CCC: Some highlights on 2024 progress

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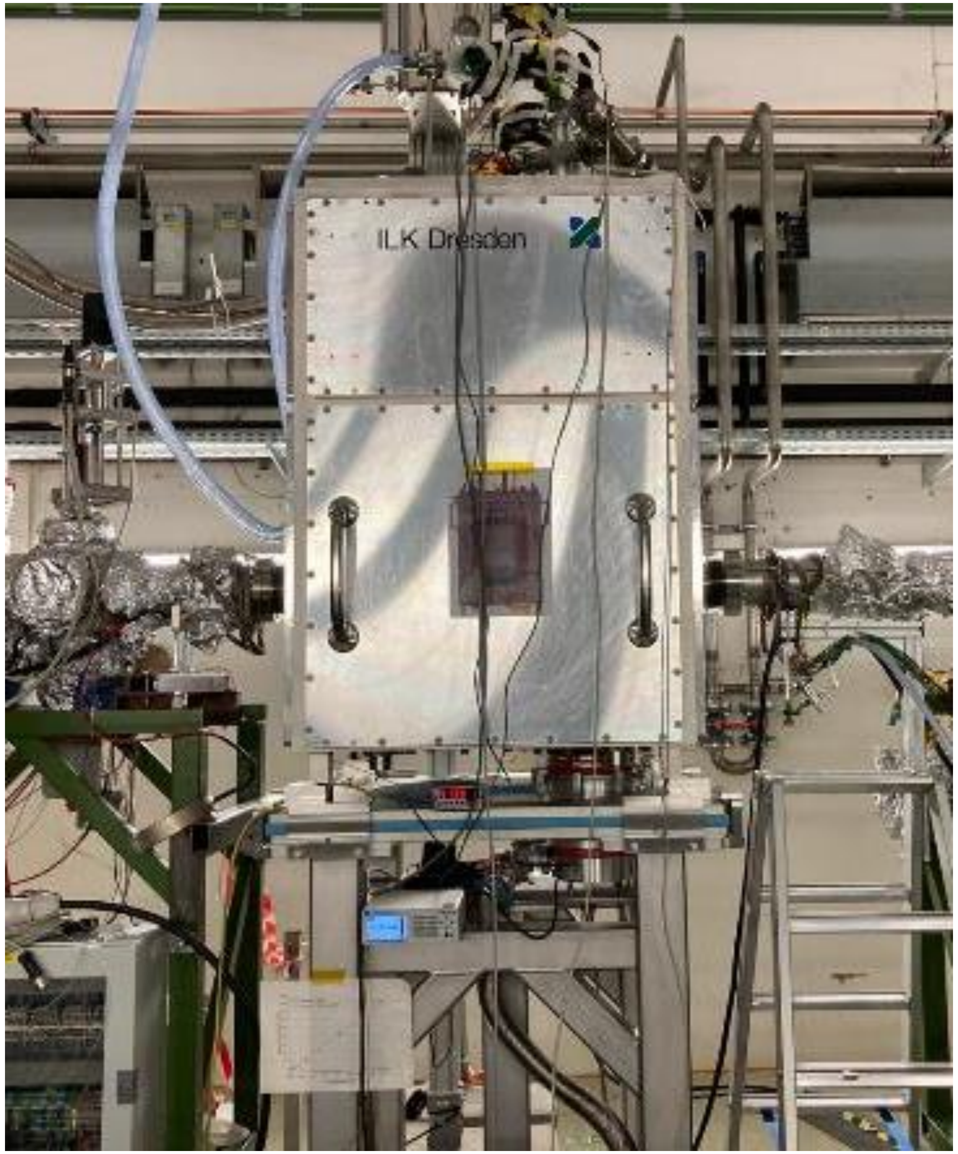
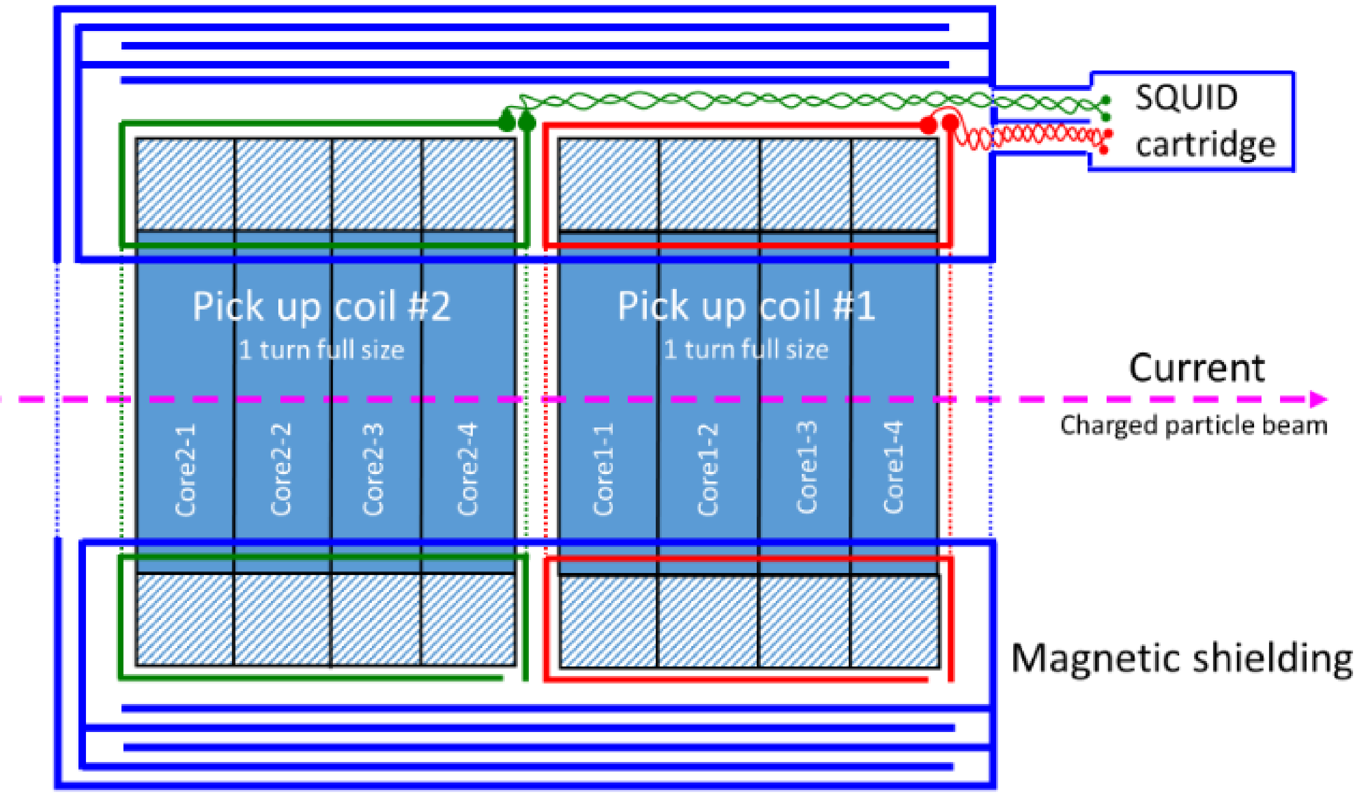
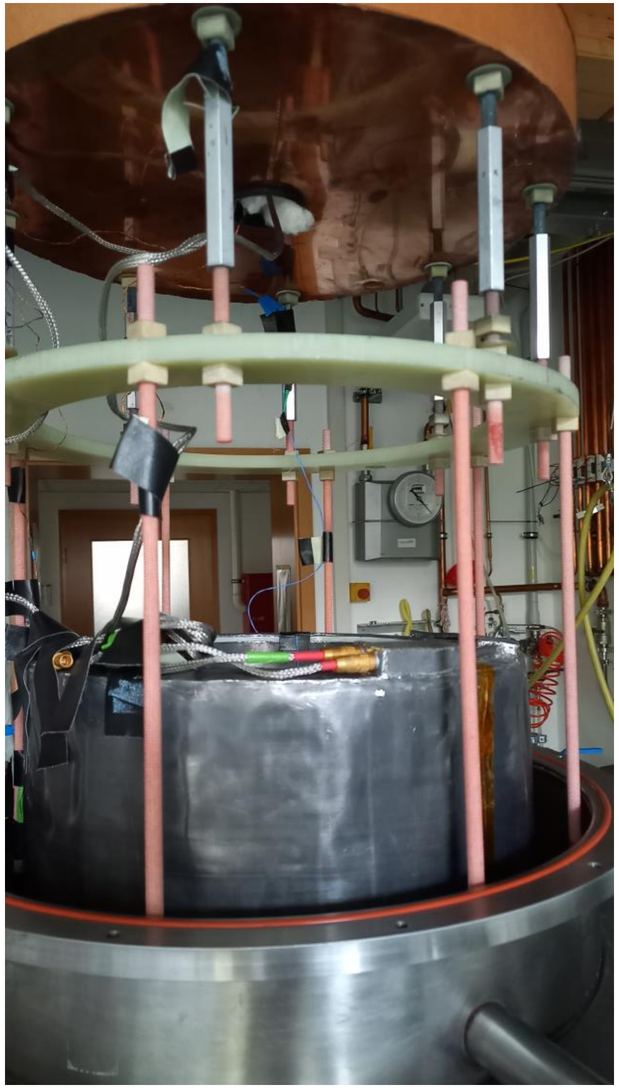


DCCC overview

- The Work in 2024 was mainly focused on the test of the DCCC to ensure a positive data acquisition on the transfer lines in may
- A short overview of the DCCC prototype that we tested it's useful:
- DCCC is an axial CCC with two high magnetic permeability cores working in parallel. Both cores are equipped with a squid and one of the two cores is equipped with a more less sensitive squid able to measure higher current value



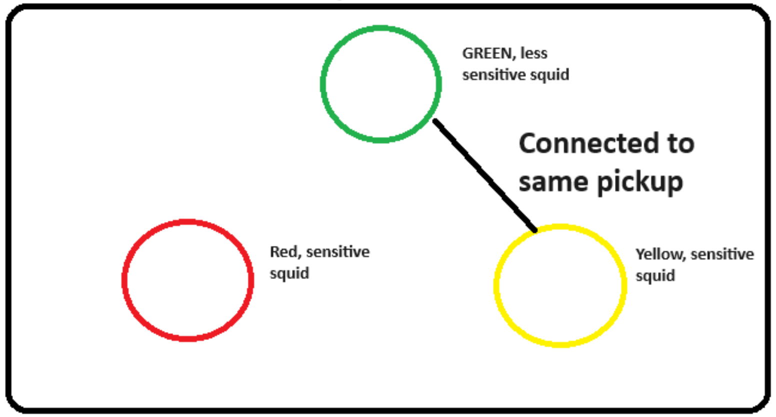
Jena cryostat



DCCC in Jena:characteristics

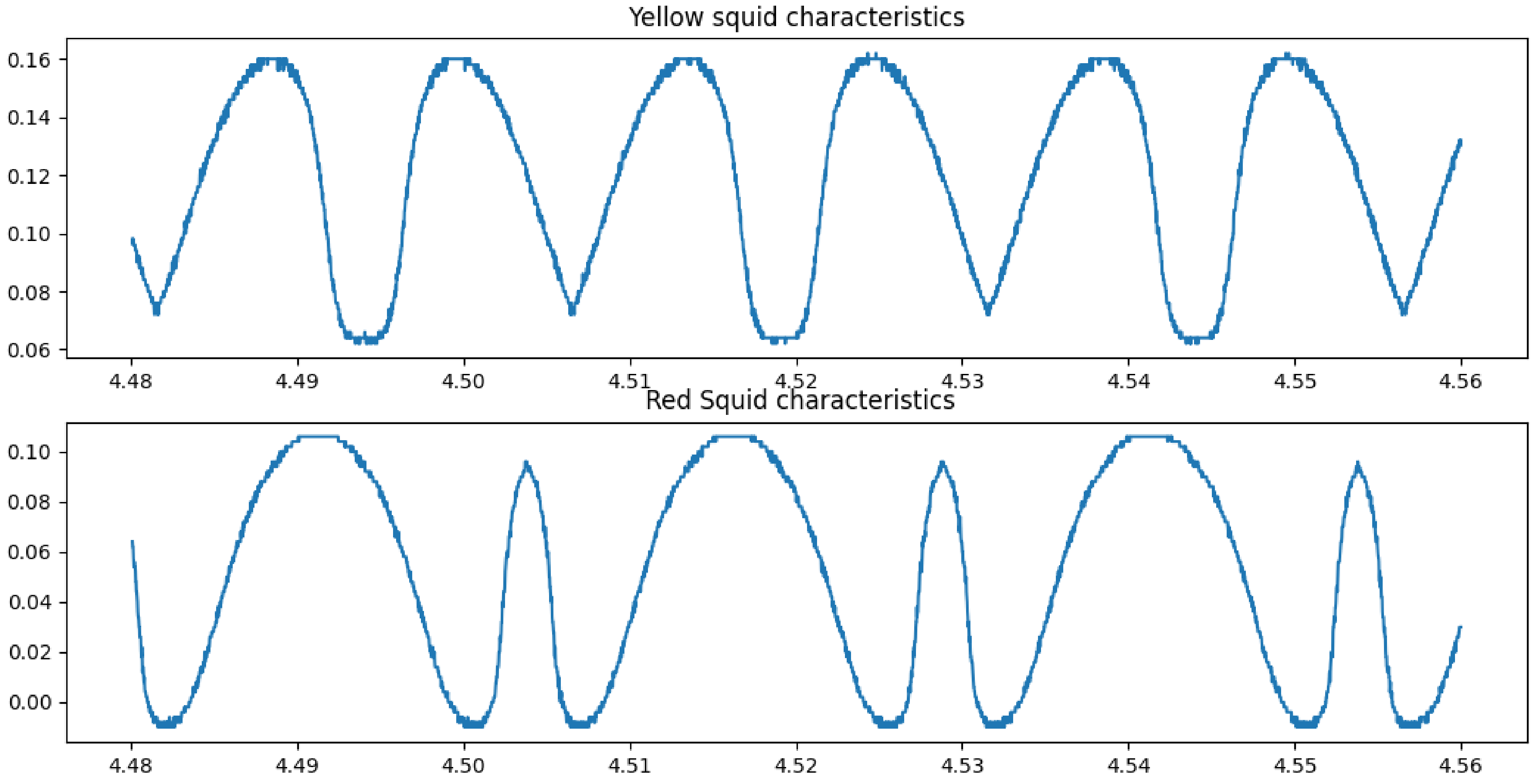
- Briefly going through the first results of the test in Jena
- We have two squid used for data analysis in jena and in GSI, the red and the yellow squid, each one connected to one core, and both in a really similar way, almost equal.

Connector box of the squids, three connectors



- Characteristics of red and yellow squid in jena: very clean, not huge influence of noise
- Expected value of modulation should be around 100 mV for a 40 µA input signal:
- Red squid: 117 mV average
- Yelow Squid: 98 mV average

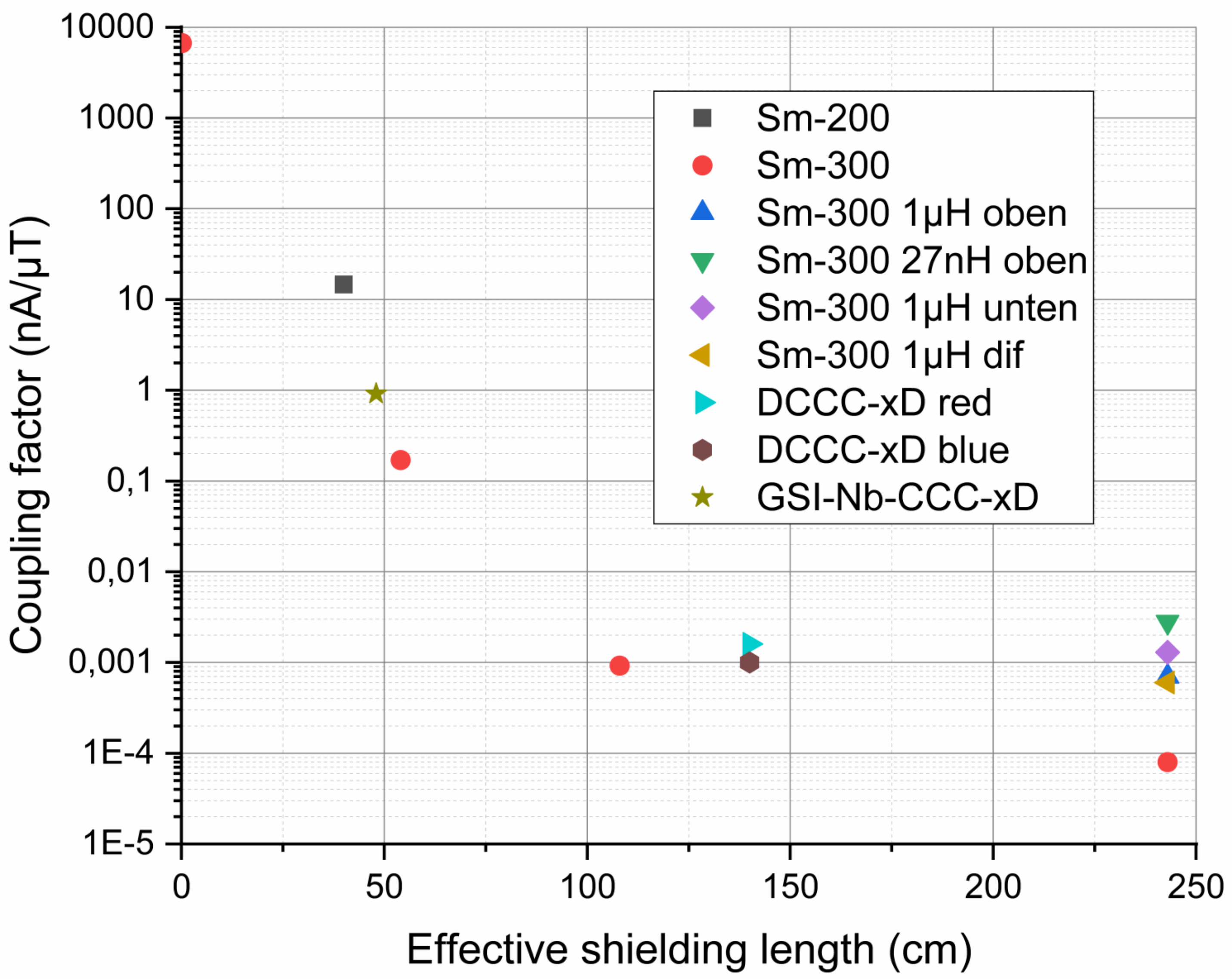
- Calibration Factor for FLL at 10 Kohm of RF:
- Yellow : 1.42 mV/nA
- Red: 1.46 mV/nA



