The University Of Sheffield.

ATLAS Phase-II Tracker Upgrade: the ITk

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The University of Sheffield

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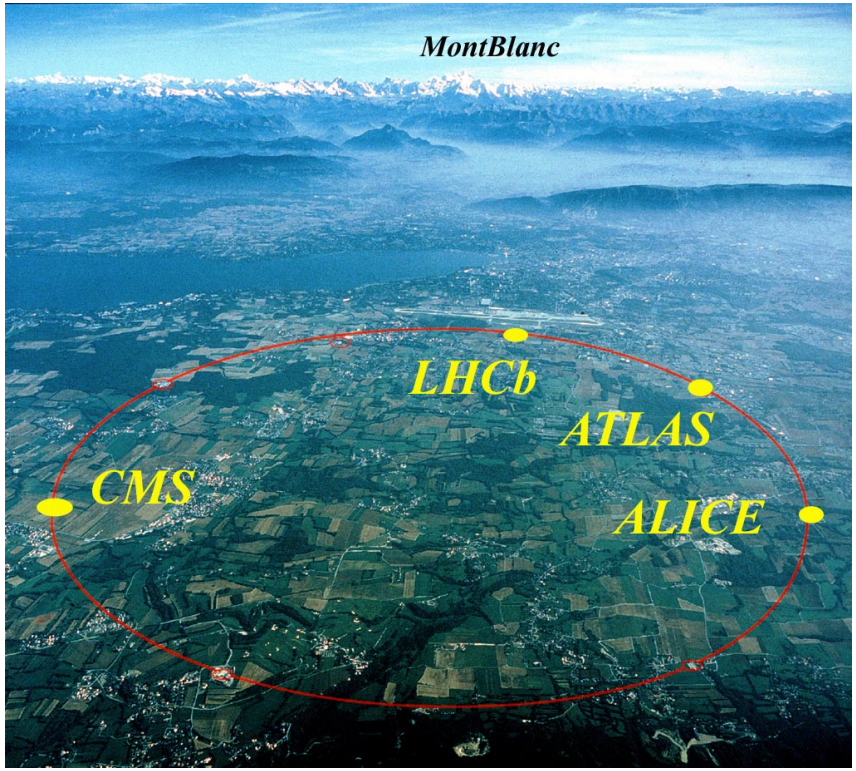
CERN and the LHC

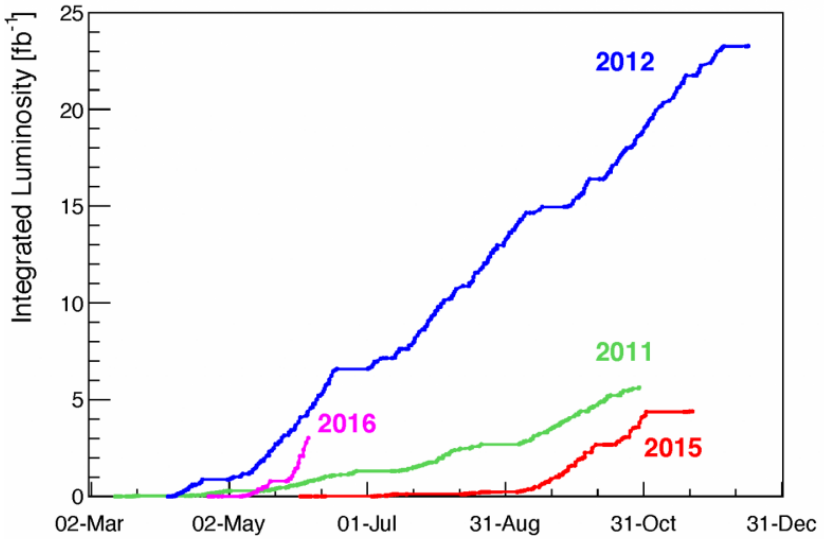
The Large Hadron Collider

- Based at CERN (21 member states),
- High Energy proton and/or Pb collisions.
- Four main physics experiments.

Unprecedented Collision Energy

- 7/8 TeV in Run-I (2012/13)
- 13 TeV in 2015/16
- Record breaking 2 fb^{-1} delivered in 1 week.
- Data is being taken now!

