Machine-Experiment Interface

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CARE-HHH-Workshop

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The LHC Experiments

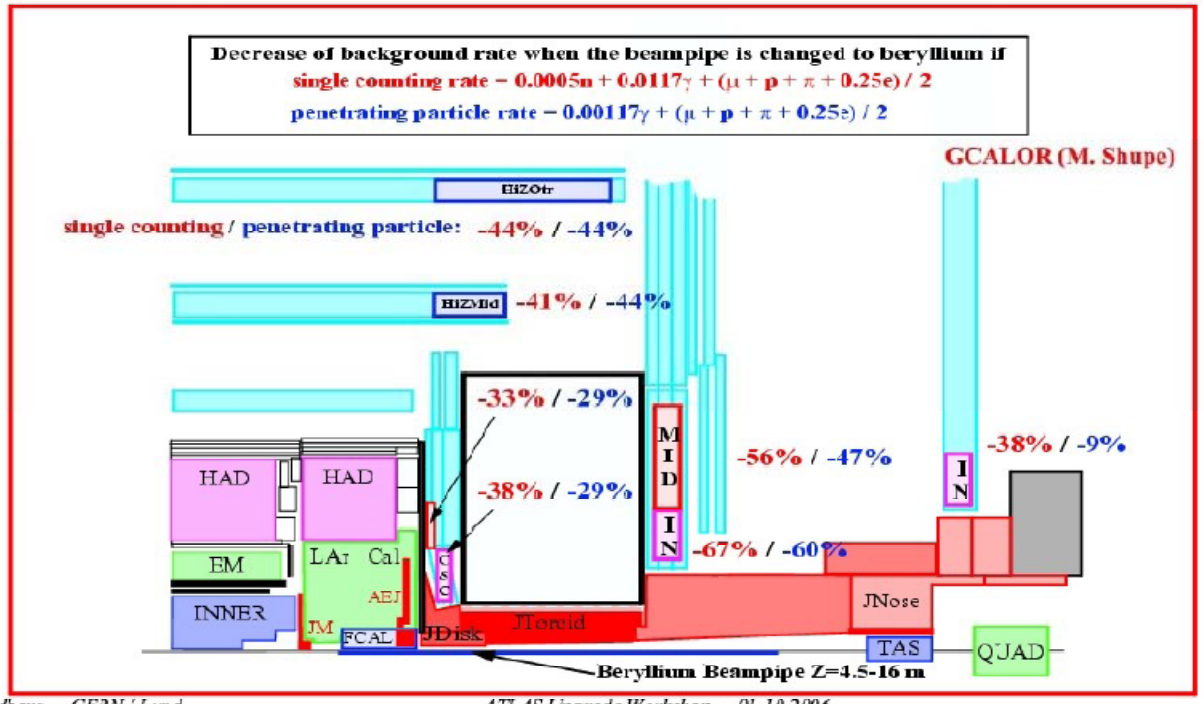
ATLAS Spare Beam Pipe

- The ATLAS B-Layer Task Force review realised that the ATLAS beam pipe cannot be replaced in a reasonable time.
  - For example, in event of accident that would spoil the LHC vacuum.
  - ATLAS proposes to make a new spare beam pipe which can be inserted without removing the Pixel.
  - Would include Be for the central pipe and SS elsewhere.
  - This should be pursued as a matter of urgency.

ATLAS Beam Pipe

A beryllium beampipe

A beryllium beampipe is also the only way of significantly reducing the background in the muon spectrometer.



Intermediate step from SS to Al

Machine Elements in ATLAS

- D0a near ID and inside calorimeter.
- D0b just behind calorimeter.
  - Best performance with both, but D0b alone is significant help.
- Q0 and TAS in JT/JF shielding.

