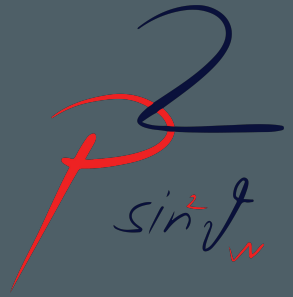


Design and Production of Pixel Strips for the P2 Tracking Detector Modules

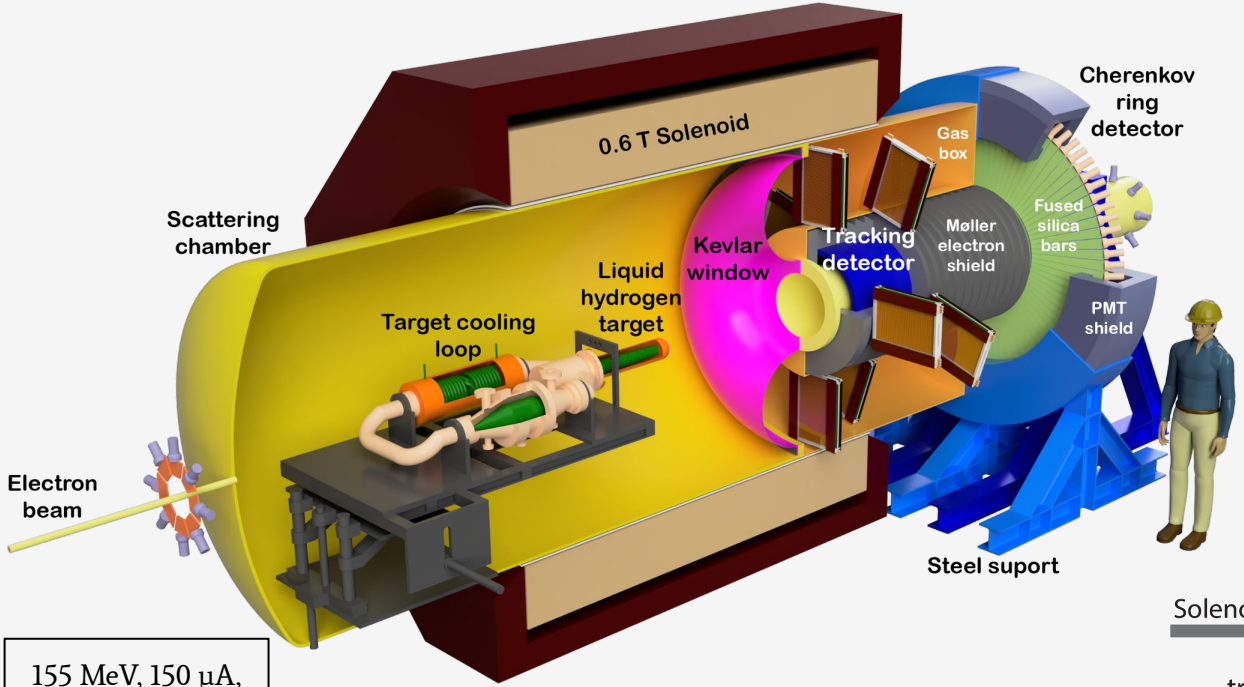
DPG Spring Meeting 2023

Lucas Sebastian Binn
Johannes Gutenberg University Mainz

JG|U

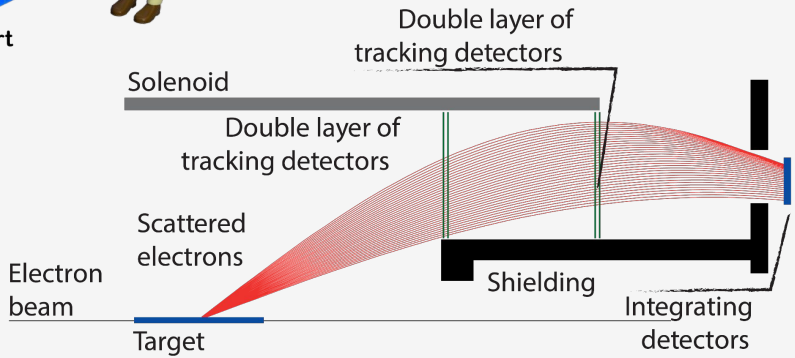
PRISMA+ DETECTOR LAB

P2 Experiment

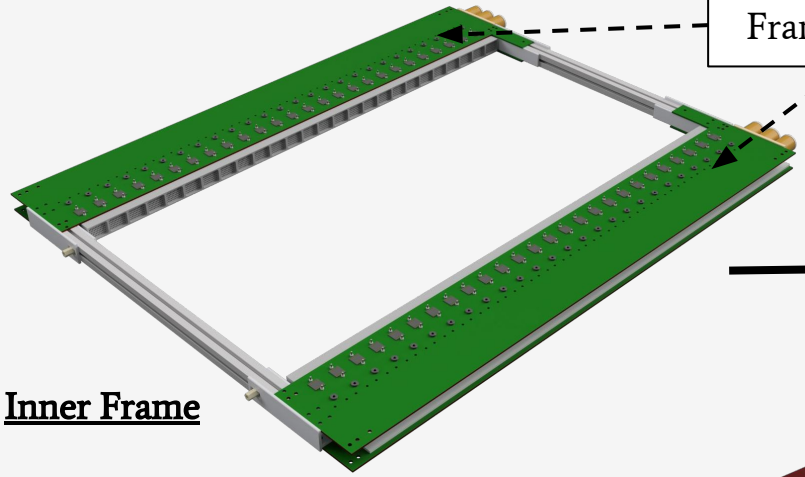


155 MeV, 150 μA,
f_{sw} = 1 kHz

- Located @ MESA in Mainz
- Determination of weak mixing angle at low momentum transfer
- Measure parity violating asymmetry in elastic electron-proton scattering
- Tracking Detector
  - Determination of average momentum transfer Q^2
  - Study of systematic effects



