



The application of GEANT4 simulation code for brachytherapy treatment

Maria Grazia Pia

INFN Genova, Italy and CERN/IT

Maria.Grazia.Pia@cern.ch

F. Foppiano[1], S. Agostinelli[1,2], S. Garelli[1], G. Paoli[1], P. Nieminen[3]

[1]*National Cancer Institute and* [2]*Physics Dept. of Genova,* [3]*European Space Agency*

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Outline

- Introduction to brachytherapy
- Application of Monte Carlo simulation to brachytherapy
- The GEANT4 toolkit and its extension targeted to medical physics
- Results
  - Simulation of the attenuation coefficients for various materials
  - Simulation of a brachytherapy radioactive source
    - *Description of ^{192}Ir source geometry used in real treatments*
    - *Simulation of the anisotropy function in water*
    - *Simulation of isodoses in water*
- Conclusions and future goals

What is brachytherapy?

- Brachytherapy is a medical therapy used for cancer treatments
- Radioactive sources are used to deposit therapeutic doses near tumors while preserving surrounding healthy tissues

- In HDR endocavitary brachytherapy:
  - a radioactive source, for example ^{192}Ir, is used
  - the source moves along catheters inserted in natural cavities of the body, e.g. vagina or bronchi; this allows the deposition of the therapeutic tumor dose right where it is needed
  - the source track is programmed by an after-loading unit

