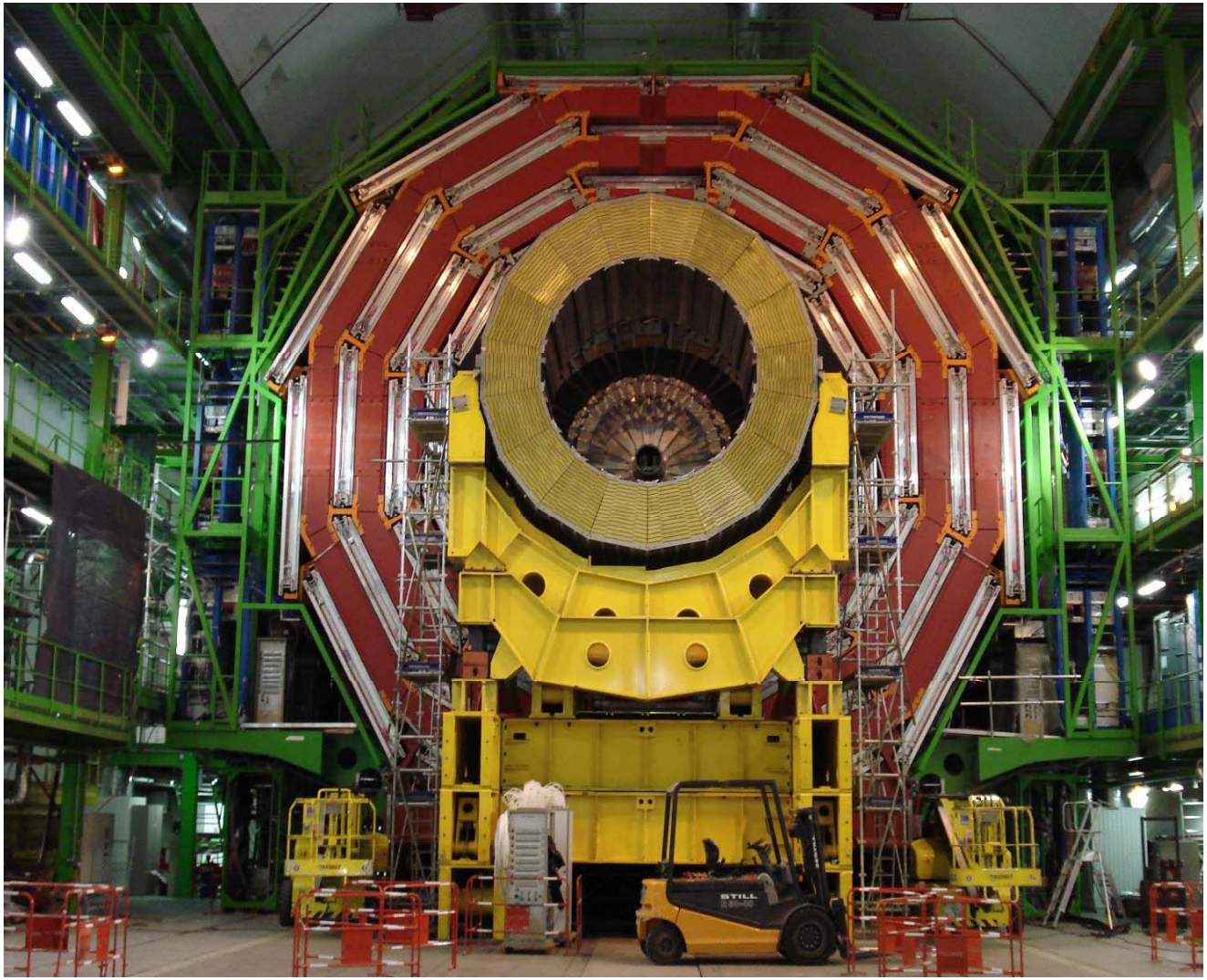
CMS Upgrade Plans

Detector upgrade needs

CMS Upgrade organization

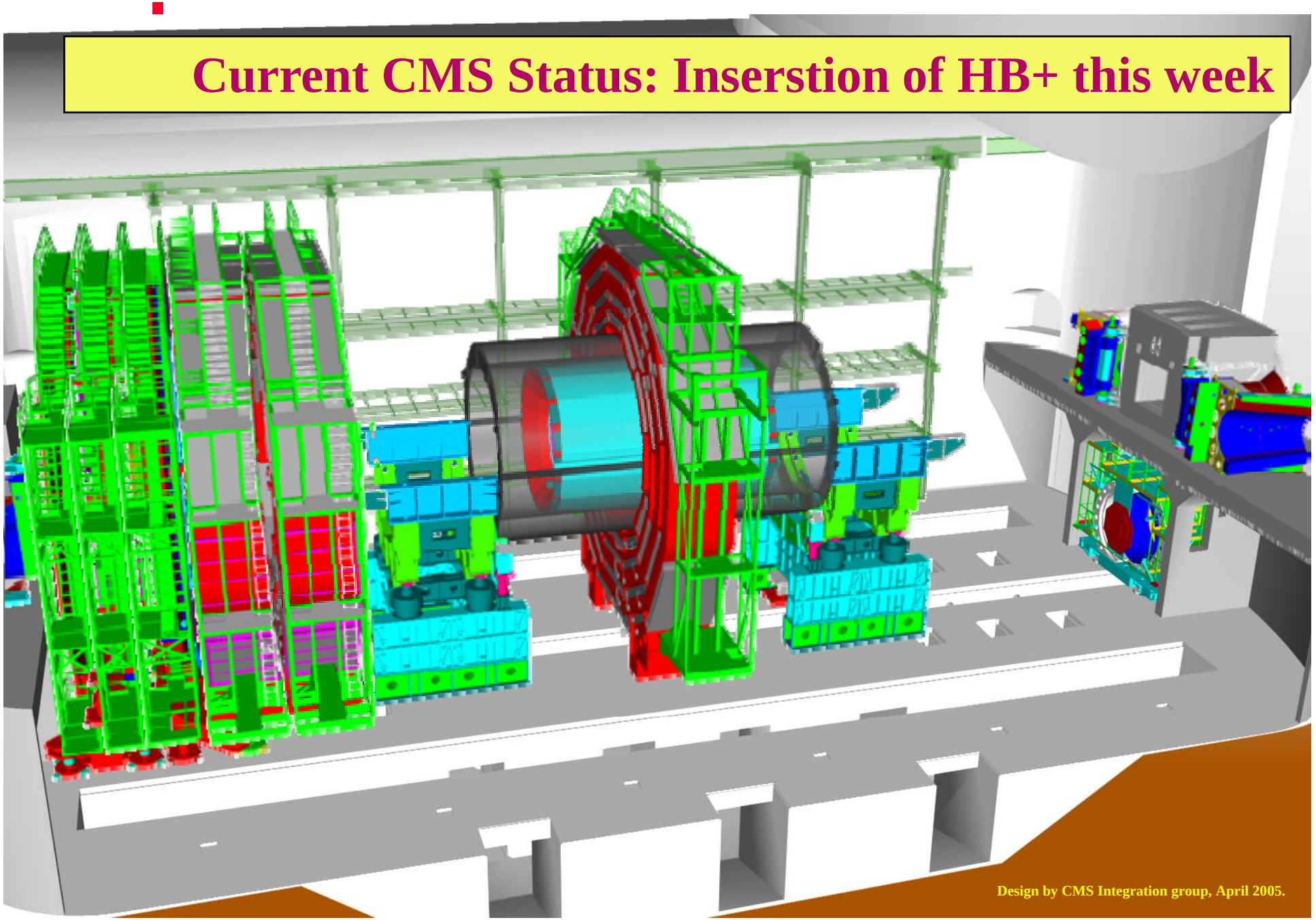
UXC: -z end fully open. HB+ ready to insert



