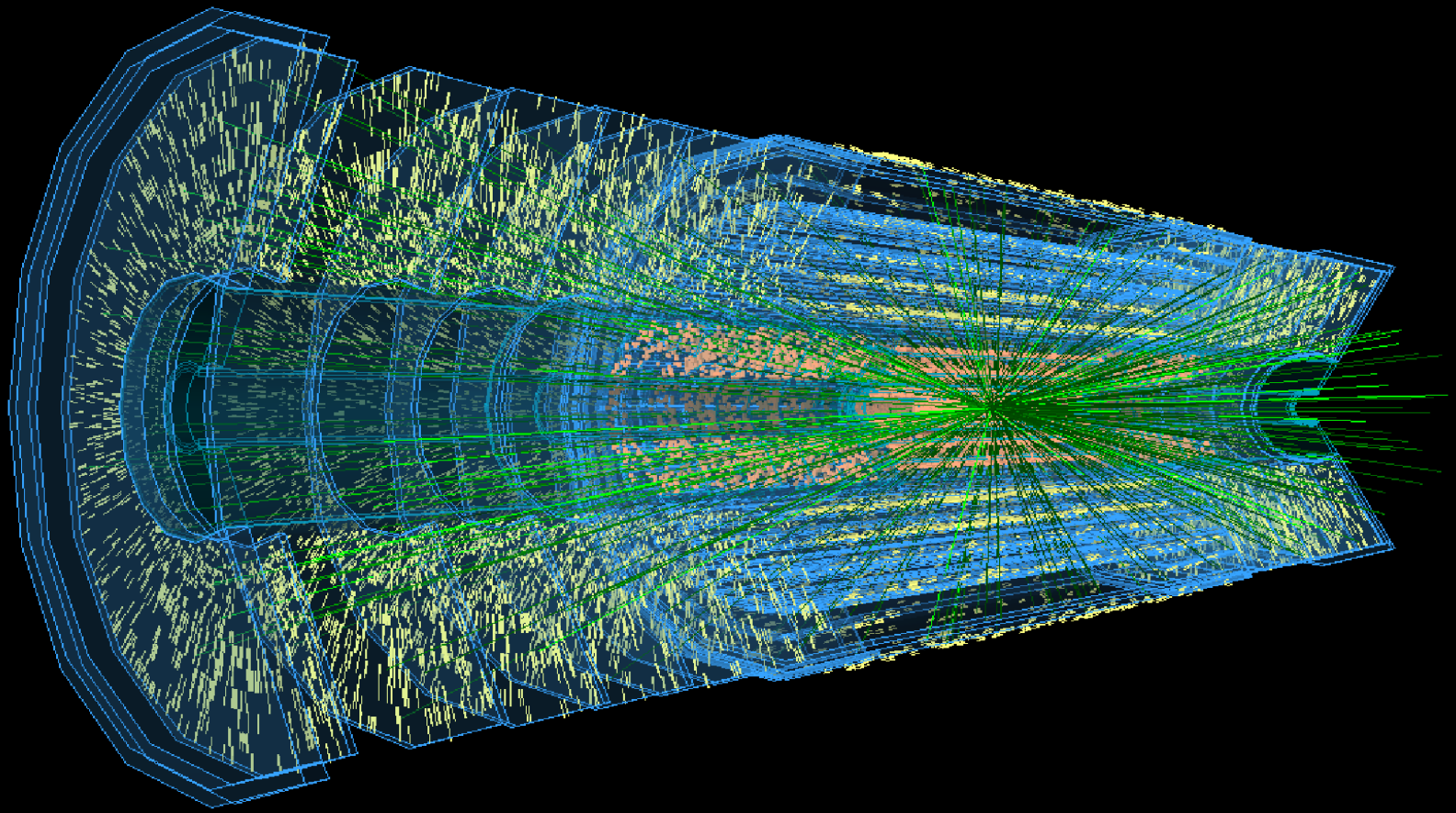
# ATLAS Inner Tracker For The HL-LHC



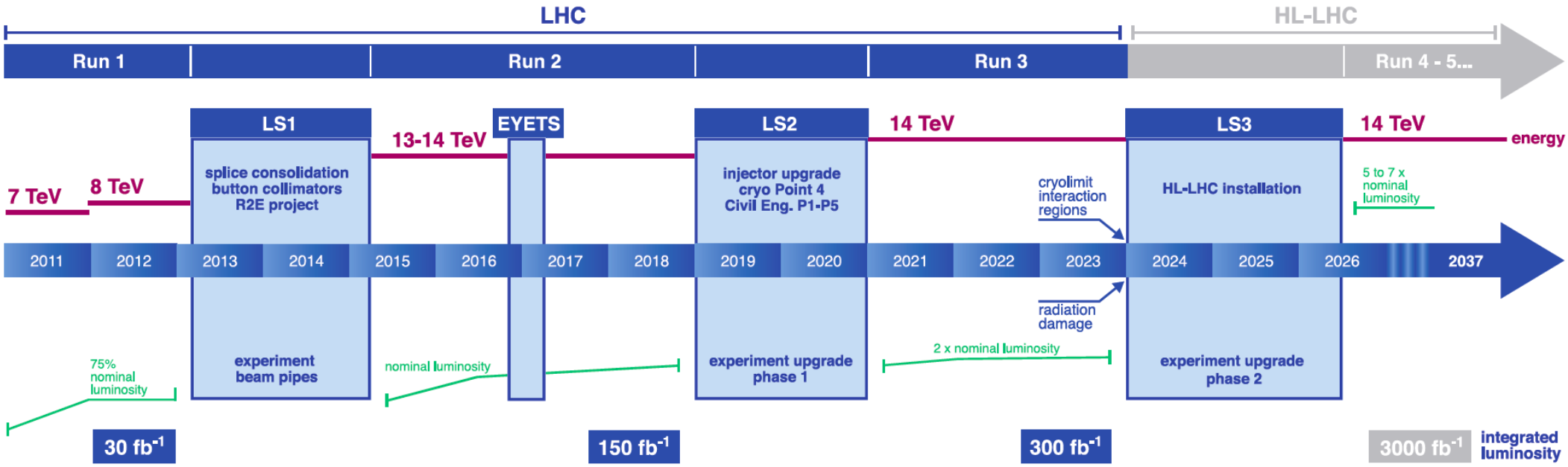
**Spåtind 2018**

Nordic Conference on Particle Physics

**Craig Wiglesworth**

UNIVERSITY OF COPENHAGEN

# Schedule For LHC / HL-LHC




**Run 3 (2021)** → 14 TeV, 55 – 80* interactions per bunch crossing, 300 $fb^{-1}$ by ~2023

**Run 4+ (2026)** → 14 TeV, up to 200* interactions per bunch crossing, 3000 $fb^{-1}$ by ~2035

*For reference: mean interactions per bunch crossing in 2017 = 38

HL-LHC will pose difficult experimental challenges with respect to:
detector occupancies, readout, trigger rates, event sizes, radiation-hardness etc

