A Liquid Metal Backward Facing Step Experiment: Facility, Instrumentation and what to Expect

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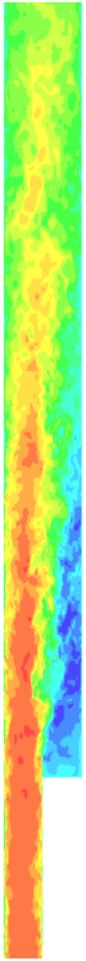
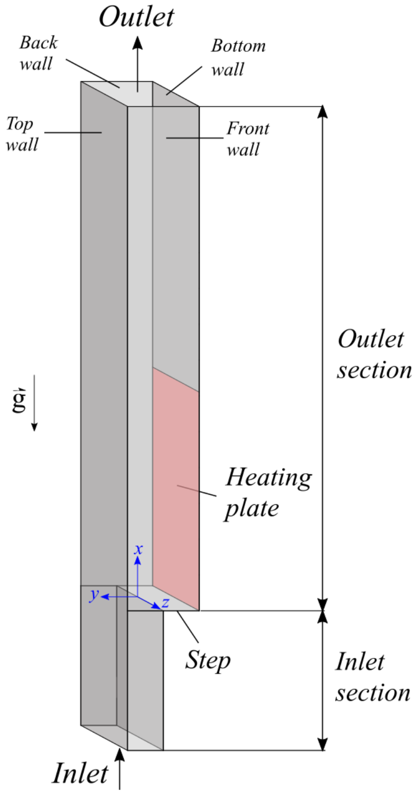
Outline of this presentation

- Motivation: why a liquid metal backward facing step experiment?
- Presentation of the DITEFA 2 facility and its instrumentation
- Measured data / data to be expected
- Outlook and further work: warning!

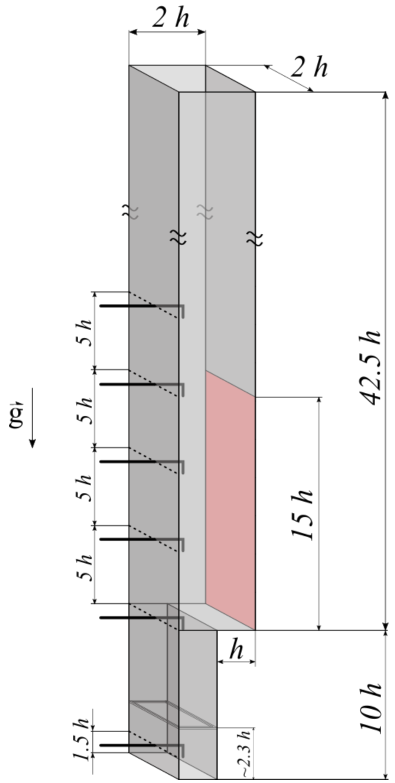
Why a backward facing step?

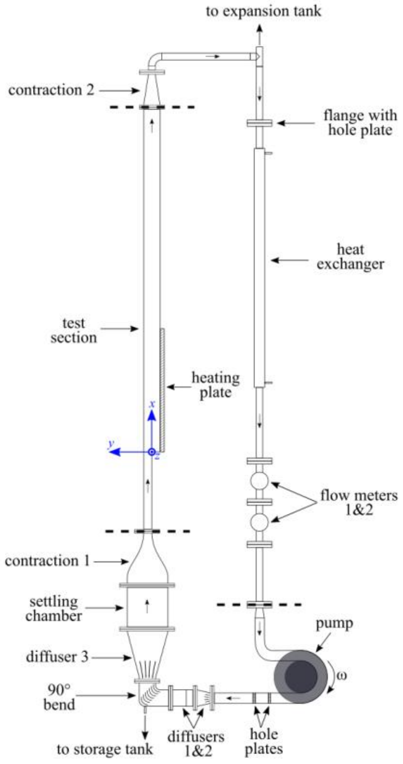
- Original motivation: to test calculation (prediction) methods under strong perturbations or non-equilibrium conditions (strong enough to invalidate boundary layer theory)
- „Nowadays“: (almost) all-flows-in-one kind of geometry for single phase flow
  - Wall bounded flow
  - Mixing layer
  - Recirculation regions
  - Dettachment/Reattachment
  - Secondary motions of the second kind (if confined)
  - Buoyancy effects (if heated)
- Logic: good results in a BFS, not bad chances of not brutally missing engineering applications (in a qualitative sense)



