CZT-based detector development at IMEM-CNR

Andrea Zappettini
IMEM-CNR

Advanced studies in the low-energy QCD in the strangeness sector and possible implications in astrophysics.

Dedicated to the memory of Paul Kienle

FRASCATI, 20-06-2013

People

Andrea Zappettini
Davide Calestani
Enos Gombia

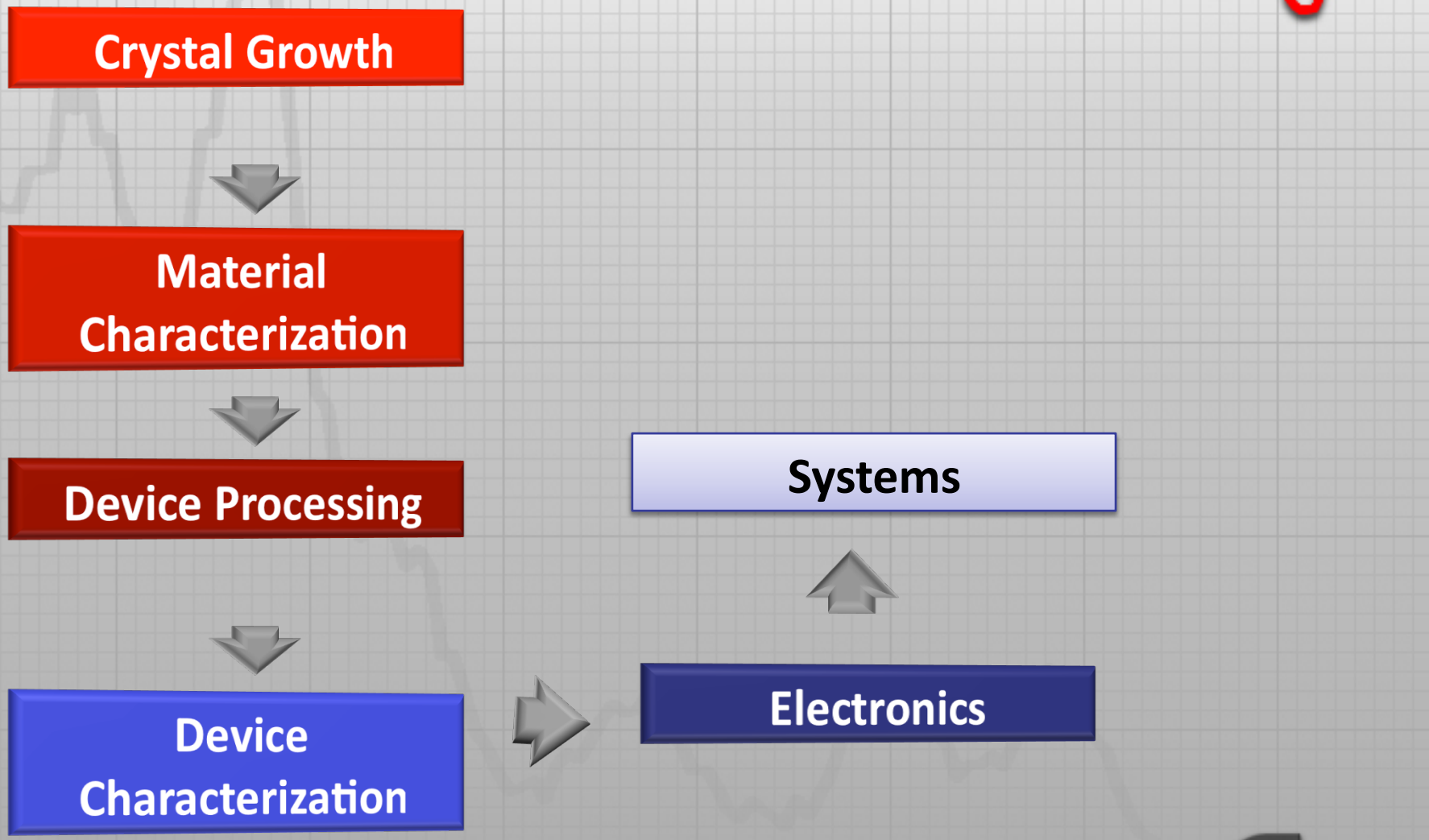
Maura Pavesi (UniPr)
Ezio Caroli (INAF-Bo)
Massimiliano Zanichelli
Giovanni Piacentini

Giacomo Benassi
Nicola Zambelli

Why CZT detectors?

- Efficient yet compact due to their high density
- Wide photon energy range (10keV-1MeV)
- Do not require cooling (RT operation)
- Solid-state: do not require fragile photomultiplier tubes
- Robust and able to withstand rapid temperature changes
- Excellent energy resolution
- Easily enabled imaging capabilities

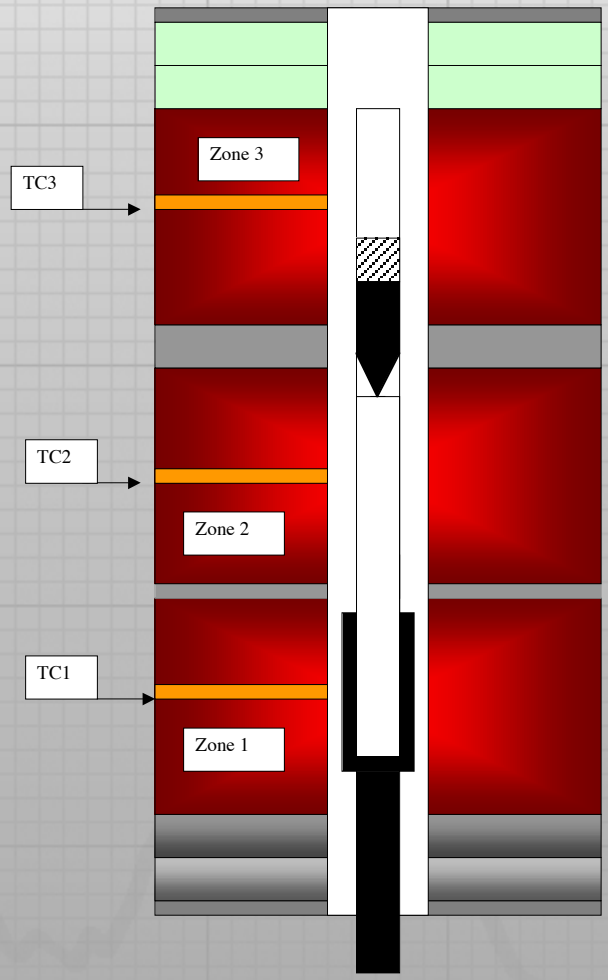
What we are doing



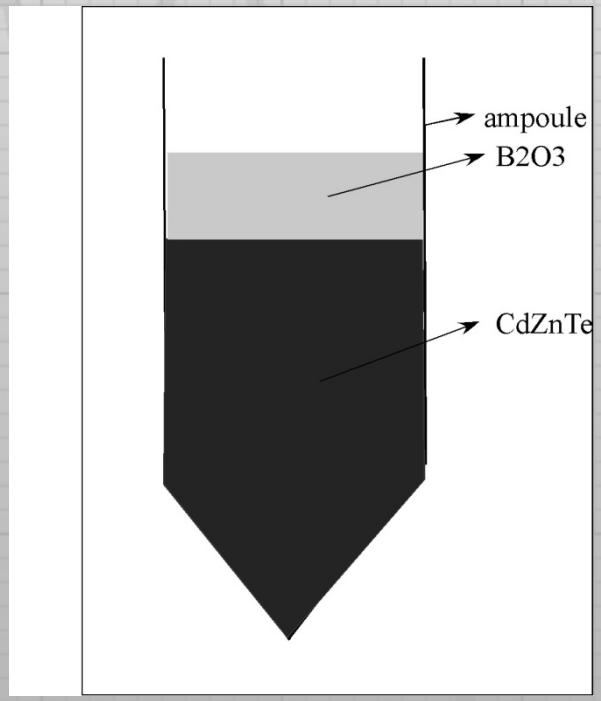
Crystal Growth

Boron Oxide Encapsulated Vertical Bridgman

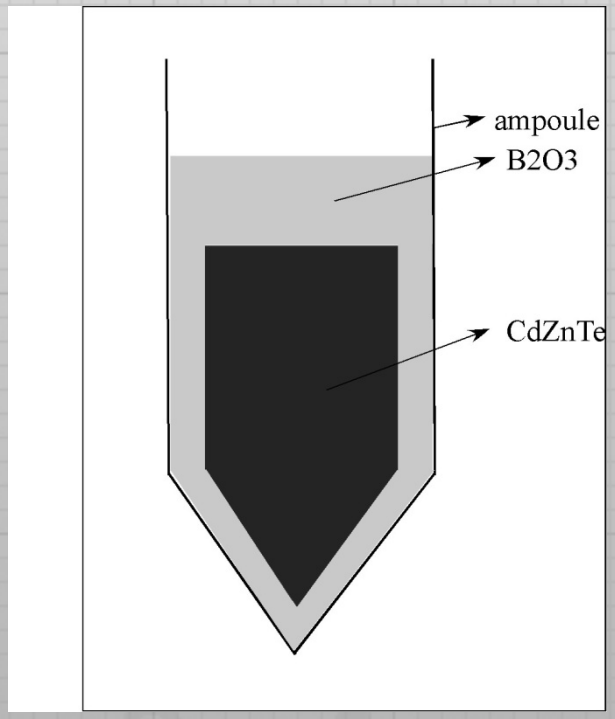
- Up to three inches.
- Up to ten bars.
- Three independent heating zones.
- In-doping
- High purity (7N) starting material



