GHENT
UNIVERSITY

FACULTY OF ENGINEERING

Forced detection and convolution based forced detection in GATE

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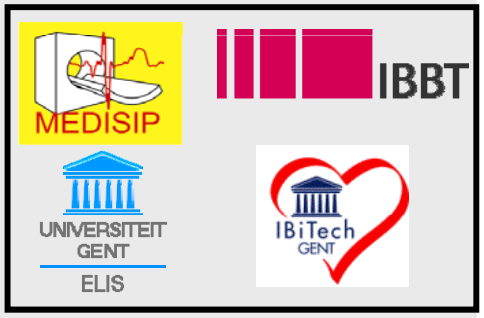
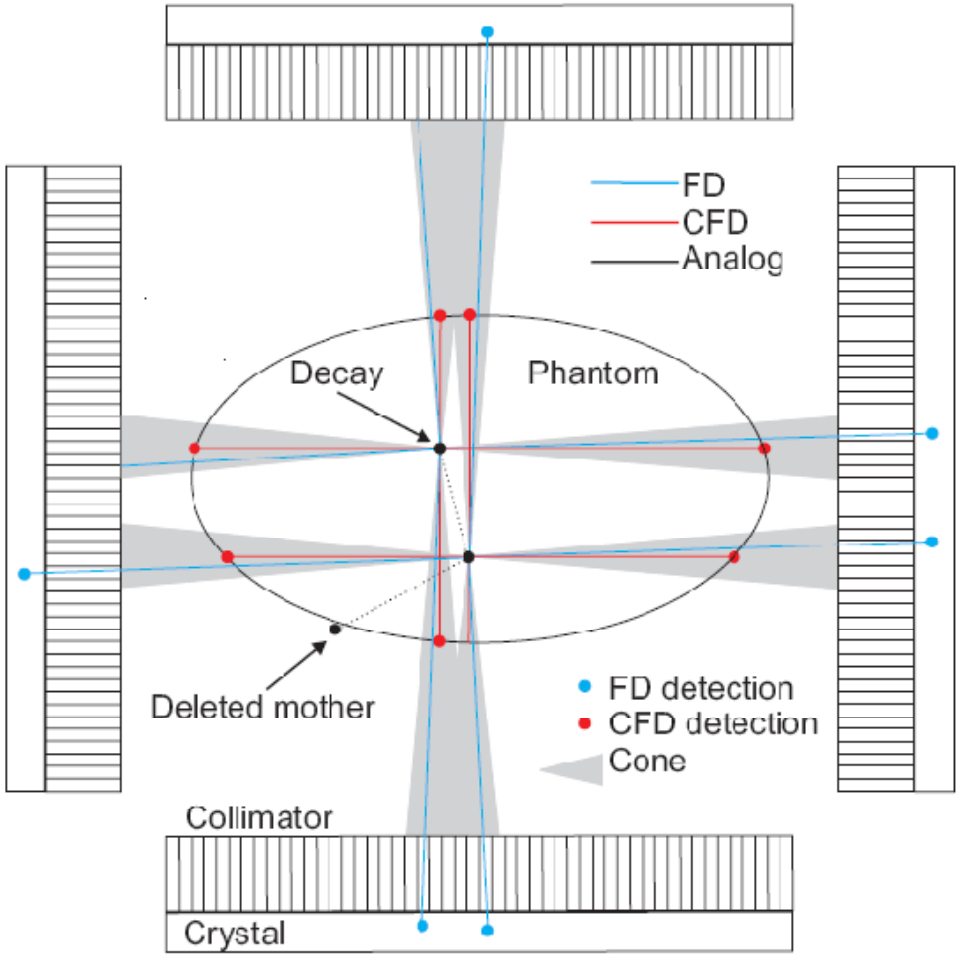


(Convolution based) Forced Detection:

- What is the conceptual idea?
- Does it just work in G4/GATE ?
- What is the conceptual idea then in G4/GATE?
  - Optimized navigator for FD/CFD
  - Lookup tables
  - Fast analysis
- Validation

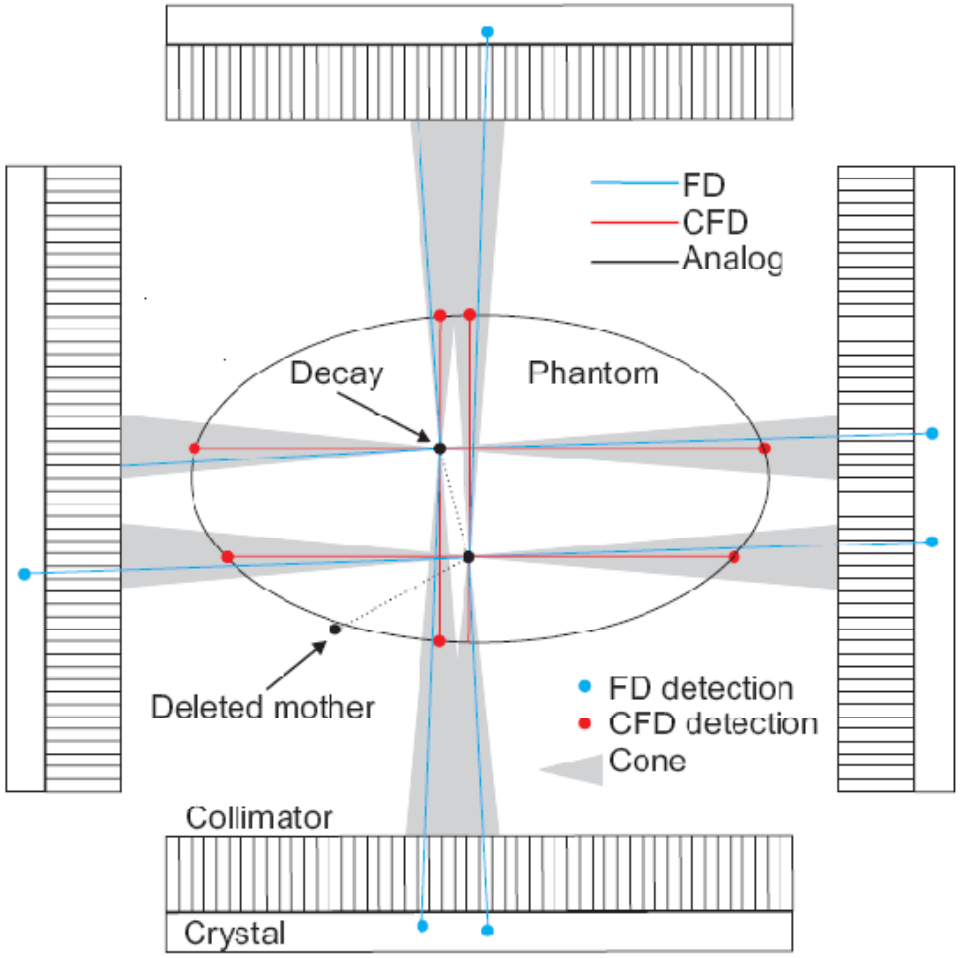
What is the conceptual idea?

- Force a particle towards the collimator at determined emission and scatter angle by creating daughter particles at every interaction in the phantom
- FD and CFD
- Apply weight corrections:
  - » Non-absorption up to the detector
  - » Non-attenuation up to the detector
  - » Emission or scatter at a determined angle
- Expect lots of detections!



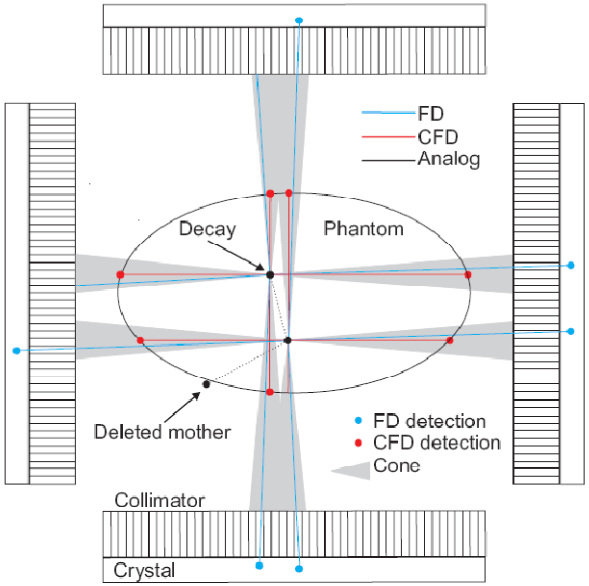
What is the conceptual idea?

