Module Production for CMS Tracker Upgrade at DESY

CMS Phase 2 Tracker

Andreas Mussgiller

WP1: R&D and Prototyping

Andreas Mussgiller, Doris Eckstein

WP2: Modules and MaPSA

Doris Eckstein, Andreas Nürnberg

WP3: Burn-In Test

Günter Eckerlin, Andreas Mussgiller

WP4: Dee

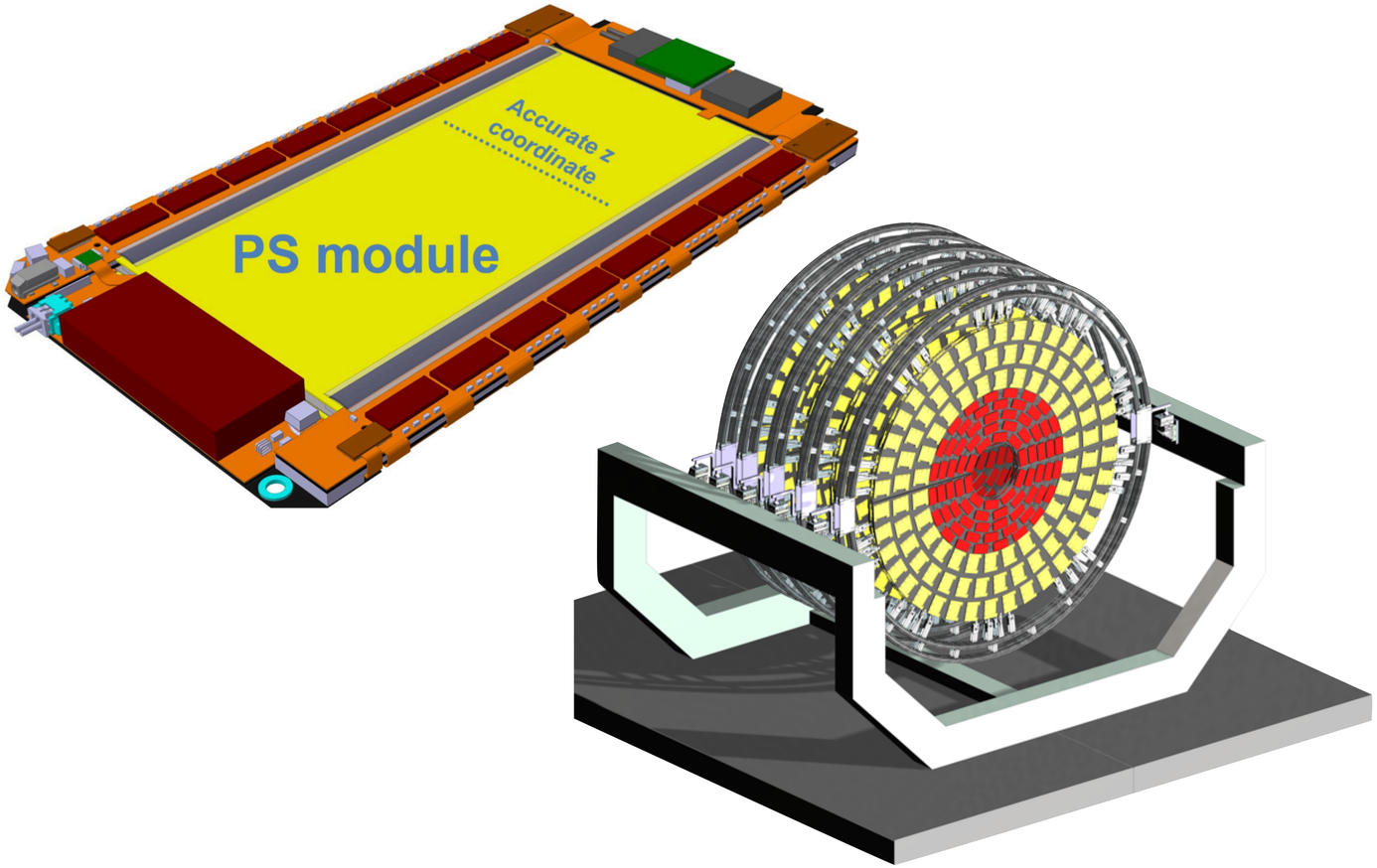
Roberval Walsh, Oskar Reichelt

WP5: TEDD

Moritz Guthoff, Oskar Reichelt

DESY will do:

- assembly of 1250 PS modules
- burnin for modules from DESY and 1000 2S modules from Aachen
- TEDD assembly



The Detector Assembly Facility (DAF)

CMS Phase 2 Tracker

Andreas Mussgiller

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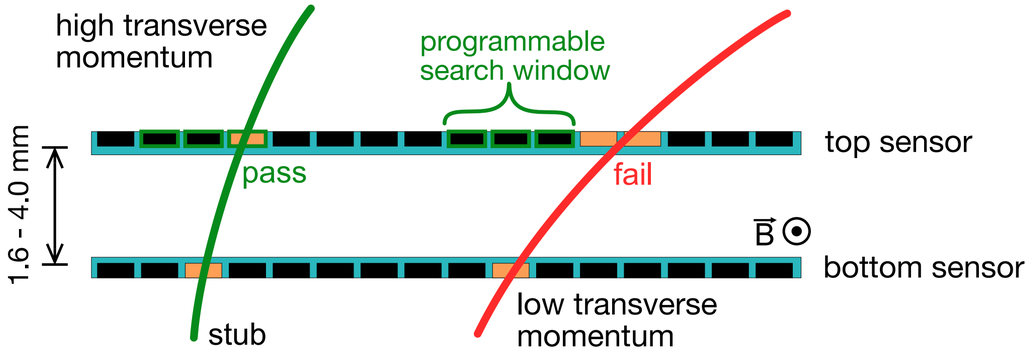
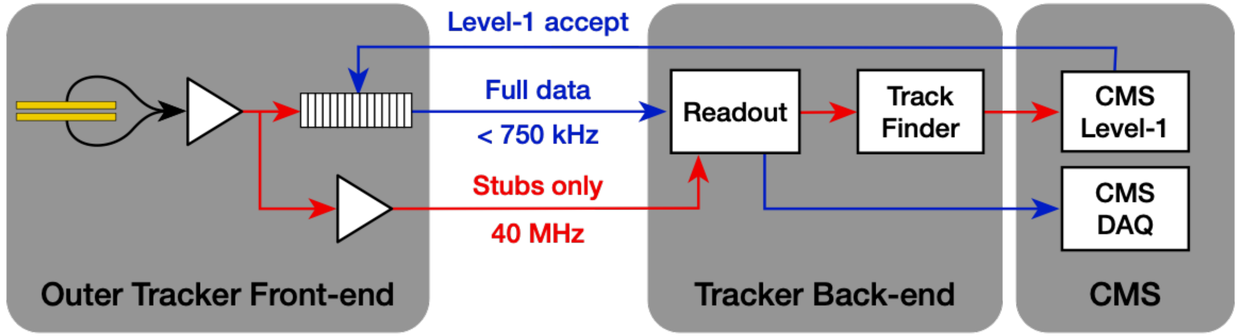
Production work flow

DAF 25c

DAF 26

CMS Module Concept

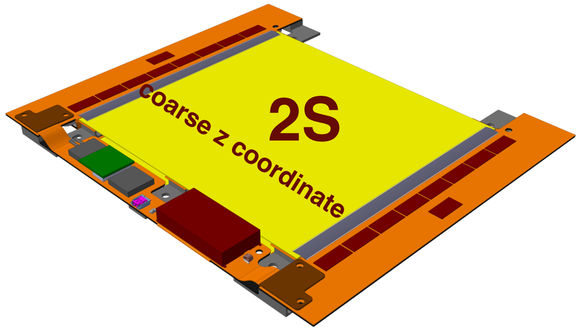


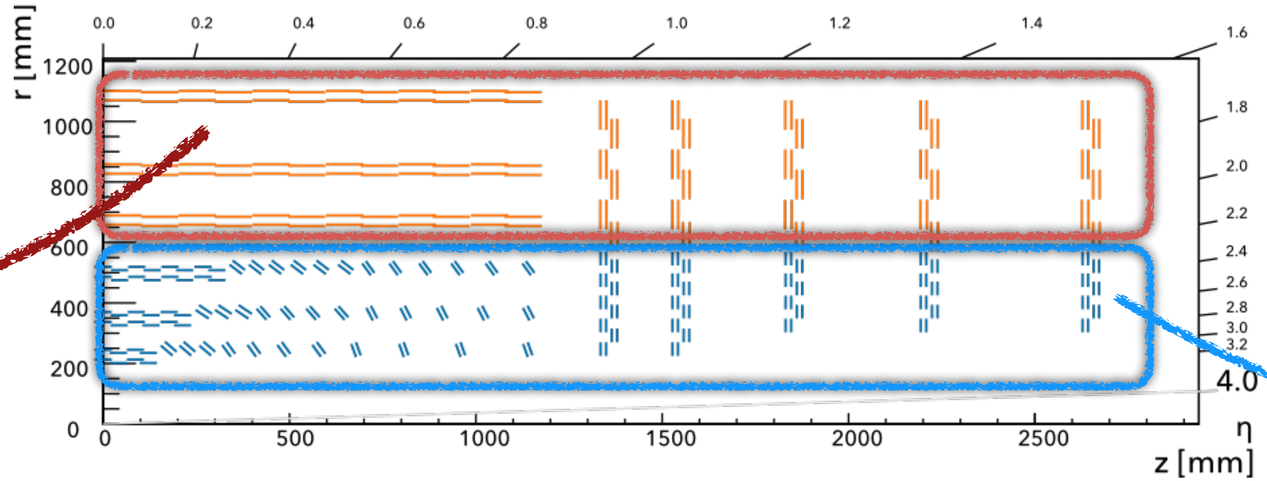


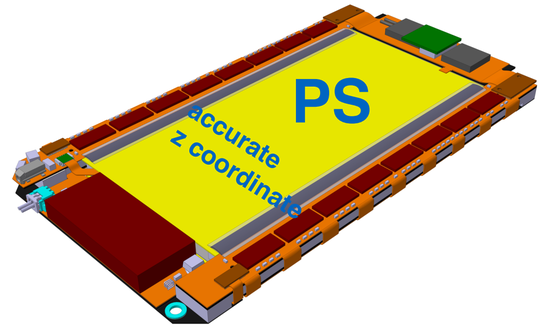
- exploit strong magnetic field of 3.8 T of CMS solenoid
- p_T discrimination on board:
  - two closely spaced sensors
  - correlate signals —> local p_T measurement
  - reject low p_T Tracks —> minimise data volume
- ‘stub’ is formed of signals found within search window

- Level-1 and readout data provided
  - ‘stubs’ are sent at each bunch-crossing (40 MHz)
  - Full data are read out on trigger decision (<750 kHz)

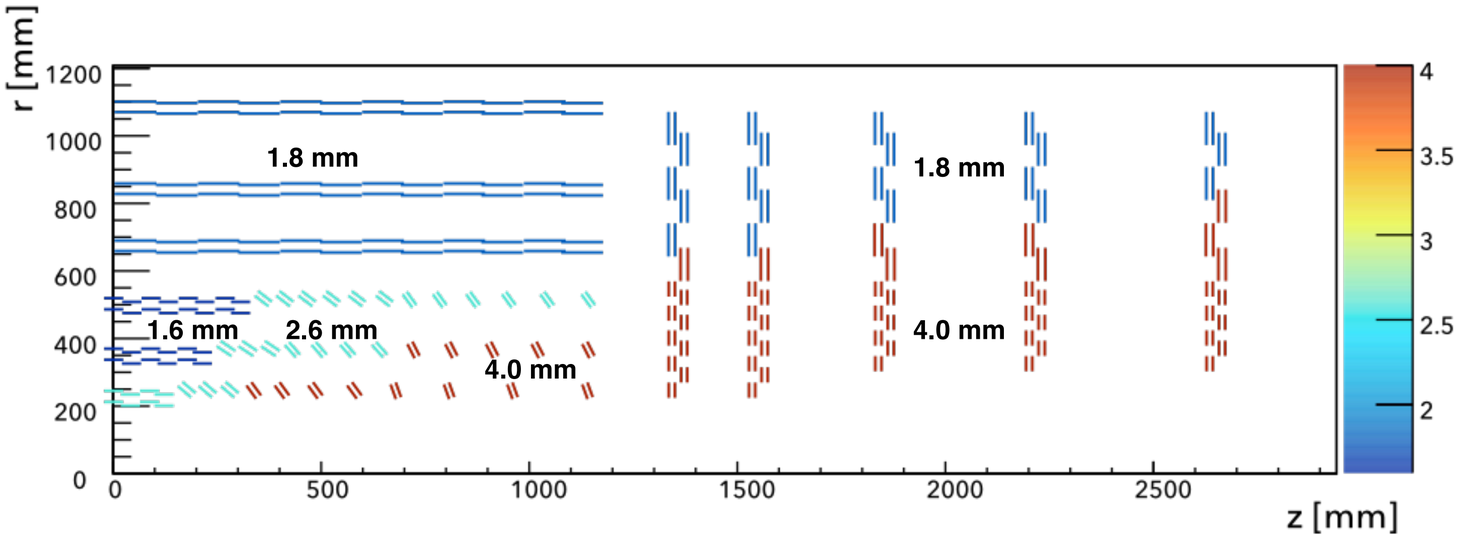
CMS Tracker Concept







- Two main types of modules:
  - 2S with two strip sensors
  - PS with one strip and one pixelated sensor
- variants differ in sensor spacing
  - arranged to optimise p_T discrimination vs. geometrical position in Tracker



