More tests for the laser wire scanner detector in PETRA:

Test of a $PbWO_4$ Crystal, low energy range

K. Wittenburg, DESY -MDI-

Internal Note DESY MDI-02-01
29-Oct-01

Introduction

It is planned to use $PbWO_4$ crystals for the detector of the laser wire scanner in PETRA. The response of this material to low energy gammas and electrons from radioactive sources are studied and described in this note.

Setup and measurements

The studied $PbWO_4$ crystal is a loan test crystal from a Russian manufacture (Ref. 6), which is one of two or three worldwide manufactures of this crystal type. It has the dimensions $1.5x1.5x23cm^3$. It was optically matched to a Photomultiplier (Hamamatsu R580, Ref. 1) window by optical silicon grease (Ref. 2). The crystal was wrapped in high quality white printing paper. The Photomultiplier was connected via a charge sensitive preamplifier (Canberra 2005) and a shaping spectroscopy amplifier (Canberra 2021, Ref. 3). The shaping constant was 4µs. The PMT voltage was set to 1700 V. The signal treatment was the same as already described in a previous note (Ref. 4). The crystal itself looks a little brown, with some dark clusters at one end.
Radioactive sources (^{137}Cs, 660 keV photons; ^{106}Ru, up 3.4 MeV β–rays) was used to check the response of the setup. The spectra are shown in the next figures (1a-d; note that the amplitude was negative):

