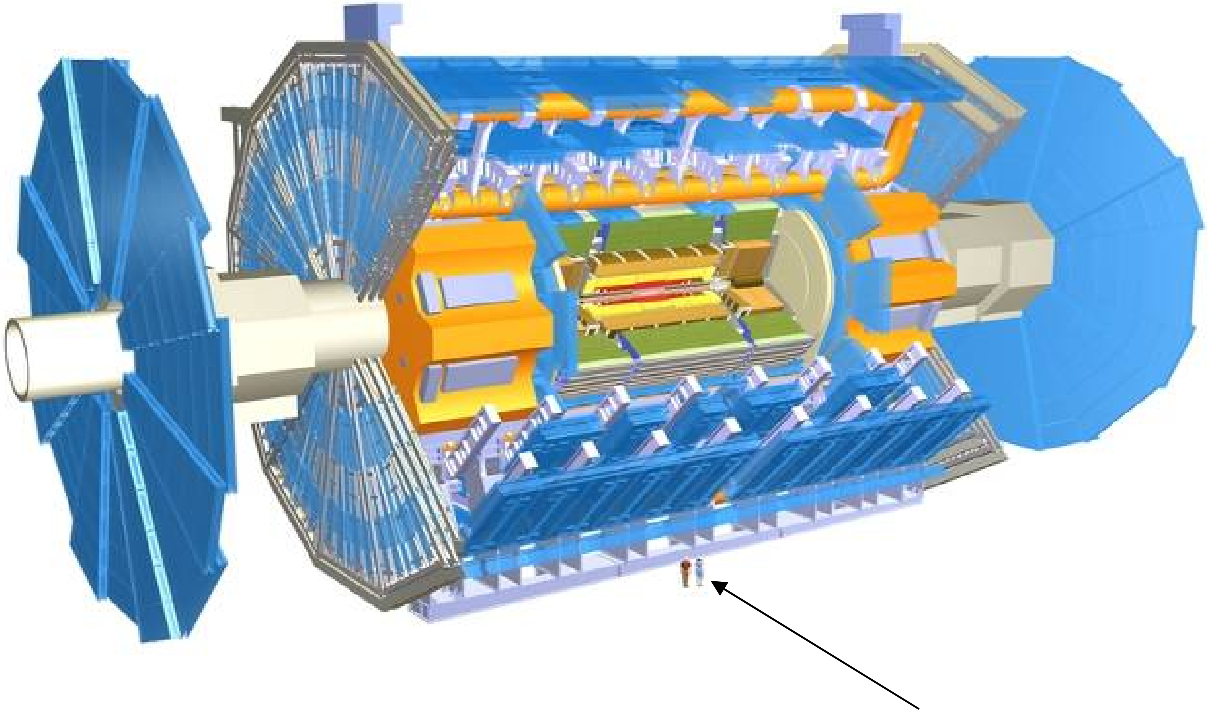
The high luminosity upgrade from an ATLAS perspective

Outline

- Short summary of upgrade issues
  system by system
- Questions to ATLAS
- "Answers"
- Conclusions



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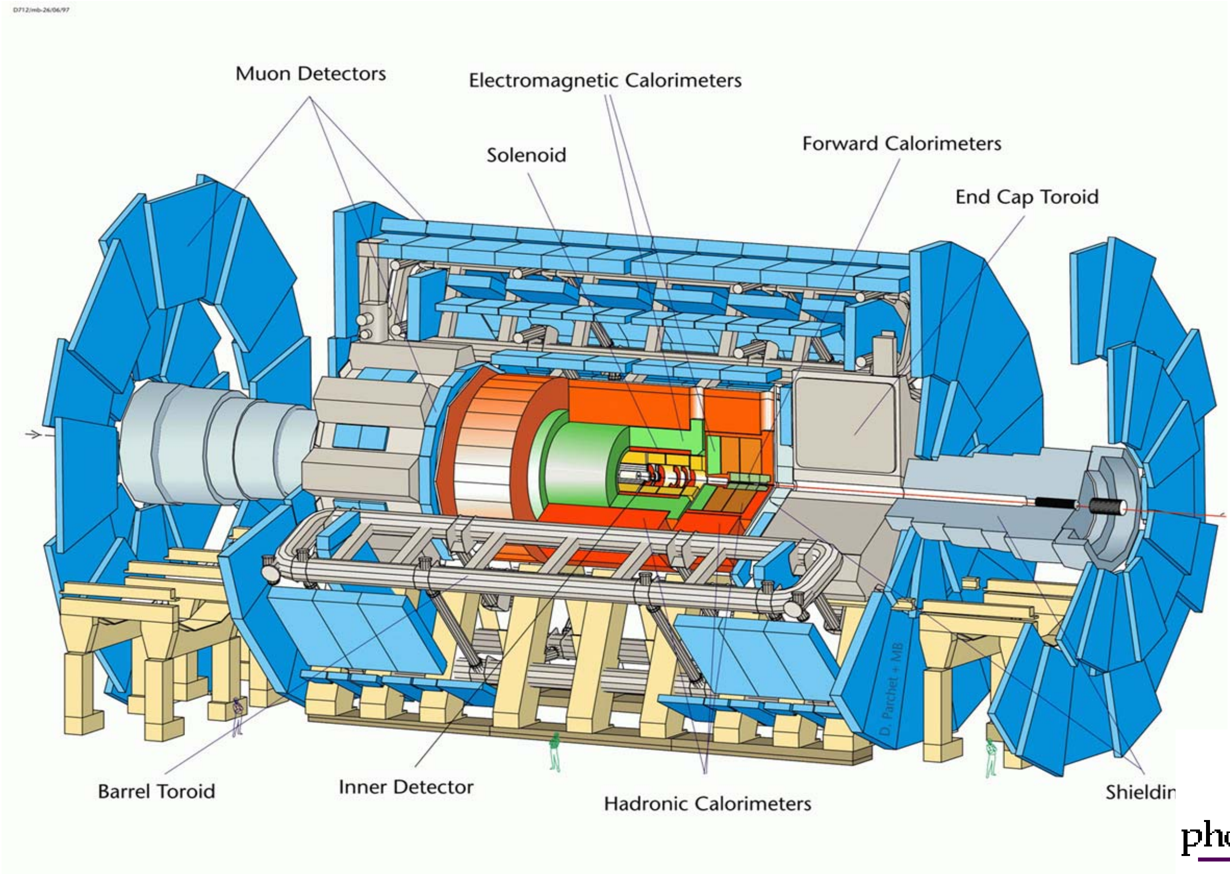
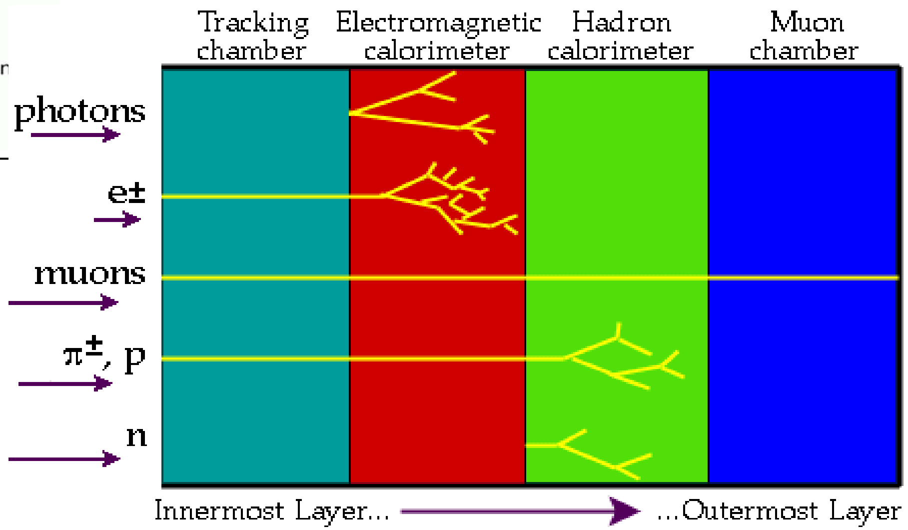
ATLAS/CERN



ATLAS

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~ 10^8 electronic channels
~ 3000 km of cables

- **Tracking (|η|<2.5, B=2T) :**
  - **-- Si pixels and strips**
  - **-- Transition Radiation Detector (e/π separation)**
- **Calorimetry (|η|<5) :**
  - **-- EM : Pb-LAr**
  - **-- HAD: Fe/scintillator (central), Cu/W-LAr (fwd)**
- **Muon Spectrometer (|η|<2.7) :**
  air-core toroids with muon chambers



High luminosity Upgrade of ATLAS

- Main goal

  To profit fully of a ~10 increase of luminosity and thus try to retain as much as possible of the capabilities of the present detector concerning tracking, energy and momentum measurements. Preserve all signatures like electron, gamma, muon, jet, missing transverse energy and b- tagging.

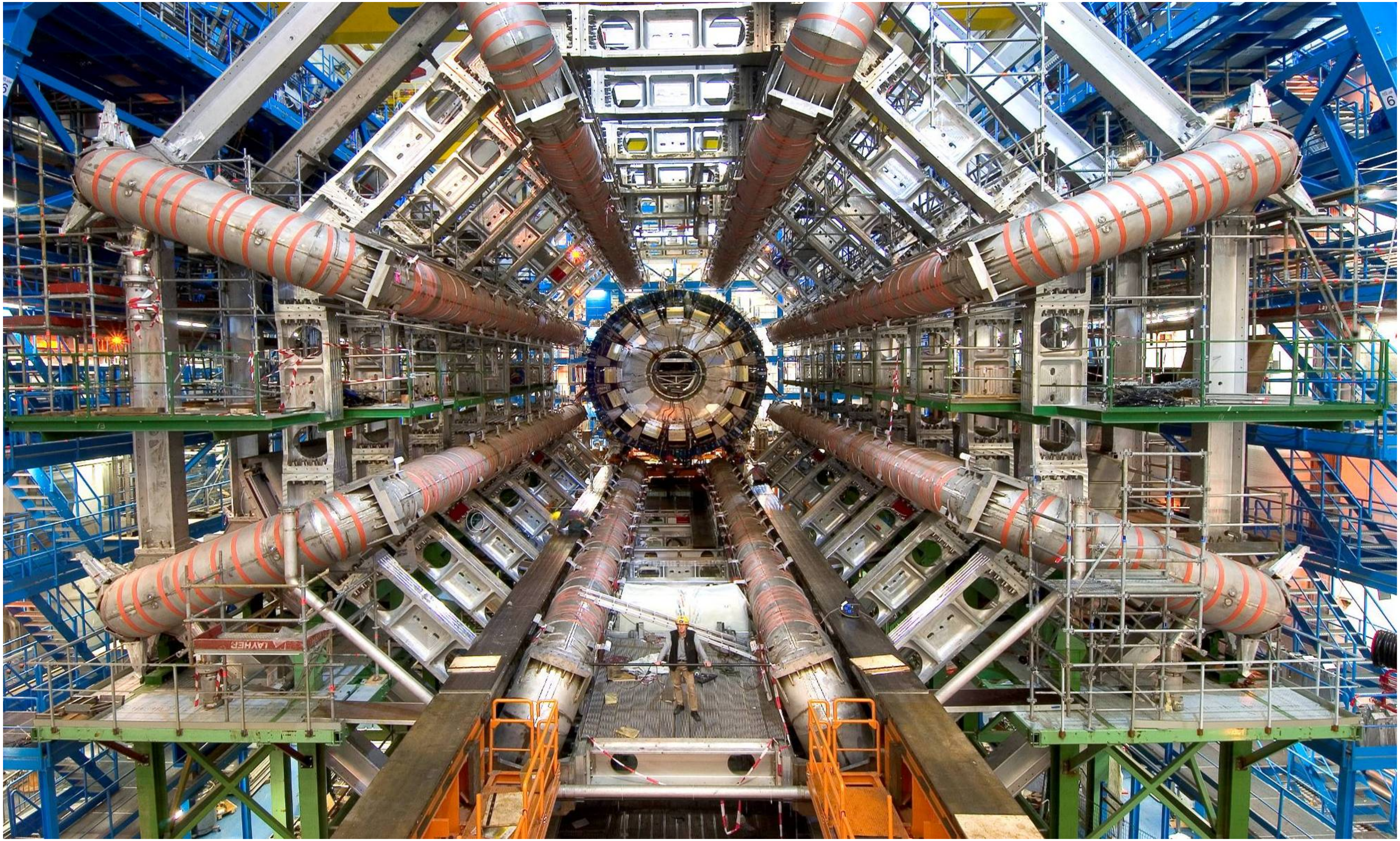
- Main overall uncertainty
  - The physics to be discovered at LHC will determine the direction in which to go .

