ATLAS
– detector and upgrade

Peter Vankov

(for the Nikhef ATLAS group)

Nikhef Annual Scientific meeting, 15.12.2015

Outline

Topics:

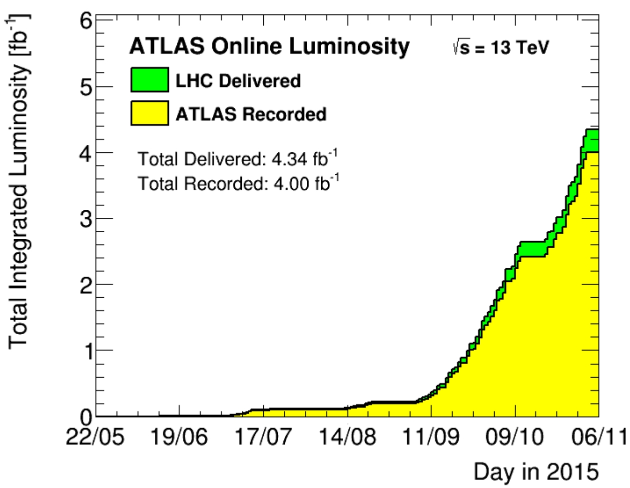
- ❑ **ATLAS in LHC Run-2**
- ❑ **ATLAS Phase 1 upgrade**
- ❑ **ATLAS Phase 2 upgrade**

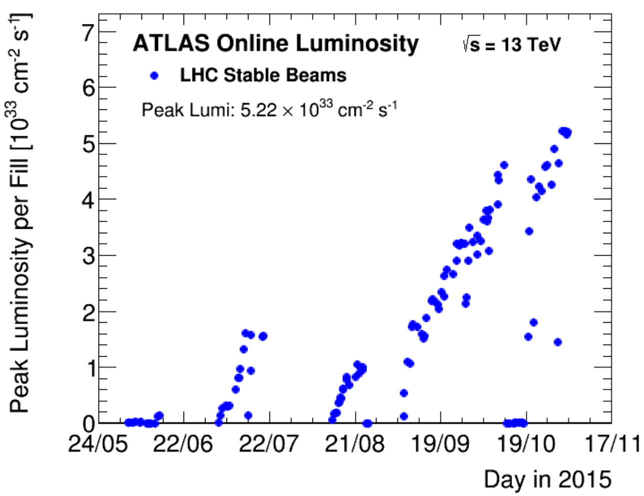
LHC in 2015

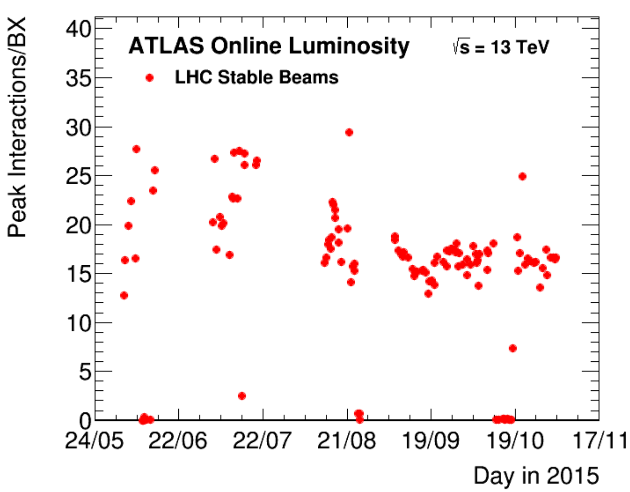
- ❑ In 2015, Run-2 started (Run-1 is 2010-2012)
- ❑ For Run-2, the LHC has been significantly upgraded, $\sqrt{s}$=8 TeV → **13 TeV,** increase of sensitivity to rare processes
- ❑ From few up to 2400 bunches
- ❑ Various running conditions (special runs)
  - ❑ different bunch crossings, low pileup, heavy ions

ATLAS detector in 2015

- ❑ Over **3 fb^{-1}** of 13 TeV pp collision data collected in 2015
- ❑ Typical Run-2 stable beams data taking efficiency: 90-96% <92.1%**>**





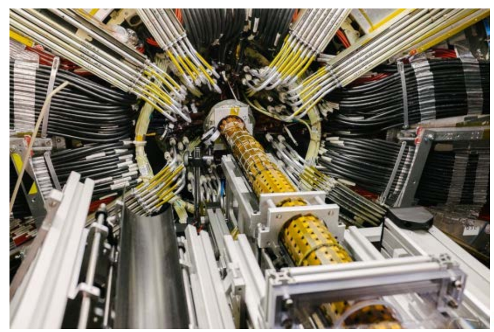


IBL – more pixels in Run-2

- A new, 4th pixel layer b/w the innermost Pixel (B-)layer and the beam pipe – the Insertable B-Layer, IBL, has been integrated in ATLAS for Run-2
  - Smaller pixels (50x400 μm → 50x250 μm)
  - Technology: planar and 3D Si sensors
  - New readout chip (FE-I4 Pixel Chip in 130nm CMOS, 26880 channels)
  - Required a new (smaller) beam pipe to fit (r = 29 mm → 25 mm)

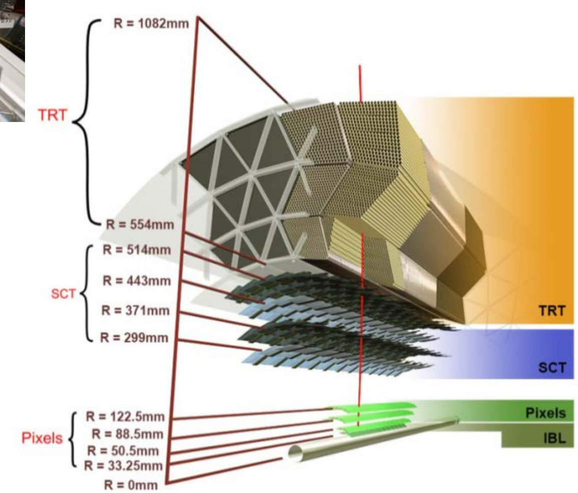
- IBL significantly improves tracking performance

- Nikhef contribution in IBL:
  - Cooling system
  - FE electronics design (FE-I4)
  - Tracking performance and alignment



- Nikhef people involved:
  - Coordinators at Nikhef: Martijn van Overbeek, Nigel Hessey
  - MT: Erno Roeland
  - Designers: Gertjan Mul, Boudewijn van der Kroon
  - Chip designers (FE-I4): Vladimir Gromov, Vladimir Zivkovic
  - Cooling commisioning: Bart Verlaat, Carolina Deluca
  - Inner Detector Alignment: Pierfrancesco Butti

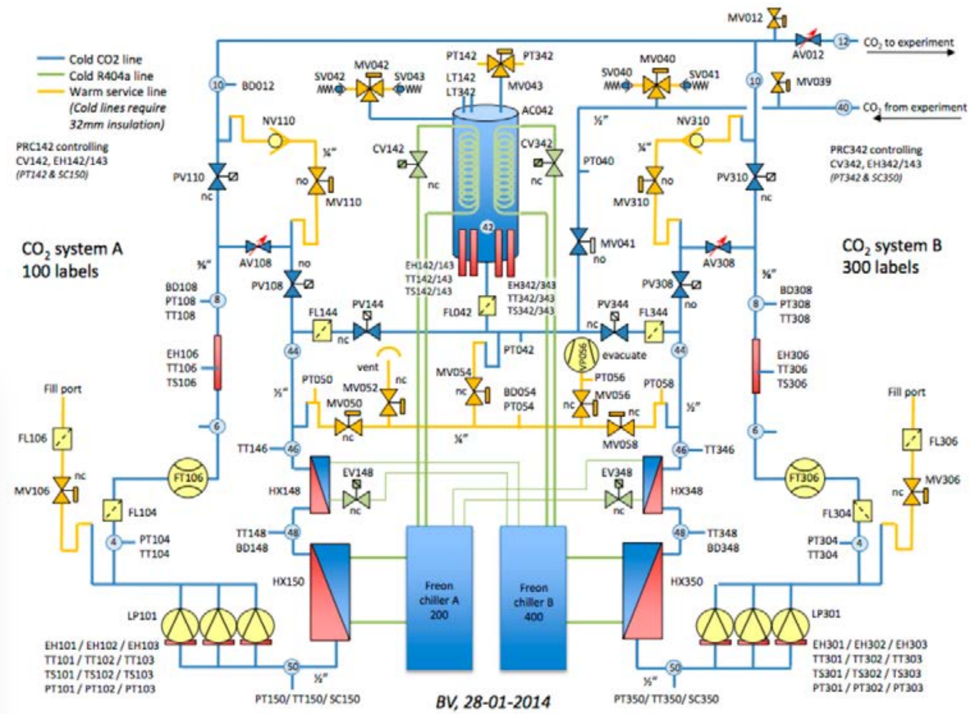
IBL info
- Number of staves: 14
- Number of modules per stave (single/double FE-I4) 32 /16
- Required cooling power: 1.5kW
- T_{evap} min at 1.5kW = - 40C
- T_{evap} max at 1.5kW = + 20C

