CMS Upgrades: Report to LHCC

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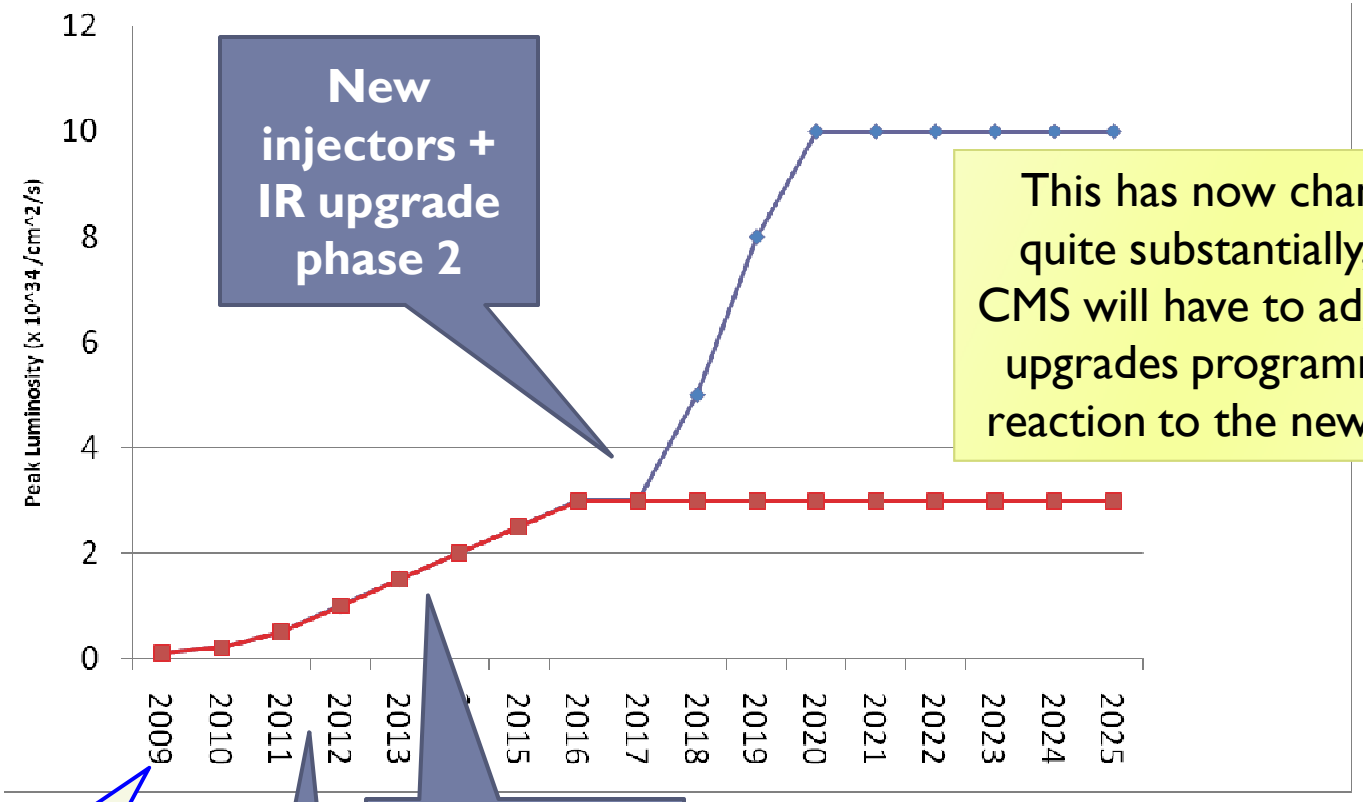
Outline

- Upgrade issues for the 2010's
- Upgrade issues for the 2020's

Agreed Scenario for Peak luminosity (CMS/ATLAS/Machine/LHCC - 2008)



New injectors + IR upgrade phase 2

This has now changed quite substantially, and CMS will have to adjust its upgrades programme in reaction to the new plans

Early operation

Collimation phase 2

Linac4 + IR upgrade phase I

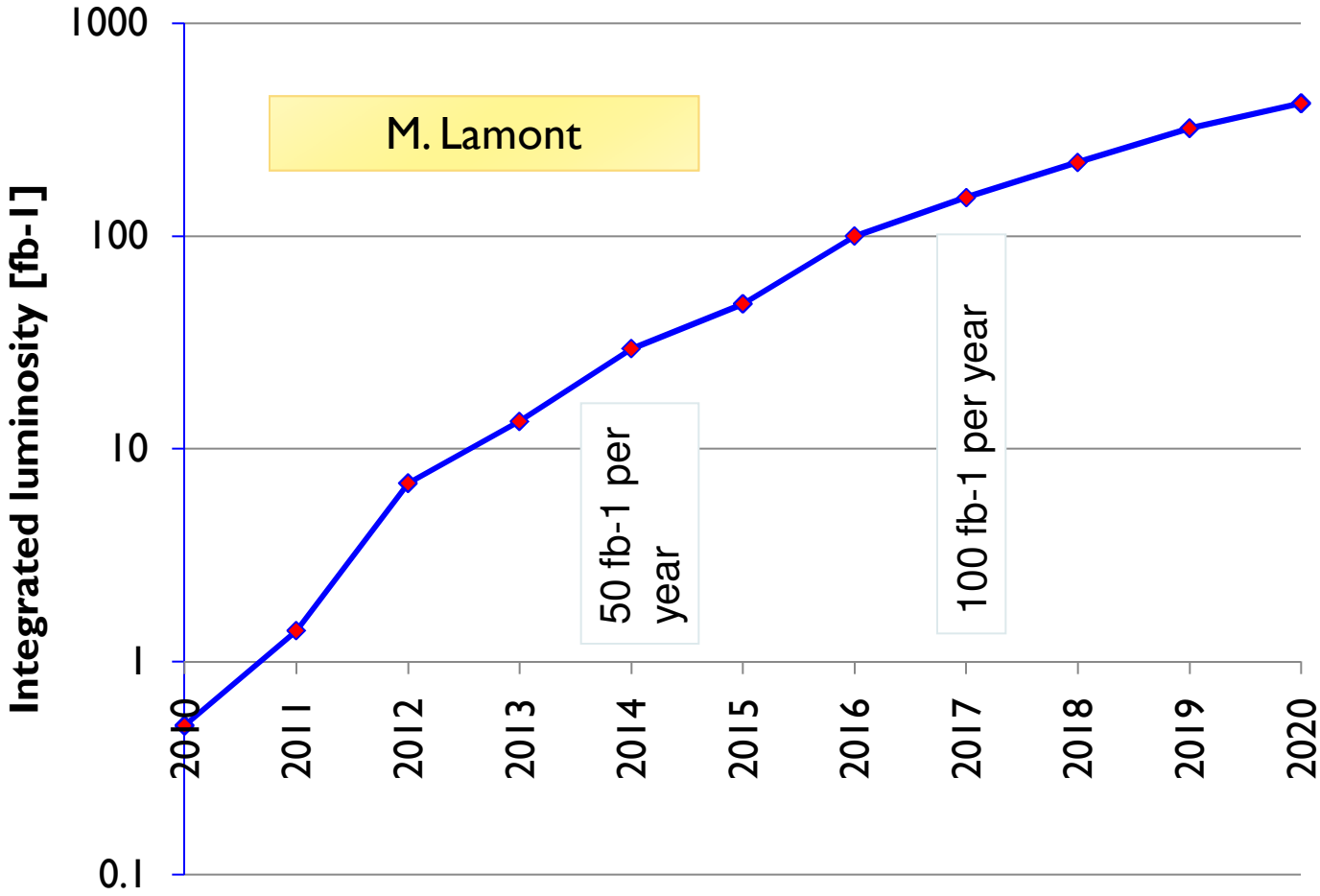
Upgrades required to keep CMS operating at maximum potential throughout

