Bundesministerium
für Bildung
und Forschung

Temperature dependence study of data link stability of MuPix11

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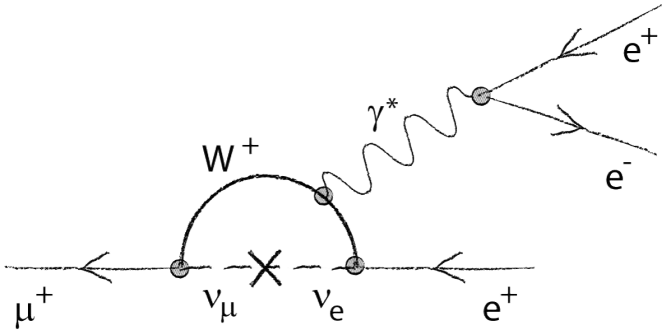
The Mu3e experiment

Goal

The decay $\mu^+ \rightarrow e^+ e^- e^+$

- violates charged lepton flavour conservation
- suppressed to BR of ~ 10^{-55}

Observing the decay would indicate physics beyond the standard model.



The decay $\mu^+ \rightarrow e^+ e^- e^+$ via neutrino oscillations

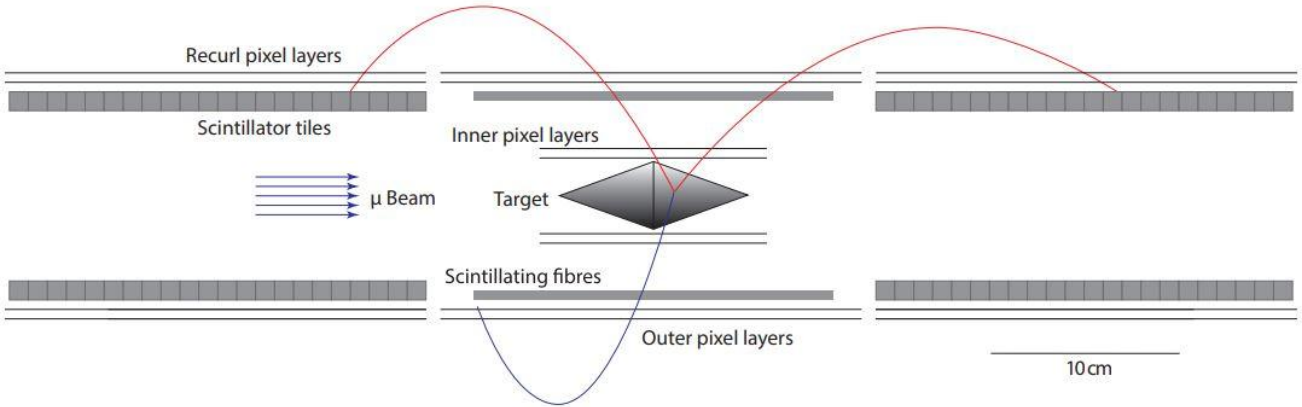
Phase I

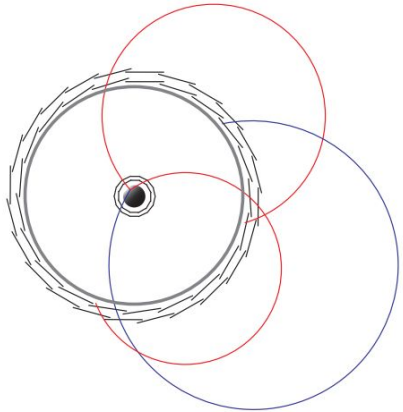
Where? At the πE5 beam line at PSI, providing muon rates up to 10^8 Hz.

Aim? Single event sensitivity 2×10^{15} on the branching fraction

➔ $> 2.5 \times 10^{15}$ stopped muons (290 days)

➔ need for detector with a high readout capability





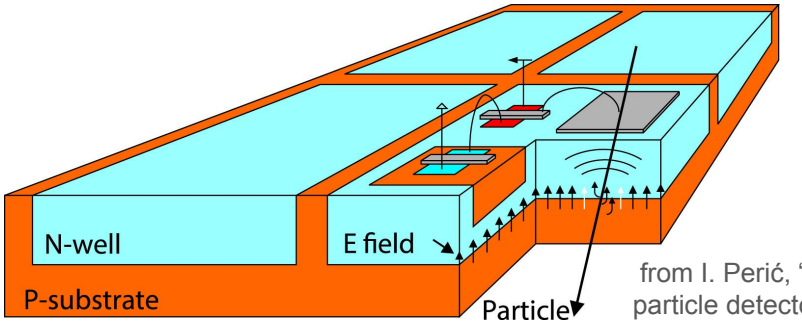
from “Technical Design Report for the Phase I Mu3e Experiment, September 2020”