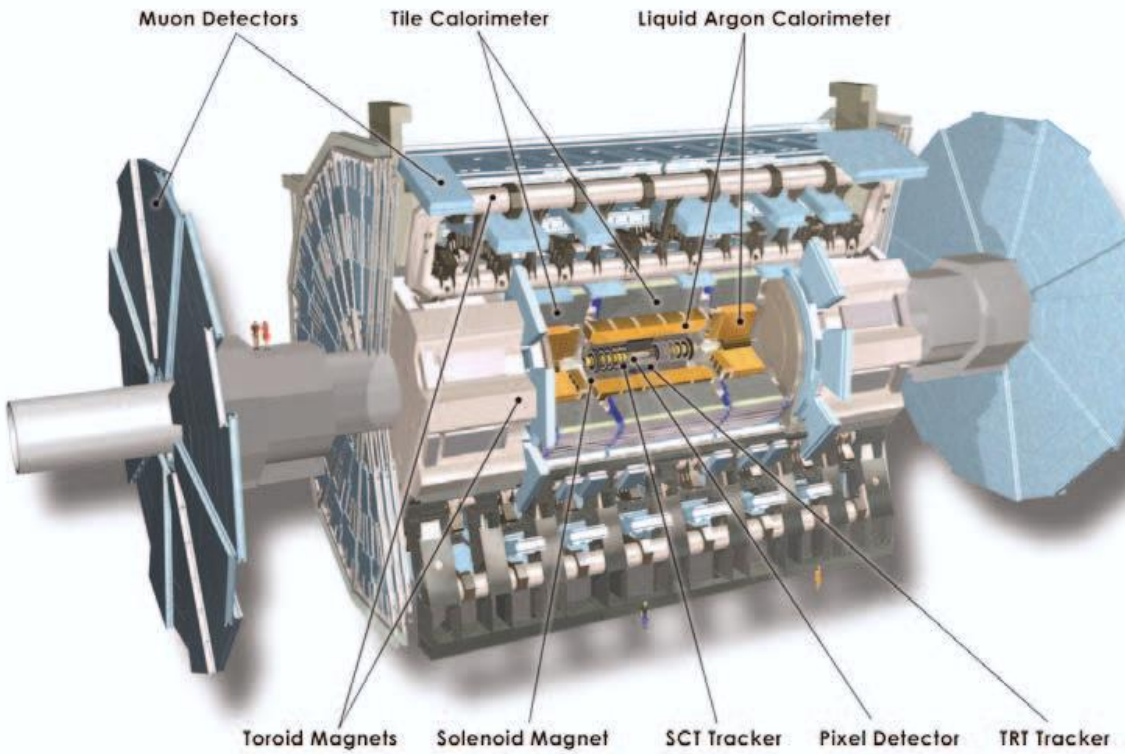




The ATLAS Experiment and Detector

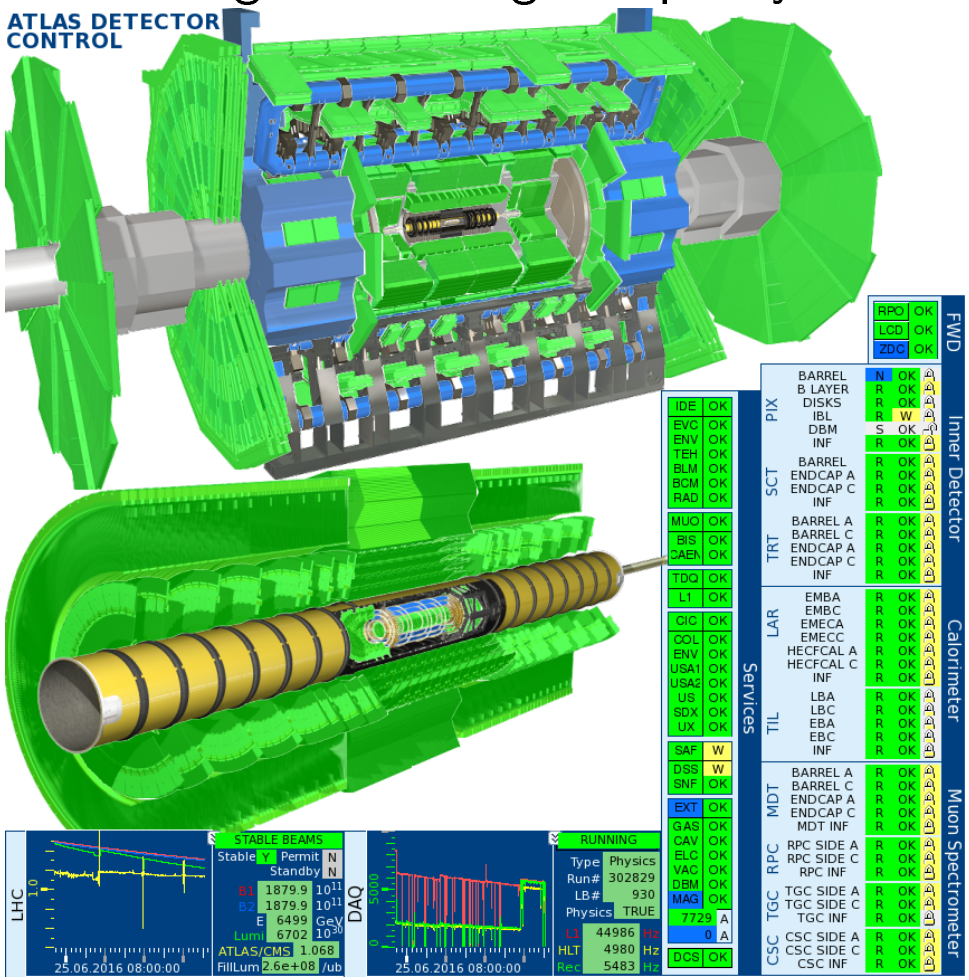
A Toroidal LHC ApparatuS

- 3000 scientists from 38 countries
- Dec 1994 Technical Proposal
- Diameter 25 m; Length 46 m
- Overall weight 7.000 tonnes
- ~ 100 million electronic channels
- ~ 3.000 km of cables
- Sub-Detectors
  - Inner Detector, Calorimeters, Muons, Forward detectors
- 3000 PC's analyzing online events + 100,000 for offline (computing grid)

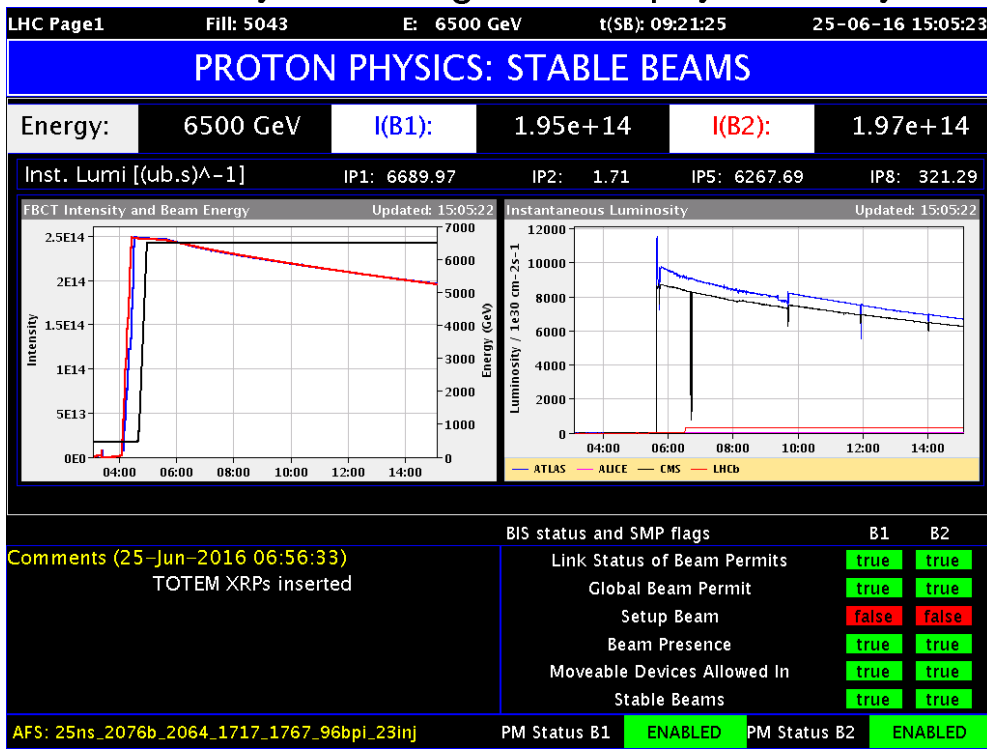


ATLAS Continued

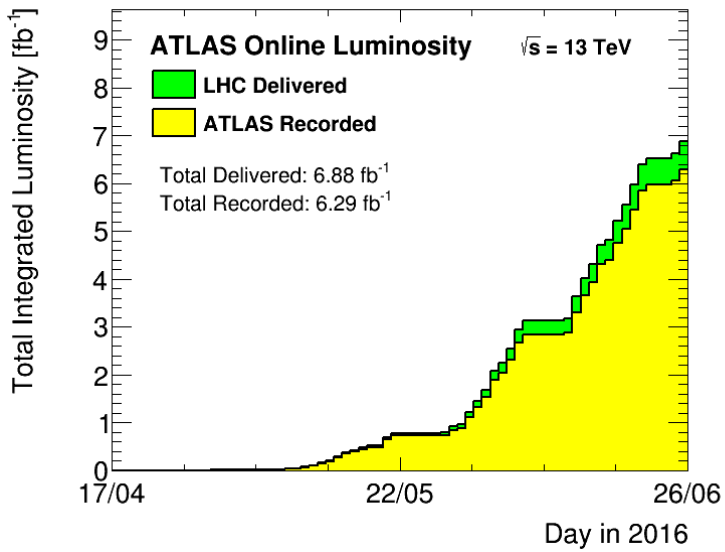
ATLAS needs all subdetectors functioning to deliver good quality data



