American Association of Physicists in Medicine

Task Group 195

Monte Carlo Reference Data Sets for Imaging Research

The American Association of Physicists in Medicine

2011 JOINT AAPM/COMP MEETING

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Task Group No. 195 - Monte Carlo Reference Data Sets for Imaging Research

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Charge The primary charge of this TG is to develop a set of Monte Carlo (MC) simulation geometries which are relevant to diagnostic imaging, perform benchmark MC studies on a number of the geometries using a variety of established code systems such as EGSnrc, MCNP, Penelope and Geant4, and report the findings. Findings will include MC measured parameters such as dose, variance in dose, and scatter to primary relationships. For scatter assessment, dose in the mathematical phantoms and in realistic imaging geometries to the detector will be evaluated.

Bylaws: Not Referenced. **Rules:** Not Referenced.

Approved Date(s) Start: 10/20/2009
End: 1/1/1900

Committee Keywords: TG195

- Board of Directors [Status]
  - Science Council [Status]
    - Research [Status]
      - **TG195 - Monte Carlo Reference Data Sets for Imaging Research** [Status]

» **Active Task Group listing**

Chair is Ioannis Sechopoulos

6 Year Veteran Geant4 User

Emory University, Atlanta Georgia

AAPM TG 195 Charge

Develop and publish a set of fully described simulations conditions and results for people to use as cases to validate their MC codes against.

The task group is 10 members that use Monte Carlo for their research.

Putting together 11 cases that, once fully described we'll all run in the different codes (Geant4, MCNPX, EGNRC, Penelope) and publish both the full description and results.

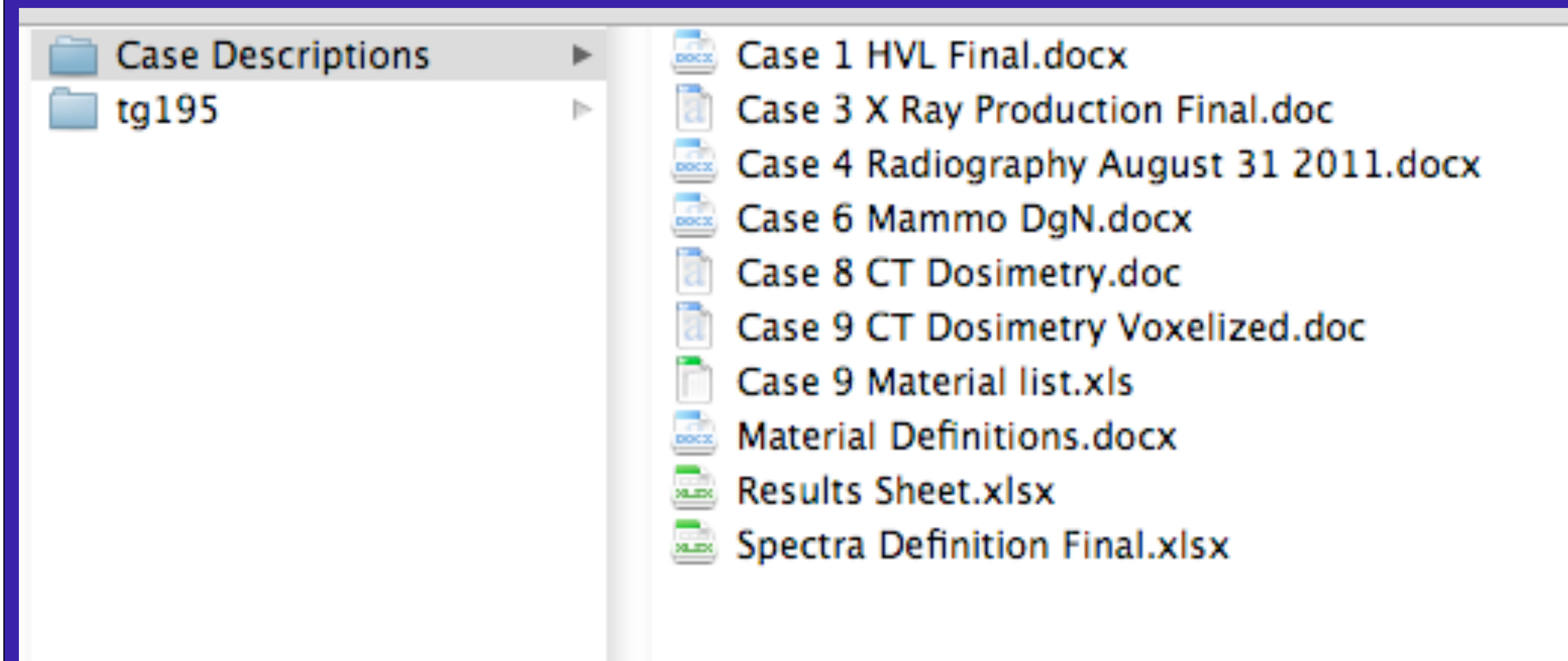
The idea is for people who want to validate their MC software, rather than search the literature trying to find similar conditions published previously and trying to figure out some of the always-missing details not included in papers, they will be able to refer to our TG report and use these fully defined case sets and compare their results to our fully explained results, and therefore consider their software validated.