Brachytherapy treatment set-up

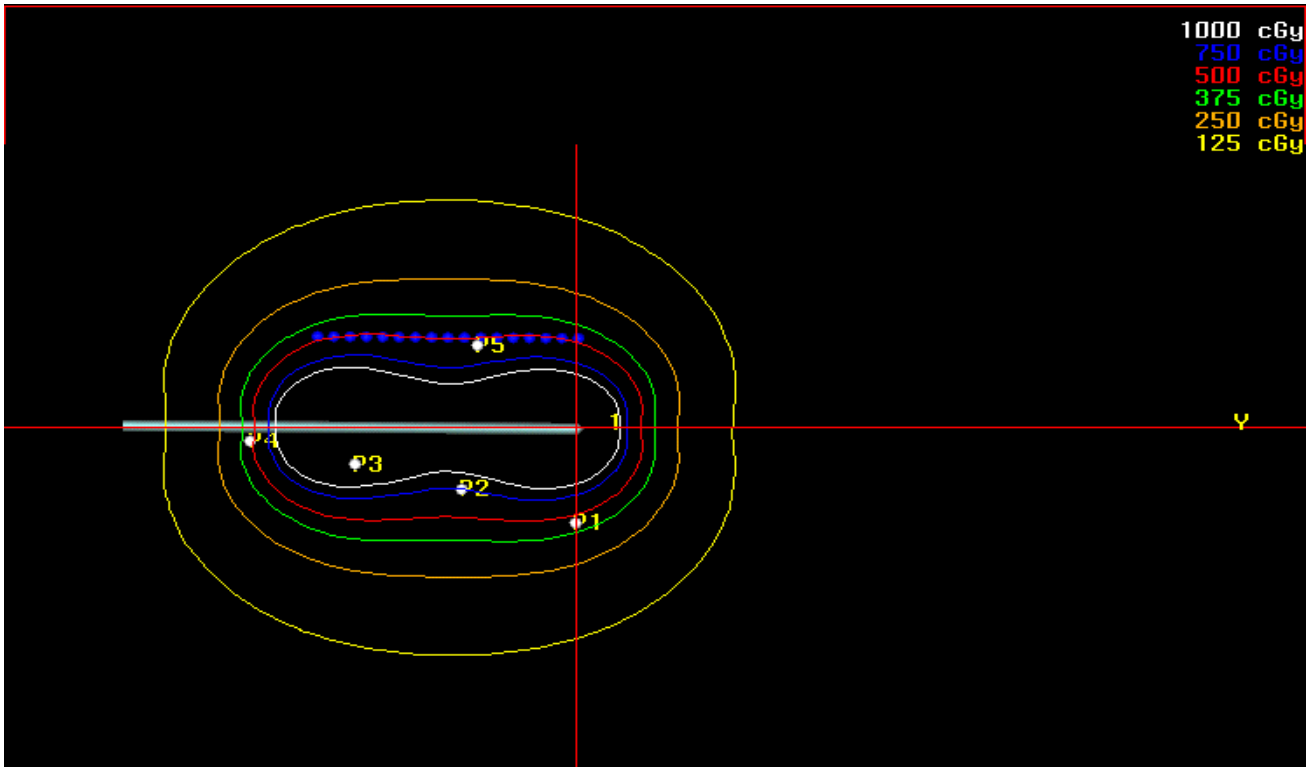
A naso-pharynx endocavitary treatment

After-loading unit

Catheter along which source moves

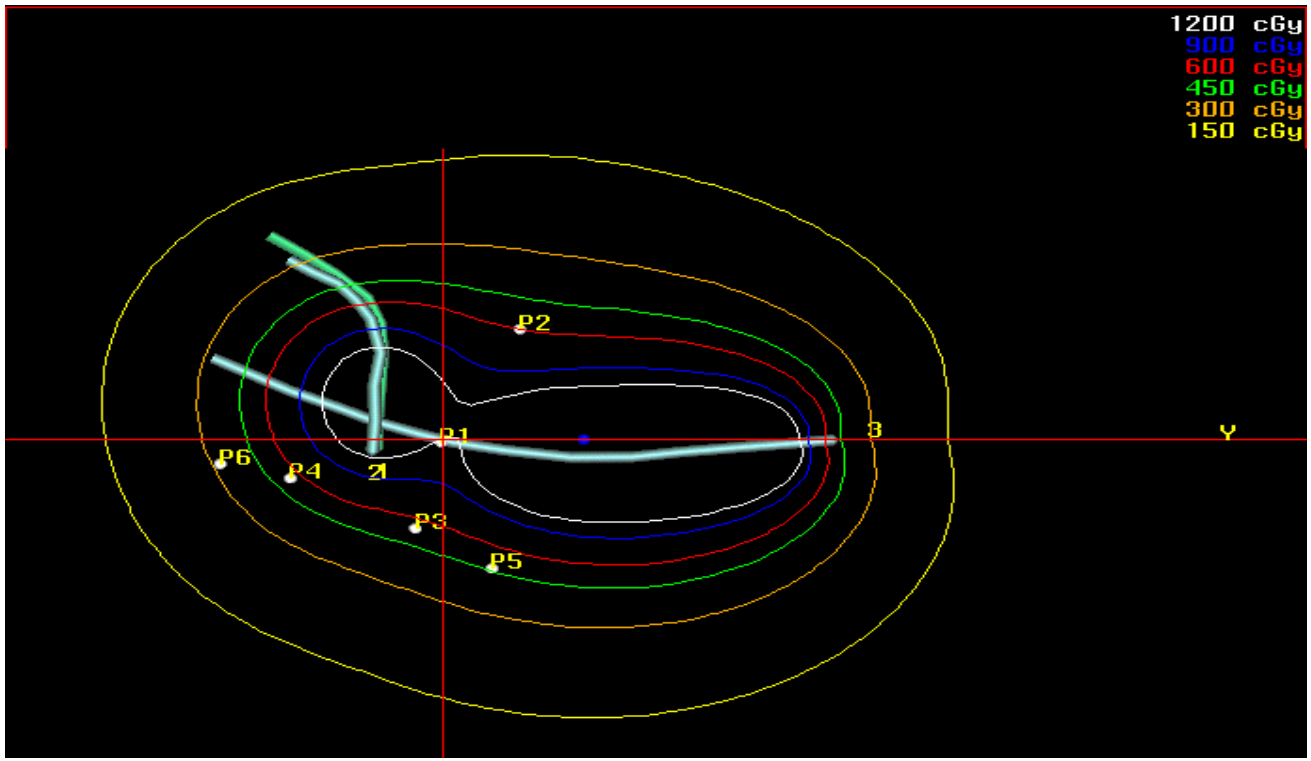
Brachytherapy treatment planning (1)

