# Optical Imaging Module Status

vesna

22nd June 2012

# *These : Caracterisation par autofluorescence de tissus cerebraux tumoraux : mesures sur fantomes et modele animal (B. Leh)*

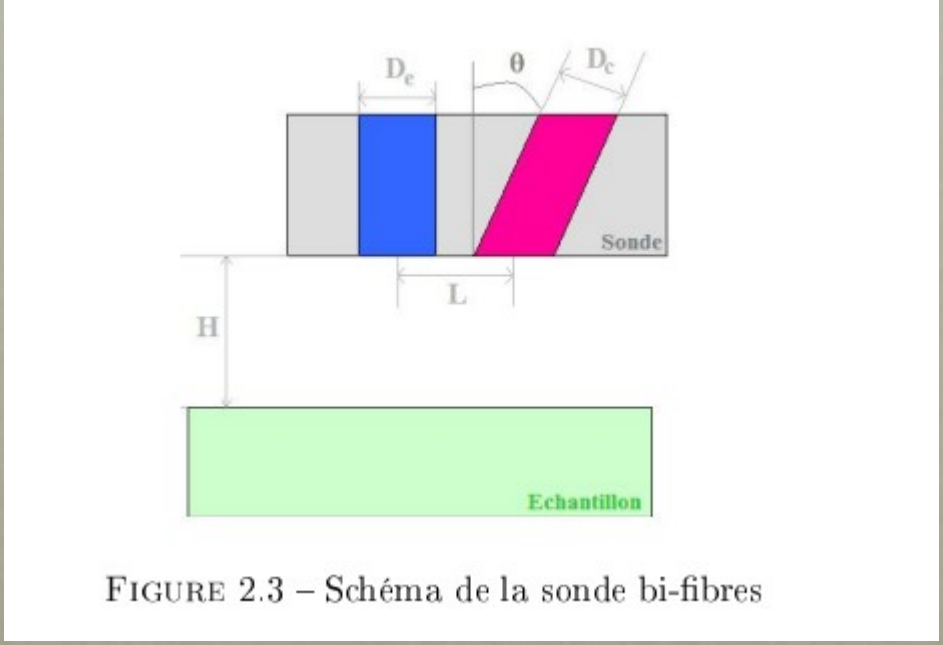
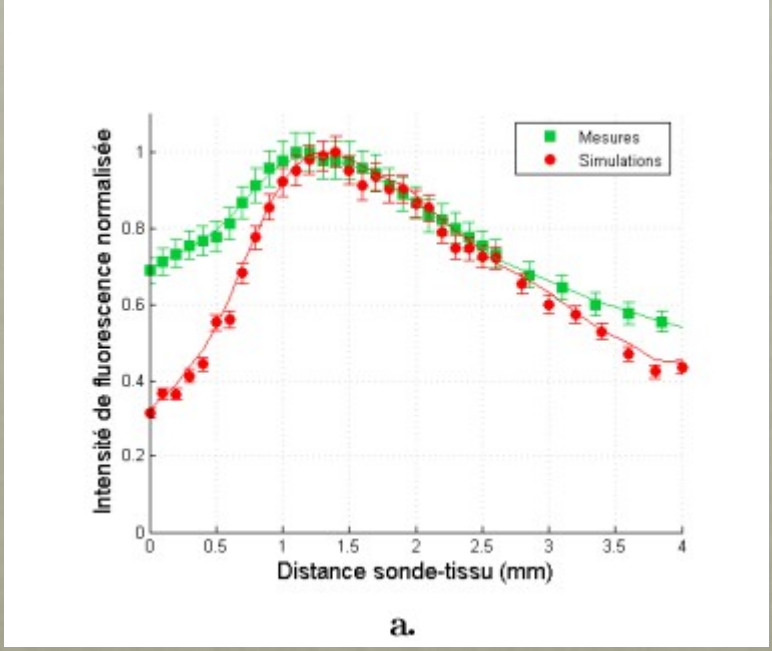



FIGURE 2.3 – Schéma de la sonde bi-fibres




a.

Excitation light @ 405nm (3.06eV)
Collect fluorescent photons for $\lambda > 410$ nm ($0<E_\gamma<3.02$eV)

Attenuation de la fibre collectrice negligeable (puissance transmise ~ 99% - p57.)
Proprietes de l'echantillon (p79) @405nm: $\mu_A = 3cm^{-1}$ , $\mu_S = 100cm^{-1}$ , g=0.87 et [Fluorophore] = $10^{-5}$ M

What are the phantom properties @ Fluorescence wavelength ?

# Light collecting Fiber : Elliptical Tube

http://wiki.opengatecollaboration.org/index.php/Users_Guide_V6.1:Defining_a_geometry

