Personal Online DosImetry Using computational Methods

EUROPEAN JOINT PROGRAMME FOR THE INTEGRATION OF RADIATION PROTECTION RESEARCH CONCERT

CONCERT-European Joint Programme for the Integration of Radiation Protection Research

The PODIUM project (2018-2019):
Personal Online DosImetry Using computational Methods

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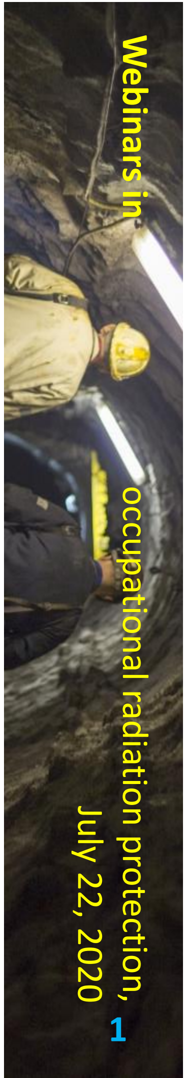
UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH Institut de Tècniques Energètiques

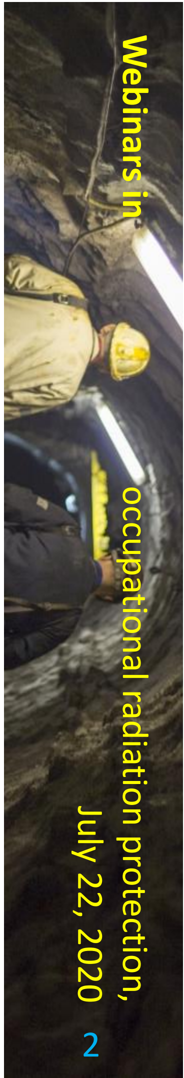
7 partners: SCK•CEN (Belgium), UPC (Spain), HMGU (Germany), LU (Sweden), PHE (UK), EEAE (Greece), SJH (Ireland)

Some of the slides have been adapted from other PODIUM partners' presentations.



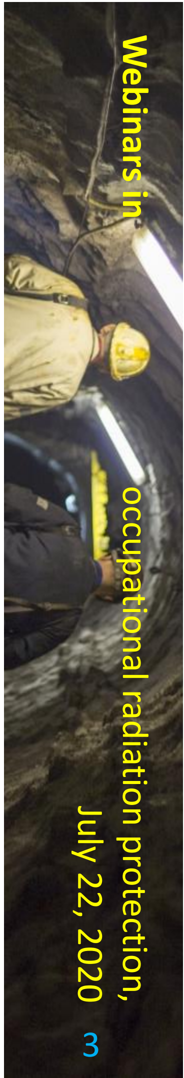
Outline

- Motivation
- Change of paradigm
- Goal of PODIUM
- Background
- Main achievements
- Conclusions and further work



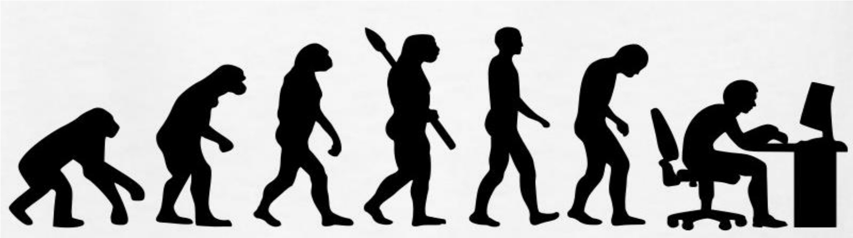
Motivation of PODIUM project
Pitfalls in personal dosimetry

- Workers don’t like to wear dosemeters.
- Workers especially don’t like to wear more than one dosemeter:
  - passive whole body; extremity and eye lens dosemeter
  - active dosemeter ....
- Still not all parts of body covered (maybe brain, heart, is needed in future)
- Not always appropriate use of dosemeters: positioning errors, not worn
- Time to receive results
- Lost of dosemeters
- Technical limitations of personal dosemeters.
- Changes in radiological quantities and requirements….



Change of paradigm

- Could **computational dosimetry** overcome the issues of the current individual monitoring system based on physical dosemeters?

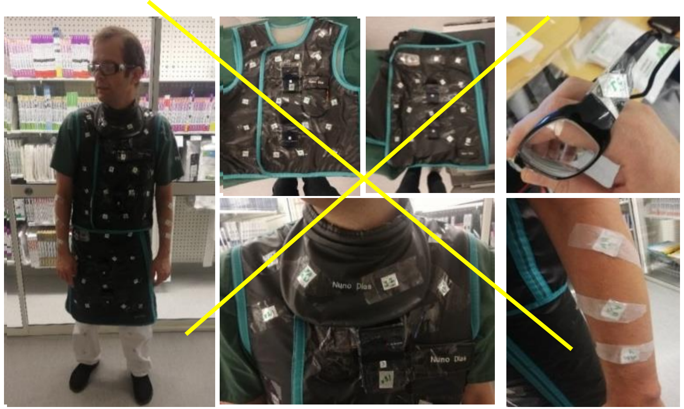


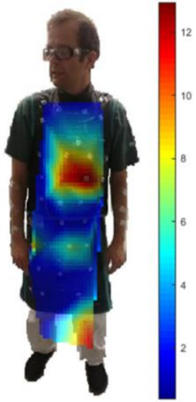
Advantages:

- Physical dosemeters would not be needed (no lost of information).
- Organ doses could be calculated (any organ of interest, better knowledge of effective dose, no need of operational quantities.
- Accuracy could be improved (personalised dose calculation).
- Information could be available in real time (or within the day).

Goal of PODIUM

- To improve occupational dosimetry by an innovative approach:
  - Development of an online dosimetry application based on computer simulations and person recognition and tracking, **<u>without the use of physical dosemeters</u>**.





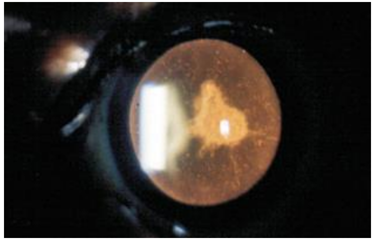
(images courtesy of LU) (image courtesy of SCK·CEN)

Feasability study – case 1

- Cardiologist and interventional radiologist are exposed to radiation during their usual work.

