Geant4 Advanced Examples: Update

S. Guatelli and F. Romano

On behalf of the Geant4 Advanced Examples Working Group

28th Geant4 Collaboration Meeting, 25-29 September, Sapporo, Japan

2023 Census

Working Group

- 25 Geant4 Collaborators
- 9 contributors
- 2022 Census: 1.8 FTE
- 2023 Census: 2.1 FTE
  - To note: the census includes Geant4 Collaborators only

Members (Census 2023)

•Susanna Guatelli (University of Wollongong, Australia) **WG Coordinator**
•Francesco Romano (INFN-CT, Catania, Italy) **WG Deputy Coordinator**
•Abdella Ahmed (former ANSTO, Lucas Heights, NSW, Australia)
•Makoto Asai (SLAC, Stanford, US)
•Jeremy Brown (ANSTO, Lucas Heights, NSW, Australia)
•Barbara Caccia (ISS, Rome, Italy)
•Pablo Caron (ONERA, France)
•Pablo Cirrone (INFN-LNS, Catania, Italy)
•Miguel Cortes-Giraldo (Sevilla University, Sevilla, Spain)
•Gabriele Cosmo (CERN, Switzerland)
•Paolo Dondero (SWHARD, Genpova, Italy)
•Milos Dordevic (Vinca Institute of Nuclear Sciences, University of Belgrade, Serbia)
•Haegin Han (/ Hanyang University, Republic of Korea)
•Christophe Inguimbert (ONERA, France)
•Omrane Kadri (King Saud University, Saudi Arabia)
•Ara Knaian (NK Labs, LLC, US)
•Damien Lambert (CEA, France)
•Zhuxin Li (CENBG, France)
•Francesco Longo (INFN-Ts, Trieste, Italy)
•Giuliana Miluzzo (INFN Catania, Catania, Italy)
•Andrea Polsini (INFN, Ts, Trieste, Italy)
•Alfonso Mantero(SWHARD srl, Italy)
•Nate McFadden (NK Labs, LLC, US)
•Claire Michelet (CENBG/LP2I Bordeaux, France)
•Luciano Pandola (INFN-LNS, Catania, Italy)
•Giada Petringa (INFN-LNS, Catania, Italy)
•Ivan Petrovic (Vinca Institute, Belgrad, Serbia)
•Floriane Poignant (National Institute of Aerospace (NIA)/NASA Langley Research Center, USA)
•Alexandra Ristic-Fira (Vinca Institute, Belgrad, Serbia)
•Giorgio Russo (CNR-Lato, Cefalù, Italy)
•Mitra Safavi (ANSTO, Lucas Heights, NSW, Australia)
•Bernardo Tomè (LIP, Portugal)
•Hans-Joachim Wenzel (Fermilab, US)
•Anna Zaborowska (CERN, Geneva, Switzerland)

New examples released in Geant4 11.2beta

- Development of a specific advanced example for **proton tomography**
  - By C. Michelet and PhD student Z. Li, Bordeaux University, France
  - **`stim_pixe_tomography`**

- Development of two examples describing **ESA telescopes**
  - By P. Dondero, A. Mantero and R. Stanzani, SWHARD s.r.l., Genova, Italy
  - **`Xray_TESdetector`**
  - **`Xray_SiliconPoreOptics`**
  - see presentations by A. Mantero and R. Stanzani, in Parallel 2A

