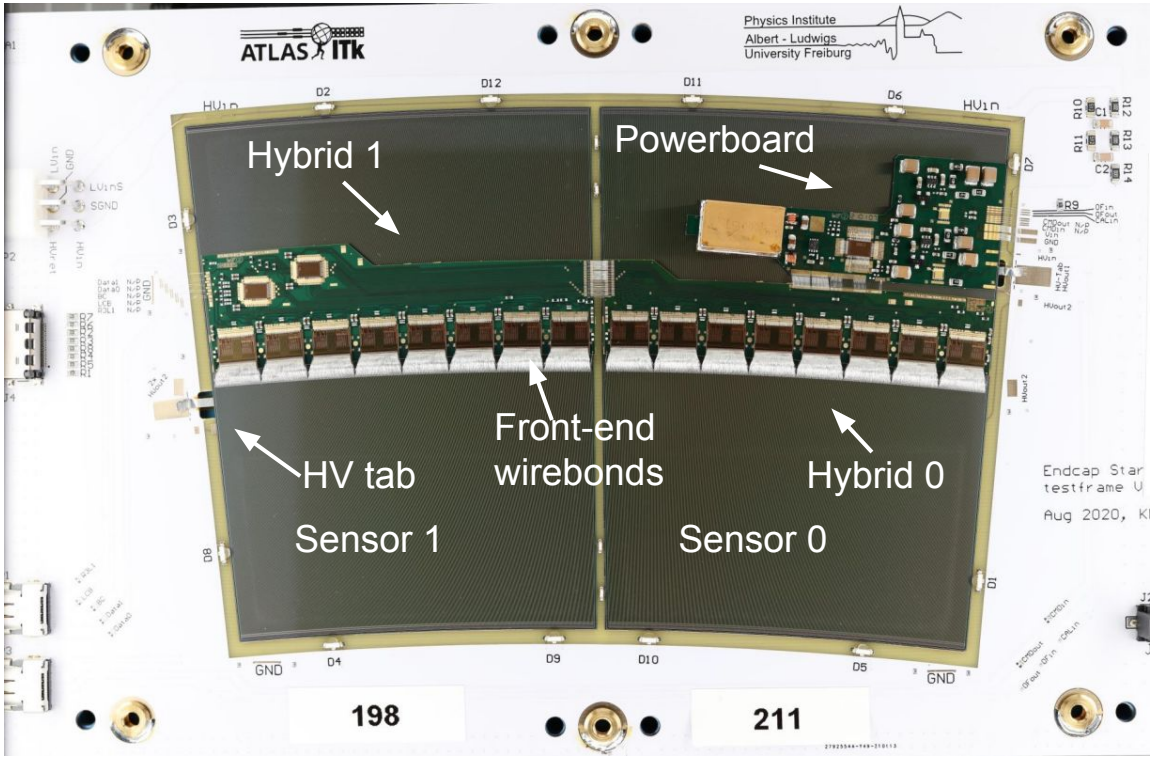
ATLAS ITk@DESY Day: **Modules**

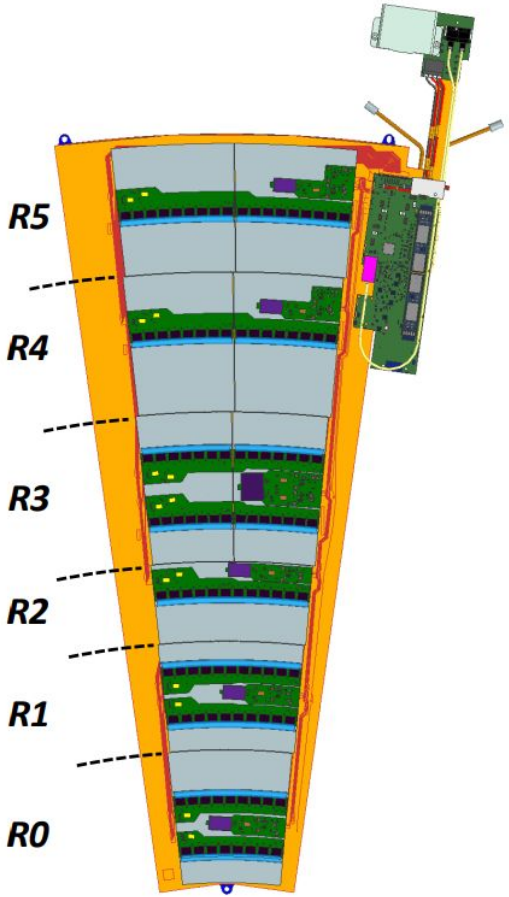
Module building and testing team in Hamburg
(Sören Ahrens, Lukas Bayer, Céline Gerdts, Sarah Heim,
(Eric Hüpel), Serhat Ördek, Kunlin Ran, Christian Sander, Lisa Sitnikova)
- with a lot of thanks to our module colleagues in Zeuthen -
ATLAS ITk@DESY Day
September 21st, 2023

Module production in Hamburg

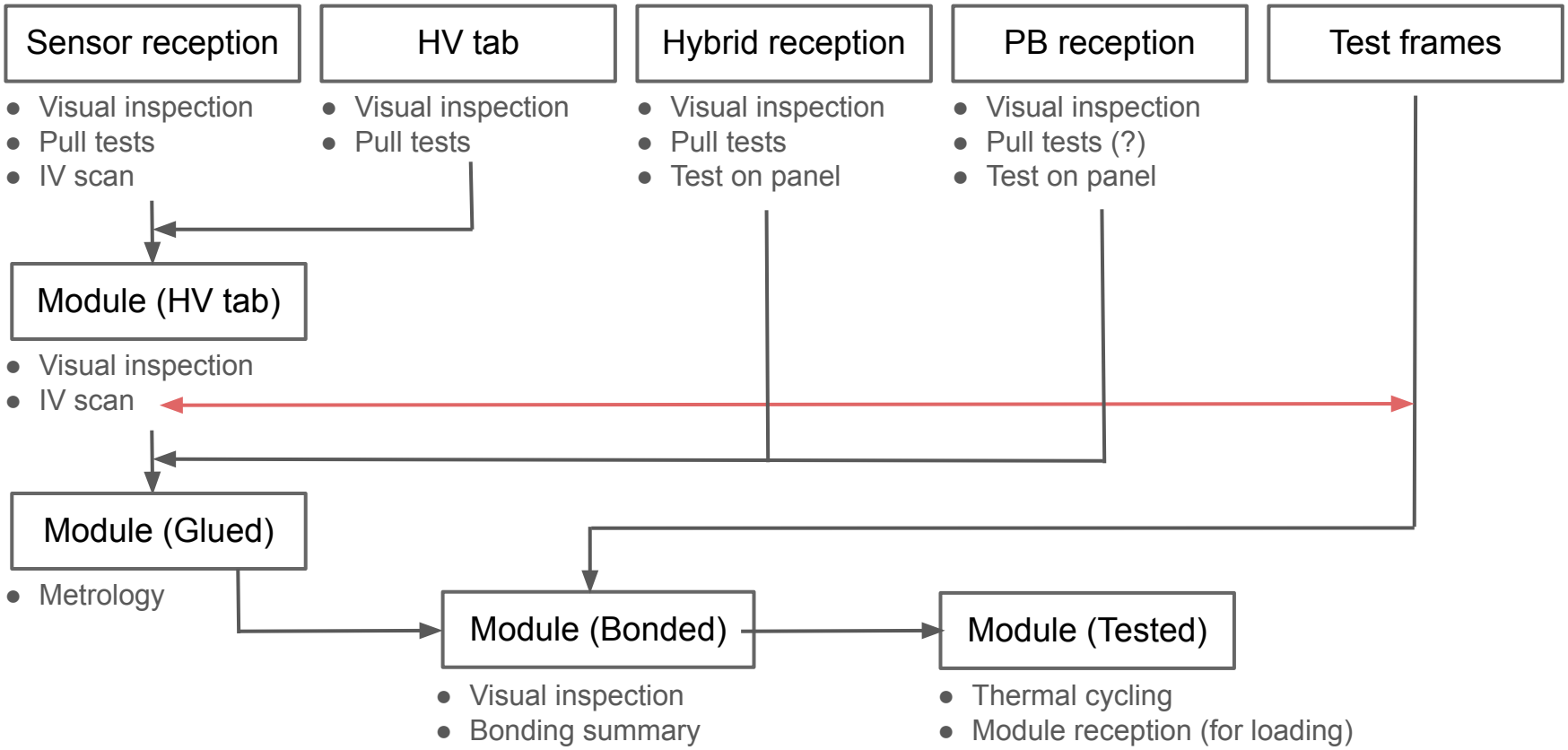
In Hamburg, we will be building R2 and R4 end-cap modules



