

Status of APD Screening in Bochum

Panda Collaboration Meeting 18/3

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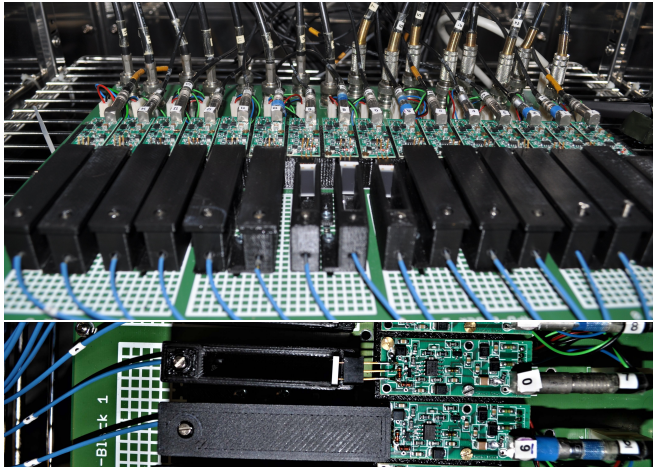
Readout of EMC crystals

- Readout of crystals for the forward endcap EMC:
 - ▶ 768 crystals in the endcap (very close to the beam pipe) are read out by VPTTs
 - ▶ Most crystals read out by two APDs each
 - Full EMC is read out by $\approx 30\,000$ APDs
 - 8 APDs are supplied by one power supply and need to be matched
 - Properties vary between APDs
 - Properties are dependant on temperature
 - Values provided by manufacturer were measured at $20\text{ }^{\circ}\text{C}$
- ⇒ Screening and matching of all APDs for $T = -25\text{ }^{\circ}\text{C}$ is required!

APD screening setup in Bochum

- Each screening board provides 16 slots to simultaneously screen 15 APDs and one reference APD
 - APD signals read out by original Panda preamplifiers and SADC
 - Bias voltage and current measurements provided by iseg HV modules
 - Illumination of APDs by DC light and by light pulser resembling the signal shapes of crystals
 - Full setup with two boards located inside climate chamber
- ⇒ Capacity to simultaneously screen 30 APDs
- ⇒ Extension of screening capacity by 30 APDs in second climate chamber in progress

APD screening setup in Bochum

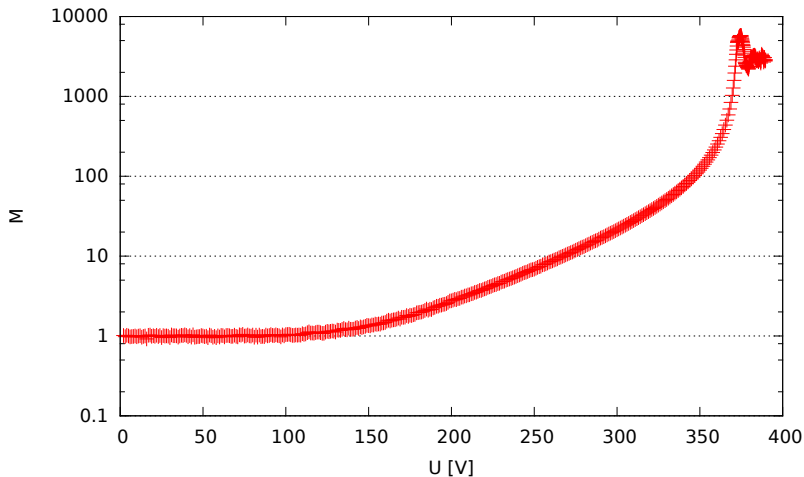


Measurement process

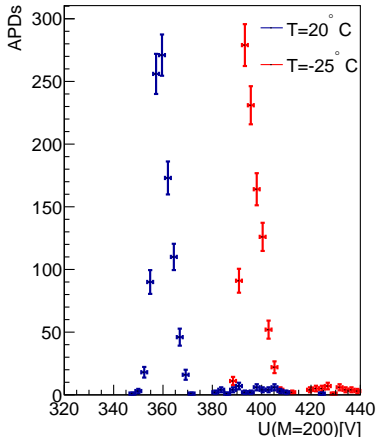
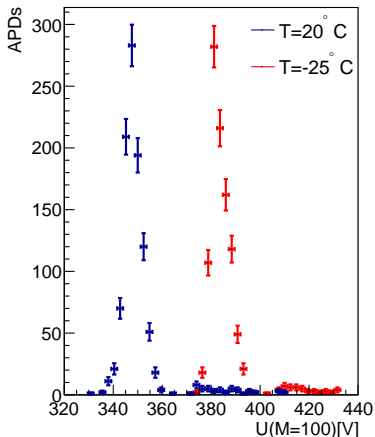
- Every APD is screened both at 20 °C and -25 °C
- Previous studies¹ showed: Measurement of dark currents and pulse shapes can be performed in parallel.
- Four measurements in total: DC- and dark currents at in a warm and cold environment
- Duration for a a full set of measurements \approx 10 h
- At full capacity, screening 60 APDs per day is possible → 300 APDs per week
- With duplicated setup: 600 APDs per week.
- As of today, \approx 1000 new APDs and \approx 350 irradiated APDs were screened and evaluated at Bochum