From Modules to TEDD

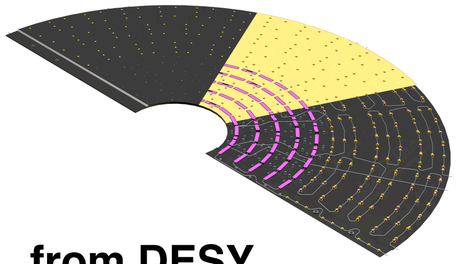
Modules
Dees

even/odd Dees

Discs

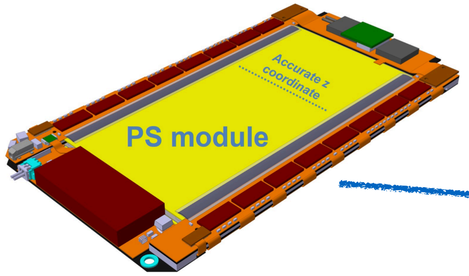
Double-Discs

TEDD



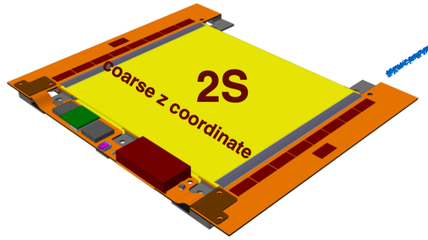
Thermal Test
Metrology

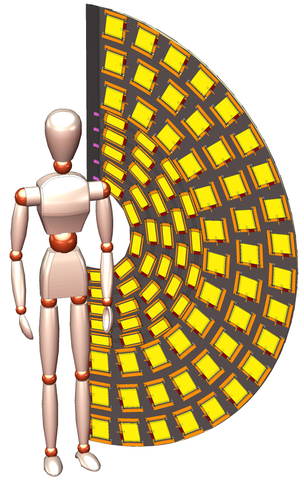
from DESY



Burn-In

from Aachen, other institutes

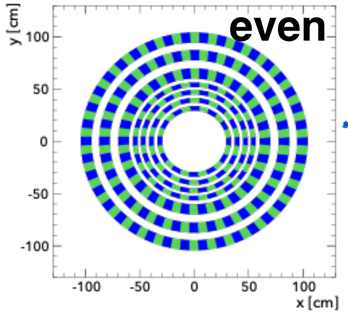


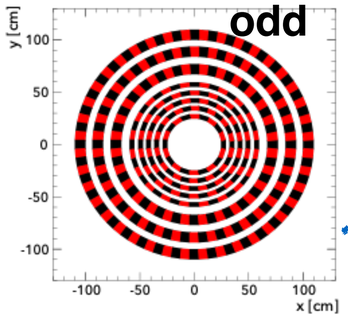


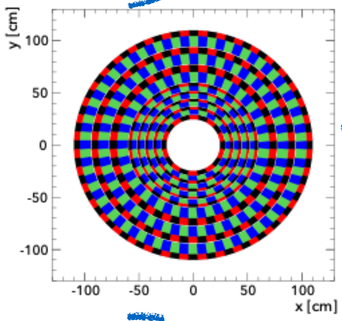
upper +
lower Dee

even +
odd Disk

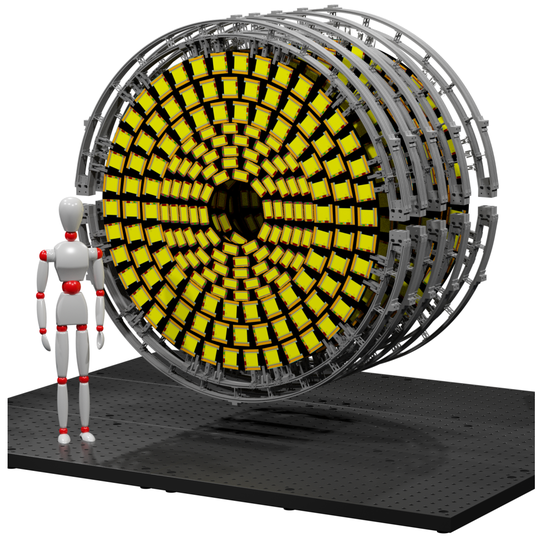
5 Double-Disks



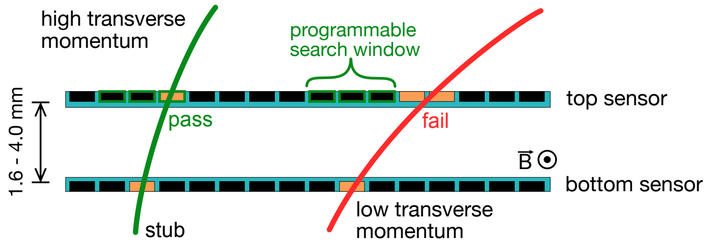




Dee Sector Test
Metrology



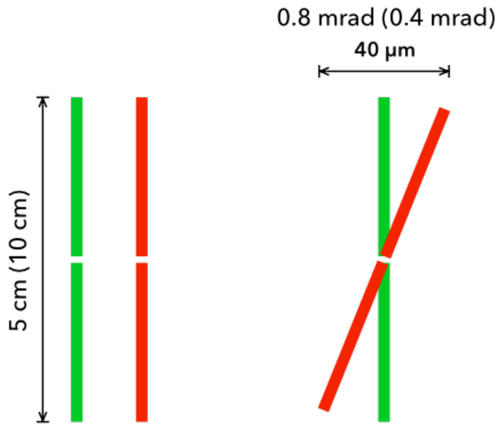
Requirements on p_T Module



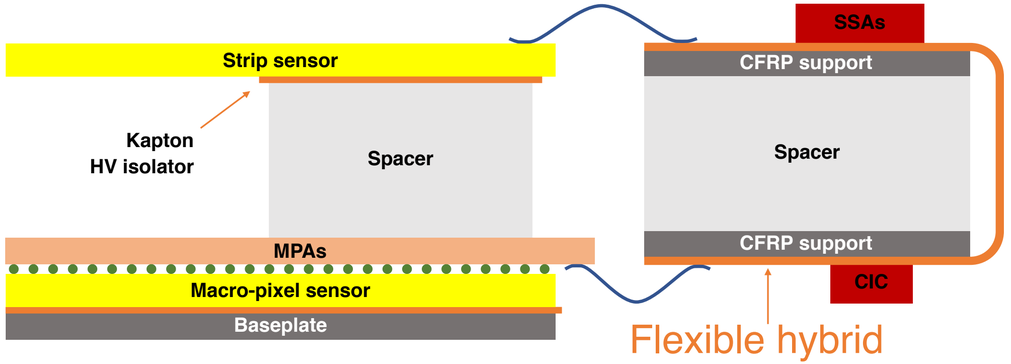
Relative sensor position

- p_T modules use programmable search window to correlate hits
- discrimination requires precise sensor alignment within module
  - parallel shifts can be corrected for in 'stub' finding logic
  - rotations result in position-dependency along strip direction

  —> max misalignment for PS sensor 800 µrad



Assembly of 2S modules jig-based
For PS we have established a partially automated assembly



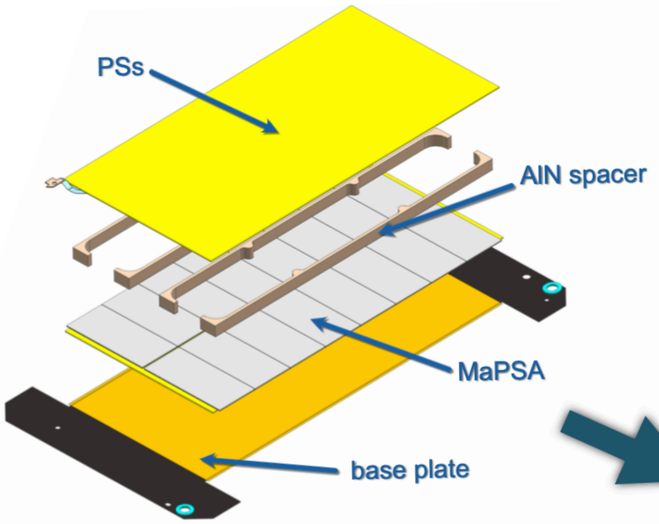
- SSA processes strip sensor data, sends data to MPA
- MPA processes macro-pixel sensor data, receives SSA data, correlates strip and pixel clusters and builds stubs
- CIC as for 2S module

- 2 x 960 strips of ~2.4 cm x 100 µm for PSs sensor
- 32 x 960 macro-pixels of ~1.5mm x 100 µm for PSp sensor
- AlN spacers replace Al-CF

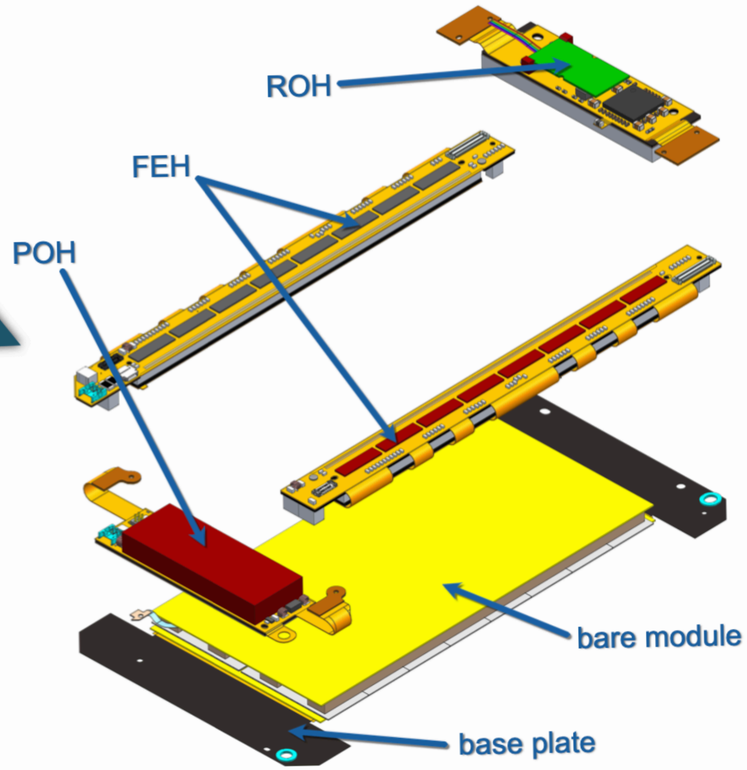
  —> no Kapton strip gluing necessary
- MPAs and sensors are cooled through base plate

  —> requires a large-area glue joint between pixel sensor and base plate

Module Assembly - PS Modules

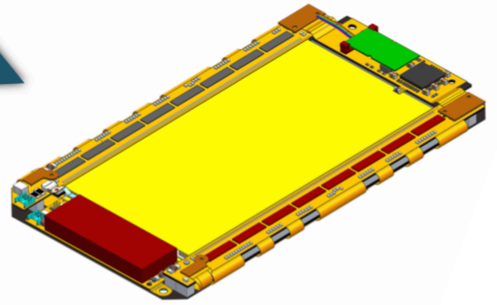


- Relative sensor to sensor alignment $\leq 800\ \mu\text{rad}$
- Assembly is done on a robotic system



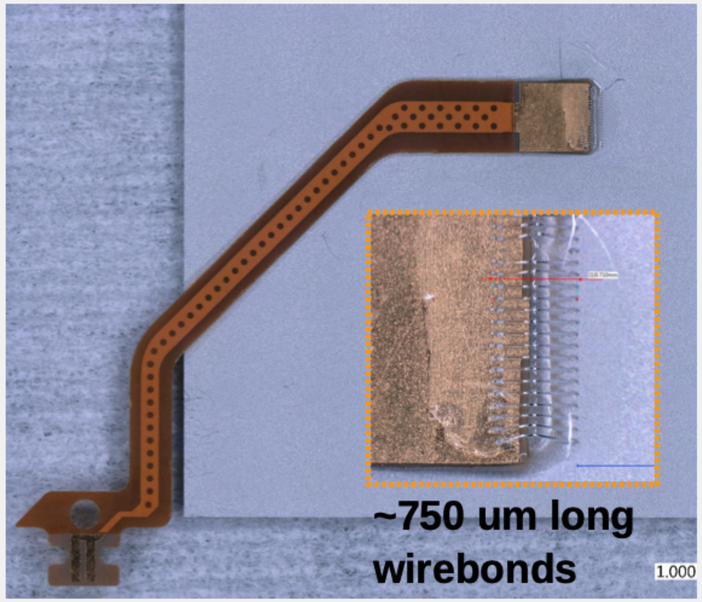
Hybrids are attached to bare module using jigs