Possible new scenarios for Phase 1 luminosity evolution

- CMS has started discussions on how to react to the outcome of the Chamonix workshop over the last two weeks
- Taking into account
  - Expected luminosity for the next two years
  - Likely shutdown times to prepare for energy increase
  - Possible luminosity evolution once the energy increases
  - CMS detector performance for physics/reliability
- We are preparing a new plan for upgrades
  - No fundamental change in what will need upgrading in phase I and phase II
  - Potential strategic changes in when we upgrade the detectors

Potential luminosity evolution over the next decade (no big LHC upgrade) – note this is not yet an agreed scenario!

Assuming 60% machine availability
Assuming 4h turn around time



This is a guess, and is missing several key elements. The lab must give us a more realistic scenario over the coming year which we all agree to plan to

Agreed at the May 2008 Upgrades Workshop
http://indico.cern.ch/conferenceDisplay.py?confId=28746

Upgrade Scope

System	Phase 1	Phase 2
Pixel	New Pixel Detector (1 or 2 iterations?)	
Tracker	FEDs?	New Tracking System (incl Pixel)
HCAL	Electronics + PD replacement	HF/HE?
ECAL	TP (Off Detector Electronics) ?	EE?
Muons	ME4/2, ME1/1 ,RPC endcap, Minicrate spares, some CSC Electronics	Electronics replacement
Trigger	HCAL/RCT/GCT to μTCA	Complete replacement

What is Phase 1 of the Upgrade?

- Contains all upgrades to CMS which take place before the long shutdown to replace the trackers of ATLAS/CMS
  - These may or may not be linked to upgrades of machine elements
    - Putting in a new beampipe – we have to decide when
      - Probably as soon is possible is the correct line to take on this
    - Putting in the new triplets – may not be in the planning now

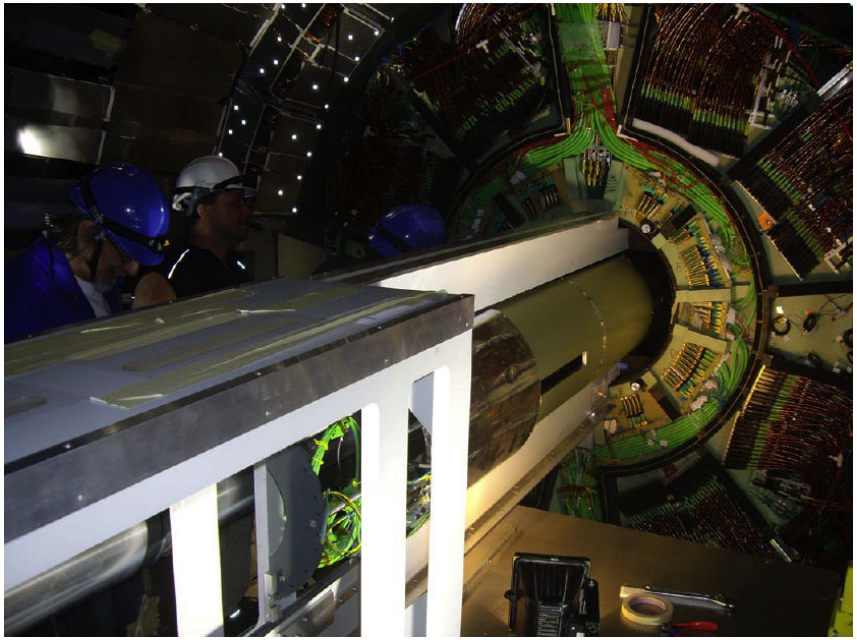
What is required of Phase I detectors?

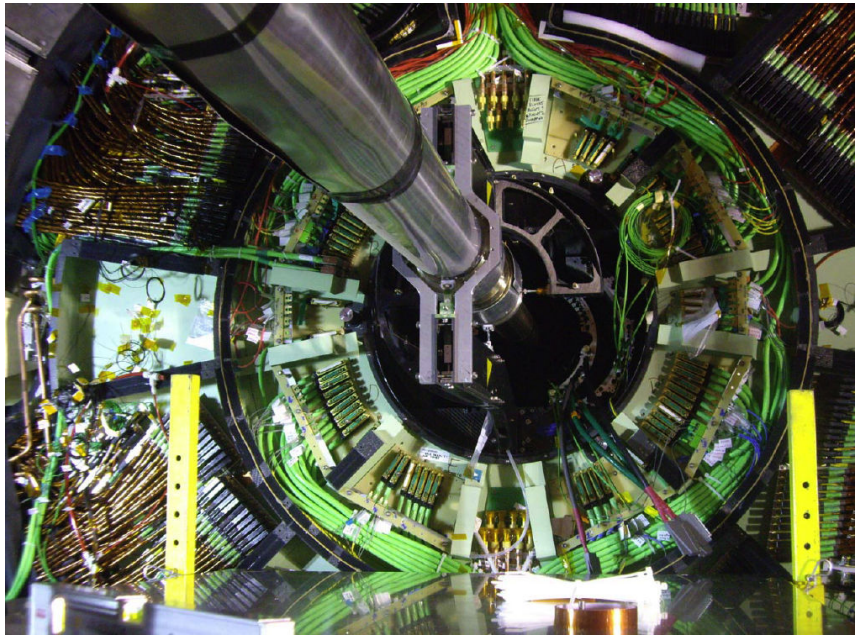
- They should be able to operate with a peak luminosity of up to 2×10^{34}
- They should be able to cope with an integrated luminosity of up to around 700/fb
  - Looking at potential increase in luminosity, this now not likely to be an issue until late in the decade.
- They should offer increased physics performance
  - In some cases this may be the most critical argument now. We want to have our best physics performance for the largest part of our collected integrated luminosity.
    - e.g. a detector which gave 20% more b-tagging efficiency might be equivalent to a lot of extra luminosity in some physics channels
  - Earlier may be better
    - Need to optimize risk/benefit

When do we need the Phase I upgrades?

