# Response of a Close to Final Prototype for the P̄ANDA Electromagnetic Calorimeter to Photons at Energies below 1 GeV

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The P̄ANDA Detector

- Fixed-target experiment
- Almost 4π acceptance
- Cooled antiproton beam using
  - Electron cooling
  - Stochastic cooling
- Proton or heavy nuclear targets
- Beam momentum 1.5 - 15 GeV/c
- Peak luminosity of $2 \cdot 10^{32}$ cm^{-2}s^{-1}
- Unique self-triggering data acquisition concept

Target Spectrometer   Forward Spectrometer
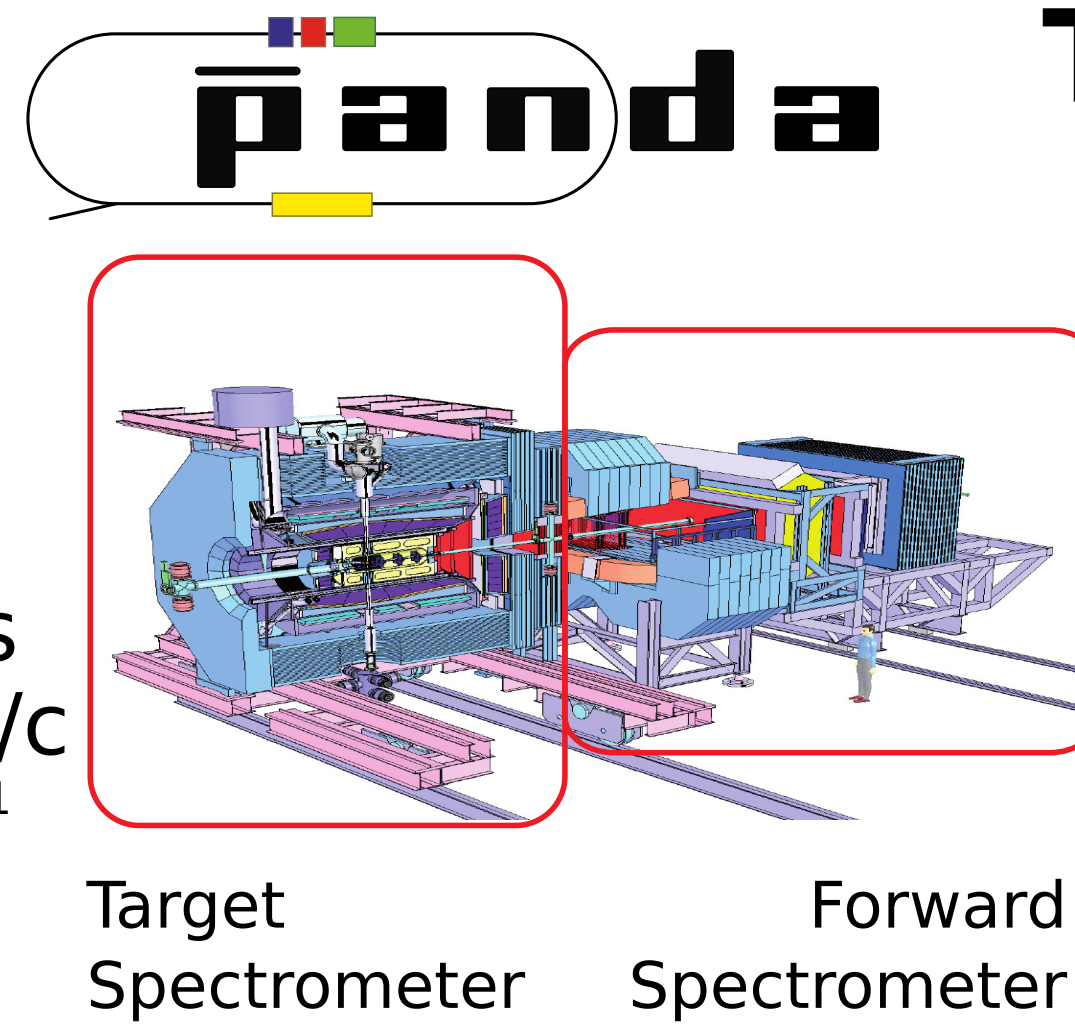
## The Electromagnetic Target Calorimeter

- Almost complete coverage of solid angle
- Efficient detection of photons in the energy range 10 MeV - 15 GeV
- Composed of ~16000 PbWO$_4$ crystals of tapered geometry
- Operation at -25°C enhances light output by a factor 4 compared to room temperature

