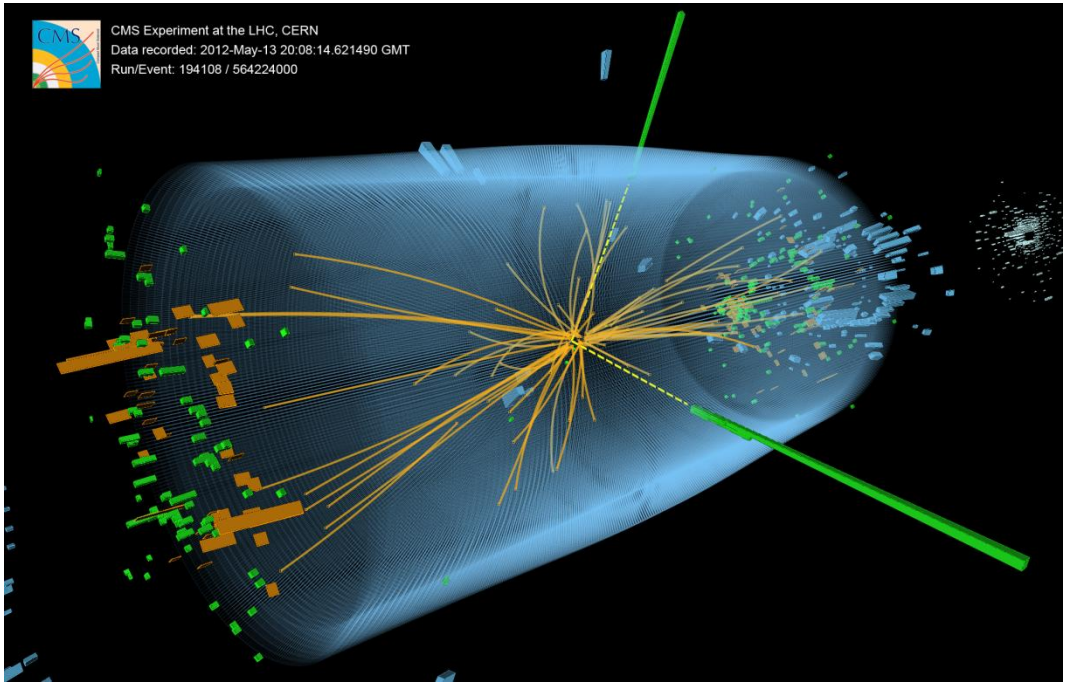


Update on CMS Upgrade Plans

Joel Butler

October 16, 2012

"The U.S. contributions to the CMS upgrade continue to be better defined and developed. We ask the PAC to comment on the proposed contributions, and what will be needed from the laboratory to make the upgrade successful."

