Characterization of the PXD Response to Gated Mode

Belle II PXD Workshop

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Overview

Introduction of PXD Response Function

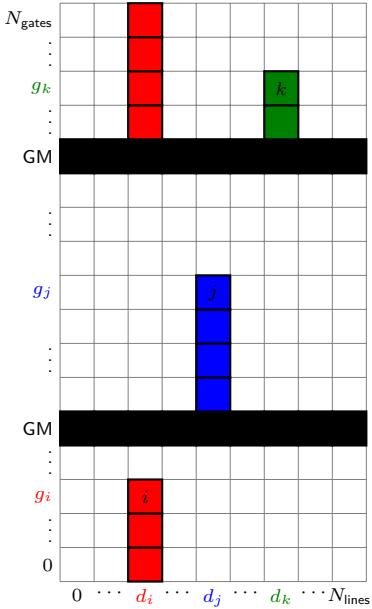
Characteristics of the Function Parameters

Future Tasks

Goals of the Characterization

- **Description:**
  - The parameterization of the pedestal difference as a function of GM position (on and off) and time
  - **Goal:** Describing the behavior with as less parameters as possible
- **Prediction:**
  - Using the parameterization to determine the pedestal behavior for each individual pixel
  - **Goal:** Determine the minimal frequency and extent of the repetition of the GM sweep measurement
- **Understanding:**
  - Finding the technical origin of the functional behavior
  - **Goal:** Ideal case: Knowledge which effect causes which functional part

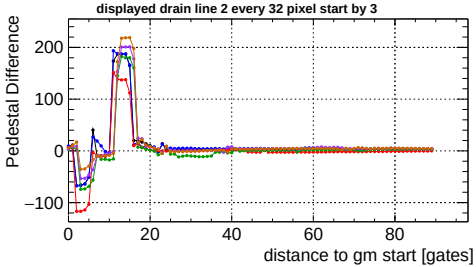
Separation between Spacial and Temporal Effects



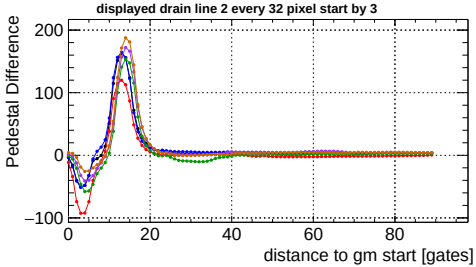
- Assuming all pixel would have the exact same GM response:
  - Only one measurement with a single GM position would be sufficient
  - Different pixel could provide the pedestal change for different times
  - But this assumption is completely unrealistic!
- Assuming an individual pixel response:
  - Using measurements with 96 ($N_{\text{gates}}/2$) different GM positions
  - Different GM positions can provide the pedestal change of the individual pixels for different times
  - Realistic scenario but with large amount of parameters (current status)
- Dependencies between pixel:
  - Using same measurements as for individual pixel response
  - Dramatic reduction of used parameters (future/ideal case)

Using a Software Low-Pass Filter to Reduce Noise

Original:



Filtered:



- Noise disturbs the function determination:
  - Parameter change due to noise → Missing dependencies
  - Challenge for fitting without proper error estimation (particular during GM window)
  - Affected time dependence of the parameters → Noise cannot be predicted
- Switching to FFT $\mathcal{F}$:

$$\mathcal{F}\left[\mathbf{I}\right](\omega) = \underbrace{f(\omega)\cdot\mathcal{F}\left[\mathbf{I}\right](\omega)}_{\mathcal{F}[S](\omega)} + \underbrace{(1-f(\omega))\cdot\mathcal{F}\left[\mathbf{I}\right](\omega)}_{\mathcal{F}[N](\omega)}$$

- Applying the Low-Pass Filter:

$$f(\omega) = \frac{1}{1+\mathrm{i}\cdot\frac{\omega}{\omega_0}} \qquad \omega_0 = 0.25\cdot\omega_{\text{max}}$$

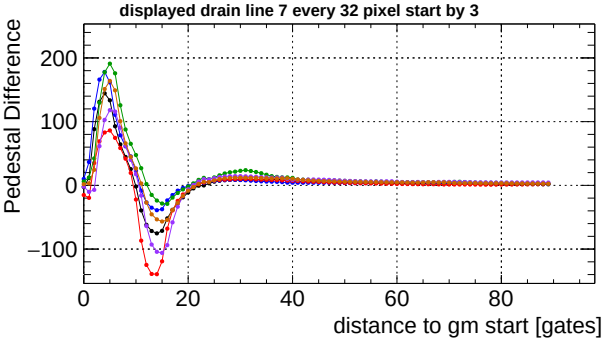
- Retrieve filtered Signal: $S(t) = \mathcal{F}^{-1}[\mathcal{F}[S]](t)$