Crystal Growth

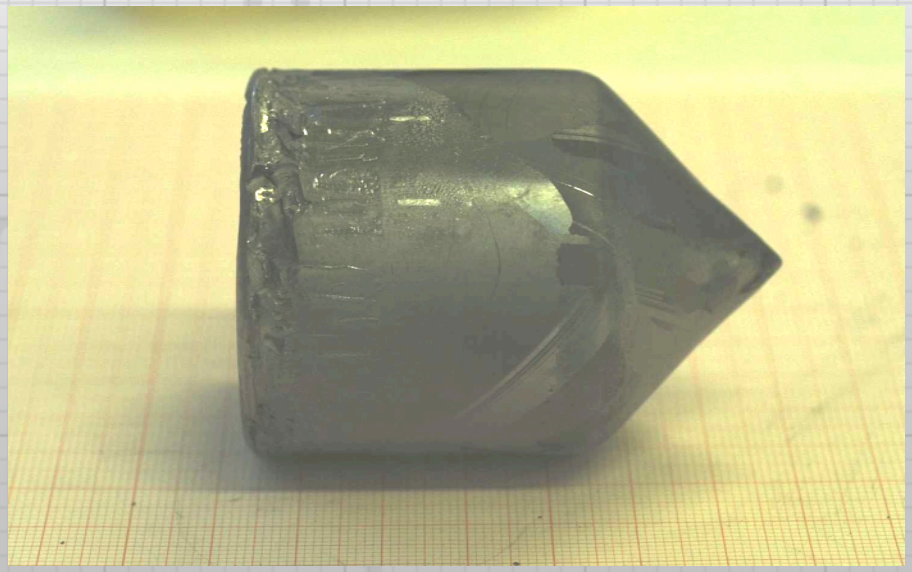


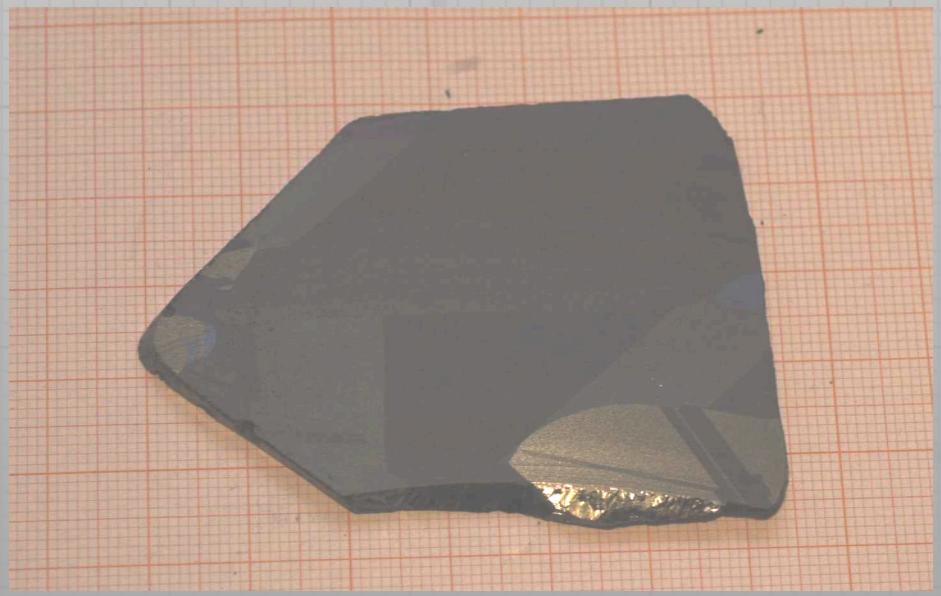
a)

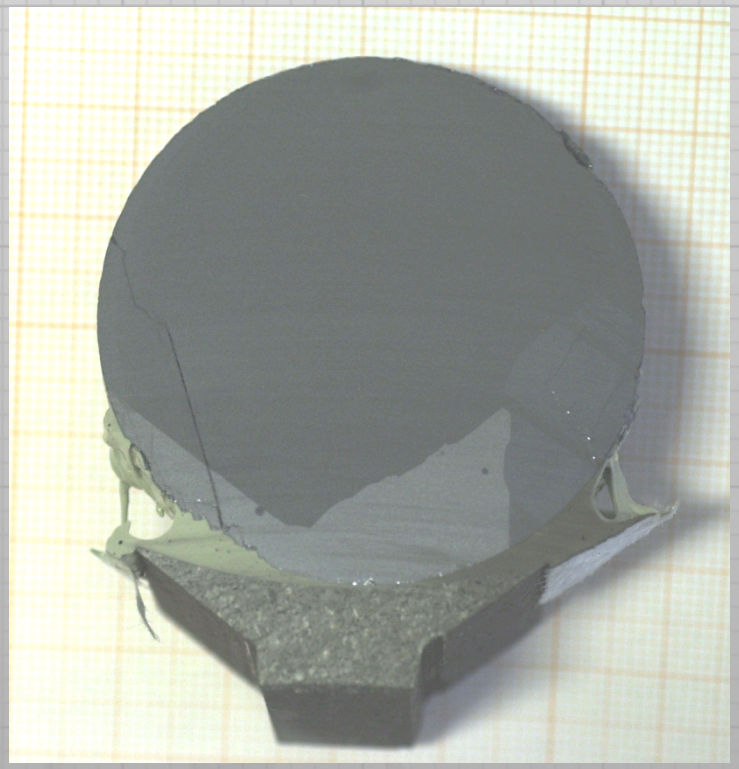


b)