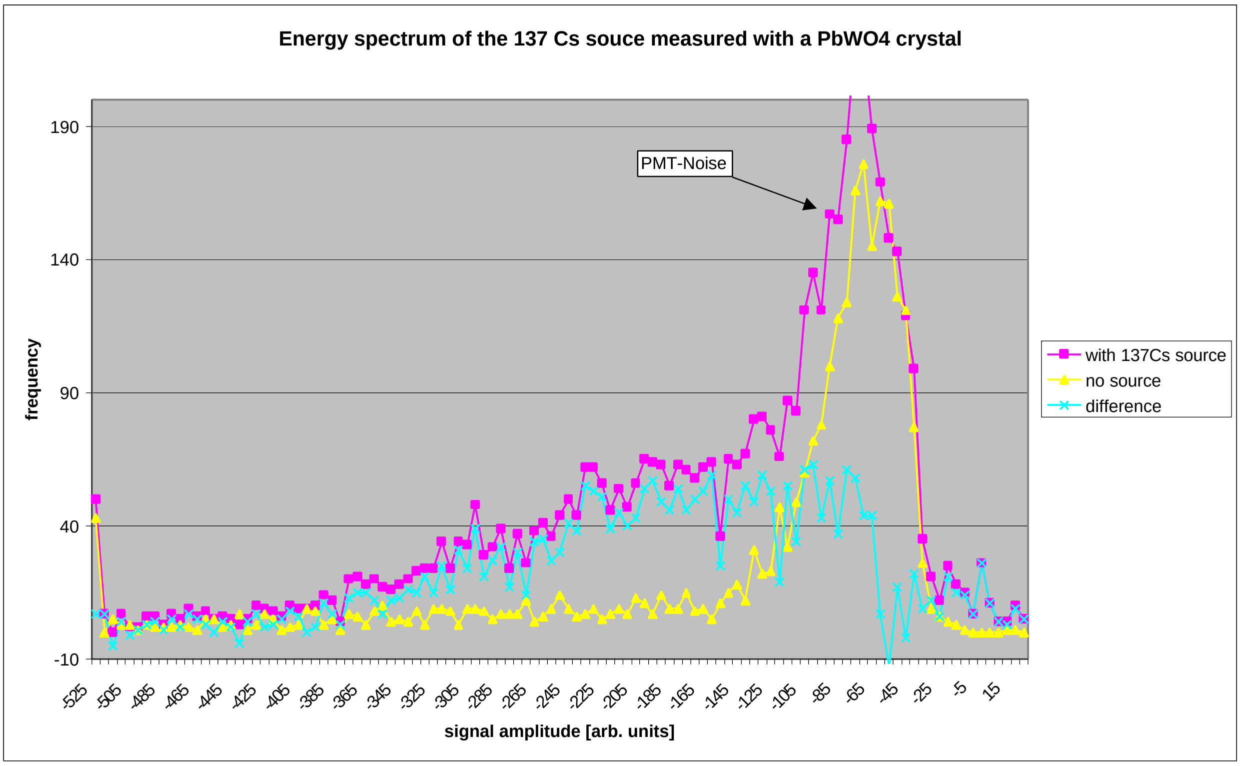

Fig. 1a: Measured spectrum of a 137Cs source, high gain

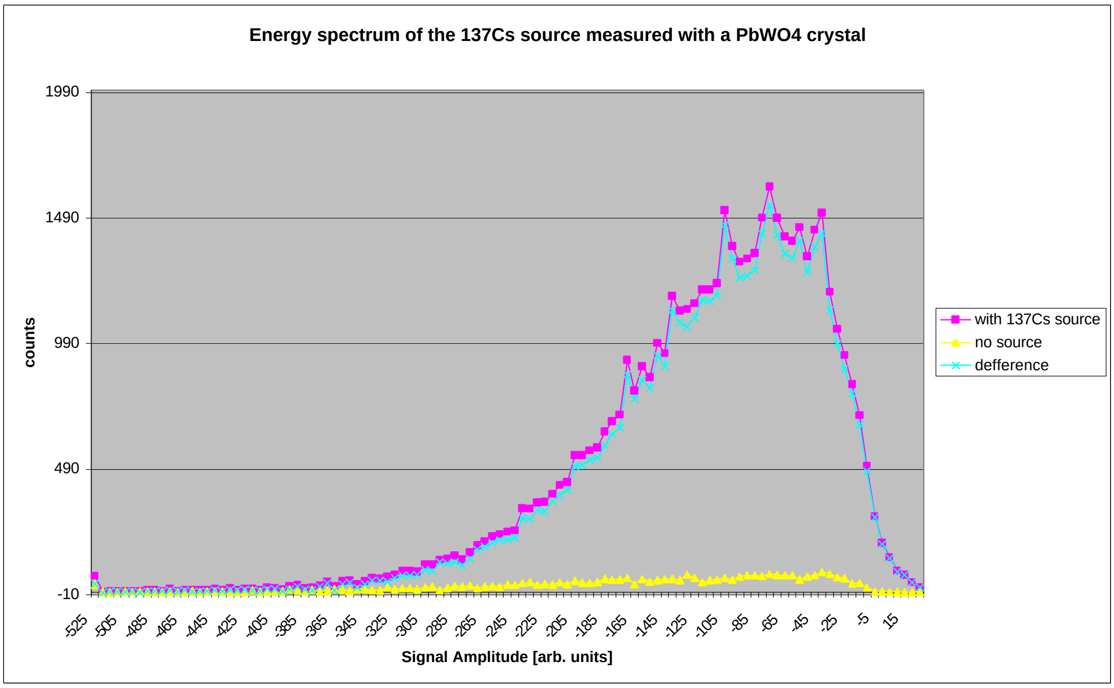

Fig. 1b: Measured spectrum of a 137Cs source, lower gain, more statistics. The higher threshold of the discriminator had suppressed the noise of the PMT.

