

Development of a (sub-)Picoamperemeter for high voltage application

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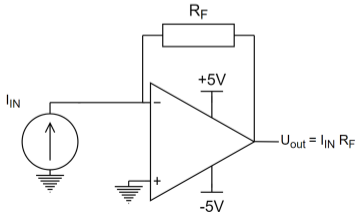
- ▶ Motivation
- ▶ Design
- ▶ Calibration measurements
- ▶ Summary and outlook

- ▶ What are the spAms used for?
 - ▶ Measurement of currents in pico ampere range (e.g. GEMs)
 - ▶ Quality control of GEM foils
- ▶ What are the requirements for the spAms
 - ▶ Usable at high voltages up to 6kV
 - ▶ Wireless communication to keep floating ground
 - ▶ Temperature-independence
 - ▶ Multiple measurement ranges ($1\mu\text{A}$ - 1nA)
 - ▶ Can have internal resistance because GEMs are ideal current sources

FRONTEND CIRCUIT

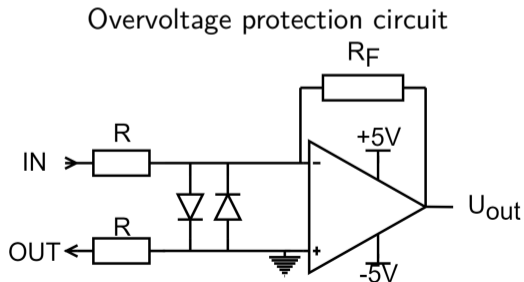
- ▶ Amplification circuit
 - ▶ Transimpedance amplifier
 - ▶ Multiple resistors R_F for different measurement ranges
 - ▶ Overvoltage protection for the OPamp

Transimpedance amplifier



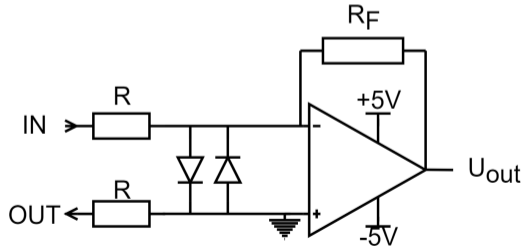
OVERVOLTAGE PROTECTION

- ▶ Use of NPN transistors instead of diodes
- ▶ Transistors have been shown to have lower leakage currents
- ▶ Two $100\text{k}\Omega$ resistors to limit current through transistors

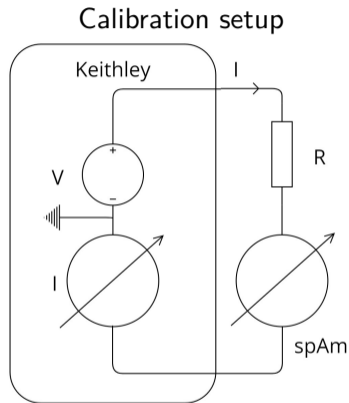


MEASUREMENT RANGES OF THE SPAMS

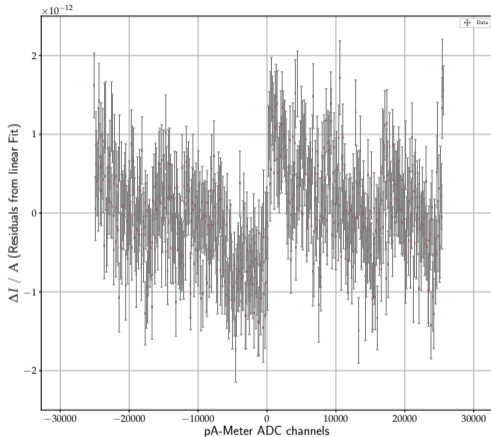
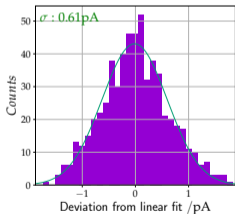
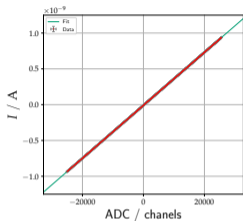
Resistance R_F	Measuring range	Resolution (LSB)
5G Ω	$\pm 1\text{nA}$	$\pm 38\text{fA}$
500M Ω	$\pm 10\text{nA}$	$\pm 380\text{fA}$
50M Ω	$\pm 100\text{nA}$	$\pm 3.8\text{pA}$
5M Ω	$\pm 1\mu\text{A}$	$\pm 38\text{pA}$



