

Monte Carlo Simulation Optimisation in Imaging - HSST

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March 2022

- What is Monte Carlo simulation?
- Why use it for medical imaging?
- Examples (demos)
- Validation of simulations
- Tools you can use
- Q & A

What is Monte Carlo simulation?

What is Monte Carlo simulation?



Based on the Monte Carlo method

What is Monte Carlo simulation?



What is Monte Carlo simulation?

The screenshot shows the WolframAlpha search interface. The search query "what is the monte carlo method" is entered in the search bar. Below the search bar are several icons: a document, a camera, a grid, and a gear. To the right of the search bar are three buttons: "Web Apps", "Examples", and "Random".

The main content area starts with "Input interpretation:" followed by "Monte Carlo method". There is a "Open code" button with a cloud icon to the right. Below this is the "Definition:" section, which contains a detailed paragraph about the Monte Carlo method. The paragraph explains that it is a problem-solving method using random numbers and observing the fraction of numbers that obey certain properties. It was named by Stanislaw Ulam in 1946, inspired by his gambling habits. Nicolas Metropolis also contributed to its development.

Under the definition, there is a "More information" link with a cloud icon. At the bottom of the page, under "Related topics:", are links to "Monte Carlo integration", "quasi-Monte Carlo method", "stochastic geometry", and "uniform distribution theory". Each of these related topics has a small cloud icon to its right.

What is Monte Carlo simulation?

The screenshot shows the WolframAlpha search interface with the query "simulation" entered in the search bar. The results are categorized into sections: Input interpretation, Definitions, American pronunciation, Hyphenation, and First known use in English.

Input interpretation:
simulation (English word)

Definitions:

- 1 noun the act of imitating the behavior of some situation or some process by means of something suitably analogous (especially for the purpose of study or personnel training)
- 2 noun (computer science) the technique of representing the real world by a computer program
- 3 noun representation of something (sometimes on a smaller scale)
- 4 noun the act of giving a false appearance

American pronunciation:
sim-yuh'l'eyshuhn (IPA: sɪmjəl' eɪʃən)

Hyphenation:
sim-u-la-tion (10 letters | 4 syllables)

First known use in English:
1340 (High Middle ages) (677 years ago)

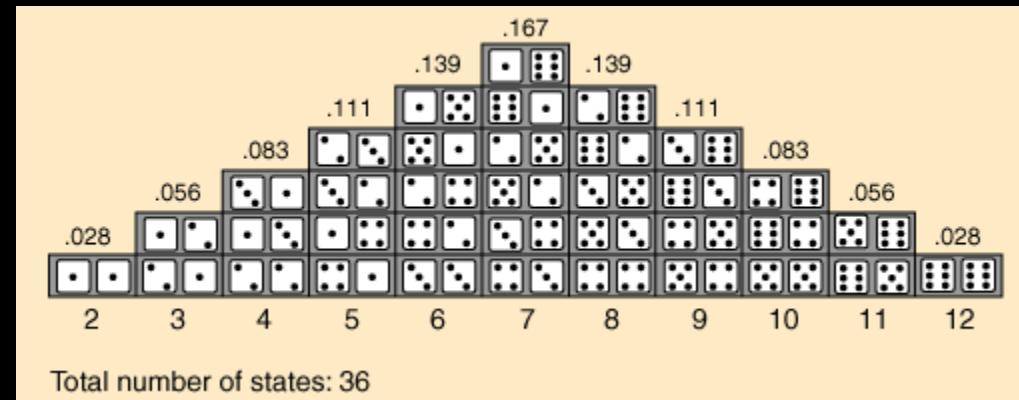
What is Monte Carlo simulation?



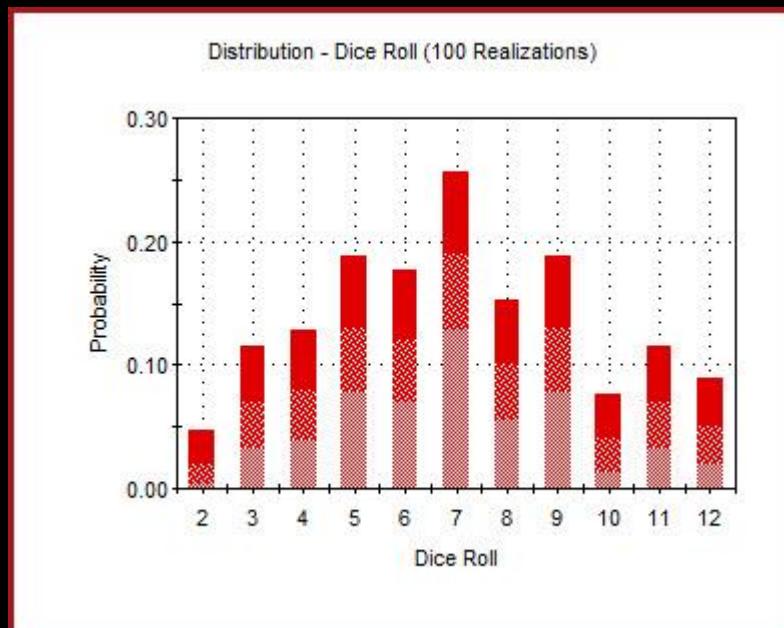
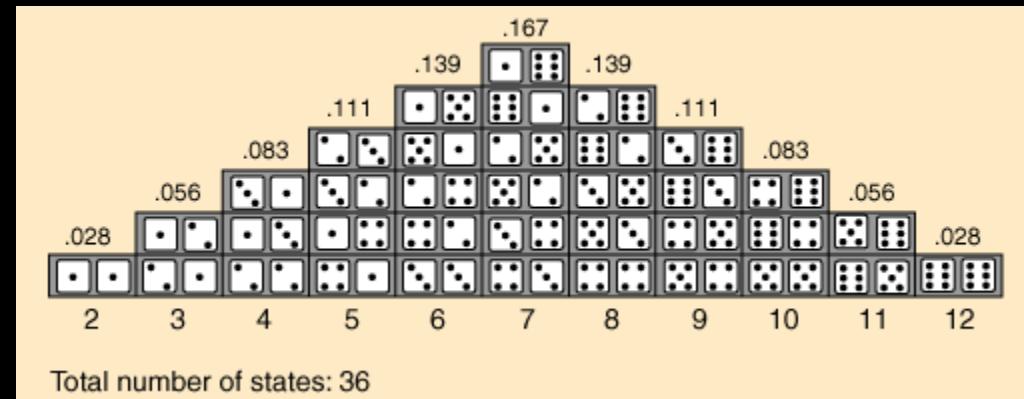
“A method which solves a problem by generating suitable random numbers and observing that fraction of the numbers obeying some property or properties. The method is useful for obtaining numerical solutions to problems which are too complicated to solve analytically.”

“A technique of representing the real world by a computer program.”

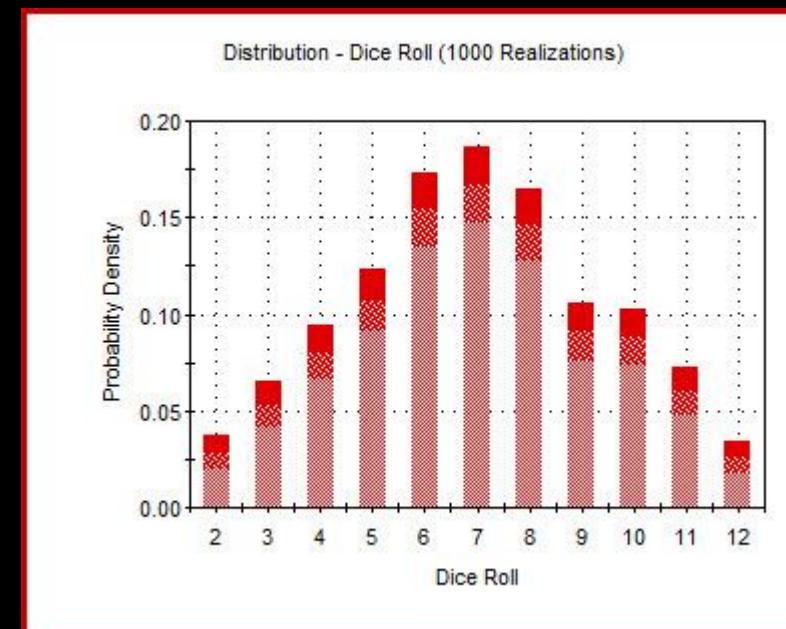
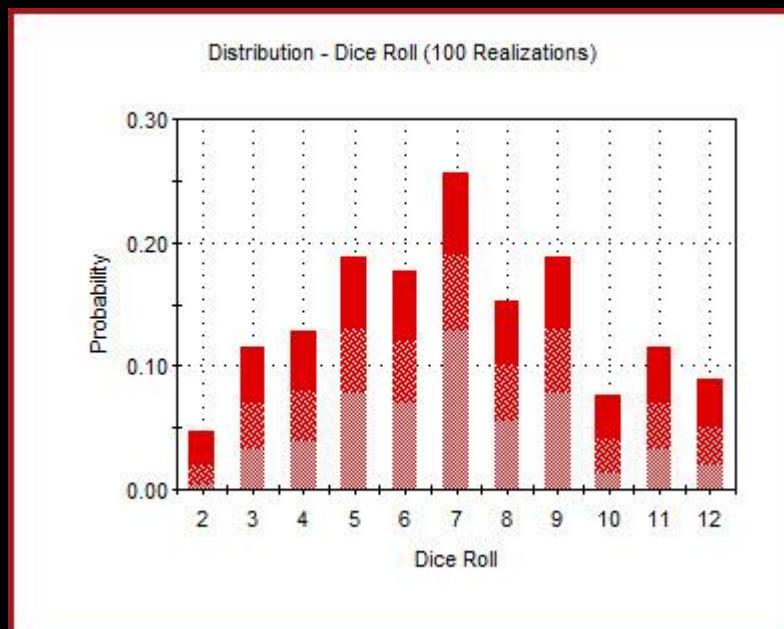
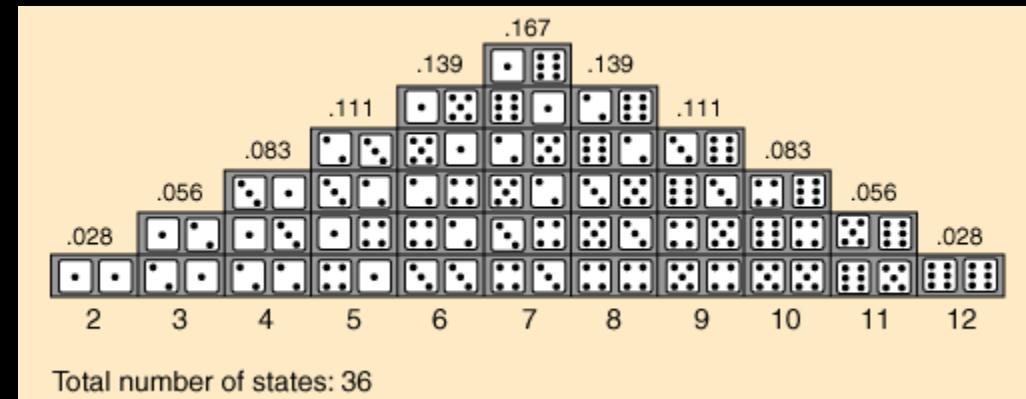
Simple Example



Simple Example



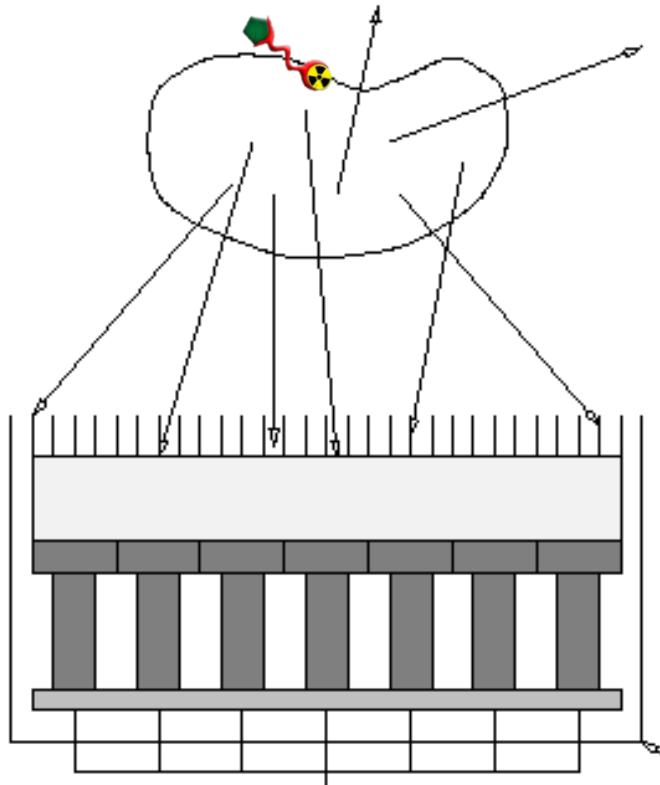
Simple Example



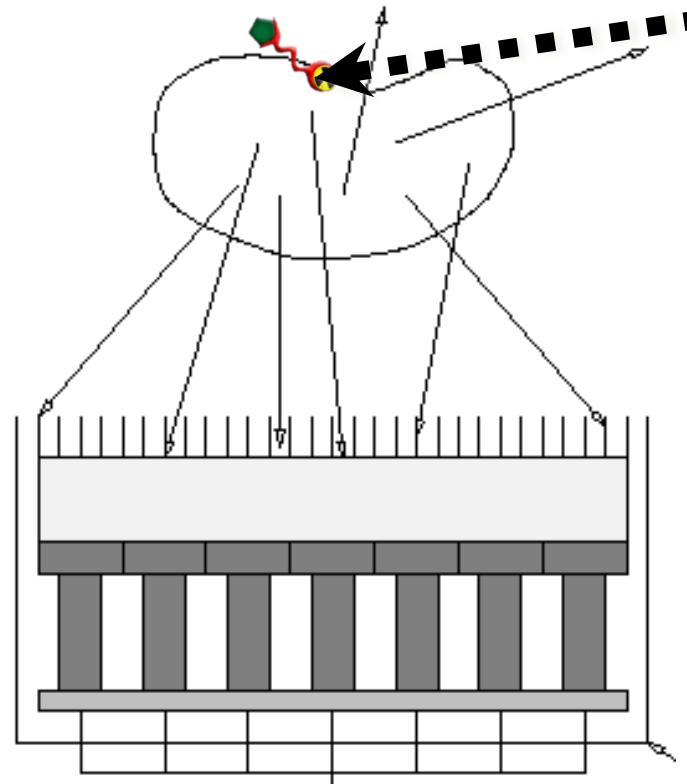
Physics and Probability

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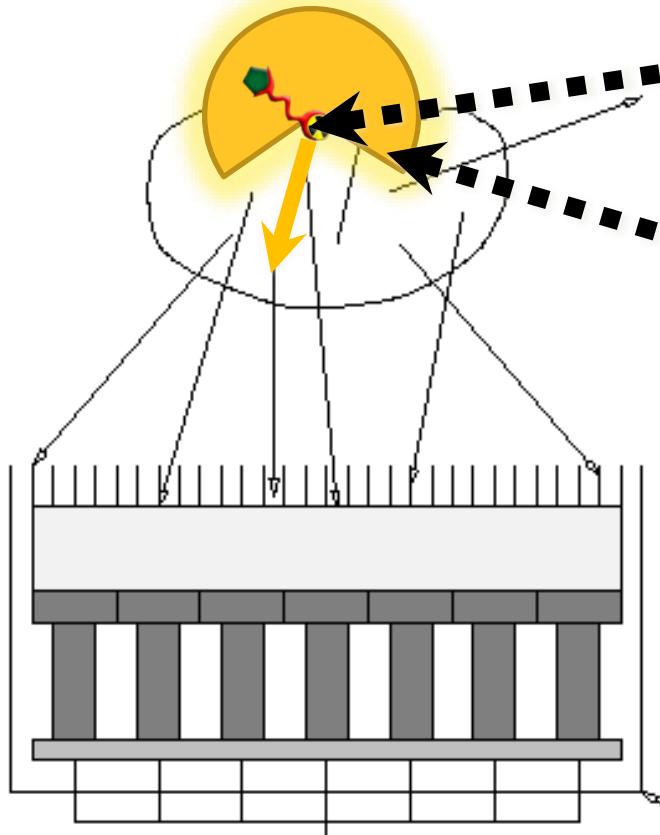


Physics and Probability



P1 = Probability of decay
[half-life]

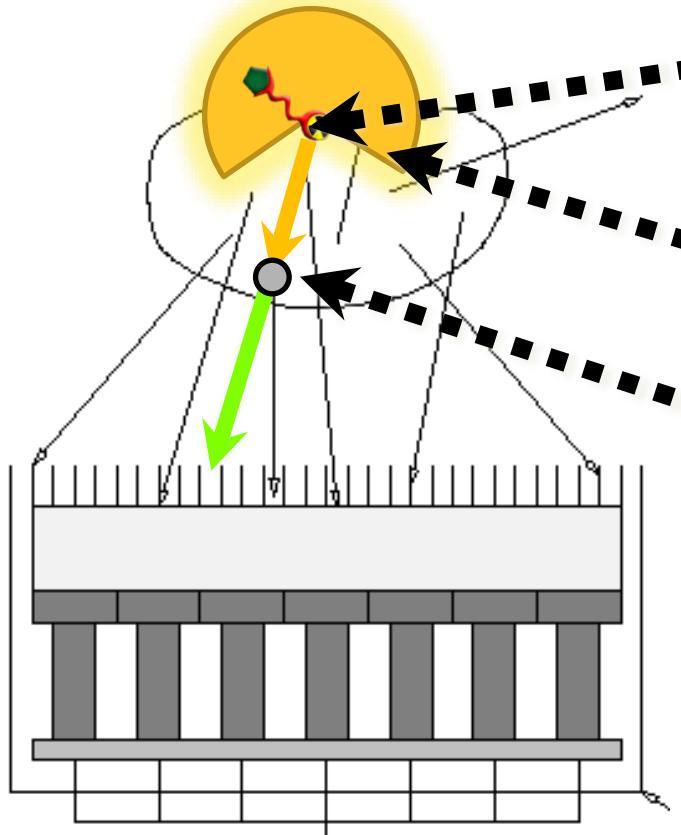
Physics and Probability



P1 = Probability of decay
[half-life]

P2 = Probability of emission direction
[isotropic]

Physics and Probability

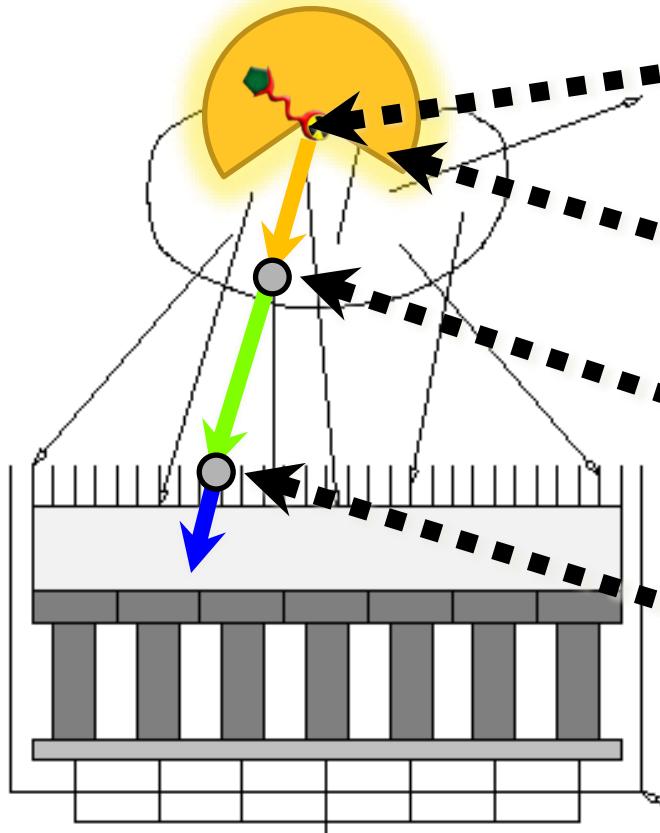


P1 = Probability of decay
[half-life]

