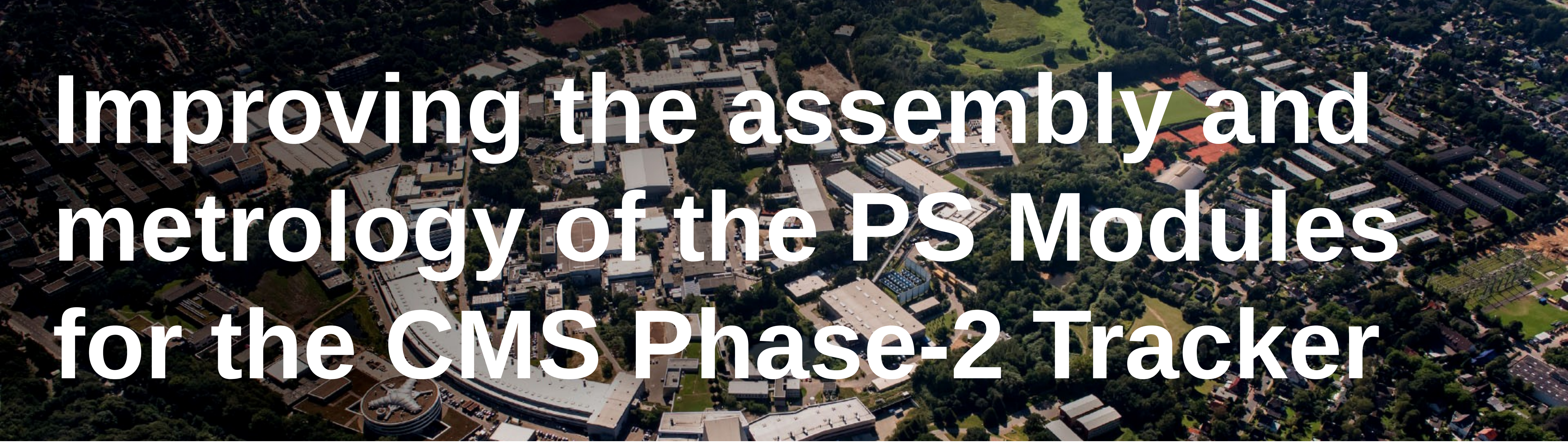
Improving the assembly and metrology of the PS Modules for the CMS Phase-2 Tracker



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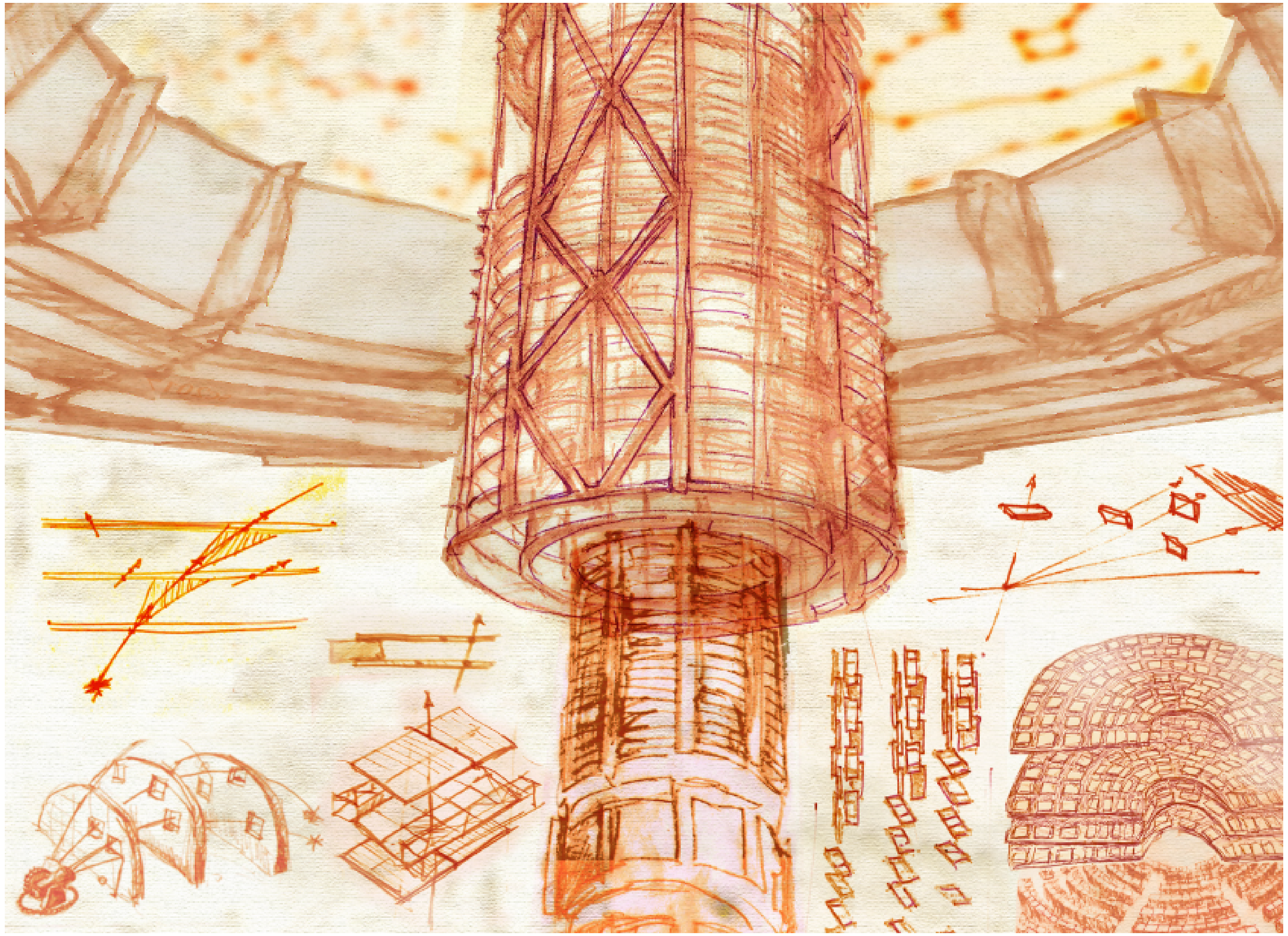
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY. CMS Politechnika Wrocławska

