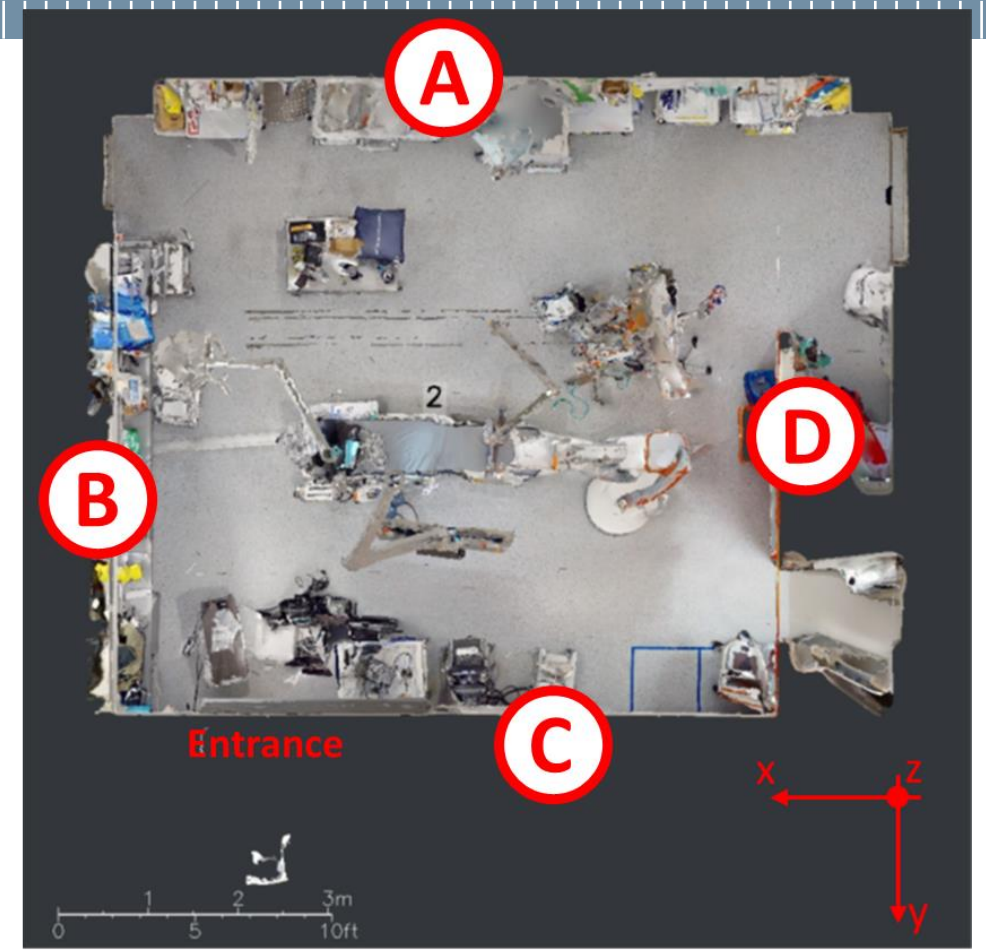
Reference system, anchors and tags

All tags:

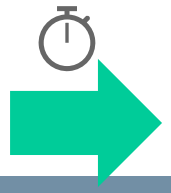
Picture from Aalst hospital, 10/12/2024



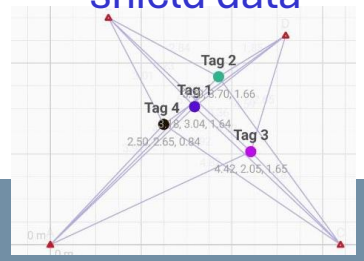
All anchors:



Camera RF:
skeleton tracking data



UWB anchors RF:
shield data



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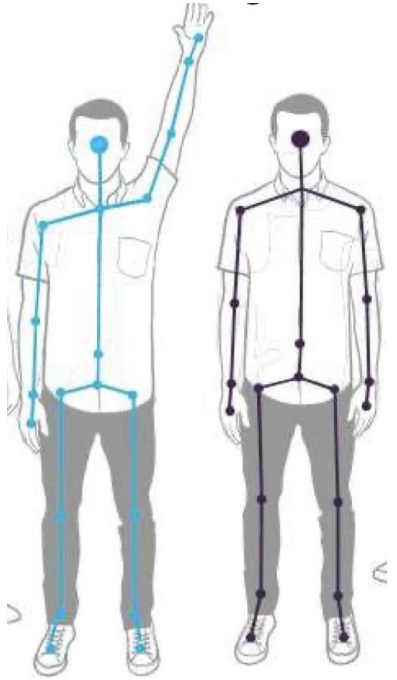
Skeletron tracking

