Diamond RnD for Fast Diamond Readout

Master's Thesis Presentation

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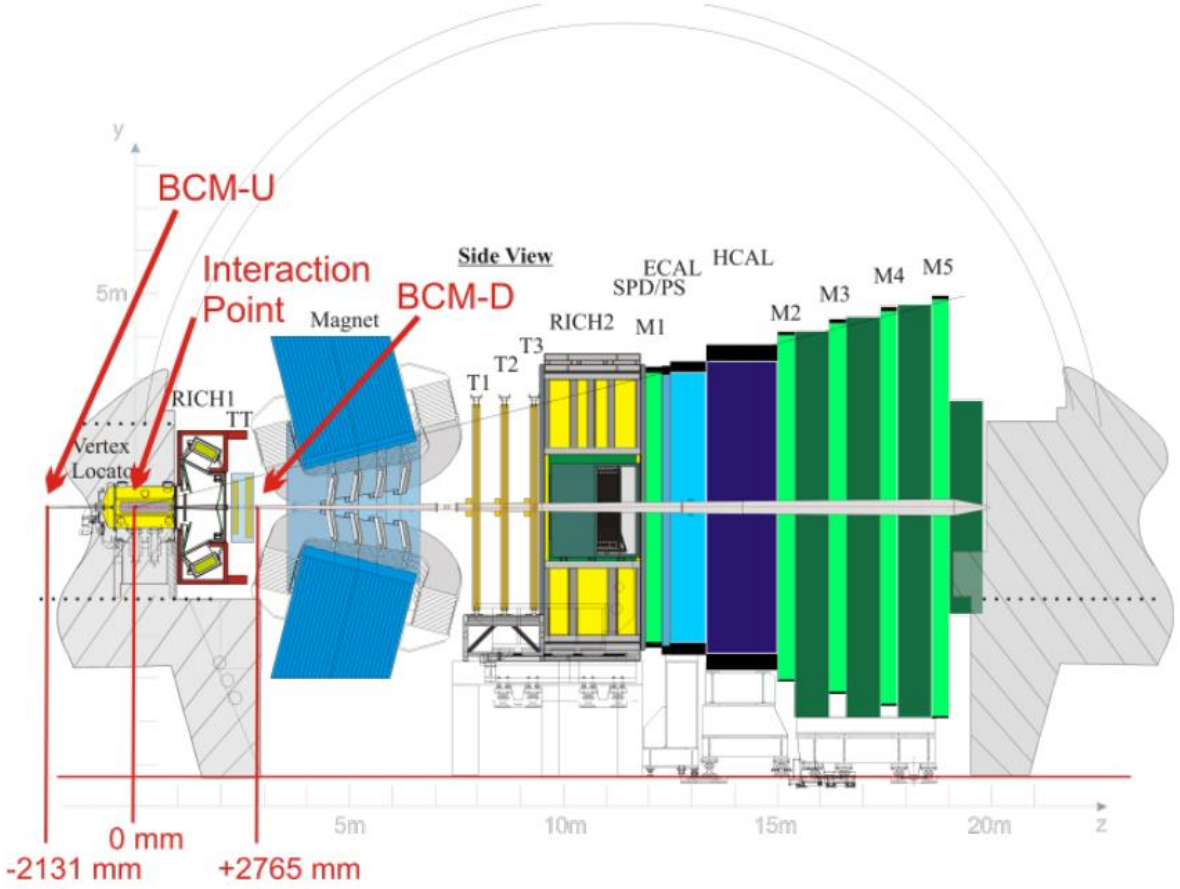
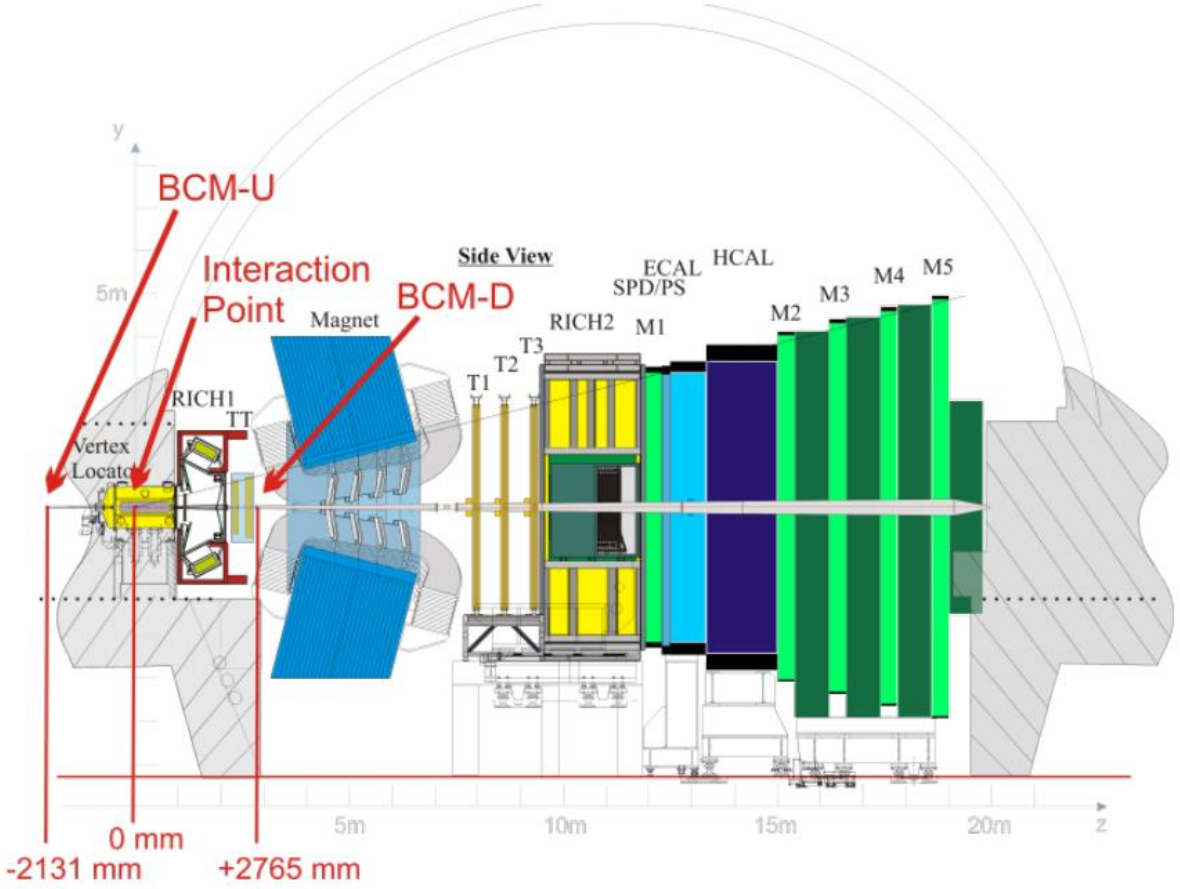
Motivation for a Fast Diamond Readout System

- Large Hadron Collider (LHC) is reaching higher luminosities
- Lage Hadron Collider beauty (LHCb) is upgraded accordingly
- important subdetector: Beam Condition Monitor (BCM)



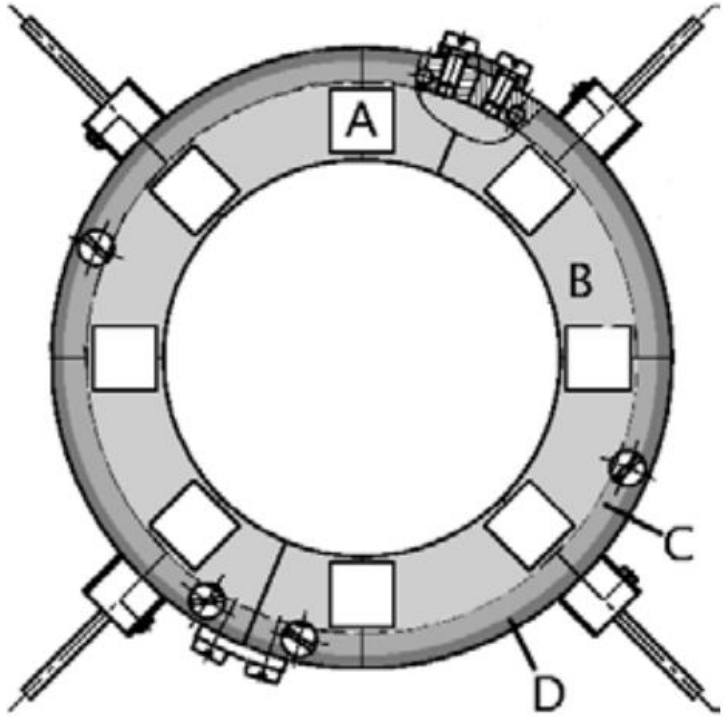
Motivation for a Fast Diamond Readout System

- located upstream and downstream to the Vertex Locator (VELO)
- protects mainly VELO by monitoring the beam
- fast (40µs) and slow (89µ) abort system