Outline

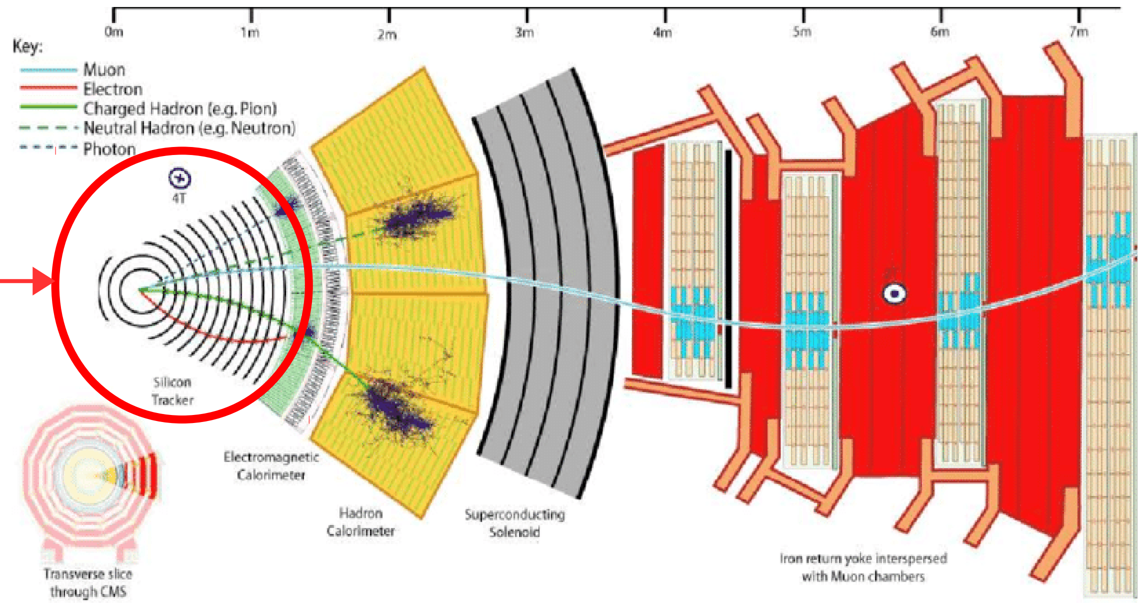


Introduction

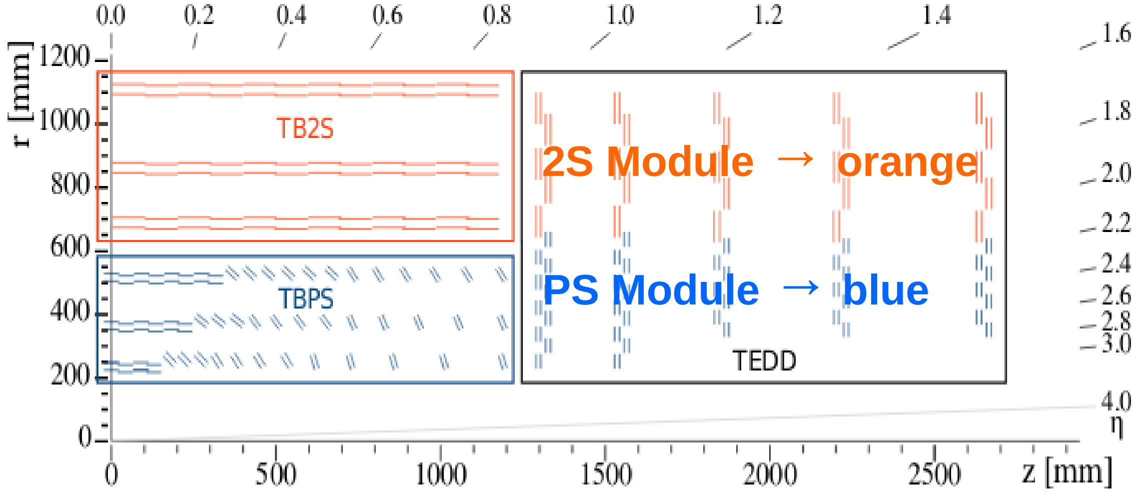
Introduction

The CMS Tracker and the HL-LHC

- **The CMS Tracker:**
  → innermost sub-detector of CMS;
  → thousands of silicon sensors used to reconstruct the trajectories of charged particles from LHC collisions.
- The future: **High-Luminosity LHC**, 2026-2038:
  → higher instantaneous luminosity (up to 5.0 x 10^{34} cm^{-2} s^{-1});
  → unprecedented levels of integrated luminosity (up to 4000 fb^{-1}).
- For the HL-LHC, CMS will install a completely new tracking detector - **the CMS Phase-2 Tracker**:
  → increased radiation tolerance, granularity and η-coverage; input to the Level-1 trigger;
  → the DESY Tracker Upgrade group contributes to construct **the new Outer Tracker**.



Pic. 1. A transverse slice through one segment of the CMS detector.



Pic. 2. A sketch of one quarter of the CMS Phase-2 Outer Tracker.

