Plate-forme de Calcul pour les Sciences du Vivant
Computing Platform for Life Sciences

Validation of GEANT4 versus EGSnrc

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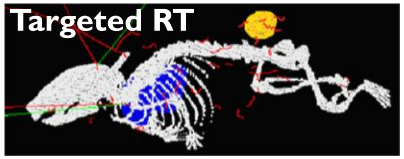
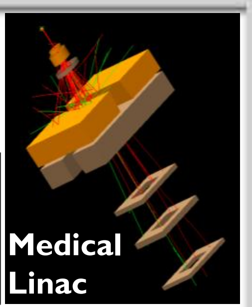
Motivation

- Electron transport crucial to provide accurate dose estimation for medical physics applications (accuracy ~2-3%)

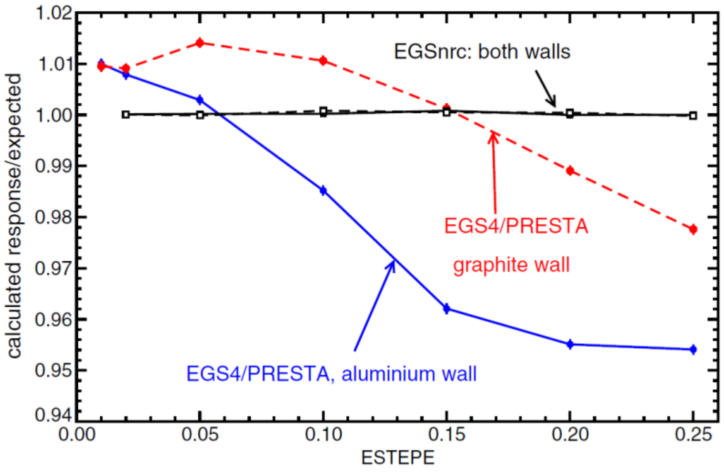




- EGSnrc : simulation of the coupled transport of electrons and photons from few keV up to ~100 GeV

- EGSnrc passes the fano cavity test :
  robust MSC algorithm
  → « golden standard »

Ion chamber response in ^{60}Co beam
Med Phys 27 (2000), 499-517



ESTEPE is the maximal fractional energy loss by step

EGSnrc electrons physics

Bremsstrahlung	NIST XS or Relativistic FBA + corrections	ICRU radiative stopping power
Inelastic collisions	Moller CSDA from Bethe-Bloch	ICRU 37
Elastic collisions	Screened Rutherford x spin correction	

Extended examples : results available

❑ TestEm11 : Pencil Beam Kernel

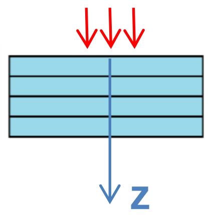
/electromagnetic/testem11/sandia/EGSnrc

Depth dose distribution

Al : 314 keV, 521 keV, 1033 keV

Mo : 500 keV

Ta : 300 keV, 500 keV, 1000 keV

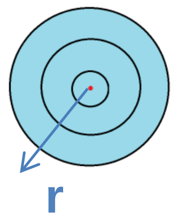


❑ TestEm12 : Dose Point Kernel

/electromagnetic/testem12/berger/EGSnrc

Enegy deposition profile

Water : 10 keV, 15 keV, 100 keV, 1000 keV

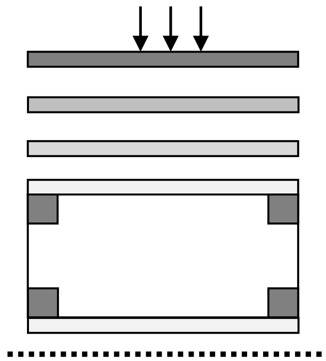


❑ electronScattering

/medical/electronScattering/EGS_13MeV

Fluence distribution

13 MeV : Be, C, Al, Ti, Au scattering foil



Multilayers configuration

- Configuration proposed by Rogers and Mohan (13th Int. Conf. On the Use of Computers in Radiation Therapy, 2000)

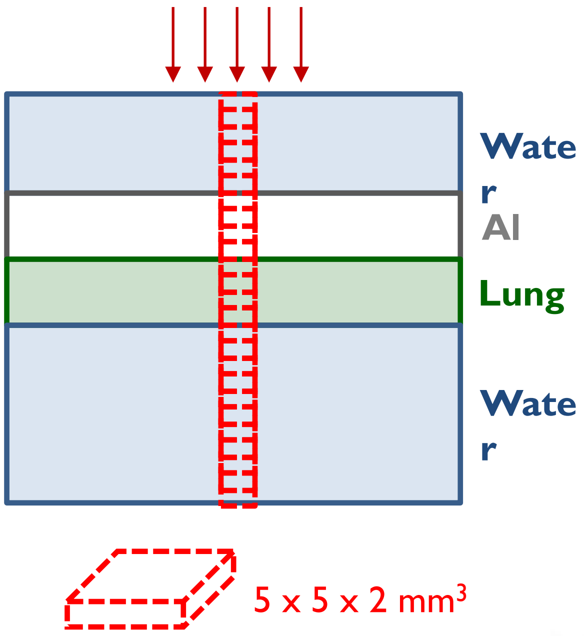
- Electrons 20 MeV : beam size = 1.5 x 1.5 cm^2
- Four layers : section = 30.5 x 30.5 cm^2
  - Water 1. g/cm^3 2 cm
  - Aluminium 2.702 g/cm^3 1 cm
  - Lung 0.26 g/cm^3 3 cm
  - Water 1. g/cm^3 9 cm
- Scoring region :