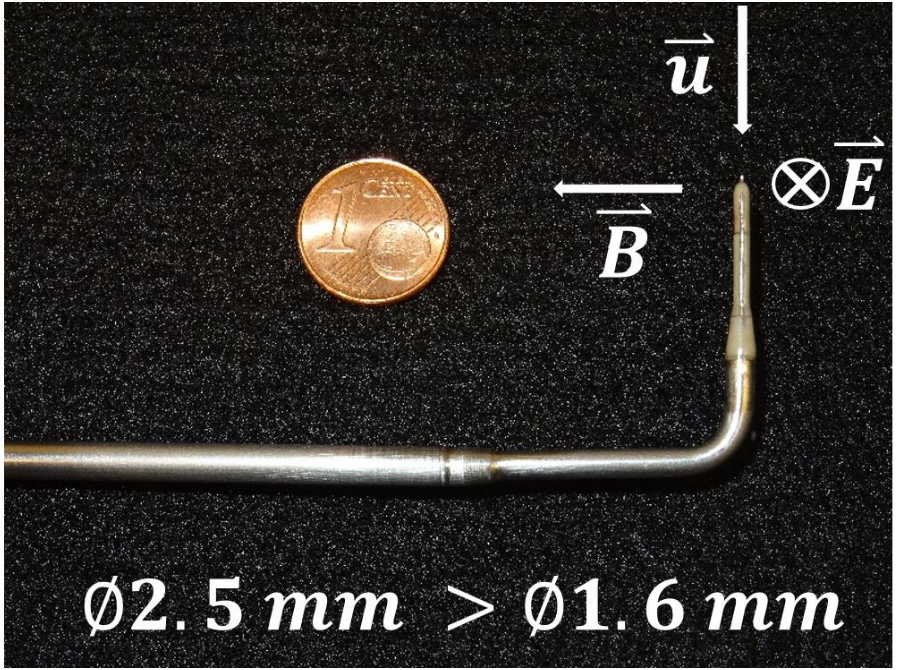


DITEFA 2 facility and its instrumentation

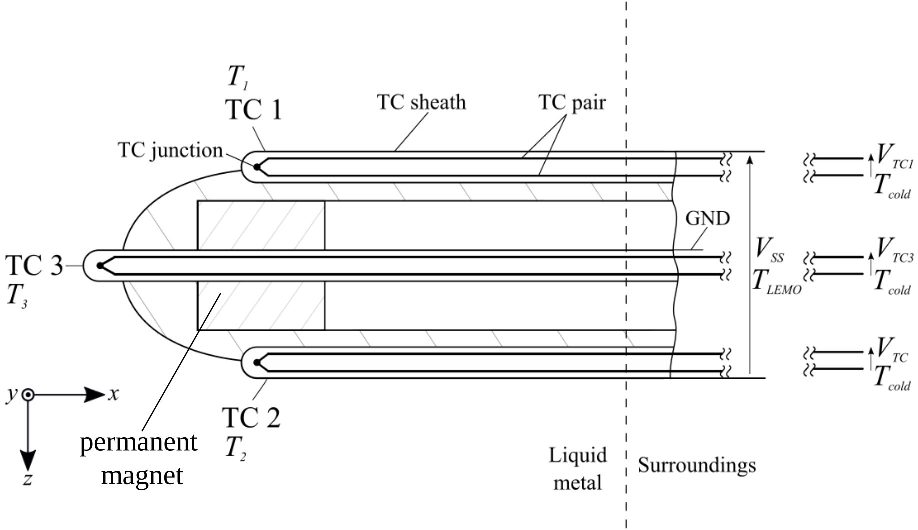




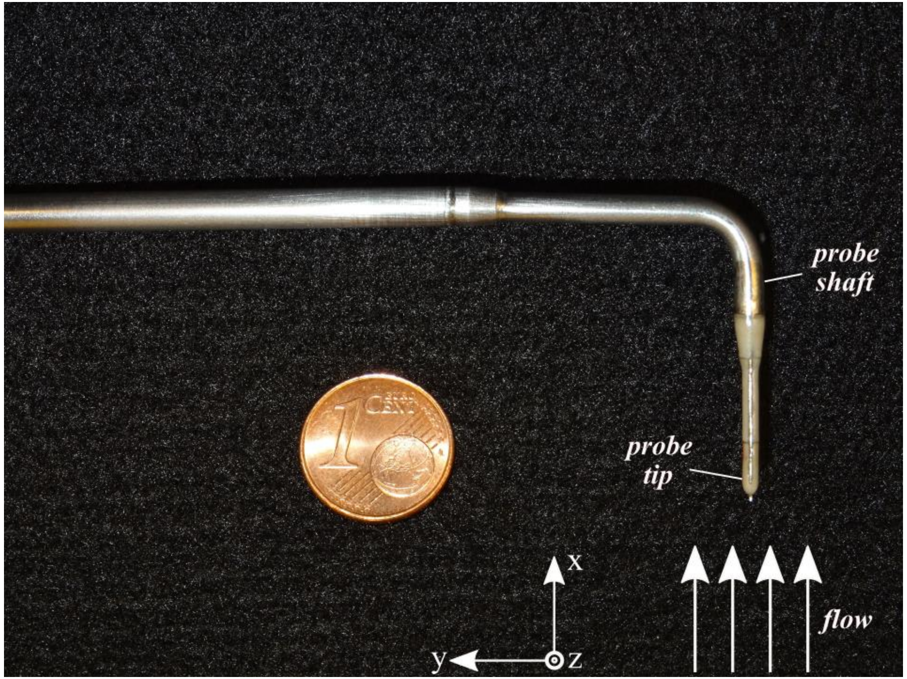
DITEFA 2 facility and its instrumentation

