PSA Performance Analysis and Optimization

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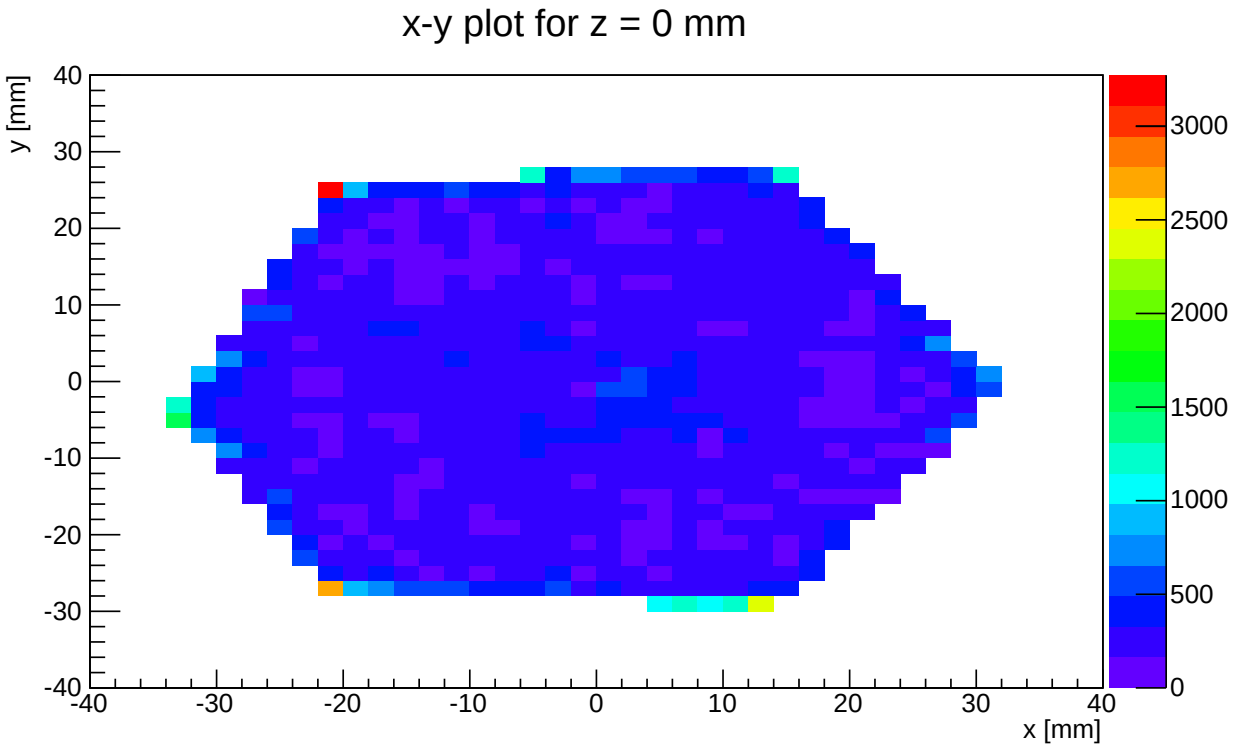
Content