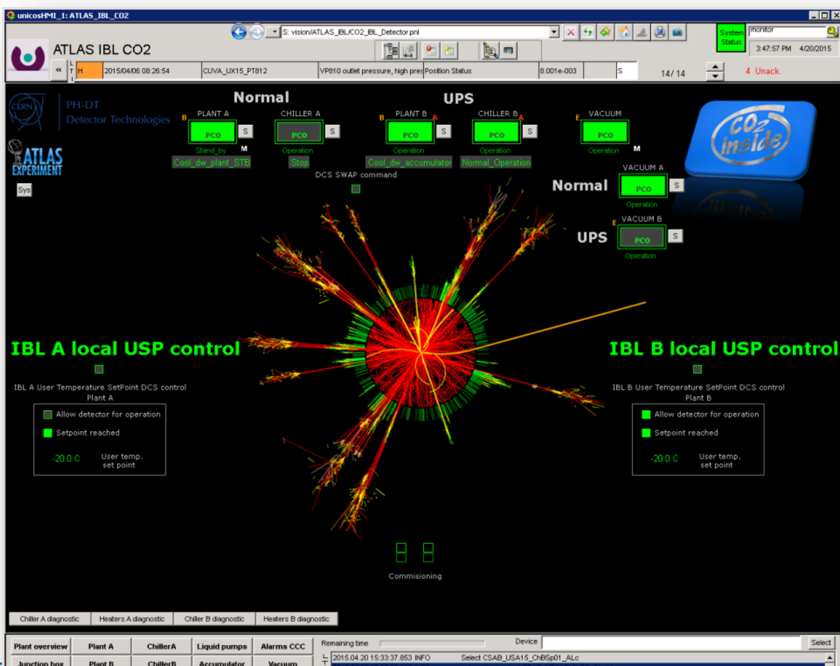


IBL CO_2 cooling system

- Designed, achieved cooling power at -40C = 3kW
- Main system elements:
  - 2 independent, redundant cooling plant cores
  - 2 independent, redundant two stage chillers
  - 1 common accumulator with redundant control
  - Common interconnection piping for maintenance operations including vacuum pump
  - Integrated internal by pass and small evaporator for stand-by operation
- Mostly smooth operation in 2015

- Bart Verlaat – overall project leader @ CERN



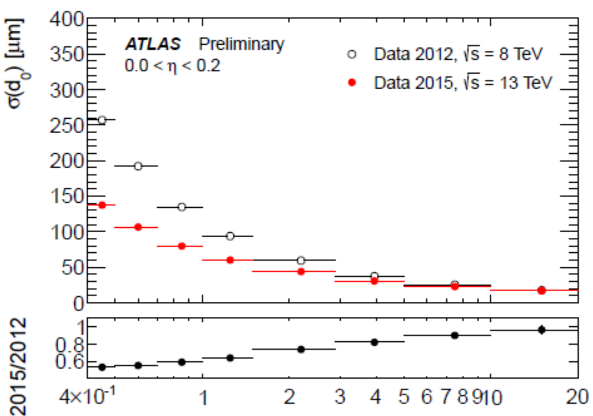


Cooling system inside the service cavern

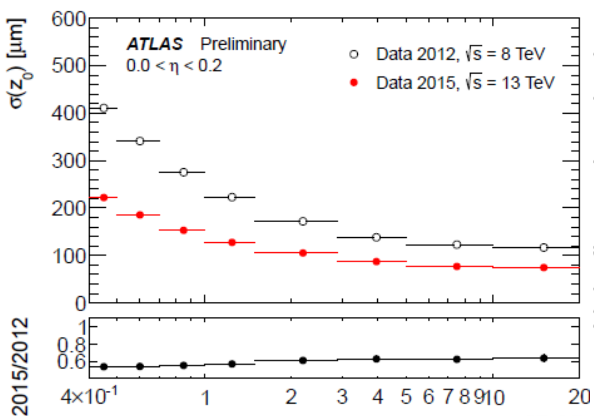
IBL performance

Nikhef

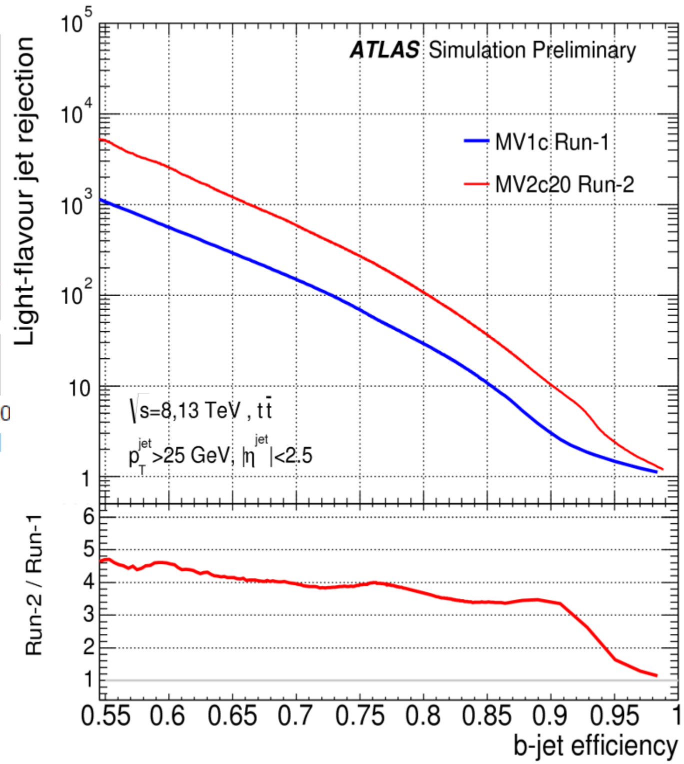
- IBL significantly improves impact parameter resolution
  - factor of ~2 gain in performance