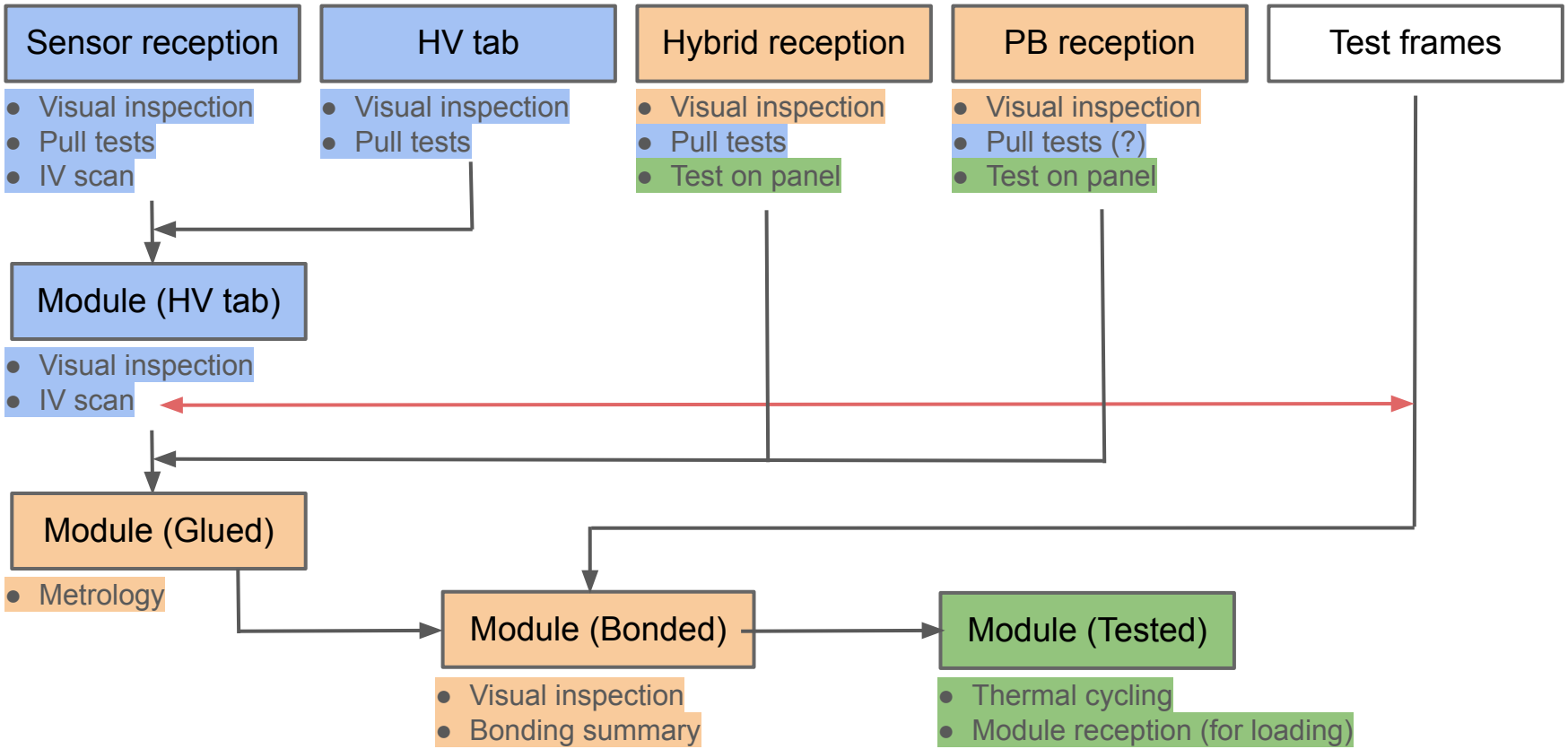
R4 module on a test frame



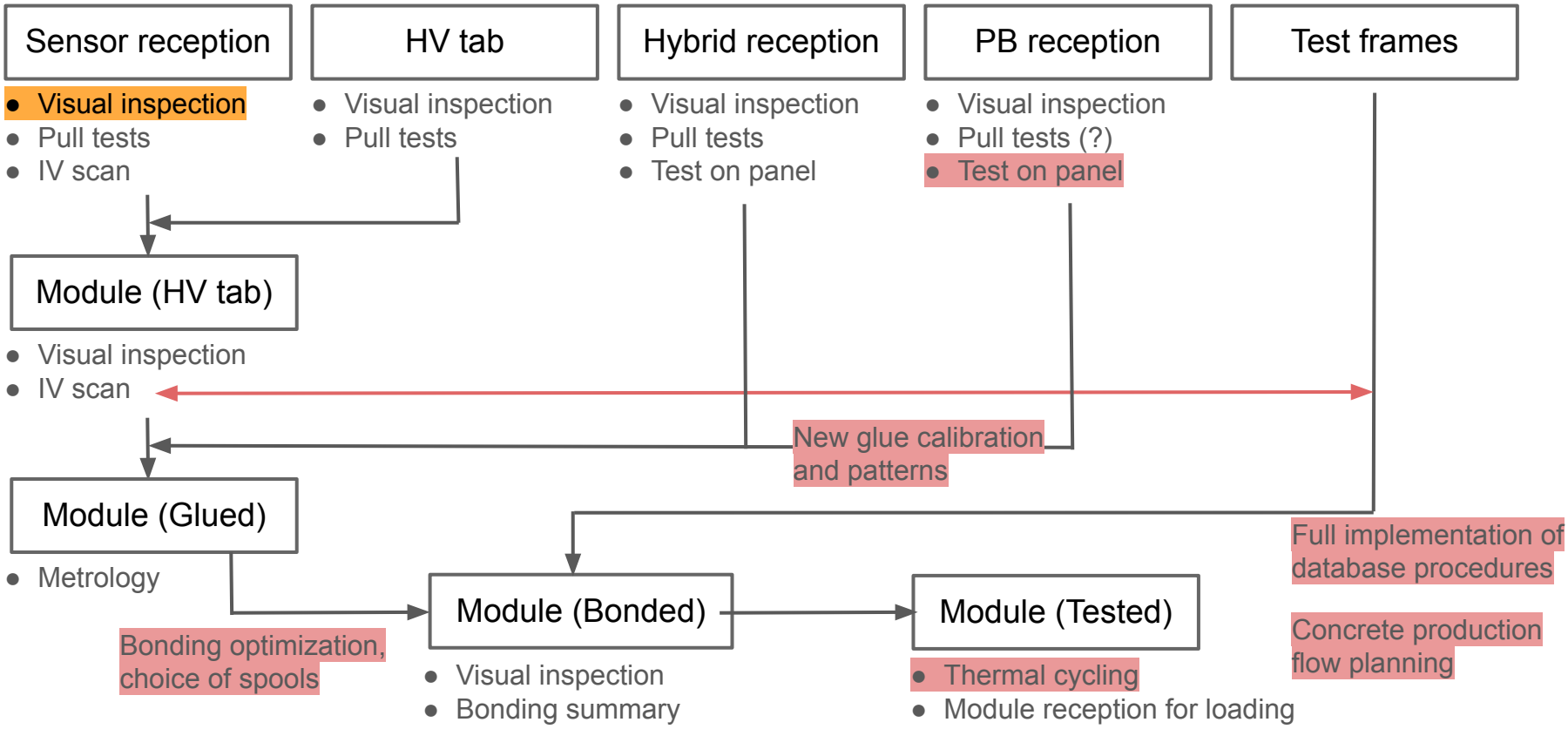
Steps in module production at DESY



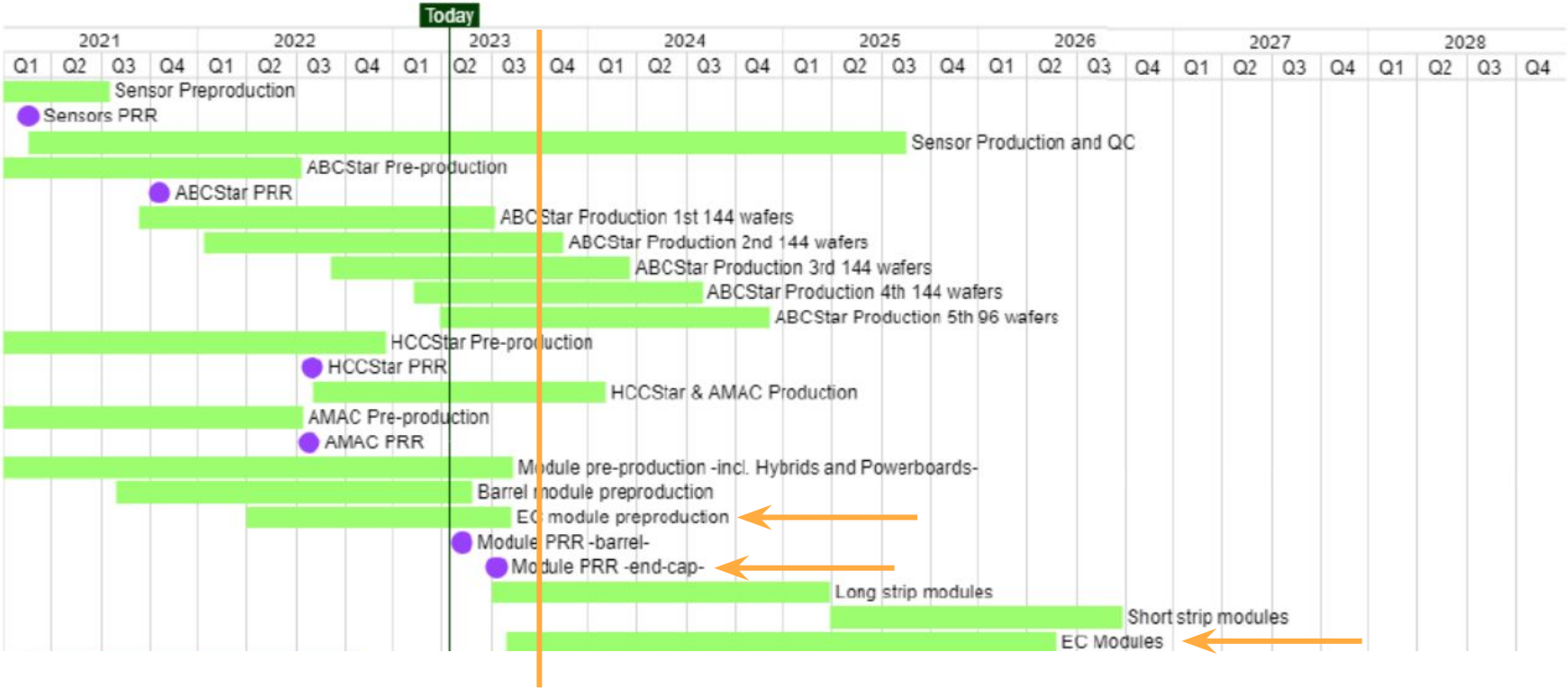
Steps in module production at DESY: part 1 part 2 part 3



Steps in module production at DESY: outstanding items



Module official production schedule



- Much of pre-production delayed by cold noise and EC powerboard redesign
- Gave us at DESY some time to establish procedures

What has been done so far at DESY HH?

Step Number	Qualification Step	Status	Ready for Review?	Review Status
1.1	Bonding Procedures	Qualification Ready	Yes	Passed
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
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
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
10.1	Reception tests: hybrids	Qualification Ready	Yes	Passed
10.2	Storage of hybrids	Qualification Ready	Yes	Passed
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	Qualification Ready	Yes	Passed
