XPOL for IXO

Ronaldo Bellazzini
INFN – Pisa,Italy

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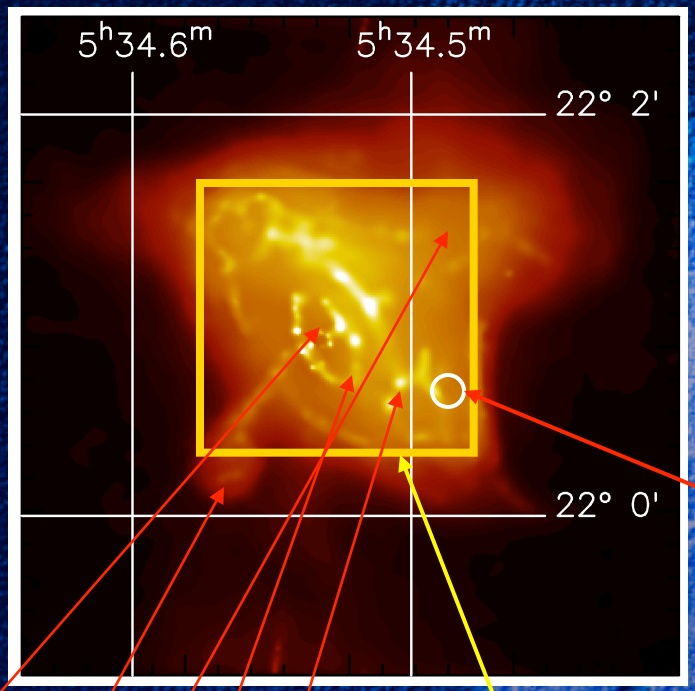
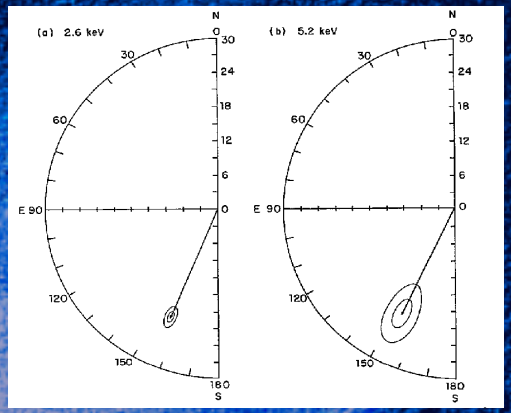
The only polarized source already known





Positive measurement: of X-ray polarization of the Crab Nebula without pulsar contamination (by lunar occultation, Weisskopf et al., 1978).

P = 19.2 ± 1.0 %

θ = 156.4° ± 1.4°

But this is only the average measurement.The structure is much more complex!

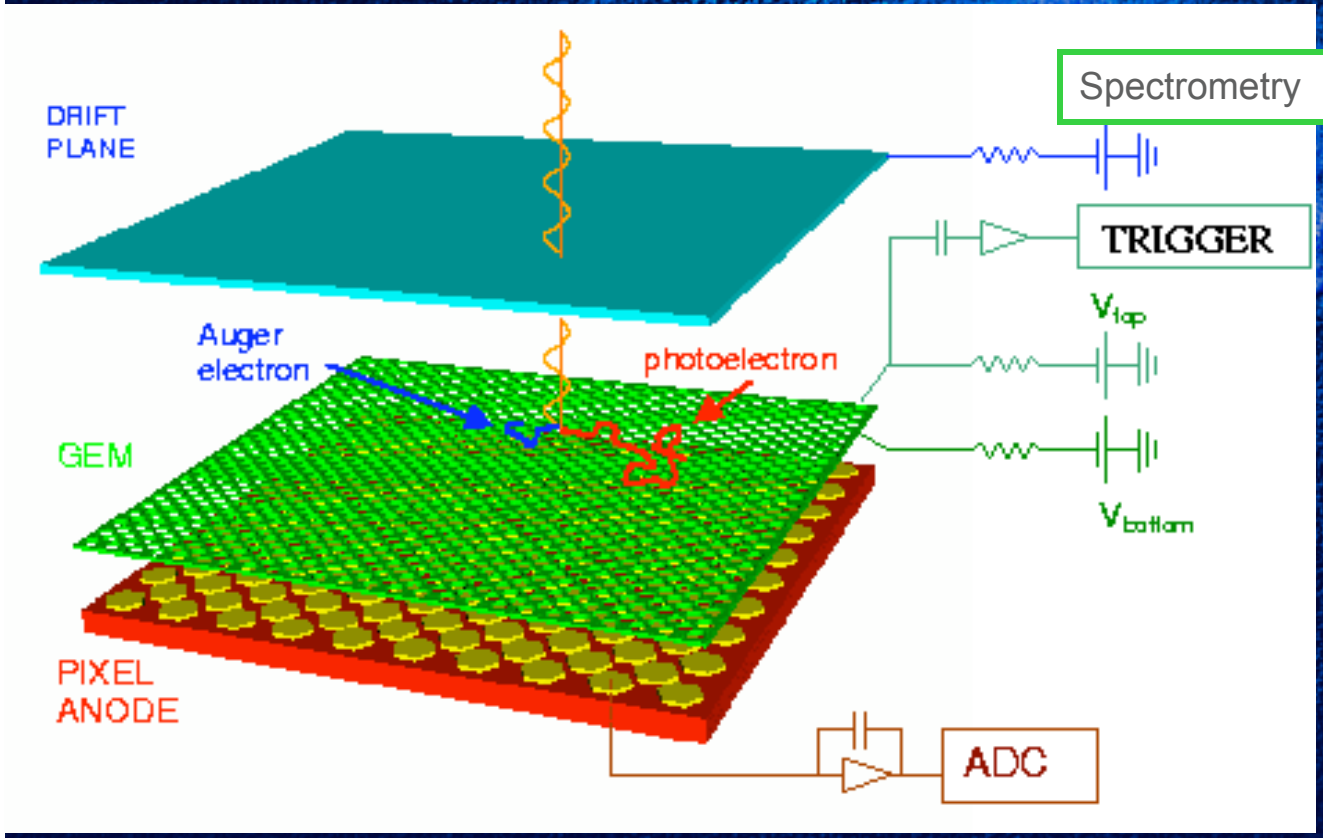
With XPOL we can perform separate polarimetry, imaging, spectroscopy and timing of details of the major structures

Telescope psf = 5”

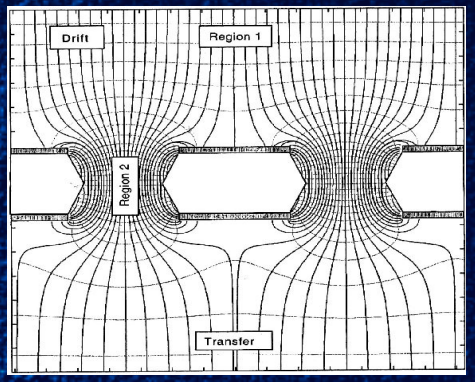
XPOL psf = 6” (f=20m)