A typical vaginal treatment plan: source moves along a single catheter



Brachytherapy treatment planning (2)

A typical intra-uterine treatment plan: source moves along 3 catheters



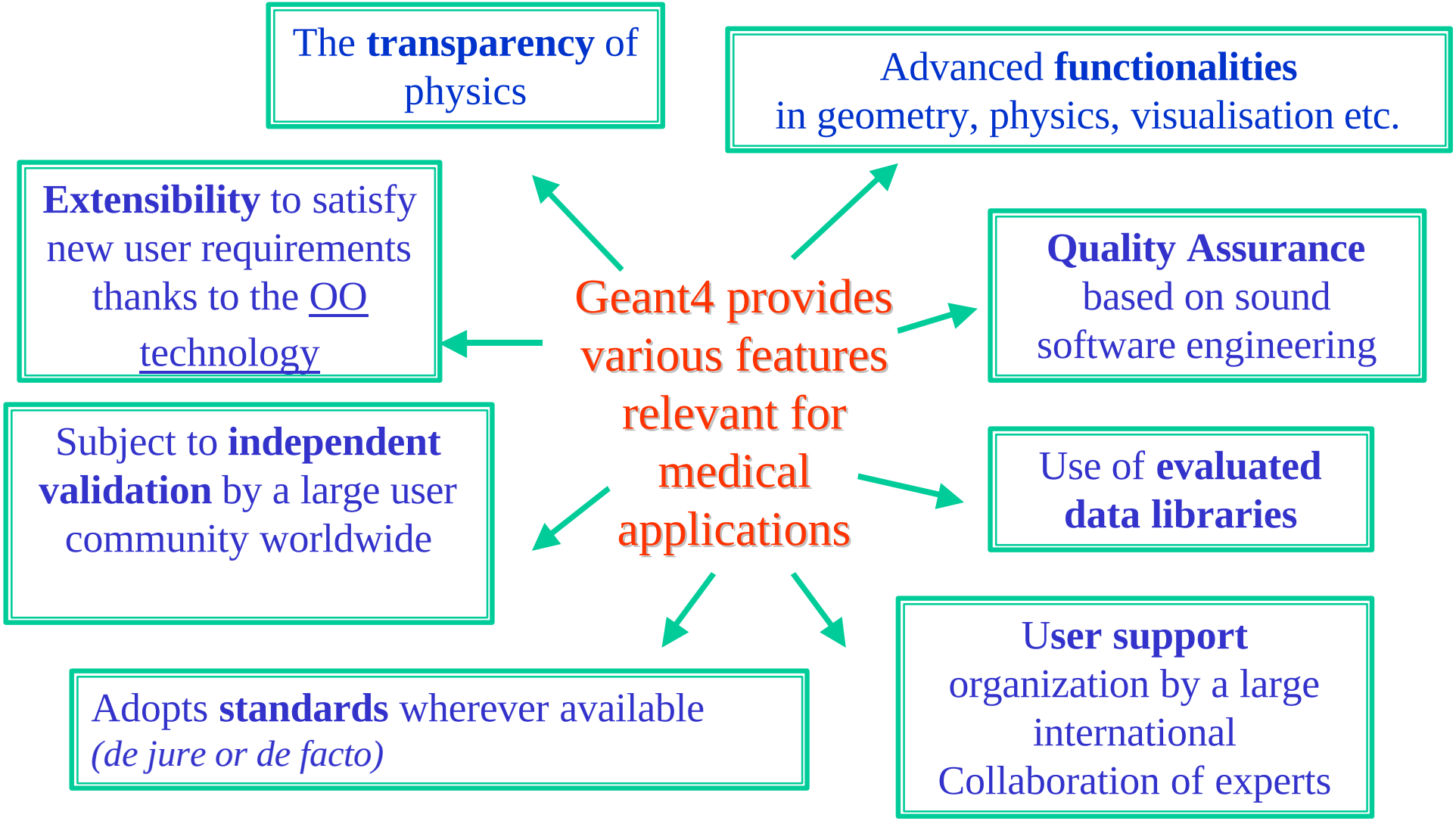
Monte Carlo for brachytherapy

Monte Carlo simulation topics for brachytherapy:

