# Status Update B-TOF

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On behalf of the Panda SciTil group

Panda Collaboration Meeting, GSI, 28.10.2020

# Outline

- Status of evaluation of Rail-Board system
- Crosstalk
- Signal Amplitude Attenuation
- Signal Rise Time attenuation
- Material Budget Comparison

# Personel

- The SMI is stepping out of PANDA effective by the end of the year
- If approved by the ÖAW (Austrian Academy of Sciences) I will stay and continue at SMI until the end of the year.
- To continue my work PANDA is looking for funds to continue to employ me for a few months
  - To wrap up the prototype development

# Raill-Board

- Goal:

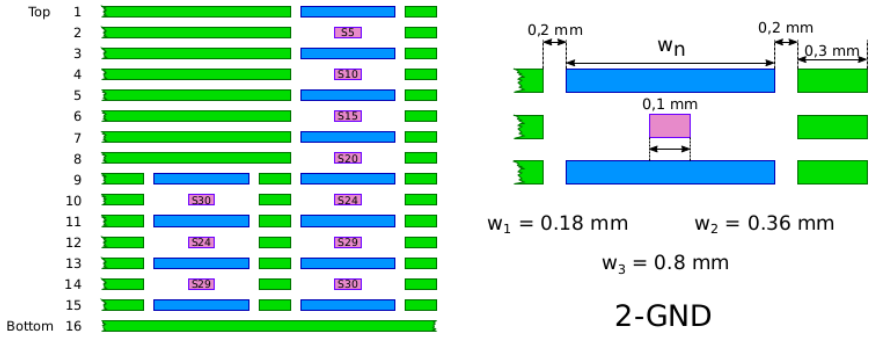
  Measure the impact of the Rail-Board on the time resolution of the system

- Preliminary Measurements:
  - Amplitude Attenuation
  - Signal Rise Time Increase

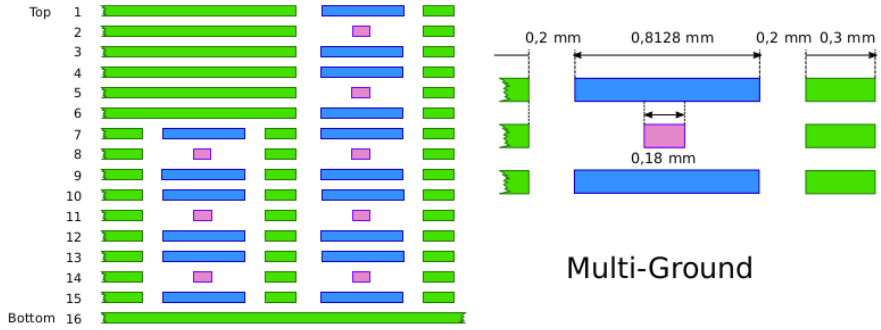
# Layouts of Rail-Board 2

- a) equivalent to Railboard 1
- Multiple versions of b)/c) implemented on board
  - b) with different ground line widths
  - c) with different via density

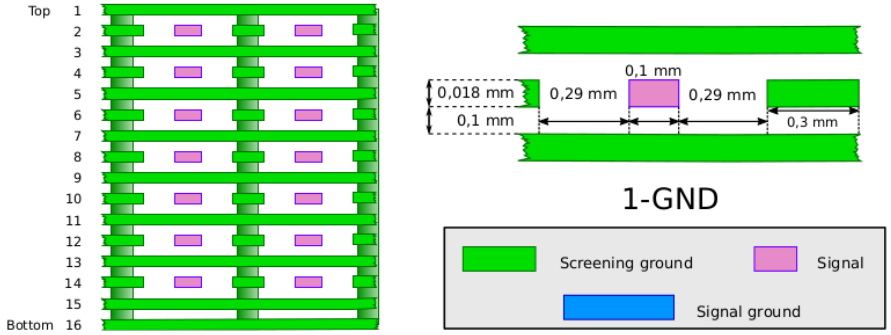
b)




a)

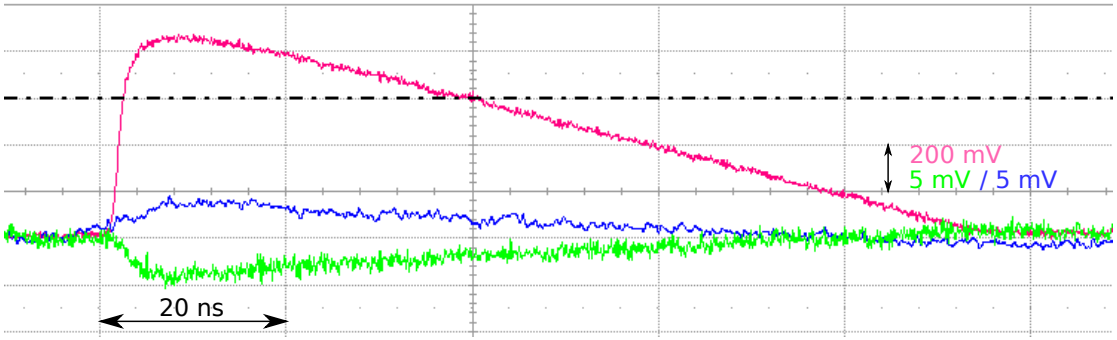


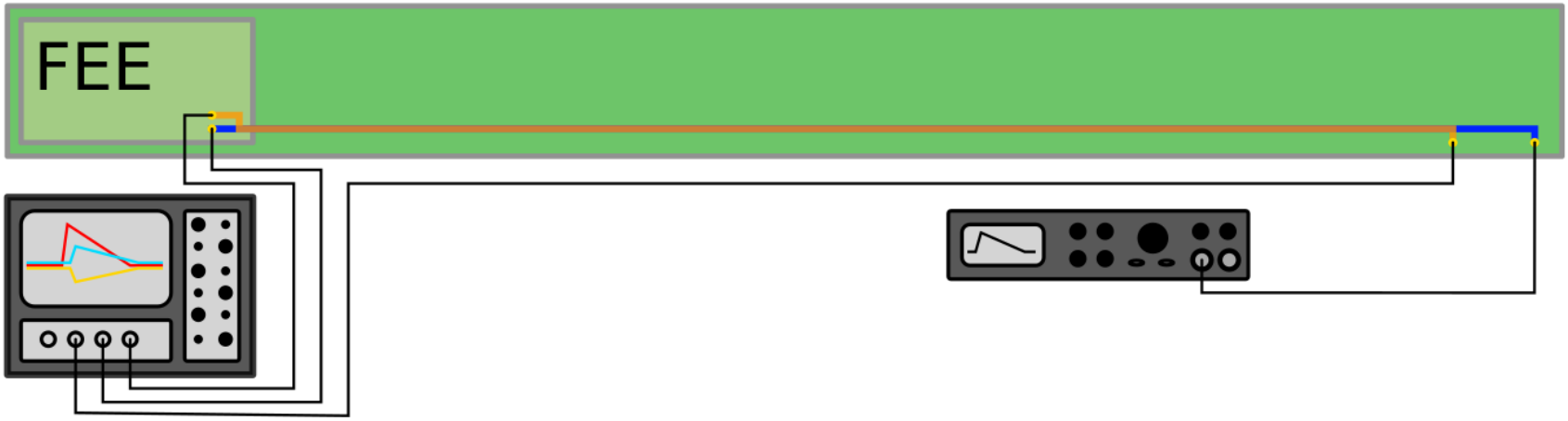

c)



