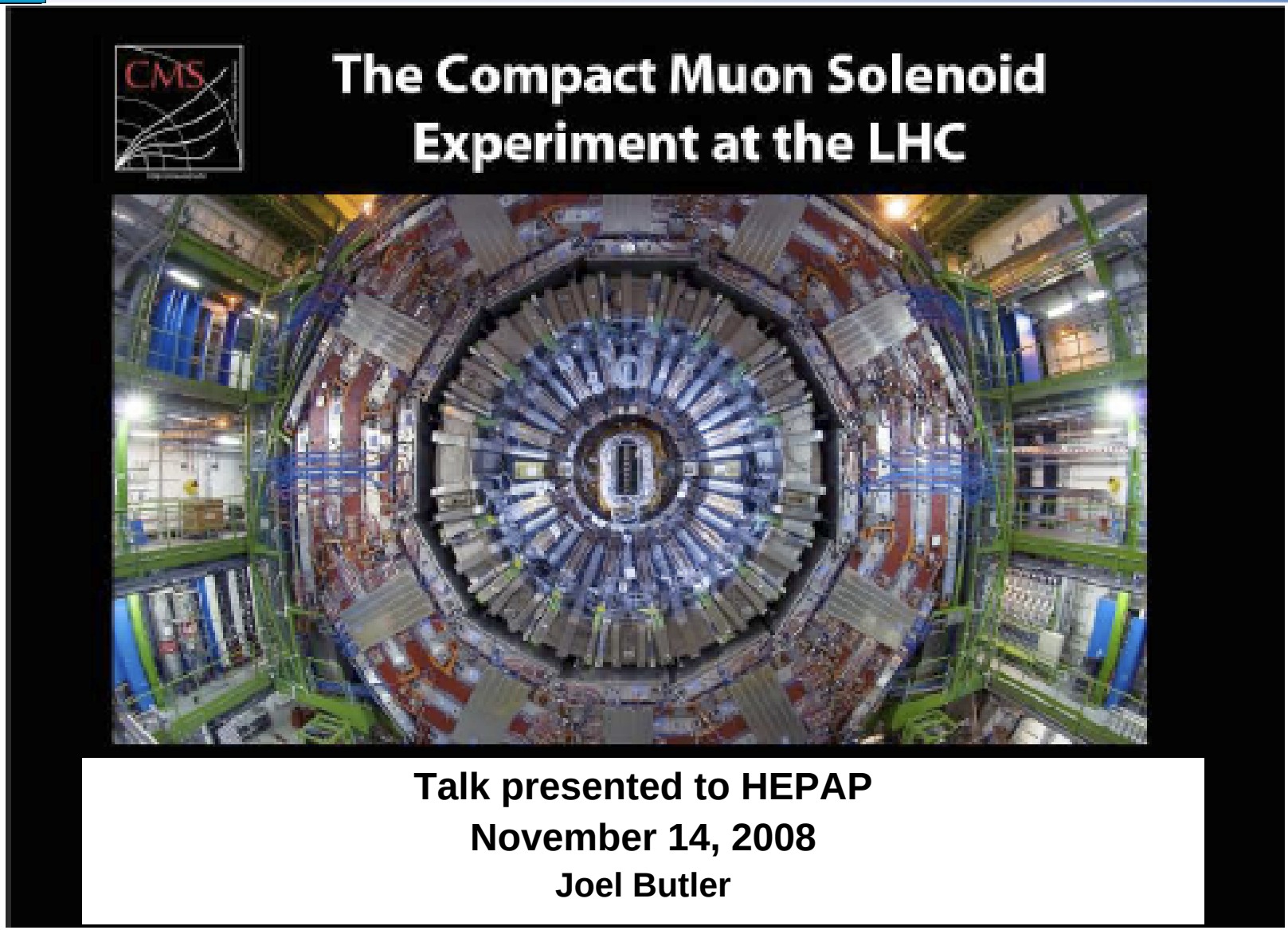
Status of CMS



Talk presented to HEPAP

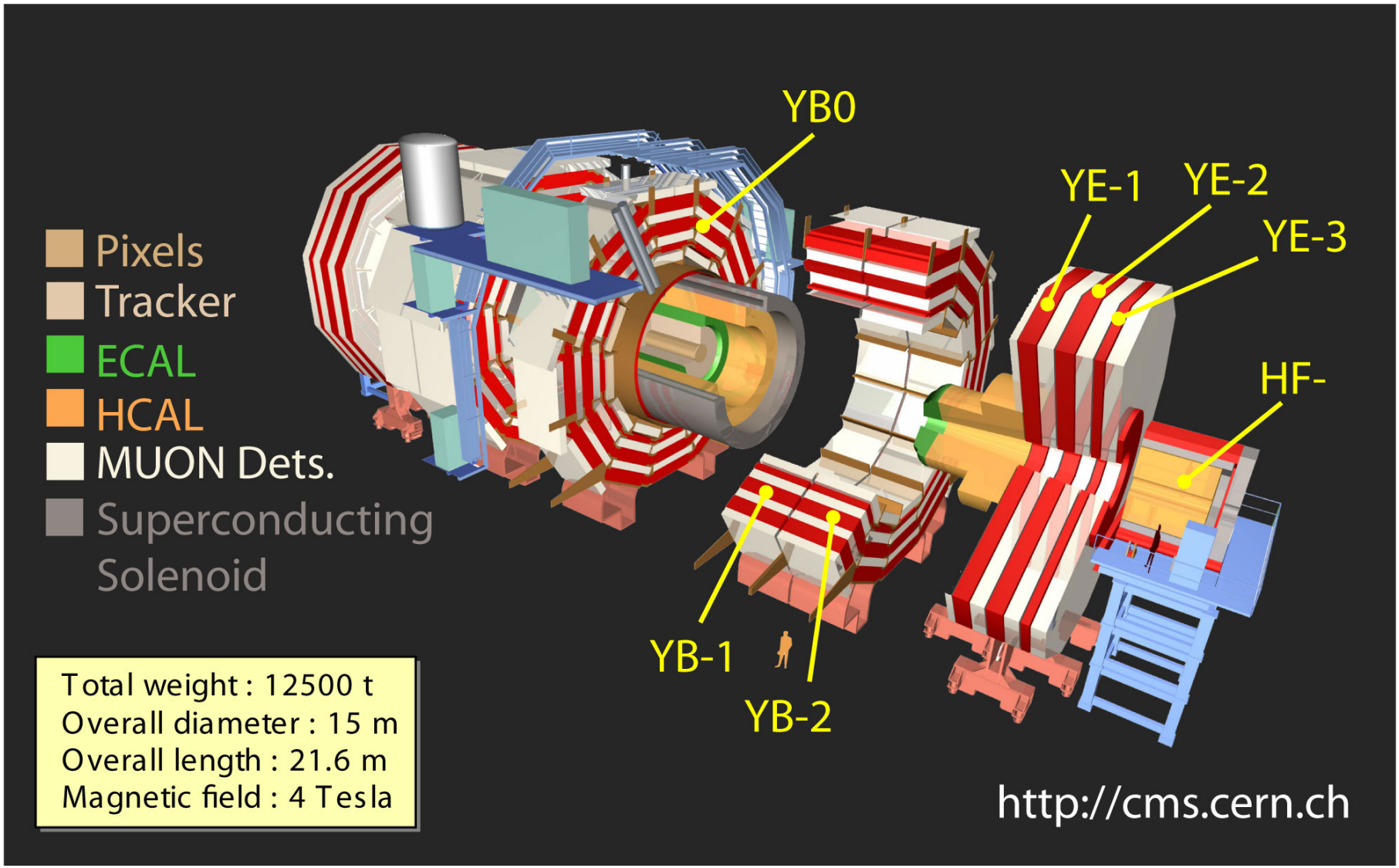
November 14, 2008

Joel Butler

Outline

1. Reminder: What is CMS
2. The final push to install CMS
3. Activities from Sept 10 – Sept 19 (beam)
4. Cosmic Run with Solenoid on (finished this week)
5. Plans for the remainder of the shutdown
6. Status of Production Computing Facilities
7. Status of Preparation for Physics
8. Upgrade plans
9. Some information about US CMS
10. Summary