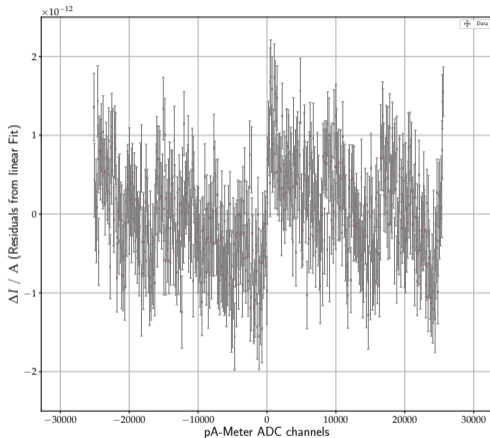
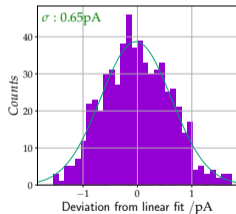
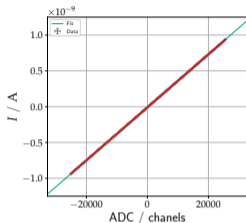
- ▶ Calibration via Keithley Modell 6517B
 - ▶ Keithley delivers voltage between ± 1 V
 - ▶ Pick a resistance so voltage drops to ± 0.04 V
 - ▶ Resistance is chosen so whole range is calibrated



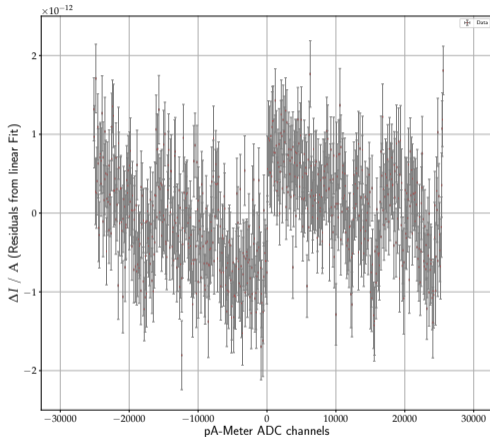
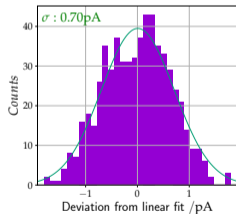
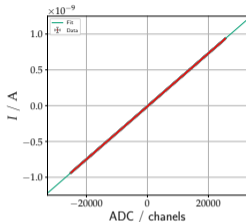
TEMPERATURE CALIBRATION FOR 20°C



