Radiation processing dosimetry

From dosimeter to distribution: going virtual

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Outline

- Current practice in radiation processing
- Current practice in radiation therapy
- Why dosimeters are not always reliable
- Implementing simulation as a primary tool
- Future outlook – accelerating adoption

This will not be comprehensive!

DISCLAIMER

I have zero first-hand experience of radiation transport simulations

I am an experimental metrologist through and through

Any claims in favour of simulation are therefore likely to be understated

ACKNOWLEDGEMENTS

There are many people working in this space and I am grateful for the following, who supplied content for this presentation:

Frédéric Tessier (NRCC), Maxwell Orok (UOttawa), Chris Howard (Nordion)

FUNDAMENTAL PROBLEM IN DOSIMETRY

We want the full 3-D dose distribution in the actual ‘thing’ being irradiated

We have access to mainly 0-D detectors

We can rarely perform *in situ* dosimetry

We have limited time and resources

THE SOLUTION IS TO EMBRACE THE VIRTUAL

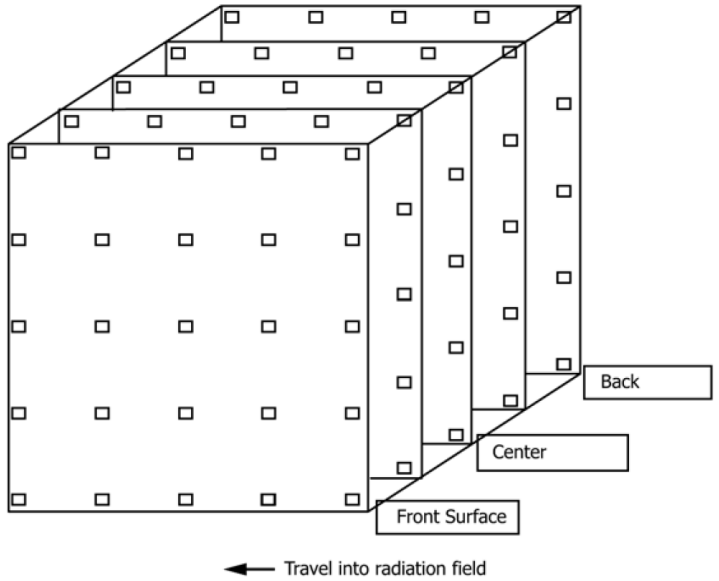
Stop thinking about dosimeters and start thinking about distributions

1. Current practice in radiation processing

ISO/ASTM 52303:2015(E)

Standard Guide for
Absorbed-Dose Mapping in Radiation Processing Facilities[1]

This standard is issued under the fixed designation ISO/ASTM 52303; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision.



- A purely experimental determination of the absolute dose and the 3-D distribution
- Time consuming and complicated
- Makes assumptions about sampling

2. Current practice in radiation therapy

Images used with permission of Elekta

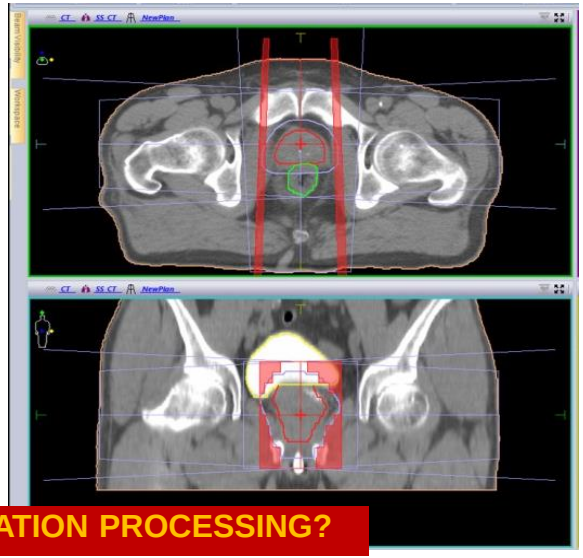
1. Radiation source with dynamic beam delivery and simultaneous imaging of target