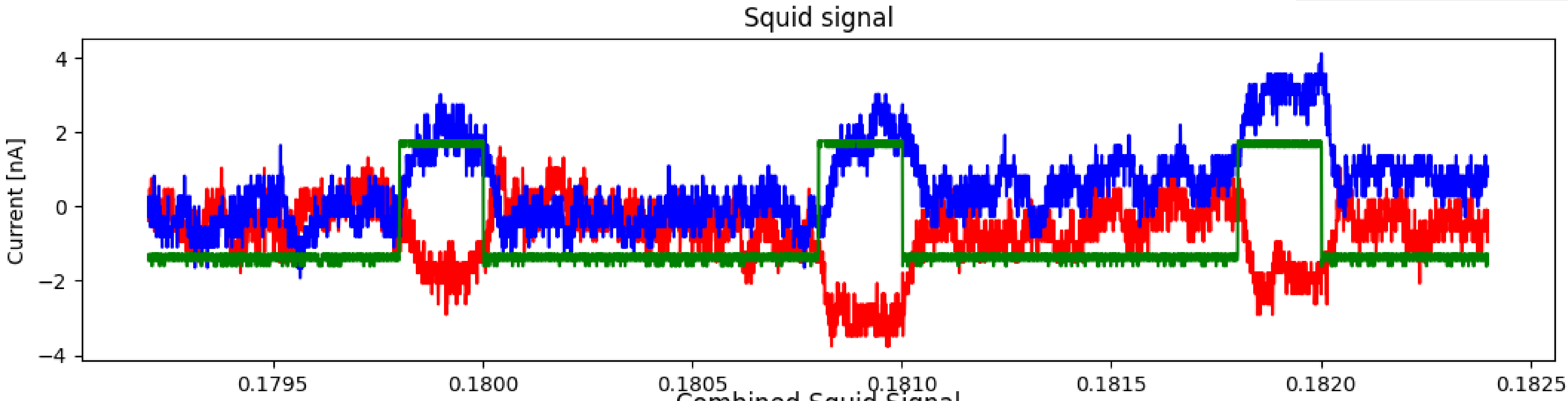
DCCC in Jena: magnetic screening

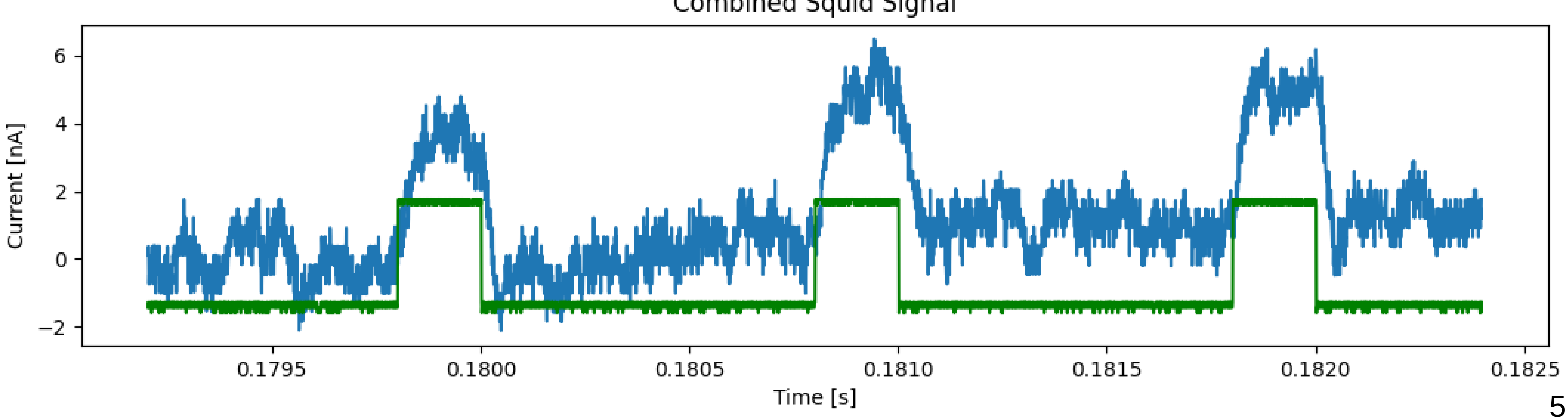
- Magnetic screening had been measured with the helmoltz coil embedded in the cryostat: as for the coreless version, the axial magnetic shielding provides a much higher magnetic screening. Even with the 1 mT field that can be produced in Jena the signal is not visible on the oscilloscope
- Using the spectrum analyzer it was possible to detect a small increase in the noise component at 5 Hz (the frequency of the sine use to generate the magnetic field), so we were able to measure a maximum effect on the noise:

- Yellow squid: 0.98nA per mT
- Red squid: 1.66 nA per mT

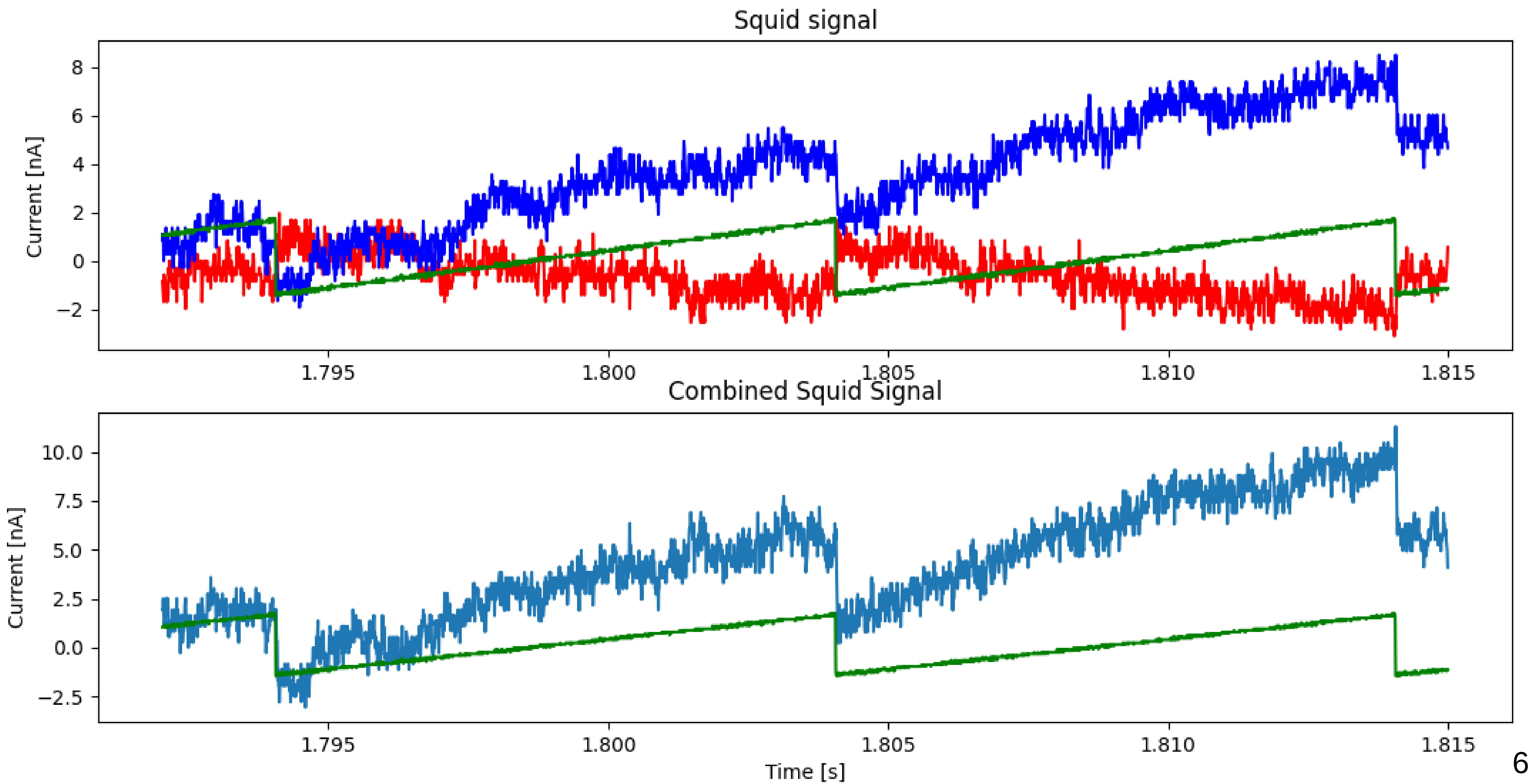


DCCC in Jena: Sensitivity



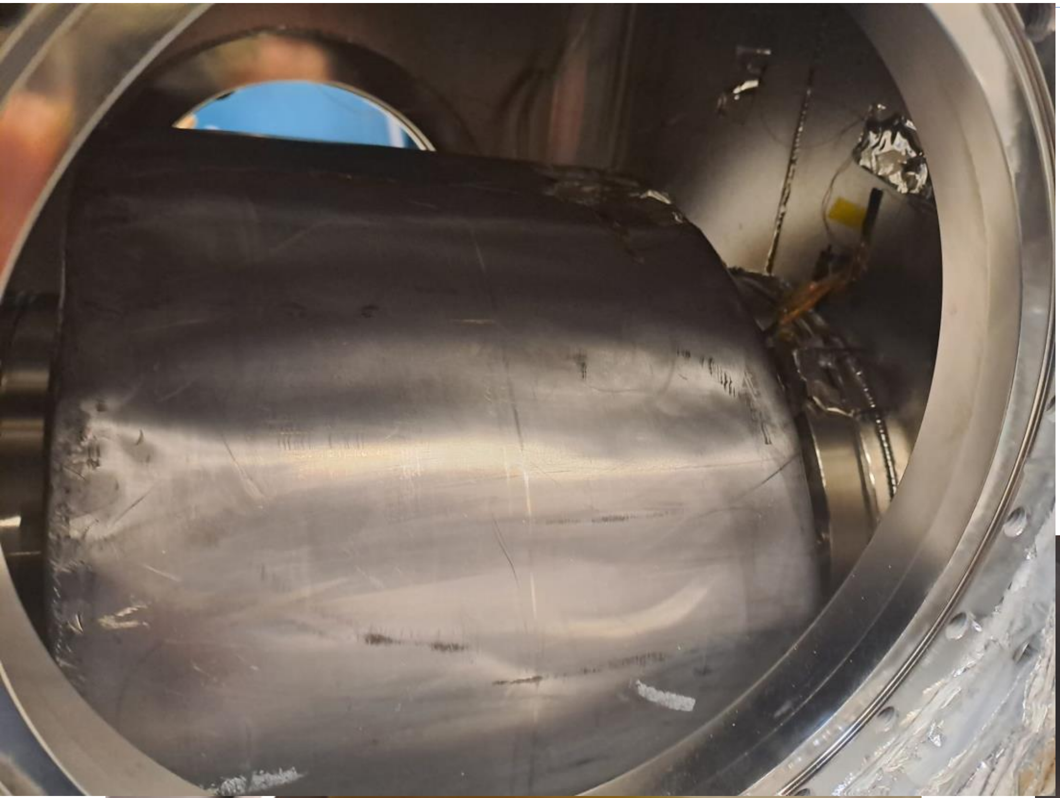


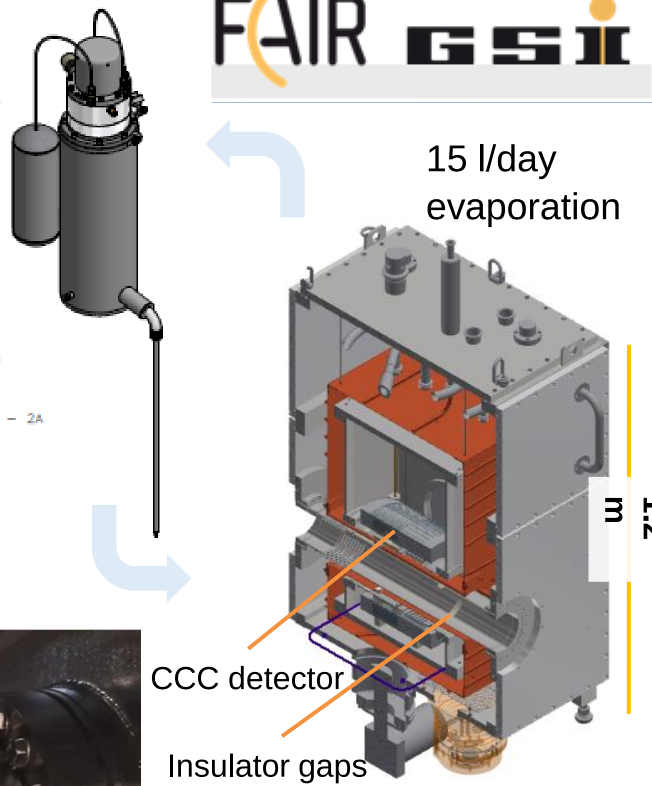
DCCC in Jena: Sensitivity

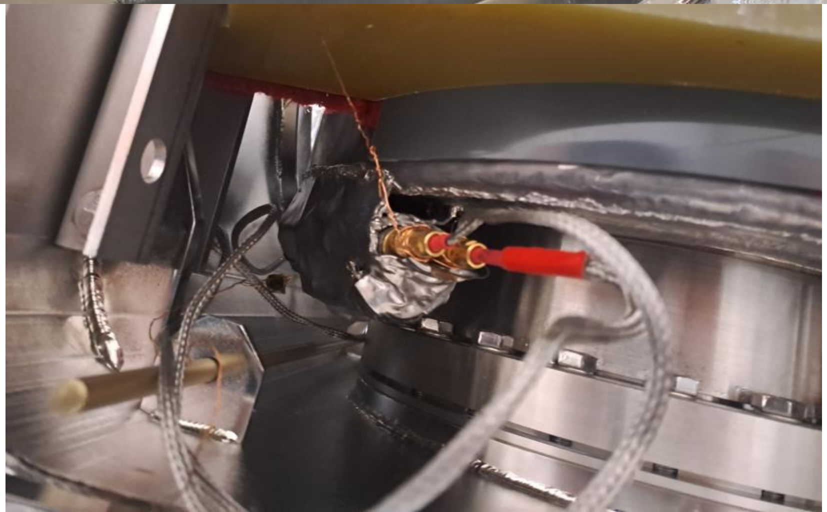


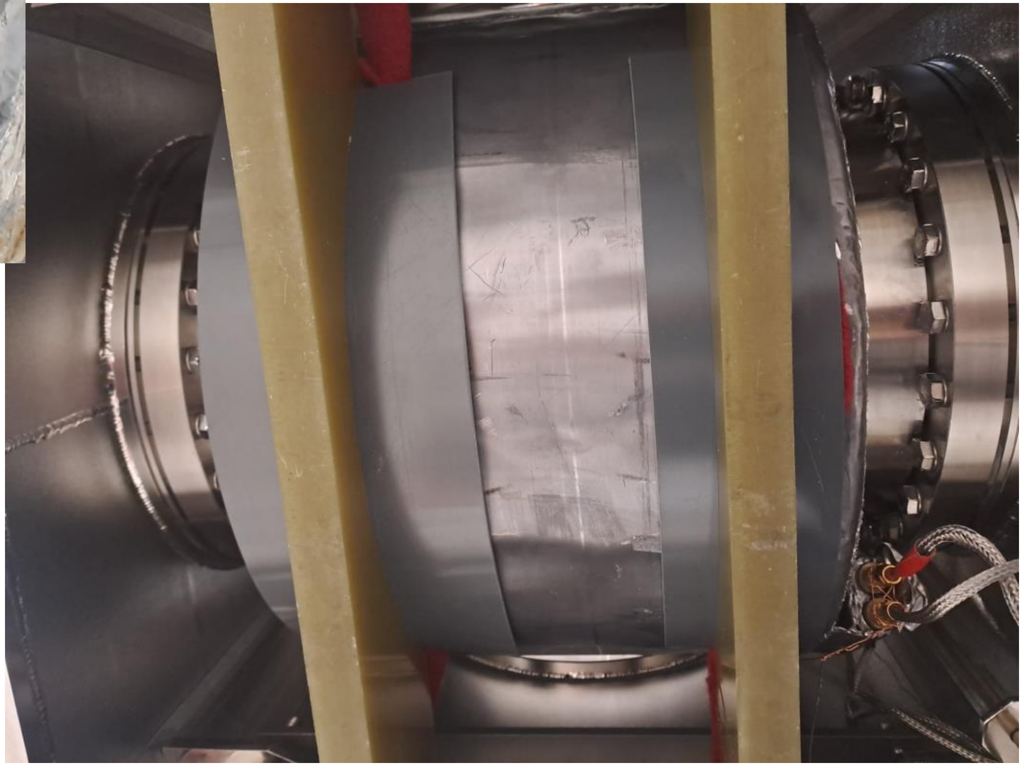
DCCC in GSI cryostat

- Gsi cryostat is by far different from the bottleneck cryostat in jena
- This picture has been collected during the installation of the DCC in the He vessel
- Only two squid used, red and yellow