IDTR-2015-007

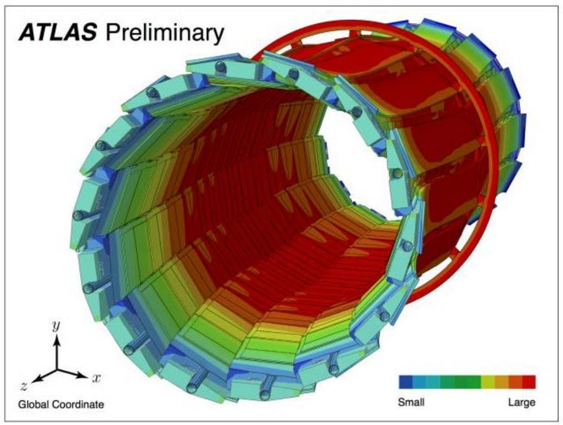


IDTR-2015-007

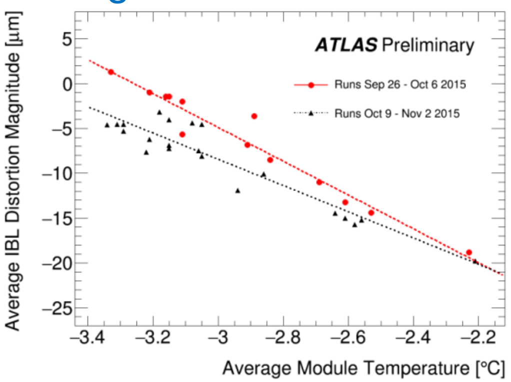


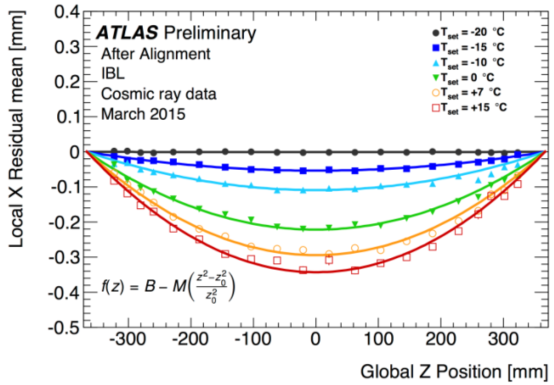
- B-tagging: Major improvement from addition of the IBL
  - At 70% b-jet efficiency:
    factor of 4 (1.75) gain in light-flavor (charm) jet rejection

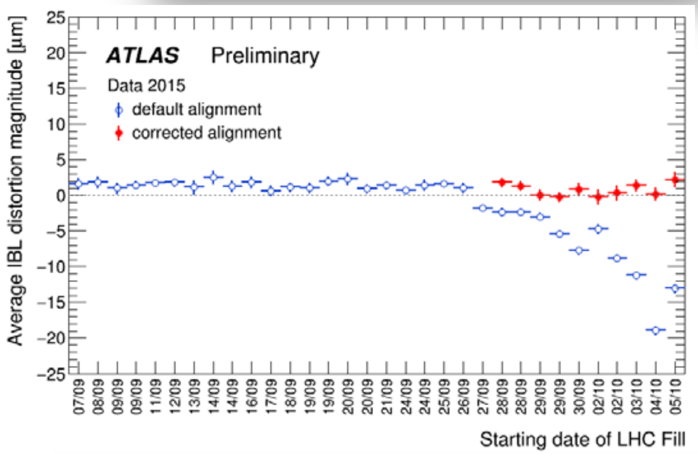
IBL issues



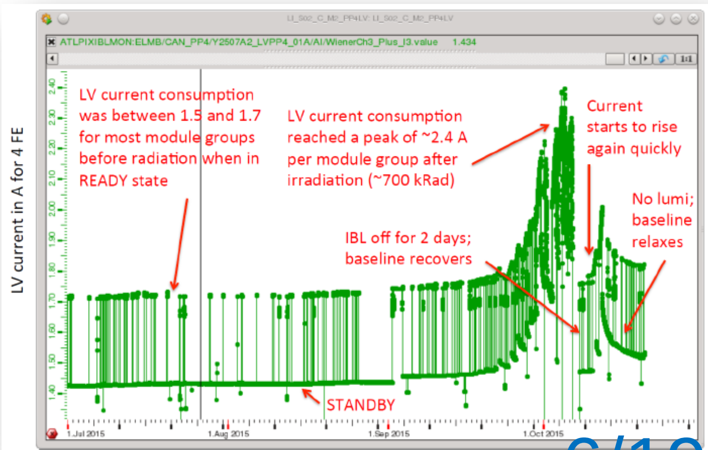
- ❑ Thermomechanical distortion of the IBL
  - ❑ The issue was discovered early in 2015
  - ❑ The staves undergo an in-plane “bowing”
  - ❑ The effect is temperature dependent
  - ❑ Direct impact on the tracking performance
- ❑ To recover the physics performances - run by run alignment corrections





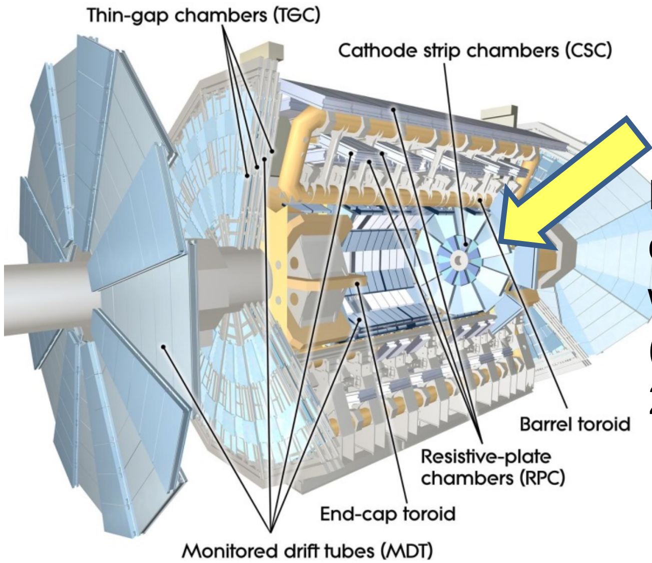


- ❑ Increase of the low-voltage current consumption with increasing integrated luminosity
- ❑ Task force formed to study the effect
- ❑ Current hypothesis: observation is due to Total Ionizing Dose (TID) in transistors
- ❑ Calibration shift due to change of **single** transistor characteristics with TID
- ❑ Model also predicts decrease of currents with increasing TID starting early next year



Muon spectrometer performance

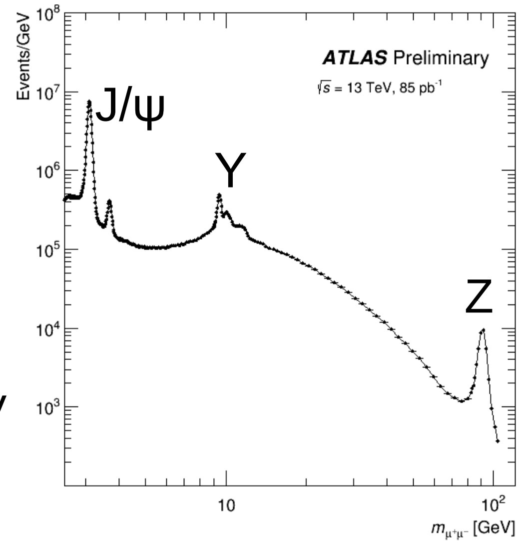
- Nikhef involvement in Muon spectrometer (MS) – operations and reconstruction software
- Reconstruction software contributions
    - Muon identification and (offline) reconstruction performance
        - Commissioning and maintenance of combined muon reconstruction with inner detector and muon spectrometer measurements (Peter Kluit, Jochen Meyer)
        - Maintenance and tuning of muon identification based on calorimeter tagged inner detector tracks (Nicolo De Groot)
        - ATLAS Muon Software Coordination, including maintenance of simulation, digitization, offline decoding and reconstruction codes (Jochen Meyer)
- Challenges in Run-2
    - new steering of reconstruction algorithms
    - (partially) new algorithms and reconstruction approaches
    - software integration of new chambers added during previous shut down

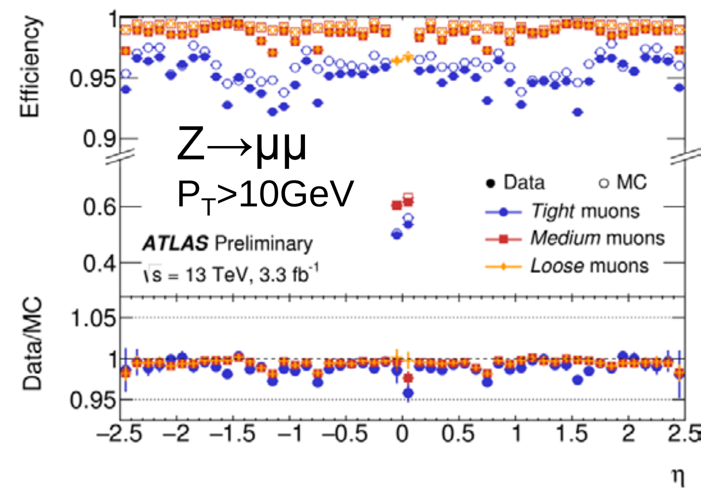


$1.3 < |\eta| < 2.7$
Planned upgrade of the muon small wheels in LS2 (Phase-1 upgrade, 2019-2020)

