Status of WP4
CMS 2

J. Nash Imperial College

Outline

- Tasks 4.1
  - Status of reporting to EU
  - Brief update on CMS upgrade activities
- Tasks 4.2
- Looking forward

Task 4.1

Description of work

Task 4.1 Coordination and organisation of CMS2

Overall coordination task for managing the upgrade of the experiment for SLHC; identification of participating institutes and their contribution, including activities related to seeking and integrating new partners; definition of the organisational project structure needed to manage the consortium of institutes participating in the construction and modification work; negotiation with institutes and funding agencies to establish collaboration agreements, cost books and reporting methods; exchange and dissemination of scientific and technical information (CERN, Imperial)

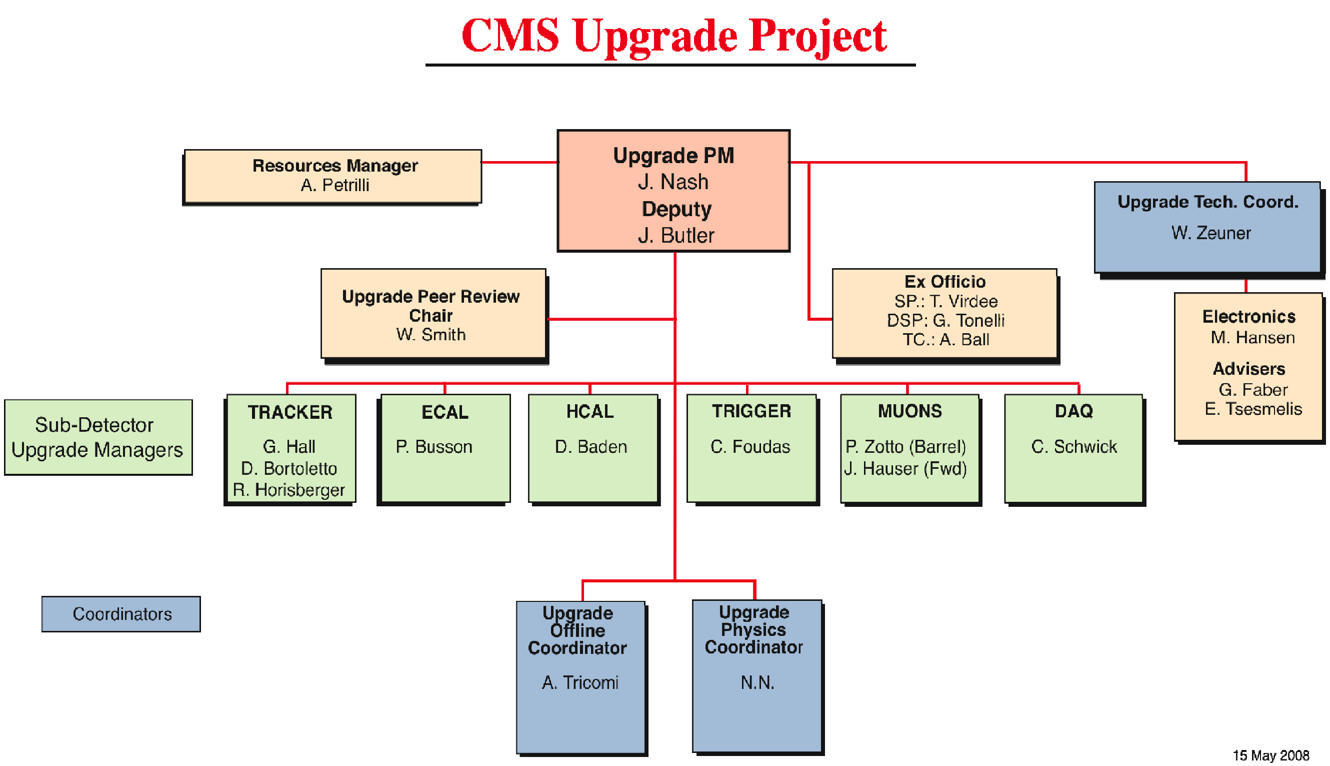
Deliverables task 4.1	Description	Nature	Delivery date
4.1.1	Project Structures for construction of systems and sub-systems	O, R	M12
4.1.2	Cost book and MoU for the upgrade and installation phase	R	M36

Milestone	Description	Nature	Expected date
4.1	Upgrade Project Scope defined	R	M18

Task 4.1.1 – Management Structure

- Project management structure defined
- Management team put in place
- Team and mandate approved by CMS
  - Now a “project” (ala Tracker/ECAL…)
- Regular meetings of management team
- Monthly meetings of overall upgrade team
  - Regular meetings of many subgroups within sub-detector upgrade projects
- Four Workshops held, more planned next year
- Report published

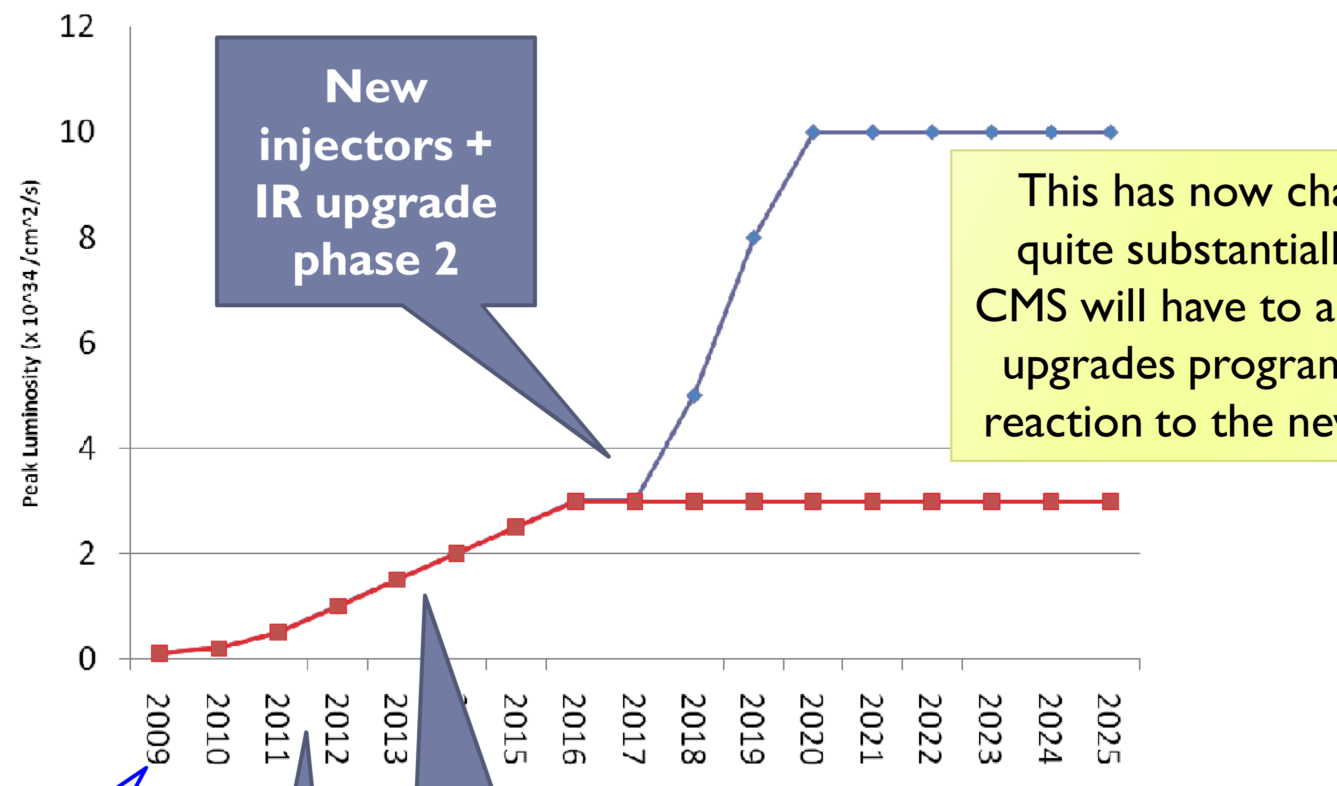
Upgrade project organization



Milestone 4.1 – Upgrade Scope

- Workshop in May 2008 at CERN to define the scope of upgrades
  - What needs to be done in Phase I, Phase 2
- Follow up workshop held November 2008 in FNAL (150 participants) to track progress, and prepare work plan for the following six months
  - Goal prepare TP for phase I upgrades
- Workshop held in May 2009 to present, approve plans for phase I upgrades, and also progress towards a "Strawman" for phase 2 upgrades.
- Follow on Workshop held in Oct 2009 at FNAL
- Report published to EU – Milestone passed
  - Explicitly break out phase I and phase 2

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



New injectors + IR upgrade phase 2

Linac4 + IR upgrade phase 1

Collimation phase 2

Early operation

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

Upgrades required to keep CMS operating at maximum potential throughout

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
    - Putting in the new triplets

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

When do we need the Phase I upgrades?