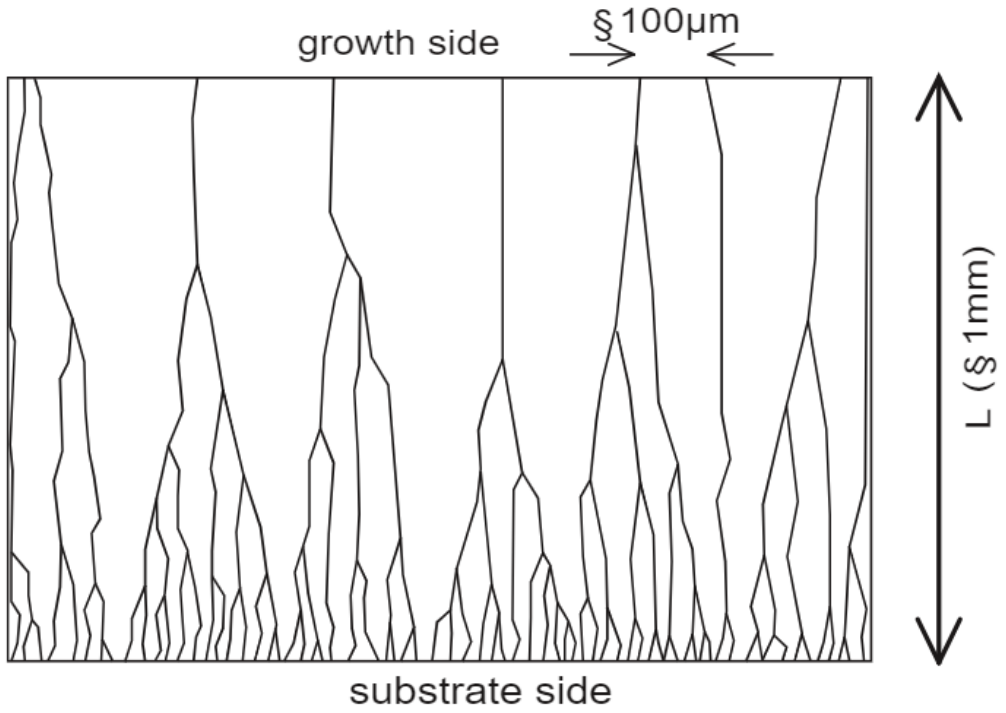
Motivation for a Fast Diamond Readout System

- BCM-U and BCM-D consist of 8 pCVD grown diamonds each
- readout based on the measured current
- for higher luminosities: even faster readout system
  - ideally with detection of single counts



pCVD grown Diamonds

- polycrystalline diamonds
- manufactured through the Chemical Vapor Deposition (CVD) process
  - substrate where diamond is grown on
  - gas mixture used to filter carbon structures out
- during manufacturing grain boundaries are created → Pumping Effect



Pumping Effect in pCVD grown Diamonds

- grain boundaries lead to the pumping effect
- boundaries can act as traps for charge carriers
  - Signal gets lost
- repeated and permanent exposure to radiation can cause a stabilization effect
  - initial traps become saturated with charge carriers
  - = pumping effect

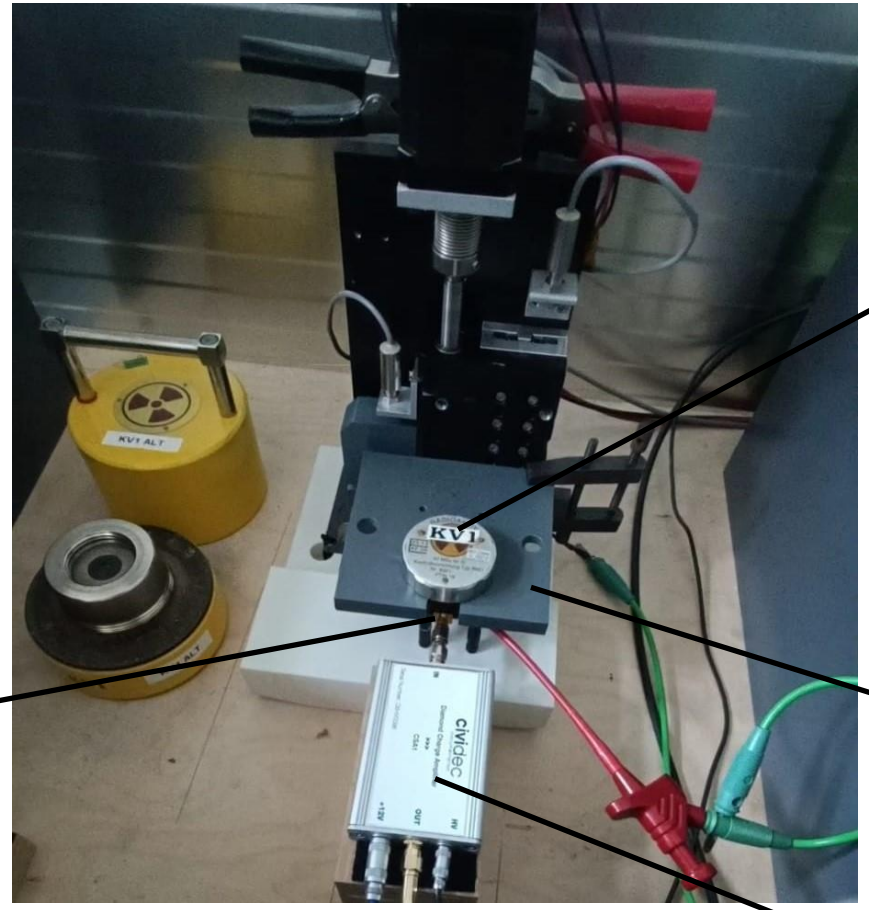
pCVD grown Diamonds

- 10mm x 10mm x 0.5mm diamonds from Element Six
- electrodes deposited via gold-titanium bilayer system, each 50nm thick
  - Differ in sensor size
- mounted on printed circuit boards (PCBs)
  - connection via aluminium wire bonding

pCVD grown Diamonds

Diamond Number	Electrode Size (mm²)
07	1
37	4
33	8
09	9
03	16
17	25
18	36
24	49
02, 13, 29, 38	64

