MPET-8

main module
preliminary V1.2

PET readout module

mesytec MPET-8 is a doubly wide NIM module which allows to connect up to 8 position sensitive photo multipliers coupled to scintillators (LSO, LYSO). The PMTs are grouped in two coincidence sections with 4PMTs each. For those two sections a fixed coincidence time window of 30ns is implemented. Signal amplitudes, positions and coincidence time of the two responding PMTs are digitized and transmitted as 10 bit values.
The modular system may consists of 8 to 32 PMTs per subsystem. The number of subsystems is not limited. A subsystem consists of up to four MPET-8 modules with the corresponding PMT frontend electronics which adapts to different PMTs. An intelligent central processing device (MCPD2) for system control and buffering transmits the data via Ethernet to a PC. The MCPD2 can serve up to 4 MPET-8 modules. An open source data acquisition and raw data visualisation software running on PC LINUX systems and a software interface to access the data via customer software is available.

Features:

- Readout of 8 twodimensional position sensitive photo multiplier tubes (H8500..)
- High rate capabilty (100kHz per PMT)
- typ 1.5% FWHM position resolution
- Good position and amplitude linearity
- Constant fraction discriminators for time signals
- 1.4ns FWHM coincidence timing for LSO or LYSO crystals.
- Remote gain and threshold adjust
- Easy interfacing to different PMTs.

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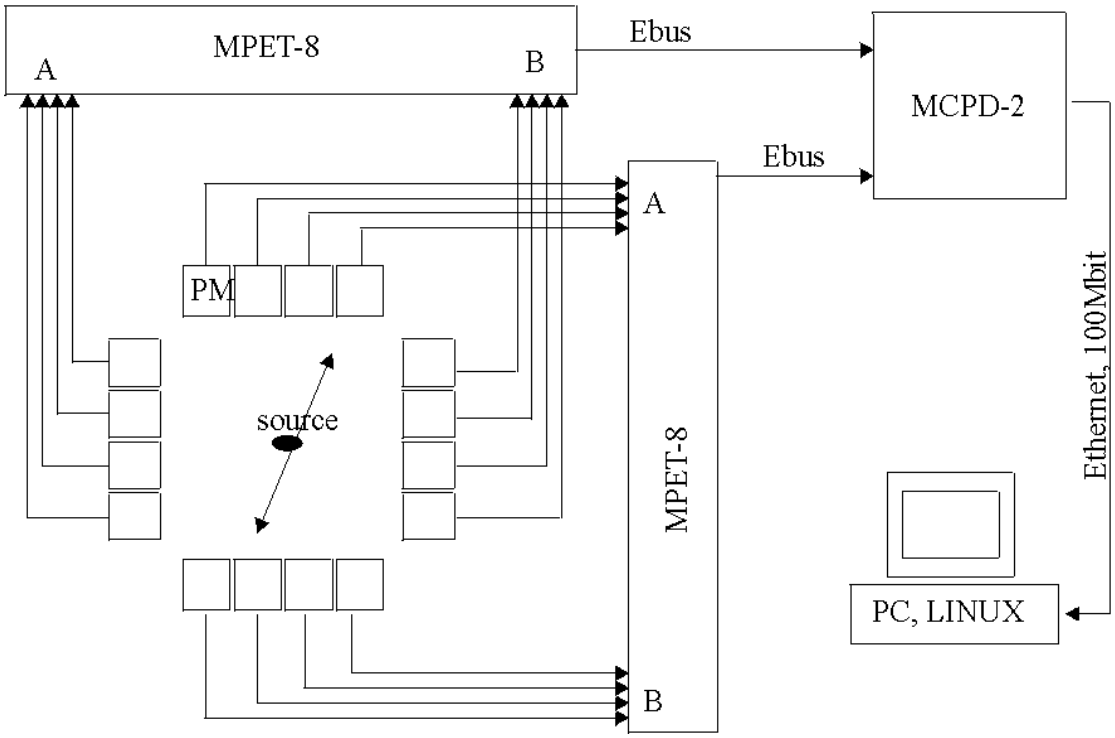
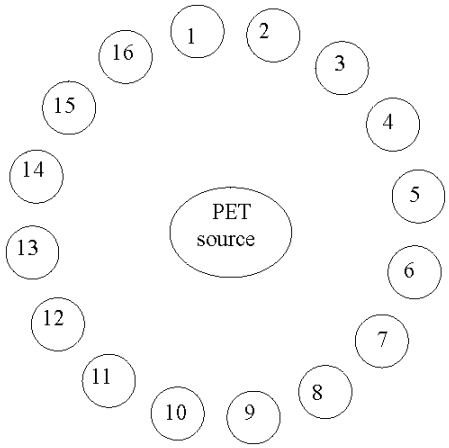
The MPET system topology

