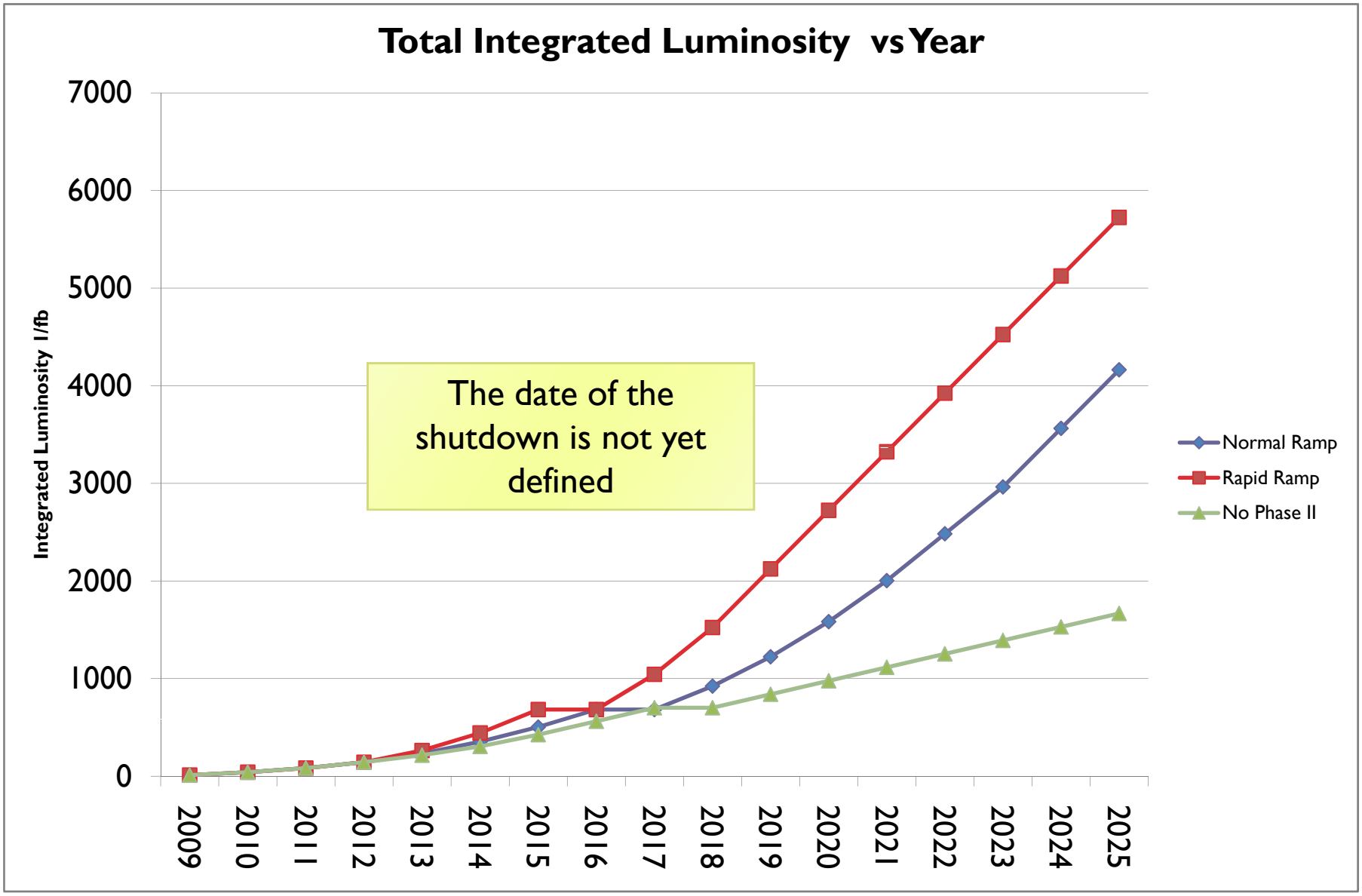
CMS Upgrade Issues

LHCC 1 July 2008


Total Integrated Luminosity vs Year
Integrated Luminosity 1/fb
7000
6000
5000
4000
3000
2000
1000
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
The date of the shutdown is not yet defined
Normal Ramp
Rapid Ramp
No Phase II

What are the key timescales/issues?

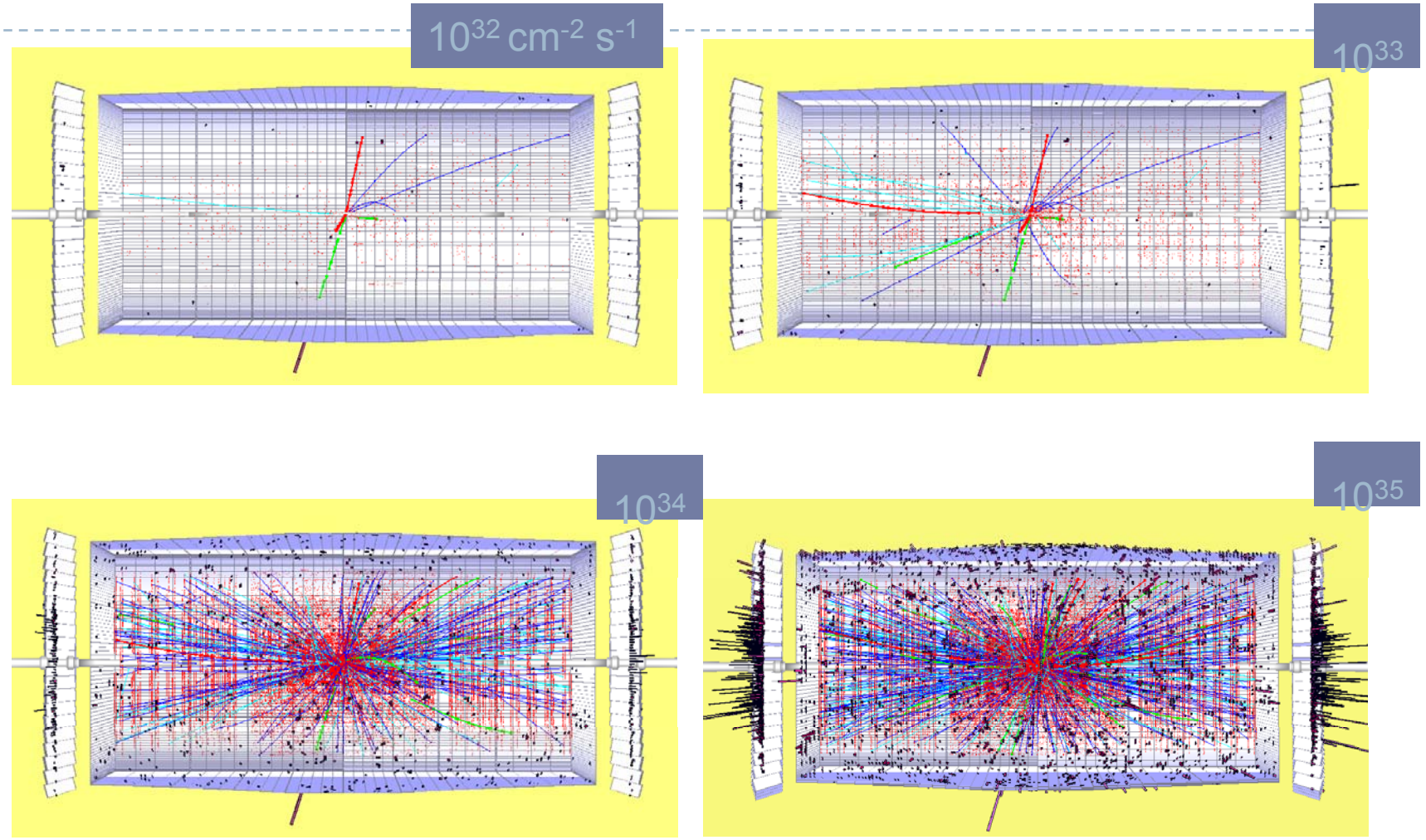
- Phase 1
  - How well do detector components handle the increasing luminosity?
    - Both instantaneous and integrated effects
  - What detector elements will need replacement/modification to cope?
    - Detectors will record >500 fb^{-1}, can they withstand this?
- Phase 2
  - What detector elements will need replacement?
  - Is there a requirement for a long shutdown?
    - How long – 18 Months? (1 Full calendar year without beam +)
    - When – sometime after the middle of the next decade
      - Developing and building new tracking detectors will take many years
    - ATLAS and CMS must agree on the dates
      - No sense in having two long shutdowns
      - Current planning
        - ATLAS earliest date around 2015, CMS not earlier than 2017
      - Reach 700 fb^{-1} (potential limit) – most optimistic 2015, conservative 2017

Issues discussed at the CMS May Upgrade workshop

- What are the "strawmen" for upgrades of each of the systems?
  - Define the scope of the upgrade projects
  - What is done in Phase I/Phase II
    - What requires a long shutdown?
    - What can/should we attempt to do before the long shutdown
    - How should we use the lengthy shutdown in 2013?
- When do we need to prepare a LOI
  - For CMS Upgrades
  - For subsystems
- When do we need to prepare TDRs