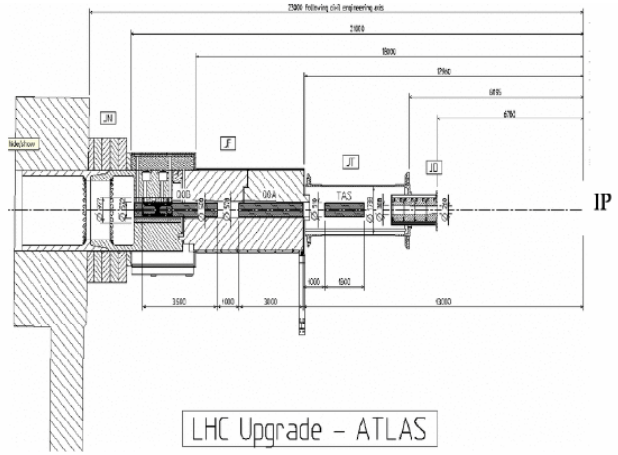
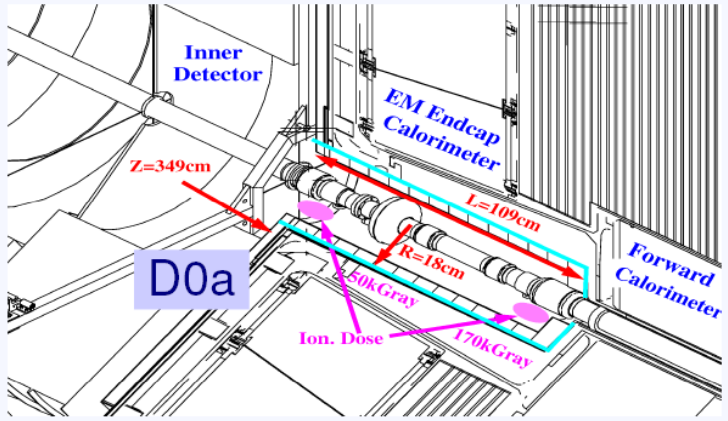
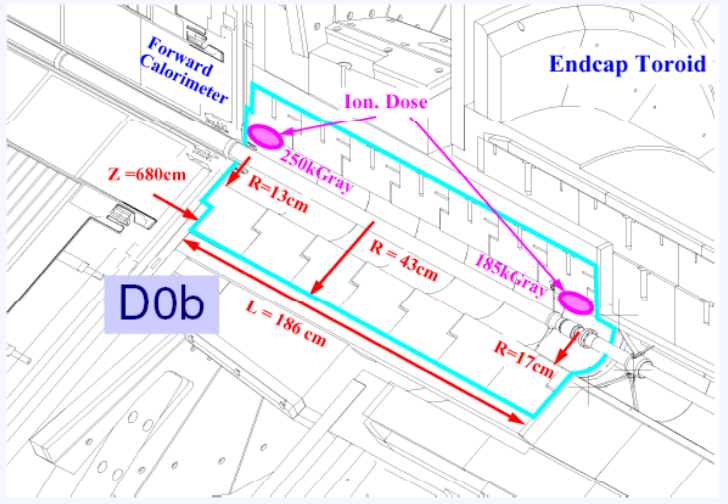


Figure 2: Integration of slim quadrupoles and TAS in the ATLAS insertion region.