# Crosstalk

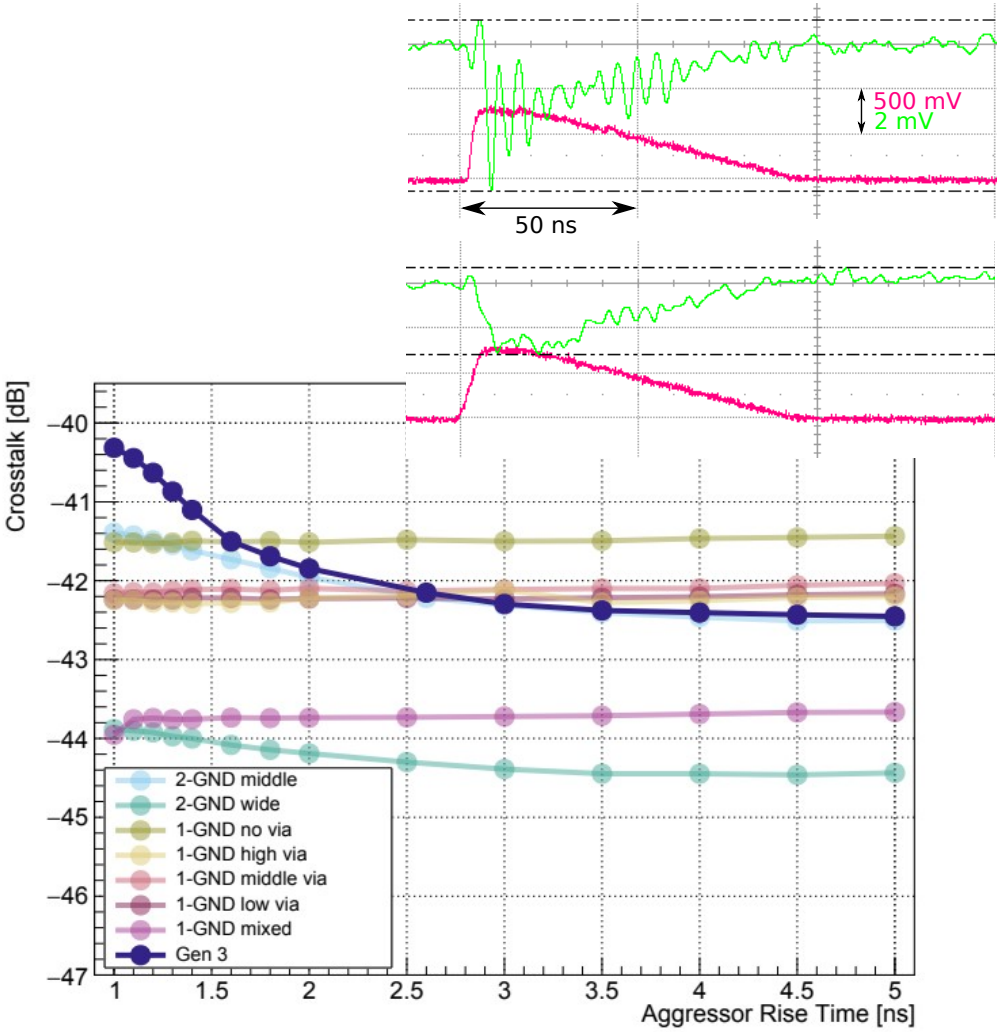
- Electrical pulses from signal generator at 20 MHz repetition rate
- 1 V Amplitude
- 1 ns to 5 ns
  10%-90% Rise Time



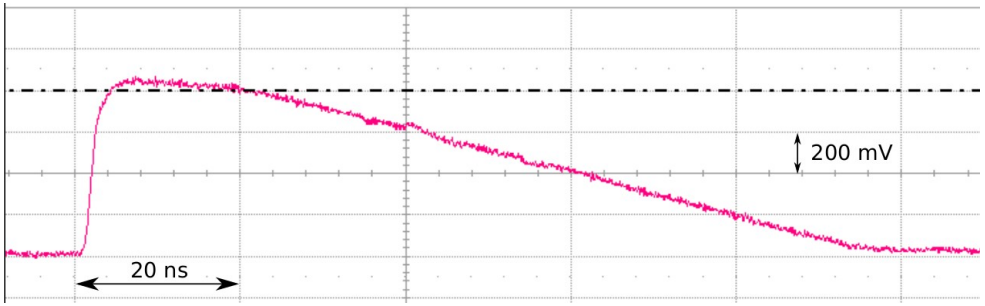
# Rail-Board Crosstalk

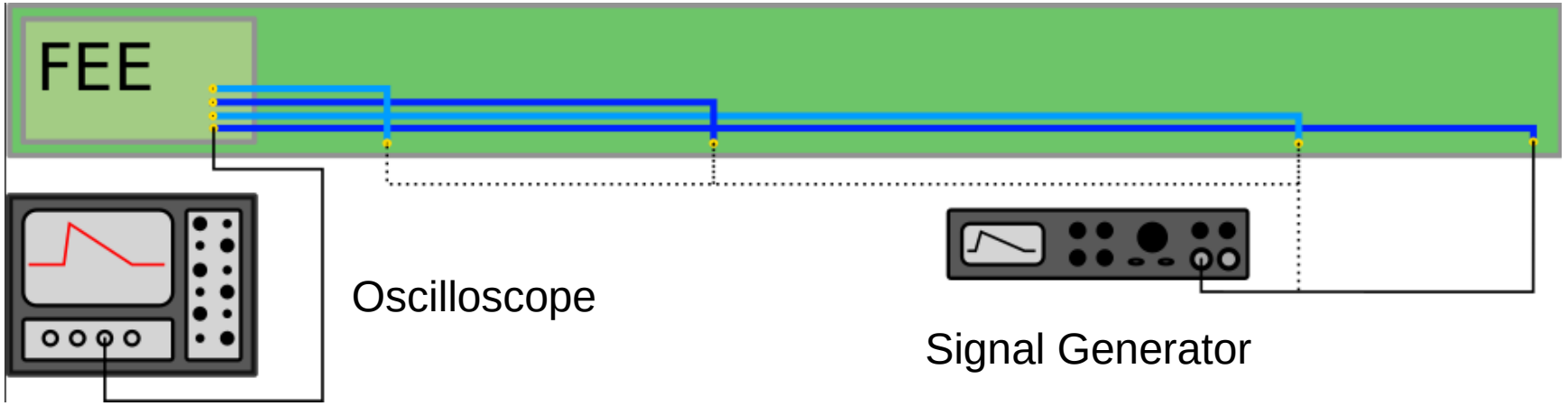
- Relevant Crosstalk is FEXT (far end crosstalk)
- Using pulses no crosstalk on board 1
- Measurements of all layouts in this figure
- Crosstalk level for Rail-Board Gen 3 large at 1 ns
  - due to reflections on the line
- Since FEXT produces pulses of opposite polarity this is no issue
  - Even with right polarity this would be acceptable levels



