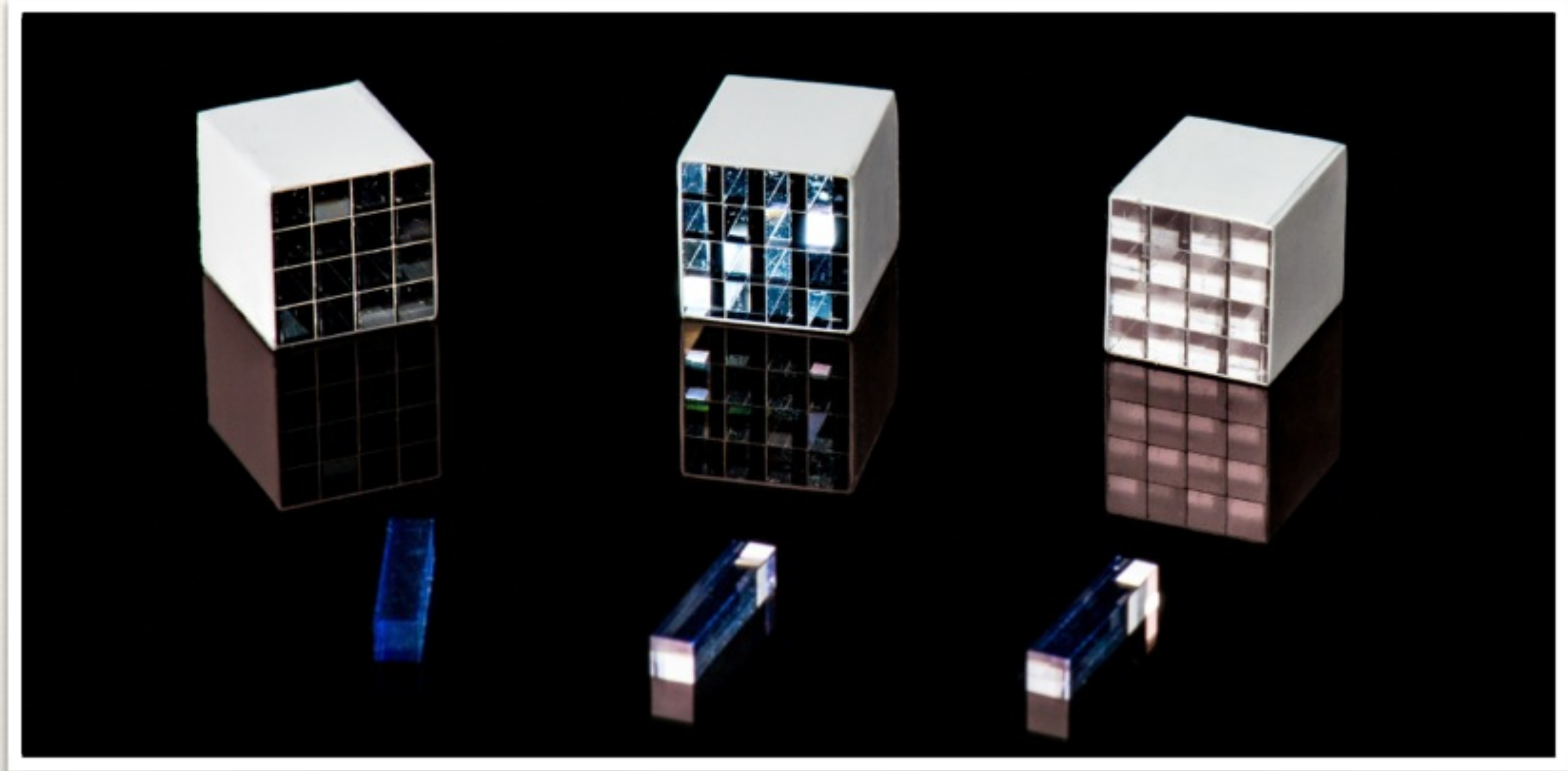


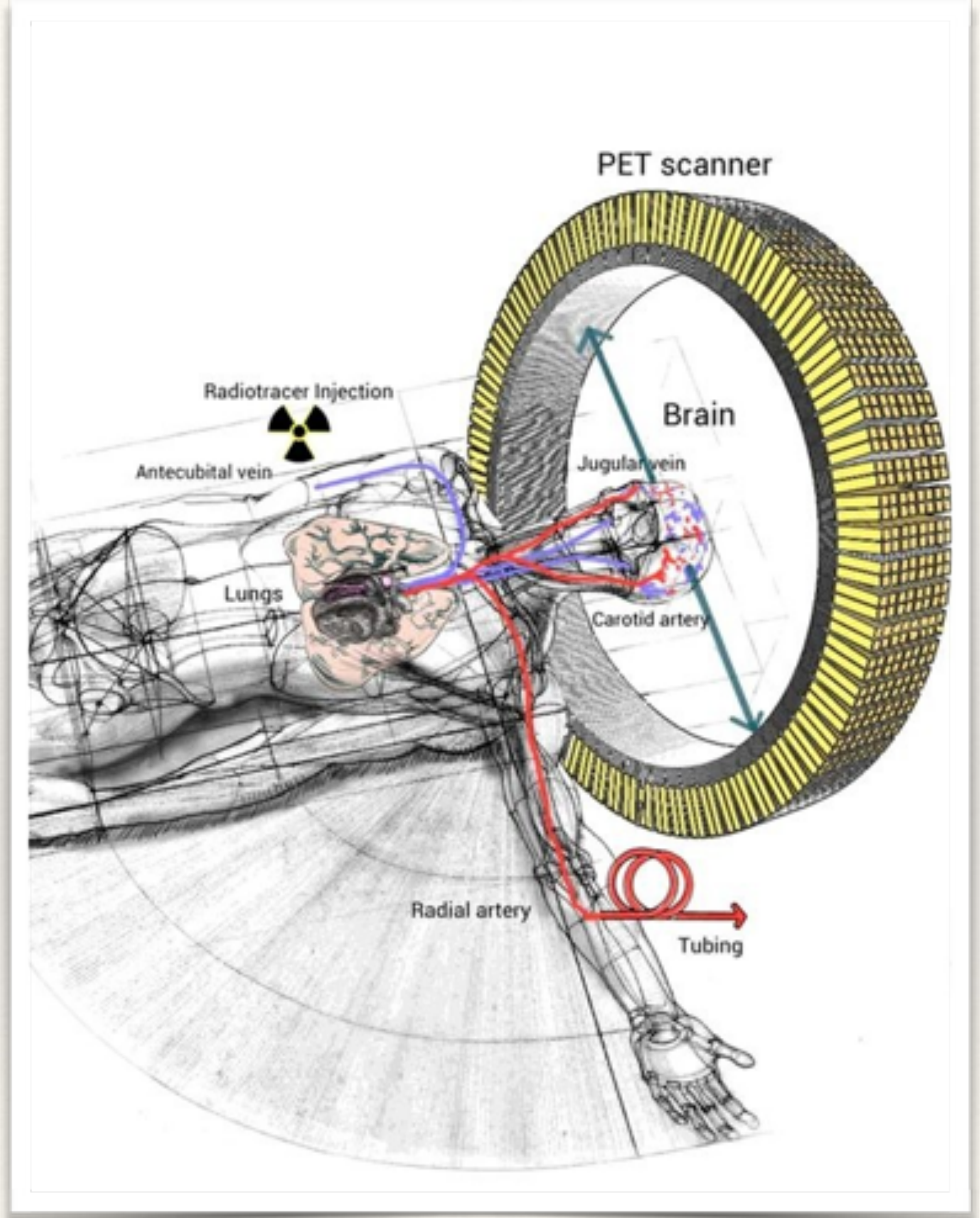
Development of innovative PET module with DOI and timing capability

Gianluca Stringhini

CERN KT Project “New ClearPEM module”
CERN KT Project “Detector module development for Whole Body PET”