2. Treatment plan based on detailed knowledge of full geometry

- Delivered dose is based on simulation

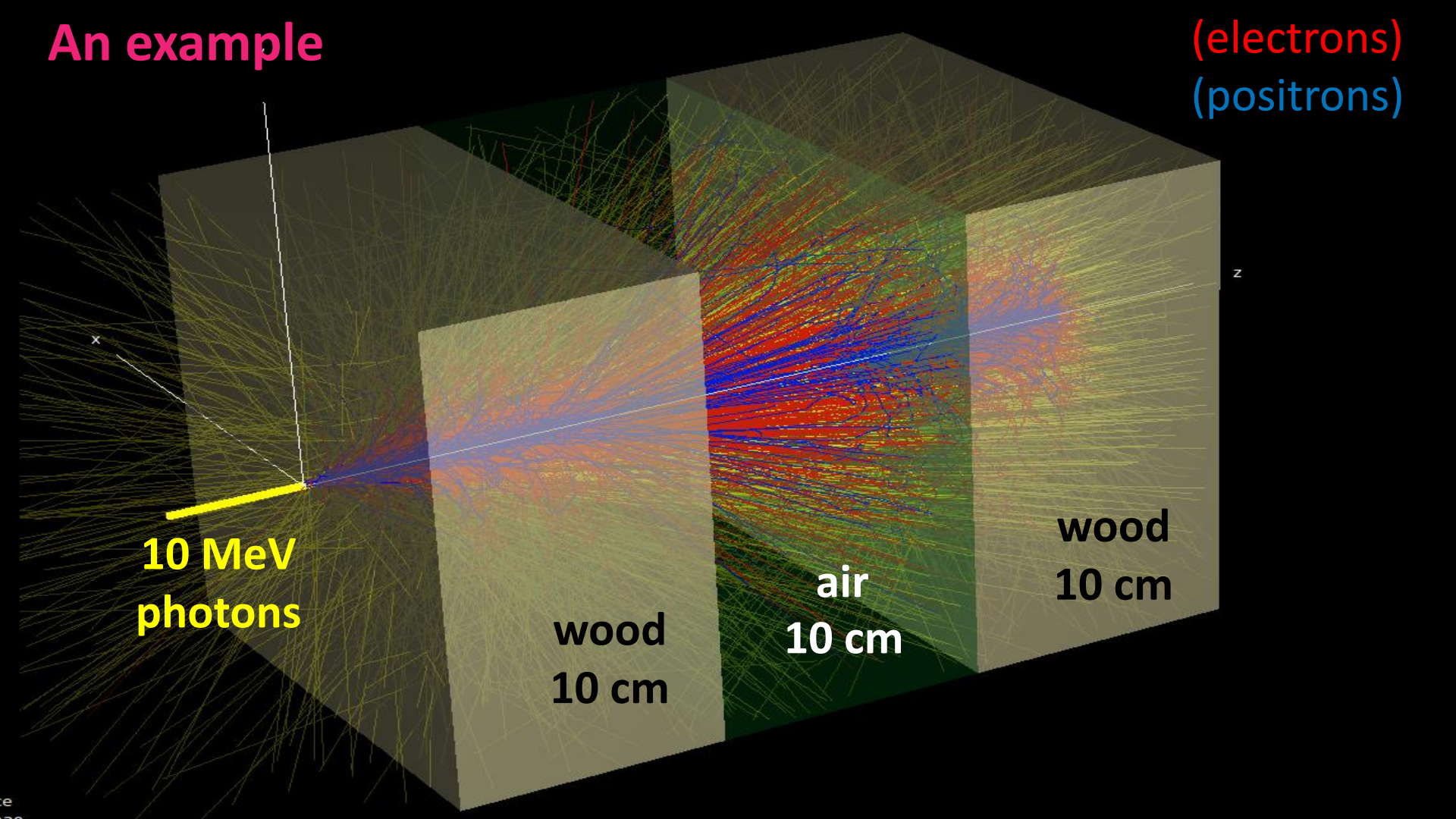
3. Various validation steps, including E2E testing

