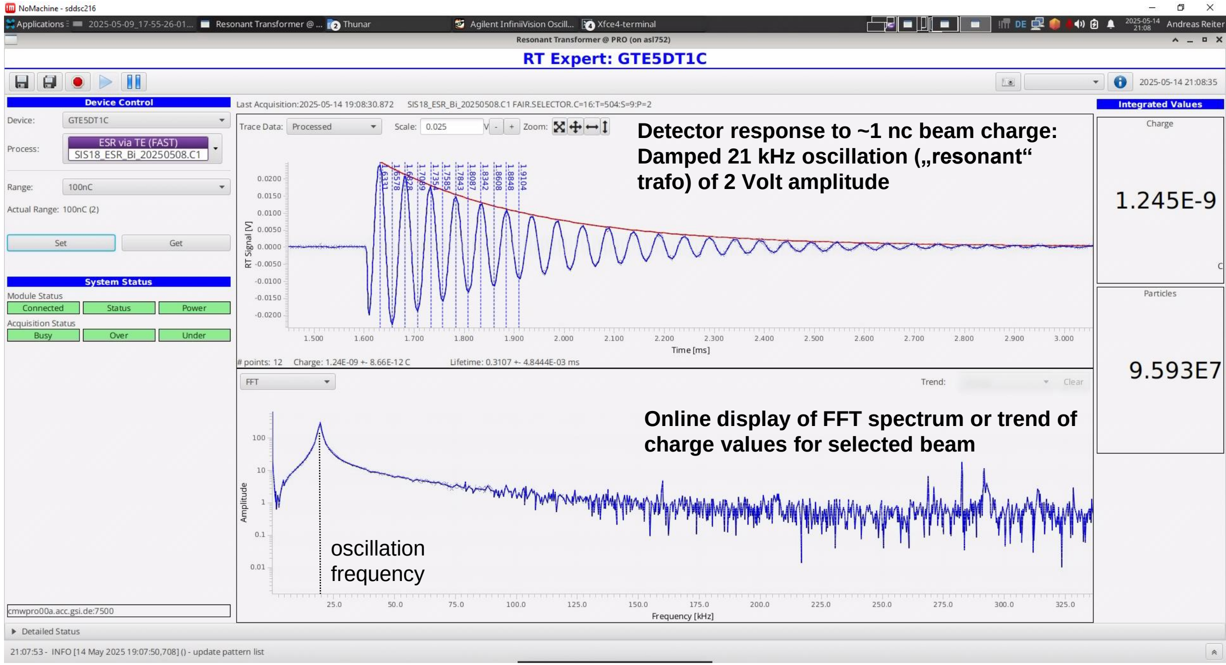
Beam Experiment No. 250: HEBT Resonant Transformer tests

Spokesperson: A. Reiter, M. Witthaus, H. Bräuning

- **Existing DAQ:**
  - **Old, outdated and unreliable**
  - Delivers only charge value based on peak detector voltage
  - No signal acquisition; unknown data quality
- **New DAQ system:**
  - FAIR hardware: new head amplifier; 4 channel connector box; µTCA ADC and CPU
  - FAIR software: FESA class
- **Test detectors:**
  - GTE5DT1C (ESR injection; GSI RT)
  - GHTPDT1C (HTP; new FAIR RT)
- **Test beam times:**
  - Parallel to SIS18 – ESR transfer
  - Dedicated shift: HTP, 8th July 2025
- **Results:**
  - **DAQ system including software with stable operation and good signal quality**
  - Added noise/distortion (10 – 100 kHz) during some experiments due to magnet power supplies, etc.



- **Next steps:**
  - Detailed analysis of data
  - Production of hardware for FAIR and GSI detectors (head amplifiers, connector boxes)
  - **Upgrade of GTE1DT1C, GHHTDT6C, GHHDDT1C in 2026 for FCC operation**

HEBT Resonant Transformer tests in ~~HTP~~ TE5 beam line

GSI HEST – Machine Experiments 2025

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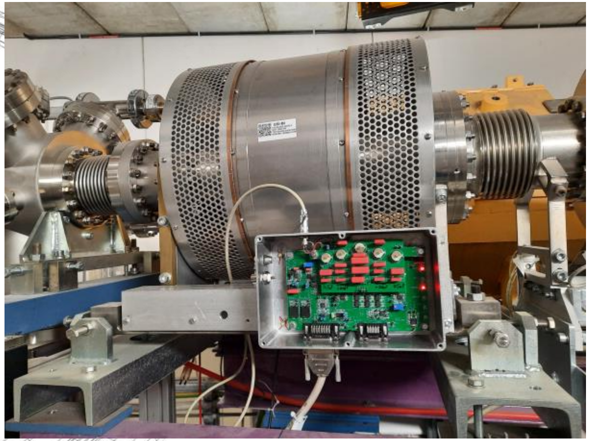
1st Dec. 2025

Use case:

Beam Transmission Monitoring

- **SIS/HEBT injection/extraction efficiency**
- **HEBT transmission efficiency**

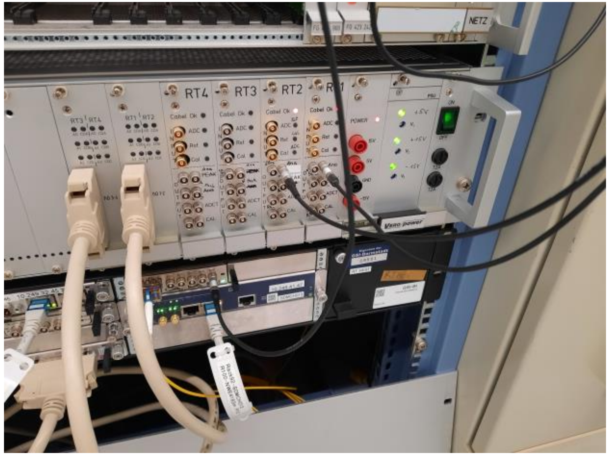


Motivation

- **Existing GSI DAQ**
  - **Old, outdated and unreliable**
  - Delivers only digital charge value based on peak detector in front-end amplifier;
  - No monitoring outputs
  - No raw signal acquisition; unknown data quality