Example name	Responsible Geant4 Collaborator	Short description
air_shower	Bernardo Tomè	Modelling of the ULTRA experiment, EUSO mission
ams_Ecal	Michel Maire	Modelling of the electromagnetic Calorimeter (ECAL) of the AMS-02 experiment
brachytherapy	Susanna Guatelli	Calculation of dose in a phantom, in the context of brachytherapy
CaTS	Hans-Joachim Wenzel	Demonstration of the *G4Opticks* hybrid workflow for the creation and propagation of optical photons on GPU's
ChargeExchangeMC	Alexey Radkov	Simulation of hadronic physics experiments of the Petersburg Nuclear Physics Institute (PNPI, Russia)
composite_calorimeter	Alberto Ribon	Example of a test-beam simulation used by the CMS Collaboration, CERN, Geneva, Switzerland
doiPET	Susanna Guatelli	Modelling of a PET scintillator system
eFLASH_radiotherapy	Francesco Romano	Modelling of a FLASH radiotherapy beamline
eRosita	Francesco Longo	Modelling of eROSITA astronomical X-ray full-sky survey mission on-board the Spectrum-X-Gamma space mission
fastAerosol	Makoto Asai	Development of a custom geometry class for accurately and efficiently simulating aerosols with many droplets
gammaknife	Francesco Romano	Simulation of an advanced device for Stereotactic Radiosurgery
gammaray_telescope	Francesco Longo	Model of a typical telescope for gamma ray analysis in the context of space exploration
gorad	Makoto Asai	Turn-key application for radiation analysis and spacecraft design built on top of Geant4
hadrontherapy	Pablo Cirrone	Model of hadrontherapy beamlines
HGCal_testbeam	Anna Zaborowska	Demonstration of a high-end High Energy Physics test beam setup, for the endcap electromagnetic calorimeter of the CMS detector CERN-LHCC-2017-023
human_phantom	Susanna Guatelli	Calculation of dose in analytical anthropomorphic phantoms
ICRP110_HumanPhantoms	Susanna Guatelli	Calculation of dose in ICRP110 anthorpomorphic phantoms
ICRP145_HumanPhantoms	Susanna Guatelli	Calculation of dose in ICRP145 anthorpomorphic phantoms
iort_therapy	Francesco Romano	Model of a typical Intraoperative Radiation Therapy beamline
lAr_calorimeter	Andrea Dotti	Simulation of the Forward Liquid Argon Calorimeter (FCAL) of the ATLAS Detector, CERN, Switzerland
medical_linac	Pablo Cirrone	Model of a typical medical linear accelerator for Intensity Modulated Radiation Therapy (IMRT)
microbeam	Sebastien Incerti	Simulation of the microbeam cellular irradiation beam line installed on the AIFIRA electrostatic accelerator facility located at LP2i Bordeaux, France
microelectronics	Christophe Inguimbert, Damien Lambert, Mélanie Raine-Theillet	Demonstration on how to activate track structure physics models for electrons in a silicon microelectronics device
nanobeam	Sebastien Incerti	Simulation of the beam optics of the "nanobeam line" installed on the AIFIRA electrostatic accelerator facility located at LP2i Bordeaux, France
purging_magnet	John Apostolakis	Modelling of electrons traveling through a 3D magnetic field in the radiotherapy context
radioprotection	Susanna Guatelli and Francesco Romano	Modelling of detectors and their response for microdosimetry for radiation protection in space
STCyclotron	Susanna Guatelli	Model of the solid target of the South Australian Health and Medical Research Institute (SAHMRI), Adelaide, South Australia
stim_pixe_tomography	Claire Michelet	Simulation of three dimensional proton micro-tomography
underground_physics	Alex Howard	Example of an underground dark matter experiment. More details are provided in the README file accompanying the example
xray_fluorescence	Alfonso Mantero	Example reproducing various setups for PIXE and XRF experiments. More details are provided in the README file accompanying the example
xray_telescope	Giovanni Santin	Simulation of a typical X-ray telescope for space exploration
xray_TESdetector	Paolo Dondero	Application of Geant4 in a space environment. Model of an X-ray detector derived from the X-IFU, the X-ray spectrometer designed and developed by the European Space Agency (ESA) for use on the ATHENA telescope.
Xray_SiliconPoreOptics	Paolo Dondero	Model of a single reflective pore used to simulate on a smaller scale the effect of the millions of pores forming the mirror of the ATHENA Silicon Pore Optics (SPO).

https://www.geant4.org/docs/advanced_examples_doc/index

33 example:

Medical: 16, Space: 11, HEP: 4, Other: 2

Work Plan 2023

- Release of a new example showing how to import in Geant4 simulations IAEA Phase Space Files (2)[*] (M. Cortes Giraldo): in progress
- Development of an advanced example showing the use of MicroElec (C. Inguimbert): in progress
- Improve the Hadrontherapy advanced example in the simulations of proton, carbon ion and helium ion beam irradiation (P. Cirrone et al)
- Development of a SPring-8 synchrotron x-ray polarimetry example for testing low energy polarised gamma-ray physics (1,2) (J. Brown) : to be started
- Update and maintenance of the medical_linac (B. Caccia and C. Mancini): in progress. The MR needs to be submitted
- Further developments of in-silico experimental microdosimetry in the Radioprotection example (1,2) (F. Romano, G. Miluzzo): in progress
- Development of a mammography example (1,2) (O. Kadri): The code needs to be revised
- Implementation of preclinical, mice, PET images to evaluate a dose distribution for new drugs (1,2) (G. Russo): timeline to be defined
- Development of two examples describing ESA telescopes (1,2) (Paolo Dondero): Done
- Update the G4 Adv Ex. Webpage: on-going
- Maintenance and code review (e.g. implementation of the extended examples coding guidelines amd migration to C++17) in selected examples (1,2)
    - On going (S. Guatelli), done in fastAerosol. Next one: underground and iort_therapy
- ChargeExchangeMC, iort_therapy, medical linac to MT: done for medical linac (needs to be submitted to MR)

Webpage

- Now we have a WG webpage and an Adv Ex webpage in the documentation
  - https://www.geant4.org/docs/advanced_examples_doc/index
  - https://www.geant4.org/collaboration/working_groups/advExamples/

- Webpages to be added for: xray_fluorescence, ICRP145_HumanPhantoms, eFLASHRadiotherapy, underground

Bugzilla

Problem 2358 (new): STCyclotron

- Platform: PC Windows
- Assignee: S. Guatelli

```
During run the example, advanced/STCyclotron, I find G4GeneralParticleSource::GetParticleEnergy()
function can not get the primary particles' energy correctly when run in Windows OS. While in Linux OS,
G4GeneralParticleSource::GetParticleEnergy() function work well. I can't solve the bug.
```

- This should be the same problem of 2508 bug report: G4GeneralParticleSource::GetParticleEnergy() only return 1 on windows

Problem 2424

- G4Exception : Cache001, when running only a few primaries with multiple sources in GPS
- Gammaknife advanced example
- Assignee: F. Romano

(S. Guatelli not managed to reproduce the problem when Geant4 is compiled MT. After further investigation, it seems that the problem appears when Geant4 is compiled with MT OFF)

