Progress Report

Long term project MD 78

Beam line ID 17

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Second period 2004, beam time June 16, 8:00 to June 22, 8:00

Title: ***"Di-chromatic angiography and fluorescence imaging, a new non-invasive diagnostic method and first application for dynamic measurements of cardiac function***

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1. Scientific program

As in the first period the exploratory phase two main subjects are continued, both related to new detectors and methods:

a) Improvement of precision for projection measurements using gadolinium based contrast agent allowing a higher available flux at the imaging detector (multi-cell Ge detector) and consequently a higher precision of the absorption measurement. This will be used for improved visualization of coronary arteries, in particular if they are shadowed by the remaining contrast agent in the ventricle and for time dependent measurement of the myocard perfusion.

In the first period it was found that the remaining beam fluctuations – for the iodine measurements still tolerable – become a major limitation of the method. The possible origin and the means of correction these fluctuation by a multicell ion chamber has been discussed before. Now the multichannel read out electronics had been installed and the functionality of the method had been tested by recording beam profiles synchronously in the ion chamber and the Ge-detector.

b) Investigation of the method of florescence tomography. The method relies essentially on the separation of the fluorescence radiation emanating from Gd from the background. It had been found, that elastic scattering and Compton scattering as well as fluorescence of other material have to be taken into account. The analysis of the previous data suggested to study the effect of background contamination as function of the x-ray energy. Therefore measurements at 65 keV have been carried out in addition to 50.4 keV.

2. Set up for measurements.

a) A new multi-cell ion chamber with improved sensitivity has been installed in the beam further upstream and tested with a multichannel electronics (16 channels, see fig.1). Scans with a pencil beam have been carries out showing the separation power.

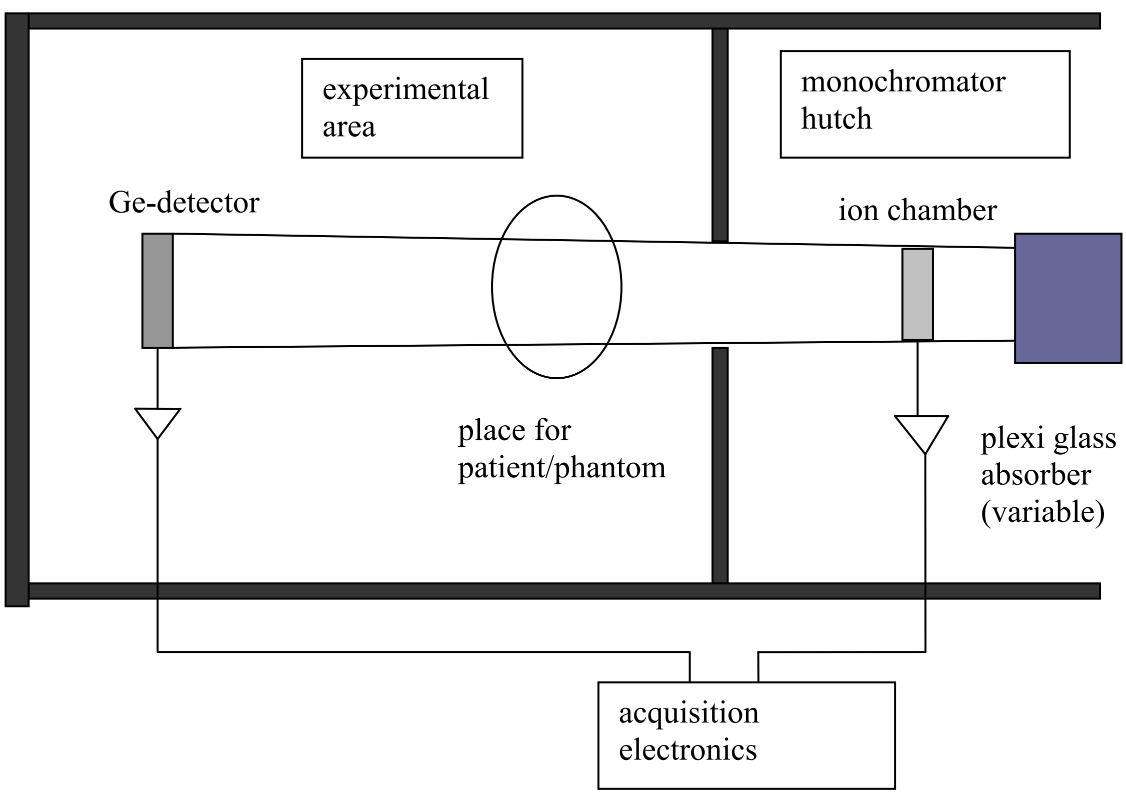

Fig. 1. Multicell ion chamber (2 x 8 channels) arrangement for test

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The Plexi- glass absorber has been used to test linearity and adjust the intensity.

b) Set-up for Xe proportional counter measurements of fluorescent and scattered radiation.