# Attenuation Measurements

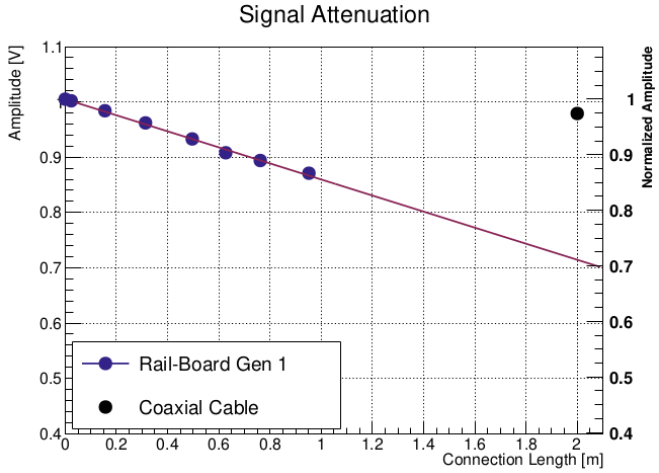
- Electrical pulses from signal generator at 20 MHz repetition rate
- 1 V Amplitude
- 1 ns 10%-90% Rise Time
- Lines of mulitple lengths measured

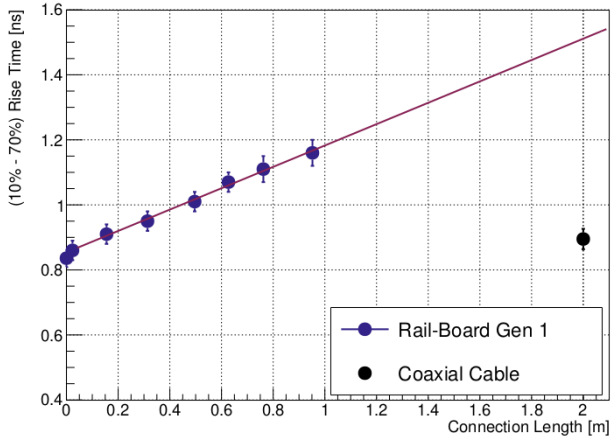


# Rail-Board 1

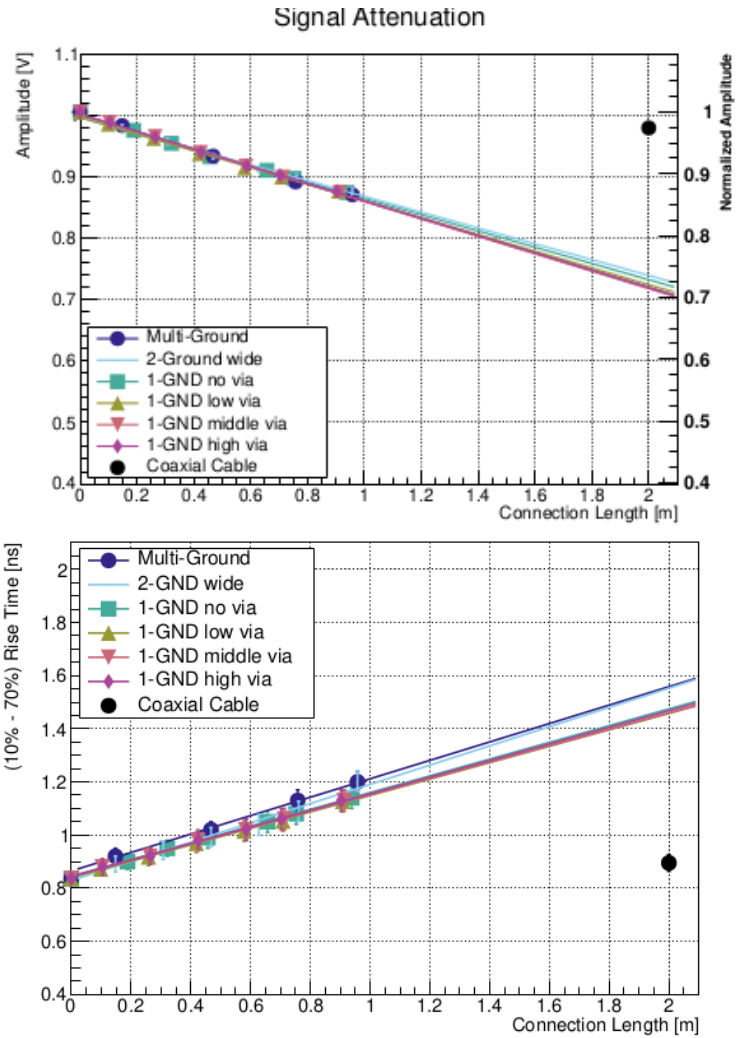
- Data compared to coaxial cable of CERN standard
- Amplitude Attenuation:
  27.5 % loss
  - Extrapolated to full length board
  - Attenuation needs to be reduced
- The rise time was measured from 10% to 70%
  - To reduce effects of reflections and other noise at the top of the signal peak
- Small initial rise time increase due to connector (50 ps)
- Rise time increase of:
  59%
  - Extrapolated to full length



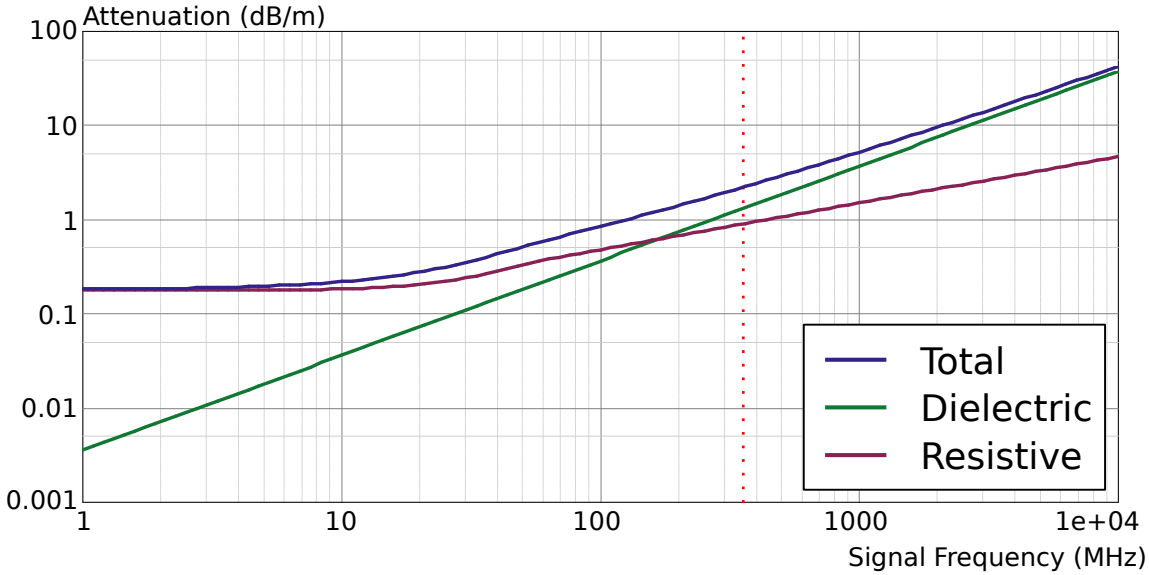
# Rail-Board 2

- Due to reflections on some lines not all layouts could be measured
- Average signal amplitude loss 26.3(8) %
  - Similar behaviour for all of them
  - No difference to previous board
- Signal rise time increase 64 %
  - 1 GND shows slightly better performance
- Attenuation still too large over the full board
  - Attempt to reduce this for next board