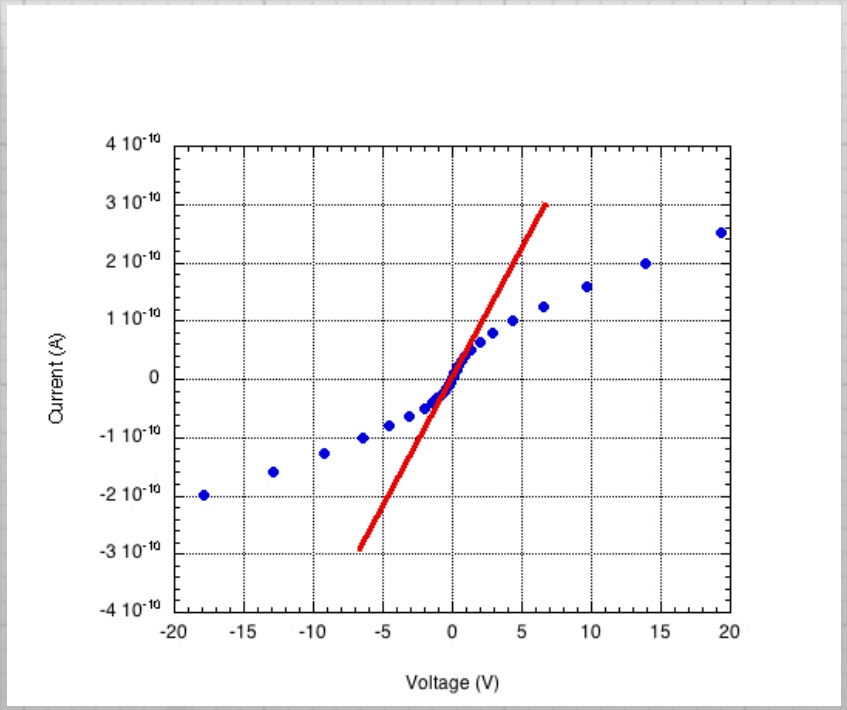
Crystal Growth







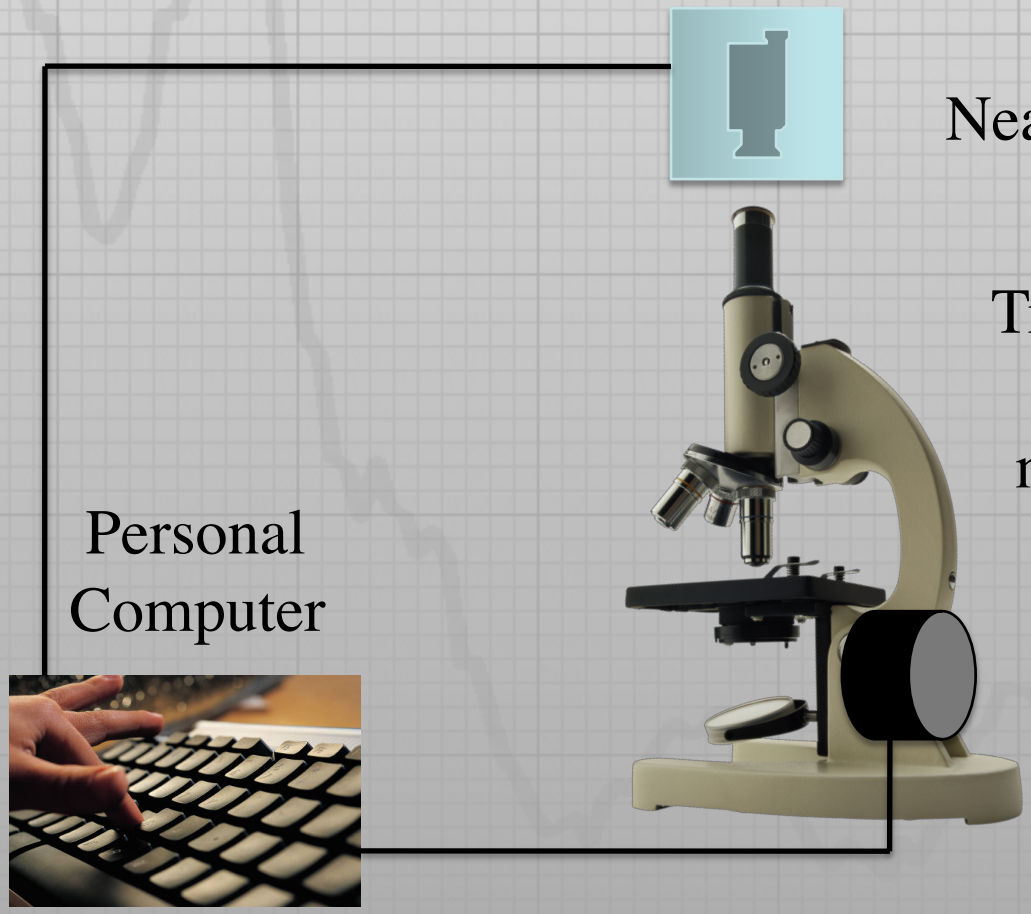
Characterization: resistivity



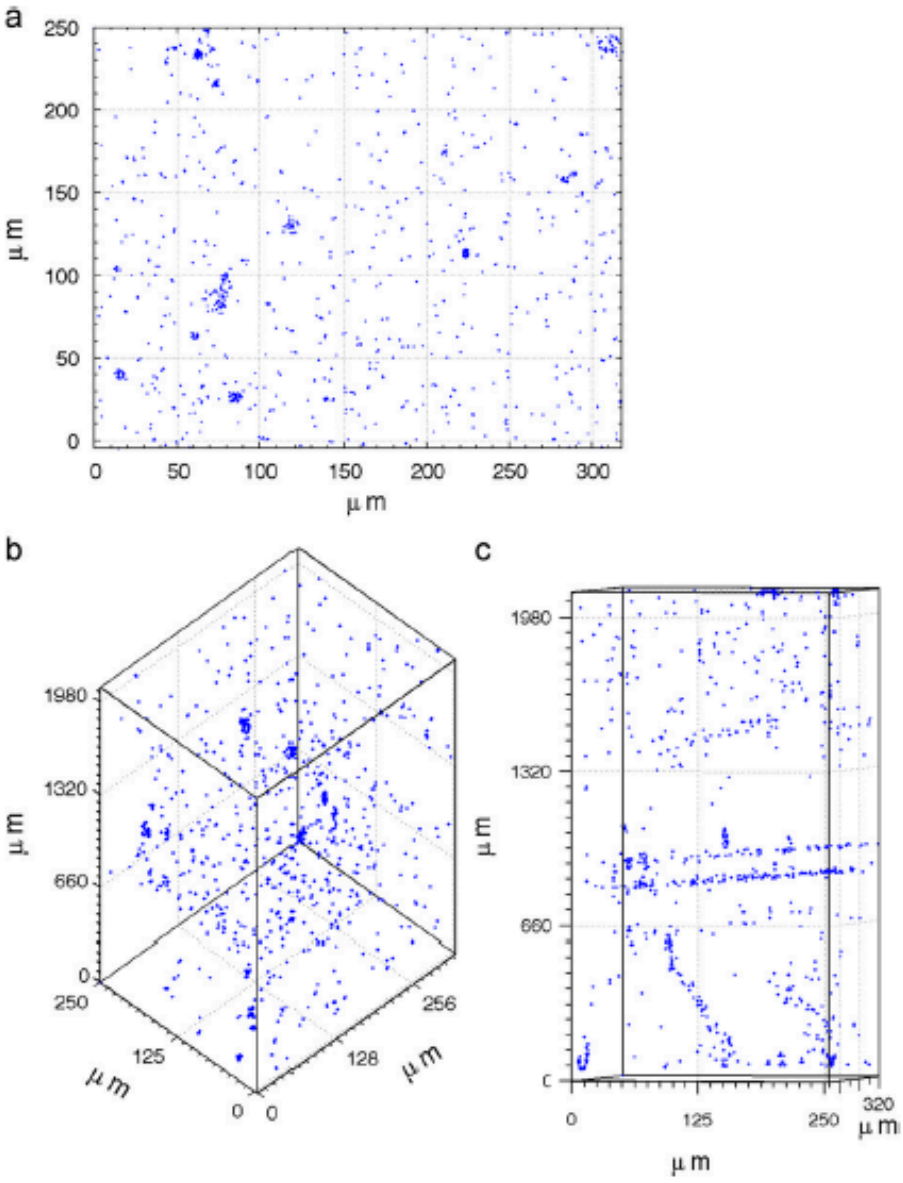
$$I = I_S\left\{\exp\left[\frac{q(V_B - IR_S)}{KT}\right] - 1\right\} \qquad R_S(I \to 0) = \frac{V_B}{I} - \frac{KT}{qI_S}$$

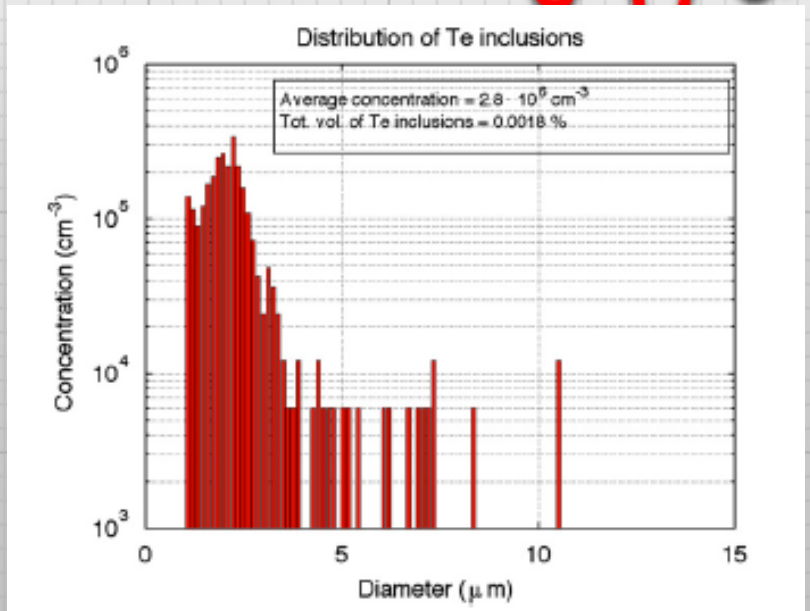
$\rho = 2.2 \times 10^{10}\,\Omega\cdot cm$