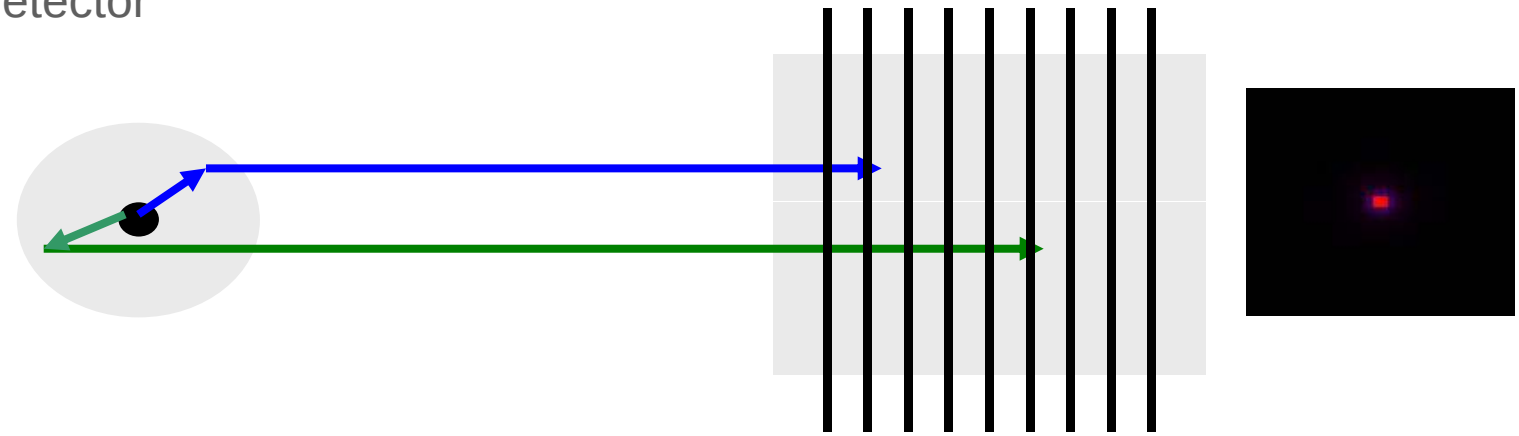
- Forced detection:
  - » Emission,scatter into a cone
  - » Collimator and detector are simulated



What is the conceptual idea?

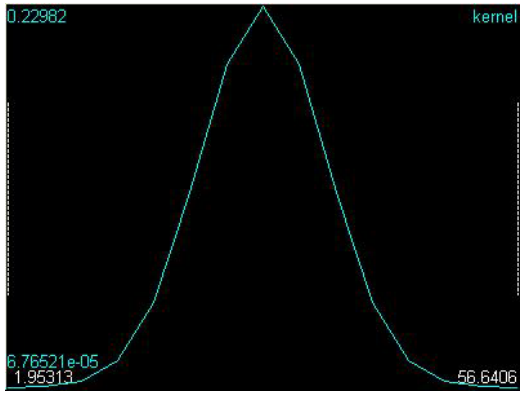
- Convolution based forced detection
  - » Emission, scatter perpendicular to the collimator
  - » Collimator, detector not modeled
  - » Apply a distance dependent blurring kernel (detector blurring)
  - » Detections are stored in subprojections by distance from the detector

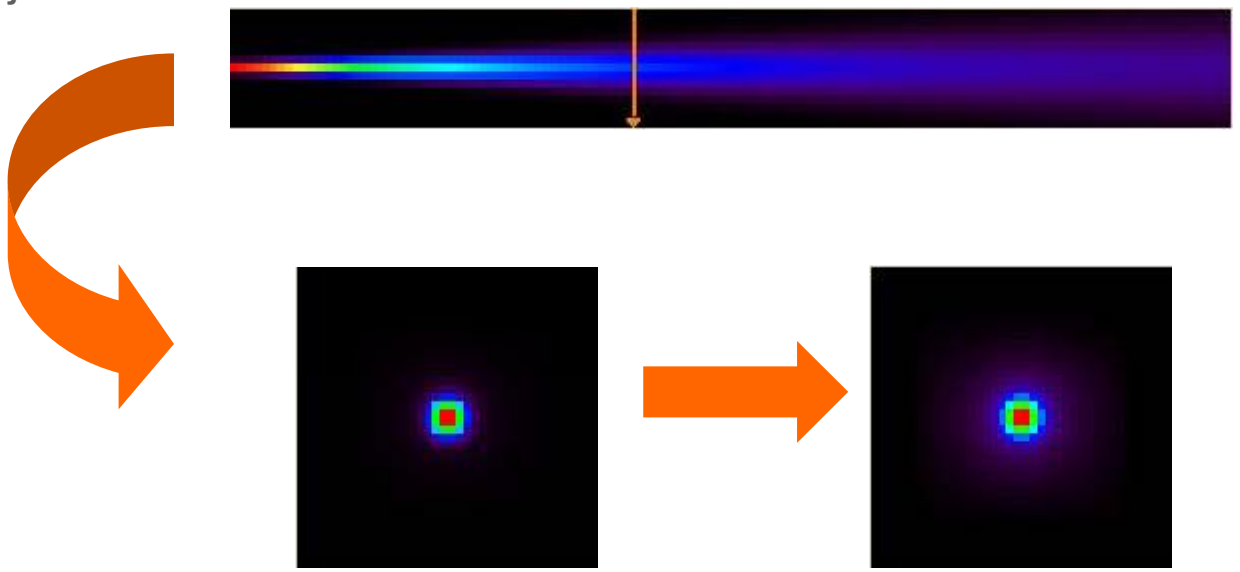




What is the conceptual idea?

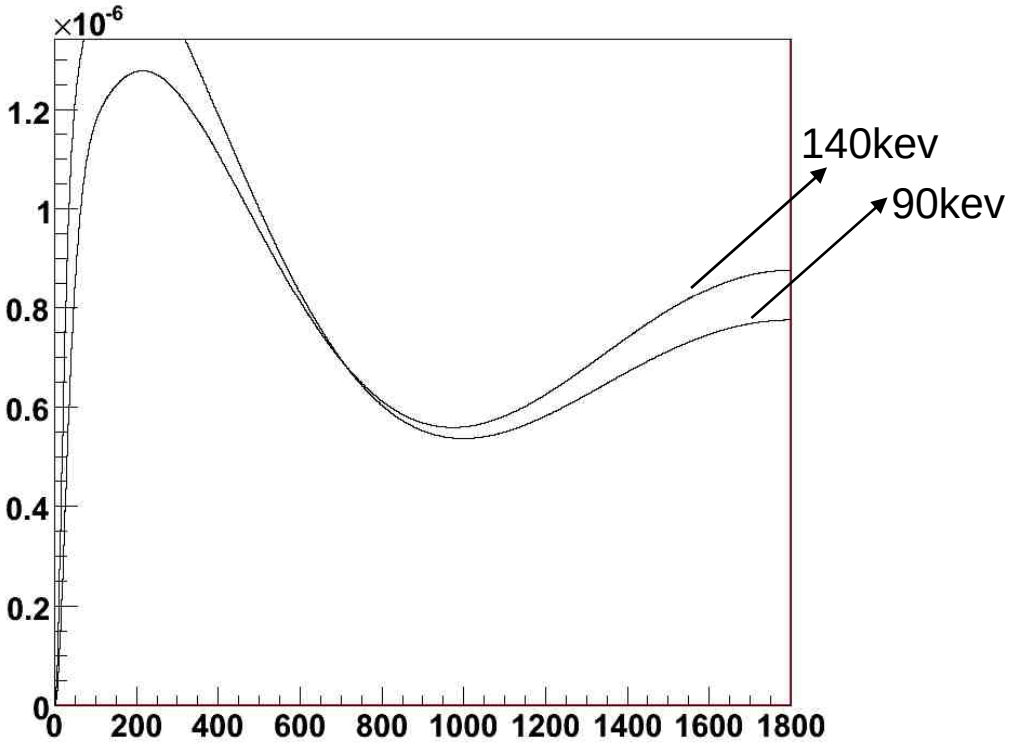
- Convolution based forced detection
  - » Subprojections are
  - » convolved with the corresponding kernel
  - » Added to the final projection





What is the conceptual idea?