5x5x2 mm^3 voxels centered on the beam axis

Geometry fully voxelized with EGSnrc

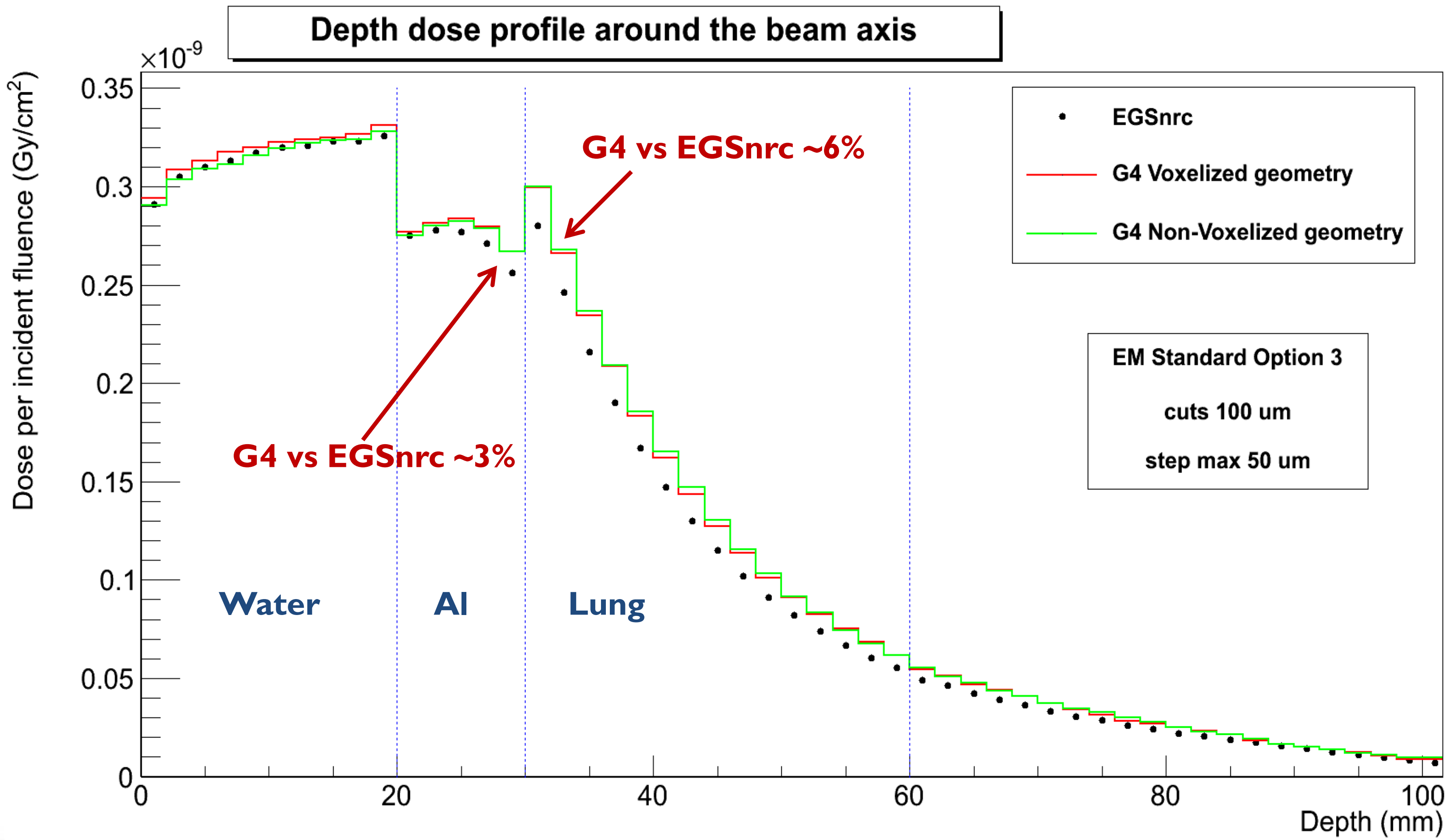
- Quantity :

Dose/Fluence = Dose/(Num primaries x field size)