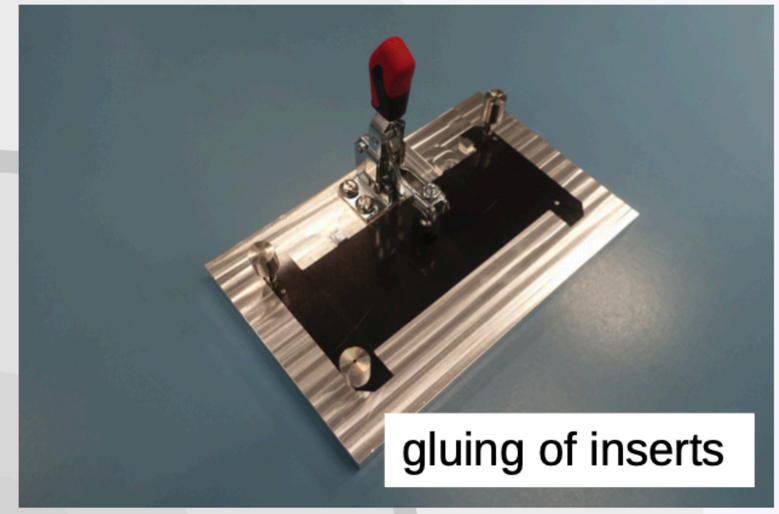
1250 PS modules to be built at DESY

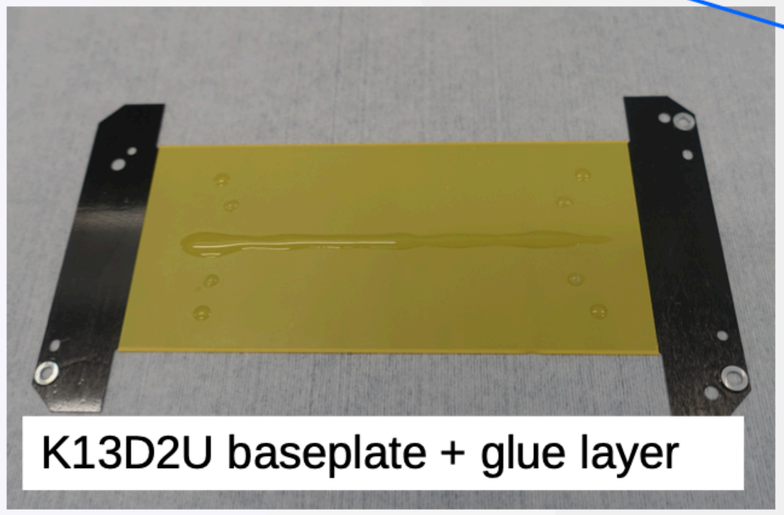


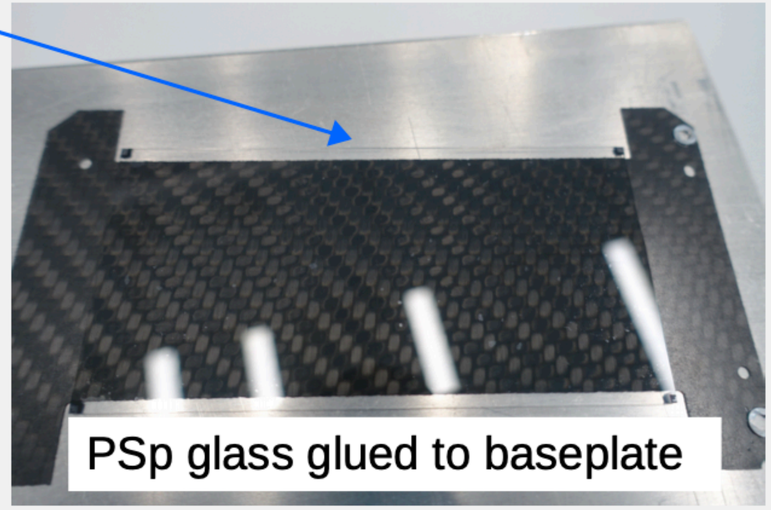
Preparation

- **Before assembly**
  - gluing of inserts + Kapton sheet onto baseplate
    → inserts via jig
    → Kapton sheet manually for now, but have jig (follow design by N. Hinton)
  - gluing of **HV tail** onto PSs backplane via jig
    → as short as possible wirebonds to guarantee fit of HV tail in machined slots
- **During assembly:** dispense slow and fast glues on **baseplate + kapton** before attaching to MaPSA
  → slow-curing epoxy by dispensing robot, **fast-curing epoxy** manually by needle
  → homogeneous glue layer between baseplate and bonded surface



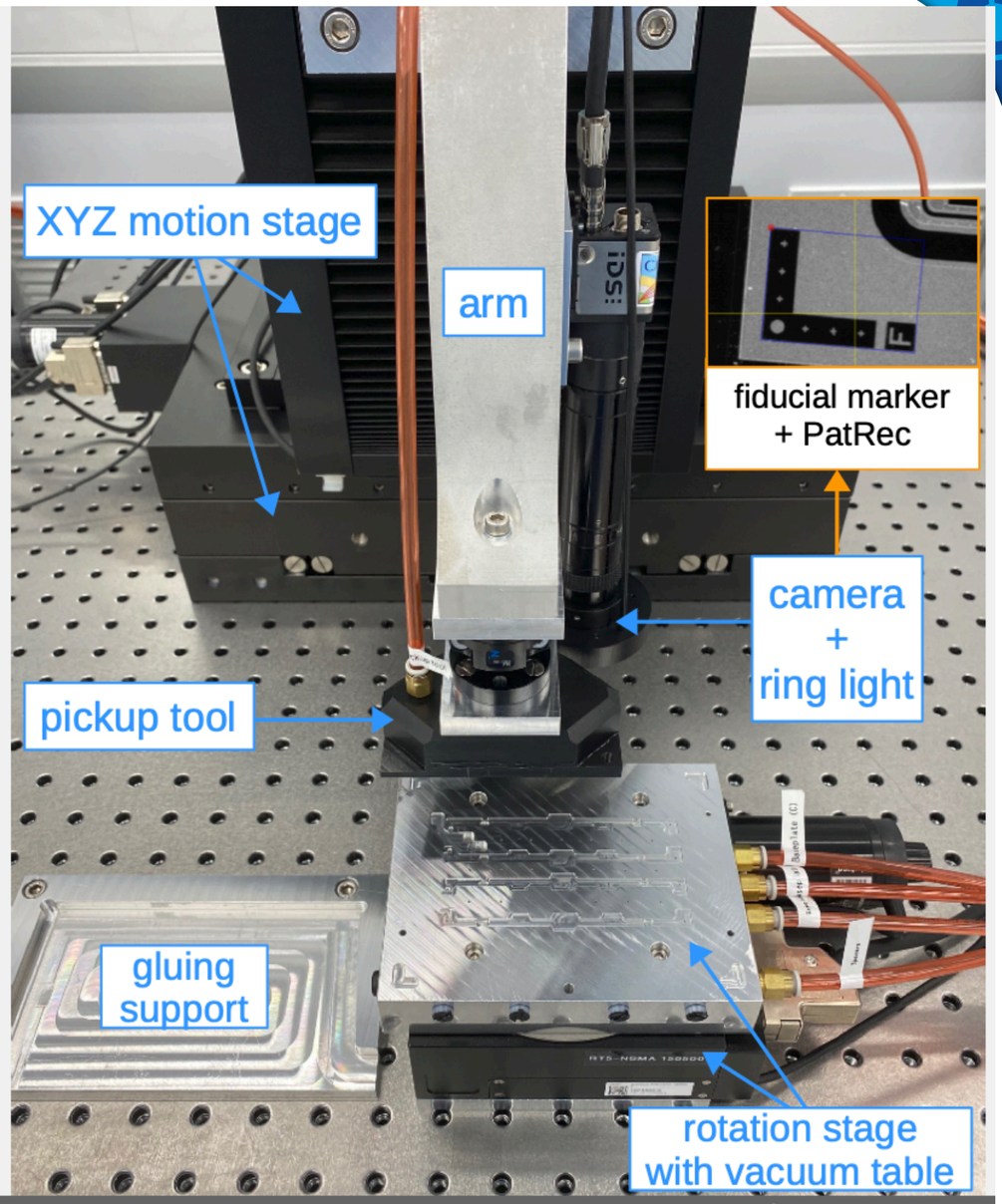

gluing of inserts


K13D2U baseplate + glue layer


PSp glass glued to baseplate

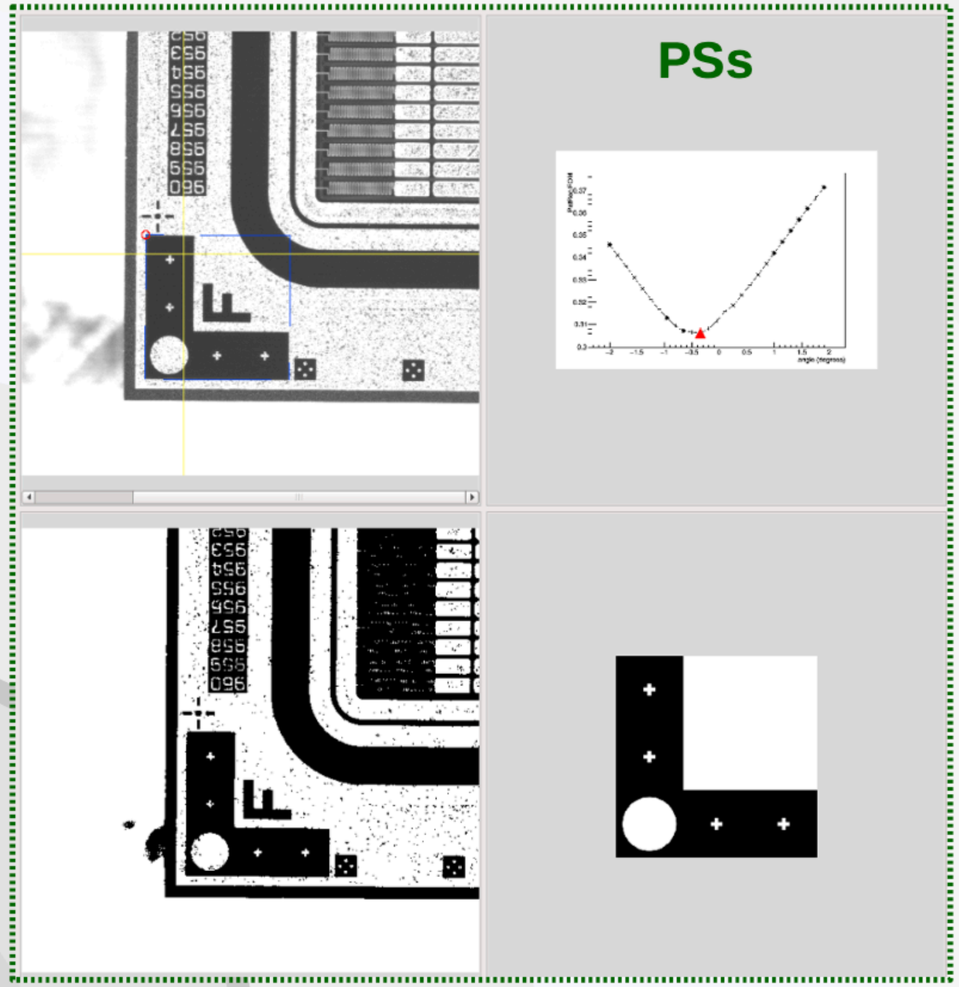
Automated assembly of bare module

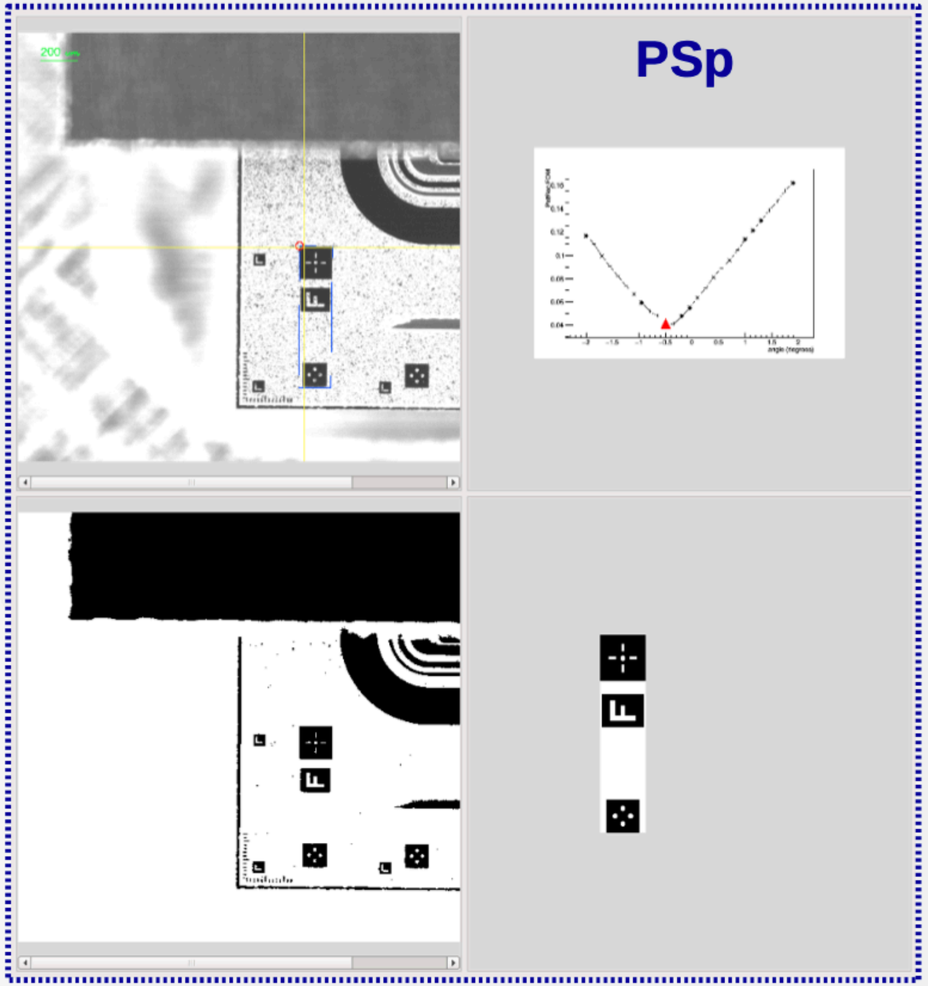
- Integrated system consists of
  - → XYZ motion stage (Δd = 5 µm)
  - → rotation stage (Δθ = 0.01°)
  - → high resolution camera equipped with ring light
- Sensors, spacers or baseplate placed on rotation stage and kept in place via vacuum
- Sensors operated via pickup tool mounted to motion stage arm
- Alignment of sensors performed using
  - → images from camera
  - → pattern recognition to determine positions of fiducial markers
- System controlled by common SW interface, developed in-house
- More information on setup in [1] [2] [3] [4]