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

Site Qualification Progress

Remaining site qualification items

- PB electrical tests (delayed by the collaboration, setup in HH ready)
- ~~Hybrid burn-in~~ (no setup, DESY-HH is exempt … tbd)
- Module thermal cycling (work in progress)
- Hybrid metrology cross-check (hybrid swap)
  (not critical, hybrid arrived in Hamburg this week)

Prototyping (2 R2 + 2 R4)

- Finalized!

Preproduction A – PPA (2 R2 + 2 R4)

- 3 of 4 modules built (one with TrueBlue)

Requested PPB readiness for HV tabbing: some follow ups

Preproduction B parts are ordered, to be started when PPA is ready

Part 0: Some words on lab infrastructure from module perspective

Cleanroom 25c

This is where the module building happens. The infrastructure includes climate, dry cabinets and machines

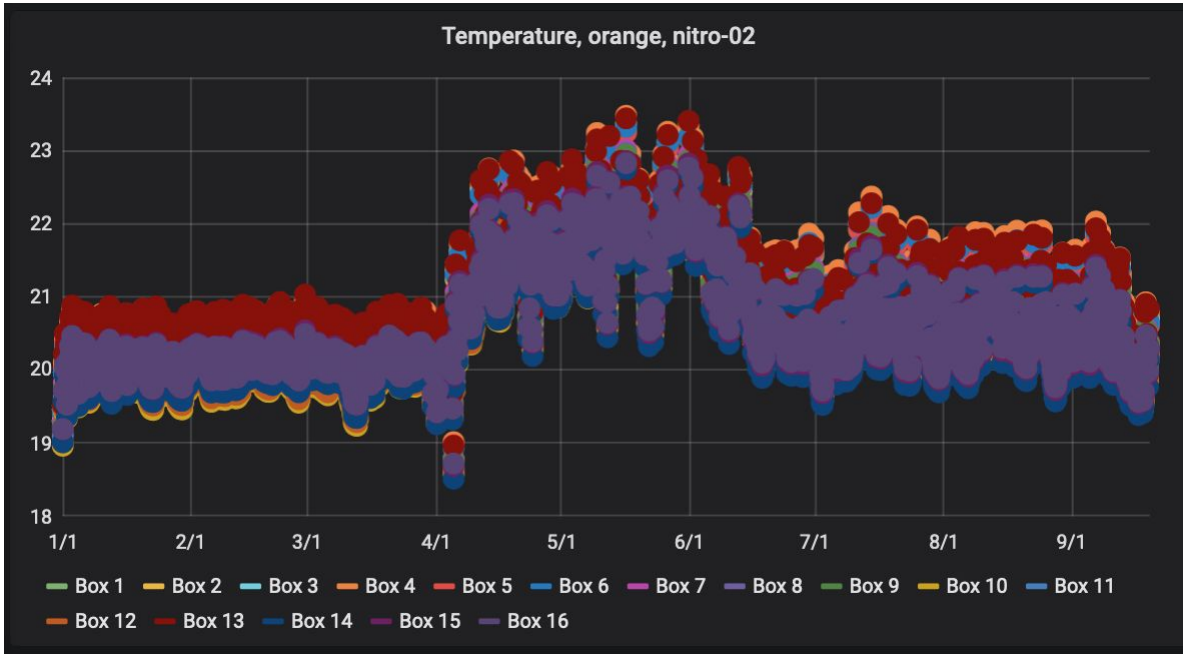
- **Status**: Cleanroom infrastructure is established and qualified

