Development of CdTe Imaging Detectors for a Compton Telescope

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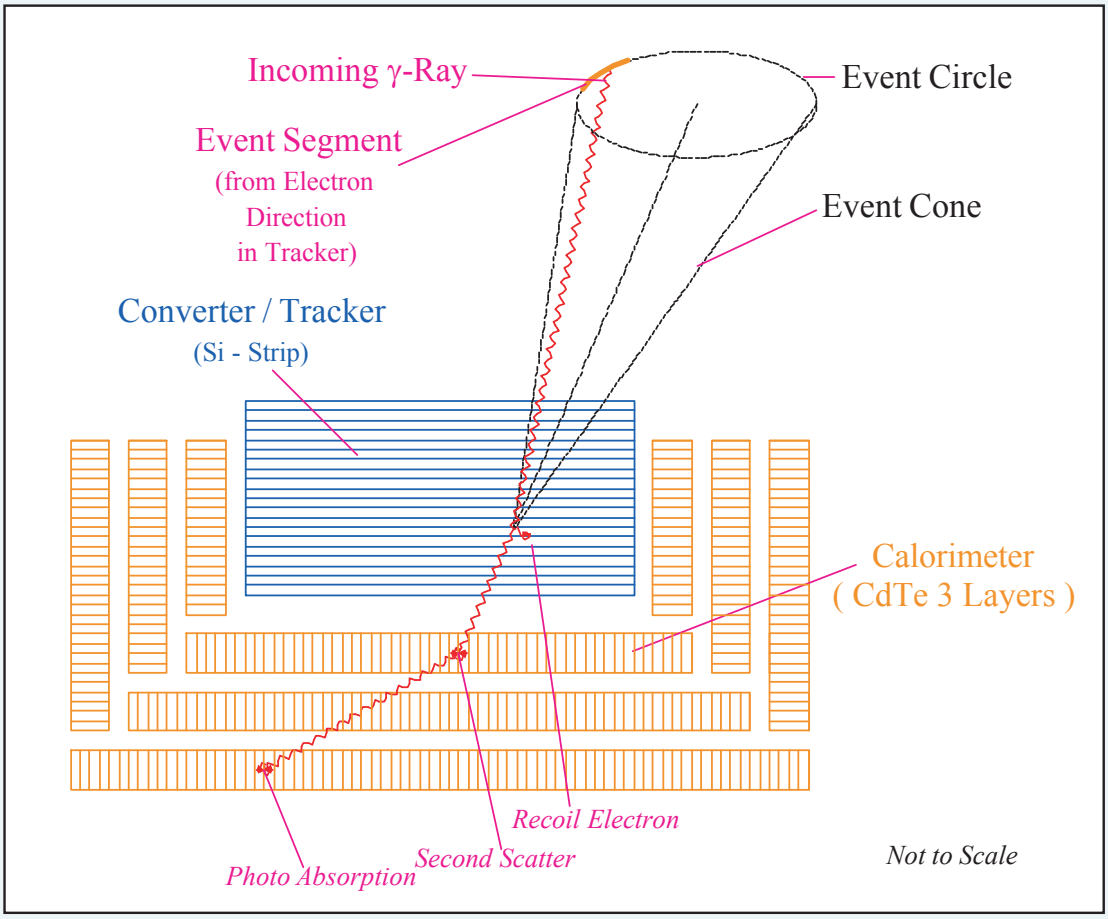
We propose the development of Schottky CdTe detectors
for the calorimeter part of a Compton telescope.

Compton Telescope

Compton Telescope consists of "Converter" and "Calorimeter".
We want to concentrate on Calorimeter part.



Si - strip detectors are prime candidates for converter part.