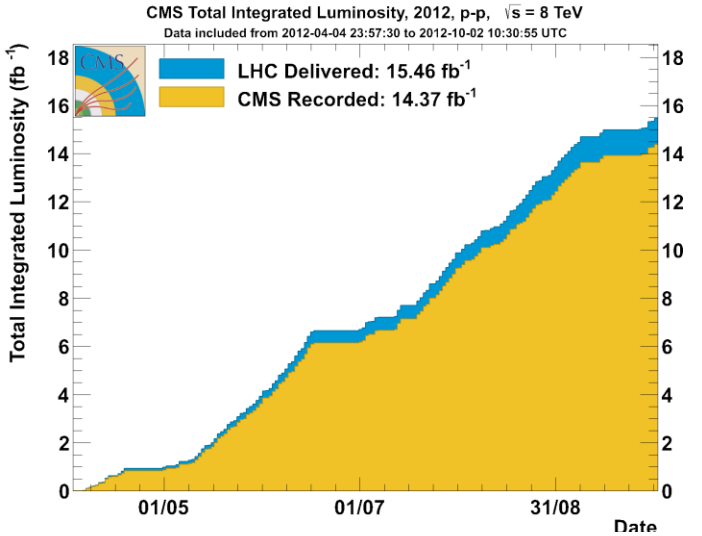
Drivers of the Phase 1 Upgrade

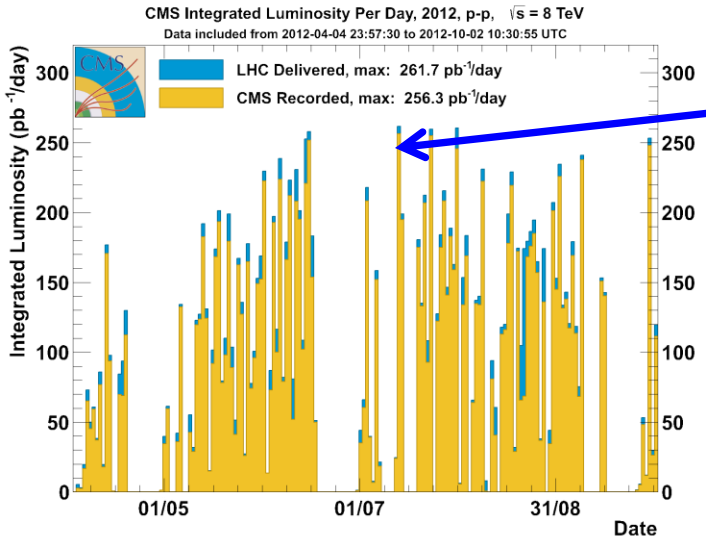
- Performance of experiment through 2012 (technical driver)
  - Especially in light of “pileup”, now ~35 (peak) interactions/crossing (50 ns bunch spacing)
- Projections vs time of LHC performance and operating parameters (technical and schedule driver)
  - 25 ns bunch spacing?
  - 50 ns bunch spacing?
- Shutdowns (schedule driver)
  - Availability of access to collision hall (UXC) for installation

Installation Opportunities

- There are edge effects in opening and closing the CMS to get access to the detectors inside the solenoid – open/close time ~2 months
  - A Long Shutdown (LS) is ~> 1 year so the available work time is >> than the open/close time
  - A Technical Stop (TS,) is ~ 3 months (e.g. winter shutdown - YETS) so available work time <open/close time
  - An Extended Technical Stop (ETS) is ~5-6 months (e.g. an extended winter shutdown) to have time to do one installation or repair operation
- Trigger and DAQ electronics in the Underground Service Cavern (USC) can take place during running but must not impact operations
- The installation schedule for upgrades is shaped by access to the collision hall

