CMS Views on SLHC upgrades

Physics Motivations

Implications of scenarios for CMS

SLHC is about the physics!

- We should be led by getting the best physics out of an upgraded machine/detector
  - Not by the highest peak luminosity
  - Even largest integrated luminosity may not be the most important metric
  - Issues
    - Integrated luminosity
    - Backgrounds
    - Acceptance
    - Pile-up

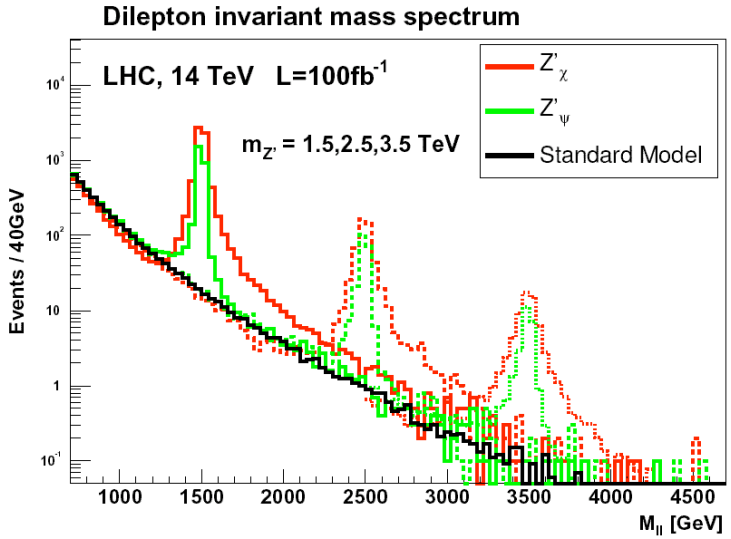
Some Physics themes

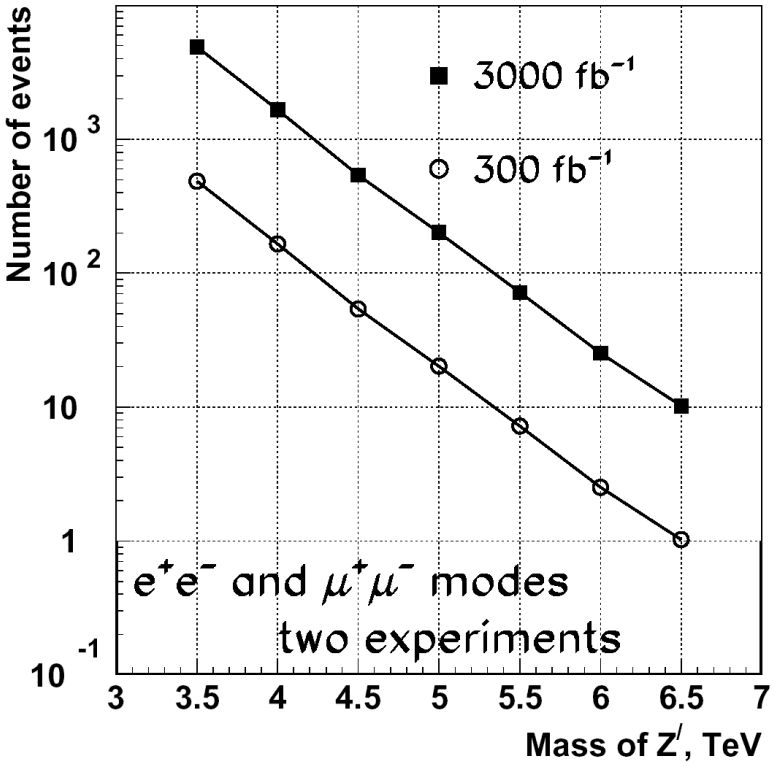
- Different physics channels require different conditions
- Three main directions
  - Damn the torpedos - FULL Luminosity
  - Lots of quality luminosity
    - Luminosity leveling?
  - Forward acceptance
- We won't know which is the most important until we have first data from the LHC
  - Important not to eliminate a physics opportunity until we are sure it makes sense to do so

SLHC Physics: Extra gauge bosons

- SLHC extends reach for Z'
  - Cross sections fall with E
  - SLHC gives access to higher E
- Good electron resolution required (including understanding saturation)

Just give us the Integrated Luminosity!



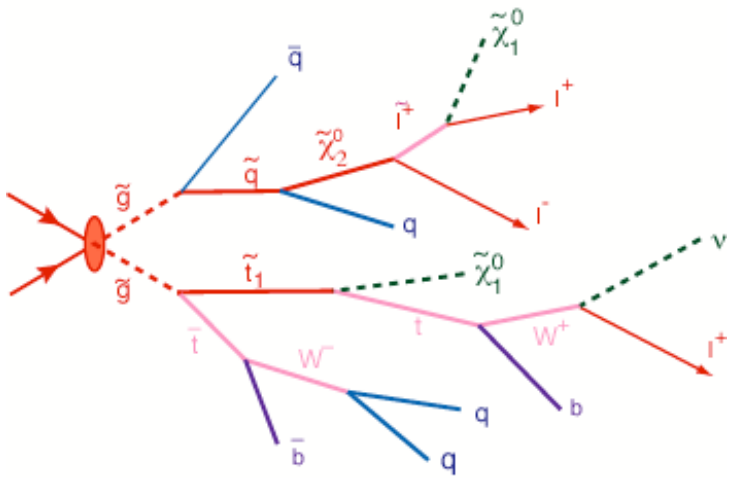


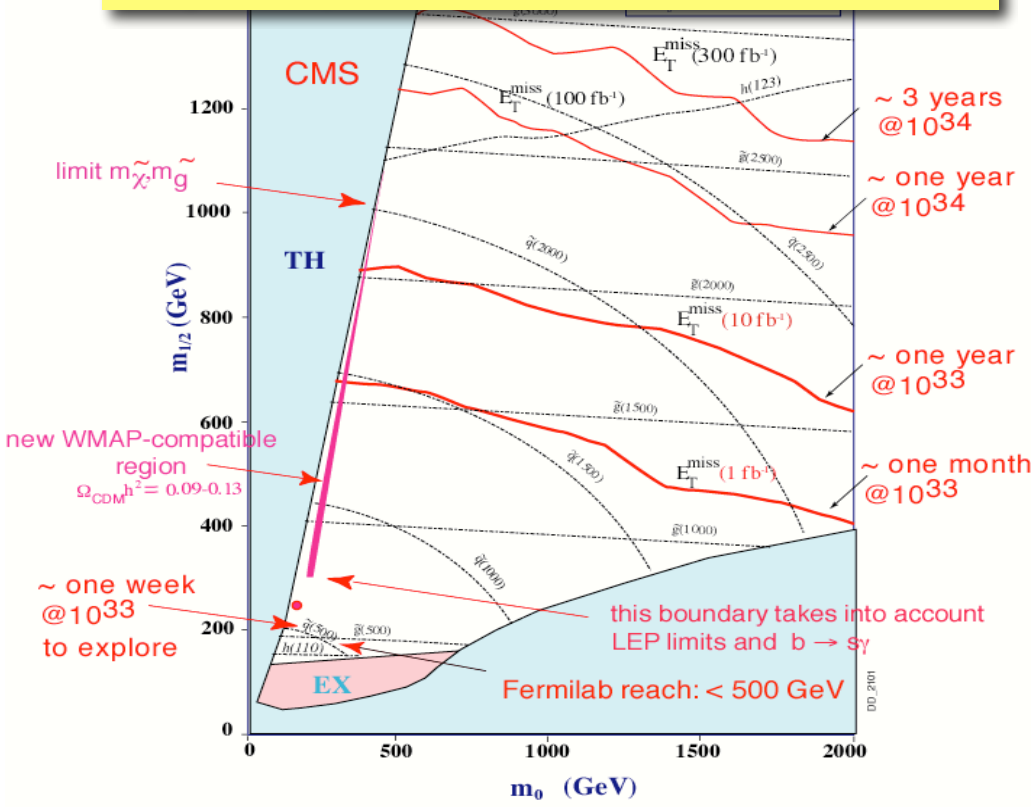
Z' mass (TeV)	1	2	3	4	5	6
$\sigma(Z' \to e^+e^-)(fb)$	512	23.9	2.5	0.38	0.08	0.026
$\Gamma_{Z'}$ (GeV)	30.6	62.4	94.2	126.1	158.0	190.0

SUSY searches - measurements

- SLHC statistics will be vital in reaching understanding of complicated SUSY channels
  - Sparticles seen, but statistics for reconstruction limited at LHC
- Performance of the detector here is vital
  - B-tagging
  - Lepton id

Here we need a lot of Integrated Luminosity, but needs to be high quality. Lower pile-up may be important.

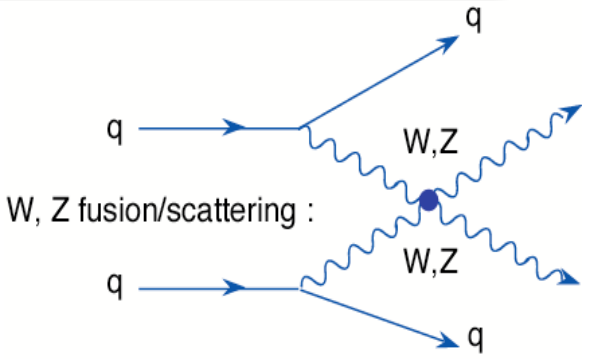




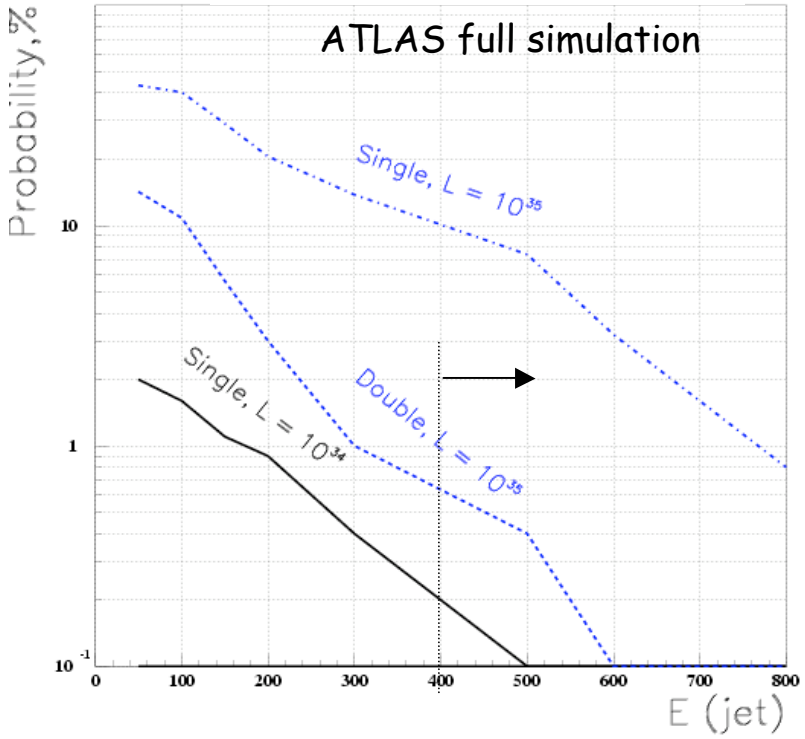
What if no Higgs is found?