LHC currently delivering data for physics analysis

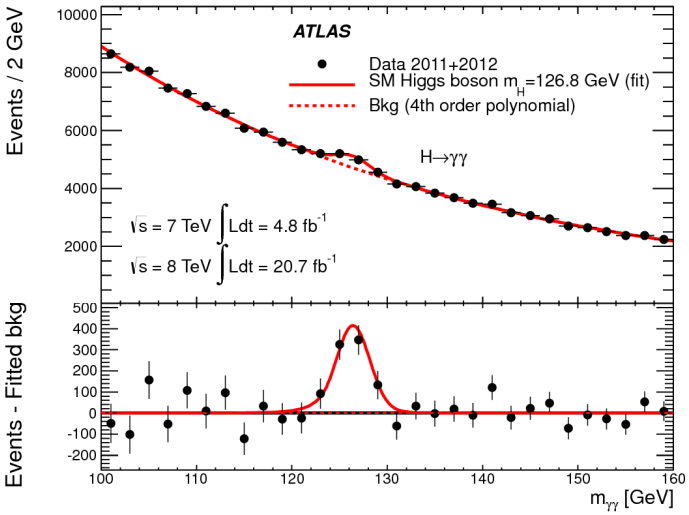


Luminosity recorded thus far



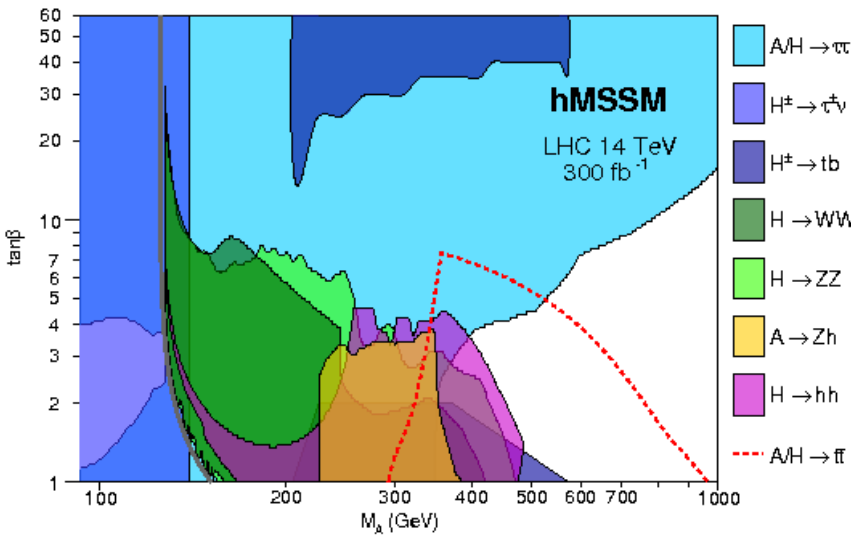
Physics Motivation

- Standard Model
  - ATLAS/CMS discovered Higgs boson in Run1 atlasexperiment.org



  - Completes the Standard Model picture
- Precisely meassure Higgs properties and self coupling.

- Dark Matter, hierarchy, supersymmetry, something new? arXiv:1502.05653



Prospects of searches for Beyond SM Higgs Bosons

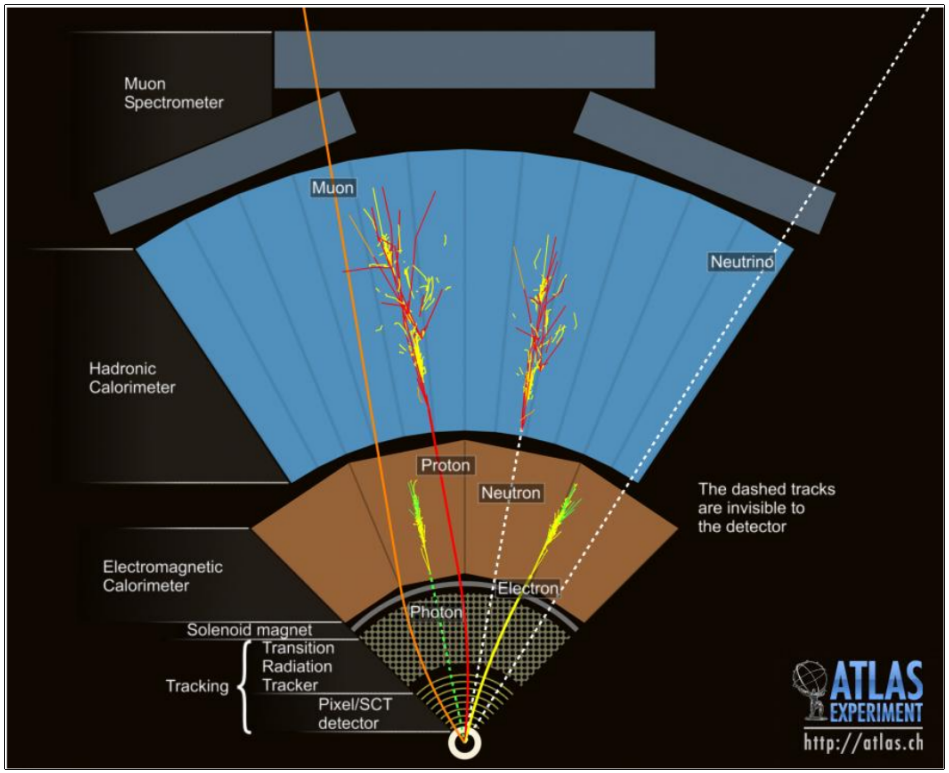
Particle reconstruction

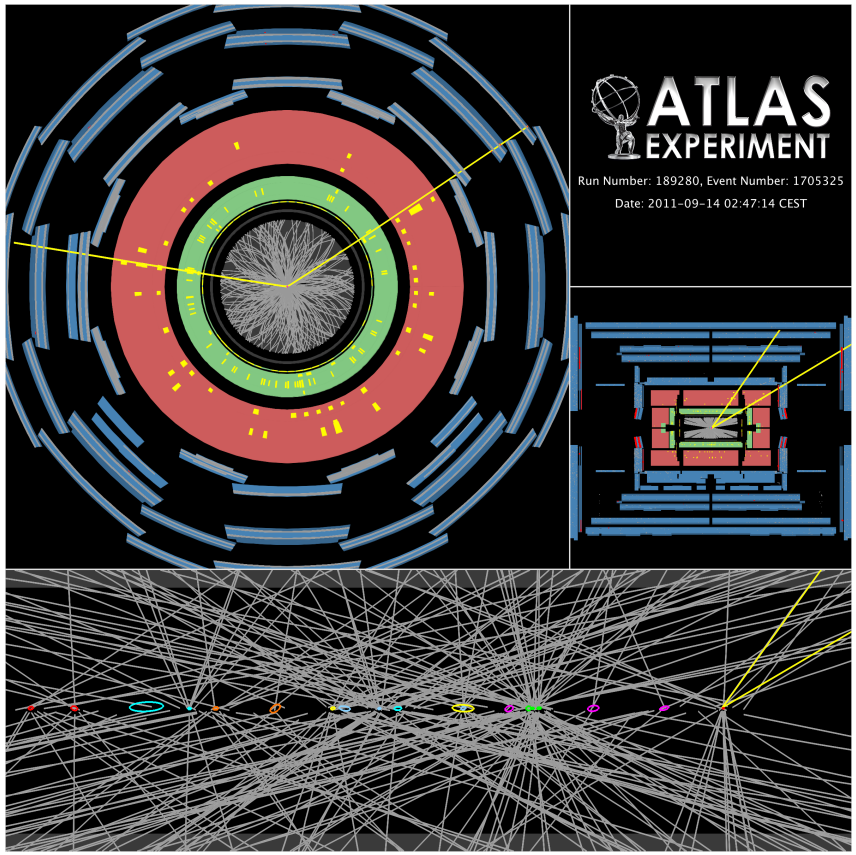
High performance tracking underpins entire ATLAS program

- Reconstruct electrons, muon, photons and hadrons with high efficiency and purity.
- Identify secondary vertices for the identification of e.g. b-jets
- Resolve tracks in core of jets.
- reconstruct vertices in high pile-up conditions and associate to hard interaction.

