ΕΘΝΙΚΟΝ & ΚΑΠΟΔΙΣΤΡΙΑΚΟΝ ΠΑΝΕΠΙΣΤΗΜΙΟΝ ΑΘΗΝΩΝ
NATIONAL & KAPODISTRIAN UNIVERSITY OF ATHENS

Τμήμα Φυσικής
Department of Physics

REC3D

An Accumulative Reconstruction Algorithm based on Volume Intersectional Information for PET

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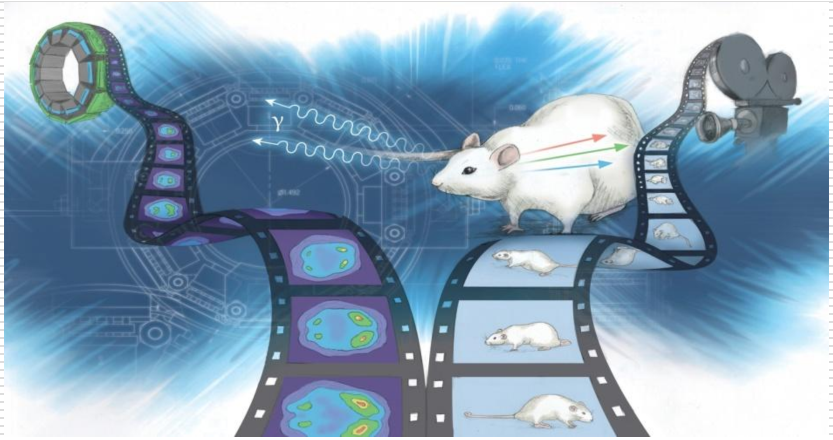
Outline

- Introduction
- REC3D
- Gate Simulations
  - Cylinder Phantoms
  - Parallel Plate PEM
- Conclusions



Reconstruction Algorithms

IMAGE RECONSTRUCTION

ANALYTICAL ALGORITHMS

A Fourier Transformation is used, which is like Randon Transformation for X-rays.

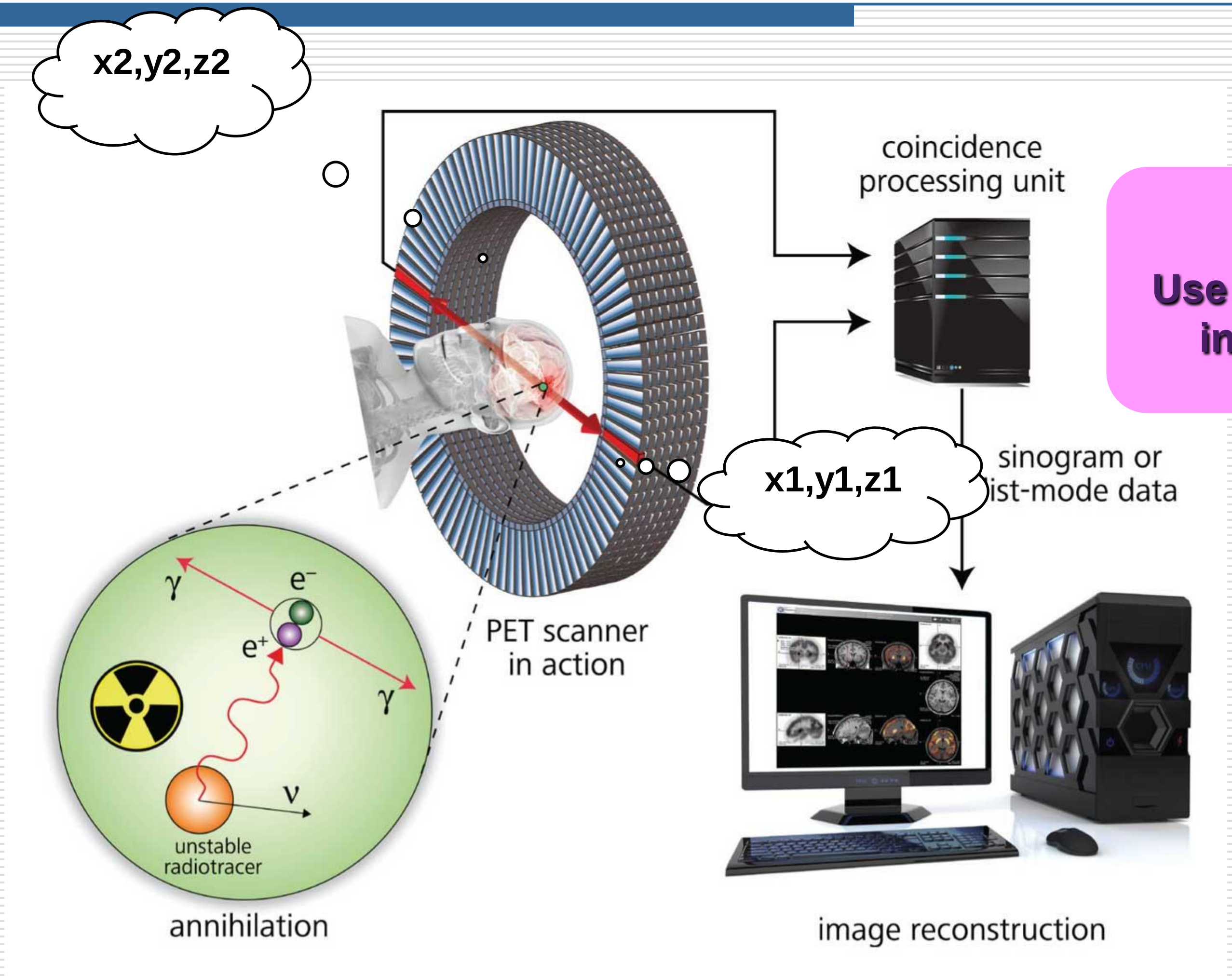
$$\mathbf{F}(\mathbf{k}_x,\mathbf{k}_y)=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\mathbf{f}(\mathbf{x},\mathbf{y})\mathbf{e}^{-2\pi i(xk_x+yk_y)}\mathbf{dxdy}$$