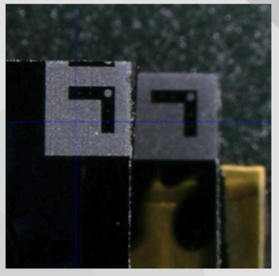
pattern recognition

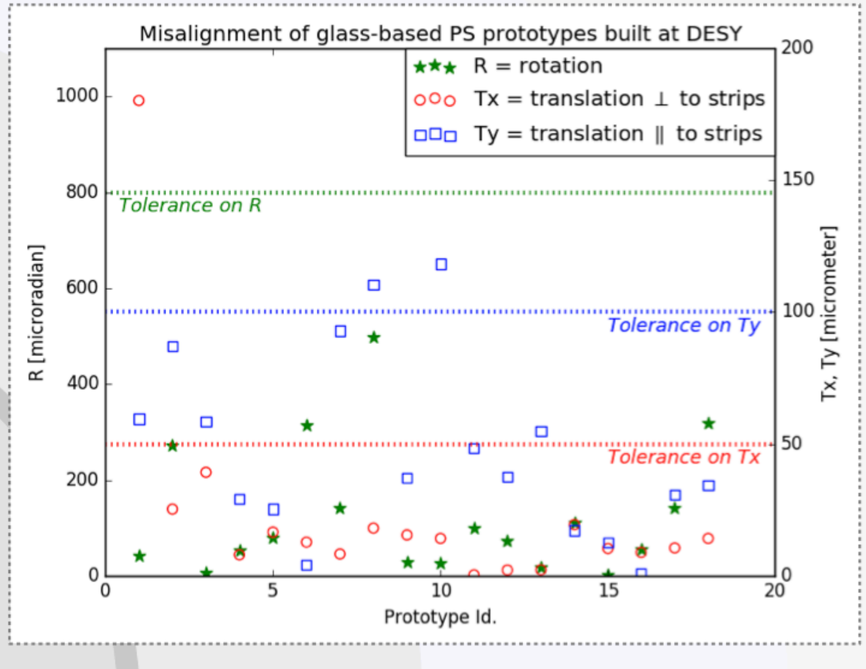
- Precise pattern recognition of fiducial markers on silicon functional sensors

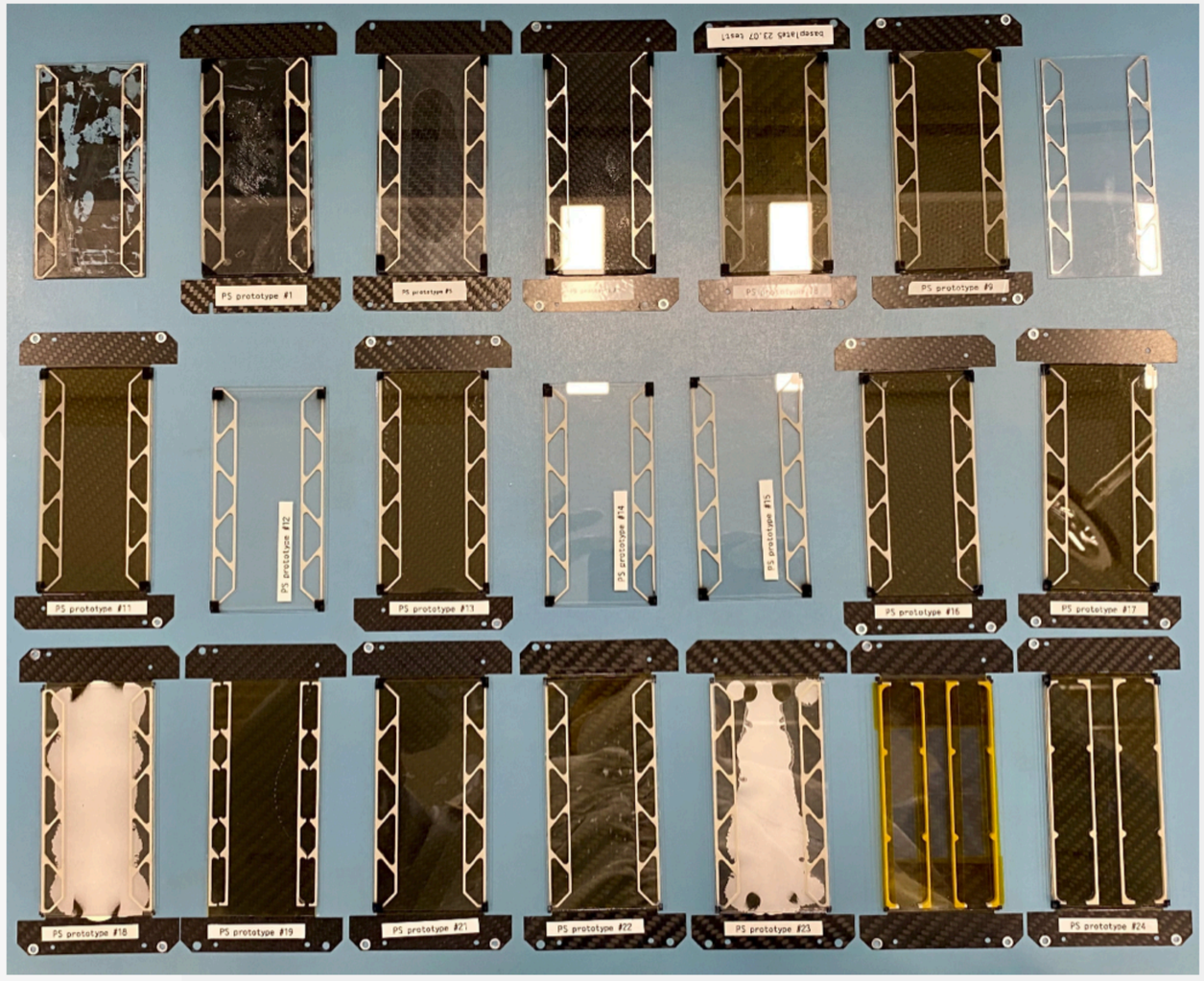




- Produced numerous mechanical prototypes using 700 µm-thick glasses with fiducial markers
  - → extensive tests of assembly procedure
  - → optimisation of assembly steps to reduce required time
- Average glass-to-glass alignment well within tolerances
  - → control positioning of spacers within 100 µm in X/Y directions and 0.1° in angle





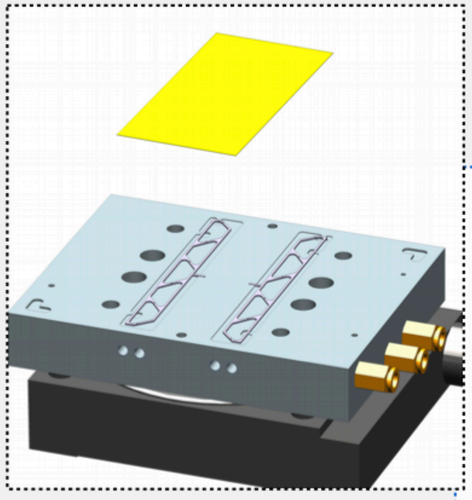


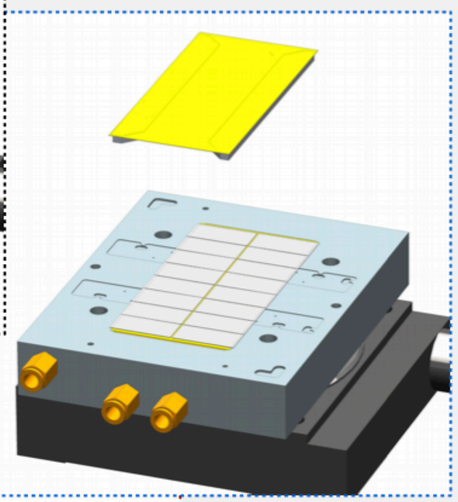
Automated assembly - steps

Assembly sequence consists of these steps (< 2 hours):

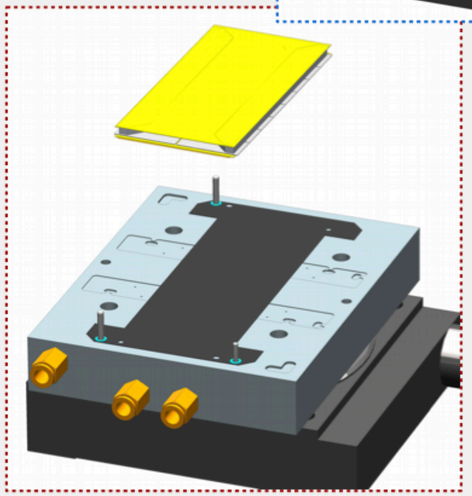
1. MaPSA placed on rotation stage, aligned and picked up
2. Baseplate with glue positioned at rotation stage,
   then MaPSA lowered onto baseplate
3. MaPSA+baseplate put aside after curing of the fast glue
4. PS-s placed on rotation stage, aligned and picked up
5. Spacers with glue placed on rotation stage, then PS-s lowered onto spacers
6. PS-s+spacers picked up
7. MaPSA+baseplate put back onto rotation stage and aligned
8. PS-s+spacers lowered onto gluing stage to dispense glue on backside of spacers
9. PS-s+spacers lowered onto MaPSA
10. PS-s+spacers+MaPSA+baseplate put aside for complete curing

- Sequence in short: 1) MaPSA to baseplate 2) PS-s to spacers 3) “2” to “1”
  → to allow for uniform pressure when gluing MaPSA to baseplate
- “Baseplate + inserts + kapton sheet” glued beforehand



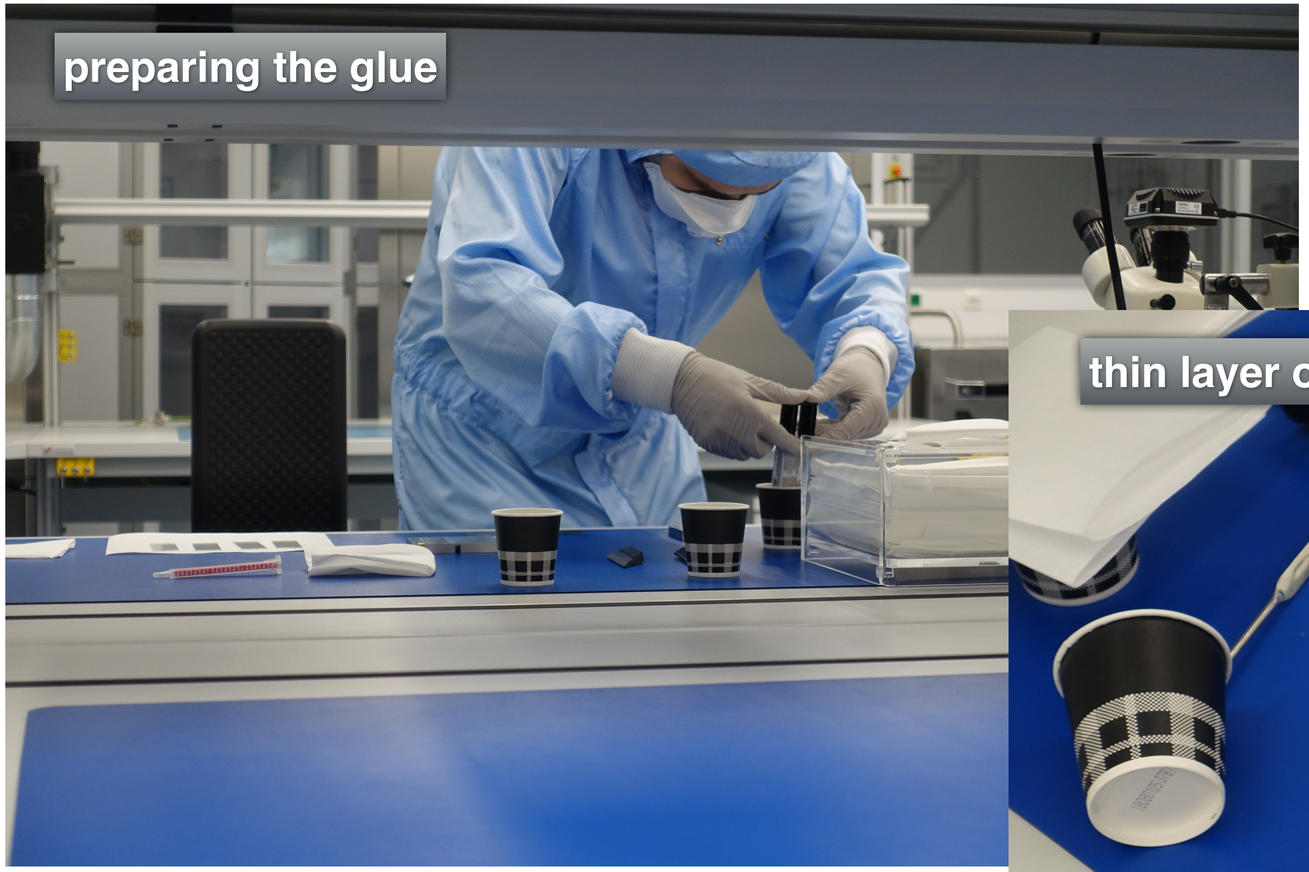


Exemplary pictures represent alternative sequence

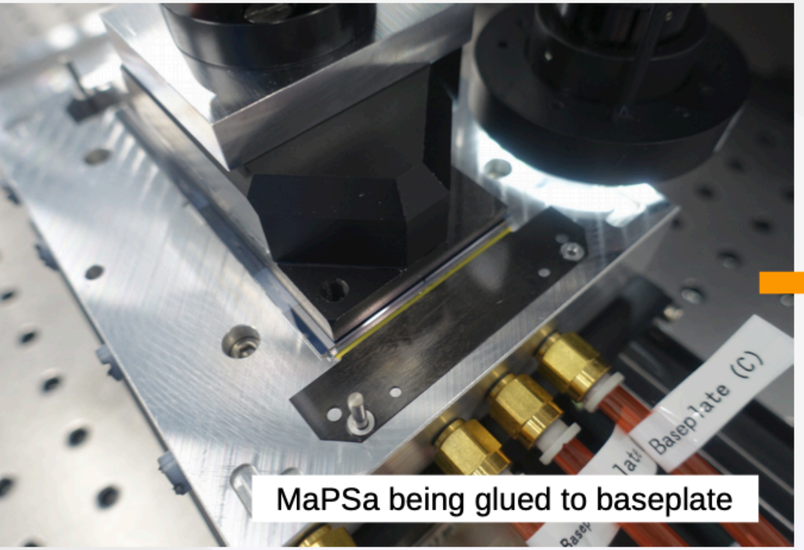


Alternative sequence: (((PS-s to spacers) to MaPSA) to baseplate) ← inner brackets first