P2 = Probability of emission direction
[isotropic]

P3 = Probability of interaction in body
[cross-section, material]

Physics and Probability



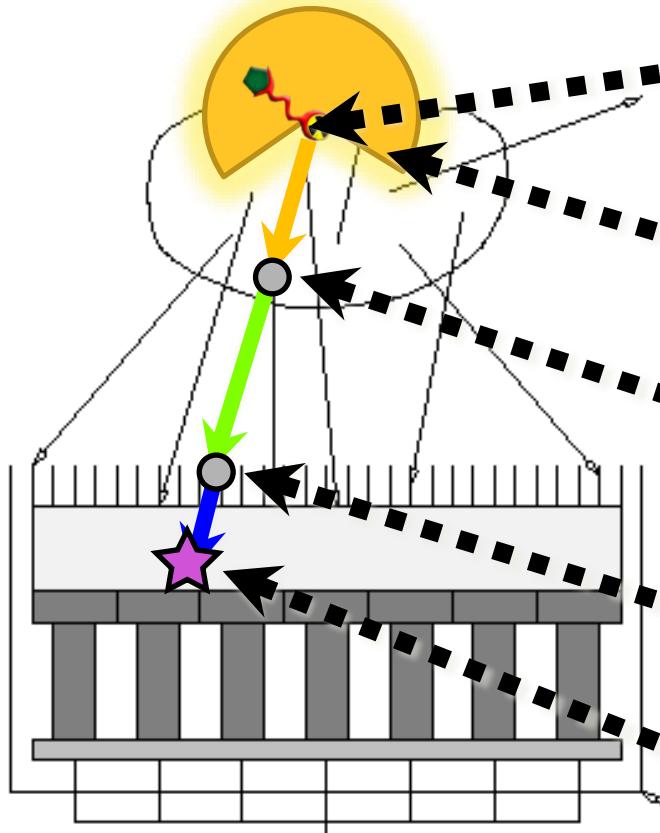
P1 = Probability of decay
[half-life]

P2 = Probability of emission direction
[isotropic]

P3 = Probability of interaction in body
[cross-section, material]

P4 = Probability of interaction with collimator
[cross-section, material]

Physics and Probability



P1 = Probability of decay
[half-life]

P2 = Probability of emission direction
[isotropic]

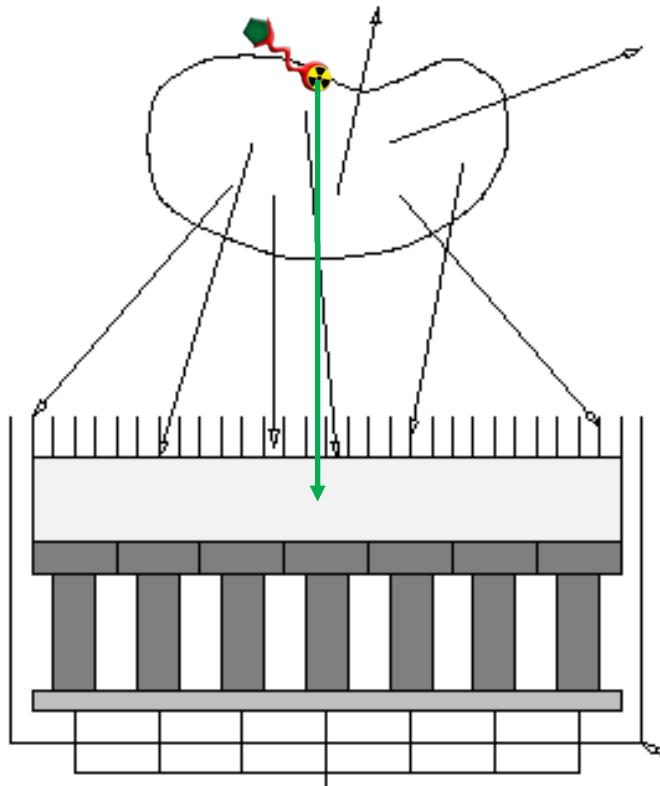
P3 = Probability of interaction in body
[cross-section, material]

P4 = Probability of interaction with collimator
[cross-section, material]

P5 = Probability of absorption in crystal
[cross-section]

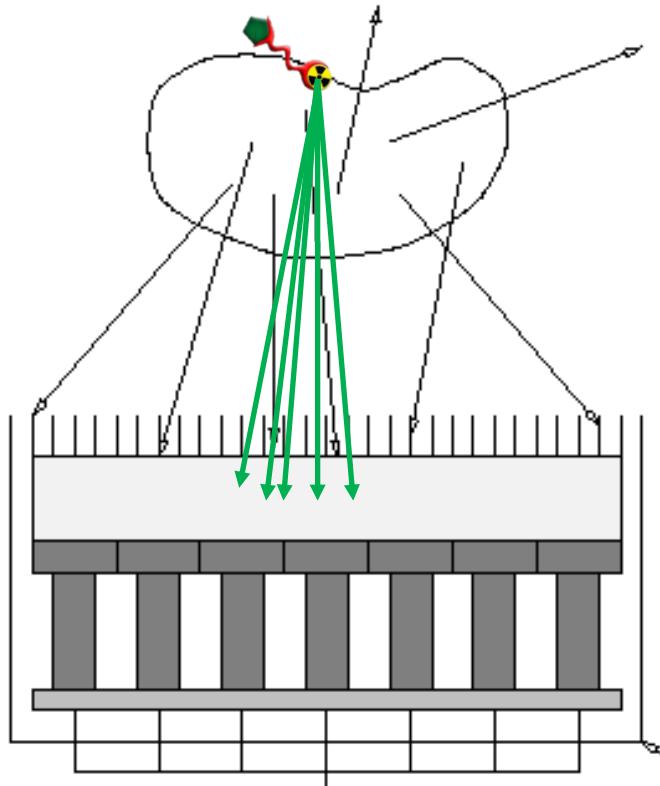
$$p(E\gamma) = p1 * p2 * p3 * p4 * p5$$

Physics and Probability



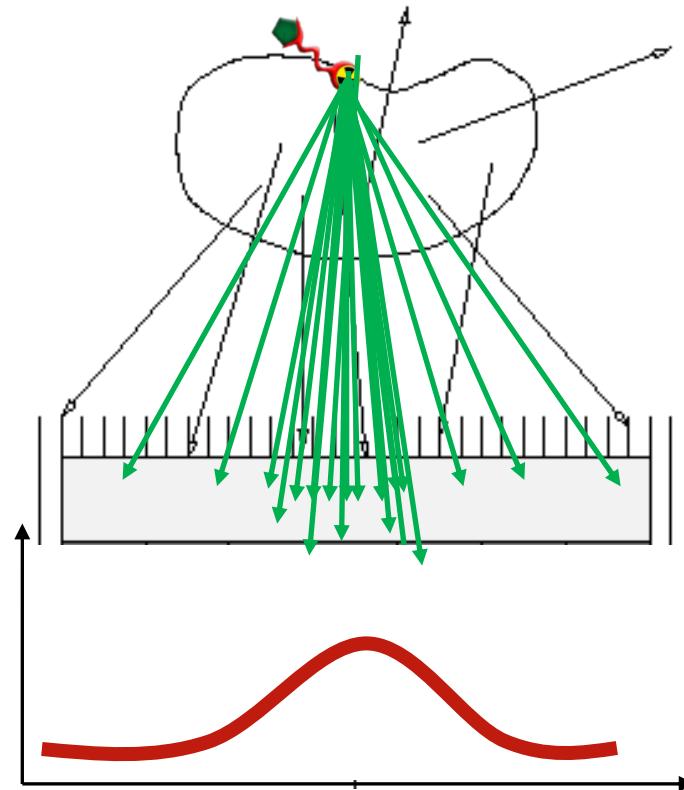
$$p(E\gamma) = p_1 * p_2 * p_3 * p_4 * p_5$$

Physics and Probability



$$p(E\gamma) = p_1 * p_2 * p_3 * p_4 * p_5$$

Physics and Probability



$$p(E\gamma) = p_1 * p_2 * p_3 * p_4 * p_5$$

- What is Monte Carlo simulation?
- Why use it for medical imaging?
- Examples (demos)
- Validation of simulations
- Tools you can use
- Q & A

Why use it for medical imaging?

Doesn't require patients

No camera time

Easily modify the system

No radiation dose (patient or operator)

Extra information (physically non-observable)

Can provide a “ground truth”

Infinitely repeatable

Optimise imaging protocols

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Blue = Positive Charge
Green = Neutral Charge
Red = Negative Charge

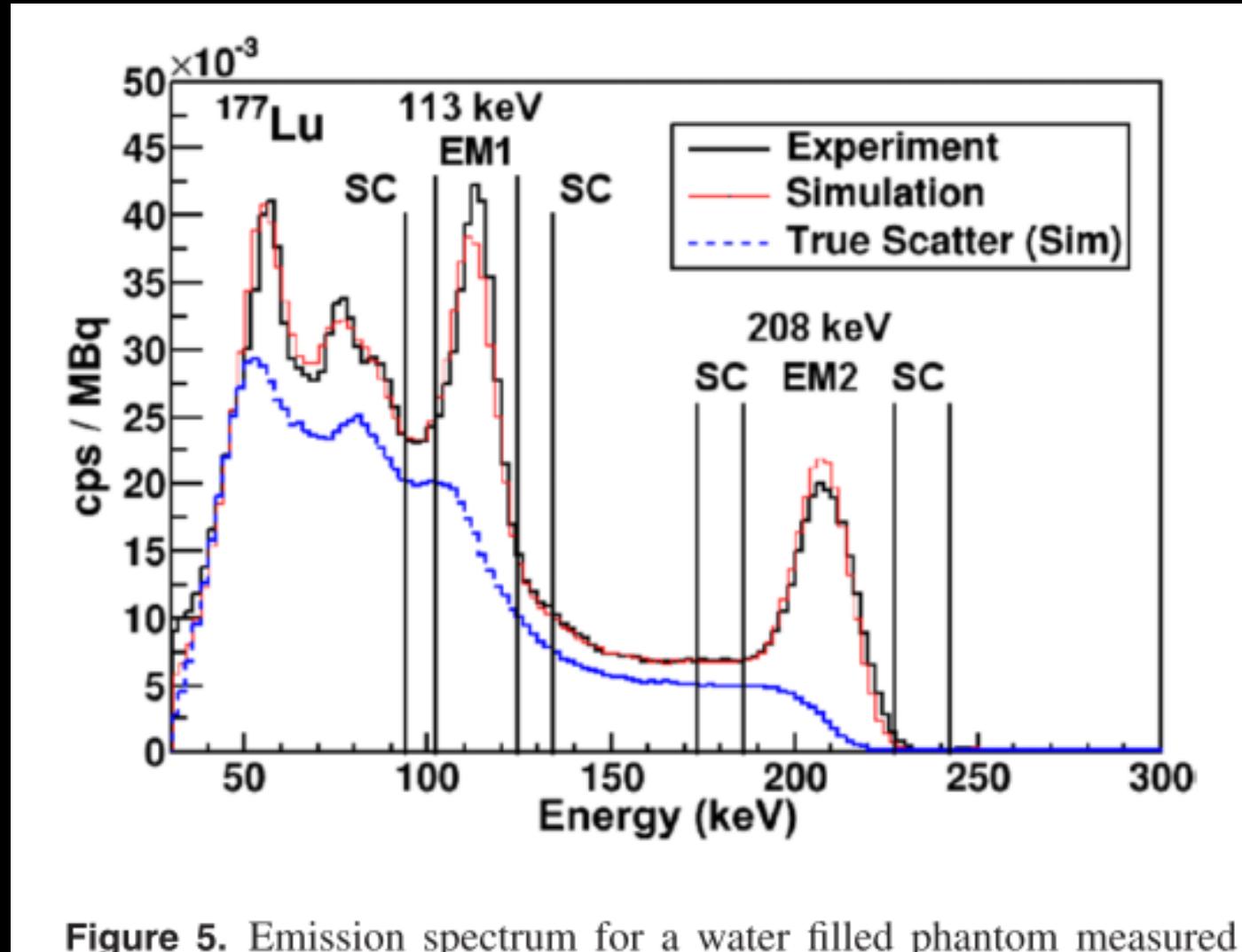


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Optimisation of imaging windows using Monte Carlo Simulation



Optimisation of imaging windows using Monte Carlo Simulation

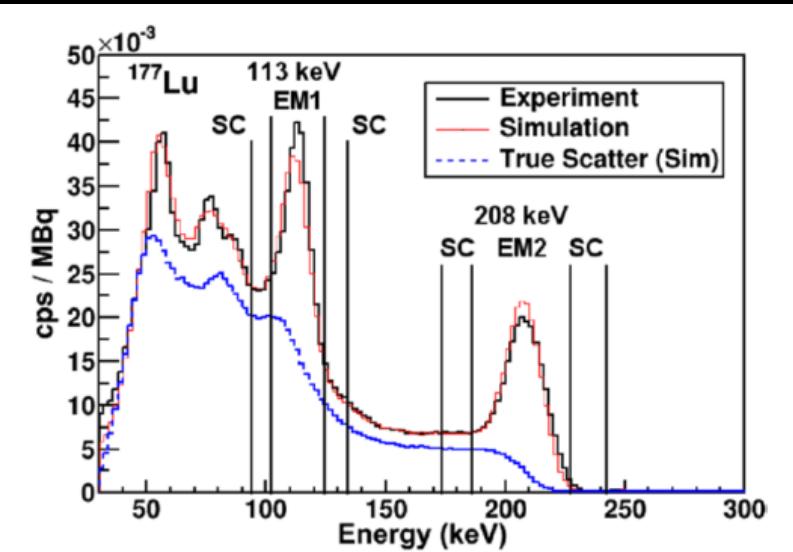
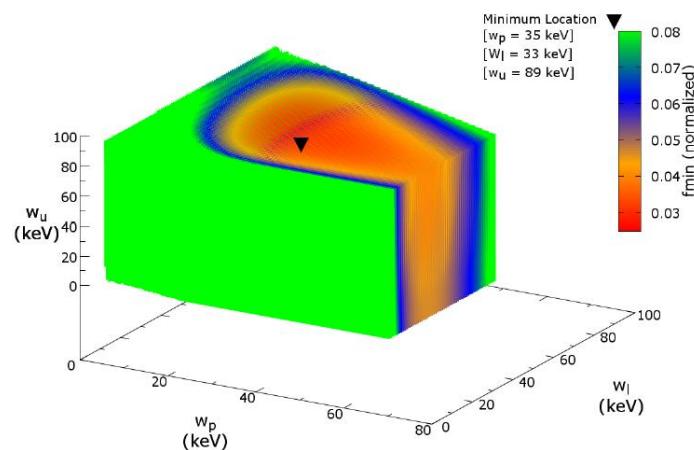


Figure 5. Emission spectrum for a water filled phantom measured



$$C_{TEW} = \left(\frac{C_l}{w_l} + \frac{C_u}{w_u} \right) \times \frac{w_p}{2}$$

$$f_{min} = \left| 1 - \frac{C_{TEW}}{TS} \right| = \left| 1 - \frac{\left(\frac{C_l}{w_l} + \frac{C_u}{w_u} \right) \times \frac{w_p}{2}}{TS} \right|$$
$$\{w_l \in \mathbb{N}^0\} \quad \{w_u \in \mathbb{N}^0\} \quad \{w_p \in \mathbb{N}^1\}$$

$$E_l + \frac{w_l}{2} > E_{min}$$
$$E_u + \frac{w_u}{2} < E_{max}.$$

Sensitive range
Camera.

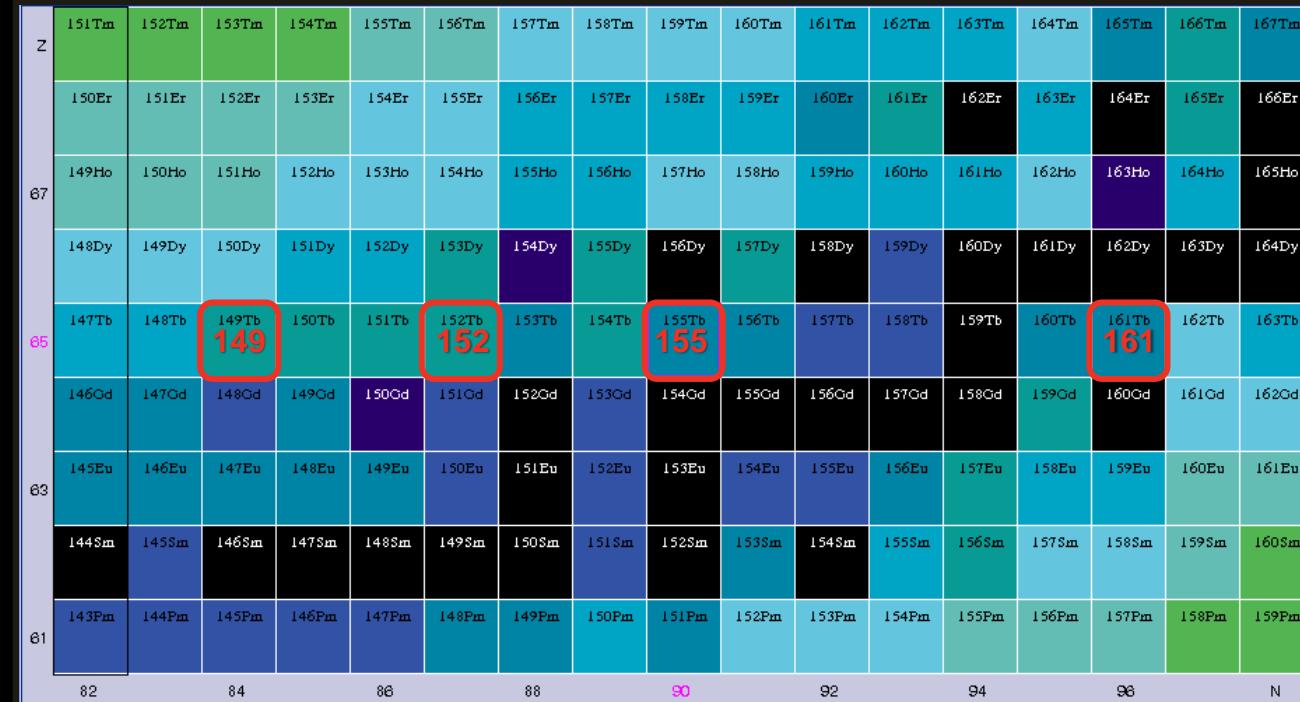
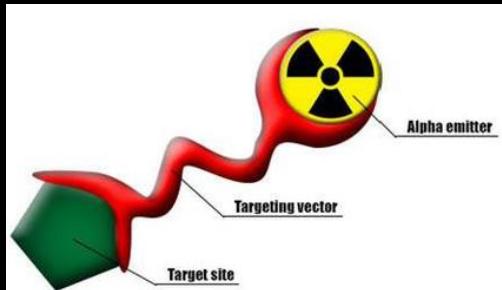
$$E_l + \frac{w_l}{2} \leq E_p - \frac{w_p}{2}$$
$$E_u - \frac{w_u}{2} \geq E_p + \frac{w_p}{2}.$$

Over-lapping
windows.

