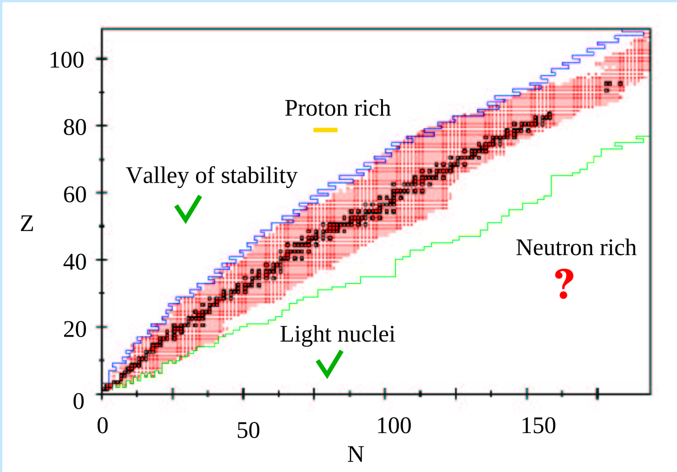
The Scan of the TIGRE detector

Martina Descovich

The physics case: why do we need new detector arrays?

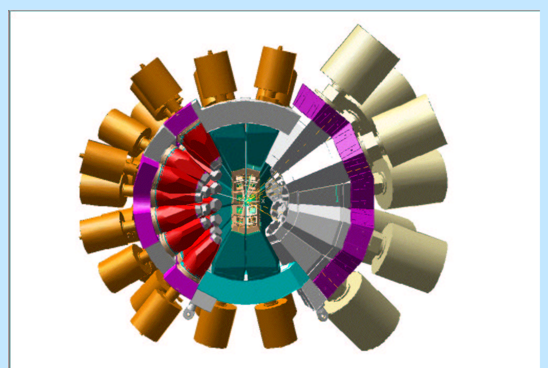


Nuclear structure experiments are based on the detection of the gamma−rays emitted by decaying nuclear states. Therefore, the progress of the nuclear structure research relies on the sensitivity of the detection system.
The state−of−the art with respect to 4π spectrometers is represented by EUROBALL (Europe) and GAMMASPHERE (US). They consist of many tens of Ge crystals provided with an anti−Compton suppression shield and are read out with analog electronics. The efficiency is ~7%, while the peak−to−total is ~50%.

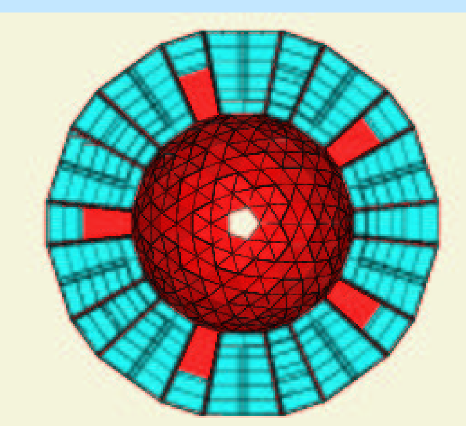
The proposal for future spectroscopy experiments is to study the nuclei at the edge of stability, under extremes of isospin. To this purpose, the use of highly efficient and highly granulated detector arrays is required. The development of such arrays is based on the concept of

GAMMA−RAY TRACKING

With a total Ge coverage and a new digital signal processing technique, which will enable extraction, on an event−by−event basis, of E, time and 3D position information, gamma−ray tracking arrays will provide a very powerful detection system (expected efficiency of ~60% and peak−to−total of ~85%, for M=1).



