A 3D High Resolution Detector for X-and Gamma-ray Astronomy

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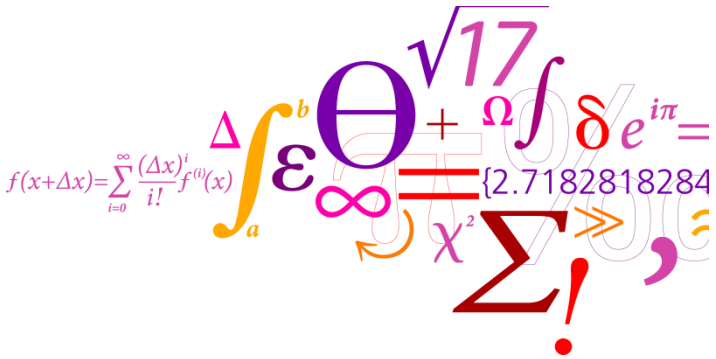
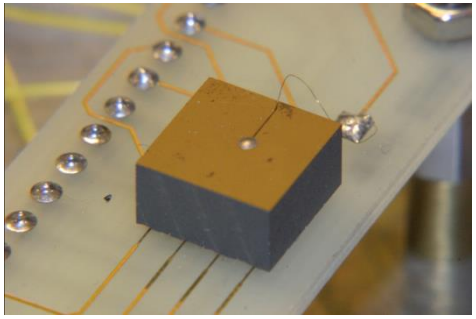


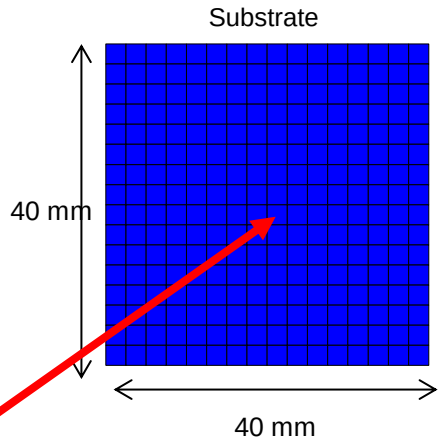
DTU Space
National Space Institute

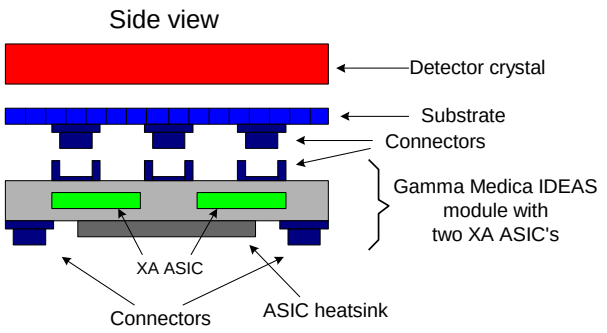
Semiconductor Detector Developments at DTU

- Novel RT Compounds: InP, GaAs, **CdTe**, **CdZnTe**, HgI2 , TlBr...
- Compared to the Si and Ge detectors
  - Higher quantum efficiency achieved due to larger atomic number ($\sigma \sim Z^{4.5}$)
  - No cryogenic cooling equipment needed
- Disadvantages:
  - Ineffective charge collection due to hole trapping
  - Difficult to produce large area defect free single crystals
  - Material in-homogeneities
- Research and test program in connection with the development of the X -and Gamma ray sensor (MXGS) for the ASIM mission

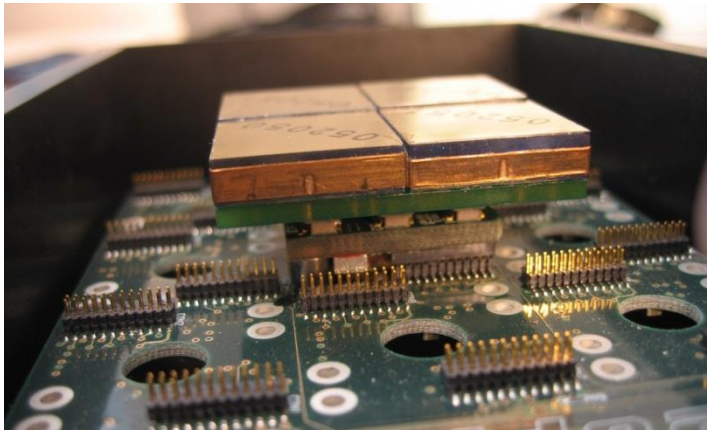


MXGS Front-End Electronics





CZT: 4 x 20 mm x 20 mm x 5 mm
Pixel pitch:2.5 mm



4 identical Detector Assembly Unit (DAU) create the total detector area of 1024 cm^2 for MXGS