Forward endcap
Barrel
Backward endcap
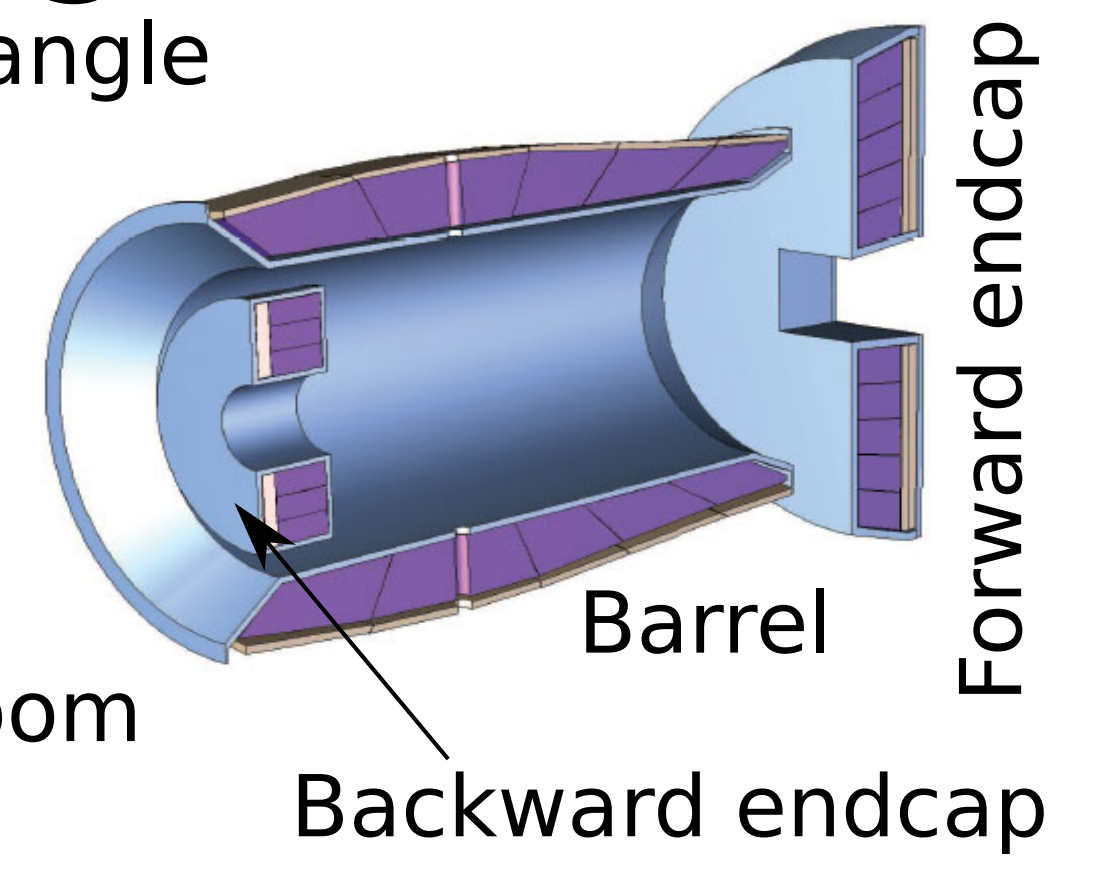
First step to the final design of the barrel EMC
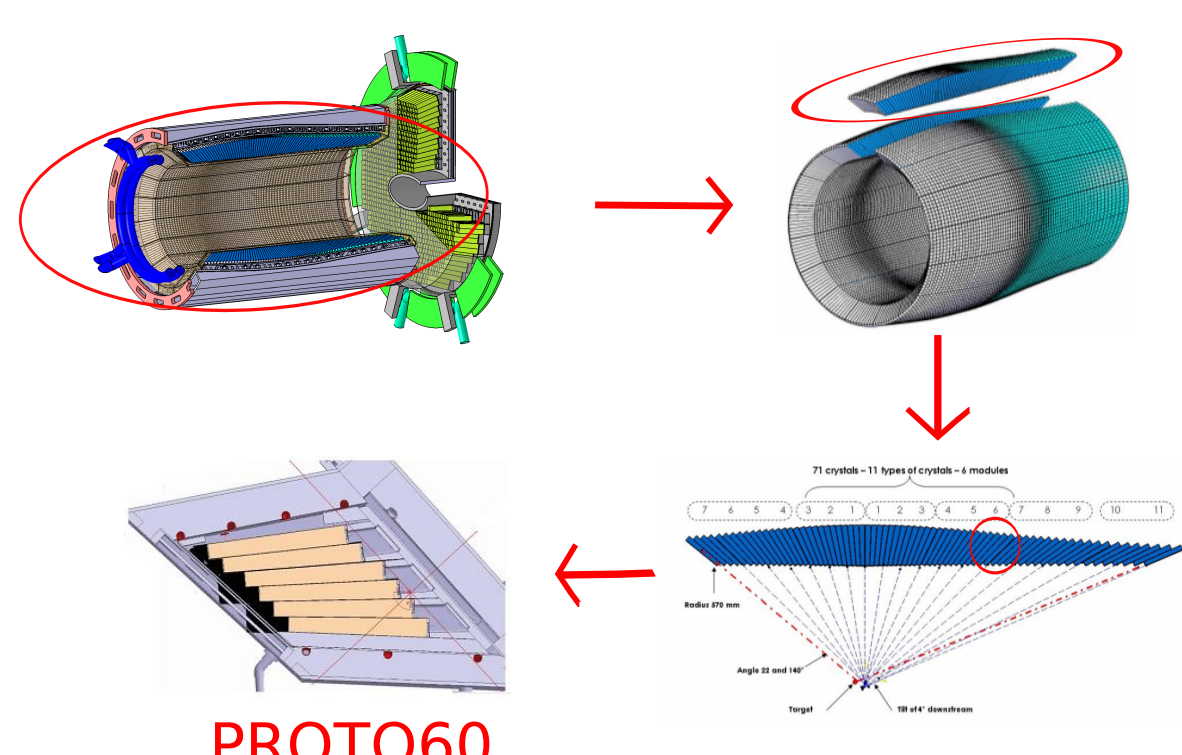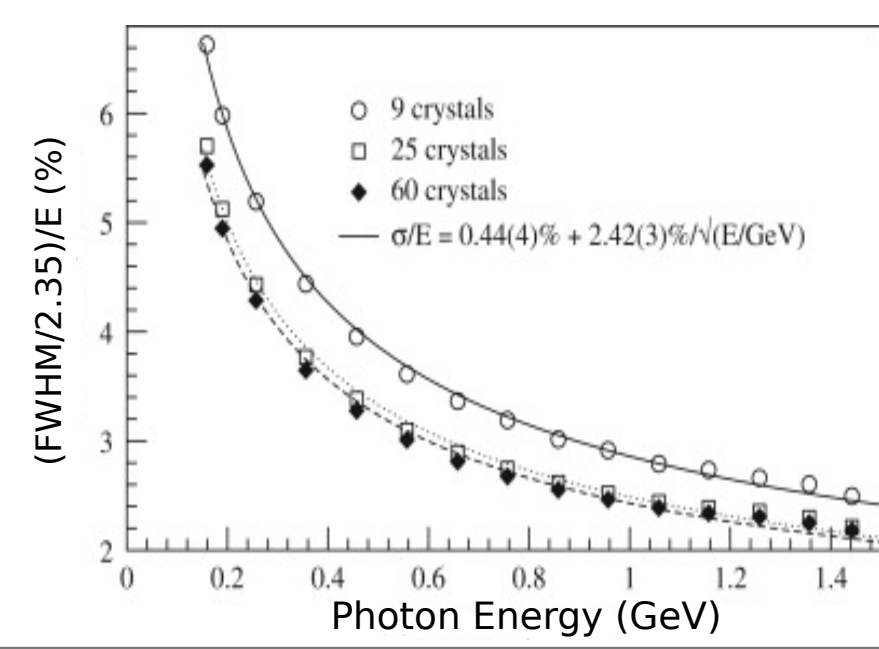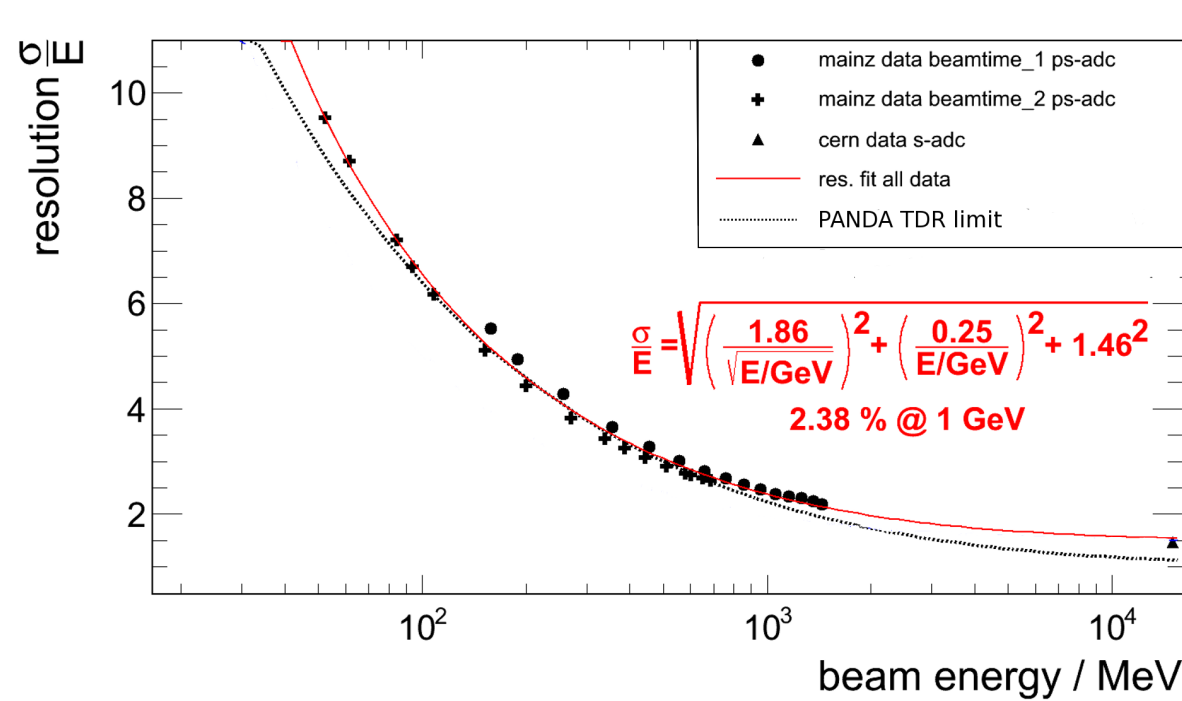
PROTO60