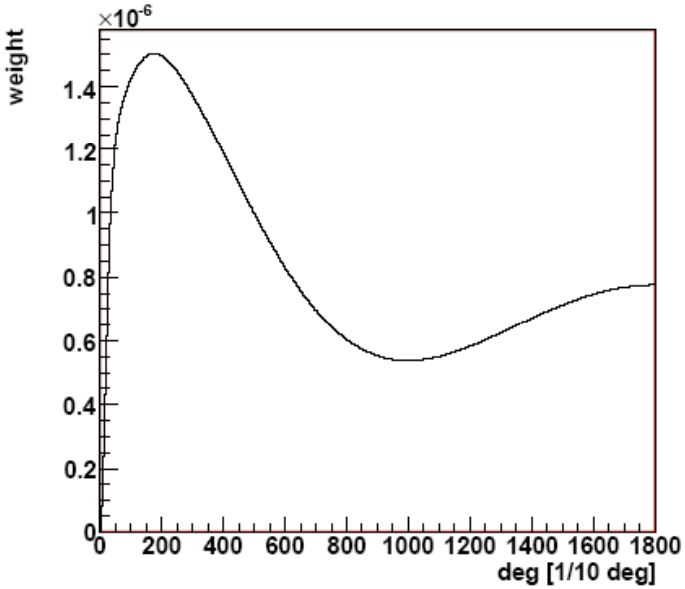
-> FD/CFD weight corrections

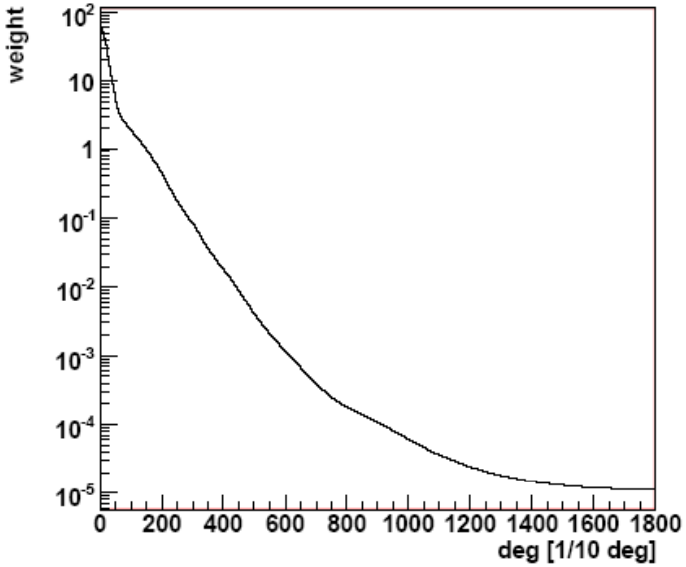


- Tables containing the probability of scatter into a solid angle are built (Compton & Rayleigh scatter)
- For 92 elements
- For each incident energy level (0 -> 160 kev (1/10th kev))
- For each scatter angle (0->180 deg (1/10th deg))
- Numerically integrated over solid angle subtended by a cone
  - Extremely small opening angle = CFD
  - Opening angle based on collimator geometry = FD

What is the conceptual idea?

-> FD/CFD weight corrections





Compton :

- The FF suppresses forward scattering at low energy
- Small scatter angles thus have a lower probability

Rayleigh :

- Strongly forward peaked at low energy
- Small scatter angles thus have a high probability
- Introduces large weight variations

Does it just work in G4/GATE?

Unfortunately, No!

Upon profiling the G4/GATE simulation, “String” was taking most of the simulation time

What is the conceptual idea then in G4/GATE?

-> a total solution that avoids all the slow parts:

» Optimized navigator for FD/CFD

- Smart by a priori knowledge : no navigation history, no search for volumes required

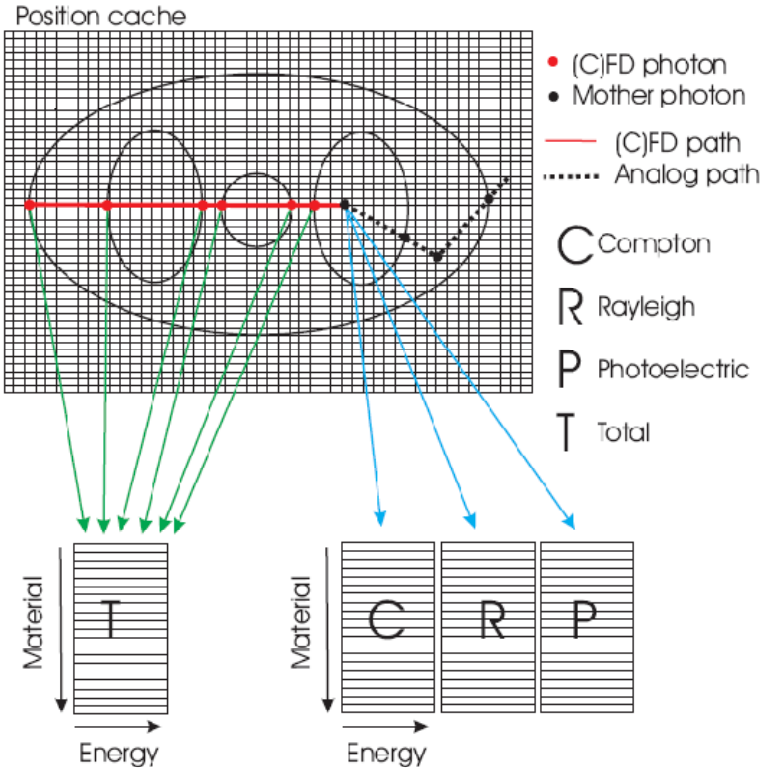
» Lookup tables

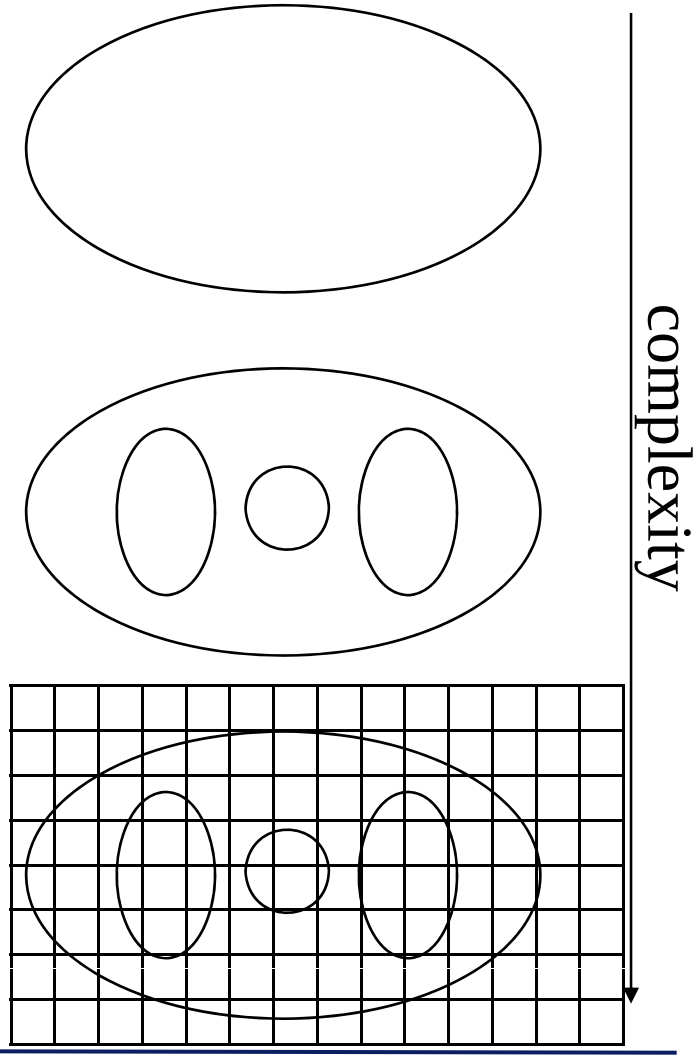
- MC mostly does almost the same thing over and over
- Cache, cache, cache everything required for MFP