Positron Emission Tomography

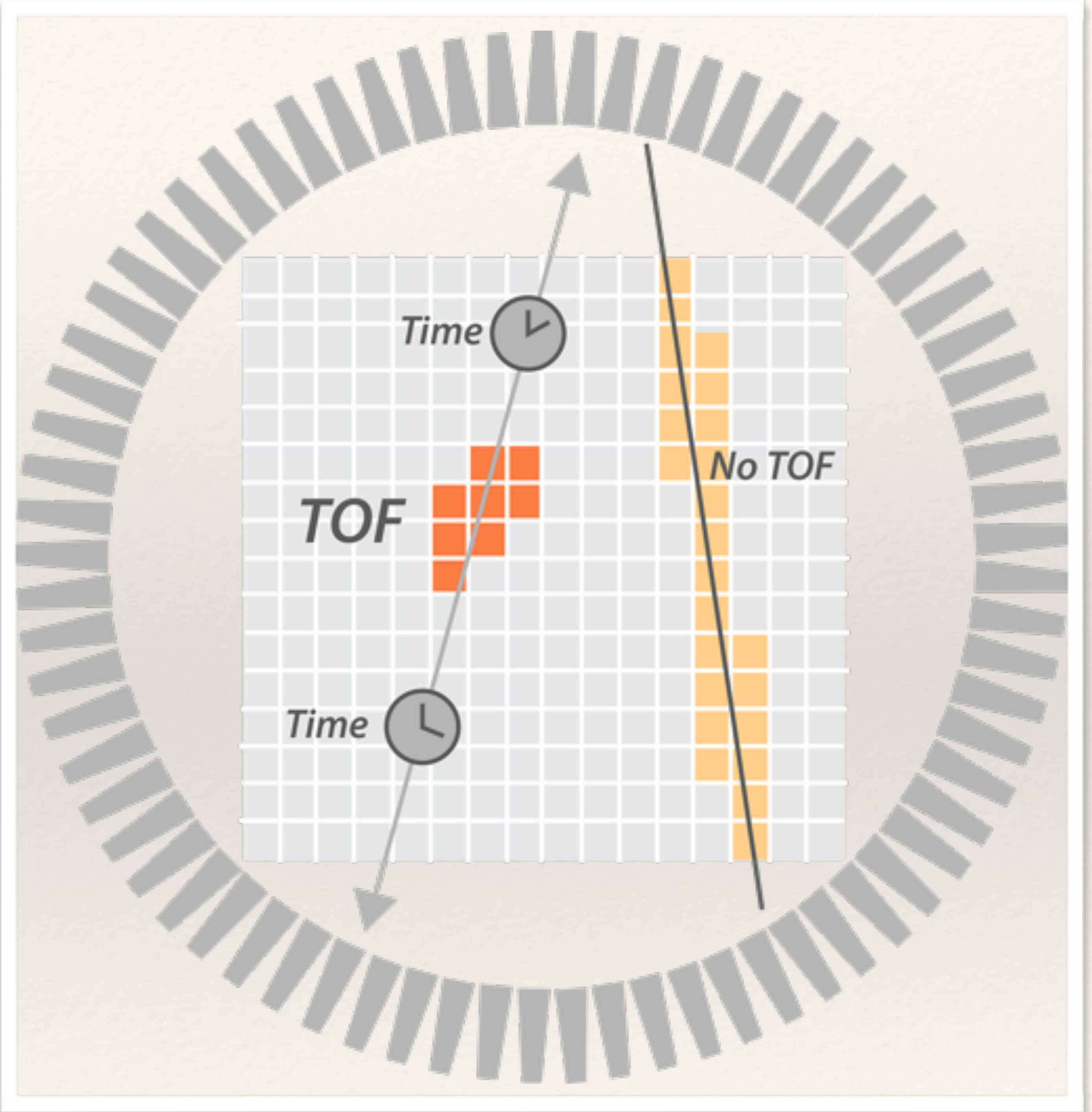
- Radiotracer labelled with a positron emitter (^{18}F-FDG)
- Positron annihilation and production of two back to back gammas (511 keV)
- Detection of the two gammas in coincidence using detectors



Time of Flight

Knowing the arrival time of the two gammas, it is possible to reduce the region where the annihilation took place and increase the signal to noise ratio.

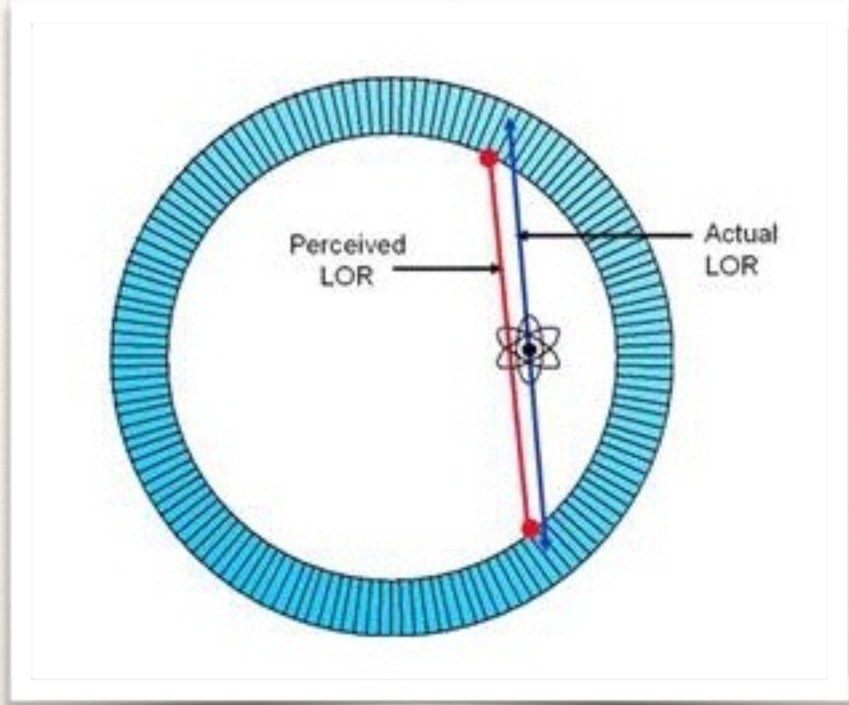
➡ Fast detector

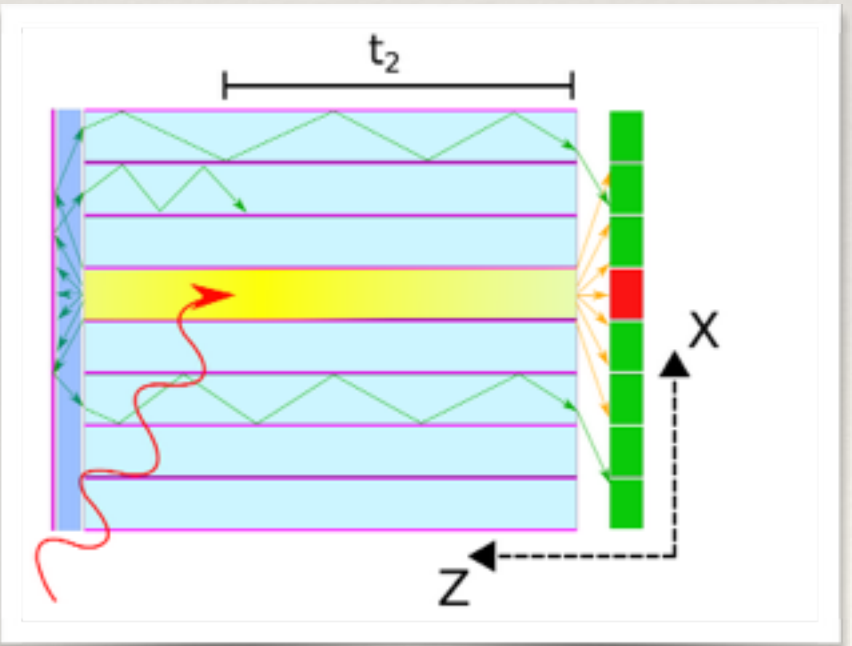


Depth of Interaction

Knowing the interaction point position along the main axis of the scintillator allow to reach high performances:

- Small animal and organ dedicated scanner: to avoid parallax error and obtain high quality images.
- Whole body scanner: to correct for the time jitter of the photon propagation along the crystal.





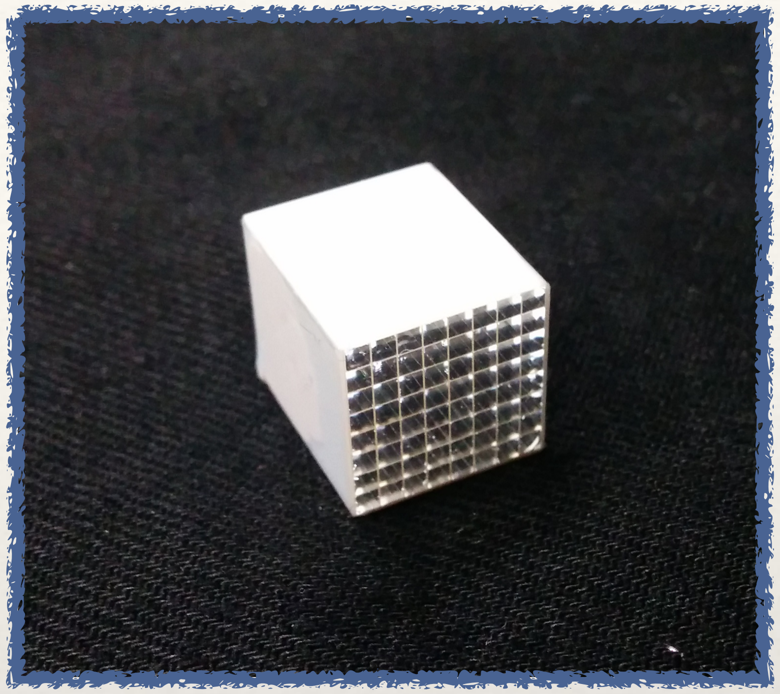
Aim of our study

To develop an innovative PET module that allows to reach high performances in term of spatial resolution and energy resolution while keeping the complexity of the system reasonably low.