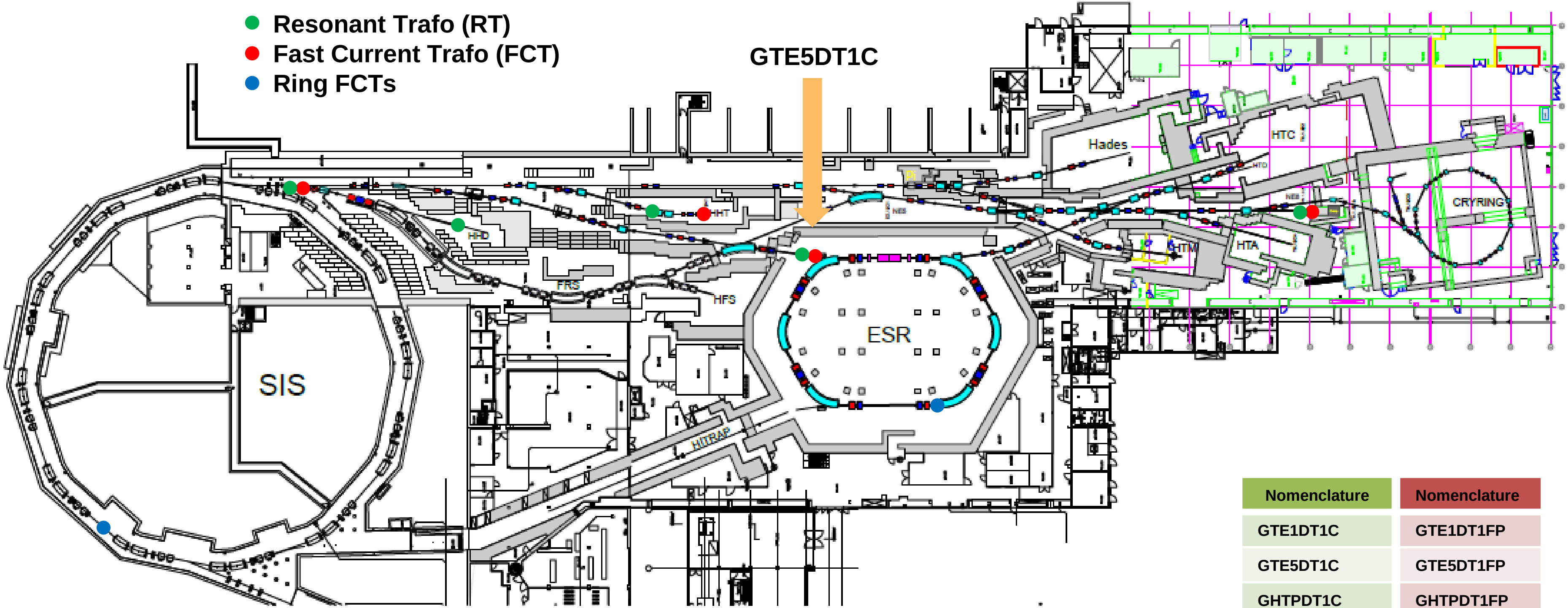
30 years →

- **New amplifier & DAQ system acc. to FAIR standard**
  - New head amplifier: 5 ranges (1 nC – 10 µC), full scale output = +/- 2 V
  - External calibration hardware (injection in dedicated windings)
  - 4 channel connector box
  - µTCA crate with CPU, 100 MSa/s 14 bit ADC (+/-5 V, 0.5 V, 50 mV), IO-board, FTRN timing receiver
  - Software: FESA class with standard interfaces (LSA, saft-lib, etc.)
  - FAIR: ES(6 RTs), FS(8), FS+(0), FS++(4), MSVC(8)



Trafos FCT & RT @GSI HEST

Status 2025



Nomenclature	Nomenclature
GTE1DT1C	GTE1DT1FP
GTE5DT1C	GTE5DT1FP
GHTPDT1C	GHTPDT1FP
GHHDDT1C	
GHHTDT6C	GHHTDT7FP

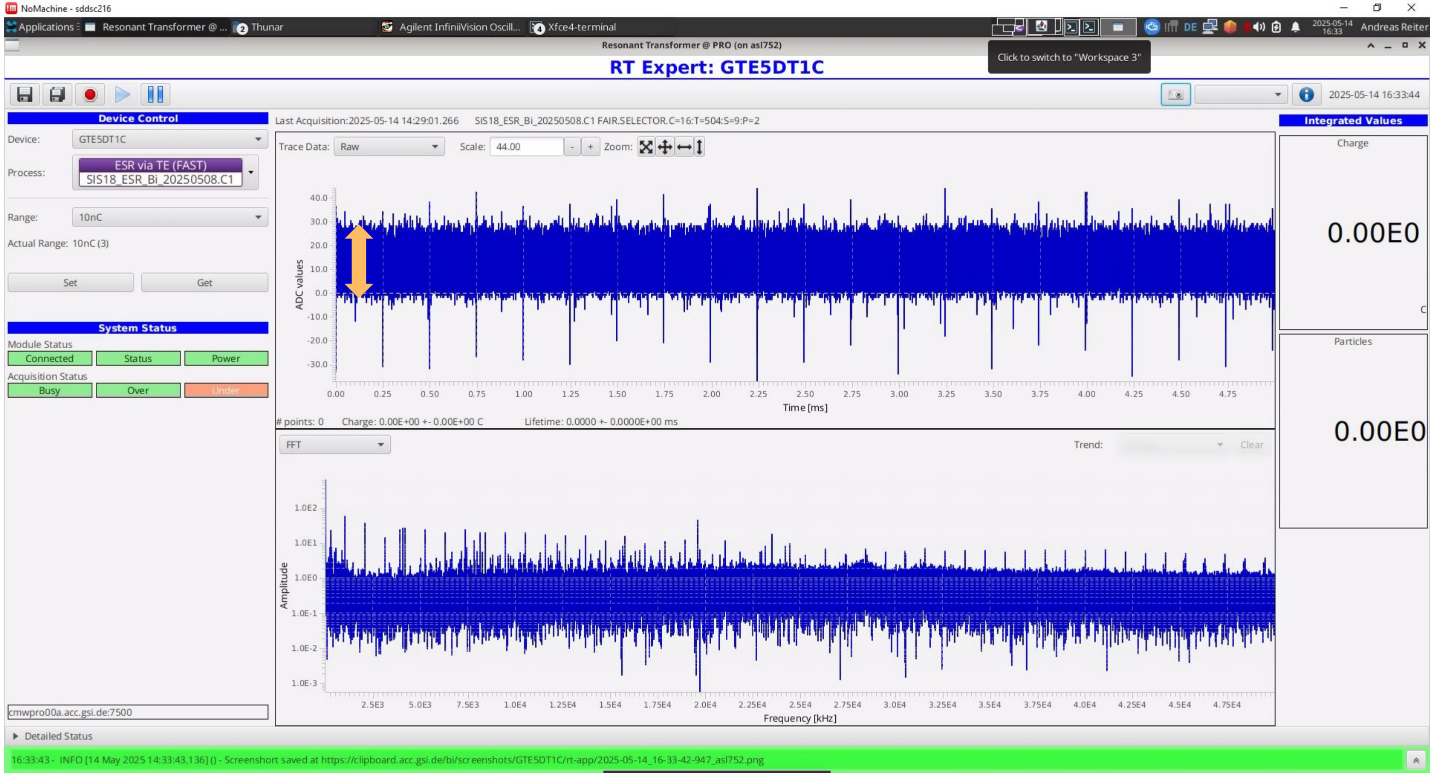
GTE5DT1C
Commissioning measurements 2025

