2019 Geant4 Collaboration Meeting, Jefferson Lab, US, 23rd-27th September 2019

Geant4 Advanced Examples: progress

S. Guatelli and F. Romano

On behalf of the Geant4 Advanced Examples WG

Snapshot

- Members (census 2019): 13 Geant4 Collaborators + 3 external contributors
- 22 Advanced Examples
  - Medical physics: 11
  - Space science: 6
  - HEP: 4
  - Other: 1

https://geant4.web.cern.ch/collaboration/working_groups/advanced_examples

Plan for 2019: progress (1)

- **Maintenance and bug fixes (1,2)**
  - Ongoing
- **Code review (e.g. implementation of the extended examples coding guidelines) in selected examples (1,2)**
  - Ongoing
  - `iort_therapy` and `medical_linac` updated in terms of scoring, general code review
  - Started in `the x-ray fluorescence` example
- **Developments of alternative approaches for LET calculation in hadrontherapy (1, 2) [*]**

Plan for 2019: progress (2)

- **Assessment of the advanced examples in terms of accuracy of the photoelectric effect cross sections and analysis of software quality metrics (1, 2)**
  - By Maria Grazia Pia
  - Goal: quantify the accuracy of the advanced examples in terms of photoelectric effect cross sections (To be started in November 2019)
- **Migration of the air_shower advanced example to MT (1,2)**
  - By B. Tome'
  - Target: next public release
- **Release of a new example for nanomedicine (gold nanoparticles in X-ray radiotherapy) (2)[*]**
  - to be postponed to next year

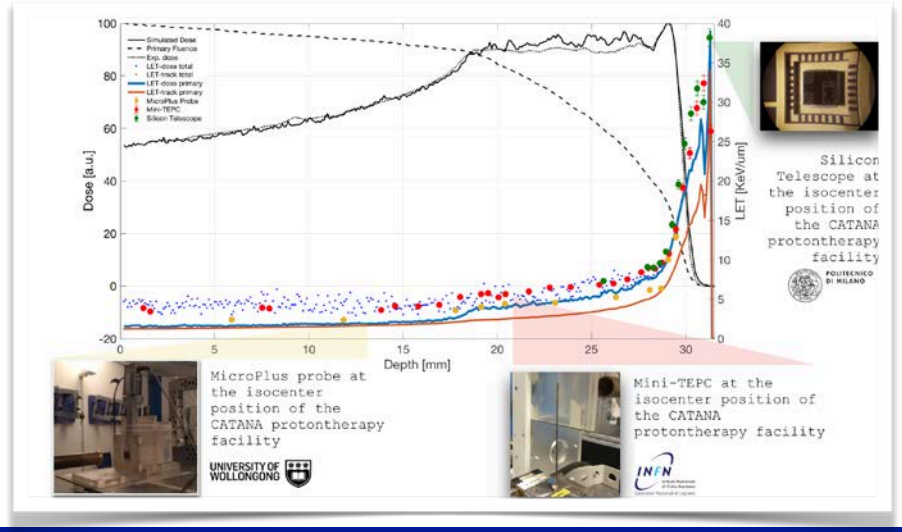
Hadrontherapy

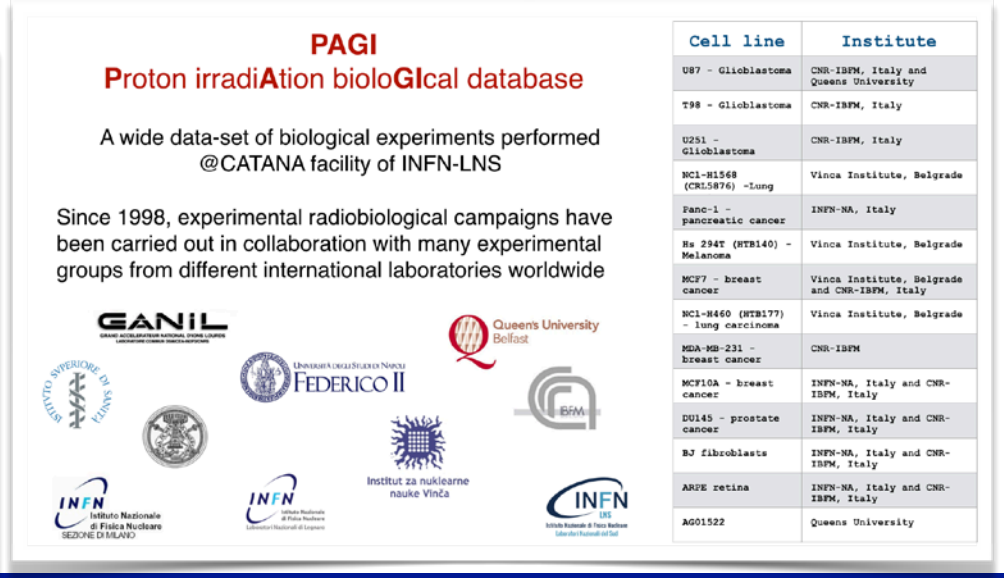
Developments of alternative approaches for LET calculation in hadrontherapy (1, 2) [*]