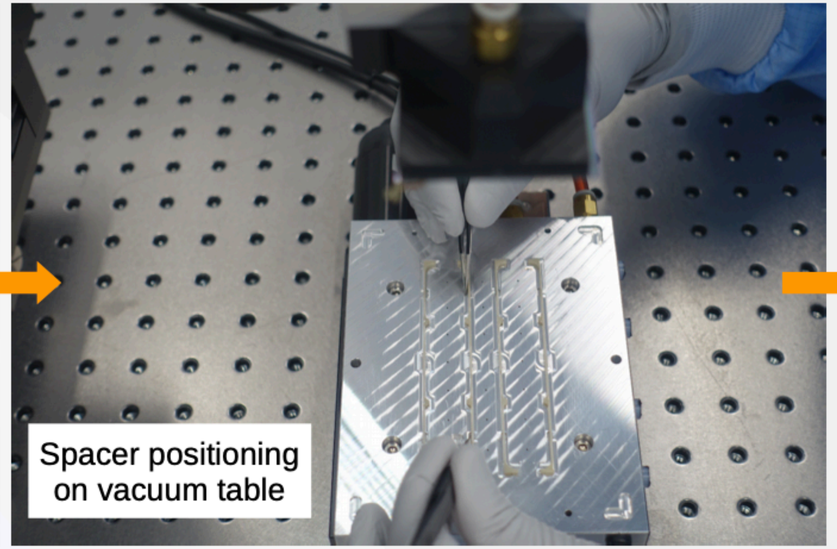
DAF 25c work on modules

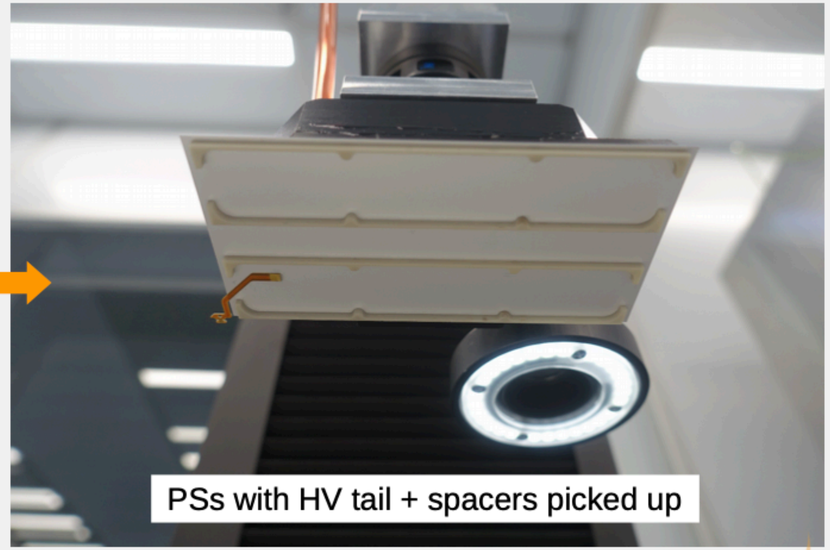


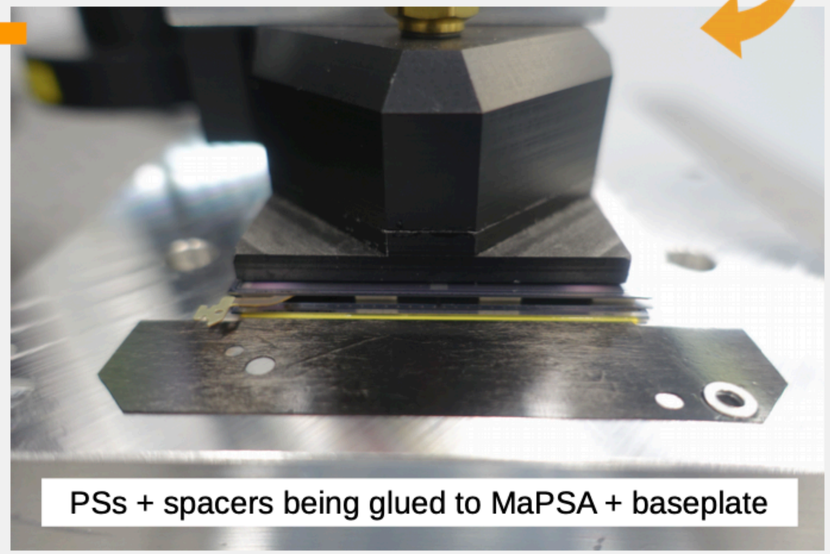
Assembly in pictures

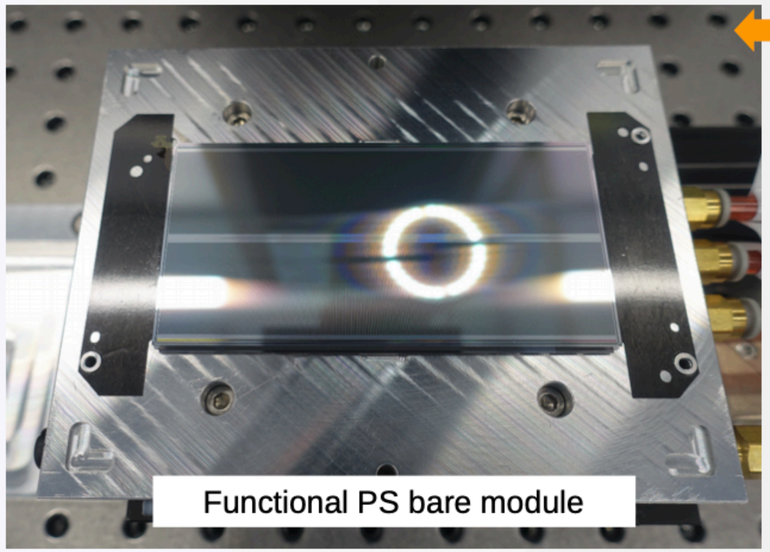


MaPSa being glued to baseplate


Spacer positioning on vacuum table


PSs with HV tail + spacers picked up


PSs + spacers being glued to MaPSA + baseplate

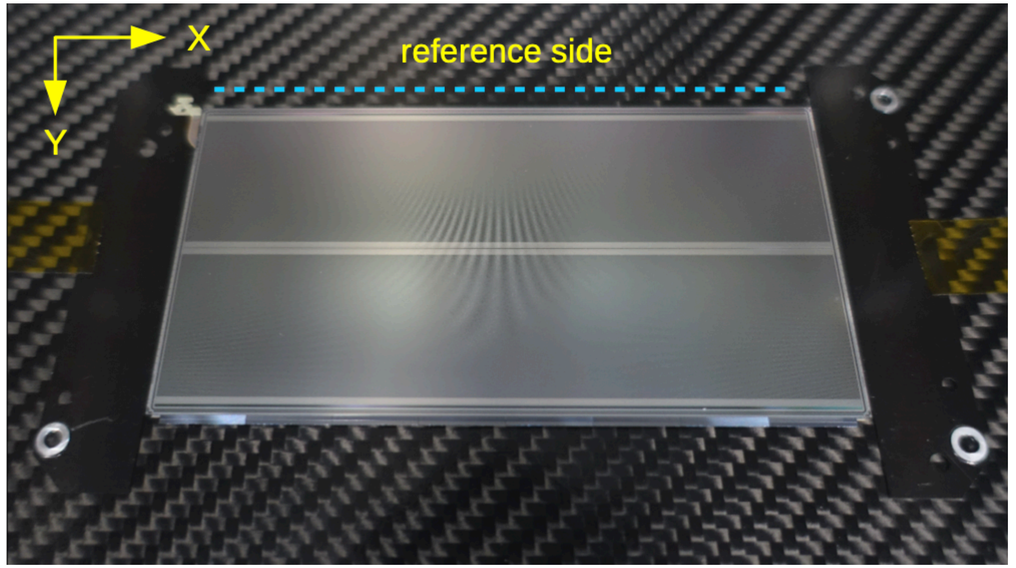

Functional PS bare module

assembly of first functioning module

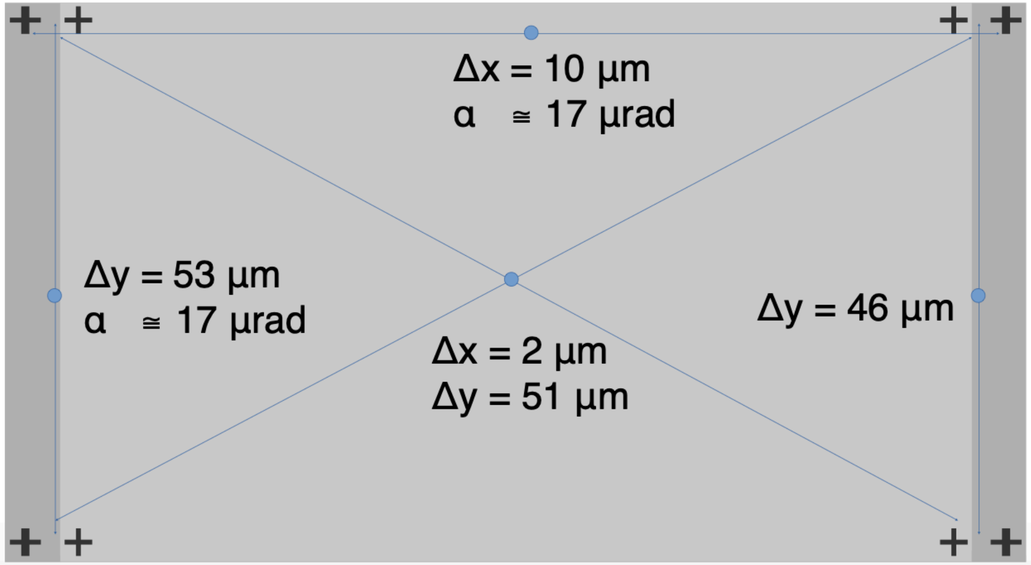
Metrology of 2nd functioning module

currently Keyence microscope used for metrology
alignment markers used
PSp sensor longer than PSs —> markers visible from top