For a good calorimeter in a Compton telescope we require :

- Large area and large depth
- High density and high average Z
- Good energy resolution
- Good position resolution
- Low energy threshold for each interaction
- Good resolution for two interactions ocurring close by
- Minimal amount of dead or inefficient material
- "Reasonable" Cost

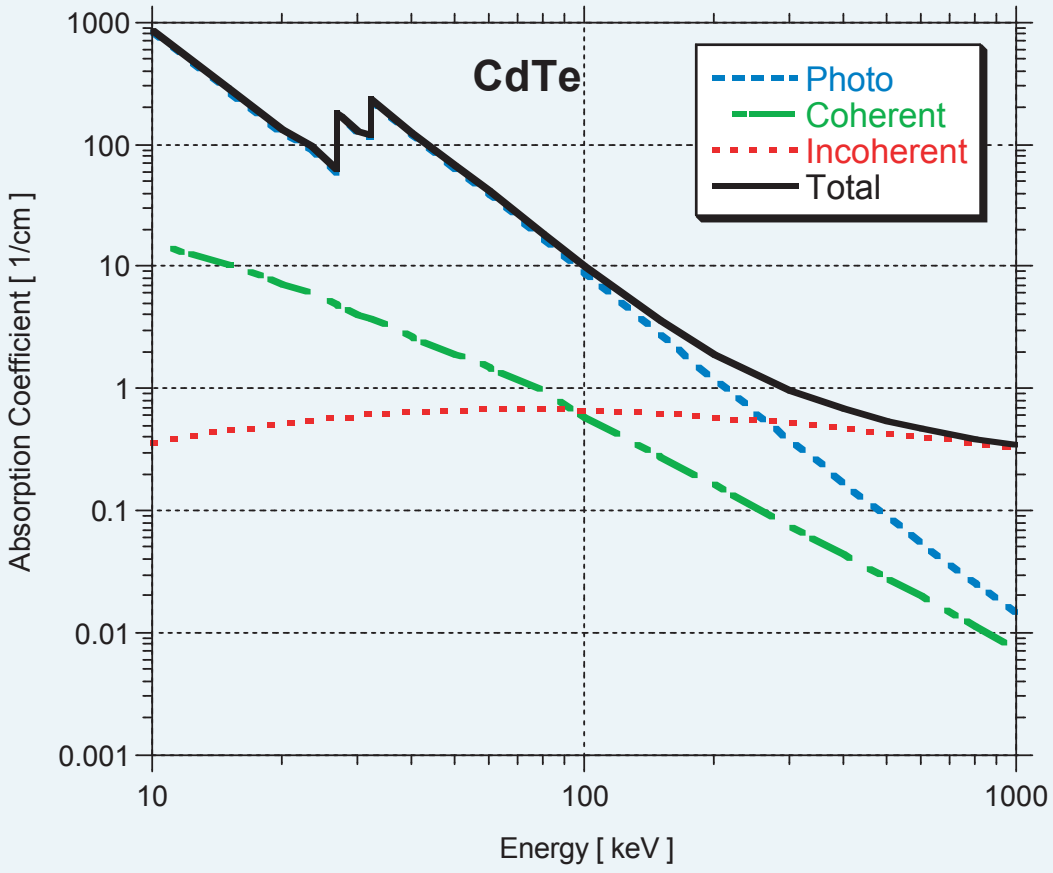
Arrays of Schottky CdTe irradiated perpendicular to the electric field promise to fulfill these requirements.

Schottky CdTe Detectors

Monocrystaline CdTe with ohmic contact on Cathode and Schottky contact on Anode side.

Properties:

Average Z :	50	
Density :	6.06	g/ccm
Bandgap :	1.46	eV
Electron mobility:	1100	$cm^2/V/s$
Hole mobility:	100	$cm^2/V/s$
Manufacturer :	ACRORAD, Tokyo	