**ATLAS will undergo detector upgrades to adapt to challenges and fully exploit opportunities offered by the HL-LHC**

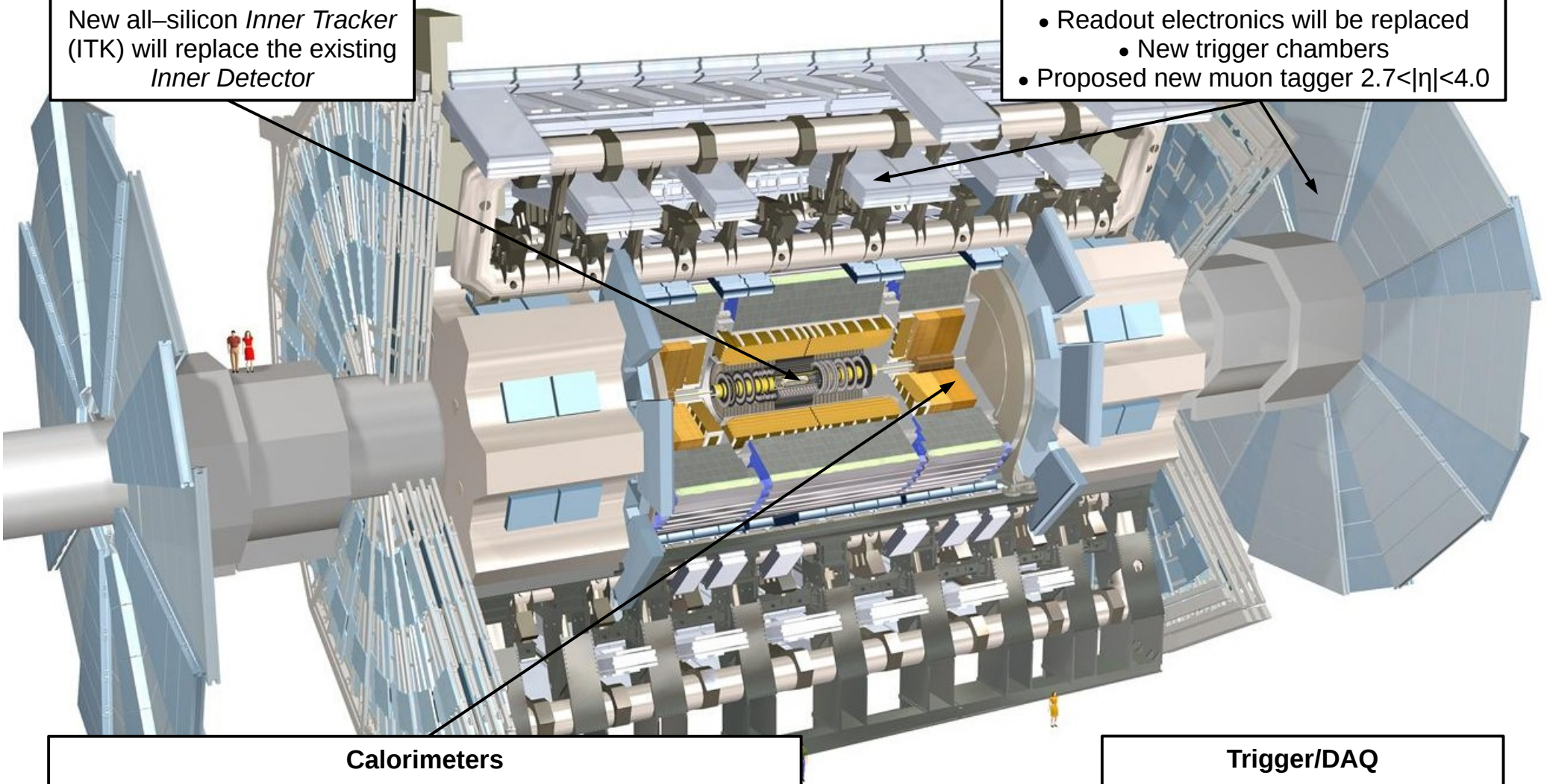
# ATLAS Upgrades For HL-LHC

**Tracking**

New all–silicon *Inner Tracker* (ITK) will replace the existing *Inner Detector*

**Muon Spectrometer**

- Readout electronics will be replaced
- New trigger chambers
- Proposed new muon tagger 2.7<|η|<4.0



**Calorimeters**

- Readout electronics will be replaced
- Proposed new forward calorimeter with increased granularity
- Proposed new *O*(10's ps) timing detector 2.4<|η|<4.3

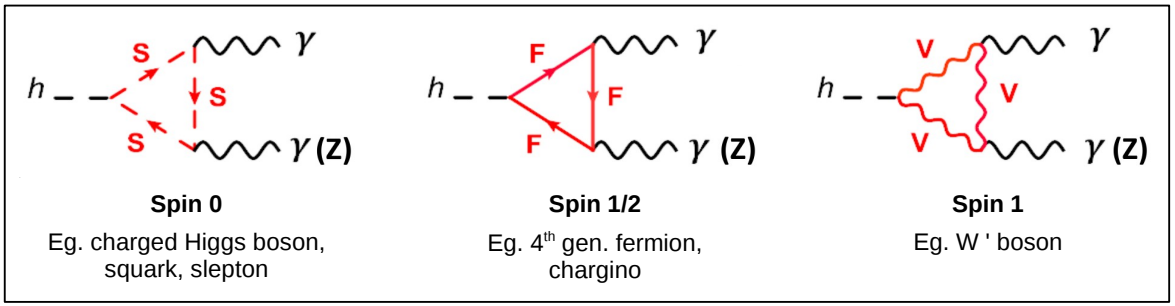
**Trigger/DAQ**

| | |
|---|---|
| L0 (calo+muon) | 1 MHz |
| L1 (calo+muon+track) | 400 kHz |
| HLT | 10 kHz |

# ATLAS Physics at HL-LHC

● **WH / ZH / ttH and H→μμ:** Statistically limited → large gains in Δμ/μ at HL-LHC. Allow access to the top and muon-Yukawa couplings.

● **H → Zγ / H → γγ:** Improved precision can probe new physics via loop diagrams.



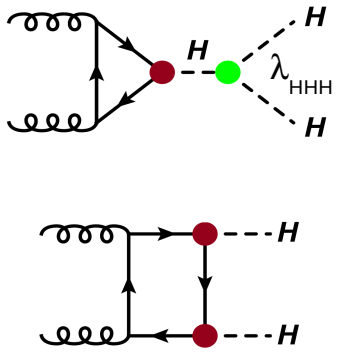

**Spin 0**
Eg. charged Higgs boson, squark, slepton

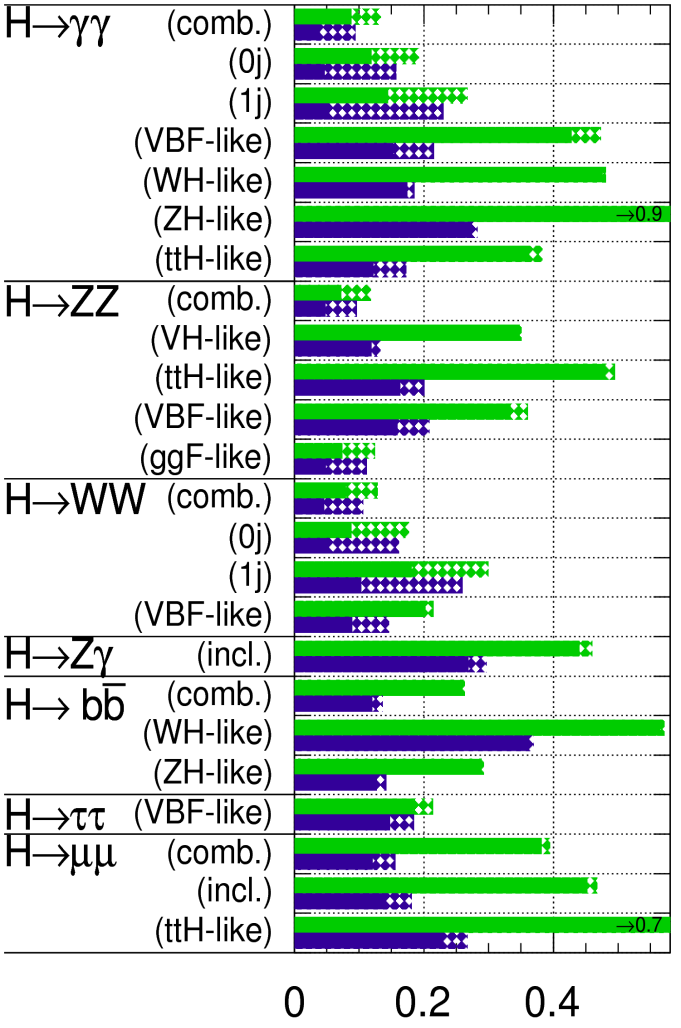
**Spin 1/2**
Eg. 4th gen. fermion, chargino

**Spin 1**
Eg. W ' boson

● **Higgs Self-Coupling:** Measurement is important to confirm the Higgs mechanism. Triple Higgs coupling ($\lambda_{HHH}$) could be observable via HH pair production.

| Decay Channel | Branching Ratio | Total Yield (3000 fb$^{-1}$) |
|---|---|---|
| $b\bar{b} + b\bar{b}$ | 33% | 40,000 |
| $b\bar{b} + W^+W^-$ | 25% | 31,000 |
| $b\bar{b} + \tau^+\tau^-$ | 7.3% | 8,900 |
| $ZZ + b\bar{b}$ | 3.1% | 3,800 |
| $W^+W^- + \tau^+\tau^-$ | 2.7% | 3,300 |
| $ZZ + W^+W^-$ | 1.1% | 1,300 |
| $\gamma\gamma + b\bar{b}$ | 0.26% | 320 |
| $\gamma\gamma + \gamma\gamma$ | 0.0010% | 1.2 |



