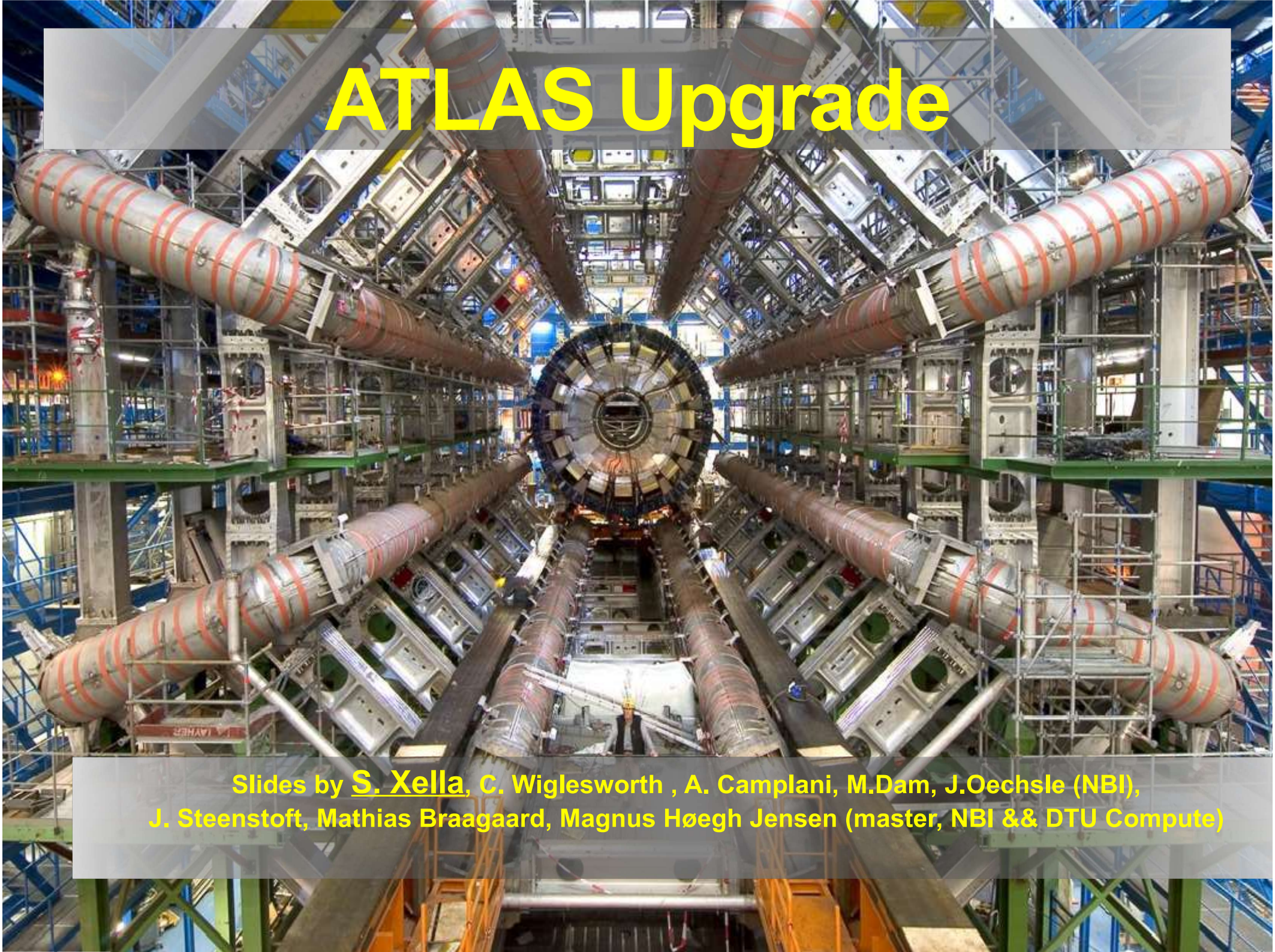
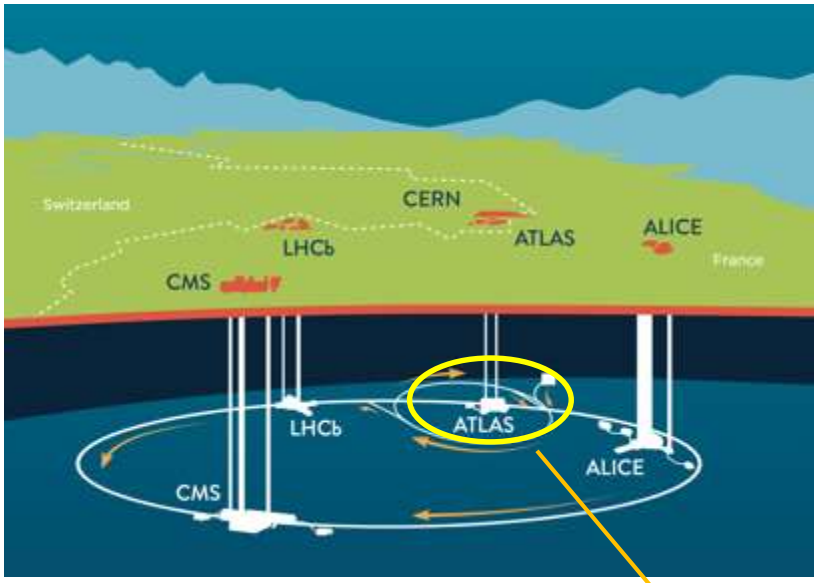


ATLAS Upgrade

Slides by S. Xella, C. Wiglesworth , A. Camplani, M.Dam, J.Oechsle (NBI),
J. Steenstoft, Mathias Braagaard, Magnus Høegh Jensen (master, NBI && DTU Compute)

The High Luminosity LHC



In 2027 the Large Hadron Collider (LHC) at CERN will provide proton proton collisions at the highest energies achieved in the lab (14 TeV) at a rate 5-7 higher than what done so far : High Luminosity LHC

LHC has provided so far ~5% of the expected HL-LHC dataset

Ultimate goal of HL- LHC :

- Study the **Higgs** properties to % level precision
- Characterize **new** fundamental forces or elementary particles, suggested by current observations

TIMESCALE:

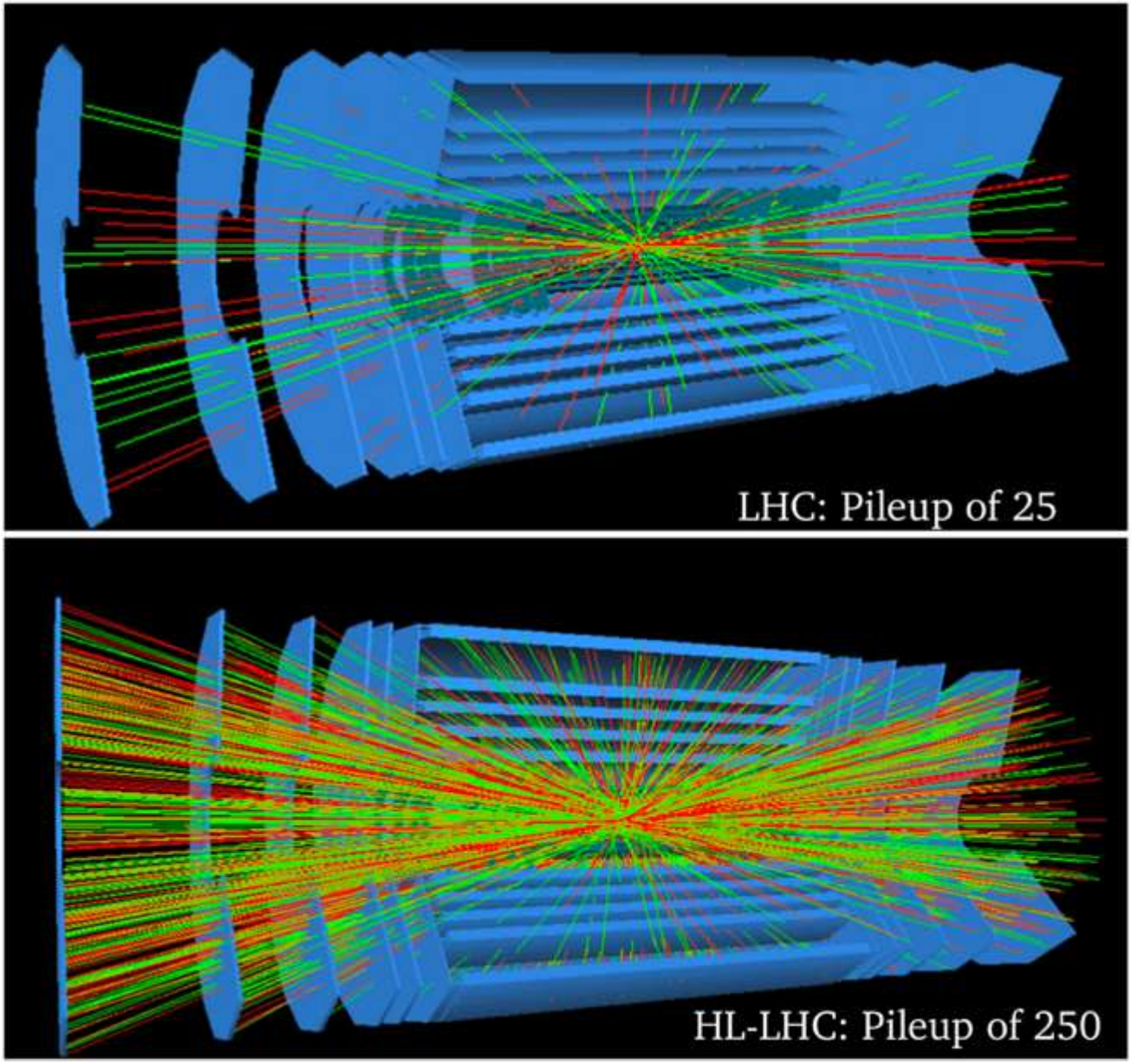
2021 – 2025:	Production
2025 – 2027:	Installation
2027 – 2036:	Data Taking

ATLAS Upgrade Activities at Niels Bohr Institute:

Produce a new Inner Tracker (ITk) system

Produce a new Hardware Track Trigger (HTT)

The High Luminosity LHC



ATLAS Tracker Upgrade:

- Increase sensitivity for physics searches.
- More granularity to counter the higher pile-up and track density, and to have more precise measurements.
- New detector designs to cope with a higher radiation environment.
- While reducing power consumption and keeping low material.

The High Luminosity LHC

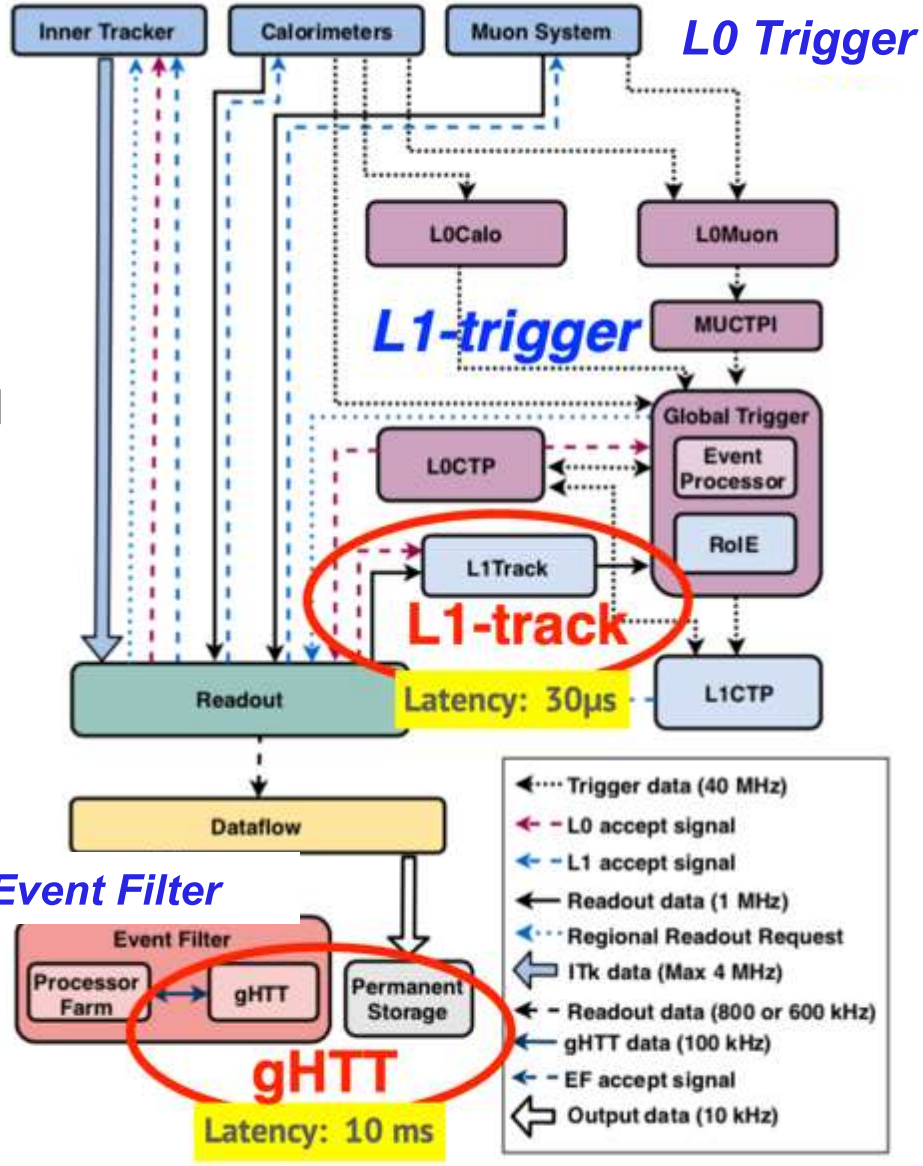
ATLAS Trigger Upgrade:

The trigger and data acquisition online system will face the following challenges:

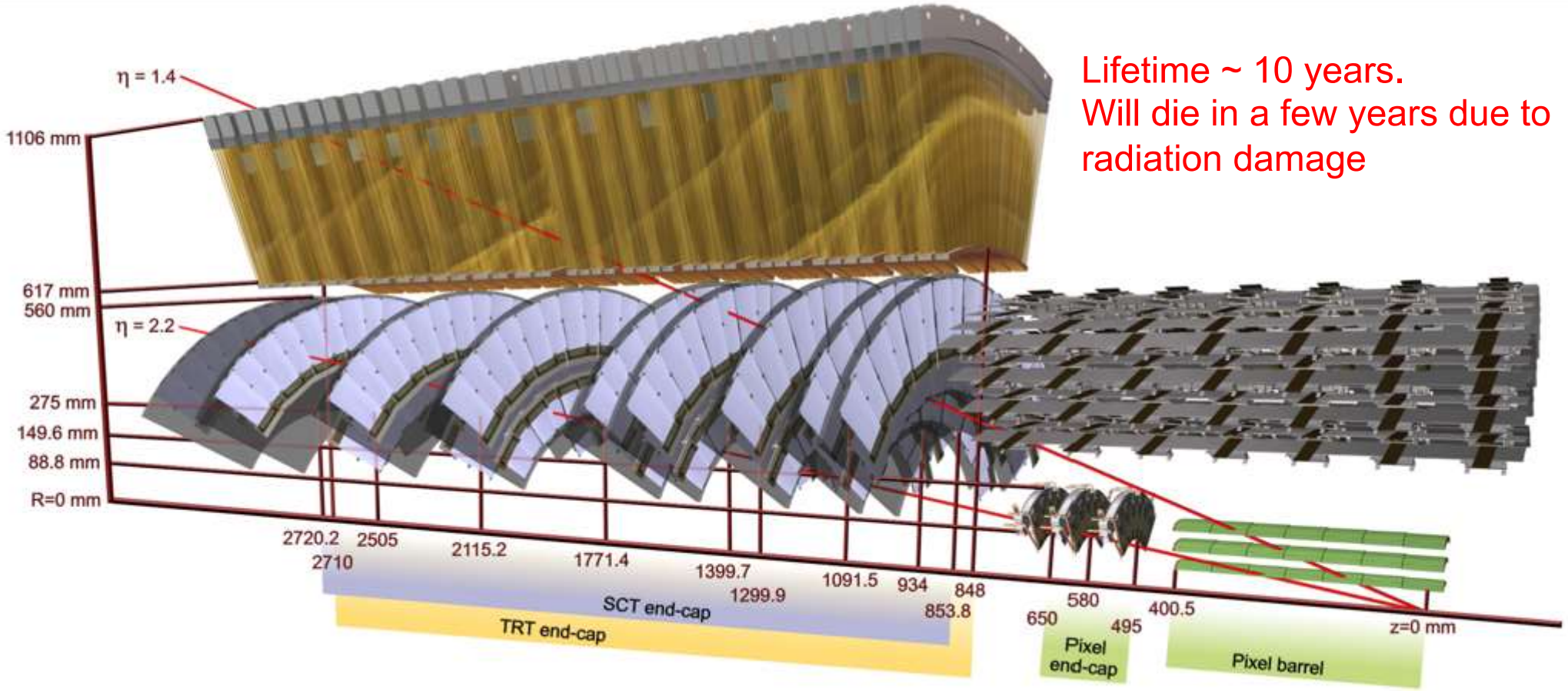
Level-1 trigger output rate: 100 kHz ➠ 1 MHz

DAQ Throughput: 1 ➠ 50 Tbps

Higher pileup ➠ after L0, processing time x 100 : unsustainable unless something changes
→ Hardware Track Trigger (HTT)



Current ATLAS tracker detector



Lifetime ~ 10 years.
Will die in a few years due to radiation damage

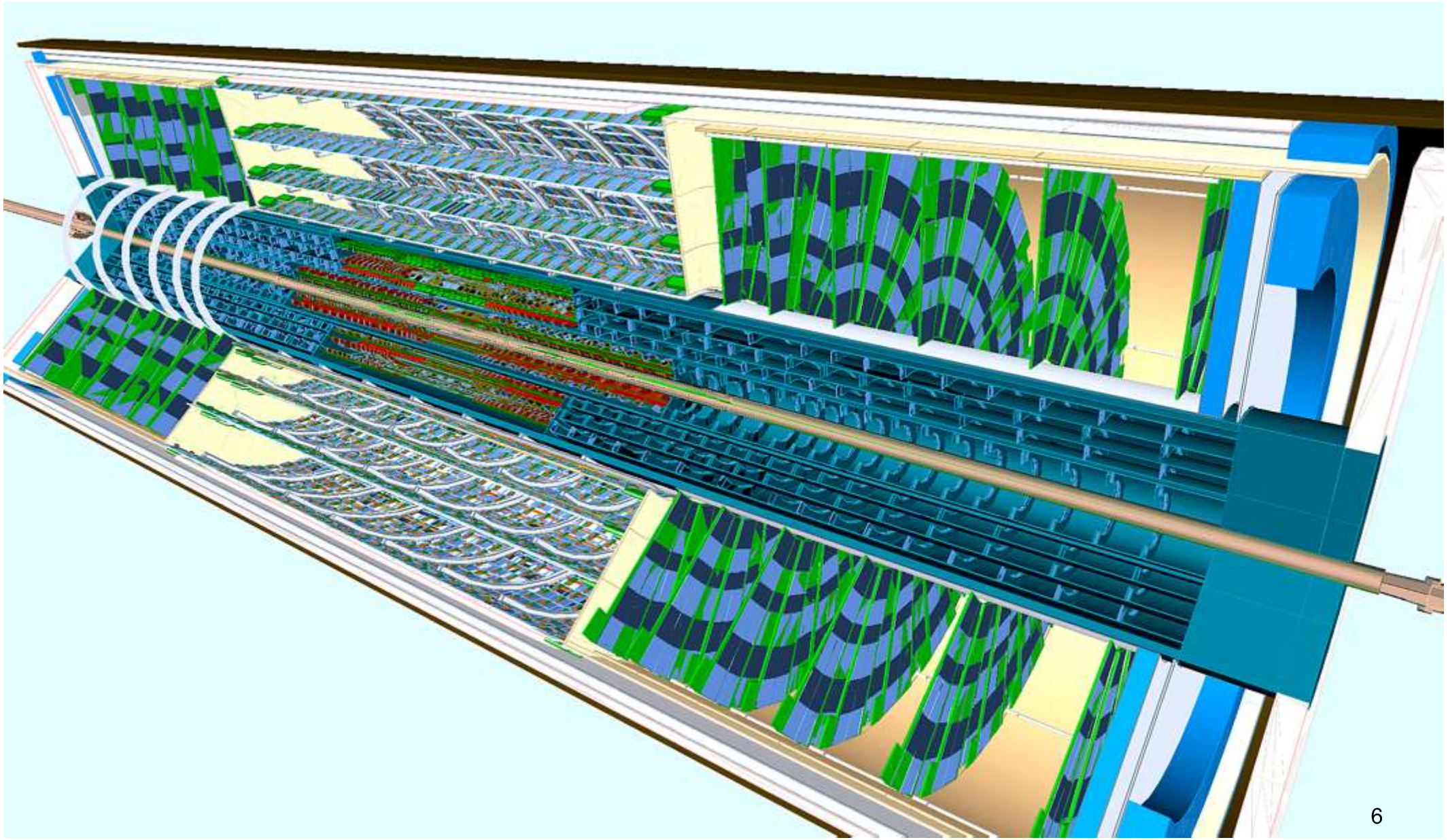
SCT: double-sided modules, 6.3M channels
- 16 μm resolution xy (580 μm z)
- 4 barrel layers, 9 endcap disks
- 80 μm in b (70-90 in ec) pitch strips