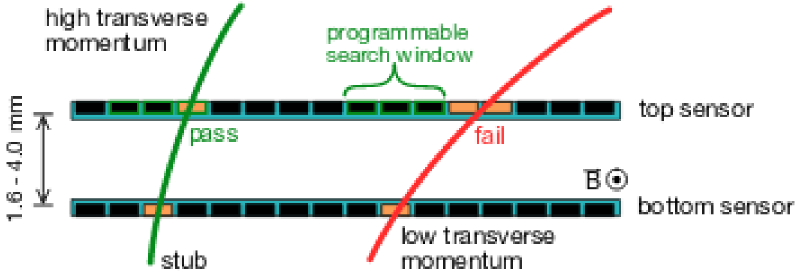
Introduction

The PS Module

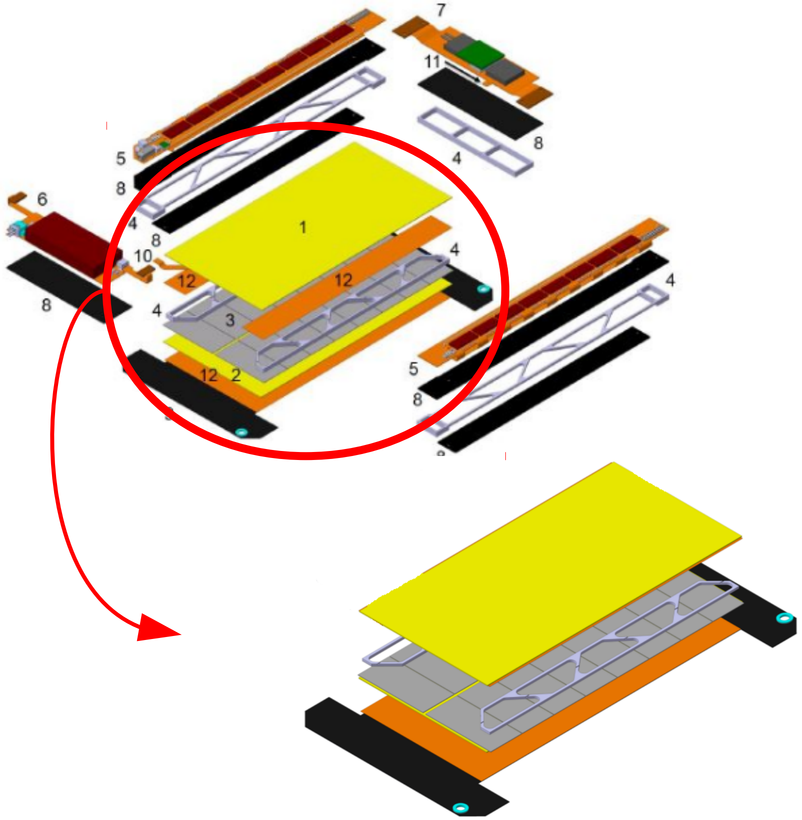
- **The CMS Phase-2 Outer Tracker:** two types of modules:
  → Pixel-Strip (PS) Modules and Strip-Strip (2S) Modules.

- **The PS Module** most important components are **2 silicon sensors** (dim.: 10 x 5 cm^2, thick.: 200 um) in a sandwich configuration.
- Stacked-sensors design will allow to have **local reconstruction of high-p_T tracks** and use this information in the Level-1 trigger:
  → Correlation of hits requires very precise assembly of the sensors: PSp-PSs max-allowed rot. misalignment < 800 urad (0.045 deg).

- **The PS Module assembly** is one of the activities of **the DESY Tracker Upgrade group**:
  → DESY will produce more than 1000 PS Modules.
  → Currently developing assembly procedure using following parts: baseplate, kapton, 2 glasses (instead of silicon sensors), spacers.



Pic. 1. Momentum measurement concept.



Pic. 2. The PS Module design.

PS Module assembly

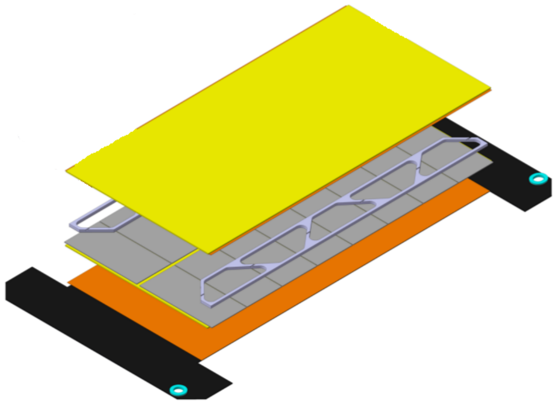
Baseplate+kapton gluing

Motivation, goal and method

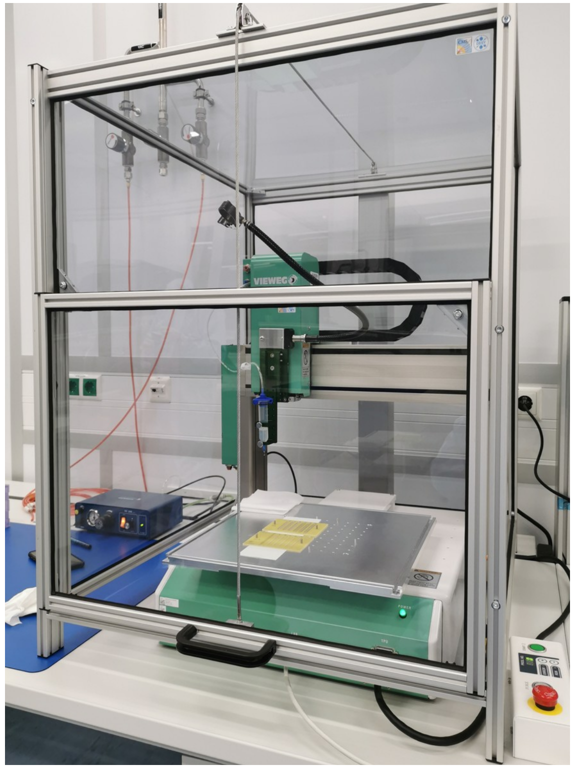
- **Motivation**:
  → The PS Module will be attached to **a baseplate** made of carbon fiber reinforced polymer in order to support the structure.
  → **A kapton foil** (thick.: 25um) on the baseplate is necessary to electrically isolate the baseplate from the PS-p sensor.

- **Goal**:
  → Development of a procedure to glue kapton foil to baseplate (and perform this step in the reproducible way).

- **Method**: Program **the automatic dispenser** to dispense glue on baseplate.
  → Development of a program to operate the automatic dispenser.
  → Tested different patterns to dispense the glue (Polytec EP 601 LV).
  → Best configuration: one 7,5 cm line in the middle, 30-40 mg of glue.



Pic. 1. The PS Module design.