A special set-up has been constructed to allow the measurement of the fluorescent and scattered radiation as function of scattering angle θ. A collimator focuses on the radiation from the center pipe filled with Gadolinium or water for comparison. the set-up allowed more precise and well defined recording of spectra as compared to the first run. the angular dependence allowed the unique allocation of observed peaks to the mechanism of origin, since the Compton scattering is angular dependent.

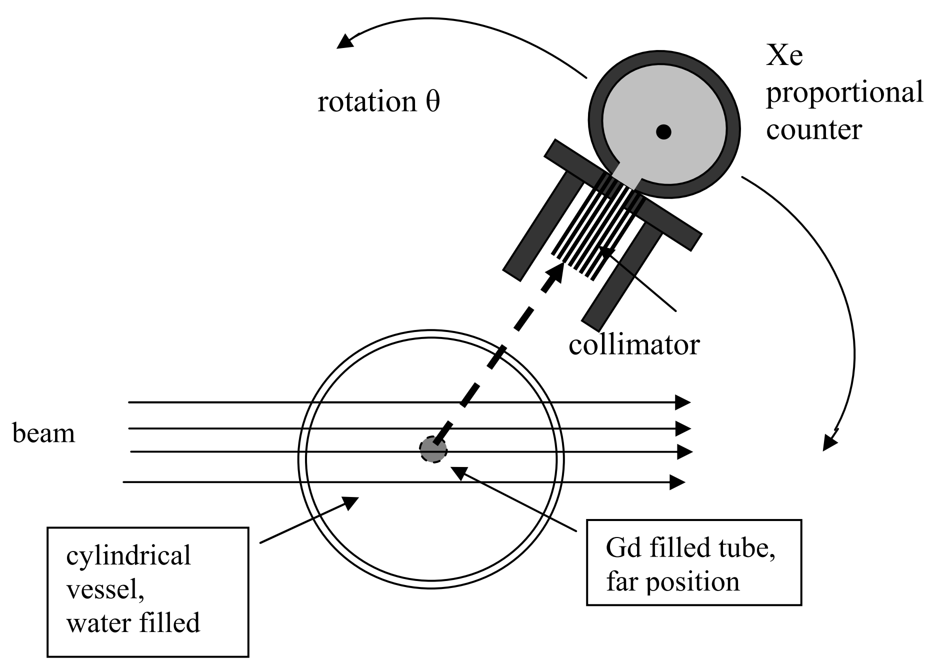

Fig. 2 Set-up for measurements of Gd-fluorescence in water using collimator. Rotation of the cylindrical vessel shows position resolution.

Fig. 3 Set-up for measurements of angular dependence for scattered radiation and Gd-fluorescence. Center: water vessel containing pipe with Gadolinium, left: Xe detector with collimator mounted on moveable arm.

Since the various peaks in the spectrum may cover partially or entirely the desired fluorescence peak and since the Compton peak changes with energy the optimum detection of fluorescence should depend on the initial energy of the x-rays. Therefore the upper energy of the primary beam has been raised above the original value of 50.2 keV to study the effect. Measurements have been performed at $E^{>}$ = 65 keV