Compact system, 4 panels



Round system



A) Compact system: two MPET-8 modules for 16 PMTs

The following setup can be realized with two modules:
PMT1,2,3,4 is in coincidence with PMT9,10,11,12 (= MPET-8 module 1)
PMT 5,6,7,8 is in coincidence with PMT13,14,15,16 (= MPET-8 module 2)

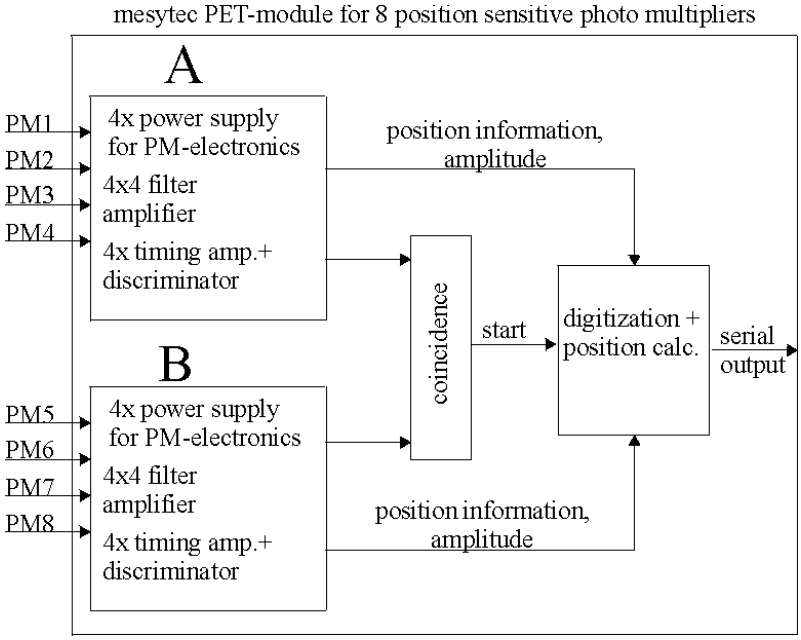
B) Efficiency optimised system: four MPET-8 modules for 16 PMTs

With 4 MPET8-modules (each PMT-output is fed to two module-inputs) the following optimised setup can be realized:
PMT1,2,3,4 is in coincidence with PMT9,10,11,12 (as above) (= MPET-8 module 1)
PMT 5,6,7,8 is in coincidence with PMT13,14,15,16 (as above) (= MPET-8 module 2)
in addition:
PMT3,4,5,6 is in coincidence with PMT11,12,13,14 (= MPET-8 module 3)
PMT 7,8,9,10 is in coincidence with PMT15,16,1,2 (= MPET-8 module 4)

so together we get a coincidence of:
PMT1,2 is coincident to 7,8,9,10,11,12
PMT3,4 is coincident to 9,10,11,12,13,14
.....
.....

MPET-8 functional overview

It includes timing coincidence and 10 bit digitization of amplitudes, positions and timing. The size is 2/12 NIM. It amplifies and processes data of up to 8 two dimensional position sensitive photo multipliers.
Of course the groups (A, B) can also have fewer PMTs. So the minimum system would be two PMTs, one in each group. For a larger system more modules can be used.



The positions of the two coincident PMTs as well as their amplitude and also the time shift between the two PMTs are digitized and transmitted via serial bus. Timing resolution (2PMTs H8500 in coincidence, for directly coupled LSO crystals with 1.8x1.8mm^2 x 10mm) is 1.4ns FWHM.
The transmitted bits contain the following information:

2x2bits ID, coincidence status
10 bit timing.
2x 10 bit amplitude,
4x 10 bit position,

Maximum rate is 100kHz per PMT (800kHz all 8 PMTs), coincident rate for all PMTs for transmission of all information: 30kHz.

The module works with a common threshold for all PMTs (which should be set to a low value) and a variable gain for each PMT input. The gains can be left on mid position when individual HV supplies are used for the PMTs. Then adjust the gain via HV.
If a common bias HV is used for several PMTs, you can adjust the PMT gain differences via gain poti. All values are remote controled via PC software.