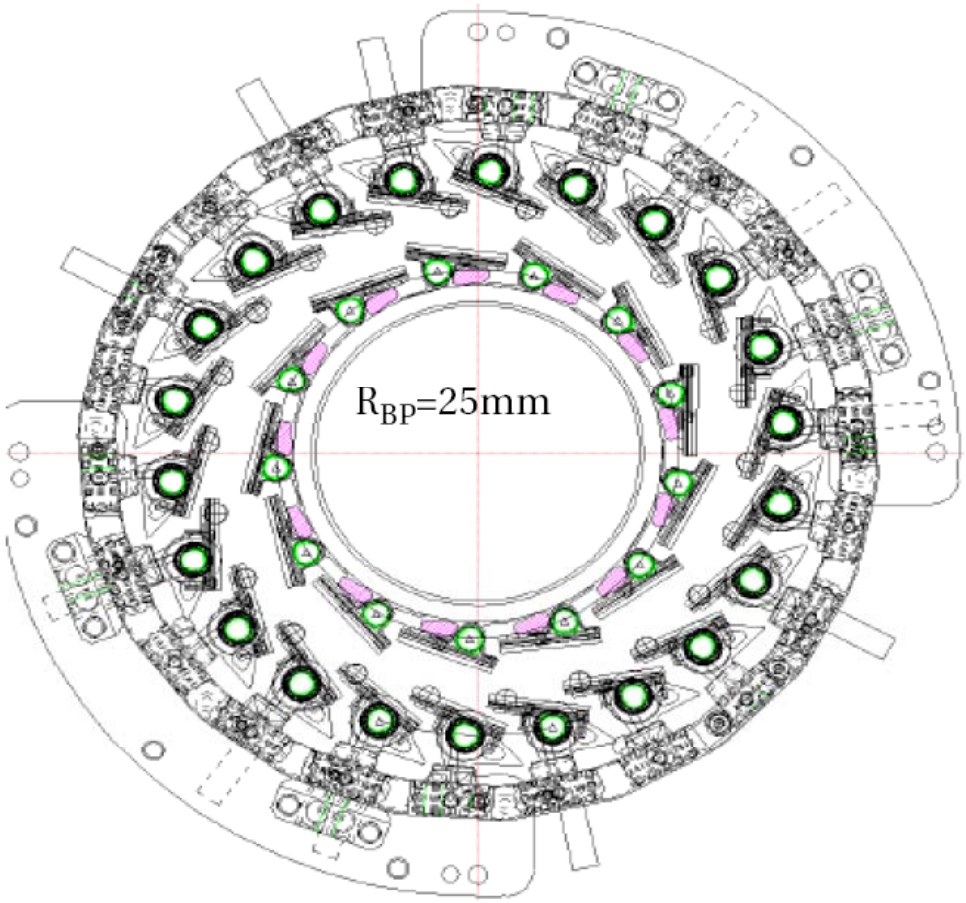


Machine Elements in ATLAS

- D0a
  - 50% background increase in the Inner Detector.
  - Destroys forward calorimetry measurement.
- D0b
  - Raises Muon System background by ~30% for the 300 evt/BC scenario.