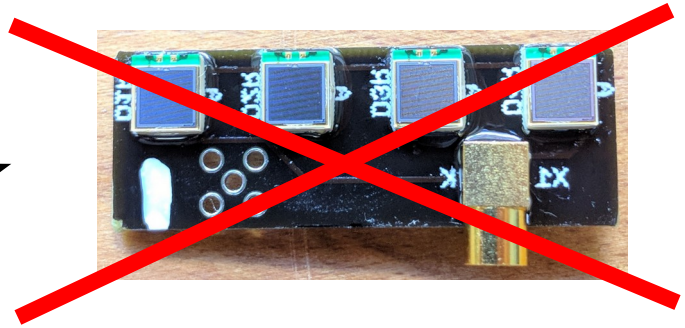
# Rail-Board 3

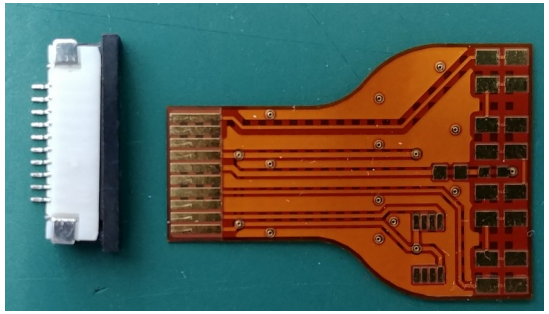
- Improvements made:
  - Wider signal lines (400 µm instead of 100 µm)
  - Low loss Material (Rogers 4003C)

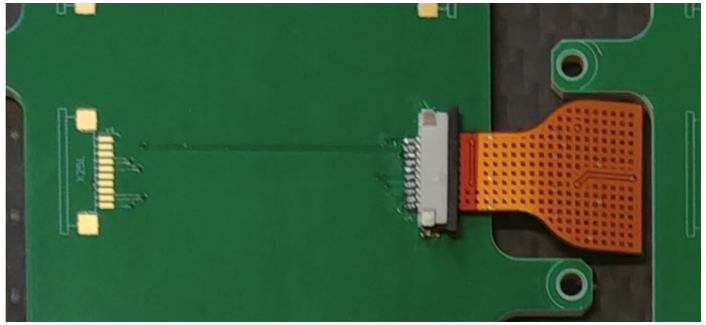


# Rail-Board 3 Connection

- Connectors are different
- Signal has to be injected via the Sensor-Board
  - Board not included in previous measurements
- This introduces additional losses not seen in previous measurements