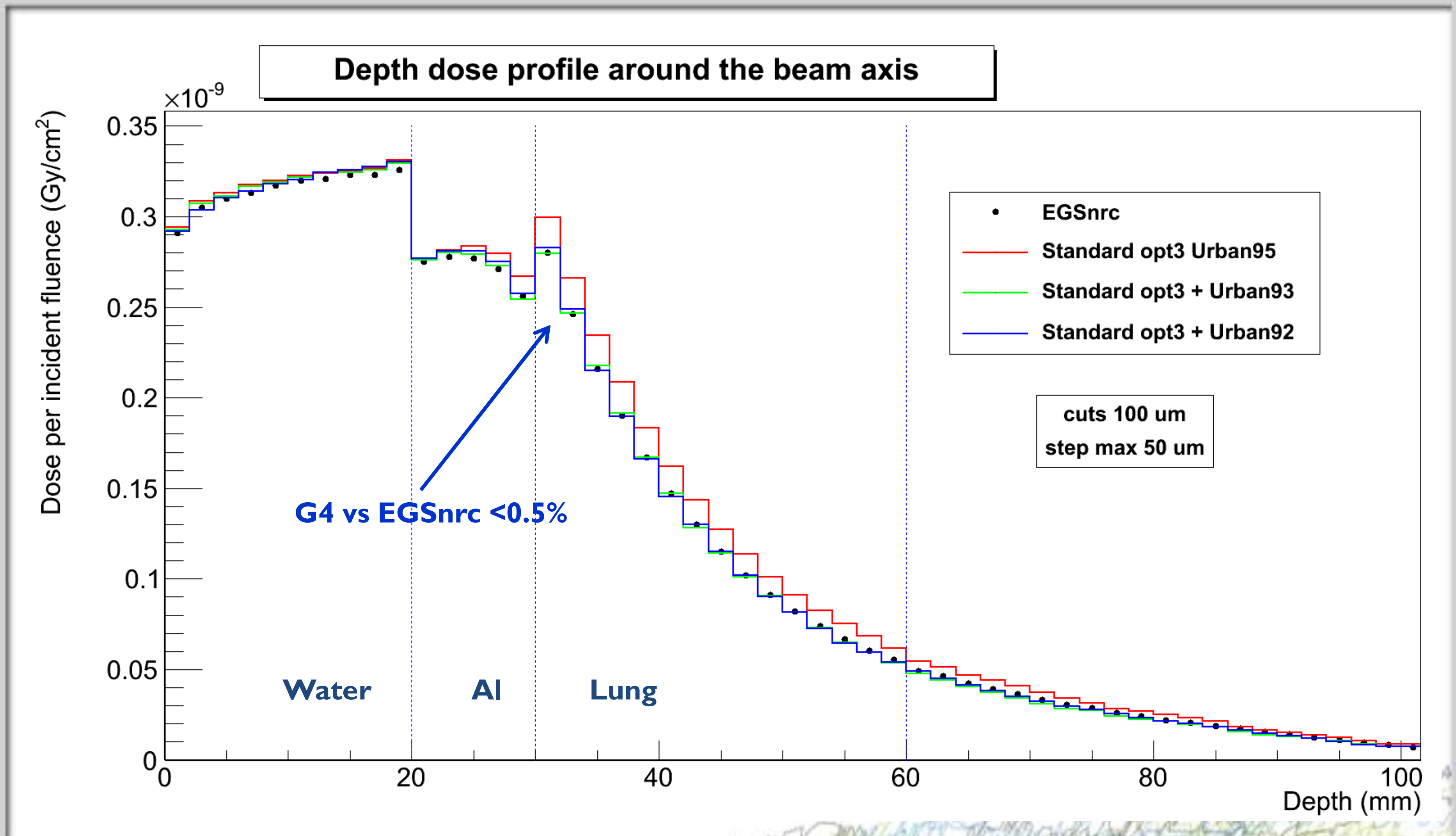


Multilayers: EM Standard

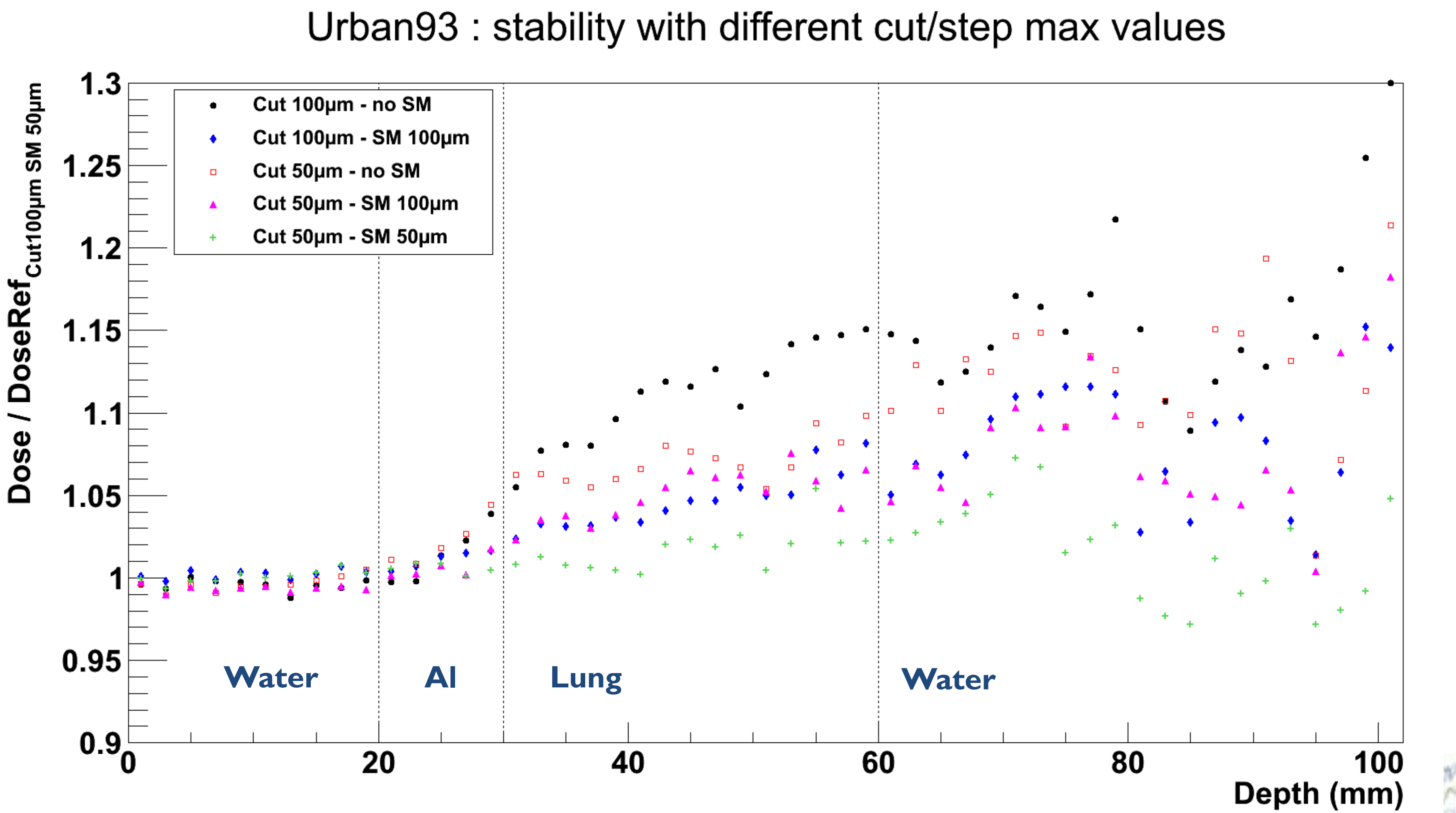
- Adaptation of Testem11 (G4 9.6.b01) to manage voxelized geometry