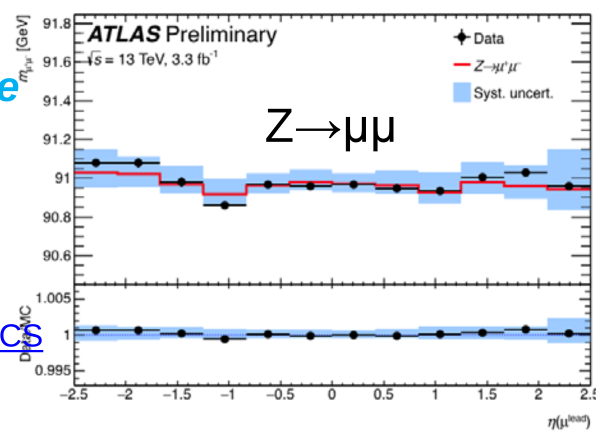
Muon spectrometer performance

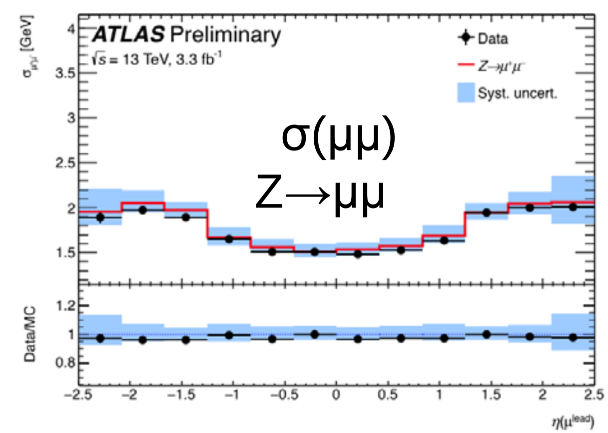
- Di-muon resonances precisely reconstructed
- High efficiency (like in Run-1) for all working points defined by the muon combined performance group
- Transverse momenta b/w 25 GeV and 300 GeV studied on Z show similar agreement





In general, very good performance of muon identification with the ATLAS MS also in Run-2

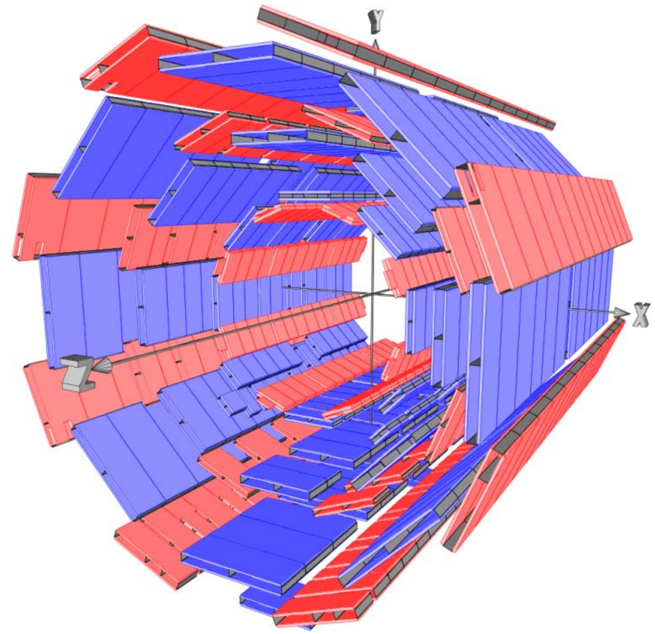




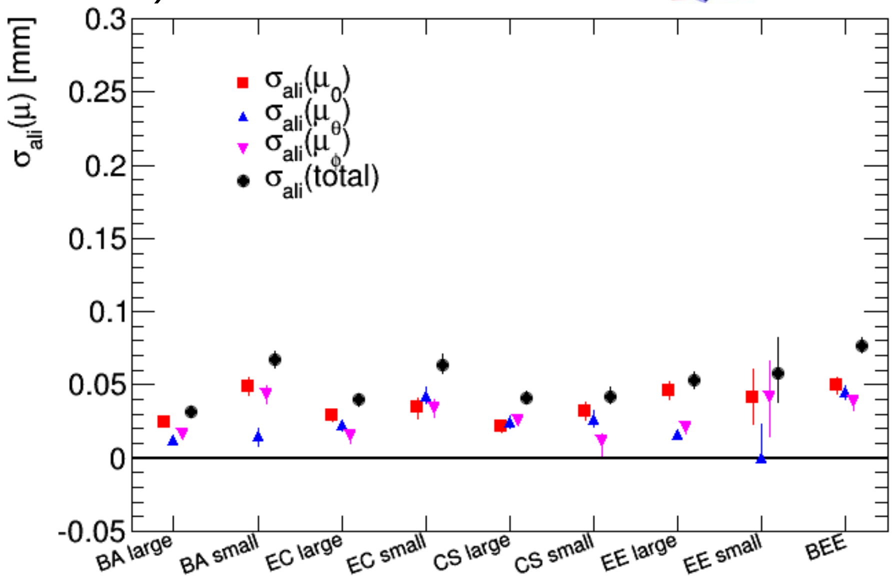
Public plots available here:
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/MUON-2015-004/index.html

Muon spectrometer operations

- Nikhef involvement in muon spectrometer operations
  - General responsibility for monitored drift tubes (MDT) operations (Gerjan Bobbink)
  - DAQ and DCS support and maintenance (Henk Boterenbrood, Thei Wijnen, Peter Jansweijer)
  - Software and electronics of frame grabbers for the RASNIK MDT alignment system (Robert Hart, Ruud Kluit, Frans Schreuder)

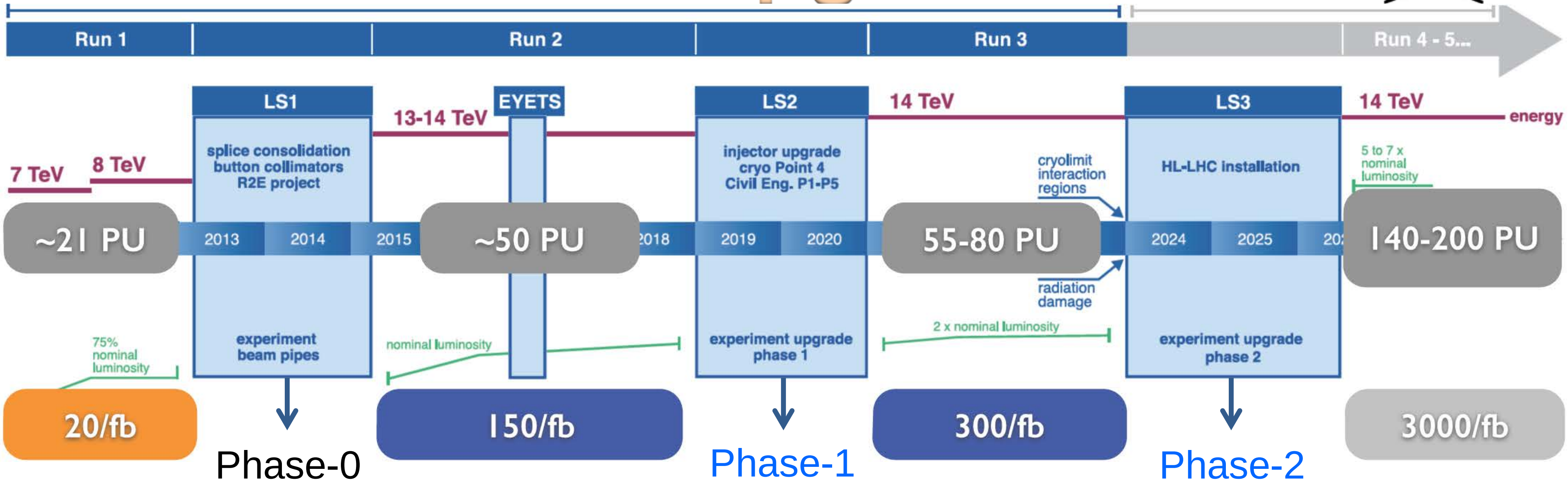


sagitta resolution usually ~50 μm



  - Muon control room shifts (various Nikhef group members)

