# Computing @ IRIS

## Dedicated Image Reconstruction Software

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**Servei Central de Suport a la Investigació Experimental (SCSIE)**

ISO 9001
BUREAU VERITAS Certification
Certificate Nº ES077144-1

scsie.uv.es

On behalf of IRIS group members

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Coord. Científico tareas de **Reconstrucción de la Imagen Médica**

Image Reconstruction, Instrumentation and Simulations for medical imaging applications (IRIS)

ific.uv.es/iris

IFIC INSTITUT DE FÍSICA CORPUSCULAR

Instituto de Física Corpuscular
ific.uv.es

IFIMED

Instituto de Física Médica
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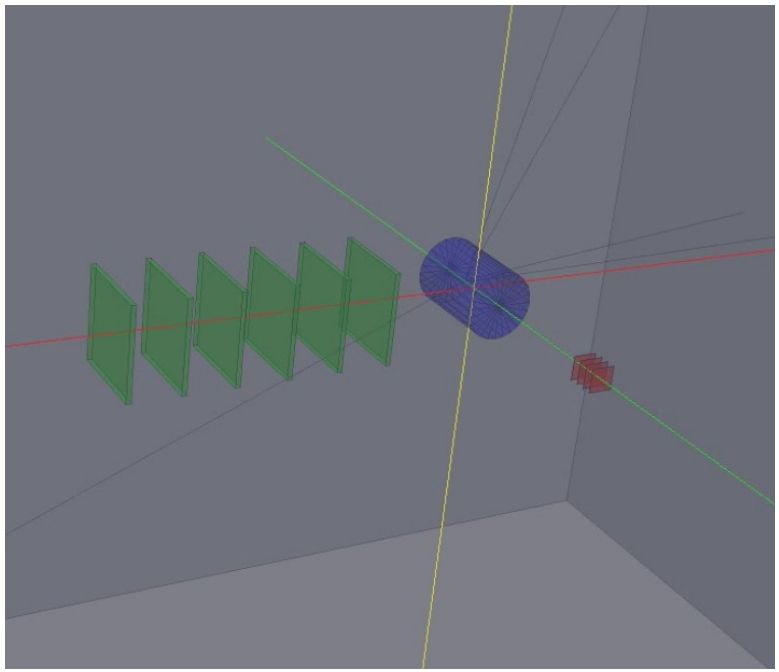
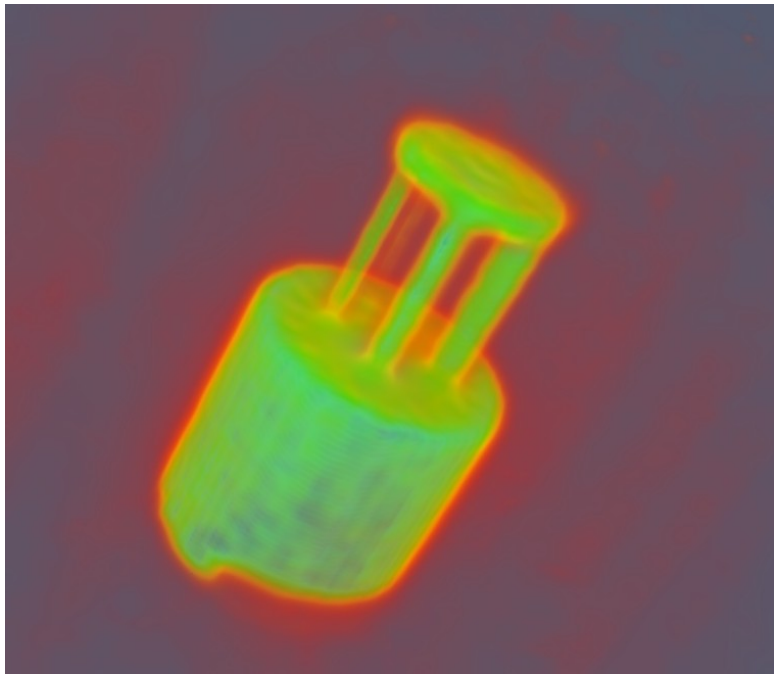
## Monte Carlo Simulations



## Image Reconstruction



# MonteCarlo simulations

Two main reasons

- To advance the device future capabilities
- To generate test data for the reconstruction algorithms

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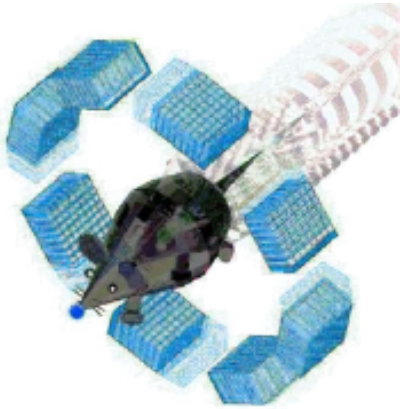
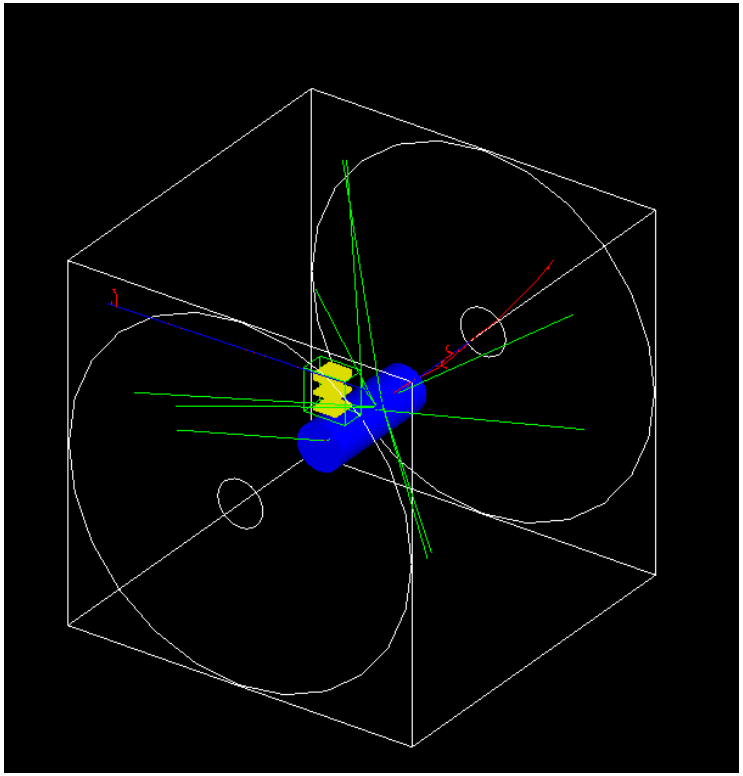
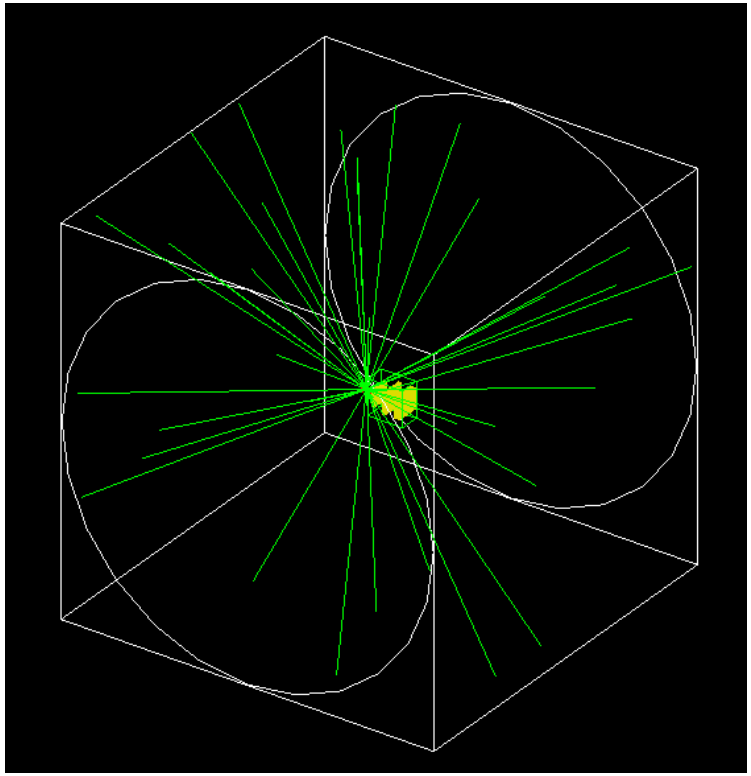
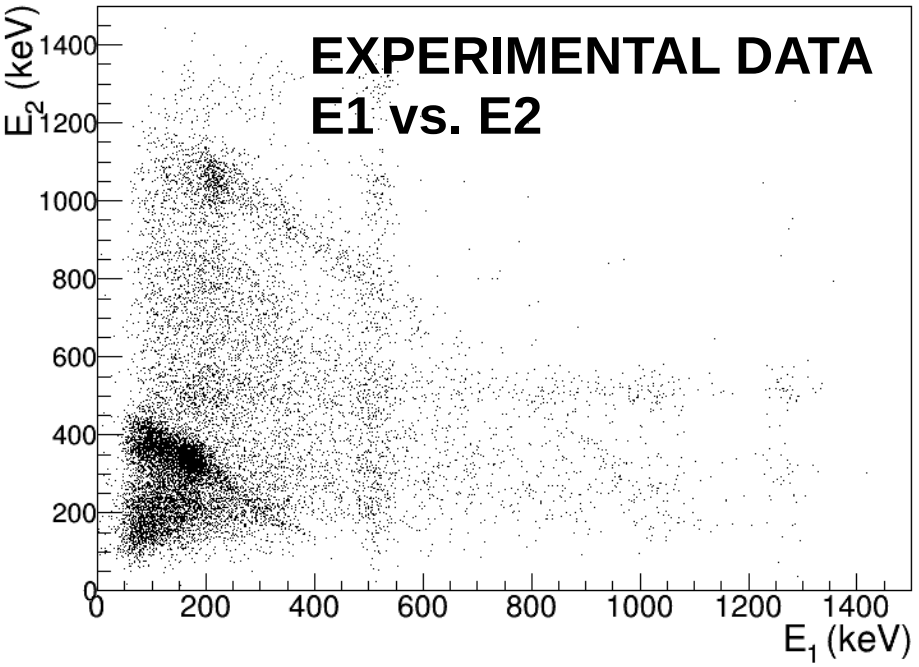