TEMPERATURE CALIBRATION FOR 25°C

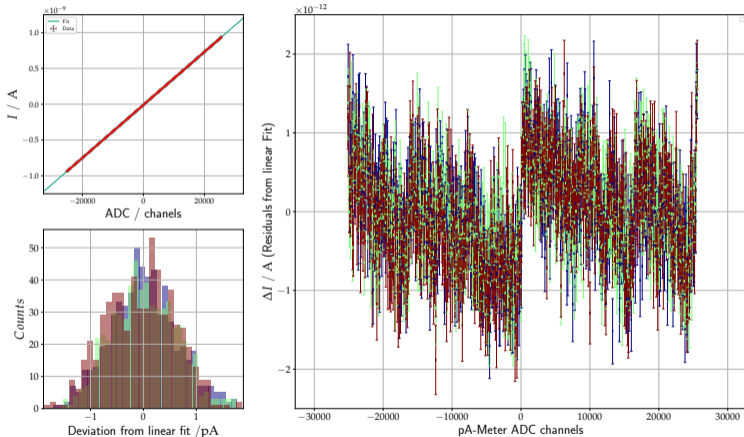


TEMPERATURE CALIBRATION FOR 30°C

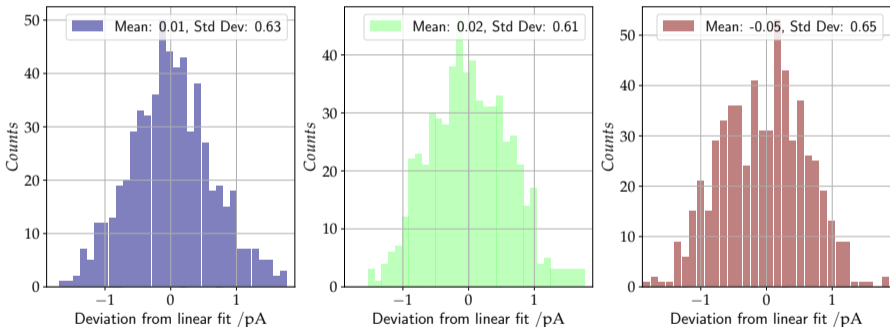


TEMPERATURE CALIBRATION OVERLAYED

20°C Blue, 25°C Green, 30°C Red



Residuals of temperature calibration



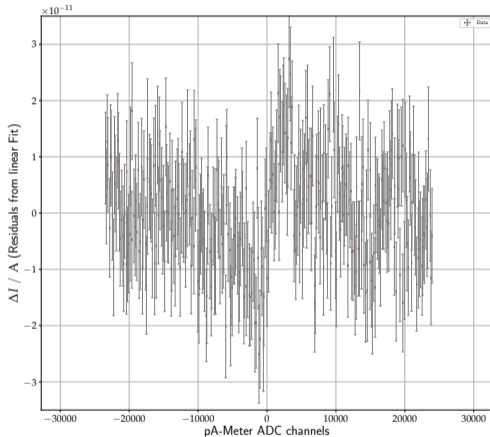
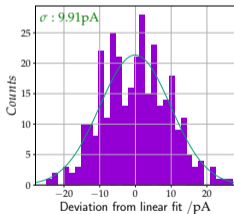
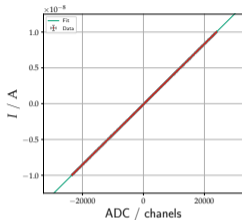
SUMMARY AND OUTLOOK

- ▶ Uncertainty of roughly ± 0.6 pA
- ▶ No temperature dependency
- ▶ Switch power supply
 - ▶ spAms require up to one batterie a day
 - ▶ Radio module requires the most power
- ▶ Extend design to allow multiple channels on one board
- ▶ Build spAms with different ranges
 - ▶ Preferred range of ± 10 μ A
 - ▶ Ranges this high cause problems with calibration
- ▶ No discharge protection studies have been performed yet

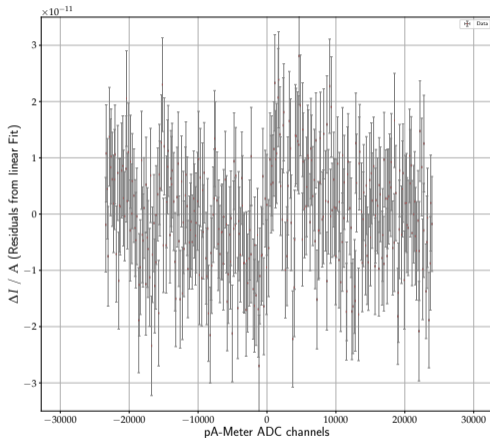
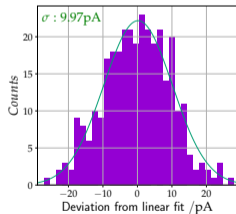
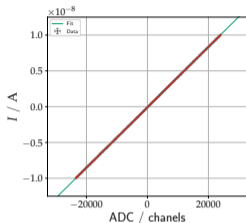
Thank you for listening