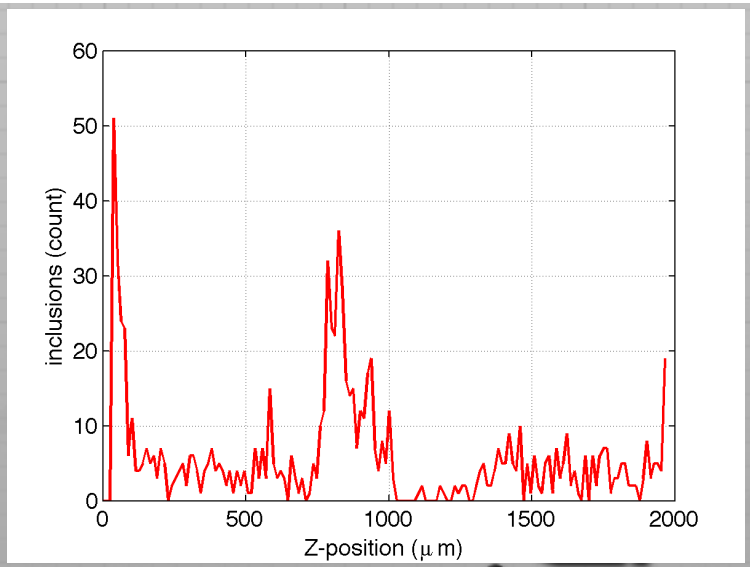
Characterization: Inclusion density



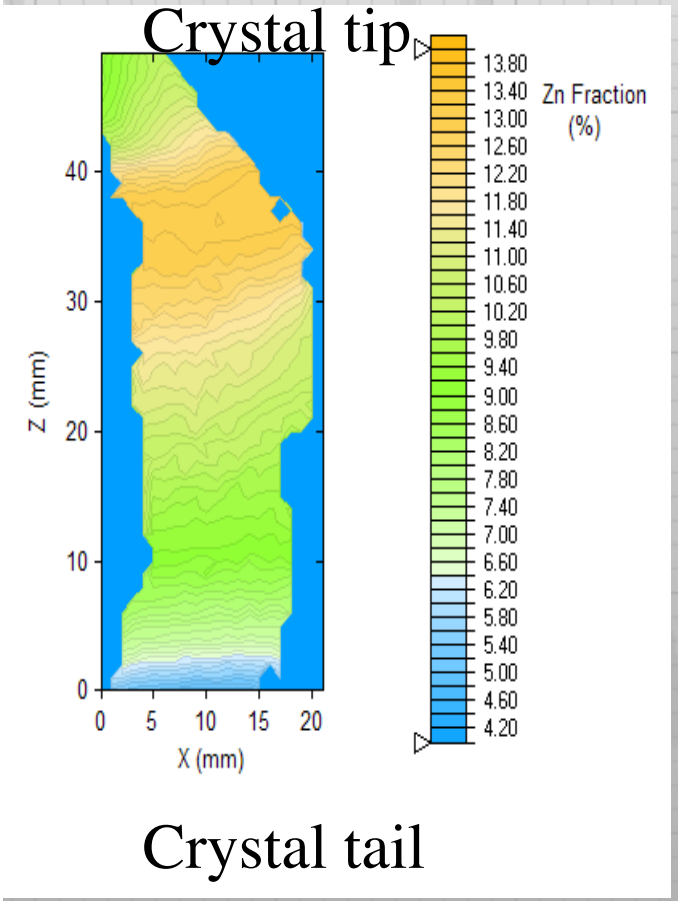
Characterization: Inclusion density

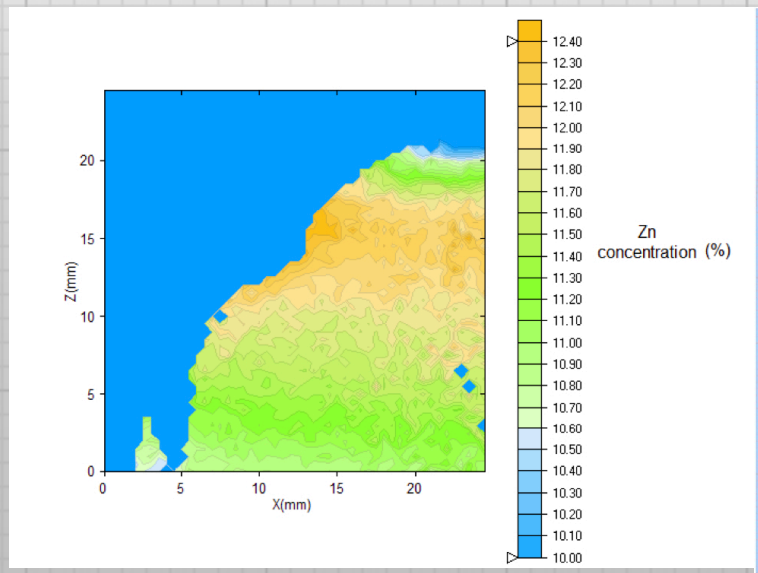


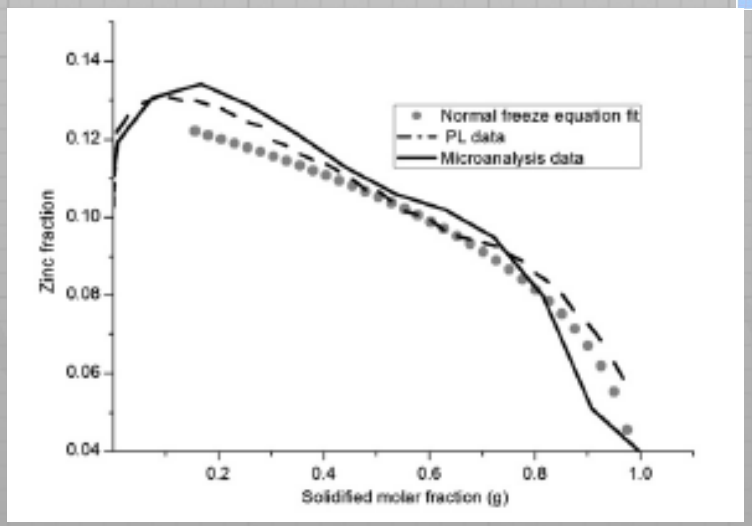




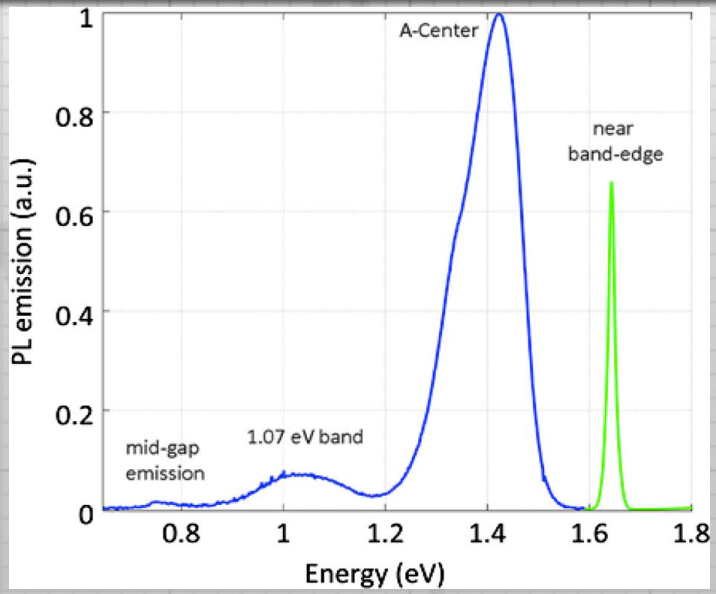
Characterization: PL mapping

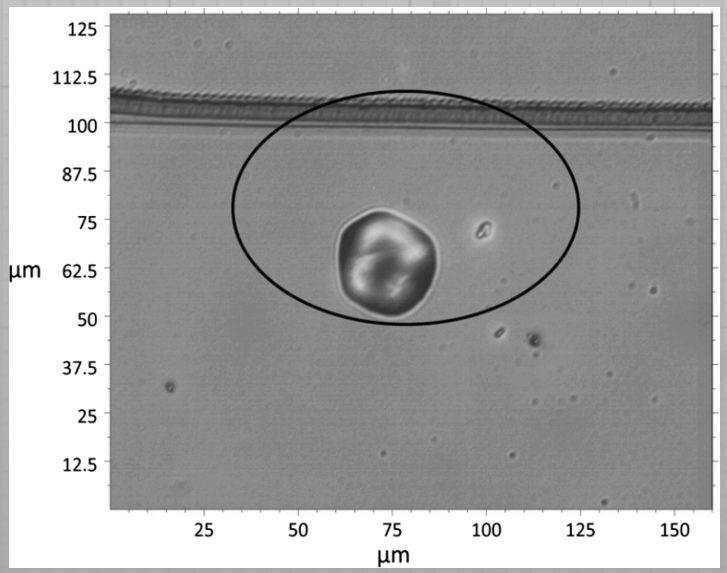


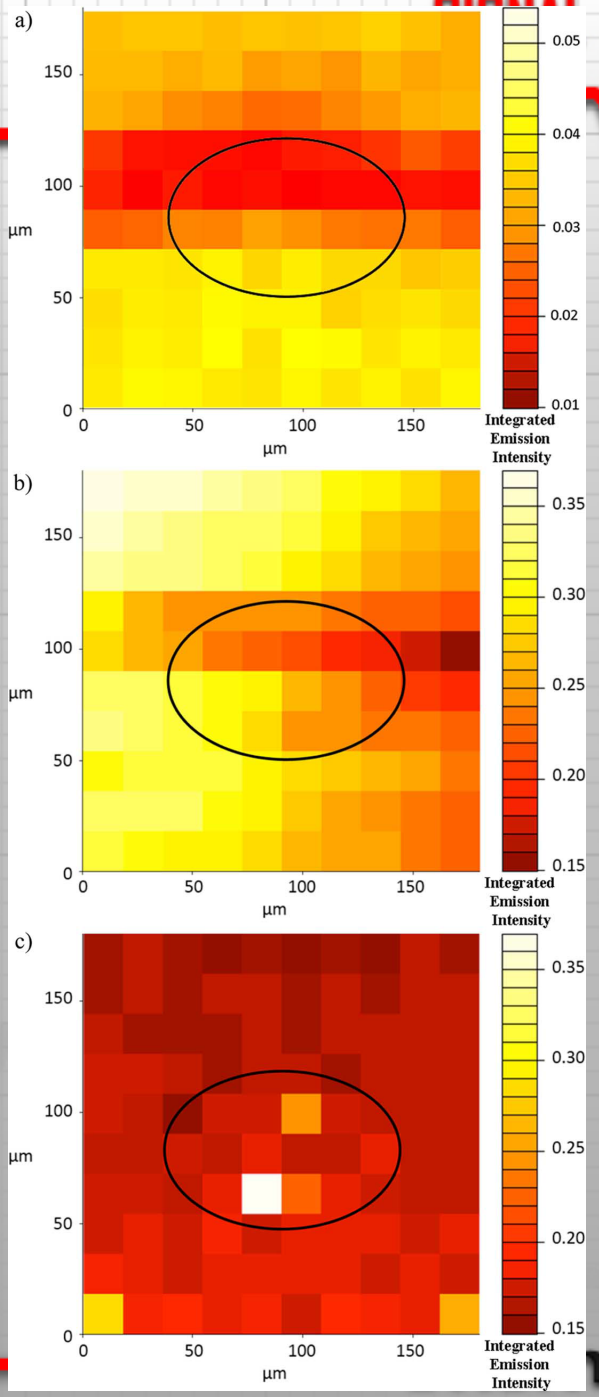




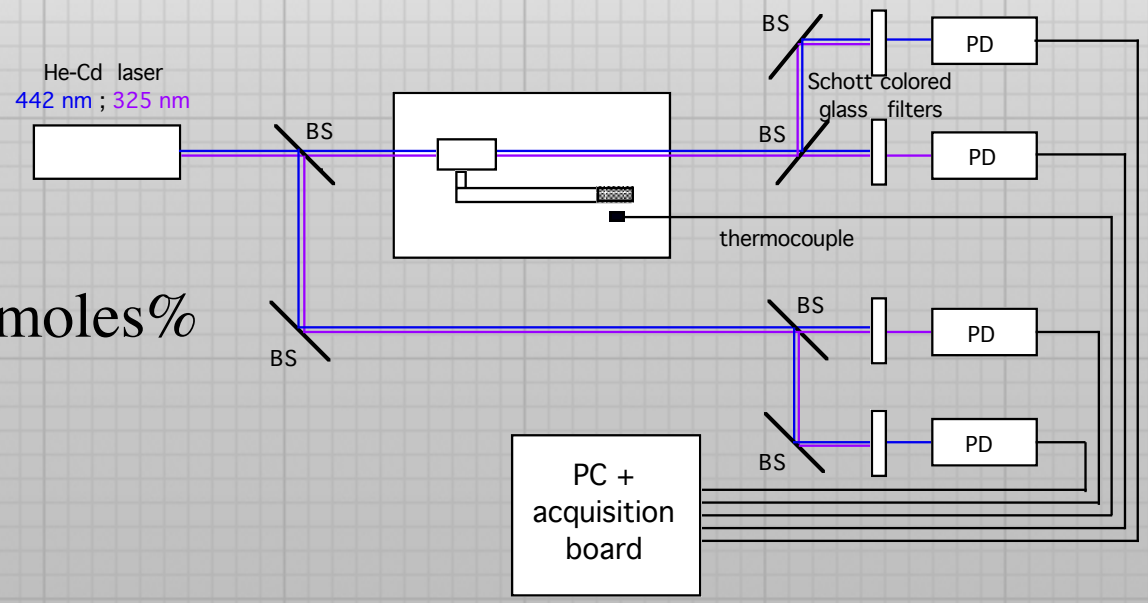
Characterization: PL mapping







Characterization: stoichiometry deviation



50.1 moles%➜50.0001 moles%

CdTe
CdZnTe
ZnTe
CdS
CdSe
GaAs
TeO2
….

5N Plus
Kromek
Redlen
Venezia Tecnologie

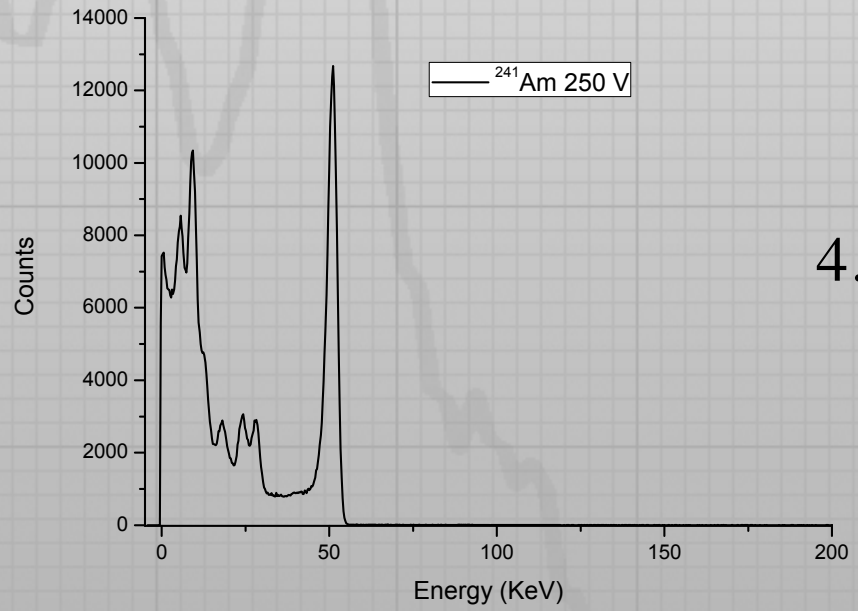
Detector preparation

- Cutting and polishing facilities
- Clean room
- Photo-lithography equipment
- Contact deposition:
  - ✓ thermal and e-beam assisted evaporators
  - ✓ Sputtering
  - ✓ Electroles deposition
- Passivation
- Bonding