- Measurement programme
  1. Noise level (with/without beam, i.e. machine cycle)
  2. System response
  3. Range check
  4. Minimum detectable signal

1. Noise level
No beam – ADC data & FFT, R = 10 nC

ADC input:
30 MHz analoge bandwidth
+/- 5 Volt at 14 bit
1 ADC unit = 0.6 mV

- Full ADC bandwidth:
  Noise level ~ 18 mVpp
- Some 4 kHz distortion from hardware power supply
- Added noise/distortion during some experiments due to magnet power supplies, etc. (10 – 100 kHz)

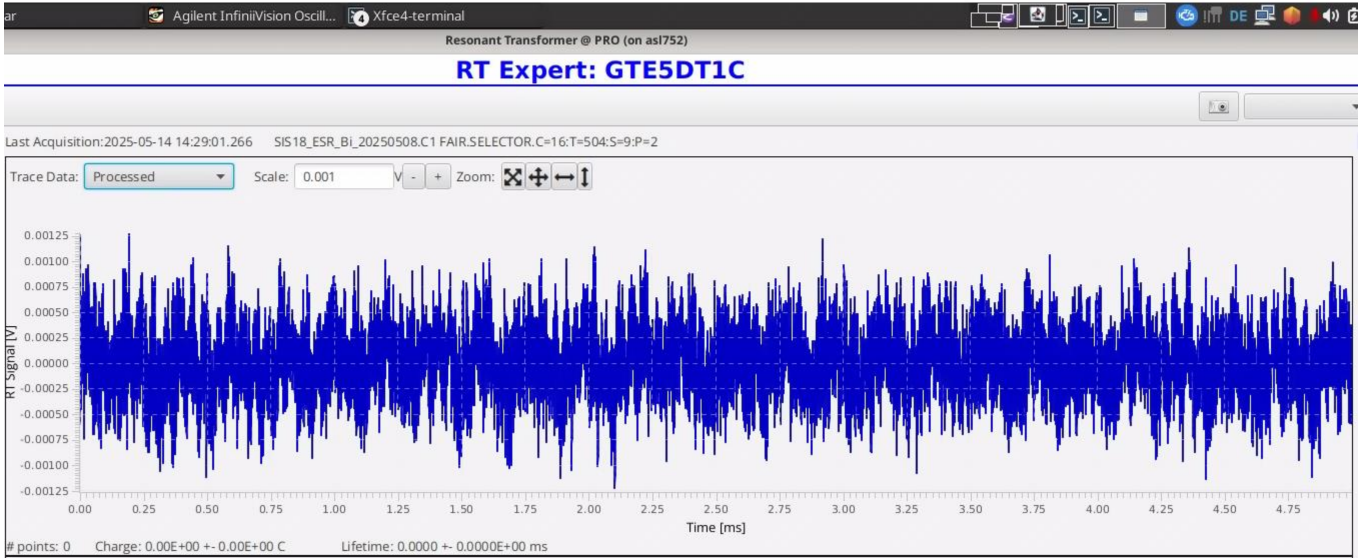


1. Noise level

No beam – Processed data, R = 10 nC

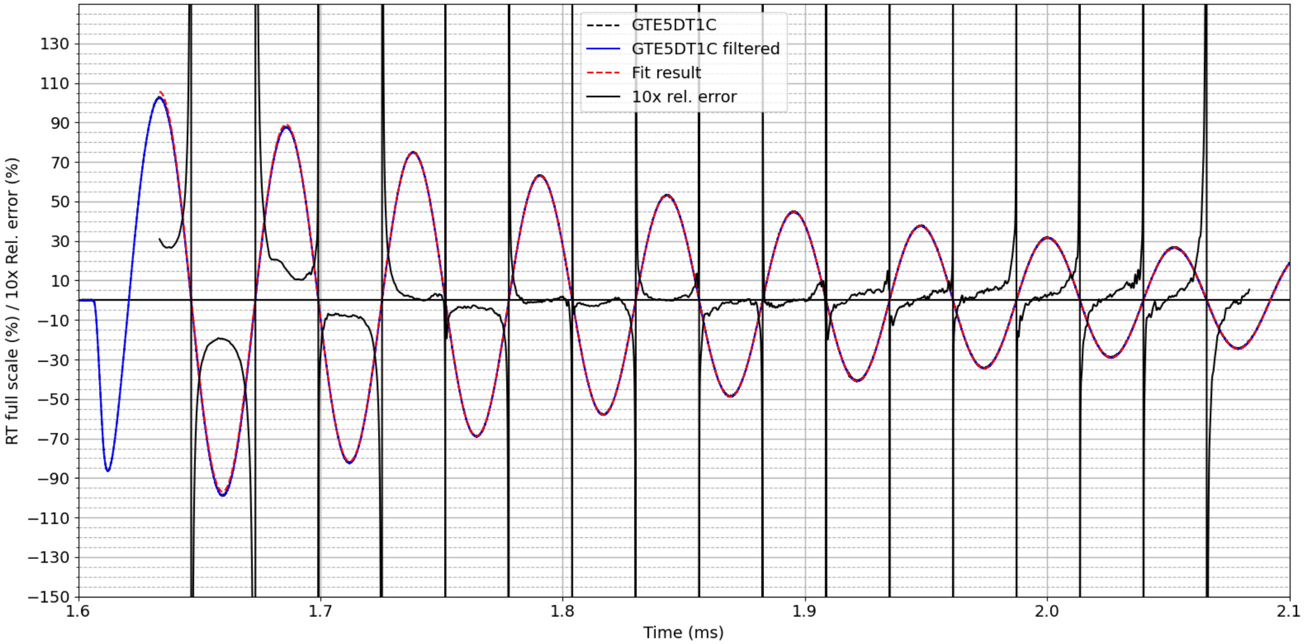
- Data processing involves conversion to voltage signal and frequency filter
- DC offset eliminated in FFT
- Frequency filter: cut at 1 MHz in FFT

- Result 1: effective noise level (under ideal conditions)
  - V = +/- 1 mV
