THMP̄ and Temperature Sensor Production

Miriam Kümmel

Ruhr-Universität Bochum
Institut für Experimentalphysik I

P̄ANDA-Collaboration Meeting 18/2
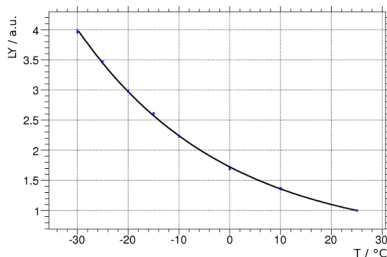June 2018

Why and how do we Measure Temperatures?

PWO-II: LY depends on T with $\frac{d(LY)}{dT} = 3\,\%/°C$ at $20\,°C$

- Goal for $\overline{P}$ANDA: $\Delta T < 0.1\,°C \rightarrow$ sensors with $\sigma_T < 0.02\,°C$
- R vs T relation of platinum quite linear

$$R(T) \approx R(0\,°C)(1 + \alpha_{Pt} \cdot T), \quad \alpha_{Pt} = 3.89 \cdot 10^{-3}K^{-1}$$

- Accuracy for temperature sensors translates to accuracy for R measurement with the THM$\overline{P}$: $\sigma_R \approx \frac{\partial R(T)}{\partial T} \cdot \sigma_T \approx 7.8\,m\Omega$

2

Status of Temperature Sensor Production

- Need:
  - 482 temperature sensors designated for forward endcap
  - 1152 temperature sensors designated for barrel (72/slice)
    (Mainz is taking care of backward endcap)
- New Production Procedure:
  - Bought foils with
    - readily etched and covered wires
    - 5 cm increased length,
    - gold plated contacts,
    - and pre-punched shapes
  - Winding platinum wire with 3D-printer
- Status:
  - Produced 826 sensors dedicated for FE/Barrel
  - Regained 38 functioning sensors from prototype 192
  - Produced 43 long-wire sensors
  - ...of which 23 were winded by the printer

New Production Procedure

- Apply voltage to Pt wire
- → Current flows through Pt wire
- → Magnetic field is generated around Pt wire
- → Pt wire is pulled into position by magnetic field of magnet arrays
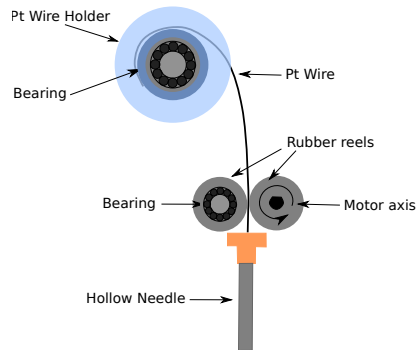- Store sensors in printed holder
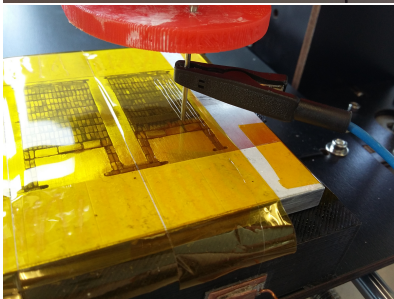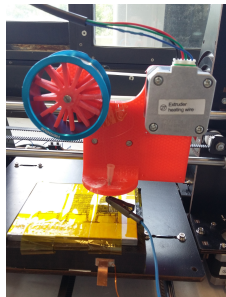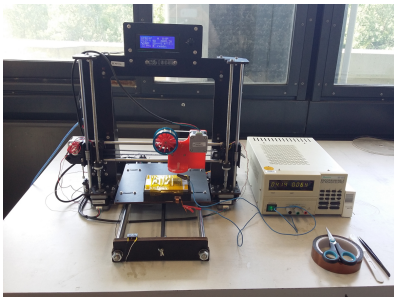
New Production Procedure

- 23 sensors with printed windings of which:
  - 2 torn apart at some point
  - 5 too low resistance
  - 3 too high resistance
- ! rolling wire off is an issue
- → use rubber reels to provide appropriate platinum wire supply "free" of force