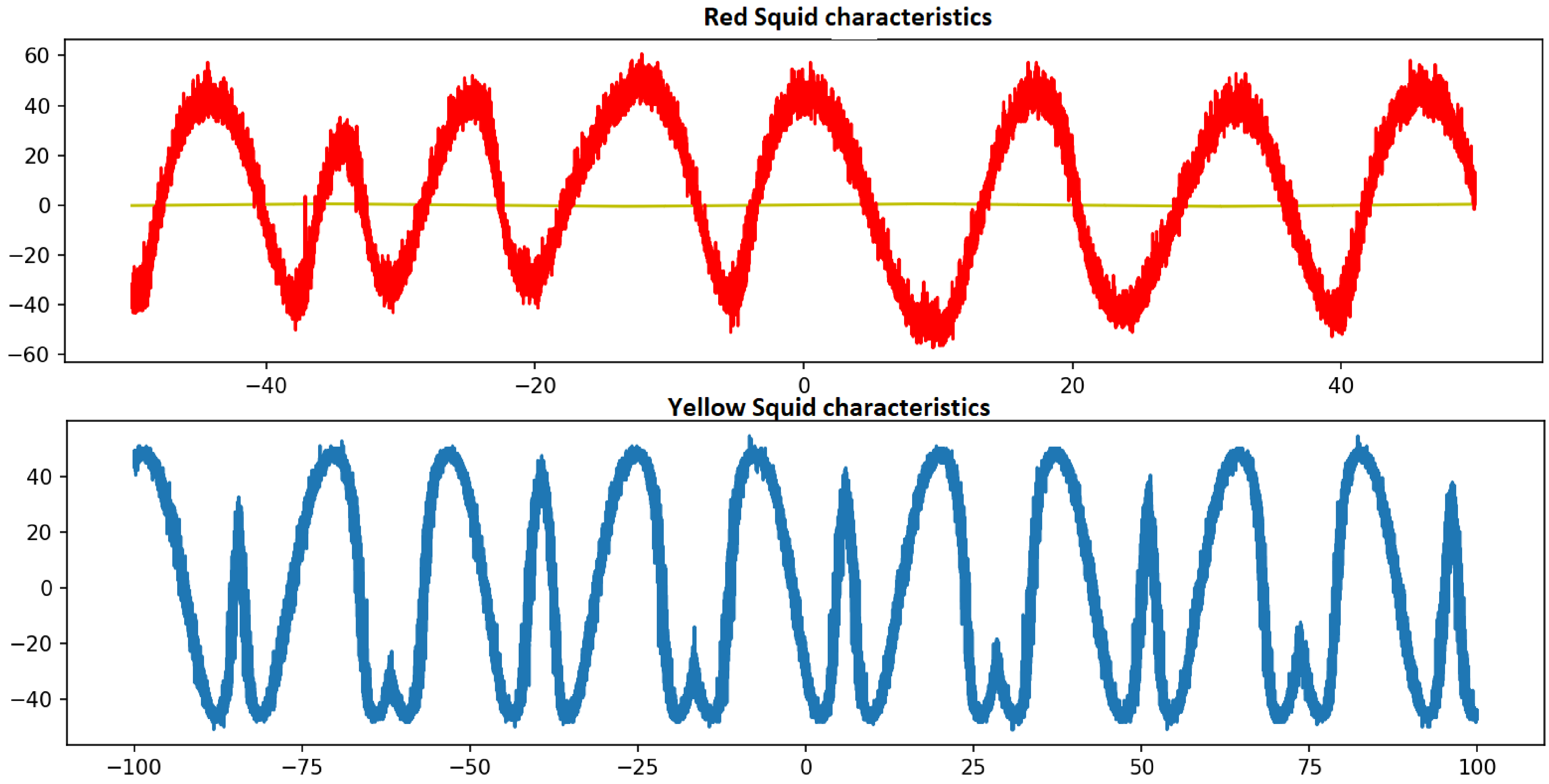






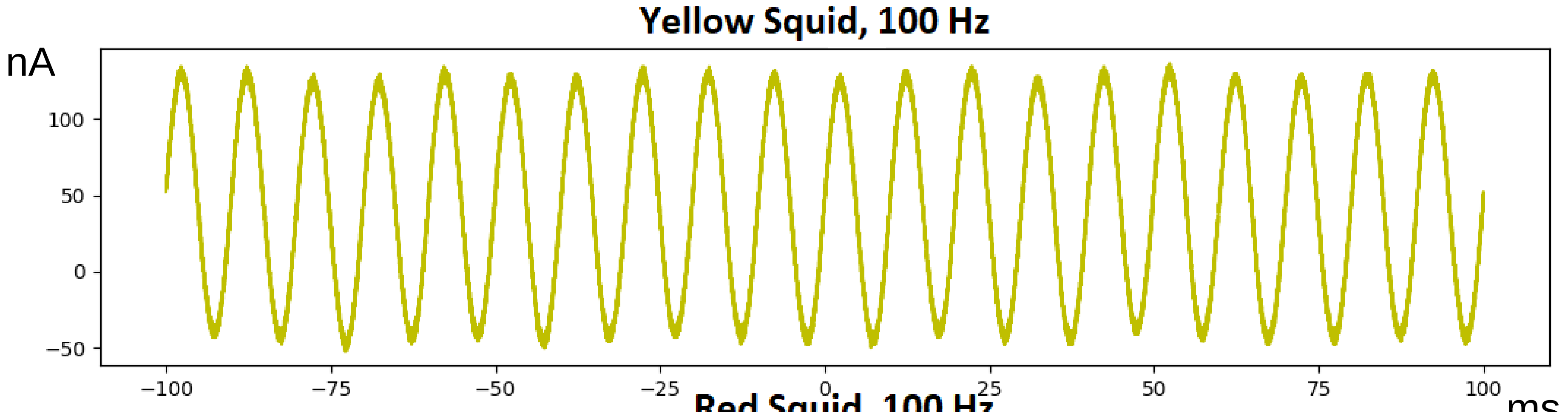
DCCC in GSI, Characteristics

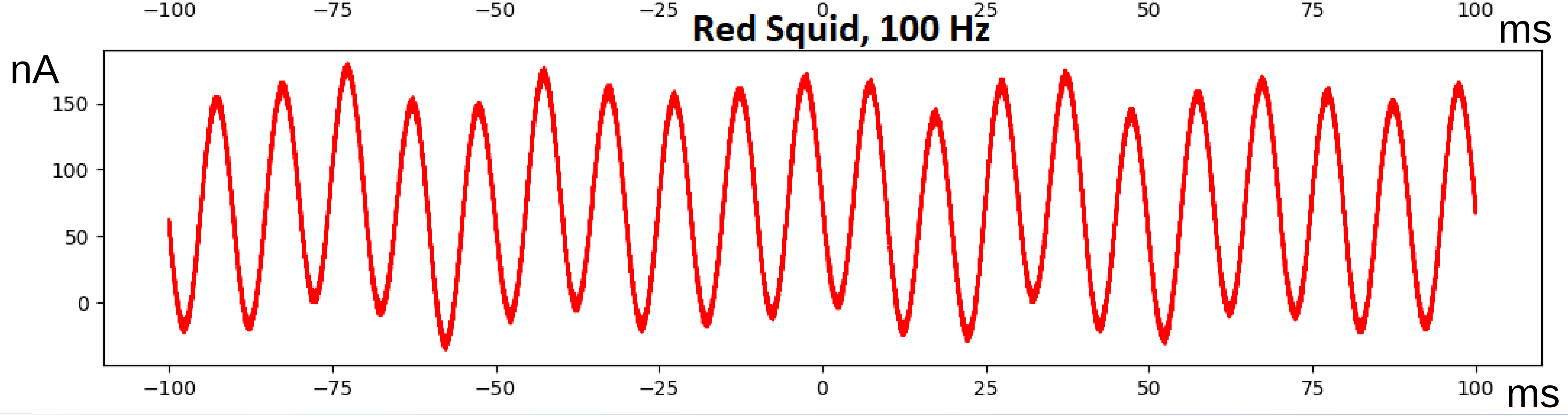
- DCCC has been installed and tested in the GSI cryostat in march, immediately after the tests in jena



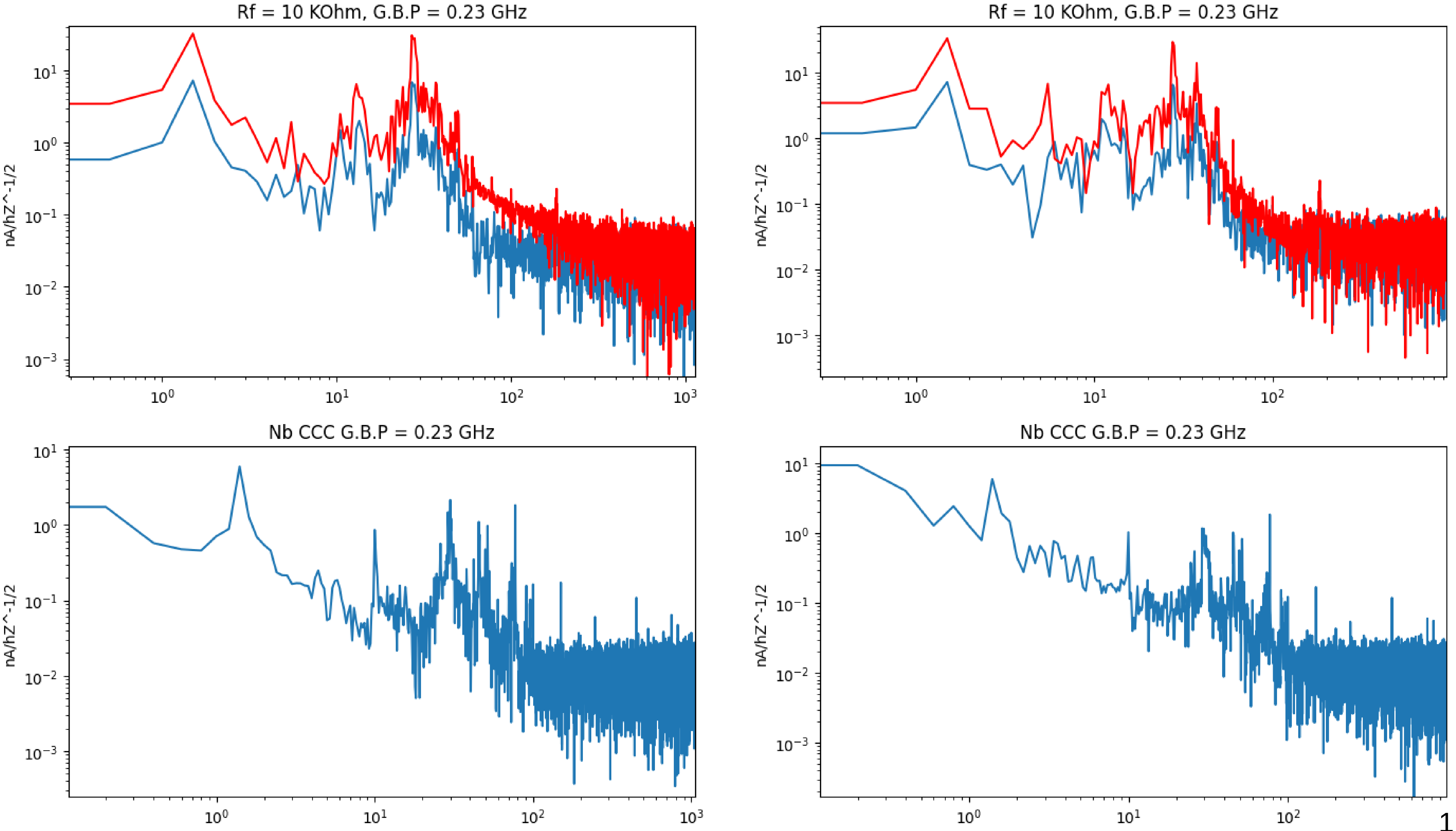
DCCC in GSI, Characteristics

- From the characteristics was already clear than the DCCC suffers more than the Nb-CCC-xD of low frequency perturbation
- Analysis of the data in FLL are able to gave more insight to it
- To note: differently from the radial Nb-CCC the values of the optimal working point has not changed due to the higher level of noise. The optimal value are the same found in Jena laboratory:
  - RED: Ib: 12.8 µA   YELLOW: Ib: 10.9 µA



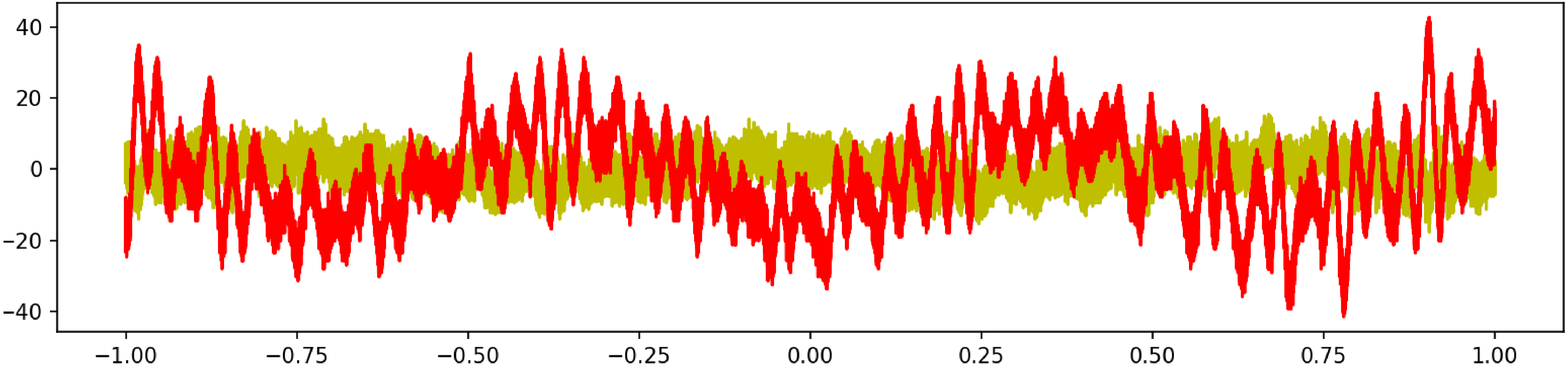


- The yellow squid is less sensitive to the low noise perturbation
- Main ones are the 30 Hz noise of the eigenmodes of the cryostat and the 10 Hz, an higher harmonic of the liquifier

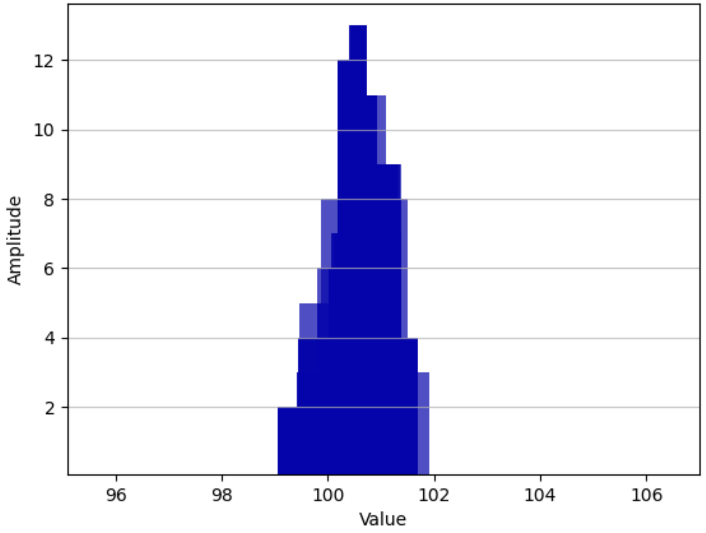

Rf = 10 KOhm, G.B.P = 0.23 GHz
Rf = 10 KOhm, G.B.P = 0.23 GHz
Nb CCC G.B.P = 0.23 GHz
Nb CCC G.B.P = 0.23 GHz
nA/hZ^-1/2
10^1
10^0
10^-1
10^-2
10^-3
10^0
10^1
10^2
10^3

DCCC in GSI, noise

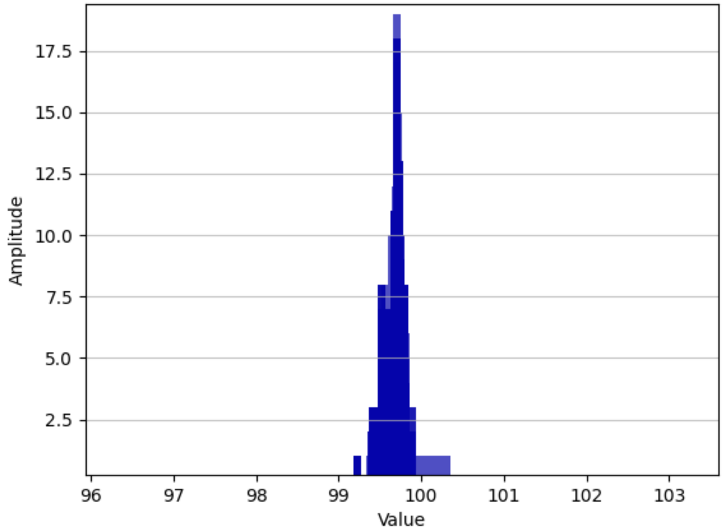
- In time domain it’s easy to see the intensity of the noise, around 10 nA for the yellow squid and higher for the red squid, to be compared with the white noise of the niobium squid, also around 10 nA.



