Belle II PXD Workshop
DESY

The ring (patterns in PXD-hitmaps)

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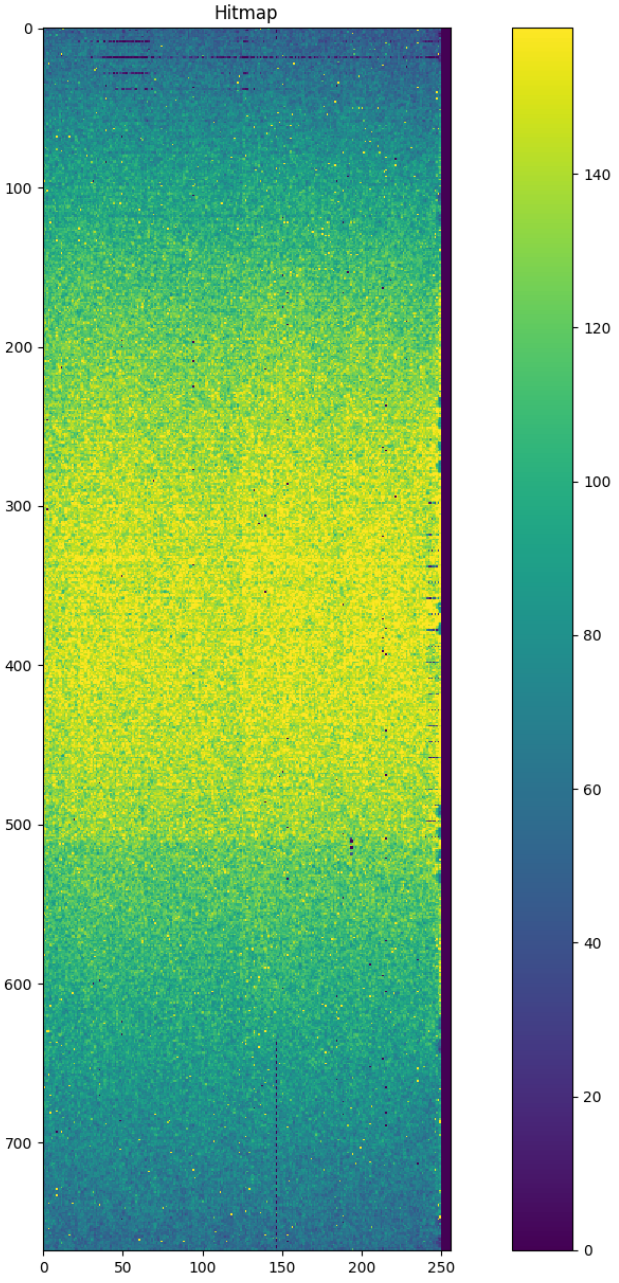
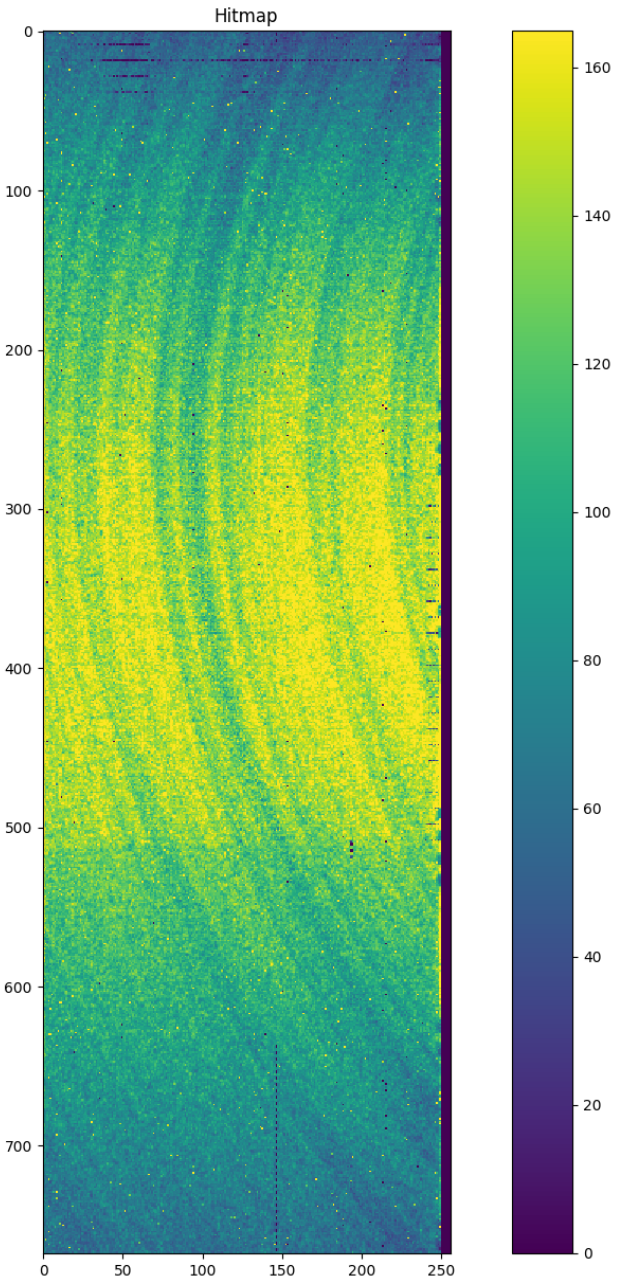
Sep 24, 2019

Module W41_IF





- Integrated hitmaps of PXD modules show ‘ring-like’ structures at certain combinations of operating matrix-voltages.

- Clearly not a good thing. Ring patterns indicate systematic loss of efficiency in certain areas of the sensor => Clear motivation to minimize the ‘ringness’ of the hitmap.

- This is thought to be an artifact of the doping procedure in the mother wafer the sensors come from.

- It is important to find a ‘good’ parameter space of operational voltages (high-voltage, drift, clear-off) where the matrix shows low levels of ring pattern.

- These voltages have already been systematically scanned, and hitmaps have been recorded at each scan point with a source.

- However there was some difficulty in quantifying the degree to which a pattern (hit-map) is ring-like.

- Philipp. W. proposed a ‘homogeniety’ variable based on the shape of the cluster charge distribution.

$$h = \Sigma_{gates}\{\langle \text{cluster charge} \rangle^2_{\text{gate i}} / \text{Var(cluster charge)}_{\text{gate i}}\}$$

- Hua tried a neural network based approach to identify the rings

- We try to define a ‘ring-score’ based on a linear combination of one flat and one very ring-like reference hitmap.

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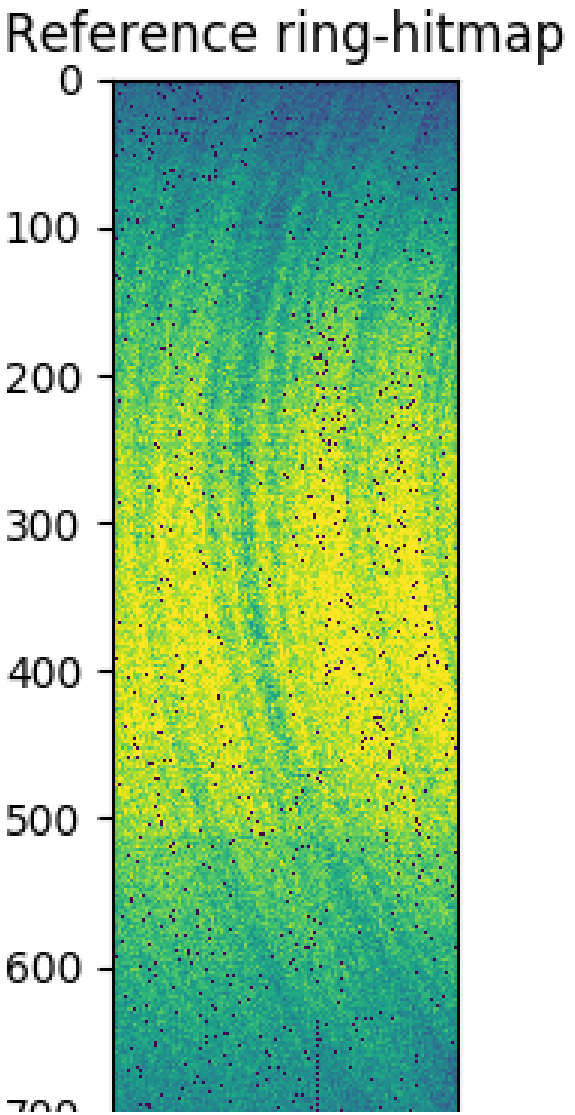
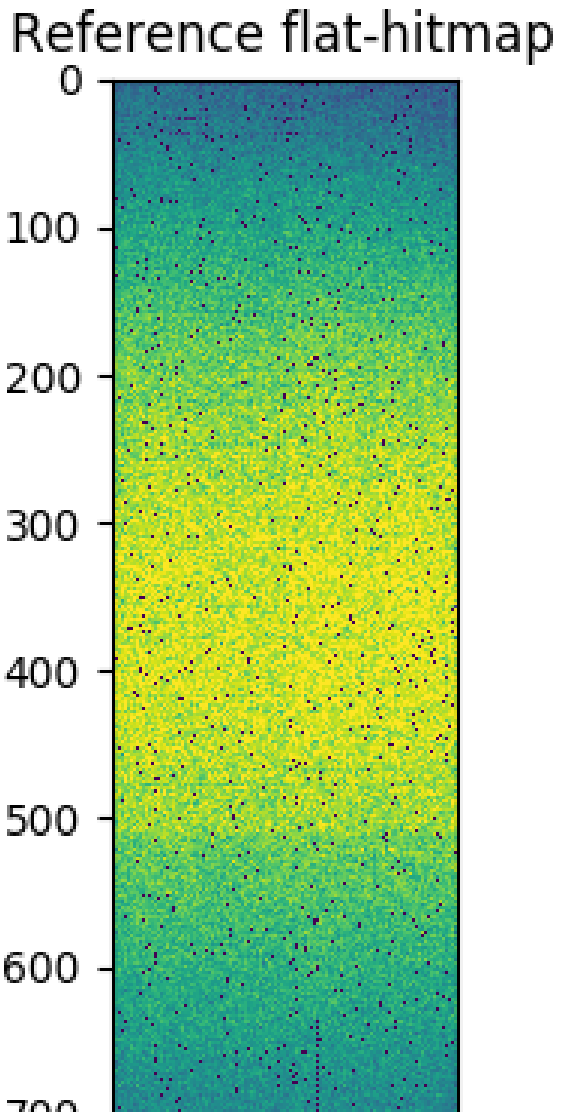




- Normalize the sample hitmap and two reference hitmaps so that they have equal area (integrated hits) after removing very noisy pixels. Subsets of the hitmaps may also be used

- Make a calculated map from the two reference hitmaps

$$\mathbf{calc\_map = a * ref\_ring + (1-a)\ ref\_flat}$$

where a is the linear coefficient which will also be the 'ring-score'

