Performance of the PROTO60

Daniel Bremer, Peter Drexler, Tobias Eißner, Werner Döring, Till Kuske, Markus Moritz, Rainer Novotny, Jürgen Schneider, Rene Schubert

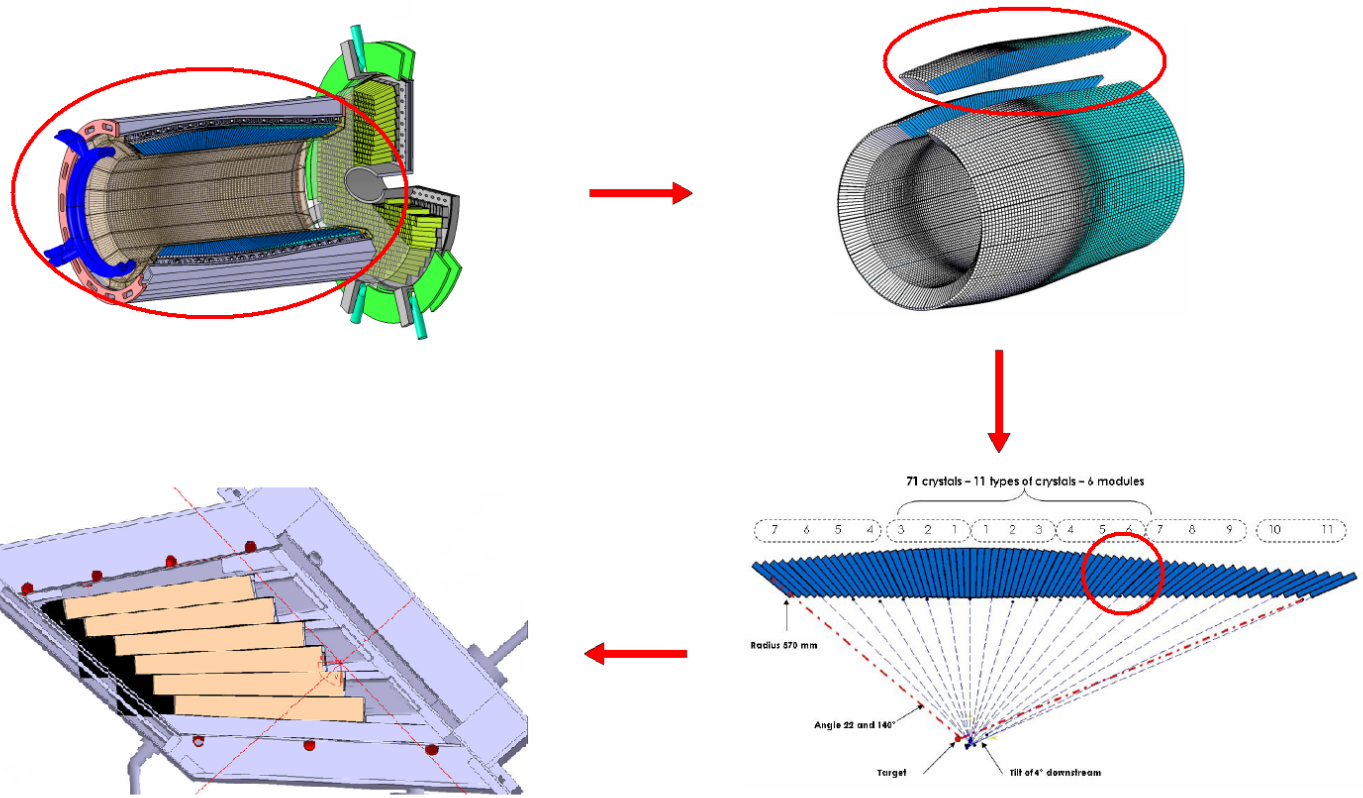
II. Physikalisches Institut Gießen

09. September 2009

Outline

The PROTO60

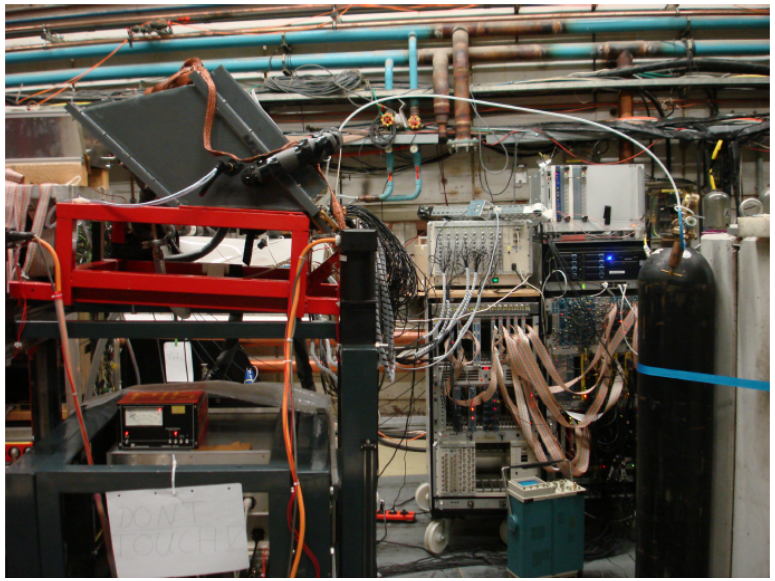
- The PROTO60 is a prototype for the Barrel EMC for $\overline{\text{P}}$ANDA
- Consists of 60 crystals with Type 6 geometry
- Readout with single Large-Area-Avalanche-Photodiode (LAAPD) at temperature $T = -25\ ^\circ\text{C}$

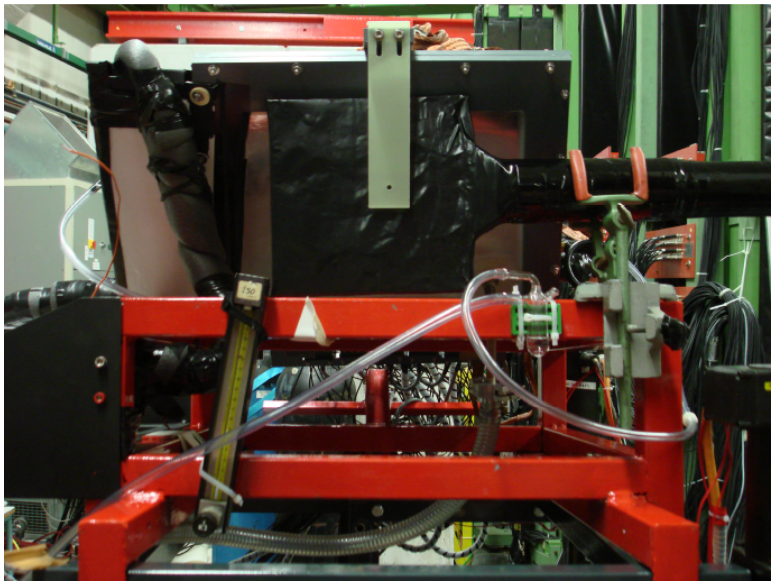


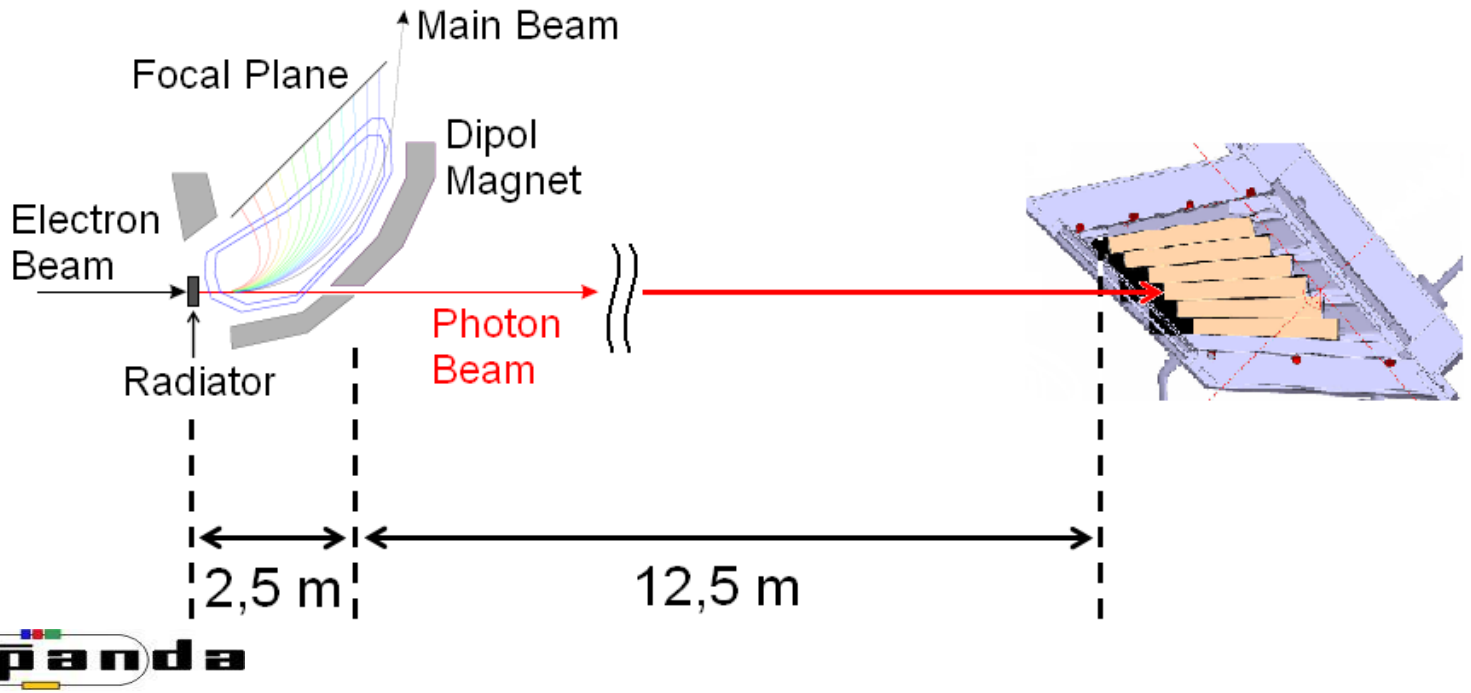
Beamtime in February 2009

- The MAMI-Accelerator together with the Tagger provides tagged Photons up to Energies of 1.5 GeV
  - 15 Tagger Channels over the whole energy range were chosen
- Four runs with 3 different beam positions (shown later)
- Readout adjusted to 200 MeV dynamic range
  - 15db attenuator after preamp crystal 35
  - 15db attenuator after preamp crystal 36 except beam in center position