Introduction

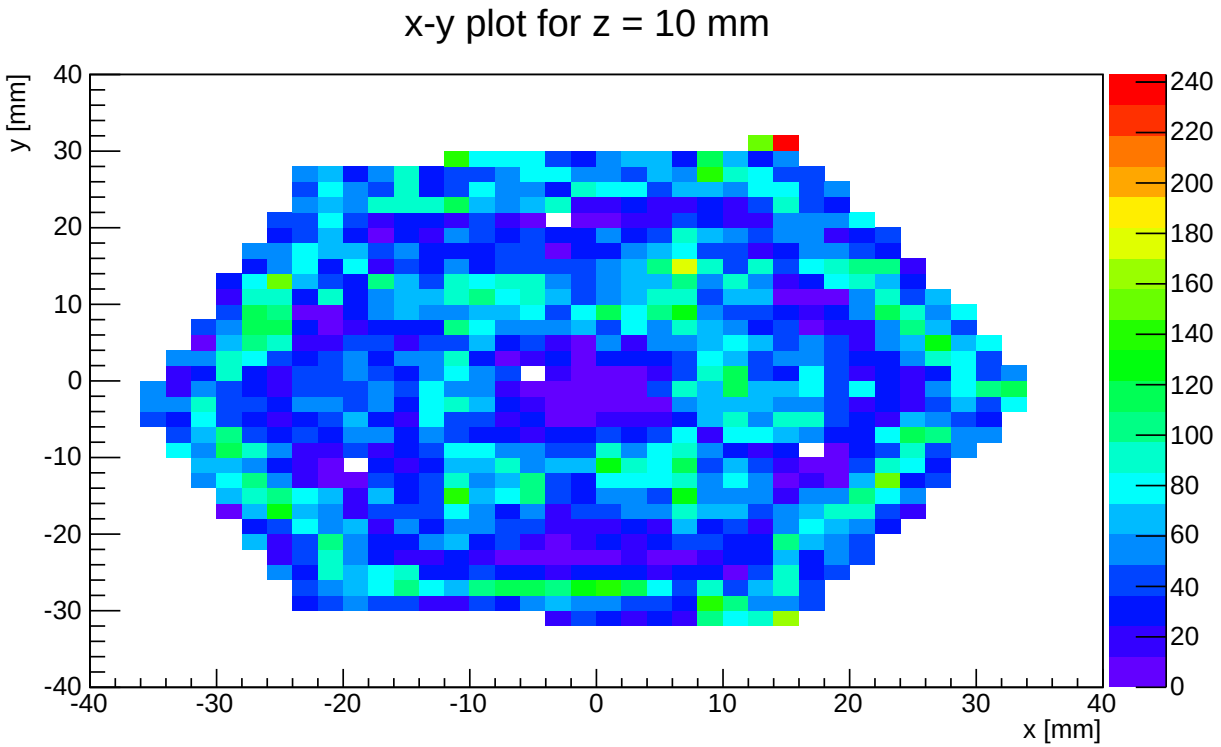
- PSA performance within specifications but: Systematic errors
- Non isotropic distribution of hits with an isotropic radiating single source
- PSA favors certain areas of the detector
- Structure of Segments visible
- Improve and optimize PSA parameters

Eu-152 Measurement



- Certain grid points at the edge of the detector have way more hits than expected by statistical fluctuation

Eu-152 Measurement



- One can see the clustering of hits and then structure of the segments although the interaction probability is the same within the crystal

Optimization method

Parameters to optimize:

- Variables in the Figure of Merit ('Distance Metric')
- Preamplifier Response function
- Differential Crosstalk

Methods and observables

- Doppler correction and peak width as measure of PSA performance
- Isotropy of distribution of hits
- Correlation of neighbouring grid points ($\Rightarrow$ Clustering)

Results using Doppler corrected Peaks

Used Data: LNL 11.22 with ^{136}Xe beam gated on the ejectile mostly using the 2^+ from ^{136}Xe (credits to Benedikt Birkenbach and Andreas Vogt)

- The interaction point is determined by calculating the Figure of Merit for each set of simulated traces and the measured trace. It is defined as:

Definition

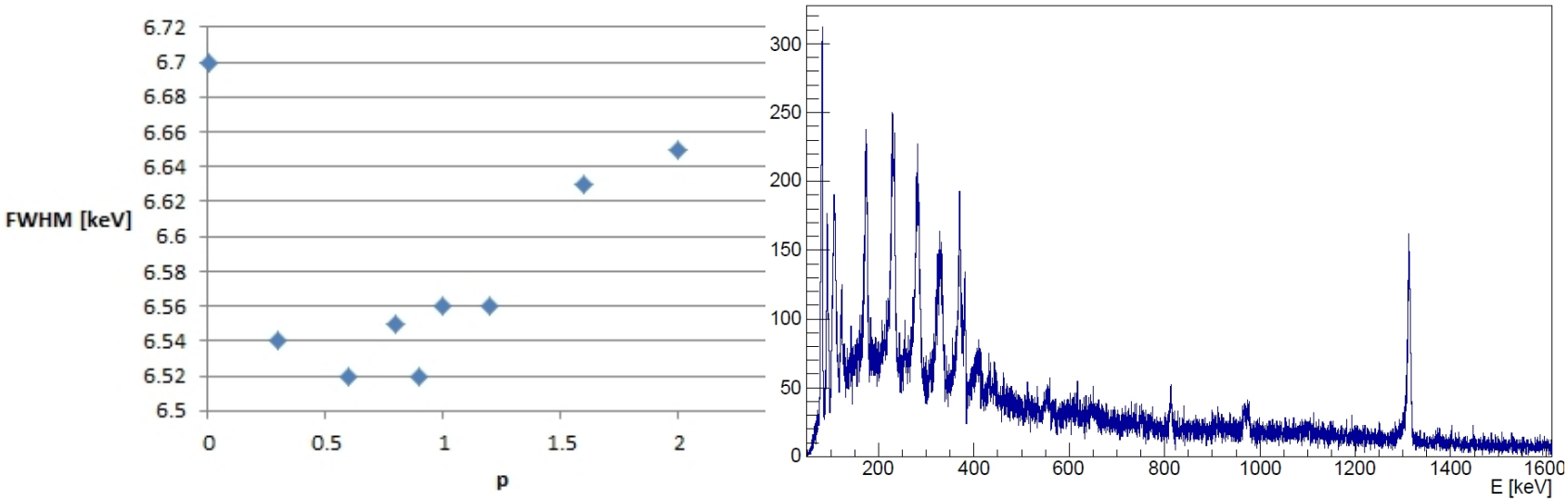
$$\text{Figure of Merit} = \sum_{\text{Segments } j} \sum_{\text{Timesteps } t_i} |v^m_{i,j} - v^s_{i,j}|^p$$

Vary p > 0, p ∈ R

One would expect best results for $p = 2$ if the difference $|v^m_{i,j} - v^s_{i,j}|$ behaves gaussian.

