ATLAS Preparation for LHC Phase-1 Upgrade

Conditions

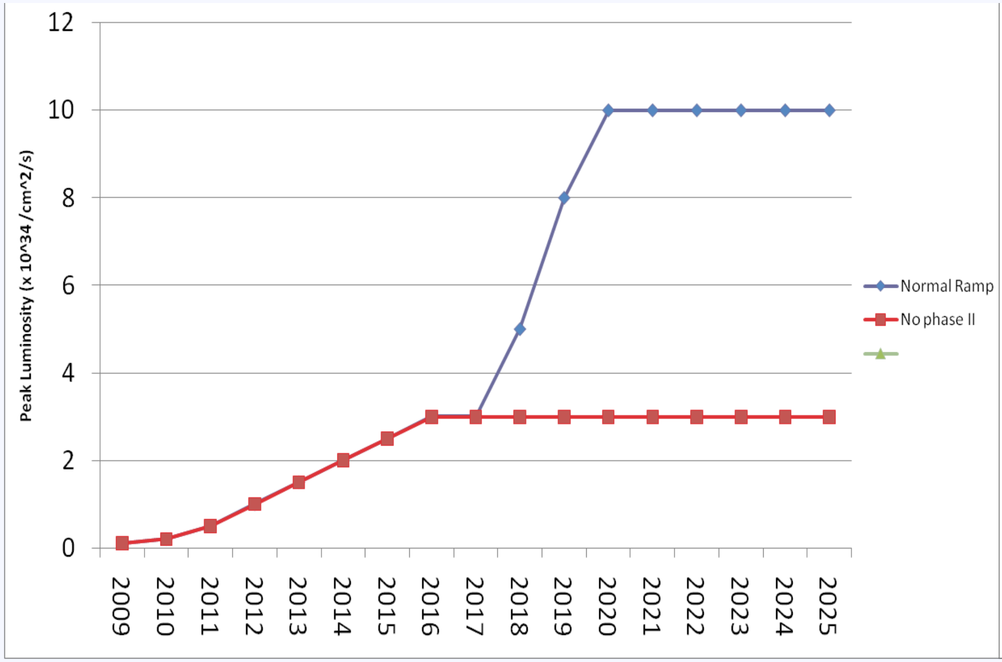
B-layer

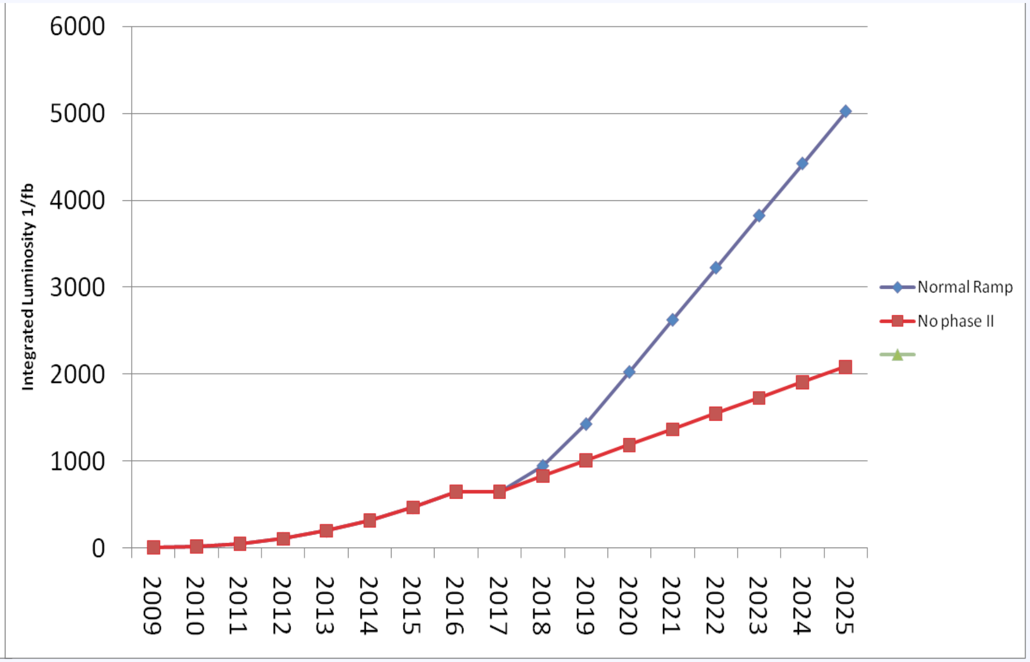
Other changes

Overview

- It was always expected to replace ATLAS B-layer before other detectors
- Life expected to be <~ 300 fb-1
- Realised during assembly that quantity and complexity of services mean any replacement is a long and delicate process
  - Longer than a standard winter shutdown (In fact more like a year)
- ATLAS set up a Task Force (“B-Layer Task Force”, BLTF) to look into options and recommend best way forward; reported at Bern ATLAS week and now to EB
  - Will cover this here
- Since Phase-1 plans unveiled and LHCC agreement on beam conditions we are beginning a review of all detector systems
  - evaluate performance in all expected conditions and decide on changes needed; status so far covered here
- ATLAS planned for 2e34 and 700 fb-1
  - Phase-1 is 50 % increase on peak rate and no change integral
    - don't expect major changes to be needed
  - But some items need improvement anyway, will also cover these where known

Conditions for Phase-1





- From LHCC/LHC/Atlas/CMS agreement (Garoby talk):