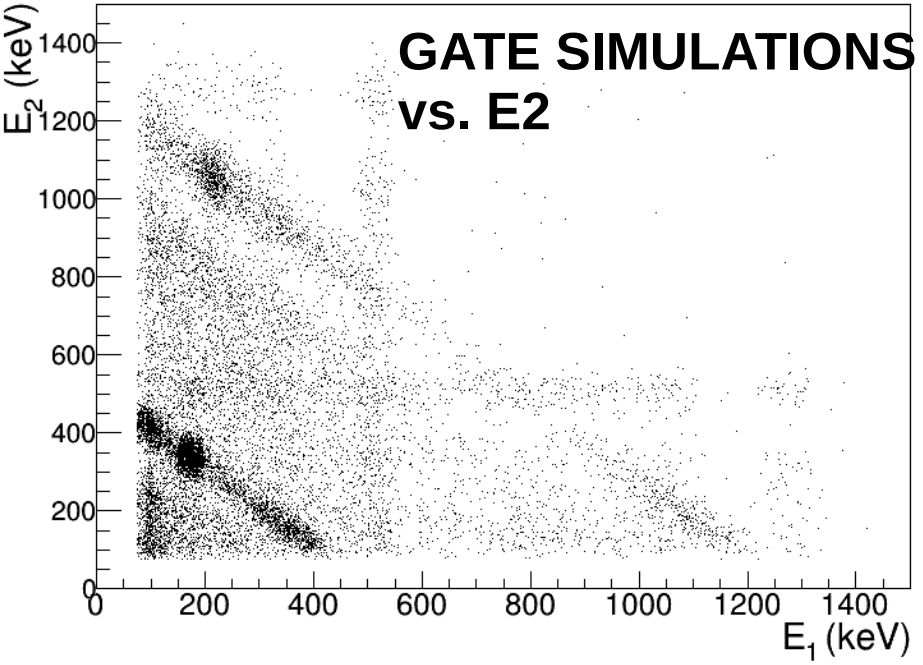
Geant 4

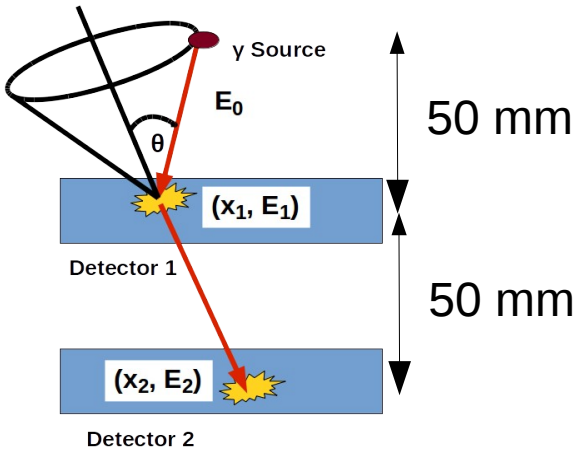


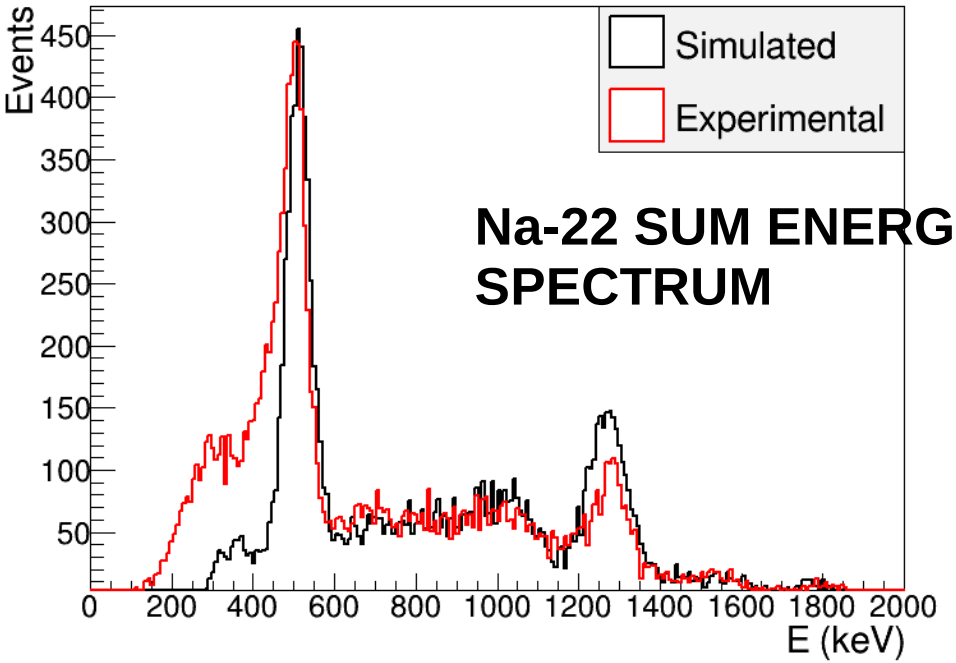


# Two-layer simulations vs. data

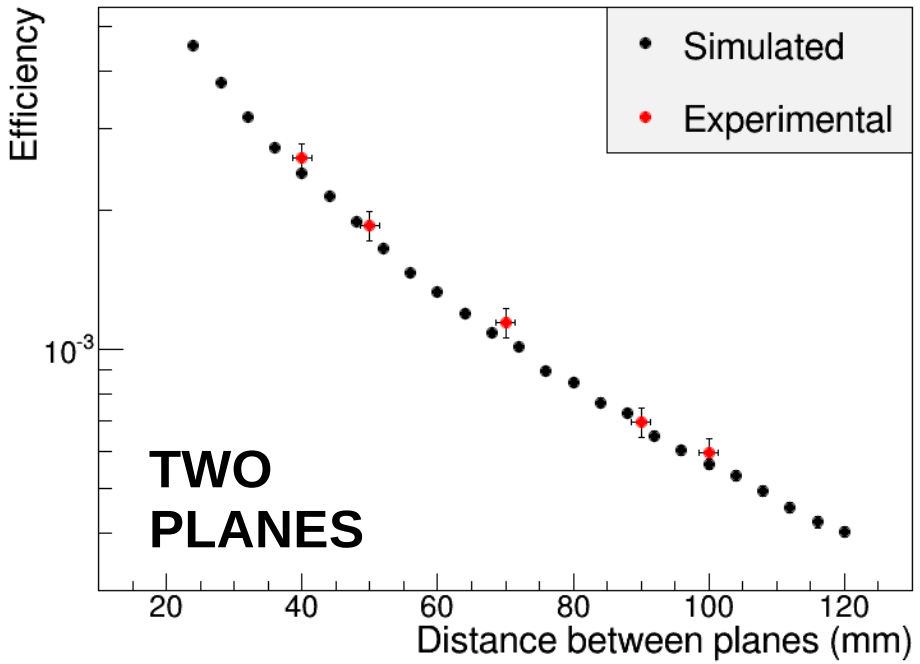


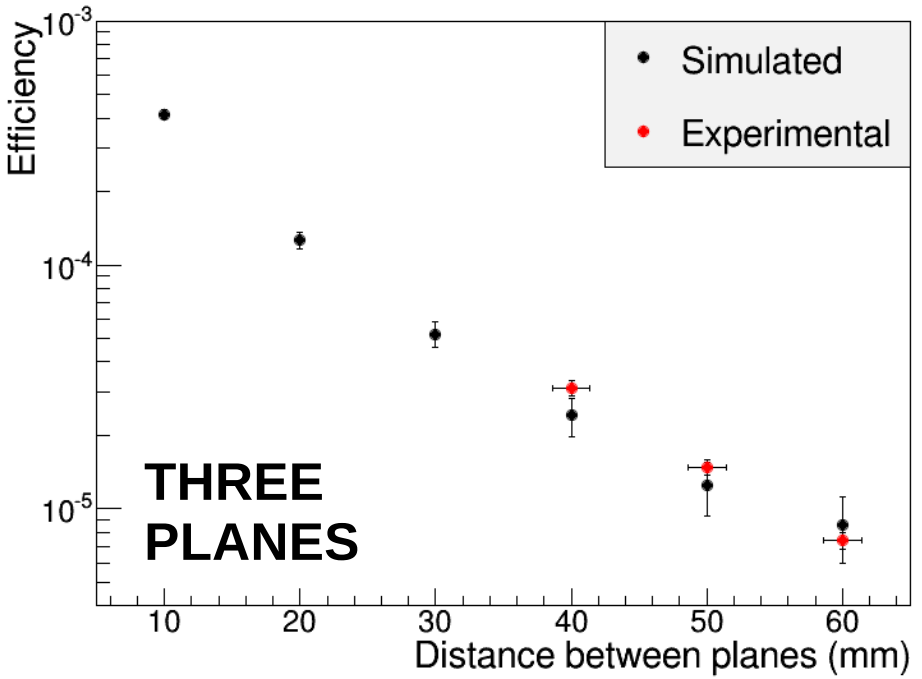



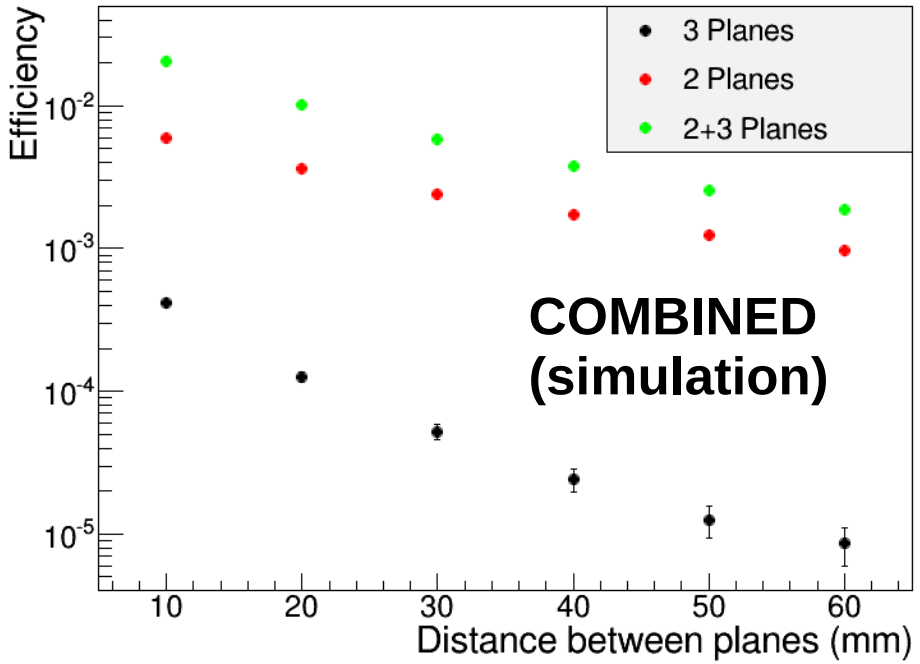



# Efficiency




**Characterization results in E Muñoz et al. Phys. Med. Biol, 2017.**

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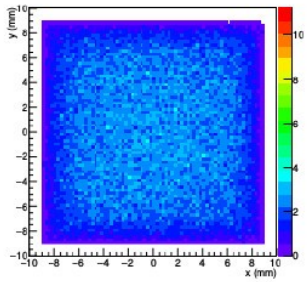
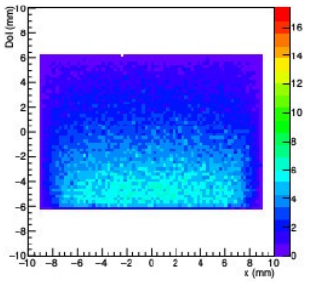
