



Exploration of the physical limits for Cherenkov PET using tiny crystals and a large cube

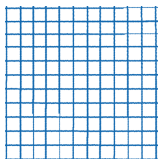
Sofia Forostenko, Werner Lustermann

sofiiaf@ethz.ch

Outline

SwissPix photosensor

with ~ 10 ps FWHM timing resolution and pixels $50\mu \times 50\mu$

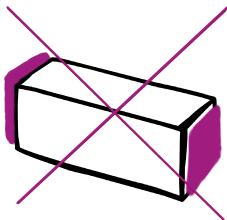


- SwissPix detector geometry candidates / possible detector geometries;
- coincidence setup configuration;
- full scanner simulation + spatial resolution estimation reconstruction-less;

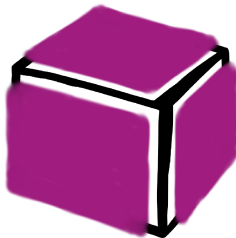
SwissPix project - detector geometry candidates



Small
 $3 \times 3 \times 3 \text{ mm}^3$



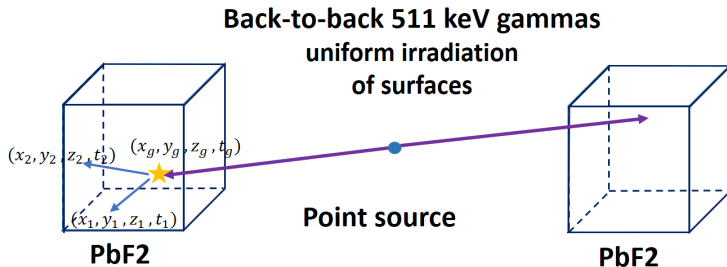
Bar
 $4 \times 4 \times 20 \text{ mm}^3$



Cube
 $25 \times 25 \times 25 \text{ mm}^3$

Three possible detector geometries

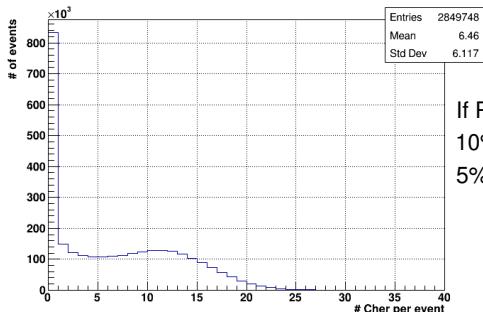
PbF2 cube - coincidence setup configuration



Sketch of the Geant4 simulation setup

Cube 25 mm x 25 mm x 25 mm

PbF2 cube - Cherenkov photon statistics - no energy cut



If PDE **30%** is applied:
10% of events have ≥ 4 photons;
5% of events have ≥ 5 photons

Amount of Cherenkov photons

57% of the events generated ≥ 4 photons

53% of the events generated ≥ 5 photons

PbF2 cube - gamma interaction position reconstruction

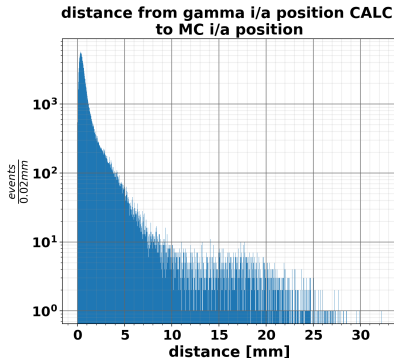
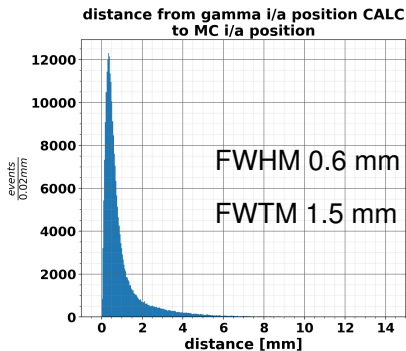
Function as combination of all photons to minimize with Scipy:

$$\sum_{i=1}^{n-1} \sum_{j=2, j>i}^n (d_i - d_j - \frac{c}{n} \Delta t_{ij})^2,$$

where $d_{i,j} = \sqrt{(x_{i,j} - x_g)^2 + (y_{i,j} - y_g)^2 + (z_{i,j} - z_g)^2}$ - photon path length,

(x_g, y_g, z_g) - coordinates of gamma interaction point and $\Delta t_{ij} = t_i - t_j$,
 $t_{i,j}$ - photon detection time.

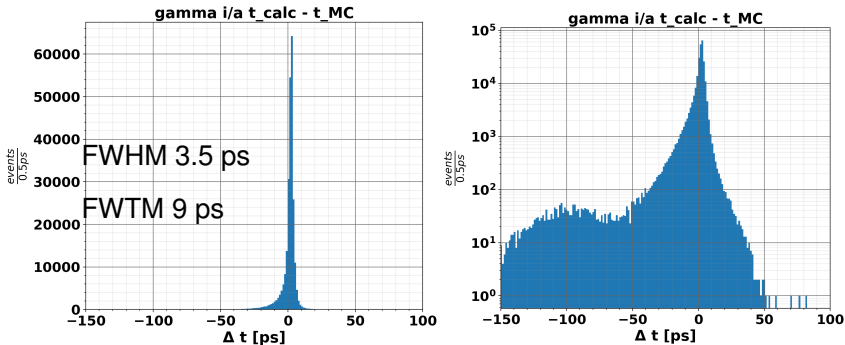
PbF2 cube - gamma interaction position reconstruction from 5 photons



Distance from gamma interaction position reconstructed to MC position, linear (left) and log (right), no time smearing.