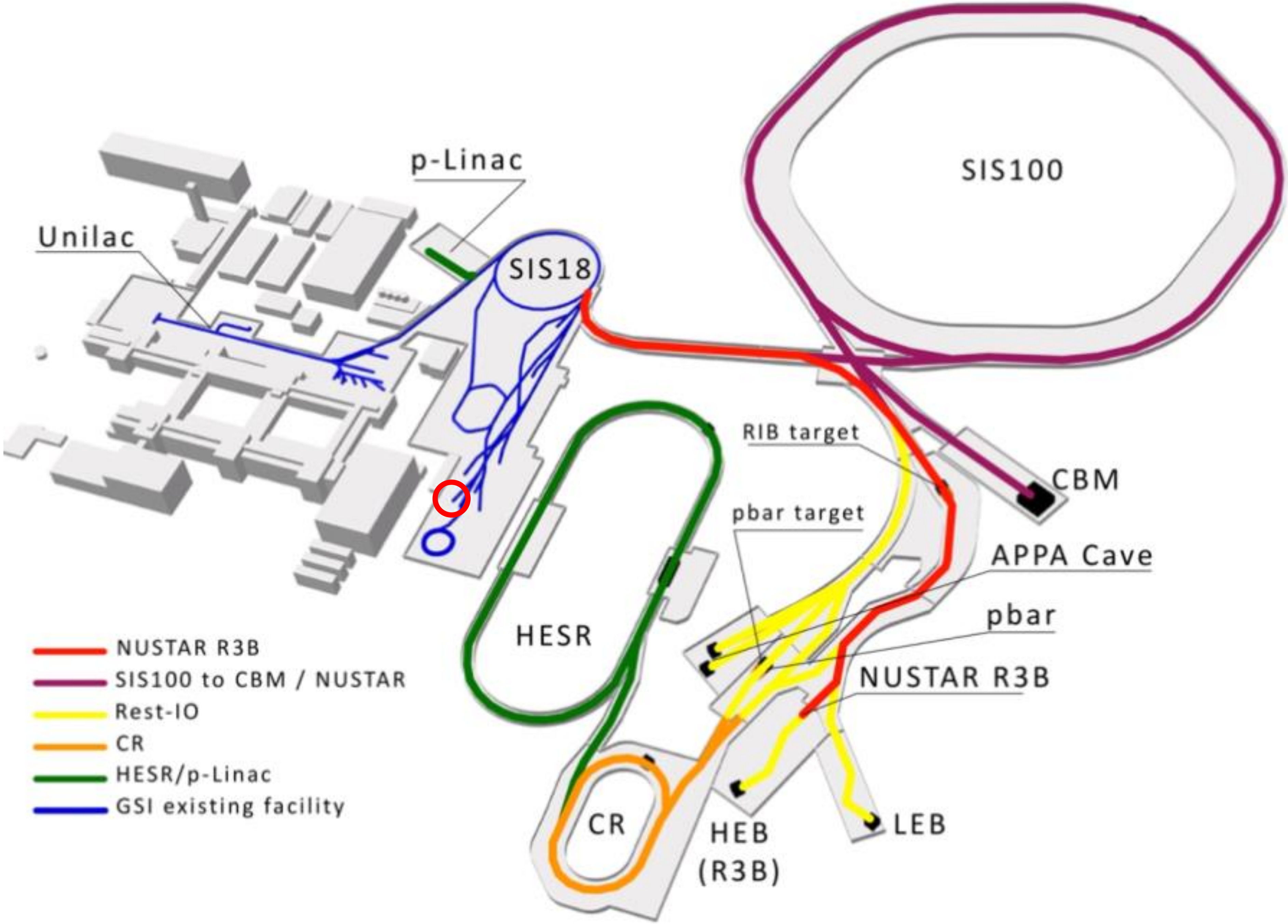
Histogram of amplitude Sine 100 Hz 100 mVpp Red Squid



Histogram of amplitude Sine 100 Hz 100 mVpp Yellow Squid

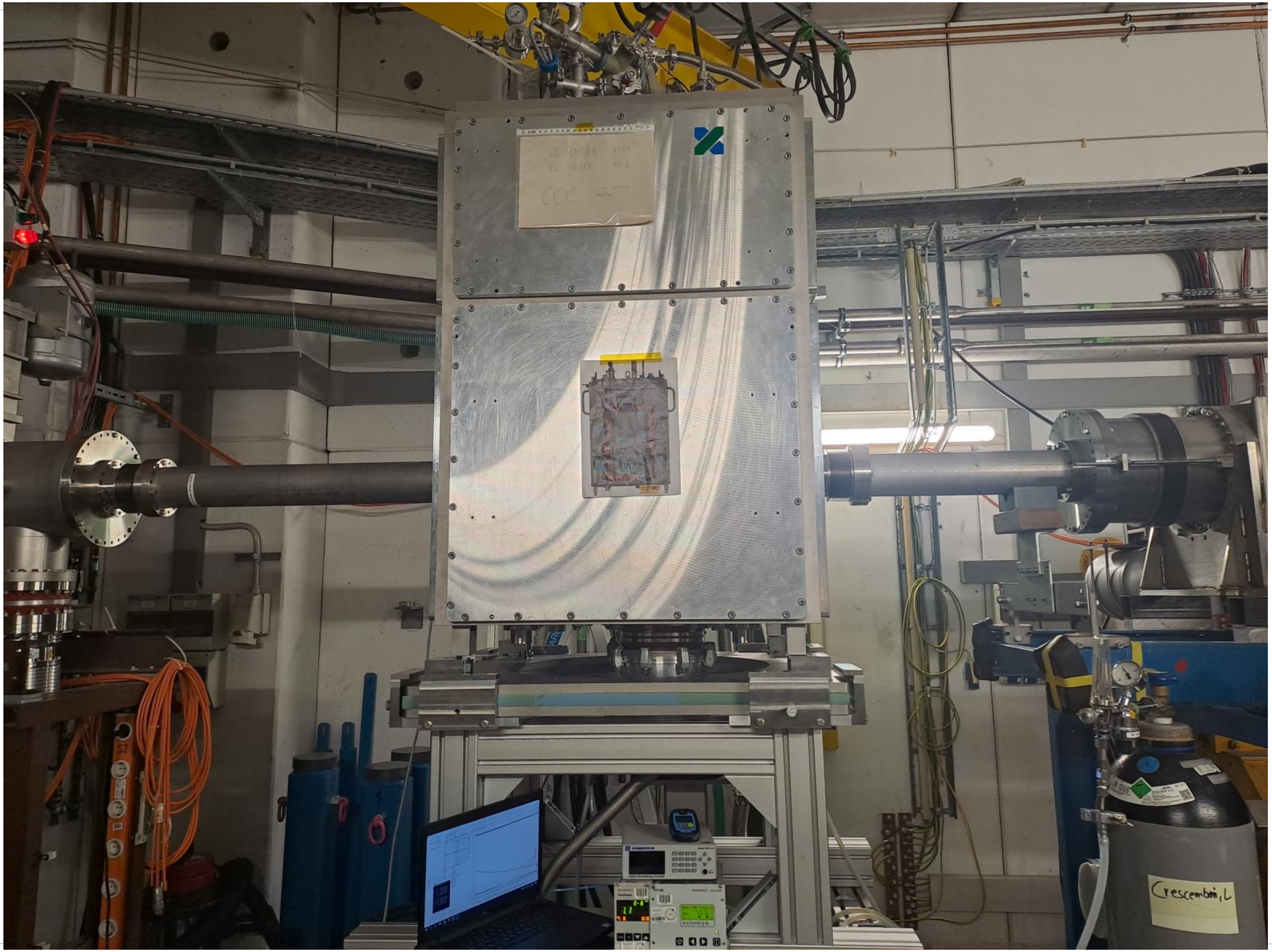


- It’s also possible to fit several data sets at a 100Hz, collected in several day and at different time, to estimate the stability of the system when used to detect signal
- The calibration factor is stable, as the optimal working point. Fluctuations are due to noise
- Obviously having an higher noise floor the red squid has an higher spread


SIS100
p-Linac
Unilac
SIS18
RIB target
CBM
pbar target
APPA Cave
HESR
pbar
NUSTAR R3B
NUSTAR R3B
SIS100 to CBM / NUSTAR
Rest-IO
CR
HESR/p-Linac
GSI existing facility
CR
HEB
(R3B)
LEB

Fair-DCCC on transfer lines

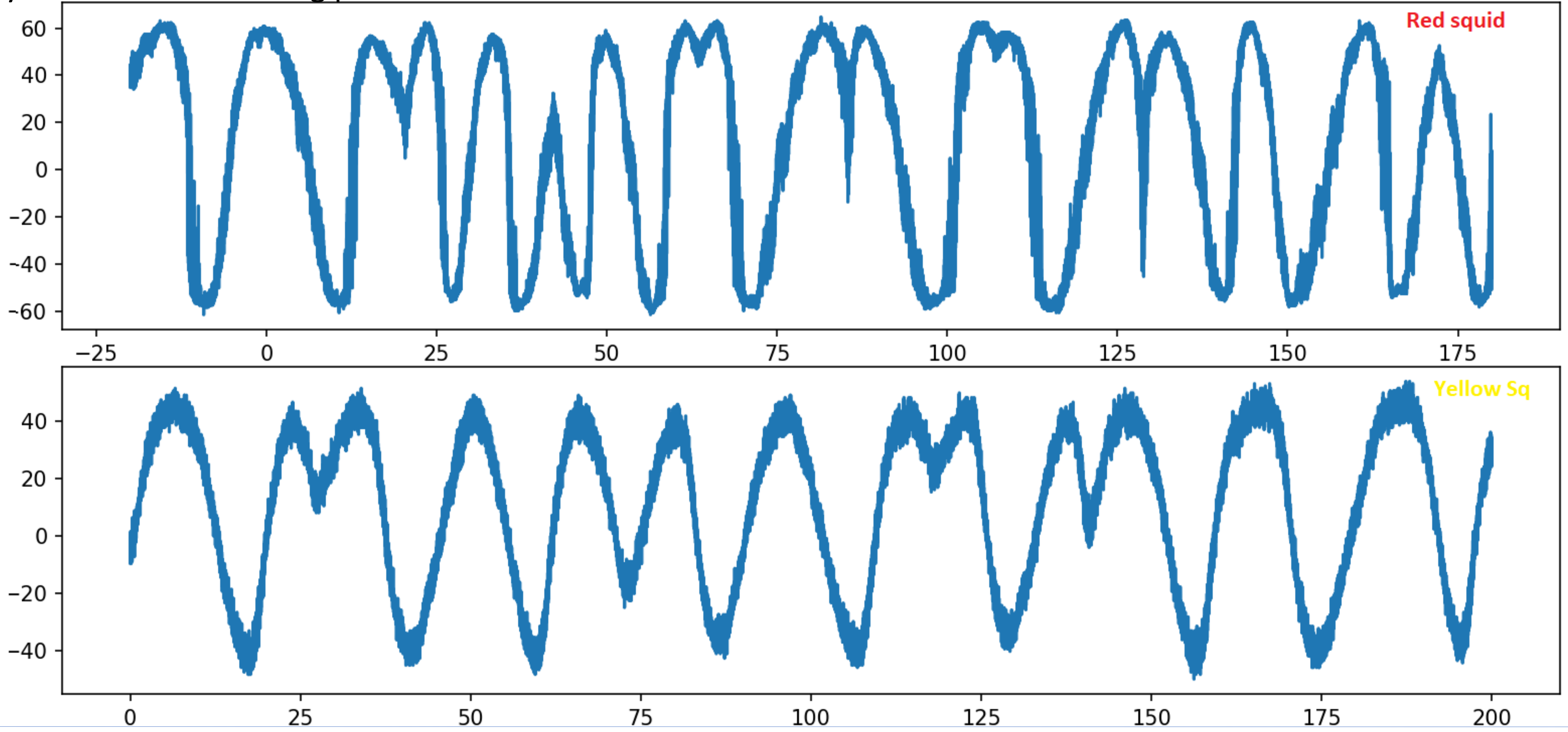
Fair-DCCC on transfer lines



Fair-Nb_CCC on transfer lines

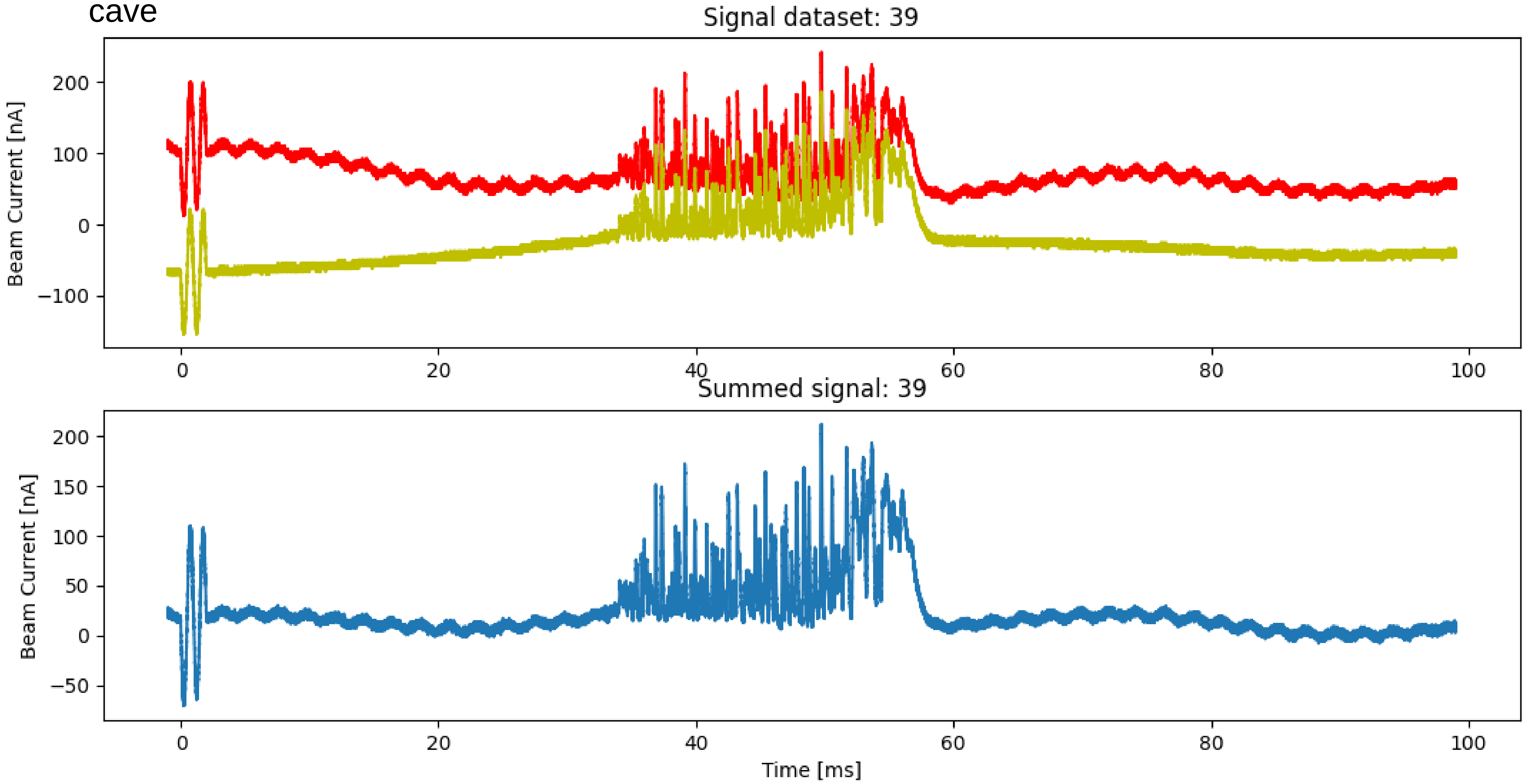
Beam Time Test, Er beam

- As first thing is essential to note that we had no huge changes in the characteristics, the optimal working point was the same.
- Unfortunately, it was immediately clear that we had a much higher noise than the in the testinghalle, especially at 10 Hz. Thus the characteristics are less stable and more noisy, especially for the red squid.
- In any case a stable working point existed



Beam Time Test, Er beam

- Particle number 10 E^8 Erbium 57+, same as nominal particle number expected in the cave