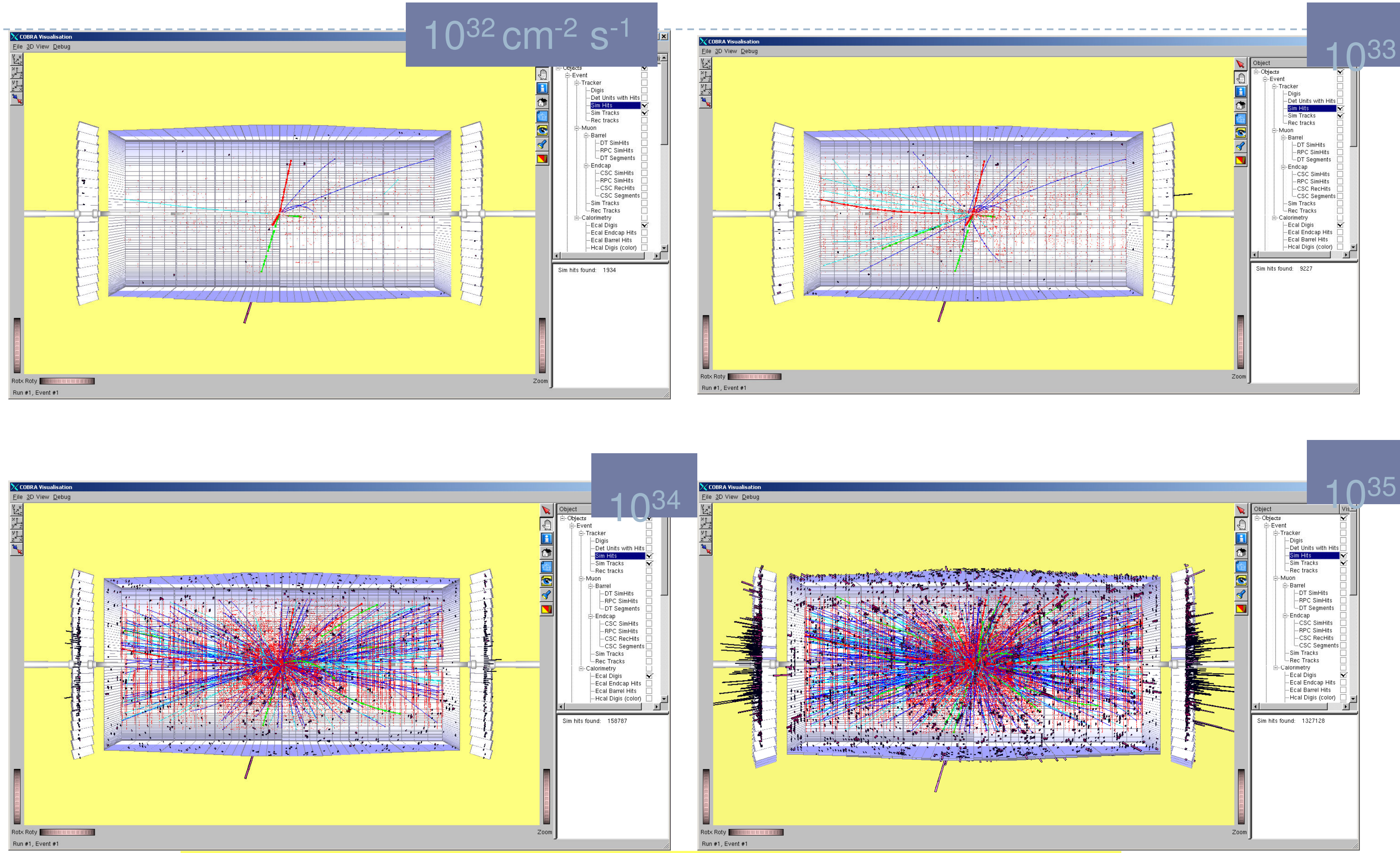
- Are the upgrades required to cope with higher peak/integrated luminosity
- Would we get benefits by introducing some of the upgrades earlier?
  - Physics/performance (e.g. reliability)
- Are there some upgrades which we would be better off delaying?
  - Pixel –
    - We are now in a position where we could produce a new detector in about two years time. We should probably aim to stay in that condition, but keep the R/D moving so that the detector gets more performant for the longer term
- Other upgrades we may want to go ahead with more quickly
  - HCAL/Muons