61 m^2 area

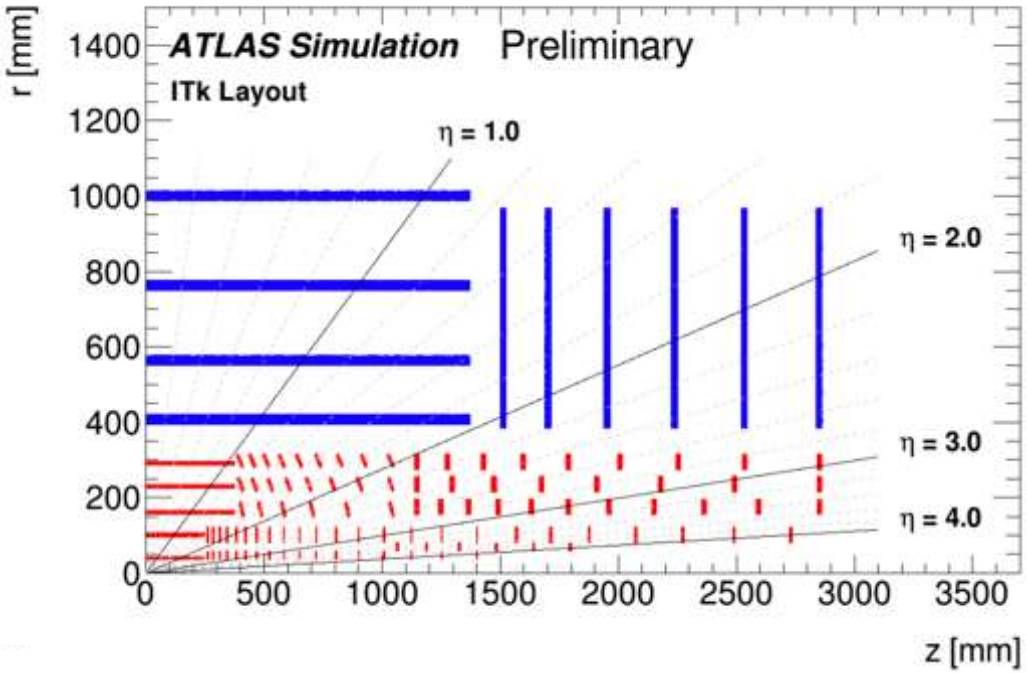
Pixel: n-on-n, hybrid , 100 M channels
- 10 μm resolution xy (110(72) μm z)
- 3 barrel +IBL, 3 endcap disks
- 400x50 μm (250x50 μm IBL) pixel size

2 m^2 area

Future ATLAS Inner Tracker (ITk)



Future ATLAS Inner Tracker (ITk)



Red: Pixel
5 barrel layers + several endcap disks
Blue: Strips
4 barrel layers + 6 endcap disks

Pixel: 3D, n-on-p, 50x50 (or 25x100) μm^2
500 M channels
Strips: double sided, n-on-p, 75-85 μm pitch
60 M channels

Operating @ -20 to -35 C
Operating Voltage ~ 500 - 700 V

Silicon area: Pixel 12 m^2 , Strips 164 m^2

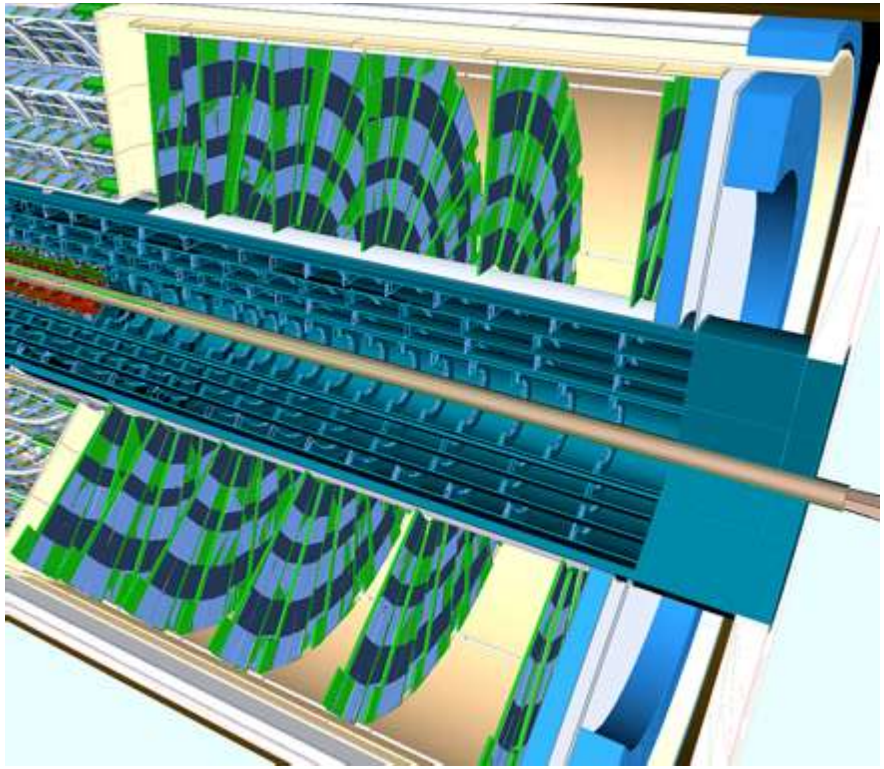
- Radiation hardness: 10+ year lifetime @ x10 integrated radiation wrt predecessor
- Granularity: baseline occupancy of < 0.1% (pixels) , < 1% (strips) @ <μ>=200
- Material budget: 30% less wrt predecessor
- Coverage increase to |η| < 4.0
- Readout: new scheme that allows fast track trigger (HTT)

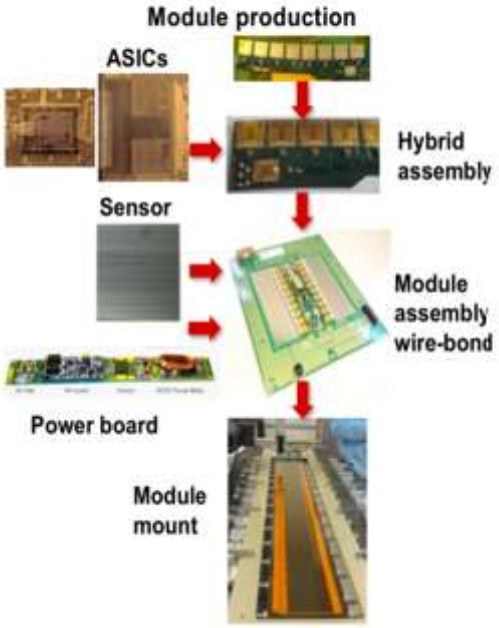
Scandinavian cluster for detector development: will make **600** modules for Endcap strip detector in collaboration with industry