Results using Doppler corrected Peaks

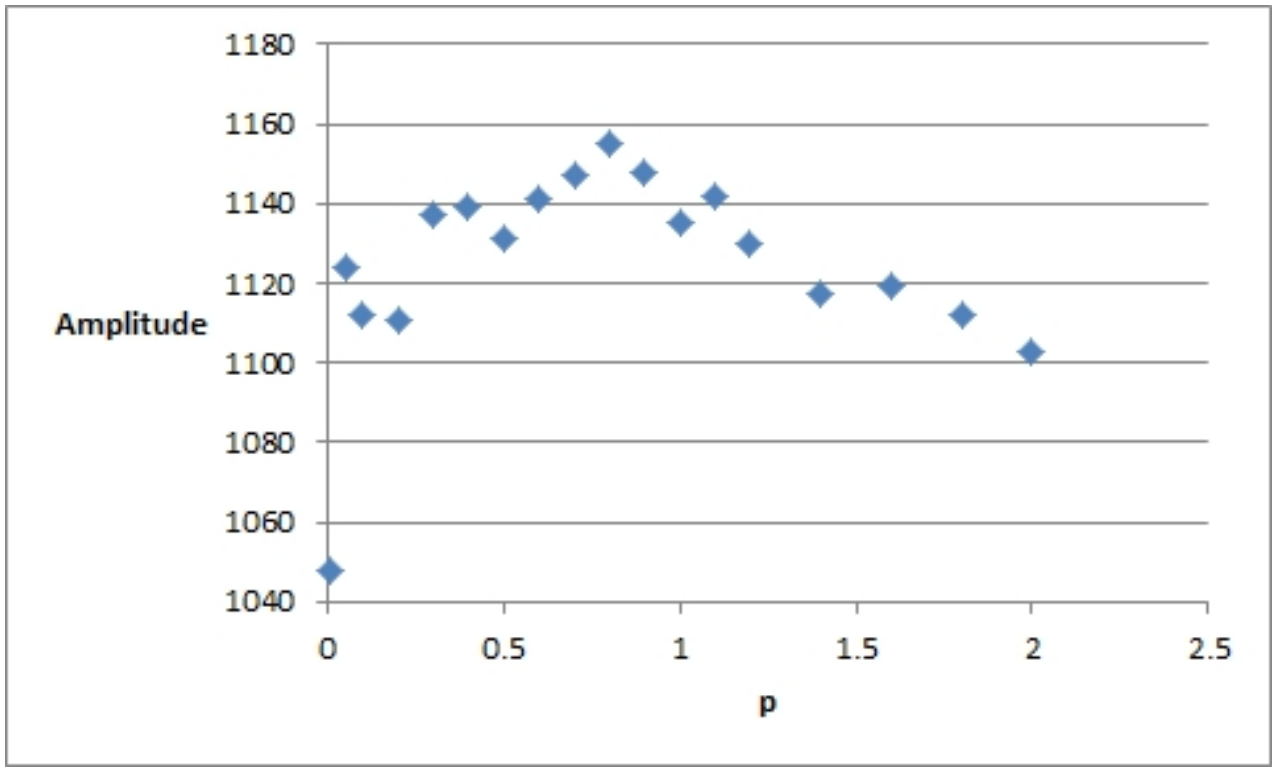
Variation of the exponent



- One can see a behaviour showing a minimum
- But value changes significantly when changing fit parameters only slightly
- Low statistics lead to high errors of the corresponding fit 0.2 keV

Results using Doppler corrected Peaks

Therefore the amplitude is considered when choosing a rougher binning to get a value independent of fit parameters:



The behaviour seems to be somewhat more consistent.

Additional Methods

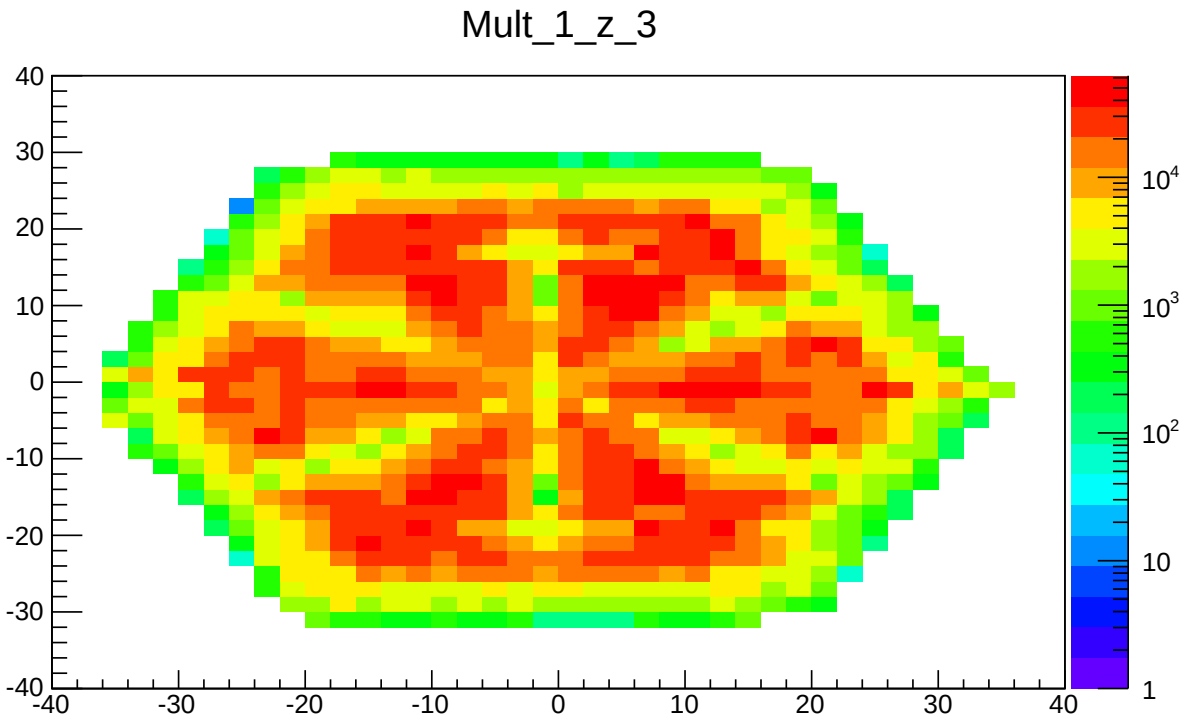
The Doppler correction method cannot detect slight variations in the PSA performance. Low statistics in the gated spectra is a problem aswell.
$\Rightarrow$ more tools are needed

Isotropy of hit distribution and clustering of events

- Single isotropic radiating source
- Quantify how homogenious the distribution of hit is
- Are neighbouring grid points correlated?