For now we are concentrating on x-ray based diagnostic tests (mammography, radiography, CT), but if this goes well, I expect to have follow-ups for nuclear medicine diagnostics and even therapy.

6 Cases, Each with Data

Benchmarks are well described.

Numbering goes from Case 1 to Case 9 (3 cases were eliminated from the originally defined set)



Case 1

TG195: Monte Carlo data sets for imaging research.
Specifications for Half Value Layer (HVL) case.

Aims

- Verify the accuracy of half-value layer calculations.
- Create a reference set of Monte Carlo simulations of half value layer in mammography and radiography.

Geometry (figure 1)

- Filter is a disk of thickness **t** mm and diameter 40 mm. The central axis of the filter coincides with the +z axis. The superior face of the filter lies in the plane z=+100 mm.
- Simulations are done for two thicknesses (**t**), corresponding to the theoretical half-value layer (HVL) and quarter value layer (QVL), respectively, as given in table 1.

Materials

- Filter material is aluminum.
- The rest of the geometry is filled with air.

Radiation source (figure 1)

- Radiation source is an isotropic x-ray point source at the geometry origin (x=0, y=0, z=0). The source irradiates a central circle of 1-mm diameter at the superior face of the filter.
- Simulations are done for monoenergetic photons and for spectra as given in table 1.
- Number of simulated source particles is such that the statistical uncertainty is 1 % on the *primary* total energy fluence in the case of monoenergetic incident photons, and on the *primary* differential energy fluence in any given bin in the case of incident spectra.

Scoring

- Scoring is done in a central circle of 10-mm diameter at the plane z=+1000 mm with and without the filters.
- For monoenergetic incident photons, the quantities scored are: (1) the primary energy fluence (ψ_p) at the incident photon energy; and, (2) the non-primary (ψ_{np}) differential energy fluence (e.g., coherent and incoherent scatter, fluorescence, etc from both air and/or filter), binned in 0.5 keV bins between zero and the incident photon energy.
- For incident spectra, the quantities scored are the primary (ψ_p) and the non-primary (ψ_{np}) differential energy fluences using the same bin definitions as the incident spectrum.
- Energy fluence is converted into collision air kerma (**k**) off-line. **k** is calculated for the primaries (k_p) and non-primaries (k_{np}). The mass energy absorption coefficient is evaluated at the central energy of each bin.
- Output is the following four air kerma ratios:
  (1) k_p at t=HVL / k_p at t=0,
  (2) k_p at t=QVL / k_p at t=0,
  (3) (k_p+k_{np}) at t=HVL / (k_p+k_{np}) at t=0,
  (4) (k_p+k_{np}) at t=QVL / (k_p+k_{np}) at t=0.

