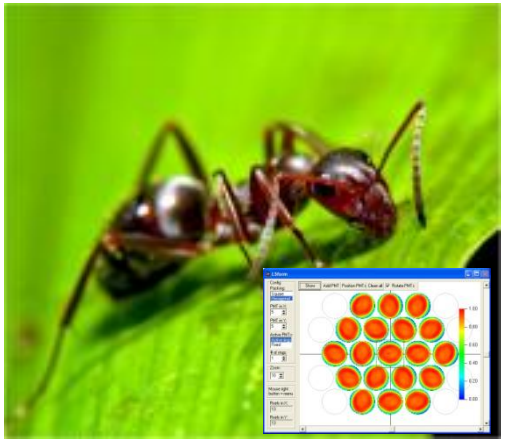
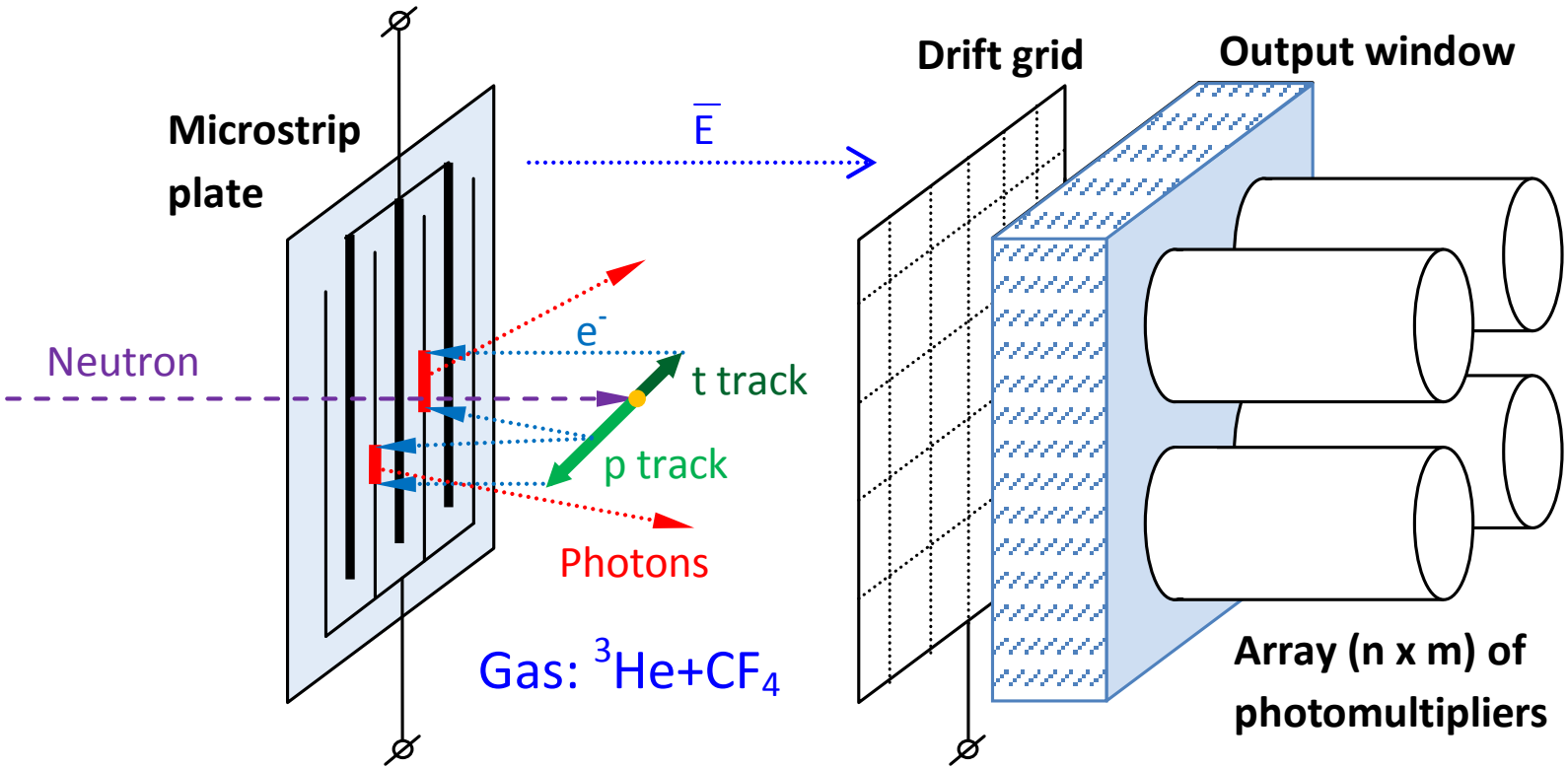


ANTS: a simulation kit for Anger-type neutron detectors

A. Morozov, M.M.F.R. Fraga, L.M.S. Margato, L. Pereira and F.A.F. Fraga

Detector concept



$$n + {}^3He \rightarrow {}^1H + {}^3H + 0.764\ MeV$$

Detector highlights

A detector of this type is being developed in the frame of FP7 - NMI3 collaboration.

- Spatial resolution (both X and Y): 0.5 mm
- Detector area: 200 mm x 200 mm
- Count rate: up to 1 MHz
- Detection efficiency: >50%
- Better than 10^{-7} gamma sensitivity

Detector simulations

Our group has developed a dedicated package:
ANTS (Anger-type Neutron detector - Toolkit for Simulations)

The package was used by the collaboration to:

- finalize the detector design and optimize the operation conditions in order to reach the declared spatial resolution;
- choose the optimal image reconstruction technique leading to the minimum spatial distortions and the best possible resolution uniformity over the field of view.

Package highlights

- Detailed physical models
- Very flexible detector configuration
- Four localization algorithms
- User friendly:
  - ✓ fully interactive and graphical interface
  - ✓ extensive visualization of the input and output data
  - ✓ built-in cross-tests
  - ✓ fast

Main window

Detector configuration window

ANTS v0.55 LIP-Coimbra, 2011 andrei.morozov@coimbra.lip.pt

Parameter file Settings Autosave Help Exit

DETECTOR

Configure detector

PMT arrangement: 4 PMTs

PMT active diameter: 36000 µm

PMT center to center: 39000 µm

Photocathode shape: Round

Localization ALGORITHM

Center of Gravity — Configure

Apply distortion correction to resolution data — Configure

NEUTRONS to simulate: 100

Show reconstruction during simulations

Show displacement-corrected reconstr.