    Different machine upgrade scenarios have different physics potential.
  - Background rates and radiation levels

    ⇒ we have to find compromises between narrowing down the number of options and keeping doors open.

- Main constraints
  - "reasonable " changes in terms of cost and time.
  - Keep as much as possible of big mechanical structures, support structures , magnets, cryogenics….
  - Volume for services can not be increased

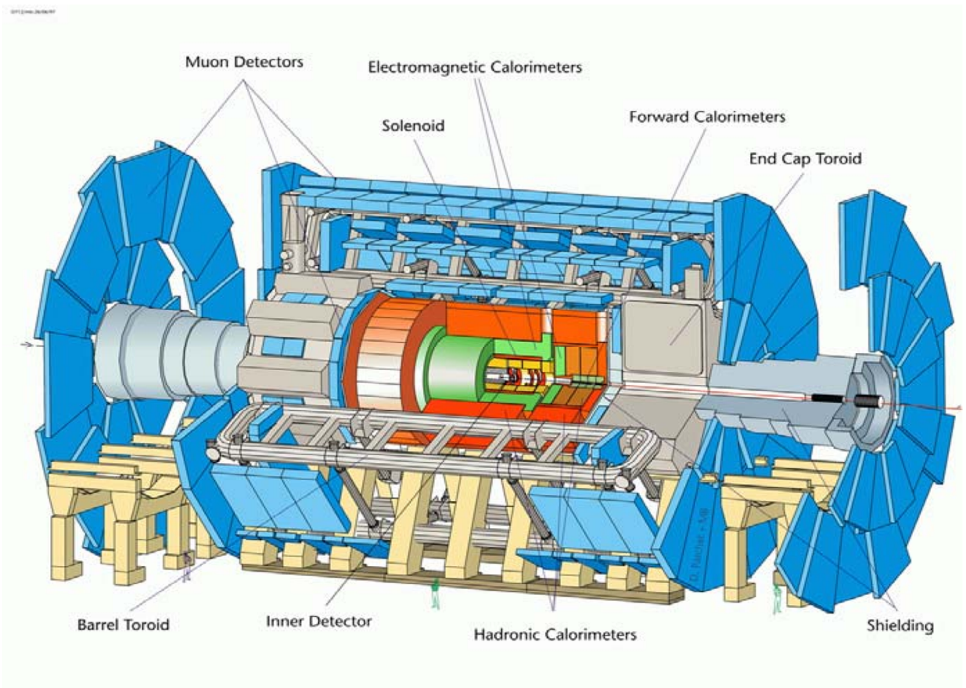
What is *not* planned to be upgraded

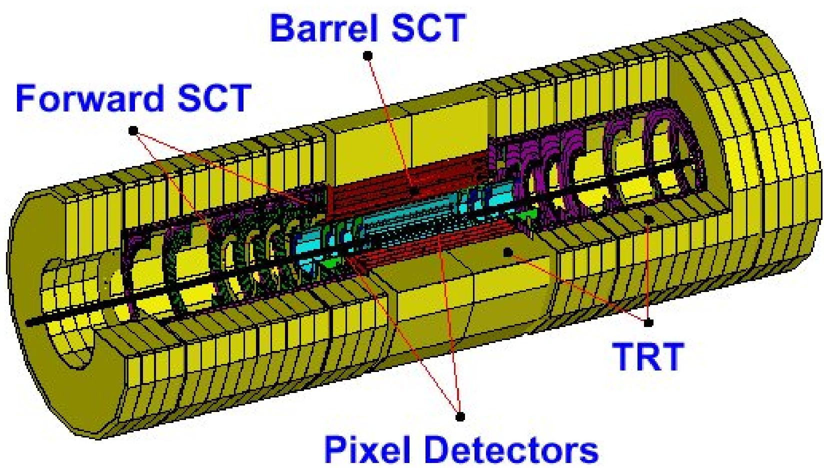


Short summary of upgrade issues-system by system

- The inner detector
- The Calorimeters
- The Muon system
- The TDAQ
- Others (electronics, beam pipe ,counting room…)

The Inner detector





The Inner Detector (ID) is organized info four sub-systems:

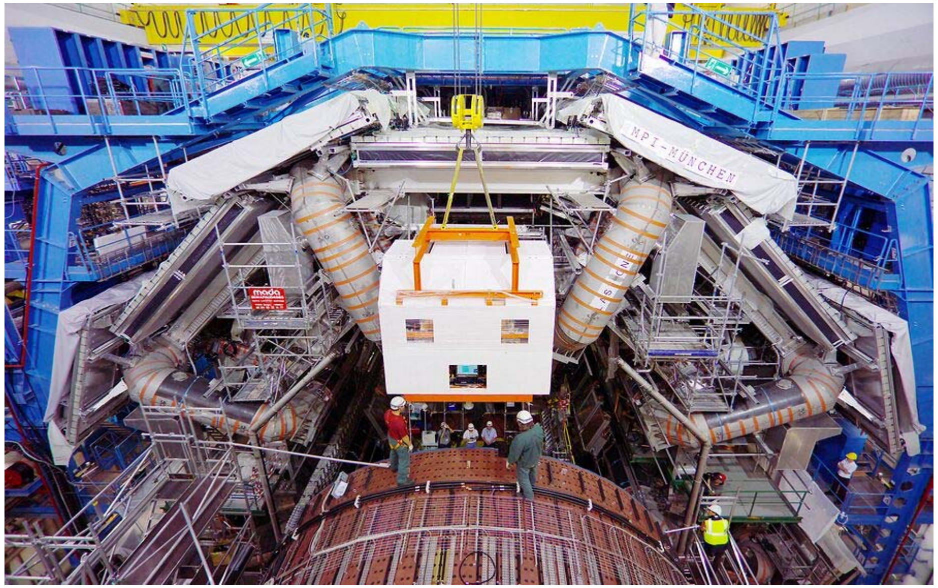
Pixels (0.8x10^8 channels)

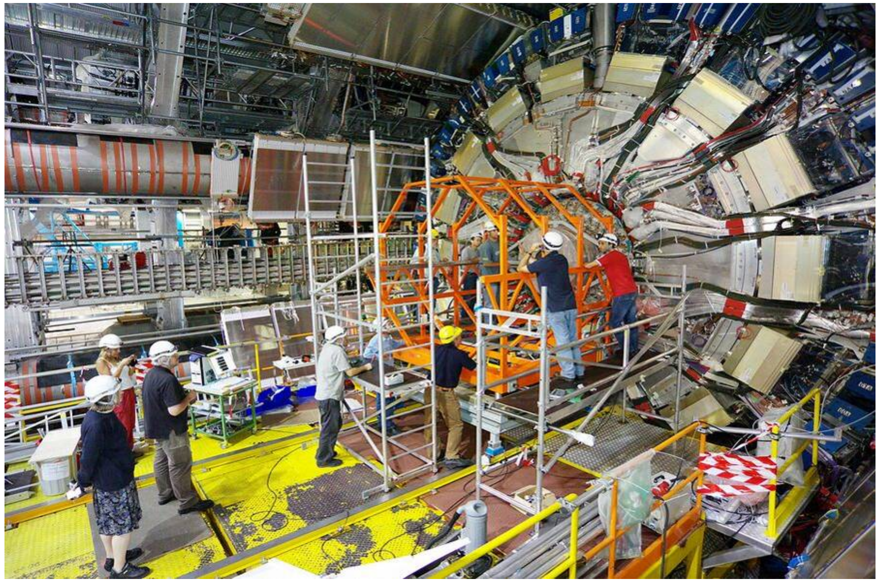
Silicon Tracker (SCT) (6x10^6 channels)

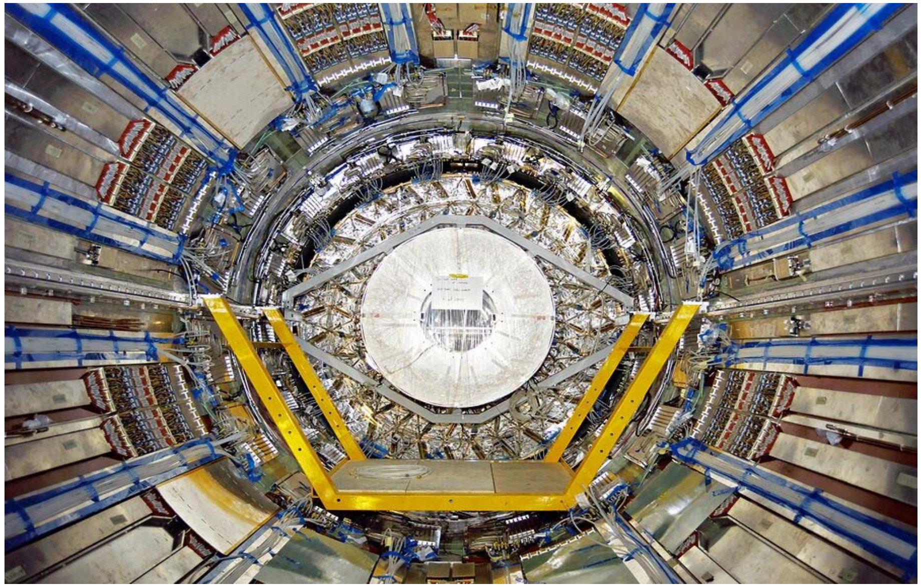
Transition Radiation Tracker (TRT) (4x10^5 channels)

Common ID items

The inner detector - today







The inner detector-high luminosity upgrade issues

- x 10 in luminosity $\Rightarrow$ most of the sensors of the inner detector will die in a couple of months
- x 10 in luminosity $\Rightarrow$ 10 000 charged particles in $\eta < 3.2$
  The TRT will have occupancy close to 100%

For the Inner Detector we are not talking about an "upgrade" but a complete replacement i.e a NEW Inner Detector

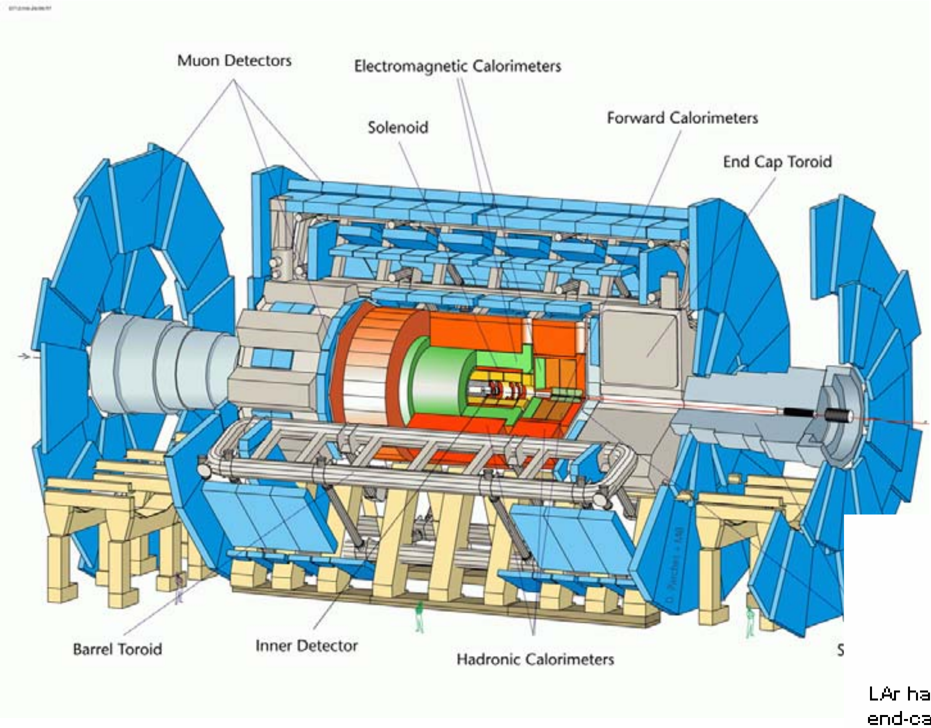
Extensive R&D has to start now !
ATLAS R&D for present detector started > 15 years ago
Many R&D projects are now being discussed
and are at the point to start within ATLAS