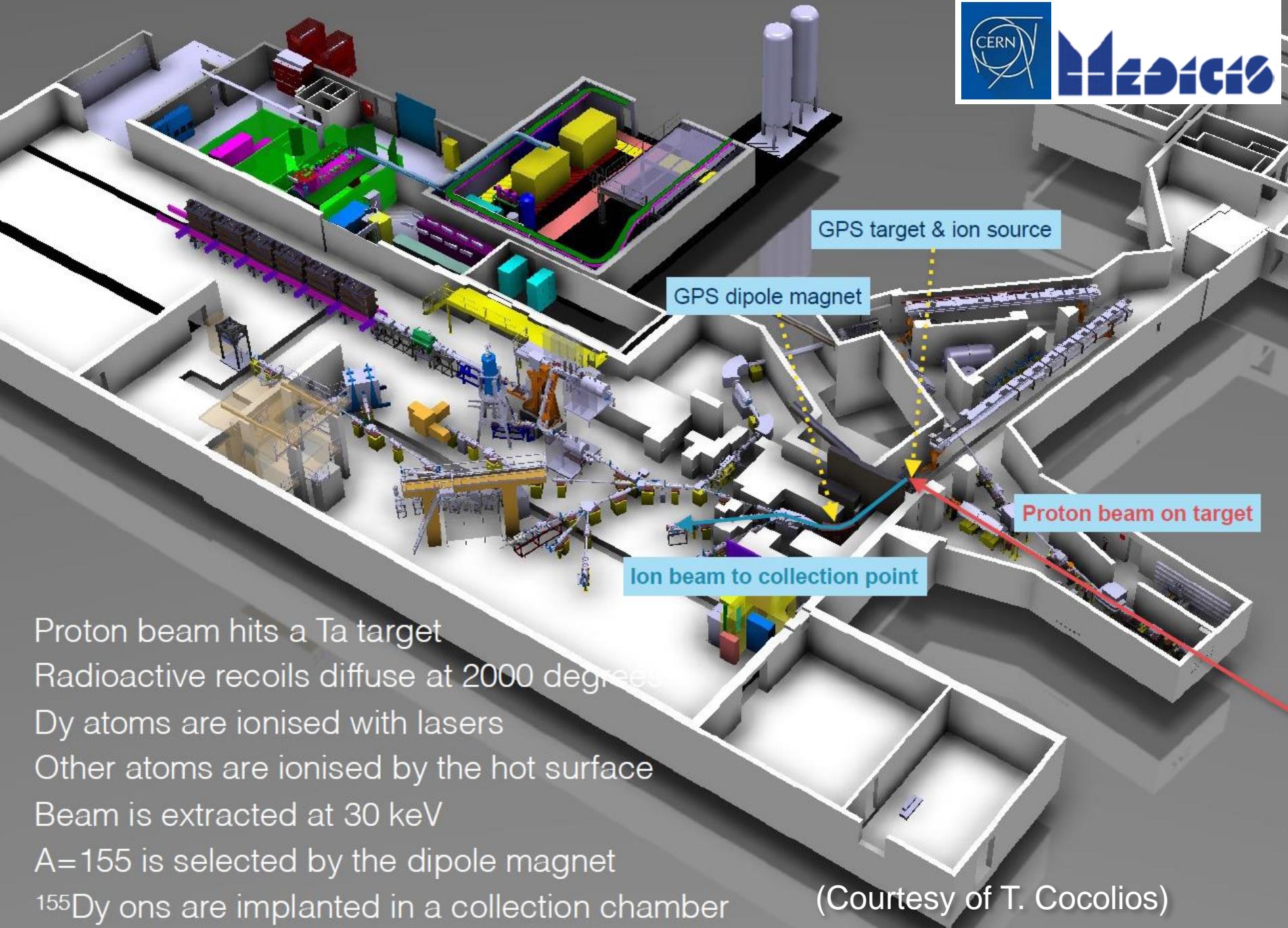
Tb₆₅ (Theranostic Isotope Quartet)

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	Decay Mode	Half-life	MRT Application
149Tb	α, β^+ (17%, 7%)	4.12 hours	Therapy (α)
152Tb	β^+ (17%)	17.5 hours	PET Imaging
155Tb	EC (100%)	5.32 days	SPECT Imaging
161Tb	β^- (100%)	6.89 days	Therapy (β^-)



Medical physics questions for ^{155}Tb

How to image it?

- Which gamma-rays to look at?
- What energy gate to set?
- Which collimators to use?

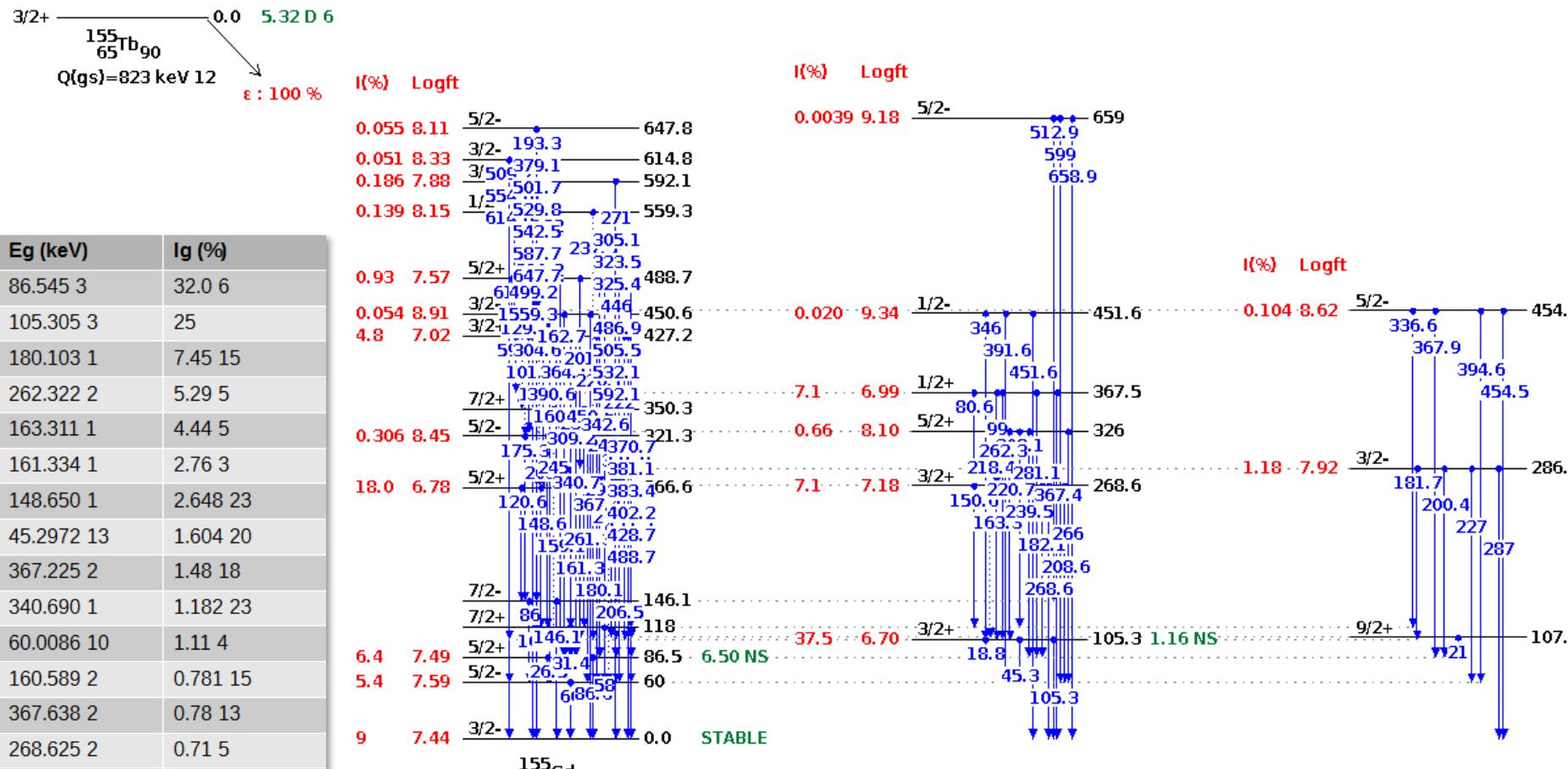


How to measure activity?

- Is there a primary standard?
- What dial factors to use on a hospital calibrator?

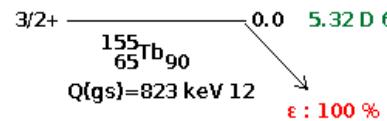


155Tb (SPECT Imaging)

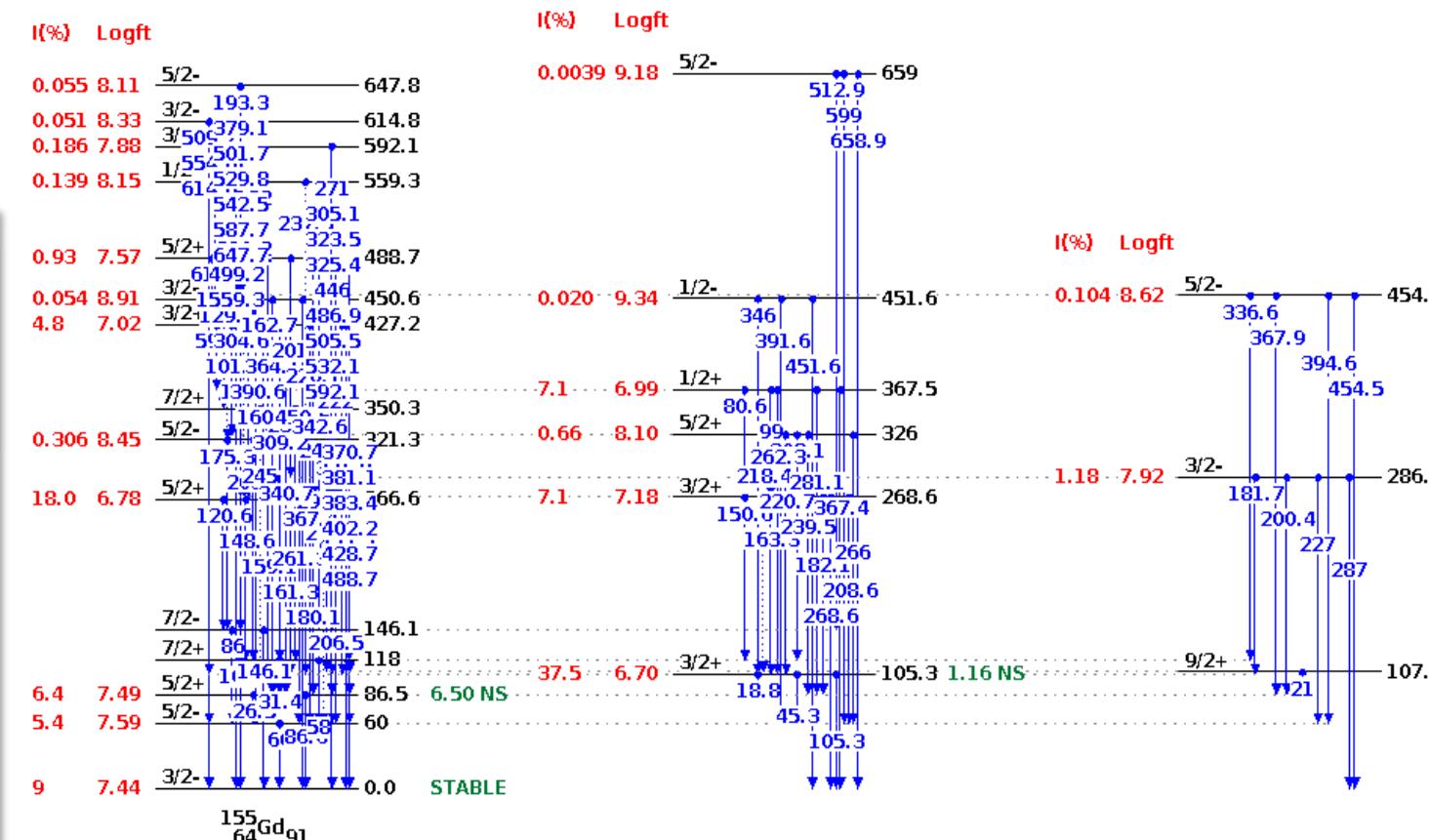


Eg (keV)	Ig (%)
86.545 3	32.0 6
105.305 3	25
180.103 1	7.45 15
262.322 2	5.29 5
163.311 1	4.44 5
161.334 1	2.76 3
148.650 1	2.648 23
45.2972 13	1.604 20
367.225 2	1.48 18
340.690 1	1.182 23
60.0086 10	1.11 4
160.589 2	0.781 15
367.638 2	0.78 13
268.625 2	0.71 5
220.778 2	0.508 5
181.694 1	0.422 5
26.533 6	0.394 13
286.999 4	0.317 6
281.087 2	0.302 4
208.089 2	0.231 13

^{155}Tb (SPECT Imaging)



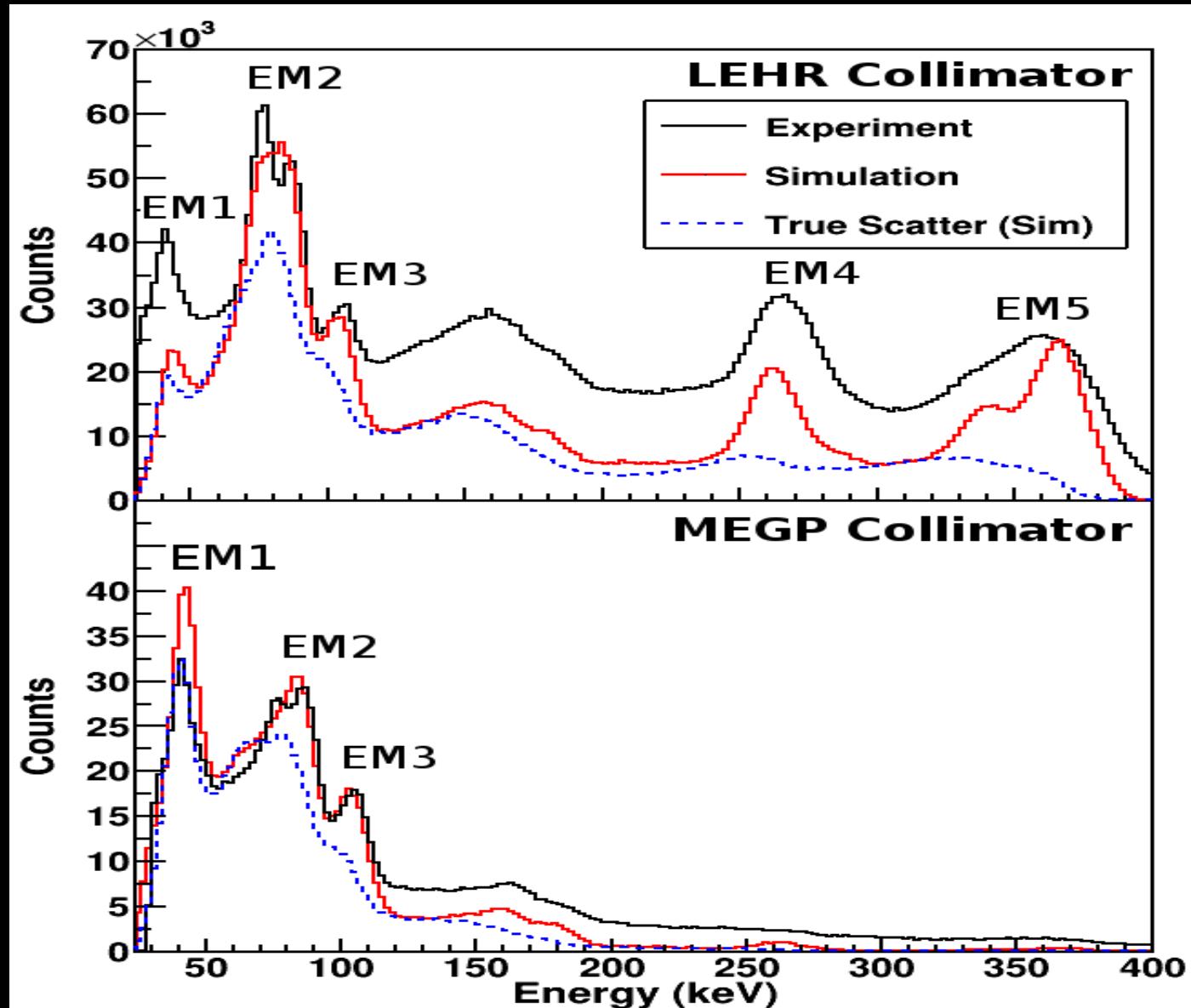
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Tb-155 SPECT

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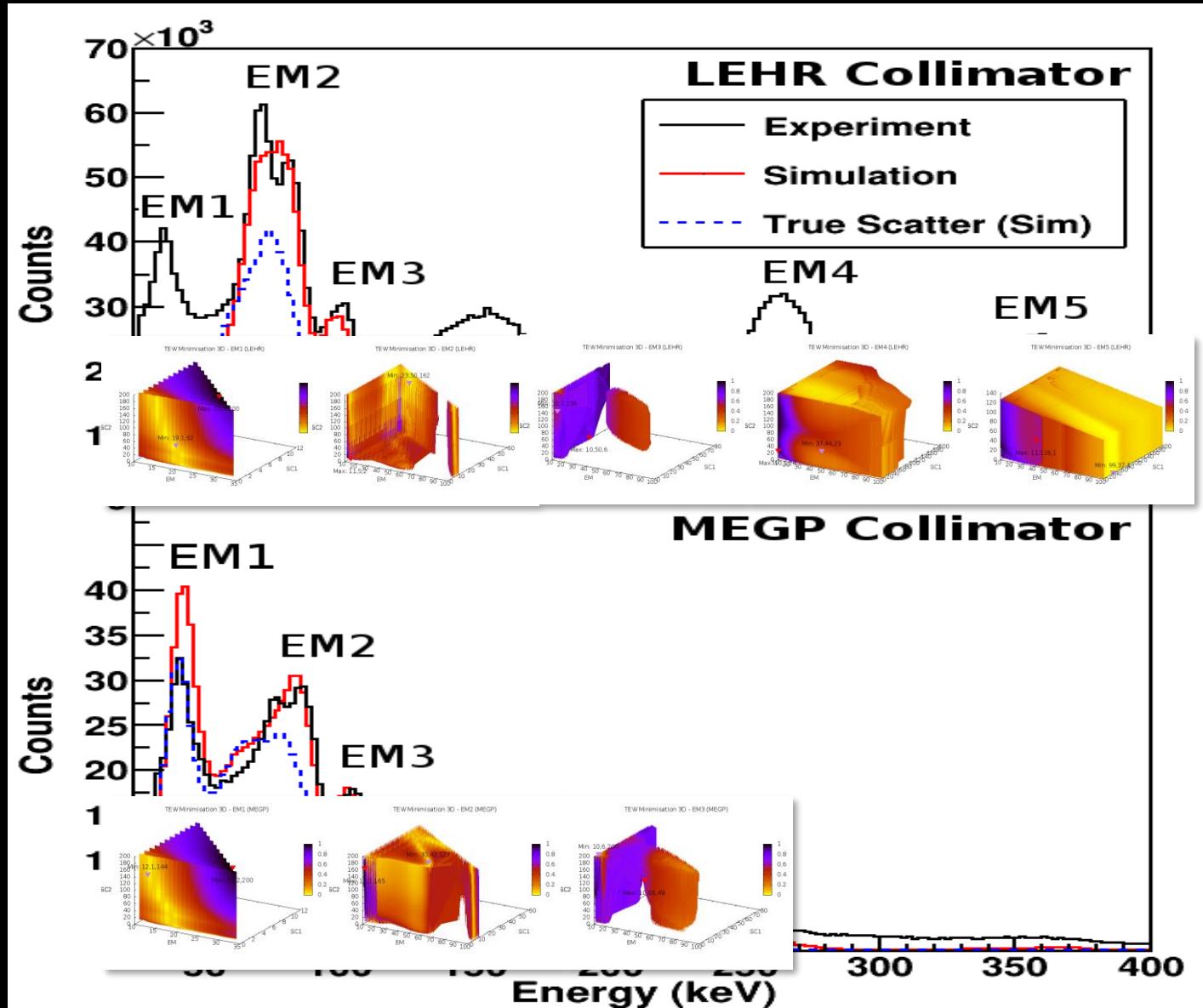
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Tb-155 SPECT