  - Could be acceptable, although many engineering issues to be resolved.
- Q0 and TAS
  - Gives a significant increase of background in Muon System as the TAS has moved outside the heavy JF shielding into the toroid shielding JT

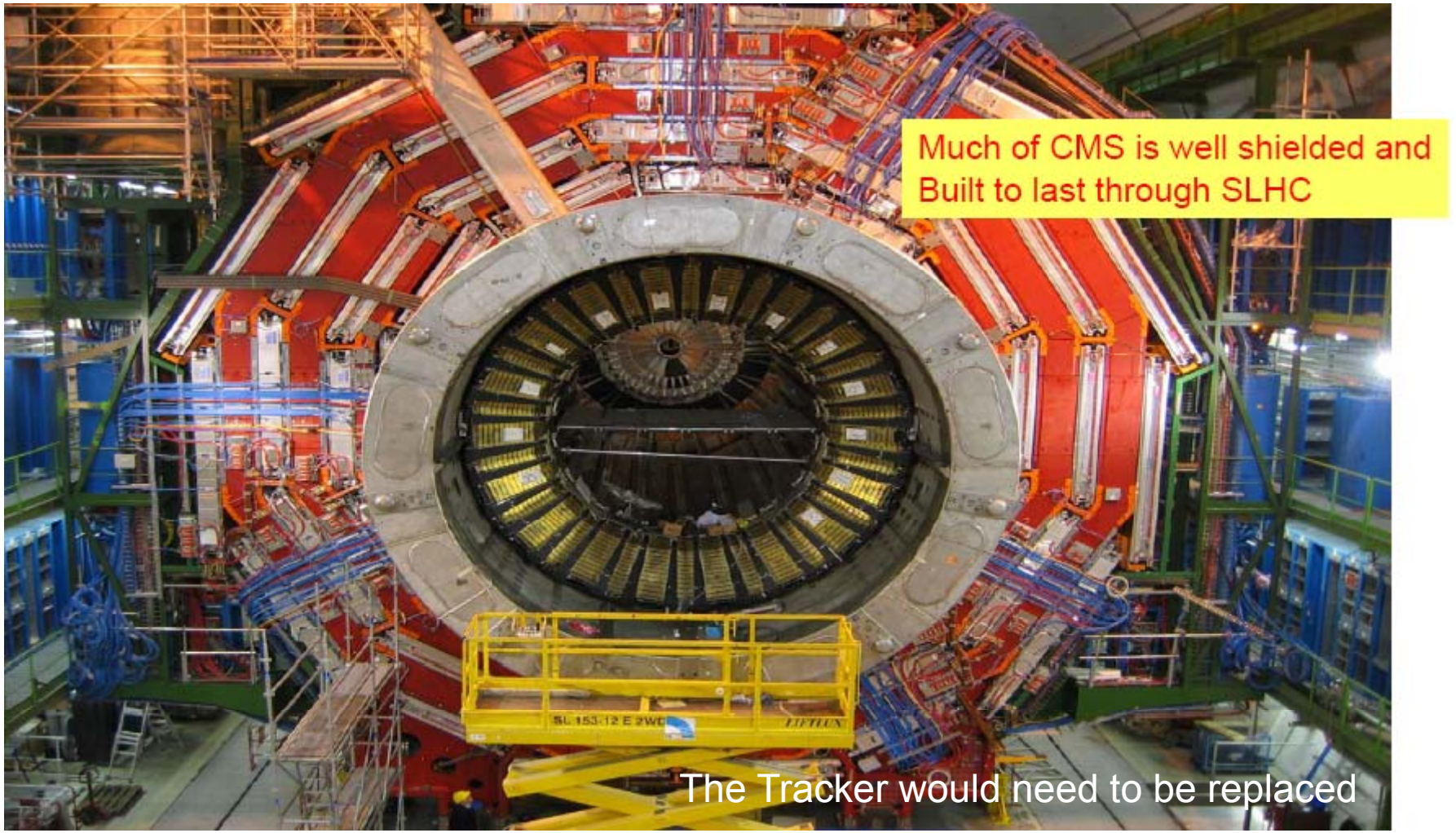
See https://edms.cern.ch/document/932316