- Normed distance between the sampe and the claculated map

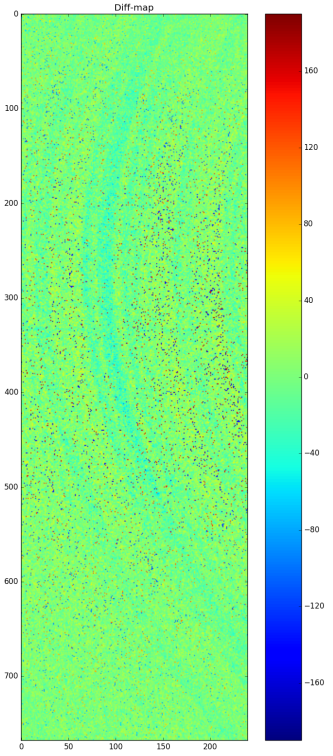
$$\mathbf{D^2(a) = \Sigma_{all\ pixels} \quad (calc\_map_i(a) - sample_i)^2}$$

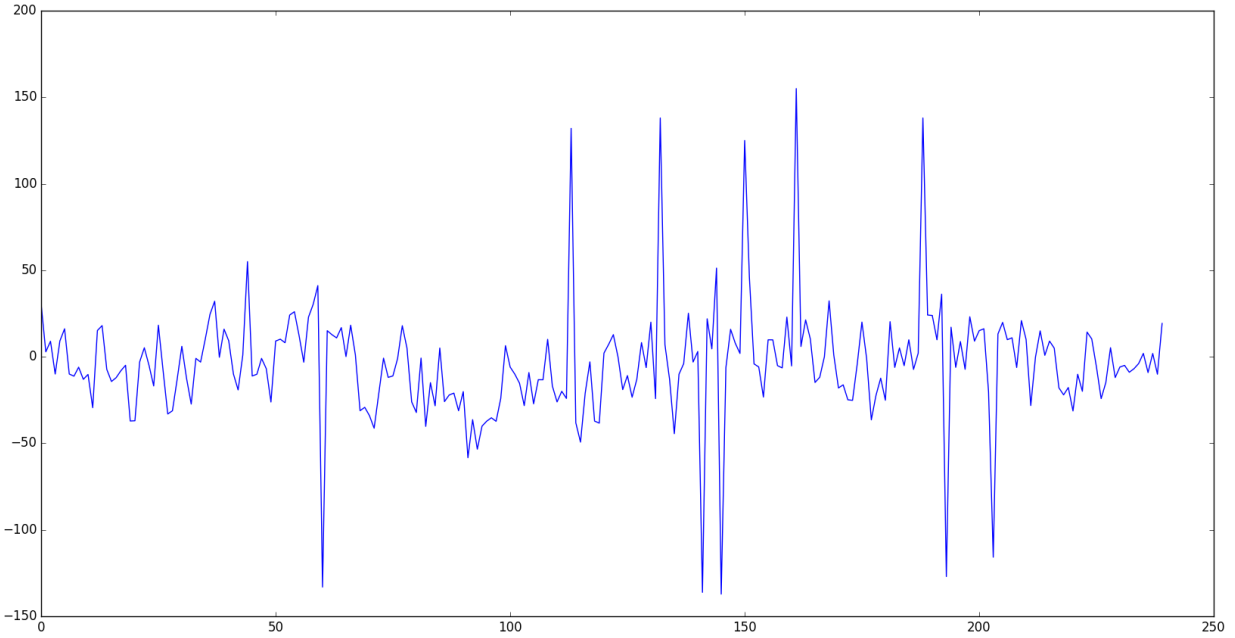
•

- Minimize D^2 w.r.t. a to obtain the 'ring-score'

$\partial D^2/\partial a = 0$ => linear equation in a
=> analytical solution of a

- Essentially a 1-parameter least-squares fit

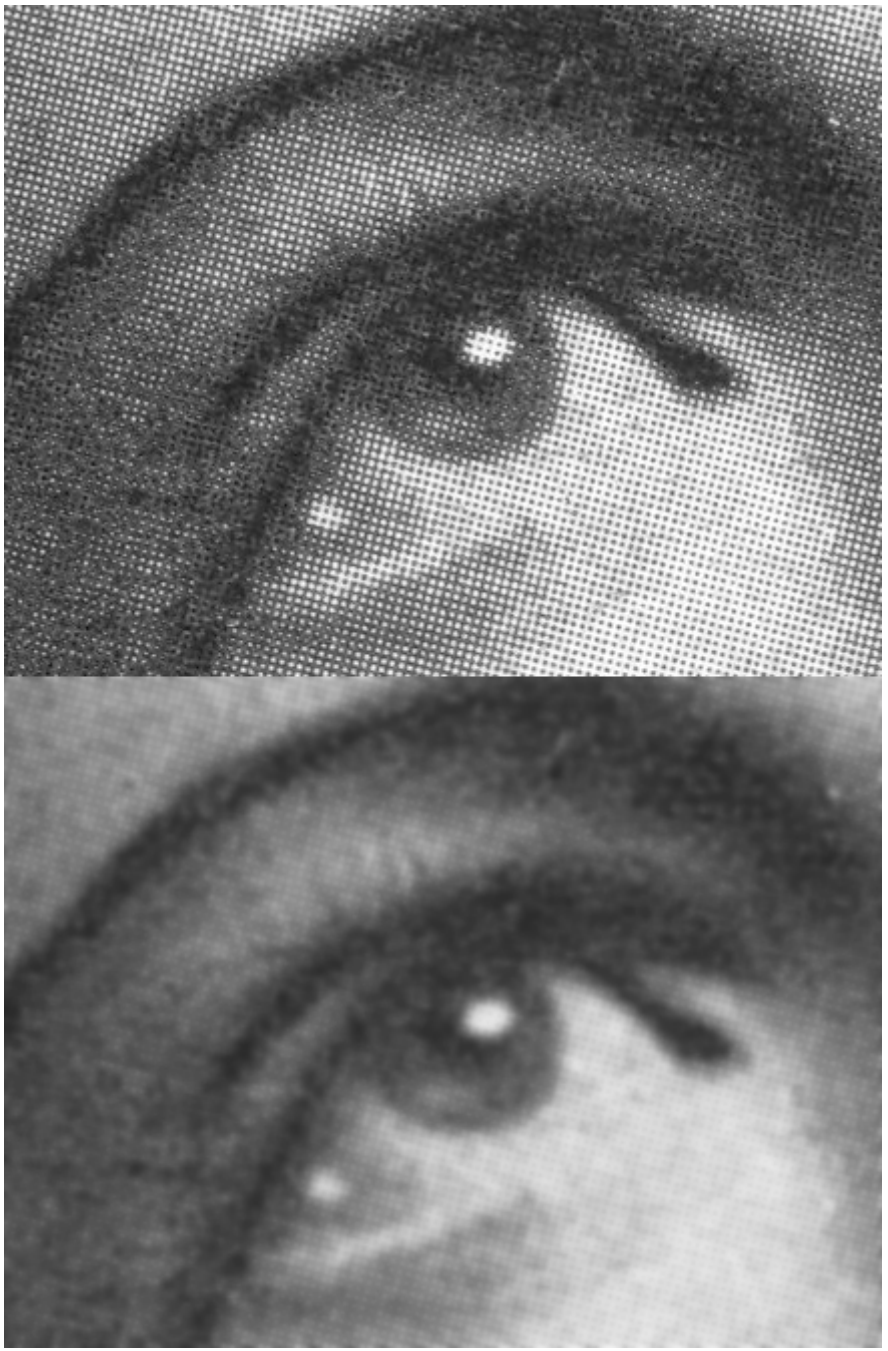




Difference map between normalized ring-like map and a flat map

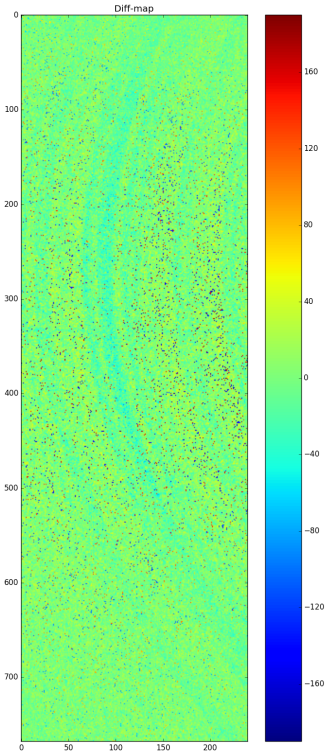
1-gate slice : gate-51

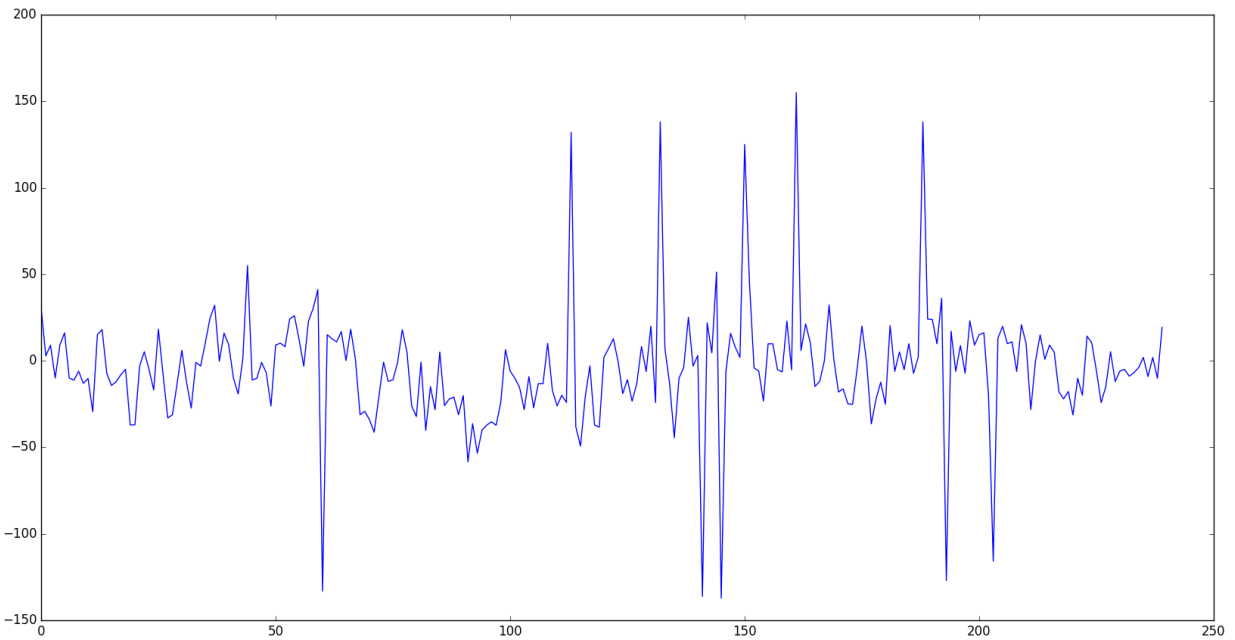
- **Problem is that the underlying shape of rings is washed away by statistical noise, noisy pixels and dead pixels.**
- **This screws up the fit and we get a ‘ring-score’ which estimated the true amount of ringness very poorly.**