Experimental Setup

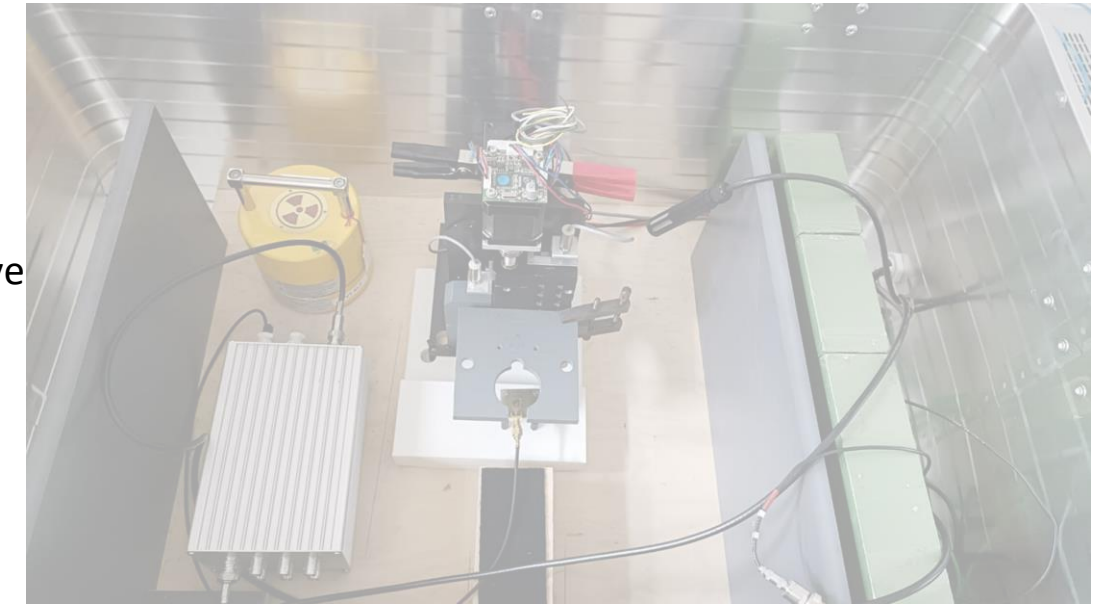


Radioactive source

Diamond Sensor

Height-adjustable table with mounting for radiation source

Amplifier



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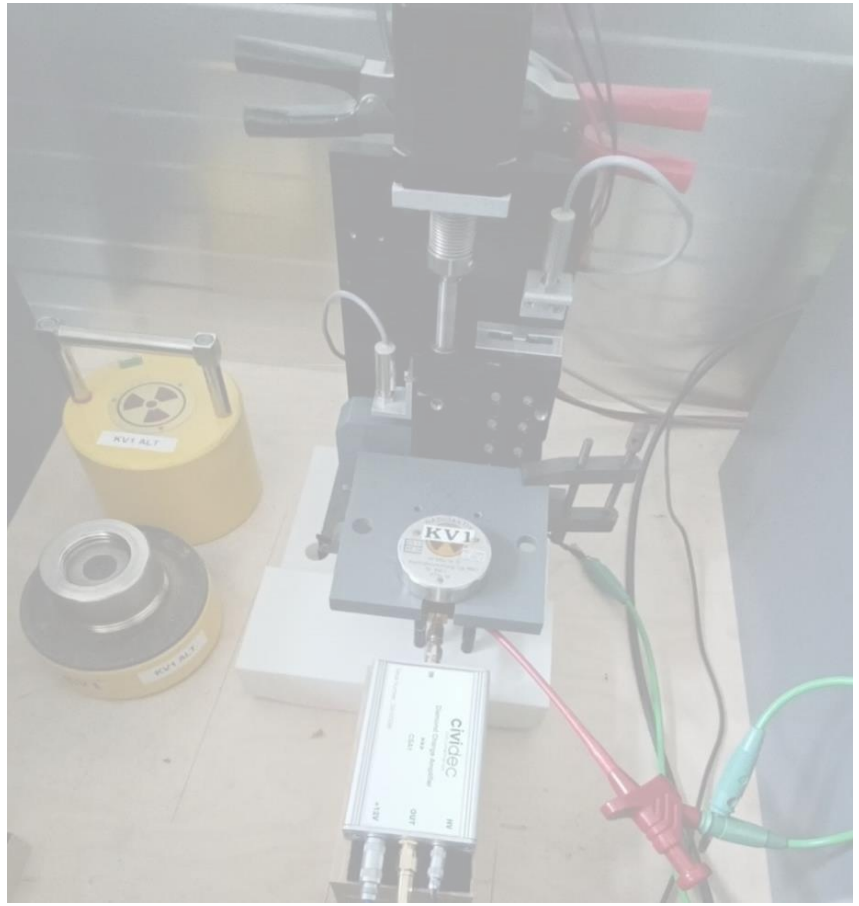
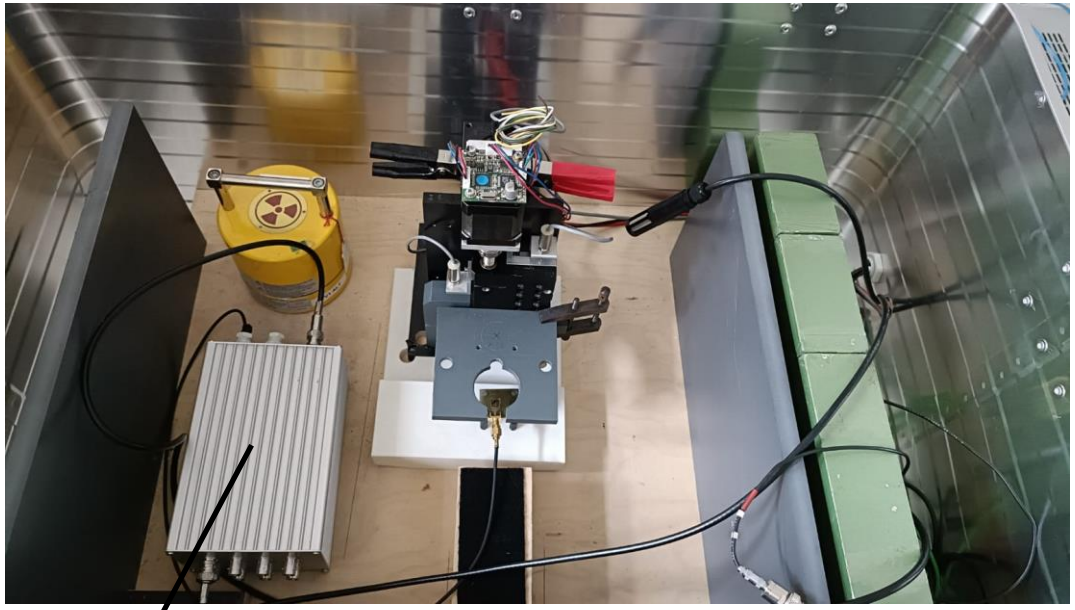
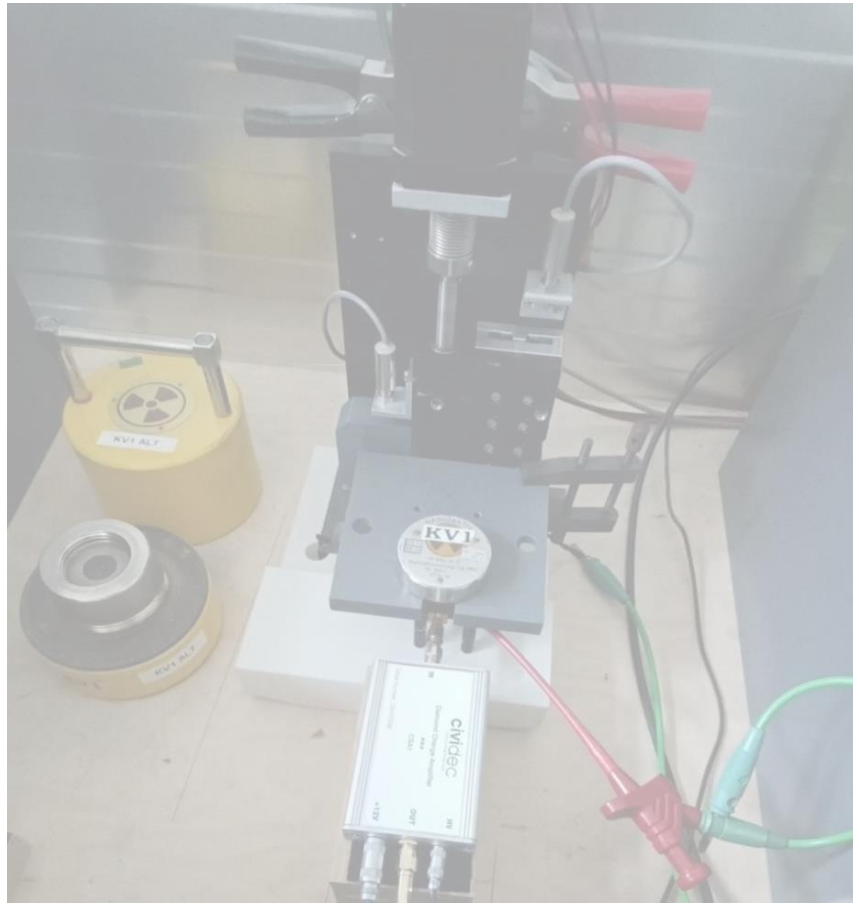
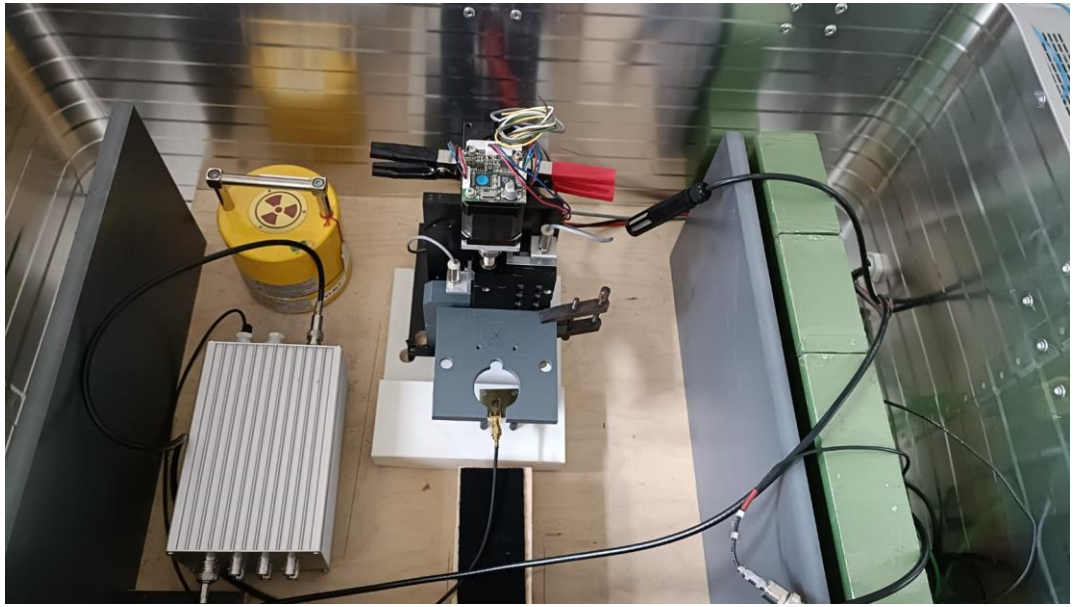