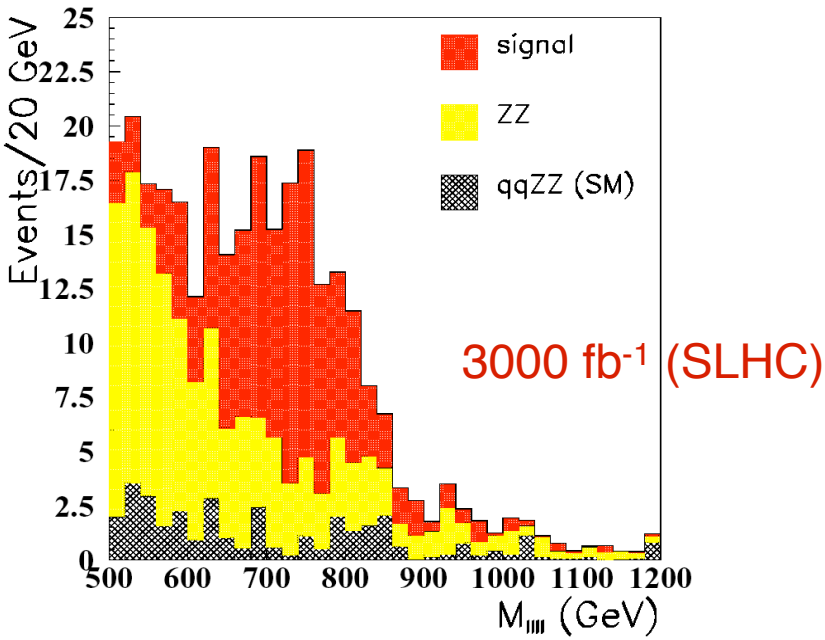
Forward tagging is essential

- Will need to look at WW scattering
  - Some mechanism required to avoid unitarity violation
- Forward Jet Tagging Essential

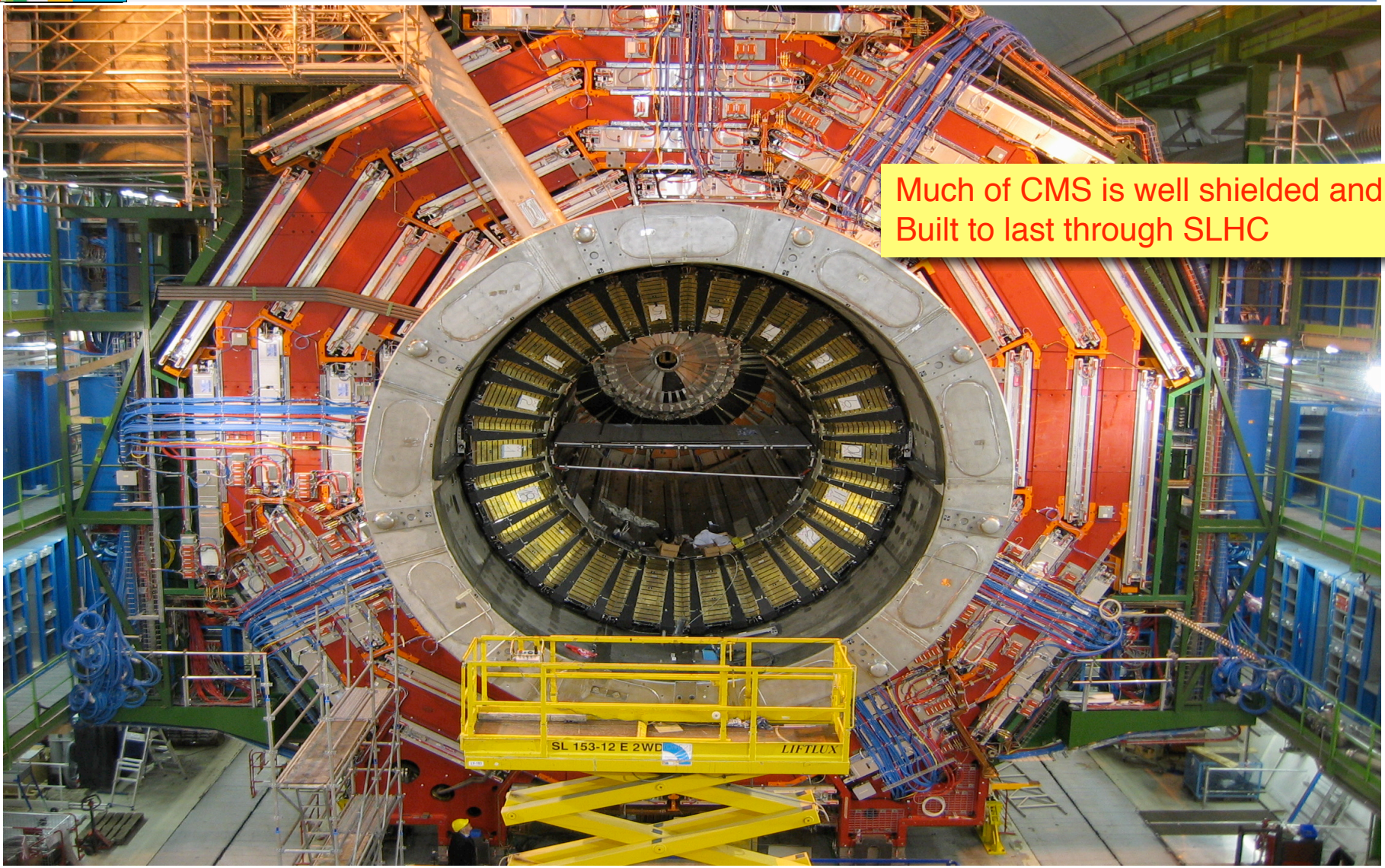


Fake fwd jet tag ($|\eta| > 2$) probability from pile-up (preliminary ...)