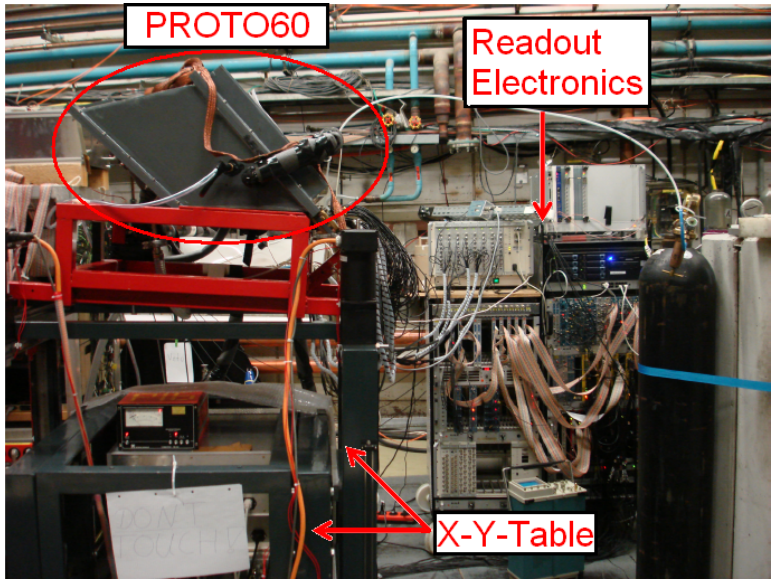
Setup

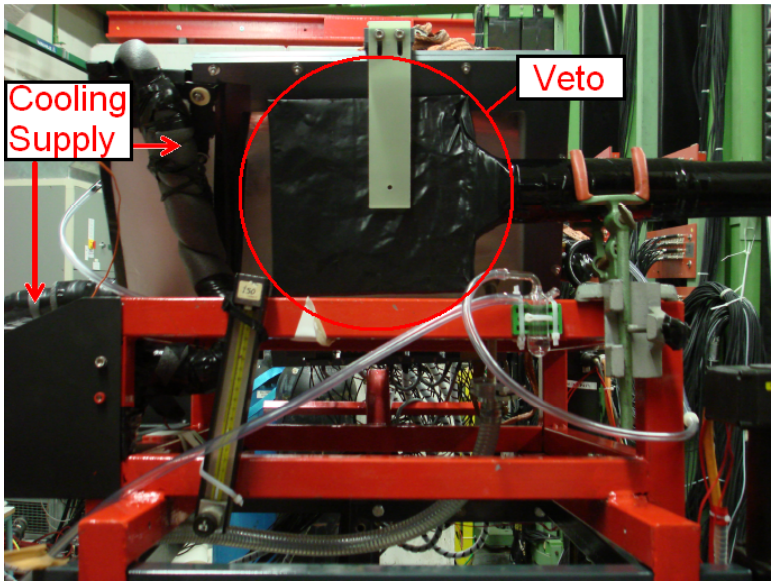


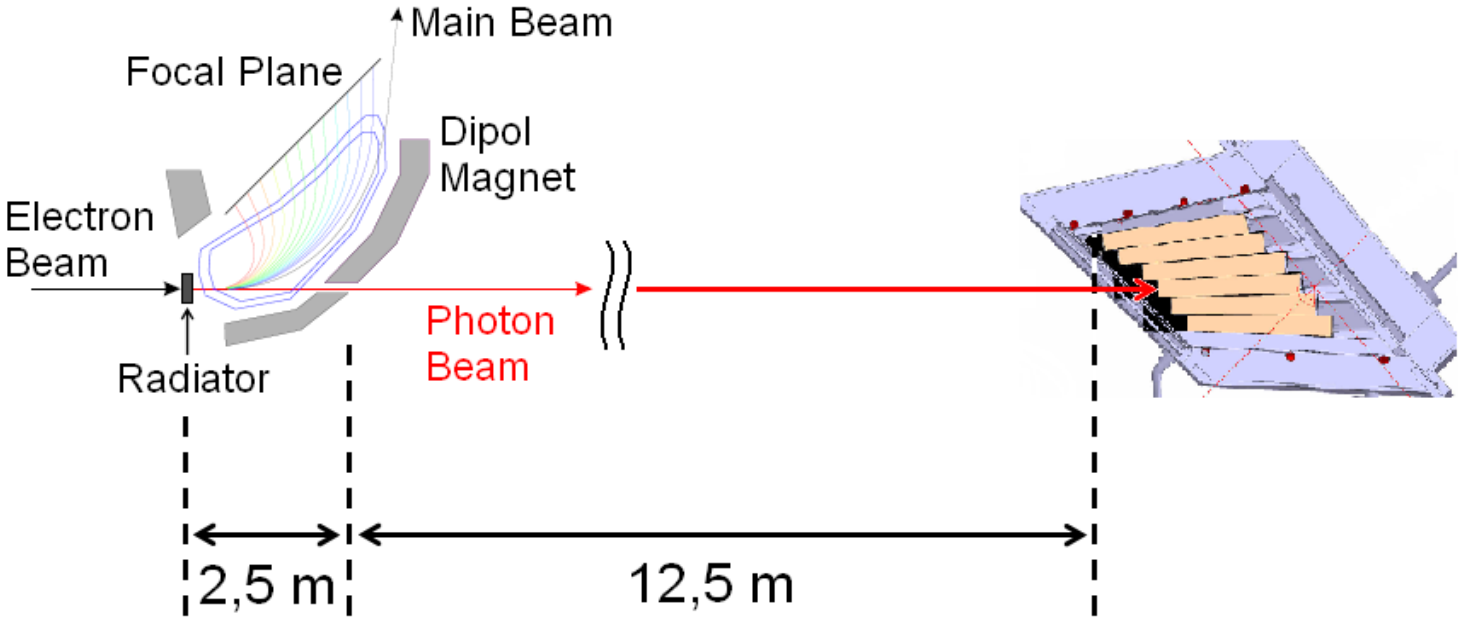




Setup

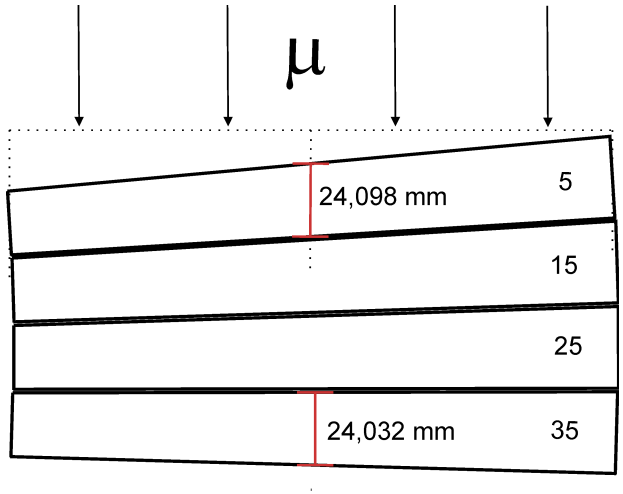

PROTO60
Readout Electronics
X-Y-Table

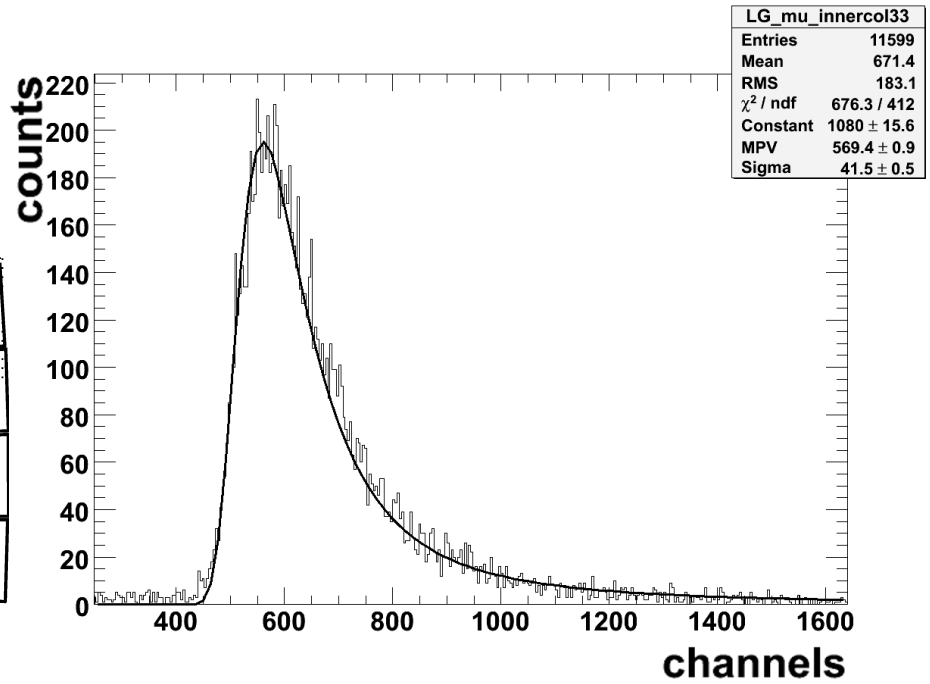

Cooling Supply
Veto


Main Beam
Focal Plane
Dipol Magnet
Electron Beam
Photon Beam
Radiator
2,5 m
12,5 m