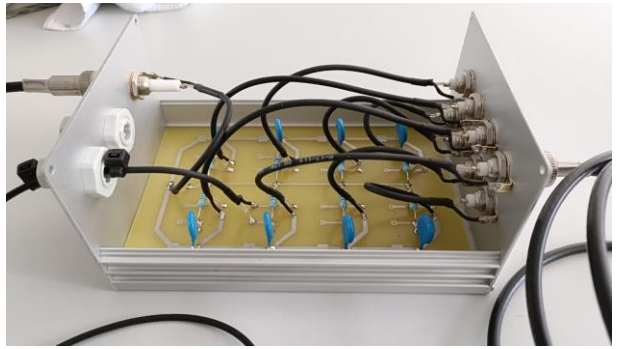


BCM circuit box

Experimental Setup







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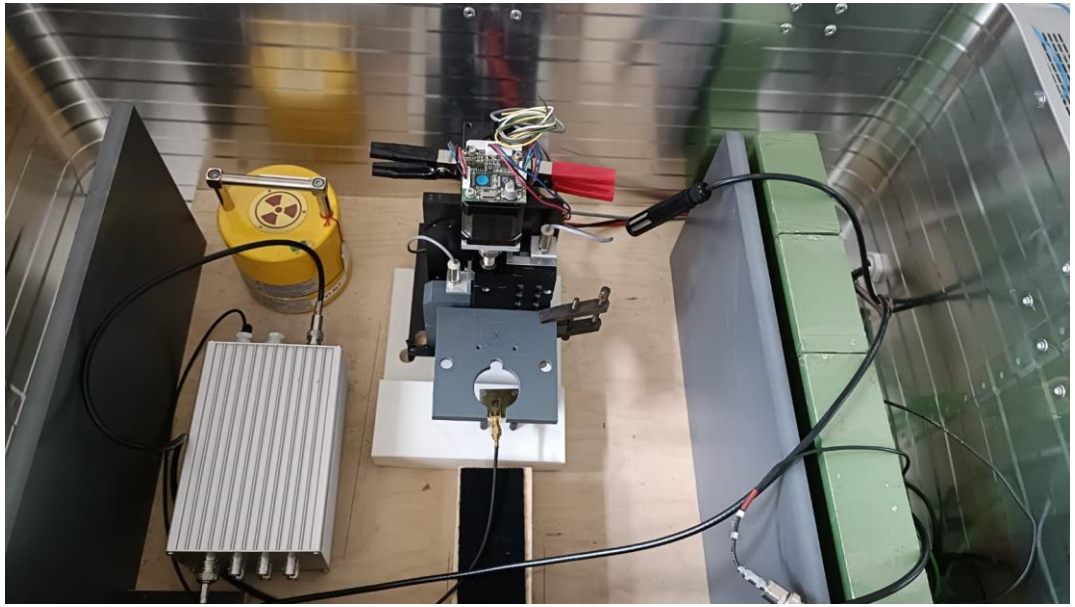
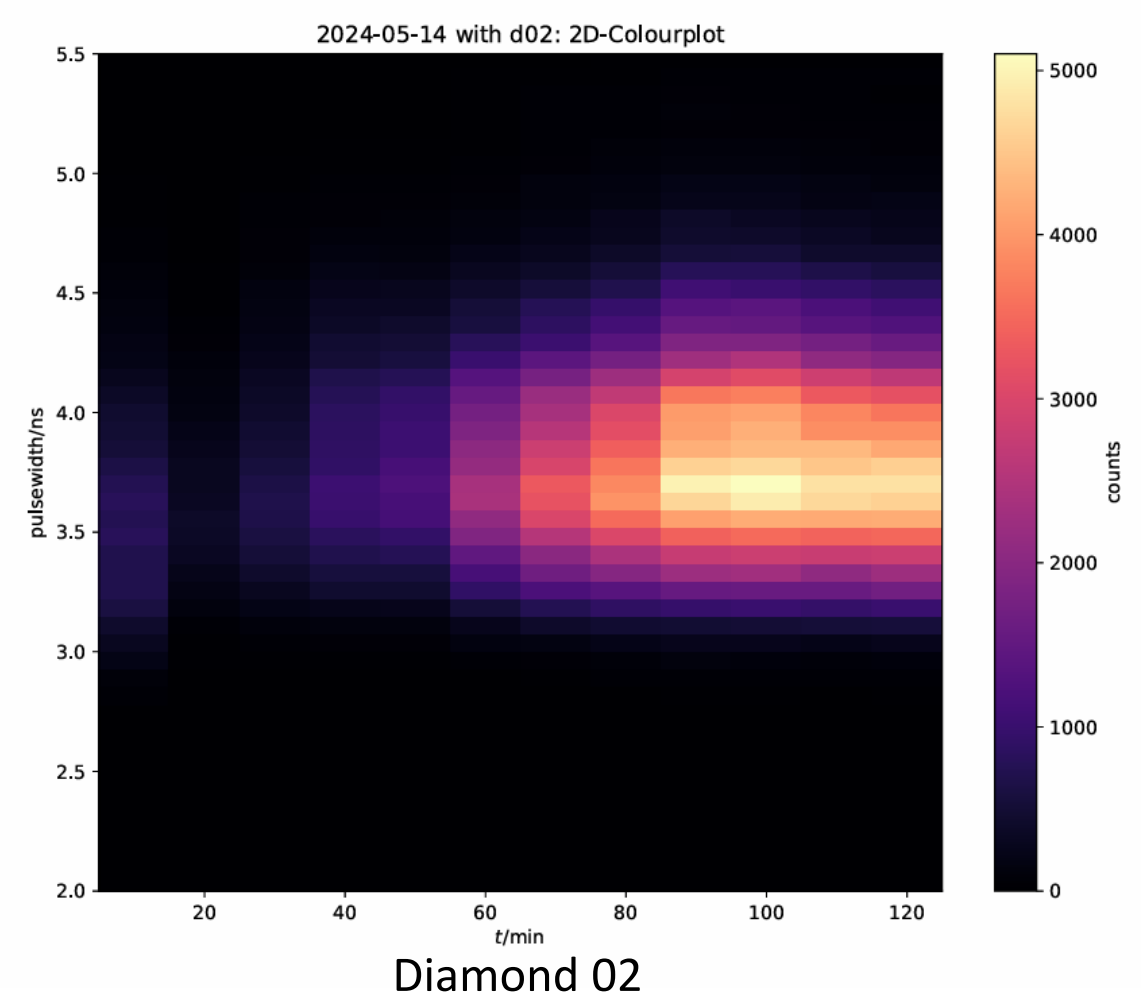


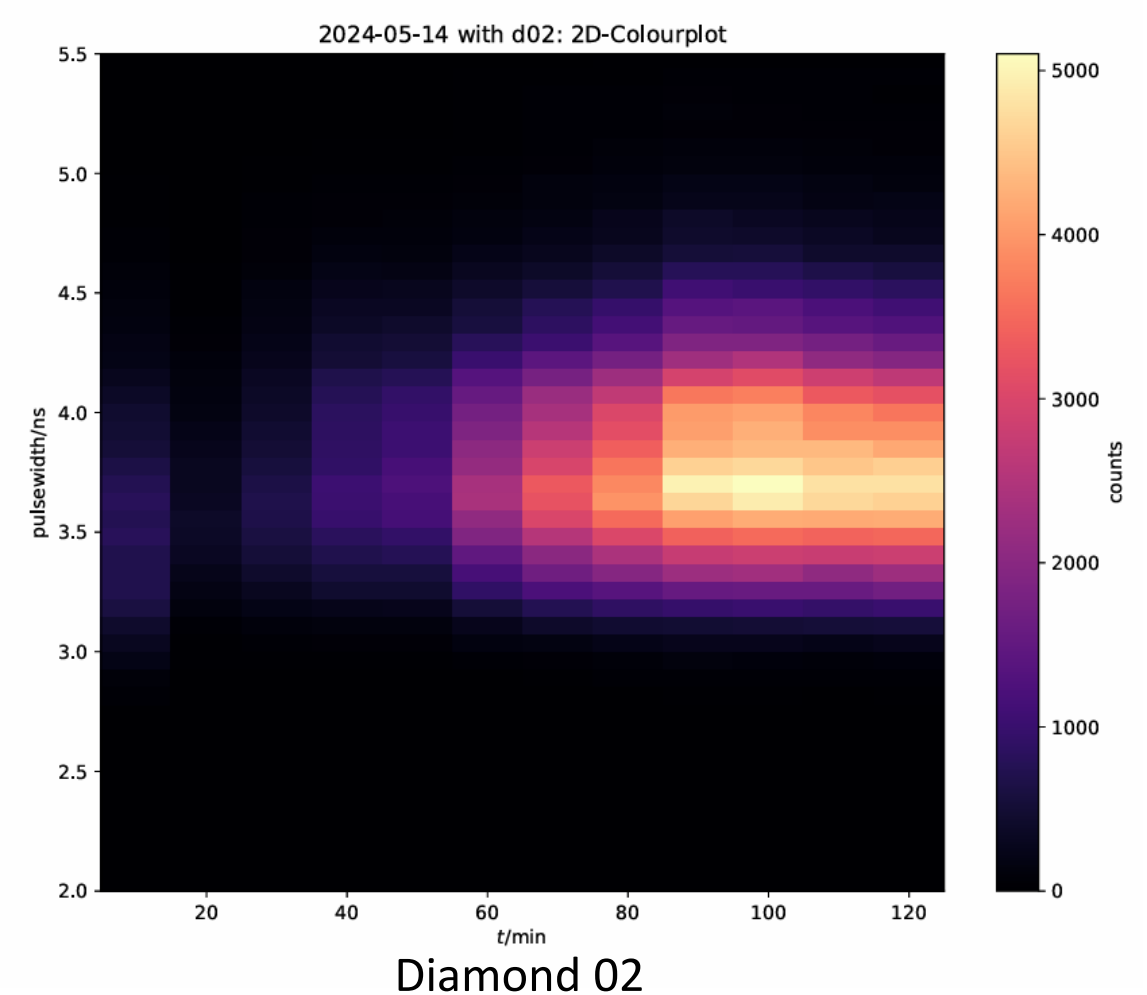
Testing the Diamonds Functionality



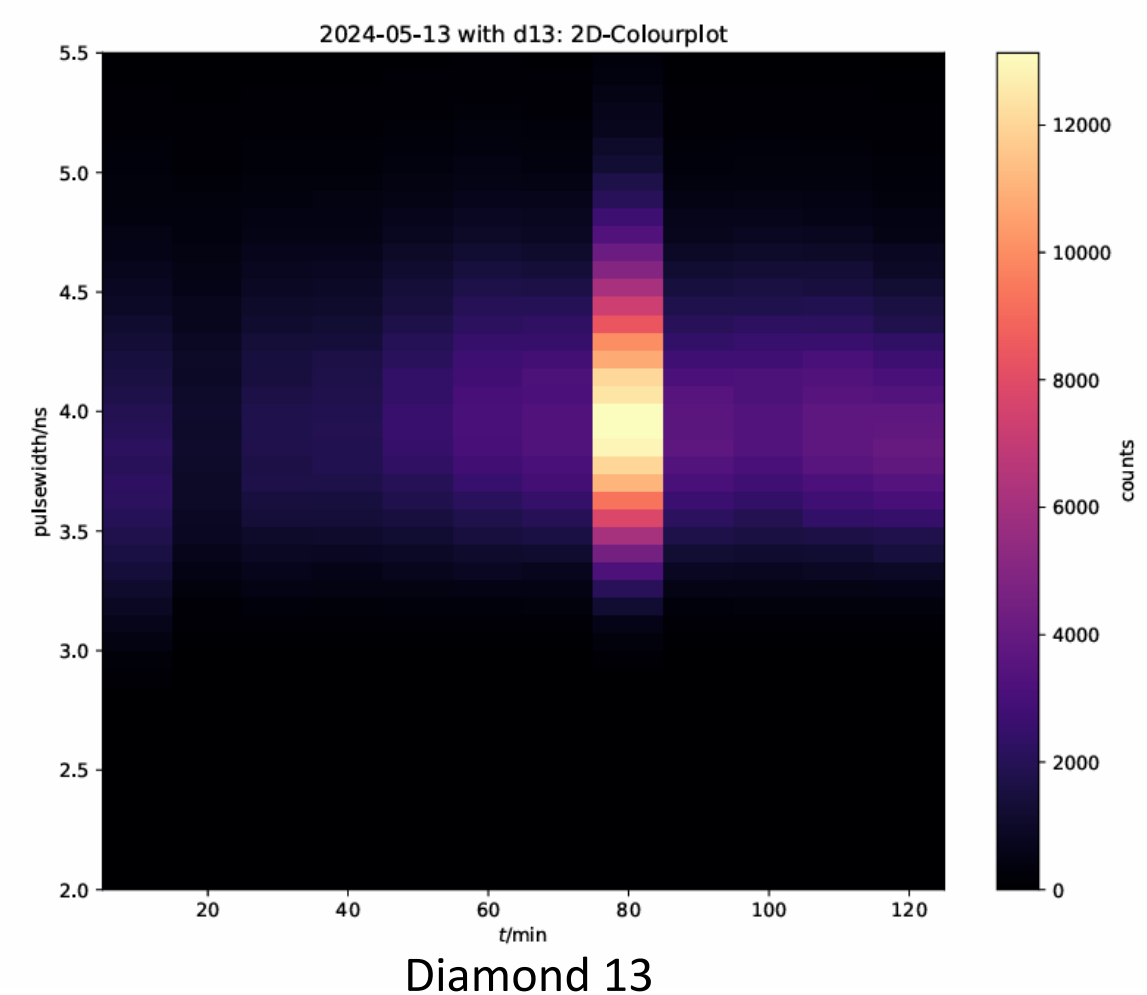
Diamond 02

- amount of counts per pulse width and time are measured and visualized
- expected: rising amount of measured counts with the time, or almost constant signal strength

