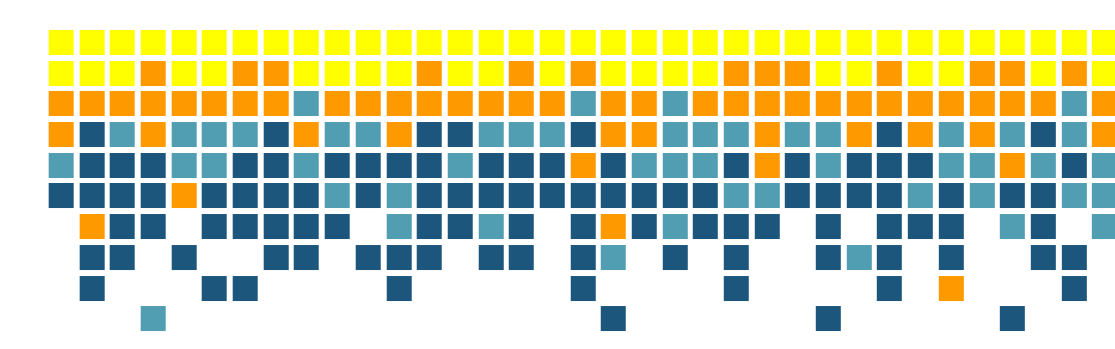
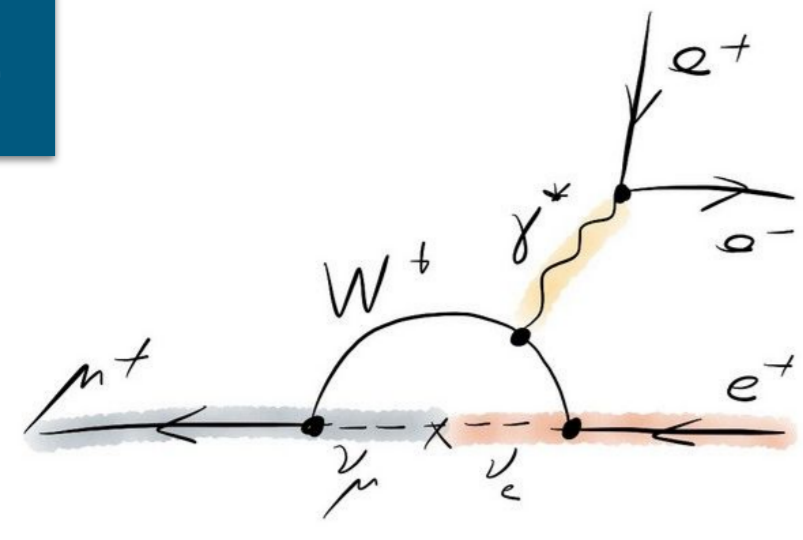


