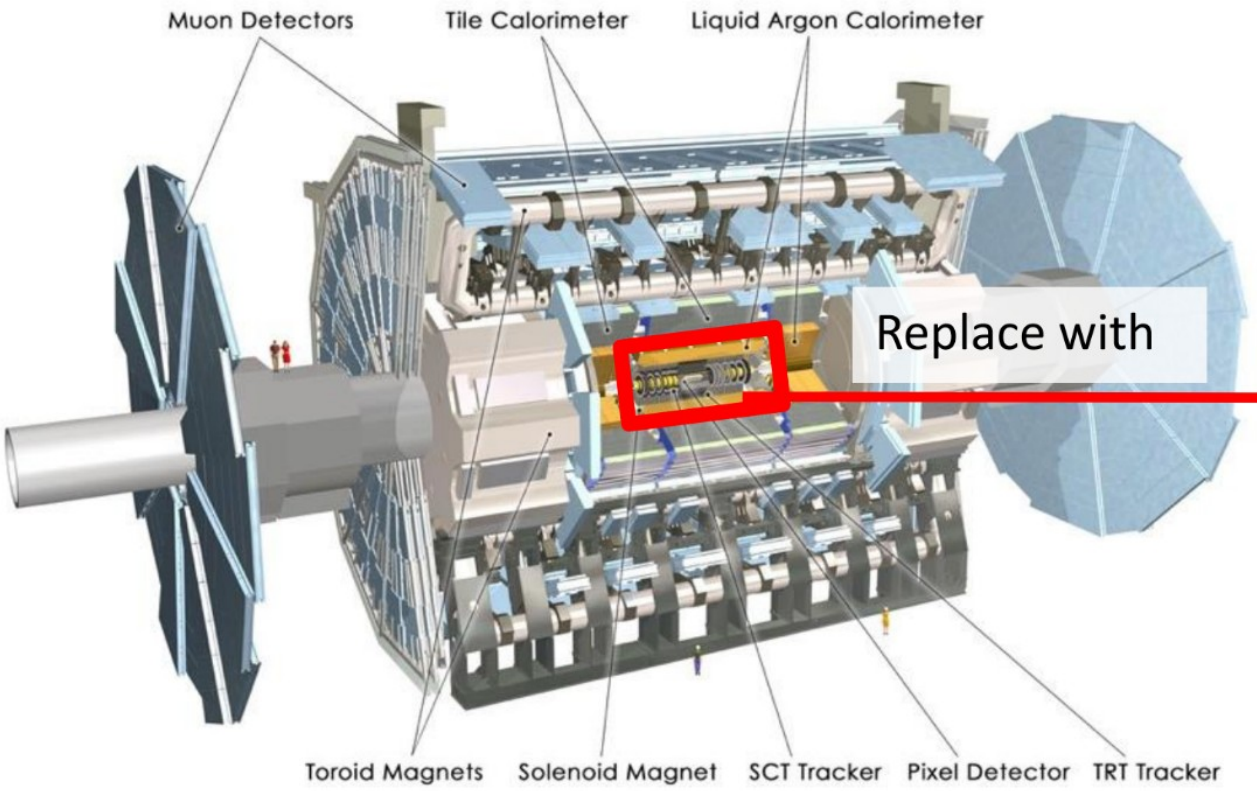
How do you build a detector

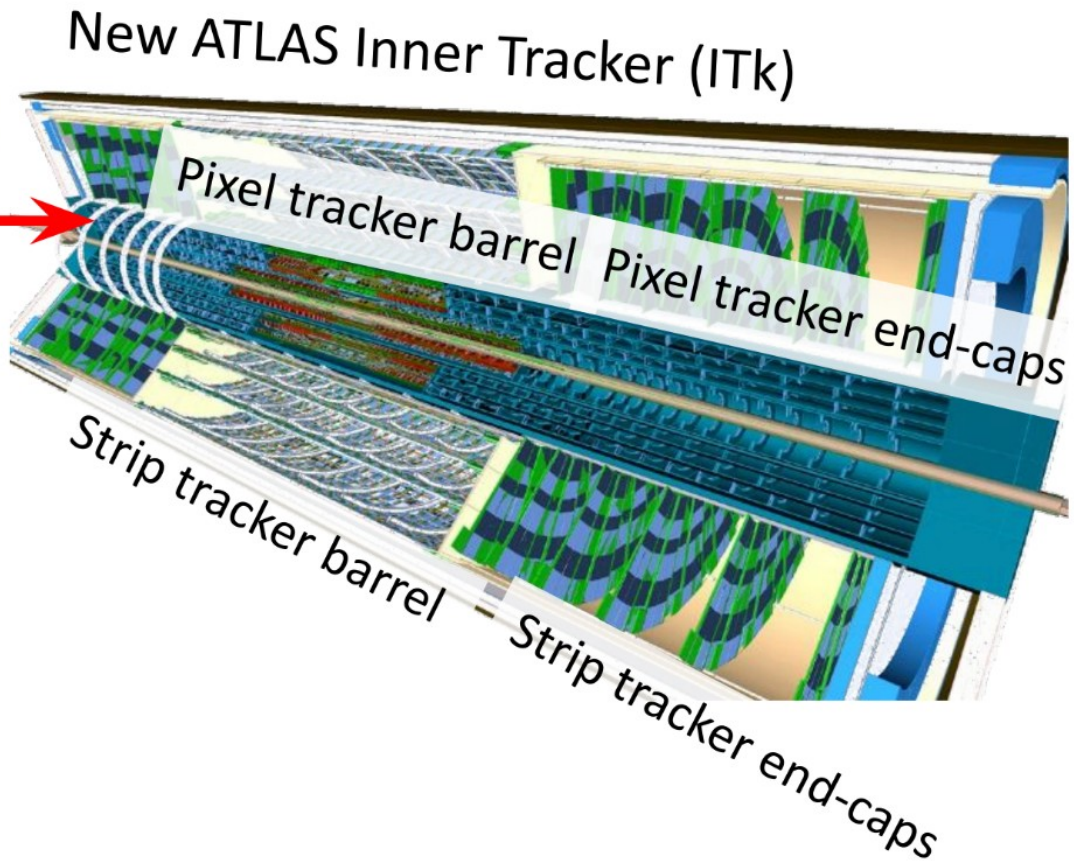
Module building for the ITk

Elizaveta Sitnikova
10.10.2023

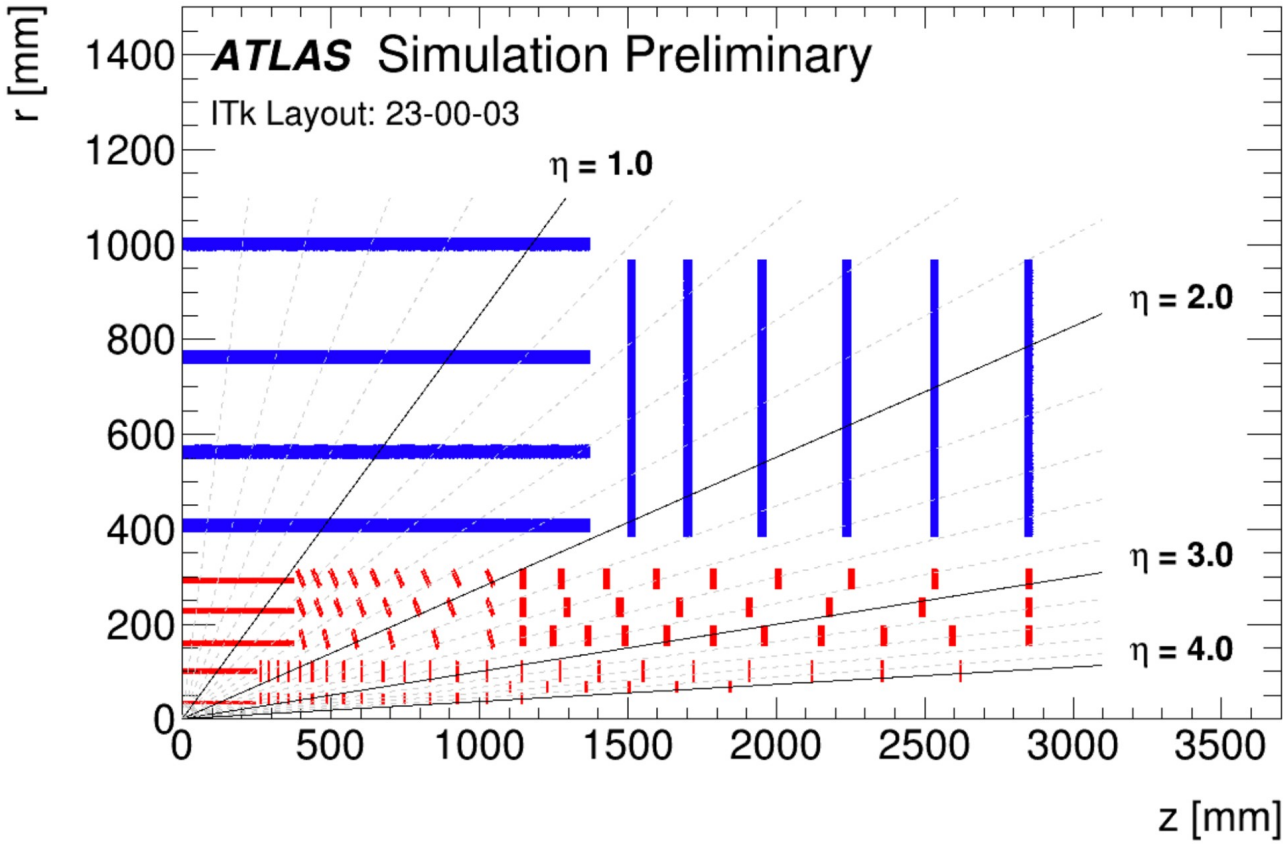
ITk



Replace with



ITk


ATLAS Simulation Preliminary
ITk Layout: 23-00-03
η = 1.0
η = 2.0
η = 3.0
η = 4.0
r [mm]
z [mm]
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200
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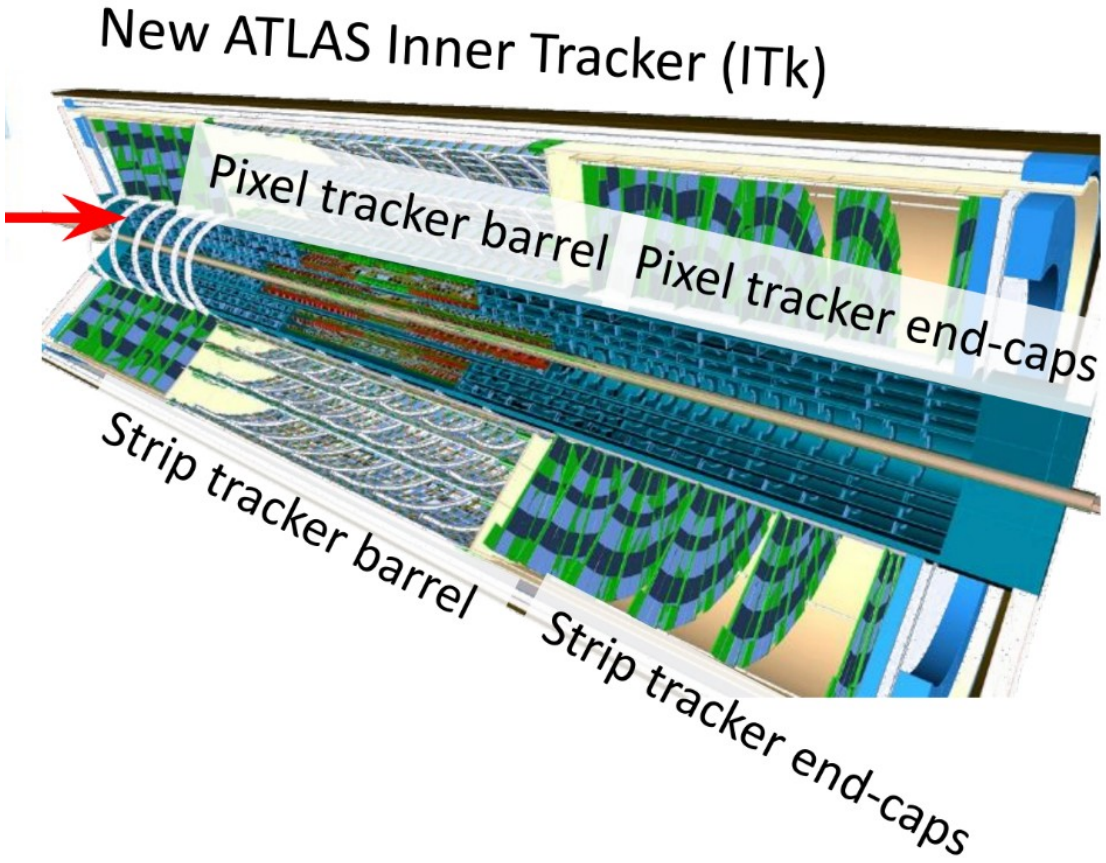
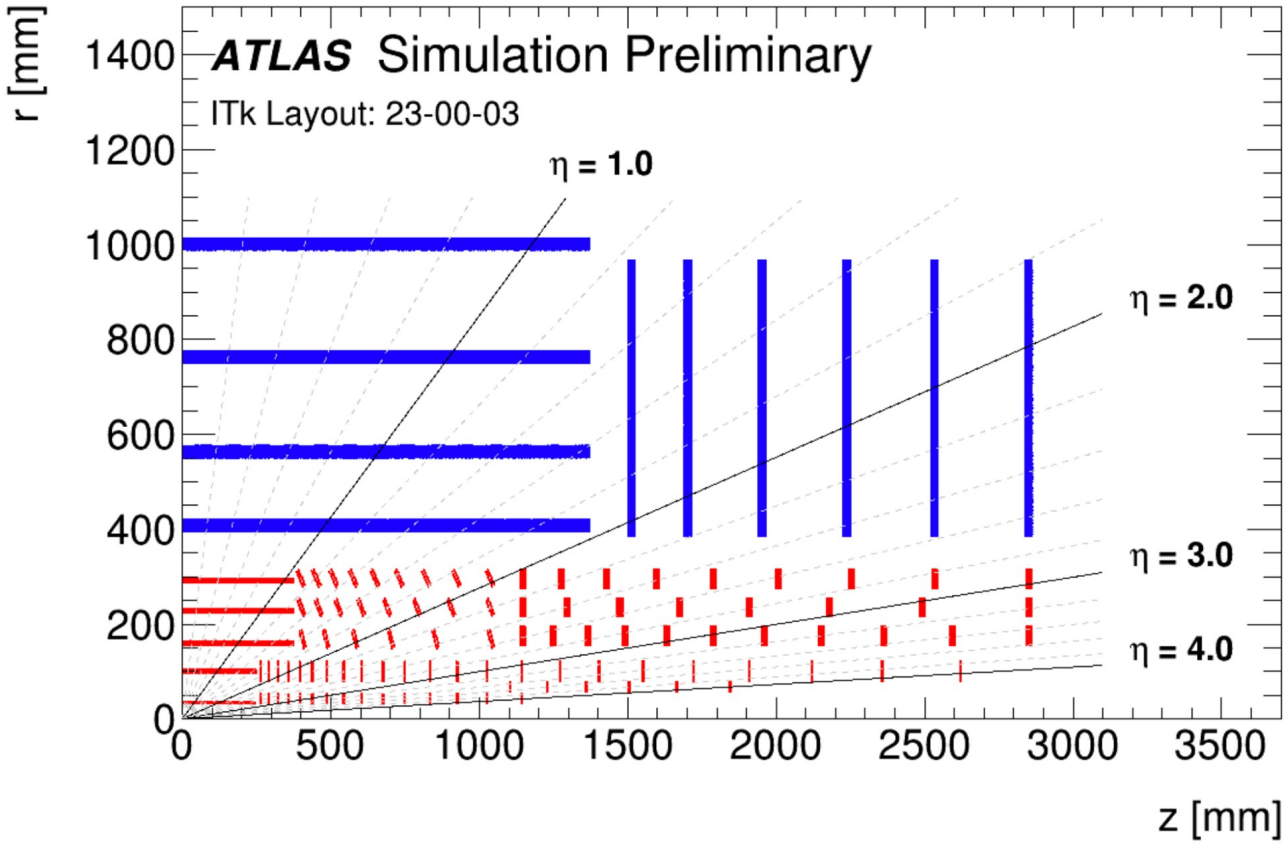

New ATLAS Inner Tracker (ITk)
Pixel tracker barrel
Pixel tracker end-caps
Strip tracker barrel
Strip tracker end-caps

ITk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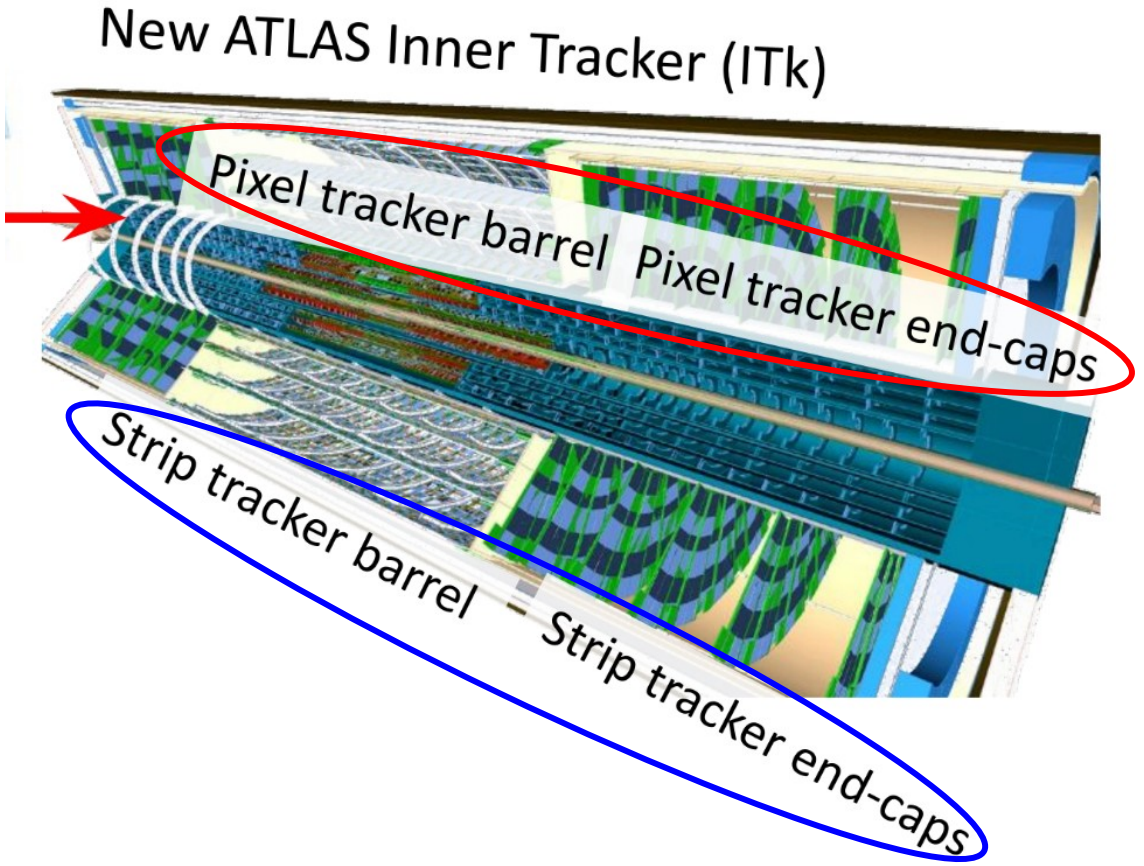
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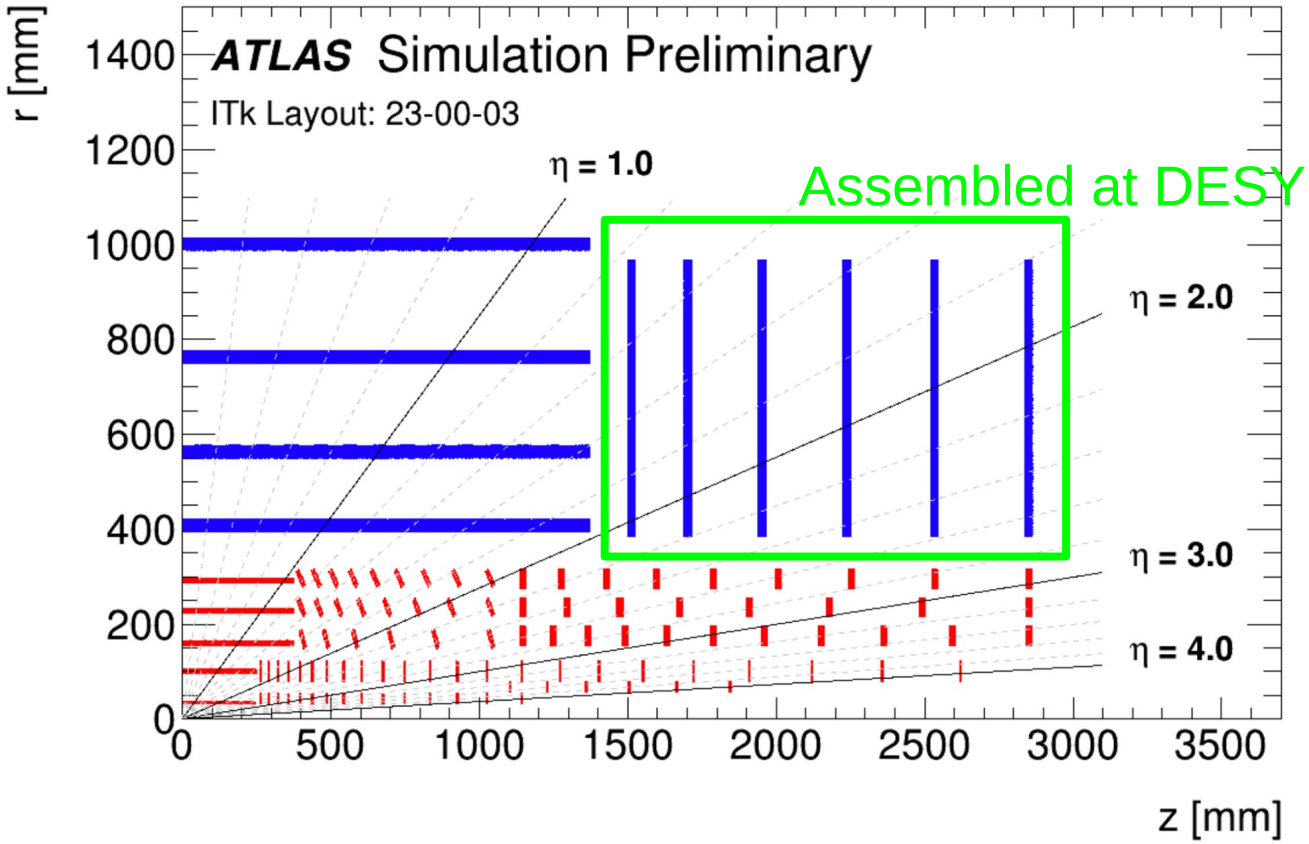
ATLAS Simulation Preliminary
ITk Layout: 23-00-03
η = 1.0
η = 2.0
η = 3.0
η = 4.0
Assembled at DESY
r [mm]
z [mm]
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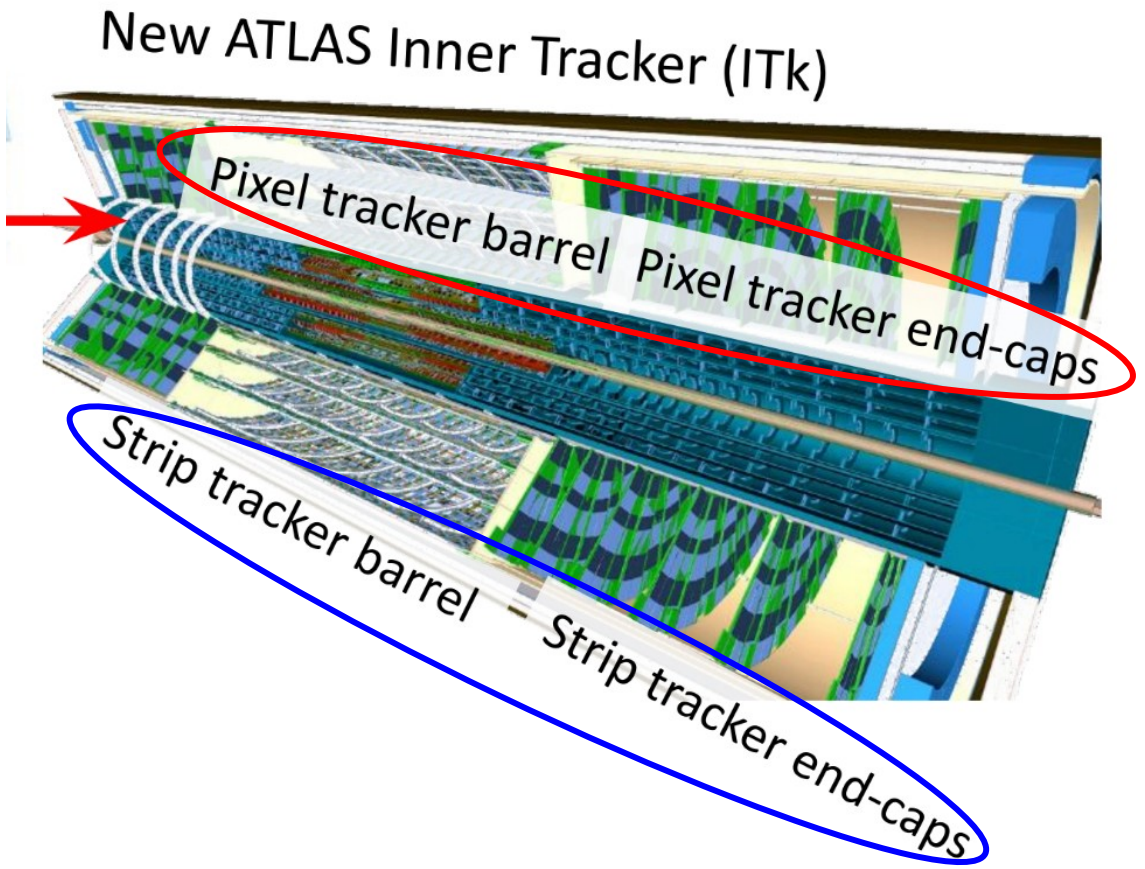
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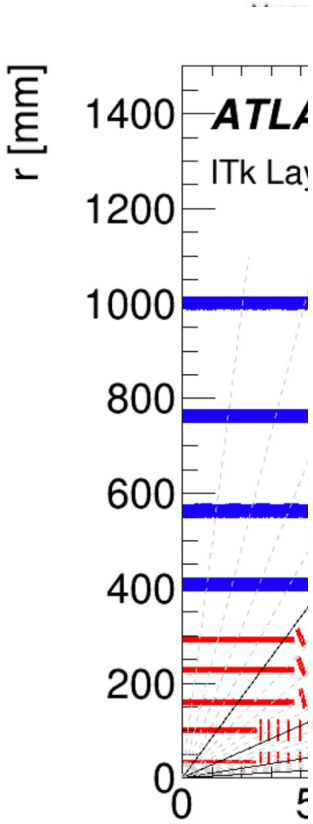
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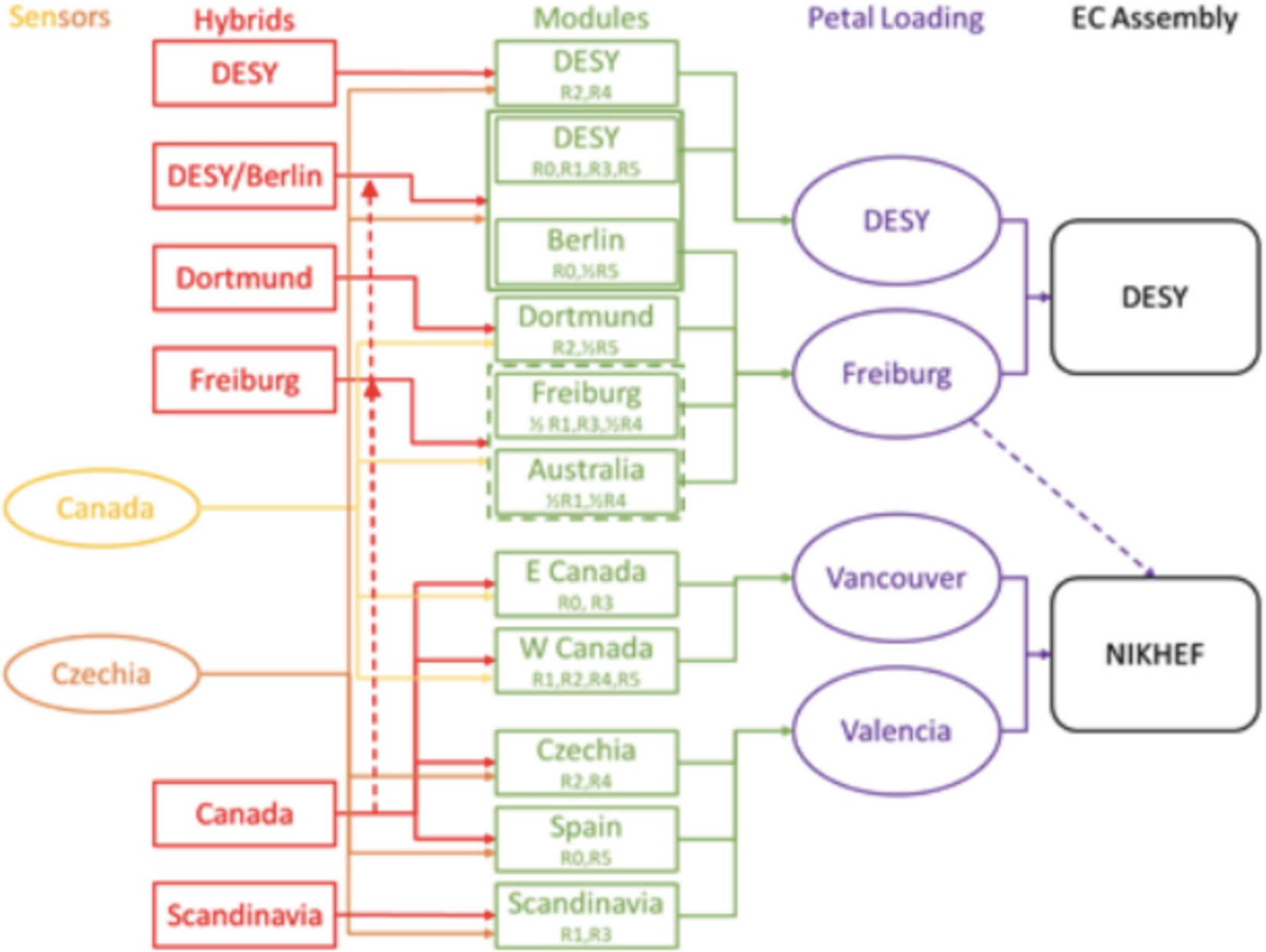
ATLA
ITk Lay


Sensors
Hybrids
Modules
Petal Loading
EC Assembly
DESY
DESY/Berlin
Dortmund
Freiburg
Canada
Czechia
Canada
Scandinavia
DESY
R2,R4
DESY
R0,R1,R3,R5
Berlin
R0,½R5
Dortmund
R2,½R5
Freiburg
½ R1,R3,½R4
Australia
½R1,½R4
E Canada
R0, R3
W Canada
R1,R2,R4,R5
Czechia
R2,R4
Spain
R0,R5
Scandinavia
R1,R3
DESY
Freiburg
Vancouver
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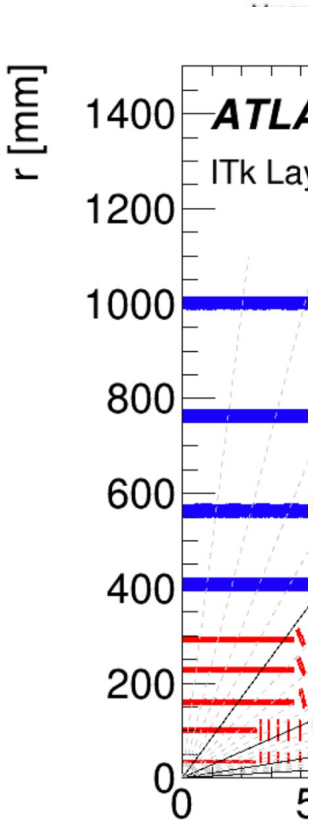
DESY
NIKHEF

er (ITk)


ixel tracker end-caps
racker end-caps

ITk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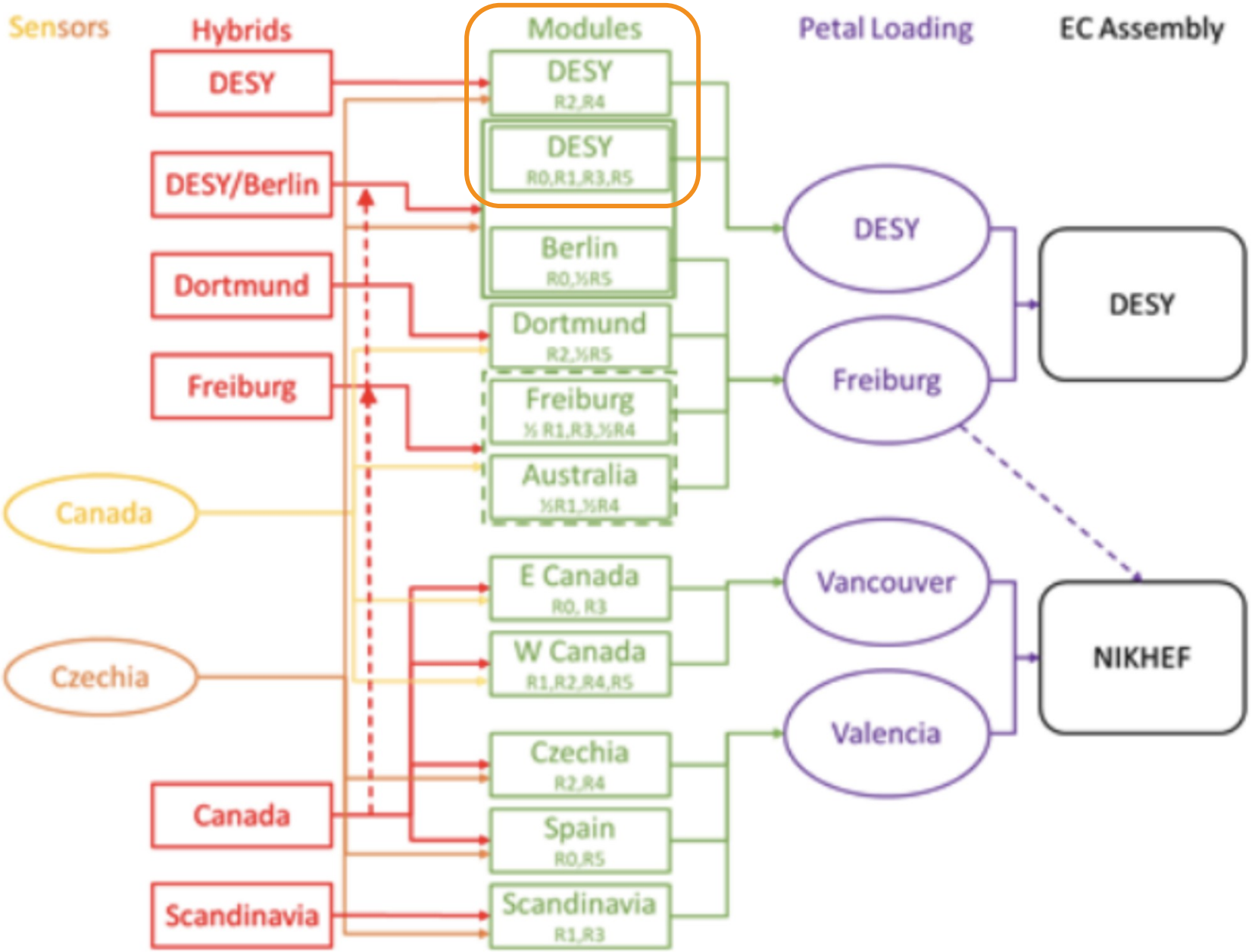
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DESY
NIKHEF

er (ITk)


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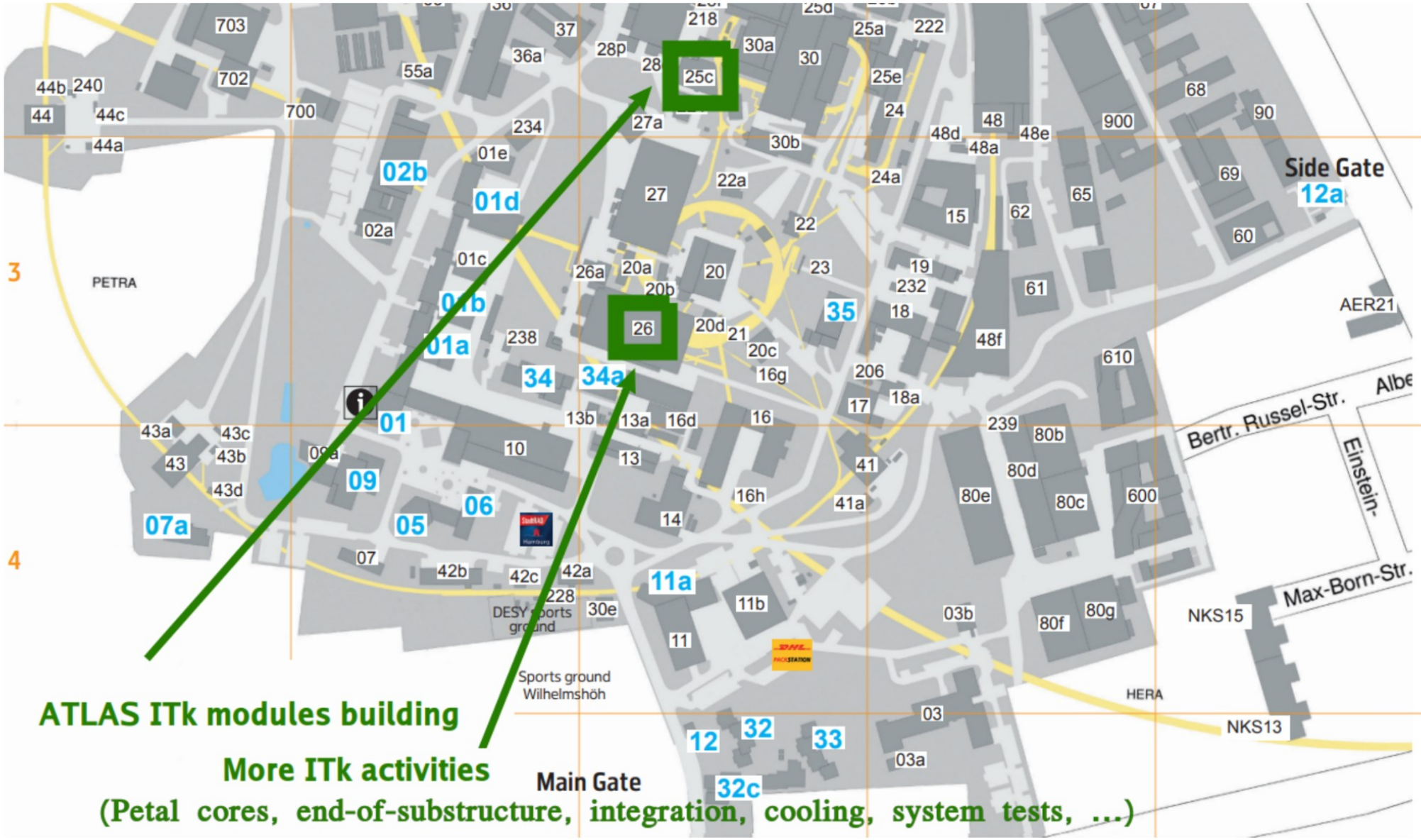
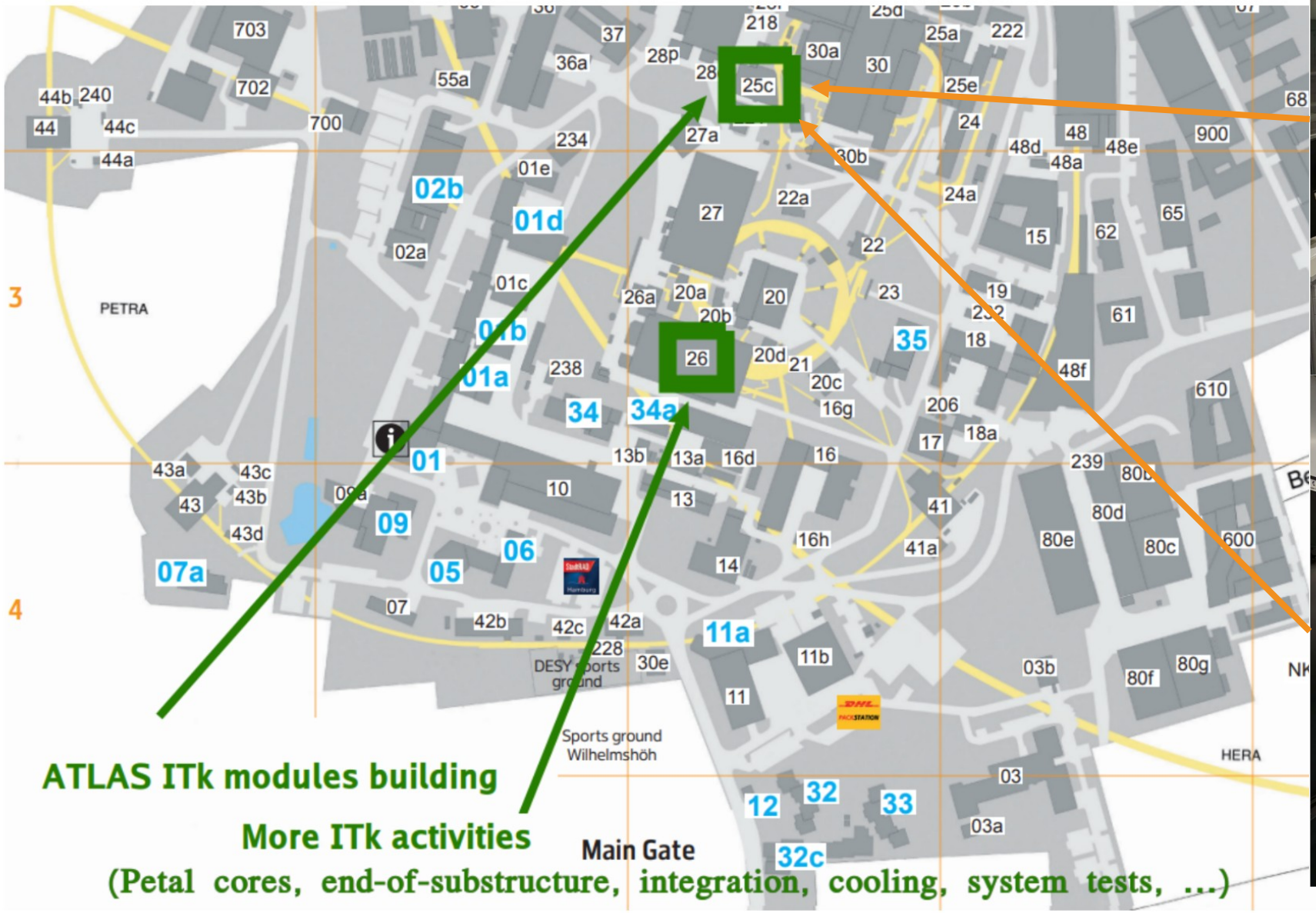
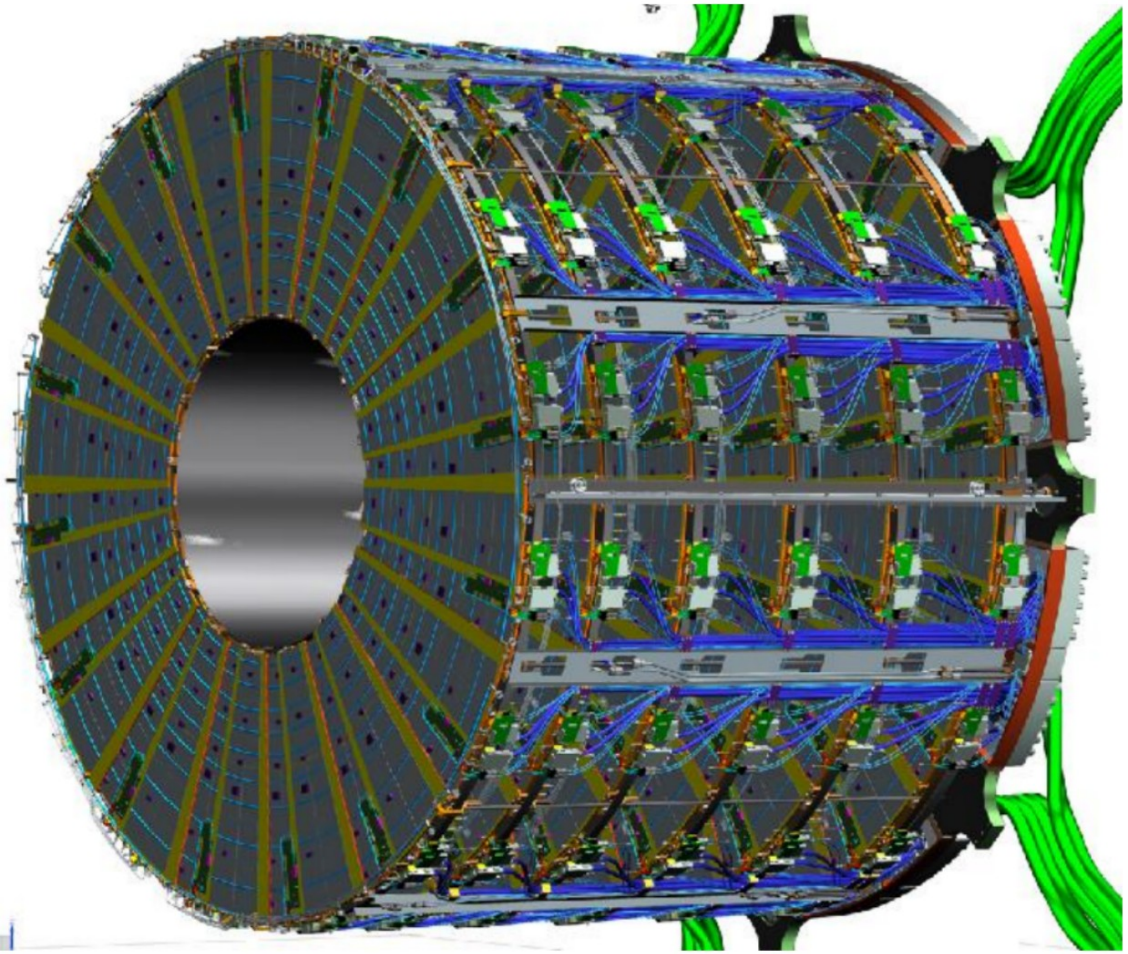
DESY facilities



DESY facilities



What exactly are we building?