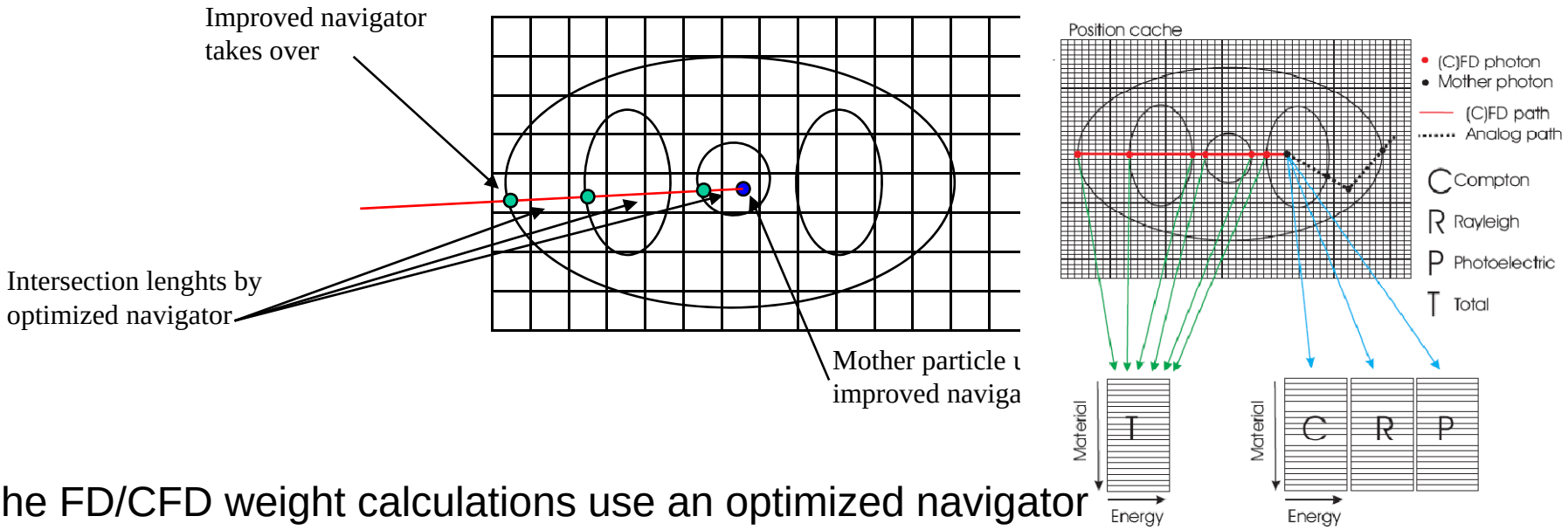
» Fast analysis

- The analysis in GATE is too slow: hit collections, event histories, hits to pulses and digis
- Fast analysis required based on arrays instead of classes

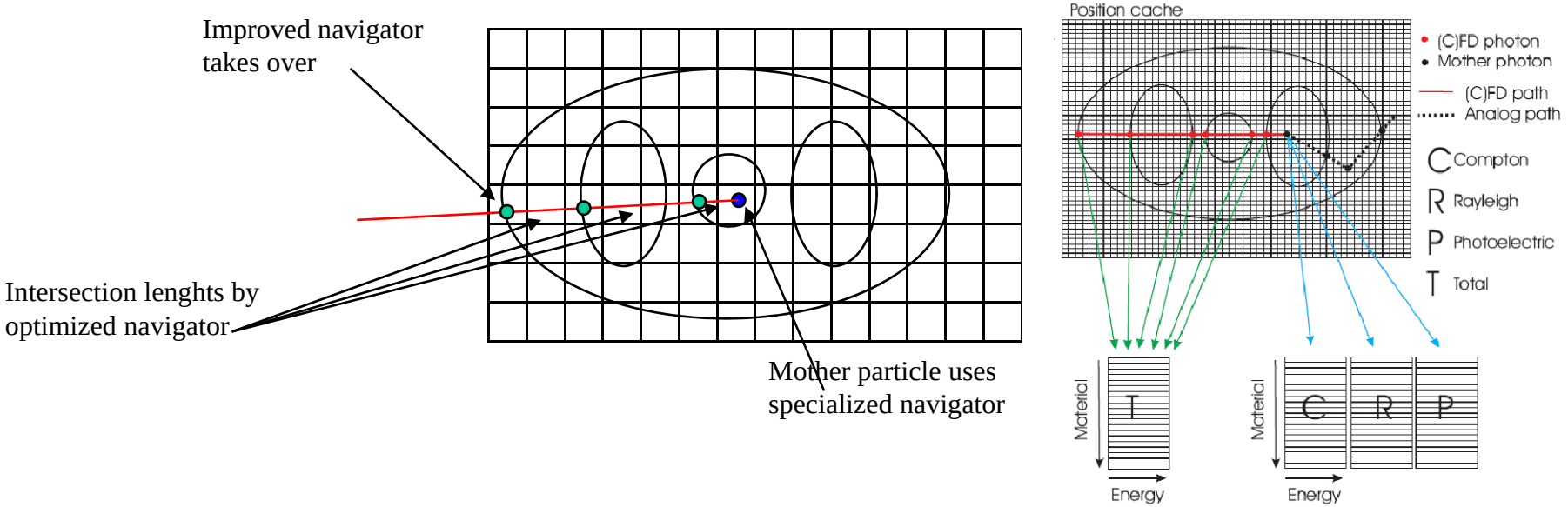
FD/CFD optimized navigation





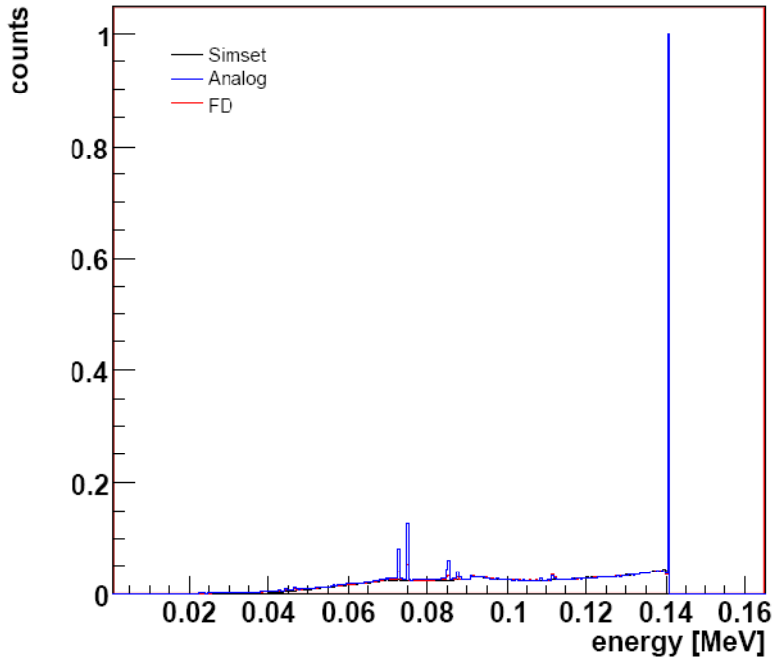


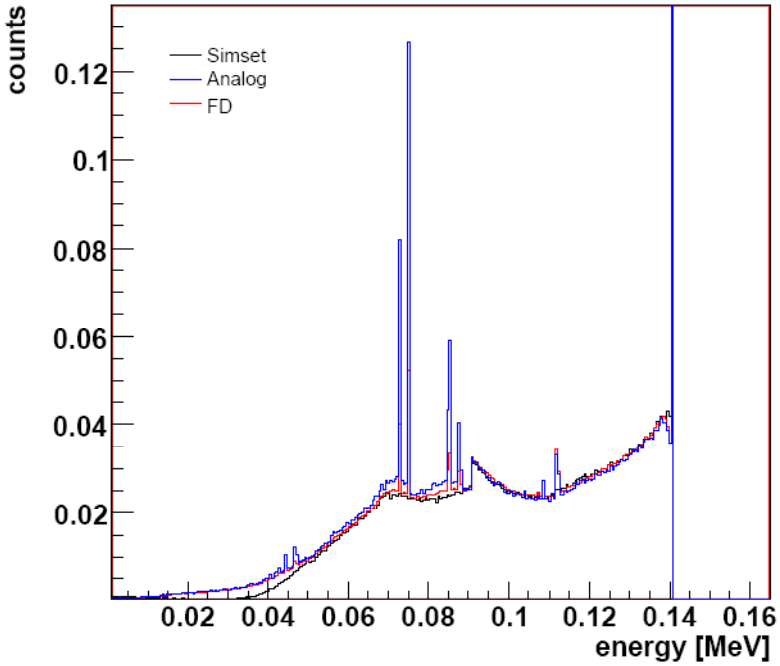
- The FD/CFD weight calculations use an optimized navigator
  - Finding the right volume took most of the navigation time
    - A navigation grid is placed over the phantom
    - The volumes, transforms and materials are sampled and cached in the grid at startup
  - A priori knowledge is used :
    - Initial volume is known
    - Direction remains the same until outside of the phantom