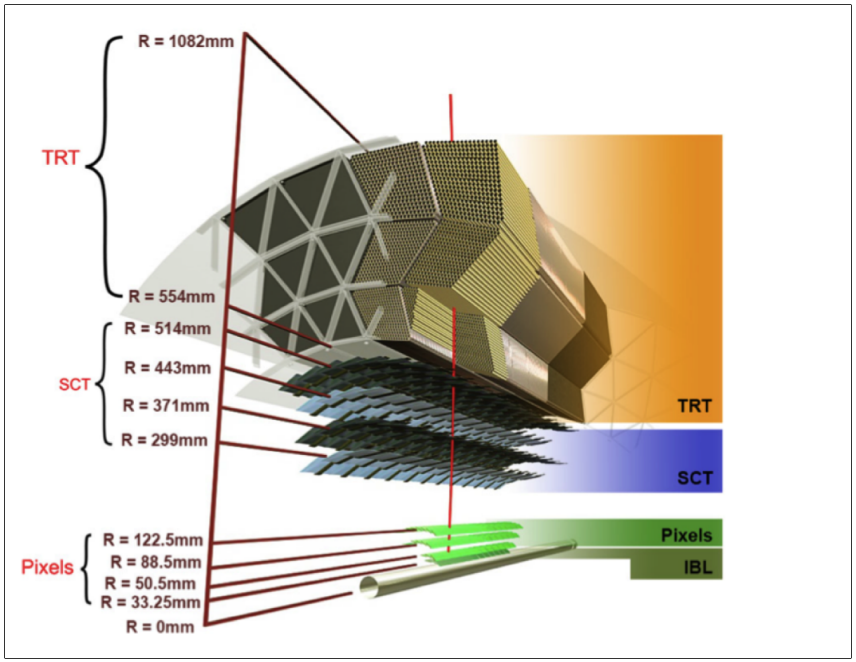
20 vertices in event (pile-up)

ATLAS Experiment © 2016 CERN





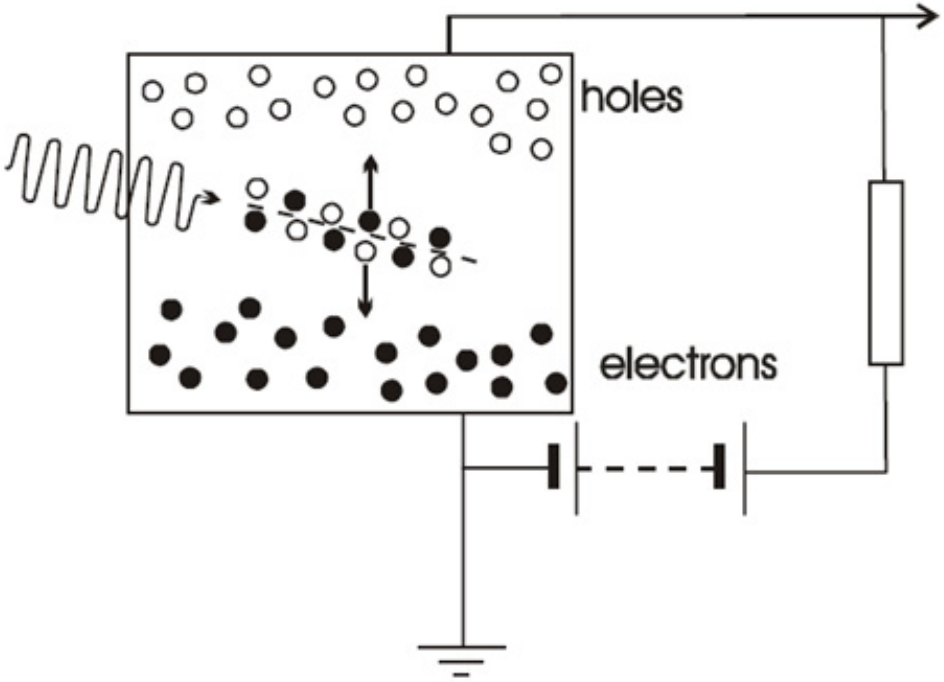
Limitations of the current ID

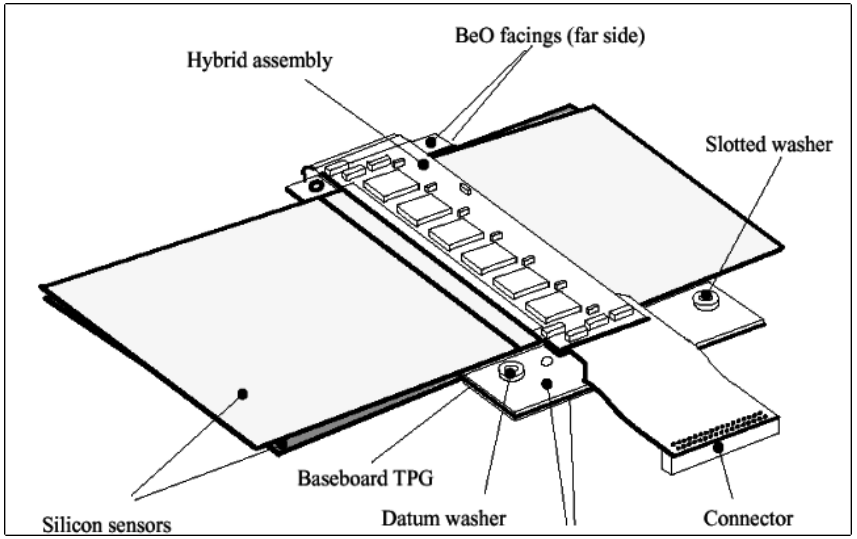


2015 J. Phys.:Conf. Ser. 664072025

- 4 pixel layers + 4 silicon strip layers + transition radiation tracker (straws)
- operate for 10 years at peak energy of 14 TeV
- $\approx$ 23 vertices per 25 ns bunch crossing
- Level 1 trigger rate of 100 kHz
- Radiation Damage
  - strip fluency $\approx$ **.2 MeV**
  - **1 MeV** n_{eq} needed for HL-LHC
- Bandwidth Saturation due to μ
- Occupancy
  - strips unable to distinguish tracks (e.g high pT_{jet})