1. The CMS Detector

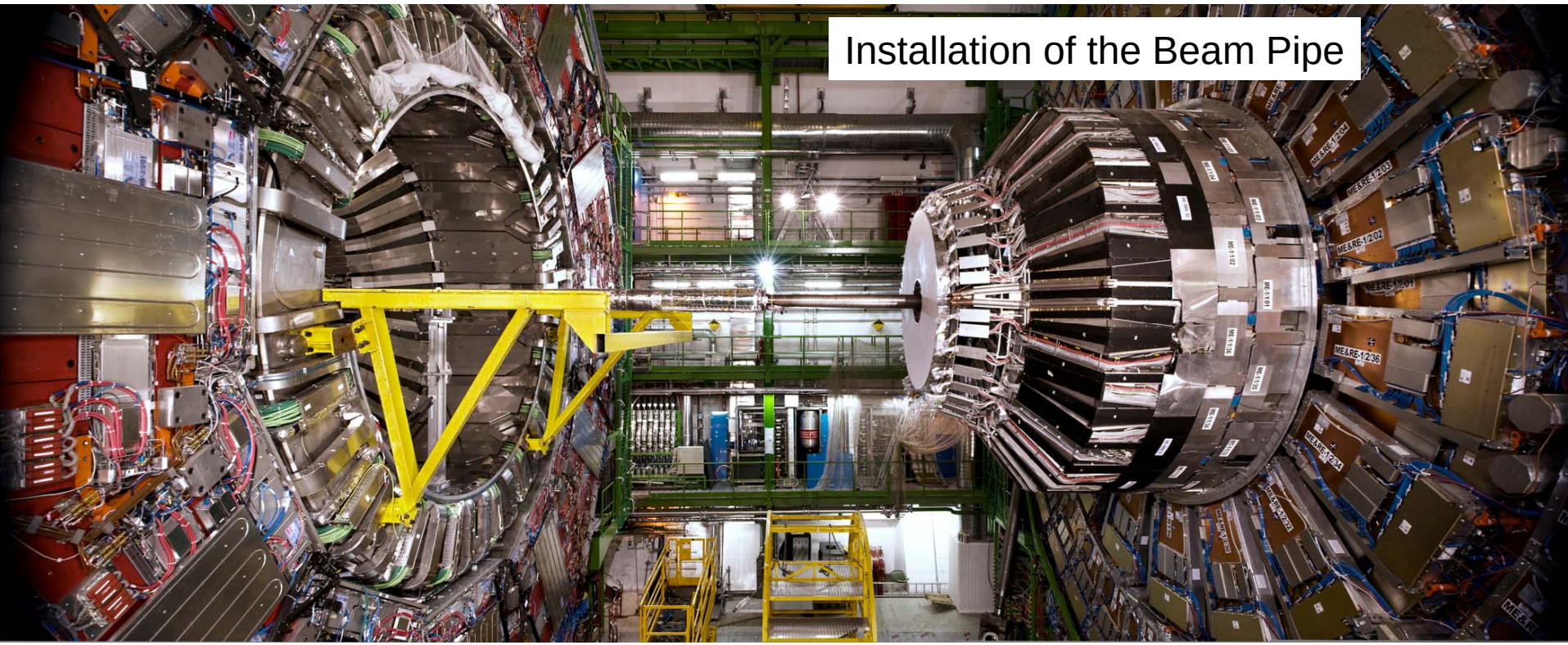


CMS Design Features

- **Very large solenoid – 6m diameter x 13 m long**
  - **Tracking and calorimetry fit inside the solenoid**
    - **Particle energies are measured before they pass through the solenoid coil and cryostat, which would degrade their resolution**
- **Very strong field – 4T**
  - **Coils up soft charged particles**
  - **Provides excellent momentum resolution**
- **Tracking chambers in the return iron track and identify muons**
  - **This makes the system very compact**
  - **Weight of CMS is dominated by all the steel and is 12,500 Tonnes**
- **Tracking is based on all-silicon components**
  - **A silicon pixel detector (with 68M pixels) out to ~ 20 cm**
  - **A silicon microstrip detector (11M channels, 200M^2) from there out to 1.2 m**
  - **Gives CMS excellent charged particle tracking and primary and secondary reconstruction**
  - **High segmentation results in very low occupancy**
  - **Silicon detectors are very radiation hard**

CMS was built on the surface. The pieces, some greater than 2000 Tonnes, were lowered into the Collision Hall. The Hall was made available late so installation did not begin until Nov 2006 and utilities did not appear until the spring of 2007