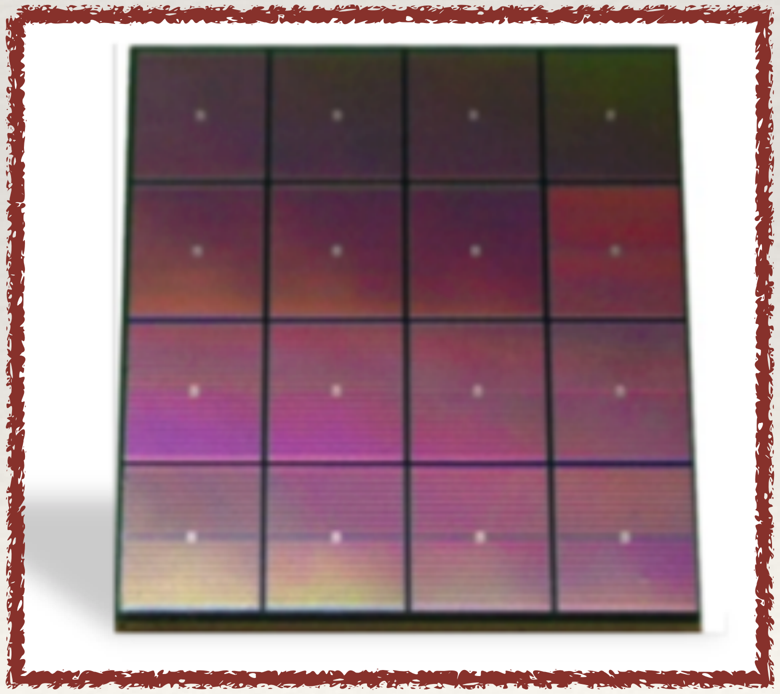
- 4 to 1 coupling between the scintillator and the detectors
- Depth of Interaction (DOI) capability with a single side readout
- High timing performances

Our innovative PET module

- LYSO crystals matrix (8x8)
- Crystal dimensions: 1.5x1.5x15 mm^3
- Separation foil: ESR
- Lateral surfaces of the crystals depolished

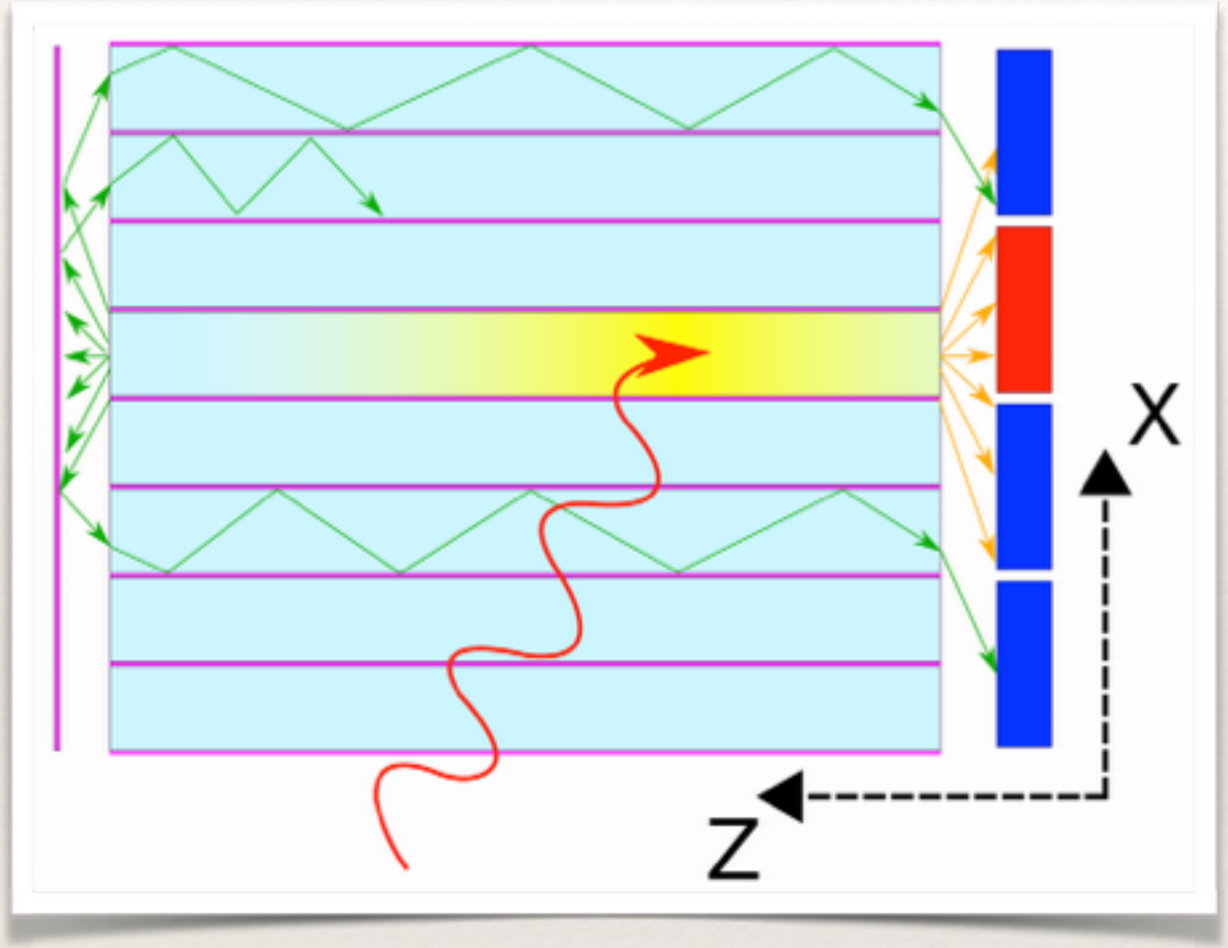


- 4x4 MPPC array from Hamamatsu
- Active area 3x3 mm^2
- Pitch 3.1 mm



M. Pizzichemi et al., 2016 A new method for depth of interaction determination in PET detectors, *Phys. Med. Biol.* 61 4679

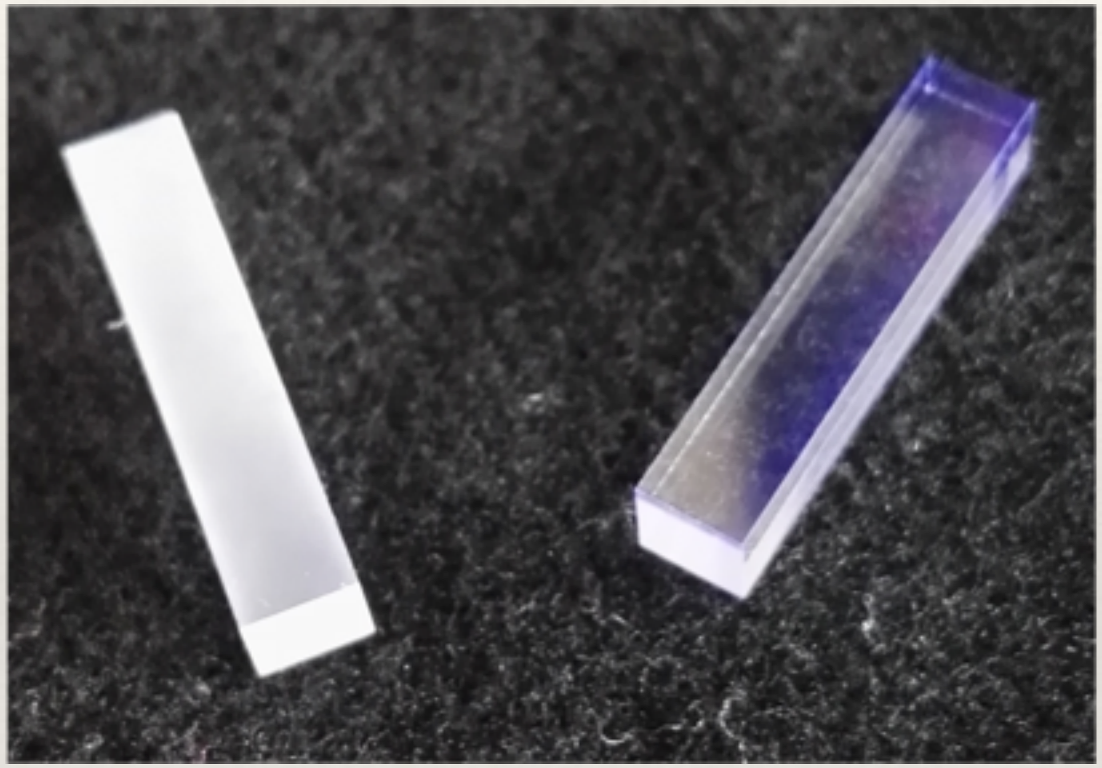
A new approach to the DOI



- Only one side readout
- Light guide on top of the module
- Reflector that redirects the light to the detector
- optical treatment of the lateral surface of the crystals

M. Pizzichemi et al., 2016 A new method for depth of interaction determination in PET detectors, *Phys*. *Med*. *Biol*. 61 4679

A new approach to the DOI



Optical treatment of the lateral surfaces of the crystals: **DEPOLISHING**.