ITTERATIVE ALGORITHMS

OSEM,MLEM

$$\lambda_i^{new}=\frac{\lambda_i^{old}}{p_i}\sum_j^{N_i}\frac{n_j^* p_{ij}}{\sum_k^N \lambda_k^{old} p_{kj}}$$

Image Reconstruction



Basic Idea

Use of raw data from 2 interaction Points

Image Reconstruction

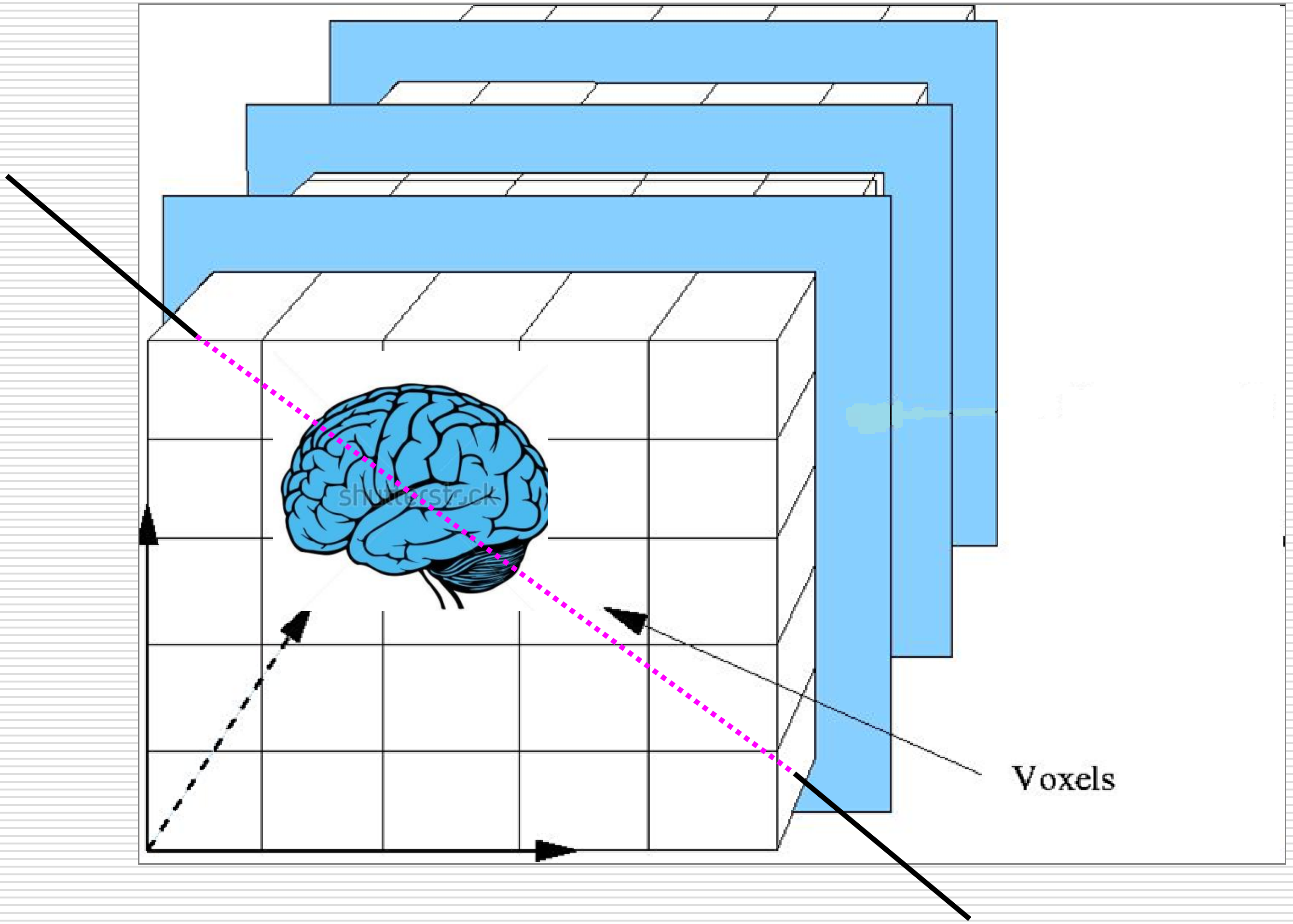


Image Reconstruction

For a certain Z plane and two points P1(x1,y1,z1) , P2(x2,y2,z2) the line that will intersects the plane is given by the equation :

$$\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1} = \frac{z - z_1}{z_2 - z_1}$$