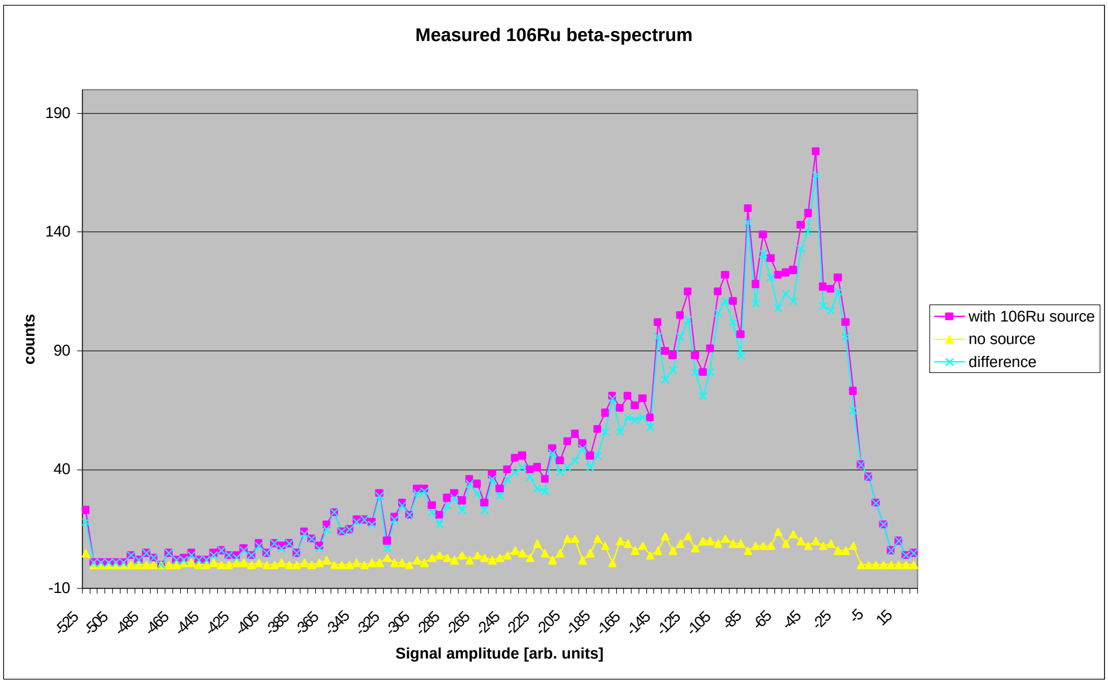

Fig. 1c: Measured spectrum of a 106Ru source (up to 3.4 MeV βs), lower gain. The higher threshold of the discriminator had suppressed the noise of the PMT.

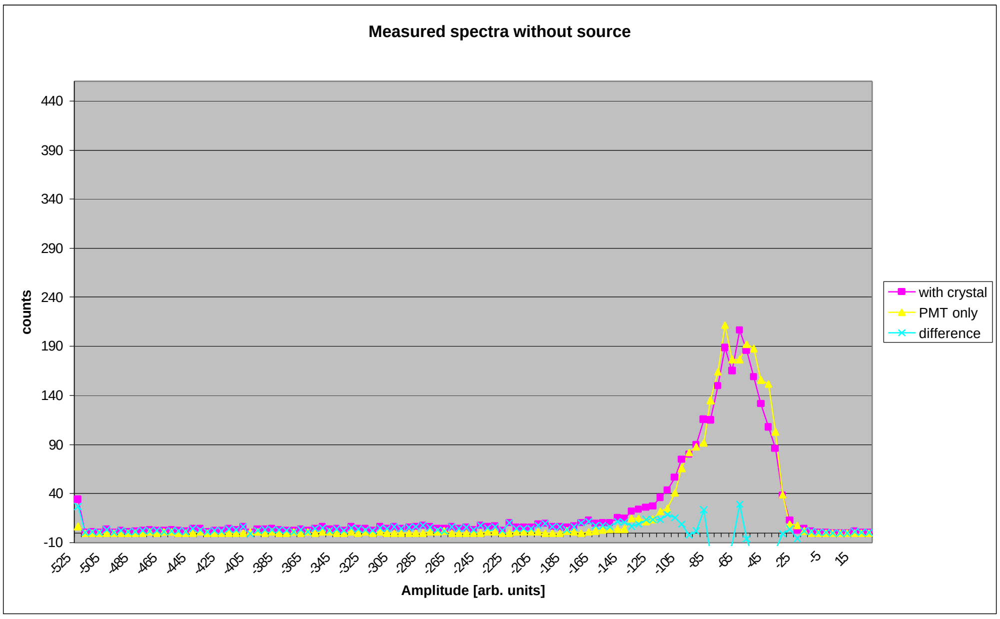

Fig. 1d: Spectra with and without the crystal connected to the PMT

Observations:
1) No typical 660 keV peak can be observed.
2) There are counts above the noise level even without a source.

To 1) No 660 keV peak observable: Probably the intrinsic resolution of PbWo4 is not good enough to detect the peak. The manufacture of the crystals wrote me a mail concerning the light yield of the crystal: "*Detected amount of light from scintillator (Technical Light Yield, TLY) is a product of Light Yield and Light Collection. Light yield of PWO (1 cm3) is 18-20 phe/MeV . The TLY of crystals with dimensions a,b,c where a is length and b x c is cross section depends on the ration between a and b,c. Let say when a/b and a/c are more than 10, the conditions for the light collection are not optimal and TLY decreased. Moreover ,when crystal is rectangular, the situation even worse and TLY may be about 50% of LY or even worse. The situation may be a bit improved while crystal is a bit tapered. The LY about 12 phe/Mev can be achieved in this case. So at room temperature 12phe/Mev from tapered crystal with PMT readout is the best option to be proposed. The TLY increase through cooling can be achieved (Temperature coefficient LY is 2%/C) however decay time also will be increased.*"
The yield of Photoelectrons (phe) can be calculated as following:
The amplitude of the PMT at 1700 V for the ^{137}Cs source was about (including 50% error) 60 mV on 50 Ω (=0.12 mA) within 5 ns (see Fig. 2). The gain of the PMT at this voltage is about 5 x 10^6. So the charge leaving the photocathode is about 1 photoelectron/660 keV, which is in good agreement with the expected phe from the manufacture, taken into account, that the crystal looks a little brownish. The statistical error and therefore the resolution is $1/\sqrt{1}$ = 100%.