Connectors

- Dynode signal input: LEMO standard connector.
- Flat wire 2x8 pole connector. Use twisted pair cable. Includes power supply from MPSD-8

PIN	Discription
1	neg B+C
2	pos B+C
3	neg A+D
4	pos A+D
5	neg C+D
6	pos C+D
7	neg A+B
8	pos A+B
9	gnd
10	gnd
11	-5V
12	+5V
13	gnd
14	+6V
15	gnd
16	gnd

When connecting one PMT to several MPET-8 mudules, connect pins 11 to 16 only once. There should be only one termination at the end of the PMT cables, so remove all but one termination connector (inside MPET-8 case).
Connect the chain IO-connectors at the front panel. always connect "high" to "low". The signals suppress multiple transmission of all coincident MPET-8 modules for one event.

Input sensitivity
The internal gain setting varies the gain by a factor of 4. Larger factors can be adjusted by variation of the PMT Bias voltage.
Legal gain settings are from 64 to 255 corresponding to a gain variation of 0.5 to 2. At gain = 1 (setting 128) the sum amplitude at the input for full range is 1V (sum of A+B+C+D).
For the H8500 interface this corresponds to a charge of 1.5^{-10} C or 10^9 electrons.

Power consumption:
no PMTs connected
+6V, 600mA
-6V, -150mA

With 8x H8500 base drivers connected:
+6V, 1000mA
-6V, -360mA

Data Processing

The goal is to get two 2d-positions (or crystal IDs) from two PMTs which respond in coincidence. Strict (or variable) conditions on coincidence time and amplitude are wishful. In this concept most of the signal filtering is made via software. The hardware threshold should be low to allow a software threshold or (window) setting after software calibration.

The following 9 values are transmitted per event:

- Addresses of the two responding PMTs (for example 1A, 3B)
- Amplitudes of the two PMT signals (10 bit each)
- Positions X0,Y0,X1,Y1 of the two responding PMTs, 10 bit each .
- Relative timing of the two PMTs. (10bit)

The following steps are necesary to process the events by customer software.

- Identification of the crystal positions, implement a filter window for each position.
- Correct amplitudes of each crystal (slope parameter)
- Implement a common amplitude window for the calibrated data

- For identical length of the PMT signal cables, a timing calibration usually is not necessary. A coincidence window can be directly applied to the transmitted timing information.

Operating the MPET-8

Step by step start up.

Electronics:

- 1 PC ,
- 1 NIM-bin,
- 1 MCPD-2 module,
- 1 MPET-8 module,
- 2 H8500 base drivers
- 2 PMTs
- 2 Channels of HV suppl for PMTs

Cables:

- 1 Ethernet PC to MCPD-2,
- 1 BNC + Feedtrough terminator (or T-piece with 50Ohm terminator) for eventbus
- 2 twisted pair cables (2..5m long) to connect base drivers to MPET-8
- 2 Lemo cables, same length as twisted pairs, length shoulde be matched to +-0.5m.

Proceed the following way:

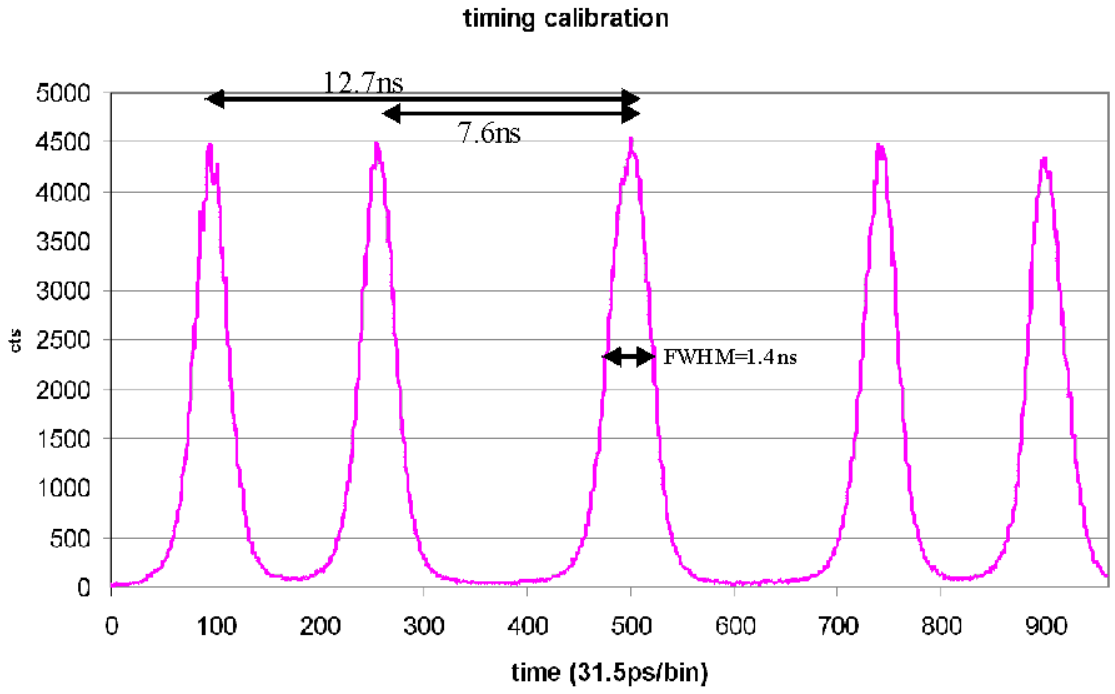
- Put MPET-8 and MCPD-2 to the NIM-bin.
- Power up the bin (both modules may also be inserted to a powered bin)
- The power LEDs of both modules should light up.
- connect the eventbus BNC (up to 20m). It must be connected directly to one of the 4 bus outputs at MCPD-2 and must be terminated at the MPET-8 module with 50 Ohm.
- Connect Ethernet. For test use a cross over cable directly conneted between PC and MCPD-2.
- Now you can start the MPET software. With the built in pulser you can produce coincident data at any two input channels and control amplitude, position and timing spectra.
- Now connect two PMTs with base drivers via twisted pair and Lemo cables to MPET-8 input A0 and B0.
- Apply bias HV to the H8500 PMTs (about -750V).
- The green input LEDs should light up (from intrinsic LYSO decays) when the signals get above the threshold. Without a pet-source there should not be coincident events, which means the bus LED does not light up.
- When you put a pet-source between the two PMTs the bus LED sould light up because of the coincident events.
- When you start the software (with the default setting) you should see the data in the spectra.

Measurements with MPET 8

Setup: two H8500 (Hamamatsu) PMTs. Two crystal arrays were used: 6x10, 10x10, size 1.8x1.8x18mm. The crystals were illuminated by a 22Na source with 200kbq. PMT bias voltages were 715V. To get reasonable plot sizes, the 2D spectra and projections out of 2D spectra are sown in 256x256 resolution, although the rawdata are transmitted in 10 bit format (1024-64 bins).