Diagonals intersection —> x,y alignment
Reference vs. opposite side —> tilt

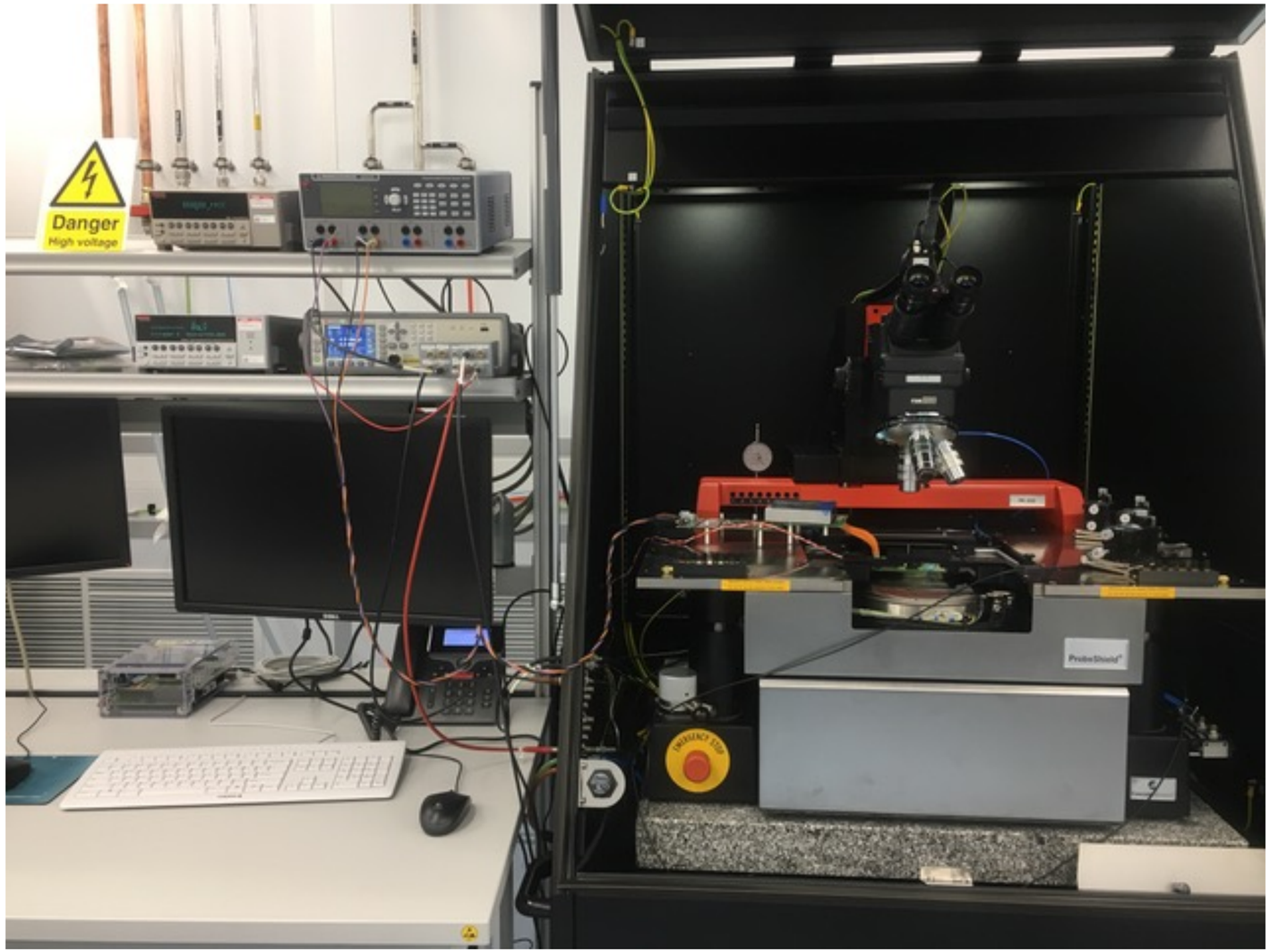


- New bare module: all measurements are within specifications:
  - $\Delta x \leq 50\ \mu\mathrm{m}$
  - $\Delta y \leq 100\ \mu\mathrm{m}$
  - $\alpha \leq 800\ \mu\mathrm{rad}$
- Further characterisation measurements ongoing



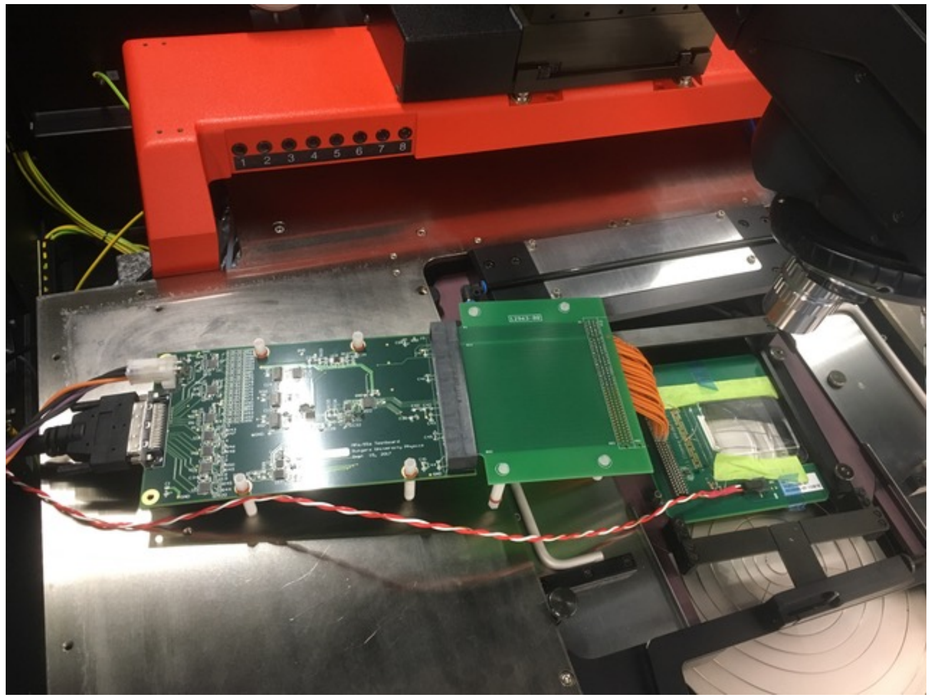
Tests on Probestation

semi-automatic probestation

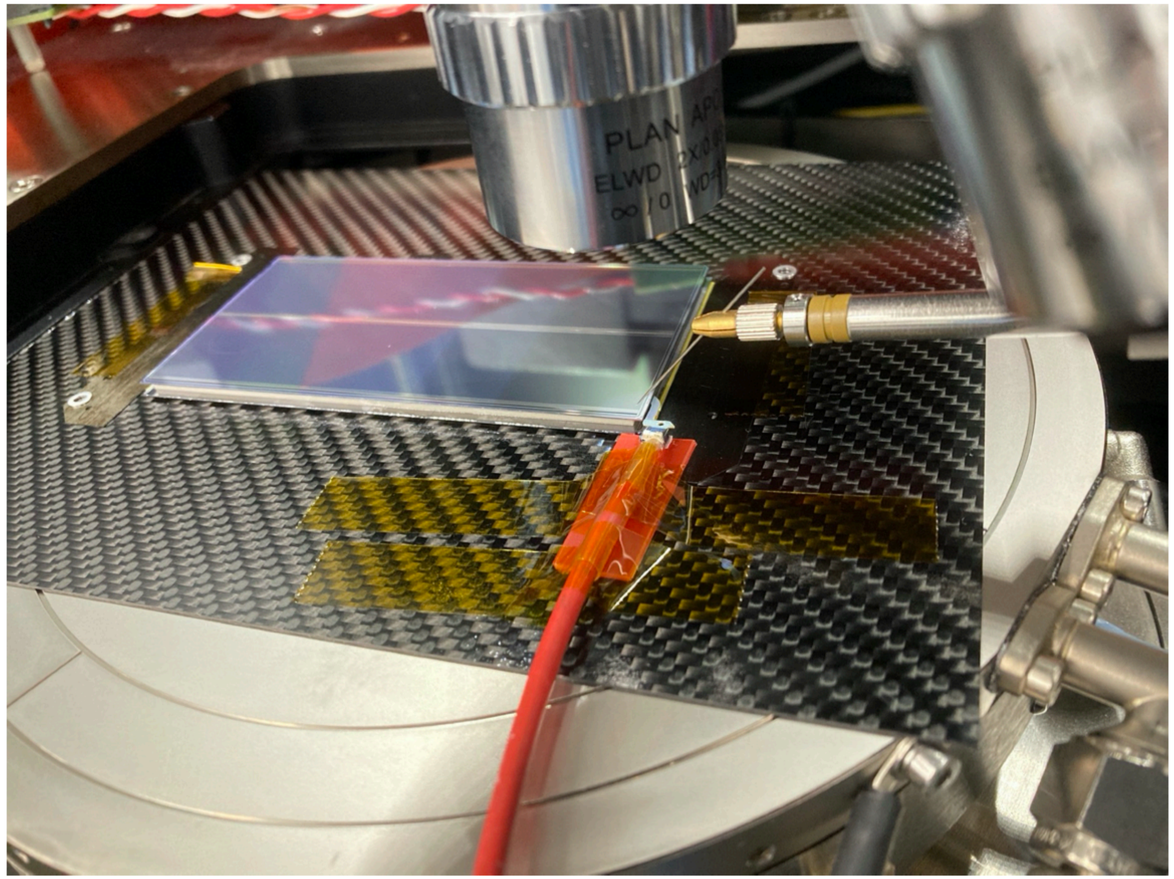


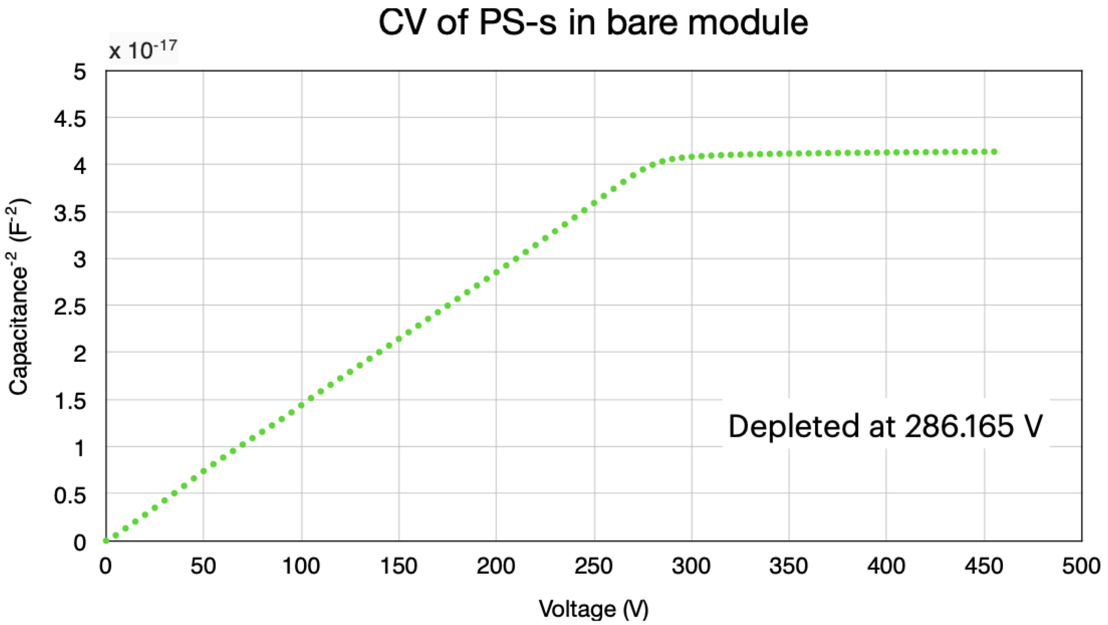
Ginger PhD involving

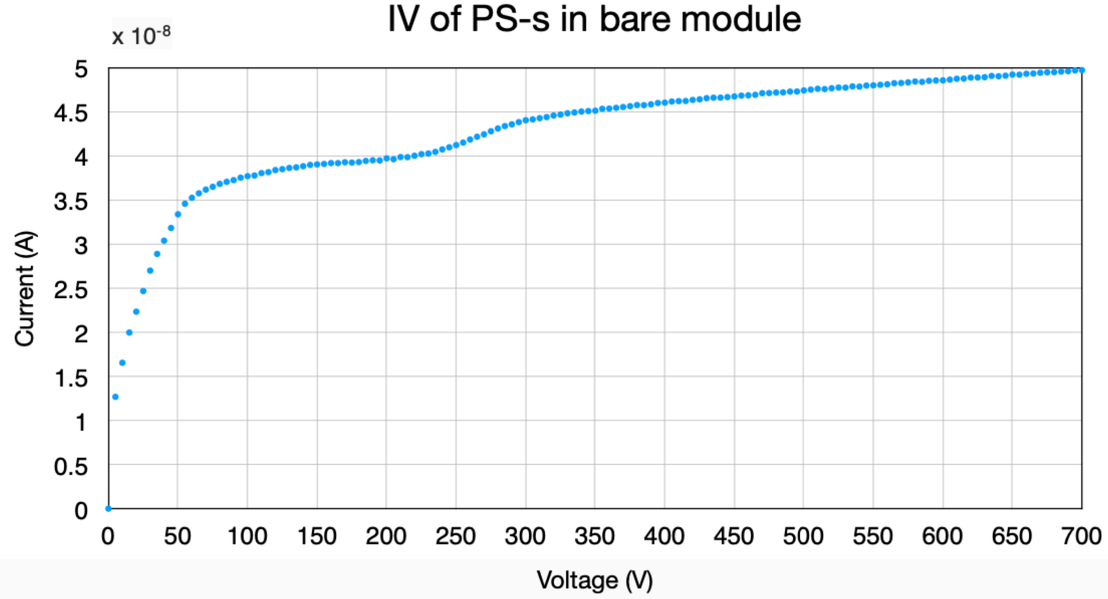
- setup of MaPSA Test
- MaPSA = pixelated sensor bonded to MPA chip
- requires dedicated test card-setup, test software and analysis procedure
- will be complemented by measurements of module in the test beam and analysis of data