Simulation PARAMETERS

Photons per neutron (in 4Pi): 250000 — Configure

Apply smearing

Wavelength-resolved photon tracking — Configure

Simulate refraction in the output window — Configure

Apply AREA dependence of PMT response

Load / Show PMT area sensitivities

Apply ANGULAR dependence of PMT response

Load Show

Simulate PROTON/TRITON tracks — Configure

Simulate neutron capture !

Simulate transverse diffusion of electrons — Configure

Simulate READ-OUT electronics — Configure

Single point | Area | Neutron mask | Exp_data | Misc | Sim #: 18

Source position: X -12400 µm, Y -15400 µm

Show effective PMT hits

Show simulated photo-electrons

Show expected photo-electrons

SIMULATE one event

Save PMT hits

Show photon origins

SIMULATE N events

Stop Save XY data

Show distribution of: reconstructed X

# of bins: 20

Log info Save log

```
---Simulation # 18  Run # 1----------
                X, um     Y, um     Photons/e
Actual:         -12400    -15400    274860
Reconstructed:  -11705    -13353    276929
  Delta:        695       2047      0.7527%
Corrected:      -12116    -15603
  Delta:        284       -203
---------------------------------------
---Simulation # 17  Run # 2----------
      Actual, um   Mean, um   Sigma, um   Resolution, um
X     -12400       -11935     325         1488
Y     -15400       -13369     291         1457

                   Corrected   Sigma from   Distortion
                   mean, um    solid angles factor
X                  -12737      302          0.5138
Y                  -15626      278          0.4696
---------------------------------------
---Simulation # 17  Run # 1----------
                X, um     Y, um     Photons/e
Actual:         -9400     -8000     241746
```

Detector configuration

MSGC

Window

PMT

Grid

Gas filling

CF4 pressure: 1 bar

He-3 pressure: 1 bar

Gas temperature: 24 C

Detector configuration

MSGC-to-PMT distance: 16000 µm

Window thickness: 5000 µm Optics

MSGC-to-window distance: 10000 µm !

Gas gap after the window !