http://indico.cern.ch/conferenceDisplay.py?confId=28746

CMS from LHC to SLHC

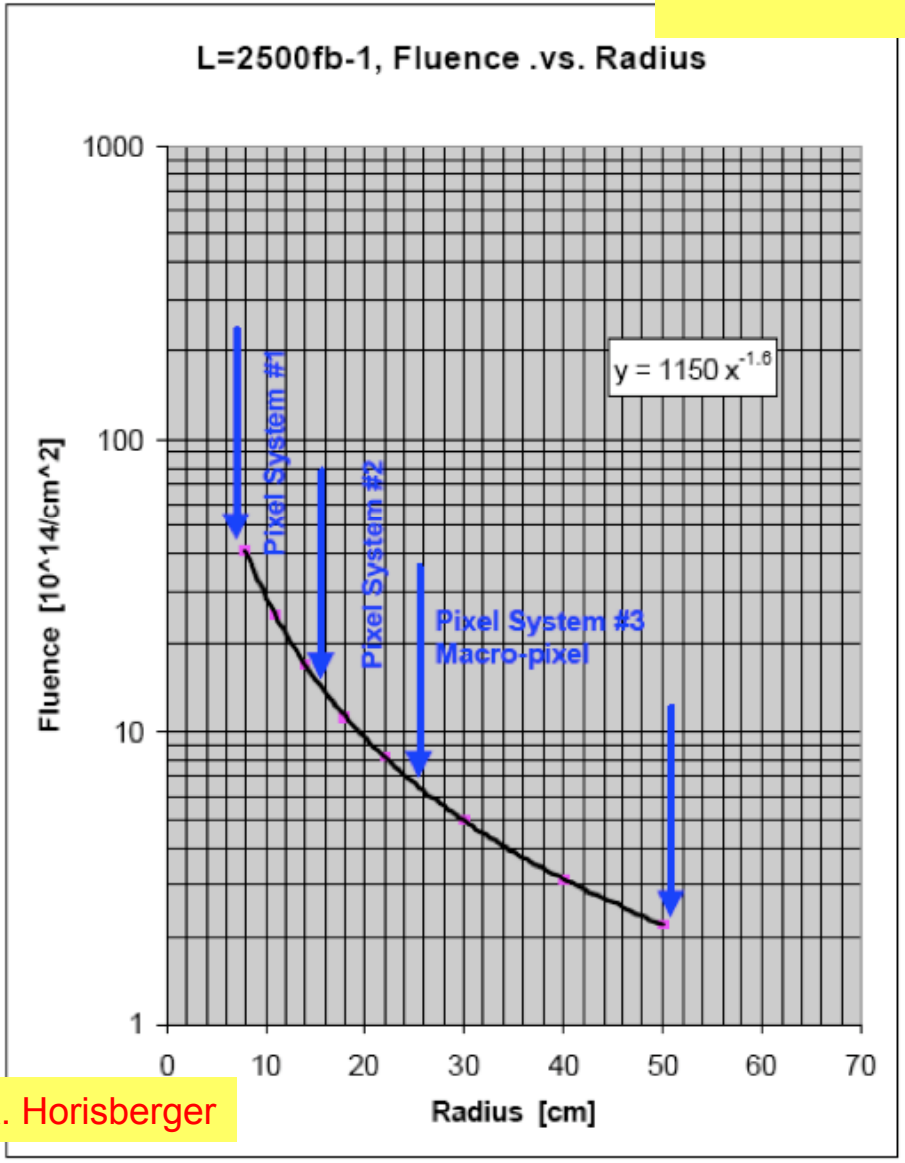


The tracker is the key detector which will require upgrading for SLHC Phase 2

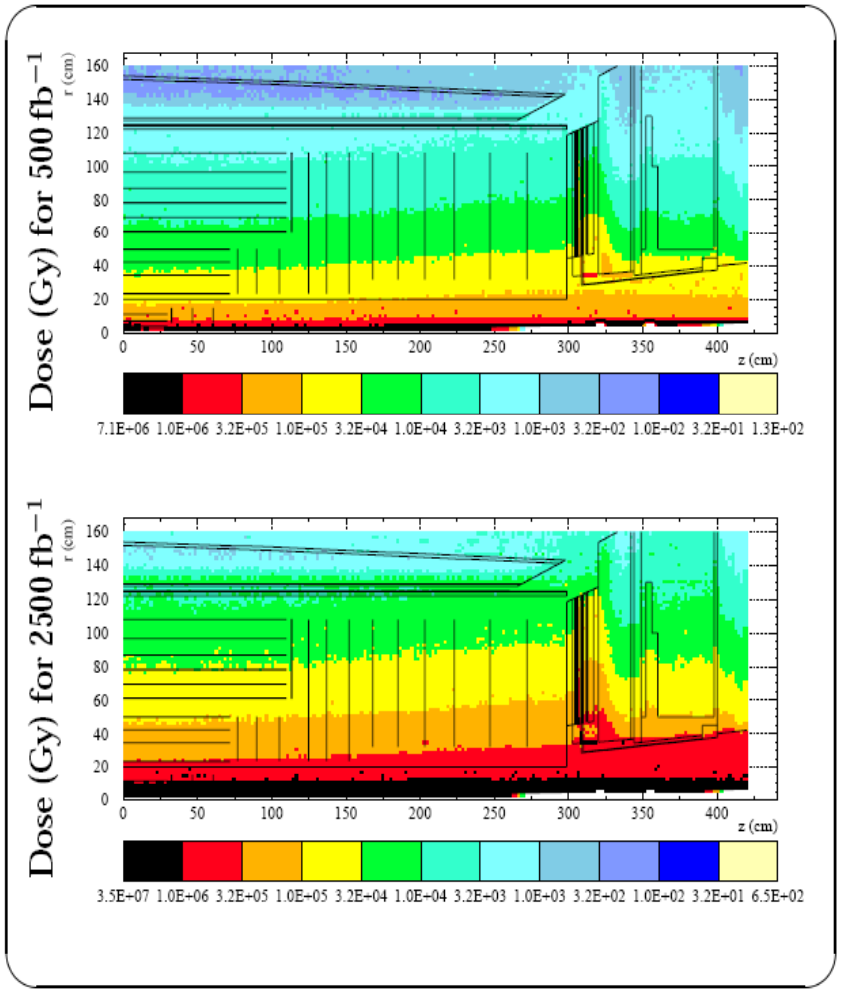
I. Osborne

Radiation environment for trackers

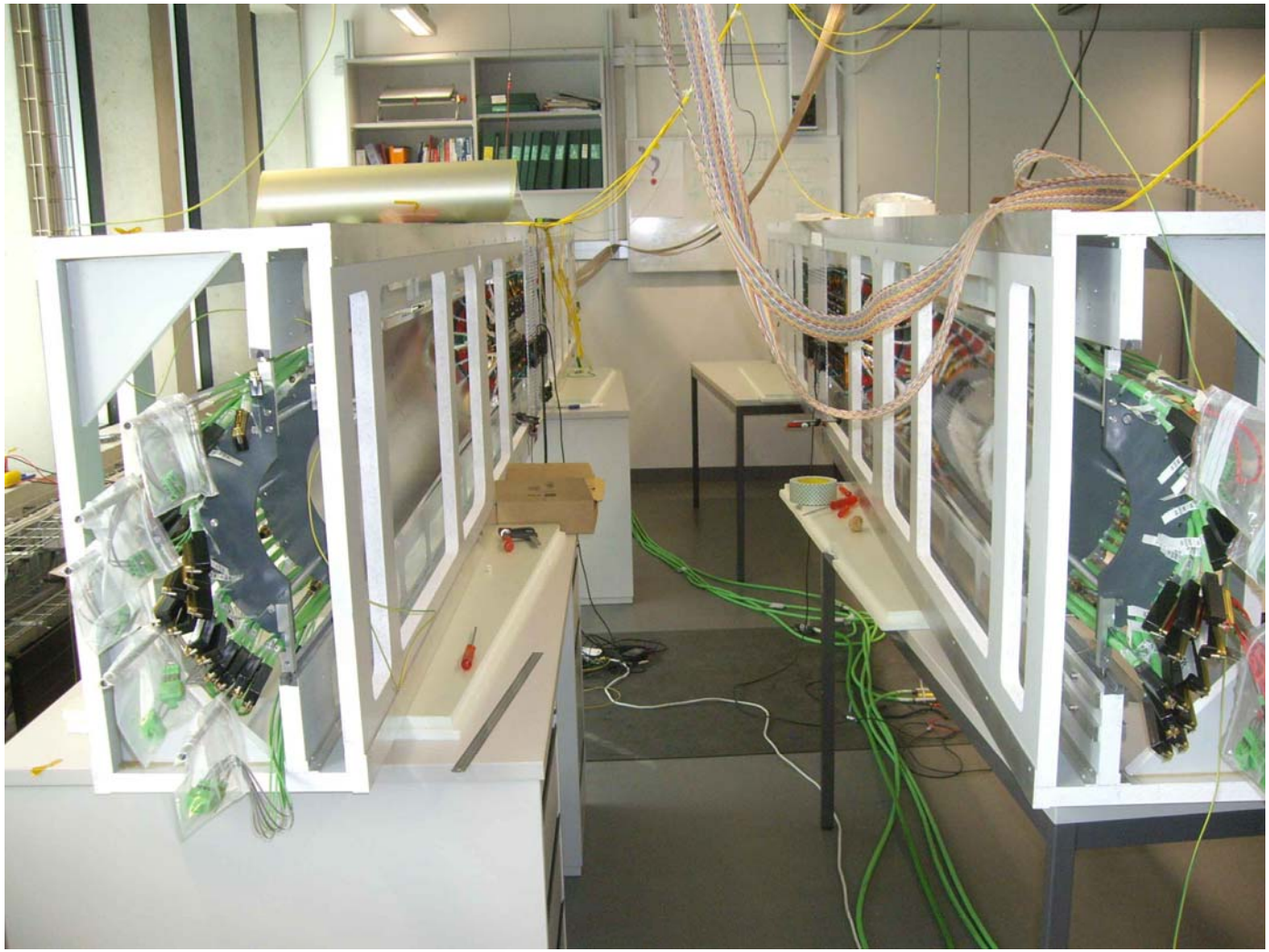
Except for the very innermost layers many current technologies should survive SLHC