Noise Analysis

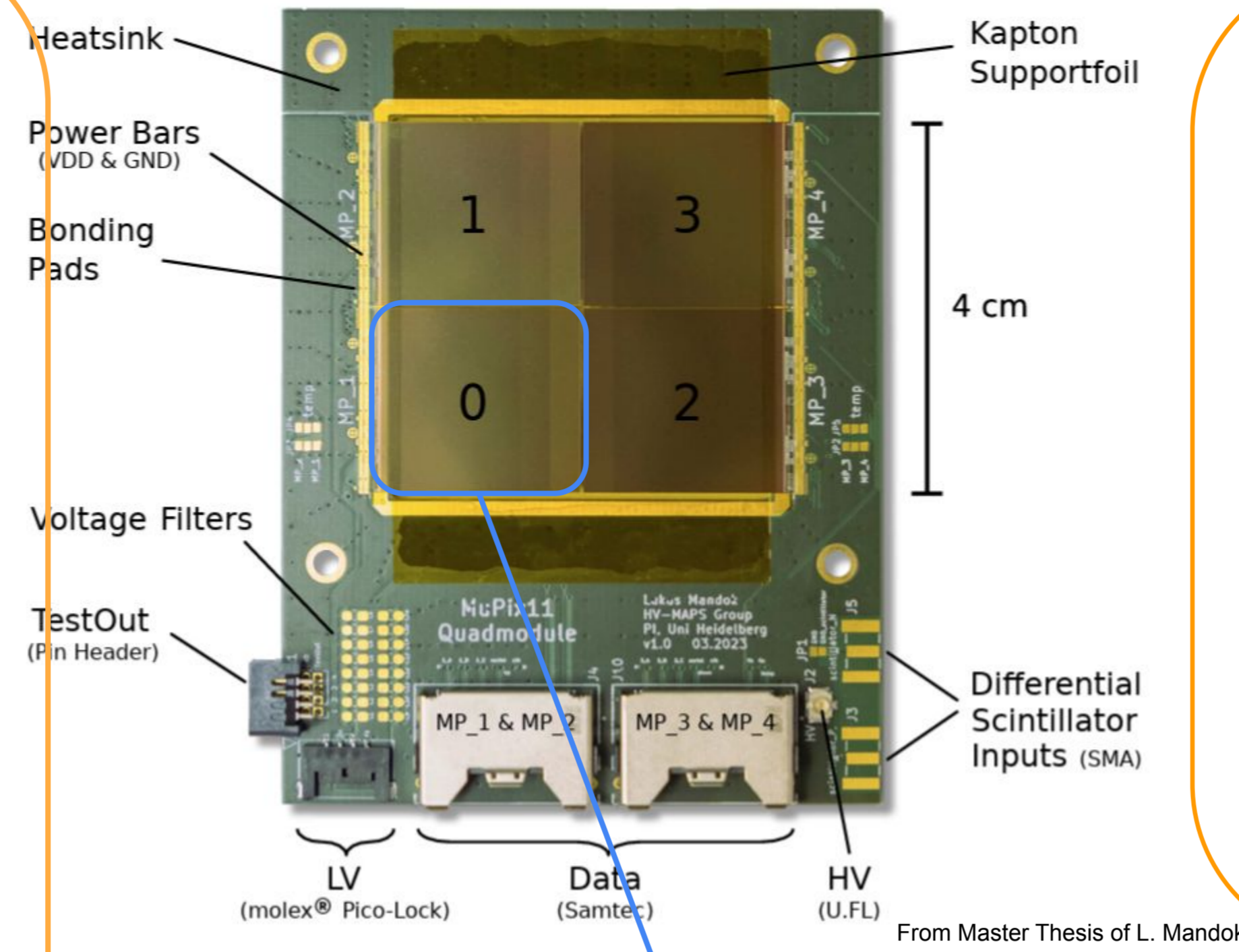
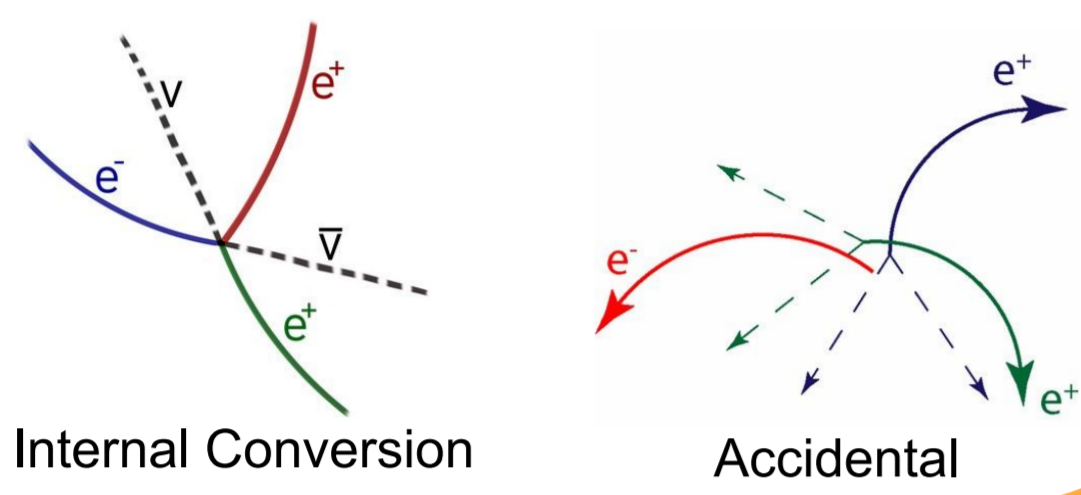