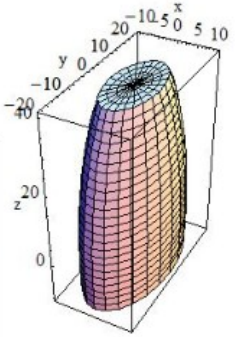
Table 3.2: Commands of the sub-tree geometry for different shapes

| BOX | TRPD |
|---|---|
| setXLength: Set the length of the box along the X axis | setX1Length: Set half length along X of the plane at -dz position |
| setYLength: Set the length of the box along the Y axis | setY1Length: Set half length along Y of the plane at -dz position |
| setZLength: Set the length of the box along the Z axis | setX2Length: Set half length along X of the plane at +dz position |
| **SPHERE** | setY2Length: Set half length along Y of the plane at +dz position |
| setRmin: Set the internal radius of the sphere (0 for full sphere) | setZLength: Set half length along Z of the trapezoid |
| setRmax: Set the external radius of the sphere | setXBoxLength: Set half length along X of the extruded box |
| setPhiStart: Set the start phi angle | setYBoxLength: Set half length along Y of the extruded box |
| setDeltaPhi: Set the phi angular span (2PI for full sphere) | setZBoxLength: Set half length along Z of the extruded box |
| setThetaStart: Set the start theta angle | setXBoxPos: Set center position X of the box |
| setDeltaTheta: Set the theta angular span (2PI for full sphere) | setYBoxPos: Set center position Y of the box |
| **CYLINDER** | setZBoxPos: Set center position Z of the box |
| setRmin: Set the internal radius of the cylinder (0 for full cylinder) | **PARALLELEPIPED** |
| setRmax: Set the external radius of the cylinder | setDx: Set Dx dimension of the parallelepiped |
| setHeight: Set the height of the cylinder | setDy: Set Dy dimension of the parallelepiped |
| setPhiStart: Set the start phi angle | setDz: Set Dz dimension of the parallelepiped |
| setDeltaPhi: Set the phi angular span (2PI for full cylinder) | setAlpha: Set Alpha angle |
| **CONE** | setTheta: Set Theta angle |
| setRmin1: Set the internal radius of one side of the cone (0 for full cone) | setPhi: Set Phi angle |
| setRmax1: Set the external radius of one side of the cone | **POLYCONE** |
| setRmin2: Set the internal radius of one side of the cone (0 for full cone) | setProfile: Set vectors of z, rInner, rOuter positions |
| setRmax2: Set the external radius of one side of the cone | setPhiStart: Set the start phi angle |
| setHeight: Set the height of the cone | setDeltaPhi: Set the phi angular span (2PI for full cone) |
| setPhiStart: Set the start phi angle | **HEXAGONE** |
| setDeltaPhi: Set the phi angular span (2PI for full cone) | setRadius: Set the radius of the hexagon |
| **ELLIPSO** | setHeight: Set the height of the hexagon |
| setLong: Set the long axis length of the ellipse | **WEDGE** |
| setShort: Set the short axis length of the ellipse | NarrowerXLength: Set the length of the shorter side of the wedge in the X direction. |
| setHeight: Set the height of the ellipse | XLength: Set the length of the wedge in the X direction |
| | YLength: Set the length of the wedge in the Y direction |
| | ZLength: Set the length of the wedge in the Z direction |

ellipsoid (G4Ellipsoid)

```
<ellipsoid
        name = "ellExample"
        ax = "10"
        by = "15"
        cz = "20"
        zcut1 = "0"
        zcut2 = "4"
        lunit = "mm" />
```

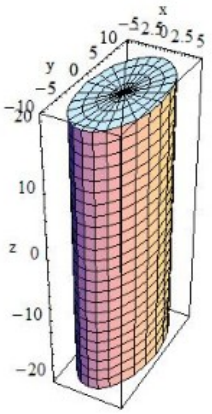
| name | Ellipsoid name |
|---|---|
| ax | x semi axis |
| by | y semi axis |
| cz | z semi axis |
| zcut1 | cutting the bottom part of the shape off |
| zcut2 | cutting the upper part of the shape off |
| lunit | unit of ax, by, cz, zcut1 and zcut2 |



eltube (G4EllipticalTube)

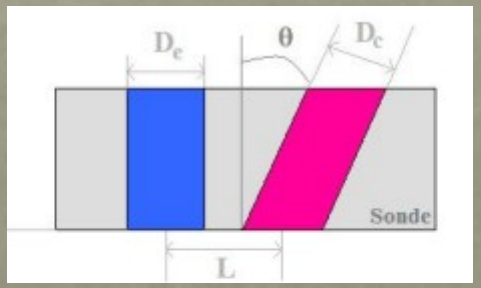
```
<eltube
        name = "eltExample"
        dx = "10"
        dy = "15"
        dz = "20"
        lunit = "mm" />
```

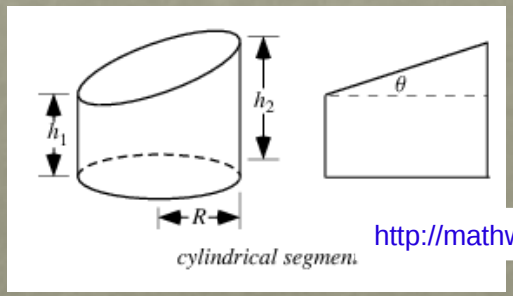
| name | Elliptical tube name |
|---|---|
| dx | x semi axis |
| dy | y semi axis |
| dz | z semi axis |
| lunit | unit of dx, dy and dz |



gate/source/geometry/src/GateElTub.cc **NEW**
gate/source/geometry/src/GateElTubMessenger.cc
gate/source/geometry/include/GateElTub.hh
gate/source/geometry/include/GateElTubMessenger.hh

Using GATE, the detecting surface would be the **elliptical surface**.The slope in the simulation geometry is not needed as long as the ellipse has the correct dimensions corresponding to a 11° tilt.