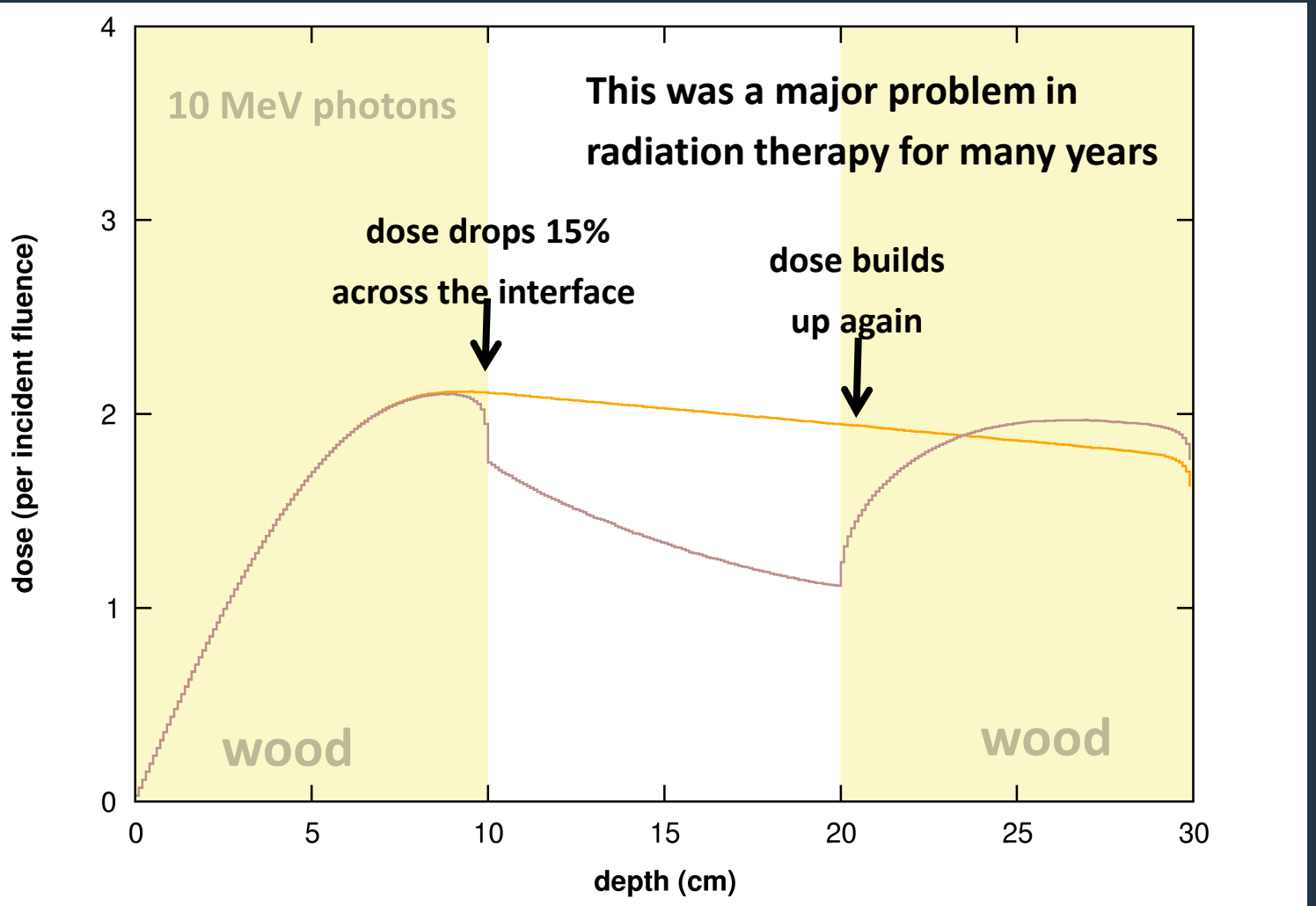
- QA of individual components (mechanical, radiation, delivery, imaging)
- Some external validation of entire process (audit, credentialing)