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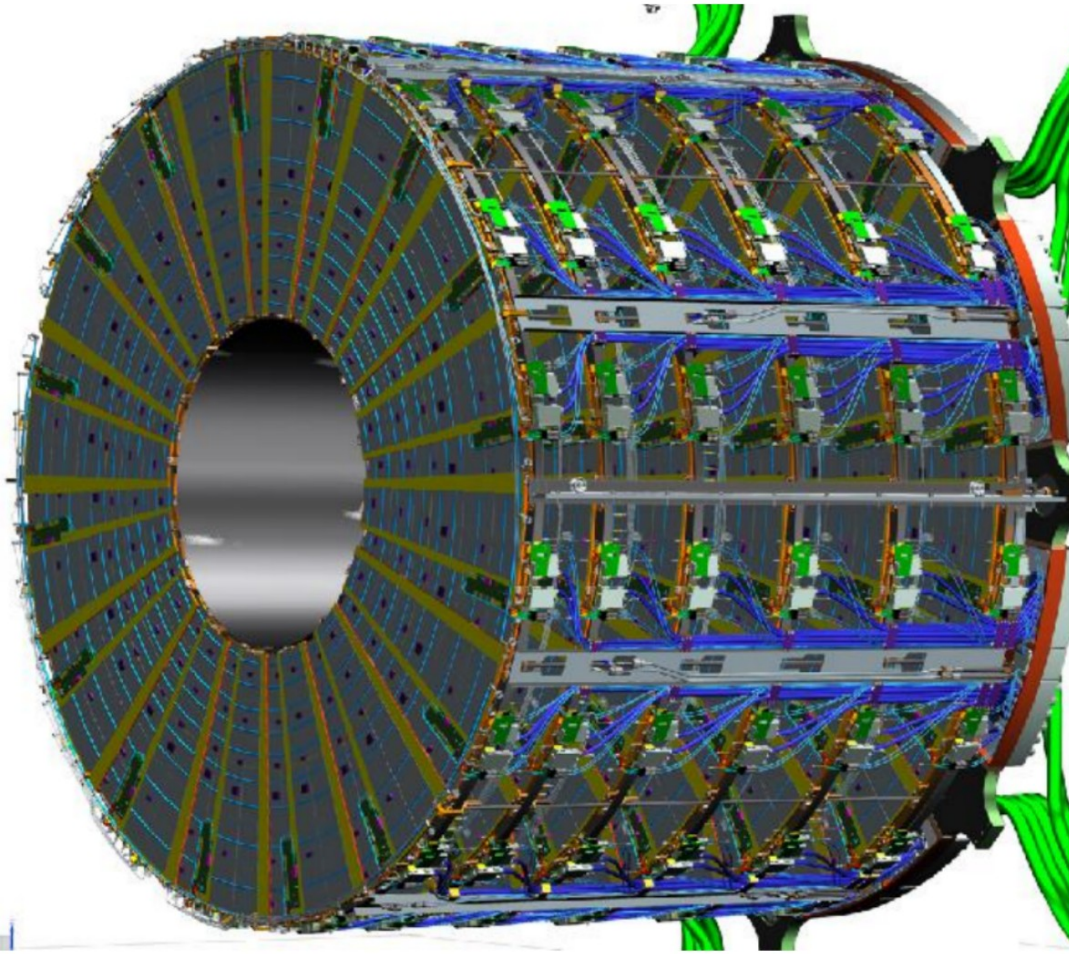

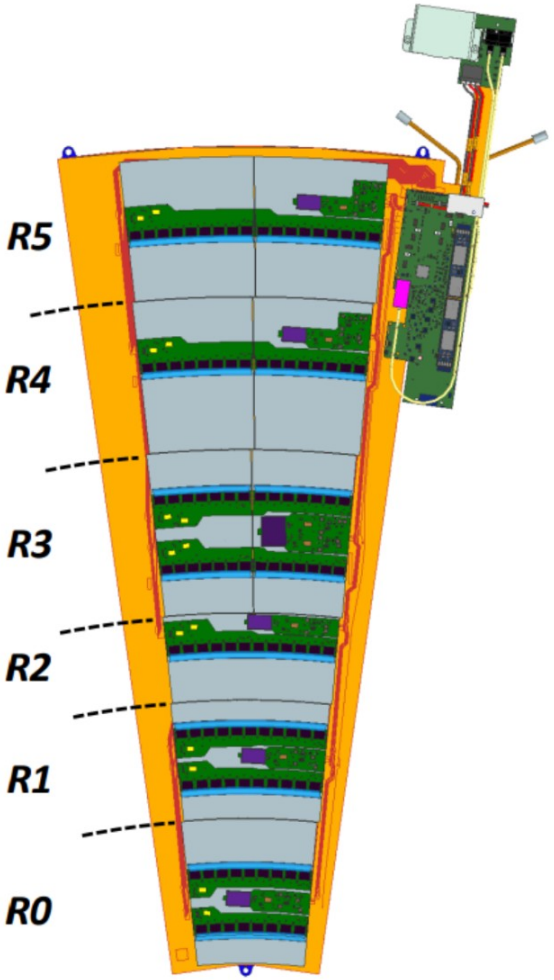

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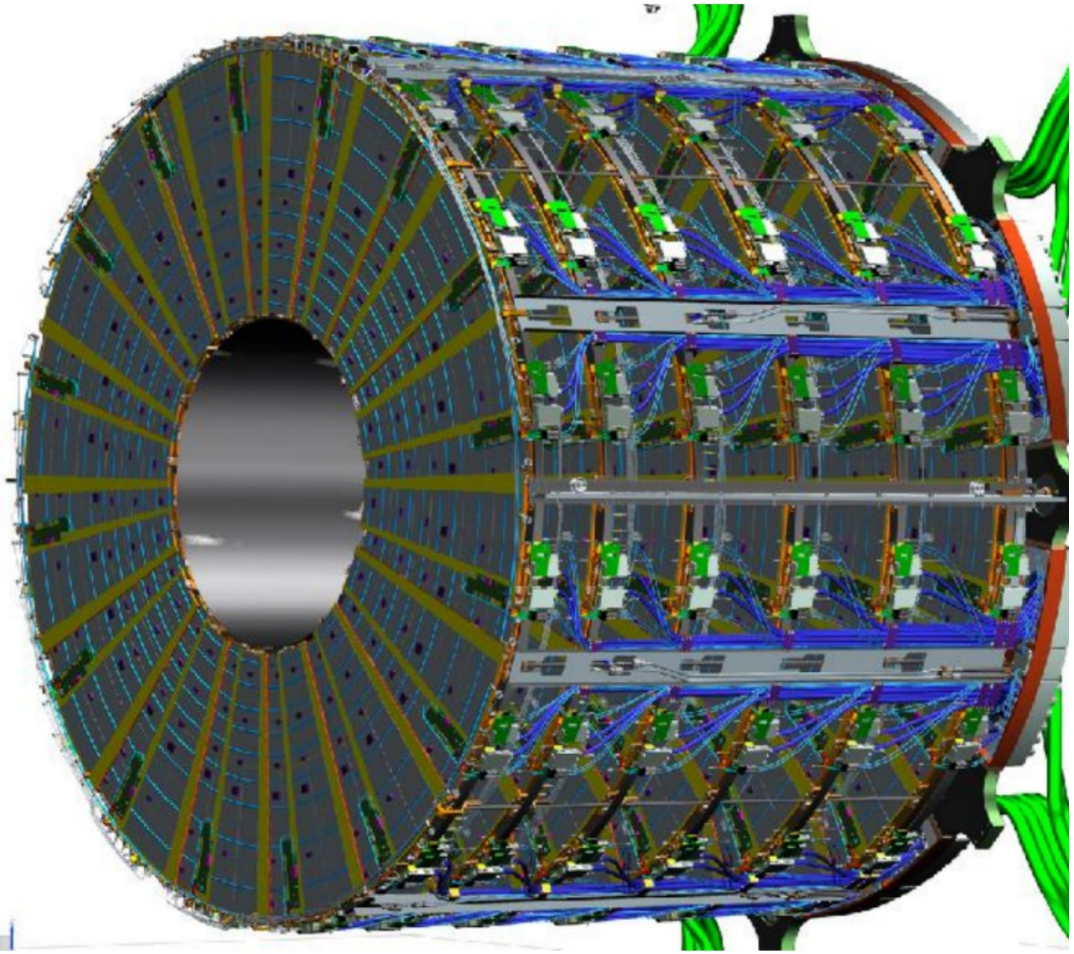
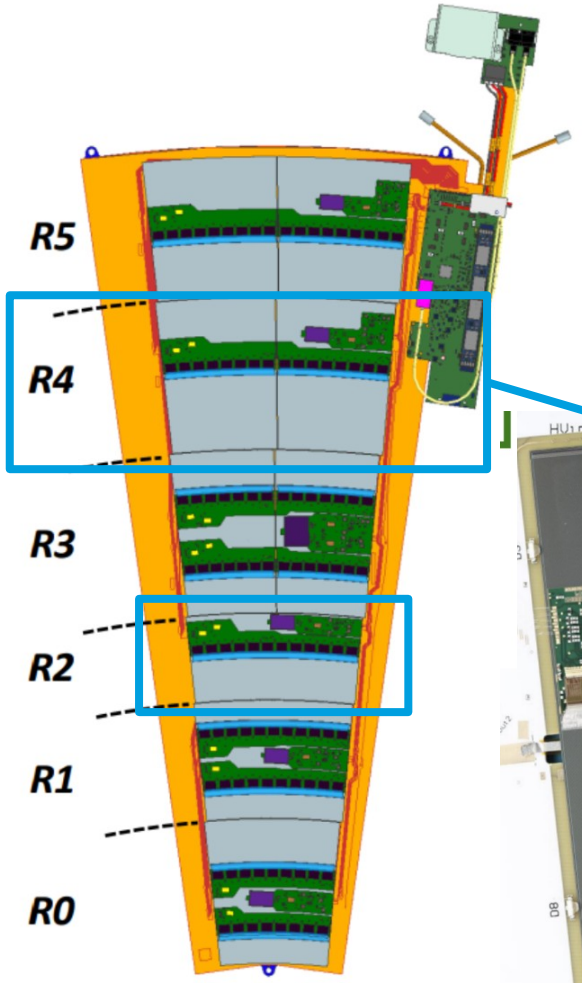
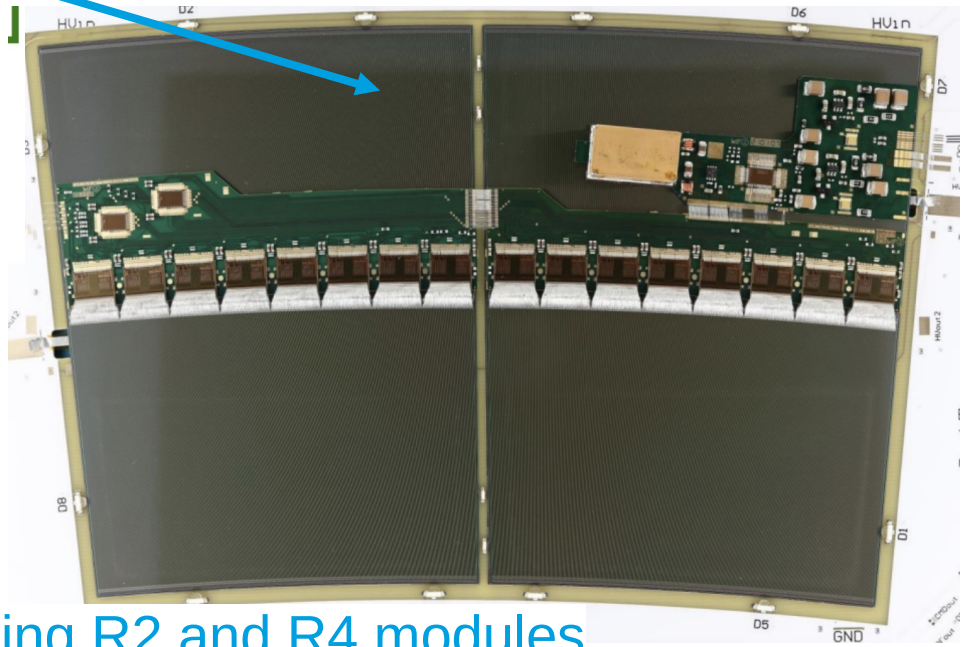
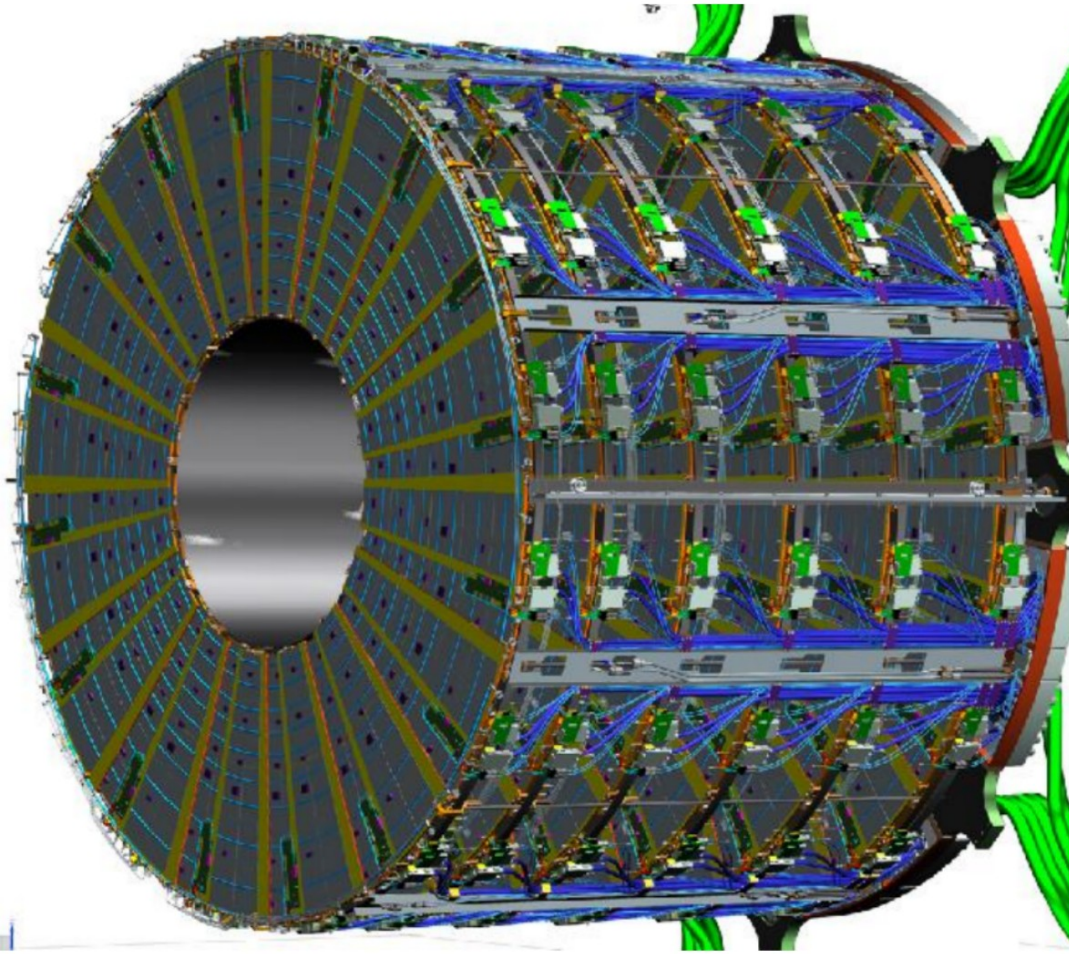


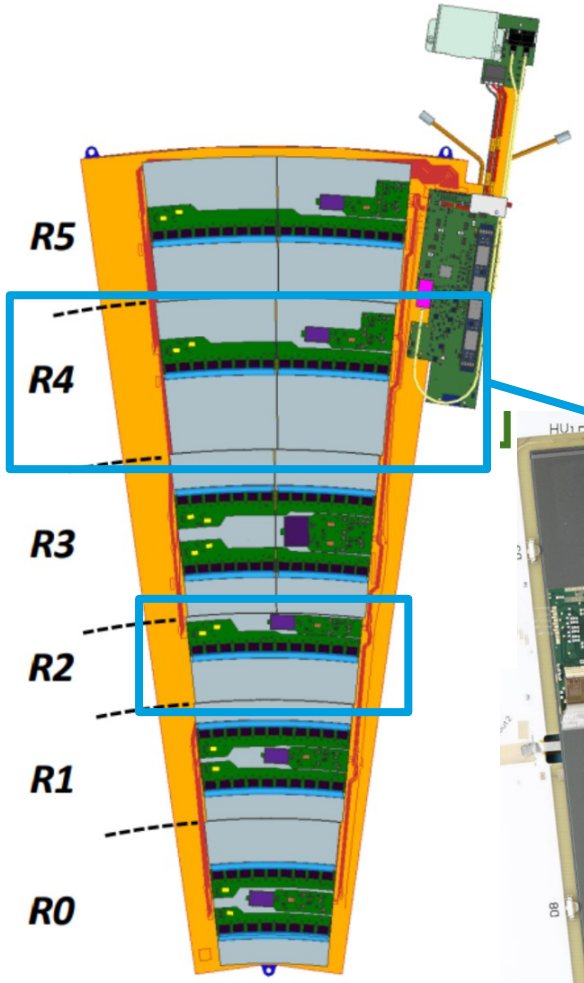


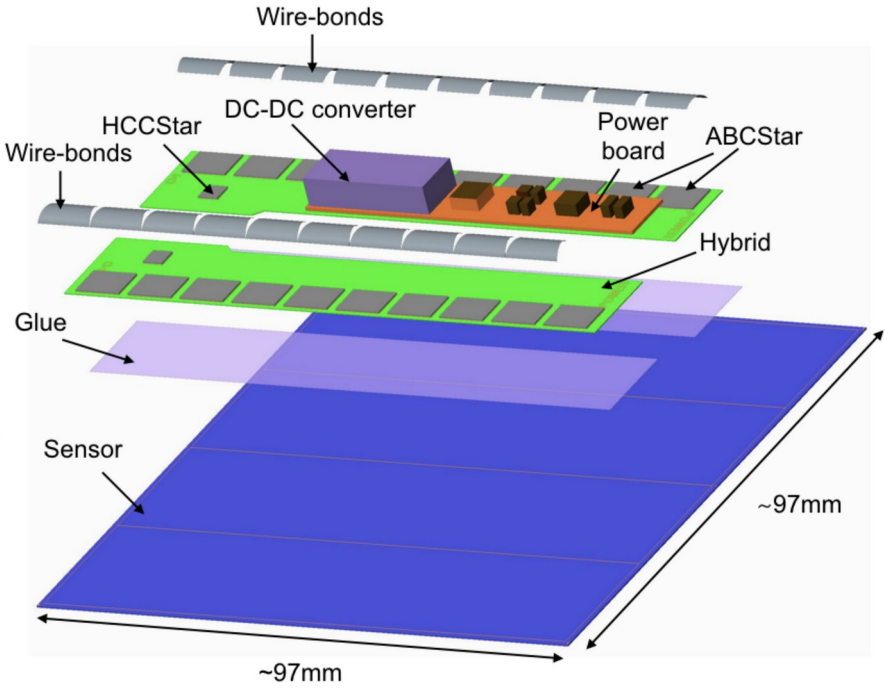


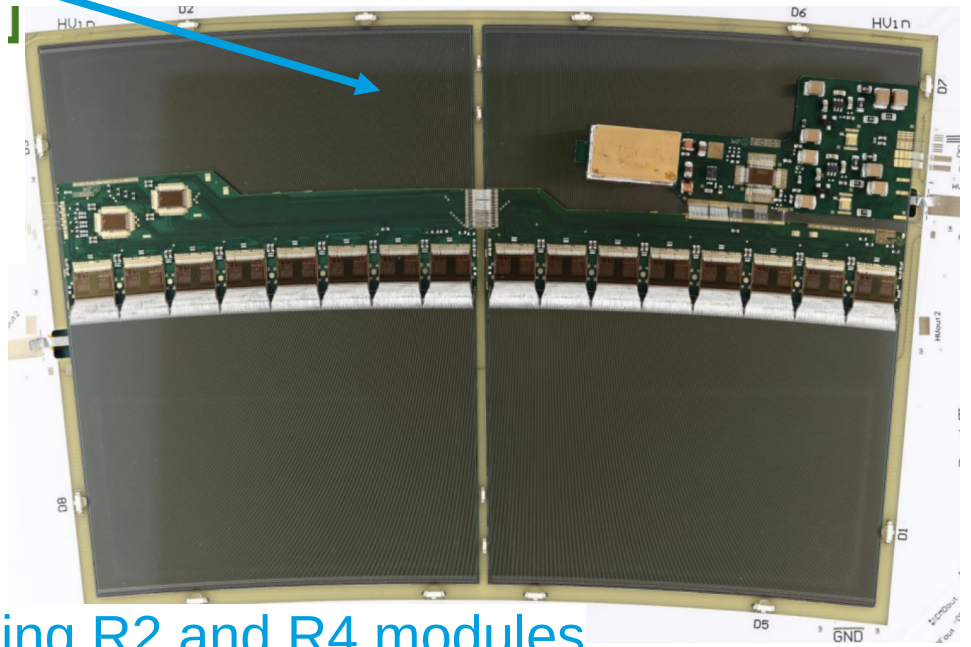
in **DESY-Hamburg** we are assembling R2 and R4 modules

What exactly are we building?