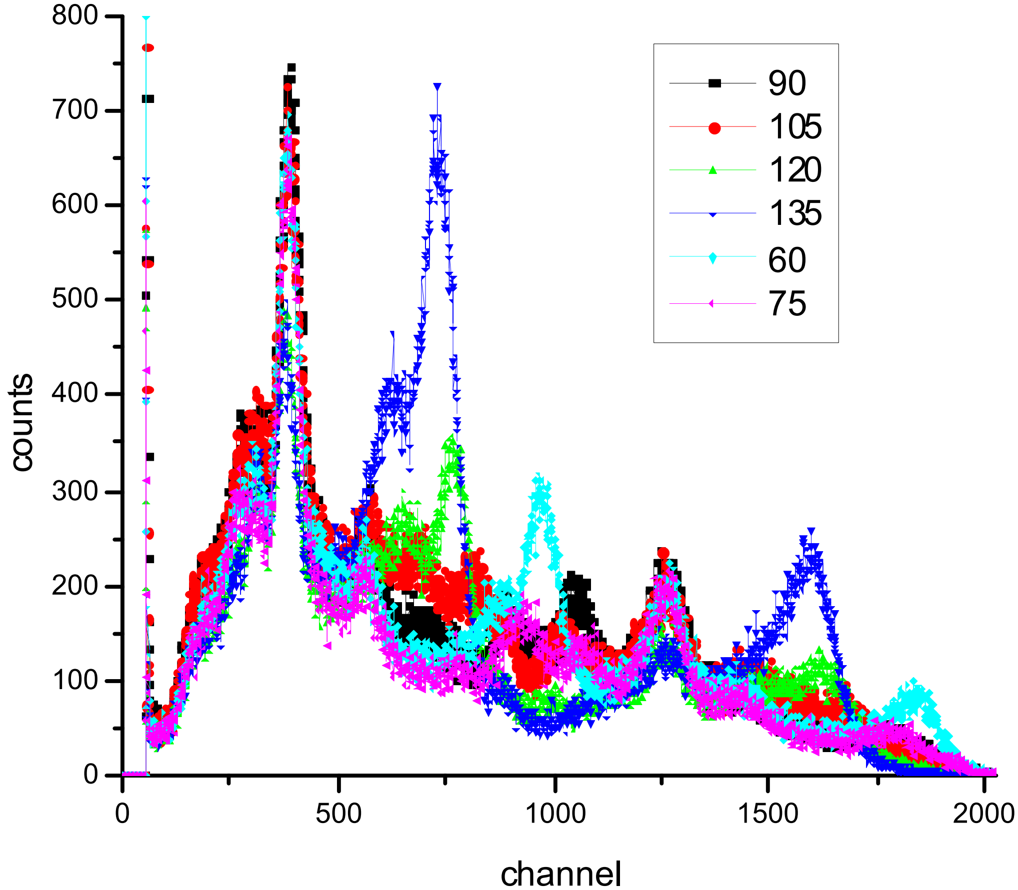

Fig. 4. Spectra recorded with set-up of fig.2,3for different angles. Photopeak of scattered radiation (at about channel 400) is constant and Compton peaks are variable. Other peaks see text.

3. Discussion of results.

Ion chamber beam monitoring

The ion chamber has been successfully installed and tested. The positional scan showed good separation of the electrodes (< 1mm) as necessary for separating the beams.
An essential test concerns the monitoring behavior. For this end the measured intensity of the ion chamber channels 8..15 has been used to construct a polynomial intensity distribution of the beam profile (fig. 5). This shape had been confirmed in the previous run. Using the best fit the correction factors for individual channels could be determined (electronic gain calibration).