Hands and eyes are always close to the beam

Hands are sometimes inside the beam

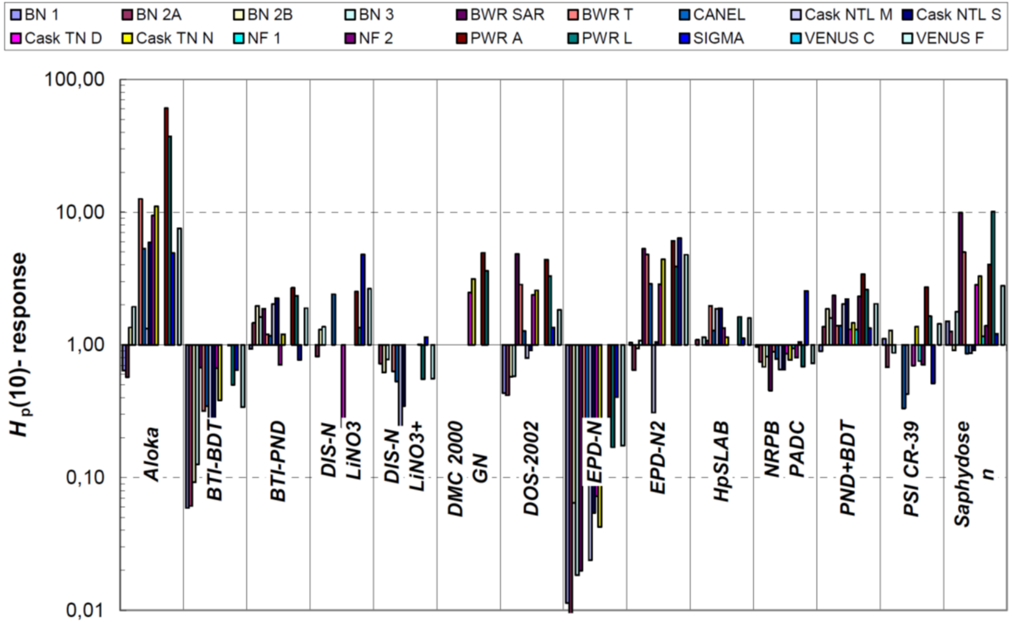


Tissue damage

From *ORAMED training material,* available at www.oramed-fp7.eu

Feasability study – case 2

- Workplaces with neutron or gamma neutron fields



Workplace fields involving neutrons typically quite complicate: large geometries, wide energy ranges, mixed fields.

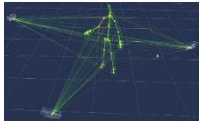
Neutrons personal dose-meters have highly energy-dependent responses:

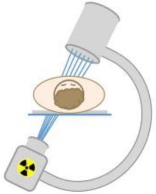
±2 orders of magnitude variation in workplace fields!

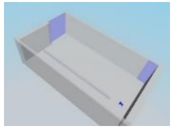
From Final report (summary) Evaluation of Individual Dosimetry in Mixed Neutron and Photon Radiation Fields (EVIDOS)
https://cordis.europa.eu/project/id/FIKR-CT-2001-00175/reporting

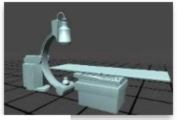
How is PODIUM virtual dosimetry system working?

Staff movement monitoring and Radiation field mapping









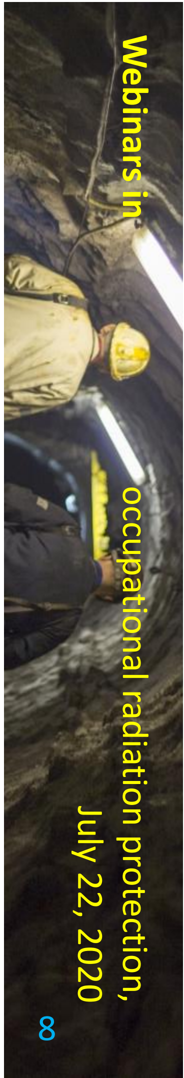
Motion Tracking Input

Radiation Source Input

Geometry Input

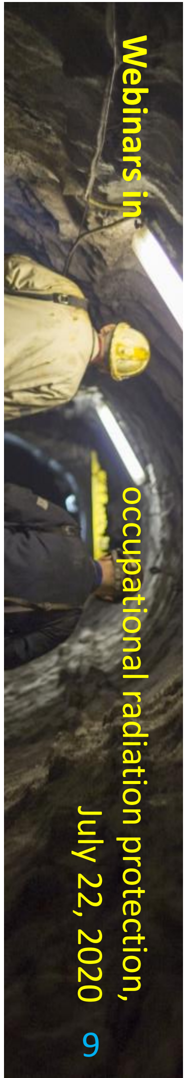
MC Dose Calculation

Look-up tables pre-calculated data



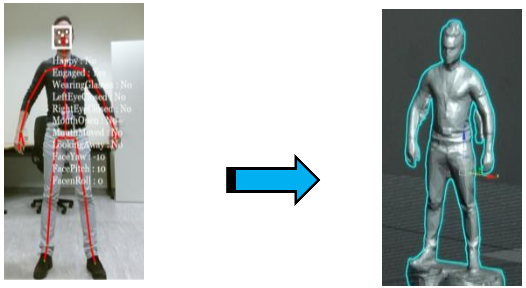
Personal Online DosImetry Using computational Methods

Background



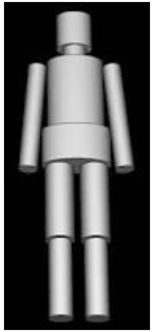
Position tracking technology

- Markerless tracking based on computer vision
- **RGB-D** cameras: combine color information with per-pixel **depth** information
- **Cheap nowadays**
- **Microsoft® Kinect V2 .0**

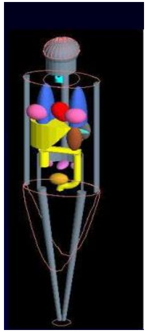


Phantoms for computational dosimetry

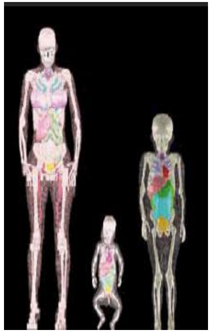
1950's	1960's	1980's	2000's
Simple phantoms	Stylized phantoms	Voxel phantoms	Hybrid phantoms



BOMAB Phantom



ORNL Phantom

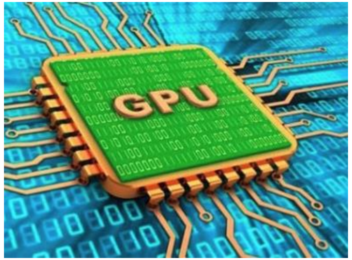


Irene, Baby & Child Voxel Phantoms

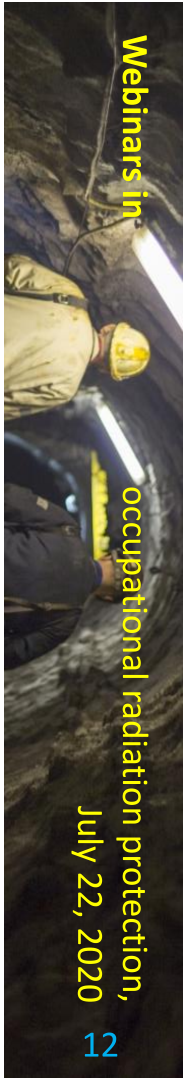
Adult male Phantom

Realistic Anthropomorphic Flexible Phantom

Calculation power, Monte Carlo

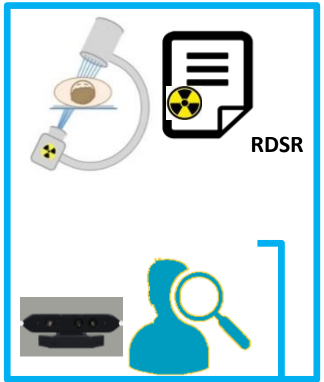


2018 Fast radiation transport calculation



Workplan and structure

Main milestone: An online dosimetry application for interventional procedures



WP0: Management
Coordinator and WP leaders (PMB)