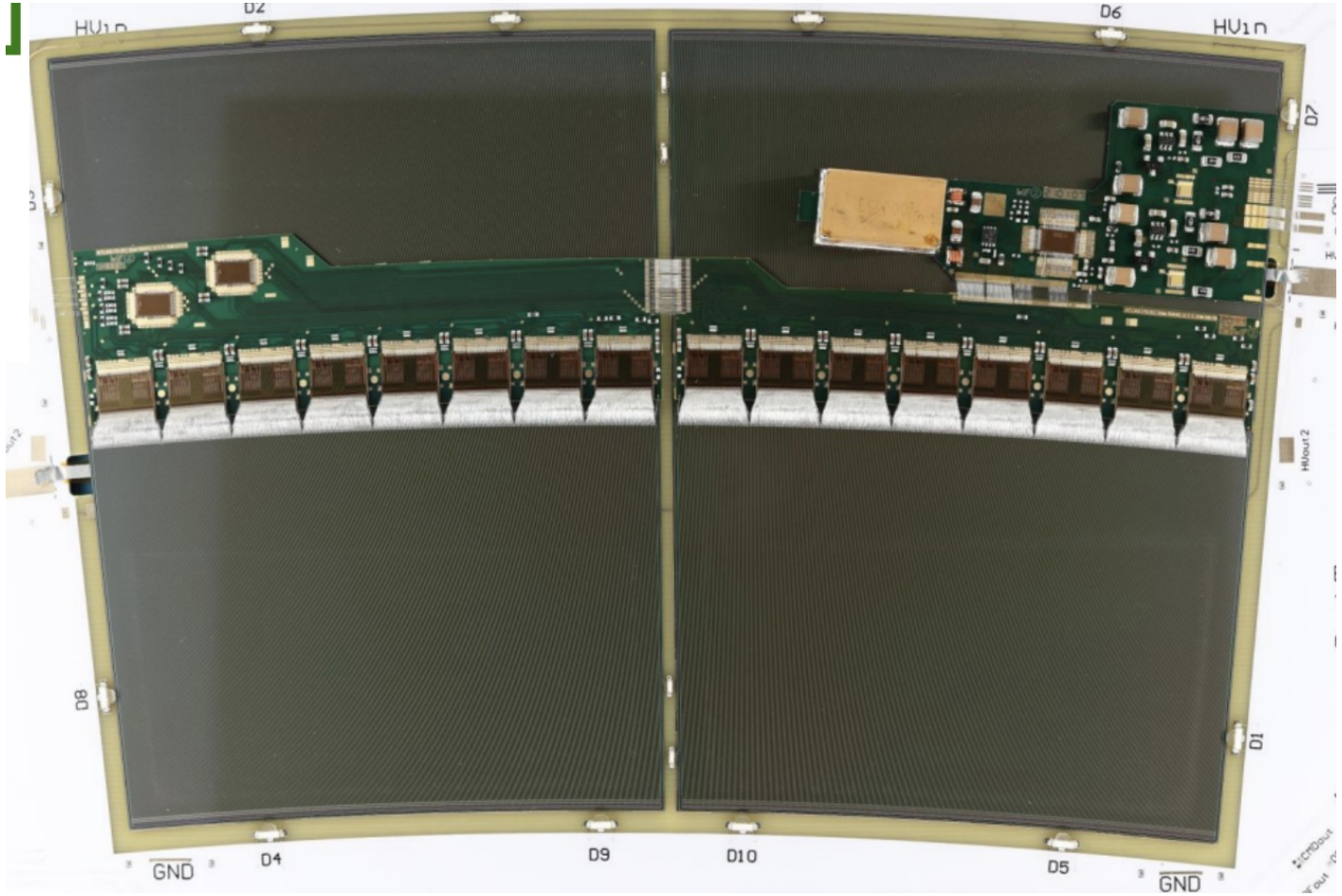


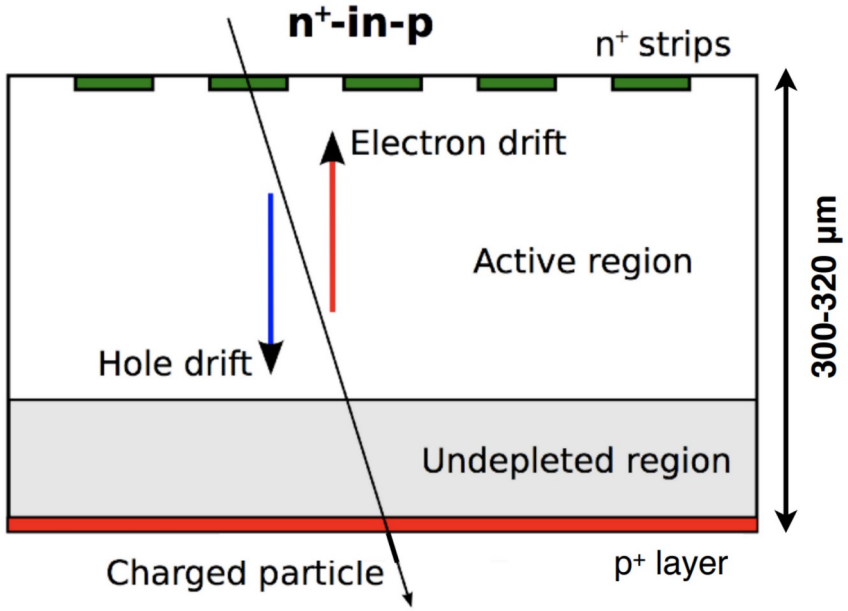


in **DESY-Hamburg** we are assembling R2 and R4 modules

Let’s look at a module closer

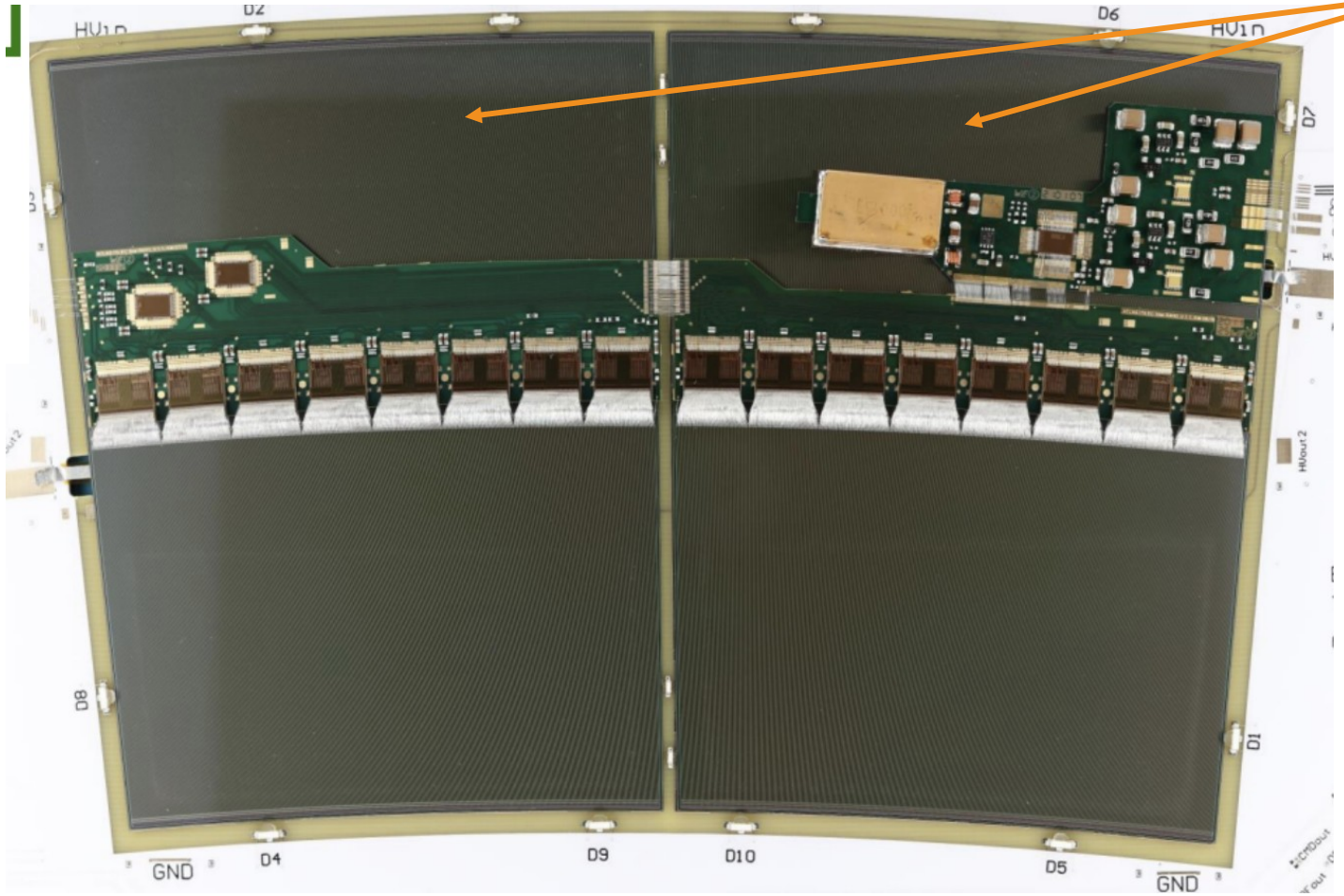
Using R4 as an example



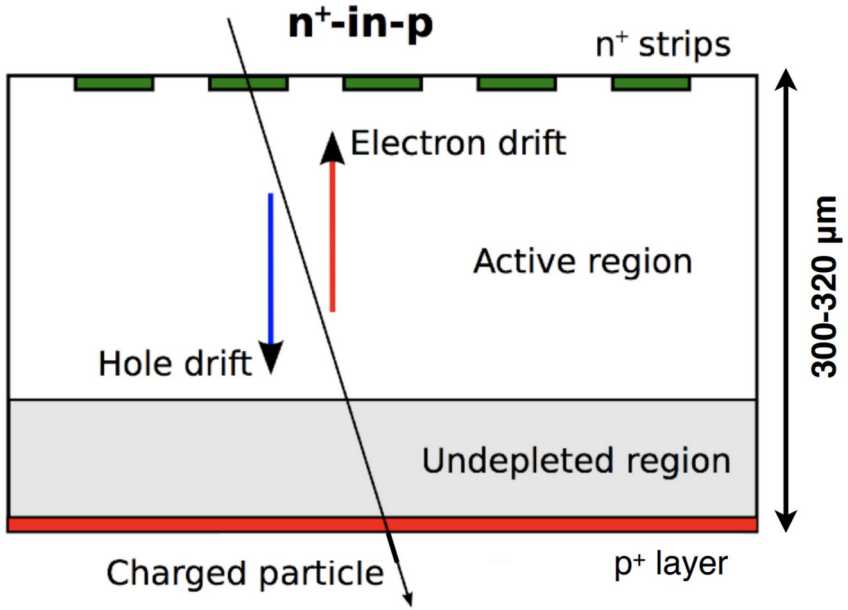


Let’s look at a module closer

Using R4 as an example

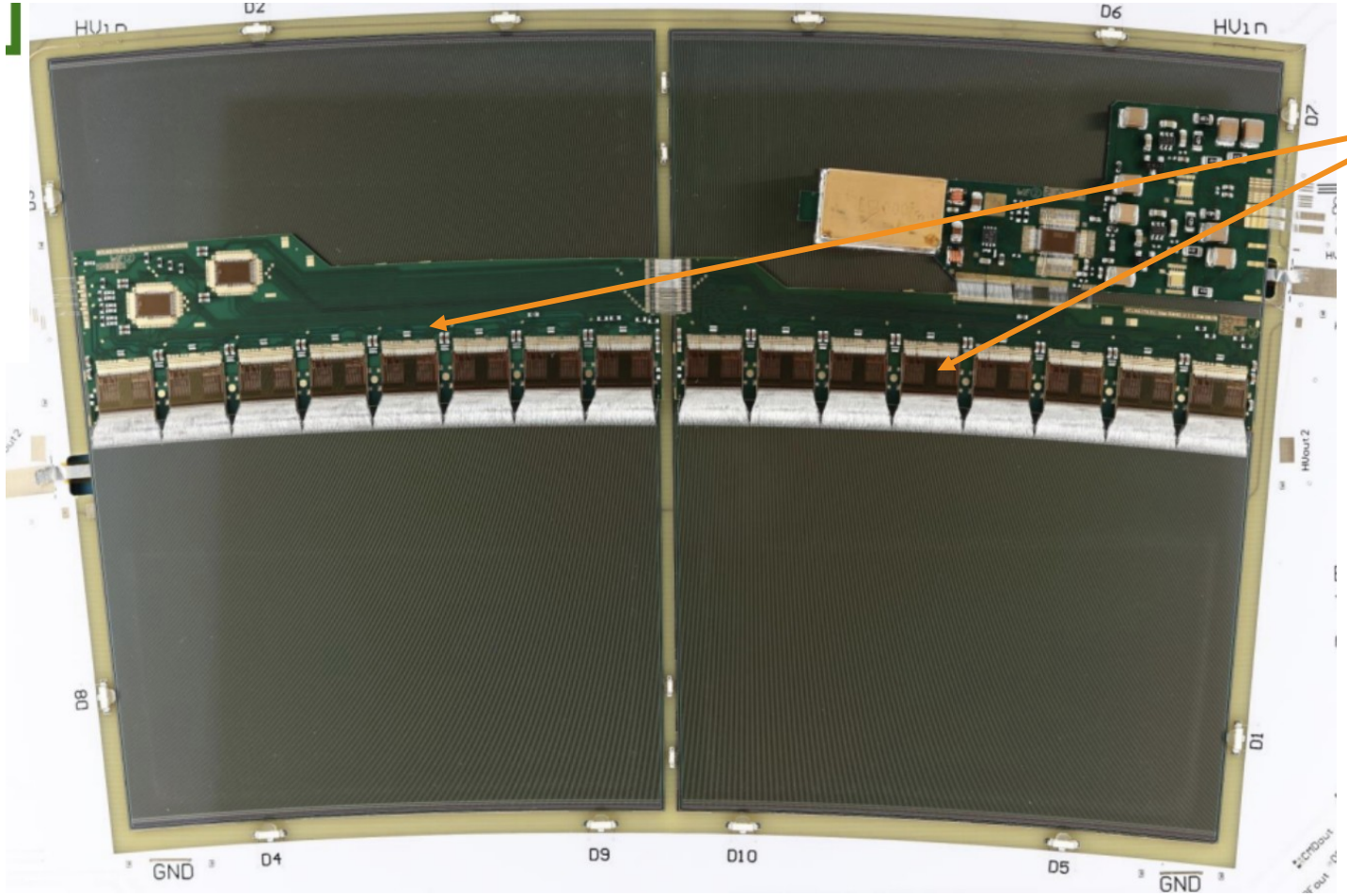


silicon strip sensors - medium for particle detection



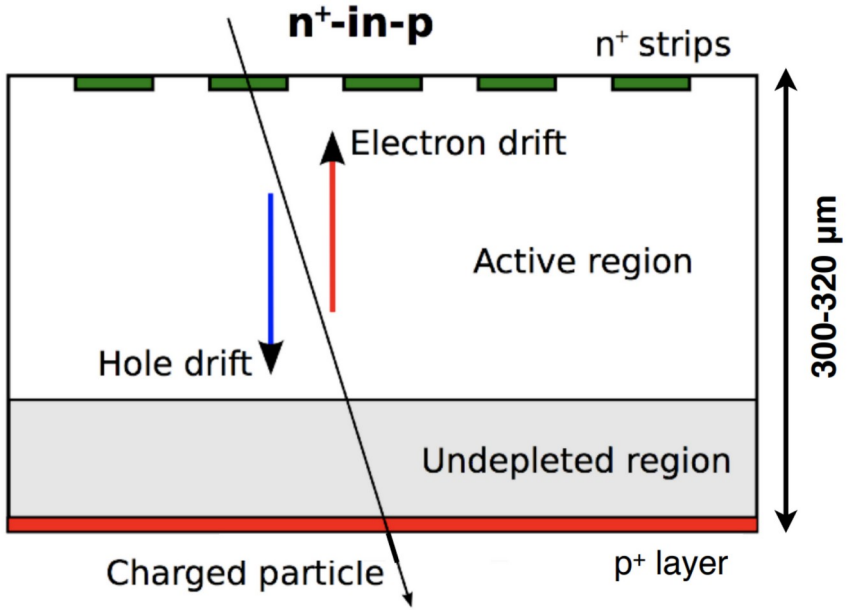
Let’s look at a module closer

Using R4 as an example



silicon strip sensors - medium for particle detection

hybrids with chips for reading out data from the strips



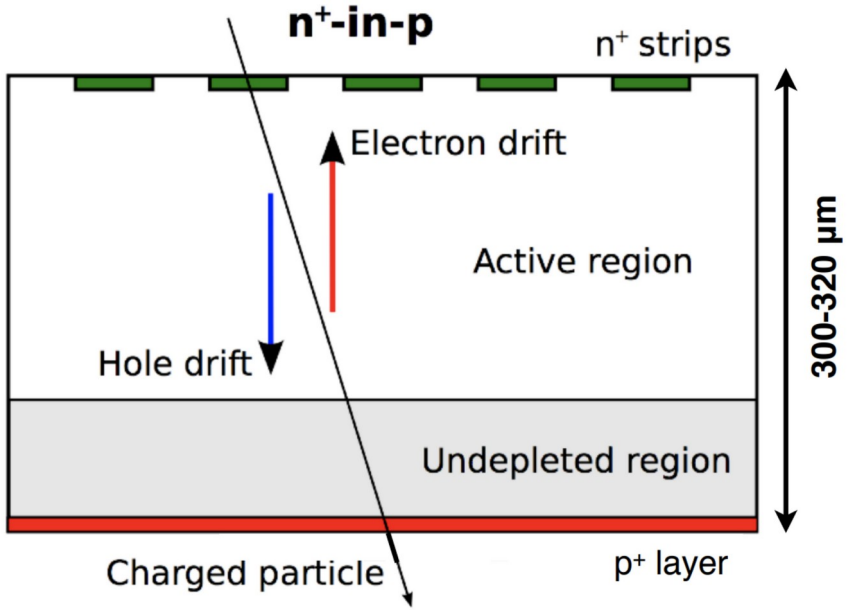
Let’s look at a module closer

Using R4 as an example

silicon strip sensors - medium for particle detection

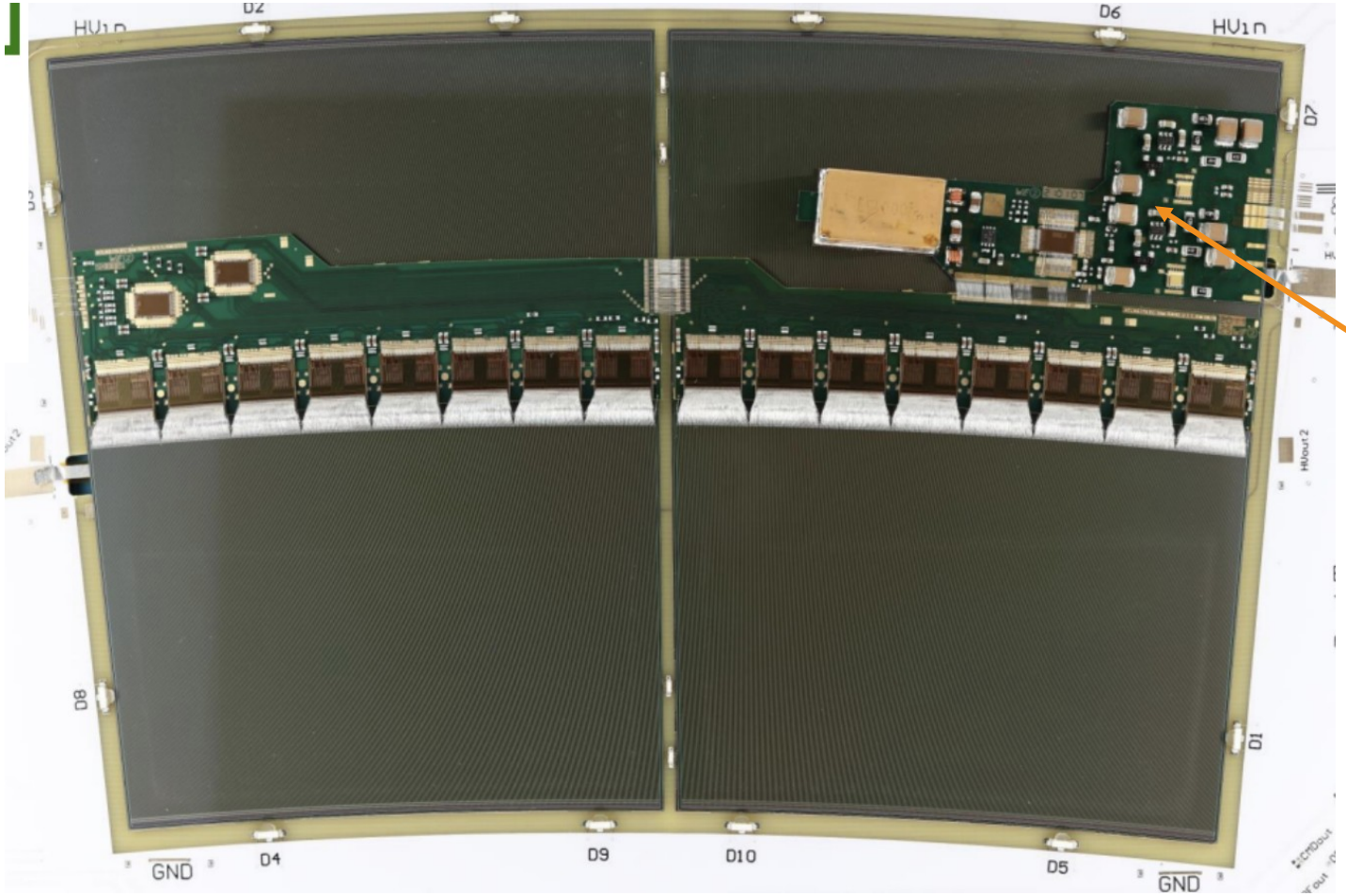
hybrids with chips for reading out data from the strips

HV-tabs to supply high voltage to the sensor



Let’s look at a module closer

Using R4 as an example

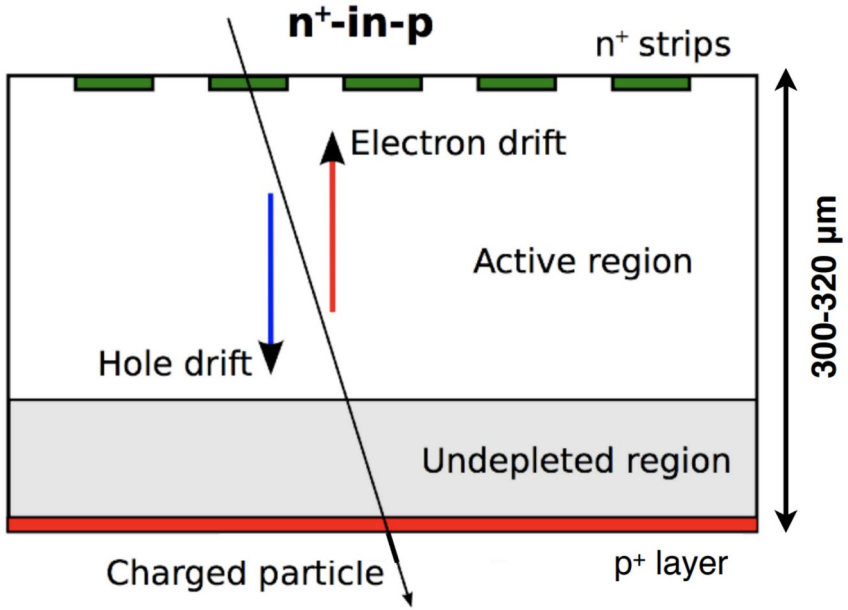


silicon strip sensors - medium for particle detection

hybrids with chips for reading out data from the strips

HV-tabs to supply high voltage to the sensor

powerboard to control the module’s work



Let’s look at a module closer

Using R4 as an example

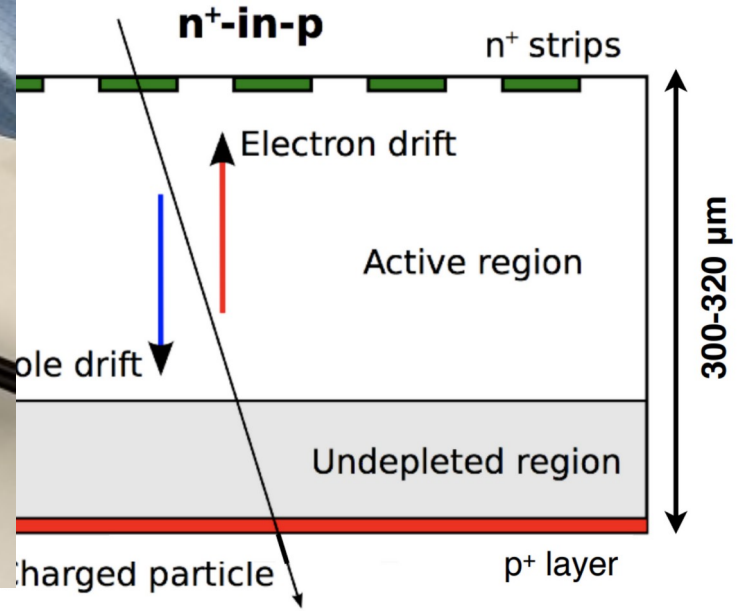
R4 sensor with a hand for scale

n strip sensors - medium for
le detection

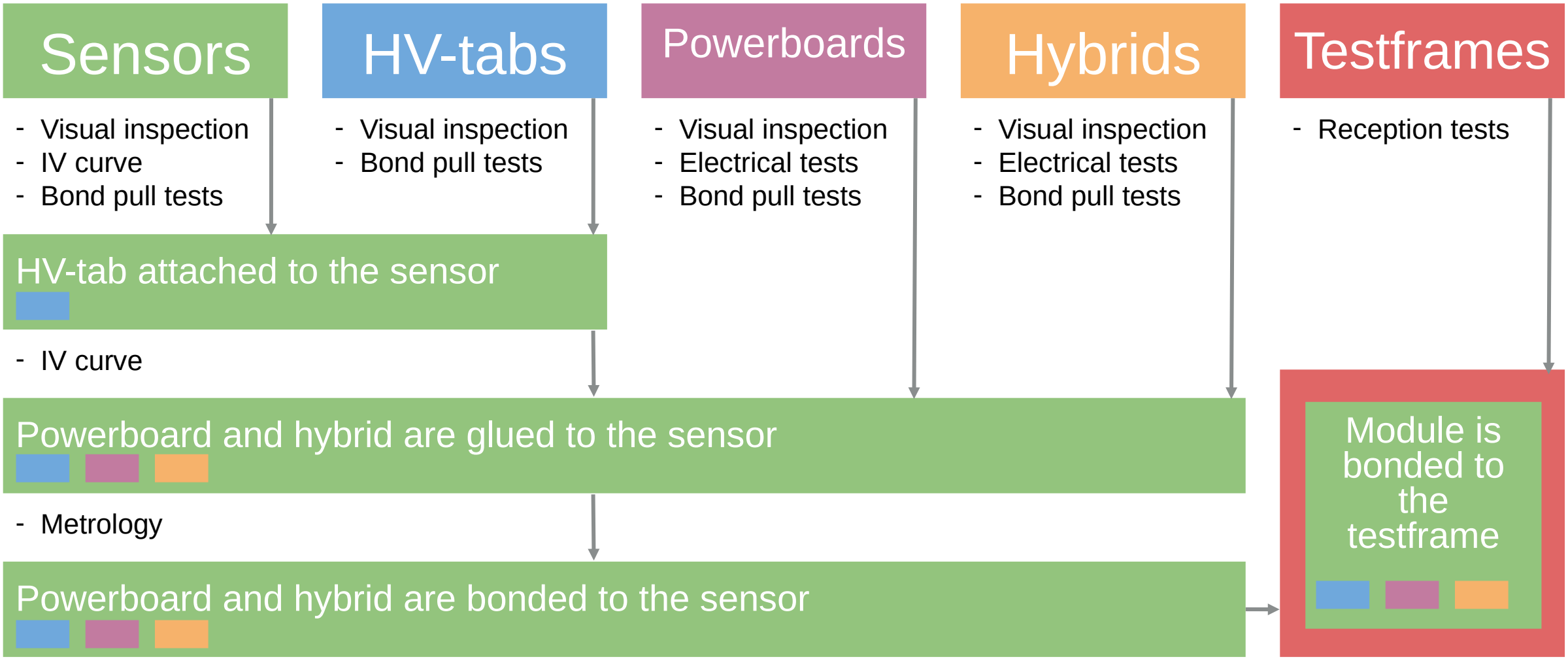
ds with chips for reading out data
he strips

bs to supply high voltage to the
or

rboard to control the module’s work

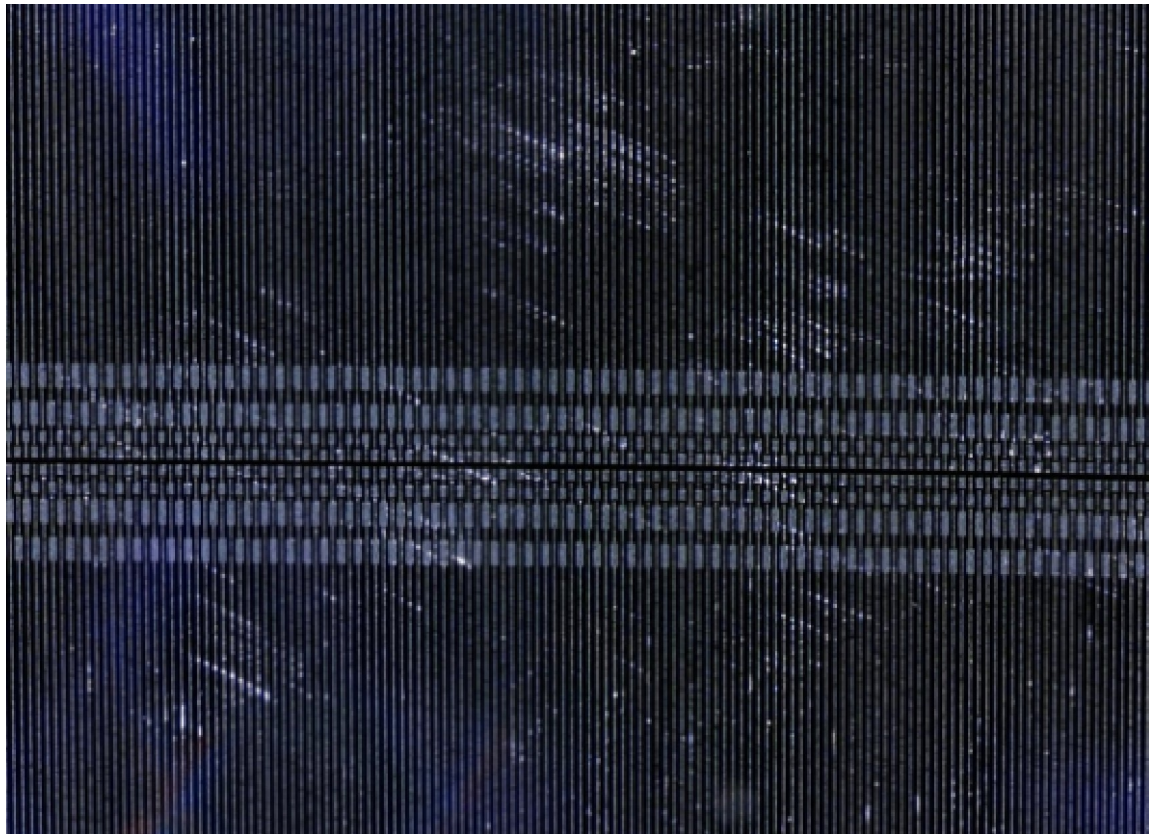


Module building process

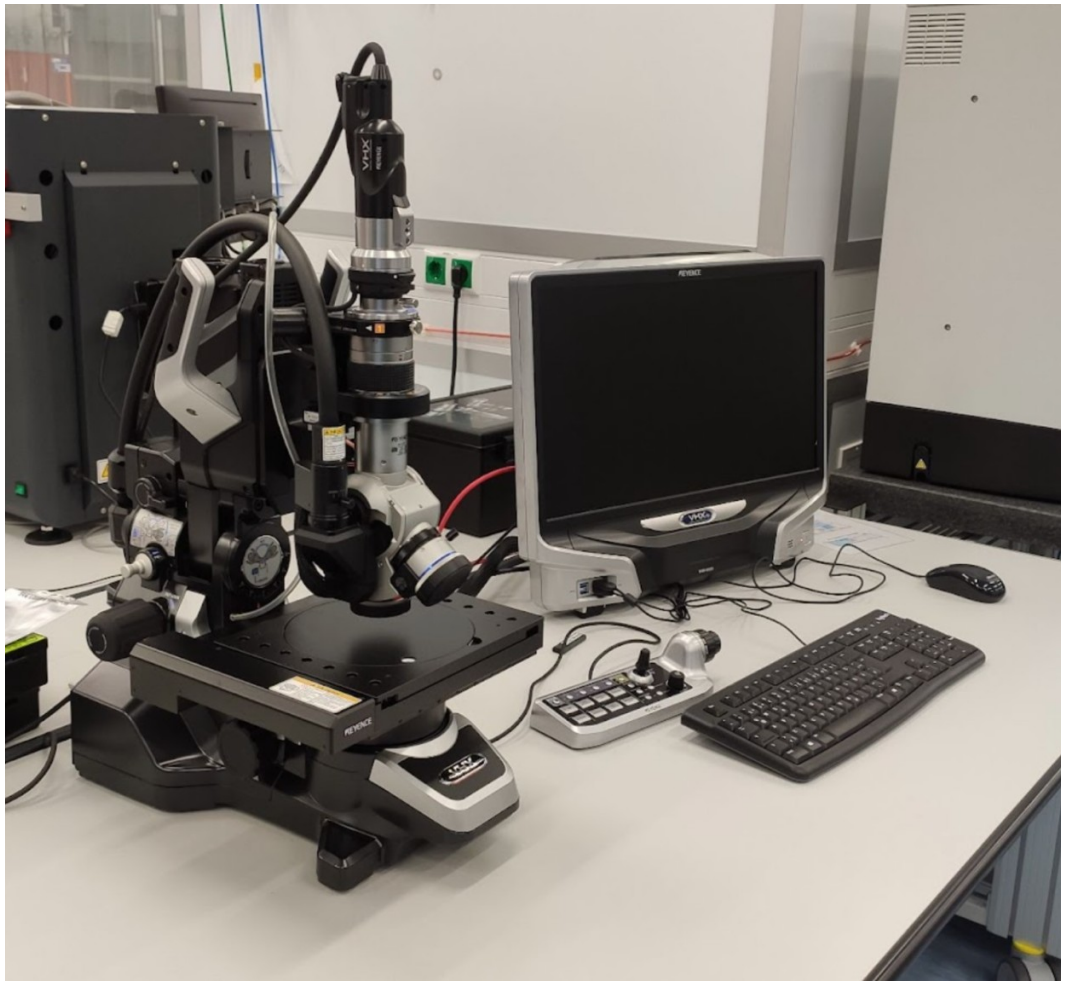


Visual inspection

Visual inspection of the components is mostly done using a microscope



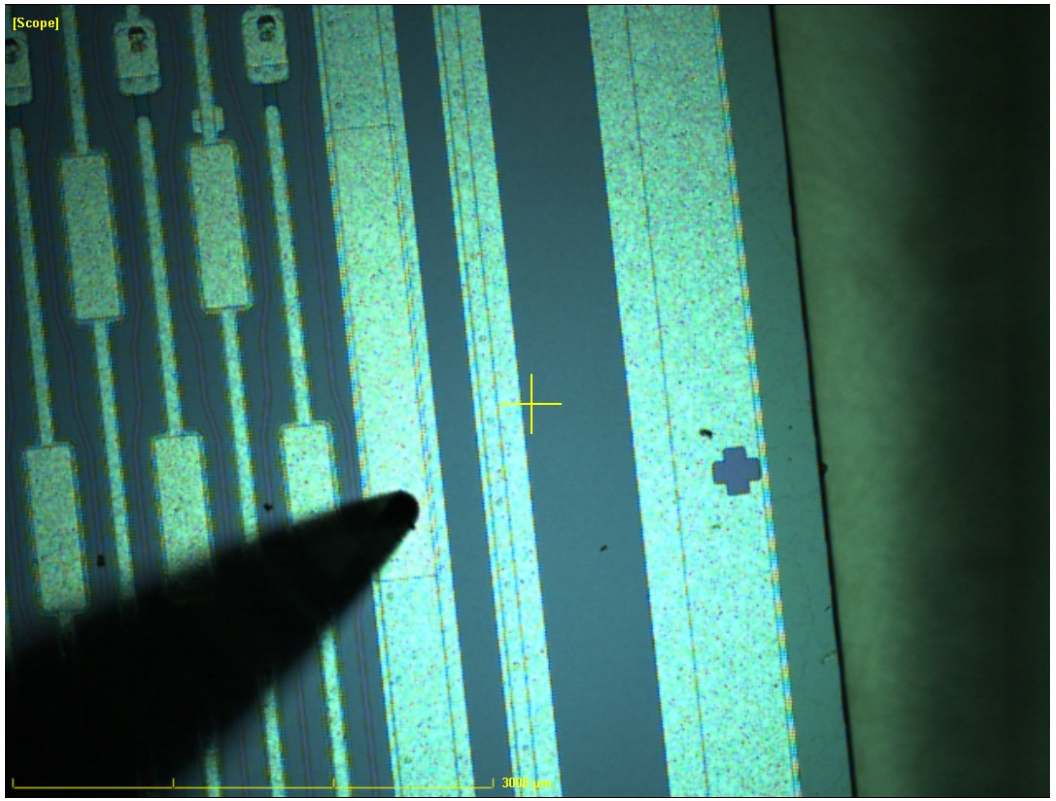
Picture of a scratched sensor

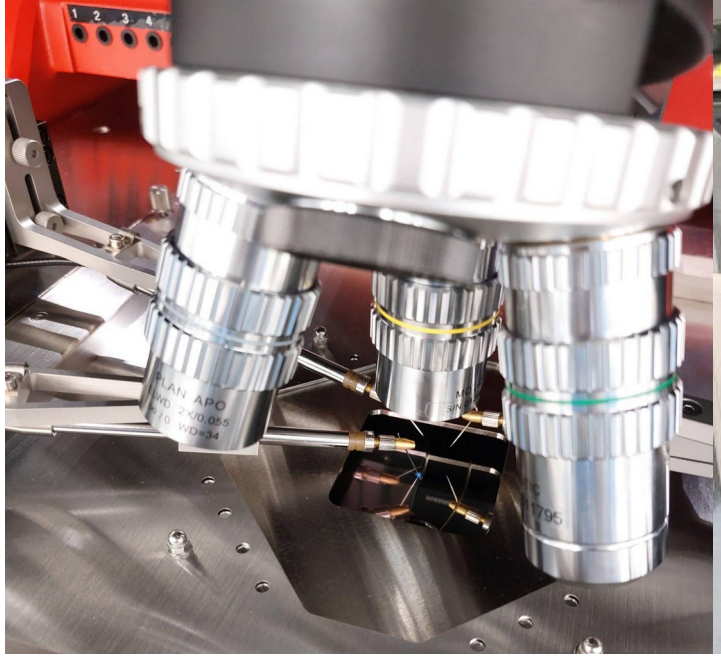


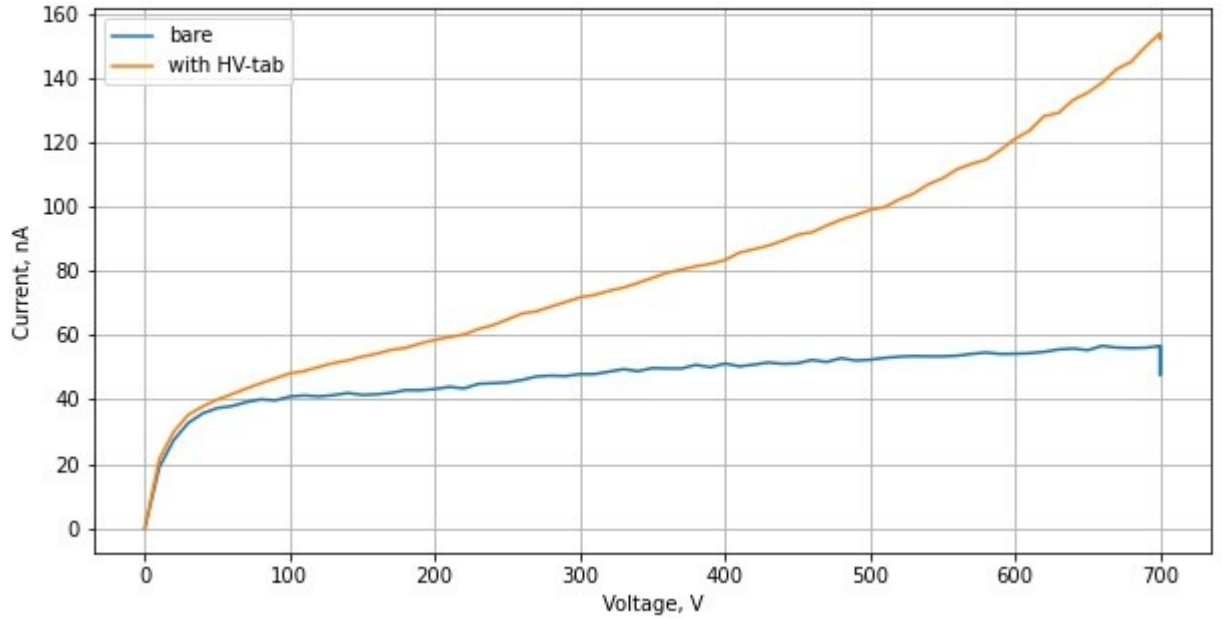
Microscope, that is used for visual inspection

Sensor IV curve

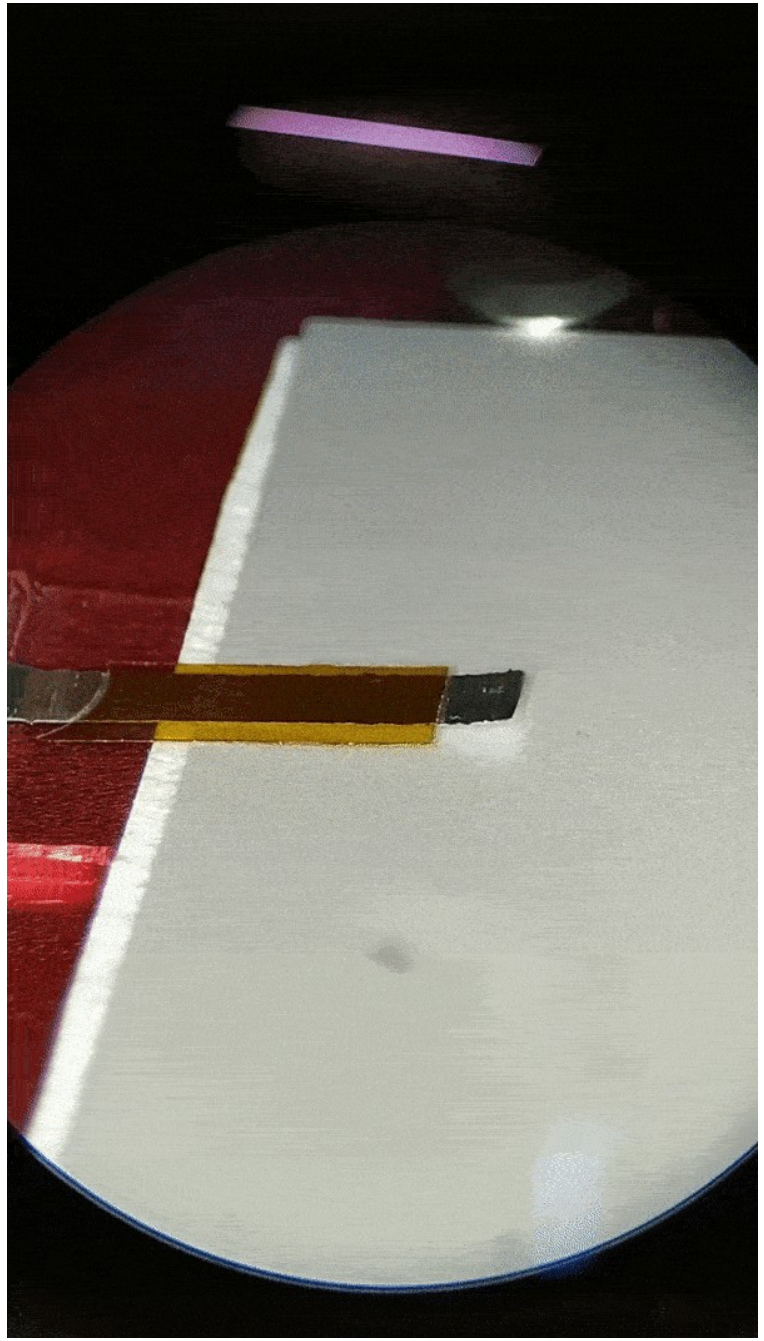
The IV curve for a bare sensor is measured using a probe station





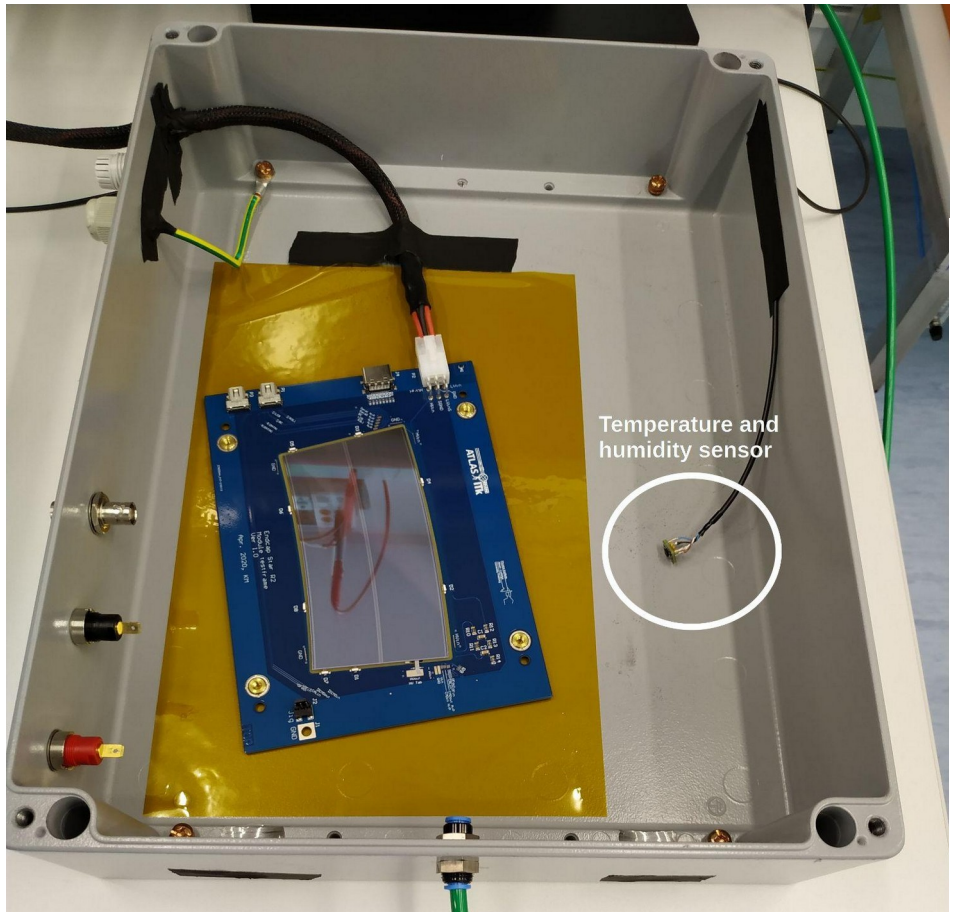


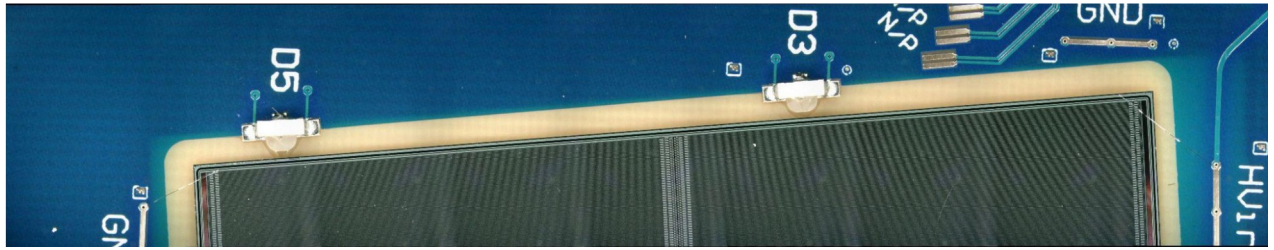
HV-tab attachment

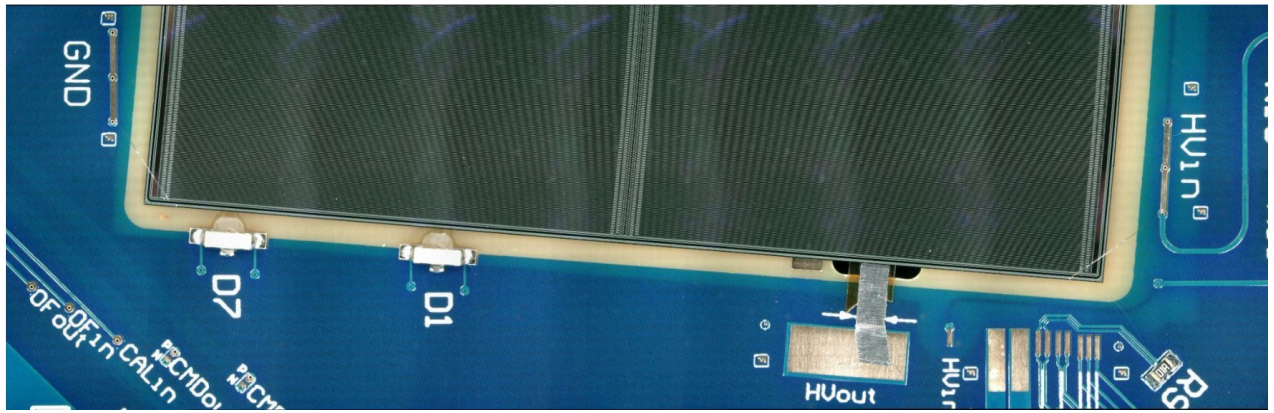


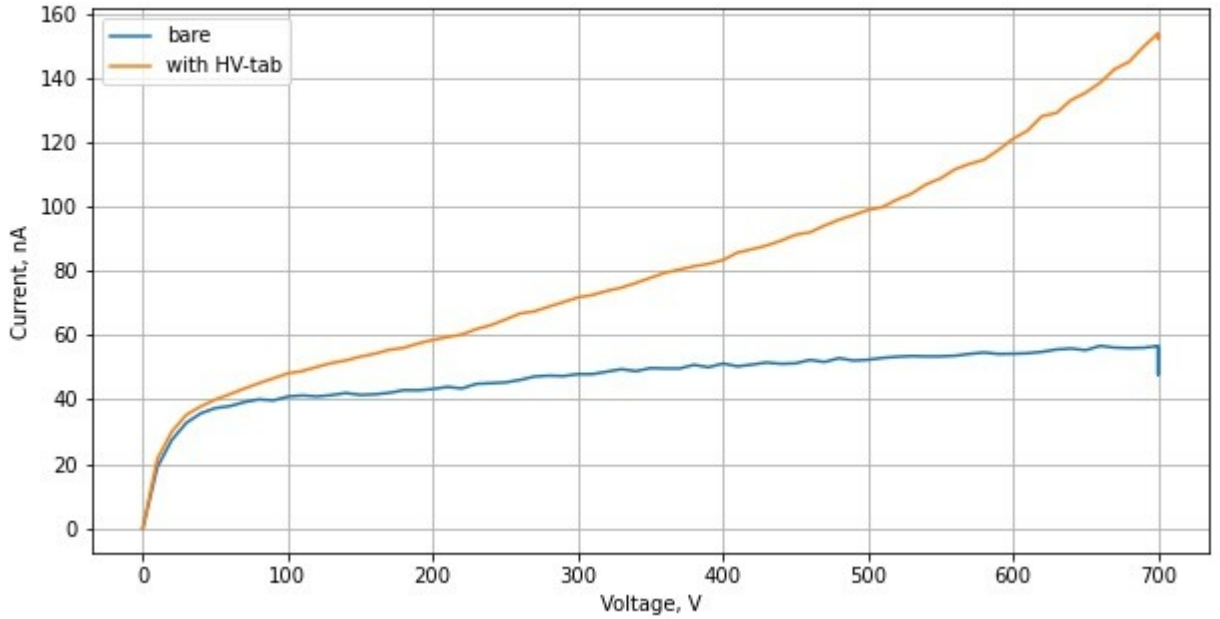
Module IV curve

Module is bonded to a test frame and a different setup is used to measure the IV curve



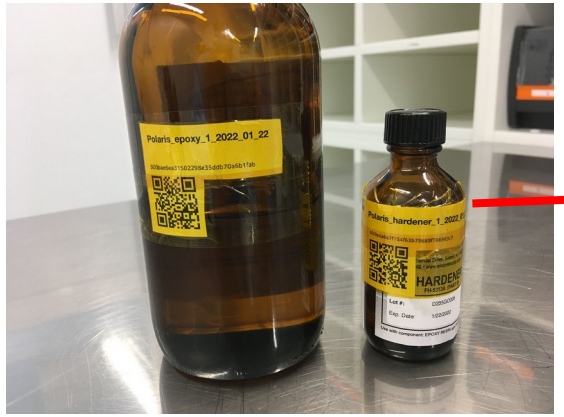






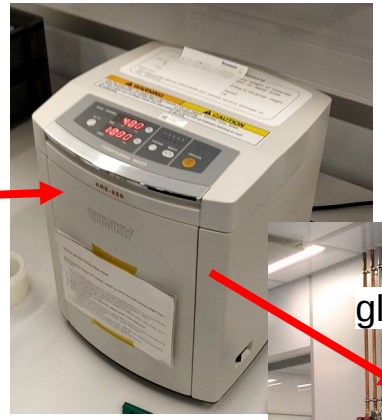
What glue do we use?