Therefore two new values are introduced:

Analysis



Analyze xy-Plots for different z for every detector

Analysis

- The bin content of each bin of a xy-plot for a certain depth z is read out
- The mean bin content is evaluted by $Mean = \sum_{i,j}^{N} BinContent_{i,j} \cdot \frac{1}{N}$
- Where N is the number of bins

Error of single Measurement

$$Error = \sqrt{\frac{\sum_{i,j} (BinContent_{i,j} - Mean)^2}{N}}$$

Which is not the Error of the Mean which would be $\frac{Error}{N-1}$ but the Error of the single Measurement of the Bin Content of one pixel. For comparison the Error has to be normalized by the Mean value.

Correlation Coefficient

- As this Error does not consider the xy-position of the bins, a Correlation Coefficient is defined as to describe the clustering of hits in the detector

Correlation Coefficient

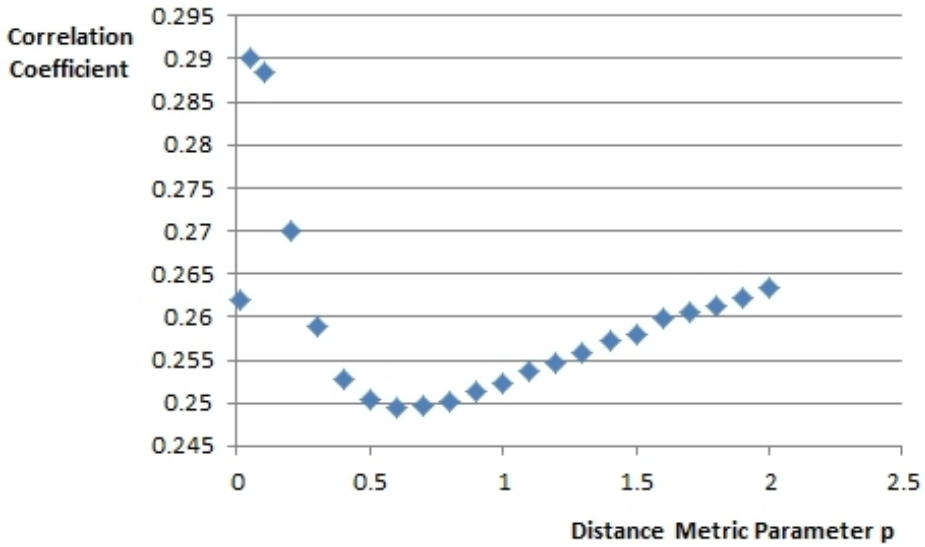
When BC is the Bin Content, $E(BC_{i,j})$ the Expectancy Value for the bin (i,j),the Covariance Cov is given by

