LHCC Poster Session - CERN, 23 March 2011

ATLAS Upgrade Plans

ATLAS and the LHC High-Luminosity Challenges

ATLAS Physics Goals

Many Physics analysis will benefit from increased statistics

Electroweak Symmetry Breaking / Higgs

If the Higgs is found at the LHC, what kind of Higgs?

→ Measurement of Higgs couplings to fermions and bosons

→ Higgs self-couplings

Triple gauge boson couplings

What if there is no light Higgs boson?

Strongly coupled Vector Boson system $W_L Z_L \rightarrow W_L Z_L$

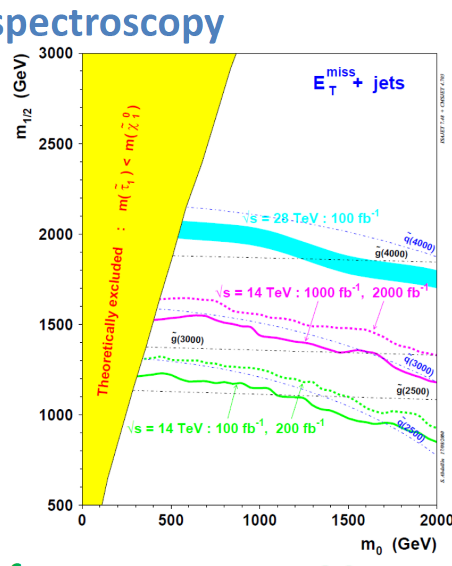
Supersymmetry

Extend discovery reach (if not found) or spectroscopy

Extra dimensions

New forces

W',Z' gauge bosons



Exciting Physics requiring to maintain detector performance over >20 years!

Expected Detector Performance

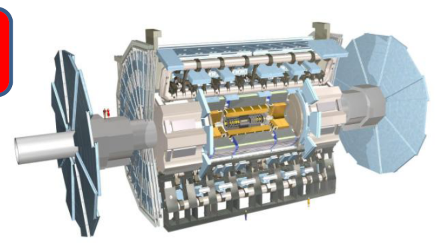
Physics potential relies on crucial detector abilities:

Tracking and *b*-jet tagging | **Electron & Muon Identification** | **Forward-jet tagging and central-jet veto**

LHC luminosity upgrades will have 2 major effects degrading performance:

Higher detector occupancies

Detectors at low radii and large η most affected: *Inner Detector, forward calorimeter and forward muon wheels*



Harsher radiation environment

Barrel calorimeters and muon chambers largely untouched

Lots of solutions are being developed:
- higher granularity detectors
- higher readout bandwidth
- increased radiation-hardness
- reduced material ...

Main motivations for upgrades:
- Improvement of detectors with new technology
- Replacement of damaged components
- New detectors able to live in SLHC conditions !

Major coming upgrade will be the insertion of a new pixel detection layer (IBL)

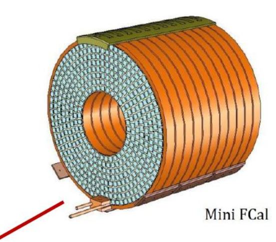
Timeline

Run 1 - 7TeV	Phase-0 Upgrade	Run 2 - 14 TeV	Phase-I Upgrade	Run 3 - 14TeV	Phase-II Upgrade	Run 4 - SLHC
2013	>15 months	2017	2018	2021	2022-3	2031?
Luminosity: $\sim 10^{33} cm^{-2}.s^{-1}$, 2-3fb^{-1}		$10^{34} cm^{-2}.s^{-1}$, ~50-100fb^{-1}		$2.10^{34} cm^{-2}.s^{-1}$, ~300fb^{-1}		$5.10^{34} cm^{-2}.s^{-1}$, >3000fb^{-1}
Average # of Pile-up interactions: ~5		~25		~50		>200

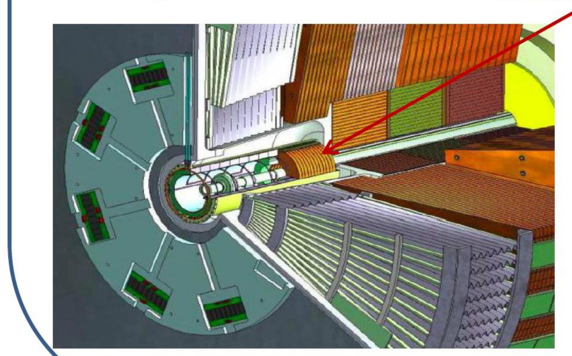
Experimental Challenges

Phase I — Calorimeters

- Improving e/γ triggering will require full granularity readout of the calorimeter and improved resolution
  → Electronics has to be upgraded
- Forward Calorimeter:
  Extending to η=4.9, this detector will see very intense particle fluxes, causing:
  - Charge build-up in LAr gaps, reducing charge collection
  - Voltage drop across HV resistors
  - + LAr could boil from beam heating!



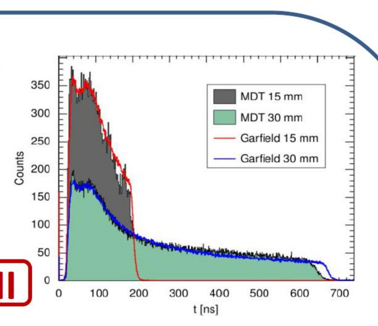
Mini FCal



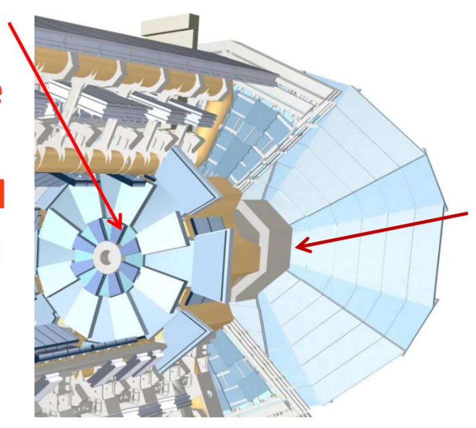
→Investigating a mini 'warm' calorimeter that would absorb the e.m. jet component, halving the energy deposit in the FCAL
- with radiation-hard electronics
- and smaller gaps (250μm → 100μm)

Phase I — Muon Systems

- Replace Cathode Strip Chambers (CSC) with new technology:
  →Smaller diameter drift tubes, high-rate TGCs, or micromegas?



Could secure tracking at high rate and improve the trigger



Phase II Forward region has to be upgraded due to increased occupancy
→ Replacement of Monitored Drift Tubes with tubes radius reduced from 30mm to 15mm (much shorter drift time)

- Bring Muon Drift Tubes trigger at L1

+ Addition of forward shieldings

Phase I — Trigger/ DAQ

- Topological trigger = ability to look at 2 or more trigger objects at L1
- Hardware-based fast track-finder to provide helix parameters to L2

Phase II At SLHC, challenge is to reject 5x as many events 5x bigger
→ More triggers, longer L1 latency
→ Increased data storage and bandwidth

Inner Detector Cooling

- SCT cooling suffers from pressure drops
  + Reliability issue of compressors

Phase 0 → Installation of a thermo-siphon system allowing gravity injection
→ use of C_3F_8/C_2F_6 mixture for SCT and Pixels cooling

2kW thermo-siphon demonstrator already installed in the ATLAS Pit

Beam Pipe

Phase 0 Current BP
- produces high backgrounds (n, γ) in the muon systems
- becomes radioactive

⇒ Replacement by an aluminum one (10-20% background reduction)

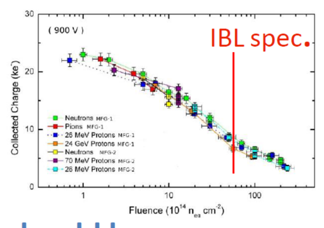
Phase II All-beryllium BP! (background ÷2)

Sensor

How to maintain very high hit efficiencies with high accumulated radiation dose?

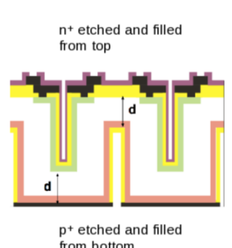
2 technologies under study:

Planar: + very well-known, high yield
− suffers from charge recombination with increasing fluence (sensor thickness ~200μm)



But should be overcome with sufficient bias voltage

3D sensor: Charge carriers collected 'horizontally' on a shorter distance
+ • Large signal even after irradiation
• lower bias voltage
• smaller width of inactive edges
− Manufacturing yield and uniformity are uncertain

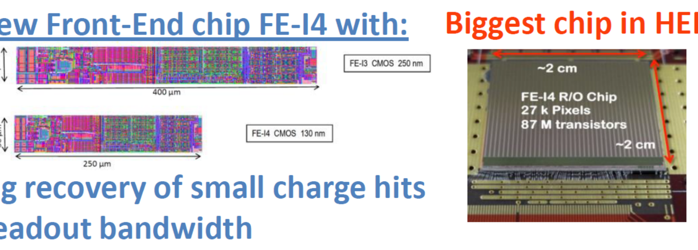


⇒ Critical factor will be the electrical performance with electronics

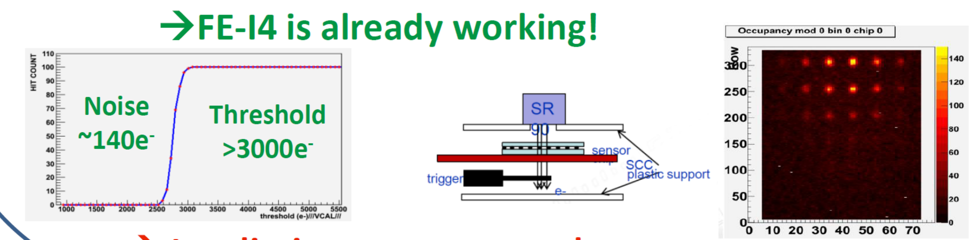
Electronics

How to face increased occupancies and resist to radiation?

Development of a new Front-End chip FE-I4 with: Biggest chip in HEP!
- smaller pixel size
- CMOS 130nm
- local memory inside pixels allowing recovery of small charge hits
→ Big increase of readout bandwidth
- radiation-hard electronic design (*i.e.* Singe-Event-Upset tolerant latches)



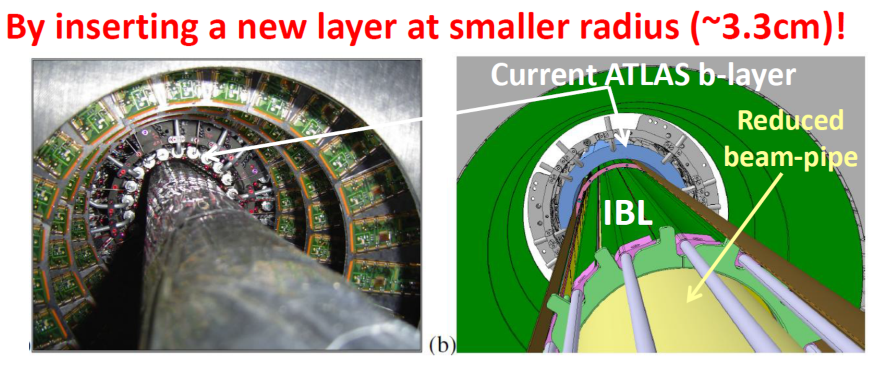
→FE-I4 is already working!



→ Irradiations tests are underway

Phase 0 — Insertable B-Layer (IBL)

Why IBL?
→Increase ATLAS Physics reach
→Compensate for defects in existing *b*-layer
By inserting a new layer at smaller radius (~3.3cm)!



Benefits: → Better resolution on the impact parameter of tracks
→ Improvement of the reconstruction of vertices in the event

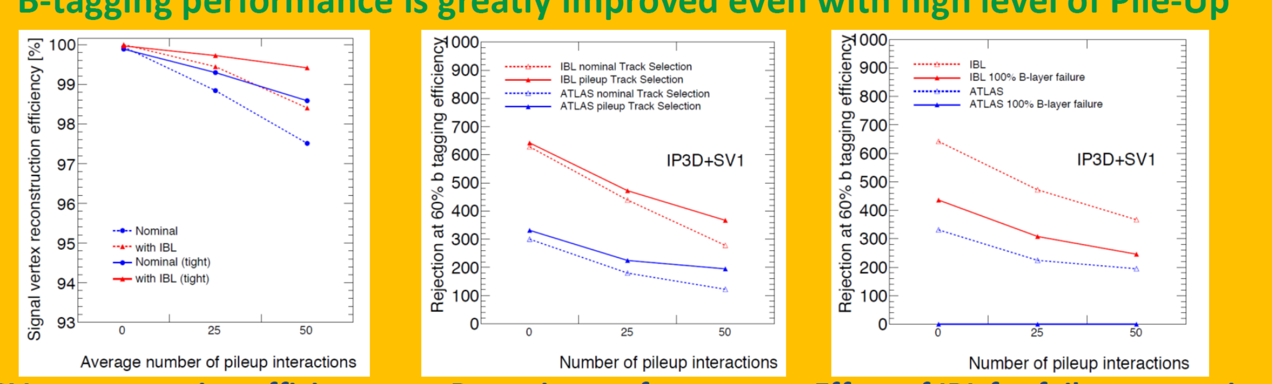
IBL challenges:

Much higher particle fluxes 1/R²
→ Radiation, occupancies, 2-track separation issues in dense jets

Increased amount of material
→ Impact of nuclear interactions and multiple scattering

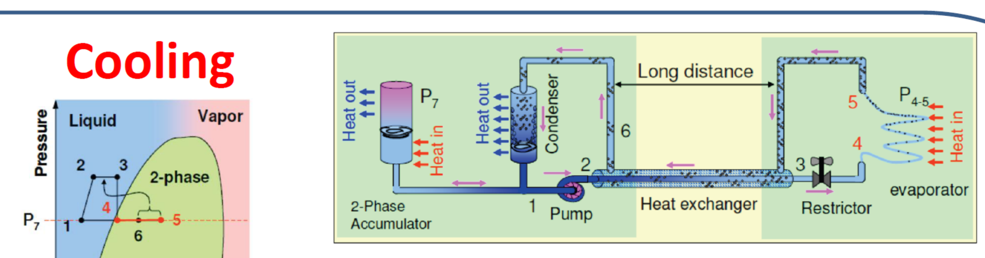
Impact on Physics

B-tagging performance is greatly improved even with high level of Pile-Up



PV reconstruction efficiency | B-tagging performance | Effect of IBL for failure scenario

Cooling

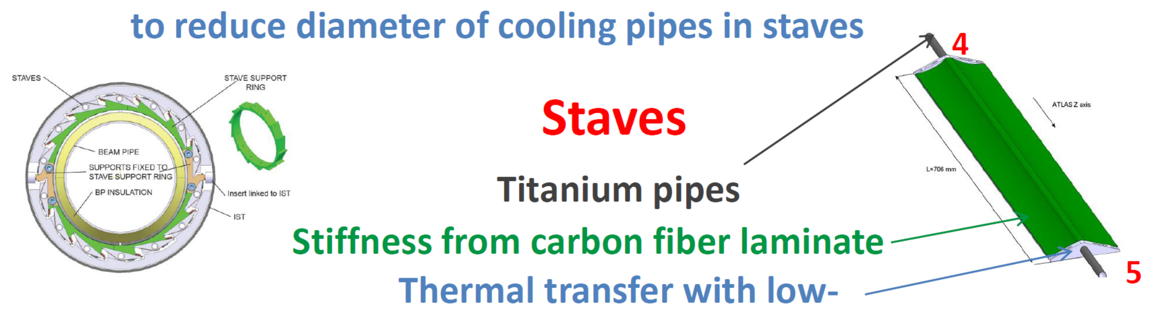


2-phase Accumulator Controlled Loop

CO2 cooling: CO2 has a high volumetric cooling capacity and would allow to reduce diameter of cooling pipes in staves

How to reduce material?

Staves

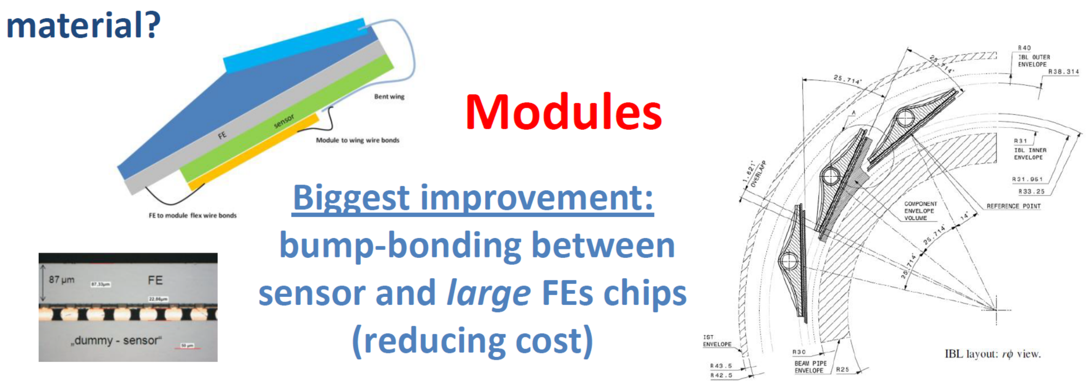


Titanium pipes

Stiffness from carbon fiber laminate

Thermal transfer with low-density carbon foam material

Modules



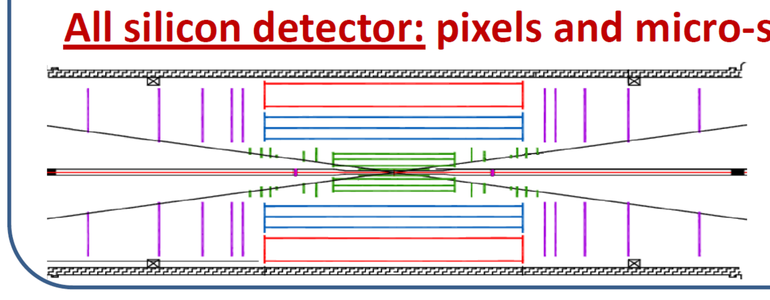
Biggest improvement: bump-bonding between sensor and *large* FEs chips (reducing cost)

Installation

2 options:
- original plan was to *insert* IBL during Phase-I on-detector
- Installation for Phase-0 is very challenging, and might take advantage of the possible replacement of pixel service quarter panels (nSQP) *on the surface*

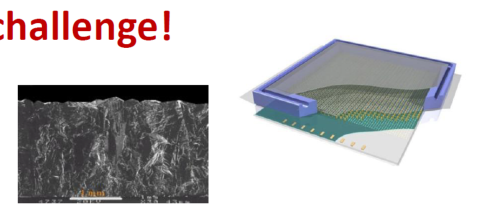
Phase II — New Inner Tracker !

All silicon detector: pixels and micro-strips

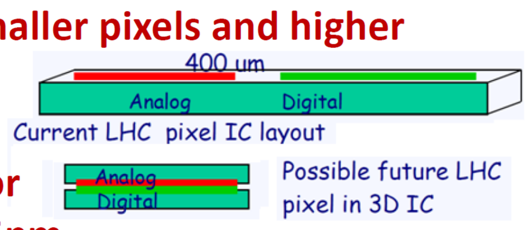


~400M pixels
~45M strips!
9 layers

Pixel sensors: After 3000fb^{-1} collected, maintaining efficient charge collection is a real challenge!
→ P-type, 3D silicon
→ Diamond,
→ Gossip



Electronics:
- FE-I4 can be used for outer layers
- B-layer will need smaller pixels and higher bandwidth
→investigating 3D electronics, and/or CMOS technology 65nm



Current LHC pixel IC layout | Possible future LHC pixel in 3D IC

Services: Multiplexing, Bi-phase CO2 or fluorocarbons cooling

Staves: New materials for lightweight stable mechanics, with good thermal conduction

Nicolas Bousson, for the ATLAS Collaboration

ATLAS EXPERIMENT