for the MuPix11 in the Mu3e Experiment

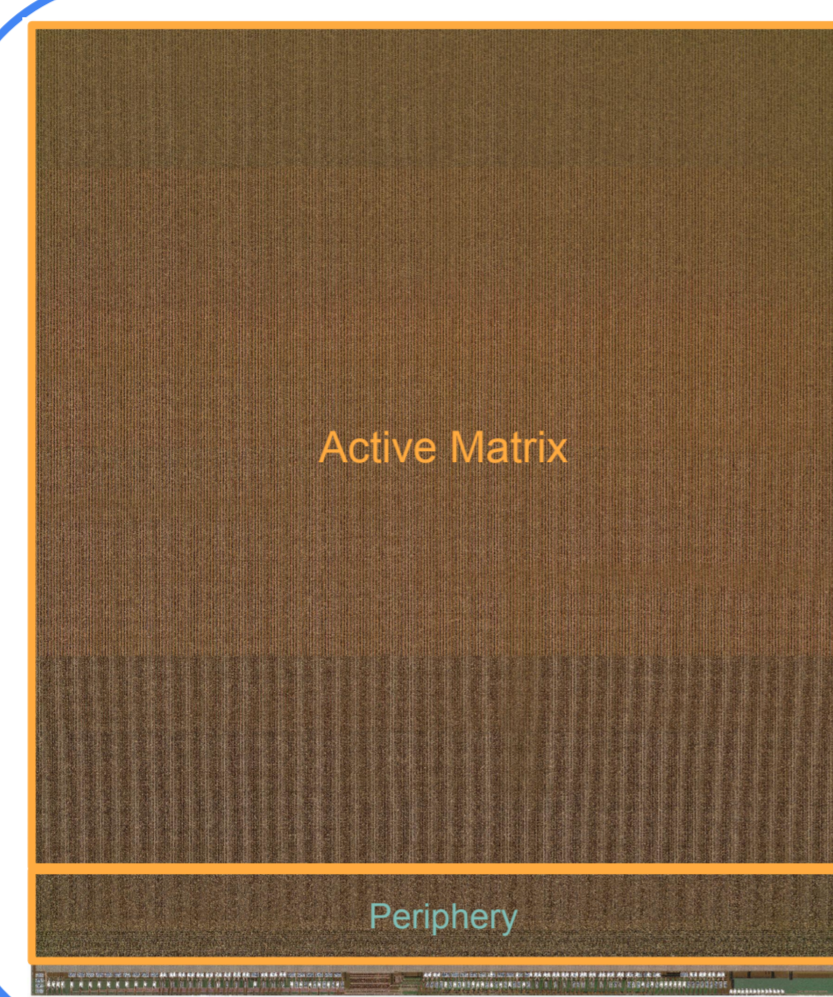
Mu3e



- Search for the cLFV decay
→ $\mu^+ \rightarrow e^+ e^- e^+$ (SM: BR < 10^{-54})
- Current limit (SINDRUM 1988):
→ BR < 10^{-12} @ 90 % CL
- Sensitivity Goal (Phase I):
→ 1 in 10^{15} decays
- High intensity μ^+ beam
→ Up to 10^8 muon stops / second
- Background suppression below sensitivity level