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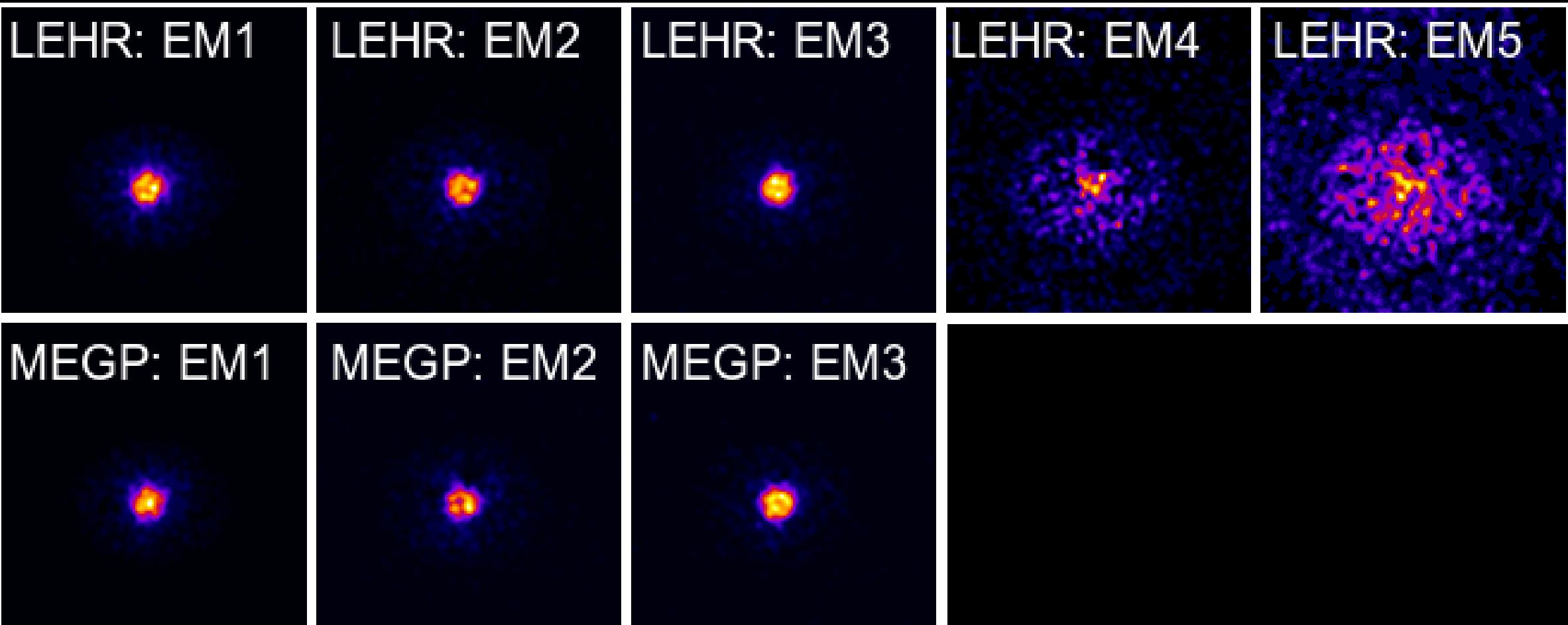
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SPECT Imaging (List mode)

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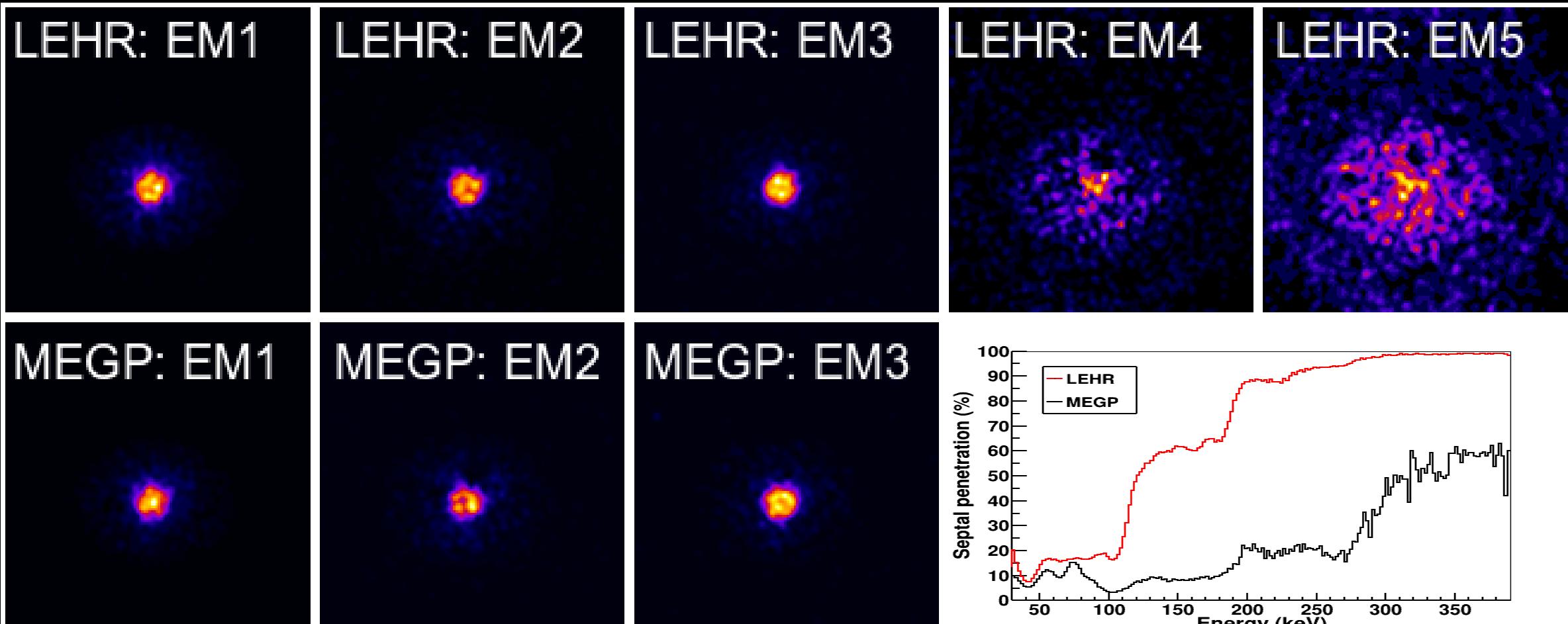
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SPECT Imaging (List mode)

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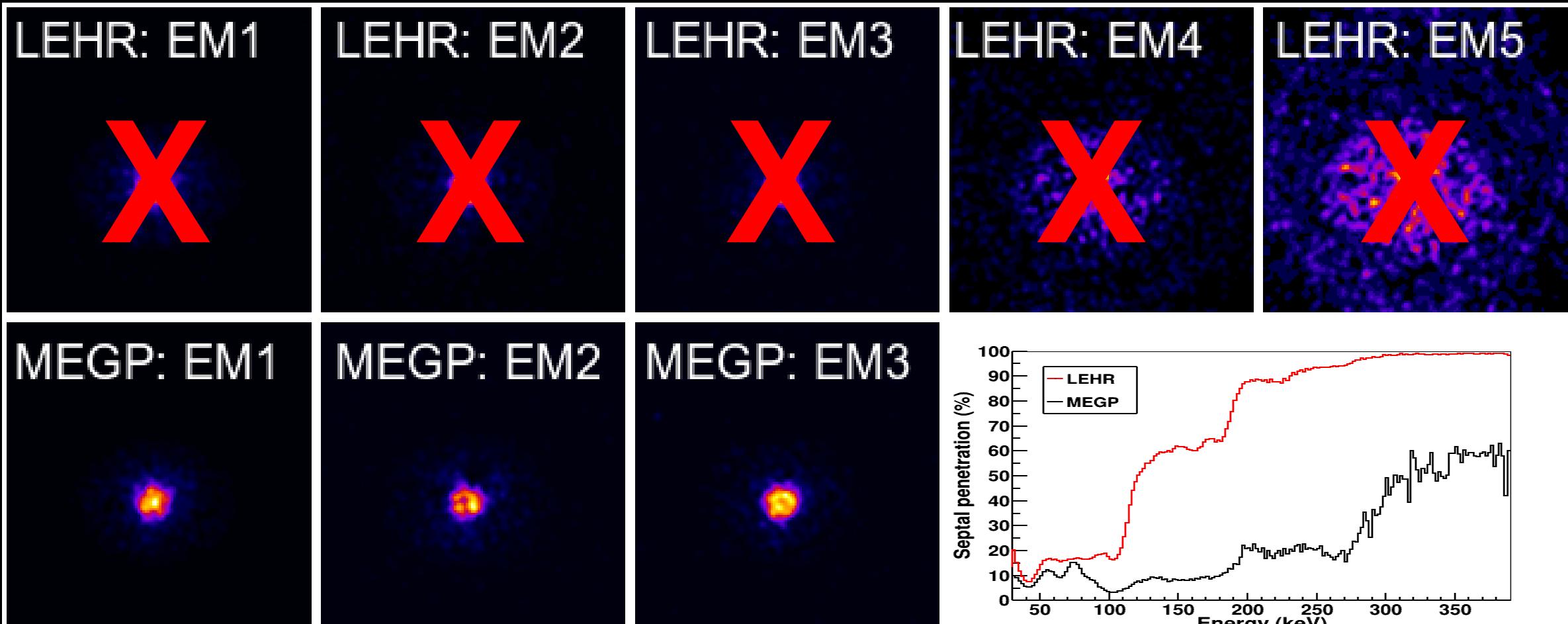
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SPECT Imaging (List mode)

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Validation of simulations



- Can you trust the results from a simulation?

Validation of simulations

- Can you trust the results from a simulation?

- Yes - if the simulation has been validated

- ✓ Geometry
- ✓ Detector modelling
- ✓ Physics models (dependent on energy range)
- ✓ (Nuclear) Data

Comparison with experimental data

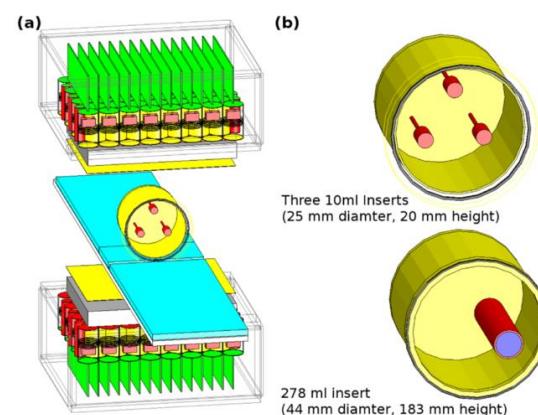
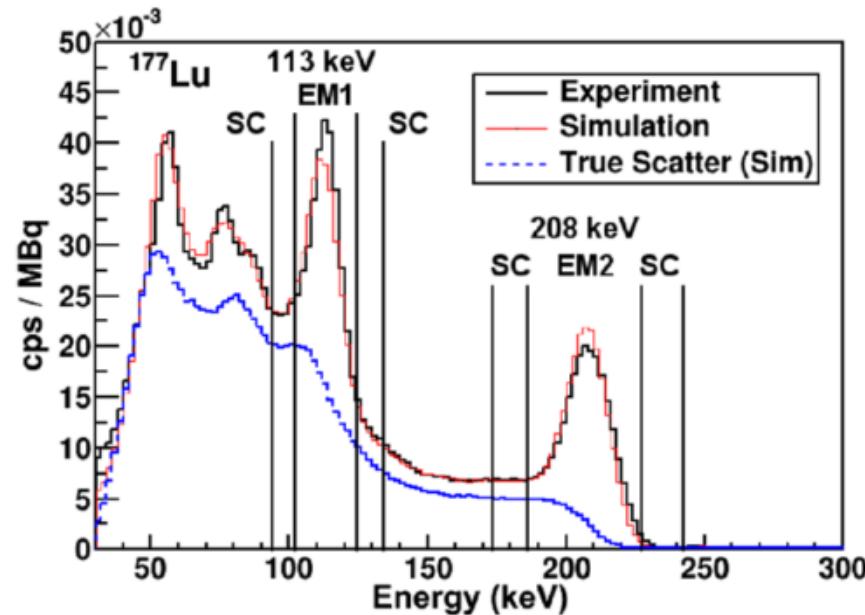
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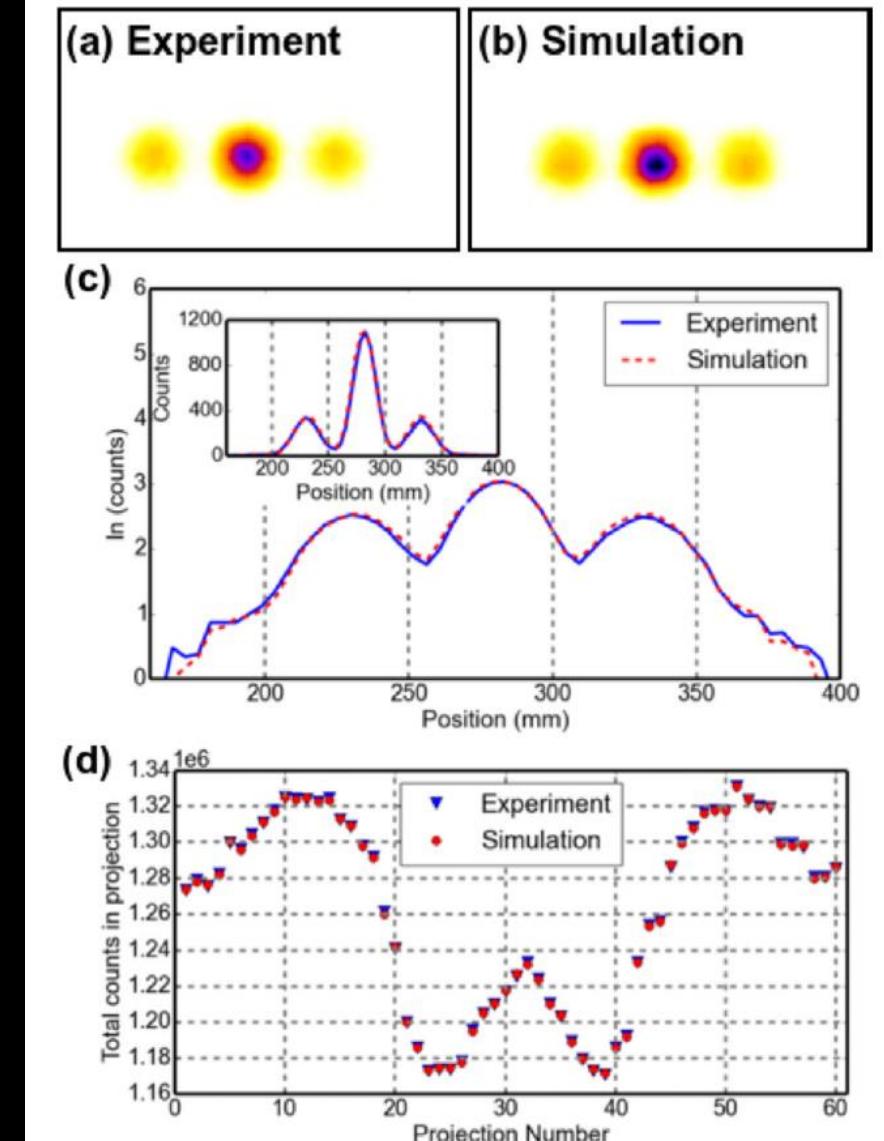
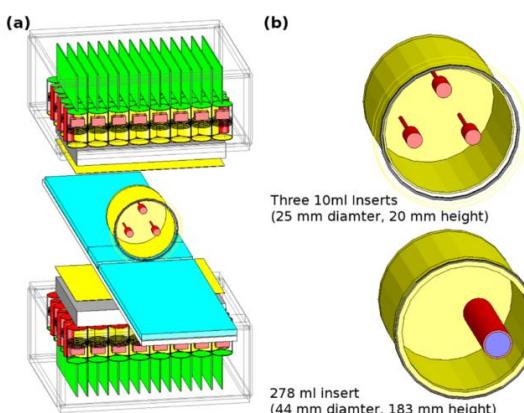
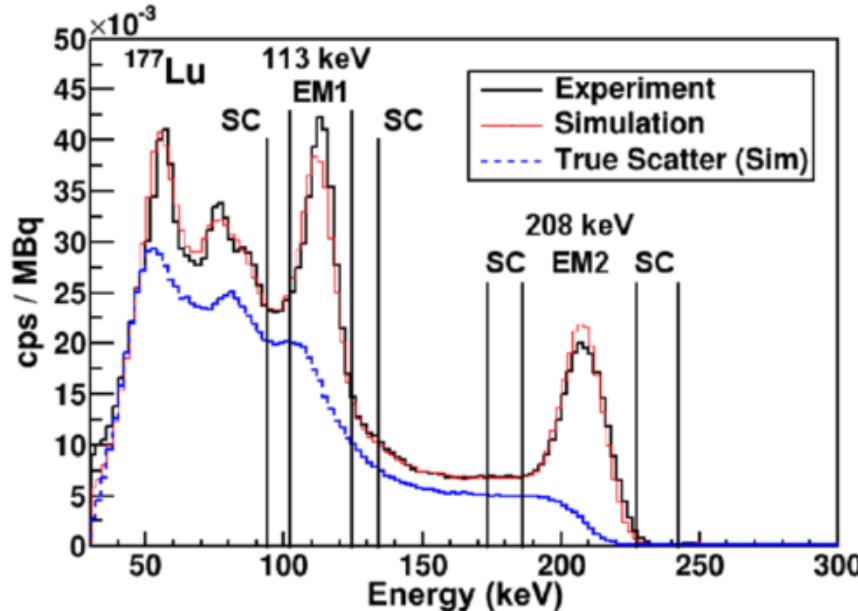
The influence of triple energy window scatter correction on activity quantification for ^{177}Lu molecular radiotherapy

Andrew P Robinson¹, Jill Tipping², David M Cullen¹
and David Hamilton²



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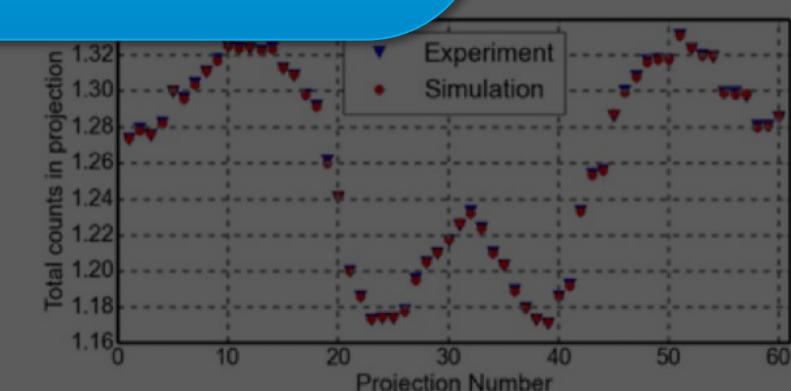
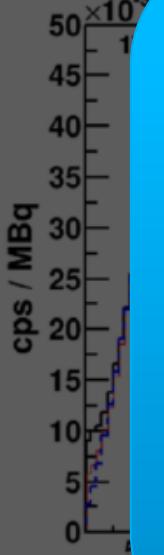
The influence of triple energy window scatter correction on activity quantification for ^{177}Lu molecular radiotherapy

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(a) Experiment

(b) Simulation

“Validates the global photon transport, geometry and material composition of the model for the full range of direct observables from a commercial SPECT camera.”