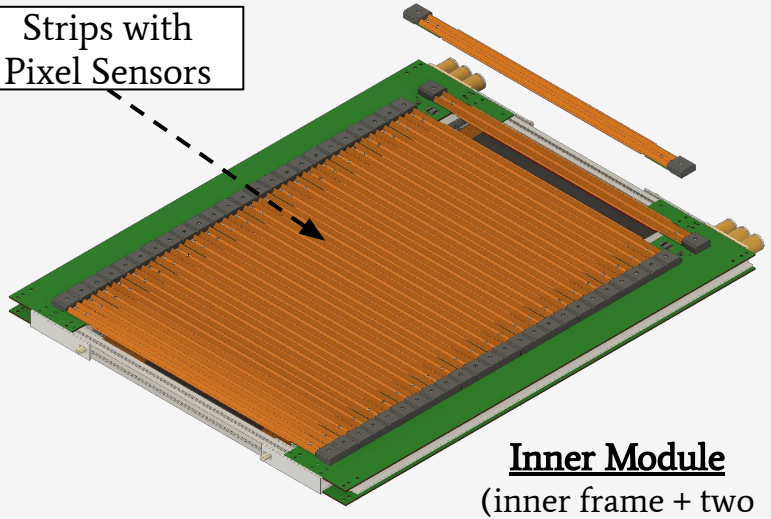
Tracking Detector Module



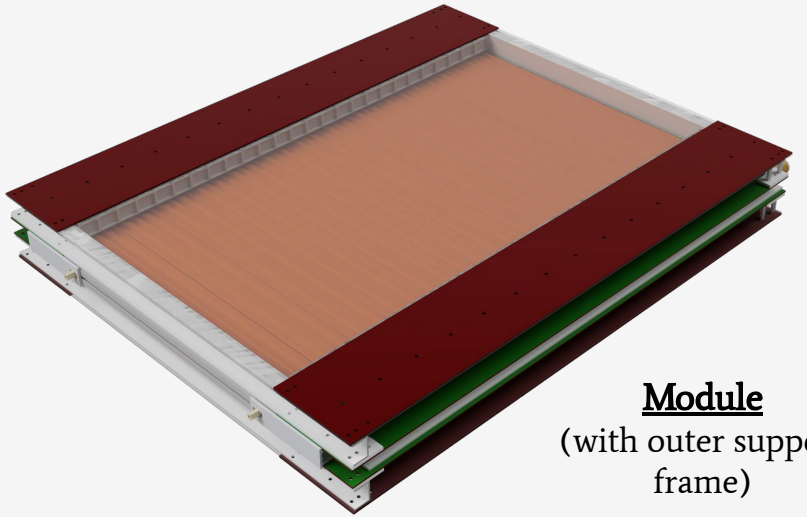
Frame PCBs

Strips with Pixel Sensors

Inner Frame

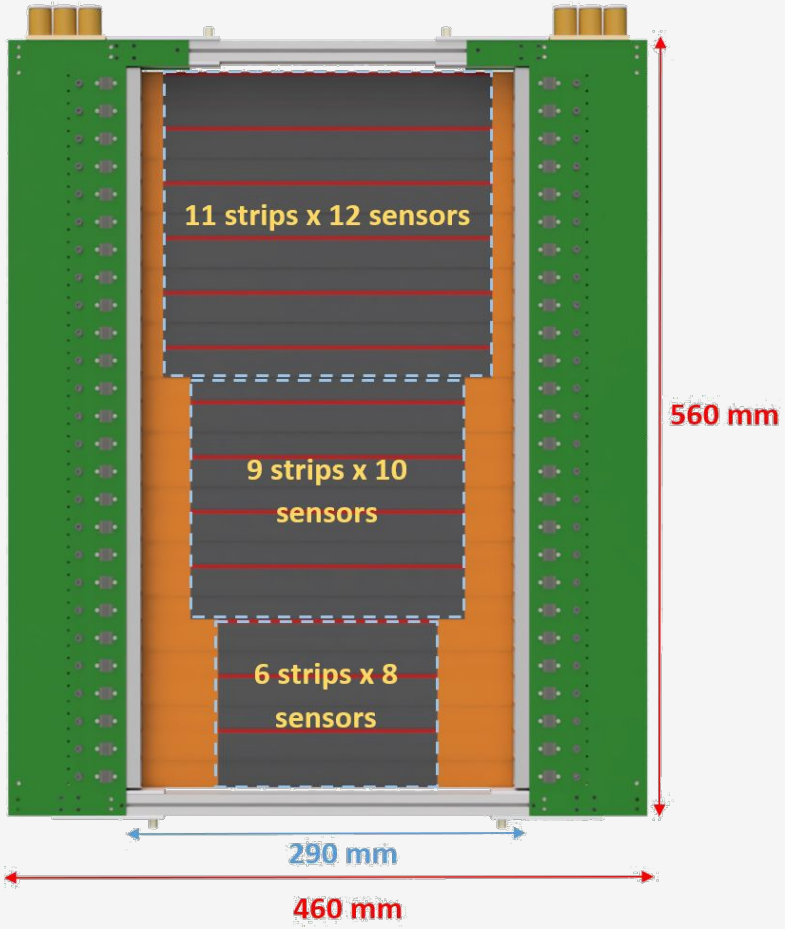


Inner Module
(inner frame + two sensor planes)

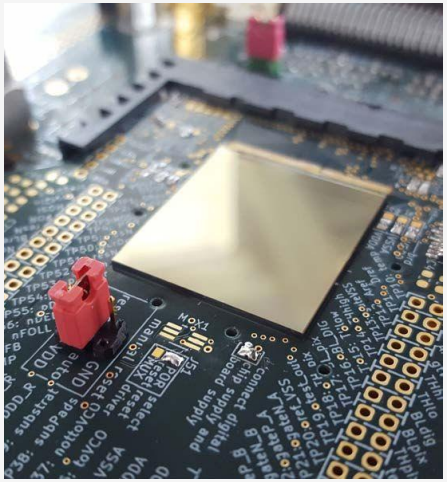


Module
(with outer support frame)