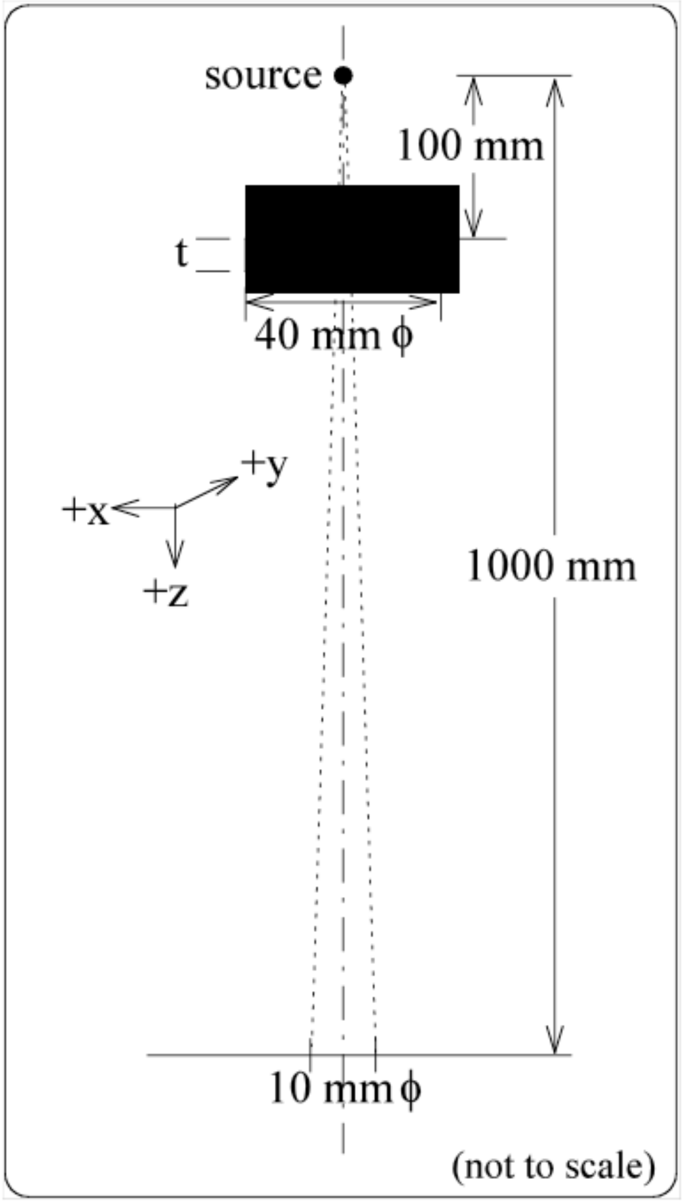


Figure 1: Geometry for HVL measurements.

Case 3

TG195: Monte Carlo data sets for imaging research.
Specifications for x-ray production case.

Aims
- Verify the accuracy of electron transport and x-ray generation in typical tube targets.
- Create a reference set of Monte Carlo simulations of x-ray generation from typical tube targets in mammography and radiography.

Geometry (figure 1)
- Target is a slab of height 25 mm, width 80 mm and thickness 10 mm. The center of the front face of the slab is at the geometry origin (x=0, y=0, z=0). The slab is tilted at an angle θ relative to the +z axis.

Materials
- Target material is either molybdenum or tungsten, depending on the incident electron kinetic energy (table 1).
- The rest of the geometry is filled with vacuum.

Radiation source (figure 1)
- Radiation source is an electron beam parallel to the +x direction and uniformly covers a circle of diameter 3 mm centered at the geometry origin (x=0, y=0, z=0).
- Electrons are monoenergetic with the energies given in table 1.
- Number of simulated source particles is such that the statistical uncertainty is 1 % on each bin of the scored x-ray energy distribution from 7.5 keV and up. Uncertainties for bins below 7.5 keV should still be reported.

Scoring (figure 2)
- Energy distribution is scored in 1 keV bins for photons crossing the plane z=+100 mm at five square areas, 10 mm x 10 mm each. The locations of the scoring areas are given in figure 2.
- For each square area, the output is the energy distribution, the integral fluence and the integral energy fluence. Areas 2, 1 and 3 reflect the heel effect while areas 4, 1 and 5 reflect symmetry.