ATLAS Insertable B-Layer (IBL)



- Smaller beam pipe:
  - Is R=25 mm possible?
- Keep space for heating and shielding: 6 mm.
- Insert new B-layer into the present pixel detector in situ, with some clearance.
- Proposed by the ATLAS B-layer task force.
- Safety margin against BP movements needs even smaller BP.
- Need further discussions between ATLAS and AB.

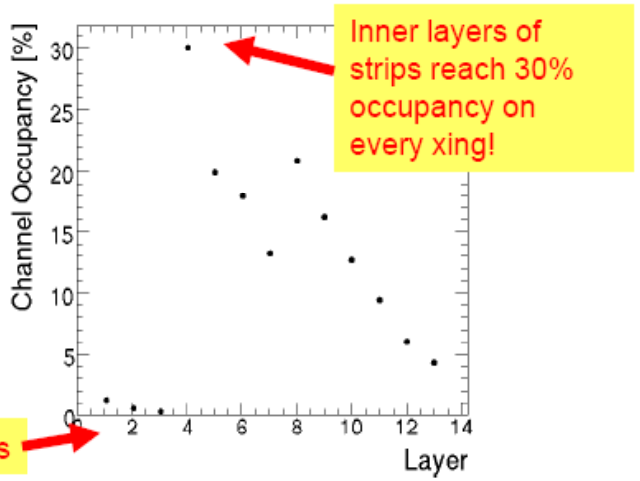
CMS - Detector

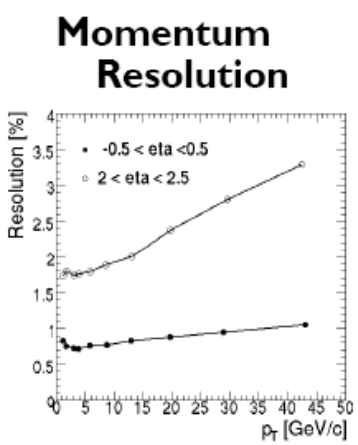


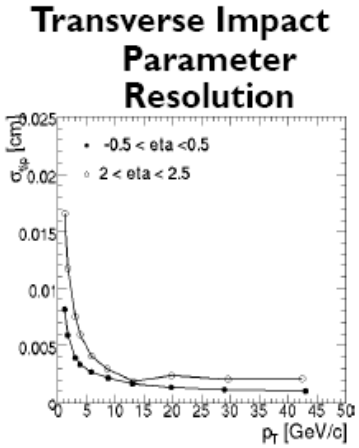
CMS – Minimum Bias Events

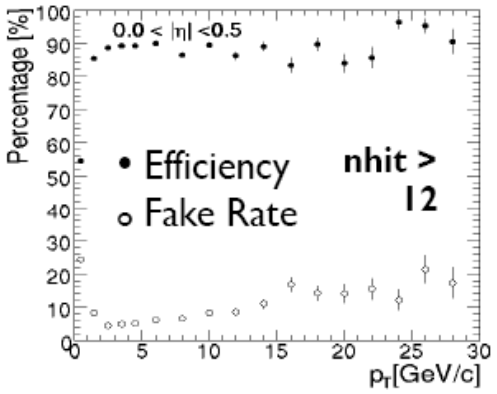
Tracking with 500 min Bias events

- Study of current CMS tracker for Heavy Ion events
- Track density very similar to 50ns running
  - $dn^{ch}/d\eta$/crossing ≈ 3000
  - Tracker occupancy very high
  - Need more pixel layers/shorter strips
- Tracking possible
  - When tracks are found they are well measured
  - Efficiency and fake rate suffer
  - CPU Intensive



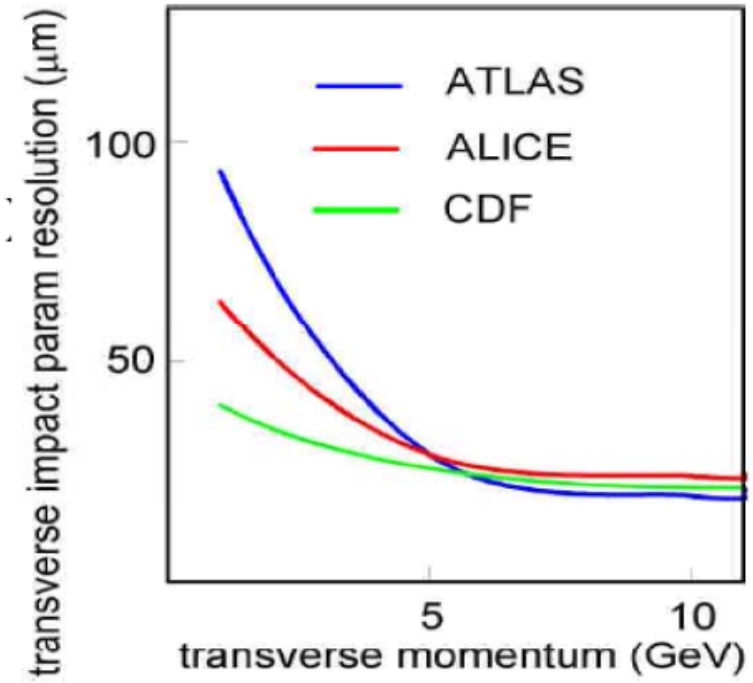






ALICE - Requirements

- Smaller beam pipe diameter for better c and b tagging desired:
  - From R=2.9 cm to R=1.3 cm like at the Tevatron.
- Thinner beam pipe desired:
  - From 0.8 to 0.4 mm Be
- To be discussed with machine groups.



ALICE - Requirements

- ALICE will run at least a few weeks low-luminosity pp every year (before heavy ion runs)
  - Other LHC upgrades would need to allow for this.
- ALICE is considering a possible heavy-ion luminosity upgrade
  - To be discussed after the first heavy-ion run.

LHCb - Requirements

- Running Conditions
  - LHC Baseline – run at 2 – 5 x 10^{32} $cm^{-2}s^{-1}$
    - Integrated luminosity 9 fb^{-1}
    - Limitation is hadron triggger
  - Phase-I – run at 10 x 10^{32} $cm^{-2}s^{-1}$
    - Integrated luminosity 25 fb^{-1}
    - Limitation is tracking efficiency (radiation)
  - Phase-II – run at 50 x 10^{32} $cm^{-2}s^{-1}$
    - Integrated luminosity 110 fb^{-1}
    - Limitation is probably upgraded tracking

LHCb - Requirements

- Phase-I and Phase-II luminosity limits due to number of pp interactions per crossing.
  - Limited to a few interactions per bunch crossing by trigger and tracking.
  - Therefore, LHCb want as many crossings/sec. (25 ns.) as possible.
  - Doubling the bunch spacing (50 ns) will half the integrated luminosity.
- Additional requests
  - Luminosity leveling for high luminosities (10×10^{32} $cm^{-2}s^{-1}$)
  - Longer luminous region