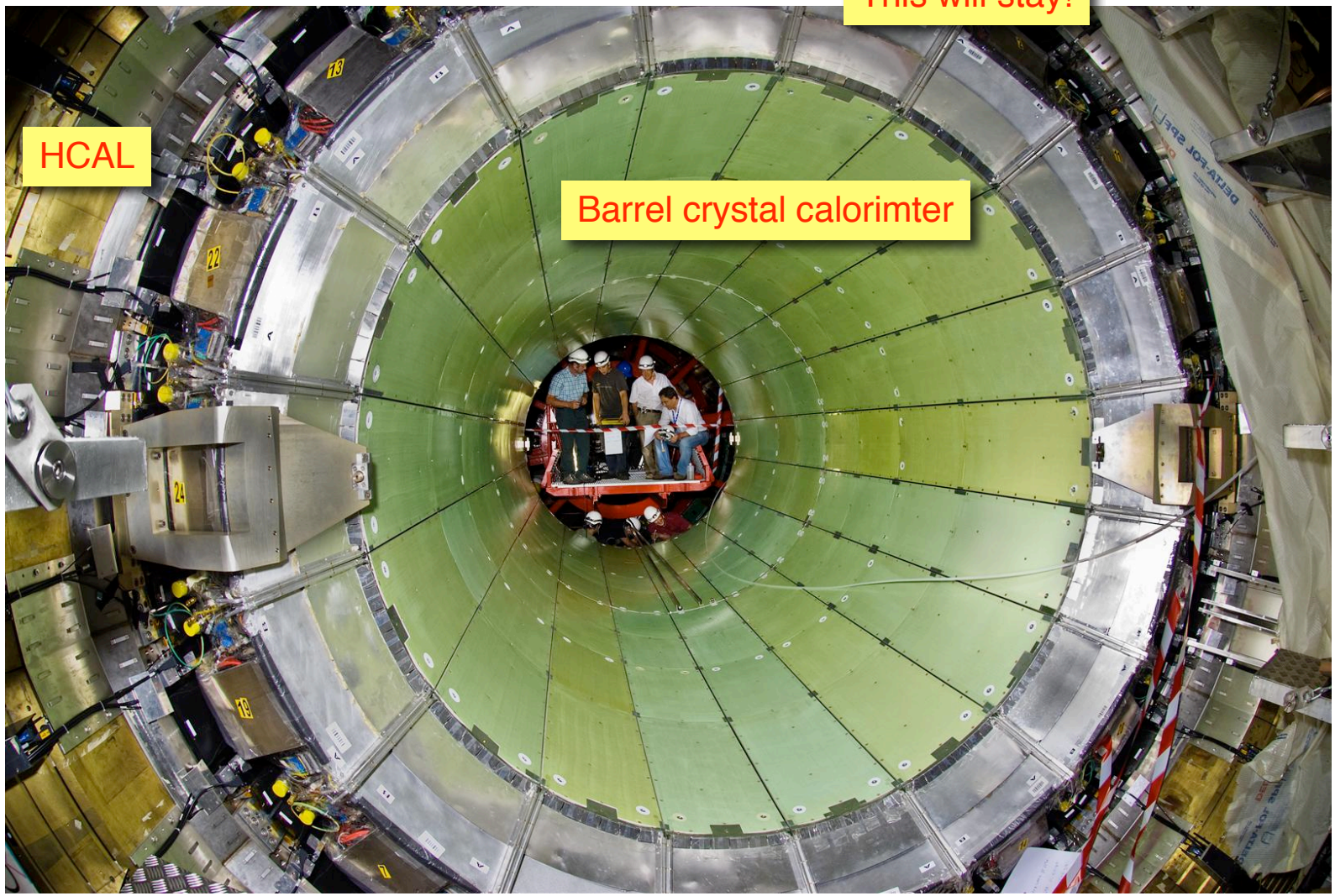




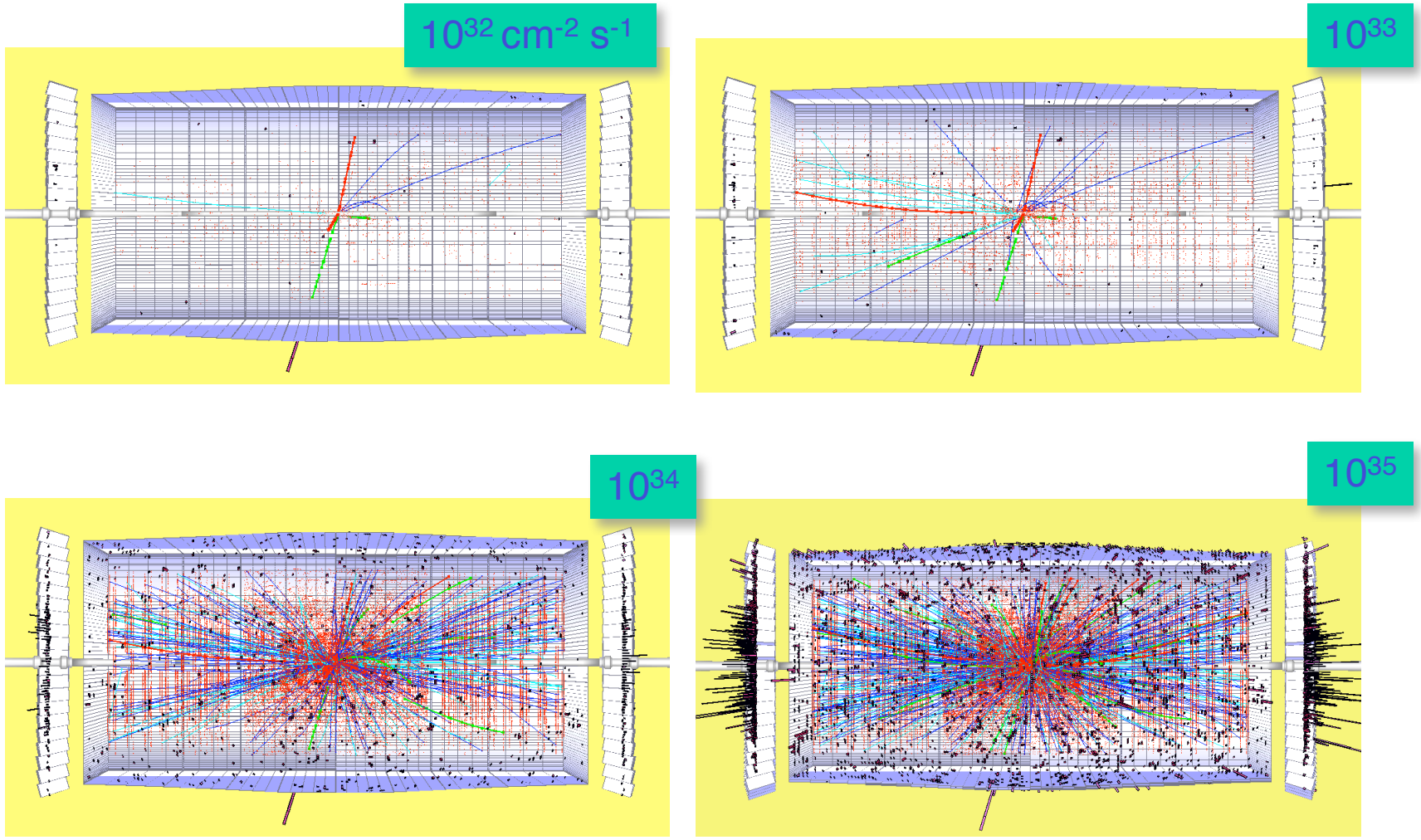
CMS - What stays, what goes…



Reminder what we need to upgrade



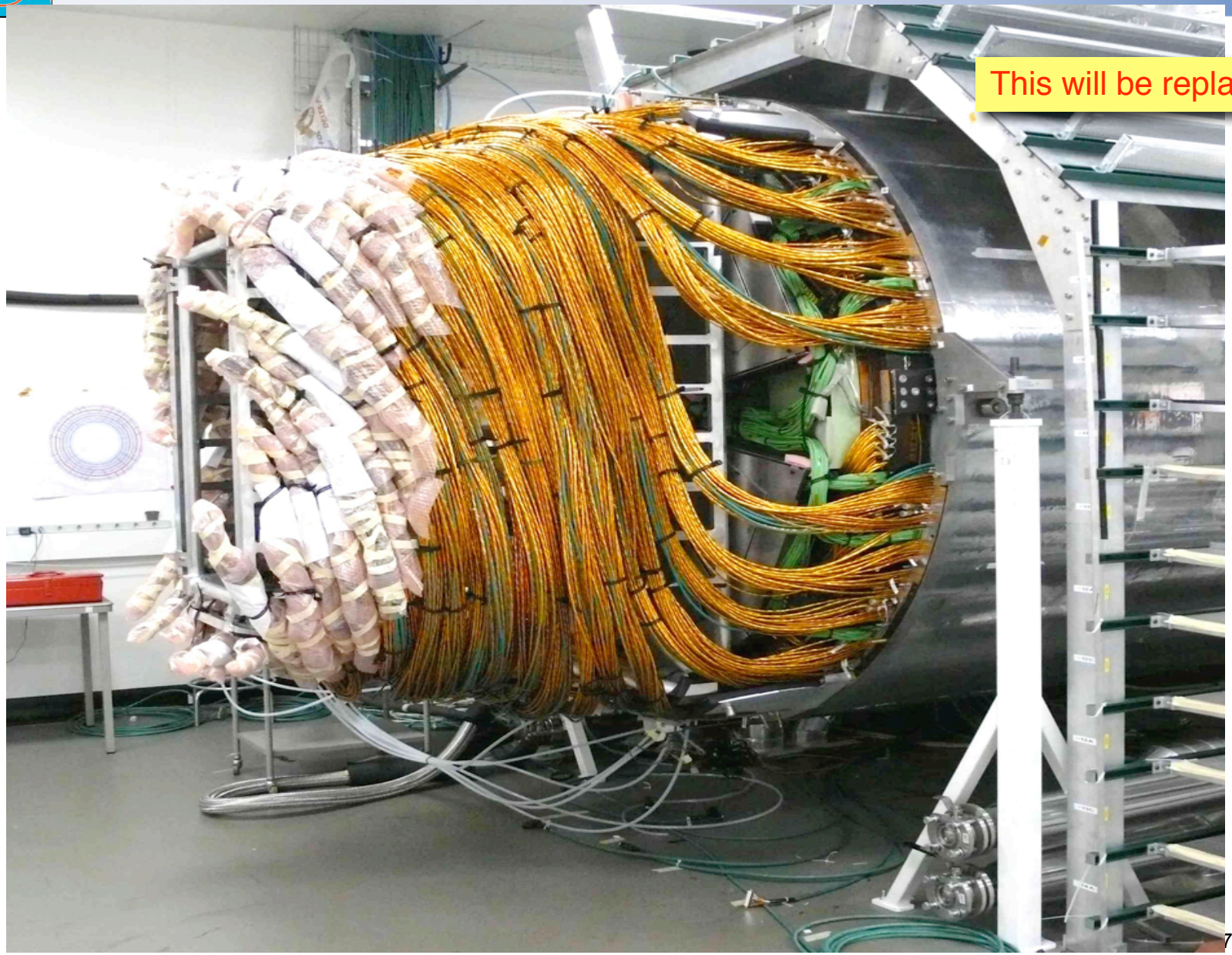
CMS from LHC to SLHC



The tracker is the key detector which will require upgrading for SLHC

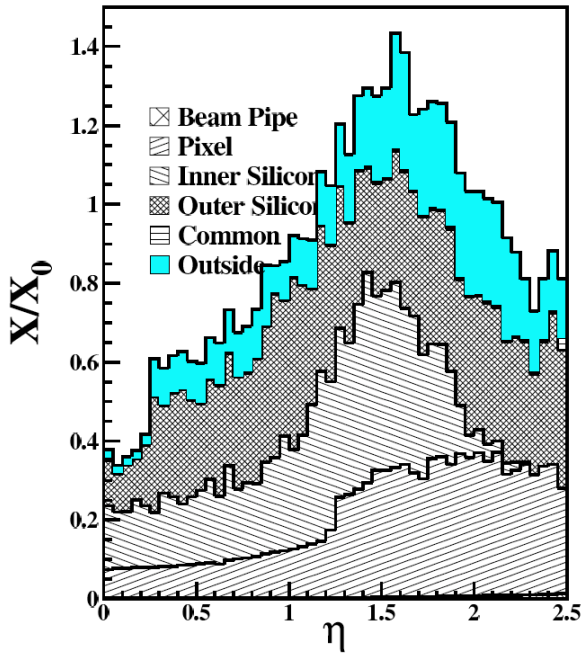
I. Osborne

Tracker Readied for Transport to Pt5



Key issues for tracker upgrades

- Power
  - How to get current needed to the electronics
  - More complicated front ends will want more power
    - DC-DC converters, Serial powering
- Material Budget
  - Can we build a better/lighter tracker?



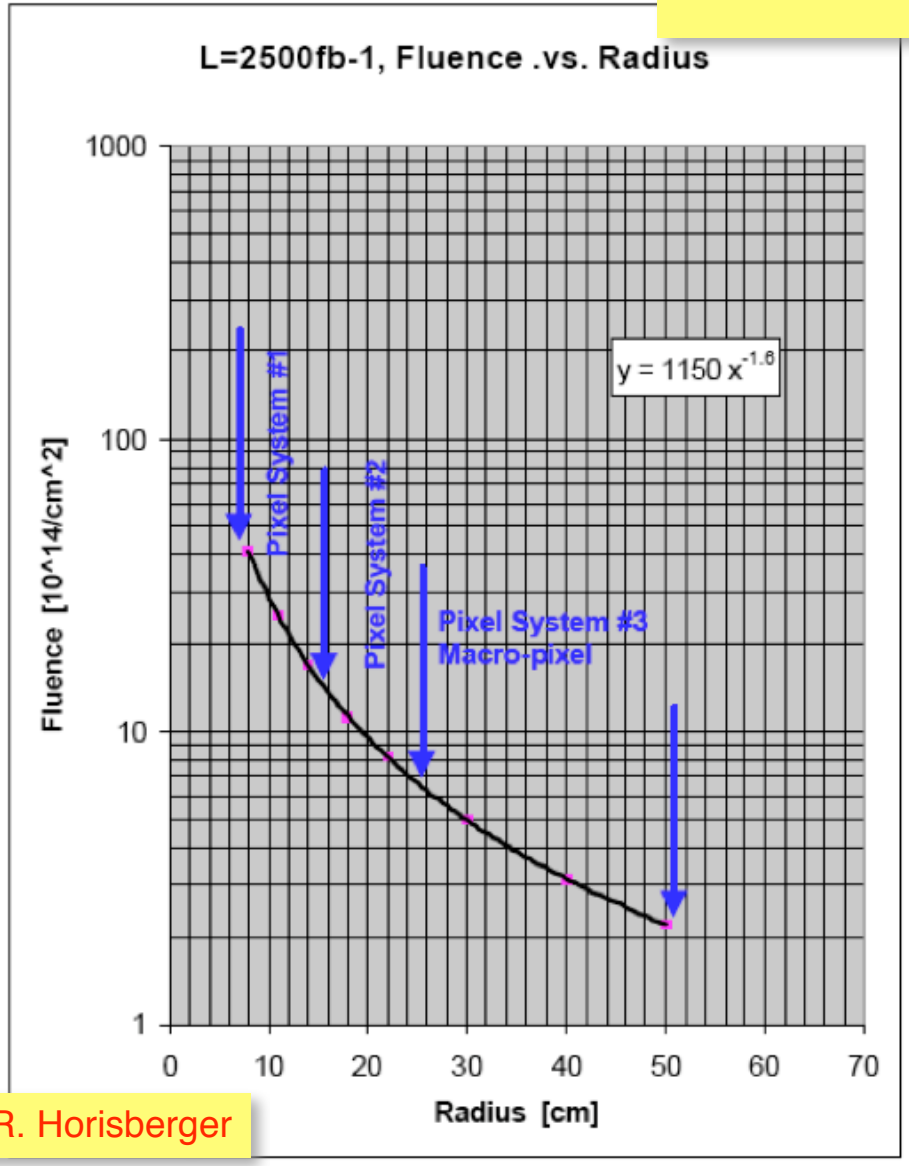
Tracker R&D focus

- Performance and detector layout
- Sensor material and operation
- Outer tracker readout system definition
- Pixel system and triggering
- Manufacture and material budget

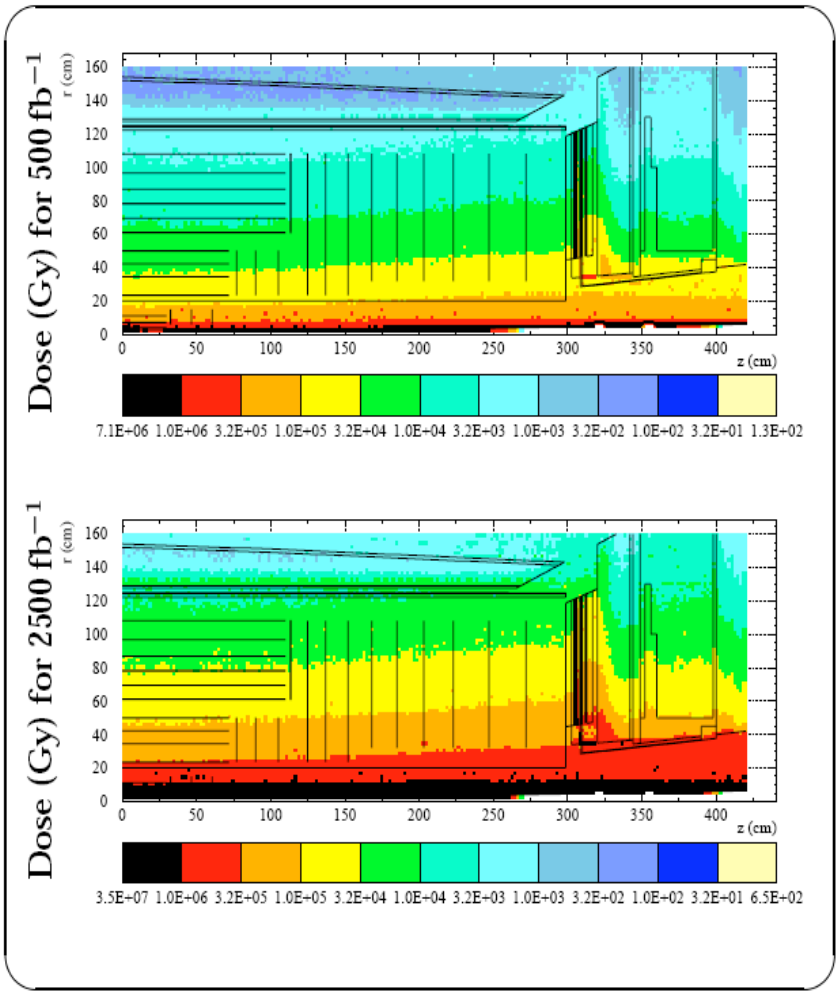
From Physics TDR Vol 1 (LHCC 2006-001)

Radiation environment for trackers

Except for the very innermost layers current technologies should survive SLHC



R. Horisberger



Walter's issues to discuss

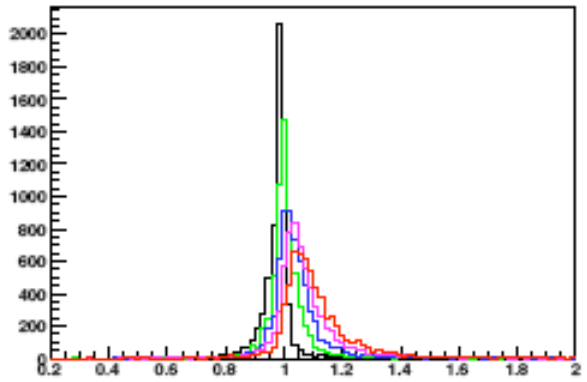
- Effect of Pile-up
  - How does this impact the ability to extract the interesting physics
- Effect of Integration
  - What happens to acceptance
  - What happens in the detectors
    - Backgrounds
  - Other impacts
    - maintenance
- Luminosity leveling
  - Yes please if you can

The effect on physics of large pile-up

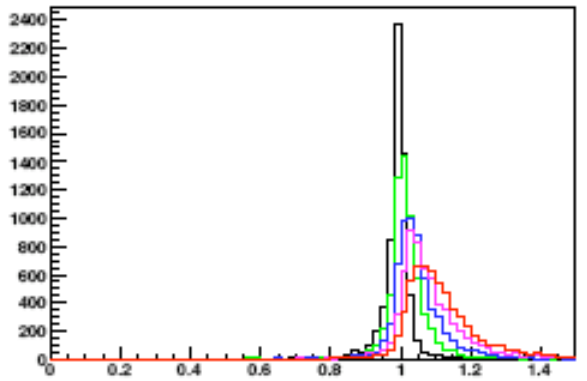
- We need to evaluate whether we can extract any physics at all in the presence of up to 400 pile-up events per crossing
- This is not a trivial study
  - Technically difficult
  - Also depends on geometry of a new tracking device
  - Timescale for full answers is more like years than months

Fast simulation

- We can do a fairly accurate modeling of the pile-up in the calorimeters with a fast simulation
  - Pile-up is very much like noise
  - Can see for instance how electron identification might suffer
- Fast simulation for a tracker is not yet easy to implement
  - Don't know the tracker design
  - Pattern recognition is an important issue