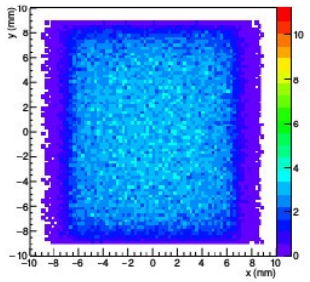
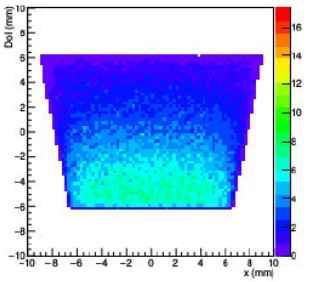
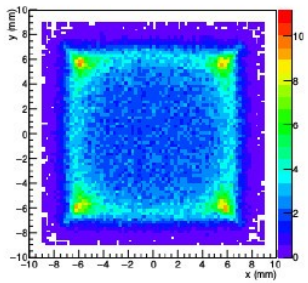
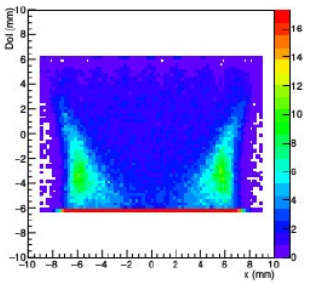
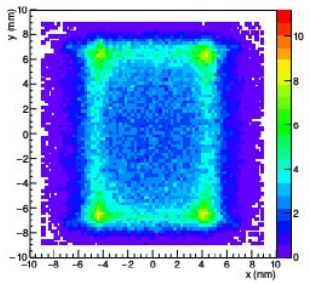
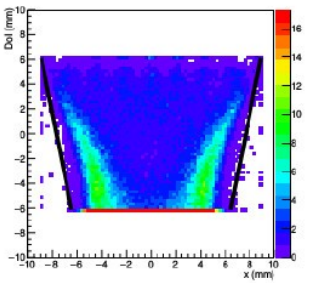
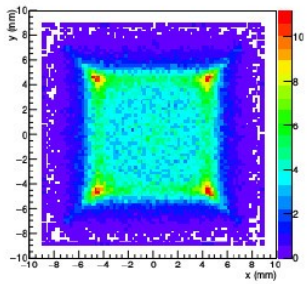
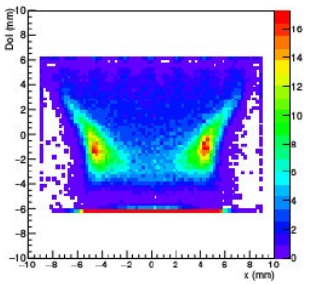
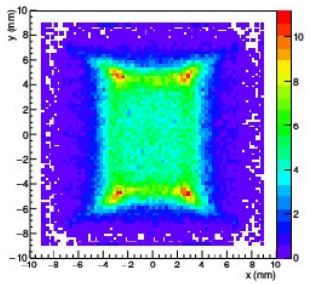
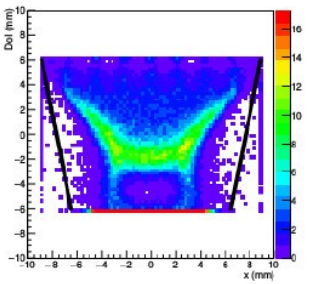
| | cuboid | | tapered | |
|---|---|---|---|---|
| | XY | XZ | XY | XZ |
| ground-truth |  |  |  |  |
| VS0 |  |  |  |  |
| VS1 |  |  |  |  |