⇒ **Using only filtered Signal for the characterization**

Determine the Shape of the Function

There are 3 parts distinguishable:

1. "On Resonance" after going in GM
2. "Off Resonance" after going out of GM
3. "Tail Bump" after the "off resonance"



- Each of this parts will be described by an individual Cauchy (Breit-Wigner, Lorentz) distribution:

$$\mathcal{C}_i\left(t;\ A_i, \bar{t}_i, \tau_i\right) = \frac{A_i}{1+\left(\frac{t-\bar{t}_i}{\tau_i}\right)^2}$$

$i \in \{\text{on, off, tail}\}$ $\quad$ $\bar{t}_i :=$ Shift/Mean/Position

$A_i :=$ Amplitude $\quad$ $\tau_i :=$ Width

- Final Function f: Superposition of all three functions plus constant offset

$$f = \sum_i \mathcal{C}_i + \mathrm{C} \qquad \mathcal{C}_i\left(t;\ A_i, \bar{t}_i, \tau_i\right) = \frac{A_i}{1+\left(\frac{t-\bar{t}_i}{\tau_i}\right)^2} \qquad i \in \{\text{on, off, tail}\}$$

Fit Procedure for Parameter Determination

Procedure divided into 3 steps:

1. **Step:** Parameter Estimation
   - Dividing the the signal according to the three parts: $[0,$ GM length$]$, $[$ GM length$, 18]$, $[2 \times$ GM length$, 75]$
   - Determine the estimate for $(A_i, \bar{t}_i, \tau_i)$ by (value @ mean position, mean, standard deviation), respectively
2. **Step:** Parameter Pre-Fit
   - Perform a pre-fit of an individual Cauchy distribution for each part using parameter estimate as initial values
   - Apply plausibility conditions: $\bar{t}$ within the interval, $0.25 < \frac{A}{A_{\text{init}}} < 2$, $\tau \in [0, 0.5 \text{ Max}]$
3. **Step:** Final Parameter Fit
   - Perform a full fit of f using the pre-fit result as initial values applying same plausibility conditions

$\Rightarrow$ Final Parameter Determination

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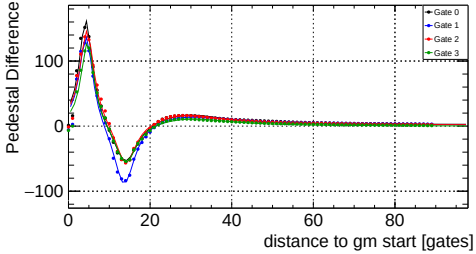
Characteristics of the Function Parameters

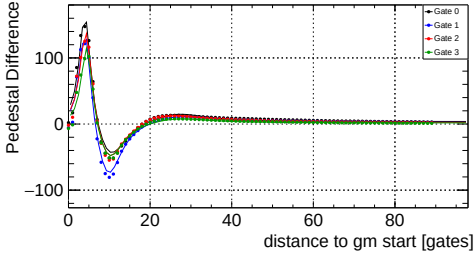
Future Tasks

Overview and Specifications

GM Length 10, H1021, drain line 0:



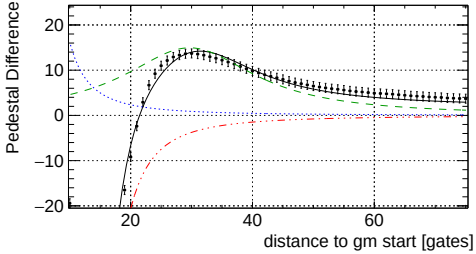
GM Length 6, H1021, drain line 0:



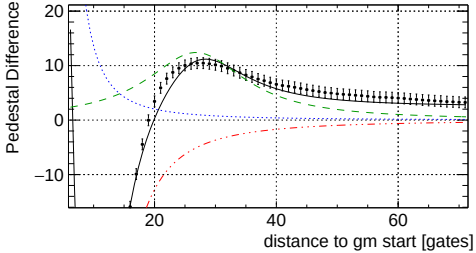
- Function f is qualitatively in good agreement with the measurement
- No anomalies were found (yet)
- Following the parameter results from the measurement at KEK on the 18.12.2019
- 19 Modules were measured, only H1021, H1022 are shown.
- Measurement were performed with GM length 10 and 6

Detailed View on Tail Bump

GM Length 10, H1021, drain line 0, gate 1:



GM Length 6, H1021, drain line 0, gate 1:



Plot Legend:

- Solid points: Measurement with error: 1
- Solid line: Combined Fit
- Dashed Lines:
  Individual Cauchy distributions using final parameter fit
  - First distribution
  - Second distribution
  - Third distribution