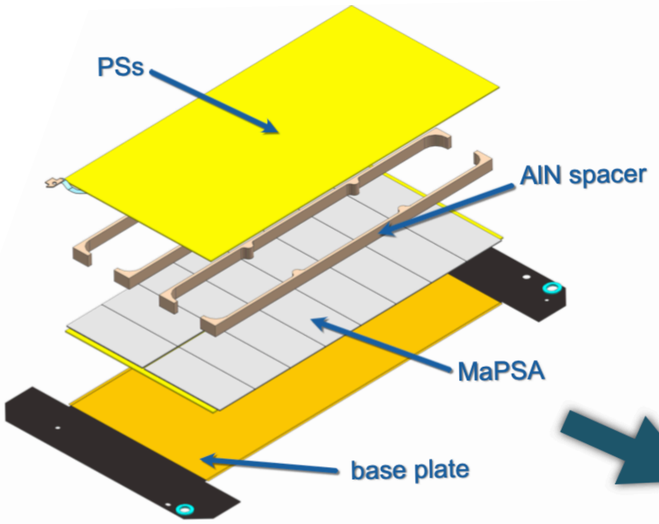
CV and IV of PSs sensor of bare module



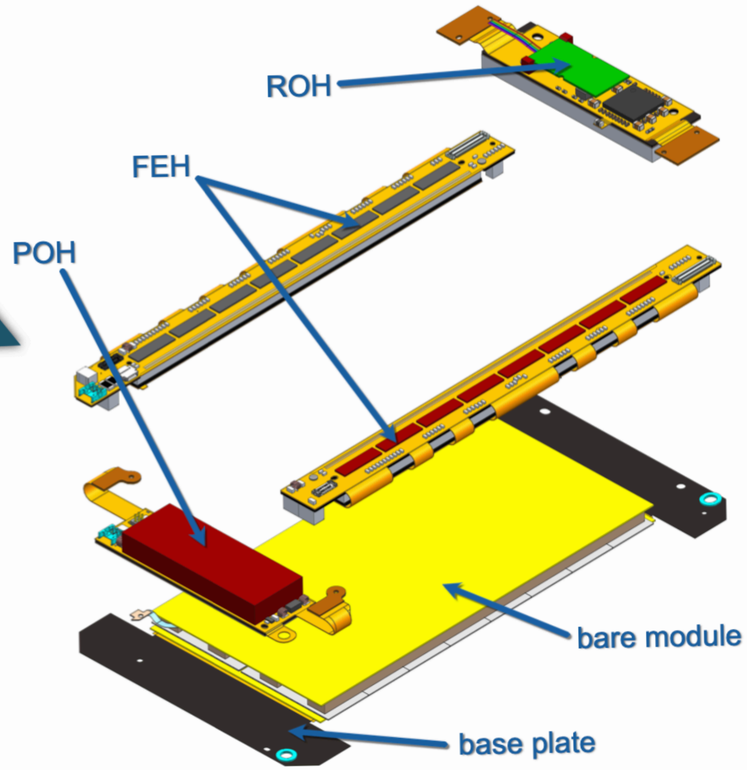




Module Assembly - PS Modules

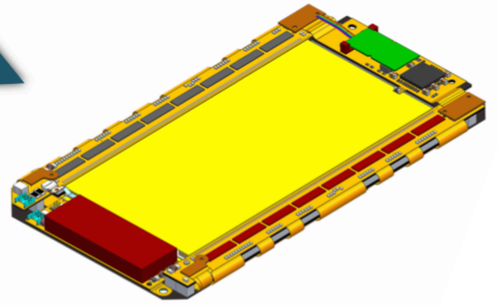


- Relative sensor to sensor alignment $\leq 800\ \mu\text{rad}$
- Assembly is done on a robotic system



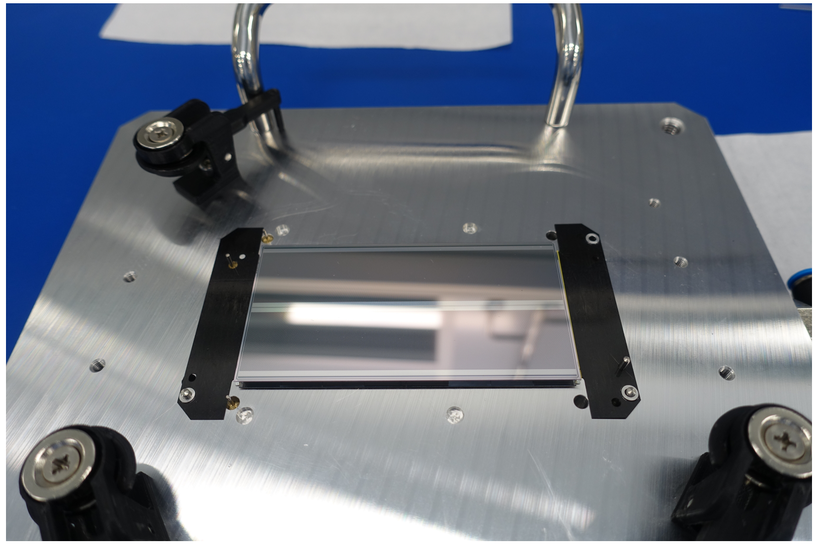
Hybrids are attached to bare module using jigs

1250 PS modules to be built at DESY



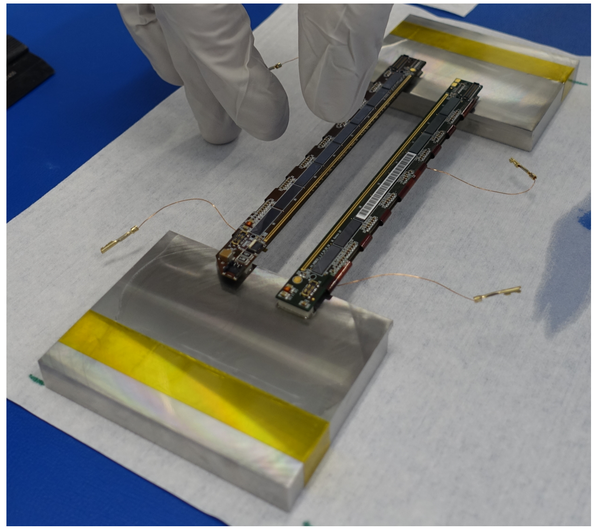
Hybrid Glueing

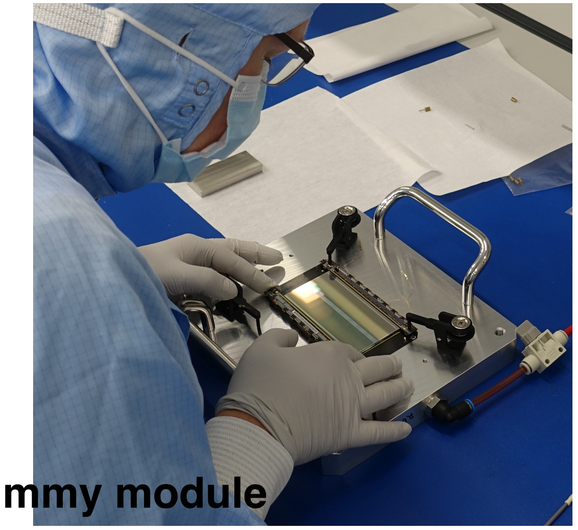
hybrid glueing jig manual



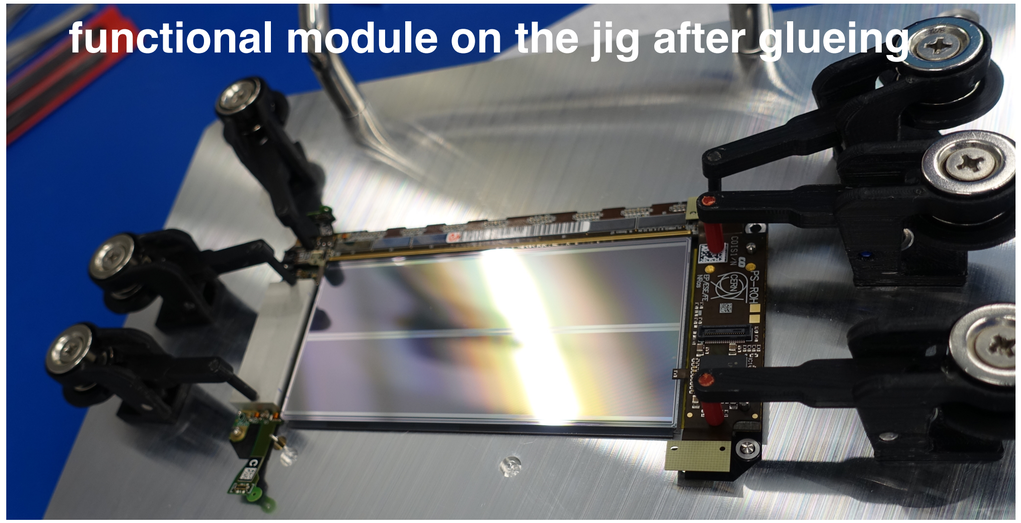
- Glueing trained on dummy module
- gained experience with jig

- amount of glue controlled through Kapton tape thickness
- works well





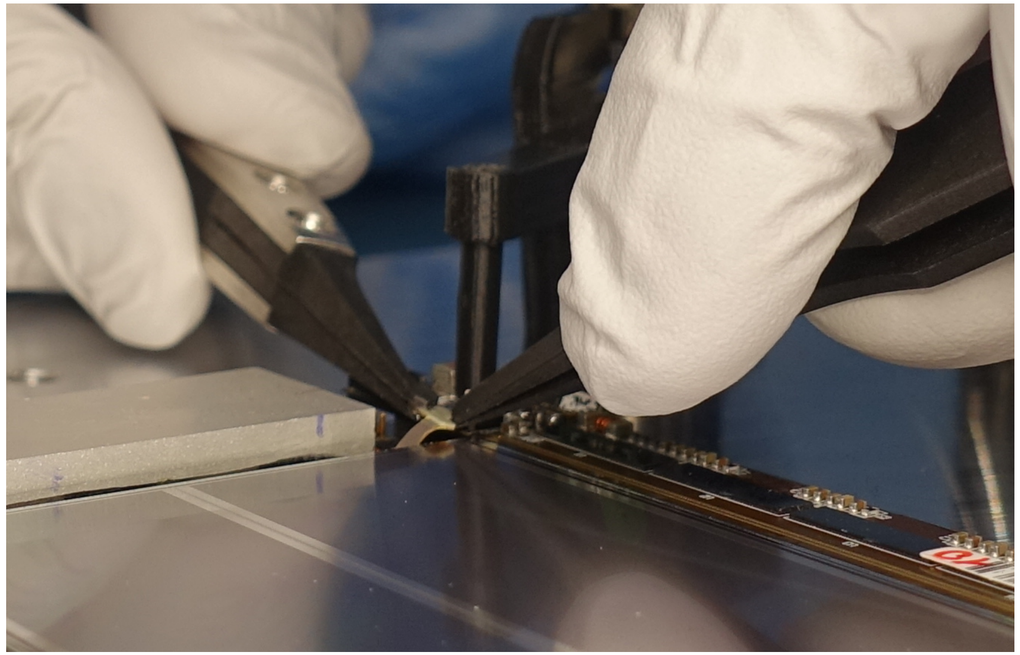
training with dummy module



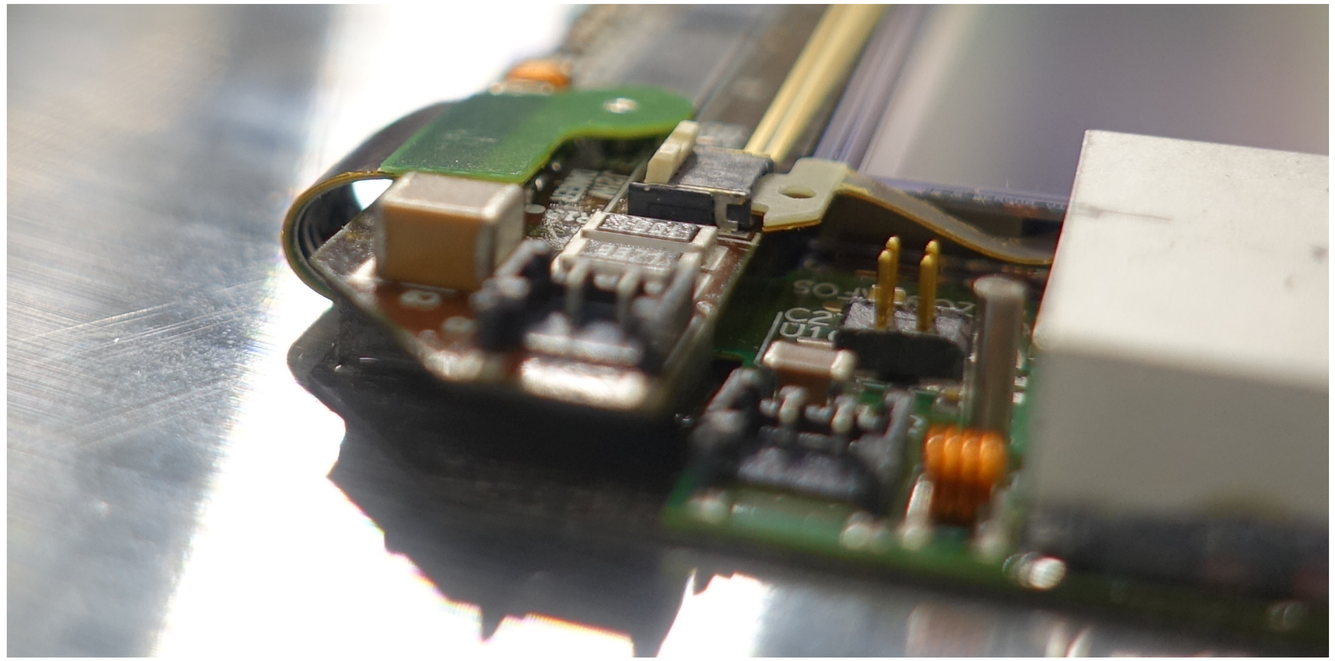
functional module on the jig after glueing

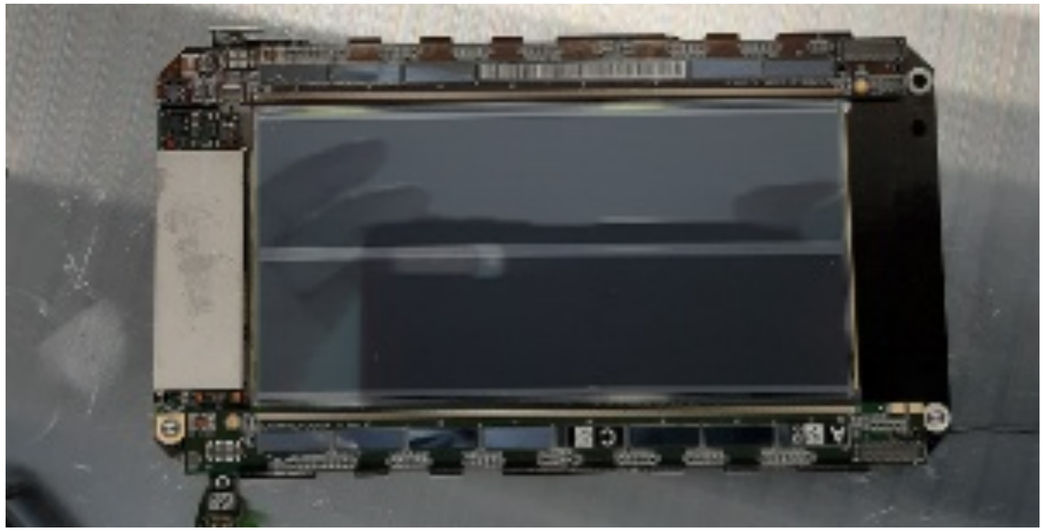
Connections etc.

