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Time Resolved Optical Tomographic Imaging
A Simulation Study

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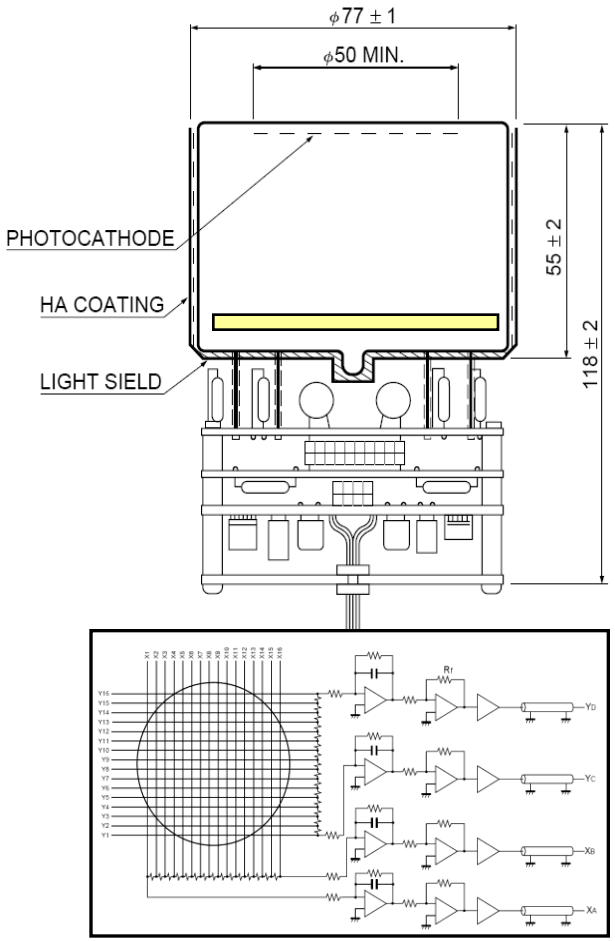
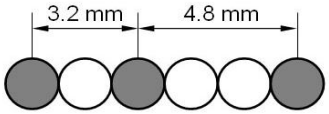
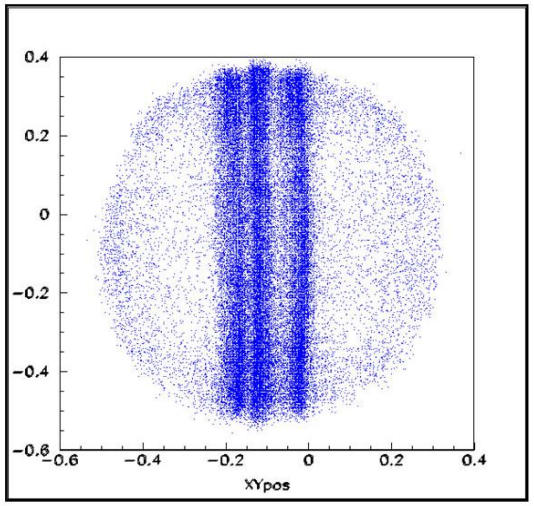
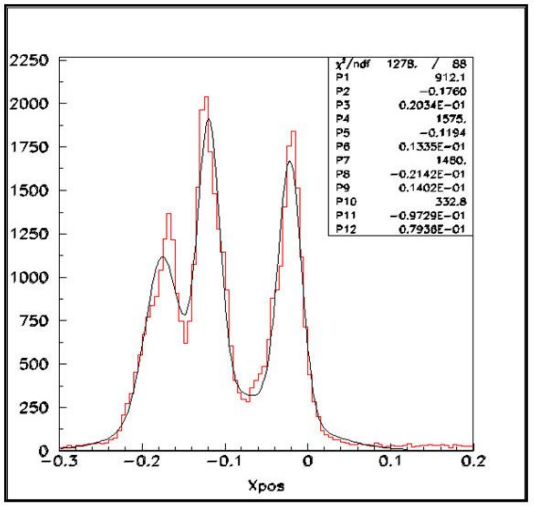
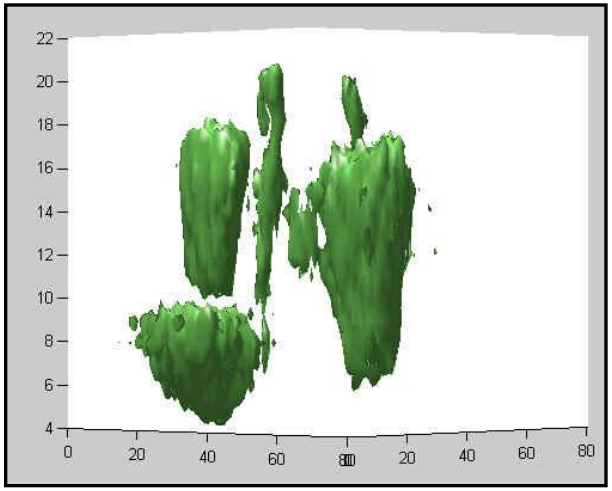
Position Sensitive Small-field γ-Camera system











Characterization of the γ-Camera System on planar and tomographic level

- The system's resolution in planar imaging has been found to be:

$\langle\sigma_X\rangle = (0.95 \pm 0.05)$ mm	$\langle\sigma_Y\rangle = (1.07 \pm 0.07)$ mm

- The resolution on tomographic level has been found:

2 mm in both X and Y Axis

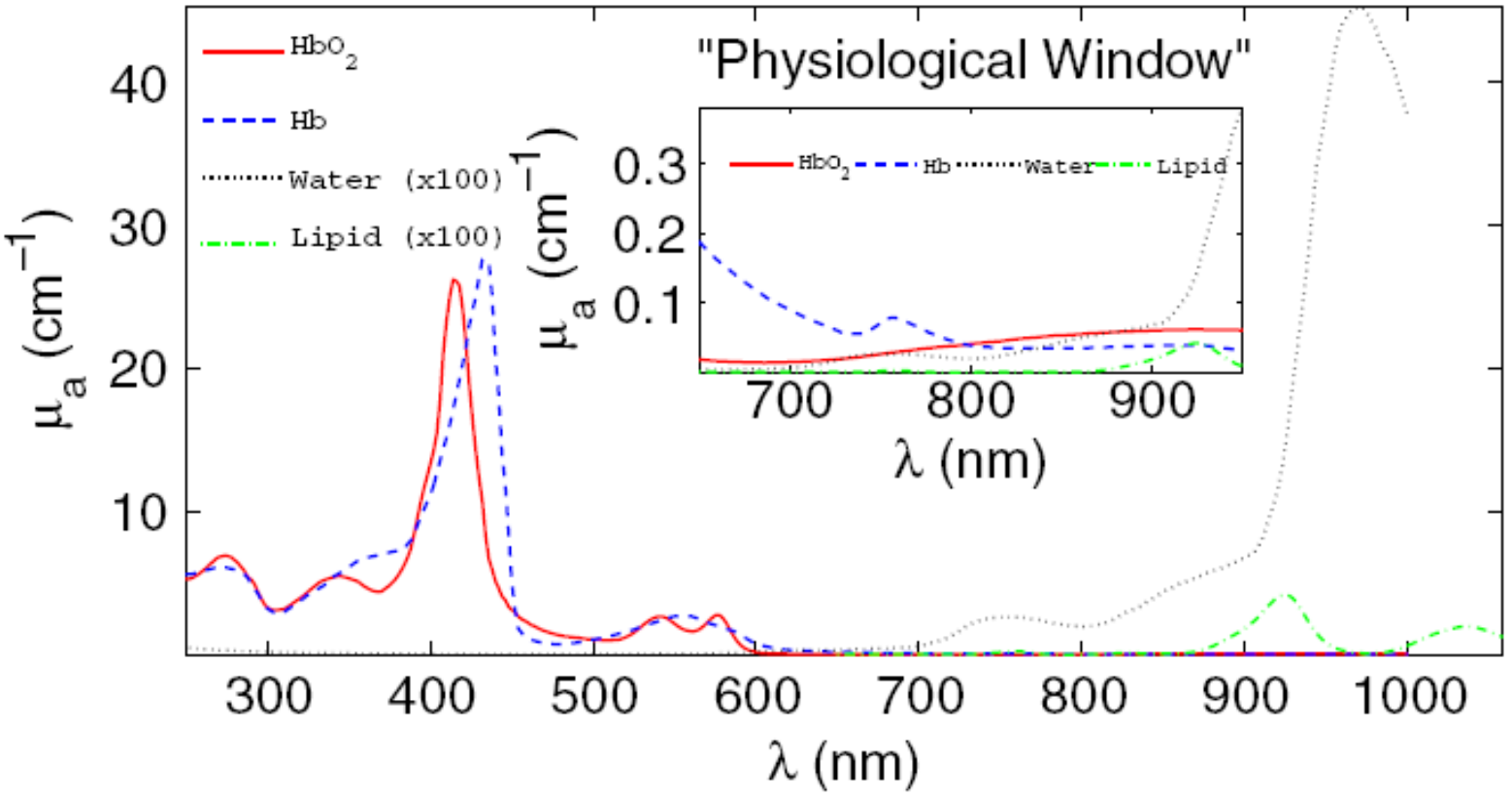
- The sensitivity on tomographic level is determined:

$V = 0.080\ cm^3 \leftrightarrow 20\ \mu Ci$

(minimum volume which can be detected with special activity 0.25mCi/cm^3)

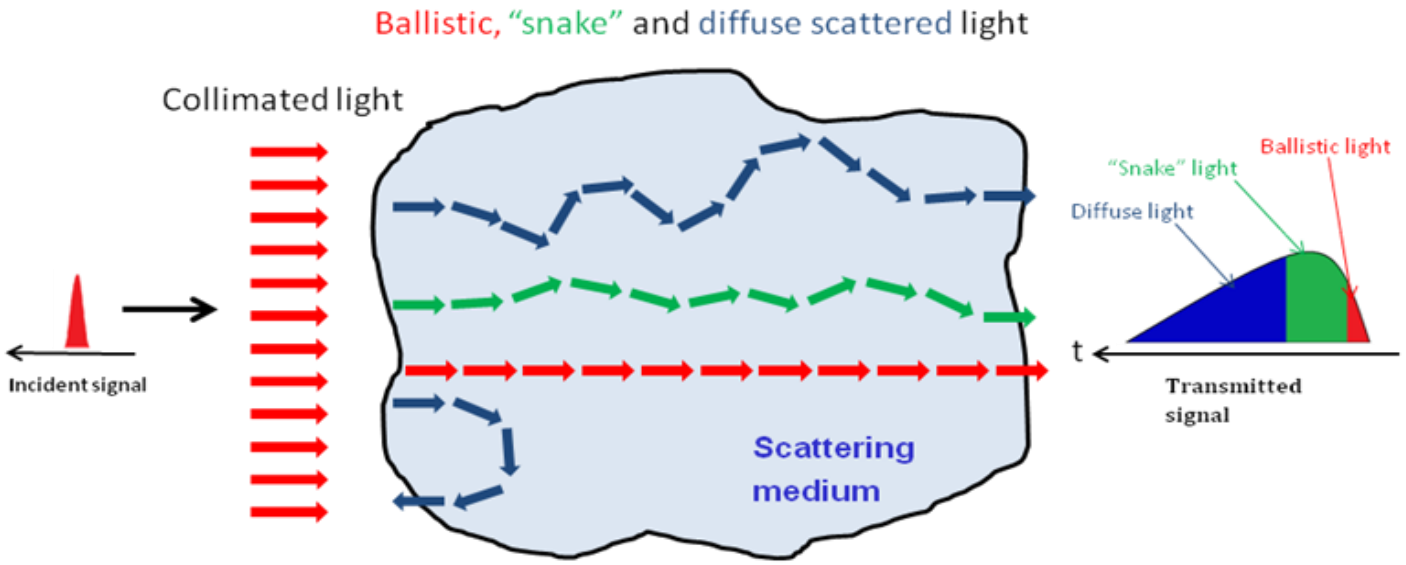
Principle of Optical Imaging

Discovery of the optical window for the light absorption in tissues by Jöbsis (μ_α, absorption coefficient)