Silicon Detectors



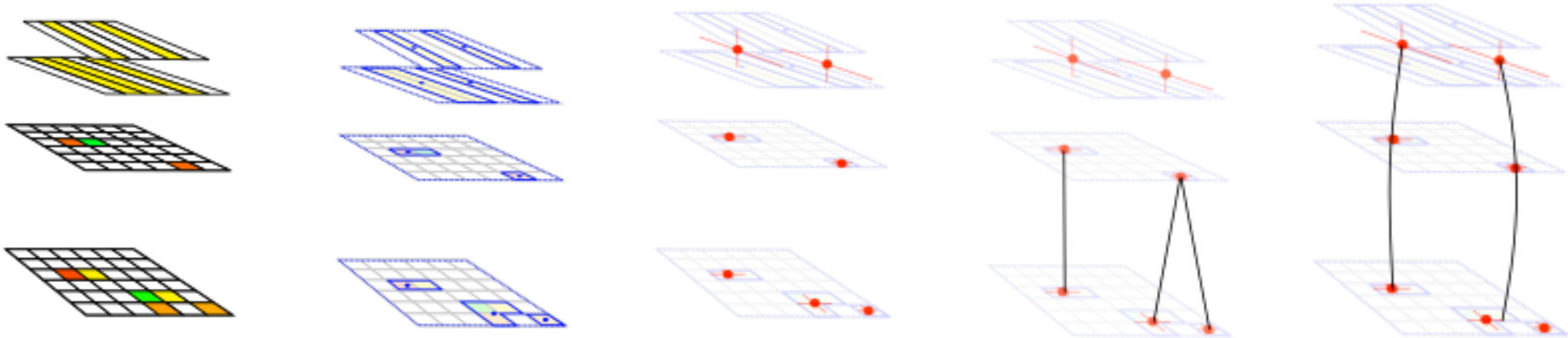


cds.cern.ch/record/974073

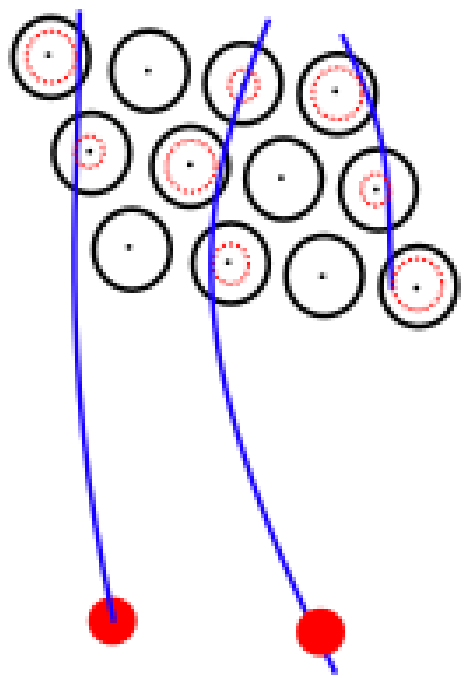
2 back-to-back scrip modules 40 mrad offset provides coordinate precision

- 4 pixel layers + 4 silicon strip layers
- n-in-p sensors
  - cost effective + radiation hard
  - low ionization energy (3MeV)
  - fast collection times.
- Radiation damage
  - Increase leakege current (low Temperature)
  - n p-type (high Voltage)

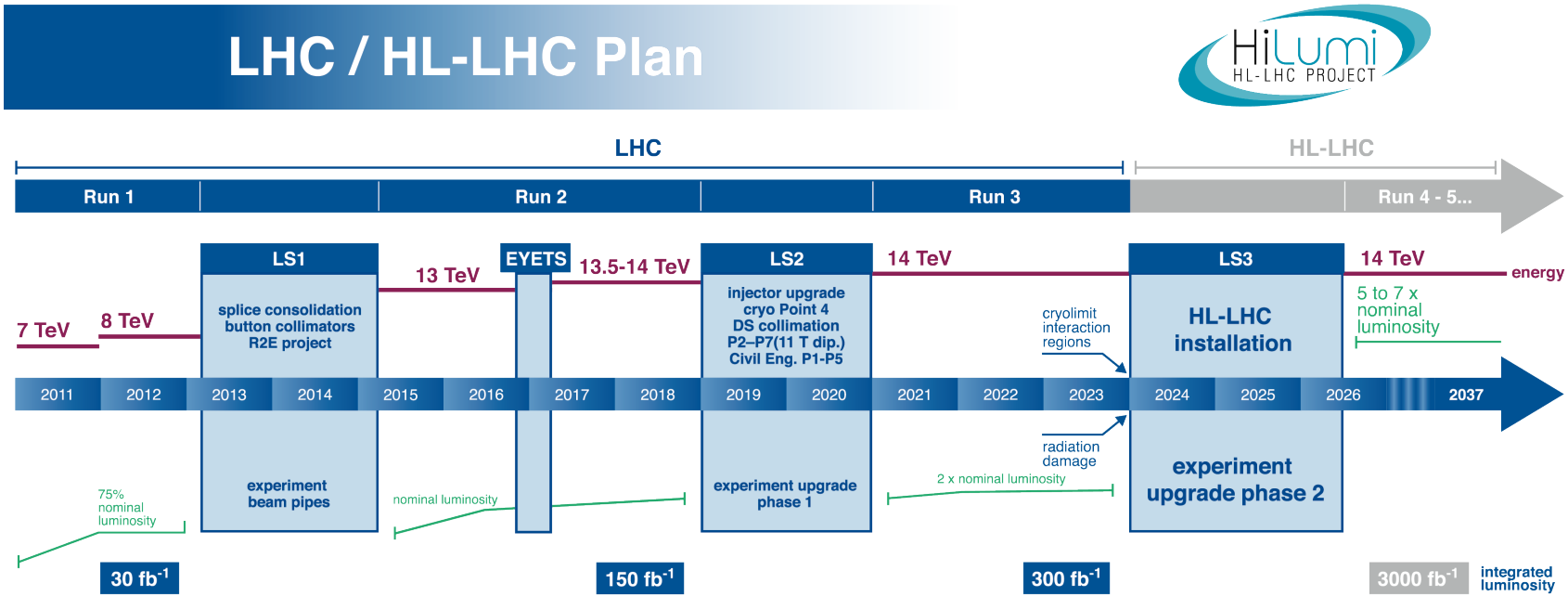
Building tracks in the ID



1. Raw data from Pixel and silicon strips
2. Clustering of hits
3. Space points determined
4. Track identification and extrapolation
5. Ambiguity algorithm
6. Combined with straw tracker (transition radiation tracks)



Plan for the High Lumi LHC

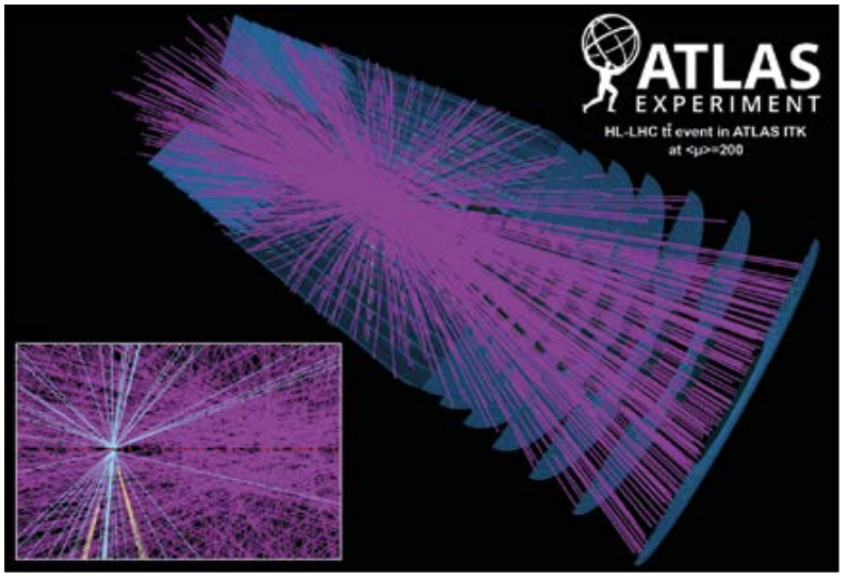


- LHC luminosity upgrade is planned in three stages:
  - Phase 0 (2015-2018): 8→13-14 TeV , $\mu \approx 80$, with 150 fb^{-1} until LS2.
  - Phase 1 (2021-2023): 14 TeV. Integrate to 300 fb^{-1} until LS3.
  - Phase 2 (2026-2030): HL-LHC upgrade with $\mu \approx 200$, 3000 fb^{-1}.
    3000 fb $^{-1}$ $\times$ σ_{HggF}(14TeV) $^{\approx 5\times 10^4 \text{fb}}$ 150 Mil Higgs