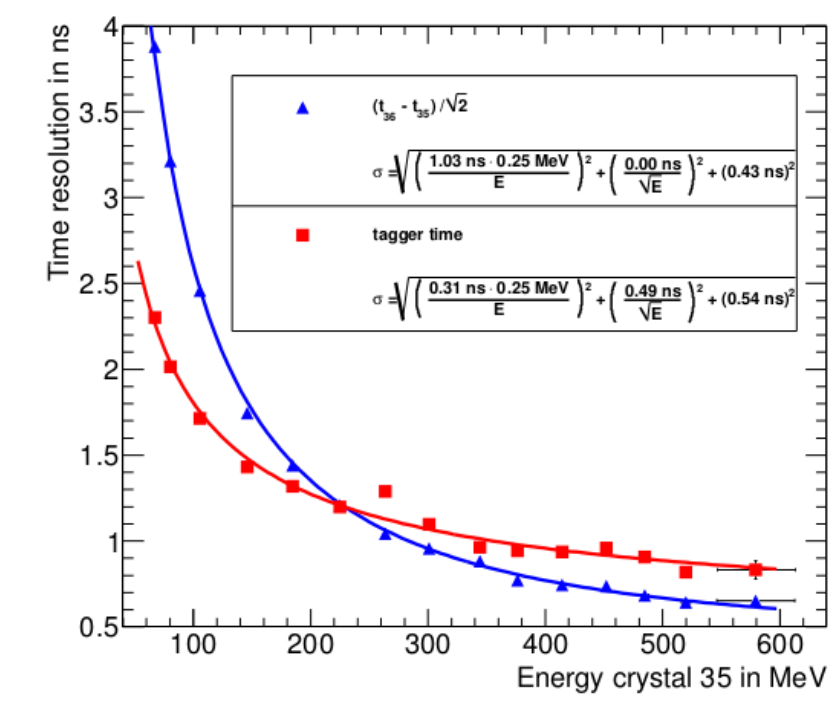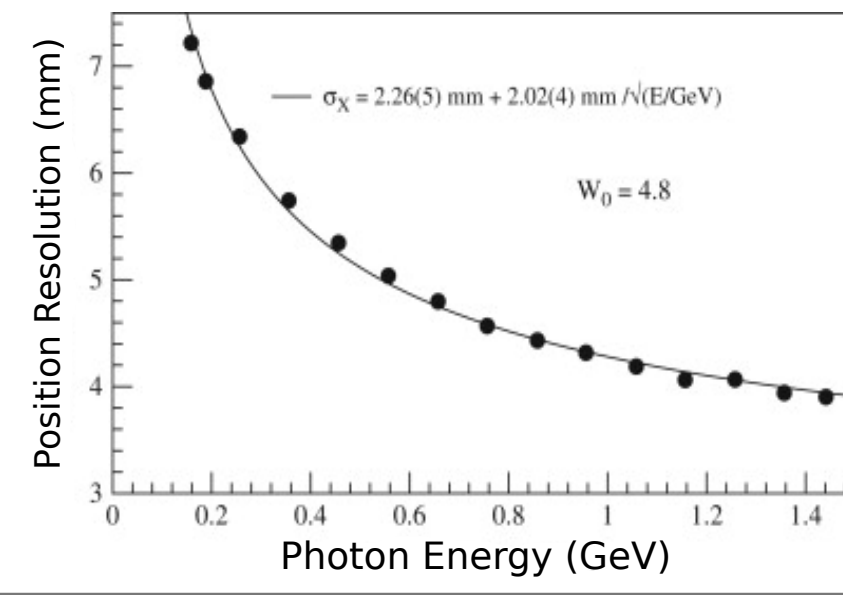### PROTO 60

- 60 tapered PWO-II crystals
- **Readout:** single LAAPD (1 cm^2 quadratic)
- Low-noise low-power preamplifier
- Operation at -25 °C

