ATLAS ITk Barrel Strip Module Production

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ATLAS EXPERIMENT

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Tsinghua University

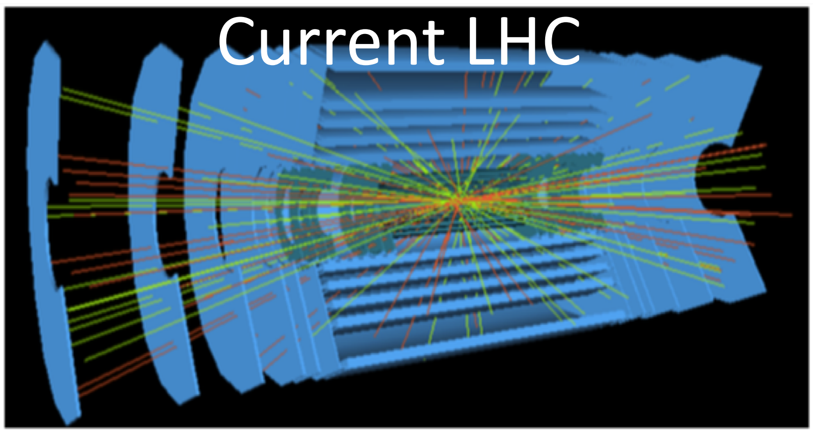
Outline

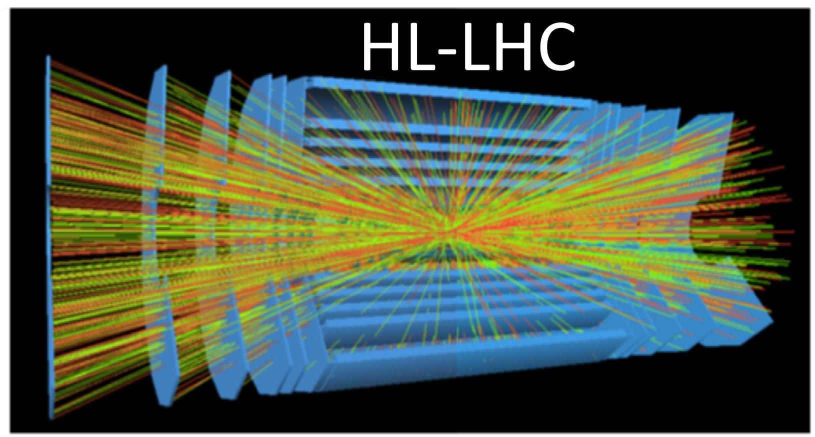
- ATLAS Inner Tracker (ITk)
- Module Production:
  - Module production at RAL
  - Hybrid and module assembly, electrical tests
  - Wire bonding: bond testing, 2x2 jig, encapsulation
- IHEP/THU clean room
- Summary

Introduction: LHC -> HL-LHC

High Luminosity-LHC (HL-LHC) is foreseen to be completed in 2026.

- Aim to increase the integrated luminosity to about ten times the original LHC design.
- Improve the precision of the Higgs measurement, better sensitivity to new physics.

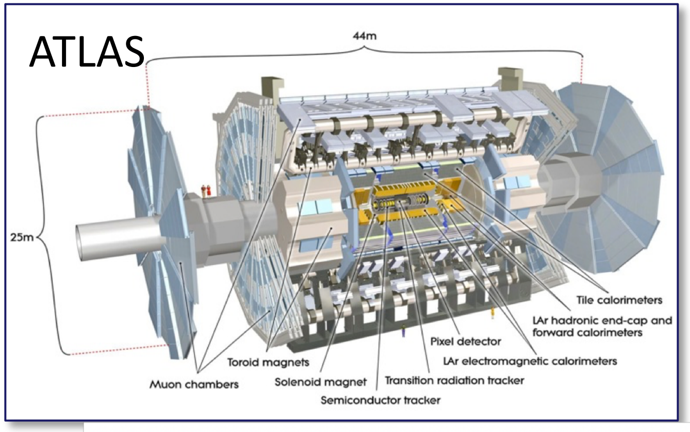


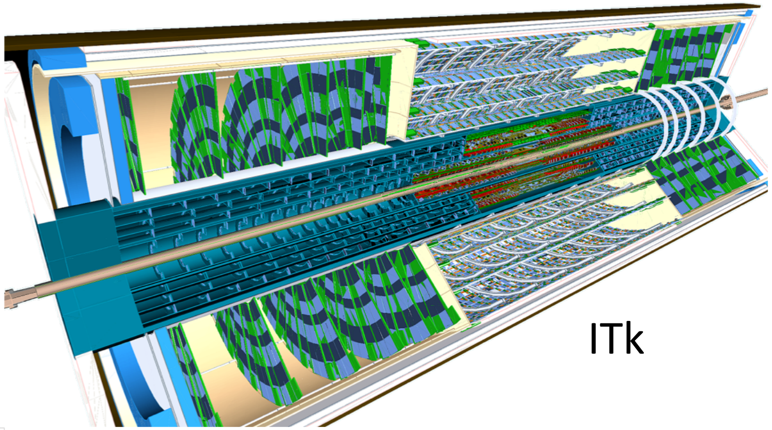


ATLAS Inner Tracker will improve resolution and solve signal pile-up.

ATLAS Inner Tracker (ITk)

New all-silicon Inner Tracker (ITk) will replace current ATLAS inner detector.

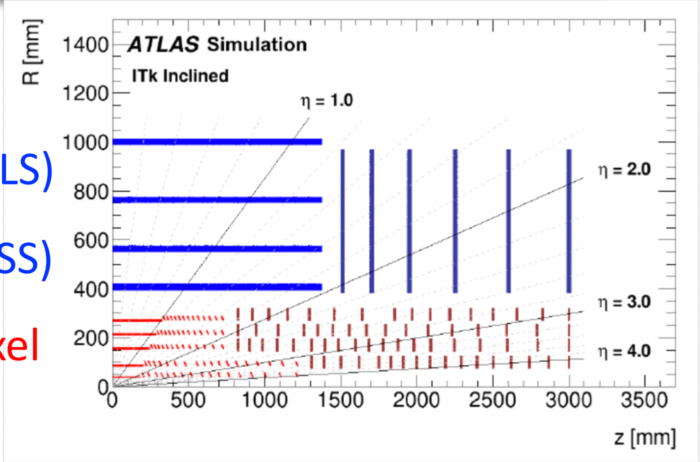




Long Strip (LS)

Short Strip (SS)