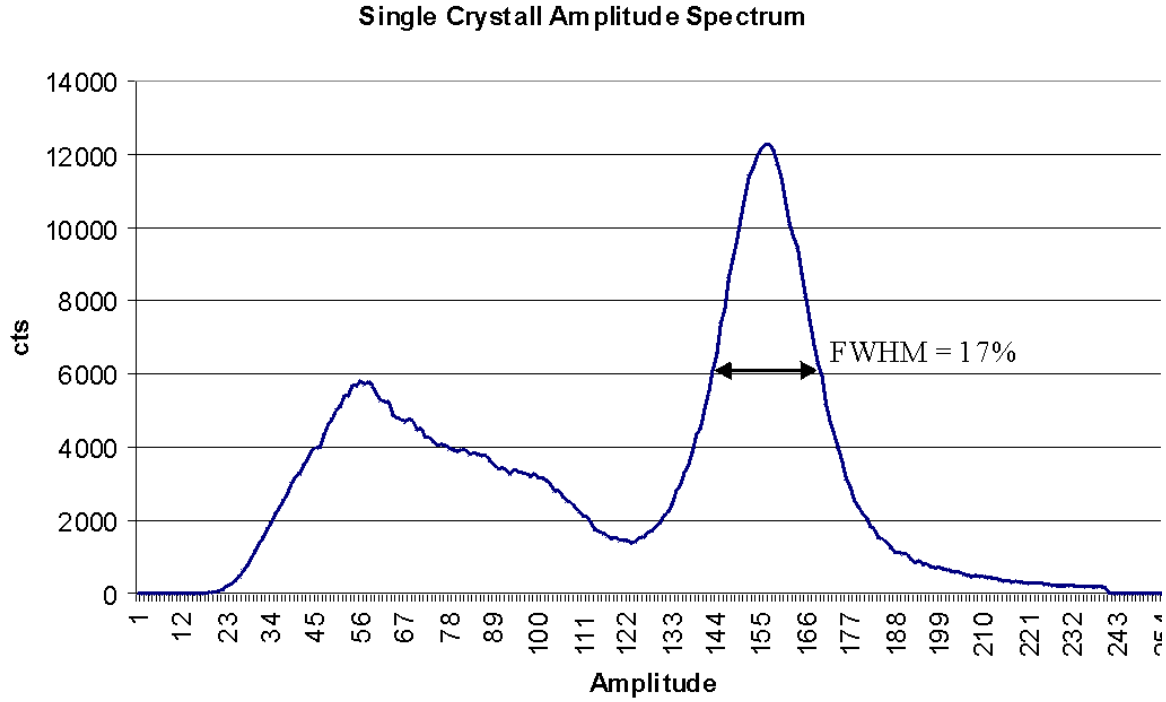
Coincidence timing resolution

Measurement of time resolution with two PMTs H8500 and LYSO scintillation crystals aplied. A 22Na positron souce was used inbetween the two PMTs.
The coincidence window was measured to be open for 35ns. The timing range in the spectrum is 30ns. (Measured with a 7.6ns and a 12.7ns delay cable which was applied on either side of the dynode outputs). The timing resolution was measured to 1.4ns FWHM.

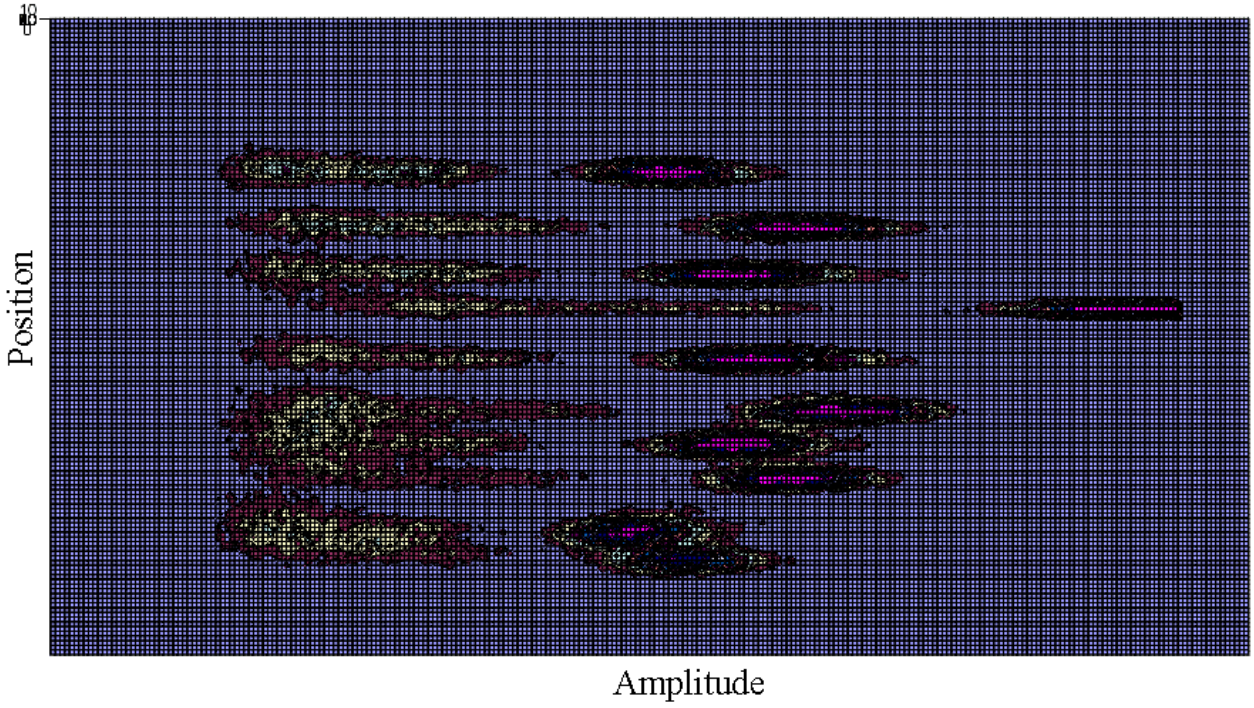


Amplitude resolution

The detected amount of light is influenced by the crystal quality (reflective coating, tranparency) and the position dependent quantum efficiency of the PMT.