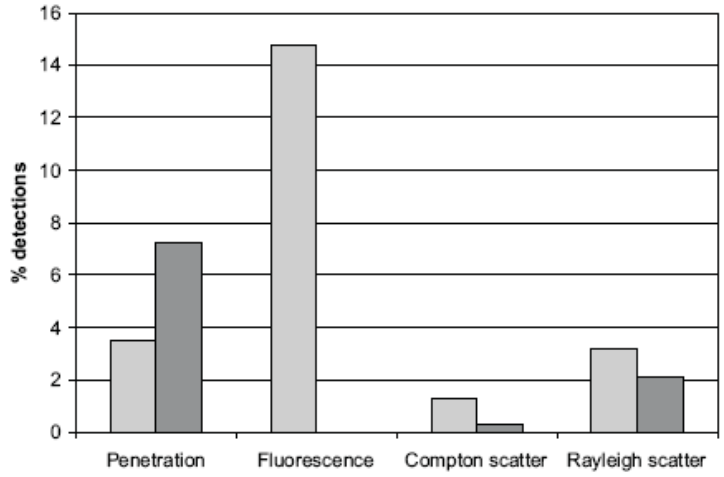
- The FD/CFD weight calculations use an optimized navigator
  - For voxelized phantoms :
    - The navigation grid can be matched to the voxel grid
    - An incremental Siddon algorithm is used
- The mother particle navigation is done by the specialized navigator for parameterized volumes
- Once the FD/CFD photon copy leaves the phantom, the specialized navigator takes over again

FD validation: point source in water

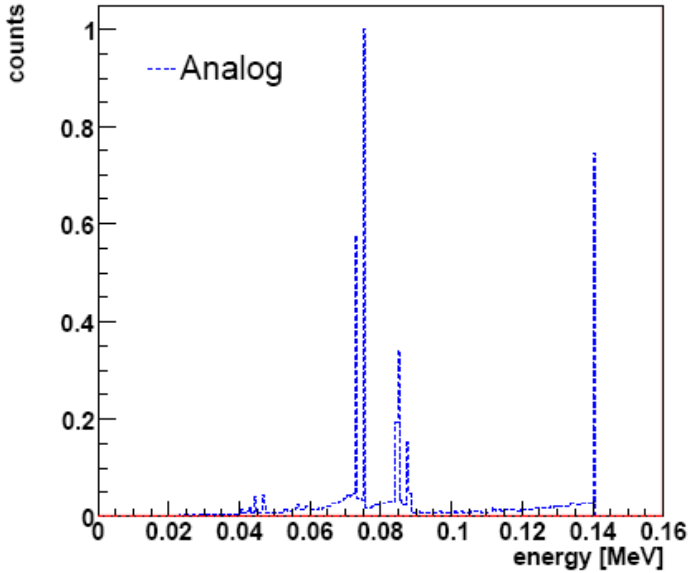




FD validation: collimator scatter and penetration

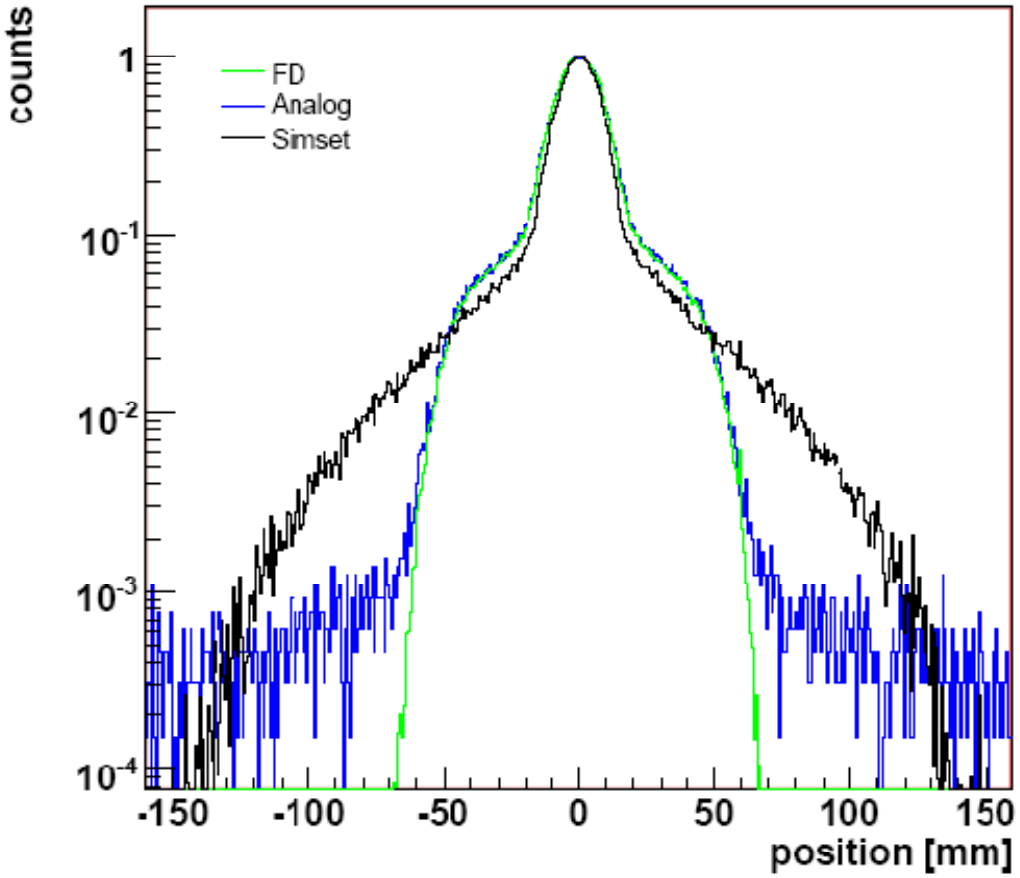


(a) Percentual contributions to the total amount of detections (light grey) and to the total amount of detections within the photopeak window (dark grey).

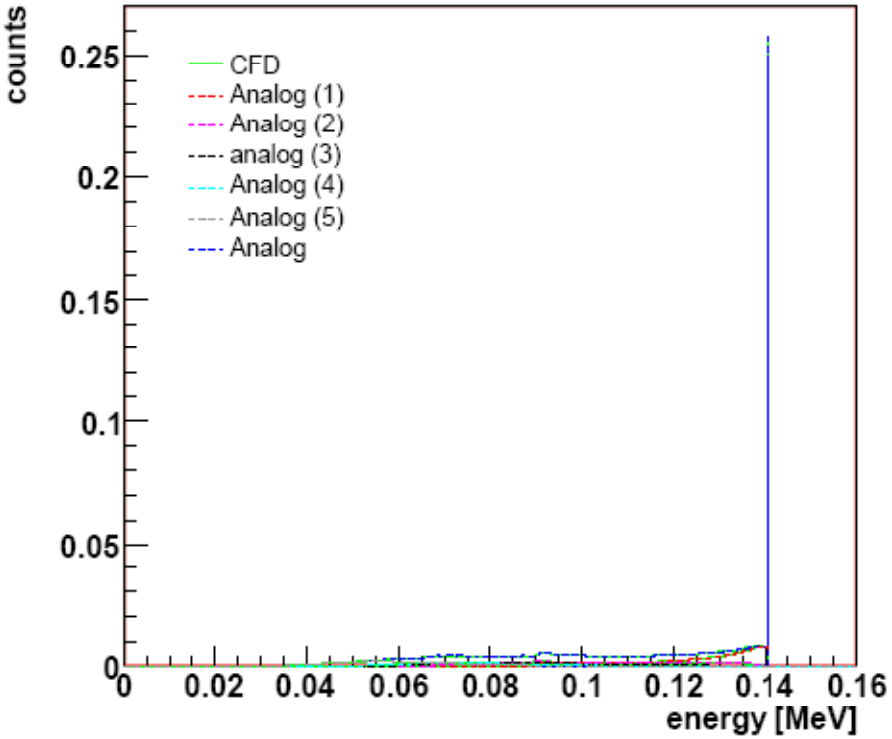


(b) Energy spectrum normalized to the maximum.