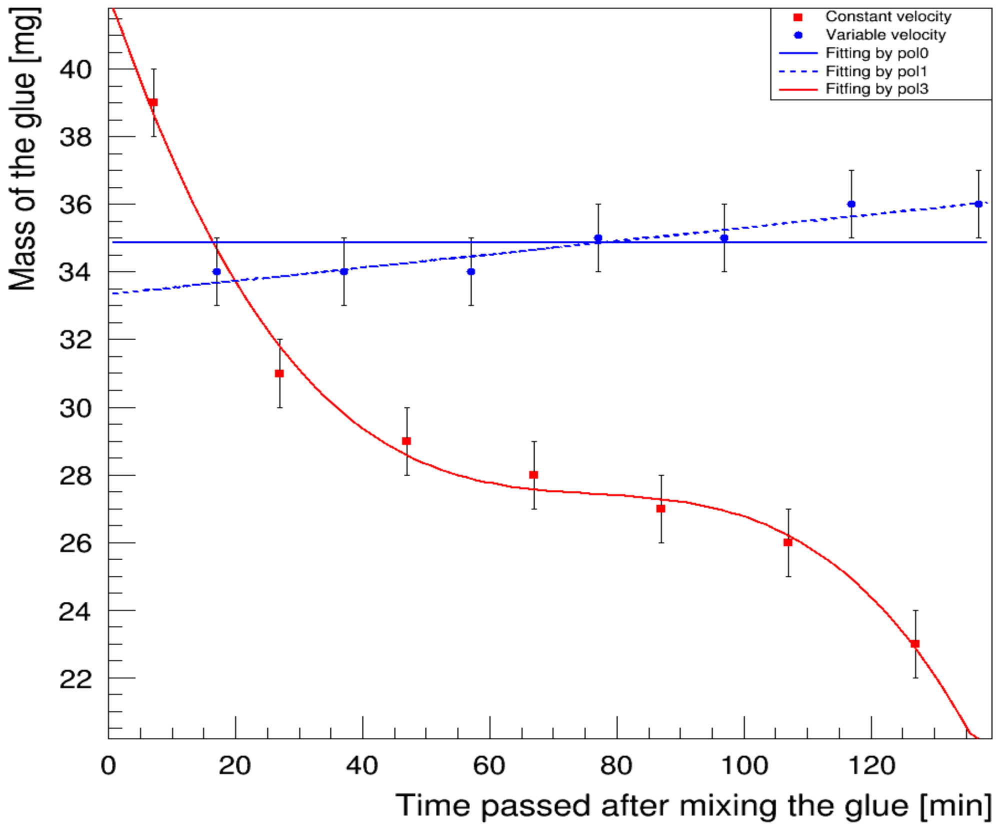


Pic. 2. The automatic dispenser.

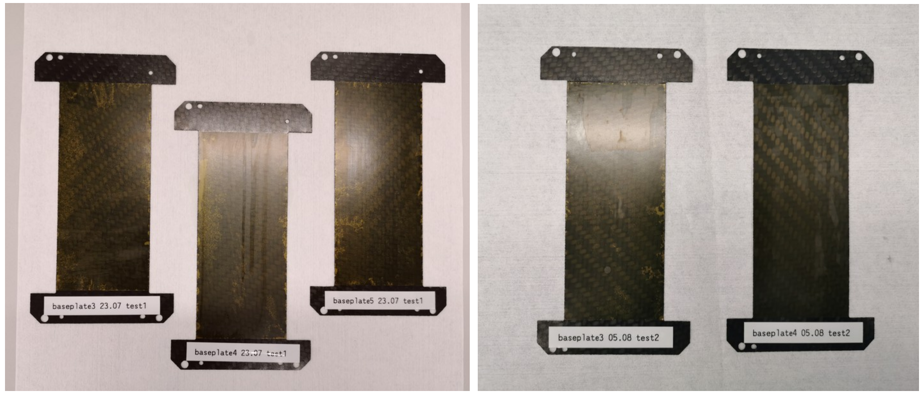
Baseplate+kapton gluing

Results

- Two important factors to account:
  1. Modification of the routine parameters - **dispensing velocity** - wrt time passed after mixing the glue:
     → Goal: constant amount of the glue.
     → Red: constant velocity;
     Blue: adjusted velocity.
     → Found rule to adjust dispensing velocity wrt time.
  2. Method of manually **squeegeeing** (after dispensing).
     → Improper squeegeeing can lead to air bubbles.



- **Results**:
  → Development of the procedure to dispense the glue.
  → Glued 7 prototypes using different methods (last 3 without air bubbles).
- **Next step:** Improve the positioning of kapton on baseplate (currently done manually).



Pic. 1. Glued baseplates (5 of 7) with kapton foil on top.

Baseplate+sensors gluing

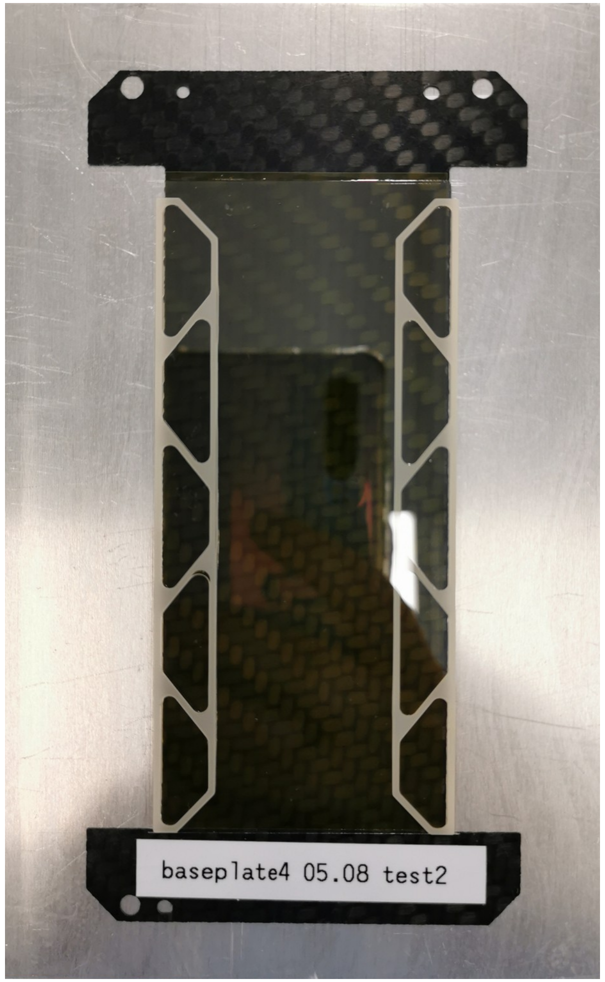
Gluing baseplate to glass+glass sandwich

- **Motivation**:
  → Development of a procedure to glue baseplate to sensors-sandwich obtaining thin glue layer with full coverage.

- **Method**: development of a routine with the automatic dispenser:
  → Goal: thickness of glue layer: ~25 um → amount of glue: ~100 mg.
  → Best configuration: one 8,5 cm line in the middle + 4 dots in the corners.

- **Results**:
  → Successfully applied the procedure in assembly of last 2 prototypes (1 with 200 um thickness glasses, 1 with 700 um thickness glasses).
  → Good coverage of the glue layer (only few small air bubbles between baseplate and glass).