Uppsala, Copenhagen (NBI),Lund, Oslo Universities and industry partner

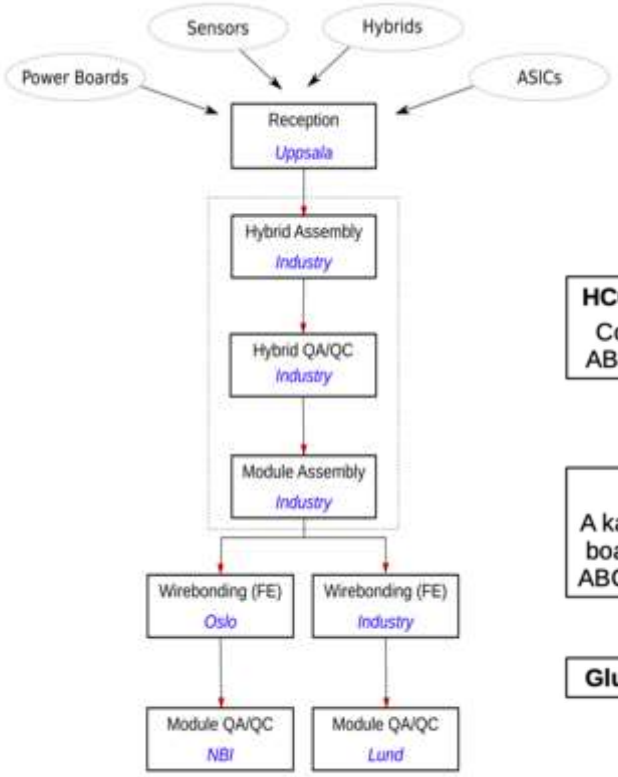
NOTE
YOUR MANUFACTURING PARTNER

https://www.note.eu/sv/

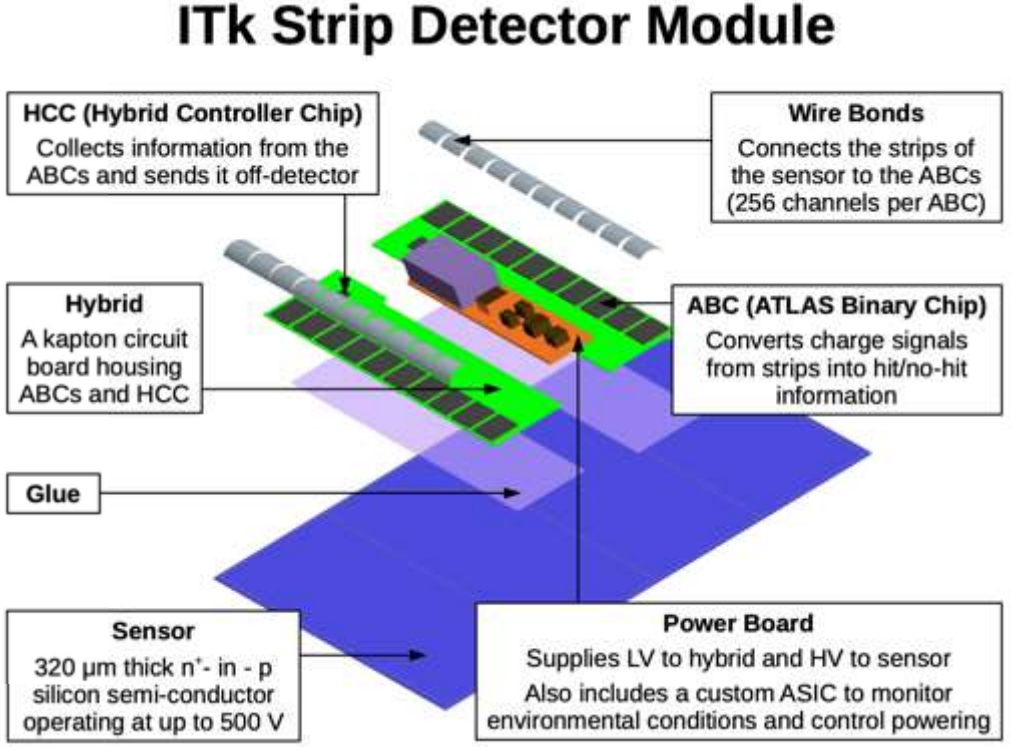