WP1: Work place description: staff movement monitoring and radiation source mapping
UPC, SCK, PHE, LU

WP2: Dose simulations using computational phantoms and Monte Carlo methods
HMGU, UPC, SCK, PHE

WP3: Development of the software tool
SCK, HMGU, UPC

WP4: Assessment and validation of the on-line system in an Interventional radiology hospital environment
LU, SJH, EEAE, UPC

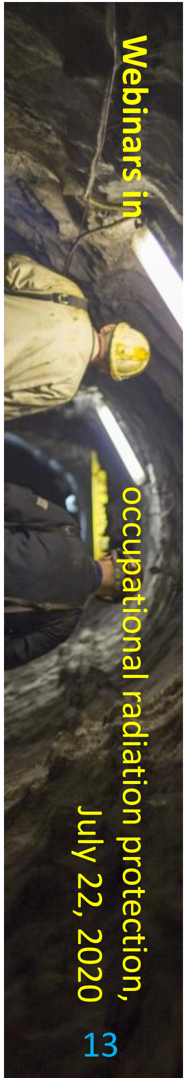
WP5: Application in neutron dosimetry
PHE, SCK

WP6: Dissemination of the results of the project
EEAE, LU, SJH, UPC

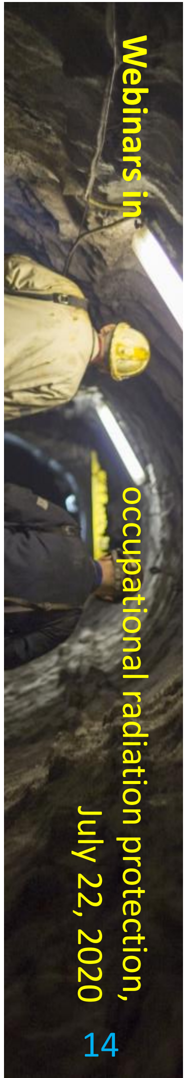
Dose calculation

Verification in hospitals

Verification in neutron fields

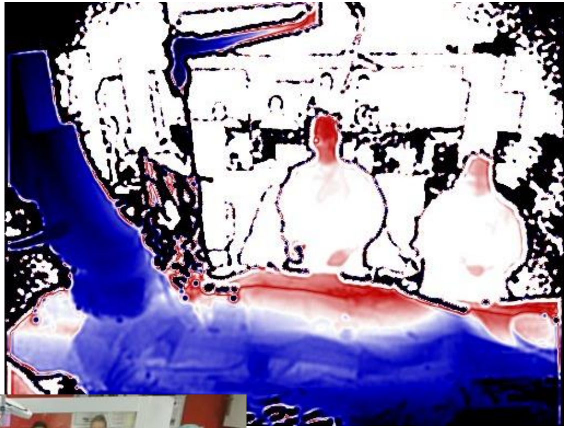


Main achievements for each workpackage



WP1: Tracking – 1 camera

- One Kinnect system (RGB+depth sensor)

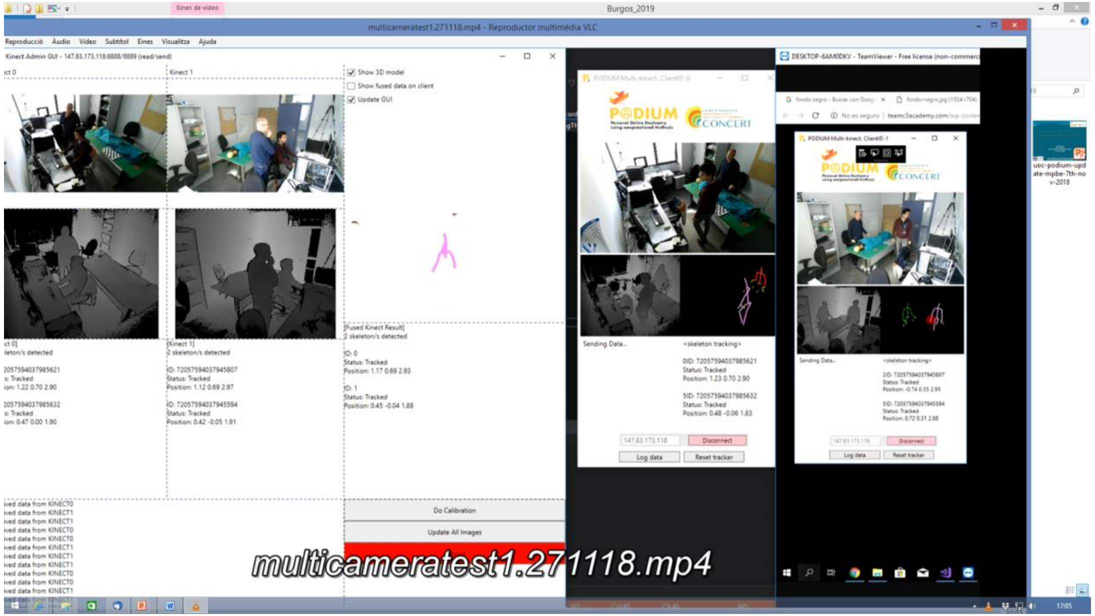


Occasionaly miss-positions; occlusions by shielding.

(test in Uz-VUB-Brussels, image courtesy by SCK-CEN)

WP1: Tracking – 2 cameras

- Multi-camera system (2 cameras under tests):



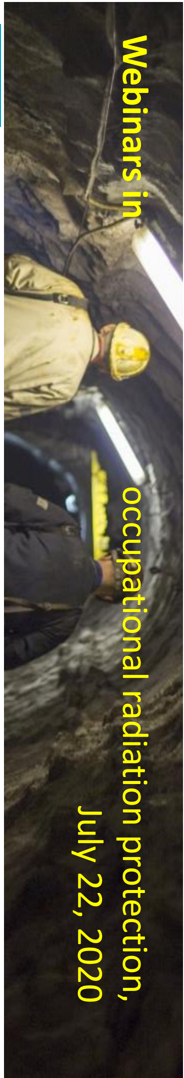
Main advantages:

- Occlusions of skeletons are avoided.
- The field of view is increased.
- Even when two or more people are close they are correctly identified.