Table 1: Simulation parameters

Case	Target	Incident electron kinetic energy (keV)	Anode tilt angle (degree)
Mammography	Mo	30	15
Radiography	W	100	11

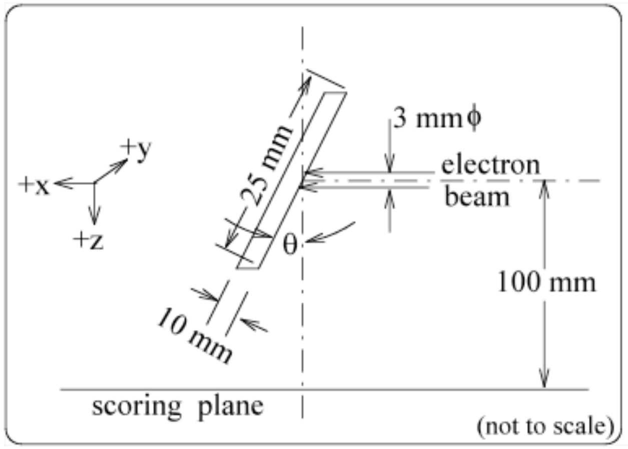


Figure 1: Geometry for x-ray production measurements.

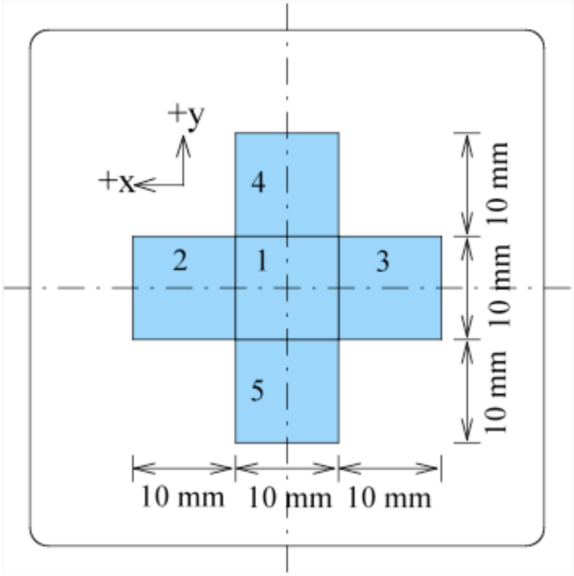


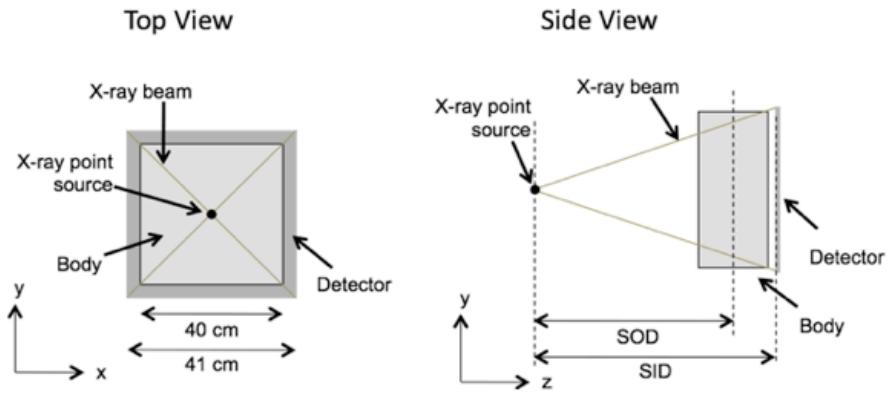
Figure 2: Five square areas of measurement (dark) at the scoring plane.

Case 4

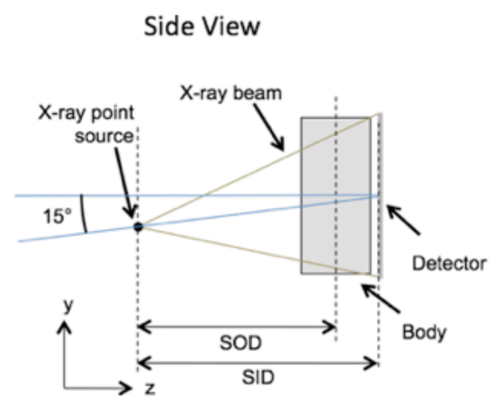
TG 195: Monte Carlo Reference Data Sets
Radiography Dosimetry and Scatter Case Description (Case #4)

Geometry Description

Zero Degree Radiography X-Ray Source Position:



15 Degree Tomosynthesis X-Ray Source Position:



Aim:

- Verify the accuracy of x-ray transport and interaction characteristics in general radiography and whole body tomosynthesis simulations.
- Depending on the application, either the dosimetry or the scatter results can be tested.