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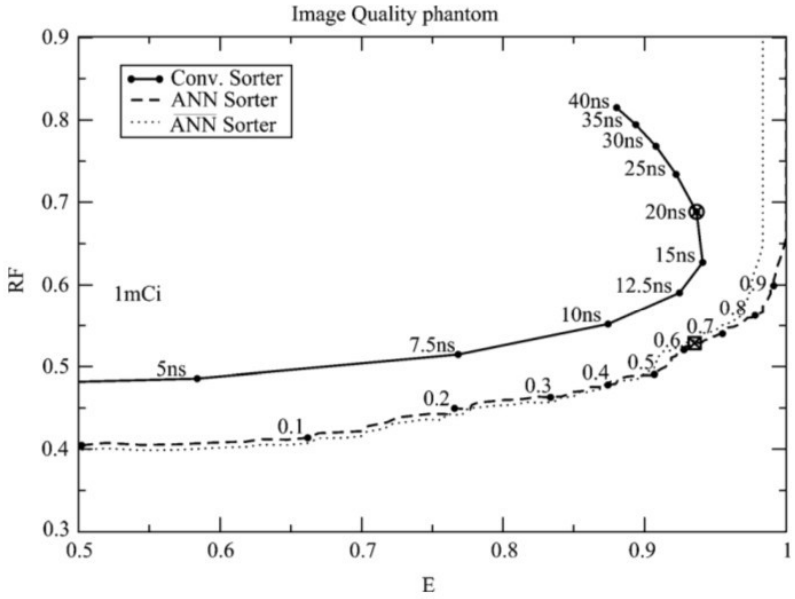



Fig. 7. RF and E values for the IQ phantom. The crossed circle, ⊗, corresponds to the standard coincidence window width of 20 ns. The different windows and thresholds used for obtaining the graph are indicated. The crossed square, ⊠, corresponds to the threshold used to compare with the standard window. The $\overline{ANN}$ corresponds the ANN sorter with the extra condition of no detection events duplicities, see Section IV.

The points that define the lines in all these graphs are ob-

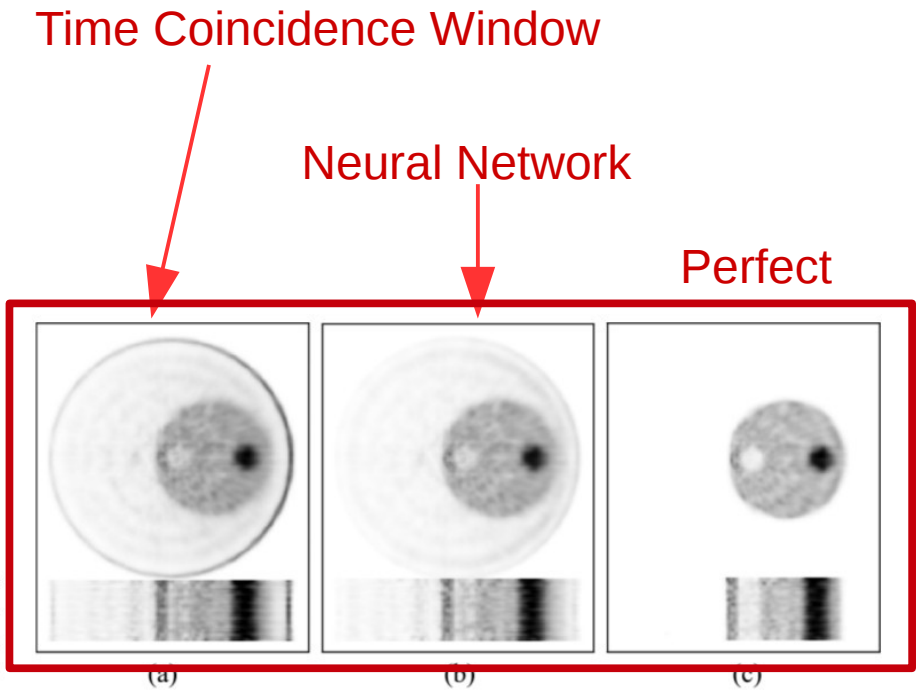
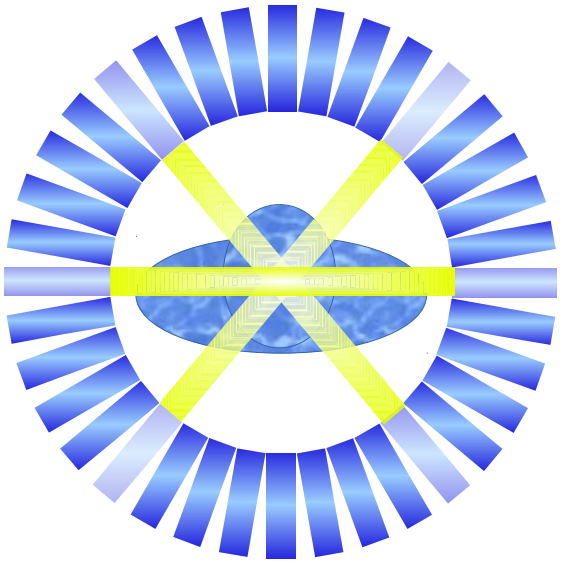



Fig. 8. Central transaxial and coronal slices of reconstructed image volumes of the IQ phantom after 30 iterations. Using the sorted data produced by: a) the conventional sorter, b) the ANN sorter and c) the ideal sorter (no randoms). The number of coincidences stored in each data set was $37.1 \times 10^6$, $24.5 \times 10^6$ and $12.3 \times 10^6$ respectively. (a) Conventional; (b) ANN; (c) Ideal.