Strip Configurations & Sensors

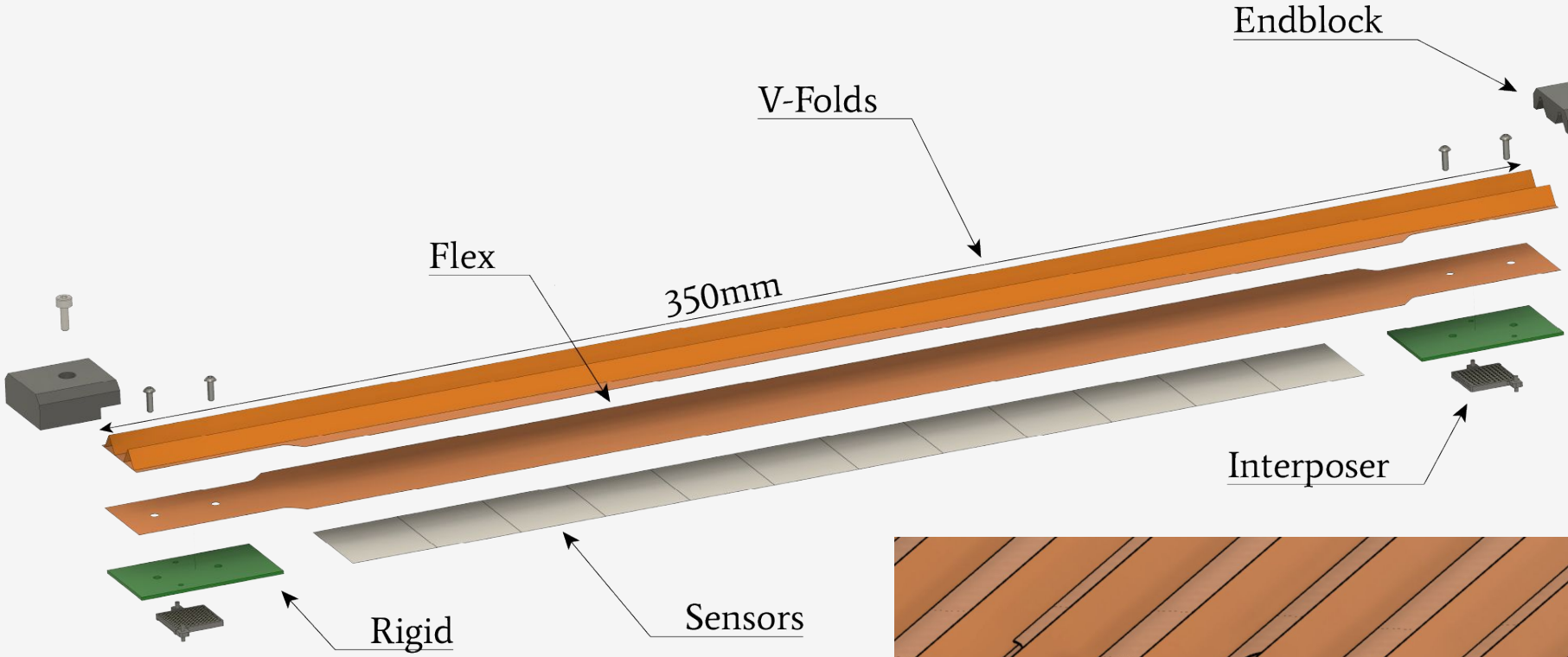


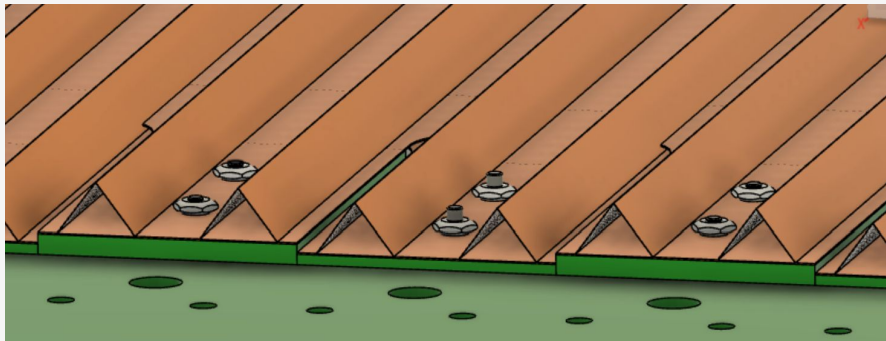
- 540 pixel sensors per module
- Similar pixel sensors as used in the Mu3e experiment
  → knowledge in group
- Monolithic, 50 µm thickness
  → reduced material budget
  → reduced multiple Coulomb scattering
- Radiation-hard



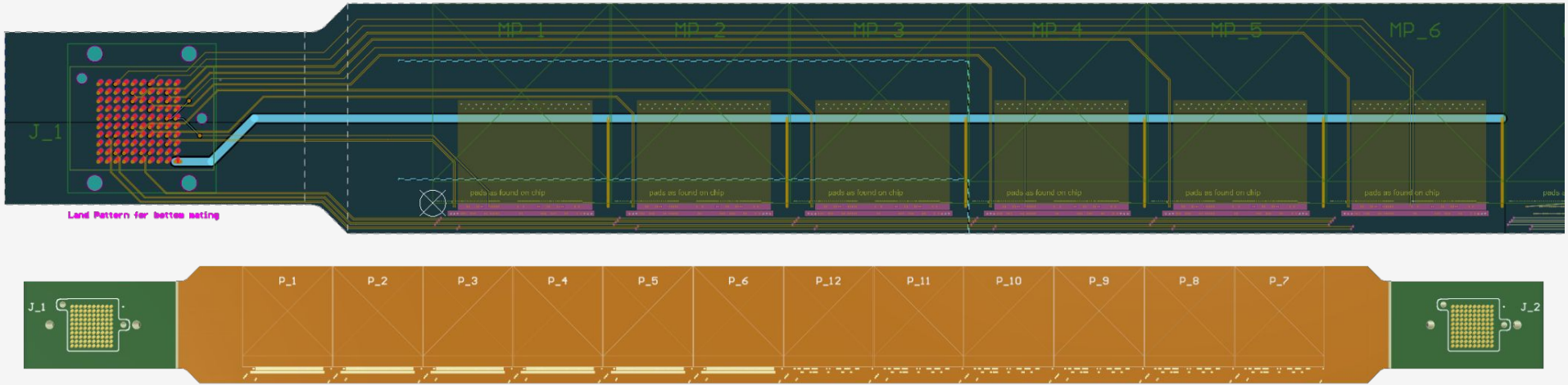
[MuPix 10]

Structure of the Strips





Specifications

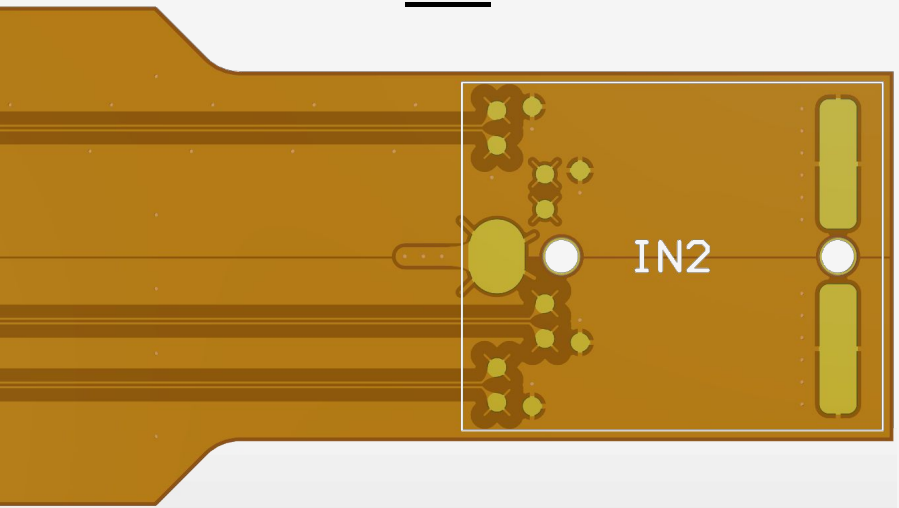


- Two layer flex (with rigid parts at the ends)
- 9 µm copper thickness, 25 µm dielectric → X_0= 1.45‰
- Commercially available production of rigid-flex comes with compromises