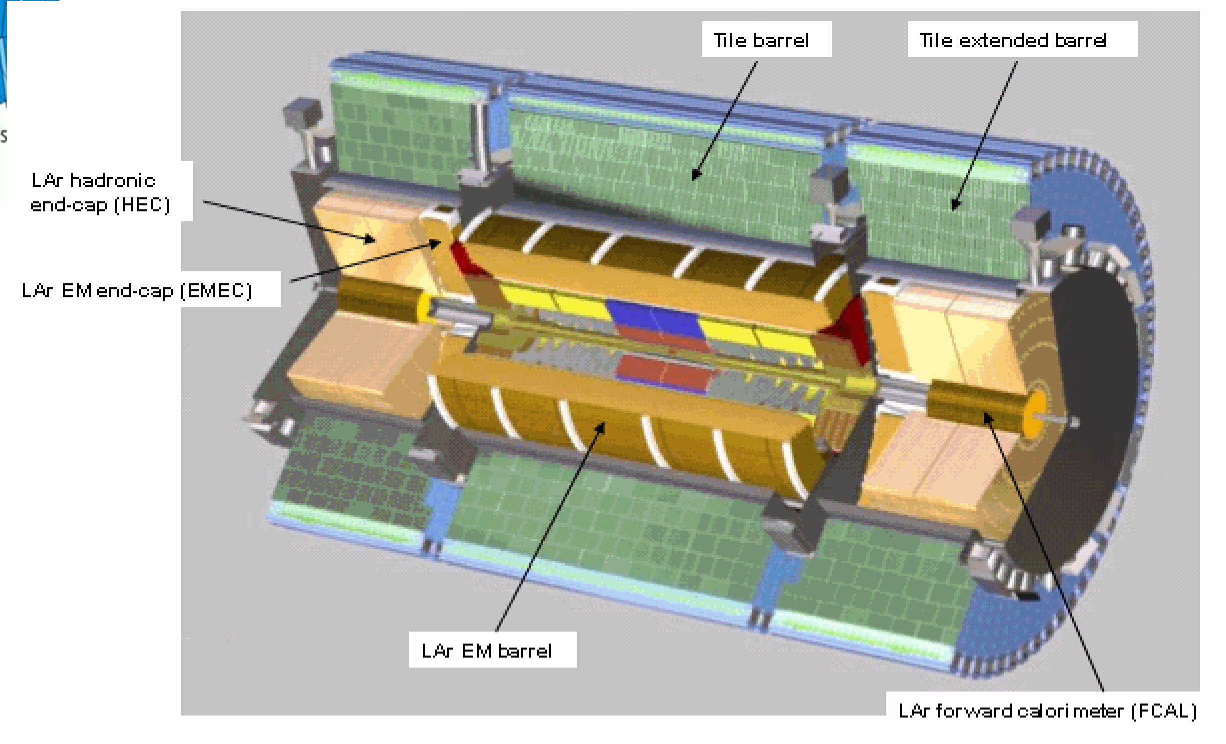
Some R&D proposals

ATL-P-MN-0002	Radiation Test Programme for the ATLAS Opto-Electronic Readout System for the SLHC for ATLAS upgrades
ATL-P-MN-0003	Development and Integration of Modular Assemblies with Reduced Services for the ATLAS Silicon Strip Tracking Layers
ATL-P-MN-0004	Proposal to develop ABC-Next, a readout ASIC for the S-ATLAS Silicon Tracker Module Design
ATL-P-MN-0005	Radiation background benchmarking at the LHC and simulations for an ATLAS upgrade at the SLHC
ATL-P-MN-0006	Development of non-inverting Silicon strip detectors for the ATLAS ID upgrade
ATL-P-MN-0007	Evaluation of Silicon-Germanium (SiGe) Bipolar Technologies for Use in an Upgraded ATLAS Detector
ATL-P-MN-0008	Development, Testing, and Industrialization of 3D Active-Edge Silicon Radiation Sensors with Extreme Radiation Hardness: Results, Plans
ATL-P-MN-0009	Research towards the Module and Services Structure Design for the ATLAS Inner Tracker at the Super LHC

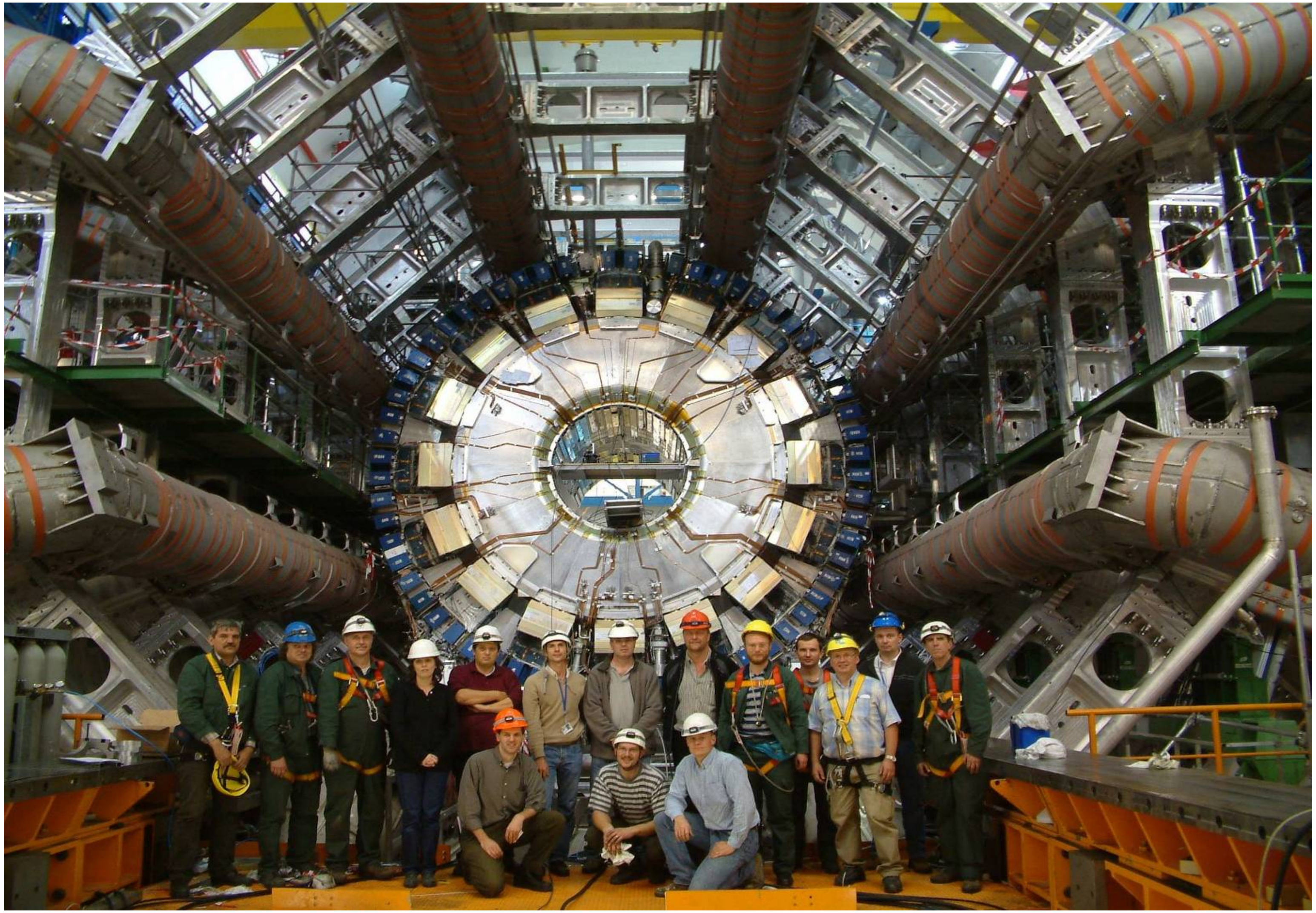
Important:Powering and cooling will also require R&D

Calorimetry





Liquid Argon and Tile calorimeter - Today



Liquid Argon –high luminosity upgrade issues (end cap /forward region)

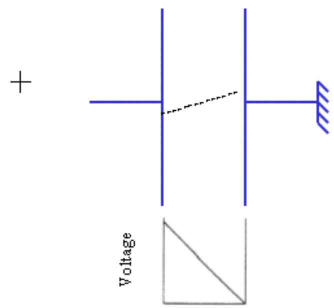
* Ion build-up ⇒ loss of signal

R&D ongoing

(important for forward calorimetry)

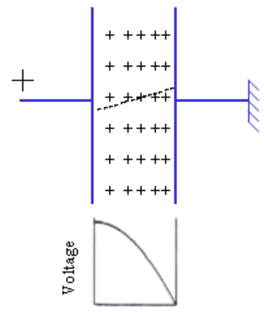
Argon Gap with track

Low Luminosity



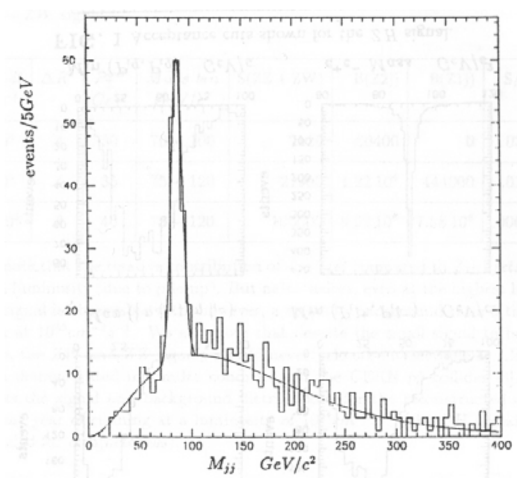
Argon Gap with track

High Luminosity

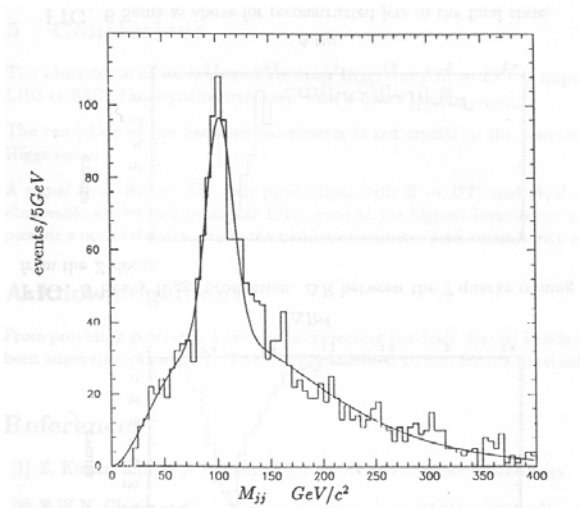


* Pile up

No pile up



Pile up (40 events)