Experiment Vacuum System (© Ray Veness)

Consolidation

- ATLAS: Replace stainless steel chambers VA (& VT) and bellows with aluminium for background and ALARA reasons, prepare spare central Be beam pipe.
- LHCb: Replace defective UX85/3 Be chamber, optimise UX85/2 supports, replace stainless steel bellows with aluminium.
- CMS: Re-evaluate forward vacuum chamber supports and gas injection system operation for magnetic fields.

Upgrade

- Phase-1 Upgrade: New forward chambers in ATLAS and CMS, new TAS and/or TAS chambers, new VAX region (TAS-Q1).
- ATLAS: New Insertable B-Layer, Tracker upgrade (Be) beam pipe.
- CMS: Tracker upgrade (Be) beam pipe.
- New materials and manufacturing methods for transparent chambers.
- FP420-type forward physics moving beam pipes.
- LHC Phase–2 Upgrade concepts.

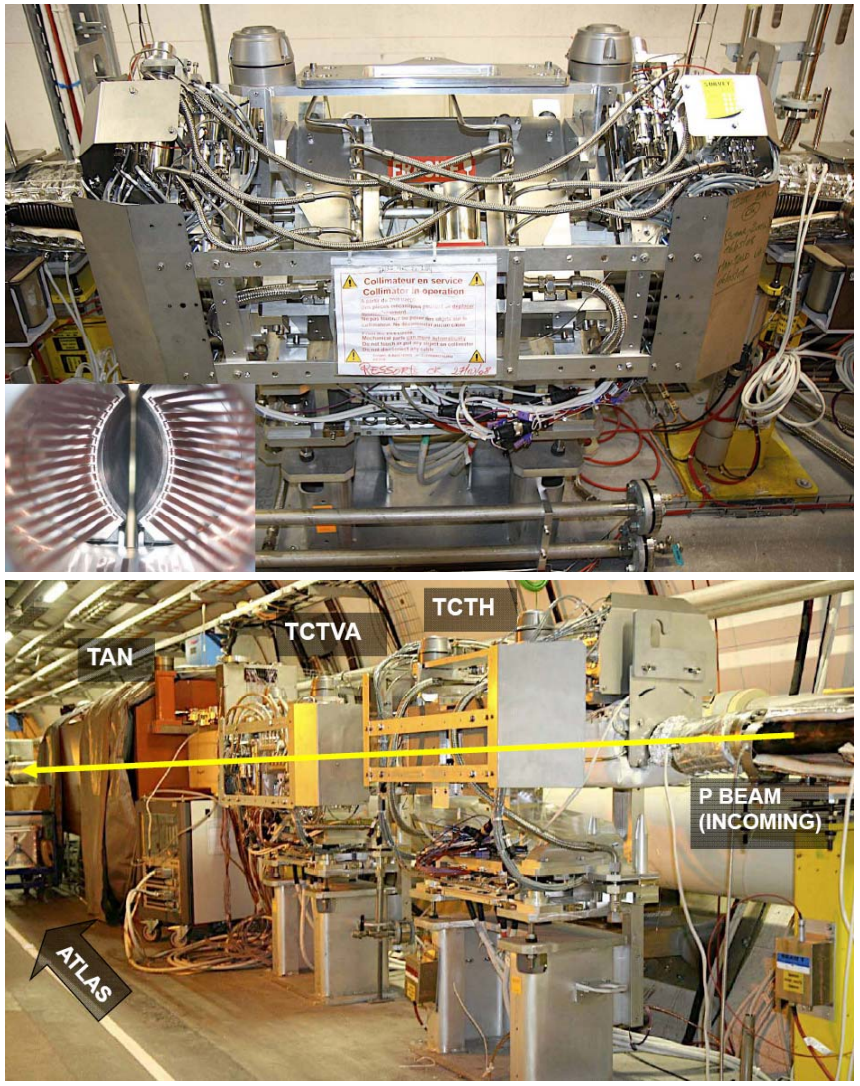
Apertures LHC Upgrade Beam Pipes

- History
  - ATLAS requested a smaller beam pipe diameter in Z ±3.5m for B-layer and PIXEL upgrades.
  - Presentation to ATLAS Tracker Upgrade Workshop in 2006 based on aperture requirement at injection (which was the limit for the current beam pipe radius).
  - A number of open questions remained to be answered (e.g., future optics and collimation) with final value expected some time after machine start-up.
- Information required from ATLAS and CMS
  - Formal statement needed on range of β* in IRs 1 and 5 required for physics
    - TOTEM or other high β* optics required after LHC Phase-1 Upgrade?
  - Latest information on structural stability of experiment caverns.
- Next steps
  - Calculate baseline aperture of beam pipe in cavern, taking into account new information on triplet and collimation.
  - Make detailed simulations based on beam loss, background and machine protection before agreeing final value.

Collimation System
(© R. Assmann)

Collimation System

- Phase-1 graphite collimators have large contribution to machine impedance.
- Phase-2
  - Additional Cu scrapers & collimators.