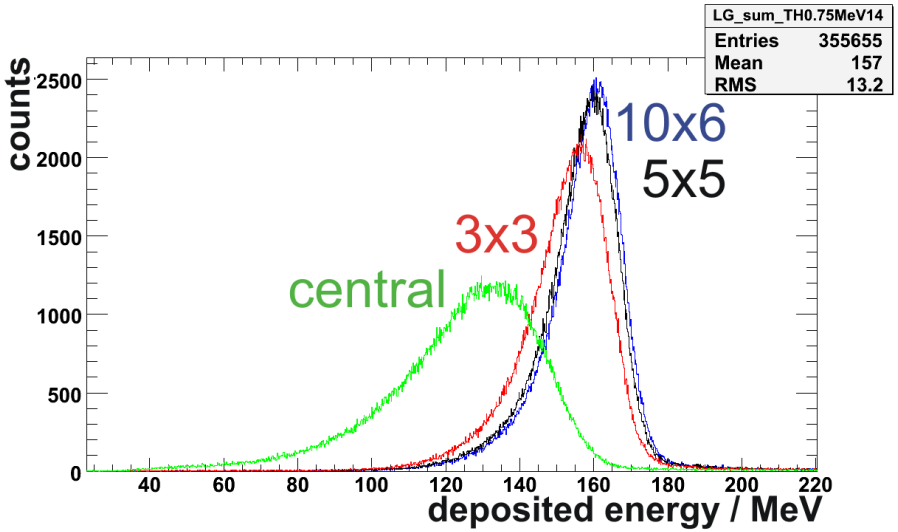
Cosmic Calibration

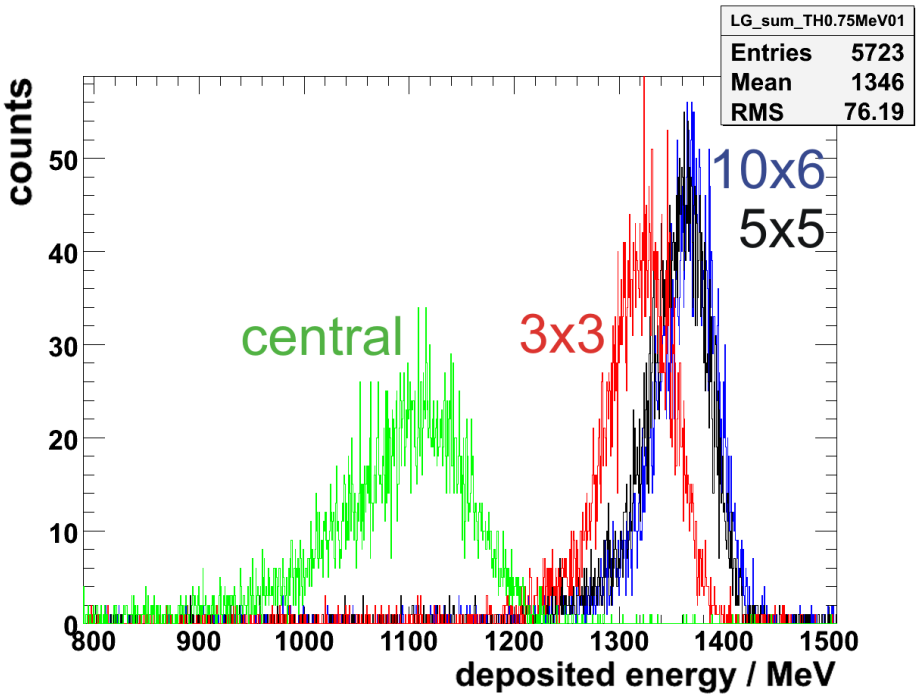
- Calibration was done with Cosmic Muons
  - Average stopping power in PWO [PDG]: $10.2 \frac{\text{MeV}}{\text{cm}}$
  - Average passlength per crystal of the PROTO60: 2.4 cm
  - This gives an average energy deposition of 24.5 MeV
  - Deviation of calibration due to passlength variations ≤ 0.27 %





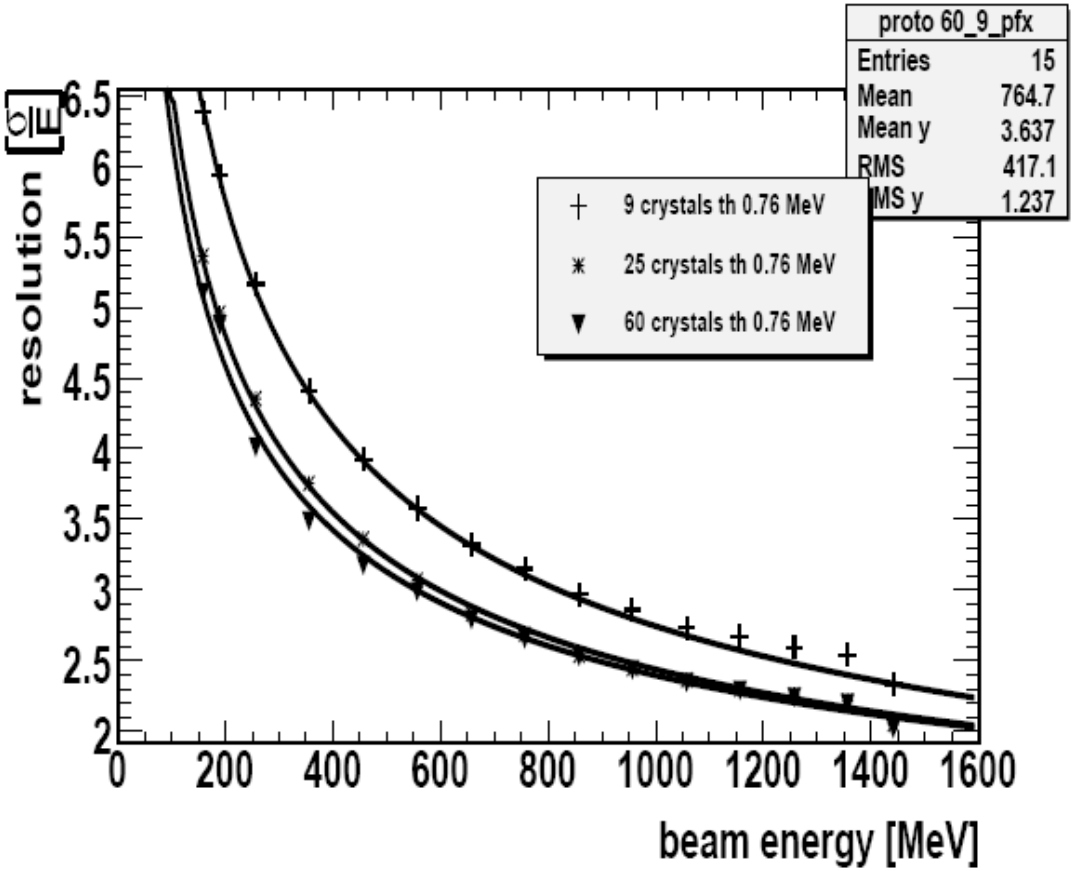
Line Shape





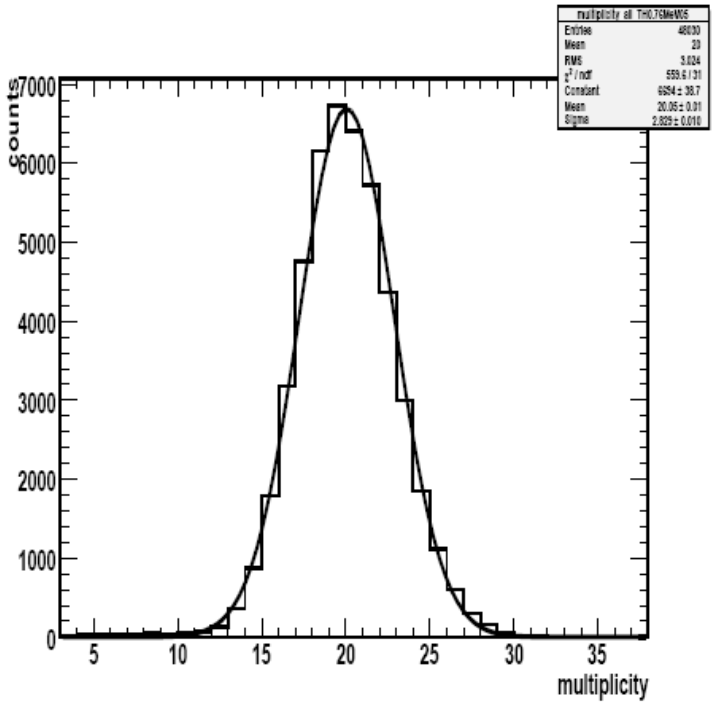
- **Above:** Line shapes for different arrays at 0.158 GeV photon energy
- **Below:** Line shapes for different arrays at 1.441 GeV photon energy
- Energy treshold of 0.75 MeV

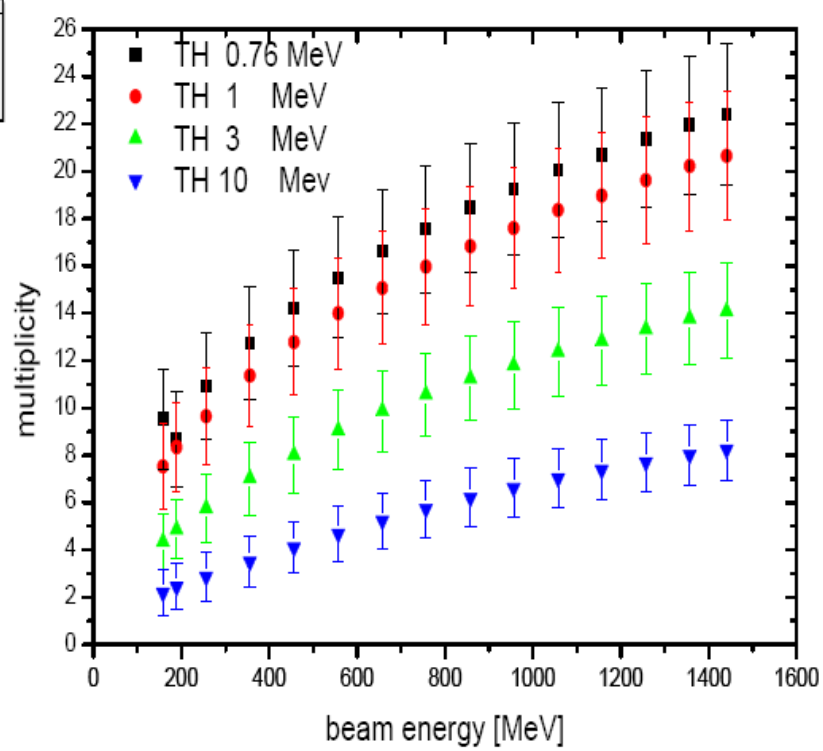
Energy Resolution for Different Arrays



	Whole PROTO60	5 × 5	3 × 3
$\frac{\sigma}{E}$	$0.626\ \% + \frac{1.770\ \%}{\sqrt{E/\mathrm{GeV}}}$	$0.528\ \% + \frac{1.911\ \%}{\sqrt{E/\mathrm{GeV}}}$	$0.307\ \% + \frac{2.436\ \%}{\sqrt{E/\mathrm{GeV}}}$
at 1GeV	2.396 %	2.439 %	2.743 %