ATLAS Upgrades



- ATLAS collaboration has devised a detailed program to reflect the changes in the LHC conditions towards the HL-LHC, characterized by high track multiplicity and extreme fluences, with intention to
  - *maintain/improve the present detector performance, ensuring optimal physics acceptance as the instantaneous luminosity increases*
- The foreseen, major ATLAS upgrades include:
  - **Phase-1** (2019/2020 LHC shutdown)
    - Installation of a New Muon Small Wheels (NSW)
    - Fast Track Trigger (FTK), LAr L1 and L1Calo upgrade
  - **Phase-2** or HL-LHC (2024/26 LHC shutdown):
    - Inner Detector challenged by high radiation & occupancy
    - Build completely new all-silicon ID (pixel and strips)
    - 100 kHz L1 trigger →1 MHz L0 trigger; L1 track trigger; overhaul of detector readout and of TDAQ

Nikhef has strong participation in both Phase-1 and Phase-2 upgrades

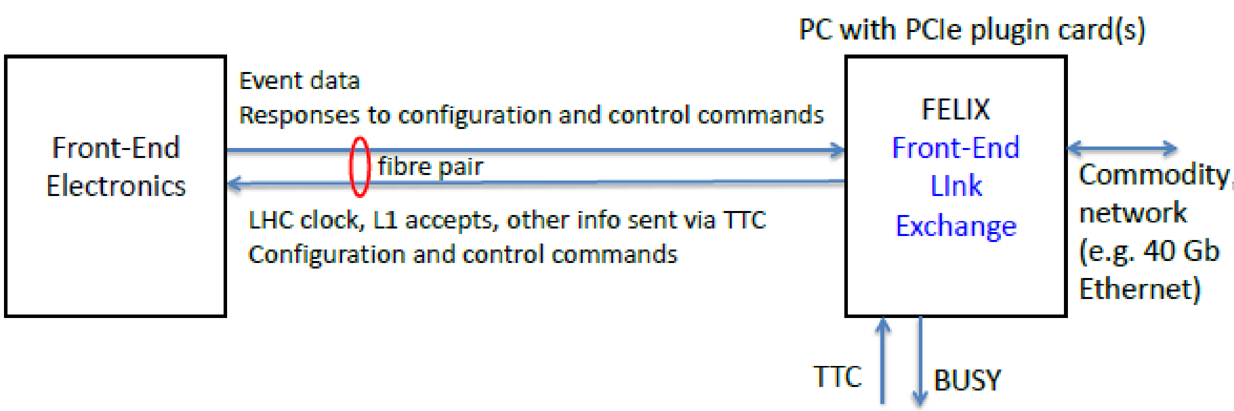
Phase-1 upgrade

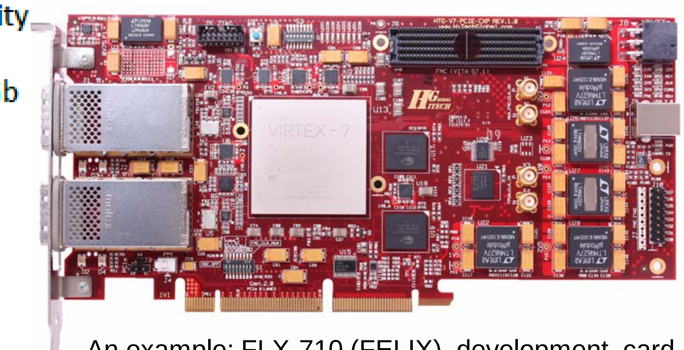
- Nikhef most important Phase-1 hardware upgrade project (intention to contribute to FELIX also for Phase-2)
- FELIX – FrontEnd LInk eXchange
- A new approach for interfacing the Front-End electronics in Phase-1 for the New Small Wheel muon detectors and new first-level trigger electronics making use of data of the LAr calorimeter
- Interfacing for the DAQ and DCS for the NSW detectors and the LAr L1 and L1Calo systems

FELIX

Nikhef people involved:

- Frans Schreuder
- Andrea Borga
- Henk Boterenbrood
- Jos Vermeulen
- Mark Donszelmann



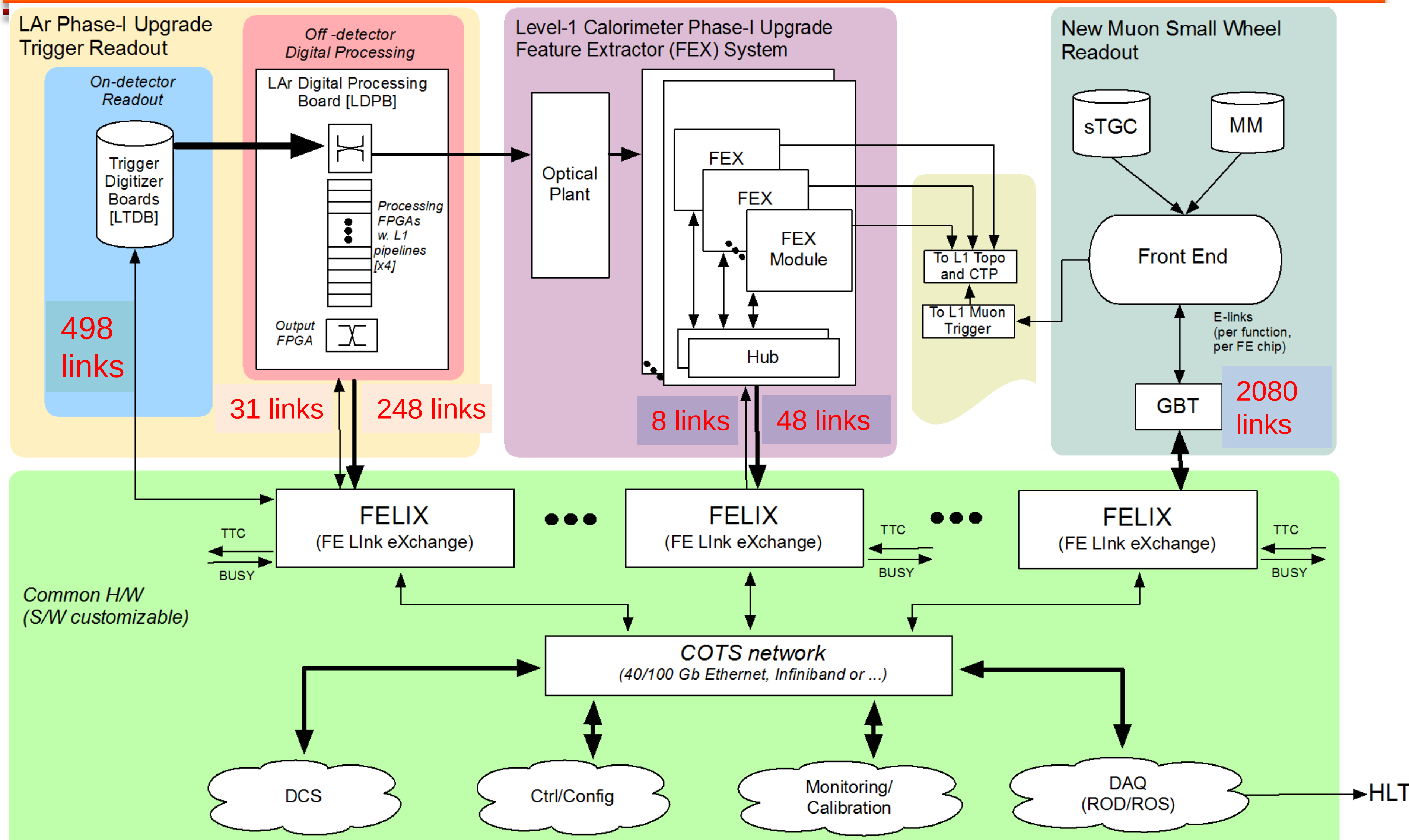


An example: FLX-710 (FELIX) development card

- HiTech Global HTG-710
- Virtex-7 X690T
- PCIe Gen 3 x 8 lanes
- 2x12 bidir CXP connectors
- FMC connector