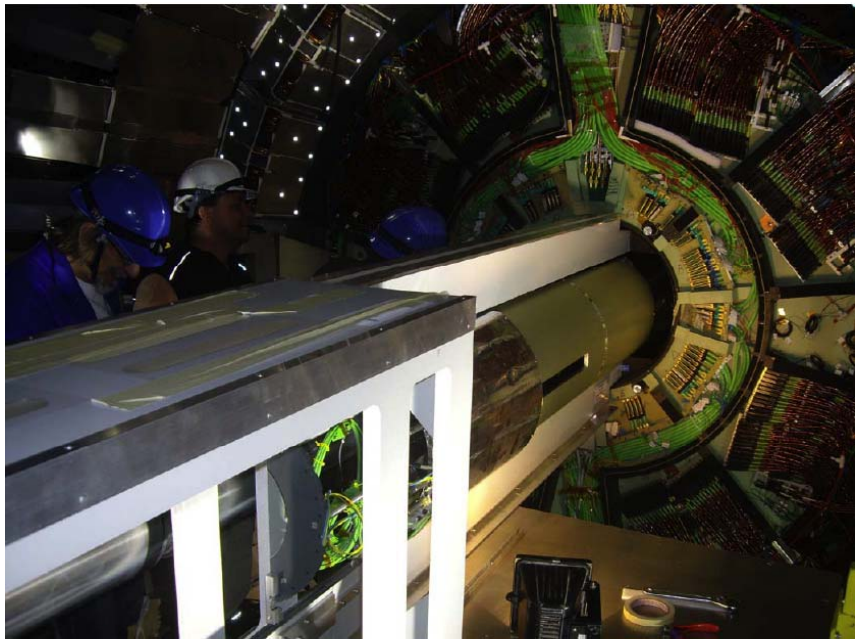
R. Horisberger

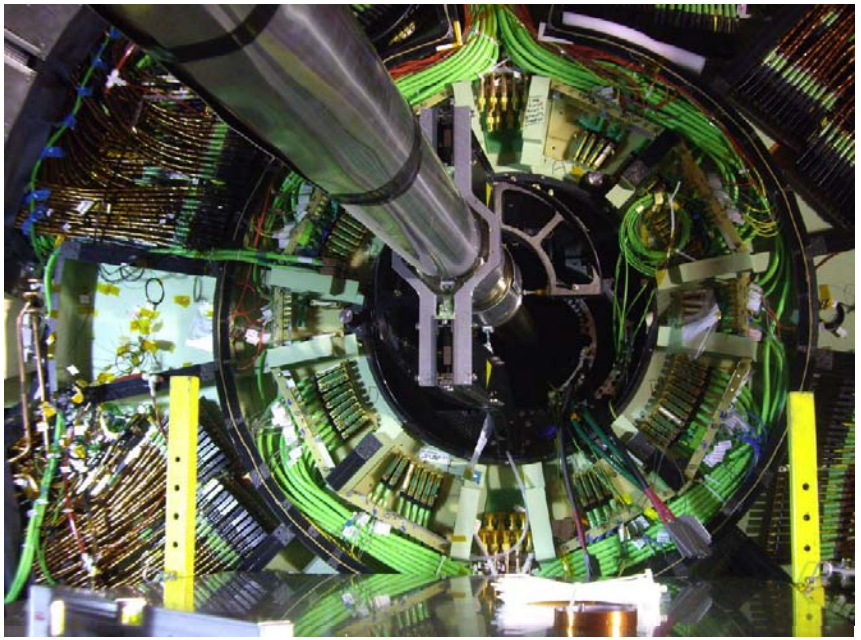


CMS Pixel system can be removed in a very short time period



Trial insertion of Pixel system





Insertion of the Pixel was done in a few hours

Phase I issues for tracking

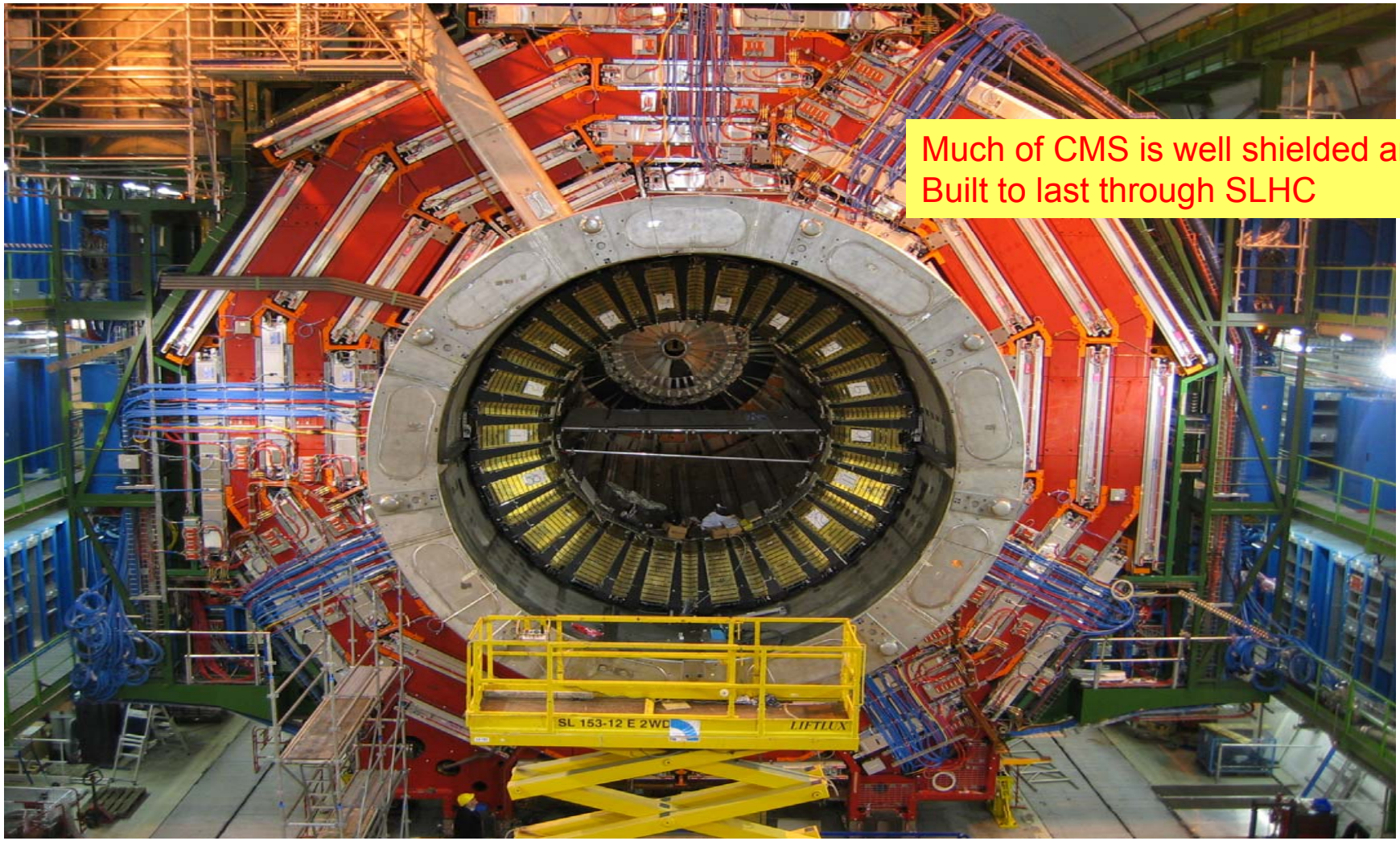
- Rough estimate of pixel layer lifetimes

  4cm layer should survive a minimum of 200fb^{-1}
- Will have to replace the pixel detector during phase I
  - How often?
  - How much to replace?
  - New features
- Looking at reducing the material in the replacement pixel detector, and potentially adding a fourth layer
- Outer tracker looks robust to survive Phase I

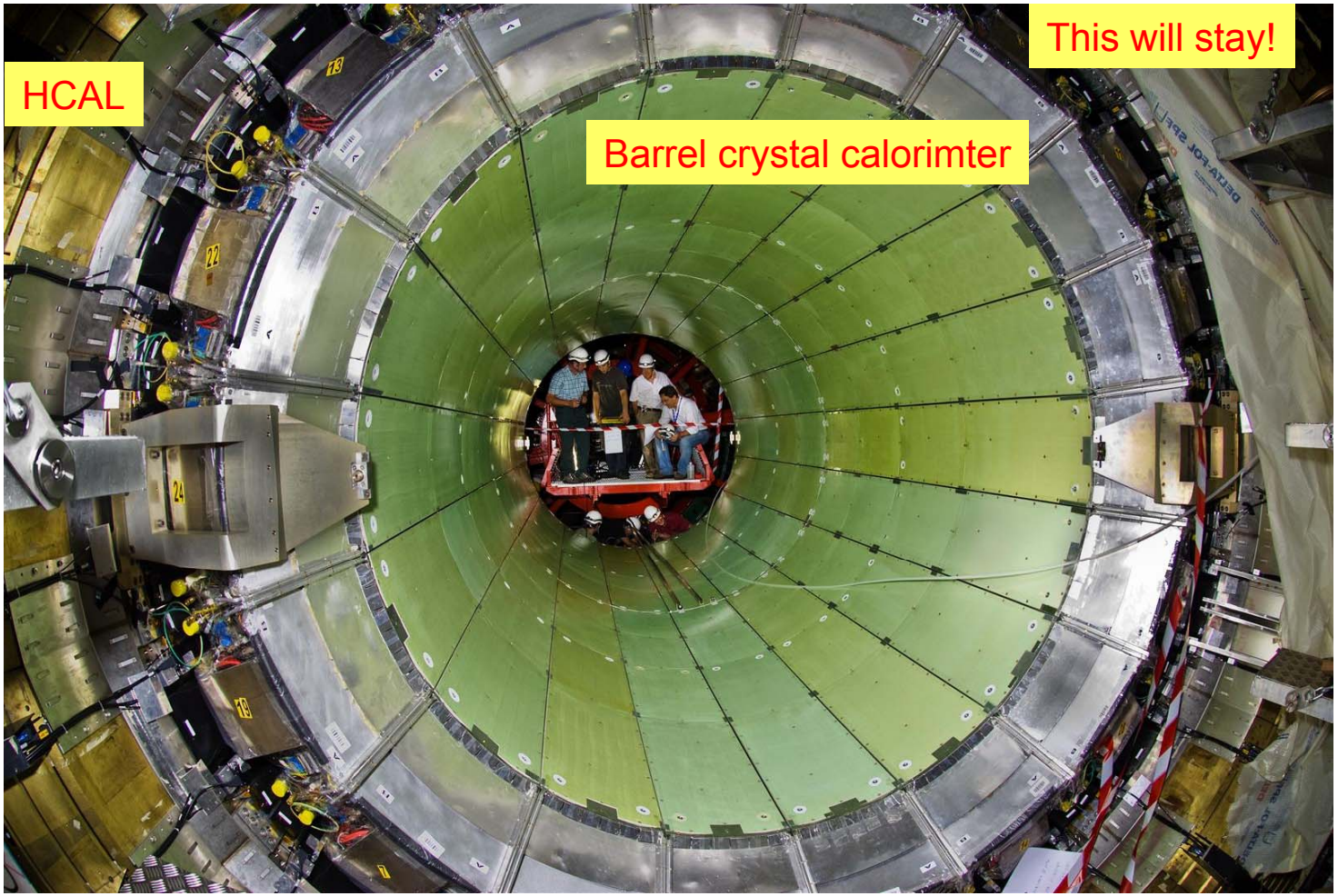
BPIX Options for 2013 replacement/upgrade – R. Horisberger

Option	Layer/Radii	Modules	Cooling	Pixel ROC	Readout	Power
as 2008						
0	4, 7, 11cm	768	C_6F_{14}	PS46 as now	analog 40MHz	as now
1	4, 7, 11cm	768	C_6F_{14}	2x buffers	analog 40MHz	as now
2	4, 7, 11cm	768	CO_2	2x buffers	analog 40MHz	as now
3	4, 7, 11cm	768	CO_2	2x buffers	analog 40MHz μ-tw-pairs	as now
4	4, 7, 11cm	768	CO_2	2xbuffer, ADC 160MHz serial	digital 320MHz μ-tw-pairs	as now
5	4, 7, 11, 16cm	1428	CO_2	2xbuffer, ADC 160MHz serial	digital 640 MHz μ-tw-pairs	DC-DC new PS

