Reunion IMNC/SHFJ
20 April 2012

Mie scattering cuda code: status and plan

- Recipe for the Implementation of the Mie Scattering process
  - Table of scattering length and anisotropy (mc_cst.cu).
  - Choose a new deflection angle (θ) for the photon propagation according to the Henyey-Greenstein approximation (mc_fun.cu):

$$p(\cos\theta) = \frac{1 - g^2}{2x(1 + g^2 - 2g\cos\theta)^{3/2}}$$

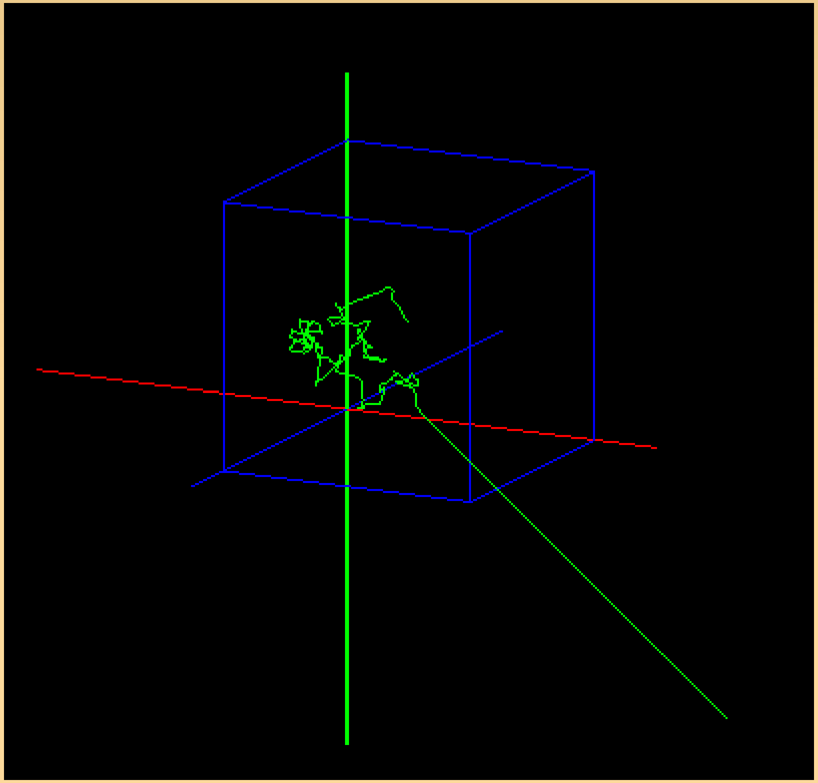
g: anisotropy

  - Calculation of the mean free path is done in the woodcock tracing function (mc_fun.cu)

$- \log \mu(E)$ with $\mu(E) = 1/CS(E)$ → In order to follow the existing code implementation, we might actually create a Table of CS instead of μ.

Code writing (Mie scattering in water) + validation against Gate CPU by the end of April.

Gate-CPU validation setup

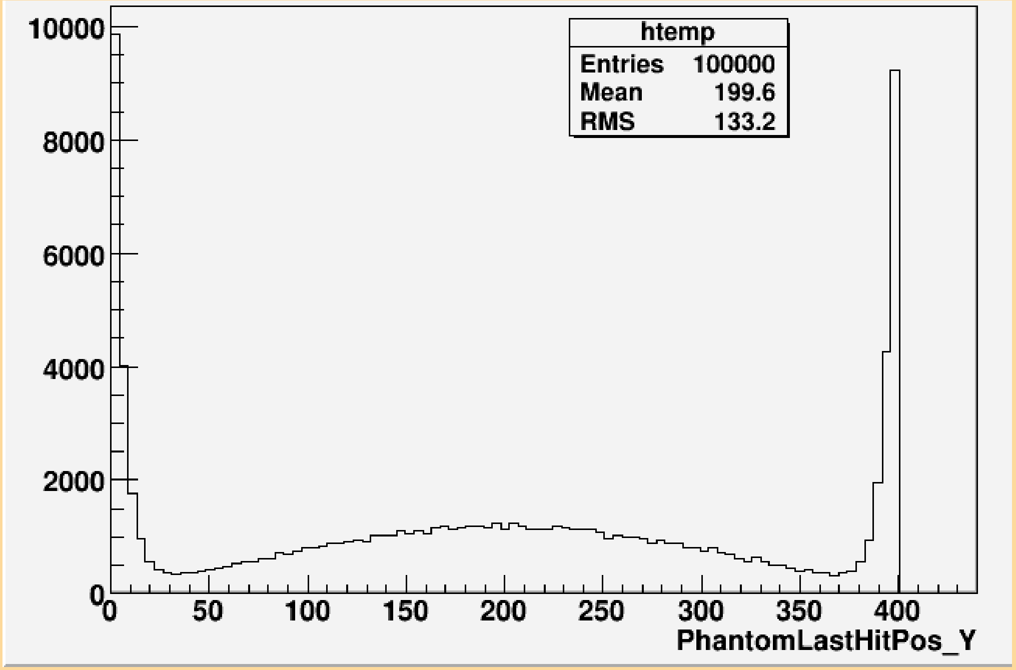


Water box (400,400,400) mm

Source of optical photons at (200, 200, 200) mm

6 eV optical photon

Mie attenuation length = 6mm



Quelques verifications...