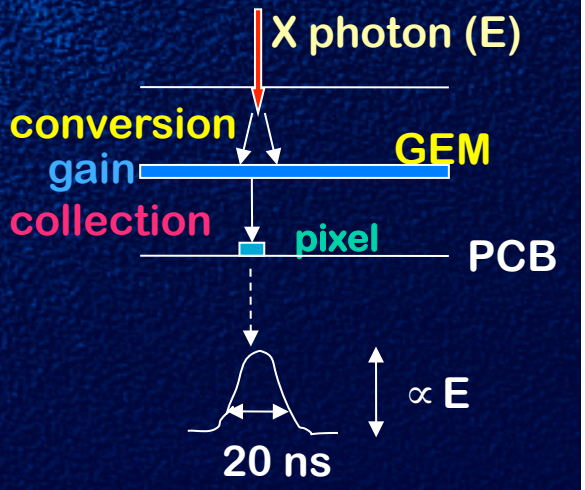
The principle of detection

$$\frac{\partial\sigma}{\partial\Omega} \propto \cos^2\phi$$



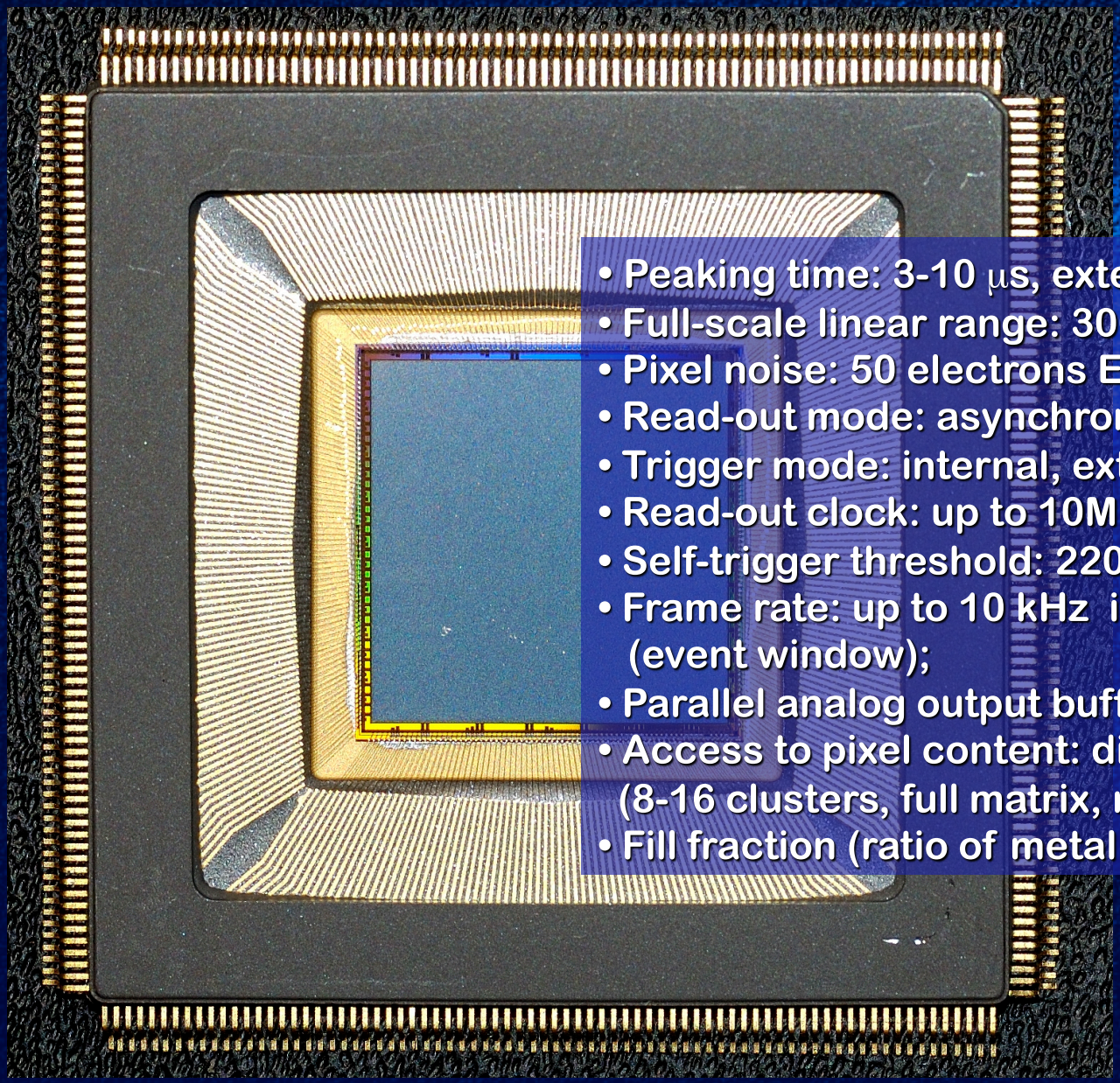
GEM electric field





Polarization information is derived from the tracks of the photoelectron, imaged by a finely subdivided gas detector.

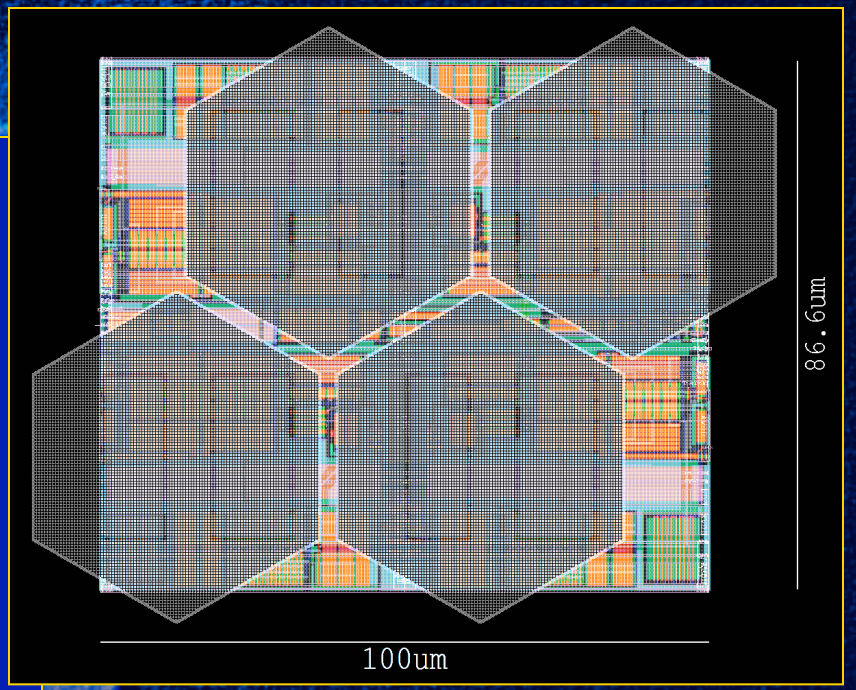
ASIC features



- Peaking time: 3-10 μs, externally adjustable;
- Full-scale linear range: 30000 electrons;
- Pixel noise: 50 electrons ENC;
- Read-out mode: asynchronous or synchronous;
- Trigger mode: internal, external or self-trigger;
- Read-out clock: up to 10MHz;
- Self-trigger threshold: 2200 electrons (10% FS);
- Frame rate: up to 10 kHz in self-trigger mode (event window);
- Parallel analog output buffers: 1, 8 or 16;
- Access to pixel content: direct (single pixel) or serial (8-16 clusters, full matrix, region of interest);
- Fill fraction (ratio of metal area to active area): 92%)