MuPix11

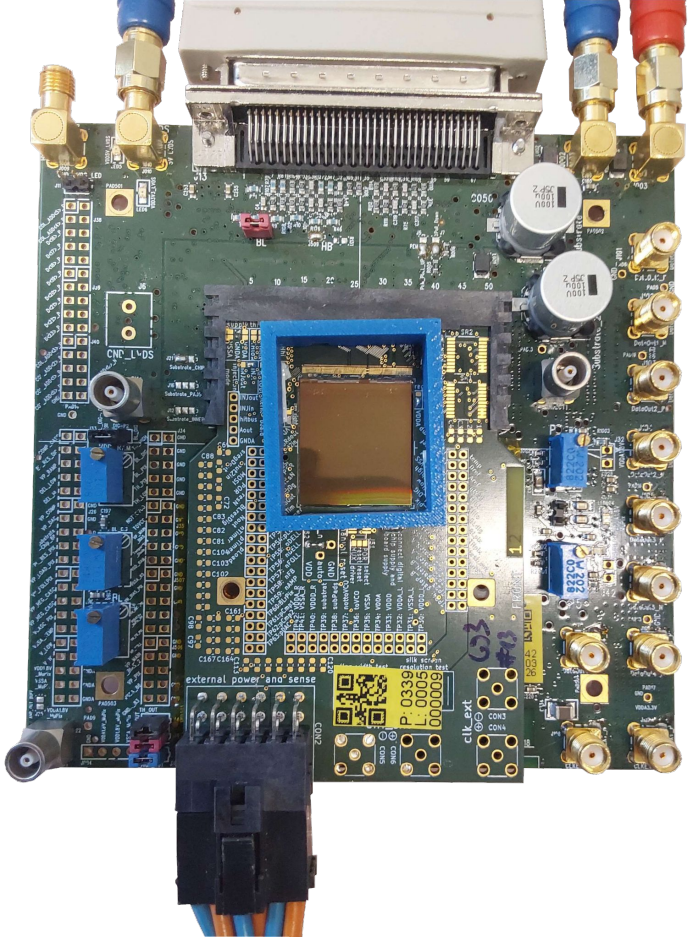
The MuPix11 is a **H**igh-**V**oltage **M**onolithic **A**ctive **P**ixel **S**ensor (HV-MAPS) developed for Mu3e ($2x2cm^2$, 256x250 pixel).

Advantages

- ultra thin (down to 50 µm)
- high readout capability (1,25 Gbps data link speed)
- precise time and spatial resolution



from I. Perić, “A novel monolithic pixelated particle detector implemented in high-voltage CMOS technology”



Cooling

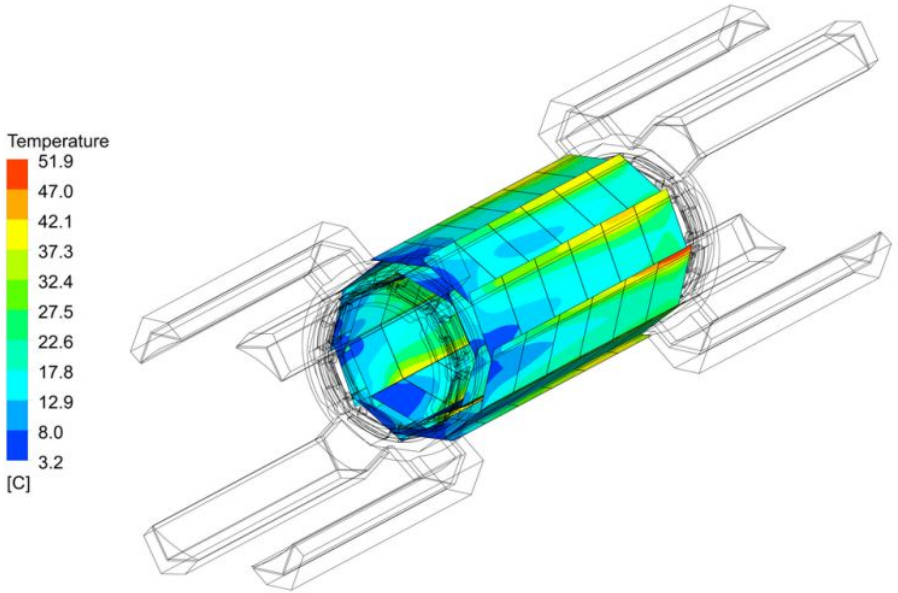
cooling power of 350 mW/cm^2

→linear cooling with gaseous helium parallel to muon beam

→ Sensors will be exposed to a large temperature range

→ How does the link quality depend on the temperature?