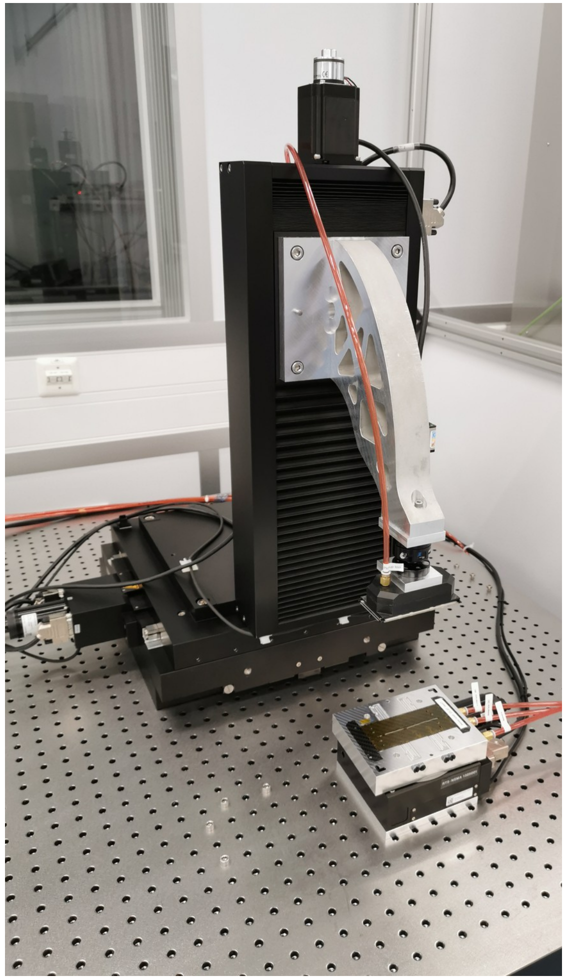
- **Next step:** More testing, measurement of the thickness of the glue layer.



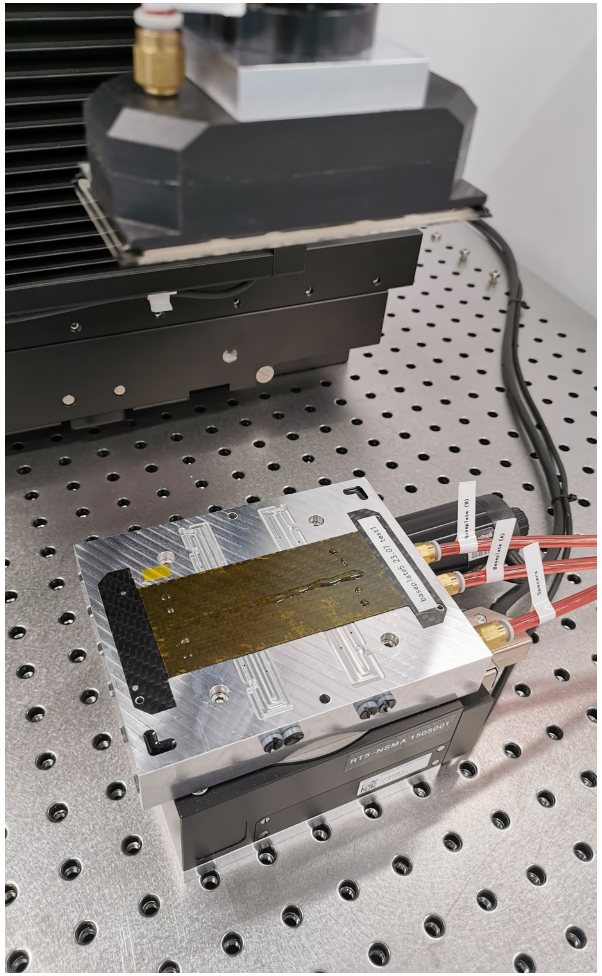
Pic. 1. Assembled PS Module.

Baseplate+sensors gluing

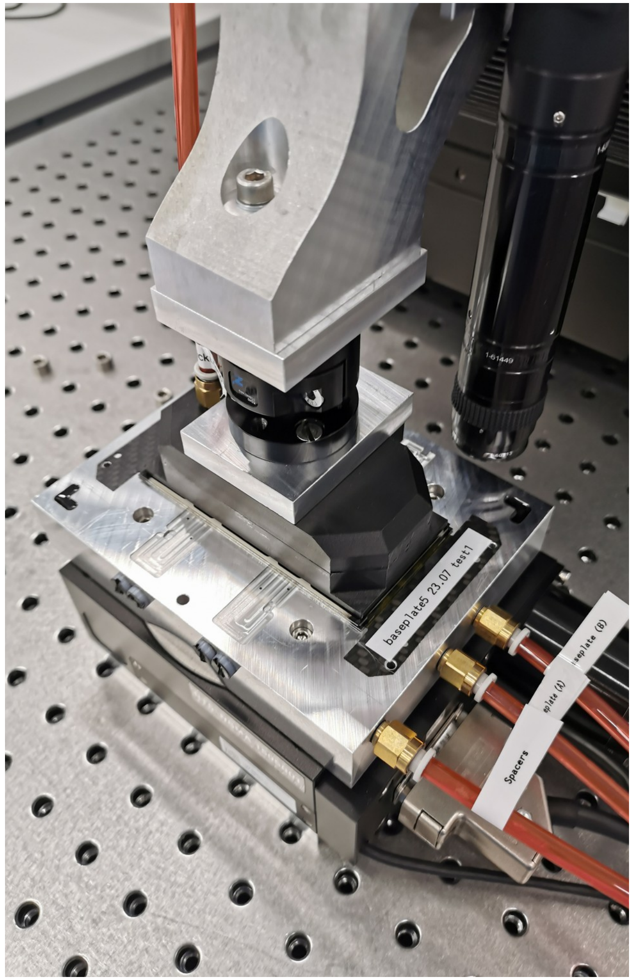
Gluing baseplate to glass+glass sandwich



Pic. 1. The assembly robot.



Pic. 2. Kapton+baseplate.



Pic. 3. Gluing the parts together.

Pic. 4. Assembled PS Module.

PS Module
metrology measurements

PS Module metrology measurements

Measurements of rotational misalignment of PS sensors

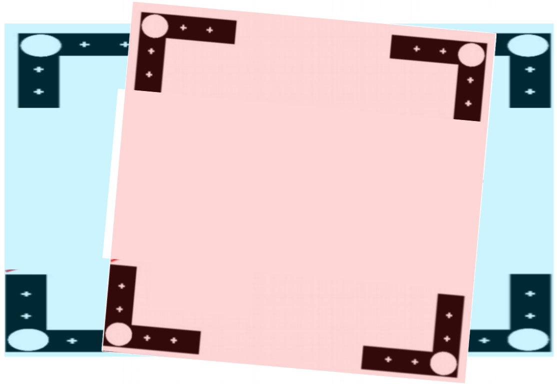
- **Motivation**:
  → Verify if components of the PS Module prototypes are assembled well.