CMS - What stays, what goes phase 2

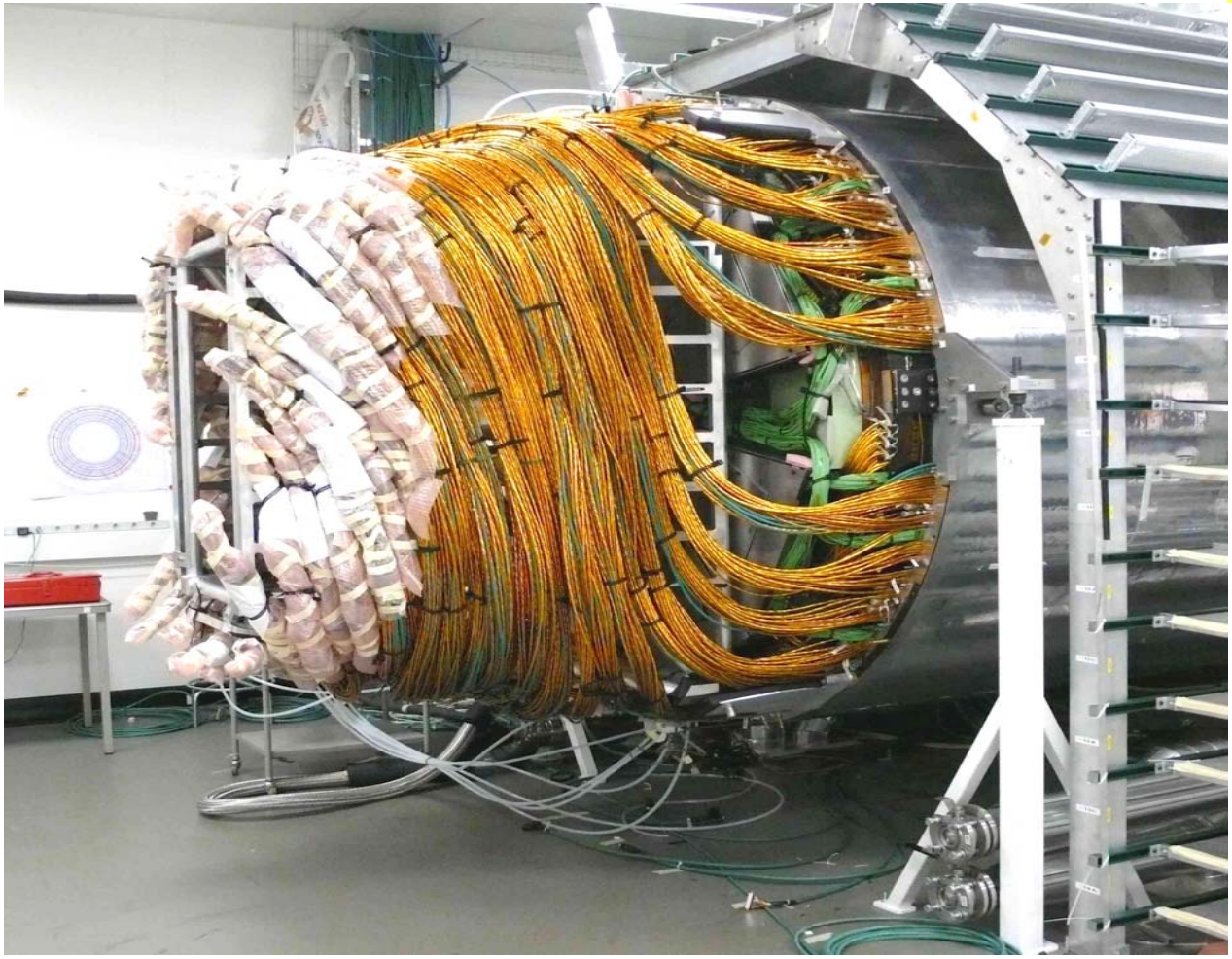


Reminder what CMS will need to upgrade



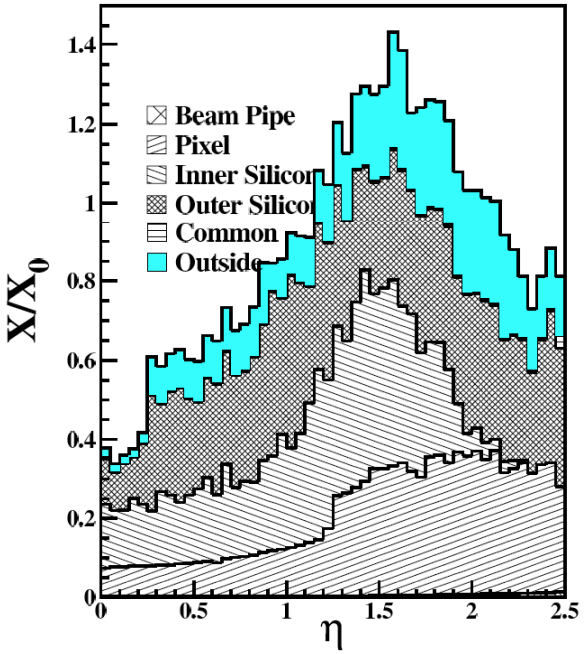
Tracker Readied for Transport to Pt5

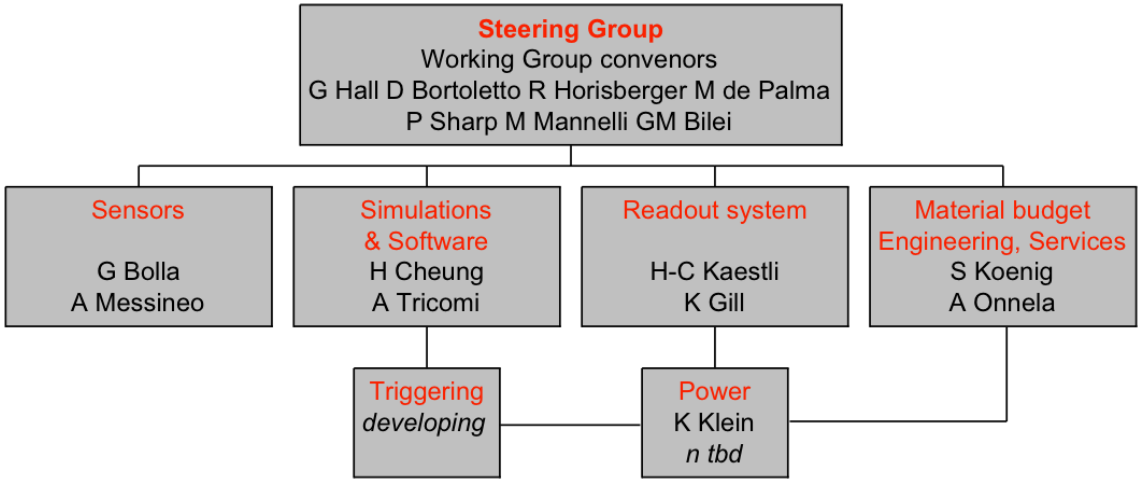
This will be replaced



Key issues for tracker upgrades

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





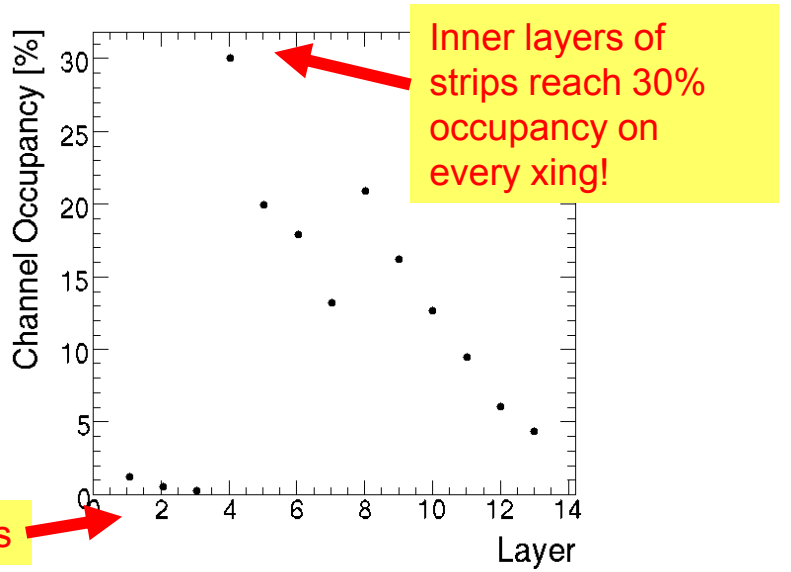
From Physics TDR Vol 1 (LHCC 2006-001)

The effect on physics of large pile-up

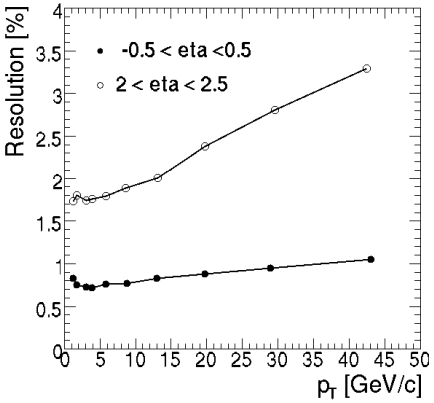
- We need to evaluate how well we can extract any physics at all in the presence of up to 400 pile-up events per crossing
- This is not a trivial study
  - Technically difficult
  - Also depends on geometry of a new tracking device
  - Timescale for full answers is more like years than months
- CMS Tracker simulation group has been hard at work creating tools for modeling new tracker designs
  - Expect detailed simulation results from "strawman" designs in the coming year

Tracking with 500 min Bias events

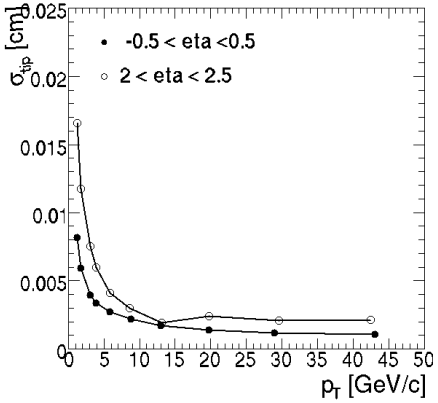
- Study of current CMS tracker for Heavy Ion events
- Track density very similar to 50ns running
  - $dn^{ch}/d\eta$/crossing ≈ 3000
  - Tracker occupancy very high
  - Need more pixel layers/shorter strips
- Tracking possible
  - When tracks are found they are well measured
  - Efficiency and fake rate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