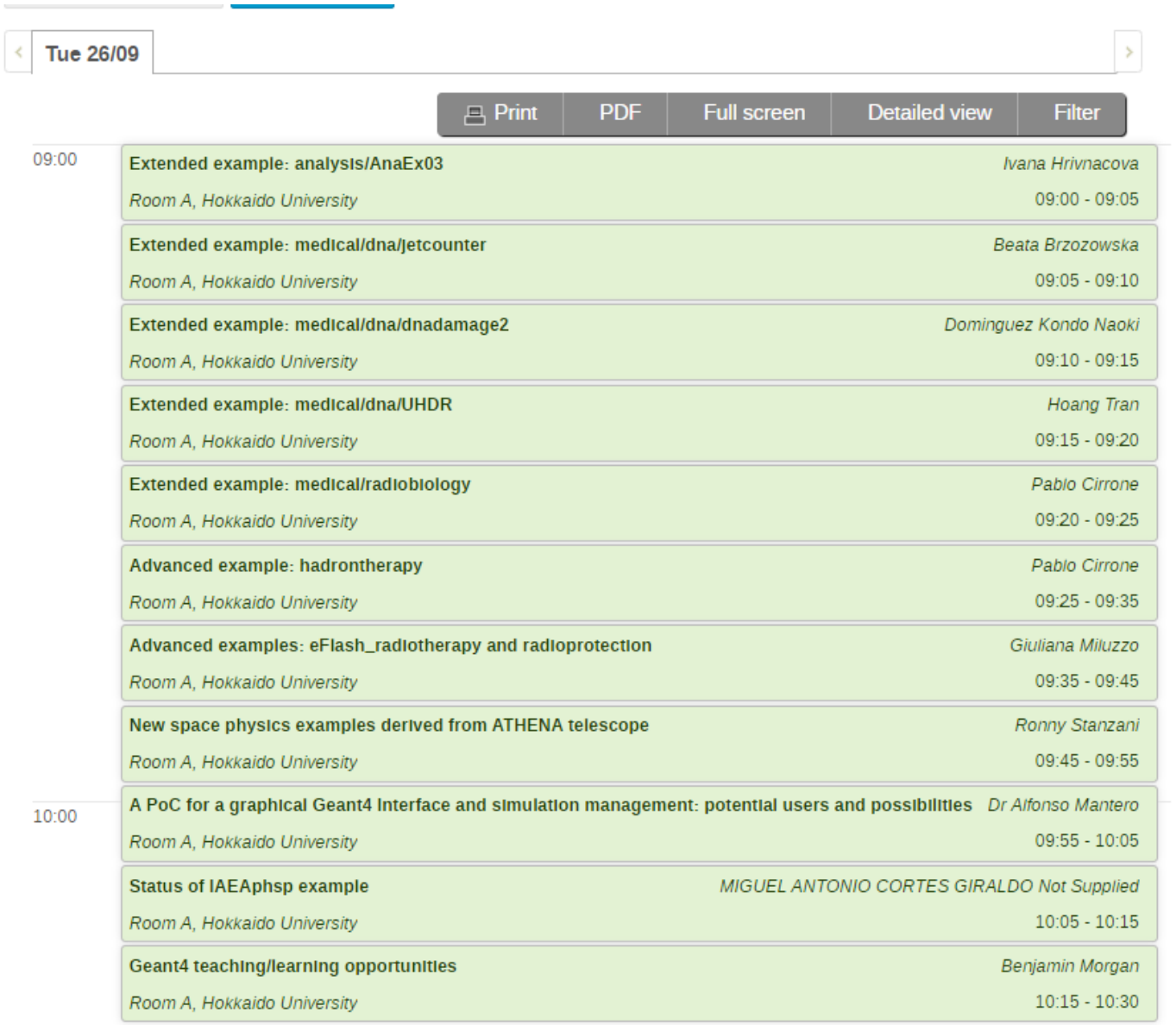
Problem 2548 - Microelectronics Example Crashing With Macro File. Solved by D. Lambert.

Problem 2338 and 2503 – underground, executable crashes when running included macros. Problem with the physics list and alpha particles. To be done (A. Howard and S. Guatelli)

Problem 2563- enabling and/or disabling certain physical processes makes the simulation stop after a few events in the purging_magnet. Solved by J. Apostolakis

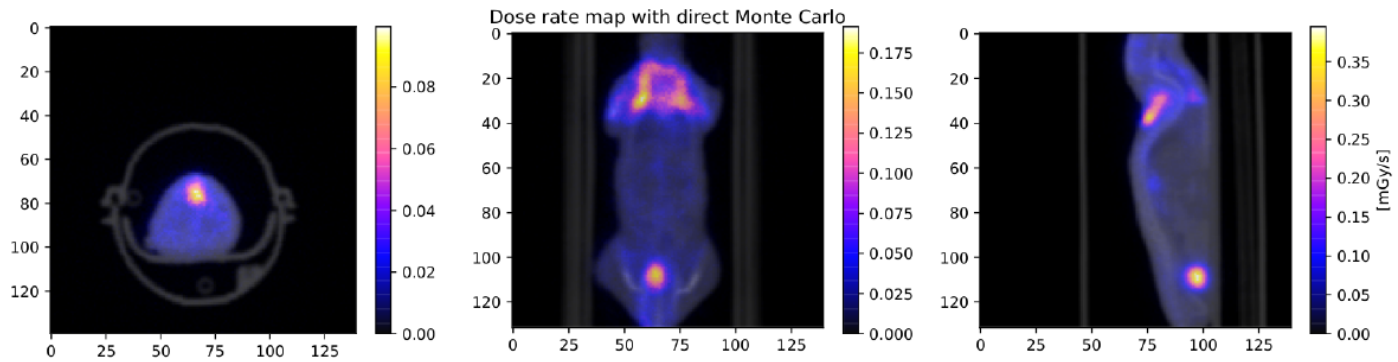
Some of the next developments

- Please, look at Parallel Session 2A
- Here I mention the contributions that have not been presented in the Parallel Session