Internal trigger functionality

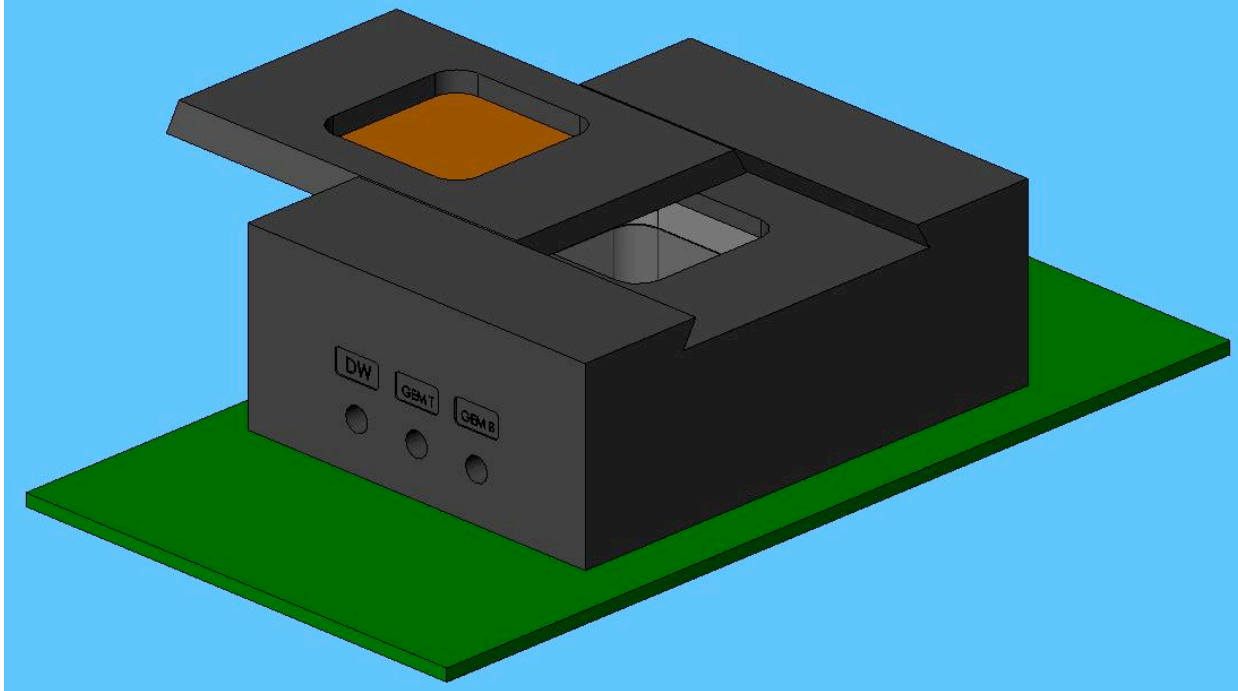
- ✓ mini-clusters of 4 pixels contribute to a local trigger with dedicated shaping amplifier
- ✓ threshold < 3000 e^- (10% FS)
- ✓individual pixel trigger mask
- ✓independent trigger level for each 16 clusters
- ✓event localization in rectangle containing all triggered mini-clusters + user selectable region of 10 or 20 pixels
- ✓the chip calculates the event ROI (X_{min},Y_{min} – X_{max},Y_{max}) for subsequent sequential readout of selected area

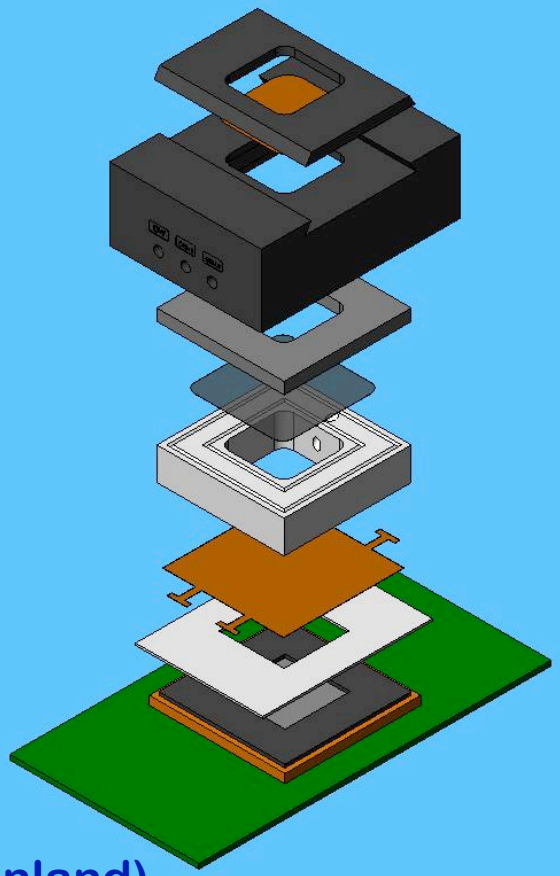


XPOL v2 under design

- optimization of the ROI (factor 5 reduction of data tranfer)
- dead time reduction from 200μs to 10μs
- threshold reduction from 3000 e^- to 300 e^-

Sealed device
(only clean materials, baking & outgassing)





Collaboration with Oxford Instruments Analytical Oy (Finland)

The sealed device

Collaboration with
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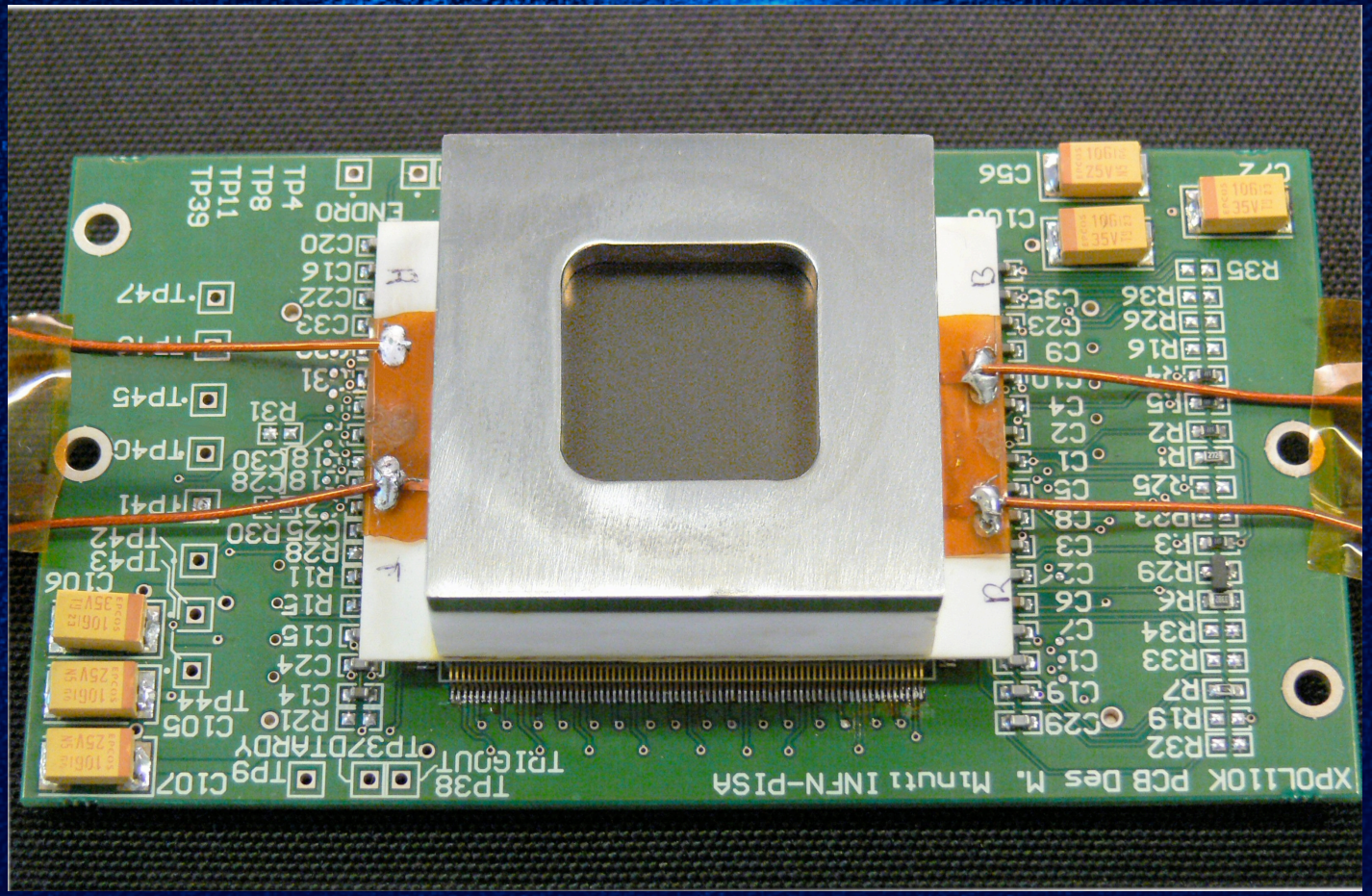