Waveshifters in front of PMTs Setup

Drift grid defines the drift gap

MSGC-to-grid distance: 9000 µm

Drift field: 2000 V / cm

MSGC

Activate MS anodes Orientation: Vertical / Horizontal

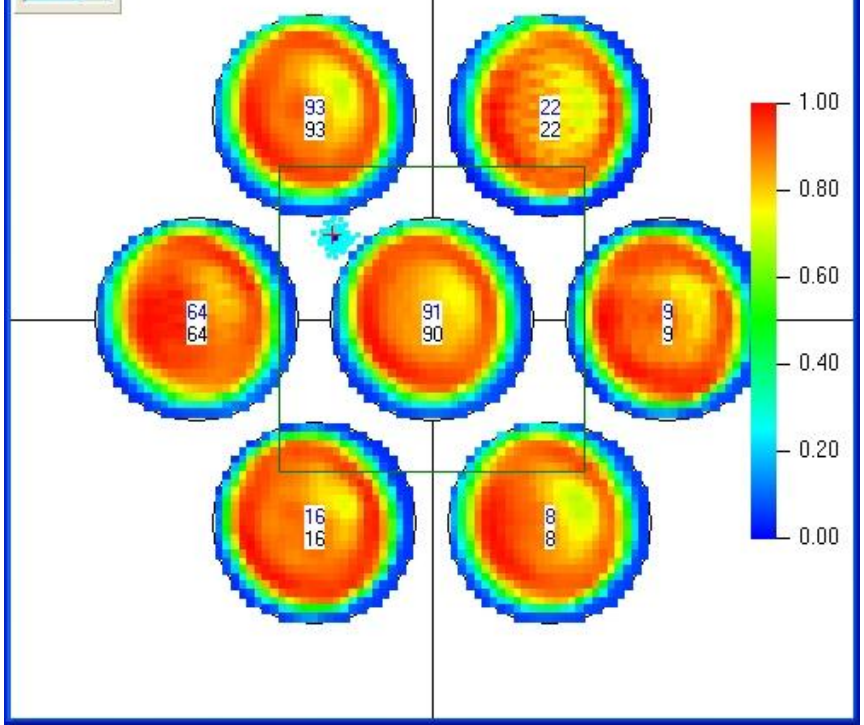
Show anodes

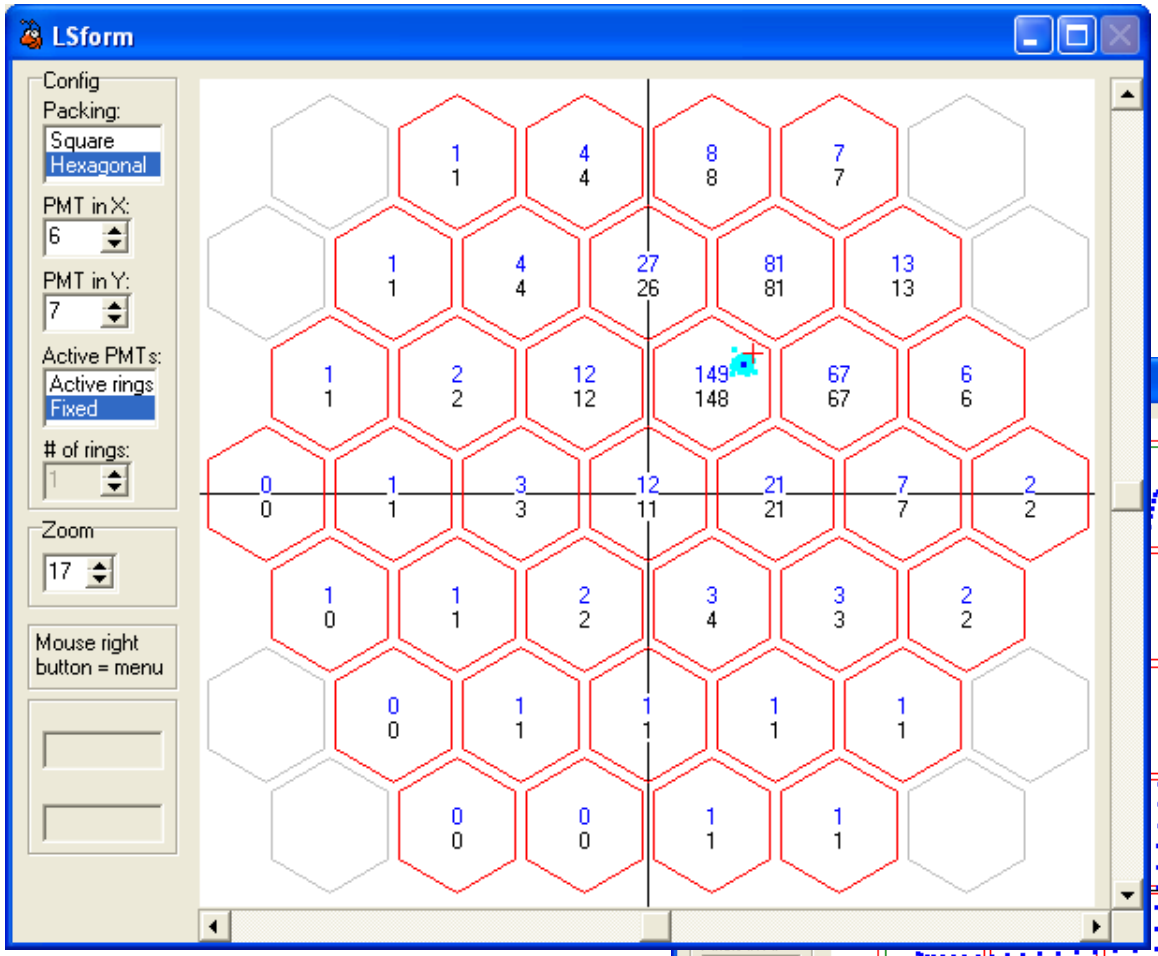