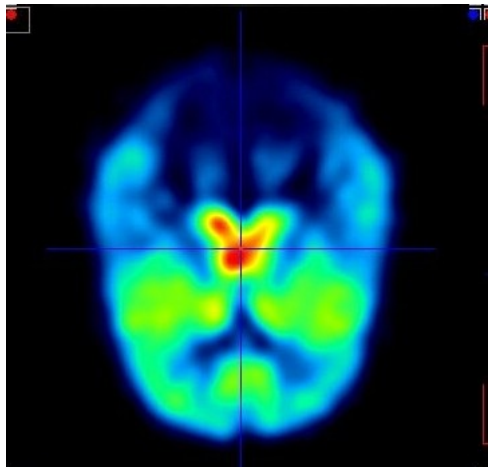
# Image Reconstruction (DIRS)

One or our **main strengths** is to develop **Dedicated Image Reconstruction Software**

**“tailor-made” software** specific for each particular device able of exploiting at maximum its imaging capabilities



$$n_j^{k+1} = \frac{n_j^k}{\sum_{i=1}^{I} a_{ij}} \sum_{i=1}^{I} a_{ij} \frac{m_i}{q_i^k}$$

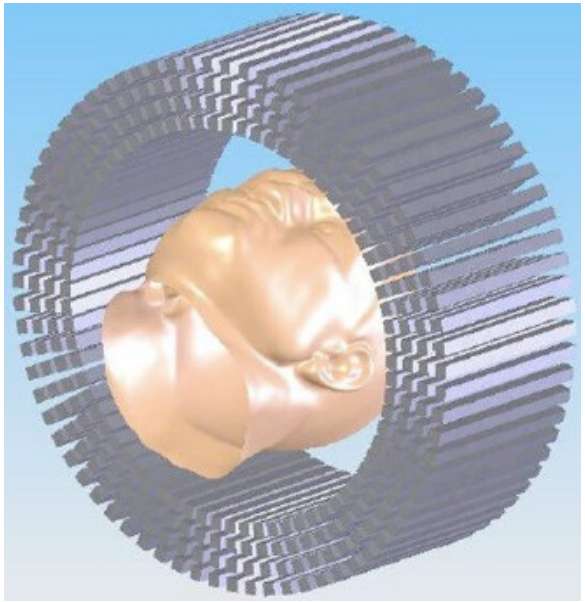


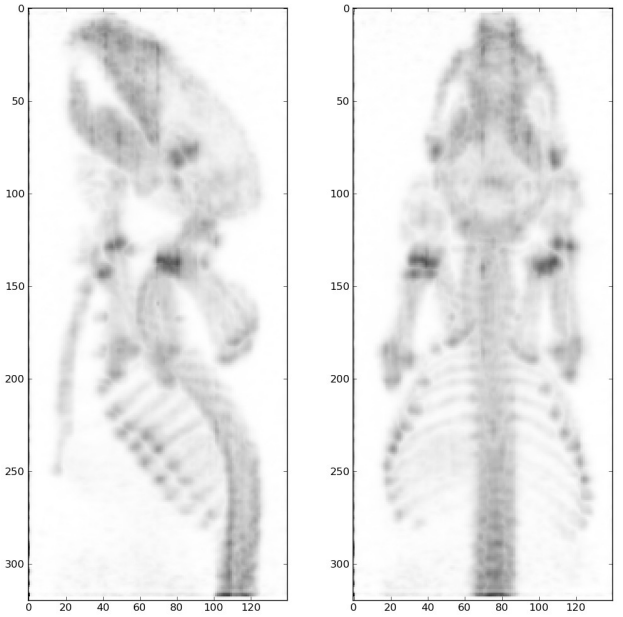
Data acquisition

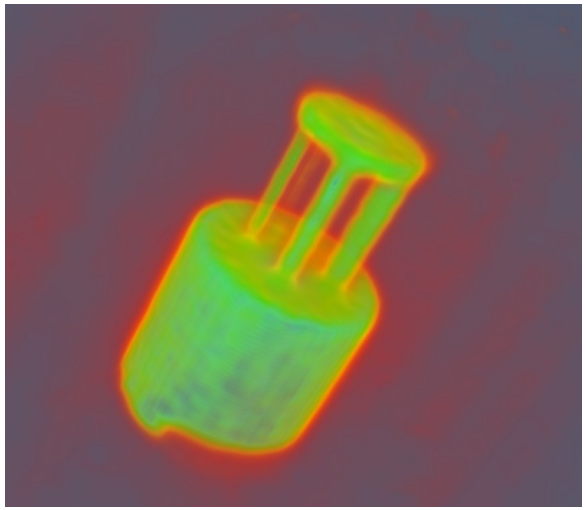
***Image Reconstruction***

Medical Image

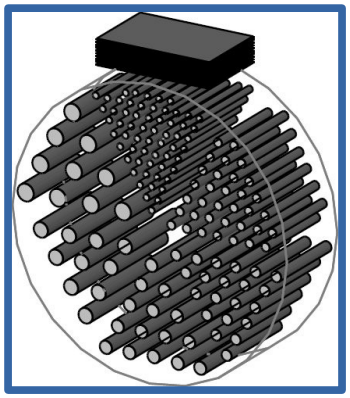
# Image Reconstruction (DIRS) :: AXPET

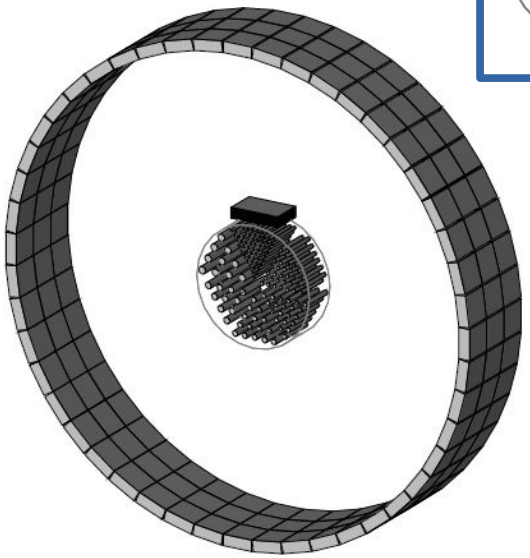


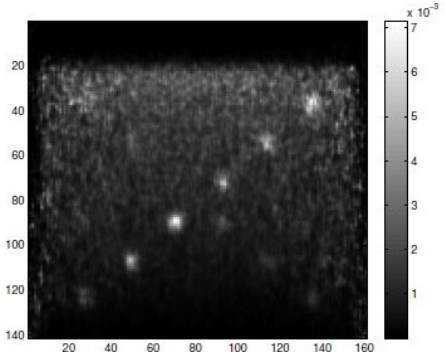


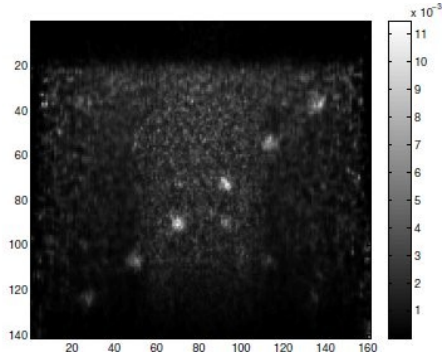



# Image Reconstruction (DIRS) :: PET + probe

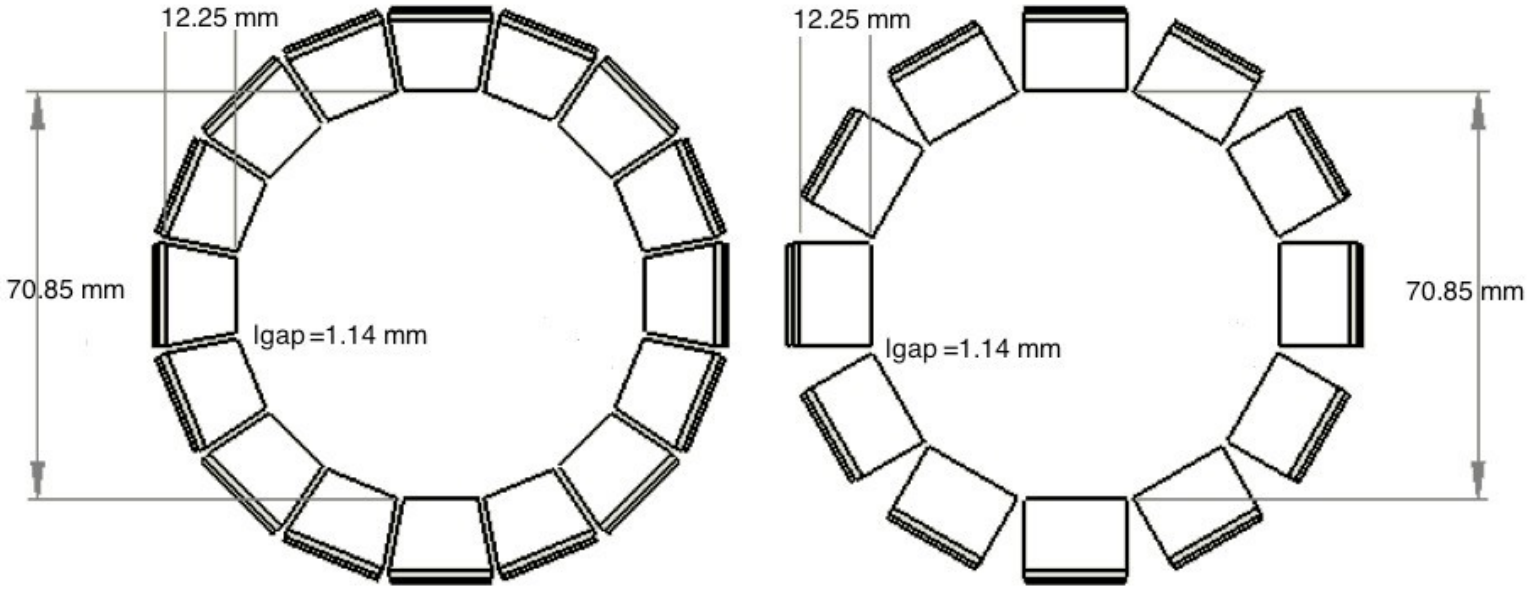






