On a **Geant4** *based Dose Planning Method(DPM) like simulation:*

fast and accurate 3D dose simulation in highly granular geometries

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Outline

Contents

What is DPM? Why?

- *Dose Planning Method*[a] (DPM) is a **fast** and **accurate** dose simulation *Monte Carlo for photon, electron radiotherapy* treatment planning
- the algorithm, i.e. the EM shower modelling, is highly optimised (in terms of speed and accuracy) for voxelized geometry: a (large) set of small volumes resulting e.g. from imaging
- special γ and $e^-/e+$ transport that permits **long transport steps across** (several) heterogeneity/**boundaries while keeping the precision**:
  - γ $\Longrightarrow$ *Woodcock-tracking* of photons
  - e^-/e^+ $\Longrightarrow$ special MSC that simplifies to a pure discrete process
- **a `Geant4`-based but standalone prototype has been developed** (`dpm-g4cpp` `GitHub` repo.)
- with the following **motivations**:
  - investigate the possibility of **utilising the corresponding** e^-/e^+ **MSC** and/or ***Woodcock-tracking*** for γ transport, or even **the complete DPM like algorithm** in the HEP detector simulation domain $\Longrightarrow$ these might **greatly accelerate the** corresponding simulations, **especially in case of granular geometries** (e.g. `CMS-HGCAL`, `ATLAS-EMEC`) while keeping/**increasing the current accuracy**
  - prototype for providing a Monte Carlo simulator for photon and electron real-time (< 1 [s]) radiotherapy treatment
    - in collaboration with *Alex Howard & Marco Barbone* (Imperial College London)
    - goal: originally on FPGA but finally GPU is already suitable to reach the goal

[a] J Sempau, S. J. Wilderman, A. F. Bielajew, Phys. Med. Biol. 2000 Aug; 45(8):2263-91

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Ok but why? We have accurate EM shower simulation in `EMZ/EM-opt4`.

- this is true: `EMZ/EM-opt4` utilises the accurate e^-/e^+ tracking from the `GS` model (stays accurate under any conditions)
- however, for the accurate e^-/e^+ tracking one need to:
- 1. use accurate distributions:
  - for the *angular deflections* due to multiple Coulomb scattering (MSC) as well as for the corresponding *longitudinal* and *lateral* post-step point positions
  - the `GS` model provides such distributions (when used with its most precise setting as in `EMZ/EM-opt4`)
- 2. be able to move the track to that post-step position:
  - **leads to very conservative stepping resulting higher and higher number of simulation steps with decreasing volume sizes/increasing geometry granularity**
- practically none of the description of MSC (we currently have in `Geant4`) is suitable **for accurate and fast** EM shower simulation in highly granular geometries
- this is why:
  - the **DPM like** e^-/e^+ transport, especially the **description of MSC, permits long transport steps across boundaries**
  - MSC simplifies to pure discrete process
  - no displacement is needed and no problem with moving from boundary to boundary (i.e. crossing an entire volume in a single step)
  - can **greatly reduce the number of e^-/e^+ simulation steps in granular geometries**
  - **without loss of accuracy**