WP1: Two tracking systems

Two tracking systems have been developed:

- One-camera tracking: Demonstrates to be enough for procedures where the operators can be seen from the position of the camera without obstacles and they don’t change much their positions. It can work with some overlap between bodies but not with total occlusion.
- Multi-camera tracking: Besides increasing the view area, it overcomes most of the occlusion problems that appear with the one camera system. If needed, one can connect more than two cameras with a simple calibration procedure. The main drawback is that, at present, it needs one computer per camera.



WP1: Radiation source input
Interventional radiology - cardiology

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RDSR

Dose management system

Qaelum

DREPORT

…

X-Ray spectrum

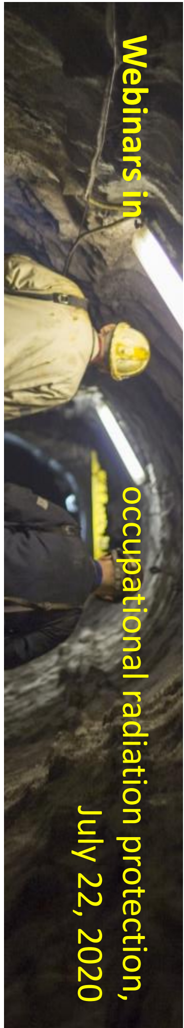
- Tube potential (kVp value)
- Tube current
- Added filtration
- Target material
- Voltage waveform

Tube Angulation

- C-arm projections
- Radiation field

Ideally: on line information. In practice once the procedure is finished. Time synchronization with tracking system is needed.

UPC



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WP1: Radiation source input
Neutron workplaces

Secondary Standard Calibration Laboratory with Am-Be neutron source moderated by water containers
=
Simulated workplace well characterized

Transport container with spent MOX fuel in controlled area
=
Real workplace field , not well characterized

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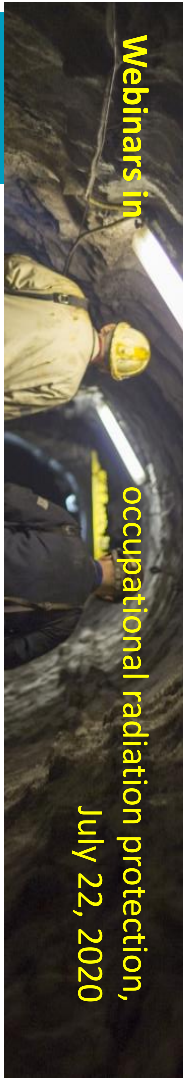
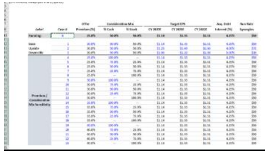


WP1:Neutron workplaces, dose mapping

- Geometry modelled with MCNP6.2 using macrobodies
- Source modelled with neutron energy spectrum. For unknown sources: iterative approach.
- Build map by characterizing fluence-energy-angle distribution of neutron and photon field as function of position $\Rightarrow$ Then apply $E(\varphi)/\Phi$ conversion coefficients
- Validation with survey instruments measurements.


+

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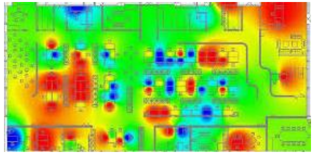
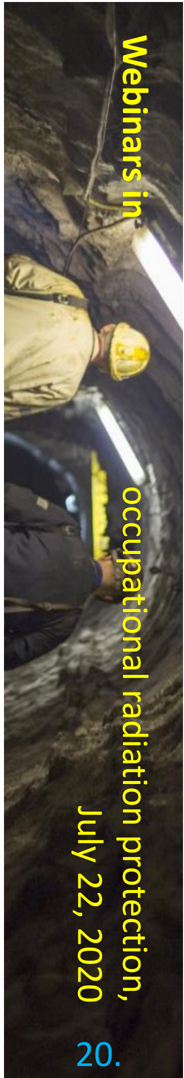



+

→


+ →

$$\int \dot{E}\, dt$$



WP2: Dose calculation

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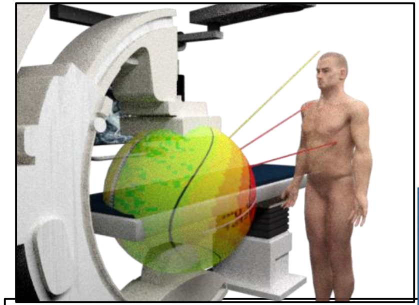
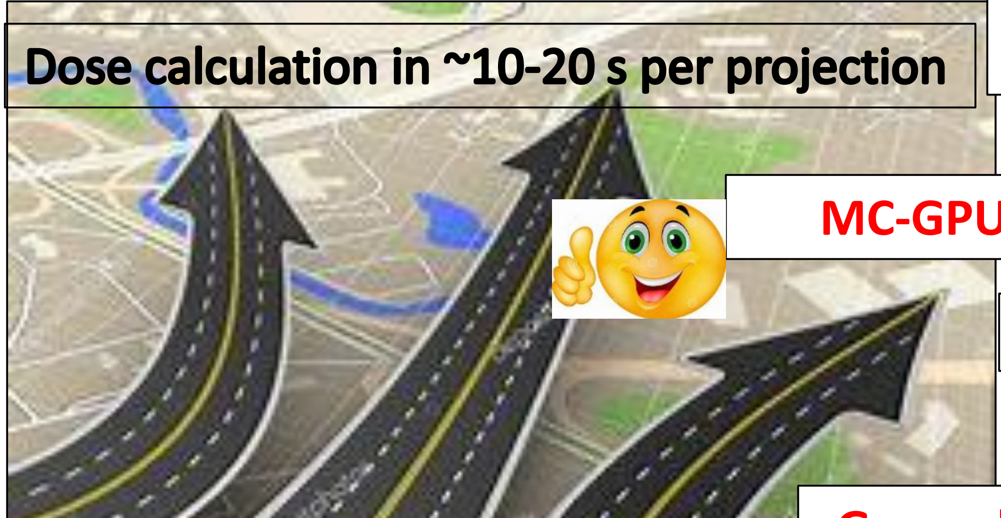
Look-up tables pre-calculated data

