Barrel TOF FEE status

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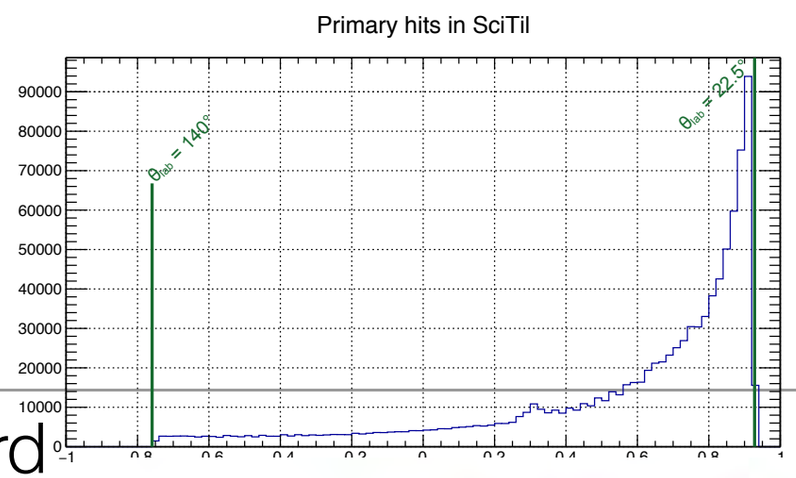
on behalf of the SciTil group

29.05.2018, GSI

Barrel-TOF Design

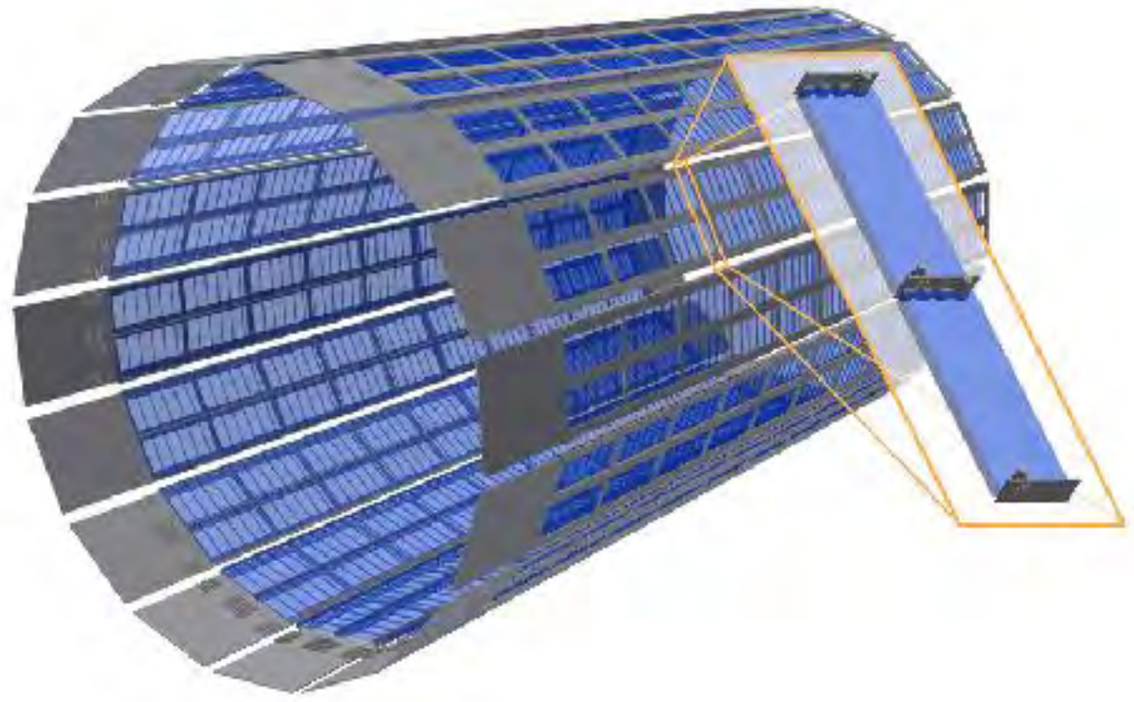


Simple, cable-less design => railboard

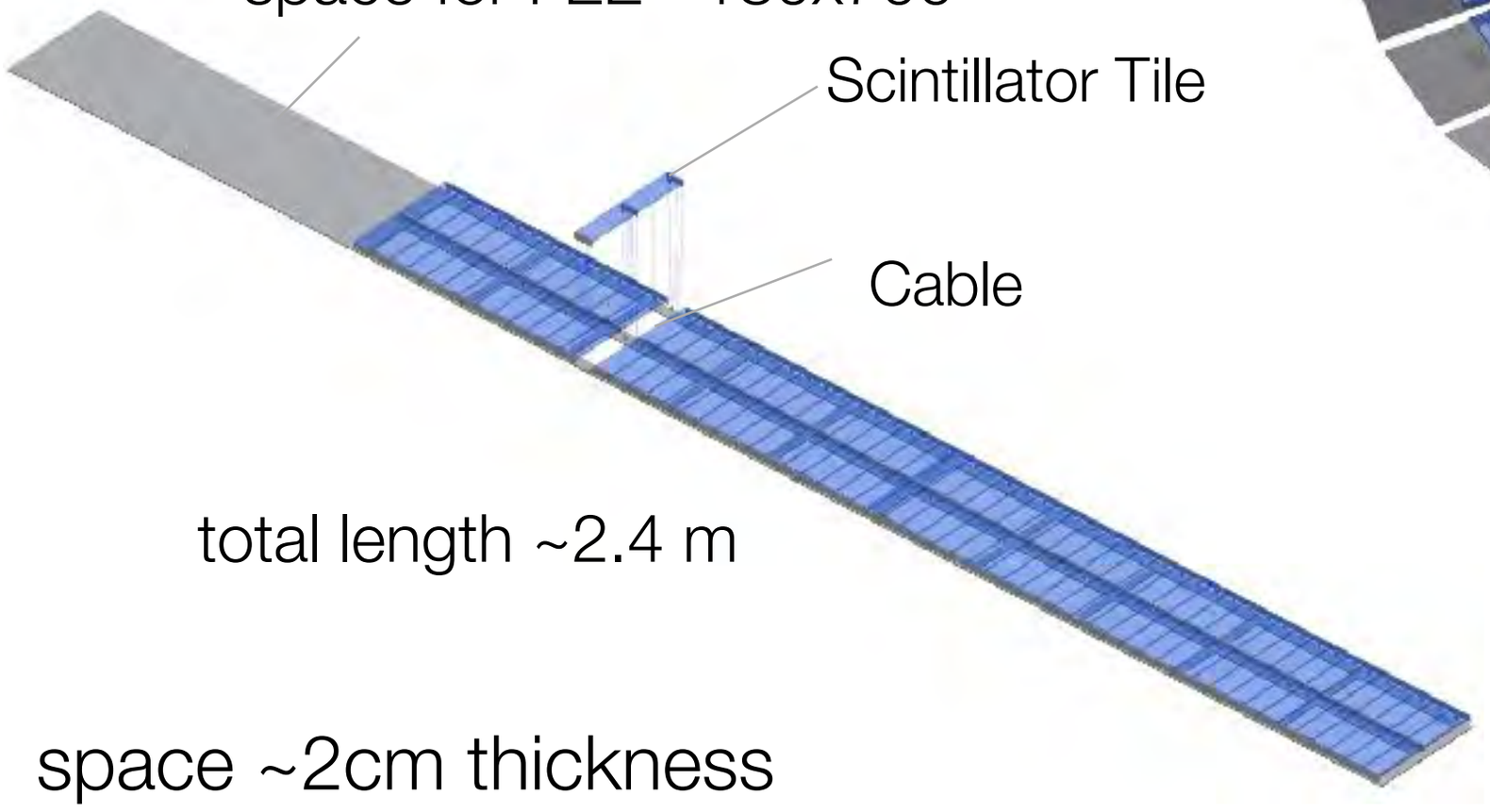
16 Super modules

240 ch. /SM

max. 40 kHz /ch.



space for FEE ~180x700



total length ~2.4 m

space ~2cm thickness

no space for existing/commercial boards, probably

Status

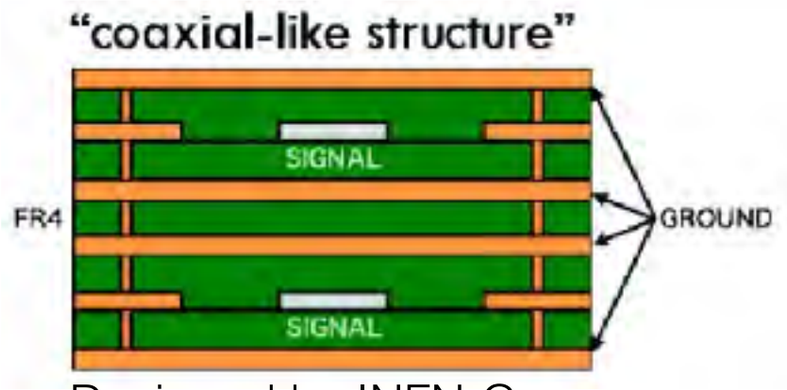
- R&D slowed down due to financial and political situation of PANDA in Vienna
- Manpower
  - 1 PhD (S. Zimmermann), 1 Master (W. Nalti), KS
  - 1 Engineer (~0.2 FTE?)
  - 1 PD??

subtasks
for the first full-scale prototype

- design of low-loss, low-xtalk microstripline
- large PCB supplier
- TOFPET2 ASIC
- calibration system with LED
- temperature sensor
- interface to PANDA
- integration

Micro Stripline Technique

- Coaxial-like structure to transmit signals over a PCB board, realised on a multilayer PCB board, that features
  - High density
  - Good shielding from external noise
  - High bandwidth
  - Low crosstalk
  - Mechanical strength
- 3 (cupper) layers per signal