- **Energy resolution**

$$\frac{\sigma}{E} = \sqrt{\left(\frac{1.86}{\sqrt{E/\text{GeV}}}\right)^2 + \left(\frac{0.25}{E/\text{GeV}}\right)^2 + 1.46^2}$$
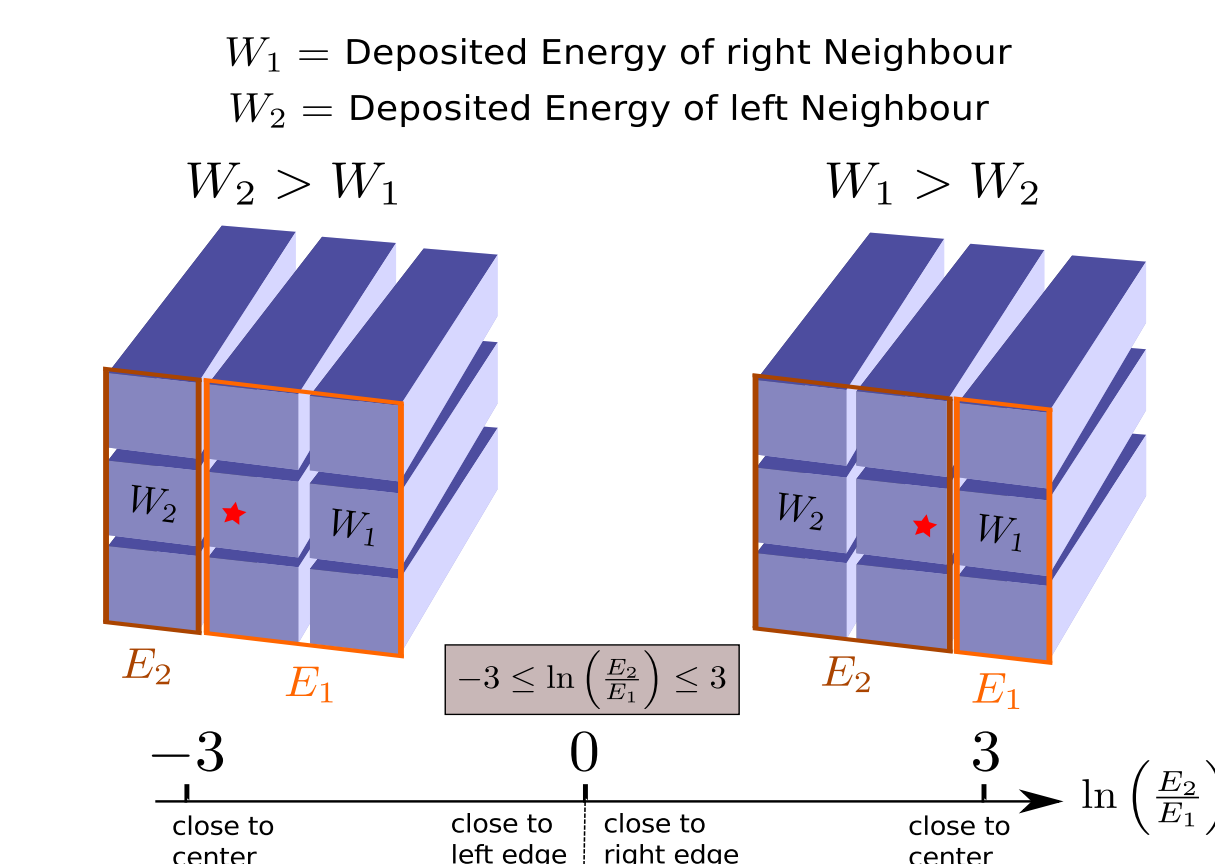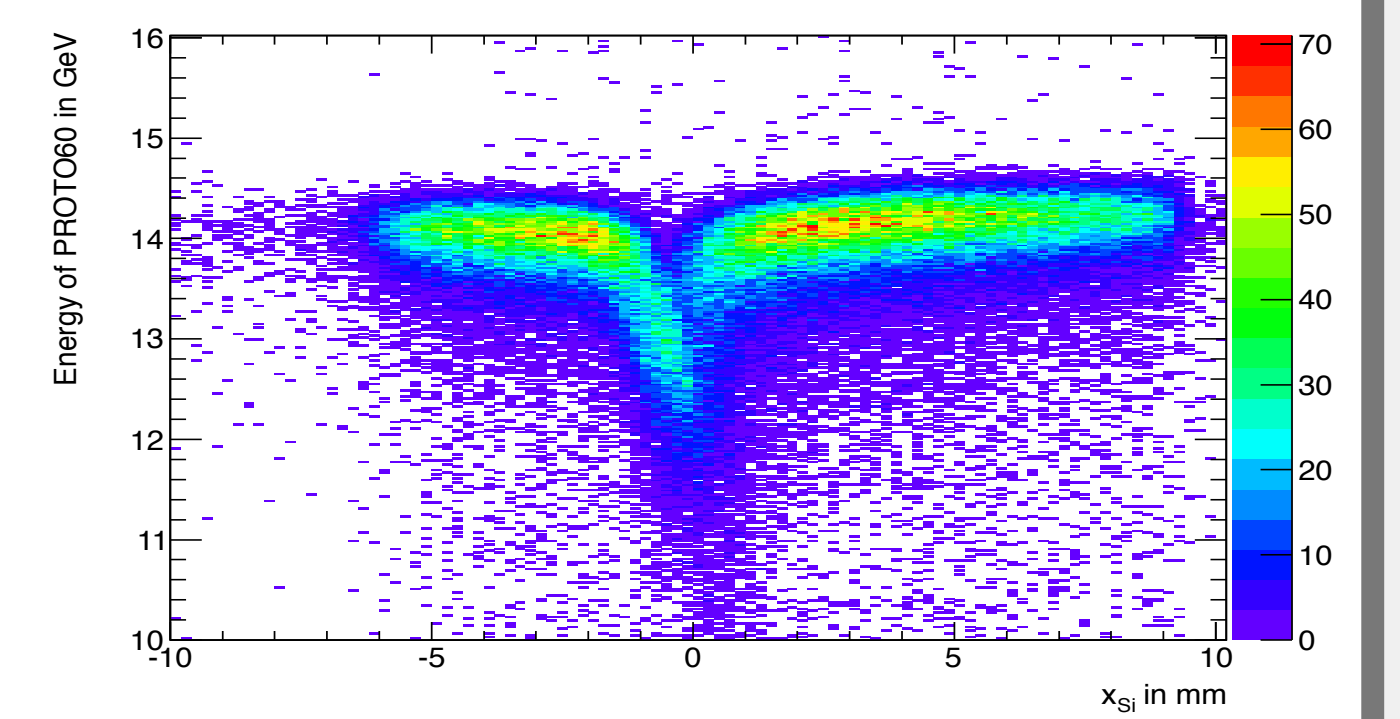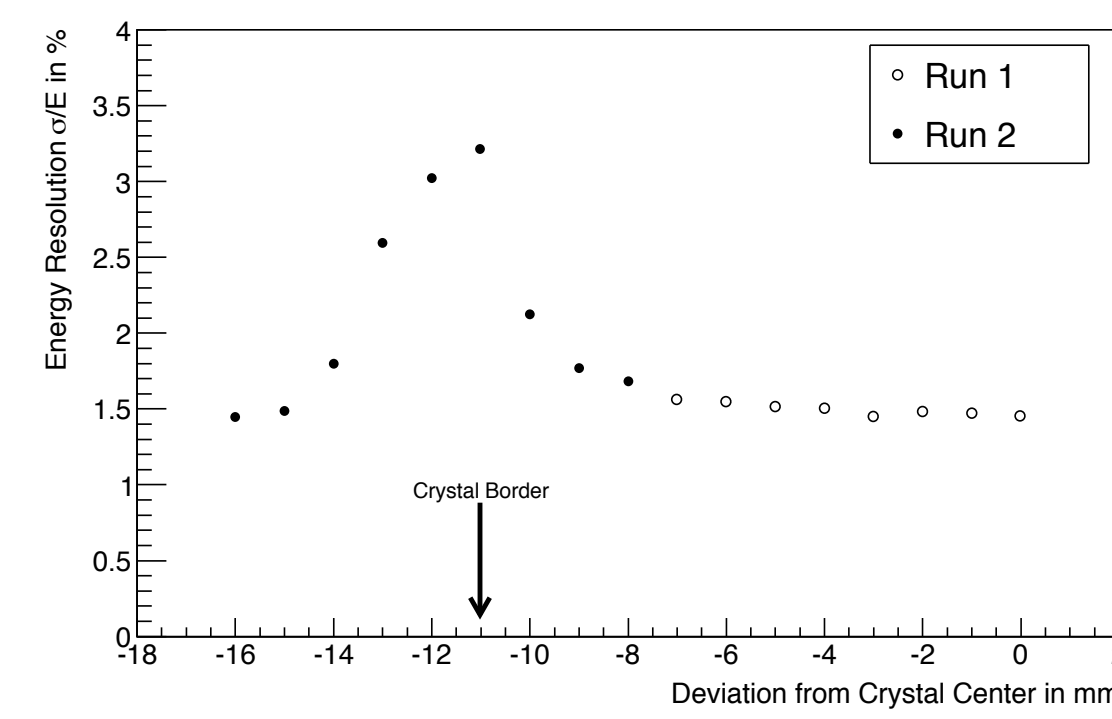2.38 % @ 1 GeV

- **Time resolution**

- **Position resolution**
(logarithmic weighting)

$$\sigma_x = 2.26(5) \text{ mm} + 2.02(14) \text{ mm}/\sqrt{(E/\text{GeV})}$$
$W_0 = 4.8$