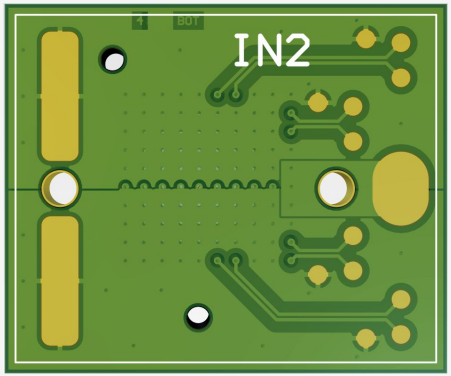
→ idea to solder rigid-flex ourselves

Soldered Rigid-Flex

Flex

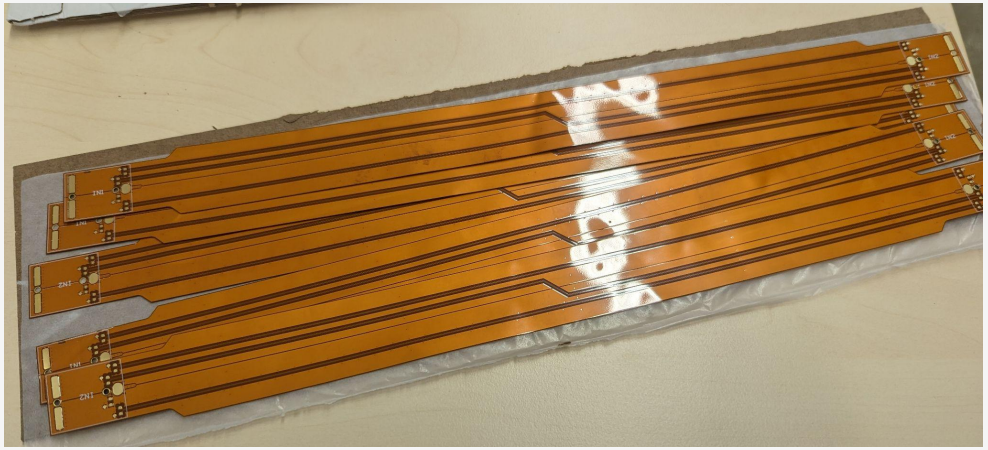


Rigid

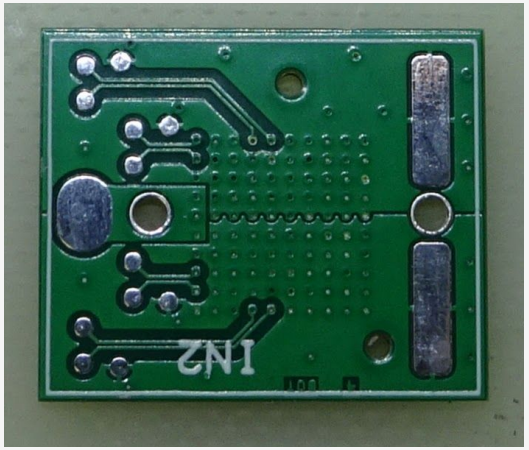


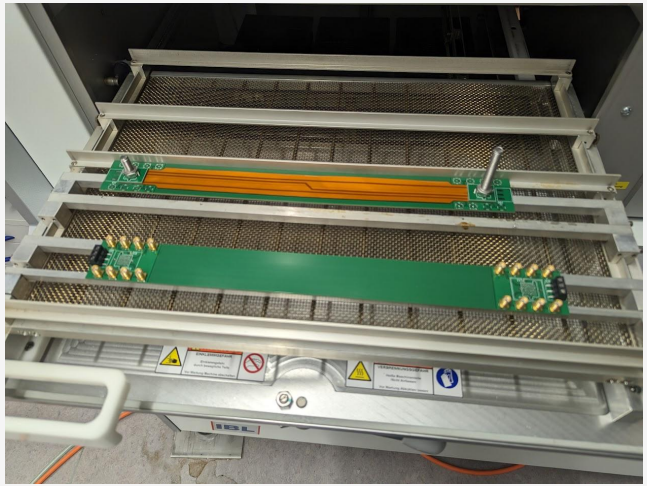
Solder matching patterns using reflow oven.

Soldered Rigid-Flex



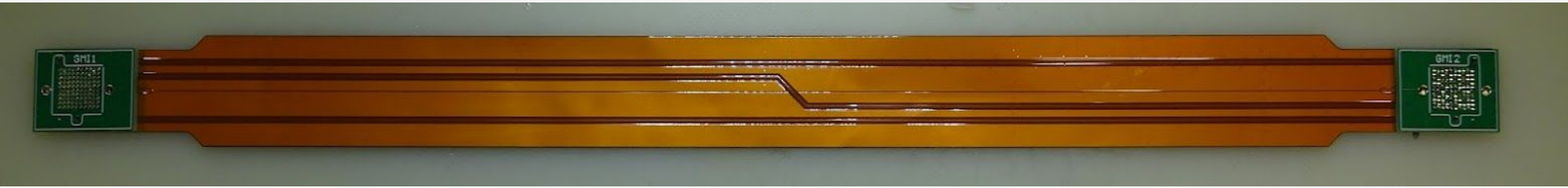
+



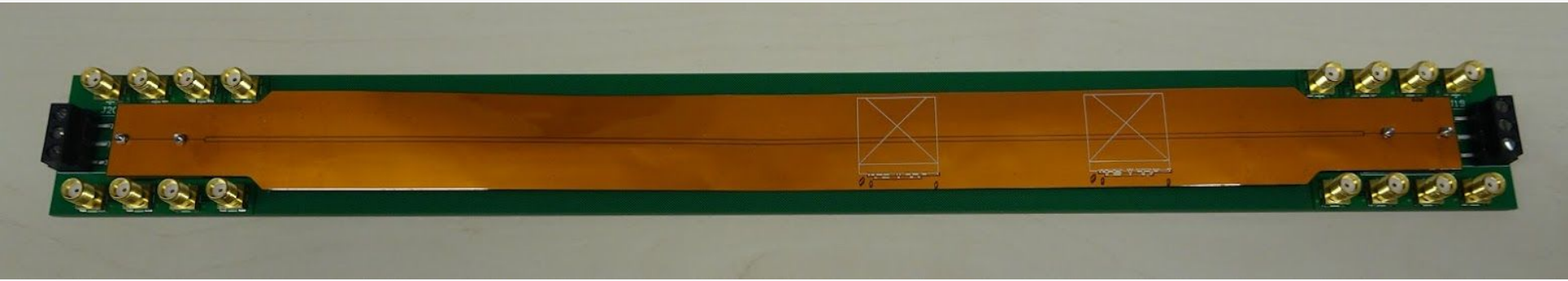


Soldered Rigid-Flex

Rigid-Flex

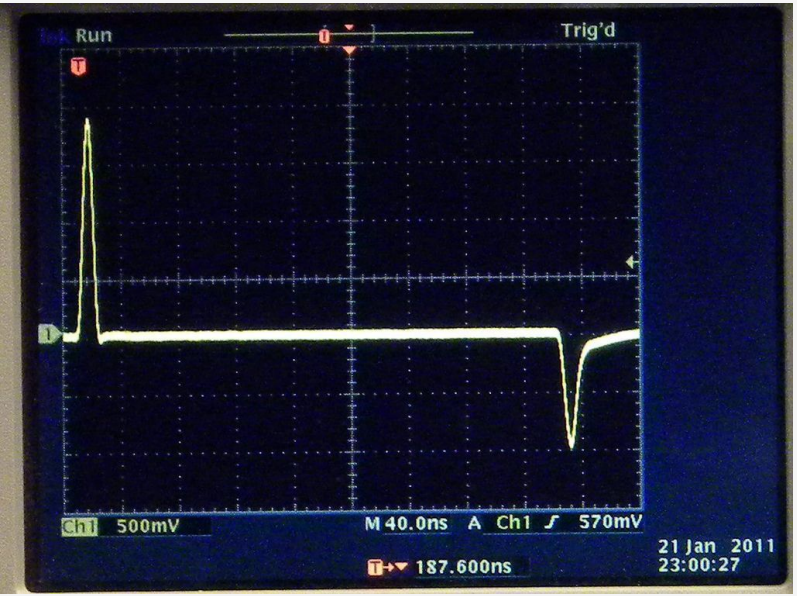


Test Jig (with mounted rigid-flex)



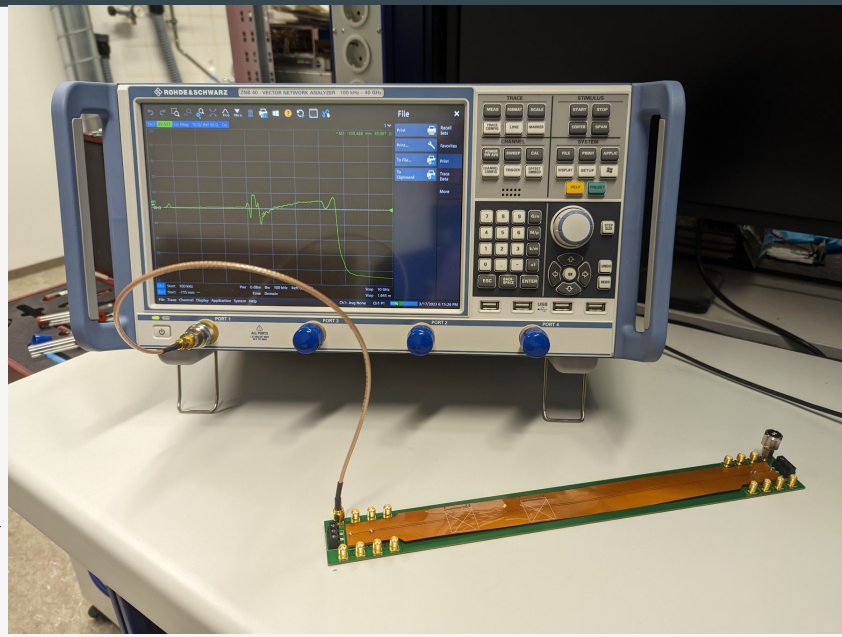
Time Domain Reflectometry

- Non-invasive characteristic impedance measurement along conductor
- Reflection of signal at change of characteristic impedance
- Verify differential line impedance (constant) (signal integrity @ 1.25 Gbit/s)



