# Backward End-Cap Activities

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PANDA Collaboration Meeting 19/2

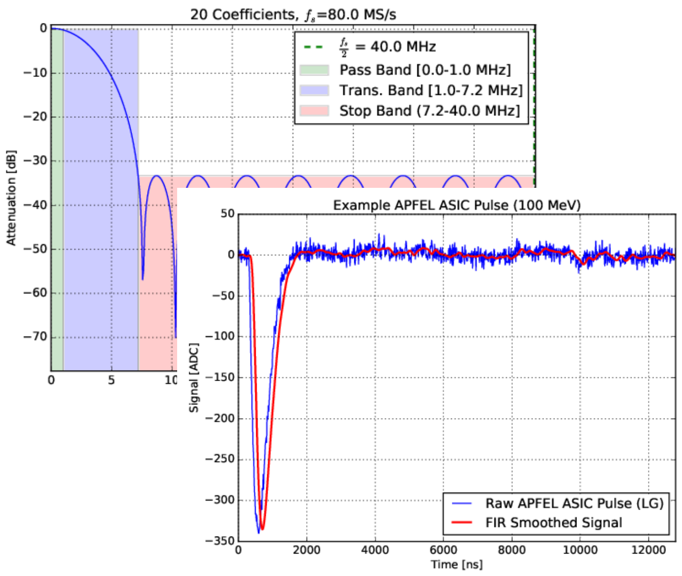
26.06.19

# Backward End-Cap Activities

- Time Based Simulation Framework
- In Situ APD Characterisation

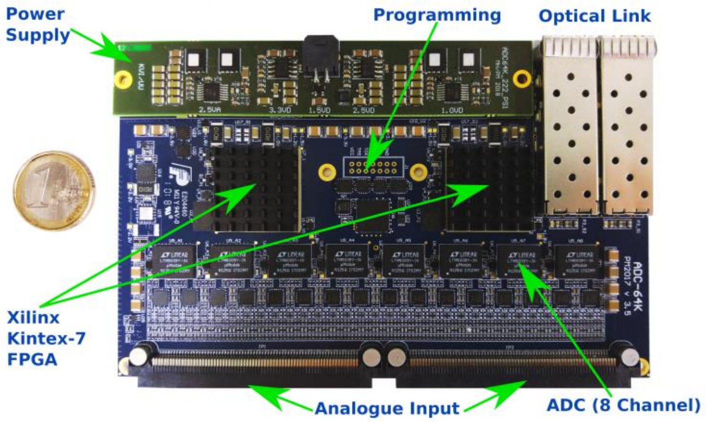
# Time Based Simulation Framework – Mainz SADC Firmware

## Finite Impulse Response Filtering

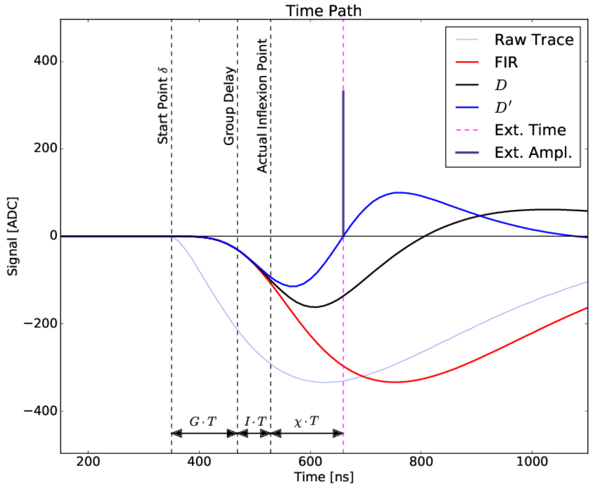



- 20 coefficients
- Efficient implementation (Distributed Arithmetics)

## SADC (PM2017 v 3.5), Uppsala

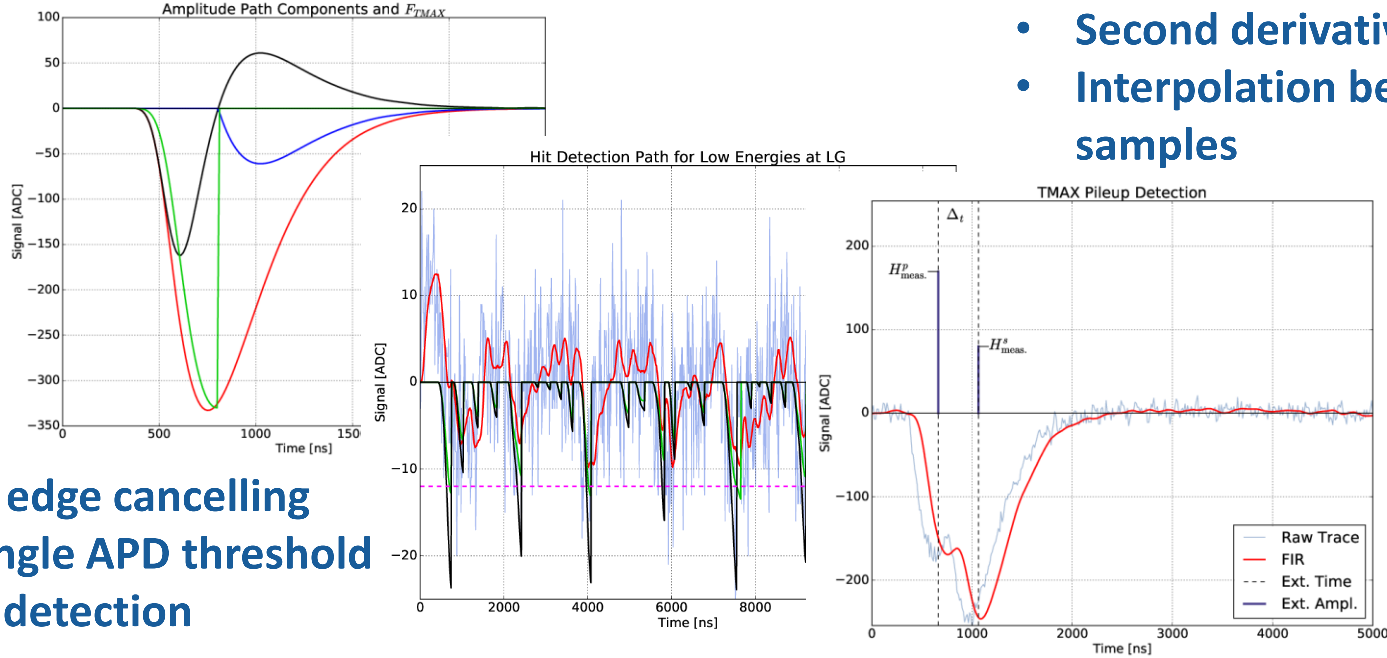



## Time Extraction




- Second derivative
- Interpolation between samples

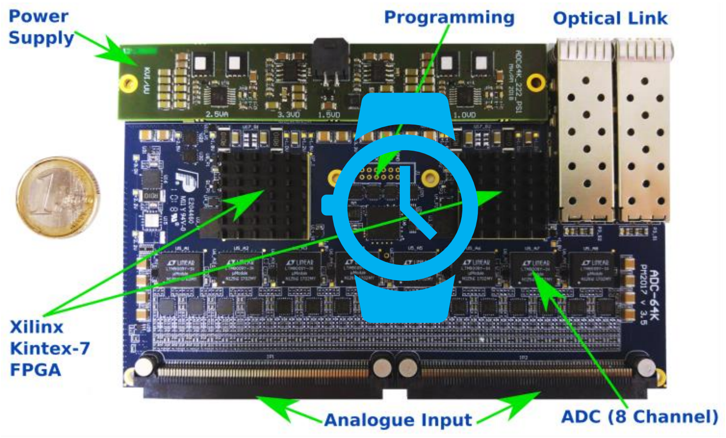
## Amplitude Extraction + Hit Detection




- Falling edge cancelling
- Low single APD threshold
- Pileup detection

# Time Based Simulation Framework – Origin

## Hardware Development




- Time consuming development
- Logic simulation (test benches)
- Filter coefficients?
- Extraction parameters?
- Different methods?
- Different APD gains?