Testing the Diamonds Functionality



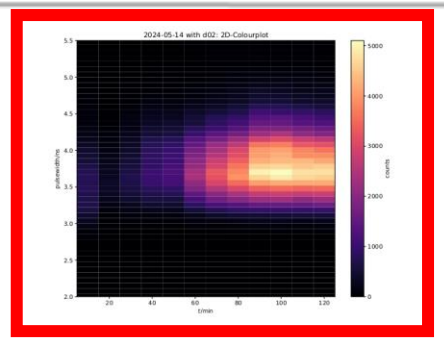
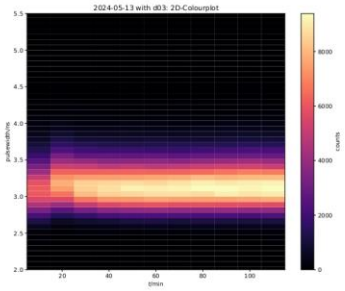
Diamond 02



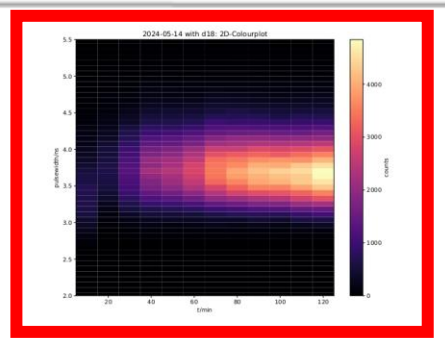
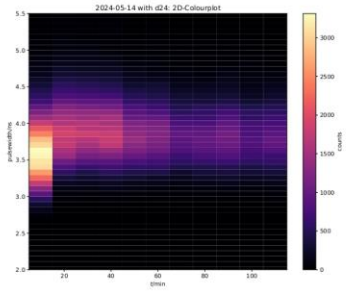
Diamond 13

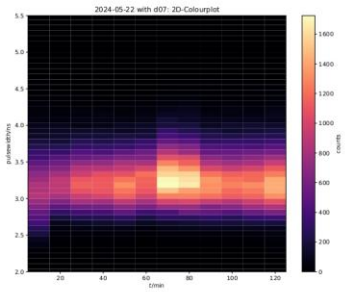
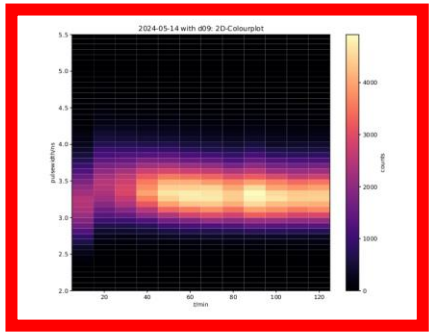
Testing the Diamonds Functionality

d02

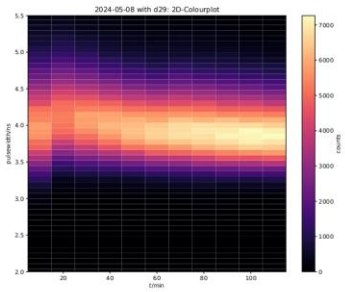
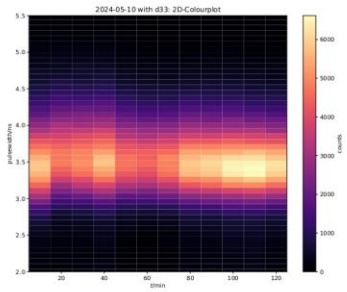



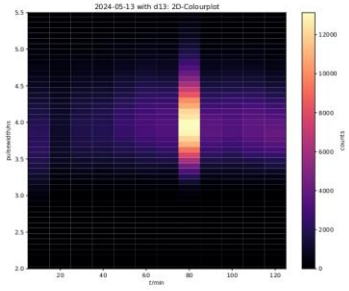
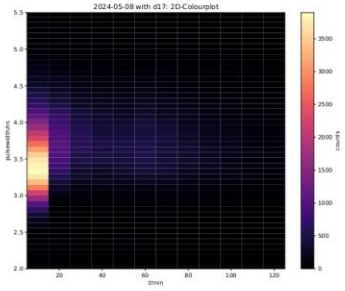
d18

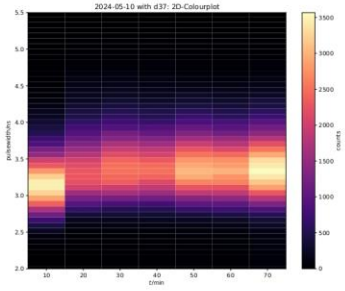
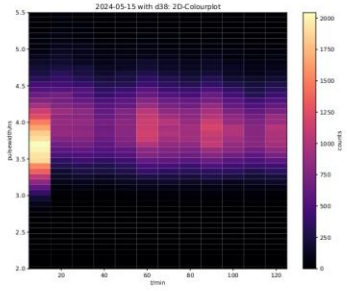