Pixel

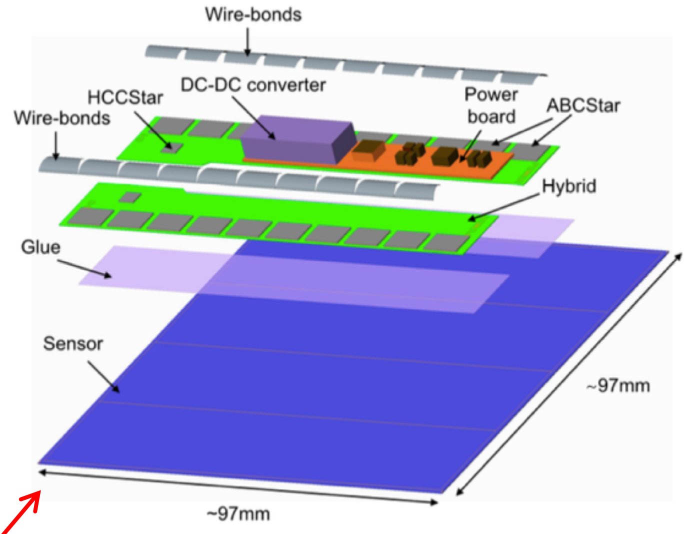


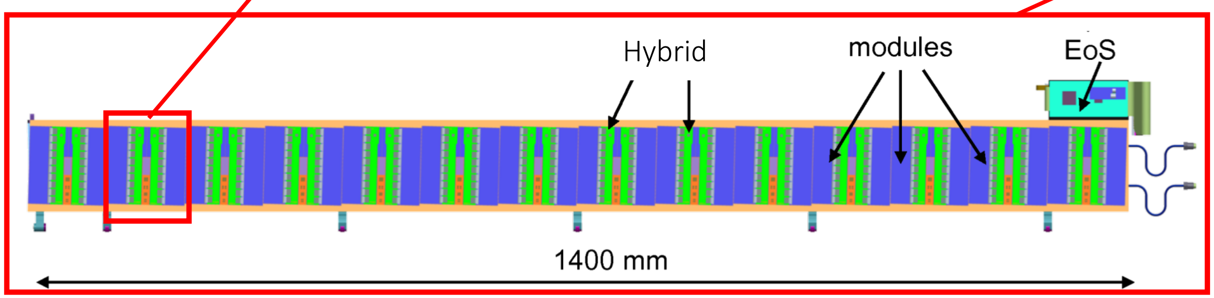
IHEP/THU will contribute 1000 barrel strip modules (10 m^2 silicon) for ITk.

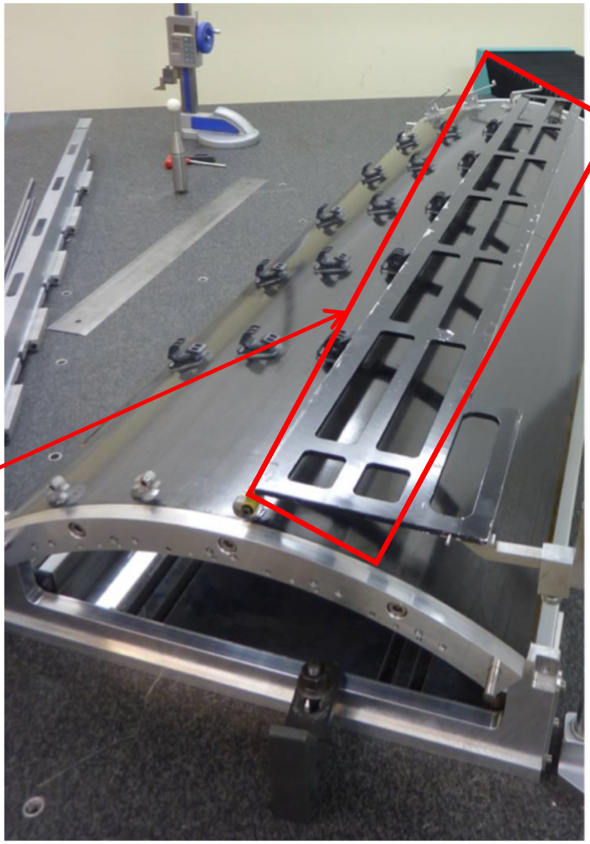
ITk Silicon Strip Detector Concept

- Global structure: 4 layers of silicon strip tracker in Barrel
- Local structure (Stave): 28 barrel modules on each stave