HL-LHC Upgrade

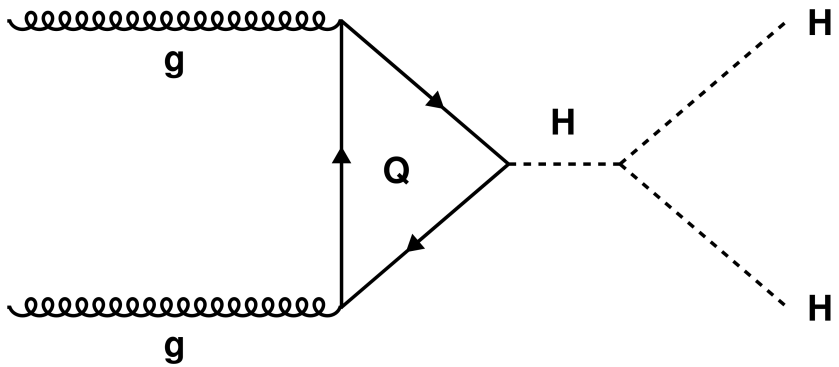
HL-LHC

- By 2023 LHC delivers 300 fb^{-1}
- Detector will be changed.
- HL-LHC will deliver $\times 5$ the design luminosity.
- Very High PileUp 140–200 $< \mu >$CERN-COURIER 56 1



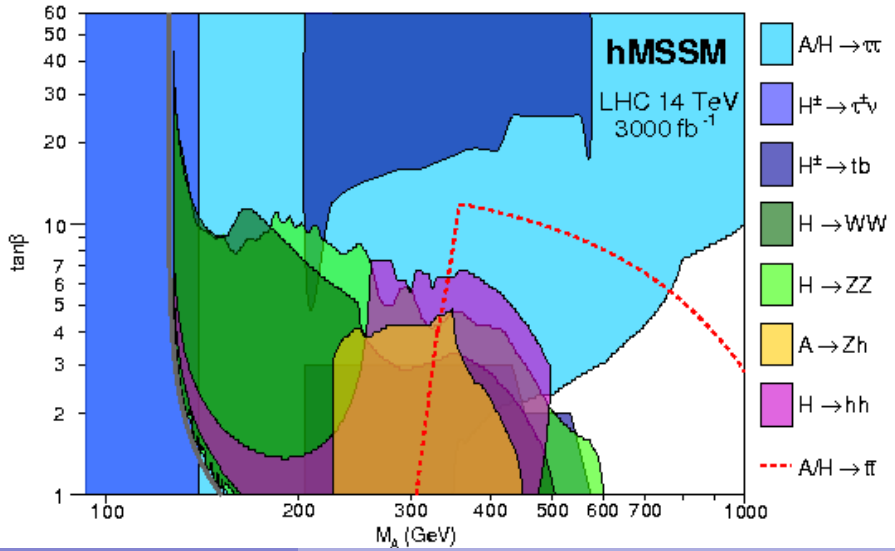
Motivation

- Precision measurement of Higgs
- Higgs Self coupling:



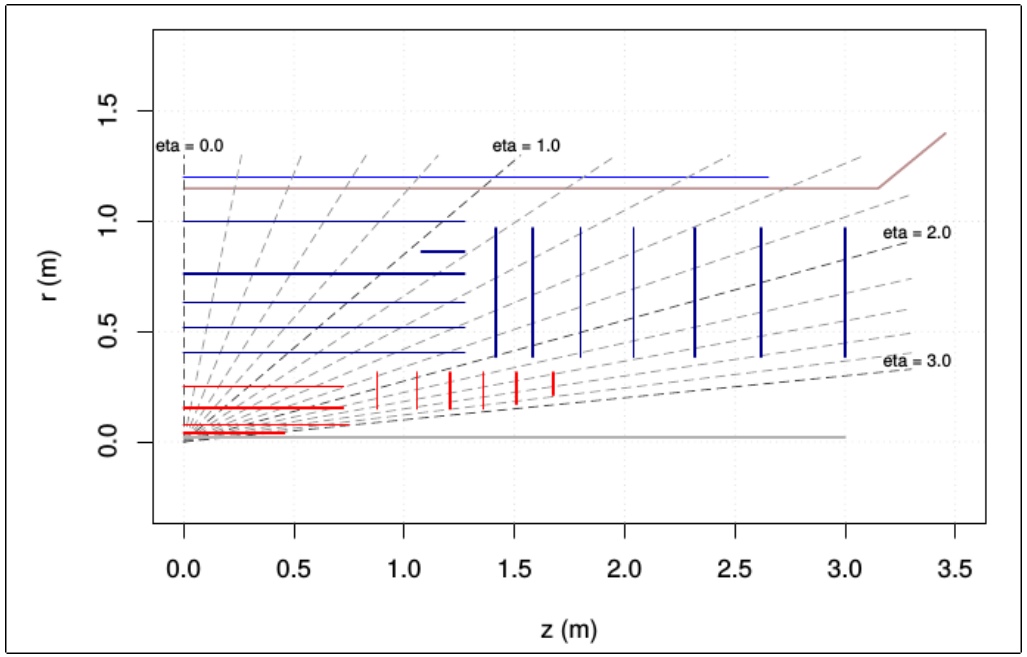
- Searches beyond SM

arXiv:1502.05653



ITK Requirements and Layout

Baseline layout of ITK



CERN-LHCC-2012-022

Requirements

- Identify vertices in high pile-up.
- secondary vertices for b-tagging jets
- Resolve tracks in core of jets.

- all-silicon-detector tracker is proposed, with
  - pixel sensors at the inner radii
  - surrounded by microstrip sensors.
- Barrel
  - 4 pixel layers
  - 3 short-strip layers
  - 2 long-strip layers
- Forward regions
  - 6 pixel disks
  - 7 strip disks

Silicon Strip sensors.

- **focus on strip detectors**
- **University of Sheffield**

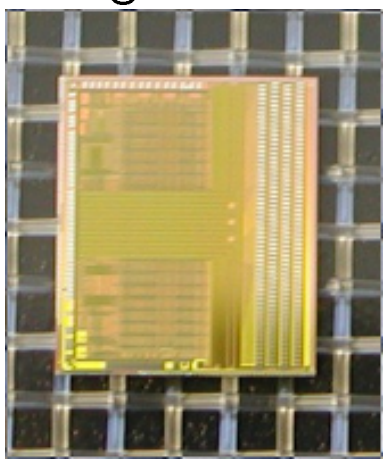
one of the strip module building institutes

- Class 100 cleanroom
- μm precision wirebonding and construction requires clean environment

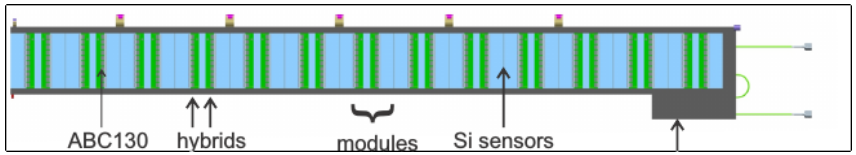
Wirebonder

Strip Detectors

- Si strip detector
  - 99mm × 99mm strip sensors in the ITK upgrade
  - electrodes are subdivided independent 'strips' through the sensor.
  - Operate at -20^{o}C
  - provides localized ionization signal from incident particle.
  - individual strips are read out though ASICs chips