From Master Thesis of L. Mandok

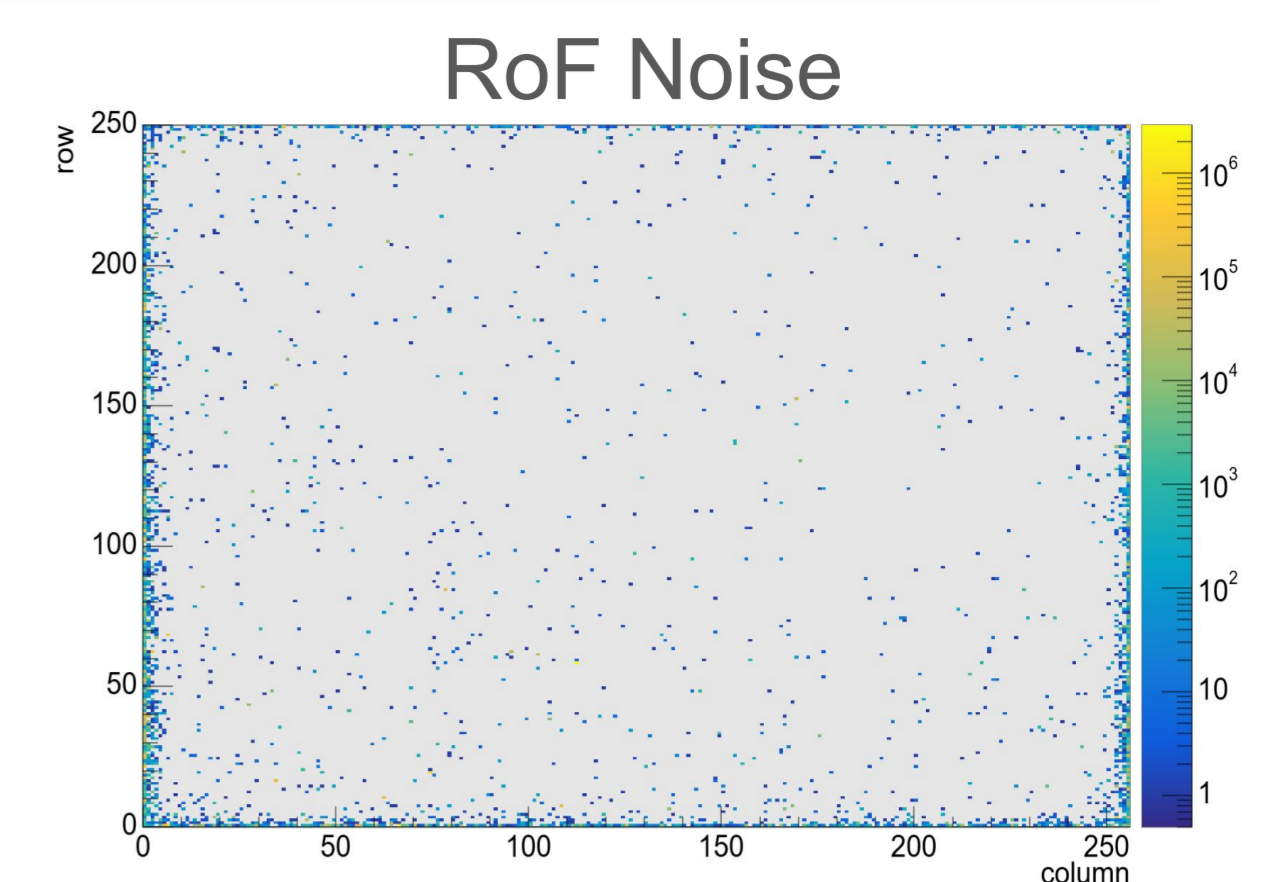


Pixel size [μm^2]	80 x 80
Pixel matrix	256 x 250
Active area [mm^2]	20.48 x 20.0
Sensor size [mm^2]	20.66 x 23.18
Thickness [μm]	50
Radiation length [x/X_0]	~ 0.5%
Resistivity [Ωcm]	80
Data links	3 + 1 (mux)

Ring of Fire

Noise characteristics:

- High rate spatially structured and reproducible pattern
- Observed across multiple-chip configuration setups (ladders and quads)
- HV network causes the noise



Questions to be answered

- How does Noise appear in time?
- Does it have a characteristic frequency?
- Could such a frequency be correlated with specific effects?
- Is noise caused by the HV source or is it induced by sensors coupling over the HV line?

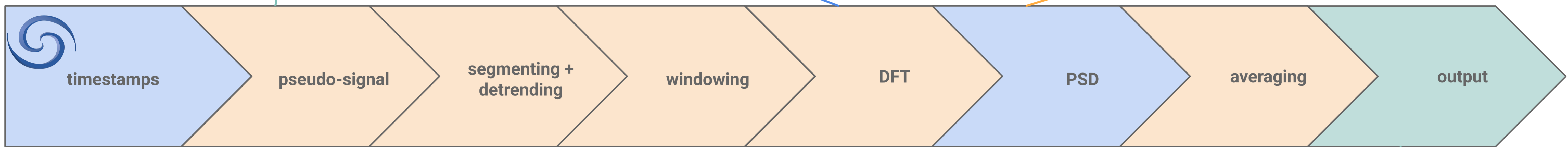
Tools that might answer these questions?