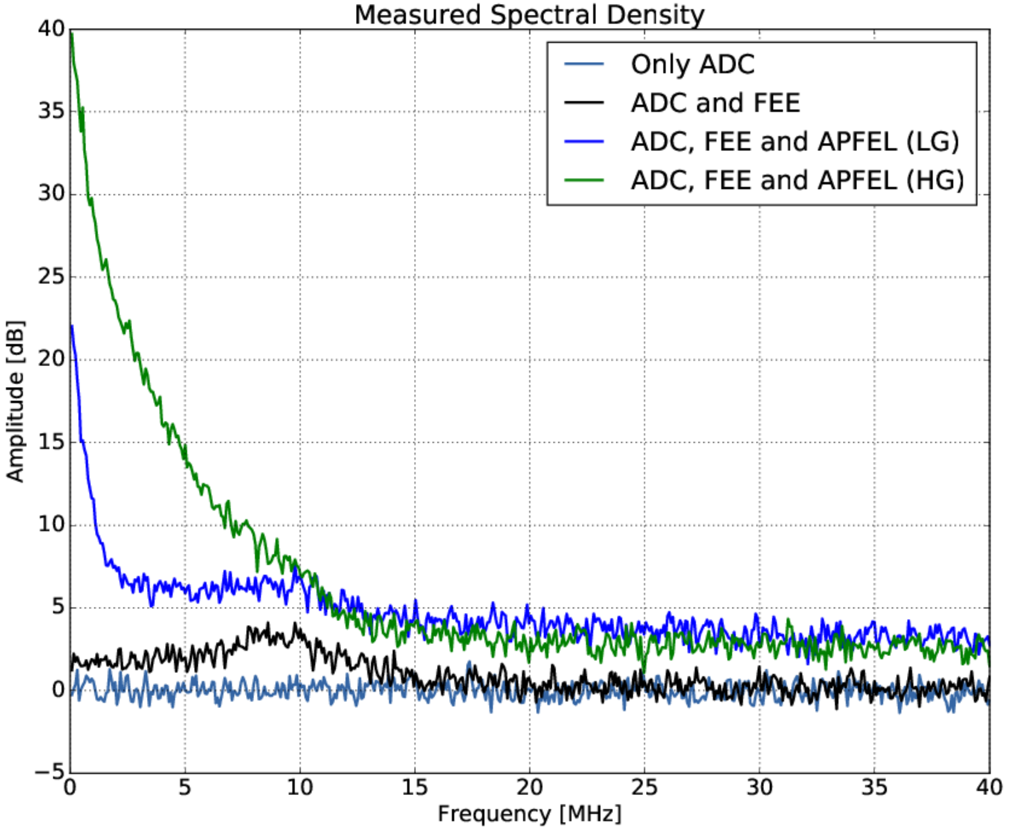
Solution

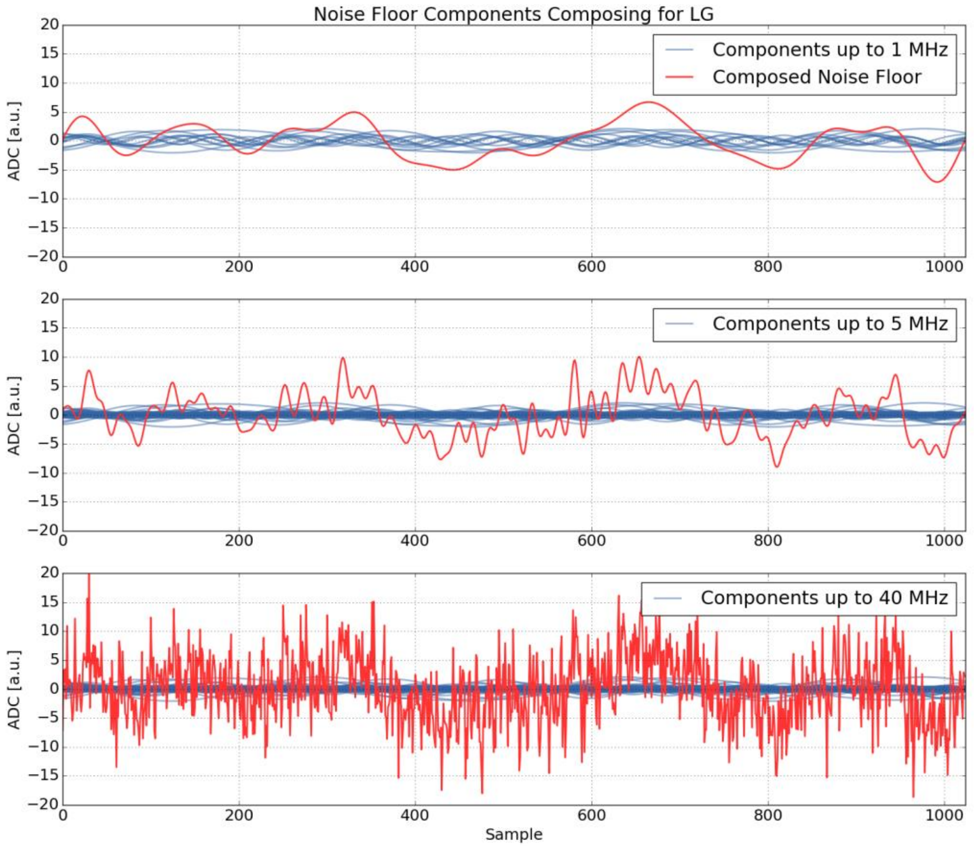
**Raw Signal Simulation**
- Trace simulation
- Realistic noise floor
- Arbitrary energies and appearance times
- Arbitrary APD gains

**Parameter Extraction**
- Software version of hardware algorithms
- Finite resolution
- Fix point arithmetics

**Analysis**
- Comparing of extracted events with input events
- Efficiency, noise hit rate, relative resolution, linearity, …

# Time Based Simulation Framework – Realistic Noise Floor

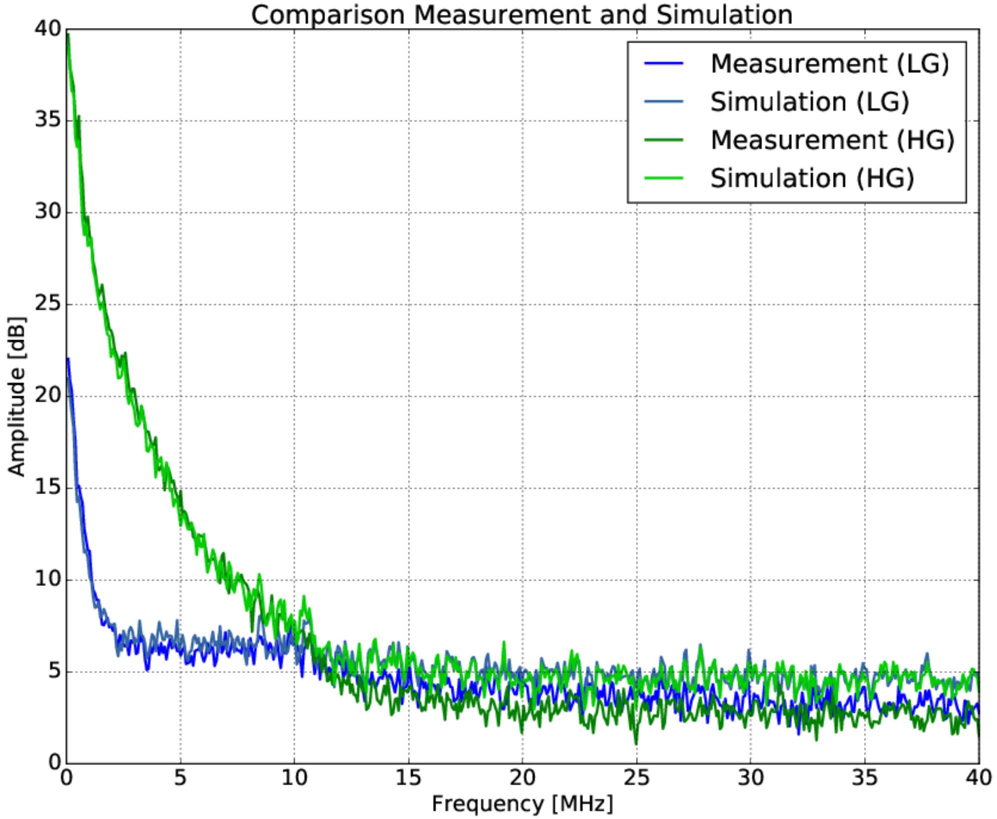


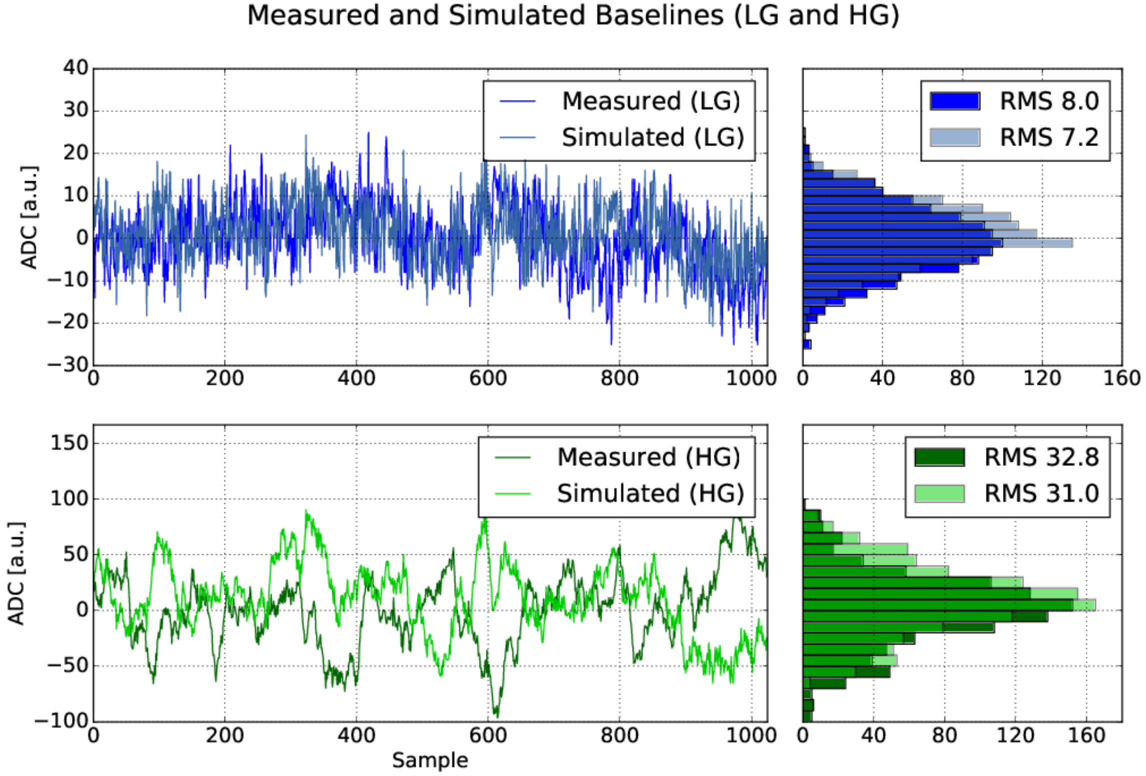




- **Baseline measurement with SADC**
- **Determination of spectral density**
- **Normalised to ADC (0 dB)**
- **Strong APFEL contribution**

- **Baseline generator**
- **Inverse Fourier-Transformation**
- **Mixing components according to spectral density**
- **Uniform distributed phases**

# Time Based Simulation Framework – Realistic Noise Floor

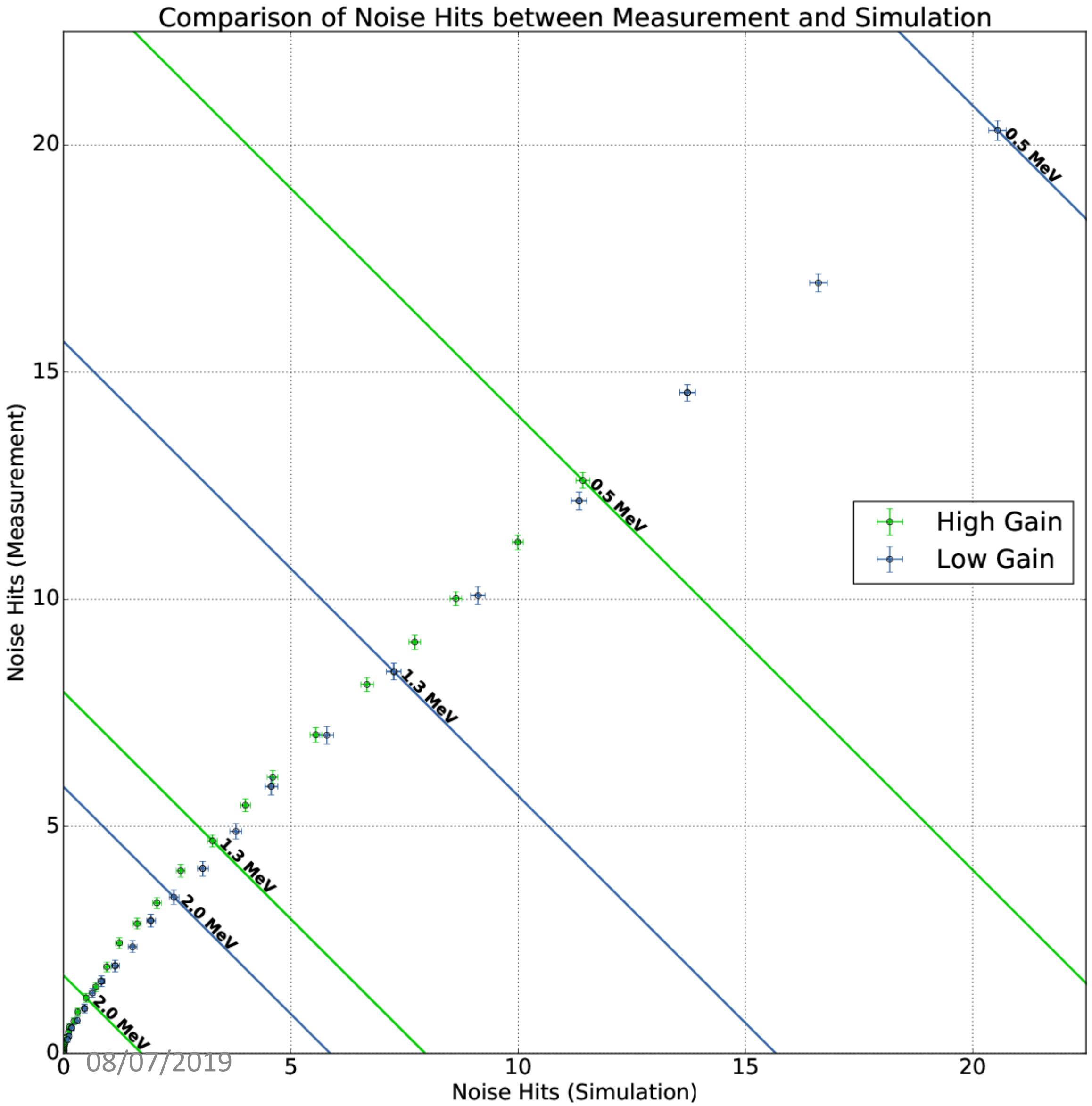



- **Good agreement at relevant frequencies**
- **Small discrepancies (~2-3 dB) at high frequencies**