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- this is why: **looks like a dream...**
  - the **DPM like** e^-/e^+ transport, especially the **description of MSC, permits long transport steps across boundaries**
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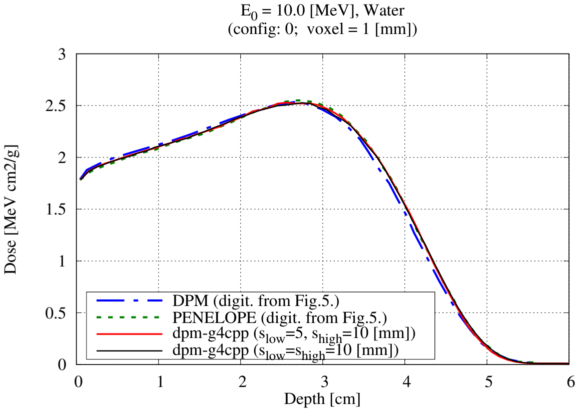
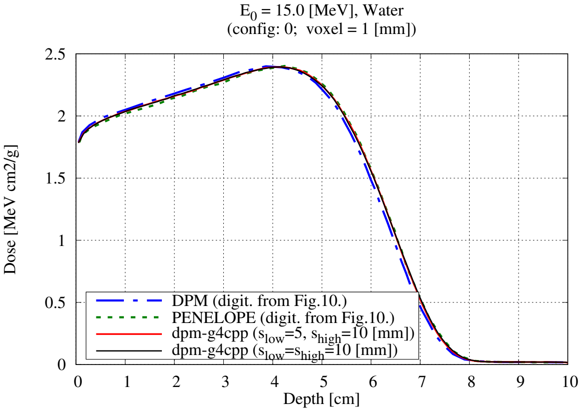
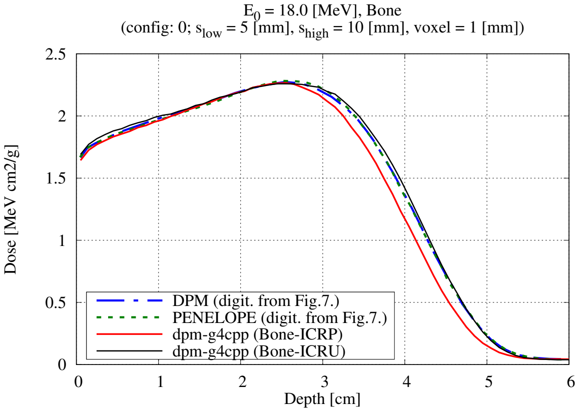
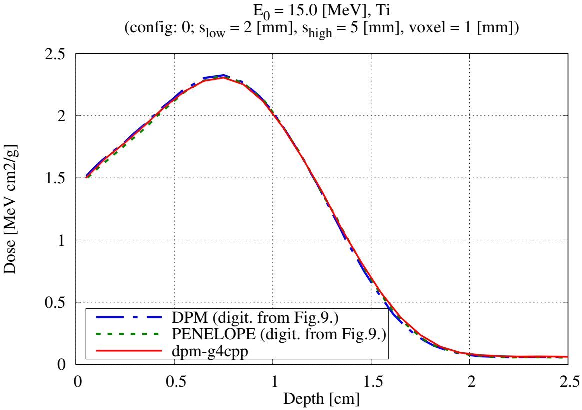
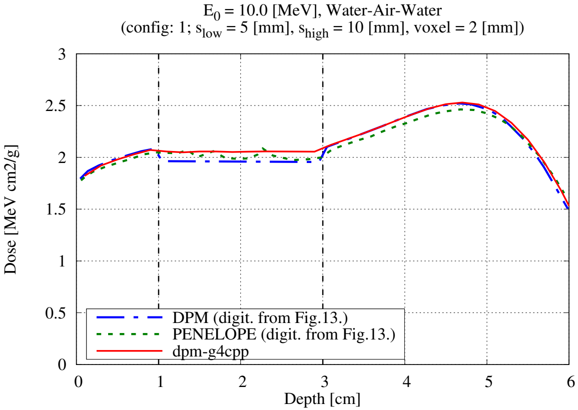
Contents

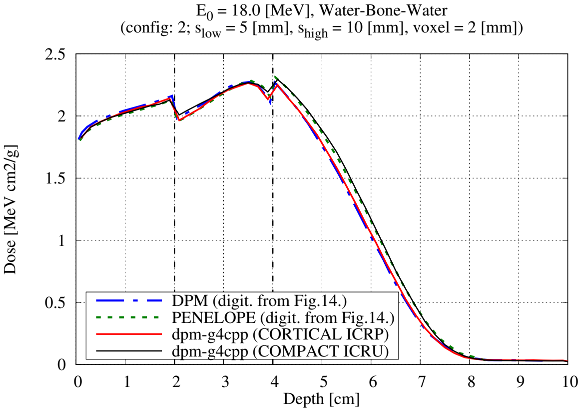

E_0 = 10.0 [MeV], Water
(config: 0; voxel = 1 [mm])
Dose [MeV cm2/g]
Depth [cm]
DPM (digit. from Fig.5.)
PENELOPE (digit. from Fig.5.)
dpm-g4cpp (s_{low}=5, s_{high}=10 [mm])
dpm-g4cpp (s_{low}=s_{high}=10 [mm])

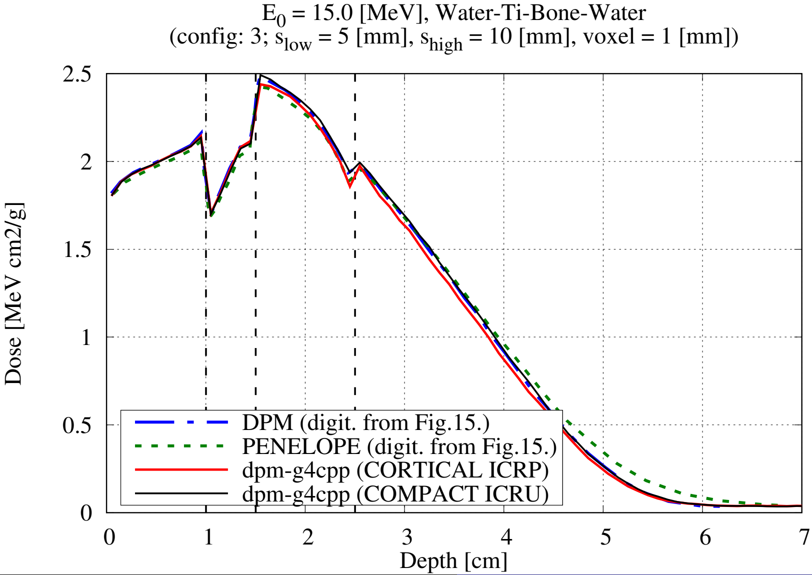

E_0 = 15.0 [MeV], Water
(config: 0; voxel = 1 [mm])
Dose [MeV cm2/g]
Depth [cm]
DPM (digit. from Fig.10.)
PENELOPE (digit. from Fig.10.)
dpm-g4cpp (s_{low}=5, s_{high}=10 [mm])
dpm-g4cpp (s_{low}=s_{high}=10 [mm])