- Discrete Fourier Transform (DFT) of the signal
- Power Spectral Density (PSD)

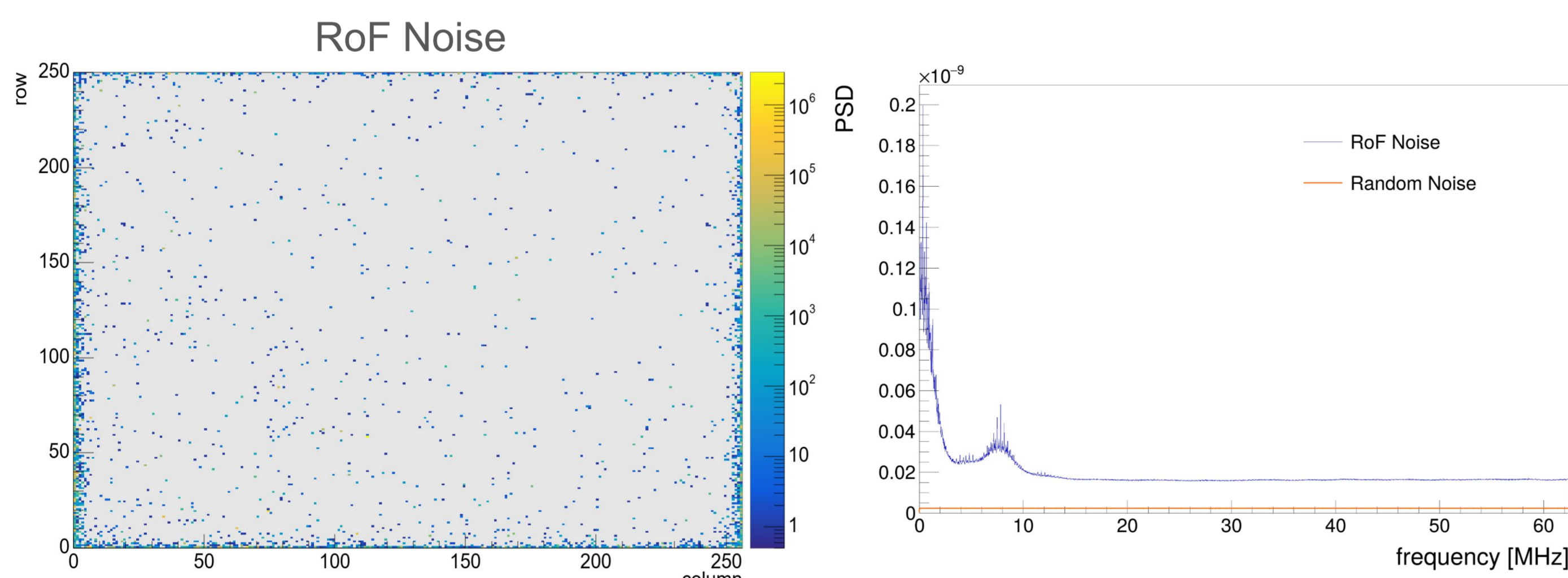
$$X[k] = \sum_{n=0}^{N-1} x[n] e^{-\frac{i2\pi kn}{N}}$$