Uncertainties....

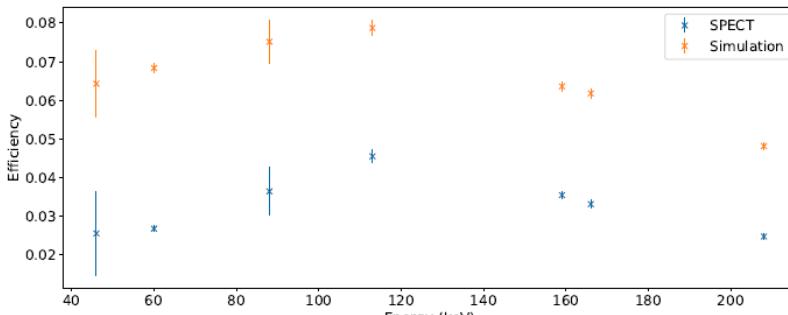


Figure 4: A comparison of the absolute detection efficiency of the SPECT camera and the simulation for the calibration sources stated in Table 2.

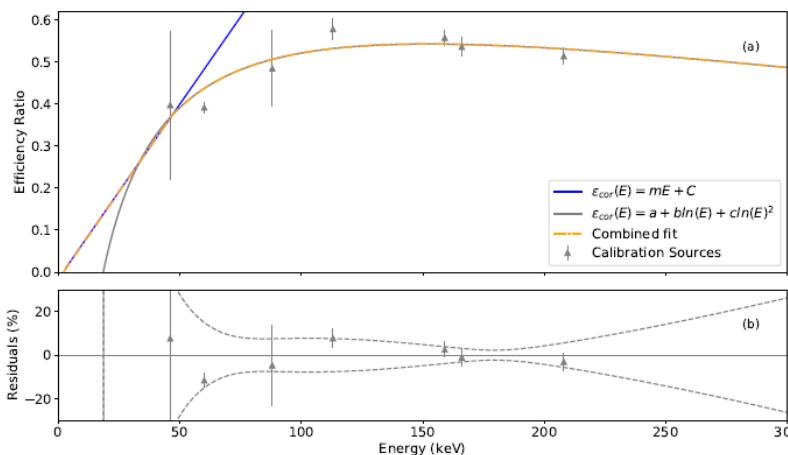


Figure 5: The data used to create the efficiency correction. The grey points show the ratio of experimentally-measured and simulated efficiency for the calibration sources. (a): the data points with the two fits discussed in the text and the superposition of the two functions, shown as an orange dot-dashed line, used for the efficiency correction. (b): the residuals of the fit to the data. The error bars on the residuals are the standard uncertainty of each data point and the dashed lines represent the uncertainty of the fit.

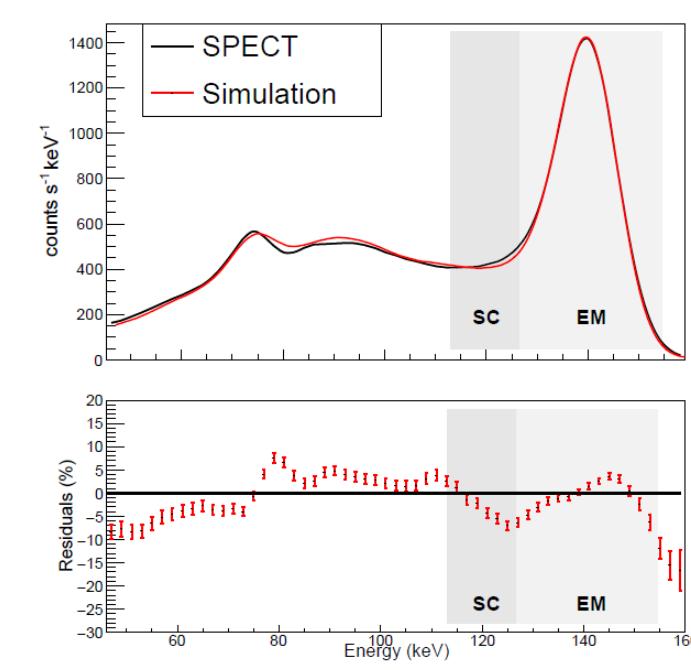
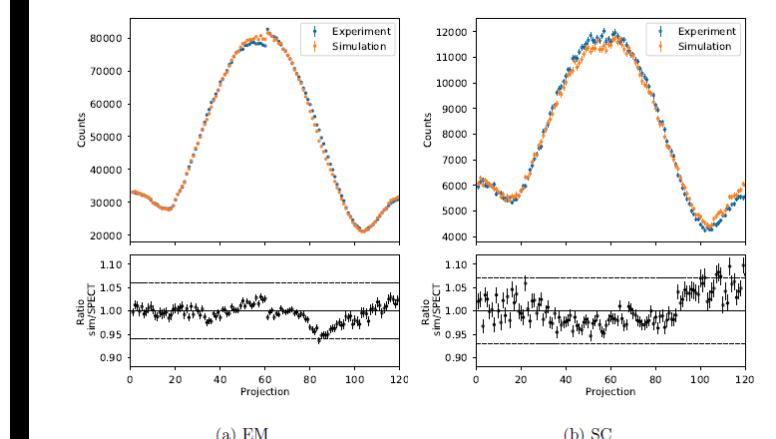


Figure 6: A comparison of the total simulated energy spectrum and the total spectrum extracted from the SPECT images for the cylindrical phantom of ^{99m}Tc . Each spectrum has been plotted with 2 keV bins, with a smooth curve through the bins. The bottom plot shows the percentage residuals. The emission (EM) and scatter (SC) windows are shaded.



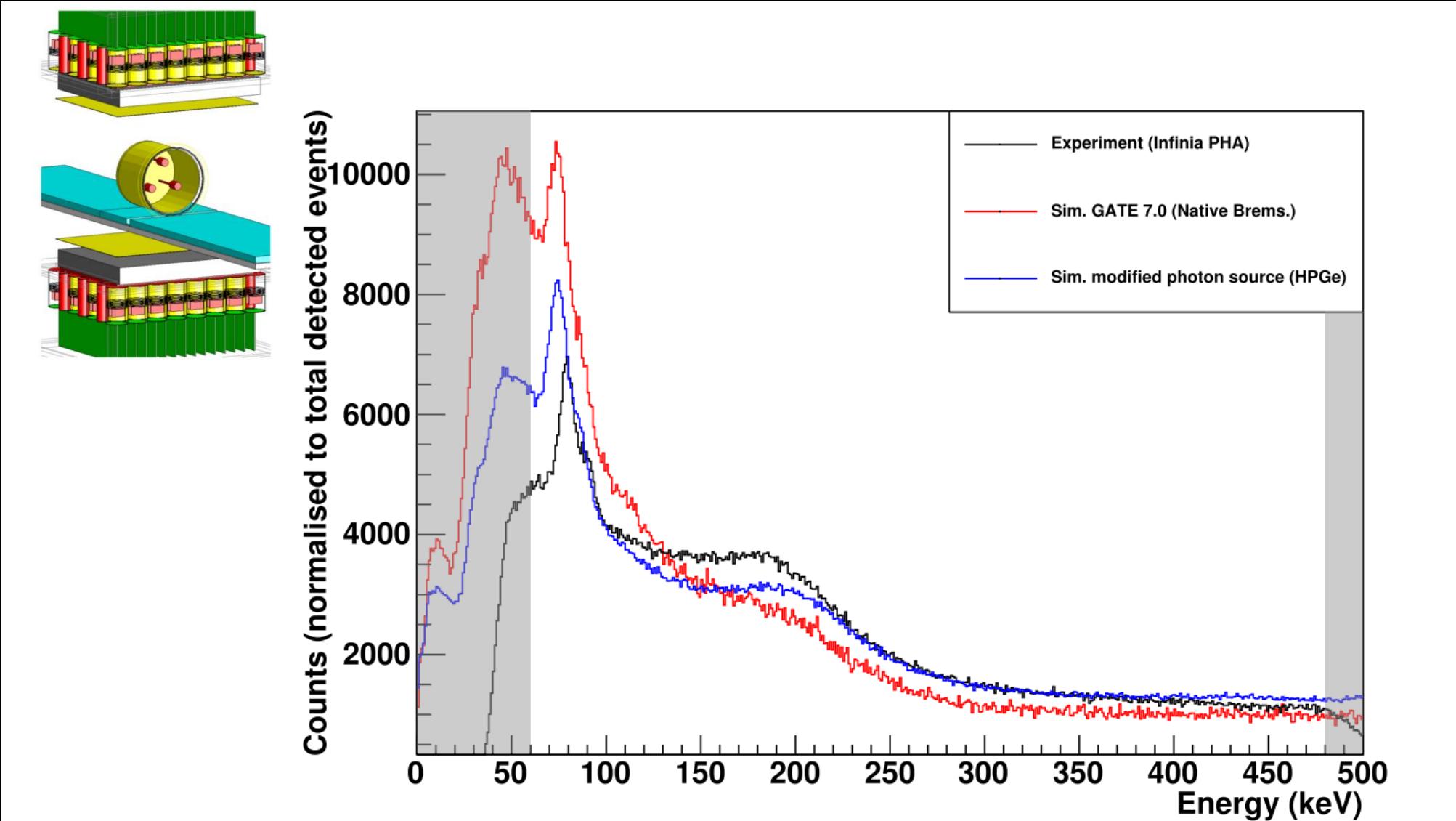
(a) EM

(b) SC

^{90}Y Bremsstrahlung Imaging

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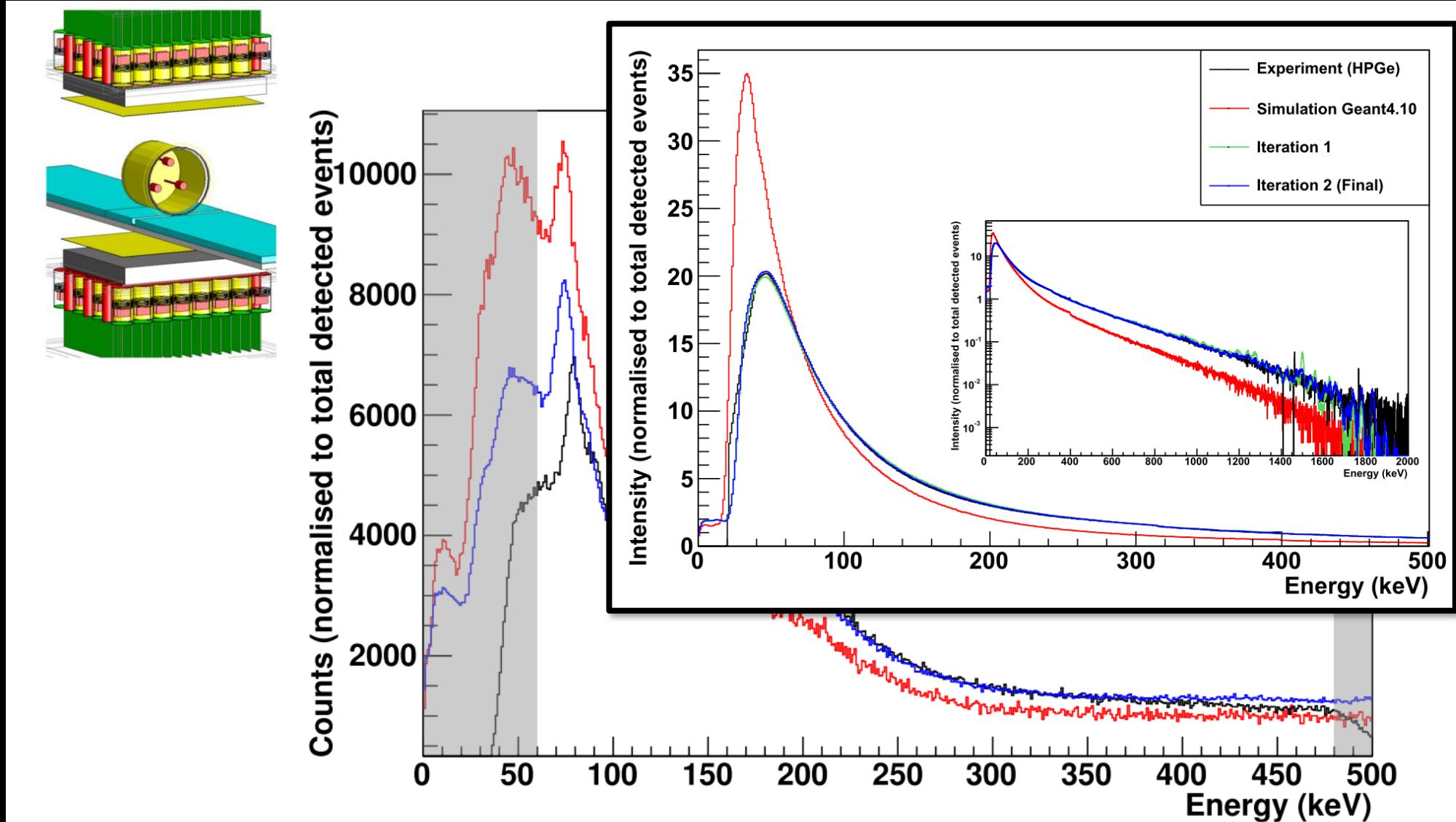
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^{90}Y Bremsstrahlung Imaging

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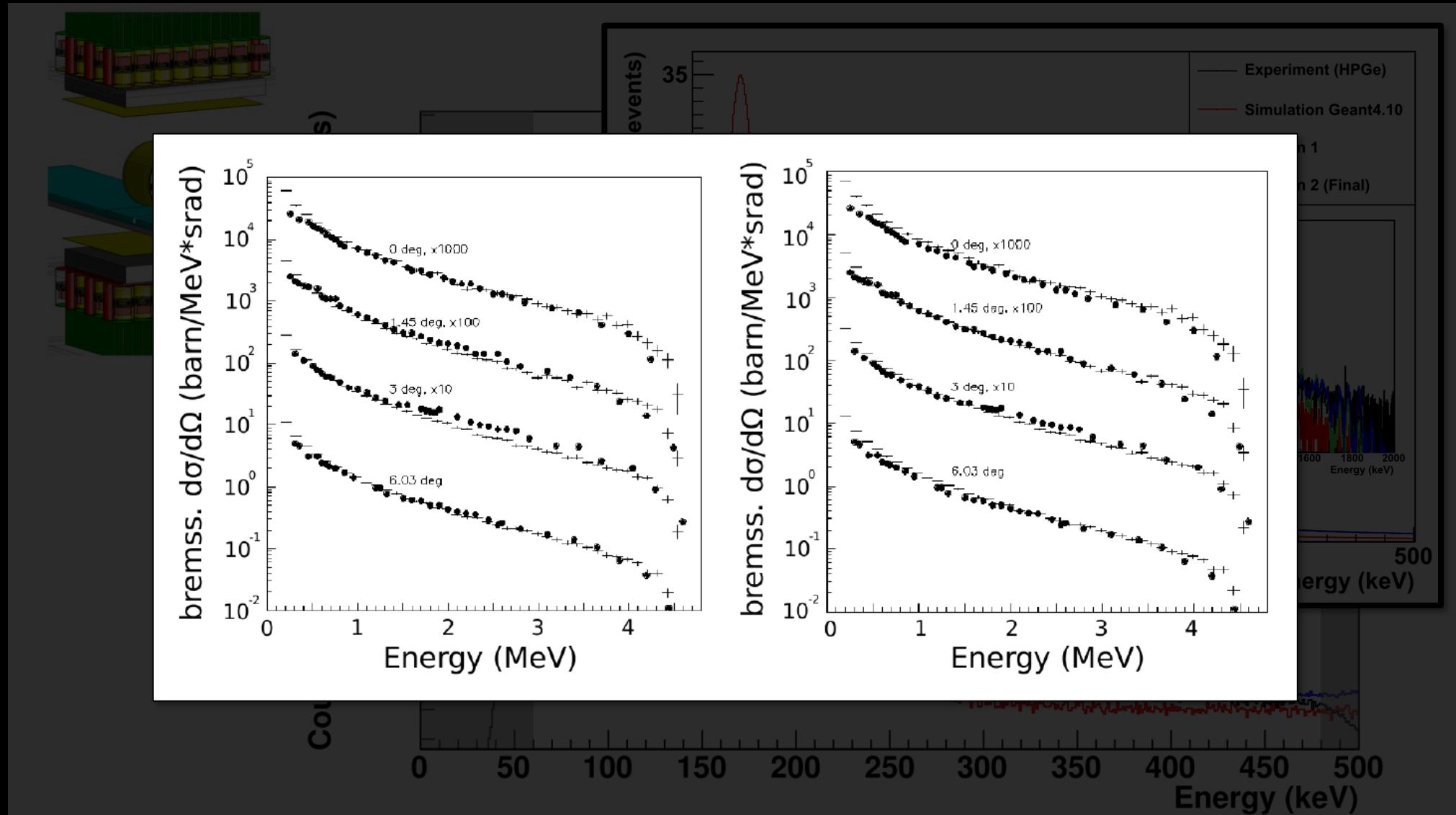
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^{90}Y Bremsstrahlung Imaging