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

Detector Challenges
CMS from LHC to SLHC

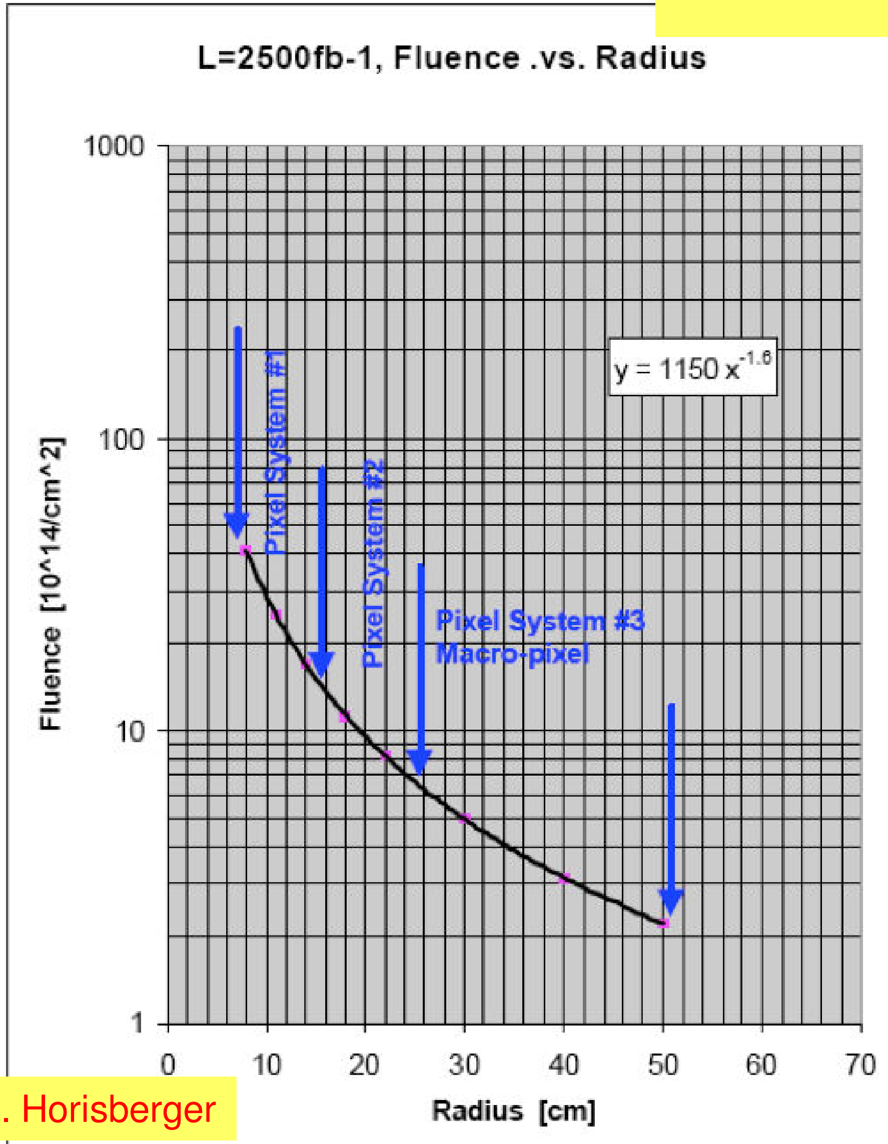


The tracker is the key detector which will require upgrading for SLHC Phase 2

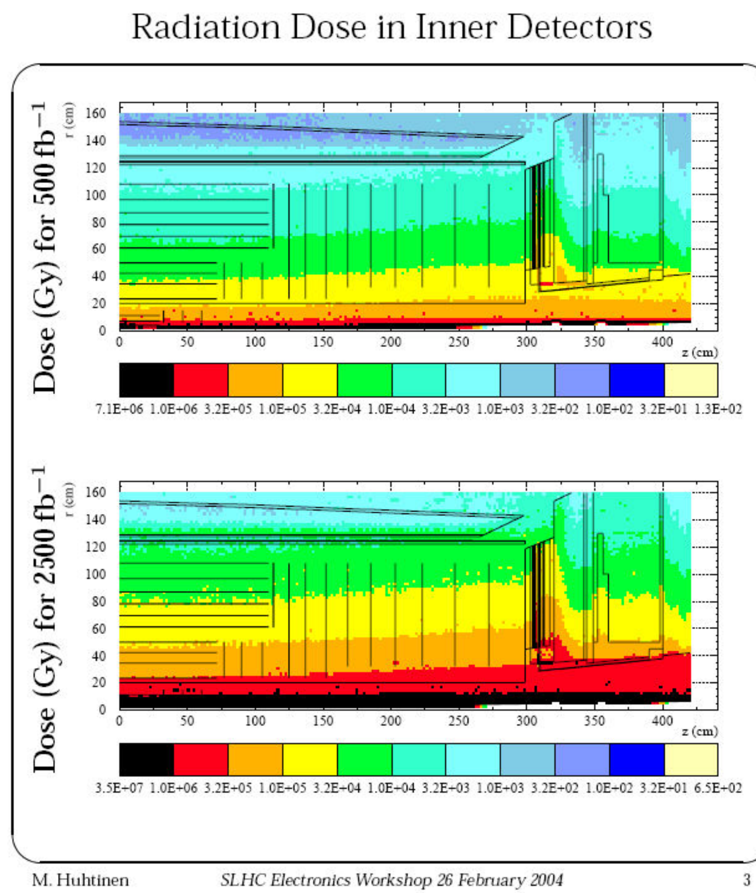
I. Osborne

Radiation environment for trackers

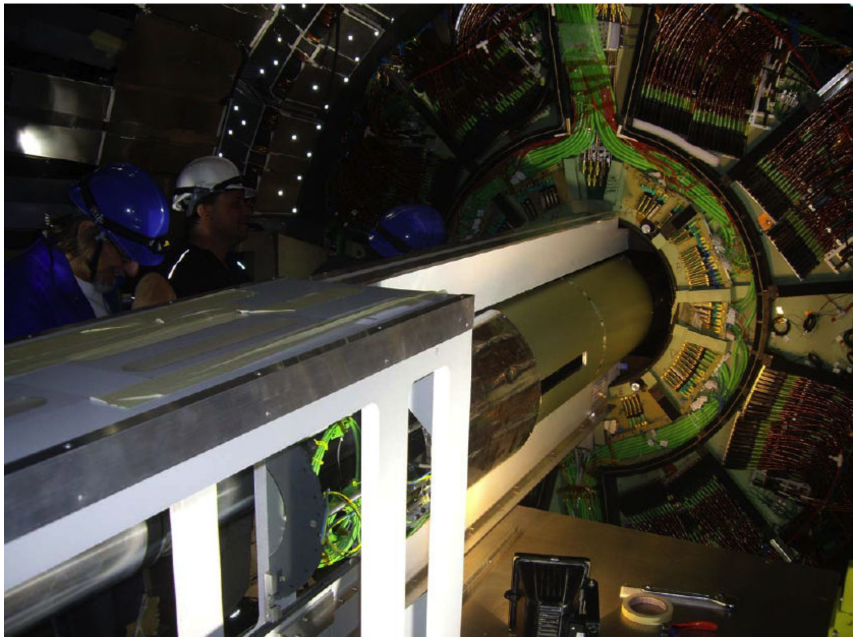
Except for the very innermost layers many current technologies should survive SLHC