Luminosity Performance



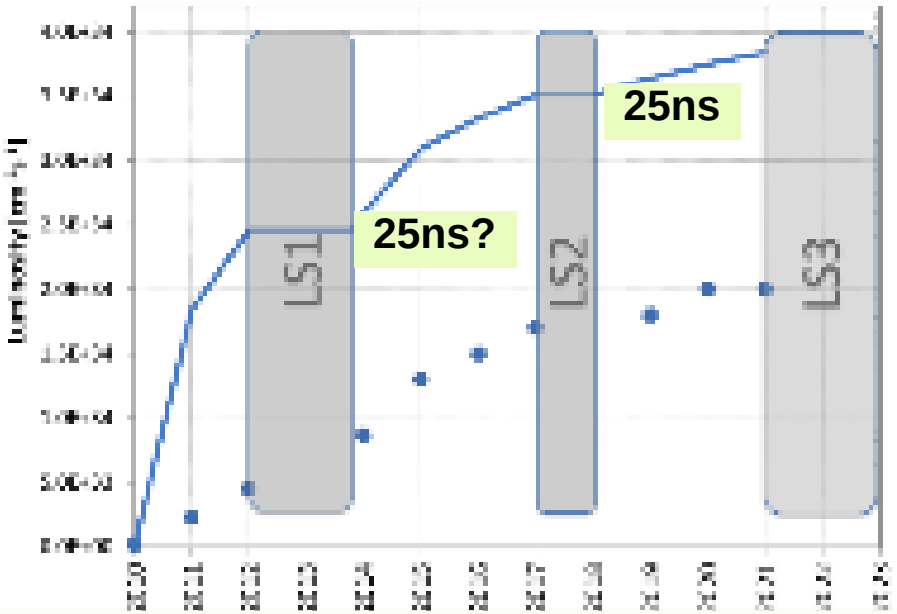


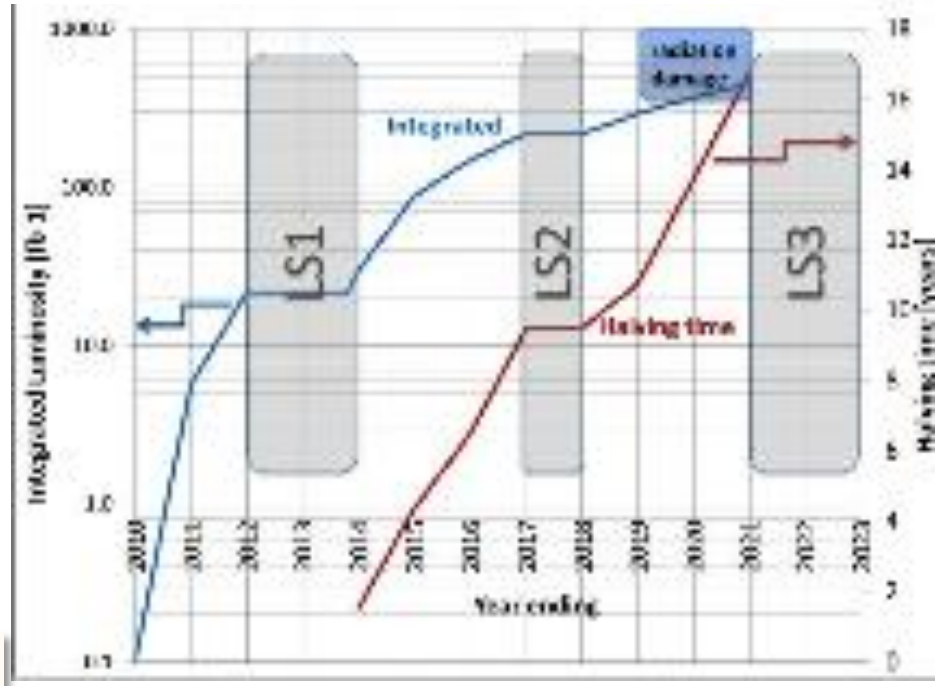
- LHC delivered 15.46 fb^{-1}
  - CMS recorded 14.37 fb^{-1}
- Peak Luminosity 7.5x$10^{33}cm^{-2}s^{-1}$
- Bunch spacing 50 ns
- Pileup at beginning of store ~35
- LHC is above "energy-scaled" design luminosity already.
- LHC is well-above design pileup.
- Our best DAY was 261.7 pb^{-1} !
  - Radiation degradation has appeared and will be a real issue
  - SEU's are also a problem

Upgrade drivers:

- Pileup – impact on trigger and analysis (detector performance)
- Radiation damage

LHC Performance and Schedules





Conditions
- ~ 2x10^{34} by LS2, higher after LS2
- ~ 200fb^{-1} by LS2, ~ 500fb^{-1} by LS3
- 25ns is the plan, but … easier and more reliable at 50ns?
- Integrated luminosity is the goal

For the Upgrades
- "Baseline" PU~50, study ~100
- Lumi-leveling will come into play at some point

	Number of bunches	β* [m]	Half X-angle [μrad]	Ib SPS	Emit SPS [um]	Peak Lumi [cm^{-2}s^{-1}]	~Pile-up	Int. Lumi [fb^{-1}]
25 ns	2800	0.50	190	1.2e11	2.8	1.1e34	23	~30
50 ns	1380	0.40	140	1.7e11	2.1	1.8e34 β* level	81 β* level	?
25 ns low emit	2600	0.40	150	1.15e11	1.4	2.0e34	48	52
50 ns low emit	1200	0.40	120	1.71e11	1.5	2.2e34	113	?

CMS Upgrade Projects

LS1 Projects: in production
- Completion of muon coverage (ME4)
- Improve muon operation (ME1), DT electronics
- Replace HCAL photo-detectors in HF (new PMTs) and HO (HPD→SiPM)

Phase 1 Upgrades: TDRs in preparation
- Pixel detector replacement
- HCAL electronics upgrade
- L1-Trigger upgrade

Phase 2: Working Groups
- Tracker replacement, Track Trigger
- Forward Region: Calorimetry, and Muons?
- Further Trigger upgrade?

- Longevity → Phase 2
- Phase 2 Scope
- Targeted R&D program

} 2013

- Technical Proposal — 2014

Goal of Upgrade: achieve at least the same efficiency, and hopefully better, than we had at 7×10^{33} at 8 TeV with 2×10^{34} at 14 TeV for 25 ns or 50 ns bunch spacing

US Work in LS1

- **Improvements to detector**
  - **needed to deal with higher luminosity (and energy) in 2015**
  - **Correct problems observed during the run**
- **Muon trigger improvements**
  - **Add fourth plane of CSCs**
  - **change ME1/1 electronics to provide single strips to trigger**
- **HF PMT replacement (always planned)**
  - **1800 multianode PMTs delivered, tested , and shipped to CERN**
  - **PCB production (socket, adapter, baseboard) ongoing - will finish by March 2013**
  - **Decision to order new cables - pending funding availability**
  - **HV PS system selected (CAEN) - purchase order to be placed**
  - **Finalizing the mechanical components of the readout boxes**
- **HO SiPM (replace HPDs)**
  - **All SiPMs delivered and production of electronics boards completed**