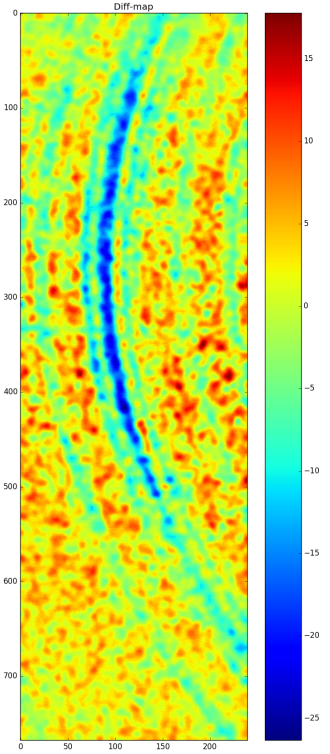
Gaussian filter

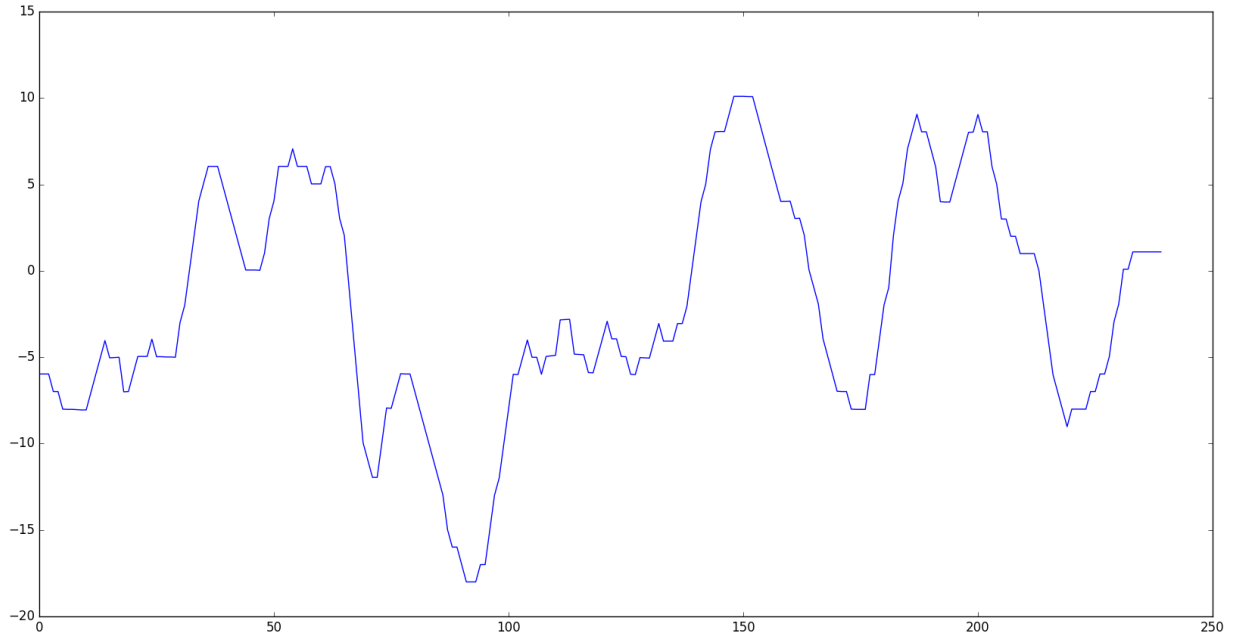
- Used widely in image processing to reduce noise
- This is achieved by convolving with a 2-D Gaussian kernel (easily done with the scipy package)
- This way the shot noise in our hitmaps can be smoothened out and the underlying structure can be obtained



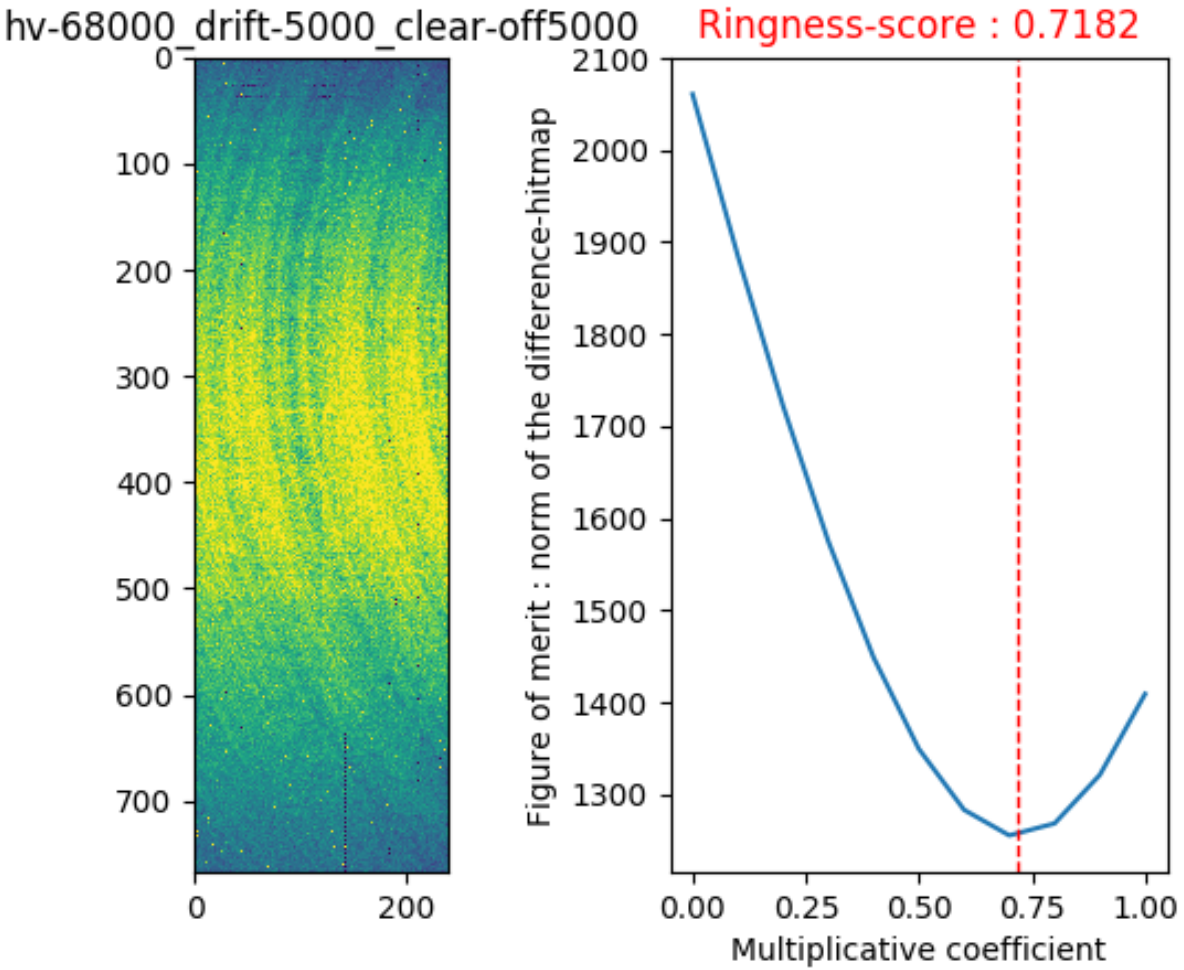


Gaussian filter





Module W41_IF



Example of the score calculated for one measurement

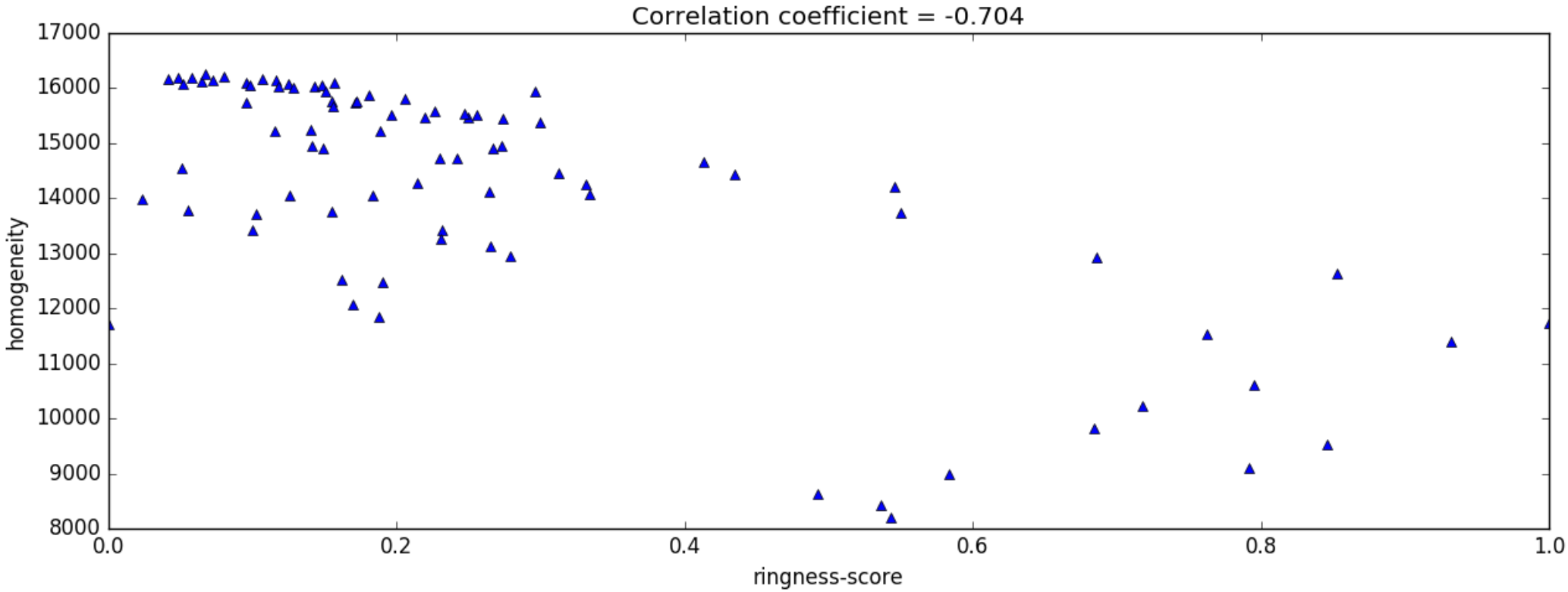
- Very fast: Set of 84 hitmaps of a single module analysed in ~2 mins