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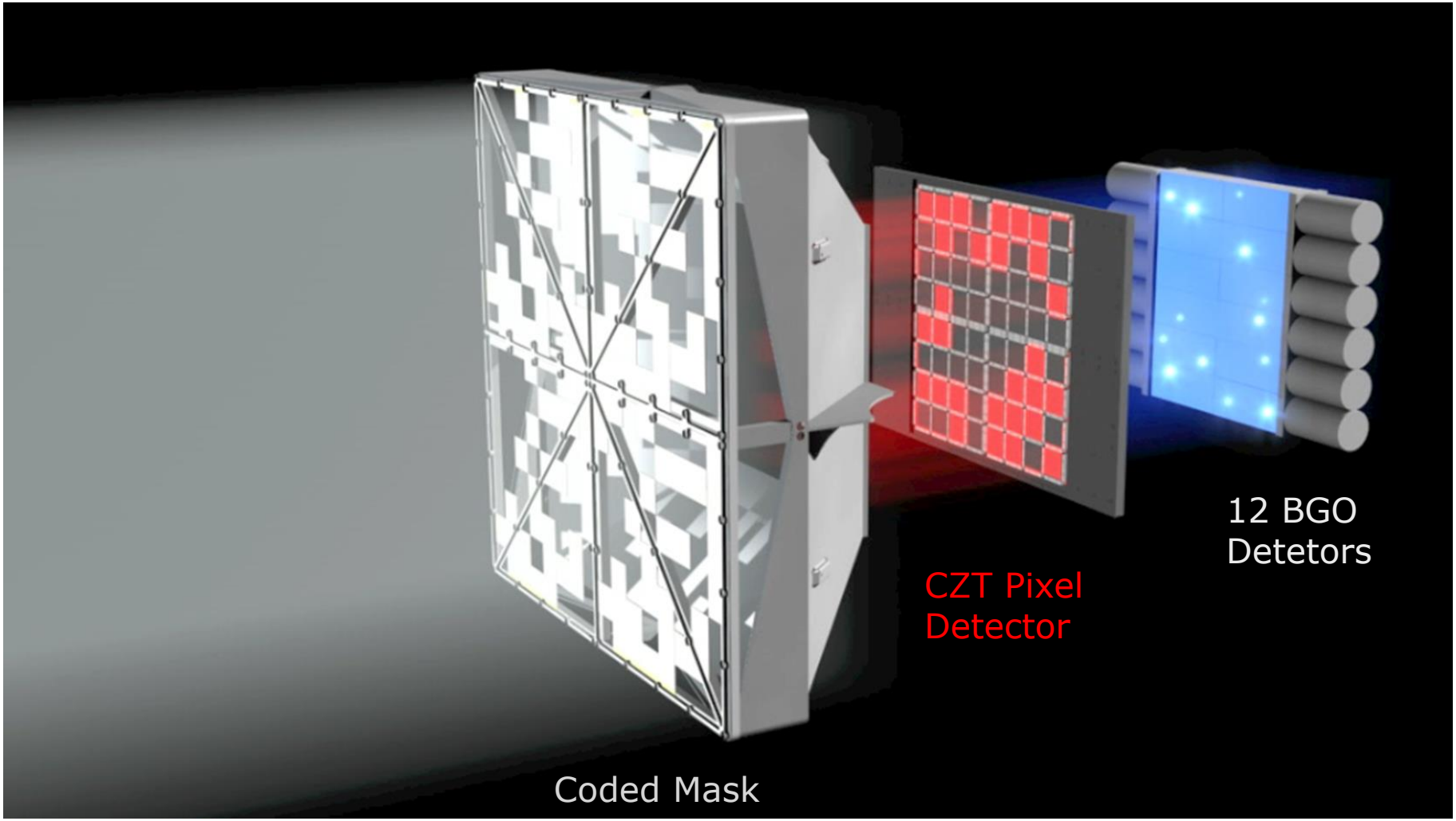
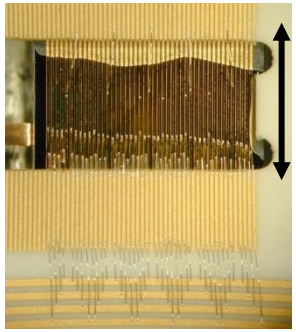
The Atmosphere-Space Interactions Monitor (ASIM) for the International Space Station