Production Facility at Lab 8


Axxiom machine


Gerber machine


Gerber control

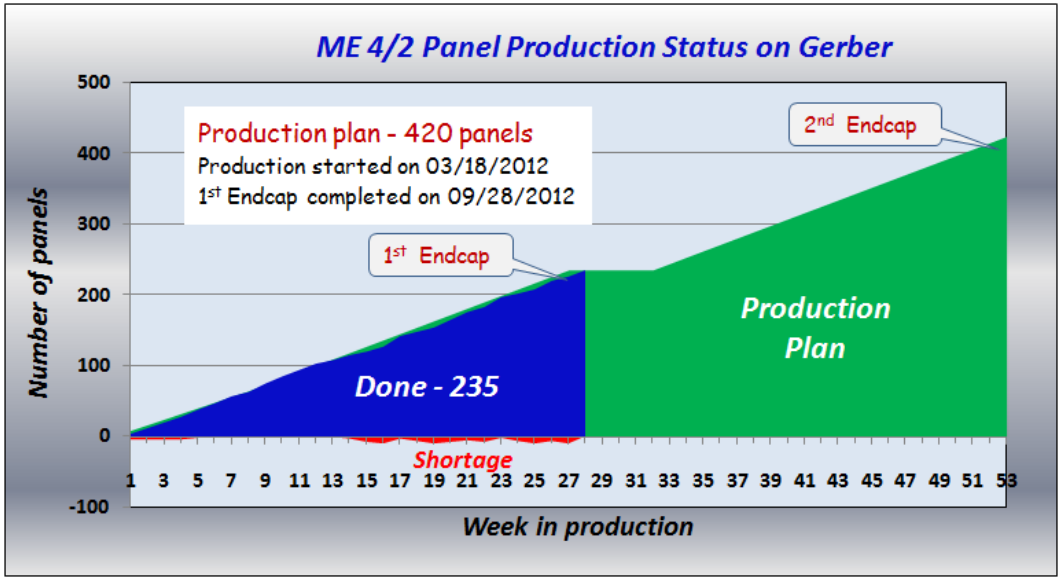
The AXIOM and Gerber machines used for panel cutting, drilling and strip milling.

All machine sare fully operational and ready for panel machining.

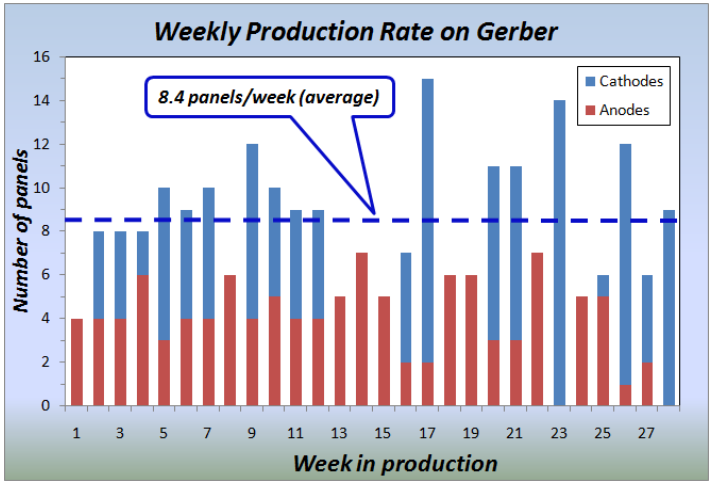
New parts, bits and diamond saw blade required for the production have been procured.

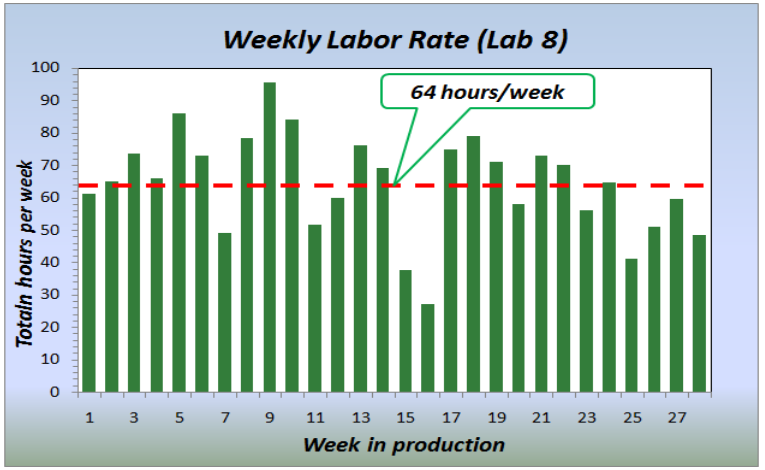
Panels are 5m x 1.5 m (actually trapezoid)
~500