3D cameras



Skeletron tracking

Source simulation

Dose

Dosimetria computazionale On-Line

skeleton tracking

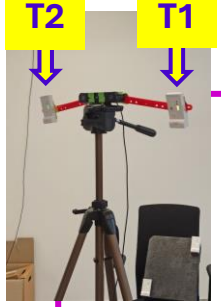
ZED X

GSML cable

ZED Box

T2 **T1** *shield tracking*

camera RF transform



T3

T4

Tags (x4)

Anch (x4)

List (x1)

UWB

UWB

Micro USB cable

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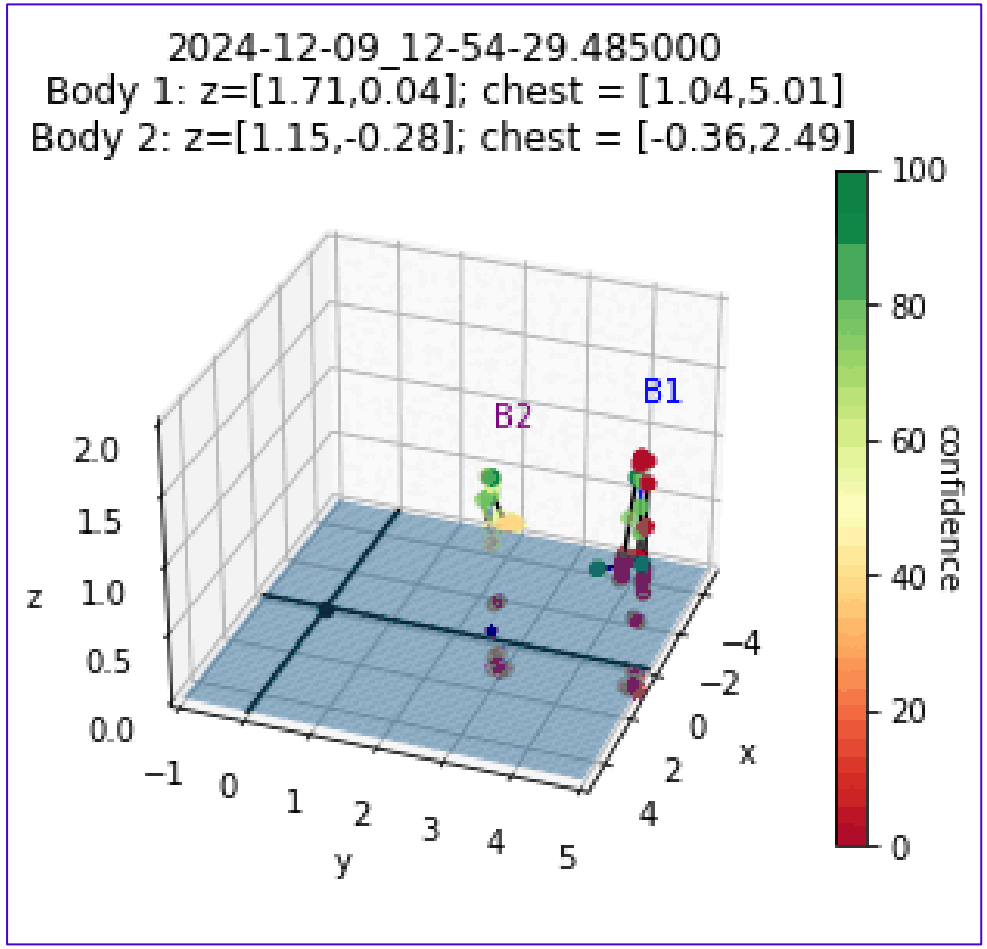
Motion tracking