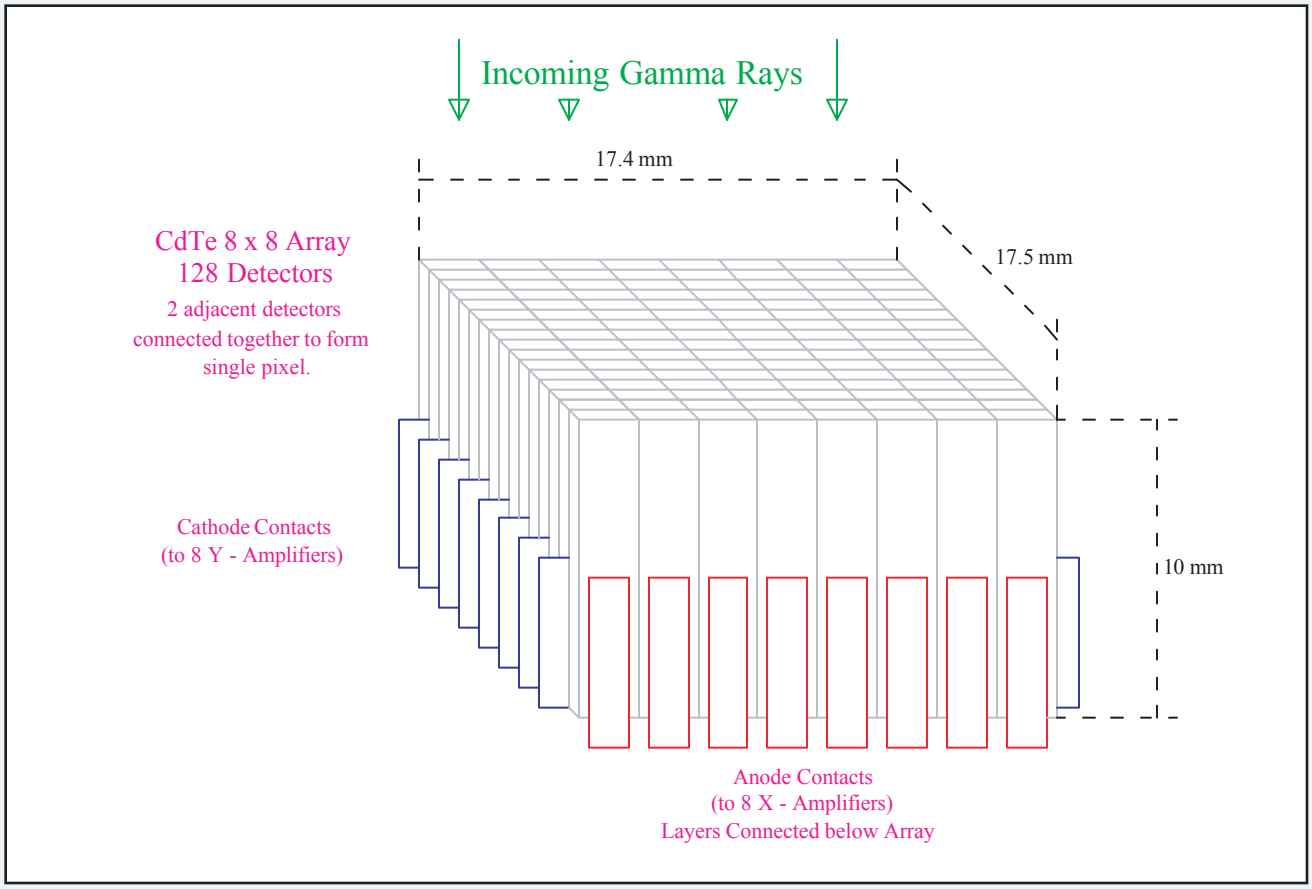


In tests at the Columbia Astrophysics Lab the Schottky CdTe detectors proved well suited for imaging arrays.

Basic Calorimeter Module

The basic module consists of 8 x 8 pixels, 2 mm x 2 mm area, 10 mm deep.

Each pixel consists of two 2 mm wide,10 mm long, and 1 mm thick CdTe Schottky detectors back to back.