Calculation of radiobiological quantities:

- Linear Energy Transfer
- Dose
- Relative Biological Effectiveness

Validation work

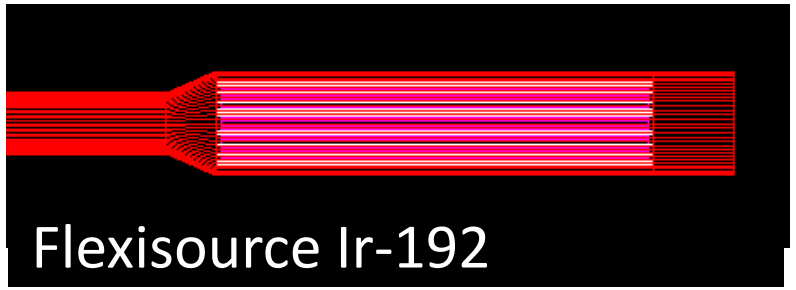


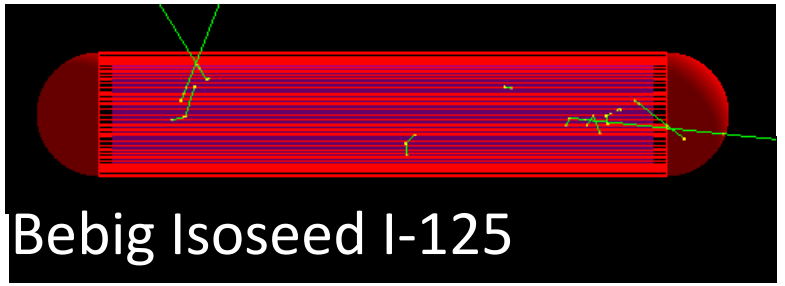


In addition

Advanced Example: Brachytherapy

- **Current authors: S. Guatelli, D. Cutajar, A. Le (CMRP, UOW)**
- Calculation of the energy deposition in a water phantom of:
  - Bebig Isoseed I-125, Oncura 6711 (new in Geant4 10.5)
  - Flexisource Ir-192 (Med. Phys 33(12), 2006, 4578-4582)
  - Ir-192 TG186 reference source (Med. Phys. 42 (2015), 3048-3062.
  - Leipzig applicator
- It shows how to define a radioactive source
  - With the definition of the emitted particles from the radionuclide
  - Or with the Radioactive Decay module
- Calculate the energy deposition/dose in a water phantom (scoring mesh)