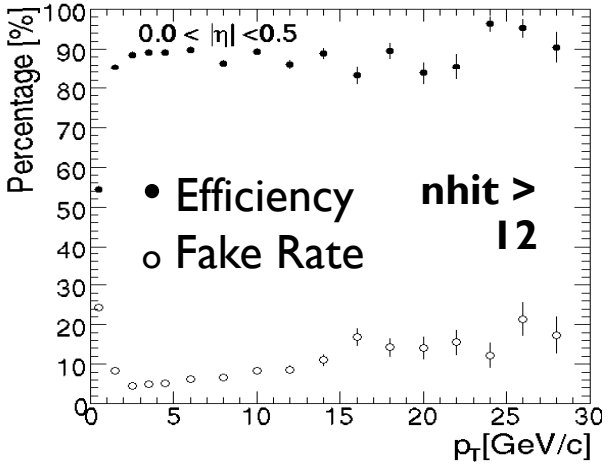


Momentum Resolution



Transverse Impact Parameter Resolution

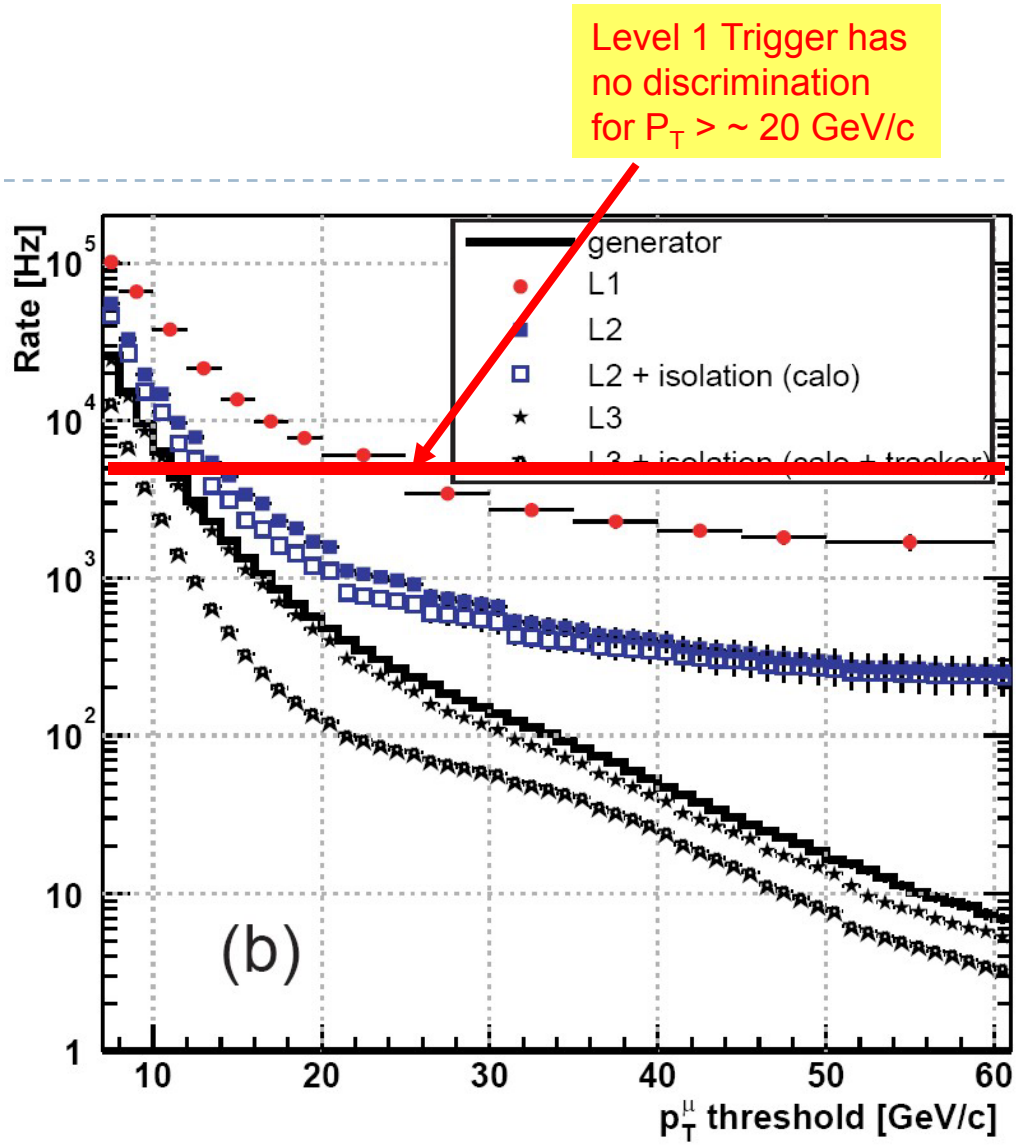




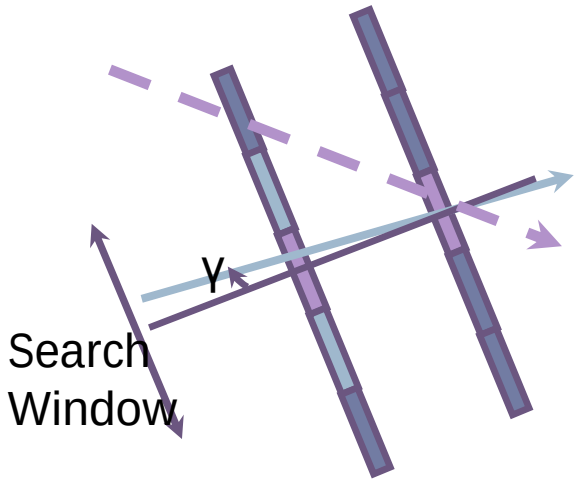
C. Roland

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
  - 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* $L = 10^{35}\ cm^{-2}.s^{-1}$

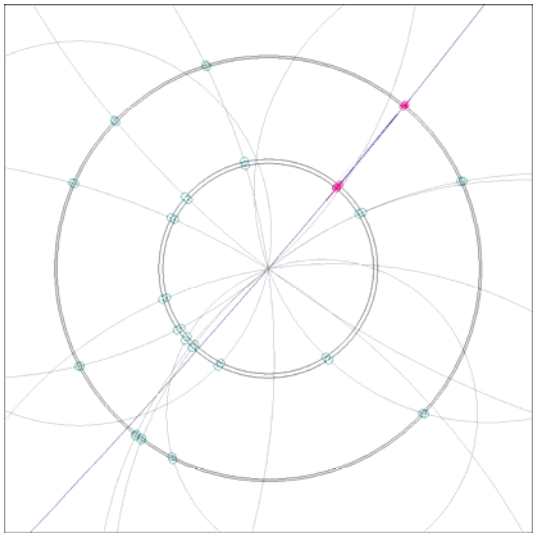


Concepts:Tracking Trigger



High momentum tracks are straighter so pixels line up

Pairs of stacked layers can give a P_T measurement

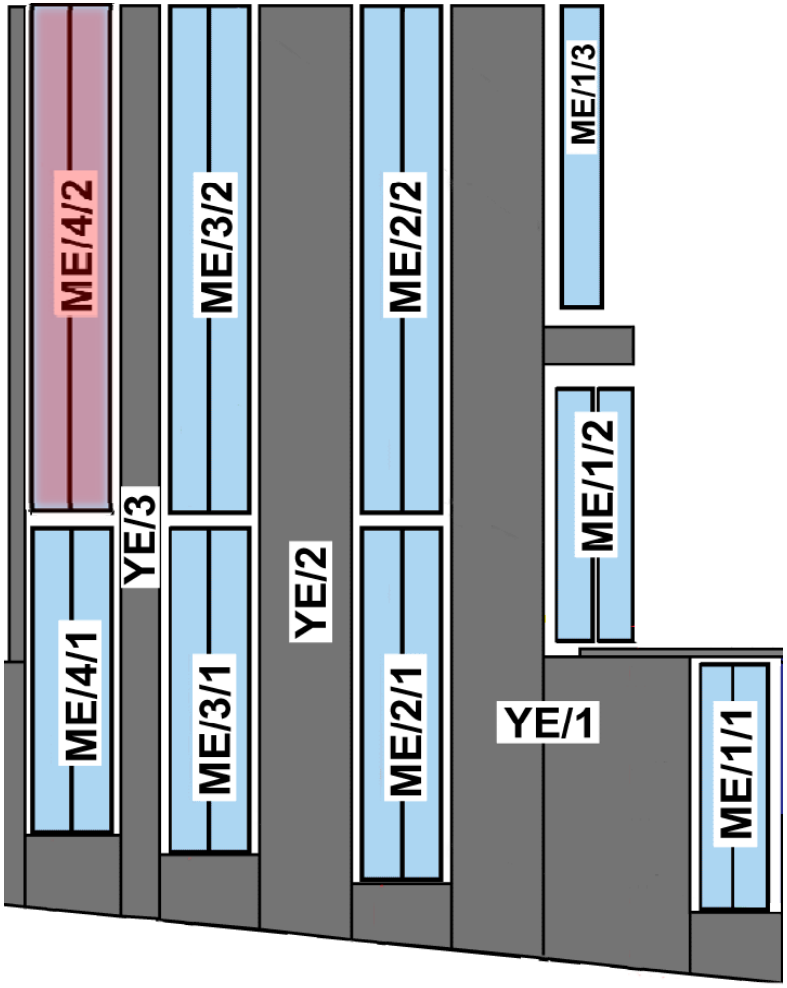


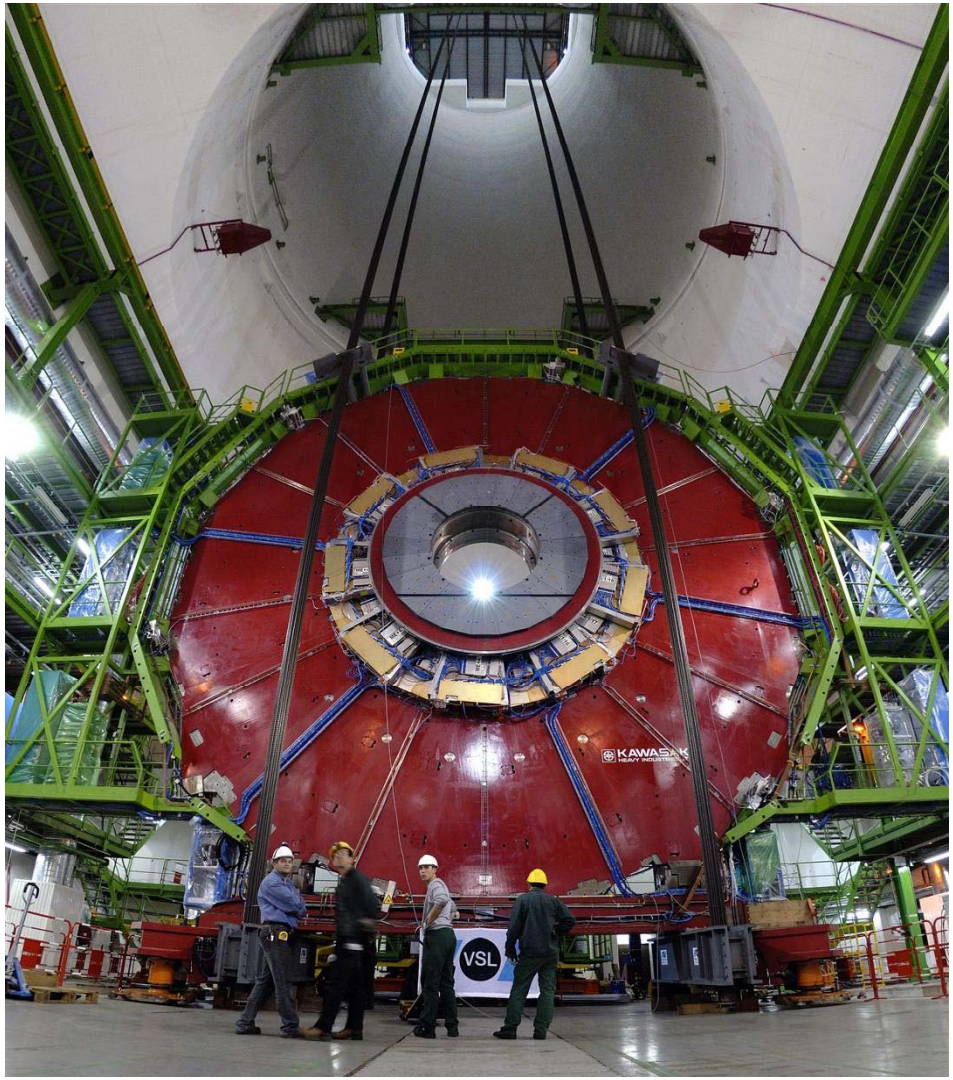
Geometrical p_T-cut - J. Jones, A. Rose, C. Foudas LECC 2005

- 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 inside
  - 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

Endcap CSC Muon Phase 1 Upgrade (ME4/2)