The **DEPOLISHING** increases the probability for a optical photon to escape from the crystal during a lateral surface scattering.

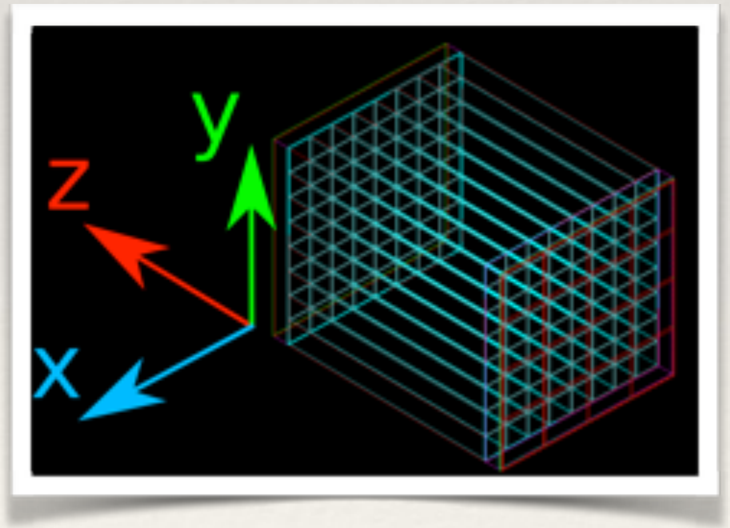
It leads to a correlation between the light collected by the detector and DOI.

M. Pizzichemi et al., 2016 A new method for depth of interaction determination in PET detectors, *Phys*. *Med*. *Biol*. 61 4679

The procedure

Obtain the (x,y,z) interaction point for each event using combinations of the detected charges information:

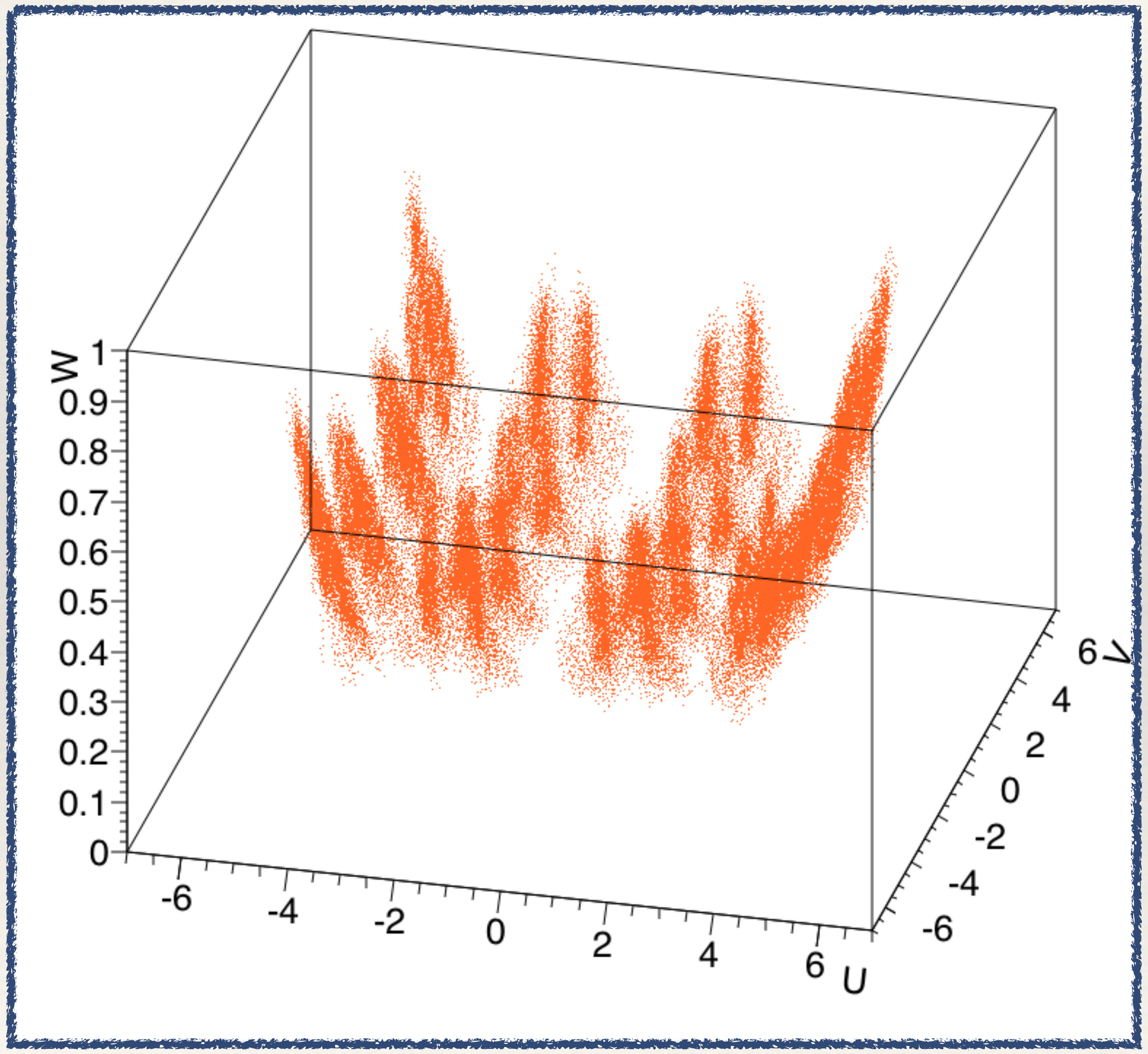
$$u = \frac{1}{P}\sum_{i}^{16} p_i X_i \qquad v = \frac{1}{P}\sum_{i}^{16} p_i Y_i \qquad w = \frac{p_{max}}{P}$$

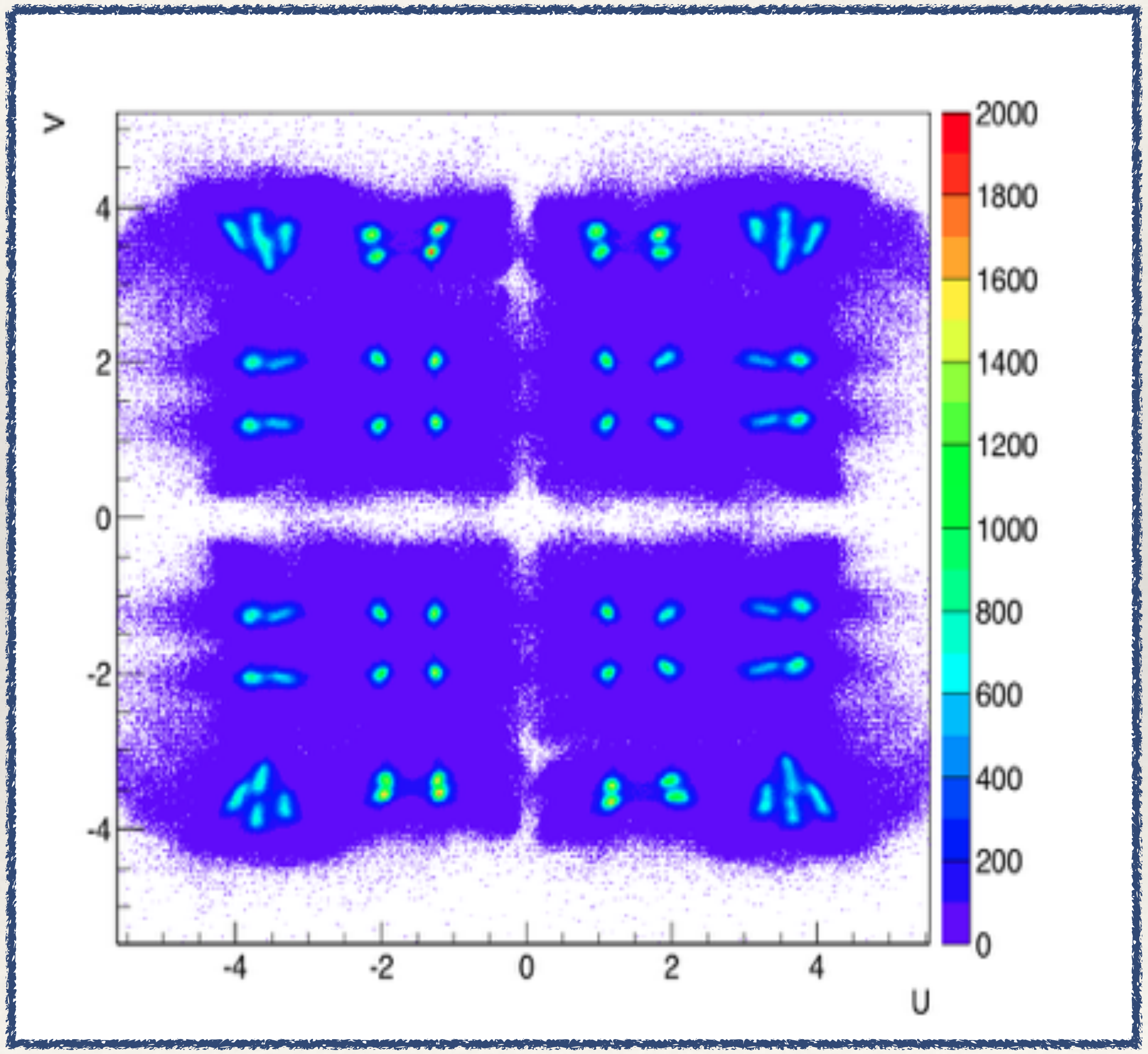


- p_i : charge collected by the i-th detector
- X_i and Y_i : positions of the center of the i-th detector
- P: sum of the charges collected by the detectors for each event
- P_{max}: maximum of the charge collected among the i charges collected