EUROBALL (IRES, Strasbourg)



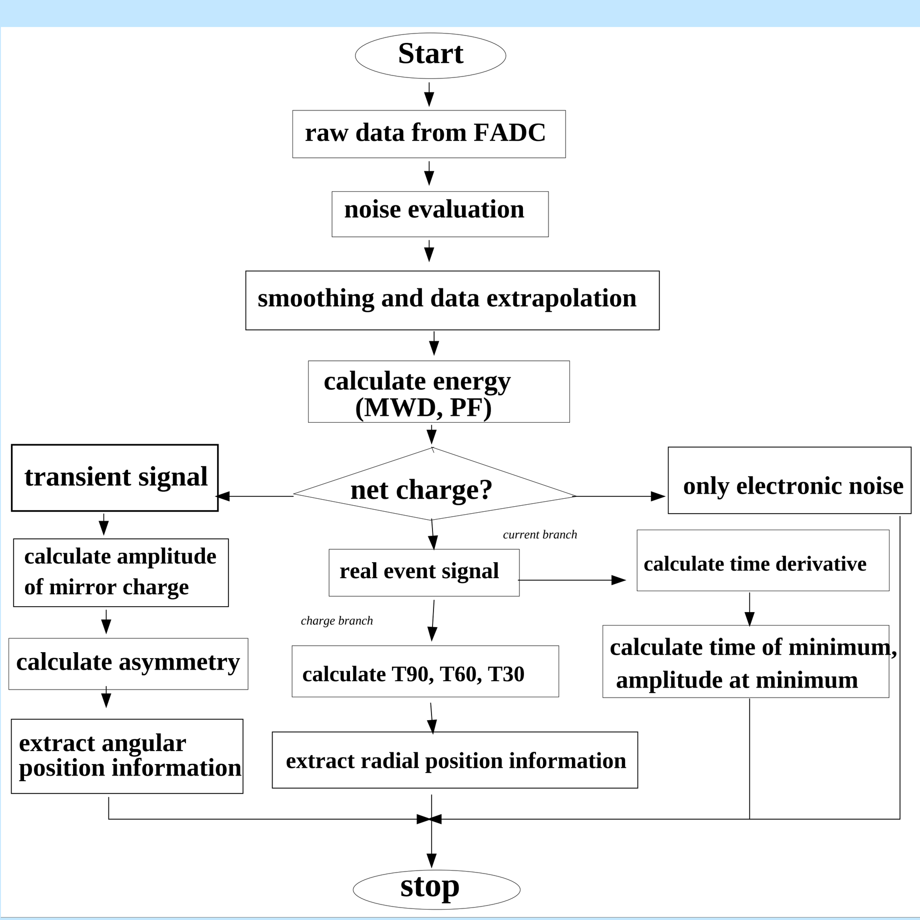
possible GRETA (LBNL, Berkeley)

Tracking arrays will be made of 100s of highly segmented HpGe detectors. They will allow us to determine the interaction position of each gamma and to deconvolve multiple gamma−ray events.
The segmentation provides 2D coarse position information, azimuthal and longitudinal, while an improved position resolution and radial position information are provided by

PULSE SHAPE ANALYSIS.

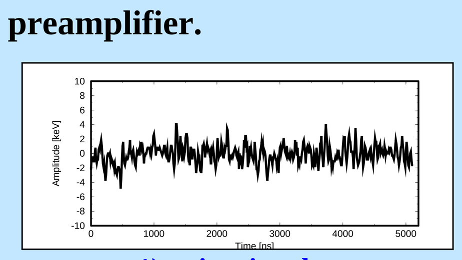
Pulse Shape analysis is based on the fact that the shape of the preamplifier signal depends on the interaction position.

The Pulse Shape Analysis (PSA) Algorithm

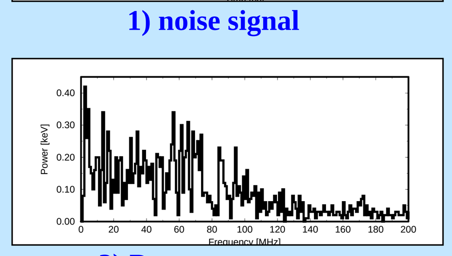


Noise Analysis

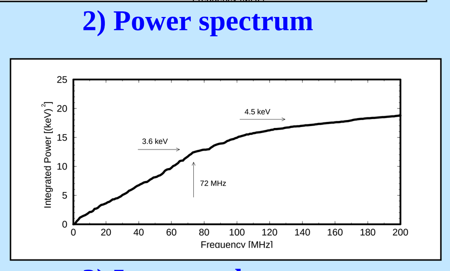
A detailed Fourier analysis has been carried out in order to investigate the noise characteristics of the detector preamplifier.