- FELIX acts as intelligent switch: server PCs connected to commodity network send and receive data via FELIX -> functionality implemented currently in firmware implemented in software: better maintainability, no dependence on firmware developers, software running on COTS hardware
- FELIX for Phase-1: COTS server PCs with PCIe cards
- Fibre pairs transfer different types of information for which currently separate connections are used

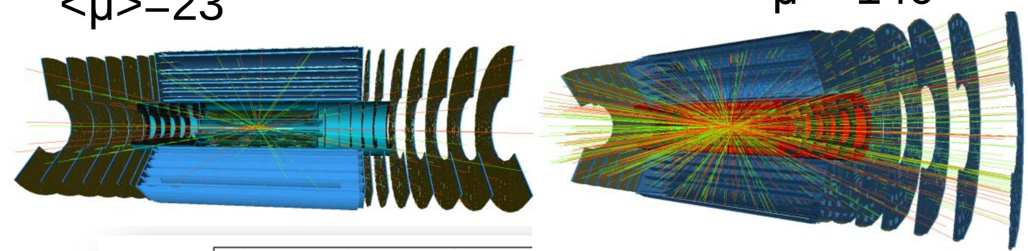
FELIX in Phase-1



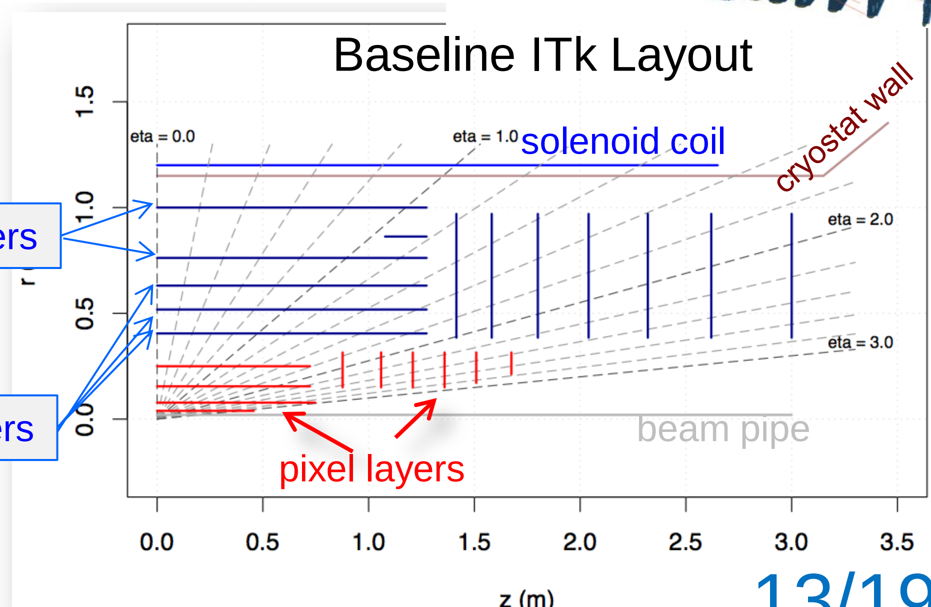
ATLAS Phase-2 upgrade: new tracker

- Current Inner Detector (ID) - designed to operate for 10 years at $L=1\times10^{34}\ cm^{-2}s^{-1}$ with <μ>=23, @25ns, L1=100kHz
- Limiting factors at HL-LHC
  - Bandwidth saturation (Pixels, SCT)
  - Increased occupancies (TRT, SCT)
  - Radiation damage (Pixels (SCT) designed for 400 (700) fb^{-1})

➲ New Inner Tracker for HL-LHC (ITk)
- All-silicon tracker, no TRT
- Higher granularity
- Improved material budget
- Baseline: Layers of Si pixels and micro-strips

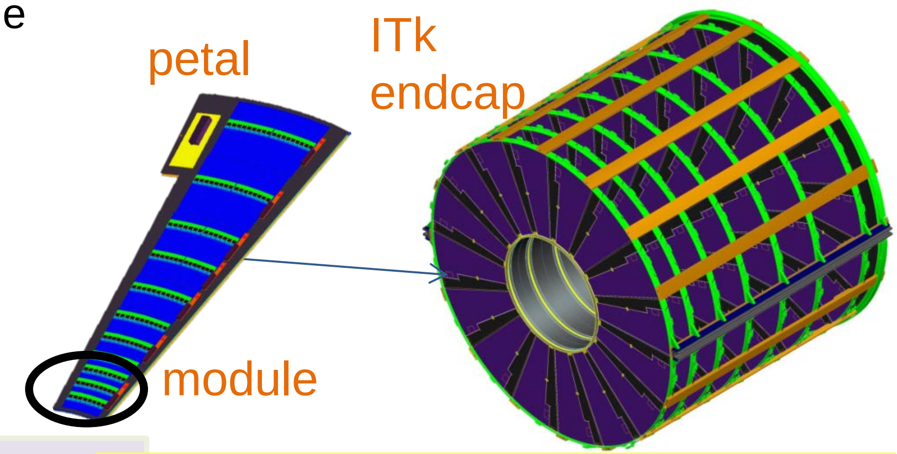


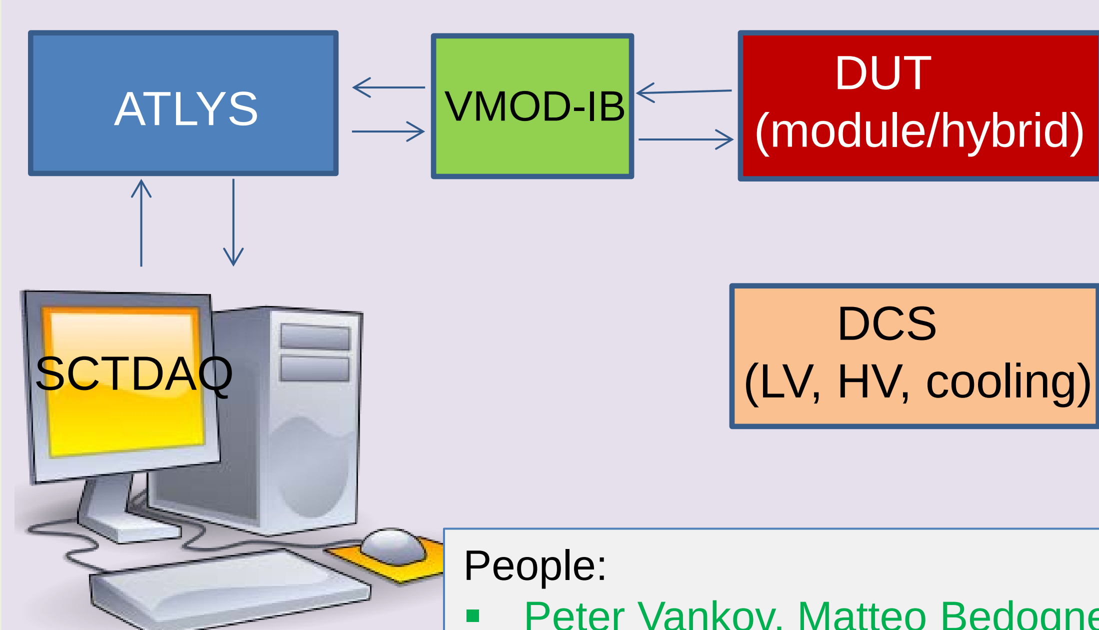
- Nikhef is strongly involved in building the new ATLAS ITk detector for the HL-LHC:
  - Si-strip endcap building/assembly/tests
  - Global support design/production
  - Si-strip sensors tests
  - Pixel chip R&D
  - Simulations, layout design and performance
  - Testbeam studies of Si-strip sensors