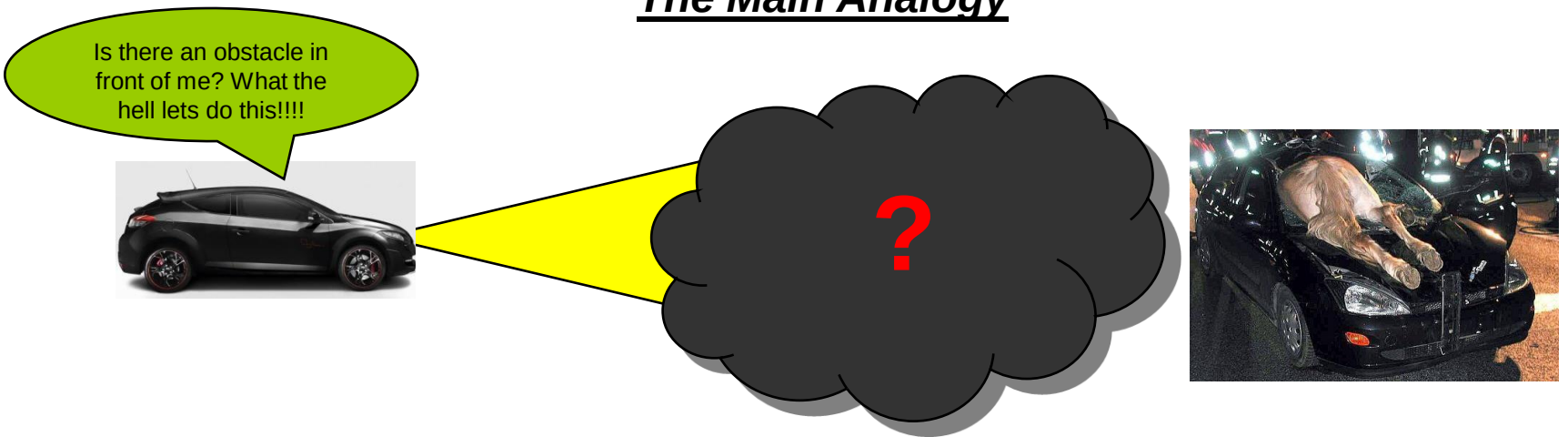
Jobsis, F.F. (1977). *Noninvasive infrared monitoring of cerebral and myocardial sufficiency and circulatory parameters. Science 198, 1264-1267.*

Time-Resolved Photon Propagation



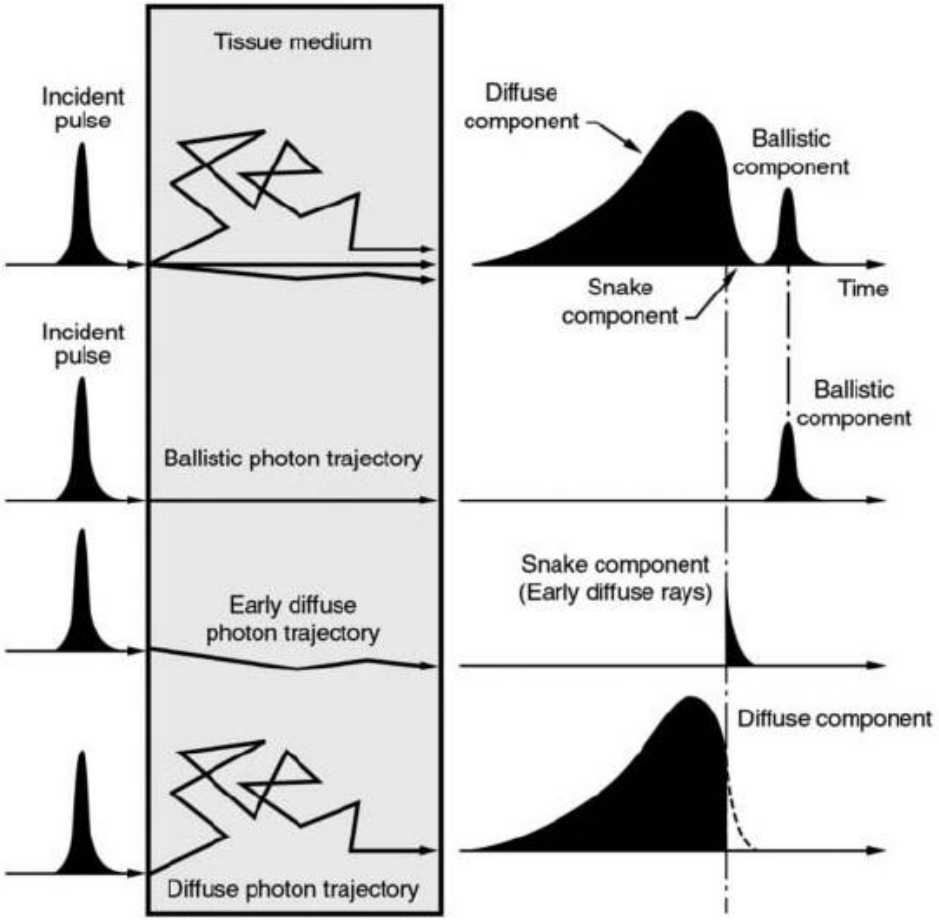
earliest arriving *ballistic* light (< ~ 1ps) ⇒ diffraction-limited resolution (μm)
next arriving *snake* light (< ~100 ps) ⇒ degraded resolution (10's – 100's μm)
later arriving *diffuse* light (> ~100 ps) ⇒ severely degraded resolution (cm)

The Main Analogy



Optical Imaging

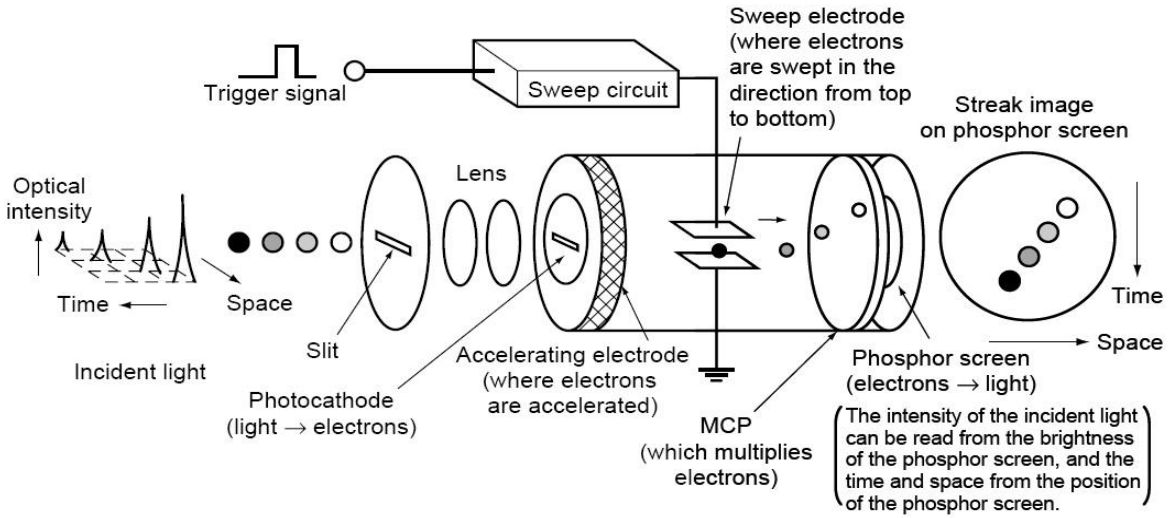
The duration of the pulse depends on the physical width of the medium under investigation.