Full list of plots may be found in the files:

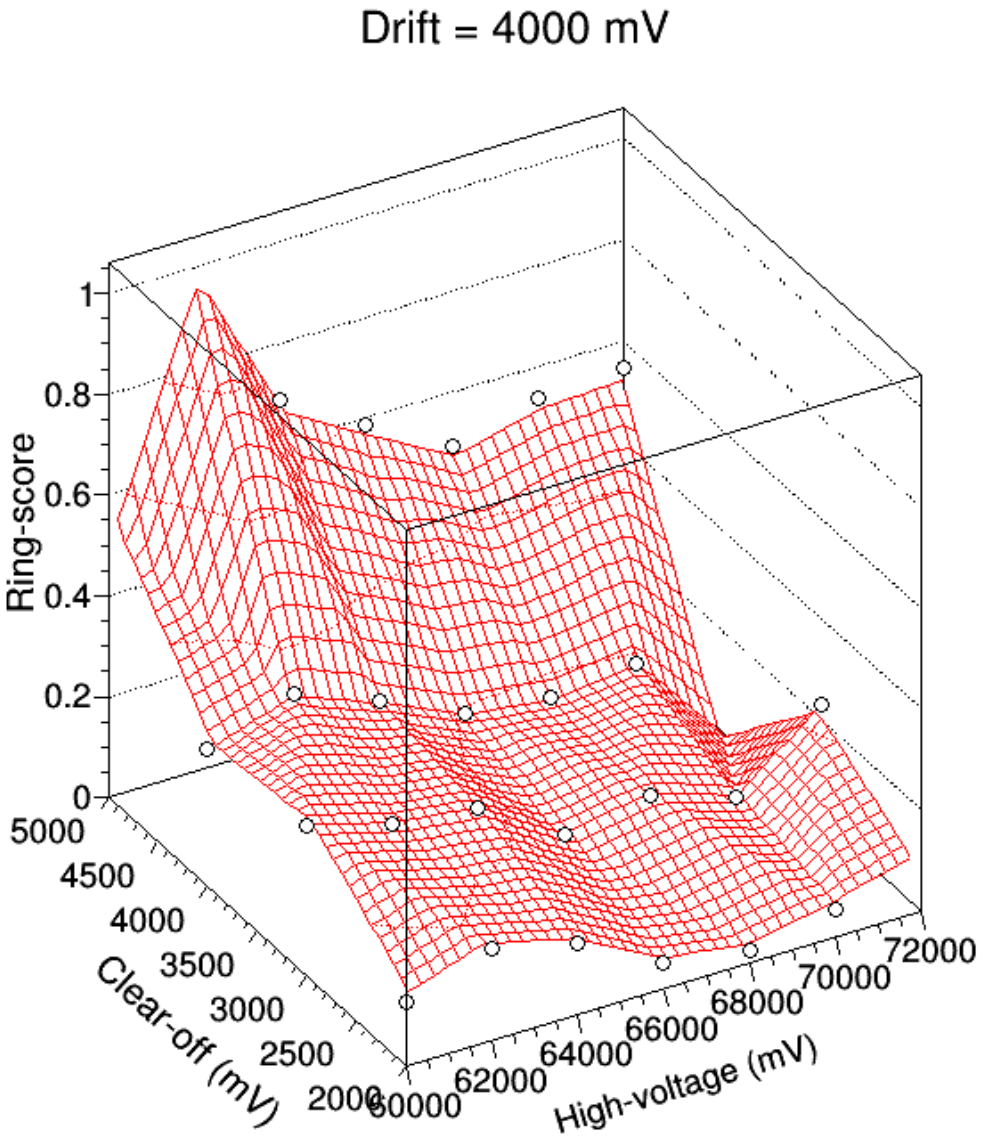
1) ring_scores_W03_IB_2017_12_04_002.pdf
2) ring_scores_W41_IF_2018_03_28_001.pdf
3) ring_scores_W44_IF_2018_03_20_001.pdf
4) ring_scores_W45_IB_2017_12_04_002.pdf

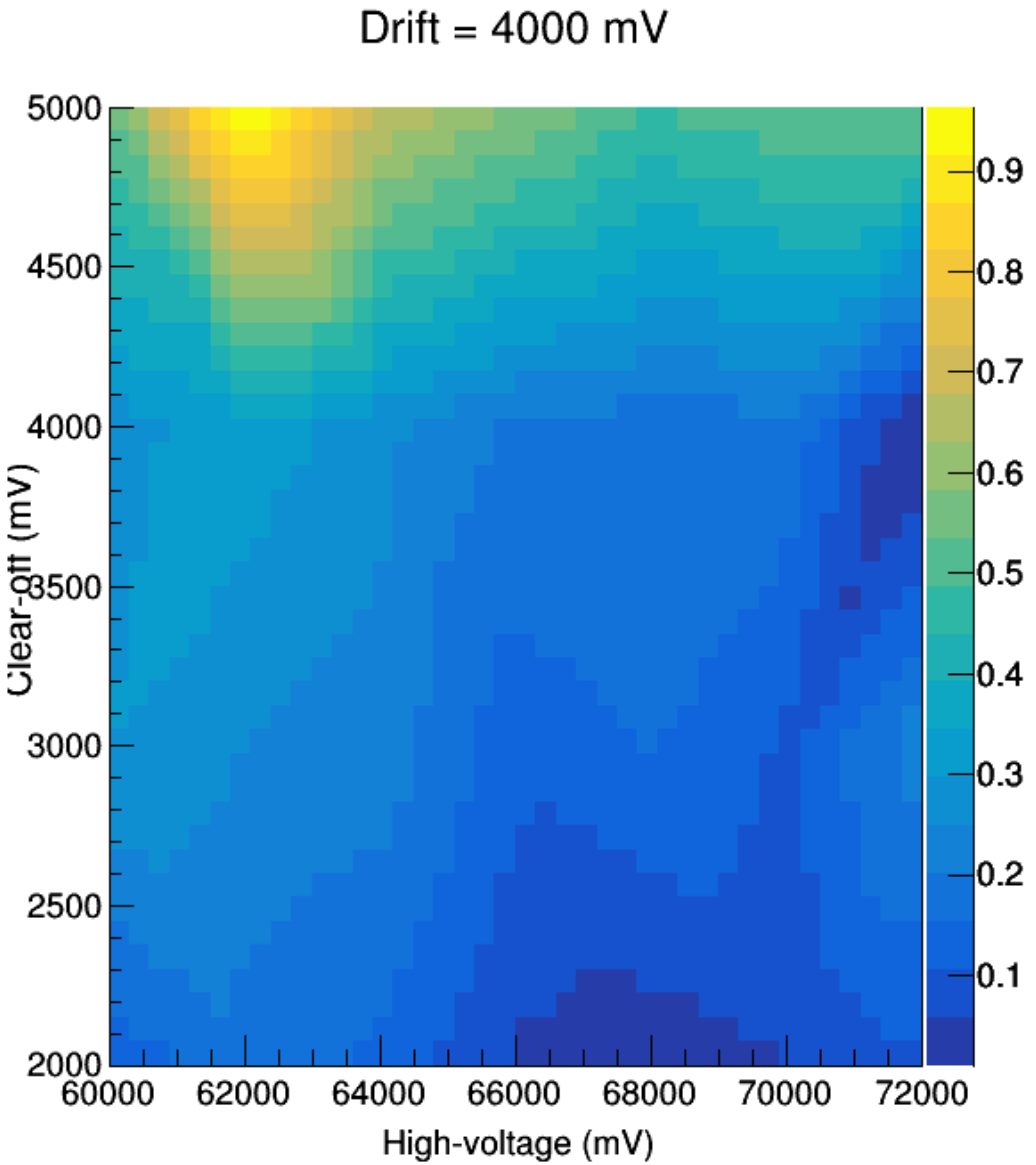
The ‘homogeneity’ variable is quite well correlated to the ‘ring-score’ variable

Module W41_IF



Module W41_IF





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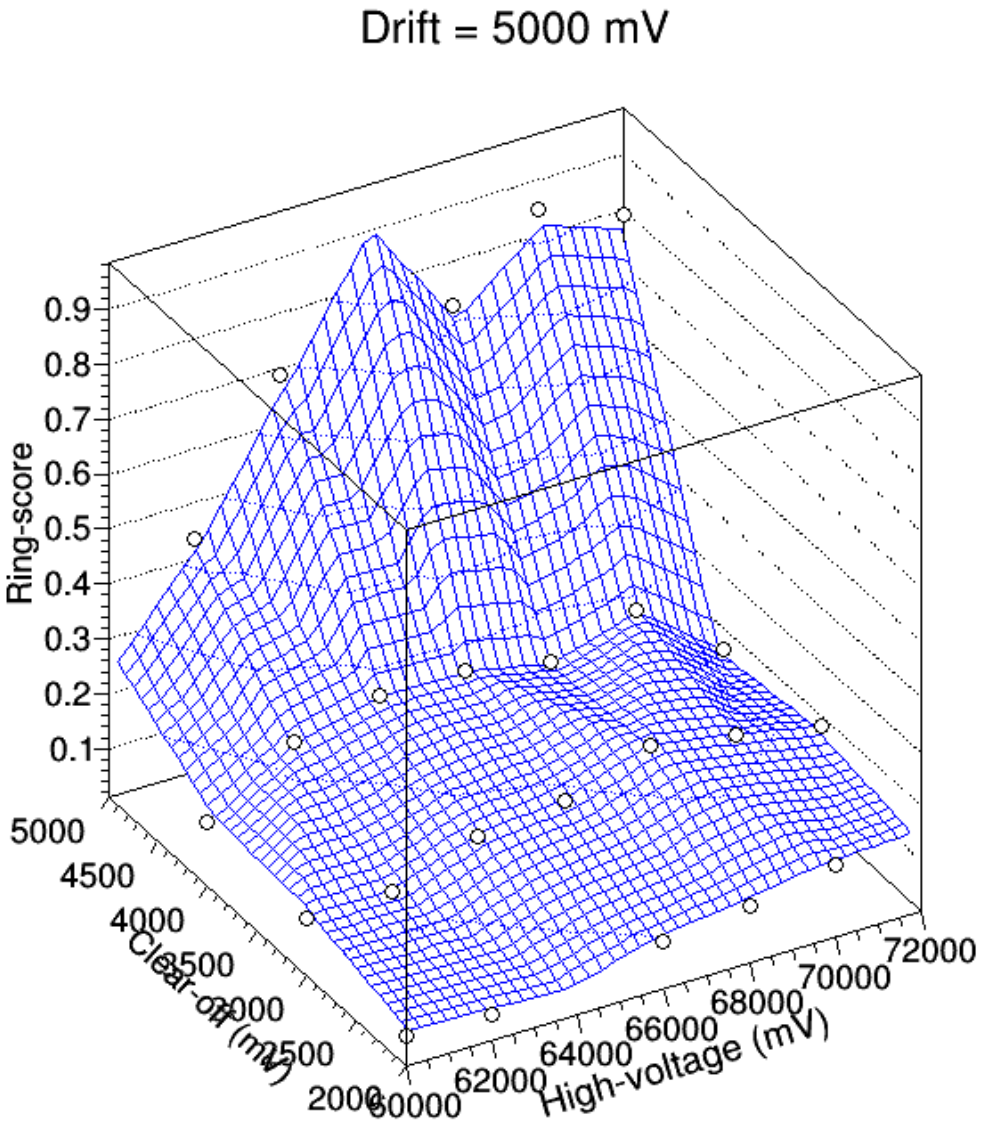

