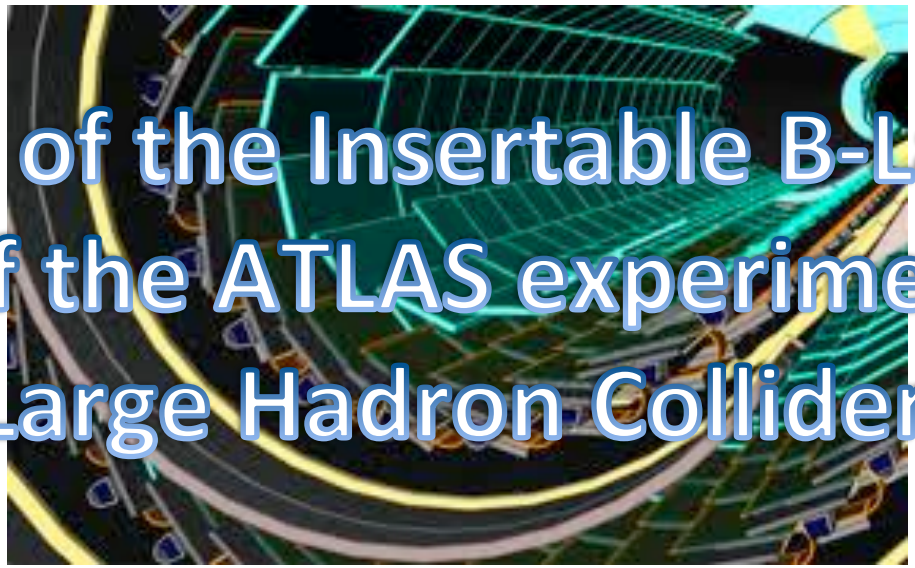
Overview of the Insertable B-Layer (IBL) Project of the ATLAS experiment at the Large Hadron Collider



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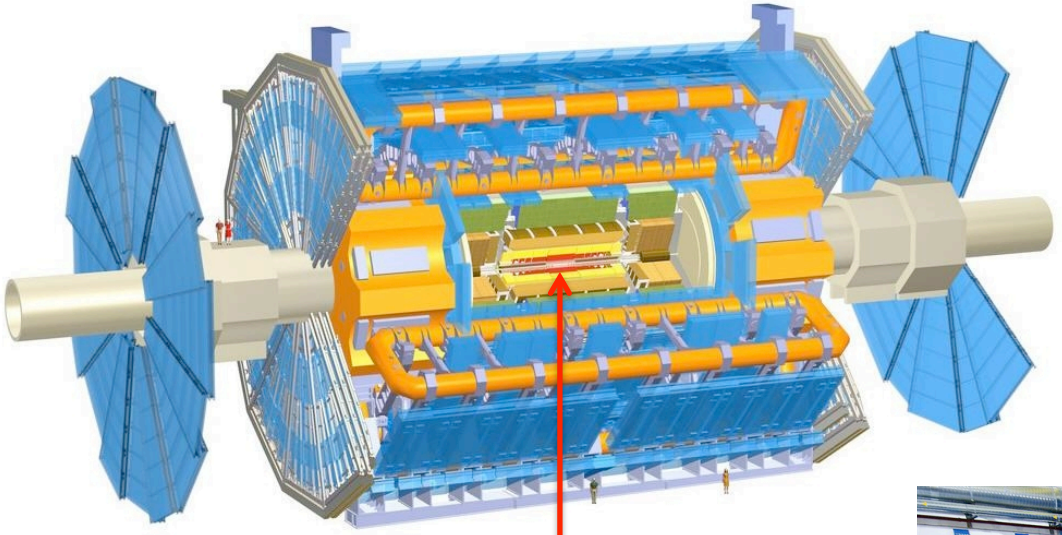
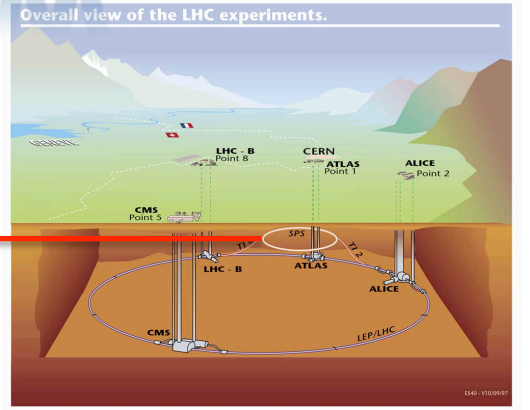
OUTLINE

- ATLAS overview
- Pixel detector
- The Insertable B-Layer (IBL)
  - Motivation
  - Sensor and FE-I4 readout chip
  - Staves quality assurance
  - Final test (surface)
  - Staves selection and assembly
  - IBL lowering and insertion
  - Service testing (pit)
- Conclusion

