

Update on the Advanced Examples

27th Geant4 Collaboration Meeting
26th-30th September 2022, Rennes, France

S. Guatelli and F. Romano

On behalf of the Geant4 Advanced Examples Working Group

air_shower	B. Tomè	Detection system for cosmic ray shower simulation
ams_Ecal	M. Maire	Simulation of an Electromagnetic calorimeter
brachytherapy	S. Guatelli, D. Cutajar	Dosimetry for endocavitary, interstitial and superficial brachytherapy
CaTS	H.-J. Wenzel, K. Genser, S. Y. Jun	Shows the use of opticks from within Geant4 for the creation and propagation of optical photons
composite_calorimeter	A. Ribon	A composite electromagnetic and hadronic calorimeter
ChargeExchangeMC	A. Radkov	Simulation of charge exchange real experiment
doiPET	A. Ahmed , S. Guatelli , M. Safavi	Simulation of a detector system for PET
eRosita	F. Longo, A. Polsini	PIXE simulation with Geant4
fastAerosol	A. Knaian, N. MacFadden	Modelling of particle interactions with
gammaknife	F. Romano	A device for Stereotactic Radiosurgery with Co60 sources for treatment of cerebral diseases
gammaray_telescope	F.Longo	A simplified typical gamma-ray telescope with advanced description of the detector response
gorad	M. Asai	Model of a NASA space mission
hadrontherapy	G.A.P.Cirrone	Simulation of a transport beam line for proton and ion therapy
HGCal_testbeam	A. Zaborowska	High-end High Energy Physics test beam setup, for the endcap electromagnetic calorimeter of the CMS detector [CERN-LHCC-2017-023]
human_phantom	S. Guatelli	Dosimetry in analytical anthropomorphic phantoms
ICRP110_HumanPhantoms	S. Guatelli, M. Large, A. Malaroda, J. Allison	Dosimetry in ICRP110 Phantoms
ICRP145HumanPhantom	H. Han, J. Allison, S. Guatelli	Dosimetry in ICRP145 Phantoms
lort_therapy	G. Miluzzo, J. Pensavalle , F. Romano	Simulation of a IORT device
lAr_Calorimeter	A. Dotti	Simulation of the Forward Liquid Argon Calorimeter of the ATLAS Detector at LHC
medical_linac	B. Caccia, S. Pozzi, C. Mancini, G.A.P. Cirrone	A typical LINAC accelerator for IMRT,
microbeam	S. Incerti	Simulation of a cellular irradiation microbeam line using a high resolution cellular phantom
microelectronics	M. Raine	Simulation of tracks of few MeV protons in silicon
nanobeam	S. Incerti	Simulation of a nanobeam line facility
purging_magnet	J. Apostolakis	Electrons travelling through the magnetic field of a purging magnet in a radiotherapy treatment head
radioprotection	D. Bolst, S. Guatelli, J. Magini, G. Miluzzo, F. Romano	Microdosimetry with diamonds and silicum detectors for radioprotection in space missions
STCyclotron	F. Poignant, S. Guatelli	Modelling the production of radio-isotopes
underground_physics	A. Howard	A simplified typical dark matter detector (such as the Boulby Mine experiment)
xray_fluorescence	A. Mantero	Elemental composition of material samples through X-ray fluorescence spectra
xray_telescope	G. Santin	A simplified typical X-ray telescope (such as XMM-Newton or Chandra)

New Advanced example: ICRP145Phantom

- ICRP Publication 145 on Adult Mesh-type Reference Computational Phantoms
 - Ann ICRP . 2020 Oct;49(3):13-201. doi: 10.1177/0146645319893605.
- Use of the General Particle Source
- Calculation of the **dose in the organs of the phantoms**
- To be released in Geant4 v.11.01, with the permission of the ICRP, in agreement with the original developers of the models/Geant4 simulation (available on the web):
 - **Principal developer:** Haeginh Han / Hanyang University, Republic of Korea
 - Min Cheol Han / Yonsei University Health System, Republic of Korea
 - Banho Shin / Hanyang University, Republic of Korea
 - Chansoo Choi / University of Florida, USA
 - Yeon Soo Yeom / Yonsei University, Republic of Korea
 - Jonghwi Jeong / National Cancer Center, Republic of Korea
 - Chan Hyeong Kim / Hanyang University, Republic of Korea
- **Code review done**