$\sigma/E = 0.44(4)/\%i + 2.42(3)/\%i/\sqrt{(E/\text{GeV})}$
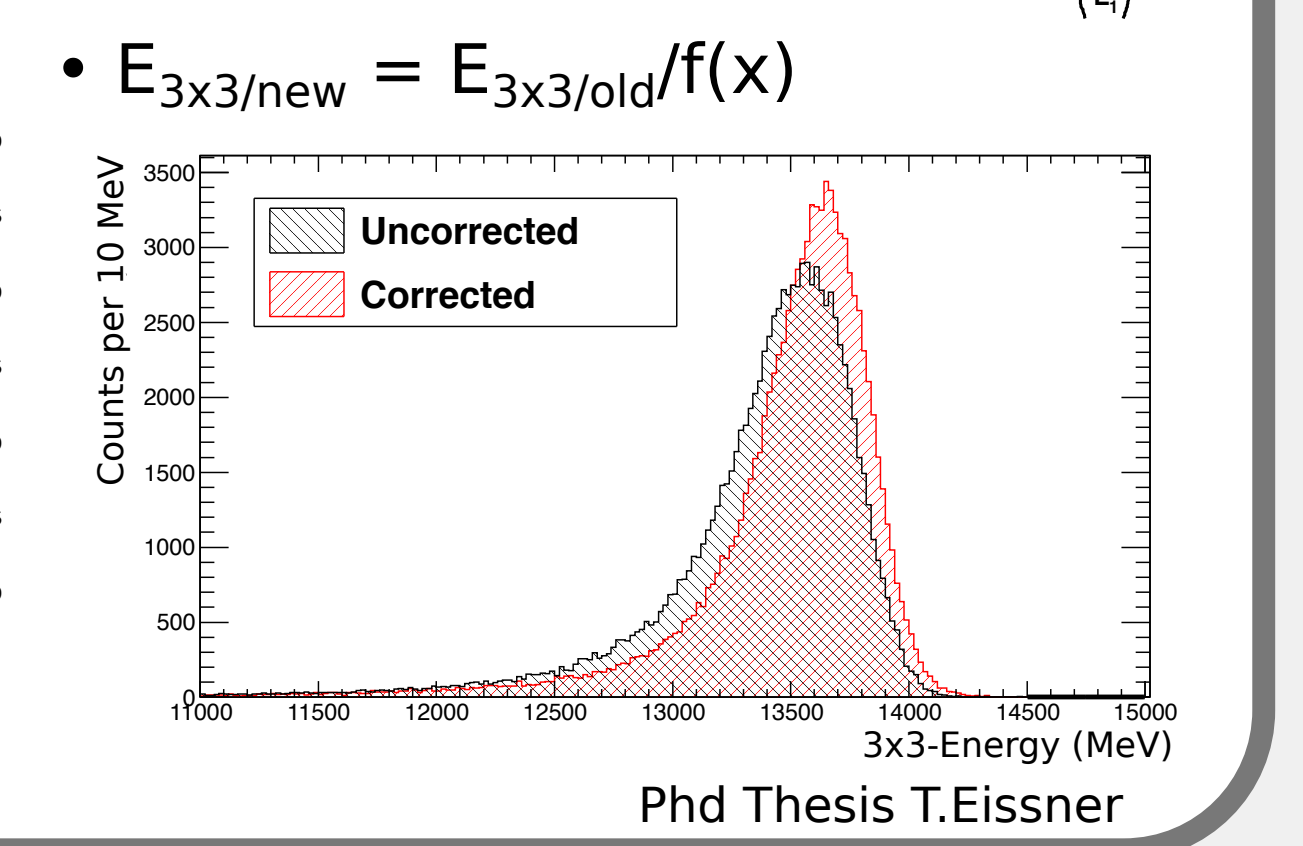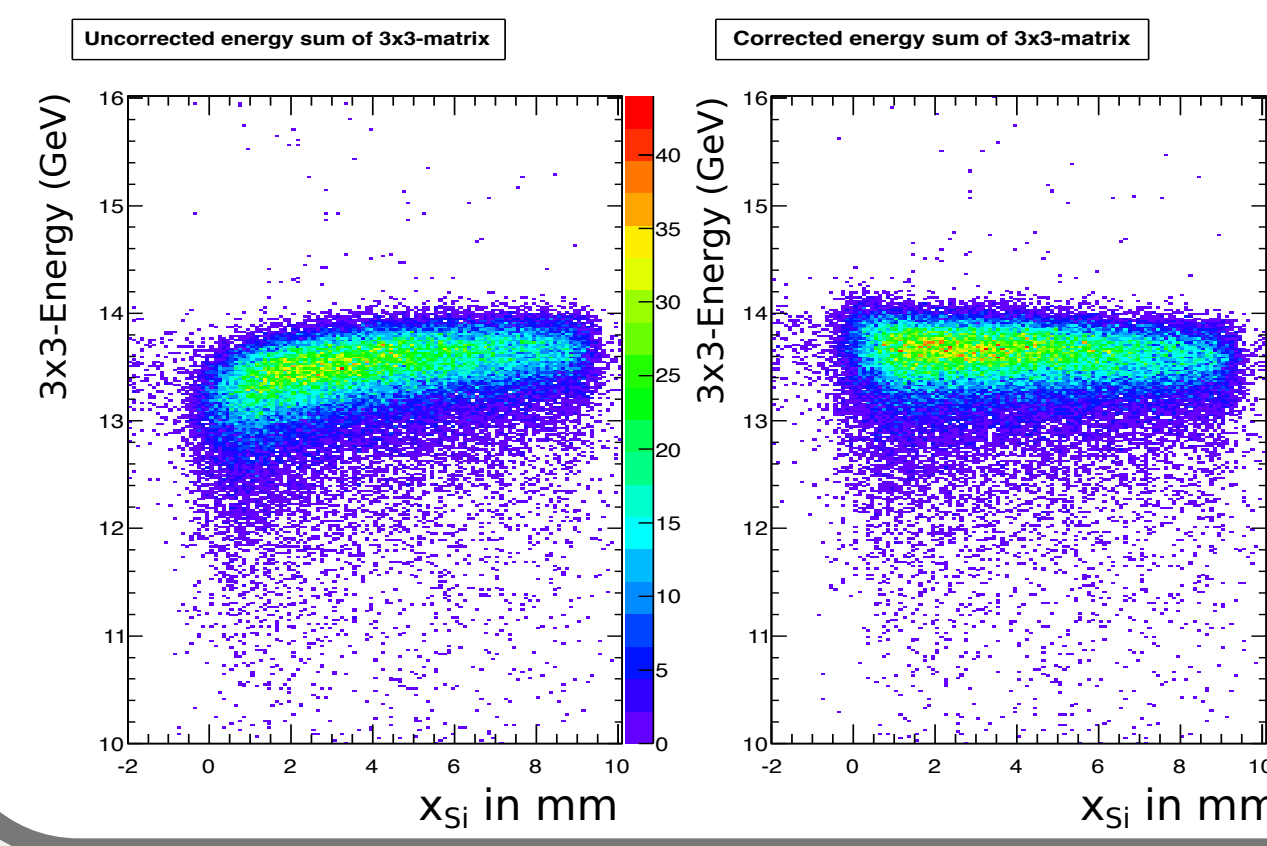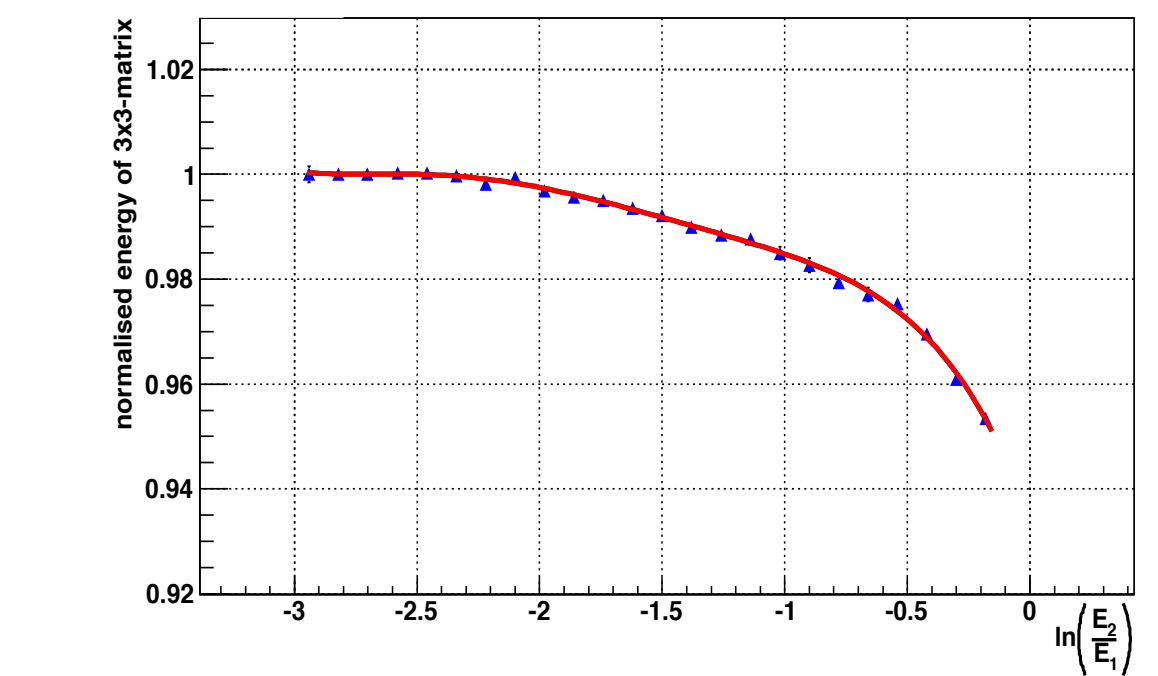- 9 crystals
- 25 crystals
- 60 crystals