- Some things still to be done, improved
  - Vacuum strength - we had problem gluing two modules at the same time, the vacuum did not seem strong enough. To be investigated
  - Nitrogen regulation for the cabinets (currently constant flow - want to go to a humidity-driven system) - Eric was working on a board for this, timeline not clear (could use help here)
  - Clean water situation?
  - Particle dustmeters need to be debugged most likely (very few counts, no spike seen when we blow on it)

IMPORTANT! WE NEED TO BE ABLE TO PARALLELIZE MODULE BUILDING, WITH THE ABSOLUTE MINIMUM OF 2 AT THE SAME TIME

Cleanroom 25c

- Temperature in the clean room approaching temperatures from beginning of the year, temperatures in the offices in 25c too cold in summer and too warm in winter - in contact with T. Rothermund from MKK: broken temperature switch, possibly issues with flowboxes



Part 1: Sensor reception, HV-tab attachment, pull tests

Bare-sensor testing

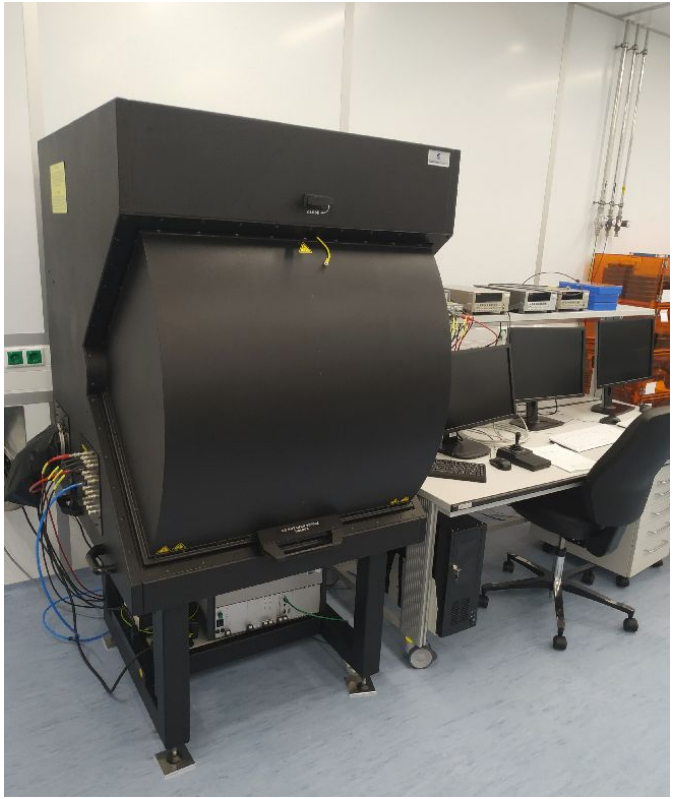
Before using them, sensors must be tested (IV scan)

- **Status**: setup finalized, qualified
- Nominal method: probe stations
- Alternative method: on a test frame
- No changes expected for PPB/production
- Instructions: confluence link
- Database interactions: method exists

- **Personpower**: Lisa and Christian for the probe station. Anyone who knows how to test modules should know how to measure IV for a sensor bonded to a test frame

- **Duration**: 30 min per sensor
  + time for bonding if needed

ADDITIONAL STEP: VISUAL INSPECTION VIA MICROSCOPE; PHOTOBOX – DOES NOT EXIST YET – NEEDS TO BE BUILT) ~30 MIN

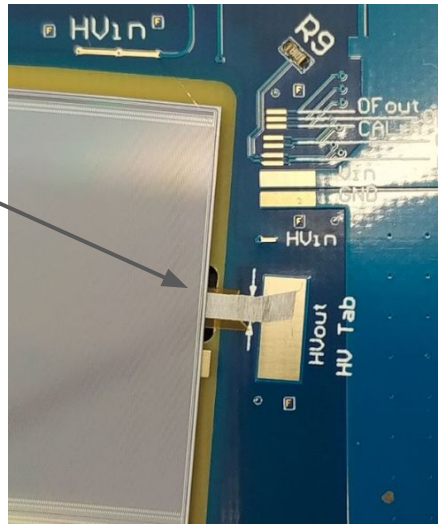


Probe station

HV tabbing

High-voltage (HV) tabs are used to supply high voltage to sensors

They are tab-bonded directly on the backside of a sensor with a special bonding wedge (currently done on smaller bondmachine G5)



HV-tab bonded to the back of an R2 sensor

- **Status**: setup finalized, qualified,
  further bonding parameter optimization needed

- **Quality of HV tabs** needs to be regularly monitored. It is possible that bonding parameter optimization will also be needed during production

- **Personpower**: Céline (Eric - 1 day/week)
- **Duration**:
  - HV-tab attachment: ~30 min
  - Bonding parameter optimization: ~2+ days

Visual Inspection Rejection Grading for HV Tabs

A) Tab misformed during production

B) End of tab broken, or completely bent over

C) Discoloration of tab

D) Tab became dislodged during shipping

E) Degradation of aluminum

F) Cuts

G) Deep creases

H) Very ragged edges

I) Residues of cut outs capton side (lasercut)

J) Residues of cut outs Al side (lasercut)

NEED MORE TECHNICAL BONDING MANPOWER
=> SEARCH FOR SOLUTION IN PROGRESS

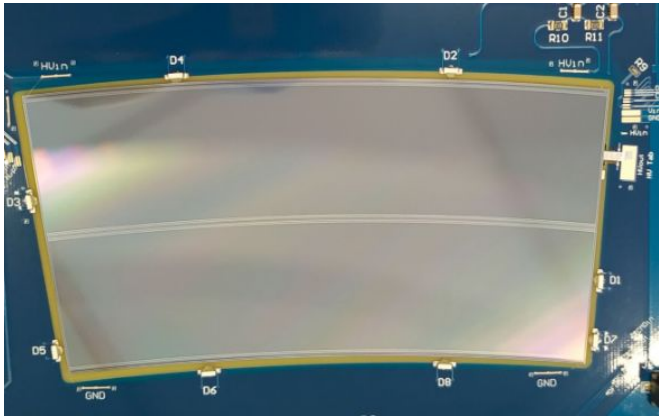
Sensor testing after HV-tab attachment

After an HV-tab attachment, sensor performance is tested again.
For this, sensor is bonded to a test frame.