Beam Time Test, Er beam

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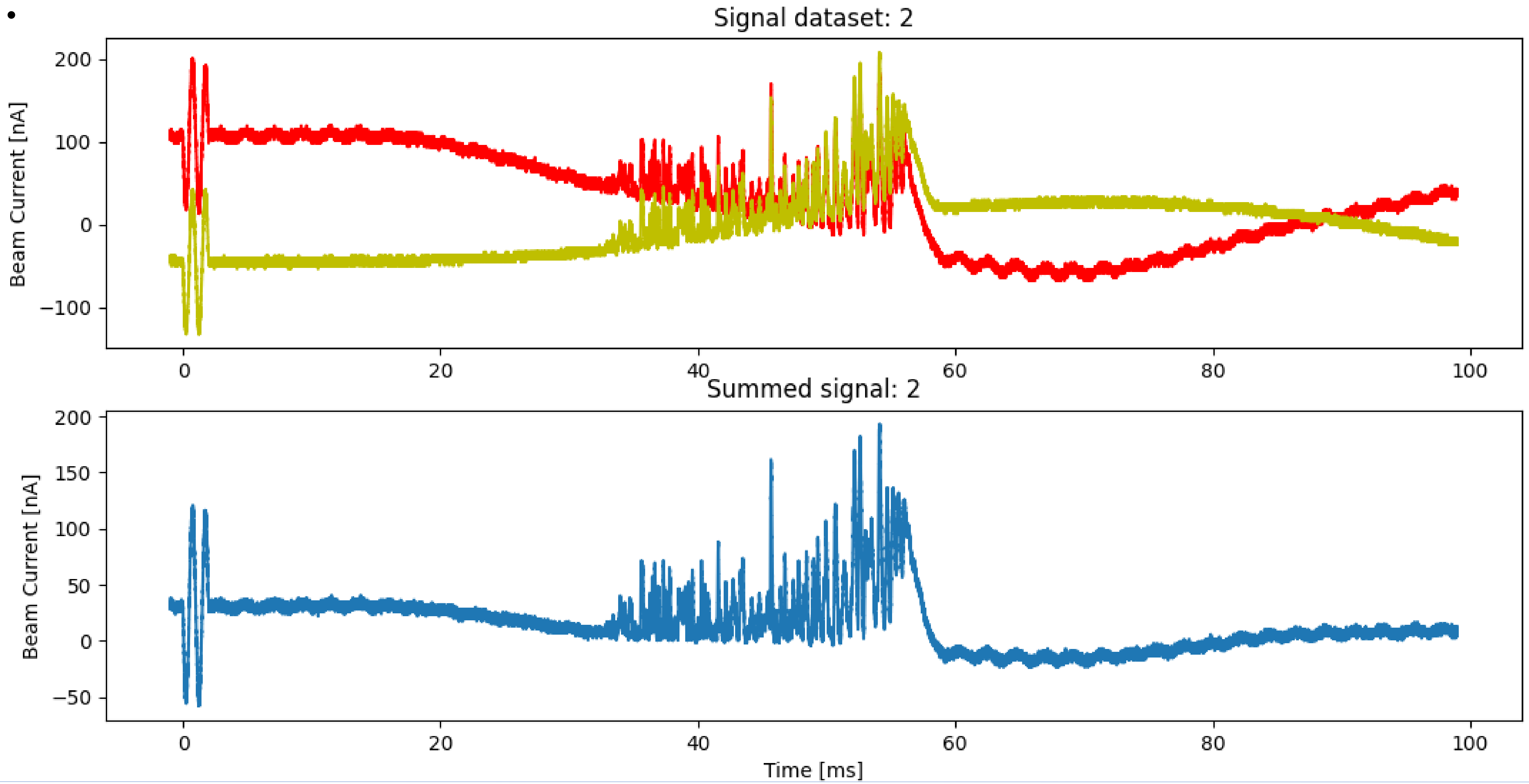
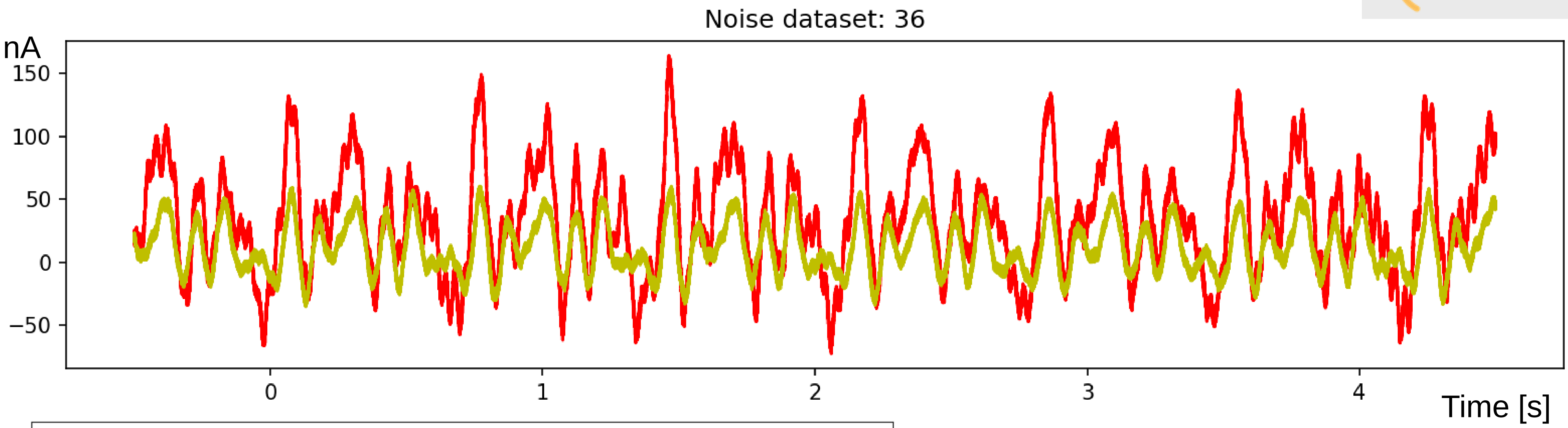
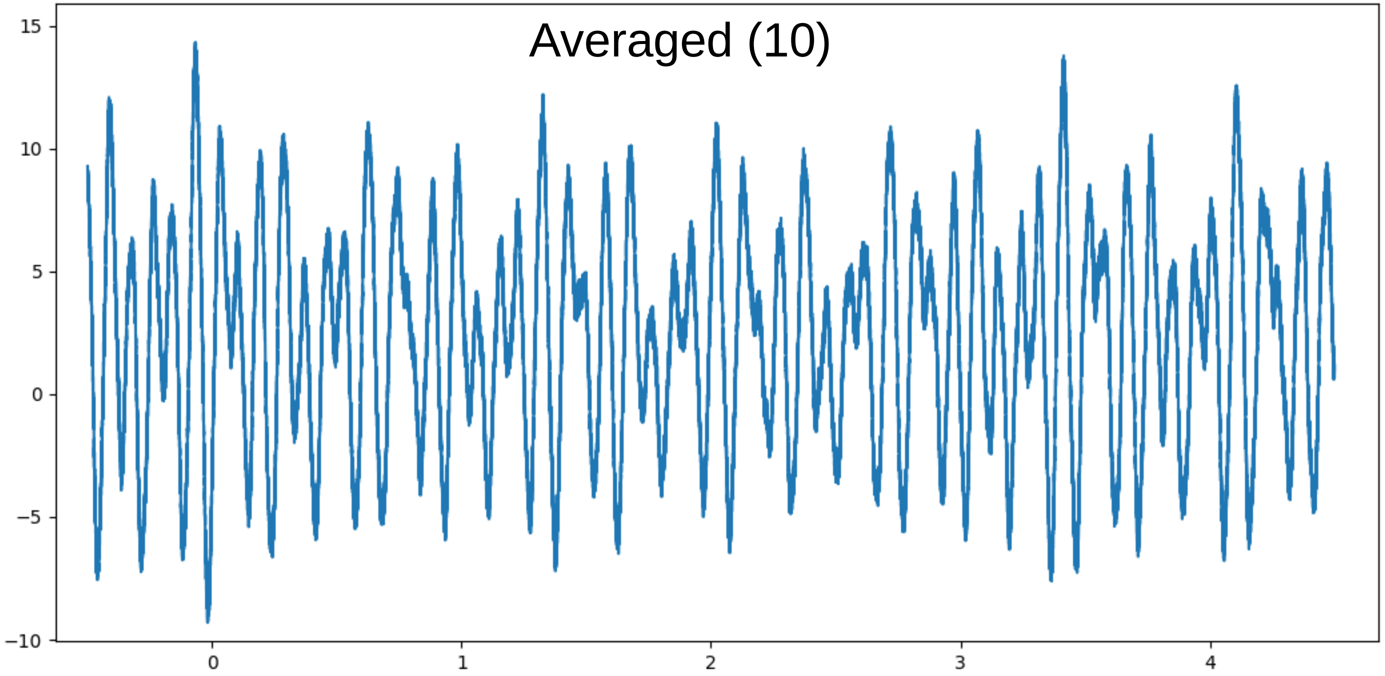


Beam Time Test, Er beam

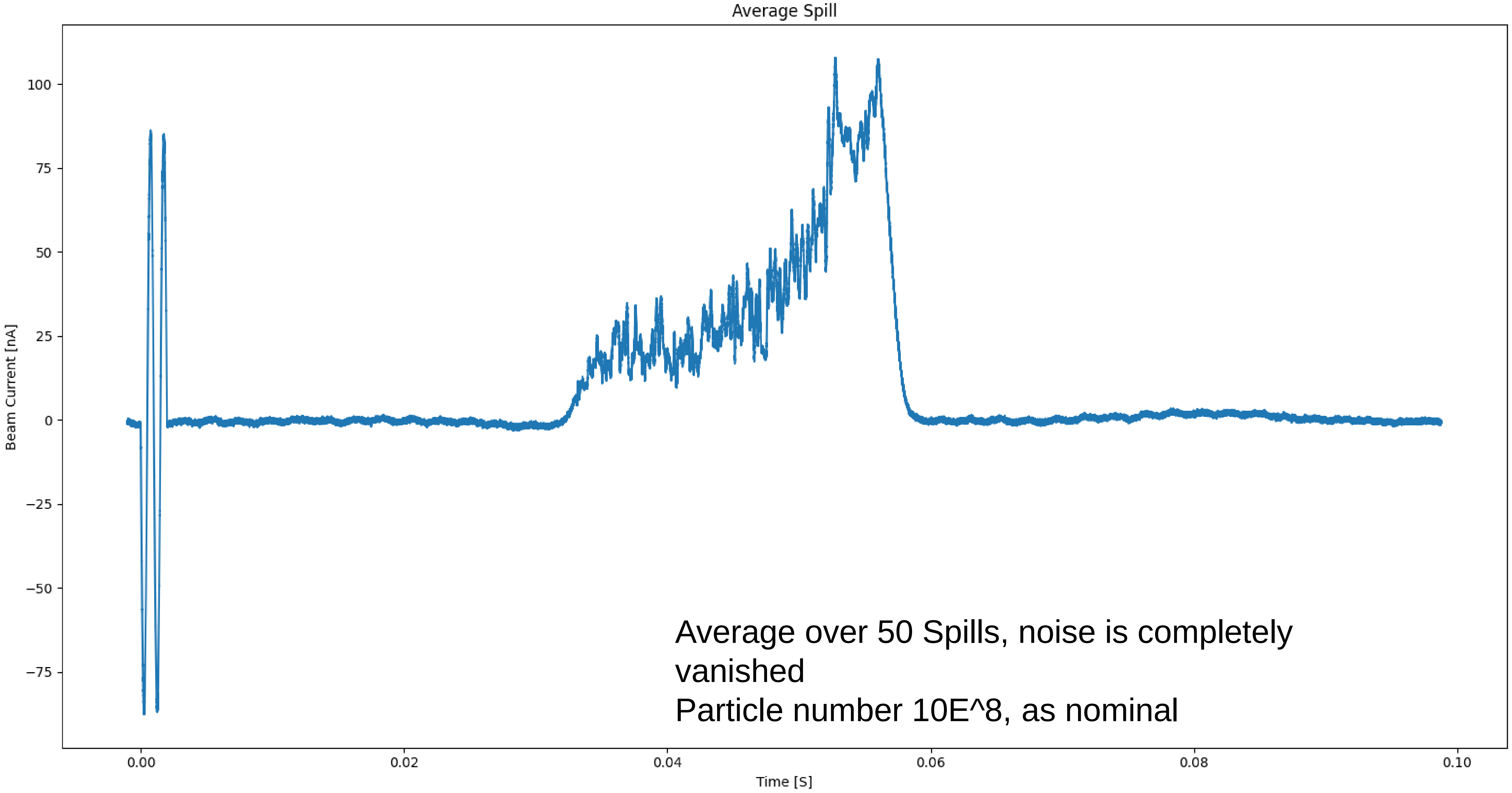




- It’s clearly visible how the noise it’s different between the two channels in intensity
- It’s also a real noise, visible by both channel at the same time
- The average over 10 datasets already bring down the noise of a factor 10, because the noise is periodic
- This means that is possible to try to filter it out

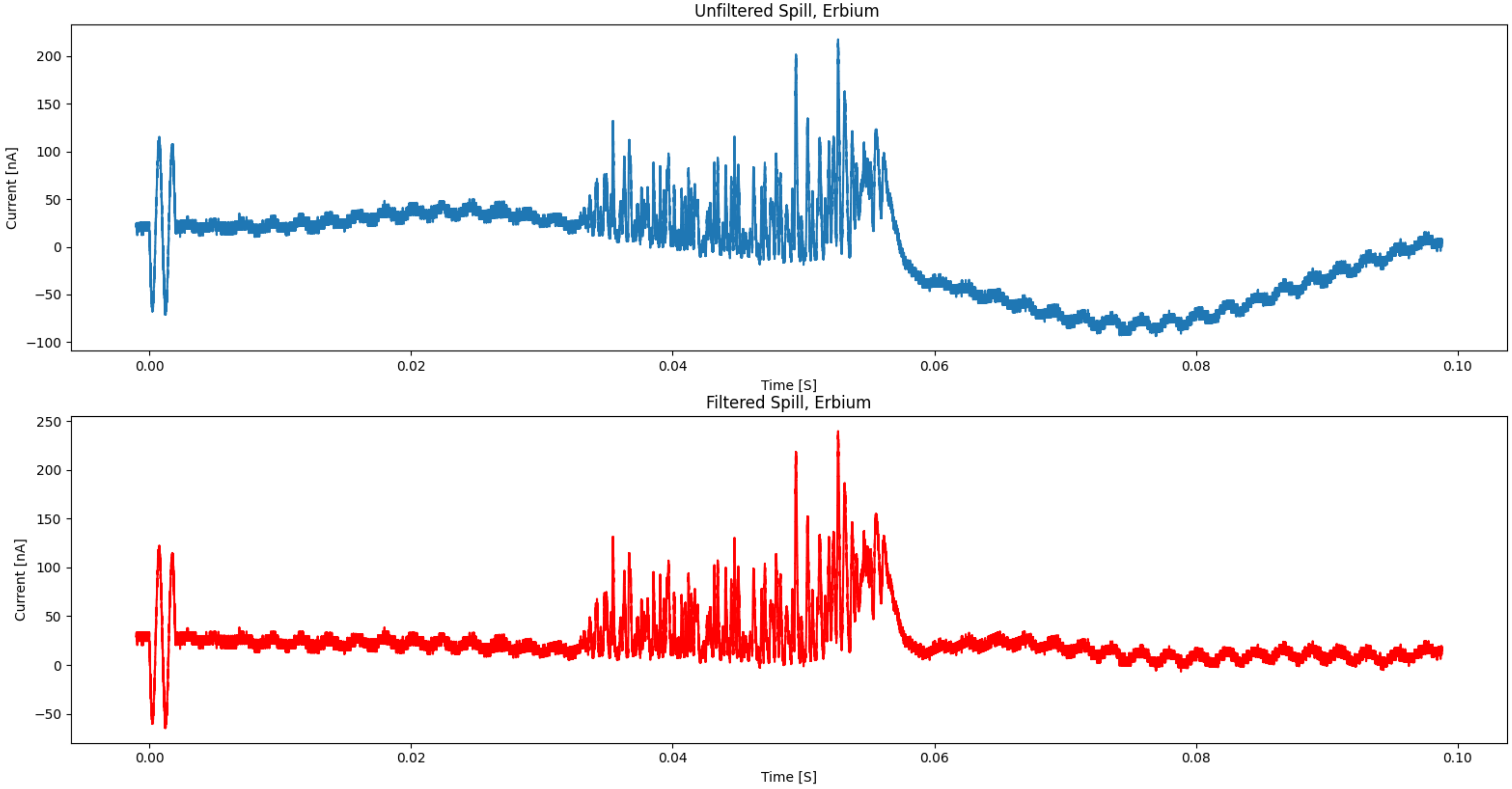
Beam Time Test, Er beam

- If the noise is really periodic, than an average over several spill should remove the noise completely



Beam Time Test, Er beam

- First attempt of a filter, combination of a band block filter at 10 Hz, one at 30 Hz, and the band block filter for the liquifier armonics.