  - Vpp = 2 mV



2. System Response
RT oscillation – comparison to theoretical RLC model

RT response to beam excitation is a damped oscillation at ~ 20 kHz and decay time constant given by inductance L and total loss R.
Some ~3% deviation at start of RT response (1st period). Measured response in good agreement with theory.



Result 2: Measurement system (RT sensor, amplifier, cable transmission, connector box, ADC) seems to work correctly.

3. Range check
1 nC beam, R = 1 nC

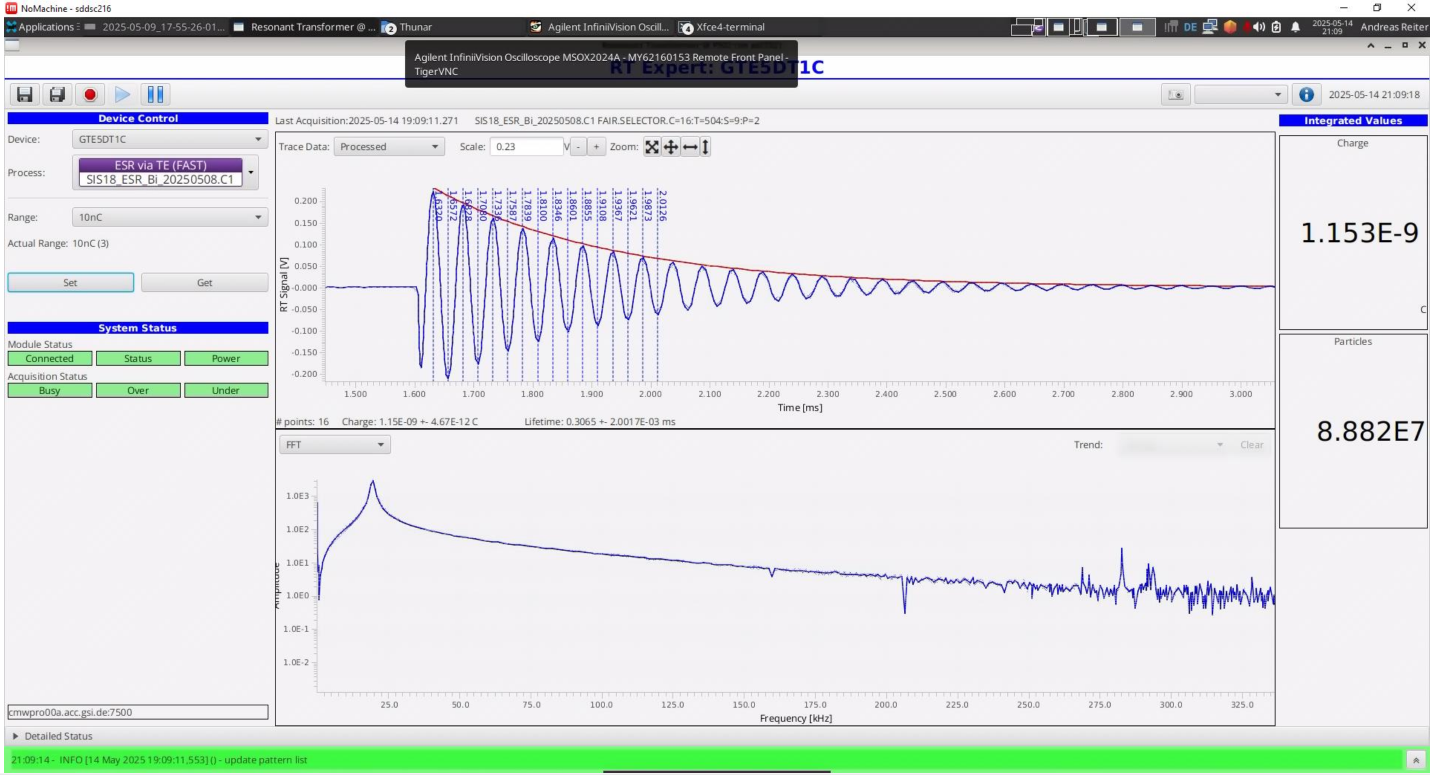
- Expected amplitude ~ 2.0 V

- Software analyses several maxima and minima to calculate total charge
- Processed data: DC excluded and upper limit 1 MHz
- Amplitudes are extracted from a P2 fit around the maximum position
- Max. no. of extrema used: 30
- If signal falls below a threshold, the peak search is stopped.