D. Cutajar


S. Guatelli


A. Le

CENTRE FOR MEDICAL RADIATION PHYSICS

UNIVERSITY OF WOLLONGONG AUSTRALIA

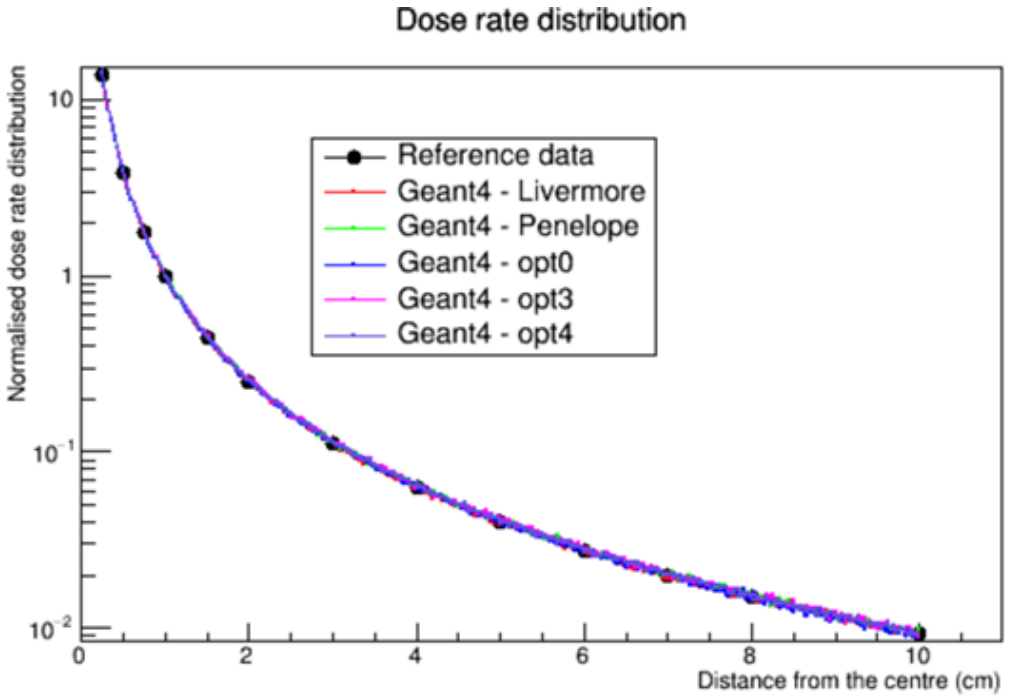
Comparison to reference data

Part of the Geant4 Medical Physics Benchmarking

Since Geant4 10.3, it is possible to calculate the g(r) and compare it directly to reference data

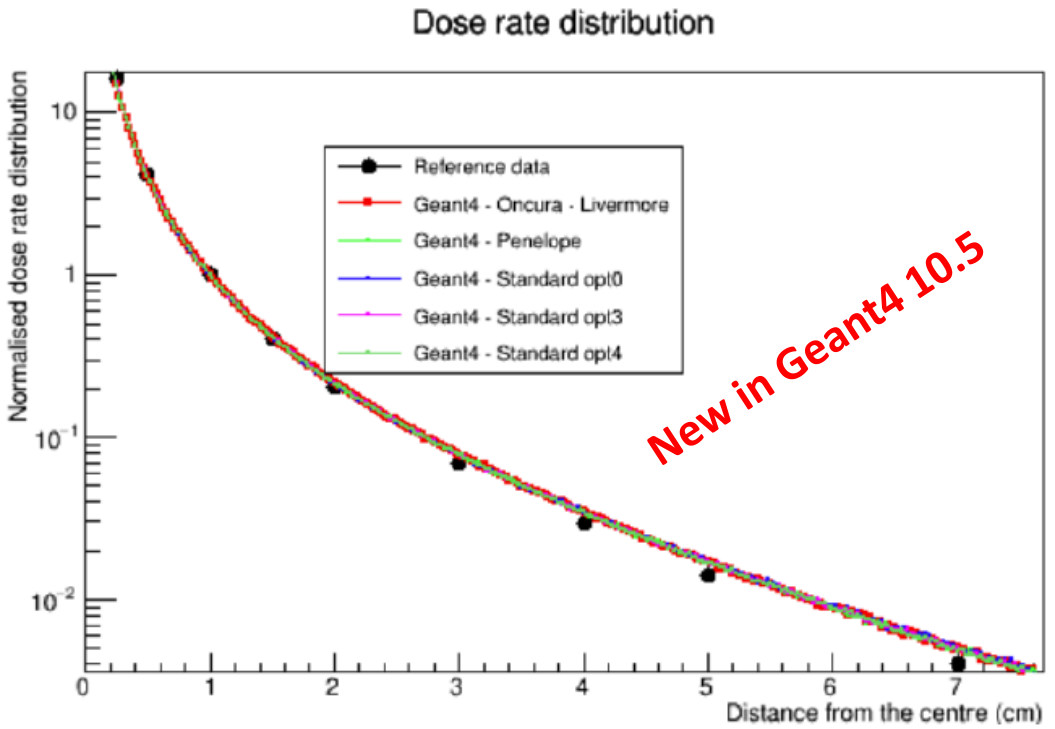
$$g(r) = \frac{\dot{D}(r,\theta_0)G(r_0,\theta_0)}{\dot{D}(r_0,\theta_0)G(r,\theta_0)}$$

Flexi source (HDR)



Reference data: Granero et al, Med. Phys 33(12), 2006, 4578-4582

Oncura 6711 source (LDR)



Reference data: Dolan et al, Med. Phys. 33(12), 2006.