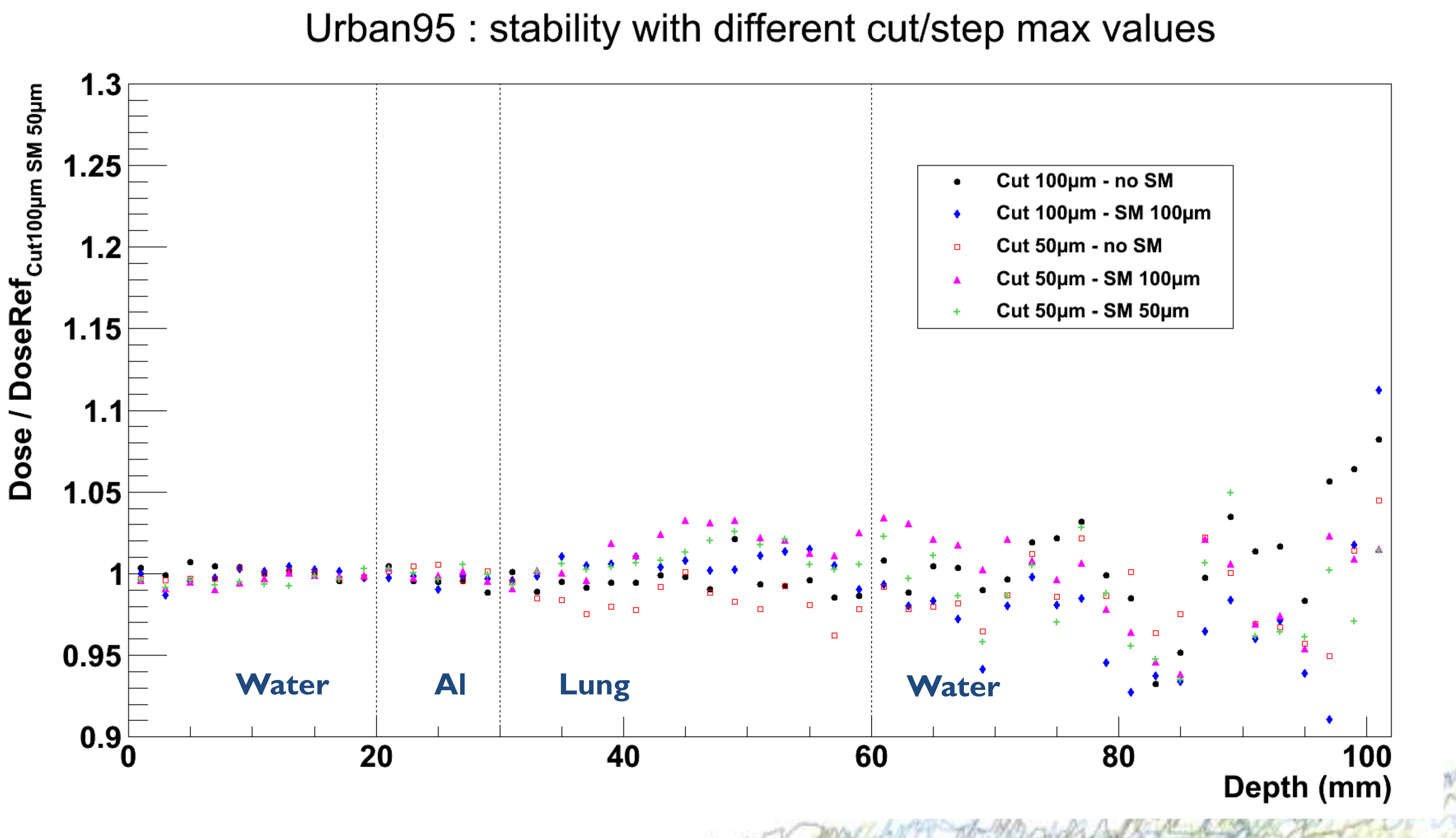
Multilayers: Urban's Models



Multilayers: Stability cut/step max 1/2



Multilayers: Stability cut/step max 2/2



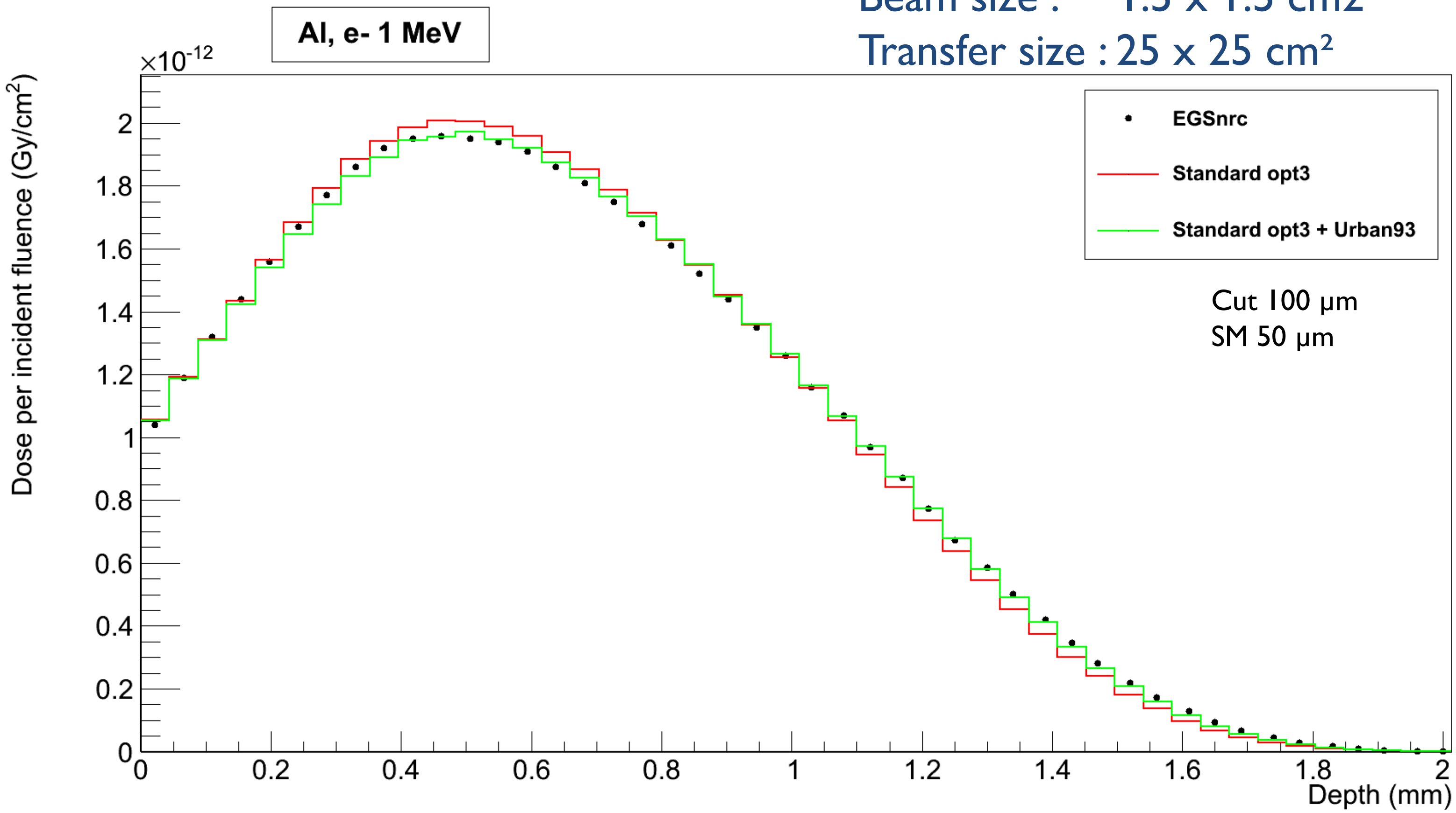
TestEm11: Response for large transfer size