E/E_{true} barrel

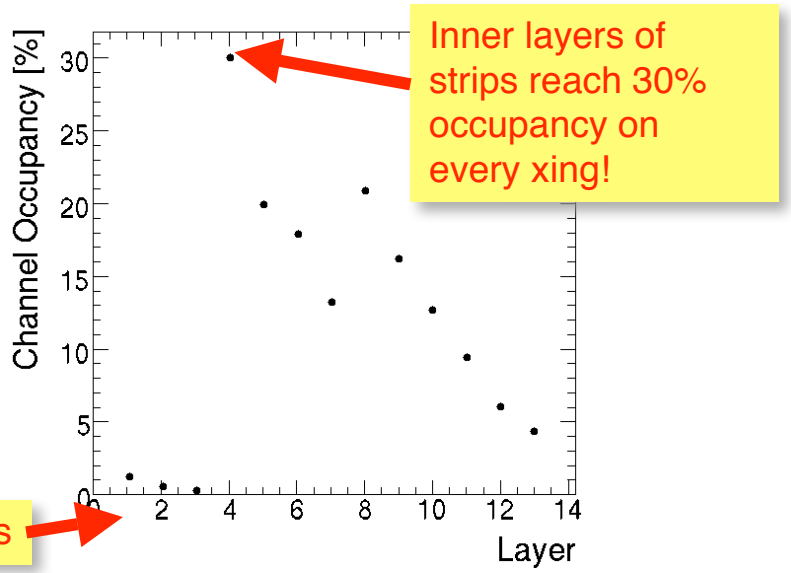


P/P_{true} barrel

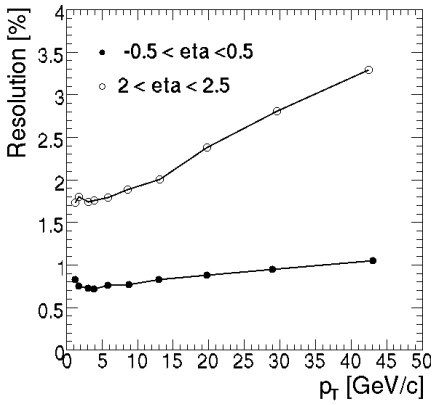
L. Prepolec

Tracking with 500 min Bias events

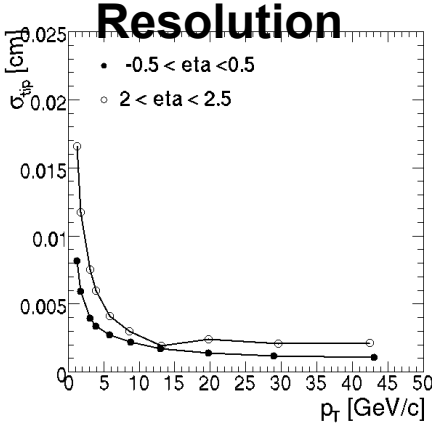
- Study of current CMS tracker for Heavy Ion events
- Track density very similar to 50ns running
  - $dn^{ch}/d\eta$/crossing ≈ 3000
  - Tracker occupancy very high
  - Need more pixel layers/shorter strips
- Tracking possible
  - When tracks are found they are well measured
  - Efficiency and fake rate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

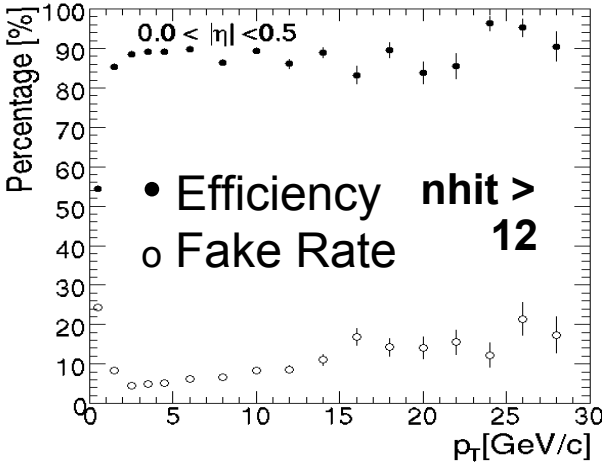


Momentum Resolution



Transverse Impact Parameter Resolution



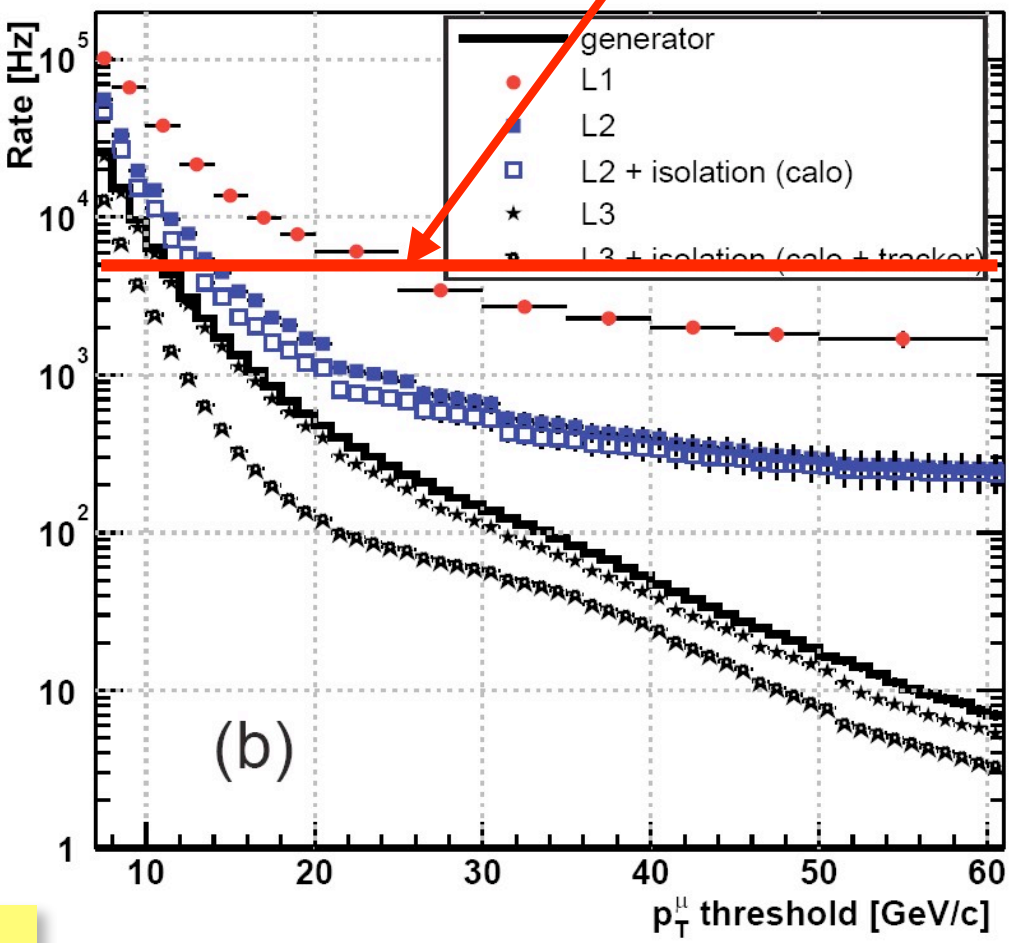


C. Roland

Level 1 Trigger

- The trigger/daq system of CMS will require an upgrade to cope with the higher occupancies and data rates at SLHC
- One of the key issues for CMS is the requirement to include some element of tracking in the Level 1 Trigger
  - There may not be enough rejection power using the muon and calorimeter triggers to handle the higher luminosity conditions at SLHC
  - Adding tracking information at Level 1 gives the ability to adjust P_T thresholds

Level 1 Trigger has no discrimination for $P_T > \sim 20$ GeV/c

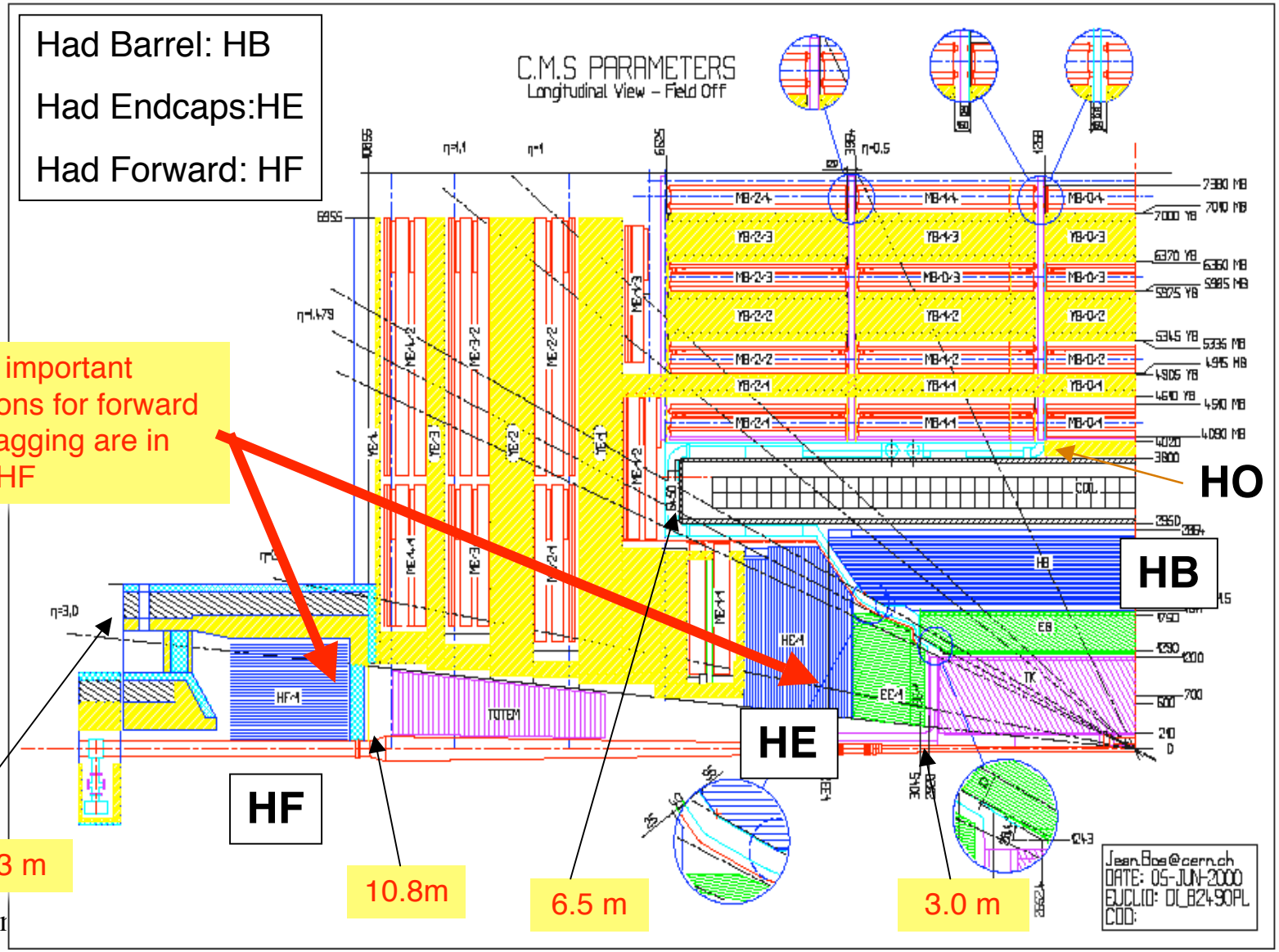


How well does a tracking trigger cope with large pile-up?

Integration issues

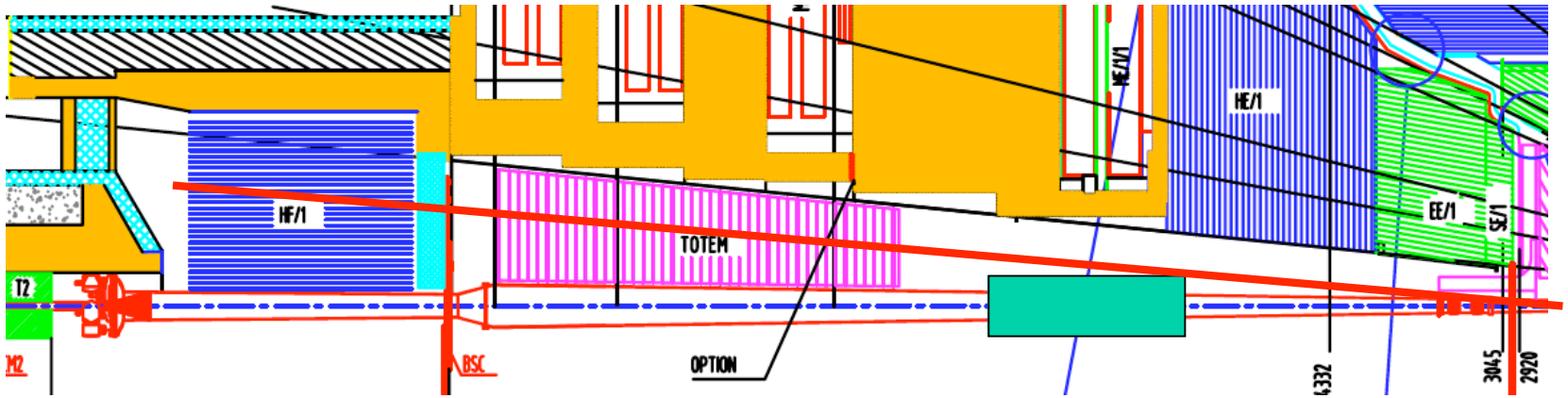
- Location of magnet(s) inside of UXC55 of any sort will require substantial changes to the CMS infrastructure
- What happens to the detector?
  - Obscuring forward calorimeter
  - Backgrounds in the detector
  - Maintenance of the detector
    - CMS is meant to open for maintenance access this is a very different situation than ATLAS
- What happens to the proposed shielding?