Simulated temperature on the outer layer

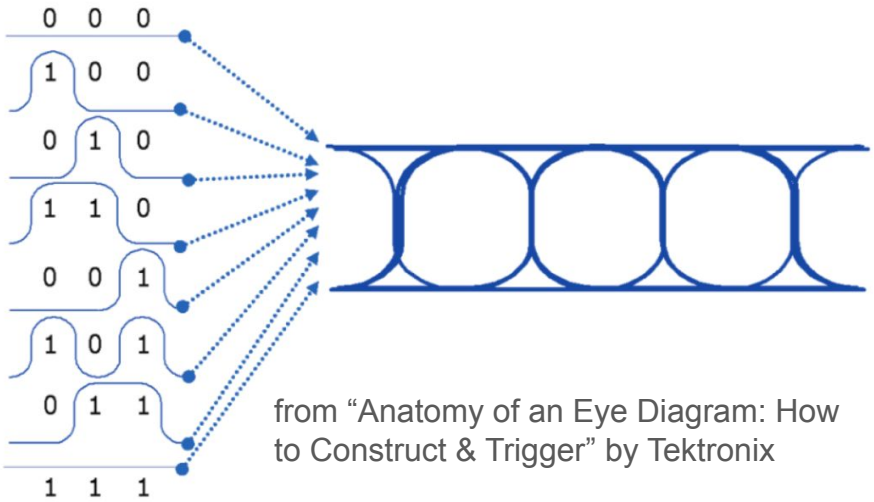


from “Technical Design Report for the Phase I Mu3e Experiment, September 2020”