Higher order energy correction

- Significant energy loss and leakage in between crystals

W_1 = Deposited Energy of right Neighbour
W_2 = Deposited Energy of left Neighbour

$W_2 > W_1$ $W_1 > W_2$

$-3 \leq \ln\left(\frac{E_2}{E_1}\right) \leq 3$

-3 .... 0 .... 3 $\ln\left(\frac{E_2}{E_1}\right)$
close to center | close to left edge | close to right edge | close to center

- Plot relative peak position of each bin as a function of $\ln(E_2/E_1)$
- fit with polynomial to get f(x)

- $E_{3x3/new} = E_{3x3/old}/f(x)$

Uncorrected energy sum of 3x3 matrix
Corrected energy sum of 3x3 matrix

Uncorrected
Corrected

Phd Thesis T.Eissner

PROTO120

- 120 PWO-II crystals of the 3 most tapered types
- Close to final mechanics and cooling
- **Readout:** 2 LAAPDs per crystal (1 cm^2 rectangular)
- Custom designed APFEL ASIC
- Two channels with different gain for each LAAPD
- Dynamic range of 10000 (1 MeV to 12 GeV)
- Programmable amplification of 16/32
- High rate capability (up to 500 kHz)
- Low power comsumption: 55 mW/ch

-25°C | APFEL | Digitiser
1
LAAPDs
2
SADC | FPGA Feature Extraction
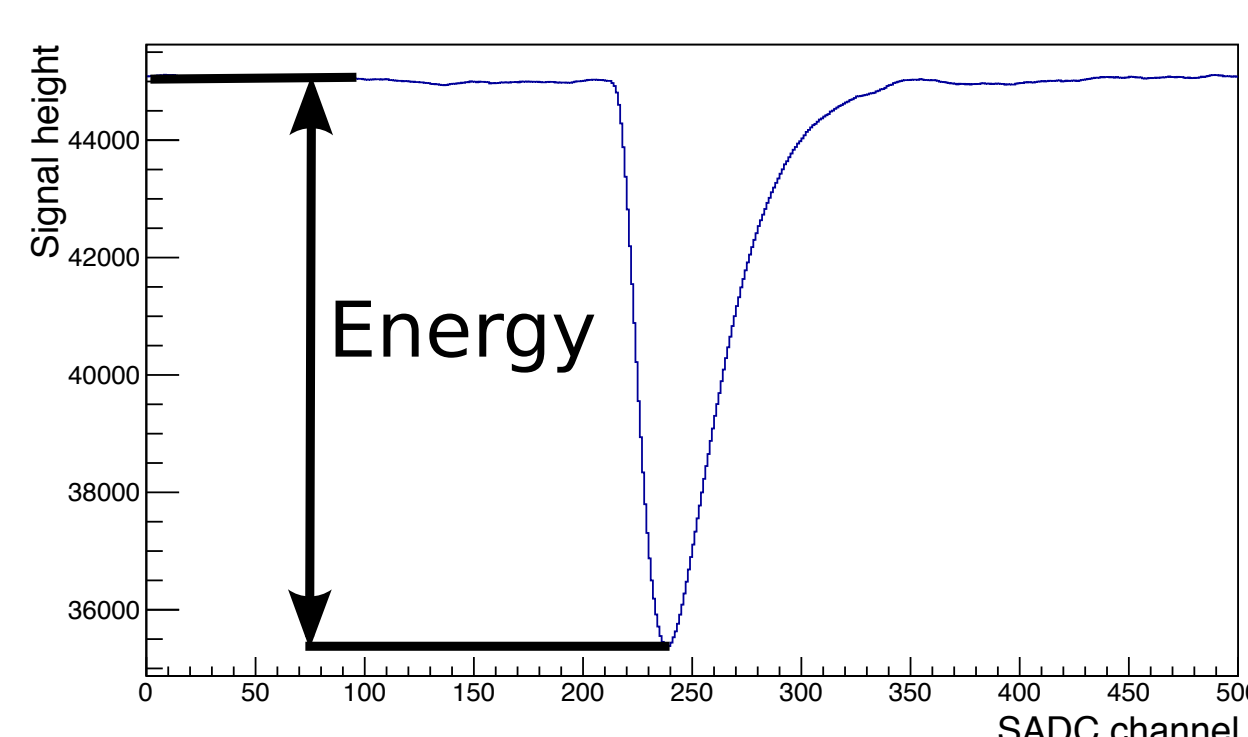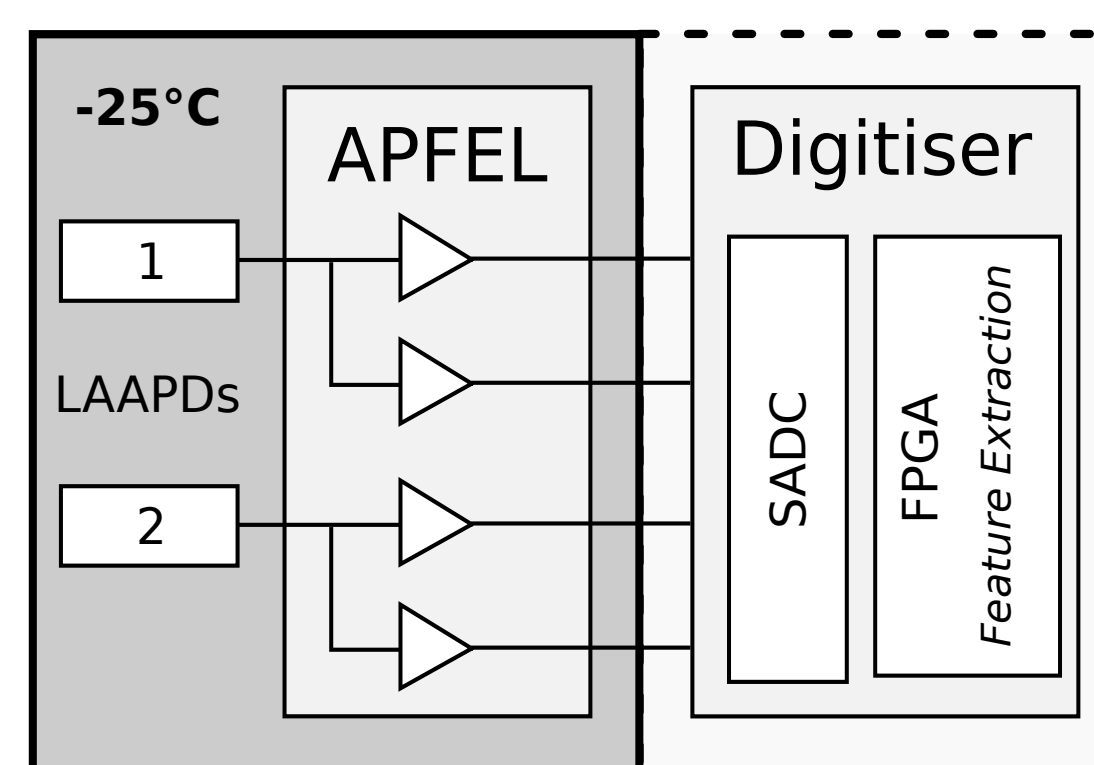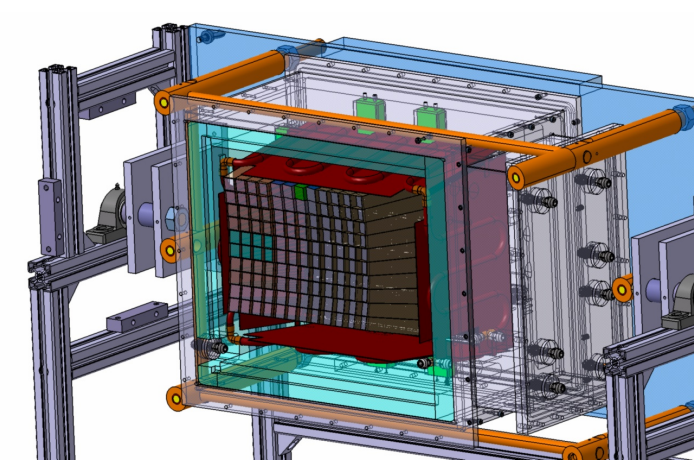
SADC:
- 50 MHz
- No additional timing branch