$$f_k = k \cdot \Delta f$$

$$S[k] = \frac{|X[k]|^2}{f_s N U}$$



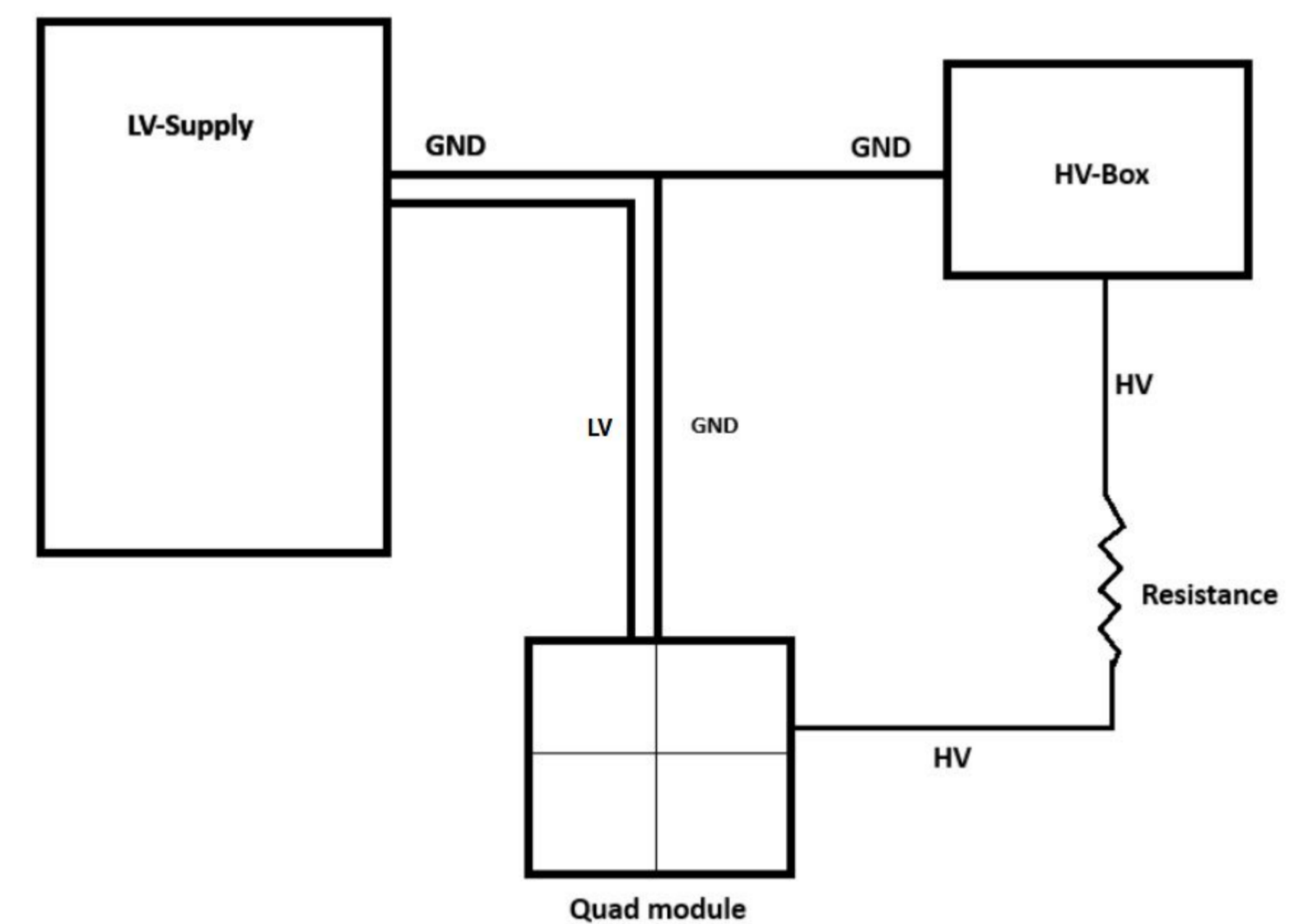
Fourier Analysis Comparisons between RoF and Random Noise data samples