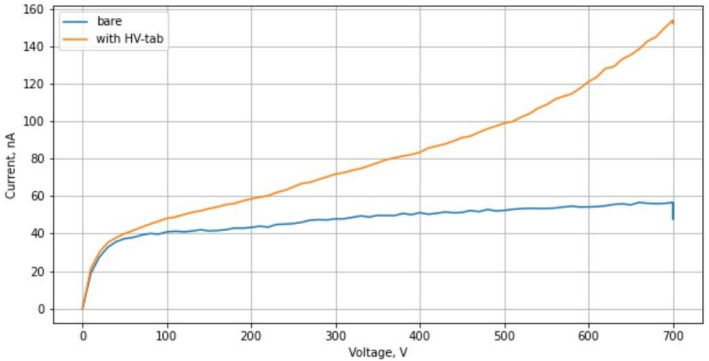
- **Status**: setup finalized, qualified
- Method: on a test frame
- No changes expected for PPB/production
- Instructions: confluence link
- Database interactions: method exists

- **Personpower**: Lisa + anyone who knows how to test modules

- **Duration**:
  - IV measurement: 20 min per sensor
  - Bonding to the test frame: ~20 min per sensor



Each corner of the sensor is bonded to the test frame

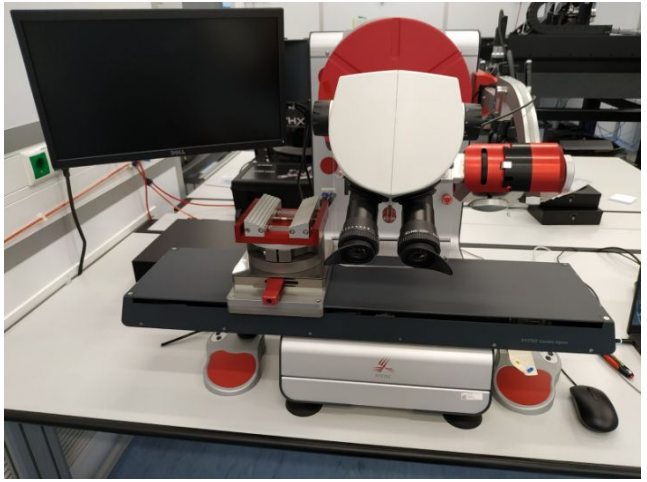


Sensor IV before and after HV-tab attachment

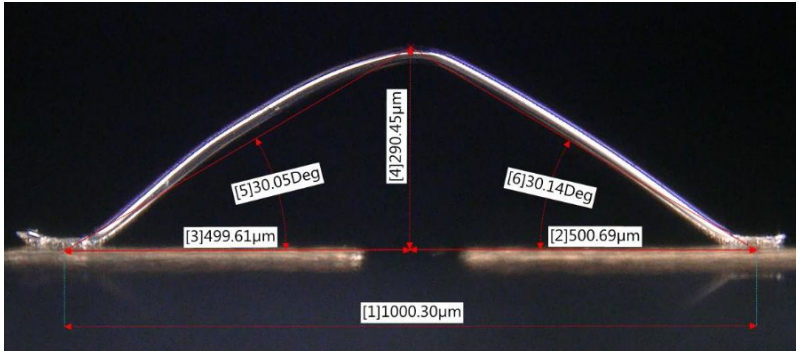
Pull testing

- Different surfaces on which bonding is performed are regularly tested (confluence link)
  - Sensors (half-moons) (3 month circulation)
  - Hybrids (3 month circulation)
  - ASICs (3 month circulation)
  - Powerboards (no pull testing, yet?)
  - HV tabs (at beginning and end of every session, per batch)
- On each tested surface, > 100 wires are bonded and pulled until they break.
- Some failed tests mean that bonding cannot proceed until a new bonding parameter optimization is done.

- **Status**: setup finalized, qualified
- **Personpower**: Céline (Eric)
- **Database interactions**: method implemented
- **Duration**: 2 hours per test (including bonding)
- **How often**: not clear yet (descoping discussed)



Wirebond pull tester



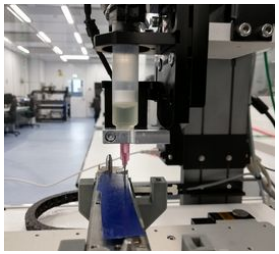
Angle and height at which wires are pulled

Part 2: Module gluing, bonding and metrology. Production schedule.

Module gluing

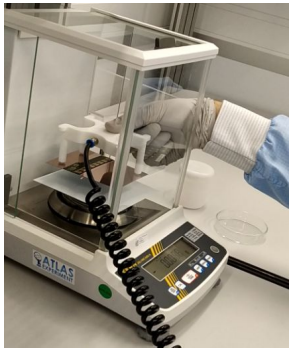
Start dispenser (increases pressure over time)

Glue mixing

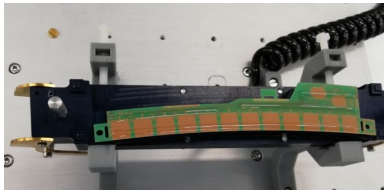


Filling and mounting the glue syringe

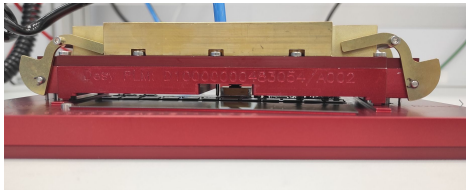
Loading correct glue patterns



Weighing components



Calibration and dispensing

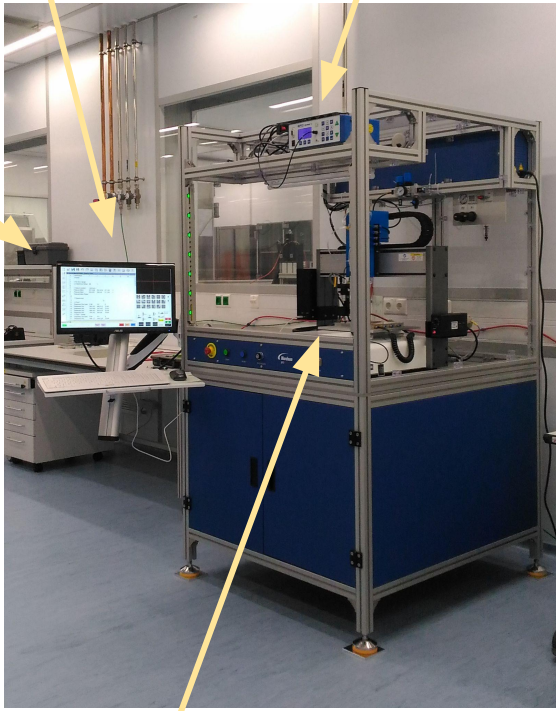


Glue curing (4 - 8 h)

After mixing, everything has to be done in ~40 min

Robot control

Pressure control



Work area

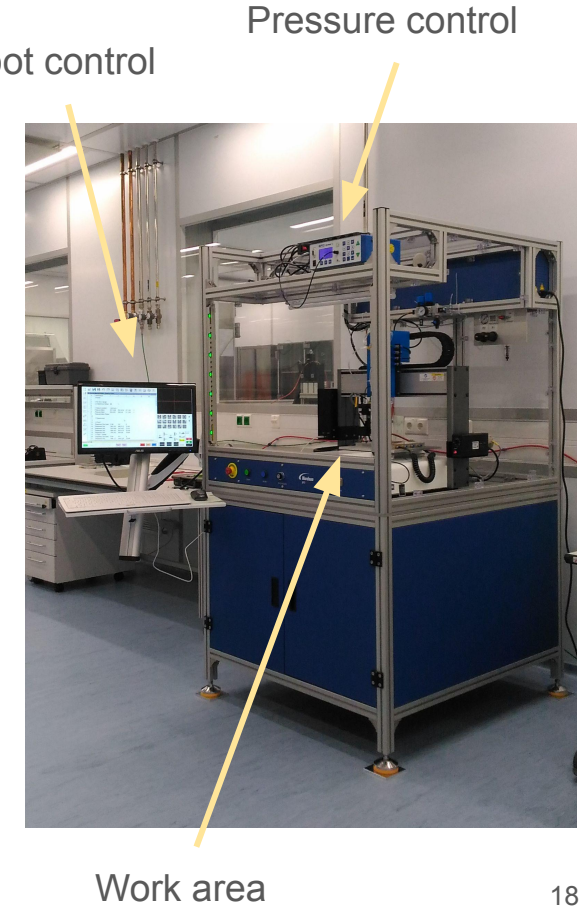
Module gluing

Status of different gluing tasks

- **Chip to hybrid**: UV glue (backup site) setup finalized, qualified

- **Hybrid/powerboard to module**: setup finalized, qualified, glue has changed to TrueBlue and we are likely asked to glue with FalseBlue also (this requires new pressure calibrations and potentially new glue-pattern optimizations)