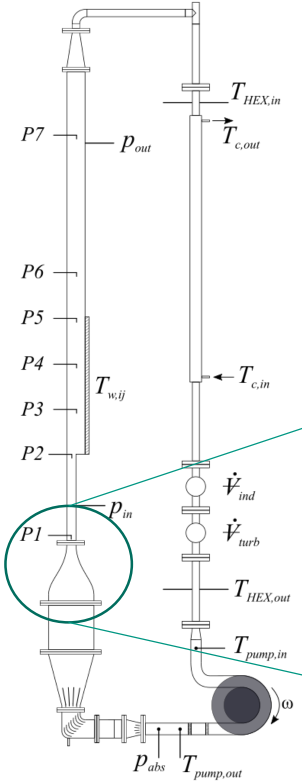


Velocity signal measured over the thermocouple (TC) sheath



DITEFA 2 facility and its instrumentation

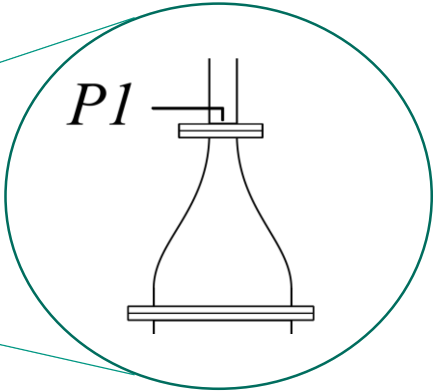




calibration

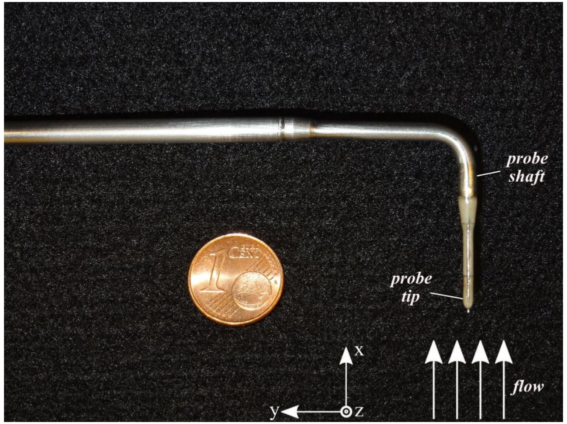
⇩

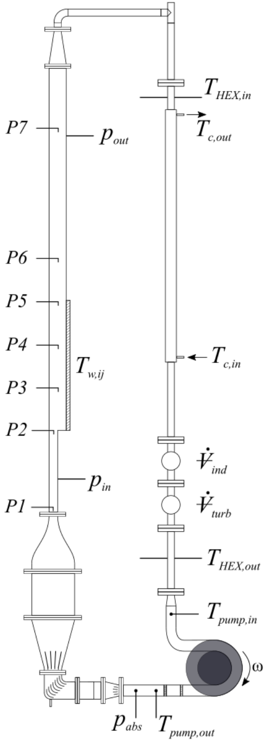
$$U_{bulk} = \frac{\dot{V}}{A}$$