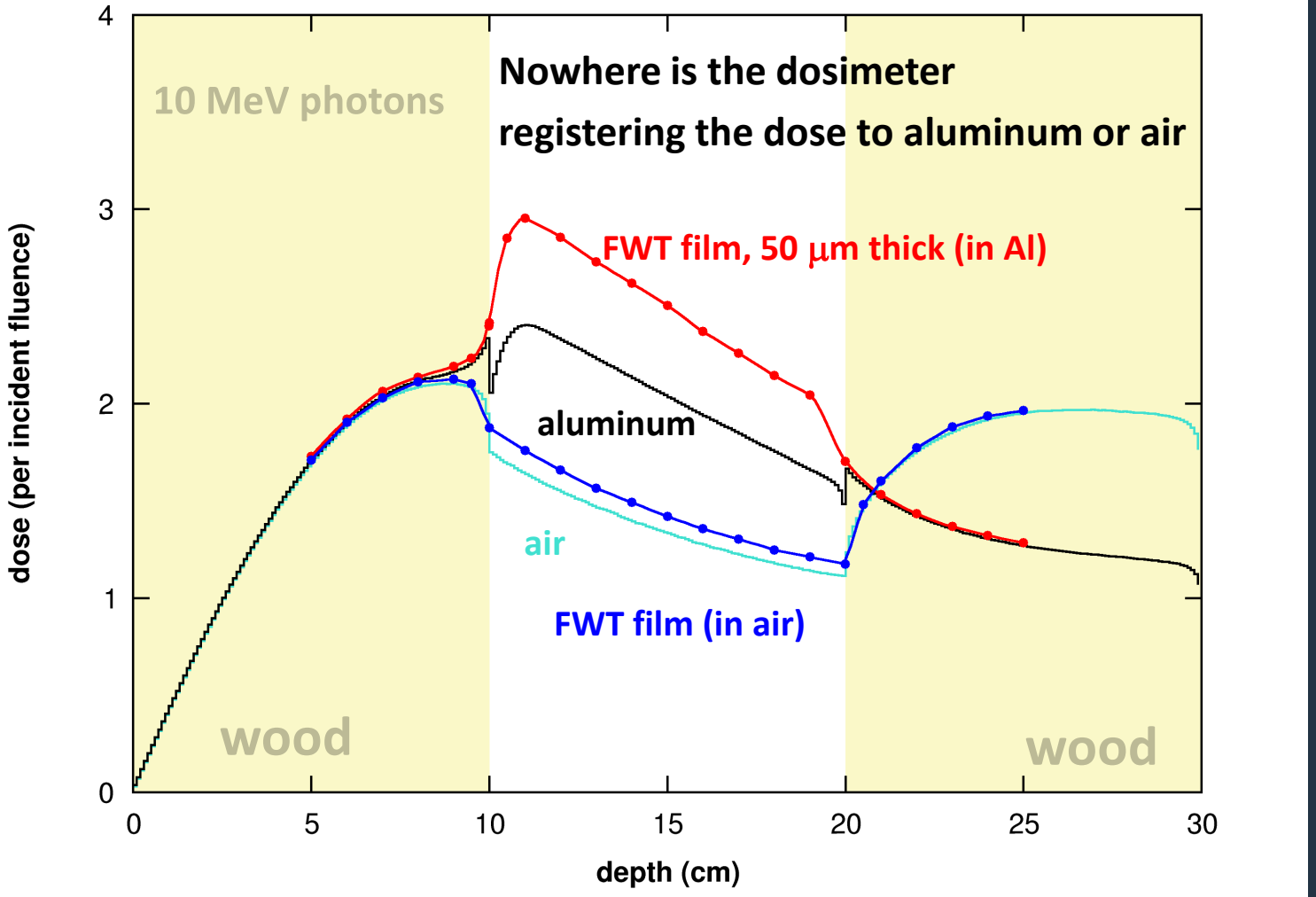


WHY NOT HAVE THIS FOR RADIATION PROCESSING?