resin + hardener

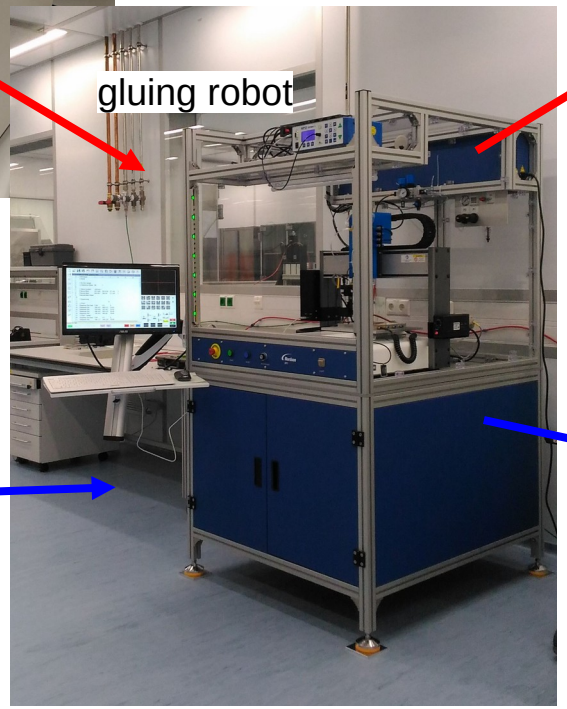


100 resin : 9 hardener
(measured with a scale)

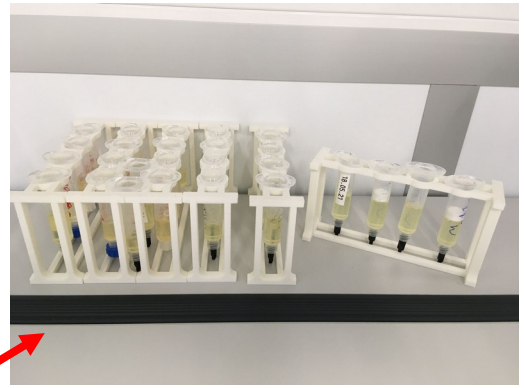
mixing and degassing



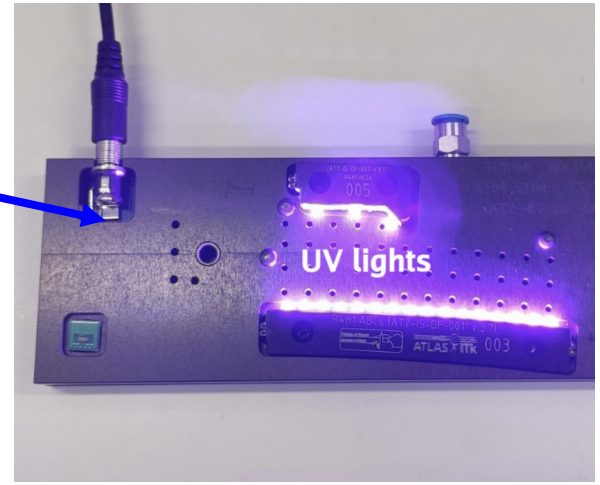
gluing robot



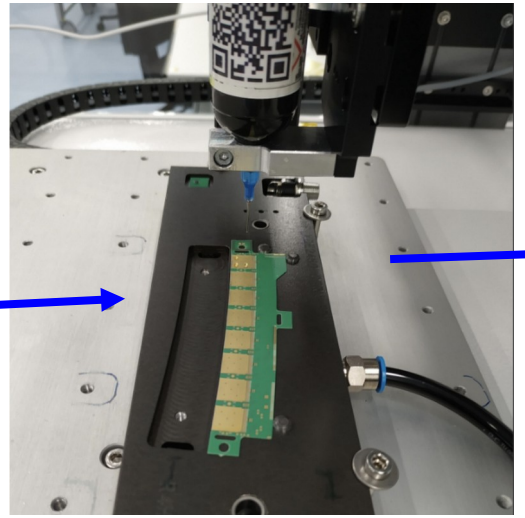
8 hours to cure, remaining glue stored
in case of problems with the module



cured using UV-light

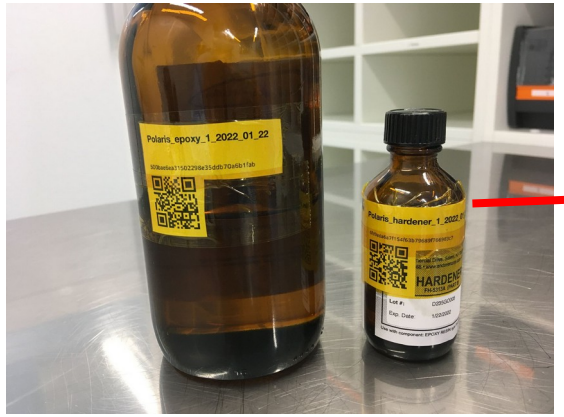


UV glue



What glue do we use?

resin + hardener



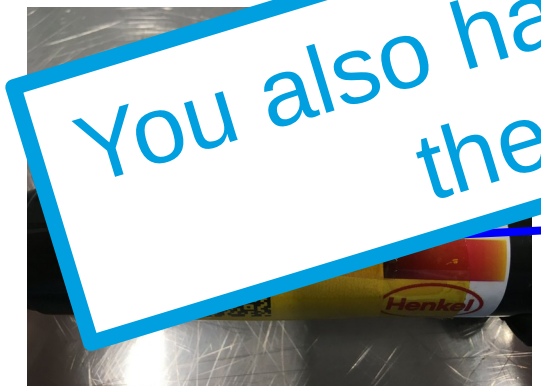
100 resin : 9 hardener
(measured with a scale)

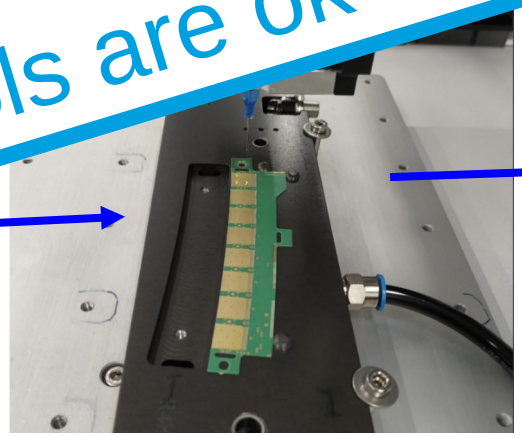
mixing and degassing

8 hours to cure, remaining glue stored in case of problems with the module

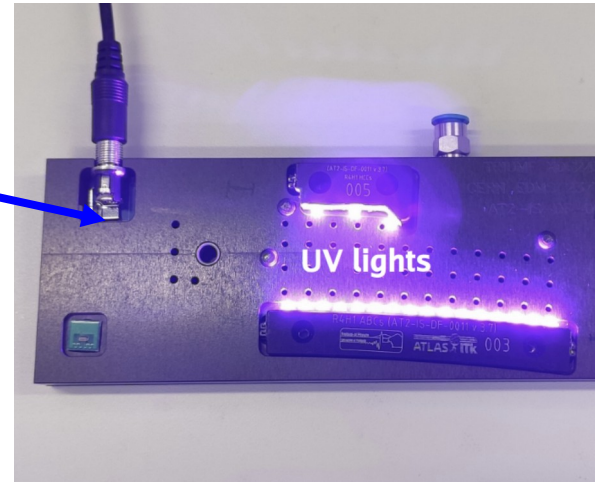
You also have to find the right pattern, make sure that the tools are ok and program the robot

UV glue

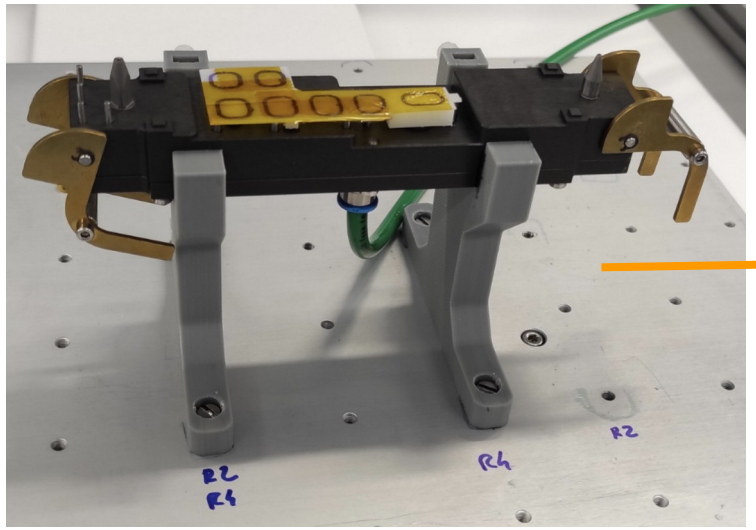


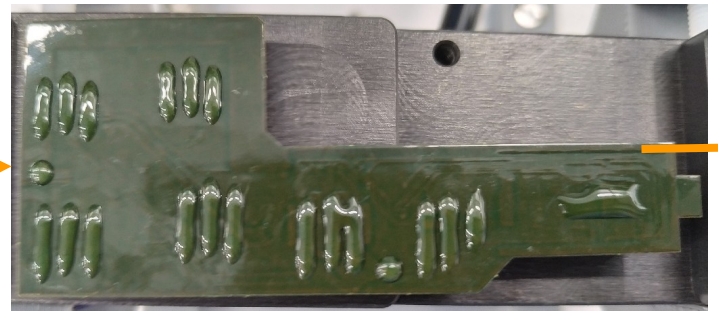


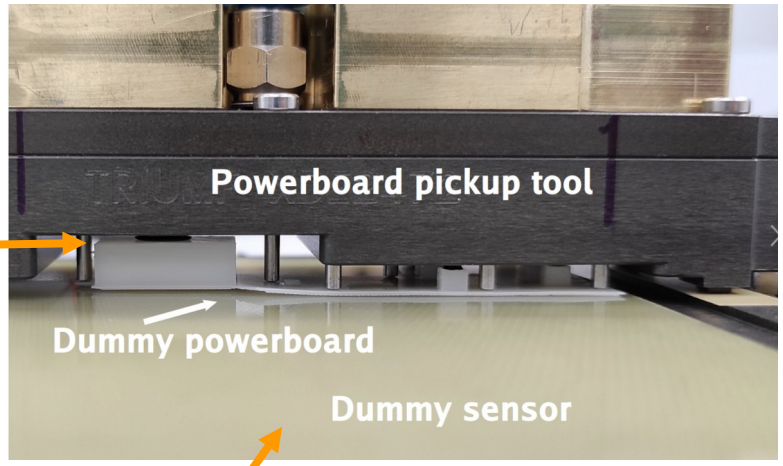
cured using UV-light

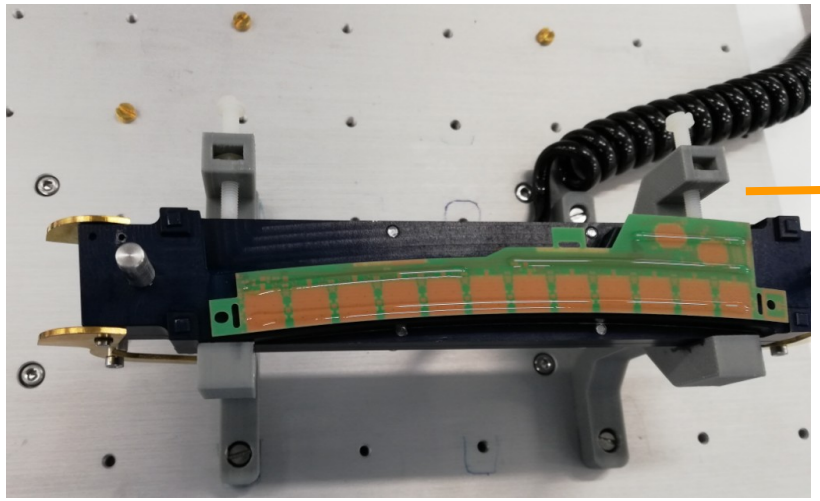


Powerboard and hybrid gluing





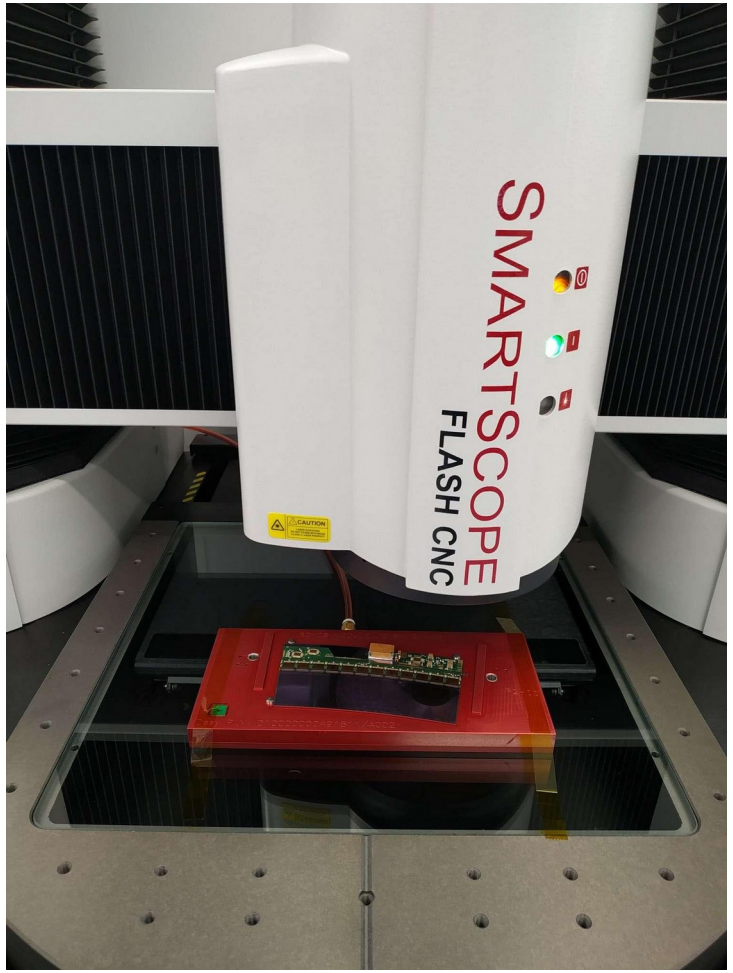


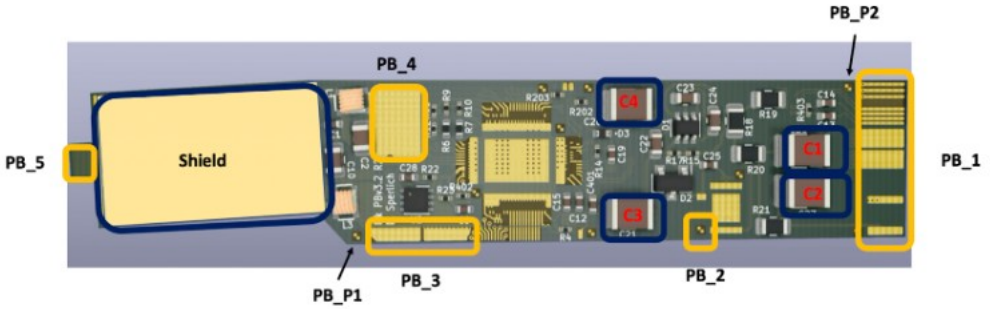


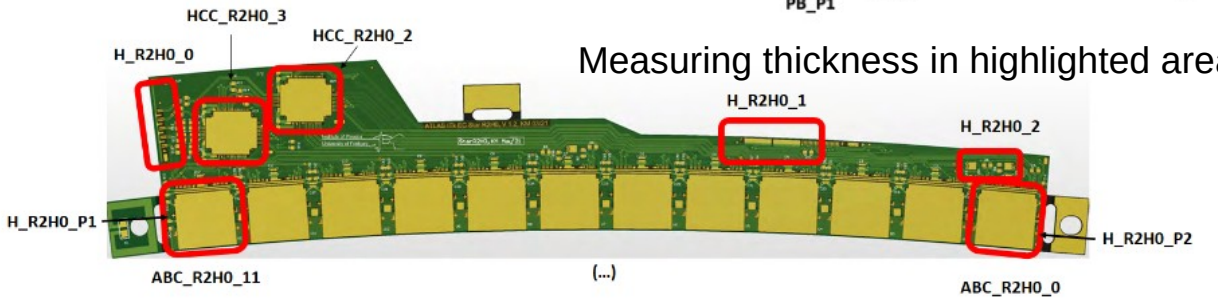
(but with a hybrid instead of a powerboard and the corresponding pickup tool)

Module metrology

Metrology is done using a SmartScope



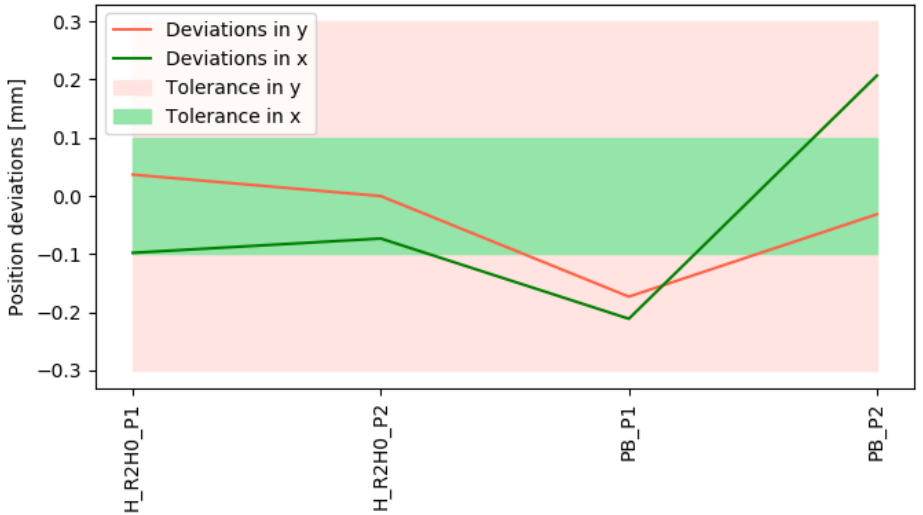




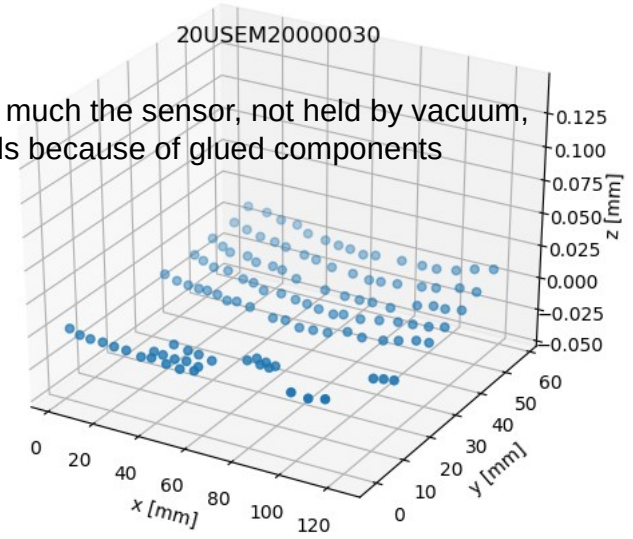
Measuring thickness in highlighted areas

Module bow: 0.0100 mm

Positions of fiducial marks are measured to determine if components are glued in the right place

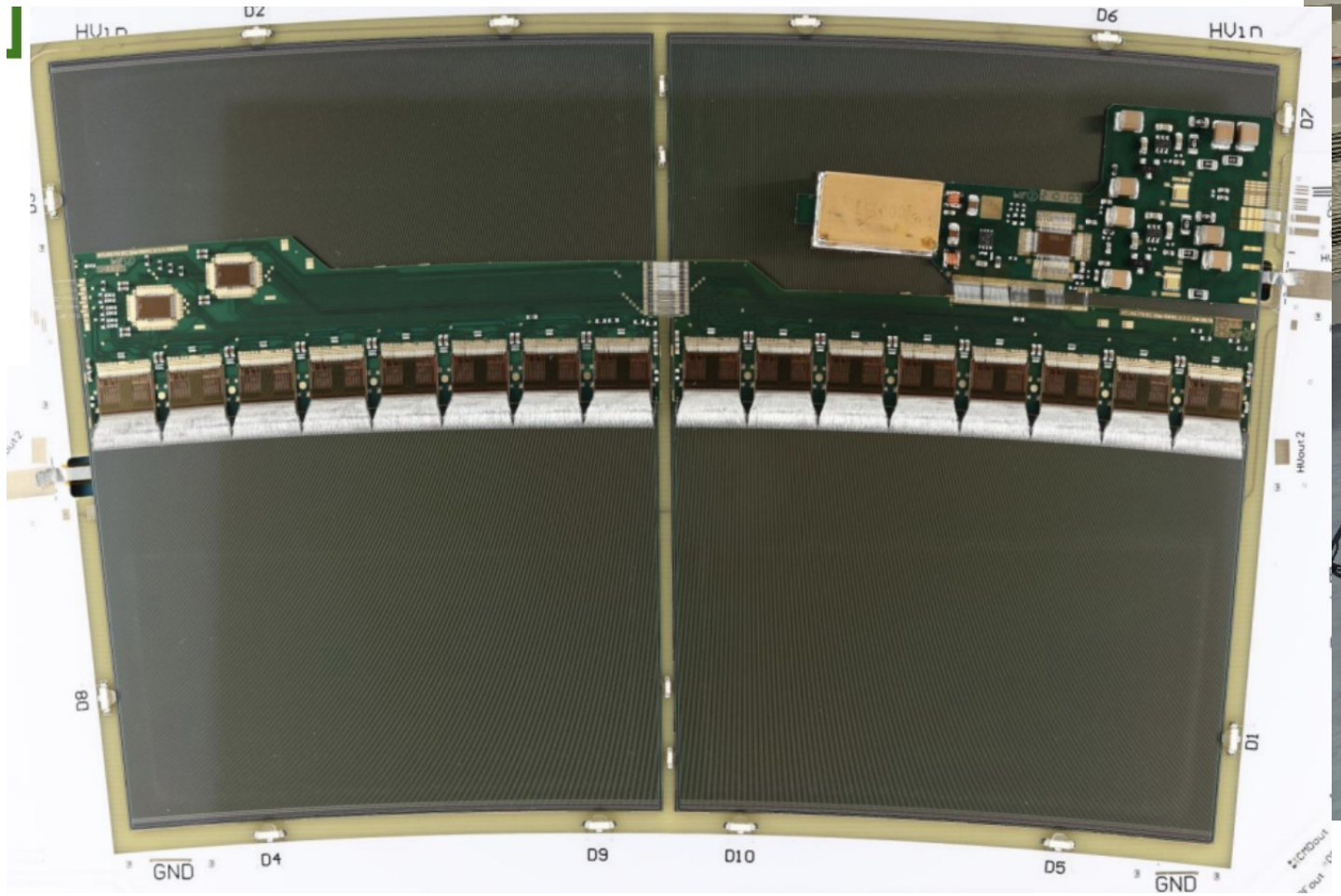


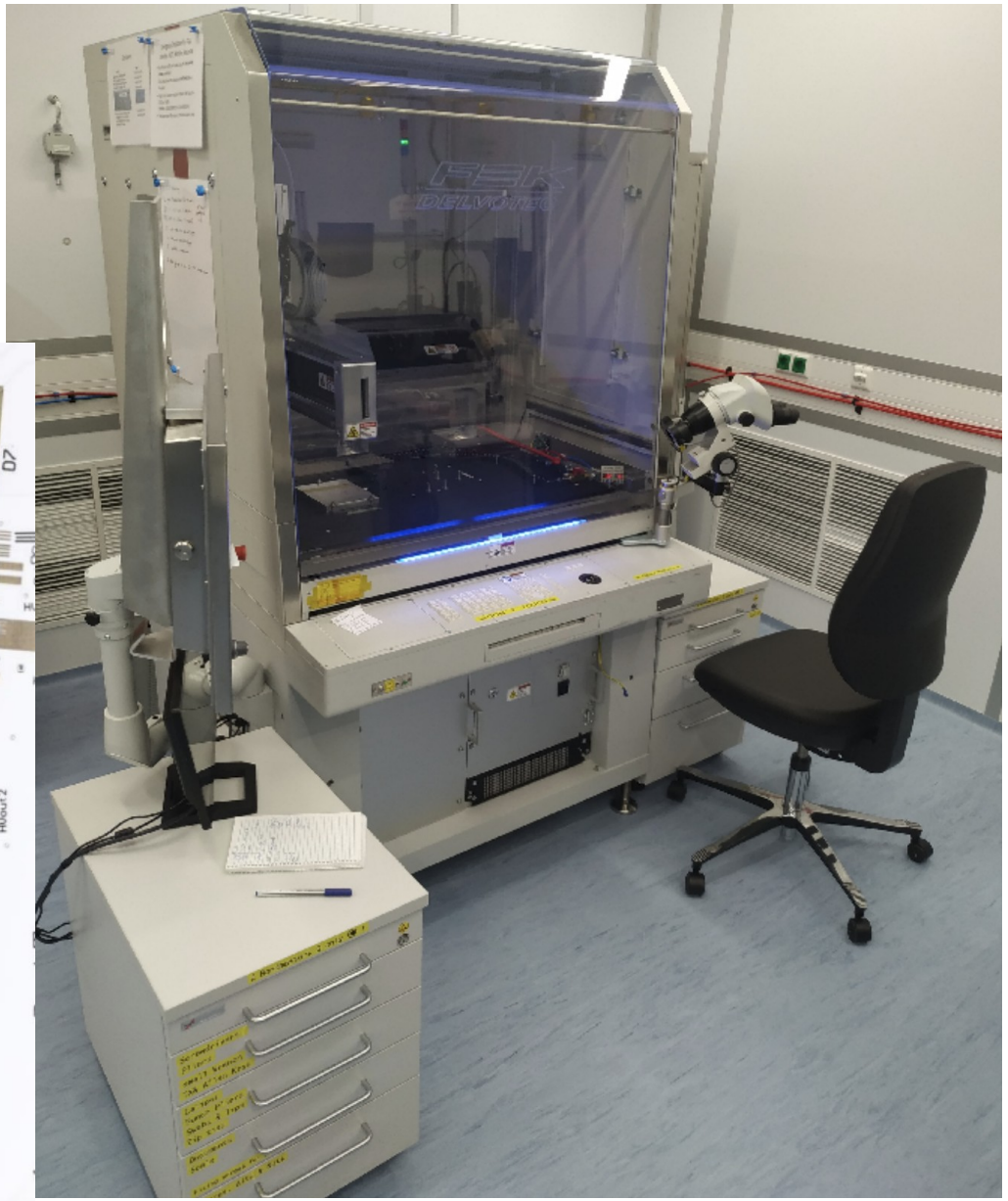
How much the sensor, not held by vacuum, bends because of glued components



What is bonding?

Electrical connection between components is achieved through wirebonds





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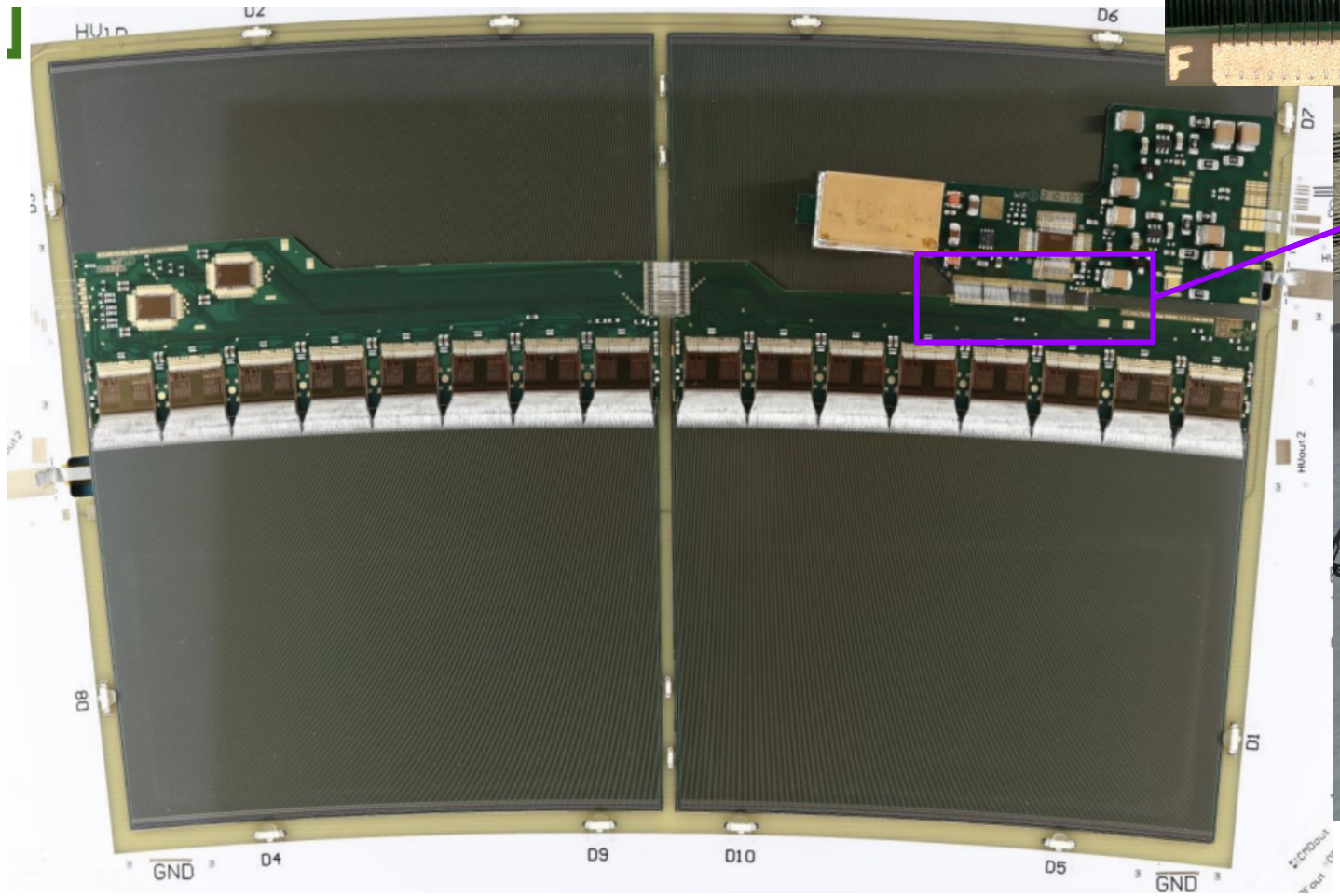

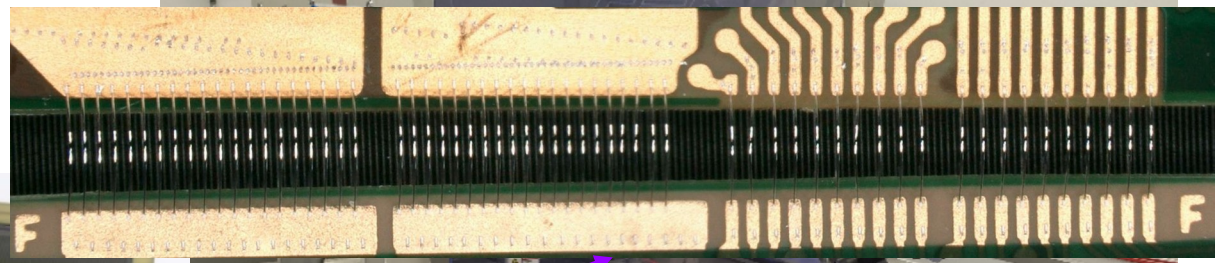

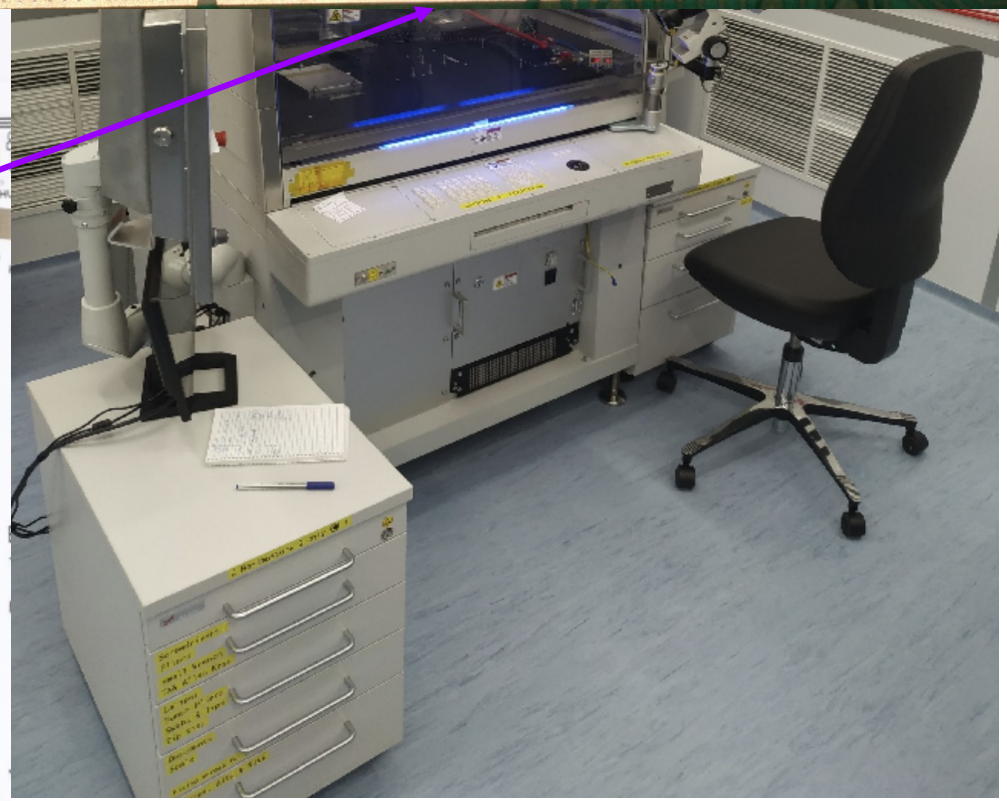

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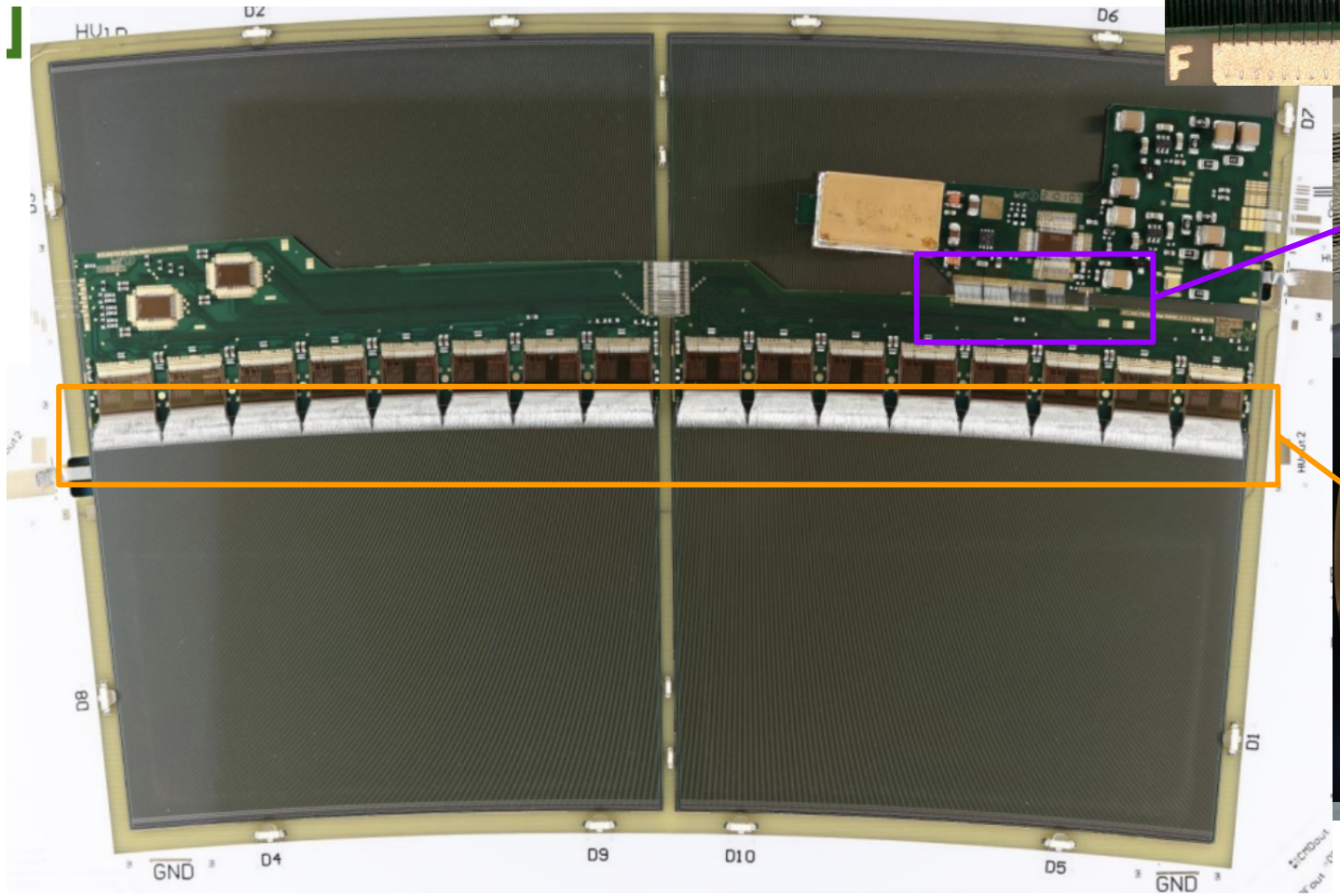