1/2

ALUMINIUM

Beam size : 1.5 x 1.5 cm2

Transfer size : 25 x 25 cm²



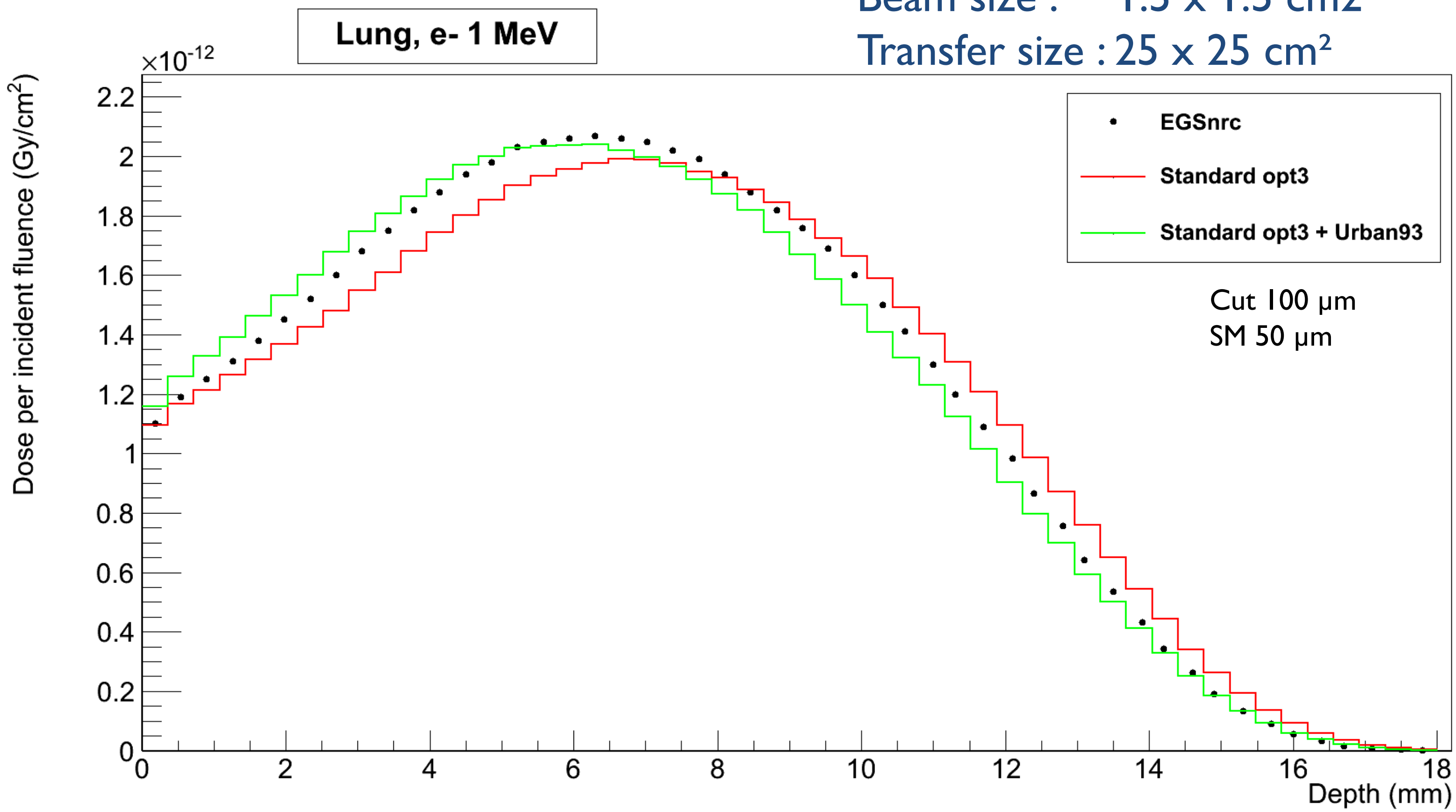
TestEm11: Response for large transfer size