1) noise signal

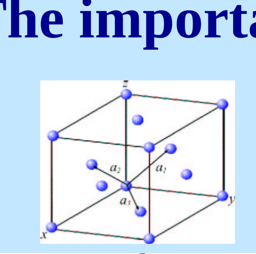


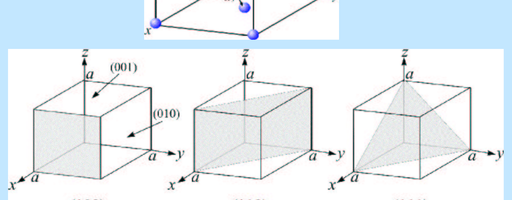
2) Power spectrum

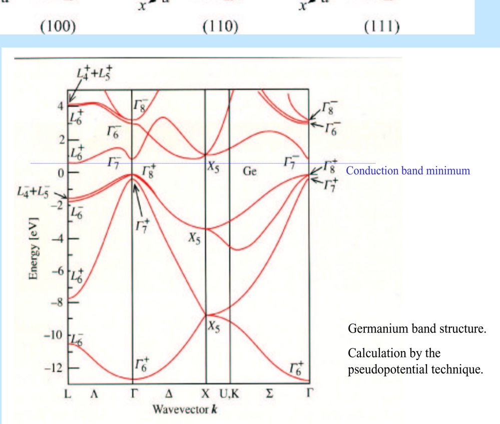


3) Integrated power

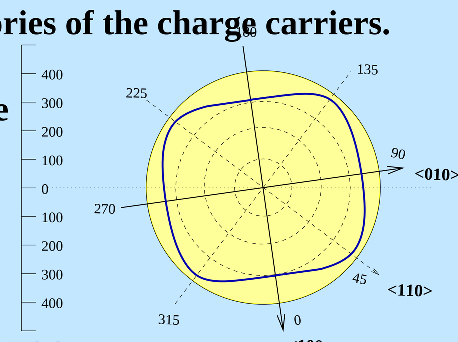
The importance of the crystal orientation







The Ge bandstructure is characterised by the splitting of the tetrahedral bonding orbitals into bonding and antibonding orbitals.
Ge is an indirect band semiconductor, having the minimum of the conduction band along the <1 1 1> direction. The structure of the valence band maximum is more complicated, presenting three different bands at k=0.
As a consequence of this band structure, the mobility of electrons in the lower conduction band and holes in the upper valence band is anisotropic.
The anisotropy affects the two main aspects of the charge collection process: 1) the collection time, 2) the trajectories of the charge carriers.
The first effect influences the shape of the signals, while the latter determines a preferential direction for the charge collection. This phenomenon has been predicted by simulations and experimentally observed [1].



[1] L. Mihailescu et al., Nucl. Instr. and Meth. A369 (2000) .

Conclusion

A scan of the 6x4 segmented detector has been performed at the University of Liverpool.
Pulse Shape Analysis Algorithms have been tested on real detector data.
Energy and position information have been obtained from the digitised signals.
Electric field and crystal orientation effects have been investigated.
The performance of the front ring suggests that the detector has to be opeated at higher bias.