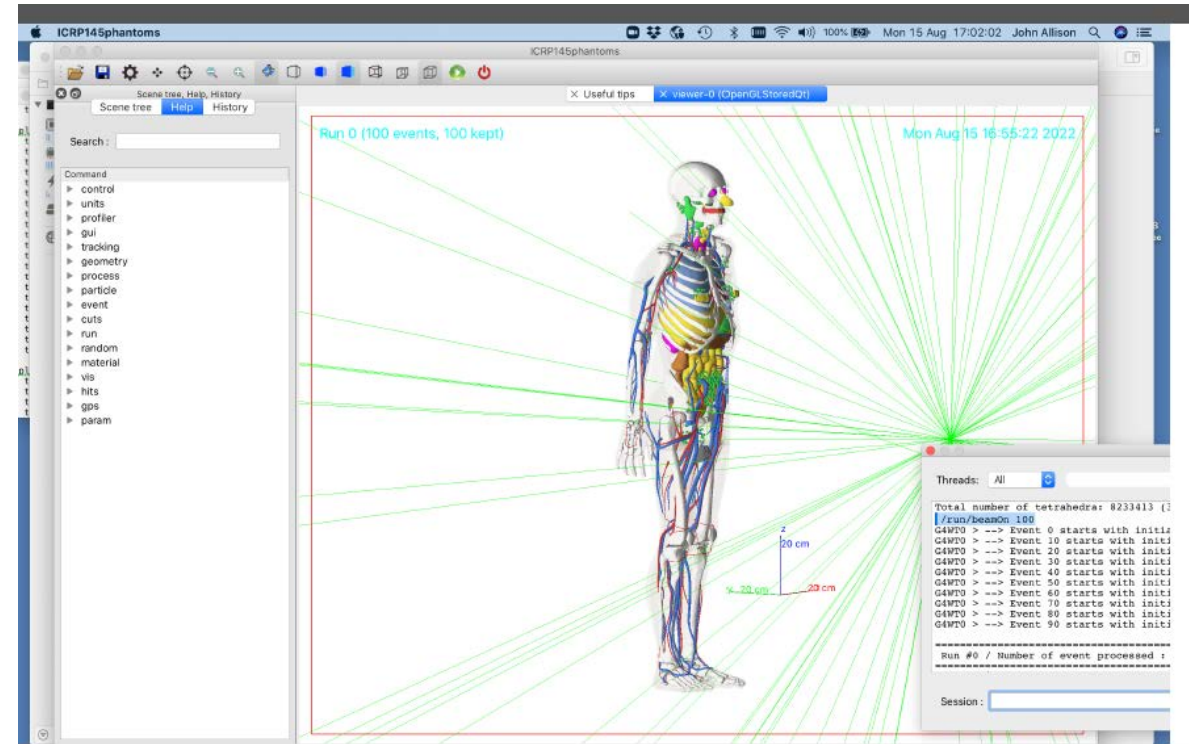
Fast drawing in the ICRP Human Phantoms examples series

- Modified to take advantage of developments in **graphics_reps** (Evgueni Tcherniaev) and in **visualization** (John Allison)
 - “Special Mesh Rendering”: presented in the vis session by J. Allison and E. Tchaerniev
- The human phantom and beam trajectories can be visualised in a performant way
- Total number of tetrahedra: **8,233,413** (32,933,652 faces) are reduced to **4,807,770** facets (14%) for visualisation (tracking is not affected):

[/vis/viewer/set/specialMeshRendering](#)

[/vis/viewer/set/specialMeshRenderingOption surfaces](#)

[/vis/drawVolume](#)