- Livermore - Evaluated Photon Data Library EPDL97 including:
- photoionization, photoexcitation, coherent (Rayleigh) and incoherent (Compton) scattering, and pair and triplet production cross sections.
- http://www-nds.iaea.org/epdl97/za1to100.htm
- EPDL97 includes data down to 1eV (*"but we can only safely use this data down to about 1keV"*)
- All cross sections are in barns per atom.
- All energies are in MeV in the ENDL format

Section Efficace Rayleigh Livermore

http://www-nds.iaea.org/cgi-bin/epdl97.cgi?file=data/endl/epdl97/za001000

Atomic number 1 – incident particle photon

```
Content-Type: image/zvd

  1000  7  0  1.007970+0 9707045 2  0.0         0.0         0.0
71  0  0  0.0         0.0         0.0         0.0         0.0
 1.000000-6 9.887553-6
 1.059784-6 1.235246-5
 1.126020-6 1.538627-5
 1.196396-6 1.933495-5
 1.271171-6 2.449127-5
 1.350619-6 3.121326-5
 1.392826-6 3.537646-5
 1.481238-6 4.569015-5
```

Energie (MeV) Cross section (barn/atom)

Cross section Livermore Rayleigh

~ 60keV

H: 6.095369 10^{-2} MeV ==> 1.240517 10^{-3} barns
O: 5.831018 10^{-2} MeV ==> 4.355844 10^{-1} barns

Table 1. Atom densities of steel and water

Element	Atom density (atoms/barn·cm)
Water	
Hydrogen	6.68E–02
Oxygen	3.34E–02

Water cross section = 1.240517 10^{-3} x 6.68 10^{-2} + 4.355844 10^{-1} x 3.34 10^{-2}
= 0.001463 mm^{-1}

D'apres le code cuda, la CS Livermore Rayleigh for 60keV in Water = 1.389 10^{-3} mm^{-1} OK!

Les CS per atom sont x 10^{-22} pour etre en mm^2 dans le code cuda et la densite atomique est en 1/mm3 (d'ou l'exposant 19):

```
// Atomic number density of each element of materials
__constant__ float mat_atom_num_dens [119] = {
        // Air C N O Ar
        8.02083098025e12f,  4.18797071465e16f,  1.12537829977e16f,  2.49430178811e14f,
        // Water H O
        6.685593328e19f,    3.342796664e+19f,
        // Body H O
        6.67801861861e+19f, 3.34228869345e19f,
```

Cross section and Attenuation length

- mean free path: $\lambda = 1 / (N \times \sigma)$

Number of target particles per unit volume

Interaction cross section per target

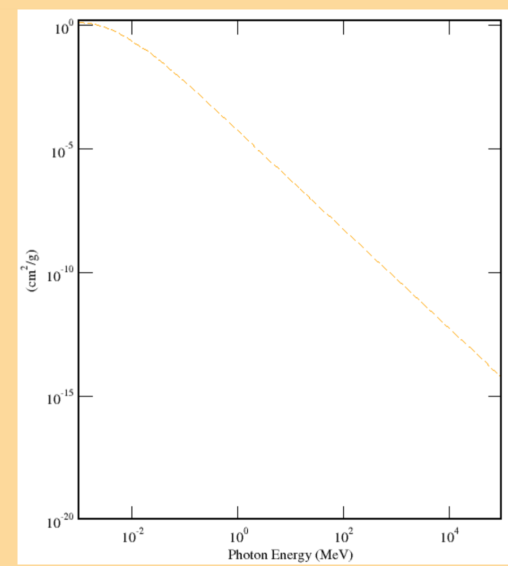
1) In Geant4, the Mie scattering GetMeanFreePath() returns the MIEHG parameter which is the attenuation length (in mm).