[Oscilloscope]

FFT



[Vector Network Analyser]

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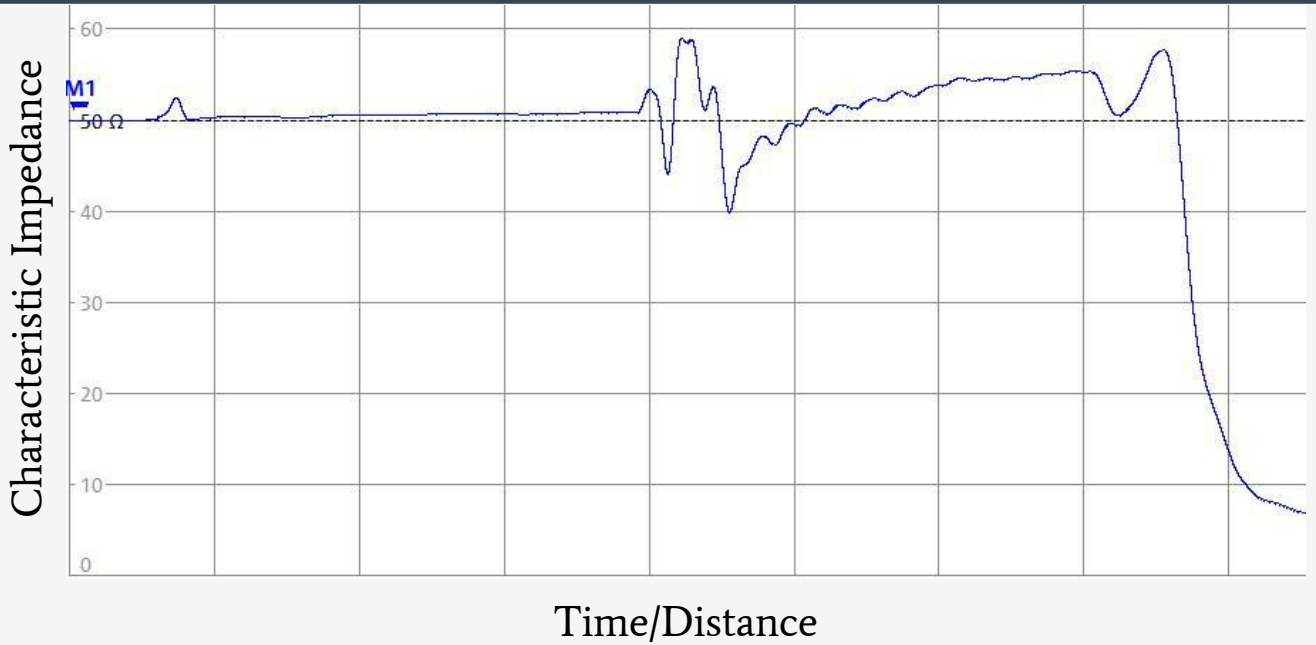
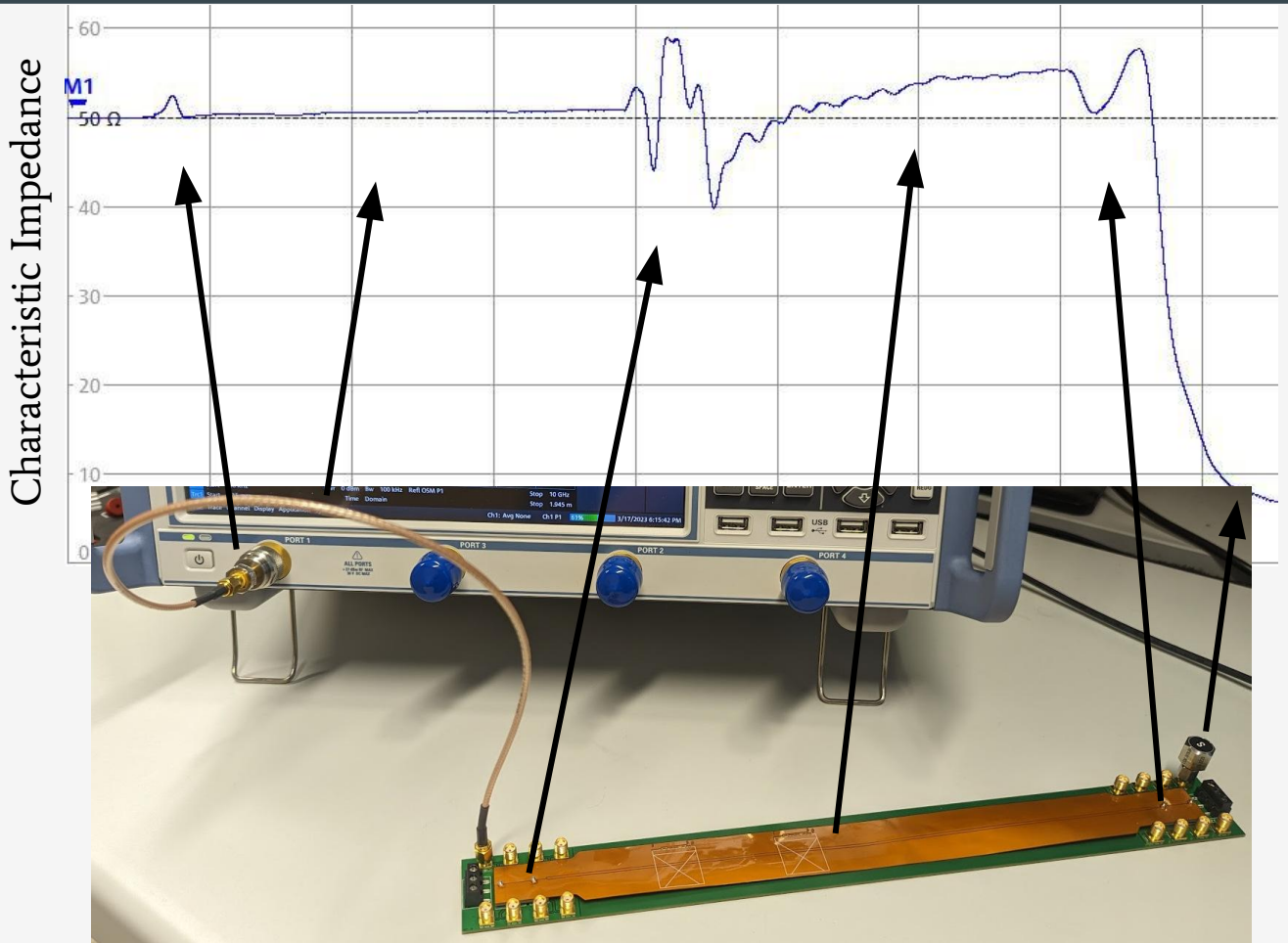
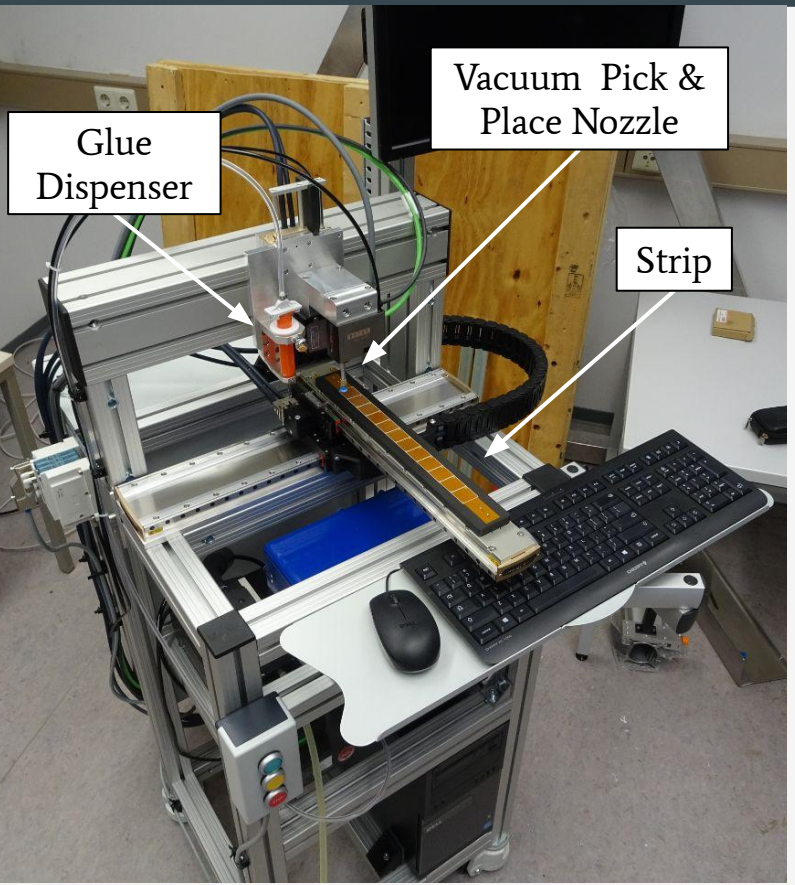
Time Domain Reflectometry