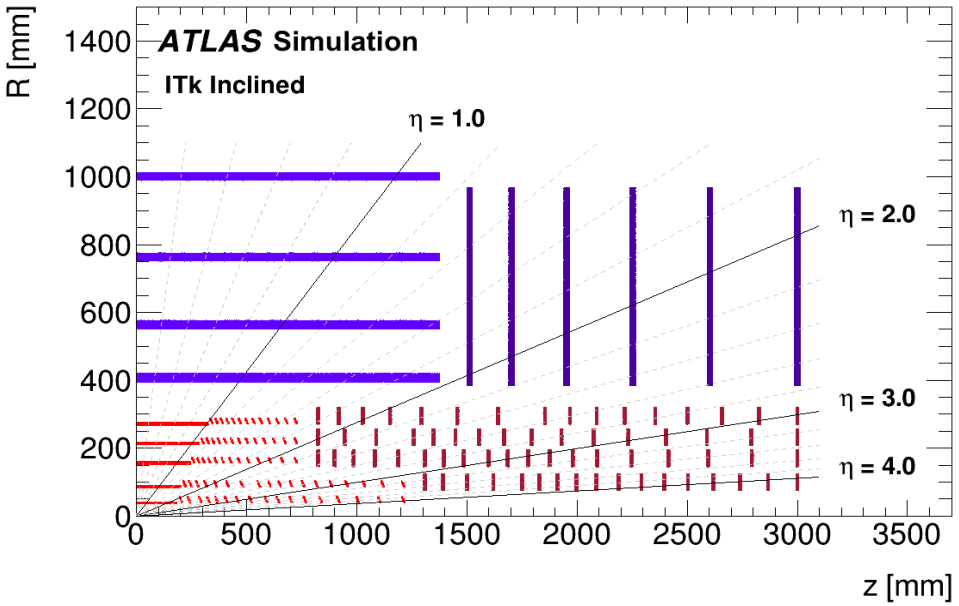




https://twiki.cern.ch/twiki/bin/view/AtlasPublic/UpgradePhysicsStudies

# The Inner Tracker (ITK)

The current Inner Detector was only designed to survive expected radiation exposure up to end of Run 3 (2022)

For the HL-LHC the current Inner Detector will replaced with an all–silicon (pixel and strips) **Inner Tracker (ITK)**




**Highlights of the Inner Tracker Design....**

- Increased radiation hardness: 10+ year lifetime (@ x10 integrated radiation)
- Increased granularity: baseline occupancy of < 0.1% for pixels, < 1% for strips @ <μ>=200
- Reduced material budget: > 30% less
- Extended η coverage: |η| < 2.5 → |η| < 4.0
- New readout scheme: allows implementation of a track trigger at earlier stage of triggering

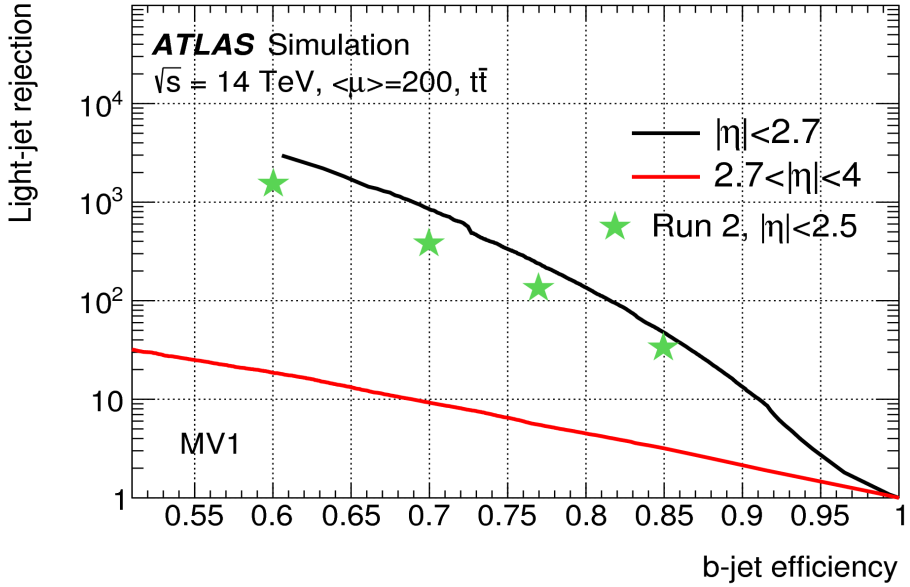
| | **Pixels** | **Strips** |
|---|---|---|
| **Barrel Layers** | 5 | 4 |
| **Endcap Disks/Rings** | many rings | 6 disks |
| **Number of Channels** | ~800 M (80 M) | 60 M (6 M) |

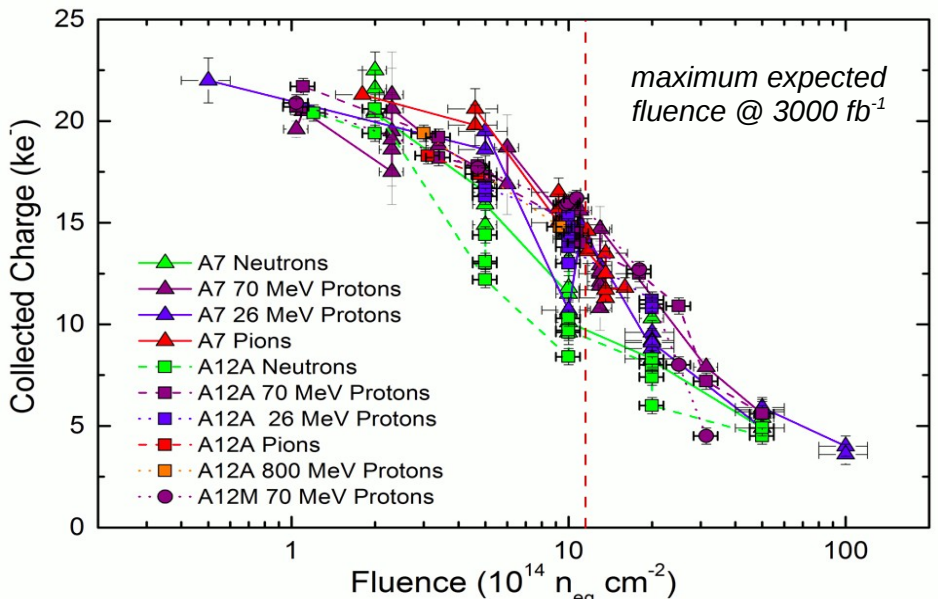
* *The values for the current ATLAS Inner Detector*

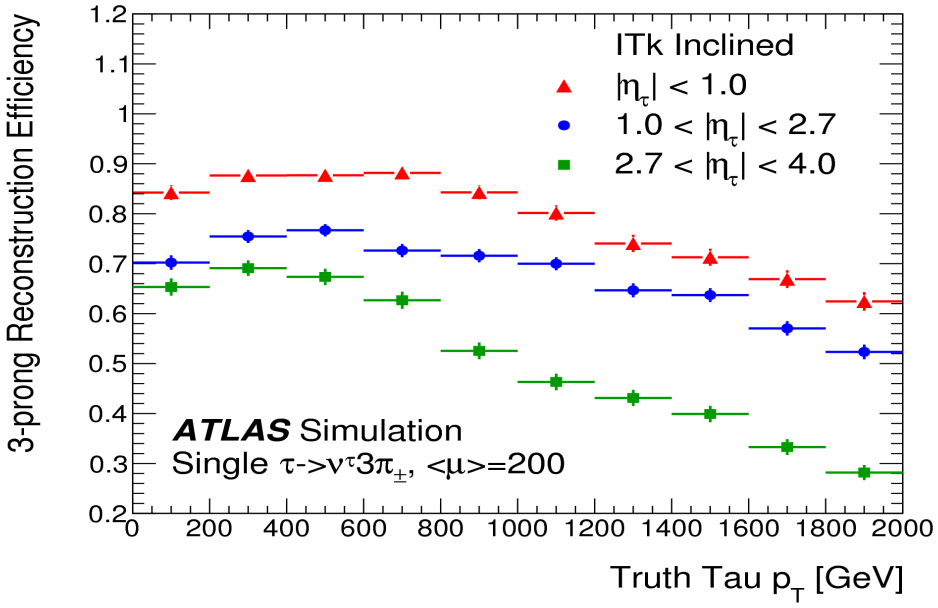
# Inner Tracker Performance

The Inner Tracker is expected to perform at least as well as the current Inner Detector despite the much harsher challenges of the HL-LHC