Panel Machining Status at FNAL



On schedule, On budget





Endcap Muon – CSC Improvements

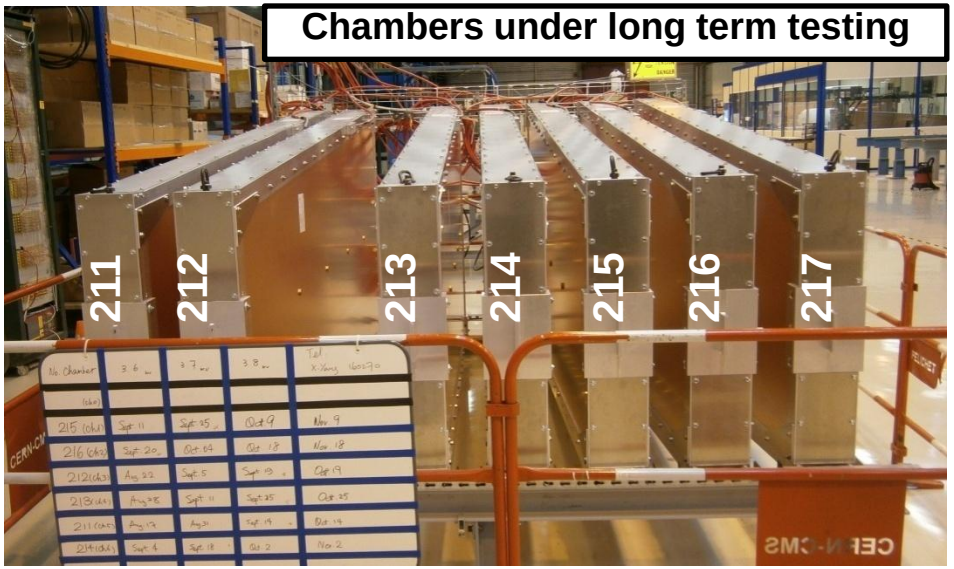
ME4/2 status

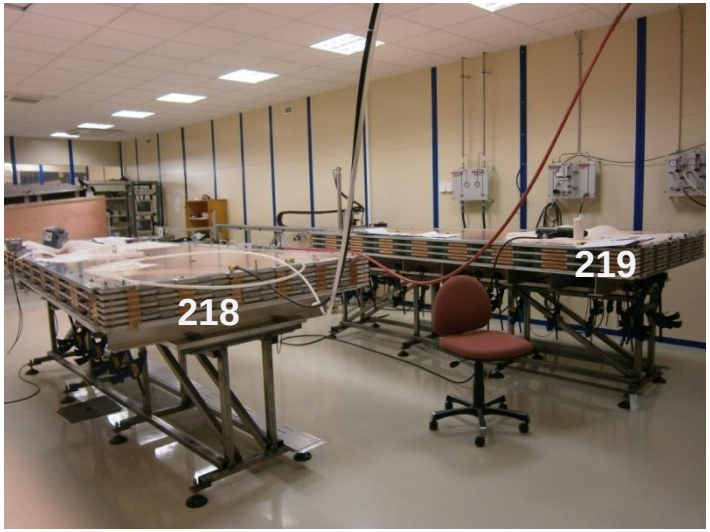
- Panel production going well – 269 panels finished, 213 shipped to CERN, 56 more ready to ship
- Finished panels for 1st end cap!

Factory status

- 18 chambers assembled / 9 in storage, ready for installation, rest in various testing phases
- On track for completing 1st endcap beginning of February

- 2nd endcap panel production starting
  - Should get first batch of panels from Plascore 3rd week in October





Pixel and HCAL TDRs

Each TDR contains

- **Motivation for the upgrade, and performance of new detector**
- **Technical description – the bulk of the document**
- **Summary of organization, cost and schedule**

New Element

- **The Physics Case for the TDRs are now the responsibility of the Physics Analysis Groups**
- **As a result, the physics case is being worked on by more people who are experts and is more developed than it was even 6 months ago**
- **Upgrade physics studies are reviewed using the "standard procedure" CMS uses for reviewing all its physics results**