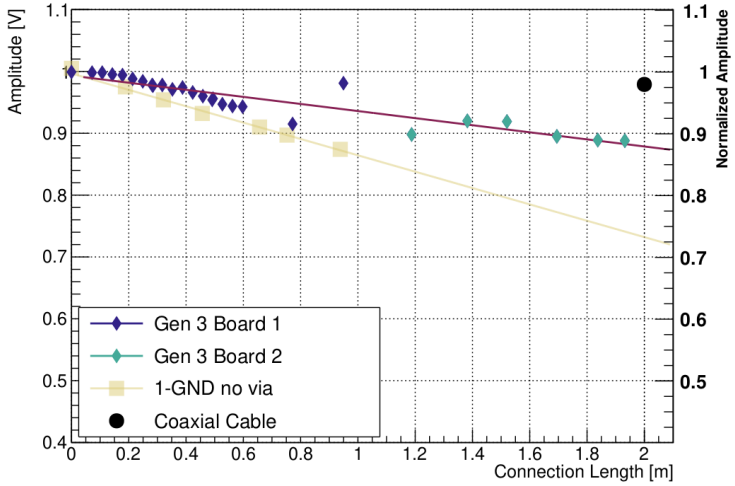


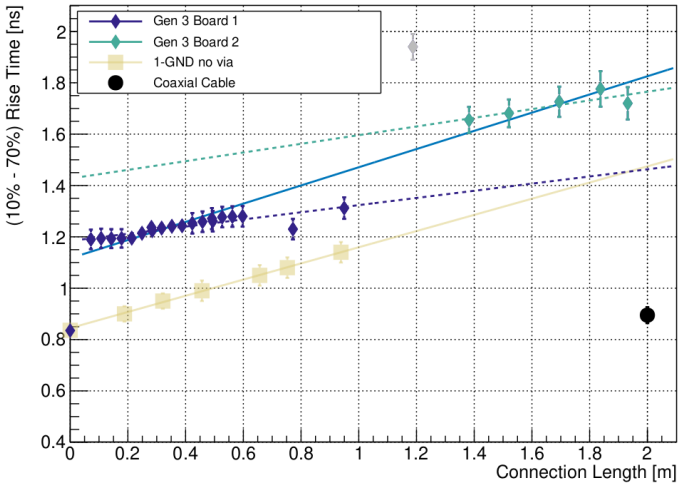




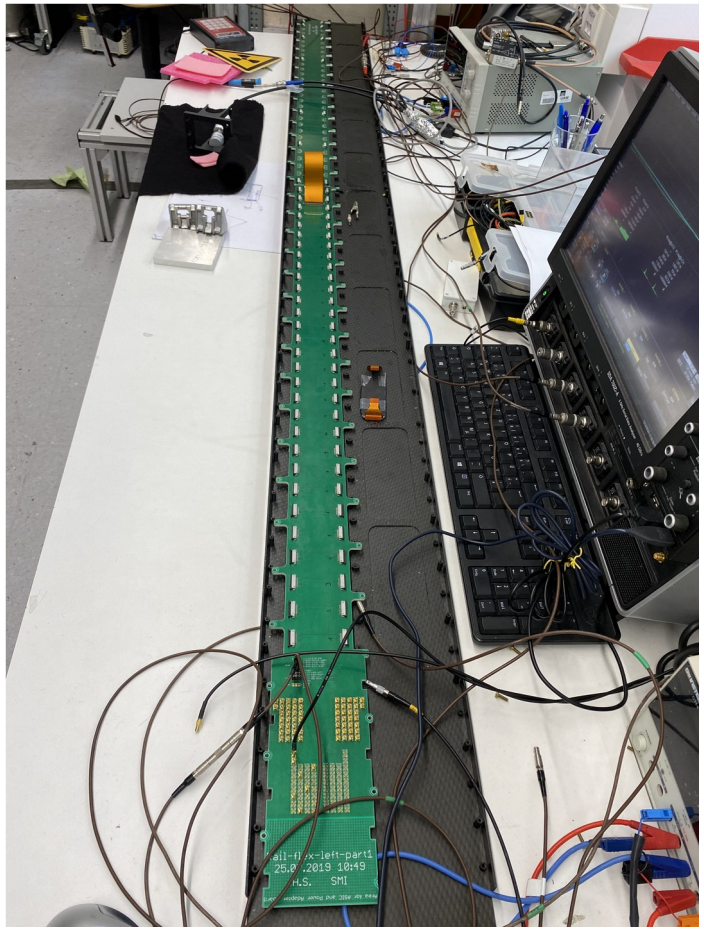
# Rail-Board 3

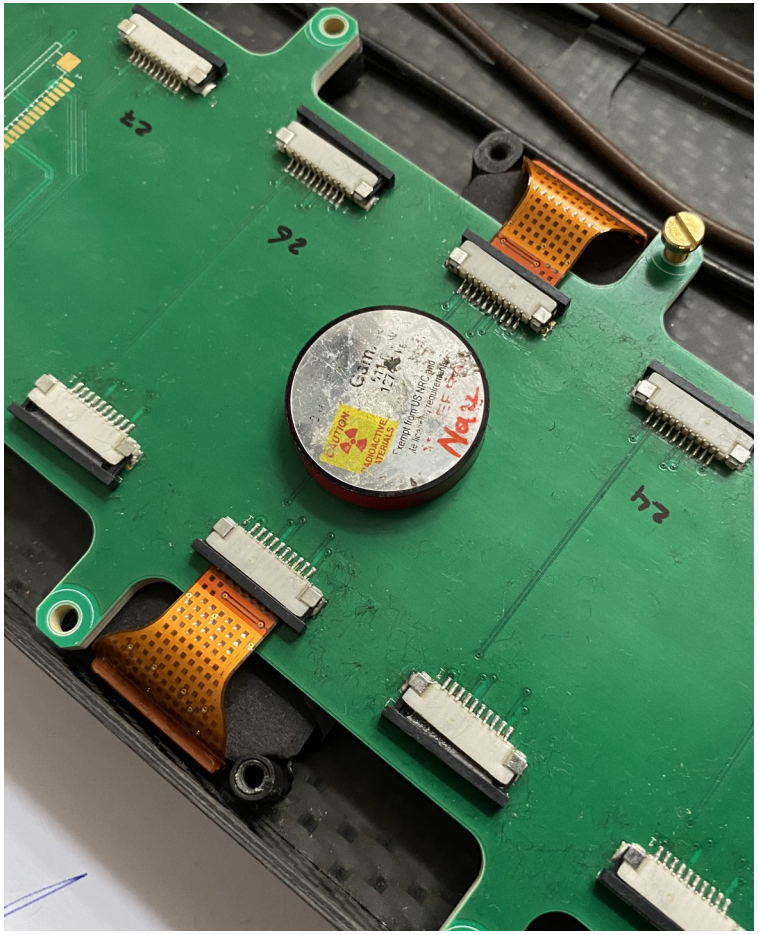
- Signal amplitude attenuation significantly reduced
  - Loss of 11.7(5) % over full length
- No amplitude loss at connectors
- Large rise time increase at the connectors
- Rise time results less clear
  - Either one continuous increase after connecting to first board
    - Parallel to increase seen on previous board
  - Additional risetime increase between boards (after 0.9 m)
    - Lower increase along the board
- Effects on actual sensor signal and time resolution unknown