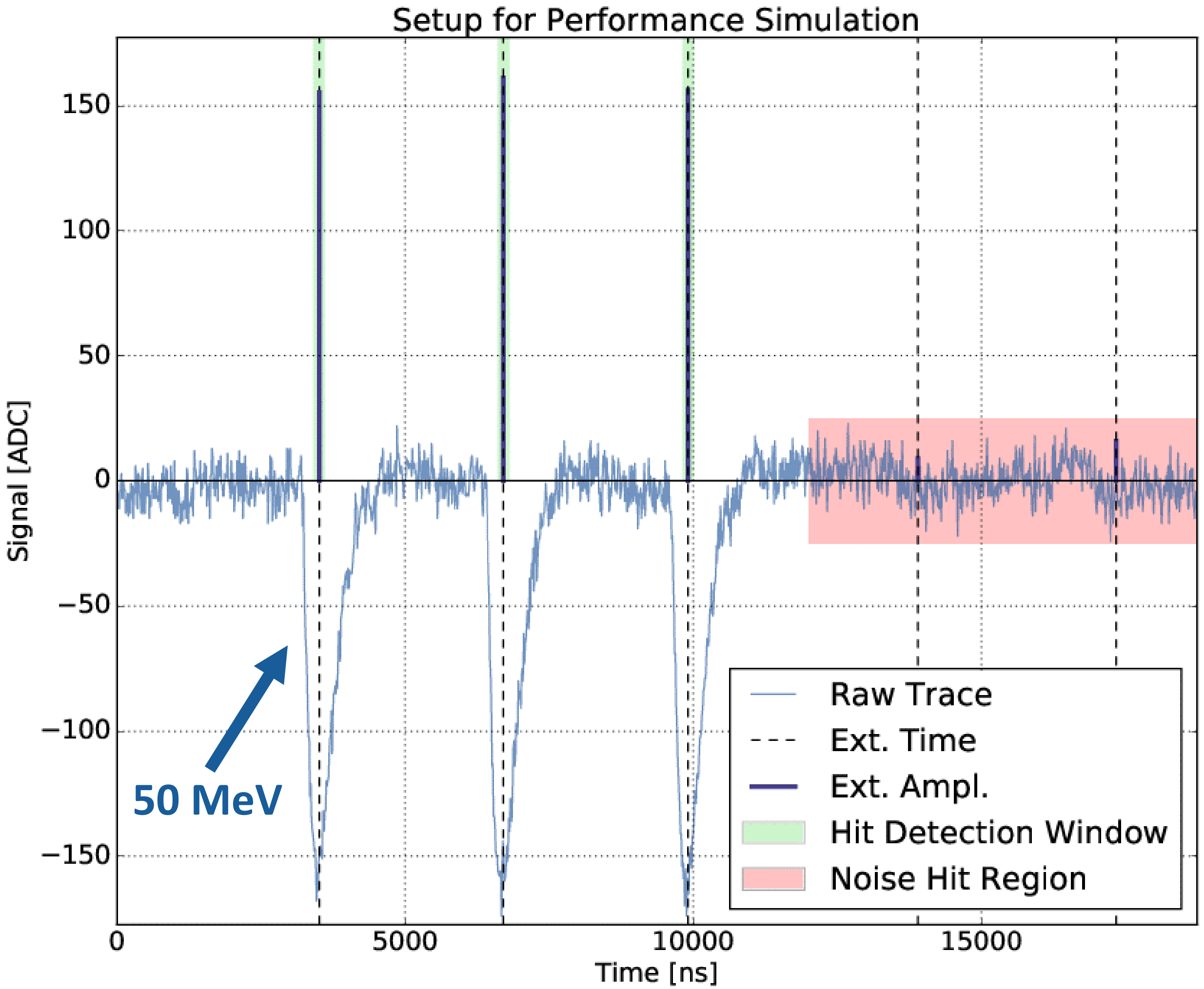
- **Similar RMS**
- **"Looks" similar!**
- **Similar enough?**

# Time Based Simulation Framework – Realistic Noise Floor



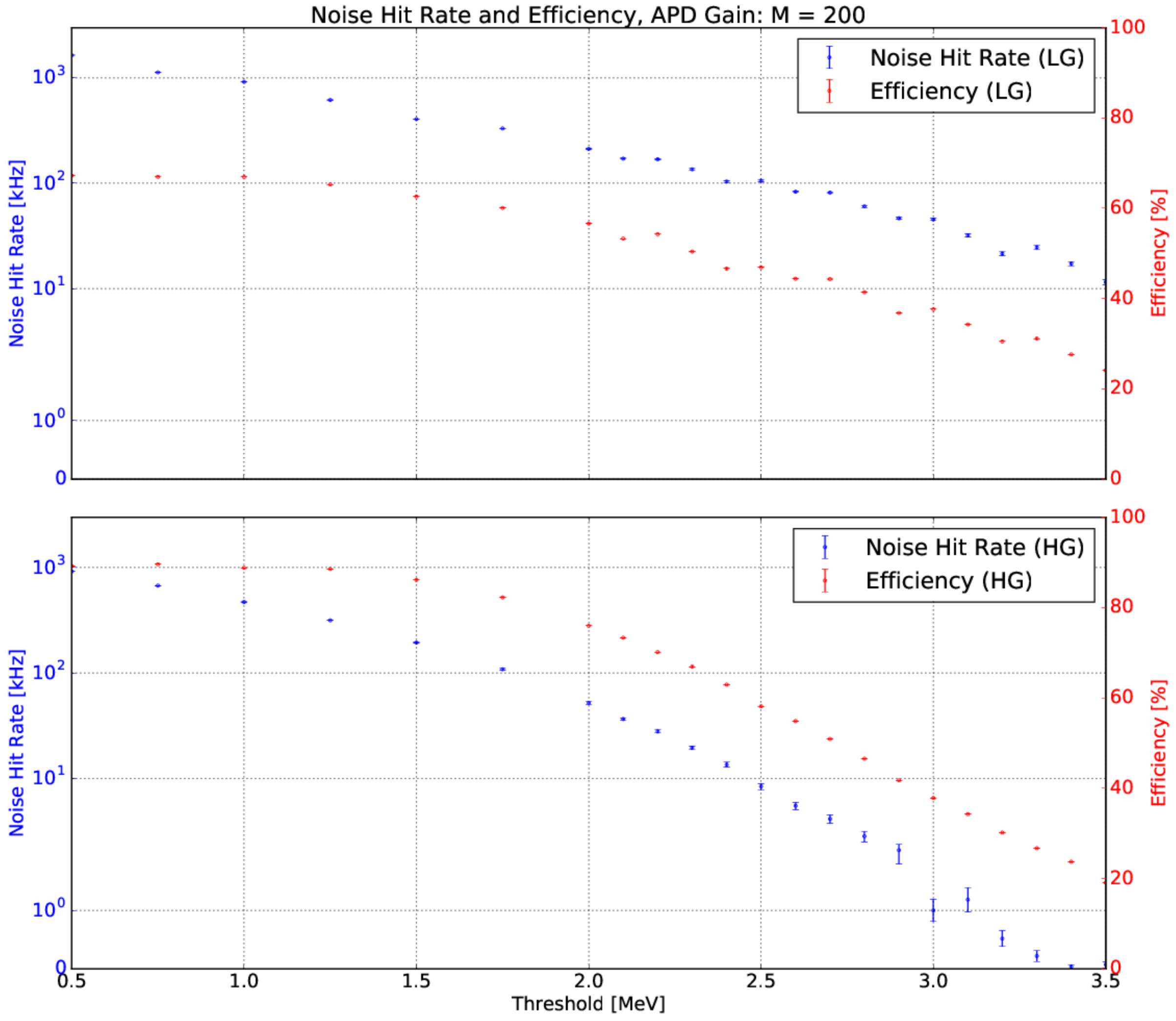

- **Parameter extraction applied at both: simulated baselines and measured baselines**
- **1024 sample baselines (12.8 µs)**
- **Average number of noise hits at given threshold**
- **Perfect simulation →points congruent with angle bisector**
- **Simulation → slightly less (1-3) noise hits**

# Time Based Simulation Framework – Simulation Procedure




- **4000 traces per energy or threshold**
- **3 pulses per trace**
- **12000 possibly detectable true hits**
- **Noise hit region**

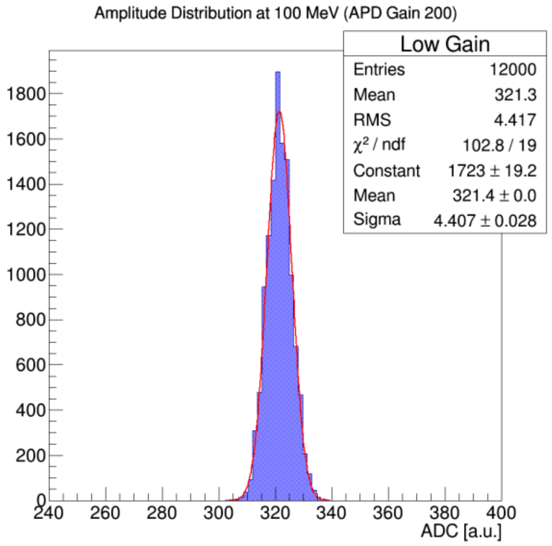
# Time Based Simulation Framework – Noise Hit Rate