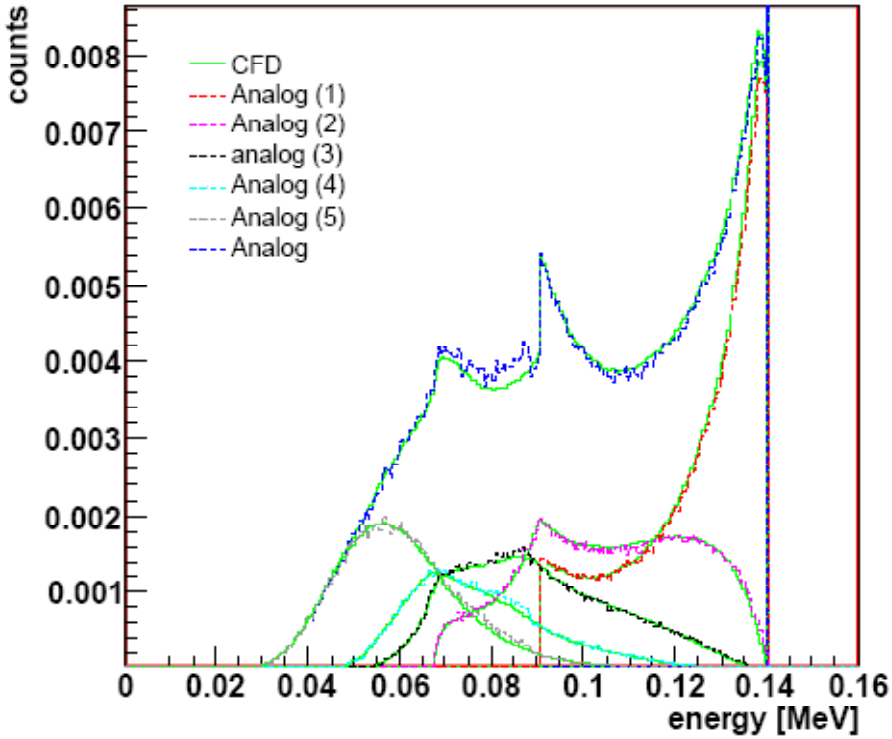
FD validation: point source in water PSF



CFD model validation: point source in water

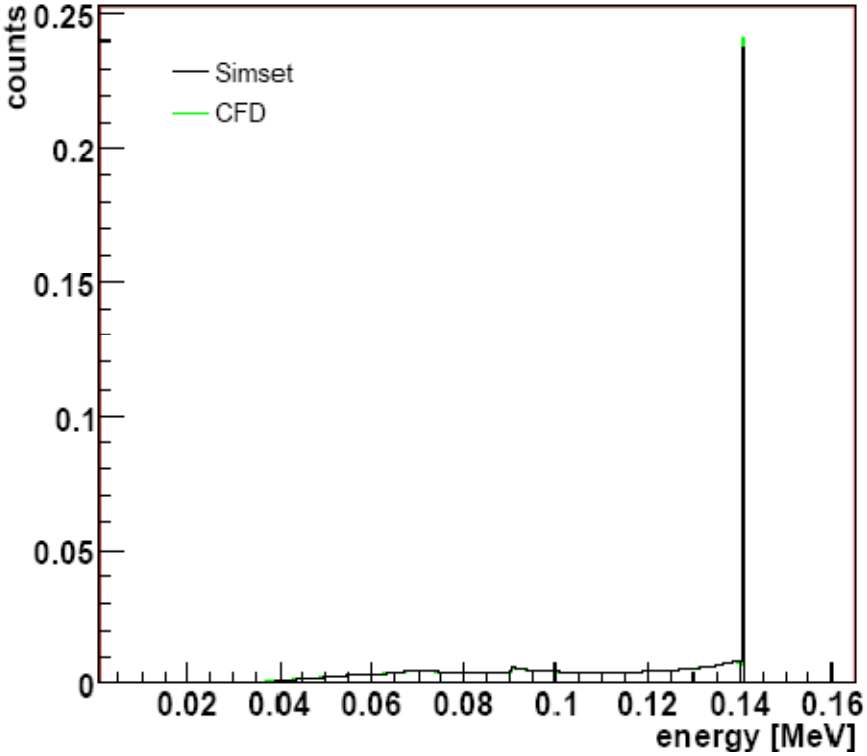


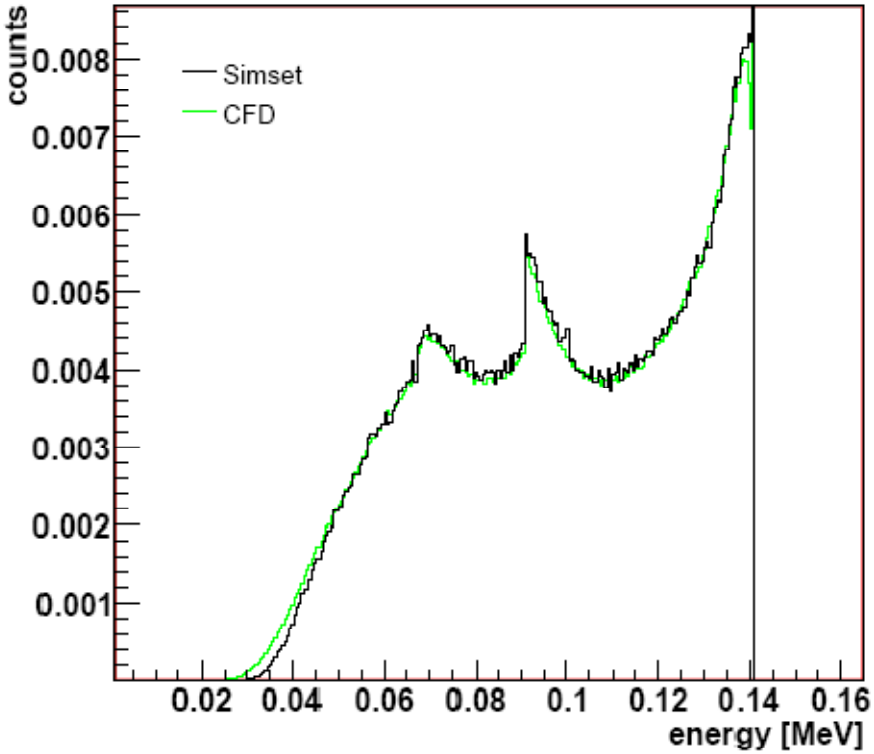
(a) Full spectrum



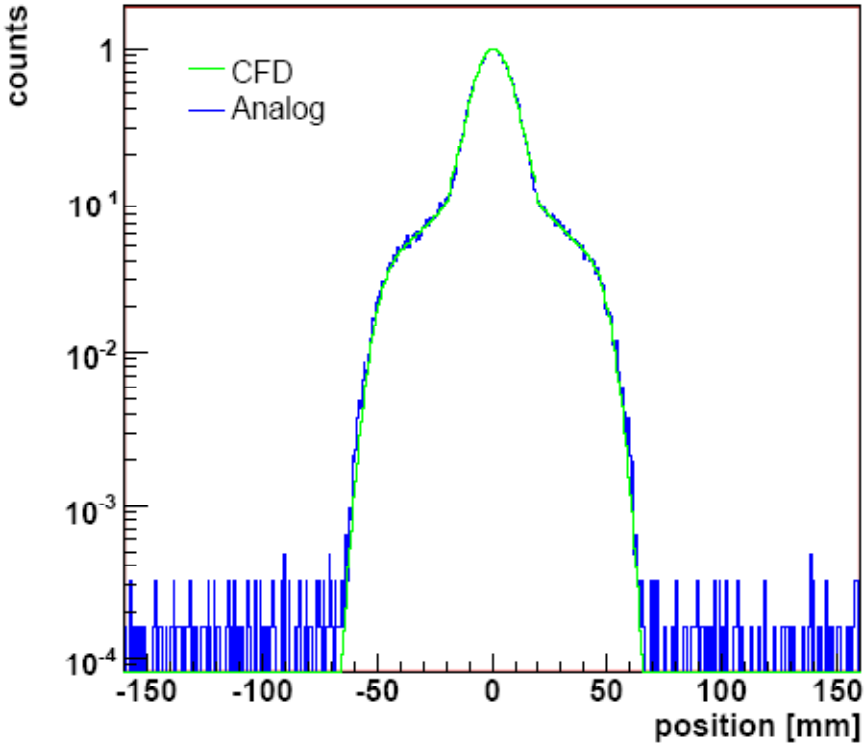
(b) Zoomed

CFD model validation: point source in water (SimSET)