Designed by INFN-Genova
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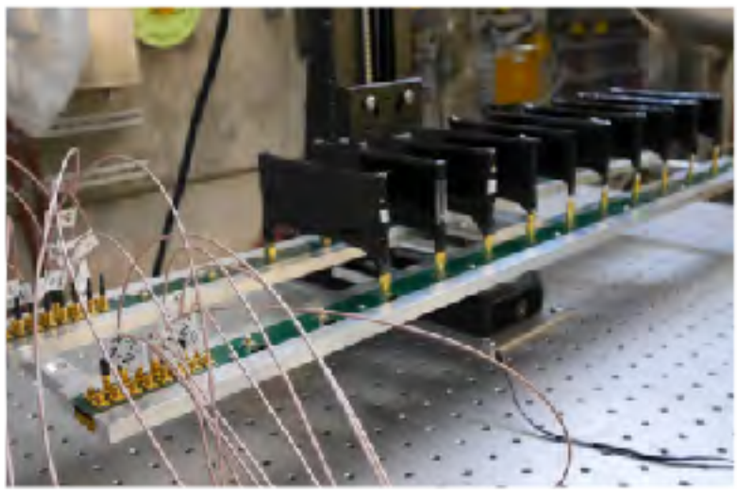
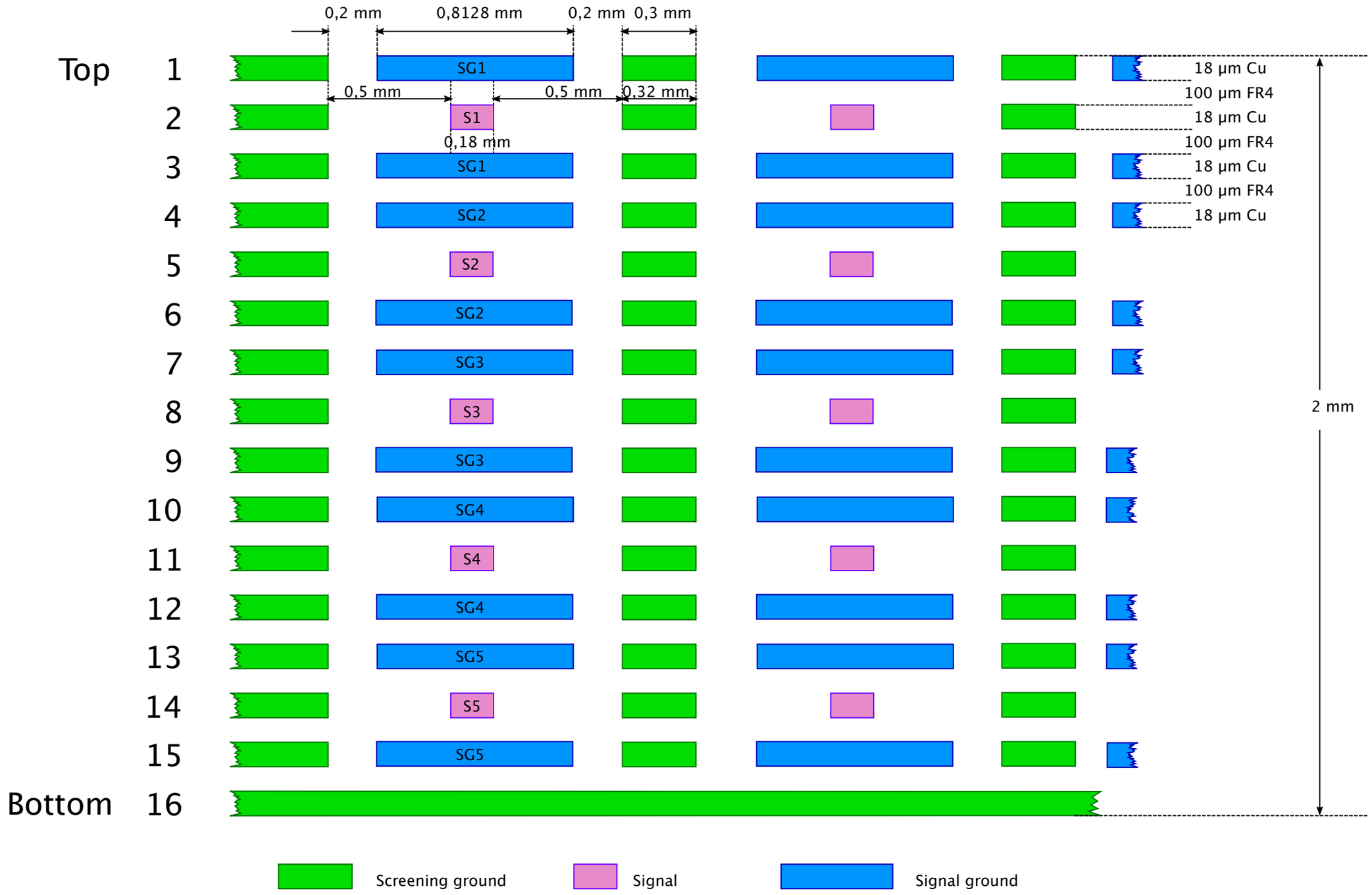
Stefan Ritt <stefan.ritt@psi.ch>