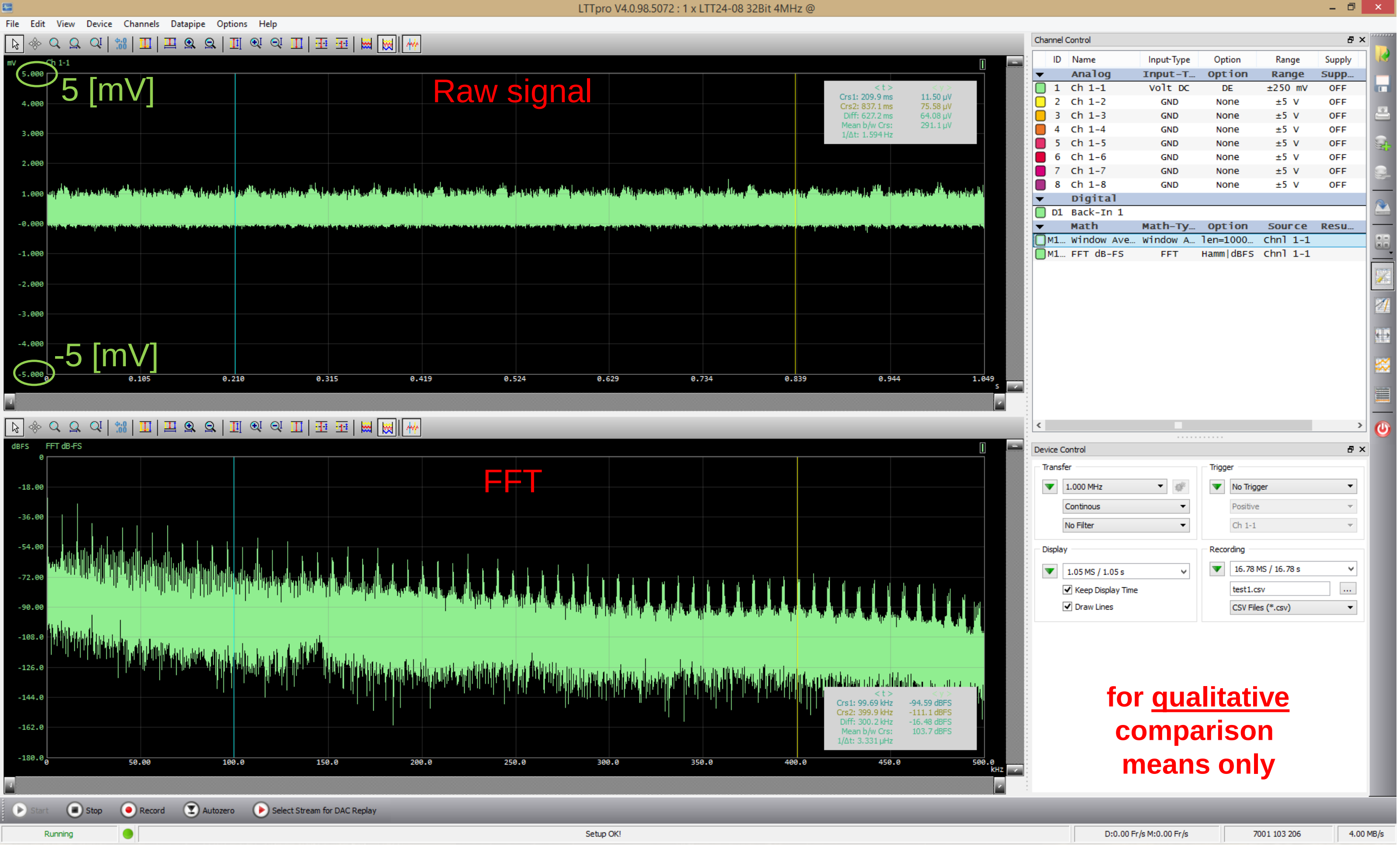


DITEFA 2 facility and its instrumentation

- Noise/drift level problems of permanent magnet probe:
  - Frequency converter (FC) / variable frequency drive
  - Ambient noise (hall heaters, sun, hall air circulation)
  - Power line (not optimum)
  - Grounding of thermoelectric-cable