ATLAS: OVERVIEW

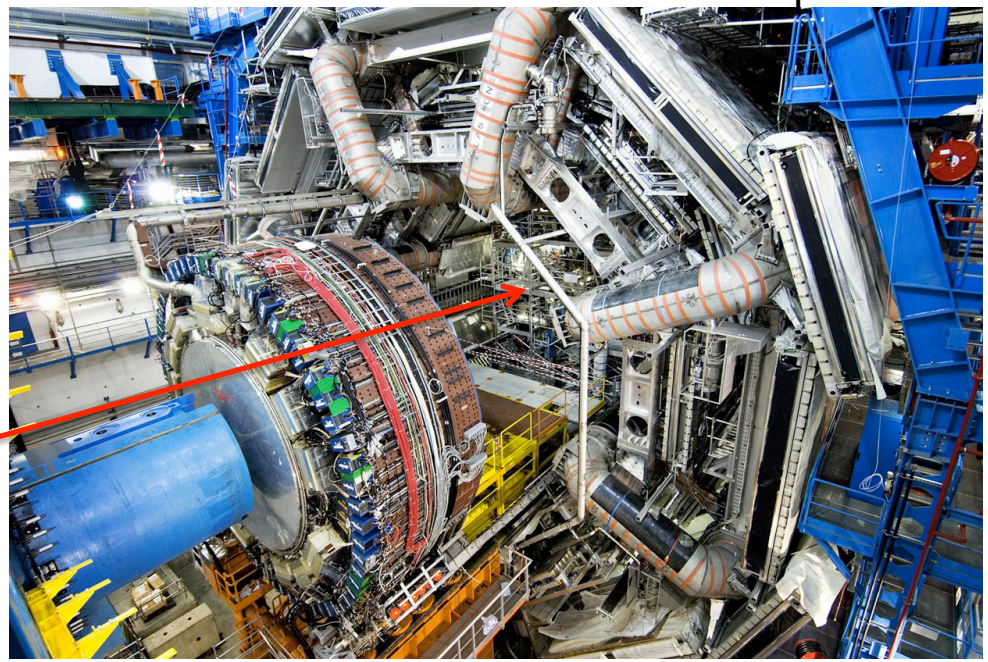
General-purpose particle detector



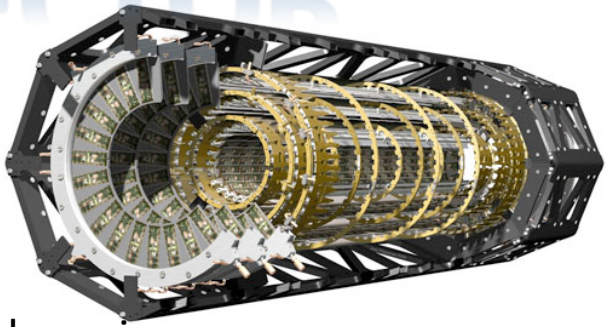


LHC: p+/p+ collider
Data taken since ~2010
Up to 8TeV

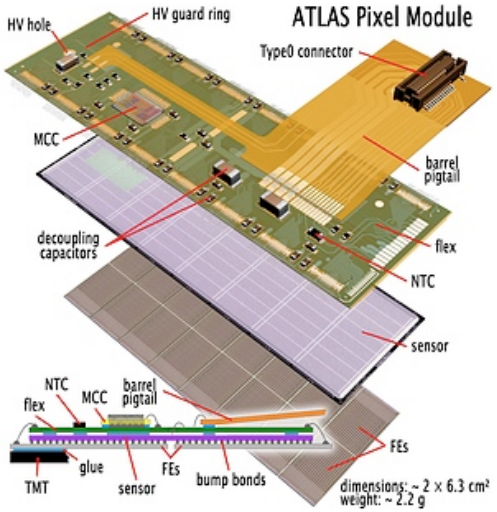
- Dedicated detection systems
  - Muon chambers
  - Calorimetres
  - Trackers
    - Transition radiation tracker
    - Silicon strips (SCT)
    - **Pixel detector**



ATLAS PIXEL DETECTOR



- 3 layers: 5, 8 and 12cm to the interaction point
- 3 disks per side
- Operated from 2009 to 2012
- Taken back to the surface in Apr. 2013 for a service upgrade and repairs
  - % of operational detector from 95% brought back up to 99%
- Back to the pit in Dec. 2013 – fully reconnected in March 2014
  - % of operational detector: 98%
- Hybrid technology using bump-bonding
- FE-I3 Front-end technology
- Pixel size: 50x400μm^2 - Resolution: 10μm (rϕ) 115μm (z)
- 1744 modules (13/stave on barrel)
- >80M channels