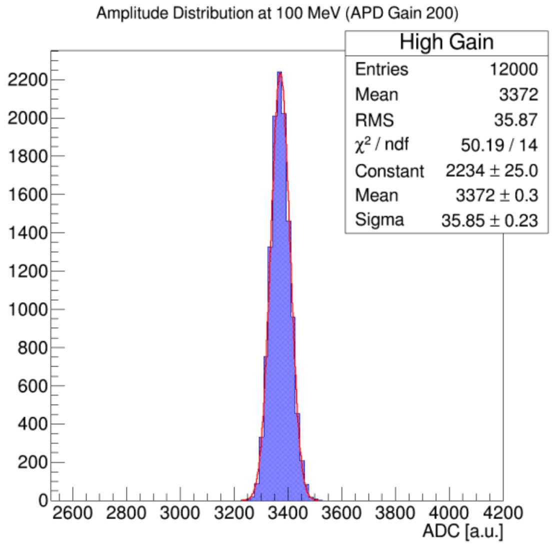


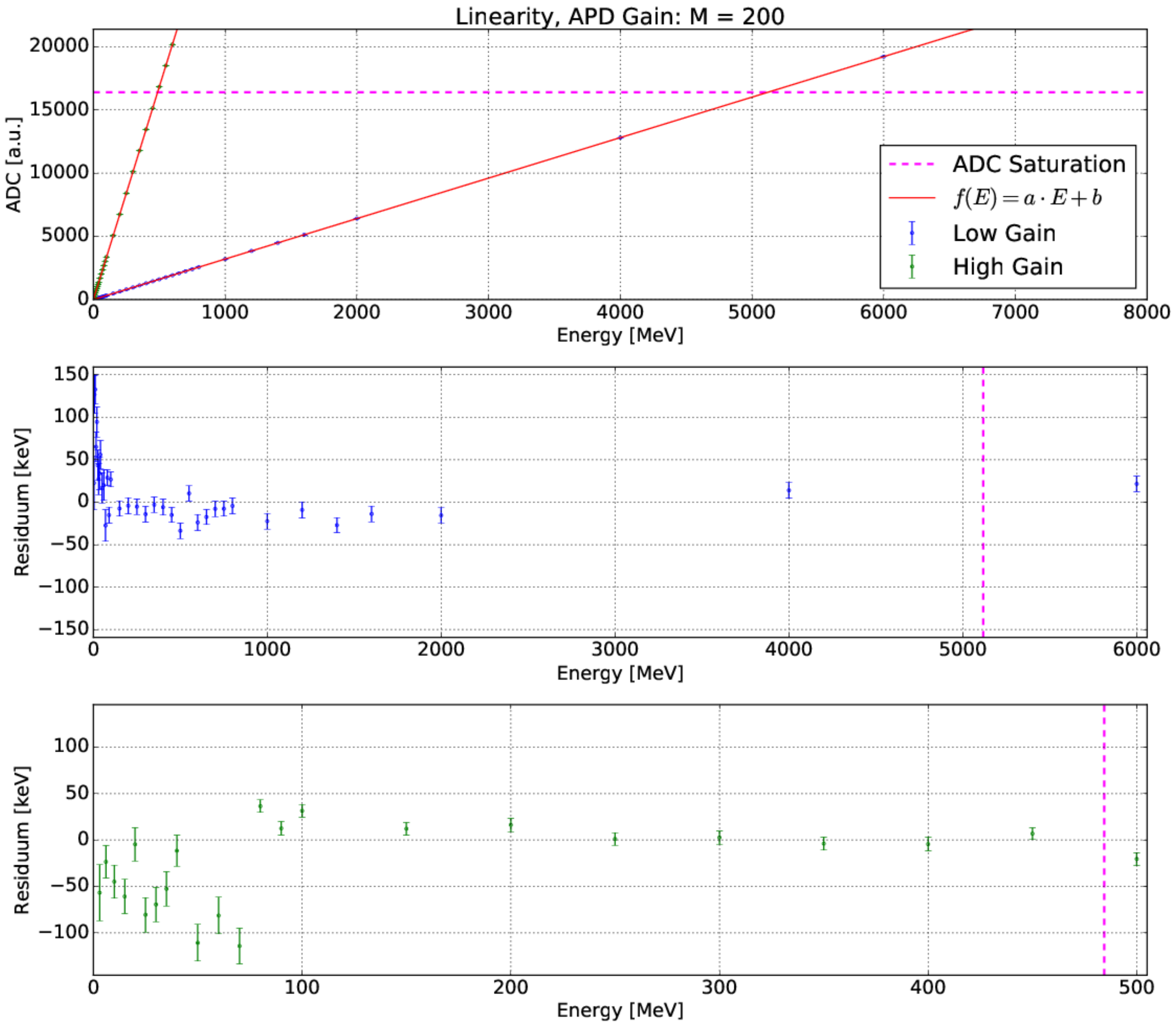

- **Example: APD gain 200**
- **3 MeV events**
- **Current firmware implementation: up to 558 kHz/channel**
- **Up to 90 % efficiency at APFEL HG**
- **Online comparison?**

# Time Based Simulation Framework – Linearity

- **Example: APD gain 200**
- **Residua < 150 keV**

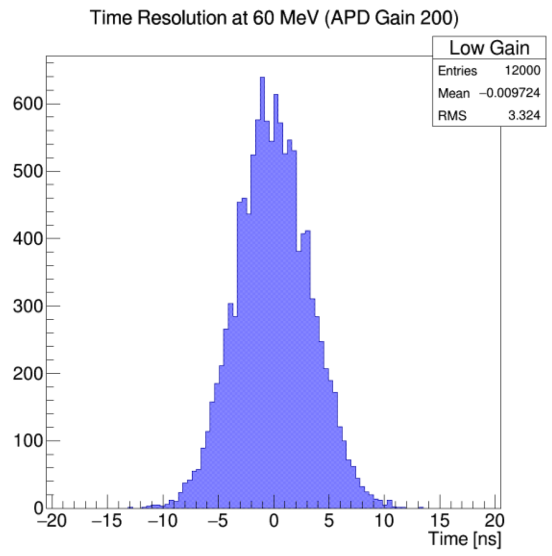


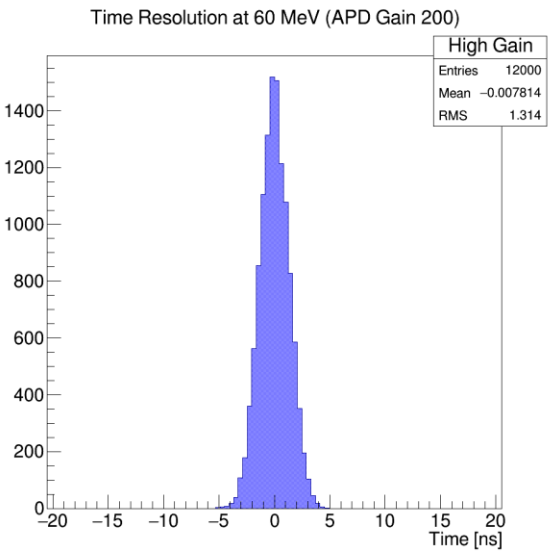



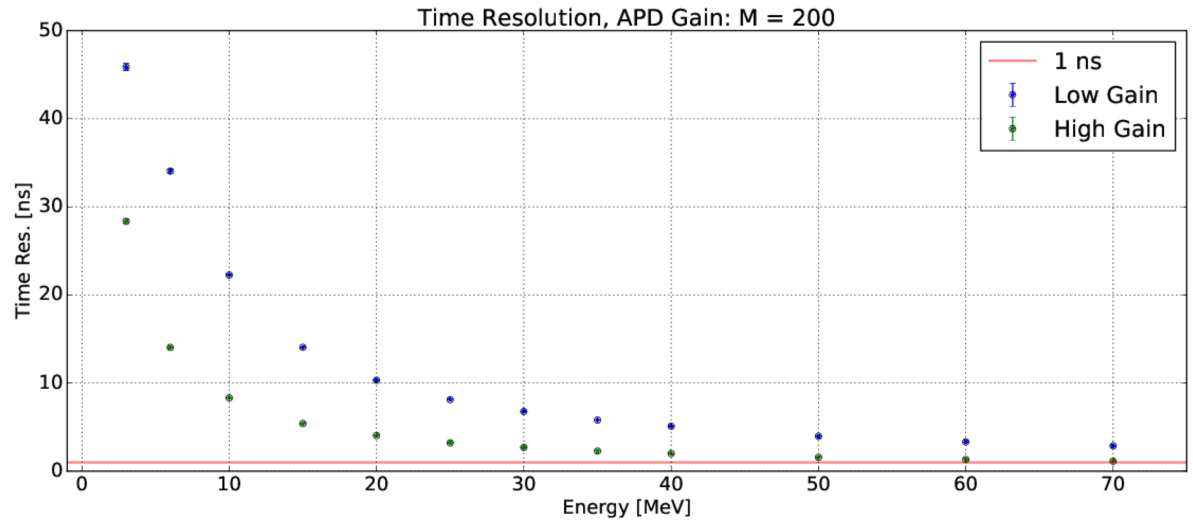



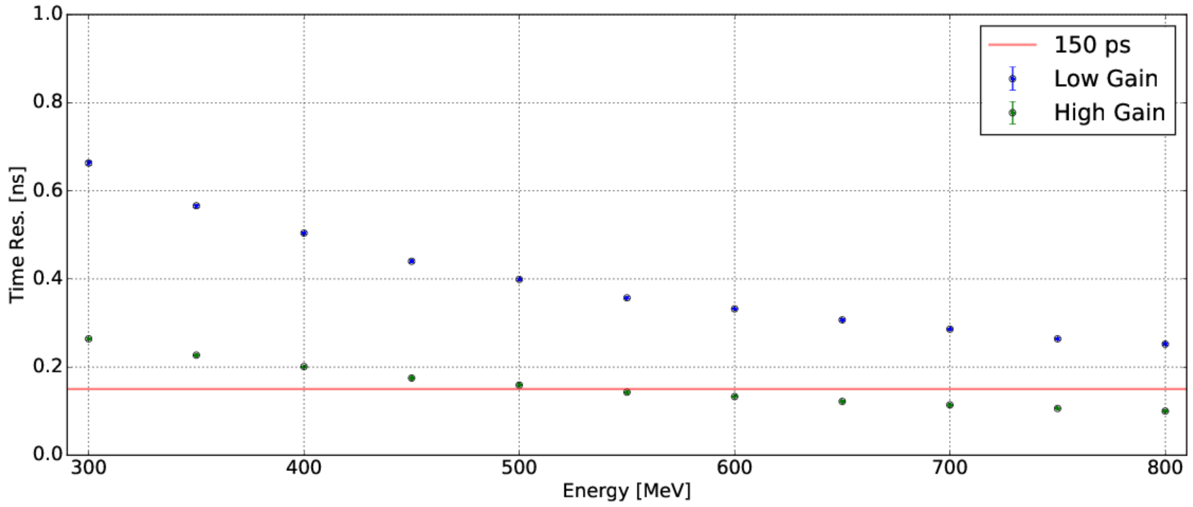
# Time Based Simulation Framework – Linearity

- **Example: APD gain 200**
- $\Delta t = t_{ext} - t_{set}$
- **RMS < 1 ns for E > 60 MeV**
- **RMS < 150 ps for E > 500 MeV**