FPGA:
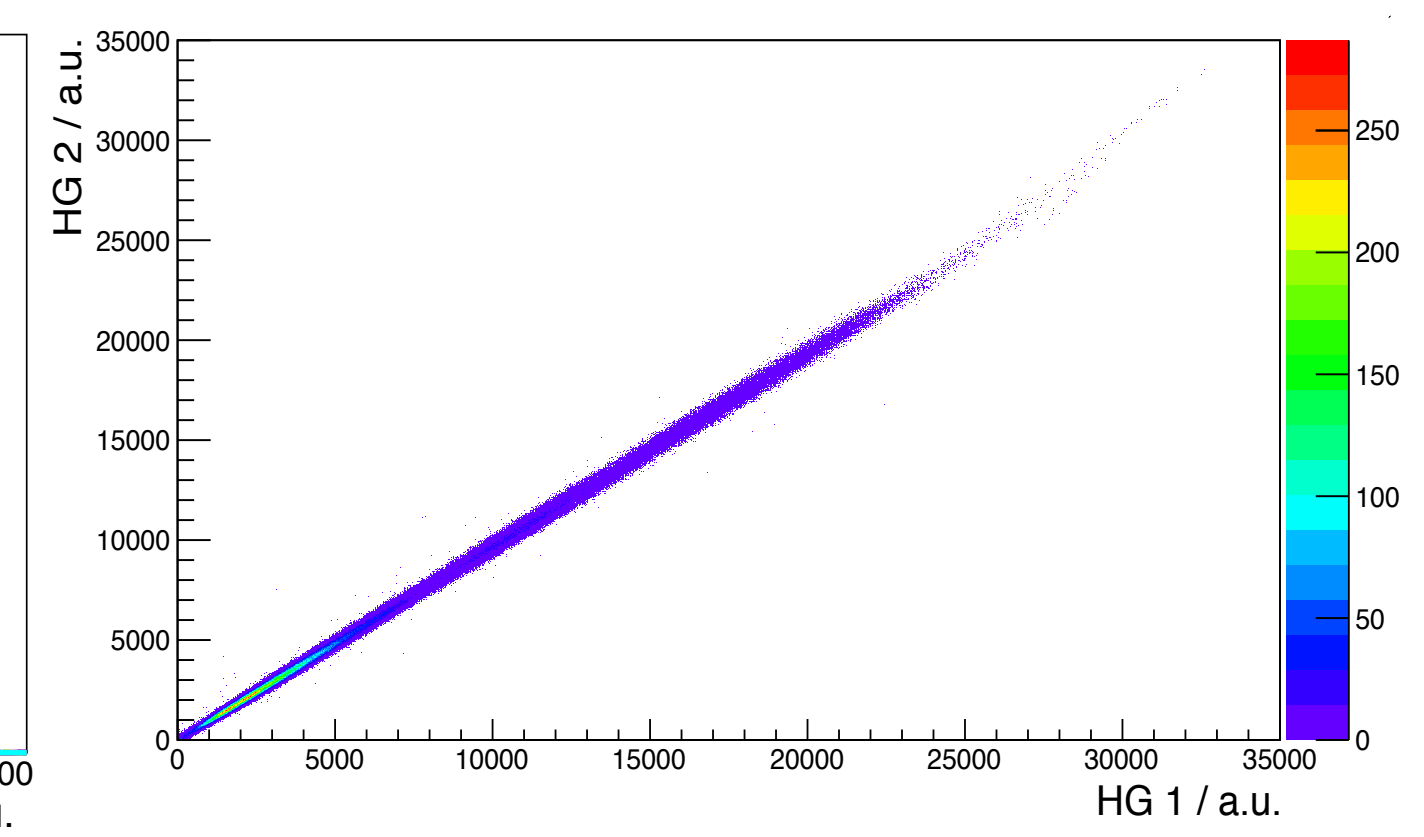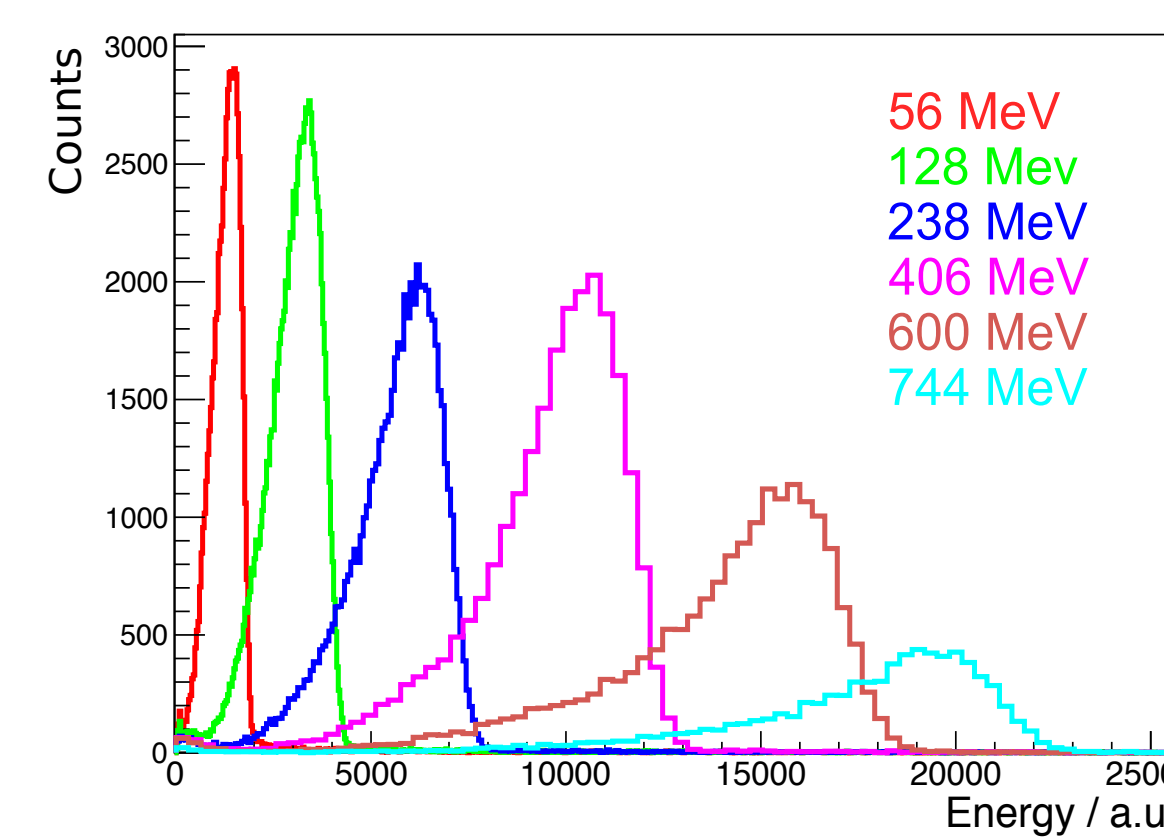- Online pulse data processing
(not in PROTO120)