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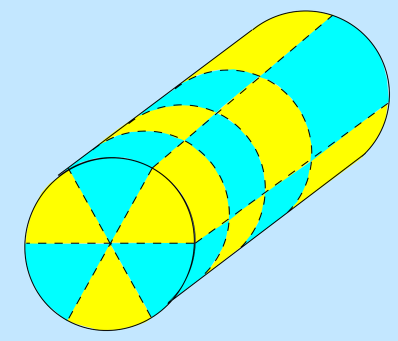
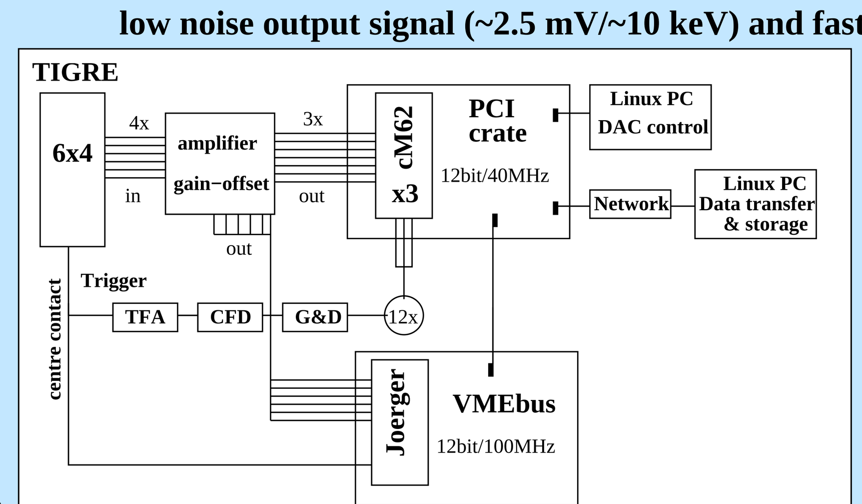
All the TMR European Collaboration

TIGRE:

The 6x4 prototype detector



TIGRE consists on a n−type HpGe crystal, 65 mm diameter by 80 mm length, with a 24−fold segmentation on its outer boron implanted contact. Both the centre and outer contacts have fast preamplifiers (Koeln design) fitted with WARM FET.
Due to its high granularity and fast electronics, TIGRE represents a unique example of a tracking detector.
It has good energy resolution (~2.1− 2.5 keV @ 1.3 MeV), low noise output signal (~2.5 mV/~10 keV) and fast rise time.



Some aspects before PSA

PSA will enable an event−by−event classification of the preamp signals depending on their characteristic shapes.
The ultimate goal of Pulse Shape Analysis is to provide a list of parameters (energy, time and three spatial coordinates) as input to the tracking algorithms.

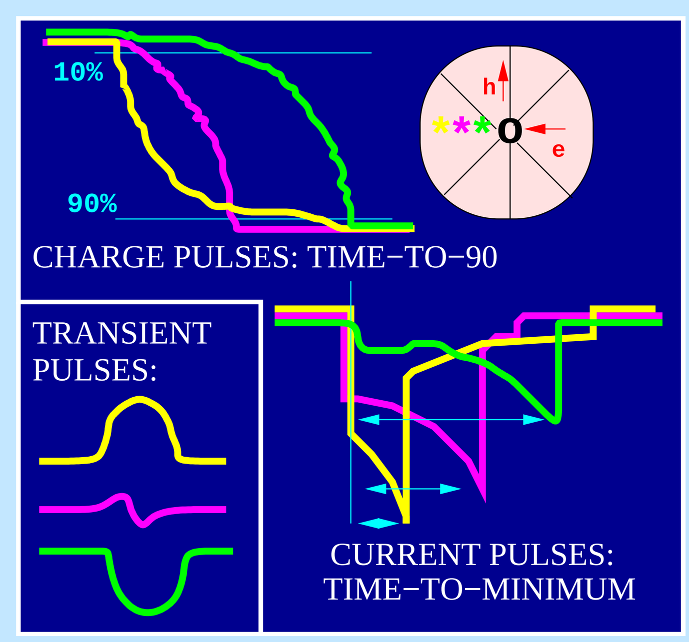
Why do we need a scan?

In order to improve the effective granularity of TIGRE and to allow the development of pulse shape analysis algorithms, which relate the pulse shape features with the interaction position, a calibration of the pulse shape with respect to the entry point of the gamma−ray has to be made.
The only way to know the entry point of the gamma−ray is to perform a detector SCAN.