2) Dark counts: Maybe due to 'self scintillating'? Maybe the crystal was used in an accelerator environment and is a little bit activated? However, the main amplitudes are in an energy range of below about 2 MeV, therefore it will not be important for the laser wire application.

Timing

For possible multi-bunch measurements, the pulse decay of the detector should be faster than the bunch distance (96 ns in PETRA). The pulse decay of the PbWO4 crystal was measured with a 5GS/s Tektronix scope type TDS 684A. The PMT output was directly connected to the scope, using a 50 Ω termination. The results for 137Cs pulses and for higher amplitudes (probably due to cosmics) are shown in Fig. 2 a-b.

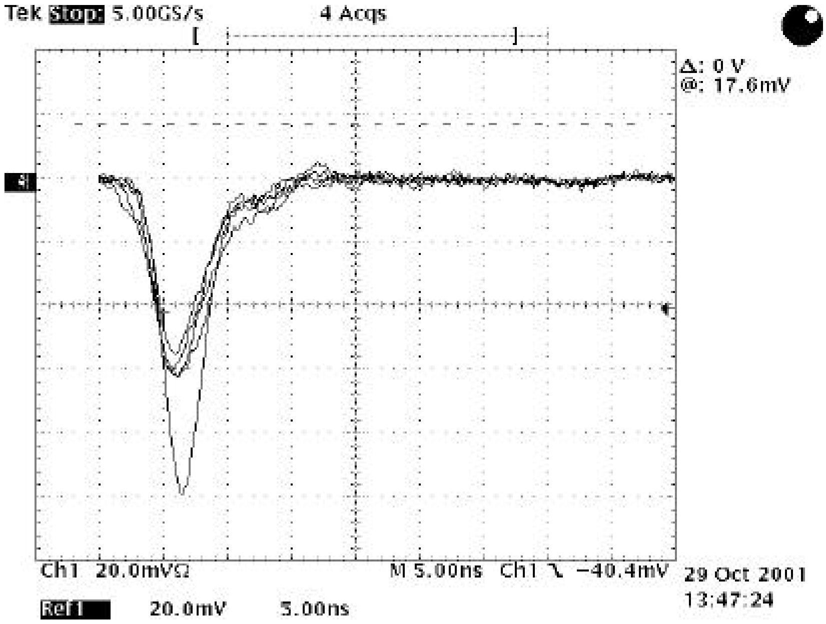

Fig. 2a: Response to a 137Cs source, 20 mV/div, 5 ns/div, five different traces

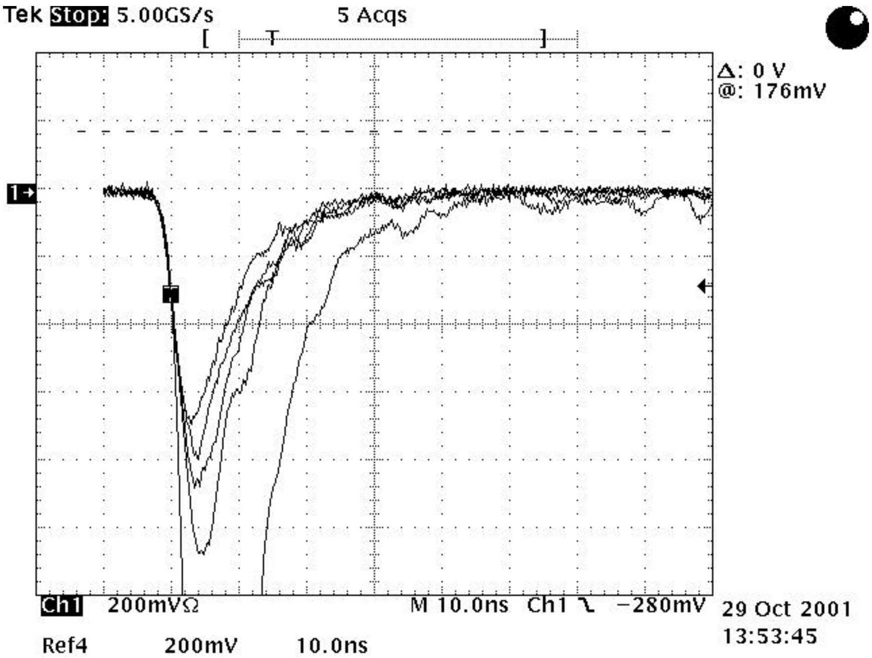

Fig. 2b: Response to cosmics, 200 mV/div, 10 ns/div; five different traces.

The Figures show, that the signal is decayed after at least 50 ns down to a level of less than 1% in amplitude. This was also expected by the manufacture: *“Let us define your requirements for timing parameters. Are they related to amplitude of a signal or to its integral? When we claim 97 % it means that 97% of the light is emitted within 100 ns. On the other hand the amplitude of the signal will be less than 1% in 100 ns“* .