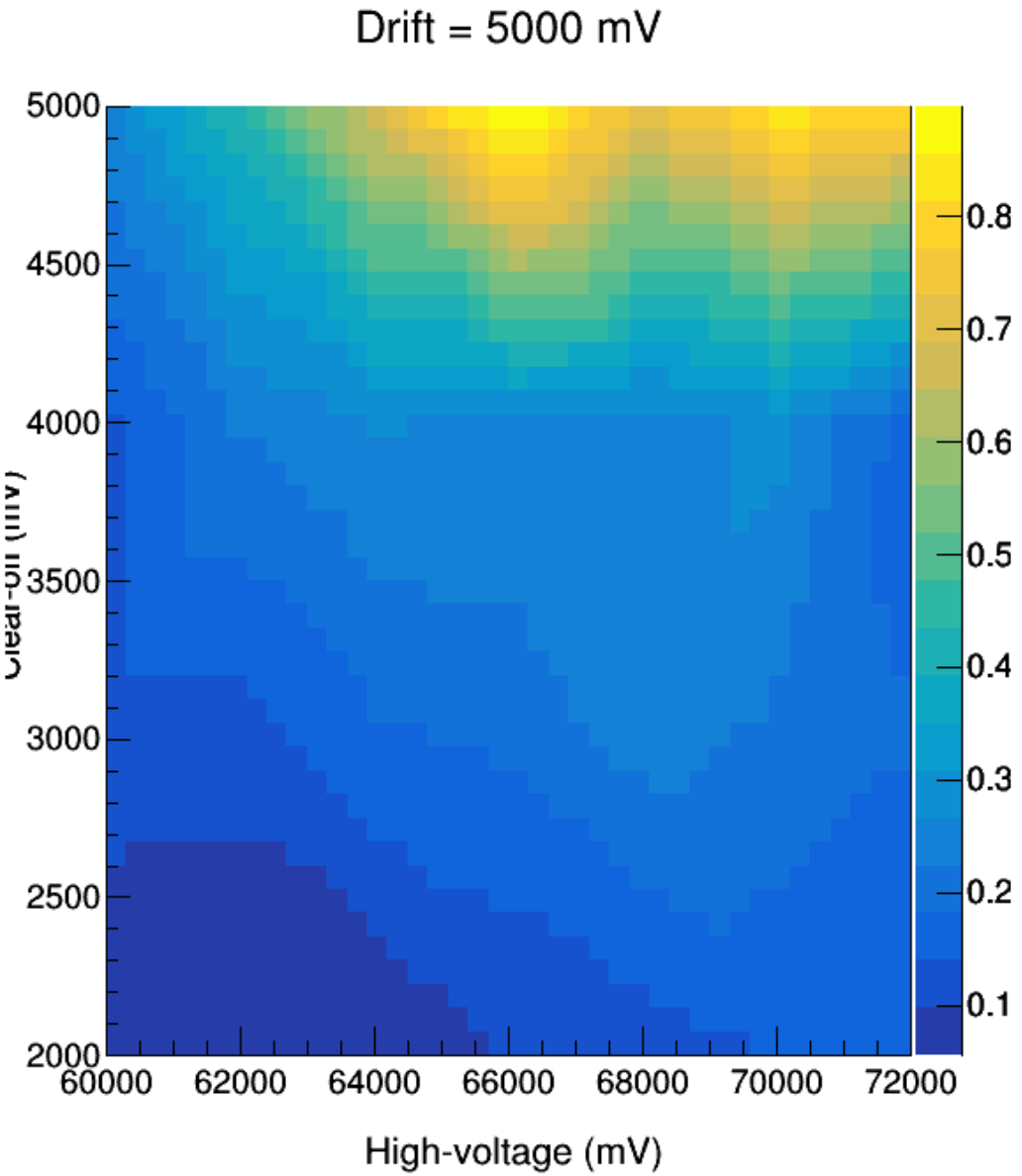

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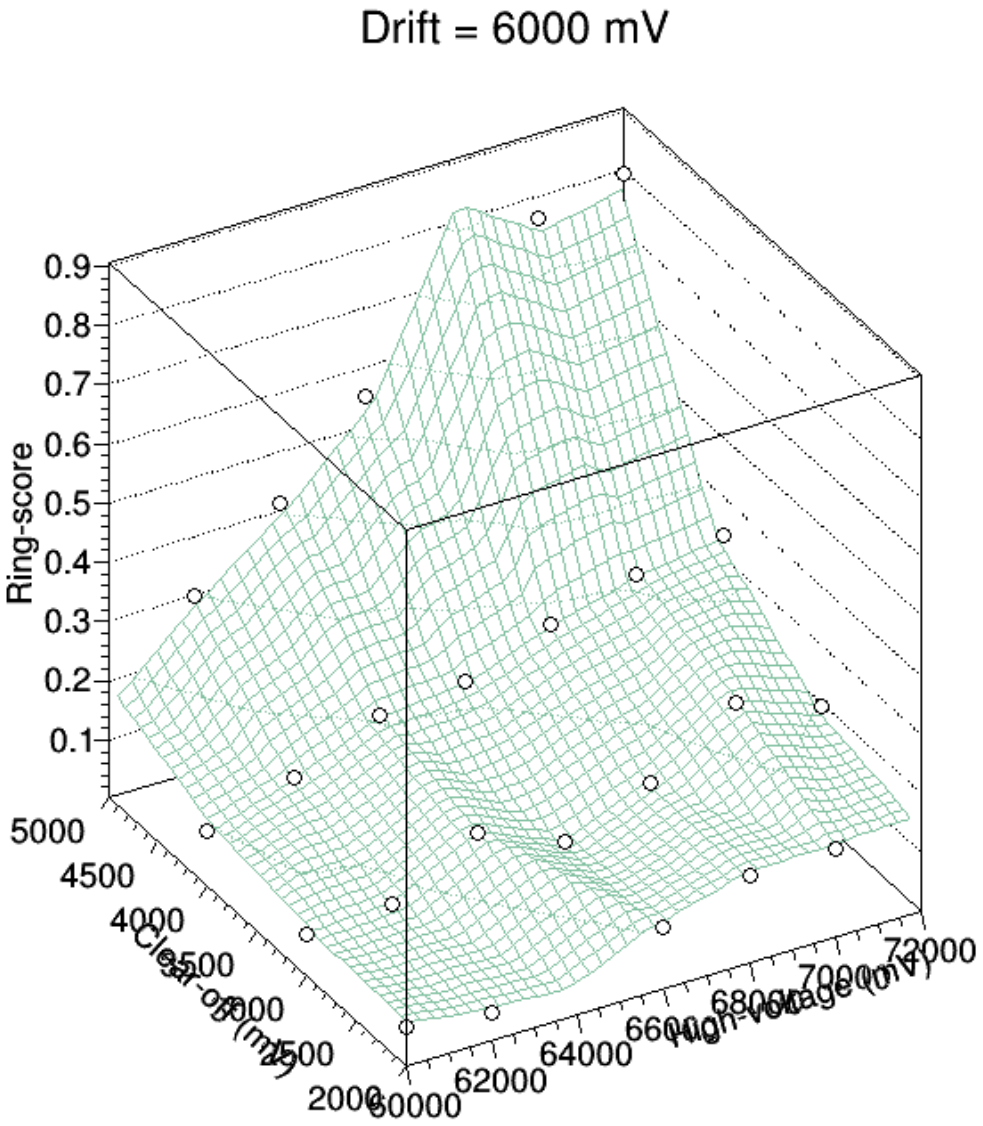