- Are the upgrades required to cope with higher peak/integrated luminosity
- Would we get benefits by introducing some of the upgrades earlier?
  - Physics/performance
  - Reliability
  - ALARA
- Are there some upgrades which we would be better off delaying?
  - Particularly an issue for the Pixel detector, do we do a little more R/D to optimize the performance of a new detector for the new landscape.
- Other upgrades we may want to go ahead with more quickly
  - HCAL/Muons not much reason to delay, proceeding early allows easing of integration problems
- We need to sharpen the physics arguments (especially for phase I physics) as soon as we'll have data and results at 7TeV.

Fast insertion of CMS Pixel system

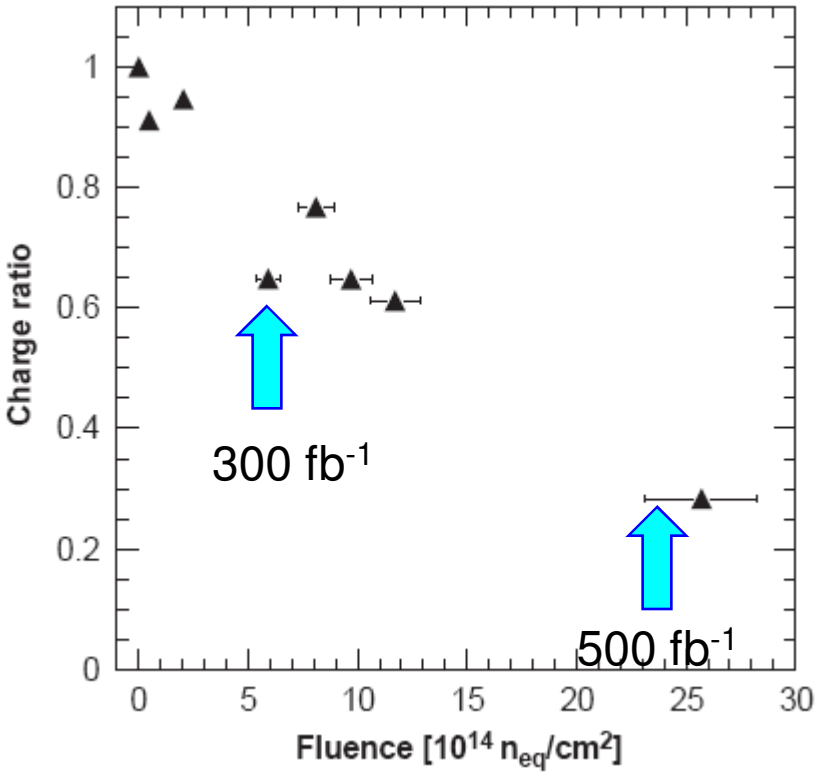


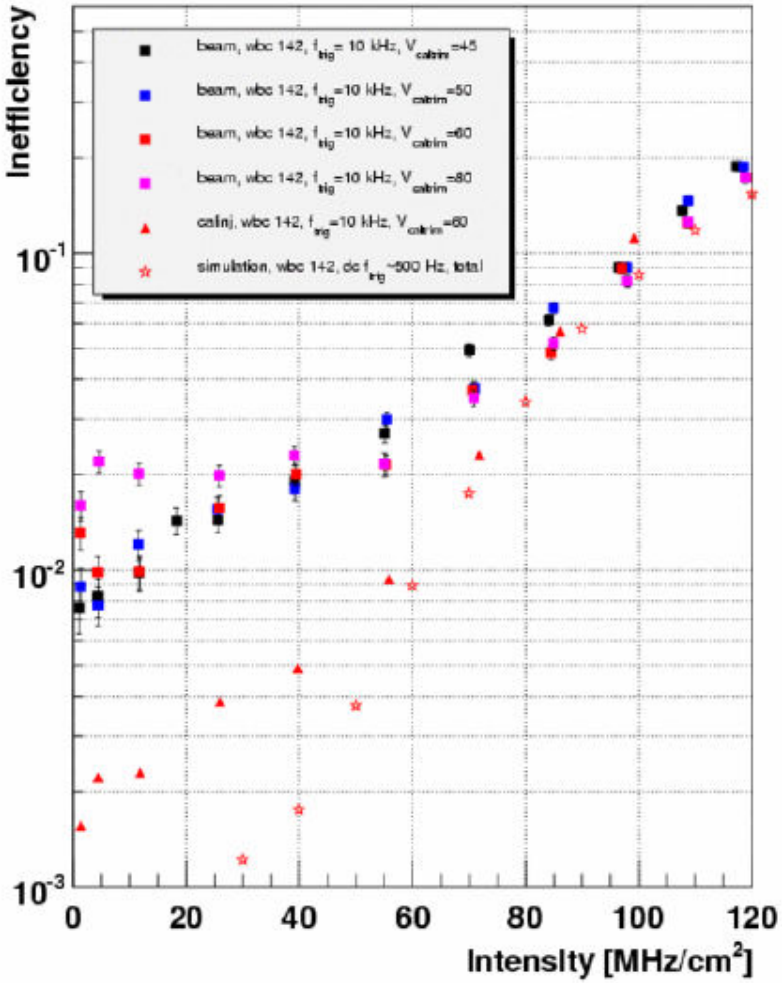


Insertion of the Pixel was done in a few hours. But preparatory work requires a few weeks. We are however very flexible.