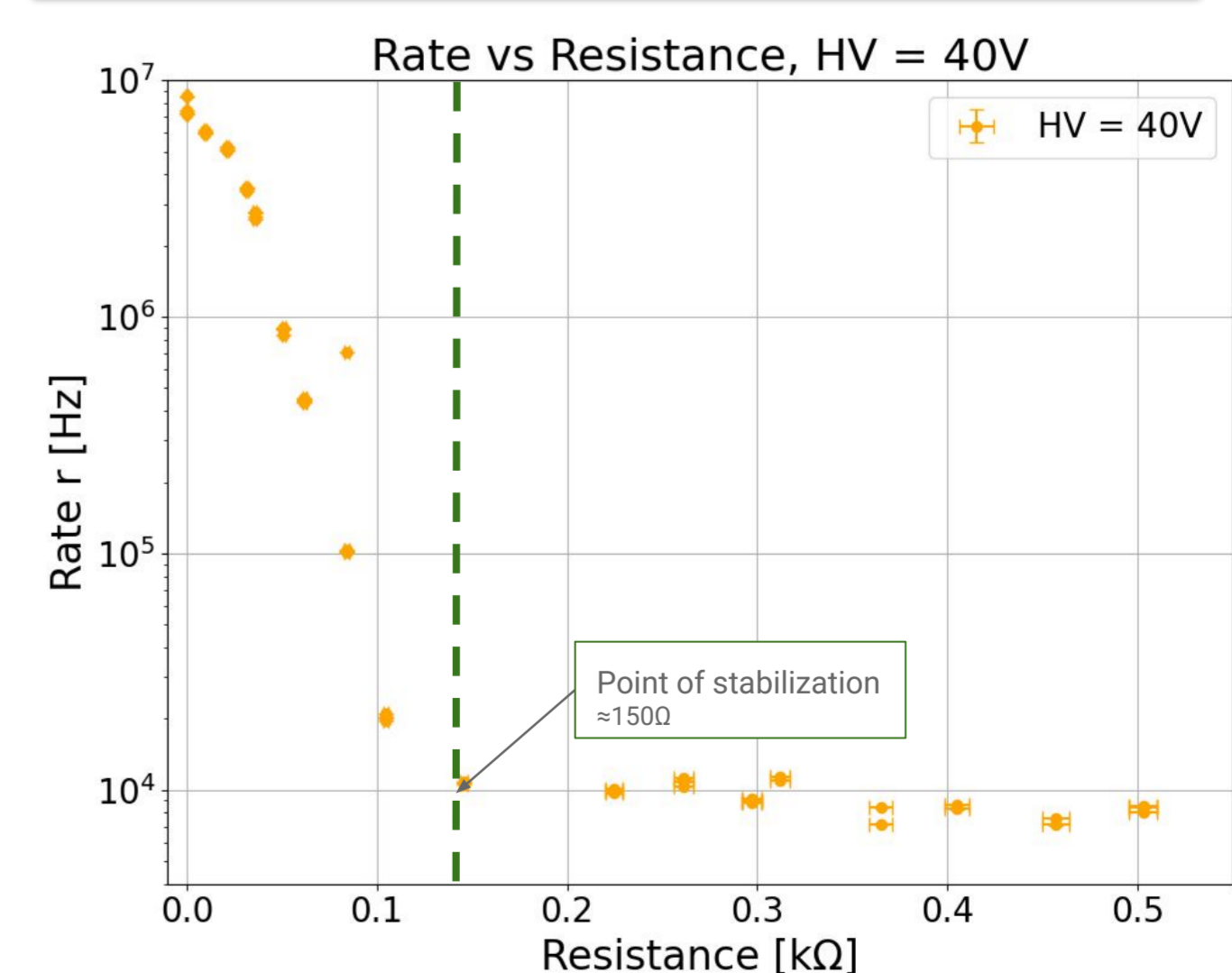
Fourier Analysis Settings

Sampling period [ns]	8
Sampling frequency f_s [MHz]	125
Number of FFT bins N	8192
Frequency step Δf [kHz]	15.26
Window length [μs]	65.5
Nyquist frequency [MHz]	62.5

Direct Noise mitigation study



Noise Hit Rate vs HV-Line Resistance



Conclusions

- Noise contribution frequencies are found in the 0-5 MHz range.
- A characteristic frequency around 7.8 MHz is observed.

Next steps

- Validate Fourier analysis chain
- Investigate source of 7.8 MHz peak
- Possible source related to timestamp bit error (7.8 MHz corresponds to 128 ns = 2^7 ns).
- Perform Fourier Analysis again with coarser sampling period, to focus on low frequency range sensitivity.

by Antonios Kontopoulos¹ for the Mu3e Collaboration

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