The intersection point is given by:

$$\mathbf{x_n = \frac{z_0 - z_1}{z_2 - z_1} \bullet (x_2 - x_1) + x_1}$$

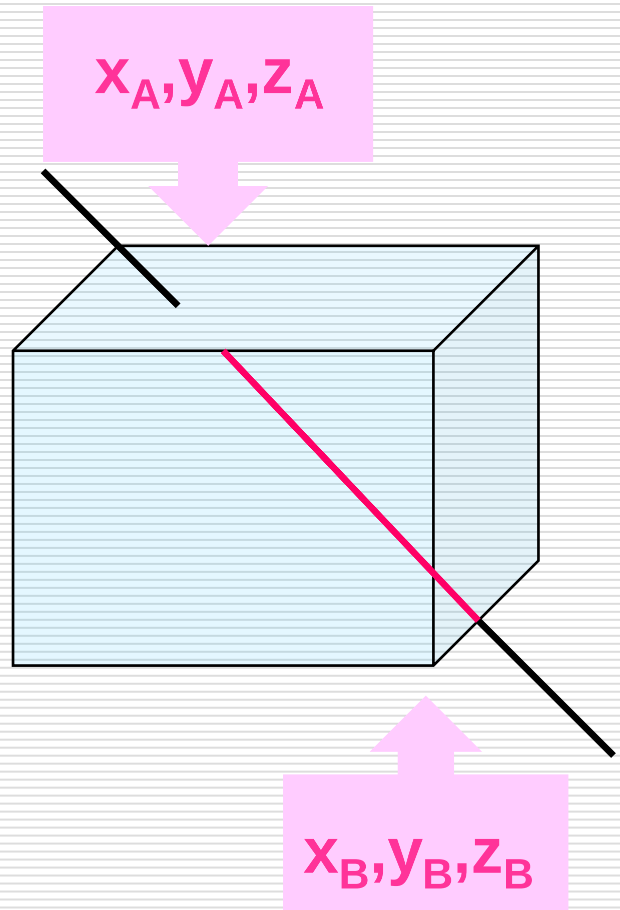
$$\mathbf{y_n = \frac{z_0 - z_1}{z_2 - z_1} \bullet (y_2 - y_1) + y_1}$$

Image Reconstruction

Euclidean distance **that the line has traversed in each voxel is:**

$$\mathbf{Dis} = \sqrt{(x_B - x_A)^2 + (y_B - y_A)^2 + (z_B + z_A)^2}$$

The distance Dis is basically an accumulative weight factor, which is used to assign the luminosity distribution in each voxel .

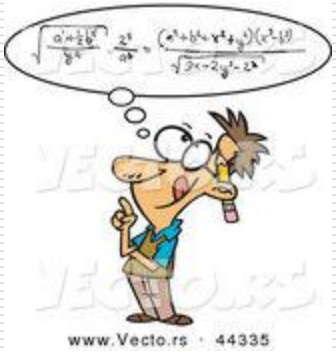


Total Number of steps : N^3

Accelerated image Reconstruction

Instead of scanning the whole voxelized Volume in order to save computation time and having Dis already calculated we make a step further to calculate the first Derivative :

- $DivX = \frac{C_{2x} - C_{1x}}{De}$
- $DivY = \frac{C_{2y} - C_{1y}}{De}$
- $DivZ = \frac{C_{2z} - C_{1z}}{De}$



This way we can “predict” the path of the LOR inside the Volume.

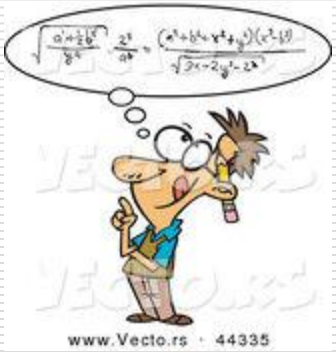
Accelerated image Reconstruction

In order to insure high accuracy we introduce a specific step to the calculation of the derivative.

$$QQ\left(1\right) = C_1\left(1\right) + 0.01 * x_{step} * DivX$$

$$QQ\left(2\right) = C_1\left(2\right) + 0.01 * y_{step} * DivY$$

$$QQ\left(3\right) = C_1\left(3\right) + 0.01 * z_{step} * DivZ$$



QQ(1),QQ(2),QQ(3) are the intersection points of the LOR inside every voxel and xstep, ystep, zstep insure that during the Div calculation we stay inside the voxel .