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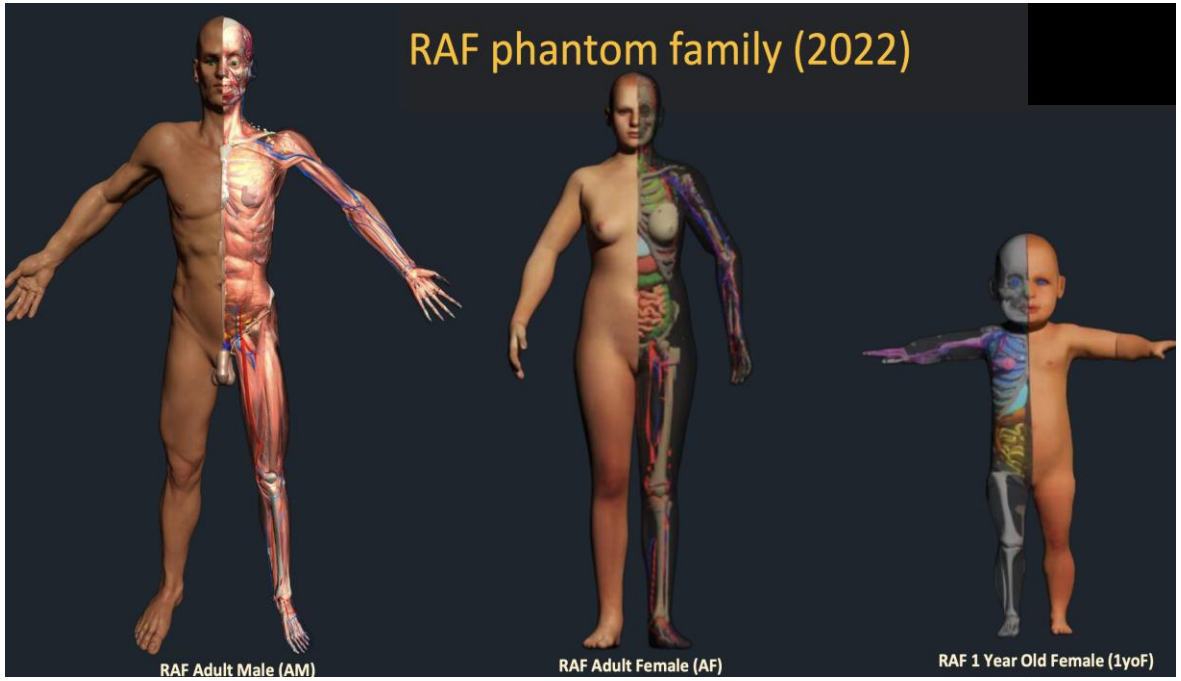
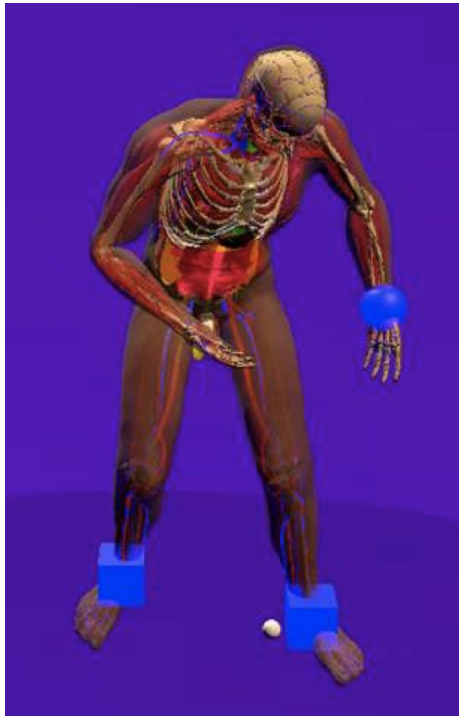
Computational Phantoms





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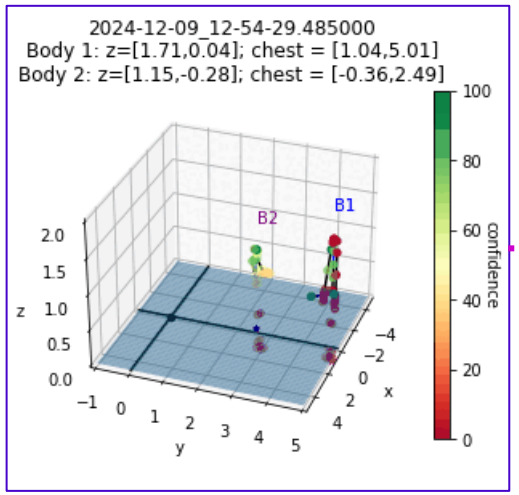
Computational Phantoms

Tracked joints position



Compute **end effectors**

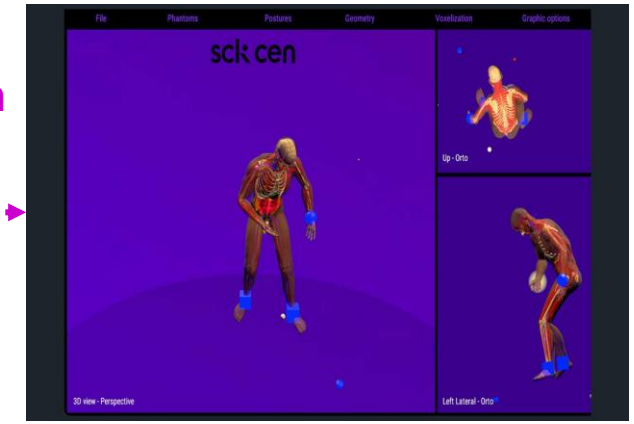
- Feet
- Hands
- Head look-at

Interactive Posture Program (IPP)