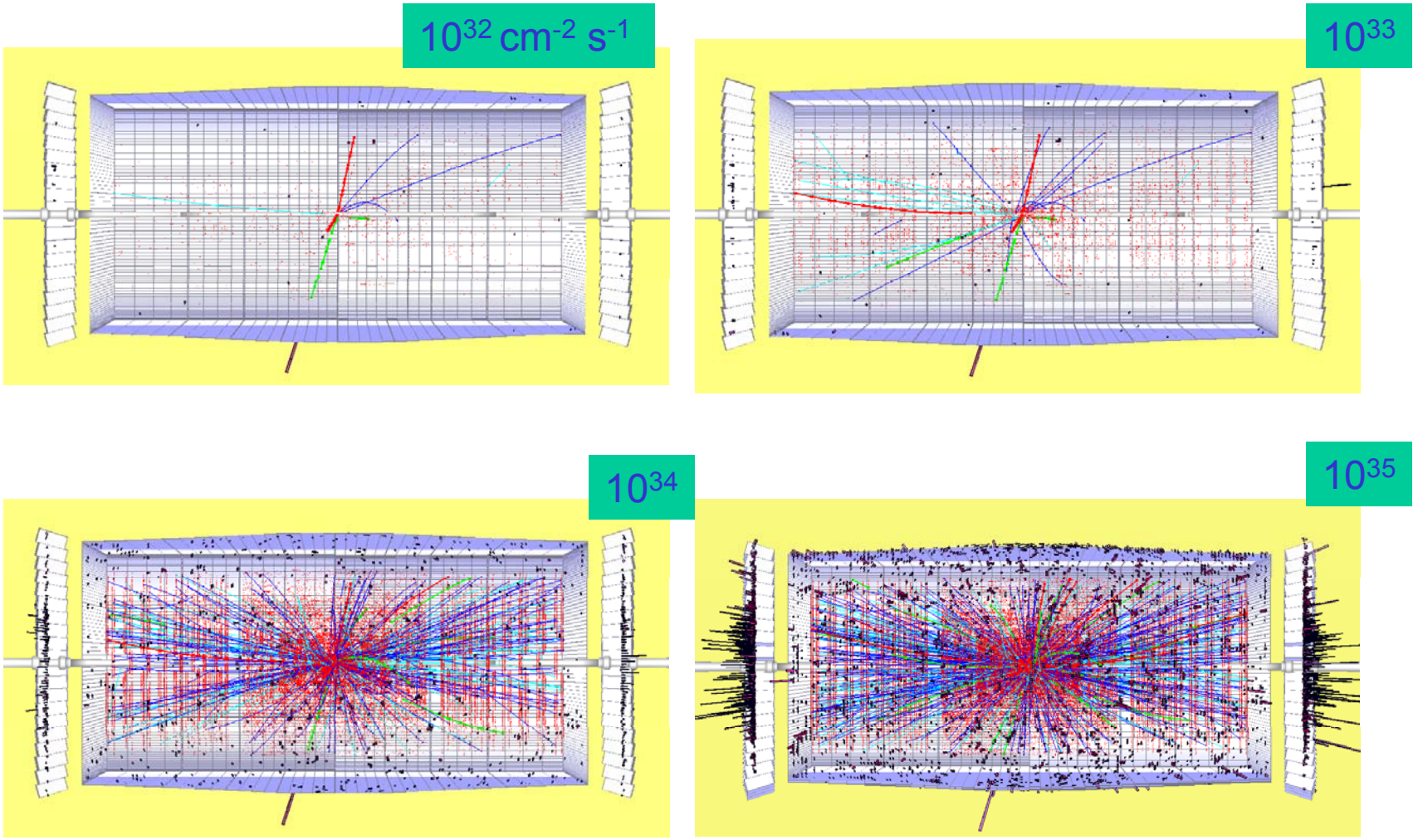
Haven't quite Finished CMS Yet…

But planning to upgrade the bits not yet installed!

Current CMS Status: Inserstion of HB+ this week



CMS from LHC to SLHC

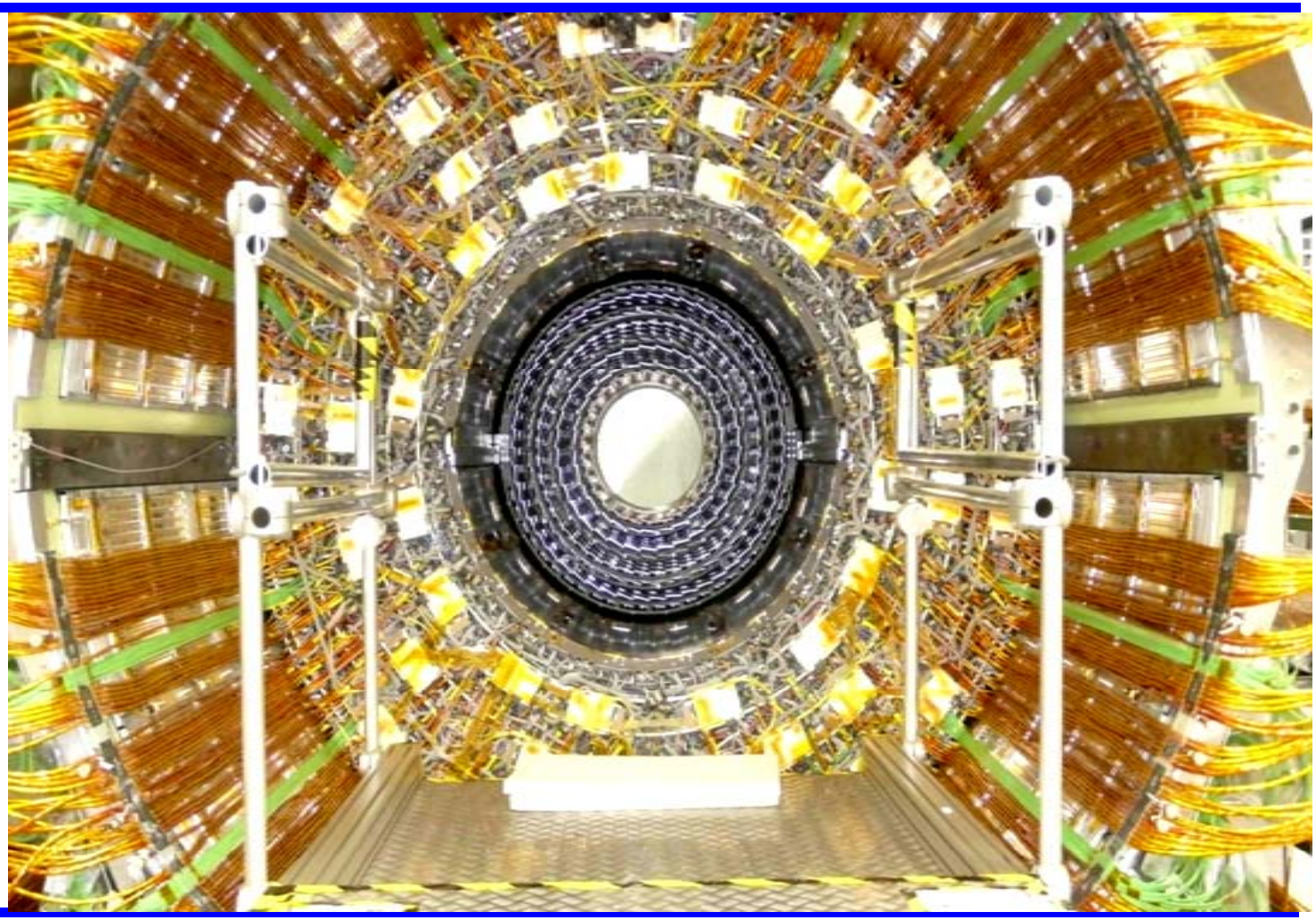


The tracker is the key detector which will require upgrading for SLHC

I. Osborne

CMS Tracking System Up-date - January 07

TIB+ Inserted into TOB+ Seen from the - End

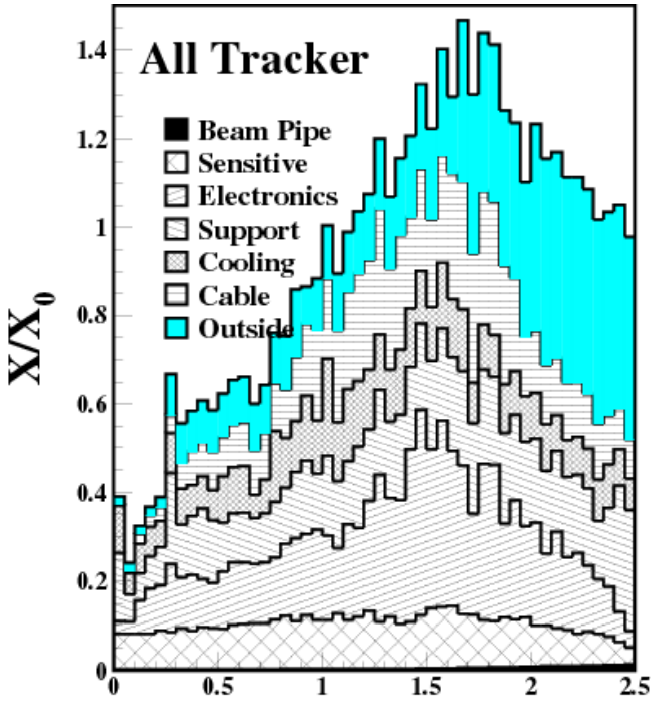


CMS Tracking System Up-date - February 07

The Aachen Team with TEC + End Cover Removed to show Silicon

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?