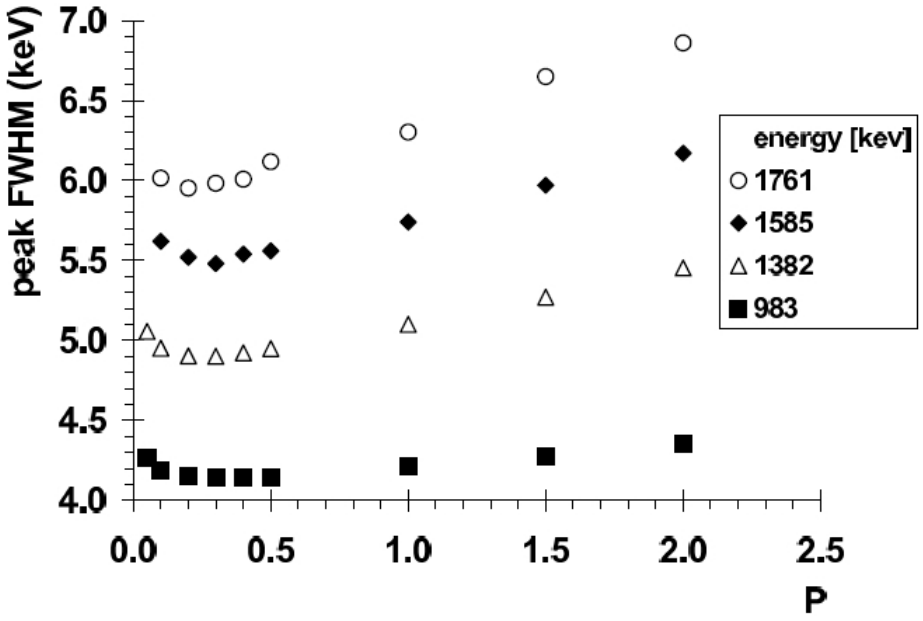
$$Cov = E[(BC_{i,j} - E(BC_{i,j}))(BC_{i,j+1} - E(BC_{i,j+1}))]$$

As the assumed distribution is isotropic the Expectancy value for all bins is the same, namely the Mean. To get a comparable Correlation Coefficent one has to normalize the Covariance

$$Corr.Coeff. = \frac{Cov}{\sigma_{i,j}\sigma_{i,j+1}} = \frac{Cov}{Error^2}$$

Distance Metric with the Correlation Coefficient





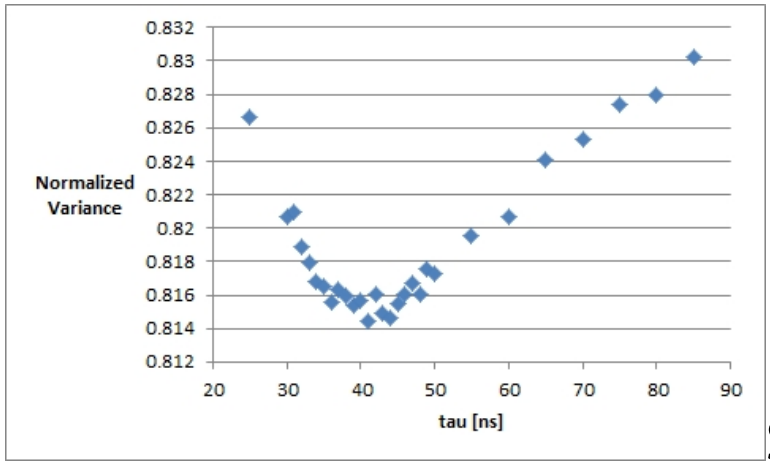
[2]

- Consistent behaviour with Doppler correction method
- more accurate

Response Function

Convolution of real signal and detector response

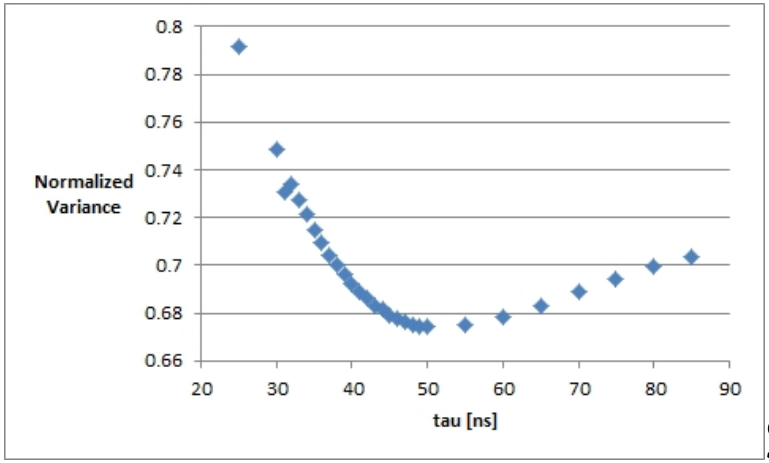
- Preamplifiers and digitizers smear out a step function
- One gets something like exponential saturation
- For Correction one needs to get the derivative $\Rightarrow$ exponential decay parametrized by decay parameter τ for each slice