MSGC pitch: 1000 µm Offset: 0 µm

PMTform X: -12391 Y: -10652

Zoom 23

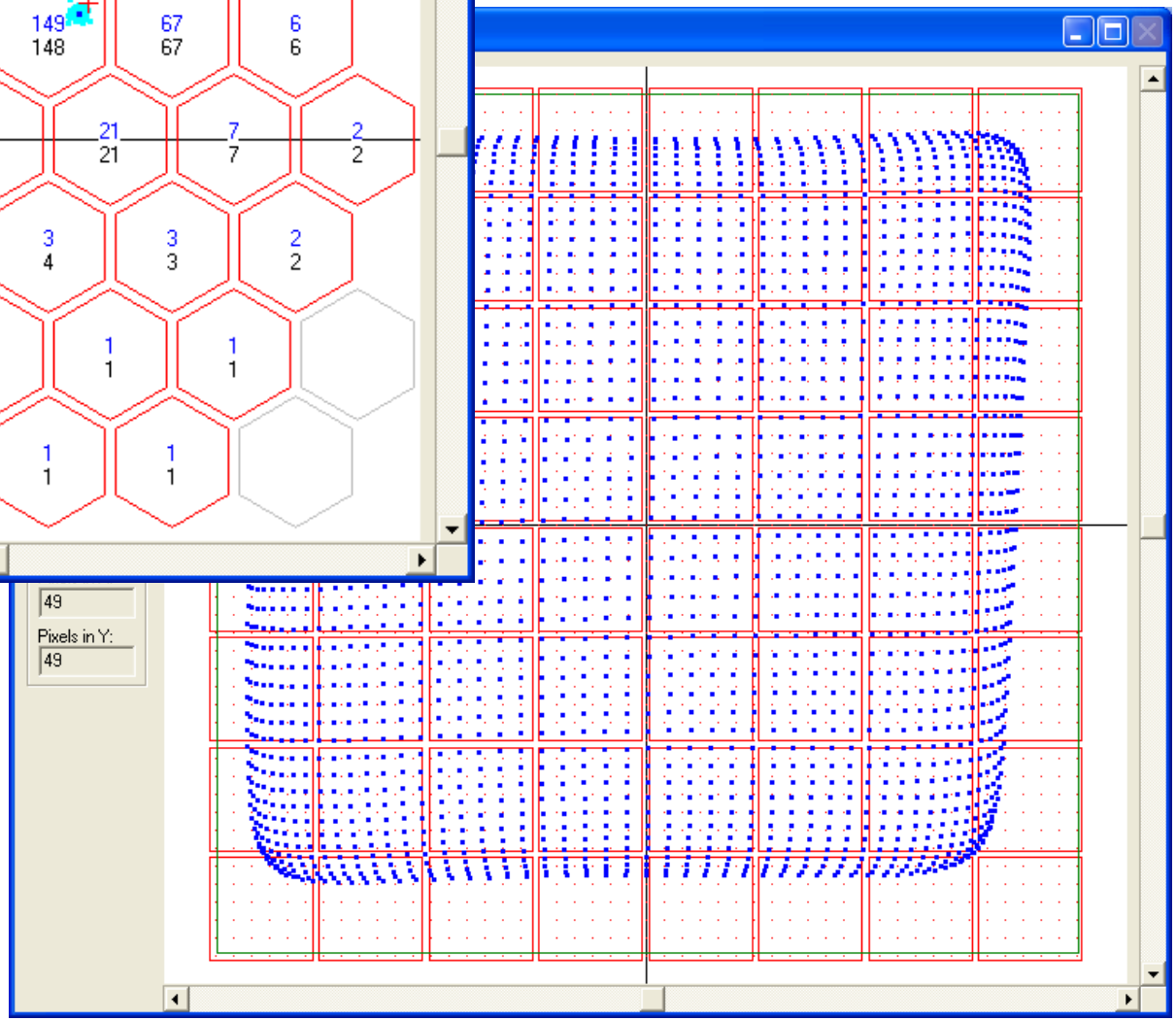
"Small scale" PMT window



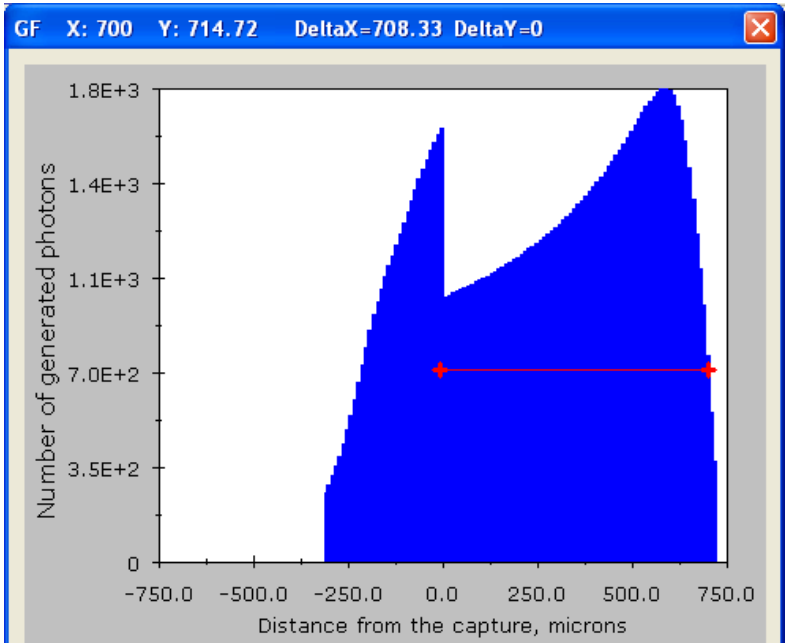


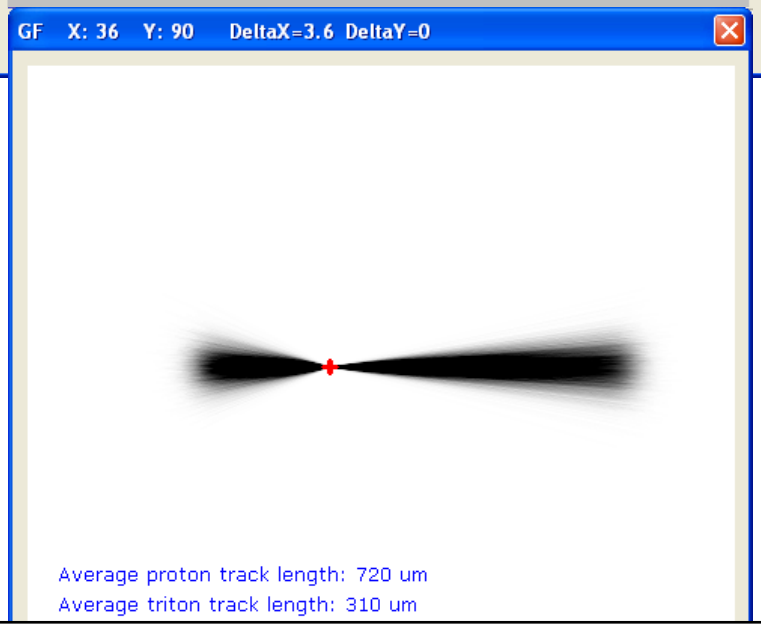
“Large scale” PMT window: gamma camera PMT array