Limitations in Phase 1

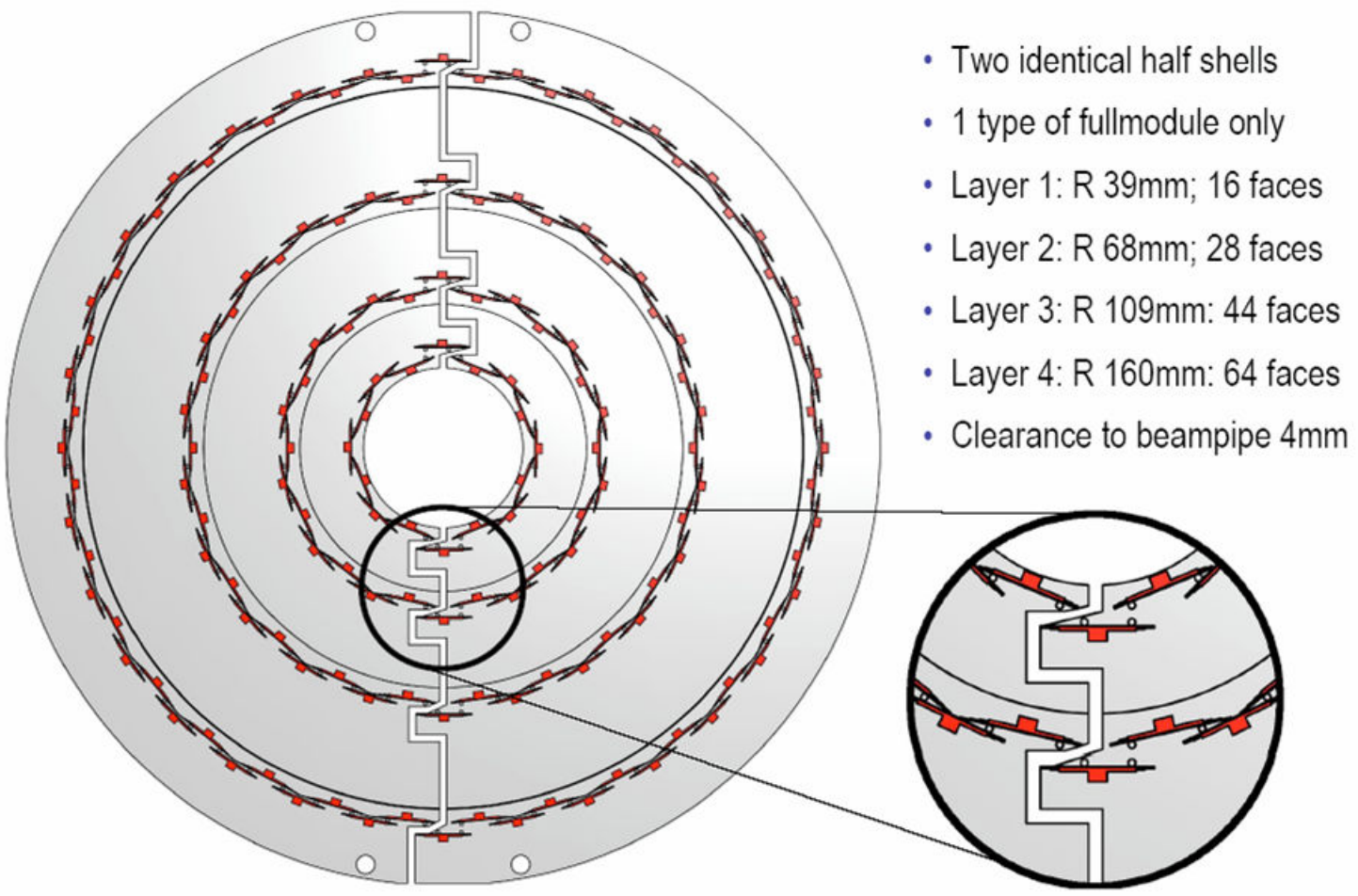
- Radiation damage due to integrated luminosity. Likely to be 2017-8 when we see these effects
  - Sensors designed to survive $6\times10^{14} n_{eq}/cm^2$ (~ 300 fb^{-1}).
  - n-on-n sensors degrade gradually at large fluences





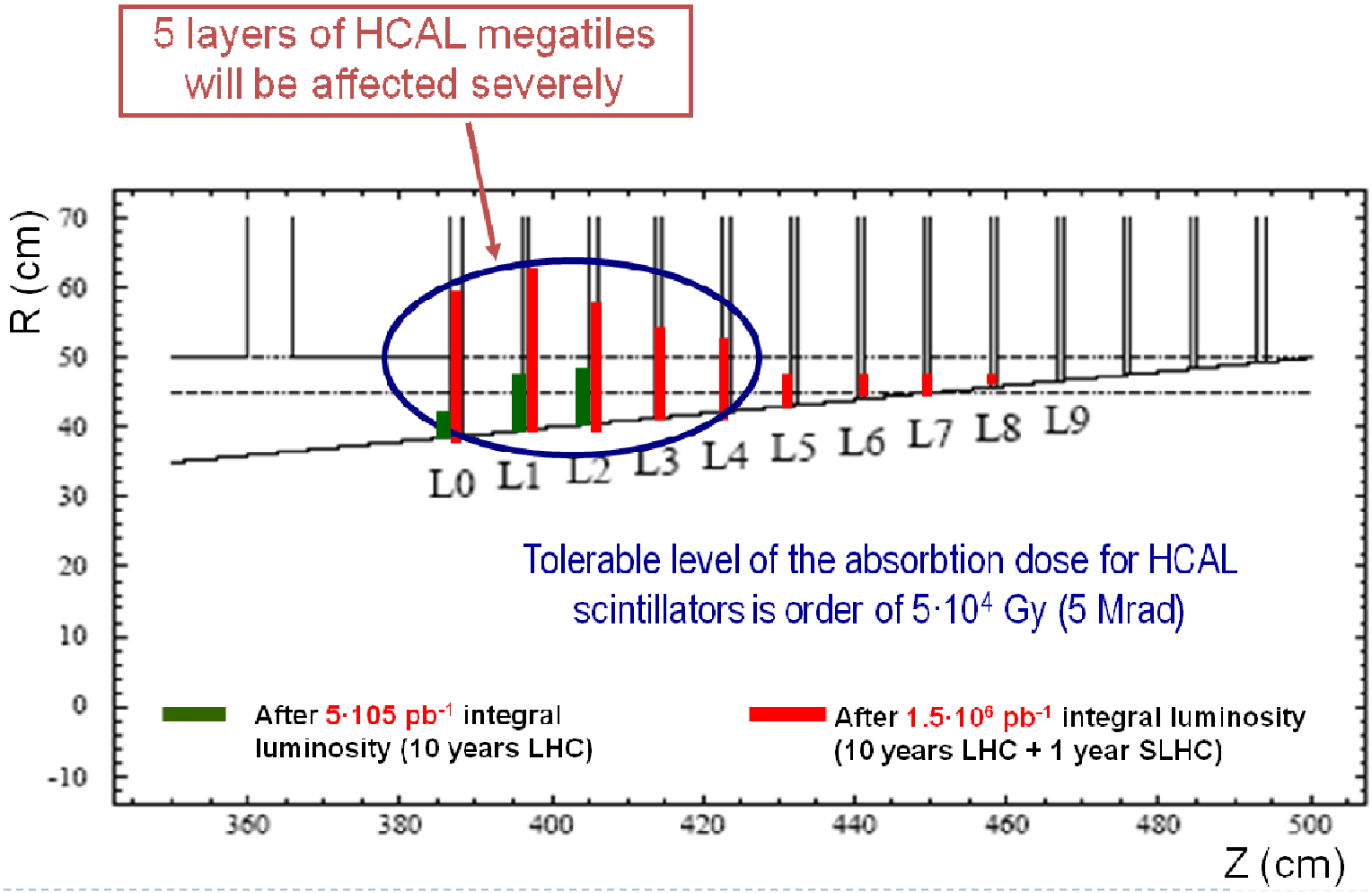
Dead time will rise to ~12% due to increase in peak luminosity

CMS BPIX Upgrade Phase 1 (2013)



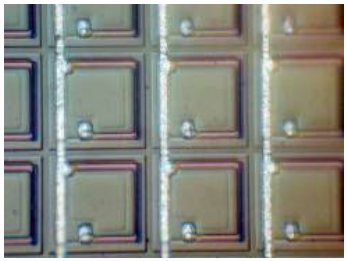
New design adds a fourth pixel layer, is capable of higher rate running, and total material is substantially reduced from current 3 layer Pixel detector. In addition inner layer modules can be replaced during shutdown