R-Z cross-section

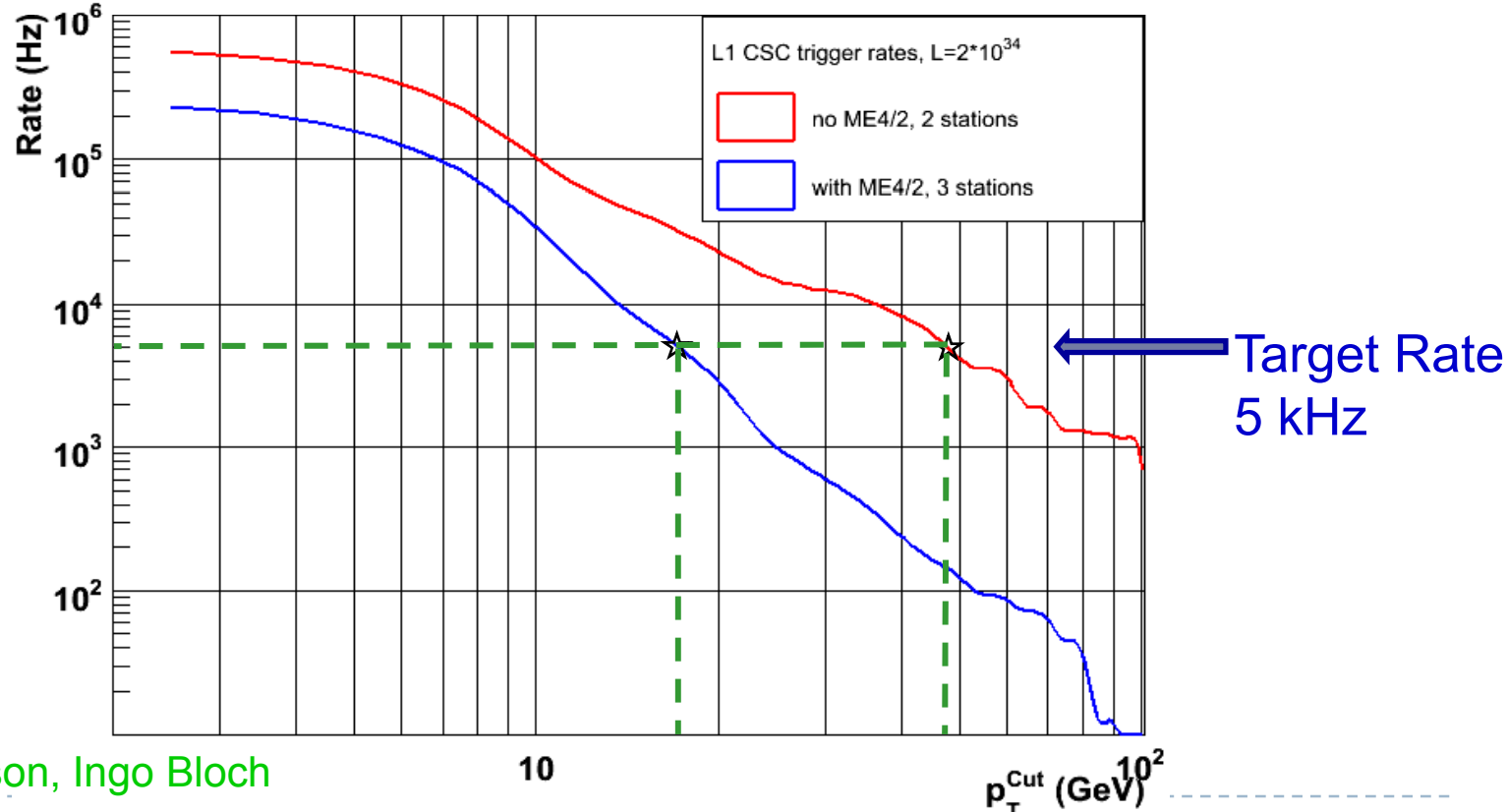




"Empty" YE3 ready for ME4/2

Phase 1 : Muons ME4/2 upgrade motivation

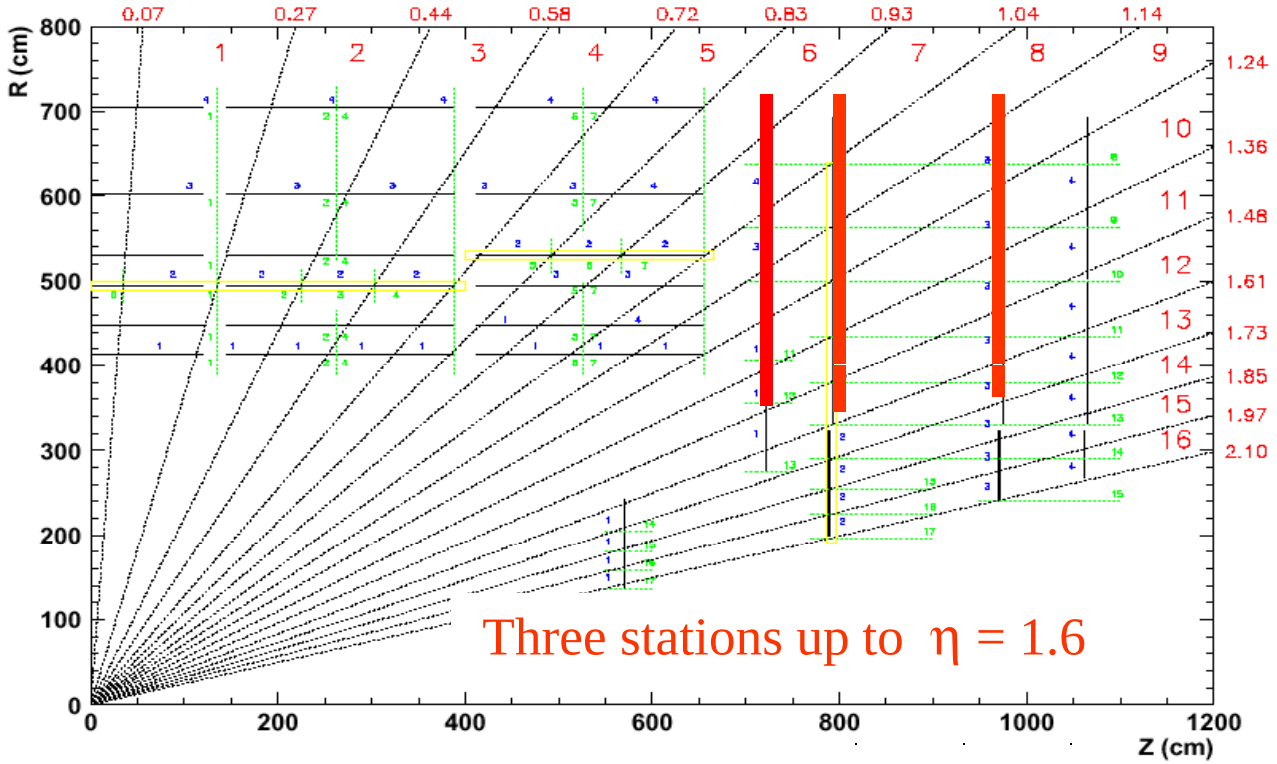
- Compare 3/4 vs. 2/3 stations:
  - (Triggering on *n* out of *n* stations is inefficient and uncertain)
- Recent simulation with & without the ME4/2 upgrade:
  - The high-luminosity Level 1 trigger threshold is reduced from 48 → 18 GeV/c

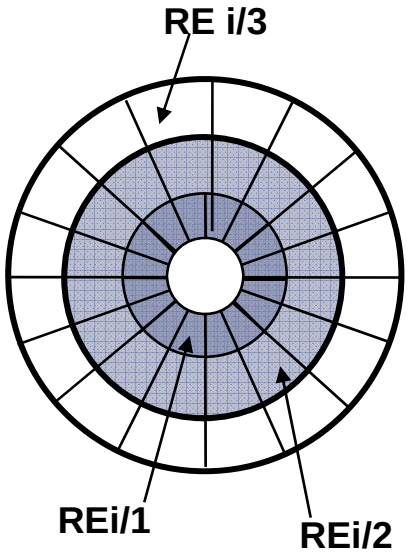


Rick Wilkinson, Ingo Bloch

The start up RPC endcap system

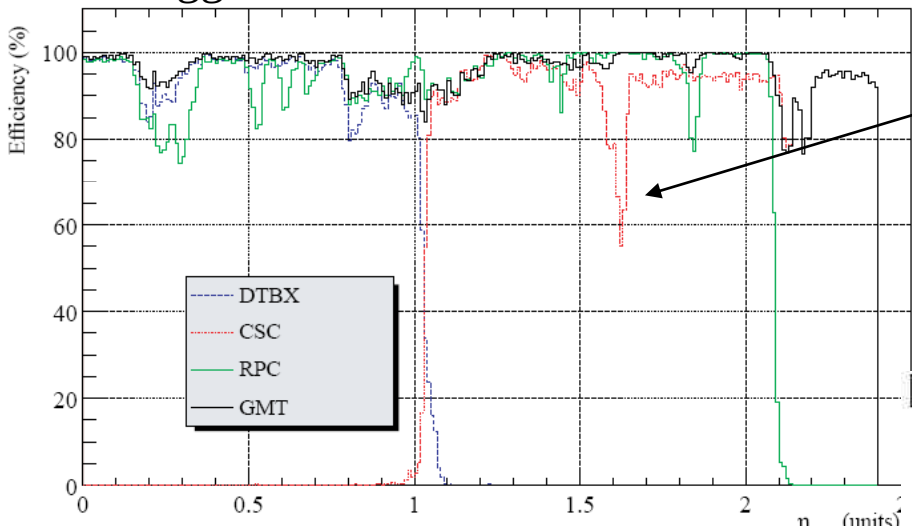
	RE 1/1	RE 1/2	RE 1/3	RE 2/1	RE 2/2	RE 2/3	RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2	RE 4/3
No. of chambers	36*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2