Experimental details of the scan

A scanning apparatus has been developed at the University of Liverpool.
A scanning table driven by an automated stepper motor enables the movement of a well collimated source across the whole front face of the germanium crystal.
The pulse processing occurs via a compact PCI crate.
The front face of the detector was scanned in 2 mm steps with a ^{137}Cs source.

Results form the scan performed on the TIGRE detector



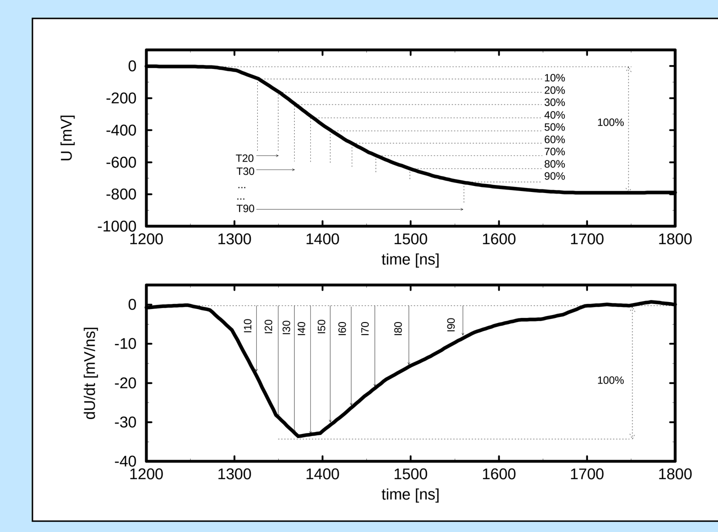
What kind of information can be extracted from the digitised signal?

−RADIAL POSITION INFORMATION:

− from the rise time of the net charge signal
− from the time to maximum of the current signal.
The current signal is obtained as the time derivative of the charge signal.