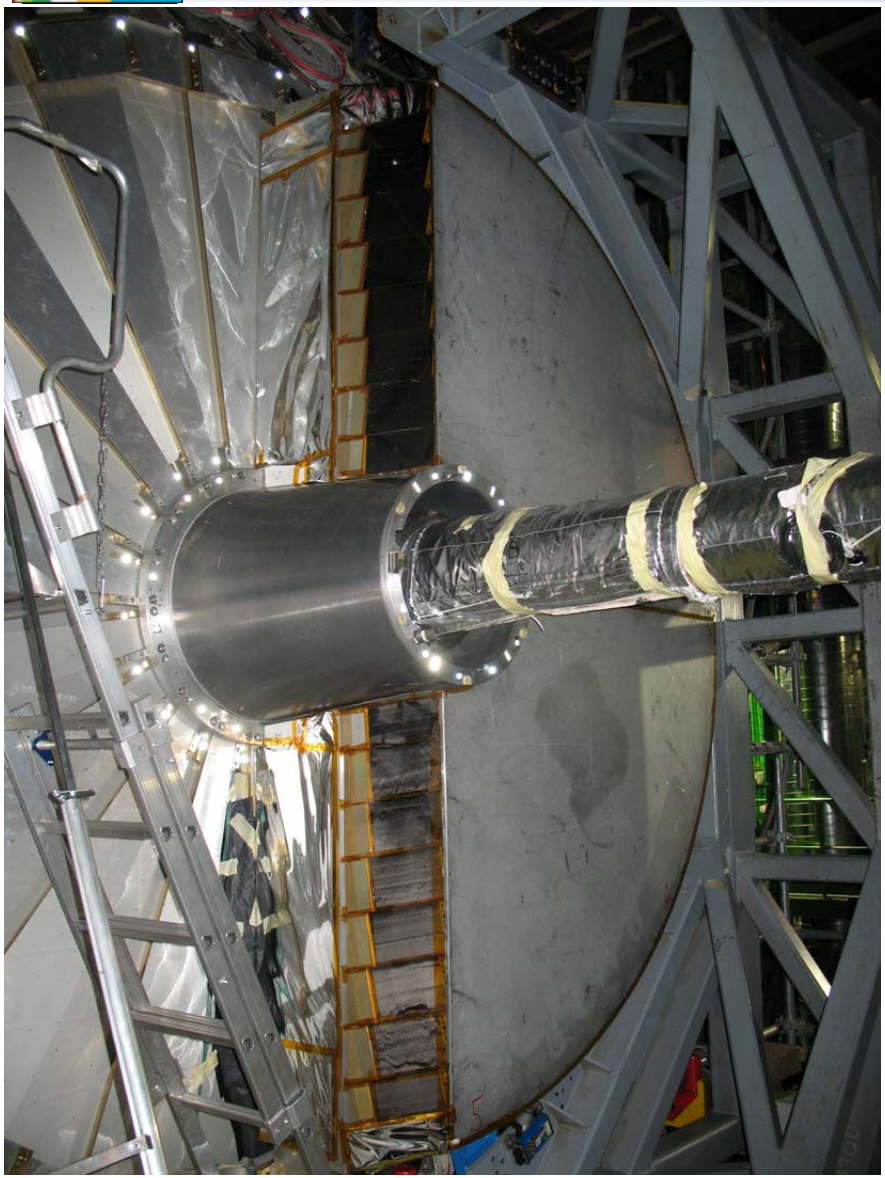
2. The Final Installation Push

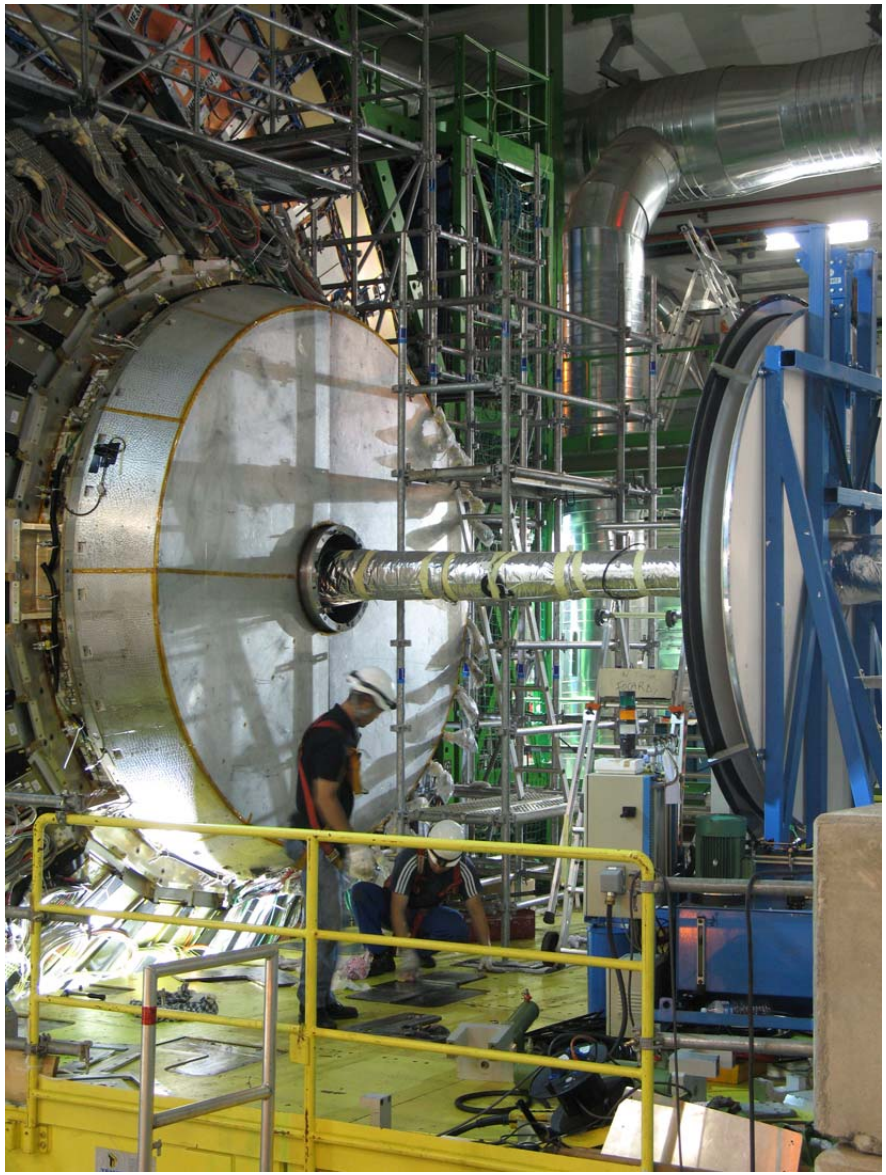


Guido Tonelli, " For Opera lovers it has been our "Aida triumphal march"

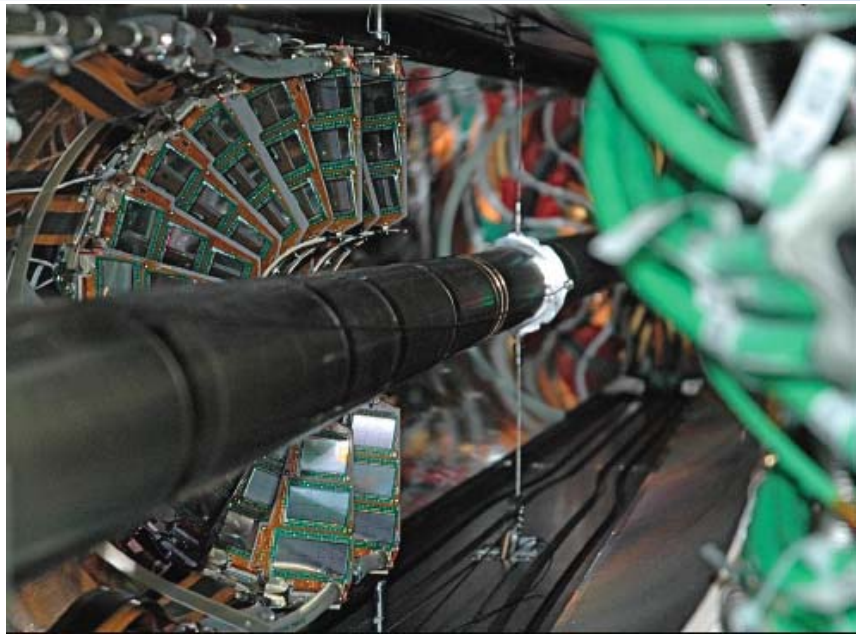
Dee 1	**July 17**
Dee 2	**July 22**
BPIX	**July 23-27**
Dee 3	**July 29**
FPIX	**July 29-31 -- This is the last US piece of the Construction!**
Dee 4	**August 1**