CMS HCALs

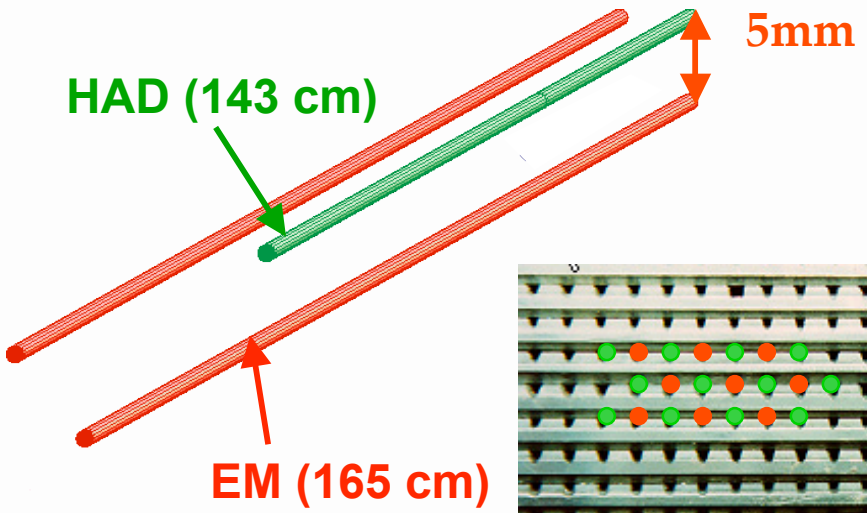

Had Barrel: HB
Had Endcaps:HE
Had Forward: HF
C.M.S PARAMETERS
Longitudinal View – Field Off
The important regions for forward jet tagging are in HE/HF
HO
HB
HE
HF
14.3 m
10.8m
6.5 m
3.0 m

So you want to put a D0 in front of HF!

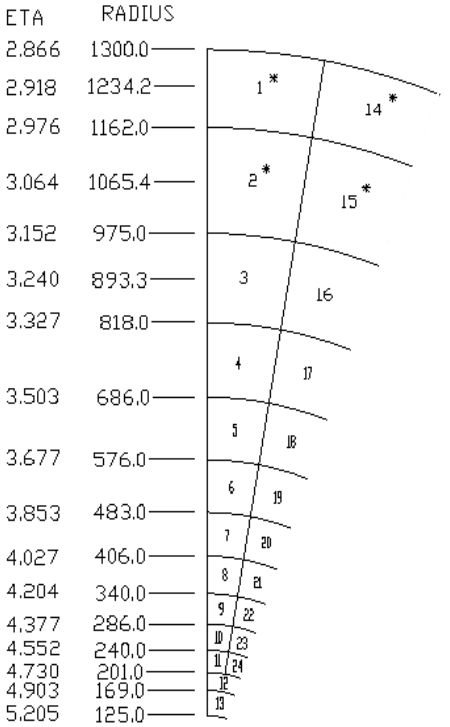
- Could we do this without replacing HF?
  - No way without obscuring part of the detector
  - But perhaps lower eta region still usable
- Will the HF still be useful at SLHC



HF detector

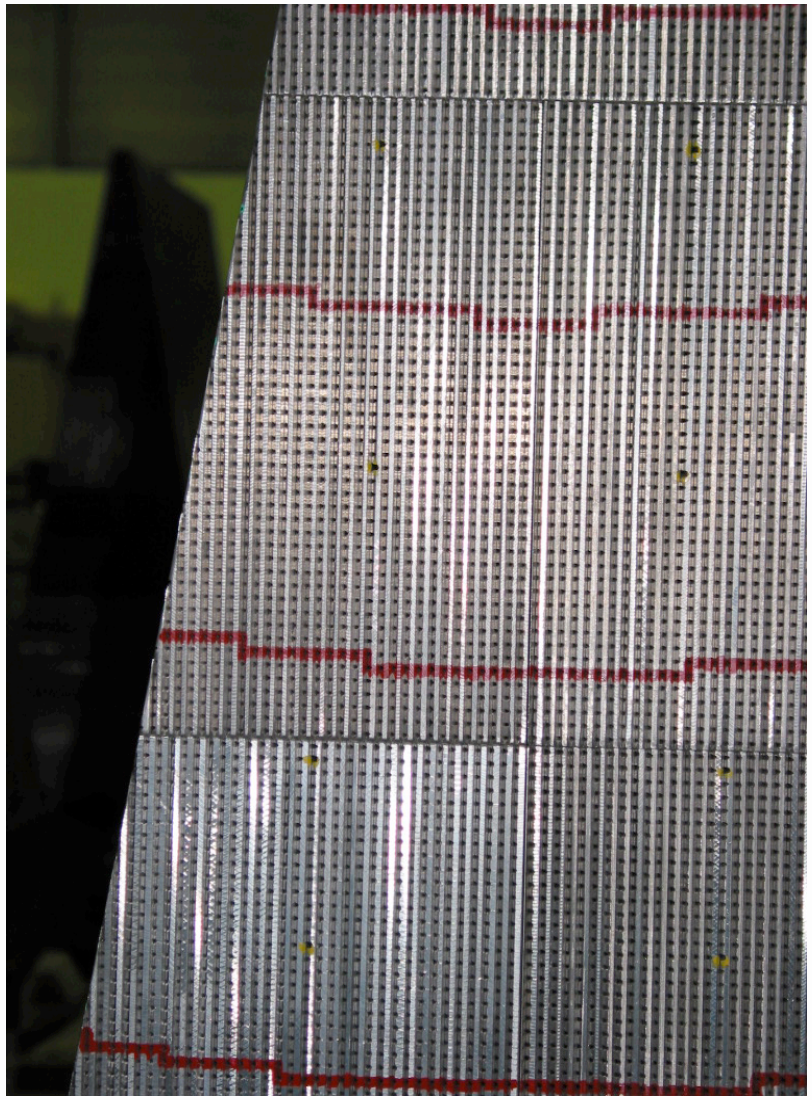


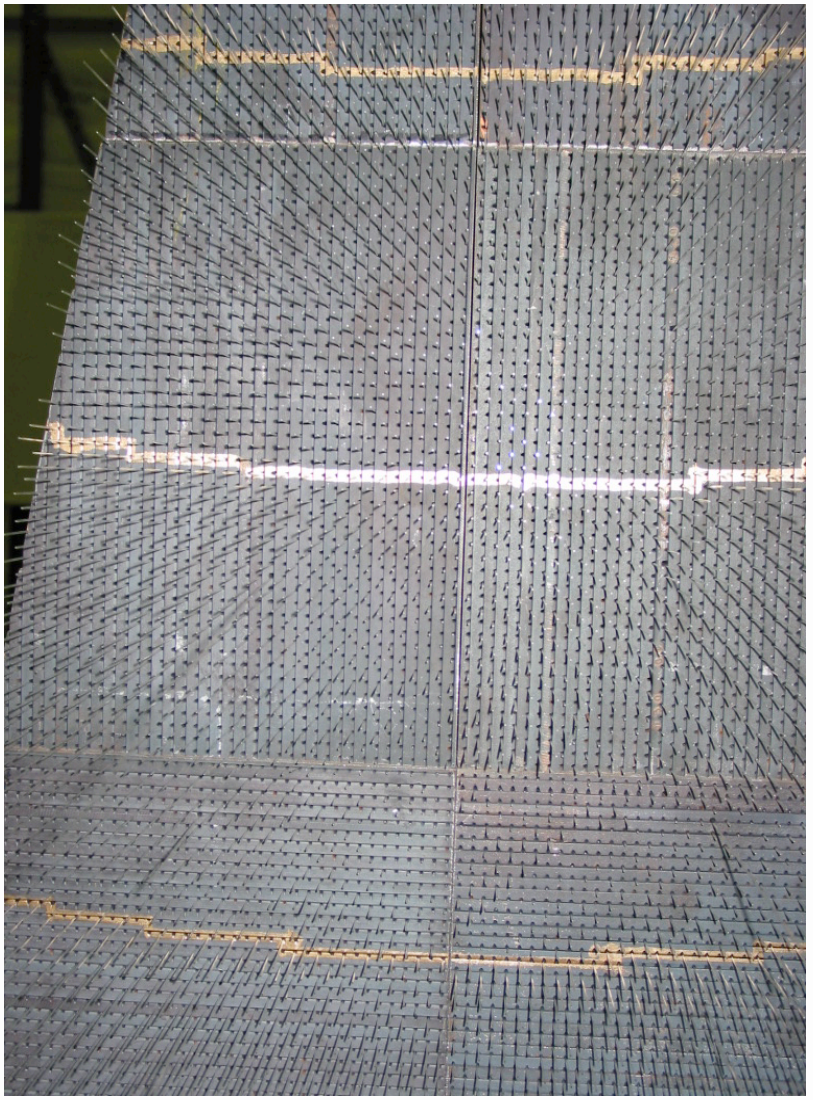
To cope with high radiation levels (>1 Grad accumulated in 10 years) the active part is Quartz fibers: the energy measured through the Cerenkov light generated by shower particles.



Iron calorimeter
Covers 5 > η > 3
Total of 1728 towers, i.e.
2 x 432 towers for EM and HAD
η x ϕ segmentation (0.175 x 0.175)