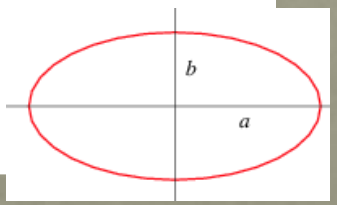


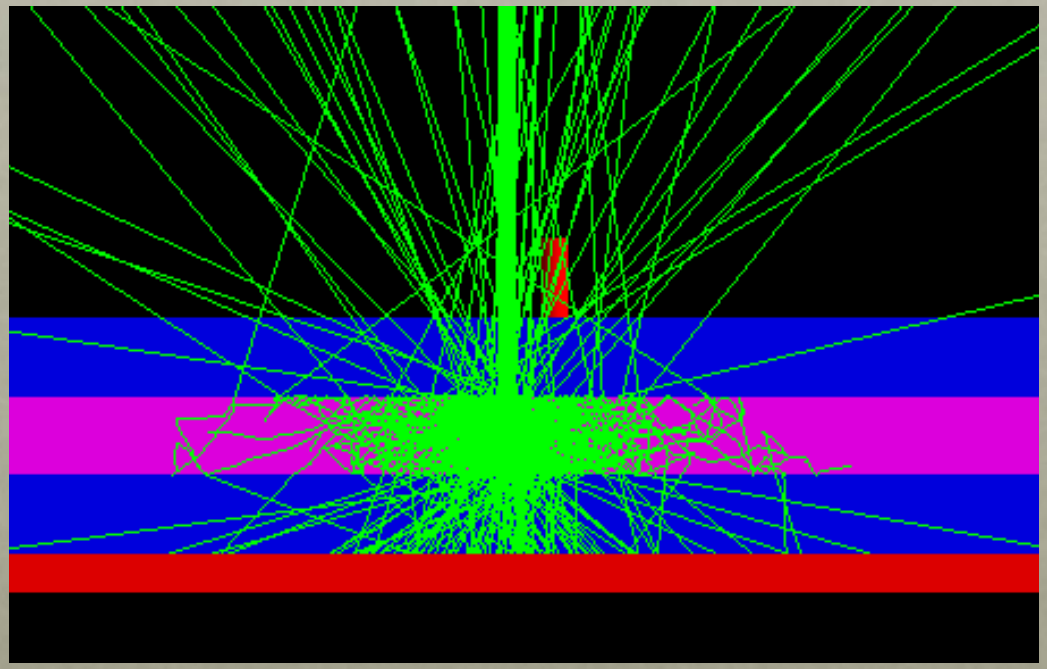

Since the top cap is an ellipse with semimajor and semiminor axes

$$a = \frac{1}{2}\sqrt{(2R)^2 + (h_2 - h_1)^2}$$
$$= R \sec\theta$$
$$b = R,$$

http://mathworld.wolfram.com/CylindricalSegment.html

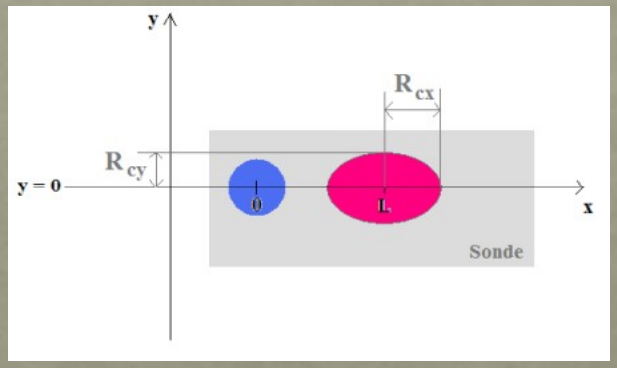


# Preliminary result using GATE



Reflectance

Transmittance




$$R_{cx} = \frac{D_c}{2\cos\theta} \qquad R_{cy} = \frac{D_c}{2}$$

θ = 11°
$R_{cy}$ = 182.5 µm
$R_{cx}$ = 185.9 µm

```
<!-- SAME absorption and scattering for the excitation and Fluorescent photon: -->
<material name="GFP">
    <propertiestable>
      <propertyvector name="RINDEX" energyunit="eV">
        <ve energy="4.13" value="1.4"/>
        <ve energy="3.54" value="1.4"/>
        <ve energy="3.1" value="1.4"/>
        <ve energy="2.75" value="1.4"/>
        <ve energy="2.48" value="1.4"/>
        <ve energy="2.38" value="1.4"/>
        <ve energy="2.34" value="1.4"/>
        <ve energy="2.25" value="1.4"/>
        <ve energy="2.21" value="1.4"/>
        <ve energy="2.17" value="1.4"/>
        <ve energy="2.14" value="1.4"/>
        <ve energy="2.07" value="1.4"/>
        <ve energy="2.0" value="1.4"/>
        <ve energy="1.9" value="1.4"/>
        <ve energy="1.85" value="1.4"/>
        <ve energy="1.77" value="1.4"/>
        <ve energy="1.0" value="1.4"/>
      </propertyvector>
     <propertyvector name="ABSLENGTH" unit="cm" energyunit="eV">
        <ve energy="4.13" value="0.33"/>
        <ve energy="3.54" value="0.33"/>
        <ve energy="3.1" value="0.33"/>
        <ve energy="3.07" value="0.33"/>
        <ve energy="3.06" value="0.33"/>
        <ve energy="3.05" value="0.33"/>
        <ve energy="2.75" value="0.33"/>
        <ve energy="1.77" value="0.33"/>
        <ve energy="1.0" value="0.33"/>
      </propertyvector>
```