Pt Wire Holder

Pt Wire

Bearing

Rubber reels

Bearing

Motor axis

Hollow Needle

Status of THM$\overline{\text{P}}$ Production

- Need:

Purpose	MBs	T-PBBs	p-PBBs
forward endcap	10	74	6
test slice	2	12	4
remaining slices	26	180	28
backward endcap	3	20	4
spare	5	35	5
total	46	321	47

- Status:
  - 15 fully equipped and tested THM$\overline{\text{P}}$-mainboards
  - 92 fully equipped and tested temperature sensor PBBs
  - 25 fully equipped and tested pressure/humidity sensor PBBs
  - $\rightarrow$ Remaining boards and components are ordered!

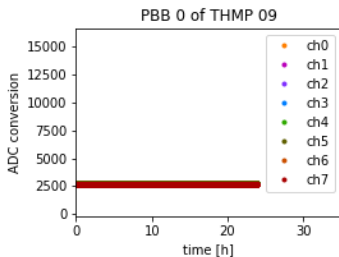## THMP̄ Calibration Procedure

- All readout channels connected to known fixed resistances by usage of dedicated calibration boards
- Vary THMP̄ temperature by means of a climate chamber
- → Temperature dependence is linear!
- Repeat measurement with all channels connected to other known fixed resistances
- Select temperature stable data, determine mean and standard deviation
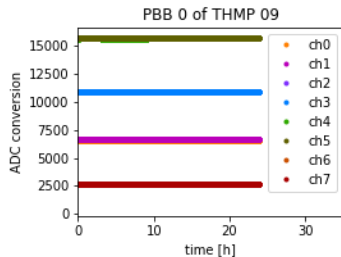- Fit $R(K, T) = p_{00} + p_{01}T + p_{10}R + p_{11}TR$ to the data
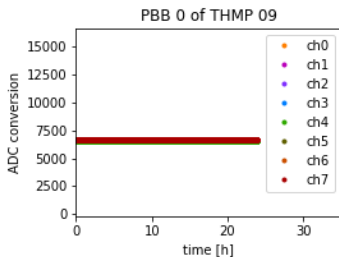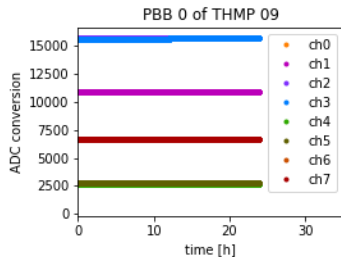

7

THMP̄ Calibration Procedure

- Production of calibration boards expensive
- → Use 2 kinds with different resistance values
- Each kind yields 4 different resistance values
- Original connecting scheme prone to cabeling errors
- New connecting scheme can be checked easilyi before the start of a measurement

Original scheme

New scheme

THMP̄ Calibration Procedure

- Production of calibration boards expensive
- $\rightarrow$ Use 2 kinds with different resistance values
- Each kind yields 4 different resistance values
- Original connecting scheme prone to cabeling errors
- New connecting scheme can be checked easilyi
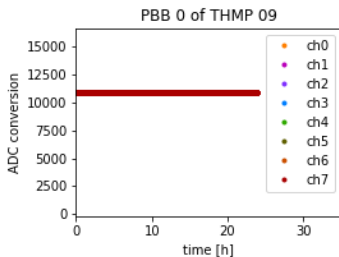 before the start of a measurement
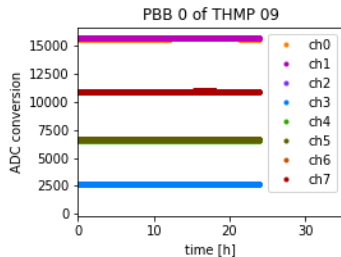
Original scheme

