Open and new requirements: medical and bio science

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Open requirements

- Extend the Geant4-DNA physics models for ions below 1 MeV/u for Boron Neutron Capture.
  - Warming up stage, by Jose` Ramos Mendez and collaborators, UCSF, US
- Extend energy and material coverage of G4-DNA beyond DNA and liquid water.
  - **DNA bases**: under development by Sara Zein (CENBG, France), Marie Claude Bordage (INSERM and Paul Sabatier University, France) and Sebastien Incerti (CENBG, France)
  - **Gold**: to be released in Geant4 by D. Sakata, D. Bolst and S. Guatelli in 2021
- Develop proton transport models for Geant4-DNA above 100 MeV. The need is the coverage of the entire range of interest in proton therapy (250-300 MeV).
  - Carried out by Damián Domínguez-Muñoz, PhD student @ Sevilla U., supervised by Miguel Cortes-Giraldo, (and did last year an internship with Marie-Claude Bordage).
- Make EPICS2017 models available in Geant4 (electrons, photons) as an alternative to Livermore.
  - Zhuxin Li (PhD student), Claire Michelet and Sebastien Incerti (CENBG, France).
  - Talk in the Geant4 EM parallel session (Friday the 18th September)

New Requirements

Physics

1.1 To extend the low-energy hadronic processes for the ParticleHP below 1 MeV at least for $^{11}B(p,\alpha)2\alpha$ reaction channel

- Currently the total cross section is available down to 1 MeV
- Data available in EXFOR
- Other channels for p-^{11}B and p-^{10}B could also be taken into account

- This requirement is important for the use of Geant4 in enhanced hadrontherapy by means of B drugs

Source: P. Cirrone, LNS, Italy

Physics

1.2 Photo-nuclear processes with photon energies below 20 MeV may be improved

- E.g. ^{9}Be at around 20 MeV
- G4LEND provides better agreement
- Source: Nicolas Arbor, Université de Strasbourg

Physics for PET studies

1.3 Model positronium creation and annihilation

- In more than 40% cases, the e^--e^+ annihilation proceeds in the tissue via creation of positronium
- O-Ps (triplet spin state) is formed with a probability of 25%, it decays via either 2γ (pick-off) or 3 γ annihilations.
- In Phys. Med. Biol. 64 (2019) 055017
  - lifetime of a given o-Ps atom generated with the exponential probability density distribution
  - the momentum vectors of photons from the o-Ps → 3γ decay generated according to the predictions of the quantum electrodynamics
- 3-γ annihilation is available in *G4EmStandardPhysicsWVI* Physics List

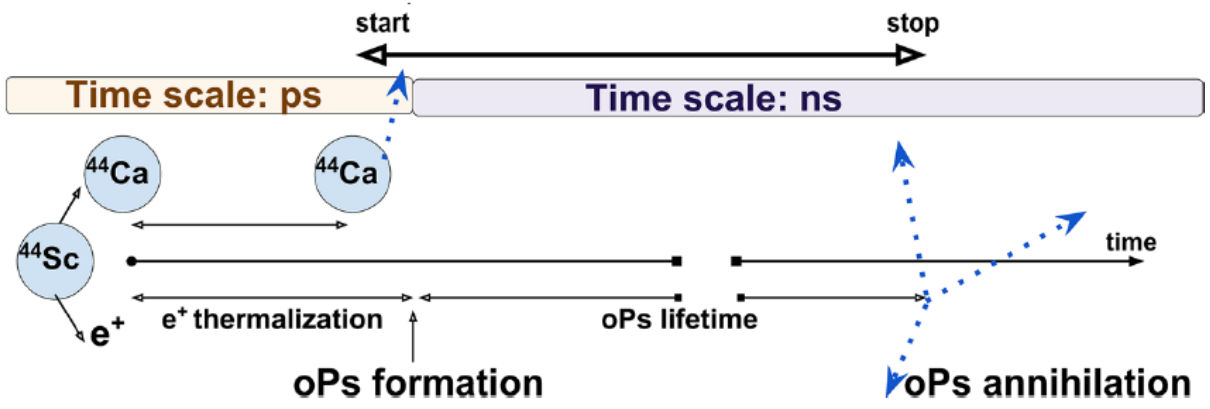


Figure courtesy of Phys. Med. Biol. 64 (2019) 055017

Note: with current PET technology, e^--e^+ annihilations via creation of positronium have 40% probability -> 0.5% 3-γ annihilation.