2/2

LUNG

Beam size : 1.5 x 1.5 cm2

Transfer size : 25 x 25 cm²

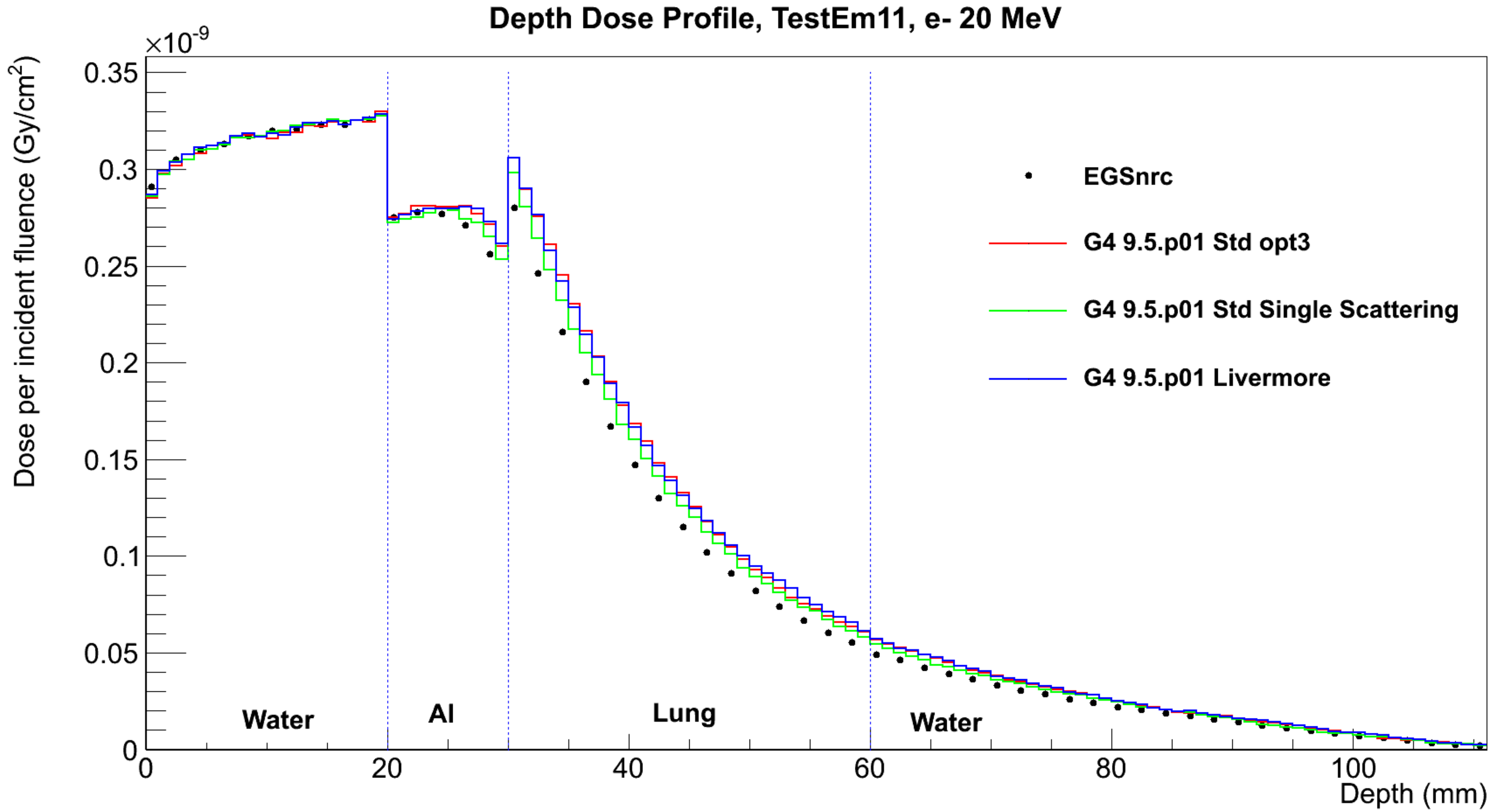


Conclusion

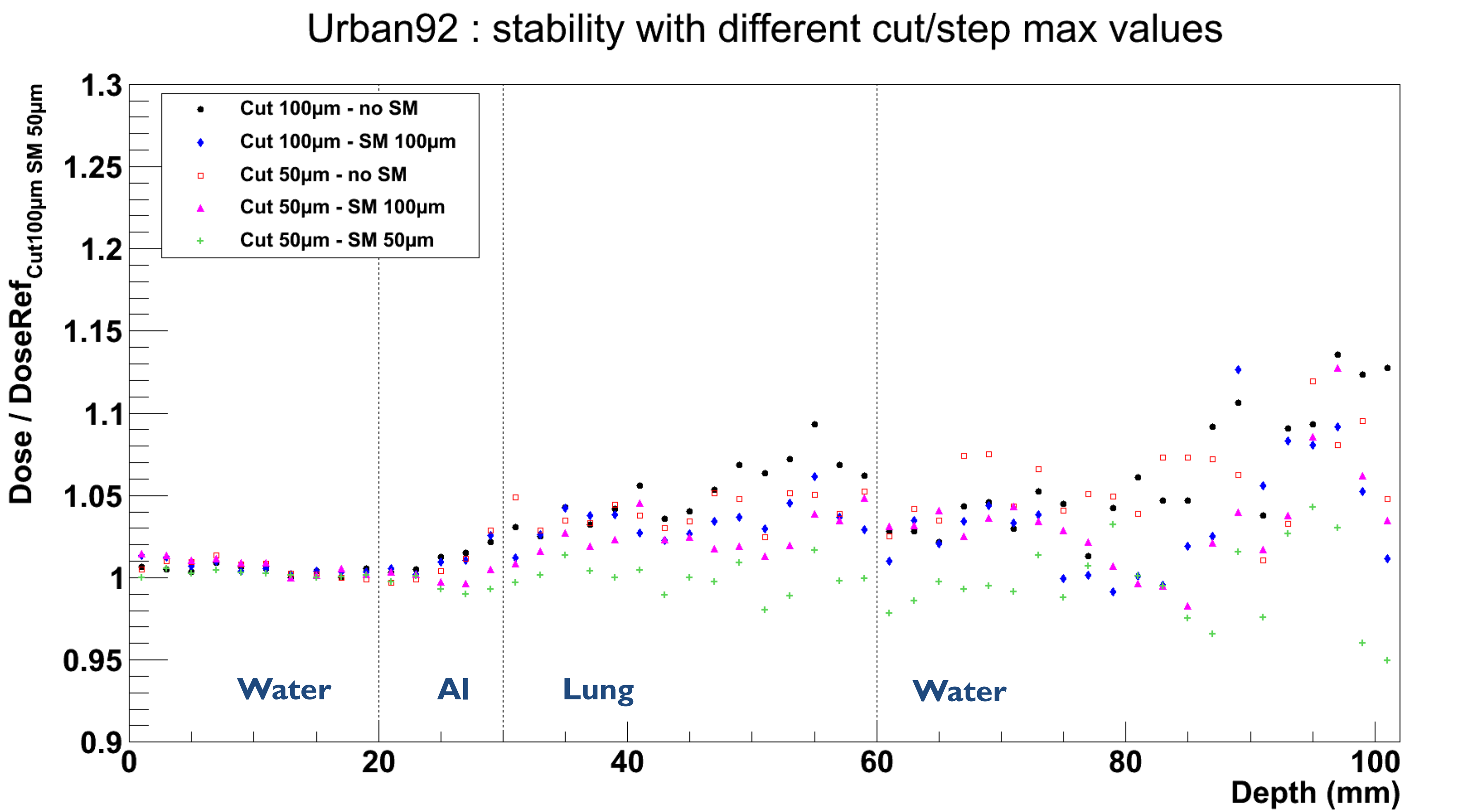
- Geant4 for RT applications:
  - EM Physics List Standard option3 not adapted for RT applications : Urban95 by default
  - Nevertheless… Urban95 less step size dependent
- Validation vs EGSnrc :
  - Benefit of a robust MSC model : reference when no experimental data
  - Ready to continue comparisons / provide results for G4 Collaboration

THANK YOU !