New advanced example: doiPET 10.5

- Nuclear medicine/PET
- Currently under integration in Geant4
- Authors:
  - M. Safavi & A. Ahmed, Australian Nuclear Science Technology and Organisation
  - A. Chacon and S. Guatelli, University of Wollongong

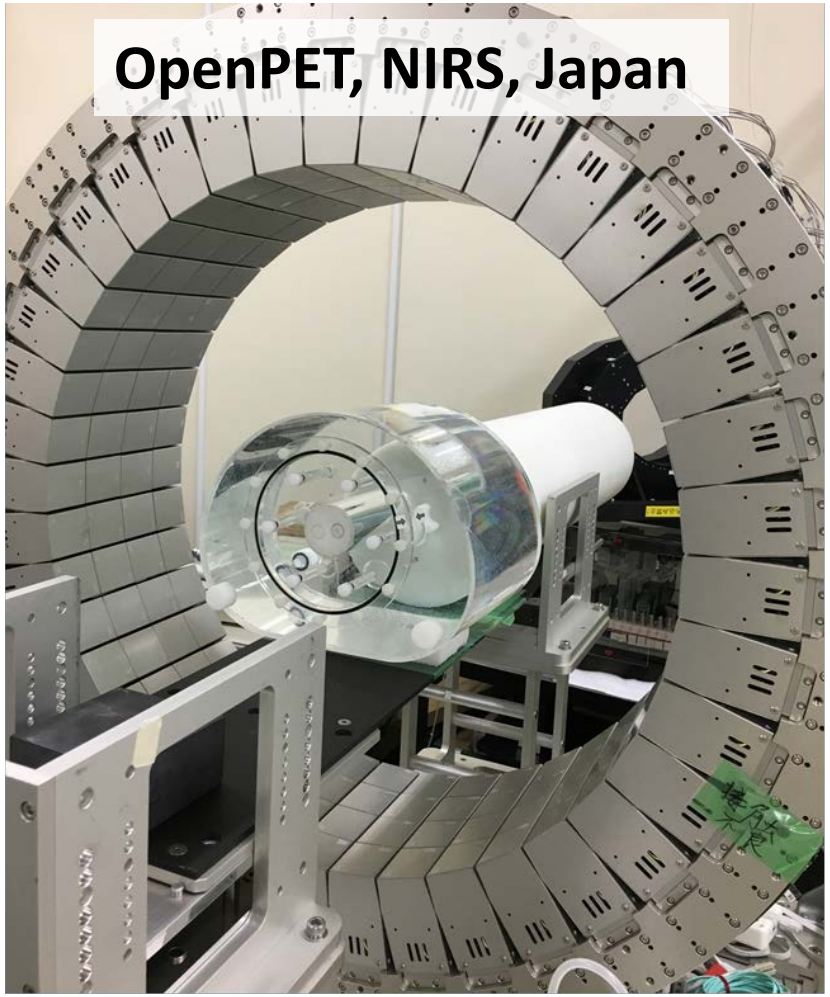


Fig. DOI-enabled whole-body PET scanner (image from Taiga-lab, NIRS, Japan)