- **Measurements of the markers**:
  → of all 8 existing modules using a microscope;
  → of 2 modules using SmartScope (to compare to microscope data).

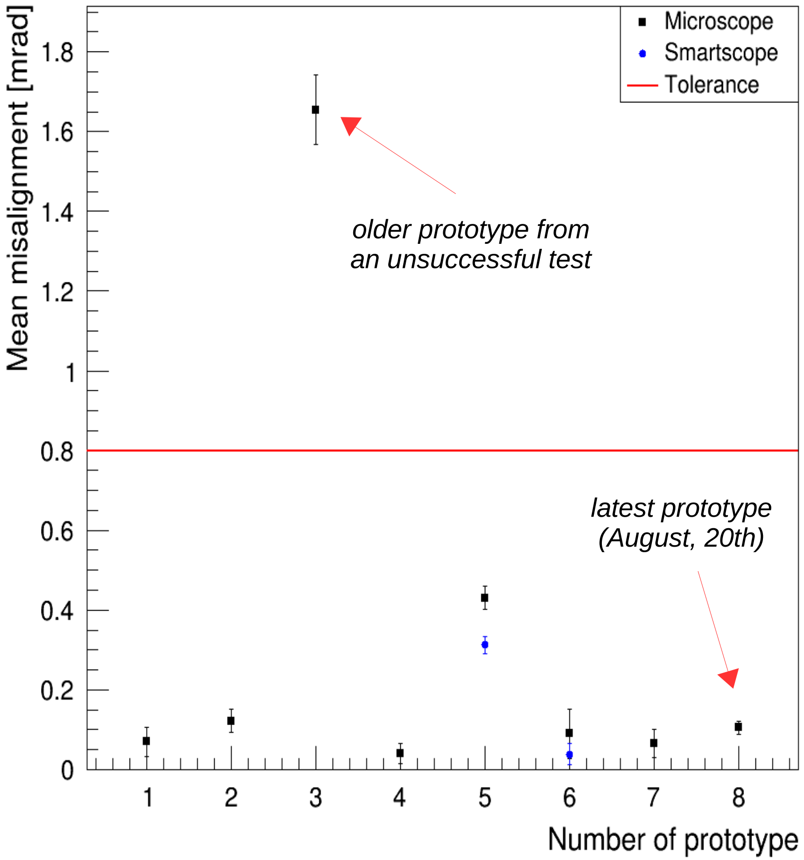
- Development of a program to analyze microscope data (python, ROOT).

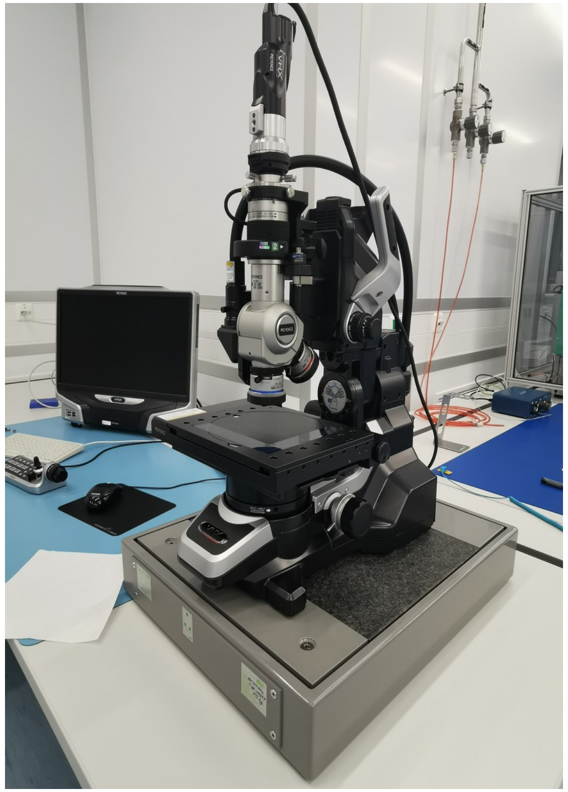
- **Results**:
  → 7 out of 8 prototypes have rot. misalignment within specifications (< 800 urad).

- The procedure and tools can be applied to new PS Modules in the future.



Pic. 1. Misalignment concept.





Pic. 2. The microscope in 25c.

Summary

Summary

PS module assembly

- Developed the procedures to perform 2 steps of PS Modules assembly: baseplate+kapton and baseplate+sensors gluing.
- Successfully applied the procedures in assembly of last 2 prototypes (1 with 200 um thickness glasses, 1 with 700 um thickness glasses).
- Good coverage of the glue layer (only few small air bubbles between baseplate and glass).

Metrology measurements

- Developed the procedure to analyze microscope data.
- 7 out of 8 prototypes have rot. misalignment within specifications (< 800 urad).

Next steps

- Improve the positioning of kapton on baseplate (currently done manually).
- Measurement of the thickness of the glue layer between baseplate and sensors-sandwich.
- Improve the metrology tools by adding additional features.

Thank you

Contact

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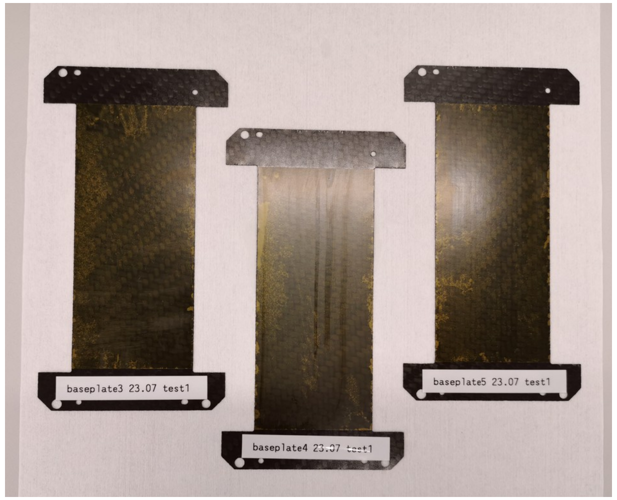
Back-up