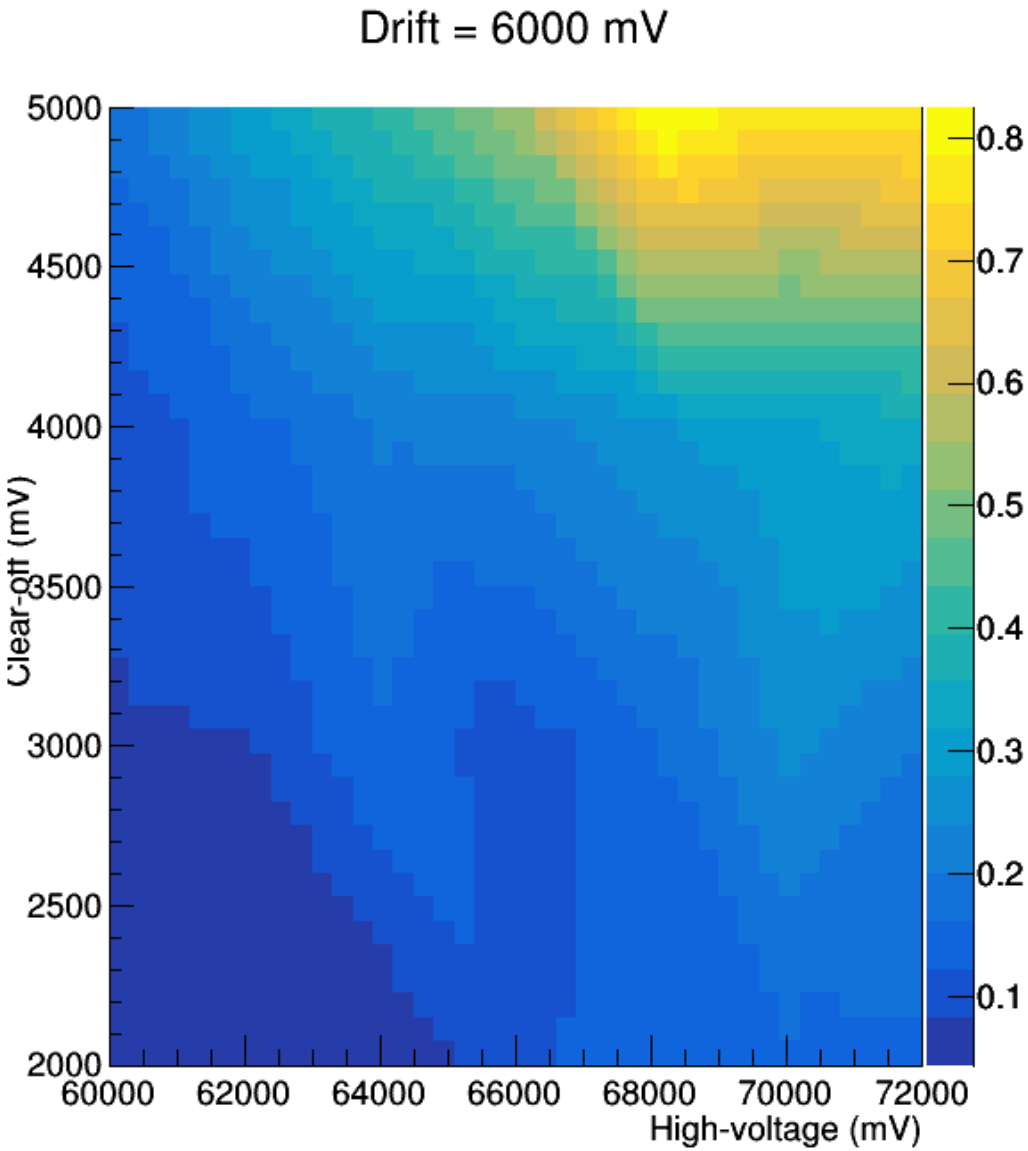
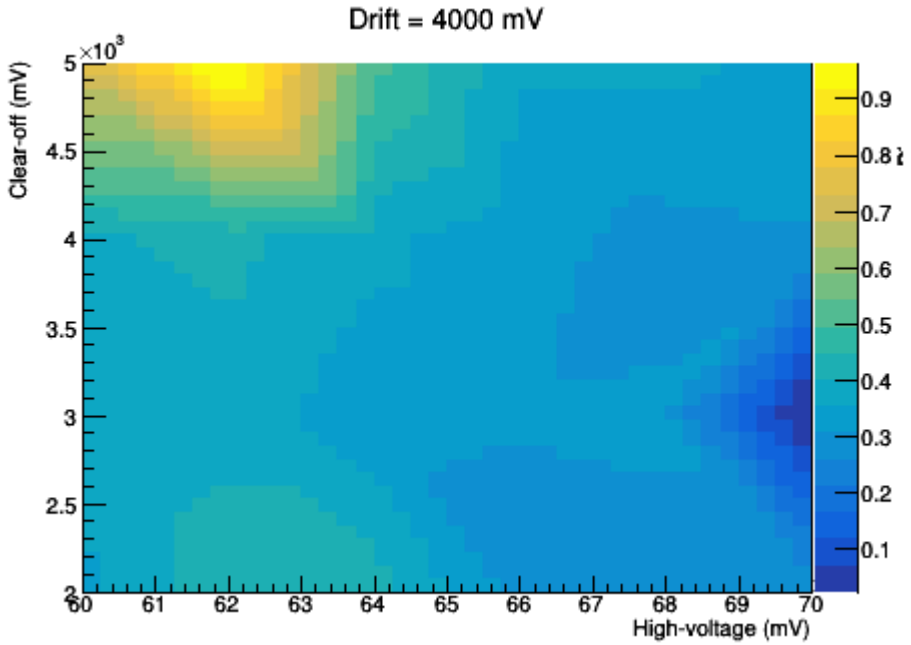
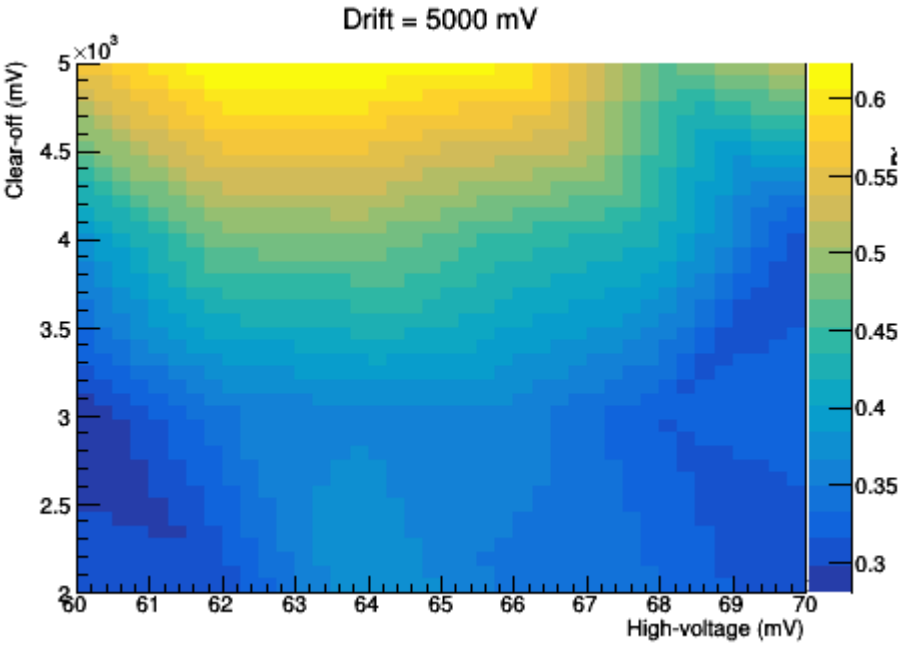
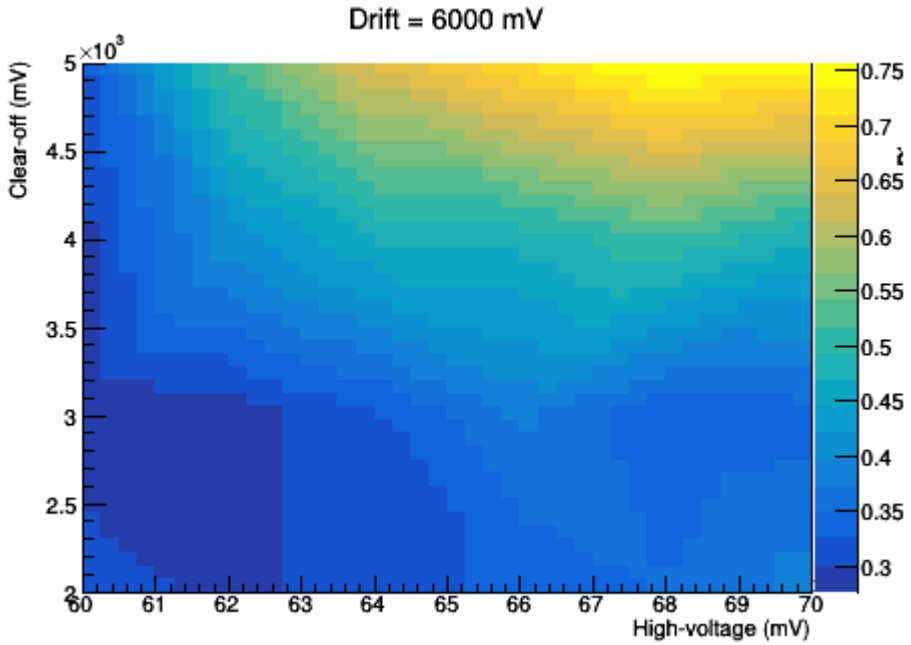