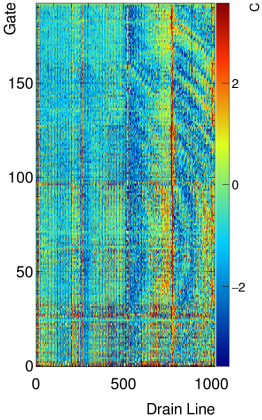
Fit Challenges:

- Fit performs in almost all cases very stable
- If 'tail bump' is to small:
  - Parameters get off (very large or very small values)
  - Possible solution: Remove tail fit for such pixels
- Fit very sensitive to interval cut between off and tail part
  - No generic solution has been found yet
  - Further measurements with different GM length

Parameter C Display

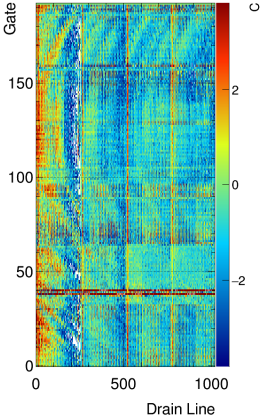
H1021,

GM length 10:



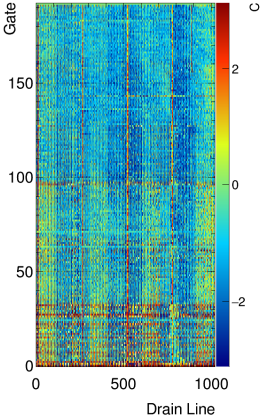
H1022,

GM length 10:



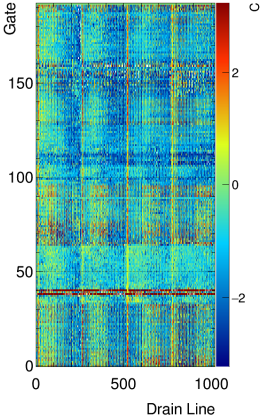
H1021,

GM length 6:



H1022,

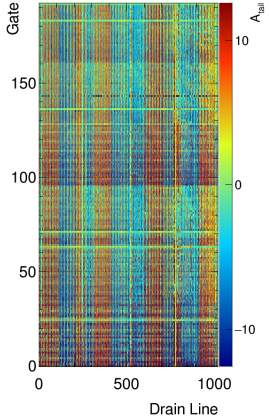
GM length 6:



Parameter A_{tail} Display

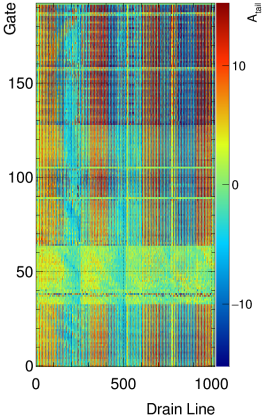
H1021,

GM length 10:



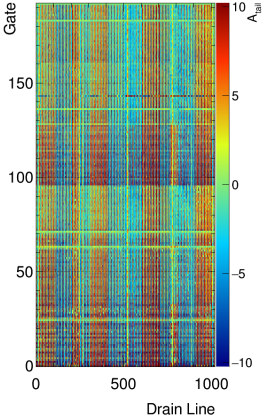
H1022,

GM length 10:



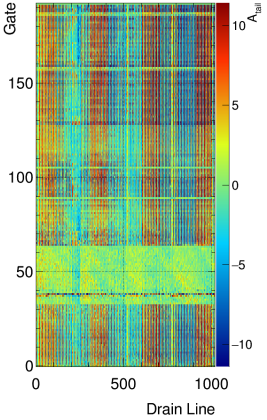
H1021,

GM length 6:



H1022,

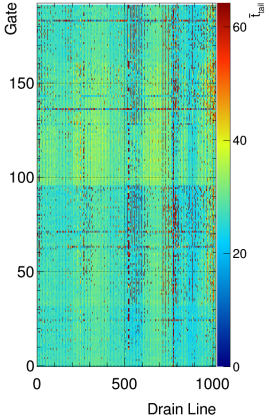
GM length 6:



Parameter $\bar{t}_{\text{tail}}$ Display

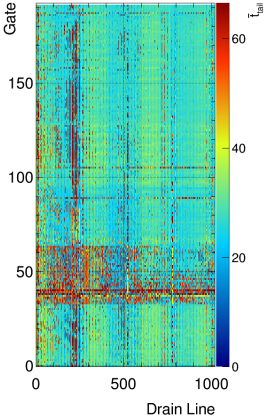
H1021,

GM length 10:



H1022,

GM length 10:



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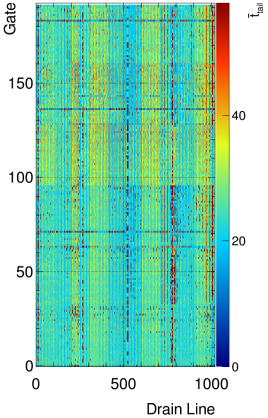