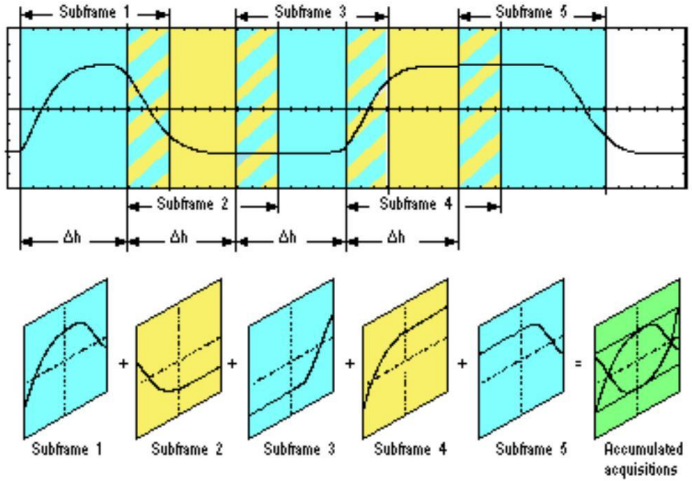
Eye diagram

An Eye diagram is a graphical overlay of the same signal at different times

→ all transitions are summed to a pattern



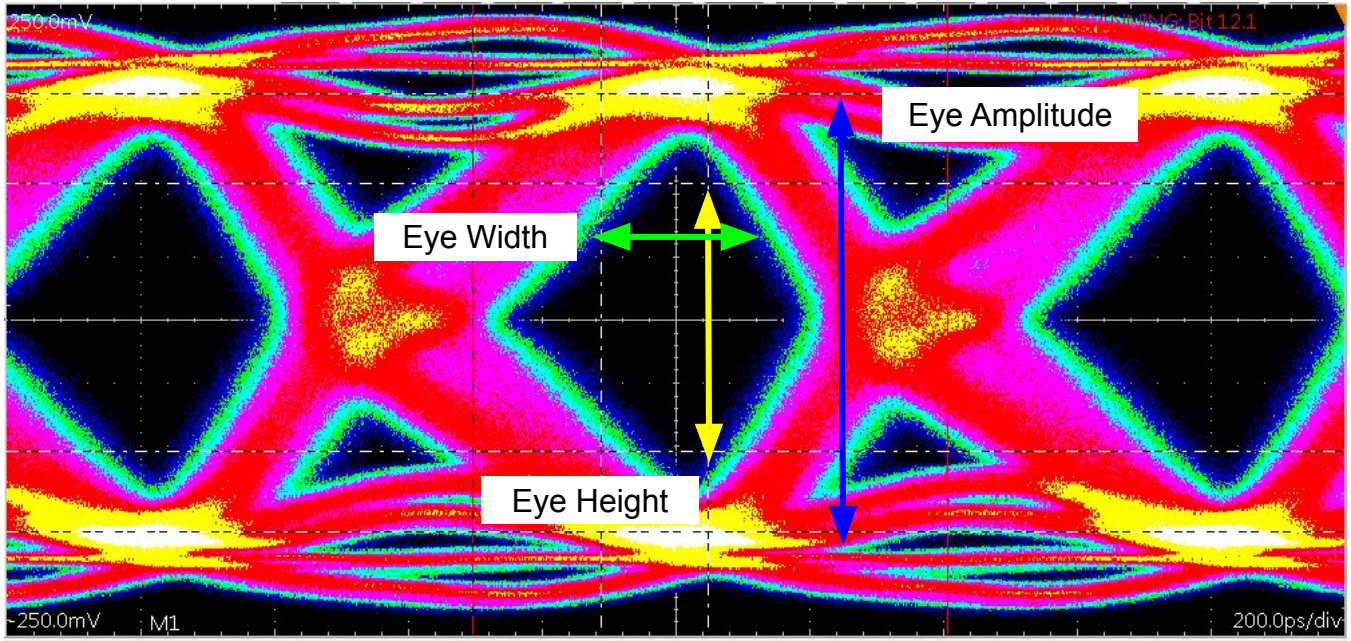
from “Anatomy of an Eye Diagram: How to Construct & Trigger” by Tektronix



from “DSA8300 Digital Serial Analyzer Printable Application Help”

stable signals with a steady bit rate should have sub-frames of same length

Eye parameter

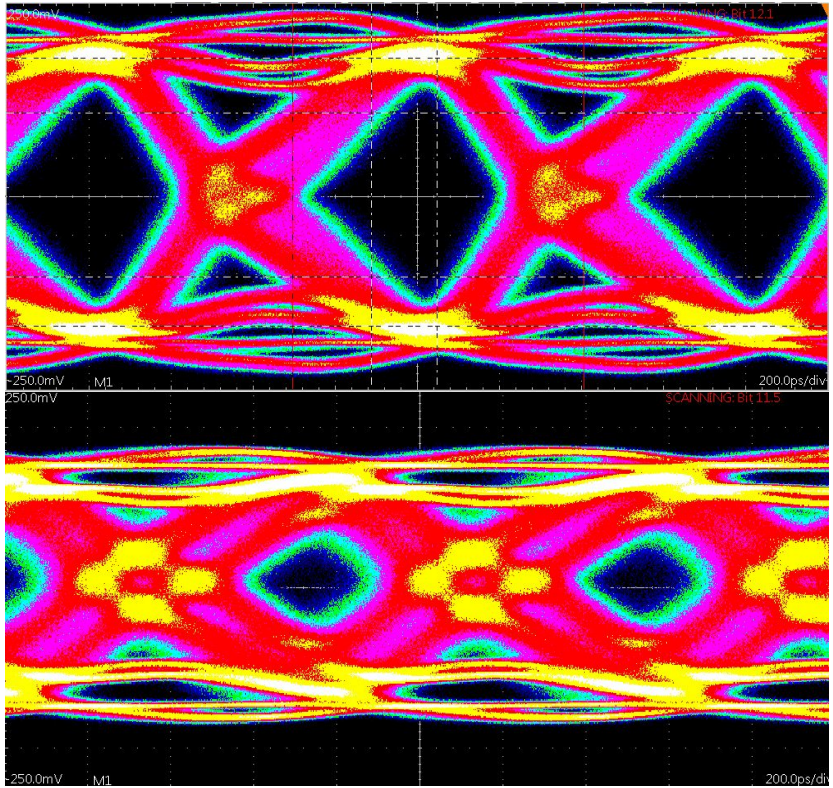


Eye Height = (High – $3\sigma_{high}$) – (Low + $3\sigma_{low}$)

Eye Width = (t_{cross2} – $3\sigma_{cross2}$) – (t_{cross1} + $3\sigma_{cross1}$)