- The resulting amplitude envelope is shown as red line on top of the processed data.

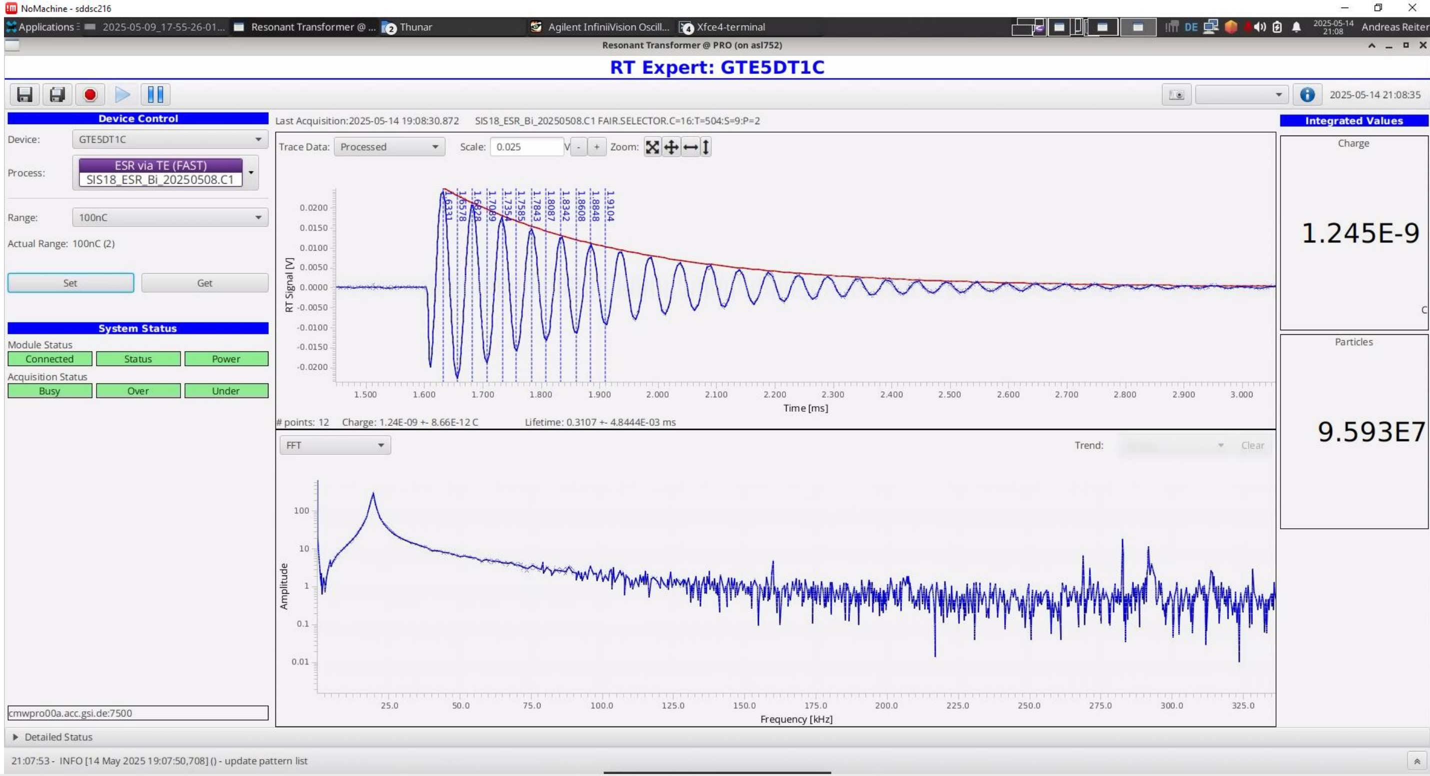
3. Range check
1 nC beam, R = 10 nC

- Expected amplitude ~ 0.2 V



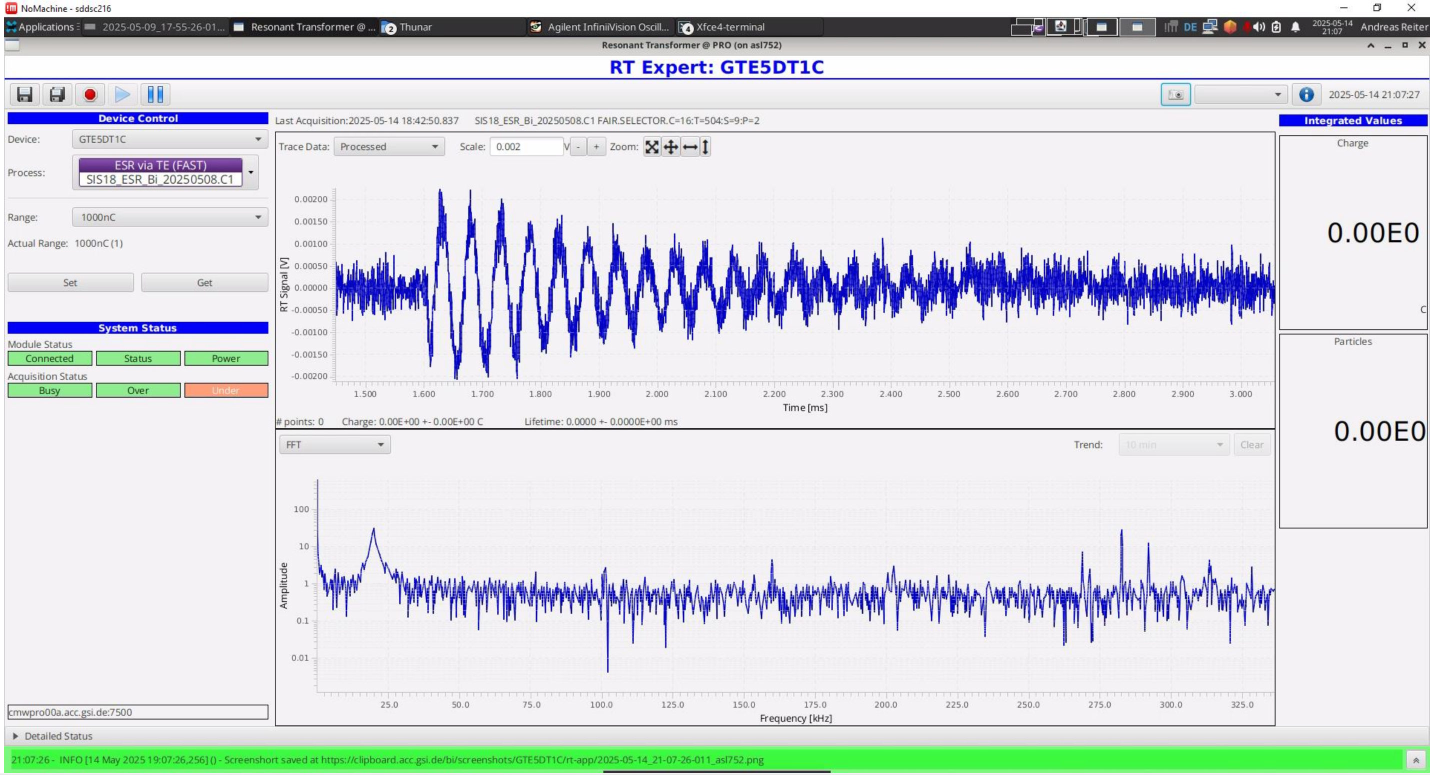
3. Range check
1 nC beam, R = 100 nC