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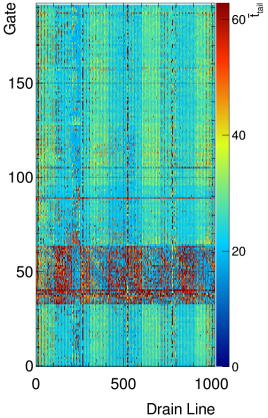
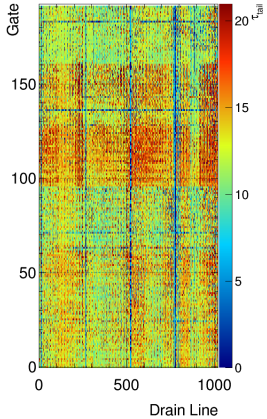
GM length 6:



Parameter τ_{tail} Display

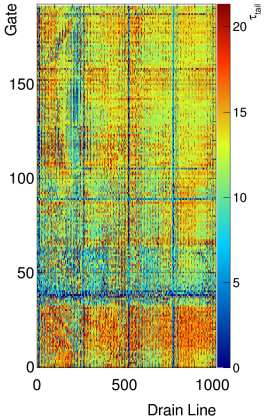
H1021,

GM length 10:



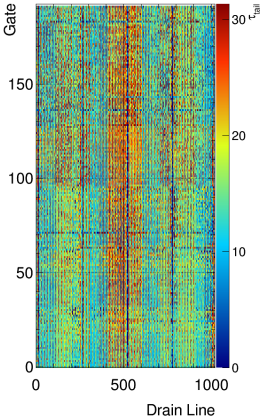
H1022,

GM length 10:



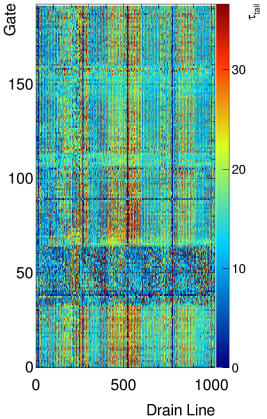
H1021,

GM length 6:



H1022,

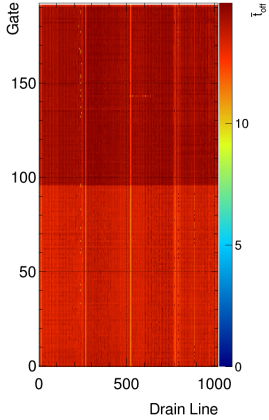
GM length 6:



Parameter $\bar{t}_{\text{off}}$ Display

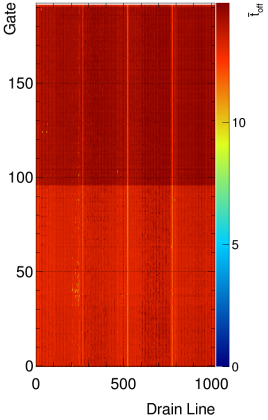
H1021,

GM length 10:



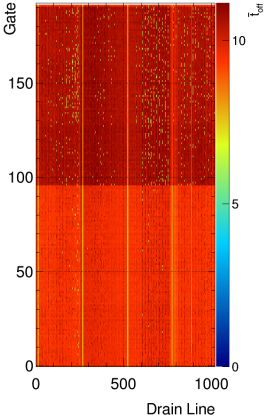
H1022,

GM length 10:



H1021,

GM length 6:



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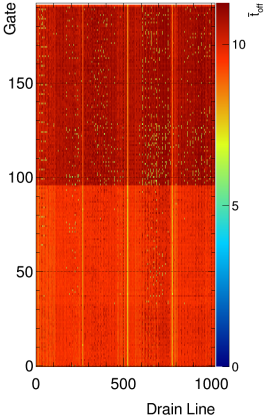
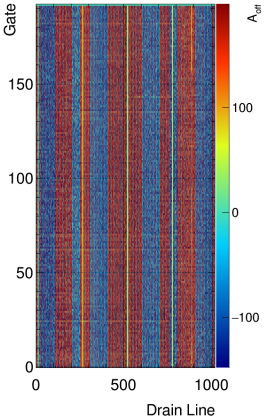
GM length 6:



Parameter A_{off} Display

H1021,

GM length 10:



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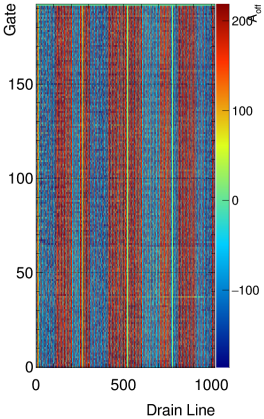
GM length 10:



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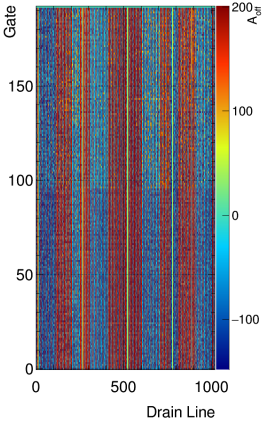
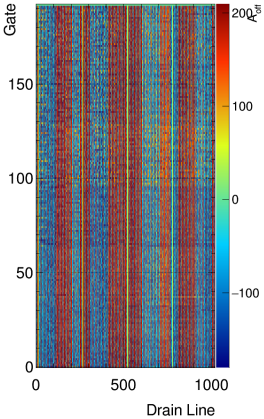
GM length 6:



H1022,

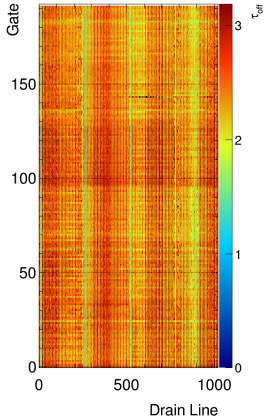
GM length 6:



Parameter τ_{off} Display

H1021,

GM length 10:



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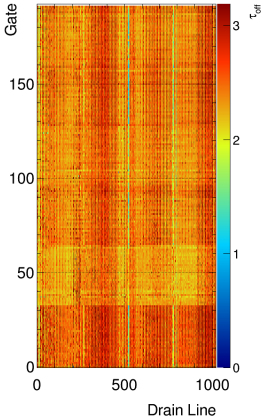
GM length 10:



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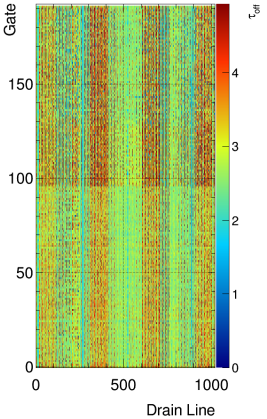
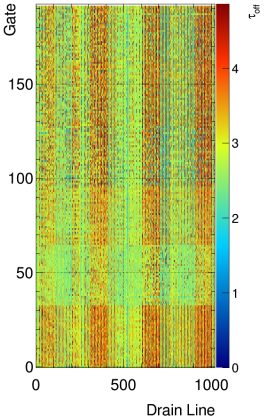
GM length 6:



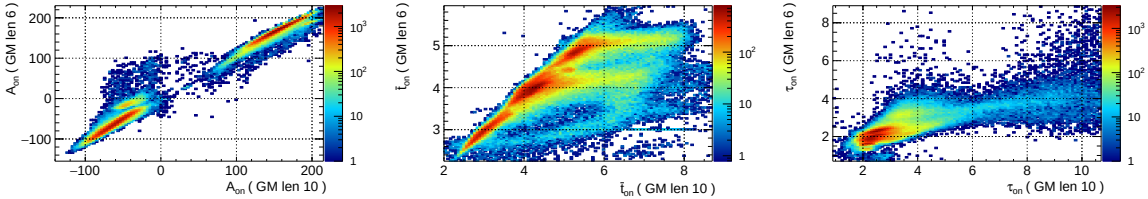
H1022,

GM length 6:

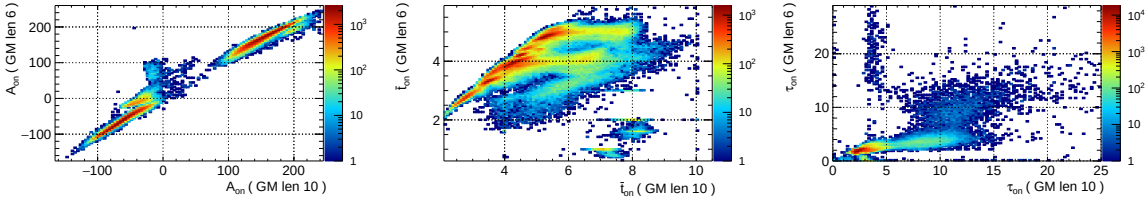


Parameter Dependencies between Different GM lengths

H1021

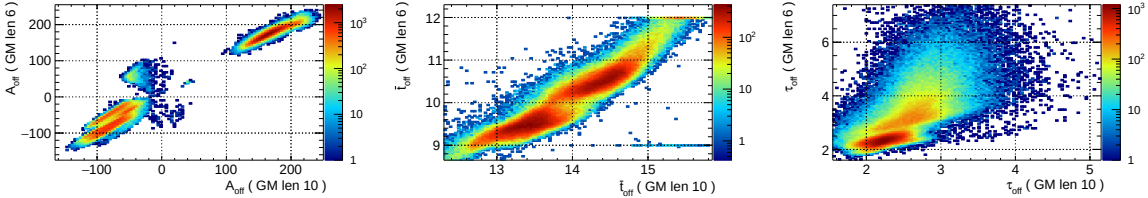


H1022

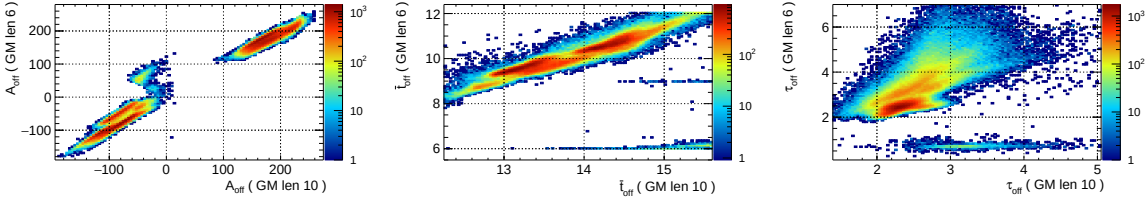


Parameter Dependencies between Different GM lengths

H1021



H1022



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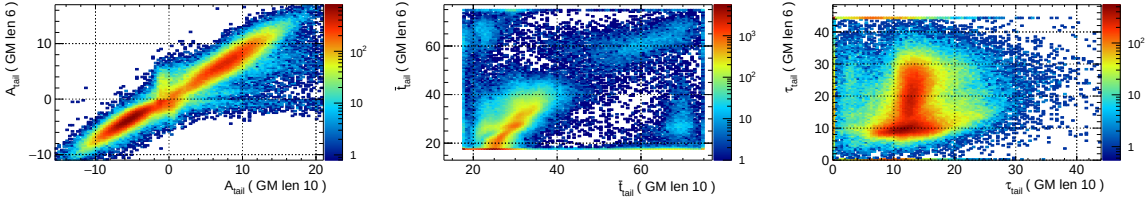
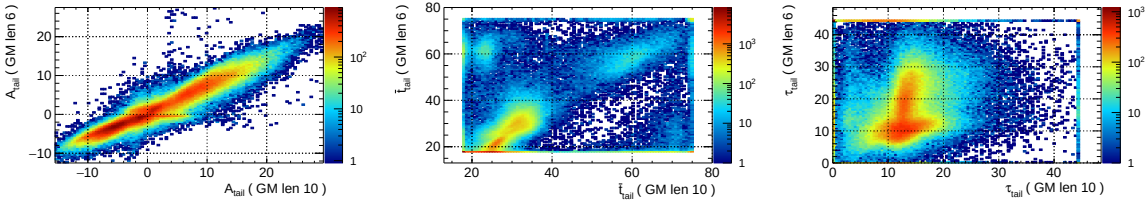
H1021

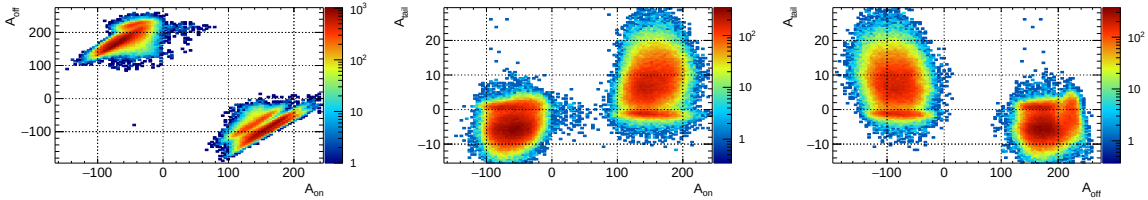


H1022

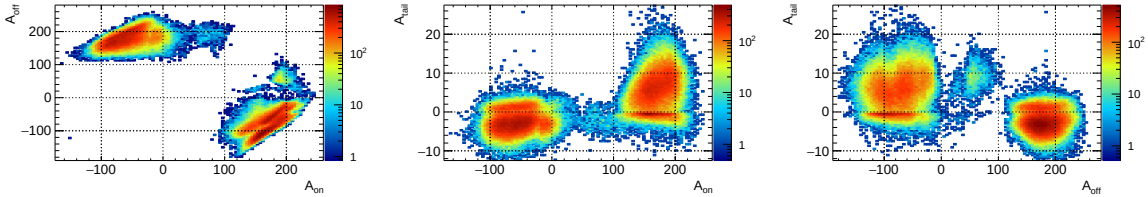


Parameter A Dependencies (H1022)