- Dose calculation
  - *Computation of dose deposition kernels for treatment planning dose calculation algorithms based on convolution/superposition methods*
  - *Separation of primary, first scatter and multiple scatter components for complex dose deposition models*
  - *Computation of other model-dependent parameters, e.g. anisotropy function*
  - *Accurate computation of dose deposition in high gradient regions (i. e. near sources)*
- Verification of experimental calibration procedures

GEANT4

is an Object Oriented Toolkit for the simulation of the passage of particles through matter



GEANT4
Low Energy Electromagnetic Physics

Geant4 *Low Energy Electromagnetic* package extends the coverage of physics interactions

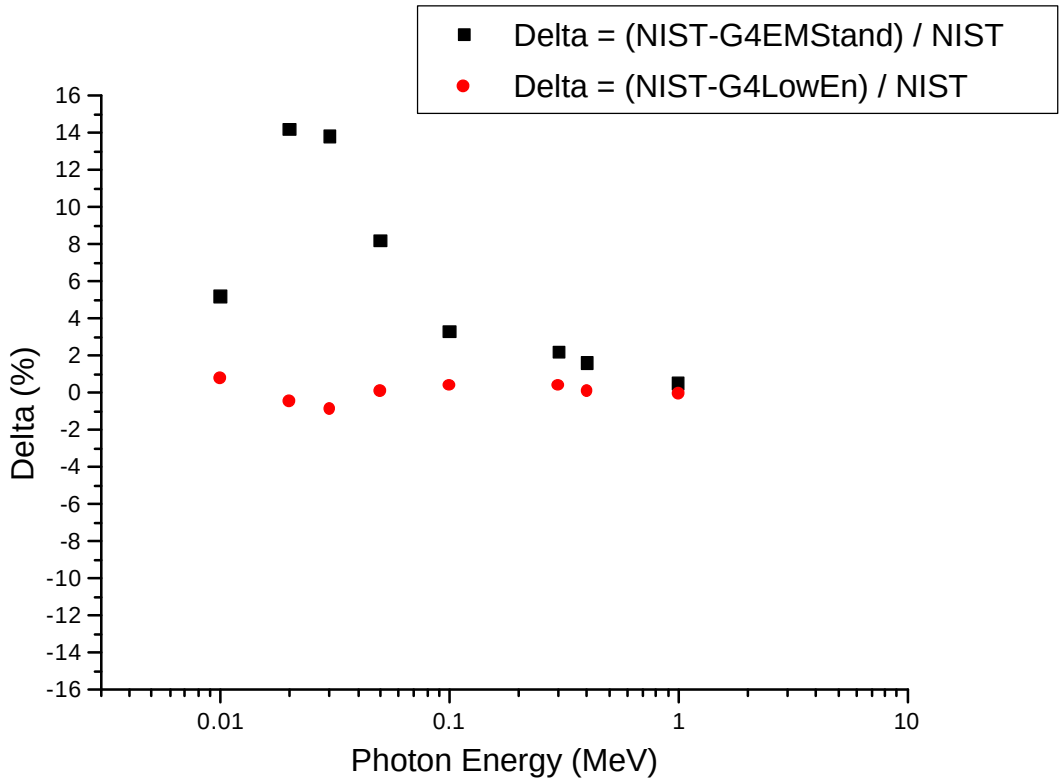
down to 250 eV for electrons and photons
- *based on the LLNL data libraries*
- *shell effects*

down to ~ 1 keV for hadrons and ions
- *Bethe-Block above 2 MeV*
- *Ziegler and ICRU parameterisations* (with material dependence)
- *free electron gas model*
- *quantal harmonic oscillator model*
- *charge dependence (Barkas effect)*