Multilayer configuration : Std, LE, SS



Multilayers: Stability cut/step max



Materials for the multilayer configuration

Water

```
G4Material* H2O =
new G4Material("Water", 1.000*g/cm3, 2);
H2O->AddElement(H, 2);
H2O->AddElement(O, 1);
H2O->GetIonisation()->SetMeanExcitationEnergy(78.0*eV);
```

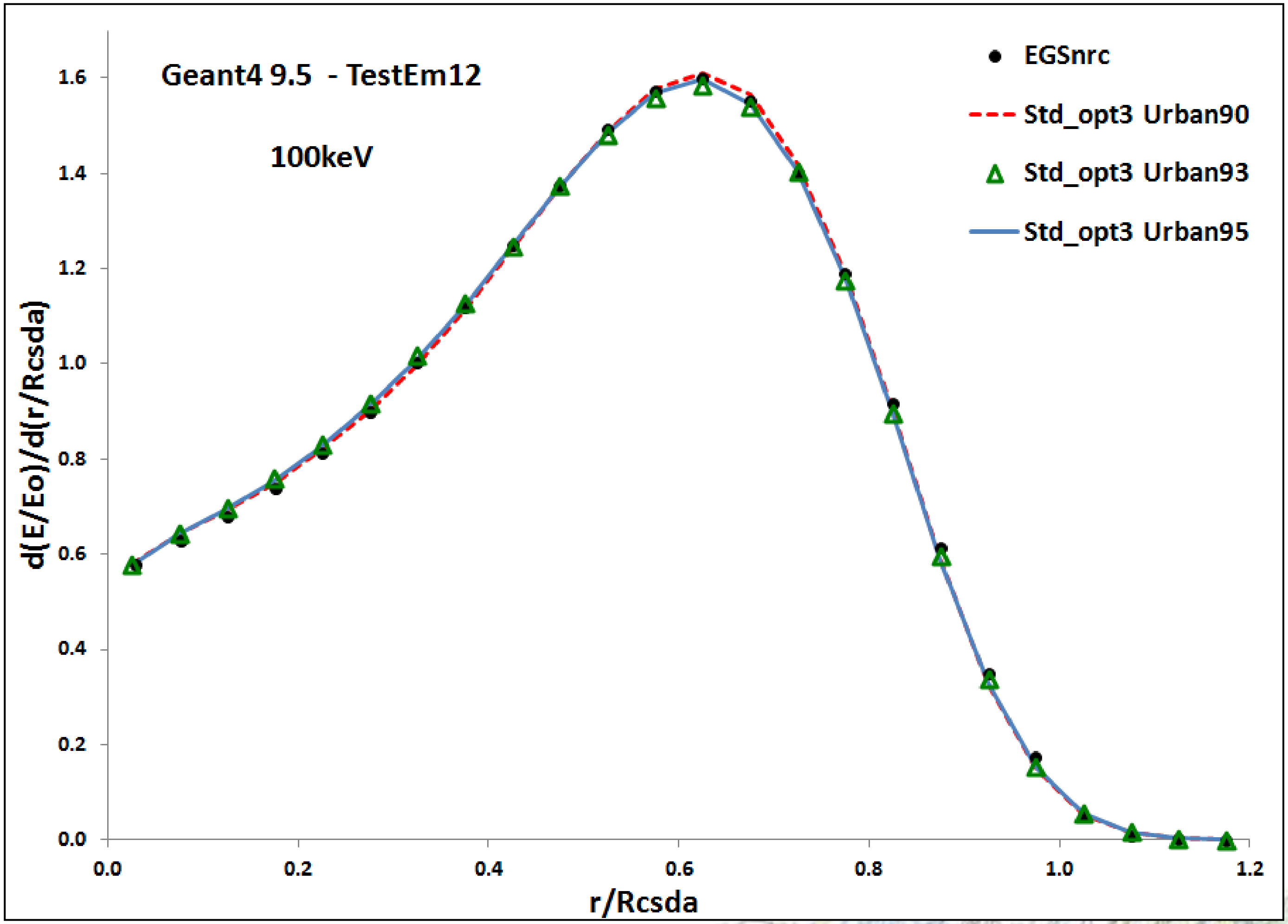
Aluminium EGS

```
G4Material* Al_EGS =
new G4Material("AluminiumEGS",13,26.98*g/mole,2.702*g/cm3);
Al_EGS->GetIonisation()->SetMeanExcitationEnergy(166.0*eV);
```

Lung

```
G4Material* lung =
new G4Material("Lung", 0.26*g/cm3, 9);
lung->AddElement(H, 0.103);
lung->AddElement(C, 0.105);
lung->AddElement(N, 0.031);
lung->AddElement(O, 0.749);
lung->AddElement(Na, 0.002);
lung->AddElement(P, 0.002);
lung->AddElement(S, 0.003);
lung->AddElement(Cl, 0.003);
lung->AddElement(K, 0.002);
lung->GetIonisation()->SetMeanExcitationEnergy(75.2*eV);
```

TestEm12: Water, electrons 100 keV



TestEm12: Water, electrons 15 keV