RPC trigger efficiency

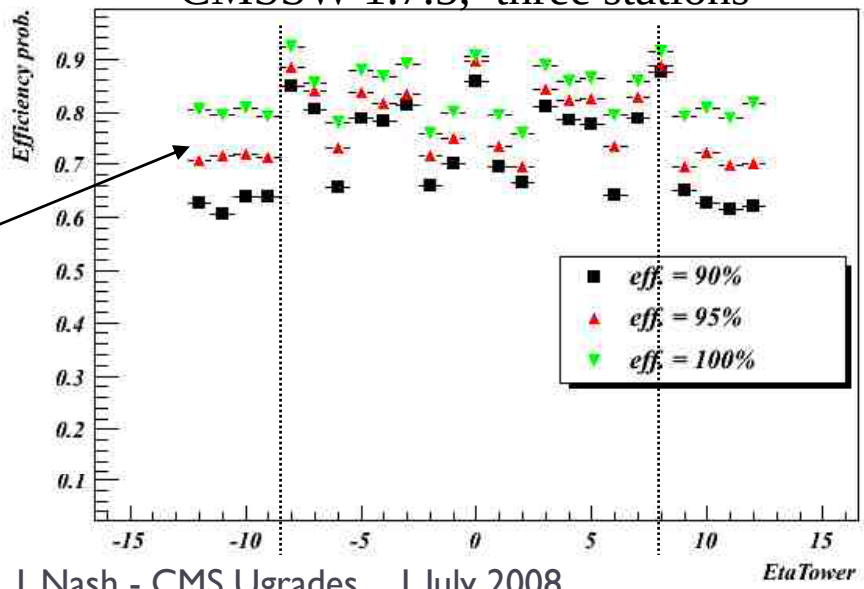
Trigger CMS TDR, four stations



Importance of high η restoration

Importance of four stations restoration

CMSSW 1.7.5, three stations

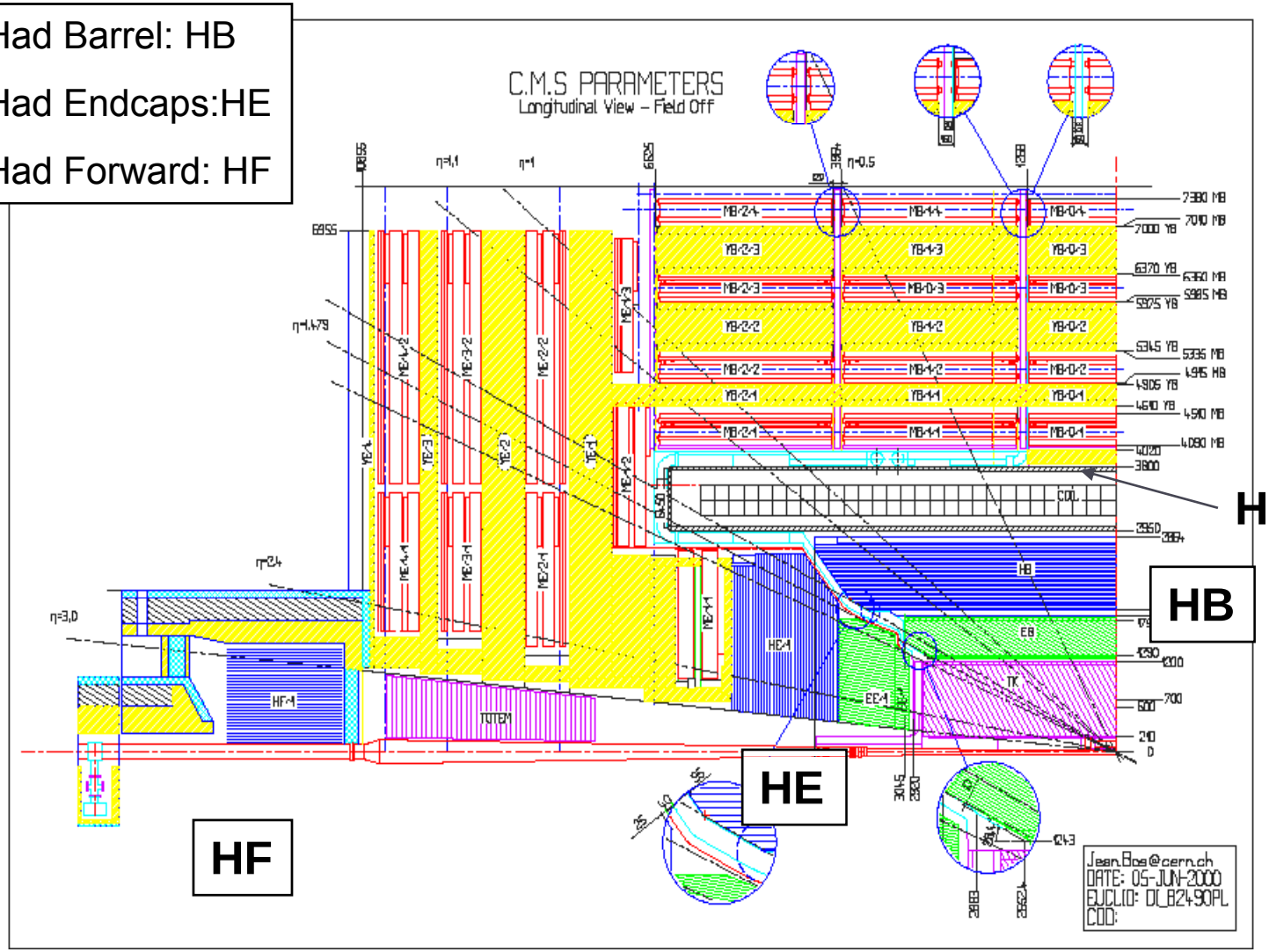


CMS HCALs

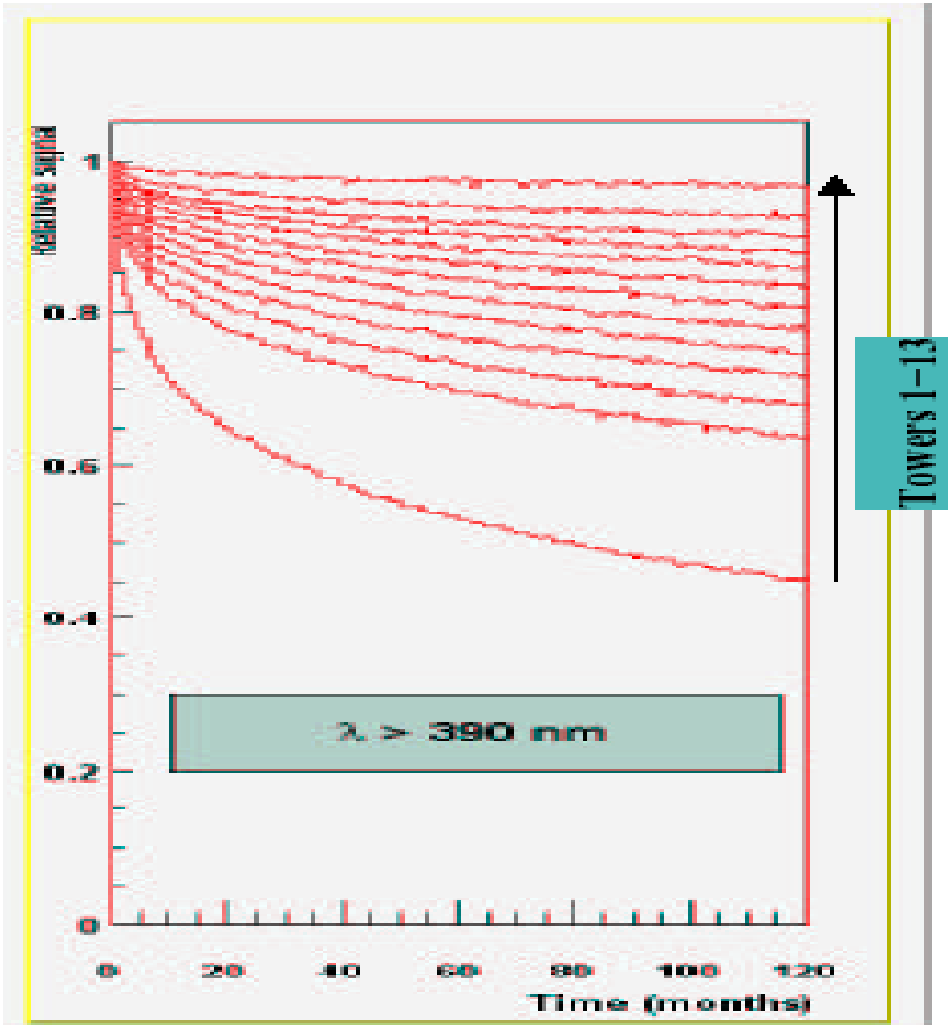
Had Barrel: HB

Had Endcaps:HE

Had Forward: HF



HF Damage

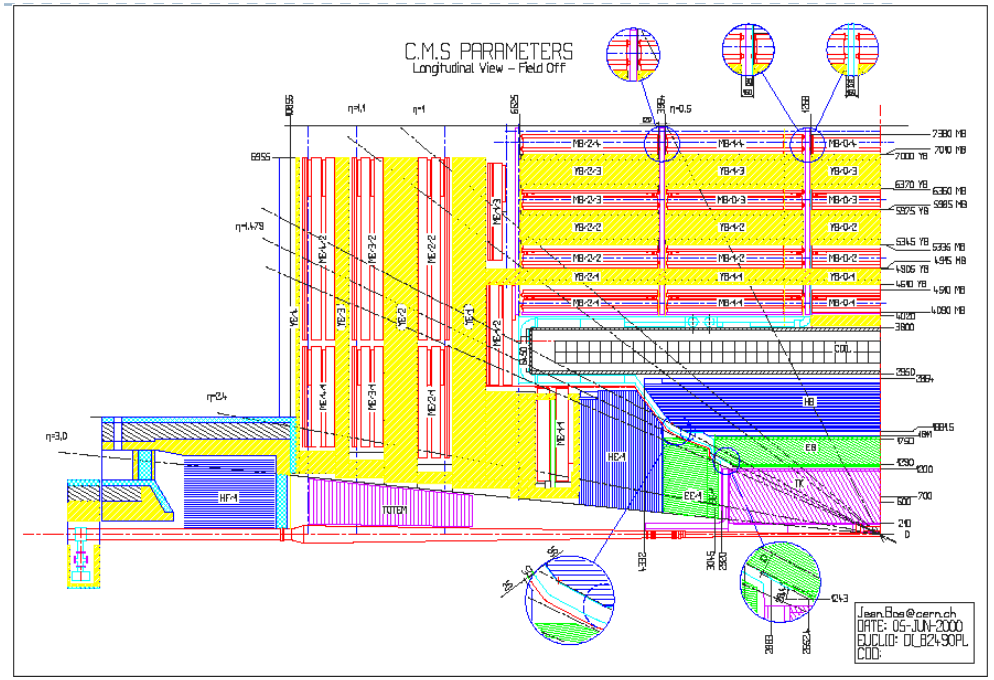


- Tower 1 loses 60% of light during LHC, down to 4% of original after SLHC.
- Tower 2 down to 23% after SLHC.
- SLHC "kills" a few high eta towers.

Andre Gribushin

Calorimeters/Muons Phase 2

- ECAL
  - Crystal calorimeter electronics designed to operate in SLHC conditions
  - VPT in Endcap and Endcap crystals themselves may darken at SLHC
    - Very difficult to replace – Highly activated
- HCAL
  - HF may be blocked by potential changes to the interaction region
  - HF/HE vital in looking for WW scattering
- Both Calorimeters suffer degraded resolution at SLHC
  - affects electron ID, Jet resolutions –
    - simulations needed
  - Increased segmentation for HCAL may help – SiPM

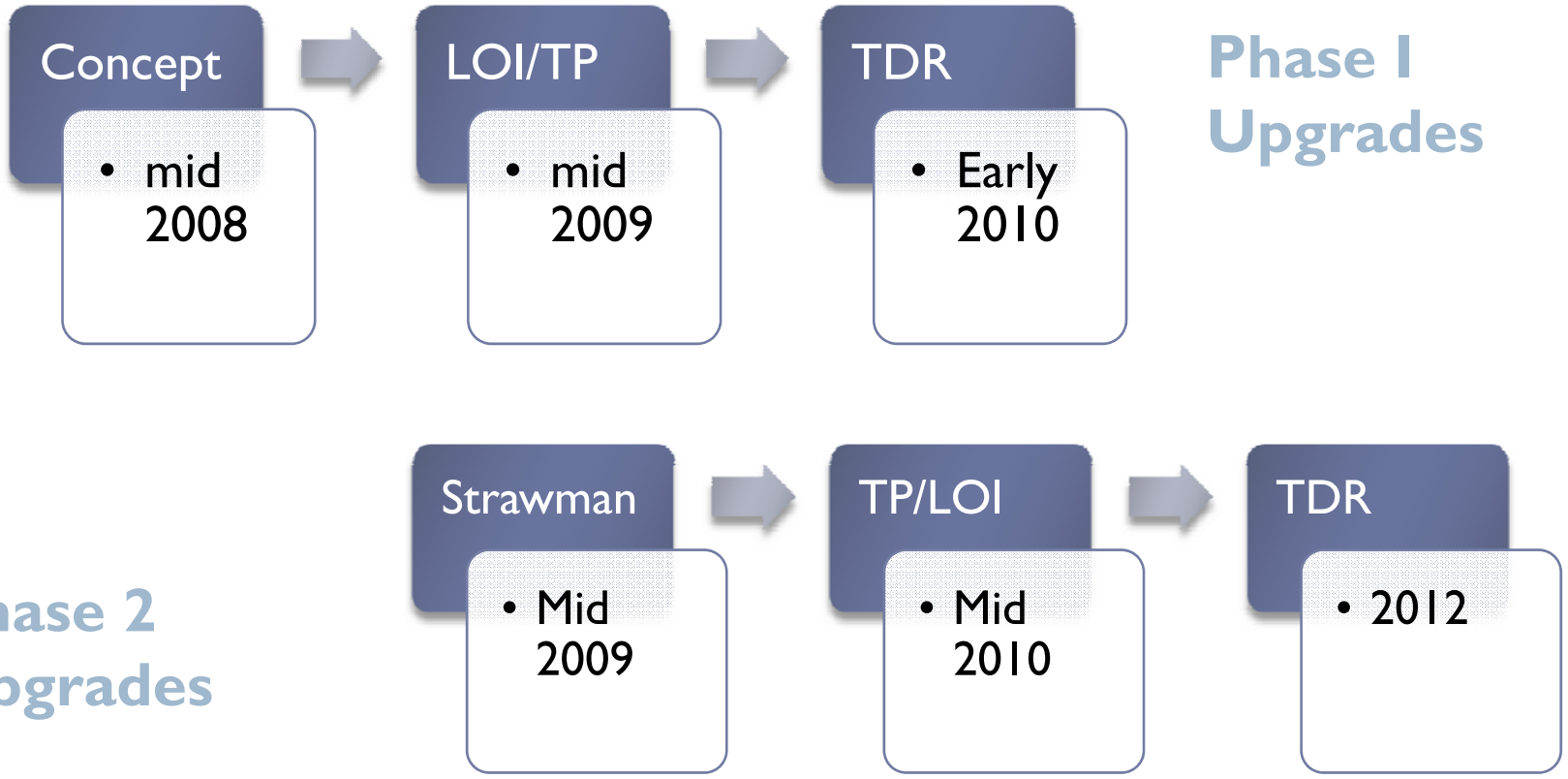


- MUON
  - system front end electronics look fairly robust at SLHC
    - Cathode Strip Chambers/RPC Forward : Drift Tubes /RPC Barrel
- Trigger electronics for the muon systems would most likely need to be replaced/updated
  - Some Electronics is "less" radiation hard (FPGA)
  - Coping with higher rate/different bunch crossing frequency
  - May have to limit coverage in η (η > 2) due to radiation splash
    - This effect will be known better after first data taking, potential additional cost of chamber replacement

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

Documents


Concept
• mid 2008
LOI/TP
• mid 2009
TDR
• Early 2010
Phase I Upgrades
Strawman
• Mid 2009
TP/LOI
• Mid 2010
TDR
• 2012
Phase 2 Upgrades

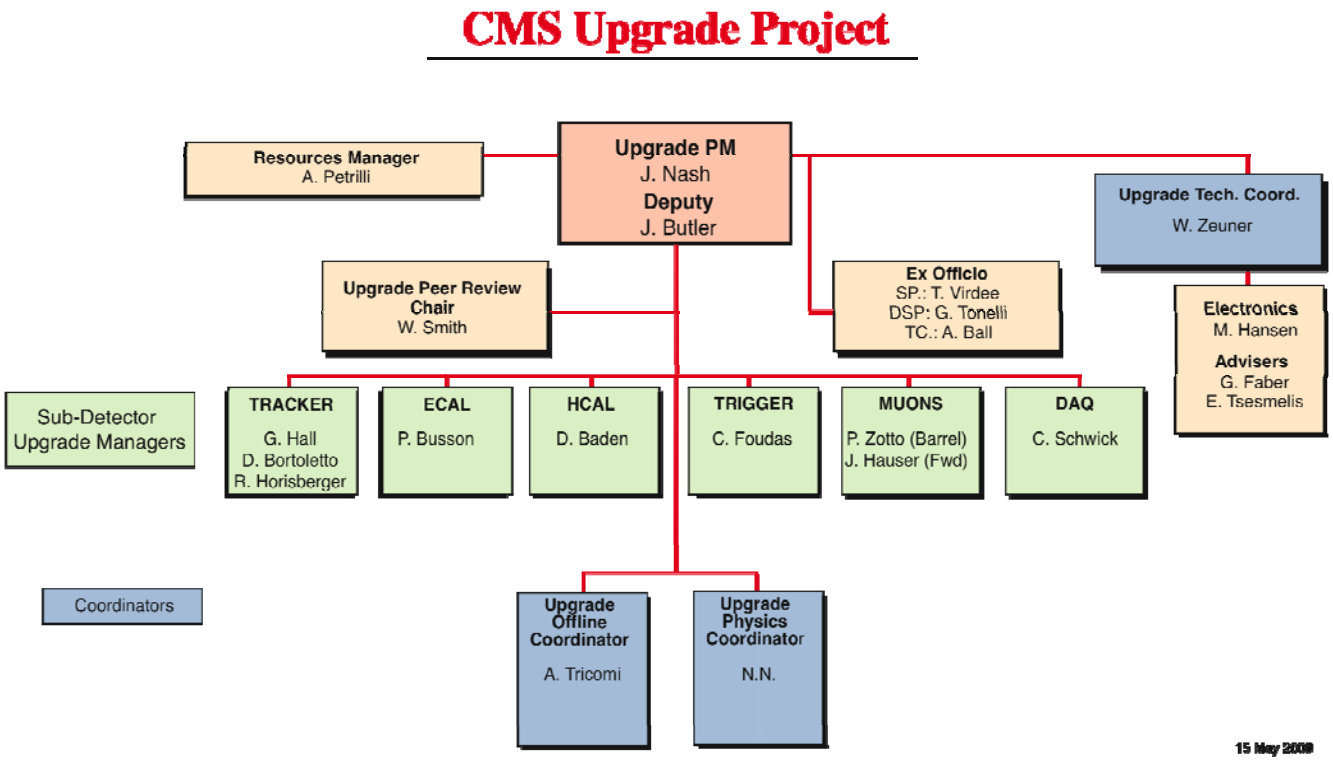
Next Steps

- Produce an Integrated project plan for Phase I
  - Large number of systems expect to produce upgrades many of which involved interleaved installation issues
  - Some of these are already rather advanced and need to be integrated into the planning
- Define timescales/scopes for reviews of each upgrade
  - PDR > ESR/EDR > PRR?
- Request milestones/deliverables down to level … for each project
  - TDR > Production > Installation >
  - Start to track these milestones
    - Will require resources

Planning for Phase 2

- Too early for detailed planning of phase 2 upgrades
- Must understand the overall scope of the upgrade
  - This is driven by the geometry/functionality of the new tracker
  - Simulations will be vital in understanding
- Tracker TP should focus the direction of upgrades in other systems which may depend on tracker functionality
  - For example the inclusion of tracking information in the trigger
- Build a detailed plan by the time of the phase 2 TDRs
  - Will also have a much clearer idea of the machine timescales
- However a key issue which may come up earlier than this is the date of the long shutdown

CMS Upgrade Management



CMS R/D Proposals

Proposal Name	Proposers	Submitted
R&D on Novel Powering Schemes for the SLHC CMS Tracker	RWTH Aachen, contact: Lutz Feld	September 2007
Research and Development for CMS tracker in SLHC era	*Lenny Spiegel (Fermilab), Jorma Tuominiemi, Jaakko Haerkoenen, Panja Luukka, Eija Tuominen, Sandor Czellar (Helsinki Institute of Physics, HIP), Martin Frey, Alexander Furgeri, Frank Hartmann, (Karlsruhe University), Vincent Lemaitre (Louvain University), Alexander Kaminski, Dario Bisello (University of Padova), Regina Demina, Yuri Gotra, Sergey Korjenevski (University of Rochester)*	September 2006
Redesign of the Phi and Eta Trigger Track Finders for SLHC	Vienna and U. A. Madrid Groups	September 2007
Redesign of the Global Trigger and Global Muon Trigger for SLHC	Vienna Group	September 2007
SLHC Calorimeter Trigger R&D Program	University of Wisconsin	October 2007
CSC Level-1 Track-Finder Trigger upgrade	Florida, Rice, UCLA	October 2007
Study of suitability of magnetic Czochralski silicon for the SLHC CMS strip tracker	**Contact persons:** Panja Luukka, Jaakko Härkönen, Regina Demina, Leonard Spiegel	October 2007
R&D for Possible Replacement of Inner Pixel Layers With Aims for an SLHC Upgrade	Alice Bean , Timothy Bolton, Aaron Dominguez, Wolfram Erdmann, Cecilia Gerber, Roland Horisberger, Angel L´opez	October 2007
R&D in preparation for an upgrade of CMS for the Super-LHC	University of Bristol Brunel University Imperial College London Rutherford Appleton Laboratory	October 2007
Upgrade of CMS Barrel Muon Detector	CIEMAT,Universidad de Cantabria,Torino, Bologna, It Padova, Bari, Pavia, Napoli, RWTH Aachen, Madrid, Legnaro, Frascati	October 2007

CMS R/D (page 2)

CSC Endcap Muon Upgrades	Contact Person: Jay Hauser	October 2007
Reference Link Project For High Speed Optical Data Link R&Ds	SMU, Minnesota and OSU	October 2007
The Versatile Link Common Project	Francois Vasey and Jan Troska, Physics Department, CERN, Geneva, Switzerland Christian Olivetto and Jean-Marie Brom, Institut Pluridisciplinaire Hubert Curien, Strasbourg, France Cigdem Issever, Todd Huffman and Tony Weidberg, Department of Physics, Oxford University, United Kingdom Jingbo Ye, Department of Physics, southern Methodist University, Dallas TX, USA	November 2007
3D detectors for inner pixel layers	**Contact Person (Project Leader/responsible): Daniela Bortoletto/Simon Kwan**	December 2007
CMS HCAL Calorimeter Electronics Upgrade	Contact Person: Drew Baden, University of Maryland	December 2007
Proposal for US CMS Pixel Mechanics R&D at Purdue and Fermilab in FY08	Daniela Bortoletto, Simon Kwan, Petra Merkel, Ian Shipsey, J.C. Yun	December 2007
R&D for Thin Single-Sided Sensors with HPK	Contact Person: Marcello Mannelli	January 2008
materials, technologies and simulations for silicon sensor modules at intermediate to large radii of a new CMS tracker for SLHC	Hamburg, Karlsruhe, Louvain, Vienna, Vilnius	March 2008

Conclusions

- CMS is progressing on defining the scope of phase 1 and phase 2 upgrades
- A substantial program of R&D is well underway
- The coming years will see development of detailed project plans for the upgrades
- Need to work with the LHCC to understand the transition from phase 1 to phase 2