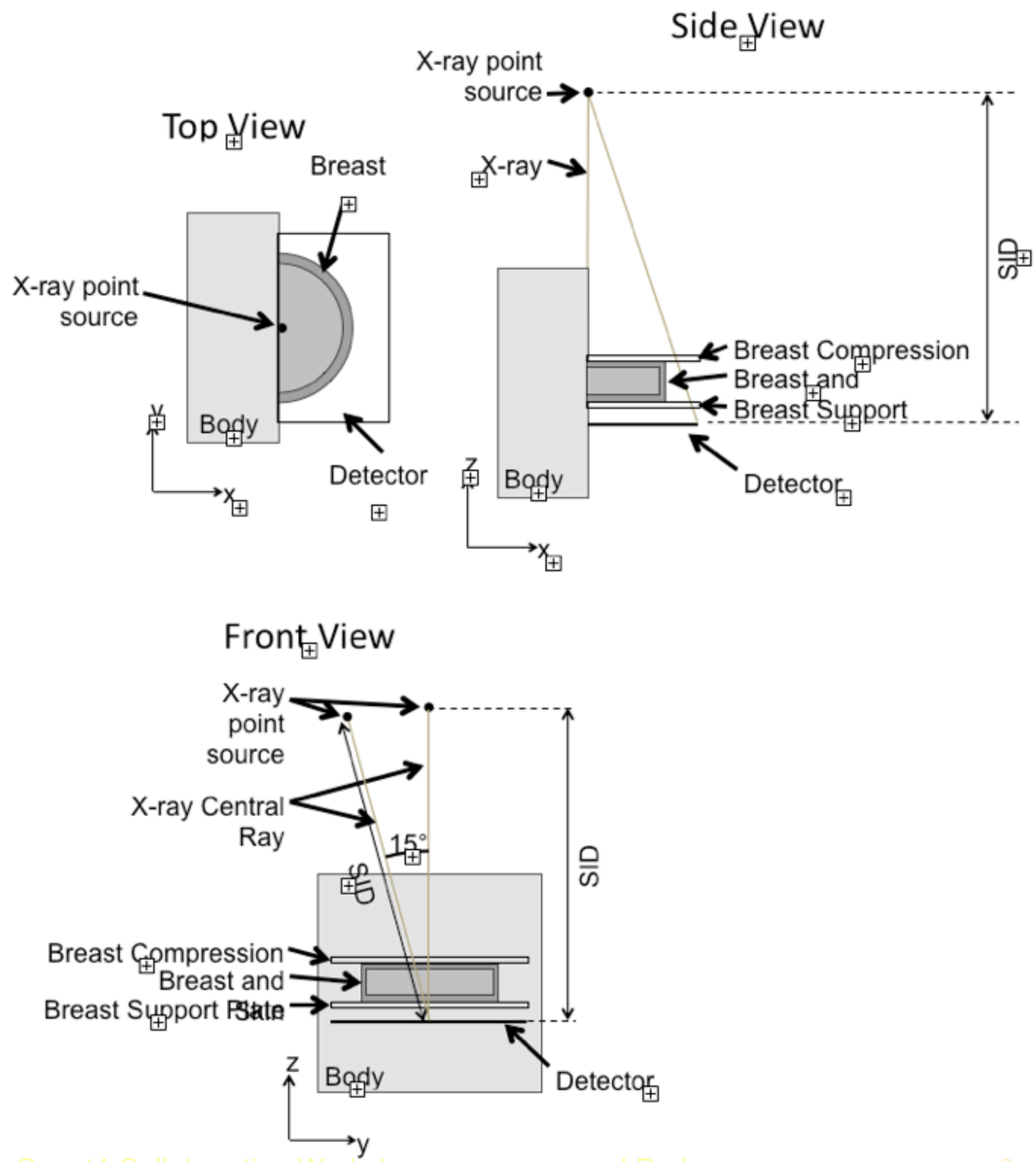
Solids:

- Body: Box with thickness (x-direction) T = 200 mm, width (y-direction) W = 400 mm and height (z-direction) H = 400 mm.
- Ideal detector: Rectangle 410 x 410 mm.