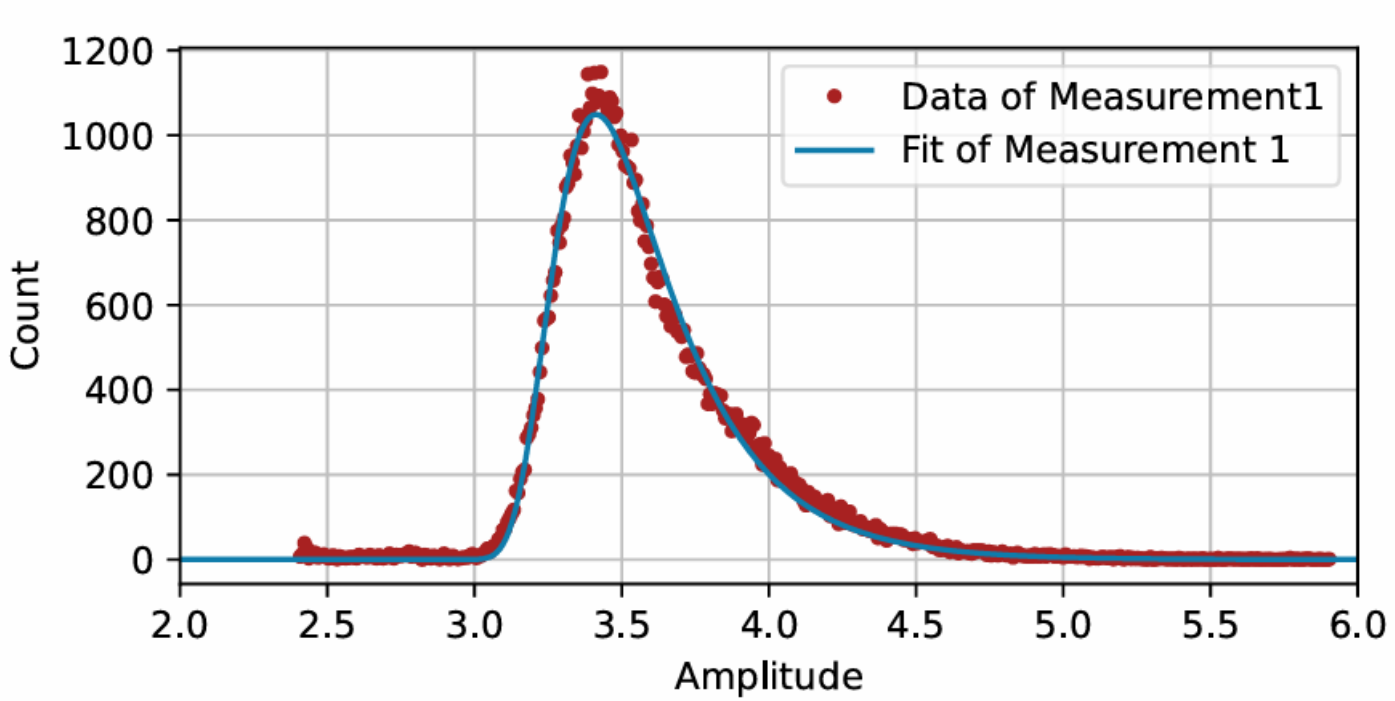
d09

Testing the Diamonds Functionality – Moyal Fit

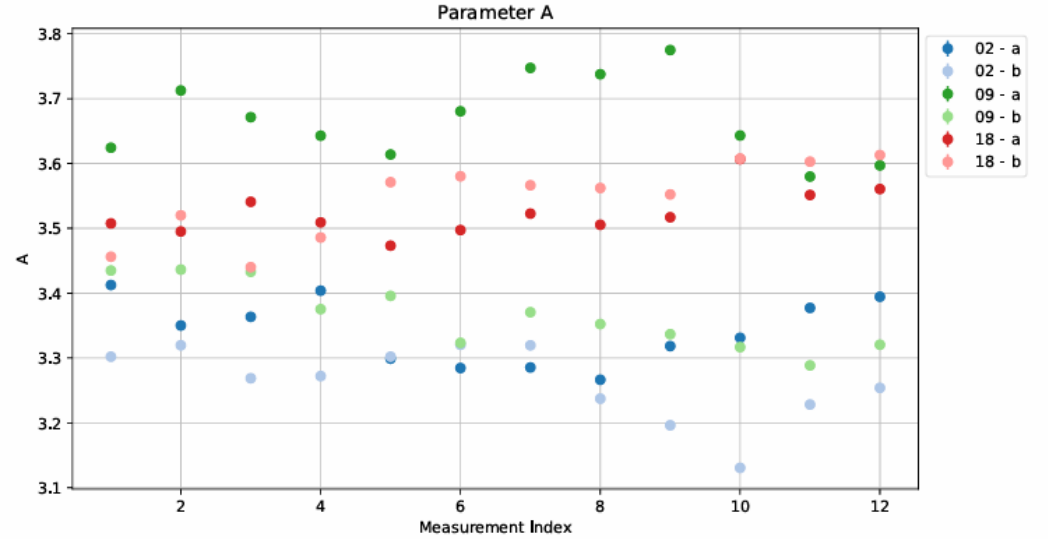


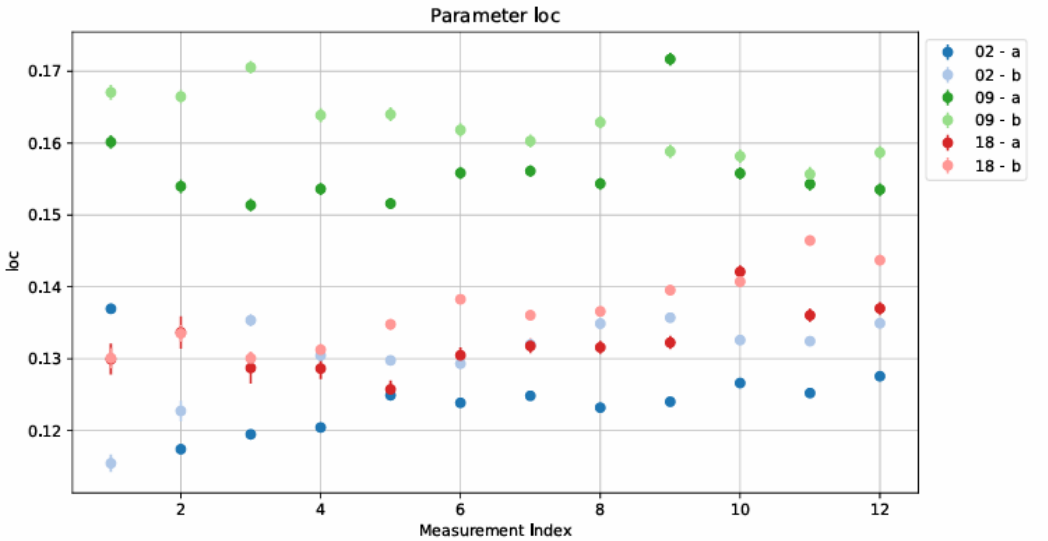
- Moyal distribution describes energy loss less complex than a Landau distribution
- fit function:

$$f(x) = \frac{\mathrm{A}}{\mathrm{scale}} \frac{1}{\sqrt{2\pi}e^{-1/2\left(\frac{x-\mathrm{loc}}{\mathrm{scale}}+e^{\frac{x-\mathrm{loc}}{\mathrm{scale}}}\right)}}$$