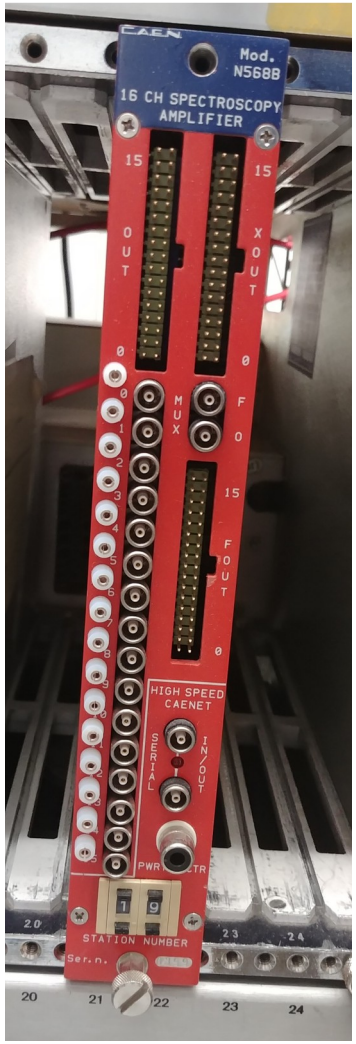


# Measurements using Real Signals

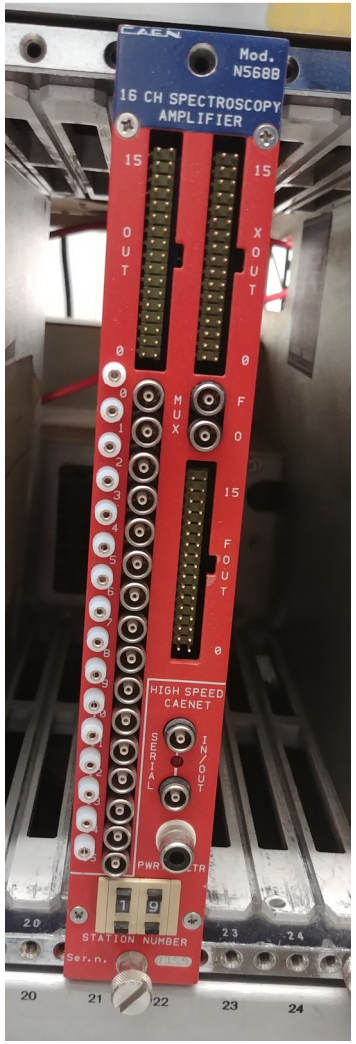


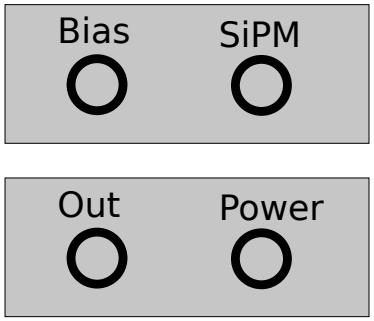




# Signal Amplification

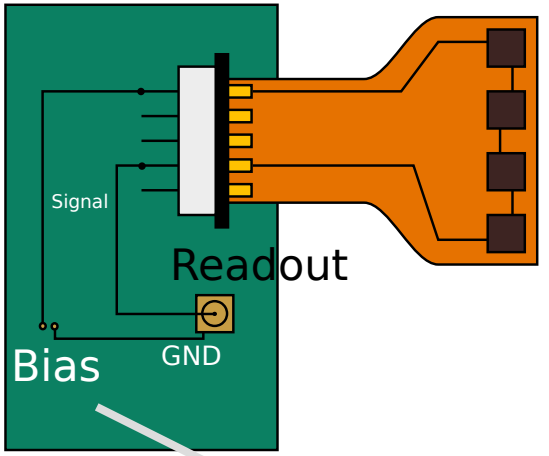
used

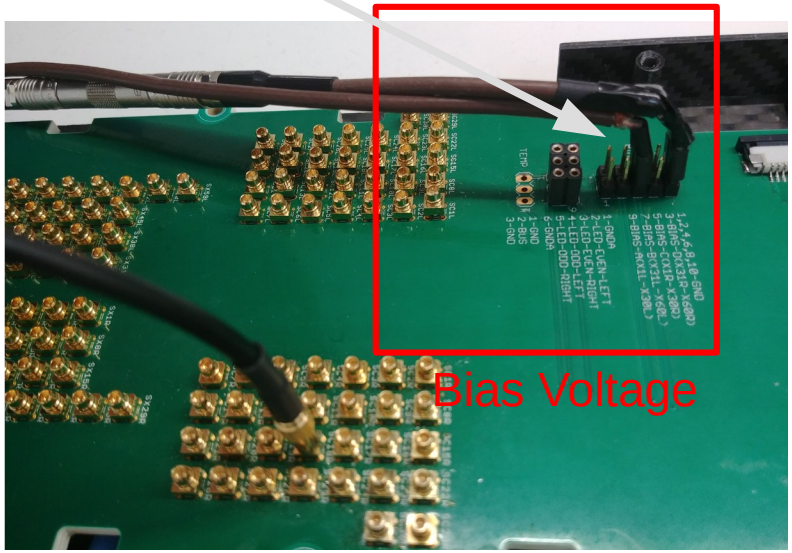



Not used

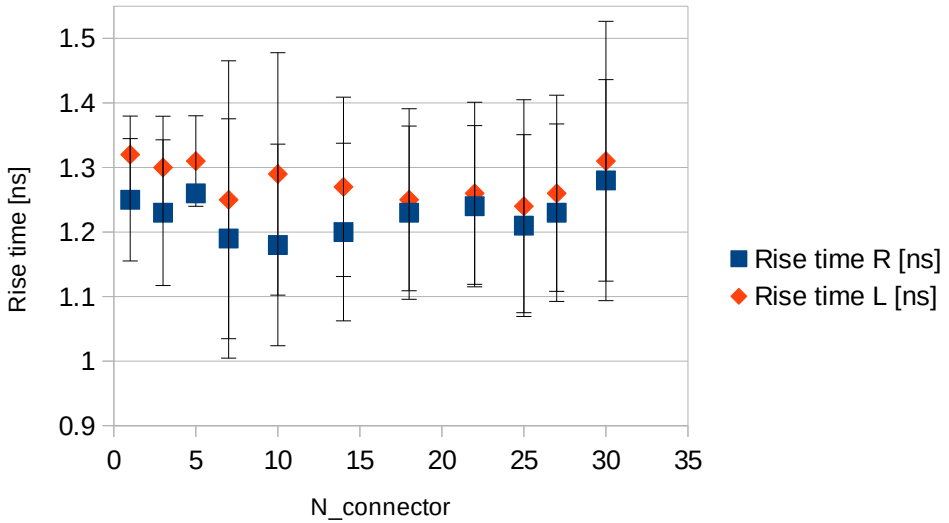
Do not fit to connection scheme

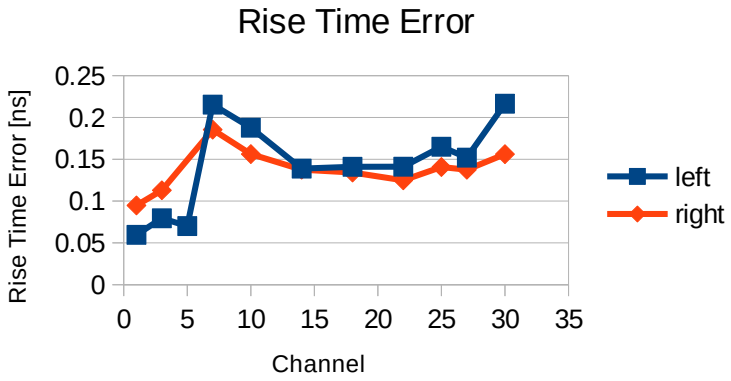


# Measurements using Real Signals

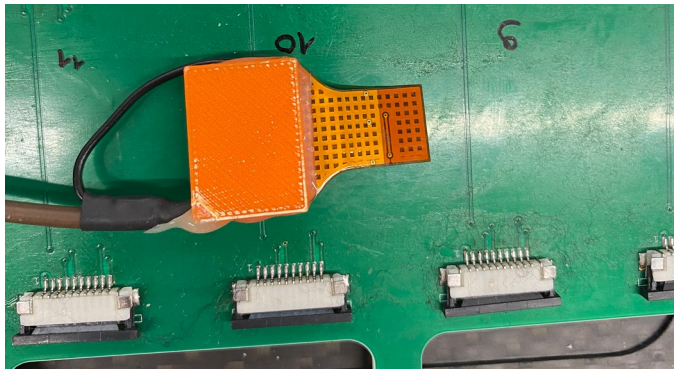
- A scintillator tile wrapped in aluminium foil is attached to the Rail-Board
- $^{22}$Na source was used uncollimated
- A trigger on large signals of channel L (left)
- Rise time not affected by channel position



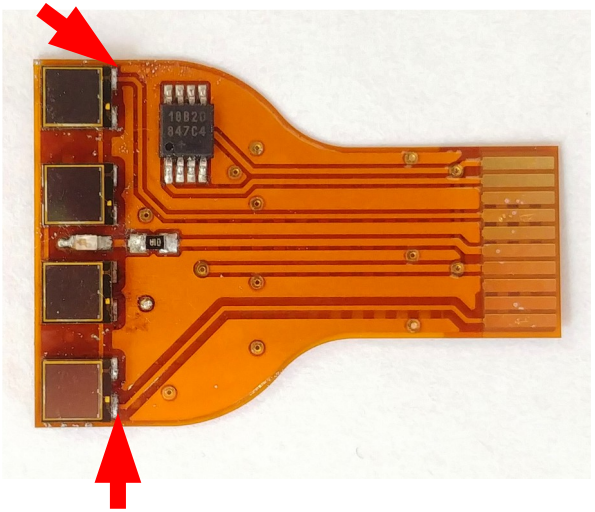



# Additional Learnings

- Flexible sensor is very sensitive to mechanical manipulation
- Using and bending it multiple times can lead to breaking of electrical connection



- Mechanical reinforcement behind the SIPMs helps with longevity
- Adding tear drop transition from pad to transmission line might reduce breaking



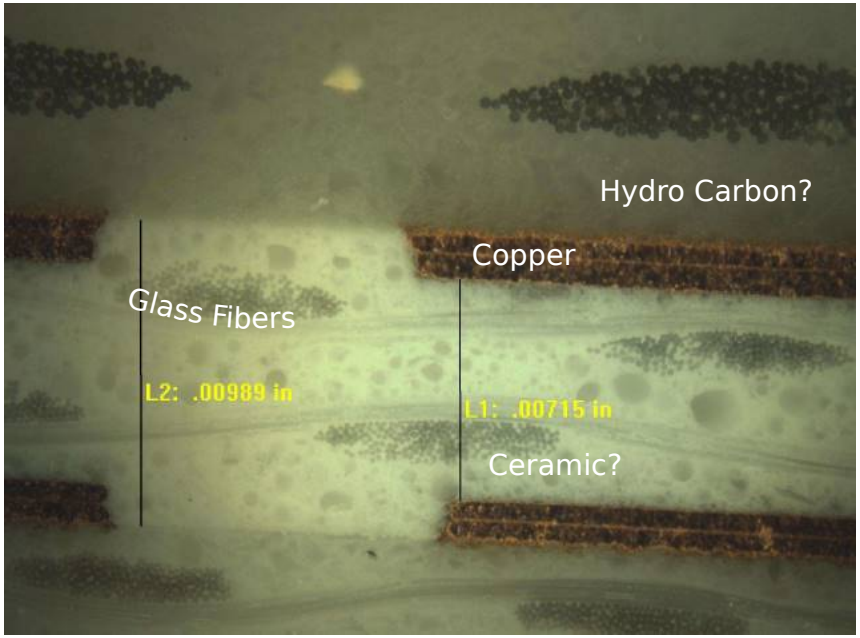
# Material Budget

- New Calculations of the Material Budget
- Majority of the additional material is substrate to keep 50 Ohm when widening the traces
- Keeping the same line width of Board 3 (400 µm) with FR4 would increase material budget even more since substrate thickness would have to be increased