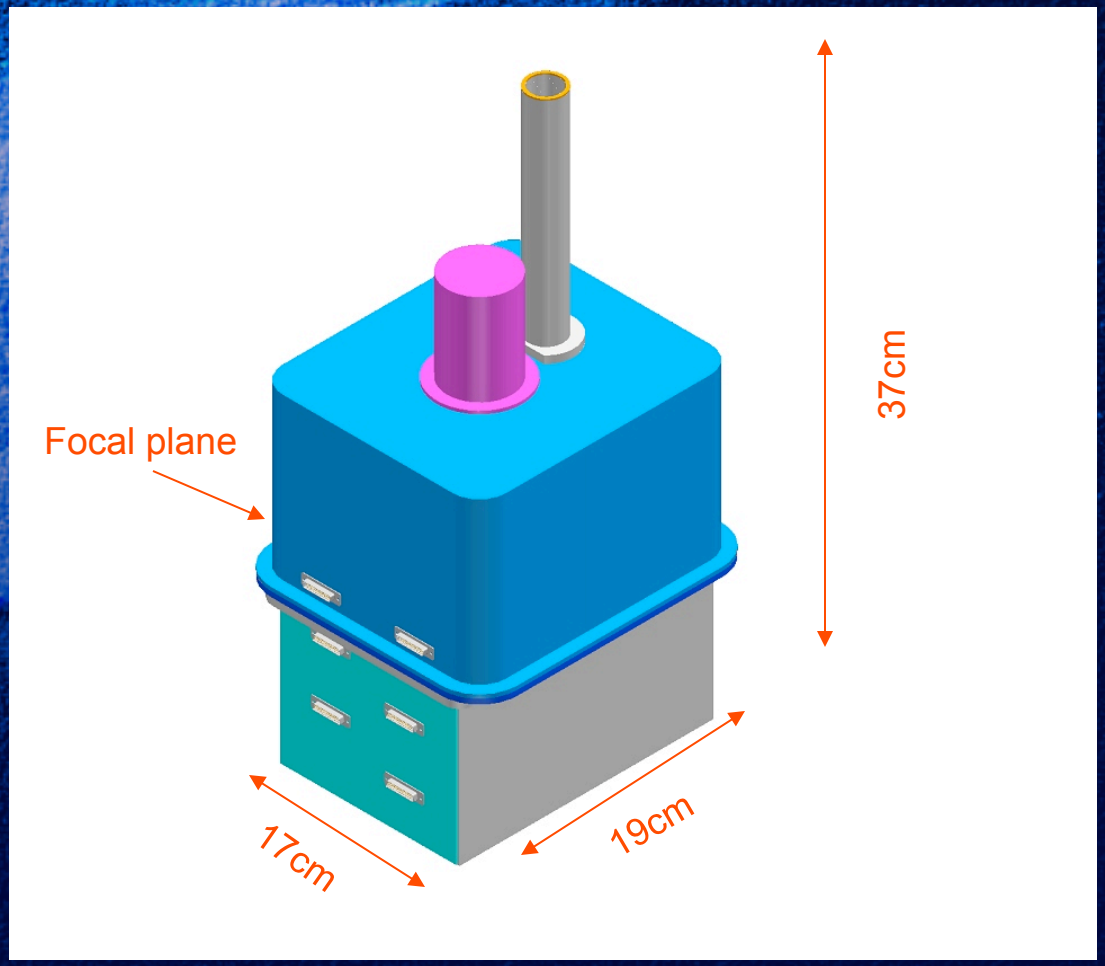
The detector is still working with unchanged performance after 2 years from the construction

IXO setup

Filter wheel with 7 positions
- Closed
- Open
- ^{55}Fe source
- Cu fluorescence source
- Polarized source
- Diafragm
- Be filter

The Back End Electronics contains the comand and communication electronics of the ASIC and the HV supply.
The Control Electronics with the instrument CPU can be allocated far from the focal plane
M=11kg, P=37W

The setup with the protectoin enclosure



XPOL with the BEE and the filter wheel

Tracks reconstruction

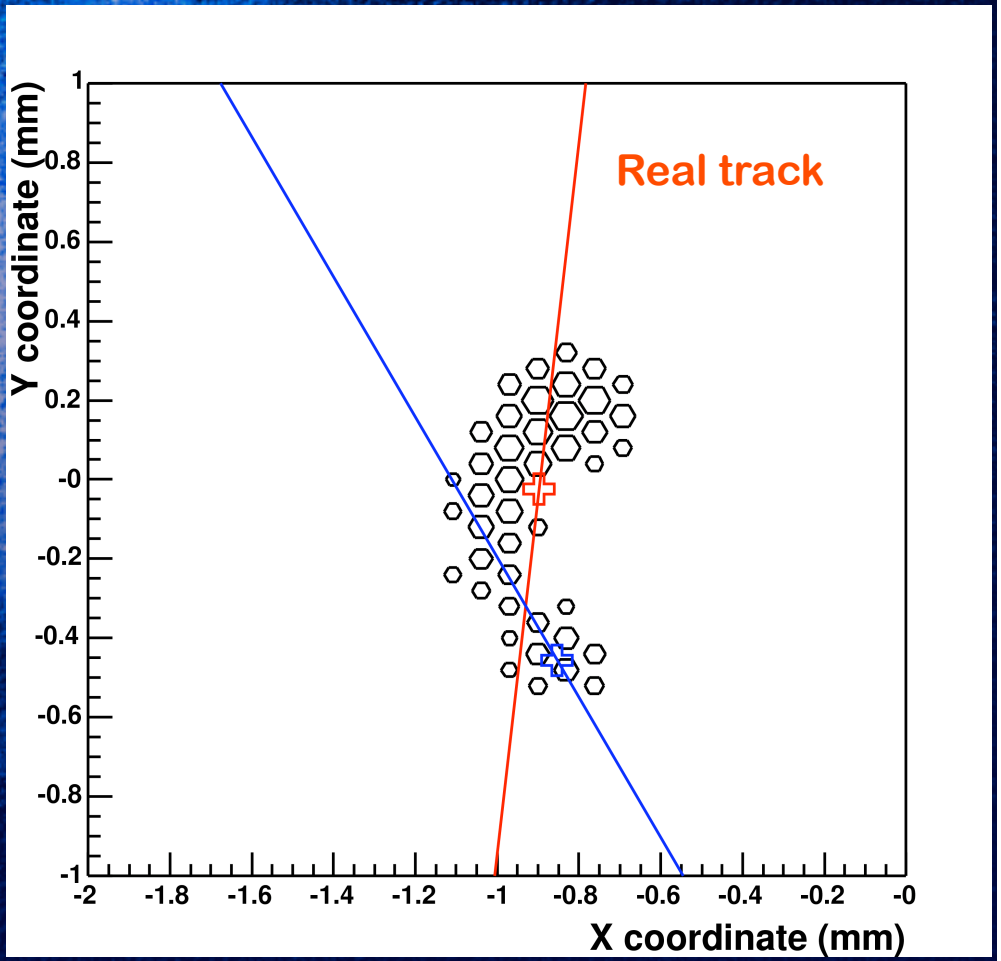
1) The track is recorded by the PIXel Imager