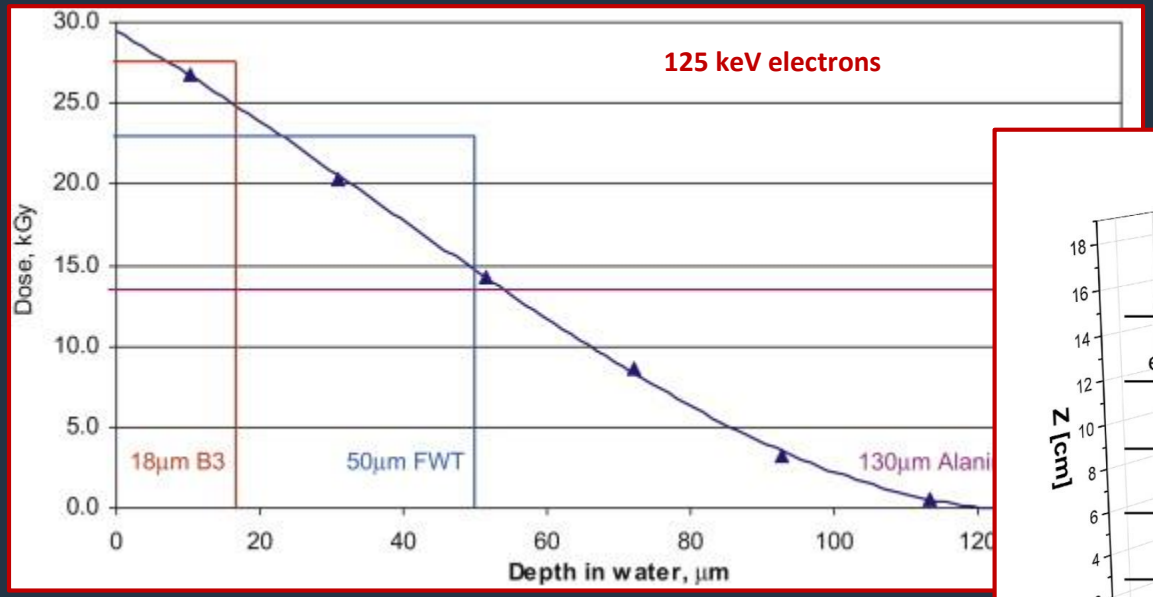
An example


(electrons)
(positrons)
x
z
10 MeV
photons
wood
10 cm
air
10 cm
wood
10 cm

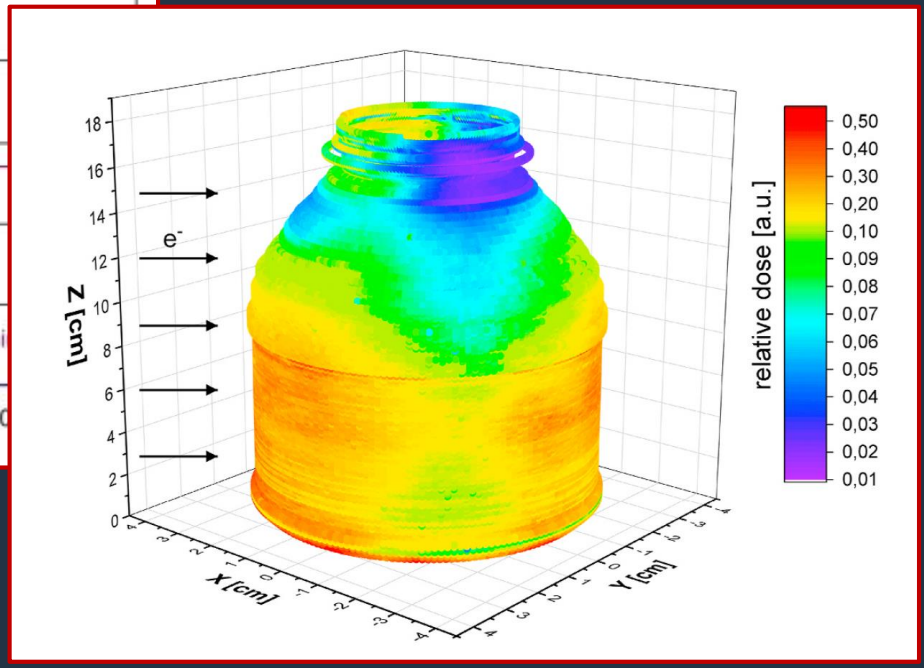

10 MeV photons
This was a major problem in
radiation therapy for many years
dose drops 15%
across the interface
dose builds
up again
wood
wood
dose (per incident fluence)
depth (cm)
0
1
2
3
4
0
5
10
15
20
25
30


10 MeV photons
Nowhere is the dosimeter
registering the dose to aluminum or air
FWT film, 50 μm thick (in Al)
aluminum
air
FWT film (in air)
wood
wood
dose (per incident fluence)
depth (cm)
0
1
2
3
4
0
5
10
15
20
25
30

It’s even worse at low energies



Helt-Hansen et al, 2010