| | Material | $X_0$ [mm] | $d_{eff}$ [mm] | $d_{eff}/X_0$ [%] | Cutout [%] |
|---|---|---|---|---|---|
| **Gen 1** | Copper | 14.4 | 0.03 | 0.21 | |
| | FR-4 | 155.0 | 0.71 | 0.46 | 52.9 |
| | **Sum** | | | **0.67** | |
| **2-GND wide** | Copper | 14.4 | 0.03 | 0.21 | |
| | FR-4 | 155.0 | 0.50 | 0.32 | 66.4 |
| | **Sum** | | | **0.54** | |
| **2-GND narrow** | Copper (GND) | 14.40 | 0.02 | 0.11 | |
| | FR-4 | 155.00 | 0.29 | 0.19 | 80.4 |
| | **Sum** | | | **0.31** | |
| **1-GND** | Copper | 14.4 | 0.03 | 0.20 | |
| | FR-4 | 155.0 | 0.33 | 0.22 | 77.8 |
| | **Sum** | | | **0.41** | |
| **Gen 3** | Copper | 14.4 | 0.04 | 0.29 | |
| | Rogers | 197.2 | 2.08 | 1.15 | 30.8 |
| | **Sum** | | | **1.45** | |
| **Gen 3 FR-4** | Copper | 14.4 | 0.04 | 0.29 | |
| | FR-4 | 155.0 | 2.59 | 1.67 | 30.8 |
| | **Sum** | | | **1.97** | |

# $X_0$ Rogers Material

- Radiation length estimated from image provided by Roger Corp.
- Given density of 1.79 g/cm³
- Ceramic "probably $Al_20_3$"




| Material | Composition | $\rho$[g/cm³] | $X_0$ [g/cm²] |
|---|---|---|---|
| RO4003c | 1.000 | 1.79 | **32.2 ± 1.5** |
| AL2O3 | 0.195 ± 0.026 | 3.97 | 27.94 |
| Hydro Carbon | 0.705 ± 0.026 | **1.10 ± 0.15** | **42.00 ± 2.00** |
| Glass | **0.100 ± 0.050** | 2.4 | 25.66 |

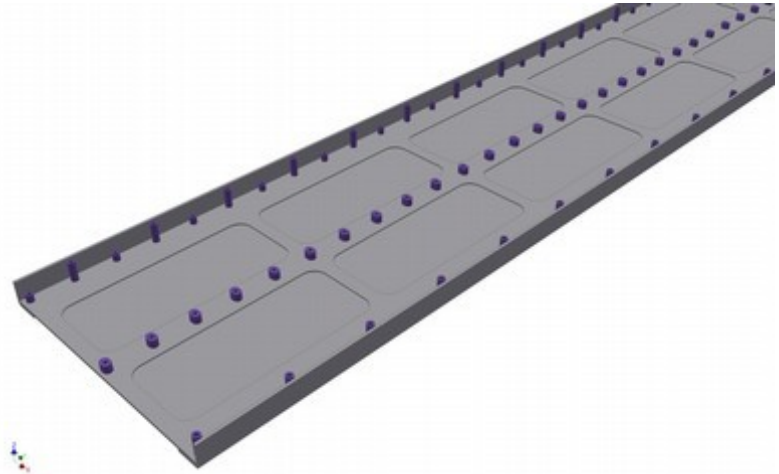
# Outlook

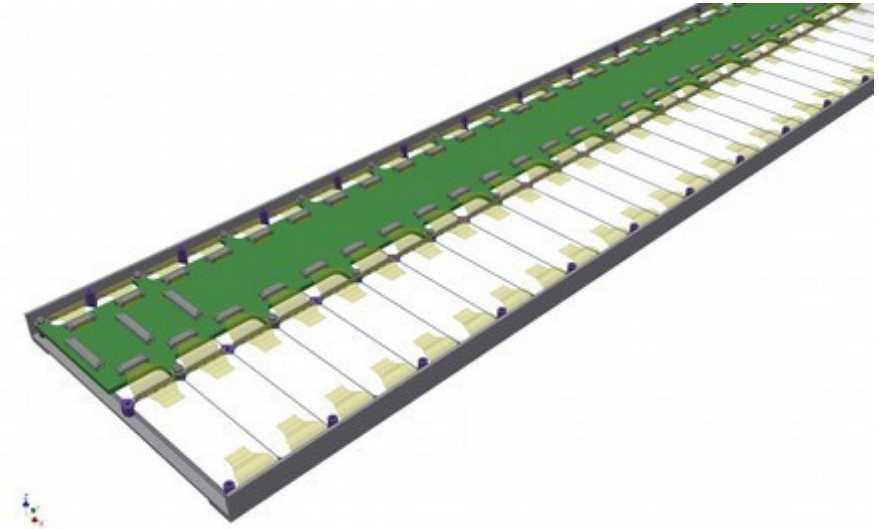
- Next step is to setup time resolution measurements with the scintillating tile
  - Trigger behind scintillator necessary to get events with full penetration
- Take TOFPET 2 ASIC out again for readout
- I was never able to read out our own SiPMs
  - Only the provided test sipms
- Do time resolution scans across the Rail-Board using the TOFPET

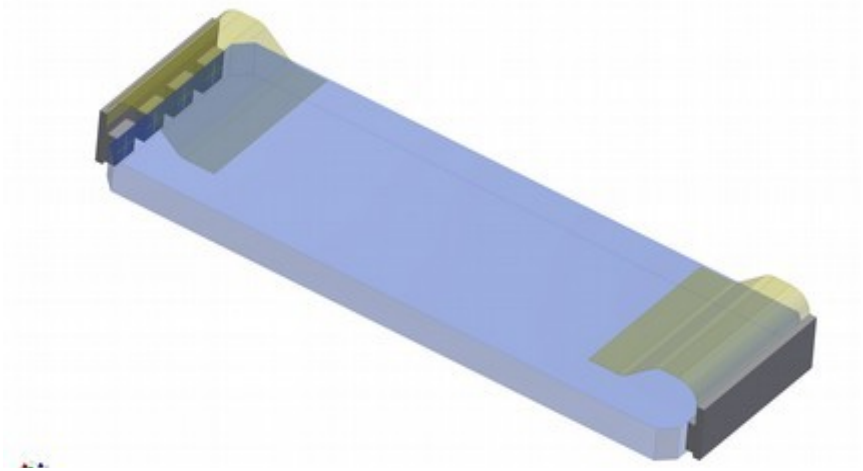
# Thank You for your Attention!