Inverse kinetics algorithm

Input: end effectors
Output: phantom realistic pose

Phantom realistic movement



P. Lombardo et al.,
PODIUM presentation, 2022

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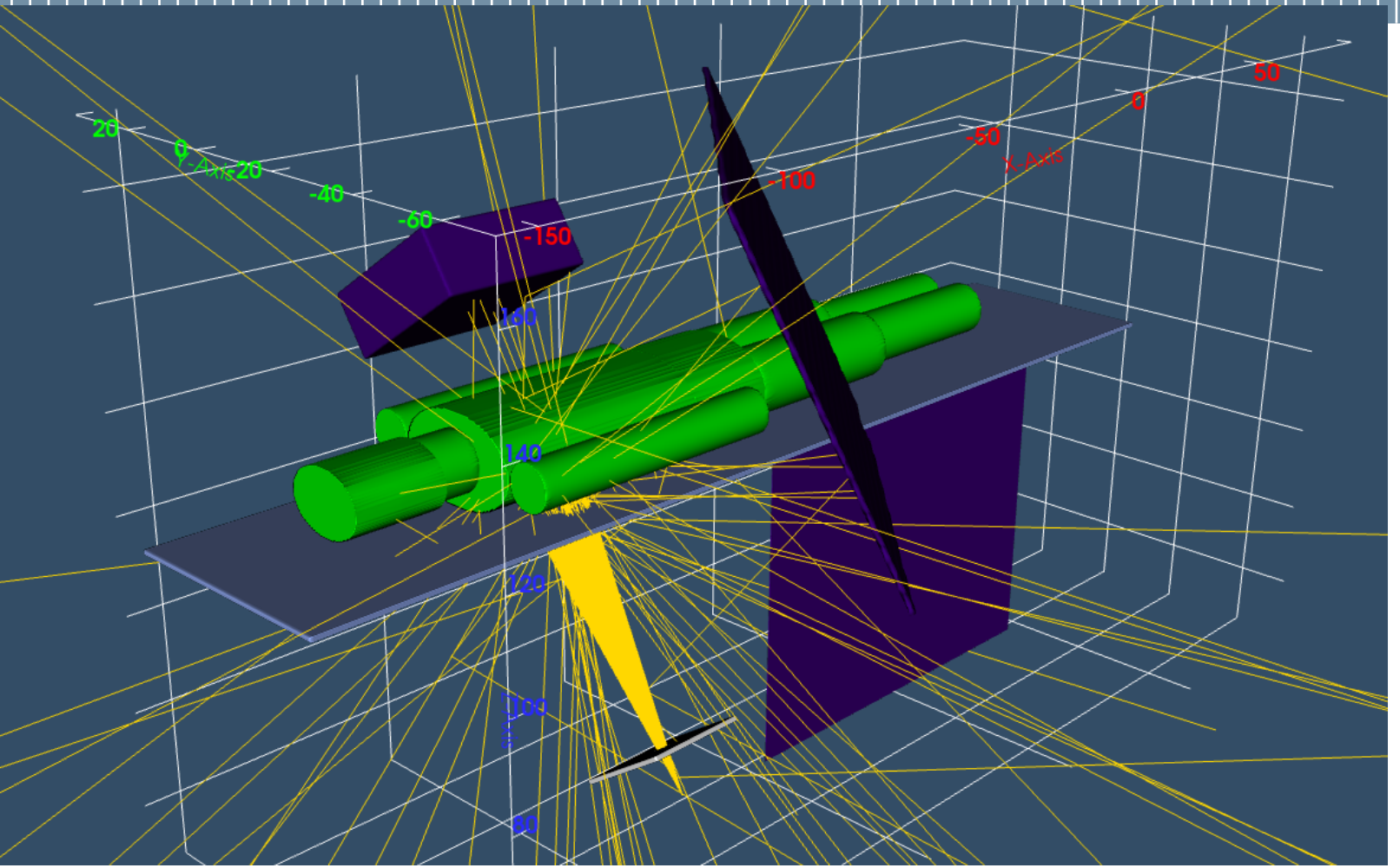
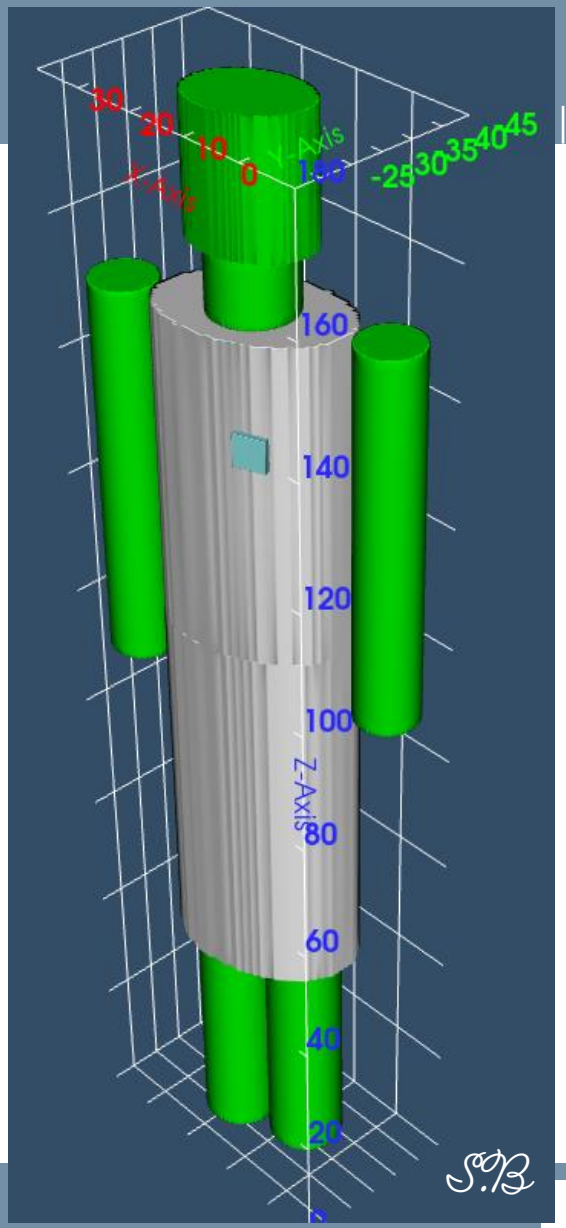
Simulation of the radiation field





