Sensors wafer probing procedures and status

SVT Working Meeting
December 15-19, 2025

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on behalf of the SVT WP2

INTRODUCTION

Vertical Probing

SVT will need **300-400 MOSAIX/LAS wafers.**

Monolithic Active Pixel Sensors testing traditionally in HEP is achieved by:

- Carrier Card: destructive test
- **Wafer Probing: guarantees 100% coverage**

MOSAIX/LAS will have 8x 10.24 Gbps data out links that can be operated also as slow as 160 Mbps,
The **expected testing time** for 1 MOSAIX is:

- **12 - 24 h** if readout at **160 Mbps**
- **15 mins - 1 h** if readout at **10.24 Gbps**

Common Probe card technologies in the industry are:

- **Cantilever probe card: generally operational up to 300 MHz**
- **Vertical probe card: can operate beyond 20 GHz**

Wafer Vertical Probing guarantees full Production Testing, at the highest possible throughput

Vertical Probing – Testing sites – Throughput scenarios

Current Wafer Probers within the collaboration:
MPI: MIT (vertical), Czech Technical University (cantilever), Brunel University (vertical?)
Form Factor: Oak Ridge (vertical), BNL (vertical)
Assumptions:

- Number of Wafers: 400
- Number of Sensors (MOSAIX / LAS) per Wafer: 5 / 14
- **~ 5600 Sensors to Test in total**

- **Normal shift time / working day: 8 hours**
- **Shift time / working day for an Automatic system: 24 hours** (using a Wafer automatic loading system)
- Wafer handling time: 15 minutes (30 minutes every 25 wafers for the Automatic system)
- Test Time by **Cantilever Probing: from 12 hours up to 24 hours**
- Test Time by **Vertical Probing: from 15 mins to 1 hour**

These numbers are based on preliminary assumptions

That must be corrected in the coming months based on the experience we will build testing ER2 wafers

Vertical Probing – Testing sites – Throughput scenarios

Technology	Test Time per Sensor	Handling Time (hours)	Sites	QC Time (hours)	QC Time (working days)
Cantilever	12 hours	100	3	22433	2804
Vertical	1 hour	100	1	5700	712
Vertical	1 hour	100	3	1900	237
Vertical - Multipoint	1 hour	100	1	1966	245
Vertical - Automatic	1 hour	8	1	5608	233 (24h)
Vertical - Multipoint/Automatic	1 hour	8	1	1874	78 (24h)

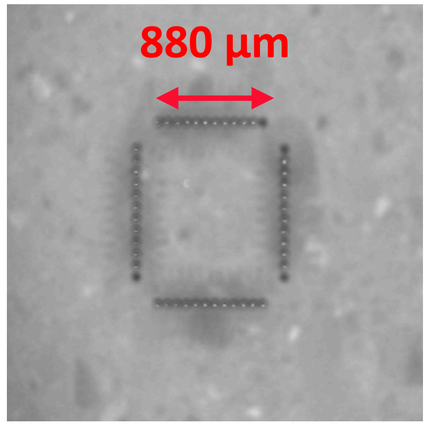
Approaching Production QC **relying on Cantilever Probing only looks prohibitive**,
Multi-site Vertical, Multi-point Vertical, Automatic Vertical would guarantee the fastest throughput
It is important to investigate how we could push the QC limits, if need be

Wafer Probing Station at CERN – Development Site

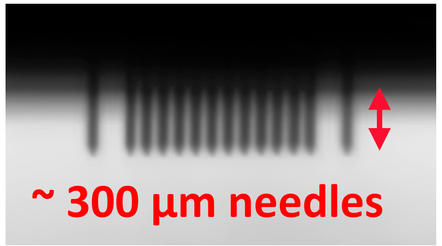
MPI TS-3500 SE Automated test system, acquired by MIT
Installed in CERN Departmental Silicon Facility (DSF)

Main specifications:

- Designed to load up to 300 mm (12”) wafers
- Micro-holes (200 µm) chuck for thin wafers handling
- Several cameras installed:
  wide, chuck (vertical probing), off-axis (vertical probing), VCE
- Automatic Probe To Pad Alignment compensation
- Wafer wallet (25 wafers loader)
  could be added for higher automatization



Needles - front view (chuck camera)



Needles - side view (VCE camera)

Since last SVT Working Meeting:

MOSAIX - Wafer probing: progress, plans, discussion: 09/07/2025 SVT Working Meeting
https://indico.bnl.gov/event/28216/timetable/#20250709.detailed

CONCLUSIONS (09/07/2025)

- Prototype probe card with vertical probe technology fully validated
- Design of MOSAIX probe card well advanced for single/multi point
- Design of MOSAIX/LAS probe card for multipoint still under discussion

SINCE THEN…

- More results obtained and presented with the prototype vertical probe card
  https://indico.cern.ch/event/1502285/contributions/6554595/

- **The MOSAIX/LAS modular probe card concept has been detailed** and discussed with MPI

- **The MIT Wafer Prober upgrade has been detailed** and discussed with MPI for on-wafer sensor characterization

- **Software for Wafer Prober remote control and automation has been expanded**

MOSAIX/LAS VERICAL PROBE CARD CONCEPT

MOSAIX/LAS

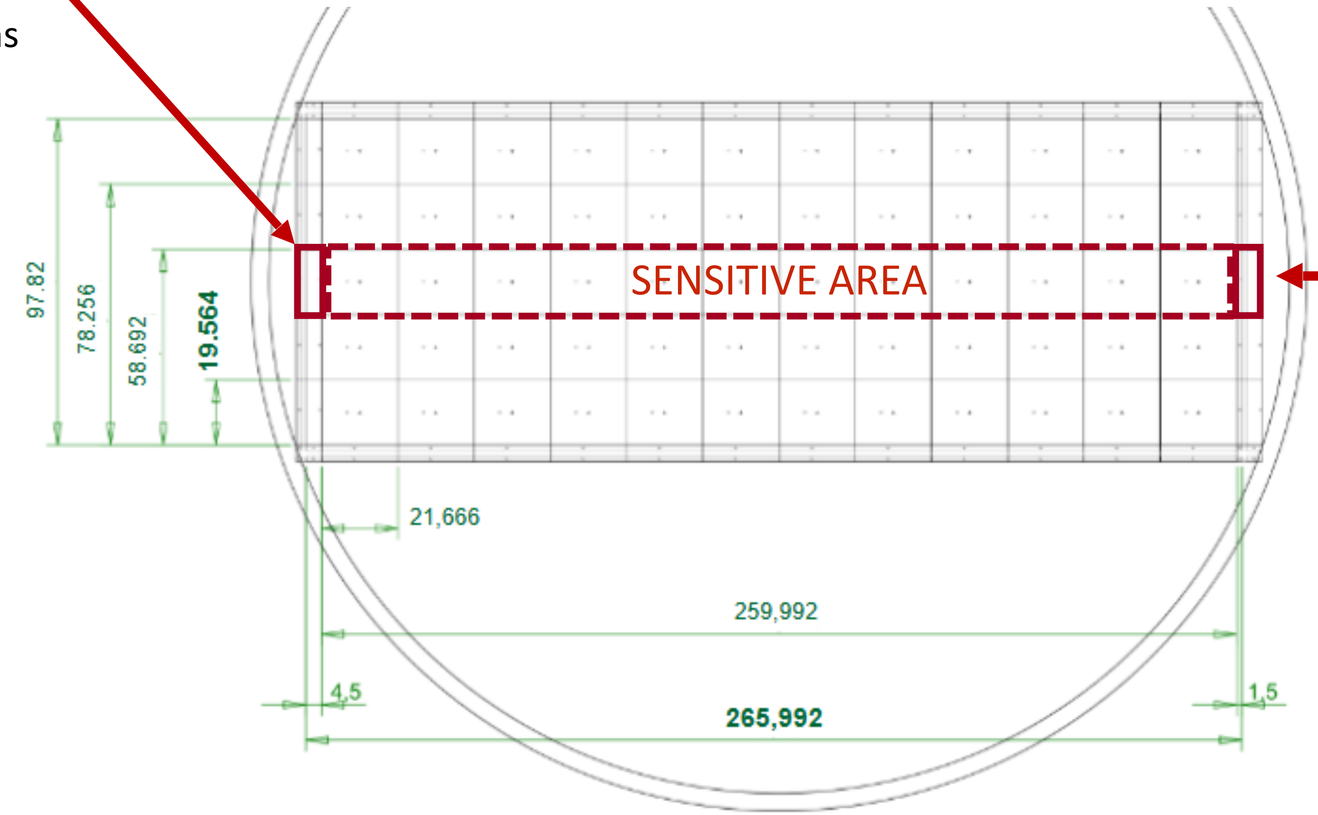
The LEC contains all nets necessary to operate and test MOSAIX/LAS
the focus at the moment is to **develop first a probe card for the LEC**

LAS wafer reticle is yet to be defined, and **might be different from MOSAIX**,
yet, ideally, **the testing infrastructure could be unique**

Left Endcap (LEC)

The LEC hosts all the communication pads to the outside world plus different power domains and substrate biasing

- **152** pads in total:
  - **Data Out:**
    8x 10.24 Gbps differential links
  - Slow Control: 2x 320Mbps differential links
  - Power domains
  - Substrate bias



300 mm wafer

Right Endcap (REC)

The REC hosts mainly pads dedicated to powering

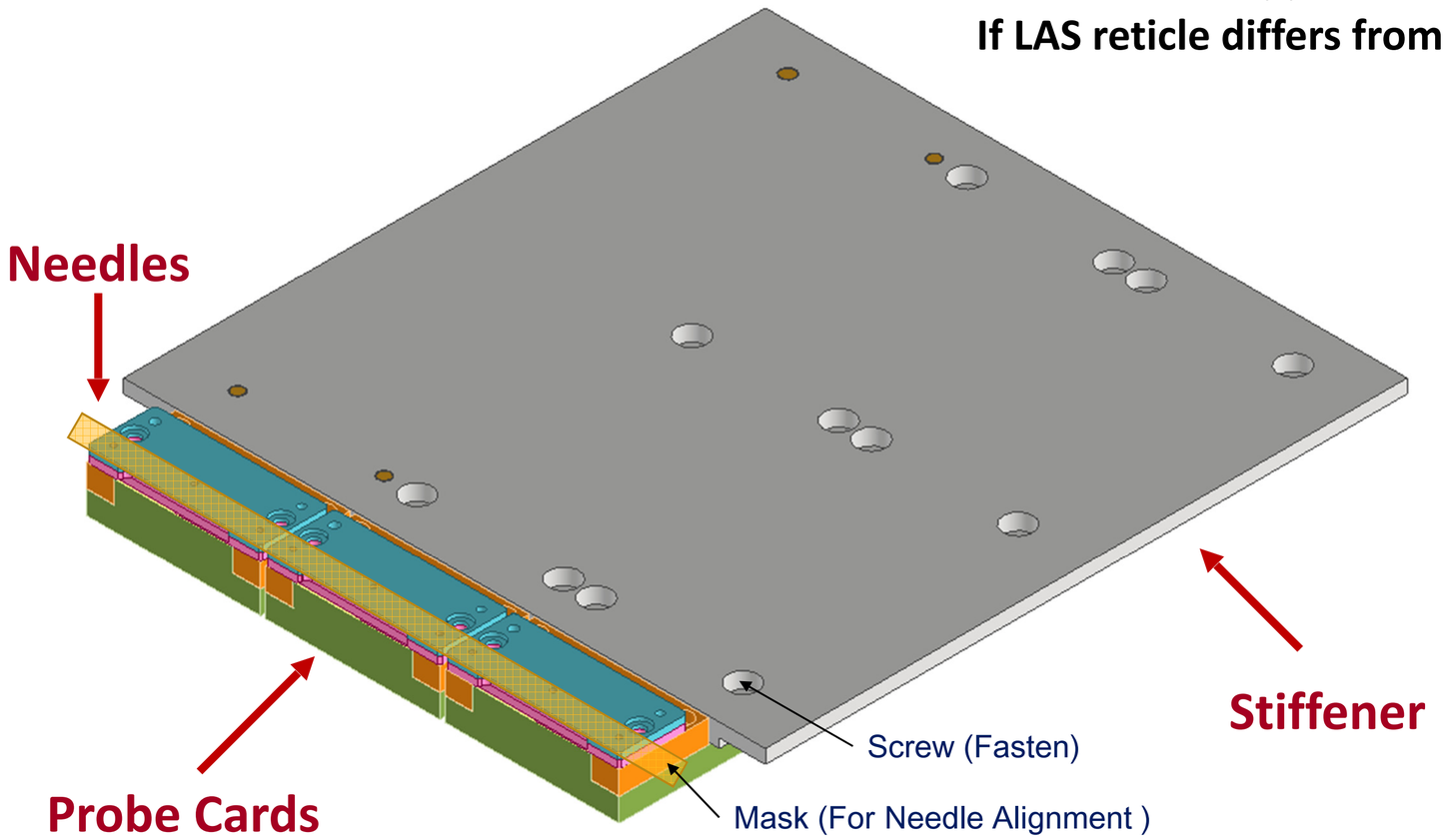
- **161** pads in total:
  - 2x test differential pairs
  - **Power domains**
  - Substrate bias

LEC (LEGO) Probe Card (single/multipoint)

LEGO like - modular Probe card:
a LEC Probe Card block that can be installed on a stiffener.

The stiffener is a support with mounting points that **matches the wafer reticle,**
If LAS reticle differs from MOSAIX, only a different stiffener is needed

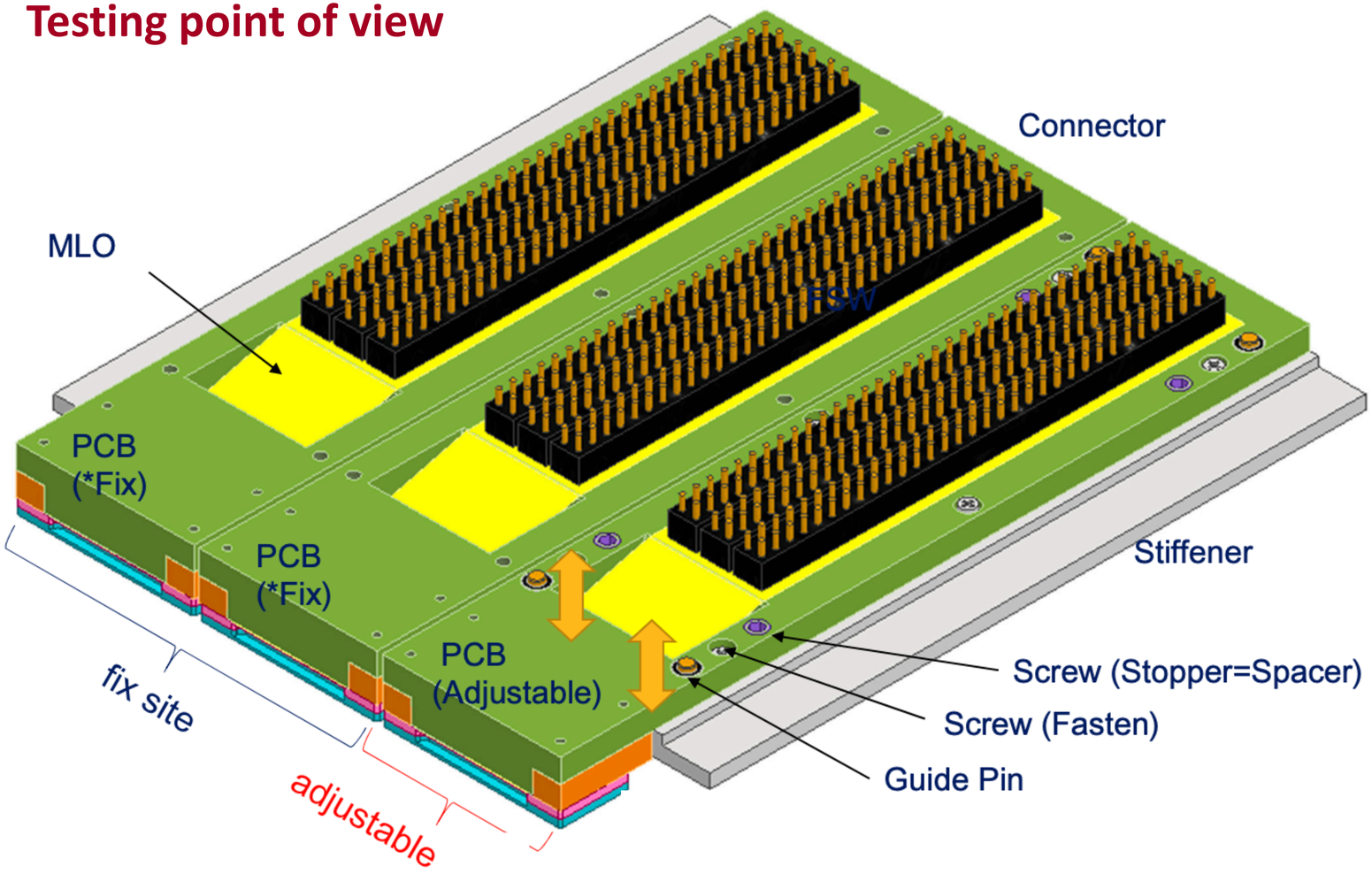
Wafer point of view

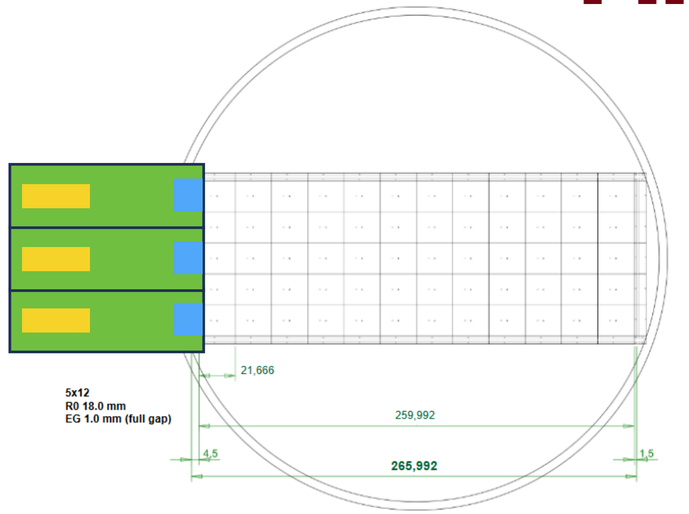


- The frame can contact **up to 3 MOSAIX /LAS in parallel**
- This modular concept allows to **remove or insert as many cards as needed** (LEGO approach)
- XY position of each card can be adjusted adapting only the stiffener: **any multipoint reticle positioning** can be reached only adapting the stiffener

LEC (LEGO) Probe Card (single/multipoint)

Testing point of view





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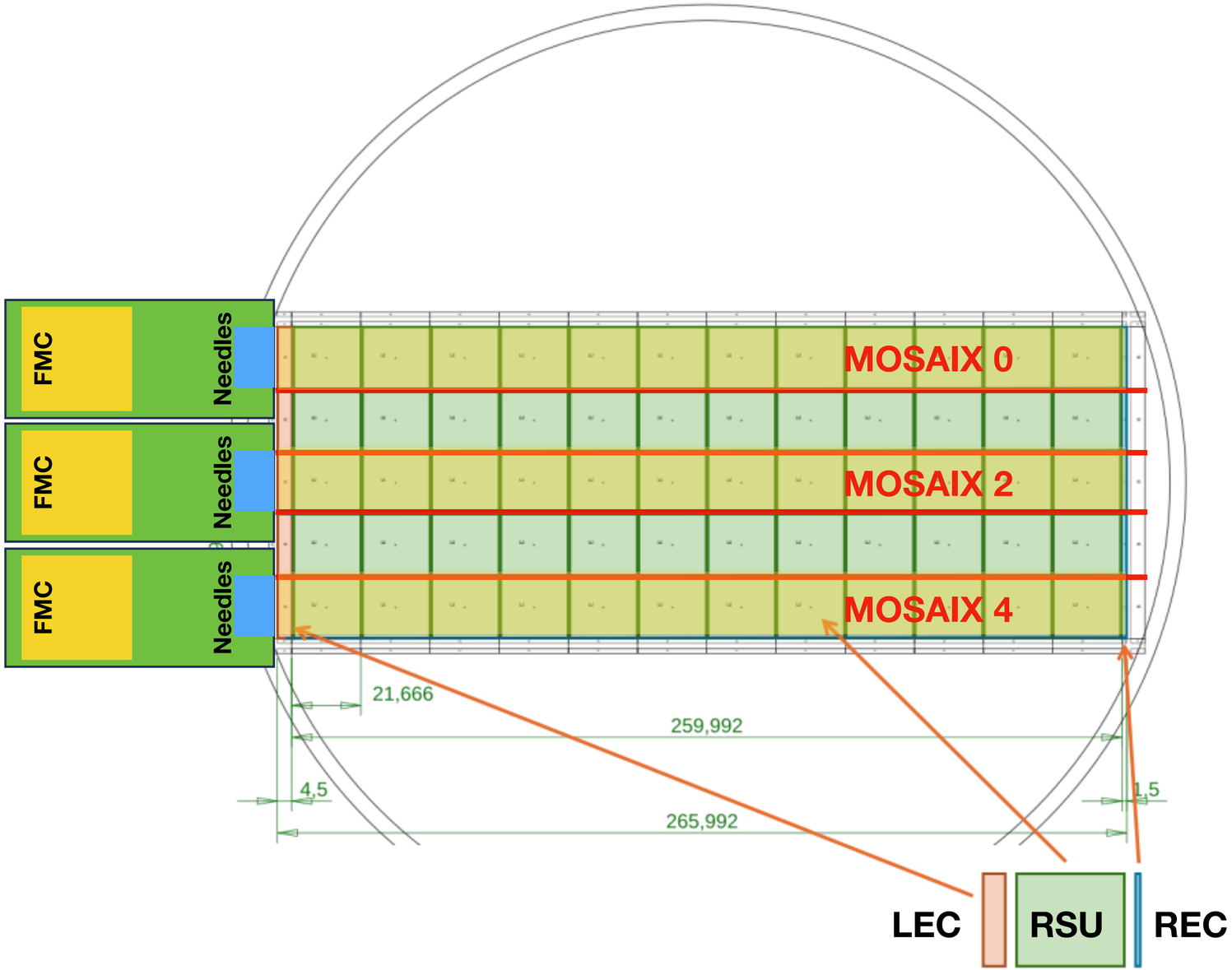
LEC Probe Card – Testing Configurations



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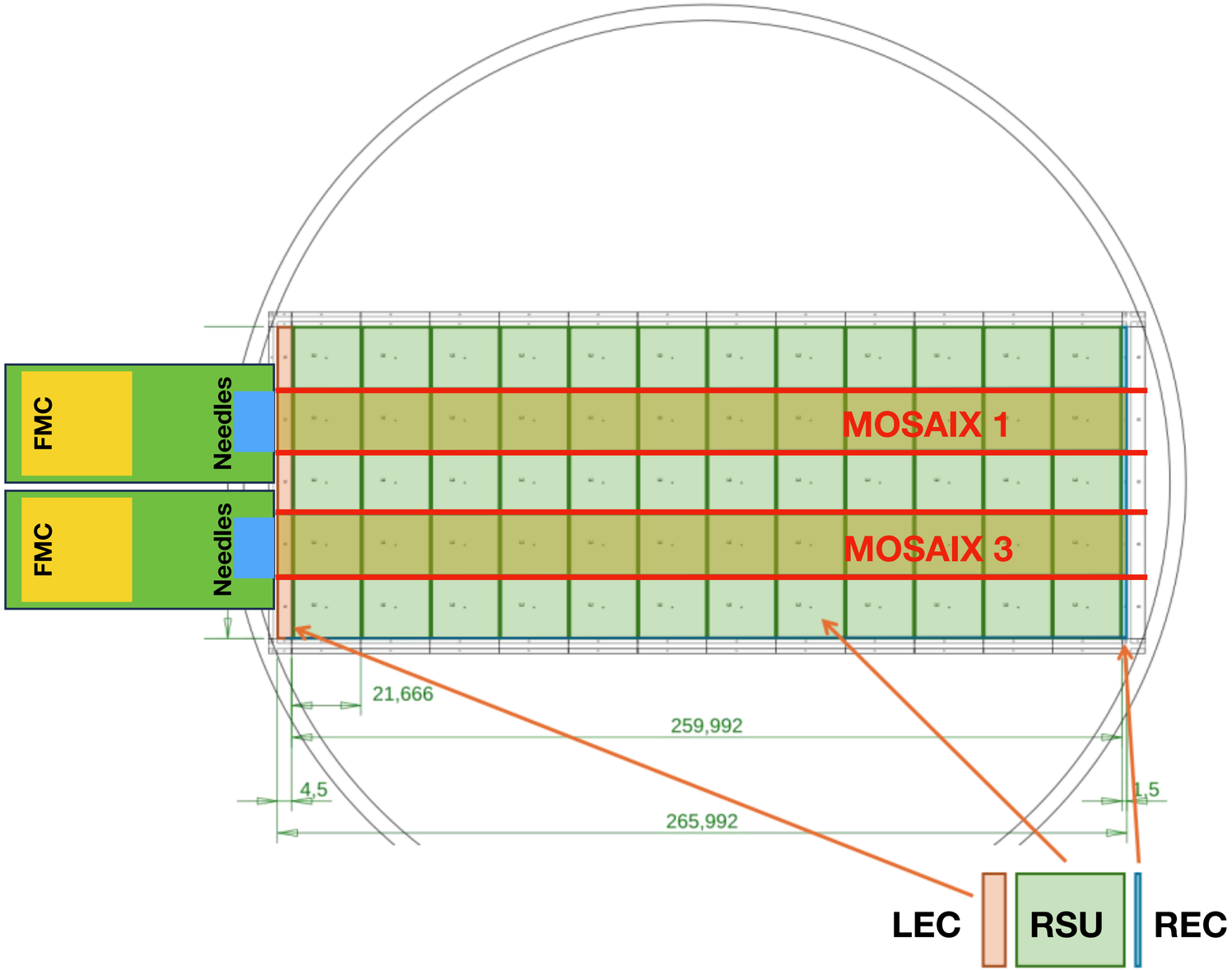

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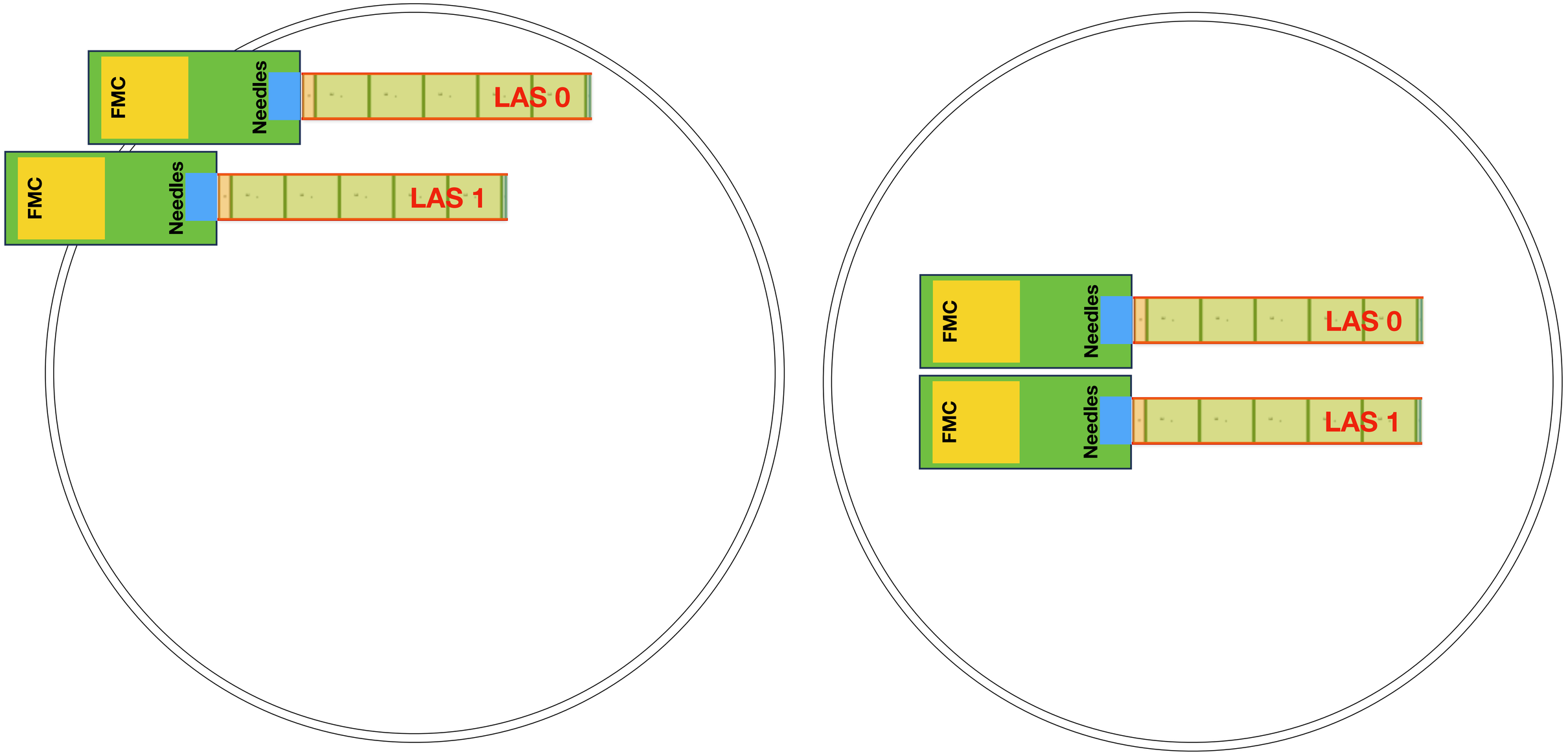


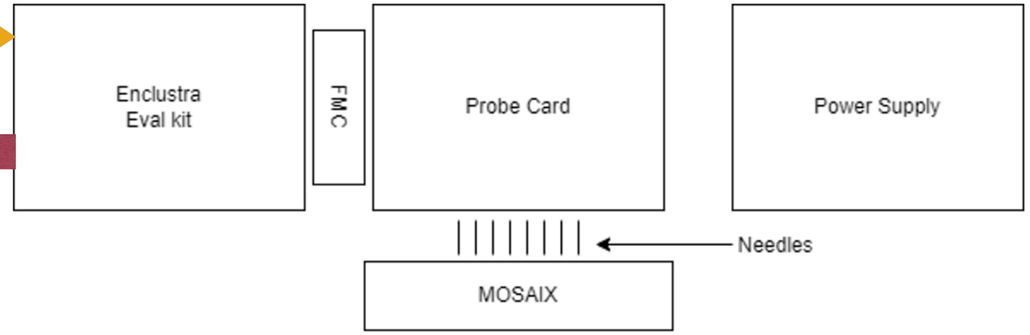
LEC Probe Card – Setup

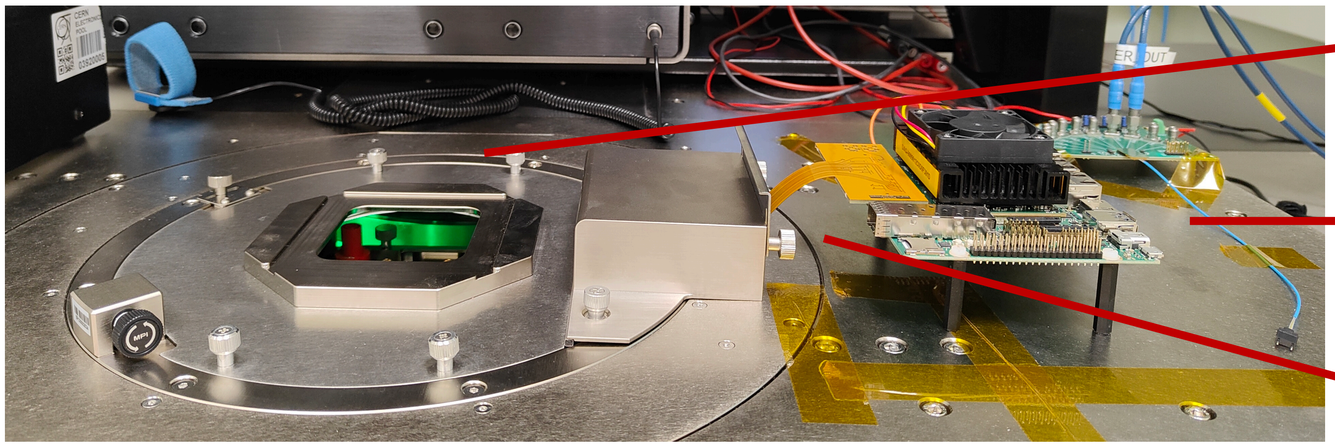
1x FPGA for each MOSAIX-LAS

Will require the addition of a FPC
to connect the Probe Card to the FMC / Enclustra

Configurations and control commands

Data and monitoring information





Probe Cards

Enclustra

FPC

WAFER PROBER UPGRADES

Wafer Prober Upgrade – Sensor Studies

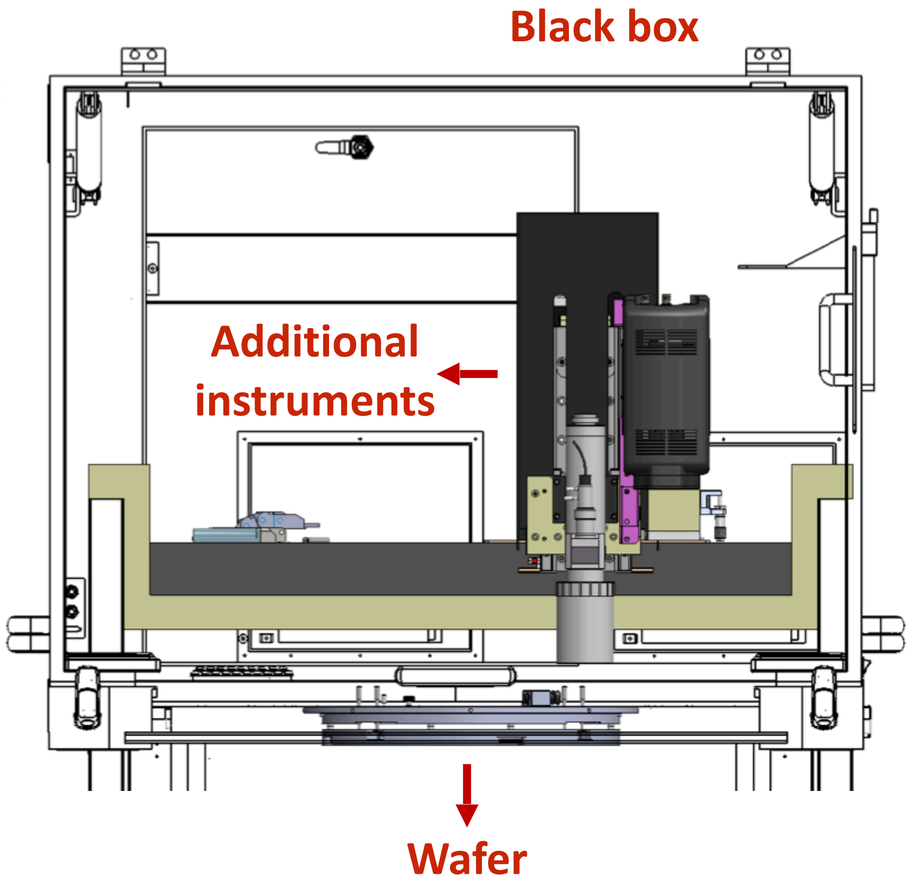
While the **electrical tests** are critical to **verify the ASIC operation**,
It **will** possible to **study also the sensor characteristics** on-wafer by expanding the setup instrumentation

An upgrade of the machine has been planned with MPI (spring 2026): a mechanical holder will be added on the wafer aperture on which it will be possible to mount additional instruments on a x,y stage:

- Laser Source
- Radiation Source
- Thermal Camera

A box will be added to enclose the entire testing instrumentation

Exploiting the Laser Source and possibly the Radiation Source,
It may be possible to characterize the sensor charge collection directly on-wafer!

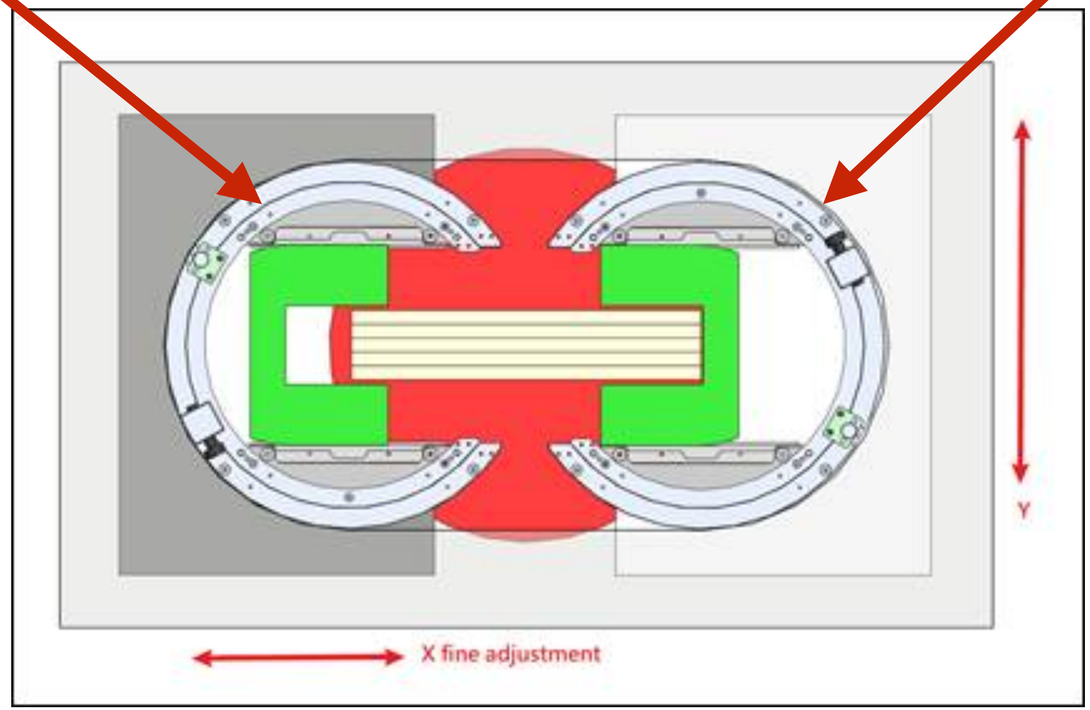


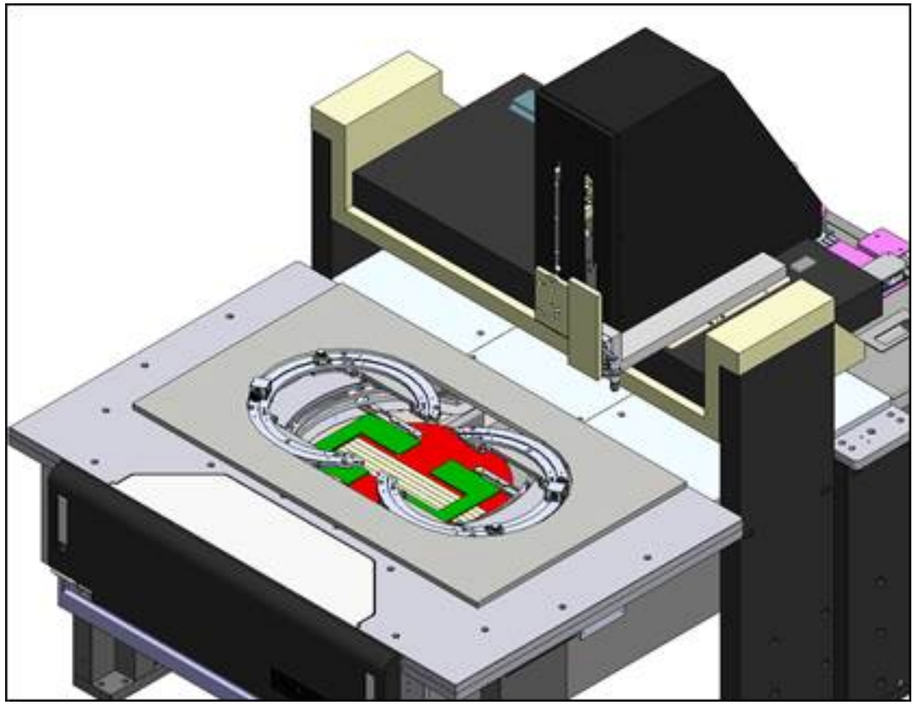
Wafer Prober Upgrade – Double Probe Cards

While LEC is enough to operate MOSAIX/LAS, **complete testing can be achieved only by powering both LEC and REC**
Two separate probe card holders can be hosted on the machine allowing to use two separate probe card technology
Since REC does not host Gbps data links, it could be equipped with a cheaper cantilever probe card

LEC probe card

REC probe card





Wafer Prober Upgrades

Black Box

Additional instruments:
Laser Source
Radiation Source
Thermal Camera

Double
Probe Cards

Additional Enclustra
for parallel testing of
MOSAIX/LAS

SOFTWARE AUTOMATION UPGRADES

Software Upgrades – Commands and Sequences

ListAvailableCommands:

- MoveChuckXY
- MoveChuckZ
- **RunPTPA**
- StepNextDie
- **GoToDie**
- **OpenProject**
- FindHome
- SwitchCamera
- MoveChuckHome
- Unload
- Cleaning
- **AlignWafer**
- **GoToContact**
- GoToSeparation
- AutoFocus
- Load
- **MoveChuckToWorkArea**
- LocalMode
- GoToPreviousDie
- **Initialize**
- ShowProjectStatus
- GetInfo
- help
- RunSequencer
- ListProbers
- ListChipTypes
- ResetAgent
- GetAgentState

The user can connect to the machine and contact the wafer without specific knowledge of the Prober commands and Software

While for the moment the Software had been developed to be tested on MPI WP
It will be extended for compatibility with other machines in the collaboration

Initialize
The user remotely connects to the wafer prober on which the test should be performed

OpenProject
The user specifies the wafer, chip and probe card to be used, the Software selects the Project file

AlignWafer
The machine aligns the wafer with its references

GoToDie
The machines moves to the chip location to be tested

RunPTPA
The machine runs a fine-tuning of the alignment locally on the die under test

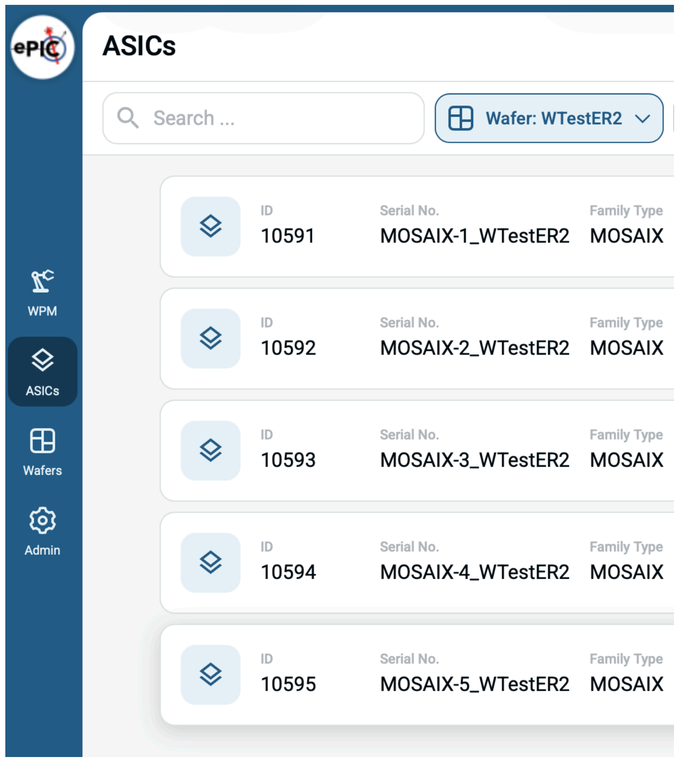
MoveChuckToWorkArea
The machine moves to the correct working location to contact the die

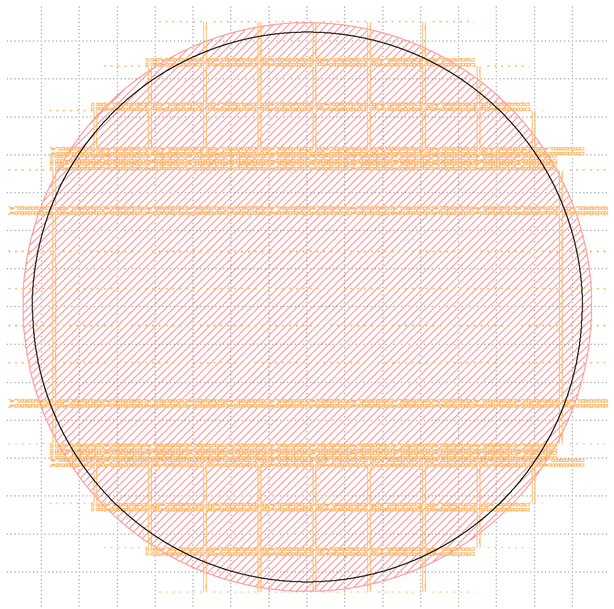
GoToContact
The machine applies contact between the probe card and the chip under test

Sequence

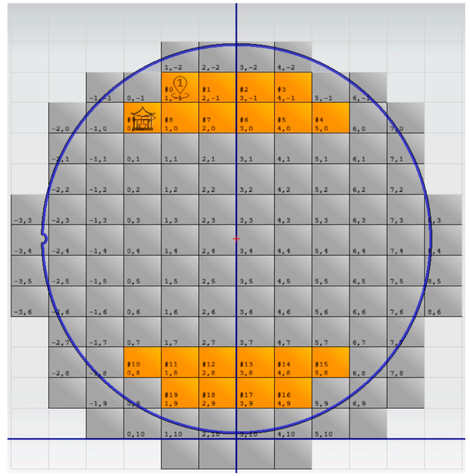
Software Upgrades – Global to Local Maps

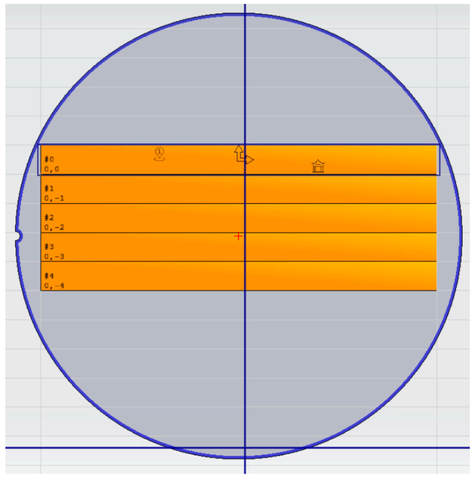
While the **Wafer Map is unique and contains all different chips**/dies
the **wafer prober works with different maps and project files for each different die**/chip





Global Map





Local Maps

The UI displays a list of chips based on the Database information on the wafer selected,
When the user selects a die, the Software will:
open the appropriate project, move to the correct die position and contact the wafer

Summary

- The technology to achieve 10.24 Gbps wafer probing has been extensively exercised with NKF7
- **A modular probe card for MOSAIX/LAS is being finalized and it will be produced in January 2026**
  allowing **multipoint on-wafer probing for different reticle geometries** using only one probe card design
- The **wafer prober at CERN will be upgraded** to extended testing automation capabilities,
  and to **enable characterizing the sensor properties on-wafer**
- The **wafer prober Software has been expanded integrating all core functionalities** needed to operate the machine
  Work is in progress to finalize Global-Local Maps integration and pre-defined sequences of operations
  This software developed and tested for MPI will be expanded to be compatible with Form Factor instruments

Thank You!

We are looking forward to characterize MOSAIX and LAS at 10Gbps in the coming months!