¹Leon Knarr, Bachelor's thesis

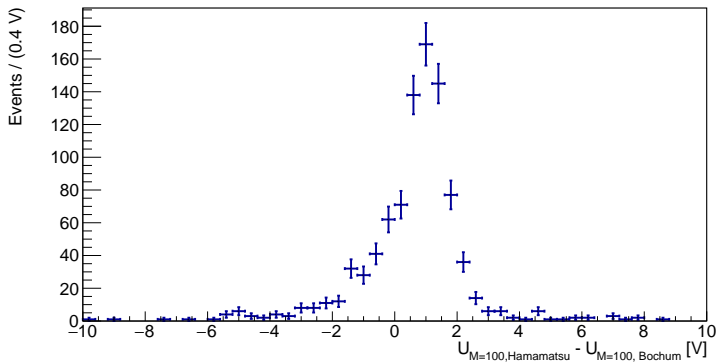
Exemplary gain curve



Bias voltages for $M = 100$ and $M = 200$ for forward endcap

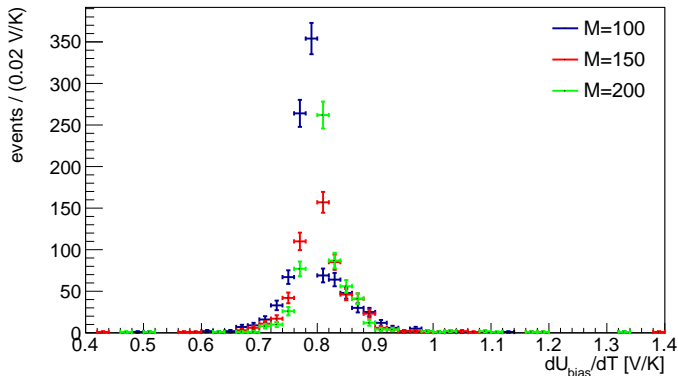


Comparison to values provided by Hamamatsu at $M = 100$



- Slight deviation from the manufacturers values is observed
- Deviations are well within parameters explained by temperature uncertainties ($\Delta T \leq 2 \text{ K}$)

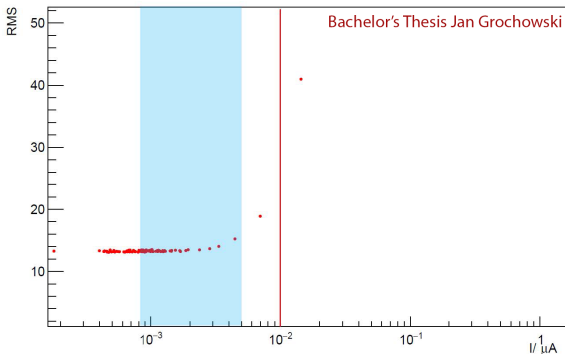
Temperature dependency of bias voltages



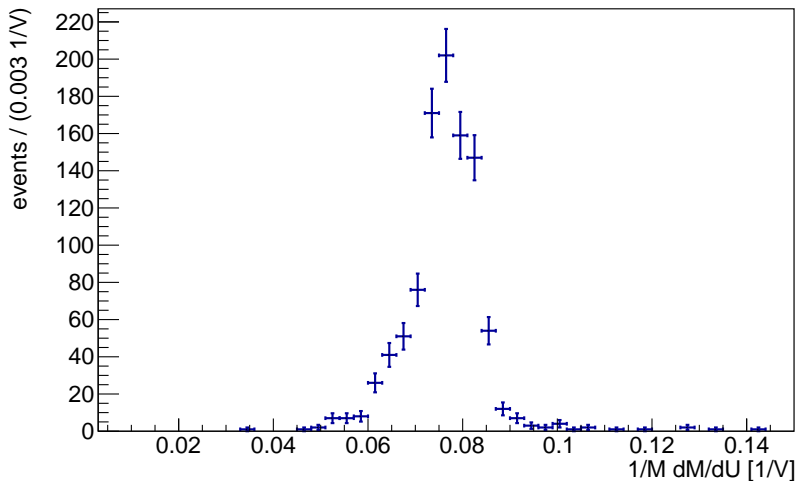
- Distribution of difference between bias voltages at $T = 20^{\circ}\text{C}$ and $T = -25^{\circ}\text{C}$ is narrow \rightarrow Linear correlation between bias voltage and temperature

SADC noise measurements

- Noise measured at the SADCs depends on the dark current in the APD
- Maximum acceptable dark current can be estimated from the noise at the SADC
- Noise limit of $3 \cdot \sigma(M = 200) \Rightarrow I_{\text{dark,max}} = 10 \text{ nA}$



Slope at $M = 200$



Selection criteria for forward endcap

- Maximum dark current at $M = 800$:

$$I_{dark}(M = 800) < 10 \text{ nA}$$

- Matching criteria:
 - ▶ ΔU_{bias} at $M = 200$
 - ▶ $\frac{dM}{dU}$ at $M = 200$

Irradiation effects

- After the initial screening: Irradiation of APDs with 37 Gy
- Annealing for 48 hours at 80 °C.
- Short circuit of the APD pins during irradiation and annealing
- Second screening iteration after irradiation and annealing
- Continuous checks on the effects of irradiation, e.g. on bias voltages or temperature gradient

Summary and outlook

- APD screening in Bochum ongoing, current capacity of 300 APDs per week, soon to be doubled by second setup
- Results are in agreement with data from the manufacturer
- Selection criterium for APDs for the forward endcap:
 - ▶ $I_{Dark}(M = 800) < 10 \text{ nA}$
- Matching criteria:
 - ▶ ΔU_{bias} at $M = 200$
 - ▶ $\frac{dM}{dU}$ at $M = 200$
- Work on measurement process focussed on increasing output