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Dosimetry results

Dosimeters data (Dose aware

RaySafe™

First operator

Second operator

First nurse

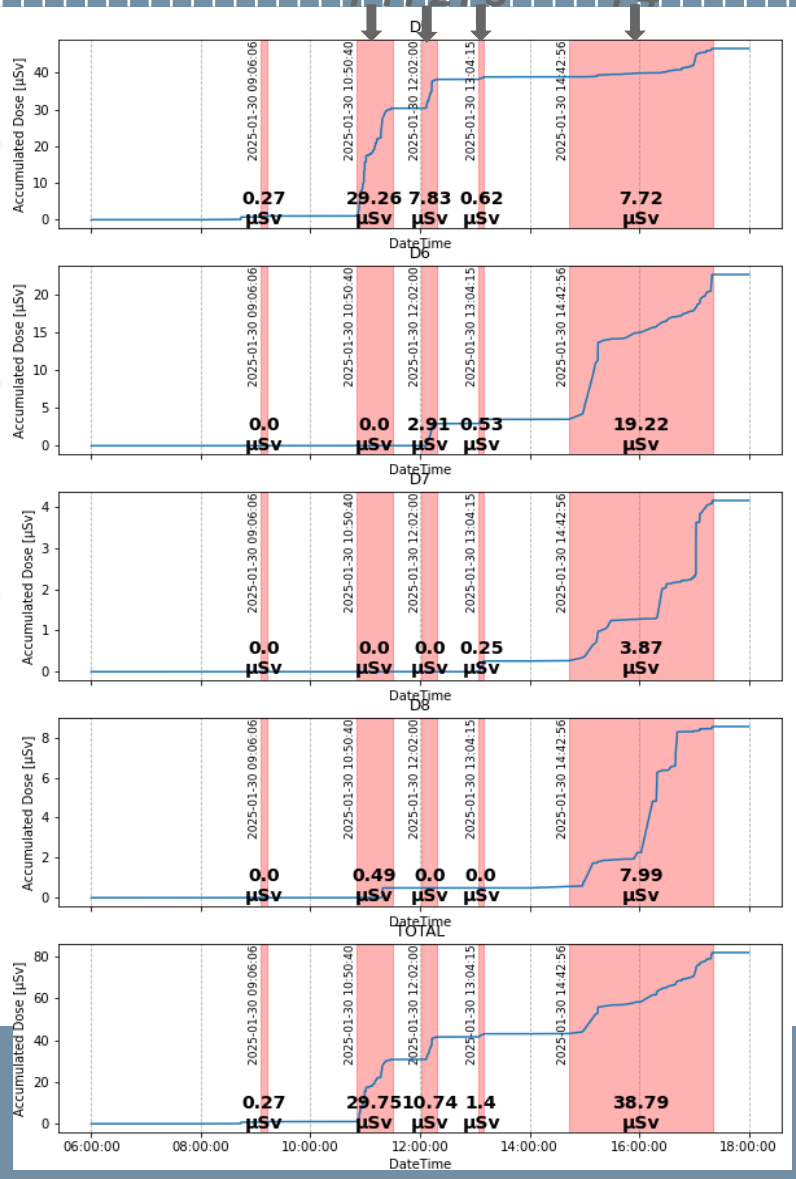
Second nurse

TOTAL

Jan 30th

Apr 18th

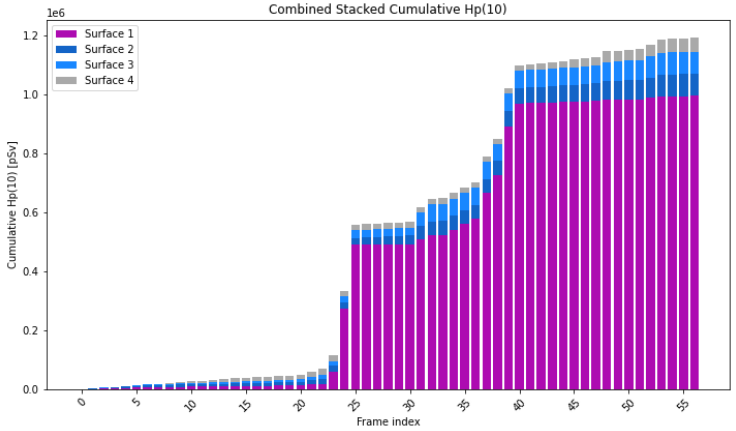
P1 P2 P3 P4 P5 P6 P7 P8