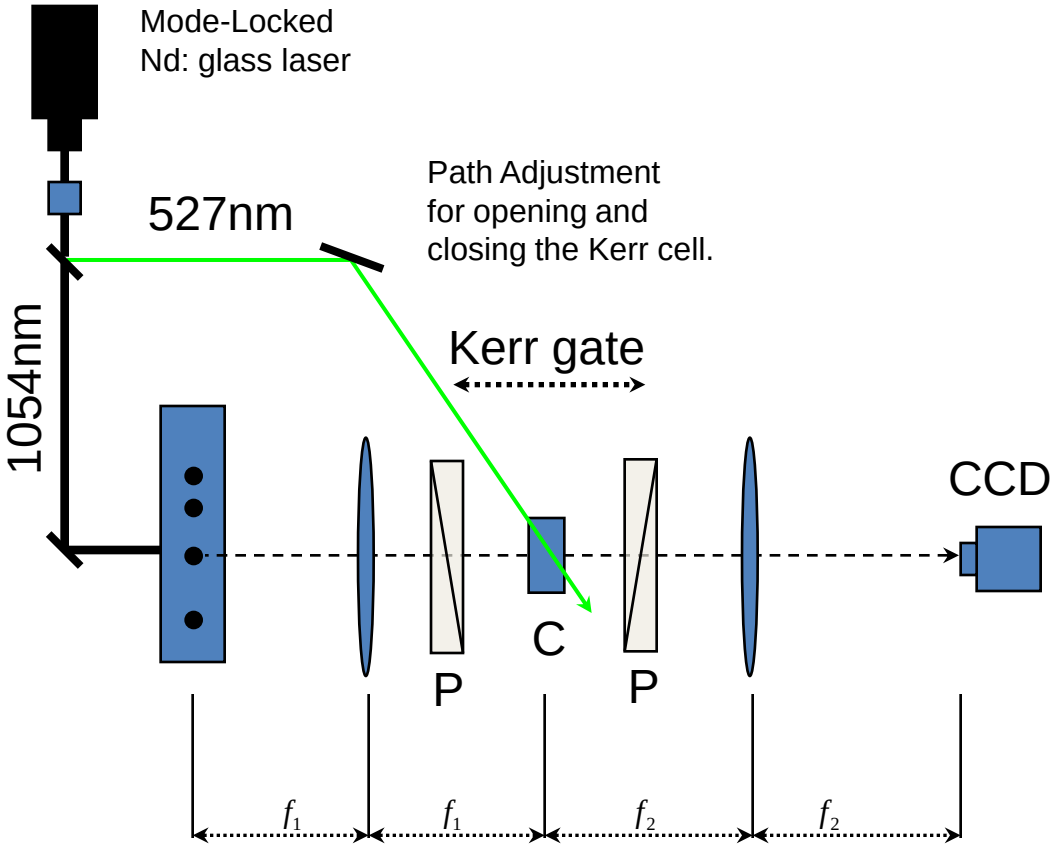
Time Gates

Collecting the early arriving photons by utilizing different physical procedures and methods.

- Streak Camera Methods
- Optical Kerr Gates
- Optical Coherent Imaging
- Holographic Methods
- Four-Wave Mixing Gates
- Coherent anti-Stokes Raman Scattering Gates
- Second-Harmonic Generation Gate
- Parametric Sum and Difference Frequency Generation Gates
- Stimulated Raman Scattering Gates



Streak Camera



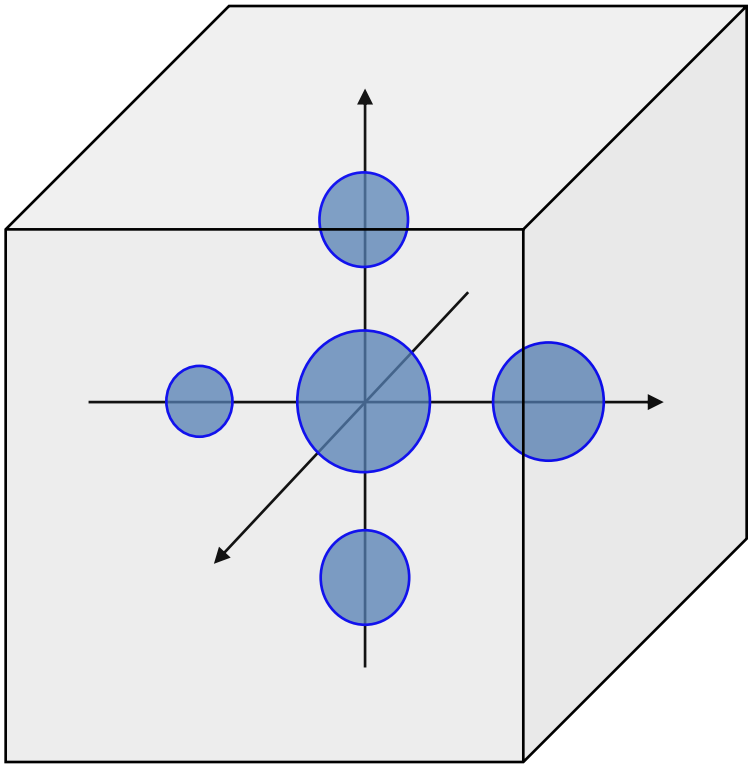
Optical Kerr-Fourier Gate (Kerr Time Gate + Fourier space Gate)