2) Baricenter evaluation

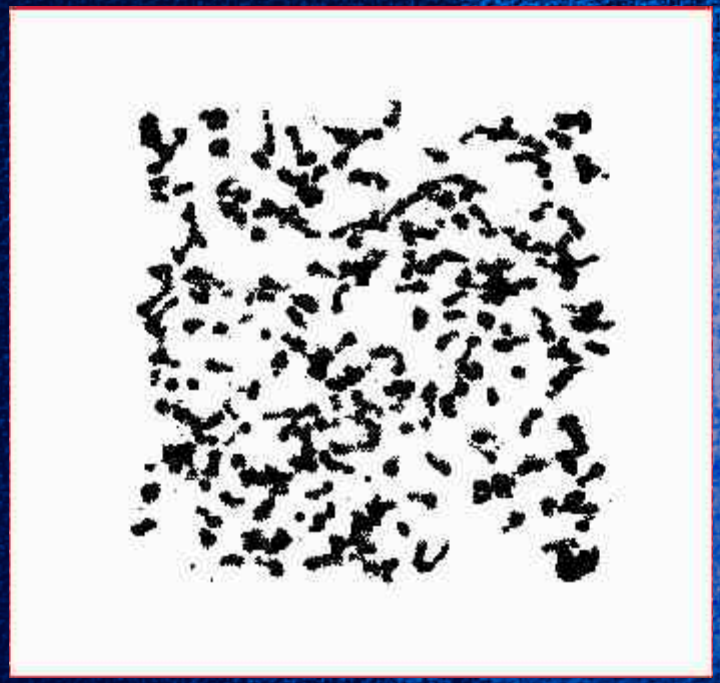
3) Reconstruction of the principal axis of the track: maximization of the second moment of charge distribution

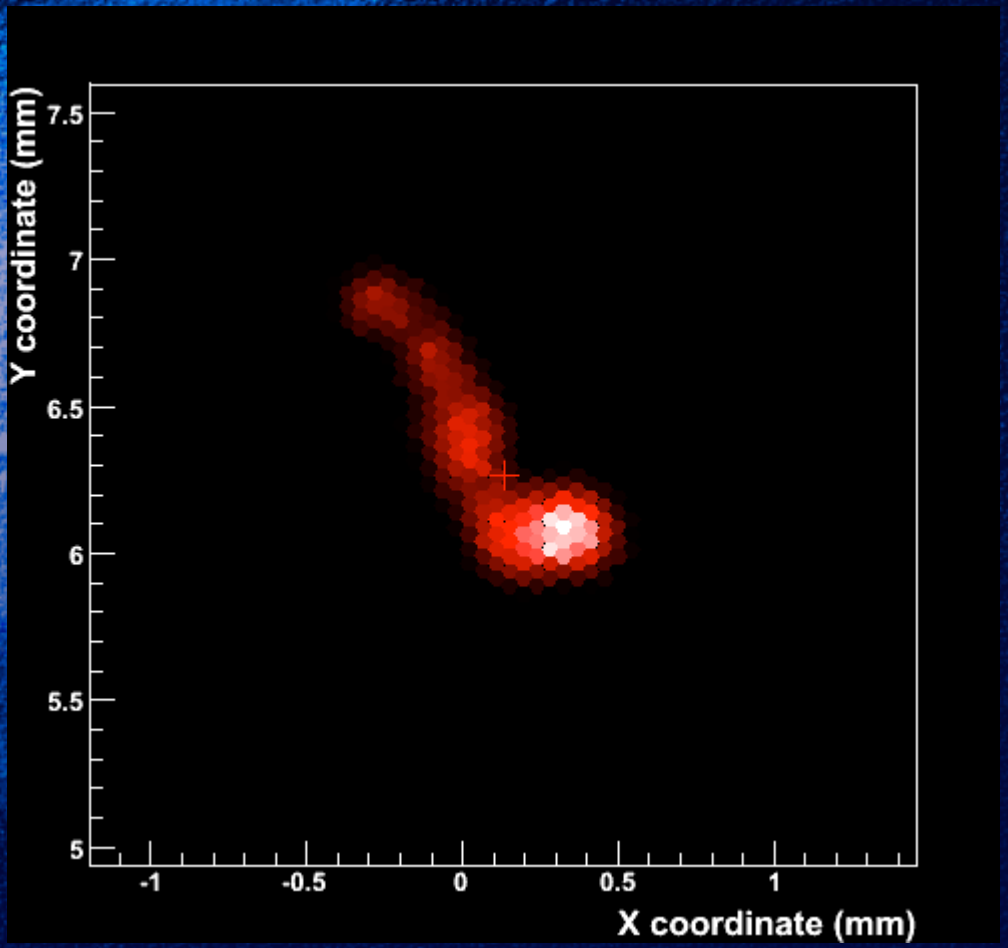
4) Reconstruction of the conversion point: major second moment (track length) + third moment along the principal axis (asymmetry of charge release)

5) Reconstruction of emission direction: pixels are weighted according to the distance from conversion point.