In some case, the Inner Tracker is expected to perform **better** than the current Inner Detector

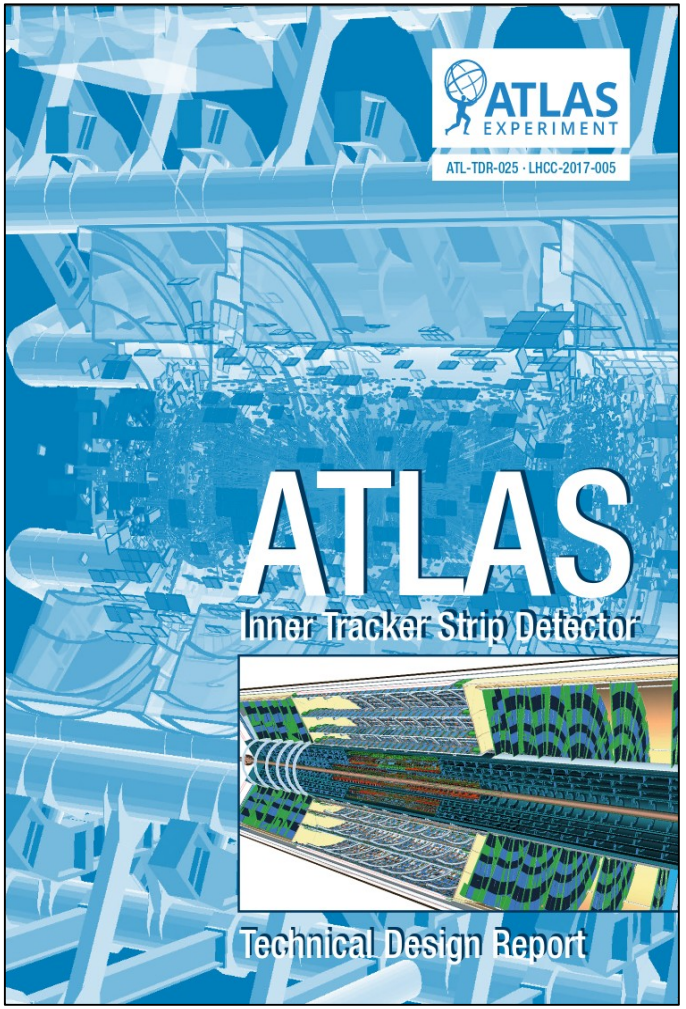


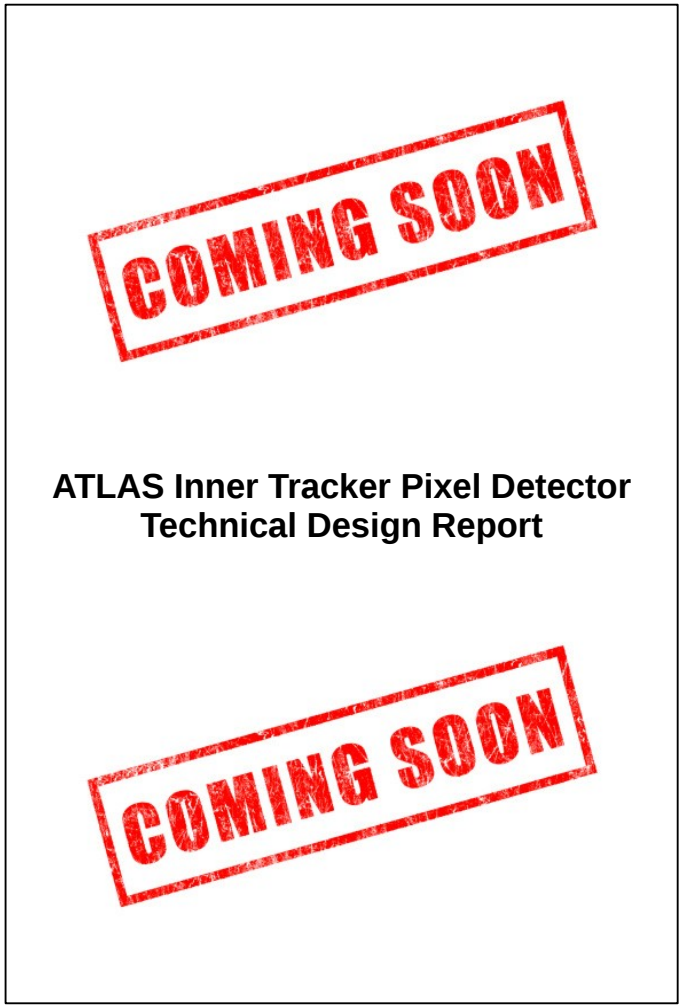



# Inner Tracker Current Status

The Inner Tracker project will soon begin to move from a R&D phase to a prototyping phase



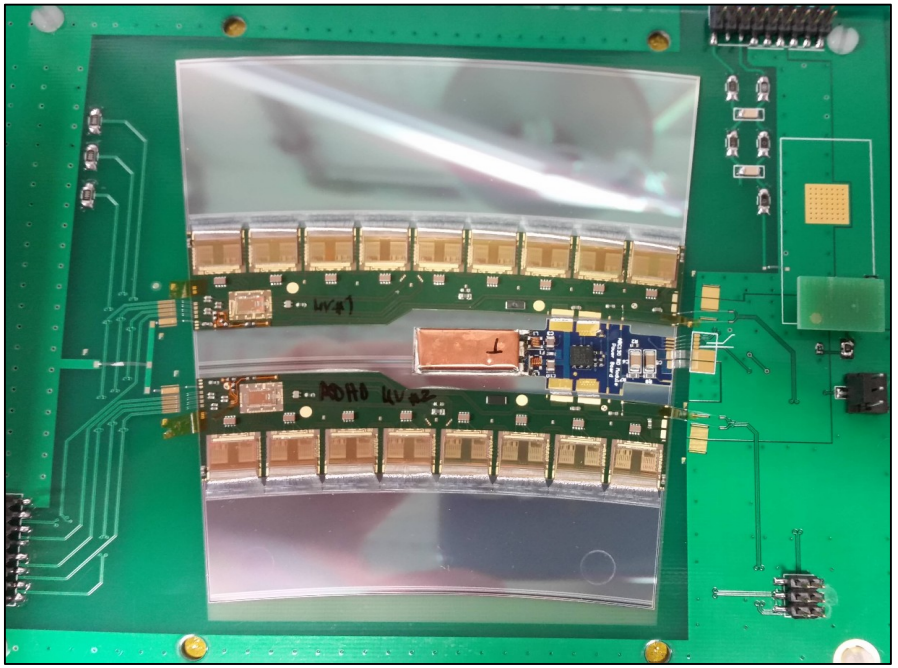

*https://cds.cern.ch/record/2257755*

# Nordic Activities on Inner Tracker

**University of Copenhagen, Lund University**, and **Uppsala University** are participating in **Inner Tracker Strips** project

In collaboration with an industrial partner **NOTE** we plan to build **1000 ITK Strip Modules**