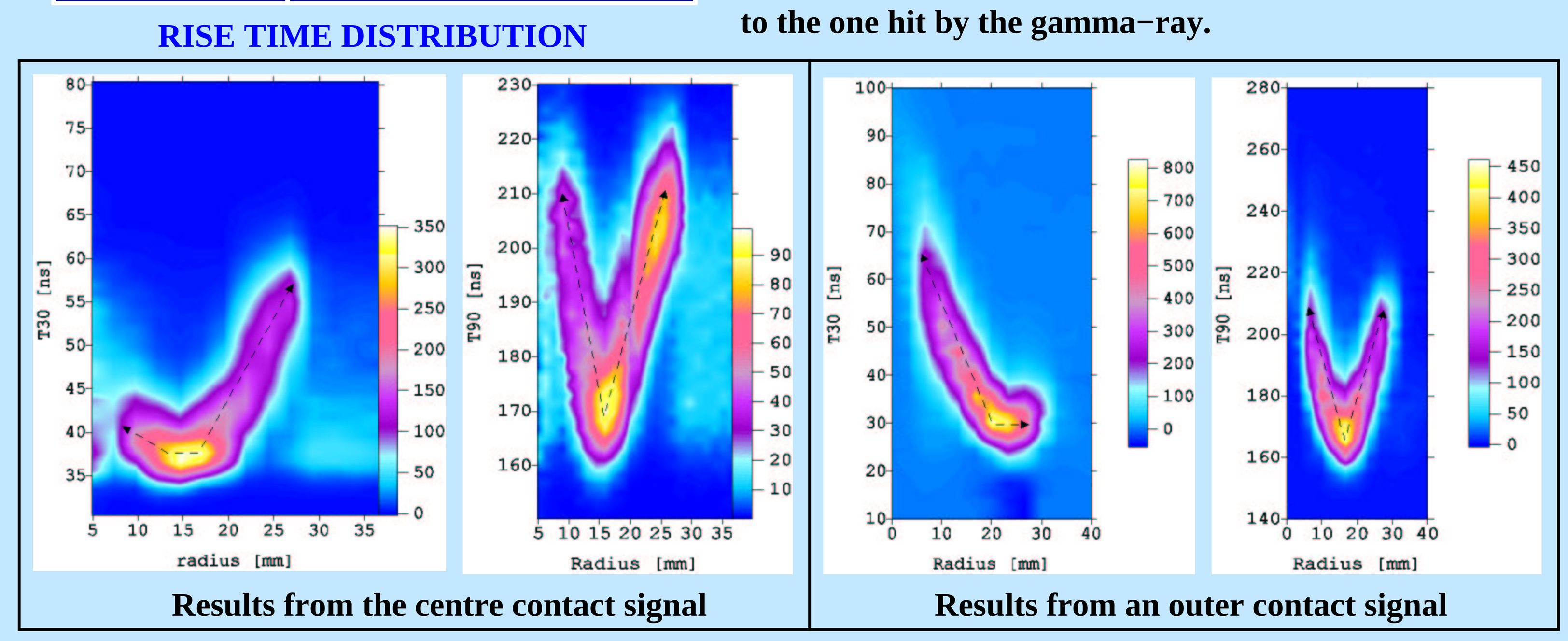
−AZIMUTHAL POSITION INFORMATION

− from the amplitude of the transient charge signal.
In a segmented detector a transient charge signal is induced on the electrodes adjacent to the one hit by the gamma−ray.



Some of the parameters extracted by the pulse shape analysis routine.

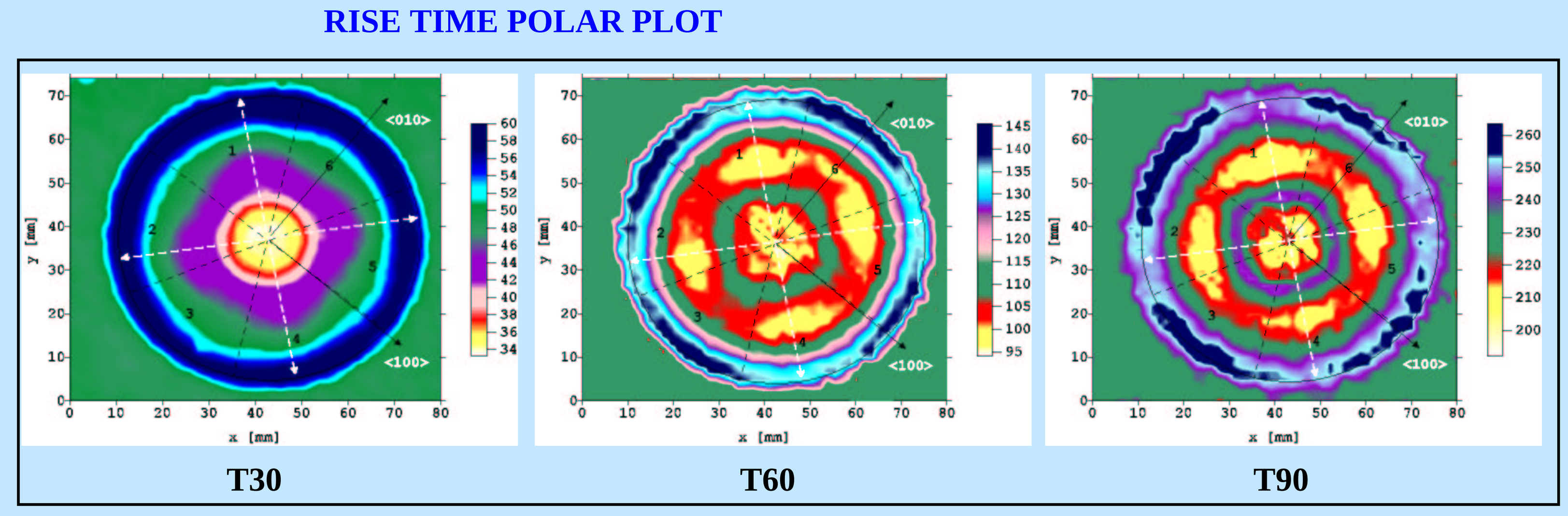
RISE TIME DISTRIBUTION



Results from the centre contact signal — Results from an outer contact signal

T30 and T90 time as a function of the radial position of the source with respect to the centre of the crystal volume.
Results are displayed as a contour plot, the colour scale shows the most probable value of RT at a given radial distance.
The T90 distribution shows, as expected, a V−shape with minimum at mid radii.
The T30 distribution reaches a saturation value a small radii.