Feature extraction:
- trace recorded by SADC
- energy = pedestal - minimum

Energy

Lineshapes:
- linear energy response

56 MeV
128 Mev
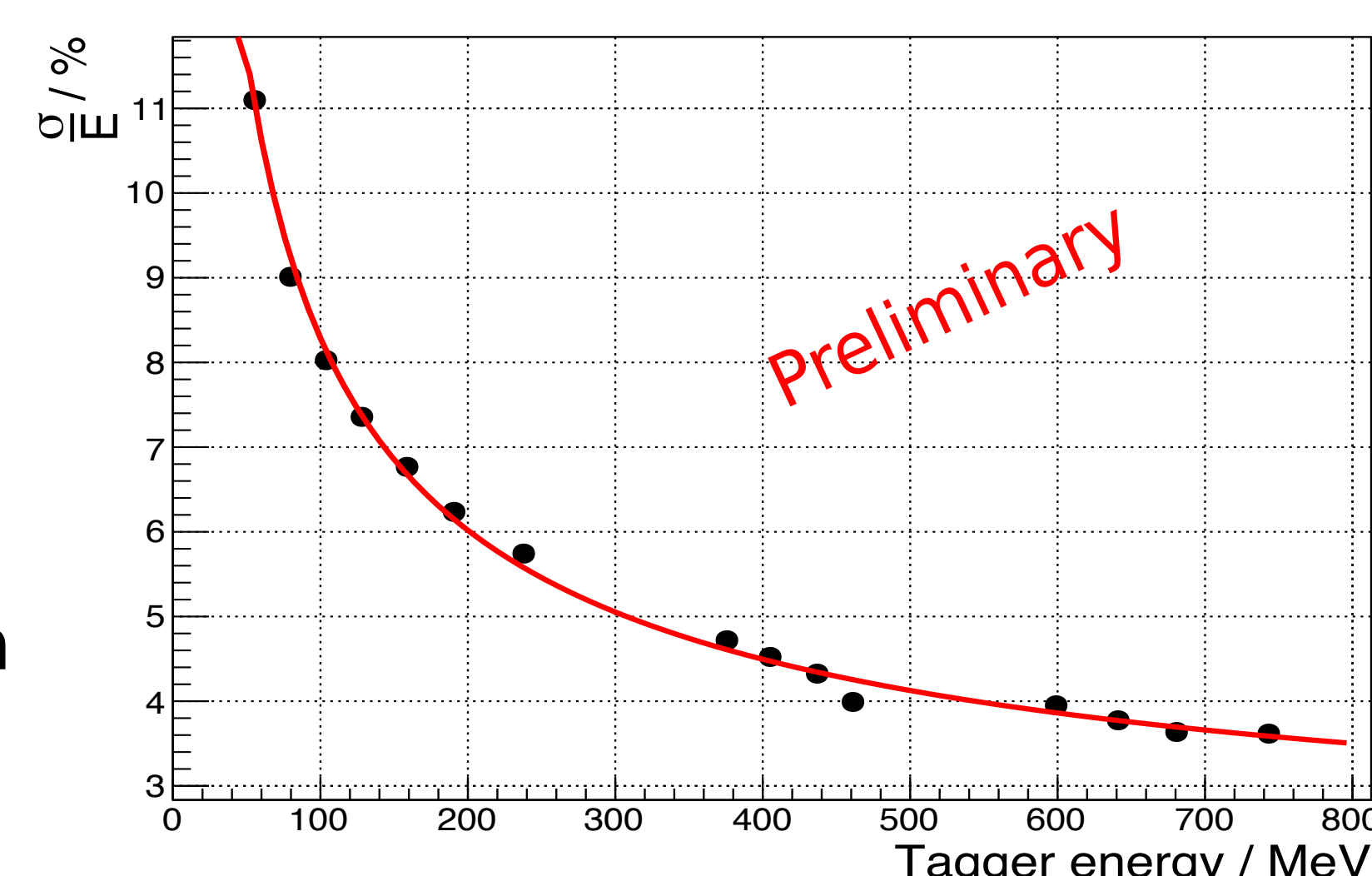238 MeV
406 MeV
600 MeV
744 MeV

APD response:
- linear correlation in the region of the dynamic range

Energy resolution:
- Energy resolution of 3x3 matrix with module threshold of 3 MeV

Preliminary

Outlook
- PROTO60 fullfilled TDR requirement
- comparable results with PROTO120
- studies with PROTO120 ongoing