Accelerated image Reconstruction

The total number of steps in this method is :

$$\text{Max Total Steps: } \sqrt{N_x^2 + N_y^2 + N_z^2}$$

To compare the two methodos :

$$\frac{N^3}{N\sqrt{3}} \approx \frac{N^2}{2}$$

The factor N^2 /2 is translated to less computation time

Evaluation of REC3D

In order to evaluate the effectiveness of Rec3D we made:

- ✓ **Gate simulations of two different type of Scanners.**
- ✓ **Evaluation of Image Reconstruction.**
- ✓ **Comparison between REC3D and commercially available programs.**

GATE

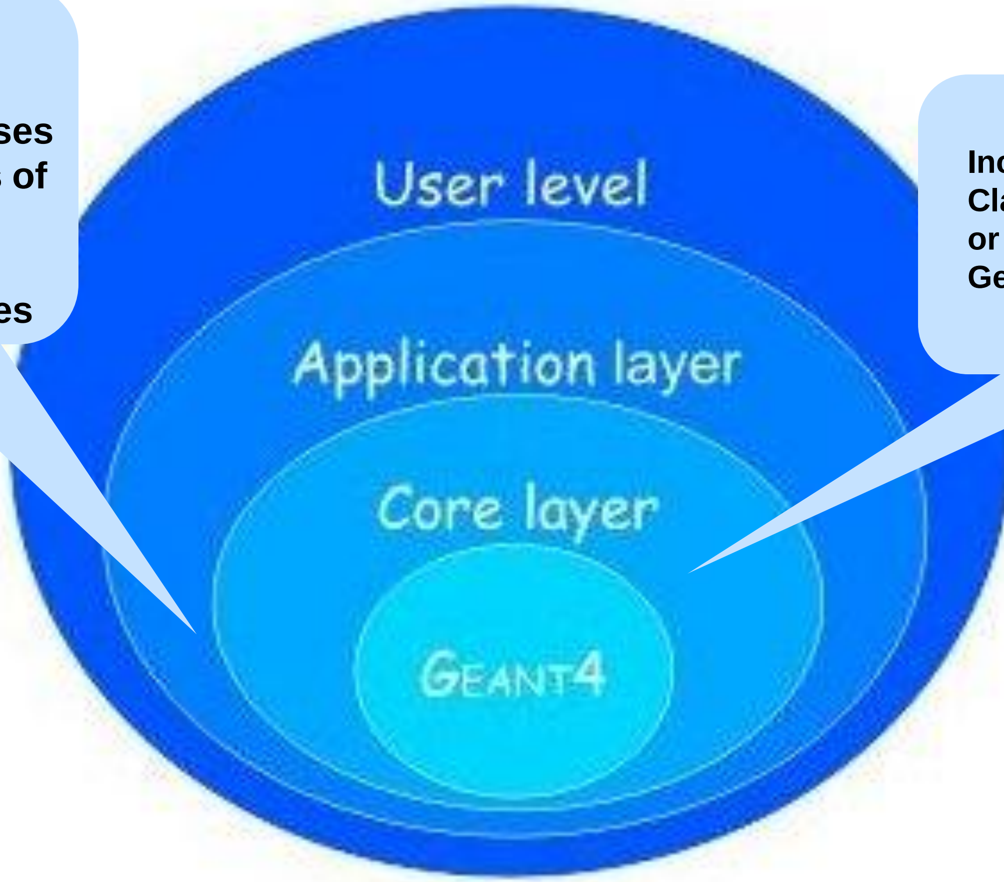
Gate, the Geant4 Application for Tomographic Emission, combines the advantages of the general-purpose Geant4 simulation code and of specific software tool implementations dedicated to emission tomography.

Indeed, GATE takes advantage of the well-validated physics models, of the geometry description, and of the visualization and 3D rendering tools offered by Geant4 but has a distinctive characteristic the modeling of time-dependent processes.

GATE

Application layer

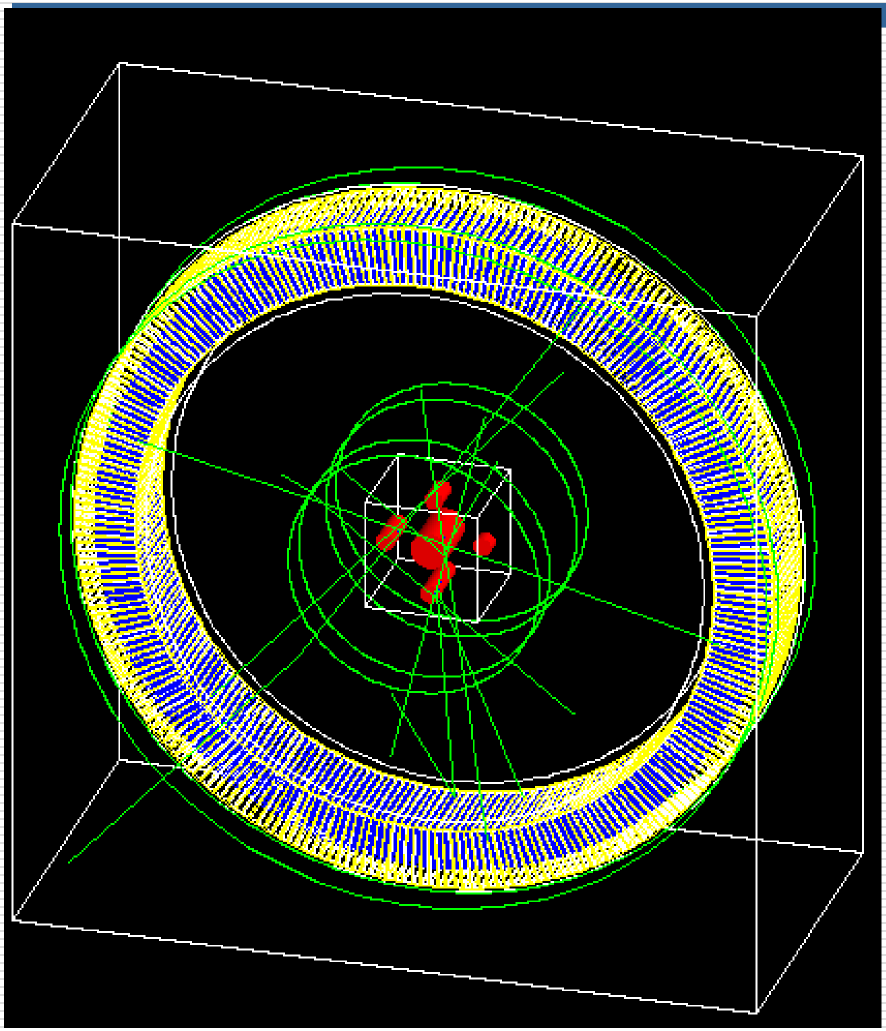
This layer is composed by Classes from basic Classes of the core layer to model specific objects or properties