“Large scale” PMT window: Multi-anode PMT simulation



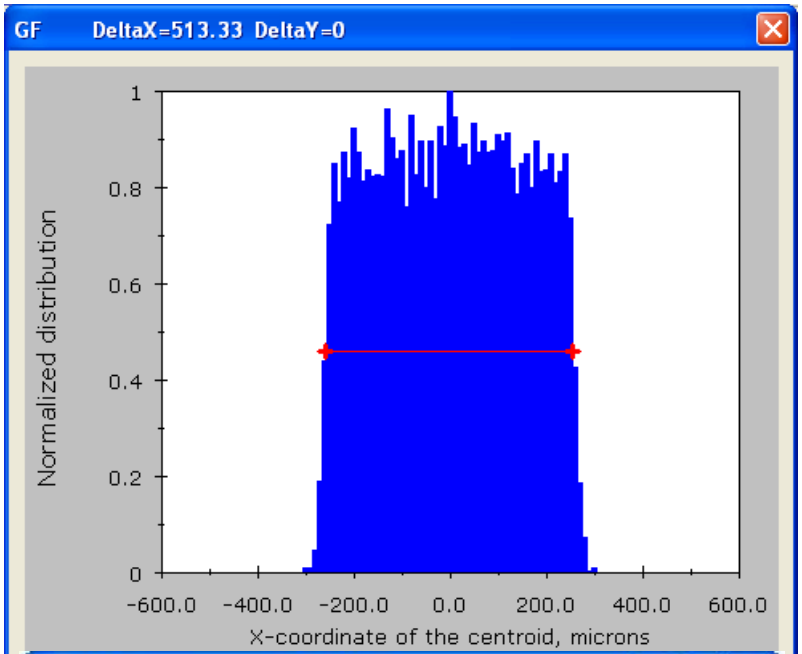
Energy deposition density in 6 bar CF_4

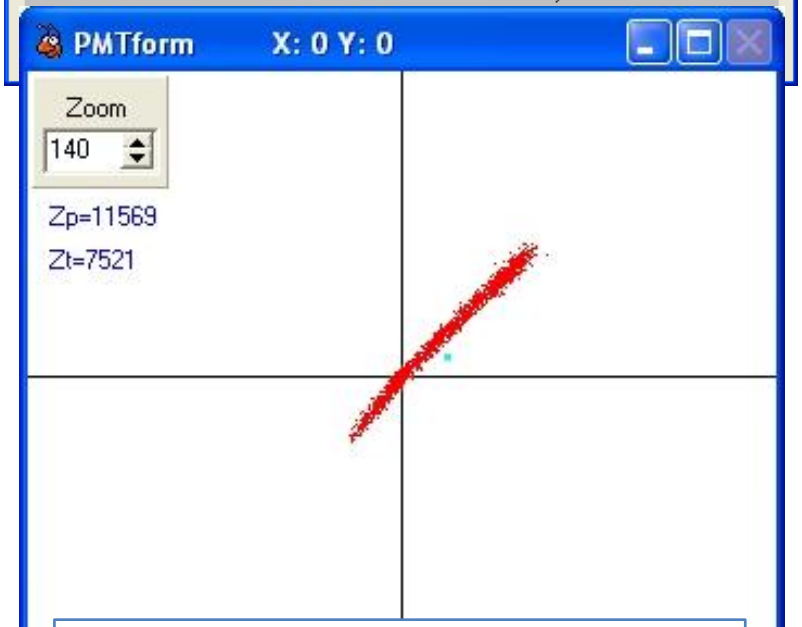




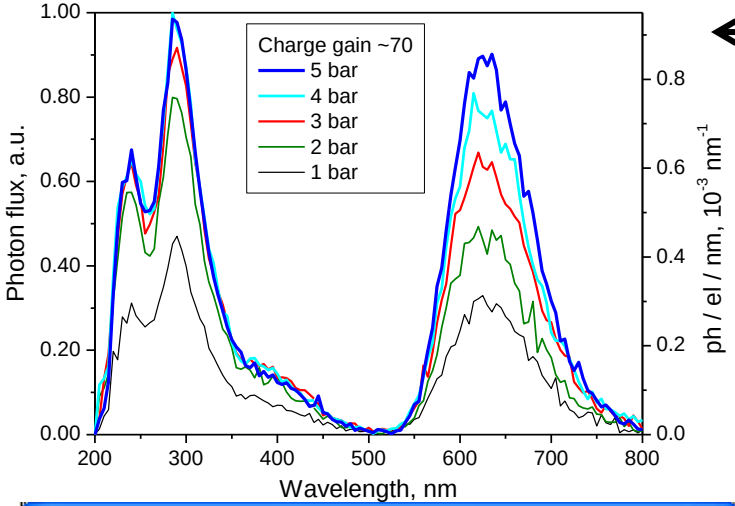
Proton and triton straggling simulation

FWHM due to the energy deposition asymmetry



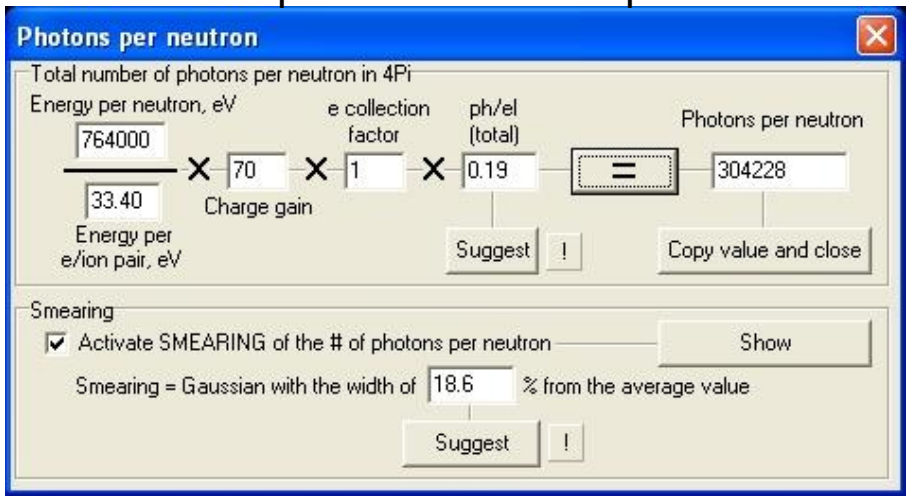


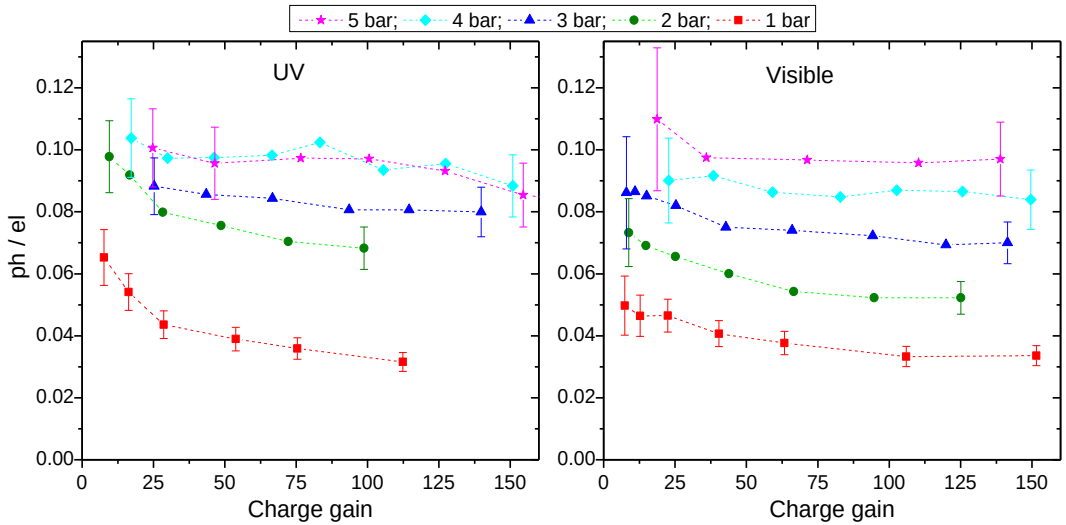
Footprint of the photon emission



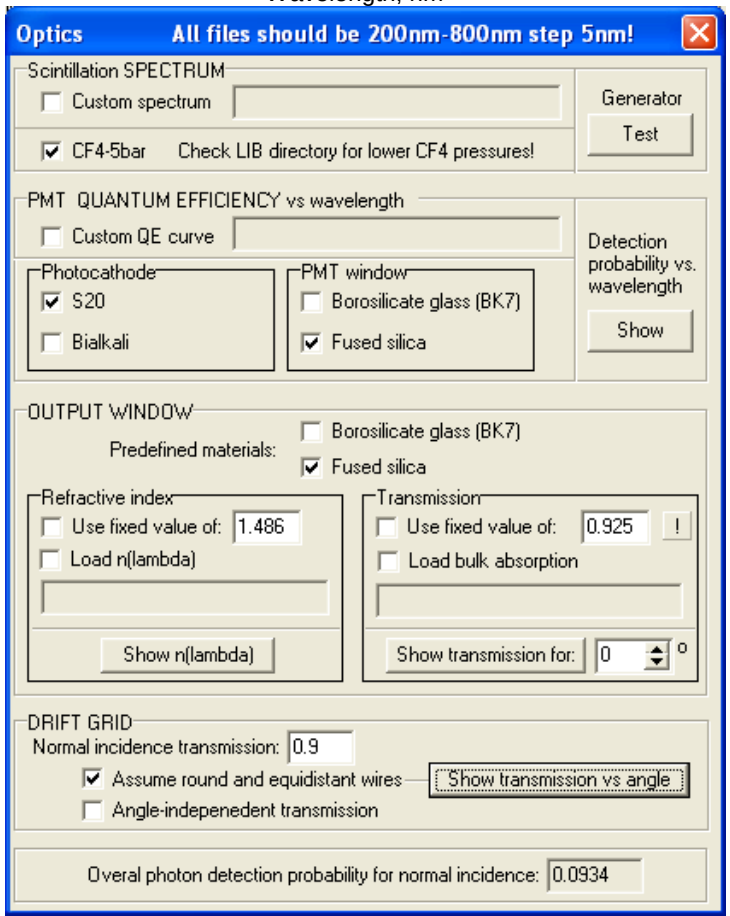
← CF_4 emission spectra for pressures from 1 to 5 bar