Steps documented here



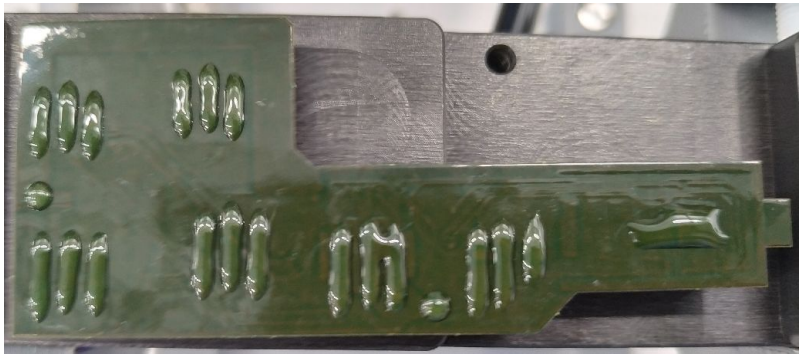
Gluing status

- Seeing discrepancy in glue pressure calibrations throughout lifetime of True Blue batches
  - To be understood if there are inter-batch differences, as well (need more statistics)
- Developed an iterative/averaging procedure that gives us fairly stable results
  - Calibration expected to be done every 2 months in the beginning

R2H0 hybrid glue pattern

Expected changes:

- Currently adjusting R4 patterns (R2 patterns are done, and first R2 module was glued with TrueBlue)



R4 powerboard glue pattern

Personpower: Kunlin, Serhat, (Eric)

Duration: Gluing hybrids and powerboards on modules takes quite long at the moment, includes

- pulling hybrid-test-frame bonds off, cleaning tools (a few hours)
- Gluing each PCB separately (a few hours)
- => currently we glue ~1 module/week (need to speed up! Part of this is manpower limitations)

Need more manpower (part-time Technician + part-time fellow) for production

Metrology

Using smartscope to measure:

- 3D position of hybrid / PB / chips
- Glue thickness, curvature of module (“bow”)

Status: Setup finalised, qualified (hybrid swap ongoing)

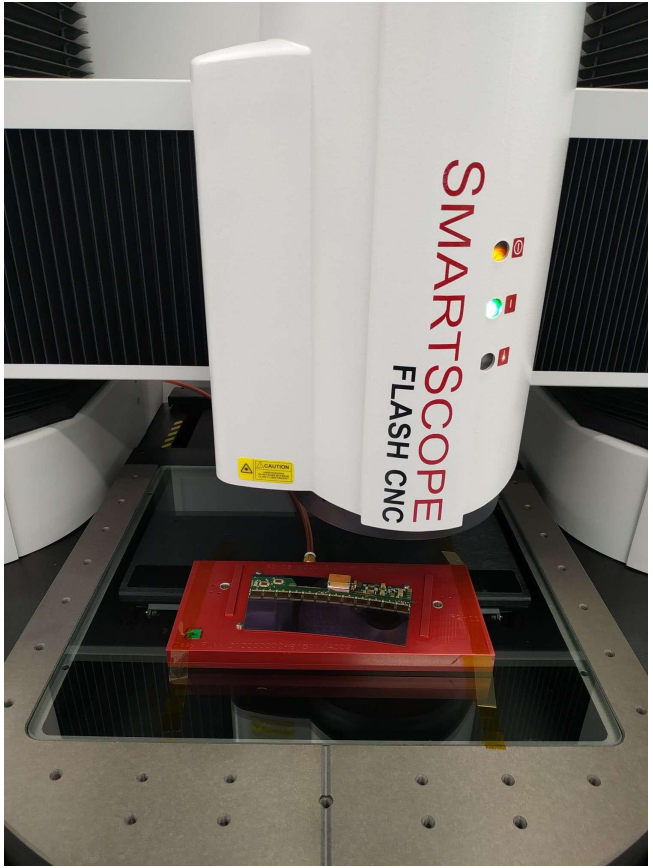
Changes expected for PPB PBs, slight change in routines, should be fixable in 1-2 days

Instructions: Confluence link

Database interactions: method developed

Personpower: Serhat, (Kunlin/Sarah), (Eric)

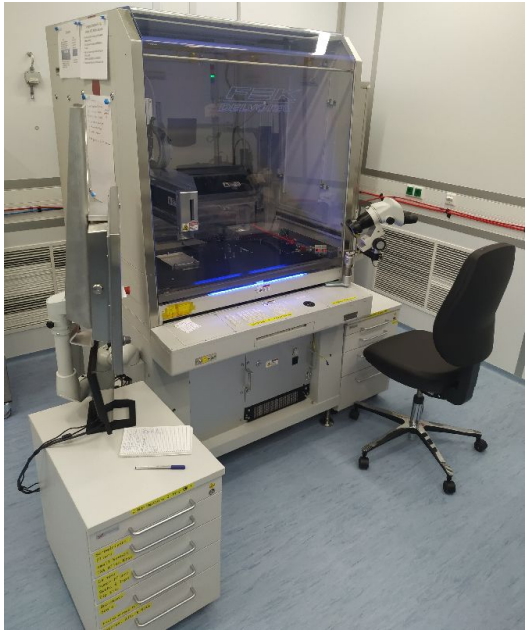
Duration: 15 min per half-module
(should be done right after glue-curing to free the assembly jigs)



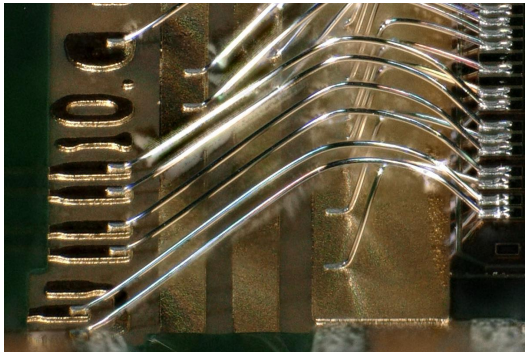
Module bonding

- 25 um aluminum wires are used to establish the electrical connections for
  - power
  - clock/trigger and data transfer
- wires are “welded” with ultrasonic power to metallic surfaces
- wires connect
  - chips-hybrid (we are backup site for this, doing it for PPA)
  - chips-frontend (sensor)
  - powerboard-hybrid
  - module-testframe/petal

- wirebonding is a non-trivial process
  - many parameters (US power, loops)
  - very surface-dependent (and surfaces can age)
  - most sensitive process in terms of cleanliness (oil, silicone, fingerprints, dust) => cleanroom and material need to be kept clean



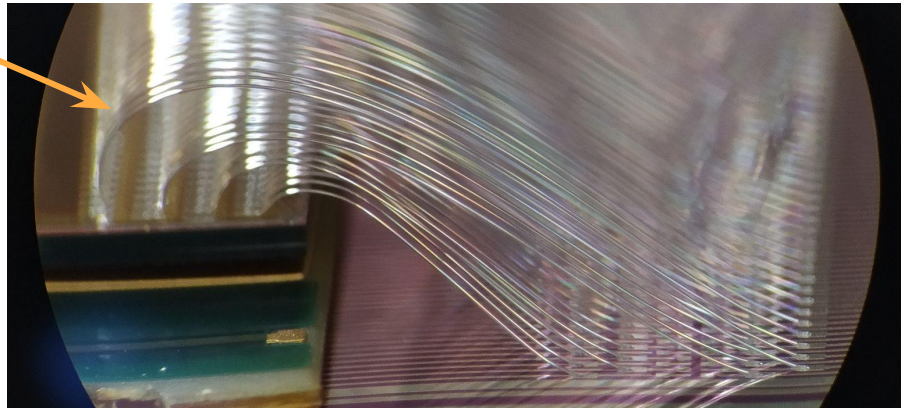
Bonding machine



Chip-hybrid bonds

Module bonding

- **Status:** setup finalized, qualified
- **Personpower:** Céline
- **Problems**
  - Delays due to touching wires after machine service
  - Parameter changes due to spool changes/machine calibration/possibly additional sources
  - Want to test spools from different manufacturers
  - Maybe we should in the end buy a force measurement box (suspicion is that the calibration is off)
- **Changes expected for PPB/production?**
  - Version changes can lead to loop changes
  - Bond patterns?
- **Status database interactions**
  - Work started, scripts need to be automatized (?)
- **Duration**: 2-3h per sensor
- Plus spool and tool changes