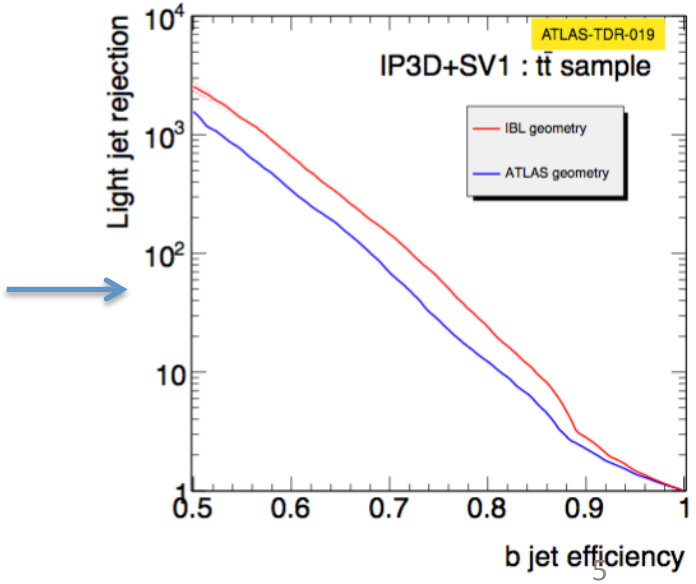


IBL: MOTIVATION

First upgrade of ATLAS tracker

- Run II: Increase of LHC energy (8→13TeV) and luminosity ($10^{34}cm^{-2}s^{-1}$ →factor 2.2)
  - Pixel detector: showed great performance but:
    - At the end of Run I, 6% dead module on b-layer
      → Limitation in b-tagging
    - Designed for a luminosity of $10^{34}cm^{-2}s^{-1}$
      - FE-I3 readout inefficiency in b-layer will be 5% to 10% at L=2.2. $10^{34}cm^{-2}s^{-1}$
  - Original goal was to replace the b-layer
    - Impossible to extract a single layer out of the pixel detector
      - Ended up adding a layer: IBL (and extracting the whole package!)

- Insertable b-Layer aim:
  - Compensate inefficiency, radiation damage and losses of pixels/modules
  - Improve precision measurement with an additional point closer to the interaction point, improve vertexing, tracking and b-tagging performance

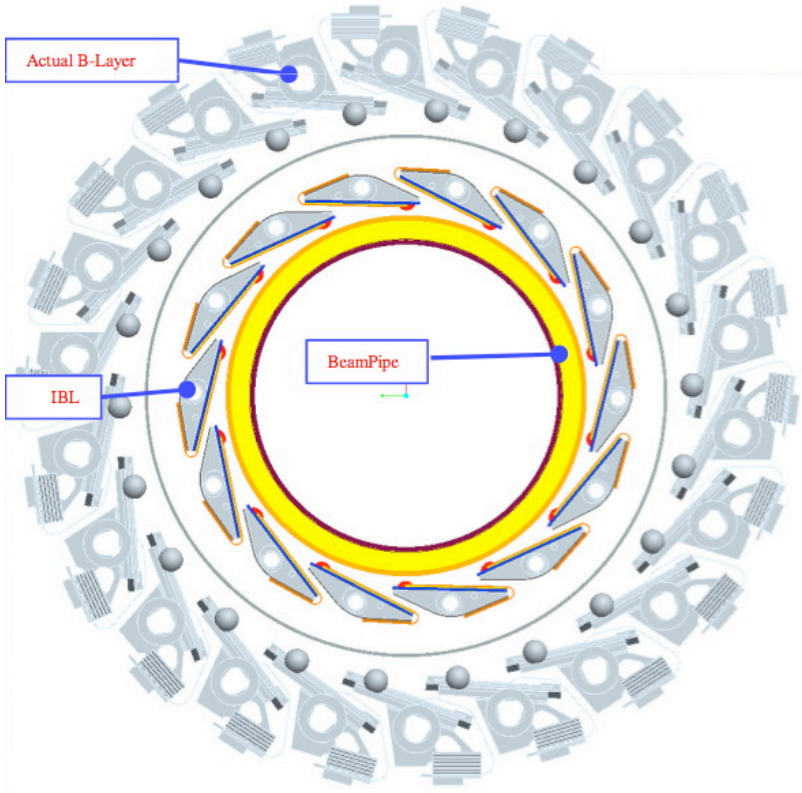


Comparison of geometry with or without IBL

IBL: OVERVIEW

- 4^{th} layer of pixel as part of the Pixel detector 1st upgrade
- Smaller beampipe: 2.9cm → 2.5cm
- 14 staves
- 3.3cm away from the interaction point
- New Front End technology: FE-I4B
- Smaller pixels 50x250μm^2
  - Resolution <10μm (rϕ) 80μm (z)
- Inactive edge reduction: 450μm in pixels → 200μm

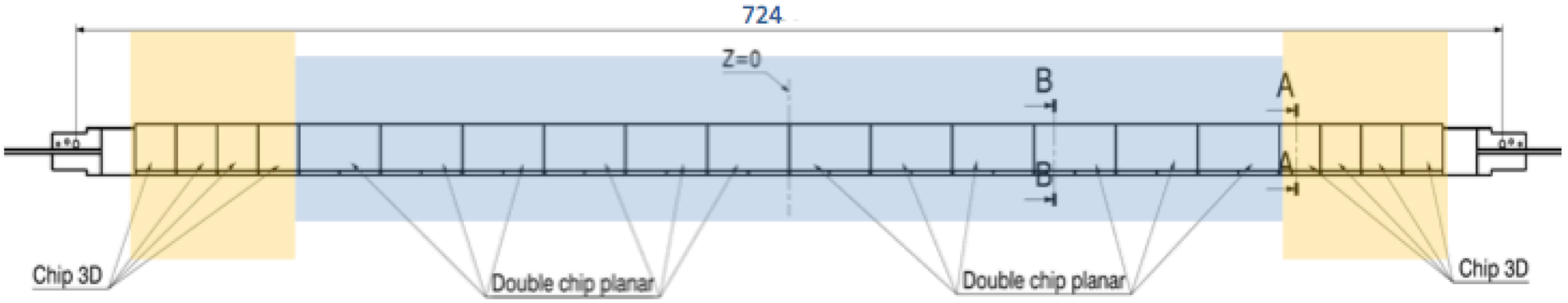
- Cooling:
  - Pixel and SCT share the same cooling system
    - Using C_3F_8
  - New technology for IBL
    - CO_2: 2 cooling plants running in parallel