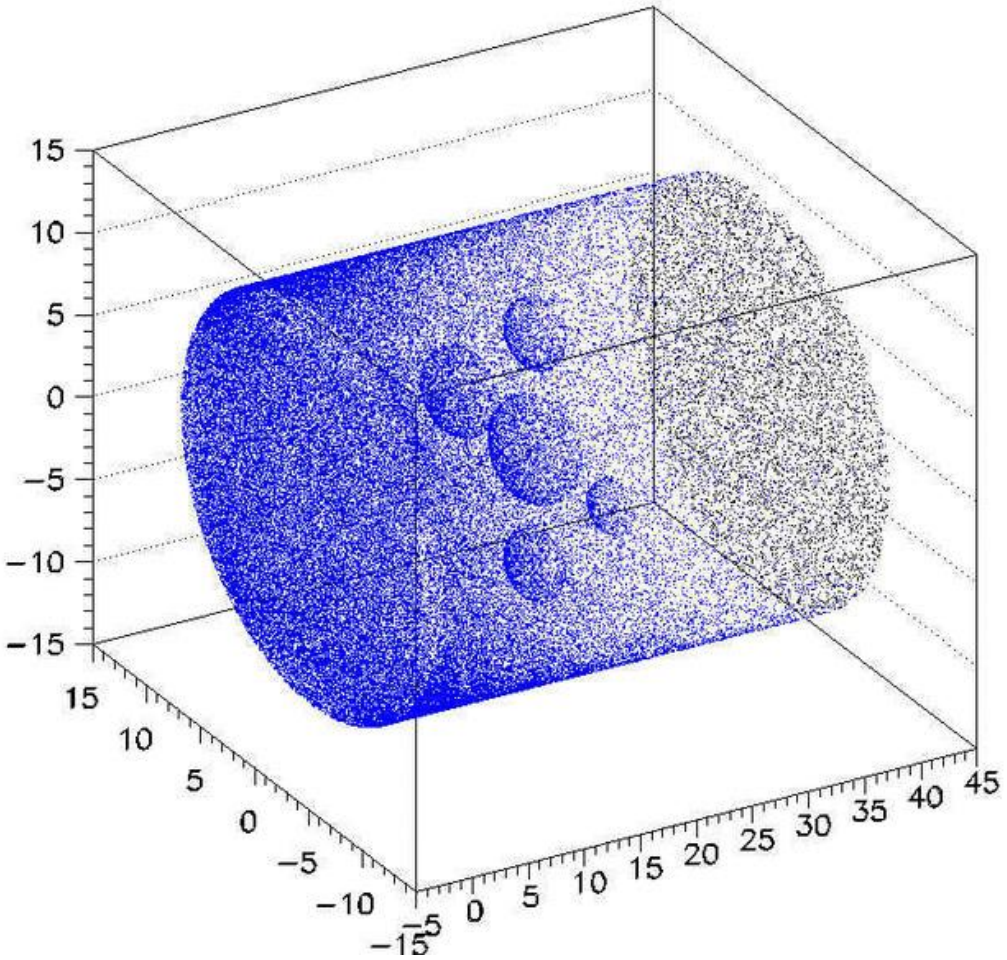
C: Carbon disulfide Kerr cell acts as a ultrafast shutter in a camera. It is triggered by an intense gating pulse / aperture ~8 ps

P: Calcite Polarizer

K: Phase-matched potassium dihydrogen phosphate witch generates the 527nm (to open the Kerr Gate.

Optical Phantom





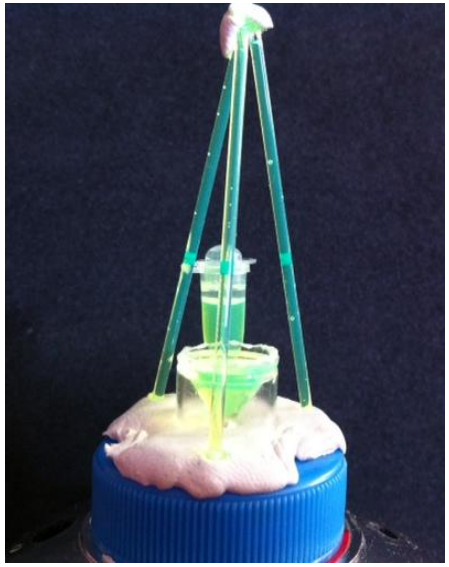
The phantom consists of 5 spheres (BGO n=2.15) in an air cylinder

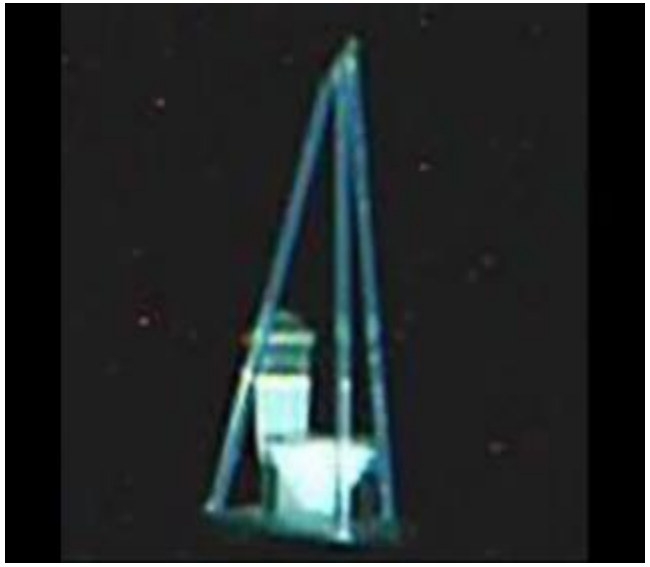
DAQ and Reconstruction

- Recorded from 0^o – 360^o 24 projections with a step of 15^o.
- Every projection was sliced several times along the Z- axis after taking into account different time cuts.
- Using accelerated ART algorithm for each z-level the tomographic image was reconstructed.
- All the tomographic images were contour plotted creating a 3-D image.

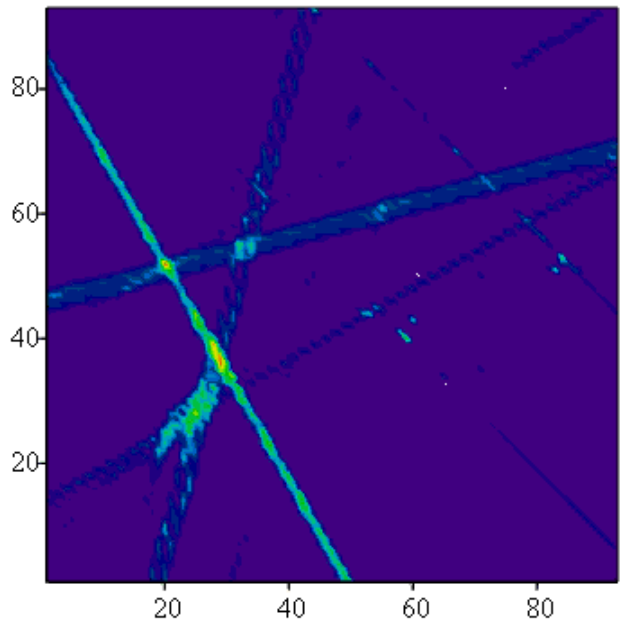
Testing Our Interactive Algorithms for Optical Photons (Early Work)

- Phantom: Three capillaries shaping a triangle pyramid and two cylidro-conoidal tubes on and off axis, all filled with fluorescent liquid (Cyalume) capable of emitting on green.