Eye “size” ≡ signal quality

Stability



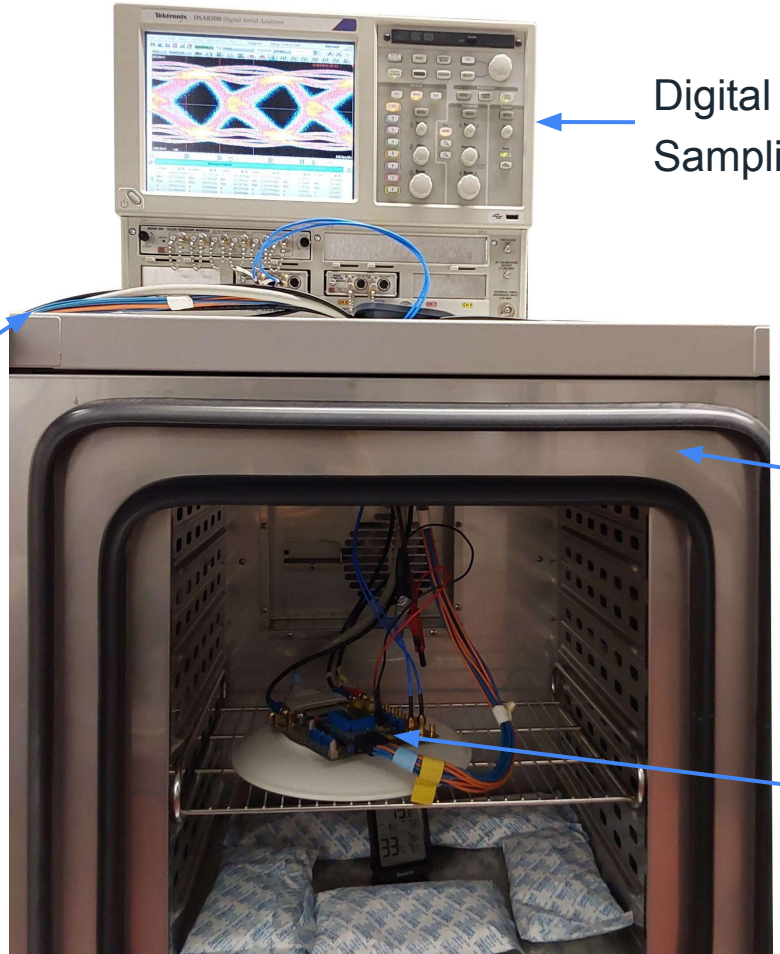
Eye diagram for a stable output signal

Eye is too small

→ no clear differentiation between 0 and 1

→ unstable output signal

Setup



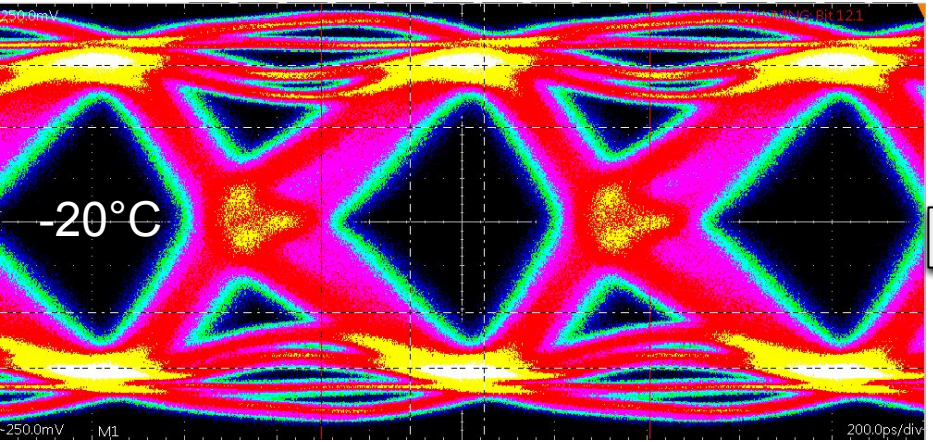
Digital Serial Analyzer
Sampling Oscilloscope