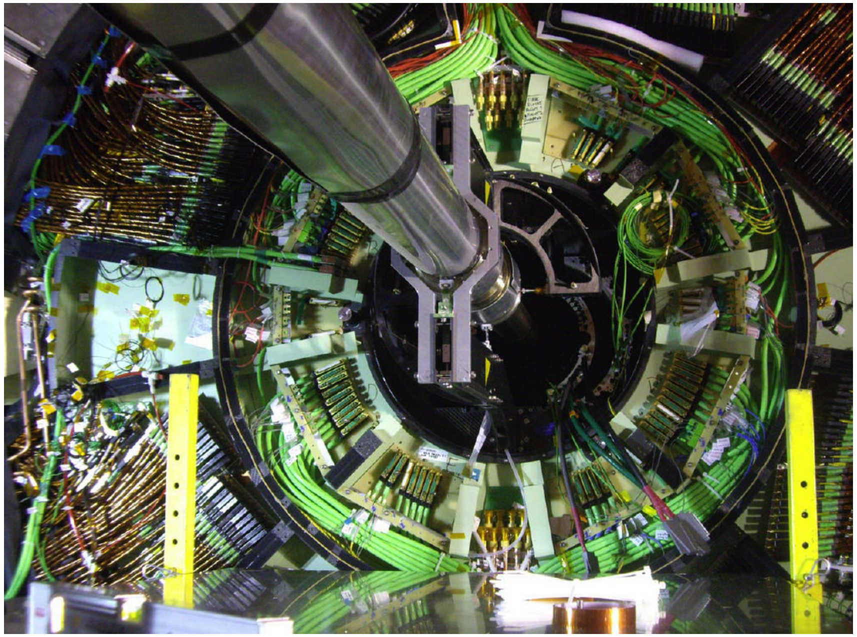


R. Horisberger



Fast insertion of CMS Pixel system

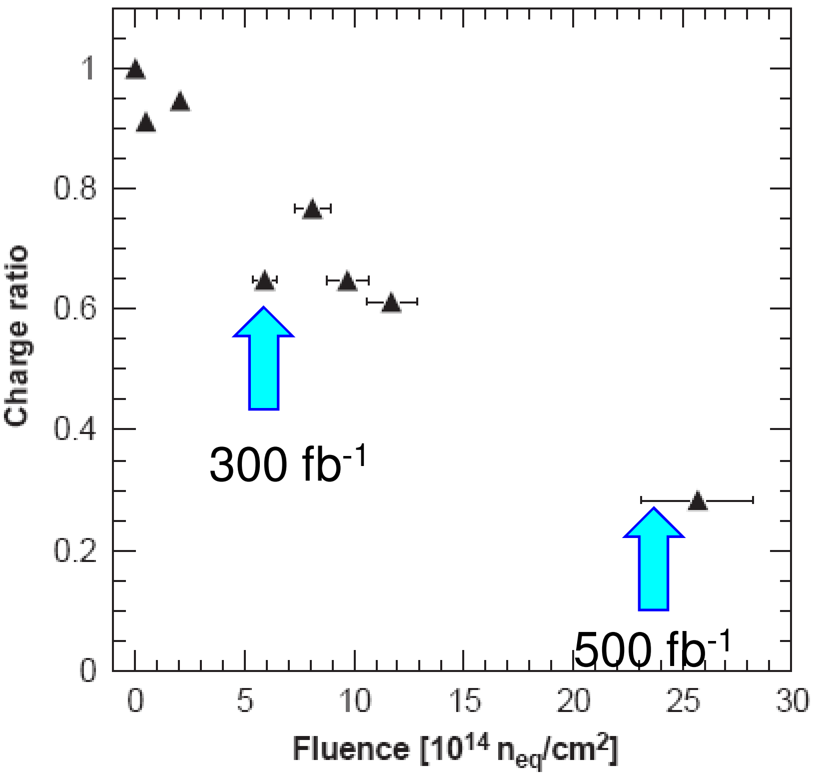


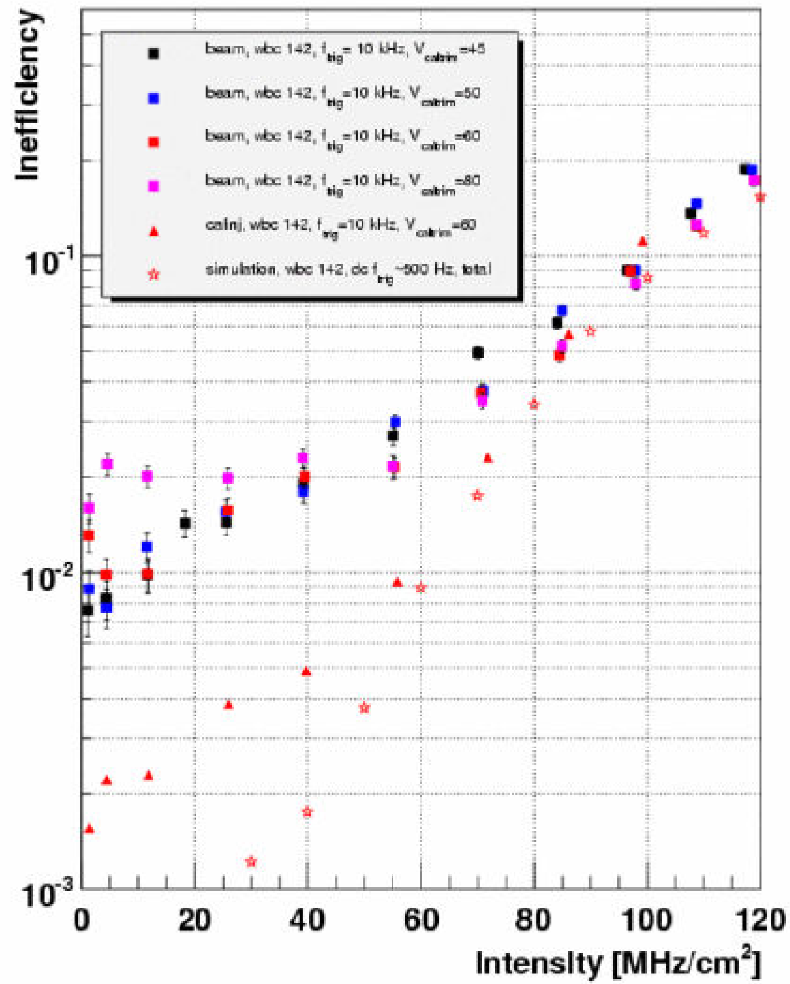


Insertion of the Pixel was done in a few hours

Limitations in Phase 1

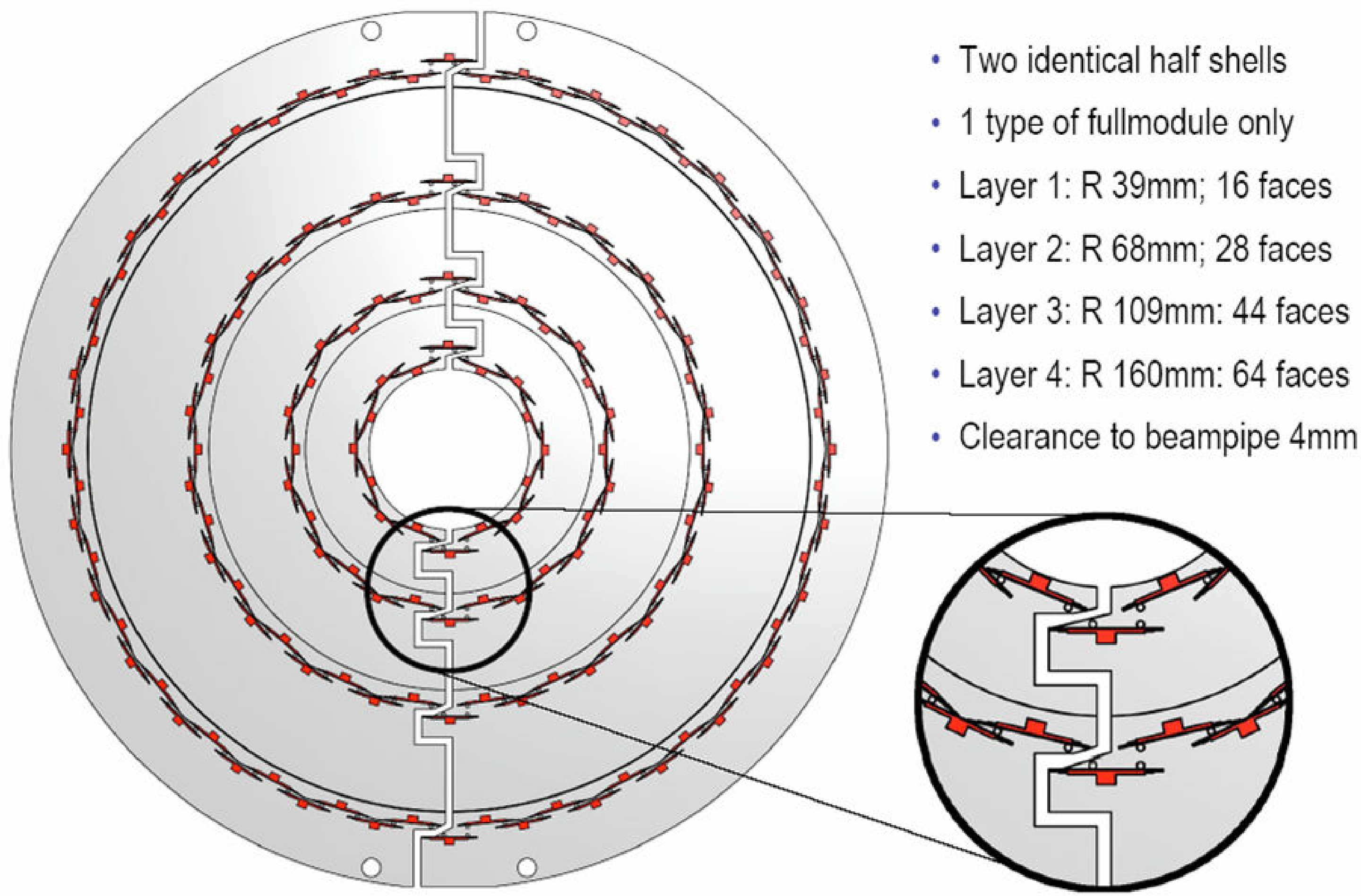
- Radiation damage due to integrated luminosity.
  - Sensors designed to survive $6\times10^{14} n_{eq}/cm^2$ (~ 300 fb^{-1}).
  - n-on-n sensors degrade gradually at large fluences





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

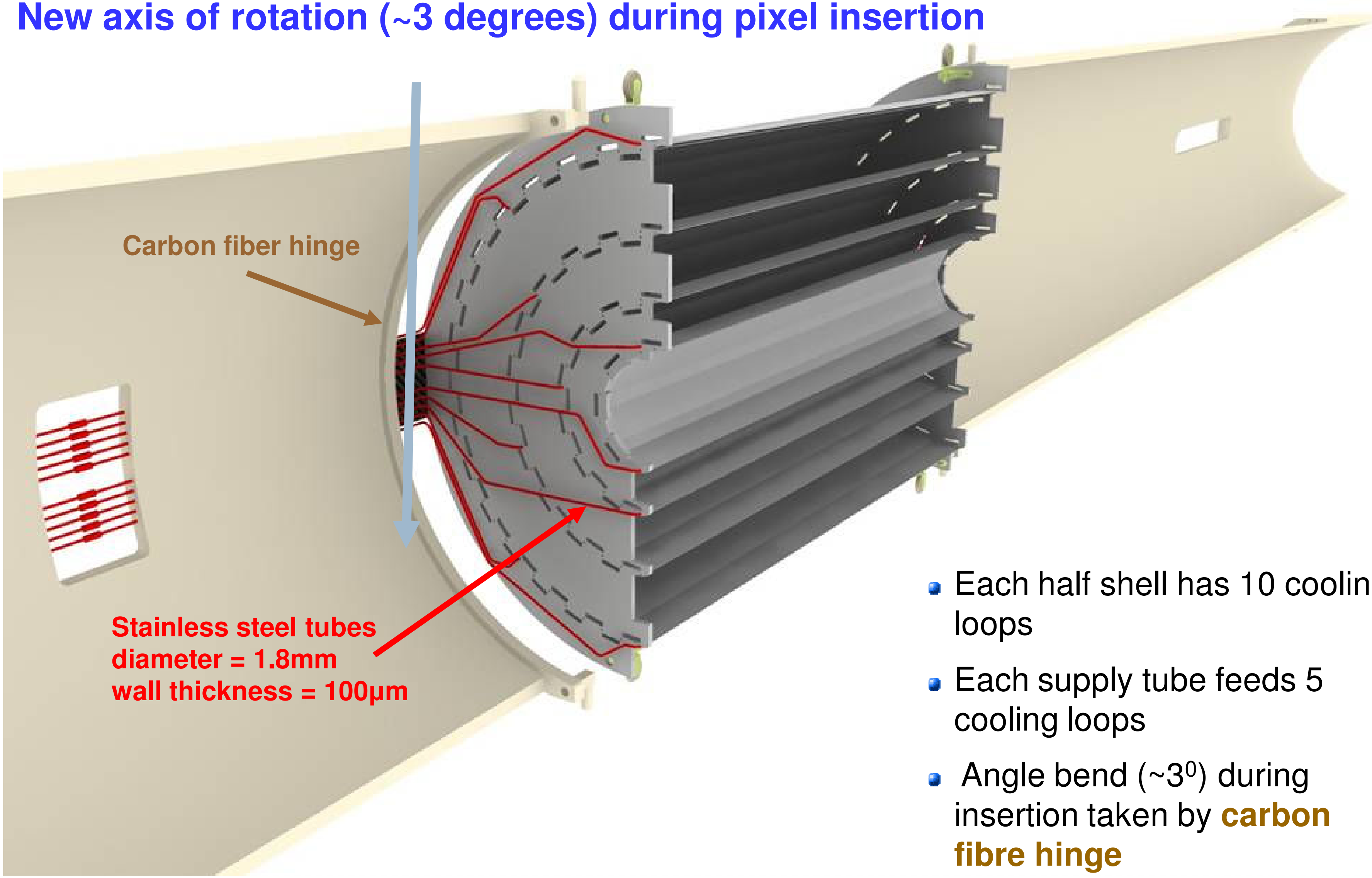
CMS BPIX Upgrade Phase 1 (2013)