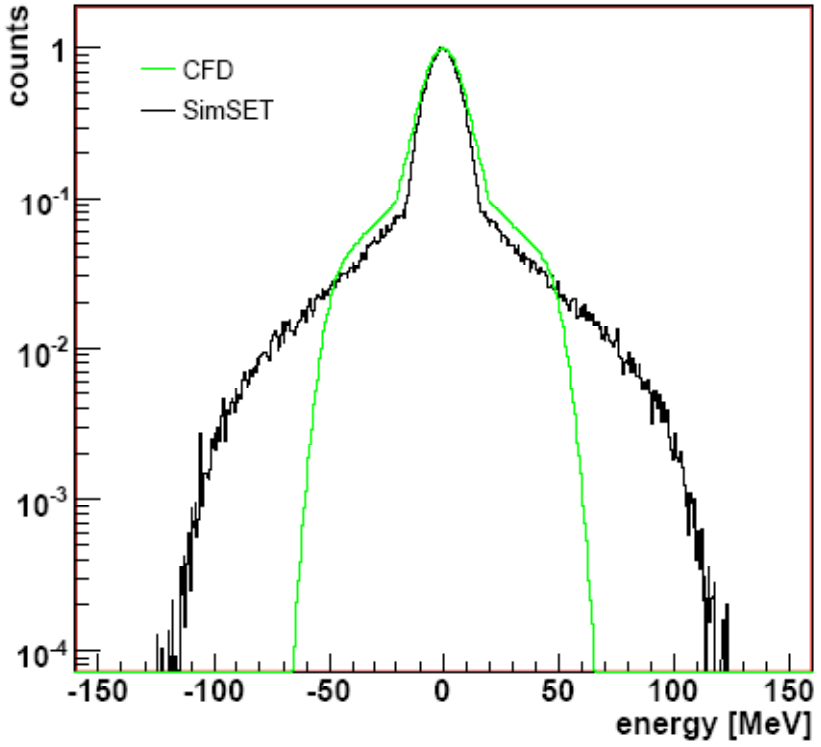




CFD model validation: point source in water PSF

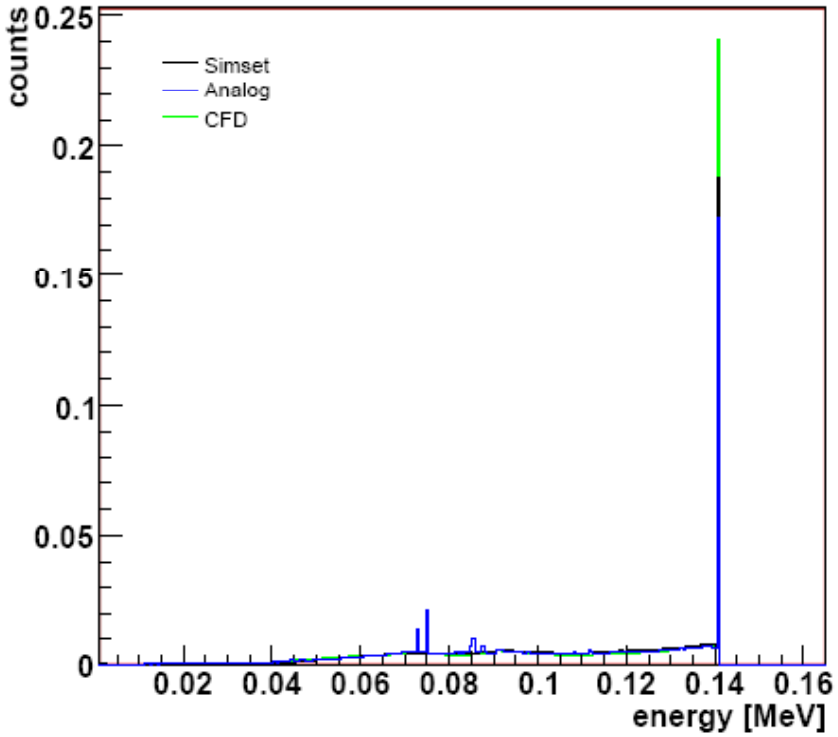


(a) CFD vs sGATE PSFs

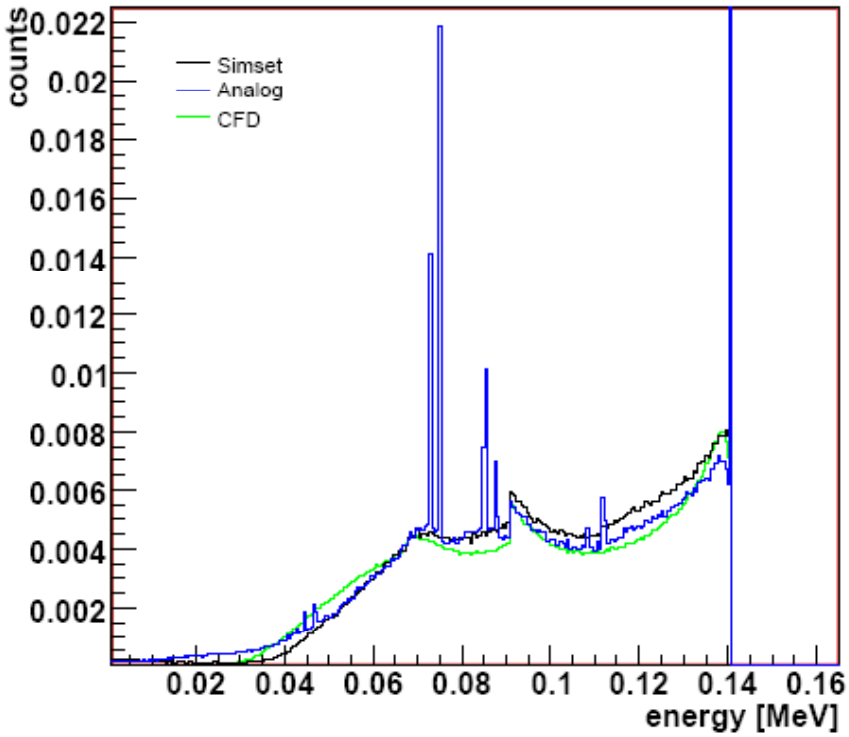


(b) CFD vs sSimSET PSFs

CFD validation: point source in water

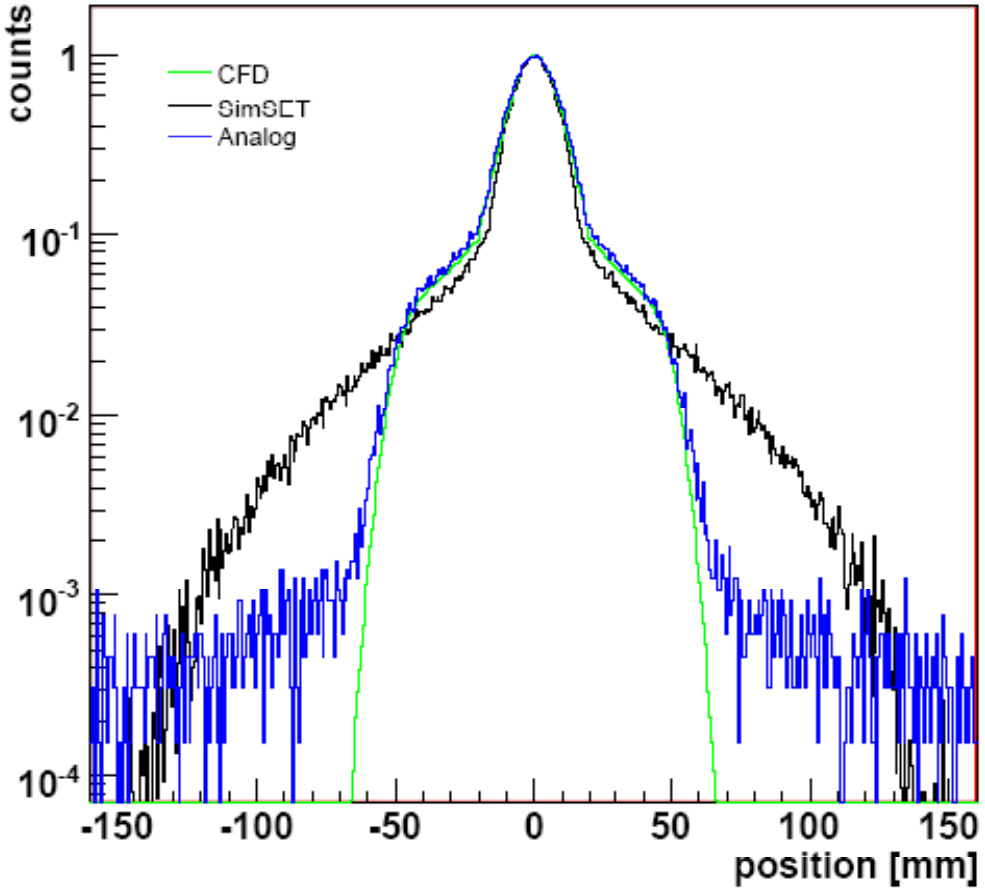


(a) Full spectrum

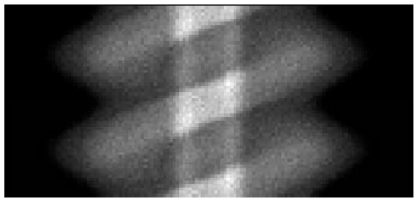


(b) Zoomed

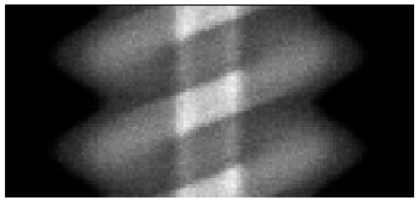
CFD validation: point source in water PSF



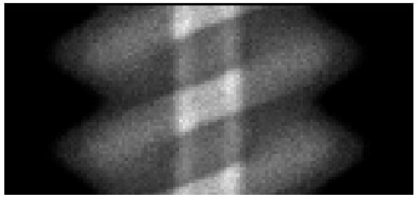
FD/CFD validation: Thorax phantom