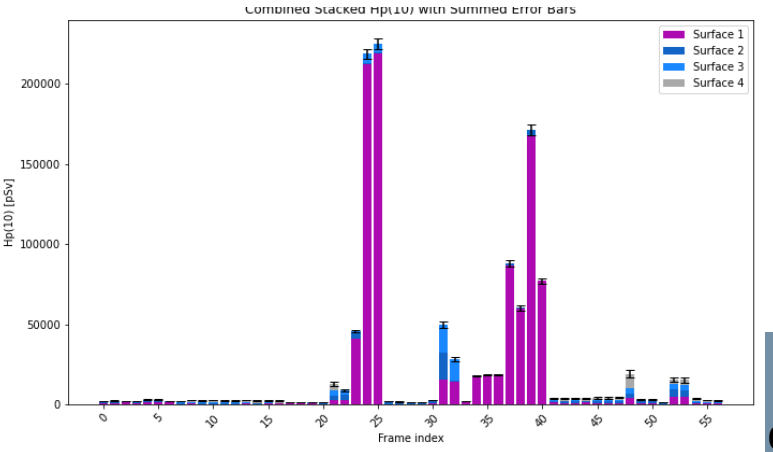


Simulation vs experimental

P3

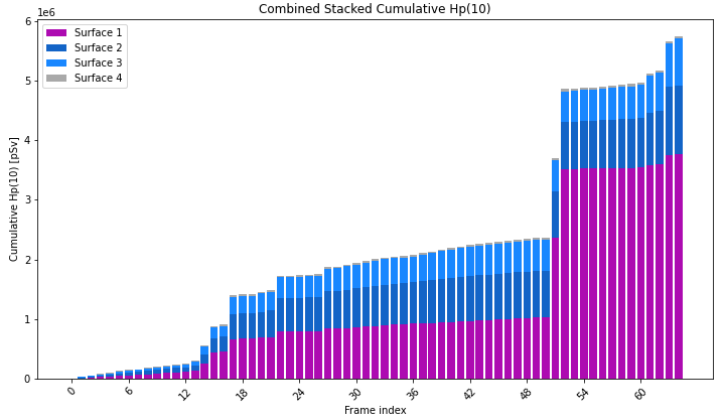
2025-01-30 13:07:13 57 simulations	Simulation Hp(10) [µSv]	Simulation relative err [%]
Scoring 1	1,00	2,11
Scoring 2	0,08	9,02
Scoring 3	0,08	8,13
Scoring 4	0,05	8,37
TOTAL Hp(10)	1,20	3,17
DOSIMETERS DATA	1.40	