Backup

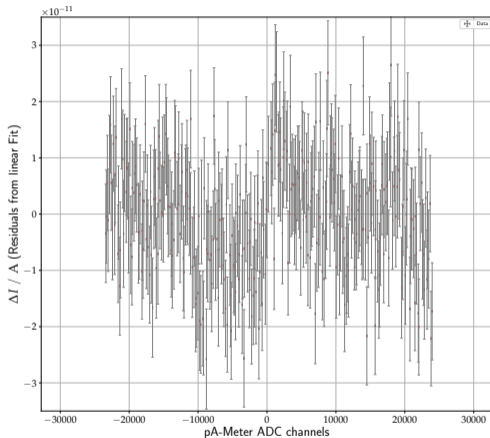
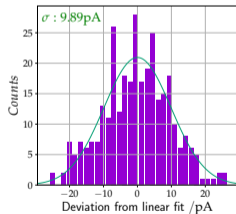
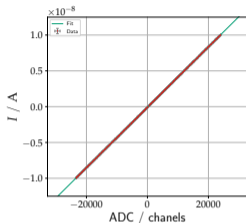
TEMPERATURE CALIBRATION 20°C



TEMPERATURE CALIBRATION 25°C

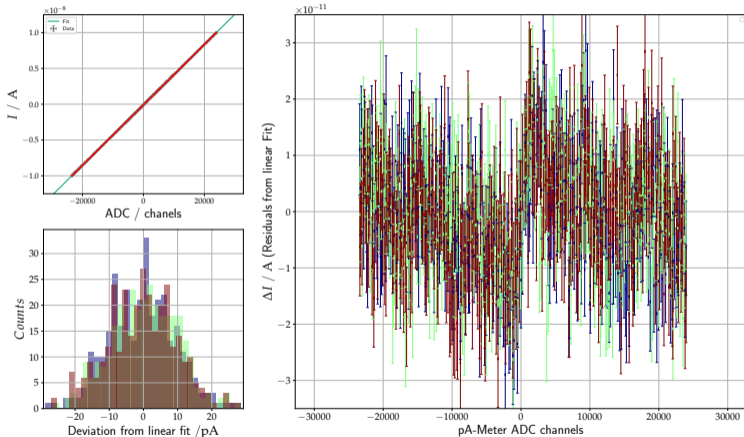


TEMPERATURE CALIBRATION 30°C



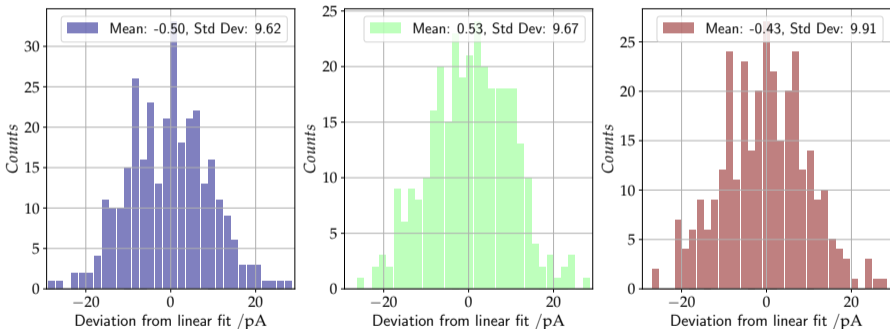
TEMPERATURE CALIBRATION OVERLAYED

20°C Blue, 25°C Green, 30°C Red



TEMPERATURE CALIBRATION SIDE BY SIDE

Residuals of temperature calibration



CALIBRATION RESULTS

Mode	Range	Uncertainty
0	$\pm 1\mu\text{A}$	$\pm 0.52\text{ nA}$
1	$\pm 100\text{nA}$	$\pm 0.1\text{ nA}$
2	$\pm 10\text{nA}$	$\pm 5.22\text{ pA}$
4	$\pm 1\text{nA}$	$\pm 0.61\text{ pA}$