GM length 10

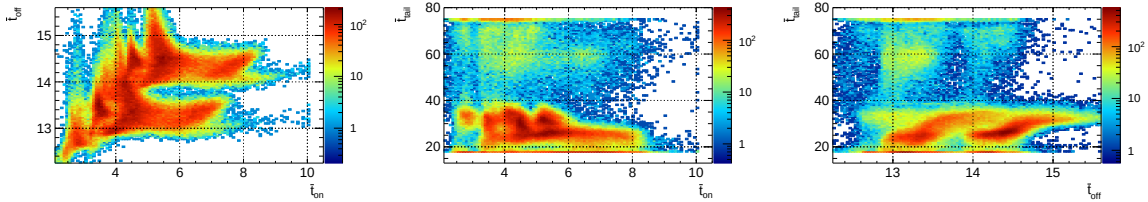


GM length 6

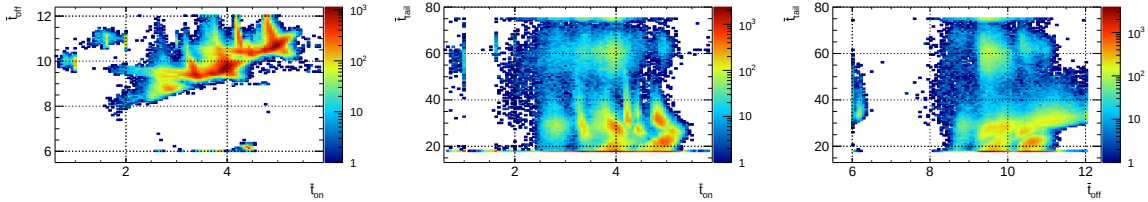


Parameter $\bar{t}$ Dependencies (H1022)

GM length 10

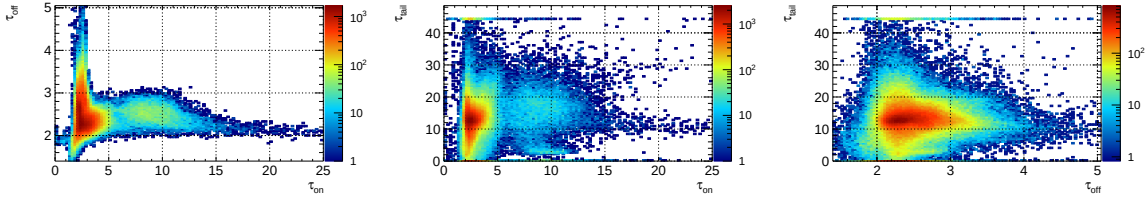


GM length 6

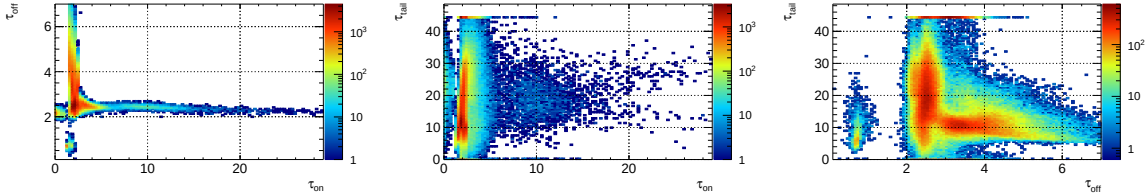


Parameter τ Dependencies (H1022)

GM length 10



GM length 6



Characterization Summary

Parameter dependencies between different ...

- **Modules:**
  - The results differ strongly between individual modules
  - Correlations are either very small or non existing
- **Drain lines:**
  - Common behavior of the parameter along single drain lines visible
  - Correlations along a drain line at least with a switcher block very likely
- **Parameters:**
  - There are almost no correlations between parameters visible
  - Pixel response to GM is described by at least 10 parameters
- **GM lengths:**
  - The differences between different GM lengths are almost as expected
  - Only the shift of the tail bump needs further studies

Introduction of PXD Response Function

Characteristics of the Function Parameters

Future Tasks

Measurements @ DESY

1. Measurement with different GM lengths:
   - Measurement for various lengths: 6,10,15,20,25
   - This should give more information on the behavior of the tail bump
   - Finalizing the description of the function
2. Long term measurement:
   - Determine the long-term time-dependence of the function parameters
   - Determine the requirement of repetition rate of GM sweep measurement
   - Intermediate measurements with GM sweep step 2,3,... possible

Conclusion

✓ **Description:**

- The description of PXD response by 3 Cauchy functions plus offset using 10 parameters represents the measurement
- Using dependencies will decrease number of parameters

▶ **Prediction:**

- Since most measurements show almost identical GM behavior → Predictability is expected
- Long term measurements at DESY will investigate this