# Image Reconstruction (DIRS) :: Full PET ring made of Continuous Crystals

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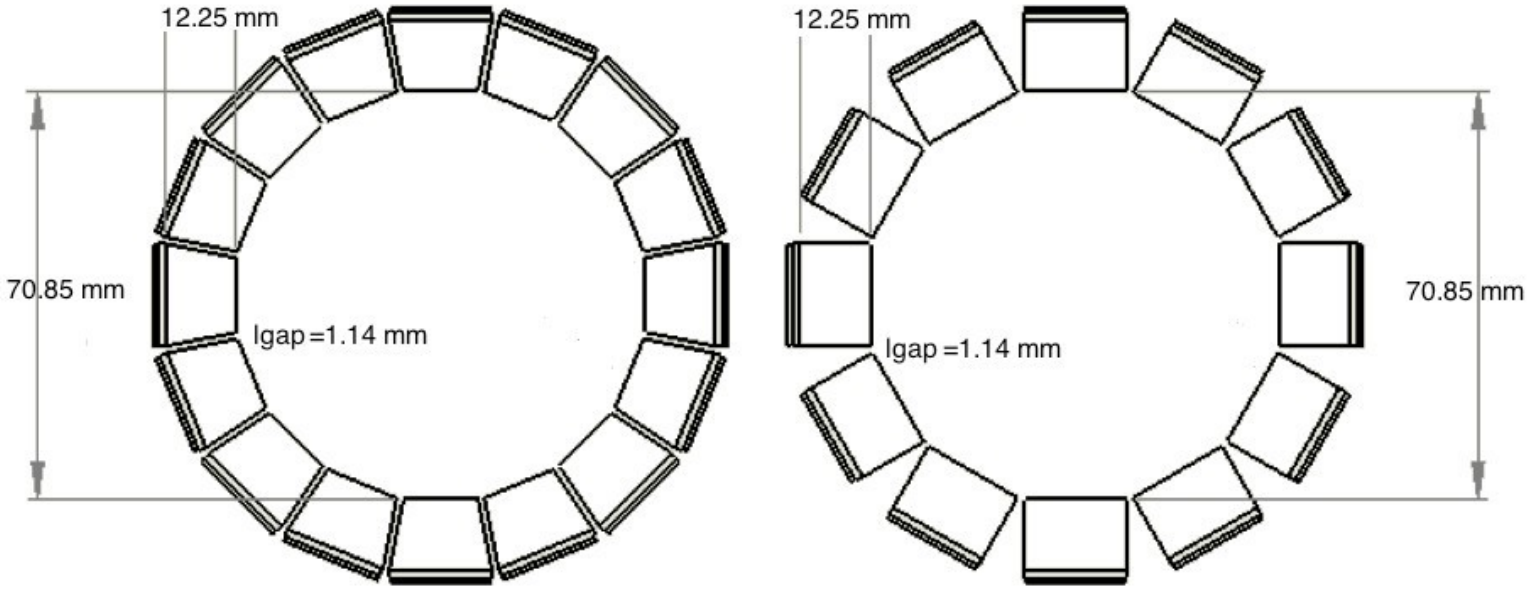
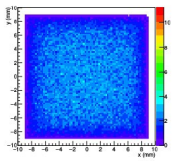
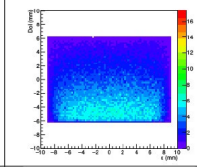
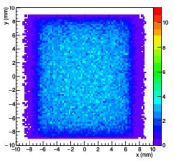
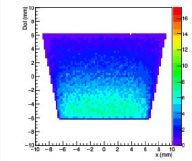
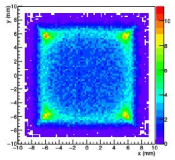
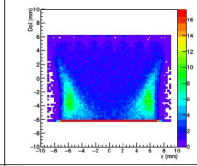
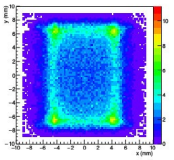
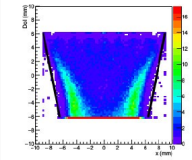
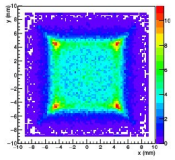
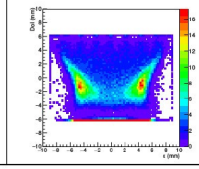
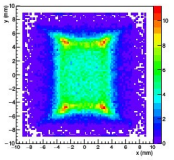
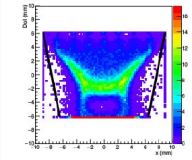


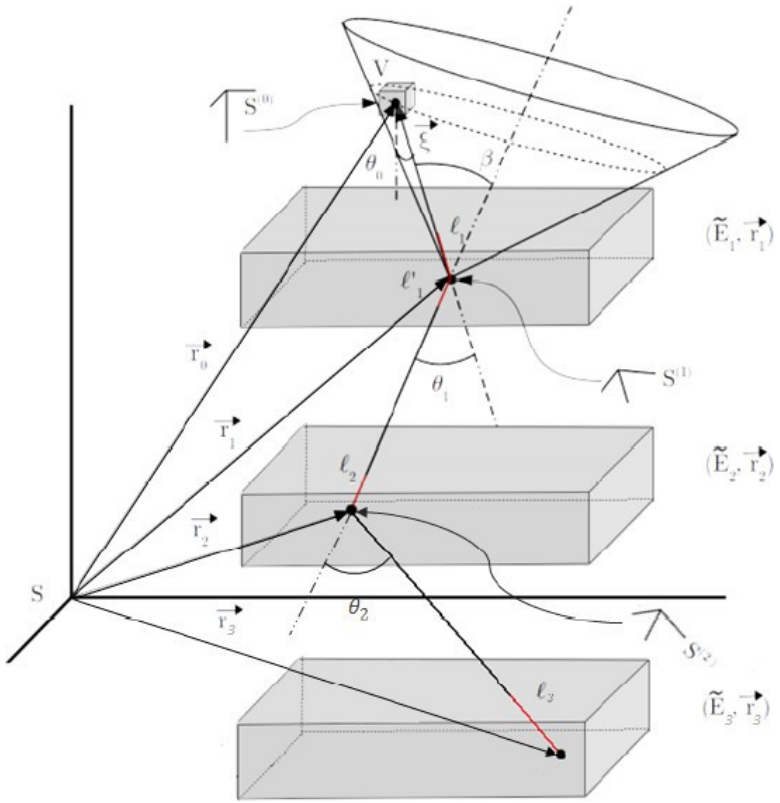

| | cuboid | | tapered | |
|---|---|---|---|---|
| | XY | XZ | XY | XZ |
| ground-truth |  |  |  |  |
| VS0 |  |  |  |  |
| VS1 |  |  |  |  |