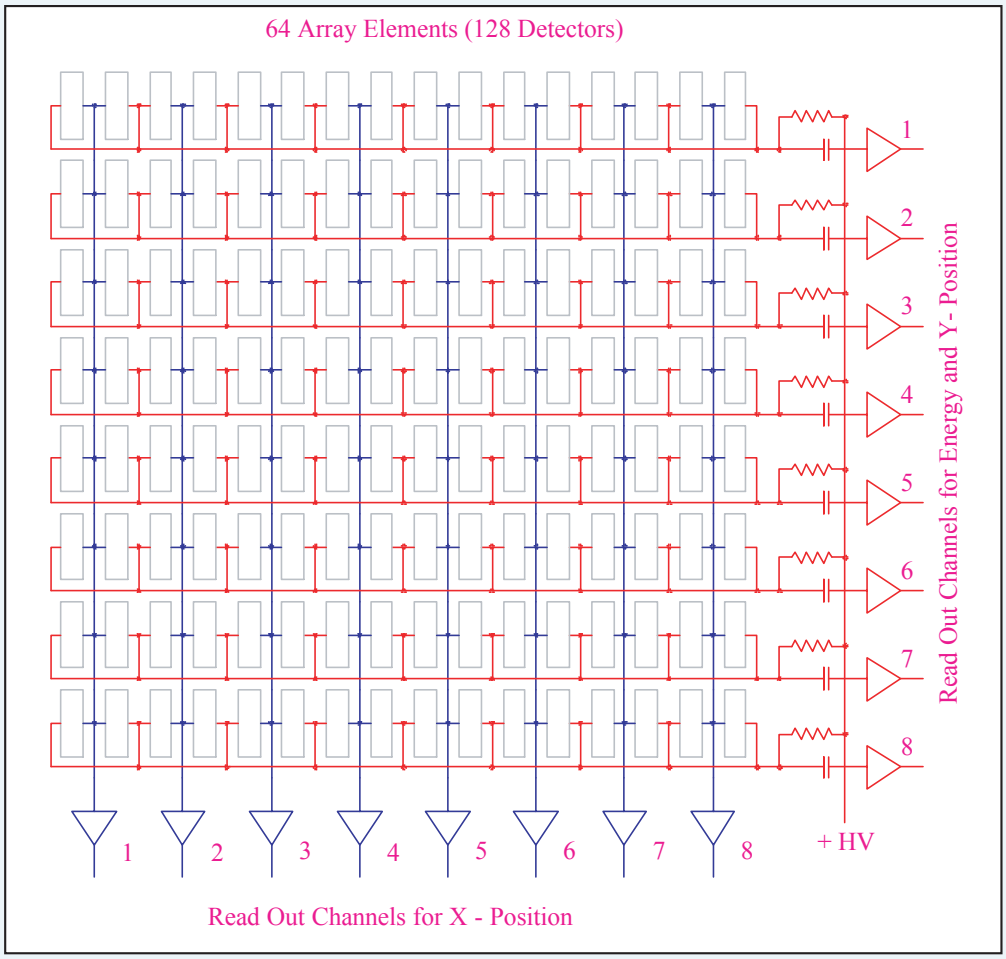


Each row has eight detectors are on one coplanar array. Only the cathode contact is segmented.
The connections are made with 1 mil brass foil to a PC board.
Only 20 % of the detector surface is covered by foil.
The depth of the basic module is 10 mm

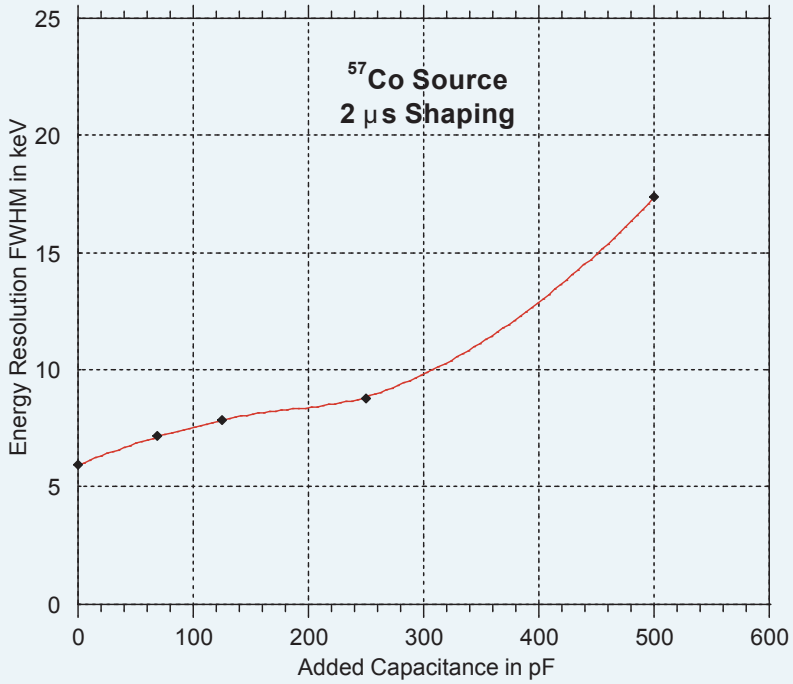
The expected position resolution is <1 mm in X and Y, and <3.5 mm in Z direction

Read Out of Calorimeter Module

The detectors will be connected to form X - Y read out.