* Beam heating of LAr
* Loss of voltage in HV system
* Radiation level of electronics

Optimes S/N between pile-up and electronic noise

Tile calorimeter –high luminosity upgrade issues

What is NOT Planned to be Upgraded

Mechanics

Optics

Photo-tubes

Decrease in light budget of Tile due to ageing (<1 % /year) and additional dose (<1.4 %/100fb^{-1})

What is Considered to be Upgraded

FE Electronics

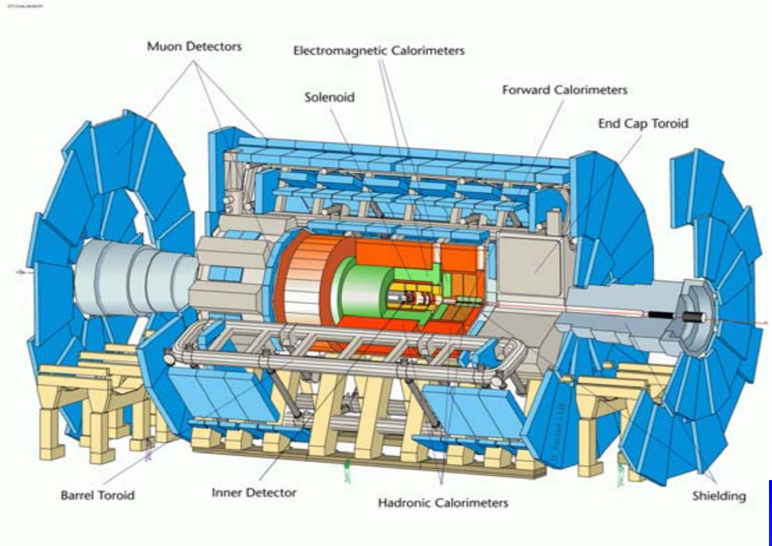
Low Voltage Power Supplies

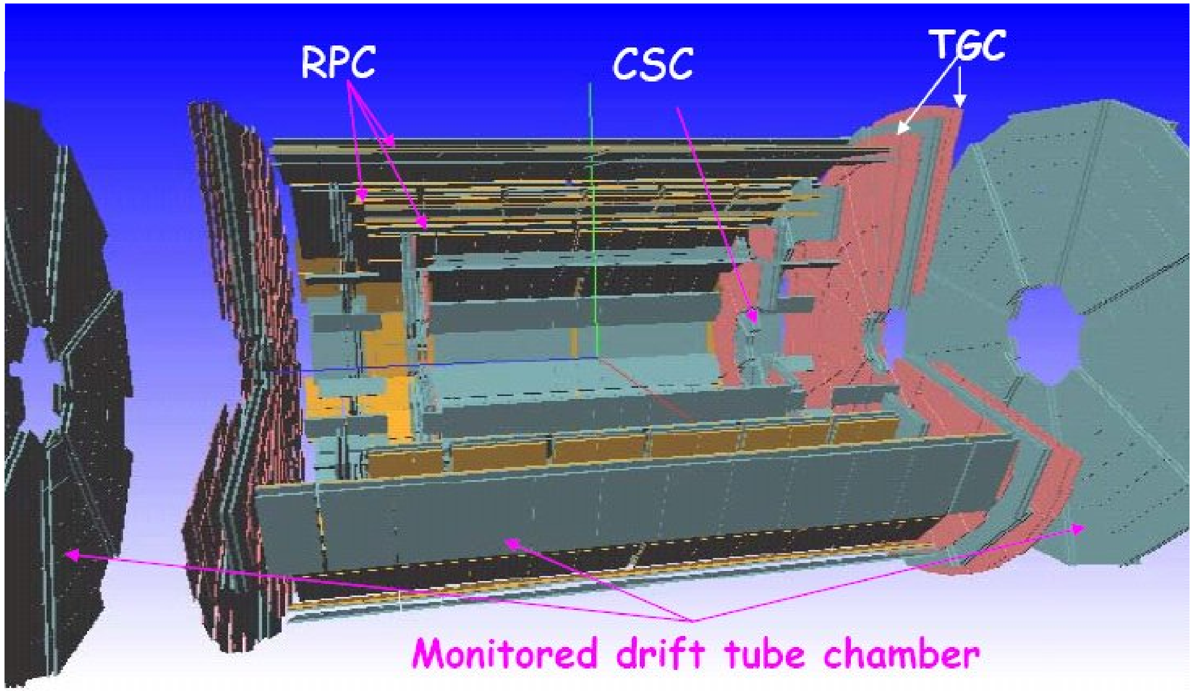
Several reasons could force a Tile FE upgrade:

Re-evaluated radiation doses

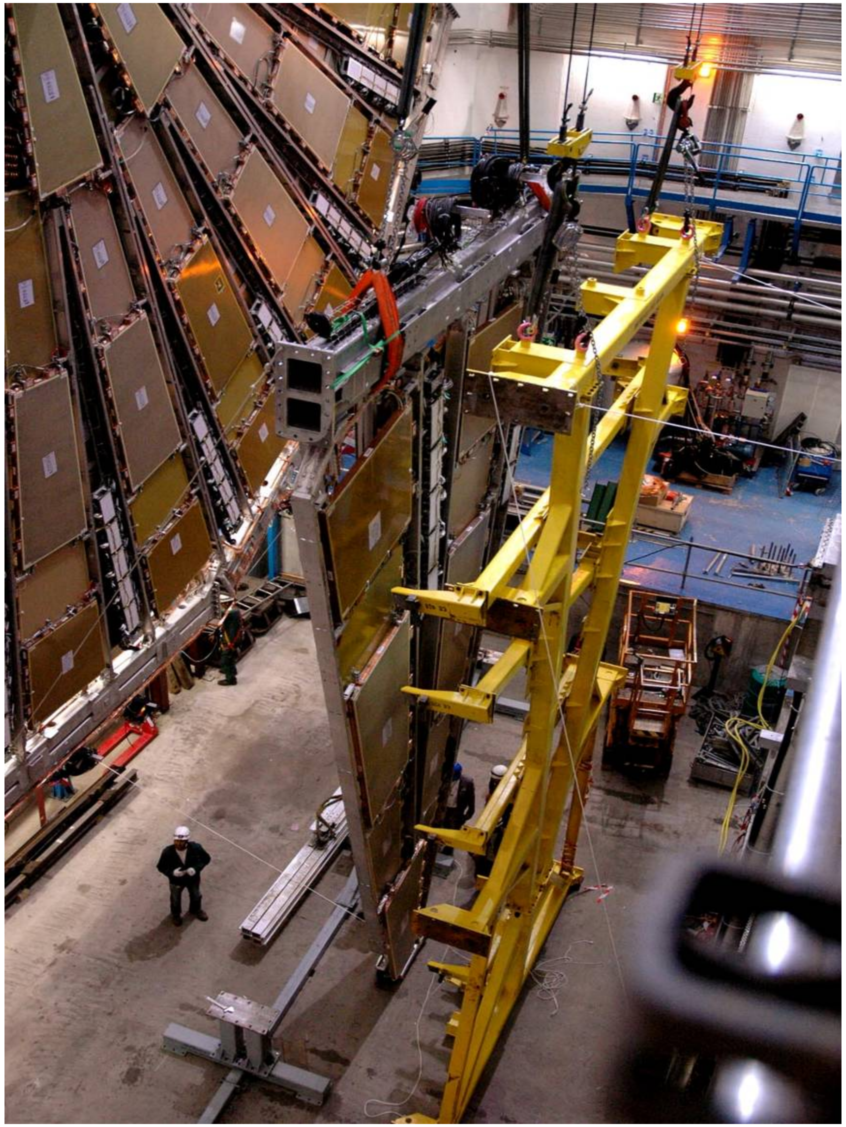
Desire to sample signal in BC time of 12.5 nsec

The Muon system



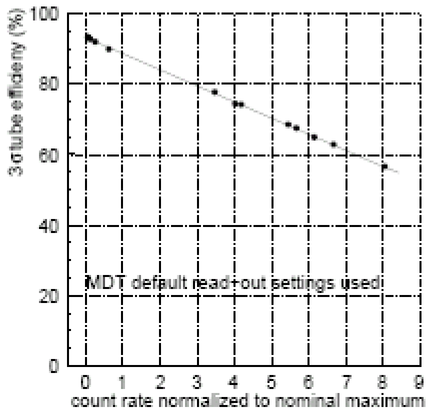


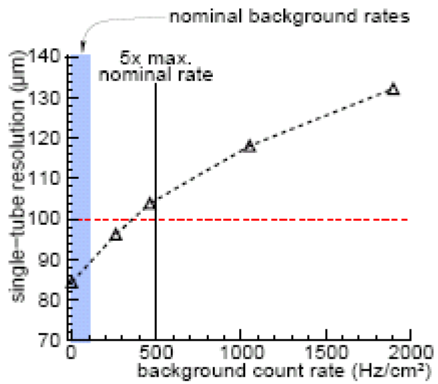
The Muon system – today



Muon system-high luminosity upgrade issues (MDT chambers as an example)

- Background counting rates of neutrons and gammas in the chambers
  Compare with nominal implies x10 . However including the safety factor we might get x 50 compared to nominal.
- Possible effects
  - Radiation damage to electronics
  - Aging
  - High occupancy⇒Inefficiency
  - Degradation of spatial resolution (space-charge fluctuation)



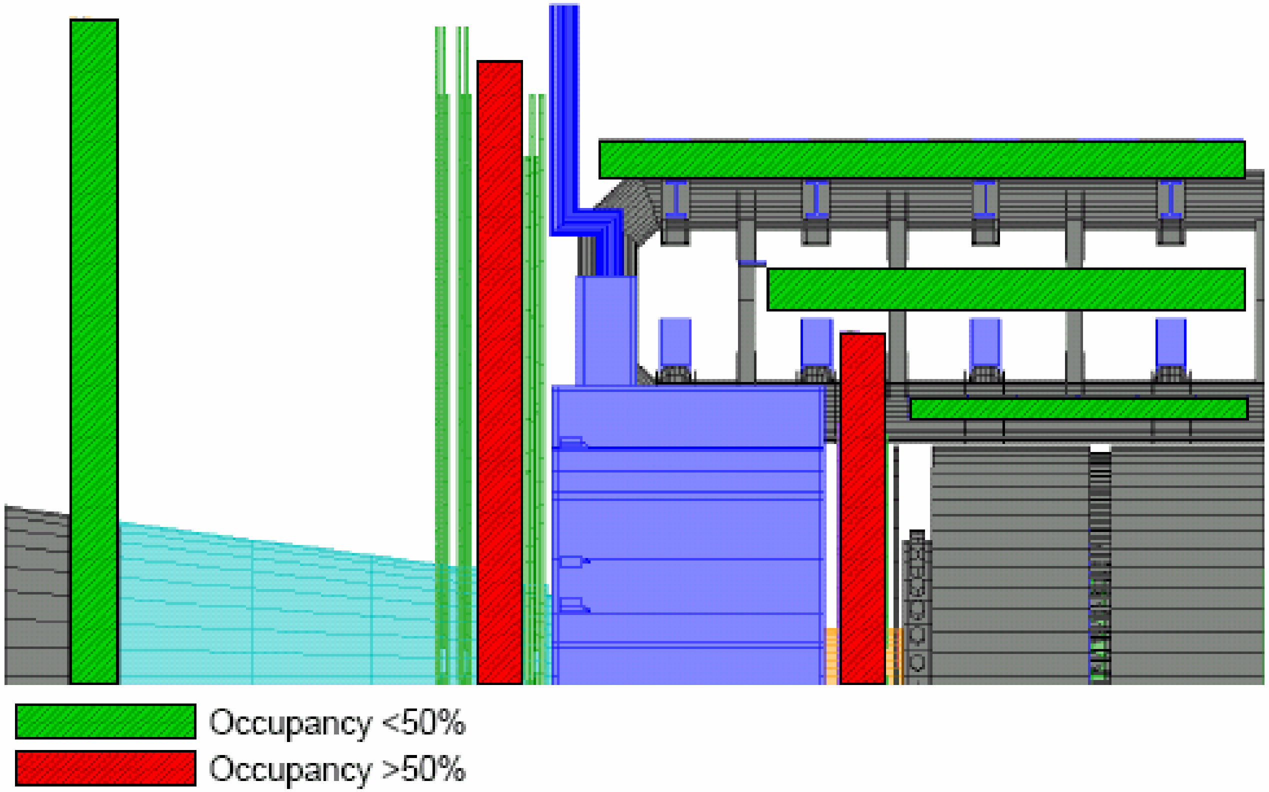


The seriousness of the background problem will be known in 2008.