Schuster et al, 2021

We struggle to even find detectors to make these measurements

BUT
Simulation is no better unless it's validated

We need dosimeters

- We're not at the stage of believing an absolute simulation, need experimental normalization, but reduced number compared to dose mapping

We need internal testing

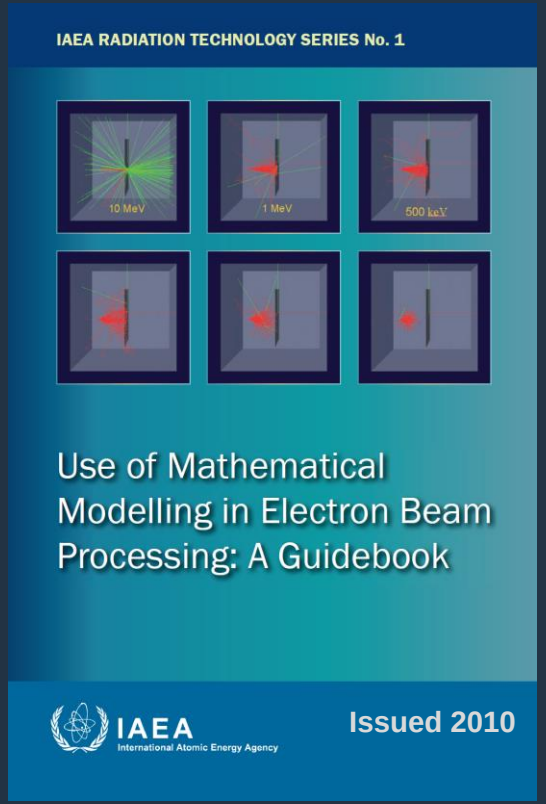
- Fano test provides a rigorous test of geometry

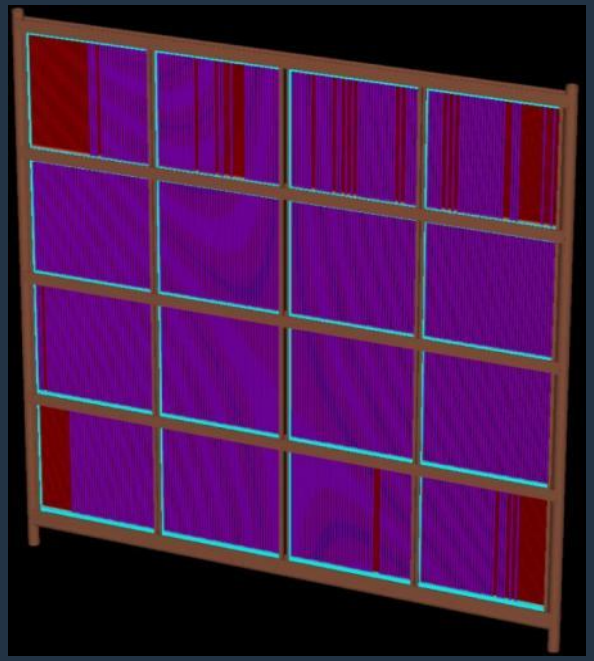
We need multiple codes

- I may say EGSnrc is the most accurate but a robust system needs multiple code implementations and careful comparisons

Implementing a better approach

This is not new!