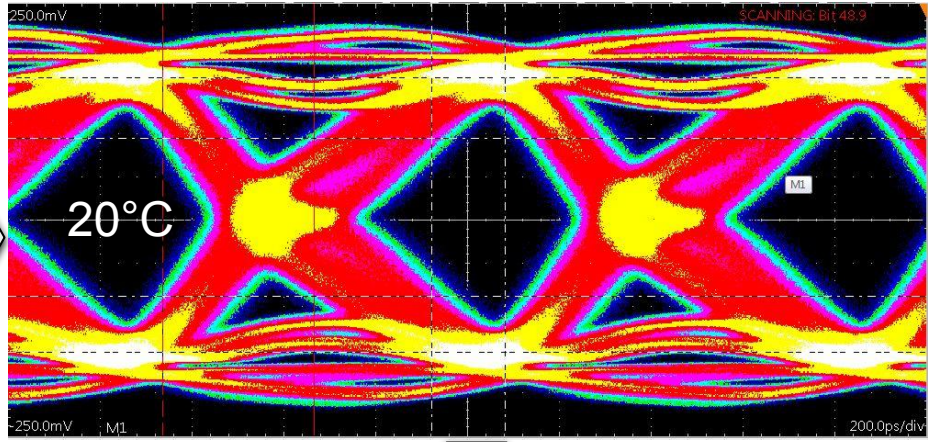
connection to
PC and power
supplies

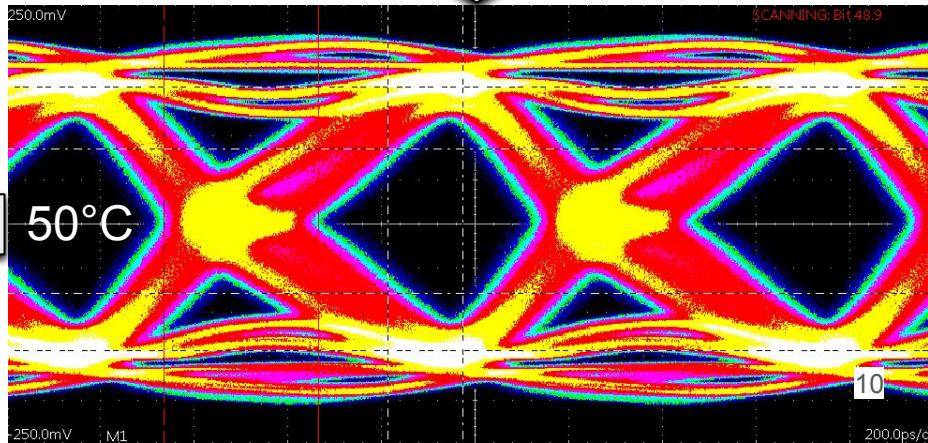
cooling chamber
(-20°C - 80°C)

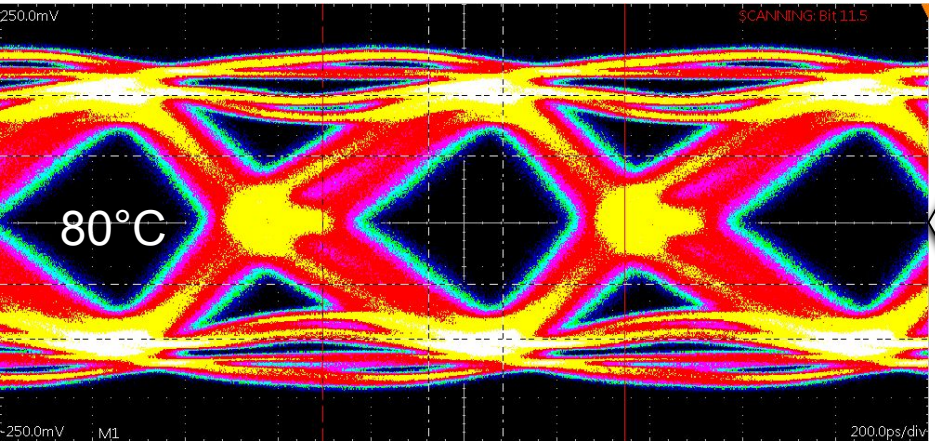
MuPix11 sensor

Temperature dependence (70 μm thickness)