*Also see the next talk on ATLAS Pixel Upgrades*



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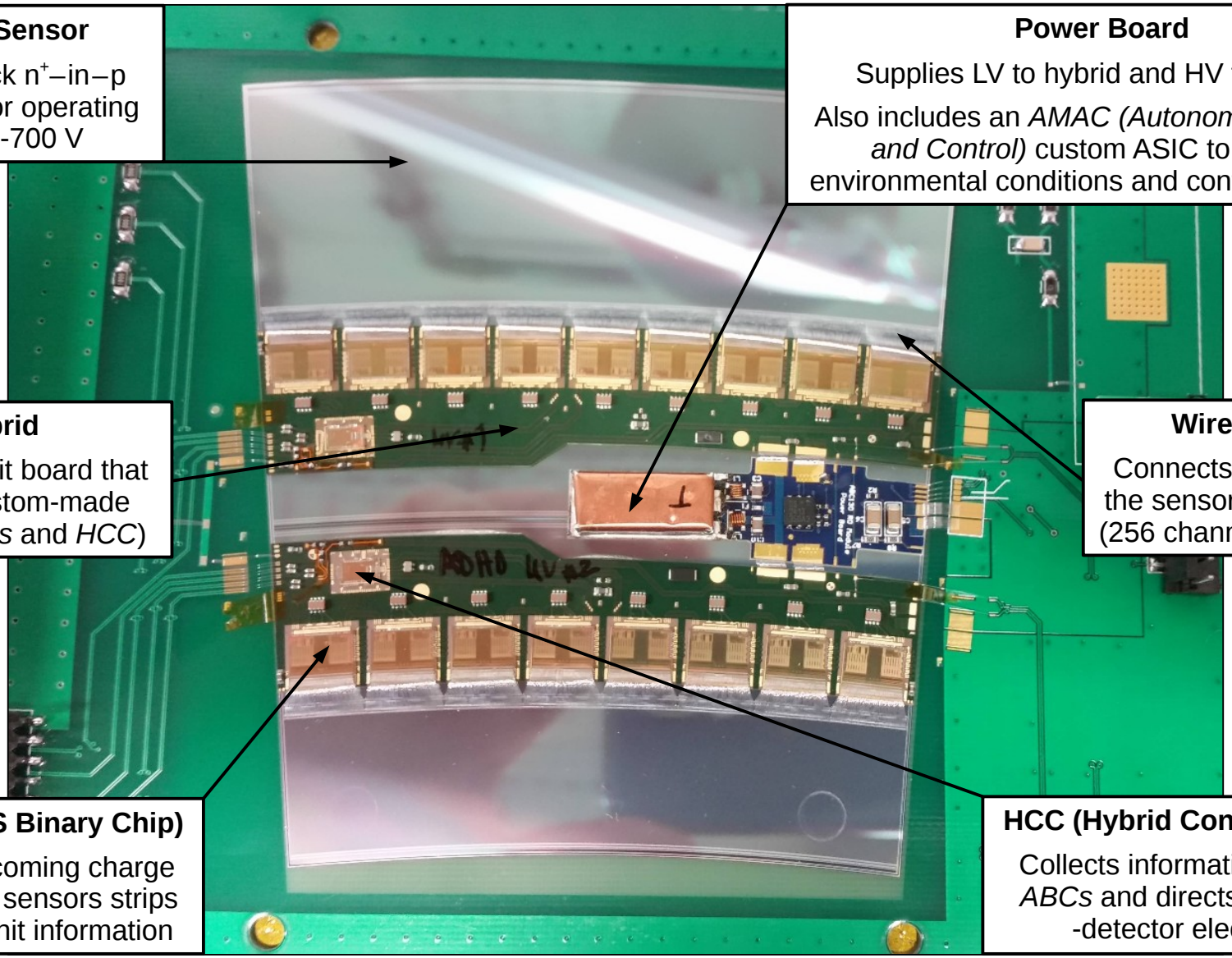
# Inner Tracker Strips Module



**Silicon Sensor**

320 µm thick $n^+$–in–p silicon sensor operating at up to -700 V

**Power Board**

Supplies LV to hybrid and HV to sensor

Also includes an *AMAC (Autonomous Monitor and Control)* custom ASIC to monitor environmental conditions and control powering

**Hybrid**

Kapton circuit board that houses custom-made ASICs (*ABCs* and *HCC*)

**Wire Bonds**

Connects the strips of the sensor to the *ABCs* (256 channels per *ABC*)

**ABC (ATLAS Binary Chip)**

Converts incoming charge signals from sensors strips into hit / no-hit information

**HCC (Hybrid Controller Chip)**

Collects information from the *ABCs* and directs it to the off -detector electronics

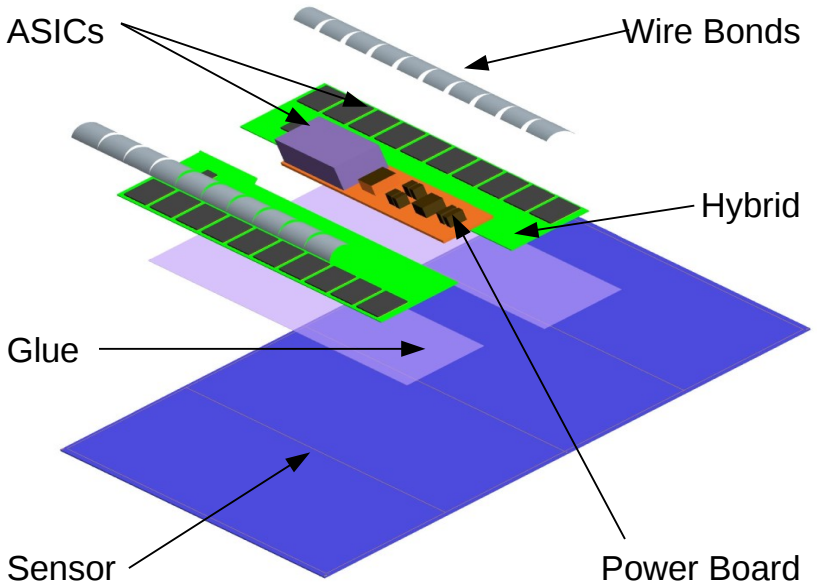
*https://indico.cern.ch/event/577879/contributions/2740169/attachments/1572654/2481972/HSTD-R0_Module_Building.pdf*

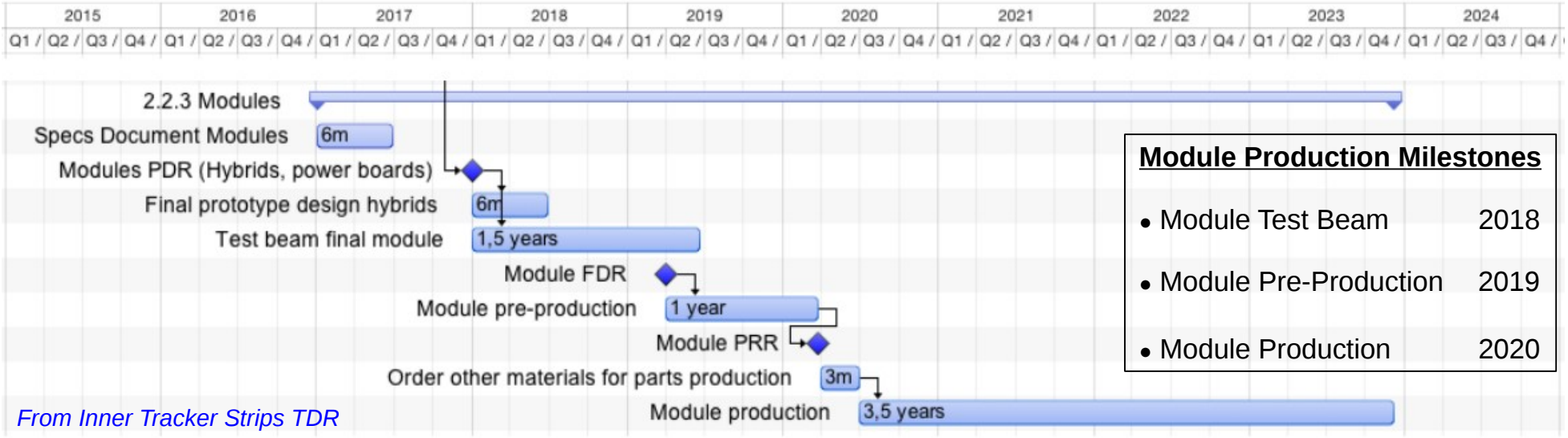
# Module Production Plan

**Module Production Steps**

- Pre-tested ASICs are glued onto hybrids and wire bonded
- Hybrids are tested electrically
- Hybrids and power boards are glued to the sensors
- ASICs are wire bonded onto sensors *
- Full module is tested