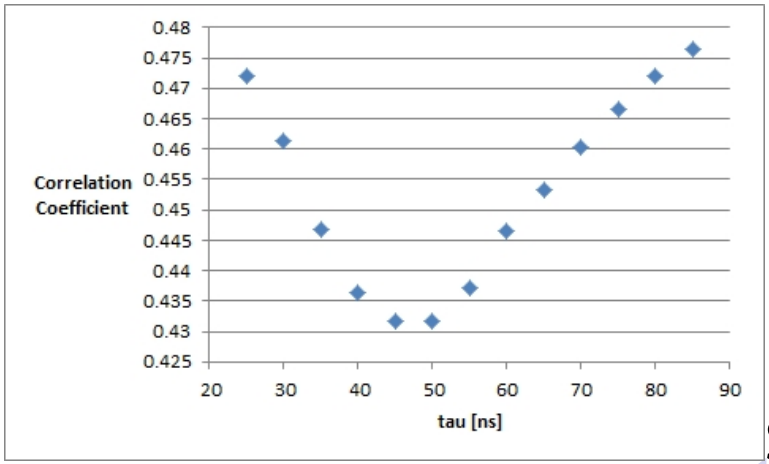
Slice 6

Response Function

Previous standard value: 35 μs



Slice 2



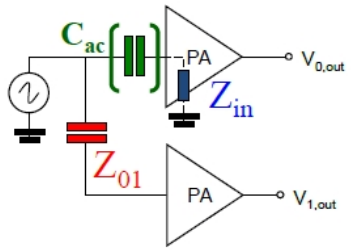
Slice 2

Differential Crosstalk

With $Z_{in} = 1/sAC_{fb} + (1/sC_{ac}) + R_{cold}$

Xtalk $\sim Z_{in} / Z_{01}$

$\sim \underbrace{C_{01}/AC_{fb} + (C_{01}/C_{ac})}_{\text{Proportional}} + \underbrace{s \cdot R_{cold} C_{01}}_{\text{+ Differential Xtalk}}$



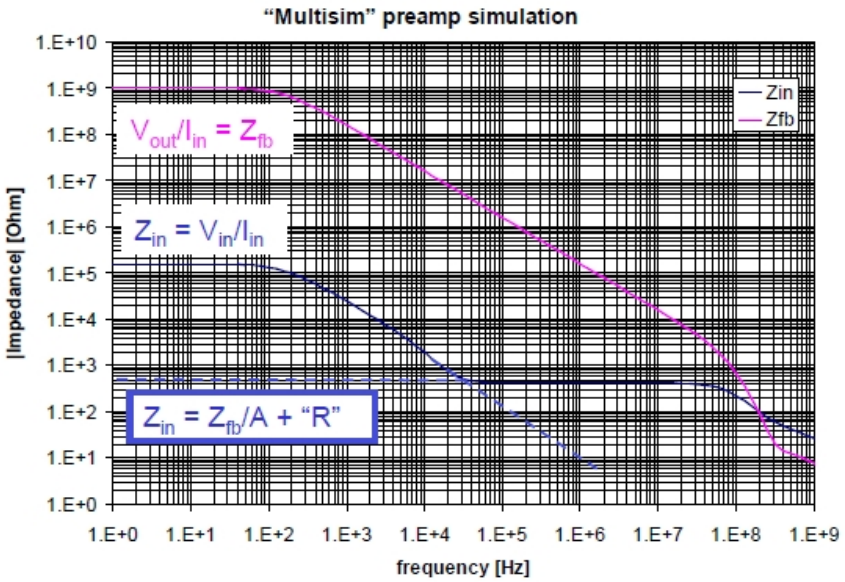
[1]

Implementation

$$\text{Average Crosstalk(Segment i)} = \sum_{j=1}^{N} \text{Crosstalk}_{i,j} \frac{1}{N}$$

$$\text{Differential Crosstalk}_{i,j} = (\text{Prop. Crosstalk}_{i,j} - \text{Avg Crosstalk}_{i})R'$$