Module



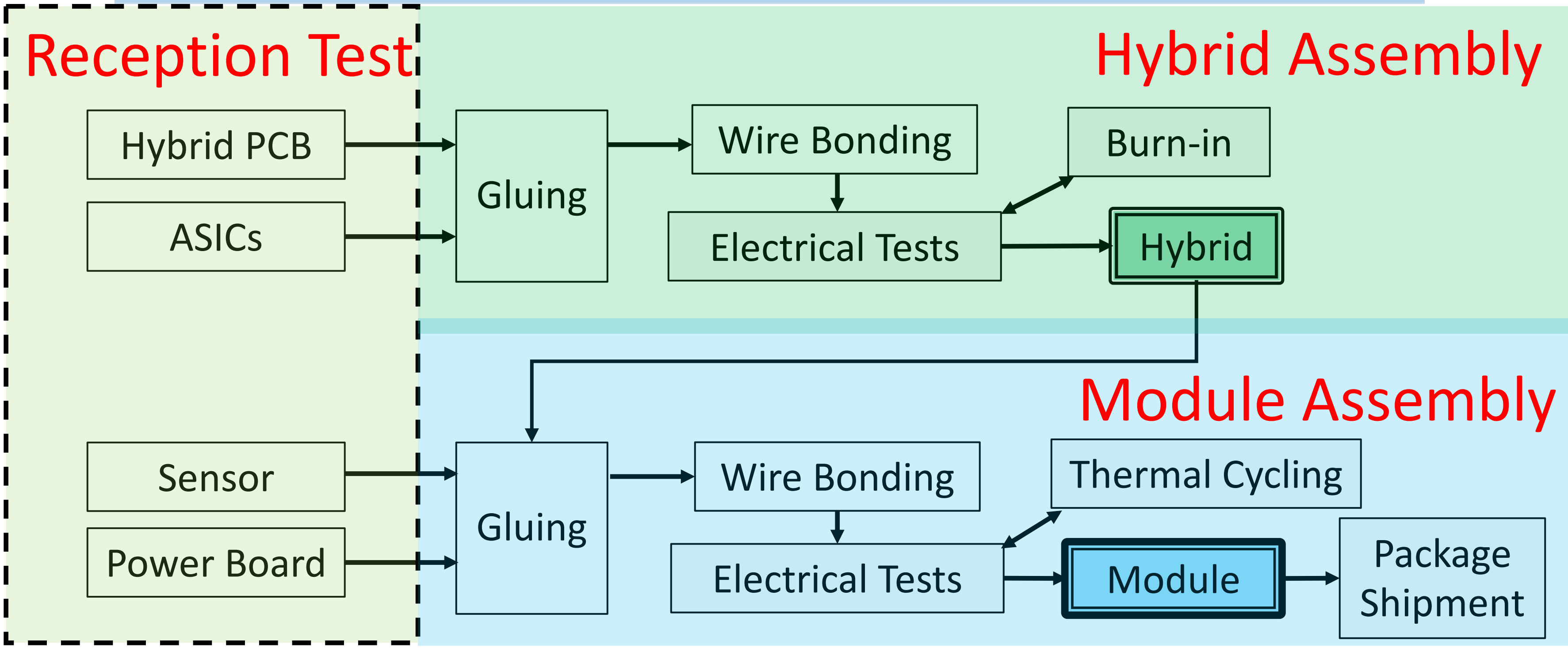




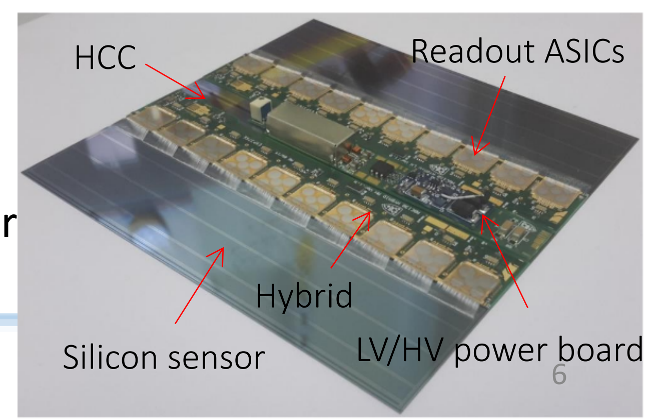
Stave = 28 modules + electronic (bus tape) + thermal (cooling pipe) + mechanics (carbon fibre)

IHEP/THU will contribute 1000 barrel strip modules.

Strip Module Assembly



- **Low-mass Kapton hybrid** with ABCStar (ATLAS Binary Chip) and HCCStar (Hybrid Controller Chip) ASICs
- **Power-Board** including DC-DC Low Voltage (LV) Power Block, monitoring ASIC , and HV multiplexer

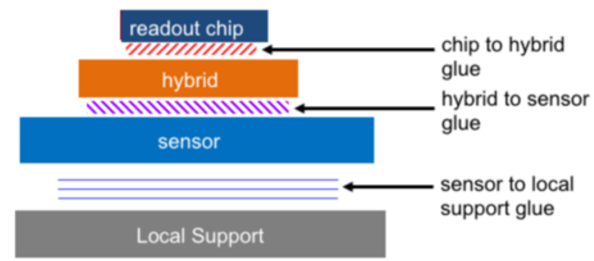


Quality Control

Based on the prototype study, along with the current ATLAS SCT detector experience, improve the quality control (QC) of module production process.

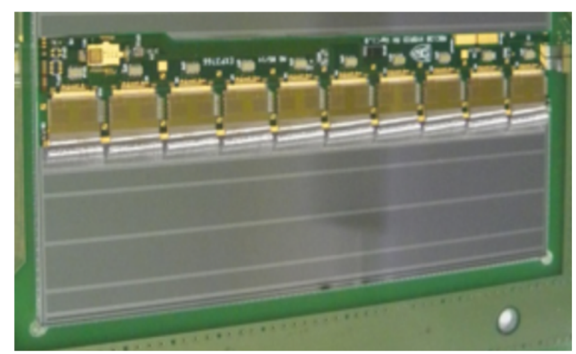
Control board QC

Reception and visual inspection of components → Hybrid Metrology → ASIC Attachment → Hybrid Metrology → Wire-bonding → Electrical Confirmation Tests → Thermal Tests

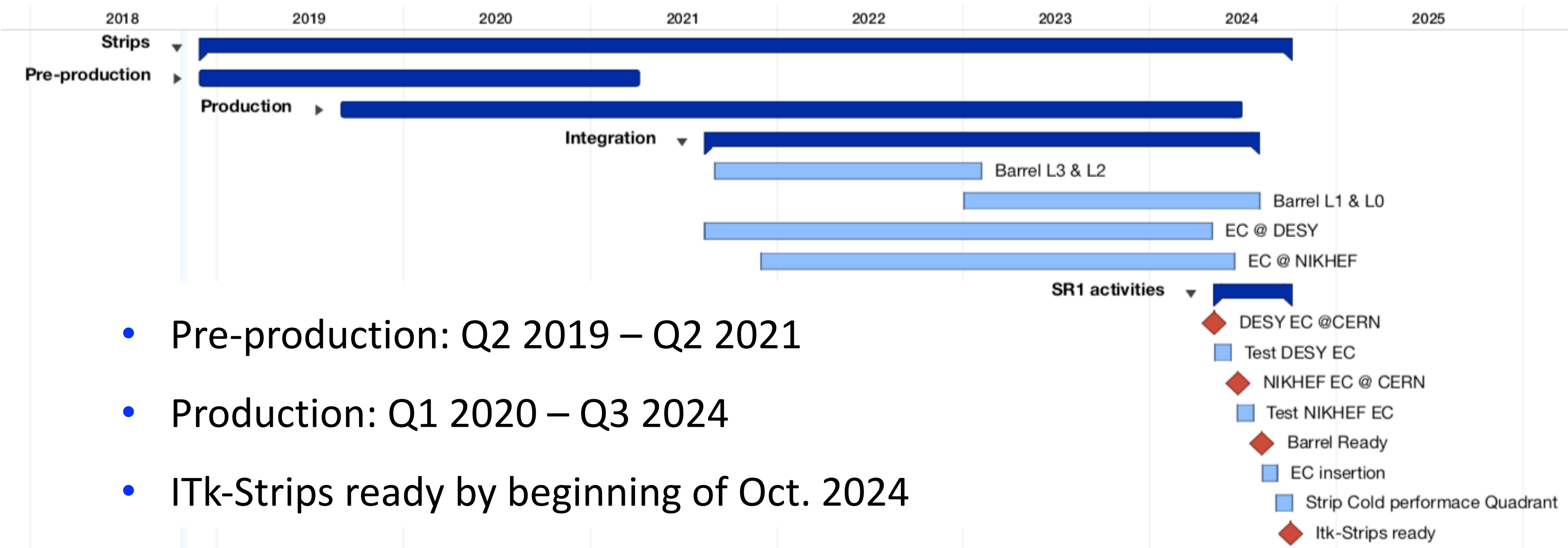


Detector Module QC

Reception and visual inspection of components → Hybrid Electrical Confirmation Tests → Hybrid Attachment → Module Metrology → Wire-bonding → Module Electrical Confirmation Tests → Module I-V Tests → Thermal Tests



ITk Strip Module Schedule



- Pre-production: Q2 2019 – Q2 2021
- Production: Q1 2020 – Q3 2024
- ITk-Strips ready by beginning of Oct. 2024

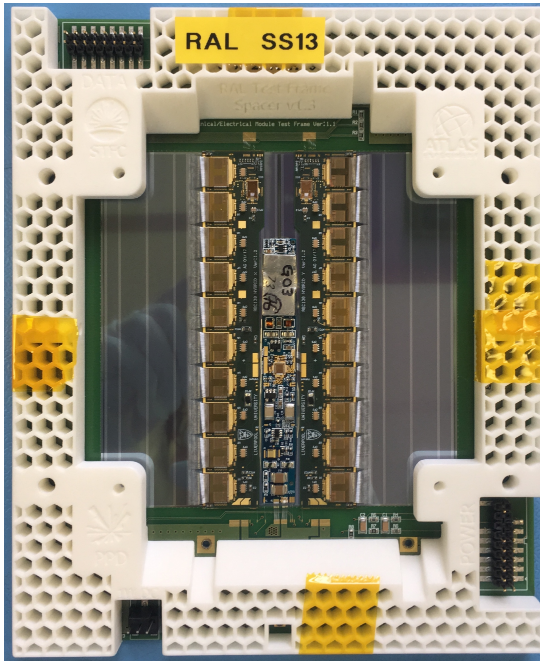
IHEP/THU plan: 1000 barrel strip modules (including hybrids)

- Half number of modules will be produced in Rutherford Appleton Lab (RAL), the other half at IHEP.
- Milestone: Plan to produce the first electrical strip module.