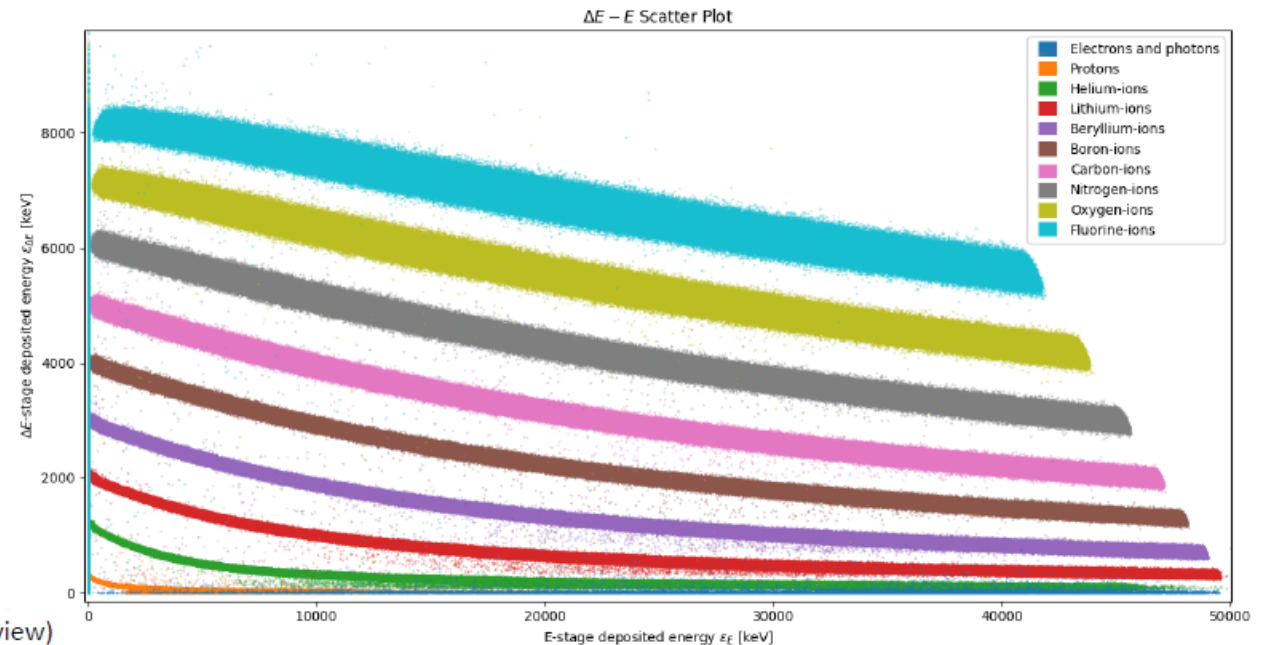
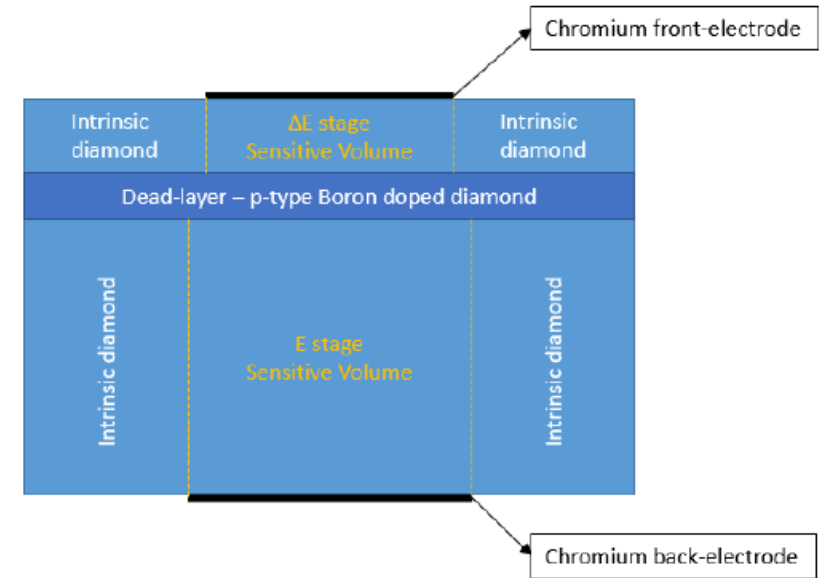
*Slide from the talk by J. Allison
in parallel session 3A*