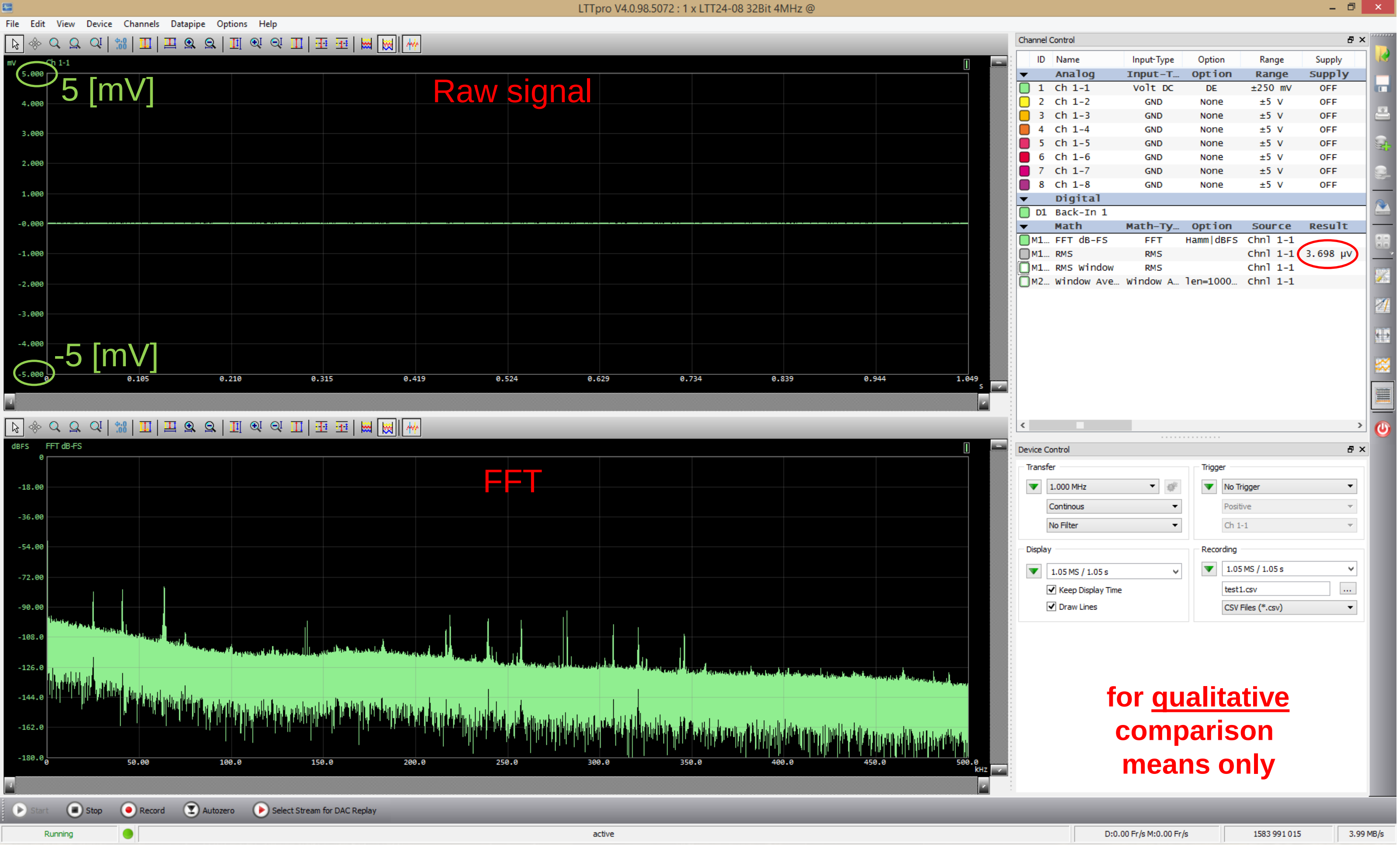




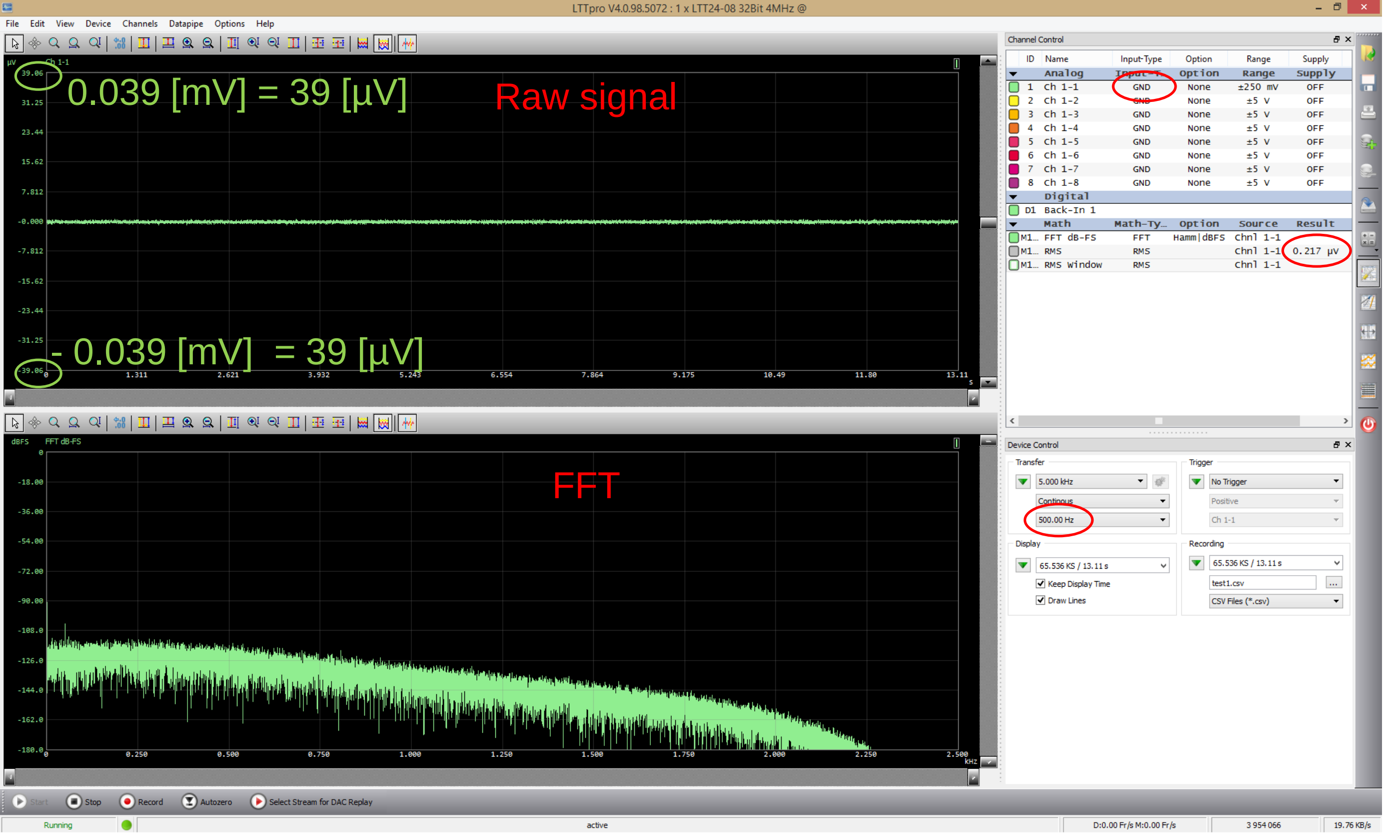
FC: on

Pump: 200 rpm

Starting point



FC: on
Pump: 200 rpm
After measures
High Sampl. R.
No filters



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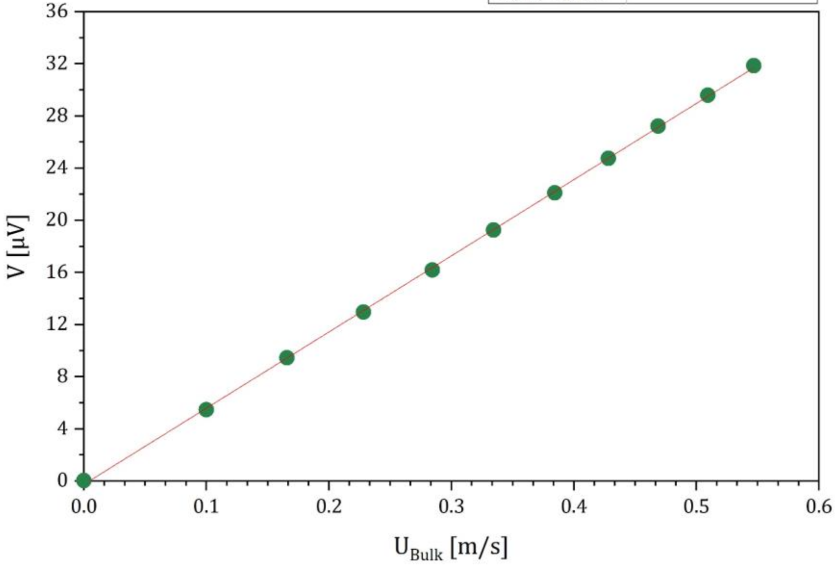
can be better, but we prefered better thermal drift capabilities

$$n_{RMS} = \sqrt{\frac{f_{cutoff}}{10}} \cdot n_{DC,10Hz} = \sqrt{\frac{500\ [Hz]}{10\ [Hz]}} \cdot 0.035\ [\mu V] = 0.247\ [\mu V]$$

DITEFA 2 facility and its instrumentation

- Calibration curve
- Absolute signals in the order of $V \sim 10[\mu V]$, i.e., signals 100 times smaller than thermocouple signals

Intercept	-0.24784 ± 0.09528
Slope	58.43701 ± 0.26789
Adj. R-Square	0.99979