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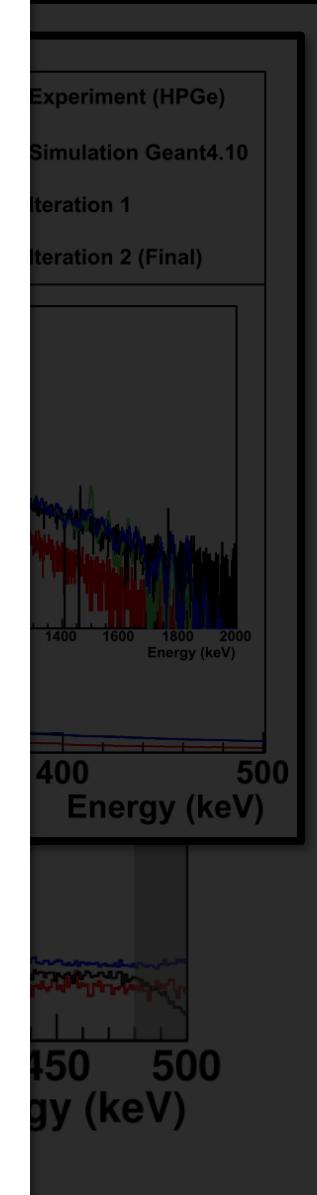
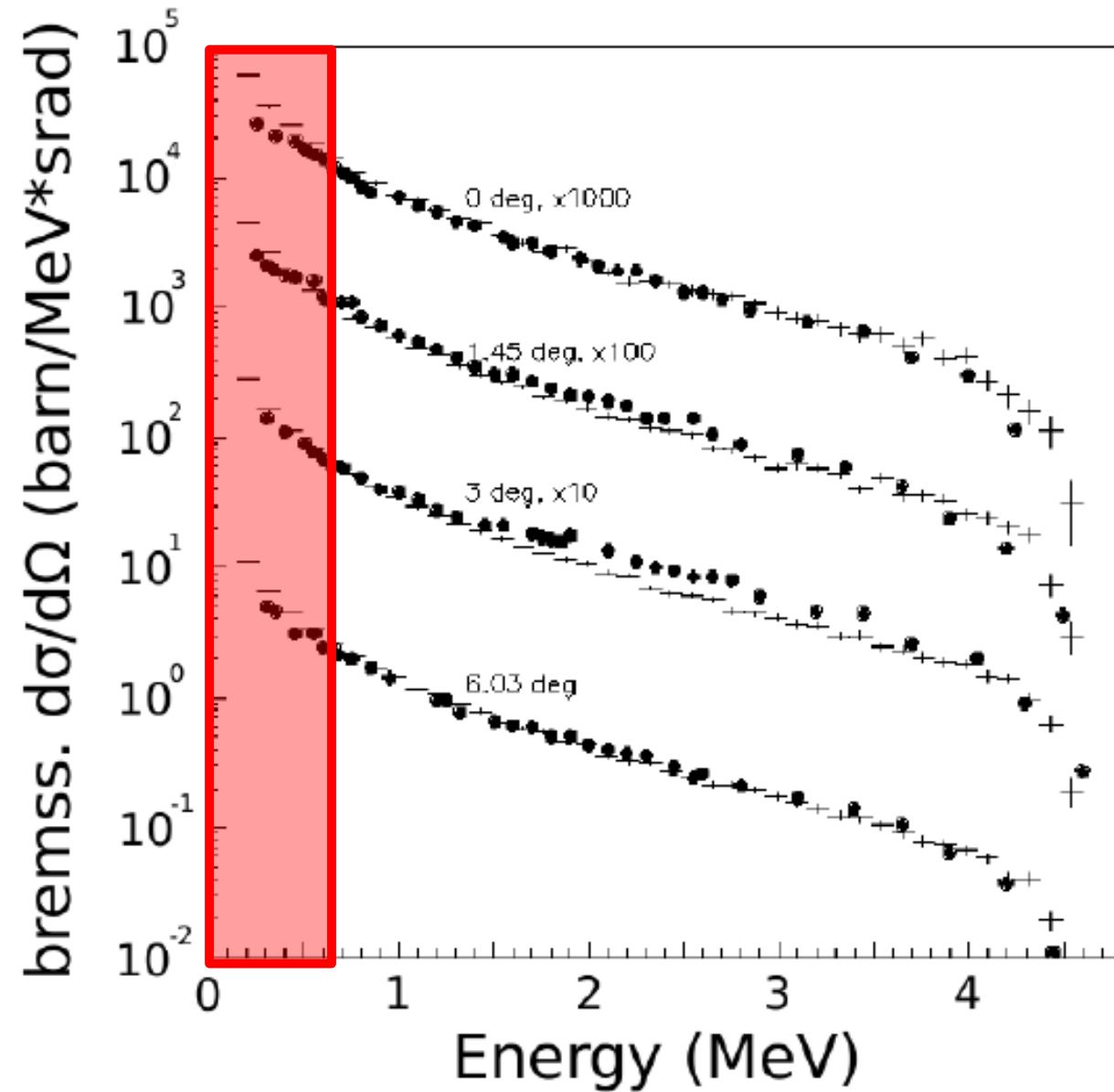
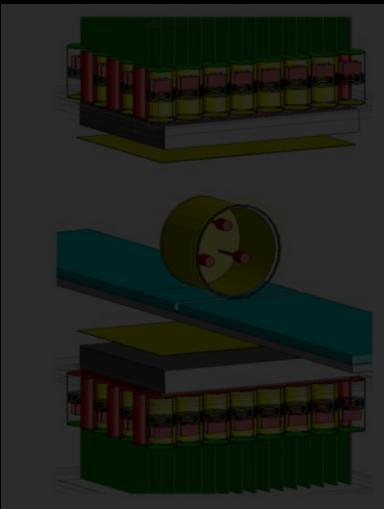
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^{90}Y Bremsstrahlung Imaging

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About this project

Objectives:

The project addresses the following scientific and technical objectives:

1. To improve modern measurement techniques for silicon detectors (Si(Li)), solid scintillator crystals ($\text{LaBr}_3/\text{CeBr}_3$) and magnetic spectrometers for measurements of beta spectra. (WP3)
2. To optimise beta spectrometers, based on Metallic Magnetic Calorimeters (MMCs), and measure new high resolution beta spectra for low (< 100 keV) and intermediate (< 1 MeV) end-point energy pure beta emitters Sm-151, C-14, Tc-99 and Cl-36. (WP2), D5, D6
3. To improve theoretical computation methods and compare the measured and calculated beta spectra. (WP1 and WP4)
4. To investigate the effect of improved beta spectra on absolute activity measurements and measure Bremsstrahlung cross-sections to quantify their effect. (WP4)
5. To facilitate the take up of the technology and measurement infrastructure developed by the project by the measurement supply chain (accredited laboratories, instrumentation manufacturers) and end users (the nuclear medicine community and the nuclear power industry). (WP5)

- MC codes **do not reproduce correctly** the bremsstrahlung production
 - Study presented at the last ICRM LS WG (**simulation of dose calibrator**)
 - Med. Phys. 37 (2010) 2943, NIM B 350 (2015) 41-48
- There is a need **to measure the cross-section** for bremsstrahlung production in order to improve the accuracy of the **simulation**
 - Use to calculate the correction for energy loss through the escape of bremsstrahlung photons in LSC and in MMCs for beta spectra measurement
- News experiments are proposed using:
 - an **electron gun** (up to 2 MeV)
 - A set-up for **gamma measurement**



OpenDose: a collaborative effort to produce reference dosimetric data with Monte Carlo simulations

Aims to provide a free and public resource of robust reference data to enable dosimetry calculations in nuclear medicine, using a variety of Monte Carlo codes through an international collaboration



Challenges

- 2 ICRP 110 reference adult phantoms (male and female)
- 140 organs (19600 target/source combinations!)
- ICRP 107: ~1200 radionuclides
- MIRD RADTABS source of decay data: ~300 radionuclides

Too big for a single institution!!!



Proposal

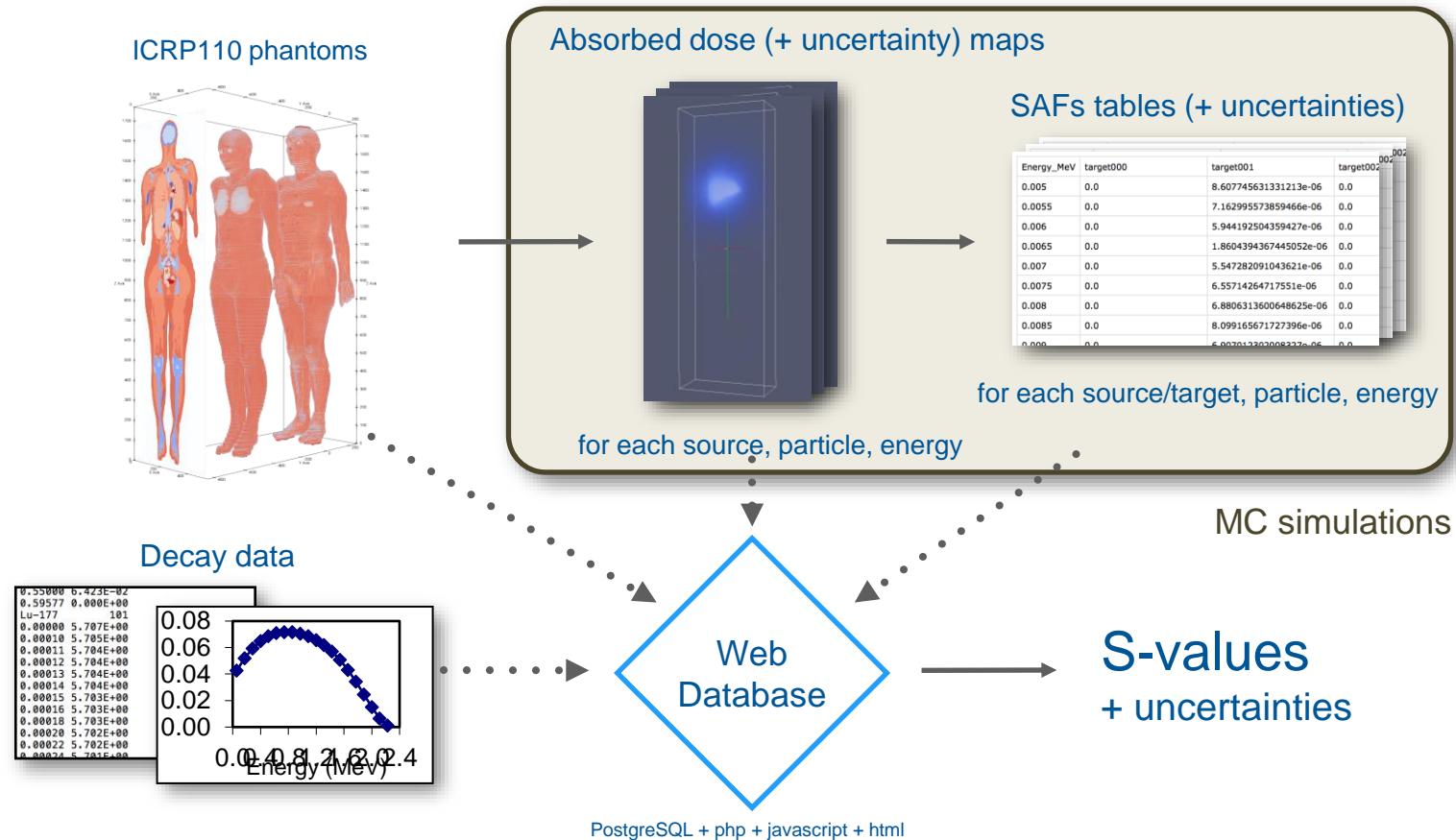
- Collaborative work, everyone is welcome!
- Create a free database
- Create an easily accessible website
- Make data available with associated uncertainties
- First meeting took place at the EANM 2016, Barcelona.

14 research teams (18 institutes)



5 Monte Carlo codes:

Geant4/GATE - FLUKA - PENELOPE - MCNP/MCNPX - EGSnrc/EGS++

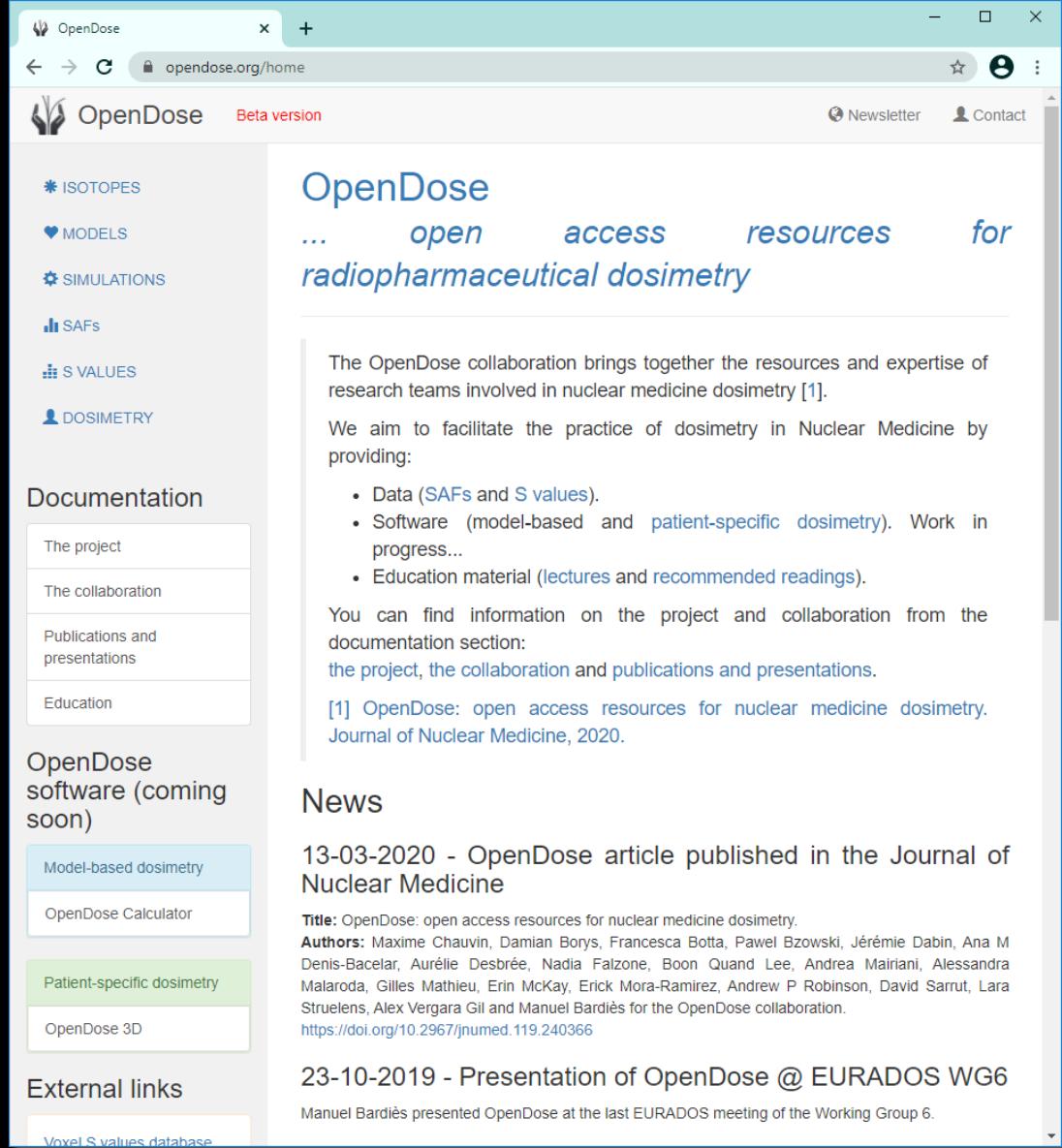


OpenDose: Open-Access Resource for Nuclear Medicine Dosimetry

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The screenshot shows the OpenDose website homepage. The header includes the OpenDose logo, a beta version notice, and links for newsletter and contact. The main content area features a large banner with the text "OpenDose ... open access resources for radiopharmaceutical dosimetry". Below the banner, a text block explains the collaboration's goal of bringing together resources for dosimetry. A "Documentation" sidebar lists project, collaboration, publications, and education sections. The main content area also discusses the software (coming soon) and its features: Model-based dosimetry, OpenDose Calculator, Patient-specific dosimetry, OpenDose 3D, and External links (Voxel S values database). News sections at the bottom mention an article published in the Journal of Nuclear Medicine and a presentation at EURADOS WG6.

OpenDose Beta version

Newsletter Contact

OpenDose

* ISOTOPES

♥ MODELS

⚙ SIMULATIONS

📊 SAFs

💡 S VALUES

👤 DOSIMETRY

Documentation

The project

The collaboration

Publications and presentations

Education

OpenDose software (coming soon)

Model-based dosimetry

OpenDose Calculator

Patient-specific dosimetry

OpenDose 3D

External links

Voxel S values database

OpenDose ... open access resources for radiopharmaceutical dosimetry

The OpenDose collaboration brings together the resources and expertise of research teams involved in nuclear medicine dosimetry [1].

We aim to facilitate the practice of dosimetry in Nuclear Medicine by providing:

- Data (SAFs and S values).
- Software (model-based and patient-specific dosimetry). Work in progress...
- Education material (lectures and recommended readings).

You can find information on the project and collaboration from the documentation section: the project, the collaboration and publications and presentations.

[1] OpenDose: open access resources for nuclear medicine dosimetry. Journal of Nuclear Medicine, 2020.

News

13-03-2020 - OpenDose article published in the Journal of Nuclear Medicine

Title: OpenDose: open access resources for nuclear medicine dosimetry.

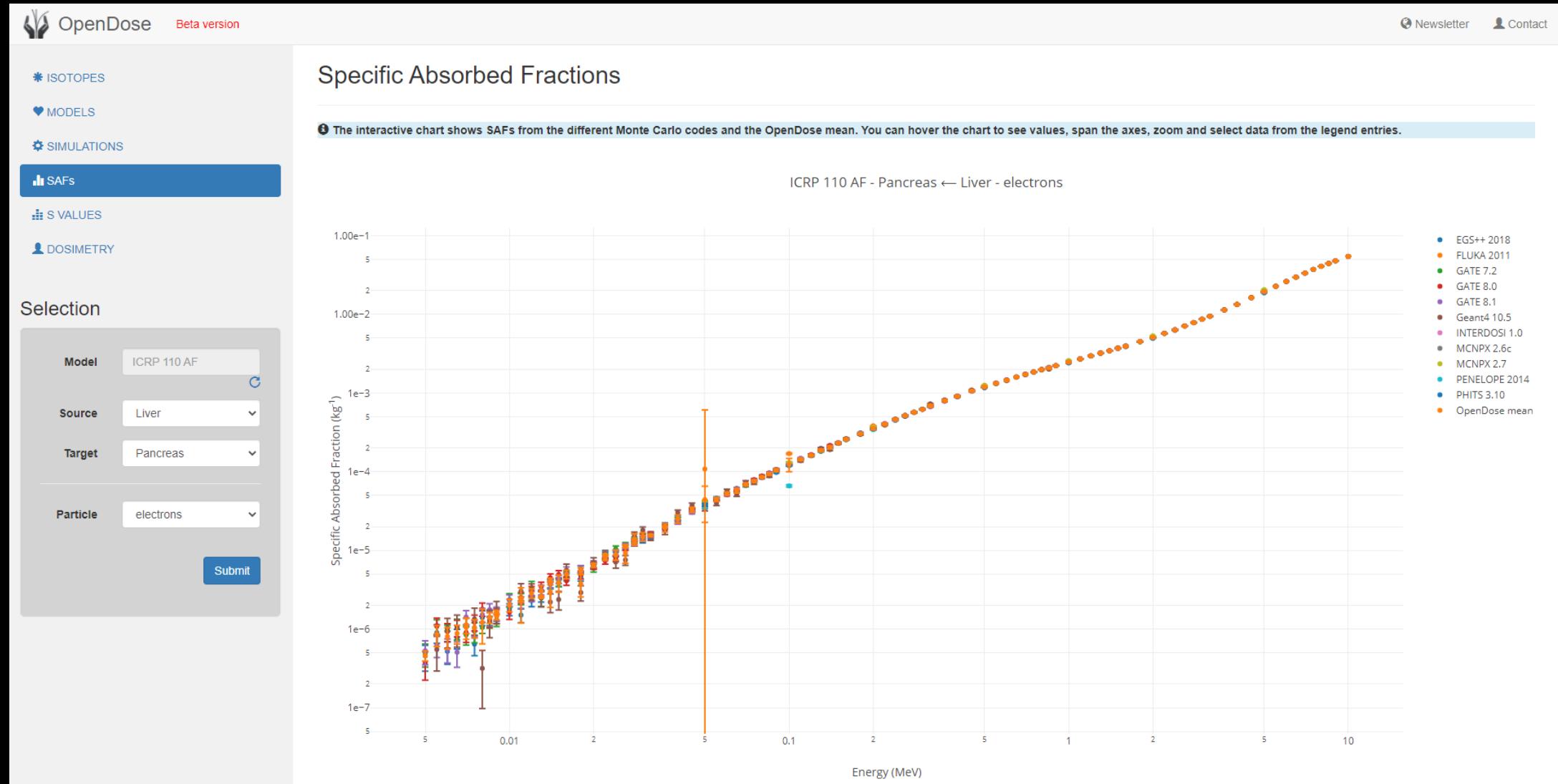
Authors: Maxime Chauvin, Damian Borys, Francesca Botta, Paweł Bzowski, Jérémie Dabin, Ana M. Denis-Bacelar, Aurélie Desbrée, Nadia Falzone, Boon Quand Lee, Andrea Mairani, Alessandra Malaroda, Gilles Mathieu, Erin McKay, Erick Mora-Ramirez, Andrew P. Robinson, David Sarrut, Lara Struelens, Alex Vergara Gil and Manuel Bardès for the OpenDose collaboration.