  - Peak luminosity rising to $3x10^{34}$ cm^{-2} s^{-1} for a year or two
    - This is slightly higher than “Ultimate” and 50 % higher than the $2x10^{34}$ that many systems worked to
  - Integrated luminosity ~100 fb^{-1} at 6-8 month shutdown end 2012
  - Further ~550 fb^{-1} to end 2016 and long shutdown for Phase-2
    - Total ~650 fb^{-1} is roughly what was designed for e.g. 730 fb^{-1} for SCT)

Basic expectations

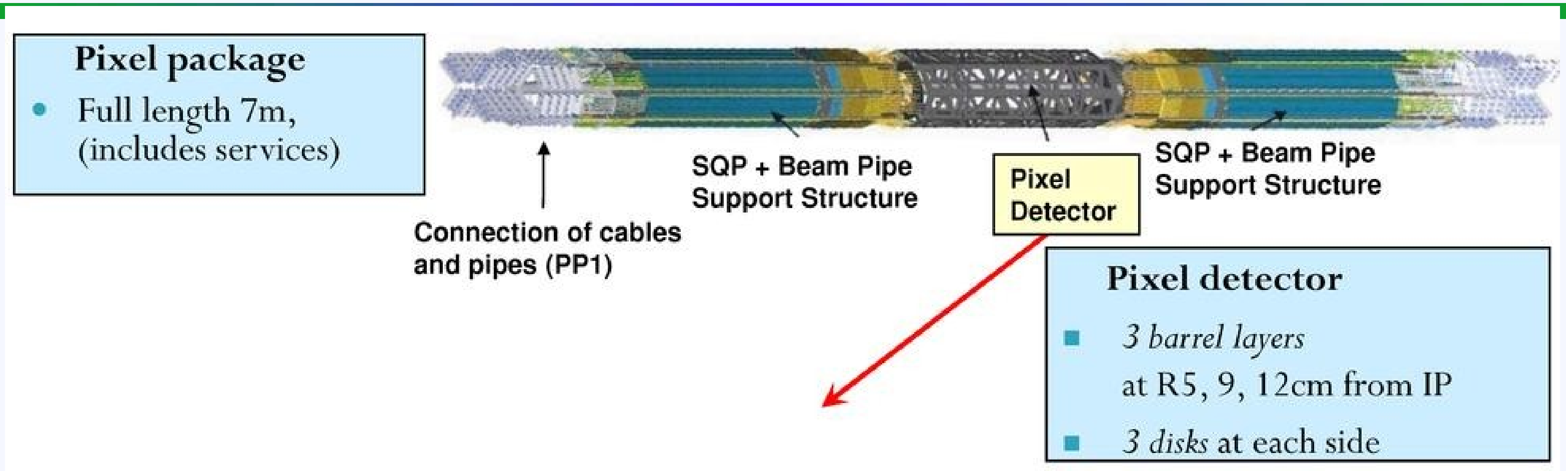
Year	Normal Ramp: Peak Lumi (x 10^{34})	Normal Ramp: Annual Integrated (fb^{-1})	Normal Ramp: Total Integrated (fb^{-1})	No phase II: Peak Lumi (x 10^{34})	No phase II: Annual Integrated (fb^{-1})	No phase II: Total Integrated (fb^{-1})
2009	0.1	6	6	0.1	6	6
2010	0.2	12	18	0.2	12	18
2011	0.5	30	48	0.5	30	48
2012	1	60	108	1	60	108
2013	1.5	90	198	1.5	90	198
2014	2	120	318	2	120	318
2015	2.5	150	468	2.5	150	468
2016	3	180	648	3	180	648
2017	3	0	648	3	0	648
2018	5	300	948	3	180	828
2019	8	420	1428	3	180	1008
2020	10	540	2028	3	180	1188
2021	10	600	2628	3	180	1368
2022	10	600	3228	3	180	1548
2023	10	600	3828	3	180	1728
2024	10	600	4428	3	180	1908
2025	10	600	5028	3	180	2088