Problems:
•brittle and fragile
•no native passivating oxide
•unstable for T>150°C

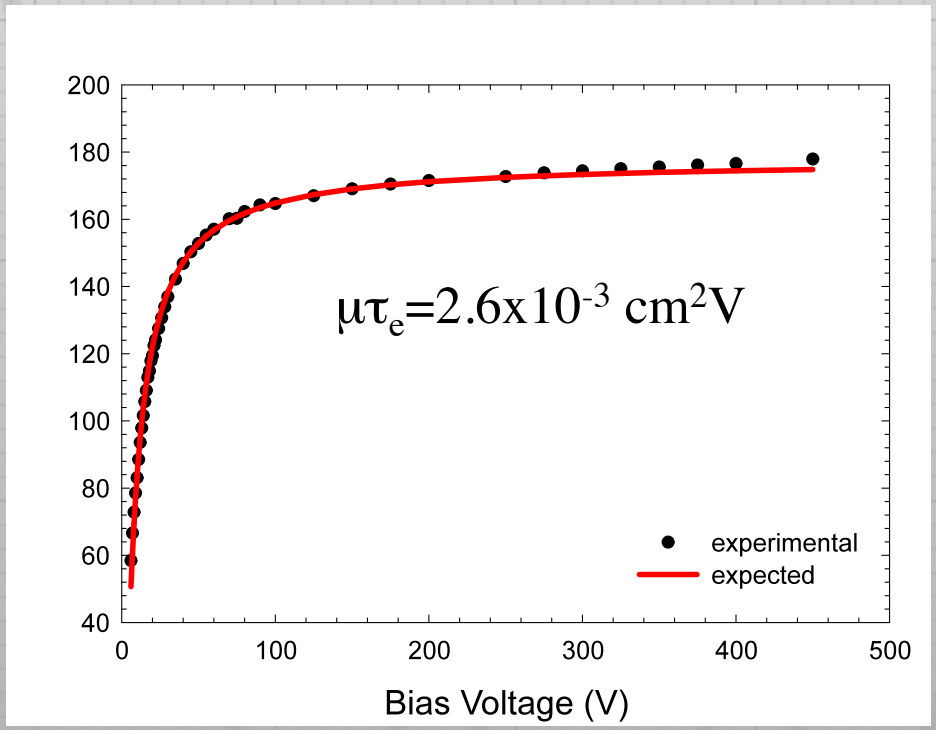
Detector test: energy resolution

Planar/planar contacts, not-collimated source, 20°C

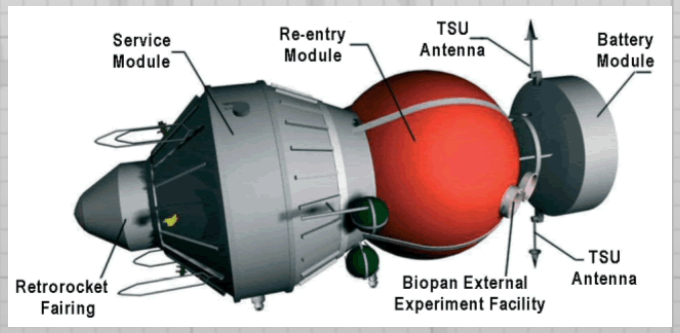


4.7%

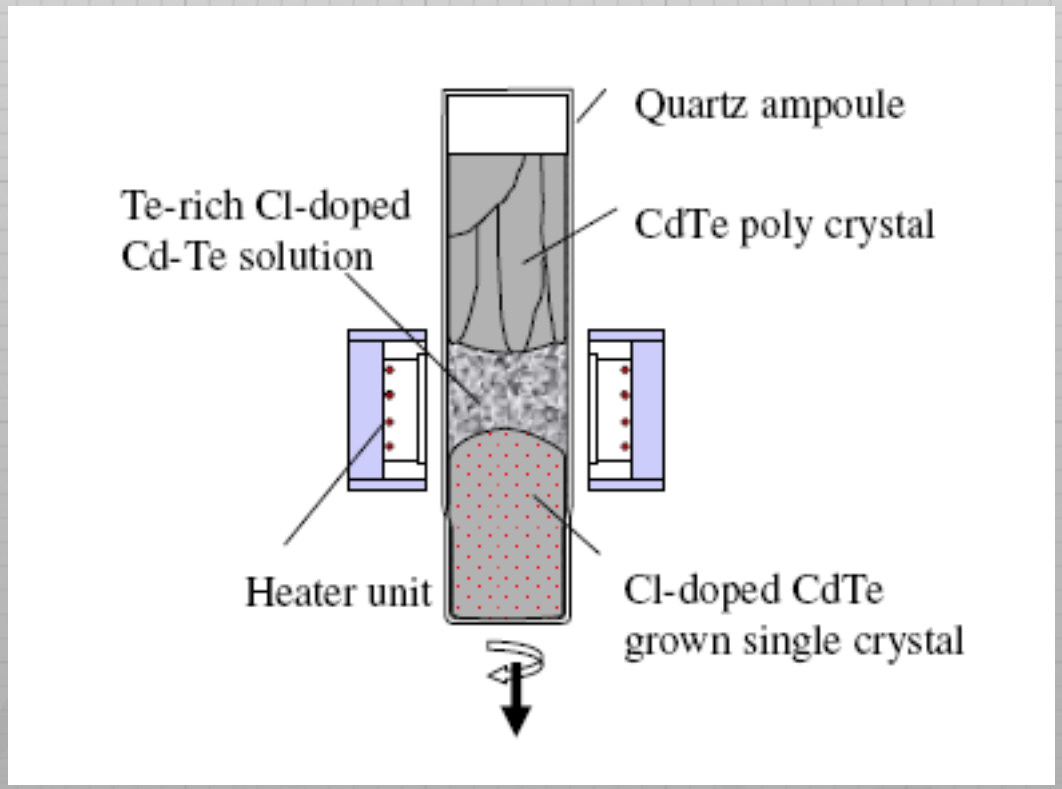
Detector test: transport properties



ESA Project: Growth of CZT in μg conditions

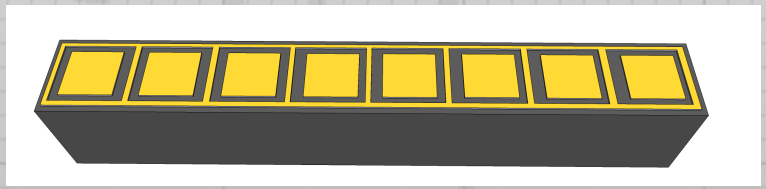


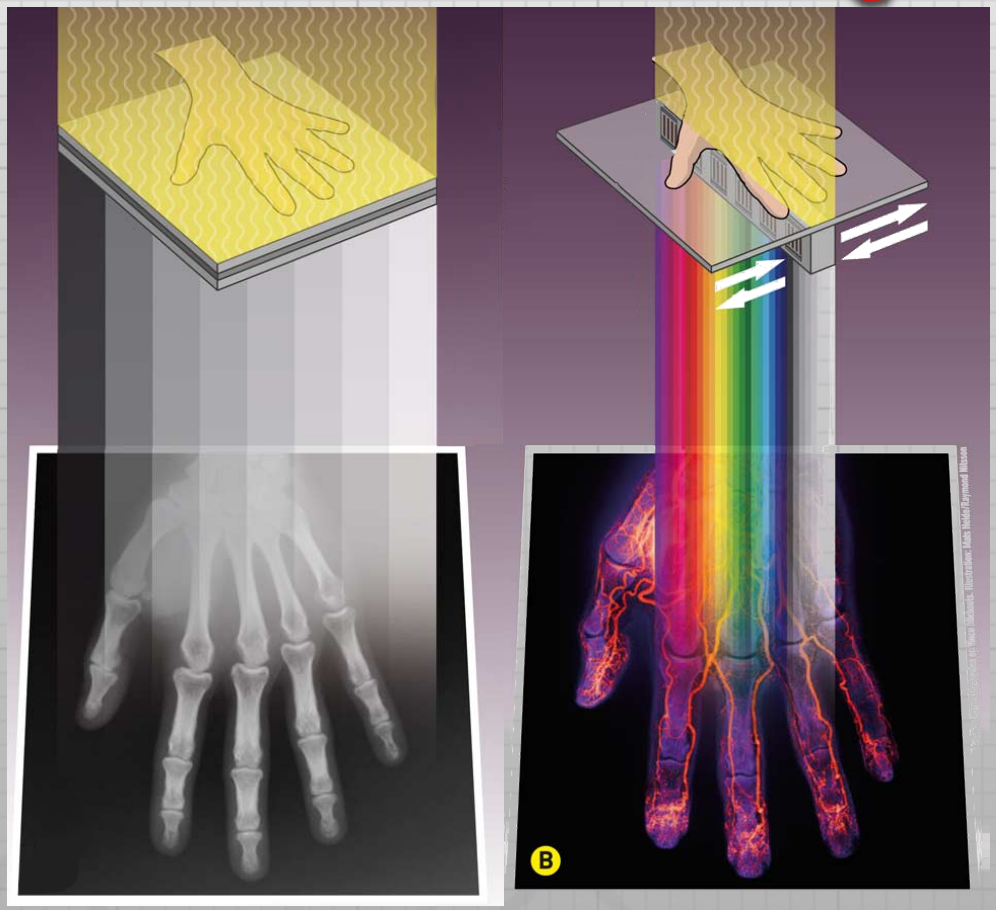
Travelling heater method



“Spectroscan” Project

Multy energy scanners for security





“Spectroscan”
MIUR Lombardia Project
PI: ALTALAB
1 m length scanner,
1000 channels, energy range:
10-160 keV

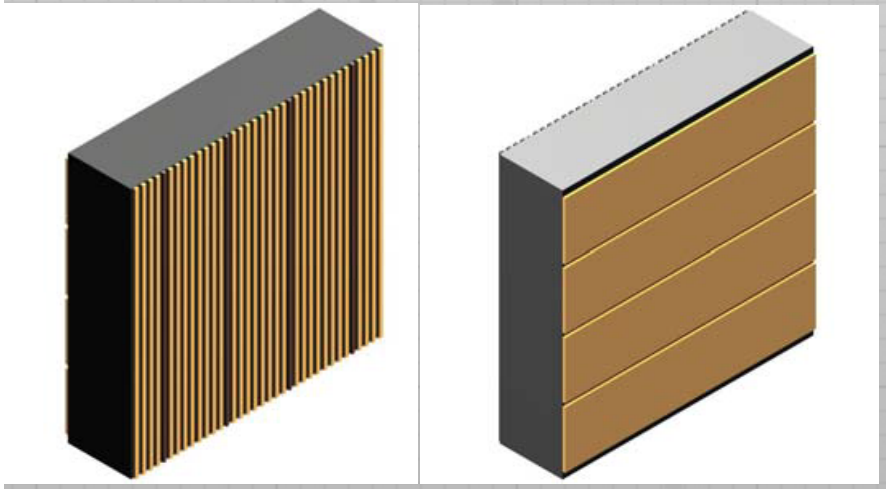
Other application fields: food control, soldering checking, …

DTU-ESA Project

Project aim:
Realization of strip-detectors based on CZT crystals for 3D imaging of X e gamma rays.