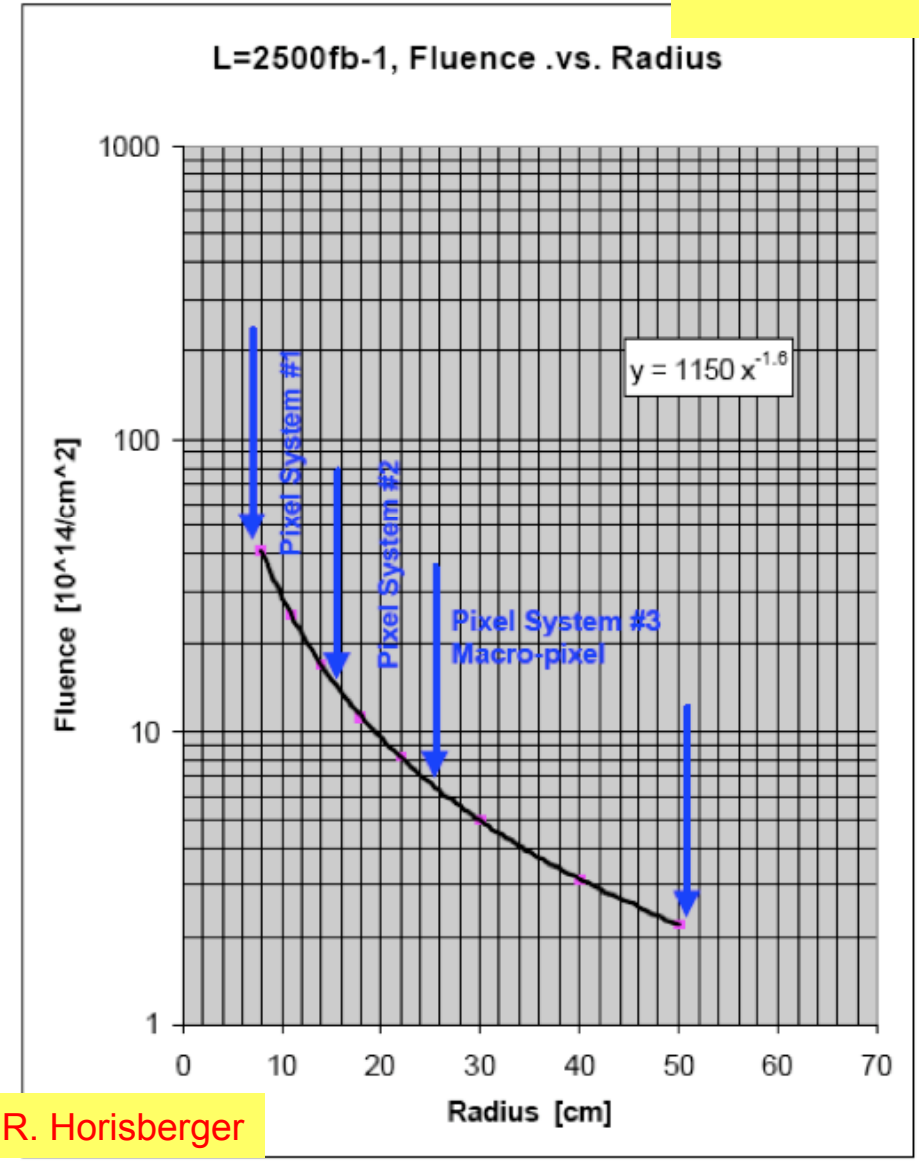


Tracker R&D focus

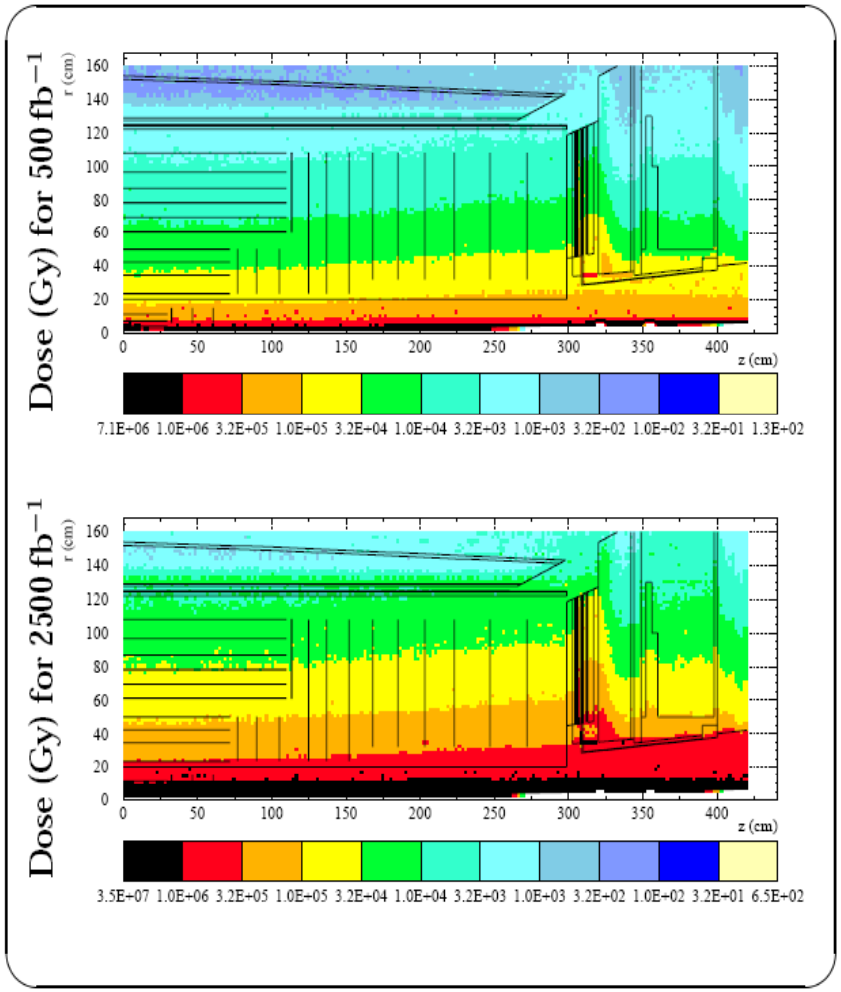
- Performance and detector layout
- Sensor material and operation
- Outer tracker readout system definition
- Pixel system and triggering
- Manufacture and material budget

Radiation environment for trackers

Except for the very innermost layers current technologies should survive SLHC

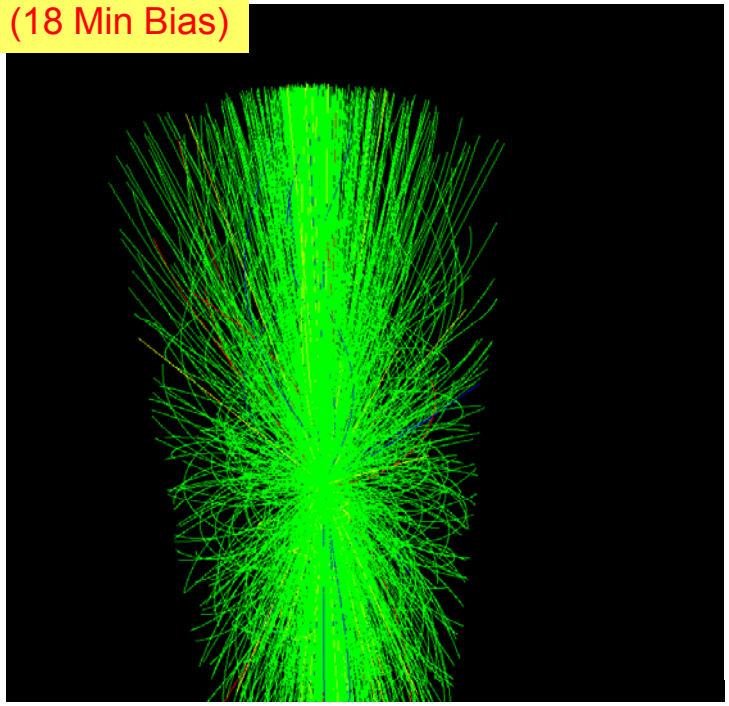


R. Horisberger

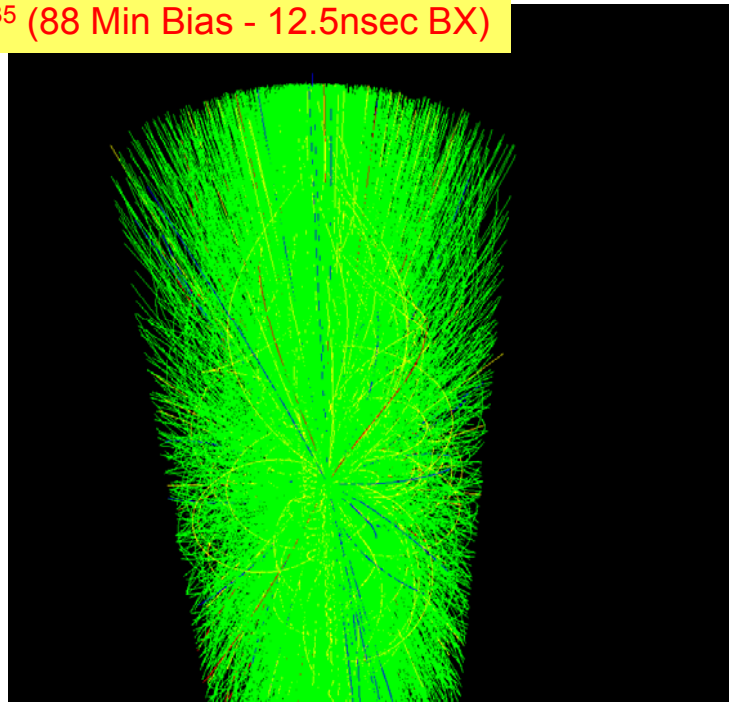


Tracker occupancy

10^{34} (18 Min Bias)



10^{35} (88 Min Bias - 12.5nsec BX)



Do we want/need an analog or digital readout tracker?