Multiplicity at Different Thresholds





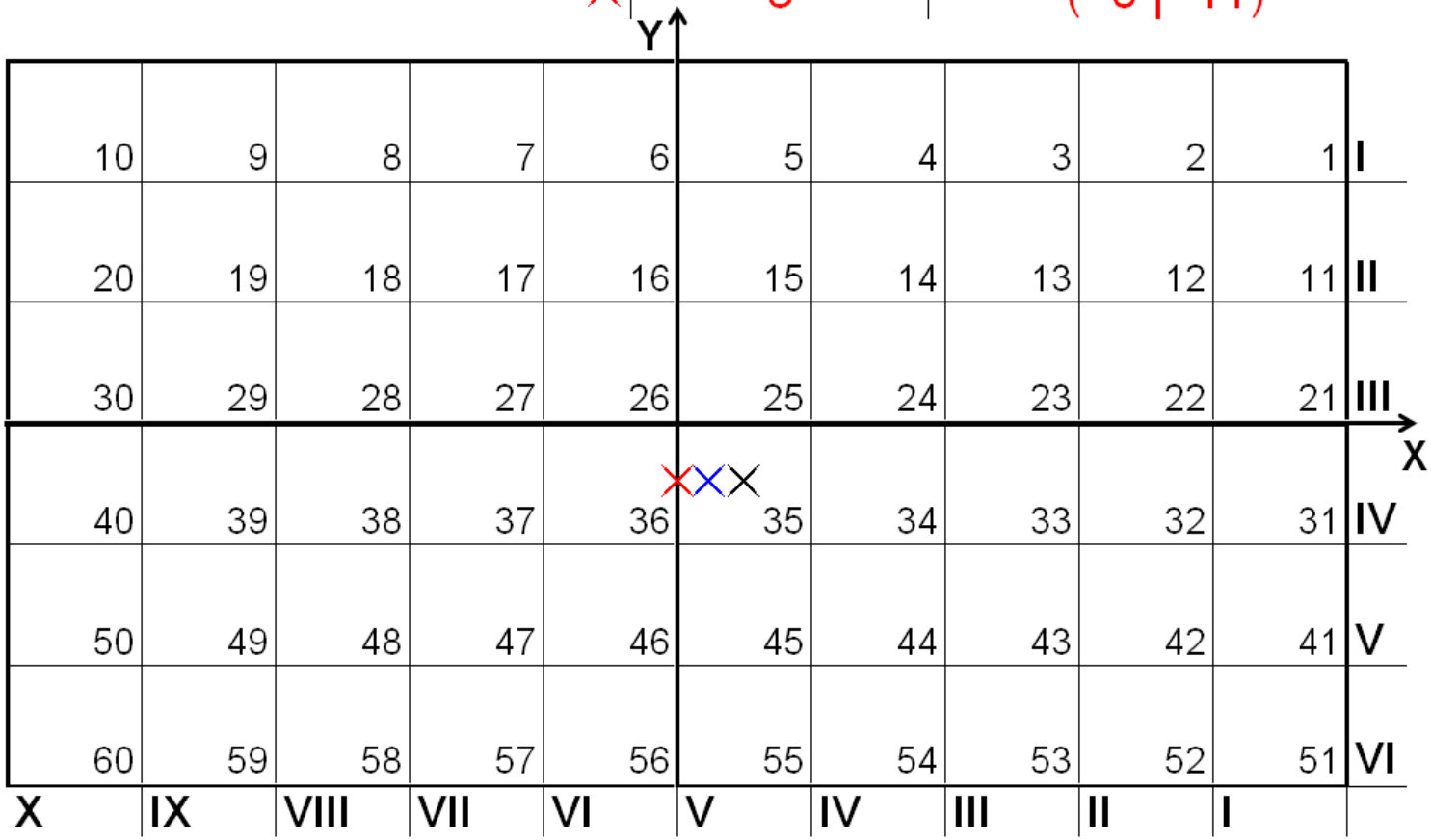
- **Left:** Multiplicity with energy threshold of 0.76 MeV for a photon energy of 1.058 GeV
- **Right:** Energy dependence of multiplicity at thresholds of 0.76, 1, 3 and 10 MeV

Position of the Beam

PANDA PROTO 60

Schematic Front View

	Run Number	Point of Impact / mm
×	1, 4	(11 | -11)
×	2	(6 | -11)
×	3	(0 | -11)



Calculation of the Point of Impact

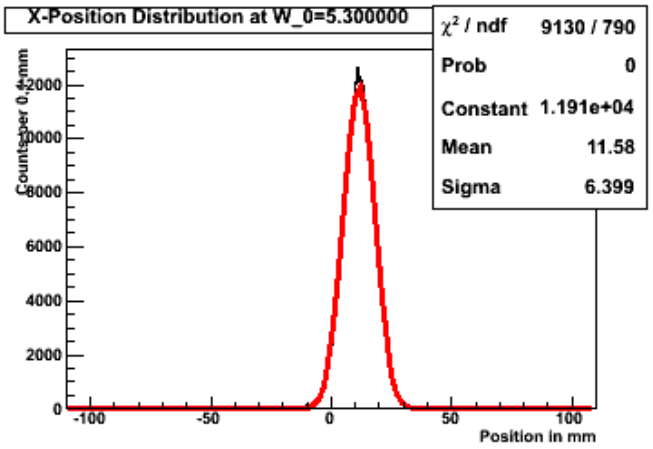
- Center of gravity algorithm with a logarithmic weighting

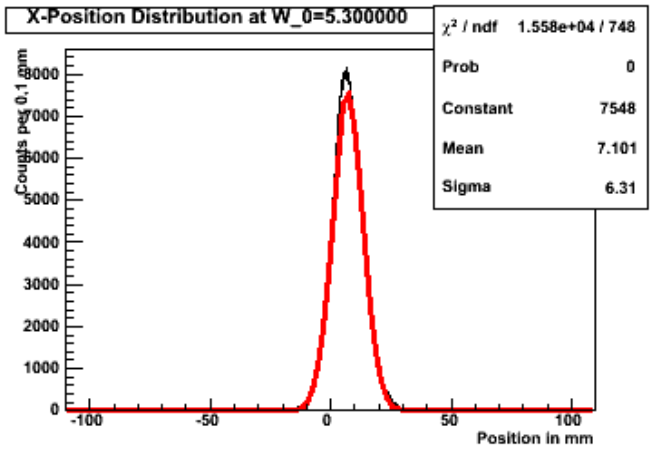
$$X_{calc} = \frac{\sum_i w_i x_i}{\sum_i w_i}; \qquad E_T = \sum_i E_i$$

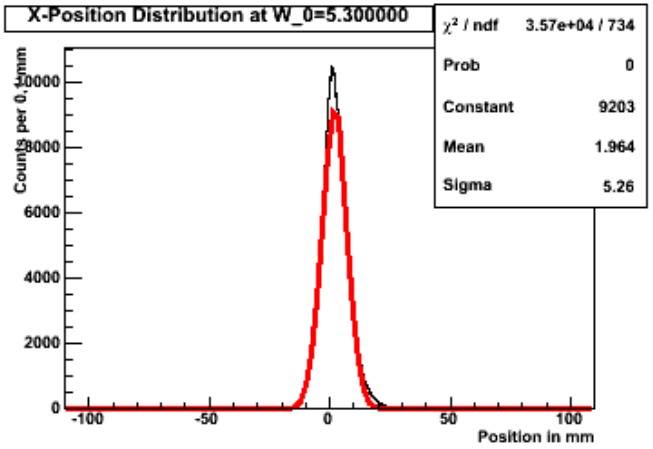
$$w_i = \begin{cases} 0 & , W_0 + \ln\left(\frac{E_i}{E_T}\right) \leq 0; \\ W_0 + \ln\left(\frac{E_i}{E_T}\right) & , \text{else}; \end{cases}$$

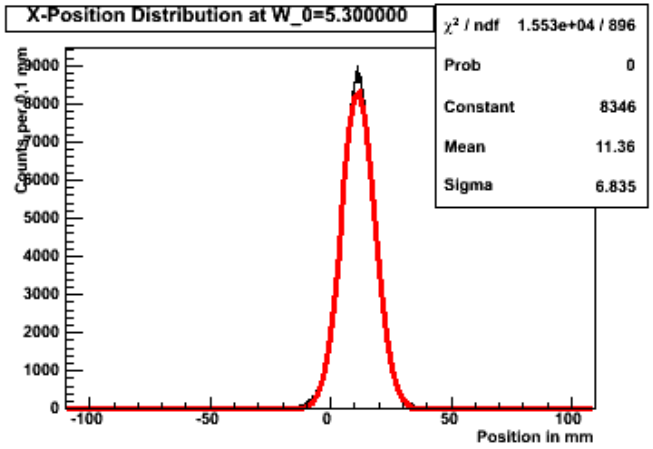
- Ideal weighting parameter should deliver a Gaussian distribution with low σ
- A value of $W_0 = 5.3$ was chosen
- All calculations without taking into account time information of the individual crystal