Strip module assembly in RAL

IHEP staff and postdoc located in RAL to make modules for the first double-side ABC130 Short-strip electrical stave.

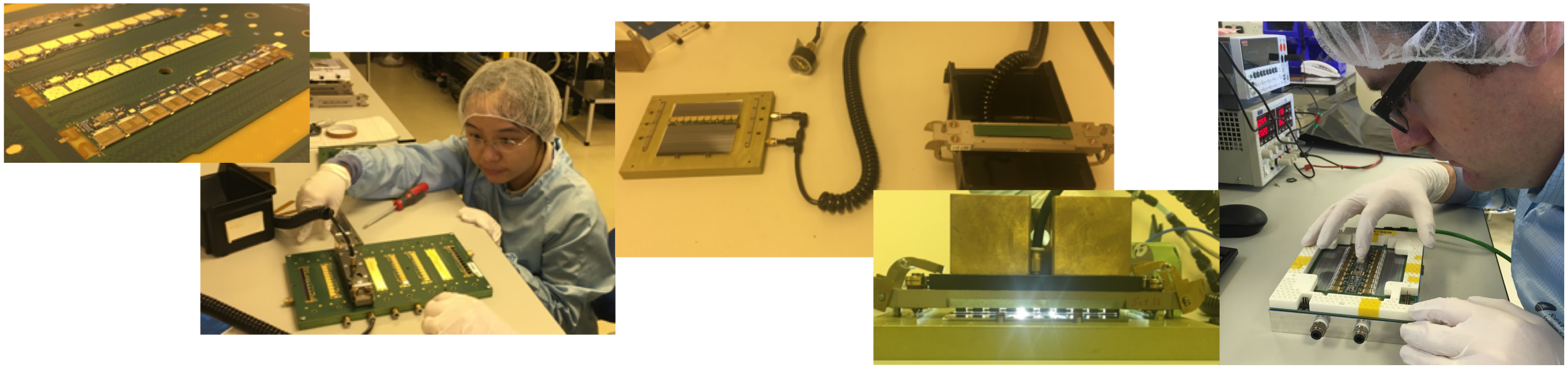
- Hybrid: Metrology, ABC130 gluing, wire bonding, electrical tests
- Module: Hybrid and power board gluing, wire bonding, electrical tests



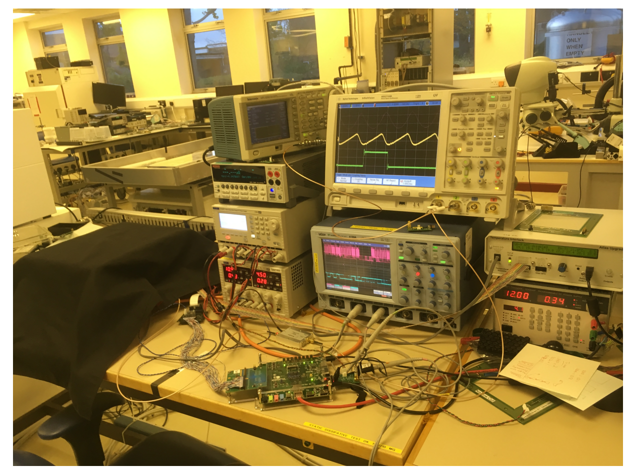
Short Strip (SS)

Long Strip (LS)

Assembly and Electrical Tests

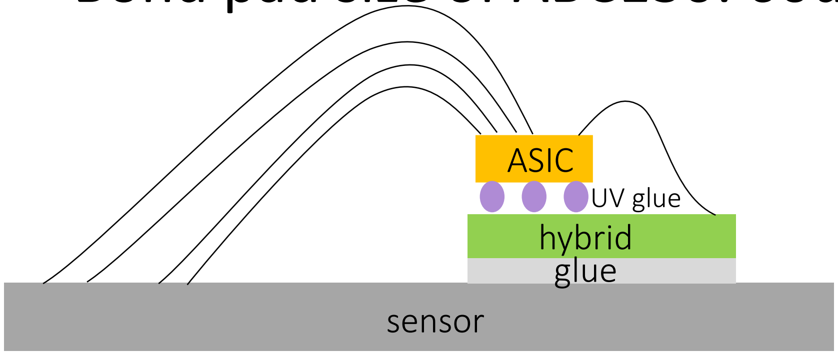


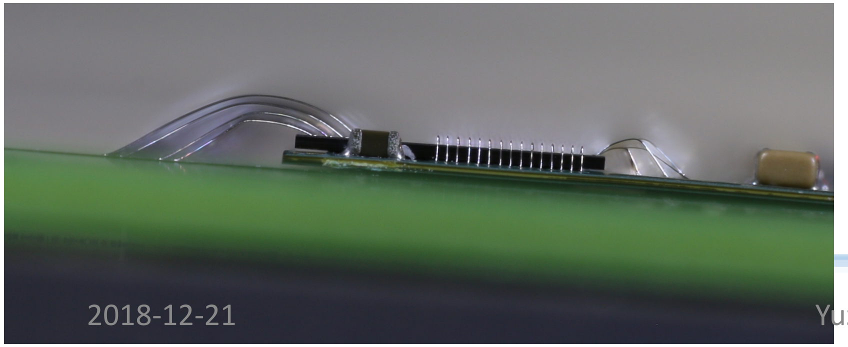
- ITSDAQ is used in the development of ITk strip detector read-out
- Software Configuration:
  - Initial, Hybrid/Module, Chip
- Calibration Tests Essentials:
  - Strobe Delay
  - Trim Range
  - 3-point gain and response curve
  - Noise Occupancy