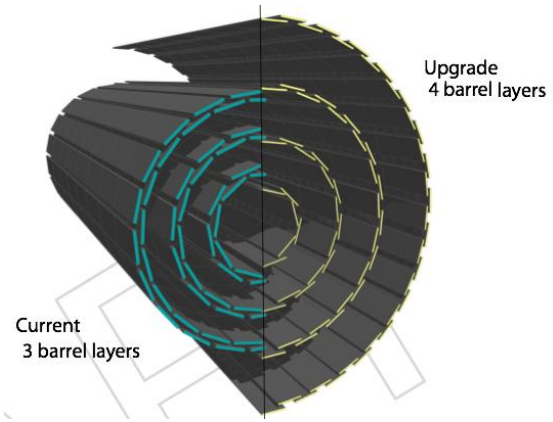
Documents

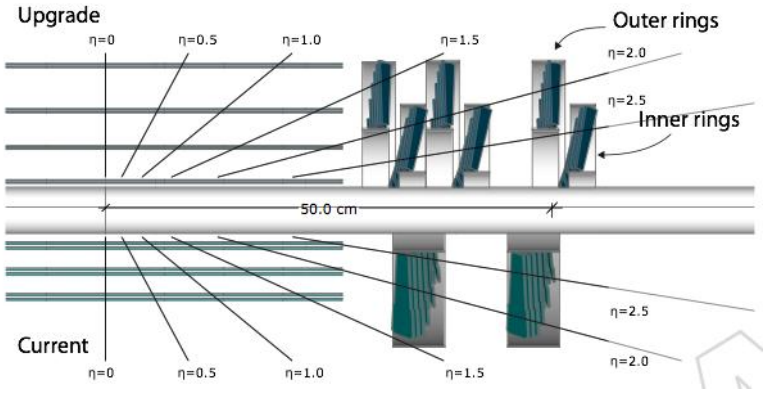
- **Updated documents were sent to LHCC to allow for their consideration at their meeting in September**
- **The designs and R&D are well advanced. We wanted and got endorsement by LHCC to ramp-up the projects in 2013**

Trigger TDR

- **This TDR is still being developed with completion expected in the spring**
  - **It is benefitting from real experience with high pileup running.**

Pixel Upgrades



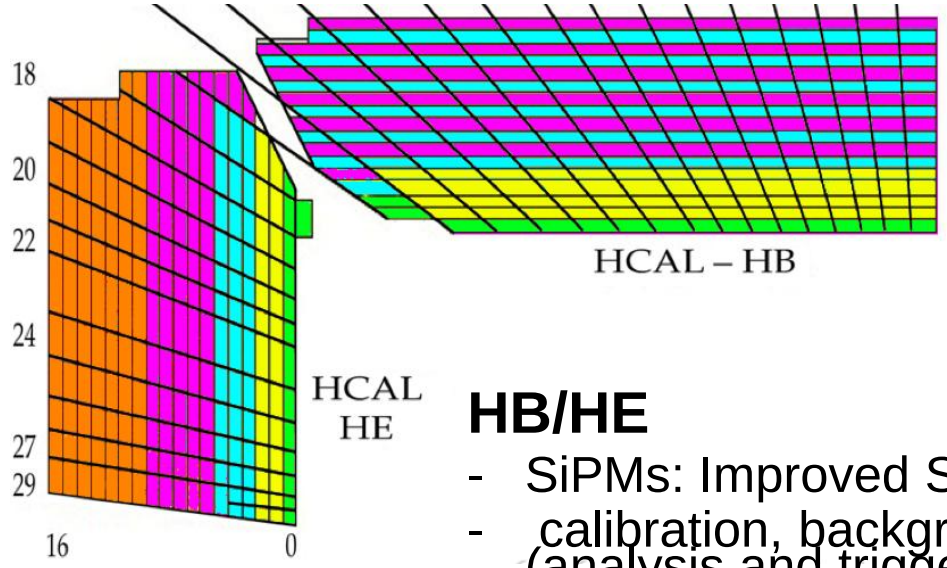


Pixels **Features of New Design**

- **Robust design: 4 barrel layers and 3 endcap disks at each end**
- **Smaller inner radius (new beampipe), large outer**
- **New readout chip with expanded buffers, embedded digitization high speed data link**
- **Reduced mass with 2-phase CO_2 cooling, electronics moved to high eta, DC-DC converters**

Ready to install by end of 2016

HCAL Upgrades



HF

- 2-channel readout per PMT, and TDC
- **identify spurious signals and recover hits**

Install at end of 2015

HB/HE

- SiPMs: Improved S/N and depth segmentation
- calibration, background and **PileUp suppression, EM** isolation (analysis and trigger)
- Timing of pulses