Working Principle of the MXGS Instrument

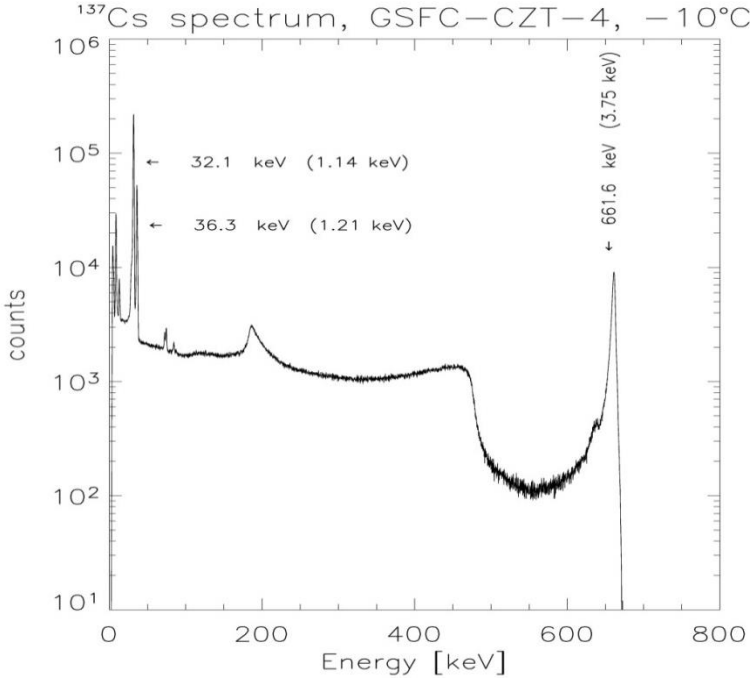


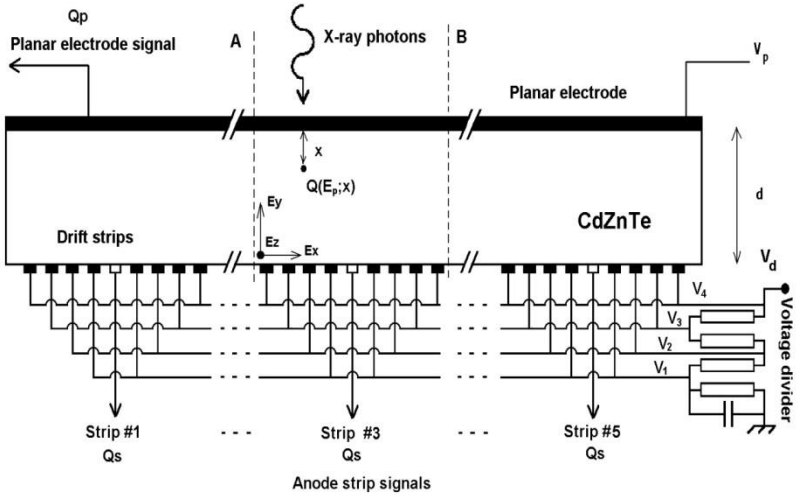
CdZnTe drift pixel detectors



1 cm

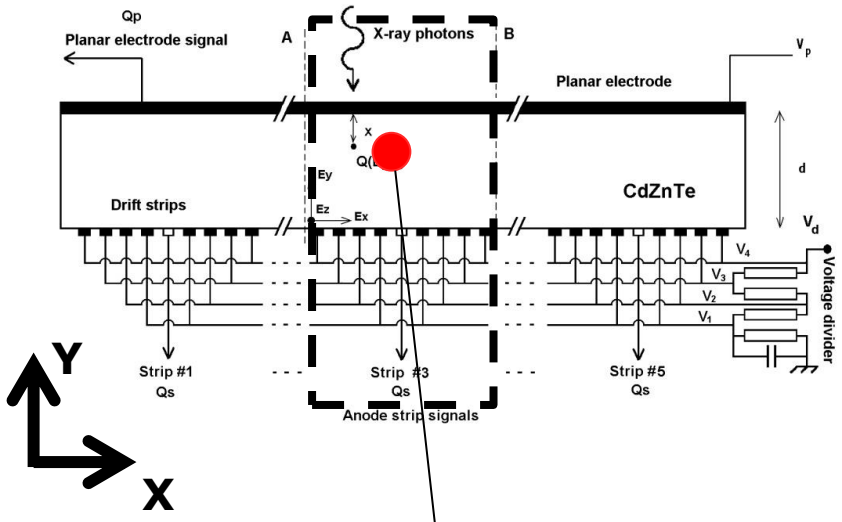
The DTU drift detector with wire connections



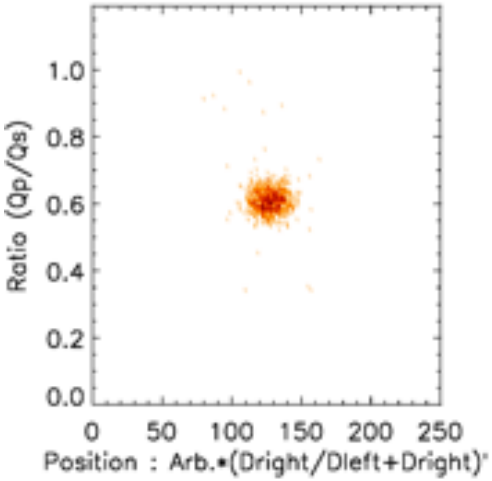


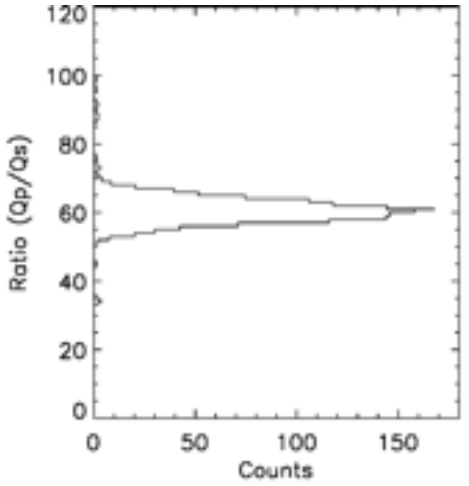
The principle of the DSM. The structure consists of a planar electrode on one side and strips on the other. A drift strip detector cell is shown between the dashed lines marked with A and B. Each drift detector consists of 8 drift strip electrodes and one anode readout strip.

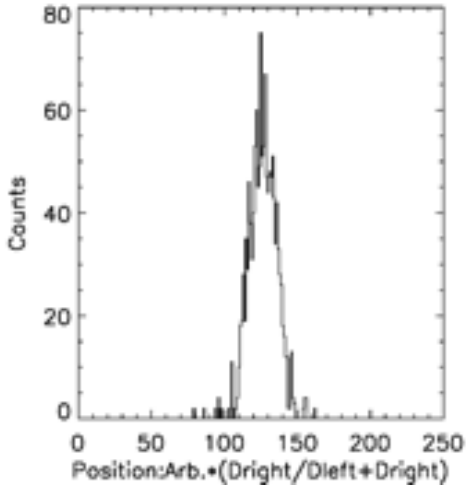
2D Position Capability

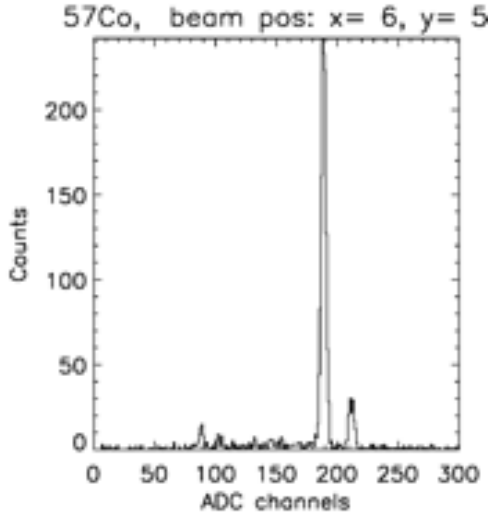


57Co source
1us shaping
Planar bias:Vp=-400V
Drift biases:
V1=-60V
V2=-120V
Beam size= Ø350um collimator
X-step= 200 um
Y-step= 400 um