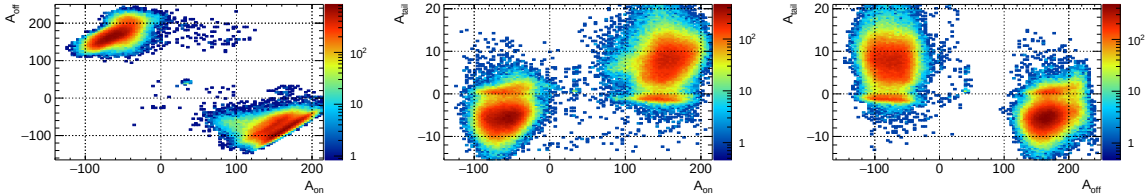
✘ **Understanding:**

- After finding a suitable function, its different parts can be related to electronic effects
- These studies will be performed later

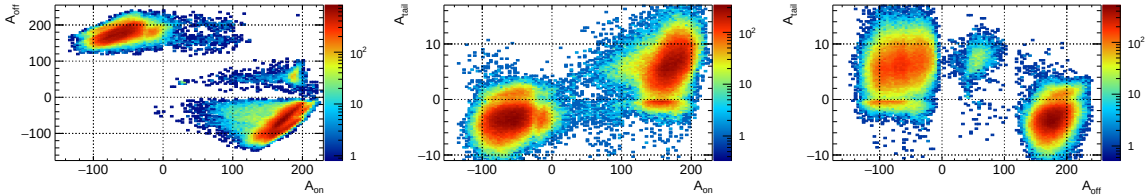
Backup Slides

Parameter A Dependencies (H1021)

GM length 10

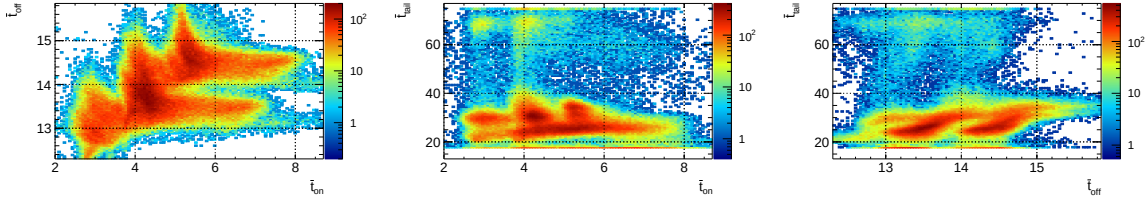


GM length 6

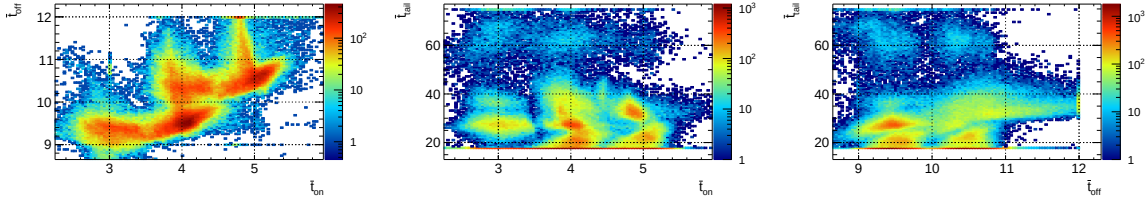


Parameter $\bar{t}$ Dependencies (H1021)

GM length 10

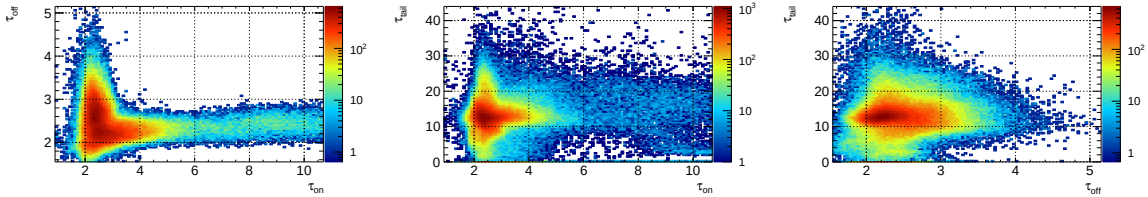
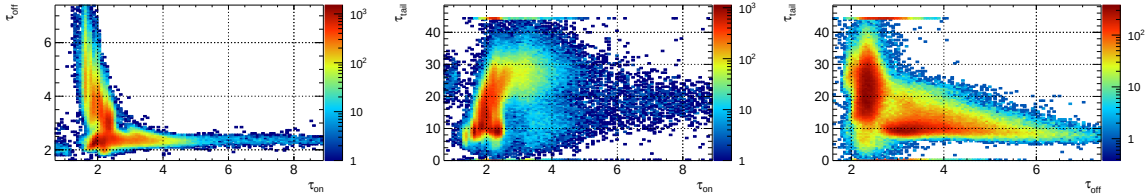


GM length 6



Parameter τ Dependencies (H1021)

GM length 10



GM length 6