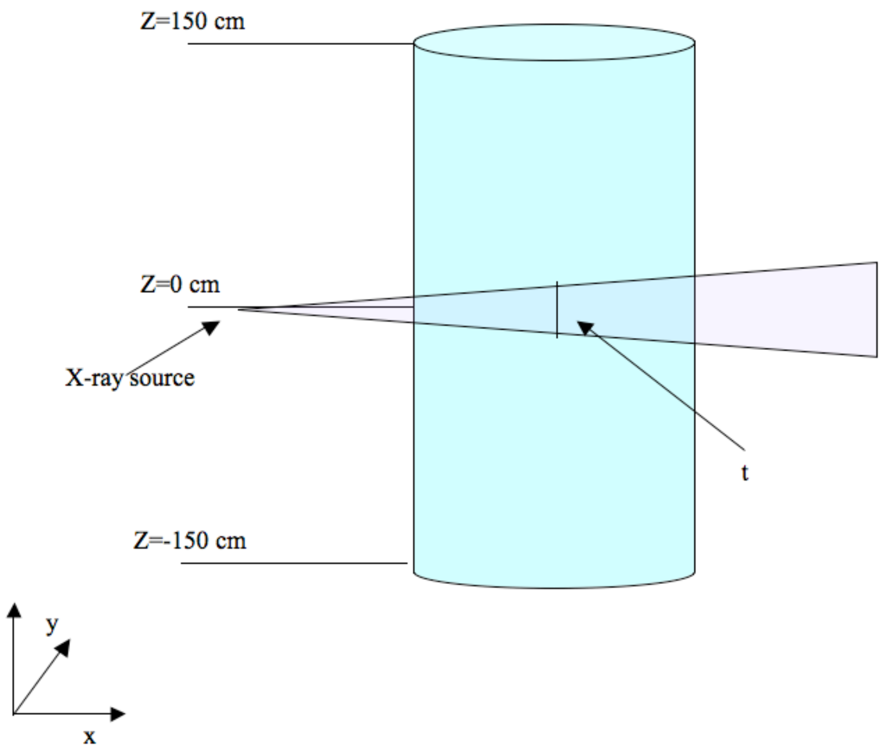
Case 6

Mammography Case Description (Case #6)