<https://doi.org/10.2967/jnumed.119.240366>

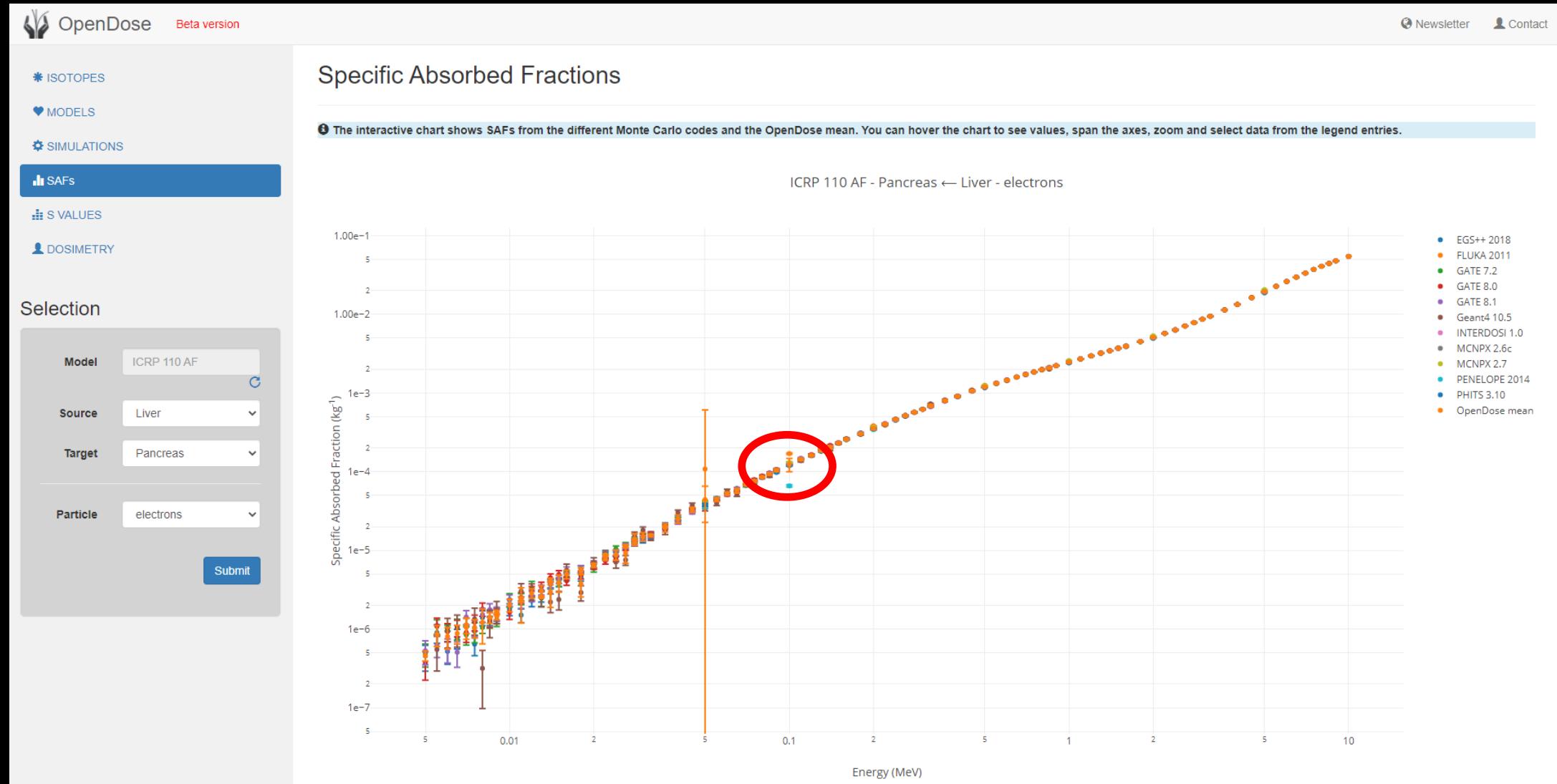
23-10-2019 - Presentation of OpenDose @ EURADOS WG6

Manuel Bardès presented OpenDose at the last EURADOS meeting of the Working Group 6.

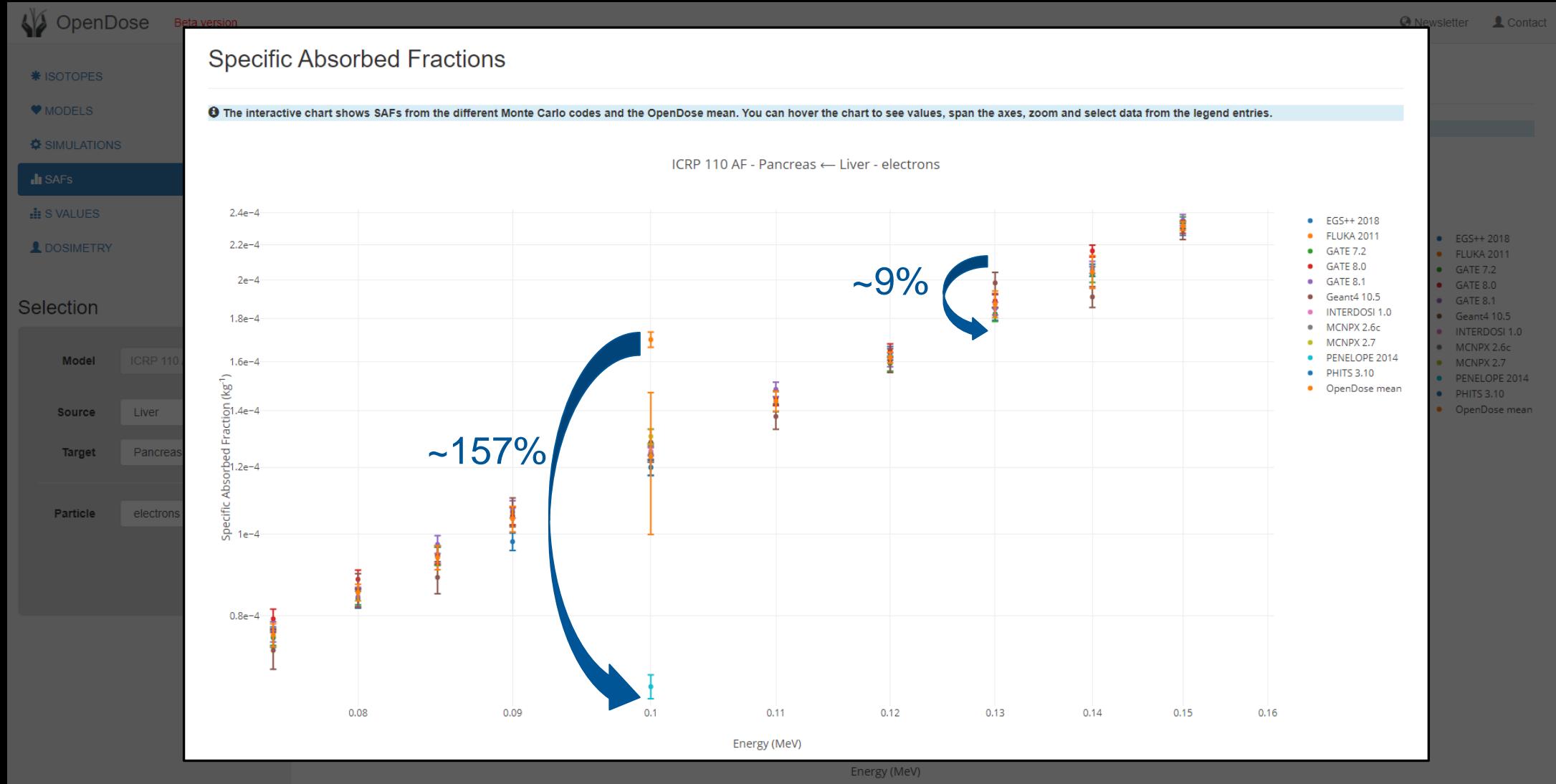
SAF results: Pancreas ← Liver (electrons)



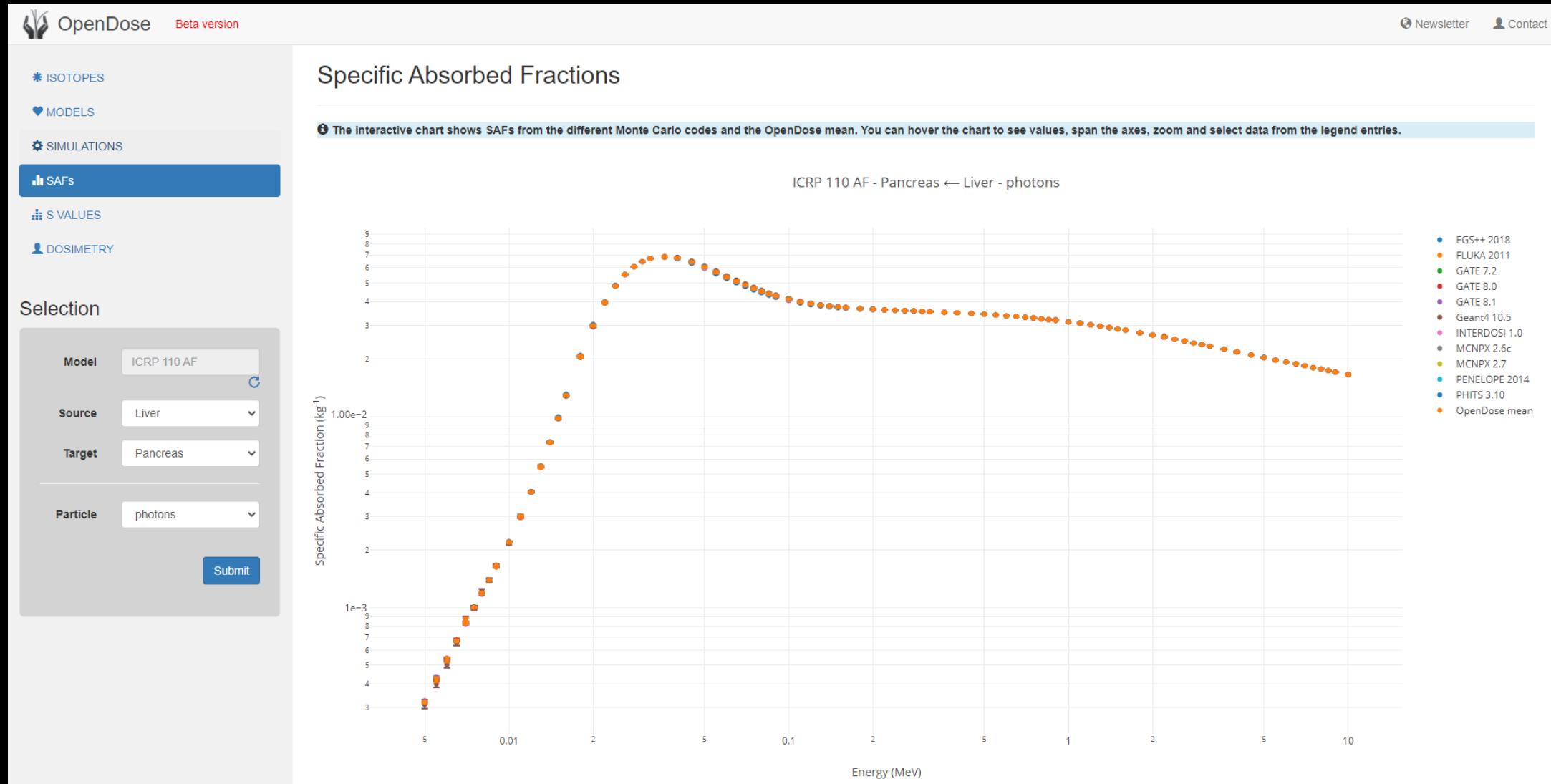
SAF results: Pancreas ← Liver (electrons)



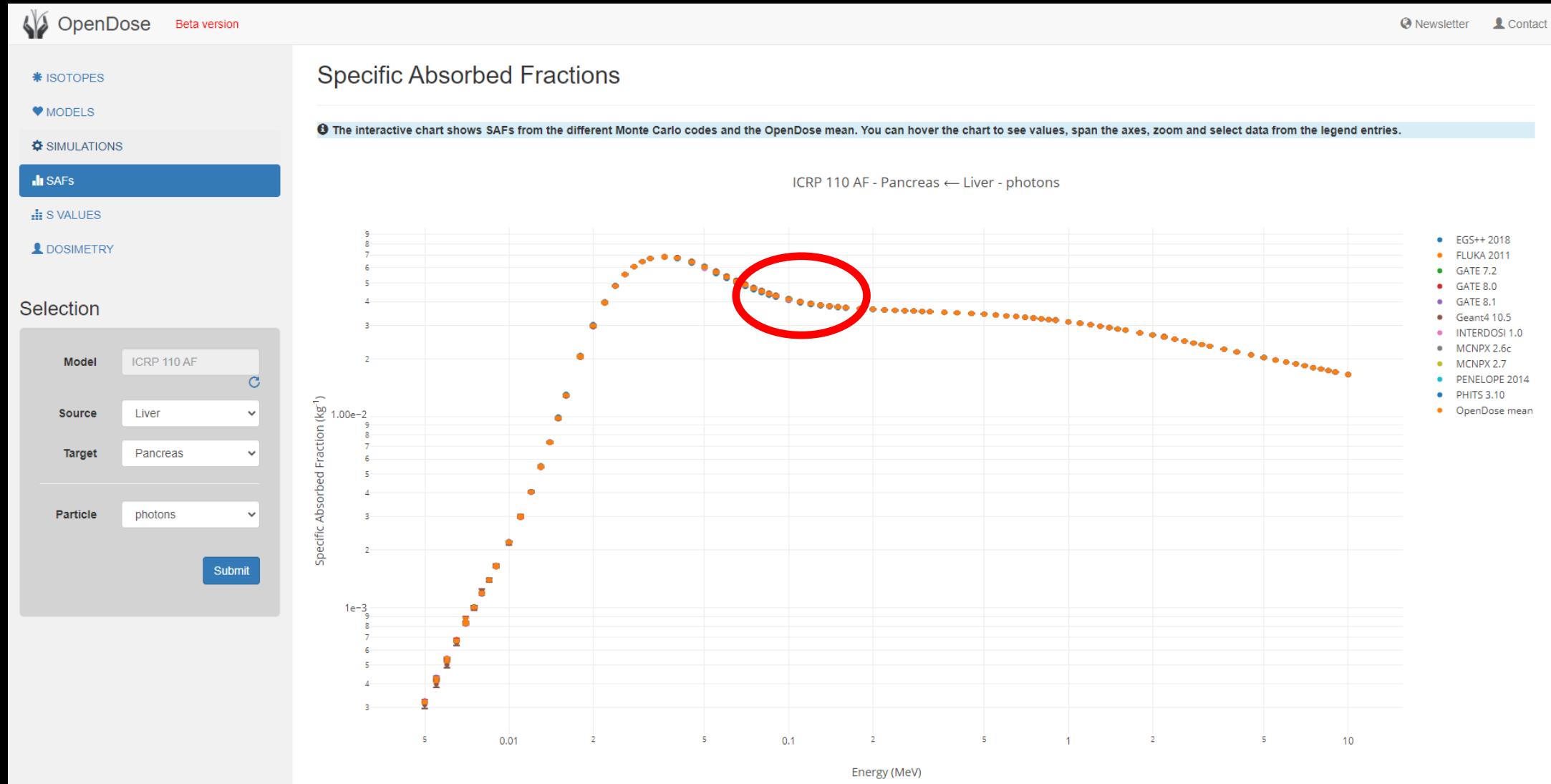
SAF results: Pancreas ← Liver (electrons)



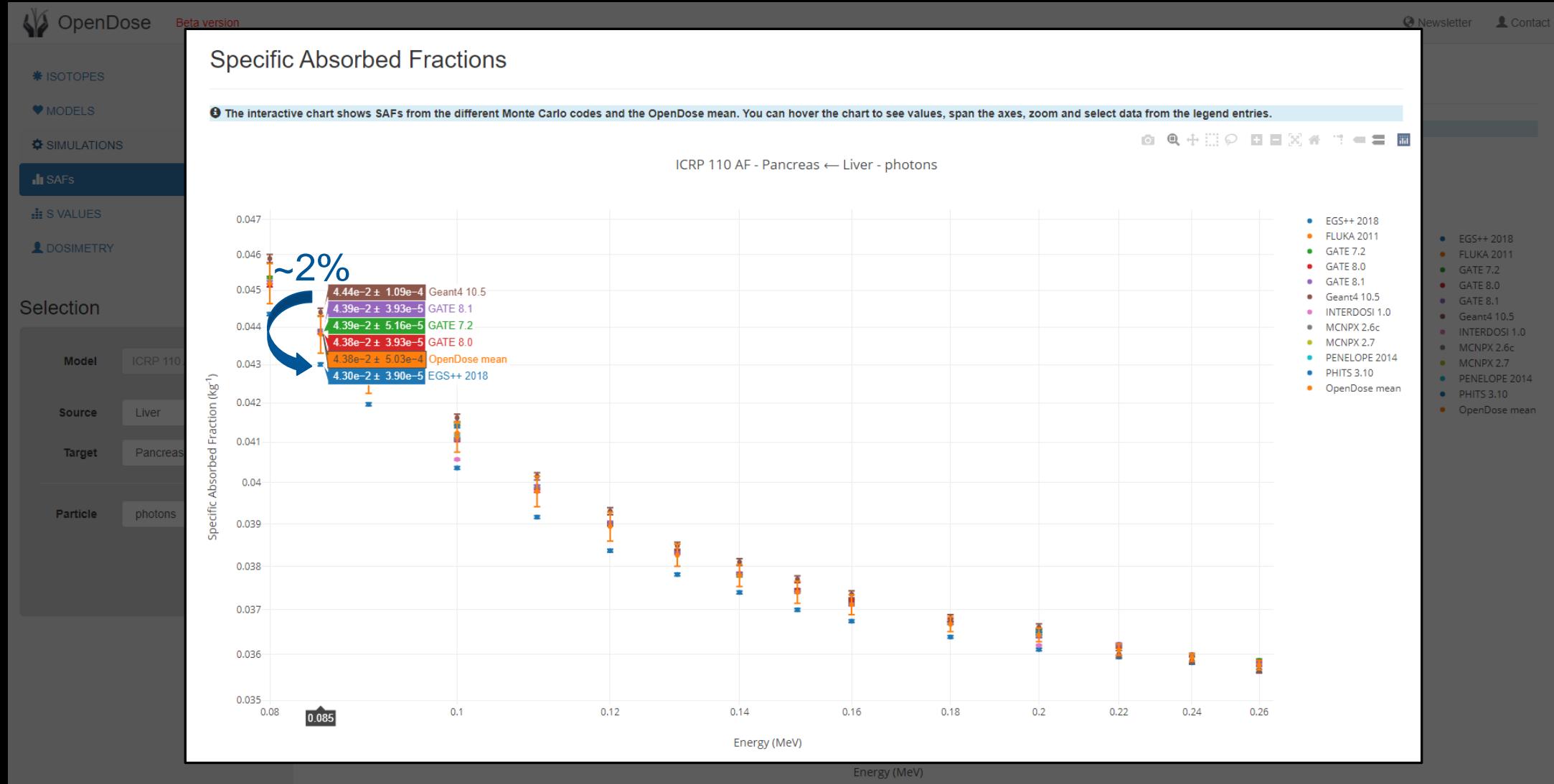
SAF results: Pancreas ← Liver (photons)



SAF results: Pancreas ← Liver (photons)



SAF results: Pancreas ← Liver (photons)



Validation of simulations

- Can you trust the results from a simulation?