Installation of ECAL Endcap Dees

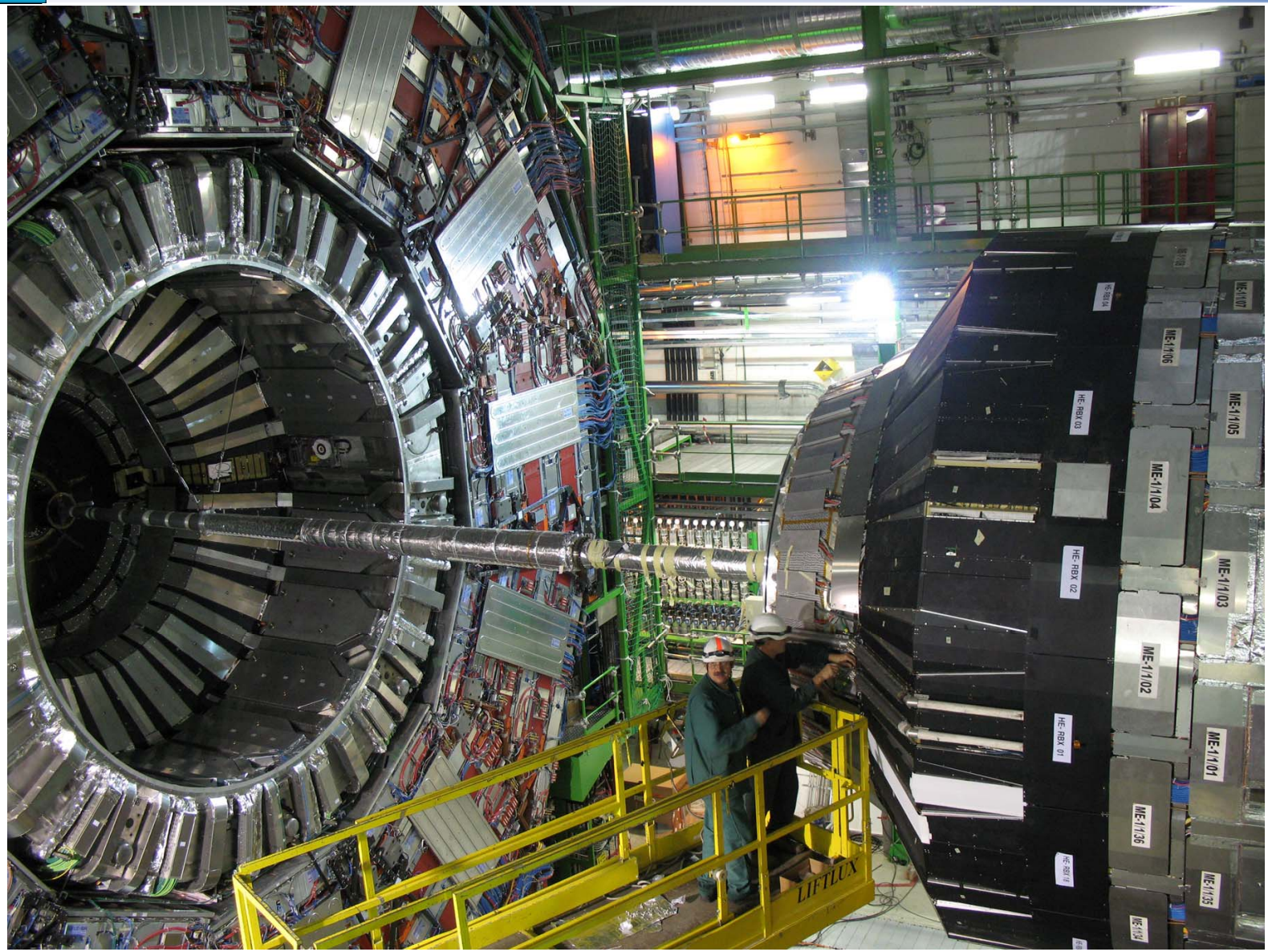




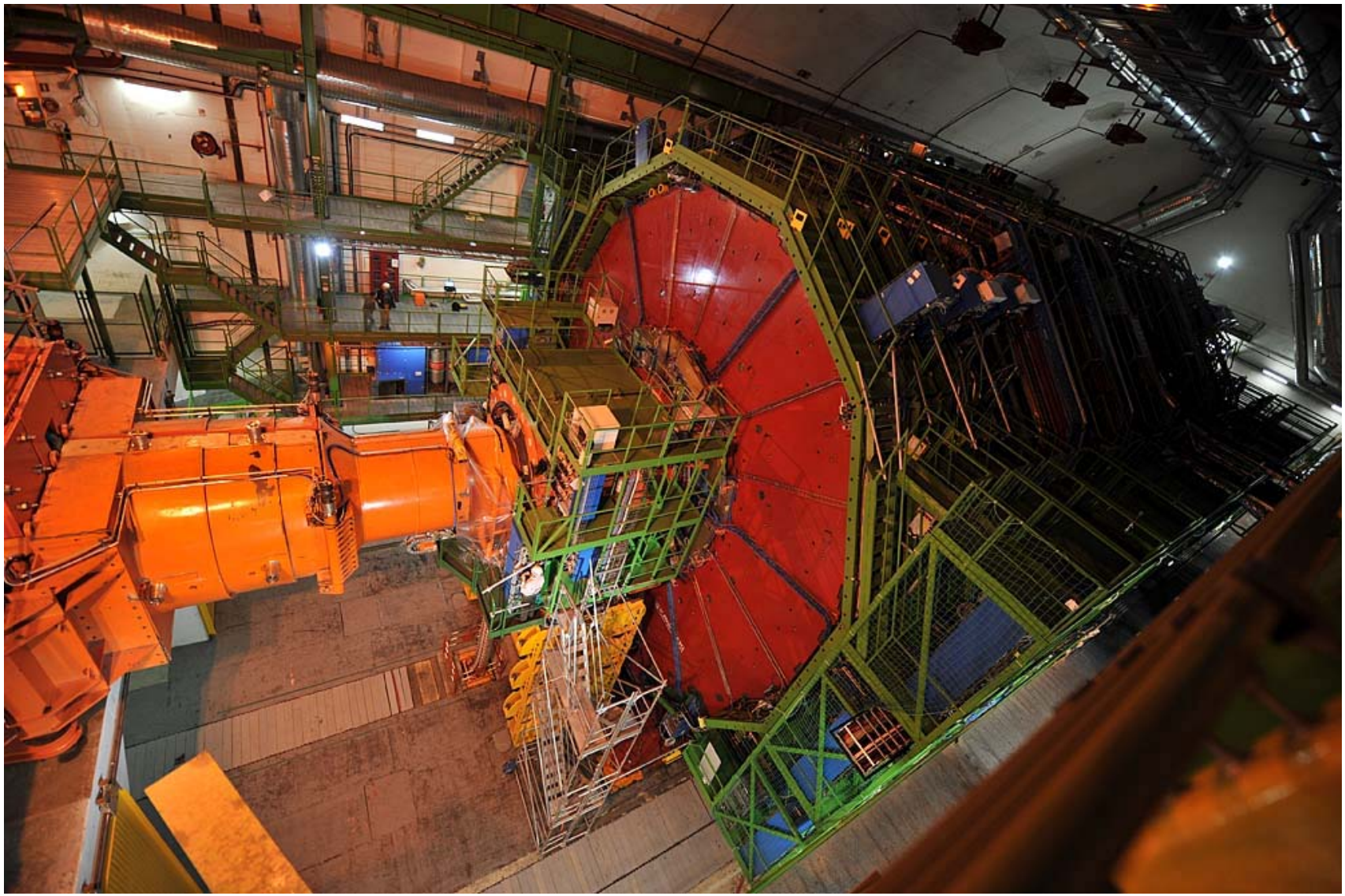
Barrel & Forward Pixels



Minus End before Closure



Final Closure

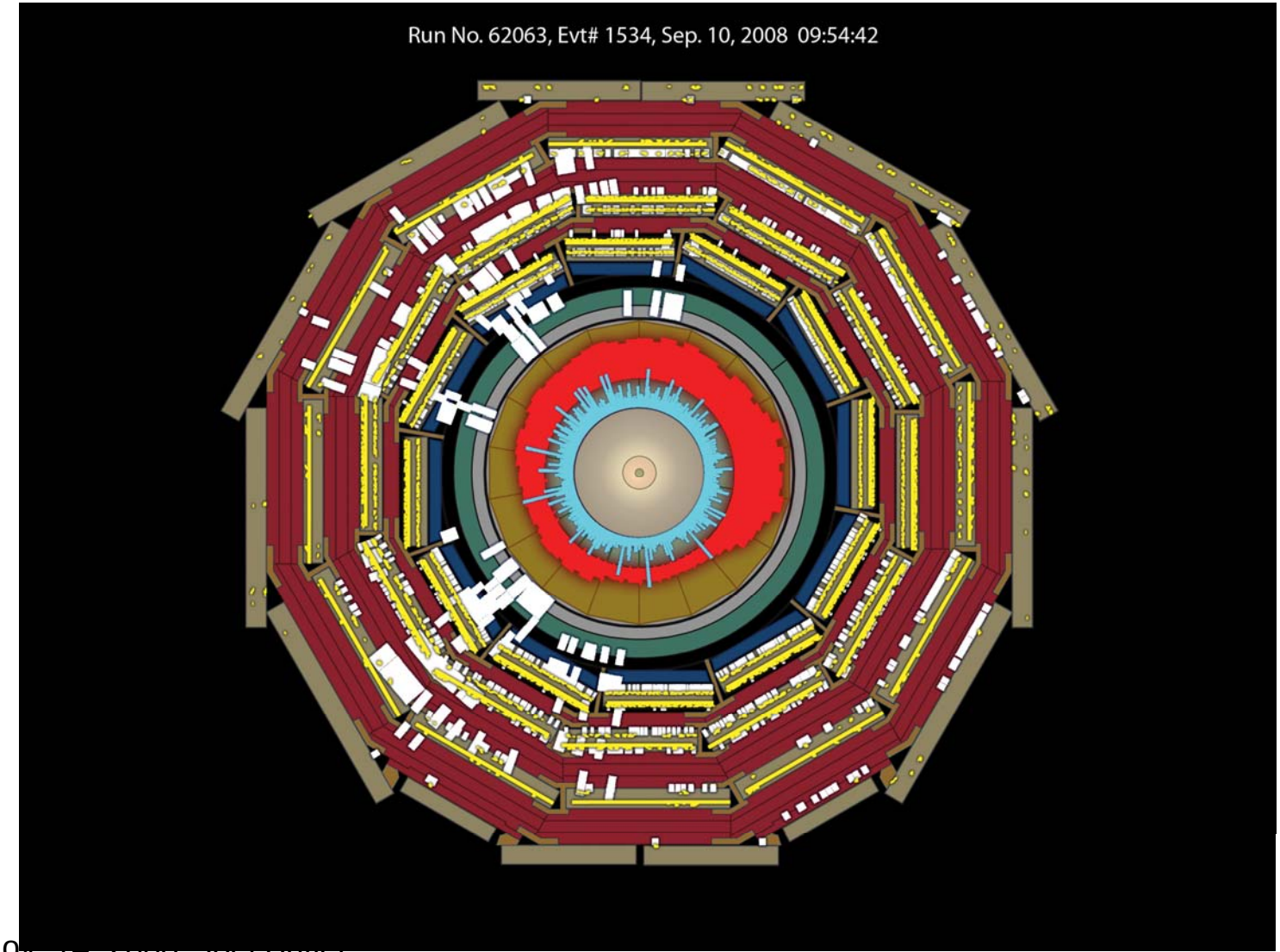


3. Installation Status on September 10, 2008 and First Beam

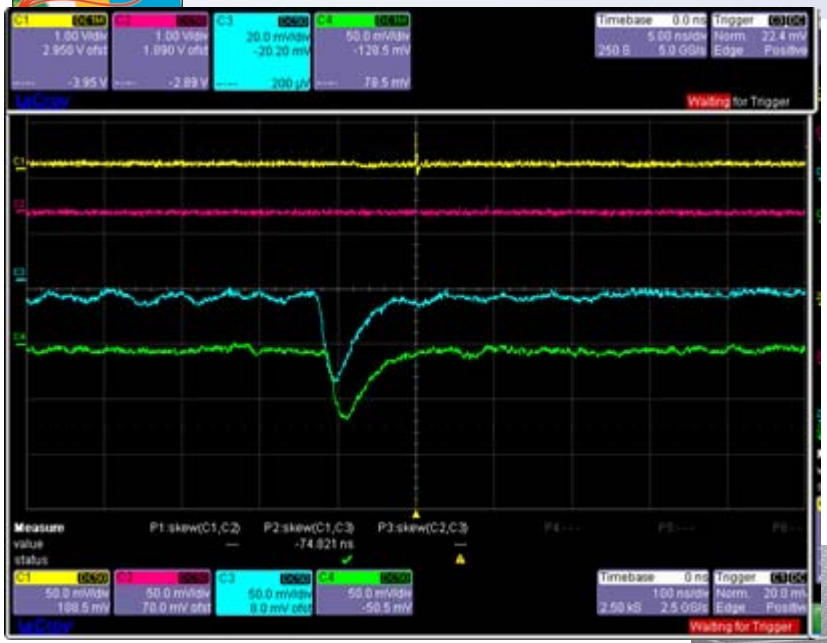
- **After almost 20 years, from conception, through design, construction and commissioning, CMS became a working experiment in September 2008**
- **At startup, the detector included**
  - **Barrel and endcap pixels**