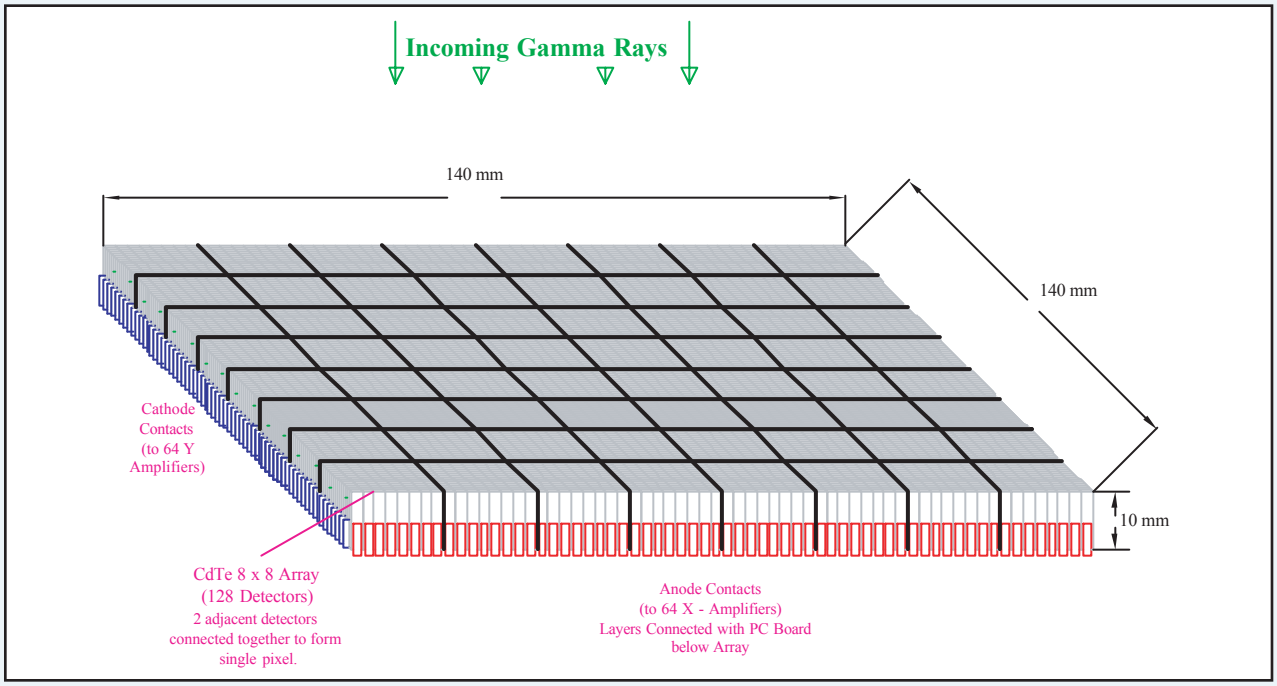


Initial Tests showed that 32 or 64 detectors can be connected together to form one X or Y "strip"



Large Arrays

Large arrays can be constructed by tiling the surface with basic modules



Possible developments :

- Basic modules with 16 x 16 pixels
- Greater depth of single layer (30 - 50 mm)
- Segmentationof anodes for position resolution in Z

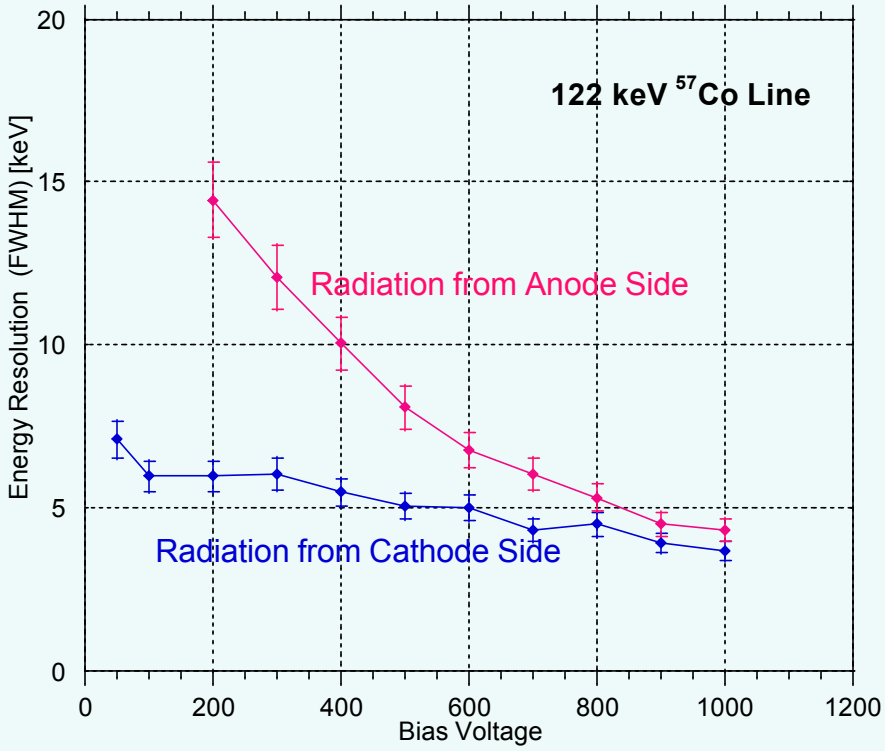
Initial tests with single detectors 2 mm wide, 1 mm thick, and up to 10 mm long show very encouraging results.