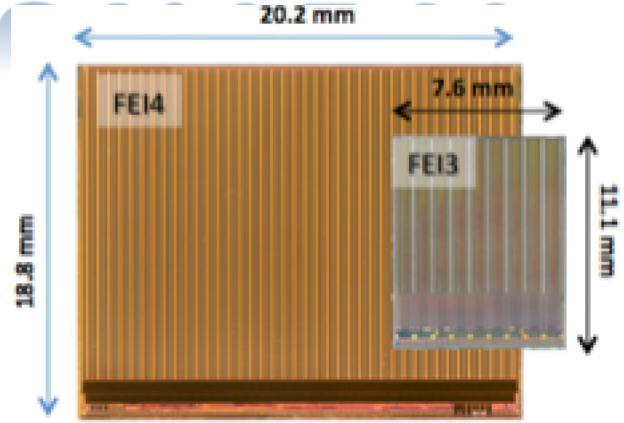
SENSORS

2 sensor technologies used: planar and 3D at high |η|

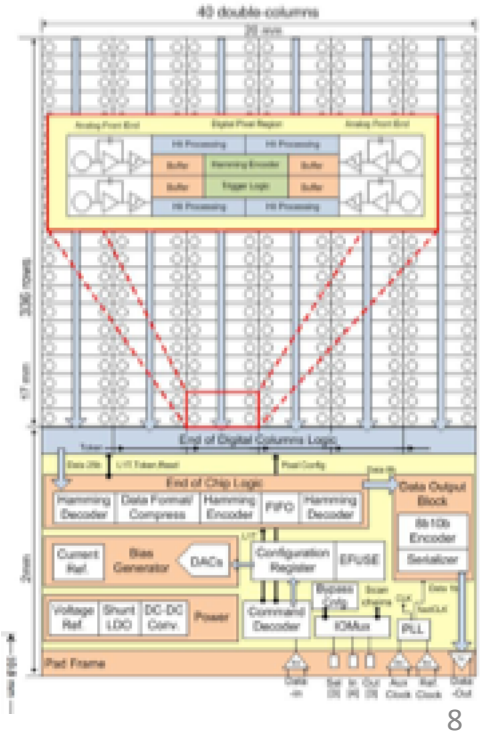
	Planar	3D
Technology	n in n	n in p
Depletion voltage before irradiation	80V	20V
Chip module	Double (1sensor→2FEs)	Single (1sensor→1FE)
Thickness	200µm	230µm