A. Ahmed


A. Chacon


S. Guatelli


M. Safavi

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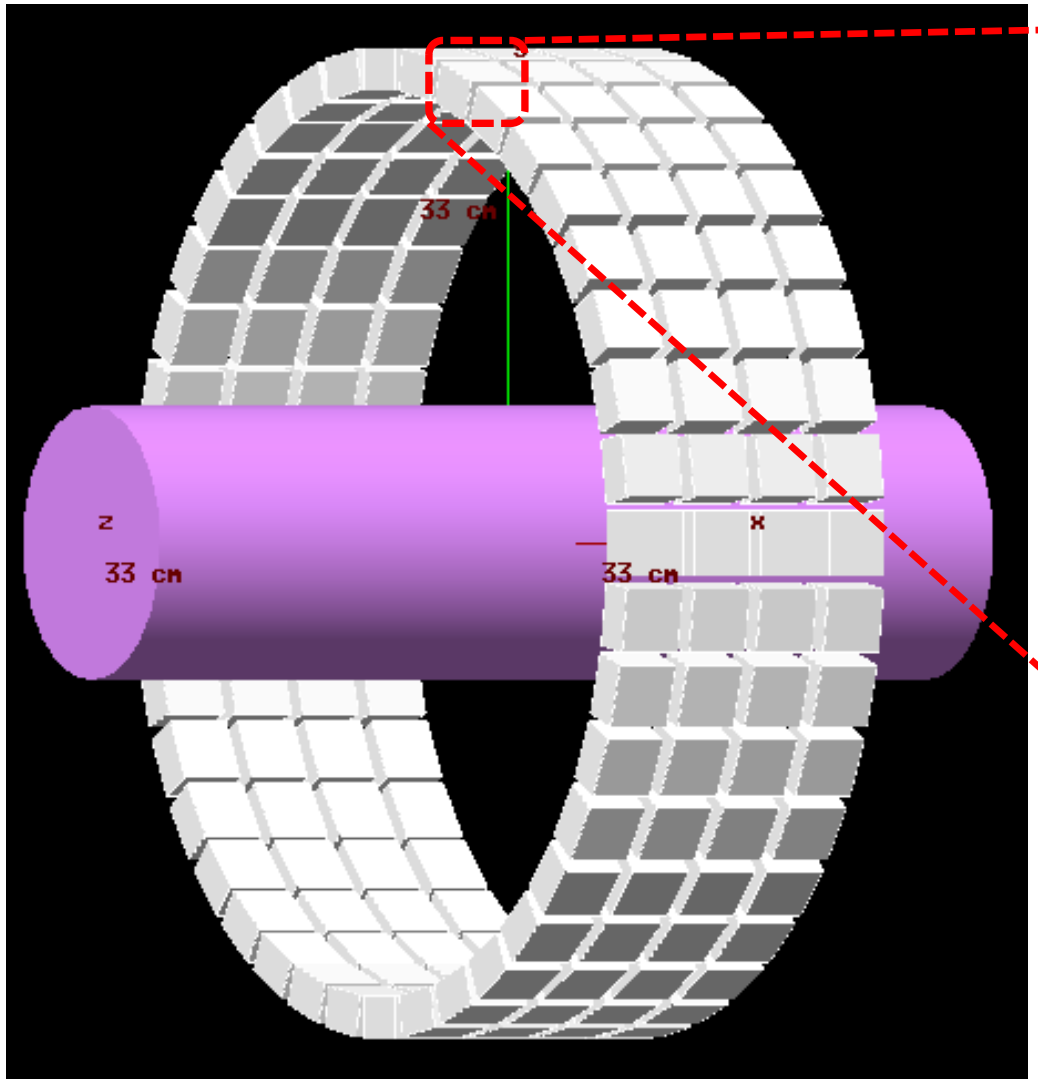
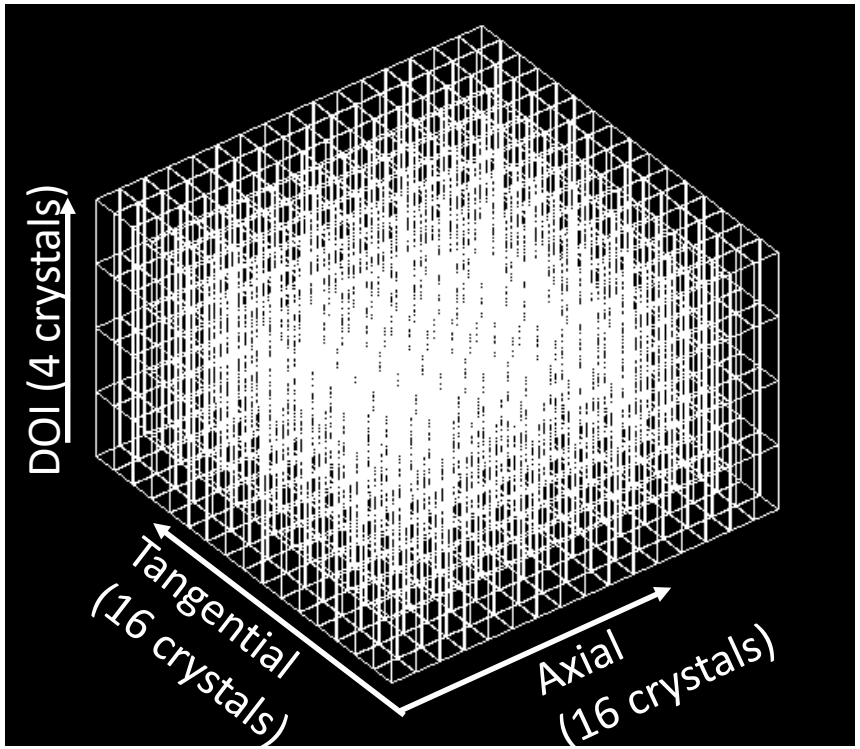
Simulated geometry of the DOI-enabled whole body PET scanner

Each detector has 16x16x4 (1024) crystals





Output of the simulation

List-mode data are obtained from the simulation either in singles or coincidence.