No pulse shape correction schemes, neither electronic or by software were used for these results.

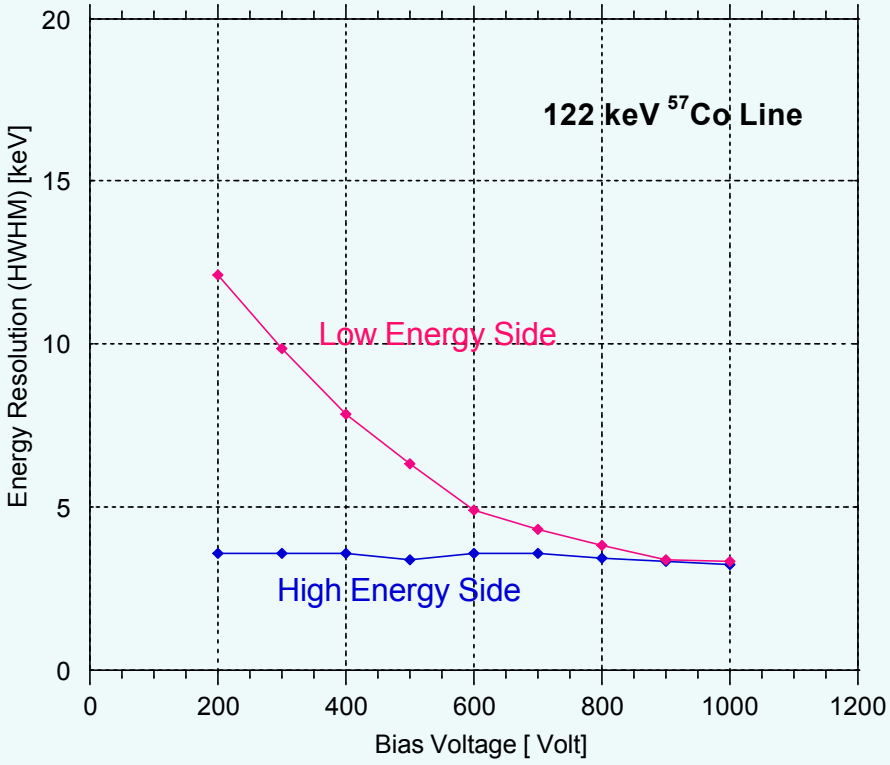
For this geometry it is important that single detectors are fully efficient in all their volume.

Homogeneity of Schottky CdTe Detectors

At high electric fields (10kV/cm) the peak position and width is the same for irradiation from the Cathode and from the Anode Surface



At high electric fields (10kV/cm) the HWHM to the low energy side and to the high energy side are the same.