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

Inertion of BPIX – Supplytube System with new CO2 Cooling

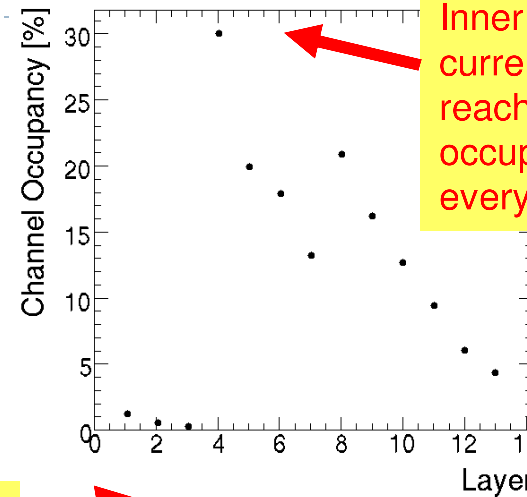
New axis of rotation (~3 degrees) during pixel insertion



- Each half shell has 10 cooling loops
- Each supply tube feeds 5 cooling loops
- Angle bend (~3^0) during insertion taken by **carbon fibre hinge**

Tracking with 100s of min Bias events

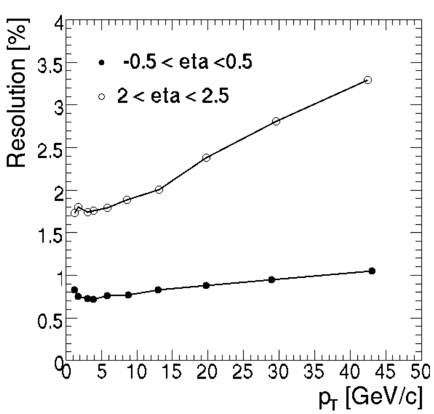
- Study of current CMS tracker for Heavy Ion events
- Track density very similar to 50ns running
  - $dn^{ch}/d\eta$/crossing ≈ 3000
  - Tracker occupancy very high
  - Need more pixel layers/shorter strips
- Tracking possible
  - When tracks are found they are well measured
  - Efficiency and fake rate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



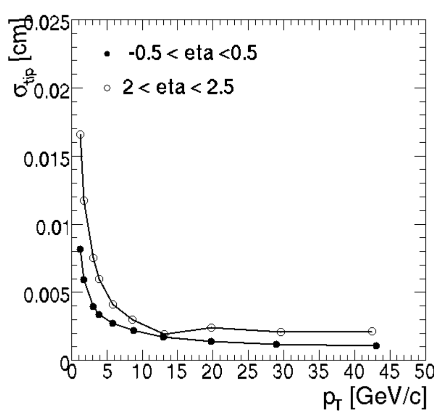
Inner layers of current strip tracker reach 30% occupancy on every xing!

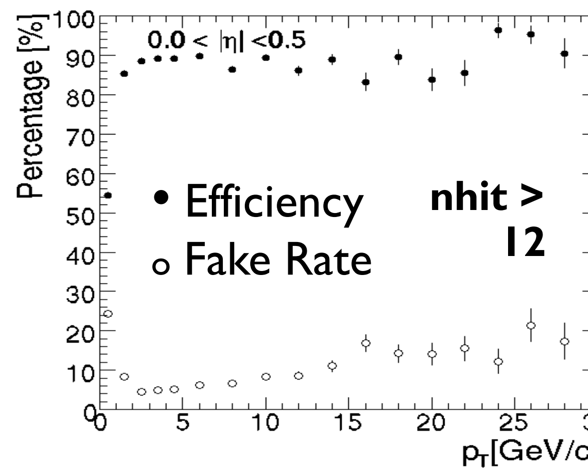
Current Pixel layers

Momentum Resolution



Transverse Impact Parameter Resolution



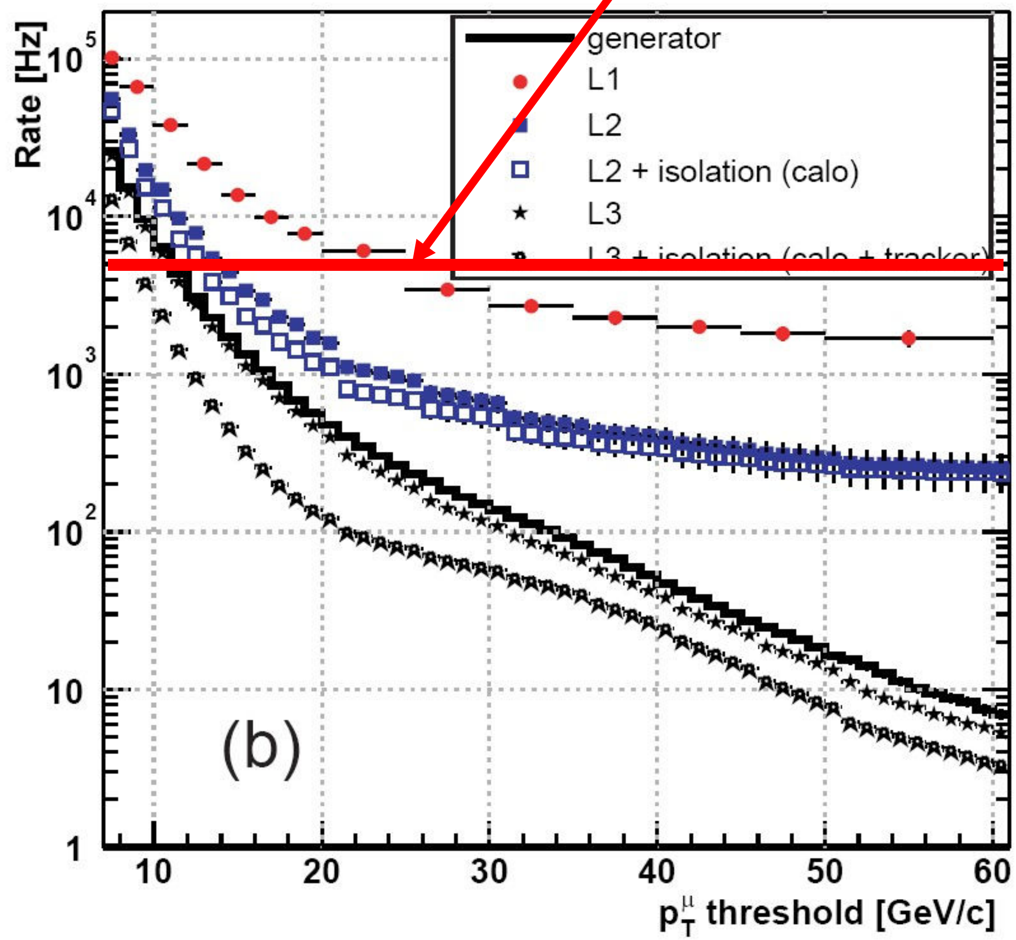


C. Roland

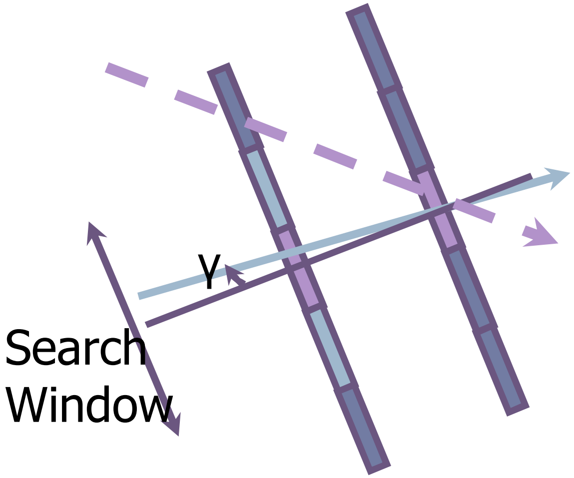
Level 1 Trigger

Level 1 Trigger has no discrimination for P_T > ~ 20 GeV/c

- 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
  - One example: 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
- Single electron trigger rate also suffers
  - *Isolation criteria are insufficient to reduce rate at* $\mathcal{L} = 10^{35}\ cm^{-2}.s^{-1}$