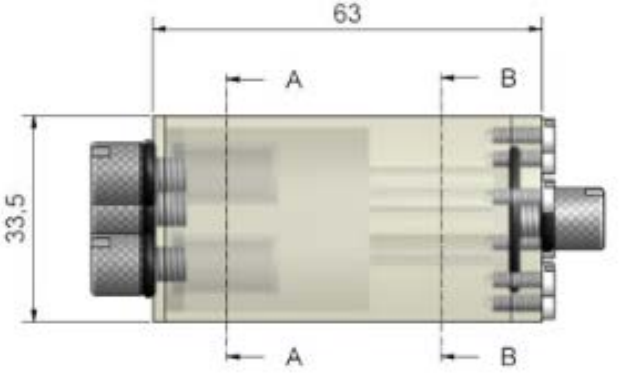


Fig. 1. Image quality phantom for small animal

(a) Singles event (that can be further processed into coincidence events)

Example of event information in the list-mode data:

eventID blockID axialCrystalID tangentialCrystalID DOICrystalID timerTag EnergyDeposition

(b) Coincidence event

Example of event information in the list-mode data:

eventID1 blockID1 axialCrystalID1 tangentialCrystalID1 DOICrystalID1 timerTag1 EnergyDeposition1

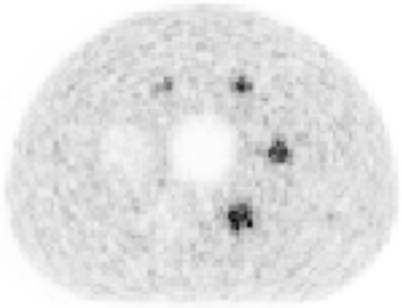
eventID1 blockID2 axialCrystalID2 tangentialCrystalID2 DOICrystalID2 timerTag2 EnergyDeposition2

Annihilation photon 1

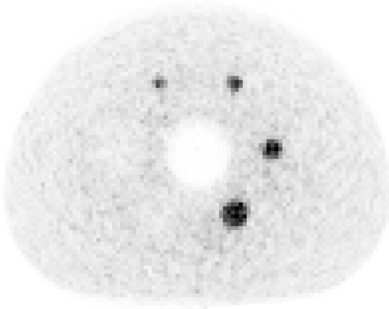
Annihilation photon 2

Conditions of the acquisition and image reconstruction	
Type of acquisition	Single based
Coincidence time window	20 ns
Energy window	400 – 600 keV
Reconstruction algorithm	List-mode OSEM
Voxel number and size	125x125x150, 3.0 x3.0 x3.0 mm^3

(a) Experimental



(b) Simulation



Revision process of the examples

Year of last developments by the main developer (svn log, Geant4 10.4.ref08)

	2004	2011	2014	2016	2017	2018
# Adv. Ex.	1	1	5	2	1	9

- Proposed in March 2019 and still under discussion (but initial positive feedback)
- It is important that the main developer takes care of the further refinement/maintenance of his/her example
  - To keep the example **updated and of interest for the scientific community**
  - If an example is not further developed/maintained by the main developer for more **than 8 years (svn, git activity, History file)**, it goes through revision
- The revision would consist in contacting the main developer and ask
  - If the example is still of current interest for the scientific community. Do we continue to maintain the example?
  - Plan on eventual revision/upgrades to keep the example of interest for the scientific community
  - Availability to still maintain the example
    - If not available, eventually identify a new main developer
  - In 2020 revision of the purging_magnet and eRosita

Conclusions

- Maintenance and code reviews are on-going
- New example: doiPET
- A revision process has been proposed to keep the examples updated.
- Presentations in workshops and conferences
  - Oral presentation: S. Guatelli et al, “Status of Geant4 Advanced Examples for medical applications”, at the Third Geant4 International User Conference at the Physics-Medicine-Biology frontier, October 29-31, 2018, Bordeaux, France
  - Poster presentation at the 2019 MCMA, Montreal, Canada. Authors: A. M. Ahmed, B. Caccia, A. Chacon, G.A. P. Cirrone, D. Cutajar, J. Davis, S. Guatelli, S. Incerti, I. Kyriakou, A. Le, L. Pandola, G. Petringa, J. Pipek, P. Pisciotta, S. Pozzi, F. Romano, G. Russo, M. Safavi. Title: Status of the GEANT4 Advanced Examples for medical physics applications