Core layer

Include some basic Classes that are common or even mandatory in all Geant4 simulations

Cylindrical PET Simulation

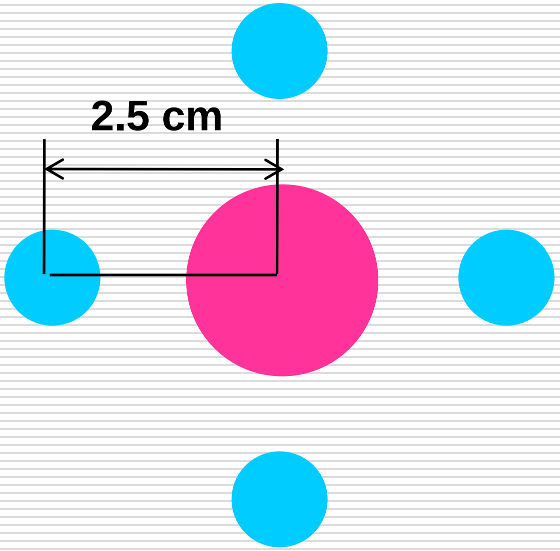


Sherbrooke 16 ring PET	
Outer Diameter	190 mm
Inner Diameter	150 mm
Height	40 mm
Crystal	BGO
Crystal size	20X3X3 mm^3
Total Number of Crystals per ring	256
Number of rings	16

Source Features

Simulation 1

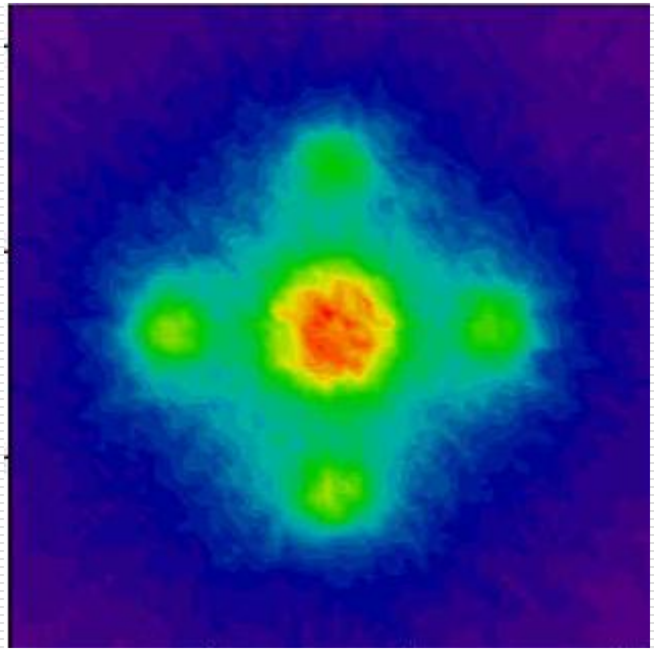
- **Source Activity: 10 kBq**
- **Type: Cylinder**
- **Number: 5**
- **PET: Sherbrooke 16rings**