  - Overall smaller impedance & 10x better cleaning.
- Phase-2 Collimators remain unchanged for LHC Triplet Upgrade.



Prediction of Beam-1 (H) Halo Losses

IR	Phase I (Perfect)	Phase I (Imperfect)	Phase II
IR1	4.9×10^{-4}	1.0×10^{-3}	7.7×10^{-6}
IR2	1.3×10^{-4}	2.1×10^{-4}	2.2×10^{-6}
IR5	6.5×10^{-6}	5.7×10^{-5}	2.9×10^{-6}
IR8	3.0×10^{-4}	7.5×10^{-4}	5.6×10^{-5}

- Numbers show fraction of overall loss that is intercepted at horizontal tertiary collimators in the various insertions (collimation halo load).
- Phase-2 collimation upgrade reduces losses in IRs by a factor up to 60!
- Beam-2 has opposite direction ➔ more losses in IR5 and less in IR1!

Consequences of Phase-1 Triplet Upgrade

- After the Phase-1 Triplet Upgrade we will have the same tertiary collimation. **Losses can still be very different:** Combination of collimation halo (collimation settings), optics and detailed aperture variation.
- **Loss studies and background studies must be redone** (collimators can be opened, potential losses before D2 or at TAN, more passing through Triplet, change of loss distribution between experiments, …).

Required Beam Loss Studies for Phase-1 Triplet Upgrade

- Detailed loss studies must be performed in order to qualify the performance of any new insertion layout.
- Important workload, but we know about HERA problems with beam losses and background after the IR upgrade.
- For example, **procedure for experimental beam pipe**:
  - Phase-1 Triplet Upgrade: Define study optics and aperture model for Phase-1 Triplet Upgrade.
  - Experiments: Define required range of β^* for each IR after upgrade (need for high β^* optics?); Propose baseline for experimental beam pipe.
  - Machine: Determine maximum beam size (optics), required normalized gap (collimation) and required machine margins (optics, beam-beam, …). This gives minimum acceptable beam pipe aperture.
  - Machine & experiments: Qualify beam loss and aperture with new baseline.