**Indice de refraction = 1.4**
**gelatine animale**
**Sigma Aldrich (p62)**

**Encre de Chine**
**$\mu_{Absorption}$ = 3cm$^{-1}$**

*Coefficient d'anisotropie de melamine formaldehyde, pas du phantom...?*

```
<property name="MIEHG_FORWARD" value="0.87" />
    <property name="MIEHG_BACKWARD" value="0.87" />
    <property name="MIEHG_FORWARD_RATIO" value="1.0" />
    <propertyvector name="MIEHG" unit="cm" energyunit="eV">
      <ve energy="4.13" value="0.01"/>
      <ve energy="3.54" value="0.01"/>
      <ve energy="3.1" value="0.01"/>
      <ve energy="3.07" value="0.01"/>
      <ve energy="3.06" value="0.01"/>
      <ve energy="3.05" value="0.01"/>
      <ve energy="2.75" value="0.01"/>
      <ve energy="1.77" value="0.01"/>
      <ve energy="1.0" value="0.01"/>
    </propertyvector>
```

*« fantome monocouche standard voir p79 »*

**Paramètres optiques par défaut** Dans la suite du chapitre, plusieurs mesures sur fantômes seront présentées. Des paramètres optiques standards sont définis : $\mu_a = 3\ cm^{-1}$, $\mu_s = 100\ cm^{-1}$, $g = 0,87$ et $[Fluorophore] = 10^{-5}\ M$. Si aucune précision n'est apportée, ces paramètres sont utilisés par défaut.

*Mais … chapitre 2 – Fantomes optiques –* ***absorption modelisee par l'encre de Chine*** *: p67*
*« … dilution d'encre utilisee pour obtenir un coeff. d'absorption de 15cm$^{-1}$??? »*

| Marque d'encre | λ d'excitation | $\frac{V_{encre\ pur}}{V_{total}}$ | Référence |
|---|---|---|---|
| Pelikan | 405$nm$ | $2 \cdot 10^{-3}$ | La présente thèse |
| Higgins | | $\sim 10^{-3}$ | [Keränen et al., 2010] |
| Pelikan | 632,8 $nm$ | $3 \cdot 10^{-3}$ | [Ninni et al., 2010] |
| Higgins | | $4 \cdot 10^{-3}$ | |
| Pelikan | 833 $nm$ | $4 \cdot 10^{-3}$ | |

TABLE 2.4 – Tableau comparatif de la quantité d'encre diluée nécessaire à obtenir $\mu_a = 15\ cm^{-1}$

**$\mu_{Absorption}$ = 15cm$^{-1}$ ou 3cm$^{-1}$?**

*« billes diffusives de melamine formaldehyde de 410nm de diametre, voir p65 »*

| Billes, diamètre | Concentration $(mg/ml)$ | Densité $(g \cdot cm^{-3})$ | $\sigma_s$ $(cm^2)$ | $g$ |
|---|---|---|---|---|
| MF, 410 $nm$ | 100 | 1,51 | $1,91 \cdot 10^{-9}$ | 0,87 |
| Si, 304 $nm$ | 50 | 2 | $2,73 \cdot 10^{-12}$ | 0,82 |
| Si, 585 $nm$ | 50 | 2 | $4,21 \cdot 10^{-11}$ | 0,94 |

TABLE 2.3 – Tableau des billes diffusives à anisotropie de diffusion permettant d'obtenir une anisotropie $g$ compatible avec celle mesurée sur des tissus cérébraux

*Ces billes ont* ***aussi*** *un coefficient d'absorption.(slide suivant)*

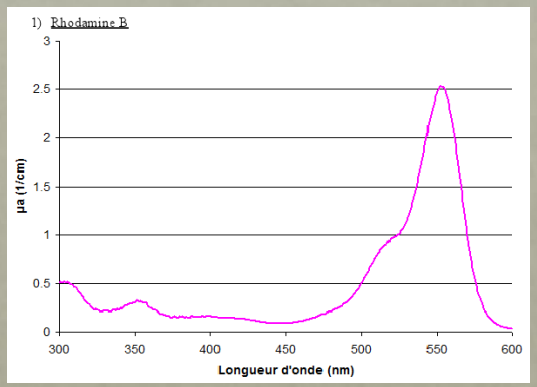
$$M_{absorption\ phantom} = M_{absorption\ encre} + M_{absorption\ billes}\ ???$$