- Expected amplitude ~ 0.02 V
  = 20 mV



3. Range check
1 nC beam, R = 1000 nC

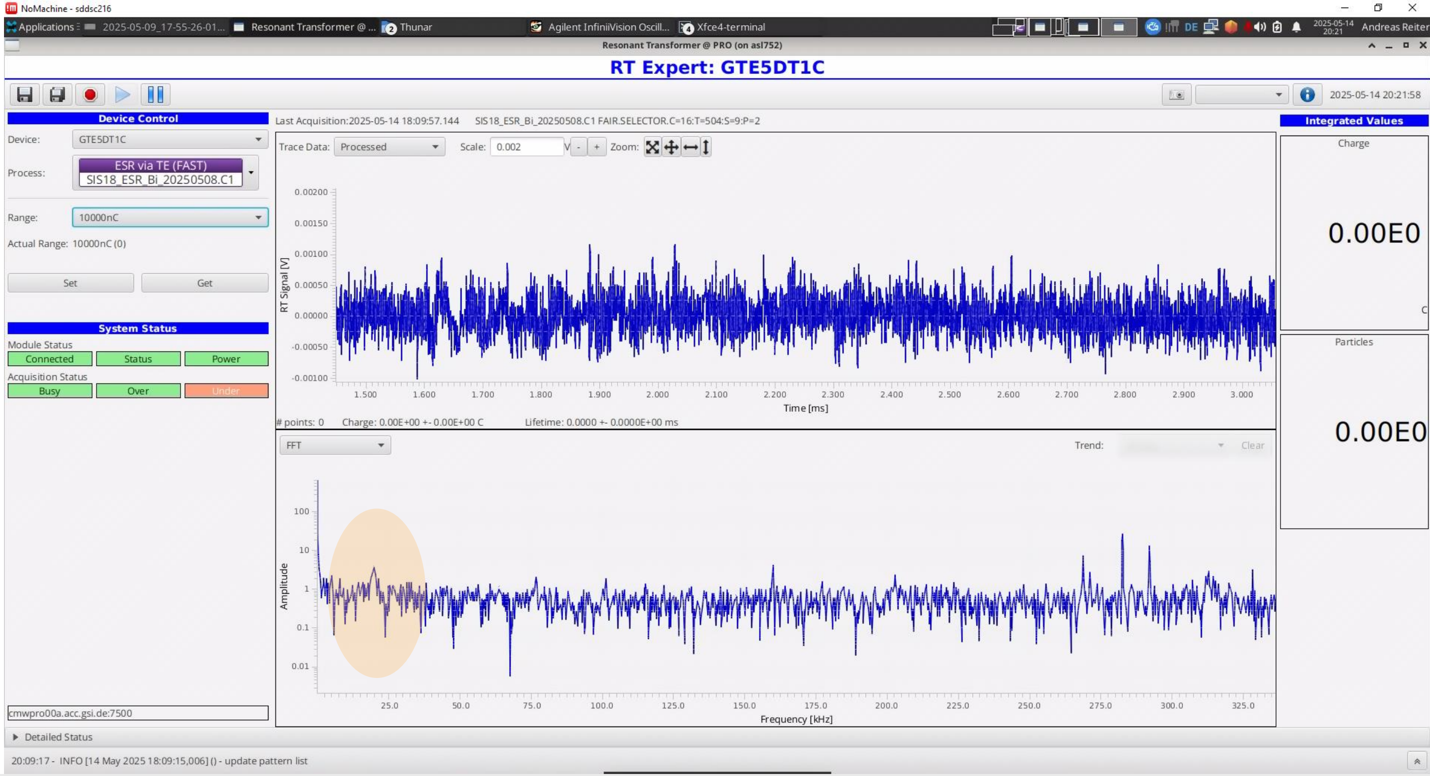
- Expected amplitude ~ 0.002 V
  = 2 mV



3. Range check

1 nC beam, R = 10.000 nC

- Expected amplitude ~ 0.0002 V
  = 0.2 mV



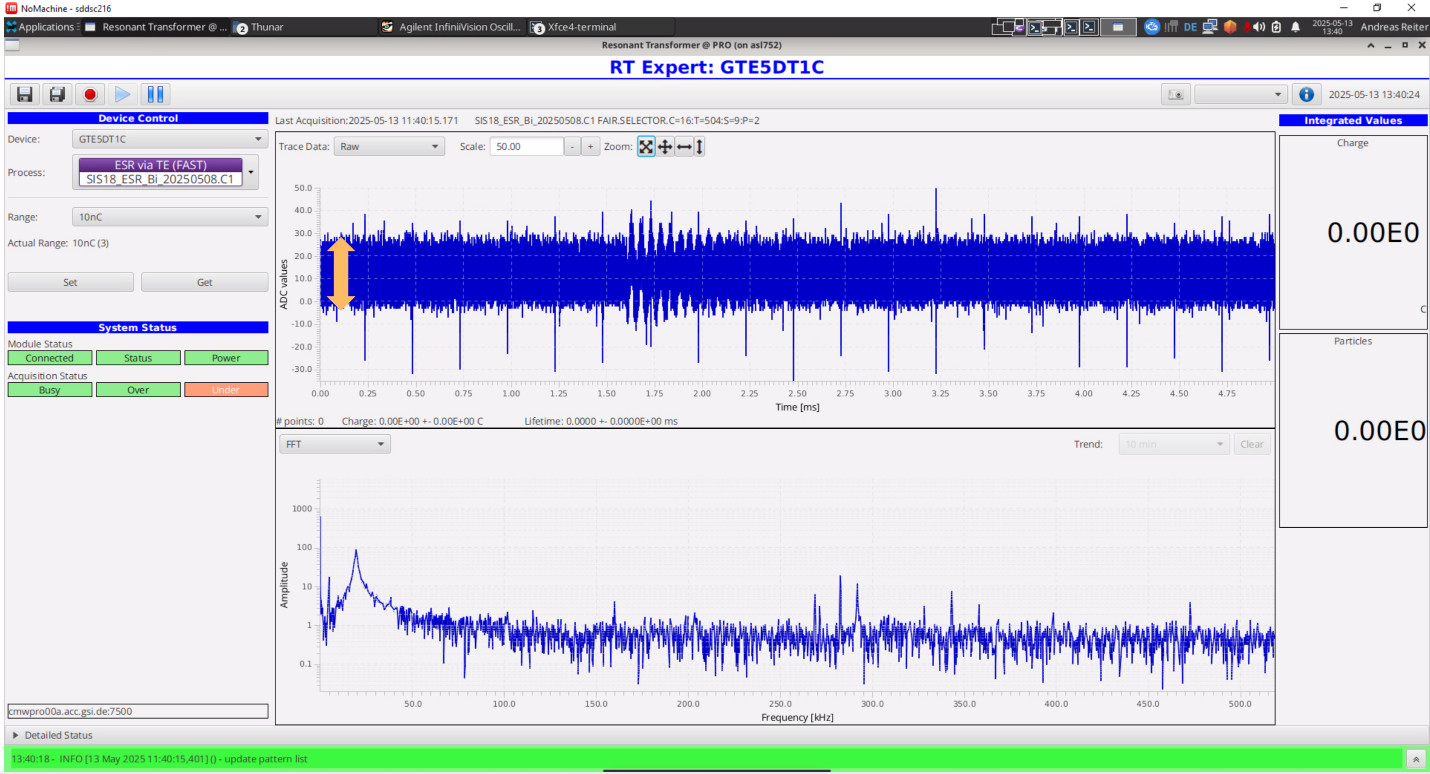