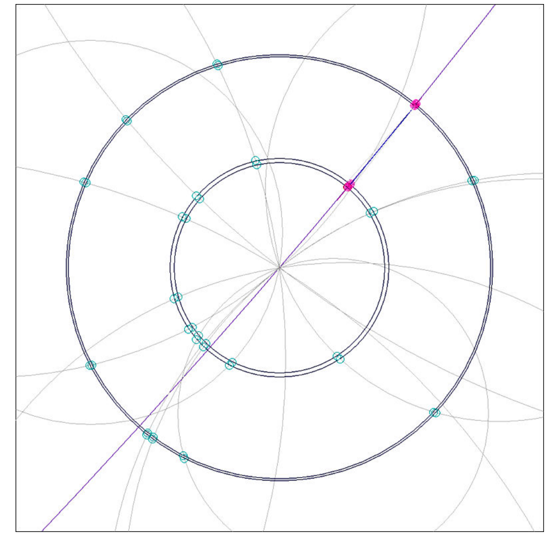


Concepts:Tracking Trigger



High momentum tracks are straighter so pixels line up

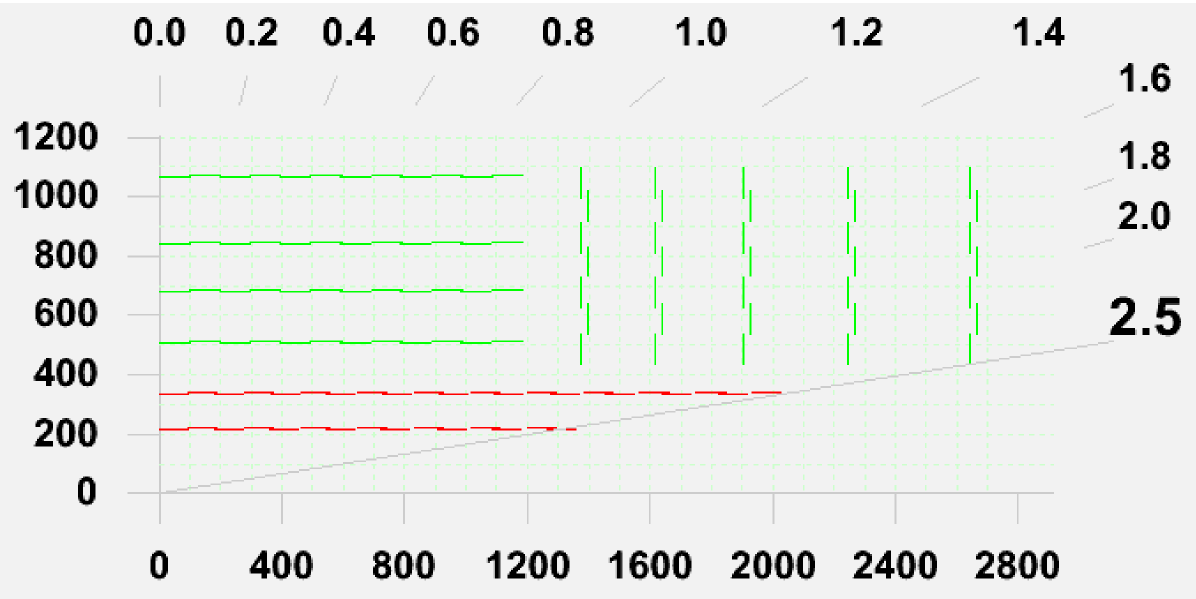
Pairs of stacked layers can give a P_T measurement

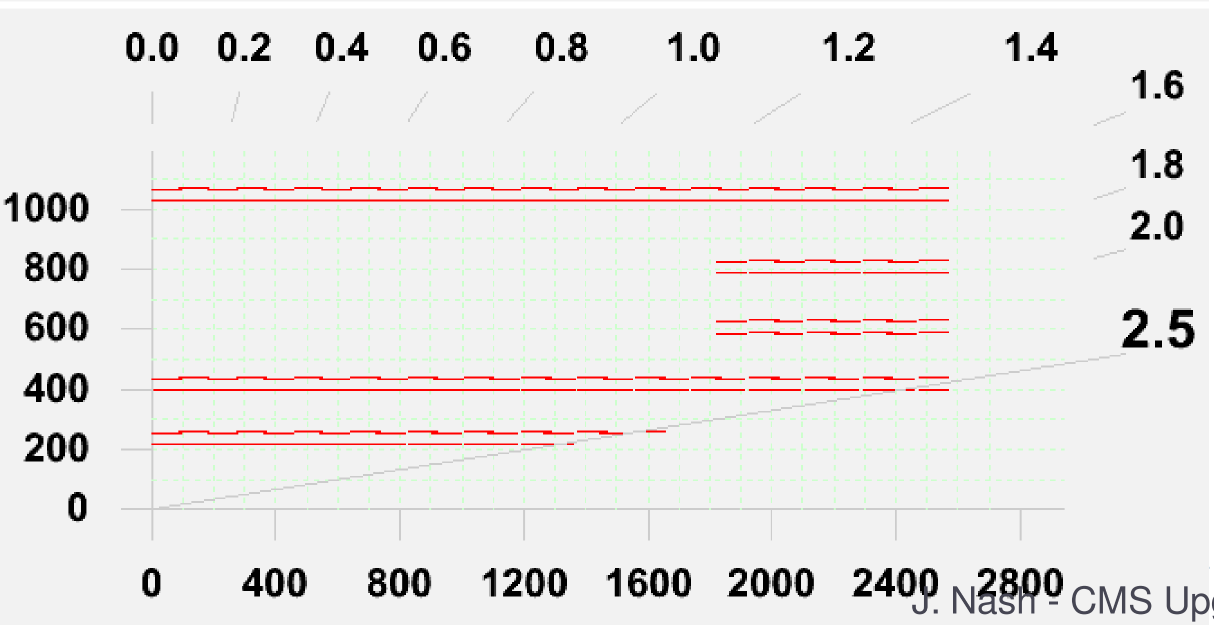


Geometrical p_T-cut - J. Jones, A. Rose, C. Foudas LECC 2005

- Why not use the inner tracking devices in the trigger?
  - Number of hits in tracking devices on each trigger is enormous
  - Impossible to get all the data out in order to form a trigger
  - How to correlate information internally in order to form segments?
- Topic requiring substantial R&D
  - "Stacked" layers which can measure p_T of track segments locally
    - Two layers about 1mm apart that could communicate
  - Cluster width may also be a handle