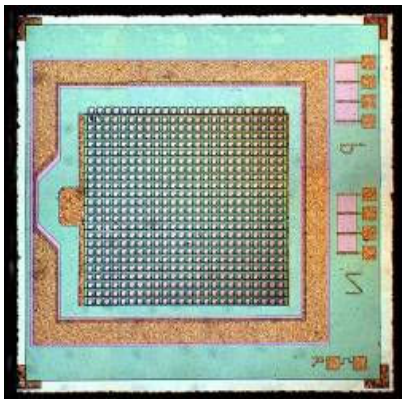
Example damage to scintillator for innermost region of Hadronic Calorimeter Endcap

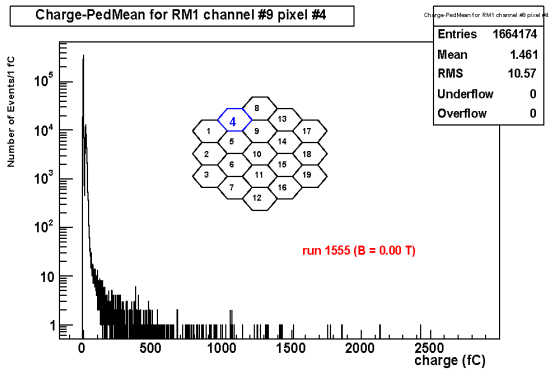


New Photodetectors for Hadronic Calorimeter- SiPMs

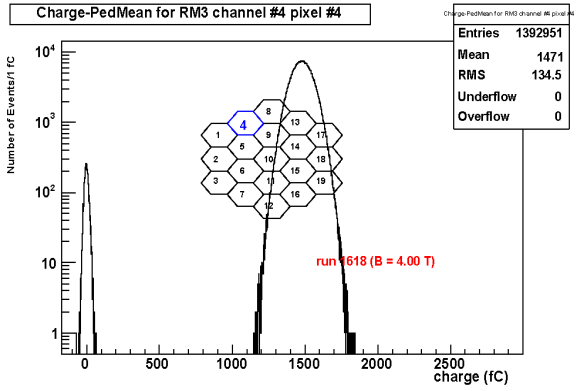
- Array of avalanche photo diodes ("digital" photon detection)
  - Array can be 0.5x0.5 up to 5.0x5.0 mm^2
  - Pixel size can be 10 up to 100μ
- All APDs connect to a single output
  - Signal = sum of all cells
- Advantages over HPDs:
  - 28% QE (x2 higher) and 10^6 gain (x500 higher)
  - More light (40 pe/GeV), less photostatistics broadening
  - Very high gain can be used to give timing shaping/filtering