Chip-frontend bonds

Module production planning

ATLAS schedule 25c, downstairs

Day	Glueing	Bonding	Testing	Other
Mo (1)	R2a Hybrids	R4 (a+b) Module bonding	Reception tests modules for petal	
Tu (1)	R2a Powerboards	R4 (a+b) bonding extra time	(Coldbox: evening/night) Modules R4 (a+b)	
We (1)	R2b Hybrids	Petal bonding, HV tabbing	Reception tests sensors (IV and visual) and hybrids and powerboards, R4 (electrical and visual/metrology) [possibly in batches R2+R4 together, possibly a second day]]	
Th (1)	R2b Powerboards	Petal bonding, HV tabbing		
Fr (1)				Weighing, metrology, microscope R2a+b
Mo (2)	R4a Hybrids (2R4H0 and 2R4H1)	R2 (a+b) Module bonding	Reception tests modules for petal	
Tu(2)	R4 Powerboards (only R4H0)	R2(a+b) extra time	(Coldbox: evening/night) Modules R2 (a+b)	
We (2)	R4b Hybrids	Pulltests	Reception tests sensors (IV and visual) and hybrids and powerboard, R2 (electrical and visual/metrology) [possibly in batches R2+R4 together, possibly a second day]	
Th (2)	R4b Powerboards (only R4H0)	HV tabbing sensors for modules R2, R4		
Fr (2)	Maintenance/Overflow Glue robot	Maintenance/Overflow Bonding	Maintenance/ Overflow Coldbox/Testing/Probe Station	Weighing, metrology, microscope R4a+b

Need to make a plan for production:

- 576 modules (counted in sensors) in 2.5 years (plus spares)
- **Minimum: 6 modules per week (2 R2, 2 R4H0, 2 R4H1)**
- Limiting factors: Curing time, person power and machine availability, number of tools, vacuum lines (to avoid chaos or weak vacuum)

Status: First version exists (estimated times were deemed realistic by different experts), but still needs work:

- Decouple numbers (gluing/bonding) and build in buffers
- New glues have shorter gluing time (4 hours?) => can glue both hybrid and powerboard on sensor in one day
- Need to make more realistic time estimates during PPB
- Make sure spool lengths and clamp exchanges are taken into account/optimized, decide usage of G5 and M17 bond machines

Personpower: Sarah, discussions with Christian, Serhat and Sergio, Ingrid

Time estimate: Should get the next version ready asap

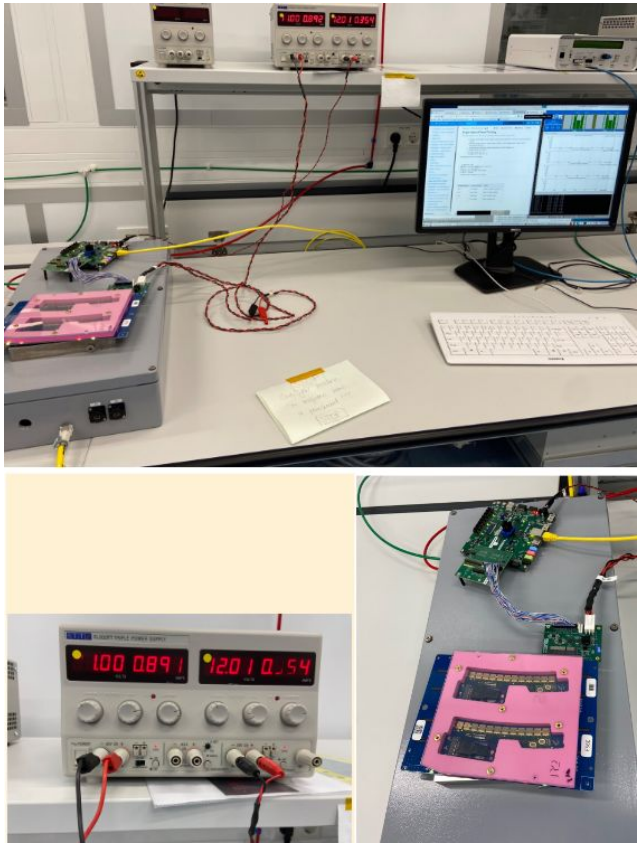
Current rate ~1 module/week => need to find ways to speed up

Part 3: Electrical reception tests.
Module thermal cycling

Hybrid reception testing

Upon reception, hybrids are tested electrically

- **Status**: setup finalized, qualified
- **Changes**: not expected for the hardware, but due to different ASIC (ABC, HCC, AMAC) versions, sometimes configuration tuning is needed. This is expected to improve for the production.
- **Documentation**:
  - confluence page
  - confluence page (single module testing)
  - site qualification document
- **Database interactions**: method exists
- **Personpower**: Serhat, Lisa, Sarah, … ???
- **Duration**: 30 - 60 min per panel (4 hybrids), all automatic



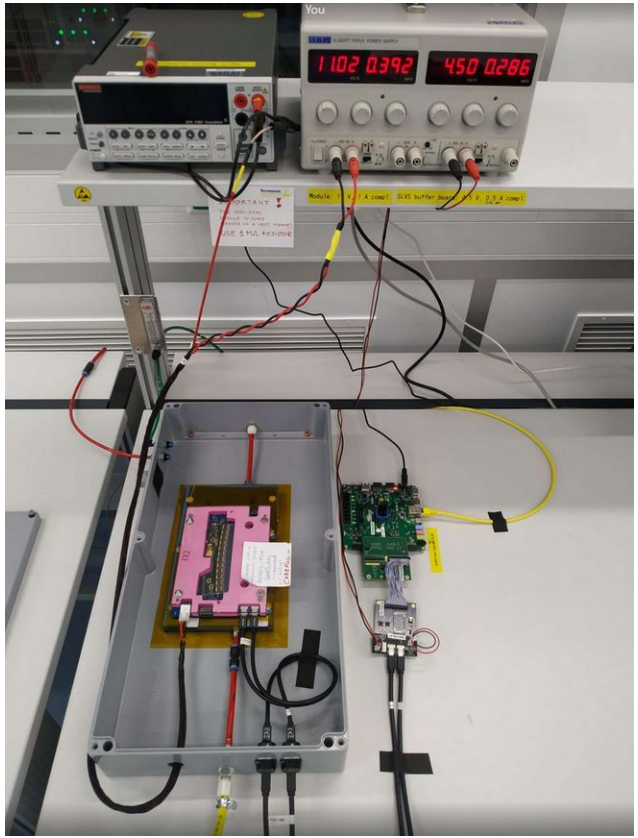
Hybrid reception testing setup

Single module testing

Single module testing is done for debugging purposes, and if some kind of transport occurred between bonding, thermal cycling, and loading.

We will have to perform single module testing for all modules shipped to Hamburg for loading them onto petals.