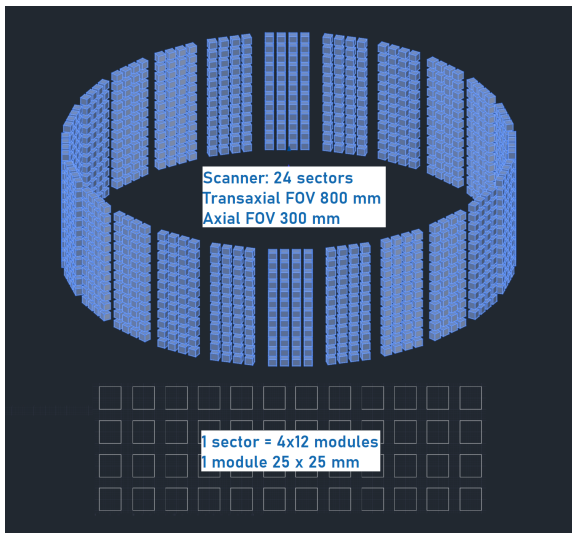
77% of events with 5 photons converged within the range (-15., 15.) mm in XYZ.

PbF2 cube - gamma interaction time reconstruction from 5 photons

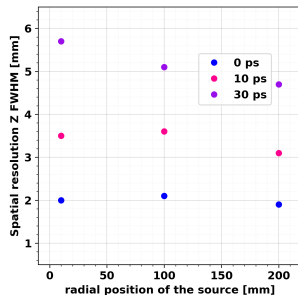
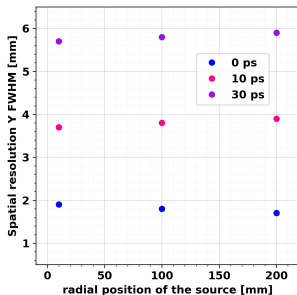
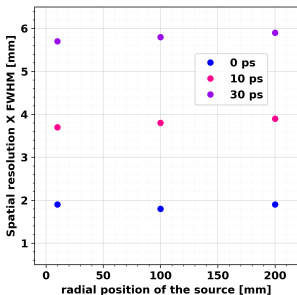


Time of gamma i/a reconstructed MINUS Time MC, linear (left) and log (right), no time smearing

Scanner geometry with PbF2 cube 25x25x25 mm³

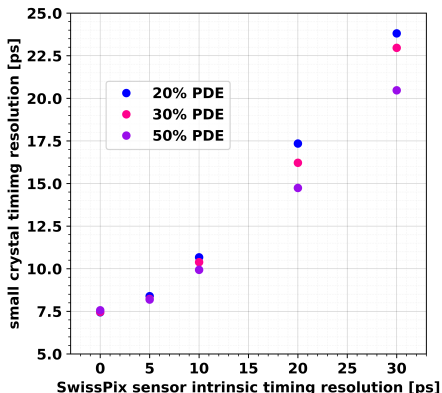


PbF2 cube full scanner spatial resolution



Full scanner spatial resolution obtained reconstruction-less

PbF2 small 3x3x3 mm³ timing resolution



Small crystal timing resolution as a function of Swisspix sensor intrinsic timing resolution

if **30%** PDE is applied efficiency of gamma detection is **37%**

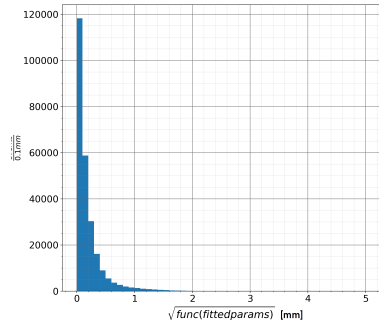
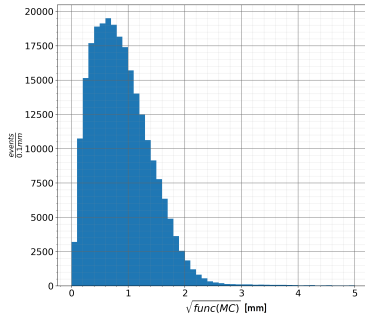
Outlook

- Full NEMA characterisation for cube;
- Full NEMA characterisation for small;
- Improvement of gamma interaction position reconstruction with neural network;

Sofiia Forostenko
Doctorate at D-PHYS
sofiiaf@ethz.ch

ETH Zürich
Inst. f. Teilchen- und Astrophysik
CERN 512-R003
Route de Meyrin
1211 Genève 23

PbF2 Cube - gamma i/a position reconstruction from 5 photons



Square root of function value with MC parameters (left) and Square root of function value with calculated parameters (right)