Collimation phase 2 (2011)

Linac4 + IR upgrade phase 1 (2013)

New injectors + IR upgrade phase 2 (2018)

ATLAS B-layer Plans

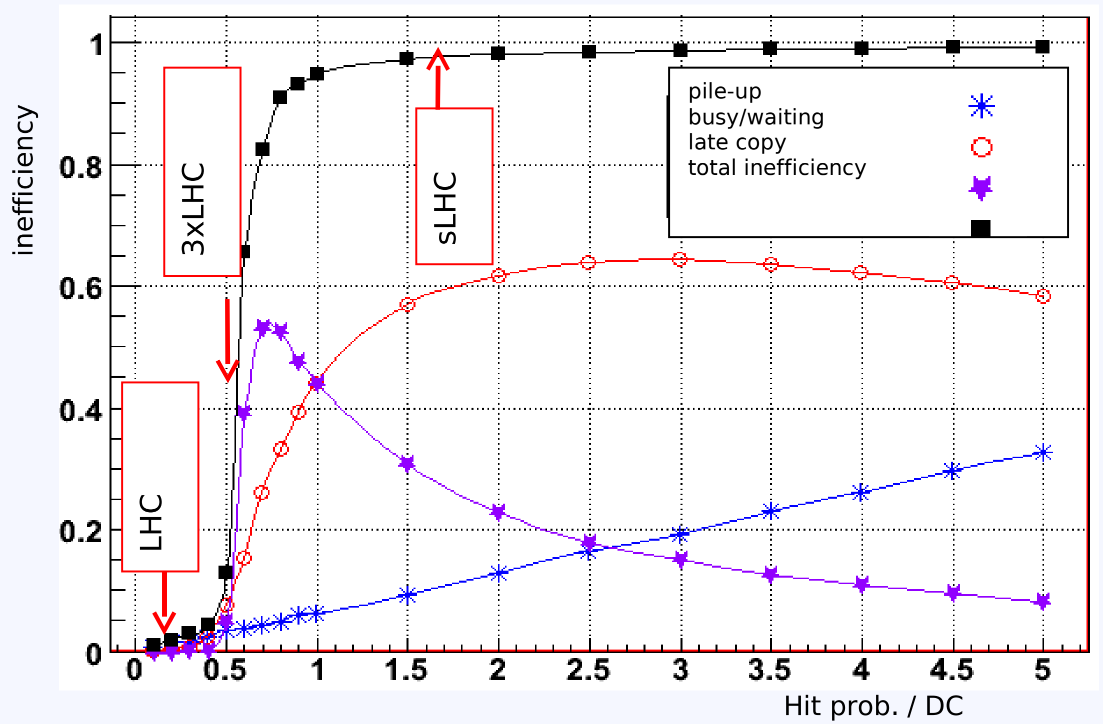


- Ref. Bern ATLAS week, Thursday afternoon
  http://indico.cern.ch/materialDisplay.py?contribId=69&sessionId=26&materialId=slides&confId=20501
- ATLAS Pixel package = pixel detector + services to ~3 m + beampipe, inside a CF support tube
  - Inserted as one piece
- First realisation: cannot repair/replace beam-pipe (e.g. vacuum leak)
  - ...order new spare beampipe which can be inserted
  - ...develop method to replace old one (cut at z = 0?)

B-layer

- Lifetime: should last beyond 2012, but not until 2017
  - Irradiation damage
    - HV limited so eventually cannot fully deplete
      - Leeds to signal loss and inefficiency
      - “Soft failure”
  - Some possible other failures (leaks, opto packages…) - “hard failures”

FEI3 inefficiencies



- Rate capability:
  - Inefficiencies become significant but OK at 2.10^{34}
  - Very bad at 3 x nominal
- B-layer has to be renewed
- Only time is longer shutdown 2012-13

Insertable B-Layer IBL

- Time to remove pixel package, open up, remove B-layer, put in a new one is ~ 1 year. BLTF set up to find best way to avoid ATLAS running a year without pixels
- Many options considered
- Only one survived scrutiny:
  - Insert a new B-layer inside the current pixel detector
  - leave the old (partially functioning) B-layer in place
  - New, smaller beam-pipe to make space
  - Cost not known, but ~5 – 7 MCHF components
- Performance has been evaluated (shown last meeting):
  - Moving to smaller R and shorter pixels gains
  - Extra material loses