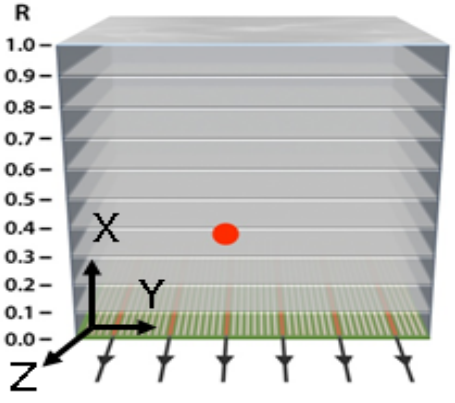


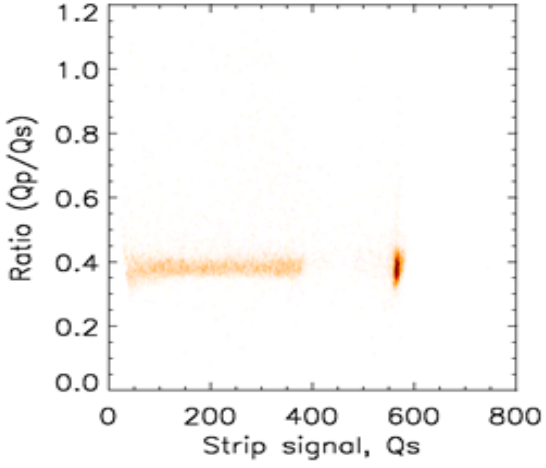


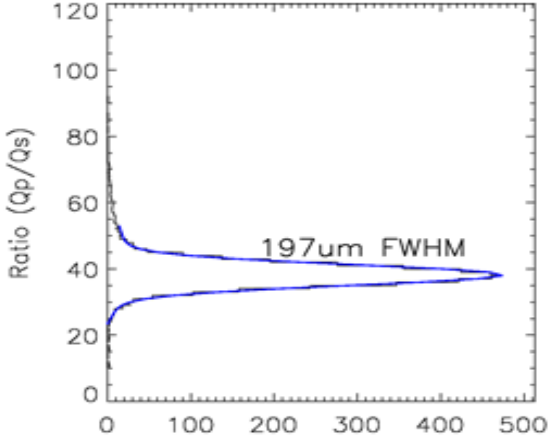




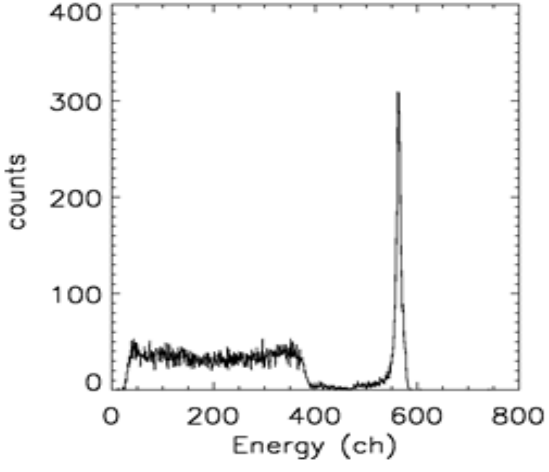
Beam 50 um x 50 um @ 500 keV

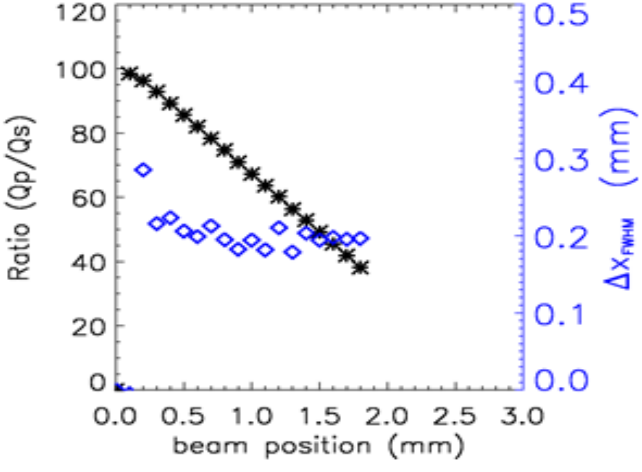






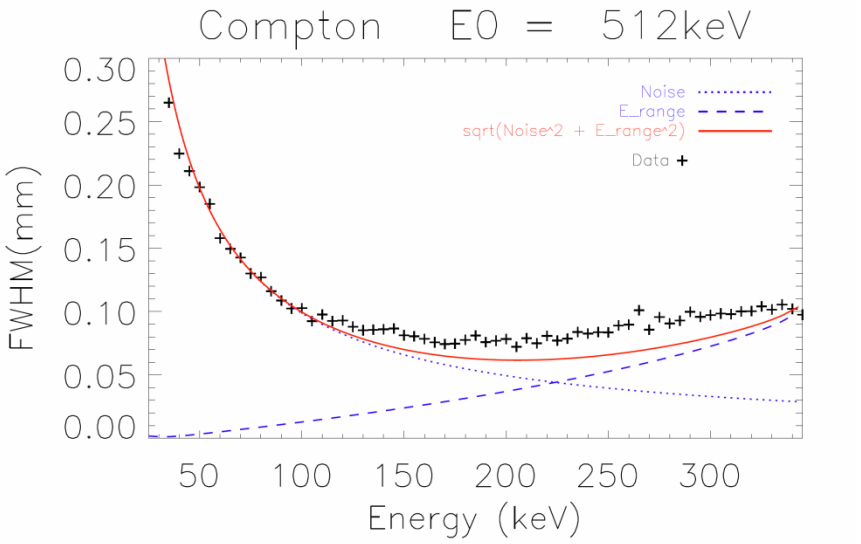
500 keV , 1us shaping
Planar bias, Vp=-150V
Drift biases:
V1=-30V, V2=-60V
V3=-90V, V4=-120V
Beam size=50 um x 50 um
X-step=100um
Y-step=100um

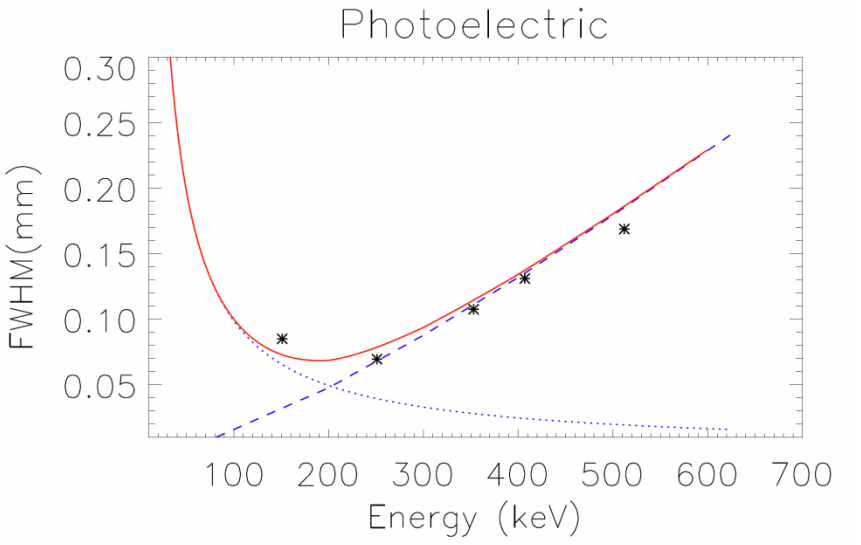




Y-position using DOI technique

Depends on non-correlated electronic noise and electron range in the CZT material