- **Status**: setup finalized
- **Changes**: not expected for the hardware, but due to different ASIC (ABC, HCC, AMAC) versions, sometimes configuration tuning is needed. This is expected to improve for the production.
- **Documentation**: confluence page
- **Database interactions**: method exists
- **Personpower**: Serhat, Lukas, (Sarah), future: Federico (for reception of modules for petal gluing)
- **Duration**: 1h per module



Single-module testing setup

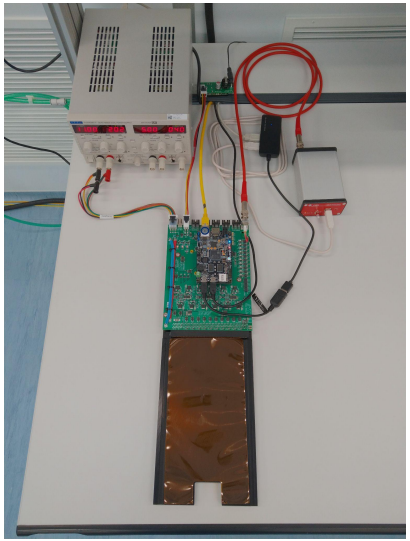
Powerboard reception testing

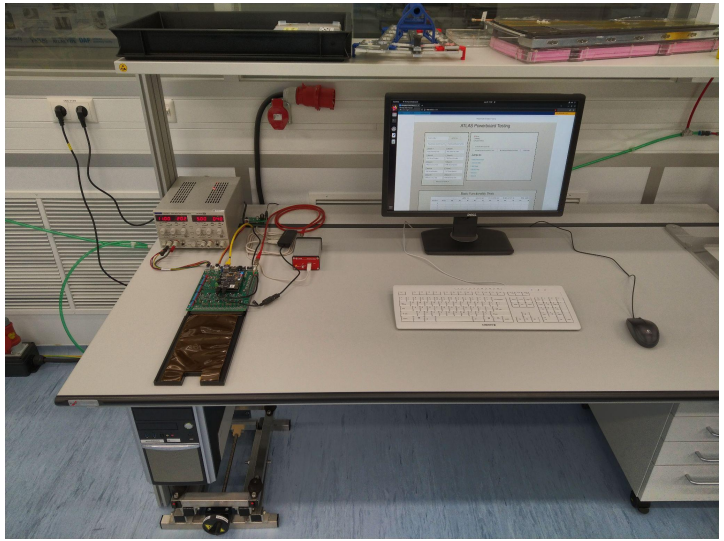
Upon reception, before gluing, powerboards will be electrically tested

Hardware equipment available. Specific LV and HV power supplies had to be ordered and they arrived.

Software has been much improved (thanks to Ben); mass testing should be possible … but not tested in HH, yet
Site qualification is not possible for now, but will be soon

- **Status**:
  setup ready (with help from Ben)
  qualification not yet possible
- Personpower: (Eric) + (Serhat/Christian)
- **Database interactions**:
  method supposedly exists
- **Duration**: <15 min





Module cold cycling (1)

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)

Interlock

Voltage control

LV power supply

HV power supply

Temperature control

Chiller

Peltier elements
(Cooled metal plates)

Temperature & Humidity sensors

HV steering for IV scans

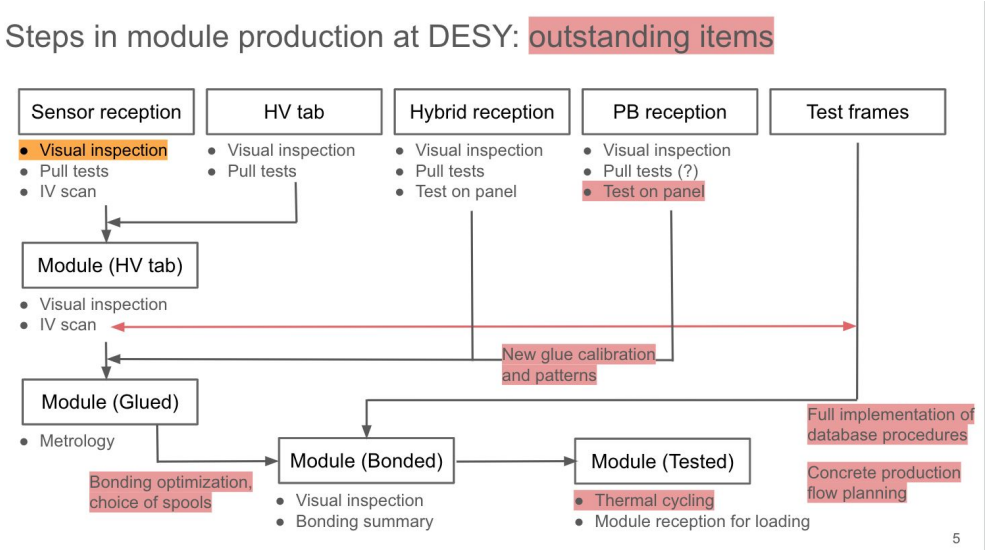
Thermal cycling and electrical testing sequence

Module cold cycling (2)

- **Status**: hardware finalized, some hardware components need further testing, software not finalized, not ready for qualification
- **Lisa achieved manual module cycling (8 cycles)**
- **Changes**: potentially needed since from the collaboration side things are not yet finalized
  (not all tests have been implemented, some software still under development)
- **Documentation**: under development
- **Missing steps**:
  - **HV steering for IV scans**: established and tested, but several issues observed
    - Non-zero current at 0 V (Torsten checking?)
    - Scans sometimes stopped because set voltage is not reached
    - Communication time needs to be further studied (?)
    - Testing on different chucks needs to be compared
  - **Coldjiglib code**: successfully installed, and some simple functions have been tested
    - Automatic cycling works (the thermal part at least) and coldjiglib tells ITSDAQ to do electrical testing once a temperature is reached
    - ITSDAQ is doing a wrong test since we have an old version, the HV is not ramped up
  - **Actual thermal cycling:**
    - Temperature sometimes behaves unexpectedly - there are weird spikes and too rapid changes
    - Necessary to finalize cycling only up to 20 degrees. The current parameters allow smooth cycling only without a module present
  - **Other developments**
    - There might be many other small tasks in order to fully automate the setup and format the test results properly
- **Personpower**: Lisa, Lukas (qualification task), Ben, Sören (for the cold box + PLC)
- **Time needed to finish the setup**: several months in the best case scenario (until ready for site qualification)
- **Duration**: ~1 day for 10 cycles (4 modules)

In summary

- A lot of work done by the module team!
  - Site qualification almost finalized
  - In the middle of pre-production
- A few outstanding to-dos, biggest:
  - Finalize automation of cold-box
  - Glue calibration (in particular if we need to do this for False Blue also)
  - Visual inspection box for reception
  - Database scripts
- For production:
  - Need to speed up as much as possible (from 1 module/week to 6 modules (counted per sensor)/week)
  - Team has been shrinking - need more manpower
    - Most bonding done by one expert currently
    - Gluing done by two part-time people (not enough! Technical help would be good here, as well)
    - Need to cover all activities with at least two people, in case someone gets sick, travels, has a huge analysis deadline, or is on vacation



Backup

Instructions for making slides (to be removed)

For each big step, we should explain the following:

(try to harmonize the slides for better readability, although some of the harmonization can come in the end)

- **Status** (already being done, completely finalized, not done at all)
- **Any problems**???
- **Changes expected** for PPB / production (new tools, new optimization, changes in the setup)
- **Database interactions** (ready, somewhat ready, not ready)
- **Personpower** (with names, for finalizing the step if not done, and for the production)
- **Time estimate** (for finalizing the step if not done, and how long it takes during production)
- **Confluence link** with documentation

Maybe prepare a slide for each “outstanding item” to explain the plans

For first part: 15 min, second and third 22.5 min (less is better)

Topic

Template slide

Short explanation of topic

- **Status**:
- **Problems?**
- **Changes expected for PPB/production?**
- **Status database interactions**
- **Personpower**:
- **Duration**:
- **Confluence link**

Picture?