- Yes - if the simulation has been validated

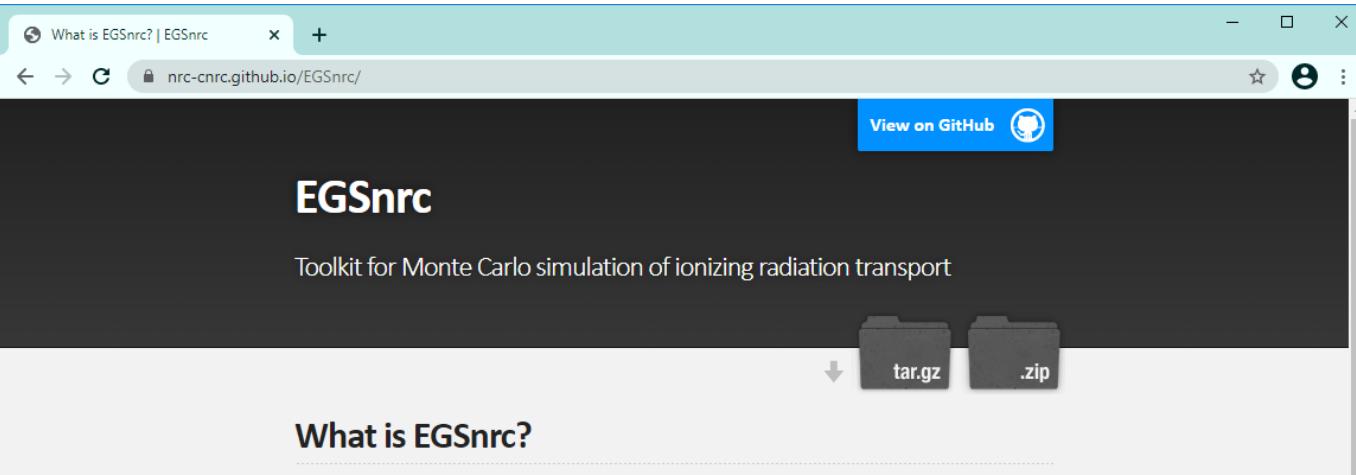
- ✓ Geometry
- ✓ Detector modelling
- ✓ Physics models (dependent on energy range)
- ✓ (Nuclear) Data

Comparison with experimental data

- What is Monte Carlo simulation?
- Why use it for medical imaging?
- Examples (demos)
- Validation of simulations
- Tools you can use
- Q & A

Tools you can use

EGSnrc (<https://nrc-cnrc.github.io/EGSnrc/>)



The screenshot shows the GitHub page for the EGSnrc project. At the top, there's a header with the project name and a 'View on GitHub' button. Below the header, the title 'EGSnrc' is displayed, followed by a subtitle 'Toolkit for Monte Carlo simulation of ionizing radiation transport'. Underneath, there are two download links: 'tar.gz' and '.zip'. The main content area is titled 'What is EGSnrc?' and contains a detailed description of the software, mentioning its history as a complete overhaul of the Electron Gamma Shower (EGS) package developed at SLAC in the 1970s, and its features like photon, electron, and positron propagation with kinetic energies between 1 keV and 10 GeV. It also notes the incorporation of crucial refinements in charged particle transport, better low energy cross sections, and the egs++ class library for modeling geometries and particle sources. A DOI link (10.4224/40001303) is provided at the bottom of this section. Below this, there's a 'Documentation' section with a list of links to various manuals and guides, such as 'Getting Started', 'EGSnrc core manual (PIRS-701)', 'BEAMnrc accelerators (PIRS-509a)', 'DOSXYZnrc voxel dose (PIRS-794)', 'egs++ geometries, sources and applications (PIRS-898)', 'g application reference manual (PIRS-3100)', 'RZ and SPH apps user manual (PIRS-702)', 'RZ GUI egs_inprz (PIRS-801)', 'BEAMDP basic manual (PIRS-509e)', 'BEAMDP advanced manual (PIRS-509c)', and 'STATDOSE 3D dose processor (PIRS-509f)'.

What is EGSnrc?

EGSnrc is a software toolkit to perform Monte Carlo simulation of ionizing radiation transport through matter. It models the propagation of photons, electrons and positrons with kinetic energies between 1 keV and 10 GeV, in homogeneous materials. EGSnrc was originally released in 2000, as a complete overhaul of the Electron Gamma Shower (EGS) software package originally developed at the Stanford Linear Accelerator Center (SLAC) in the 1970s. Most notably, EGSnrc incorporates crucial refinements in charged particle transport, better low energy cross sections, and the egs++ class library to model elaborate geometries and particle sources.

DOI: [10.4224/40001303](https://doi.org/10.4224/40001303)

Documentation

- [Getting Started](#) with guided tutorials
- [EGSnrc core manual \(PIRS-701\)](#)
- [BEAMnrc accelerators \(PIRS-509a\)](#)
- [DOSXYZnrc voxel dose \(PIRS-794\)](#)
- [egs++ geometries, sources and applications \(PIRS-898\)](#)
- [g application reference manual \(PIRS-3100\)](#)
- [RZ and SPH apps user manual \(PIRS-702\)](#)
- [RZ GUI egs_inprz \(PIRS-801\)](#)
- [BEAMDP basic manual \(PIRS-509e\)](#)
- [BEAMDP advanced manual \(PIRS-509c\)](#)
- [STATDOSE 3D dose processor \(PIRS-509f\)](#)

Tools you can use

MCNP (<https://mcnp.lanl.gov/>)

The screenshot shows the official website for MCNP, a Monte Carlo N-particle transport code. The page is hosted by Los Alamos National Laboratory. The header features the Los Alamos logo and the title "A General Monte Carlo N-Particle (MCNP) Transport Code". The main content area includes the MCNP6 logo, the text "Monte Carlo Methods, Codes, & Applications Group" and "Los Alamos National Laboratory", and a detailed "ABSTRACT" section describing the code's capabilities. A sidebar on the left provides links to various MCNP resources like news, FAQ, and user manuals. A "CONTACTS" section at the bottom lists the MCNP Team and Web Admin. A "SECURED BY SSL" badge is visible near the bottom left.

A General Monte Carlo N-Particle (MCNP) Transport Code

mcnp HOME

MCNP6
MCNP NEWS
MCNP FAQ
MCNPs
Upcoming Classes
Related Efforts
Monte Carlo Team Personnel
User Manual
Reference Collection
Forum For Users
How to get MCNP
How to cite MCNP

MCNP Highlights

SECURED BY SSL

MCNP6

Monte Carlo Methods, Codes, & Applications Group

Los Alamos National Laboratory

ABSTRACT

MCNP is a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport. Specific areas of application include, but are not limited to, radiation protection and dosimetry, radiation shielding, radiography, medical physics, nuclear criticality safety, Detector Design and analysis, nuclear oil well logging, Accelerator target design, Fission and fusion reactor design, decontamination and decommissioning. The code treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and fourth-degree elliptical tori.

Pointwise cross-section data typically are used, although group-wise data also are available. For neutrons, all reactions given in a particular cross-section evaluation (such as ENDF/B-VI) are accounted for. Thermal neutrons are described by both the free gas and S(α , β) models. For photons, the code accounts for incoherent and coherent scattering, the possibility of fluorescent emission after photoelectric absorption, absorption in pair production with local emission of annihilation radiation, and bremsstrahlung. A continuous-slowing-down model is used for electron transport that includes positrons, k x-rays, and bremsstrahlung but does not include external or self-induced fields.

Important standard features that make MCNP very versatile and easy to use include a powerful general source, criticality source, and surface source; both geometry and output tally plotters; a rich collection of variance reduction techniques; a flexible tally structure; and an extensive collection of cross-section data.

MCNP contains numerous flexible tallies: surface current & flux, volume flux (track length), point or ring detectors, particle heating, fission heating, pulse height tally for energy or charge deposition, mesh tallies, and radiography tallies.

Additions to MCNP Reference Collection (2020-09-13)
MCNP6 SQA Plan & Requirements, LA-UR-20-26666
Additions to MCNP Reference Collection (2019-11-07)

Tools you can use

Geant4 (<https://geant4.web.cern.ch/>)

The screenshot shows the official Geant4 website at <https://geant4.web.cern.ch/>. The page features a header with the CERN logo and a search bar. Below the header is the Geant4 logo: "GEANT4" in blue with "A SIMULATION TOOLKIT" underneath. The main content area has a "Overview" section with a brief description of the tool's purpose and applications. It also includes four main links: "Applications", "User Support", "Publications", and "Collaboration". A "News" sidebar on the right lists recent developments and releases.

Geant4

CERN Accelerating science

Sign in | Directory

Download | User Forum | Contact Us | Bug Reports

Overview

Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. The three main reference papers for Geant4 are published in Nuclear Instruments and Methods in Physics Research A 506 (2003) 250-303, IEEE Transactions on Nuclear Science 53 No. 1 (2006) 270-278 and Nuclear Instruments and Methods in Physics Research A 835 (2016) 186-225.

Applications

A sampling of applications, technology transfer and other uses of Geant4

User Support

Getting started, guides and information for users and developers

Publications

Validation of Geant4, results from experiments and publications

Collaboration

Who we are: collaborating institutions, members, organization and legal information

Events

26th Geant4 Collaboration Meeting, at IRISA Laboratories, Rennes (France), 20-24 September 2021.

Past events

News

2021-03-10
2021 planned developments.

2021-02-05
Patch-01 to release 10.7 is available from the [Download area](#).

2020-11-06
Patch-03 to release 10.6 is available from the [Download archive area](#).

Tools you can use

GATE (<http://www.opengatecollaboration.org/>)

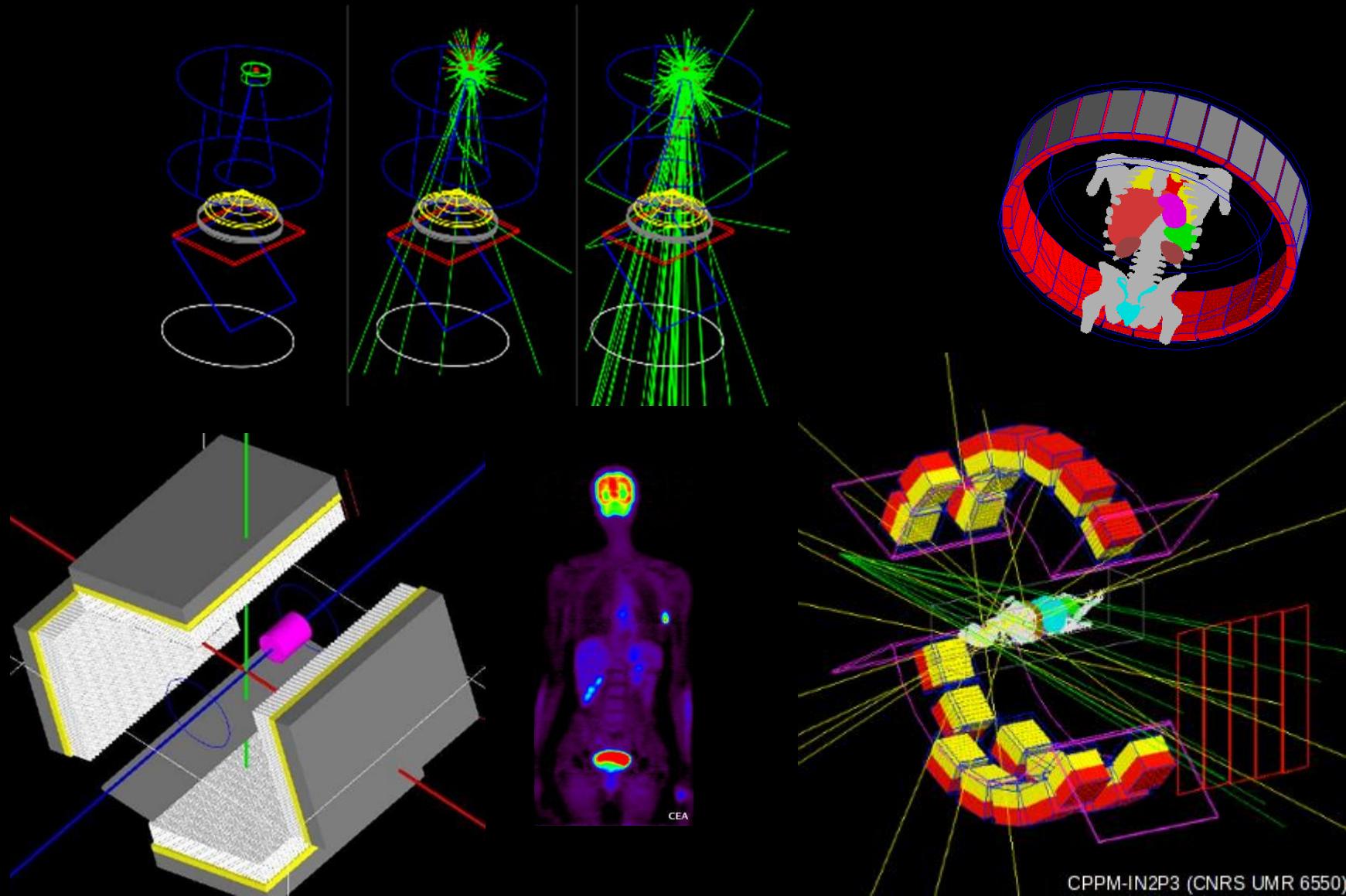
The screenshot shows a web browser displaying the GATE website at www.opengatecollaboration.org. The page features the GATE logo at the top center. Below the logo is a navigation bar with links for MAILING-LIST, DOWNLOAD, DOCUMENTATION, EVENTS, PUBLICATIONS, OPPORTUNITIES, COLLABORATION, and a search icon. The main content area contains a large image of a 3D simulation visualization. The visualization depicts a cylindrical object, likely a phantom, with various internal structures colored in green, red, and blue. Numerous thin lines, representing particle tracks or rays, originate from a central point and fan out towards the edges of the cylinder. A coordinate system is overlaid on the simulation, with axes labeled 'X 20 cm', 'Y 20 cm', and 'Z 80 cm'. To the left of the simulation, there is a white callout box containing the text: "GATE is an advanced opensource software developed by the international OpenGATE collaboration". At the bottom of the page, a footer text states: "GATE is an advanced opensource software developed by the international OpenGATE collaboration and dedicated to numerical simulations in medical imaging and radiotherapy. GATE is based on the Geant4 toolkit."

GATE

<http://www.opengatecollaboration.org/>

MEMPHYS 
Metrology for Medical Physics

NPL 
National Physical Laboratory



CPPM-IN2P3 (CNRS UMR 6550)

```
. └── AddExternalData.sh  
  └── CMakeLists.txt  
  └── example_ARF  
  └── example_CT  
  └── example_DNA  
  └── example_doseactor  
  └── example_dosimetry/  
      ├── brachytherapy  
      ├── electron_radiotherapy  
      ├── external-beam-therapy-photon  
      ├── molecular-therapy-I131  
      └── protontherapy  
  └── example_fluorescence  
  └── example_OPTICAL  
  └── example_PET  
  └── example_PHANTOM_SOURCE  
  └── example_PhysicsLists  
  └── example_Radiotherapy  
  └── example_ROOT_Analyse  
  └── example_SPECT  
  └── example_SPECT_GPU  
  └── example_TimeActivityCurve  
  └── example_TrackerDetector  
  └── example_UserFluenceSource  
  └── example_UserSpectrum  
  └── example_vpgtle  
  └── gpumacros
```

- ✓ Wide variety of examples
- ✓ Multiple modalities
- ✓ Doesn't require C++
- ✓ Large user base
- ✓ Actively developed
- ✓ Increasingly well referenced

- ✗ Still requires validation
- ✗ User developed data analysis tools
- ✗ Undocumented bugs

Monte Carlo Training

<http://www.opengatecollaboration.org/>



TRAININGS

The OpenGATE collaboration in partnership with CNRS Formation Entreprises are proposing two annual trainings organized in France: one dedicated to beginner users and one dedicated to Python data analysis. Those trainings are provided in english, they are open to 20 users maximum with 3 teachers.

Further, the collaboration can propose special trainings for companies (on site) wishing to use GATE, don't hesitate to [contact us](#) for more information.

2022:

-

8-10 March: Python data analysis for GATE simulations, [Registration open](#)

Summary

- Monte Carlo simulation can be a powerful tool for modelling imaging systems.
- There are a number of benefits to using MC:
 - Extra non-observable information
 - “Ground truth”
 - Optimisation of protocols
- Importance of validation – comparison to experimental data
- A number of packages available
(GATE is a good starting point for many modalities).

Validation of simulations

- Can you trust the results from a simulation?

- Yes - if the simulation has been validated

- ✓ Geometry
- ✓ Detector modelling
- ✓ Physics models (dependent on energy range)
- ✓ (Nuclear) Data

Comparison with experimental data

- What is Monte Carlo simulation?
- Why use it for medical imaging?
- Examples (demos)
- Validation of simulations
- Tools you can use
- Q & A

Getting Started with GATE



The screenshot shows a GitHub repository page. At the top, there's a navigation bar with links for Home, Sign up, and a menu icon. Below the bar, the repository name 'a-p-robinson / HSST-MonteCarlo-Lecture' is displayed, along with buttons for Notifications, Star (0), Fork (0), and a 'Code' button. A horizontal menu bar follows with links for Code, Issues, Pull requests, Actions, Projects, Security, and Insights. Under the 'Code' tab, a dropdown menu shows 'master'. Below this, a list of files and folders is shown, all added by 'a-p-robinson' 44 seconds ago. The list includes 'Lecture_Demos', 'Getting_Started_with_v...', 'Getting_Started_with_v...', 'HSST_MonteCarlo_Ch...', 'HSST_MonteCarlo_Ma...', and 'LICENSE'. To the right of the file list, there's an 'About' section with a note that 'No description, website, or topics provided.', an 'MIT License' link, and sections for 'Releases' (No releases published) and 'Packages' (No packages published). At the bottom, there's a 'Languages' section showing a chart where C is 59.9% and Shell is 40.1%. At the very bottom of the page, there are links for © 2021 GitHub, Inc., Terms, Privacy, Security, Status, Docs, Contact GitHub, Pricing, API, Training, Blog, and About.

<https://github.com/a-p-robinson/HSST-MonteCarlo-Lecture/>

<http://www.opengatecollaboration.org/>

<https://gate.uca.fr/download/vgate>

<https://www.virtualbox.org/>