Calculated Position Distributions



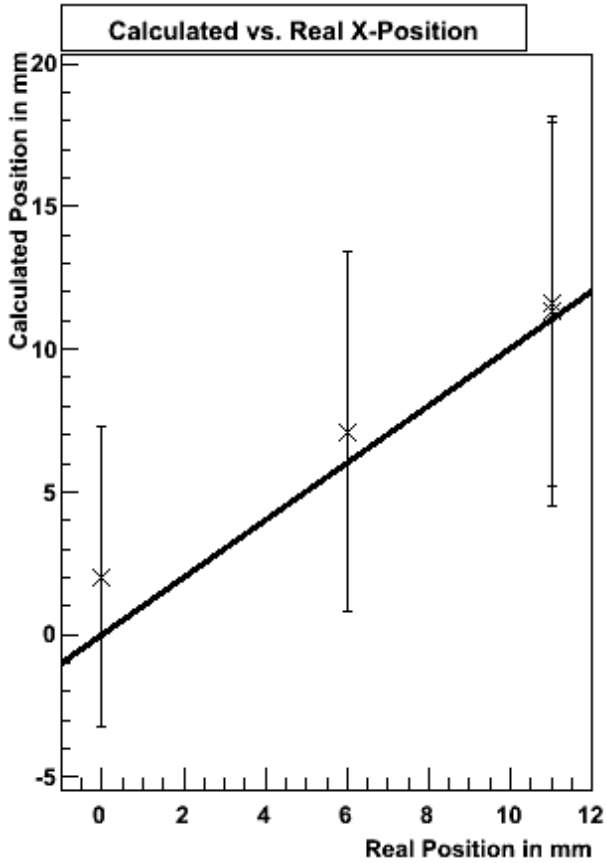


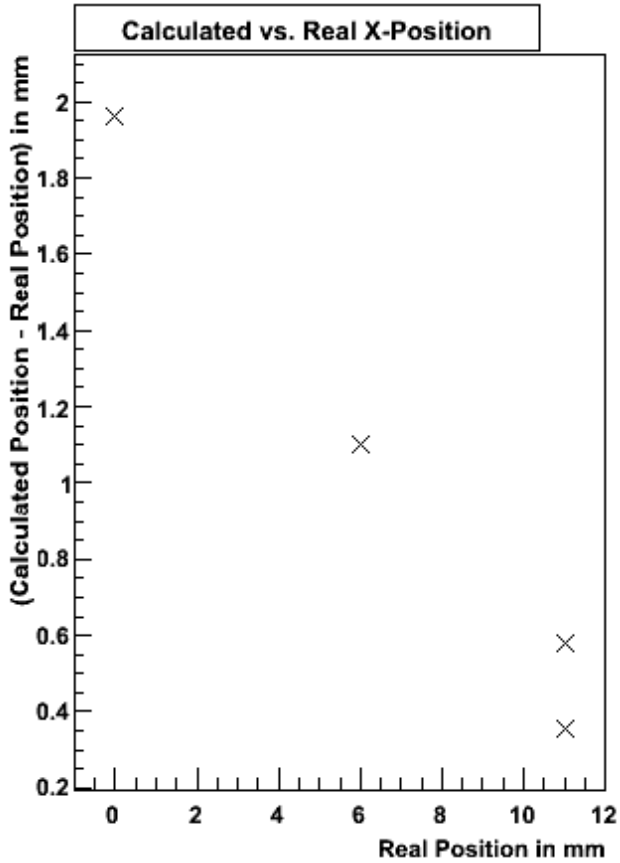




- Position distributions for different beam positions
- All 15 photon energies included

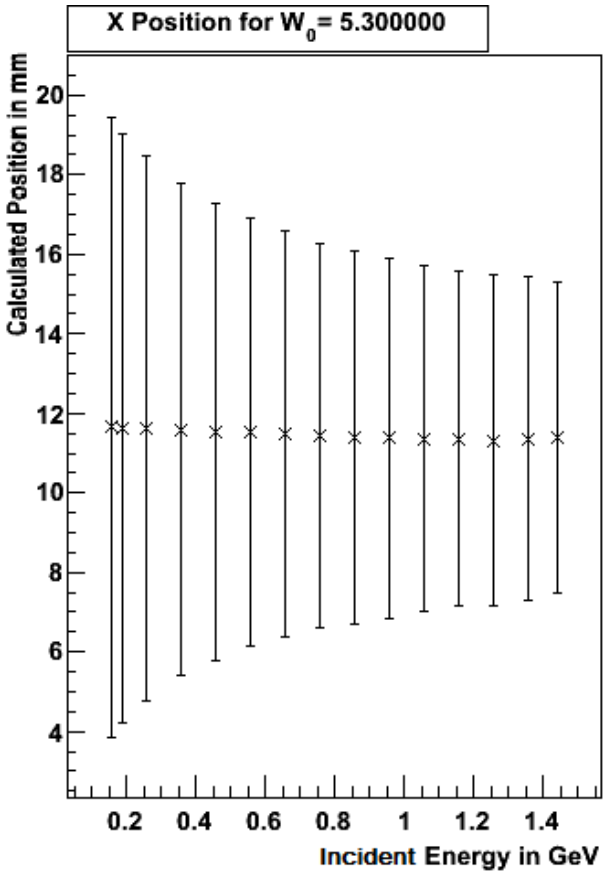
Calculated Results

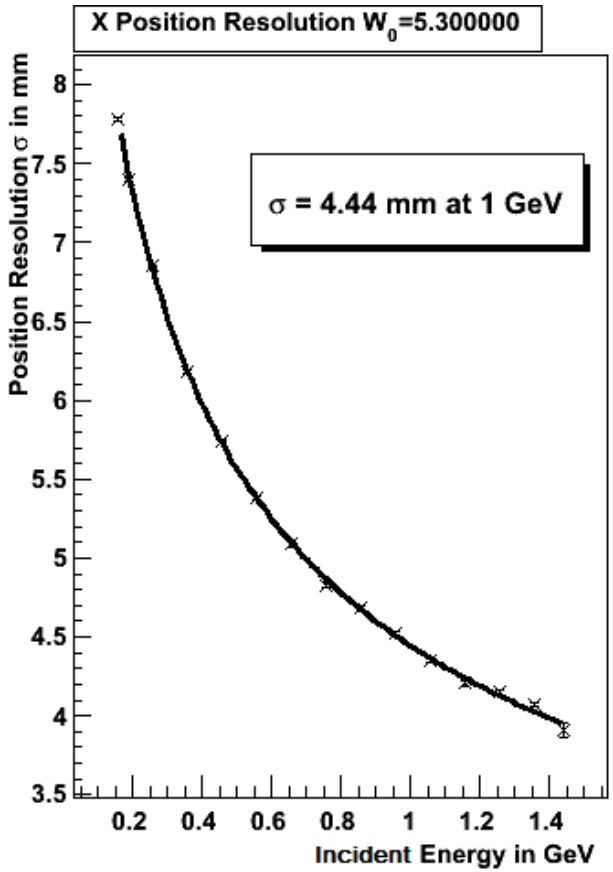




- Linear correllation between calculated and real position
- Statistical error better when shooting in between
- Systematical error increases with distance to crystal center

Energy Dependence of Resolution

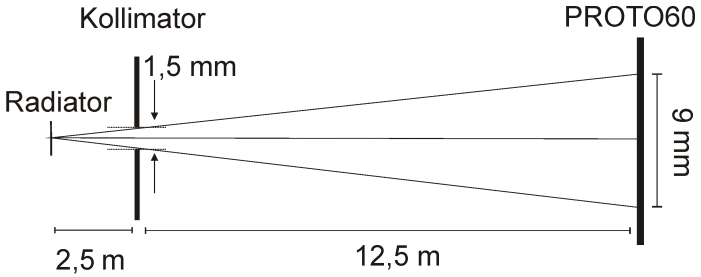


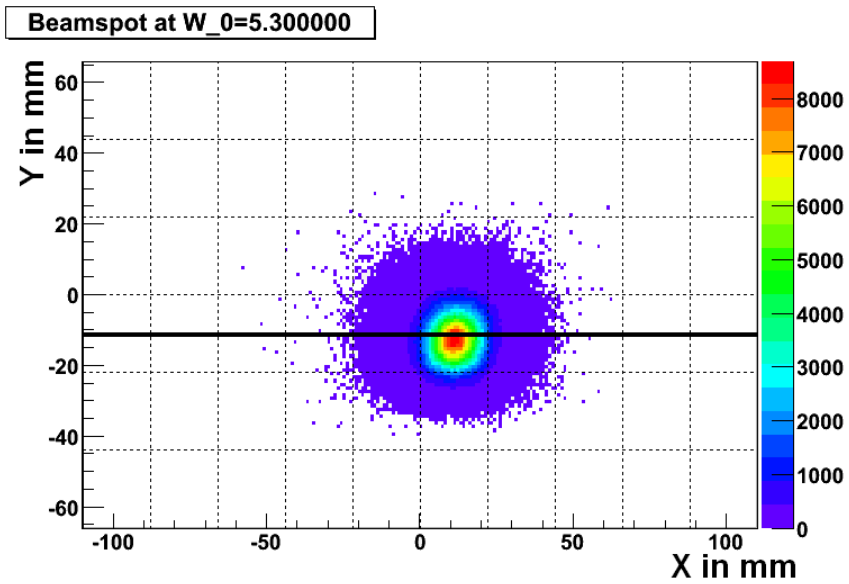


- Position calculation indpendent of incident photon energy
- Position resolution energy dependence obtained by fit:

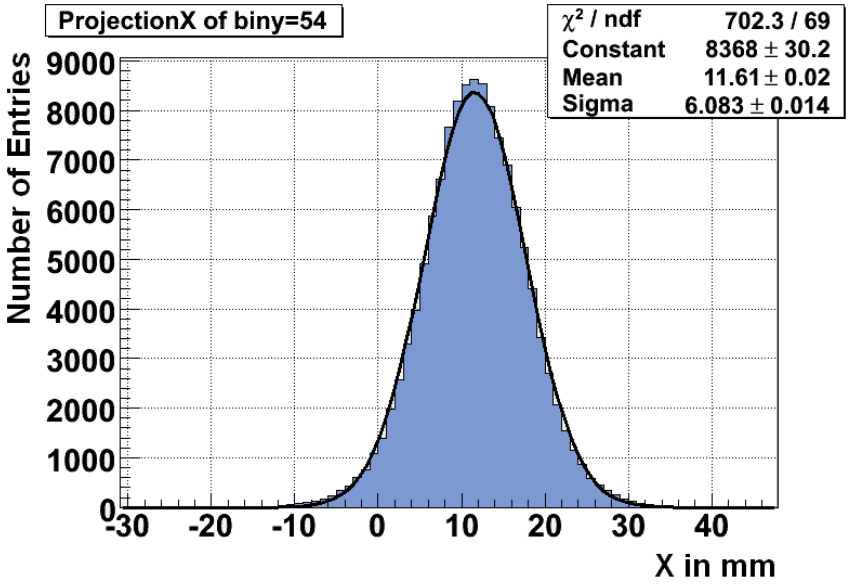
$$\sigma_y \approx \sigma_x = 1.087\ \text{mm} - \frac{0.464\ \text{mm}}{E/\text{GeV}} + \frac{3.822\ \text{mm}}{\sqrt{E/\text{GeV}}}$$

Size of the Beam





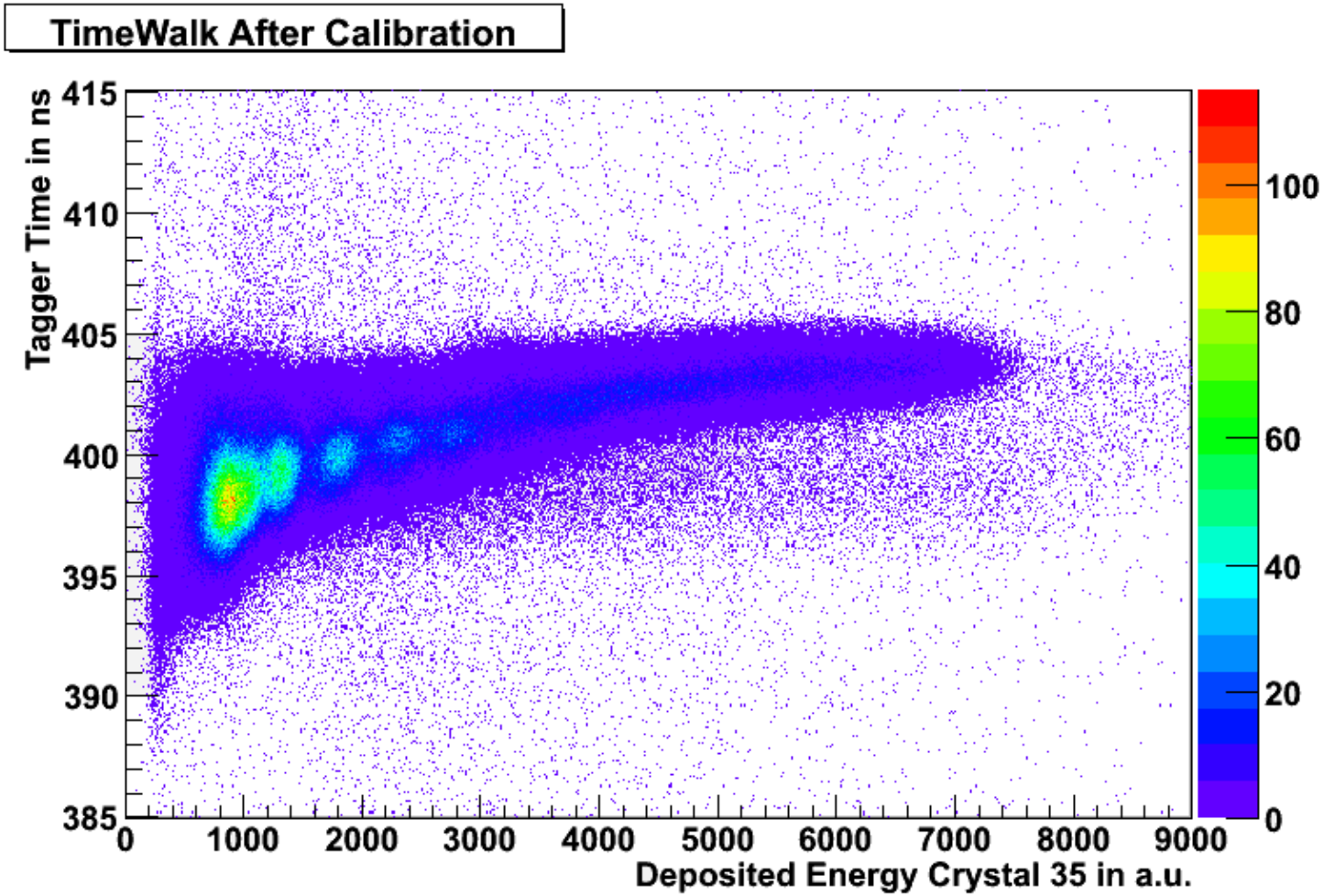
- **Above:**
  Expected beamspot size calculated from setup geometry
  - Size: Diameter
    d = 9 mm
- **Right:**
  Reconstructed Beamspot with Projection in X
  - Size:
    $\sigma = 6$ mm
    FWHM = 14 mm



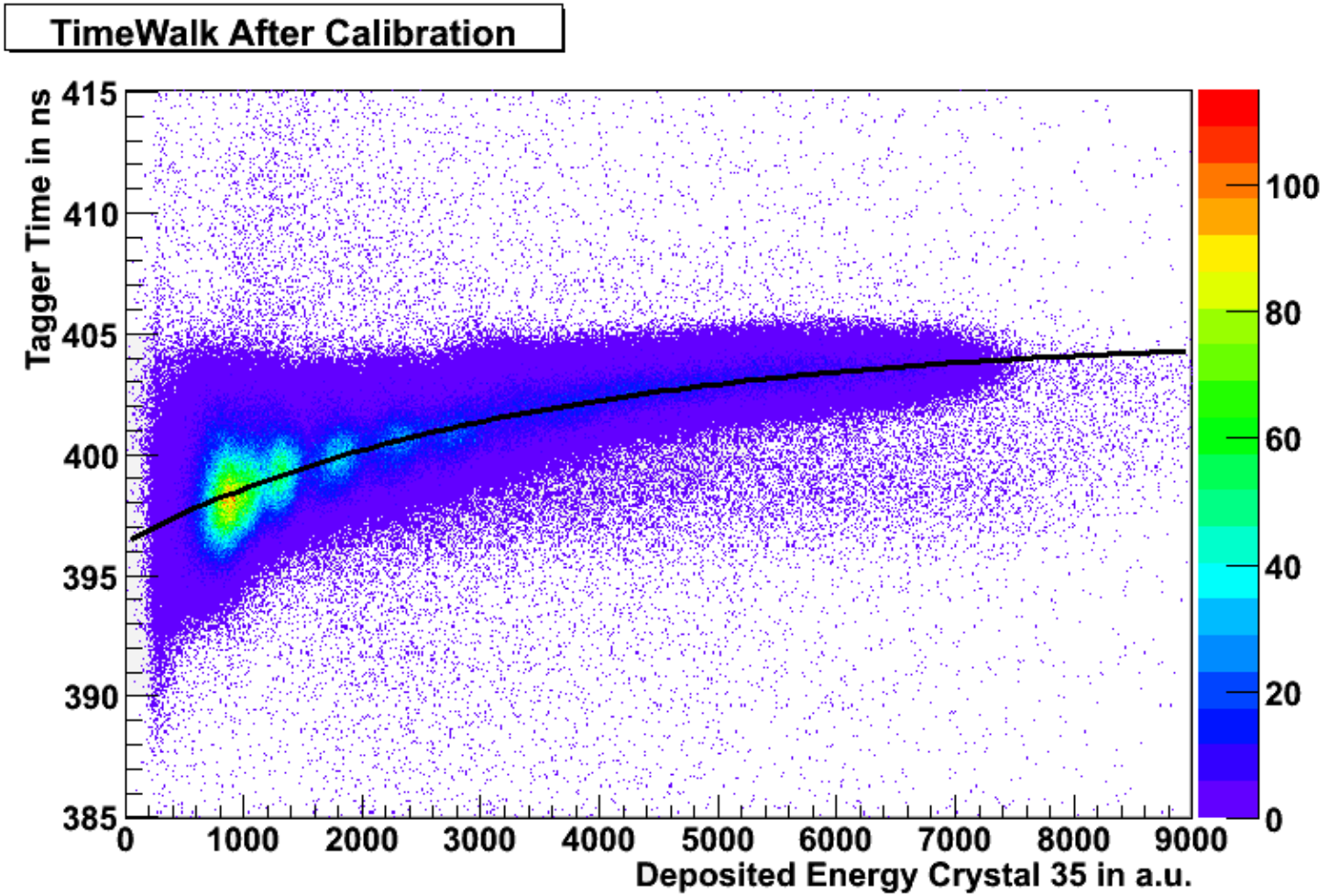
Time Information

- There was time information available against "central" crystal (35) for:
  - Each other crystal of the PROTO60
  - The 15 Tagger Channels
  - The Veto
- Constant Fraction Discriminators (CFDs) were used to get a proper timing information
  - **BUT**: No huge effort to minimize walk effects
  - Therefore we expected a Time Walk of the crystal time versus deposited energy
- Assuming the tagger time has no walk