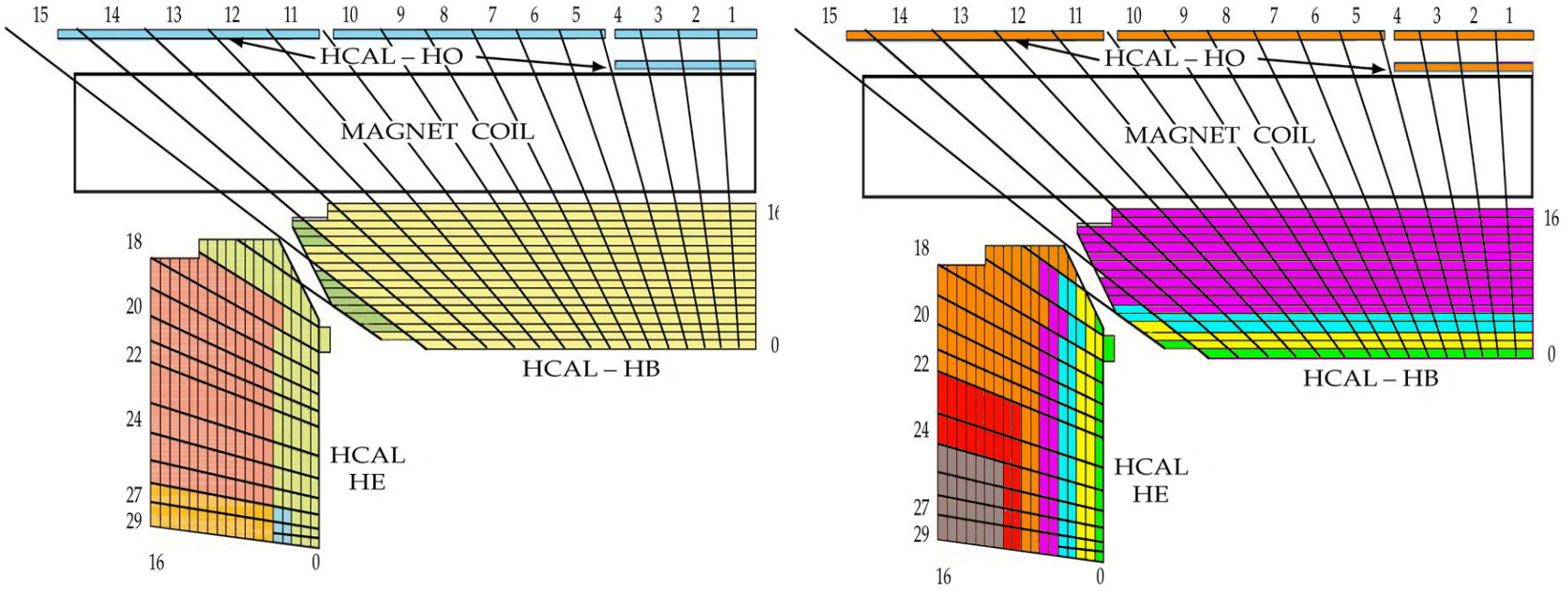


HPD



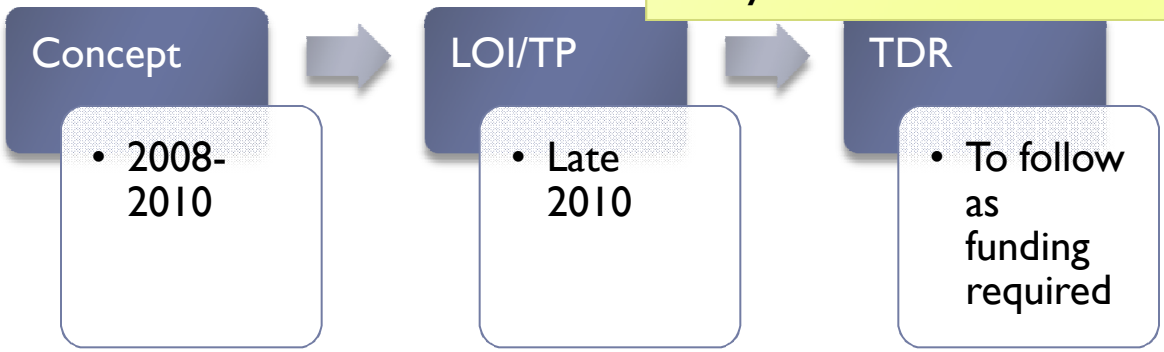
SiPM

New Photodetectors allow finer segmentation of readout in depth



Documents

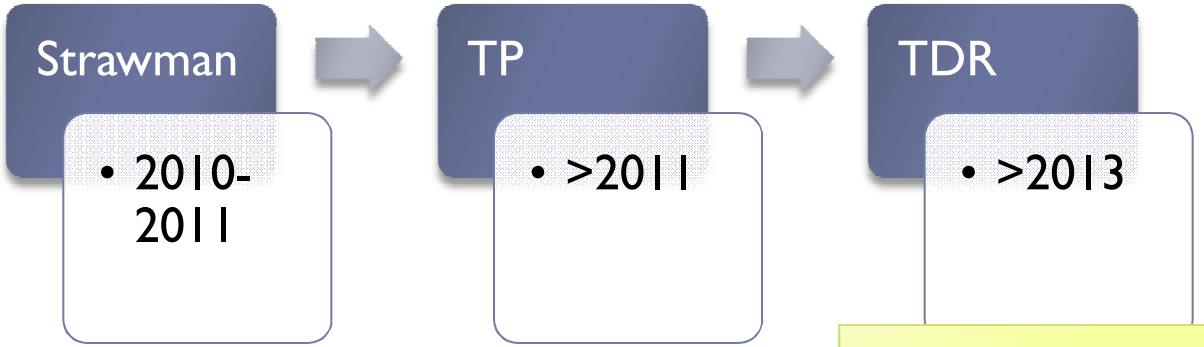
Work Plan agreed at the May Workshop 2008
Dates have been moving. Propose to produce the TP for Phase 1 by end of this year and submit to the LHCC. It will be physics driven and will help us with planning for the construction and installation of the various components. In some cases funding is needed this year.