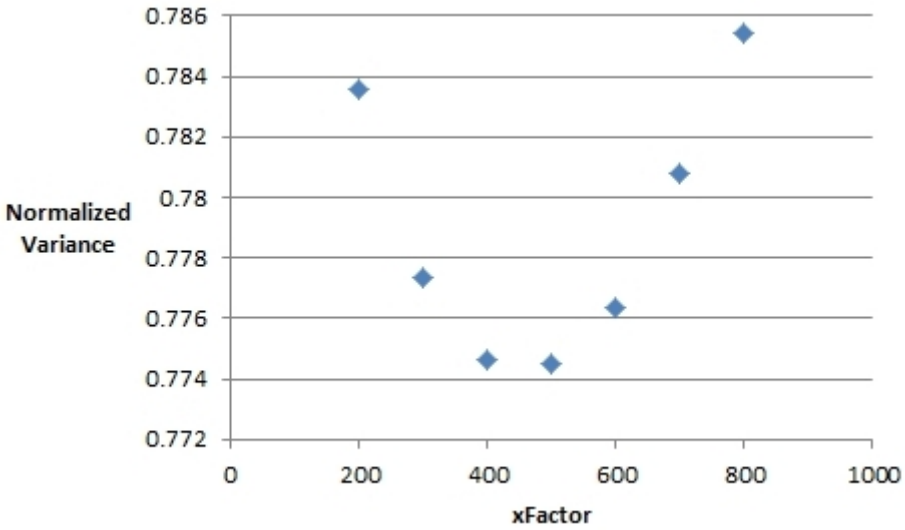
Differential Crosstalk

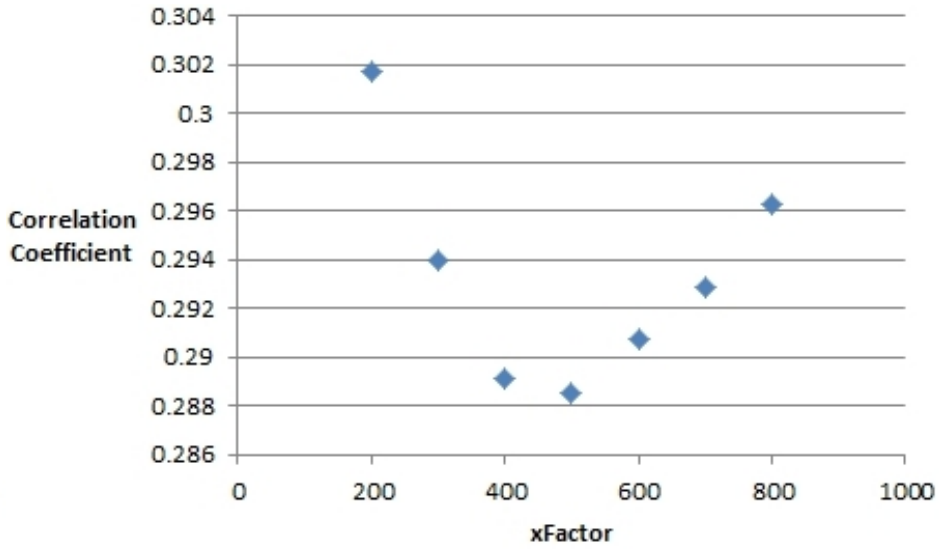


[1]

- Average Crosstalk is an estimate for core to segment Crosstalk
- Deviations from that come from segment to segment Crosstalk (mostly neighbouring segments)

Differential Crosstalk





- Variation of the Resistance R' = xFactor (a.u.)
- Both parameters give consistent results

Outlook

- Several parameters were investigated and optimized
- Clustering still exists. Exclude investigated parameters
- Analyze data of measurements with a collimated source
- Use the created tools to investigate further parameters of the producers
- Investigate the ADL bases?

Bibliography I

[1] Bart Bruyneel CEA Saclay France. Electronics. *EGAN School, Liverpool*, 2011.

[2] Francesco Recchia. In-beam test and imaging capabilities of the agata prototype detector. *Universita degli studi Padova*, 2008.