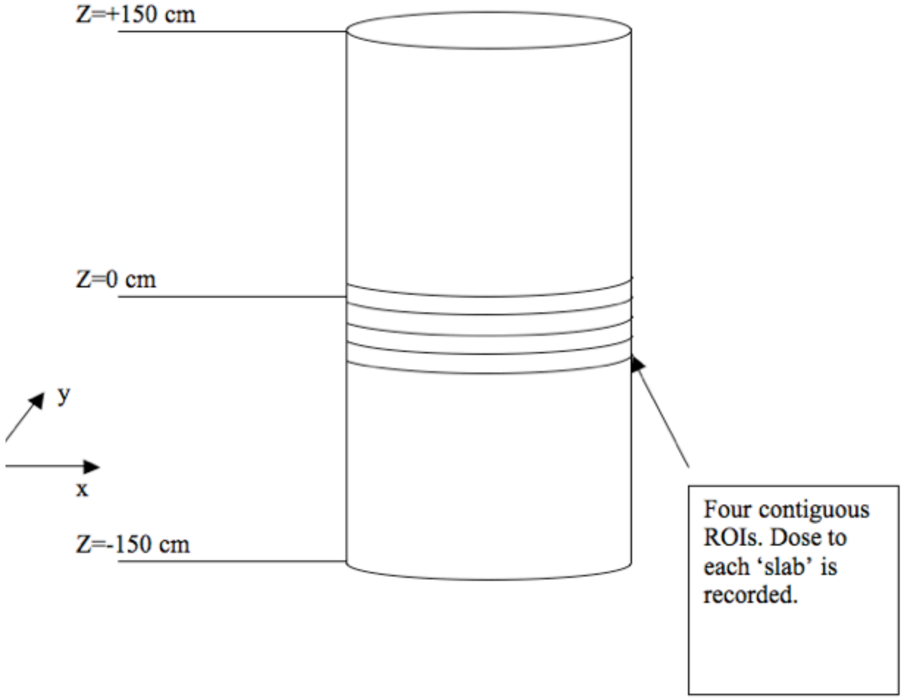
Geometry Description



Case 8

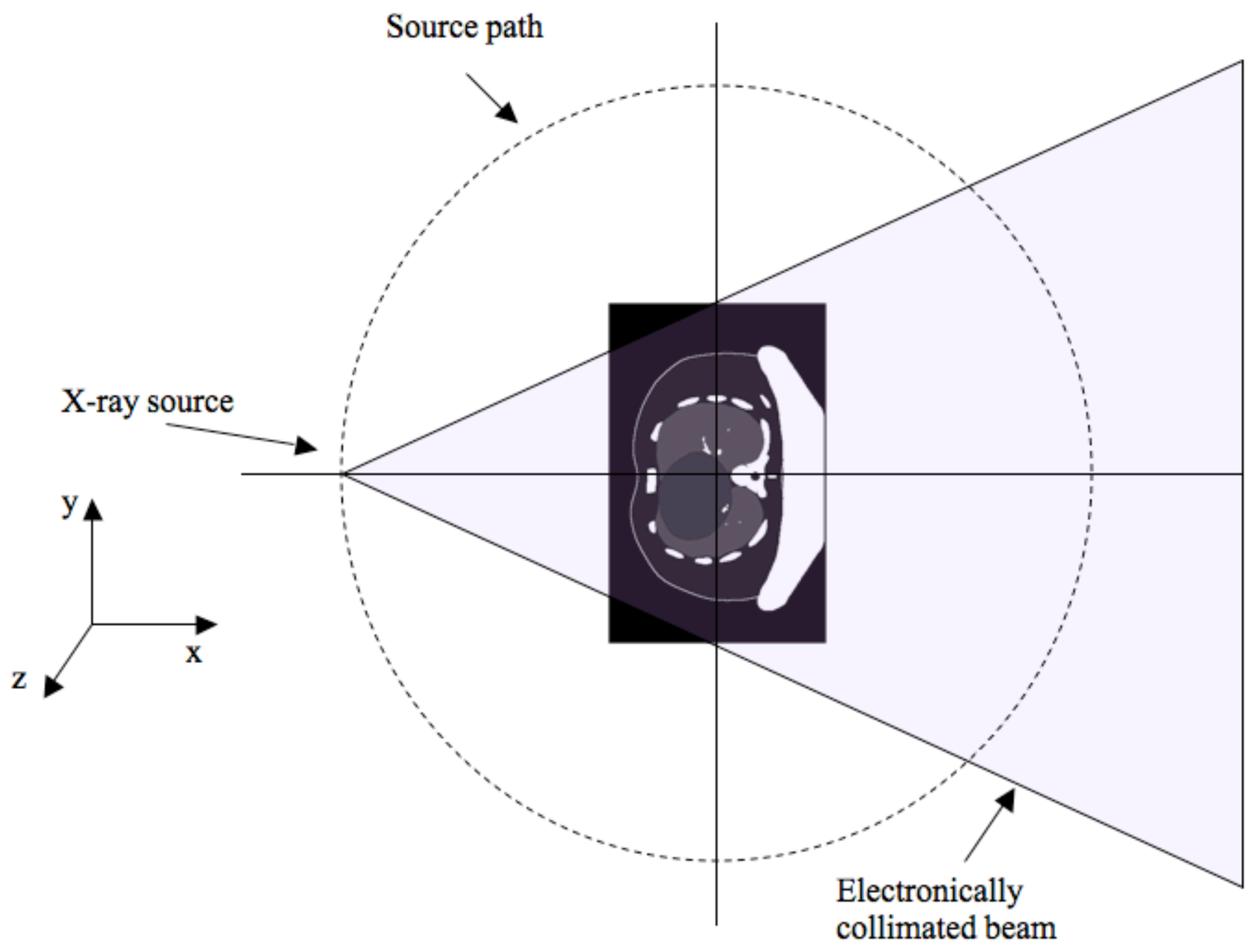


Z=150 cm
Z=0 cm
X-ray source
t
Z=-150 cm
y
x



Z=+150 cm
Z=0 cm
y
x
Z=-150 cm
Four contiguous ROIs. Dose to each 'slab' is recorded.