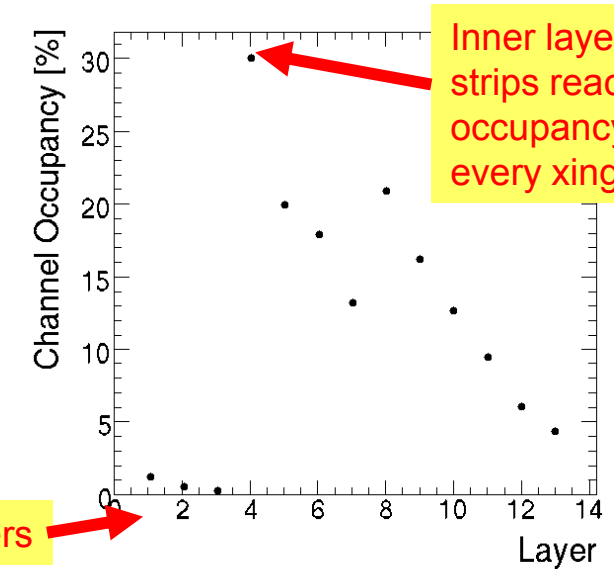
Higher granularity for inner layers needed

R (cm)	$<N_{ch}>/cm^2/12.5ns$	$<N_{ch}>/ (1.28cm)^2/12.5ns$
8	2.41	3.94
11	1.47	2.41
14	0.97	1.59

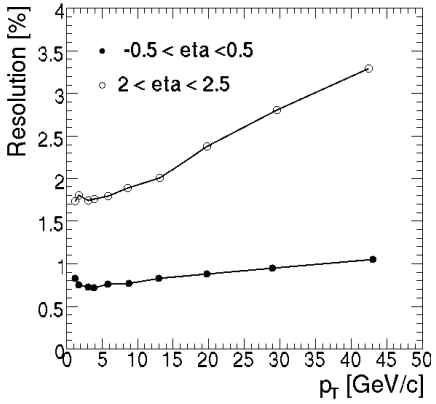
A. Rose

Tracking with 500 min Bias events

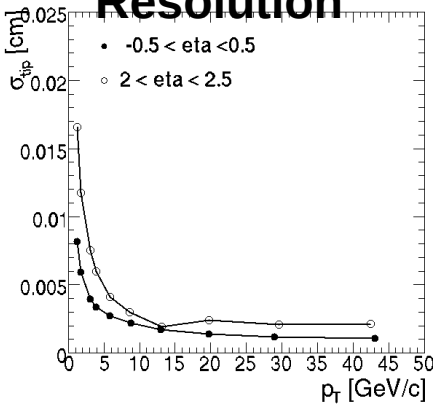
- Study of current CMS tracker for Heavy Ion events
- Track density very similar to 75ns running
  - $dn^{ch}/d\eta$/crossing ≈ 3000
  - Tracker occupancy very high
  - Need more pixel layers
- Tracking possible
  - When tracks are found they are well measured
  - Efficiency and fake rate suffer

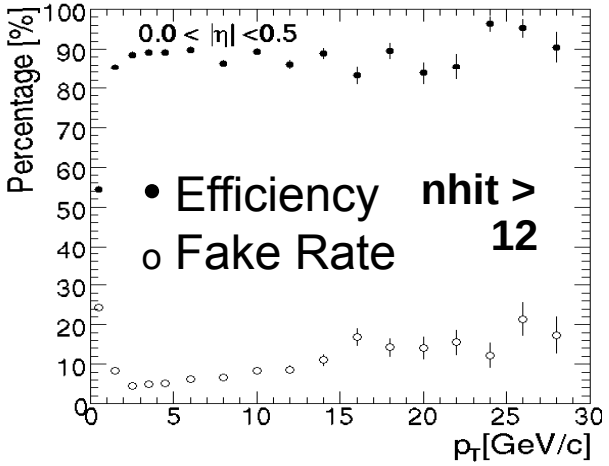


Momentum Resolution



Transverse Impact Parameter Resolution

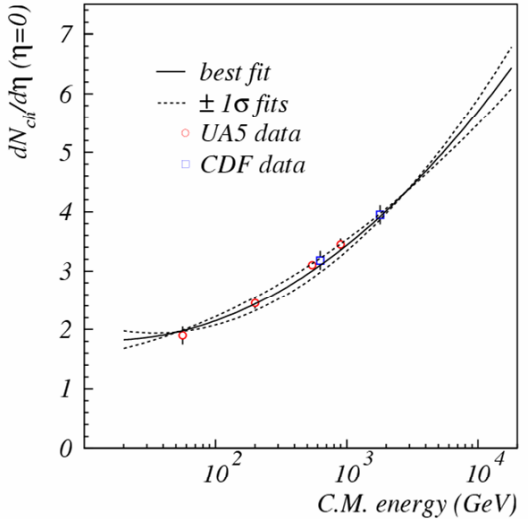


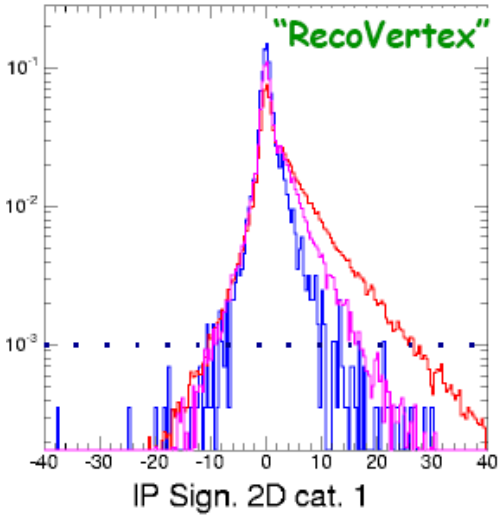


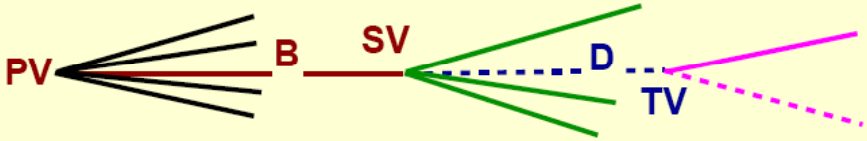
C. Roland

B-Tagging

- Pile-up overlaps with High Pt event faking a displaced vertex
  - 12.5 ns $dn^{ch}/d\eta$/crossing ≈ 600 and ≈ 3000 tracks in tracker acceptance
  - 75 ns $dn^{ch}/d\eta$/crossing ≈ 3000 and ≈ 15000 tracks in tracker acceptance
- B-tag performance depends on
  - Vertex resolution
  - Luminosity/bunch crossing
  - Size of luminous region (how far apart are the min-bias events)
- For 75ns option expect 2-3 min-bias events within 200 μm of any interesting event.
  - Need simulation to understand how much this reduces b-tagging efficiency
  - All this pushes for larger area of Pixel coverage, need to look at pixel size as well







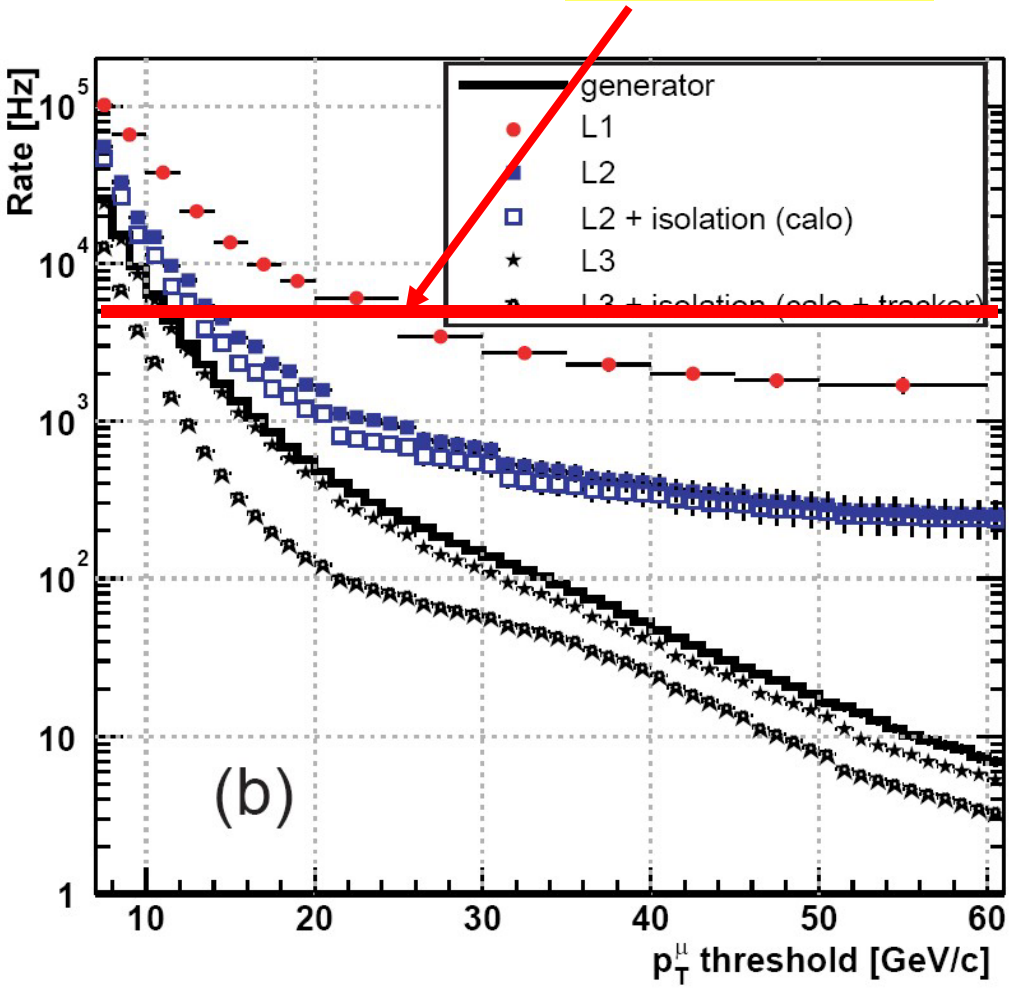
Exploit (weak) decay and production properties of b-hadrons:

- Lifetime of about 1.5 ps -> secondary (tertiary) decay vertex; displaced tracks
- High mass and decay multiplicity
- Hard b-quark fragmentation function
- Decay kinematics (e.g. rapidities)
- Semi-leptonic decays

C.Weiser A Combined SV Based B-Tagging Algorithm in CMS CMS Phys. Meeting 6/12/2005 P 3

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

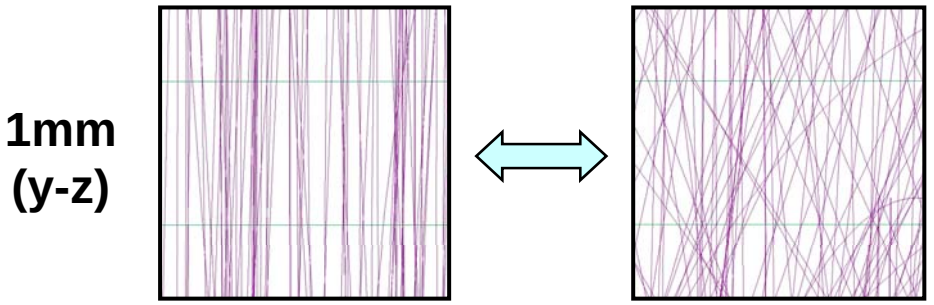


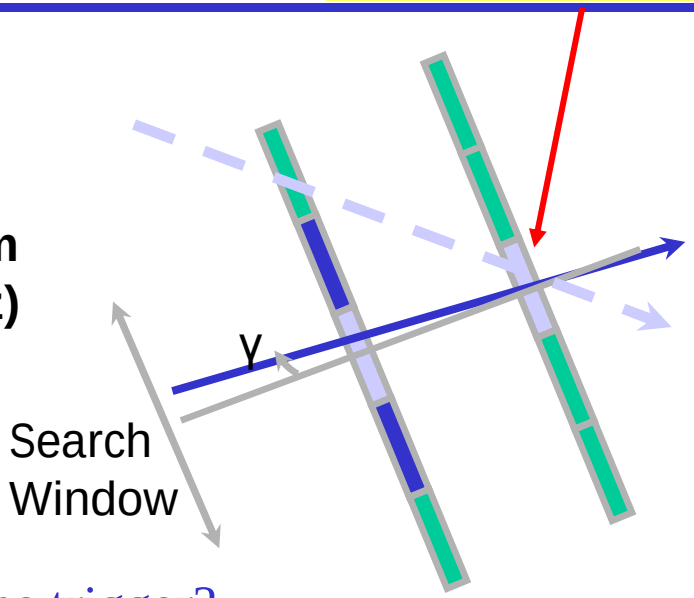
Trigger/DAQ Parameters

- Level 1 Trigger rate to stay at maximum of 100 kHz
  - Raise p_T thresholds to reduce rates
- Latency - doubled to 256 BX (6.4 μsec)
  - Extra time needed for more complex algorithms
    - Correlating with tracker information at Level 1
  - ECAL is the limit
    - Don't plan to replace the front end electronics
  - New trackers would have to respect this limit
    - Can't keep TOB as is
    - Smaller feature sizes may help
- DAQ system needs to be re-designed with increased bandwidth to handle 10 times the data volume

Tracking Trigger?

High momentum tracks are straighter so pixels line up



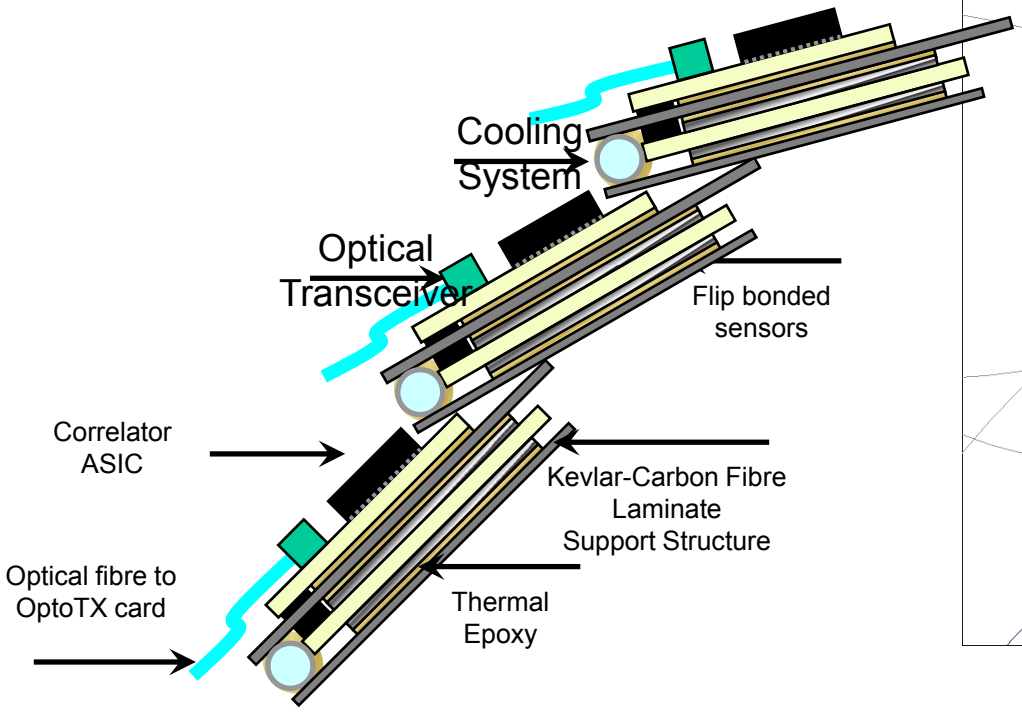


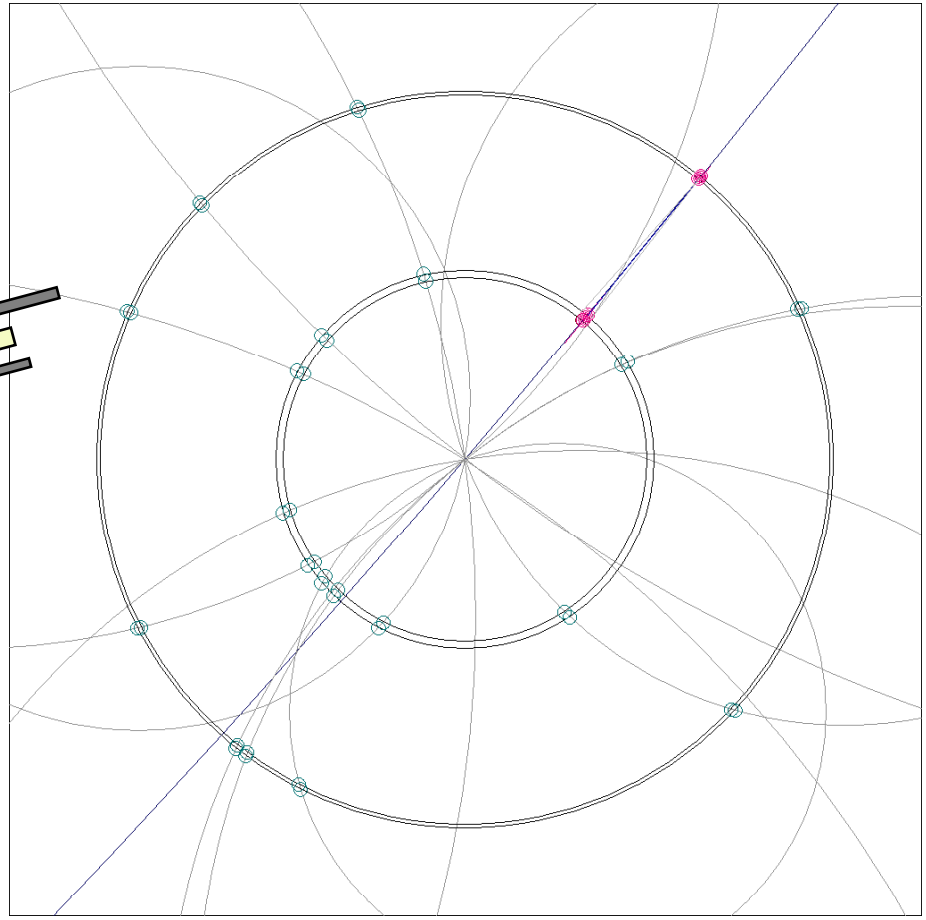
Geometrical p_T-cut - J. Jones, A. Rose, C. Foudas LECC 2005

- 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?
- Possible topic requiring substantial R&D
  - "Stacked" pixels which can measure p_T of track segments locally
    - Two layers about 1mm apart that could communicate