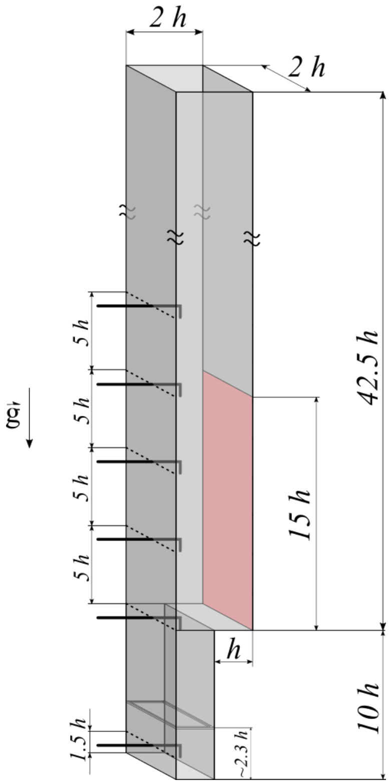
order of magnitude estimation!

$$S_{th} = 54.9 \left[\frac{\mu V}{m/s}\right]$$

$$S_{exp} = 58.4 \left[\frac{\mu V}{m/s}\right]$$

Measured data / data to be expected

- Data to be expected
  - $\langle u \rangle$ profiles
  - Nu distribution along the heating plate
- $10000 < Re_h = \frac{U_b \cdot h}{\upsilon} < 30000\ (\ldots 75000 \ldots)$
- $0.005 < Ri_h = \frac{g\beta\Delta T h}{U_b^2} < 0.2$, with $\Delta T = \frac{\dot{q}h}{\lambda}$, i.
- Measurement uncertainty for $\langle u \rangle$ with a 95% confidence interval
  - P1<5%, P2<3.5%, P3<11%, P4<27%, P5<16%, P6<6%



Outlook and further work

- Postprocess the data
- Uncertainty calculations/analysis
- Publish papers/dissertation: honest report considering all limitatations the results may contain
- Future PhD Student
  - Install a heating plate with more thermal power (to achieve higher Richardson (... and Reynolds...) numbers).
  - Install a new heat removal system and/or a heat storage system as a system temperature fluctuation damper.
  - Improve inlet boundary conditions (they are good, but you can always improve).
  - Measurement of $\langle T \rangle$-, $\langle T'^2 \rangle$- and $\langle u'^2 \rangle$-profiles $\langle u'T' \rangle$ (all possible with current instrumentation, but not the actual system setup (heat removal system + wiring of the involved thermocouples).
  - Perform spectral and wavelet analysis for u' and T'.