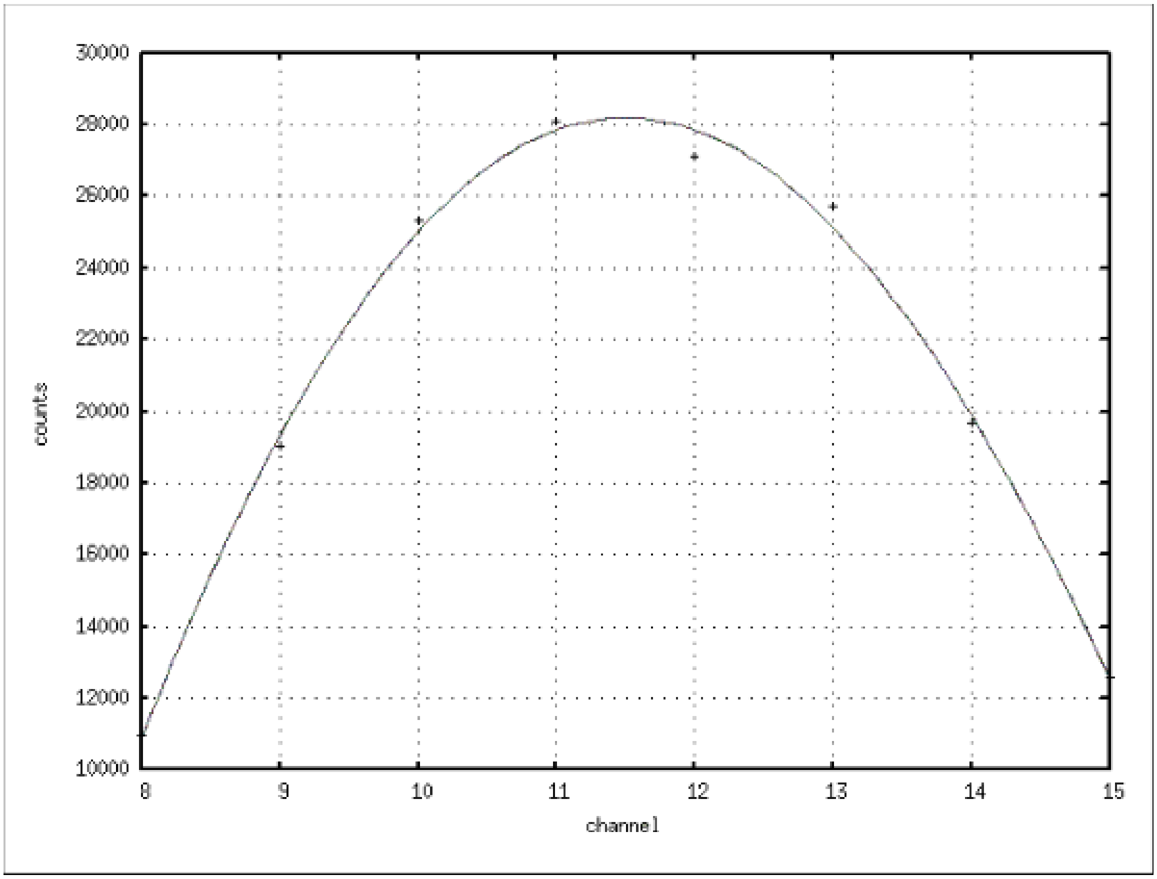

Fig. 5. Measurement with segmented ion chamber (x) and fit to beam profile.

Table 1. Correction factors for ion chamber channels

channel	8	9	10	11	12	13	14	15
factor	1.00706	0.98473	1.01208	1.00849	0.97332	1.02423	0.98944	1.00195

For the comparison with the Ge-detector measurements (monitoring) the values of channel x_n in the Ge-detector has been divided by the value of the calibration curve from fig. 5. The result for 5 arbitrarily chosen lines are shown in fig. 6. Although the ratio is not constant as function of x_n but has a smooth shape the most important feature is the fact that in each position they vary only by about 1/1000 which is compatible with the poisson noise in both detectors. The non-constant shape is probably due to some shift in the channel adjustment and is currently under investigation.