# Source	Radius	Height	Type
0	1 cm	32 mm	γ
1	0.5 cm	8 mm	γ
2	0.5 cm	16 mm	γ
3	0.5 cm	24 mm	γ
4	0.5 cm	32 mm	γ

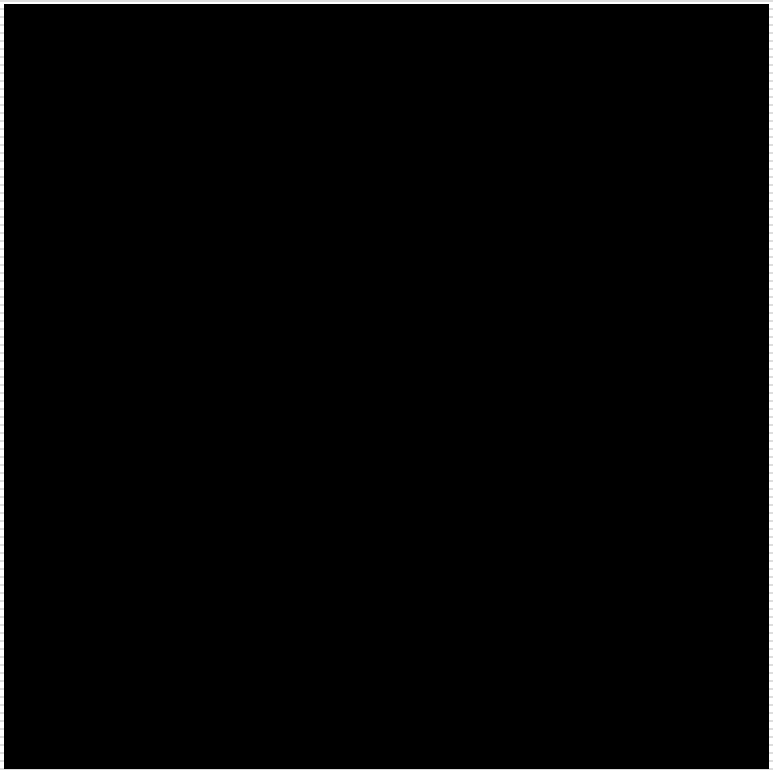
Results

OSEM

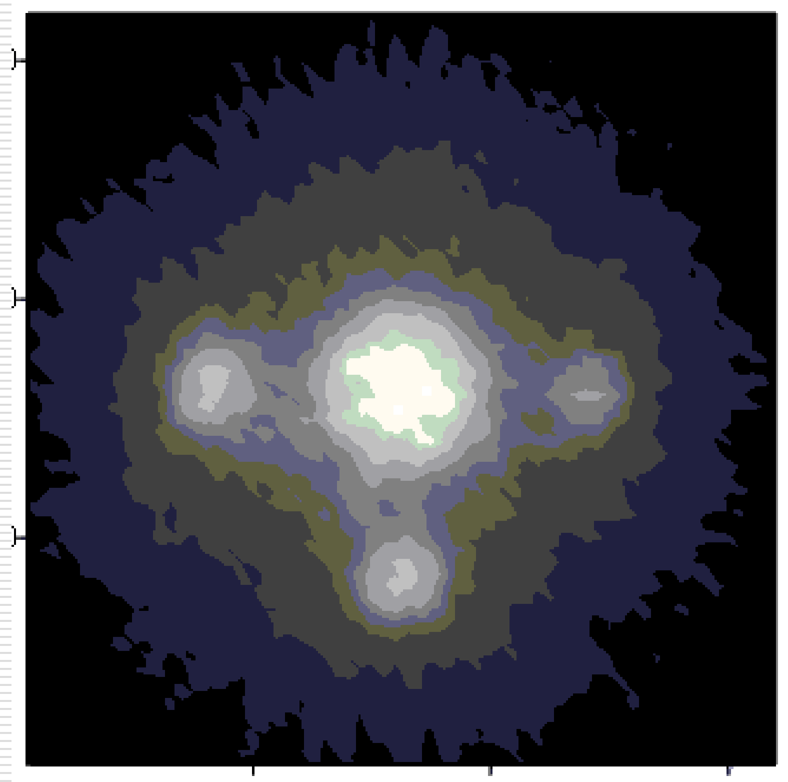


REC3D

Results

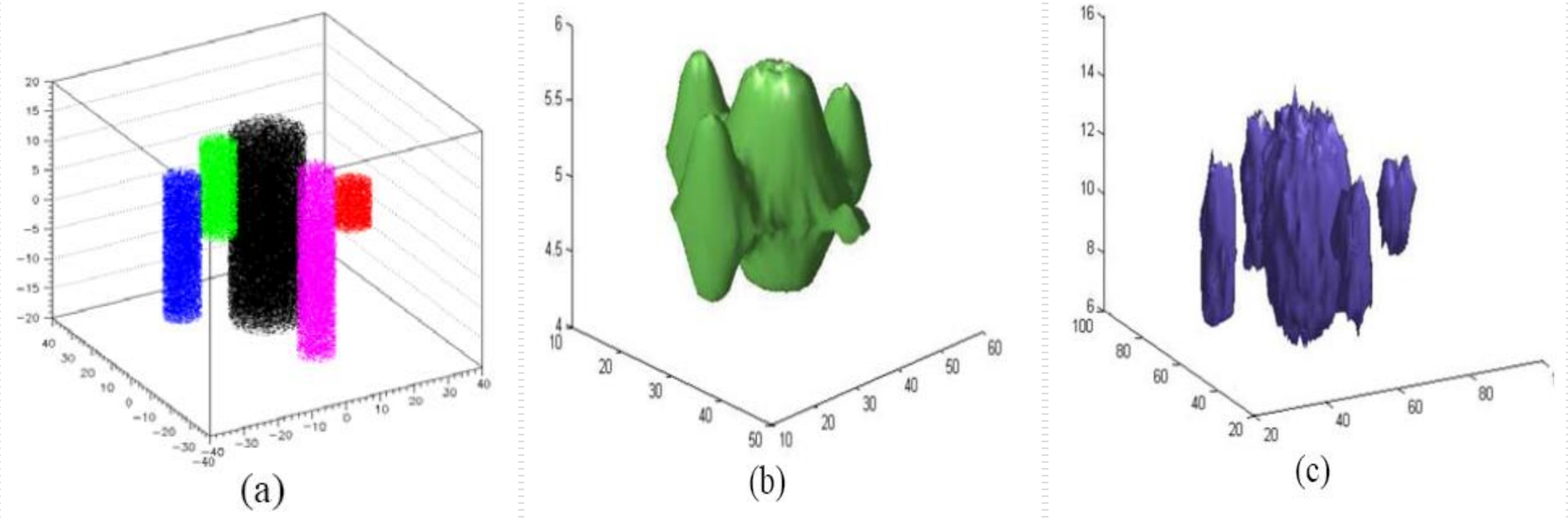


OSEM



REC3D

Results



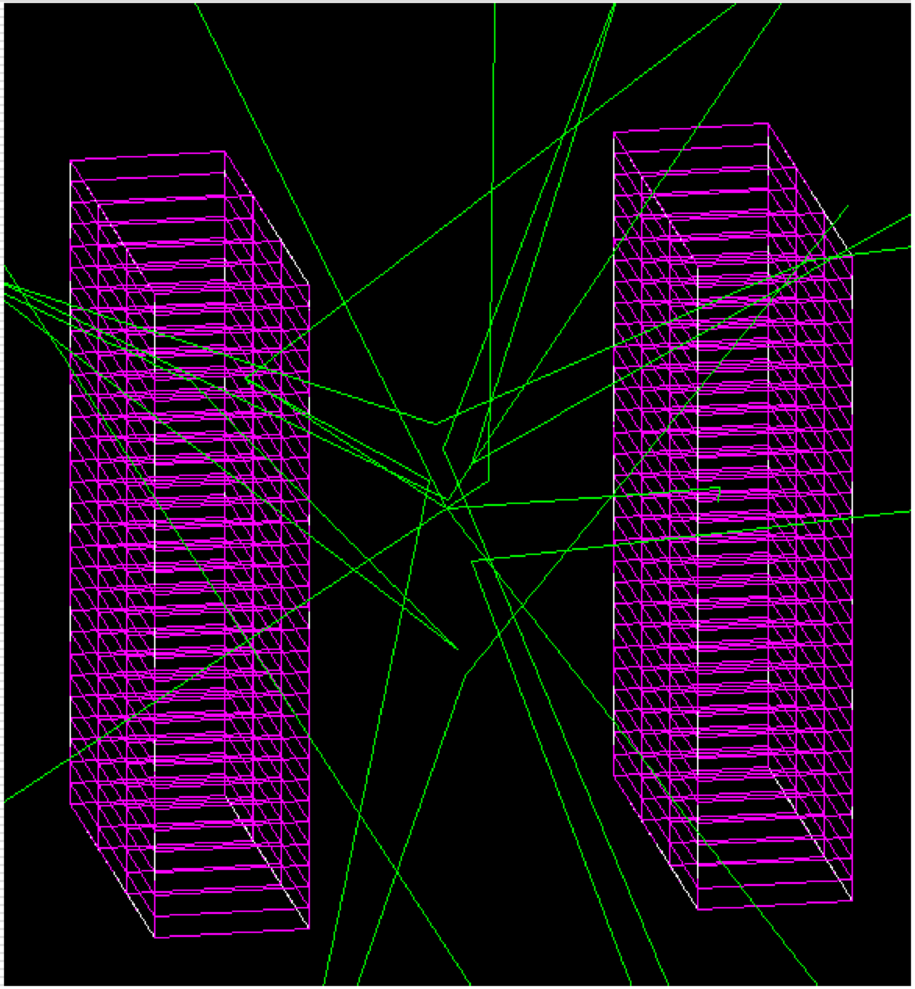
(a) Five Cylinder Simulation Phantom

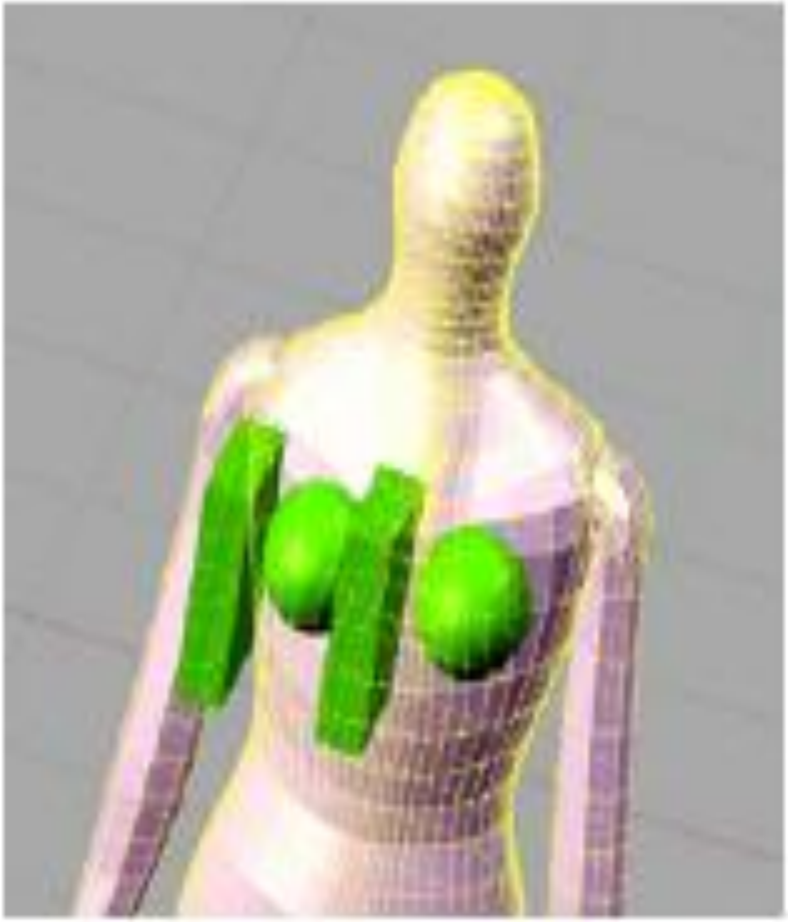
(b) Reconstruction with Non-Energy Cut

(c) Reconstruction with Energy Cut