"Photons per neutron" setup window



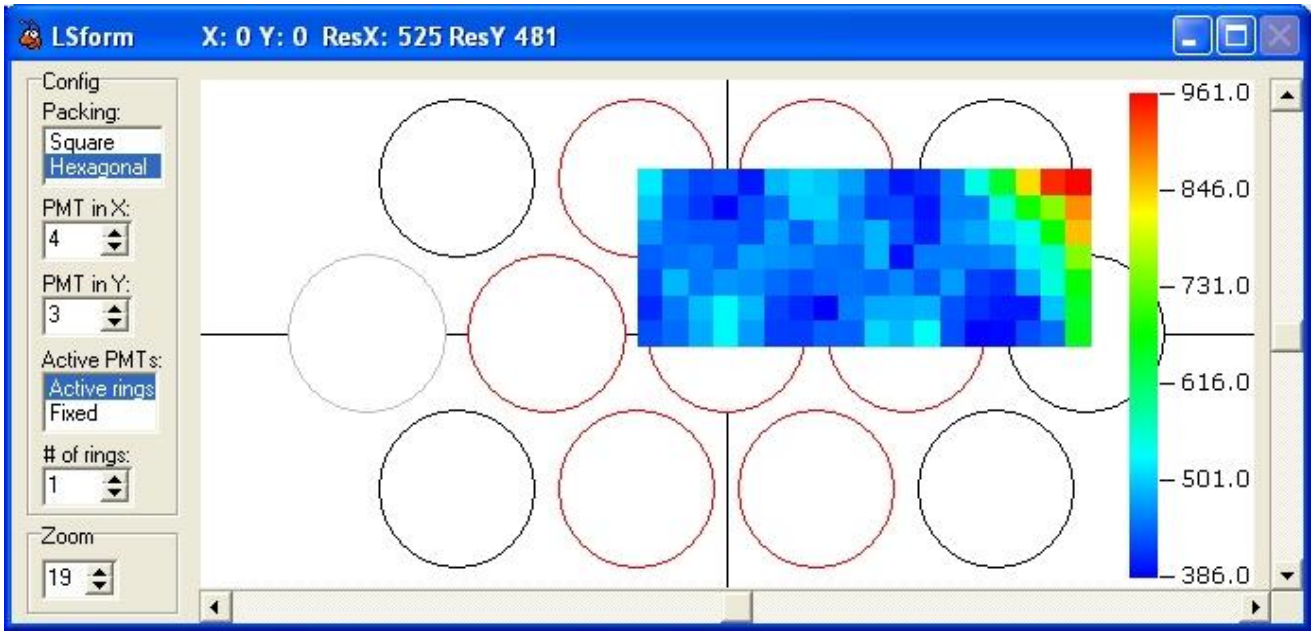


Our measured values for Ph/el vs. Microstrip gain

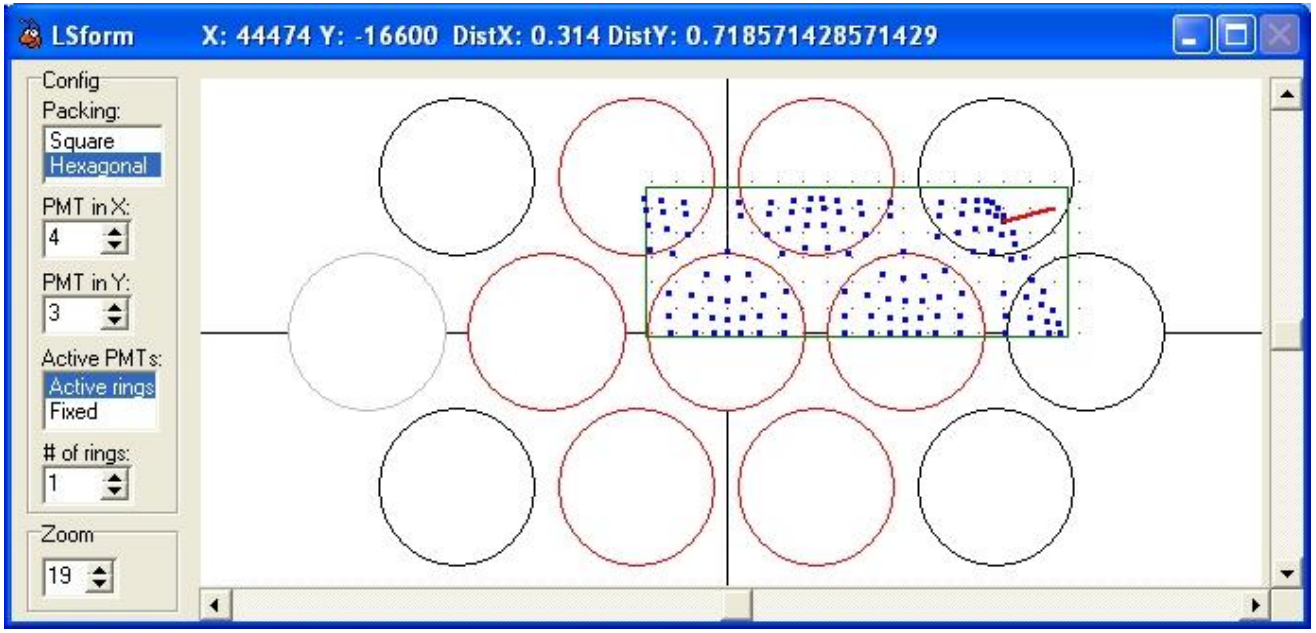


← "Optics" setup window

“Area” simulations