- No observable ADC signal

- Tiny peak around RT oscillation frequency

4. Minimum detectable signal

ADC spectrum – raw data (5 ms), R = 10 nC

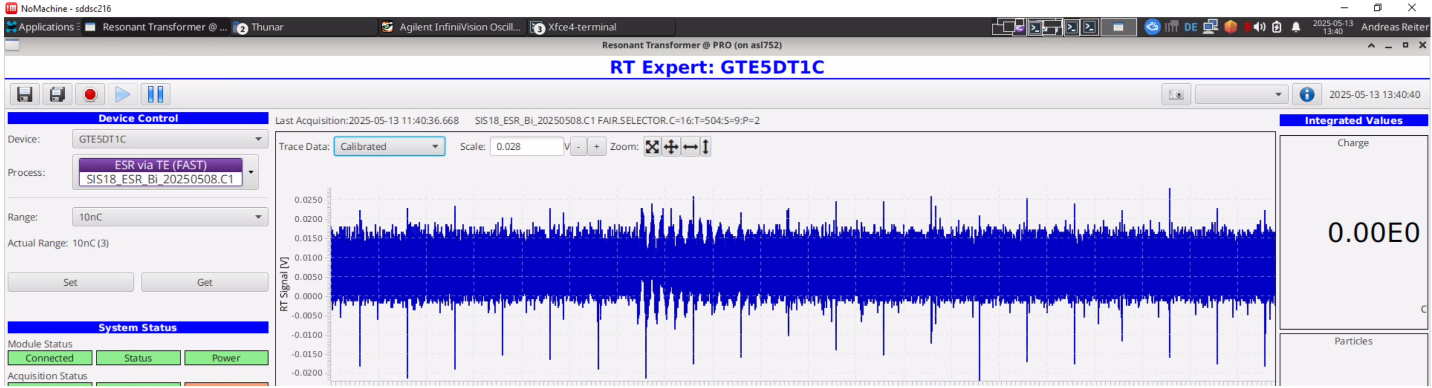
- ADC spectrum shows a weak oscillation and some 5 kHz noise
- FFT spectrum up to 500 kHz