Amplitude distribution of 10 crystals. The lower two are at the edge of the PMT:



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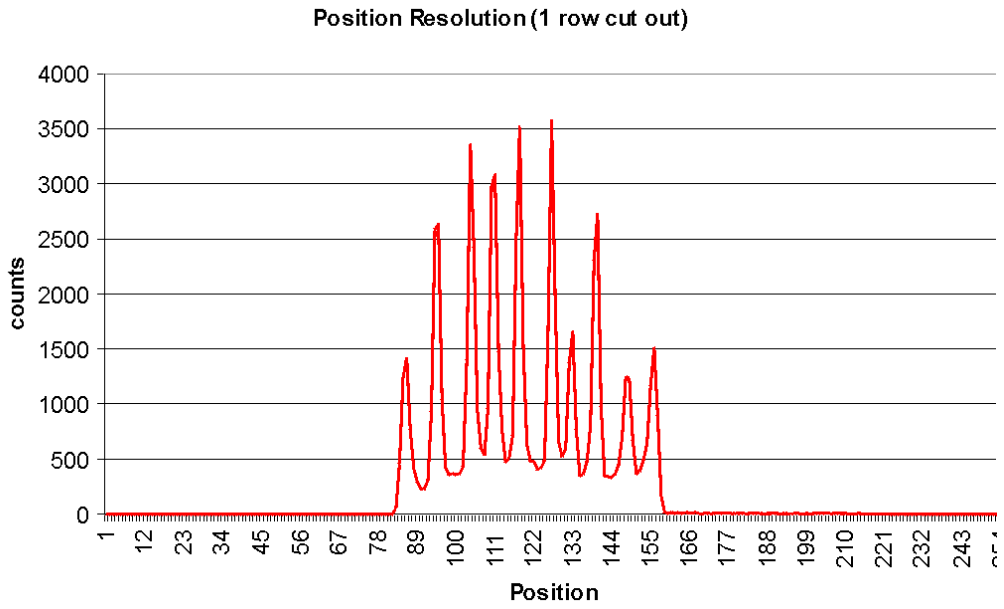
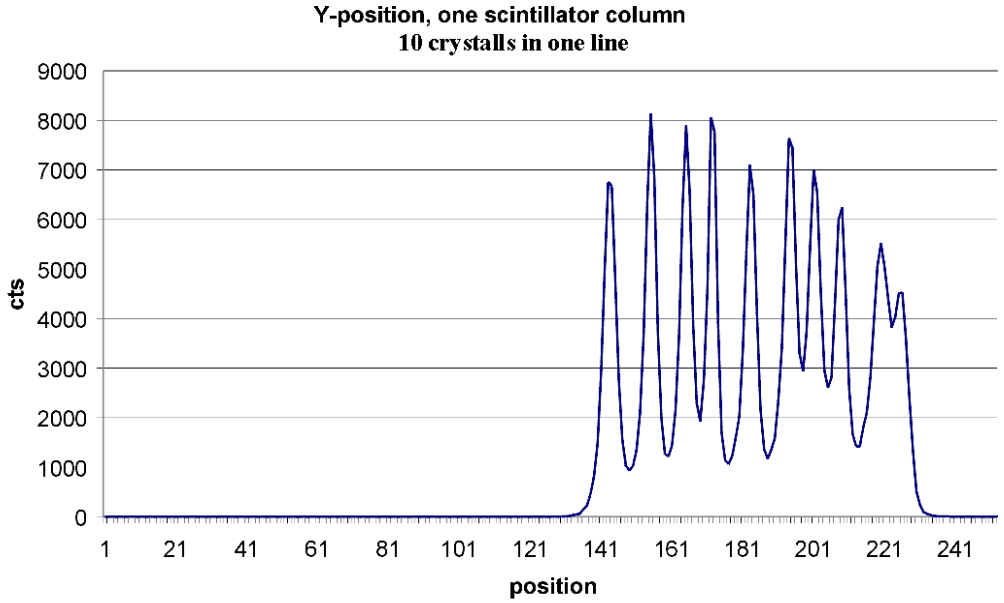
Position resoution

The position resolution was measured with two arrays of crystals: both with a pitch of 1.8mm. From 2-D-spectra one row was separated to analyse the position resolution.
An average value is about 0.6mm FWHM. There is some 10% "background"
between the peaks, which can be explained by compton scattering.