Tagger Time vs. Crystal 35



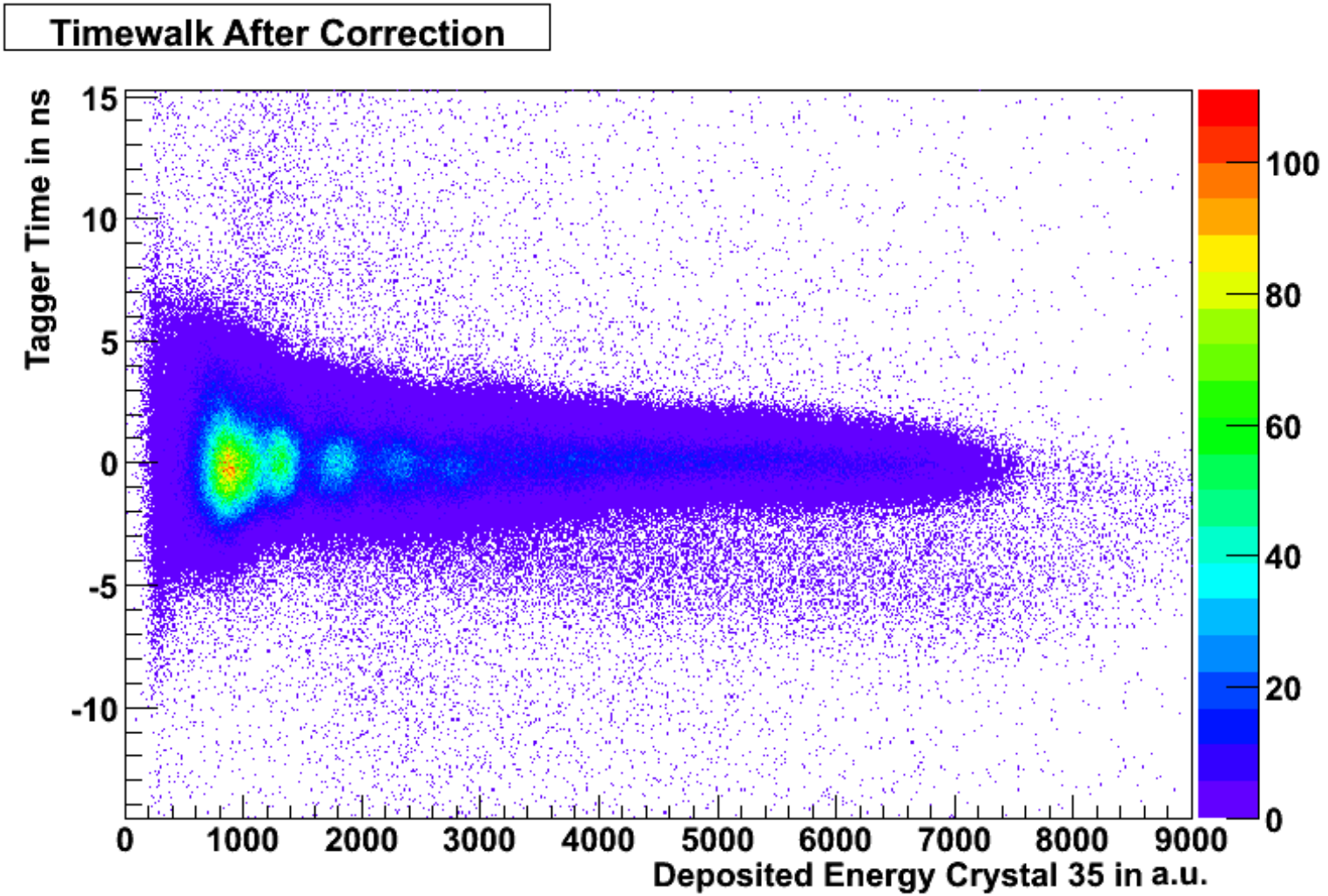
Tagger Time vs. Crystal 35



- Fitting Time Walk with 4 parameter function also used by TAPS-Group this purpose:

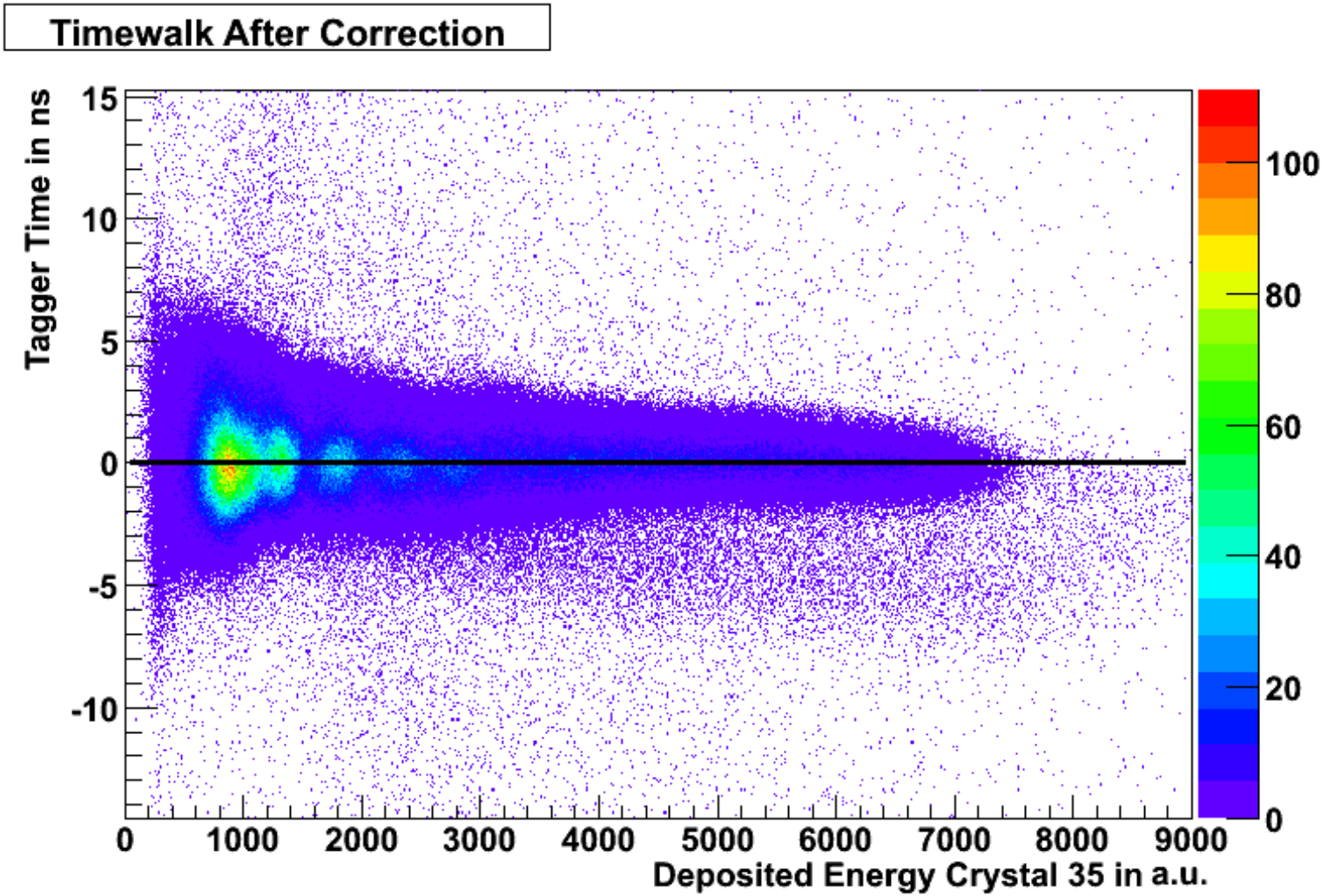
$$t(E) = A \cdot e^{B \cdot \sqrt{E} + C \cdot E} + D$$

Timewalk Correction



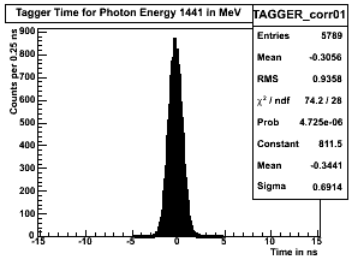
- Spectrum after substraction of the fitted function

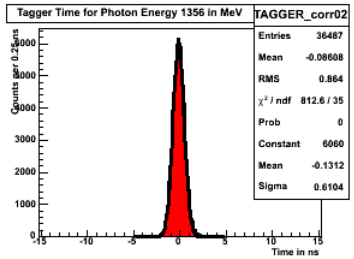
Timewalk Correction

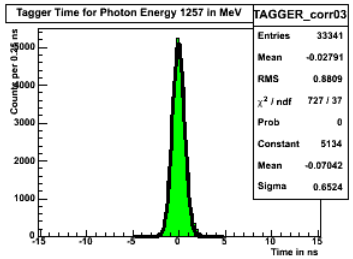


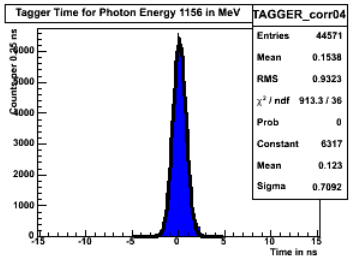
- Spectrum after substraction of the fitted function