The performances

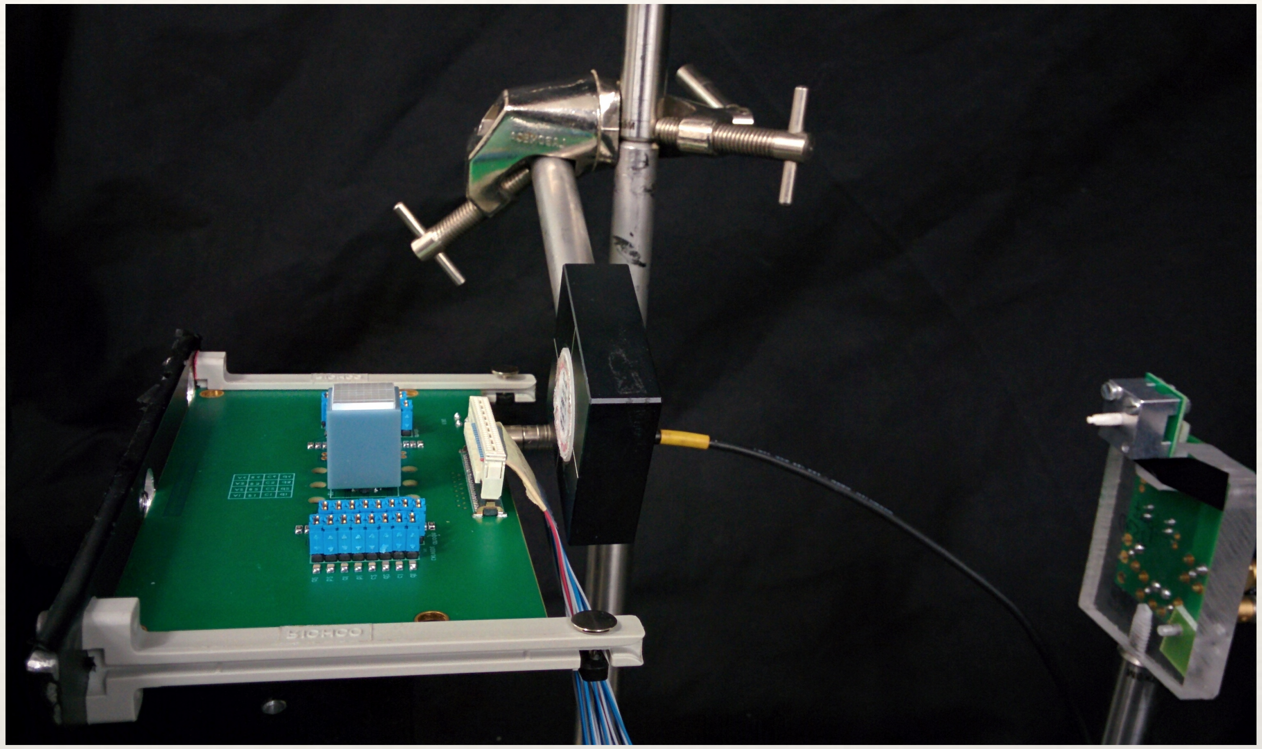
Excitation with a radioactive source Na^{22} placed 10 cm above the module