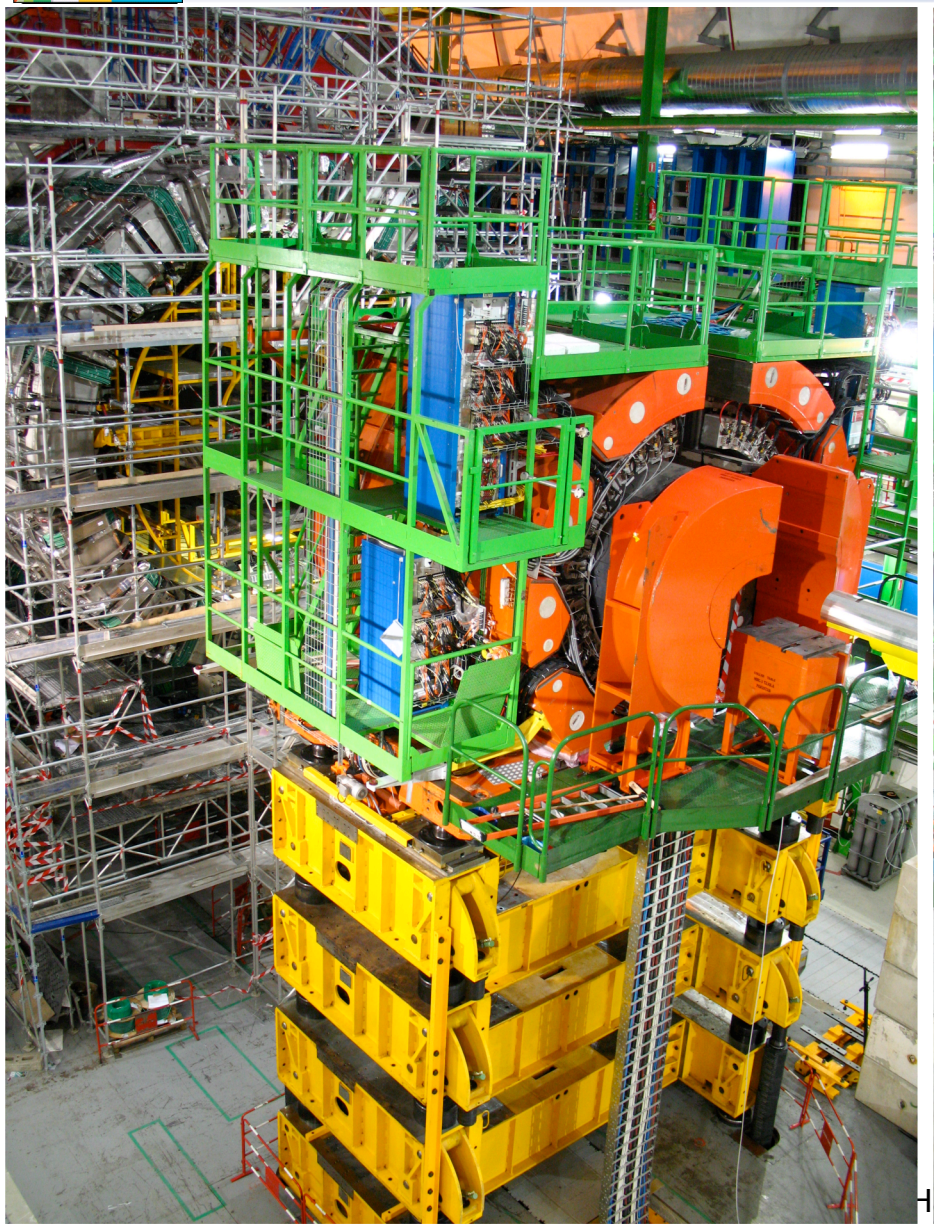
Fibers in the HF absorber

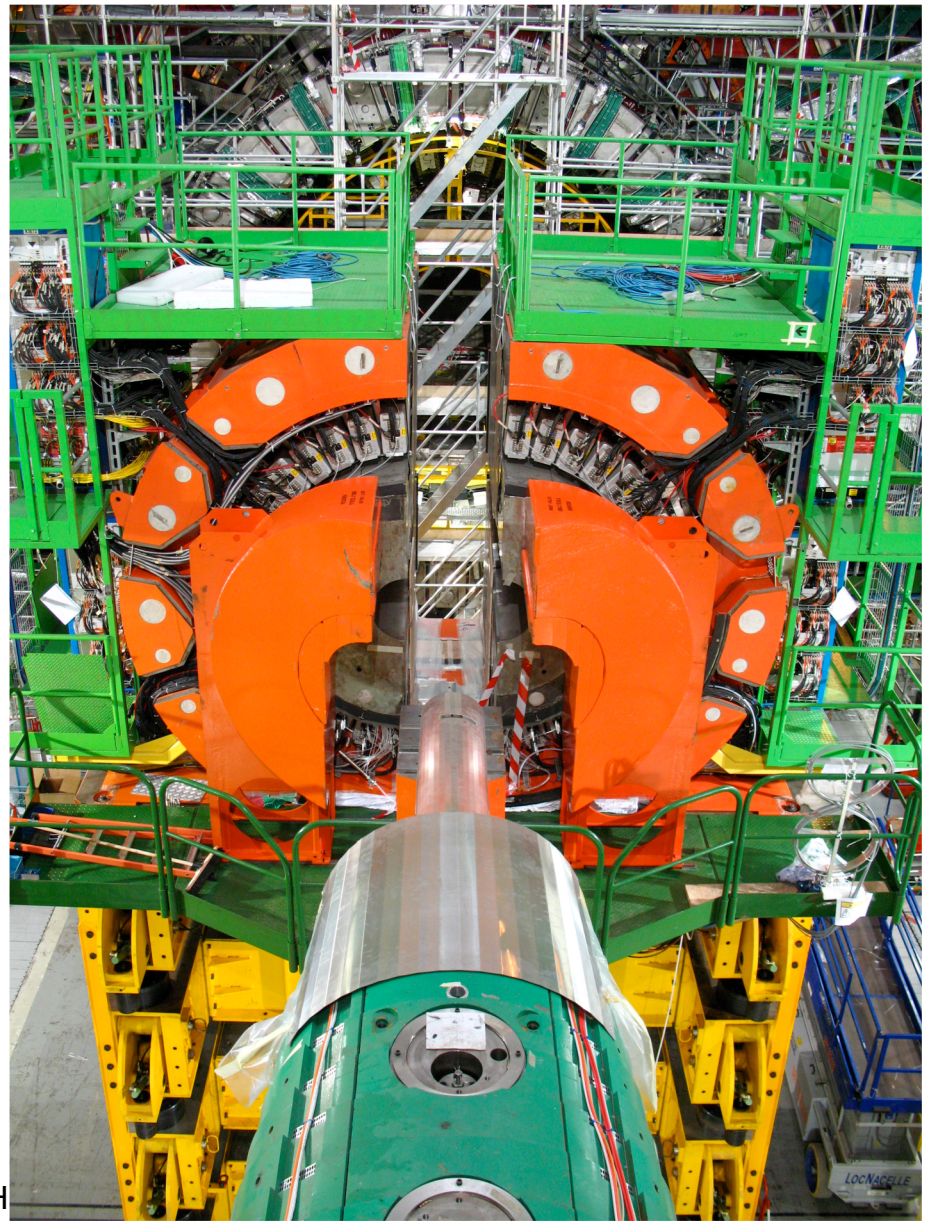




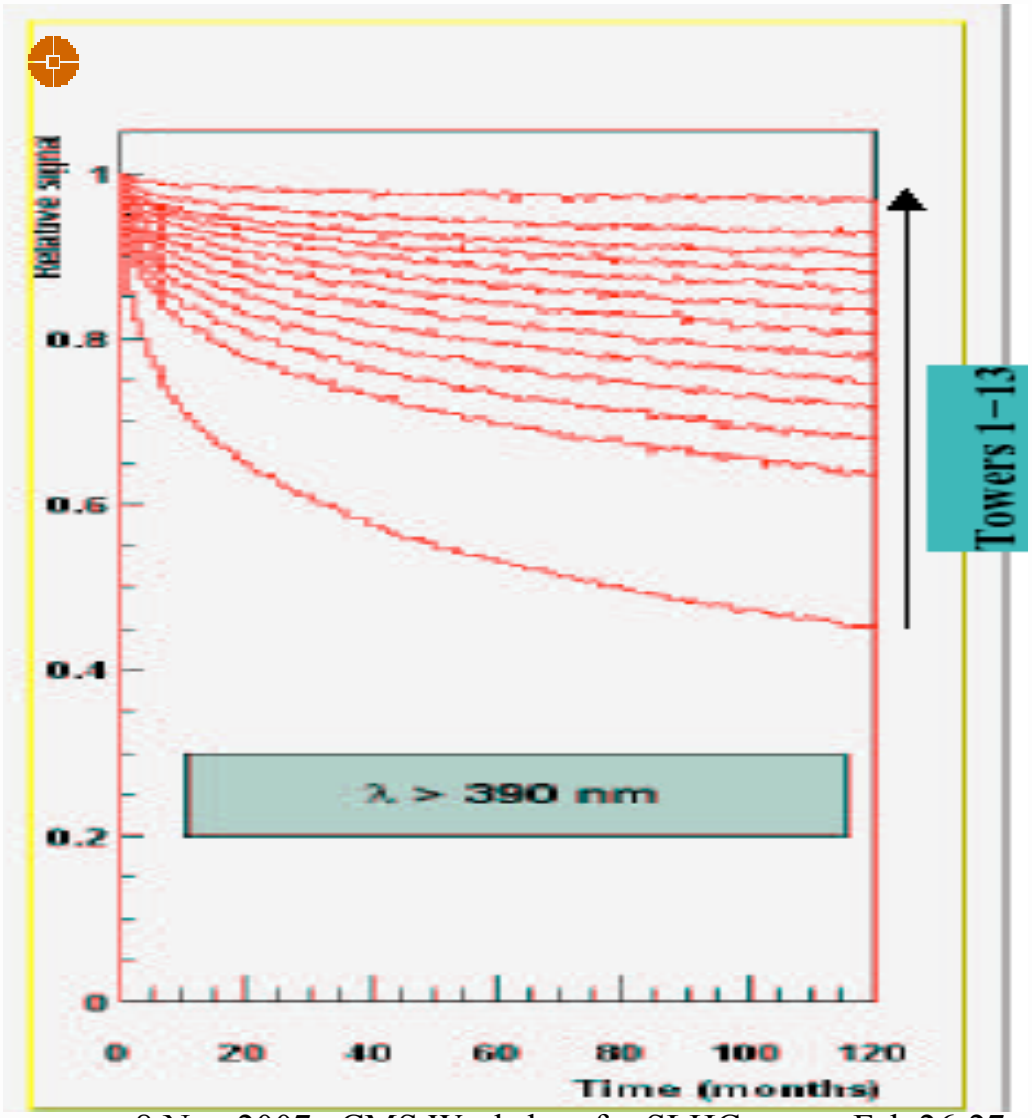
J. Freeman 8 Nov 2007 CMS Workshop for SLHC Feb 26-27, 2004

HF Riser Test





HF Damage

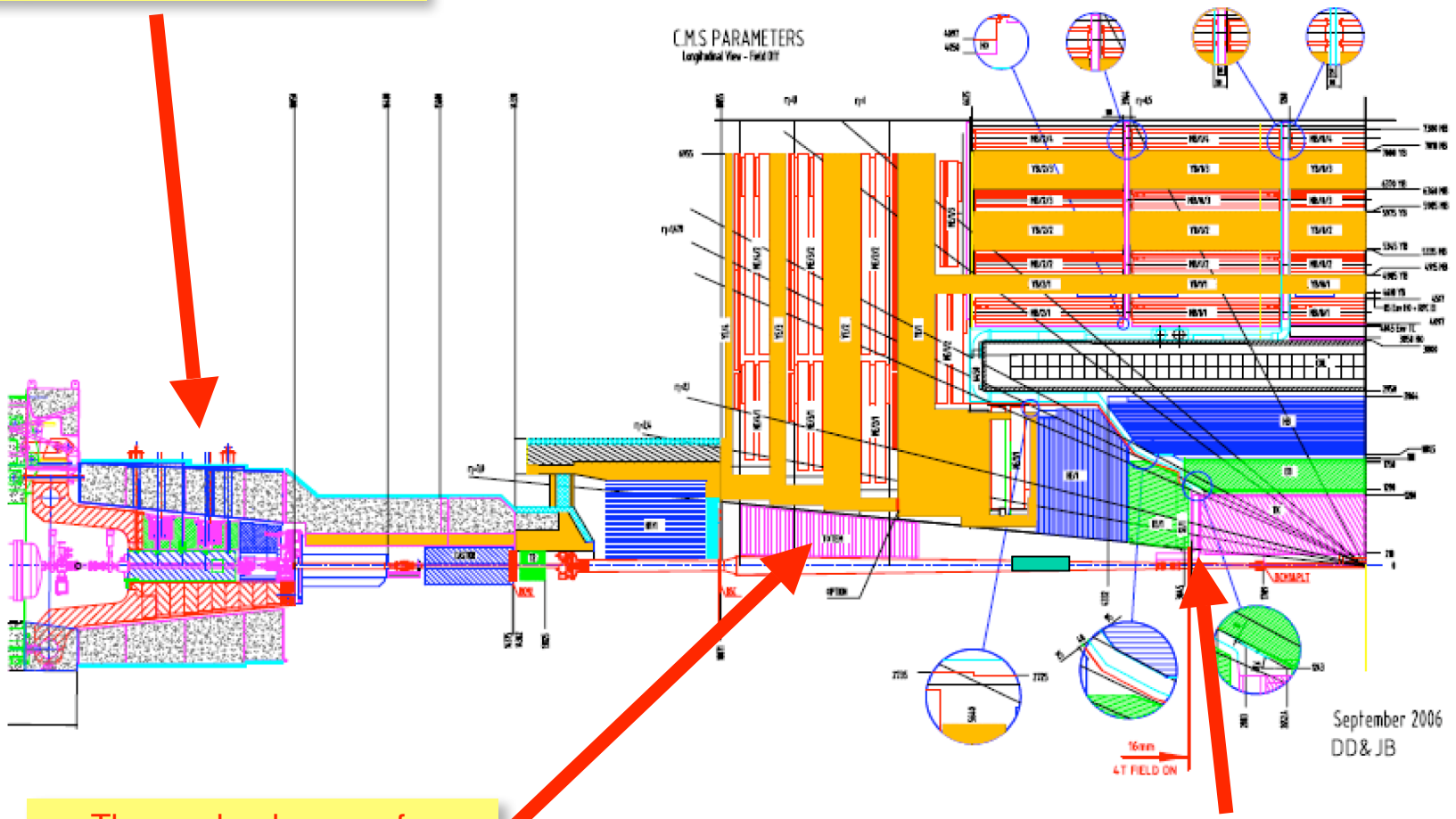


Tower 1 loses 60% of light during LHC, down to 4% of original after 10 years of SLHC. Tower 2 down to 23% after 10 years of SLHC. SLHC "kills" a few high eta towers.

It could be that the low eta regions which are least damaged are not blocked by D0, while the high eta regions which are unusable are blocked by d0

What about maintenance?