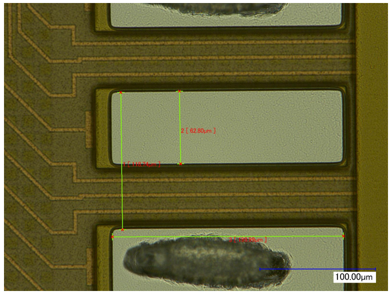


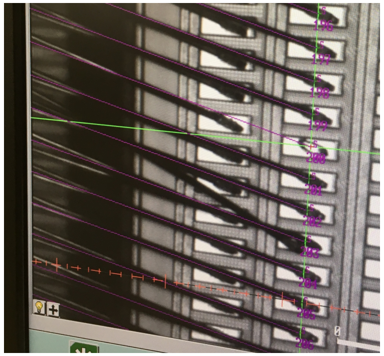
Wire bonding

- 25um Aluminum Wire
- 4-row front-end bonded from sensor to readout
  - Long strip: 2560 channels
  - Short strip: 5120 channels
- ABC130 to PCB: hybrid and power board
- Bond pad size of ABC130: 60um x 200um

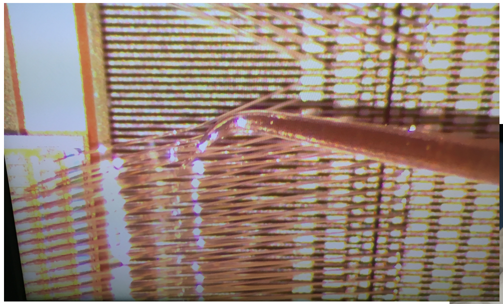


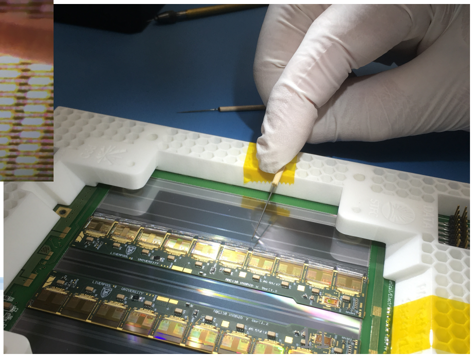






Issue

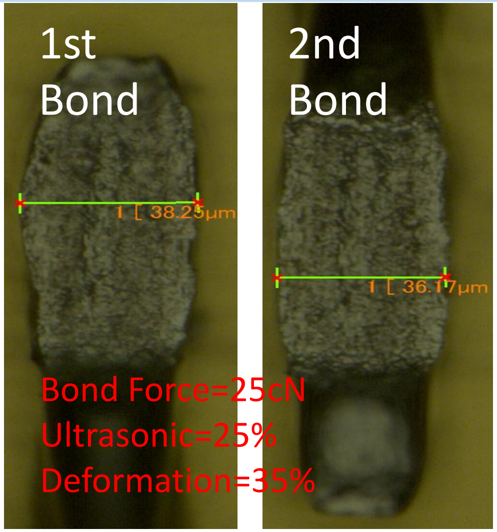


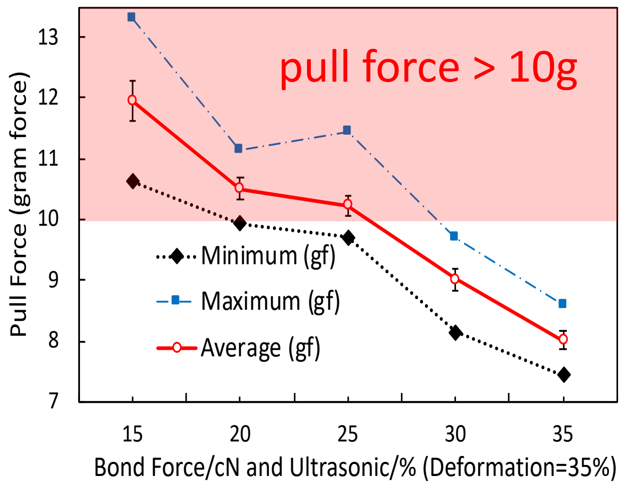


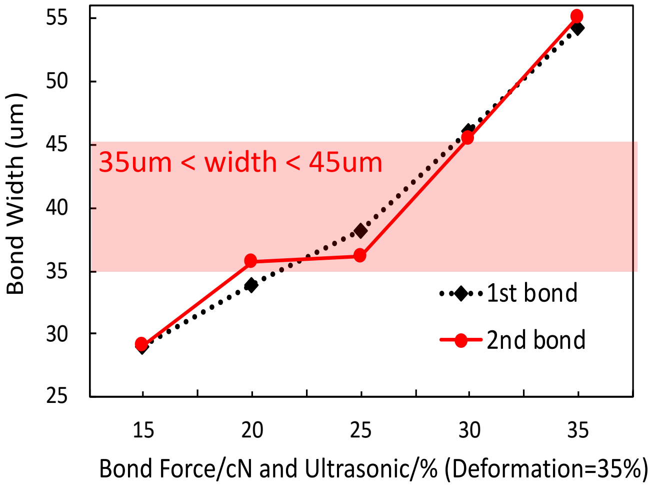
Rework

Optimize parameters for wire bonding

- Main parameters:
  - Bond force
  - Ultrasonic
  - Deformation
  - Tail length
  - Loop shape and height
- Wire bond testing: pull test