  - **Si strip Tracker**
  - **Barrel and BOTH endcap ECALs!!!!**
  - **HCAL (barrel, endcap and forward)**
  - **Muons (DTs, CSCs and RPCs)**
  - **Level-1 Trigger, ~ 40 kHz DAQ**
- **Not available at startup**
  - **Endcap Electromagnetic Preshowers**
  - **Remaining capacity for Trigger/DAQ (deferred)**
- **For initial running with beam, the solenoid and the inner tracker were left off (machine issues)**

First Events in CMS: Collimators Closed

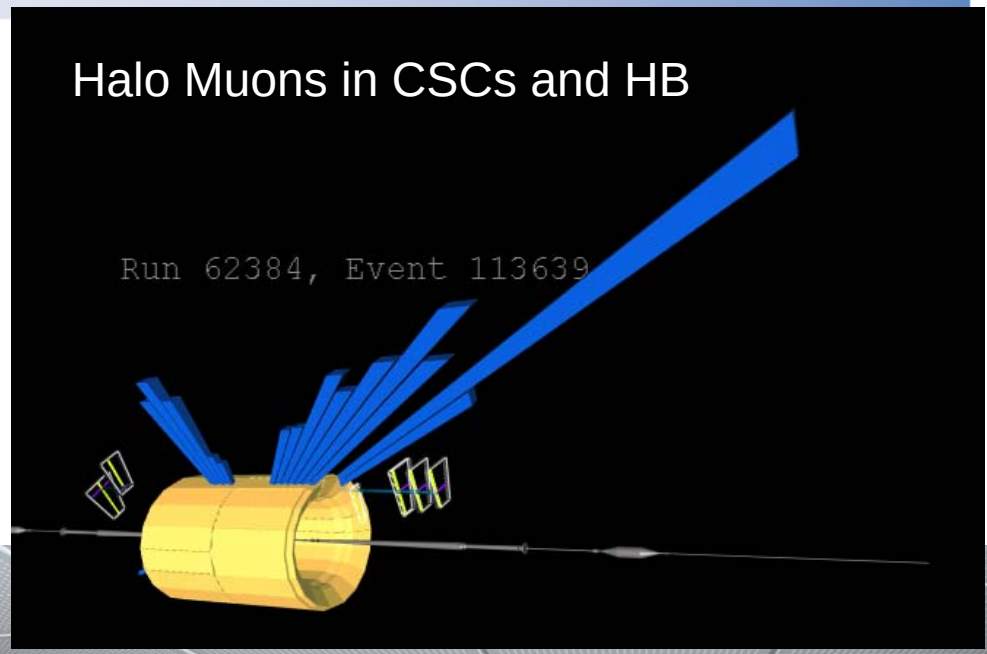
~ 2.10^9 protons on collimator ~150 m upstream of CMS