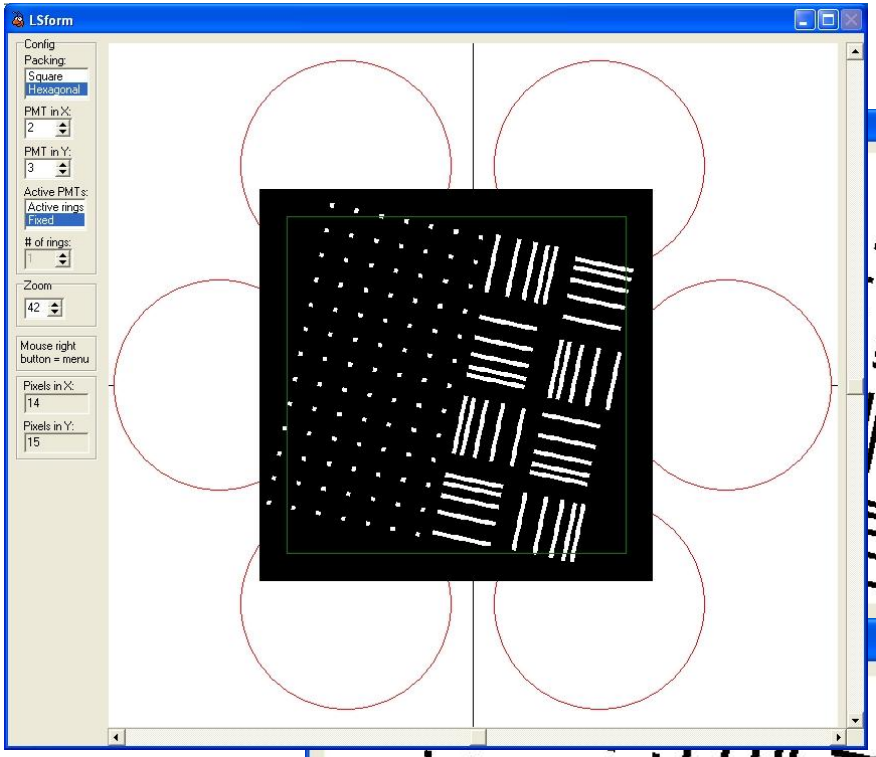


Spatial resolution (in um) over a given area of the detector

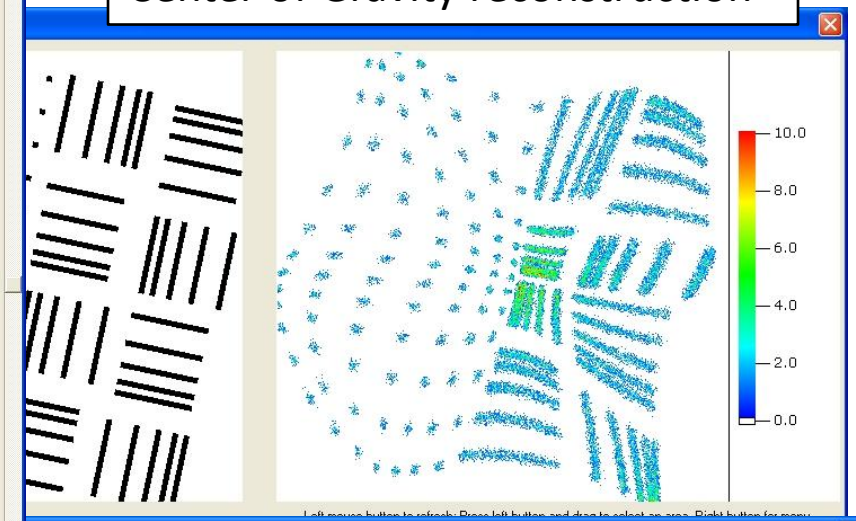


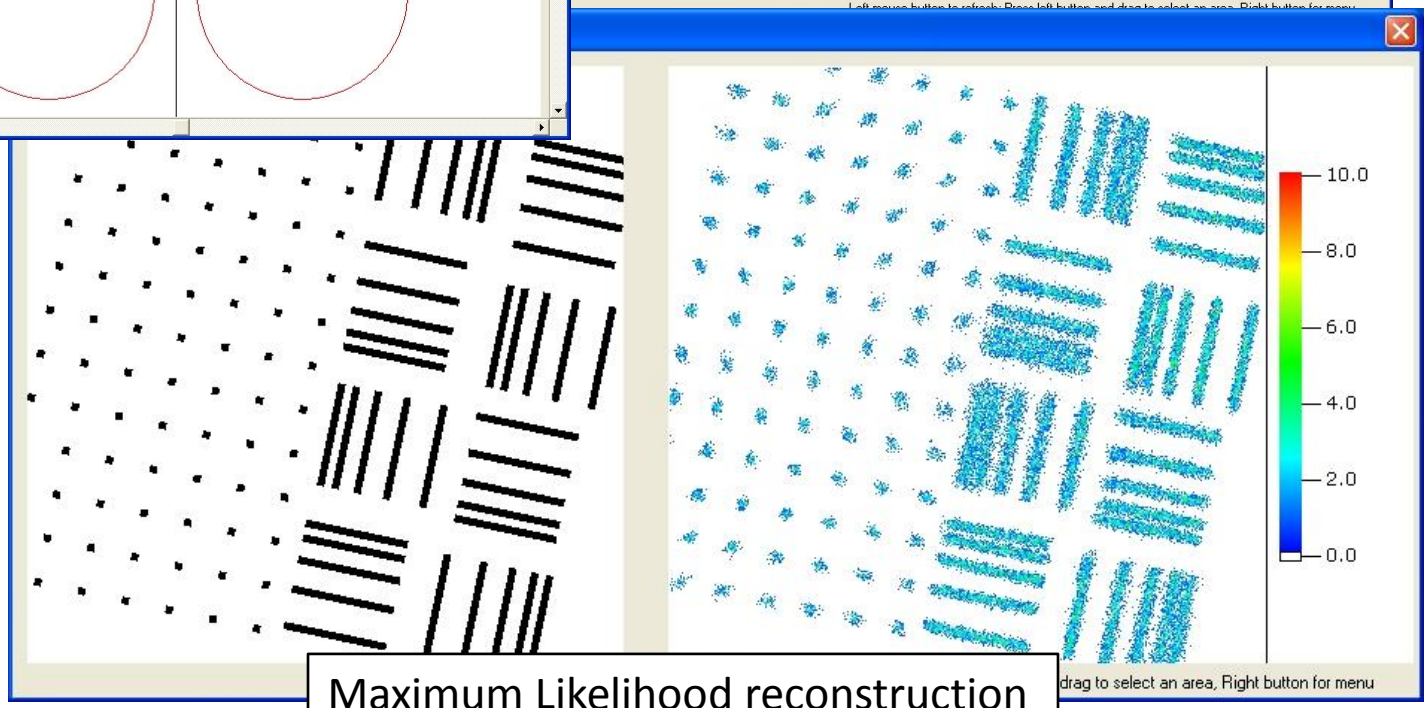
Spatial distortion for the same area of the detector