Compton continuum

Measured position resolution obtained from Compton electrons well fits with the model.

$$\Delta y = (\Delta y^2_{noise} + \Delta y^2_{el\text{-}range})^{0.5}$$

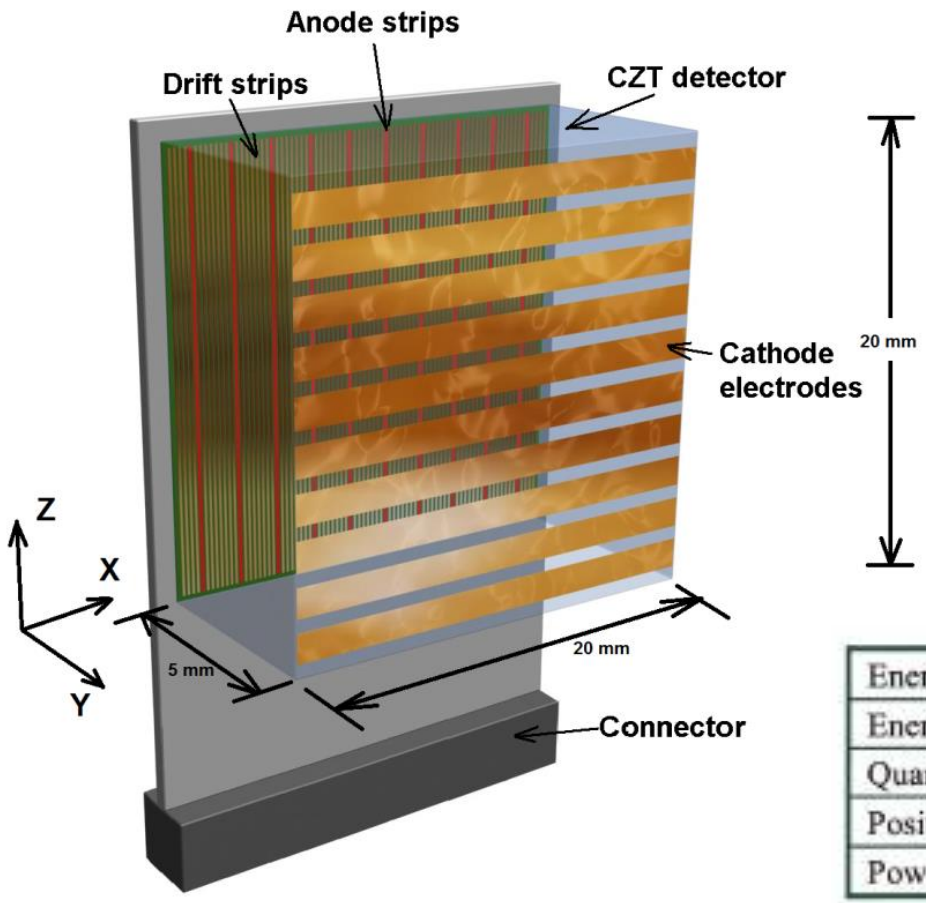
Photo peaks

Measured position resolution obtained from photoelectrons well fits with the model.

3D CZT Detector

General requirements for the high energy astrophysics instrumentation sensors are : high efficiency, good spatial resolution, good spectroscopic resolution

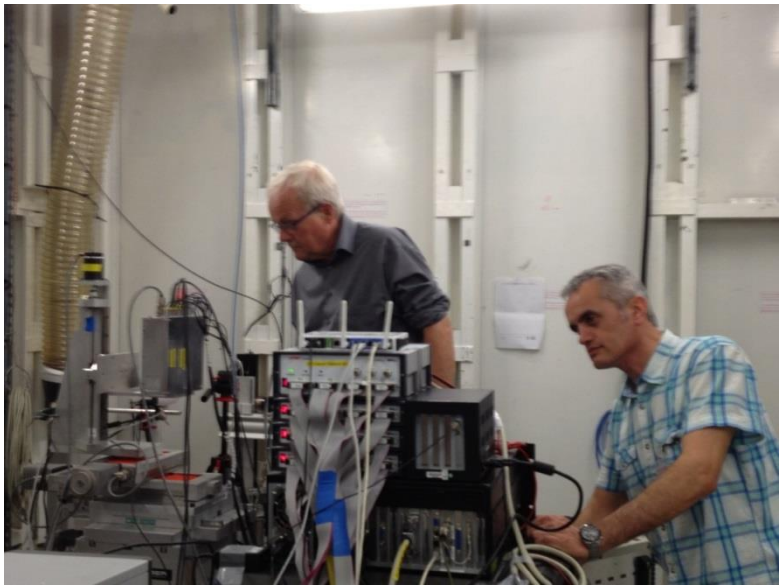
ESA development project:"3D CZT High Resolution Detectors 4000104191/11/NL/CBi".