  - Net effect is beneficial, especially if old B-layer is working at > 70 % efficiency

Current Expectations

- Need careful evaluation, subject to change
- Beam-pipe 50 mm diam
- B-layer sensors centred at 37 mm radius
- Planar sensors, probably n-in-n, maybe thinned; or 3D
- FE-I4 chip: well under development
  - 130 nm cf 250; smaller pixels (50 x 250 cf 50 x 400 micron)
  - hits stored in pixels until LVL1 (cf all data to end of column) – allows high efficiency eventually to 10 times nominal
- Evaporative CO2 cooling (cf C3F8)
  - Smaller pipes, lower coolant T: freedom in design
- Powering: serial or DC-DC/charge pump or buck converter
- Readout: electrical to z = 3 m, r = 1 m
- Services: needs new services to racks!

Pixel installation

- Integrate new B-ayer and its services with a new Be beampipe
- Cut old beam pipe at z ~ 0 and remove, managing cable supports
  - Solution under investigation; sketches show it is possible
  - Cutting activated poisonous Be
- Insert complete new package, but locate B-layer on old pixel detector
  - Must not move relative to rest of pixels! beam pipe expands and contracts too much to use as locator

Organisation

- Needs major effort now
- Involves pixel group, beam-pipe (machine), cooling, services ...
- Should fit in with Phase-II Upgrade:
  - FE-I4, sensors, CO_2 cooling as pilot projects for Phase-II
- Use Pixel group, USG, PO, TC

Other Phase-1 Changes

Beam-pipe

- Beam-pipe at large z (z > 3 m) is SS
- Generates large background in muon system
- Gets activated, making maintenance difficult
- Two Upgrade stages proposed:
  - SS -> Al
  - Al -> Be
- Be compared to SS reduces BG factor 2 in muon system
  - In fact, a factor 3 in worst regions