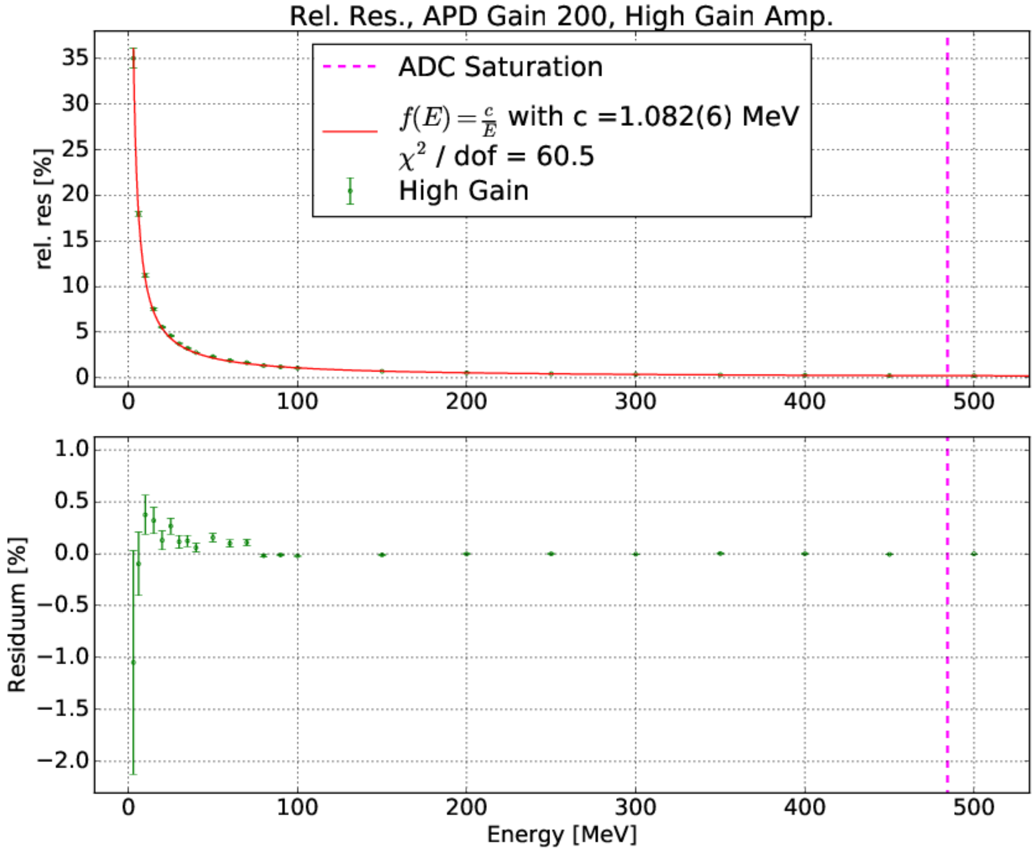



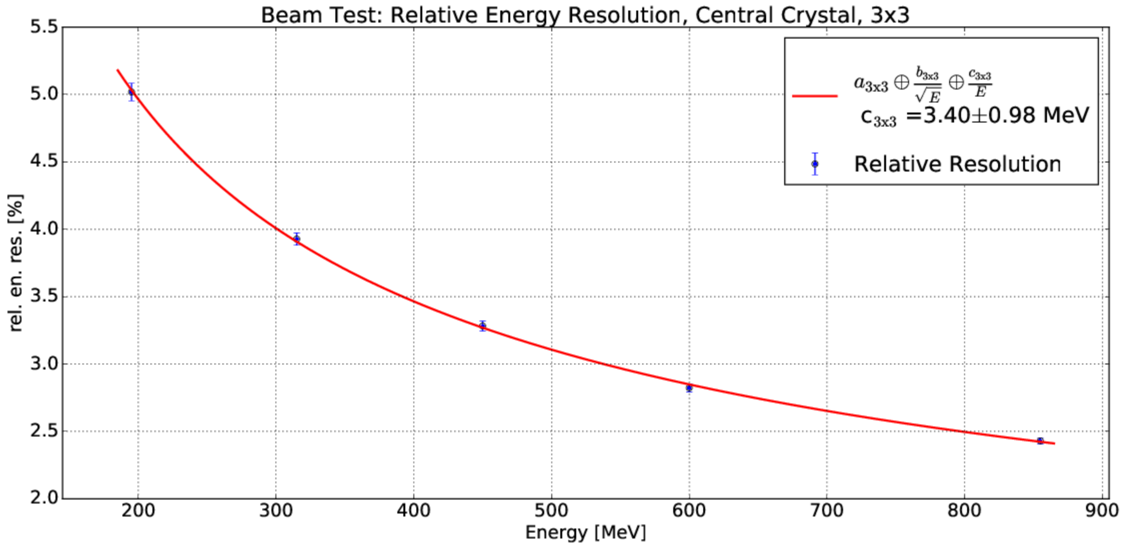
# Time Based Simulation Framework – Noise Term

## Simulation




**Single channel noise = 1.082(6) MeV**

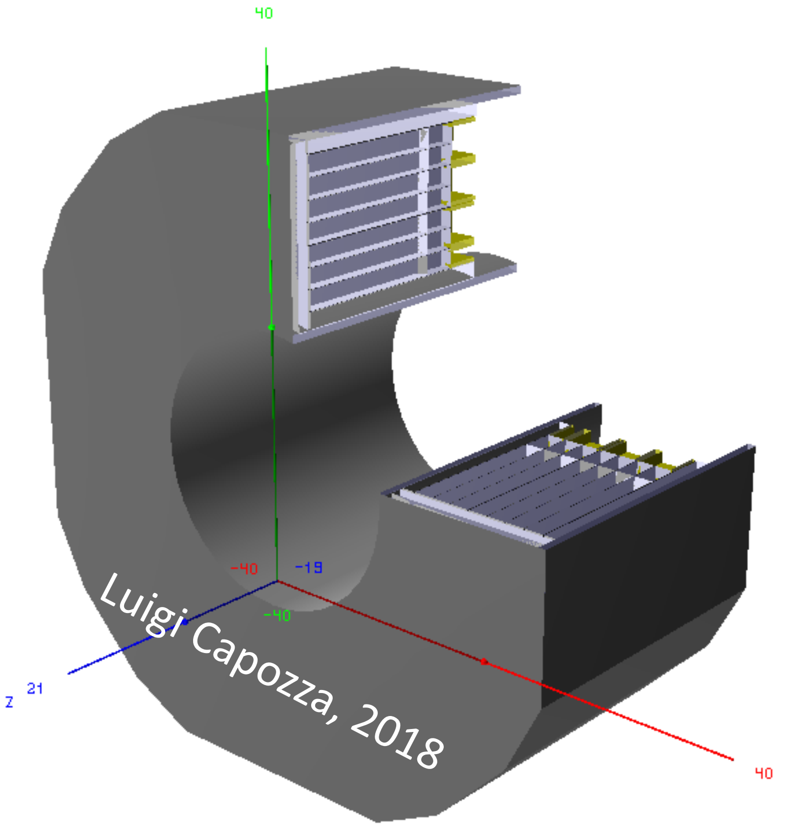
## Beam Test




**Single channel noise = 3.40(98)/$\sqrt{9}$ = 1.33(33) MeV**

# Time Based Simulation Framework – PandaRoot

- **Implementation of signal generator and parameter extraction into PANDA ROOT by Guang Zhao**
- **Computing session yesterday: "Backward endcap EMC digitization in PandaRoot"**

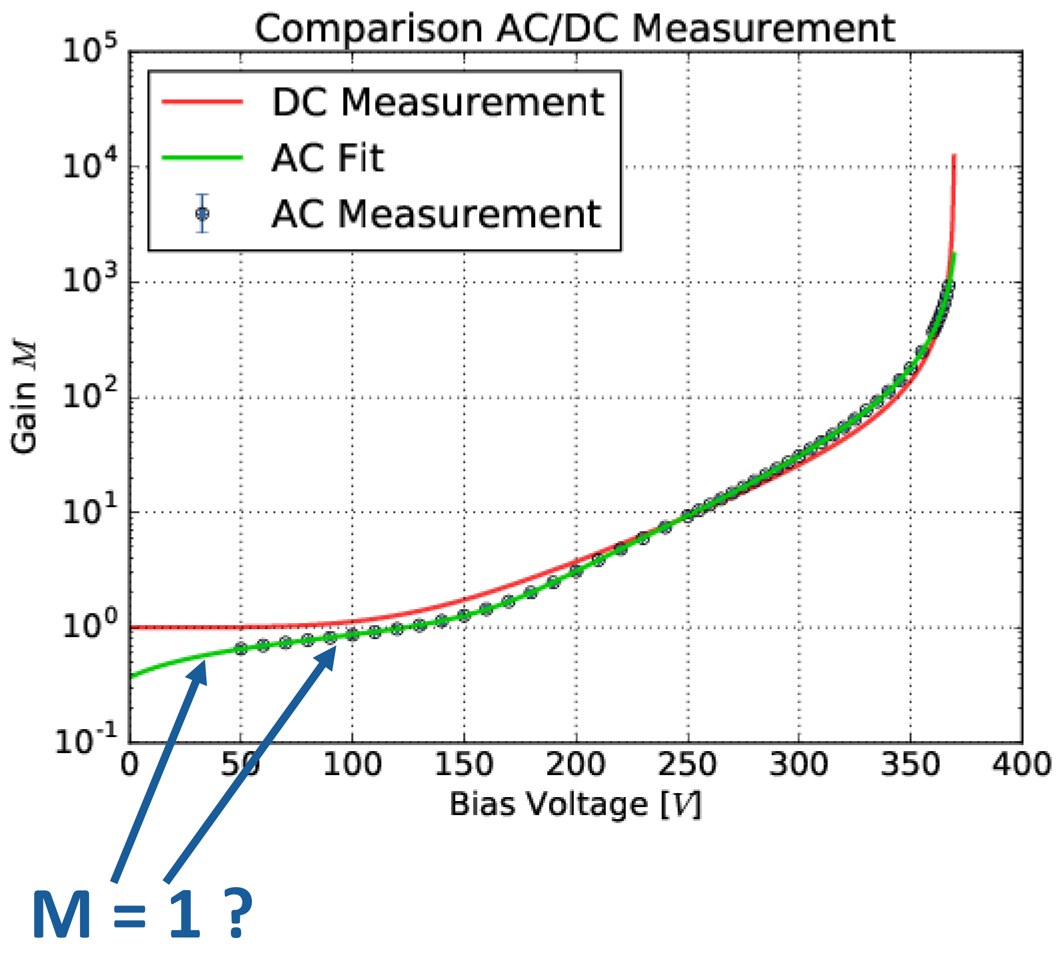


# In Situ APD Characterisation

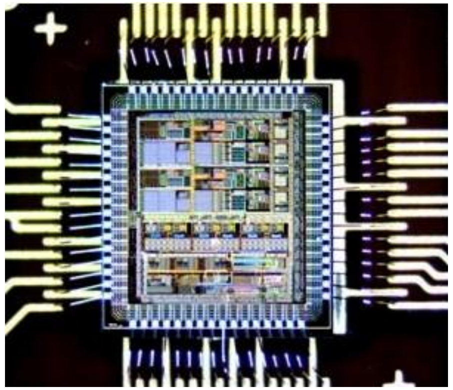
**Reasons:**
- Lack of APD characterisation data in the past
- Possibility to monitor APD characteristics inside EMC
  - Change of characteristics due to irradiation