R&D Phase 1: Studies which do not require eaxt knowledge of the level
R&D Phase 2: Detailed upgrade proposal

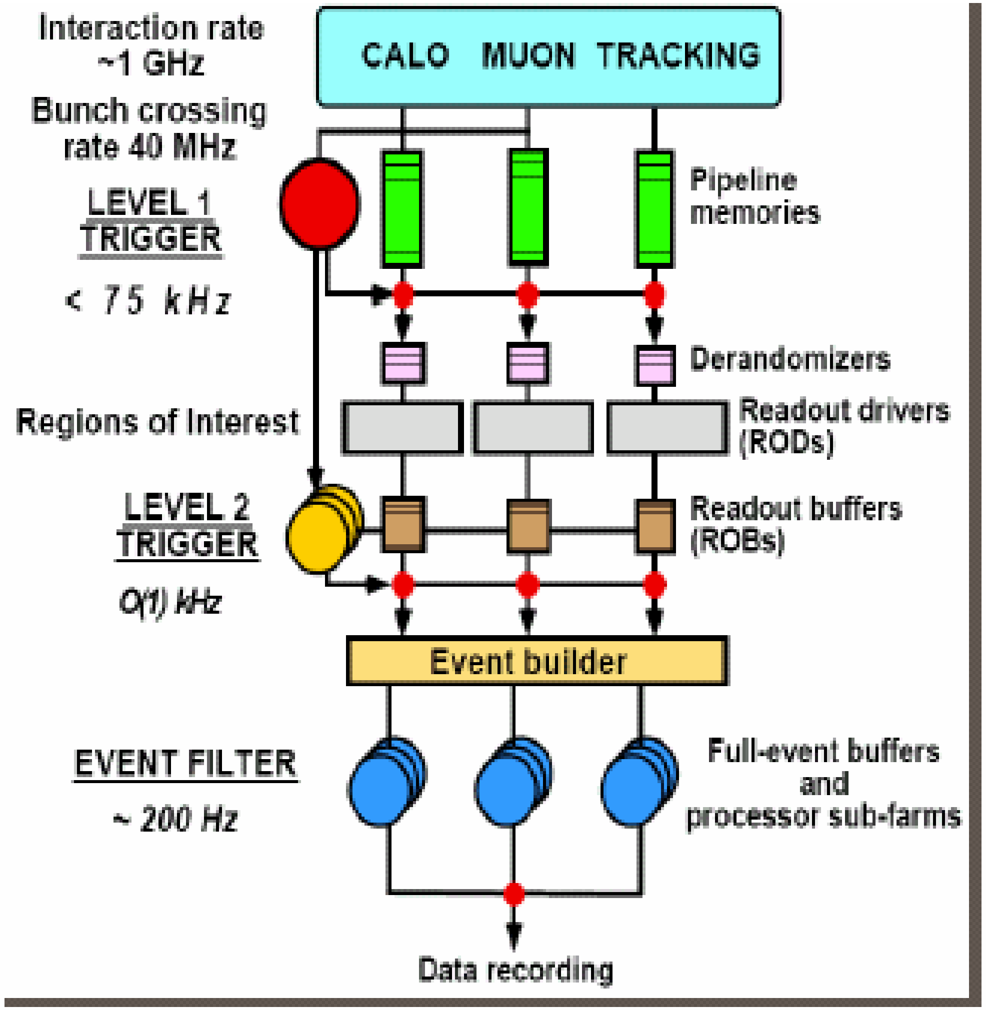
Muon system-high luminosity upgrade issues (cont.)

Limitations – Occupancies of the Chambers



In the worst-case scenario of extremely high rates the chambers in the inner and middle end-cap disk would have to be replaced by chambers with higher rate capability.

Trigger DAQ



- LVL1:
  - → synchronous
  - → algorithms in firmware
  - → maximum latency of 2.5 μs
- HLT:
  - → asynchronous
  - → algorithms in software
  - → processing time of
    - ~ 10 ms (LVL2)
    - ~ 1 s (EF)

Trigger DAQ – some upgrade issues

- increased radiation for on-detector trigger electronics
  - → permanent damage, single event upsets, ...
- change in the bunch crossing rate
  - → tight coupling of LVL1 to this quantity
- changes in the detector signals available for LVL1?
  - → more granular information (possibly better rejection)
    - e.g. possibility of having digitized LAr cell information
- increased number of electronic channels
  - → larger bandwidth needs
- increased occupancies, pile-up noise, ...
  - → degradation of algorithm performance
    - isolation cuts, fake objects, ...
  - → increased trigger rates
    - for fixed thresholds and efficiencies
  - → larger bandwidth needs

Electronics - BCO modifications

- BCOs considered
  - 12.5, 25, 50 and 75 ns
- Muon system
  - Muon drift tubes (MDT): performance OK at these rates
  - Cathode strip chambers (CSC): assessment needed
  - Resistive plate chambers (RPC): performance OK at these rates
  - Thin gap chambers (TGC): collection time too long for <25 ns → no good bunch ID
- Calorimetry
  - LAr: in case of BCO less than 25 ns → need for modification of back-end electronics
- Trigger/DAQ
  - 12.5 ns will require significant modification of LVL1 .
- TTC electronics in the front-end
  - Any BCO frequency > 40 MHz would require replacement of components (crystals / QPLL) → substantial work
- Read-out links speed limited to 32-bit/40 MHz
  - Any BCO frequency > 40 MHz would lead to combining several crossings in one data sample
  - Extra processing power necessary to disentangle them → change of back-end electronics

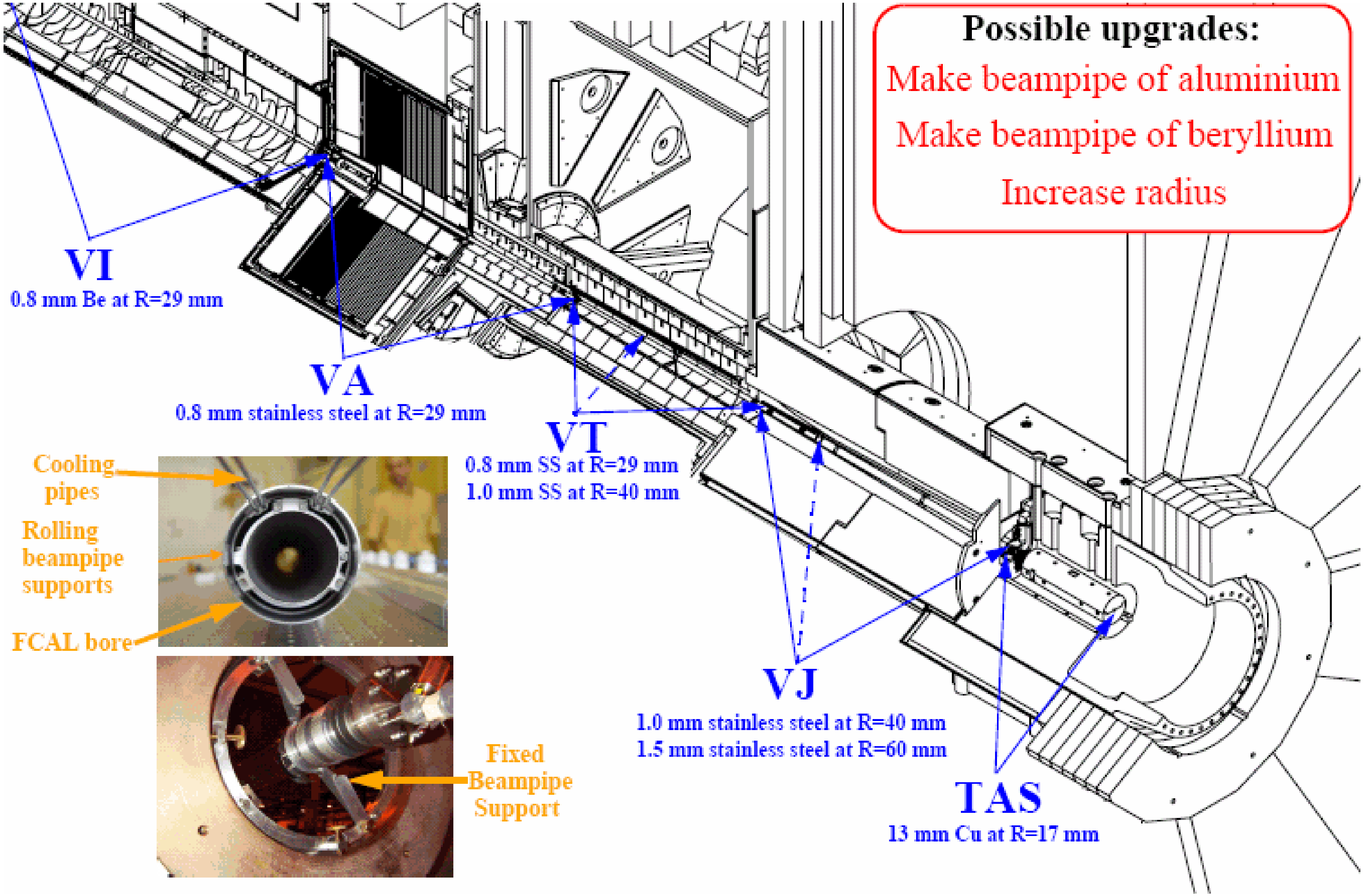
The beam pipe

Possible upgrades:

Make beampipe of aluminium

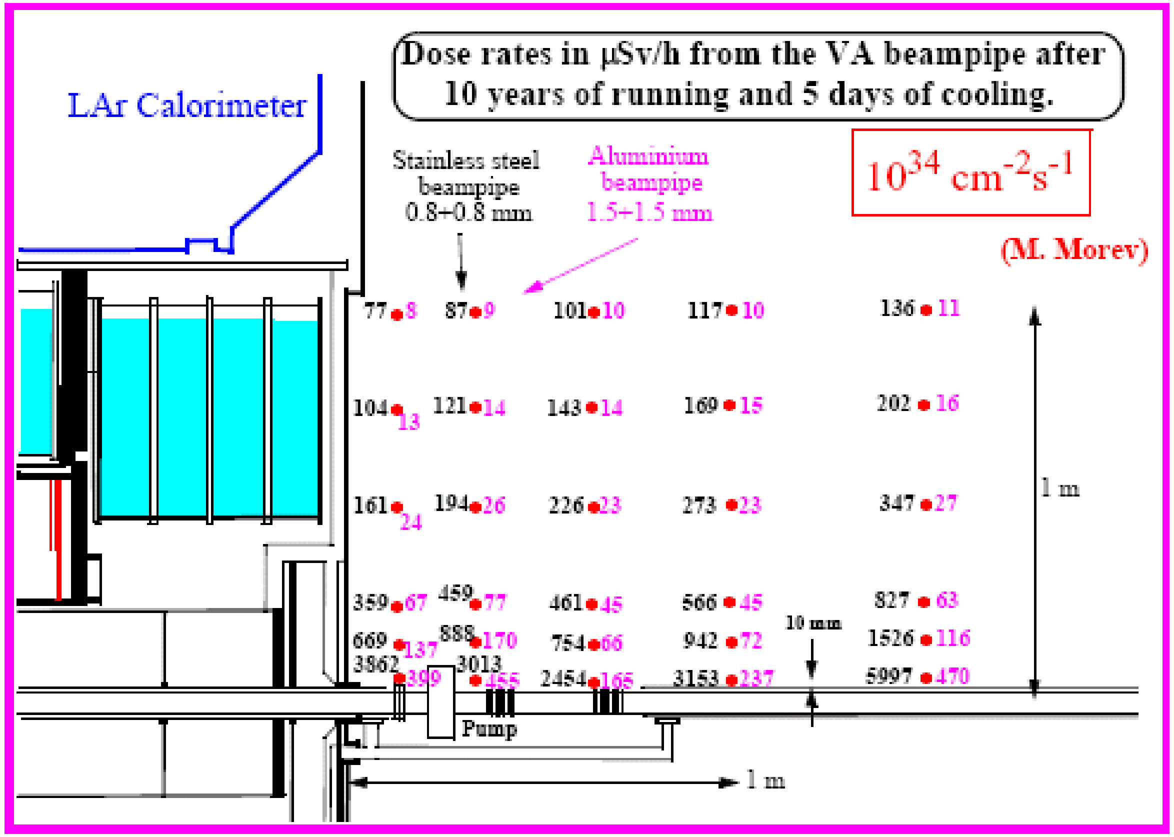
Make beampipe of beryllium

Increase radius



An aluminium beampipe

An aluminium beampipe has been proposed as an upgrade before running at 10^{34} $cm^{-2}s^{-1}$ in order to reduce the activation. Bellows etc could be a problem.