Phase I Upgrades

Pixel Muons

HCAL Trigger



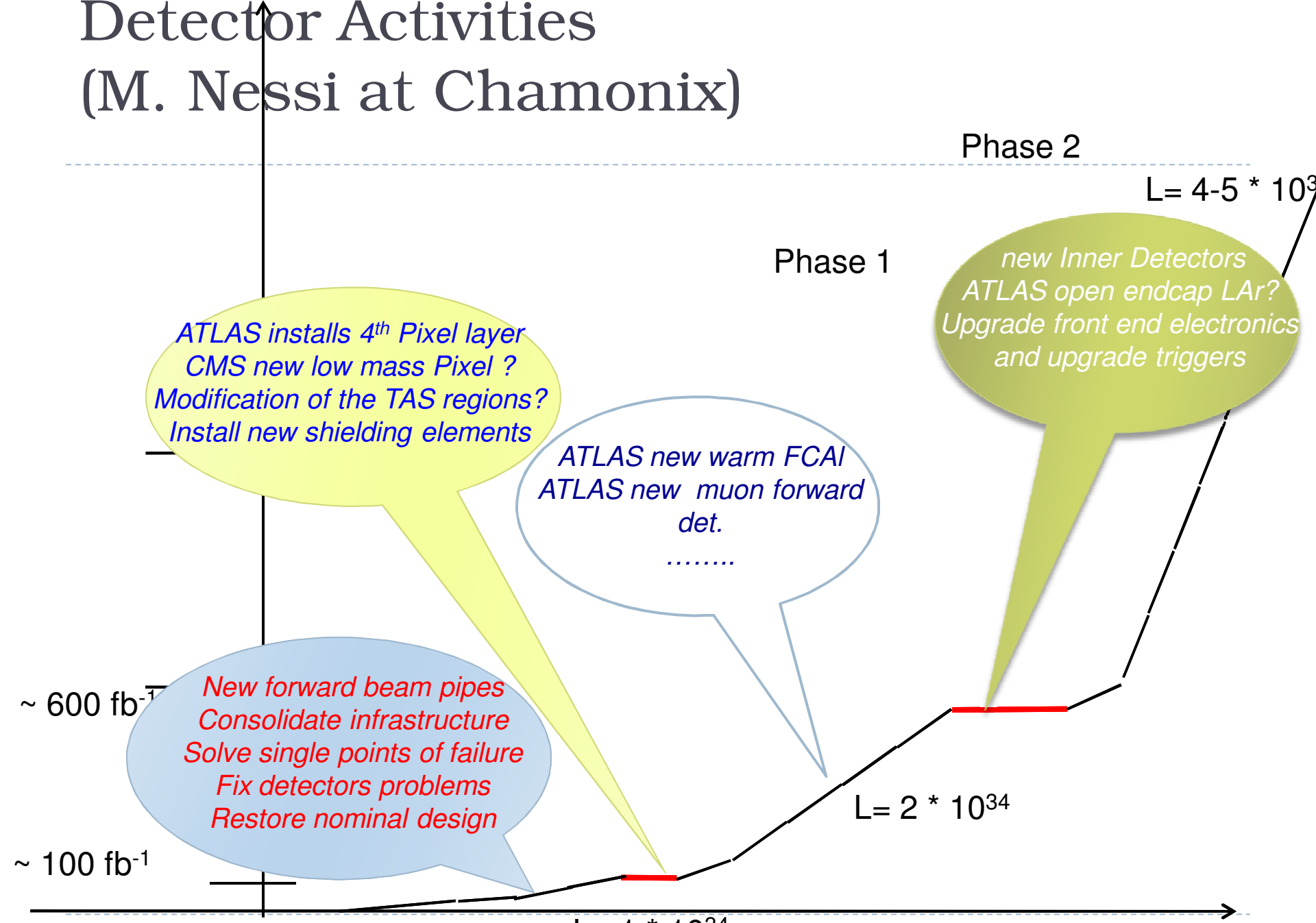
Phase 2 Upgrades

Revisit dates – Likely TP > 2011

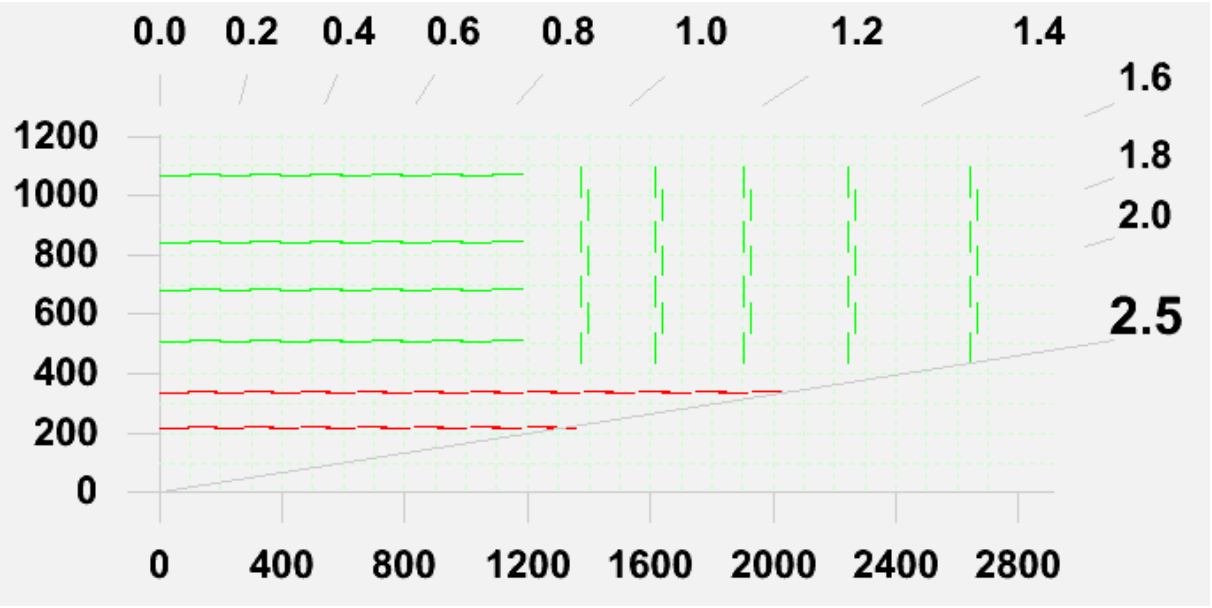
Scenarios for Phase 2

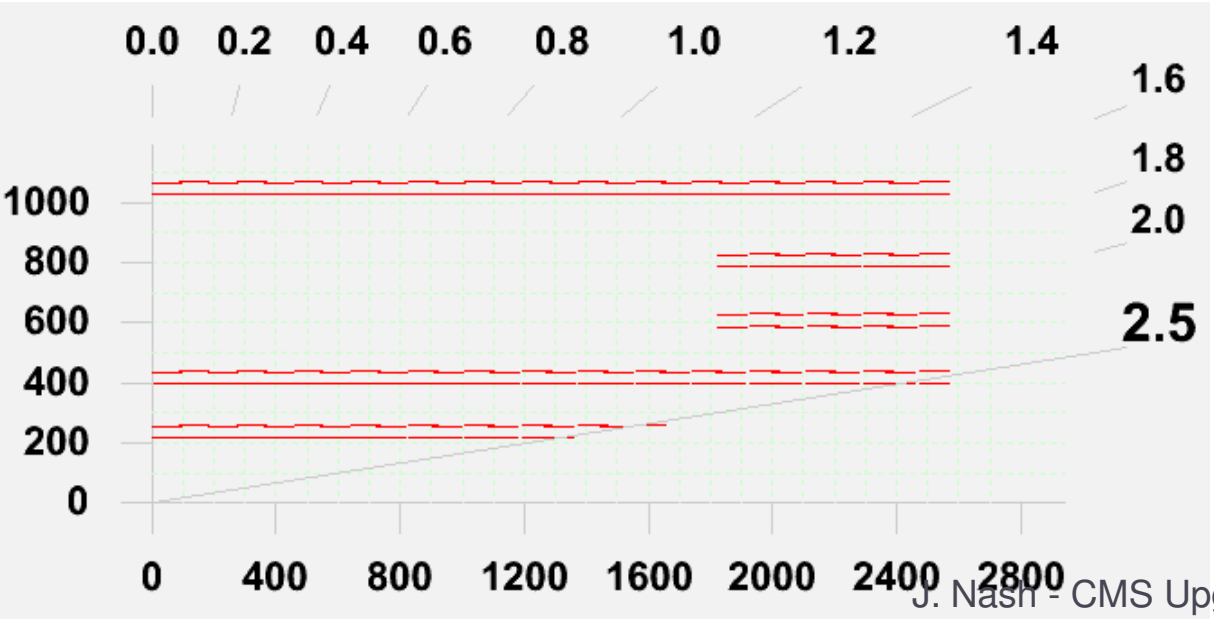
- The key issues for the phase II upgrades are the timescale, and the peak/integrated luminosity of phase II
- 300/fb-year 3000/fb are important targets which motivate producing a new central tracking detector
- 2020 as a timescale for when we switch over is also an important date
  - 10 years is a reasonable horizon for producing a new detector of this complexity. Much longer and it becomes difficult to keep the teams and knowledge in place. Difficult to actually deliver from now on a much shorter time scale
    - We clearly already adjusted our planning after Sept 19th
- The number of underlying events is also an important parameter
  - 100 events/crossing is much easier to swallow
  - Luminosity leveling if it works would clearly help in terms of operating the detector

Detector Activities (M. Nessi at Chamonix)



CMS – Studies of new tracker layouts

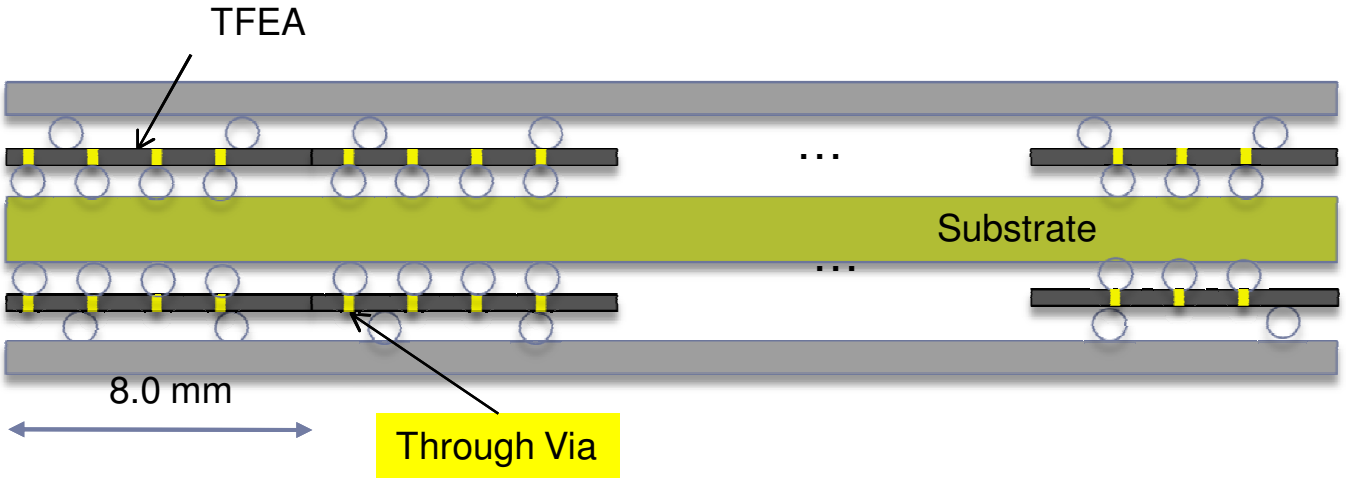




- Studying several potential layouts for a new outer tracker
- Want to increase granularity as well as minimize material in future tracker
- Need to understand how many triggering layers (in red at left), and where they need to be located in order to provide adequate triggering capability
- No final decision on layout of tracker until final requirements determined

Potential tracking layer technologies – example Double bump assembly

- Phase 2 technologies still quite advanced
- R/D needs to be pursued aggressively