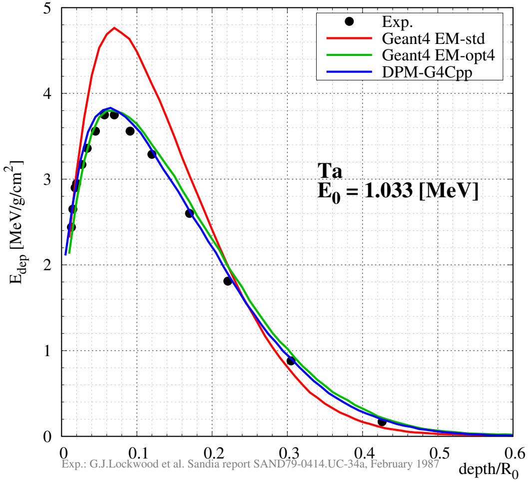

E0 = 18.0 [MeV], Bone
(config: 0; slow = 5 [mm], shigh = 10 [mm], voxel = 1 [mm])
Dose [MeV cm2/g]
Depth [cm]
DPM (digit. from Fig.7.)
PENELOPE (digit. from Fig.7.)
dpm-g4cpp (Bone-ICRP)
dpm-g4cpp (Bone-ICRU)

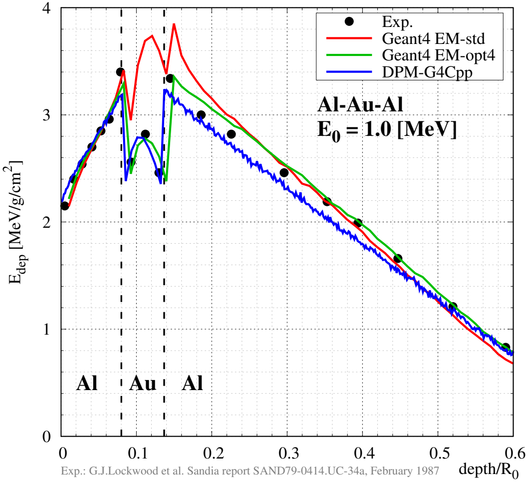

E0 = 15.0 [MeV], Ti
(config: 0; slow = 2 [mm], shigh = 5 [mm], voxel = 1 [mm])
Dose [MeV cm2/g]
Depth [cm]
DPM (digit. from Fig.9.)
PENELOPE (digit. from Fig.9.)
dpm-g4cpp


E_0 = 10.0 [MeV], Water-Air-Water
(config: 1; s_{low} = 5 [mm], s_{high} = 10 [mm], voxel = 2 [mm])
Dose [MeV cm2/g]
Depth [cm]
DPM (digit. from Fig.13.)
PENELOPE (digit. from Fig.13.)
dpm-g4cpp


E_0 = 18.0 [MeV], Water-Bone-Water
(config: 2; s_{low} = 5 [mm], s_{high} = 10 [mm], voxel = 2 [mm])
Dose [MeV cm2/g]
Depth [cm]
DPM (digit. from Fig.14.)
PENELOPE (digit. from Fig.14.)
dpm-g4cpp (CORTICAL ICRP)
dpm-g4cpp (COMPACT ICRU)


E_0 = 15.0 [MeV], Water-Ti-Bone-Water
(config: 3; s_{low} = 5 [mm], s_{high} = 10 [mm], voxel = 1 [mm])
Dose [MeV cm2/g]
Depth [cm]
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
6
7
DPM (digit. from Fig.15.)
PENELOPE (digit. from Fig.15.)
dpm-g4cpp (CORTICAL ICRP)
dpm-g4cpp (COMPACT ICRU)


Exp.
Geant4 EM-std
Geant4 EM-opt4
DPM-G4Cpp
Ta
E0 = 1.033 [MeV]
Edep [MeV/g/cm2]
depth/R0
Exp.: G.J.Lockwood et al. Sandia report SAND79-0414.UC-34a, February 1987


Exp.
Geant4 EM-std
Geant4 EM-opt4
DPM-G4Cpp
Al-Au-Al
E0 = 1.0 [MeV]
Al
Au
Al
Edep [MeV/g/cm2]
depth/R0
Exp.: G.J.Lockwood et al. Sandia report SAND79-0414.UC-34a, February 1987

Indeed not bad ...

Is it something interesting for others as well?