Radioprotection advanced example

- Example that shows how to use Geant4 for characterisation of solid state detectors for space radiation protection
 - microdosimetry
- Collaboration between:
 - Jacopo Magini, G. Parisi, and Giuseppe Schettino (University of Surrey),
 - Francesco Romano (INFN)
 - Susanna Guatelli, David Bolst (Centre For Medical and Radiation Physics, University of Wollongong)
- Talk in the parallel session 3A
- **New developments for 2023**
 - Extend the applicability of the example to the development of detectors for particle therapy Quality Assurance
 - Improvement of UI commands to allow to non C++ experts to customise the simulation
 - E.g. detector design

New detector: two-stage Diamond

- ΔE stage acts as a microdosimeter, E scores the total energy
 - allows to discriminate different hadrons in a $\Delta E - E$ plot
- Scoring modified accordingly
 - each event is labelled according to the stage in which it's scored



Pictures by Gabriele Parisi from <http://dx.doi.org/10.2139/ssrn.4203262> (under review)

New example in the pipeline

Proton imaging on biological micro-organism like *Caenorhabditis elegans* (*C. elegans*)

By Z. Li, C. Michelet and S. Incerti

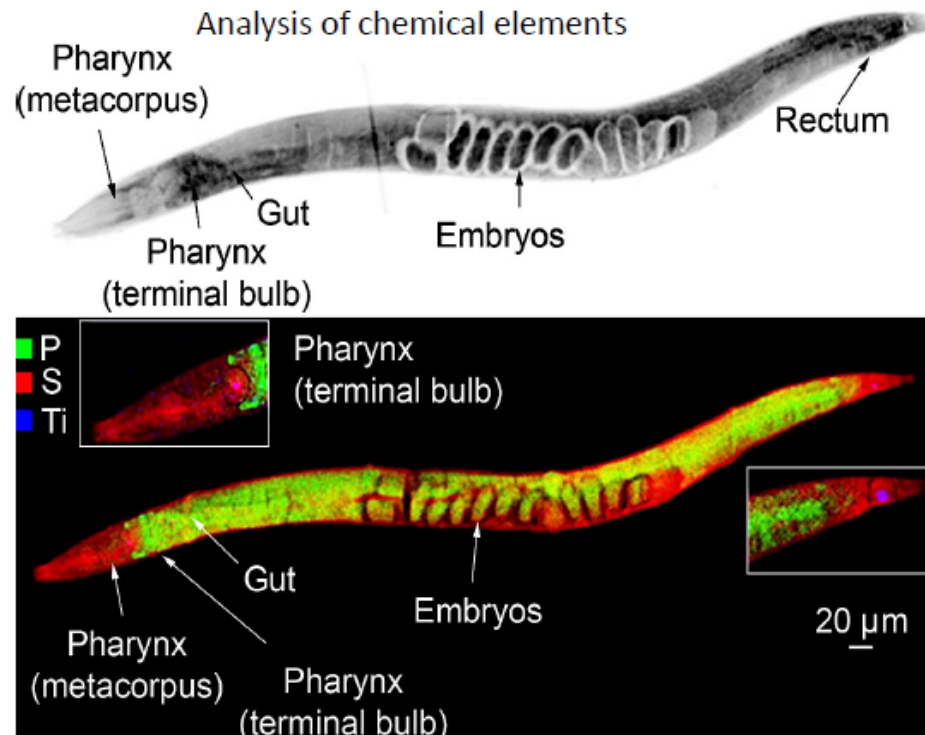
*Slide from the talk by
Z. Li in parallel session
3A*

Objective:

Understand the biological effects of contaminants, such as TiO₂ nanoparticles, widely used in cosmetics, the food industry, paints, etc.

Methods:

STIM and PIXE tomography experiments
Analysis of chemical elements



Non-destructive techniques, do not require marking, coloring...