CMS – Studies of new tracker layouts



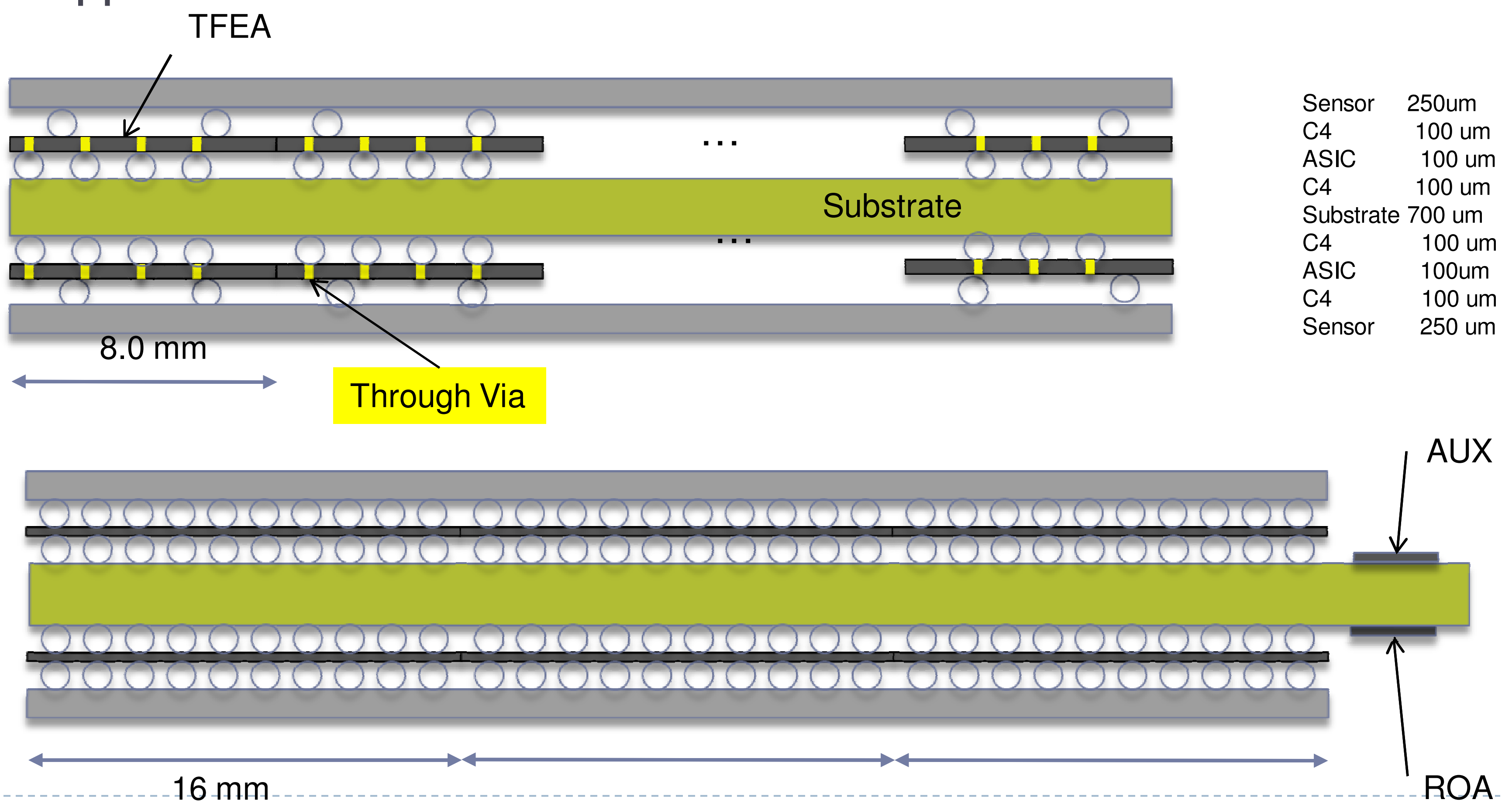


- Studying several potential layouts for a new outer tracker
- Want to increase granularity as well as minimize material in future tracker
- Need to understand how many triggering layers (in red at left), and where they need to be located in order to provide adequate triggering capability
- No final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

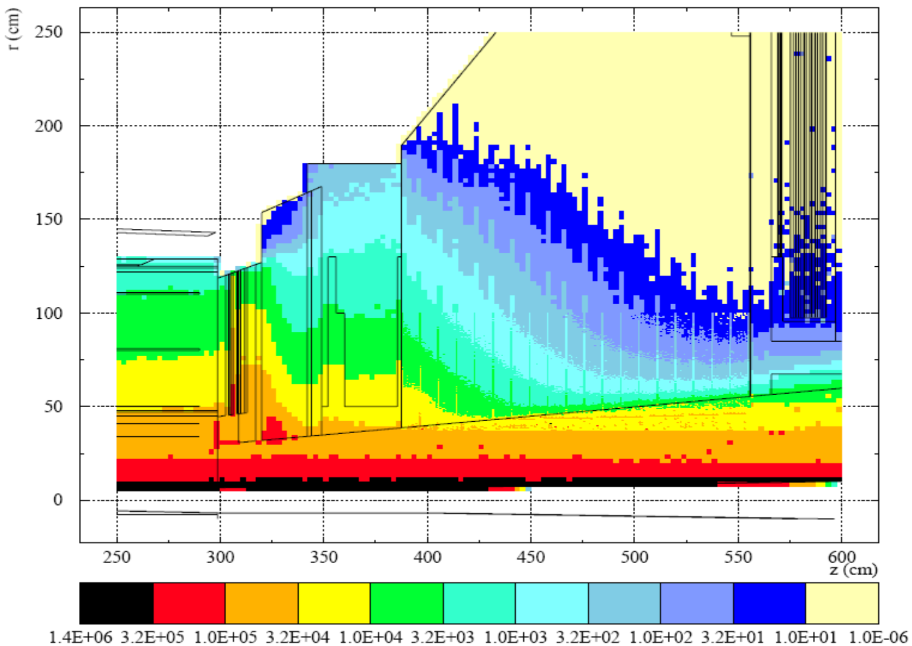
Potential tracking layer technologies – example Double bump assembly

- Such techniques are becoming available
  - eg for high density non-volatile memories and telecom applications

A Marchioro

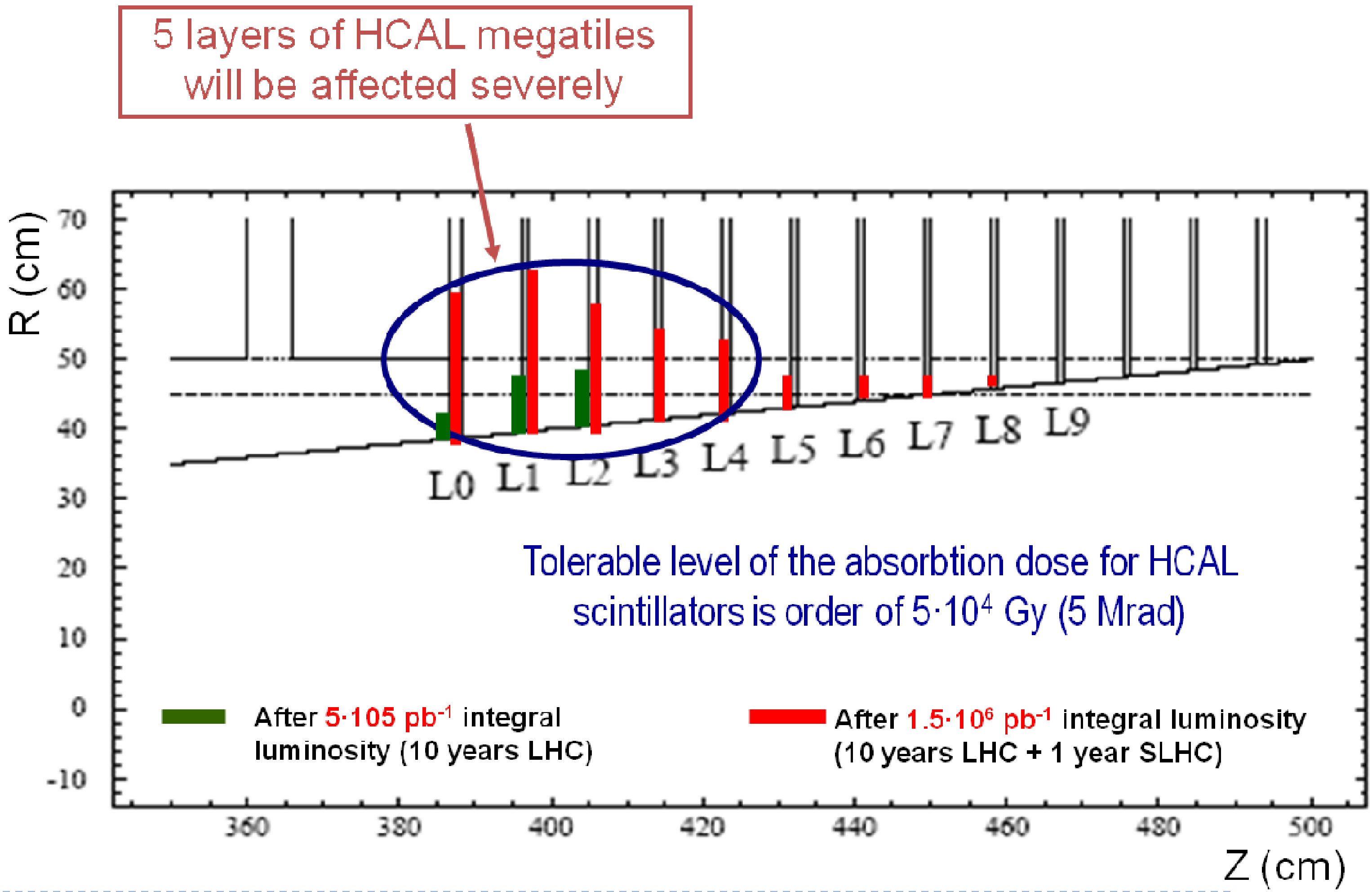


Forward calorimeters suffer particularly sever radiation environment



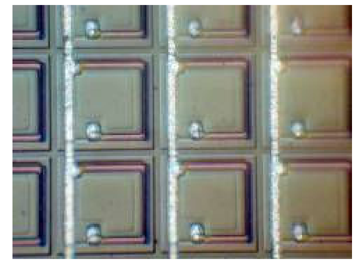
The radiation map of HE calorimeter, Huhtinen et al. (CMS IN 2001/050)
10 years at L = 10^{34} $cm^{-2}s^{-1}$ luminosity is assumed, the units are Gy