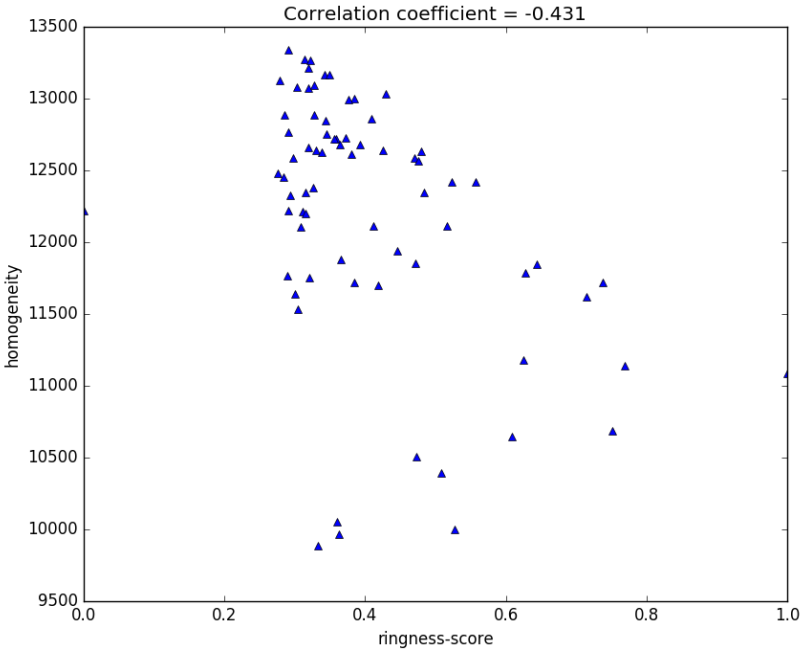


W03_IB_2017_12_04_002

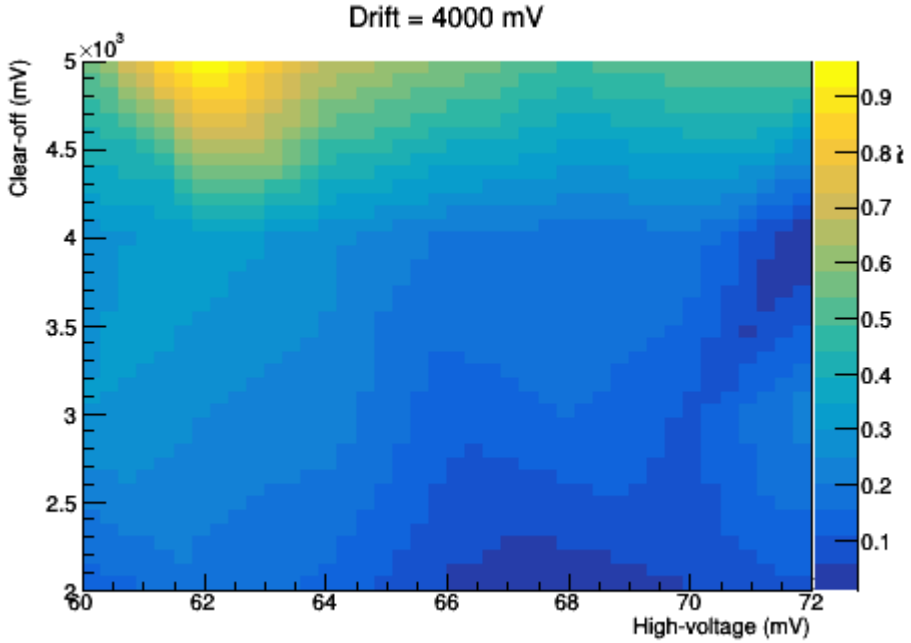


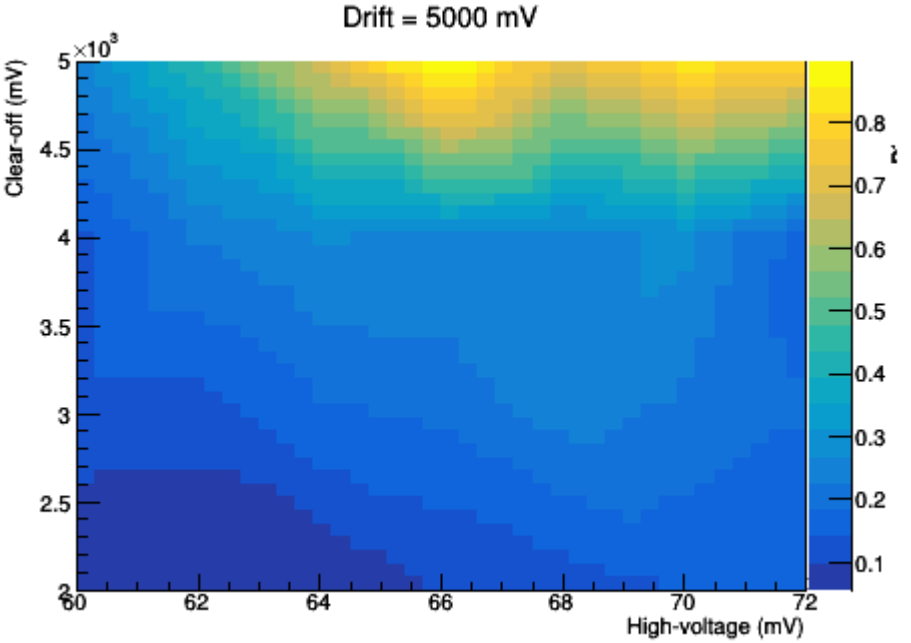


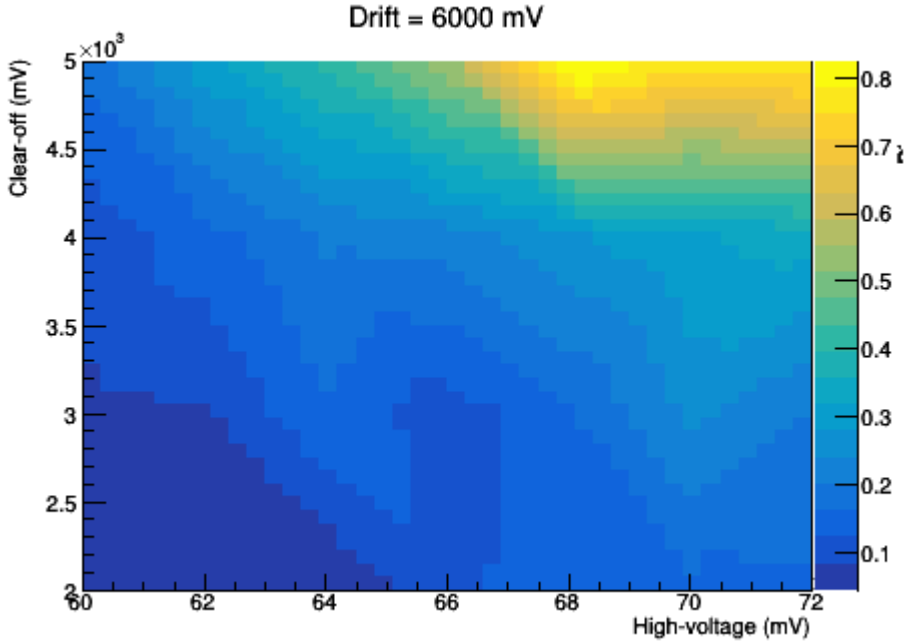


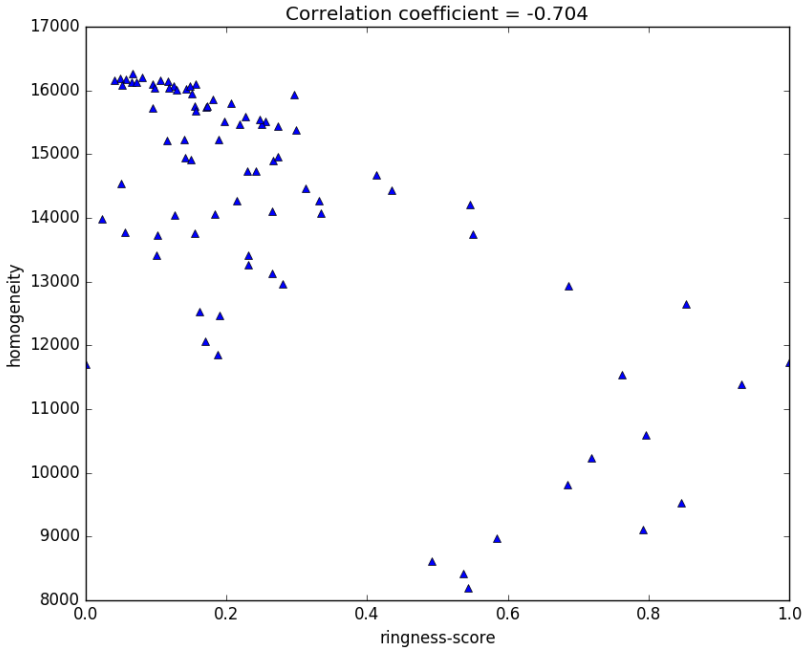


W41_IF_2018_03_28_001

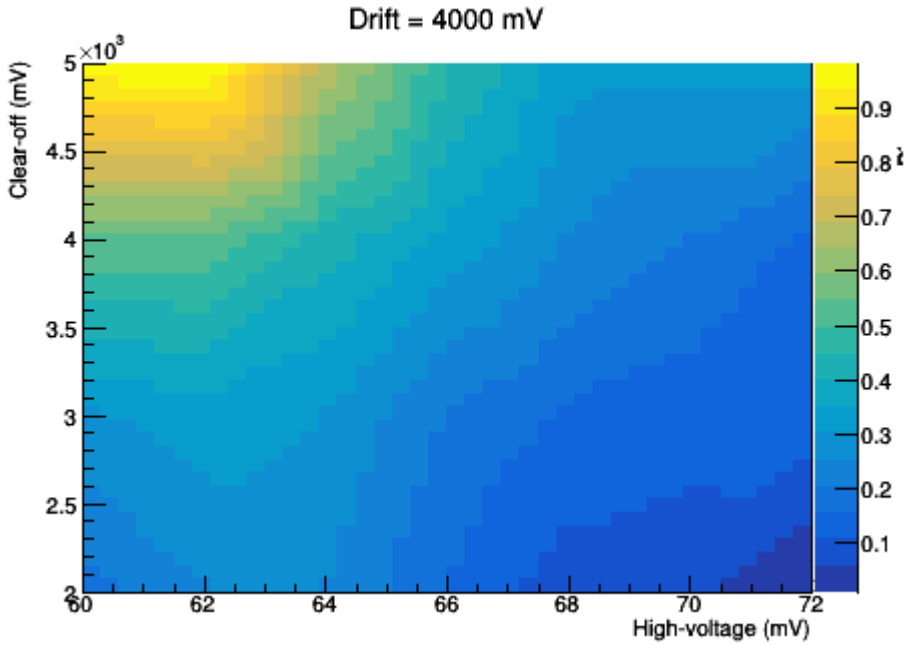


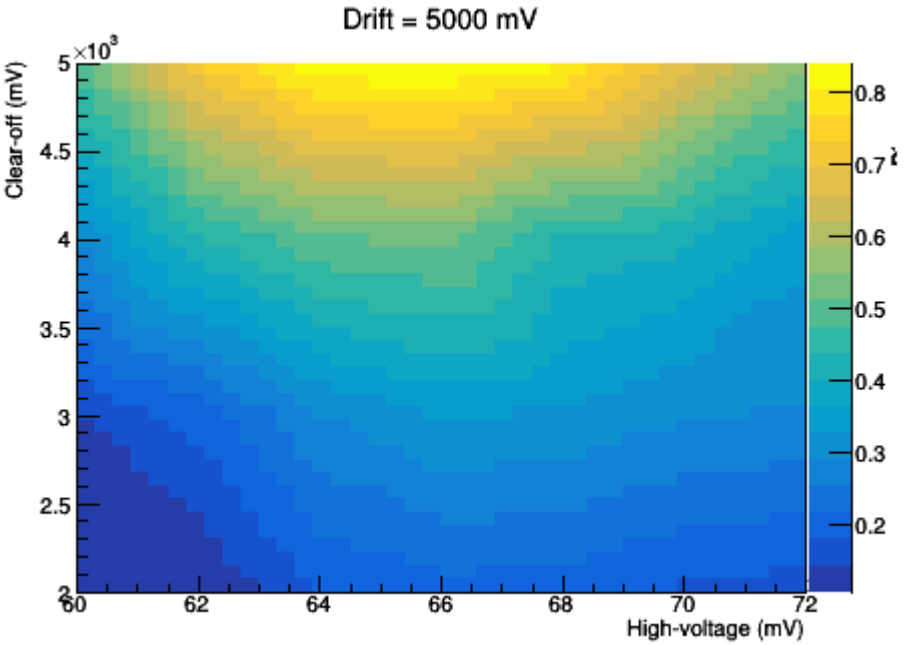


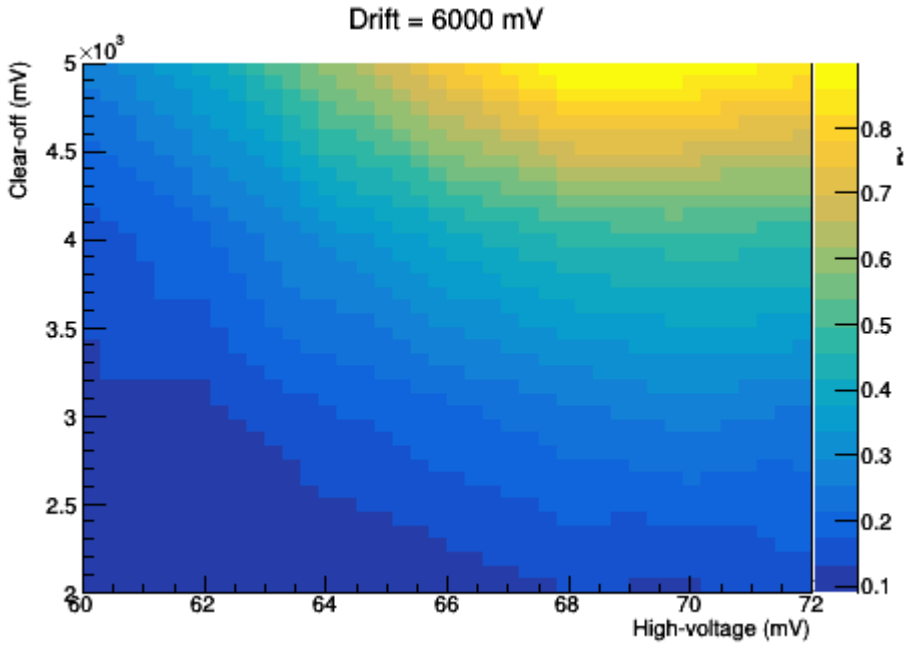


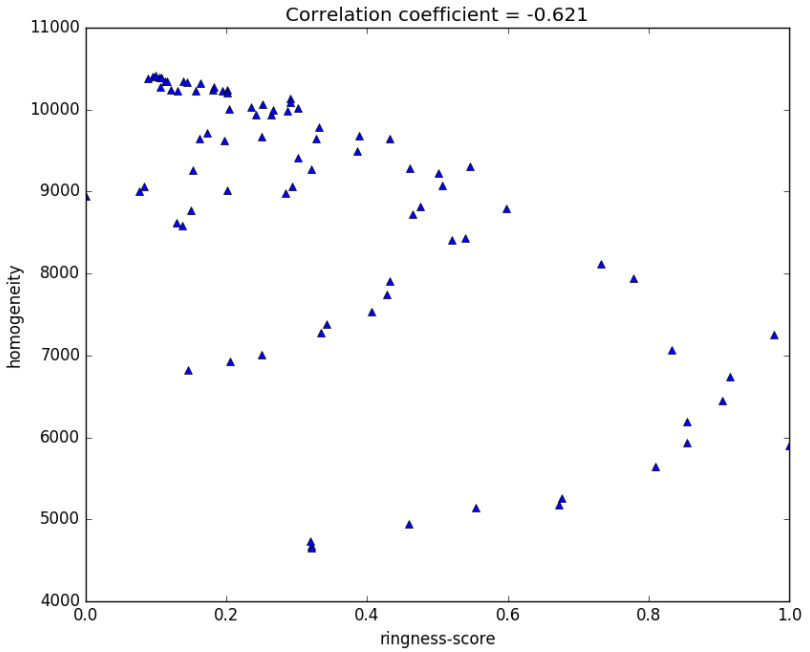


W44_IF_2018_03_20_001

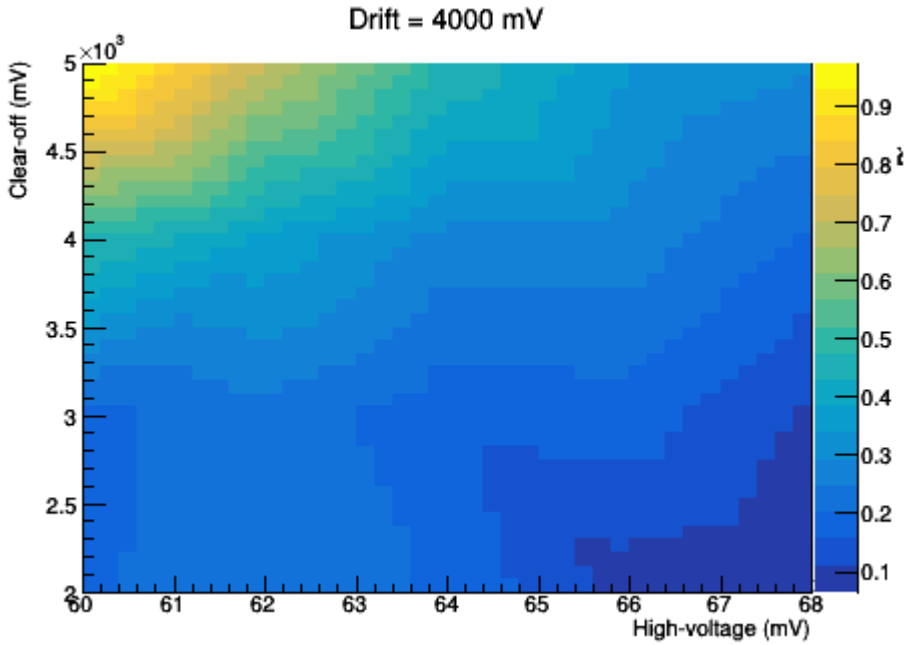


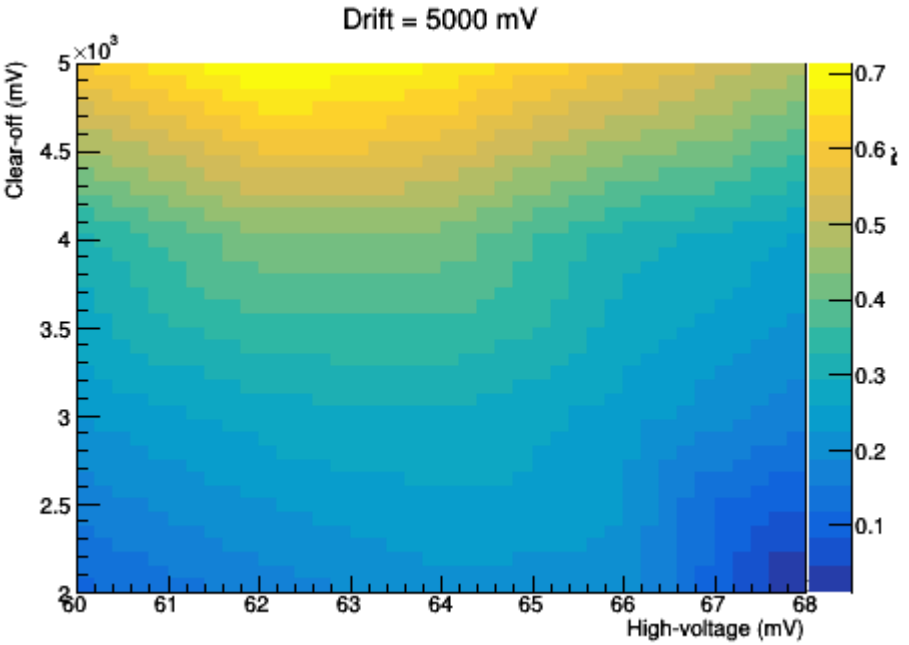


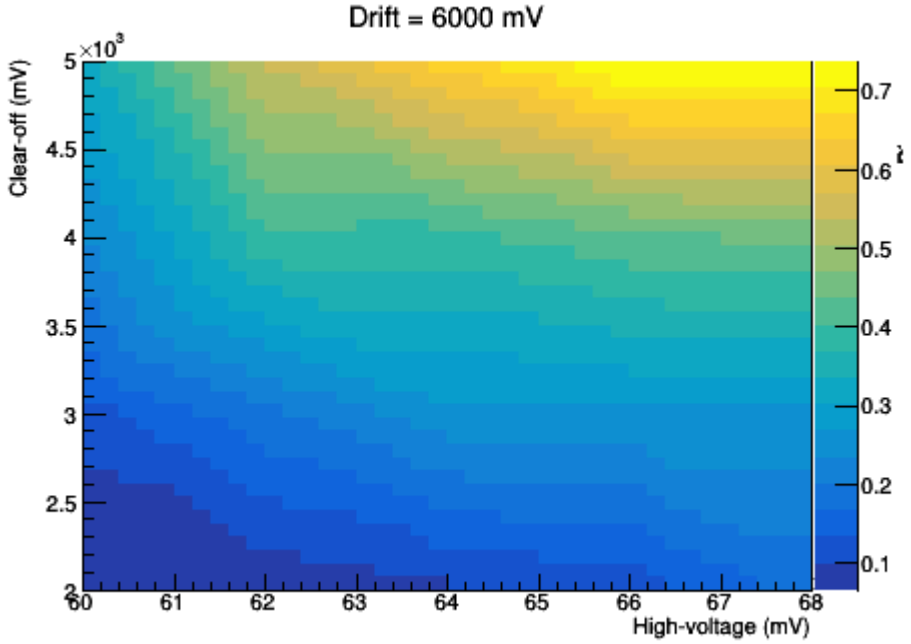


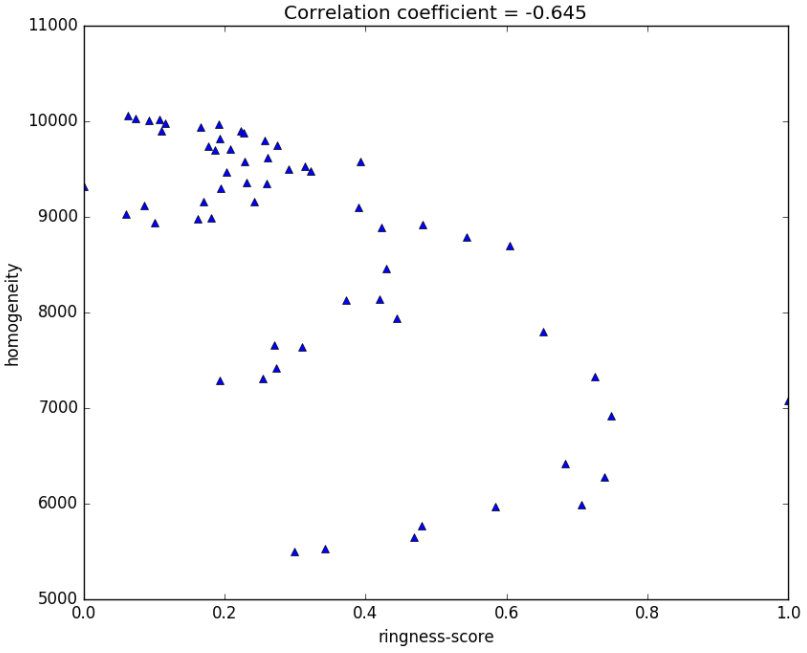


W45_IB_2017_12_04_002









Drawbacks

1) It is a relative score. So even if a particular module inherently has less ‘ringness’, the scores would still be roughly between 0 and 1 based on the reference hitmaps

2) The uncertainty on the ‘ringness-score’ is not estimated.

This can be done by converting the least squares fit to a chi^2 fit

- $D^2(a) = \Sigma_{\text{all pixels}} \; (\text{calc\_map}_i(a) - \text{sample}_i)^2$

$$\chi^2(a) = \Sigma_{\text{all pixels}} \; (\text{calc\_map}_i(a) - \text{sample}_i)^2 \; / \; \sigma_i^2$$

- But this is not that trivial as the usual poissonian √n error cannot be taken as the error σ_i as the Gaussian blur has modified this.
- Also in this case, the fitting functions/templates themselves suffer from statistical fluctuations(also modified by Gaussian blur), so this must also be added in quadrature for the estimate on the total σ_i.
- This can be done, albeit with some effort. But this probably doesnt mean a better fit, but one can get a handle on the uncertainty of the score. Question is whether the knowledge of the score uncertainty is crucial for us?

Summary

- We have a way of quantifying the amount of ‘ringedness’ of a hitmap
- With this we can analyse hundreds of hitmaps obtained at various voltage settings fast and build maps of the ‘ring-score’ as a function of the voltages
- This tells us the safe operational regime of the modules in voltage space
- The maps calculated for four different sensors from past measurements seems to indicate that modules behave rather similarly w.r.t to to applied matrix voltages
- Plan to incorporate to lab framework quite soon.