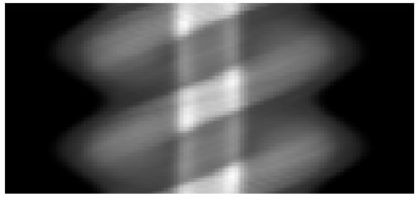
(a) Analog sinogram



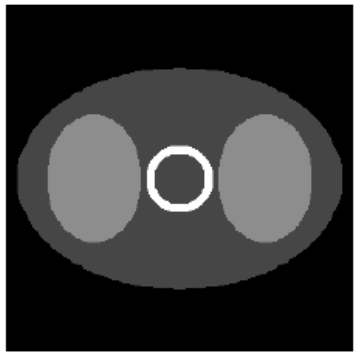
(b) SimSET sinogram



(c) FD sinogram



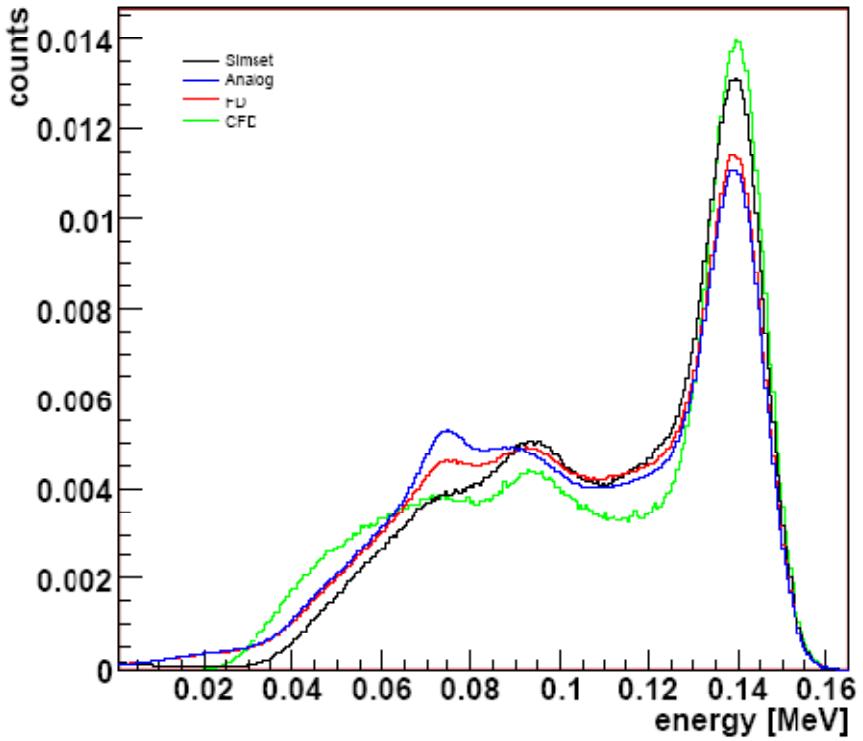
(d) CFD sinogram



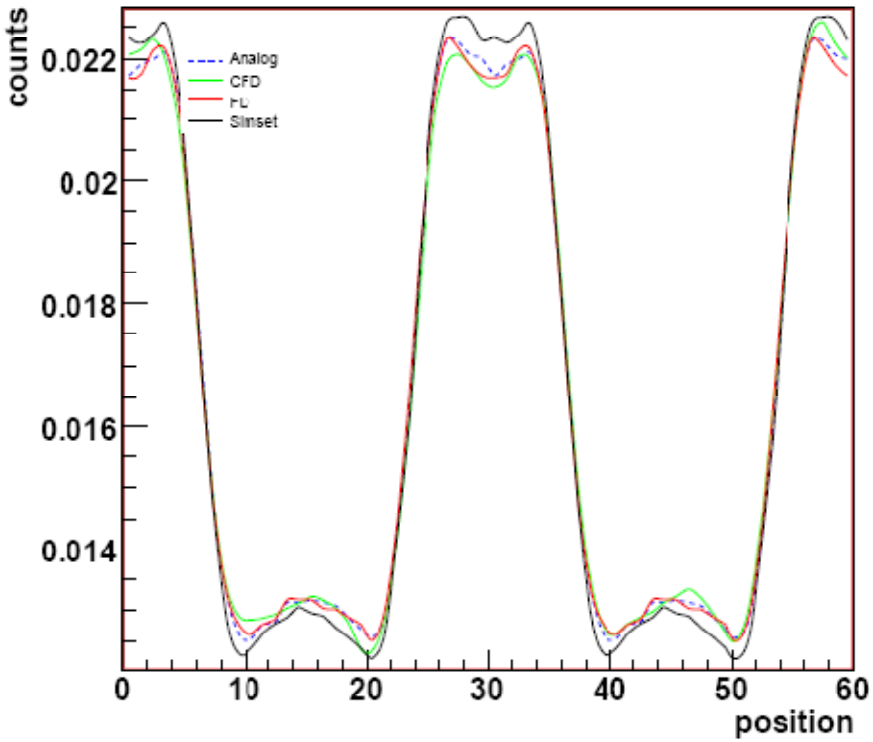
(a) Activity

(b) Attenuation

FD/CFD validation: Thorax phantom



(a) Profile



(b) Energy spectrum

FD/CFD validation: Acceleration

	FD	CFD	aGATE
RFOM	1820	1800000	1
QF	0.47	0.56	1
QF(Rayleigh)	0.24	0.12	1

On one 2.8Ghz pentium 4:

CFD: 130 second for a realistic thorax phantom sim

FD: 35 hours

Analog GATE: over 7 years