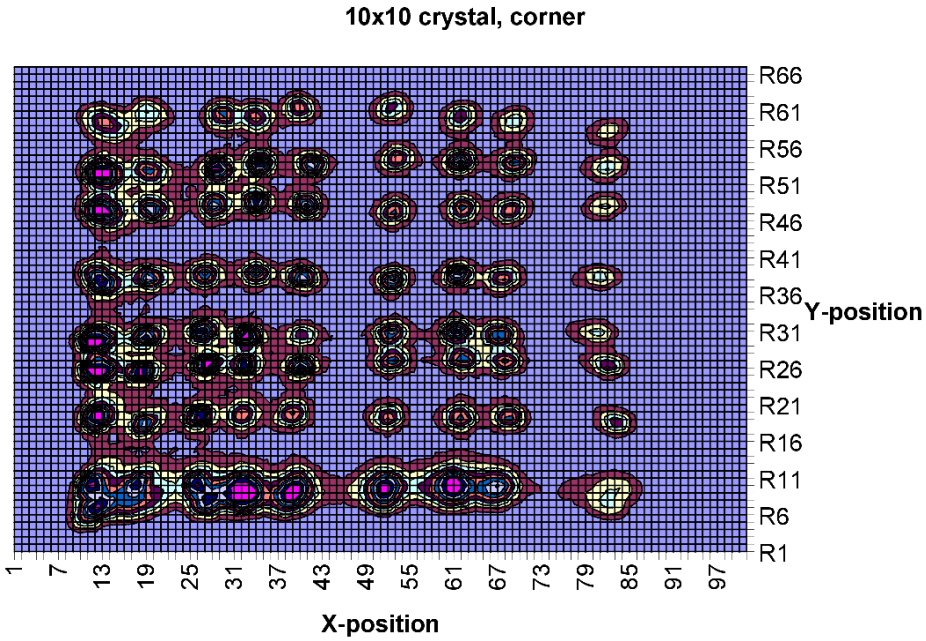
Setup with crystals near the edge of the PMT. Starting with the middle of the edge pads of the PMTs, the resolution is not significantly influenced by edge effects.



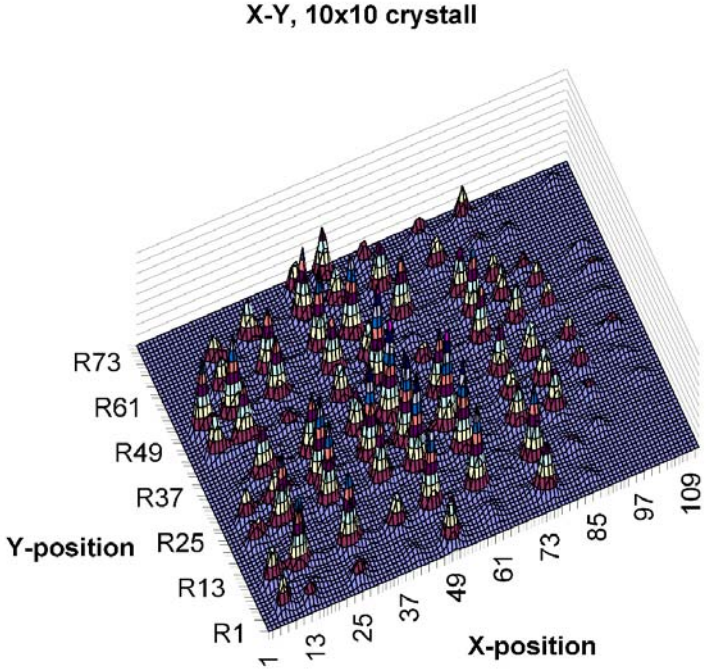
Good positon resolution is maintained at the PMT edges until the middle of the edge pads in X direction. In Y-direction the PMT has only half pads at the edges, so the non position resolving area is a bit larger. The area with goo resolution is about 7 x 6.5 pads or 35x32mm.

2-D spectra:

Crystal 10x10 matrix with 1.8x1.8mm^2 . Position lower left corner, aligned to the visible outer pad corners of the PMT pads.
Lower left corner oft the PMT:



Middle of the PMT:



Upper right corner: