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U.S. DEPARTMENT OF ENERGY

Integration and Environment for Upgrade Trackers in High Luminosity LHC

ECFA Conference, Aix-les-Bains, October 2014

Eric Anderssen on behalf of many

Integration and Environment

Integration can mean many things

- Systems engineering, design for assembly
- It is also implies modularity of services and how many components are assembled together

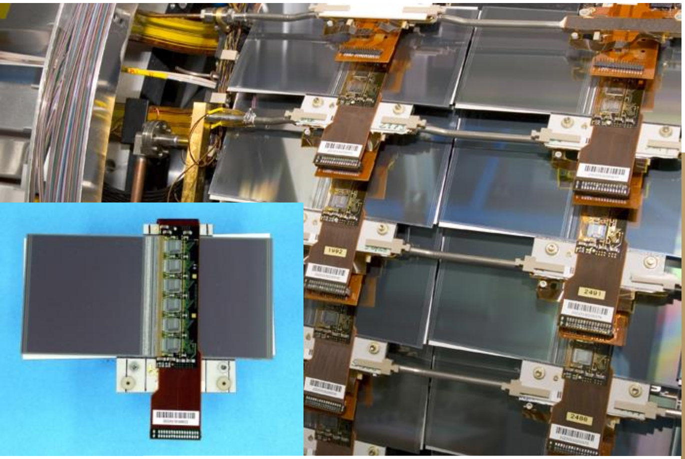
Environmental control used to mean many separate volumes within our detectors

- As our detectors become more ‘integrated’ these barriers will decrease in number or get repurposed as structure

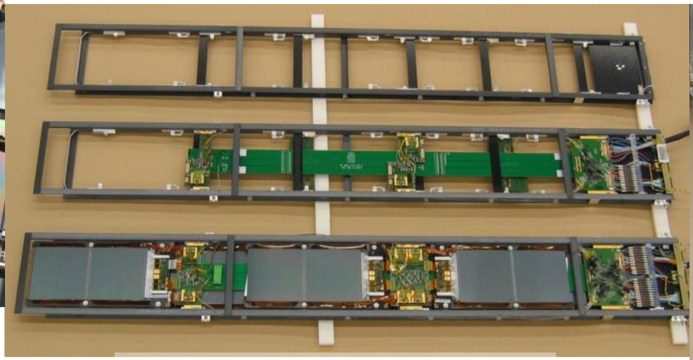
Lessons learned from current operations will be discussed

Detectors are getting larger our assembly paradigm must adapt

Increasing Integration

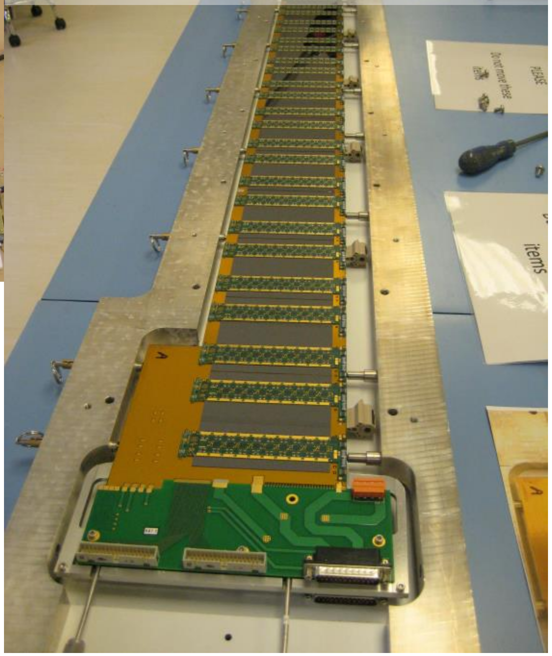


ATLAS Strips (current)



CMS Strips (current)

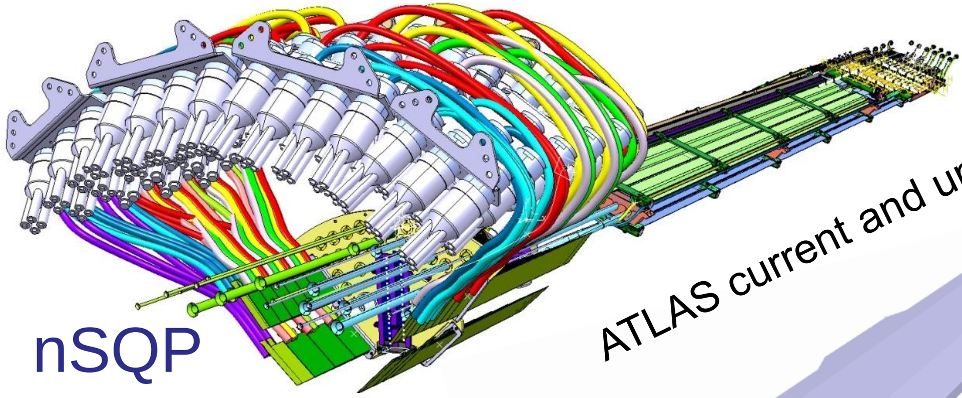
ATLAS Strips (upgrade)



Strip Stave for upgrade includes integrated cooling and electrical bus in structure

- Previous assembly was a craft-work (small parts added to a large structure)
  - Standalone electrical modules were tested then mounted and layered with services—serial
- Integrated staves push work to distributed sites where the bulk of our manpower reside
- Reduces work during final assembly

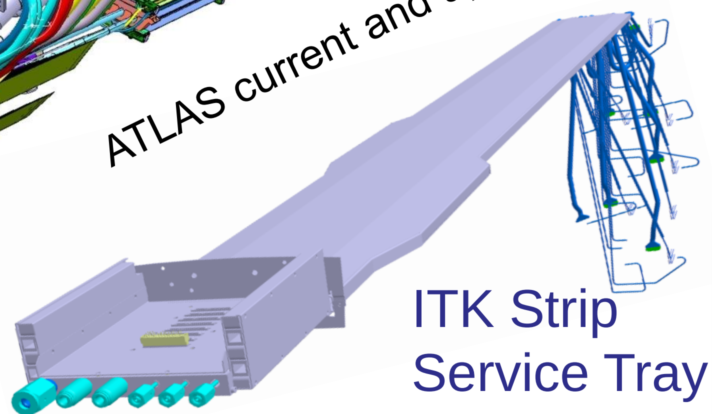
Our services should become more modular and integrated



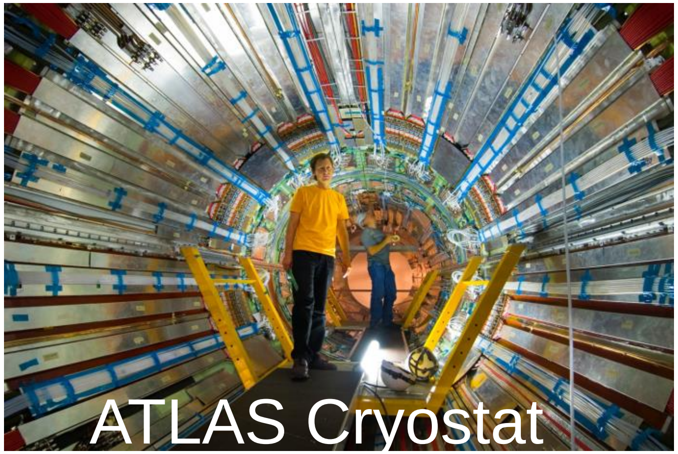
nSQP

new Service Quarter Panel—used in current ATLAS Pixel detector

ATLAS current and upgrade



ITK Strip Service Tray



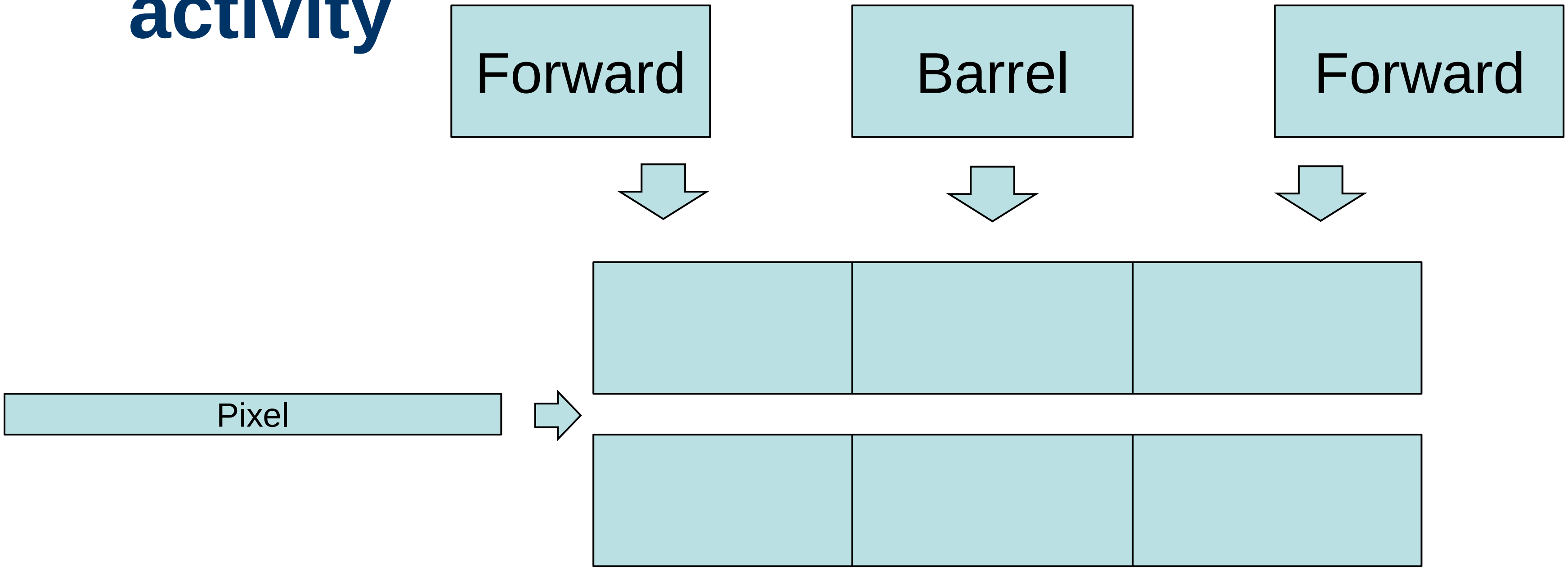
Integrated services are a necessity

- They allow for parallel and distributed assembly with only installation and connection on the final assembly

Minimizing the number of connections is also a priority

- Work in-situ will have tight limitations for our upgrades

Surface assembly is a critical path activity



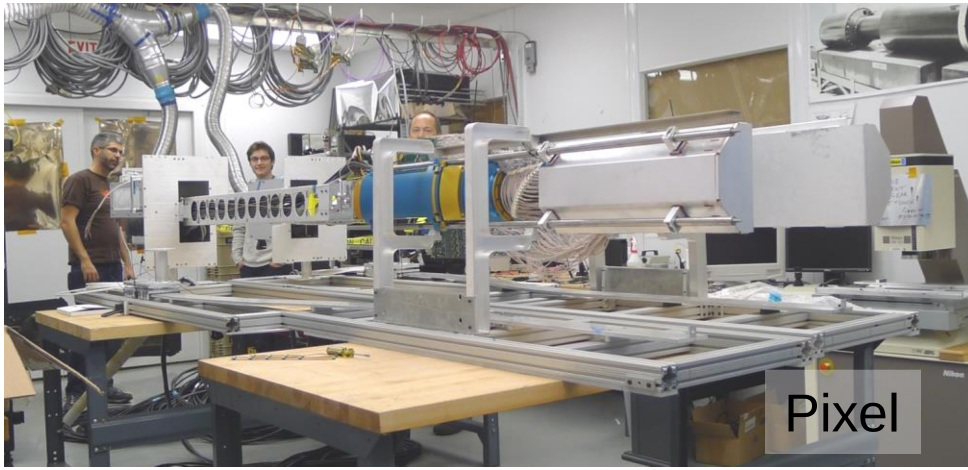
Each of the subsystems use differing technologies

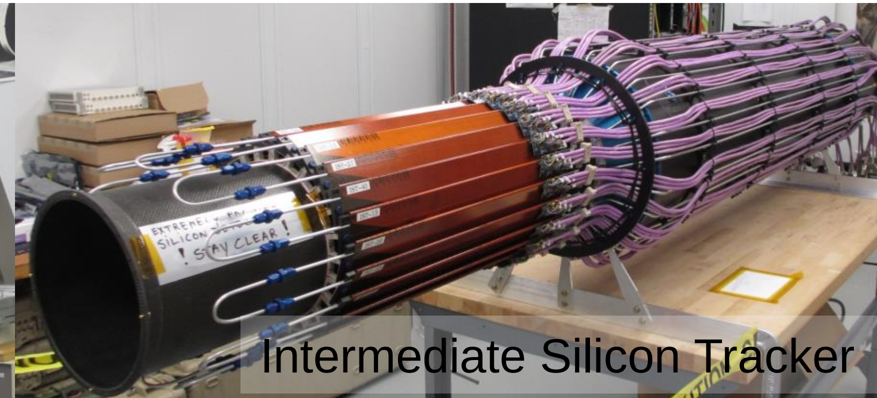
- Layout and design of the global supports should allow for independent parallel assembly of subsystems; Pixels arrive last in schedule

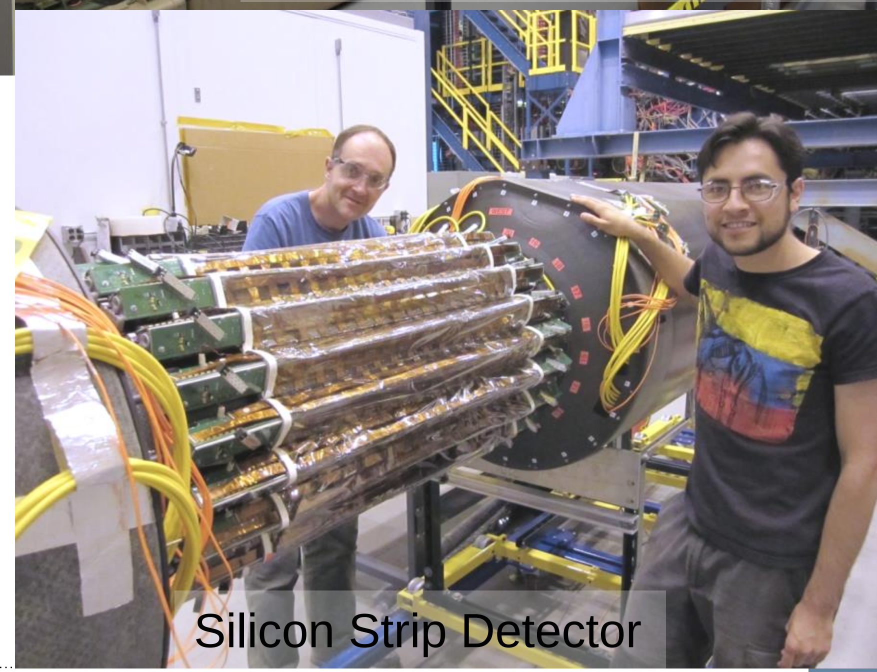
Delivery of large integrated components allows for more rapid assembly/test

- Distributing sub-assembly to offsite locations reduces impact on resource and space needs at CERN

An example from STAR HFT (Heavy Flavor Tracker)

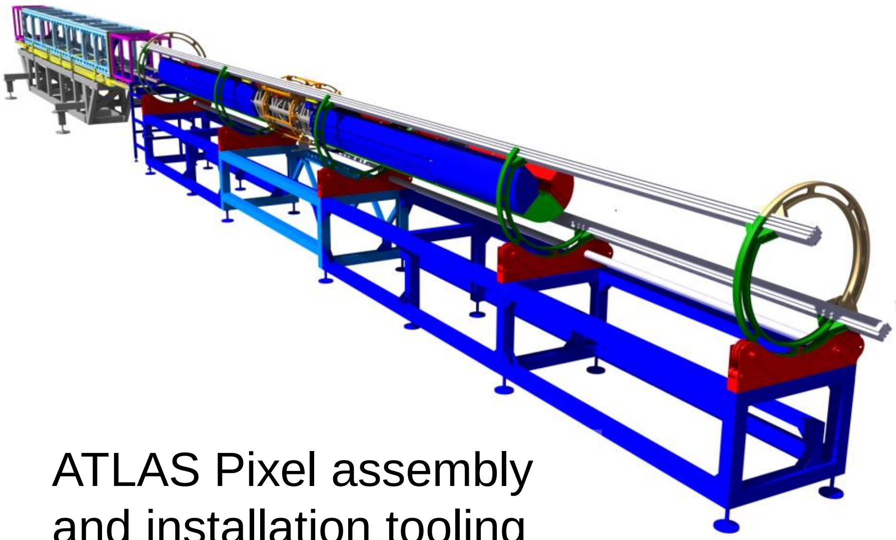




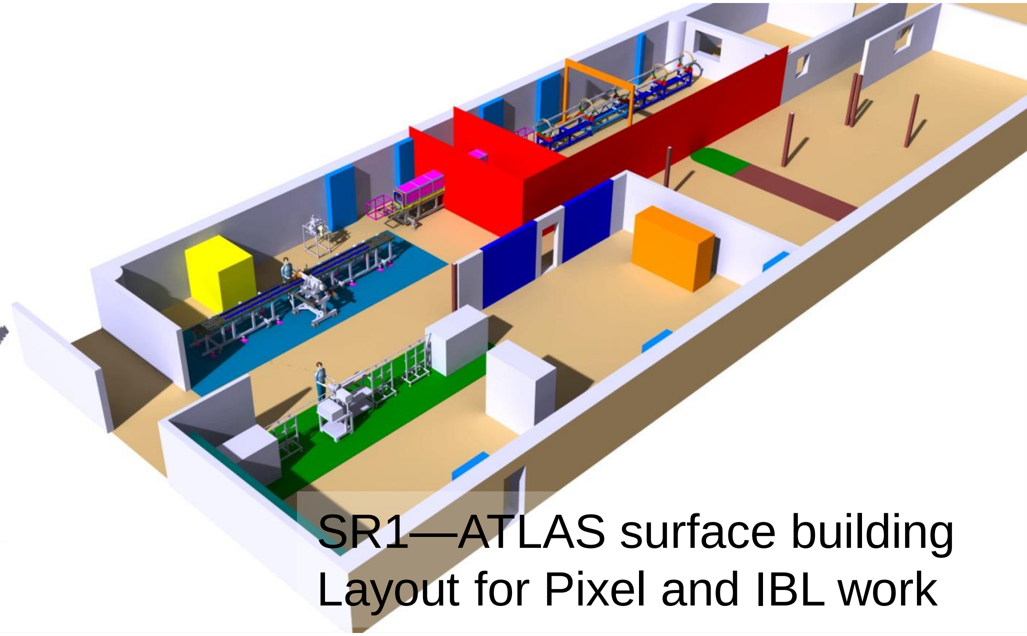


- STAR is an operating detector at RHIC—only 12wks are available to remove and replace structures between runs
- Three detectors had to be installed
  - Extra structures were produced to allow assembly while STAR was running minimizing time on Critical Path
- A similar strategy was used for nSQP (ATLAS Pixel refurbishment in LS1)

Assembly of large systems in parallel on the surface



ATLAS Pixel assembly and installation tooling

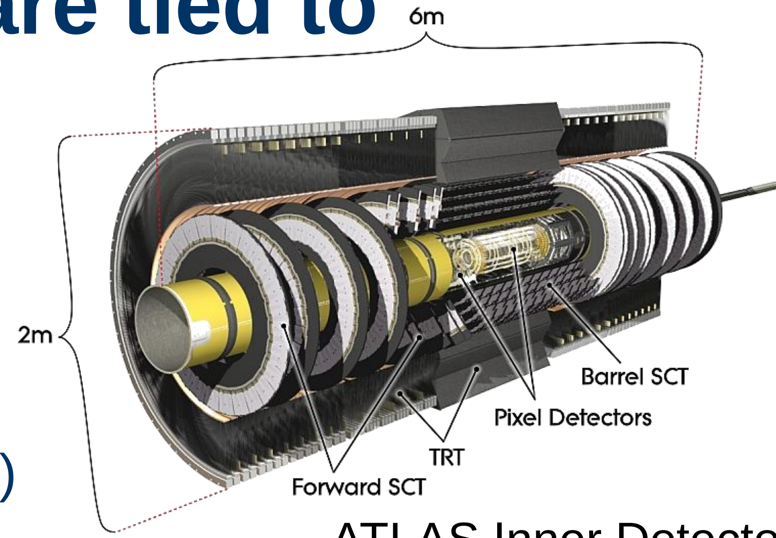


SR1—ATLAS surface building Layout for Pixel and IBL work

- Space may limit how much can be done in parallel
  - Natural phasing of Pixels relative to Strips may alleviate this
- Assembly kinematics can help to alleviate this within limits
- Detailed space planning should be included early in the planning process

Assembly kinematics are tied to Environmental control

- Currently ATLAS ID has 8 separate environmental volumes CMS has 1
  - The TRT and SCT operate at separate temperatures (2-Forwards and 1 Barrel)
  - The Pixel system and IBL are separate
- This is due to ATLAS being installed as 5 separate units in the pit
  - Barrel, 2 Forwards, Pixel and IBL
- This made some sense i.e. units could be tested stand-alone etc…
- This won't work in the future…

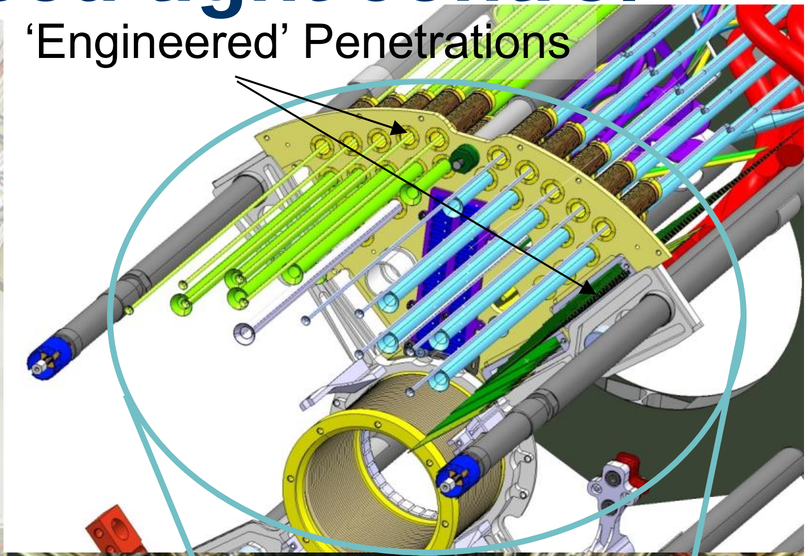


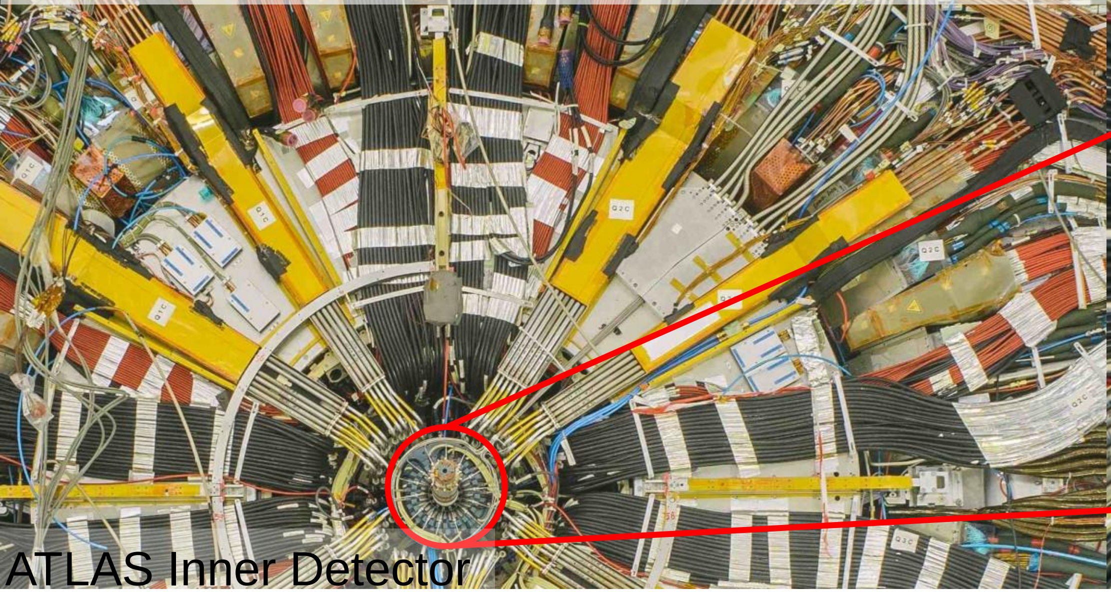
ATLAS Inner Detector

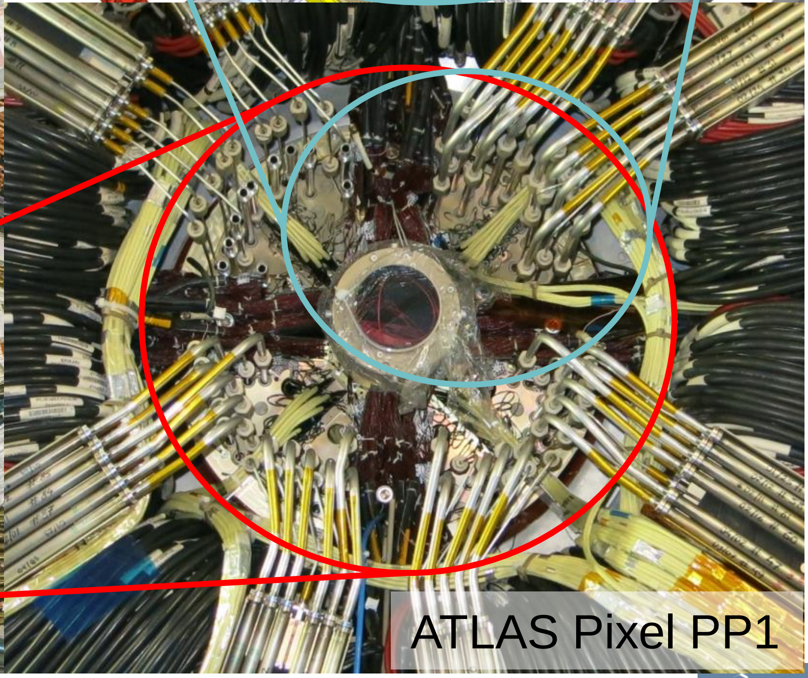
CMS Tracker installation

Service penetrations need tight control

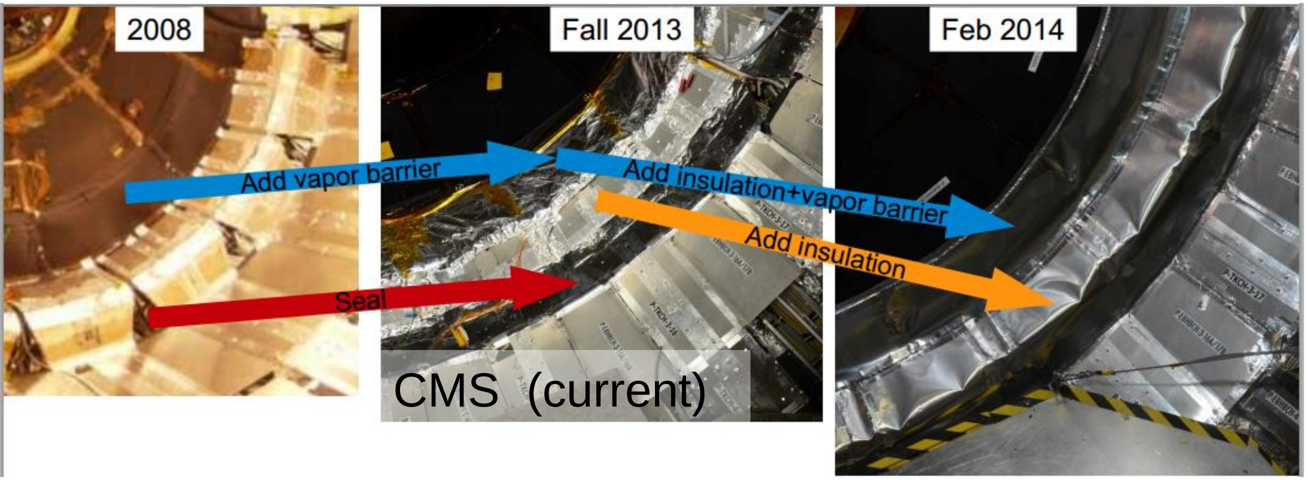
- ATLAS has an auxiliary environmental volume—the ID End Plate
- Services first penetrate their respective volumes, then the IDEP at large radius
- ATLAS Pixel example shown right, all Inner Detector services shown left
- Heaters in IDEP raised cooling exhaust temp above dew point before leaving

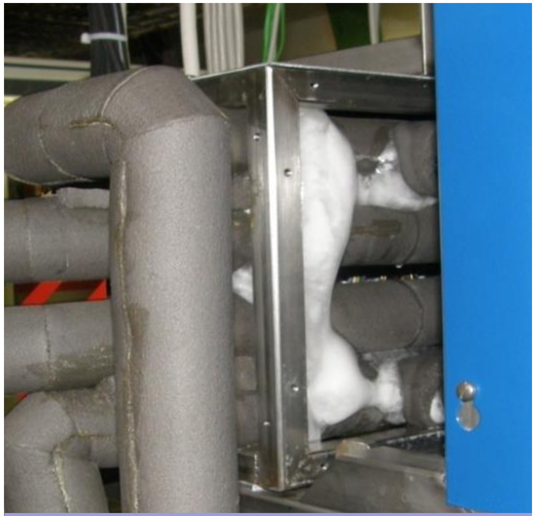






Environmental control also includes external service volumes




LHCb-Velo system


CMS Tracker system

- ATLAS did relatively well in this regard with 'engineered' solutions for all penetrations
  - ATLAS environment did leak, despite attentive design effort, N2/Dry Air flush was sufficient
- Reliance on insulation that is applied afterward (armaflex) should be avoided in the future
- A reduction of the number of penetrations by increasing modularity will help this problem

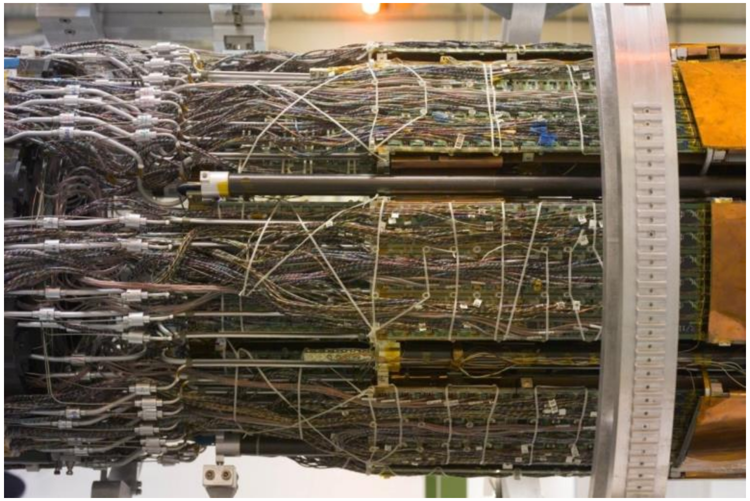
Increased Integration does increase risk, but also benefits

Risk aversion guided many design decisions in the first detectors

Stand-alone, versus bussed modules, can be individually replaced if they fail

Individually powered modules can have their voltages adjusted

Minimal modularity reduces the number of modules on a cooling circuit



ATLAS Pixel has 1 connector per module at PP0—must vastly reduce this for upgrade

All of these choices increase work; service connections and penetrations, and arguably reduce reliability

Engineers have tools and methods for minimizing risk, chief among them is quality control

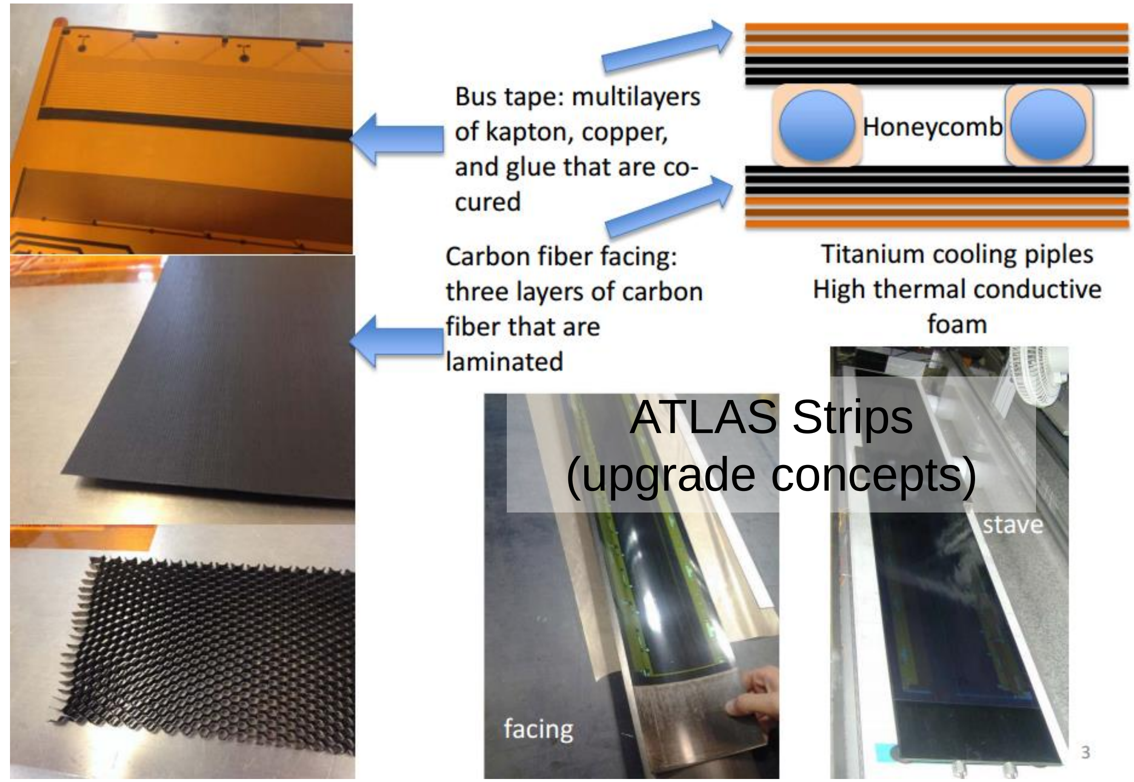
A standard method of risk mitigation is to start early and develop procedures and QC with a robust R&D effort—this has begun

Quality Control is a chief component of Integration

Flex Circuit
Co-cured with laminate

Cores bonded to facings and machined

Stave bonded together



Highly modular staves carry risk--must fully qualify at each stage of assembly

- Damage during fab/assy/handling, or faulty components (flex-circuit, tubes)

Similar methodology used in module fabrication (Known Good Die)

Outcome is Known Good Stave as input to module assembly process

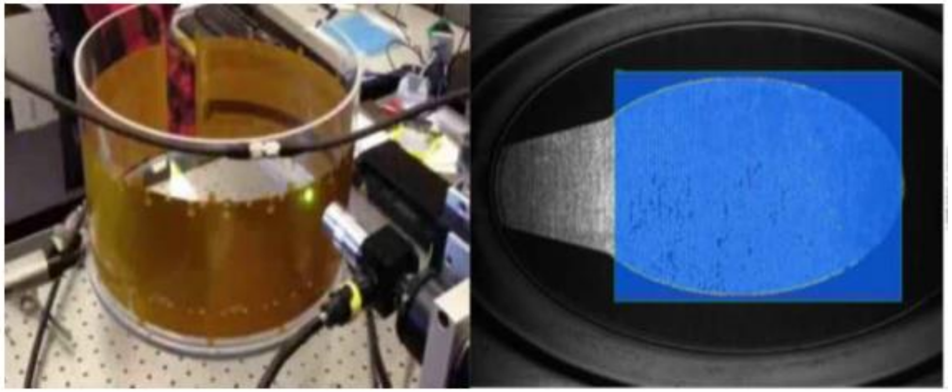
Develop new metrology and evaluation tools and techniques

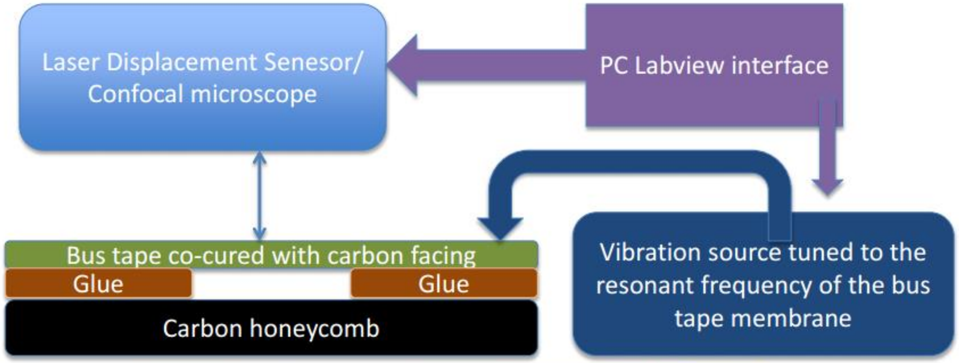
Developed in concert with fabrication processes

New tools to measure part and assembly quality in preparation for automated wire bonding

Geometry of large flex-circuits can vary batch-wise

Disbond, voids or damage in bonded assembly of staves

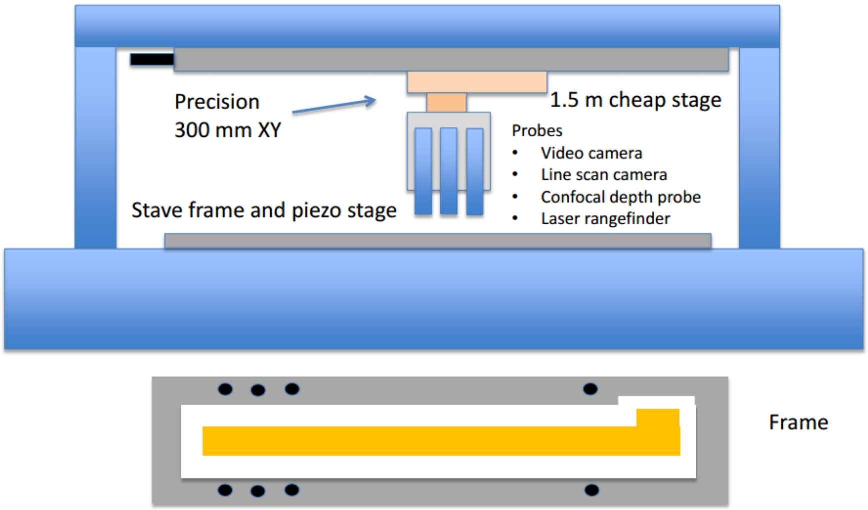




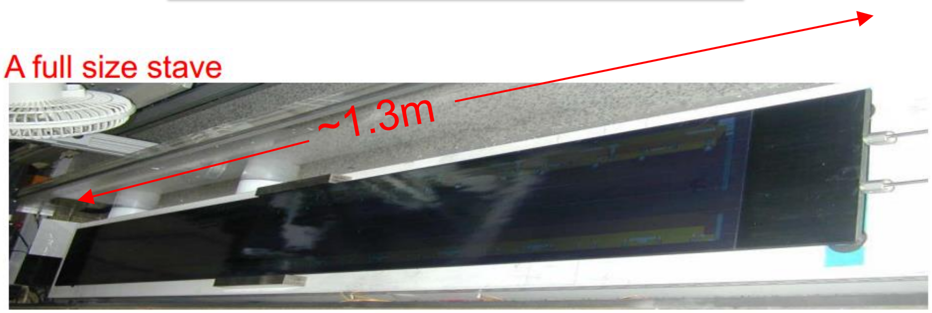
Quality Assurance tools progress with R&D of structures

Design of Large Inspection Station

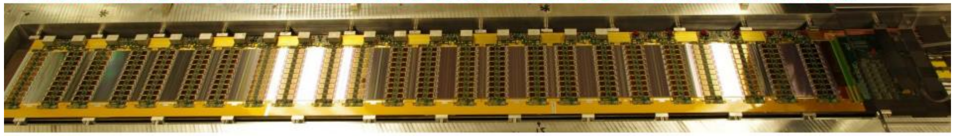
- Qualification of sub-scale prototypes indicates what problems to look for
- Scaling to full size structural prototypes also requires scale up of QC infrastructure and capability
- Order of 1000 fully qualified structures will be required
- Automation of the QC processes will be required



A full size stave



A full size stave with modules and EOS electronics mounted



Conclusion

All of the current LHC detectors were designed and built by independent teams who now have great experience

We now have several years experience operating these detectors after building and installing them

Some of the perceived risks proved irrelevant, and new ones have been identified

- Increased modularity is required to reduce service connections and penetrations of operational environments
- Increased Integration is a necessity going forward with these new detectors to facilitate fabrication and global assembly
- Quality Control should be tightly integrated with design of the new structures