**Challenges**
- AC (pulsed) characterisation differs from DC characterisation
- Where is M = 1?

**Aim**
- Find AC fit model in order to reveal DC part

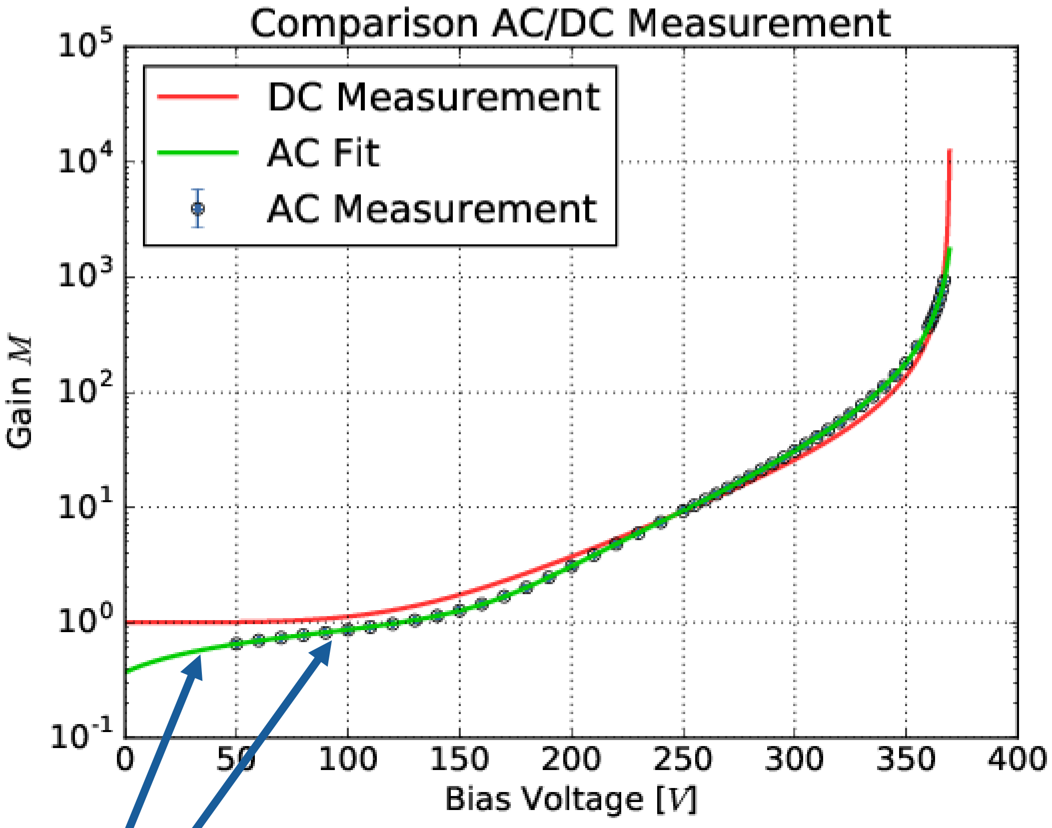


# In Situ APD Characterisation – APFEL Capacitance



**Interplay between APFEL entrance capacitance $C_i$ and detector (APD) capacitance $C_d$:**

- $Q(t) \approx \frac{Q_s \cdot (1-e^{-t/\tau})}{1+\frac{C_d}{C_i}}$ **(H. Spieler)**
- $Q(t) \propto$ **pulse amplitude**
- $C_d = C_d(U)$




**M = 1 ?**

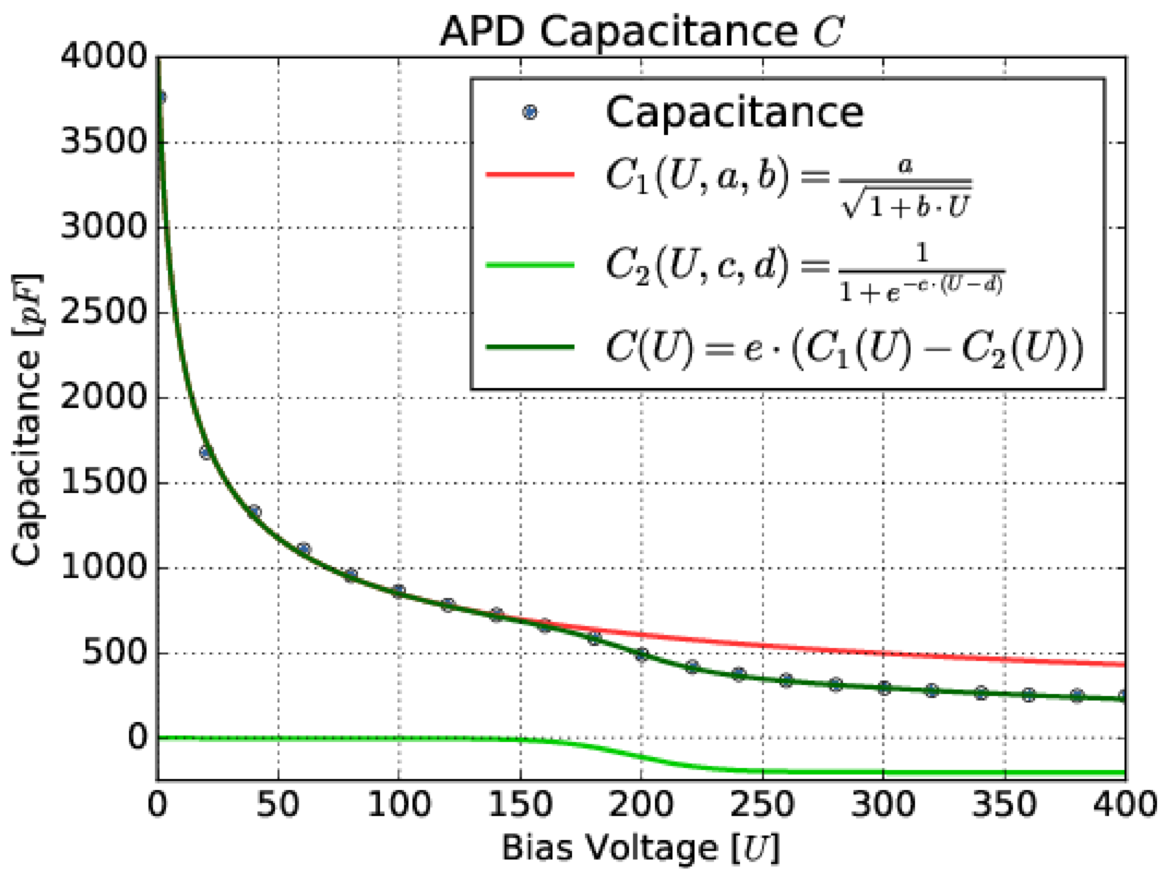
Helmuth Spieler. Semiconductor Detector Systems, volume v.12 of Semiconductor Science and Technology. Oxford University Press, Oxford, 2005

# In Situ APD Characterisation – APD Capacitance

**APD Capacitance**

- **Function of bias voltage**
- **Kink between 150 V and 250 V**
- **Model function:**

$$C_d(U, a, b, c, d, e) = e \cdot \left( \frac{a}{\sqrt{1 + b \cdot U}} - \frac{1}{1 + e^{-c \cdot (U - d)}} \right)$$



# In Situ APD Characterisation – AC Fit Function

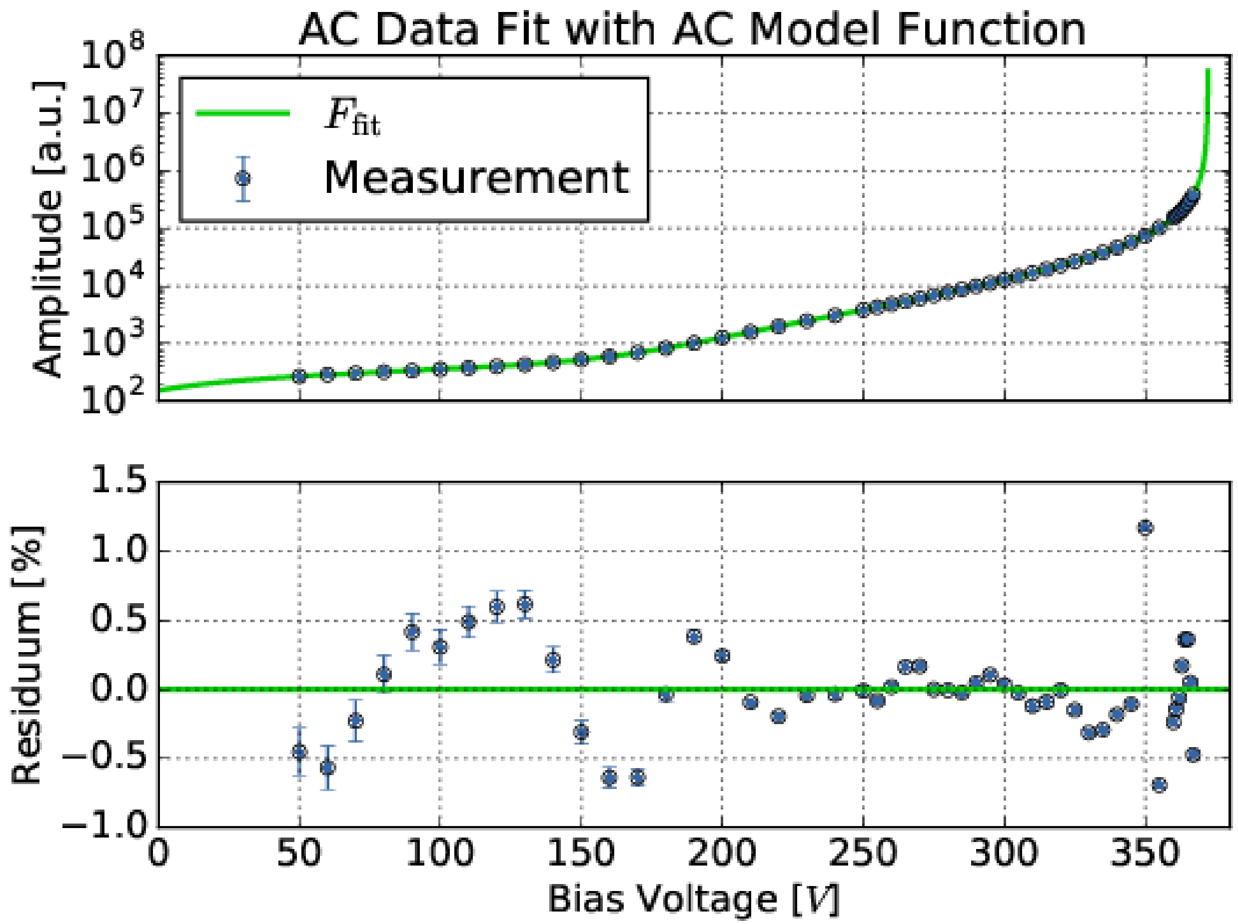
**AC Fit Function**

- **Already known DC function**
- $\tilde{f}_{DC}(U = 0) = 1$

$$\tilde{f}_{\mathrm{DC}}(U, A, U_b, \alpha) = \frac{A}{1 - (\frac{U}{U_b})^{\alpha}} + 1 - A$$

$$F_{\mathrm{fit}}(U, A, U_b, \alpha, a, b, c, d, e, R) = \frac{R \cdot \tilde{f}_{\mathrm{DC}}(U, A, U_b, \alpha)}{1 + C_d(U, a, b, c, d, e)}$$