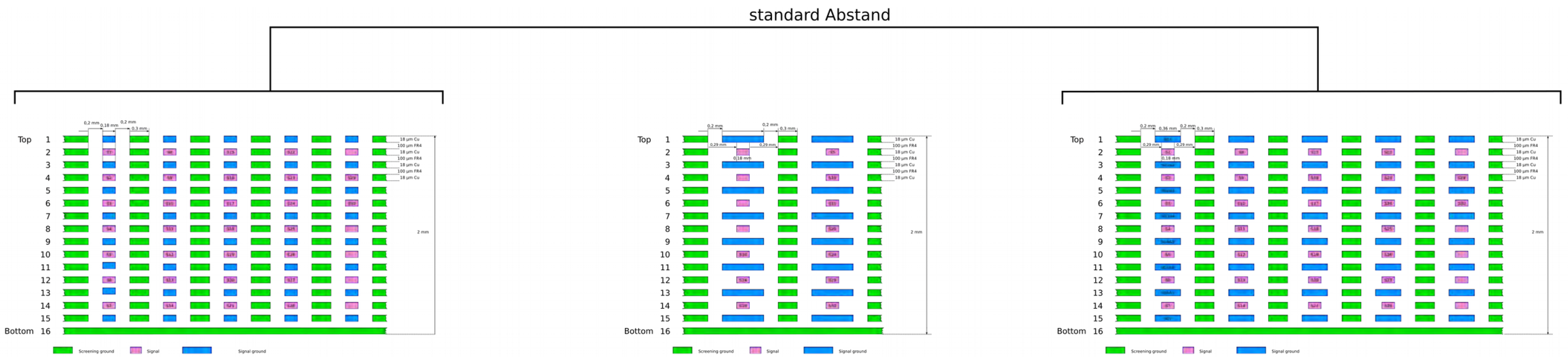


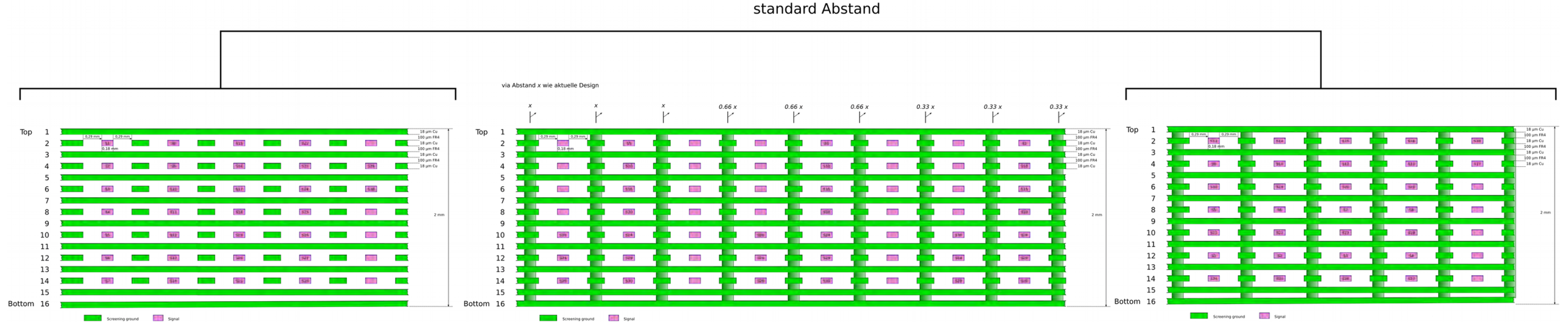
Example of MEG2 TOF

Railboard design

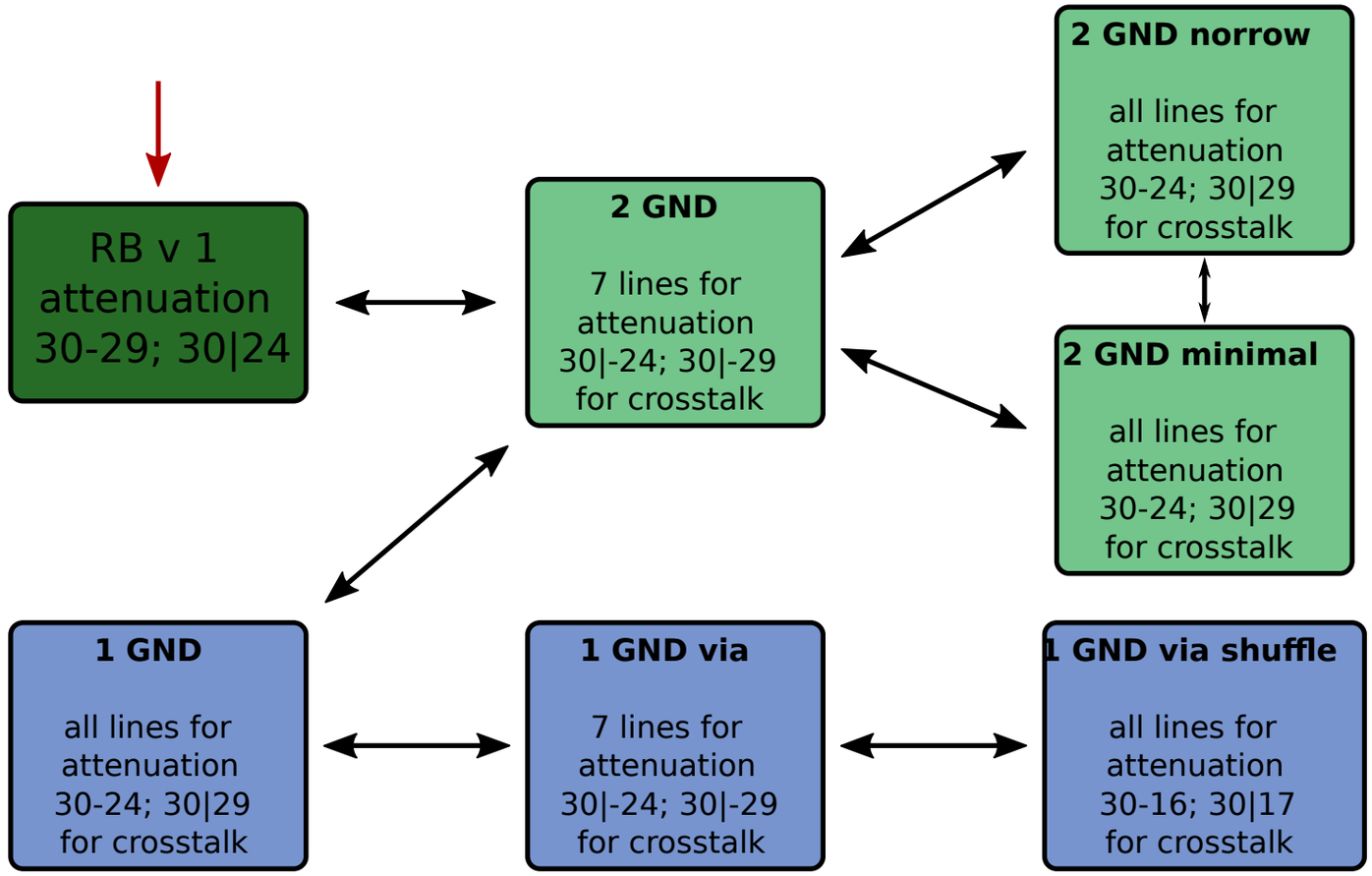


Railboard v2 schematic



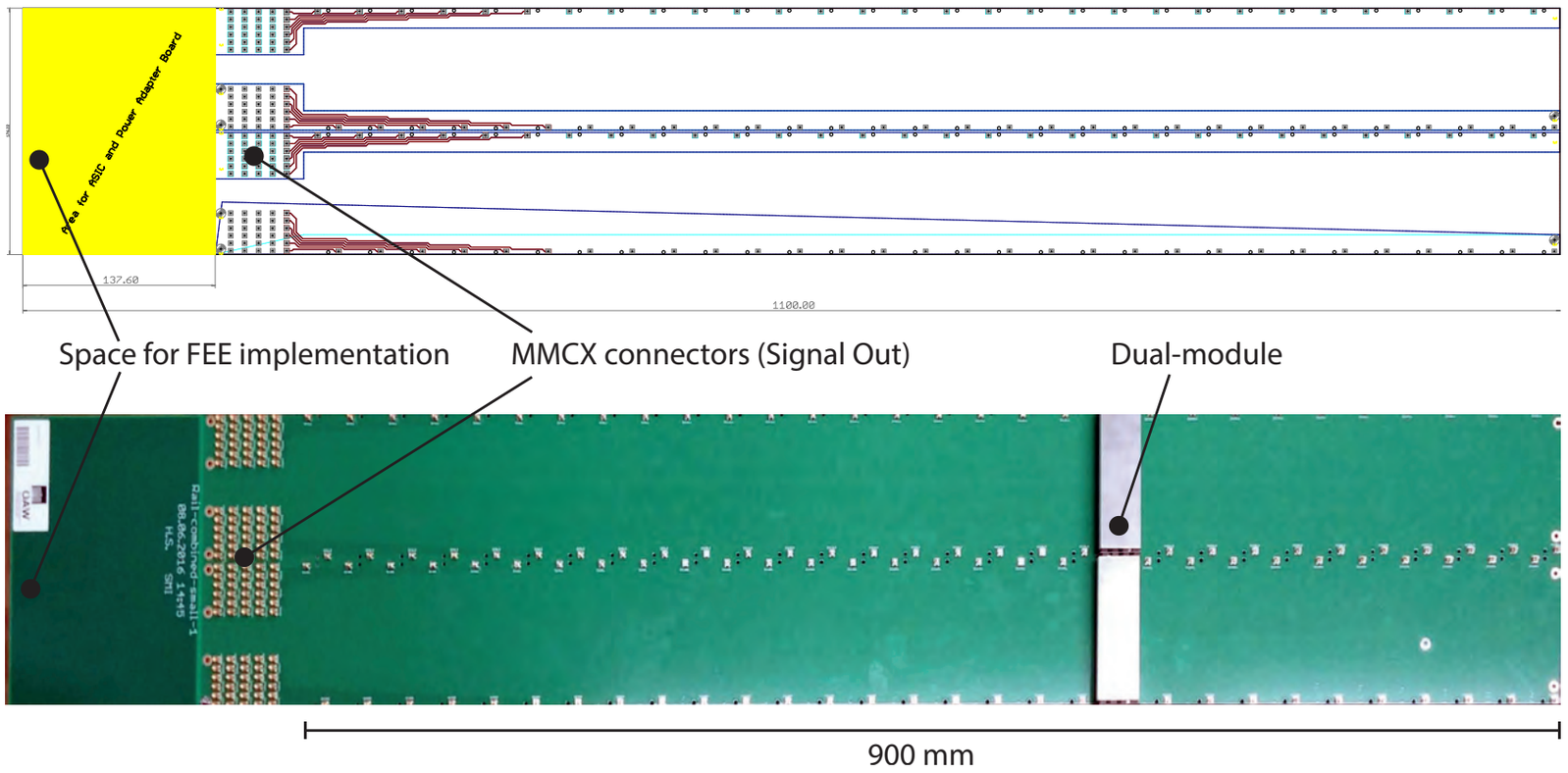


How to Structure the Measurements (Crosstalk)

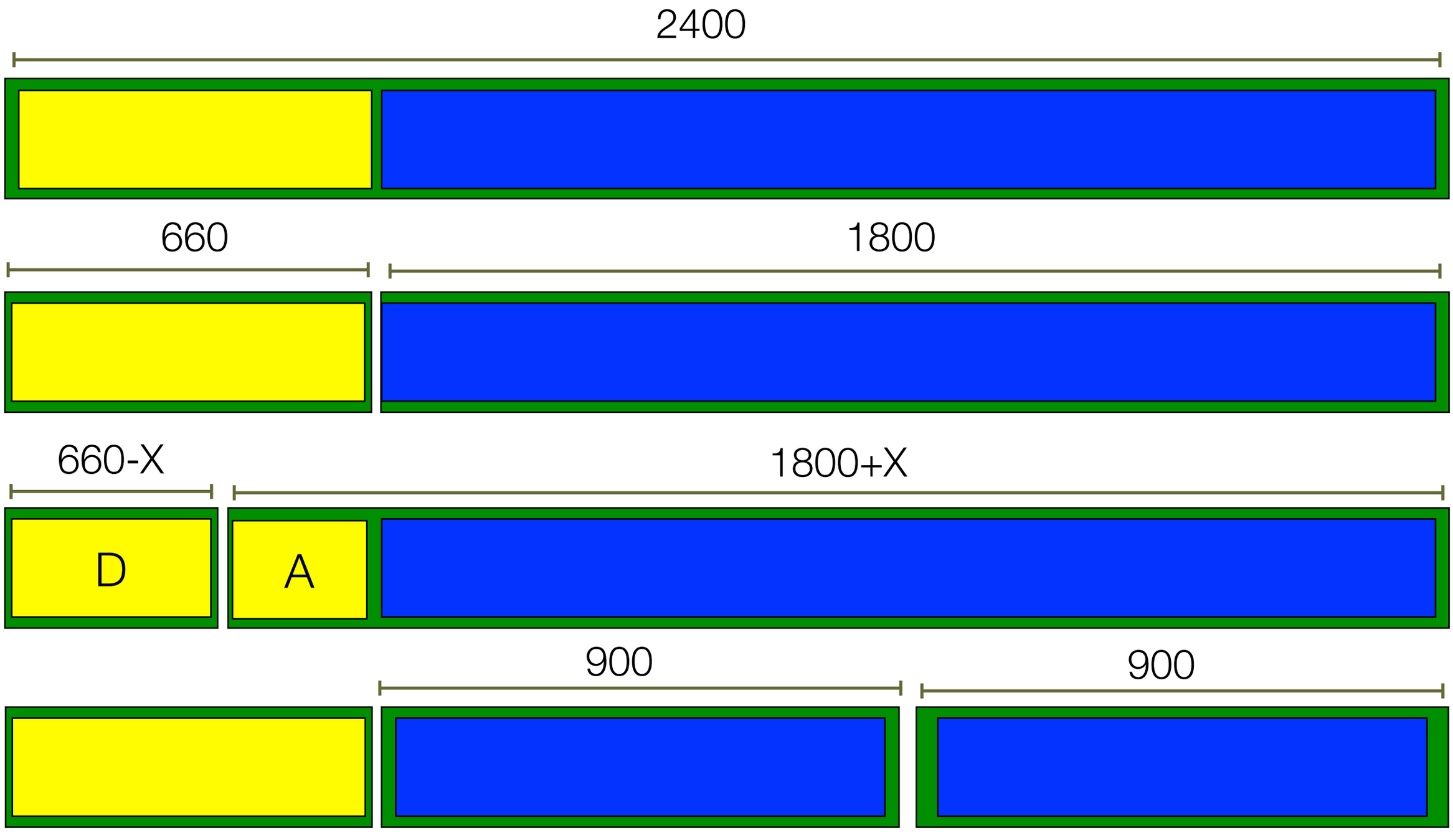


Large PCB (railboard) production issue - problem

- half length (1200mm) exists. was not really a problem.
- the same company
- a new version, after 3,5 months it finally arrived(?)



Large PCB (railboard) production issue
- solution, fallback options

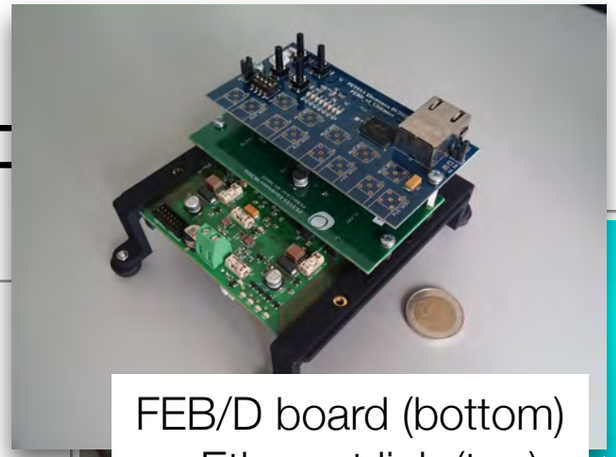


production at CERN?

TOFPET2 ASIC

- Signal amplification and discrimination for each of 64 independent channels.
- Dual branch quad-buffered analogue interpolation TDCs for each channel.
- Quad-buffered charge integration for each channel.
- Dynamic range: 1500 pC.
- TDC time binning: 30 ps
- Gain adjustment per channel: 1, 1/2, 1/4, 1/8.
- SiPM family supported: positive or negative signal polarity
- Max channel hit rate: 480 kHz.
- Configurable timing, trigger and ToT thresholds.
- Fully digital output.
- Max output data rate: 2.6 Gb/s.