RISE TIME POLAR PLOT



T30 — T60 — T90

These polar plots show the RT value (T30, T60, T90) measured at each (x,y) position of the source. The results were calculated as the centroid of the corresponding rise time distribution.
These plots show the same symmetrical trend observed in the picure above (i.e. the RT increases from the centre of the active volume to the electrodes).
Moreover a clear effect due to the crystal orientation appears.

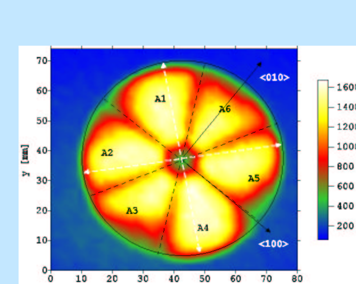
It is known in germanium at low temperature and high electric field, the saturation drift velocity has its minimum value along the <111> direction and its maximum value along the <100>. Therefore, it is possible to assign hypothetical crystallographic axis to the detector.

"Sensitivity" of the detector

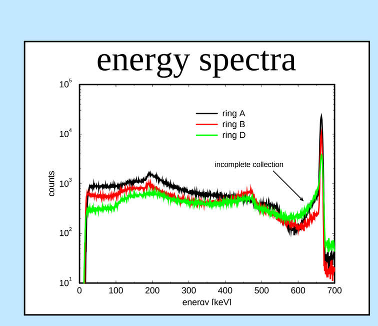
The sensitivity plots show, for each position of the scanning table, the number of gamma−events that are fully absorbed within a single segment.
Different gates were used to select the FEP.
The region of the detector where the number of counts is smaller than what is expected, are those in which the charge deposited by the gamma−ray is not fully collected at the electrodes.

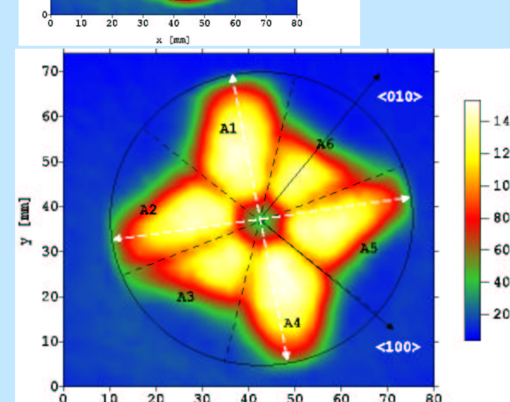
What kind of information?

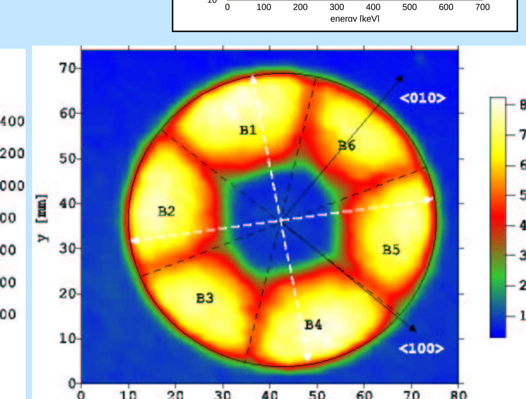
− electric field
− effective segmentation
− property of the charge collection mechanism
− crystal orientation