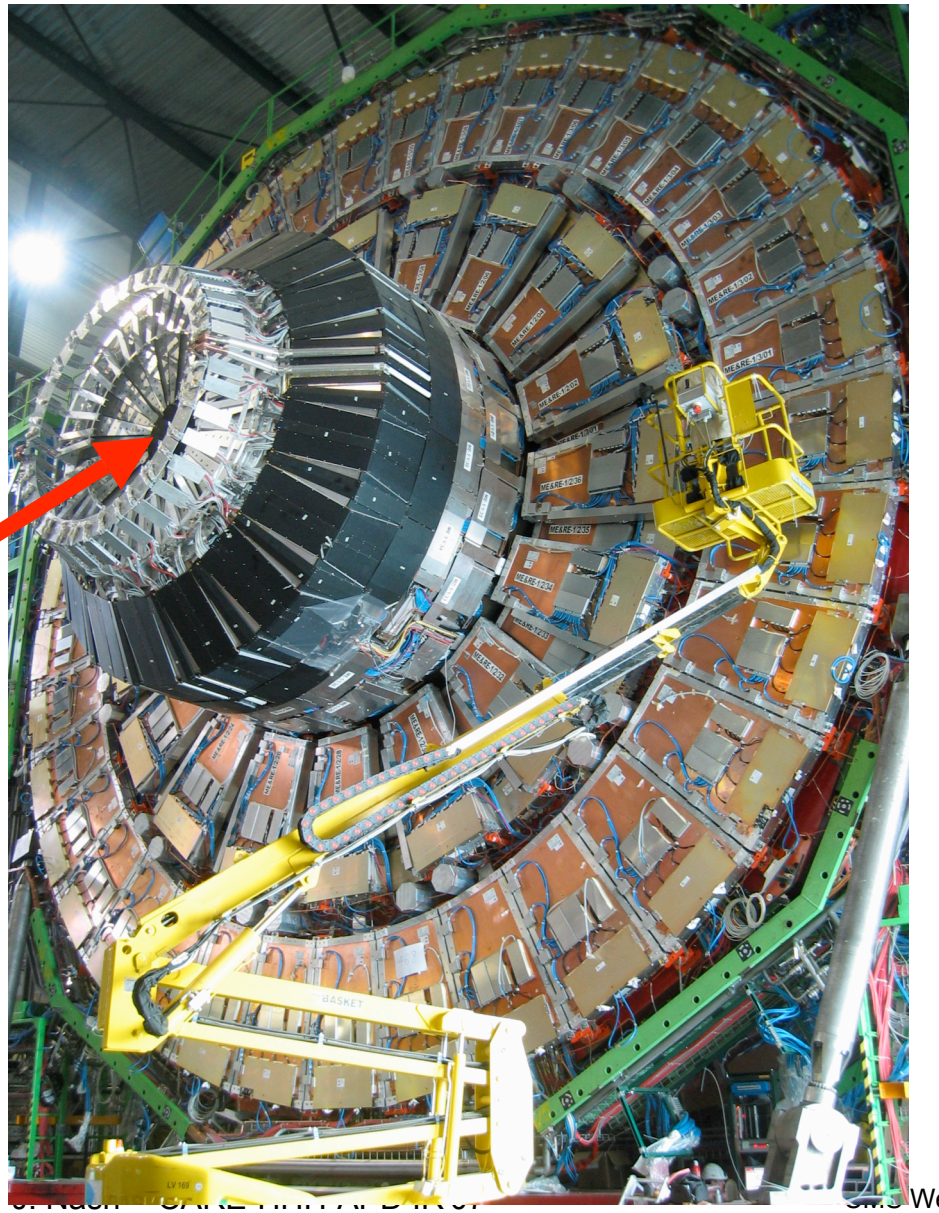
Triplet moves closer to IP



These wheels move for maintenance

Either D0 has to clear the EE, or it has to move for maintenance

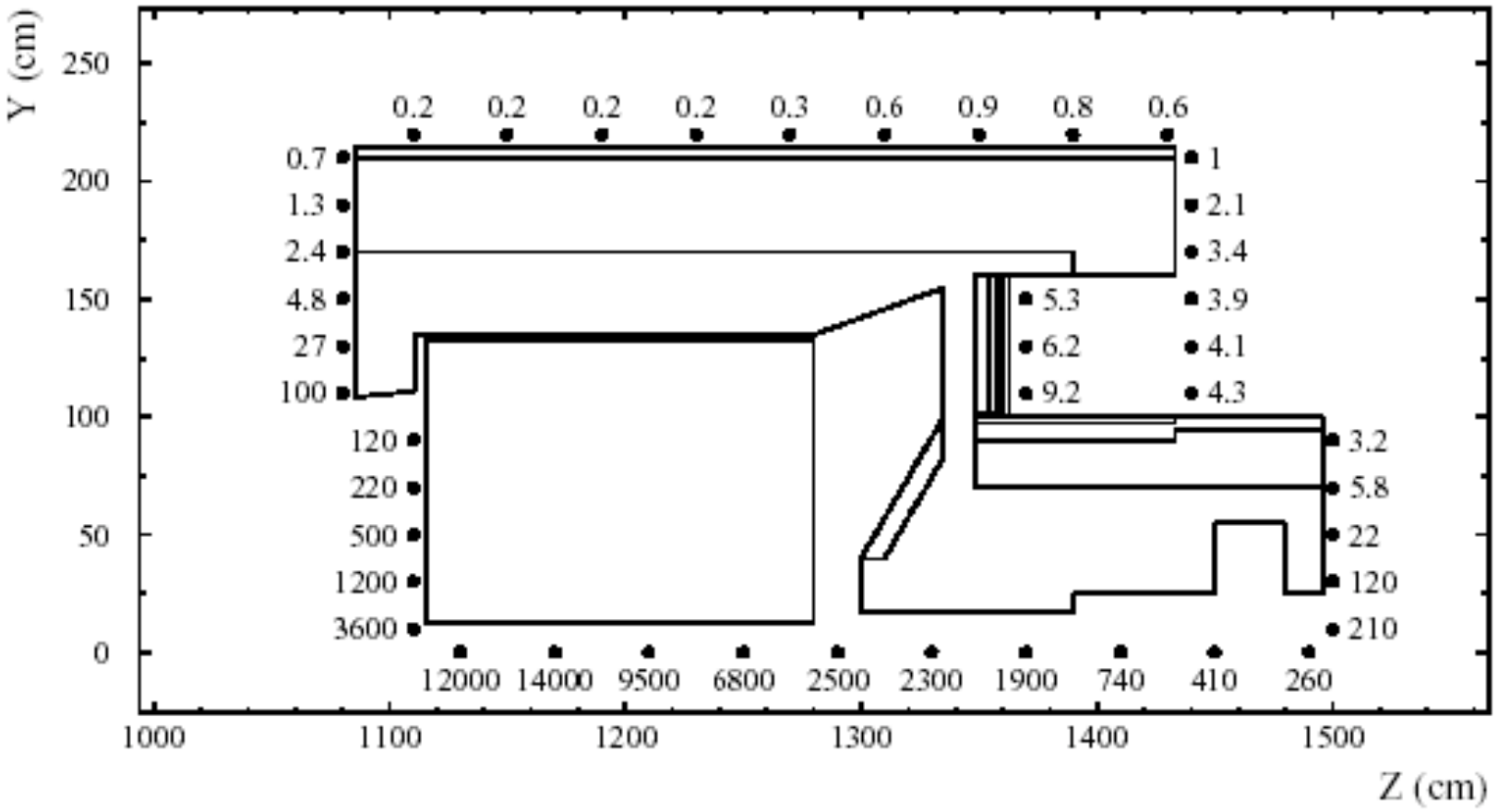
Installation of ME1/3 CSC Endcap Chambers



Well defined aperture in the endcap discs

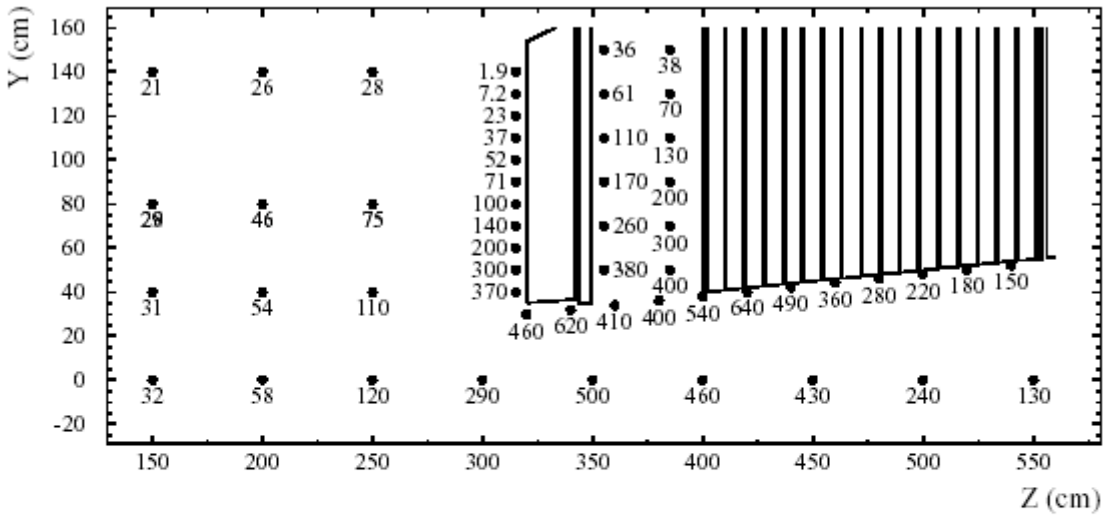
Activation in "forward" Region

Dose rates μSv/h after 10 y LHC and 1 d cooling



Activation in "endcap" Region

Dose rates μSv/h after 10 y LHC and 1 d cooling



Concentrate maintenance work on outer periphery

⇓

Typical dose rates <50 μSv/h

⇓

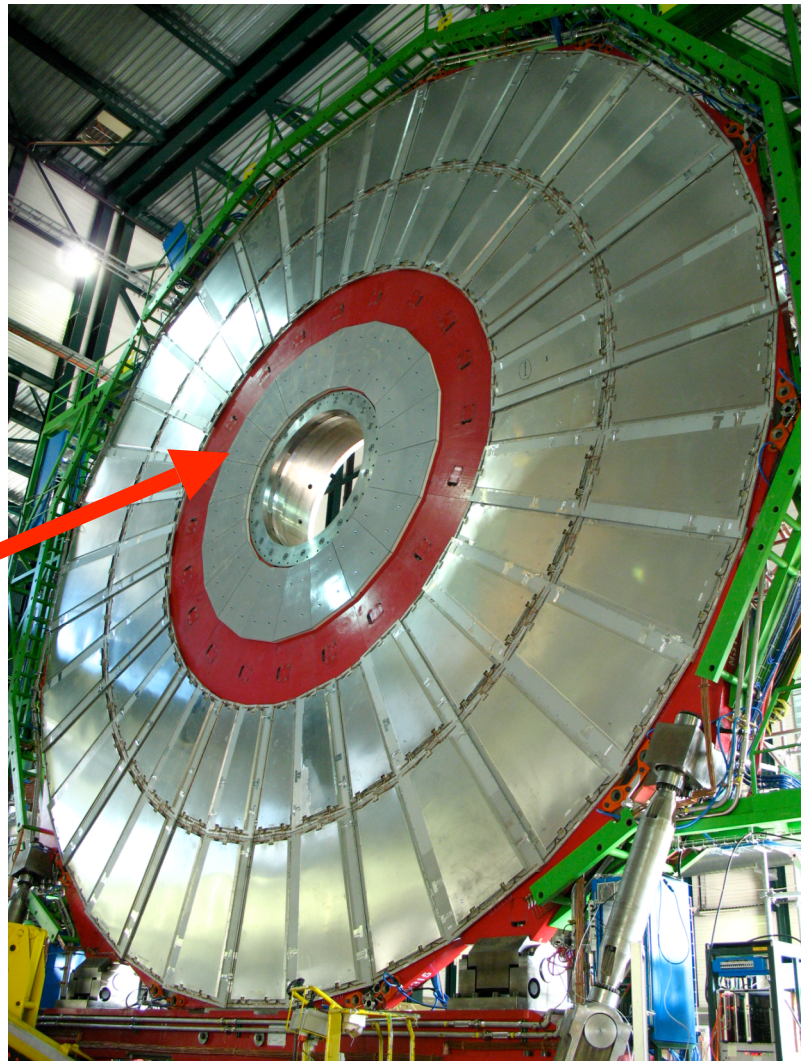
Design operations to be reasonably fast

Maintenance issues

- If it is not possible for D0 to move with the CMS wheels, or to clear them then it will be necessary to be able to install/remove it for CMS maintenance
- Activation issues
  - It may be difficult to maintain CMS in any case, so perhaps annual removal of the D0 may be enough
    - But should be a relatively quick operation
  - Don't yet have enough experience with how often we need to open CMS

Muon system shielding

- The flux return iron provides fairly robust protection for most of the muon system
- May wish to add additional shielding to the inner radius
- How is this changed by a D0?