MACACO
Medical Application
CompAct Compton camera

# Image Reconstruction (DIRS) :: Compton Telescope

Currently, main computational efforts are simulation and image reconstruction for MACACO

# Image Reconstruction (DIRS) :: Compton Telescope





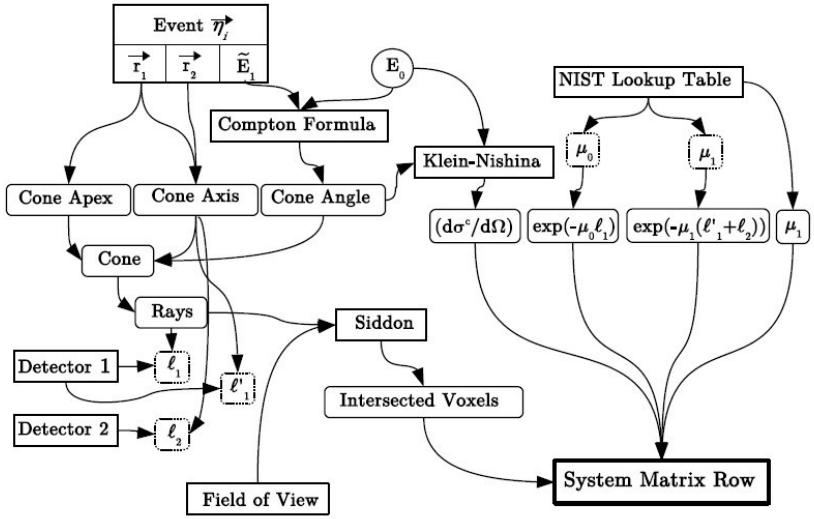
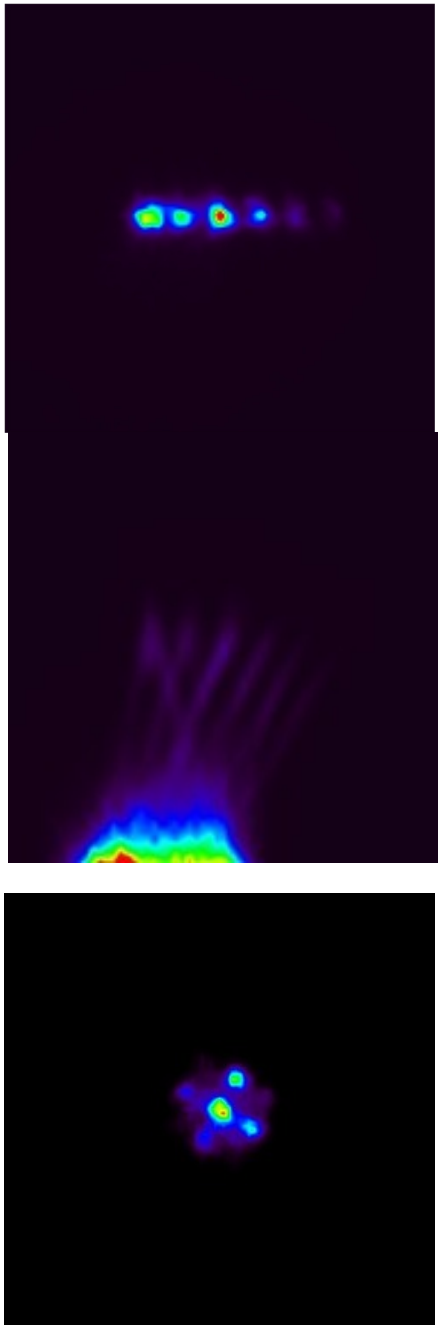



**Figure 4.** Diagram showing the process of construction of the SM row corresponding to one coincidence event.

$$dP(\vec{r}_0\theta_0\phi_0 l_1\theta_1\phi_1 l_2\theta_2\phi_2 l_3) = \frac{d^3r_0}{V}\cdot\frac{d\Omega_0}{4\pi}\cdot\frac{d\sigma_0^c}{d\Omega_1}d\Omega_1 dl_1 e^{-\mu_0\lambda_0}\cdot\frac{d\sigma_1^c}{d\Omega_2}d\Omega_2 e^{-\mu_1\lambda_1}dl_2\cdot e^{-\mu_2\lambda_2}\mu_2 dl_3\cdot\theta_v \quad (1)$$

Conventional (simple & fast)



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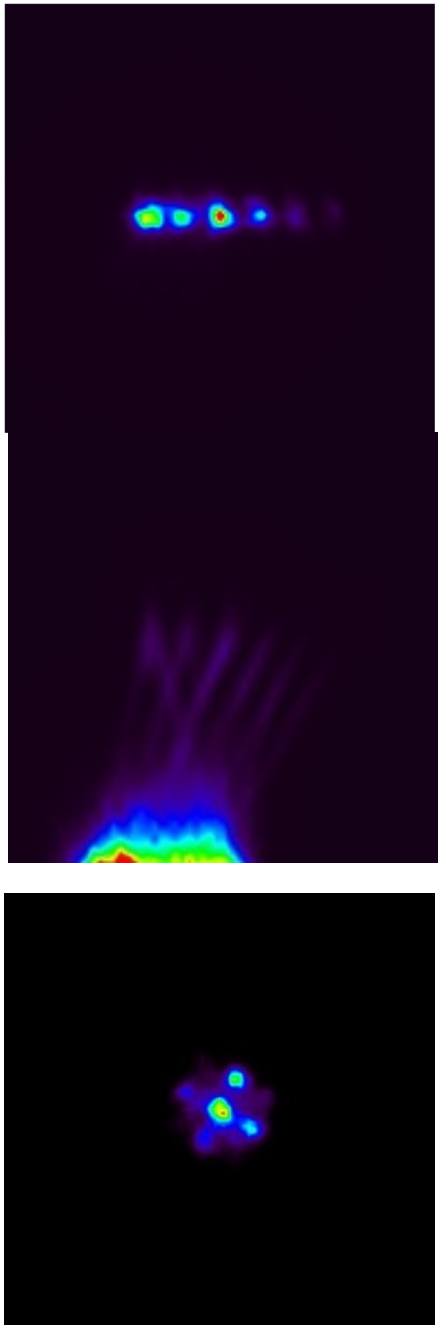
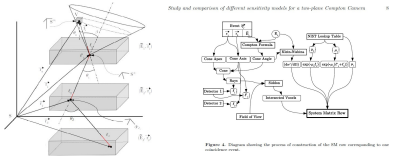
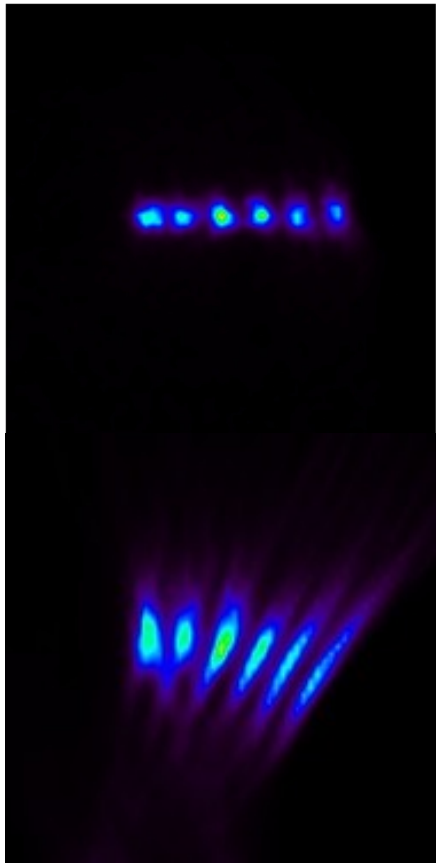