Additional Issues

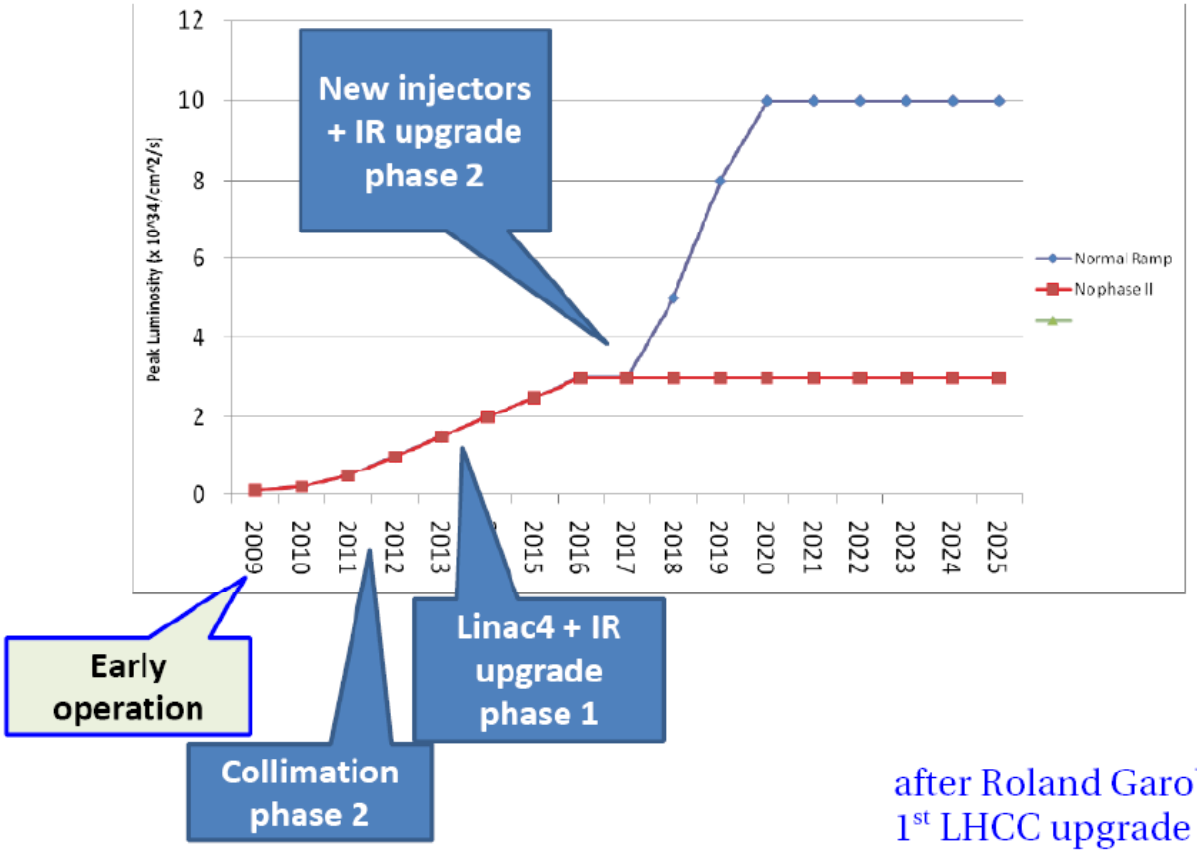
- Carry out complete simulation
  - Proton loss map → shower simulation → experiment background
- Collimation for ions?
- Interplay between collimation around experiments (e.g. ALICE – ATLAS)

Schedule & Final Remarks

Schedule

- Machine and experiments agreed on a working model at the LHCC meeting on 1st July 2008.
- Peak luminosity evolution:
  - LHC cannot exceed 0.4 x 10^{34} cm^{-2} s^{-1} until collimators installed and operational ~2012
  - In winter shutdown 2012-2013:
    - Switch from Linac2 to new Linac4: brighter beam, ultimate current
    - New large-aperture focussing quadrupoles: β^* from 55 cm to 25 cm
  - sLHC in 2017:
    - more injector chain improvements and or machine elements will give the potential for >= 10^{35} cm^{-2} s^{-1}
  - There is always a ramping time before benefitting fully from improvements

Schedule



after Roland Garoby
1st LHCC upgrade session
July 2008

Final Remarks

- Need an agreed and coherent schedule between experiments and machine.
- Need to find/create optimum forums to discuss LHC Upgrade machine-experiment interface issues.
  - e.g. LEMIC', LEB'.
  - To cover – schedule, luminosity scenarios, beam structure/conditions, machine elements in the experiments, experiment beam pipes, collimation system.

Final Remarks

- Although it may still be necessary to consider several options towards the LHC Upgrade, doing so has a cost.
  - 25 ns. is worst case for experiment read-out electronics (L1 latency buffers, shapers).
  - 400 events/bunch crossing is very challenging.
    - Requires higher detector granularity.
    - Luminosity leveling remains very attractive.
  - The experiments are designing for the worst case, even if the above combination is not proposed.

Conclusions

- Interchange between machine and experiments is advancing the LHC Upgrade and must continue.
- Strengthening of the forums to discuss machine-experiment interface issues for the LHC Upgrade is needed as a matter of urgency.
- Timescales for the submission of the respective Letters of Intent, Technical Proposals and Technical Design Reports of the experiments is being determined.