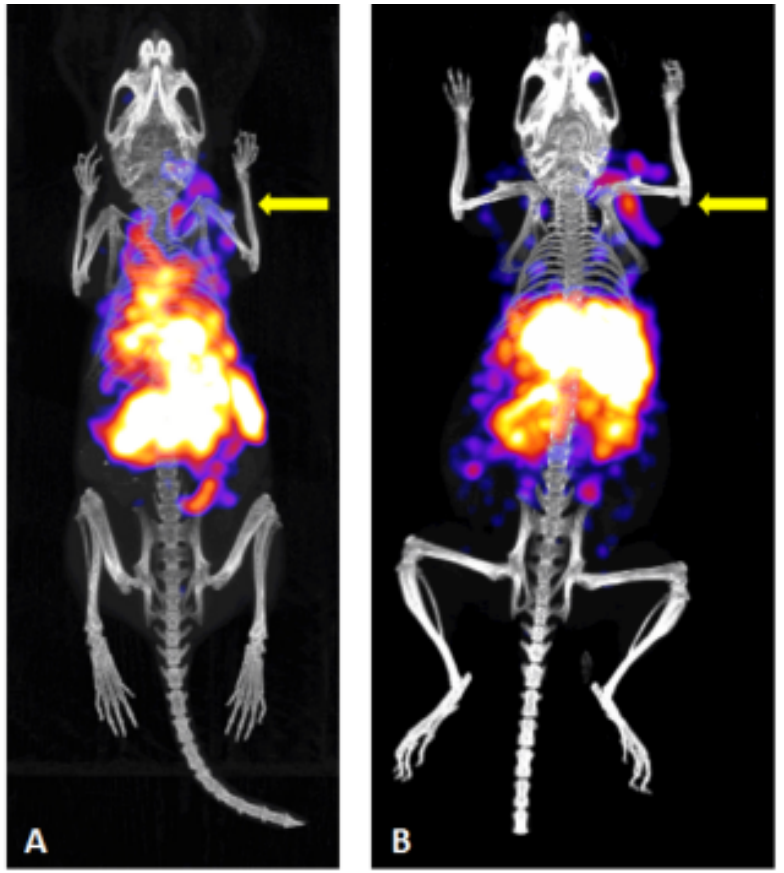


Example in nuclear medicine

- Proposed by G. Russo and collaborators
- Geant4 simulation developed in the context of the project ISOLPHARM (https://isolpharm.pd.infn.it/web/?page_id=967)
- ^{111}Ag-labeled β^--emitting drug is currently under study
  - Radiobiological study and
  - development of detectors for β^- and γ radiation (2023-2025).
- Geant4 simulation – some features:
  - Geometry of the rodent from the CT
  - The biodistribution of the drug is taken from the PET or SPECT 90
  - The radioisotope emission is modelled
  - The dose is calculated



Dose-rate map obtained from a PET/CT study using ^{18}F.



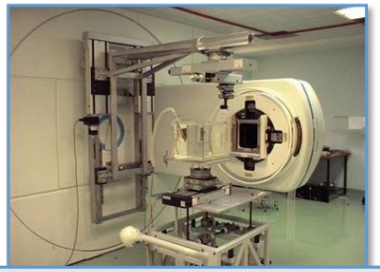
SPECT/CT study using ^{111}In.

From the talk of A. Arzenton et al, 2 March, 2023, Geant4 Advanced Examples WG meeting

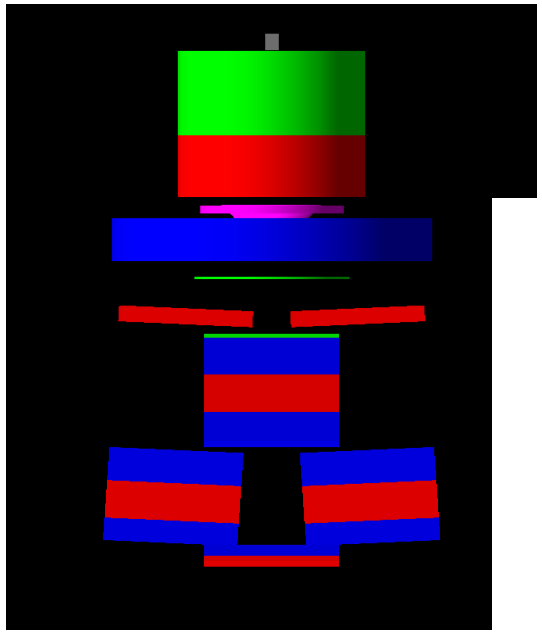
Update on the Advanced Example medical_linac