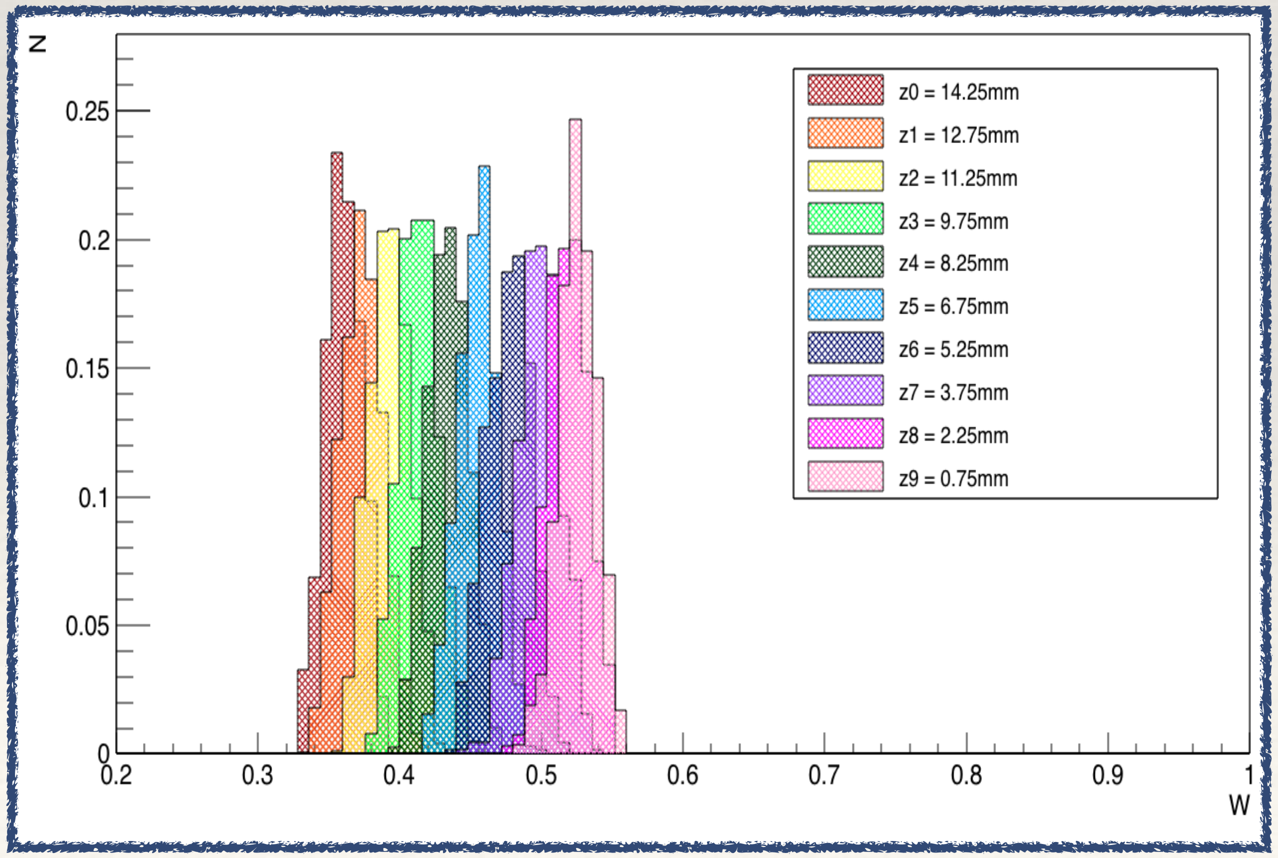


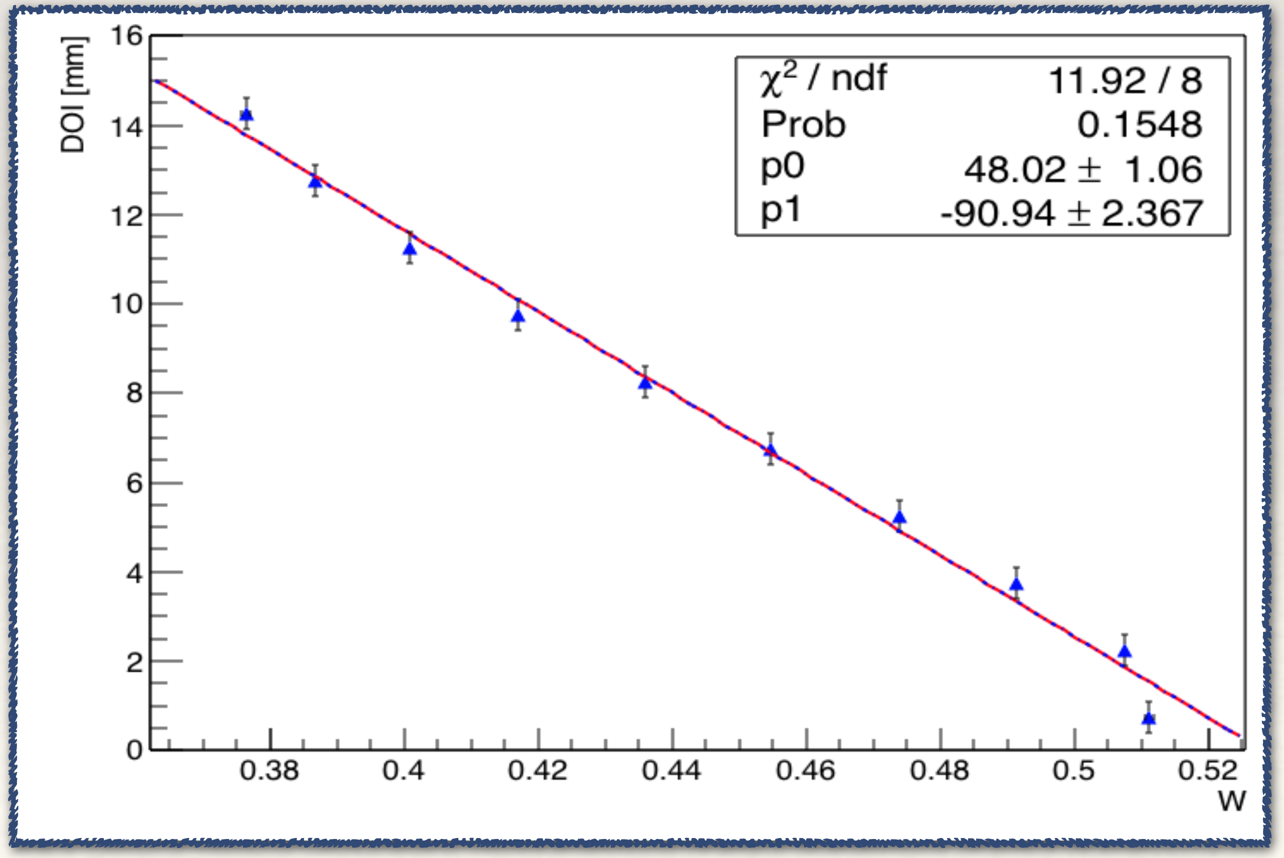


The performances

- Energy resolution: 12% (FWHM)
- Spatial resolution:1.5 mm (FWHM)
- DOI resolution: 3 mm (FWHM)

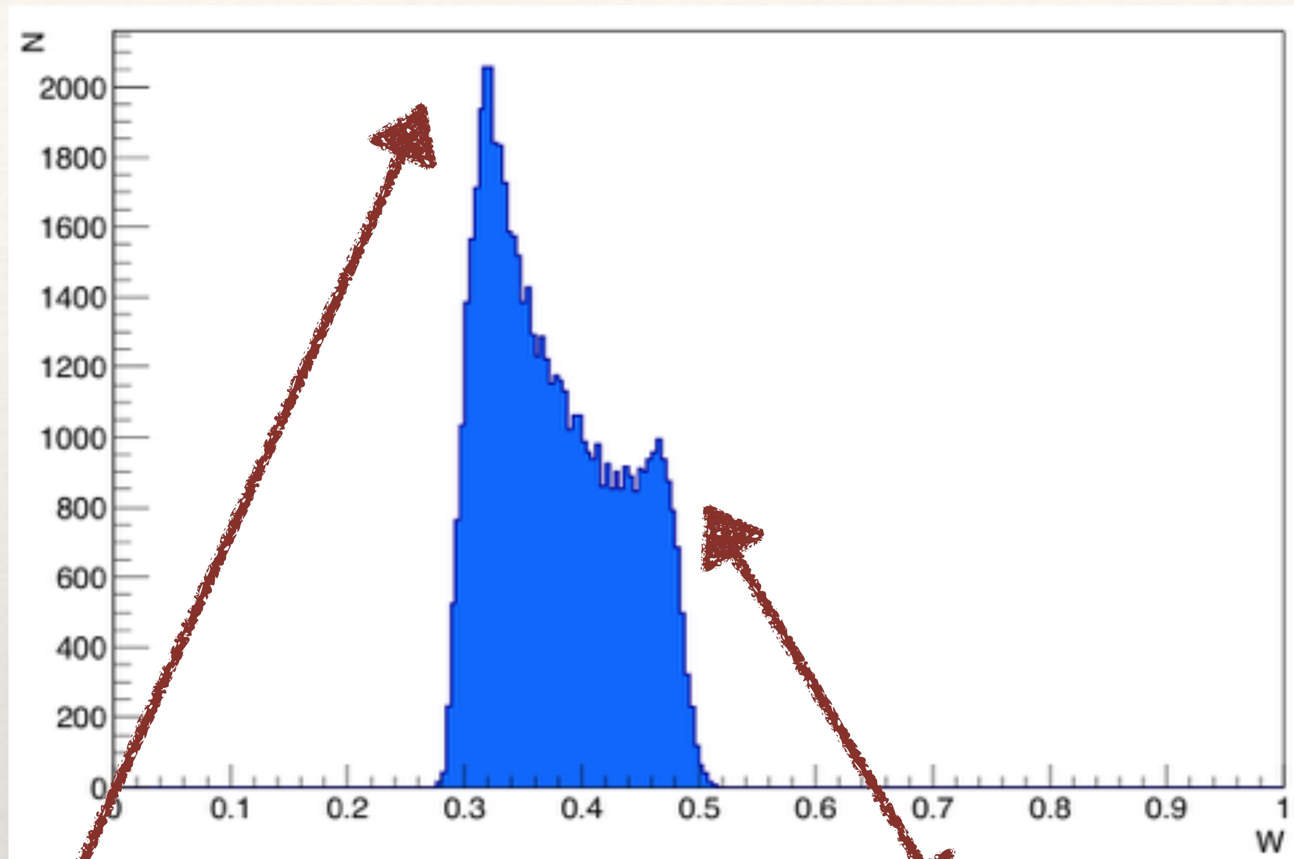


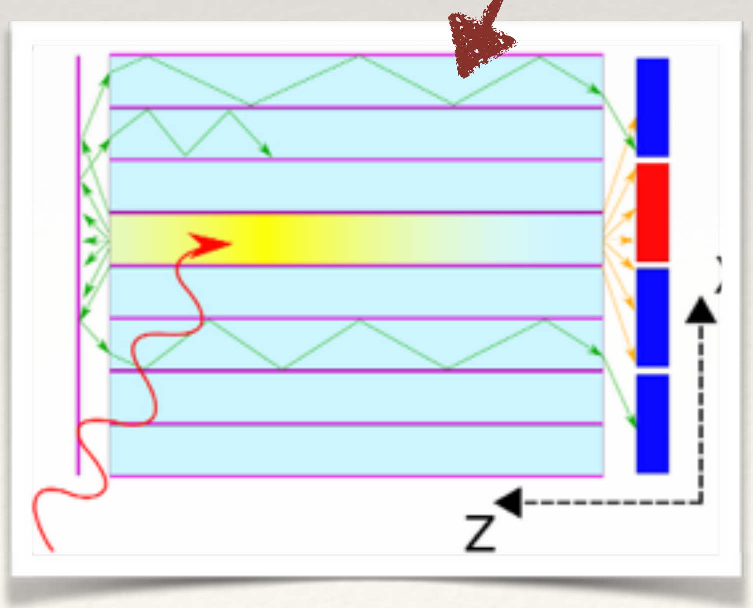


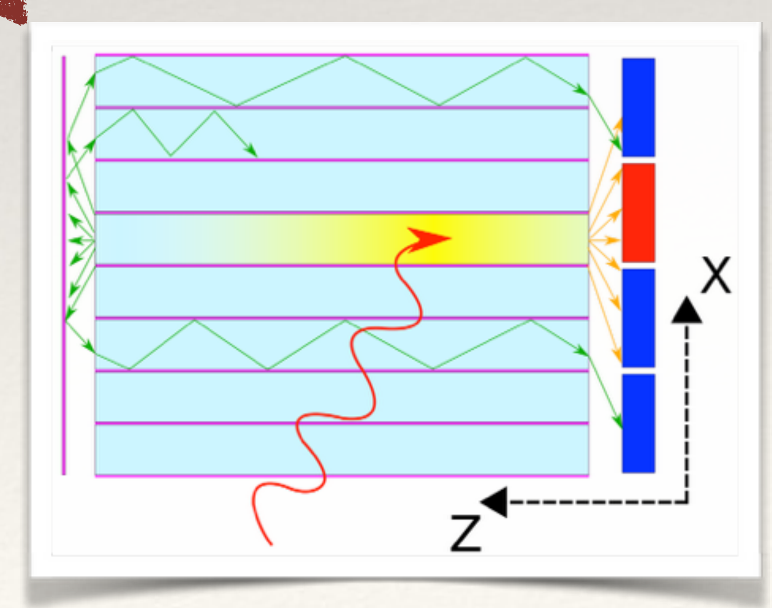


DOI Calibration

DOI calibration with the external tagging crystal is unfeasible in a real PET scanner