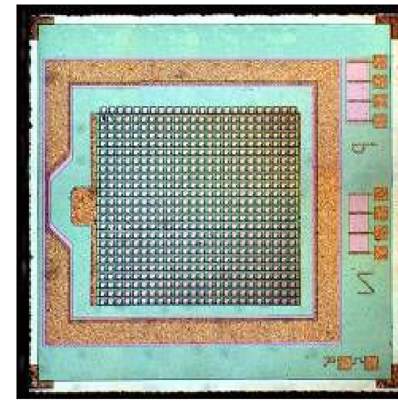
Example damage to scintillator for innermost region of Hadronic Calorimeter Endcap

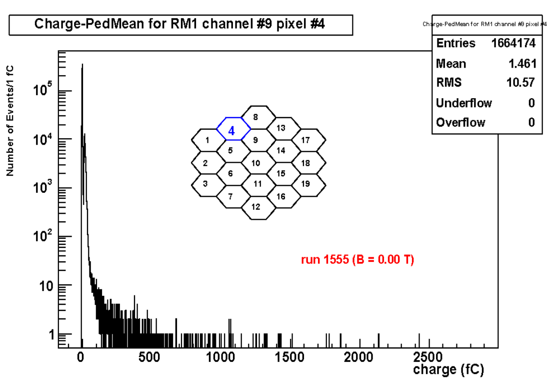


New Photodetectors for Hadronic Calorimeter- SiPMs

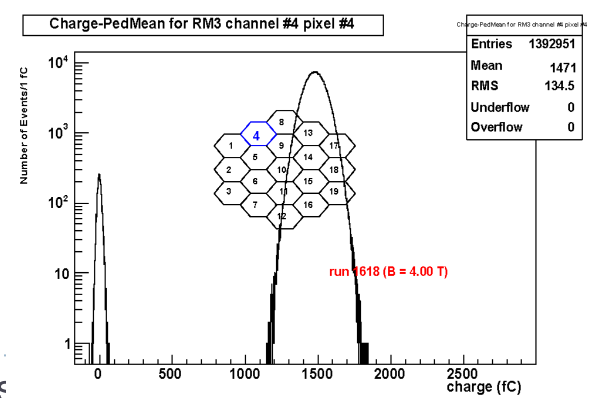
- Array of avalanche photo diodes ("digital" photon detection)
  - Array can be 0.5x0.5 up to 5.0x5.0 mm^2
  - Pixel size can be 10 up to 100µ
- All APDs connect to a single output
  - Signal = sum of all cells
- Advantages over HPDs:
  - 28% QE (x2 higher) and 10^6 gain (x500 higher)
  - More light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





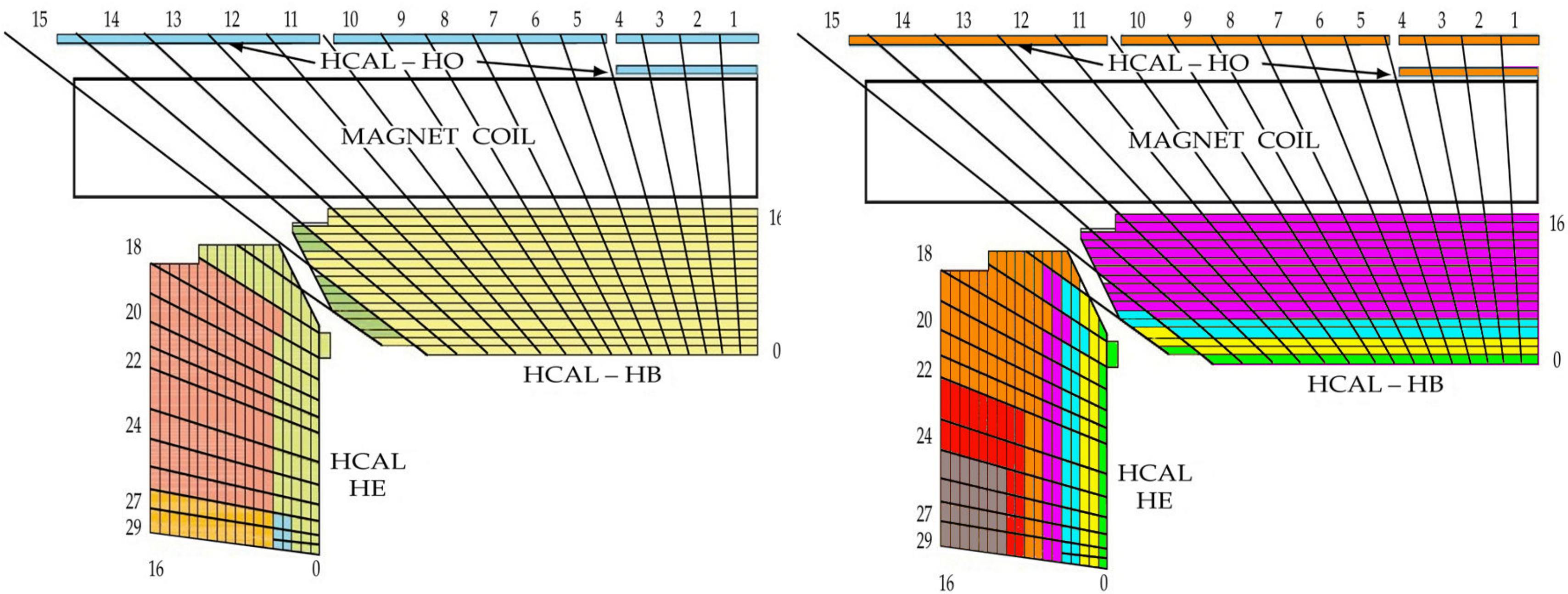


HPD



SiPM

New Photodetectors allow finer segmentation of readout in depth



Documents

Work Plan agreed at the May Workshop 2008
We should not race to produce documents, nor cut off R/D in order to meet deadlines which don't now make sense. On the other hand, want to keep momentum

Phase I Upgrades

Concept
- 2008-2010

LOI/TP
- Late 2010

TDR
- To follow as funding required

Pixel ME4

HCAL Trigger

Phase 2 Upgrades

Strawman
- 2010-2011

TP
- >2011

TDR
- >2013

Revisit dates – Likely TP > 2011

WP 4.2 Deliverables

Deliverables task 4.2	Description	Nature	Delivery date
4.2.1	Personnel and working practices of the Technical Coordination unit in place	O, R	M12
4.2.2	Key structural requirements (information repository, tools, coordination framework, safety and quality systems, integration office) and scheduling and reporting mechanisms in place	O, R	M18
4.2.3	Pilot design and schedule for the upgrade project published.	R	M36

Task 4.2.1 – Upgrade TC Unit established

- Upgrade TC named (W. Zeuner)
- Working within the current technical coordination unit.
- Have started work on defining the working methodology
- Planning for Muon system phase I upgrade (ME 4/2 Construction and installation) well advanced. Preparing area in bat 904 for construction
- Meetings between Executive Board, and Project Managers to discuss procedures for reviews, TC needs for upgrades, engineering support issues
- Report published

Task 4.2.2 – Upgrade TC methodology defined

- Working within the current technical coordination methodology.
- Examined potential changes for future operation
- Report nearly published

Conclusions

- Good progress on tasks/Milestones
  - Upgrades teams established
  - Upgrade Scope understood
    - Details being studied/prepared
- Phase I/Phase 2 split actually allows us to deliver a fairly complete upgrade plan during the course of this FP7 project
- There may be some issues with completing cost book/MOU by the end of the project, although we should be able to define how these will work. Although several upgrades are nearly "Shovel ready" we may not get funding in place on the timescale of the project due to the delayed startup of the LHC

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
  - 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 may want to decouple this from the beam-pipe installation?
    - bakeout time

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.
  - A commitment to a programme of 3000/fb 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.