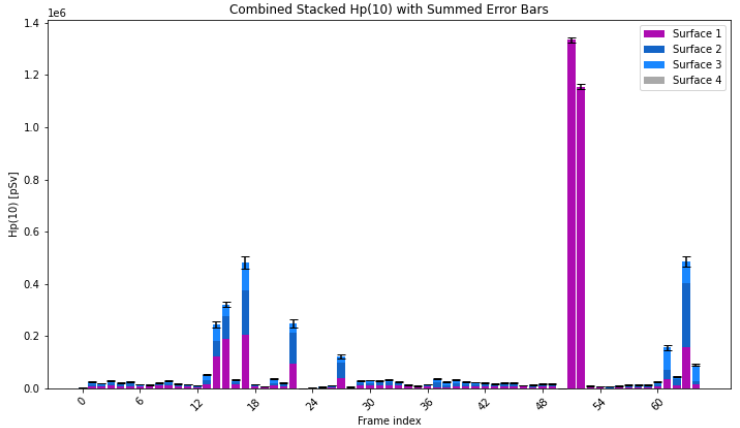




P2

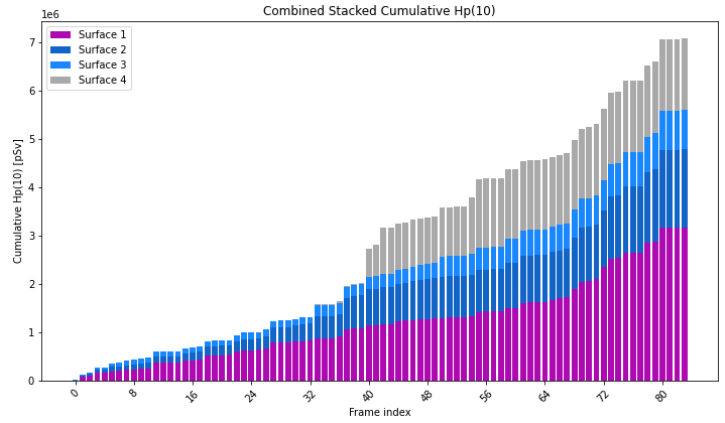
2025-01-30 12:04:58 65 simulations	Simulation Hp(10) [µSv]	Simulation relative err [%]
Scoring 1	3,77	2,03
Scoring 2	1,15	4,74
Scoring 3	0,78	5,50
Scoring 4	0,04	8,35
TOTAL Hp(10)	5,75	3,09
DOSIMETERS DATA	10.74	

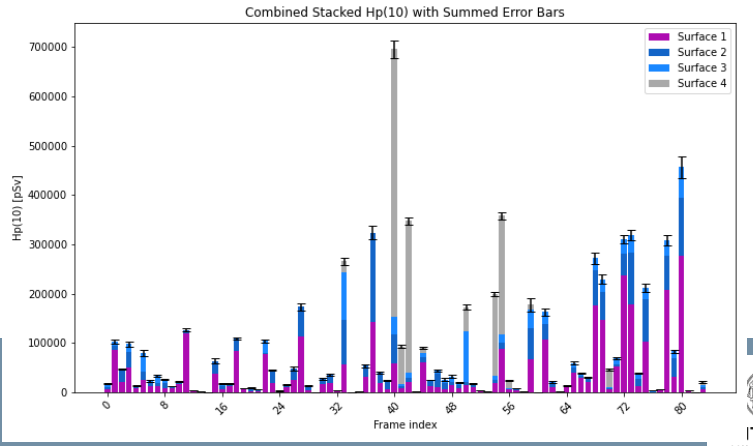




P5

2025-04-18 09:58:37 84 simulations	Simulation Hp(10) [µSv]	Simulation relative err [%]
Scoring 1	66,05	1,63
Scoring 2	10,01	3,83
Scoring 3	3,62	7,06
Scoring 4	2,85	1,70
TOTAL Hp(10)	82,52	2,14
DOSIMETERS DATA	46.02	





Simulation vs experimental

Procedure ID	Dosimeters TOTAL Hp(10) [µSv]	Simulations TOTAL Hp(10) [µSv]	Simulations TOTAL Hp(10) relative err [%]	Number of cumulated simulations
P2 - 2025-01-30 12:04:58	10.74	5,75	3,09	65
P3 - 2025-01-30 13:07:13	1.40	1,20	3,17	57
P5 - 2025-04-18 09:58:37	46.02	82,52	2,14	84