Case 9

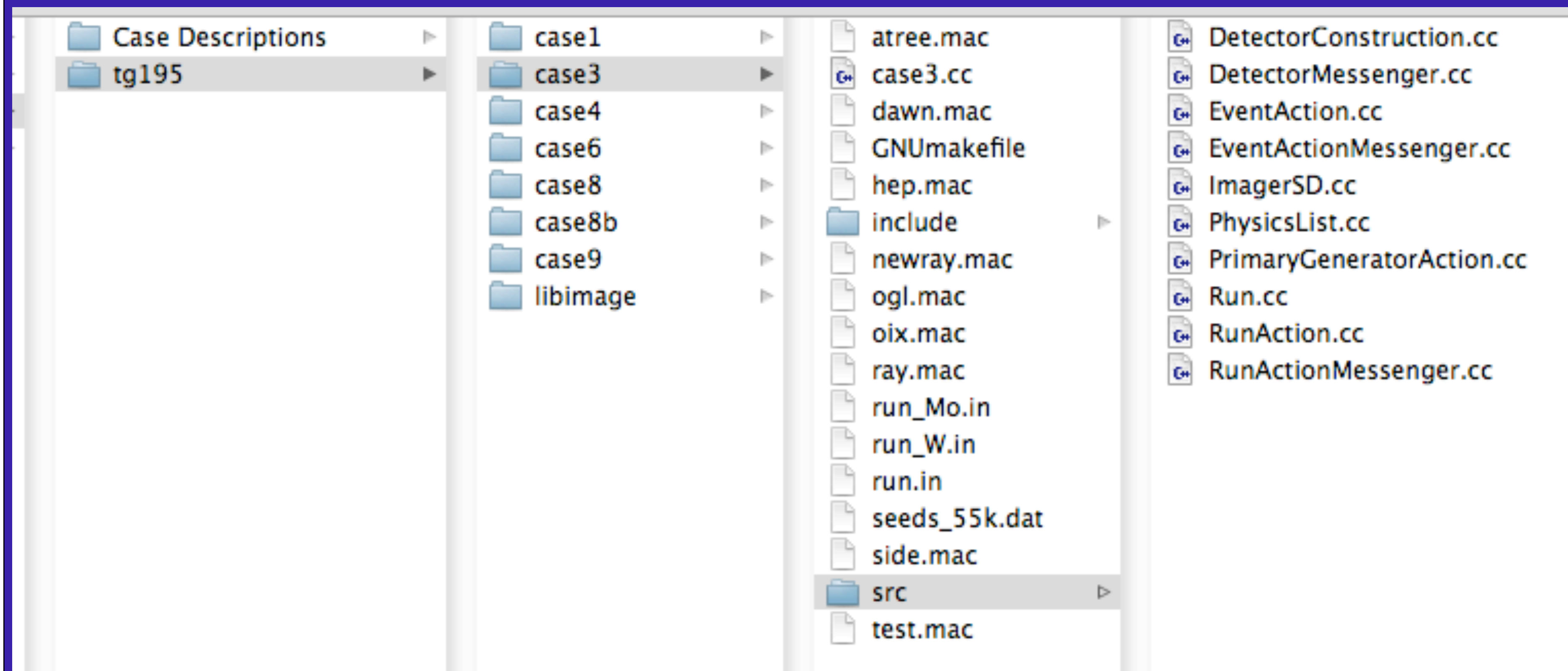

Source path
X-ray source
y
x
z
Electronically
collimated beam

Geant4 Simulations Already Prepared

Ioannis has already prepared simulations of all the cases.

4.9.4.p02, NIST materials, Sensitive Detector

Good clean code



Our Part

AAPM Task Group reports have very high impact in medical physics.

Ioannis welcomes our participation to help insure that the Geant4 code shows us at our best.

I would like an ad hoc group of us to advise him.

General checking, plus some particular concerns he has:

- I'm mostly concerned about the correct definition of the physics, especially for case #3.
- For case #3, I'm unsure about the setting of reasonable cuts to obtain correct x-ray spectra at all energies especially < ~5 keV.
- Methods to accelerate the simulations, again especially for case #3

Final results due Nov 15th

I’m in. Let me know if you’d also like to help.