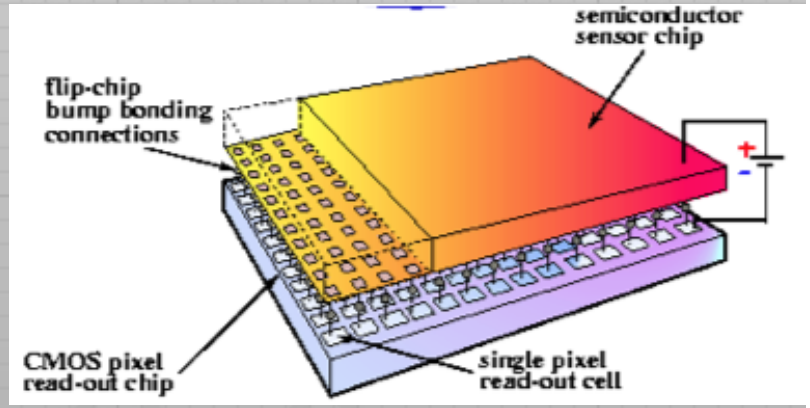
1. Why imaging 3D?
2. Why to use strip detectors?

DTU-ESA Project



2N electronic read-out channels

Pixel detector



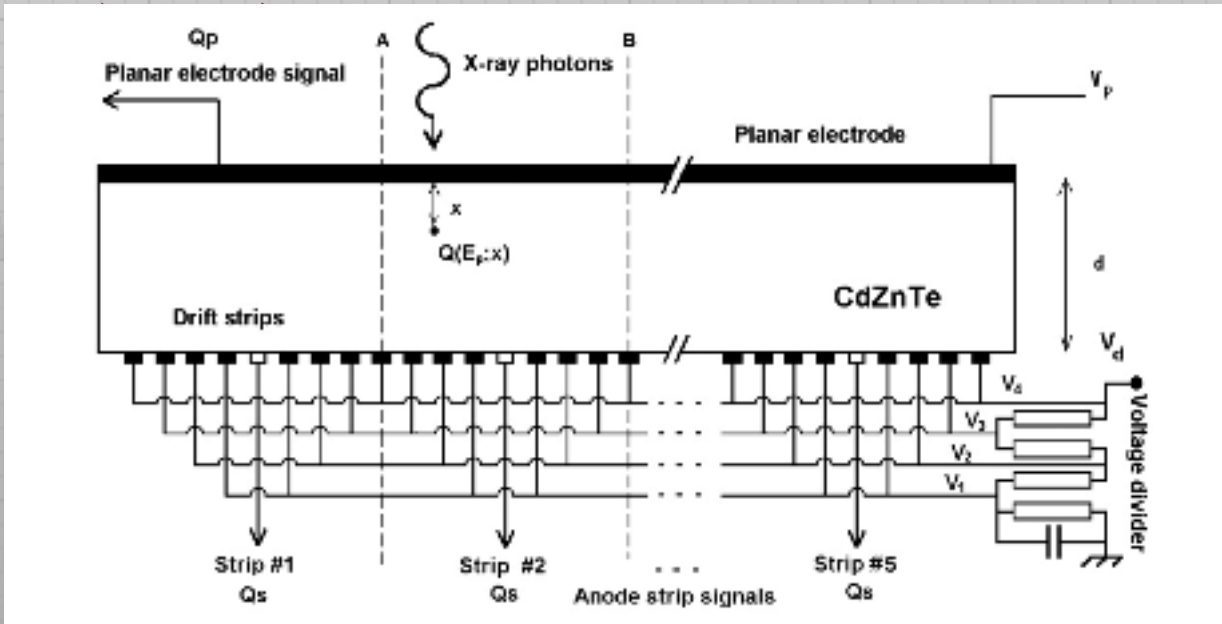
N^2 read-out channels

Drift-Strip Concept

➢The arrangement consists of a mono-electrode cathode on one side and strips on the other side of the crystal. Each drift cell is composed of an anode readout strip surrounded on each side by 4 drift strips.

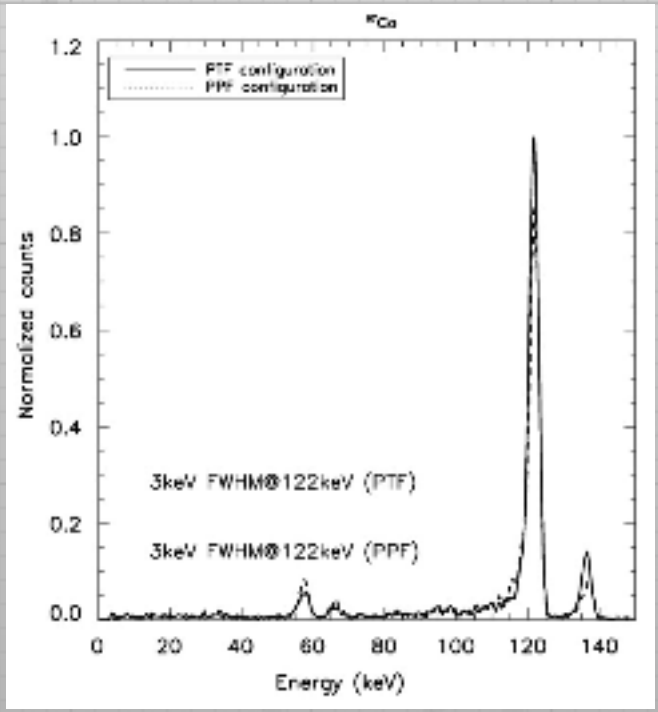
The planar electrode is held at a negative voltage with respect to the anode strips which are at ground potential.

The drift strip electrodes are biased by a voltage divider providing $-Vi=-V_d \cdot (i/4)$.