Gluing kapton to a baseplate

Results

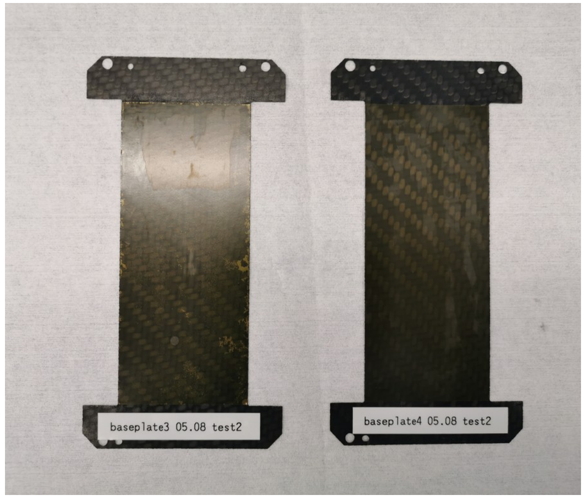
Test #1

- All: 6 cm line in the center.
- Bp3: 5 min; 1.3 mm/s; 43 mg.
- Bp4: 45 min; 1.1 mm/s; 43 mg.
- Bp5: 80 min; 0.9 mm/s; 46 mg.
- All: different methods of squeezing; by the use of force.
- All: clearly visible air bubbles.



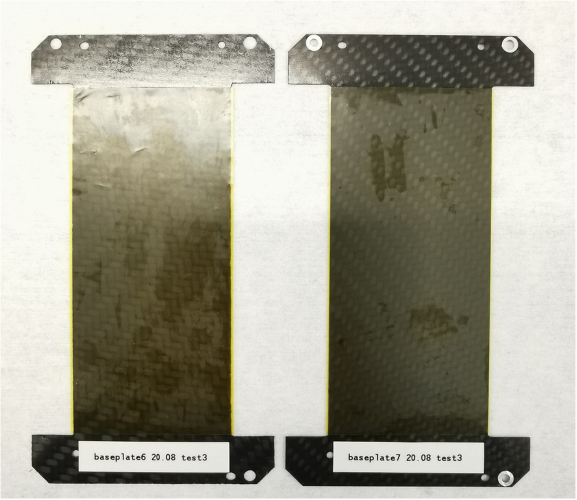
Test #2

- Both: 7.5 cm line in the center.
- Bp3: 27 min; 1.3 mm/s; 43 mg; squeezing by the use of force.
- Bp4: 72 min; 1.3 mm/s; 39 mg; squeezing without using force.
- Bp3: clearly visible air bubbles.
- Bp4: no bubbles, looks properly.



Test #3

- Both: 7.5 cm line in the center
- Bp6: 15 min; 1.3 mm/s; 62 mg; squeezing without using force.
- Bp7: 120 min; 0.9 mm/s; 72 mg; squeezing without using force.
- Both: no bubbles, look the best in comparison to the previous tests.

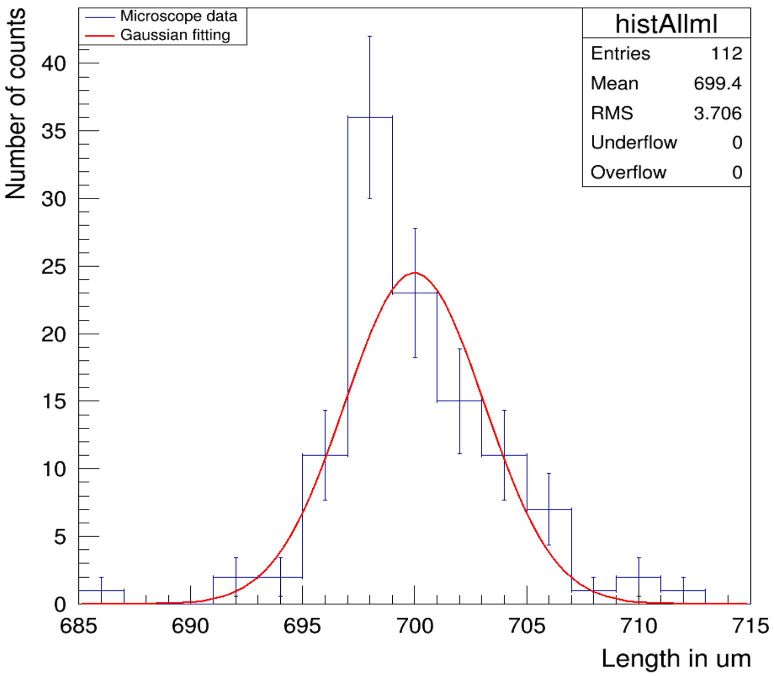


Metrology measurements

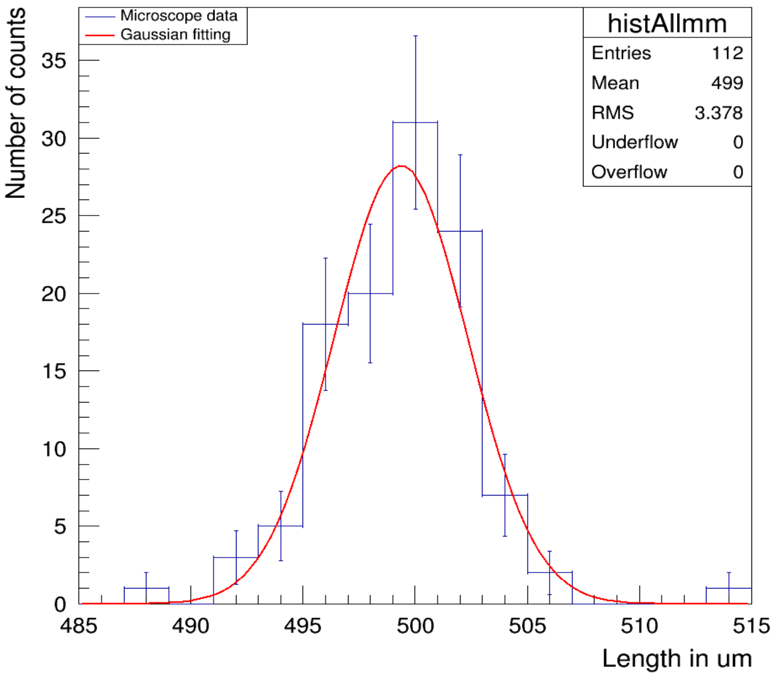
Both glasses’ marker’s long/middle/short length

- **Goal**: Additional measurements to calculate the dimensions of the markers and distances between them.
- Measurement of the markers’ dimensions of the 7 existing prototypes.
- Markers’ design lengths: long → 700 um; medium → 500 um; short → 200 um.