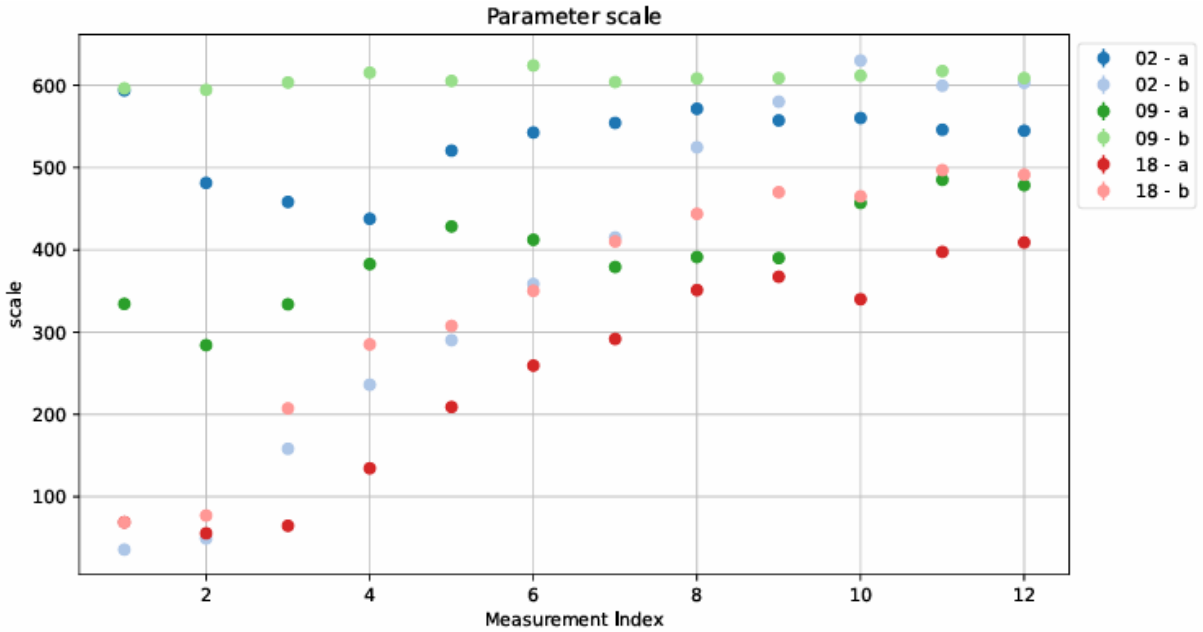
- 3 parameters

Testing the Diamonds Functionality – Moyal Fit

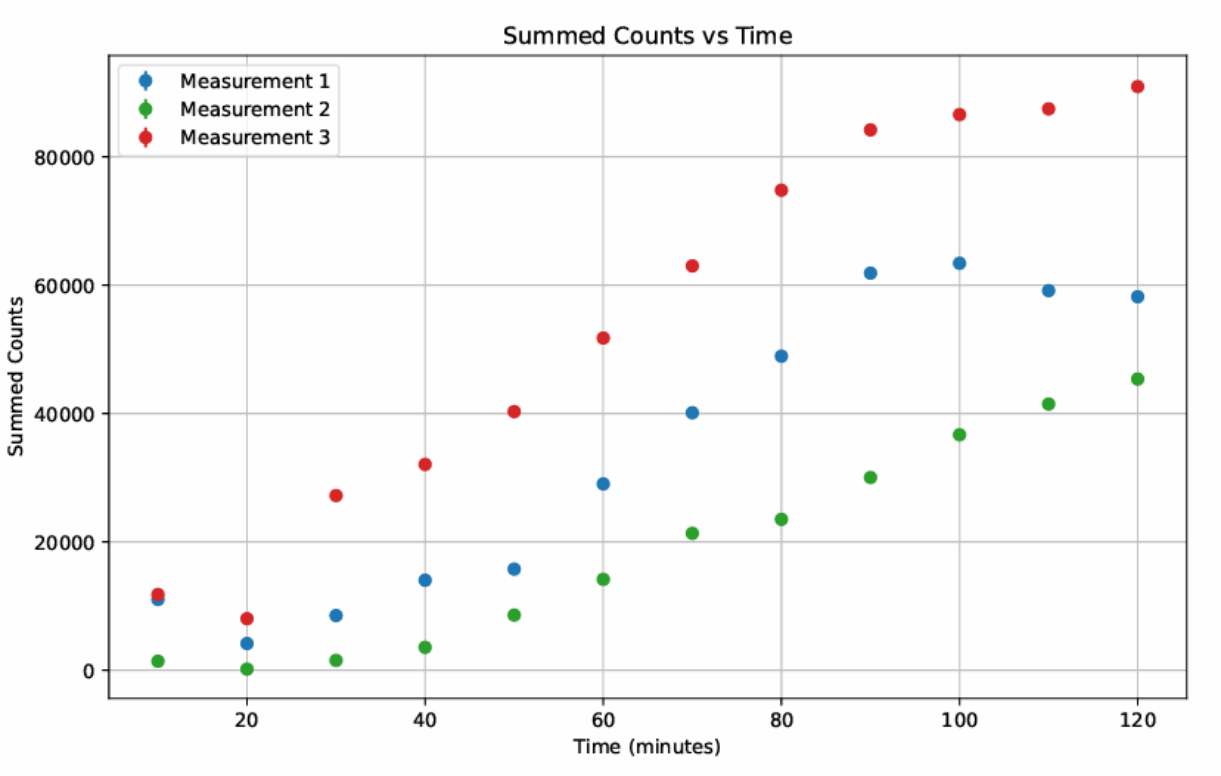




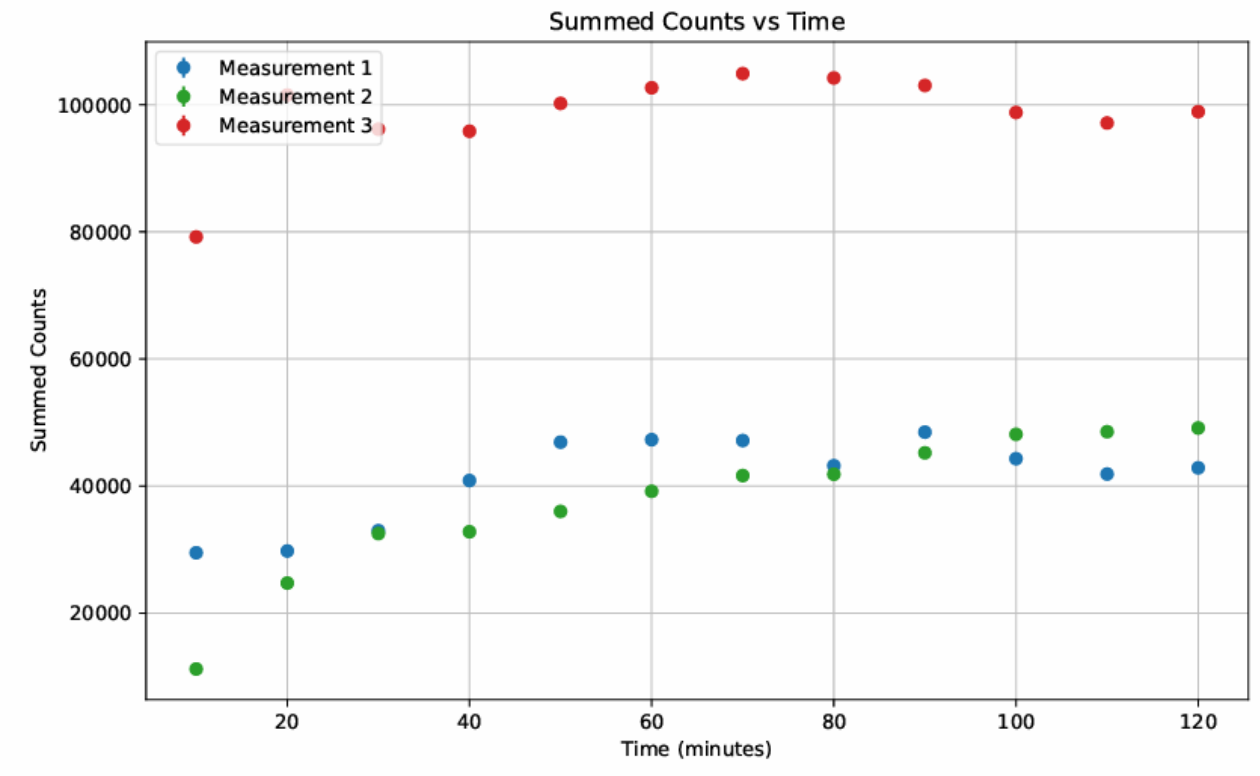
Parameters of Moyal Fit are a good indicator on reproducibility.



Testing the Diamonds Functionality – Pumping Effect



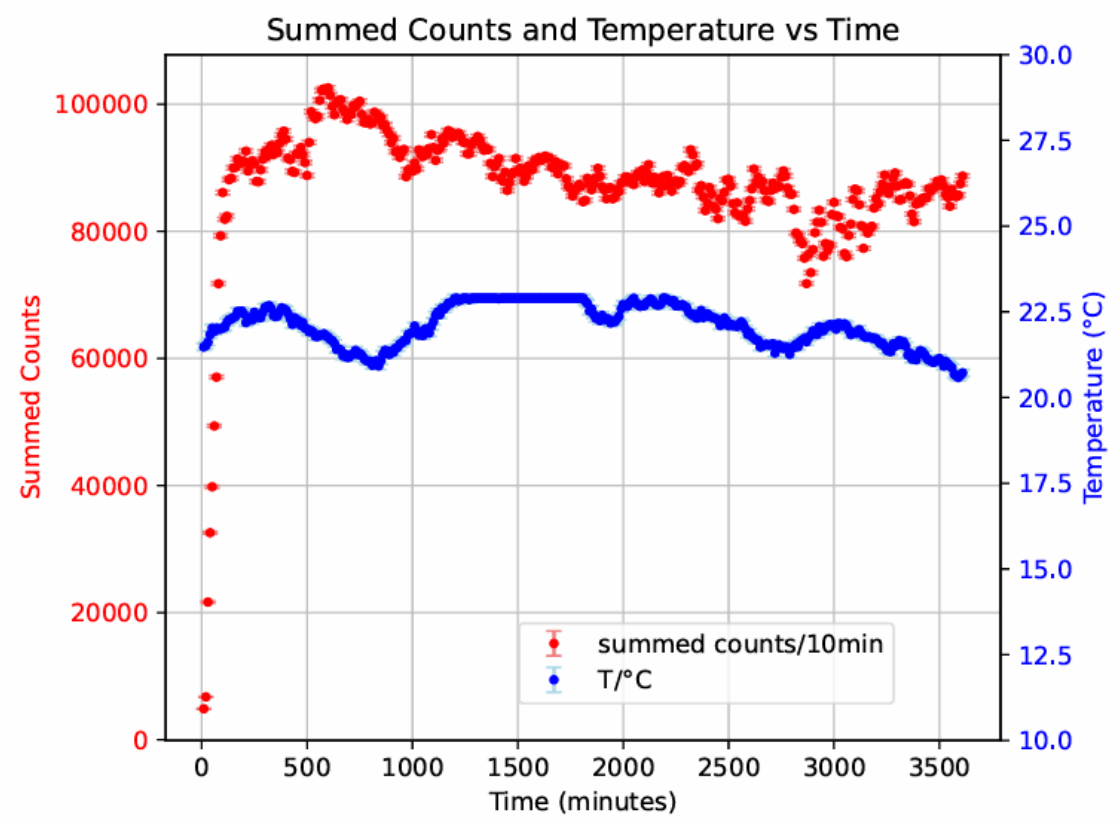
Diamond 02



Diamond 09

Long Term Measurements

- temperatur sensor is build in the setup
- counts with oscilloscope and temperature are simultaneously measured
- approach to quantify environmental influences on the measurements
- no correlation visible



Flux Measurements

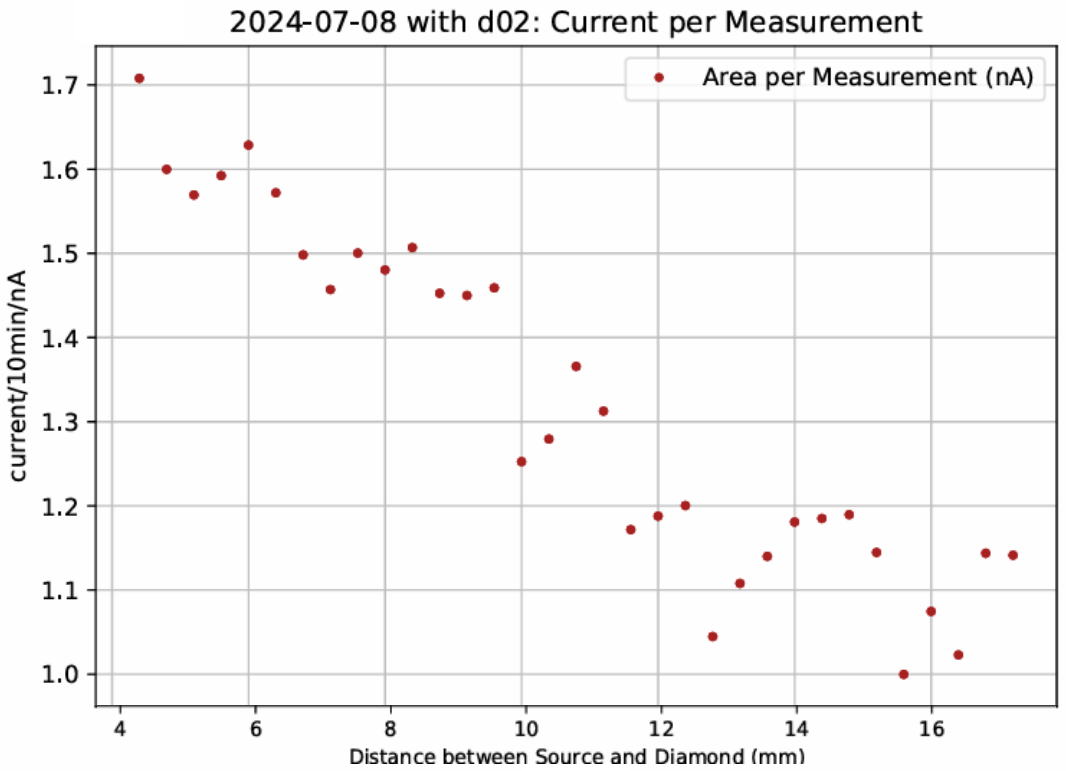
- Why measuring the flux?
  - Two measureing methods → direct comparison possible
- flux can be calculated from the oscilloscope measurements