# Definition of the Fluorescent Material

```
    <propertyvector name="WLSABSLENGTH" unit="cm" energyunit="eV">
       <ve energy="4.13" value="2.0"/>
       <ve energy="3.54" value="3.33"/>
       <ve energy="3.1" value="5.0"/>
       <ve energy="2.75" value="6.66"/>
       <ve energy="2.48" value="1.66"/>
       <ve energy="2.38" value="1.0"/>
       <ve energy="2.34" value="0.83"/>
       <ve energy="2.25" value="0.416"/>
       <ve energy="2.21" value="0.4"/>
       <ve energy="2.17" value="0.588"/>
       <ve energy="2.14" value="2.0"/>
       <ve energy="2.07" value="16.66"/>
       <ve energy="2.0" value="16.66"/>
       <ve energy="1.9" value="16.66"/>
       <ve energy="1.85" value="16.66"/>
       <ve energy="1.77" value="16.66"/>
       <ve energy="1.0" value="20.00"/>
    </propertyvector>
    <propertyvector name="WLSCOMPONENT" energyunit="eV">
       <ve energy="4.13" value="0.0"/>
       <ve energy="3.54" value="0.0"/>
       <ve energy="3.1" value="0.0"/>
       <ve energy="2.75" value="0.01"/>
       <ve energy="2.48" value="0.04"/>
       <ve energy="2.38" value="0.03"/>
       <ve energy="2.34" value="0.03"/>
       <ve energy="2.25" value="0.12"/>
       <ve energy="2.21" value="0.25"/>
       <ve energy="2.17" value="0.42"/>
       <ve energy="2.14" value="0.97"/>
       <ve energy="2.07" value="0.97"/>
       <ve energy="2.0" value="0.27"/>
       <ve energy="1.9" value="0.11"/>
       <ve energy="1.85" value="0.05"/>
       <ve energy="1.77" value="0.02"/>
       <ve energy="1.0" value="0.001"/>
     </propertyvector>
<property name="WLSTIMECONSTANT" value="1.7" unit="ns"/>
    </propertiestable>
  </material>
```

Fluorescéine diluée à $10^{-5}$ M.
Rhodamine B diluée à $10^{-5}$ M.
Billes MF, 410 nm, diluées à $\frac{V_{billes}}{V_{total}} = 2{,}3 \cdot 10^{-5}$

## *coefficient d'absorption*



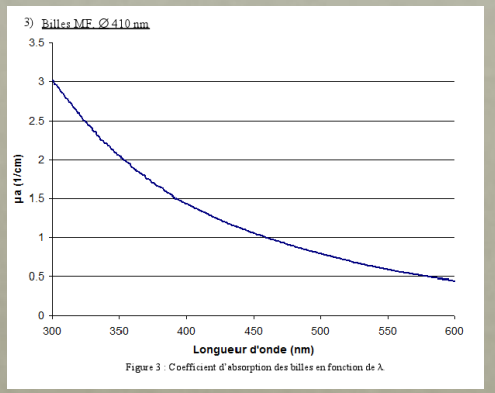



Figure 3 : Coefficient d'absorption des billes en fonction de λ

**IMNC** : fantômes optiques absorbants (~ 1 $cm^{-1}$), diffusants (100 $cm^{-1}$) et fluorescents ([fluorophore] = $10^{-5}$ M).

**Evry** : Solution diluée de fluorophore ($10^{-5}$ M)

## *Intensite de fluorescence*

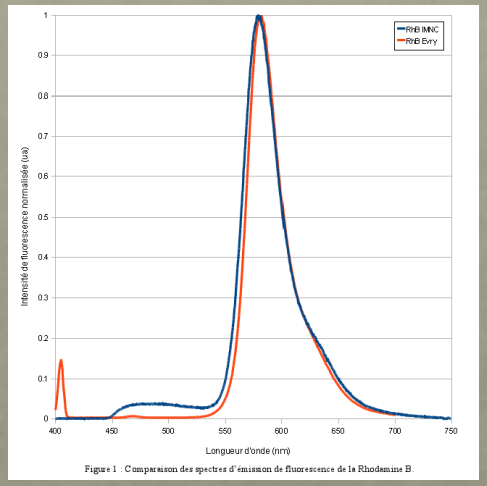


Figure 1 : Comparaison des spectres d'émission de fluorescence de la Rhodamine B.

| Solution | $V_{bille}/V_{tot}$ | $\mu_s$ ($cm^{-1}$) |
|---|---|---|
| C4 | 2.30E-005 | 0.08 |
| C5 | 3.86E-006 | 0.01 |