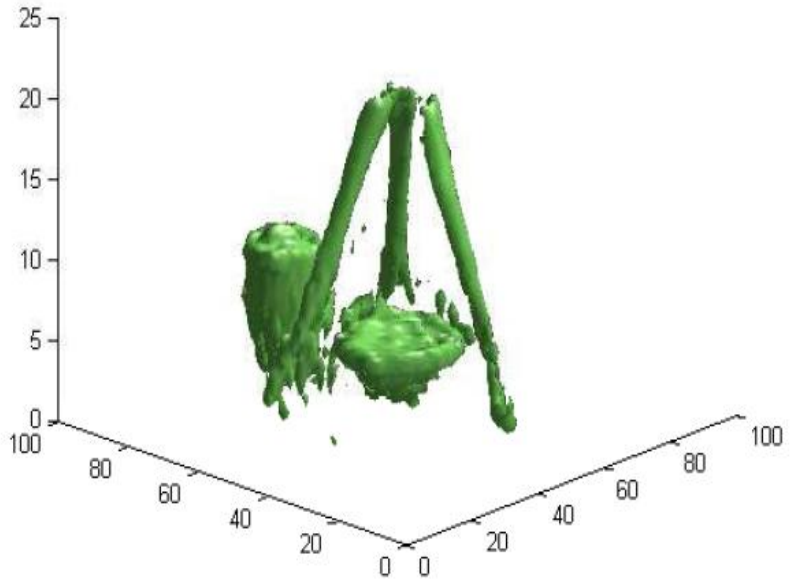




2-D (tomograms) and 3-D Reconstructed Images

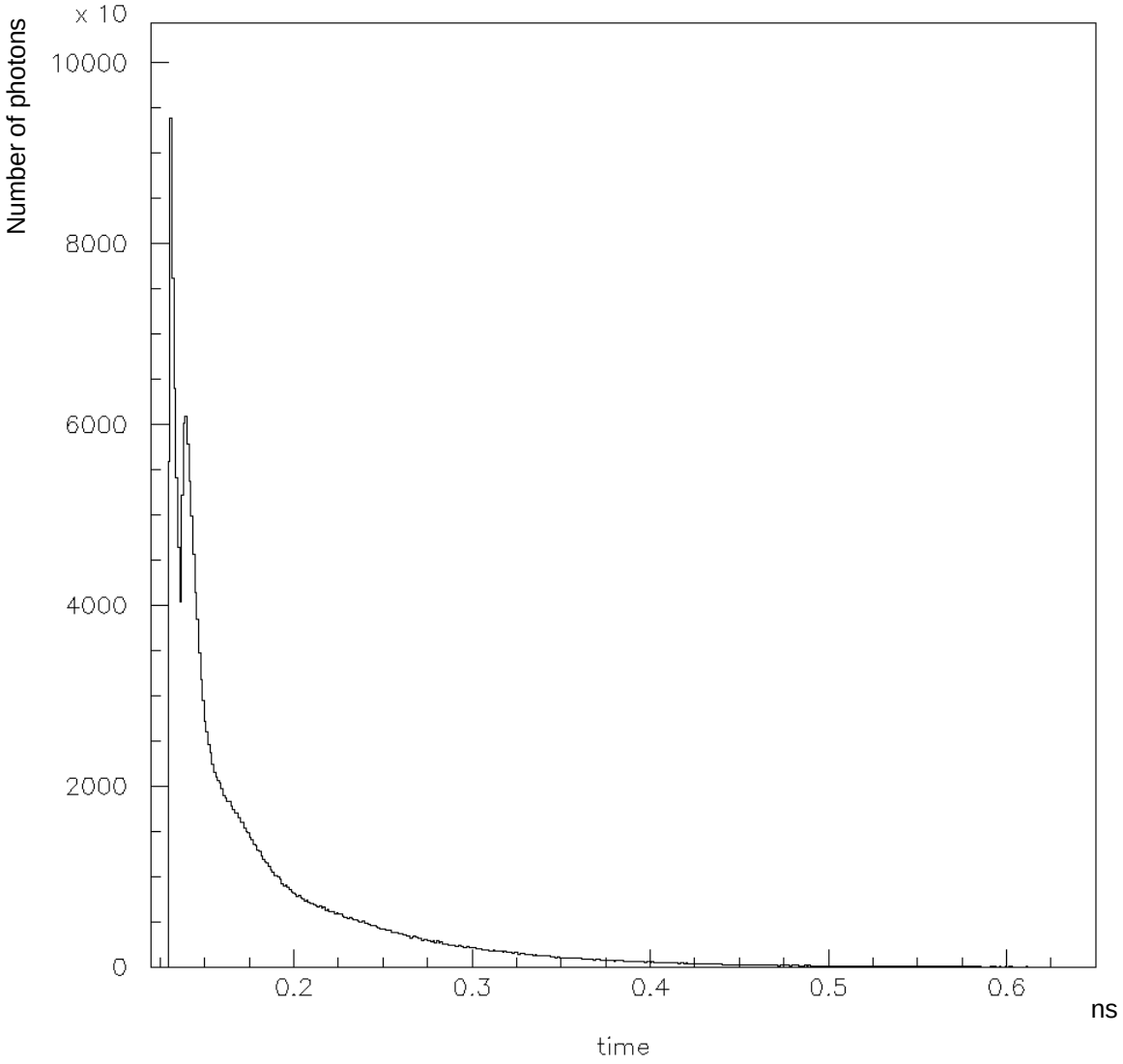


ART Reconstructed Images along the Z-axis

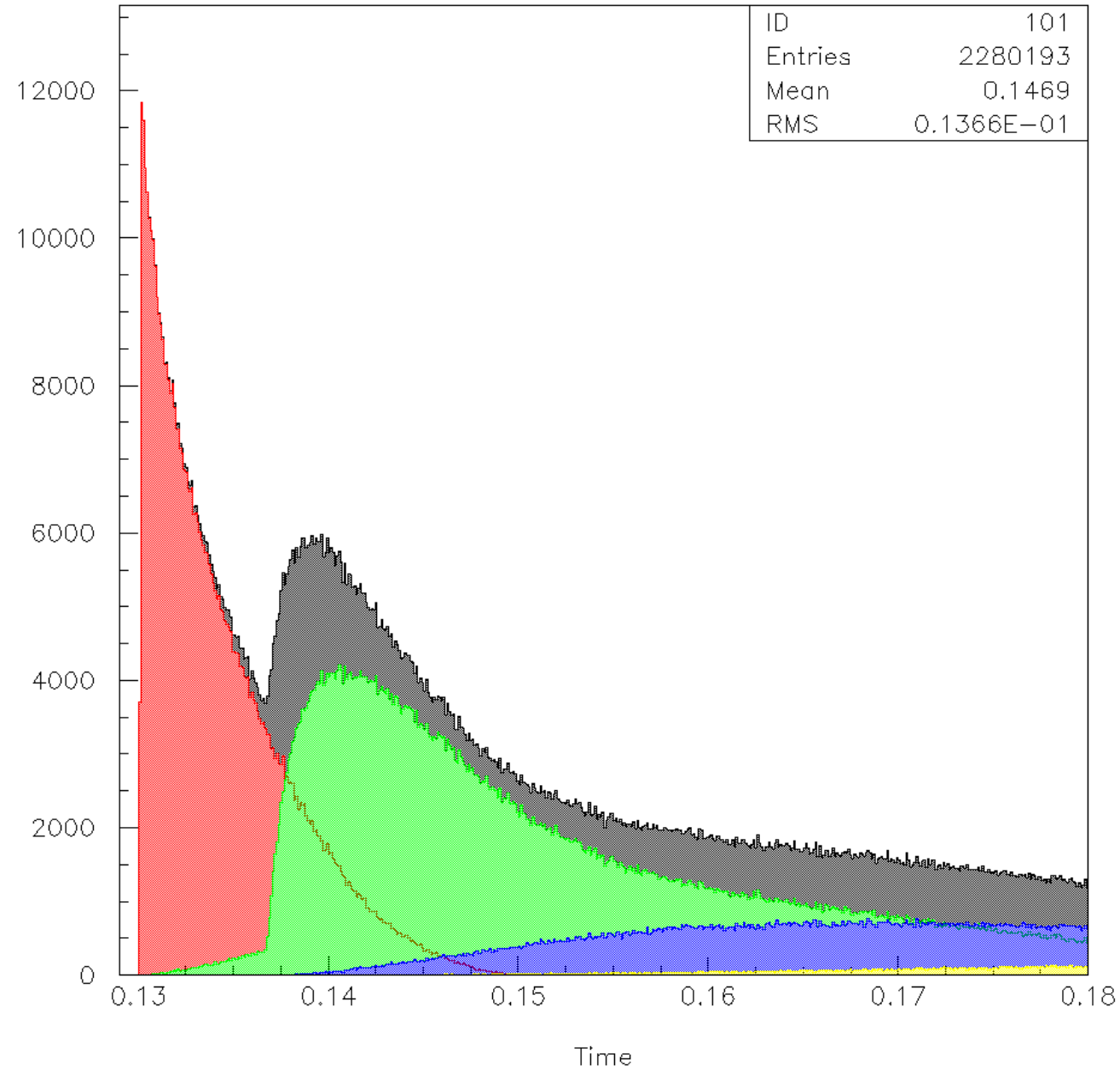


The tomographic levels have been reconstructed using the ART method and then they are contour plotted as resulting a 3-D representation.