First Events: Beam going through CMS

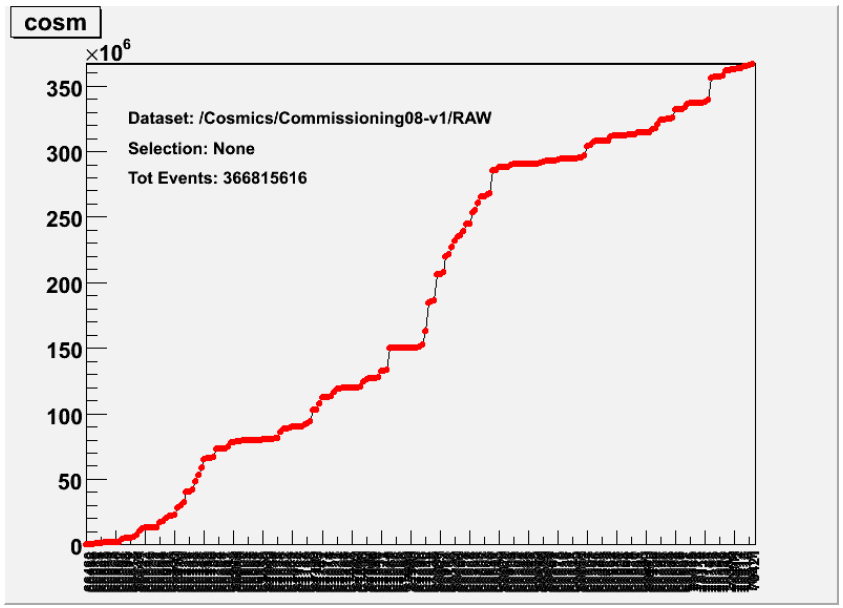


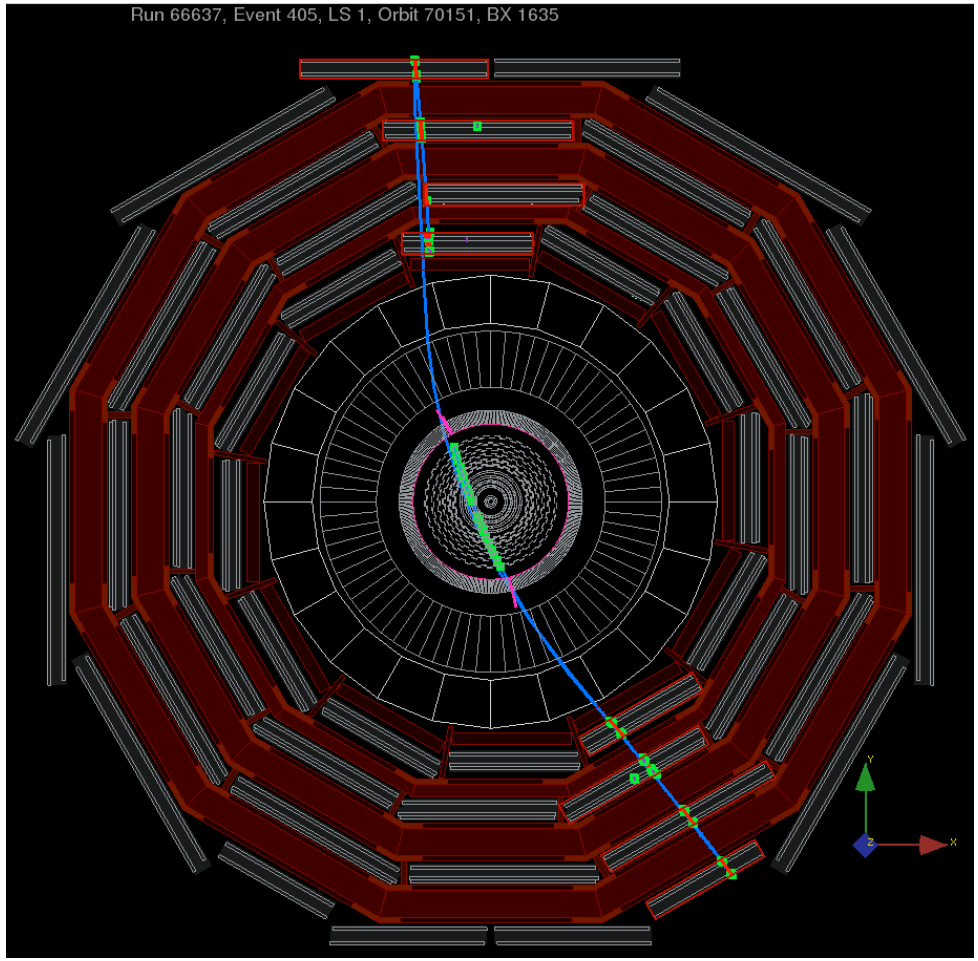
Beam Pickup (ch1) CMS Beam Condition Monitors (ch 3, 4)



4. Cosmic Run at Four (3.8) T - CRAFT

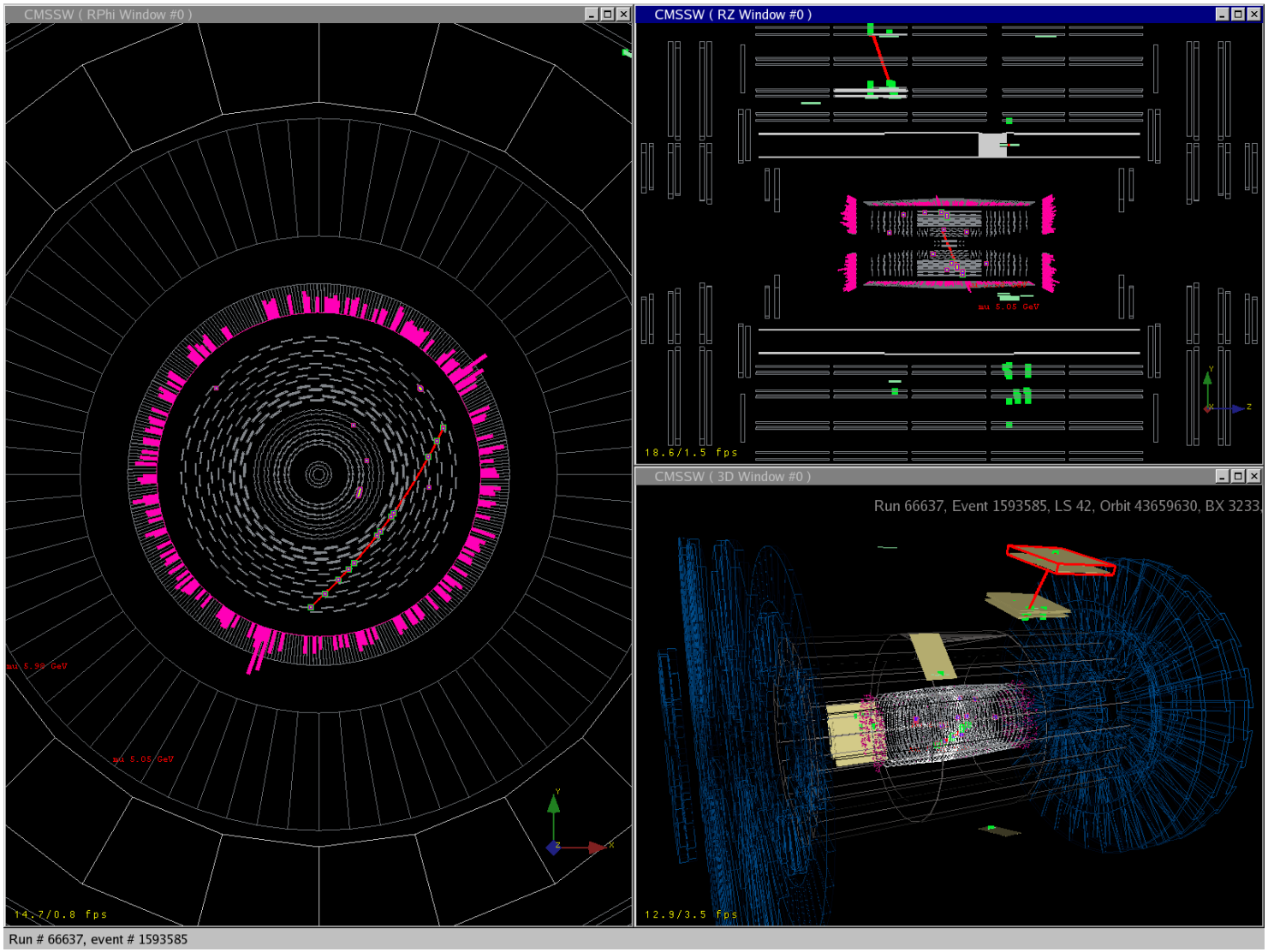
- CMS ran for 4 continuous weeks 24/7 (finished this week)
- We collected nearly 300M cosmic events with B=3.8T
  - Showing that CMS was ready for the LHC
  - There are a wealth of lessons from this exercise…





Tracking rechits (green), ECAL rechits (pink), Reconstructed Muons (blue), DT 4D segments (red), DT chambers used in global Muon reconstruction (DT + Tracker) outlined with red, RPC rechits (green bars).