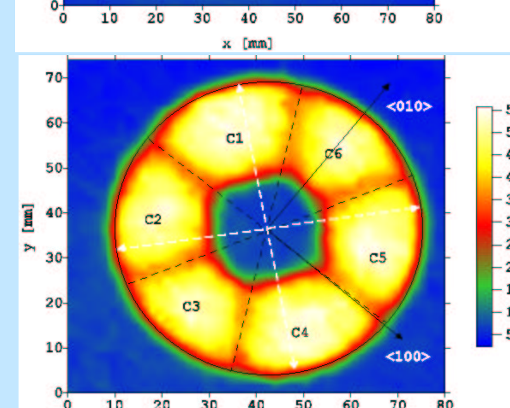


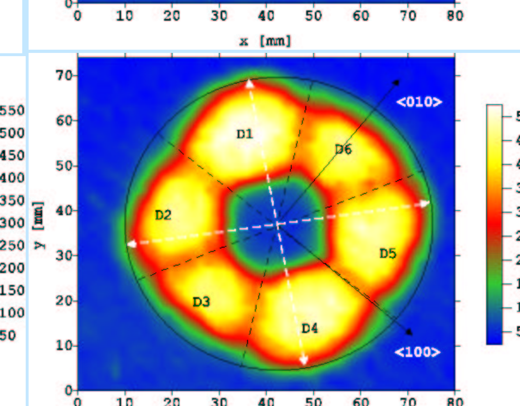
A ring, wide gate on center



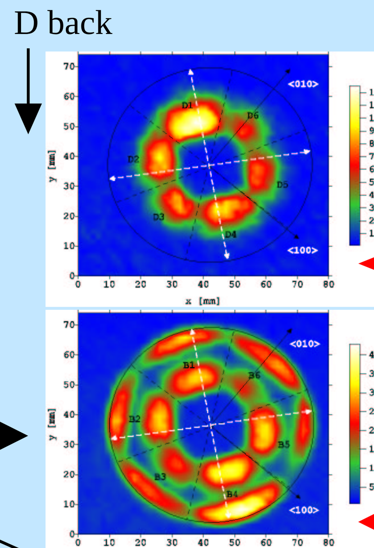






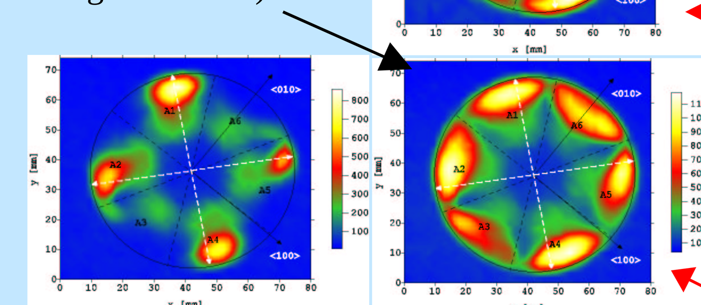


D back

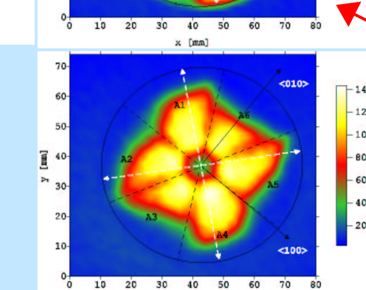


B/C front/back

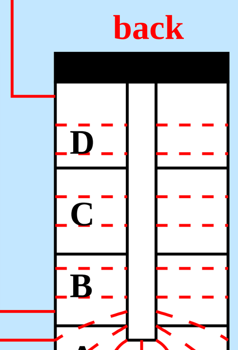
A back (wider gate on FEP)



A back (narrow gate on FEP)

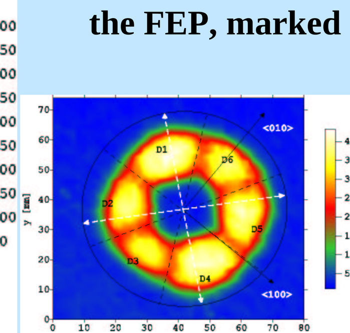


A front



By using the the amplitude of transient charge signal, it is possible to look at the performance of each ring at different depth.

In the back part of ring A, the charge is fully collected up to the edge of the crystal.
The E field in this region is more uniform.
If a tiny gate is used to select the FEP, marked effects of crystal orientaion appear.



Ring D, narrow gate on outer

The front and the back part of the detector show problems in the charge collection process, due to the particular electric field: weak at the front and complex at the back.