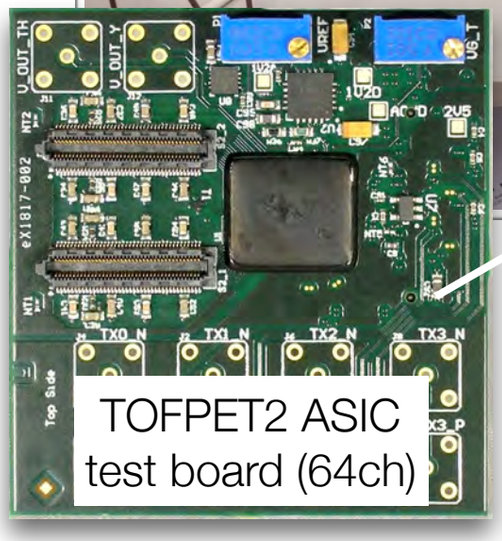
TOFF



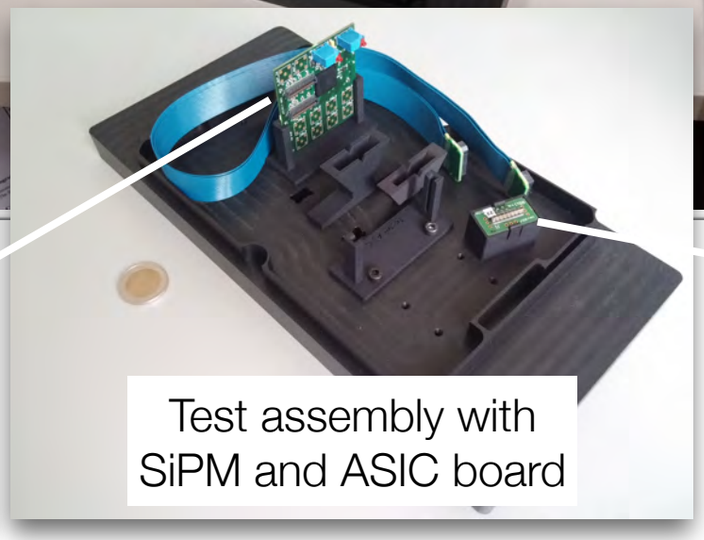
FEB/D board (bottom)
+ Ethernet link (top)

TOFPET2 ASIC Test Bench

LV power supply



TOFPET2 ASIC
test board (64ch)



Test assembly with
SiPM and ASIC board

SiPM + LYSO crystal

Trigger Setup

- 3 Triggers
  - != 3 Discriminators

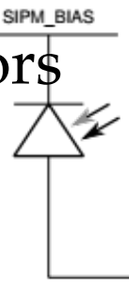
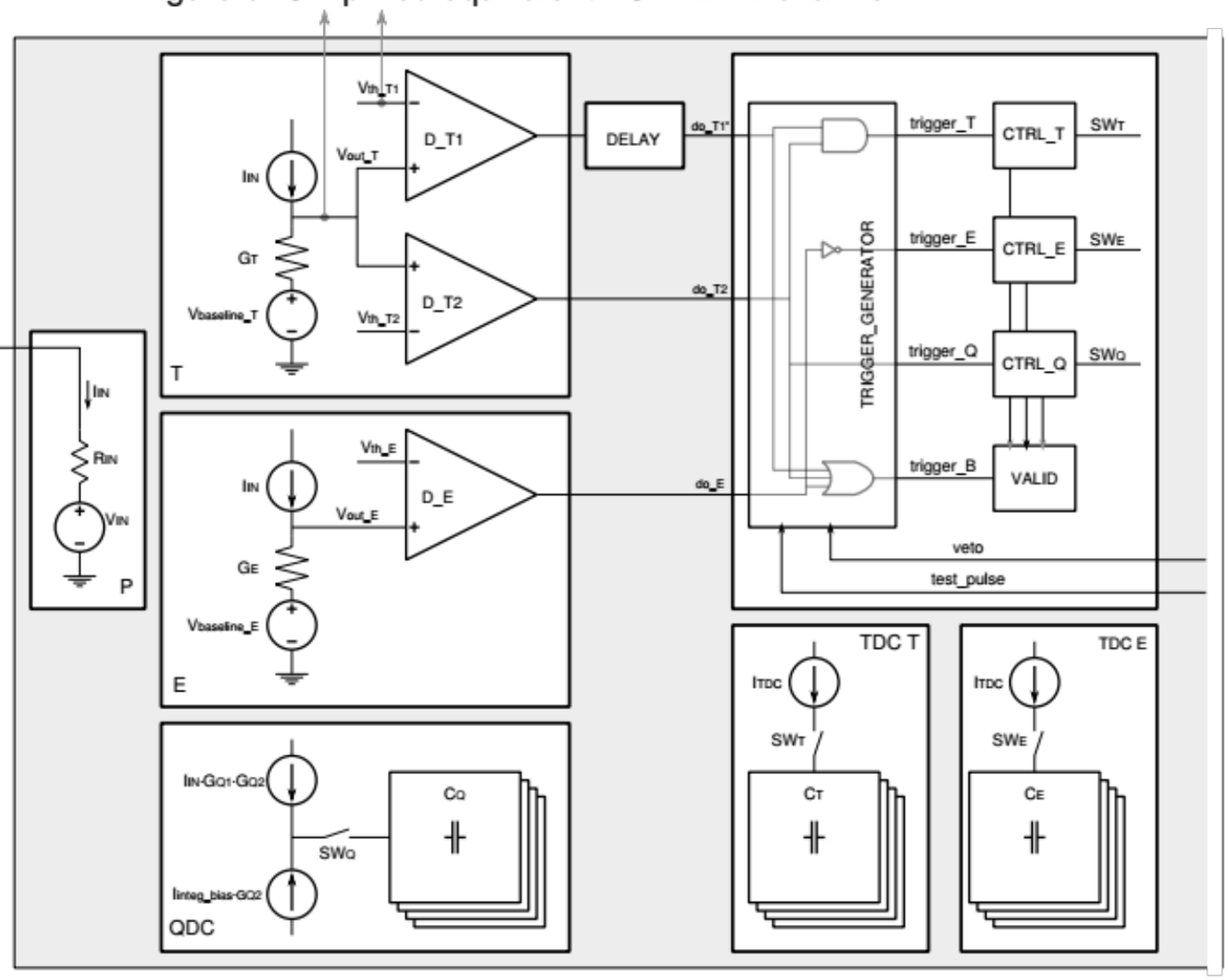


Figure 6: Simplified equivalent TOFPET 2 channel.



Trigger Process

Nominal trigger mode

TOFPET 2 implements a multi-level event trigger and rejection scheme. In the nominal operation mode:

- Event time is measured at a low threshold (vth_t1), which can freely be set as low as 0.25 p.e.
- Events which do not trigger threshold vth_t2 are rejected without any dead time from the TDC/QDC.
- Events which trigger vth_t2 but not vth_e are reject with 5 clock dead time from the TDC/QDC.
- Only events which trigger all 3 thresholds are considered valid and digitized.

Figure 10: Event trigger (nominal mode)

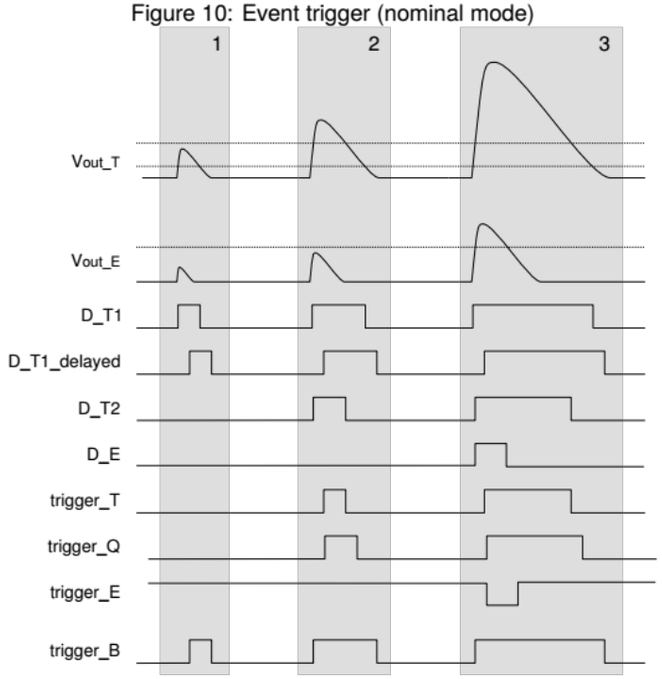
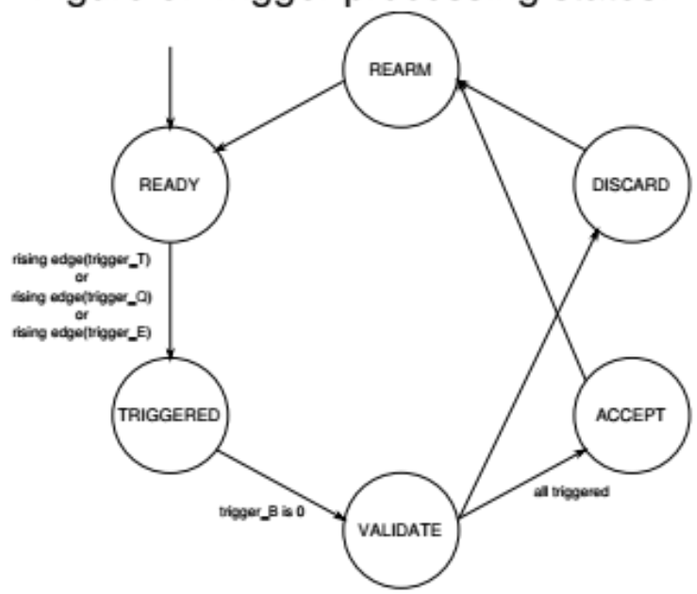


Figure 9: Trigger processing states.