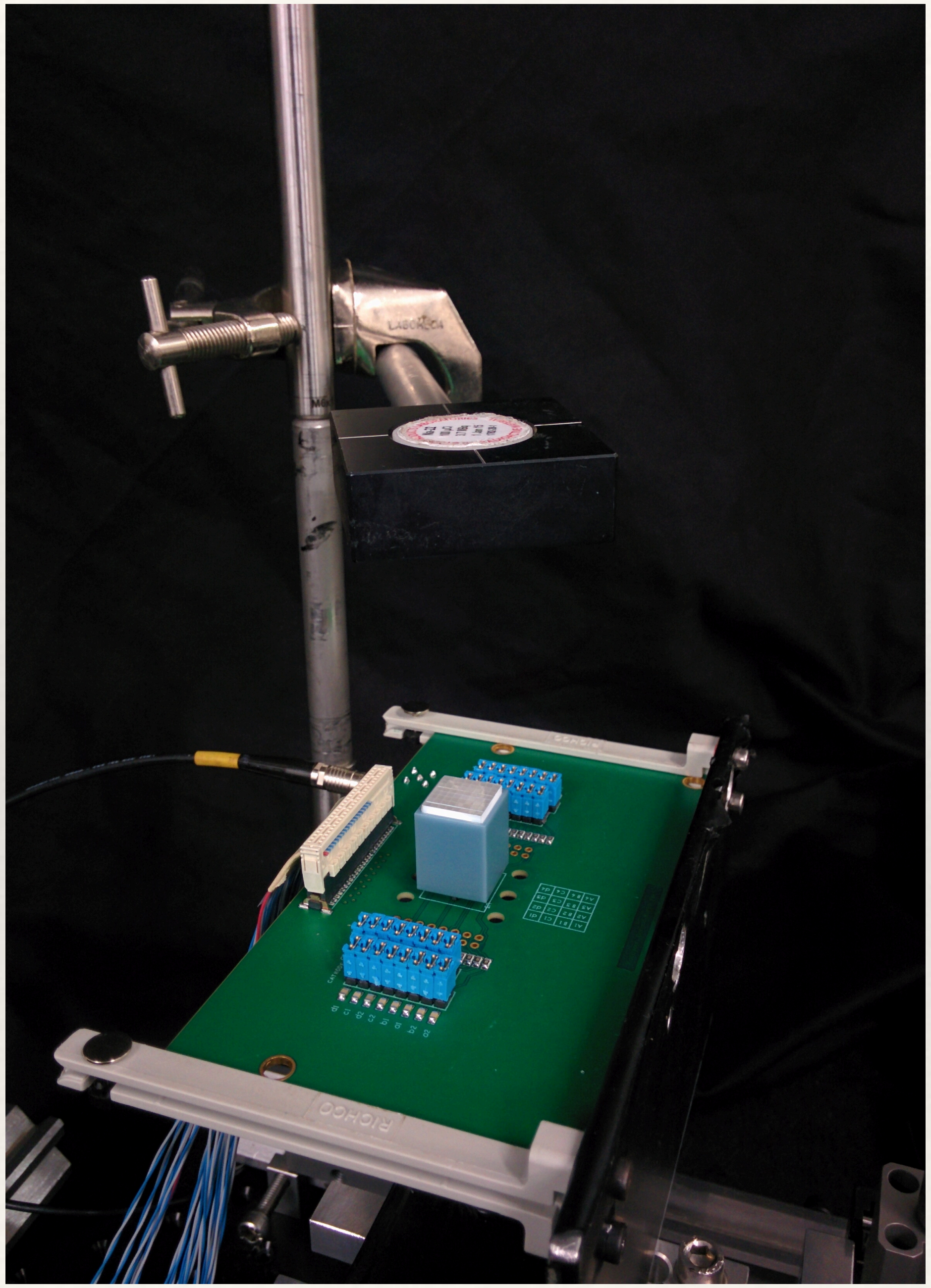


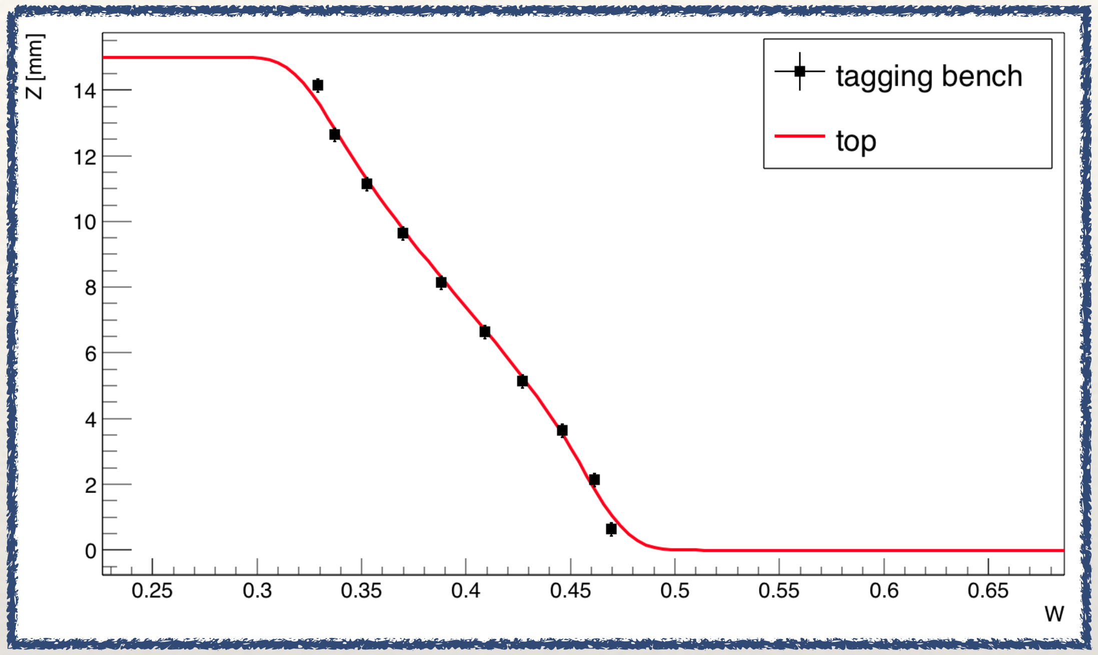


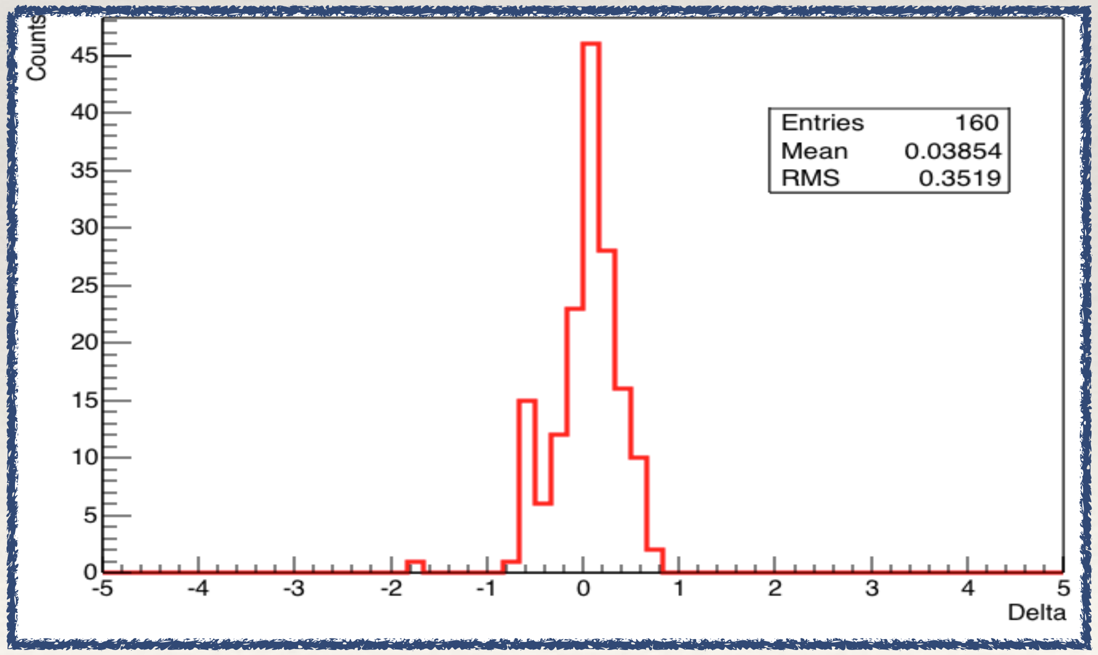


DOI Calibration

Development of a practical DOI calibration method without using an external tagging crystal.