Install front-end electronics in LS2

Physics Case for the Pixel Upgrade

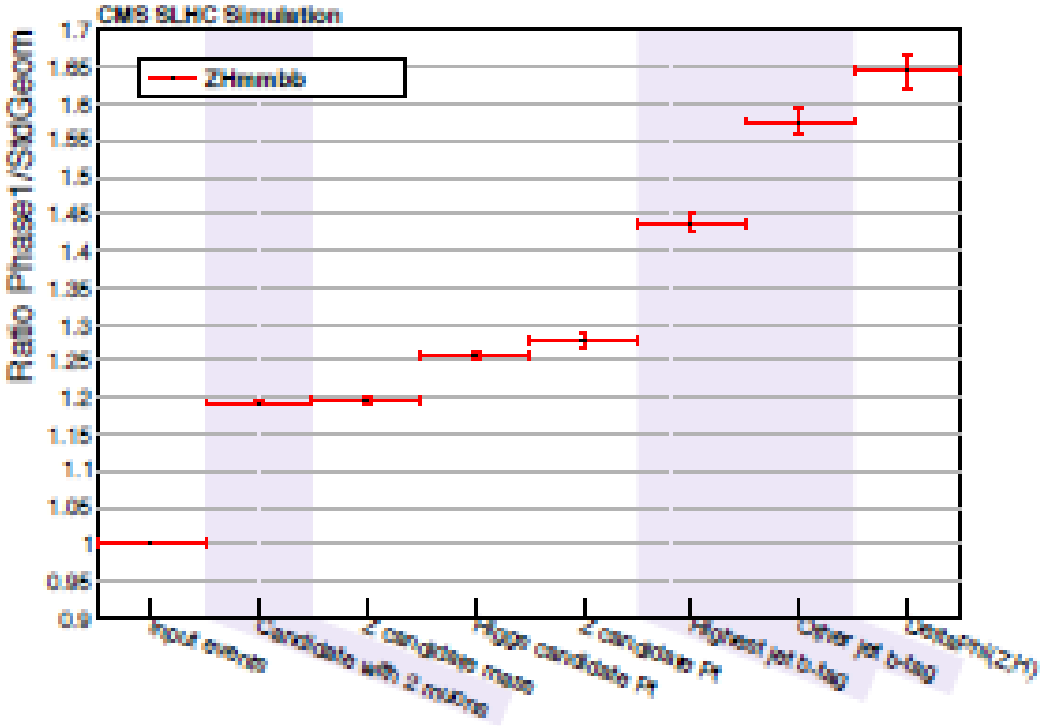


Figure 2.28: The ratio Phase-1/current of the number of events left after each cut. Values greater than 1 show increased efficiency for the Phase-1 upgrade and vice versa. The cuts where the upgraded detector is expected to excel are highlighted.

Gain in physics for ZH is 1.65 with new detector relative to performance of old detector (no radiation damage) for events with mean pileup of 50. (analysis is still a work in progress)

Likely FNAL Roles

- **Pixel**
  - **Engineering design (with others in Barrel Pixel and Purdue, Rutgers and others in US)**
  - **Electronics readout chain**
  - **Module testing, calibration**
  - **Integration center for disks, half cylinders**
    - **Test cold with CO_2 system built at SIDET**
- **HCAL**
  - **QIE ASIC**
  - **Most front end electronics**
  - **With others, SiPM R&D and production**
- **Trigger**
  - **TBD**

Proposal/Approval Status

- **LHCC (last meeting): "The LHCC endorses the HCAL and pixel upgrade without reservations"**
- **US DOE:**
  - **CD0 now approved**
  - **Plan/goal for moving forward**
    - CD-0, Approve Mission Need — FY 2012
    - CD-1, Approve Alternative Selection and Cost Range — FY 2013
    - CD-2, Approve Performance Baseline — FY 2013
    - CD-3, Approve Start of Construction — FY 2014
    - CD-4, Approve Project Completion — FY 2018
- **US NSF**
  - **Proposal for new "mid-range" Cooperative Agreement due mid-December**

Project Management

- **Effective Project Management is a necessary condition for success in the upgrades**
  - **The standards for formal project management are high and capability in this area must be demonstrated in the approval process**
  - **"Professional" (or at least trained) schedulers and financial people are needed to keep up with the many reporting requirements and to provide information to the project managers**
  - **Engineering effort is needed to guarantee quality and handle many integration issues**
    - **Especially important when integrating equipment into an experiment at another lab, especially one with a strong and somewhat different culture such as CERN**
  - **Procurement, legal , accounting, shipping services, etc**

Because FNAL has many projects and can move people with these skills from one to the next, it makes sense for FNAL to provide this aspect of the project personnel