Nikhef ITk DAQ

- The macro-assembly of the one of the two ITk Si-strip endcaps will take place at Nikhef
  - Detector modules will be tested at large scale
- Must be ready to efficiently test modules once needed
  - Setup a lab-space for testing ITk Si-strip units at Nikhef
  - Build fully operational readout and slow control chain (even though final components don't exist)





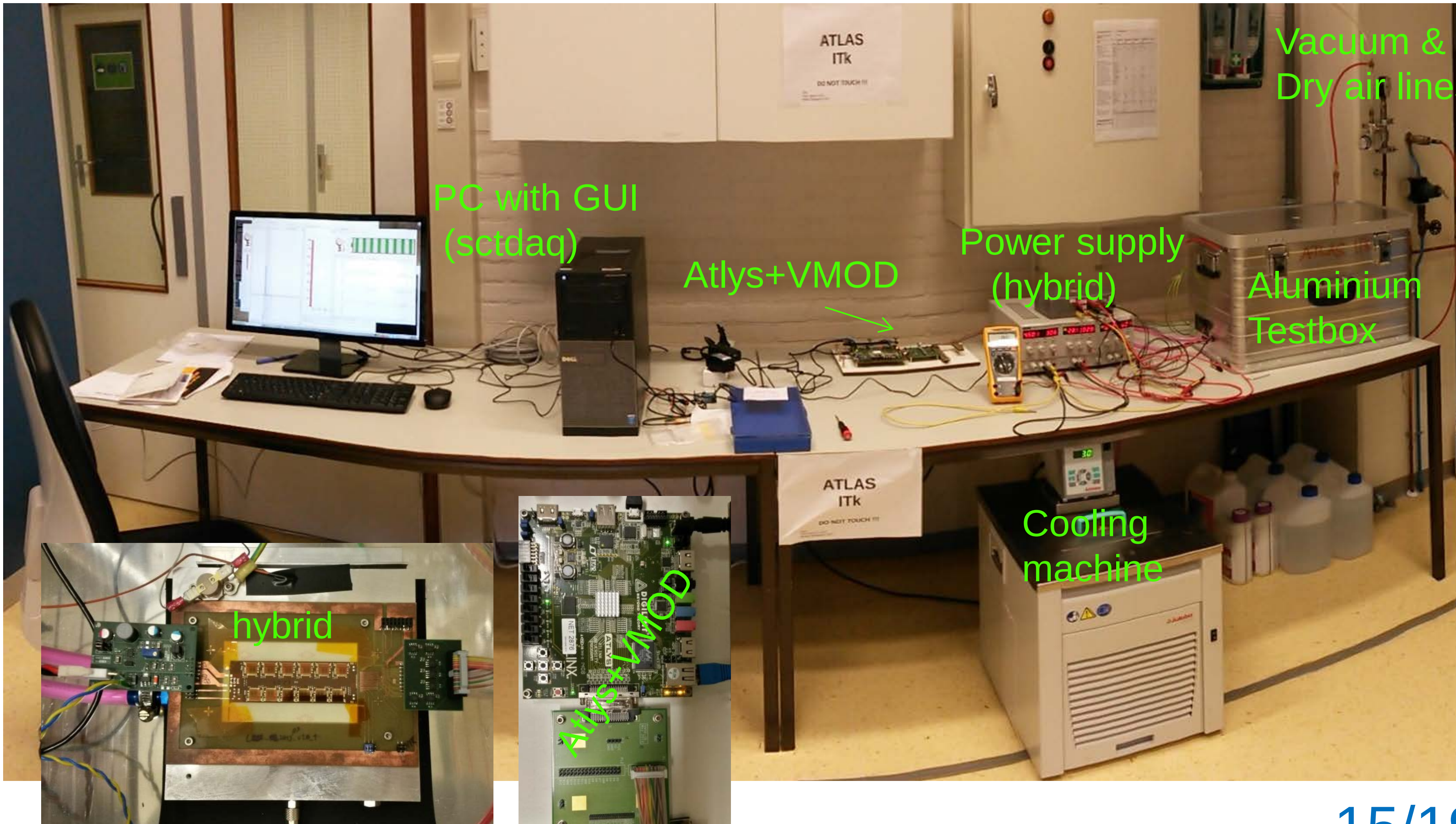
- ITk lab space @ Nikhef: H023 (clean room)
- ITk readout scheme (Atlys based)

<u>Components</u>:
- DUT = ABCN 250 nm prototype hybrid
- ATLYS FPGA – signal processing board
- VMOD-IB – interface board
- Low voltage - AIM-TTi PL303QMTP
- Cooling machine – Julabo FP50-MC
- Vacuum jig – for hybrid support/cooling
- Software – SCTDAQ, PC – Linux, slc6

People:
- Peter Vankov, Matteo Bedognetti, Wim Gotink, Loek Ceelie

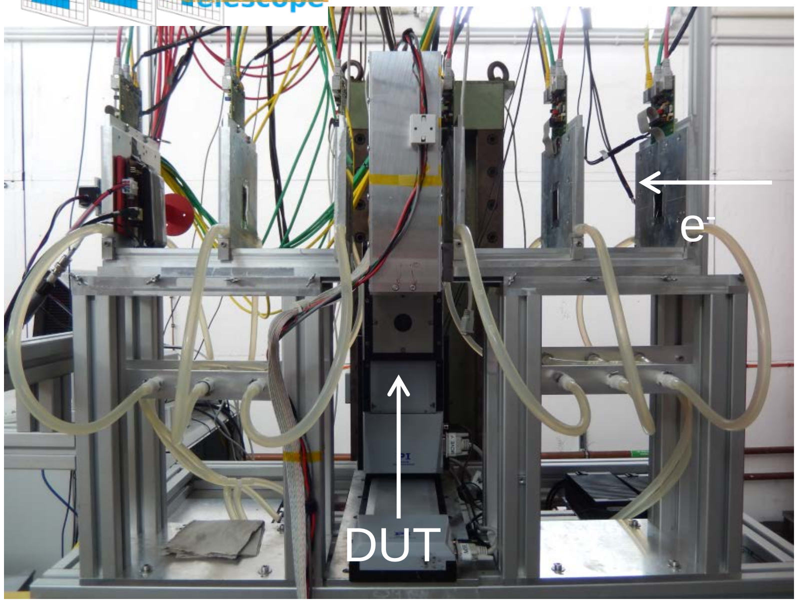
Nikhef ITk DAQ laboratory

Clean room

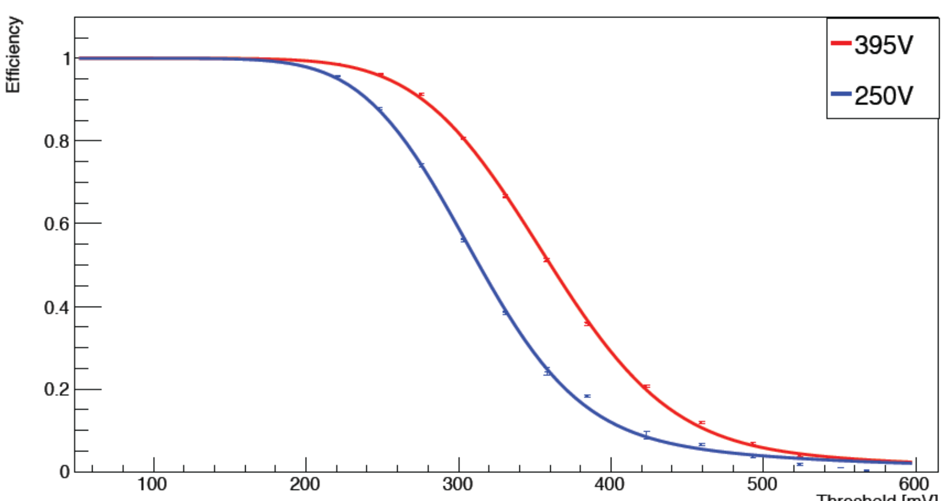


ITk Testbeams at DESY

- Lucrezia Stella Bruni, Pamela Ferrari, Bob van Eijk



- ❑ Test behavior of the ITk sensors and the new ABC130 readout chips with a beam of high-energy, charged particles
- ❑ Two testbeams in 2015
  - ❑ May 2015 - tested two silicon strips barrel hybrids with ABC130 chips
  - ❑ October 2015 - barrel module with long strips, ABC130 nm; endcap module, ABC250 nm
- ❑ The setup
  - ❑ electron beam (E_{max}= 6 GeV)
  - ❑ EUDET telescope for tracking