2) The cross section is then: $\sigma\ (mm^2) = 1/$ meanfreepath (mm)

Base XCOM du NIST où toutes les attenuations sont tabulées:

http://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html

(required) Photon Energy	Scattering		Photoelectric Absorption	Pair Production		Total Attenuation	
	Coherent	Incoherent		In Nuclear Field	In Electron Field	With Coherent Scattering	Without Coherent Scattering
MeV	cm^2/g	cm^2/g	cm^2/g	cm^2/g	cm^2/g	cm^2/g	cm^2/g
5.000E-02	1.936E-02	1.803E-01	2.725E-02	0.000E+00	0.000E+00	2.269E-01	2.076E-01
6.000E-02	1.392E-02	1.770E-01	1.493E-02	0.000E+00	0.000E+00	2.059E-01	1.920E-01
8.000E-02	8.165E-03	1.697E-01	5.770E-03	0.000E+00	0.000E+00	1.837E-01	1.755E-01

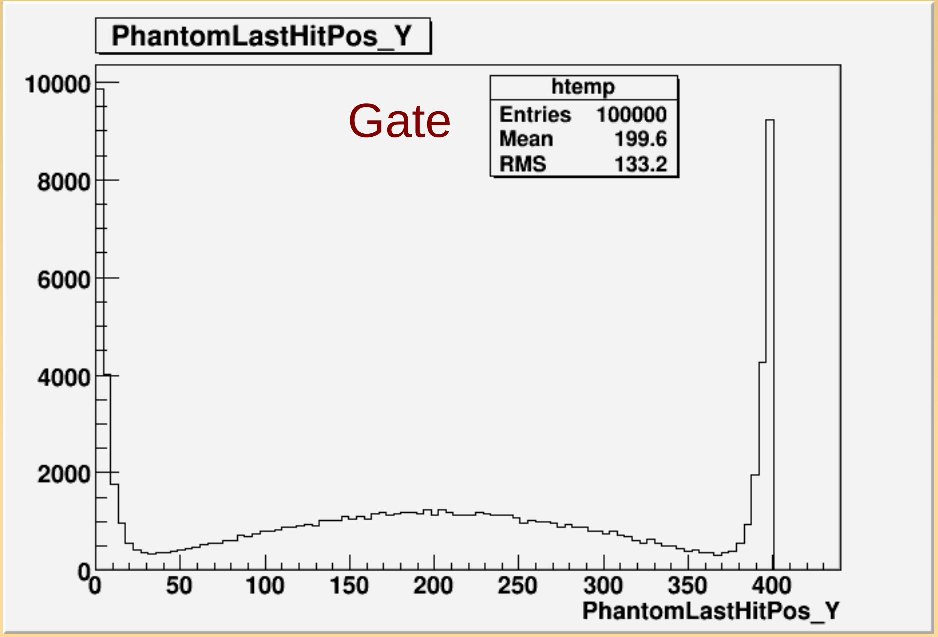


$L_{rayleigh} = 1/1.392E-2$ cm ➔ 72 cm

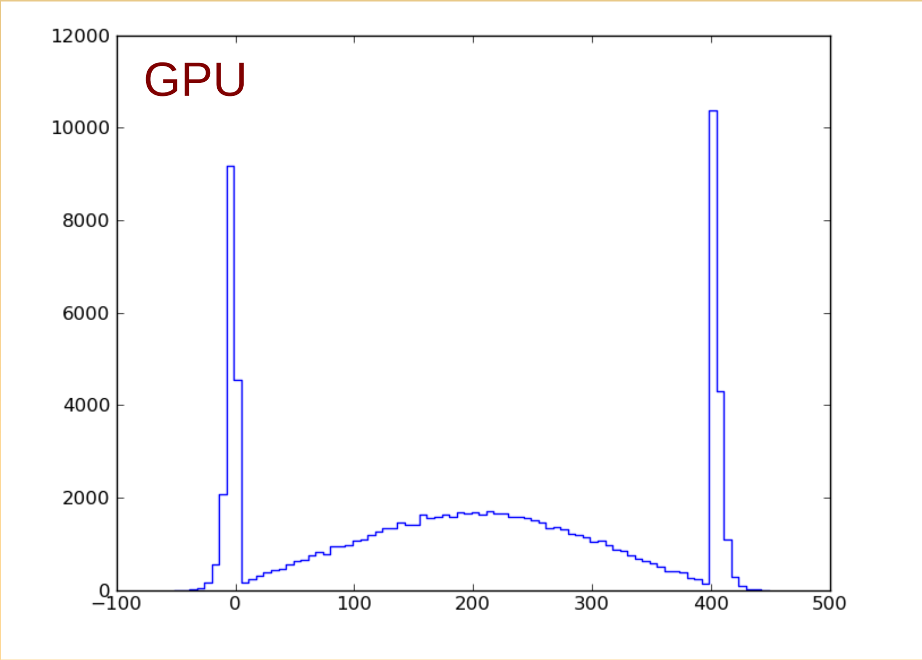
CS Livermore Rayleigh cuda= 1.389 10^{-3} mm^{-1}

gives L = $1/\sigma$ = 72cm

Mie scattering - GPU



Avec G4 le tracking fait beaucoup de petit pas, donc il est facile de stopper la particule très proche d'une face du volume.



Sur le GPU, les particules font de grands pas. Lorsqu'elles sortent du volume voxelise elles sont stoppees.

Difficile de comparer G4 et le GPU parce que la navigation est differente.

Le seul moyen de comparer serait de faire un back-raytracing des particules sur le cube.