Beam Time Test, Er beam, spill stabilization

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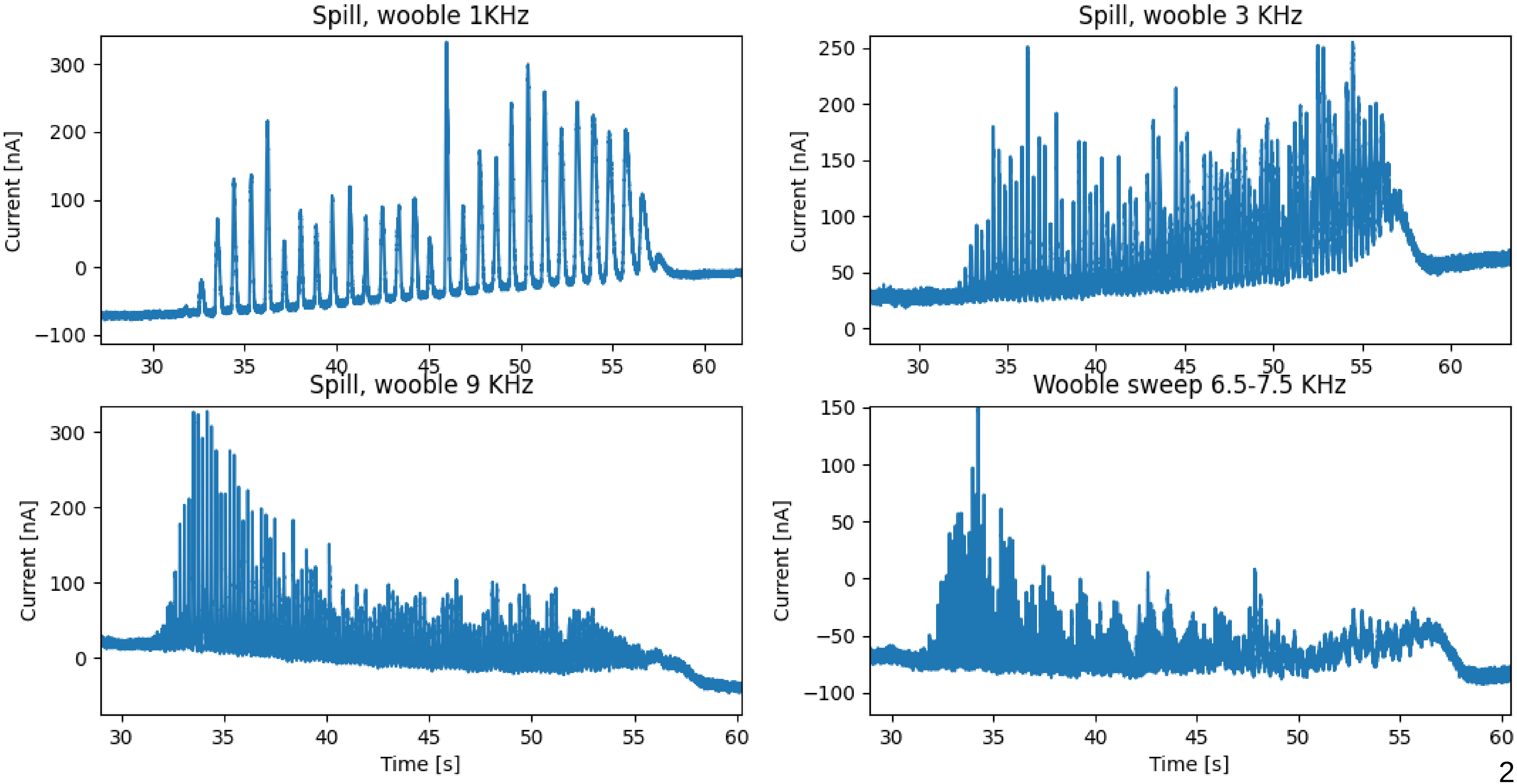
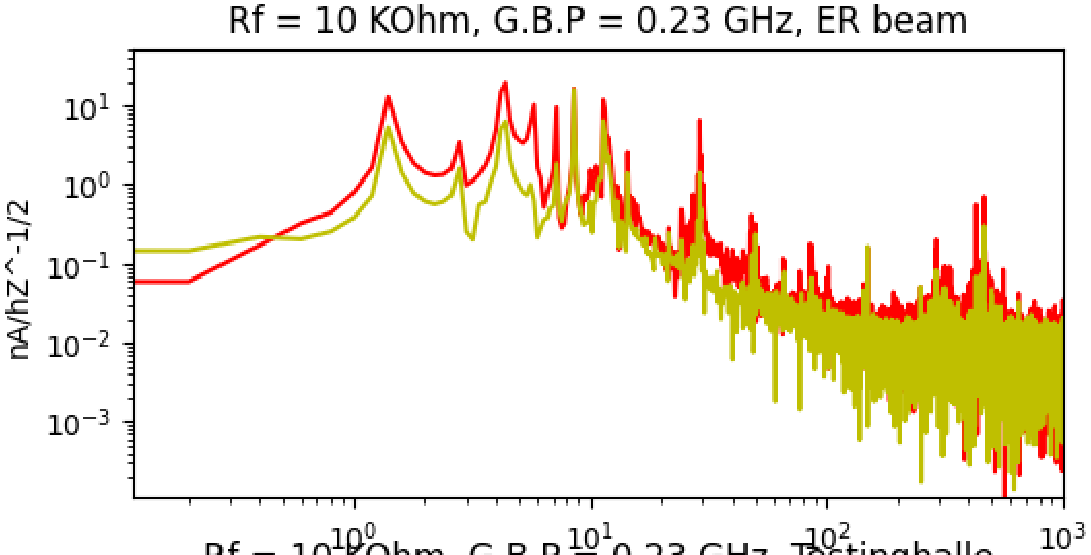
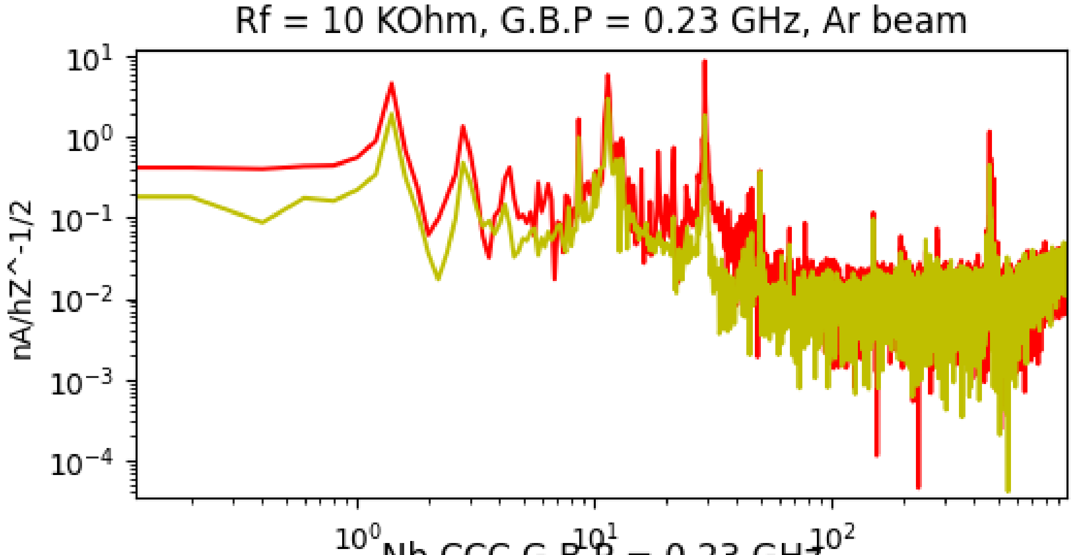
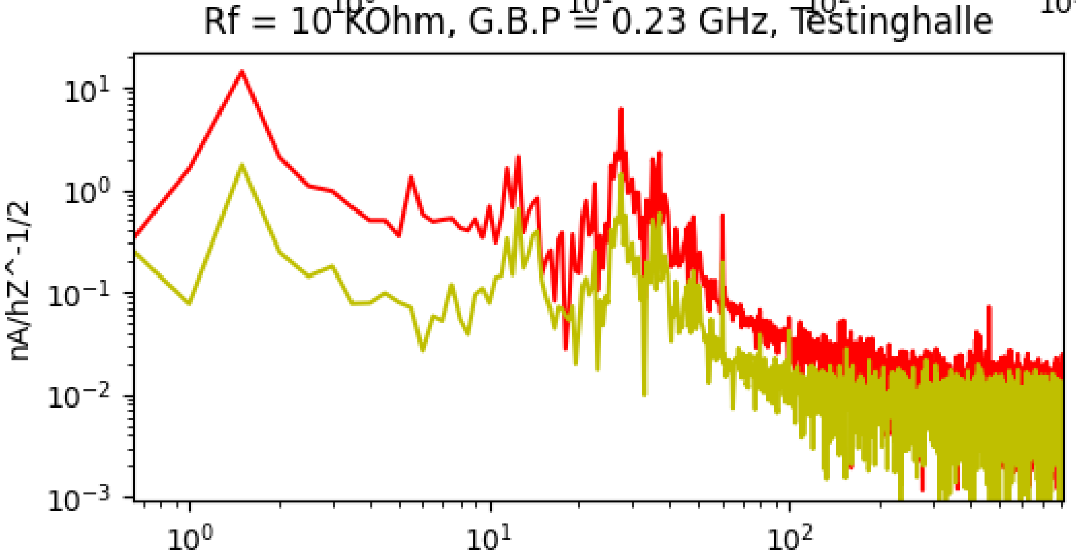


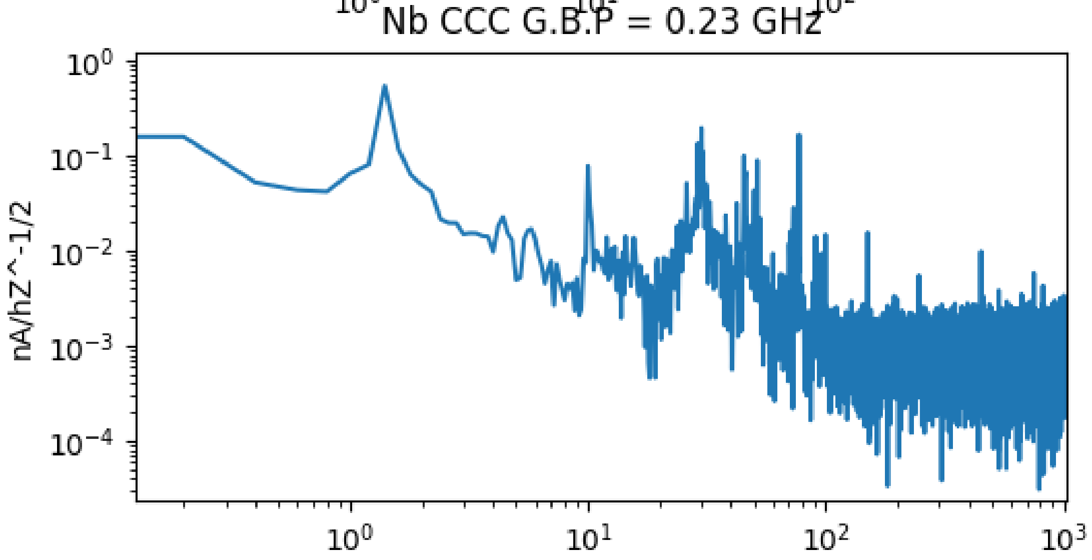
Beam Time Test, Ar beam

- After the first day of beam time we were able to access the cave and search for the source of the high intensity noise at 10 Hz
- We found out that the source was the liquifier, in particular how the liquifier nozzle was inserted in the helium container, because the nozzle itself was touching the CCC, directly coupling the compressor to the detector



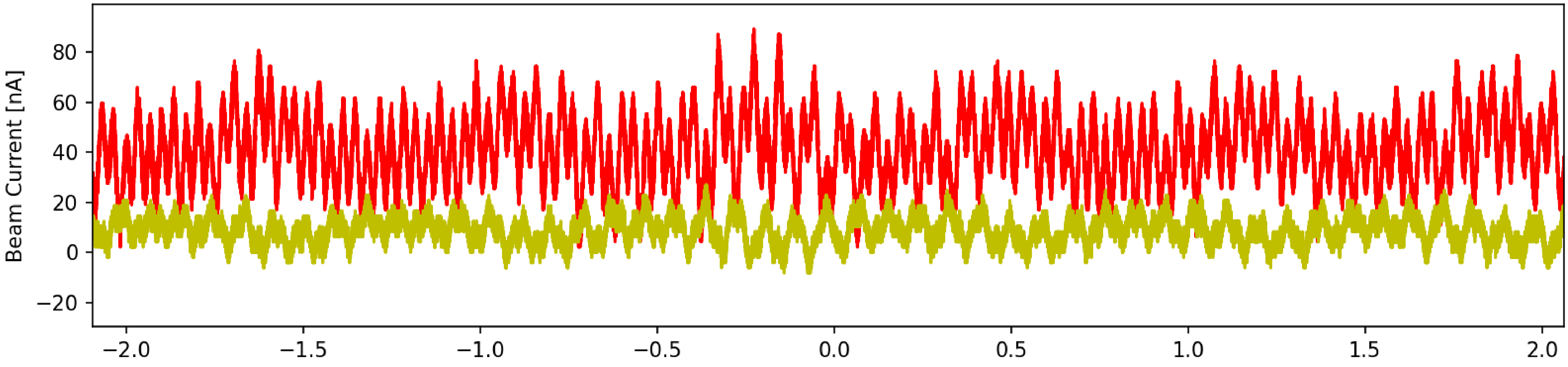






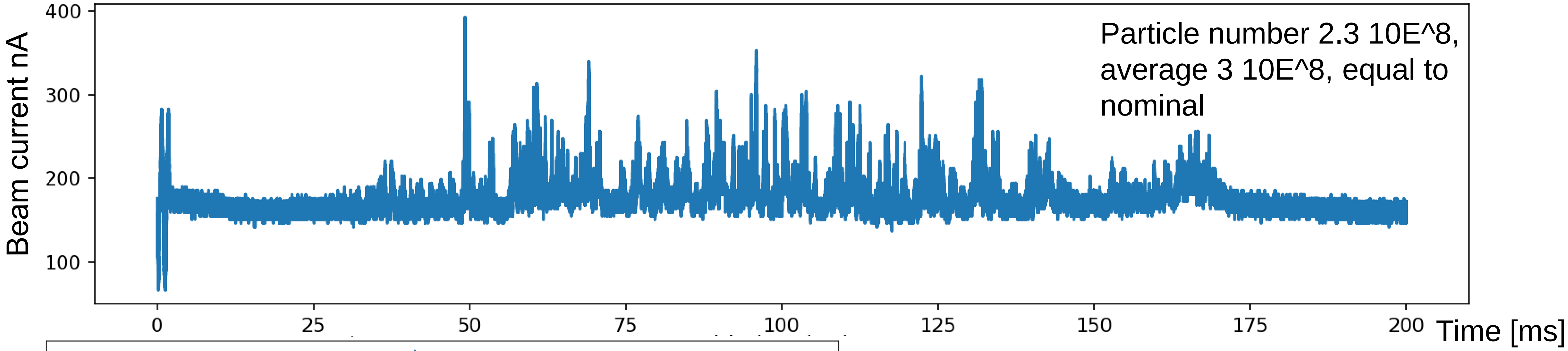
Beam Time Test, Ar beam

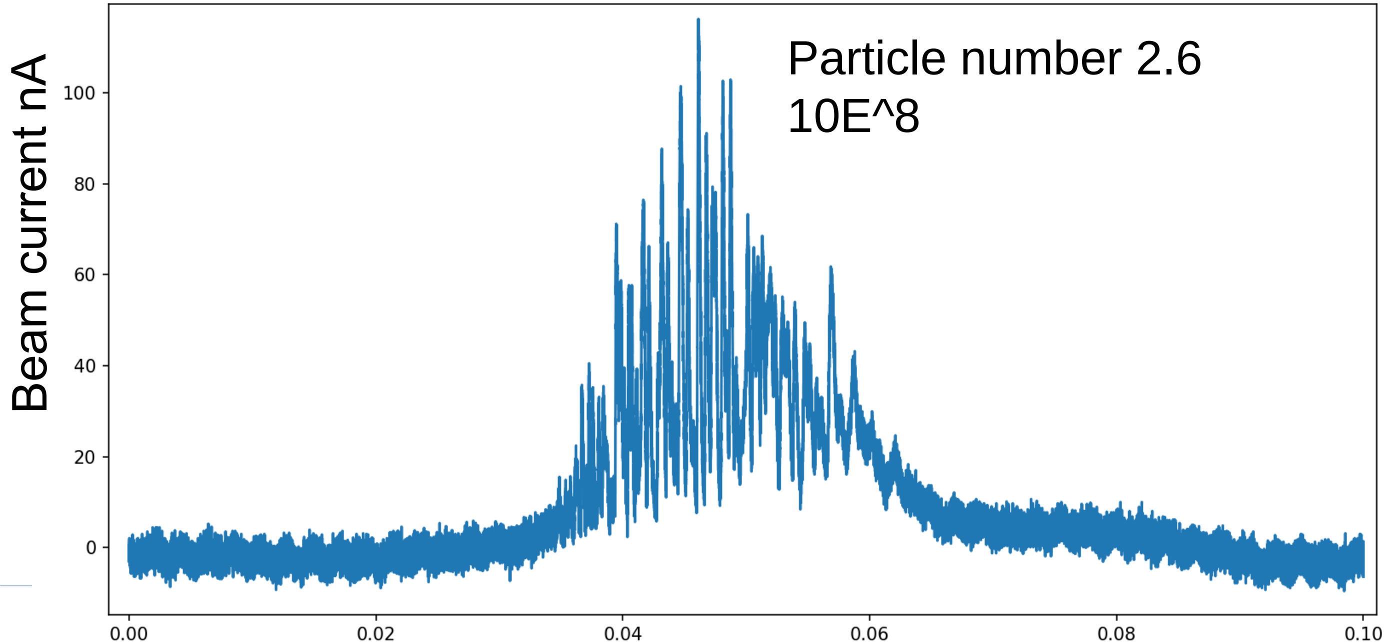
- With this small adjustment the noise dropped down for both channel
- An average value of 15 nA for the yellow squid mainly at 10 Hz
- An average value of 40 nA for the read squid, mainly combination of 10 Hz and 30 Hz
- Also the characteristics has improved, they are both less noisy and the working point is more stable