For neutrons: Dose mapping



For photons: Ray tracing technique



Dose calculation in ~10-20 s per projection

Fast Monte Carlo

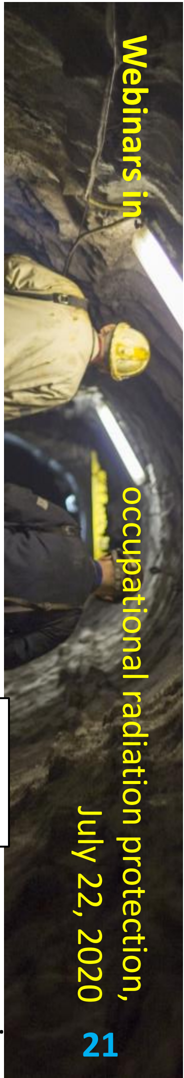
MC-GPU*

For photons

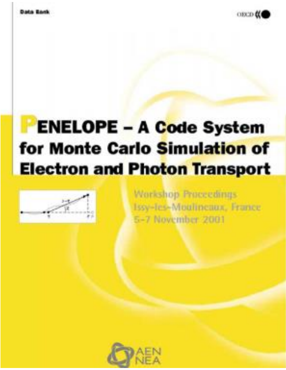
General purpose ** (PENELOPE/penEasy)

*A. Badal and A. Badano, Med. Phys. 36, 4878-4880 (2009)

** J. Sempau, A. Badal, L. Brualla, Med. Phys. 38, 5887–5895 (2011).



WP2: Fast Monte Carlo codes for interventional radiology


Data Bank OECD
PENELOPE – A Code System for Monte Carlo Simulation of Electron and Photon Transport
Workshop Proceedings
Issy-les-Moulineaux, France
5-7 November 2001
AEN NEA

AFTER PODIUM

PENELOPE/penEasyIR

MCGPU-IR

Fast and automatic simulation of a procedure

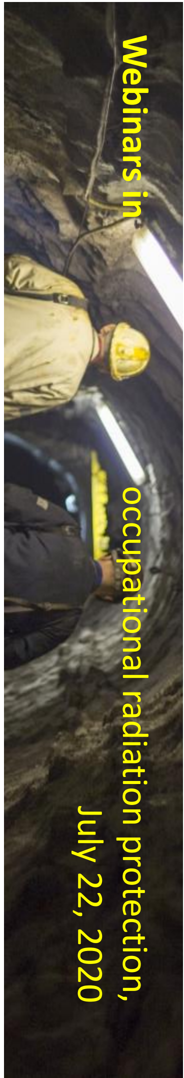
BEFORE PODIUM

PENELOPE/penEasy

Slow (minutes-hours)

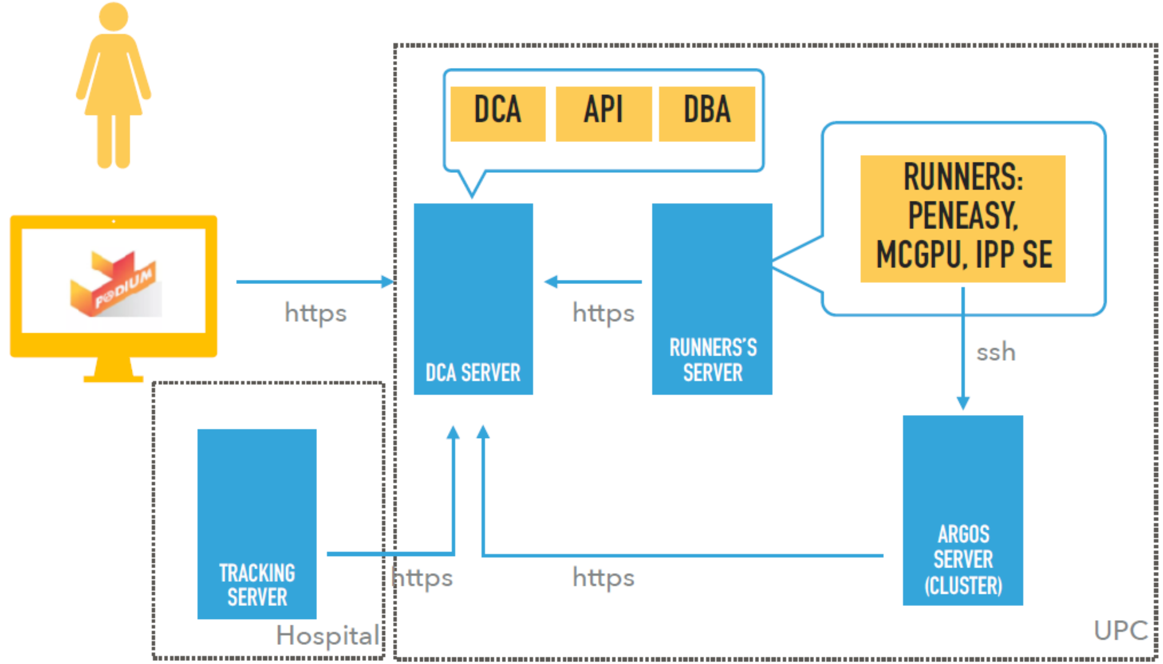
MC-GPU http://code.google.com/p/mcgpu/

Some limitations: Manual entry of radiation source ...