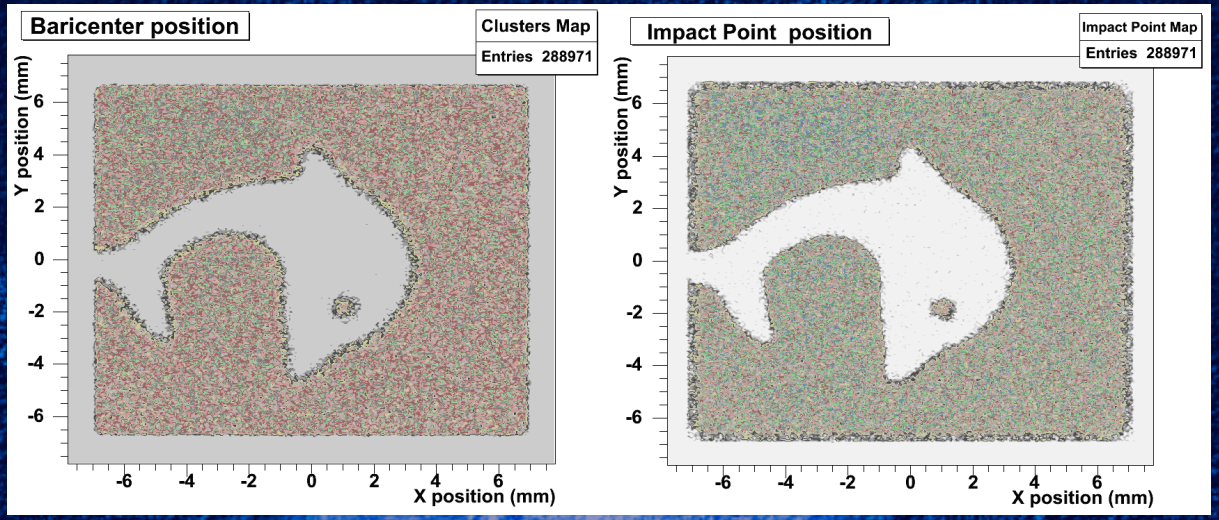


Track morphology and angle reconstruction

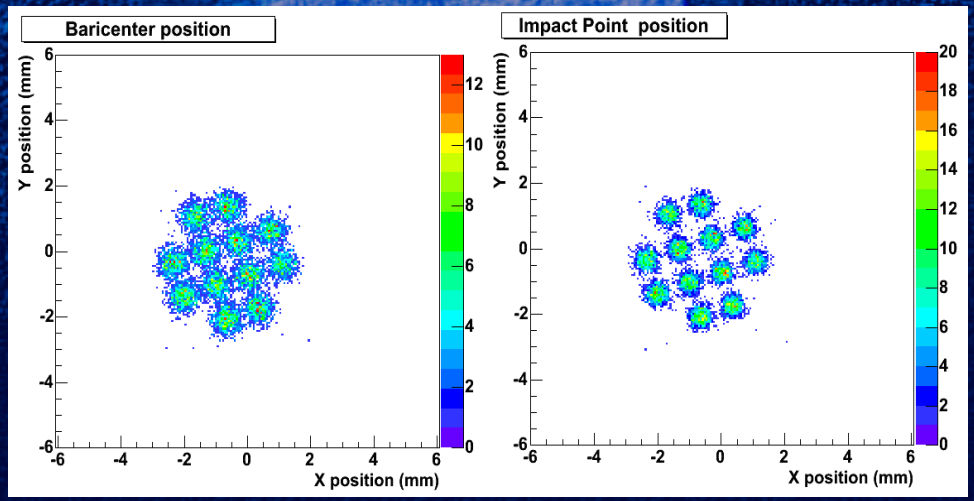




Imaging capability



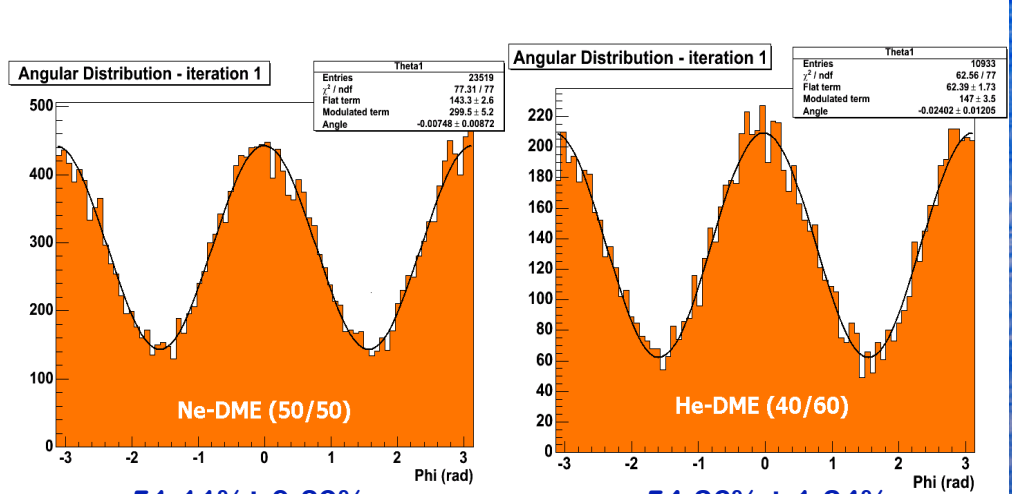
^{55}Fe source **Ne(50%)-DME(50%)**



Holes: 0.6 mm diameter, 2 mm apart.

