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Measurements of Photon Response with $PbWO_4$ Crystals and Flash-ADC readout for PANDA

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Measurements in collaboration with:
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PANDA meeting
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Outline

Motivation

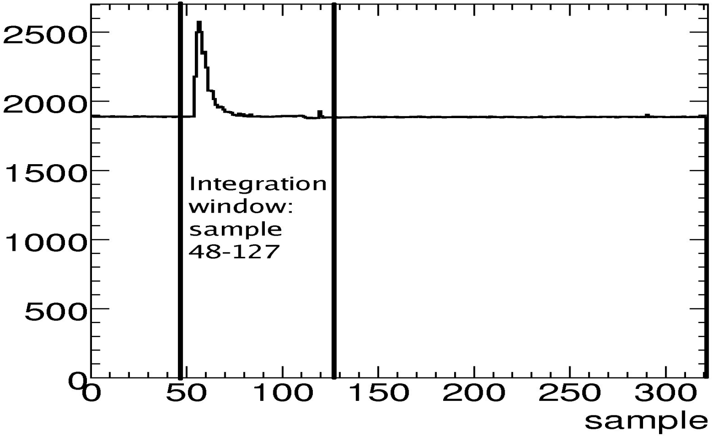
- Investigate energy response of 5×5 array of PWO crystals of forward endcap shape
- Determination of energy resolution between 13 and 84 MeV important due to the the large dynamic range of the detector (a few MeV to 12 GeV). This can only be done at MAX-Lab since MAMI provides E_γ >40 MeV.
- MAX-Lab synchrotron facility in Lund unique for its low energy photons - tagged photon beams down to 10 MeV available
- Investigate performance of Flash ADC read-out.

Flash-ADC read-out

- 16 channel LEMO input ADC, 160 MHz with a resolution of ± 11 bit (bipolar)
- 1024 samples
- Time resolution of 1.5625 ns
- Feature extraction: Amplitude, Integral, Time of arrival, multiple pulses (times, minima, maxima, partial charges)

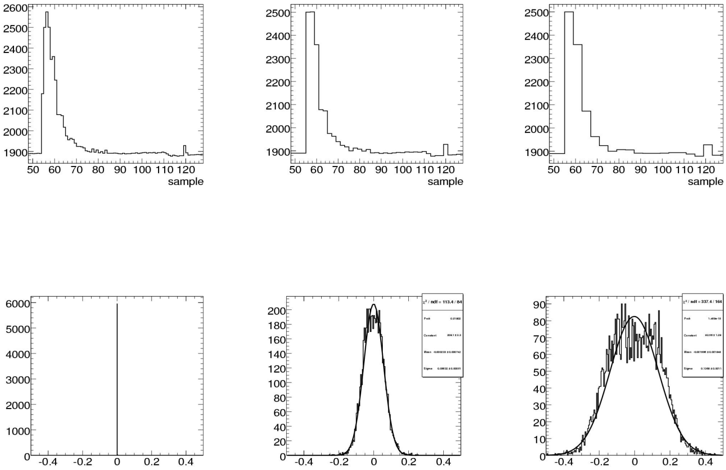
Pulse Shape

ADC information is given by the sum of samples in the integration window with the baseline subtracted.



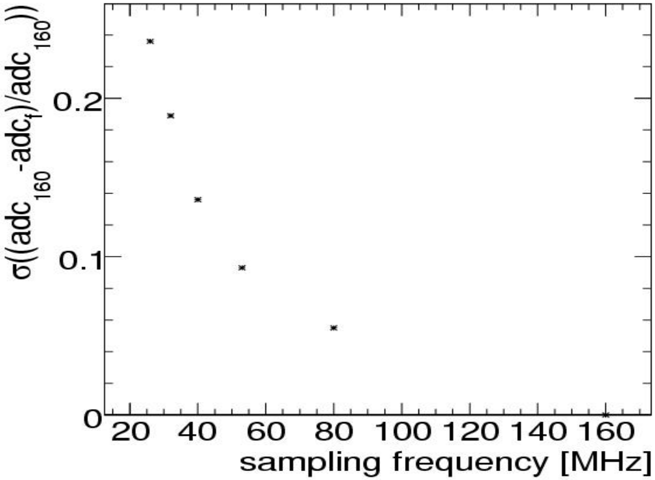
Variation of Sampling Frequency

160 MHz 80 MHz 40 MHz



Difference in ADC information between using 160 MHz and lower sampling frequencies.