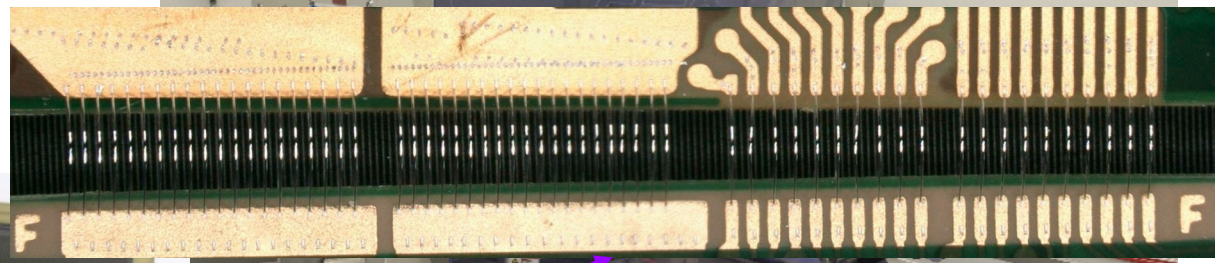

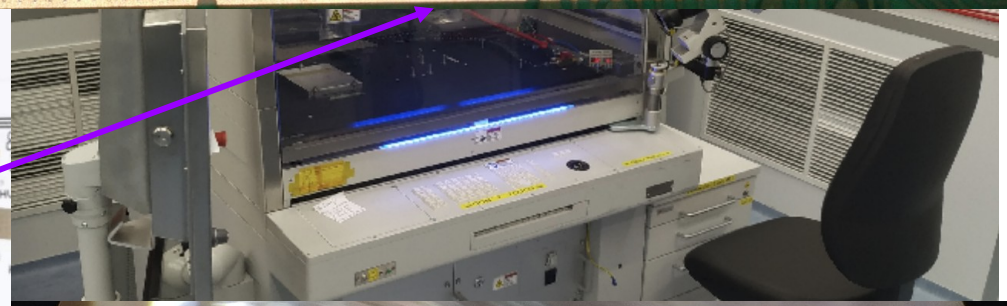

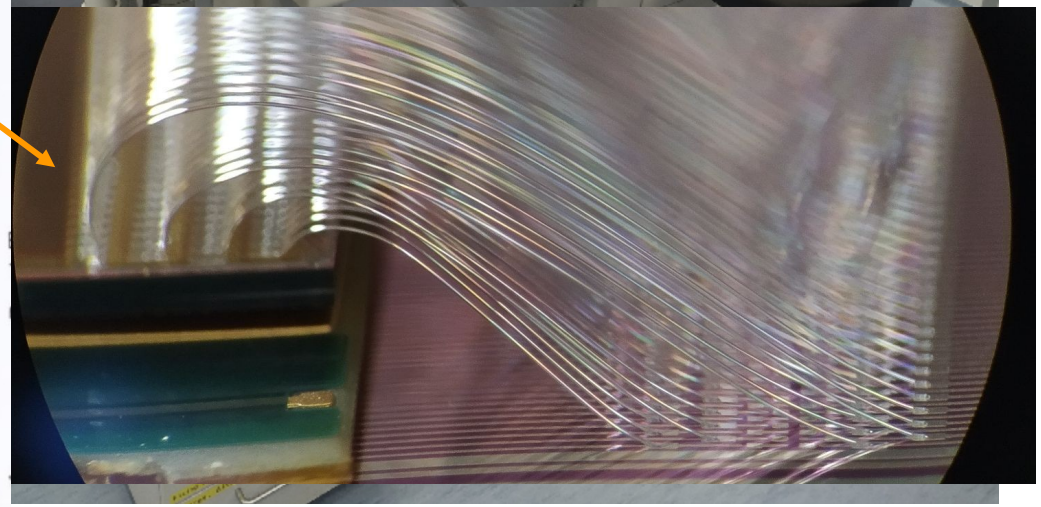

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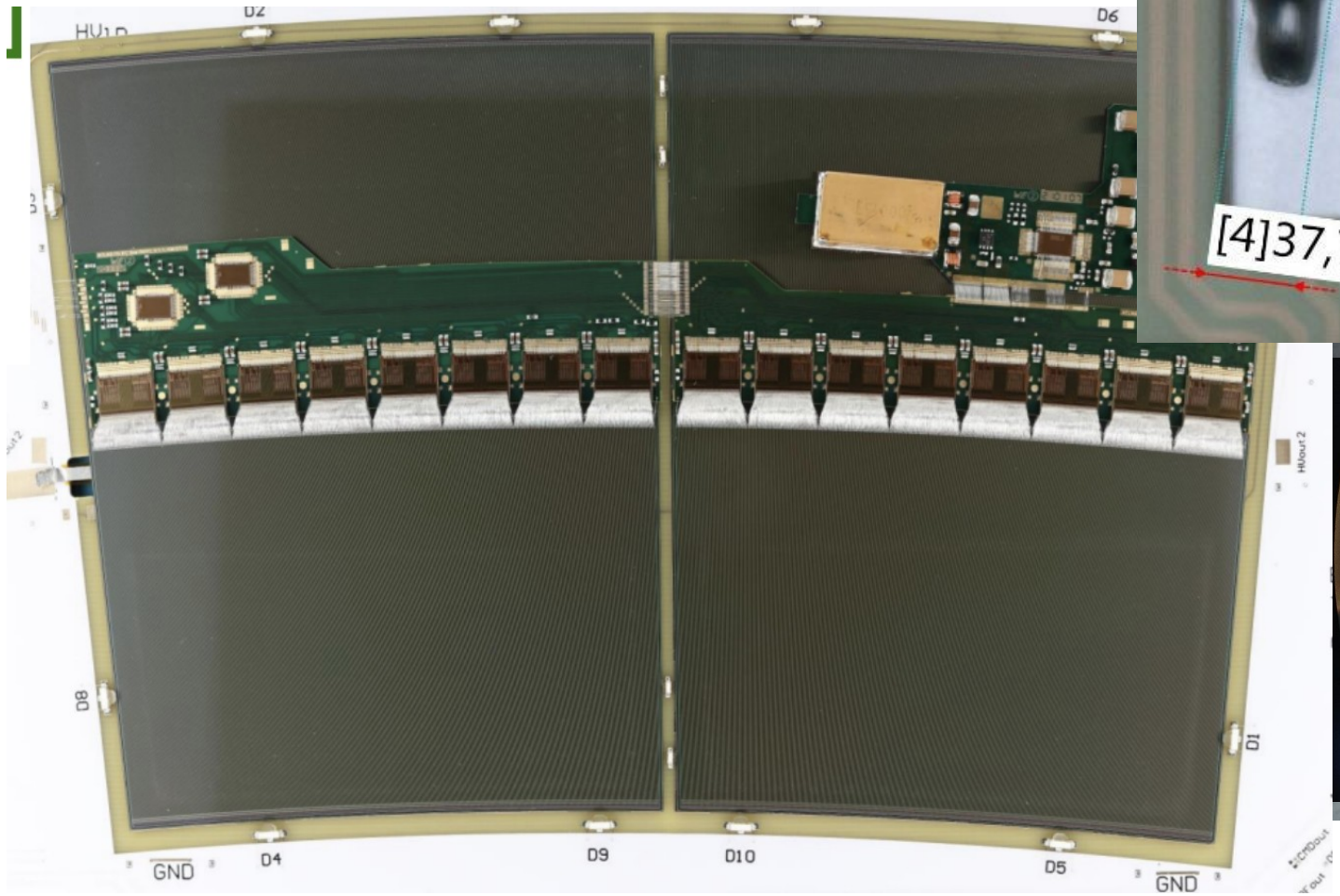

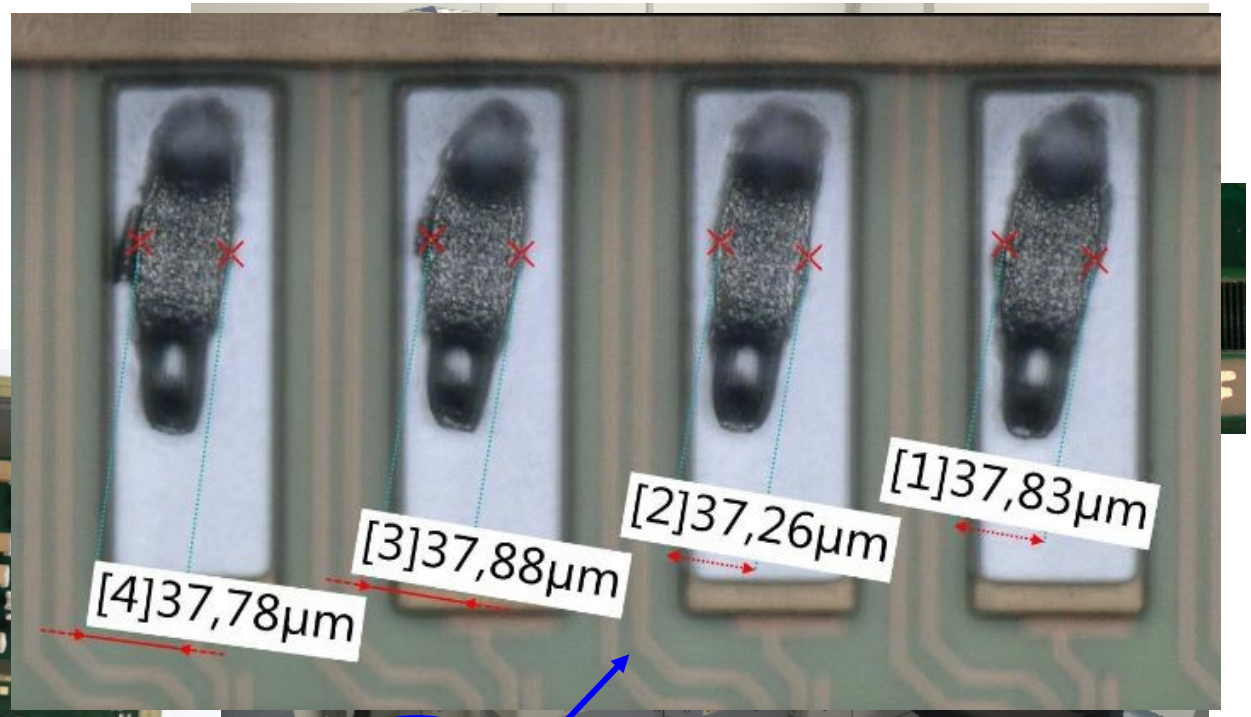

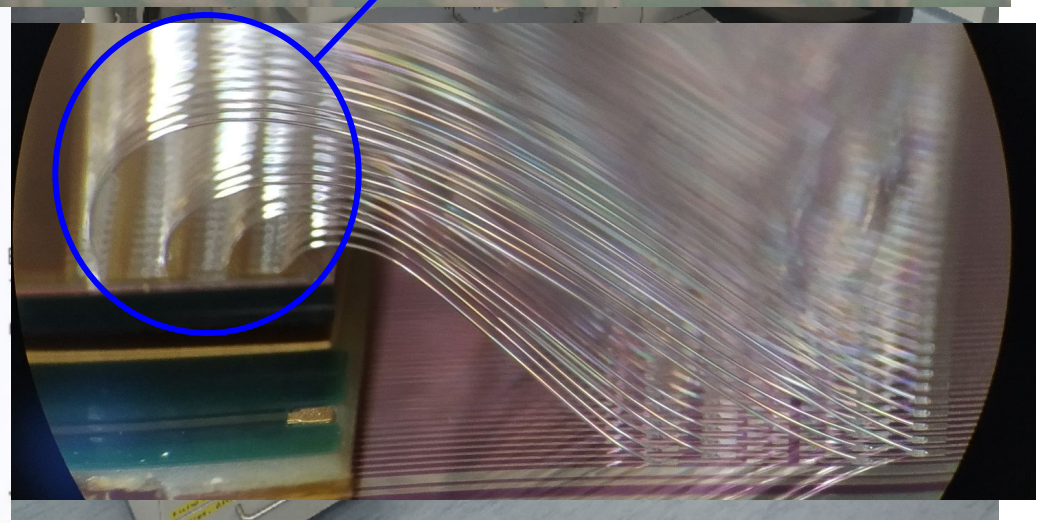

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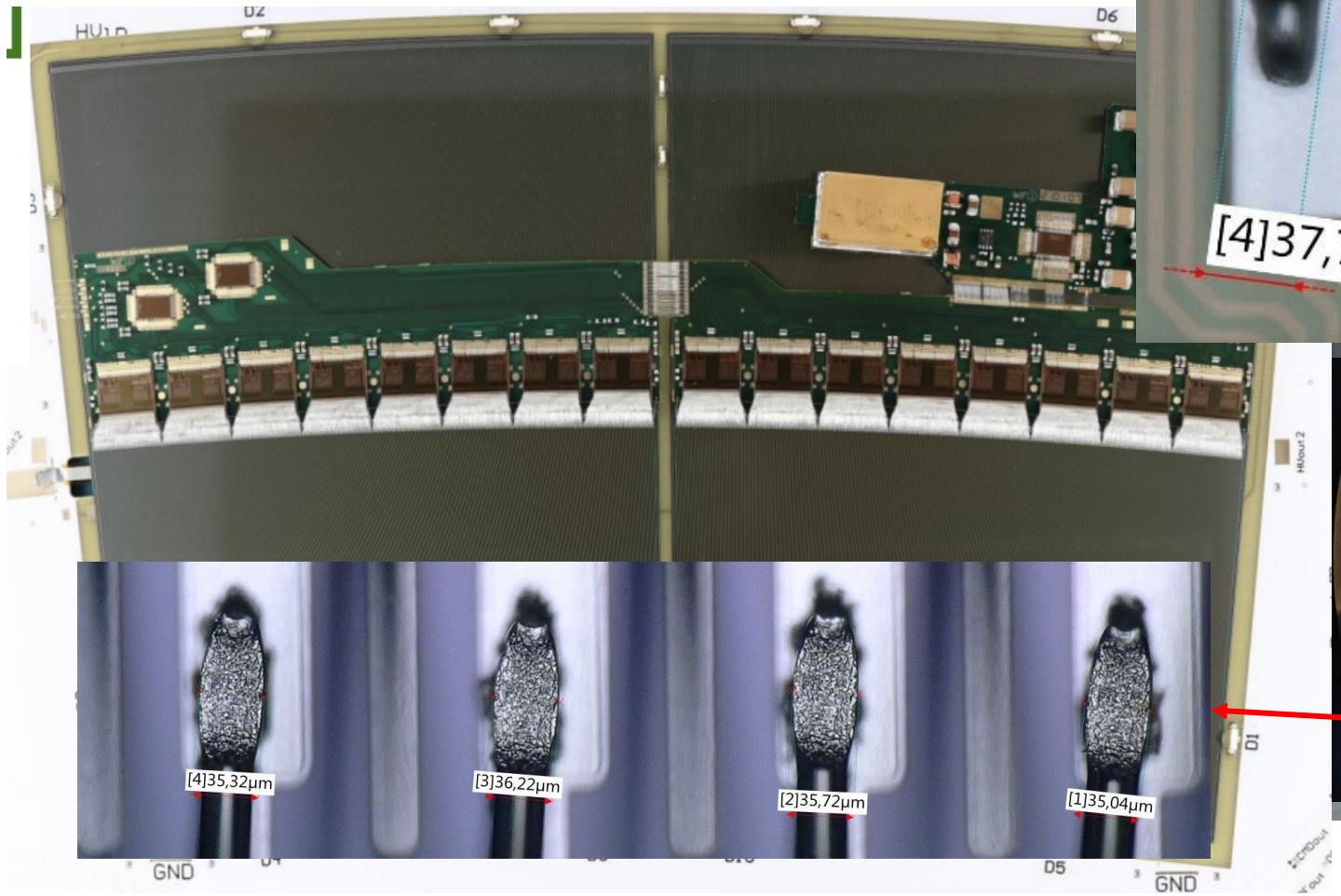
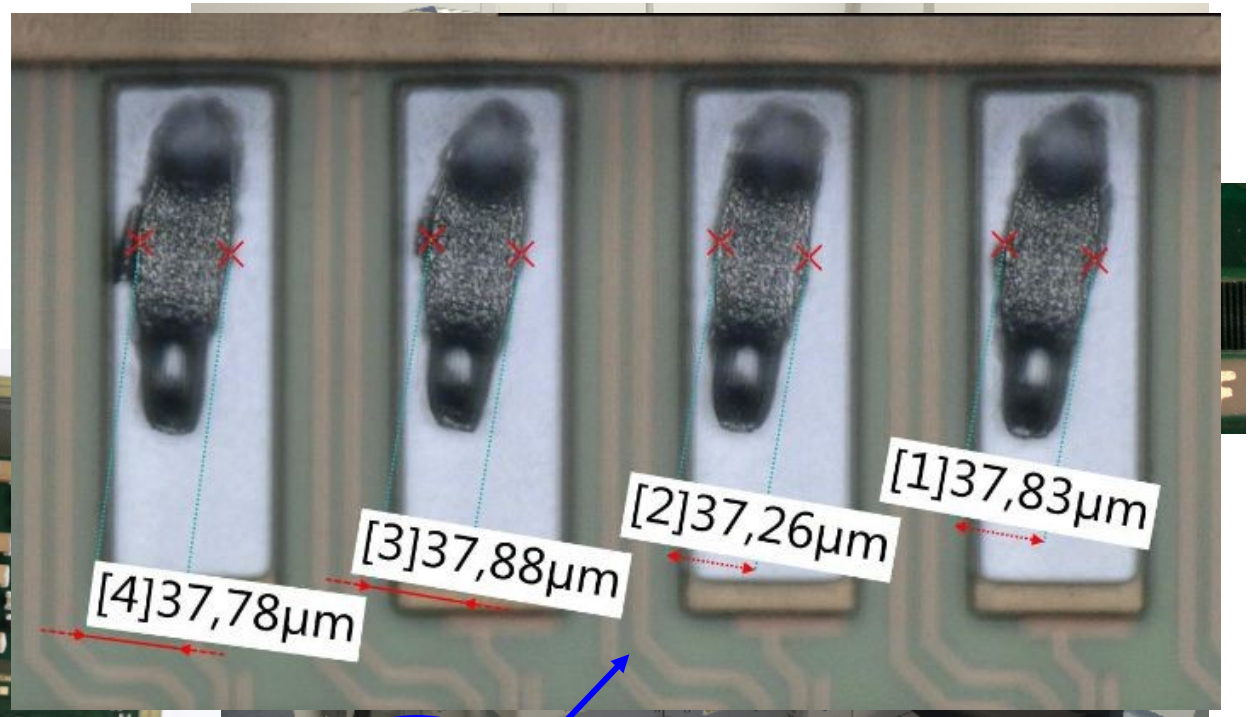
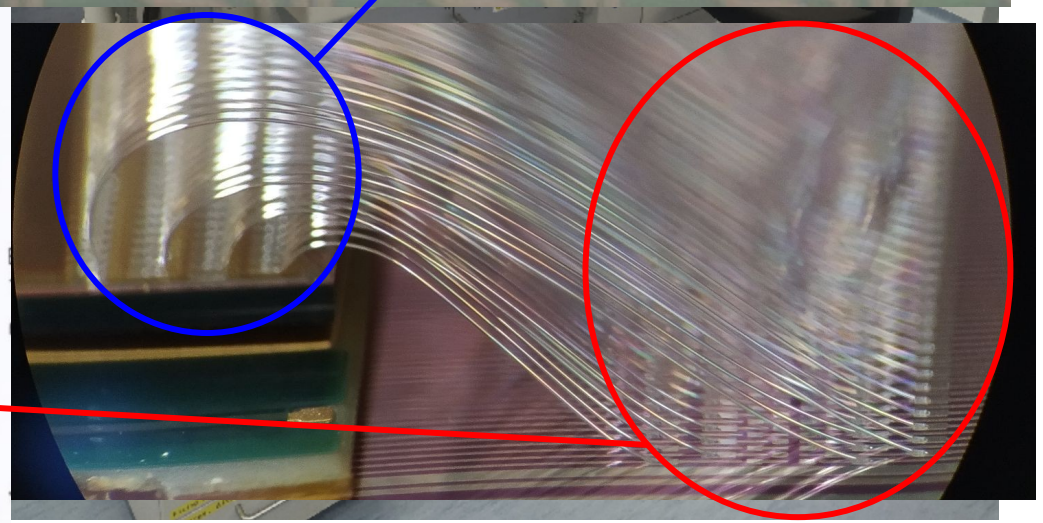
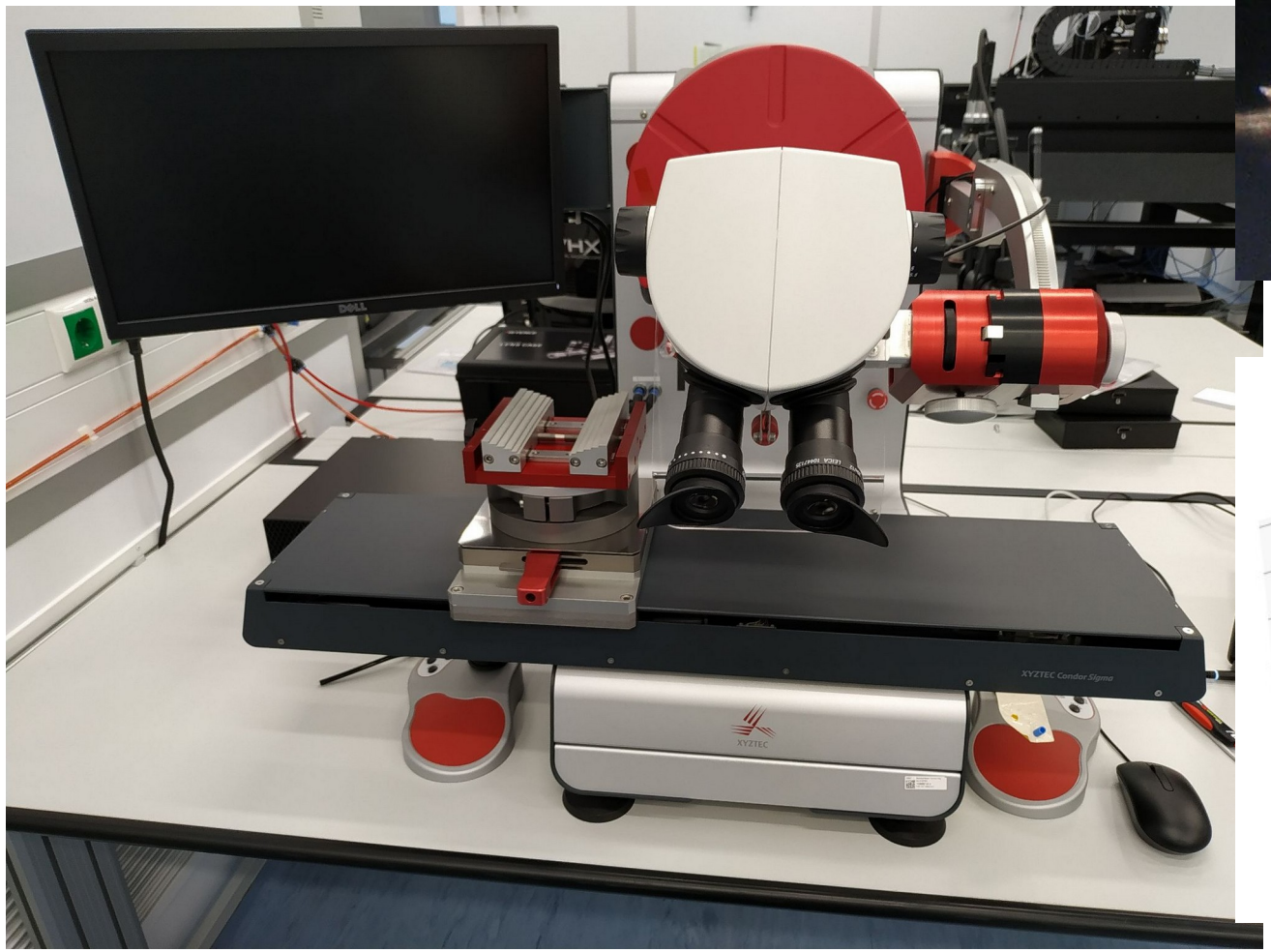


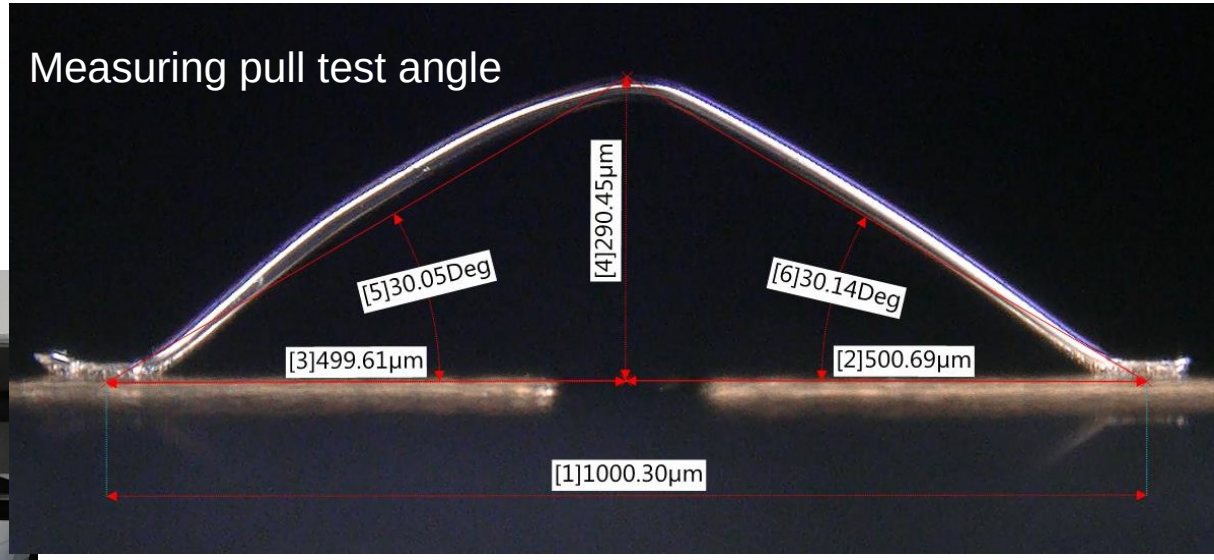


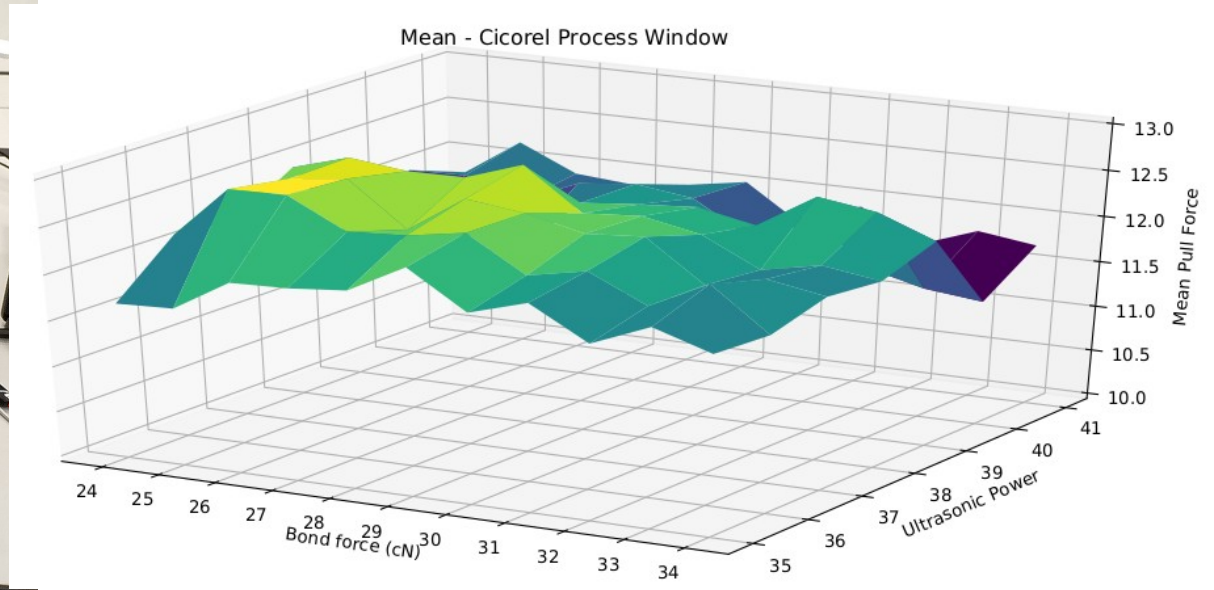


Bond pull tests

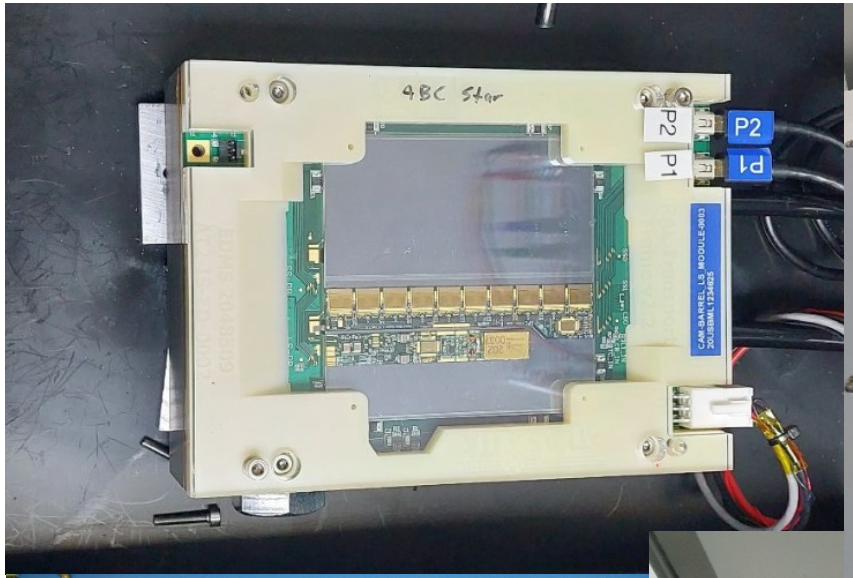
Bond pull tester

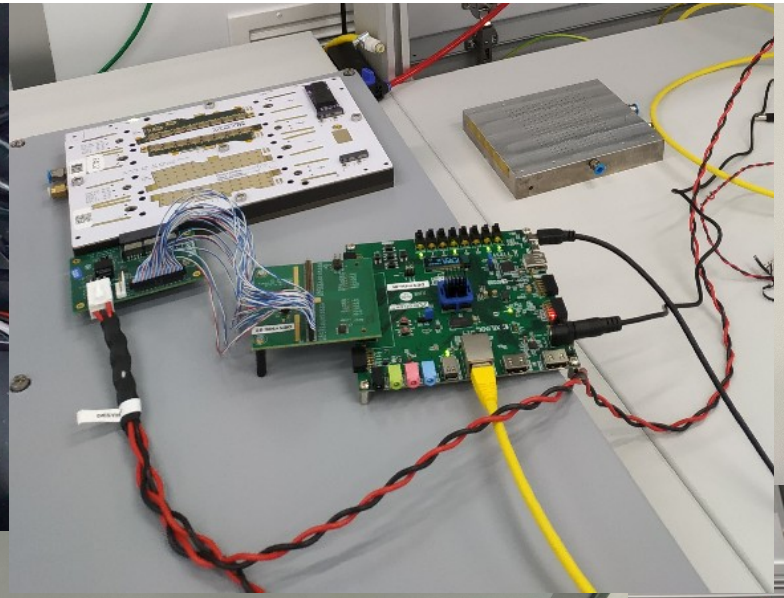


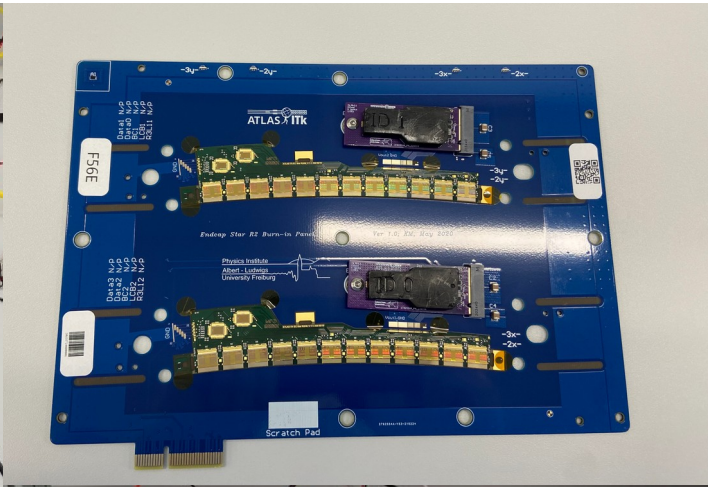


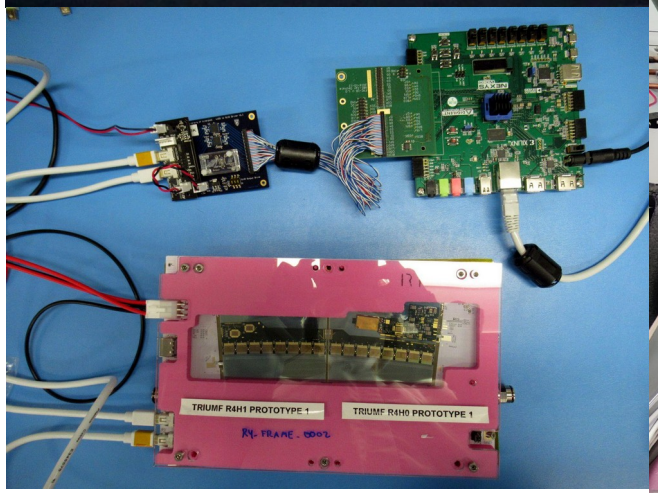


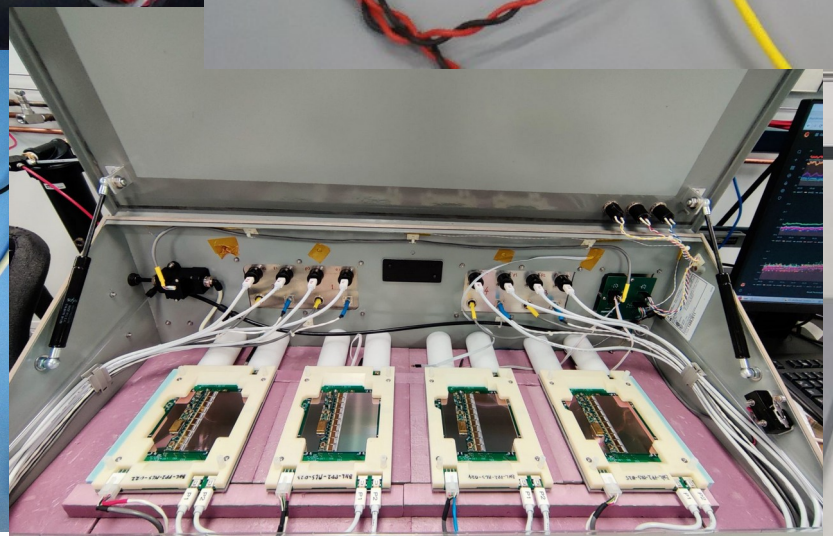
Electrical testing

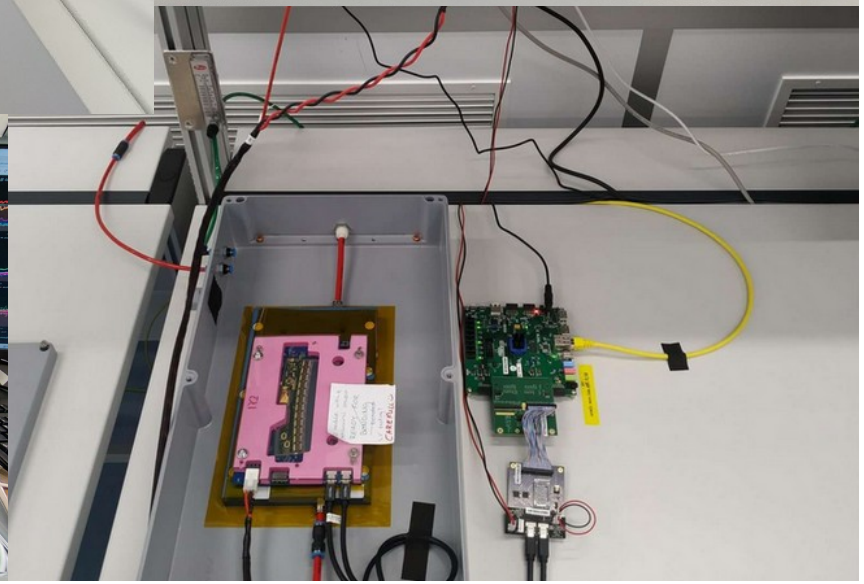






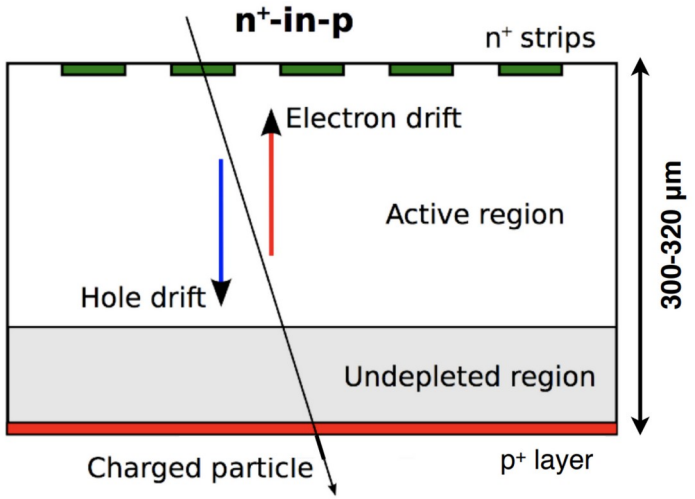






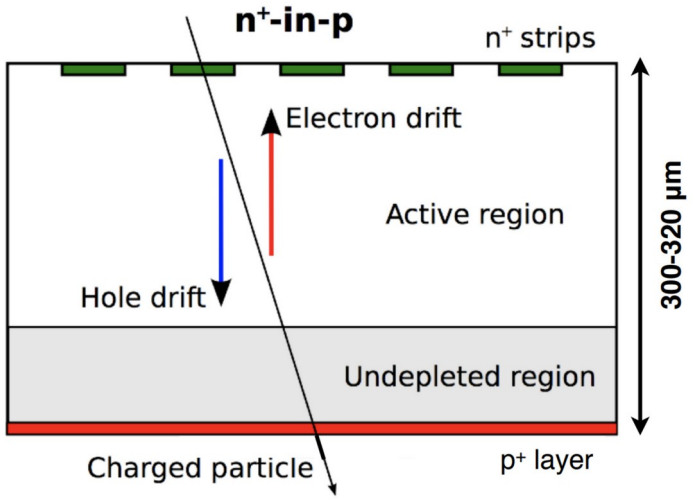
Readout principle

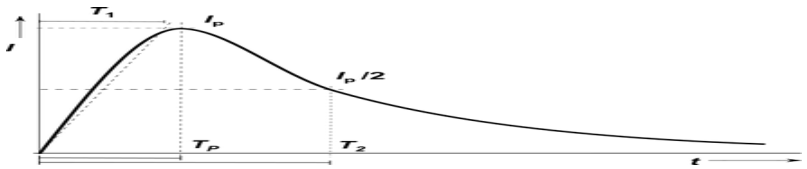
and electrical testing



Readout principle

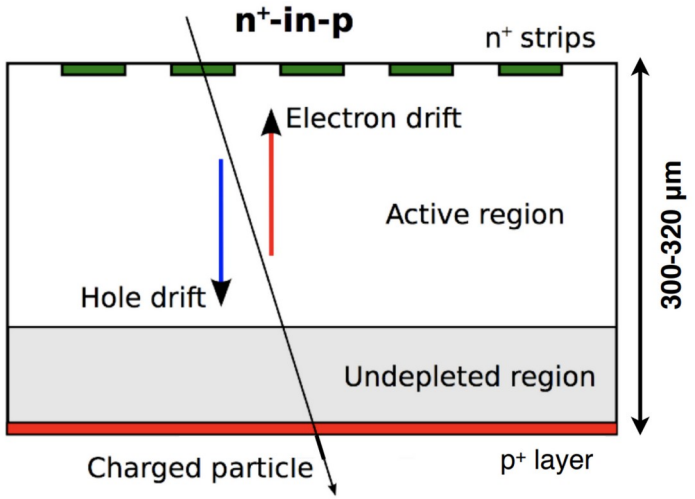
and electrical testing

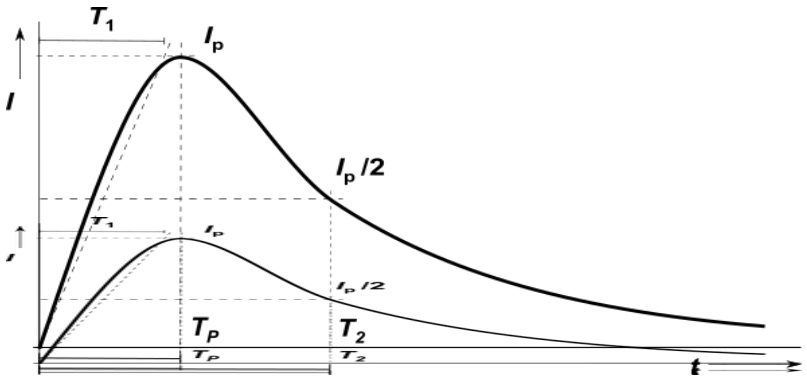




Readout principle

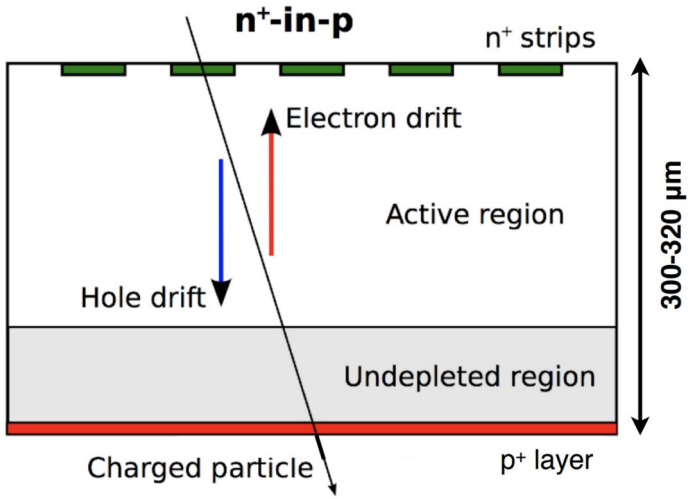
and electrical testing

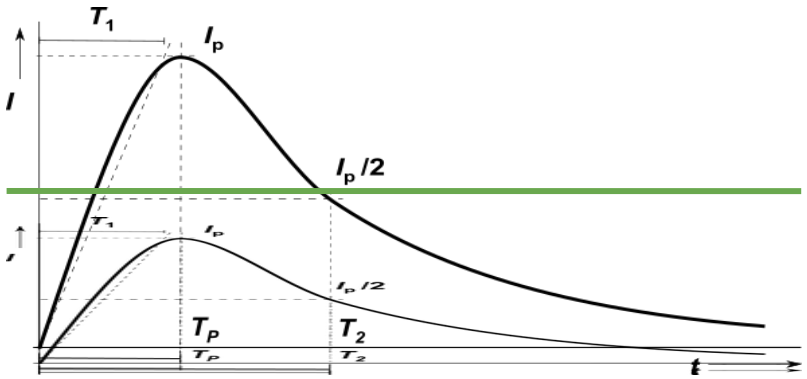




Readout principle

and electrical testing





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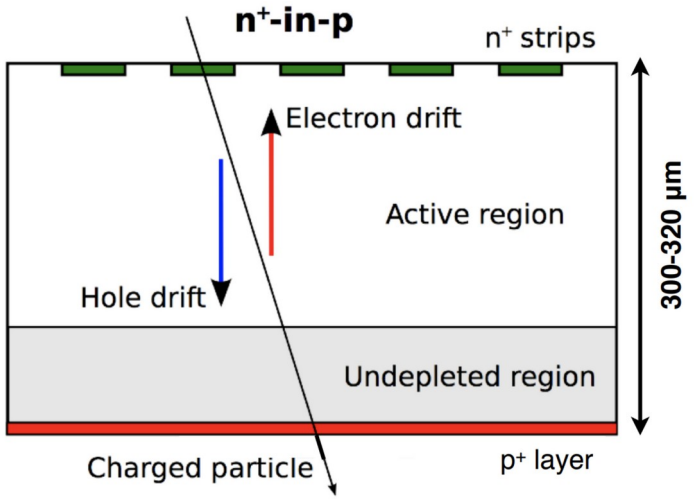
Readout principle

and electrical testing



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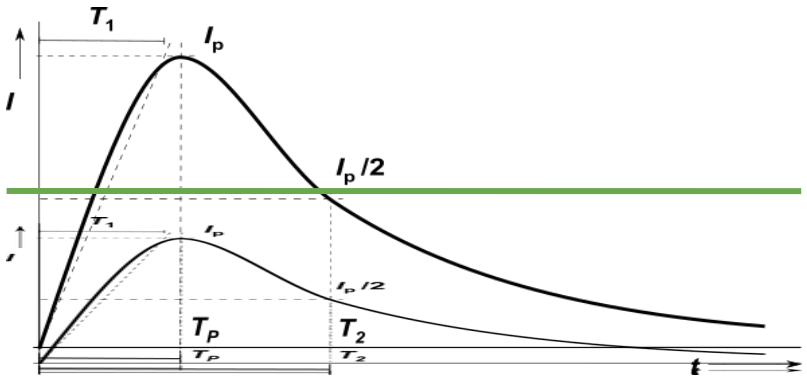

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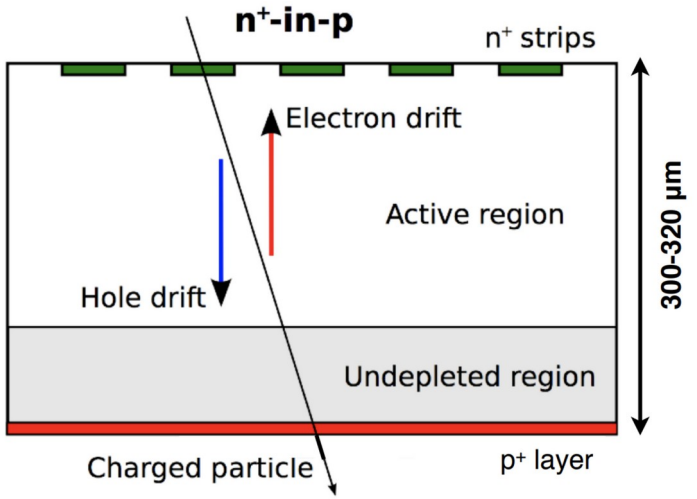
Readout principle

and electrical testing



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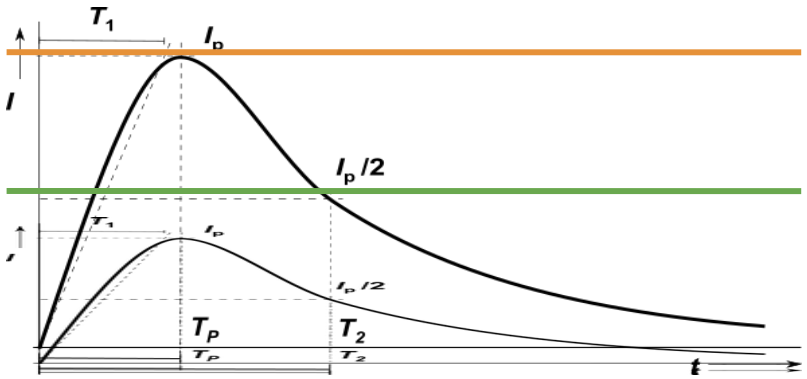

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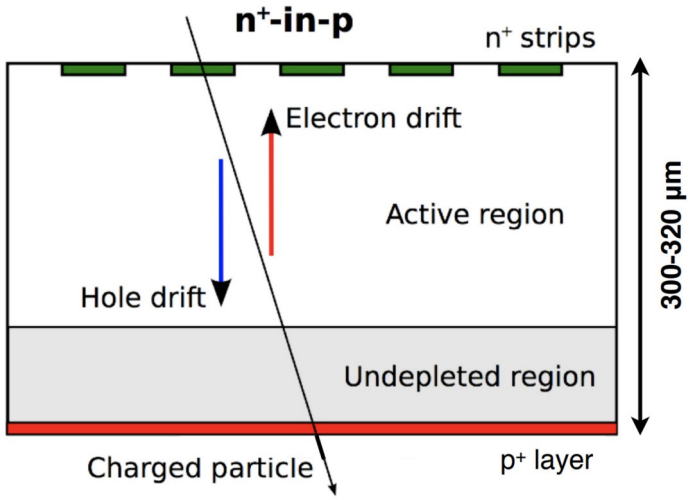
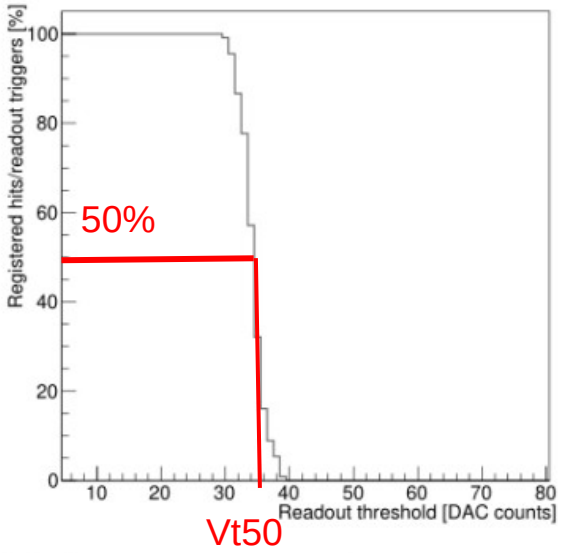
Readout principle

and electrical testing





(a) S-curve obtained from a threshold scan of a readout channel.