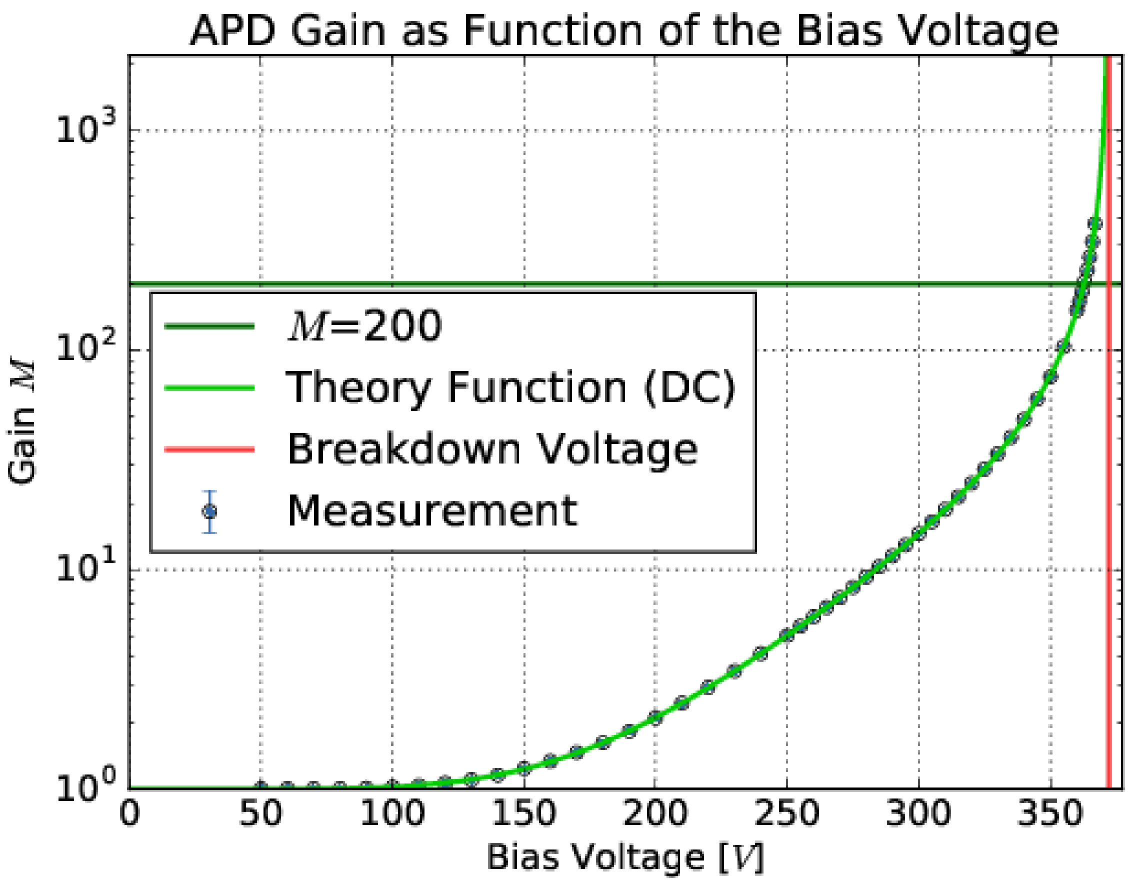
$$C_d(U, a, b, c, d, e) = e \cdot \left( \frac{a}{\sqrt{1 + b \cdot U}} - \frac{1}{1 + e^{-c \cdot (U - d)}} \right)$$



# In Situ APD Characterisation – AC/DC Transformation

**AC/DC Transformation**

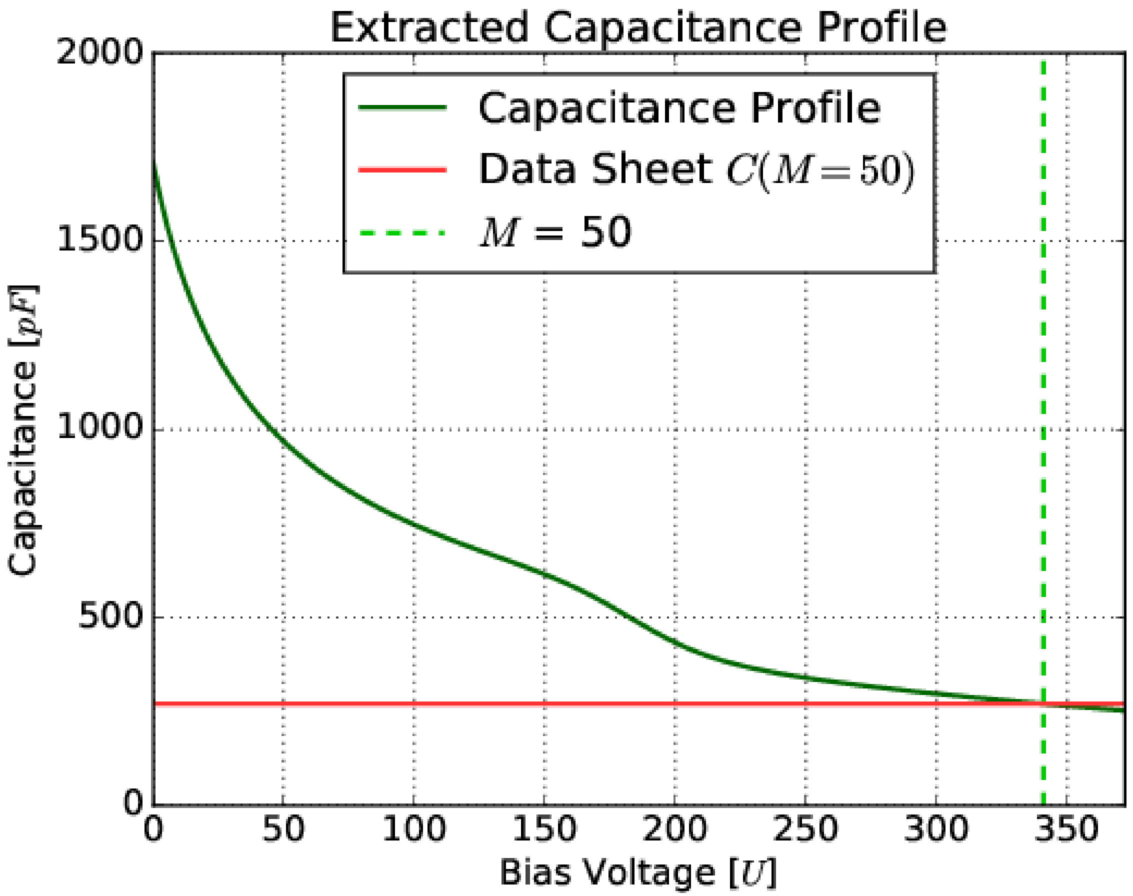
- $\tilde{f}_{DC} = \frac{F_{fit} \cdot (1+C_d)}{R}$
- **Data' = Data** $\cdot \frac{F_{fit} \cdot (1+C_d)}{R}$
- **Extraction of pure DC part**
- **Well defined normalisation (M=1)**



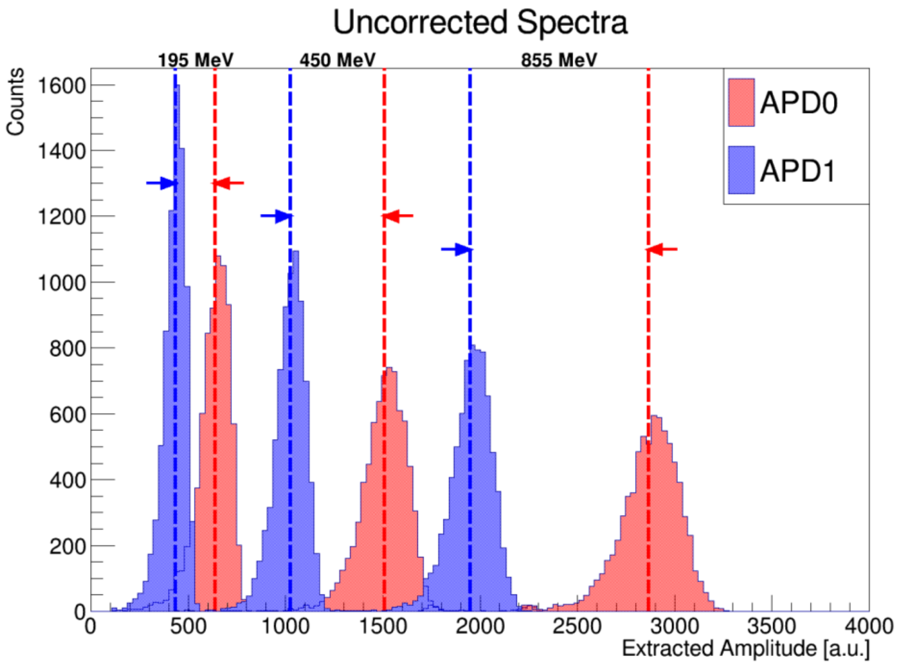
# In Situ APD Characterisation – Access to APD Capacitance