WP3: On line application

ARCHITECTURE – PODIUM SETUP



* Runners's server is a virtual machine, hosted on argos server

** DCA server is provided by Computer Science Department

Webinars in occupational radiation protection, July 22, 2020

WP3: On line application

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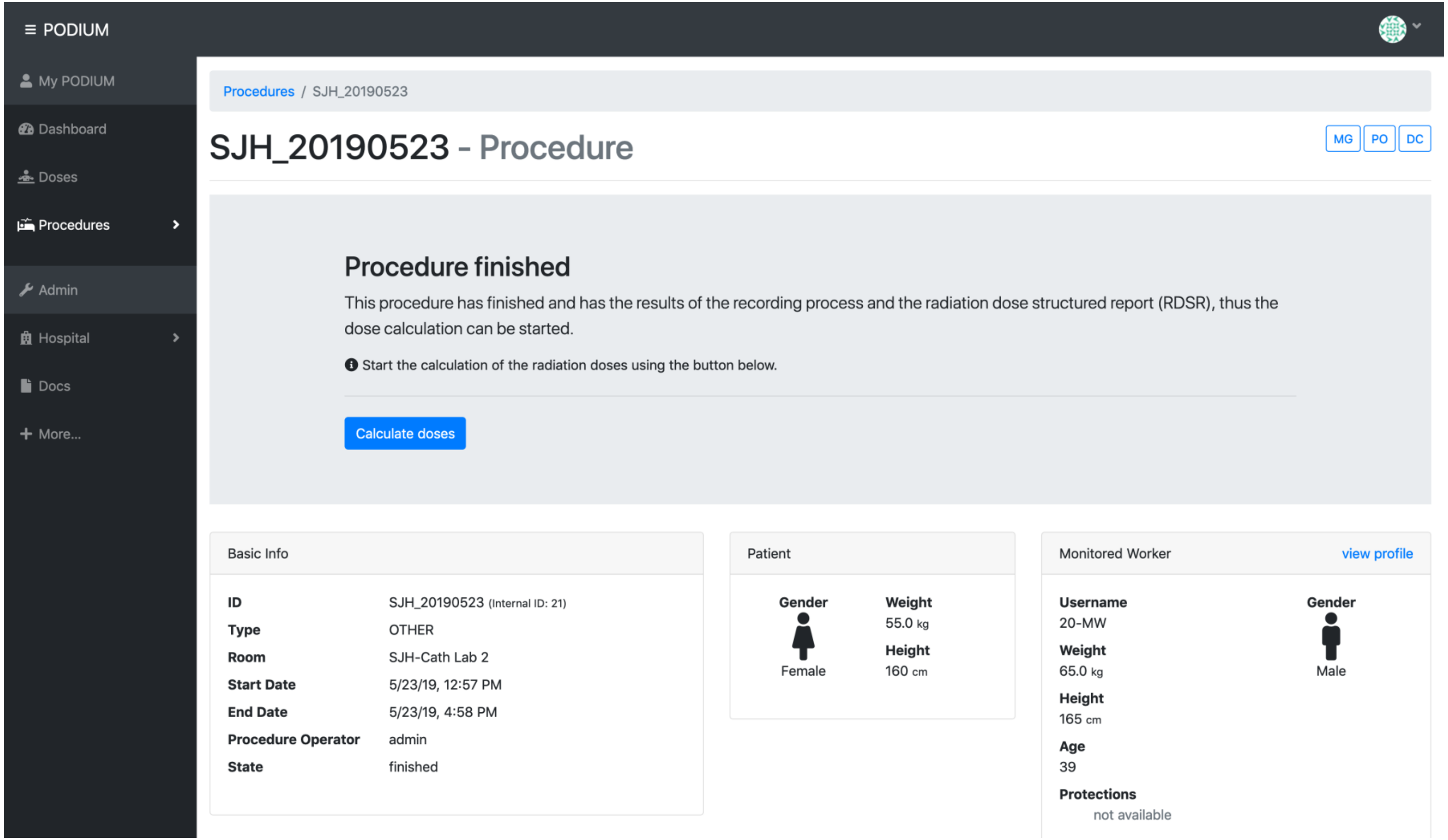
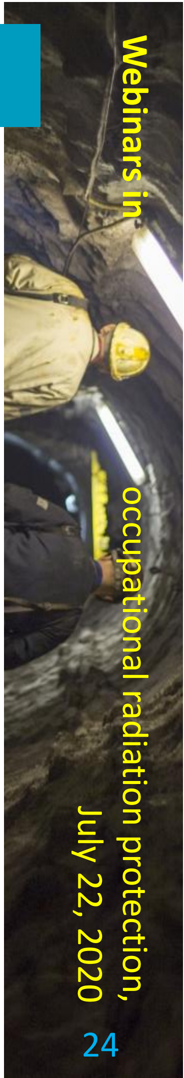


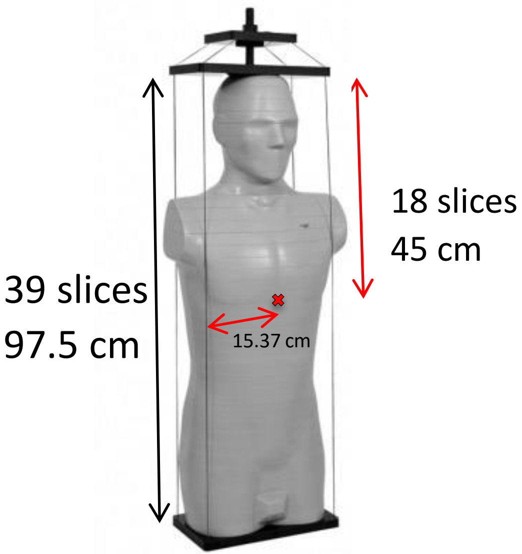
UPC



WP4: Validation in hospitals

- Measurements in Skåne University Hospital in Malmö (Sweden)

Patient phantom



The CIRS Phantom (Rayner Atom): Adult Male Rando.

X-RAY SYSTEM:
SIEMENS AXIOM-Artis

Worker phantom

CT Torso Phantom
CTU-41, Kyoto Kagaku

Passive and active personal dosemeters

- Measurements in Skåne University Hospital (cont)

Results

Case 1: Posterior - Anterior

Detector	Measurement $H_p(10)$	PENELOPE	MC-GPU Beta
		Ratio Sim/Exp	Ratio Sim/Exp
EPD1	73 ± 16	1.4 ± 0.4	1.1 ± 0.3
EPD2	72 ± 16	1.3 ± 0.3	0.8 ± 0.2
TLD1	85 ± 17	1.0 ± 0.2	0.9 ± 0.2
TLD2	134 ± 27	1.2 ± 0.2	0.7 ± 0.2

Uncertainty: 95 % CI

Case 2: 15 º angulation primary angle (range)

PENELOPE	MC-GPU Beta
Ratio Sim/Exp	Ratio Sim/Exp
0.8 - 1.0	0.6 - 0.8

- Simulation time: aprox. 2min
- Statistical uncertainty (95% CI)
    - PENELOPE/penEasy < 1%
    - MC-GPU < 5 %

- PENELOPE/penEasy: 2 x Intel Xeon E5520 Processor (2.26GHz, 8M Cache) + 1 x 160GB SATA 7200
- MC-GPU beta: 2 x 1 Intel Xeon E5-2670 v3 (2,30GHz, 12N) + 1 x VGAs NVIDIA GeForce GTX 780 3GB GDDR5

WP4: Validation in hospitals

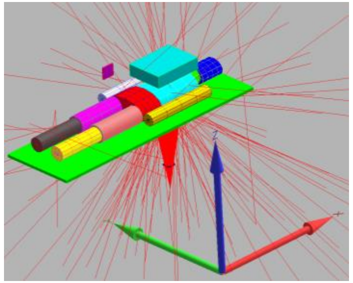
- First clinical measurements in Skåne University Hospital in Malmö (Sweden) and in Saint James Hospital in Dublin (Ireland)

Angio with Iliac Stent (Saint James Hospital)

Fluoro KAP (Gy·cm²)	Acquisition KAP (Gy·cm²)	Total time screening (min)	Number of exposures
11.25	3.52	8	68

Calculated $H_p(10)$	EPD $H_p(10)$	Ratio
68.3 µSv	55 µSv	1.24

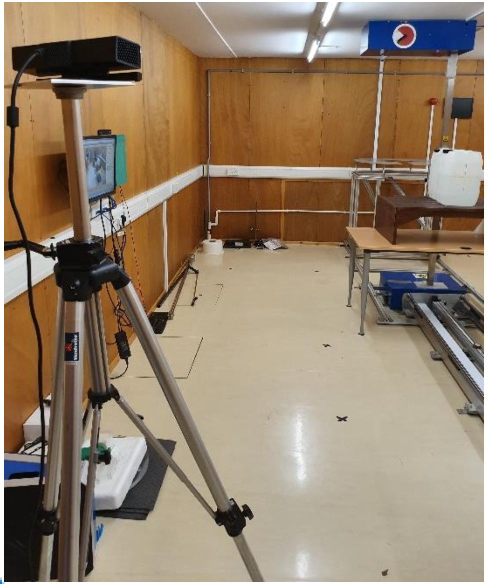
*H*p(10) measured above the lead apron with EPD
Operator not using ceiling shielding