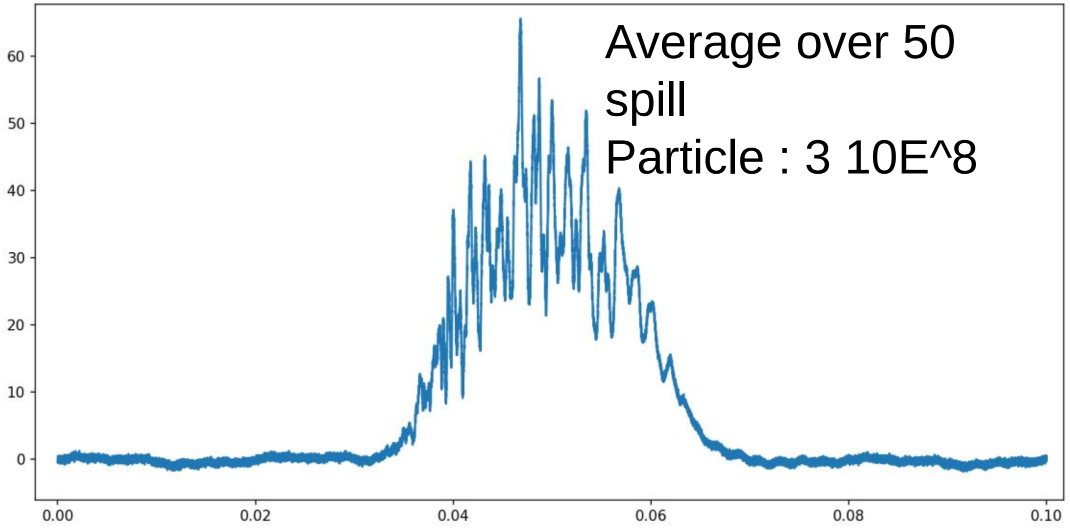


Beam Time Test, Ar beam

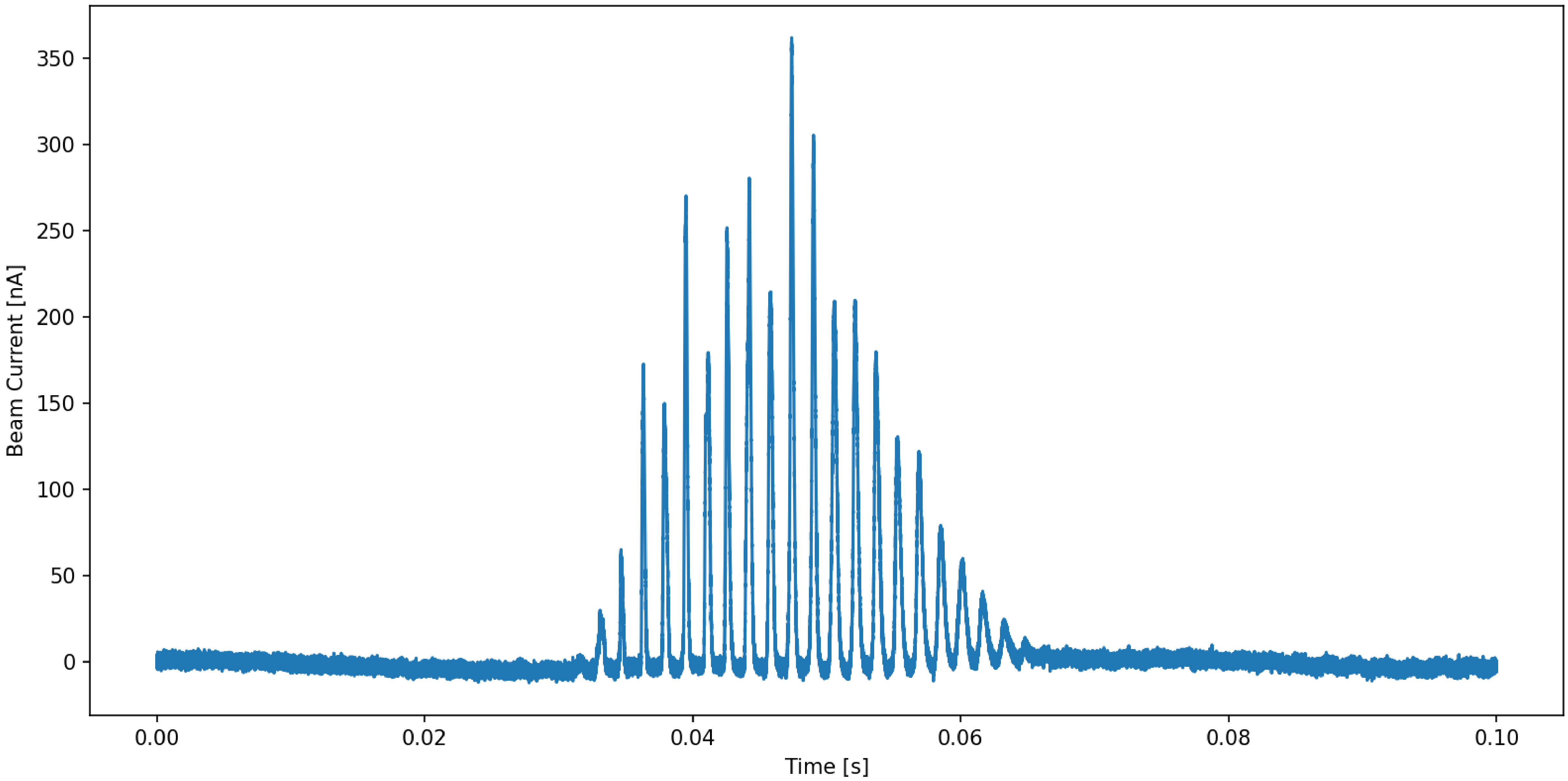
- From now on I will show only the signal of the yellow squid, that is more clean and easier to readout.
- In almost every case, though, the sum of the signal give better result, with a general higher signal to noise ratio



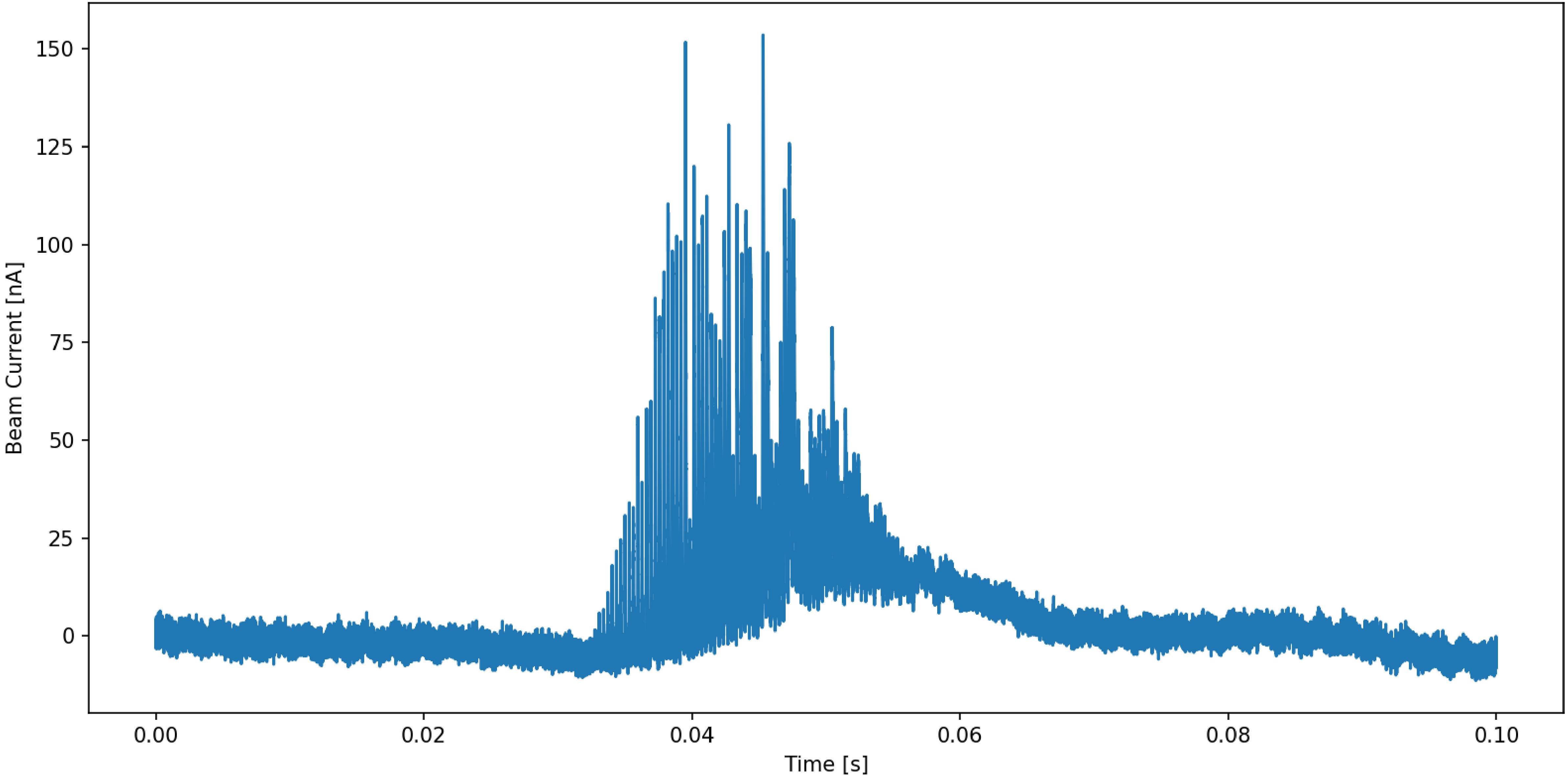




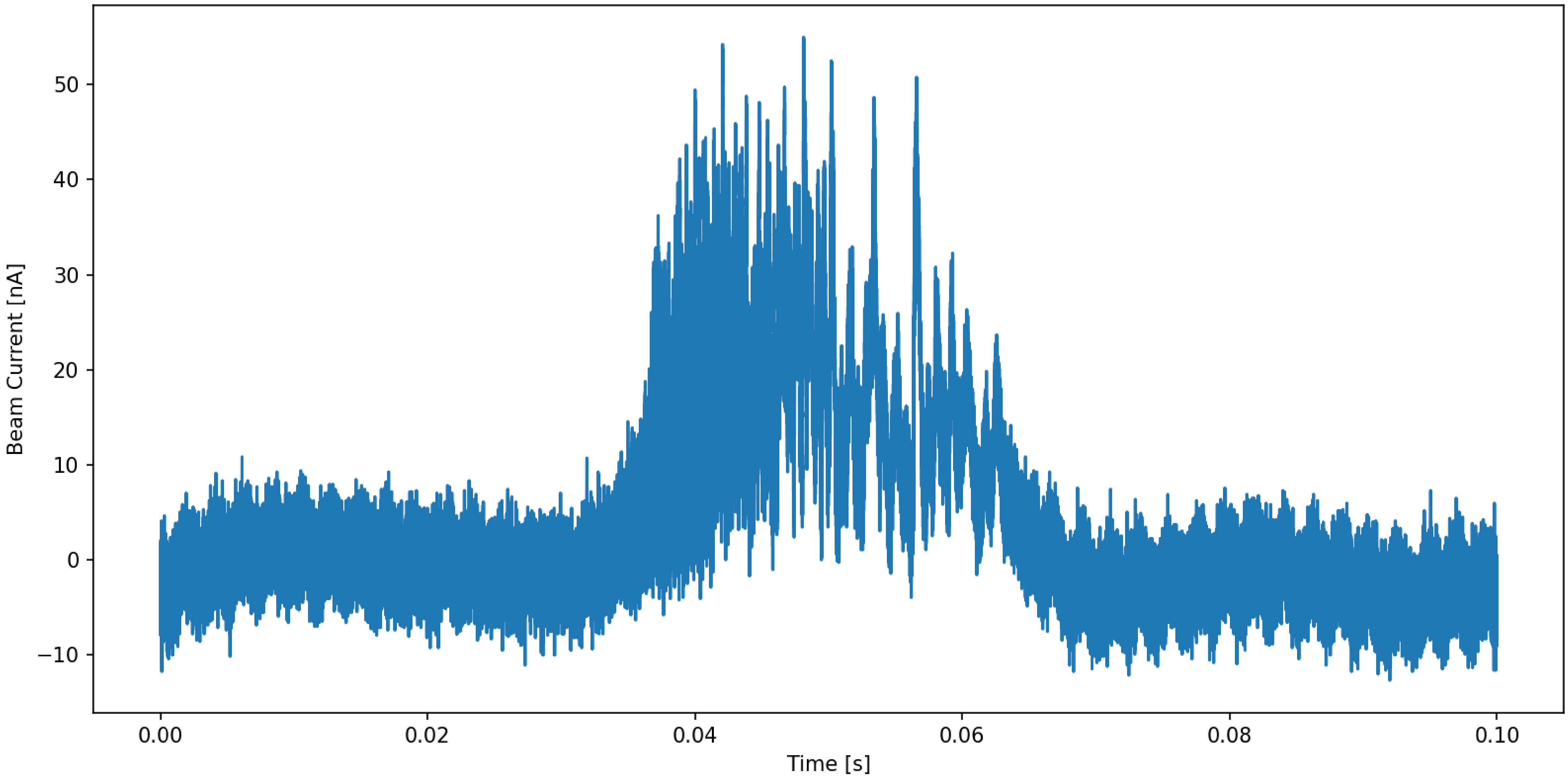
Beam Time Test, Ar beam, wooble 500 Hz



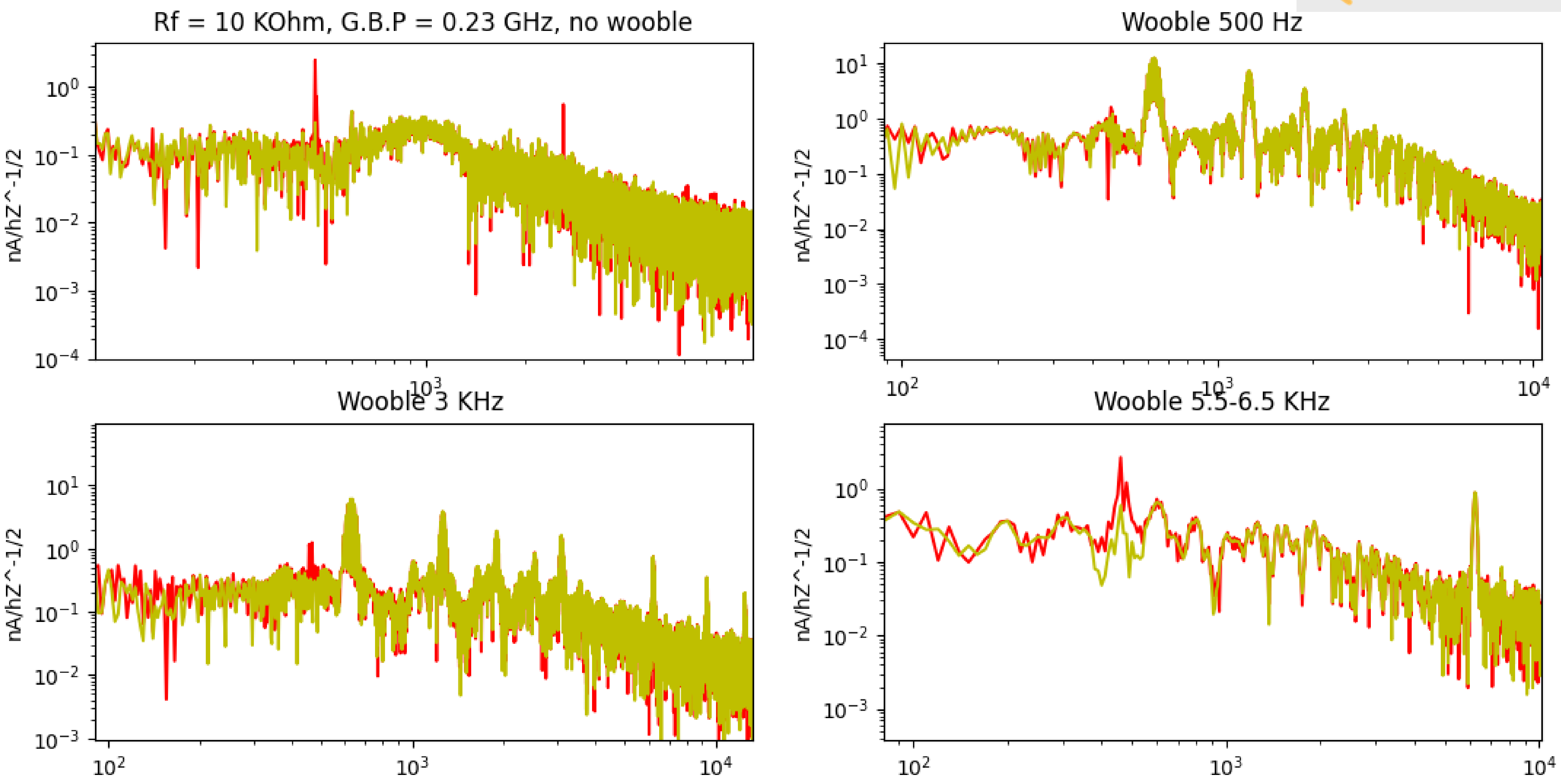
Beam Time Test, Ar beam, wooble 3 KHz



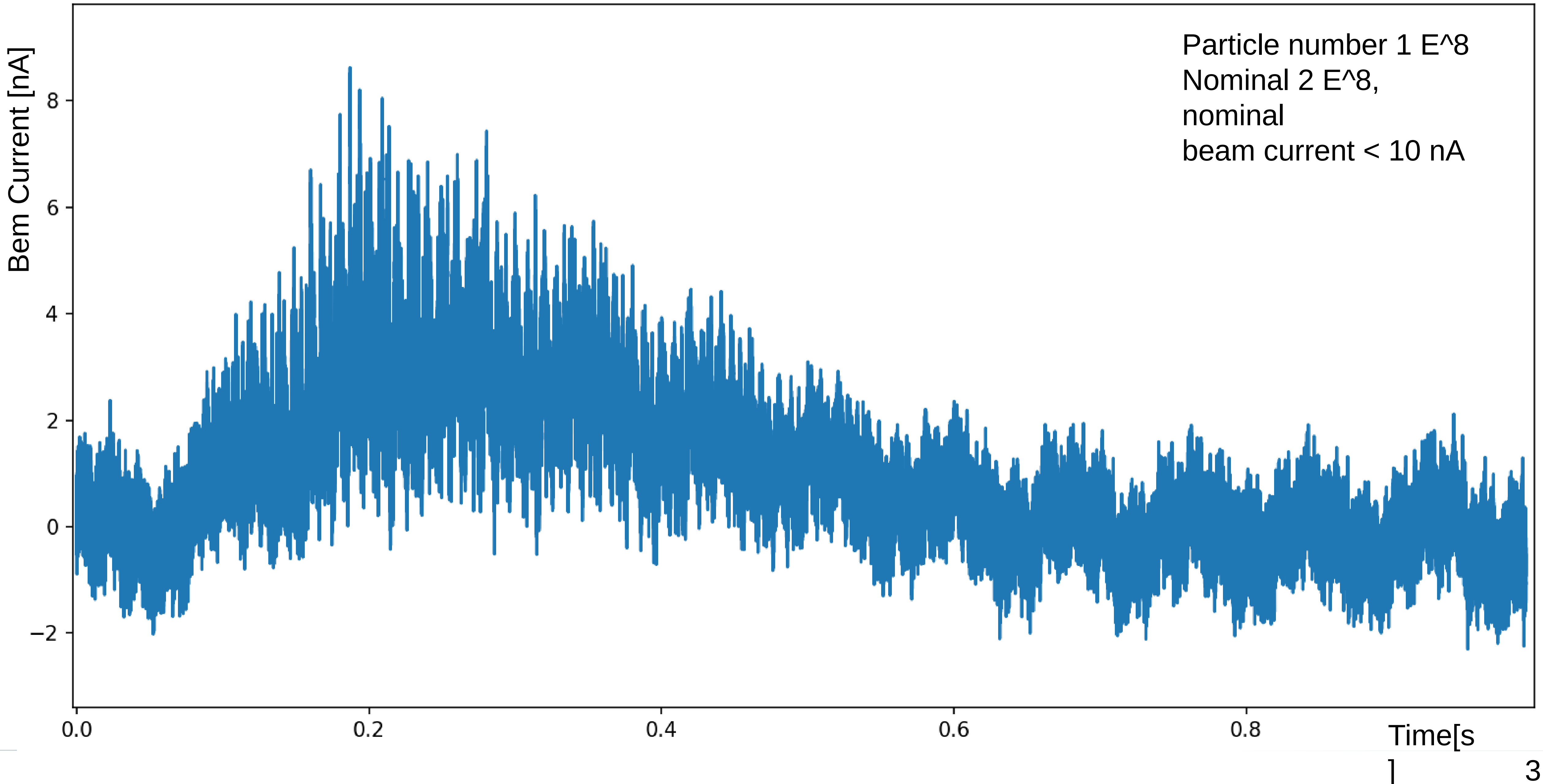
Beam Time Test, Ar beam, wooble 5.5- 6.5 KHz