- Spatial resolution ~300 nanometers in vacuum
- Detection limit ~1 ppm

STIM-T: Scanning Transmission Ion Microscopy tomography

Measurement of the residual energy of the protons after passing through the sample

→ Material thickness (g/cm²)

→ Visualization of the internal structure

Density Contrast Imaging ≈ Proton “Radiography”

PIXE-T: Particle Induced X-ray Emission tomography

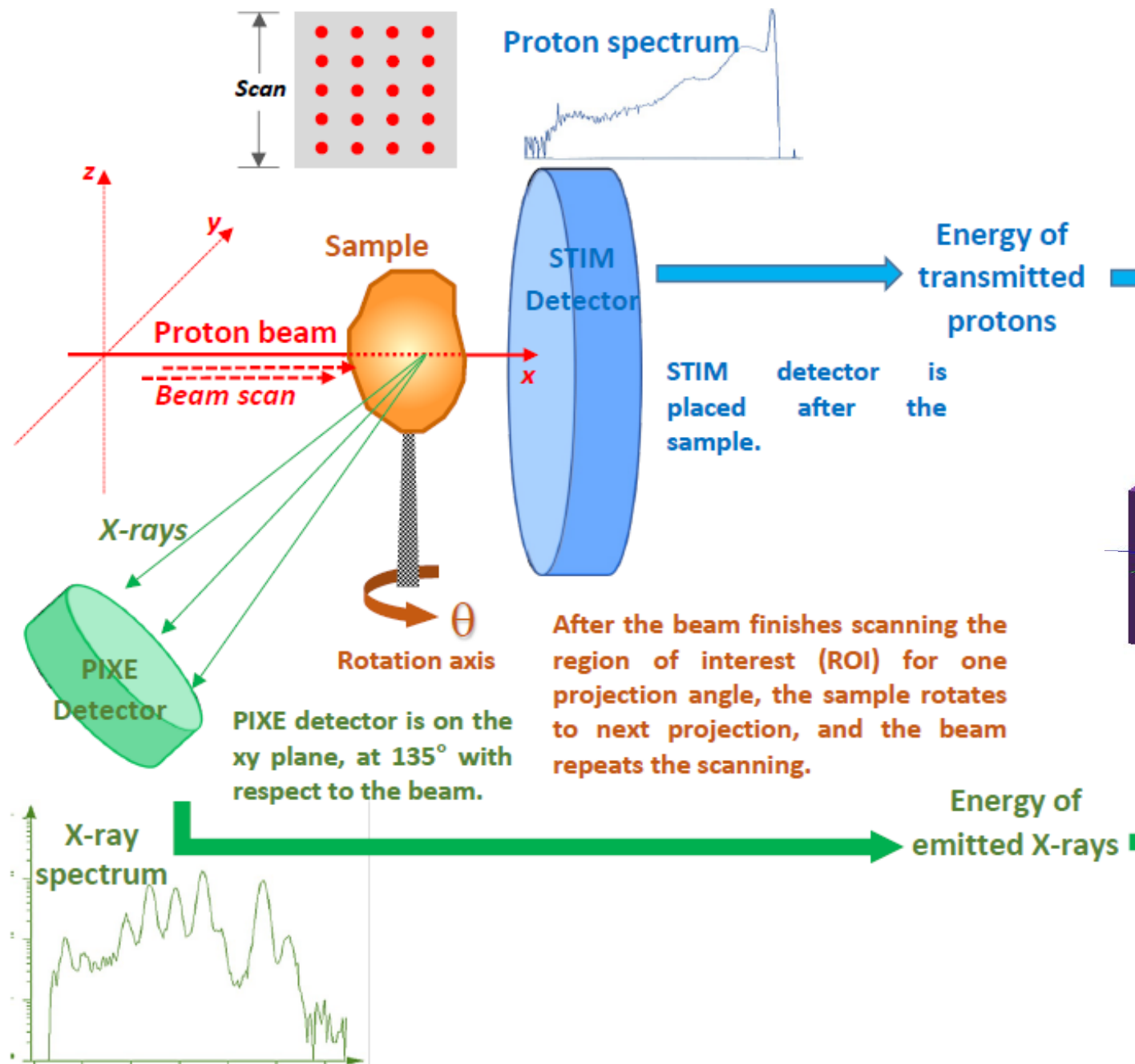
Measurement of the energy of emitted X-rays