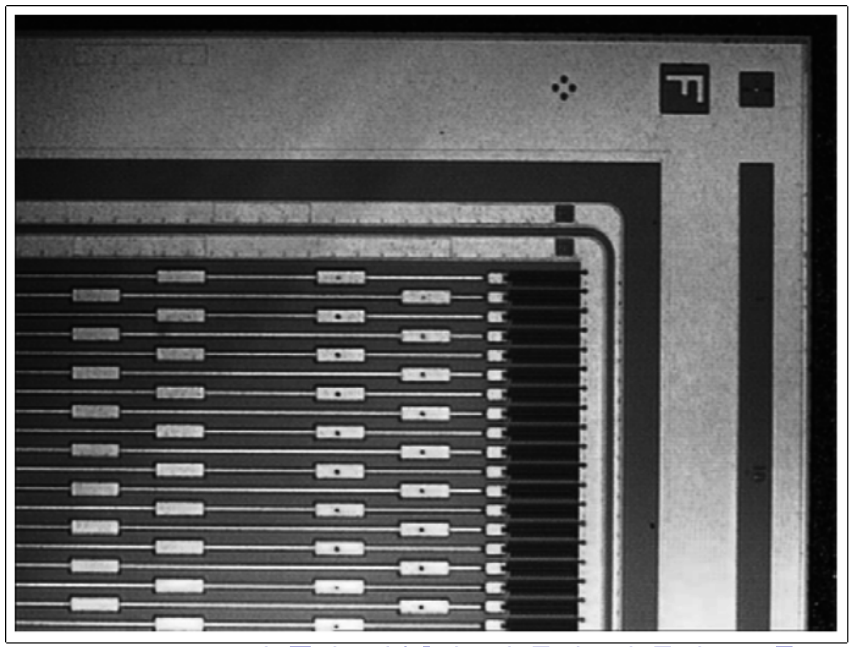


- many sensors on stave → subdividing leads to a better signal/noise



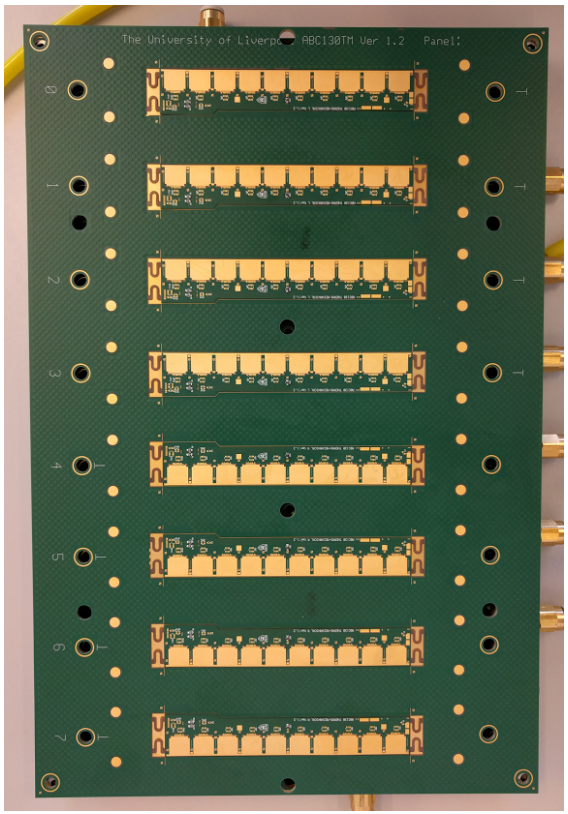
- Si strip sensor

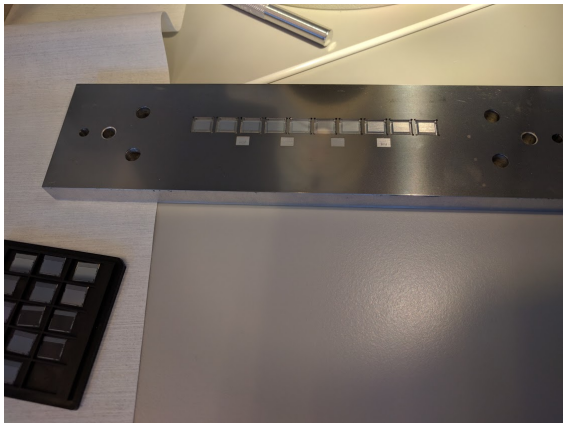
cds.cern.ch/record/974073

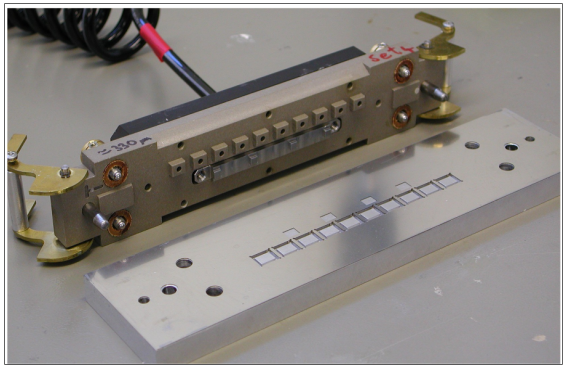


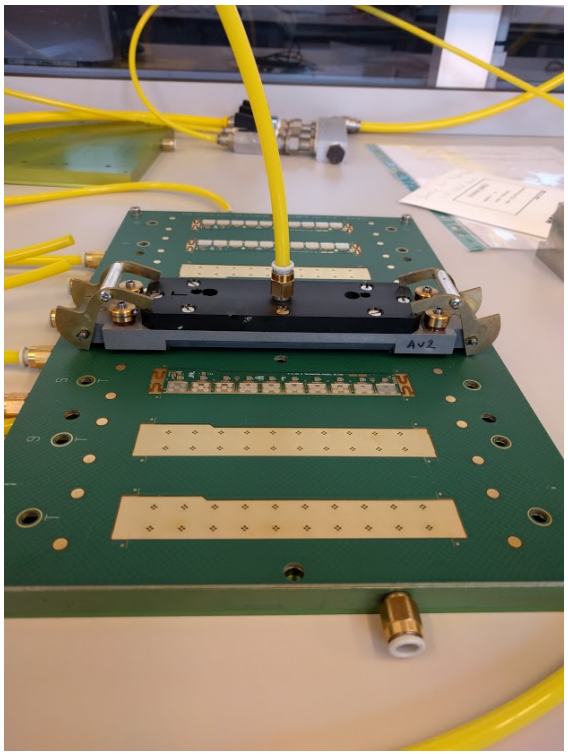
Gluing ASICS to Hybrids

- house ASICs
- deliver High-Voltage and distribute power
- provides electronics infrastructure