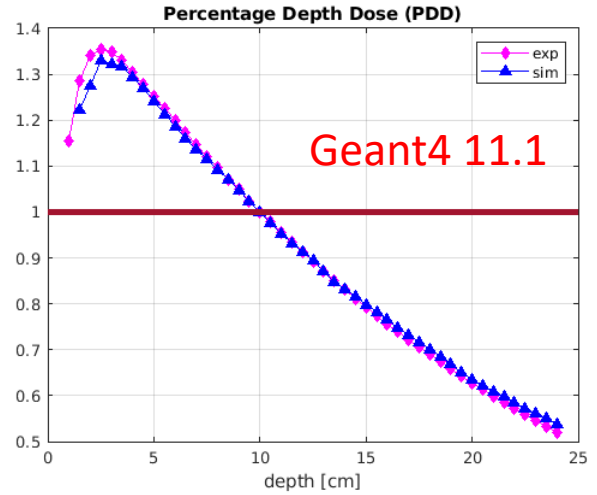
Barbara Caccia[1], Micol De Simoni[1], Carlo Mancini[2], Silvia Pozzi[1]

[1] Italian National Institute of Health (ISS) and INFN,
[2] Dept. Physics, La Sapienza (Rome, IT) and INFN



Saturne 43 LNHB linac
Exercise : photons mode, 12 MV





- Code review in **`medical_linac`**:

✓multi threading implemented

➢ongoing review of the example

➢ongoing the inclusion of experimental data documented in EURADOS Report 2020-05.

  - ➢ This simple Linac and the complete dataset of the dosimetric exp data can help users to develop the skills needed to build and calibrate a Monte Carlo simulation and perform a dosimetric analysis.

EURADOS

2020

EURADOS Report 2020-05

B. Caccia, V. Blideanu, M. Le Roy, H. Rabus, R. Tanner: **"A model validation scheme for Monte Carlo simulations of a medical linear accelerator: geometrical description and dosimetric data used in the "Linac Action"**, Neuherberg, October 2020.
View the report.

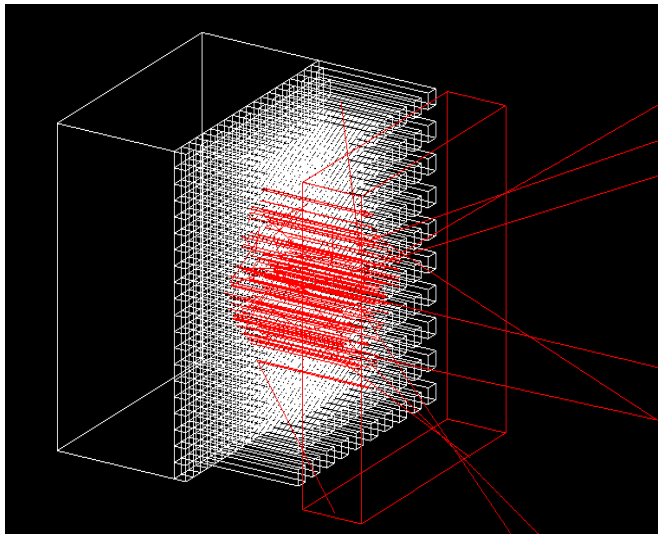
DOI: 10.12768/9rvp-fq82

https://eurados.sckcen.be/documents-publications/reports-documents#anchor-2020

Microelectronics example

C.Inguimbert, Q.Gibaru, P. Caron, D. Lambert,

- New version of microelec enables the calculation of low energy electrons in 17 materials with a track structure approach
  - Be, C, Al, Si, Ti, Fe, Ni, Cu, Ge, Ag, Au, W, Kapton, SiO2, Al2O3, TiN, BN
  - Under development



- The example will show how to use the track structure models to simulate radiation effects in microelectronics

That’s all, thank you