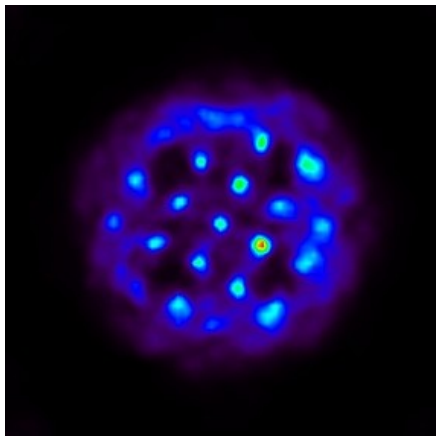


$$dP(\vec{r}_0\theta_0\psi_0 l_1\theta_1\psi_1 l_2\theta_2\psi_2 l_3) = \frac{d^2r_0}{V}\cdot\frac{d\Omega_0}{4\pi}\cdot\frac{d\sigma_0^e}{d\Omega_1}d\Omega_1 dl_1 e^{-\mu_0\lambda_0}\cdot\frac{d\sigma_1^e}{d\Omega_2}d\Omega_2 e^{-\mu_1\lambda_1}dl_2\cdot e^{-\mu_2\lambda_2}\mu_2 dl_3\cdot\theta_v \quad (1)$$

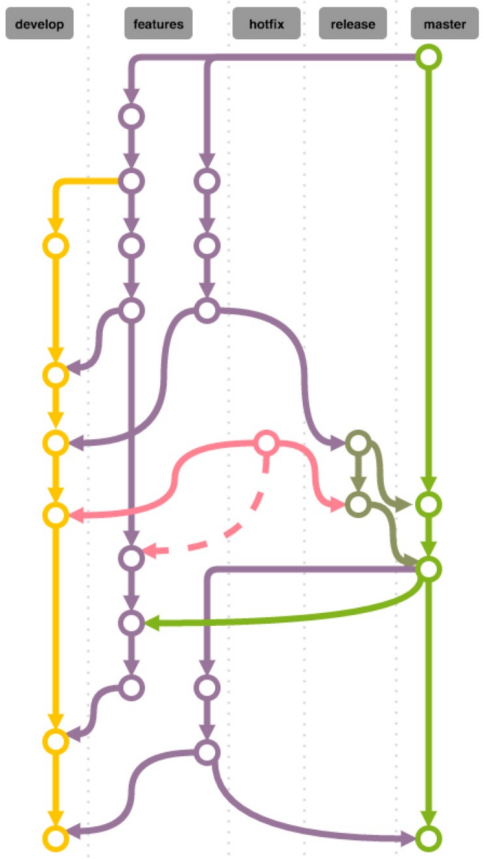
DIRS

Dedicated (detailed & slower)





# Image Reconstruction (DIRS) :: Enforced




- Highly modular to enforce **reusability** (man-power)



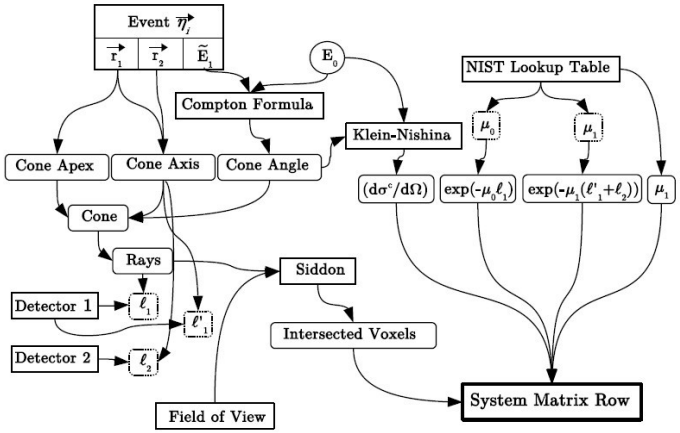
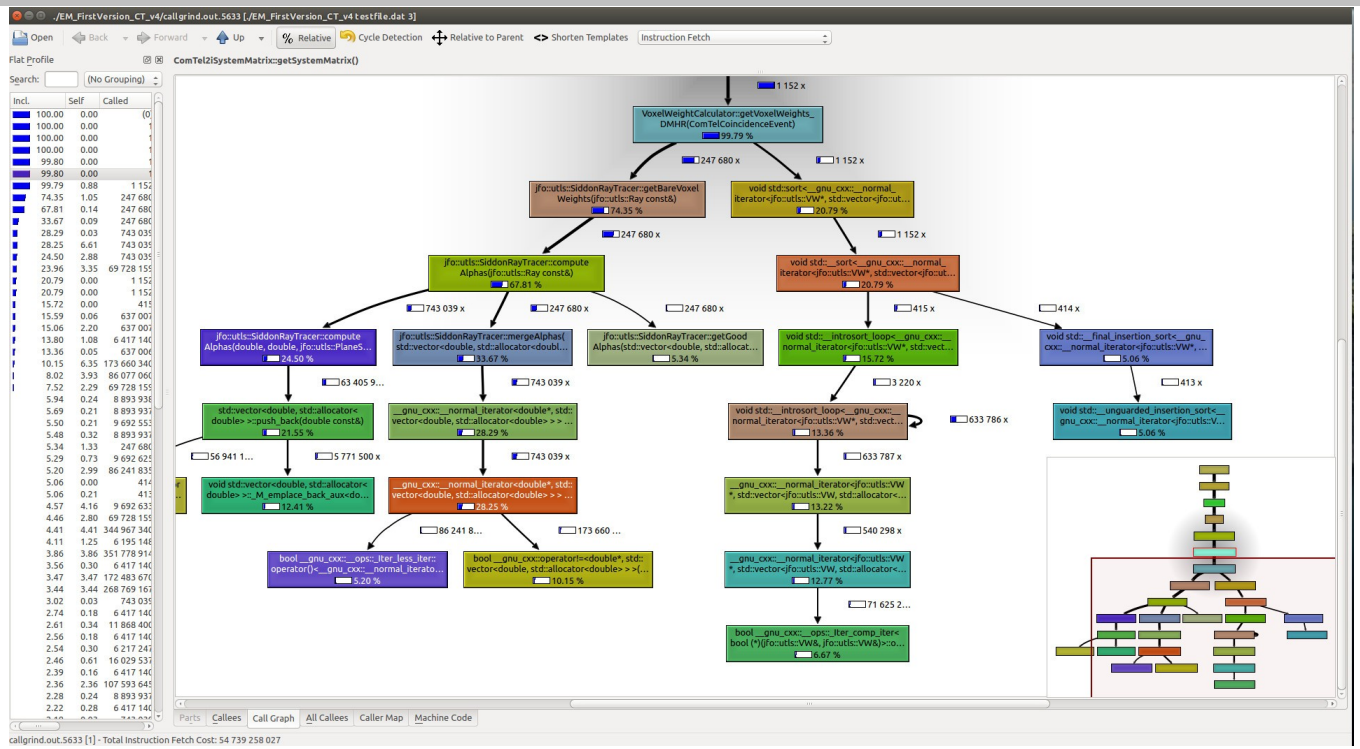



**Figure 4.** Diagram showing the process of construction of the SM row corresponding to one coincidence event.

- Control version (git)

# Image Reconstruction (DIRS) :: Recommended




- Profiling (valgrind)


- For unit testing

googletest
Google C++ Testing Framework


- C++17

Traditionally GRID has been difficult to access for us

- Install our own code
- ific vo
- Maintain installation of the code
  - Recompilations
  - Upgrades, ….
- Send and retrieval jobs cumbersome ( text interface … )
- Spurious errors difficult to deal with
  - never ending programs,
  - Blind nodes, ….

When computing power is necessary we resort to our three servers

**Total**

30 cores
44 thr
2 GHz
334 GB
6+8 TB

**alcaudon**

14 cores
28 thr
1.2GHz
256 GB
2.5 TB

**colosus**

8 cores
8 thr
2.66GHz
32 GB
2 TB

**loucypher**

8 cores
8 thr
2.4GHz
46 GB
2 TB

# Instalaciones IFIMED



***! Muchas gracias !***

IRIS