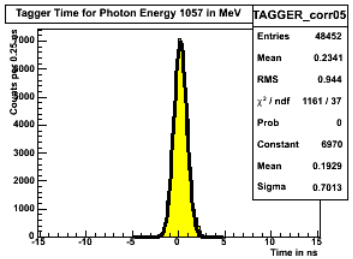
Resolution of the Central Detector

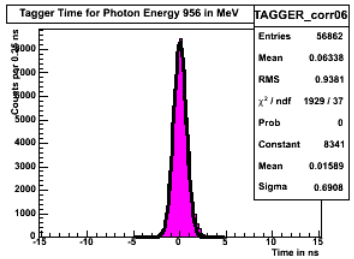


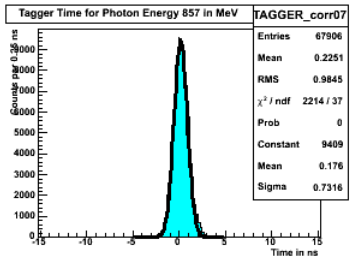


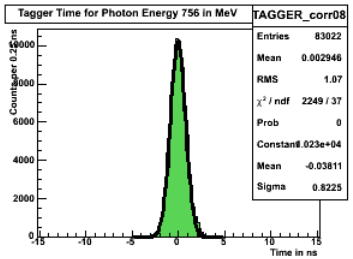


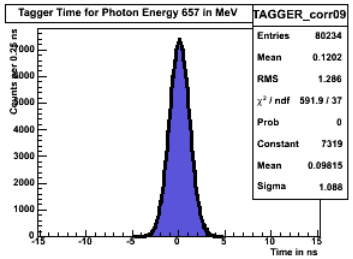


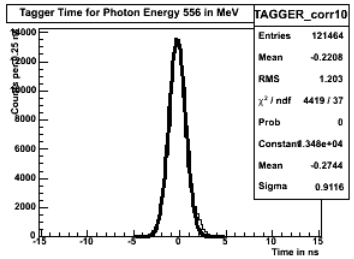


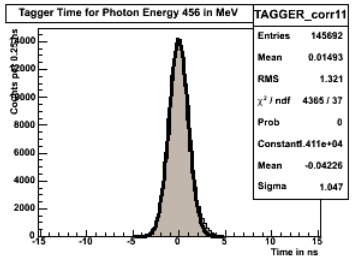


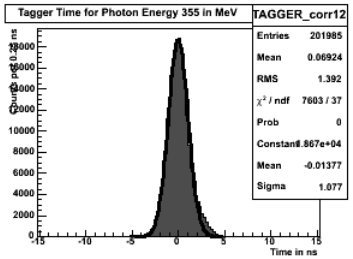


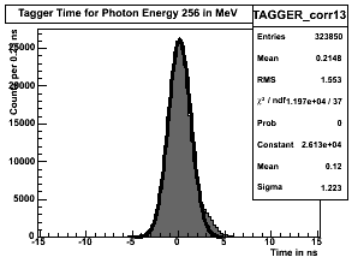


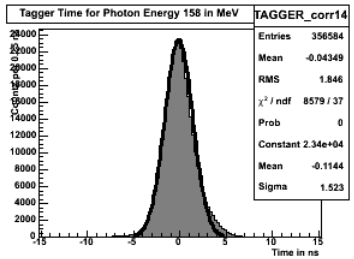


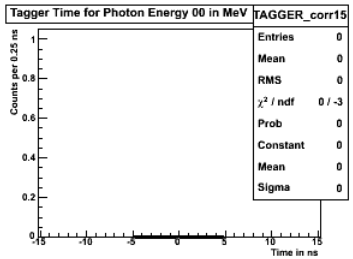


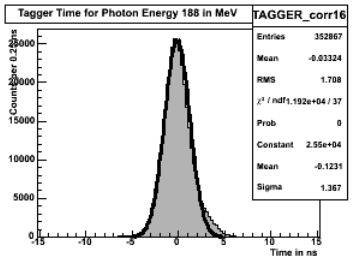




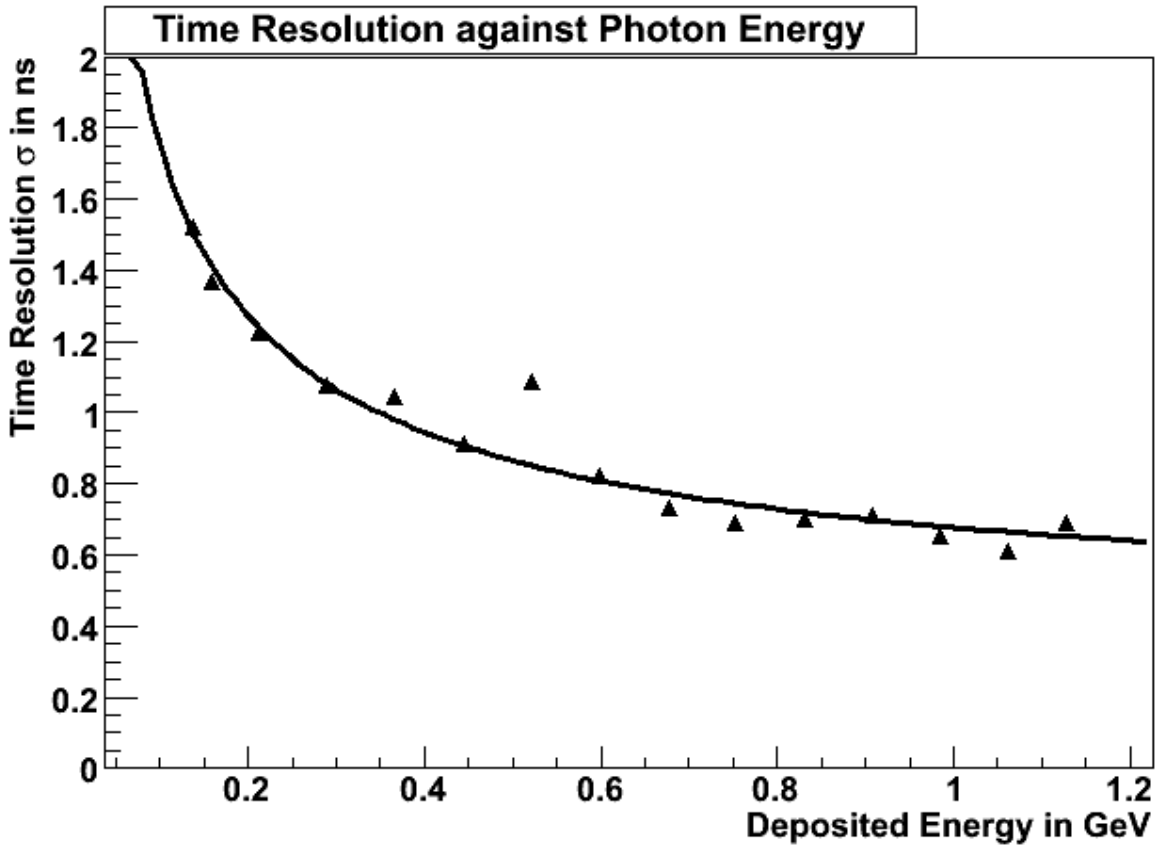








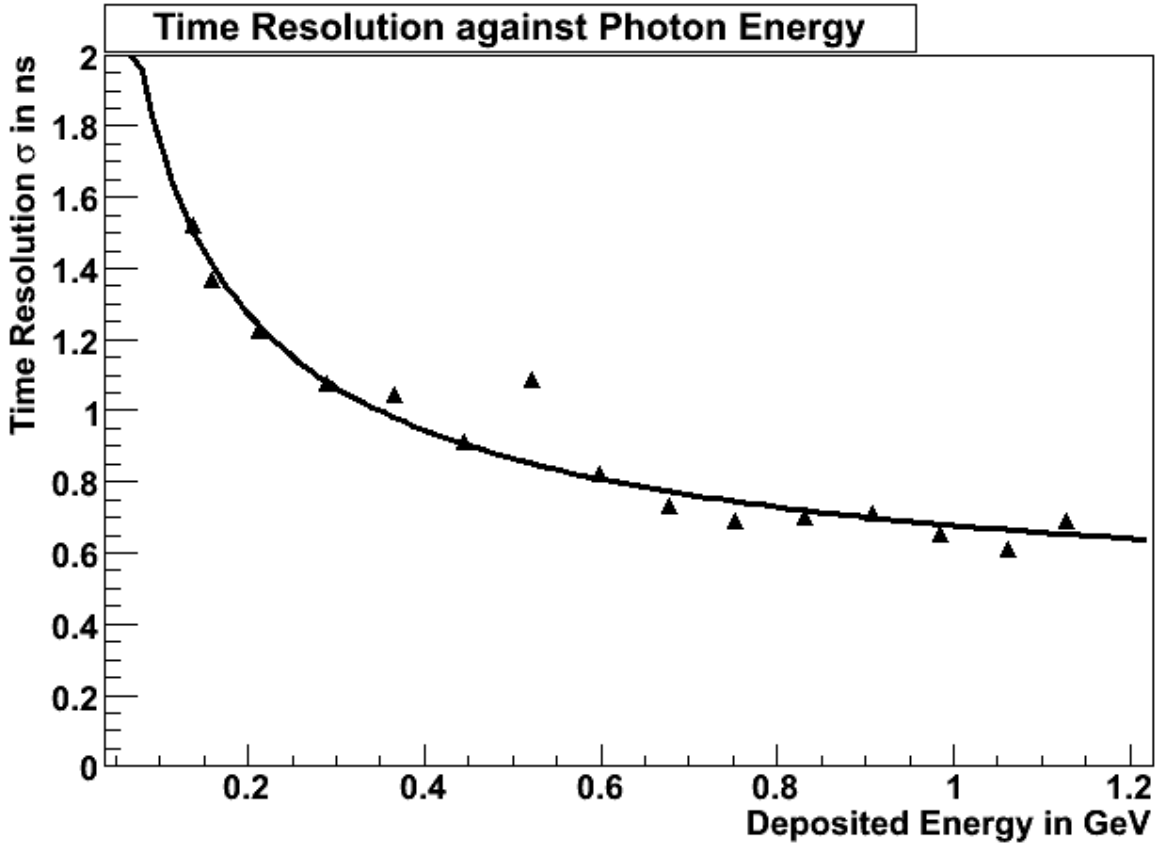
Resolution of the Central Detector



- Time resolution energy dependence obtaind by fit:

$$\sigma_t = \sqrt{(411.8\ \text{ps})^2 + \left(\frac{538.1\ \text{ps}}{\sqrt{E/\text{GeV}}}\right)^2} \hat{=} 677.6\ \text{ps at 1 GeV}$$

Resolution of the Central Detector



- Time resolution energy dependence obtaind by fit:

$$\sigma_t = \sqrt{(411.8\ \text{ps})^2 + \left(\frac{538.1\ \text{ps}}{\sqrt{E/\text{GeV}}}\right)^2} \hat{=} \underline{677.6\ \text{ps at 1 GeV}}$$

Conclusion/Outlook

We obtain the following resolutions for the PROTO60:

- The Energy Resolution is about **2.396 % at 1 GeV:**

$$\frac{\sigma}{E} = 0.626\ \% + \frac{1.770\ \%}{\sqrt{E/\mathrm{GeV}}}$$

- The Position Resolution of the PROTO60 is **below 4.44 mm at 1 GeV:**

$$\sigma_x = 1.087\ \mathrm{mm} - \frac{0,464\ \mathrm{mm}}{E/\mathrm{GeV}} + \frac{3,822\ \mathrm{mm}}{\sqrt{E/\mathrm{GeV}}}$$

- The Time Resolution of the central crystal is about **677.6 ps at 1 GeV:**

$$\sigma_t = \sqrt{(411.8\ \mathrm{ps})^2 + \left(\frac{538.1\ \mathrm{ps}}{\sqrt{E/\mathrm{GeV}}}\right)^2}$$

- Thank you for your attention!