0

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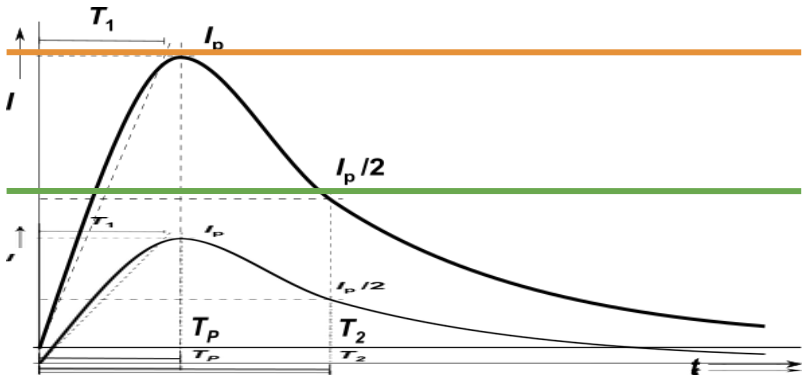
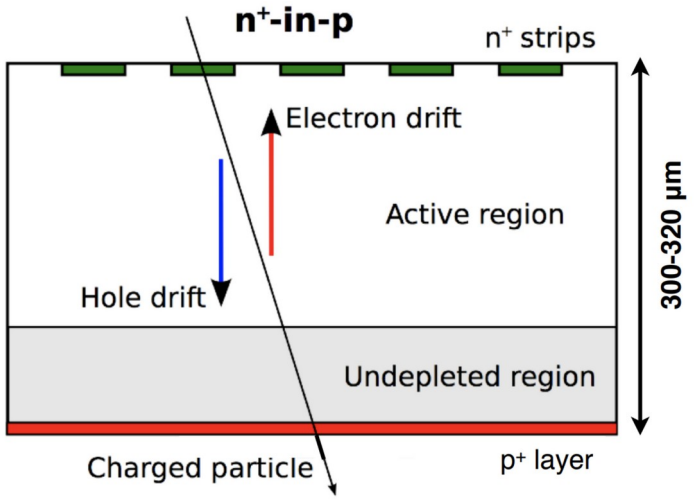
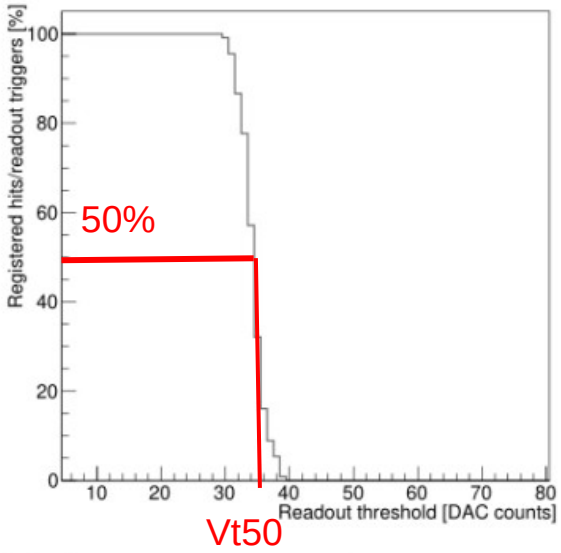
1

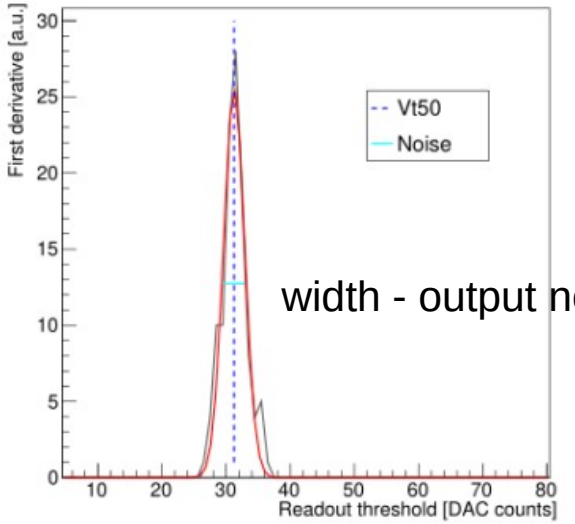


Readout principle

and electrical testing







width - output noise

(a) S-curve obtained from a threshold scan of a readout channel.

(b) First derivative of an S-curve with Vt50 and noise.

0

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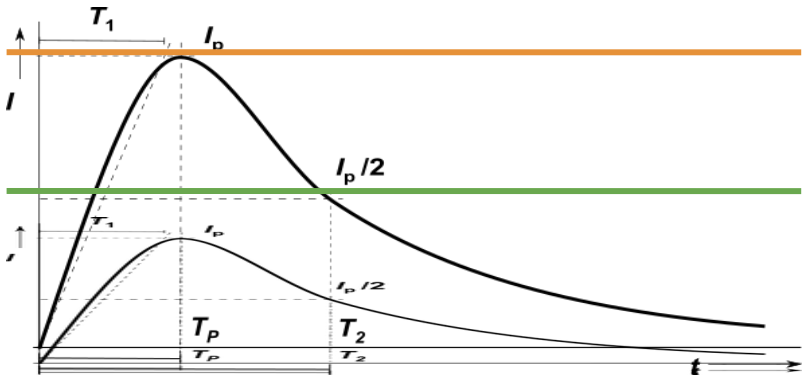
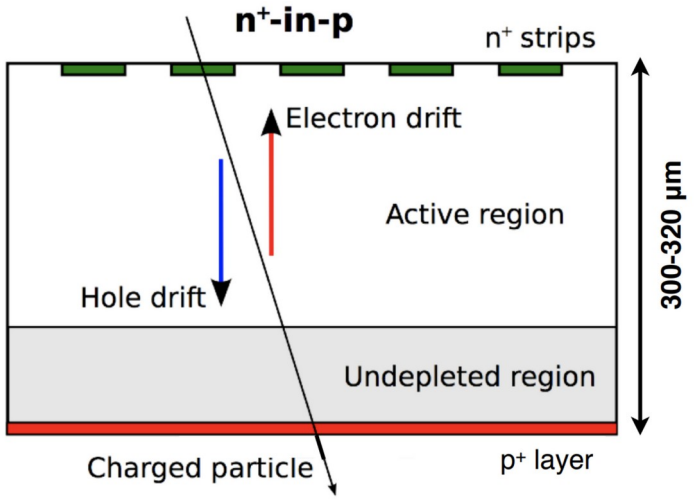
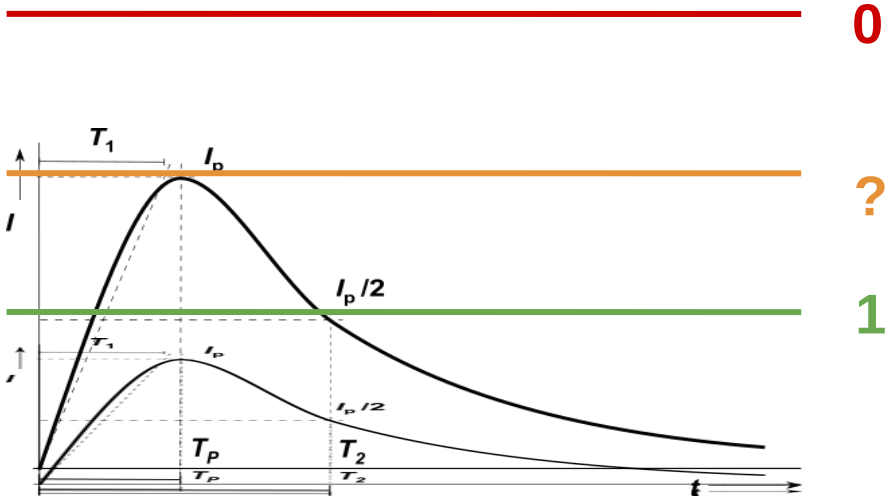


Readout principle

and electrical testing





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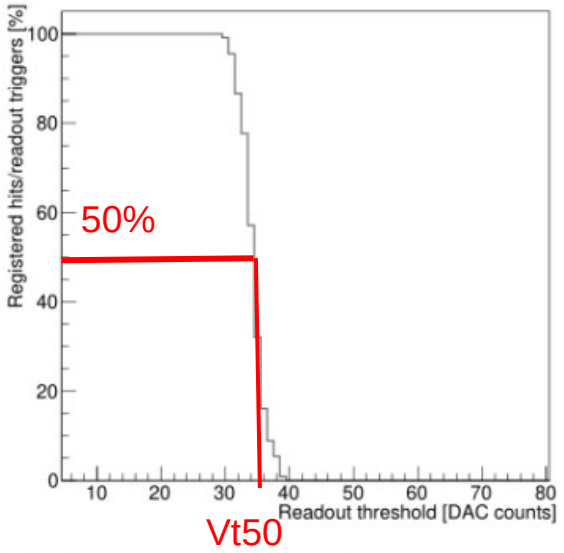
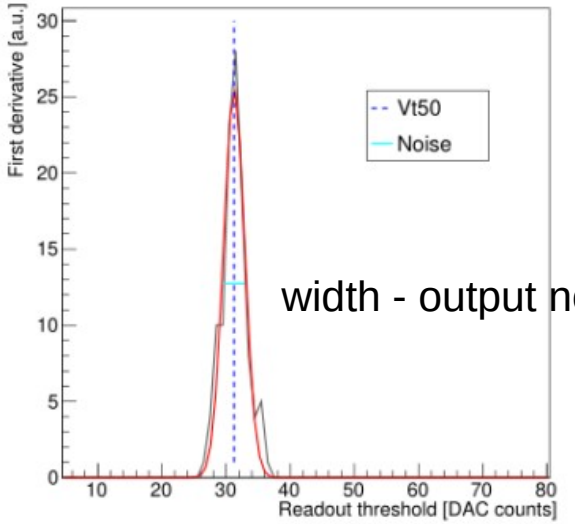
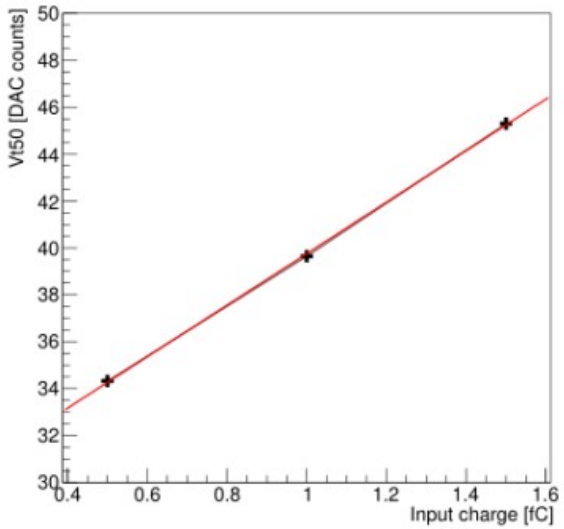




width - output noise

(a) S-curve obtained from a threshold scan of a readout channel.

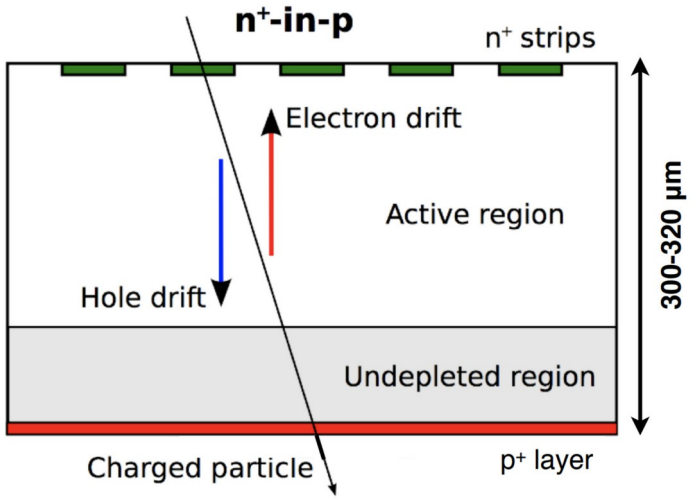
(b) First derivative of an S-curve with Vt50 and noise.

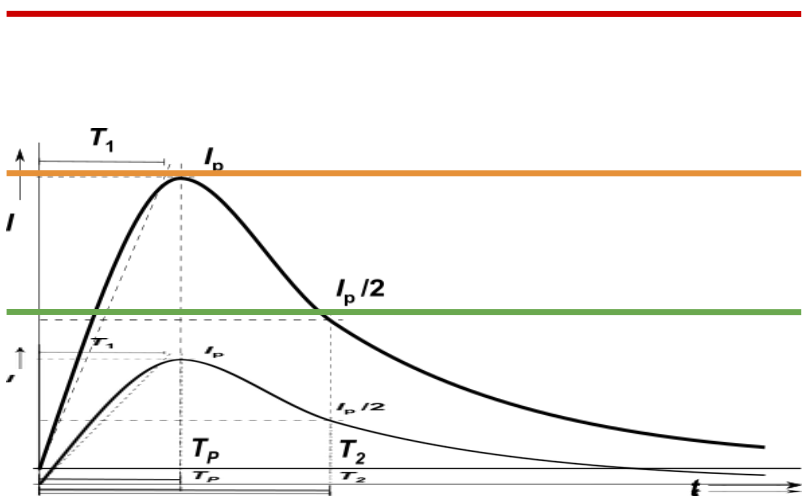


(c) Gain of individual readout channel from Vt50 measurements.

Readout principle

and electrical testing





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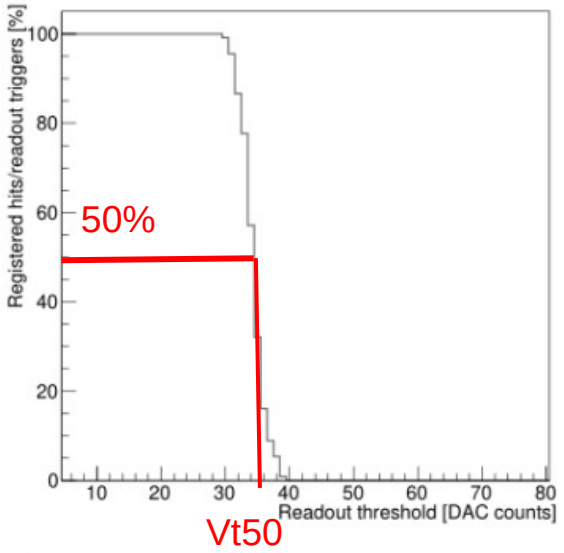

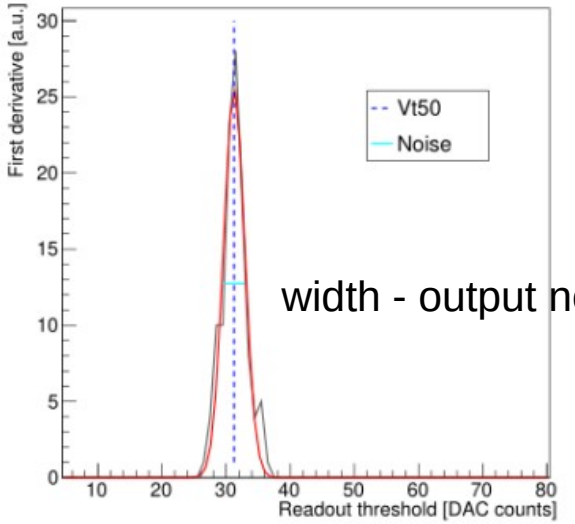

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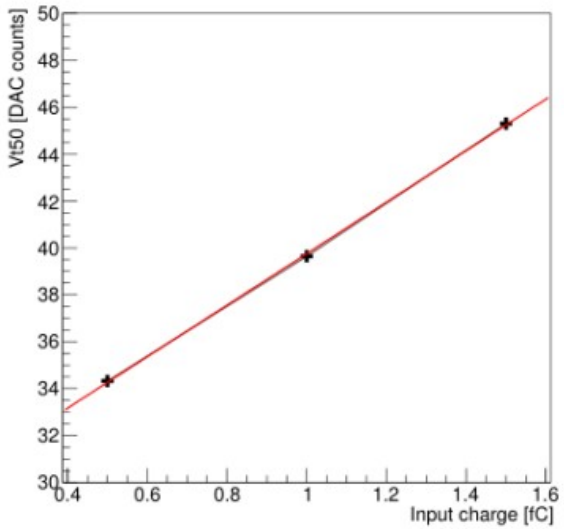
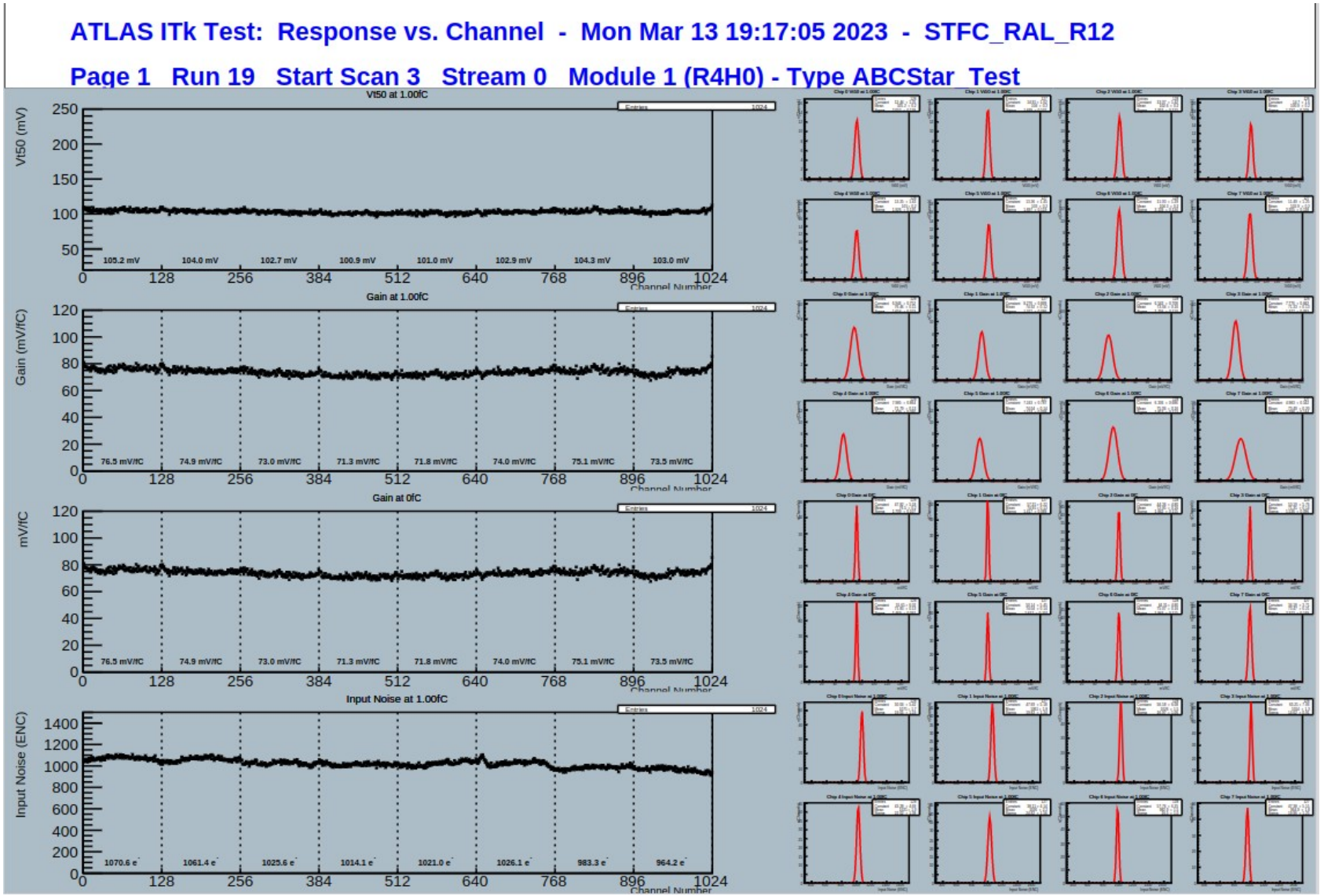


(c) Gain of individual readout channel from Vt50 measurements.

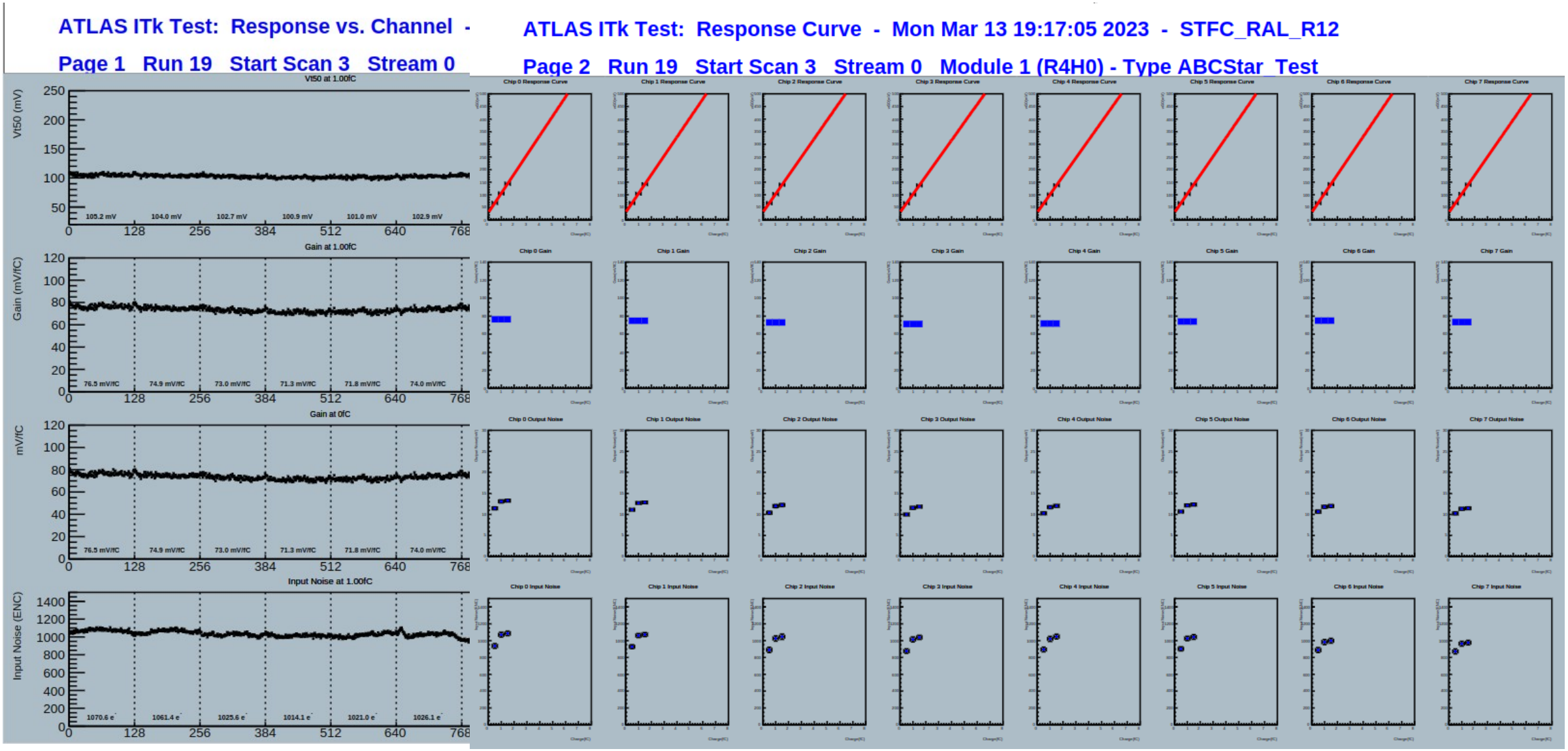
$$InputNoise[fC] = \frac{OutputNoise[mV]}{Gain[mV/fC]}$$

Test results example

Test results example

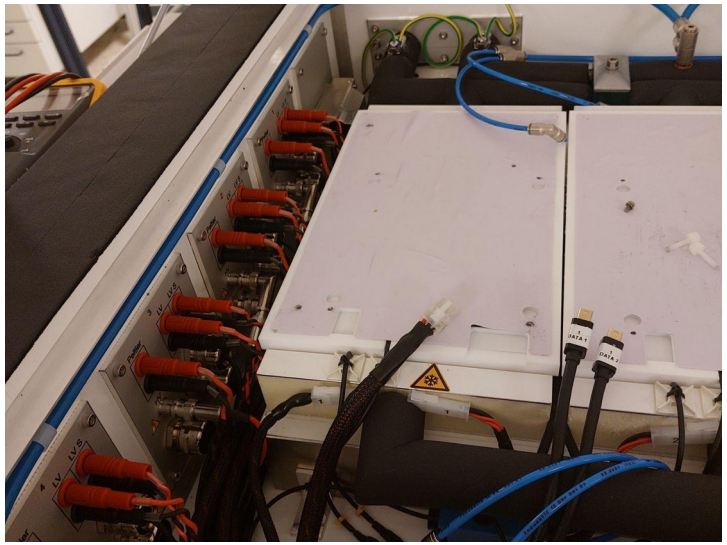


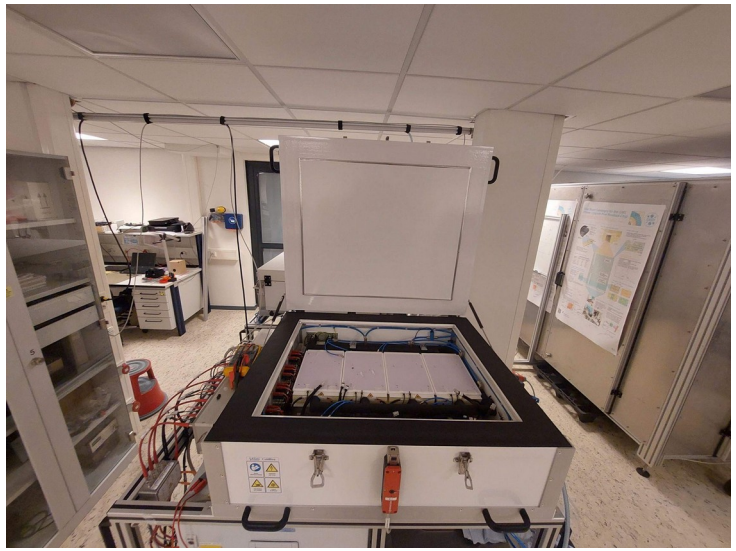
Test results example

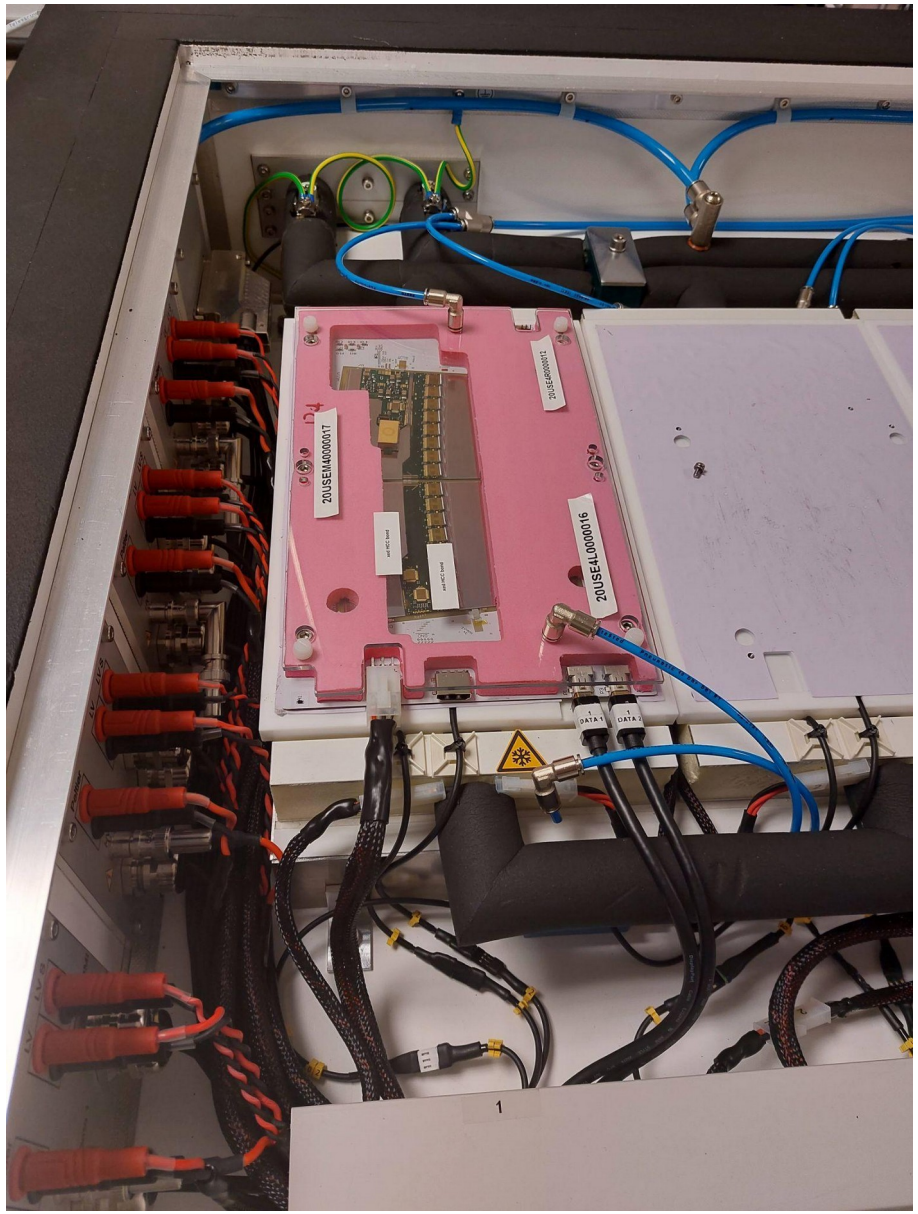


Module thermal cycling

Setup







Module thermal cycling

Coldbox is used to perform thermal and electrical module testing.