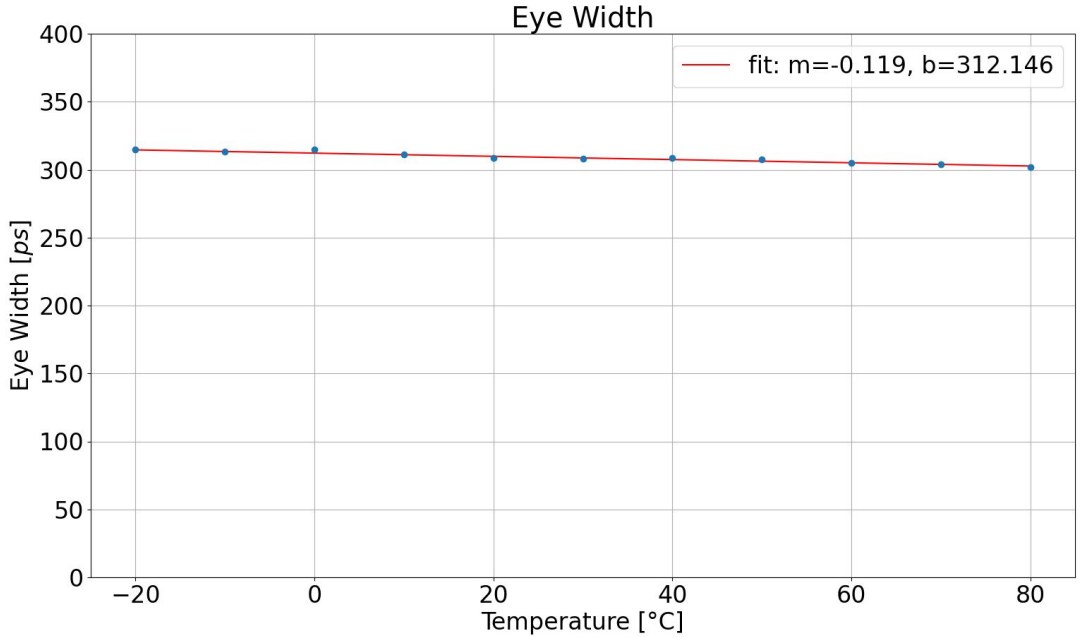






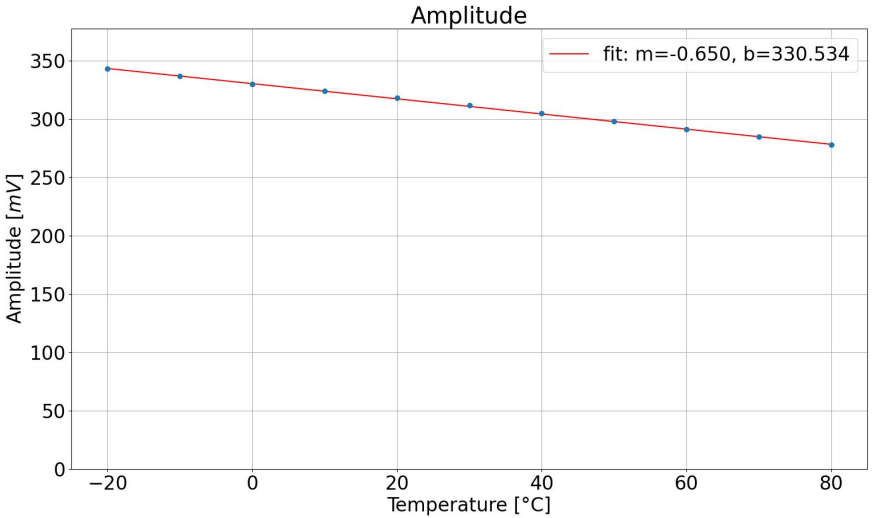


Temperature dependence Eye Width

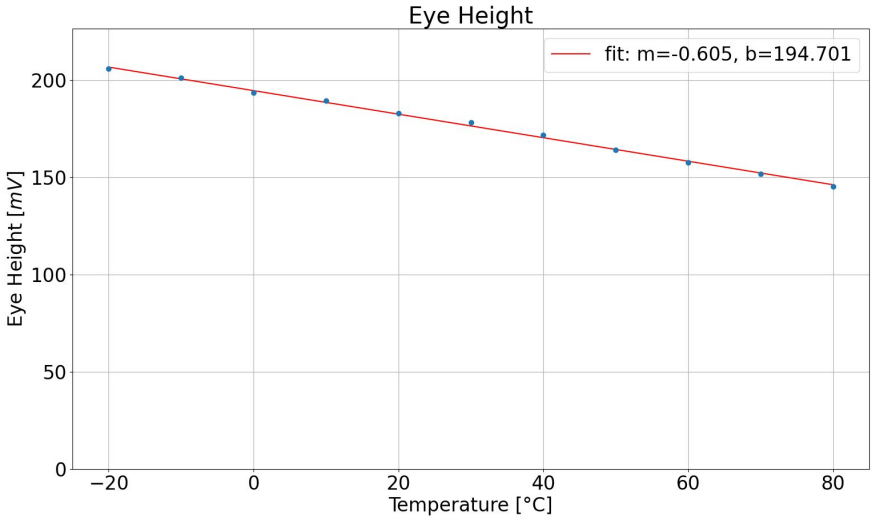


- only small changes

Temperature dependence amplitude/Eye Height

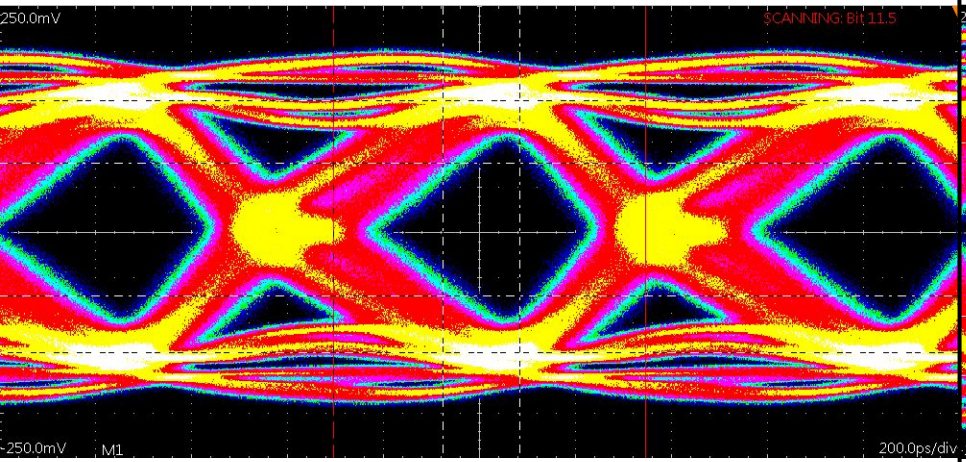
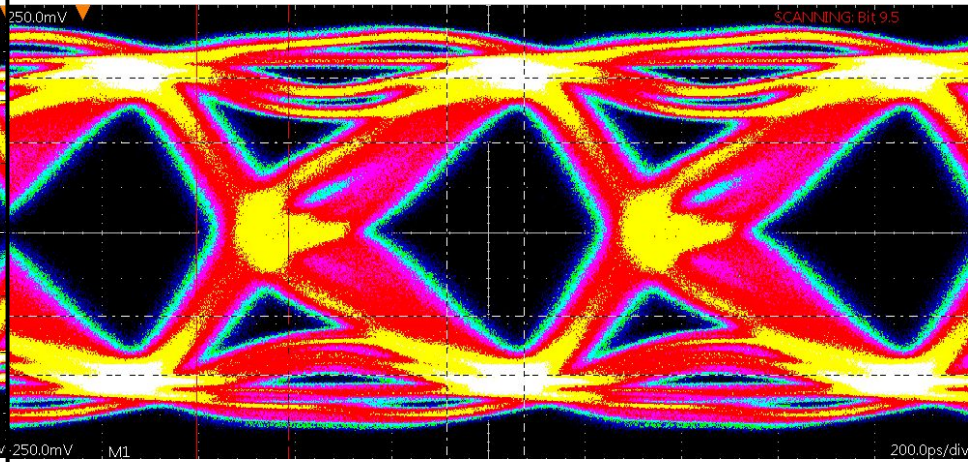


- linear decrease
- ➔ linear temperature dependence of resistors



- linear decrease due to amplitude drop

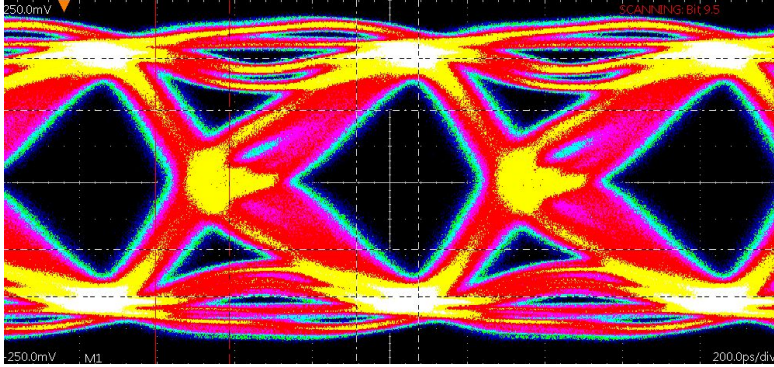
Compensating amplitude drop at 80°C

standard setting	adjusted setting
	

Amplitude [mV]	282,0	326,2
Eye Height [mV]	152,9	189,1
Eye Width [ps]	301,8	317,7

→ higher power consumption (~80mW more per sensor)

Summary and Outlook



- in the temperature range from -20°C to 80°C the default sensor settings the data links are operational
- observation of linear decrease of signal amplitude with increasing temperature
- possible recovery of the signal amplitude at the cost of higher power consumption

To do

- so far one sample investigated

➔ check for chip to chip variations (70 µm and 50 µm)