Implementing stacked layers

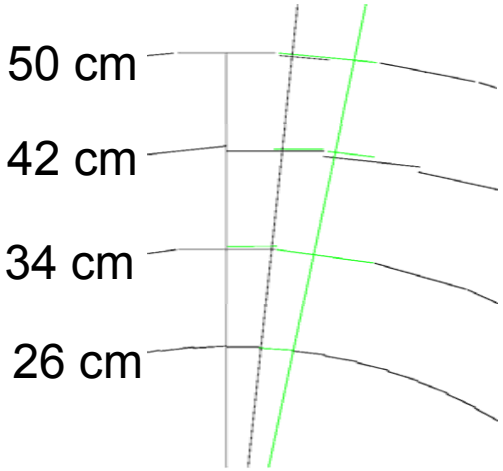
- Single stacked layer gives a Pt cut
- Two stacked layers give a Pt measurement





Other ideas for Level 1 input

- Alternative idea (F. Palla) pattern recognition in sectors (ala CDF)
- Pixel System for radii at 34, 42, 50 cm
  - Silicon strips (actual) have sensor element area of 10 to 15 mm^2
  - 10 fold increase in the luminosity would need a 10 fold decrease of it
    - Large elongated pixels of 200 μm x 5 mm
    - Sensor area 6 (r-ϕ) x 12 (z) cm^2
    - 3 - 4 fibers/module for 5 Gbps



Layer No.	Radius (cm)	Hit/module/bx[a]	No. detectors in ϕ	Hits/sector/bx[a]	Data rate*/module (Gbps)	Data rate*/sector (Gbps)	No. data links[†]/layer
1	26	3.1	82	43	5	69	1100
2	34	8.7	36	78	14	125	900
3	42	5.8	44	49	8	78	700
4	50	3.7	52	34	6	55	600

Calorimeters

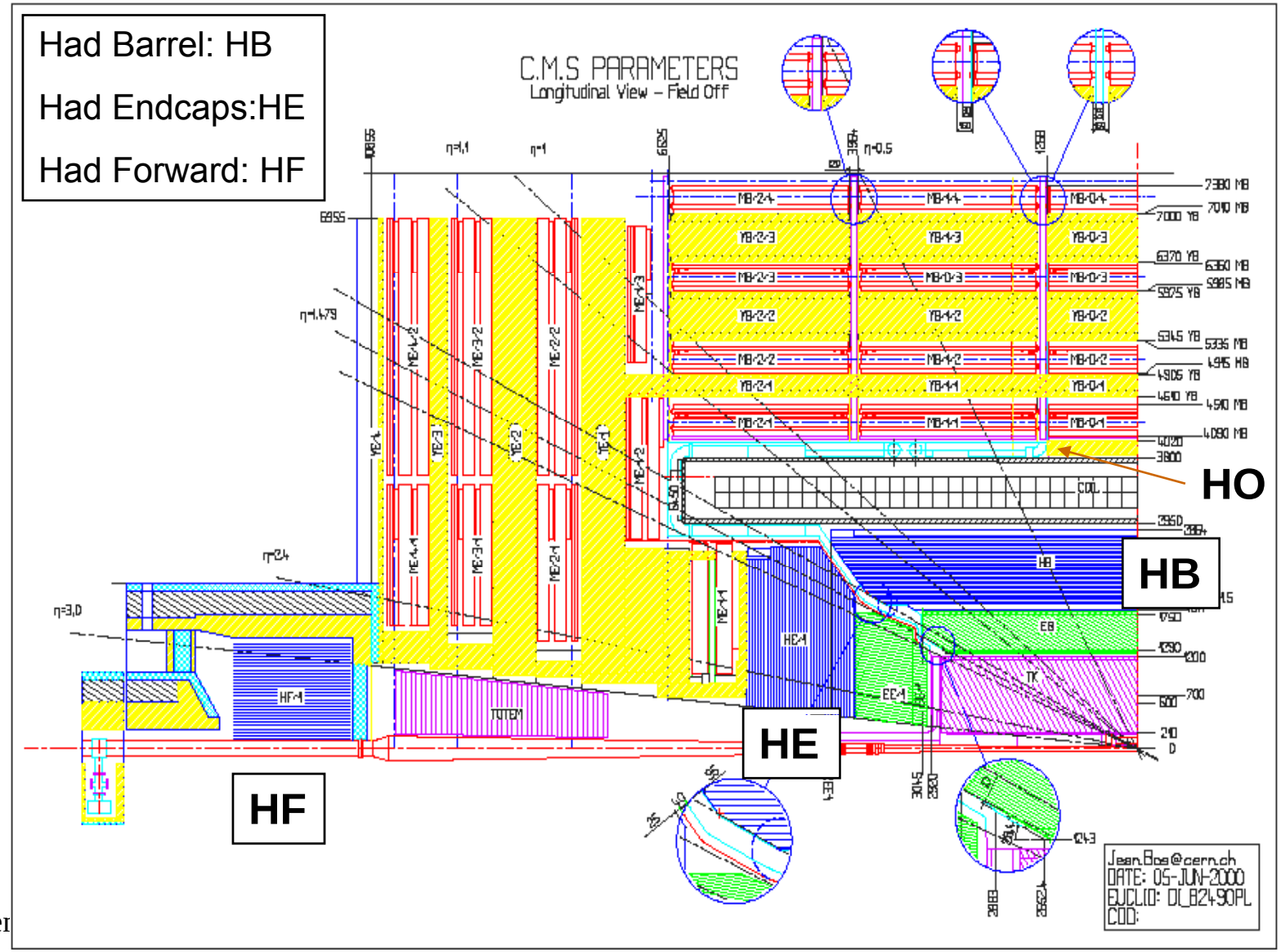
- ECAL
  - Barrel and endcap crystals and electronics designed to operate in SLHC conditions
  - Electronics for barrel is not accessible without disassembly of the barrel
  - Electronics on the Endcap could be accessed in principle, but the activation may make this difficult
- HCAL
  - Scintillator may suffer damage for $\eta>2$
    - R & D required
    - Finer granularity
  - HF some very high η towers lost
    - HF and shielding system issues with new insertion
      - Potential large additional cost