Sensor	250um
C4	100 um
ASIC	100 um
C4	100 um
Substrate	700 um
C4	100 um
ASIC	100um
C4	100 um
Sensor	250 um

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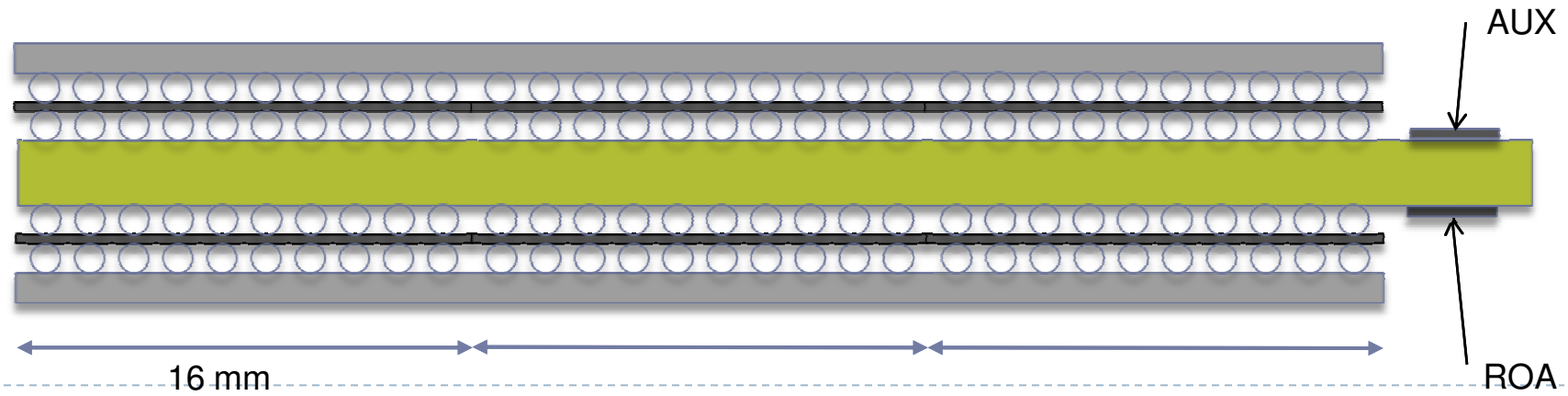


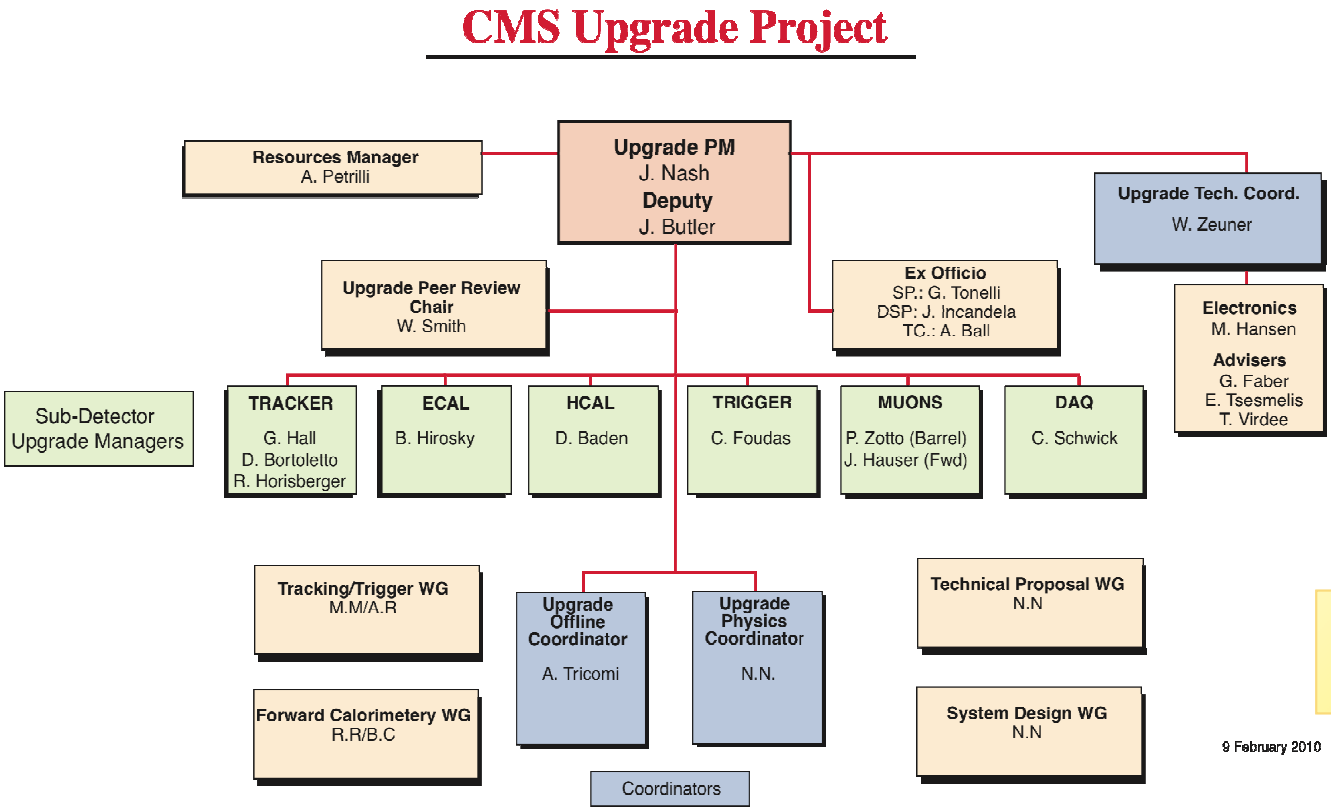
CMS view after Chamonix – early stages

- Our upgrades in the first phase to a large part decouple from the "big shutdowns"
- We will probably want to put these in in an Adiabatic fashion (Muons/HCAL/trigger) in order to give maximum flexibility for scheduling the logistical problems of the installations.
  - Don't want to try and do this all at once
  - Start early (ALARA)
  - Annual shutdowns of 3-5 months will allow us to make a lot of progress over the coming years at upgrading in this fashion
- We can put in a new pixel detector in a short time
  - Could in principle be replaced during a 3-4 month shutdown
  - We probably want to decouple this from the beam-pipe installation?
    - bakeout time
- Technical Proposal this year to help make case to funding agencies, and motivate upgrades for this decade

Longer term

- We have to have a credible programme of long term operation of the LHC in order to be able to justify the planning for the phase II upgrades
  - This is also vital for the health of CERN and the field of HEP.
  - Important commitment of the Lab to a programme of 3000/fb 300/fb-year which lasts out to 2030
- It is OK to delay by a few years, but the planning, and push of the lab is vital for the long term operation of the LHC
  - Preparing new trackers is a 10 year programme. They are very challenging, and we have to be pushing ahead with the R/D now in order to be able to consider building these devices.

Upgrade project organization



New working groups for TP, System Design