New scheme

THMP̄ Calibration Procedure

- Production of calibration boards expensive
- → Use 2 kinds with different resistance values
- Each kind yields 4 different resistance values
- Original connecting scheme prone to cabeling errors
- New connecting scheme can be checked easilyi
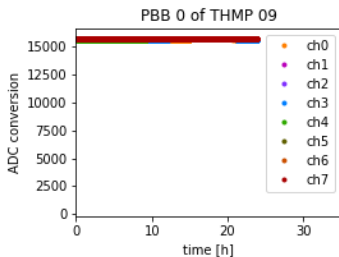 before the start of a measurement
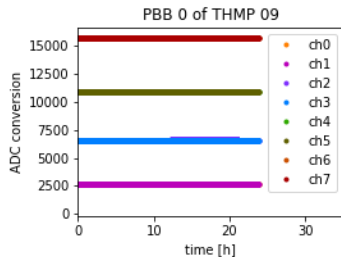
Original scheme

New scheme

THMP̄ Calibration Procedure

- Production of calibration boards expensive
- → Use 2 kinds with different resistance values
- Each kind yields 4 different resistance values
- Original connecting scheme prone to cabeling errors
- New connecting scheme can be checked easilyi
  before the start of a measurement

Original scheme

New scheme

THMP̄ Calibration Procedure

- Production of calibration boards expensive
- → Use 2 kinds with different resistance values
- Each kind yields 4 different resistance values
- Original connecting scheme prone to cabeling errors
- New connecting scheme can be checked easilyi
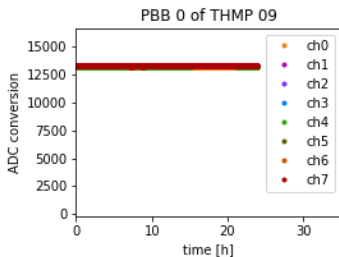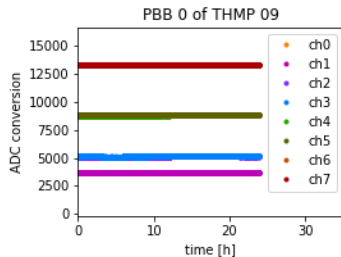 before the start of a measurement

Original scheme

New scheme

THMP̄ Calibration Procedure

- Production of calibration boards expensive
- → Use 2 kinds with different resistance values
- Each kind yields 4 different resistance values
- Original connecting scheme prone to cabeling errors
- New connecting scheme can be checked easilyi
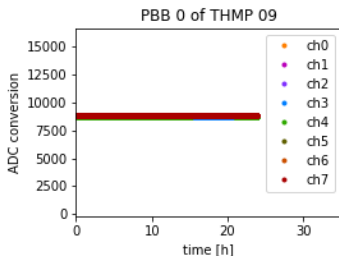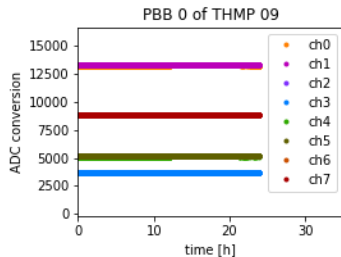 before the start of a measurement

Original scheme

New scheme

THMP̄ Calibration Procedure

- Production of calibration boards expensive
- → Use 2 kinds with different resistance values
- Each kind yields 4 different resistance values
- Original connecting scheme prone to cabeling errors
- New connecting scheme can be checked easilyi
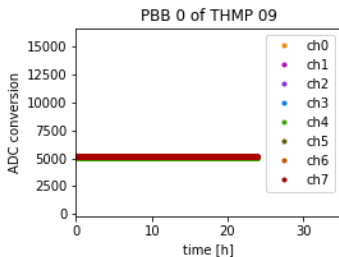 before the start of a measurement
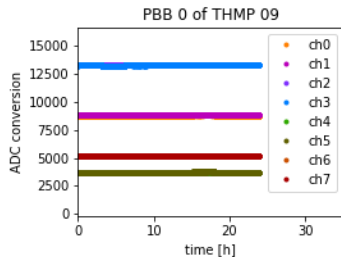
Original scheme