Progetto DTU-ESA

Drift-Strip Concept

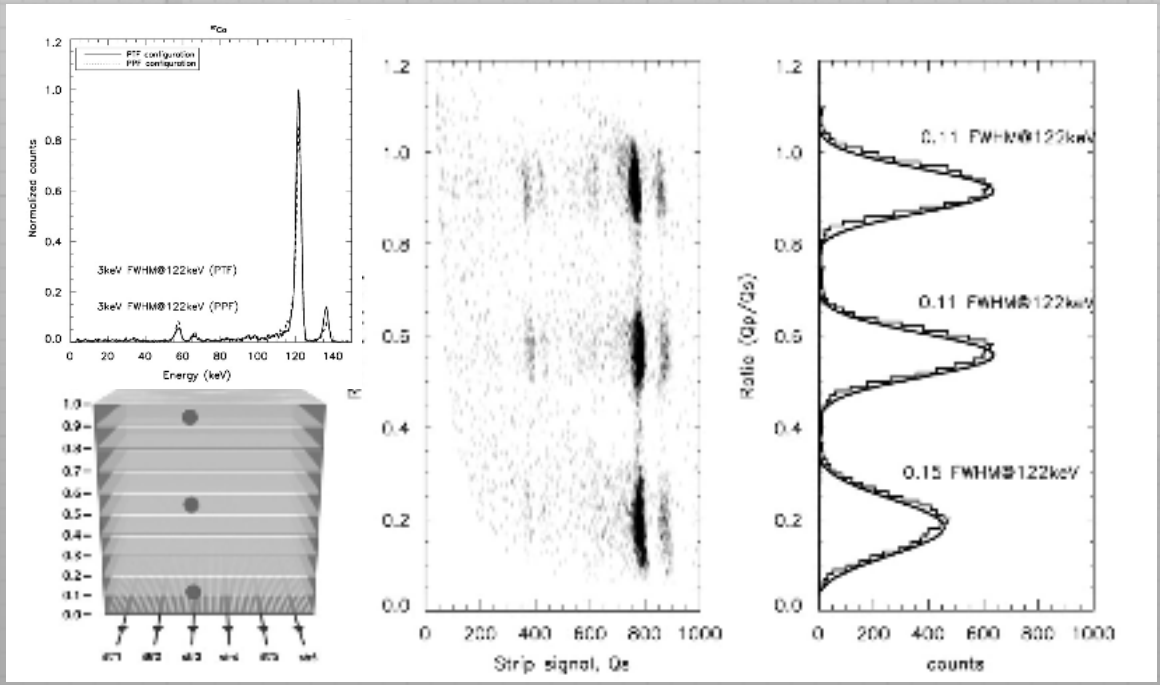


2,4%

I. Kuvvetli et al. NIMA 624 (2010) 486

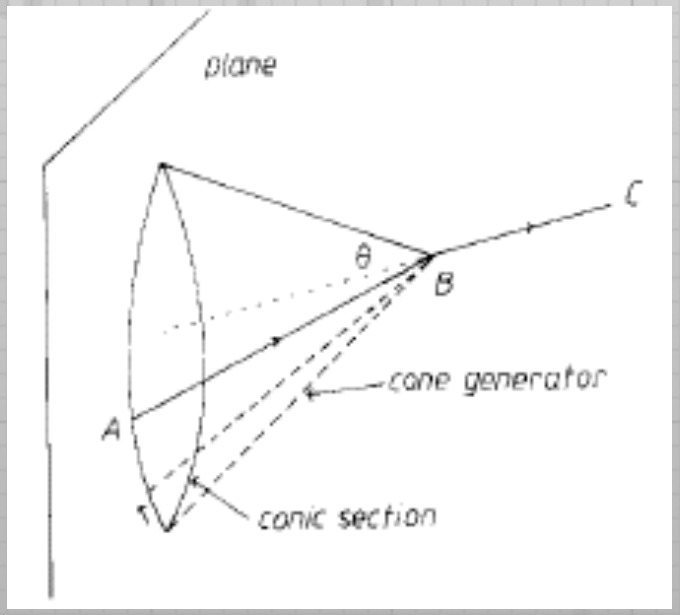
Depth information

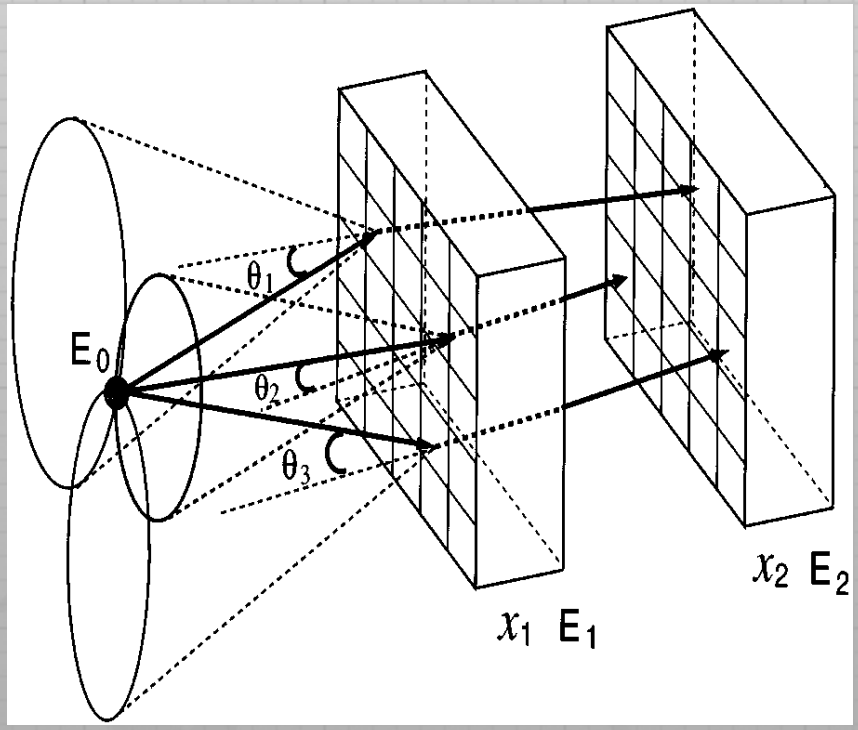
- ✓ The anode strip signal is independent of the photon interaction position
- ✓ The induced signal on cathode electrodes is dependent on the depth of interaction.
- ➢ By combining the effect of the hole trapping with the single polarity charge sensing ability, we can obtain information on the radiation interaction depth between the planar electrode and the anode strip ⇨ Ratio between the collected charges $Q_{cathode}$ and Q_{strip}.
- ➢ The depth information (R) can be used to correct the anode strip signal fluctuation caused by the electron trapping and the non ideal weighting potential effect.



DTU-ESA Project: why 3D imaging?

Thanks to 3D imaging we can use Compton events to detect source direction

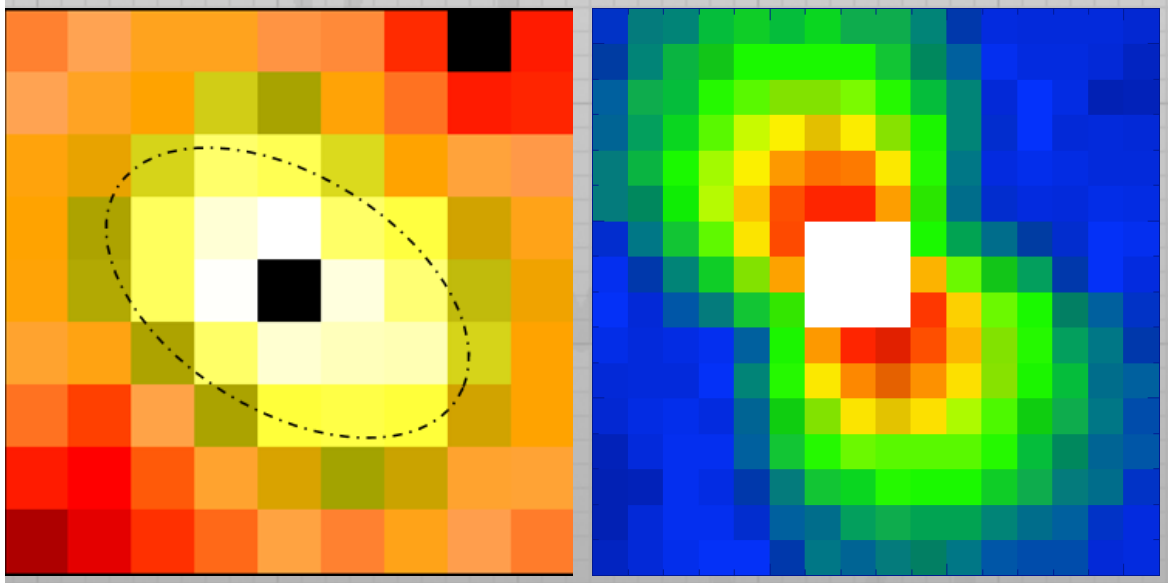




$$\cos(\theta) = 1 + m_0 c^2 \left[\frac{1}{E_0} - \frac{1}{E_2} \right]$$

DTU-ESA Project: why 3D imaging?

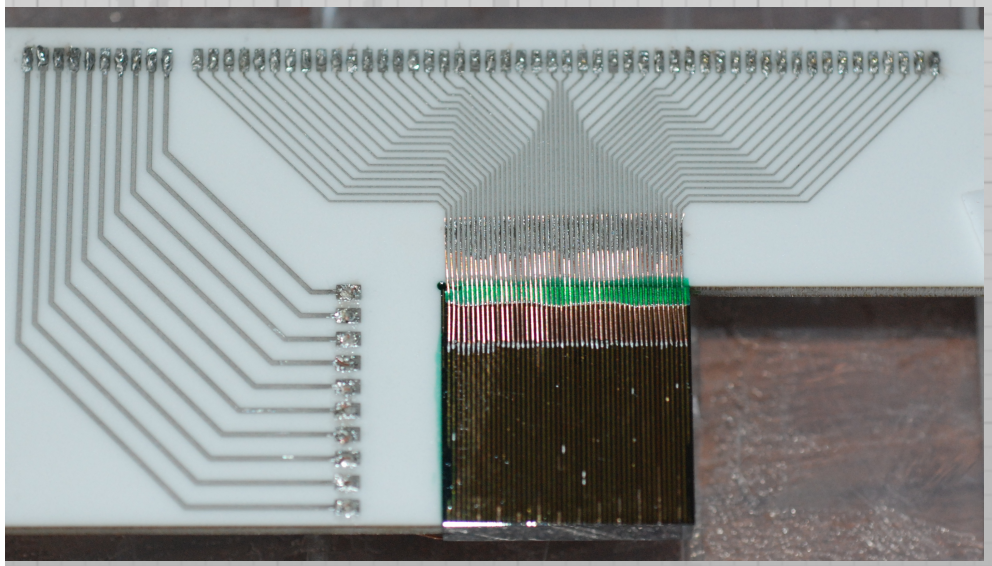
Compton events analysis gives information on polarization of gamma rays

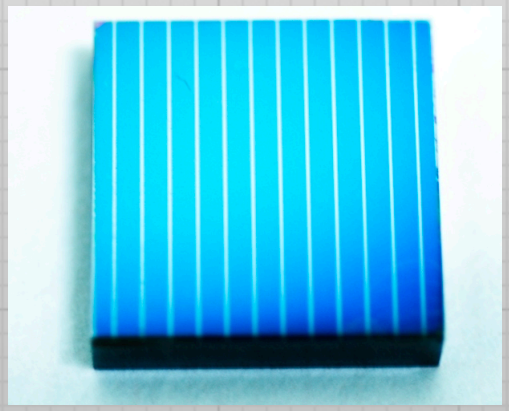


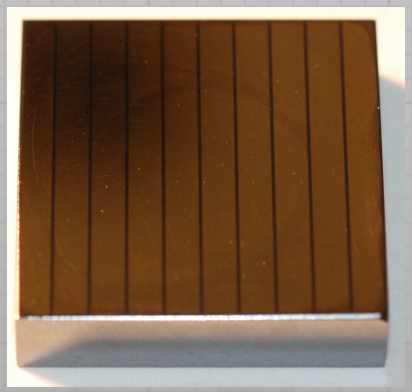
Two scattering maps at 200 keV and the polarisation axis 30° inclined with respect to the detector ones: (left) POLCA detector; (right) Caliste module