For long running and cooling times the advantage of an Aluminium beampipe is smaller.

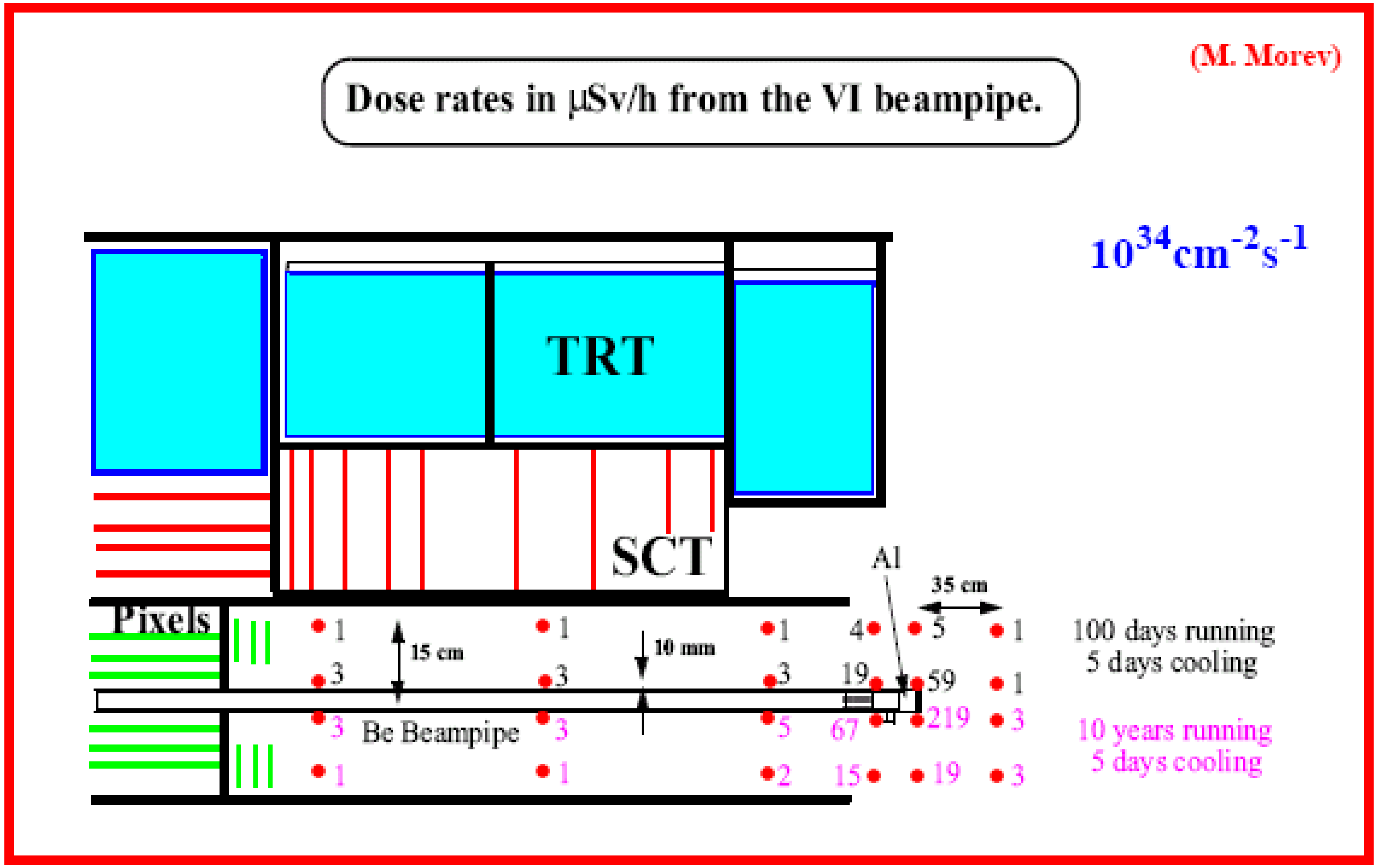
The ratio of the doserate from a steel and an aluminium beampipe with the same thickness.

Cooling time	Running time 5000d	1000d	100d	30d
1 d:	9	13	23	23
5 d:	9	15	76	181
7 d:	8	14	68	164
30 d:	4	7	22	39

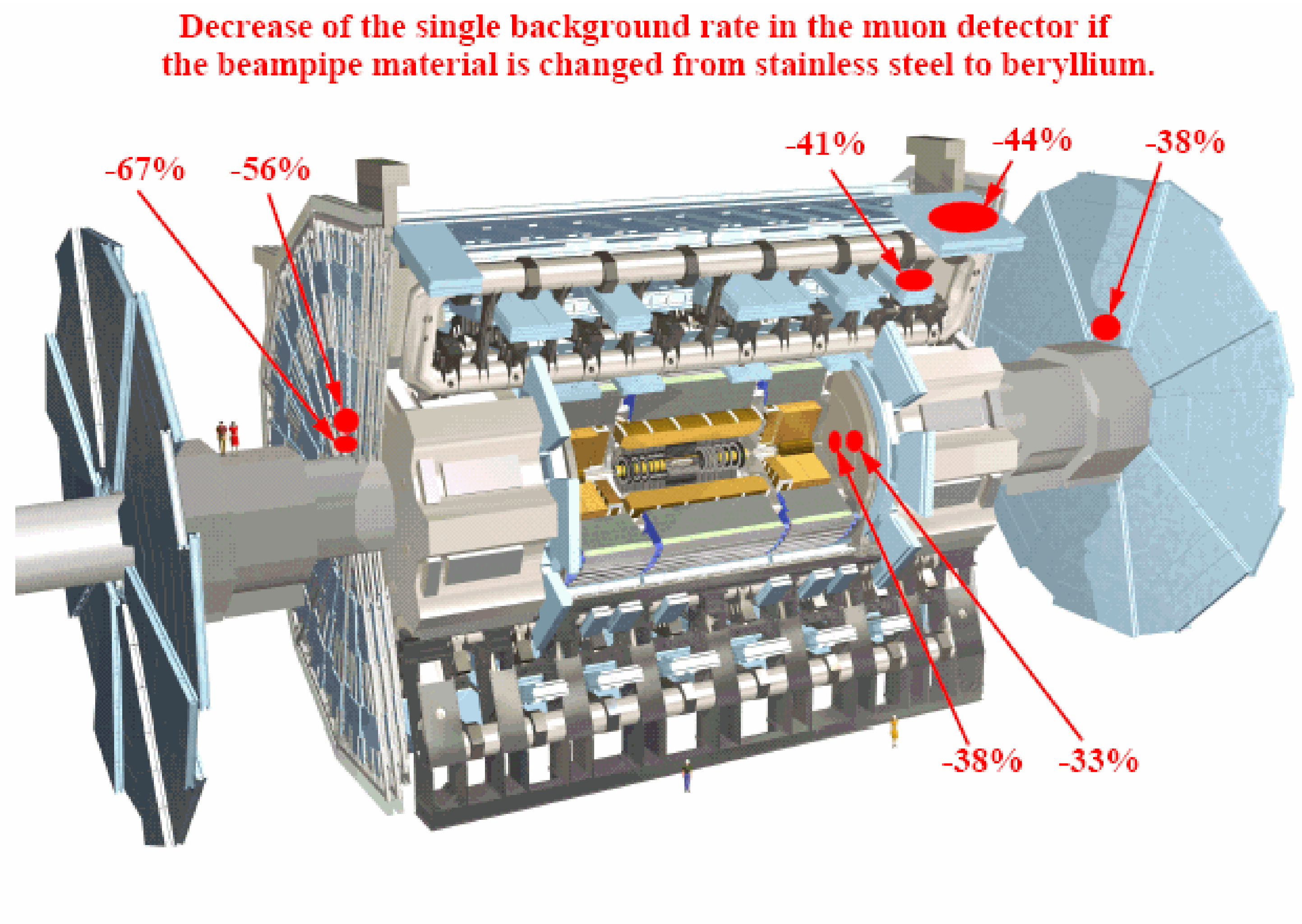
A beryllium beampipe

At SLHC we will have to consider going to a beryllium beampipe.

The activation of the beampipe will then not be an issue.



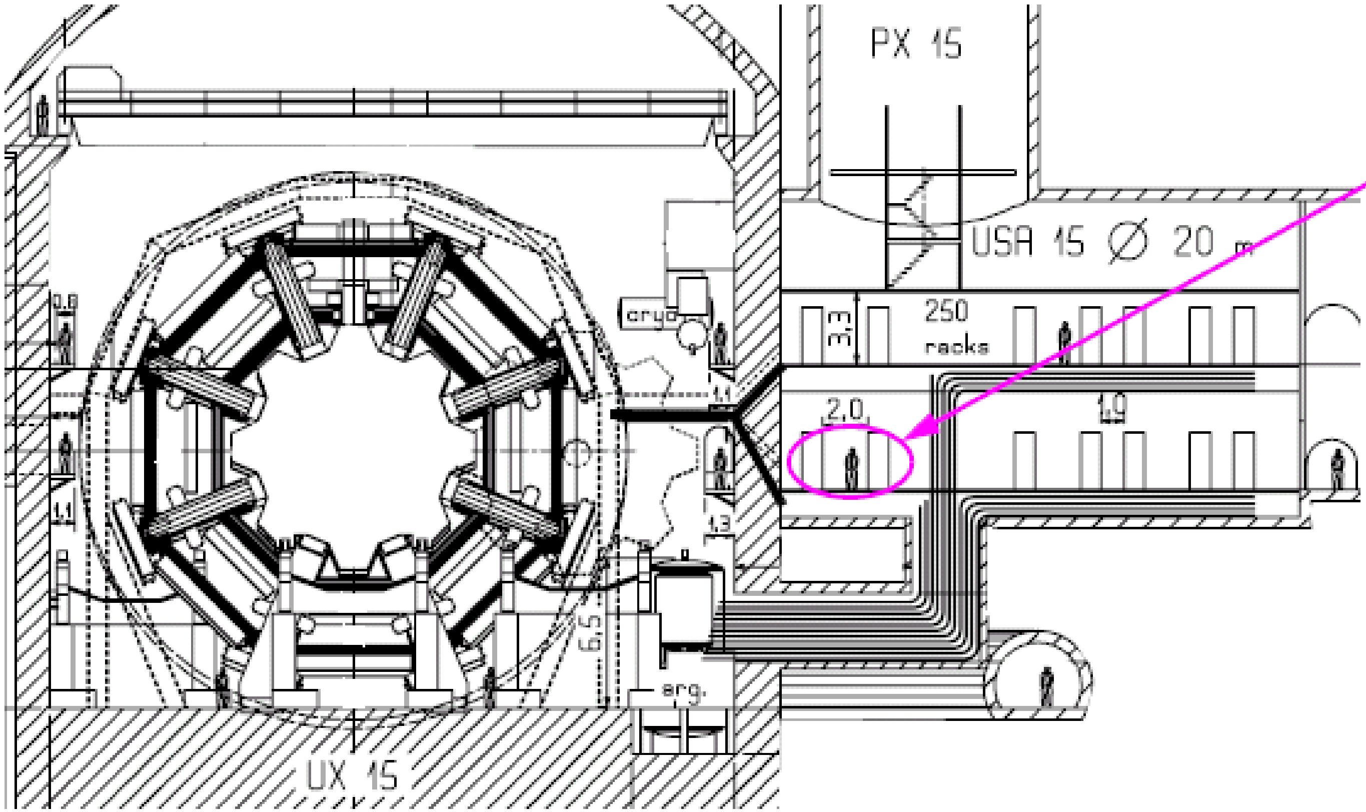
A beryllium beampipe (cont.)