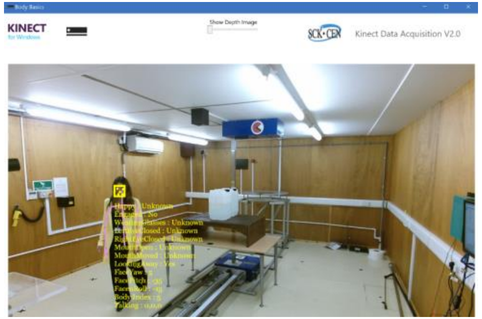


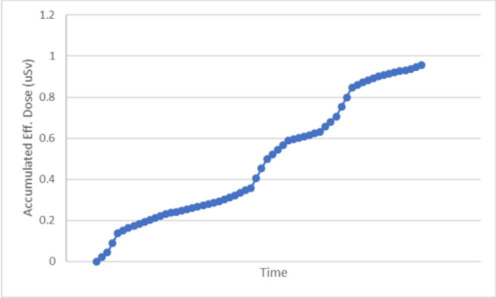
Operator with personal dosemeters for validation

WP5: Validation in PHE field

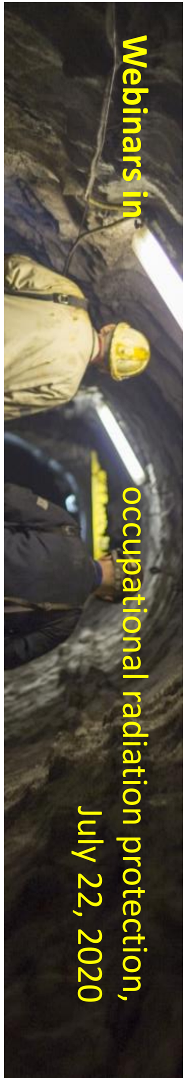
- Kinect set-up in laboratory to track people in real-time…
- Estimated 1 μSv effective dose for 1 minute activity: personal dosemeter threshold 100-200 μSv $H_p(10)$







Images courtesy of PHE



WP5: Validation in SCK·CEN field

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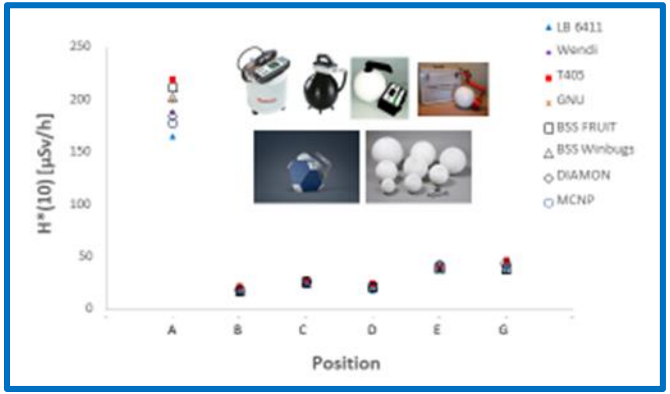
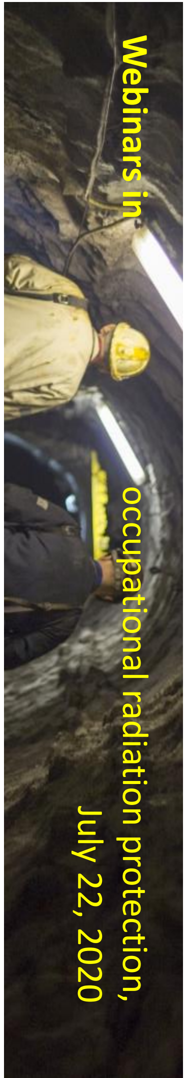
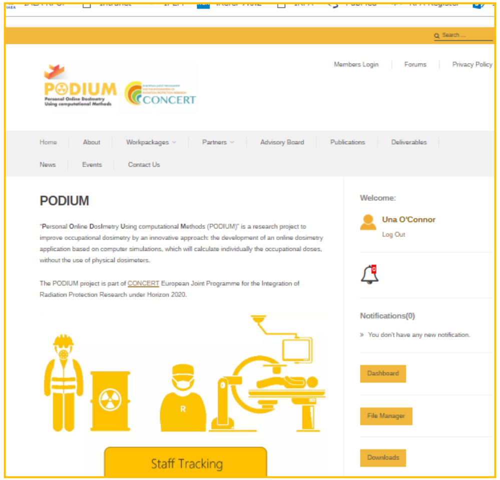


- Staff tracking during the measurements
- Effective dose rate map from simulations
- Automatic dose calculation with Python script
- Realistic dose of 7 µSv during 10 min of tracking

UPC



Final workshop



https://podium-concerth2020.eu/

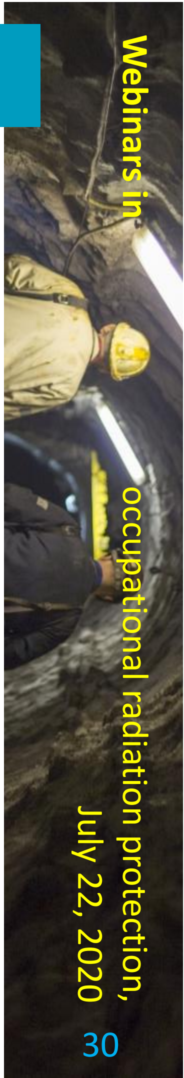
19th EAN WORKSHOP

INNOVATIVE ALARA TOOLS

JOINTLY ORGANISED WITH THE

PODIUM (Personal Online DosImetry Using computational Methods) PROJECT

Athens, 26th -29th November 2019



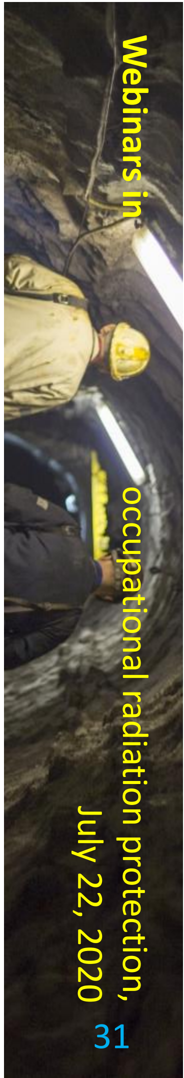
PODIUM
Personal Online Dosimetry Using computational Methods