CMS HCALs

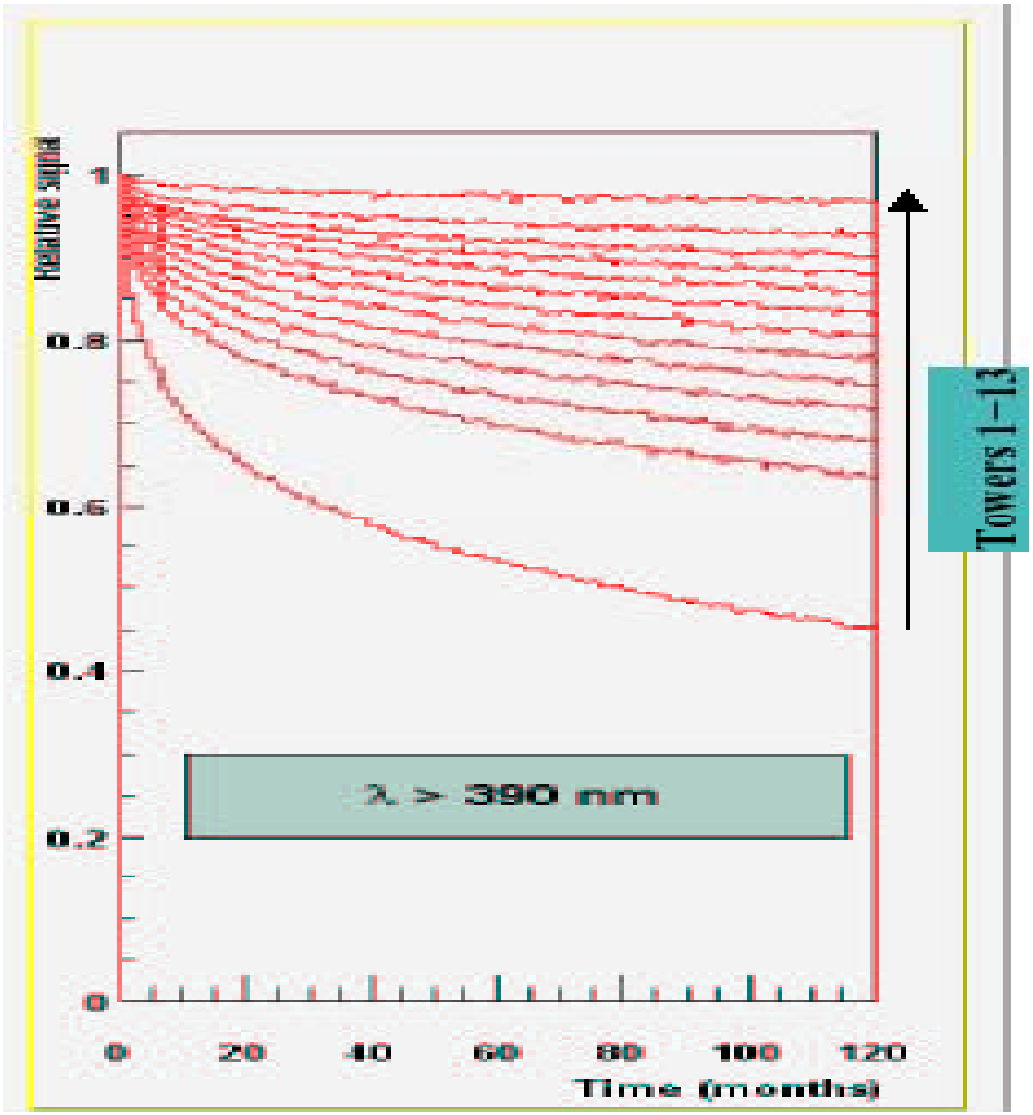
Had Barrel: HB

Had Endcaps:HE

Had Forward: HF



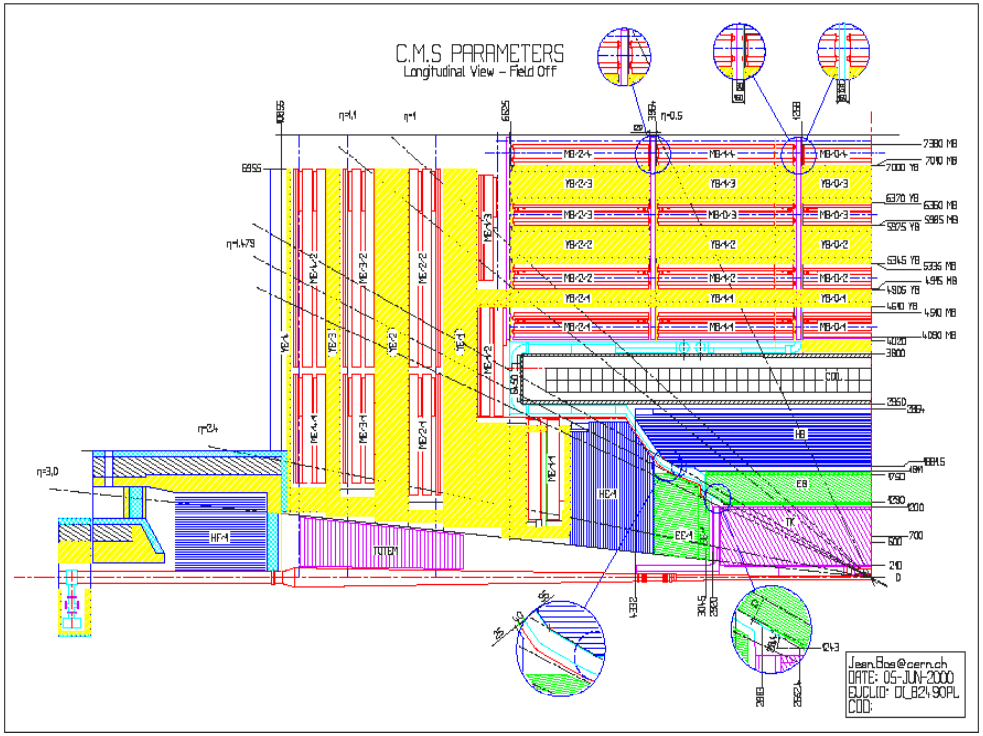
HF Damage



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

Calorimeters/Muons

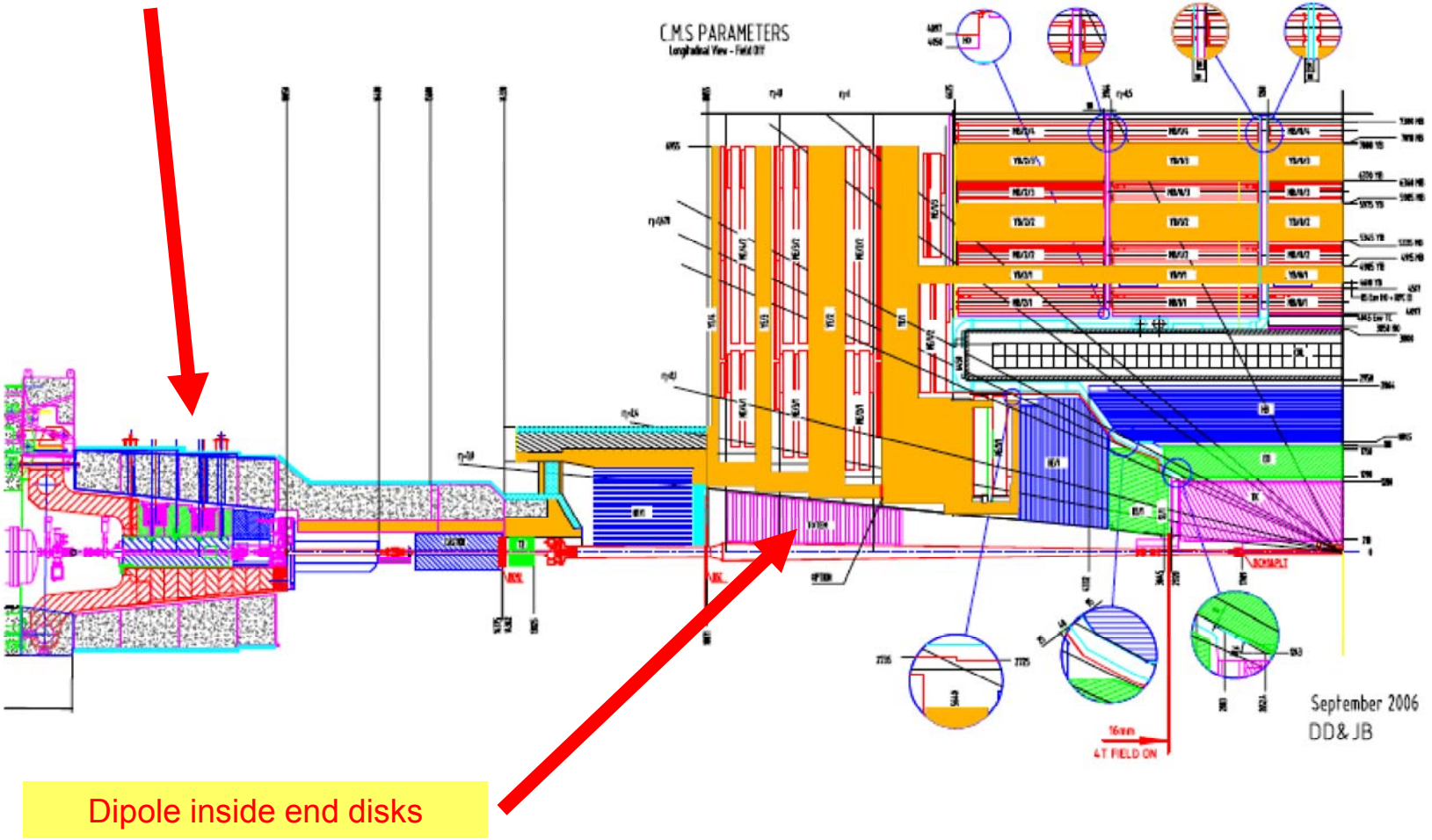
- ECAL
  - Crystal calorimeter electronics designed to operate in SLHC conditions
  - VPT in Endcap and Endcap crystals themselves may darken at SLHC
    - Very difficult to replace
- HCAL
  - HF may be blocked by potential changes to the interaction region
  - This has a direct impact mainly in the case of looking for WW scattering
- Both Calorimeters suffer degraded resolution at SLHC
  - affects electron ID, Jet resolutions



- 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

CMS IP Upgrade

Triplet moves closer to IP



Dipole inside end disks

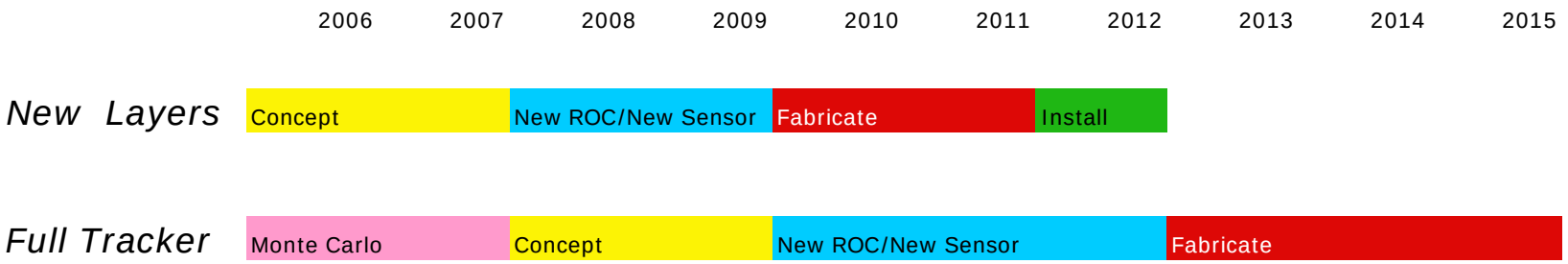
CMS R&D Proposals

- SLHC Upgrade Steering Group formed in 2005
  - http://cmsdoc.cern.ch/cms/electronics/html/elec_web/common/slhc.html
- This group is charged with
  - Recommending R&D proposals for approval to CMS MB/CB
  - Planning SLHC workshops
  - Outreach to collaboration
  - Interaction/Co-ordination with Machine and ATLAS on SLHC matters
  - Regular Reporting to Management Board/CB
- R&D Proposals get a stamp of CMS approval before going to funding agencies
  - Reviewed by SG