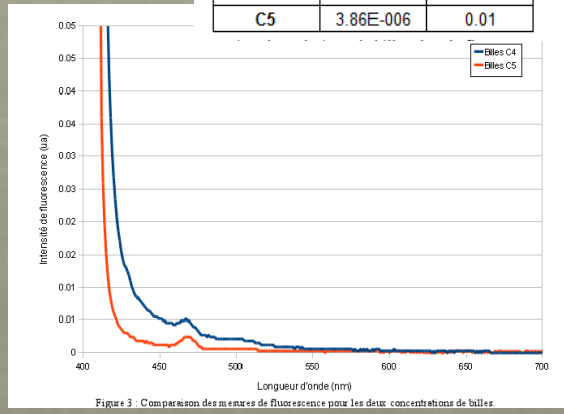
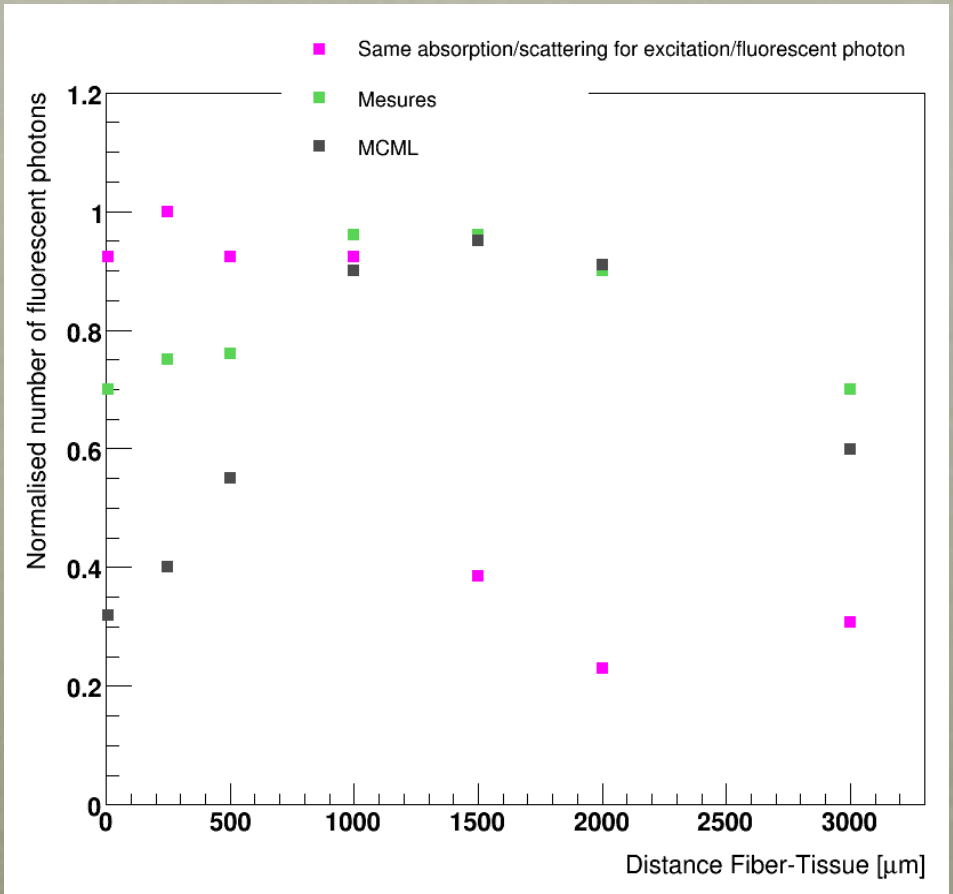
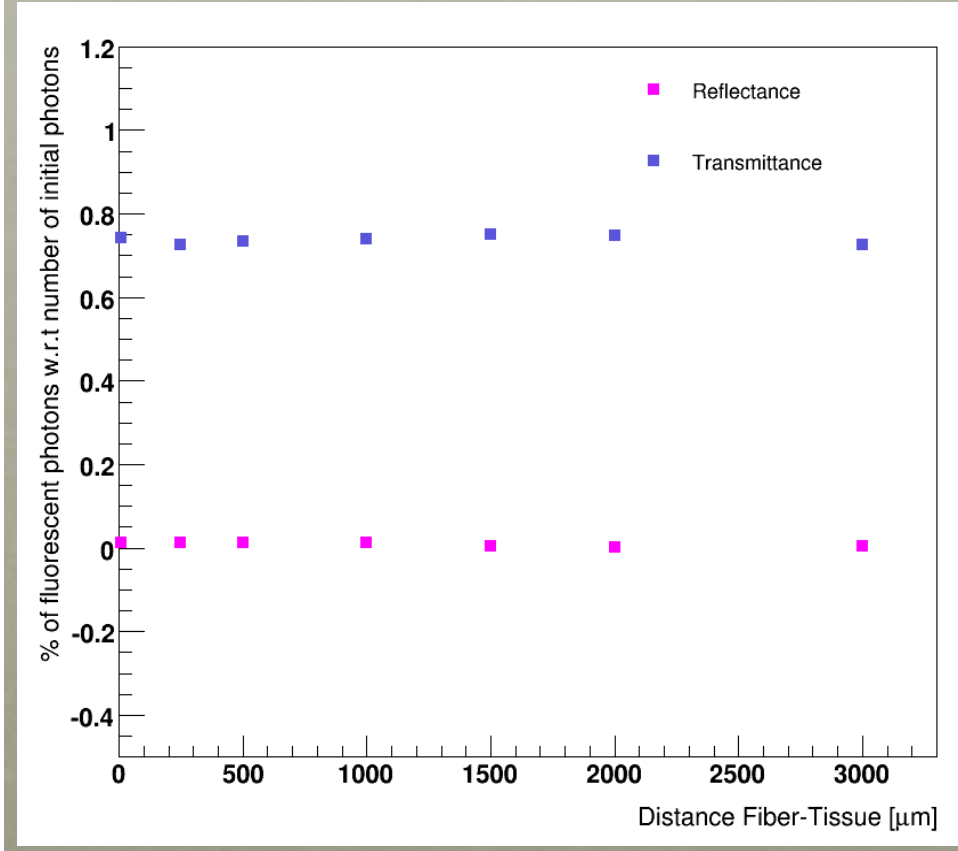


Figure 3 : Comparaison des mesures de fluorescence pour les deux concentrations de billes.