New scheme

THMP̄ Calibration Procedure

- Production of calibration boards expensive
→ Use 2 kinds with different resistance values
- Each kind yields 4 different resistance values
- Original connecting scheme prone to cabeling errors
- New connecting scheme can be checked easilyi
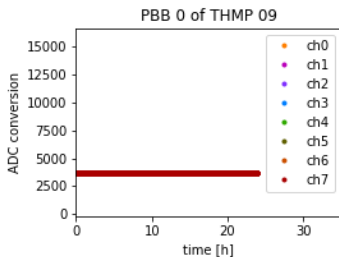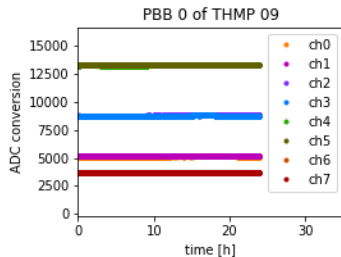 before the start of a measurement

Original scheme

New scheme

Status of THM$\overline{P}$ Calibration and Testing

- 10 THM$\overline{P}$s with 8 T-PBB each calibrated at least once

Scheme	Original		New
CBs	out of fridge	in fridge	out of fridge
01	✓		✓
02	✓		
03	✓		
04	✓✓		
05	✓		
06	×		✓
07		✓	✓
08	✓	✓✓	
09		✓	✓
0A	✓	✓	

THMP̄ Performance

- Temperature dependence is quite small
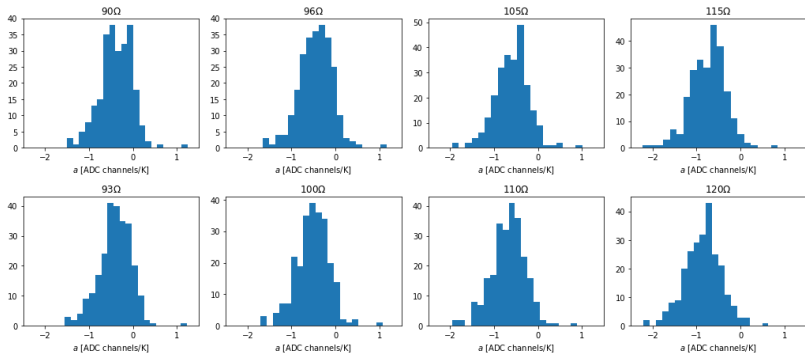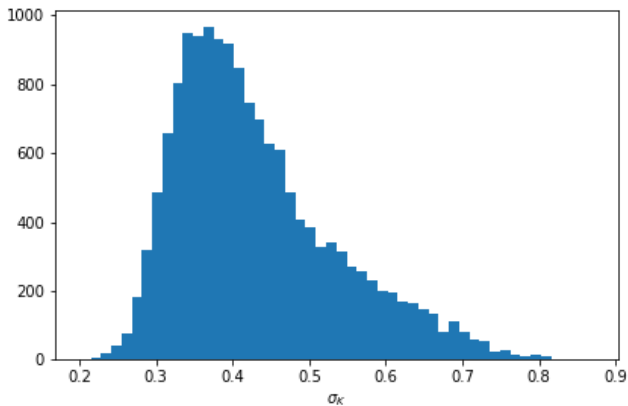
THMP̄ Performance

- Statistical uncertainty is quite small

THMP̄ Usage

- Temperature sensor calibration
- Radiation tests in Gießen (p) and at KVI (γ)
- DAQ tests
- Test of regulation of cooling system
- Test stand in Bochum
  (1st functional test of assembled submodules)
- Test stand in Bonn
  (cosmics measurement with submodules in climate chamber)

Summary and Outlook

- Temperature sensors:
    - ✓ Simplified and speeded up temperature sensor production
    - → Further improvements of the setup ongoing
- THMP̄:
    - ✓ Remaining boards and components currently ordered
    - → Assemble, test and calibrate these THMP̄s
    - ✓ Many THMP̄ calibration measurements performed
    - ✓ Small temperature dependence taken into account
    - ✓ Small statistical uncertainty of resistance measurments
    - ✓ THMP̄s used for many purposes
    - → Evaluate systematic uncertainty of resistance measurements
    - → Evaluate measurements with calibration boards in climate chamber
    - → Evaluate reproducibility of the calibration

Questions? Comments?