CMS SLHC Workshops

- Four workshops held over the past 3 years
  - http://agenda.cern.ch/fullAgenda.php?ida=a036368
  - http://agenda.cern.ch/fullAgenda.php?ida=a041379
  - http://indico.cern.ch/conferenceDisplay.py?confId=a053123
  - http://indico.cern.ch/conferenceDisplay.py?confId=a06865
- Establish requirements for upgrades of sub-detectors
- Identify R&D needed for upgrades
- Prepare potential upgrade concepts
- Additional workshops within tracker community
  - http://indico.cern.ch/conferenceDisplay.py?confId=6904
  - http://indico.cern.ch/conferenceDisplay.py?confId=12094

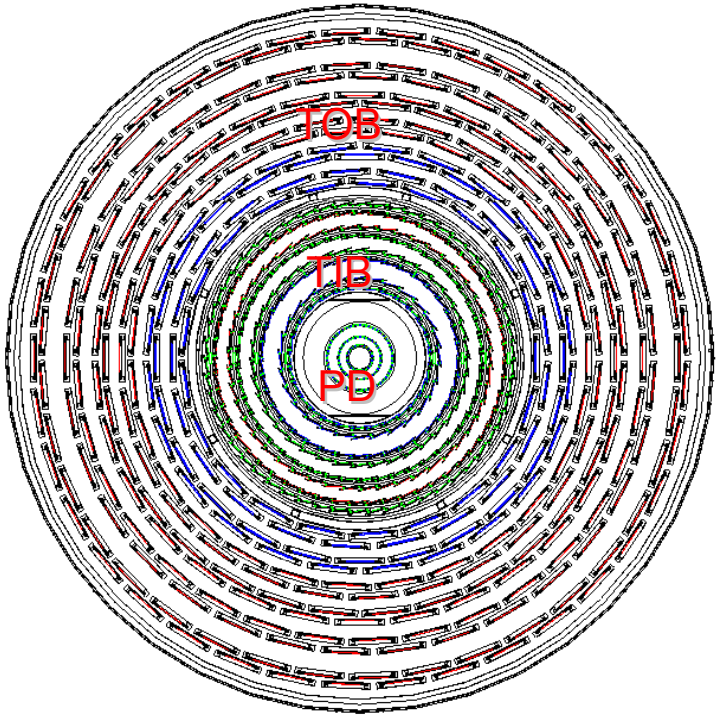
Roadmap for tracker/trigger upgrades

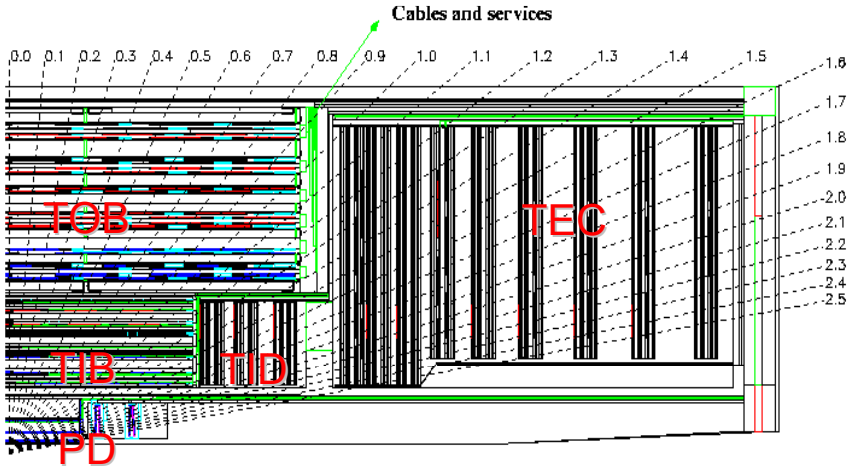


- Within 5 years of LHC start
  - New layers within the volume of the current Pixel tracker which incorporate some tracking information for Level 1 Trigger
    - Room within the current envelope for additional layers
    - Possibly replace existing layers
  - "Pathfinder" for full tracking trigger
    - Proof of principle, prototype for larger system
  - Elements of new Level 1 trigger
    - Utilize the new tracking information
    - Correlation between systems
- Upgrade to full new tracker system by SLHC (8-10 years from LHC Startup)
  - Includes full upgrade to trigger system

Ideas on a new tracker concept?

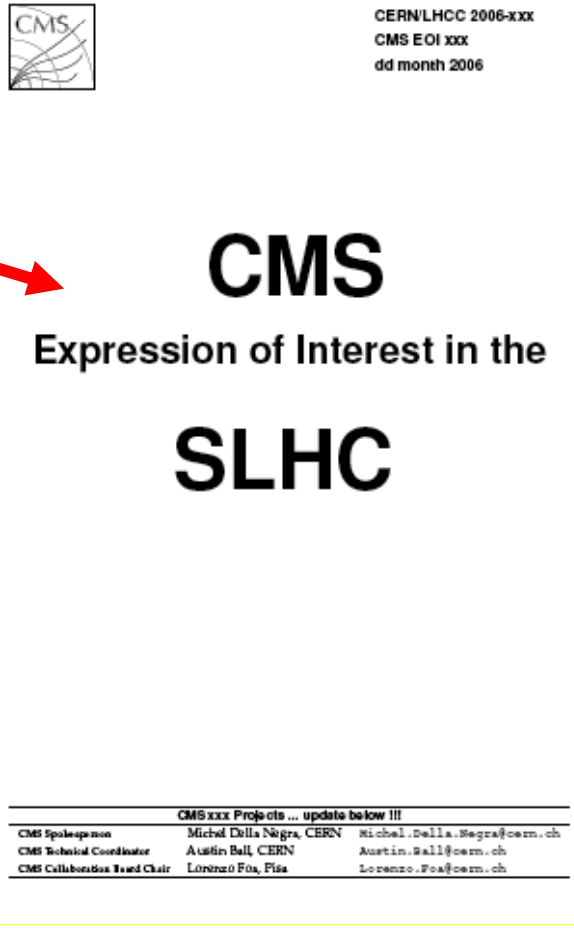
- Strawman - A much larger pixel tracker, some triggering layers, more segmented strips
  - 10 cm layer with *current* pixels (500 ChF/cm^2)
    - Around 1m^2
  - 20/40/60 cm layers with bigger pixels (100 Chf/cm^2)
    - around 25 m^2
    - 25 MChf
  - Outer layers long pixels/short strips (30 Chf/cm^2)
    - Around 170 m^2
    - 50 MChf
  - Some triggering layers.
    - 1 layer for Pt cut only or 2 layers to measure Pt
    - Or perhaps full scale hardware pattern recognition?
- This is the at the limit of affordability - How much can we re-use?
  - Can we use the TOB mechanical structures (a copy at least)
  - Can we re-use services
  - Re-use of some of the TOB - at least the concept if not the actual modules





SLHC R&D:Next steps

- Expression of Interest
  - Reasonably brief document (40 pages)
  - Brief case for upgrade
  - Outlines scope of upgrade work
    - What detectors/Timescale
  - Submitted to LHCC March 2007
  - Prepare funding agencies
- Letter of Intent
  - A larger document
  - More complete physics case
  - Includes organization and rough costings of detector work
    - Including how CMS will organize the effort
  - Submitted to LHCC
    - Allow funding agencies to “release” funding
  - Target Summer 2008


CERN/LHCC 2006-xxx
CMS EOI xxx
dd month 2006

CMS

Expression of Interest in the

SLHC

CMS xxx Projects ... update below !!!		
CMS Spokesperson	Michel Della Negra, CERN	Michel.Della.Negra@cern.ch
CMS Technical Coordinator	Austin Ball, CERN	Austin.Ball@cern.ch
CMS Collaboration Board Chair	Lorenzo Foa, Pisa	Lorenzo.Foa@cern.ch

CMS Detector Replacements

Inner Tracker	30 MChf
Outer Tracker	90 MChf
Level 1 Trigger	20 MChf
DAQ	10 MChf
Other Front Ends	10 MChf
Infrastructure	15 MChf
Total	175 MChf

Across collaboration

~ 900 FTE

Materials Cost for Collaboration (CORE)

Some of the Identified R&D areas

- Pixel technology
  - Hybrid - cheaper bonding
  - MAPS/SOI - need an answer now if it can be used
- Geometry
  - How many different sensors
  - Layout of inner/outer pixels
- Triggering layers
  - How many/Where
- Readout
  - Current ROC to 130 nm
  - New ROC to push Col hit info for stacks
  - Correlator Chip
- Link and Control technology
  - GBT?
  - Optical Links
    - Re-use of part of the plant?
- Radiation tolerance and robustness of 130nm/90nm
- Technology for a very inner layer
  - Different sensor
- Power/Material
  - DC-DC/Serial power

Conclusions

- CMS at SLHC Upgrade largely driven by tracker requirements
  - Higher granularity
  - Potentially substantially larger pixel detector
  - We may also need to understand how to form tracks with these detectors at 40 (20) MHz as input to the Level 1
- Trigger system will need replacement
- R&D required is substantial
  - Needs to start now
  - Needs to be focused
    - Important to converge on tracker design requirements
      - Need input from simulation/machine studies
- This workshop offers an opportunity to identify areas where we can collaborate while R&D is still in an early stage