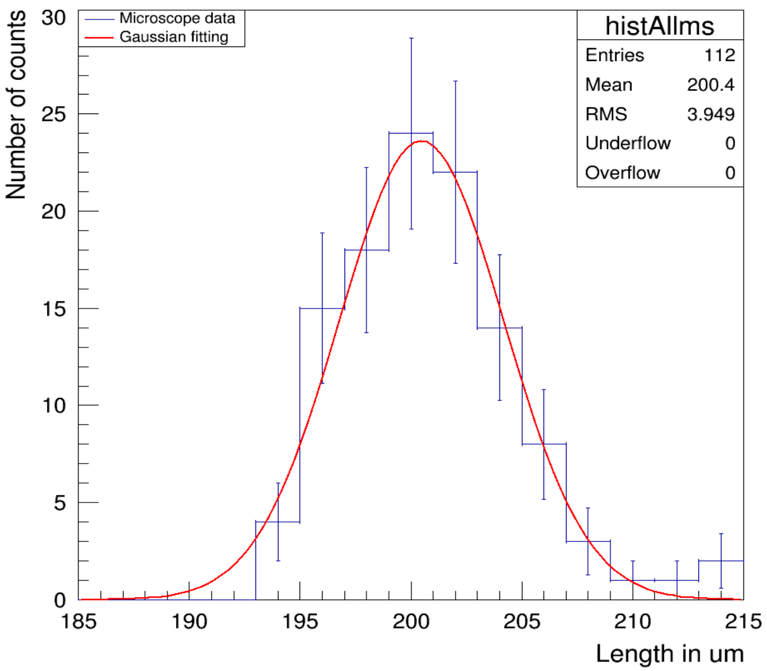
Histogram of marker's long length



Histogram of marker's medium length



Histogram of marker's short length



Conclusion: All markers’ dimensions are similar for each measured prototype and they are in good agreement with markers’ designs.

Metrology measurements

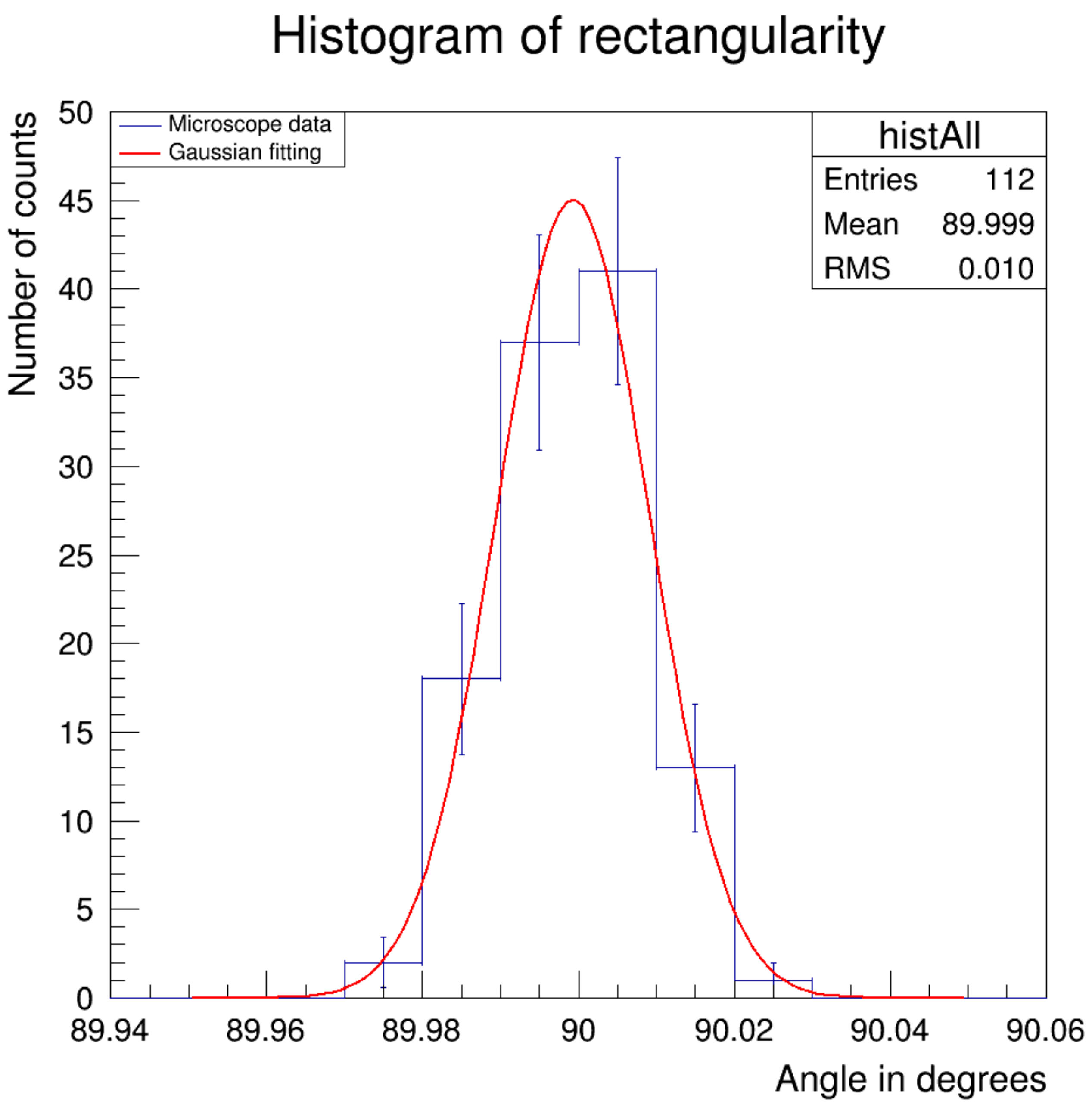
Rectangularity – quality of the markers

Final results for the microscope:

Number of the prototype	Mean angle [degrees]	Std deviation [degrees]
1.	90.000	0.008
2.	90.000	0.012
3.	90.001	0.010
4.	89.999	0.010
5.	90.000	0.008
6.	89.999	0.008
7.	90.000	0.009

Final results for the smartscope:

Number of the prototype	Mean angle [degrees]	Std deviation [degrees]
5.	90.000	0.003
6.	90.000	0.005



<u>Conclusion</u>: all the markers are positioned well.