Measurements:

- ❑ Collected charge vs. HV, vs. time and vs. position (for barrel and ec sensors with different pitch, small edges)
- ❑ Efficiency curves vs. threshold
- ❑ Noise vs. threshold
- ❑ Lorentz angle measurements with and without B-field (1T B-field available at DESY)
  - ❑ Cluster sizes and resolution vs. angle

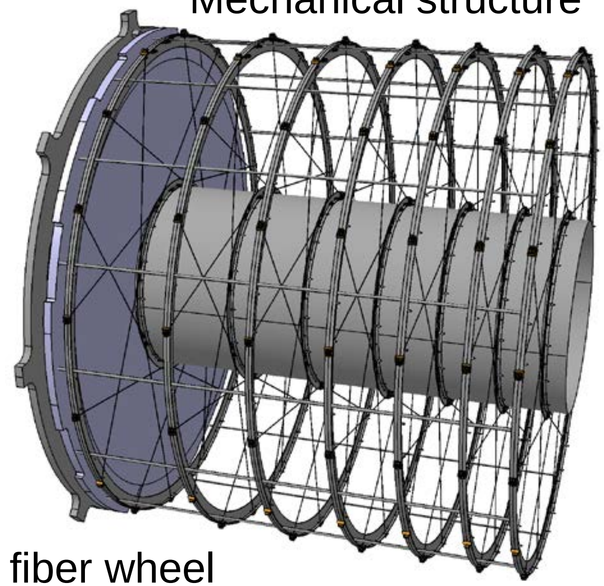
ITk mechanical design

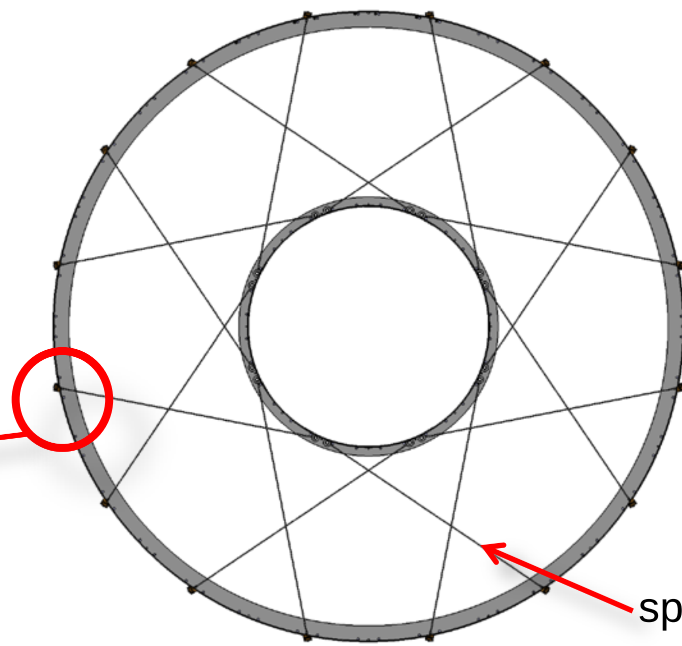
- **Goal:** design, develop technology and construct an ITk strip endcap
- **Team:** Martin Doets, Jesse van Dongen, Arnold Rietmeijer, Gerrit Brouwer, Marcel Vreeswijk, Nigel Hessey, Auke Colijn

Key elements

1. Low-mass carbon fiber wheels
2. Wheel-to-wheel connection
3. Petal mount
4. Super-structure
   - Bulkheads
   - Inner cylinder

Mechanical structure

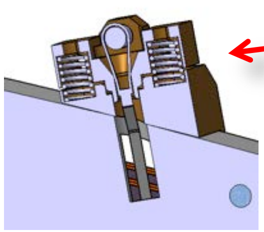




carbon fiber wheel

spokes ~ ø2mm CF

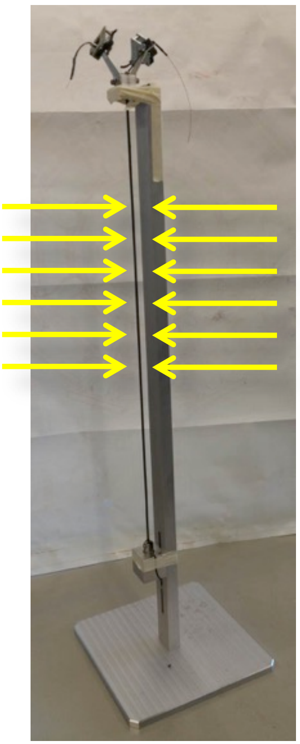
tensioning of spokes

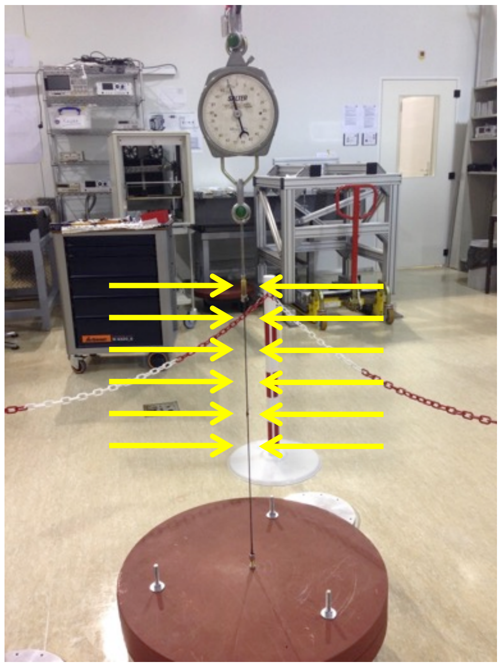


ITk mechanical design: prototypes

spokes

100 kg = strong enough

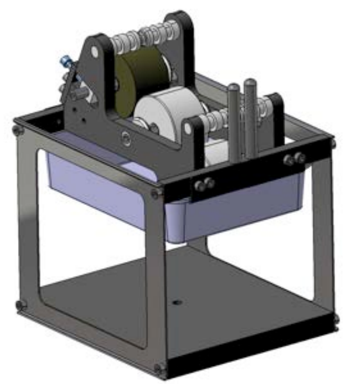




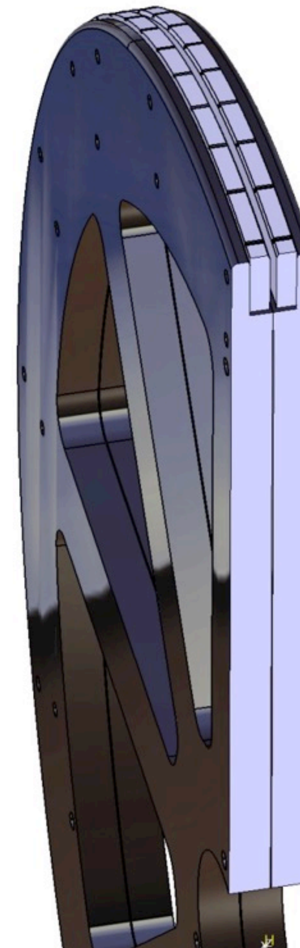
prototype production tool

wheels

wheel mold



carbon wetting tool



Summary

- The ATLAS restart after the LHC long shutdown during Phase-0 and the data taking through out 2015 has been very successful
- Generally smooth running
- ATLAS is ready for an exciting Run-2 physics program in the next 2-3 years

- ATLAS collaboration has devised a detailed, 3-phase program to reflect the changes in the LHC conditions towards the HL-LHC
- Nikhef is actively taking part in many aspects of the foreseen ATLAS upgrades