→ Location of chemical elements

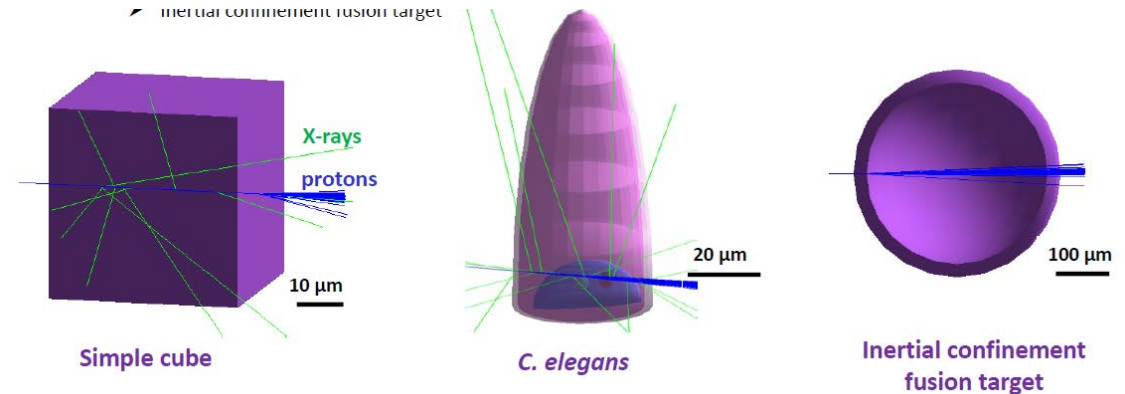
→ Quantification

Minerals, trace metals, exogenous elements (here the nanoparticles of TiO₂)...

An advanced example for 3D imaging of microscopic samples by proton tomography



Available sample geometries



Other items of the Work Plan 2022

- Release of a new example showing how to import in Geant4 simulations IAEA Phase Space Files (2)[*] (M. Cortes Giraldo): [postponed to next year](#)
- Development of a SPring-8 synchrotron x-ray polarimetry example for testing low energy polarised gamma-ray physics (1,2) (J. Brown): [postponed to next year](#)
- Microelec advanced example: [to include new Geant4-DNA cross sections for solid state materials beyond silicon \(see talk in 5A by C. Inguibert\)](#)
- Measurements and statistical analysis of size, McCabe, Halstead, Chidamber and Kemerer software metrics over at least 50% of the advanced examples; explication of the results in relation to ISO/IEC 9126 and ISO/IEC 25000 (1,2) (M. G. Pia): [In progress](#)
- Migration and improvement of the webpage (1,2) (S. Guatelli) - [Done. Webpage migrated and information has been updated](#)
- Maintenance and code review in selected examples (1,2)
 - [Technical meeting done with Ben; migration to C++11/14/17 done in brachytherapy, eRosita, human_phantom, ICRP110Phantom, ICRP145Phantom](#)
 - [In-depth code review in the human_phantom](#)
 - [Make sure that all the examples use pre-built physics lists \(where appropriate\)](#)

Other developments: to be done in 2023

- Code review in `iort_therapy`
 - Adaptation to FLASH electron radiotherapy
 - By G. Miluzzo, J. Pensavalle & F. Roman
- Code review in `medical_linac`:
 - Revision of the example
 - Inclusion of comparison to experimental data documented in EURADOS Report 2020-05
 - By B. Caccia, S. Pozzi, C. Mancini, et al
- Other matters
 - Give appropriate acknowledgment to external contributors to the Geant4 Collaboration
 - Delicate matter, especially for students
 - So far, we acknowledge the contribution in the README file and in the webpage
 - Can we do more?
 - E.g. certificate of contribution?
 - Other ideas?