Remarks

1) No systematic bias between dosimeters and simulation
2) Shields not well tracked, especially if tilted. Better to use a dedicated camera with trackers on the shield
3) Scoring area wider than the dosimeter, for better statistics. Penalising for inhomogeneous fields
4) Difficulty in identifying the operator. Recognition systems are needed

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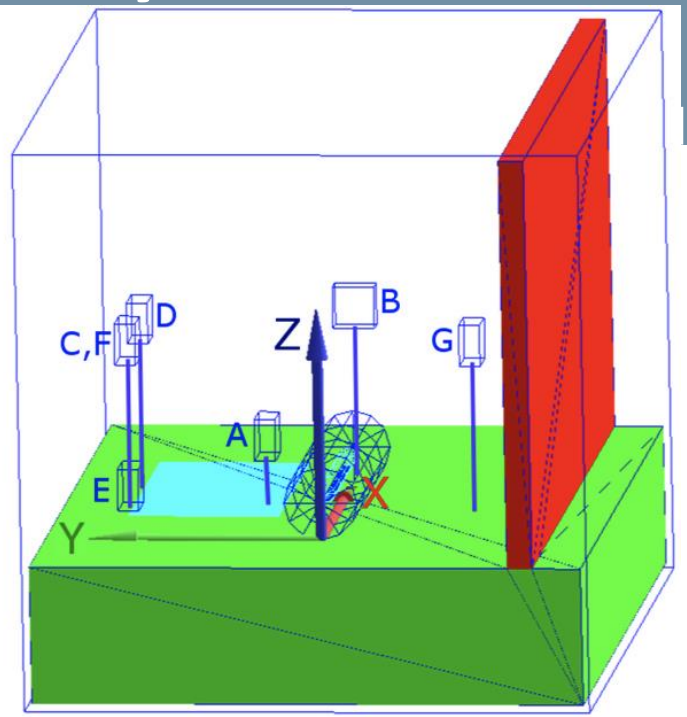
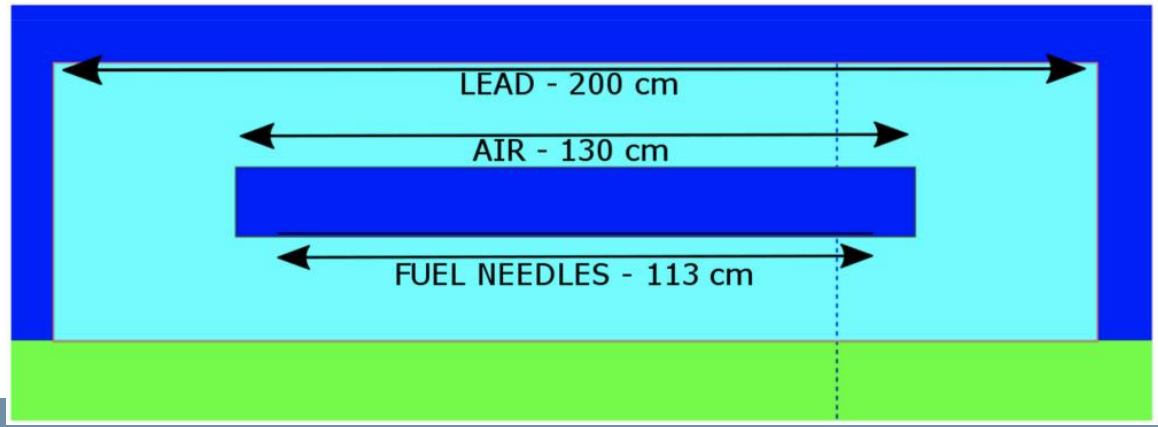
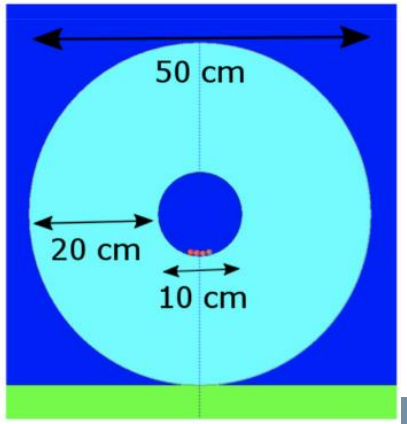
Computational dosimetry in NPP







https://doi.org/10.1016/j.radmeas.2022.106867

Computational dosimetry in NPP

https://doi.org/10.1016/j.radmeas.2022.106867

Grazie per l’attenzione

Thanks for your attention