The counting room-high luminosity upgrade issues

The 2 m thick wall between the ATLAS cavern and the USA15 electronics cavern was designed such that USA15 could be designated as a simple controlled area (i.e. unlimited access with film badge).

The present limit for a simple controlled area is 25 µSv/h based on maximum does of 50 mSv per year. This is expected to be lowered to a maximum dose of 6 mSv per year.



Prediction for 10^{34} is < 4 µSv/h

USA15 would not be a simple controlled area at 10^{35} !

A strengthening of the wall could decrease the rate with a factor 2.

Questions addressed to ATLAS

- **DO THE EXPERIMENTS RULE OUT THE "LONG-BUNCH SCENARIO" WITH ABOUT 500 EVENTS PER CROSSING?**

  Or are there physics scenarios and detector upgrade options where this scenario could be of interest?

- **CAN "SLIM" S.C. MAGNETS BE INSTALLED DEEP INSIDE THE UPGRADED ATLAS AND CMS DETECTORS (E.G., STARTING AT 3 or 6 m FROM THE IP) AND UNDER WHICH BOUNDARY CONDITIONS, SUCH AS ENVELOPE, VOLUME, MATERIAL, OR FRINGE FIELD?**

  This concerns both

  - dipoles-early beam separation scheme
  - quadrupoles- locally modify the behaviour of ß in the IP region

- **PUSH THE ENTIRE INNER TRIPLET SIGNIFICANTLY CLOSER TO THE IP**

  (L* = 13 m has been suggested)

Warning

- There are no binary answers to those questions.

- We can however point at strong preferences

Answers depends on

- The Physics we will find at the LHC
- The first operation experience of the detectors
- Real radiation levels-all we have today are simulations
- Details (mass, volume, materials)about the magnets and services to be put inside ATLAS

Q1:Long bunches-75 ns spacing 500 events/bunchcrossing?

Why we don't like it.

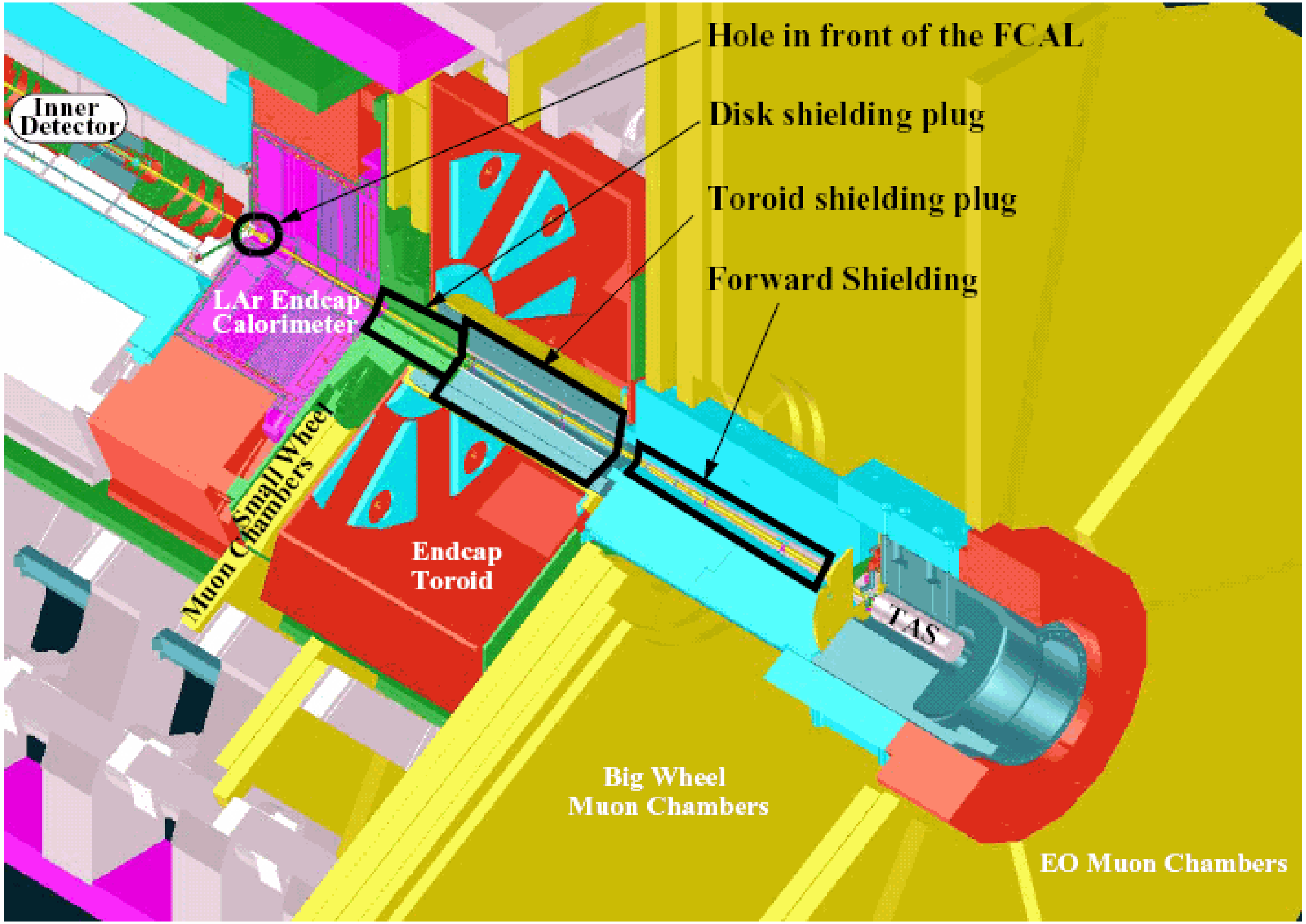
Many problems and no advantages !

- Tracker would need very high granularity to cope with 500 inelastic interactions per bunch crossing. Cost + material + space for services.
- LArg calorimeters would have too much pile-up. Low mass physics (WW scattering, light Higgs couplings...) would be impossible; high mass would be OK still.
- Electronics problem with high instantaneous rate
- Shorter beam lifetime for the same peak luminosity
  $\Rightarrow$ Lower integrated luminsoity

We only care about **integrated luminosity** and

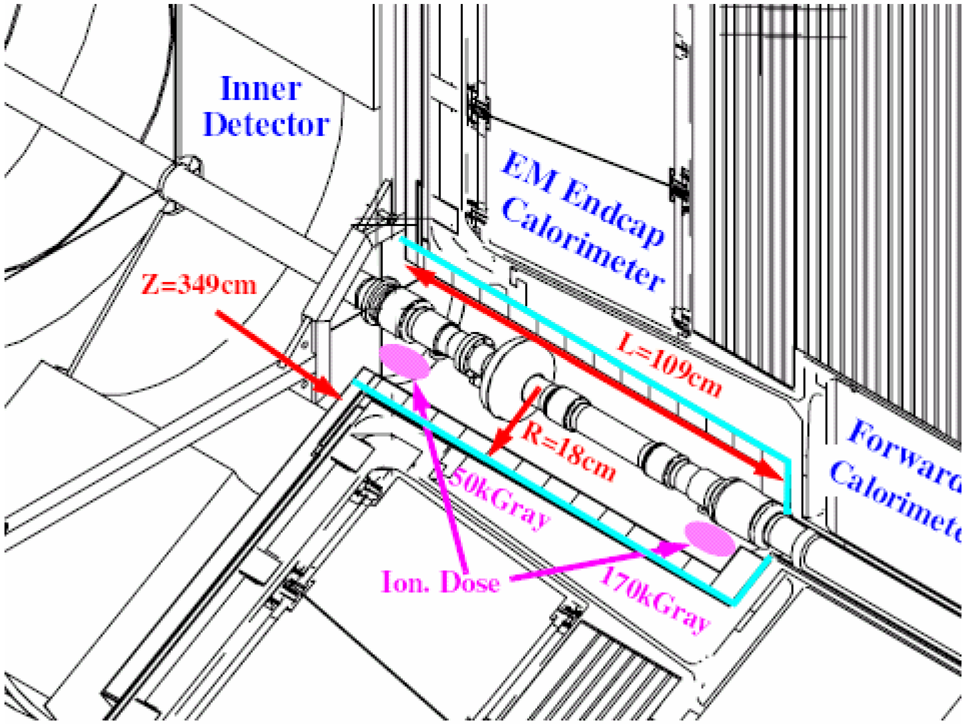
we want the **maximum annual integrated** luminosity at **minimum peak luminosity**