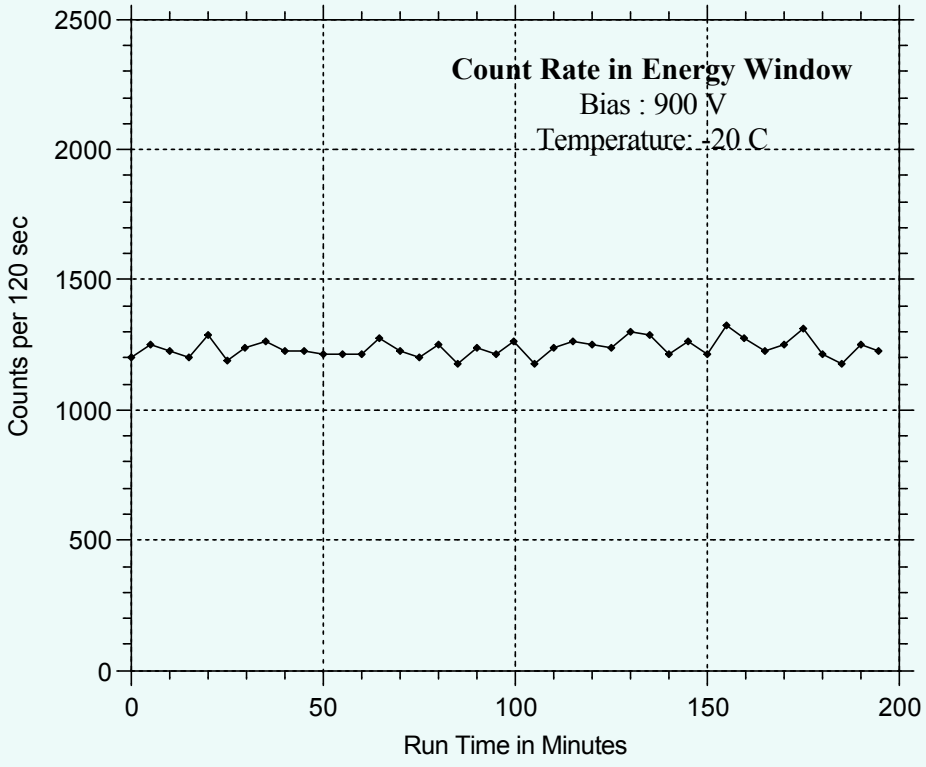
At high fields the Schottky CdTe detectors are homogeneous in all the volume.

Stability of Schottky CdTe Detectors

Early CdTe detectors showed polarization effects, i.e. a slow charge build up reducing the pulse height with run time.

Modern ohmic CdTe are modified to defeat this effect.

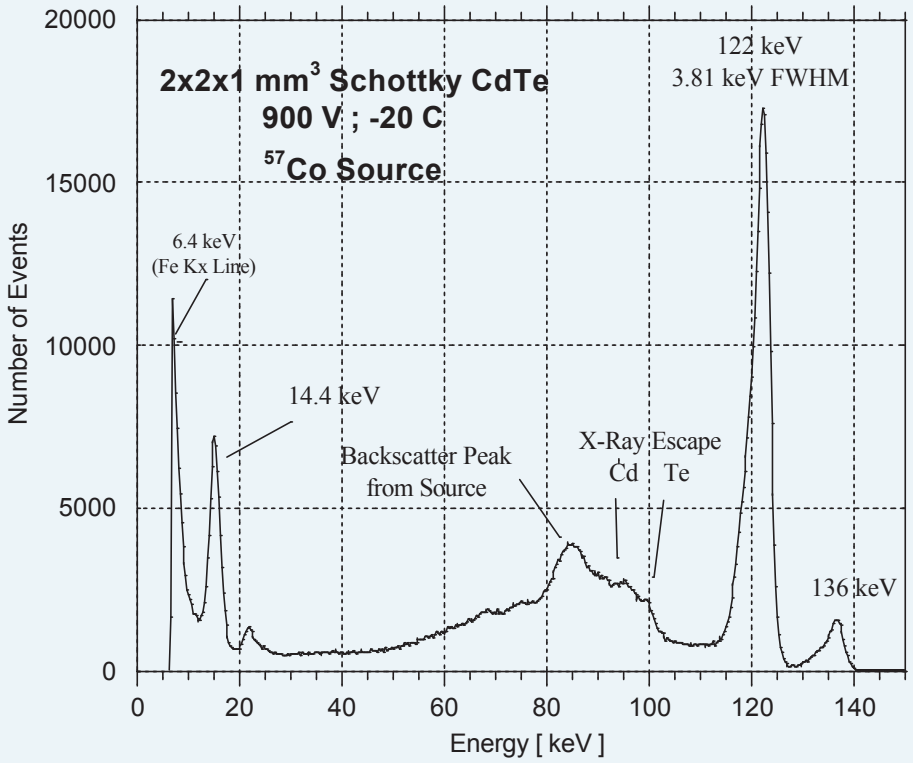
Schottky CdTe detectors are subject to polarization at room temperature and above. At lower temperatures (0°C or below) these effects disappear at high bias voltages.