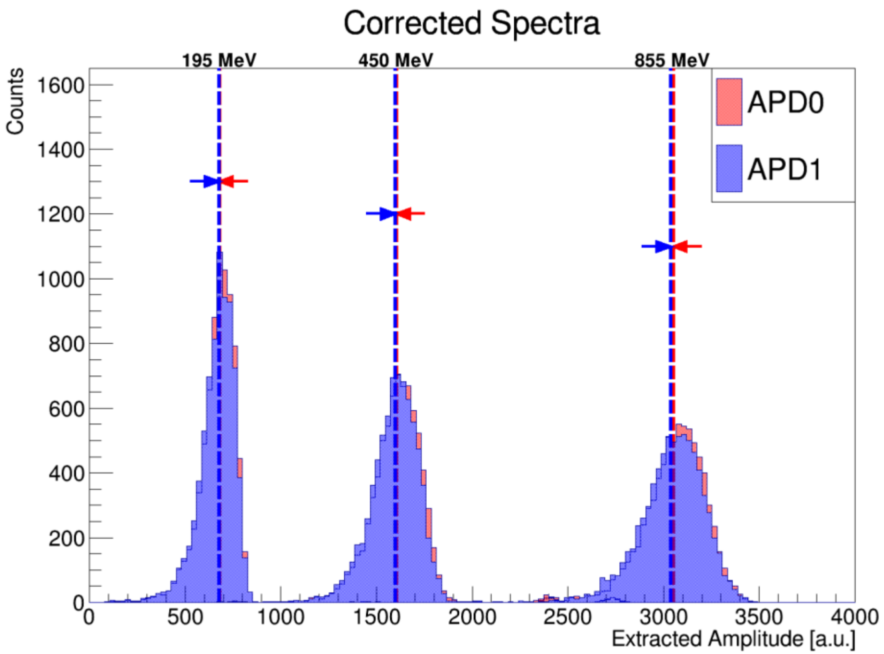
**APD Capacitance**

- **Neat by-product**
- **Need to compare with measurement**



# In Situ APD Characterisation – Correction of Beam Data



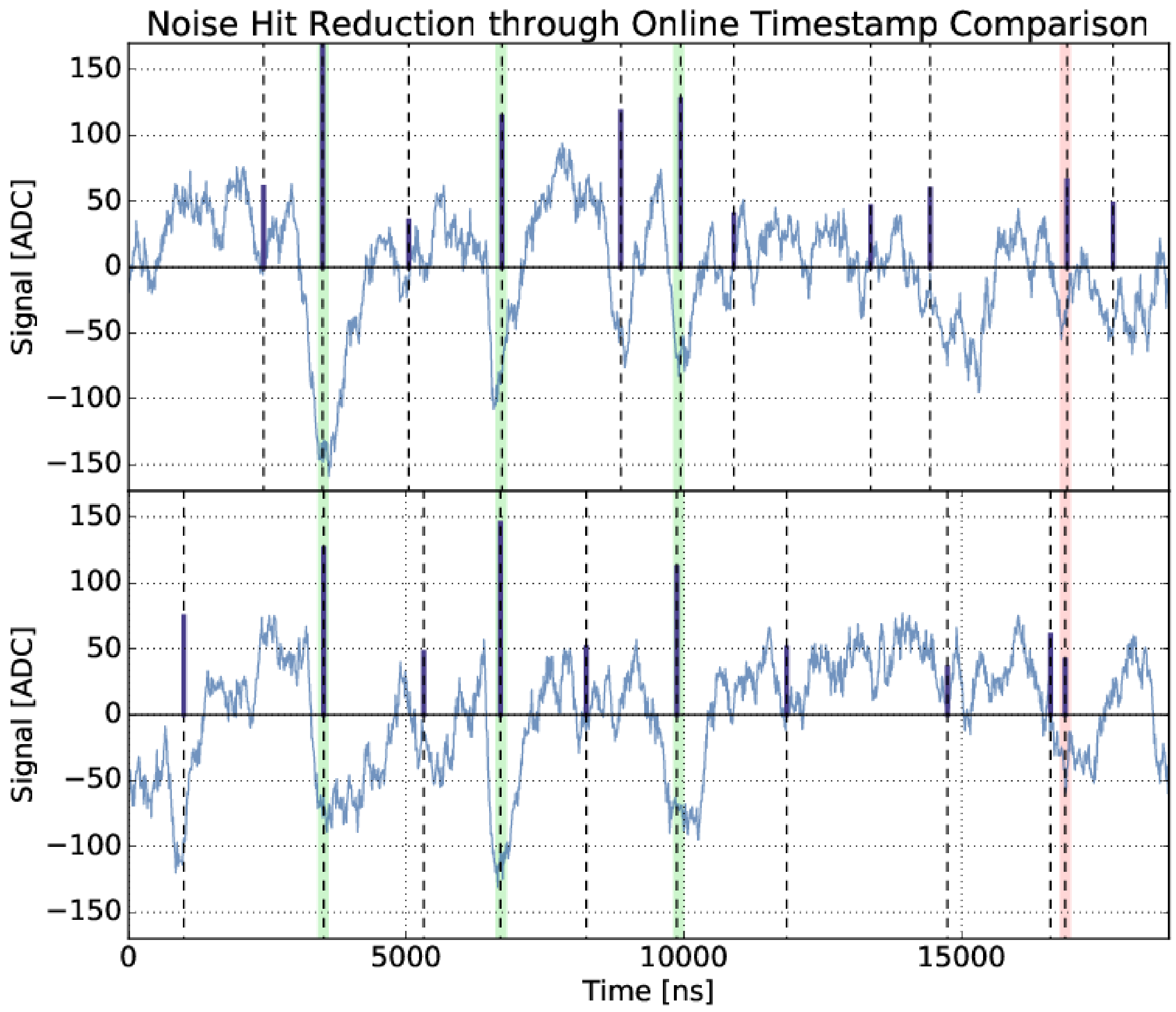

**Correction of Beam Data**

- **Example of a crystal APD pair (PROTO16-2, MAMI beam test)**
- **Corrected with in situ methode**

# Summary

- Time Based Simulation Framework
  - Originally developed for FPGA algorithms tests
  - Brought to an user-friendly shape (C++ interface)
  - Implemented in PandaRoot by Guang Zhao
- In Situ APD Characterisation
  - New approach to calibrate APDs inside EMC
  - Promising results
  - Careful measurement necessary

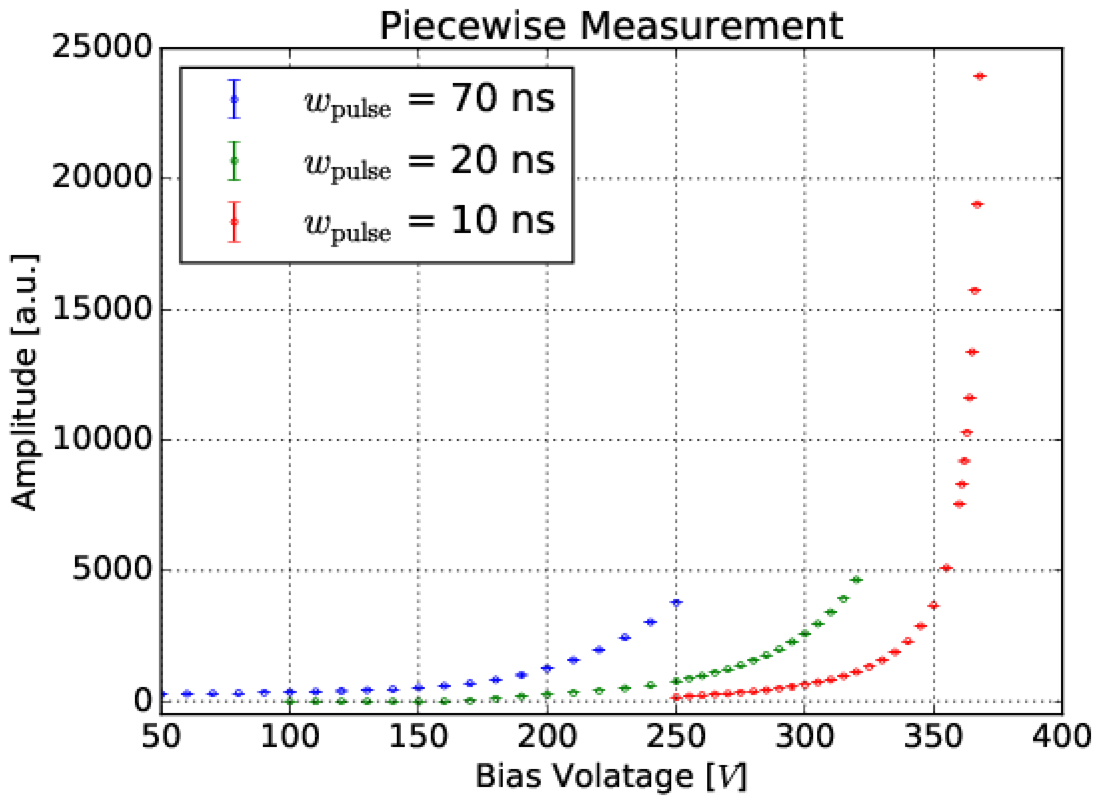
# Backup – Noise Hit Suppression

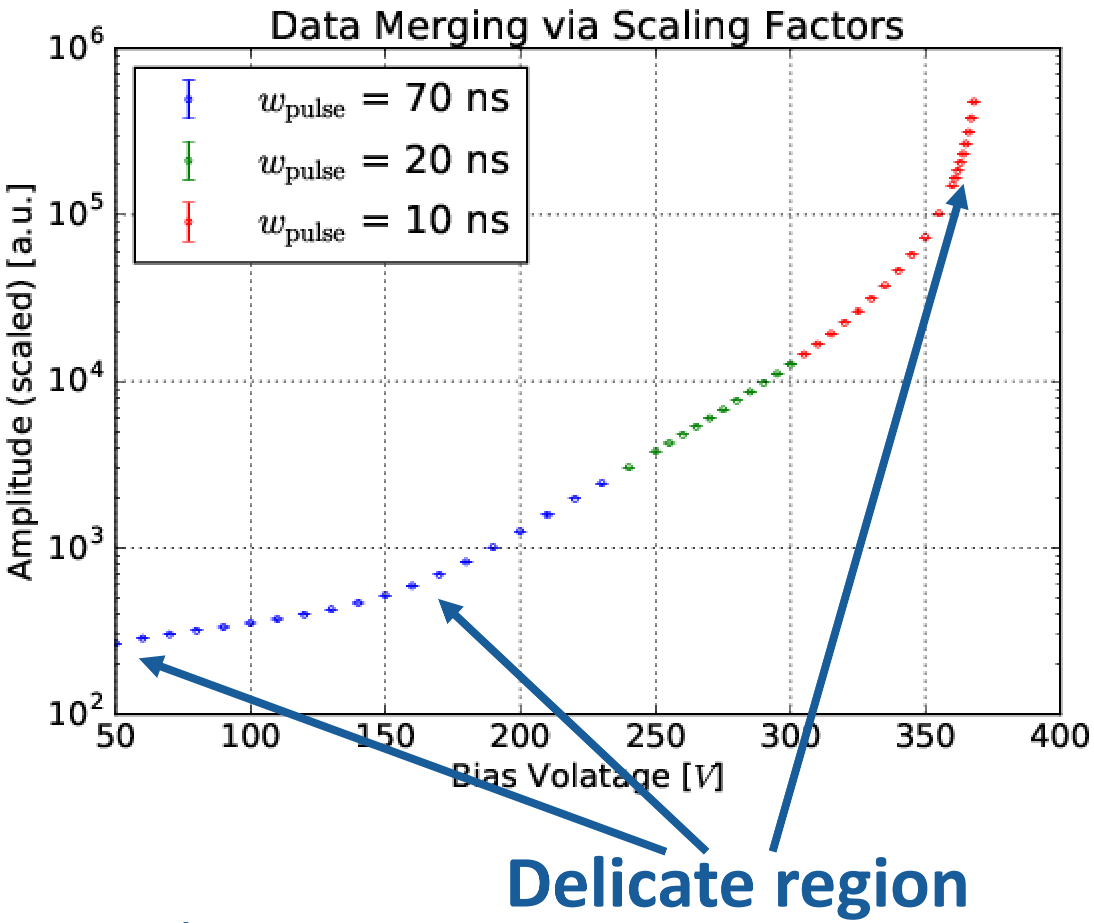



**Noise Hit Suppression**

- **Online hit comparison between APDs**
- **Lower threshold**
- **Lower noise hit rate**
- **Less redundancy (What if one APD fails?)**

# Backup – In Situ Char. Careful Measurement




**Careful AC Measurement**

- **Light intensity intervals (limited ADC entrance area)**
- **Merging data**