$$\text{current (nA)} = \frac{\text{charge (C)}}{\text{time (s)}} \times 10^9$$

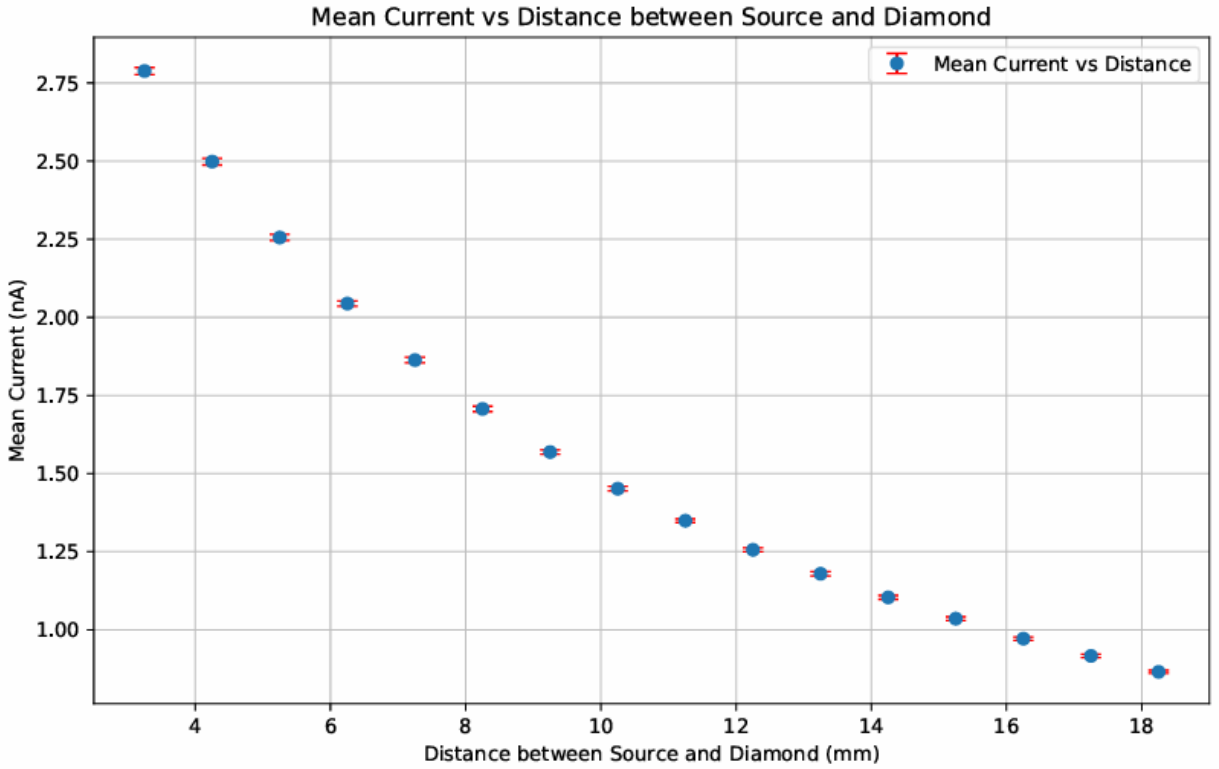
- flux can be measured directly with an Ampèremeter

Flux Measurements

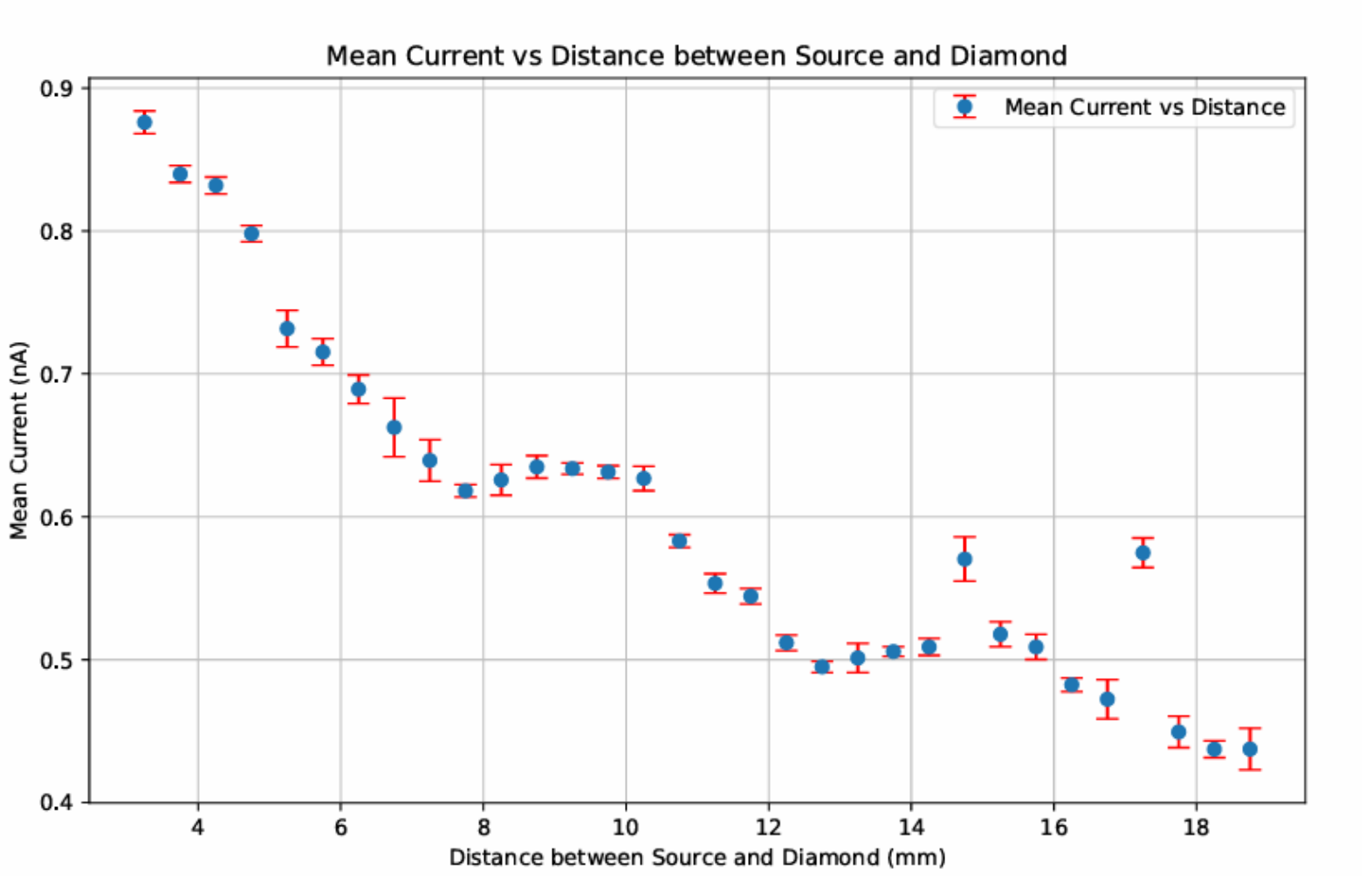
Oscilloscope Measurement



Direct Measurement



Flux Measurements



Possible Problems

- other environmental influences, for example outer lights
- experimental difficulties involving the settings of the oscilloscope

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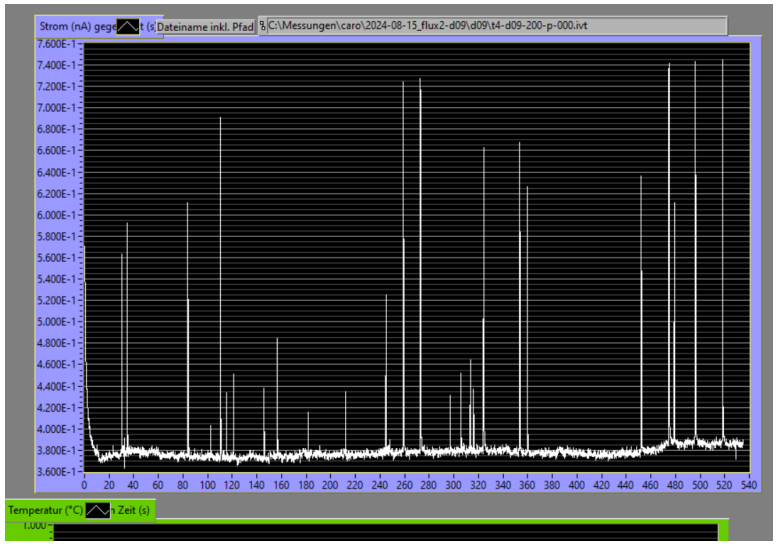
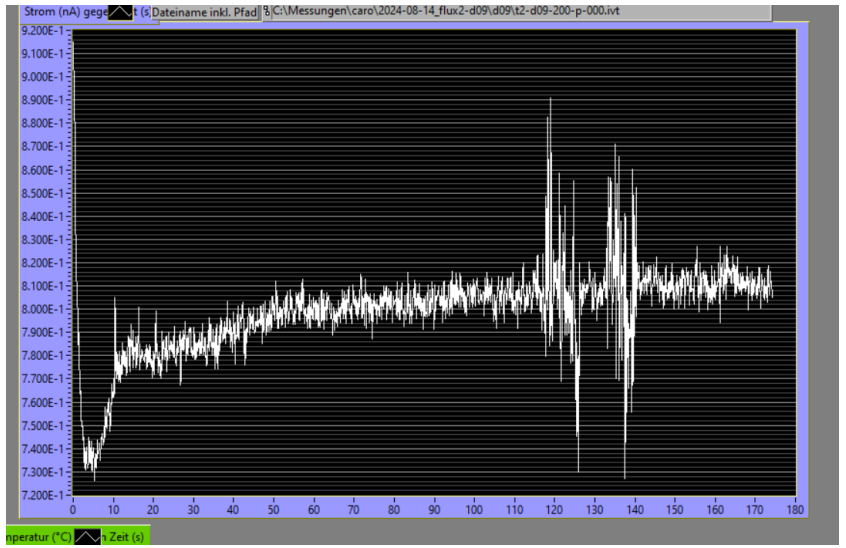
- other environmental influences, for example outer lights
- experimental difficulties involving the settings of the oscilloscope
- …and drilling





Conclusion

- diamonds are suitable for single signal measurements with the oscilloscope
- they show the already known behaviour including the pumping effect
- the measurement methods with the ampèremeter and the oscilloscope appear to be comparable
    - due to fewer clean measurement series, the necessary measurement reliability is lacking to make statements for the future of a fast diamond readout system
- for significant measurements to develop a Fast Diamond Readout System, a quieter measurement environment simulating the LHCb conditions should be created

Reference

[1] CERN. LHCb Kollaboration. 2024. url: https://home.cern/science/experiments/lhcb (20.09.2024)

[2] H. Kolanoski und N. Wermes. Teilchendetektoren. 2nd. Springer Spektrum Berlin,Heidelberg, 2016. isbn: 978-3-662-45350-6. doi: https://doi.org/10.1007/978-3-662-45350-6.

[3] F. Bachmaier. CVD Diamond Sensors In Detectors For High Energy Physics. Doktorarbeit. 2016.

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[5] Ilgner (Senior Member, IEEE), The Beam Conditions Monitor of the LHCb Experiment Ch., TNS-00807-2009, e IEEE Transactions on Nuclear Science