Time Domain Reflectometry

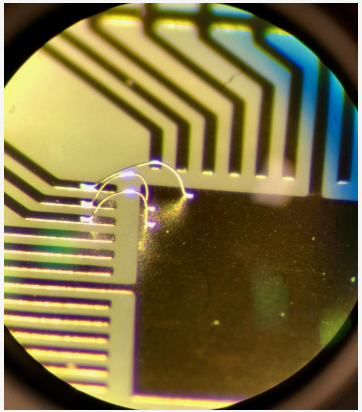


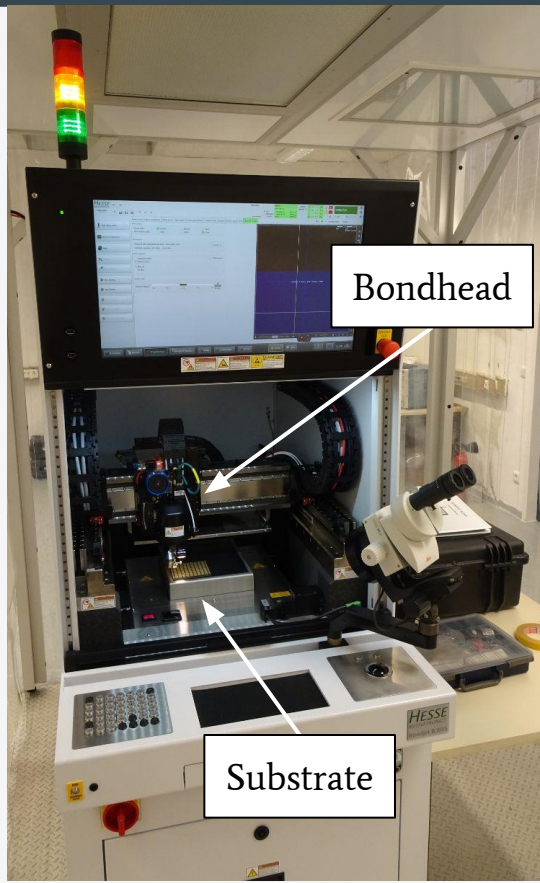
Mounting of Sensors



- Precise glue dispenser + pick & place machine
- Wire-bonding using aluminium wire
- Production of all 260 strips in Mainz

→ semi-automated processes

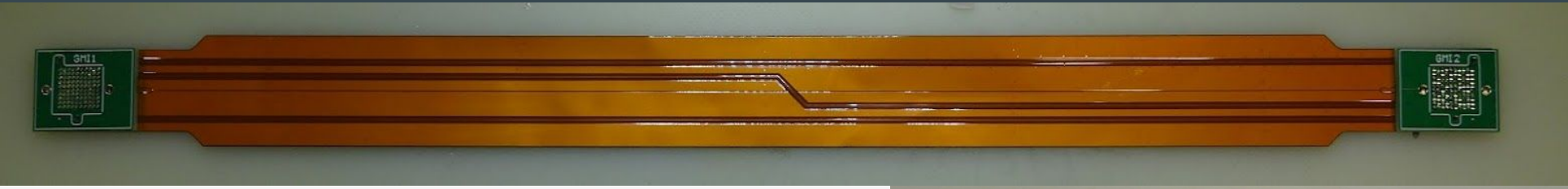




Gluebot

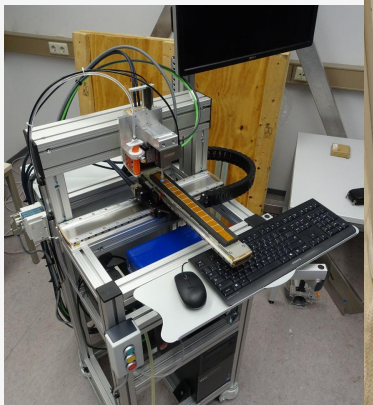
Wire-Bonding Machine

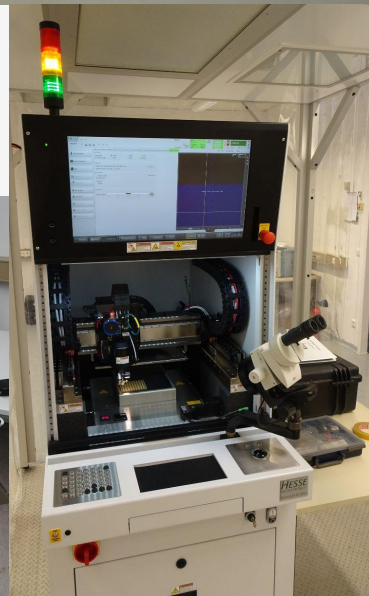
Outlook



Soldered Rigid-Flex

- Promising first results
- Electrical Properties with Test Jig (signal integrity @ 1.25 Gbit/s)
- Mechanical Tests (tension, climate chamber)
- Final Routing of Signals (10 differential lines + some single ended lines)