“Neutron mask” simulations



Center of Gravity reconstruction

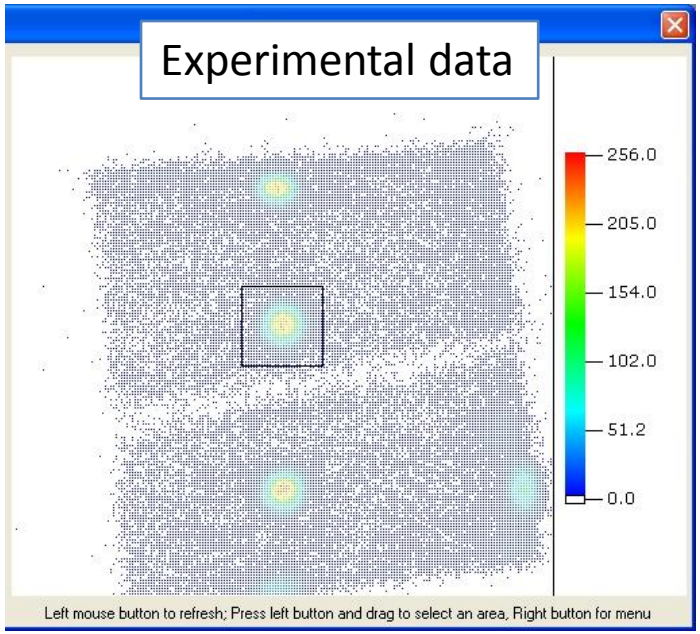




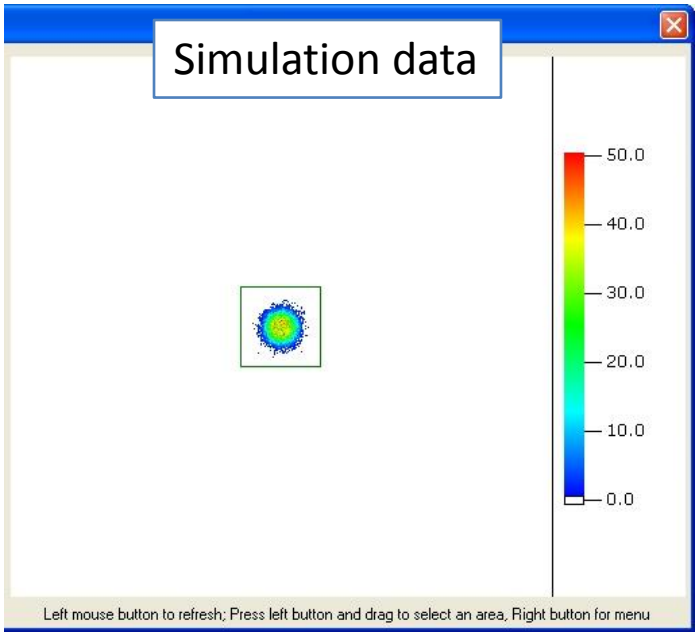
Maximum Likelihood reconstruction

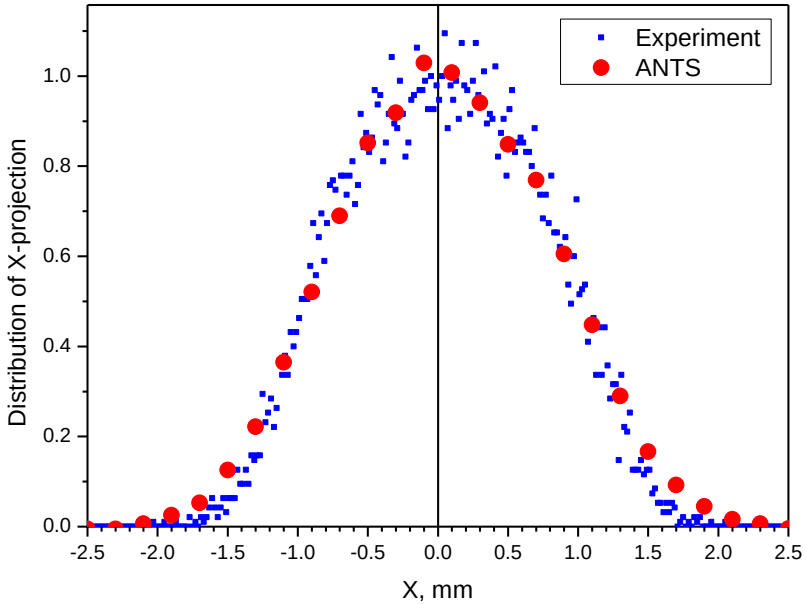
The color of the mask pixels define whether the neutrons pass the mask or not.

Validation with preliminary experimental data

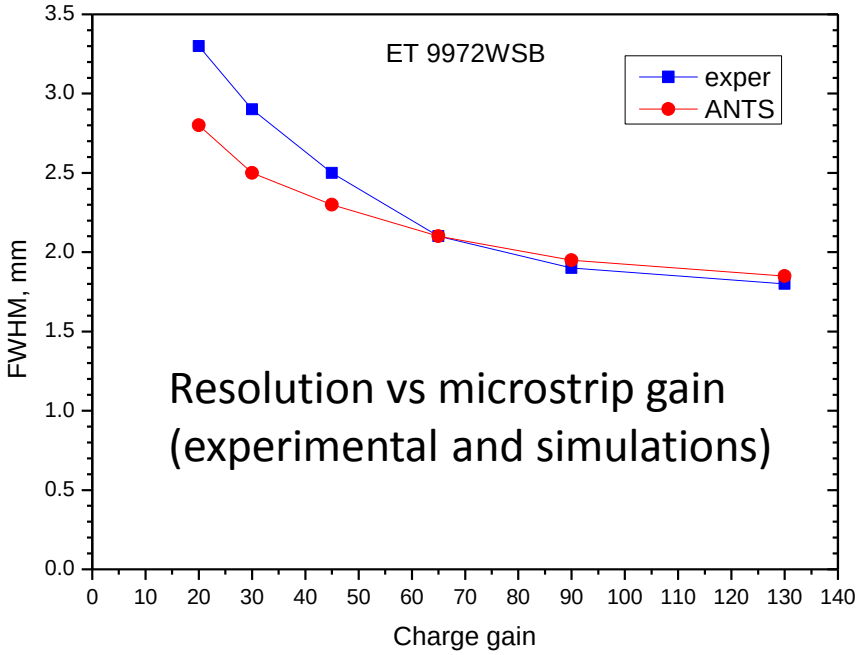


The same conditions!





Experimental and simulated profiles



Resolution vs microstrip gain (experimental and simulations)

Status

- ANTS is the official simulation package of the collaboration;
- ANTS were presented at 2011-IEEE Nuclear Science Symposium;
- Permission to freely distribute the package is obtained from the collaboration.

Future work

- To complete the experimental verification;
- To add a module for processing of experimental data;
- To add silicon photomultiplier (SiPM) support.