Further extensions are in progress

Relevant for ***medical****, space science, astrophysics etc. applications*

Simulation of m/r



Simulated water μ/ρ

(photon attentuation coefficient)

versus NIST data

with Geant4

Standard electromagnetic package

and

Low Energy extensions

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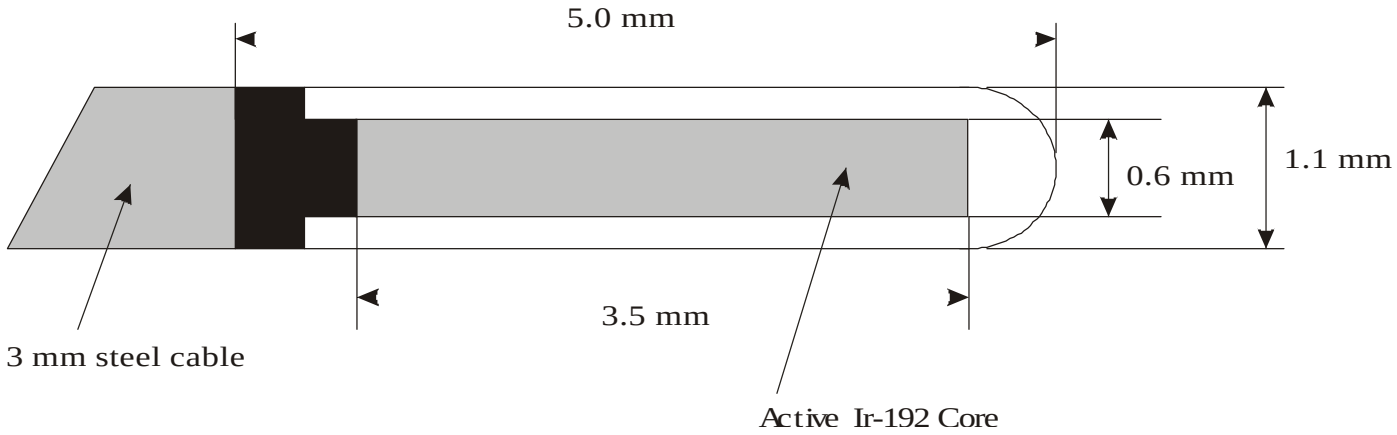
(statistical error smaller than marker size)

Description of m-Selectron ^{192}Ir source

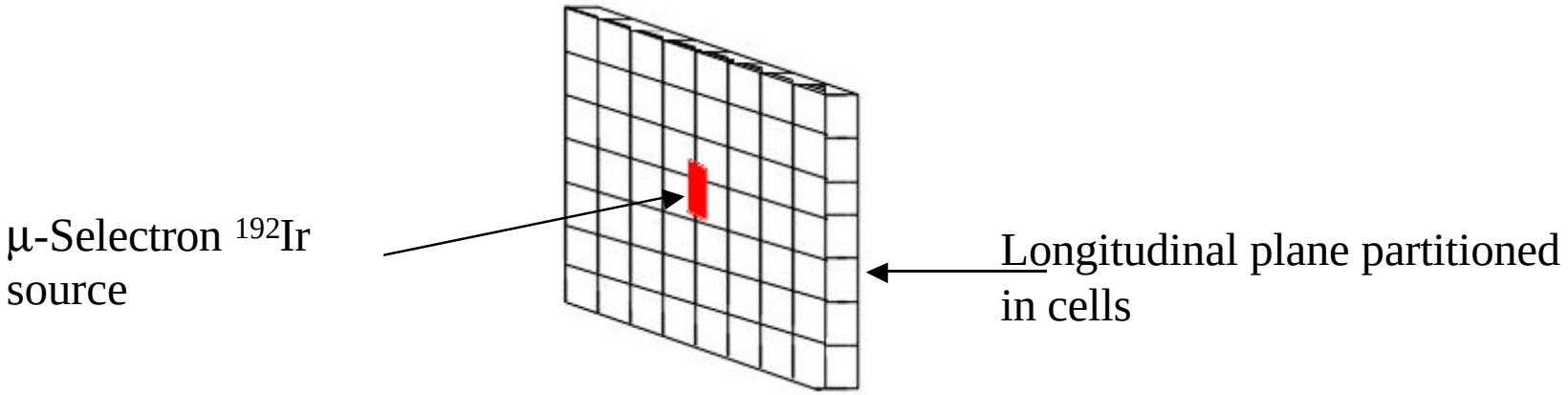
- GEANT4 allows complete flexible description of the real geometry