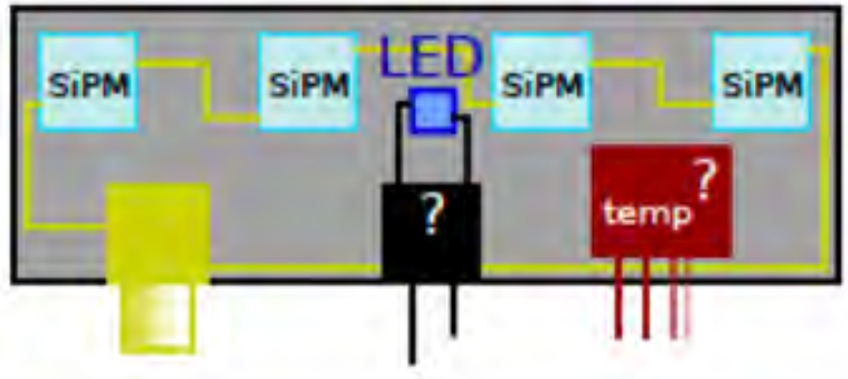
- collaboration with P̄ANDA End-Cap DIRC group on TOFPET2

Monitoring and Calibration

- Voltage and current monitoring
  - the primary parameter that influences the characteristics of SiPM
  - general health check
- Temperature
  - SMD PTC on the sensor-board
  - relative: 200 mK, absolute: 4 K
- Gain
  - DCR: 10-100 kHz/mm^2
- LED calibration system
  - SMD LED on the sensor-board

Model	V_{BD}	gain
KETEK	18 mV/K	$< 0.5\,\%$/K
Hamamatsu S13360	50 mV/K	$\sim 1.3\,\%$/K
AdvanSiD NUV	26 mV/K	$< 1\,\%$/K

Table 4.5: A short summary of temperature dependencies of SiPM characteristics. Values are taken from Ref. [10, 11, 12, 13]. The temperature dependence of break-down voltage of KETEK device is evaluated at 5 V over-voltage. Note that the absolute temperature coefficient of the gain is smaller at higher over-voltage. According to Ref. [10], the coefficient will be -0.7% at 2 V over-voltage.



The Detectors

- Maxim Integrated DS18B20
  - Conntected in parallel
  - 3 lines (Power, Ground, Data)
  - 2 line in parasitic mode
  - 64 bit unique address
  - - 55 °C to 125 °C
  - 9 to 12 bit resolution
    - 0.5 °C to 0.0625 °C
- Texas Instruments
  - Connected in series
  - 3 lines
  - 5 bit address
  - - 55 °C to 125 °C
  - 14 bit resolution
    - 0.015625 °C

Circuit diagrams

- DS18B20

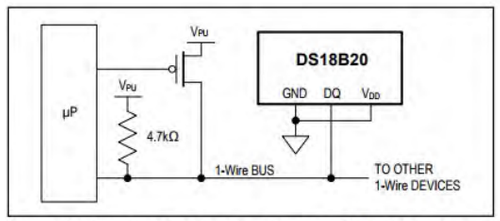


Figure 6. Supplying the Parasite-Powered DS18B20 During Temperature Conversions

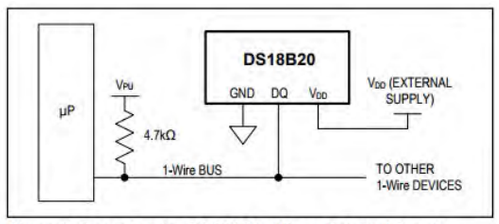
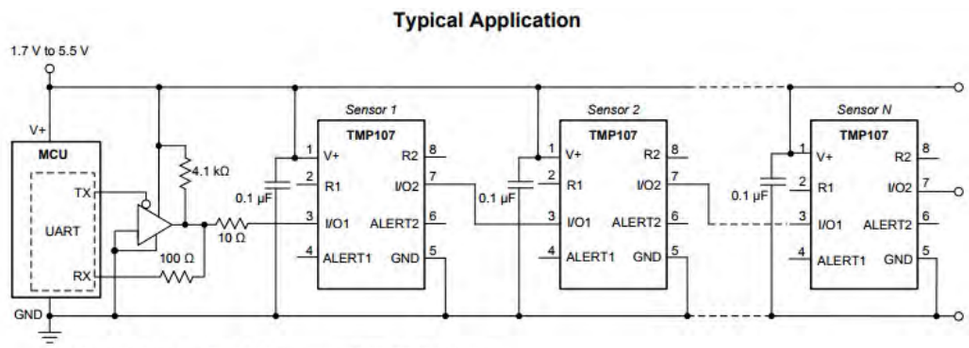


Figure 7. Powering the DS18B20 with an External Supply

- TMP107



All figures shown as TMP107 represent TMP107-Q1 as well.