FRONT-END READOUT: FE-I4

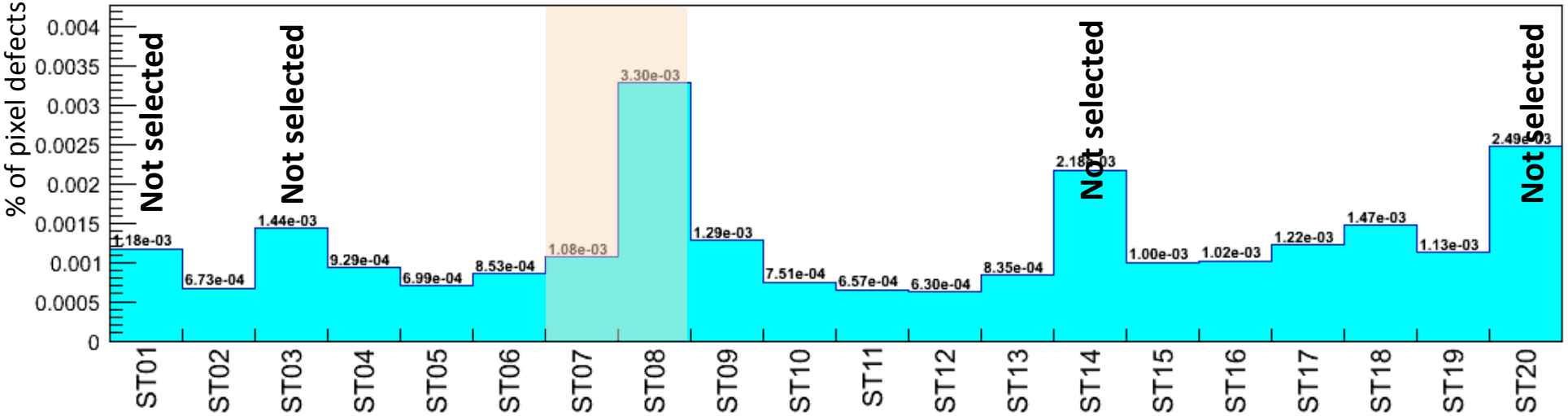


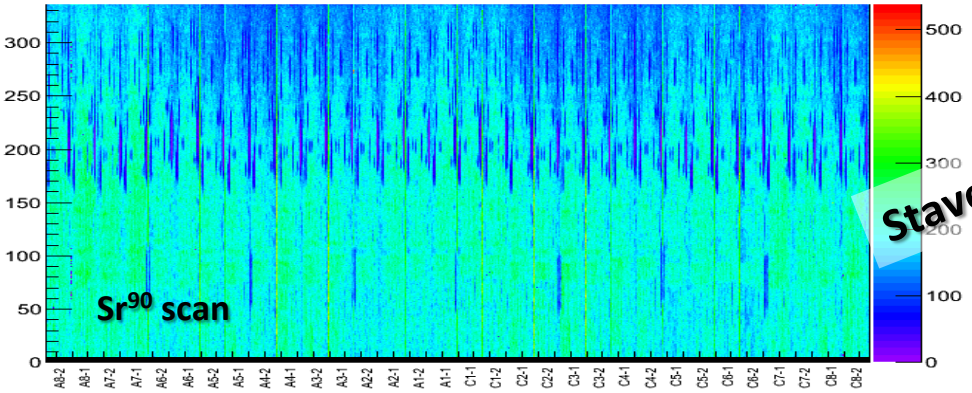
- Chip size: ~2x2cm^2
- Array size: 80 colx336 rows
- 26880 pixels/chip
- Column drain architecture with local hit storage (4 pixel region) → supports higher occupancies without saturation
- Readout speed: 160Mb/s
- Compared to present Pixel Detector:
  - Lower noise and threshold operation
  - Radiation hard to >250Mrad – 5x more radiation tolerant
- FE-I4 will be a fantastic chip for evaluation of prototypes for ITK

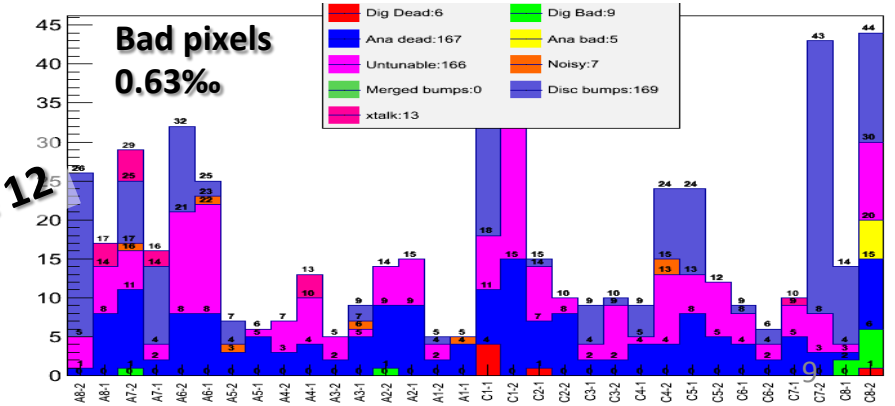


STAVES QUALITY ASSURANCE

- Dedicated setup installed at CERN in the SR1 clean room to test the staves after assembly and rank them (tuning, source scans, etc.)
- Excellent results obtained for all produced staves
- The staves installed are close or below 1‰ defect