* ***…looking for other possible wire-bonding sites***



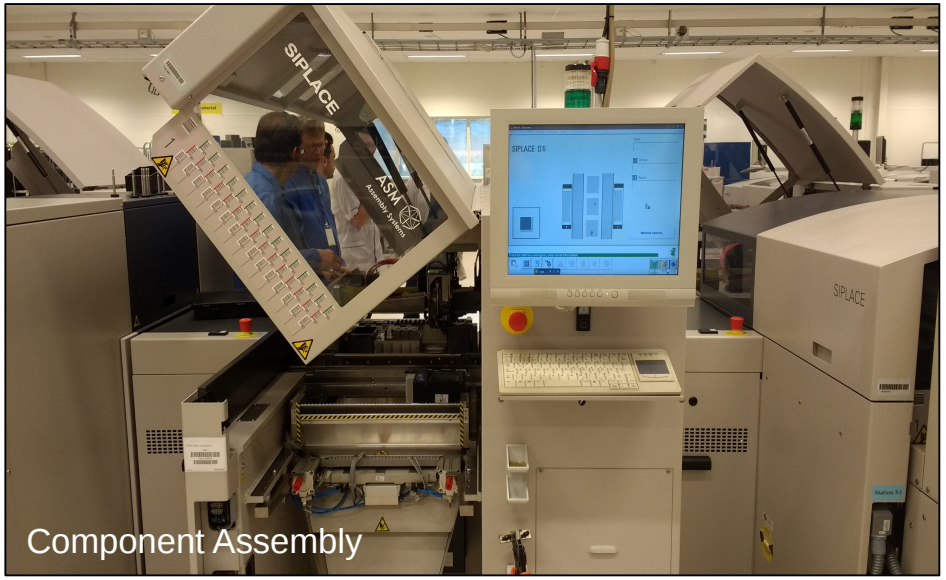

**Module Production Milestones**

| | |
|---|---|
| • Module Test Beam | 2018 |
| • Module Pre-Production | 2019 |
| • Module Production | 2020 |