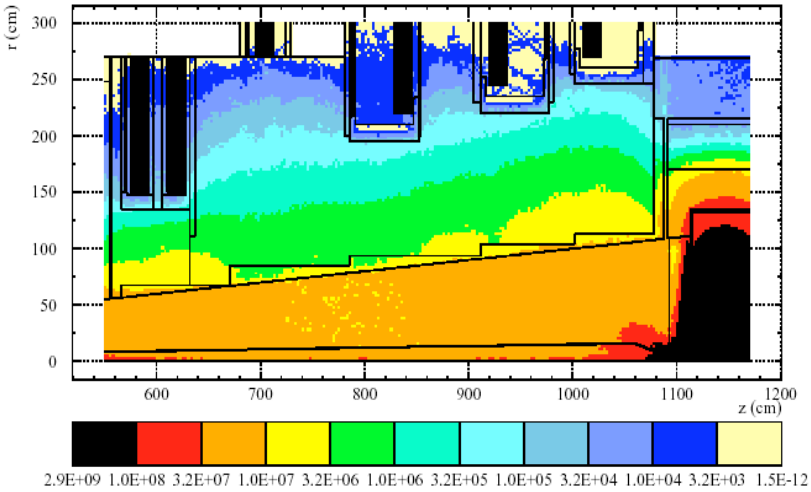


Infrastructure modifications: Yoke

Reinforced Shielding inside forward muon up to η~2

--> automatically implies replacement of inner CSC, RPC

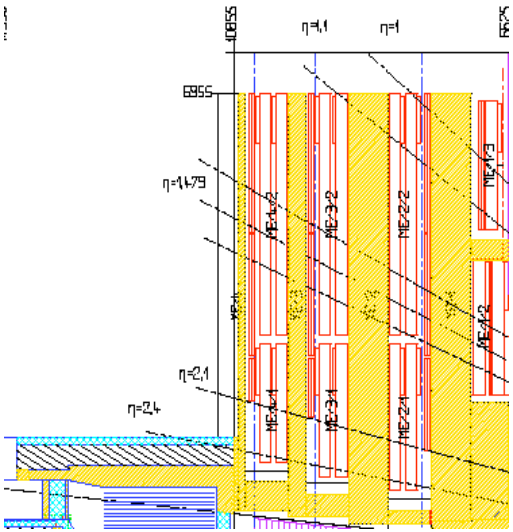
(alternatives with protection from new higl HE/EE not considered)



Supplement YE4 wall with borated polythene

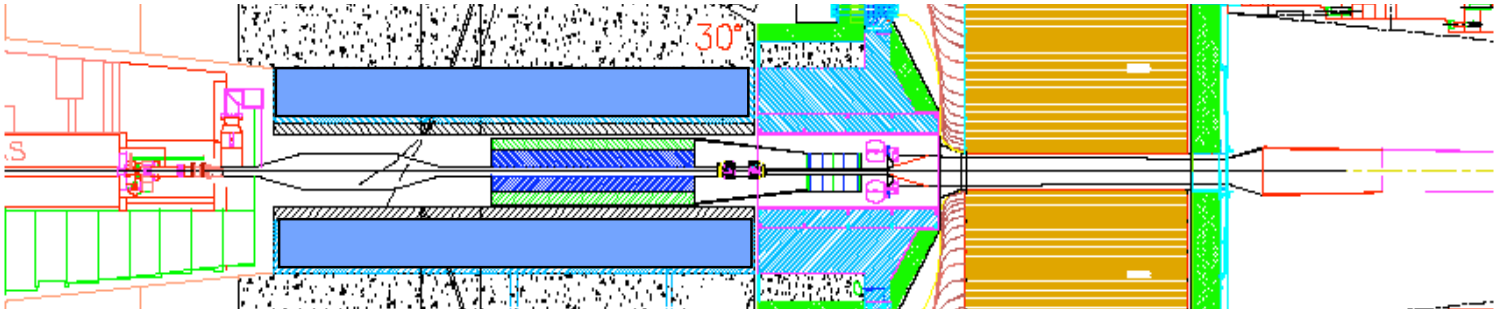
Improve shielding of HF PMT's

possibility of increased YE1-YE2 separation to insert another detector layer?



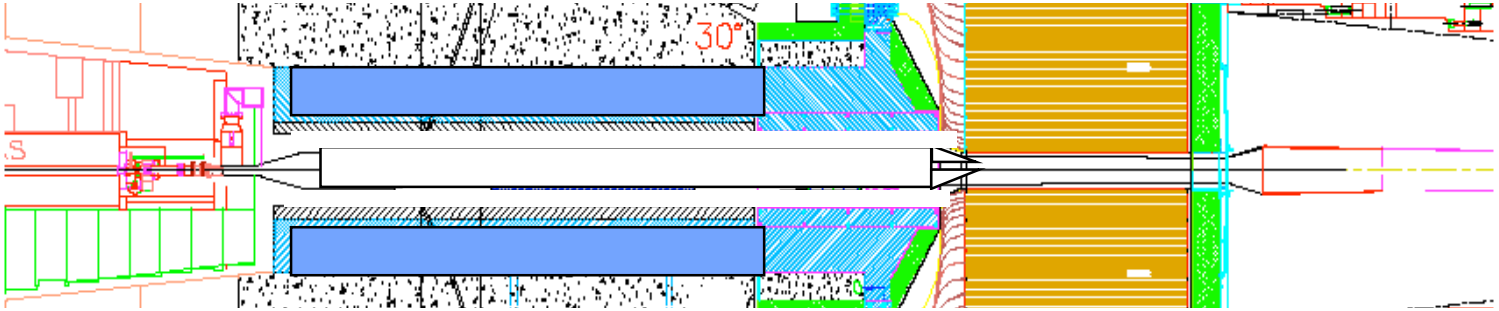
Forward beampipe

LHC



thin pipe 13-16 m believed good for 10^{34} pp
CASTOR & TOTEM easily installed/removed for special runs (eg heavy ion), interspersed with high lumi pp

SLHC



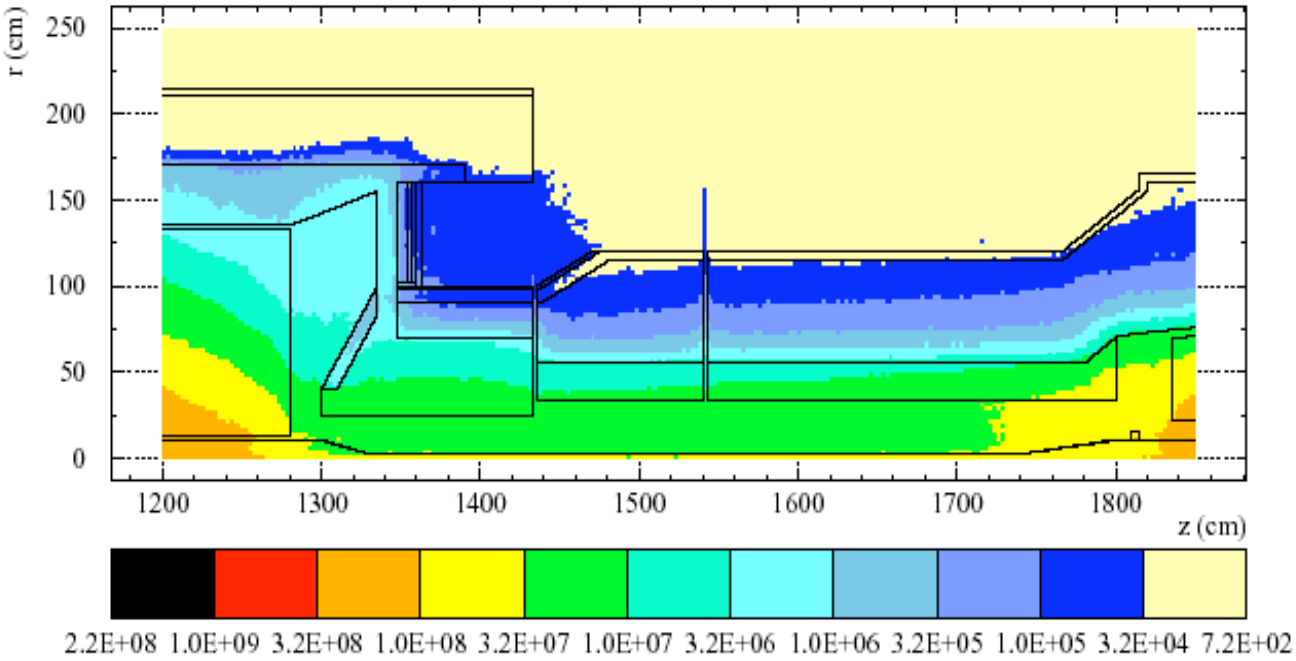
wide pipe (400mm) after HF and in its shadow

Forward shielding

Neutron (E>100keV) flux maps

shielding without CASTOR

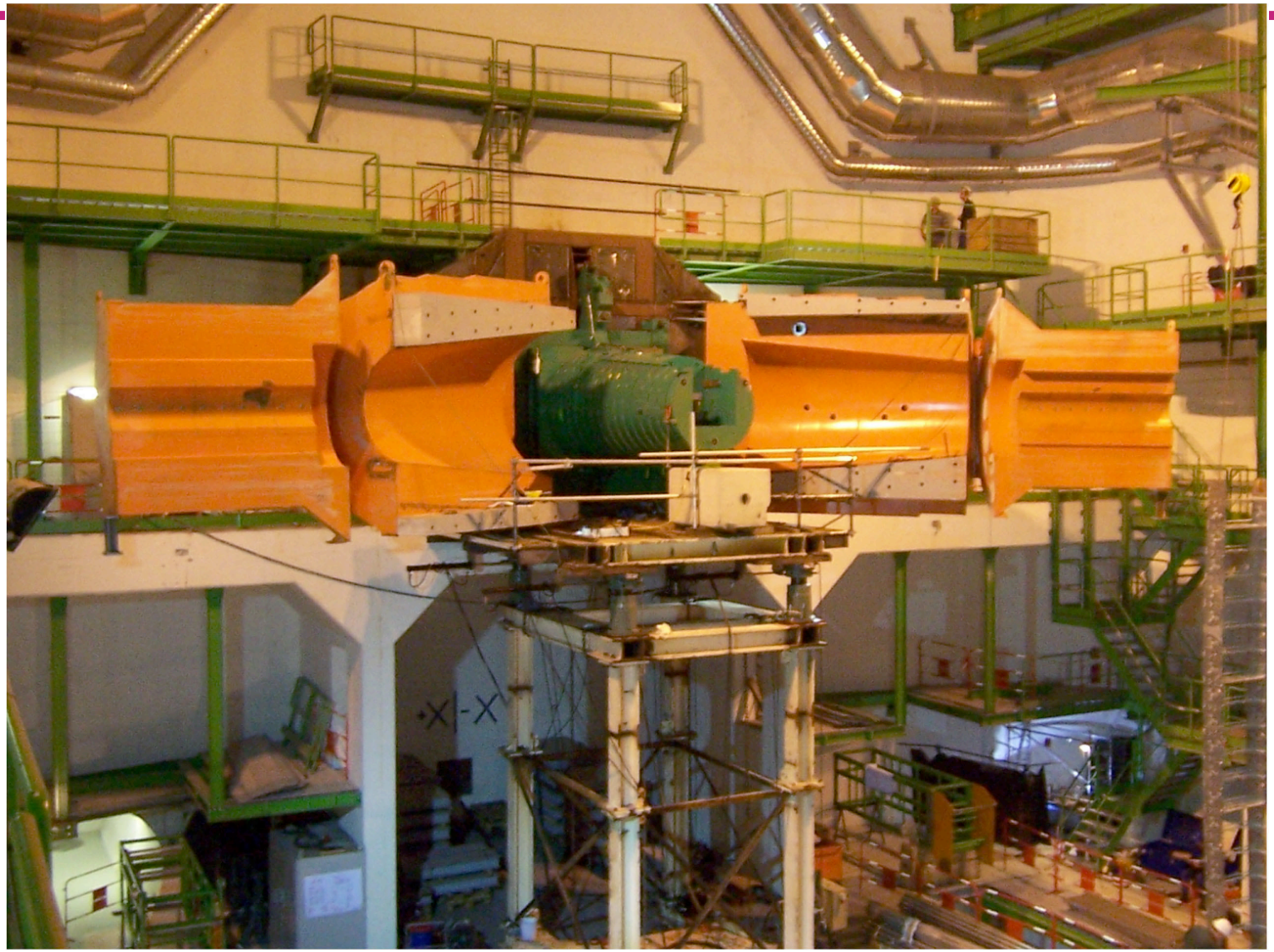
pp 10^{34} cm^{-2} s^{-1}



-well balanced along z.

(no particular weak-point)

+z end today: option to install fwd pipe when ready



HF + jacks tested

Forward region of CMS is designed to withstand the SLHC. Significant changes will be costly.

Conclusions

- Without optics change, not much need for changes to the forward regions and shielding of CMS
  - Tracker will be the major change
- Pile-up studies are underway
  - Tools now developed, but still some time before we can make a definitive statement on how much pile-up we can withstand
- Changes to the IR can lead to rather costly changes to the CMS infrastructure
  - May be possible to accommodate, but many unresolved issues
    - Can we retain forward calorimeter acceptance
      - Do we need to look at instrumenting D0?
      - Do we need a new HF, new geometry? Very expensive - what happens to the new tracker?
    - Can we build a magnet compatible with CMS operation (ie maintenance, backgrounds induced in the detector)
    - What happens to the shielding/backgrounds if there are substantial changes to the forward region