FNAL Involvement in FPIX

- **Electrical/electronics:**
  - **Al cable testing, port card design: Sergey Los (engineer)**
  - **HDI: design, testing; Mike Matulik and a layout tech in PPD. For testing, we will need a postdoc/grad student based at the LPC AND technician help from SIDET.**
  - **DC-DC conversion testing: right now, we are testing the prototype from Aachen. People involved are me, Lalith and Ryan Rivera. At some point, we will design a board for the pilot detector. Will need Jeff Andresen to work on the layout.**
  - **Pixel Opto-hybrid: design, testing, and review: people involved are Alan Prosser, John Chramowicz, and Jeff Andresen.**
  - **Pixel ROC and TBM wafer probing: Cristian Gingu (EE). We will get a postdoc/grad student to help with the testing. KSU is interested.**
- **Mechanical:**
  - **Operation of the CO2 cooling plant: Erik Voirin (Mech, Engineer)**
  - **Design, prototype fabrication, and testing of the C-C ring and TPG: Cm Lei (ME), David Butler (tech), Eileen Hahn (tech), Bert Gonzalez(tech), Designer/draftsman**
  - **Lead Mechanical engineer: Greg Derylo**
  - **Installation of pilot system at CERn: David Butler and another tech.**
  - **Consultation on mechanics for pilot system: Joe Howell.**
- **Sensor testing:**
  - **need support from SIDET tech: Bert Gonzalez, Tammy Hawkes (wire bonding tech) Sensor testing: Lorenzo Uplegger**
- **System test:**
  - **need support from SIDET tech to set it up: Mike Roman (eng phy) and his team**

FNAL Involvement in HCAL

- QIE ASIC engineering. (Tom Zimmerman, Jim Hoff) FADC Chip for HCAL upgrade.
- Expertise developing front end cards based on QIE. (Sergey Lose/ Terri Shaw) Design front end card for HCAL upgrade.
- SIPM system design (Sergey Los). Based on HO Upgrade, focus into central HCAL environment and specs)
- Firmware programming (Tom Fitzpatrick) Firmware for front end card FPGA (replaces CCA ASIC in new upgrades)
- ASIC testing (automated testing) (Al Baumbaugh, Scott Holm) (Test QIE among other new chips)
- thermo-electric system design for front ends (Sergey Los) power management and cooling design for HCAL upgrade.
- large scale front end system design and integration (Terri Shaw) System engineering for HCAL front end system
- optical fiber polishing (Lab 7, Eileen Hahn) Polish ODUs for HCAL upgrade
- vacuum deposition (Lab 7, Eileen Hahn) Mirroring fibers, depositing exotic materials like PTP and ZnO for R&D on HCAL phase 2 upgrade

New- FNAL Trigger Group

- **Current group members from FNAL: J.Berryhill, E.Gottschalk,S.Gruenendal, S.Jindariani, T.Liu, K.Mishra, M.Verzocchi (+few others expressing interest)**
- **Performance of the trigger is critical for realizing the full physics potential of CMS**
  - **studying a light Higgs boson, along with other future search goals, demand efficient, low-threshold L1 triggering of leptons, jets, taus, and MET**
  - **the existing L1 system is running at maximum capacity (~100 kHz output), and the future 14 TeV run demands improved data reduction to deal with higher pileup and higher physics cross sections**
- **The ultimate goal of the group is to become a major contributor to the L1 trigger project, for both short and long term**
- **Expertise developed at Fermilab in the area of triggering in the hadron collider environment uniquely positions us to develop solutions for the CMS trigger upgrade**

FNAL Trigger Plan

- **Short Term (Phase 1 upgrades):**
  - **Study performance of the existing system with 14 TeV and various pile-up scenarios.**
  - **Investigate possibilities of improving current L1 triggering algorithms. Contribute to the L1 upgrade TDR (Spring 2013).**
  - **Develop expertise in CMS L1 simulation software for future upgrade studies**
  - **Identify and contribute to the potential hardware upgrades**
- **Long Term (Phase 2 upgrades):**
  - **Use the developed expertise in L1 simulations to study physics-driven design requirements for the Phase 2 upgrade**
  - **Continue existing R&D efforts for track trigger development. Create system-level solutions for using tracker information at L1 in CMS. Provide feedback to the tracker upgrade group.**
  - **Play leading role in building and commissioning of such system**

Conclusions

- The case that the LHC will achieve high luminosity and that the upgrade is required now seems established
- The physics case for the upgrade is now becoming solid
- Fermilab should provide much of the electronics and mechanical engineering, with strong contributors from universities
  - Integration engineering is very crucial
- Most production consists of small subassemblies that can be done at universities or FNAL
  - Fermilab may not do much module production at SIDET since Purdue and Nebraska are funded to set up module production facilities
  - Much assembly has to be done at the experiment
- In some cases, FNAL has unique facilities, e.g. Gerber, that are needed intermittently - long term support of these is invaluable
- Project management people are crucial and best supplied by lab
- Physicists and physics graduate students will carry out many essential activities needed to turn this piece of hardware into a key component of the upgraded CMS detector