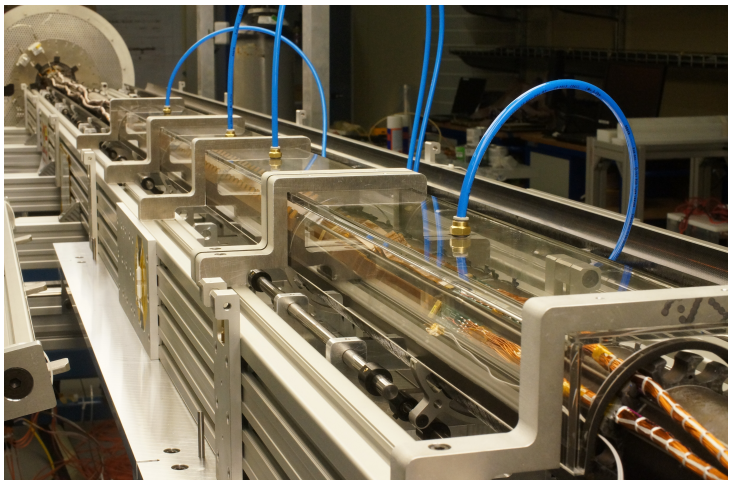




IBL: FINAL TEST

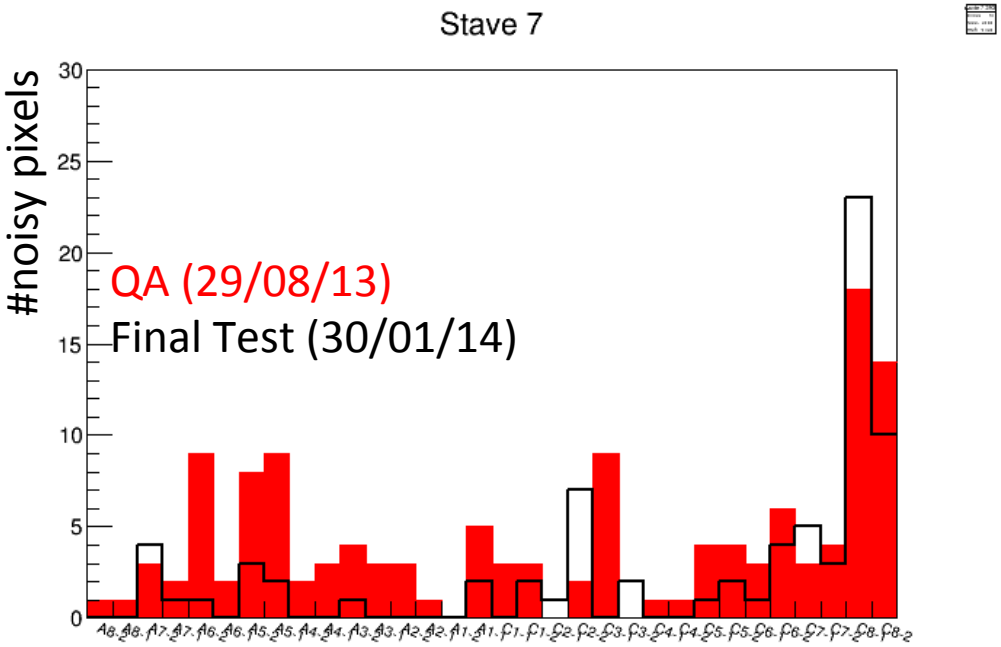
Goal: test combination of off-detector components (powering, control system, data acquisition) and on-detector components in their final configuration to validate complete functionalities – before taken to the pit

- Using 2 IBL staves (7&8) mounted temporarily on the IPT (Inner Positioning Tube)
- Setup was ready in January and operated for 2 weeks
- Used CO_2 cooling – operating conditions + 15°C – flushing dry air (2-3% relative humidity)
- Compared calibration/tuning results with results obtained during QA in Summer 2013

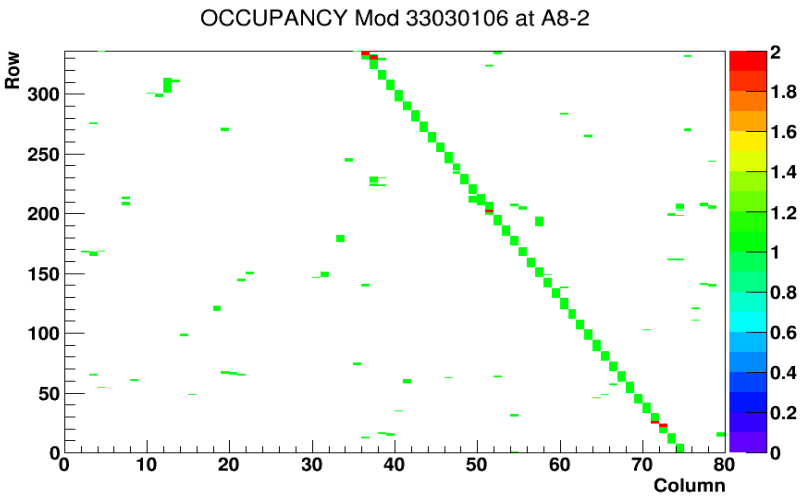


FINAL TEST OUTCOME

- Very useful and successful service testing rehearsal
- Connectivity understood and corrected on many levels (LV, HV, temp. control, etc.)
- Excellent performance obtained on working FEs: tuning down to 1500e
- No increased noise observed when running threshold scan on neighbouring stave
- First DAQ tests in close-to-real conditions

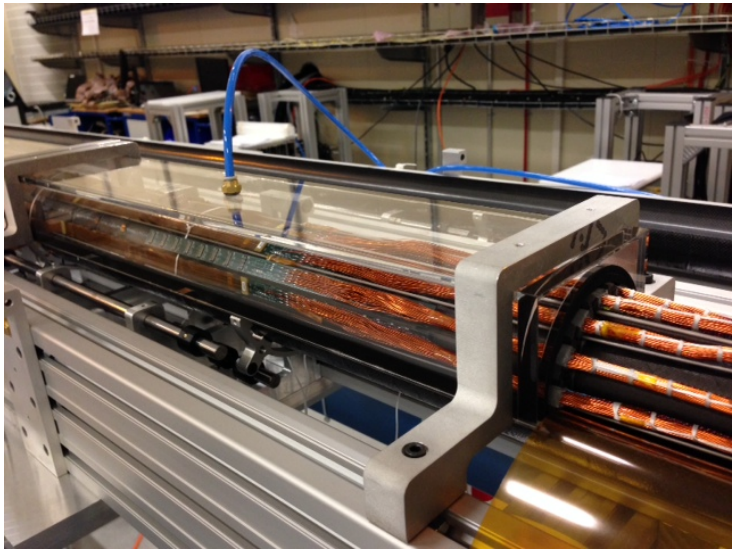


Example of a cosmic track along the entire FE (Stave 7, A8-2)