Time to Read out

- Time per Sensor read: ~12 ms
- Time for conversion: ~153 ms

# Sensors	1	5	12	60
Time [ms]	610.6	677.4	771.5	1410
Time [ms] parasitic	764.9	818.7	912.6	1550

No time difference between parasitic with/without MOSFET

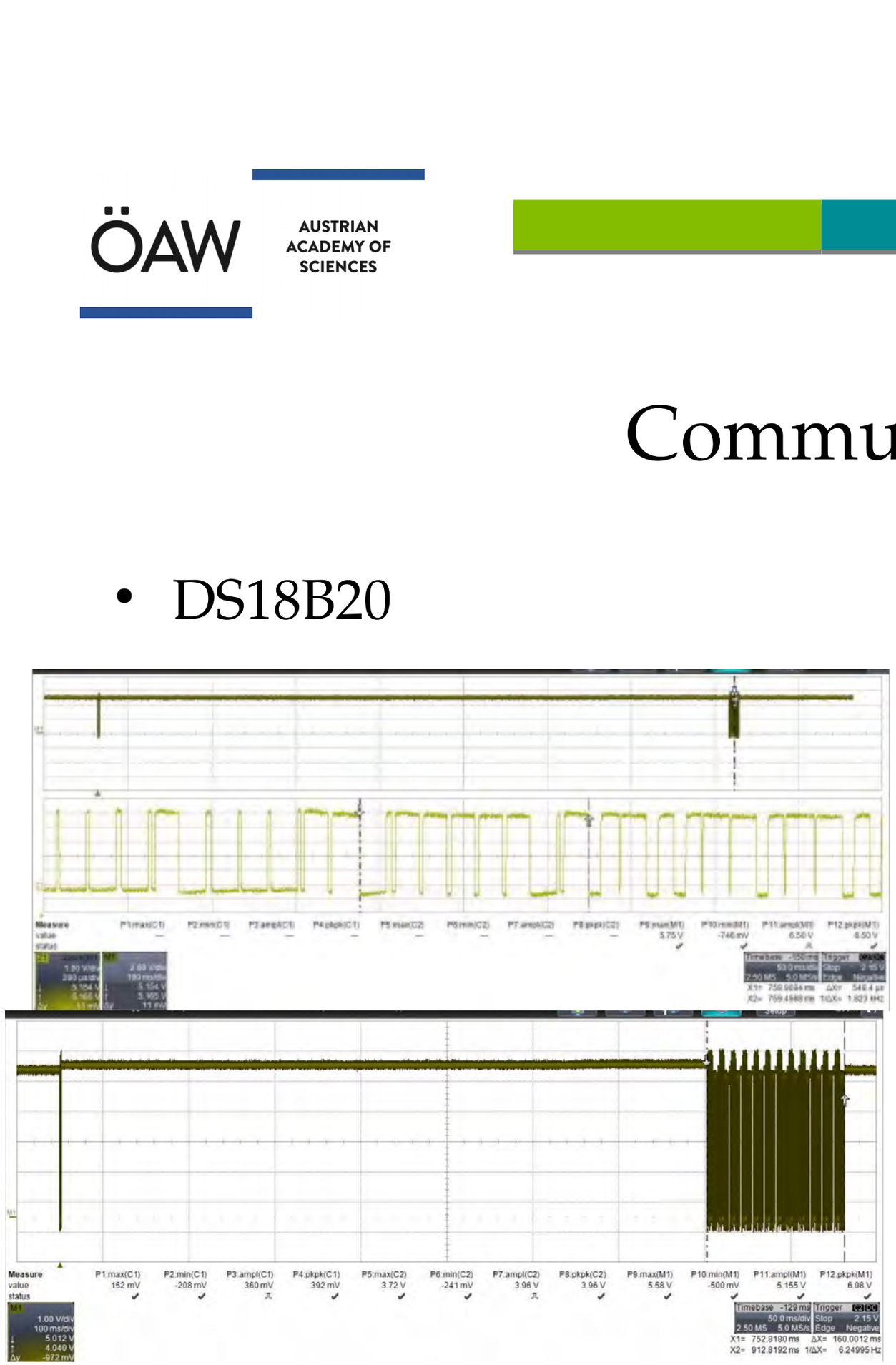
- Time per Sensor read: ~ 0.37 ms

# Sensors	4	5	32
Time [ms]	130.5	146.4	156.4

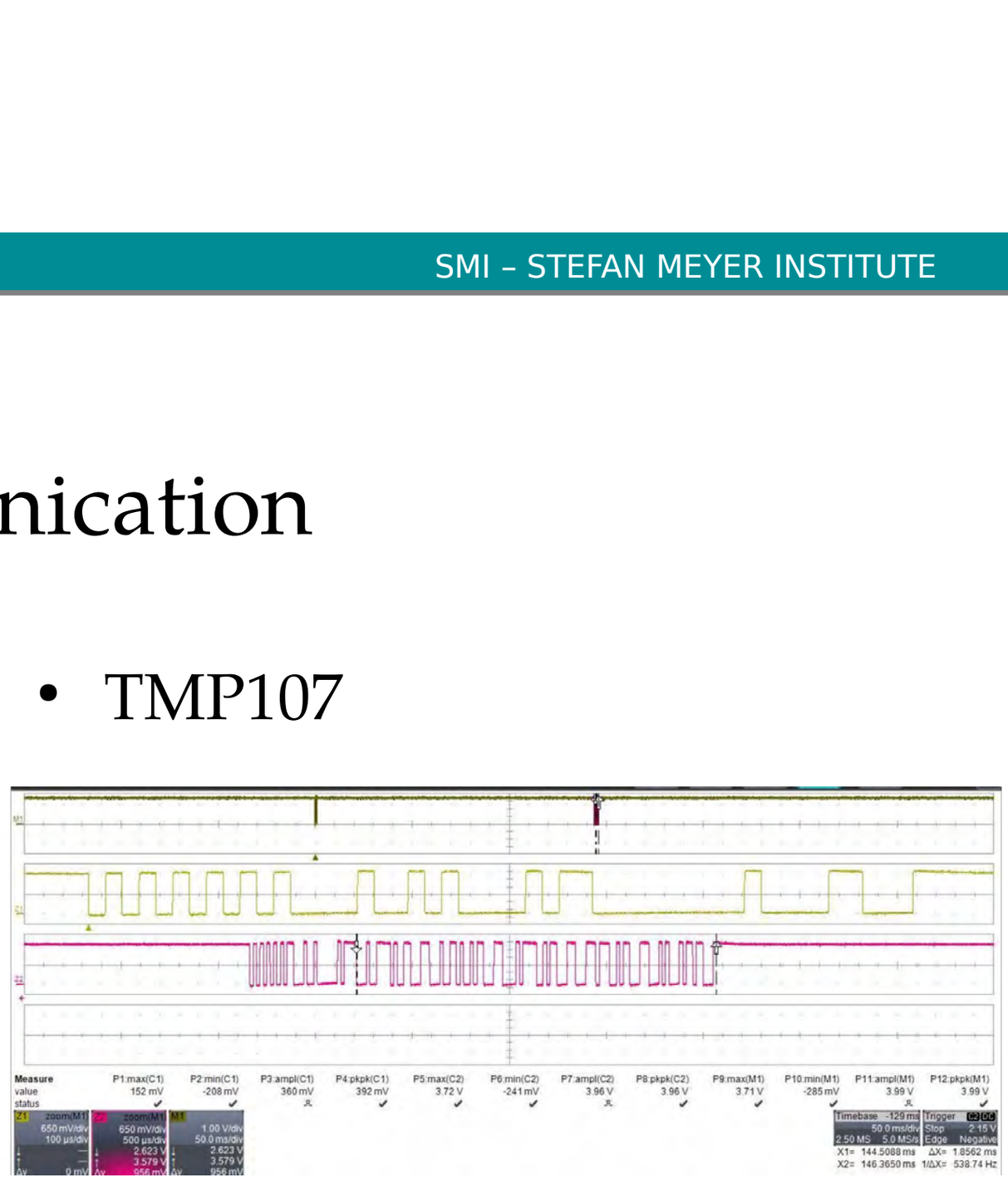
Values for 60 sensors are extrapolated

Communication

- DS18B20



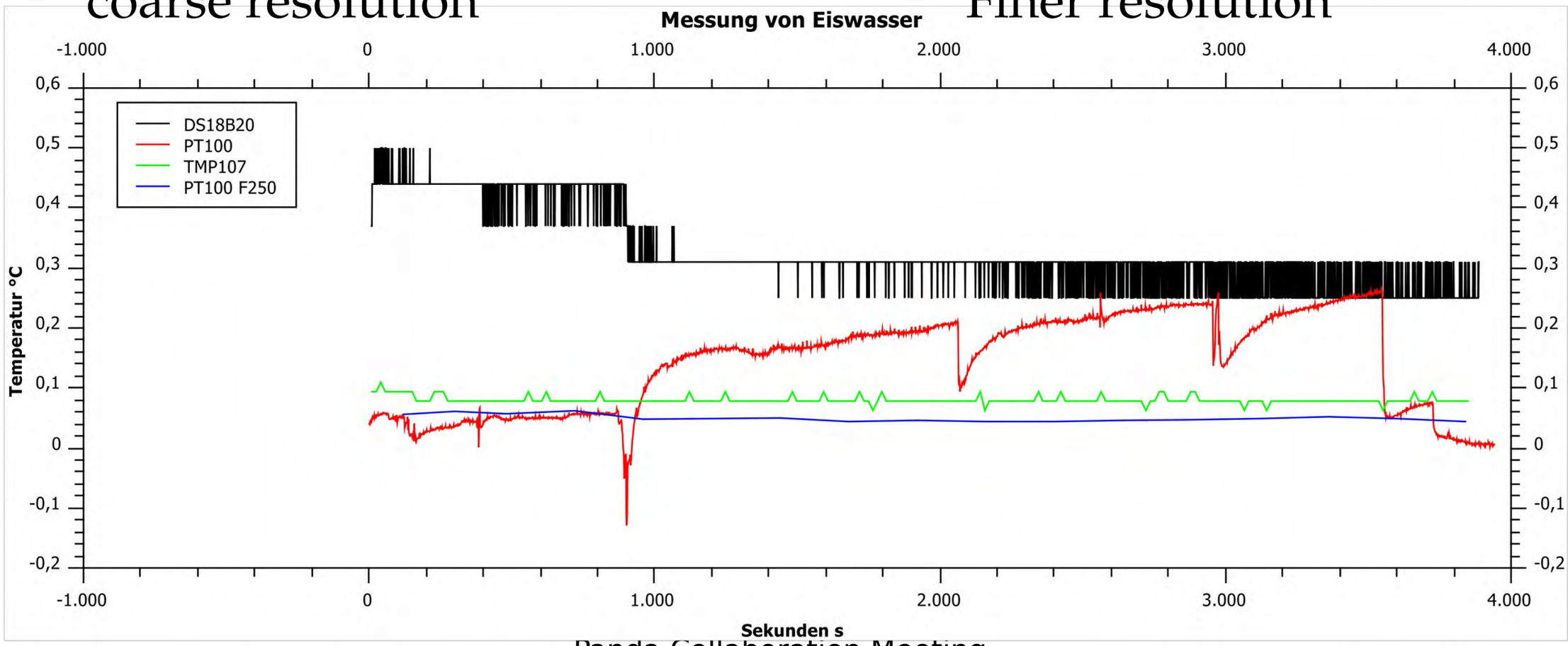
- TMP107



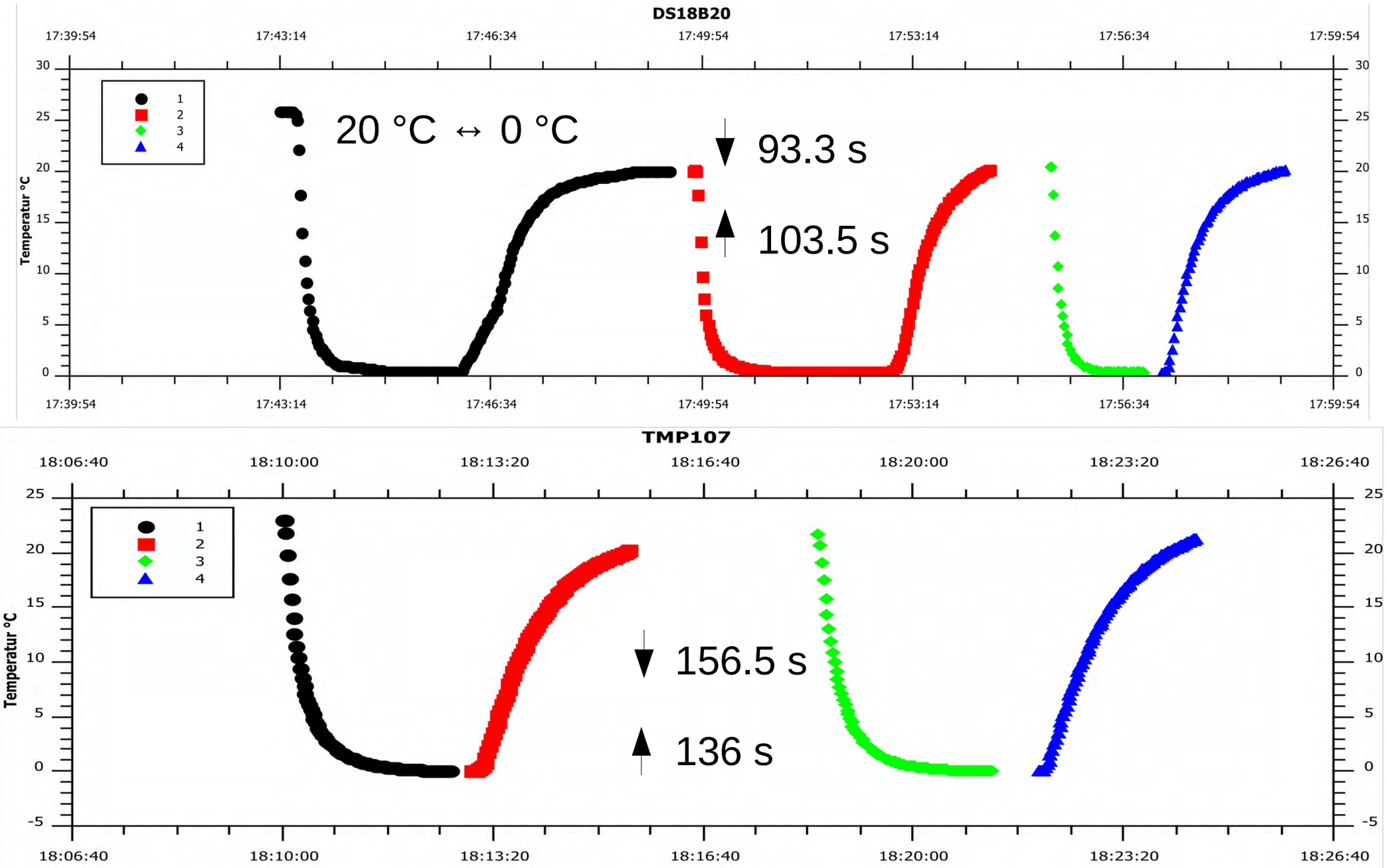
Communication is not affected by long transmission lengths. Tested up to 9 m

Fixed Point measurement

- DS19B20
  - Larger offset
  - coarse resolution
- TMP107
  - Greater stability
  - Finer resolution