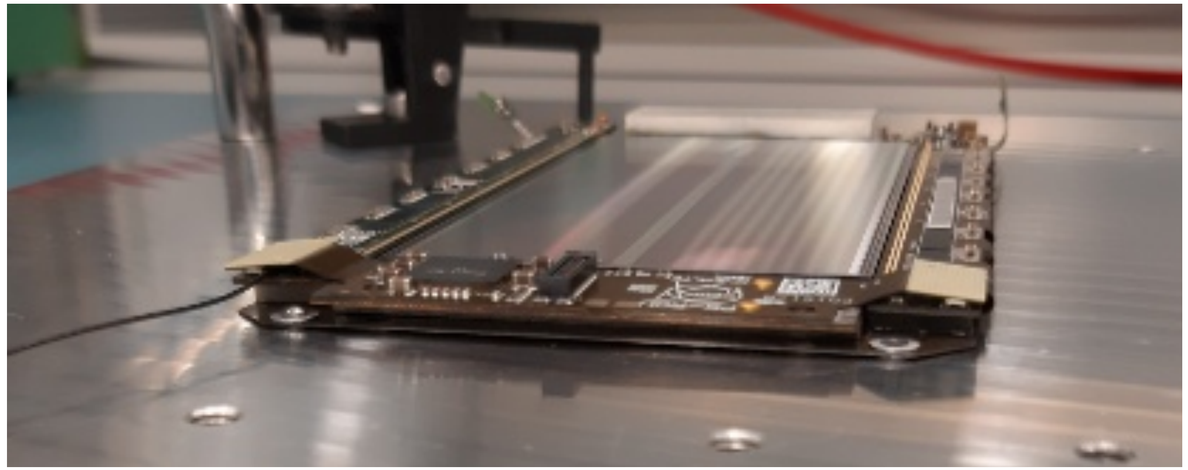
HV Tail connection: tiny but worked well



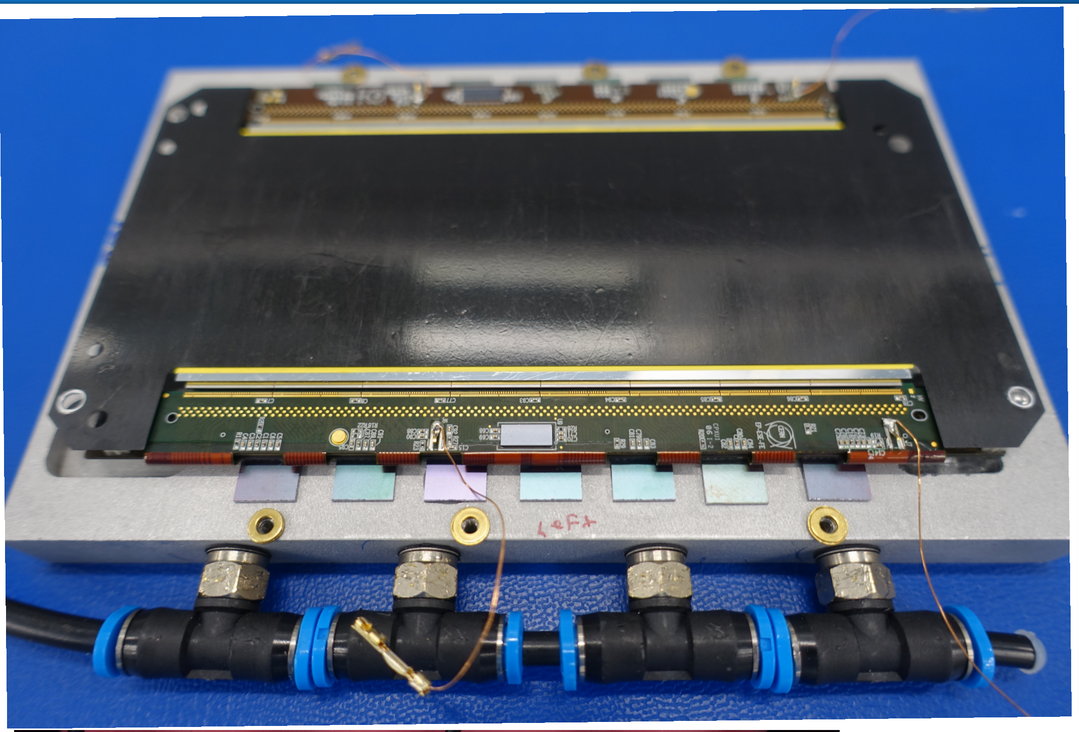
POH to FEH connected nicely

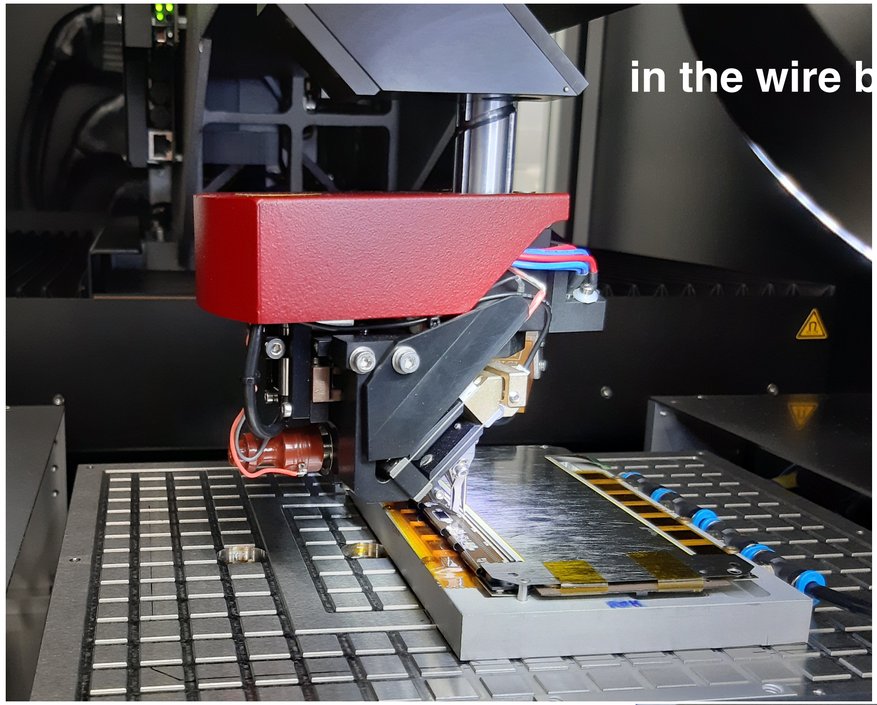


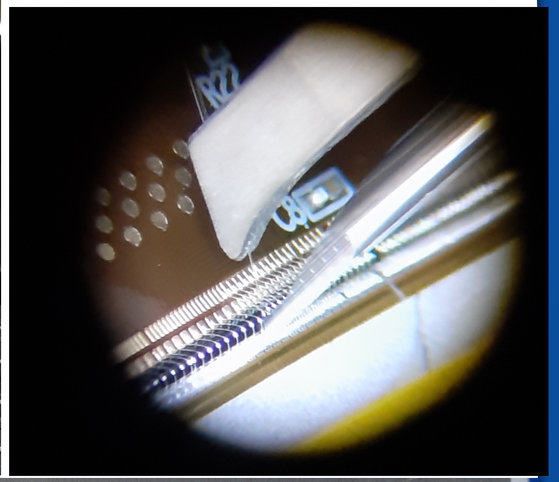


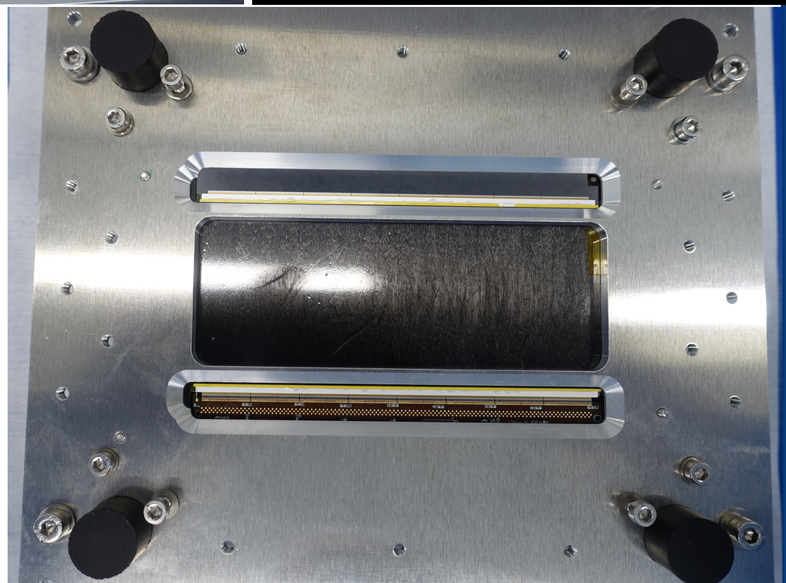


Wire Bonding









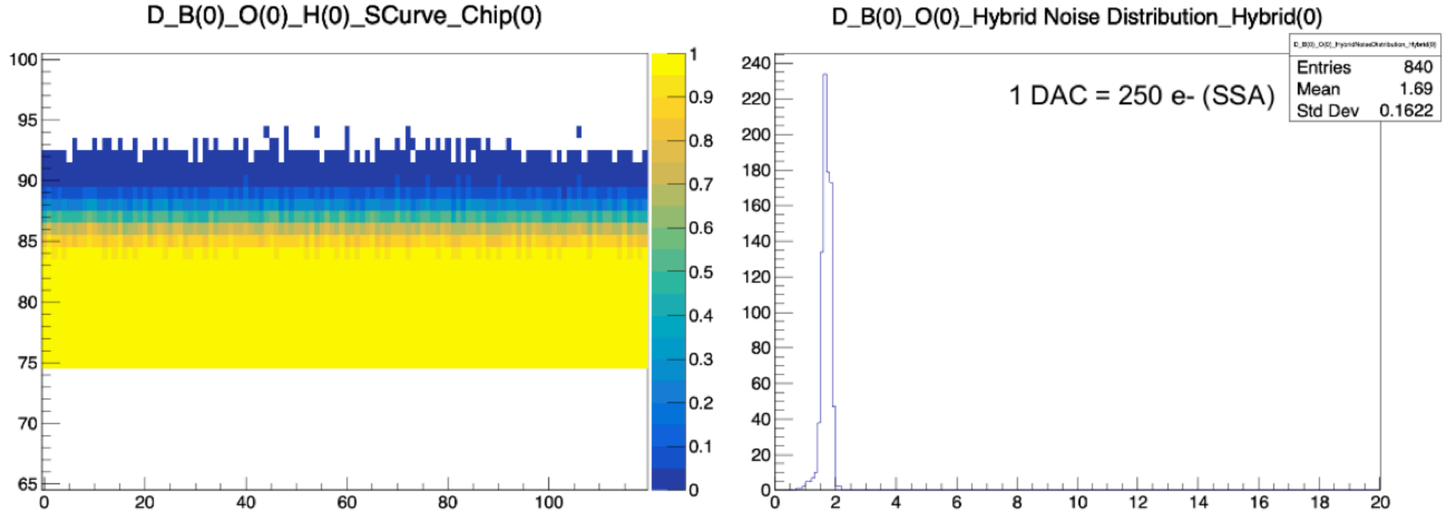
Electrical before / enbetween /after assembly

tests performed after each assembly step
Skeleton = all hybrids, no sensor connected

PS skeleton test before wire bonding

- Voltage levels : 1V05 (1.19V) , 1V25 (1.32V) , 2V55 (2.45V)
- Able to communicate with lpGBT
- Able to configure and calibrate SSAs

Charge injected : ~MIP (17k e-) = 77 DAC



PS skeleton test after wire bonding

- Able to communicate with lpGBT
- Able to configure and calibrate SSAs
- Able to communicate with MPAs (calibration still to come)