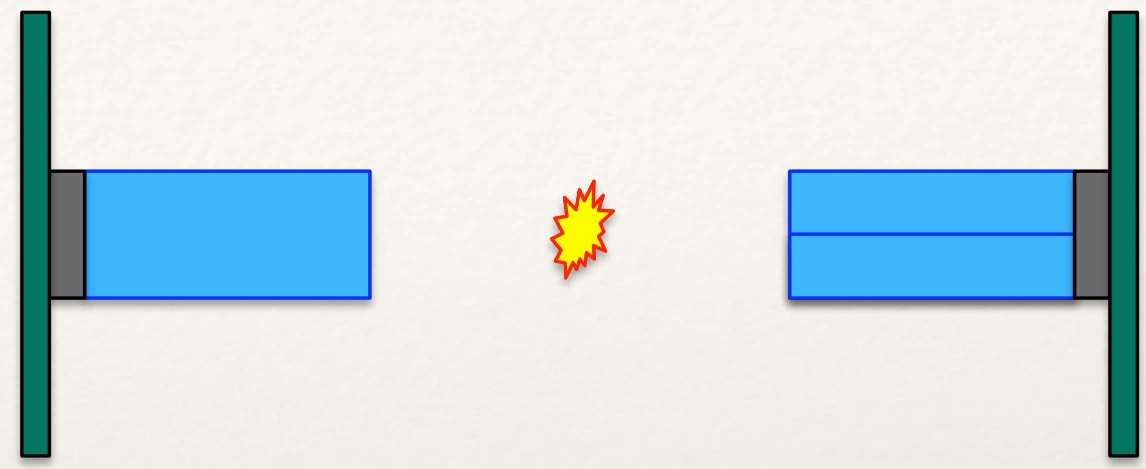


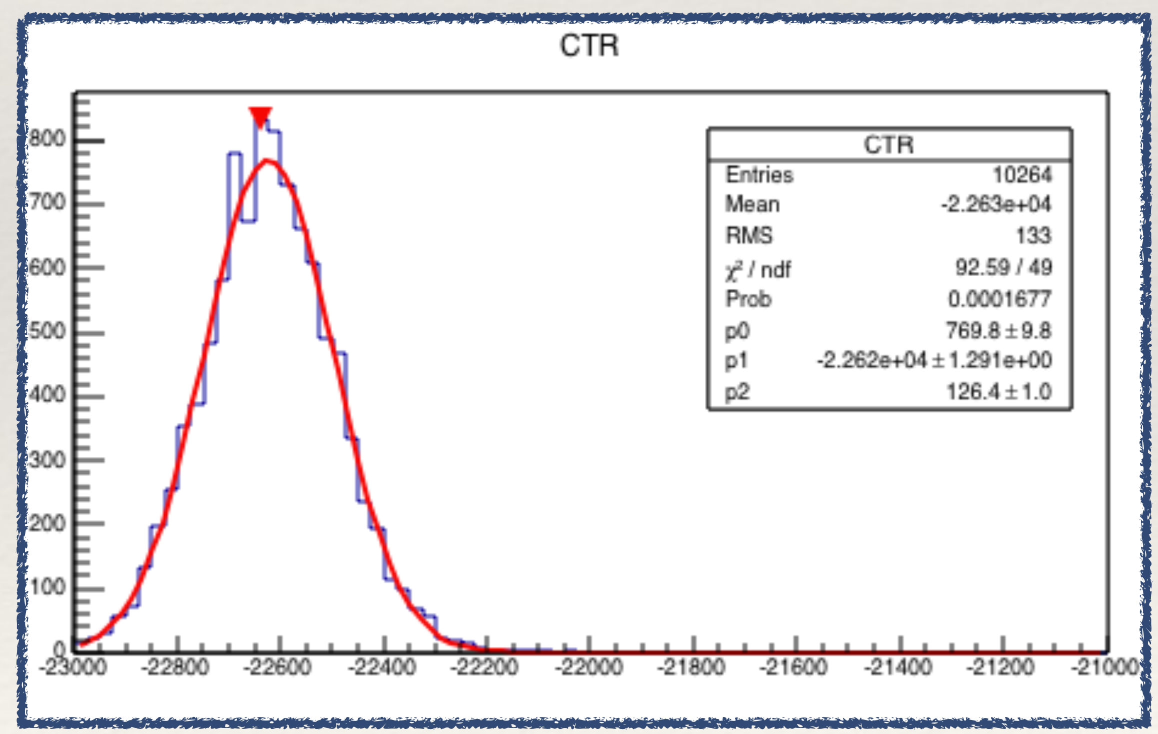
G. Stringhini et al., 2016 Development and evaluation of a practical method to measure the Depth of Interaction function for a single side readout PET detector *JINST* 11 P11014

Coincidence Time Resolution

The CTR is a fundamental parameter to reduce the signal to noise ration. Using the NINO chip (a low power front-end amplifier and discriminator) we measured the timing performances of the module.

First measurement: CTR ~ 300 ps FWHM

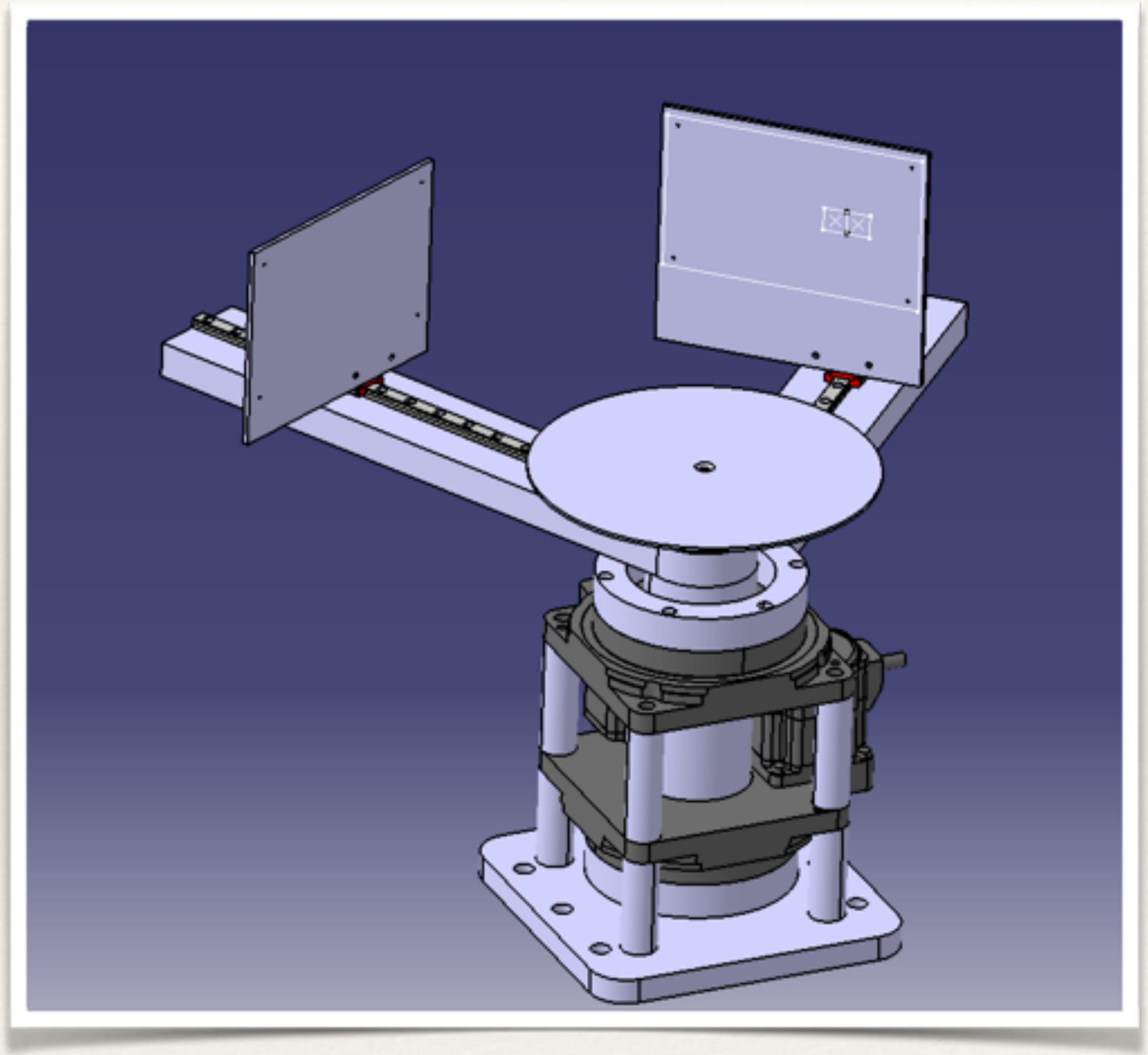




Ongoing…

Small PET demonstrator:

- ❖ Two rotating arms
- ❖ Integration of the charge
- ❖ Time information
- ❖ Reconstruction algorithm (STIR)



Credit: Oscar Sacristan De Frutos