Temperature and Humidity Monitoring for Proto192

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Introduction

Temperature and Humidity Sensors Temperature and Humidity Monitoring Board Tests of the THMP Conclusion and Outlook

PANDA Electromagnetic Calorimeter The Proto192

PANDA Electromagnetic Calorimeter

- Electromagnetic calorimeter (EMC) of the PANDA target spectrometer consists of ~ 16000 PWO crystals
- Designed as barrel with 2 endcaps
- Cooled down to -25 °C to increase light yield of PWO by factor 4
- Energy resolution: $\frac{\sigma_E}{E} \leq 1\% \oplus \frac{2\%}{\sqrt{E[\text{GeV}]}}$



Introduction

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PANDA Electromagnetic Calorimeter The Proto192

The Proto192

- Prototype of the forward endcap of the EMC consisting of 192 PWO crystals
- Allows tests of mounting, cooling, and read-out electronics
- Operation at -25 °C
- Proto192 will be used as test platform for the temperature and humidity monitoring





Introduction

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Thermal Aspects

- Temperature dependency of light yield $\frac{dLY}{dT} = 3\%/K$ at $-25~^{\circ}C$
- $\bullet\,$ Temperature stability is essential for high energy resolution temperature variation ≤ 0.1 K
- $\bullet\,$ Due to shower fluctuations, temperature gradient ≤ 0.1 K/cm
- Avoid formation of ice
- Monitoring of temperature and humidity is mandatory
 ⇒ Development of the THMP (Temperature and Humidity Monitoring Board for PANDA)

Temperature Sensors Humidity Sensors

Temperature Sensors

- 60 cm platinum wire fixed in Kapton foils with a resistance of $\sim 100~\Omega$ at 0 $^\circ\text{C}$
- Dimensions: (30 \times 20) mm² 60 μ m thick
- Aim for sensitivity of 0.05 K ($\hat{=}$ 0.02 Ω) $\hat{=}$ 0.15% change of light yield
- To be mounted along the crystal



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Temperature Sensors Humidity Sensors

Read-out of the Temperature Sensors

• Temperature Sensors are read-out via four-terminal sensing:



- Current source provides 1 mA $U_{\vartheta} = 1 \text{ mA} \cdot 100 \ \Omega = 100 \text{ mV}$
- \bullet Measurement range $-30\ ^\circ C$ to $+30\ ^\circ C$
- Signals are amplified to use full range of the ADC (0 - 4096 mV)

Temperature Sensors Humidity Sensors

Humidity Sensors HIH-4000

- Using HIH-4000 series from Honeywell
- Output voltage \propto relative humidity (RH) 0.8 3.8 V
- Size of the sensor without pins (4.2 \times 8.6) mm^2
- Operating range down to $-40~^\circ\text{C}$ and 0% RH
- Accuracy of 3.5% RH



Temperature and Humidity Monitoring Board for $\overline{P}ANDA$ (THM \overline{P})

- Designed THMP as mainboard with connectors to 8 piggyback boards
- 64 channels (8 channels per piggybackboard)
- Using 14-bit ADC with a range of 0 to 4096 mV
- Low power microcontroller with CAN-Interface



Temperature and Humidity Monitoring Board for $\overline{P}ANDA$ (THM \overline{P})

- Board is designed to operate inside the cooled area
 - \Rightarrow following conditions must be fulfilled:
 - Operation range -30 to +30 °C
 - Proper operation in a magnetic field of B = 1.3 T (forward endcap)

(barrel: magnetic field of up to 2.5 T)

- Radiation hardness up to 10 mGy/h corresponding to position behind innermost crystals
- Low power consumption

Ultra-thin cables

- Between crystals and mounting structure only 80 μm space is available
- Developed ultra-thin cables for sensors, 55 $\mu {\rm m}$ thick



Connections: temperature sensors



humidity sensors



Current Sources Prototype of the THMP Measurements in a Magnetic Field Irradiation Tests

Current Sources

- Requirement: drift should be less than $2 \cdot 10^{-4}$ 0.05 °C at 0 °C \Rightarrow 0.02 Ω at 100 Ω
- 3 different types of current sources tested

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Current Sources Prototype of the THMP Measurements in a Magnetic Field Irradiation Tests

Current Source

- Tested all sources in conditioning cabinet for temperature dependencies
- Measured sensor current
- Type 2 gives the best results
- Drift: 10⁻⁵
- At -25 °C nearly constant



Current Sources **Prototype of the THMP** Measurements in a Magnetic Field Irradiation Tests

Prototype of the THMP





Current Sources Prototype of the THM \overline{P} Measurements in a Magnetic Field Irradiation Tests

Measurements in a Magnetic Field

- First 4 min: magnetic field raises to 1.5 T
- Next 3 min: variation of angle between magnetic field and PCB (0° - 90°)
- Last minute: magnetic field goes down to 0 T



Current Sources Prototype of the THMP Measurements in a Magnetic Field Irradiation Tests

- Ran 3 tests with 200 Gy/h at the Gießen Irradiation Facility, used $\rm ^{60}Co~\gamma$ source
- In first test accumulated 660 Gy \Rightarrow Voltage regulators were damaged
- Exchanged the regulators with different types, but also damaged in second test (500 Gy)
- Humidity sensors are radiation hard up to 800 Gy
- In 3rd test only microcontroller and thrid type of voltage regulator (LP3962 from National Semiconductor) were irradiated with a dose of 700 Gy Both parts worked properly

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Conclusion and Outlook

- THMP passed all tests
- Radiation hardness tested with a dose of 700 Gy
- Works properly in a magnetic field up to B = 1.5 T
- Temperature dependency
- Set up environmental control for EPICS
- 5 boards will be produced and used in the Proto192
- Behavior at quenching of magnet has to be tested

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