Another Craft Picture



5. The Shutdown: Highest CMS Priorities

- Modifications to opening/closing system of wheels, disks and shielding
  - safer opening/closing of CMS: reduce risk to detector and beam pipe.
  - reduced exposure of personnel to activated parts.
- Modification to access platforms
  - reduce risks to detector and beam pipe
  - speed up changes
- Infrastructure (e.g. cooling, electrical power) diagnosis, repair and improvement to fix/reduce risk to detector, UXC access requirements and inefficiency (e.g. leaks, blockages, fan failures).
- Repairs to achieve required 2009 performance (e.g. humidity seal, TK cooling plants)
- Repair or re-work, necessary for final performance, in areas which will acquire significant activation. (ALARA)
- Preshower installation
  - needs complex logistic set-up and thus long shutdown
  - work area will acquire significant activation (ALARA)
- Set-up of full radiological screening and material tagging/classification/tracing for 2009 run.

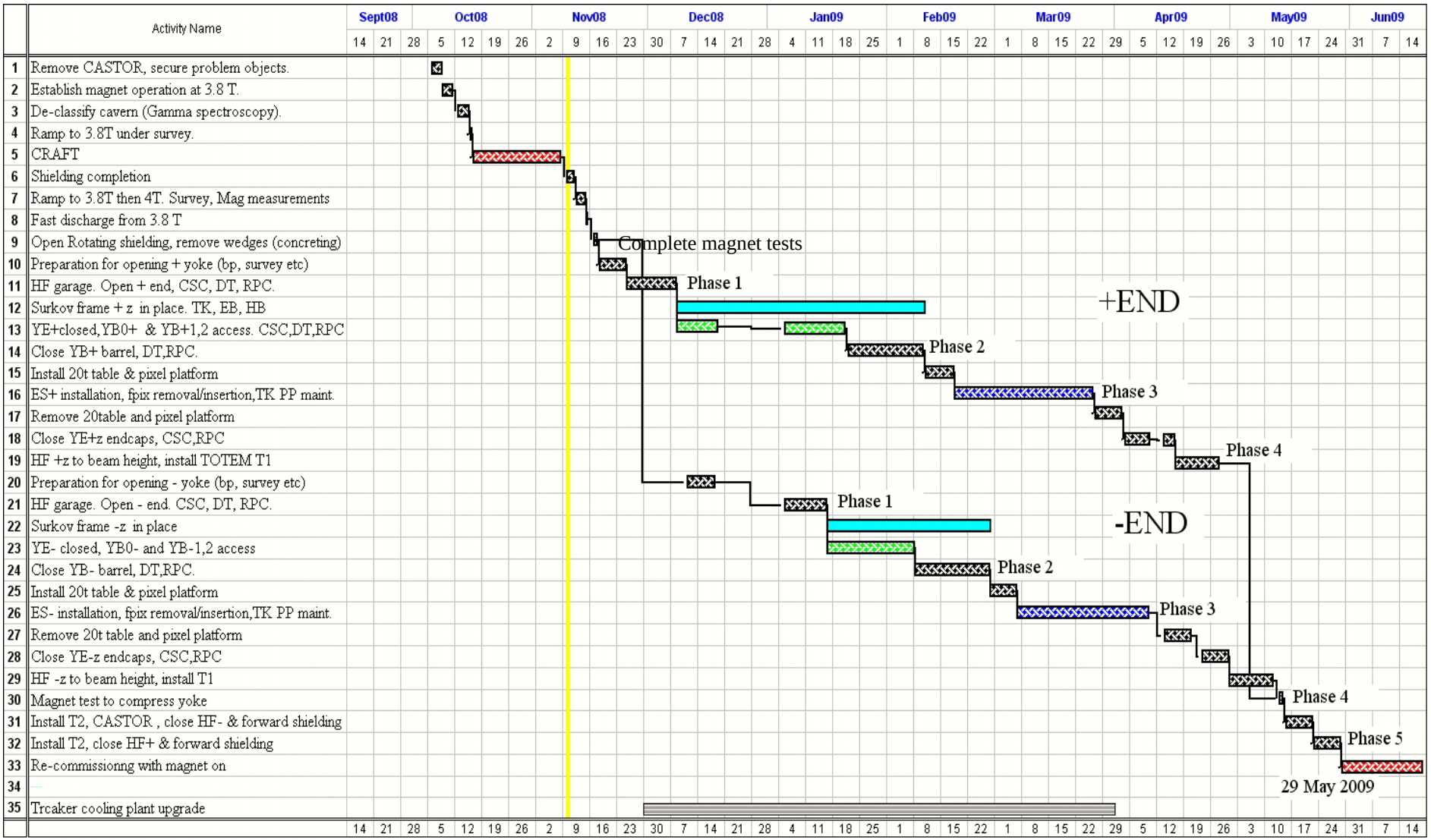
The need to work around fragile beam pipe creates new problems

Overall strategy

- Plan
  - Start opening 17 Nov.
  - Preshower installation Feb.-Mar.
  - closed and operational end of May.
  - parallel shutdown and re-commissioning as soon as possible in 09
    - Make limited cooling and power re-available as soon as possible to test new or repaired items

The biggest uncertainty in all this is the LHC schedule

Shutdown 2008-9: Schedule overview

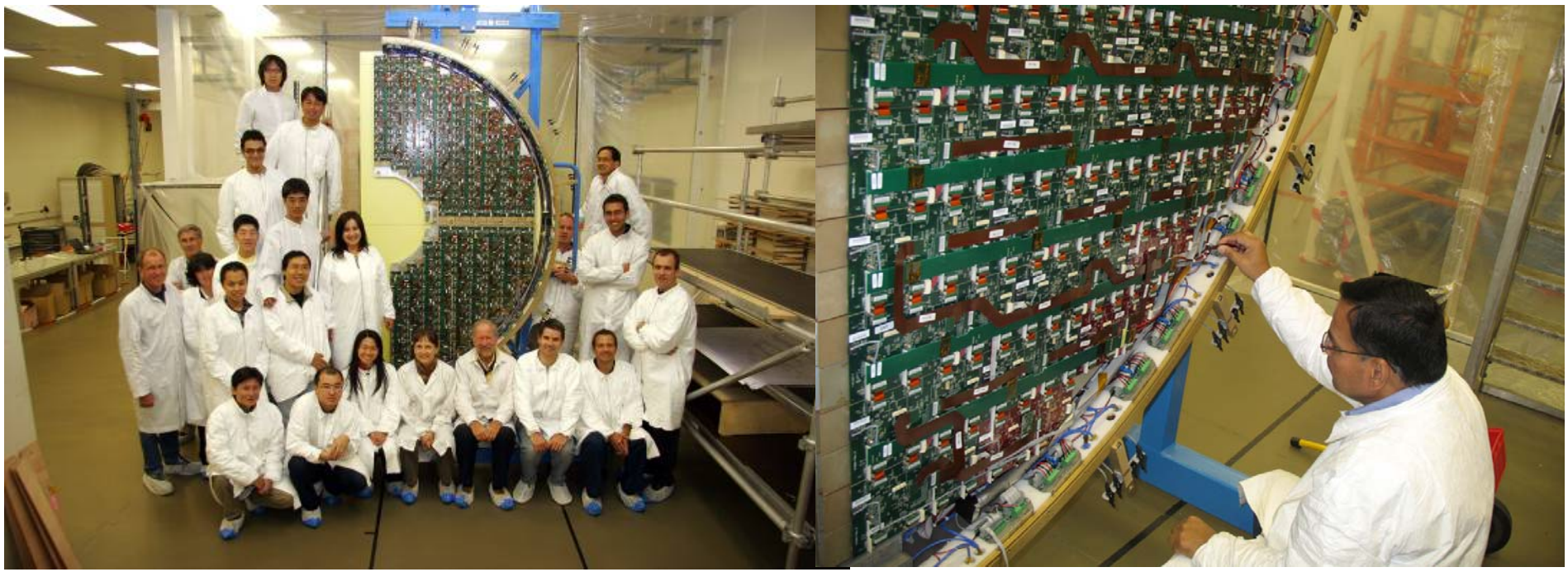


Status of the Preshower

All 520 ladders assembled and stress-tested

Ladders mounted, cabled and tested on 4 of 8 absorbers. All channels (~50k silicon strips) operational.
First two stuffed absorbers tested inside an environment-controlled tent to -15 ºC (in the old “TIF”)