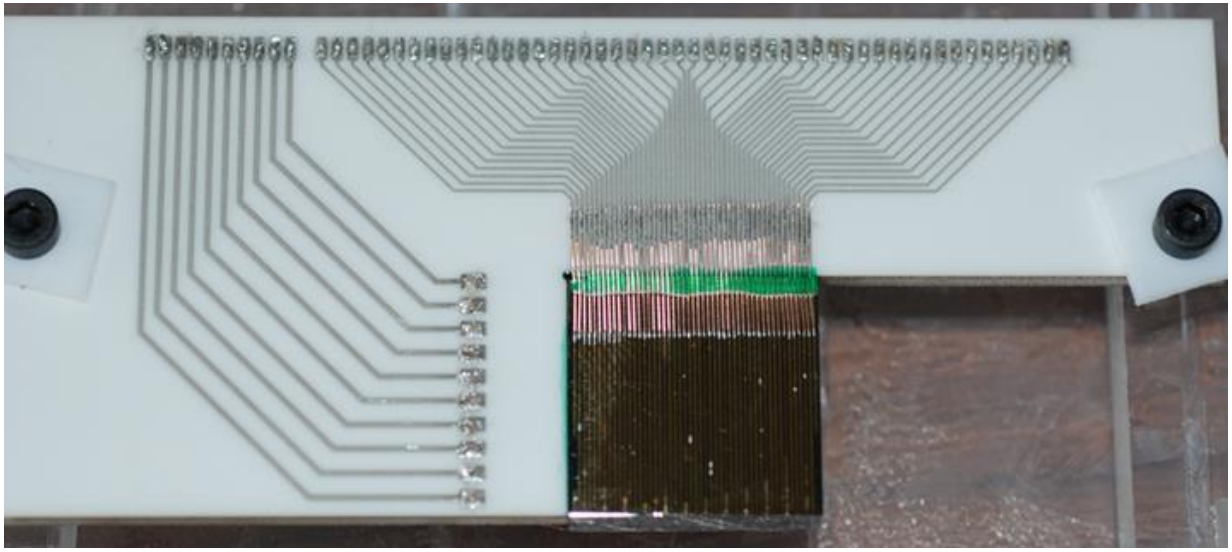
This prototype detector technology is based on CZT Drift Strip Detector.

Energy range	20-2000 keV
Energy resolution	<1% @ 662 keV
Quantum efficiency@0.3/0.5/1.0 MeV	>85/65/50 %
Position resolution (3D)	<1 mm x 1 mm x 1 mm
Power consumption (6mW/channel)	~200 mW (27 channels)

TEST AT ESRF

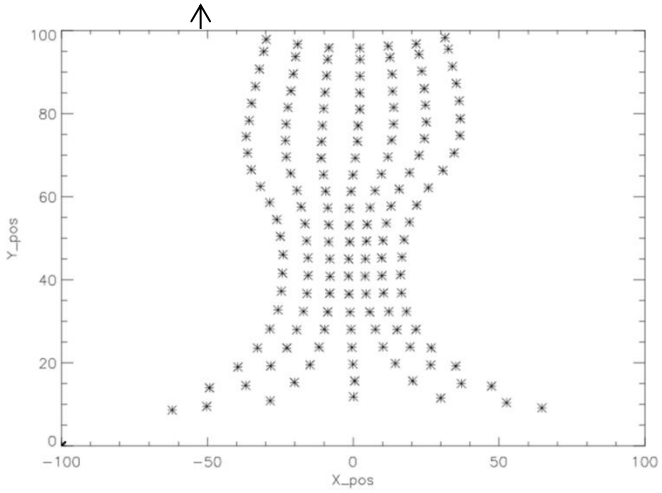


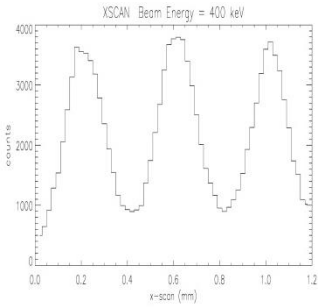
100-600 keV monochromatic beam. 50x50 μm

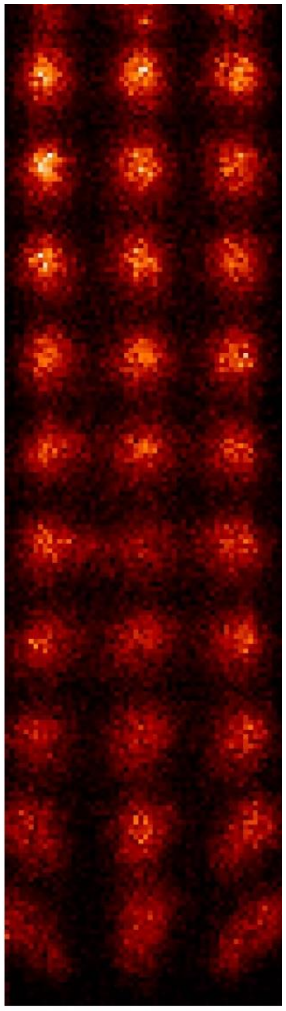


3DCZT prototype (CZT detector: 20 mm x 20 mm x 5 mm).