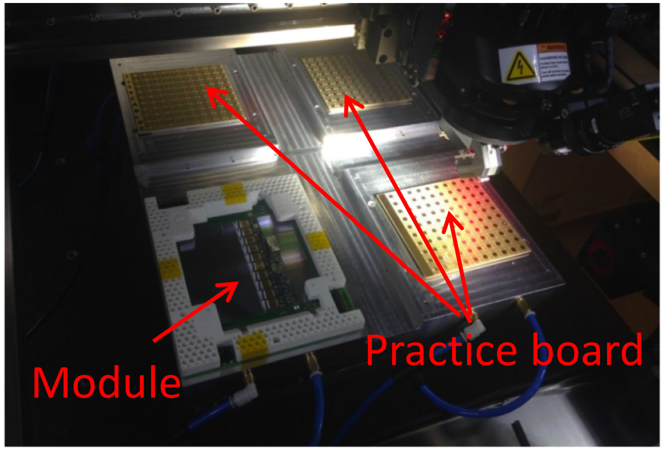


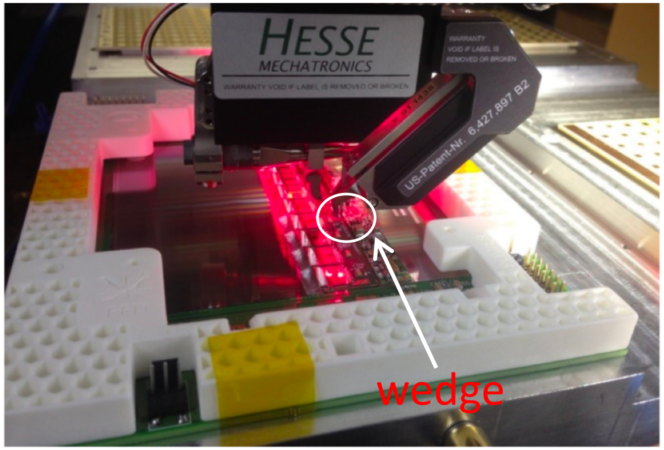


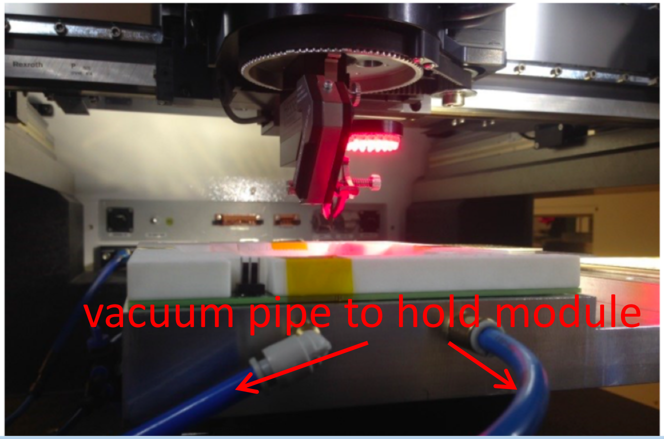


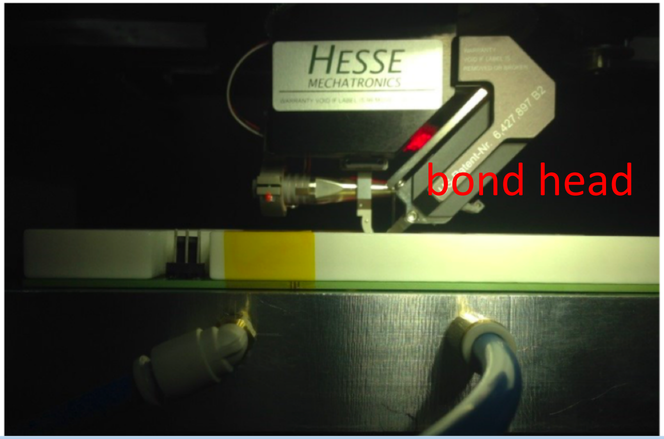
Improve wire bonding efficiency

- Developed 2x2 jig: One module each time → 4 module each time
- Optimize bonding program: pattern search works well for each module



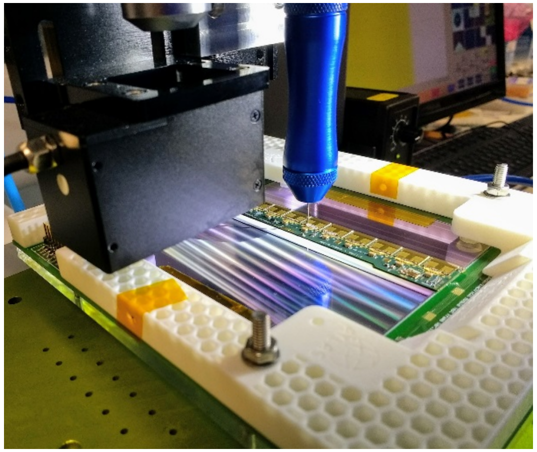




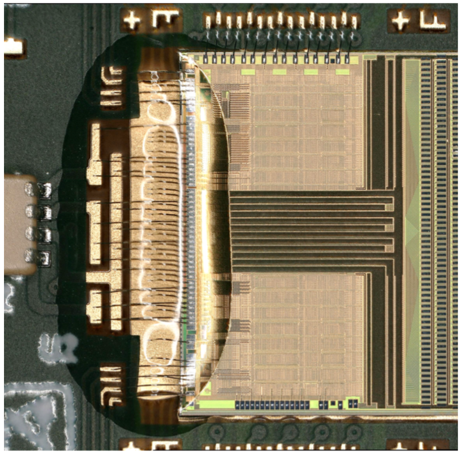


Wire protection: encapsulation

- Lesson from IBL pixel detector: wire corrosion
  - Al wire Bond Corrosion due to humidity
  - Humidity control became most important step in quality control
- Another way to protect wire bond: encapsulation (R & D with Oxford)
  - Fully encapsulate ASIC back-end wires (ASIC to hybrid)
  - More tests on going check the performance before and after



Glue dispenser to perform the encapsulation R & D



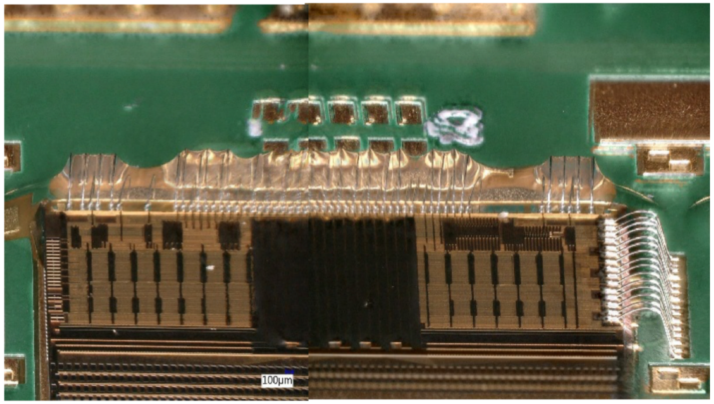
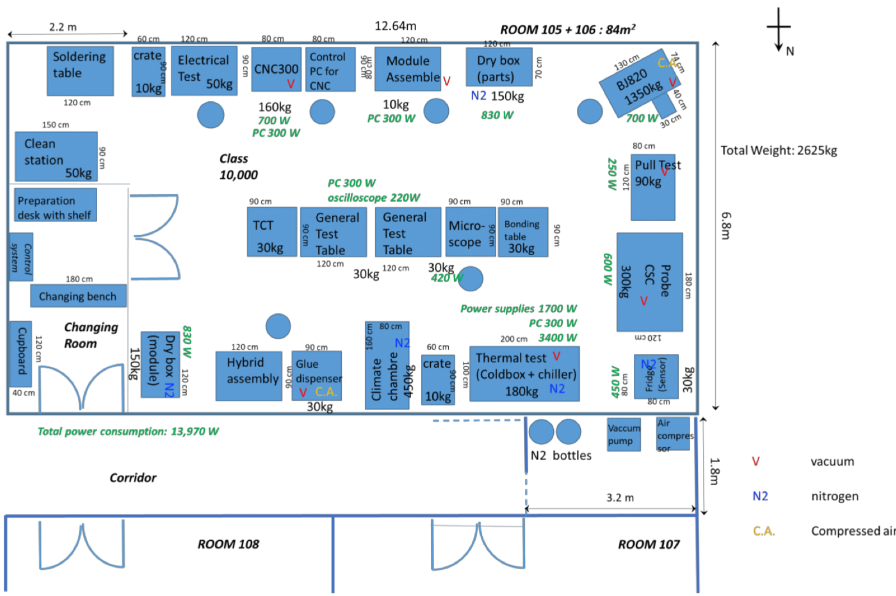


Photo of wire bond encapsulation (Sylgard 186 Silicone Elastomer)