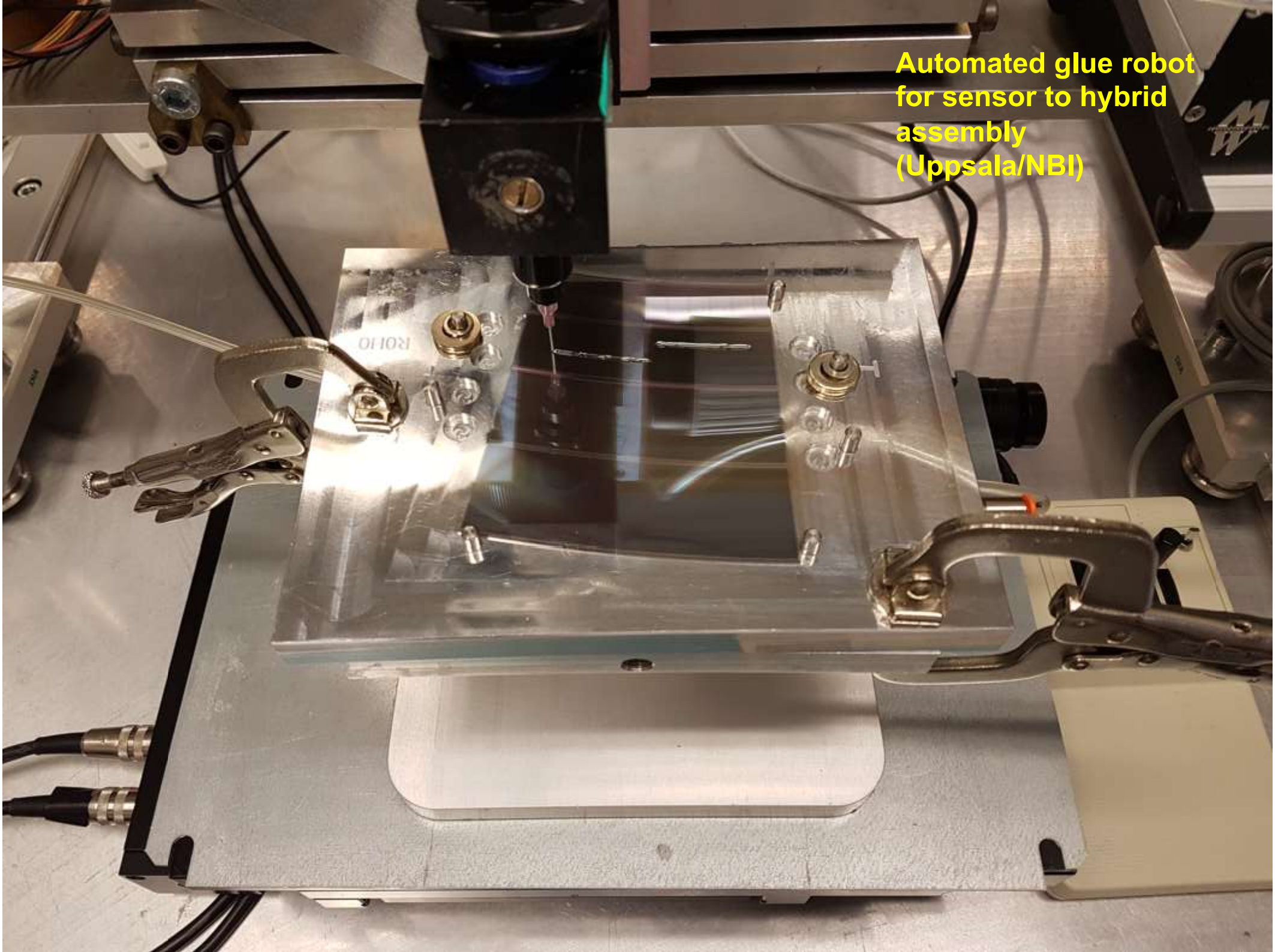


(a) Imaging the different steps of stave assembly

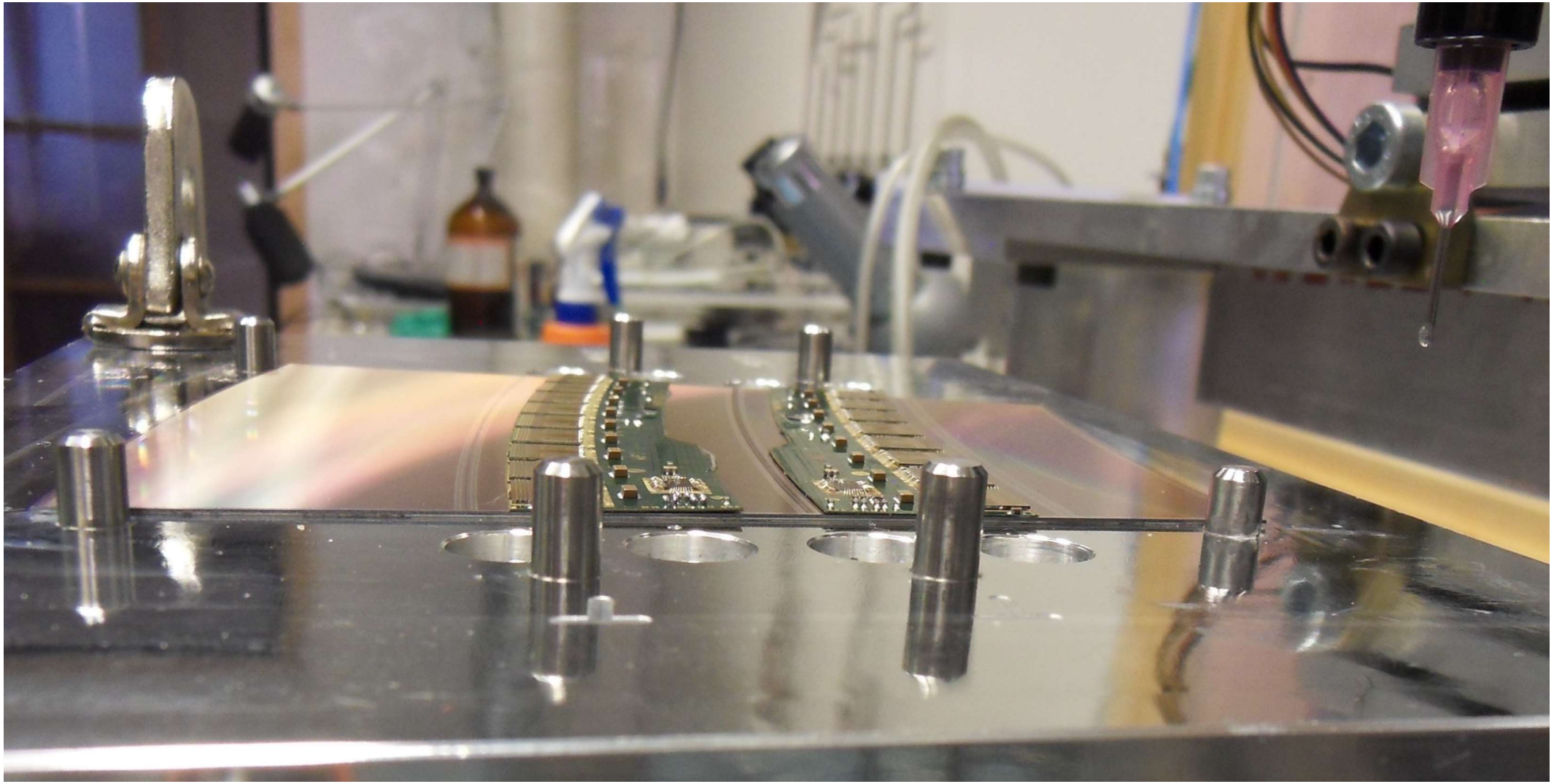


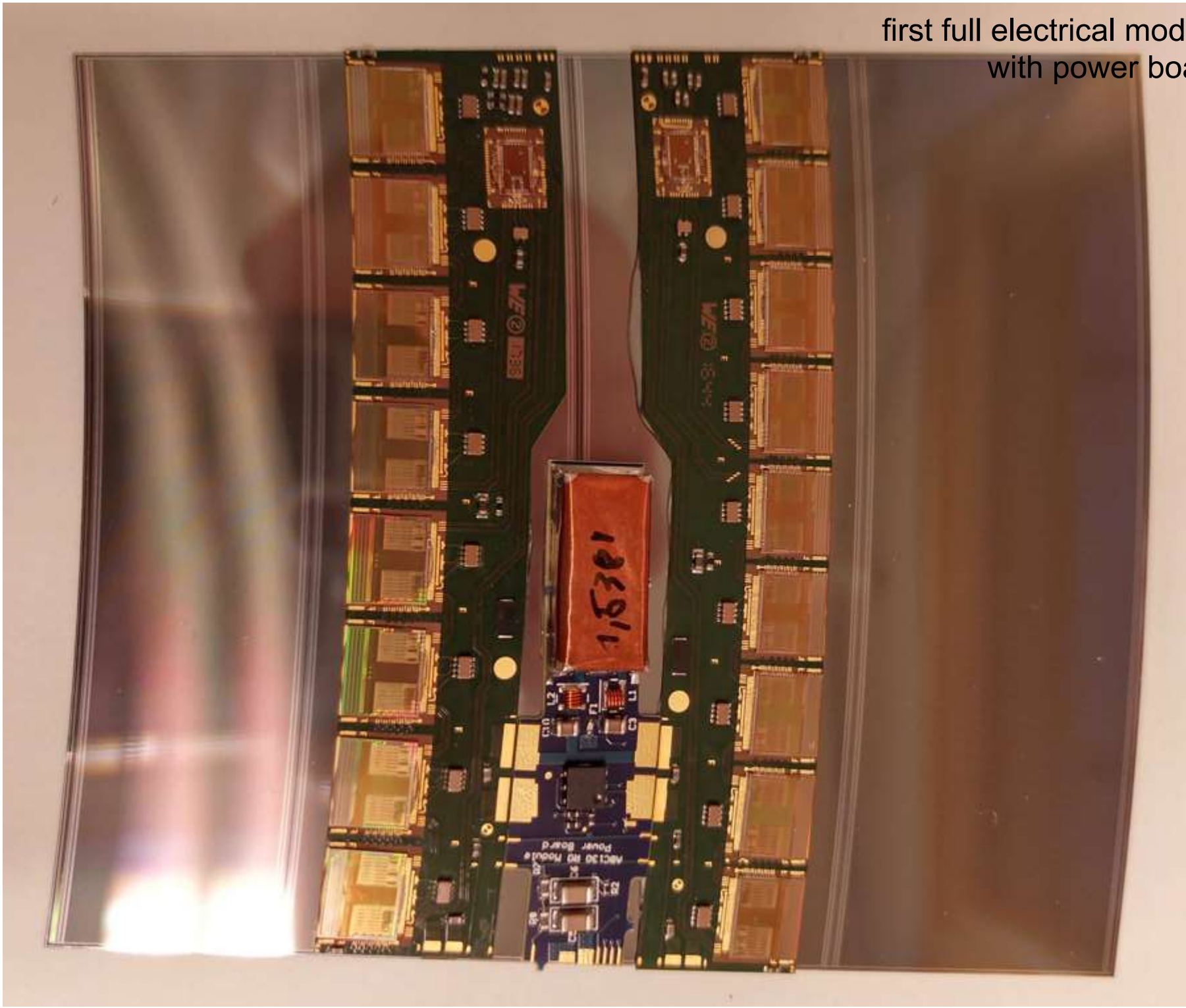
(b) Division of labour wihtin the cluster.