With slight cooling and high bias voltagesSchottky CdTe detectors do not have polarization effects.

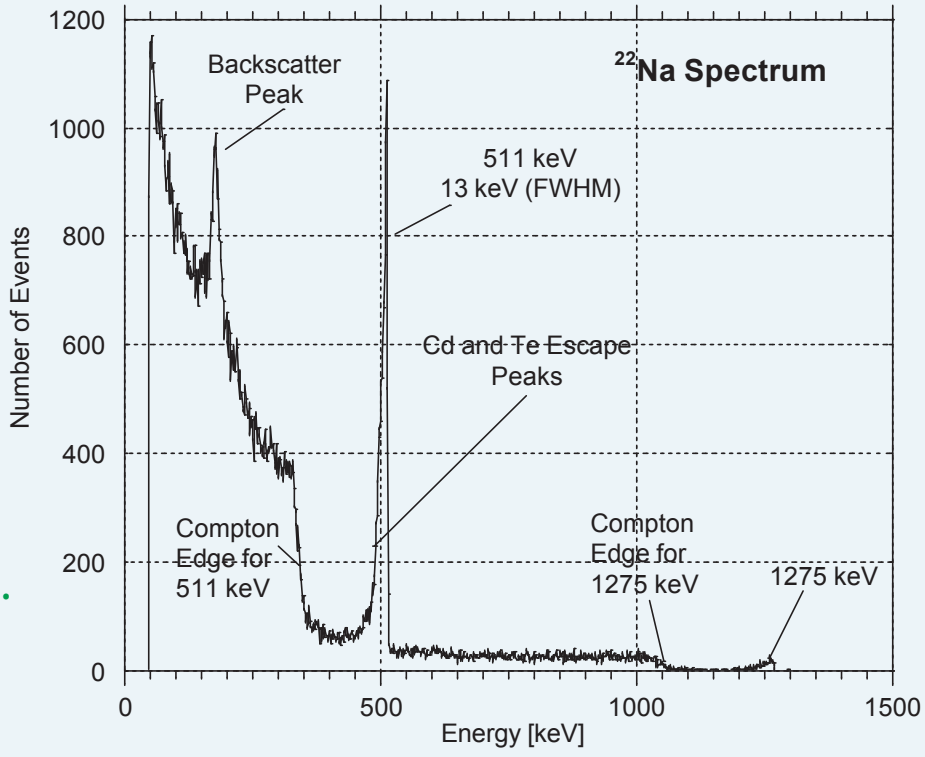
Spectroscopy with Schottky CdTe Detectors

At high electric fields (10kV/cm) the energy peaks are symmetric, defeating the 'tailing effect' caused by hole trapping.



In a large volume the escape peaks will be detected, possibly in adjacent pixels, and added to the pulse height.

Shaping time : 2 µsec.



At high fields the Schottky CdTe detectors do not show the tailing effect, i.e. broadening of peaks to low energies.

Plan for Project

We propose to develop the Schottky CdTe calorimeter arrays in a three year research project.

First Year : Construction of first basic modules and full characterization of detectors within array structure.

Second Year : Tests with various arrangements of basic modules, and tests of thicker arrays. Development of VLSI read out based on available ASICs , e.g. TA1 by IDE AS.

Third Year : Test of CdTe array in near space background condition as "piggy back" experiment on a balloon flight of LXeGRIT.

Publications for Schottky CdTe Detectors :

1. K.L. Giboni, E. Aprile; "Evaluation of CdTe Detectors with Schottky Contacts for Imaging Applications", Nucl.Instr. and Meth. A416 (1998) 319

2. K.L. Giboni, E. Aprile, I. Rochwarger; "Schottky CdTe Detectors for Imaging in Nuclear Medicine and Astrophysics", SPIE Vol. 3446, (1998) 228

3. K.L. Giboni, E. Aprile, T. Doke, M. Hirasawa, M. Yamamoto, "Coincidence Timing of Schottky CdTe Detectors for Tomographic Imaging", Nucl.Instr. and Meth. A450(2000)307