PEM SIMULATION

PEM





Design study of a high-resolution breast dedicated PET system built from CZT detectors

Hao Peng and Craig S. Levin

Simulation Features

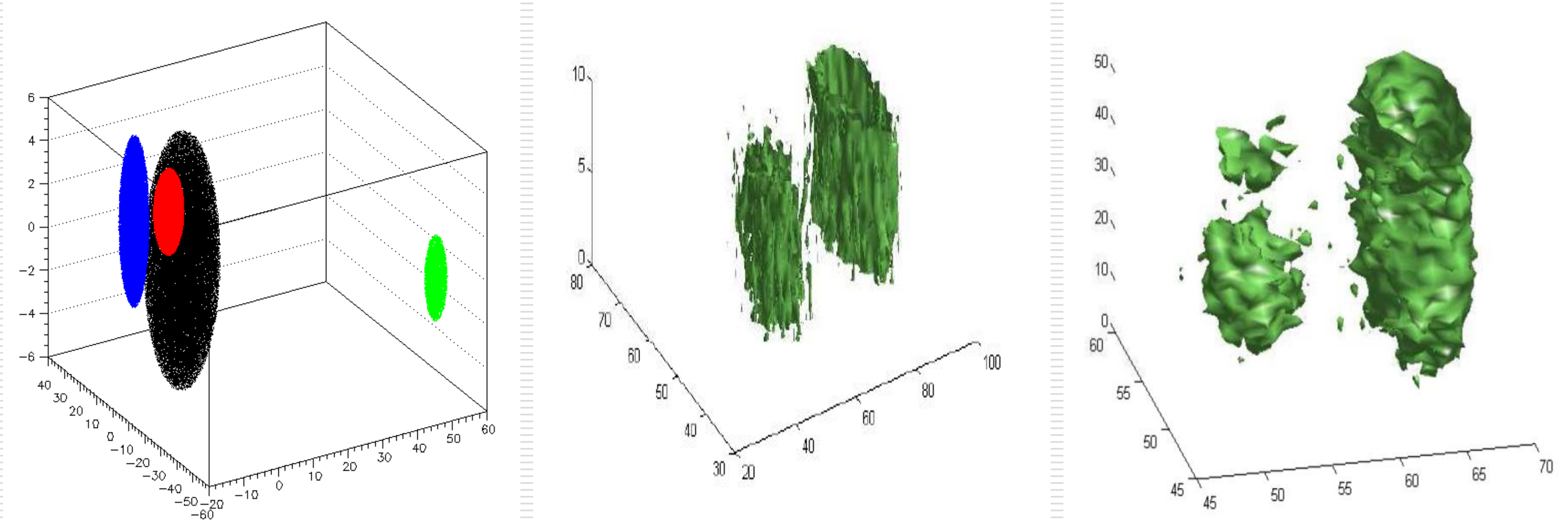
PEM	
Number of Plates	2
Plate dimension	12X15X4 cm
Crystal dimension	4X0.5X4 cm
Number of Crystals in X axis, Y axis, Z axis	3X30X1
Type of Crystal	CZT

Simulation 2

- **Source Activity: 10 kBq**
- **Type: Ellipse**
- **Number: 4**
- **PEM**

#	a=b(mm)	c (mm)	x,y,z	Type
1	10	6	0,0,0	γ
2	4	4	30,0,0	γ
3	4	2	30,10,0	γ
4	3	2	-50,50,0	γ

Results



(a) Four Ellipse Simulation Phantom

(b) Reconstruction with Non-Energy Cut

(c) Reconstruction with Energy Cut

Conclusions

REC3D

- Efficient reconstruction without artifacts
- The Real Scanning Range is defined by the user.
- The number of voxels in x,y,z axis is defined by the user.
- Can be used for any scanner geometry.
- Introduction of energy cut.
- User Friendly.

ΣΑΣ ΕΥΧΑΡΙΣΤΩ ☺

bAckUp

Γεωμετρικά Χαρακτηριστικά