Hamburg solution specific due to PLC

Cold box GUI

Coldjiglib
(thermal cycling software)

Influx Database
(real-time database)

ITSDAQ
(module testing software)

Voltage steering

Running module tests

Reporting results

Coldbox + PLC
(programmable logic controller)

Voltage control

LV power supply

HV power supply

Interlock

Temperature control

Chiller

Peltier elements
(Cooled metal plates)

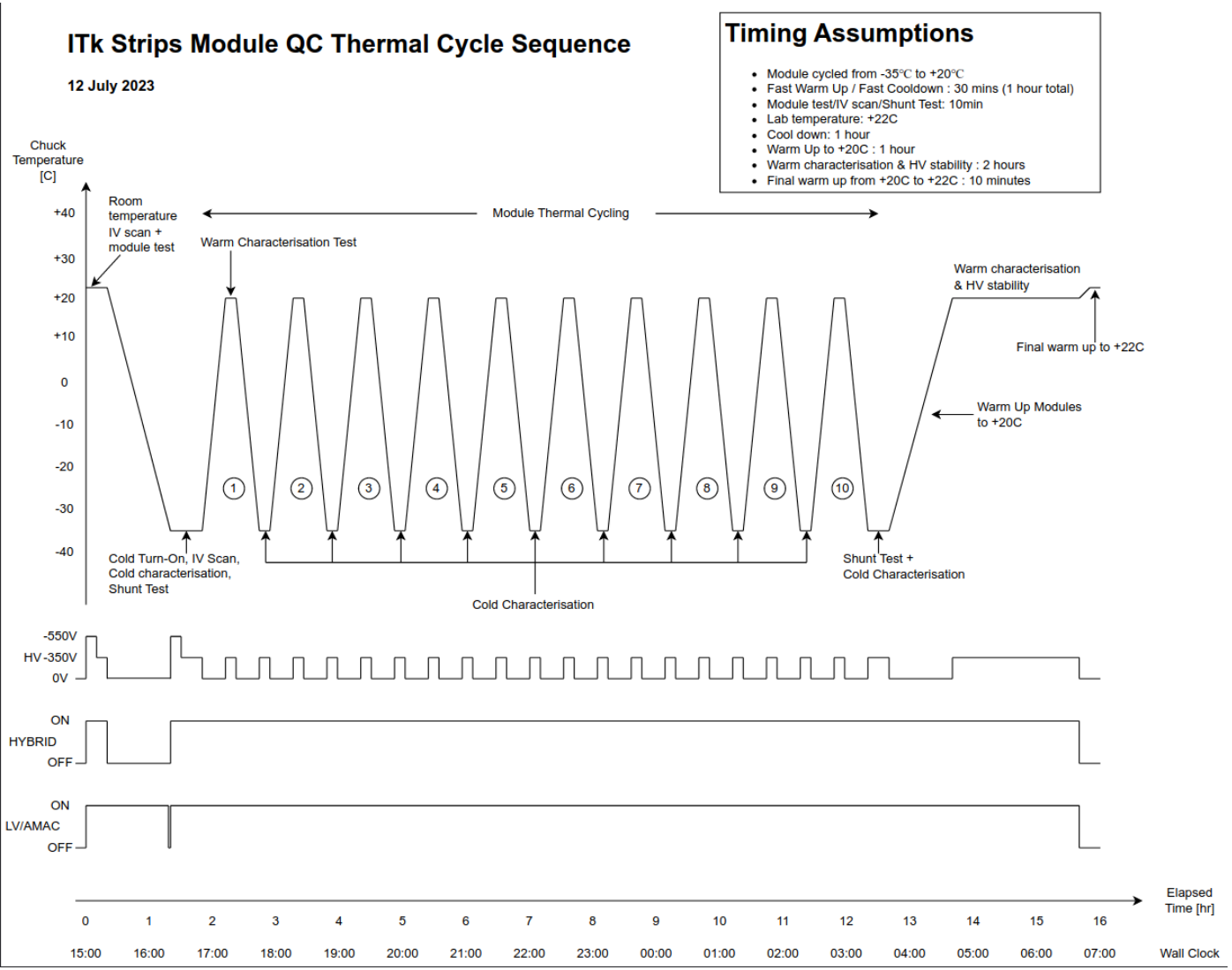
Temperature & Humidity sensors

HV steering for IV scans

Thermal cycling and electrical testing sequence

Thermal cycling

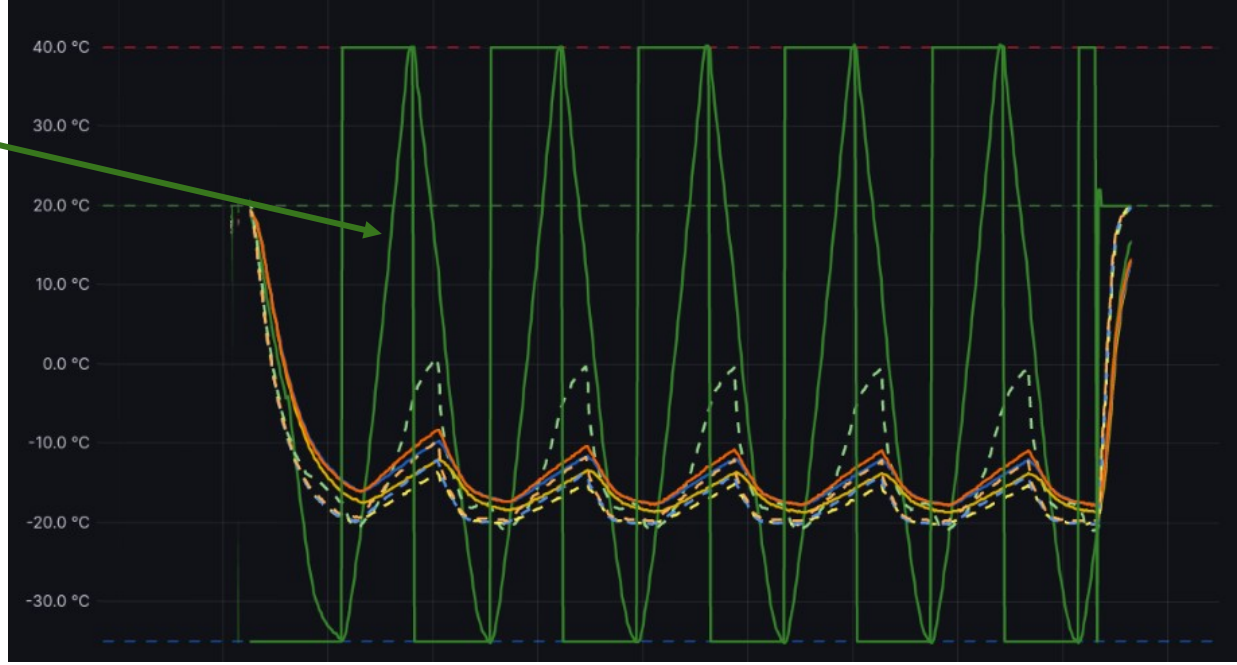
Status



Thermal cycling

Status

should look like this (close to linear temperature changes)

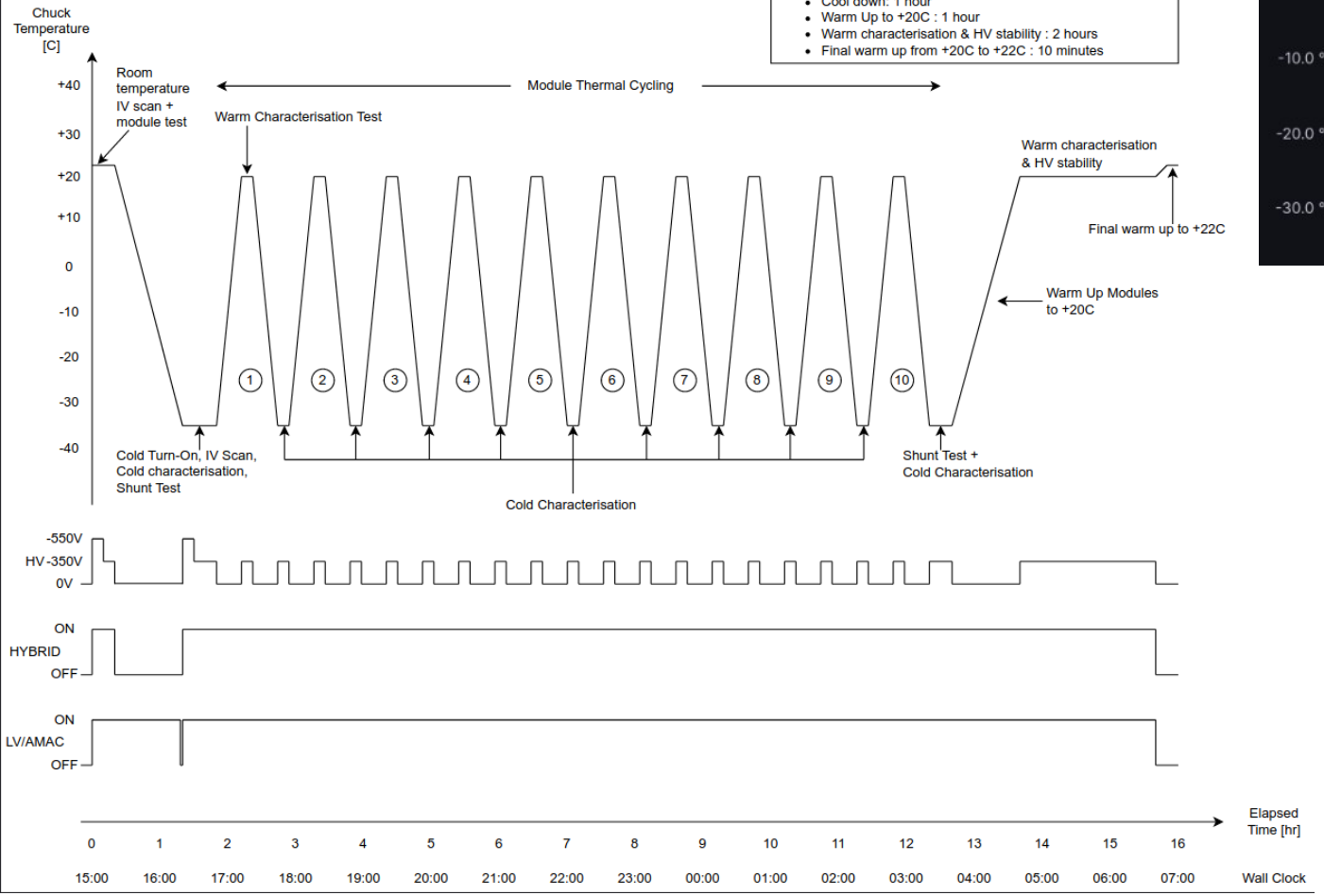


ITk Strips Module QC Thermal Cycle Sequence

12 July 2023

Timing Assumptions

- Module cycled from -35℃ to +20℃
- Fast Warm Up / Fast Cooldown : 30 mins (1 hour total)
- Module test/IV scan/Shunt Test: 10min
- Lab temperature: +22C
- Cool down: 1 hour
- Warm Up to +20C : 1 hour
- Warm characterisation & HV stability : 2 hours
- Final warm up from +20C to +22C : 10 minutes



Thermal cycling

Status

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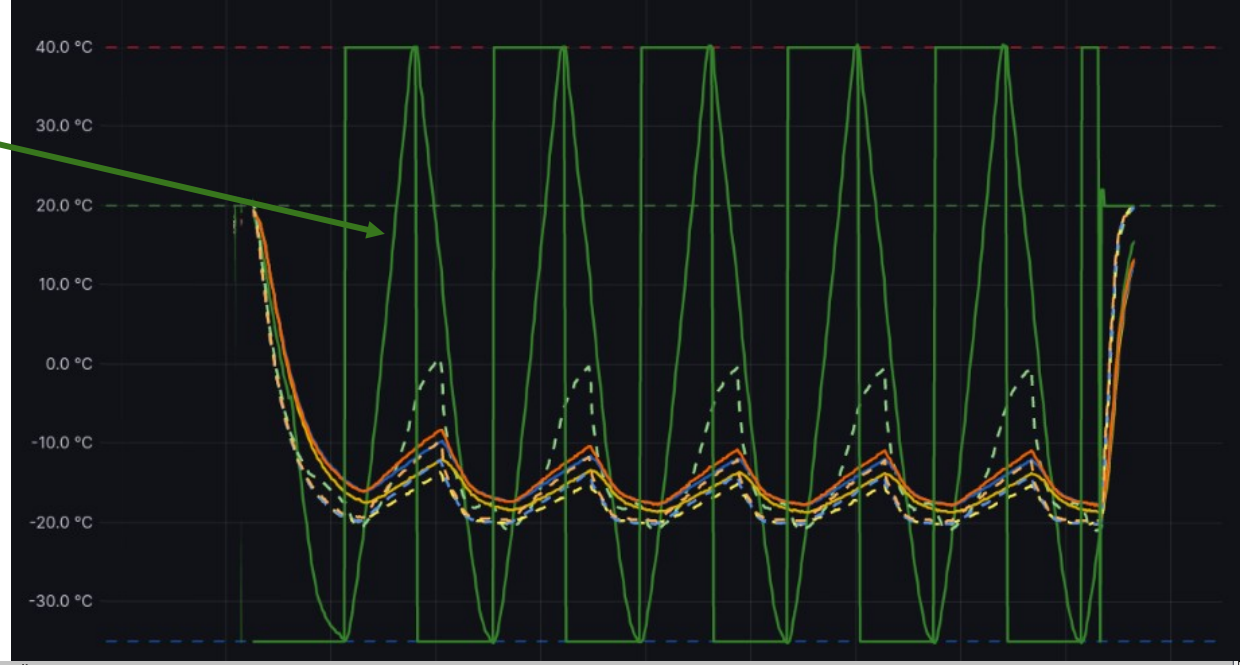

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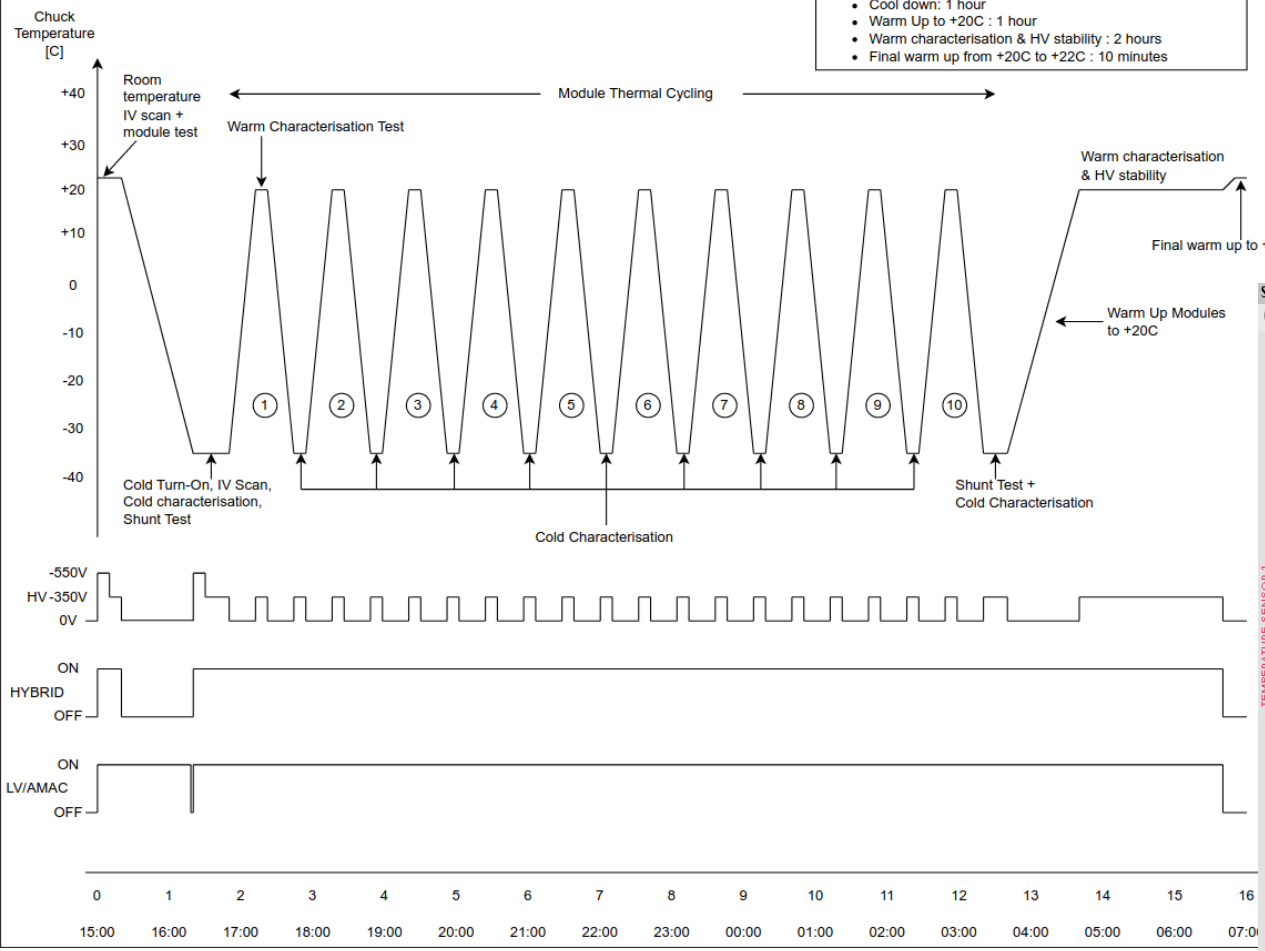
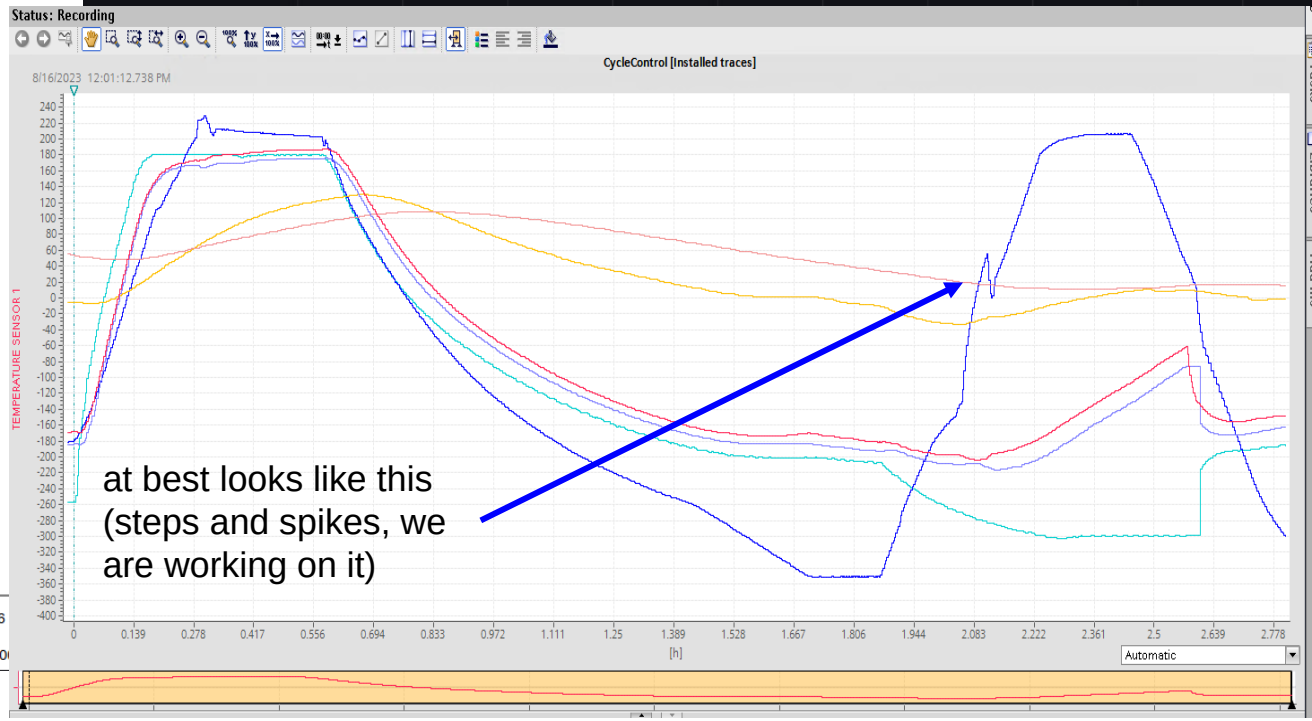




Thank you for your attention!

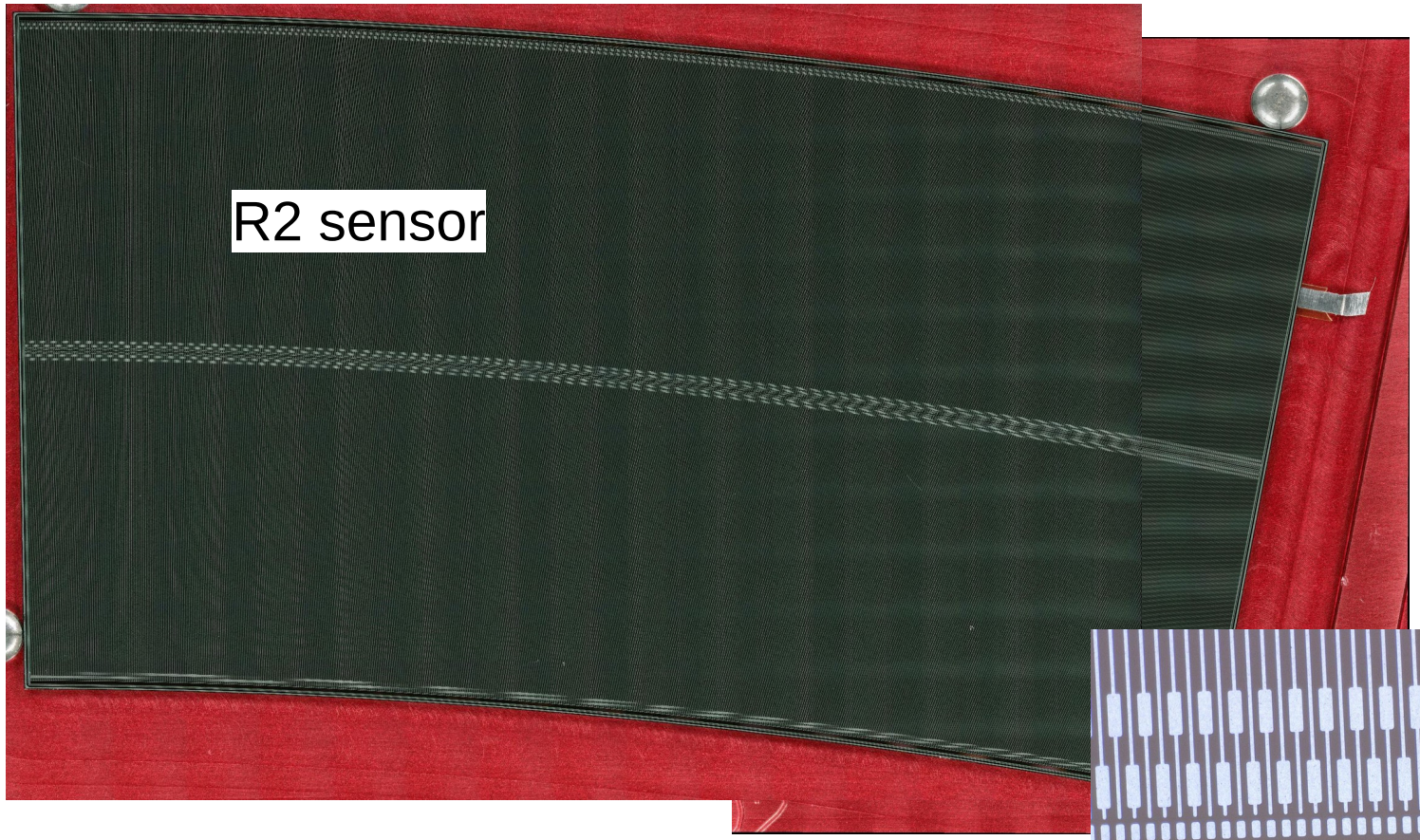
Backup

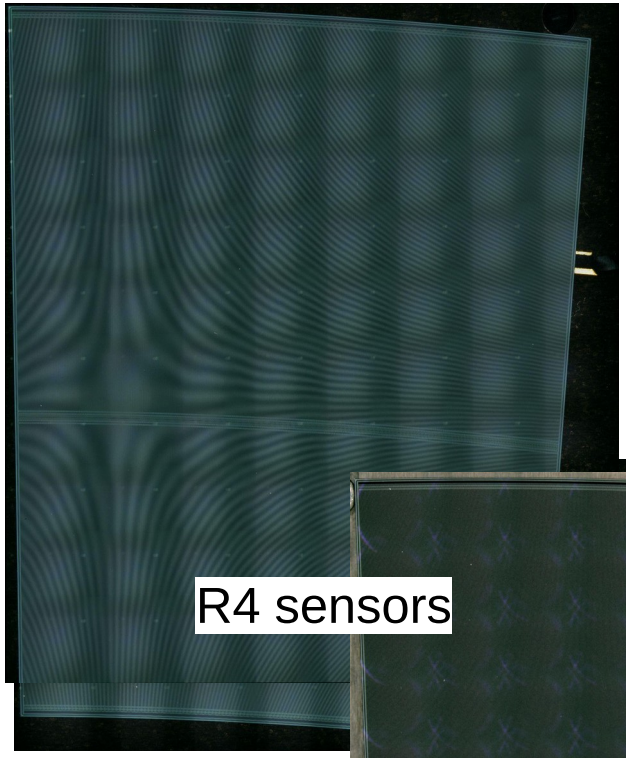
Sensor parameters

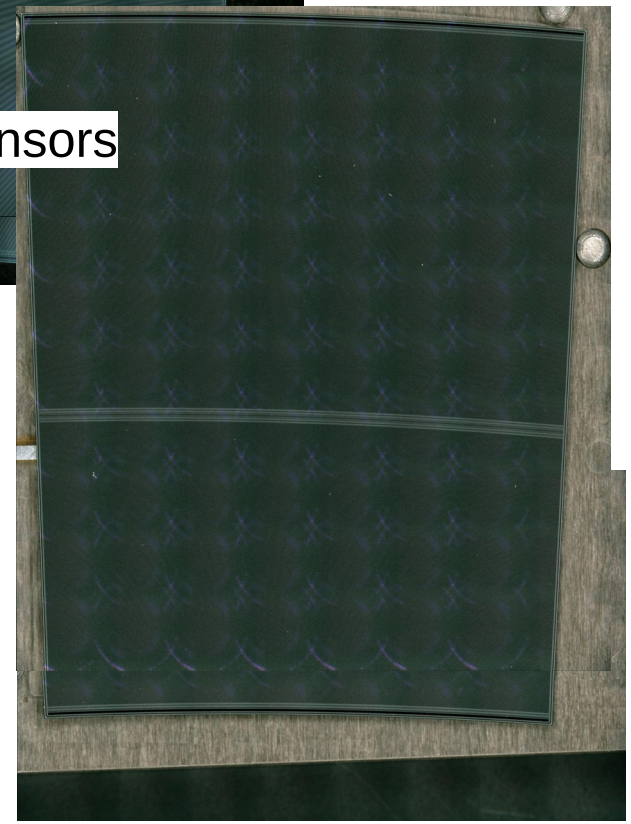
- 320 um thick
- n+ -in-p
- strip length varies from 1.5 to 6.0 cm