Variation of Sampling Frequency



Crystal and Readout Specifications

- Tapered crystals with the forward endcap shape. Front end face measures 2.47$\times$ 2.47 cm^2 and the back end face 2.60$\times$2.60 cm^2. Length 20 cm.
- 25 crystals wrapped in reflective VM2000 and mounted in a 5$\times$5 array.
- Readout using 19 mm photo multipliers and peak sensing ADCs.
- 2$\times$61 tagged energies used: 12.7-60.5 MeV and 43.1-84.2 MeV.
- Measurements performed at -25° C.

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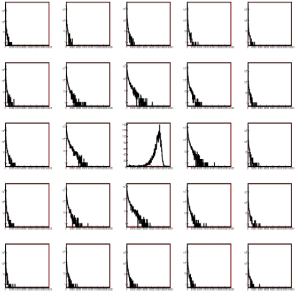
Analysis

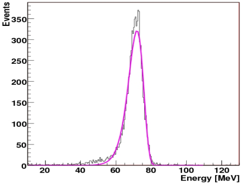
- Relative calibration by moveable table, centering each crystal in the tagged photon beam.
- Add energy contributions from the center crystal and the surrounding 24 crystals eventwise (see figure at 81 MeV)
- Resulting summed peaks have the shape of a Gaussian plus a tail, estimate peak position and sigma with a Novosibirsk fit:

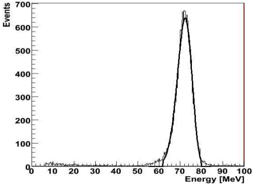
$$f(A,\tau,m_0,\sigma) = A \cdot e^{\frac{-1}{2}\left(\frac{\ln^2(1+\frac{\tau(m-m_0)}{\sigma\tau\sqrt{\ln 4}}\sinh(\tau\sqrt{\ln 4}))}{\tau^2}+\tau^2\right)} \quad (1)$$



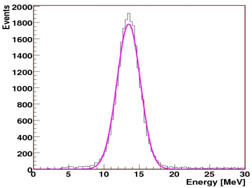
Results

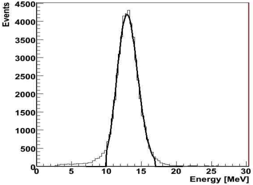
- A Novosibirsk function fitted to summed energy peaks at 72.1 MeV. σ=4.34 MeV and 3.45 MeV. τ=-0.27 and -0.12.





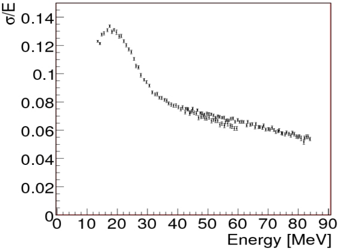
- A Novosibirsk function fitted to summed energy peaks at 12.7 MeV. σ=1.66 MeV and 1.47 MeV. τ=-0.01. and 0.07





Results

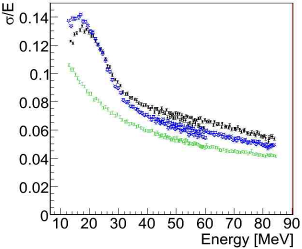
- Plotting σ/E versus incoming photon beam momenta gives results which are displayed in the figure below.

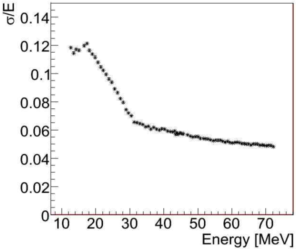


- Demanded relative energy resolution of detector: $\sigma/E = \frac{a}{\sqrt{E_{GeV}}} \oplus \frac{b}{E_{GeV}} \oplus c \leq \frac{2\%}{\sqrt{E_{GeV}}} \oplus 1\%$. This gives σ/E=20% and 9% at 10 MeV and 50 MeV, respectively.
- The energy resolution data above cannot be parametrized according to this formula (b and c become imaginary) but σ/E well below demands.

Simulations and Comparation

- Simulations using GEANT4 were performed for a crystal array of the type used for the Lund measurements. Input parameters similar to those of the analysis: 25 phe/MeV, σ_{noise}=0.5 MeV, threshold=0.7 MeV.
- The energy resolution obtained by simulations is overlayed on the experimental data in the figure below.
- Changing calibration parameters influences the resolution. Analysis is ongoing.
- Resolution from similar measurements but using peak sensitive ADCs can also be seen below. σ_{noise}=0.2 MeV and threshold just above.





Summary and Outlook

- Data taken in Lund for energy resolution measurements of a 5×5 array of PWO crystals at -25° C. Available energies are 13-85 MeV.
- Flash-ADC system used for the first time as read-out
- Analysis shows this system can be used for data taking with approximately the same results as using peak sensitive ADCs.
- Energy resolution results very good, values 15% below demanded values.
- Calibration can probably be improved to further lower the energy resolution.
- More statistics for one single energy needed to study the effect of sampling frequency on energy resolution.