# Preliminary result using GATE



# Beer–Lambert law

**Relates the absorption of light to the properties of the material.**


absorption coefficient

path length

For liquids, these relations are usually written as:

$$T = \frac{I}{I_0} = 10^{-\alpha \ell} = 10^{-\varepsilon \ell c}$$

whereas for gases, and in particular among physicists and for spectroscopy and spectrophotometry, they are normally written

$$T = \frac{I}{I_0} = e^{-\alpha' \ell} = e^{-\sigma \ell N}$$

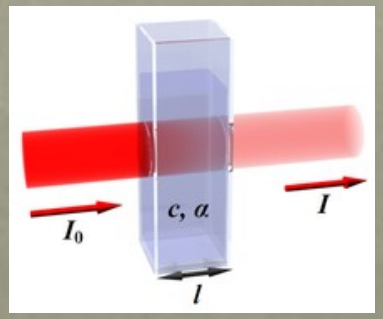
The transmission (or transmissivity) is expressed in terms of an absorbance which, for liquids, is defined as

$$A = -\log_{10}\left(\frac{I}{I_0}\right) \qquad A = \varepsilon \ell c = \alpha \ell$$

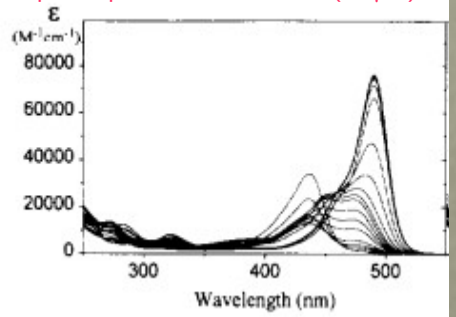
α = 1/ mean free path

whereas, for gases, it is usually defined as

$$A' = -\ln\left(\frac{I}{I_0}\right).$$




Absorption spectra of fluorescein (14 μM)




From Barbara's thesis (p.74):
$\alpha = 0{,}13\ cm^{-1}$ (at 405nm and $c = 10^{-5}M$)

$\varepsilon = 0{,}13/10^{-5} = 13000\ cm^{-1}\ M^{-1}$

# Gate v6.2 Updates

Successful installation and compilation (ccmake) of Gate v6.2

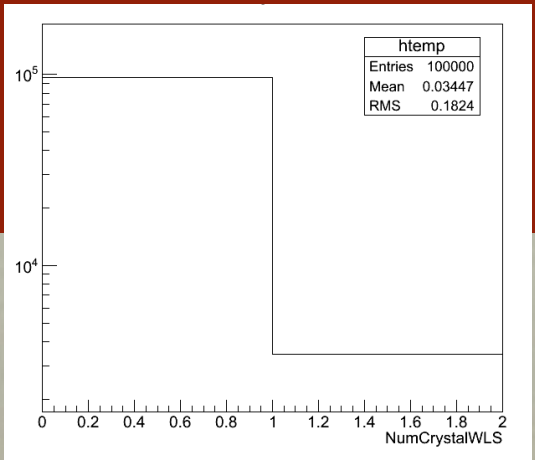
Modifications in the following classes :

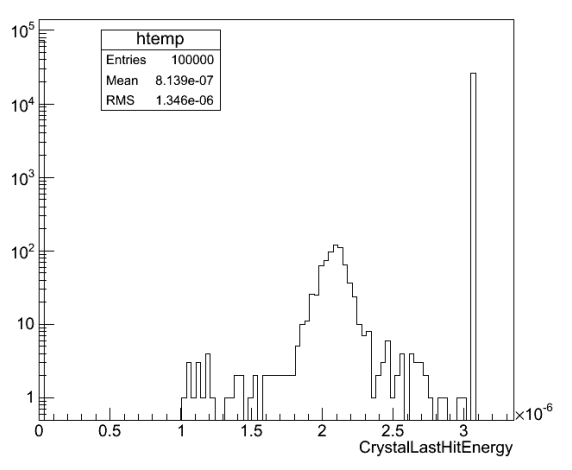
- GateFastAnalysis (remove all about the phantom hits tree)
- GateRootDefs (remove all about the phantom hits tree)
- GateToRoot (code updated – All Ntuple variables are here)

+ New classes :

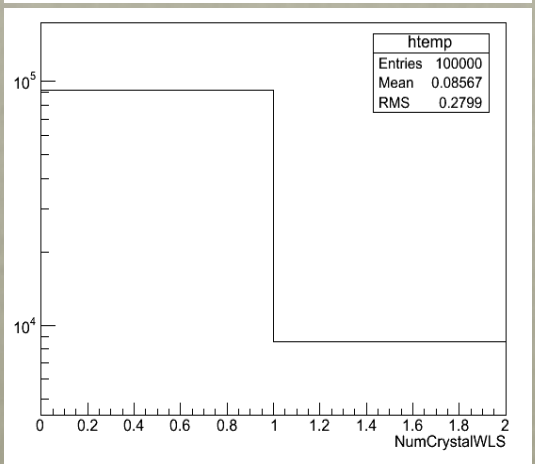
- GateOpticalWLSPB
- GateElTub (Elliptical Tub)