Conclusions

The light yield and the timing properties of a $PbWO_4$ crystal behaved as expected. Further tests with cosmics are planned (see Fig. 3). At 1.5 cm width one can expect an energy deposition of 15.5 MeV, assuming dE/dx = 1.25 MeV cm^2/g and $\rho = 8.28$ g/cm^3.

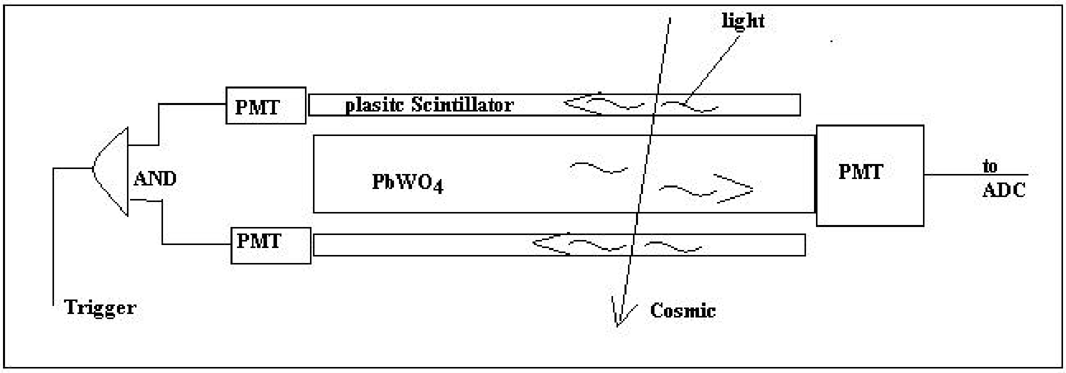

Fig: 3: Sketch of the test-setup for cosmics.

A test with a 3 x 3 matrix at higher particle energies will be useful. The DESY test beam might be a good candidate. It provides electrons up to 7 GeV. But note the difference in the light creation process in the crystal between one 7 GeV electron (test beam) and a huge amount of low energy photons with a sum of 7 GeV (laser wire).

The preferred crystal size is 23 x 23 x 150 mm^3, according to the simulations of Freddy Poirier:

"I just simulated quickly the energy deposit with Geant4 of the entire spectrum for our signal (without any beampipe). The difference in energy deposit for two crystal with dimensions 69*69*150mm (dimension equivalent to a 3by3 matrix crystal with front-face 23*23mm) and 54*54*150mm (3*3 matrix with crystal of 18mm front-face) is 1 GeV approximately for1000 photons produced at the interaction point.

This will require further checking as no beampipe wall has been added:

I've just taken the previous result where approximately 36% photons were reaching the detector. I would definitively go for the 23*23*150mm (if possible) PMT R6237 (Ref. 5) seems to be the good one".

If we will order the crystals right now, we will have them before Christmas, as promised by the manufacture. The crystals can be ordered at Ref. 6 for about 500 USD/unit: "…In case if crystal from *regular production will be used the price will be the same for 20x20 and 22x22 and 18x18 cross section crystals-500 usd/unit. Crystals which can be produced for you will have length 230 mm and any cross section within 25x25 mm …". … It* (the delivery*) will be possible before Christmas.*

One large PMT R6237 will fit he whole crystal matrix, which has the advantage of no intercalibration problems.

References

Ref. 1: http://cat1.hpk.co.jp/Eng/catalog/ETC/R580_TPMH1100E02.pdf
Ref. 2: http://www.bicronne.com/bc630.htm
Ref. 3: http://ww2.canberra.com/PCatalog.nsf/all/NIM_PDF/$file/3m2022.pdf and
http://ww2.canberra.com/PCatalog.nsf/all/NIM_PDF/$file/3m2005.pdf
Ref. 4: **Preliminary tests for the background measurements for the laser wire scanner detector in PETRA;** K. Wittenburg, DESY -MDI-, Internal Note DESY MDI-01-01, 19-Apr-01
http://desyntwww.desy.de/mdi/downloads/preliminary PETRA meas.pdf
Ref. 5: http://www.hpk.co.jp/eng/products/Etd/pmt-ho3e.htm
Ref. 6: Joint Stock Company Bogoroditsk Plant of Techno-Chemical Products (JSC BZTKhi Bogoroditsk)
Address: 301800 Russia, Tula region, Bogoroditsk
Telephone: (08761) 223 59, Fax: (08761) 217 74,
e-mail: korzhik@inp.minsk.by