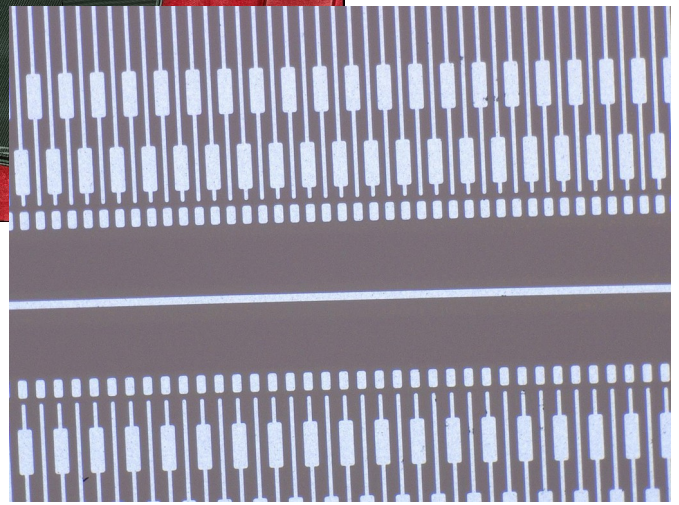
Introducing components: Sensors

Are used for detecting the particles



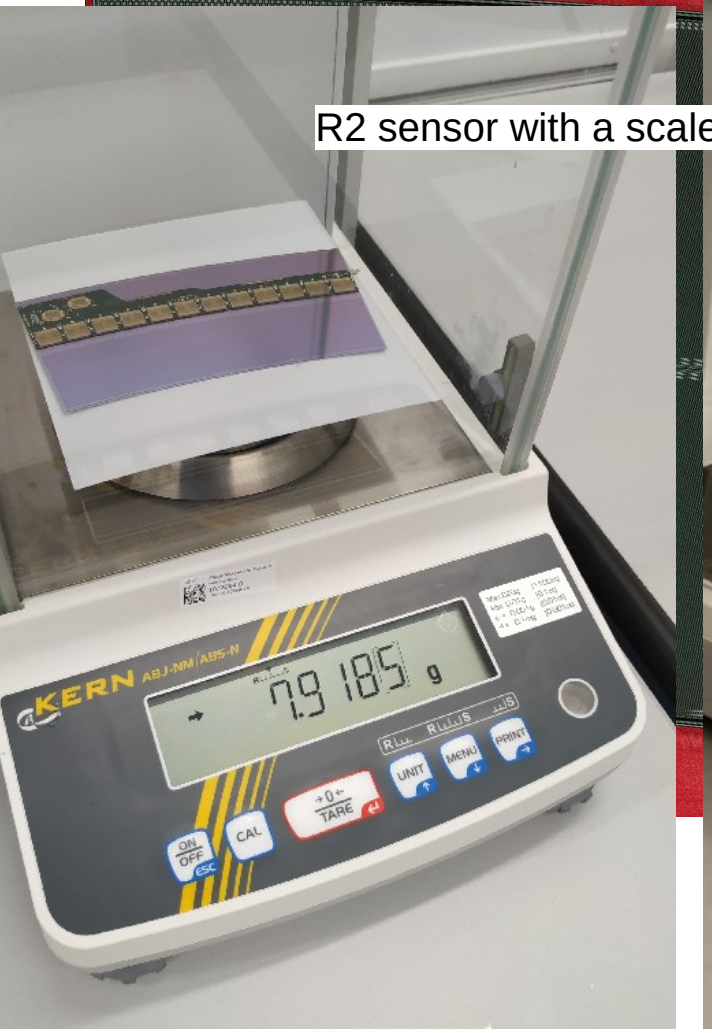




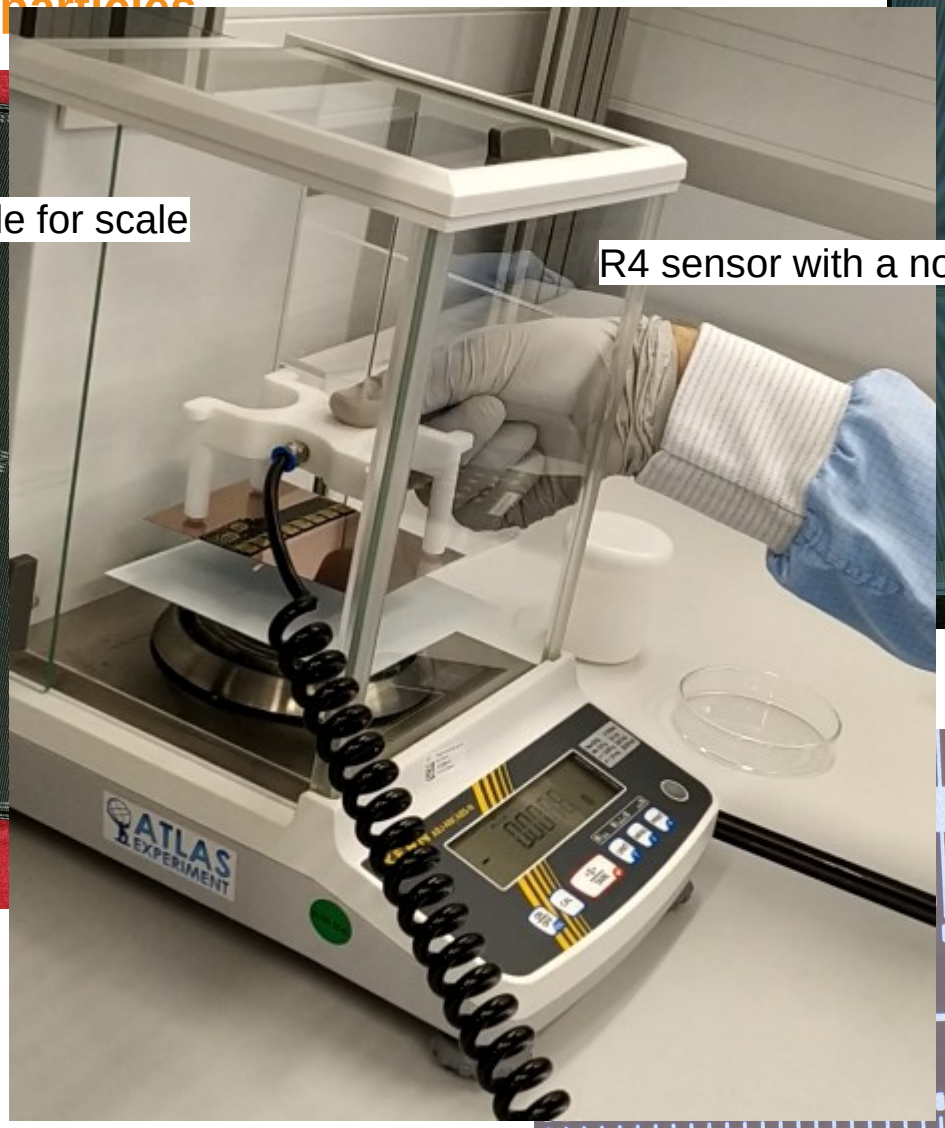


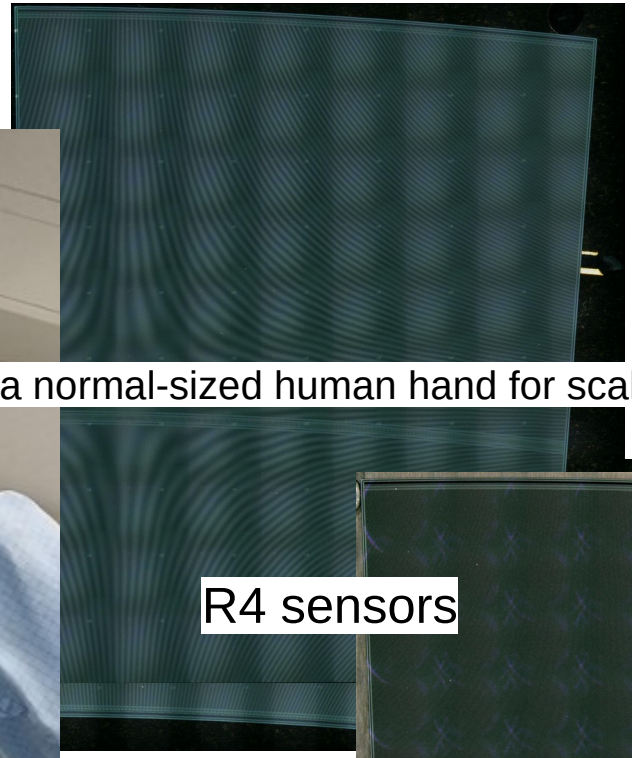
Introducing components: Sensors

Are used for detecting the particles

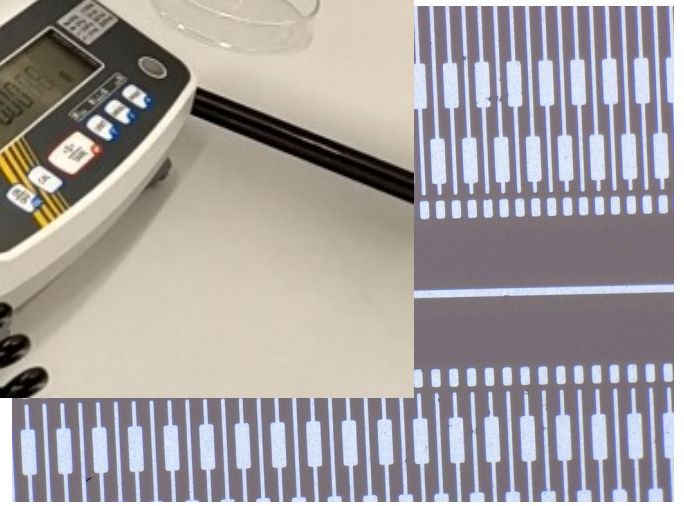


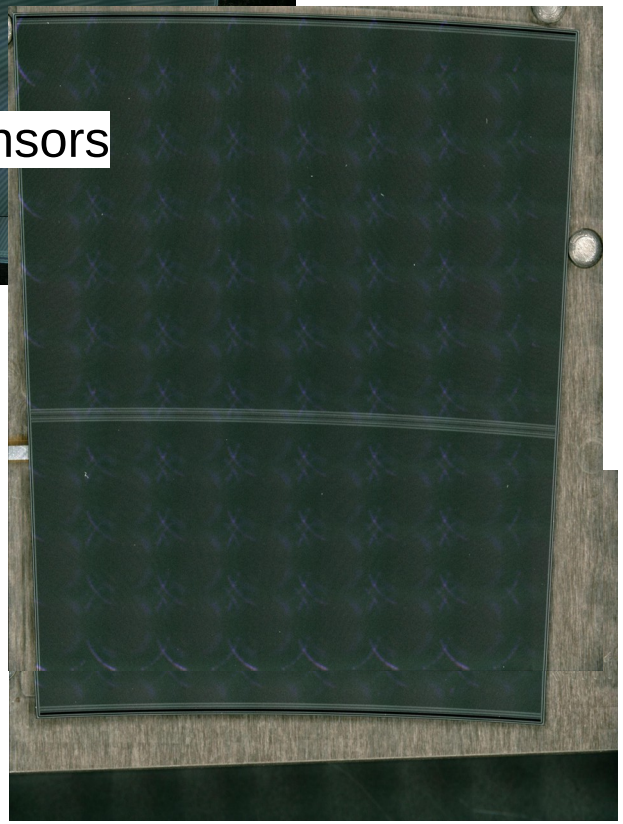
R2 sensor with a scale for scale





R4 sensor with a normal-sized human hand for scale

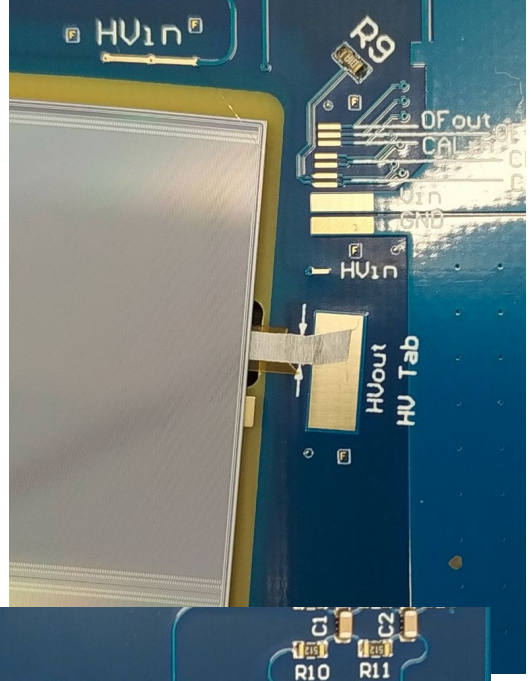


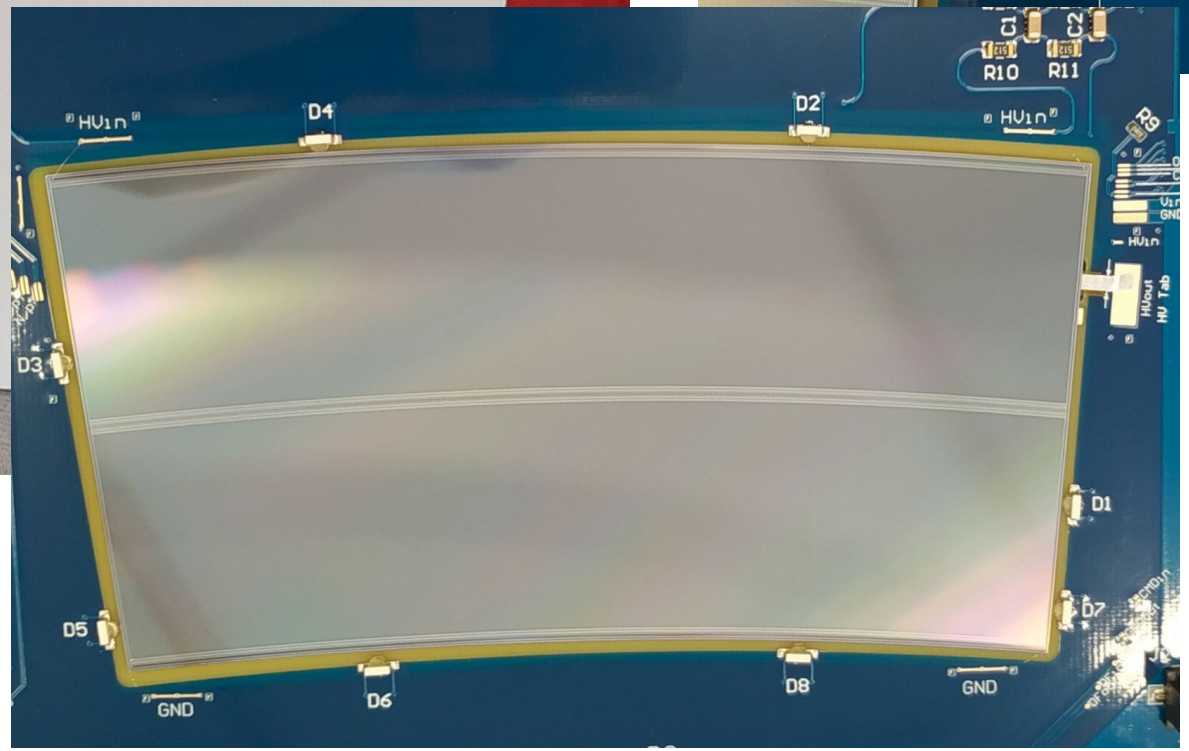


R4 sensors

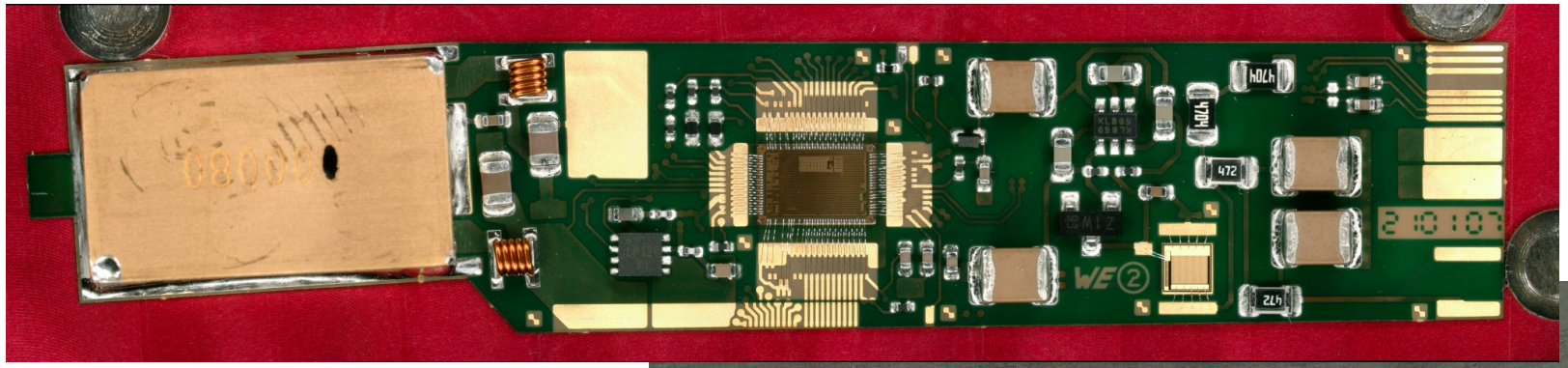
Introducing components: HV-tabs

Are used to supply high voltage to the sensor

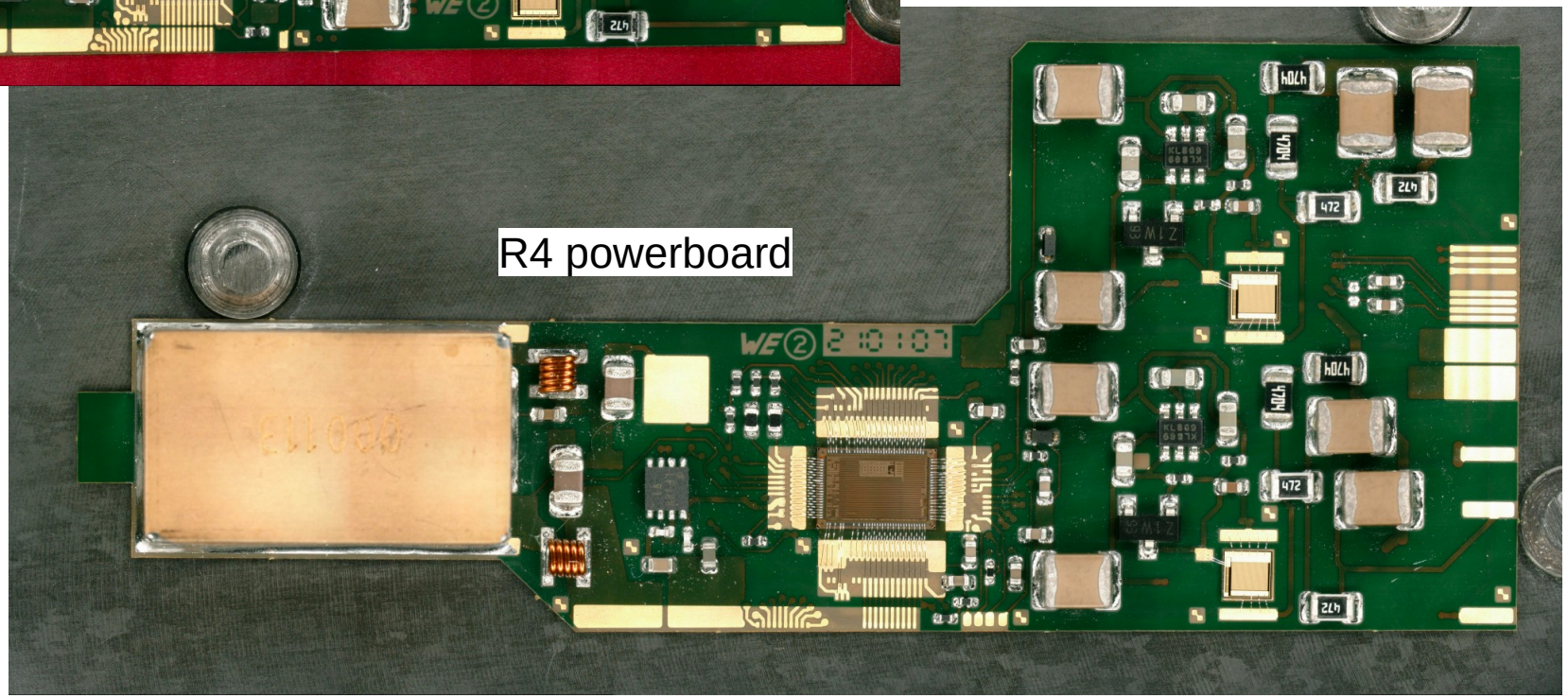




Introducing components: Powerboards

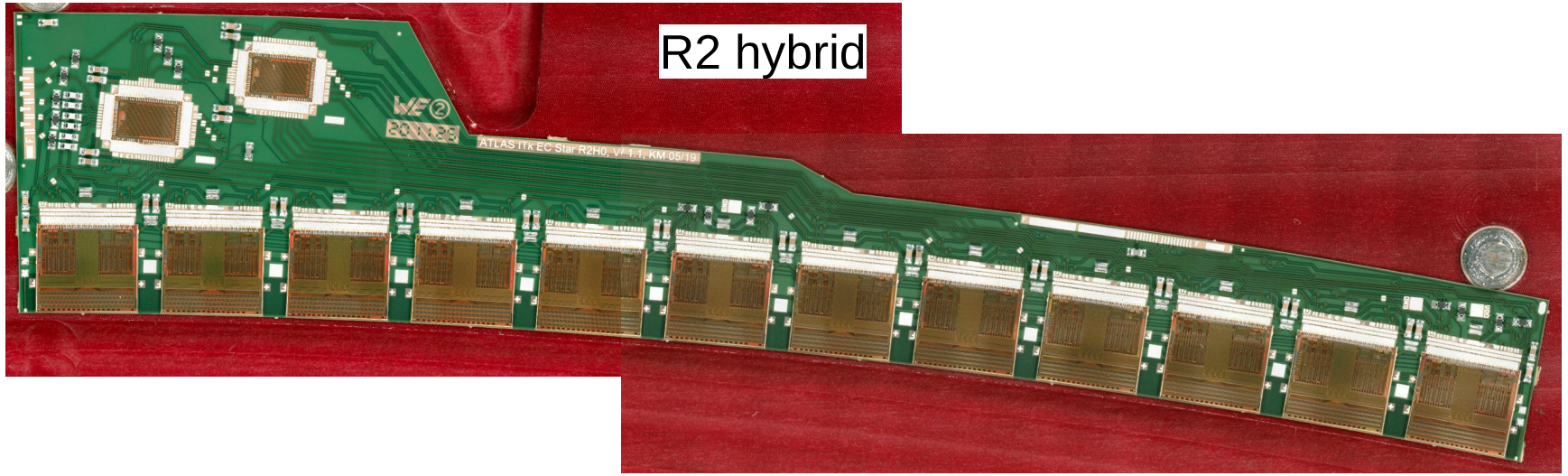


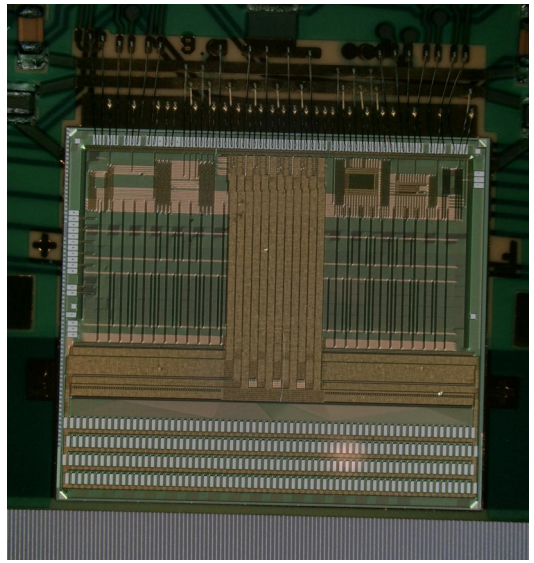
R2 powerboard

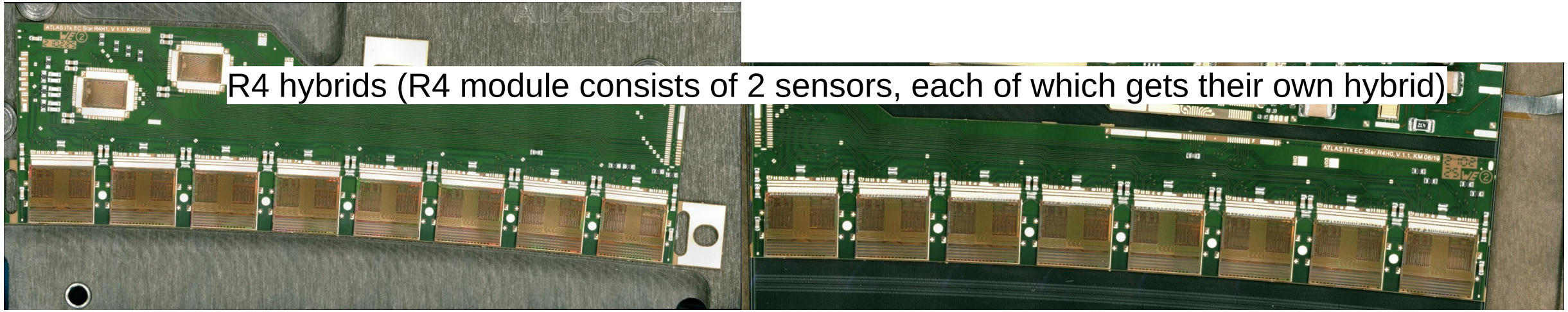


R4 powerboard

Introducing components: Hybrids

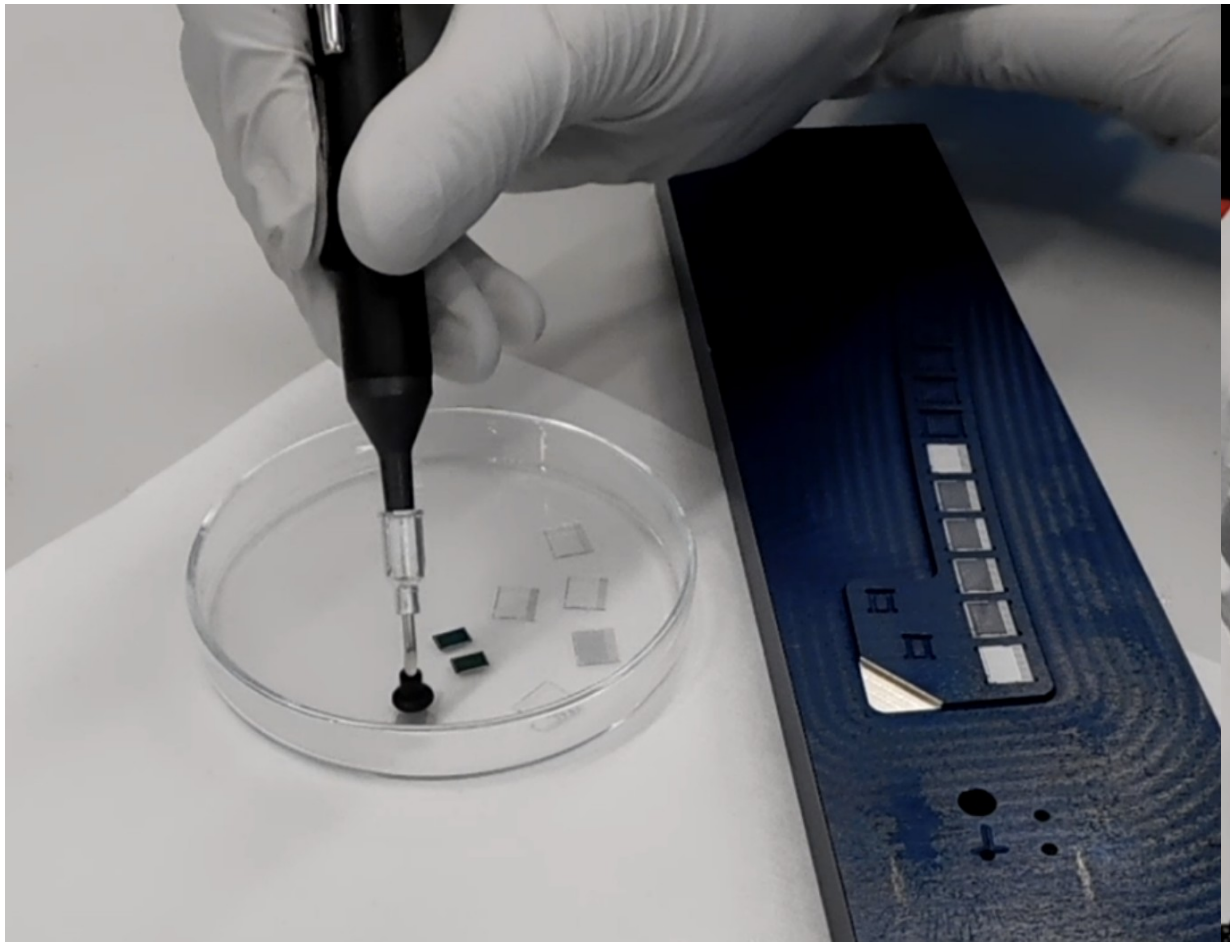


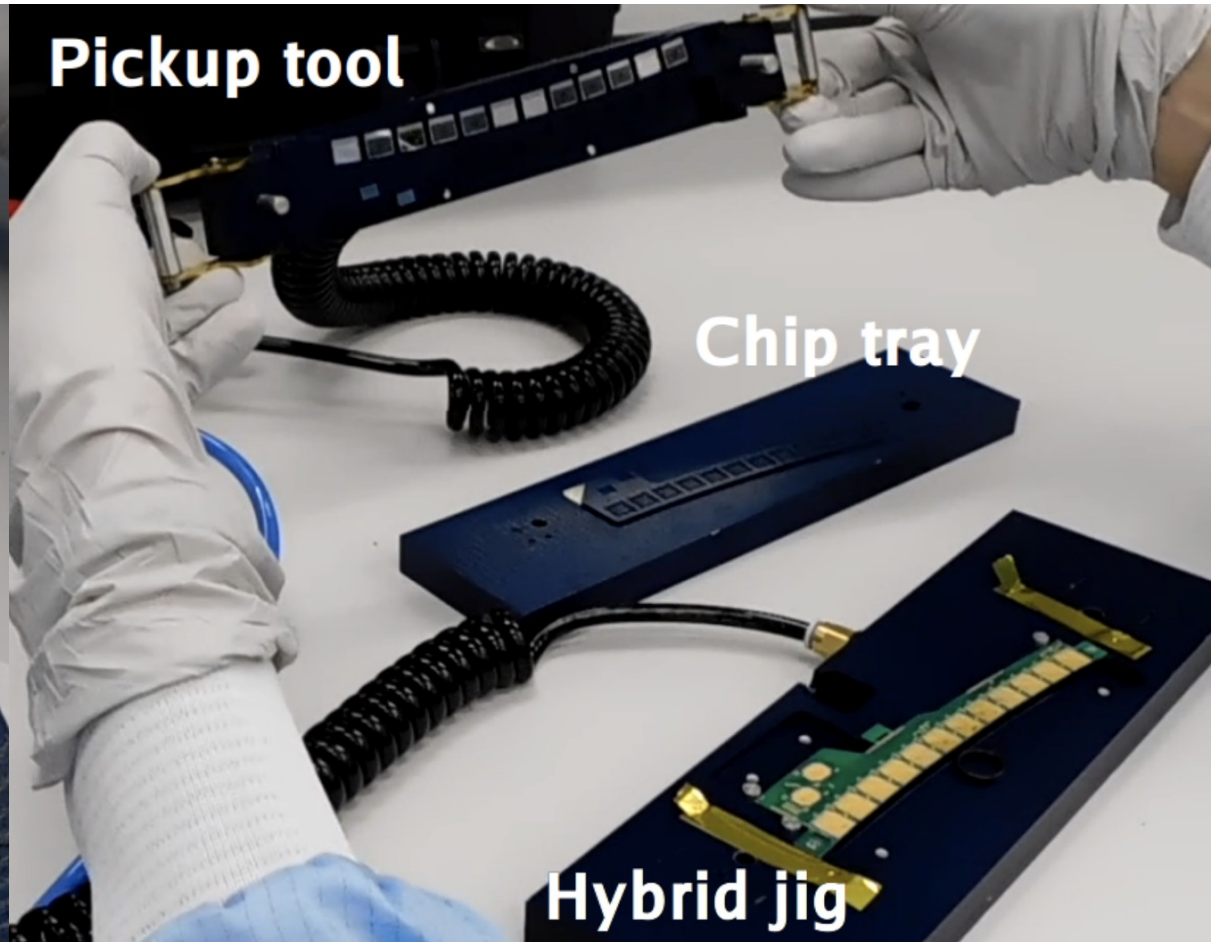




Hybrid assembly

DESY is a backup site for R2 and R4 hybrid assembly





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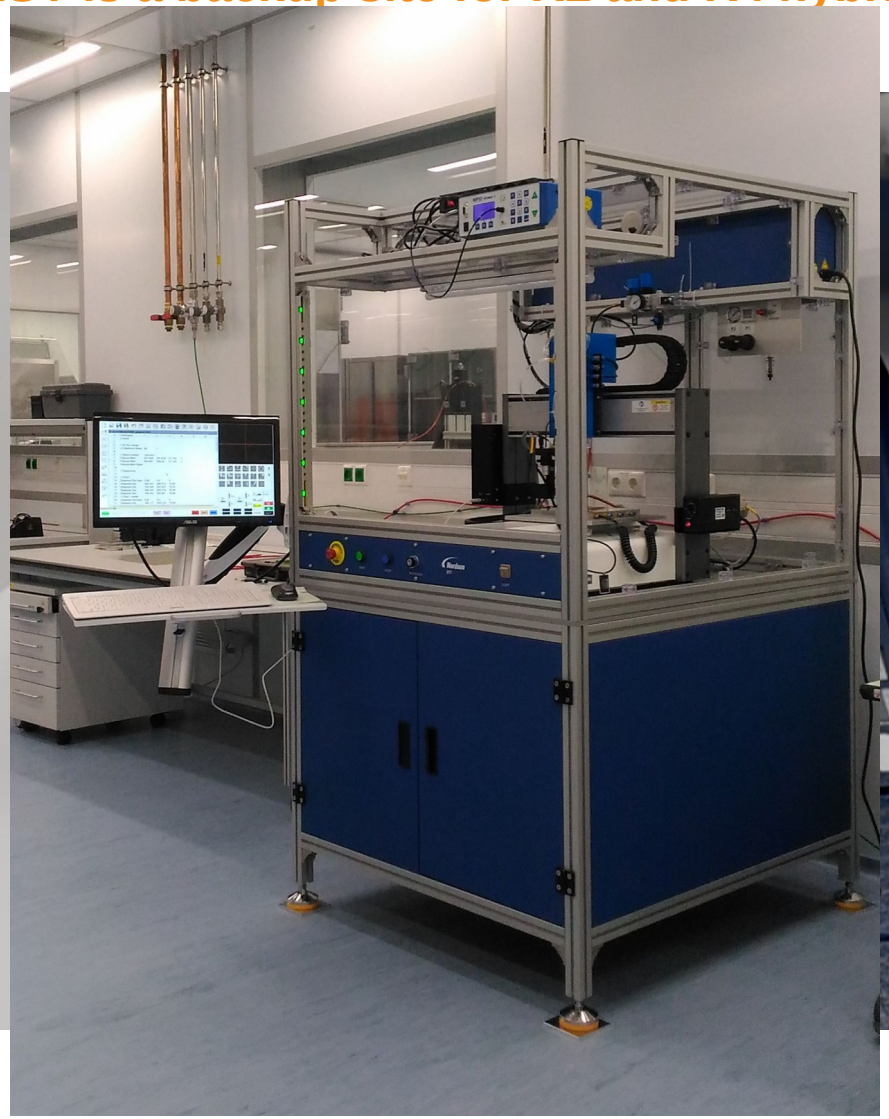

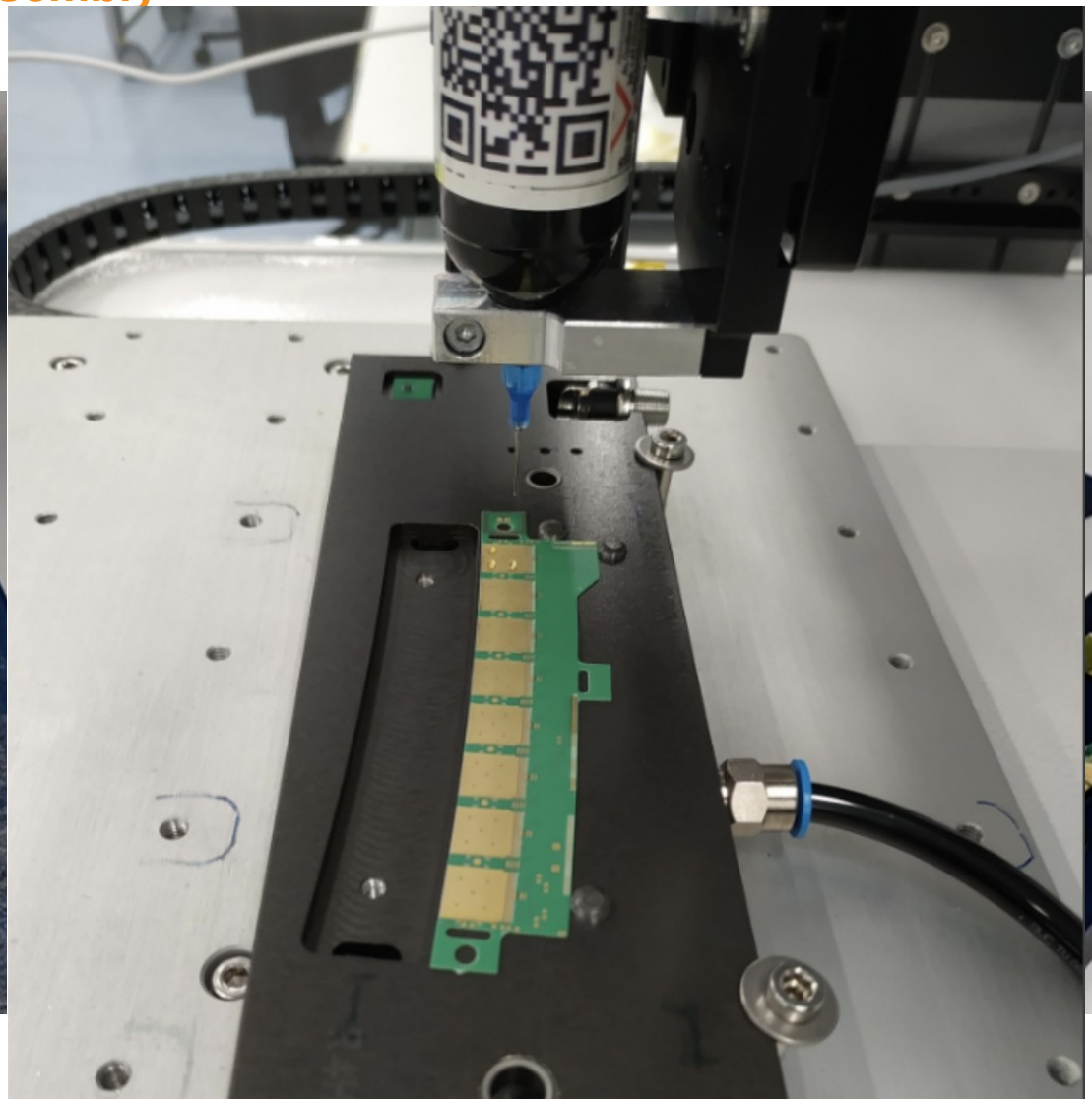

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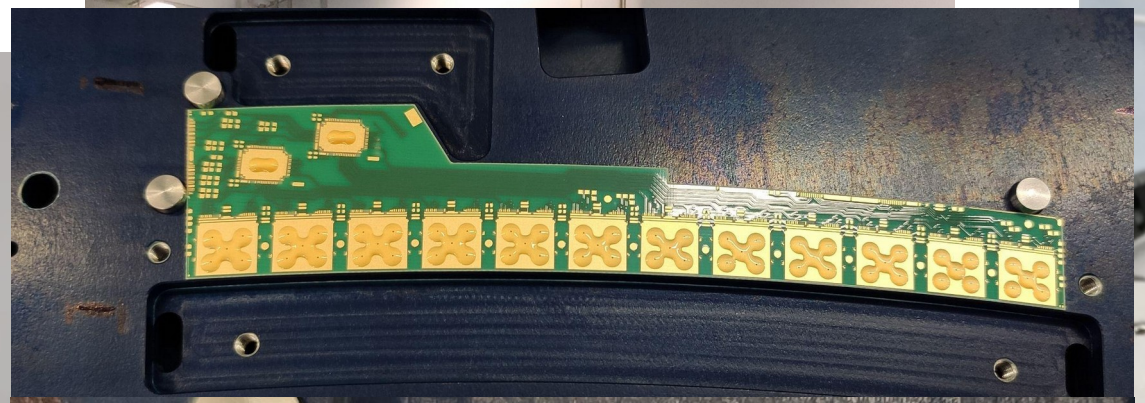
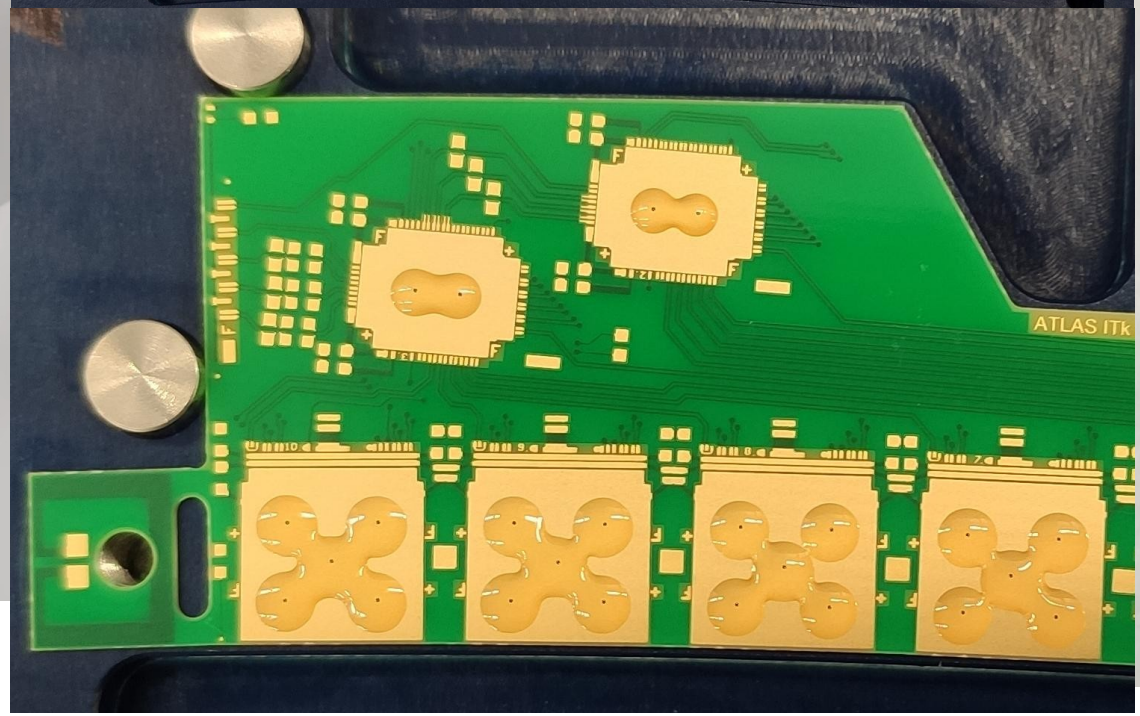




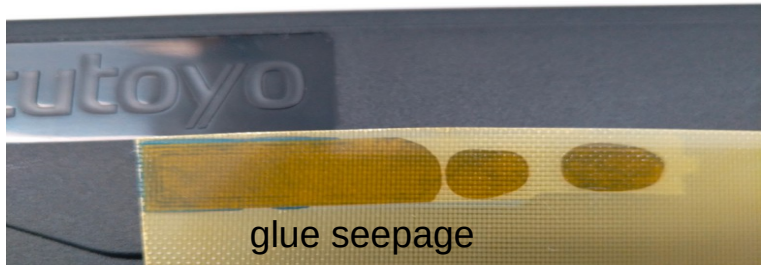
Troubles with establishing a glue pattern

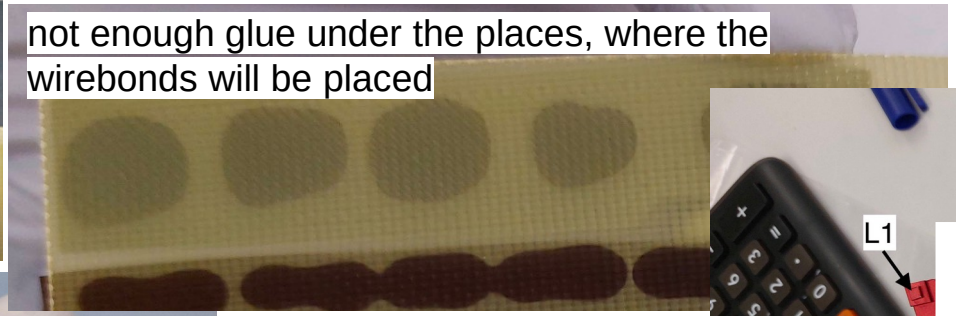
R2 powerboard as an illustration

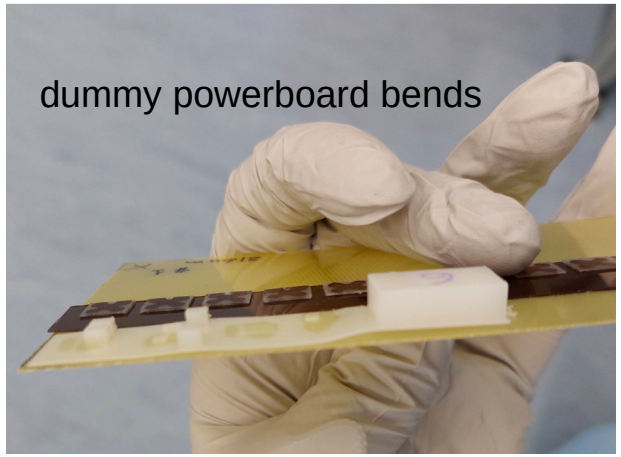
several times!

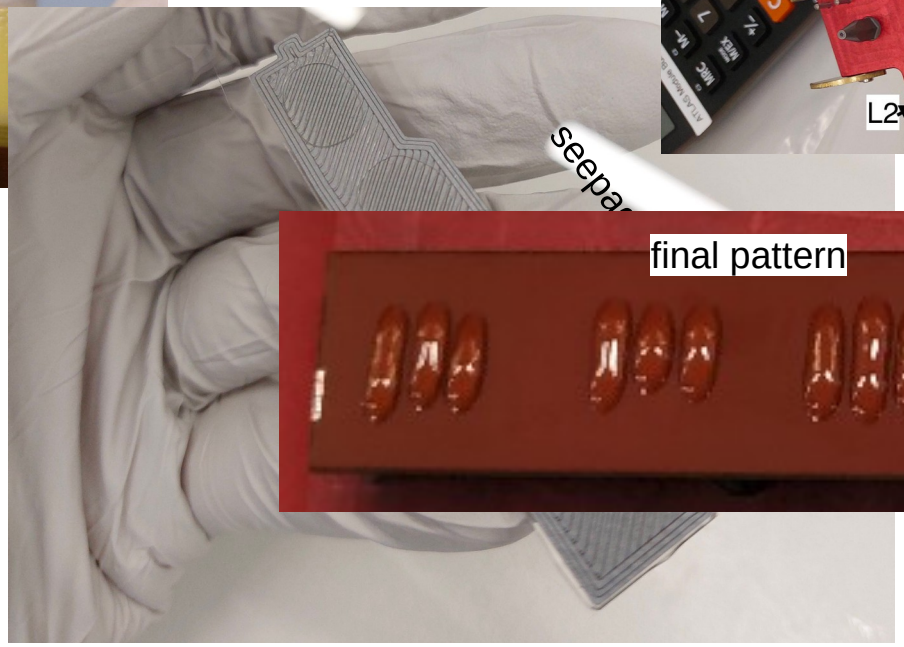
Troubles with establishing a glue pattern

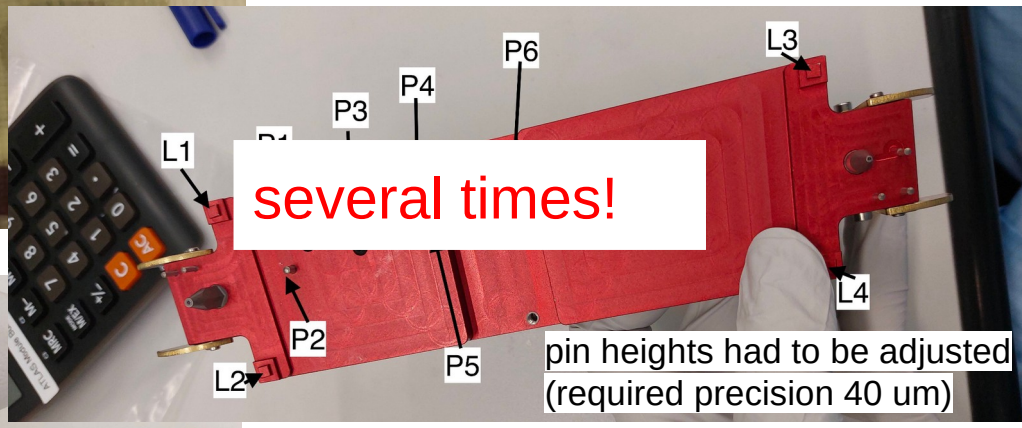
R2 powerboard as an illustration



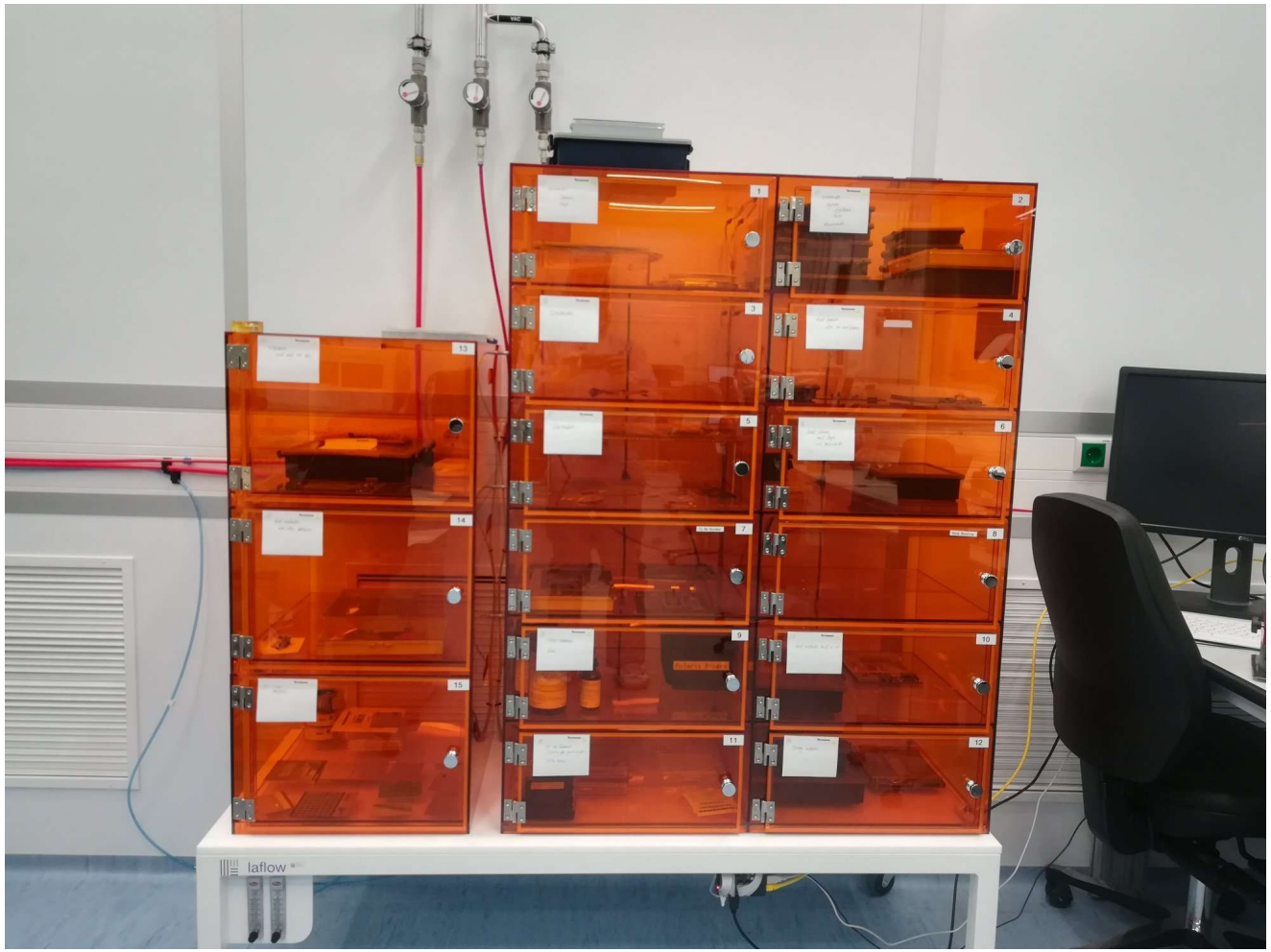




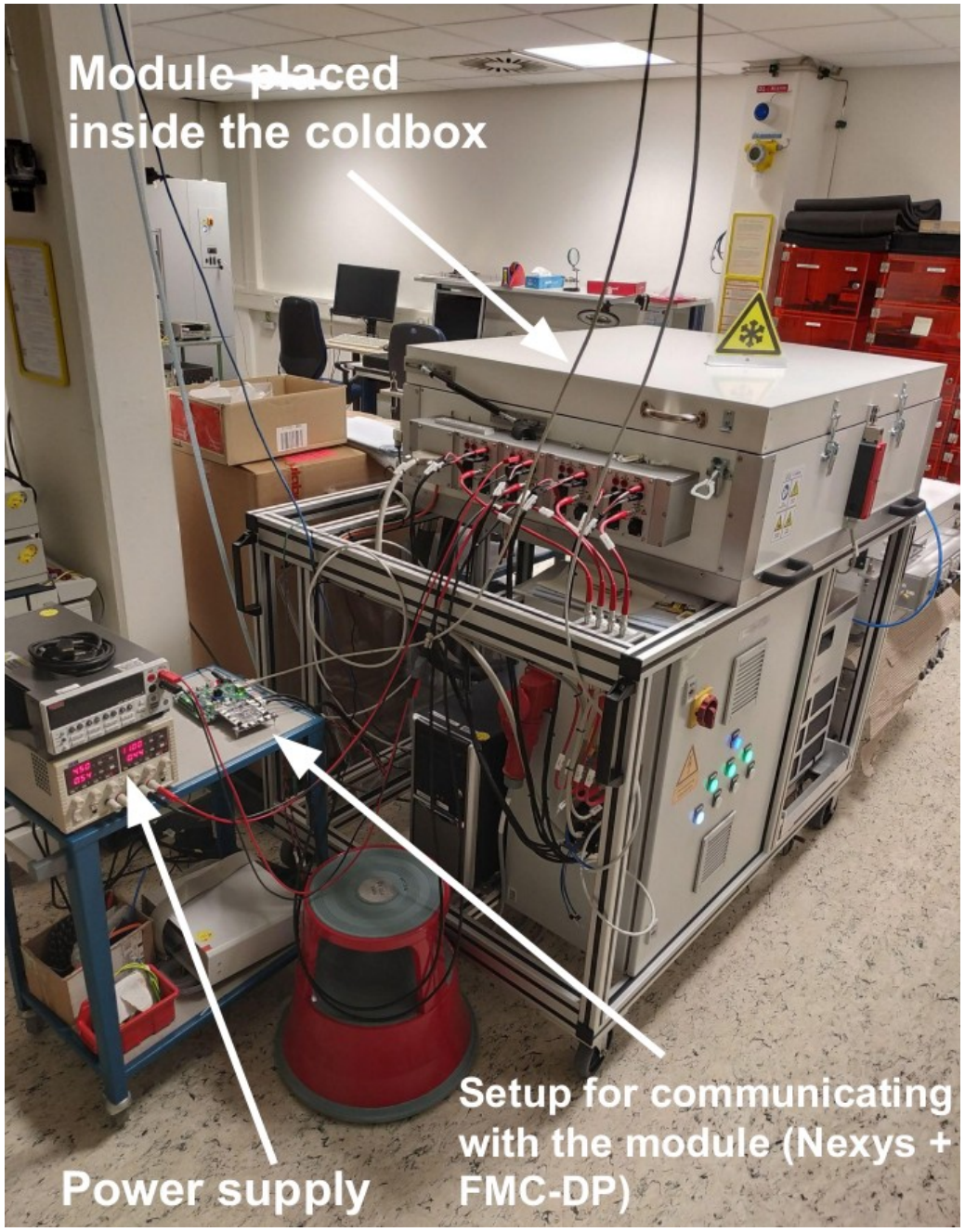




Module storage



Coldbox


Module placed
inside the coldbox
Power supply
Setup for communicating
with the module (Nexys +
FMC-DP)

Qualification progress

	Step Number	Qualification Step	Status	Ready for Review?	Review Status
HV Tab Attach	1.1	Bonding Procedures	Qualification Ready	Yes	Passed
Sensor Reception	3.1	Sensor Reception	Qualification Ready	Yes	Passed
	3.2	Sensor Storage	Qualification Ready	Yes	Passed
	3.3	Sensor I-V	Qualification Ready	Yes	Passed
PB Reception	6.1	PB Reception	Qualification Ready	Yes	Passed
	6.2	PB E tests	Requires Parts	No	Not Reviewed
	6.3	PB Vis Insp	Qualification Ready	Yes	Passed
	6.4	PB Storage	Qualification Ready	Yes	Passed
Hybrid Assembly/Testing	8.2	Storage + shipping of glue	Qualification Ready	Yes	Passed
	8.3	Assembling hybrids	Qualification Ready	Yes	Passed
	8.4	Glue weight measurements	Qualification Ready	Yes	Passed
	8.5	Bonding procedures: hybrids	Qualification Ready	Yes	Passed
	8.6	Metrology: hybrids	Qualification Ready	Yes	Passed
	8.7	Visual inspection: hybrids	Qualification Ready	Yes	Passed
	8.8	Hybrid Burn-In	Requires Parts	No	Not Reviewed
	8.10	Hybrid Storage	Qualification Ready	Yes	Passed
	8.11	hybrid QC: single panel testing	Qualification Ready	Yes	Passed
Hybrid Reception	10.1	Reception tests: hybrids	Qualification Ready	Yes	Passed
	10.2	Storage of hybrids	Qualification Ready	Yes	Passed
Module Assembly/Testing	11.1	Storage of modules	Qualification Ready	Yes	Passed
	11.2	Cleaning module jigs	Qualification Ready	Yes	Passed
	11.4	Storage + shipping of glue	Qualification Ready	Yes	Passed
	11.5	Removing hybrids from panel	Qualification Ready	Yes	Passed
	11.6	Module Assembly	Qualification Ready	Yes	Passed
	11.7	Metrology: modules	Qualification Ready	Yes	Passed
	11.8	Bonding procedures: modules	Qualification Ready	Yes	Passed
	11.9	Visual inspection: modules	Qualification Ready	Yes	Passed
	11.10	Module Thermal Cycling	Requires Parts	No	Not Reviewed
	11.11	Single module Electrical Tests	Requires Parts	No	Not Reviewed
General	13.1	Cleanroom standards	Qualification Ready	Yes	Passed
	13.2	ASIC Compliance & Handling	Qualification Ready	Yes	Passed
	13.3	Bond Pulling Procedures	Qualification Ready	Yes	Passed