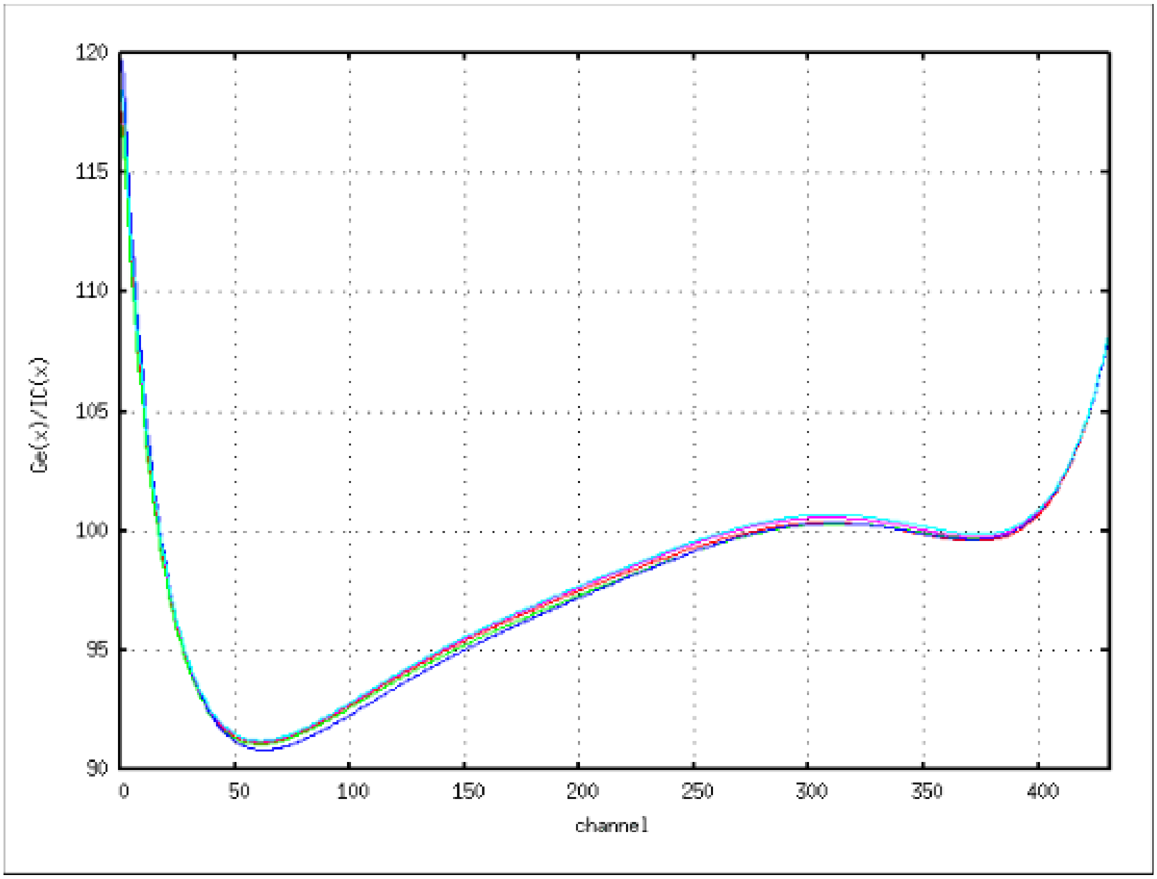

Fig. 6. Ratio of signal in Ge-detector/ signal in ion chamber calibration data vs. channel number in Ge-detector for 5 different lines..

The second estimate of the monitoring quality of the ion chamber has been measured directly. For a full scan with an integration time of t_{int} = 1 ms in each line the Ge-detector and the ion chamber have been recorded simultaneously. The correlation plot of the signals is shown in fig. 7. Again the remaining fluctuations of 1/1000 are compatible with the combined Poisson statistics. The final resolution expected will be about 0.3 10^{-3} and could be achieved with a higher photon flux.

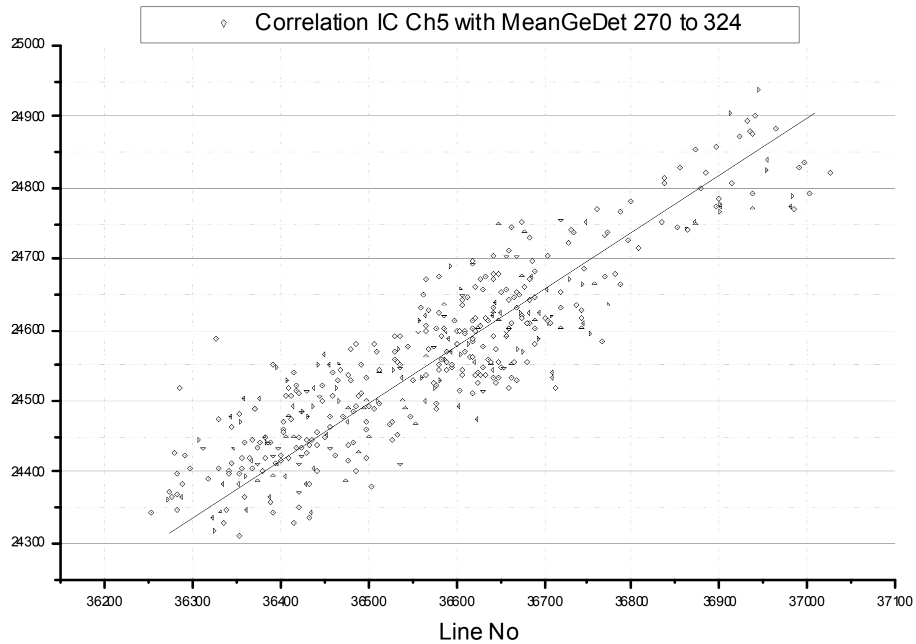

Fig. 7. Correlation plot of intensity points in Ge-detector vs. ion chamber.