Simulation of Time of Flight in TROT

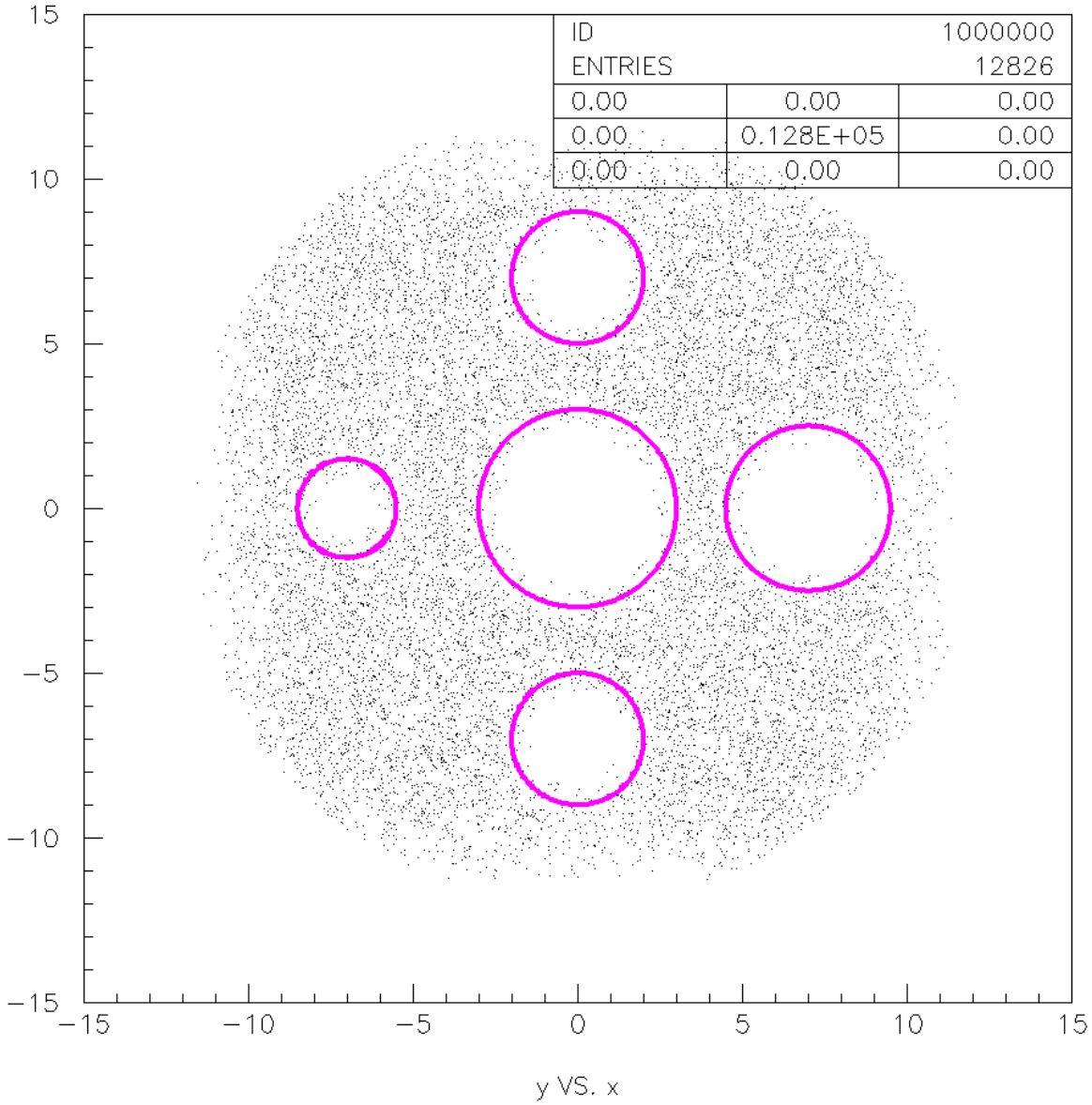


Multiple Scattering



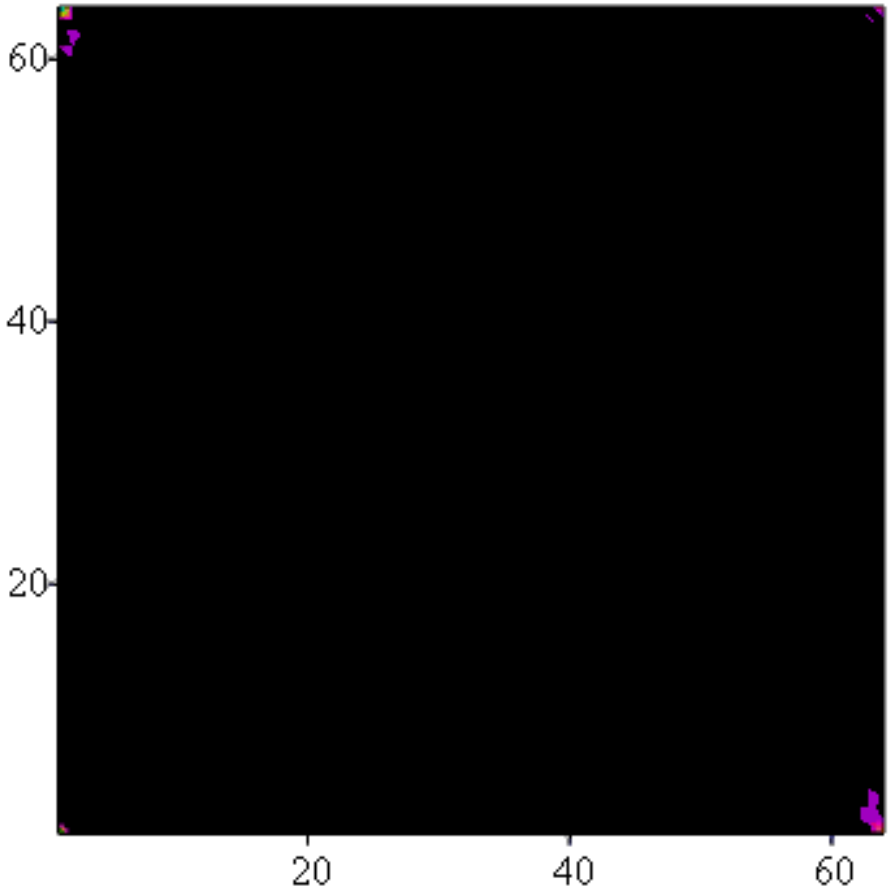
Two scatterings
Three scatterings
Four scatterings
Five scatterings

Projection Images and Time-Resolution



Time less than
130.2 pc
Events 0.6 %

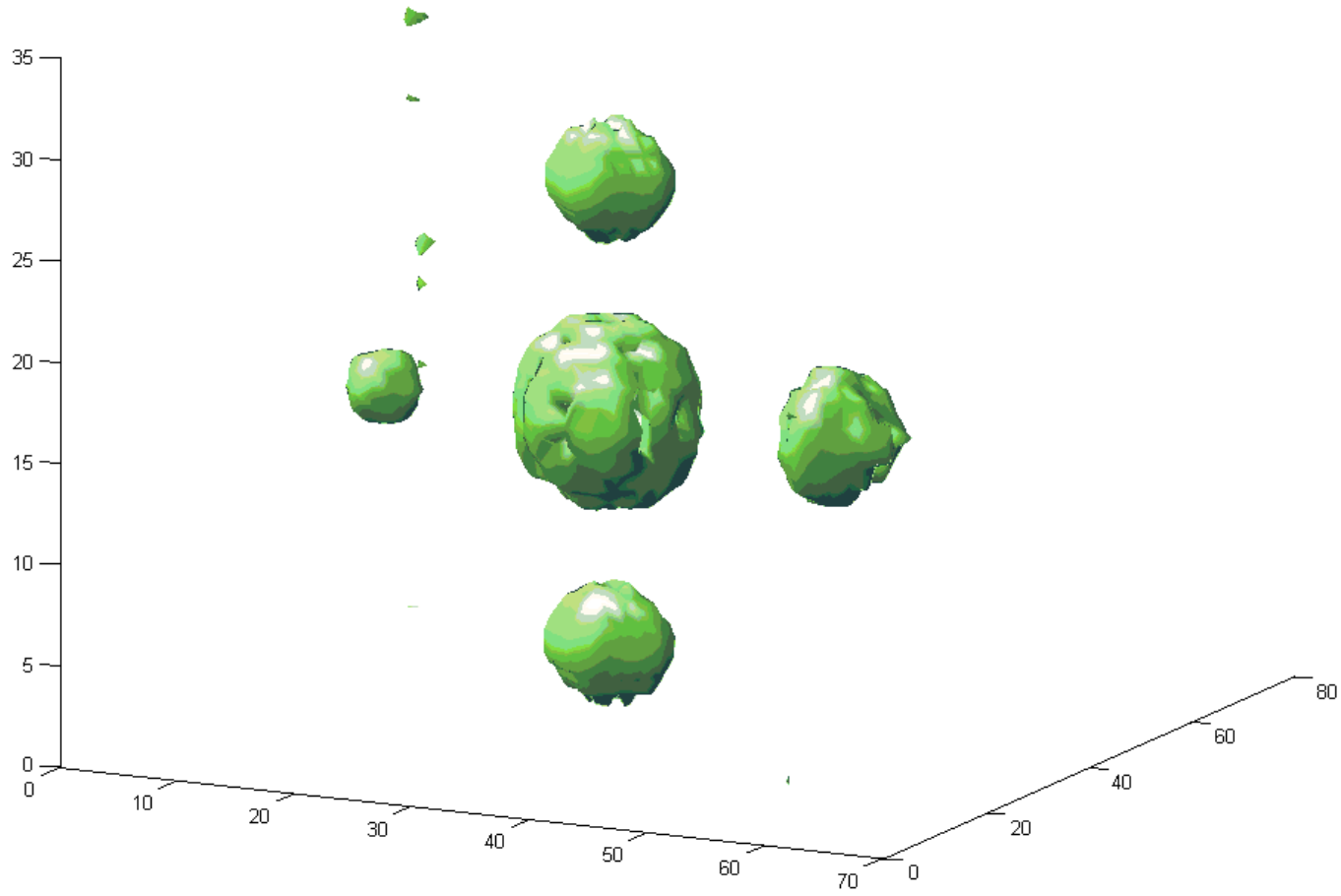
2D Reconstruction



ART Reconstructed Images
along the Z-axis for time less than
130.2 pc

3D Reconstruction

The tomographic levels have been reconstructed using the ART method and then they are contour plotted resulting a 3-D representation.



Conclusions and Future Plans

- Simulation of an optical system with DETECT2000.

- For a conservative case (small tissue thickness and low diffusivity) time gating is possible to select the ballistic light.

- Projection images can be efficiently cleared reducing the noise at the expense of the accumulated photon statistics.

- Tomographic reconstruction is possible, although shadow effects are present.

Future plans

- Expand the simulation techniques with more realistic phantoms.

- Perform the simulations in the MCX and ASAP environment.

- Check the principle of operation with a fast photomultiplier and ultra fast laser pulses.

Ευχαριστώ

Thank you

«Πάντες άνθρωποι του ειδέναι ορέγονται φύσει»

«Ουδέν άτακτον των φύσει»

«Θεός και η φύσις ουδέν μάτην ποιούσιν»

Αριστοτέλης