Other ATLAS Detectors

- Have started an evaluation of how each system will perform in Phase-I, and what changes are needed (if any), and whether R&D is needed now
- Report back by Christmas
- For each detector evaluate:
  - Sensitive detector resolution and efficiency
    - E.g. space charge, occupancy/dead-time fraction, tracking efficiency
    - Effect on jet, gamma, or track resolution
  - Data loss during transmission at peak rate
  - Total dose effects
  - What action is needed
  - What R&D is needed now
- USG will coordinate and produce a report (ATLAS EB Action to do this)
- Now go through (briefly) each sub-system...

Inner Tracker

- Rest of Pixel outside the B-Layer:
  - Should be OK: the data rate is much less than in the B-layer; integrated dose is OK. There will be slight increase of lost hits, but tolerable.
- SCT
  - Zero suppressed data. Readout will lose about 1 % of hits at 3 times nominal
  - max occupancy at nominal is 0.6 %, so expect 1.8 % at Phase-I
    - Should be OK for pattern recognition (usually like to keep below 1 %)
  - Total dose OK (as designed)
- TRT
  - Fixed data length (no zero suppression) so no extra data losses to ROD
    - But after ROD it is zero suppressed; investigate
  - Long drift time and large area of straws gives high dead fraction
    - Needs detailed assessment
  - ion build up etc.
  - R&D to different gasses? E.g. drop TR detection, get faster gas

Inner Tracker Cooling

- Current evaporative C3F8 has several problems:
  - Large pressure drop in return pipes so cannot reach the required -25 degC needed after irradiation
  - Heaters mostly working, but still control problems for some orientations
  - Compressors: low input P due to pressure drops; high output P to avoid need for liquid pumps
    - Compressors are working at their maximum: rapid wear (oiless pistons) and reliability questions – already had major failure
- Solutions to investigate:
  - Change BPR to something with lower dP
    - E.g. accumulator solution used at LHCb (zero dP), vacuum pump in line, bigger BPRs...
  - Do condensing at surface and use static head to get to high P in pit. This gives compressor lower output P since gas has less static head
  - And other ideas

Calorimeters

- LAr
  - Fixed data length: no data loss
  - Pile-up increases, acts as a noise, grows slowly (sqrt(L/L0))
    - Filtering to be optimised
  - Boiling not a problem at $3x10^{34}$
  - HV drops, ion build OK in most of eta, but needs chacking in FCAL
- Tiles
  - Fixed data length so no data loss
  - Don't expect any changes except maybe crack scintillator
  - But maintenance issues and back-ups needed in several places
  - Plus monitor rate of light-output decline with time and radiation

Muons

- Depends on BG!
- We need to urgently measure the background relative to the luminosity
- Separate n and gamma
- Need to follow up and check all radiation monitoring sensors (~7 varieties); joint group to do this
- R&D project for this was among the first approved
- See how much of safety factor 5 is used up
- Consider selective readout
  - Only readout at LVL1 in RoI
- Need to simulate trigger effects, and tune trigger
- Shielding: look at improving JF shielding (rest has no space and all is fully optimised already)
- Beam-pipe already mentioned

Electronics

- Several detectors use same technologies and these need monitoring
- E.g. D-Mill bi-polar transistors suffer n damage
- beta could drop from 120 to ~40
- Can power supplies compensate etc.?
- Needs monitoring

Trigger

- Difficult to change LVL1 (latency, rate)
- Investigate “topological” cuts e.g. isolated muon
- Can raise thresholds
  - ...needs evaluation
- High Level Trigger and Event storage:
  - Can keep improving as processor costs reduce
  - Can improve algorithms
  - Is accessible: decoupled from cavern

Summary

- Fixing the anticipated LHC evolution helps greatly to focus discussions
- Main necessity at ATLAS is Insertable B-Layer
  - Difficult but Doable
- Evaluation of other changes needed has begun
  - Seems manageable