DTU-ESA Project

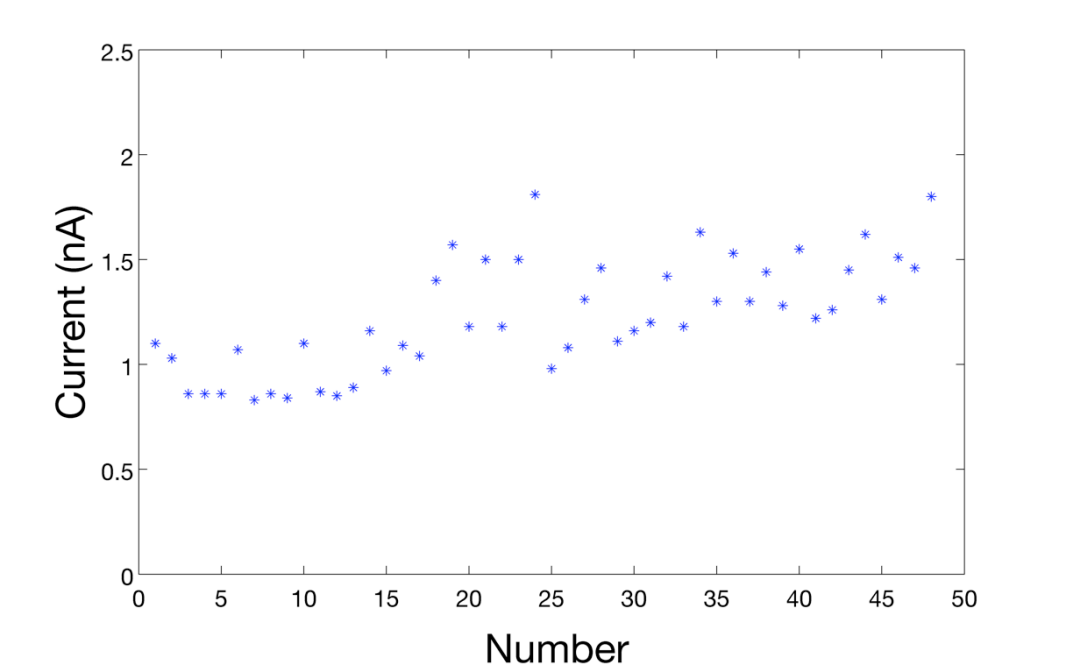
Realized detectors



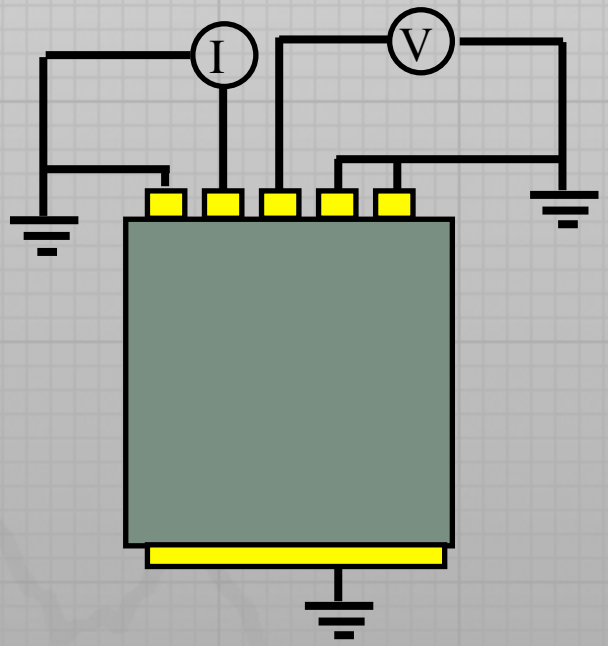




DTU-ESA Project



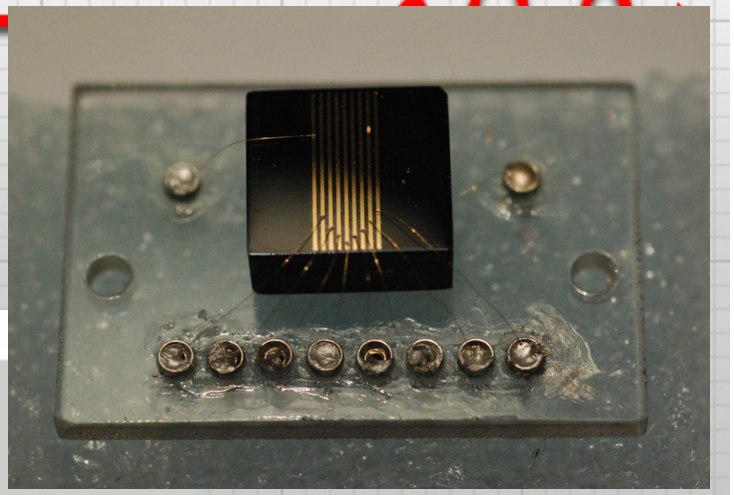
V = 100 V

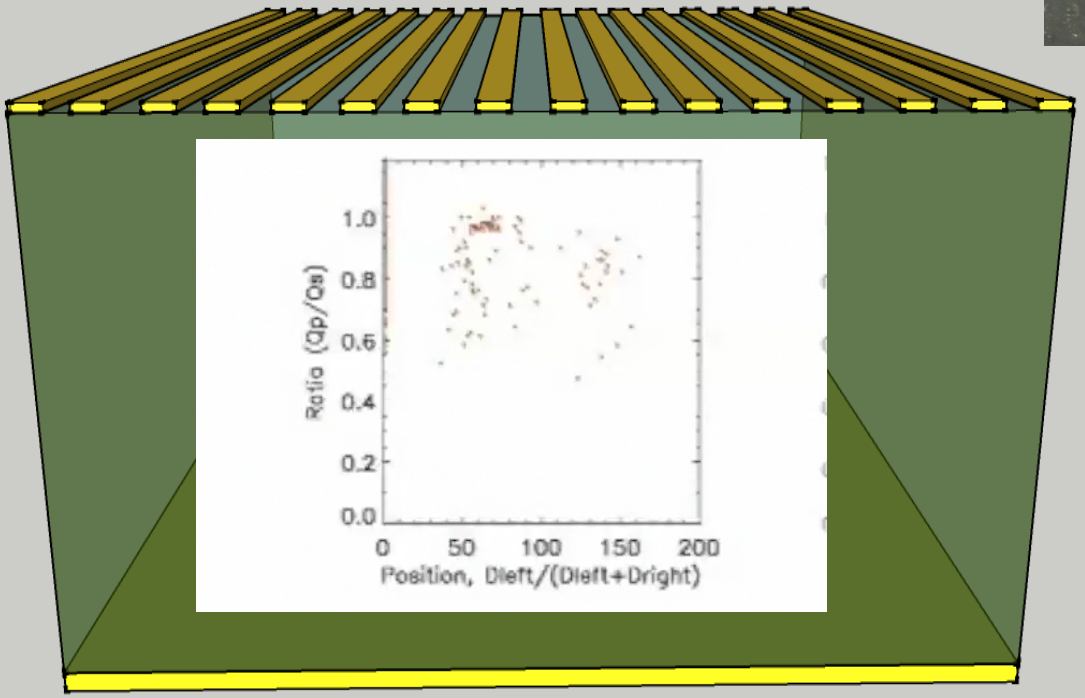


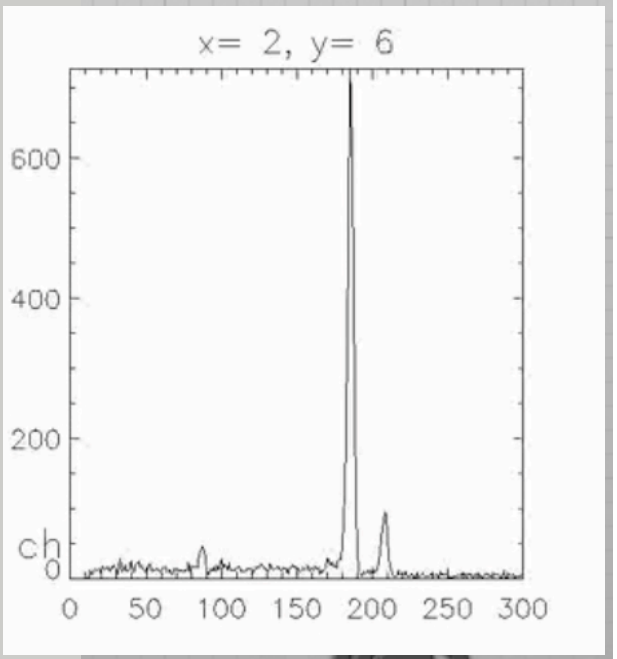
From 25 to 28 we will be at ESRF to test these detectors

DTU-ESA Project: results on 2D

2D detector

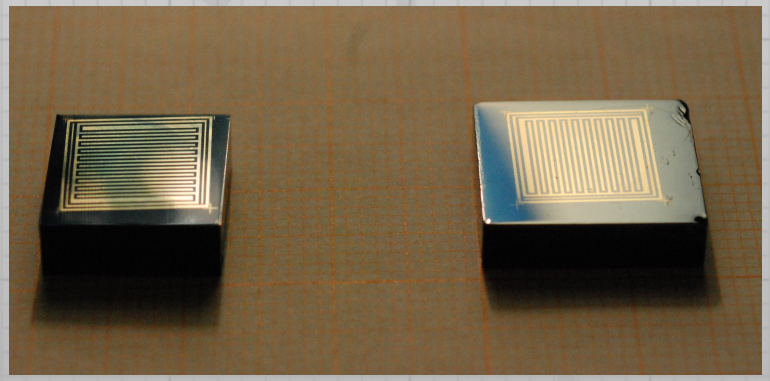


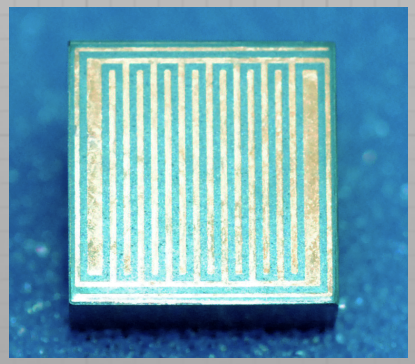


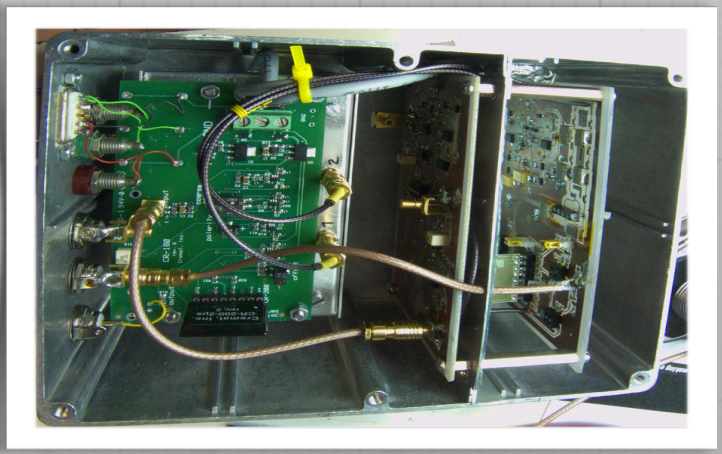


Environmental monitoring

Progetto finanziato da CARIPARMA







Spin-off

Thanks for the attention and again for the kind invitation!!!