Modulation factor

Measured with two different gas mixtures: He/DME and Ne/DME

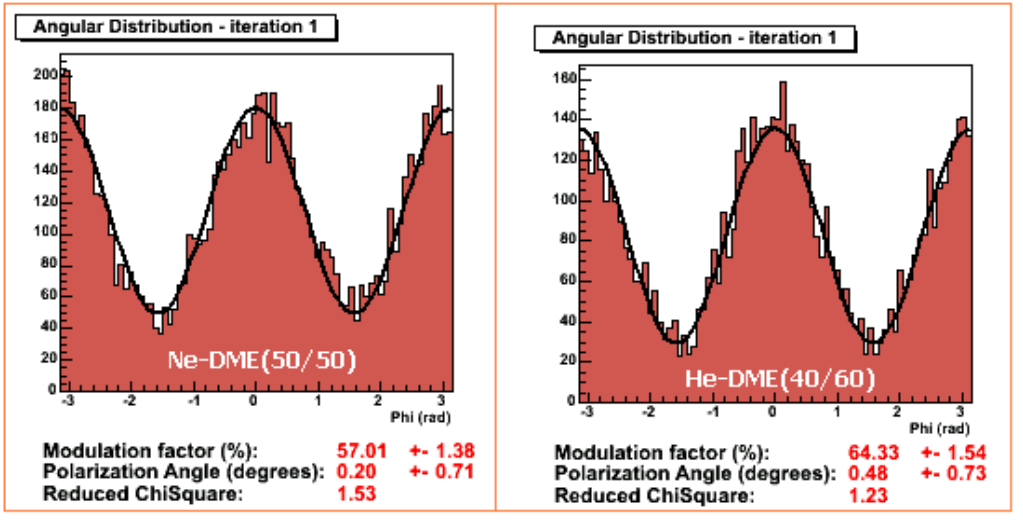


51.11%± 0.89%

54.26% ± 1.24%

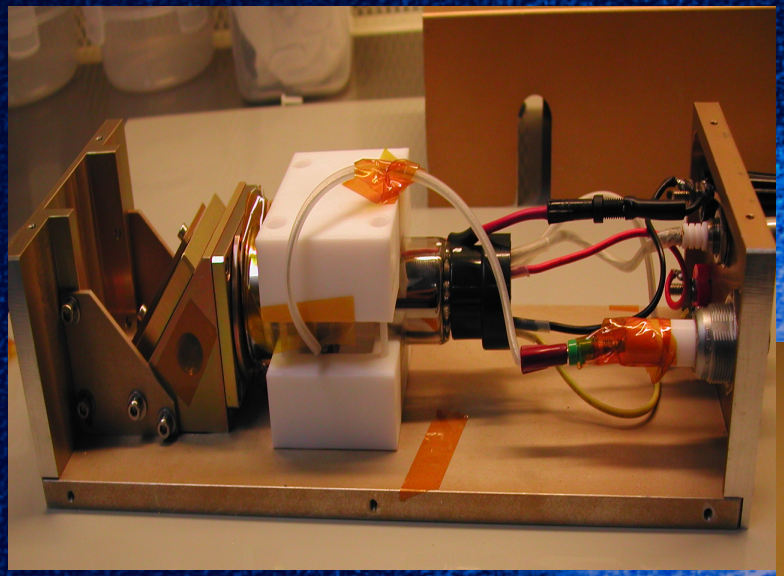
@5.4 keV Cr-line energy

@6.4 keV Fe energy

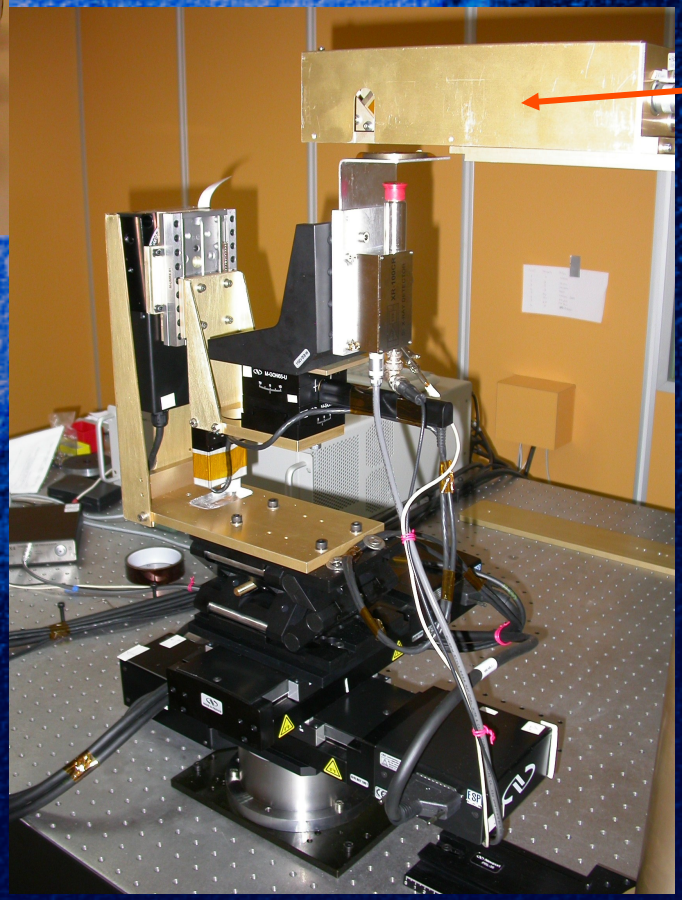


Measure of Low Energy X-ray sensitivity of XPOL

and comparison with Montecarlo estimates



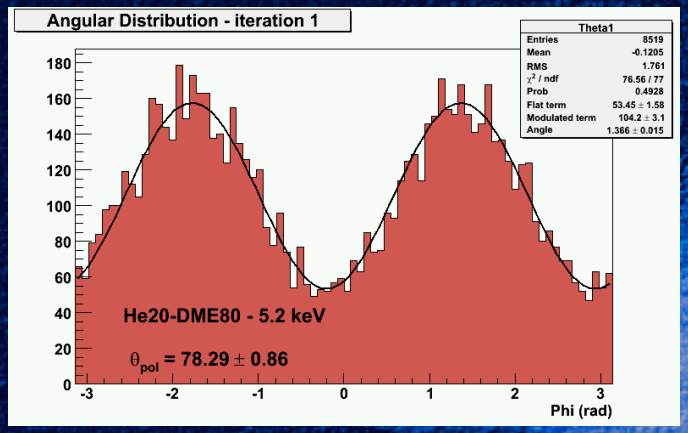
An X-ray polarizer based on selectable low energies Bragg diffraction crystals has been devised and built. (At 45° only one plane of polarization is reflected)

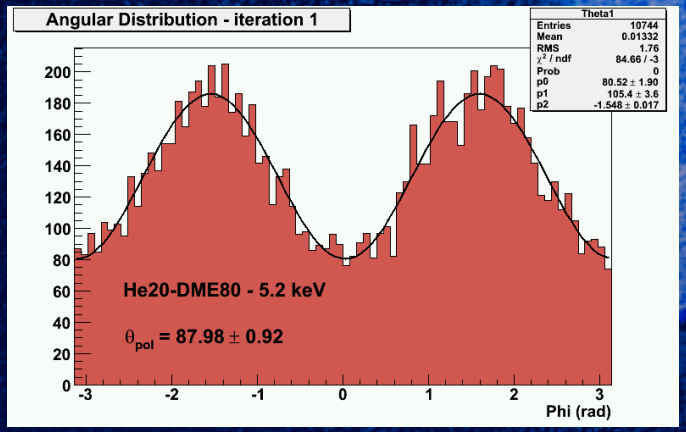


The motorized calibration bench in IASF-Roma

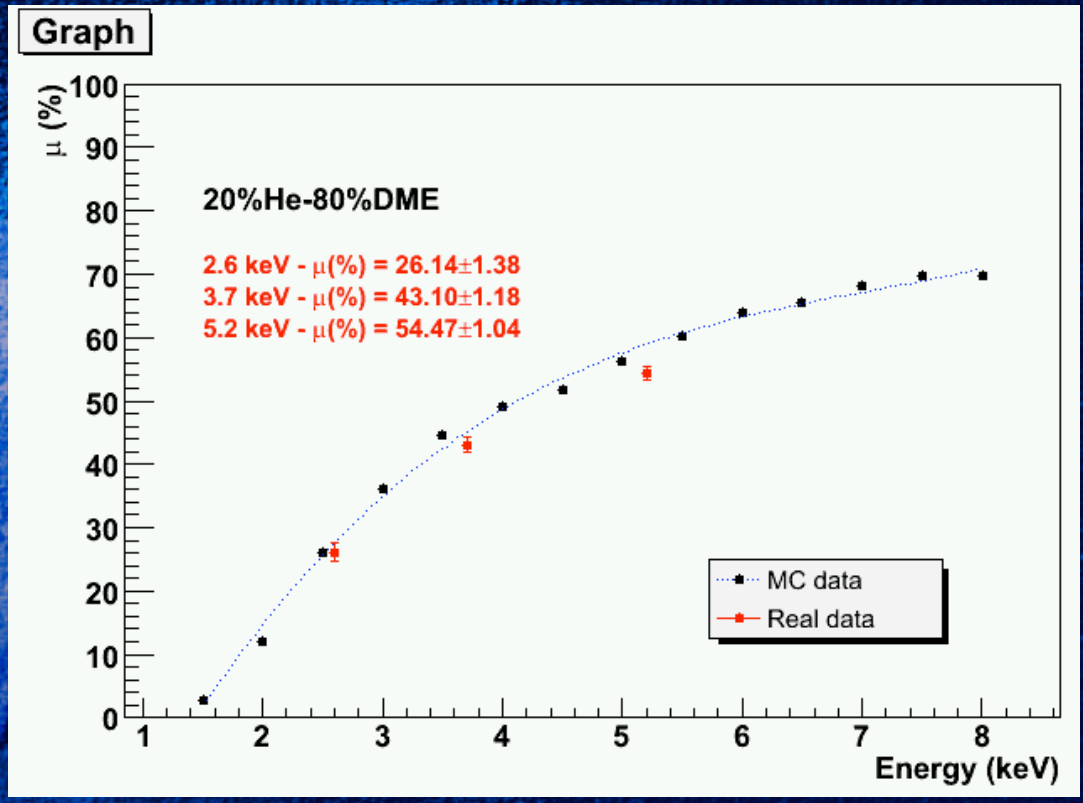
Results of the last measurement campaign

(march 2007)