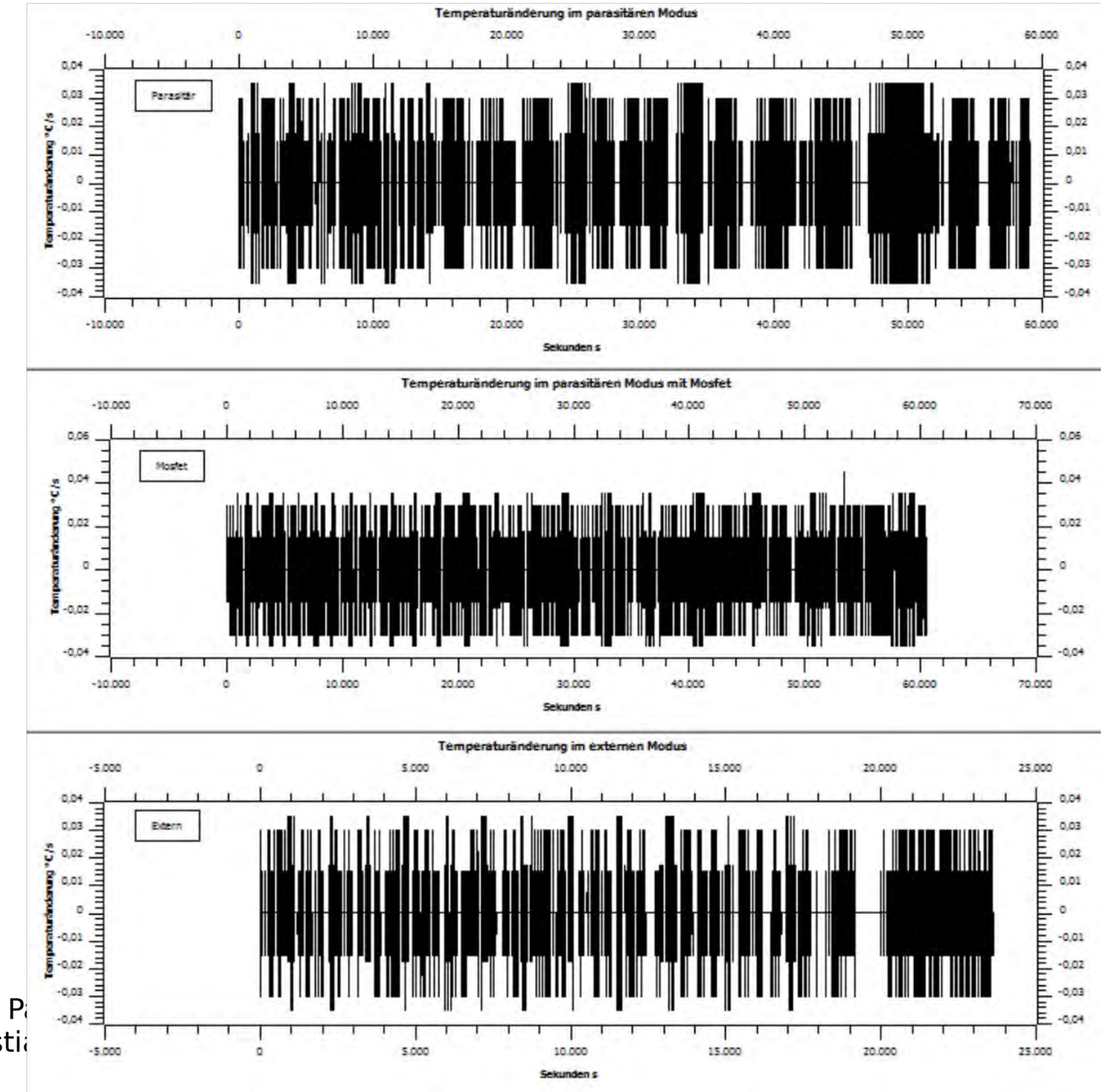


Reaction Time



Stability

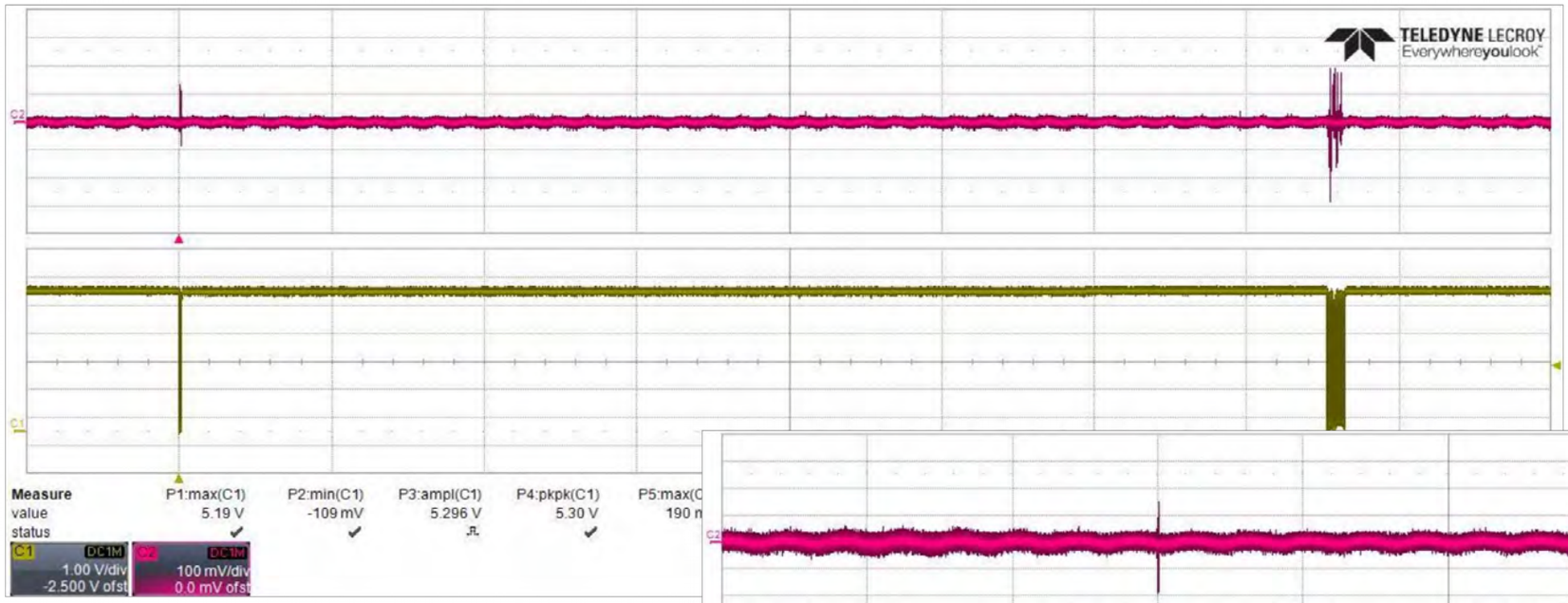
- Measured only for DS18B20
- No measurement possible for the TMP107 due to limited software capabilities
  - Were not able to continuously write data to file but only fill buffer and write to file post measurement
- No connection drops or stutters



Crosstalk

Even signal ground for both devices shows large fluctuations. Crosstalk measured (with and) without taking this into account.