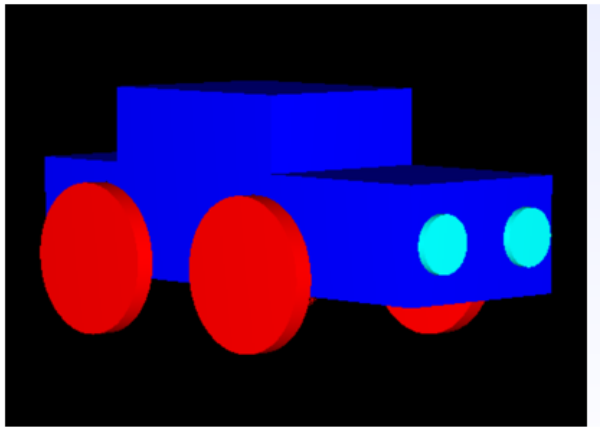


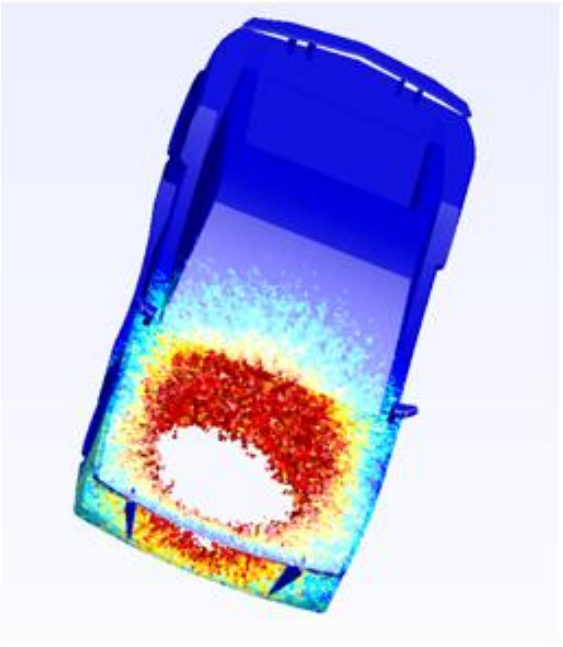
M Bailey, P Sharpe, J Sephton, NPL (IMRP 2008, London)

Monte Carlo modelling and real time dosemeter measurements of dose rate distribution at a ^{60}Co industrial irradiation plant

There are some challenges

EGSnrc is the most accurate Monte Carlo simulation tool available, but it has limitations