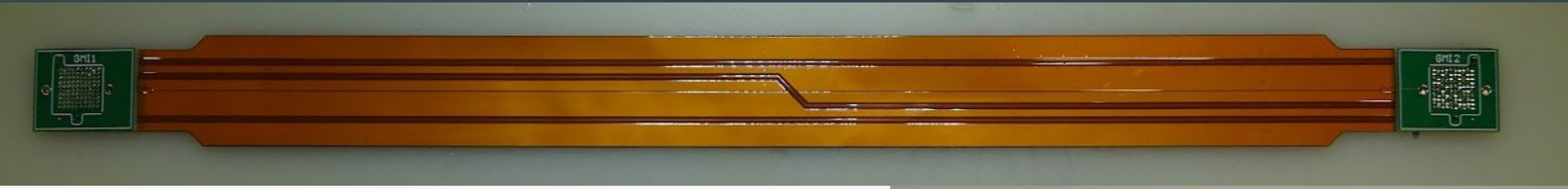




Gluing & Wire Bonding

- Glue Dispense & Wire Bonding parameters
- Placement Precision of Gluebot
- Semi-automation of processes (pattern recognition etc.)

Outlook



Thanks for your attention!

Soldered Rigid-Flex

- Promising first results
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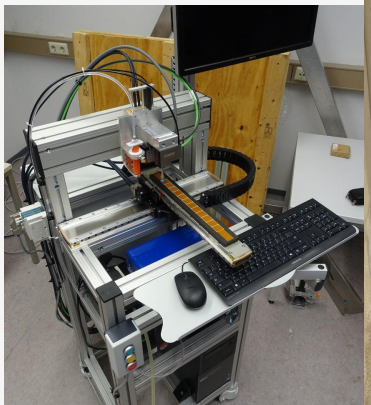
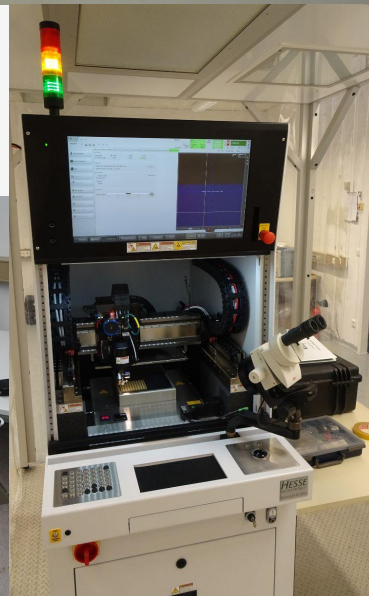


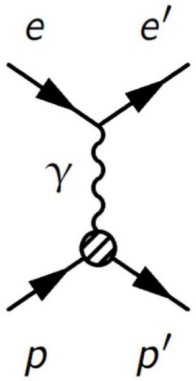


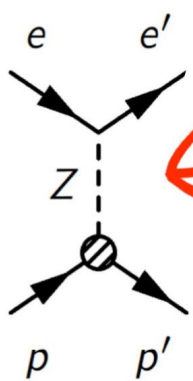
Backup

P2 - Theory

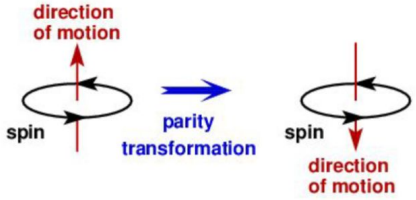
The weak mixing angle (Weinberg-angle):

$$\sin^2\theta_W = \frac{g'^2}{g^2+g'^2}$$





Violates parity!



Proton electric charge $+1$

Proton weak charge $1-4\sin^2\theta_W$

Parity violating asymmetry

momentum transfer

Asymmetry: $$A_{PV} = \frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left(1 - 4\sin^2\theta_W - F(Q^2)\right)$$

proton form factor (small @ low Q^2)

P2 - Experiment

Measuring the parity violating asymmetry in e-p-scattering

polarization of the beam

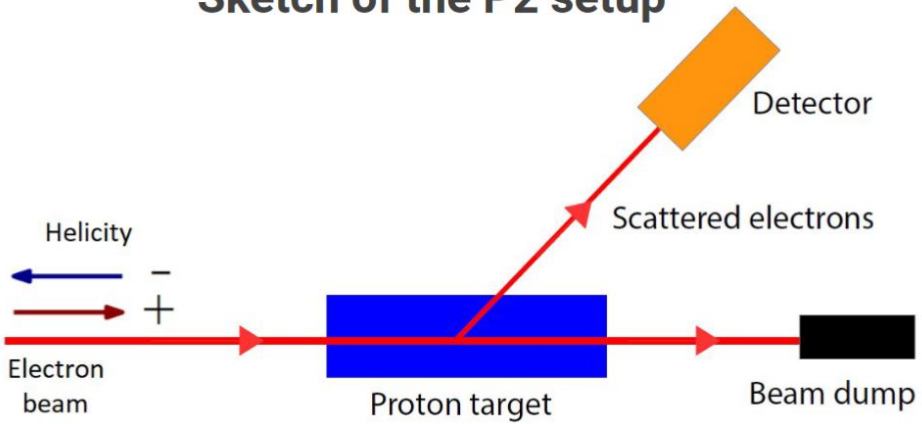
$$A_{exp} \equiv \frac{N^+ - N^-}{N^+ + N^-} = P_{beam} \cdot \langle A_{pv} \rangle + A_{app}$$

~ 30 ppb

averaged expected value

apparative asymmetry

Sketch of the P2 setup



Beam:

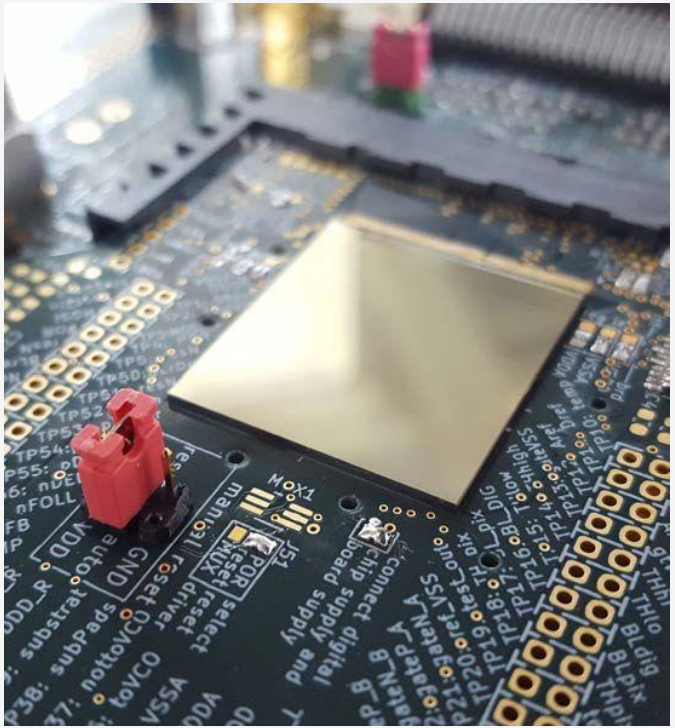
- Highly polarized (≥85%)
- Current: 150 μA = 10^{15} e^-/s
- L ≈ $2.4 \cdot 10^{39}$ $cm^{-2}s^{-1}$
- Energy: 155 MeV
- Flip helicity @ 1 kHz

Additional requirement:

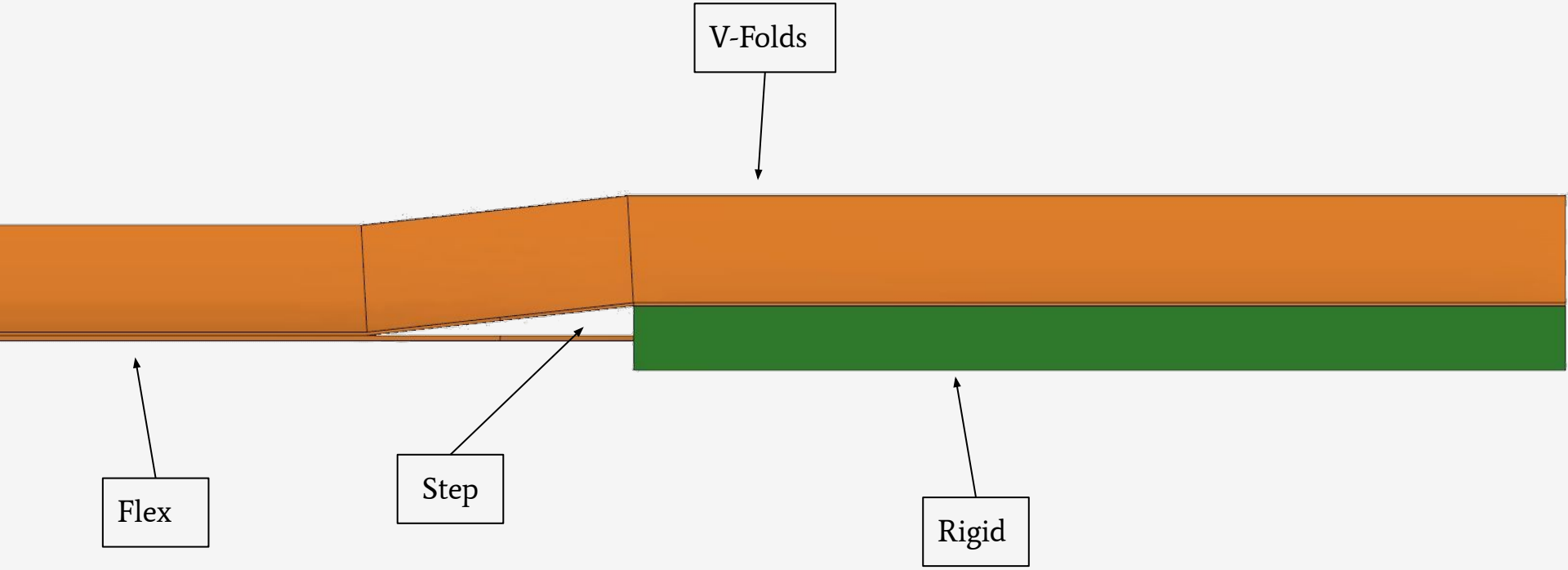
- Beam polarization: $\Delta P_b / P_b \leq 0.5\%$

MuPix 10

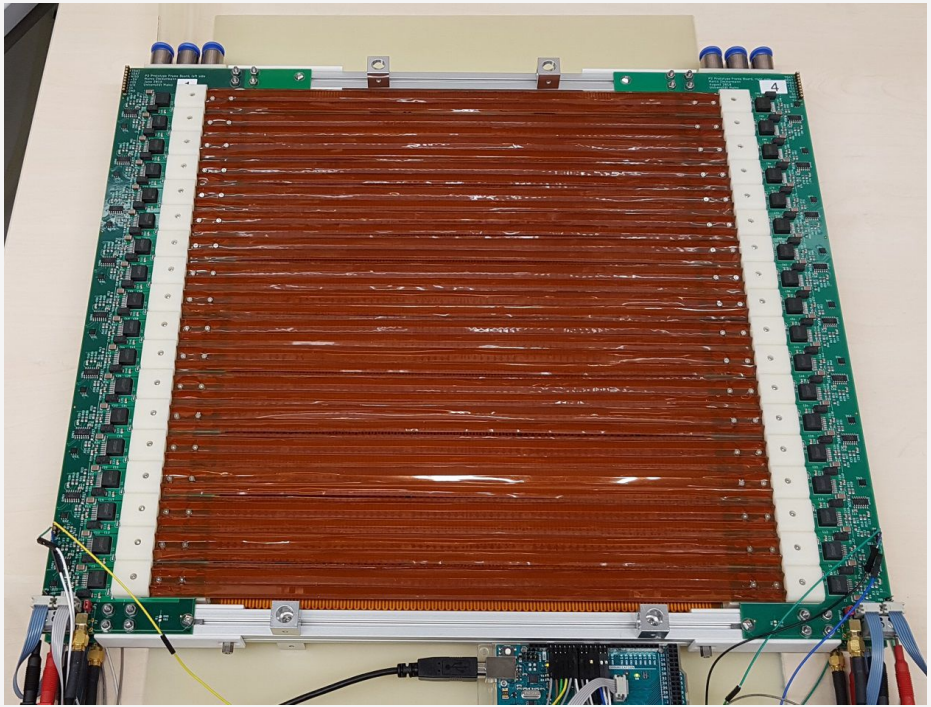
- HV-MAPS - High voltage monolithic active pixel sensors (Ivan Perić)
- Based on 180 nm HV-CMOS process
- Can be thinned down to < 50 µm
- Pixel Matrix 256 x 250
- Pixel Size 80 µm x 80 µm
- Active Area 20.40 mm x 20 mm
- Efficiency > 99%
- Noise Rate < 2 Hz / Pixel
- Power Consumption < 200 mW / cm²

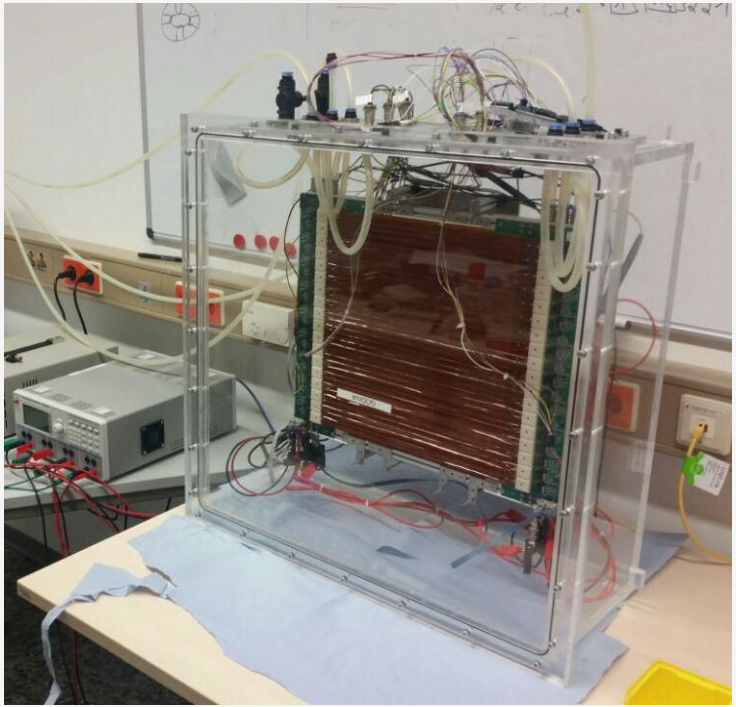


Symmetrischer Layerstack & V-Folds



Thermo Mechanical Prototype





[Marco Zimmermann & Michail Kravchenko]