Automated glue robot
for sensor to hybrid
assembly
(Uppsala/NBI)

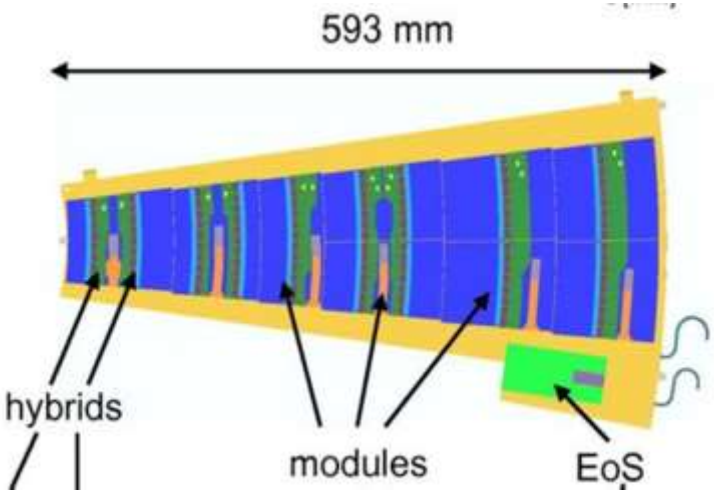
first full electrical module
made in the Scandinavian cluster

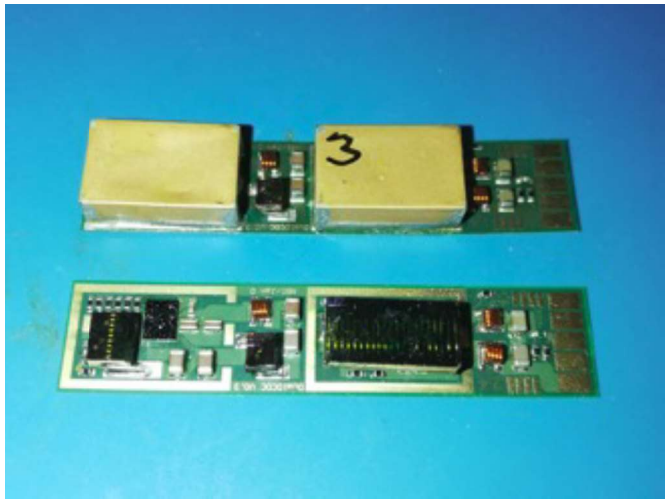



first full electrical module
with power board

Control and Read-out electronics

EoS card at the end of the stave/petal provides all the low-voltage and high-voltage power to the modules, and is the interface between the modules and the off-detector electronics.





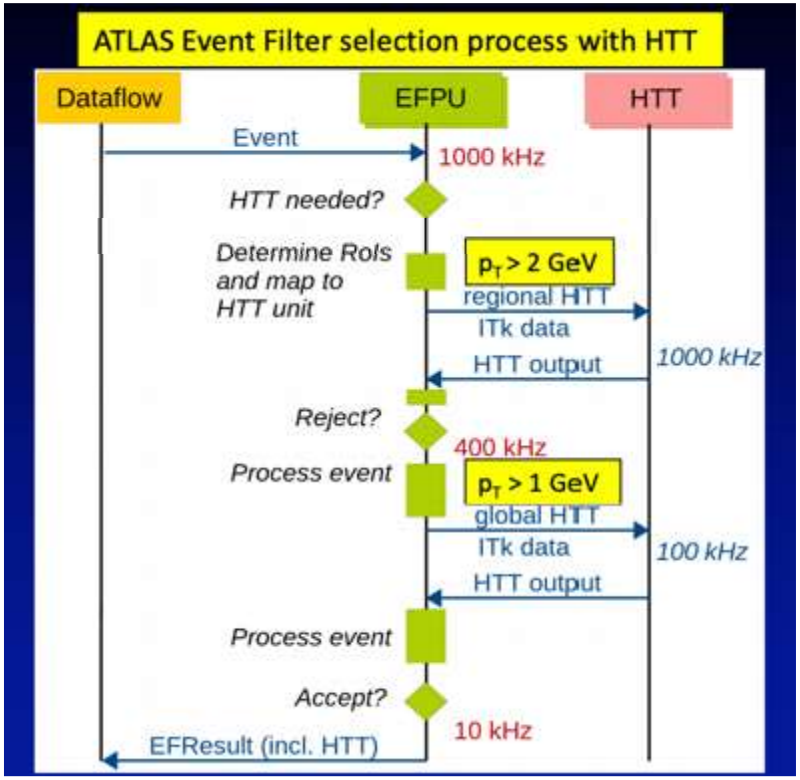
NBI is producing 1800 DC-DC convertors for EoS cards in collaboration with DK industry

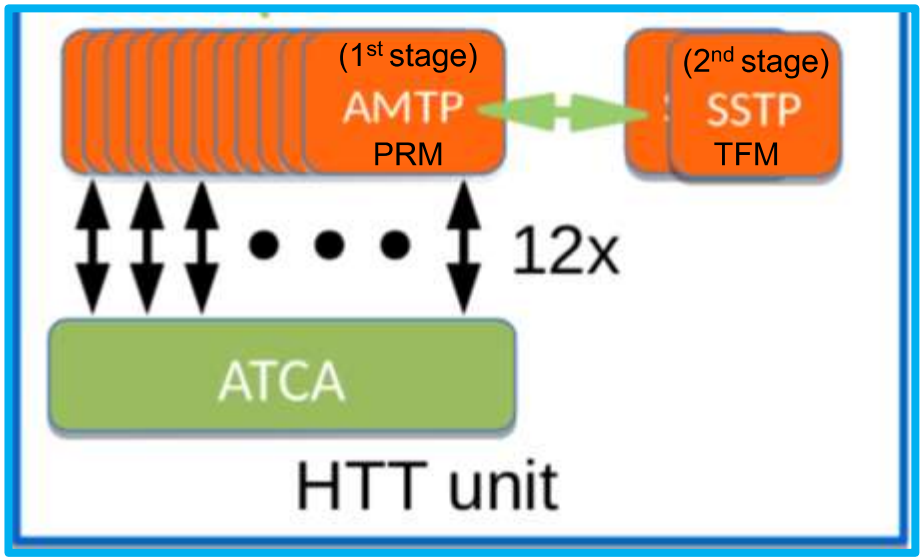
Ad-hoc designed for radiation environment of HL-LHC and low material budget requirement

ATLAS trigger upgrade

HTT is a new **massively parallel system**, based on **FPGAs** and custom Associative Memories (AM).
O(500) boards running at a 1-4 MHz Level-0 input rate.

regional, rHTT: 10% of the data/event, and only uses 8 layers of ITK (1st stage).
global, gHTT: full event data, and uses 13 layers of ITK (1st and 2nd stage).