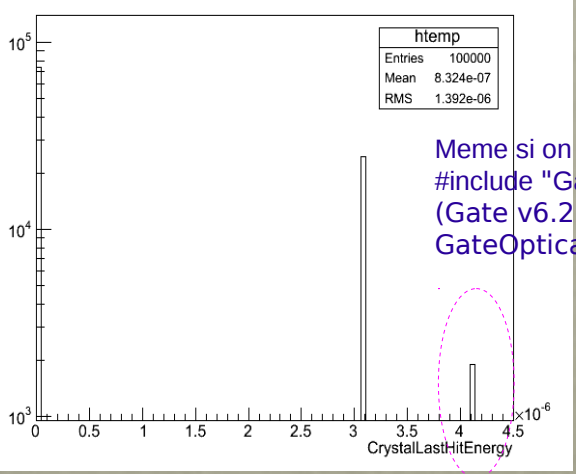
Gate v6.1
(Geant4.9.4)
+ new code




Gate v6.2
(Geant4.9.5.p01)
+ new code

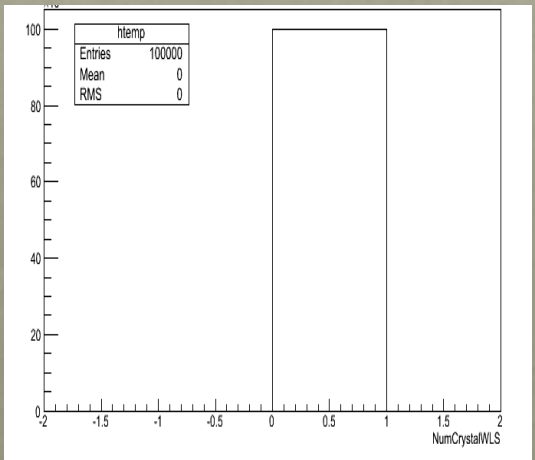


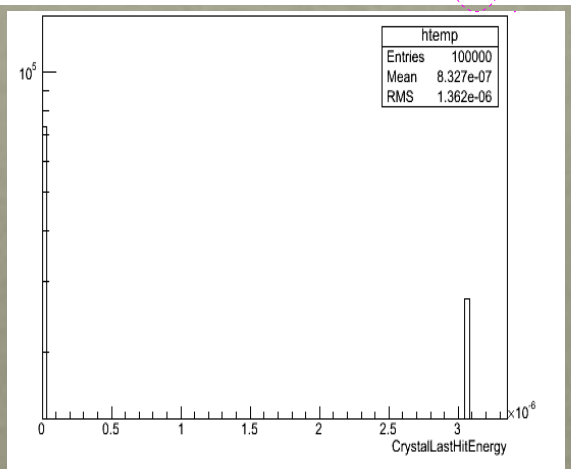




Meme si on
#include "GateConfiguration.h"
(Gate v6.2) dans le
GateOpticalWLSPB.*

Not physical !
I posted on the
Geant4 HN.
(june 21st)

Gate v6.2
(Geant4.9.5.p01)
+ new code
+ WLS disabled



```
**PostStepDoIt (after all invocations):
   ++List of invoked processes
     1) Transportation
     2) OpticalWLS (Forced)
     3) OpticalBoundary

   ++G4Step Information
     Address of G4Track    : 0x30c1690
     Step Length (mm)      : 0.2320605161930325
     Energy Deposit (MeV)  : 0
     ------------------------------------------------------------------------
       StepPoint Information              PreStep            PostStep
     ------------------------------------------------------------------------
        Position - x (mm)   :  -0.5637256855699085 -0.4693431904051834
        Position - y (mm)   : -0.04113059316868121 -0.2344379251878179
        Position - z (mm)   :   0.3918640537076097  0.3048220915864546
        Global Time (ns)    :    400000.0072948495   400000.0083785483
        Local Time (ns)     : 0.0072948494776300460.008378548263242075
        Proper Time (ns)    :                    0                   0
        Momentum Direct - x :   0.4067150100028907  0.4067150100028907
        Momentum Direct - y :   -0.833003973232309  -0.833003973232309
        Momentum Direct - z :  -0.3750830324308675 -0.3750830324308675
        Momentum - x (MeV/c): 1.244547930608846e-061.244547930608846e-06
        Momentum - y (MeV/c): -2.548992158090866e-06-2.548992158090866e-06
        Momentum - z (MeV/c): -1.147754079238455e-06-1.147754079238455e-06
        Total Energy (MeV)  :             3.06e-06            3.06e-06
        Kinetic Energy (MeV):             3.06e-06            3.06e-06
        Velocity (mm/ns)    :            214.13747           214.13747
        Volume Name         :          module_phys         module_phys
        Safety (mm)         :   0.4585171483295161  0.2268088906382863
        Polarization - x    :   0.9058540343222892  0.9058540343222892
        Polarization - y    :   0.4209257767605756  0.4209257767605756
        Polarization - Z    :  0.04743373230665295 0.04743373230665295
        Weight              :                    1                   1
        Step Status         :        PostStep Proc       PostStep Proc
        Process defined Step:           OpticalMie          OpticalWLS
     ------------------------------------------------------------------------
```

```
    ++List of secondaries generated (x,y,z,kE,t,PID):  No. of secodaries = 1
      [Note]Secondaries from AlongStepDoIt included.
      -0.4693431904051834 -0.2344379251878179 0.3048220915864546 4.129999999999999e-06 400001.7083785483      opticalphoton

#Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    8   -0.469   -0.234    0.305  3.06e-06        0    0.232       2.2 module_phys OpticalWLS
Track (trackID 1, parentID 0) is processed with stopping code 2
A new track 0x30c1790 (trackID 2, parentID 1) is passed to G4StackManager.
### pop requested out of 1 stacked tracks.
Selected G4StackedTrack : 0x30c1a90 with G4Track 0x30c1790 (trackID 2, parentID 1)
Track 0x30c1790 (trackID 2, parentID 1) is passed to G4TrackingManager.

*****************************************************************************************************
* G4Track Information:   Particle = opticalphoton,   Track ID = 2,   Parent ID = 1
*****************************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0   -0.469   -0.234    0.305  4.13e-06        0        0         0 module_phys initStep
```