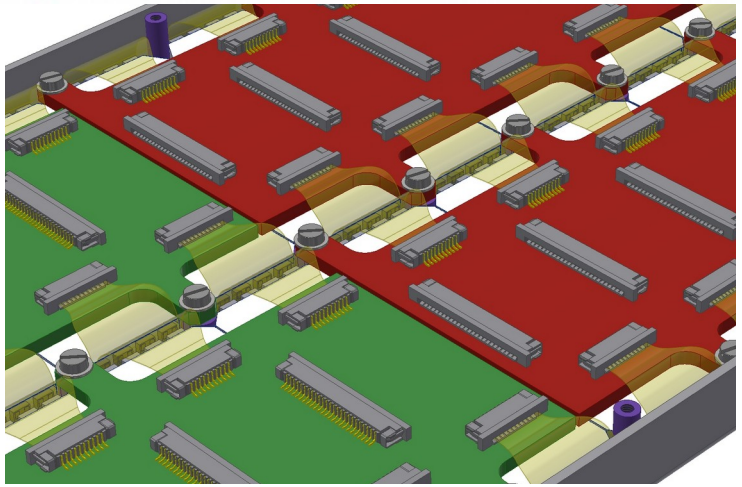
# Appendix

# Reminder of new Design





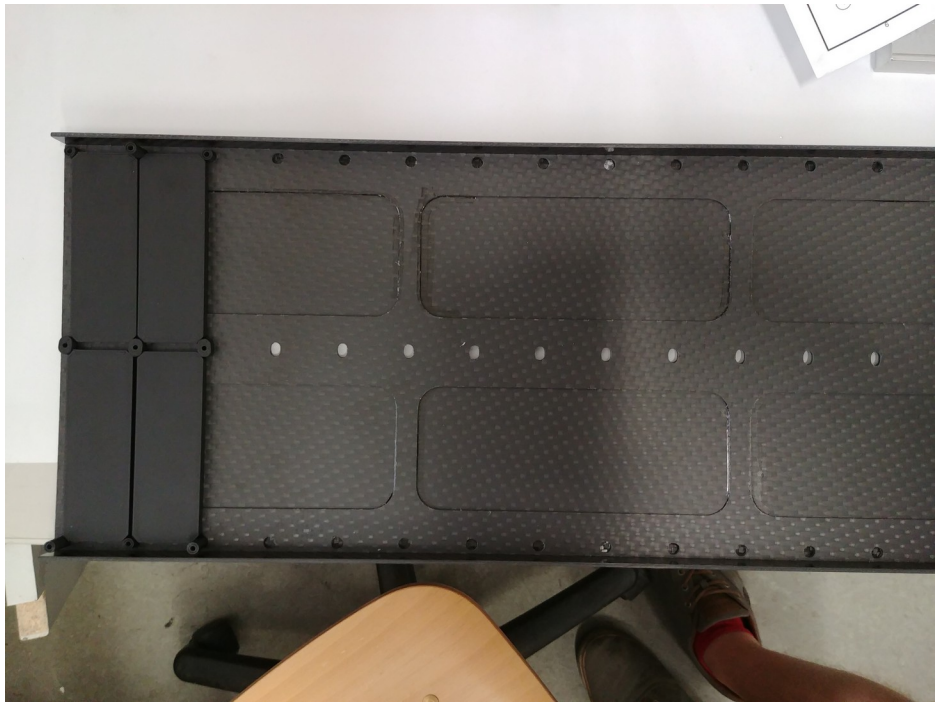




# Railboard v3 Progress

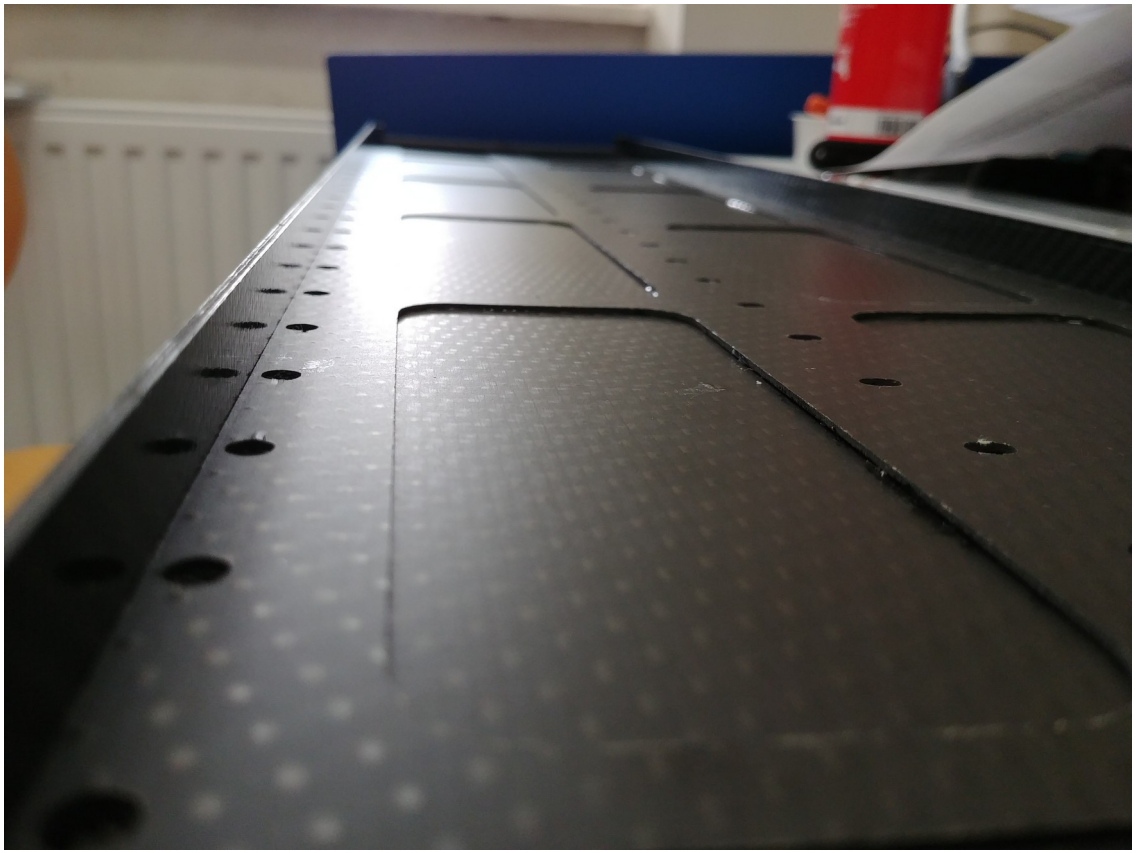
- One old railboard is now made up of 4 parts
  - 2 parts in front 2 in the back on the FEE side
- 2 of 4 PCBs have been produced
  - The FEE side is supposed to be finished tomorrow (Nov 7th)
- The boards are still in China
  - All PCB parts will be shipped together

# Railboard Carbon Holding Structure



# Railboard Carbon Holding Structure

- The carbon holding structure has been successfully been produced
- 1 mm carbon sheets were used
- High mechanical strength
  - We estimate we can reduce the needed carbon by 1/3 (0.4 $X/X_0$)



# Scintillator Chamfer

- Wrapped scintillators with chamfers should be tested against no chamfer
- Multiple points along the Scintillator are irradiated by Laser or beta source
- Measurements are done by student
- Have issue with SiPM solder breaking off of the PCB