Beam Time Test, Ar beam, wooble

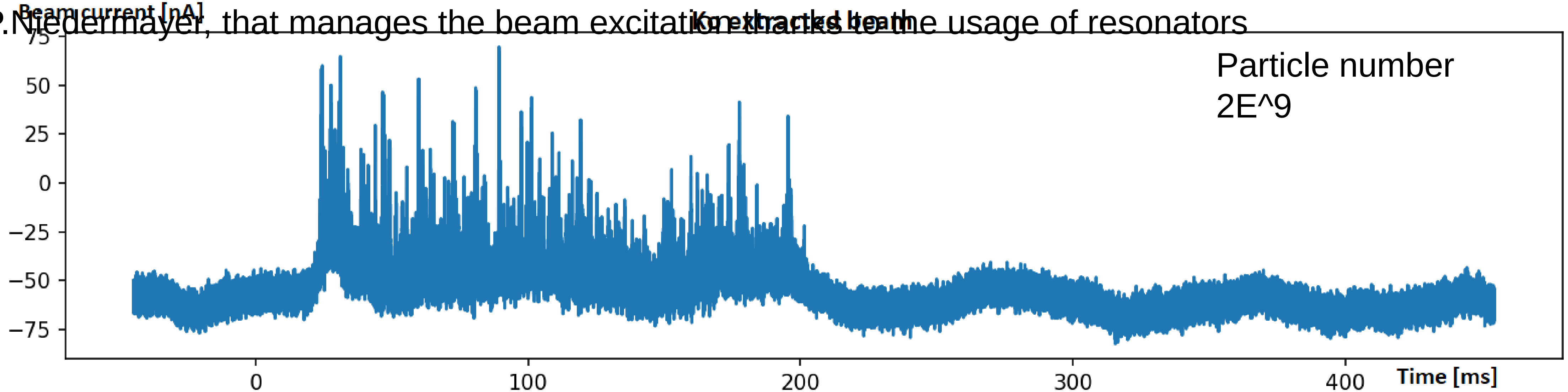


Beam Time Test, Ar beam, resolution limit

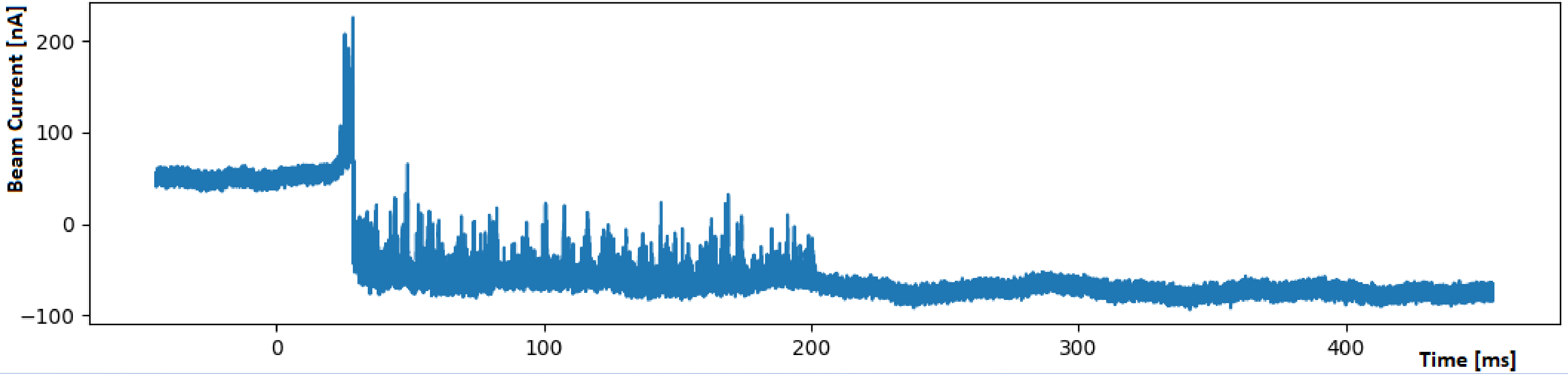


Beam Time Test, Ar beam, Slew Rate

To test higher current and different extraction method, we used the GNU radio software developed by R.Singh and P.Niedermayer, that manages the beam excitation thanks to the usage of resonators



Ko Extracted Beam, slew rate issue



Slew Rate

- For reference Slew rate on Nb-CCC with maximum bandwidth 8 KHz is 0.16 µA/µs
- First estimation of slew rate in Jena and in GSI has shown:
  - Yellow Squid: 0.4 µA/µs
  - Red Squid: 0.8 µA/µs
- What we found out on the beamline instead was that the yellow squid is much more stable and less prone to flux jump. The maximum slew rate extracted from data is compatible to previous measurement.
- Each time a slew rate problem occurs to the yellow squid the red squid always jumps, not viceversa
- The yellow squid has a much bigger operating area
- We were in any case able, with particle numbers higher than 5 10E^9, to have flux jumps in both squid, especially when we tested the KO extracted beams
- Moving the KO excitation signal to frequency over the MHz helped stability, able to reach particle beam up to 10^10, but rarely stable over 5 10^9
- In all the datasets with jumps is clearly visible a really steep slope in the spill that make the squid jump
- For the Nb-CCC we were able to generate flux jumpes using particular settings of the wooble software generating spills with huge spikes, we don’t know how the NB-CCC would act with the KO extracted beams, it was not available during the test in december. Furthermore beam machine settings with Uranium where much better than with Ar, with more stable beams

Conclusion

- The DCCC was tested in Jena, in GSI laboratory and then installed in the transfer lines at GSI
- The DCCC was successfully used to detect slow extracted beams, using for the first time also the KO extraction method, in addition to the usual Quadropule extraction
- The sensitivity of the DCCC is confirmed < 10 nA also in the transfer lines
- Even with some issue with the noise in the first day, we were able to manage a successful data analysis and the CCC data could be used to perform sensitive analysis with a noise 10 times higher than usual
- The performance of the DCCC is in general comparable with the performance of the Nb_CCC, but with the positive side of a factor 10 in cost, the possibility of parallel use of two cores to improve noise removal, and a much higher bandwidth (higher than 100 Khz)
- This test has then show the viability of the DCCC as a detector for FAIR

Next Steps

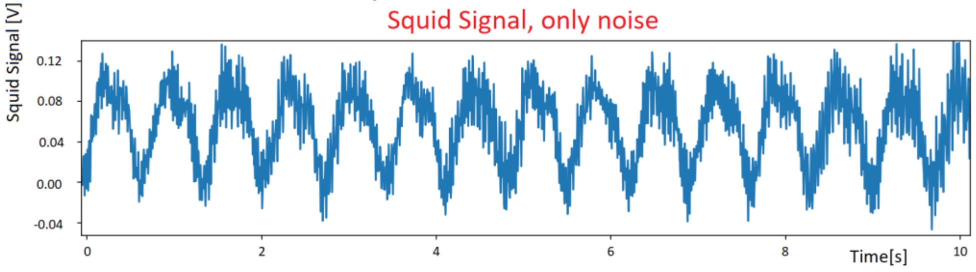
- Better analysis of noise sources (correlation with pressure variation)
- Better filtering of Erbium data to found the best way of inserting the filter in the CCC FESA
- Analysis of the optimized spill (with wooble) ongoing
- Analysis of issue with slew rate ongoing
- Direct comparison on spill optimization analysis with Nb-CCC and DCCC ongoing
- Discussion of possible improvements of the DCCC
- Finalization of the cryogenic support system

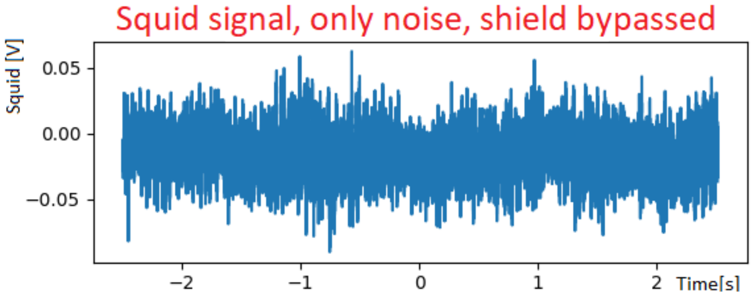
Thanks for the attention!

Cryogenics improvement

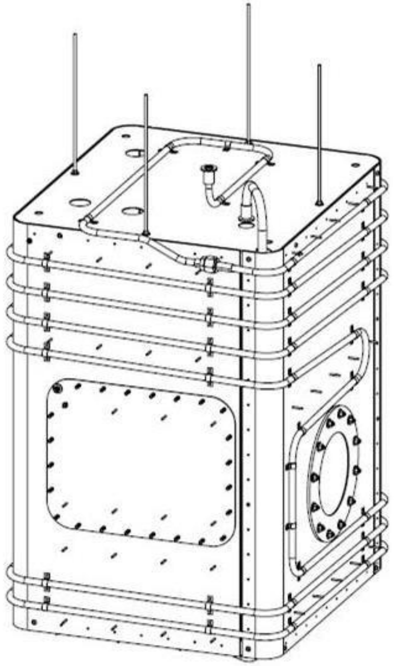
- To improve the system further we are working on a new thermal shield and on a liquifier improvement
- Our liquifier is now able to liquify 15 l/day of helium, while the evaporation rate of our system is between 20-23 l/day, depending on the settings of the flow control system, we are upgrading the system to a 25 l/day liquifier, allowing to reach an unlimited standing time
- In parallel we are working on an improved version of the existing copper thermal shield:
- Improved return line: bigger diameter and shorter length to reduce line resistance
- Rectangular section to improve thermal conductivity between cold line and main shield structure

The new shield will also reduce the 1.4 Hz periodic noise of the liquifier (compressor frequency). A shorter return line reduce the amplitude of the periodic noise, so the new shield will reduce the intensity of the noise

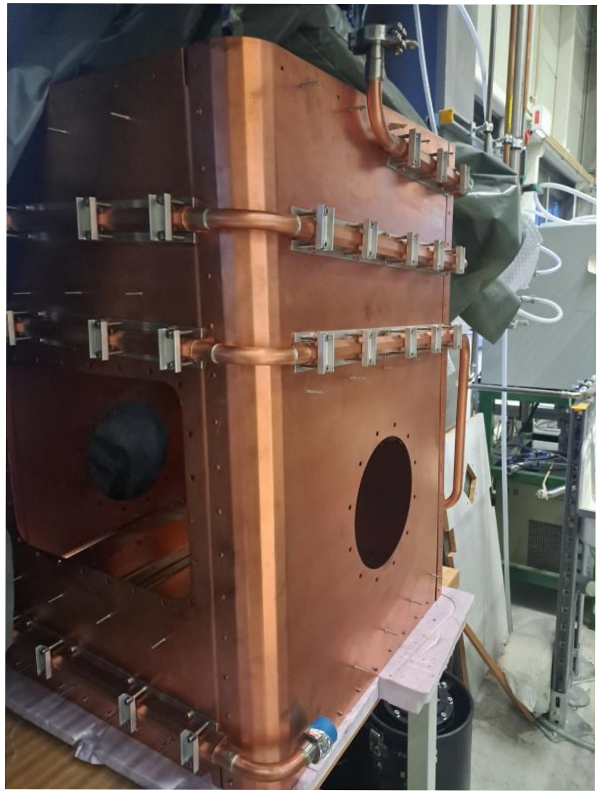




We were able to remove the noise bypassing the return line, the amplitude of the noise depends on the length of the line.

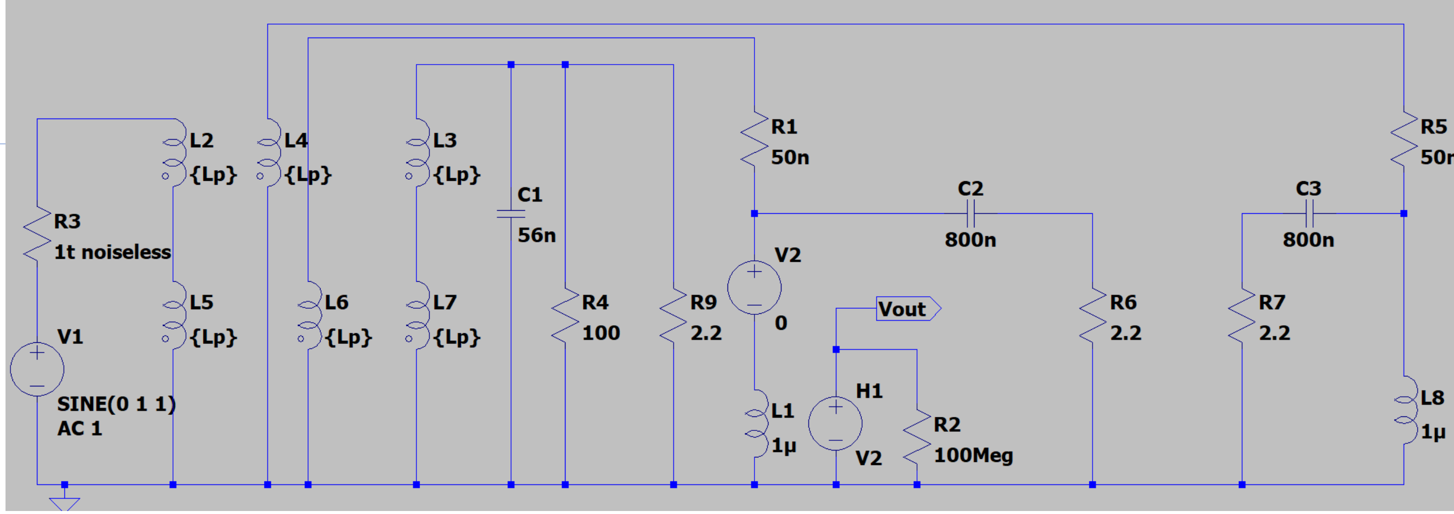


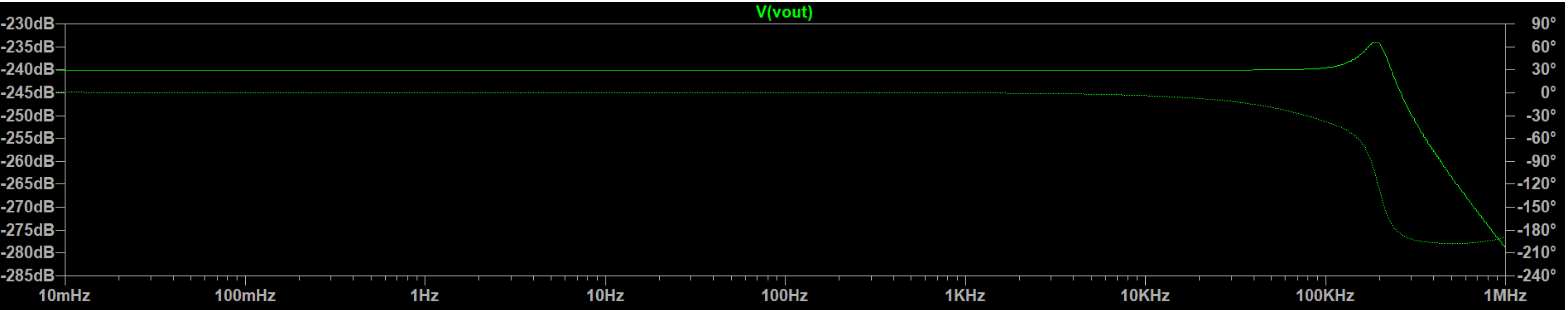
Existing shield drawing: 15 m return line of round section of 10 mm diameter



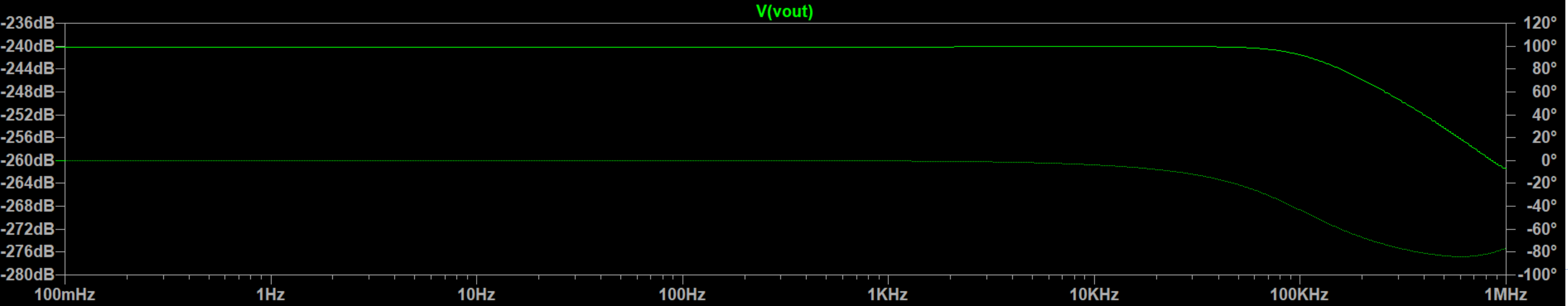

ILK Dresden

DCCC in GSI cryostat





Without 2.2 Ohm resistor on meander



With 2.2 Ohm resistor

Beam Time Test, Ar beam, Sem comparison