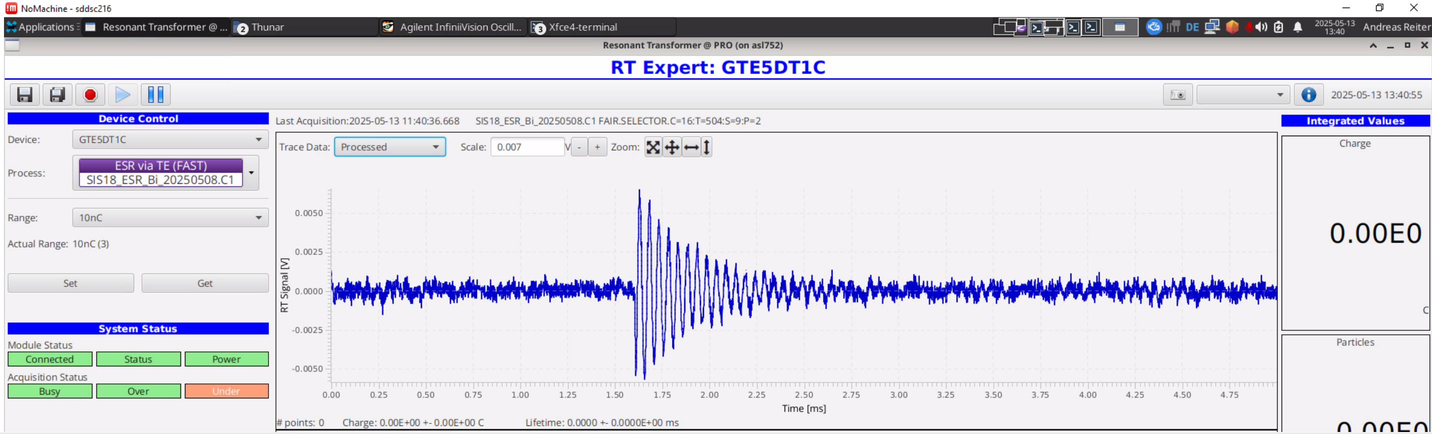
4. Minimum detectable signal

ADC spectrum – processed data (5 ms), R = 10 nC

- Voltage signal



- Processed data after filtering

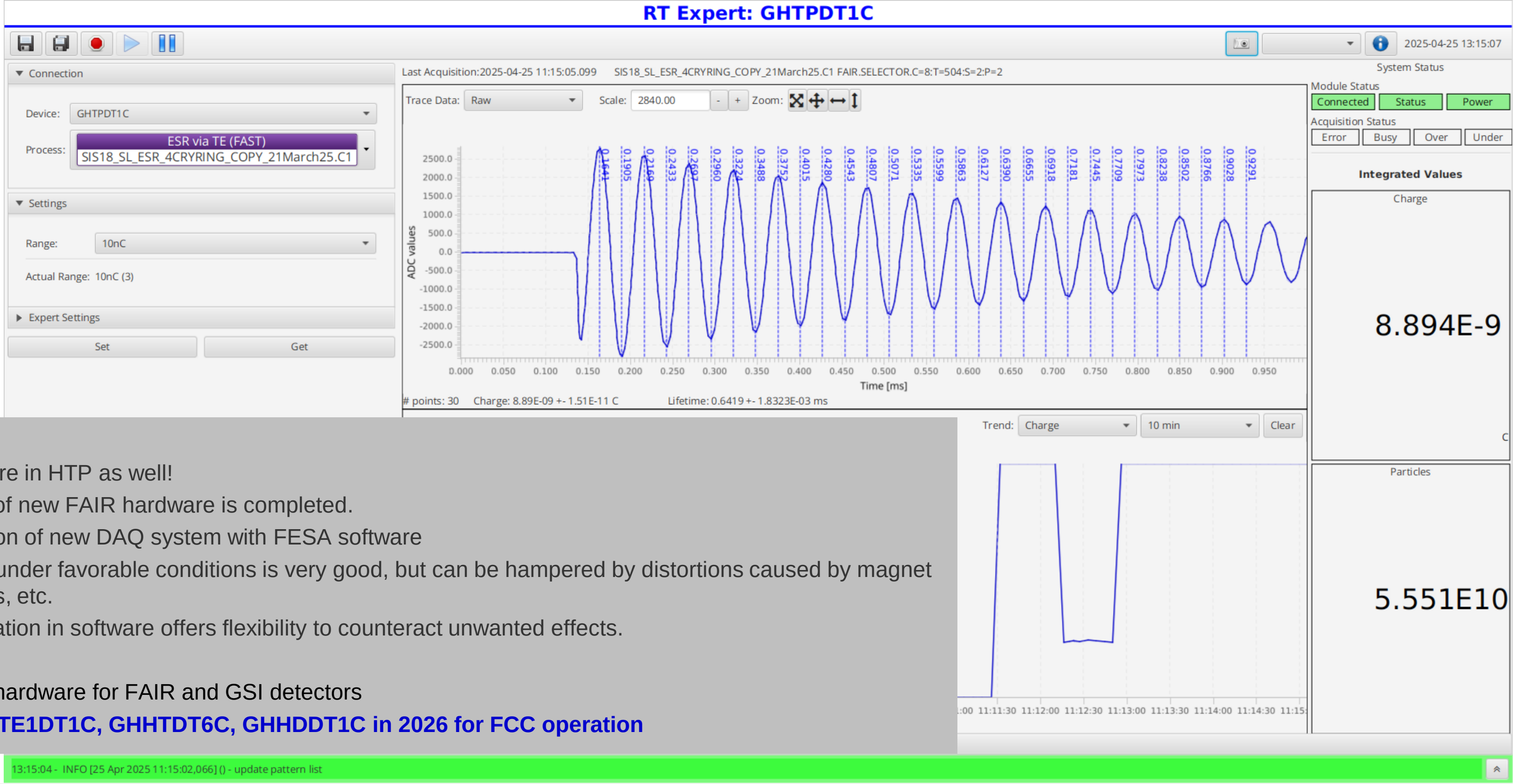


4. Minimum detectable signal
Processed data – t = [1.6, 2.7] ms, R = 10 nC

- Oscillation of 5 mV amplitude is clearly detectable
- S/N ~ 4 (S = amp, N = Vpp)

- Result 4: Estimate for minimum signal:
  ~2 mV ~1E-3 full scale
  ~10 pC for 10 nC range

Summary
RT Development



- **Results:**
  - We did measure in HTP as well!
  - Development of new FAIR hardware is completed.
  - Stable operation of new DAQ system with FESA software
  - Signal quality under favorable conditions is very good, but can be hampered by distortions caused by magnet power supplies, etc.
  - Charge calculation in software offers flexibility to counteract unwanted effects.
- **Next steps:**
  - Production of hardware for FAIR and GSI detectors
  - **Upgrade of GTE1DT1C, GHHTDT6C, GHHDDT1C in 2026 for FCC operation**