However, with next generation technology (improved time resolution to 10 ps) both 2 and 3 γ annihilations will be detectable (Phys. Med. Biol. 64 (2019) 055017)

Source: David Sarrut and Lydia Maigne, on behalf of GATE community

Materials

1.4 Making cloning of water possible from just G4_WATER multiple times

- now the process is to clone from a clone to instantiate multiple modified G4_WATER densities

-it seems there is some pointer error when trying to clone G4_WATER multiple times.

1.5 Making the pointer to touchable a vector of pointers for parallel worlds

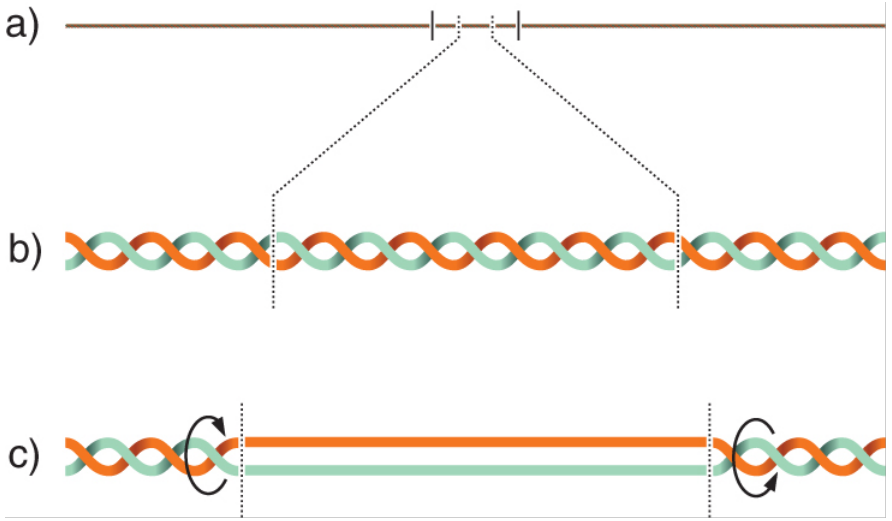
Source: J. Schuemann & A. McNamara, Harvard Medical School

Geometry

1.6 A string geometry for more realistic DNA (or other cell component) representations

-Strings are a simple tube that can have any shape, e.g. following a line but with a finite diameter. Examples are DNA, neuron dendrites, and similar geometries.

-It is possible to generate such a string from cut cylinders, but it would be nice to have a single geometry that is just a cylindrical volume that can have various shapes.



Source: J. Schuemann & A. McNamara, Harvard Medical School

Examples

1.7 Develop a Geant4 example to read IAEA phase space files and generate the radiation field

- M. Cortes-Giraldo and collaborators are developing a Geant4 Advanced Example to read IAEA phase space files.
- Source: many users working in external X-ray radiotherapy

1.8 To have an extended example to retrieve directly from the simulation Auger electron energy and associated atomic transition

- A. Mantero: update of the unit test and implementation in an extended example of Geant4 (in discussion phase)
- Source: S. Guatelli

Validation

- Crucial
- G4-Med
  - We are extending the tests to domains which are not covered yet (e.g. radioactive decay, X-ray radiotherapy, nuclear medicine, in-vivo PET for Heavy Ion Therapy)
  - Include benchmark against ICRU Report 90: Stopping Powers of electrons (and positrons), protons, α particles and carbon ions for three key materials: graphite, air, and liquid water

Geant4 is hard!

- There is the idea in the medical physics community that to use Geant4 is hard.
- Personally I think that there have been many improvements to make Geant4 “easier” for novel users, but it seems not enough.
- Possible ideas:
  - A new general purpose interface as part of Geant4?
  - Develop Geant4 examples for medical physics which are easier to use, more flexible, with an extended/advanced user interface? E.g. the user needs to change parameters in input macro files only, at least for some emblematic applications.
  - Improve documentation
  - Online tutorials/videos on how to use the Extended/Advanced Examples in medical physics
  - Establish a Geant4 bio-medical user forum
- Maybe extend the activities of the G4-Med to a subset of ideas listed above