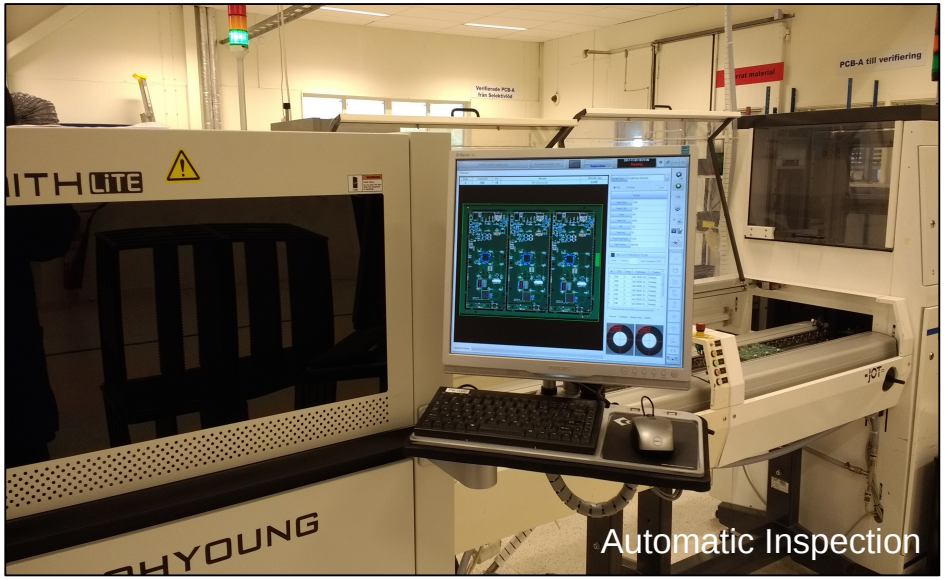
*From Inner Tracker Strips TDR*

# NOTE's Production Line

# NOTE's Production Line



Component Assembly

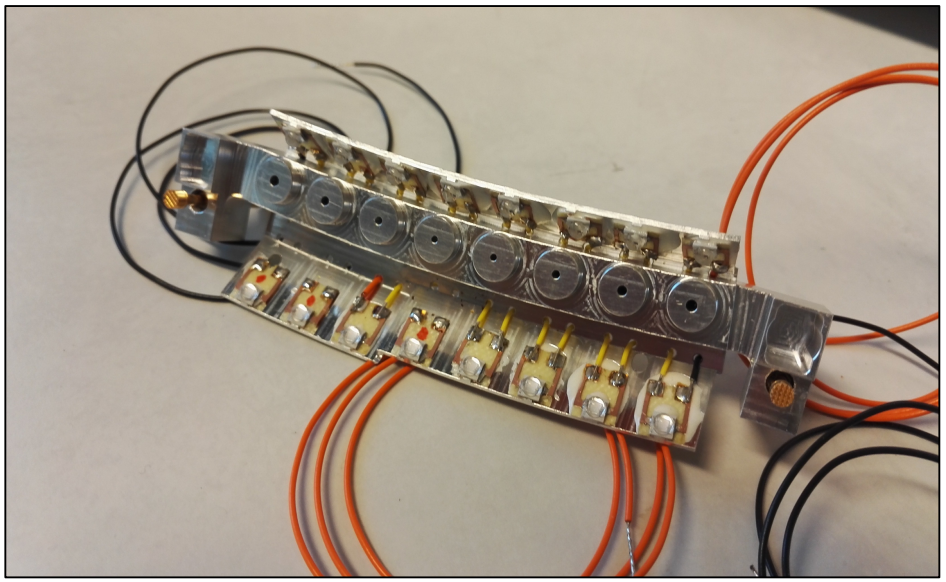


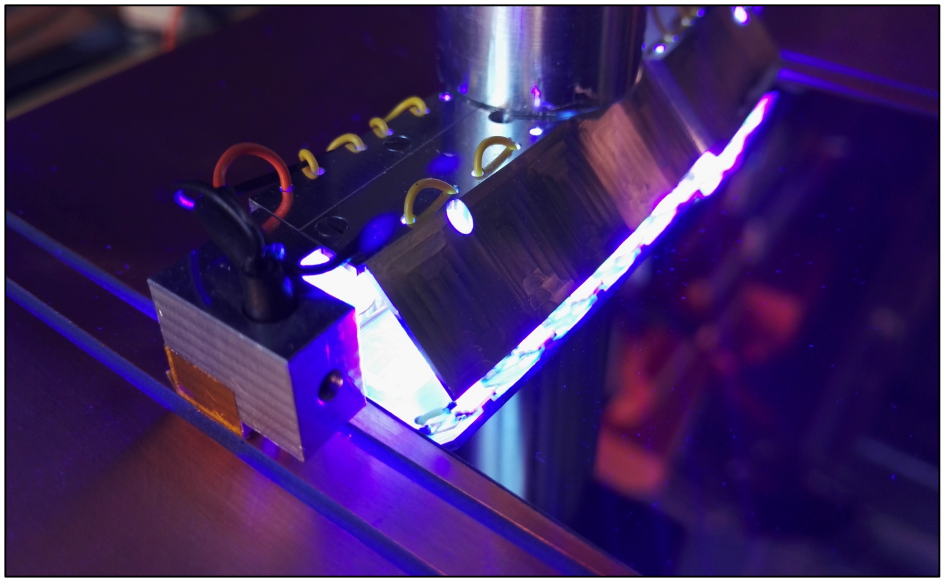
Automatic Inspection


Wire Bonding / Clean Room


Visual Inspection / Module Testing

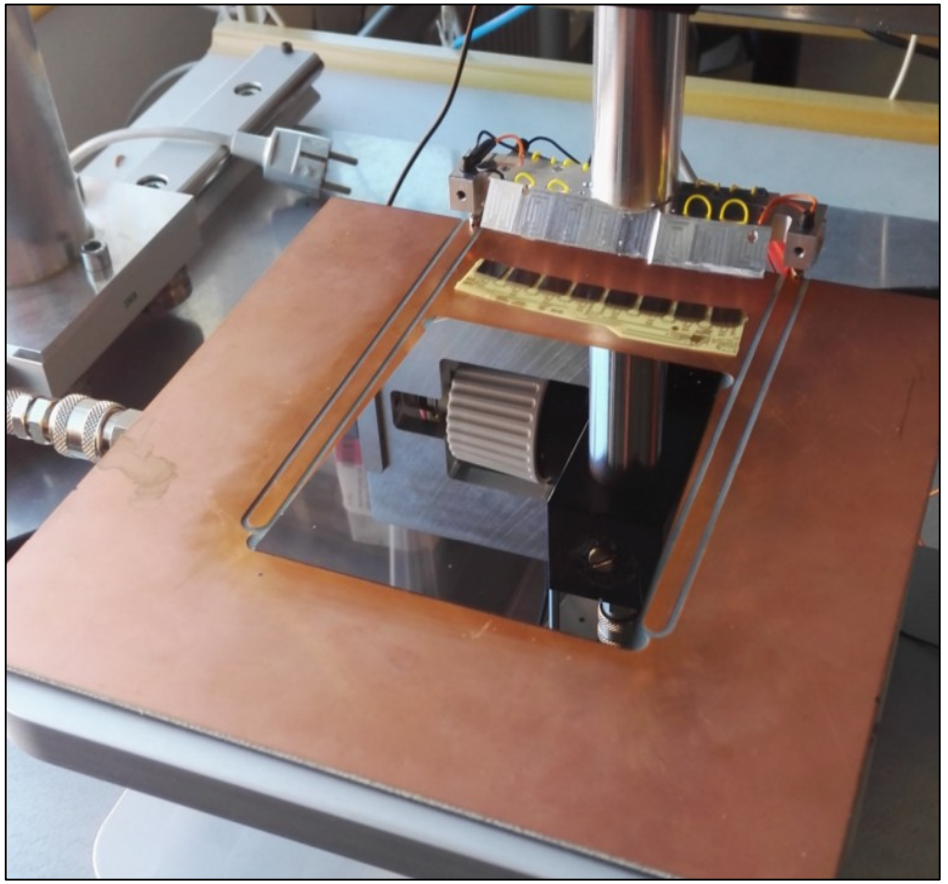
# Status of Local Developments





**Module Production Tools**

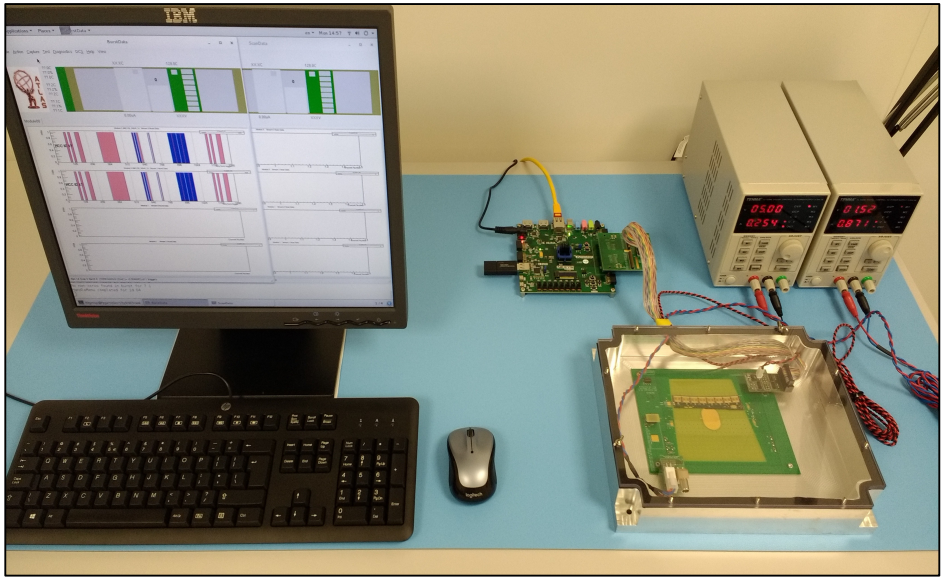
- Custom-made tools are needed for module production
- A number of prototypes have been designed and built
- The prototype tools are being tested in production line

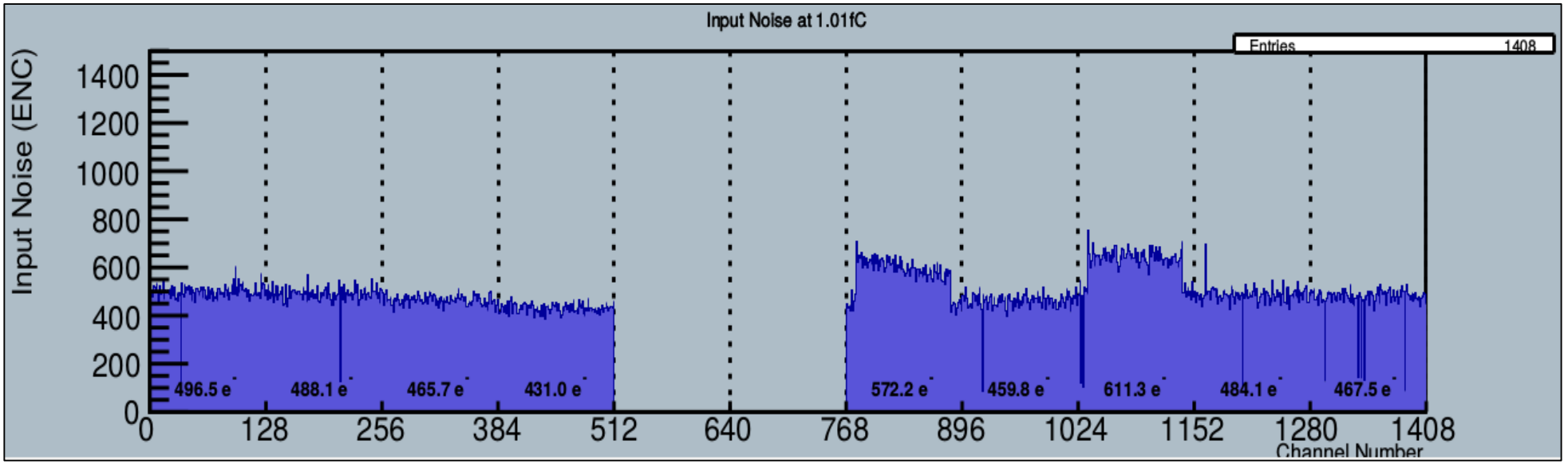


# Status of Local Developments

**Module Data Acquisition (DAQ)**

- We have set up a DAQ system for module readout
- Based on the DAQ sw for current Inner Detector
- Being used to readout prototype hybrids / modules
- Allows measurements of chip response / noise etc.