IHEP/THU Clean room

80m^2 Class 10,000 clean room being constructed

→ dedicated for the ATLAS strip module production



BondJet820

Smart scope

Probe station

- Almost waiting for check and accept
- Waiting for the setup of machines
- Plan to produce 1st electrical module in Q1 2019

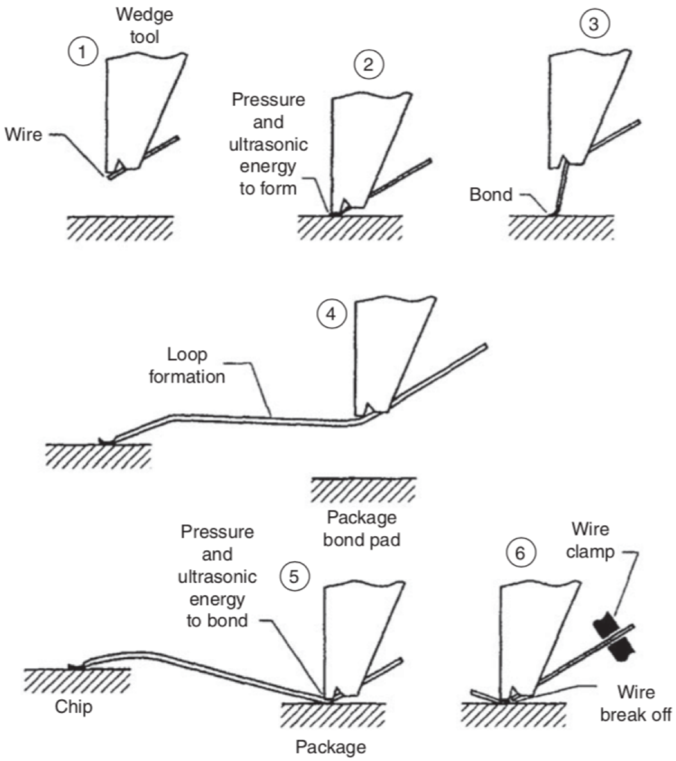
Summary

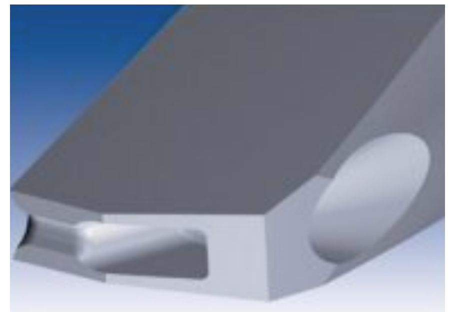
- ITk strip module schedule:
  - Pre-production: Q2 2019 – Q2 2021, production: Q1 2020 – Q3 2024
- Module production:
  - Hybrid assembly, module assembly, electrical testing
  - Wire bonding: Parameter optimization, improve bonding efficiency, encapsulation
- IHEP/THU group process:
  - Clean room will be dedicated into ITk strip module production
  - Plan to produce 1st electrical module at Q1 2019
  - Staff and postdoc based at RAL to produce modules for 1st double sided electrical stave

Thank you!