IBL ASSEMBLY

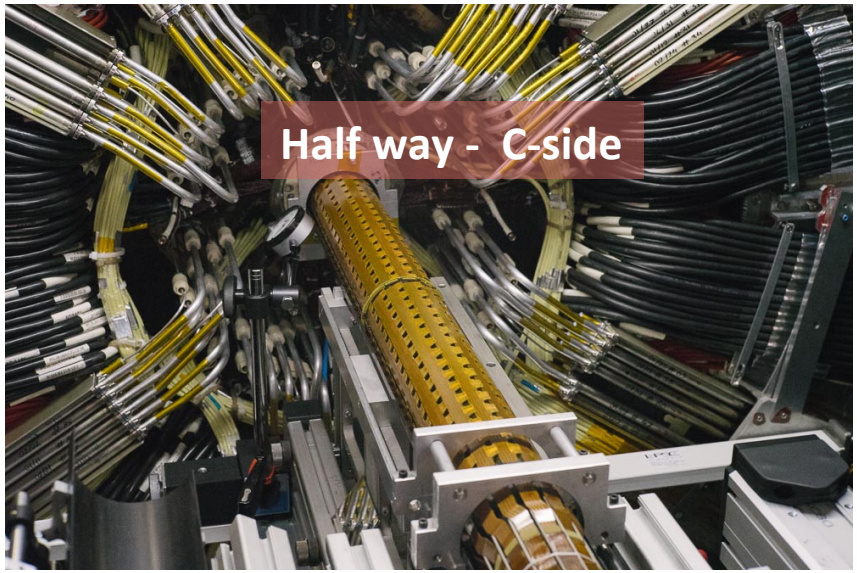
- Staves were assembled around the IPT on surface

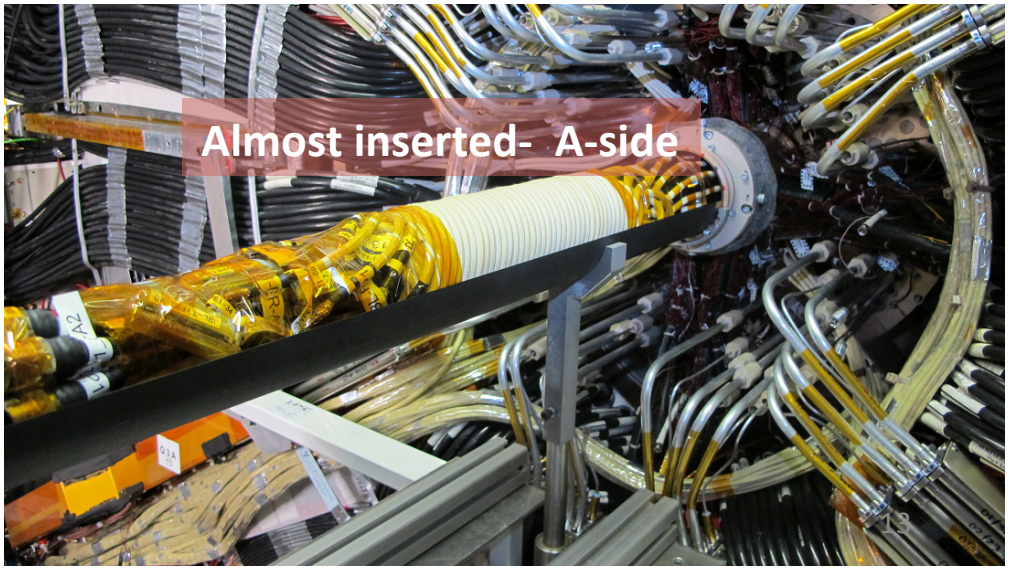


- Stave loading location optimized to have defects distributed as homogeneously as possible over the whole detector

IBL LOWERING AND INSERTION

- IBL package transported into the ATLAS cavern on the 5th of May
- Inserted inside the pixel detector on the 7th of May
- Everything went smoothly