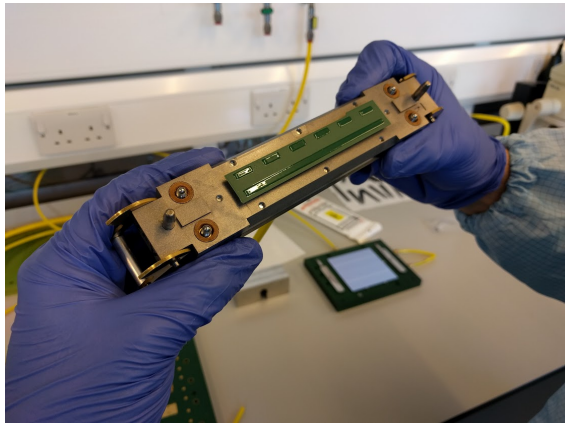


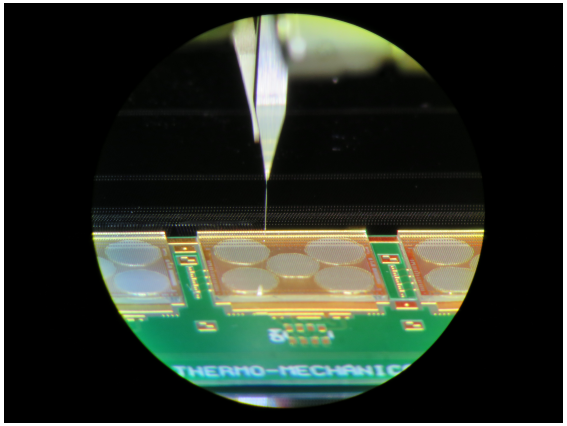


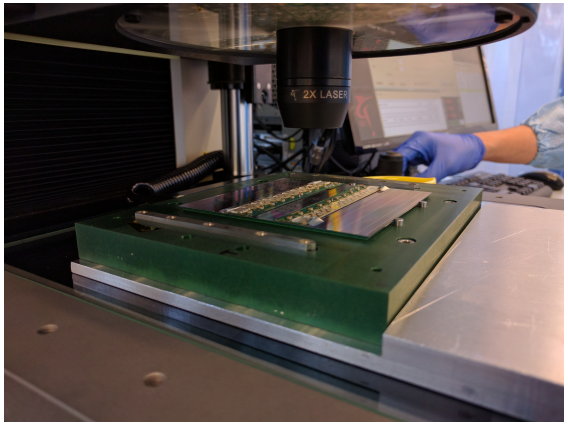


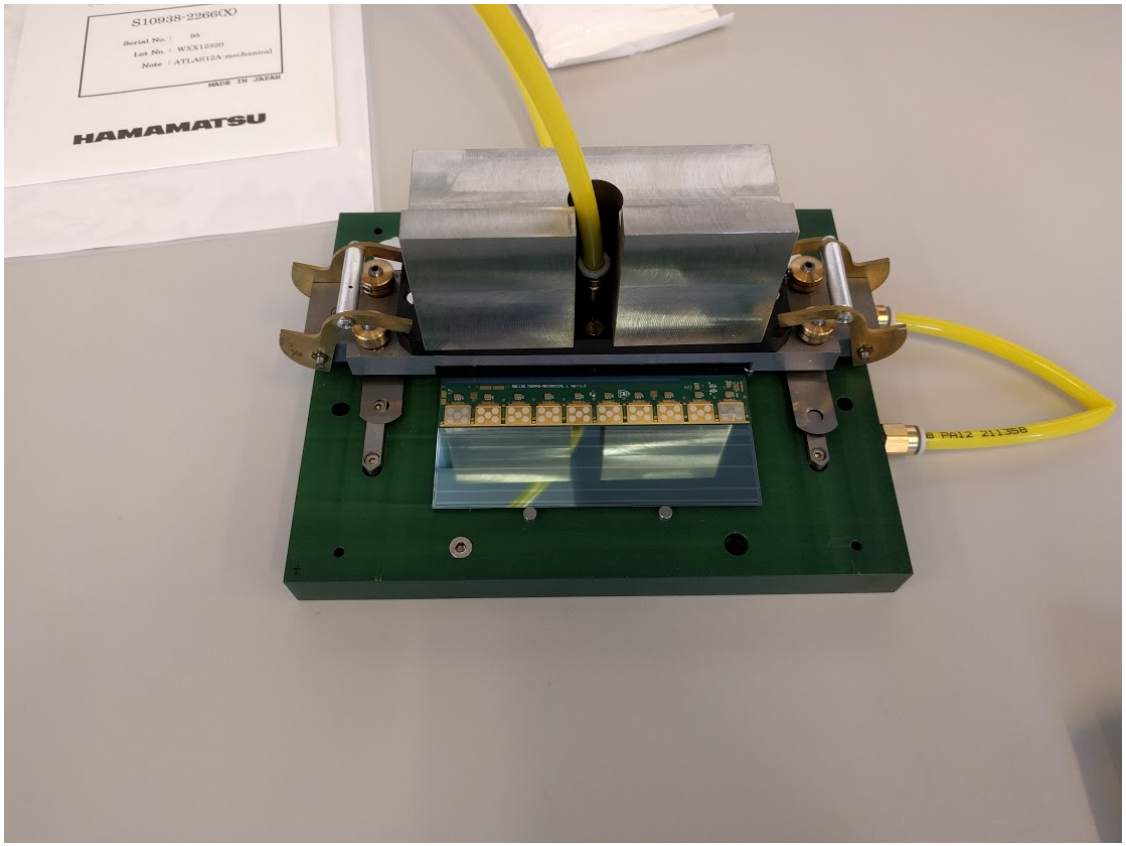


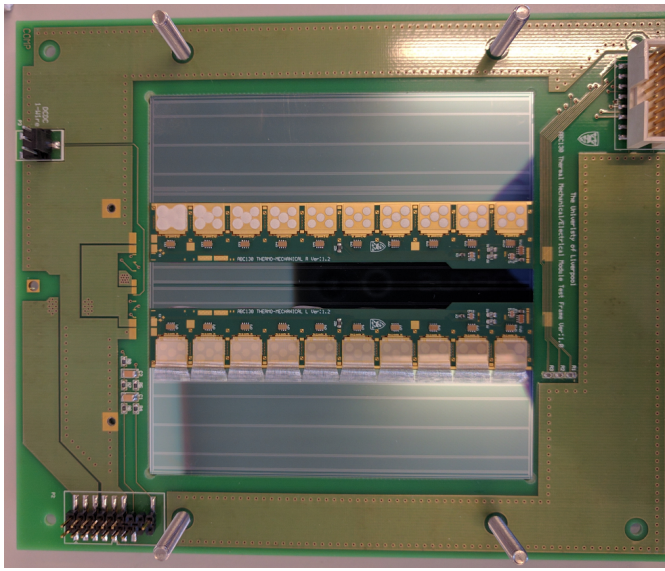
Gluing Hybrids to sensors and wirebonding



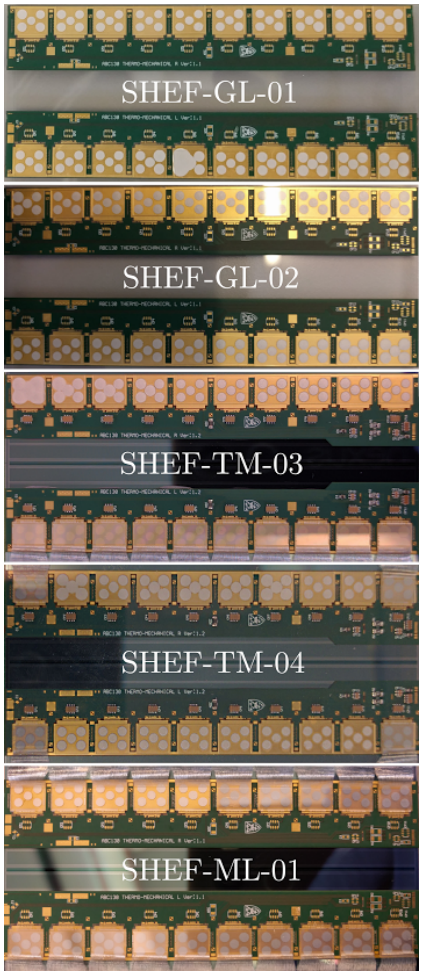








Conclusion



- HL-LHC has sound motivation: Higgs precision measurements and BSM physics.
- ATLAS will need upgrade of Inner Detector, replaced with ITK.
- ITK design already available
  - will deal with high radiation damage, pile-up and occupancy.
- Silicon strips will be pivotal part. Strip detector 10x larger than current SCT.
- R&D in final phase, moving towards

production engineering and Quality Control procedures (Sheffield).

- Detector ready for installation in 2022-2023, during long shutdown