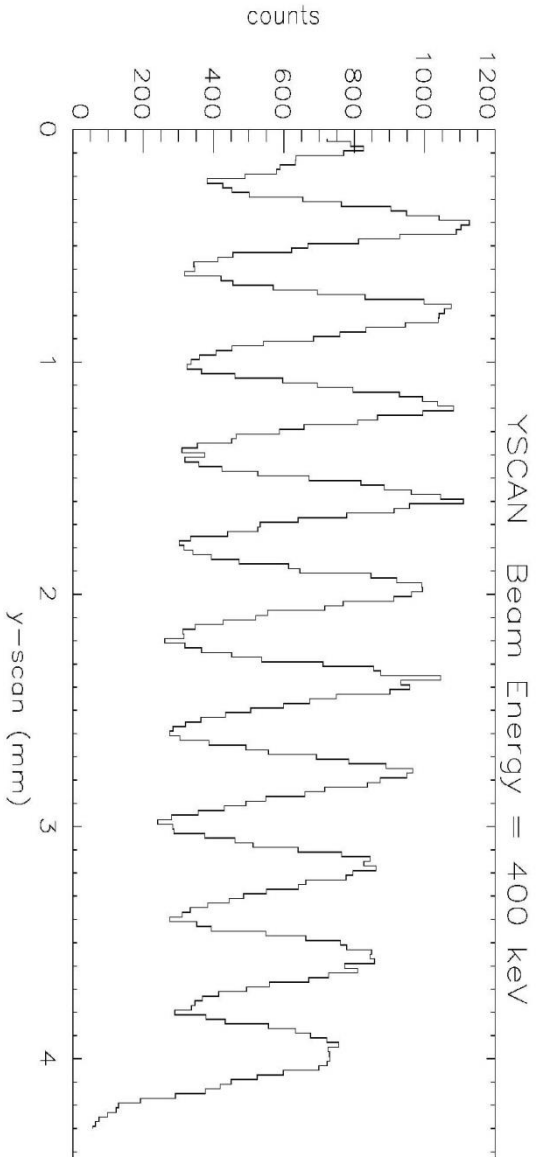
ESRF 400 keV XY Scanning



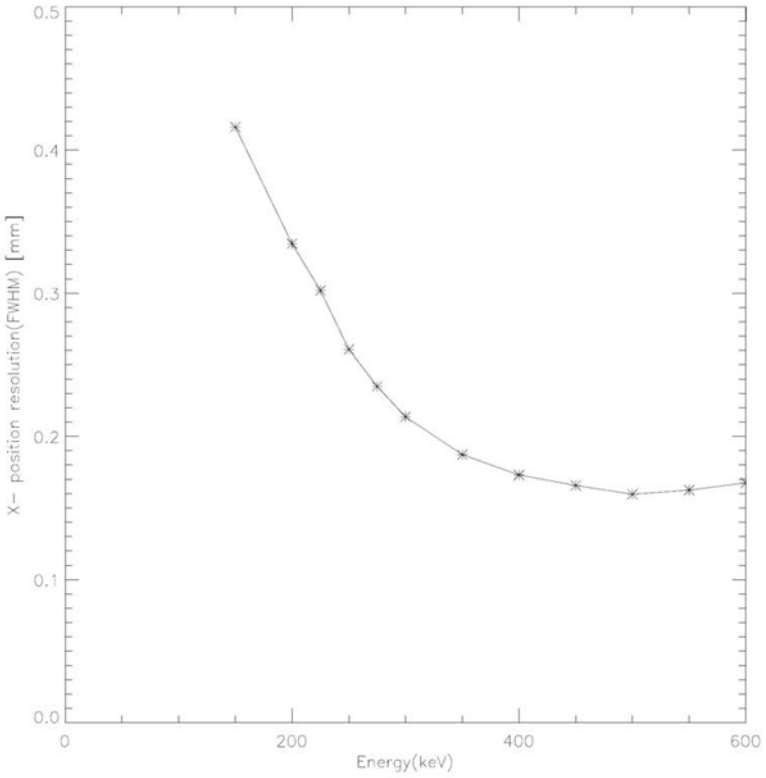




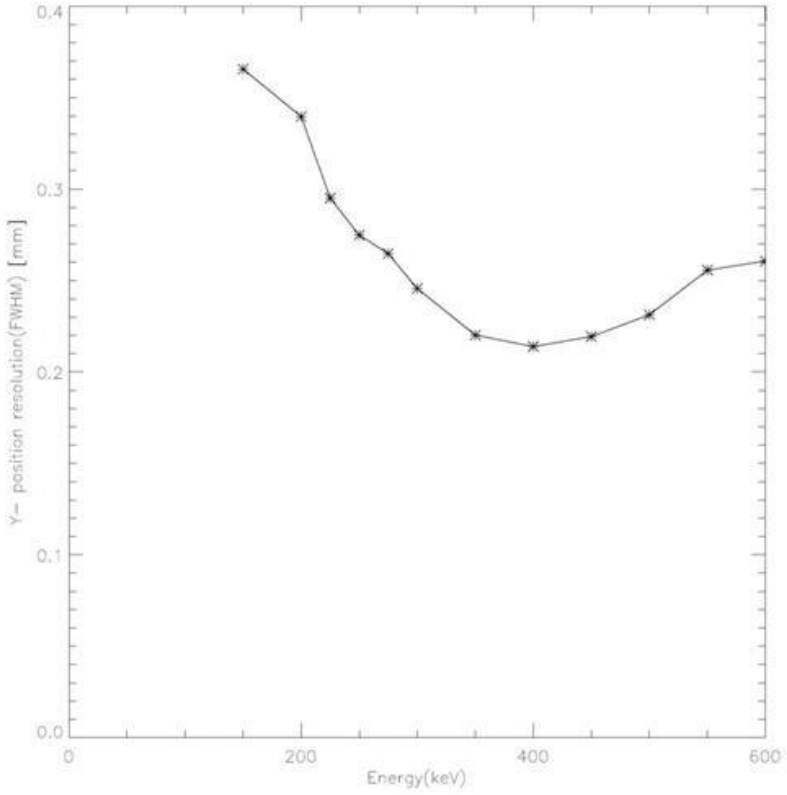
400 µm



X, Y Position Resolutions

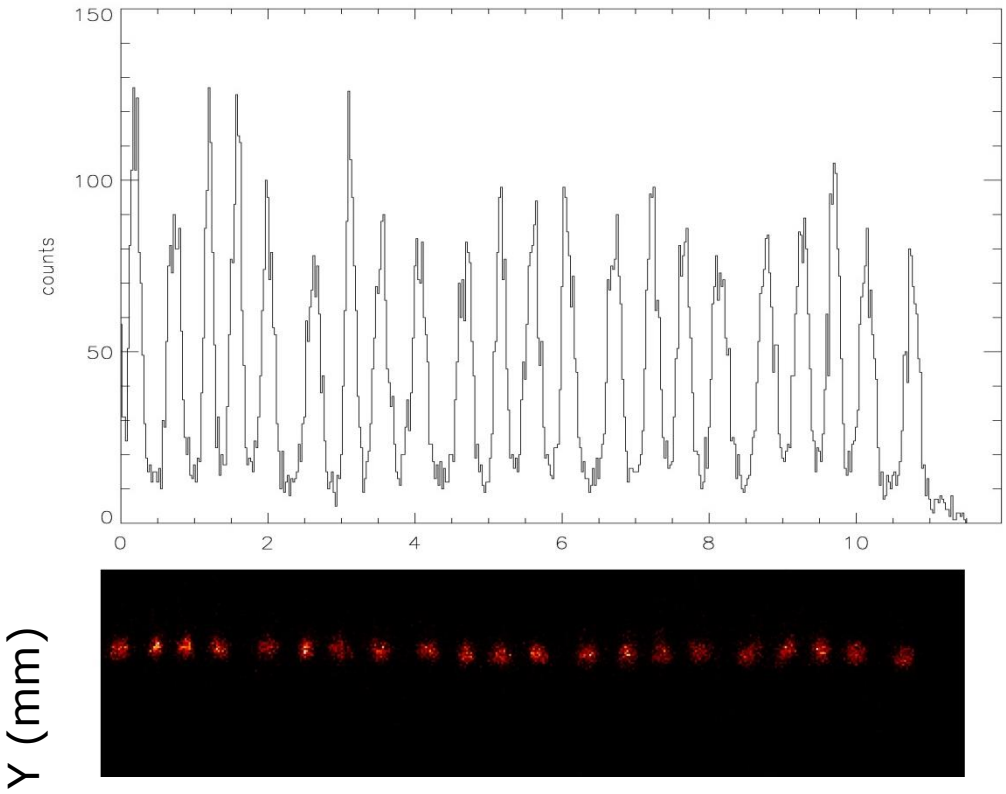


Position resolution along the X direction

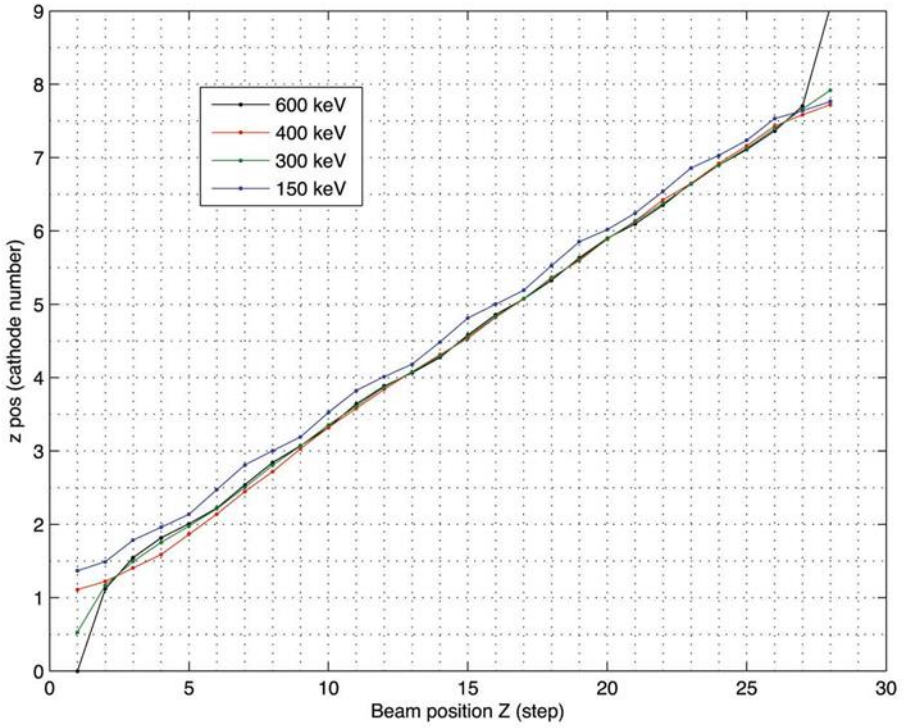


Position resolution along the Y direction.

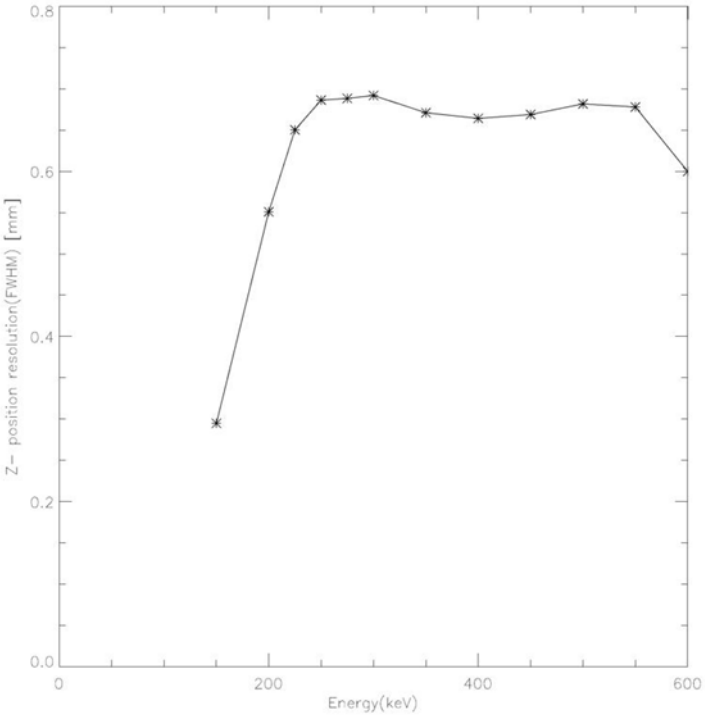
ESRF 400 keV Z Scanning



Z position Resolution



The measured beam position dependence of the actual beam position in the Z direction.



Position resolution along the Z direction.

Conclusion

- A 3D CZT X- and gamma ray proto-type detector has been designed, fabricated and tested.
- The detector demonstrates sub mm position resolutions in all 3 dimensions.
- The spectral resolution is $\Delta E/E \sim 1\%$@ 662 keV
- The detector module could be a suitable building block for a Compton Camera telescope. E.g. as a 3D position sensitive calorimeter.
- This detector could serve as focal instrument for a soft gamma-ray telescope and would provide capability for polarisation measurements.
- These options are beeing investigated at DTU Space. See also talk of Finn Christensen