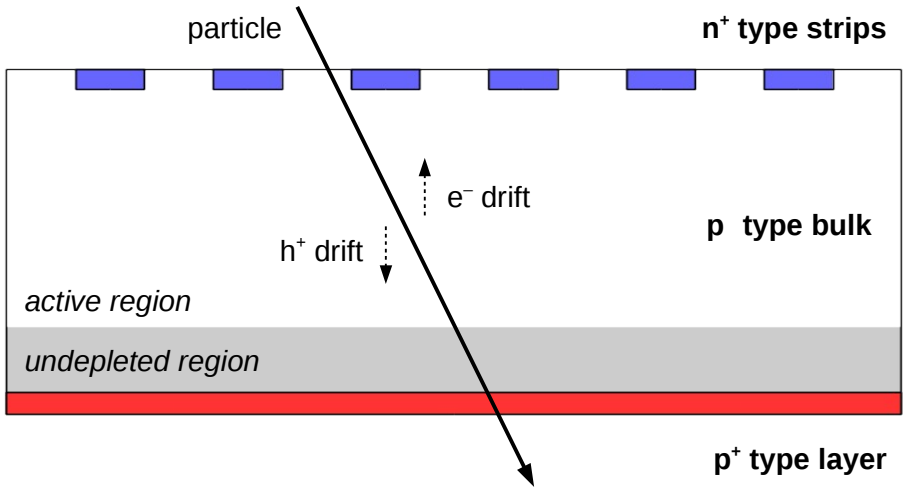


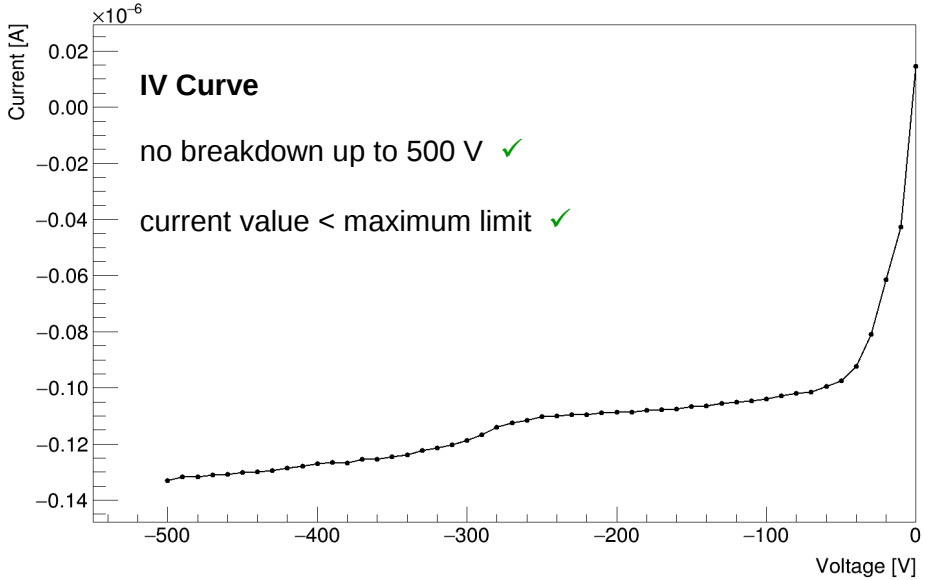
# Status of Local Developments

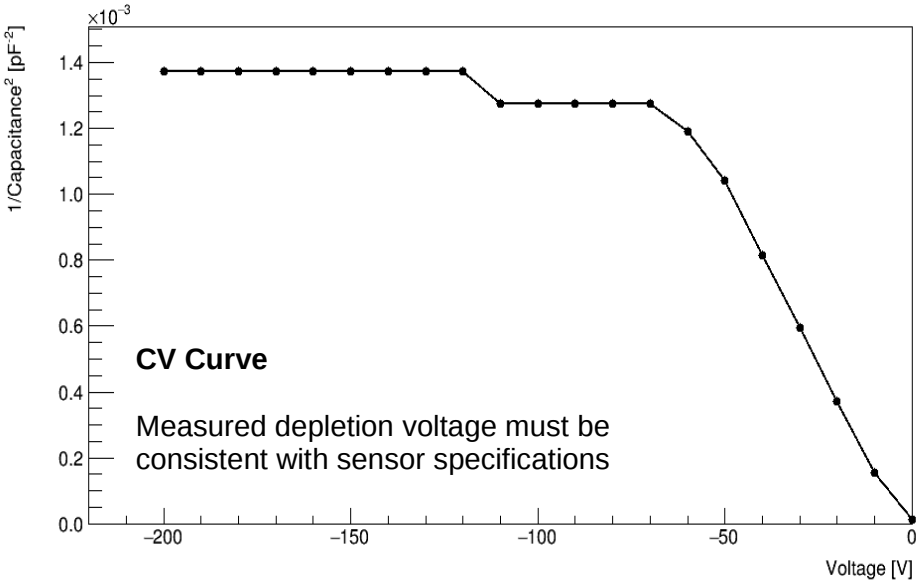
**Silicon Sensor Testing**

- Quality control tests are needed for silicon sensors
- Leakage current vs bias voltage (IV curves)
- Bulk capacitance vs bias voltage (CV curves)
- We've developed the means to perform these tests

**$n^+$– in – p silicon strip sensor**



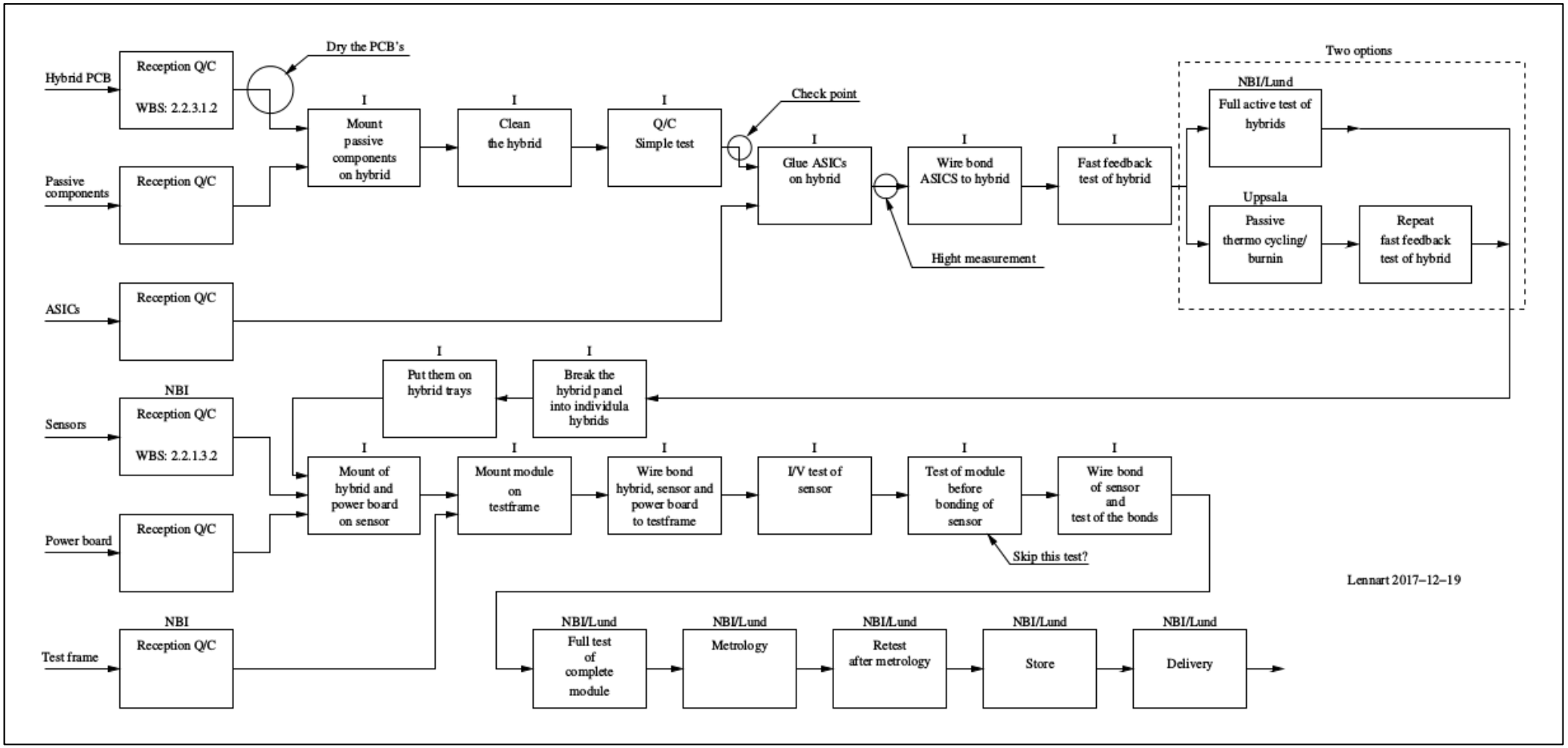



# Summary

- ATLAS is building a new Inner Tracker in preparation for the HL-LHC
- University of Copenhagen, Lund University, and Uppsala University plan to build 1000 modules
- Modules will be built with an industrial partner – *but still looking for potential wire-bonding sites*
- Module pre-production due to begin in 2019
- Both local and industrial preparations are on-going

# Backup


Hybrid PCB
Reception Q/C
WBS: 2.2.3.1.2
Dry the PCB's
Passive components
Reception Q/C
ASICs
Reception Q/C
I
Mount passive components on hybrid
I
Clean the hybrid
I
Q/C Simple test
Check point
I
Glue ASICs on hybrid
I
Wire bond ASICS to hybrid
Hight measurement
I
Fast feedback test of hybrid
Two options
NBI/Lund
Full active test of hybrids
Uppsala
Passive thermo cycling/ burnin
Repeat fast feedback test of hybrid
I
Put them on hybrid trays
I
Break the hybrid panel into individula hybrids
NBI
Sensors
Reception Q/C
WBS: 2.2.1.3.2
Power board
Reception Q/C
Test frame
NBI
Reception Q/C
I
Mount of hybrid and power board on sensor
I
Mount module on testframe
I
Wire bond hybrid, sensor and power board to testframe
I
I/V test of sensor
I
Test of module before bonding of sensor
Skip this test?
I
Wire bond of sensor and test of the bonds
Lennart 2017–12–19
NBI/Lund
Full test of complete module
NBI/Lund
Metrology
NBI/Lund
Retest after metrology
NBI/Lund
Store
NBI/Lund
Delivery

# Backup