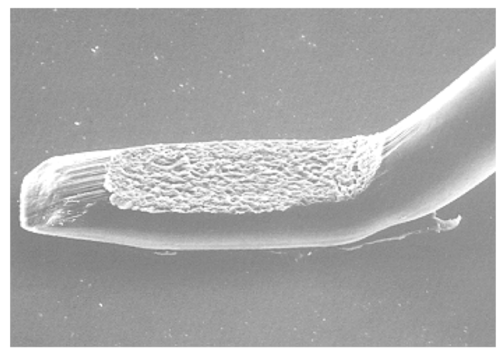
Back up

Wedge Wire Bonding

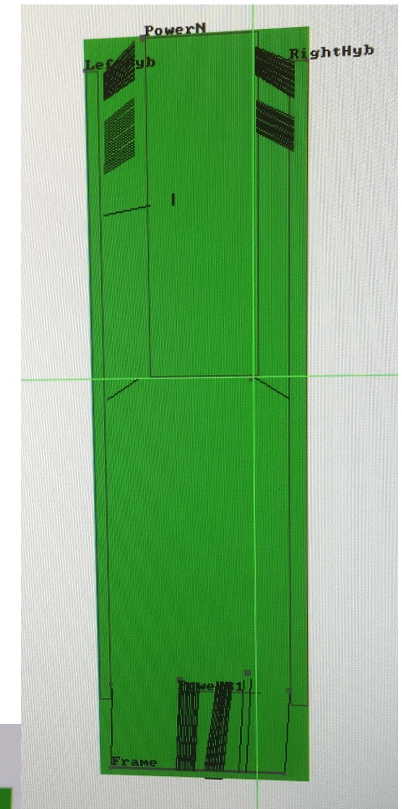


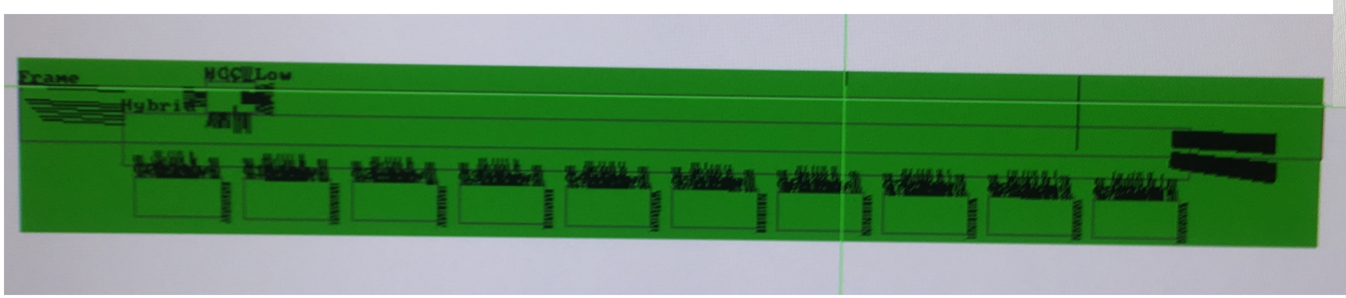


wedge



bond

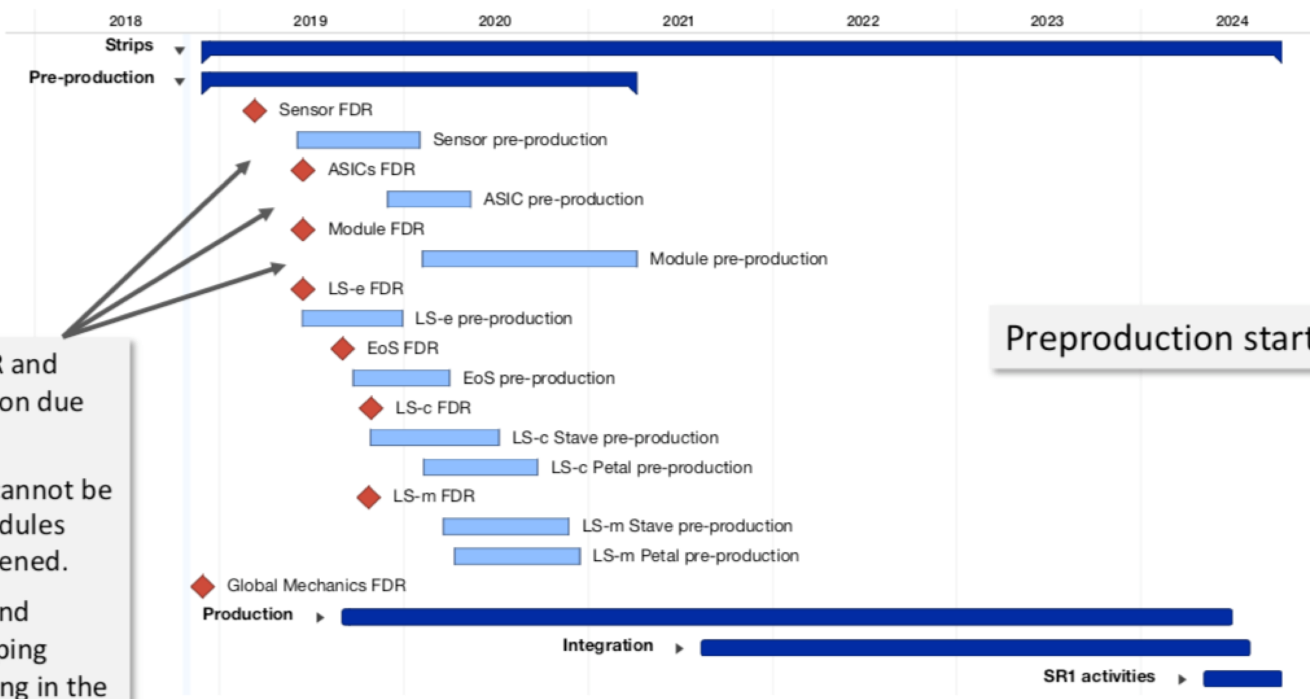




Strip Module Pre-production

Prior to PRR – Preproduction

Summary schedule



Gaps between FDR and actual preproduction due to procurement.

Sensor and ASICs cannot be shortened. For modules gap could be shortened.

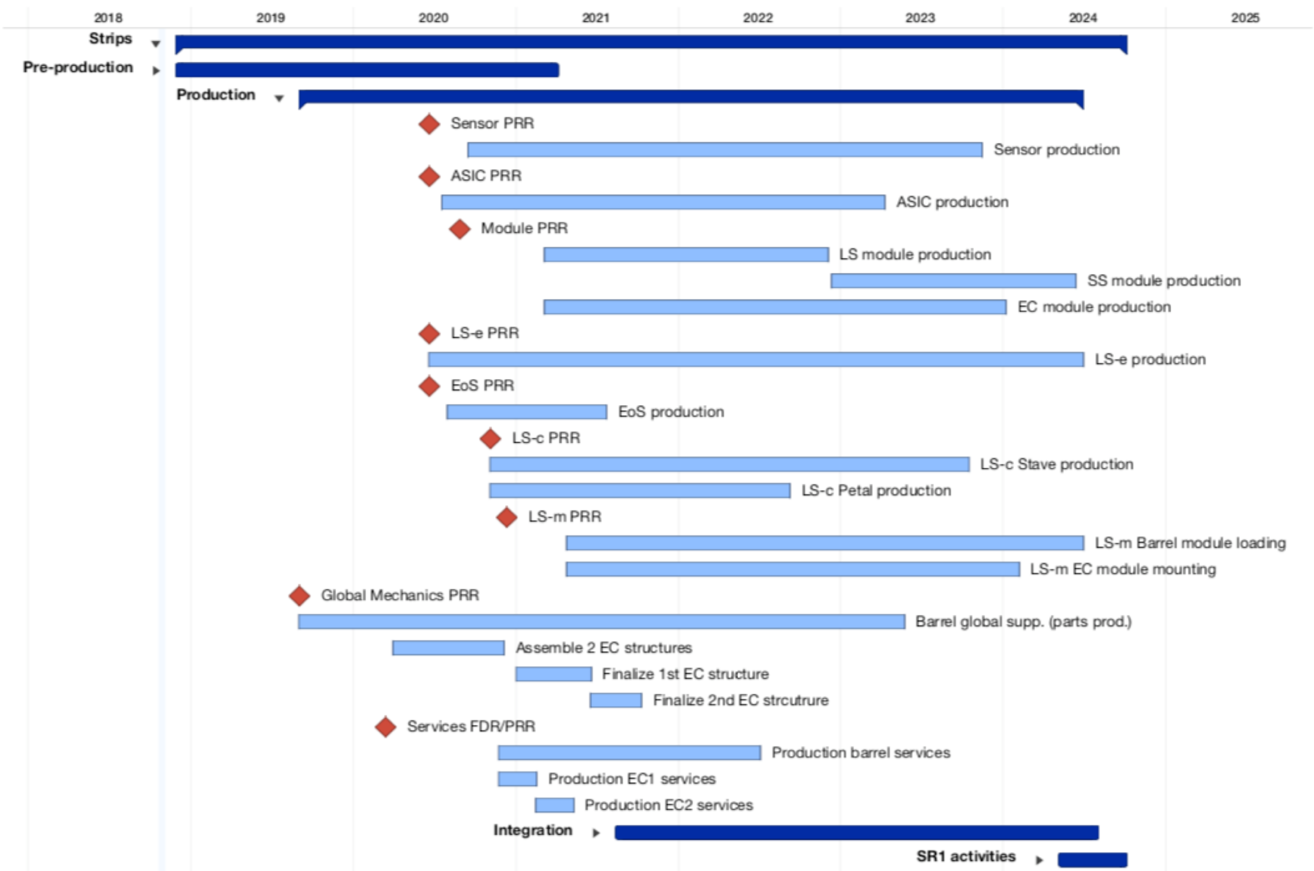
Site qualification and additional prototyping should be happening in the gaps.

Preproduction starts next year.

https://indico.cern.ch/event/772184/contributions/3210581/attachments/1750738/2836720/2018.11-AUW-Strips-Schedule.pdf

Strip Module Production

Production



Horizon 2020,
when production starts

Summary schedule

Layer	Radius [mm]	Maximal Fluence [n_{eq}/cm^2]	Maximal Dose [MRad]
Strips			
Long Strips	762	4.2×10^{14}	10.7
Short Strips	405	8.1×10^{14}	35.7
End-cap	385	1.2×10^{15}	50.4
Pixels			
Layer 0	39	2.25×10^{16}	1710
Layer 1	75	0.82×10^{16}	715
Layer 2	155	0.25×10^{16}	148
Layer 3	213	0.12×10^{16}	96
Layer 4	271	0.12×10^{16}	61
End-cap	80	0.67×10^{16}	687