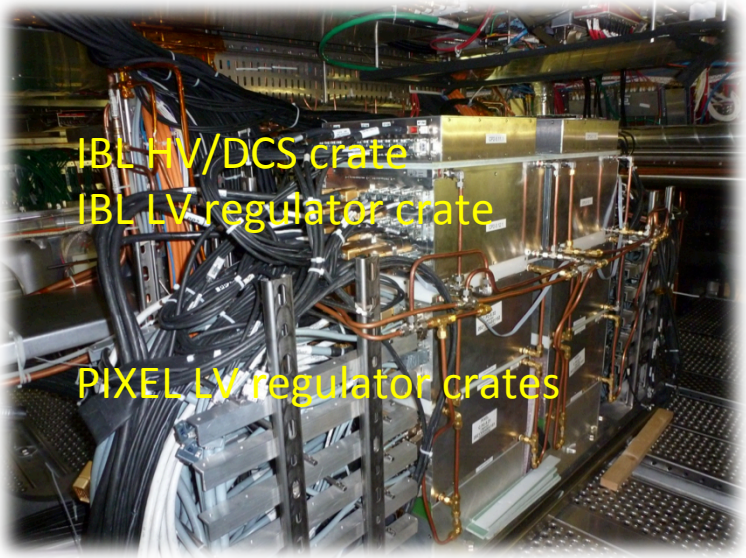
SERVICE TESTING

- Goal: test and qualify full chain of electrical services from the counting room (PP4) to the end of the IBL (PP1) and back
  - Includes:
    - Opto, LV, HV and Environment checks
    - Basic continuity and interlock checks – PP4/PP1 cross-checks
  - Doesn't include DAQ and Cooling tests
- Essential before connecting On-detector permanently to Off-detector parts

- Successfully completed on May, 19th

PP1

PP2



PP4

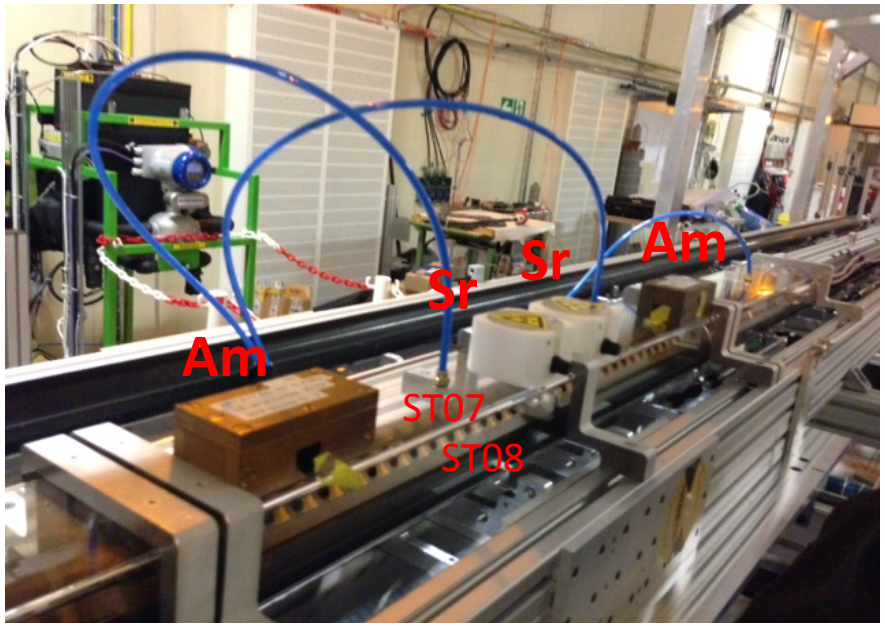
NEXT

- Detector connection in the pit: planned for this week
- Cooling service connection and final tests to be done by the middle of June
- Commissioning of the full pixel package over the summer 2014: current 3-layer Pixel Detector+IBL

CONCLUSION

- FE-I4B chip working very well
- 1st time 3D modules used for a detector
- IBL current status:
  - Staves tested, selected and installed
    - Each close or below 1‰ defect
  - On/Off-detector components compatibility successfully tested on surface
  - Detector inserted
  - Off-detector components successfully tested in the pit

BackUp

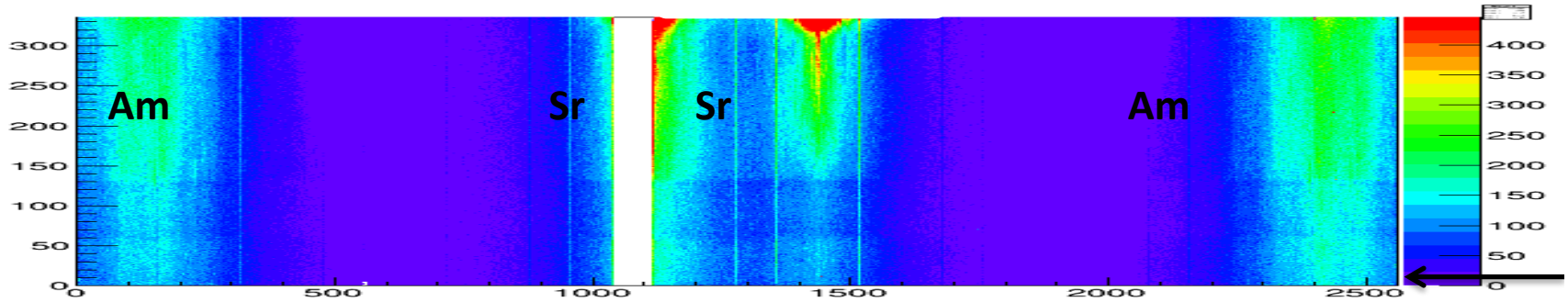


SOURCE SCAN

Am sources at end of staves
Sr sources in the middle

~1h10
1500e tuning
(additional noise masks applied)

ST07



ST08