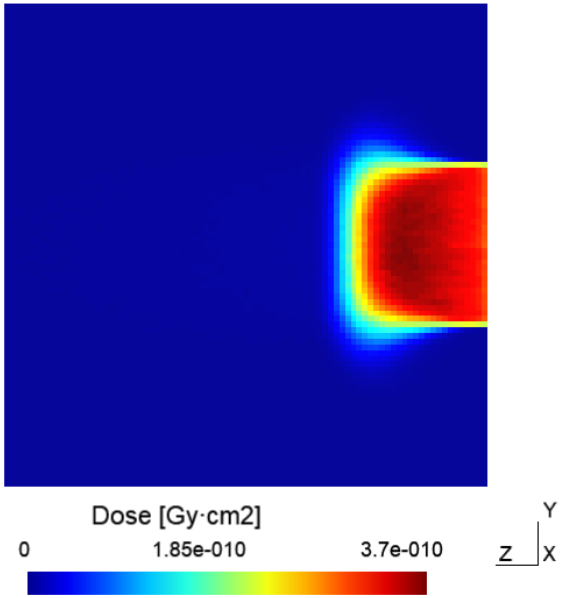




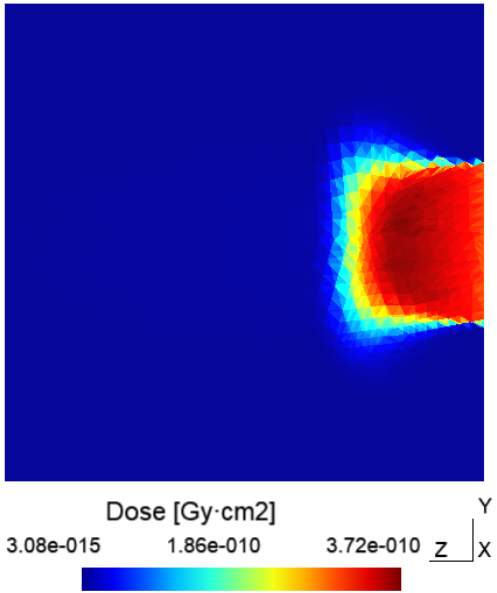
Work carried out by Max Orok at Mevex

We want the detail of the model on the right with the accuracy of EGSnrc

For radiation processing we need a different type of geometry



DOSXYZnrc (cube voxels)



EGS_Mesh (tetrahedrons).

Qualitiative agreement but mesh geometry doesn't give as smooth distributions as for cubic voxels

Both meshes have around 600,000 elements

Extension to 4-D: product scheduling (Nordion)

Problem: Organizing the selection of products that enter the Gamma Irradiator

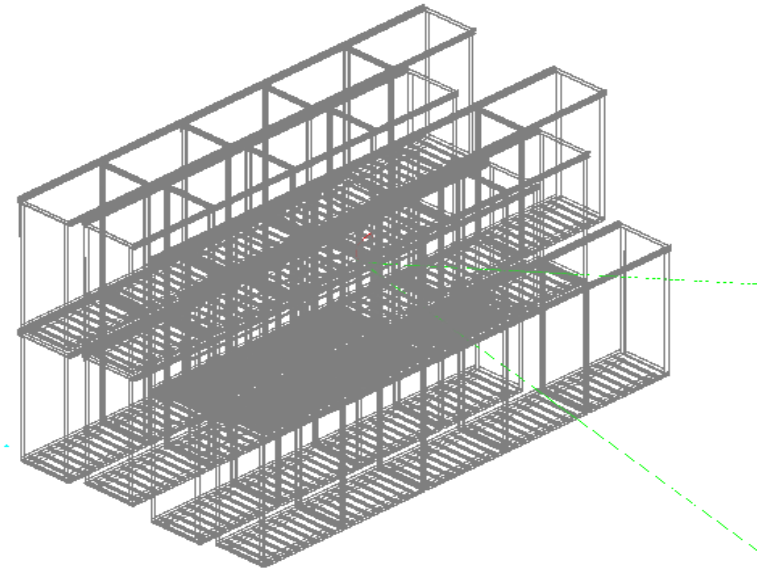
Products interact with each other (e.g., shielding)

Optimizing and determining compatibility between products (dose and density) is challenging, currently done through trial-and-error

Nordion now uses Monte Carlo to run products in the Gamma Irradiator in any given order to determine affects (e.g., Leading and/or trailing)

Products can be entered using CAD

Dose to dosimeters and/or product can be calculated



Future Outlook – how do we accelerate this?

`Is it just a case of waiting?

- **Simulations will be adopted as users develop comfort with techniques - SLOW**

Is it a lack of expertise?

- **Radiation simulation is application independent – opportunities for cross-over**

Is it a trust issue?

- **Users understand and trust physical dosimeters, but all have inherent limitations**

Is it all about regulation?

- **Will regulators accept reduced experimental validation + simulation?**

CIRMS can help with all of these!

Recognition

Experts

Connections

THANK YOU

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