CONCERT European Joint Programme for the Integration of Radiation Protection Research

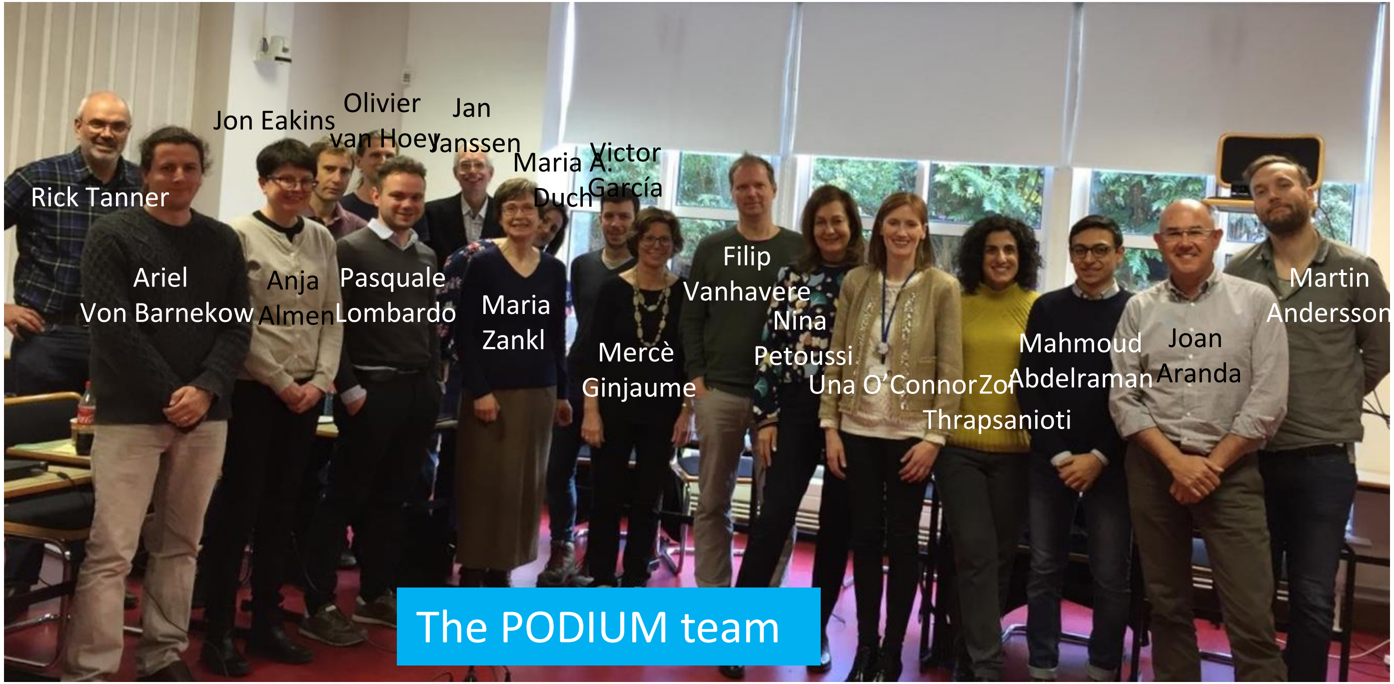
Conclusions and further work

- PODIUM results are promising (50%) and show that computational dosimetry can be a viable alternative to physical dosemeters in personal dosimetry.
- The feasibility study has been a success:
  - The technology is available for:
    - Tracking people to be monitored,
    - Calculating doses fast (by look-up table / dose mapping or Monte-Carlo)
    - having detailed and personalized phantoms.
- Challenges:
    - Include radiation protection means in the tracking and the simulation.
    - Complete automatic set-up, increase number of real tests.
    - Privacy, ethics, data protection and IT security.
    - To gain real-time position and dose information from X-ray machine.
- We are working on an exploitation plan to ensure its final developement and its introduction in the market.

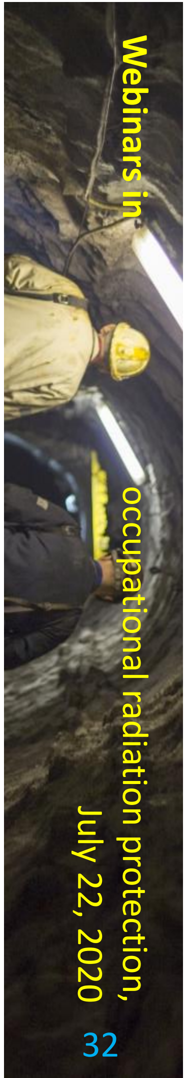
UPC



Thank you for your attention



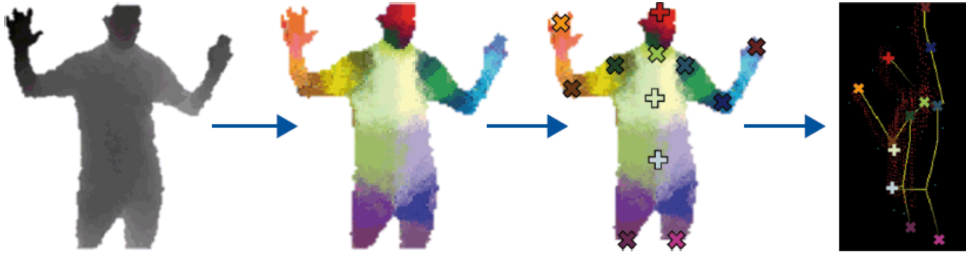
PODIUM is part of the CONCERT project. It has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 662287..



Kinect V2: Skeleton Tracking

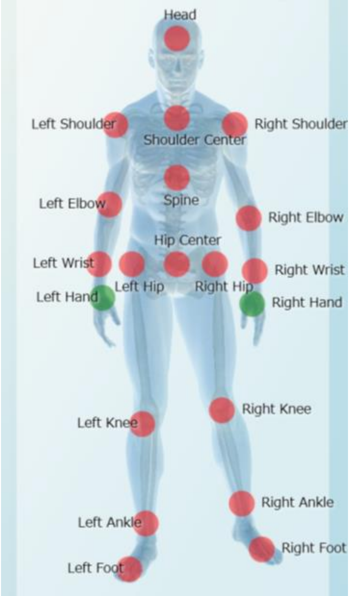
- Shotton et al. [CVPR, 2011] proposed two main steps:
  1. Find body parts
  2. Compute joint positions
- Body position is inferred using Randomized Decision Forests

100K poses → 1 million training samples



Real-Time Human Pose Recognition in Parts from Single Depth Images

Jamie Shotton Andrew Fitzgibbon Mat Cook Toby Sharp Mark Finocchio
Richard Moore Alex Kipman Andrew Blake
Microsoft Research Cambridge & Xbox Incubation



Track up to 25 joints:

- ✓ Position in 3D space in meters
- ✓ Rotation available in quaternion