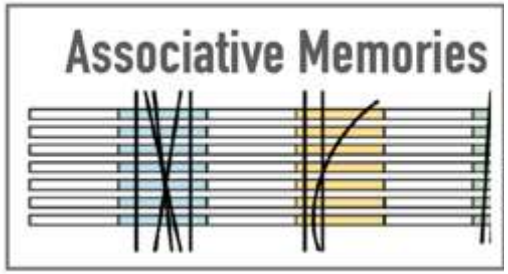
Same hdw unit can be used for rHTT or gHTT

HL-LHC trigger system will optimize processing by using an optimal combination of
FPGAs, CPUs, and possibly hw accelerators (GPU , FPGA). NBI group contributes strongly to the design.
In current design : 13824 ASICs and 1440 FPGAs in HTT.

ATLAS Hardware Track Trigger : PRM

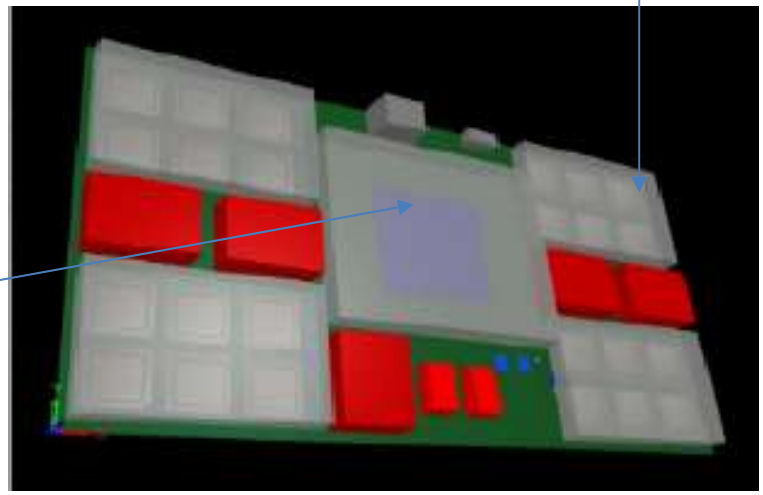
PRM board assembly in DK industry by 2026
- 200 boards (out of 500 total ATLAS needs)
- Test boards in Copenhagen
- Send to CERN for integration tests in ATCA shelves

first demonstrator : May 2020



Pattern Recognition Mezzanine (PRM)

Each pattern stored in the AM ASICs (specifically designed for ATLAS) corresponds to a sequence of eight clusters. The choice of layers and the mixture of strip and pixel layers depends on the track pseudorapidity



For each PRM board
- ~1Giga fits per sec
- peak cluster rate/layer @250MHz
- 9.2M track patterns
- Multiple I/O HighSpeed links @10 Gbps

State-of-the-art Intel Stratix 10 FPGA

PRM Firmware development

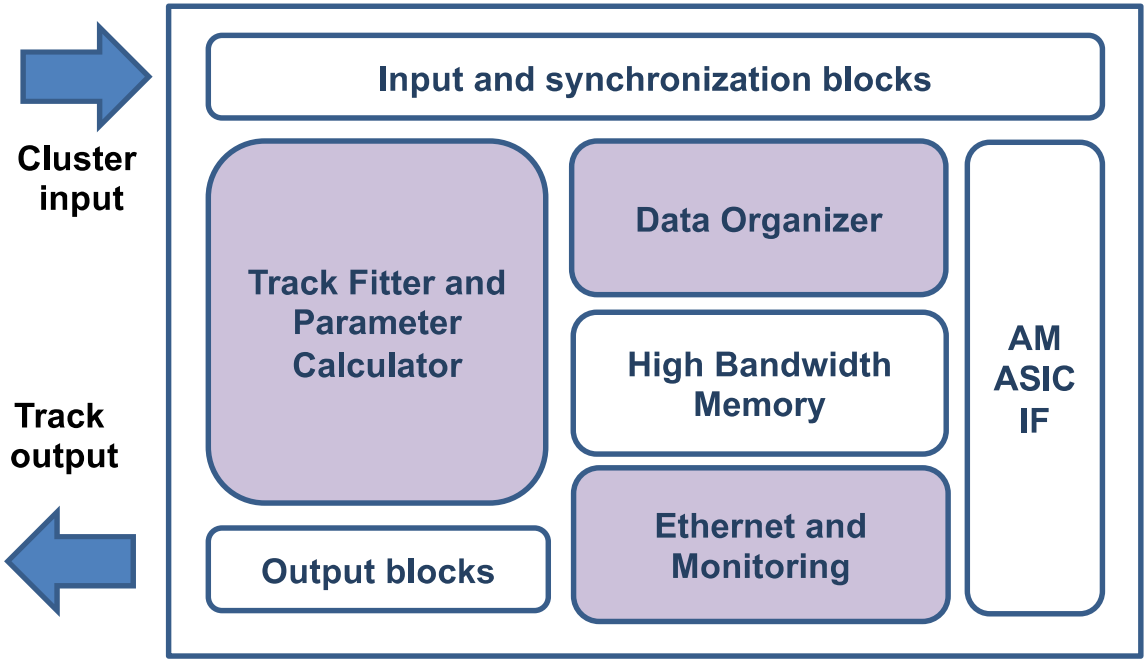
State-of-the-art Intel Stratix 10 FPGA

Stratix 10 FPGA. Intel provides support :
- Board design and review
- Firmware design review

The **Data Organizer block** is being developed at NBI. It is an on-the-fly database, that stores clusters while the AM ASICs perform the pattern recognition.

The **Track Fitter and Parameter Calculator block** has been preliminary developed in collaboration with two master students from DTU. The chi2 for track selection and the track parameters are here computed.

The **Ethernet and Monitoring block** is being developed at NBI. It handles the communication between the PRM board and external machine for data monitoring and board configuration.



Summary

Niels Bohr Institute, ATLAS group, is involved in two upgrade projects :
a new tracker and a new track trigger for the High Luminosity LHC data taking period

2020-2021 is devoted to prototypes and preproduction, while 2021-2025 will see full scale production. Eg at NBI for QA/QC of sensor modules for strip detector we expect to be busy for two-three full years

In both projects, Scandinavian Industry partners are involved.
Not all partners are yet finalized (eg industry for assembly of PRM components).

Collaboration with DTU collegues has started, hopefully will grow with time. We hope students from either sides find it interesting to get involved in these projects in the next years.