- DS18B20



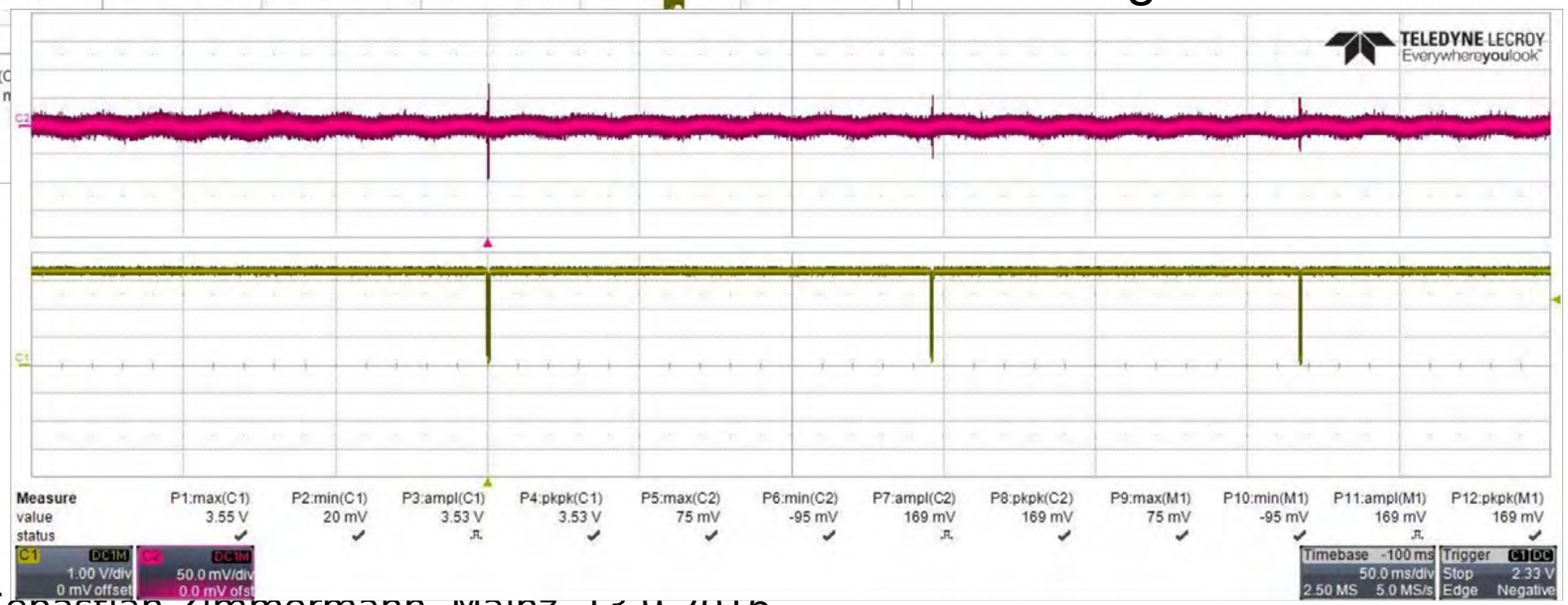
~420 mV with 5 V signals

Can go down to 3 V

- TMP107

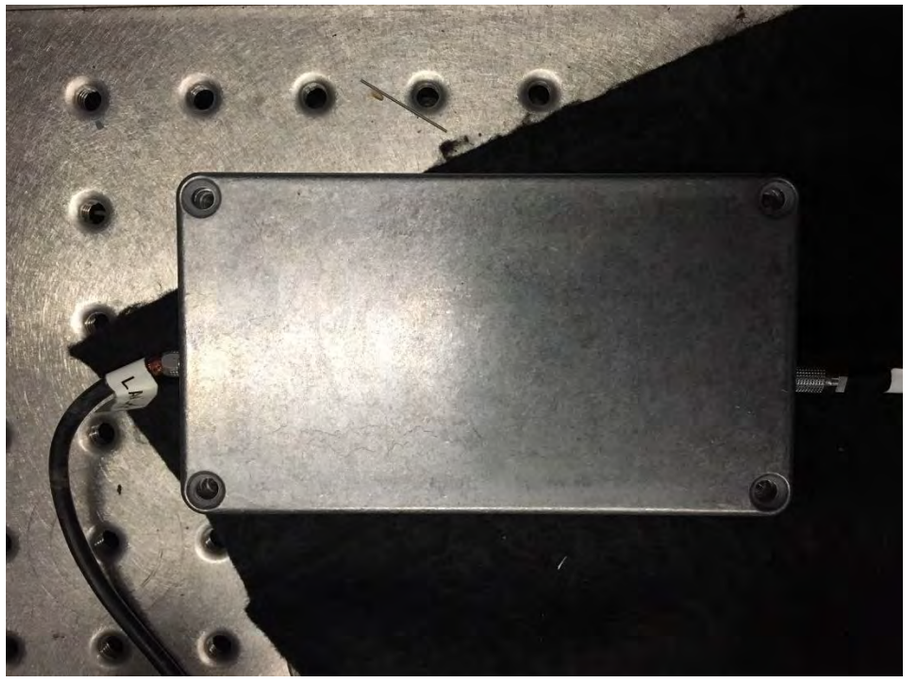
~184 mV
with 3.3 V signals

Can go down to 1.7 V

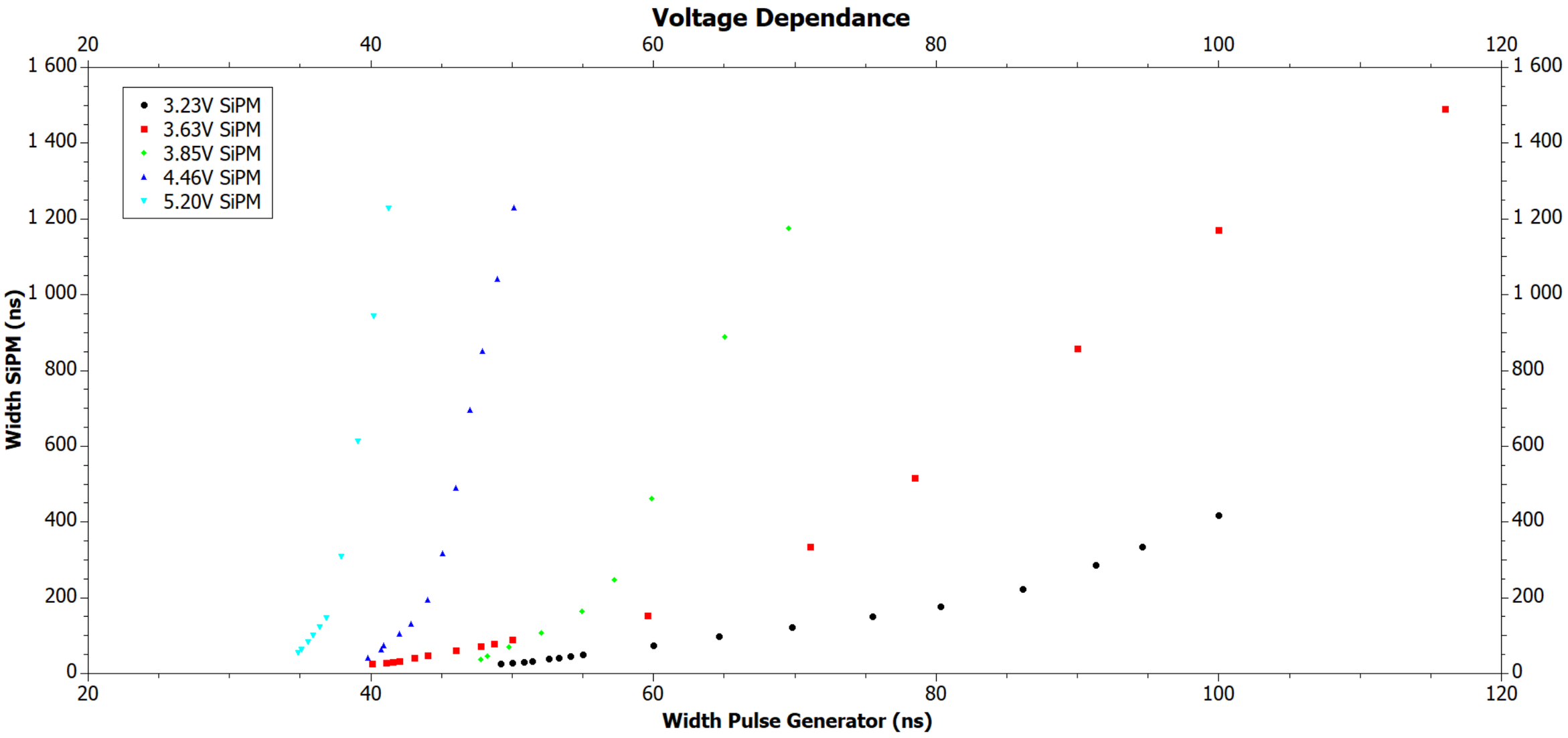


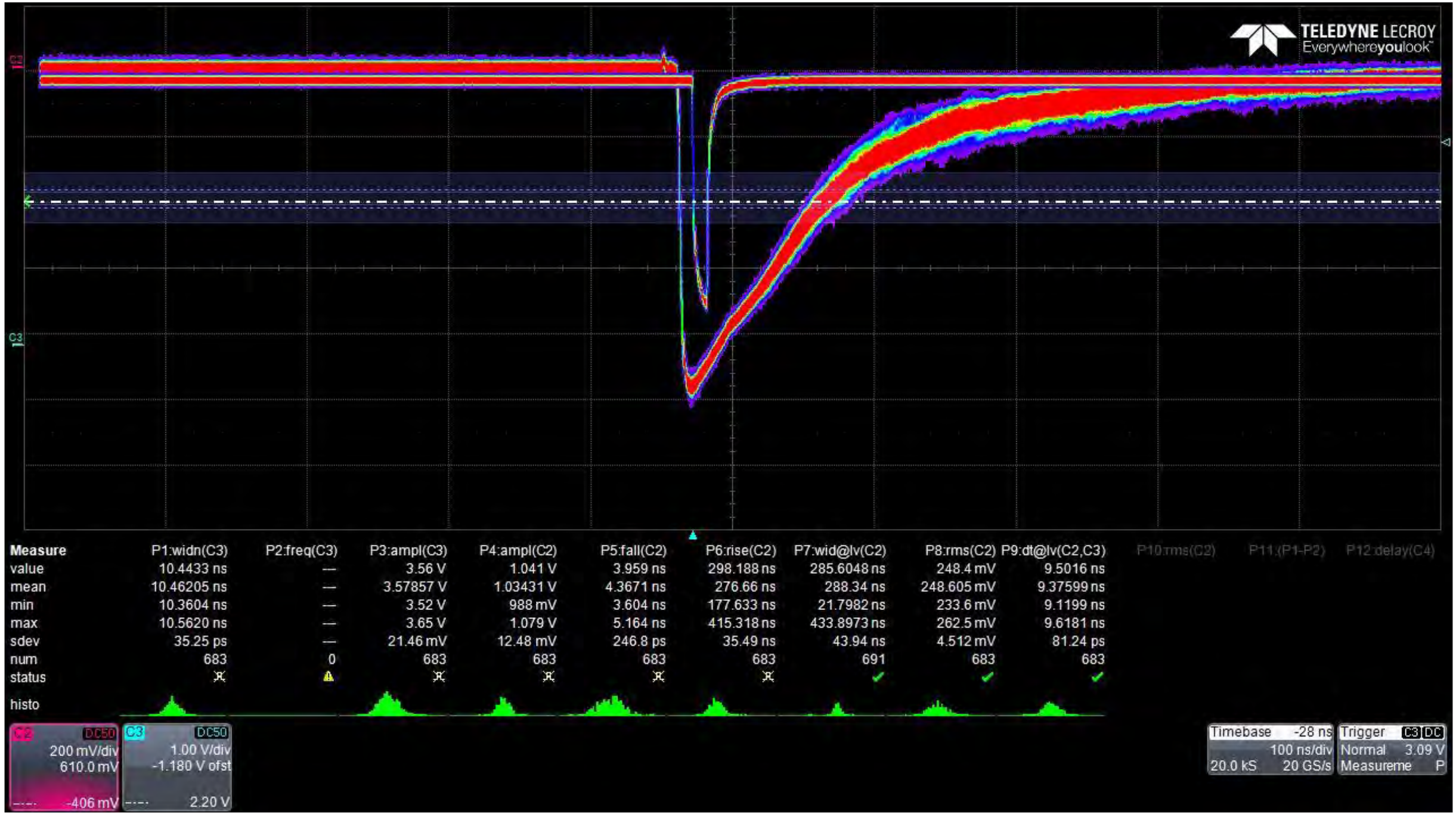
Advantage / Disadvantage

- DS18B20
  - 64 bit address
  - Arduino for read out
  - Slower read out (1550 ms a 60 sensors)
  - Coarser resolution
  - Faster temp adjustment
    (d: 93 s, u: 104 s)
  - Stable over long periods of time, no drops
  - Larger crosstalk (420 mV) due to larger signals (5 V to 3 V)
- TMP107
  - 5 bit address (32 sensors)
  - TI software for read out
  - Faster read out (156 ms a 32 sensors)
  - Finer resolution
  - Slower temp adjustment
    (d: 157 s, u: 136 s)
  - Could not do measurement due to software restrictions
  - Lower crosstalk (184 mV) due to smaller signals (3.3 V to 1.7 V)



- Hamamatsu SiPM (100µm pitch)
- Blue Kingbright LED (GaN on SiC), Threshold at 3V
- PSI Preamp
- Hewlett Packard 8082A Pulse Generator
- LeCroy SDA 760Zi-A Oscilloscope


Voltage Dependance
3.23V SiPM
3.63V SiPM
3.85V SiPM
4.46V SiPM
5.20V SiPM
Width SiPM (ns)
Width Pulse Generator (ns)
20
40
60
80
100
120
0
200
400
600
800
1 000
1 200
1 400
1 600



Measure	P1:widn(C3)	P2:freq(C3)	P3:ampl(C3)	P4:ampl(C2)	P5:fall(C2)	P6:rise(C2)	P7:wid@lv(C2)	P8:rms(C2)	P9:dt@lv(C2,C3)	P10:rms(C2)	P11:(P1-P2)	P12:delay(C4)
value	10.4433 ns	—	3.56 V	1.041 V	3.959 ns	298.188 ns	285.6048 ns	248.4 mV	9.5016 ns			
mean	10.46205 ns	—	3.57857 V	1.03431 V	4.3671 ns	276.66 ns	288.34 ns	248.605 mV	9.37599 ns			
min	10.3604 ns	—	3.52 V	988 mV	3.604 ns	177.633 ns	21.7982 ns	233.6 mV	9.1199 ns			
max	10.5620 ns	—	3.65 V	1.079 V	5.164 ns	415.318 ns	433.8973 ns	262.5 mV	9.6181 ns			
sdev	35.25 ps	—	21.46 mV	12.48 mV	246.8 ps	35.49 ns	43.94 ns	4.512 mV	81.24 ps			
num	683	0	683	683	683	683	691	683	683			
status												
histo												

Time-Resolution distribution (3mm)

- Managed time-resolution down to 50ps (LED direct in front of SIPM)
- SiPM output voltage between 1.0V and 1.2V (330 to 400 photons)
- No such time-resolution for lower or higher output
  - Need to test SMD LED and take into consideration the use of 3 LEDs per side, if needed

Others

- 1 2-years PD position in Vienna (B-TOF FEE development)
  - has been canceled.
  - fighting internally to get this post.

Summary

- R&D continues ..
- “subtasks” converging.
  - full length railboard, production at CERN?
- Should get serious with TOFPET2 readout and integration
- collaboration with P̄ANDA End-Cap DIRC group on TOFPET2
- 1 PD position, hopefully

Backup