- ^{192}Ir energy spectrum
  - **currently described as monochromatic at 356 keV**
  - **will soon be described by the new GEANT4 RadioactiveDecay class**

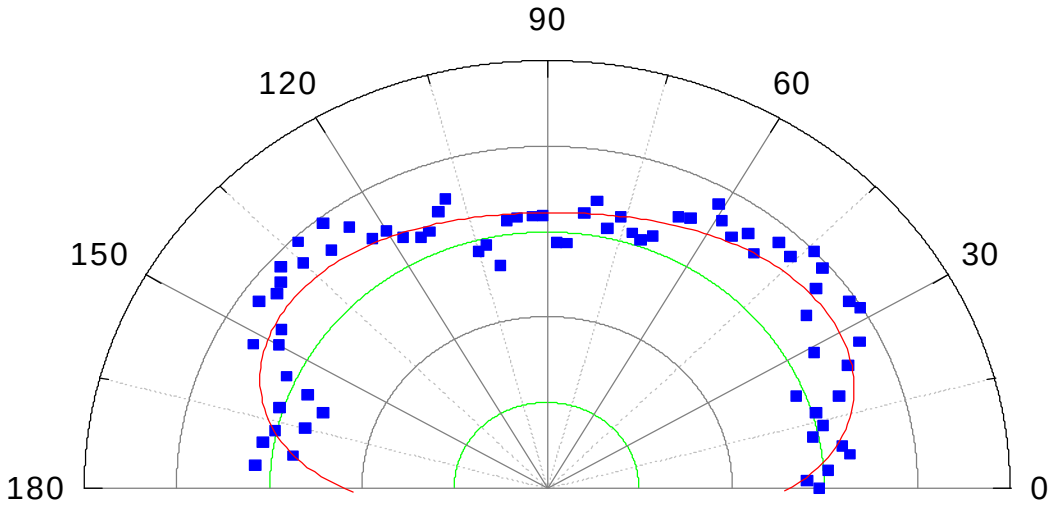
Simulation of dose deposition in water

- The simulated source is placed in a 30 cm water box
- The dose deposition is investigated in the longitudinal plane
- Plane is partitioned in 1 million $1mm^3$ voxels
- A minimum of 10 millions photons are generated on the 4π solid angle



Investigated quantities: anisotropy

- The dose deposition is not isotropic due to source geometry and auto-absorption, encapsulation and shielding effects
- Anisotropy can be described by a simple angular function which can be computed by re-sampling our simulated voxels grid calculations



Investigated quantities: isodoses

- The simulated dose deposition data can also be used to derive isodoses

Conclusions and future goals

- Monte Carlo simulation is useful in brachytherapy both to obtain model-dependent parameters and to verify experimental data
- GEANT4 offers reliable particle-matter Monte Carlo simulation in a flexible modern object-oriented toolkit
- We have used GEANT4 to simulate μ/ρ coefficients and a commercial brachytherapy source with full dose deposition

- More realistic description of ^{192}Ir source energy spectrum with the new GEANT4 RadioactiveDecay class
- Simulation of shielded brachytherapy applicators