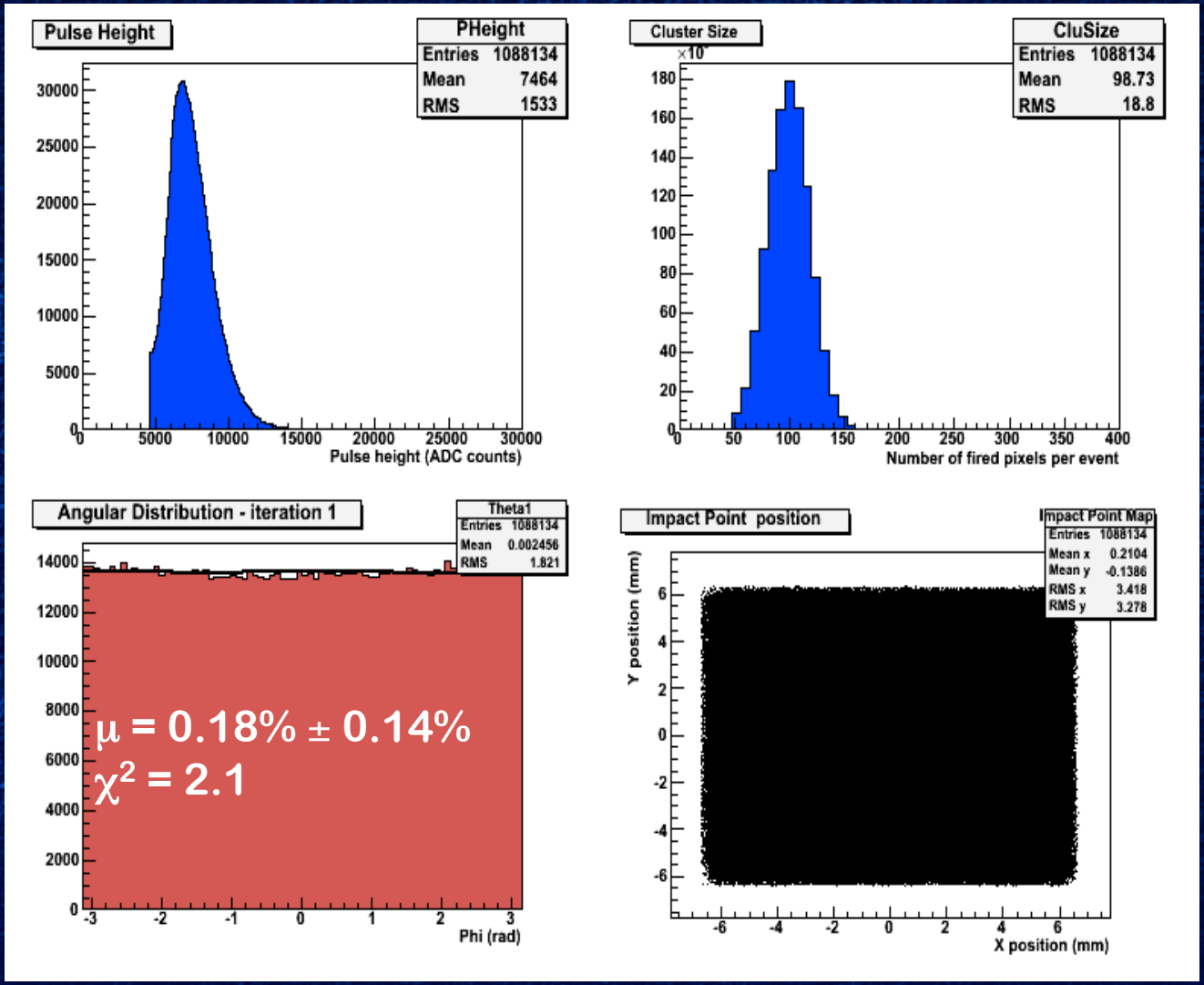


5.2 keV polarized photons for two angular rotatio of the polarizer showing the good angular sensitivity.



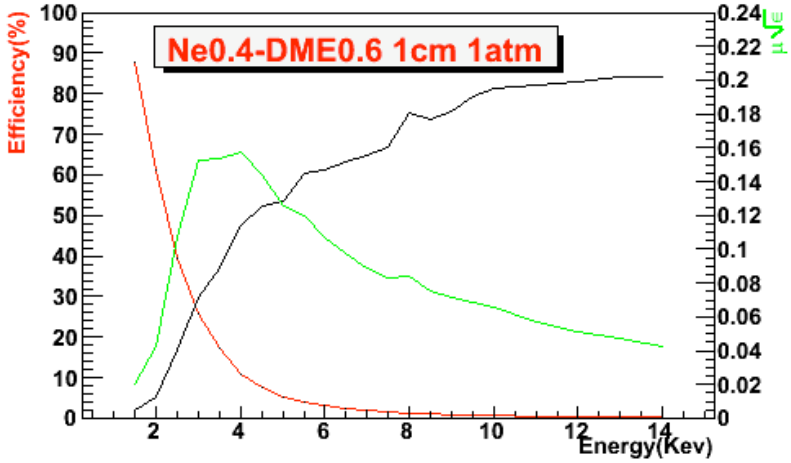
The modulation factor measured at 2.6 keV, 3.7 keV and 5.2 keV with XPOL has been compared with the Monte Carlo previsions. The agreement is very satisfying.

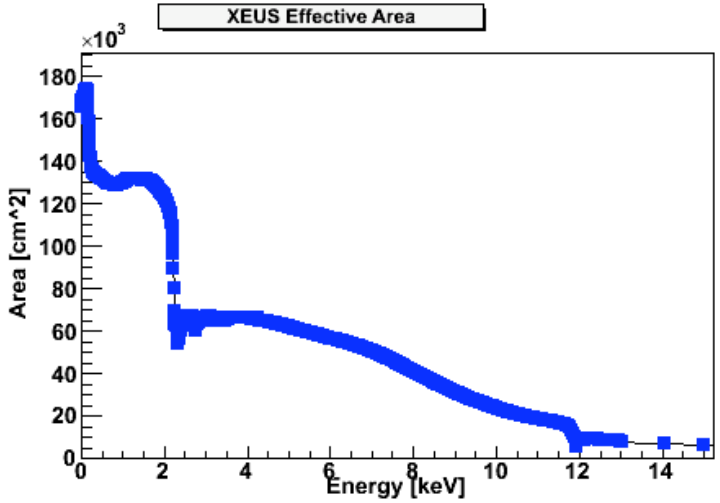
Residual modulation

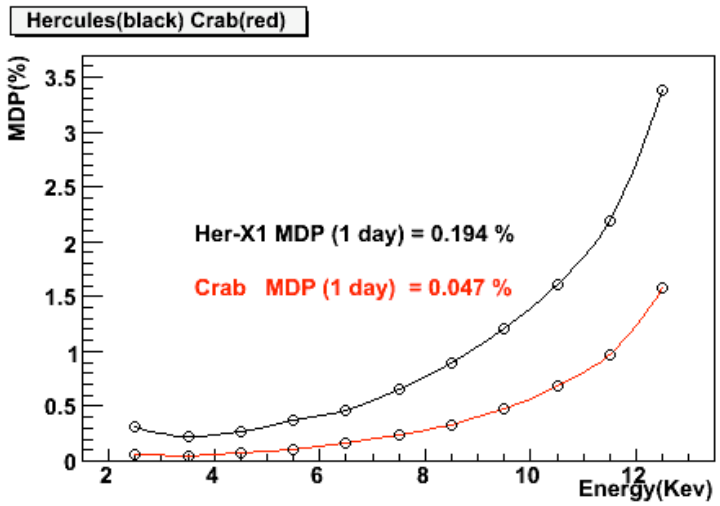


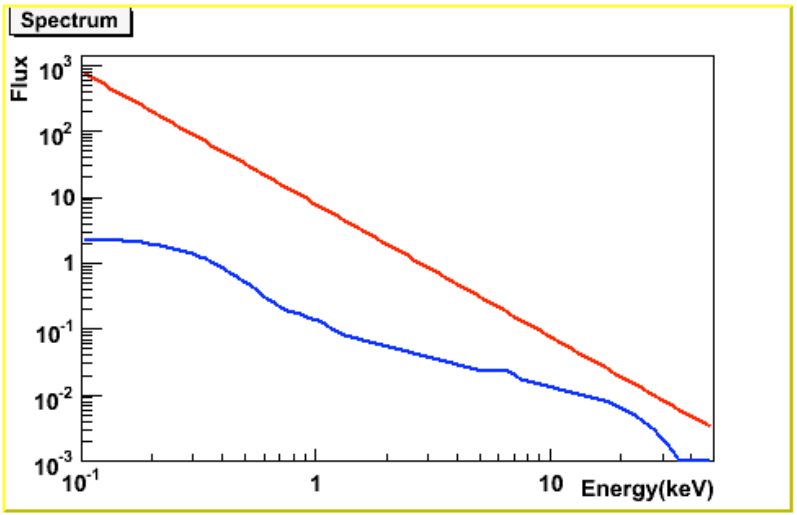
Pulse height distribution, number of channels of the cluster, residual modulation, source image (flat field illumination) obtained with ^{55}Fe source in Ne(20%)-DME(80%)

MC simulation
MDP for Crab & Her-X1









XEUS mirror effective area is considered in simulation

Conclusions

With the presented device the class of Gas Pixel Detectors has reached the level of integration, compactness and resolving power typical of solid state detectors.

The results of the environmental tests performed on a sealed prototype demonstrate that this device can well survive to the harsh space environment and is qualified for flight.

The measure of a very low residual modulation and of a modulation factor well above 50% which has been obtained with this device will likely allow polarimetric measurements at the level of ~1% for hundreds of galactic and extragalactic sources….

… a real breakthrough in X-ray astronomy
if compared with the traditional X-ray polarimeters sensitivity.