Q2: Slim magnets inside ATLAS



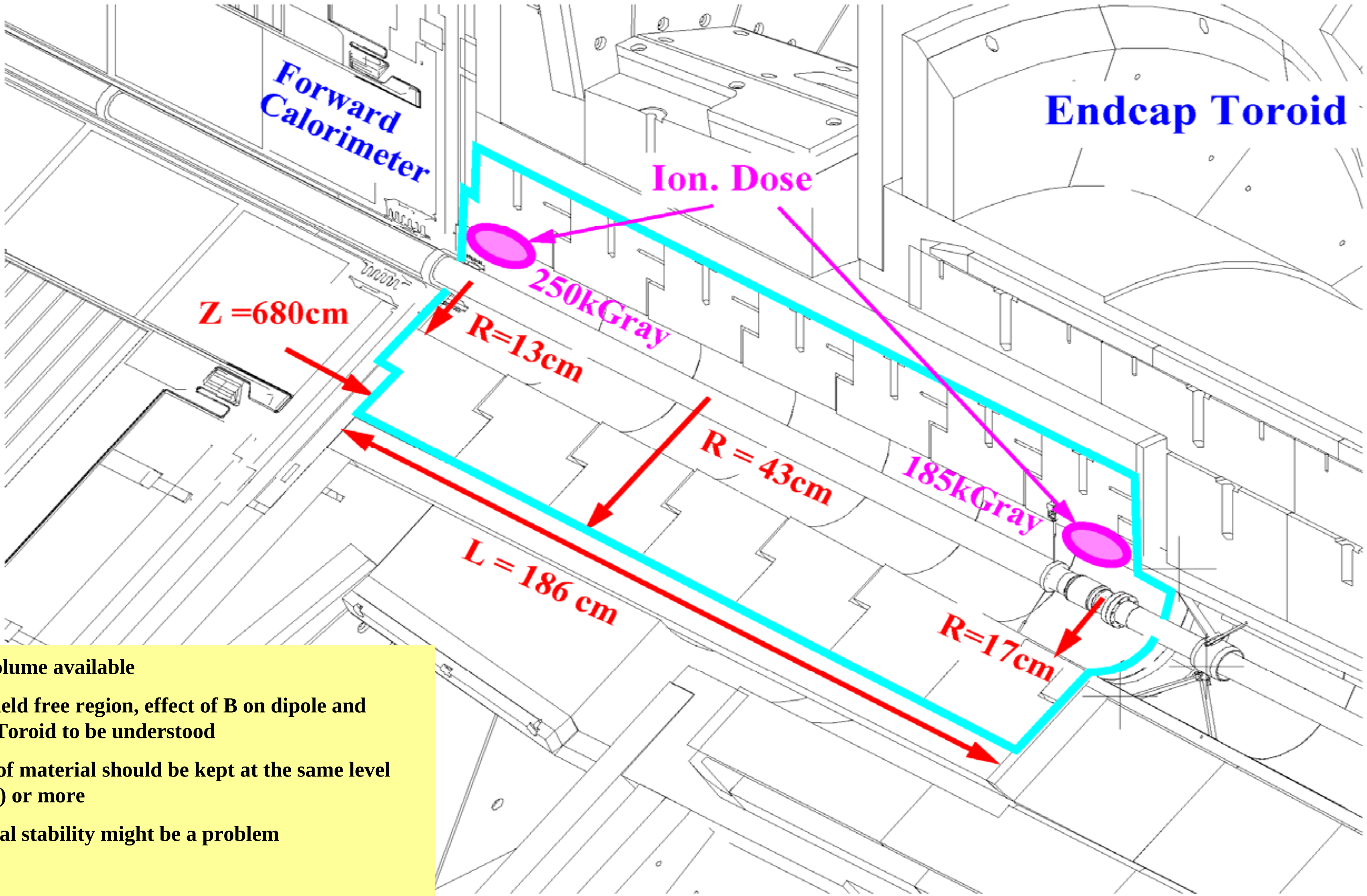
Position 1 – Replace JM shield

Replace the JM shield in the alcov in front of FCAL by a low mass magnet



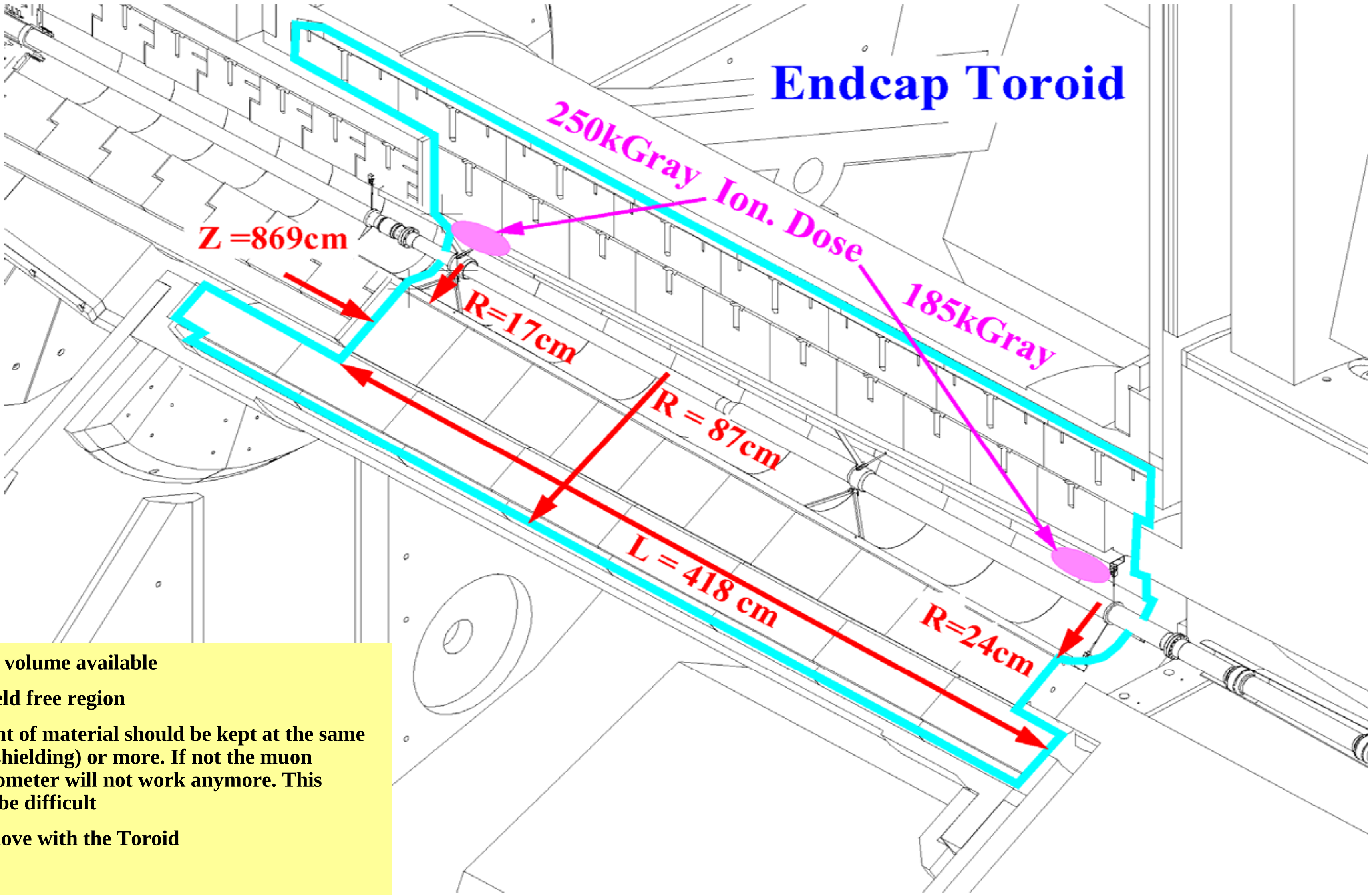
- Small volume
- Neutron radiation in the Inner detector will increase
- Interactions in the magnet will increase the background
  - The resolution of FCAL will be affected
  - Activation
  - Magnet service routing

Position 2- Disk shielding plug



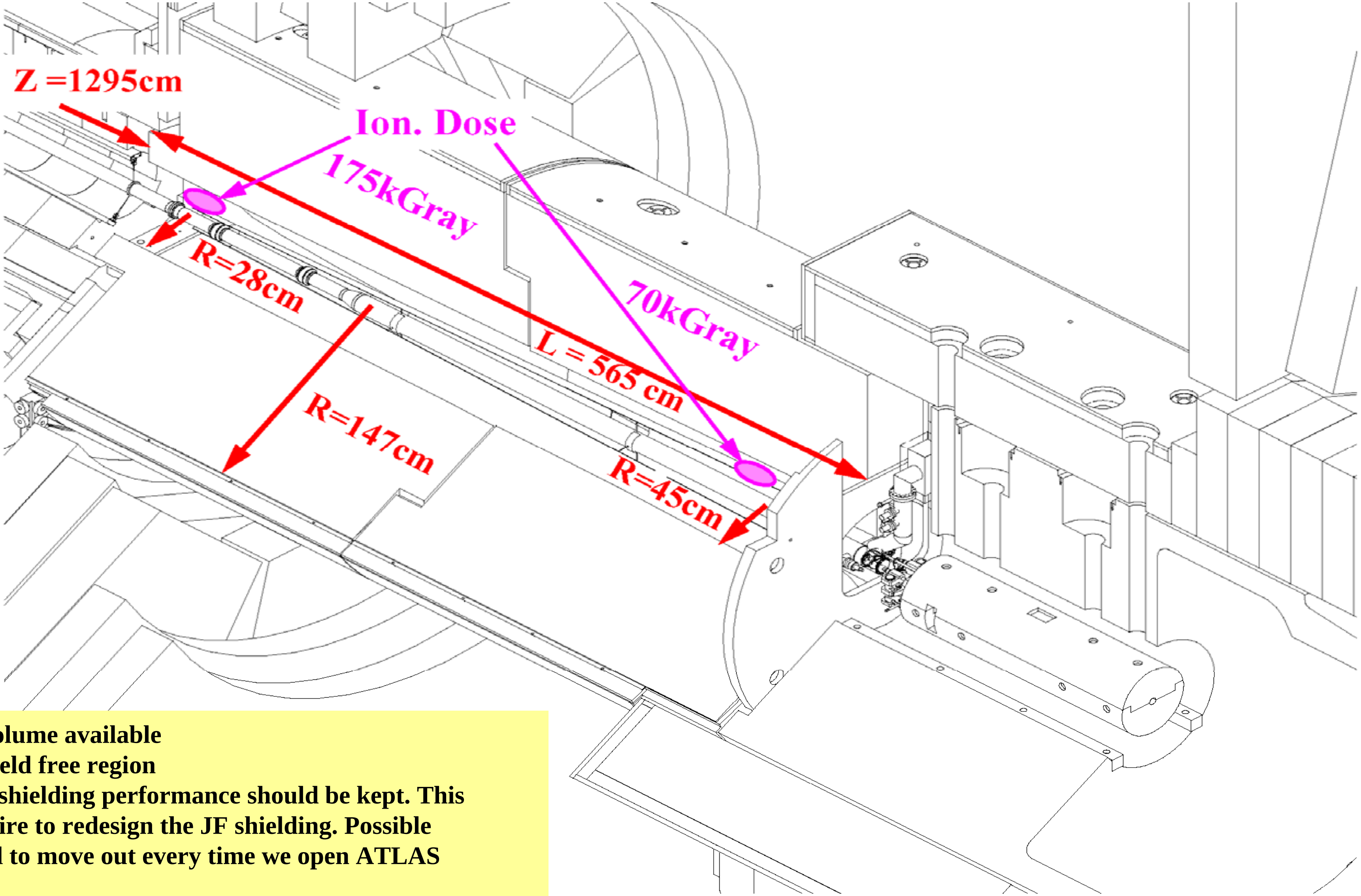
- Large volume available
- Not in a field free region, effect of B on dipole and dipole onToroid to be understood
- Amount of material should be kept at the same level (shielding) or more
- Mechanical stability might be a problem

Position 3-Endcap toroid shielding



- Large volume available
- In a field free region
- Amount of material should be kept at the same level (shielding) or more. If not the muon spectrometer will not work anymore. This might be difficult
- Will move with the Toroid

Position 4- Forward Shielding



- Large volume available
- Almost field free region
- Original shielding performance should be kept. This might require to redesign the JF shielding. Possible
- Will need to move out every time we open ATLAS

Q3:Push the inner triplet signifacantly closer to the IP? (L* =13m ?)

- Total redesign of the shielding and its structures
- Space available has to be compatible with Big Wheels. i.e. Magnet has to fit within the Shielding Envelope.
- Magnet will have to be removed each shut down to allow access to the ATLAS detector. (So every year during the winter shut down)
- Access time – Removal of the Magnet and re-installation needs to be done in day or two otherwise it will cut down on the already very limited access time we have.
- Stability questions needs to be addressed.
- Looks like more than an “upgrade”.

Conclusions

- Aim of the upgrade is to preserve the capabilites of the ATLAS detector at a luminosity of $10^{35}/cm^2/sec$
- We need to replace the Inner Detector but we want to minimize other changes. Especially we want to avoid significant changes to large mechanical structures and also we want to minimize changes to services (cables and pipes)
- We want maximum annual integrated luminosity at minimum peak luminosity
- 75ns/500 events per bc has many problems and only disadvatages for us
- We need to be guided by
  - Physics at 7 TeV
  - Early operation experience
  - Real radition levels at the LHC
- We have started an active R&D programme
- **Main focus is to get started with ATLAS autumn 2007**

ATLAS autumn 2007