Fluorescence detection

The spectra in fig. 4 have been analyzed with respect to the origin of the peaks. As in the previous run the fluorescence signal was very well visible without additional scattering material. Adding a water surrounding created a large number of additional peaks and attenuated the desired intensity of the fluorescence radiation to the level of loosing it completely in the background. Fig. 8 gives an account of the situation where the calculated expected peaks are plotted as function of angle. It should be noted that, because of the effect to record in the Xe proportional counter, in addition to the full energy E_0 as well two escape peaks $E_{esc1} = E_0 - K_\alpha$ and $E_{esc2} = E_0 - K_\beta$ appear while the second one is consideraly weaker. However the Gd-fluorescence produces as well the series of K_α and K_β – lines. In this way a rather complex scenario is created and reproduced in fig. 8a and 8b. It is easily recognized that the separation of the fluorescence lines (mainly the escape lines) for the 50.2 keV data is not very efficient because the Compton scattered events cover this region most of the time. For the 65 keV data the sets are well separated. Clearly the multiple scattered events are not included into the calculations but are present in the measured spectra (fig. 4) and it can be concluded that the influence is tolerable.

In addition Monte Carlo calculations have been started confirming the results. It is expected that more precise measurements out of the horizontal plane (lin. polarization) still improve the result and are foreseen to be investigated in the next run (September 04).

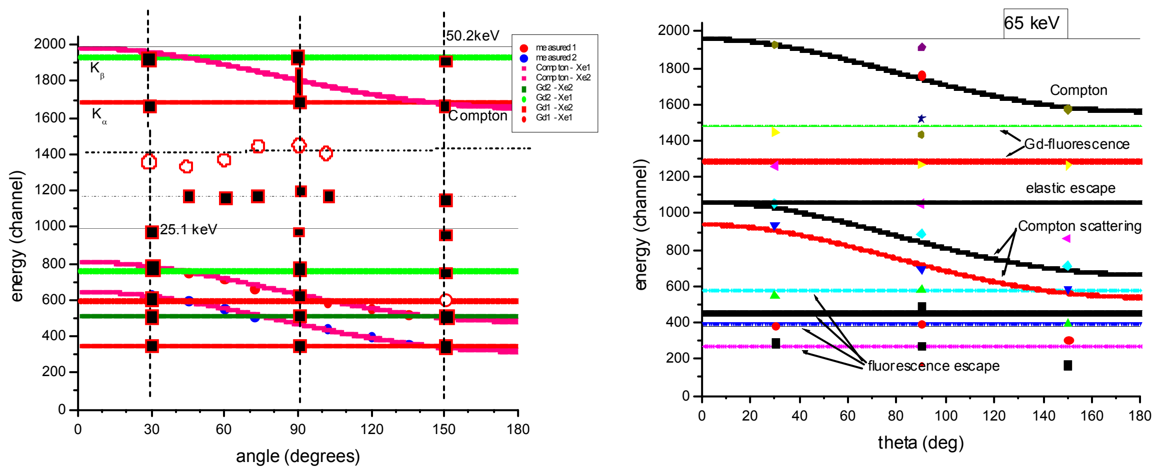

Fig. 8 position of spectral peaks as function of scattering angle. Lines: calculation, points: identified peaks. a. left: 50.2 keV, b. right: 65 keV.

4. Experimental program in the next runs (September, November 04)

a) The main goal is the measurement of the transmission measurement with Gd contrast agent for a quantitative study in a test animal using the Ge- detector. In particular the arteries of the left CA (LAD and CX) will be investigated. First time resolved measurements of the myocard perfusion will be obtained using optimized projections and optimizing the temporal separation between images. The data will be used as input data for the development of a cardiac perfusion model.

b) The spectral response of the Gd-fluorescence as compared to scattered radiation (elastically and Compton scattering) will be optimized using the position sensitive multiwire drift chamber in a mounting allowing an angular scan.
The position sensitive detector with a test collimator of full length (400 mm) will be installed and simple phantoms containing Gd contrast agent will be imaged.