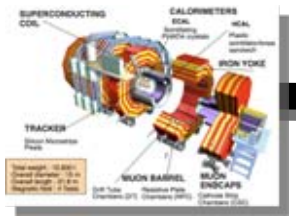
Target: get ES ‘ready for installation’ by the end of 2008



ES prior to moving the absorber into the tent

6. CMS Computing Model

- **Reminder of CMS Computing Model:**
  - **user submit jobs, workload management system submits to where data is**
  - **data movements are triggered by operators, physics organizers, users**



Tier-0

600-800MB/s to 7 Tier-1 centers

100 MB/s between Tier1s

Tier-1 **Tier-1** **Tier-1** **Tier-1** **Tier-1**

50-500 MB/s burst Tier1->Tier2s

Tier-2 **Tier-2** **Tier-2** **Tier-2** **Tier-2** **Tier-2**

Computing Infrastructure: Tier-1

- **Fermilab Tier-1 has reached goals of a four-year procurement ramp**
  - **Meeting the obligations of the U.S. to CMS Computing and providing analysis resources for the LHC Physics Center at Fermilab**
  - **met WLCG milestone for completion of the 2008 pledge**
    - **Part of the worker node early purchase for FY09 is complete**
  - **division between Tier-1 and LPC CPU resources**
    - **well defined through batch slots, but operationally flexible**
    - **Recently allocated a larger fraction to Tier-1 to support scale testing and cosmic re-reconstruction**

FNAL Tier-1 and LPC Summer 2008	Tier-1+LPC	7500 Batch Slots	Processing Nodes
	Tier-1+LPC	11MSI2k	Processing Capacity
	Nominal Split	5100 T1, 2400 LPC	
	Disk T1	2.0PB	dCache (1600MB/s IO)
	Disk LPC	0.5PB	Dedicated to Local Analysis
	Network	20Gb/s	CERN to FNAL
	People	30FTE	Includes Developers and Ops

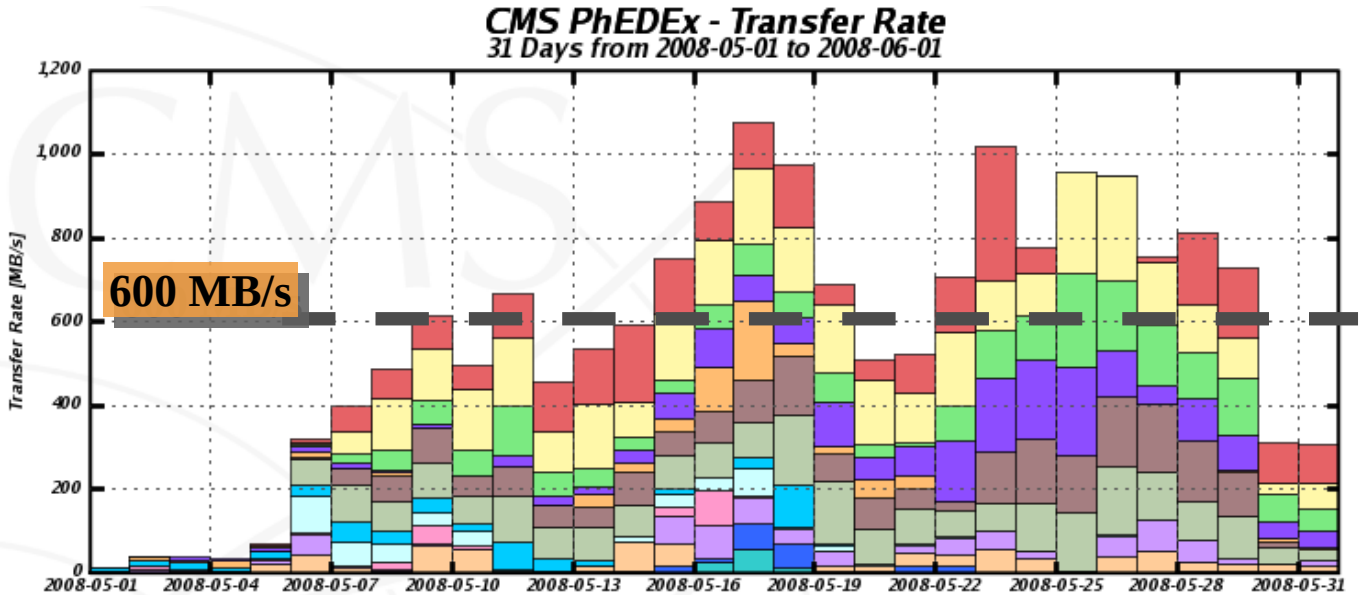
Computing Infrastructure: Tier-2s

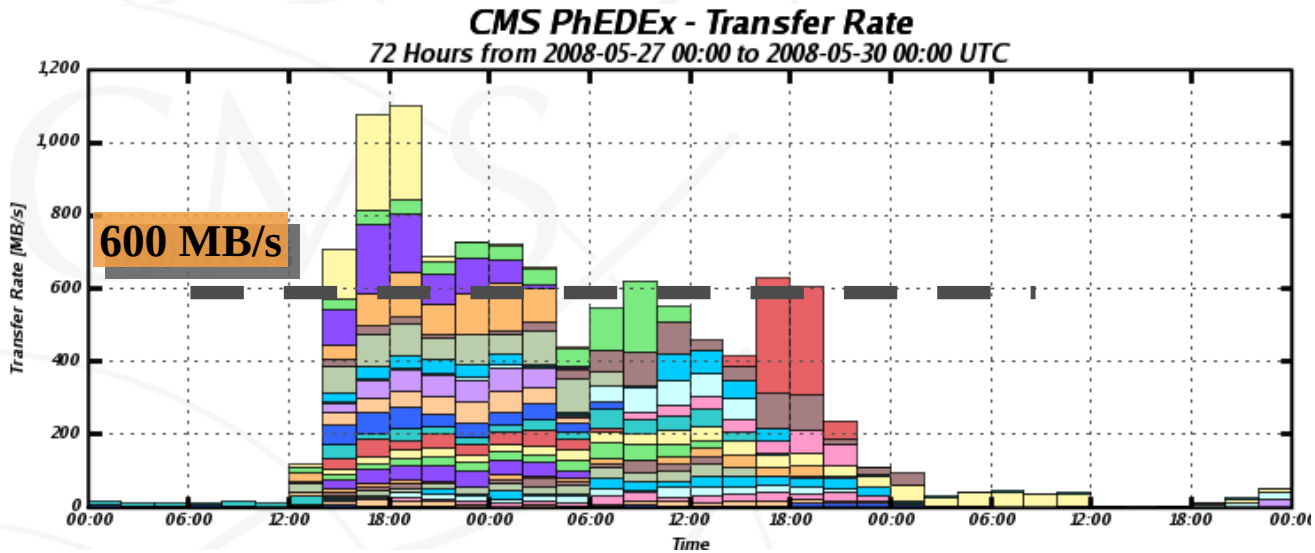
- **U.S. Tier-2s extensively used for simulation and analysis**
  - **all SEVEN the US Tier-2 sites reached nominal capacity this summer**
  - **FY09 Tier-2 ramp to double storage and increase CPU by 50%**
- **Tier-2 program great success thanks to very engaged sites**
- **Organized sites in CMS to support physics analysis for users**
  - **associated sites with specific physics/detector performance groups**
  - **allocated disk space for groups, and disk space for individual users**

US-CMS Tier-2 Summer 2008	CPU T2	1MSI2k	Tier-2 Processing Nodes
	Disk T2	200TB	dCache (200MB/s IO)
	Network	2.5-10Gb/s	WAN Networking
	People	2FTE	Supported Tier-2 Operations

Moving the Data Around

- **Transfers from CERN to Tier-1s work as required**
  - **Tier-1 succeed to archive to tape, serve data locally and distribute to remote centers.**
  - **Infrastructure scales well**



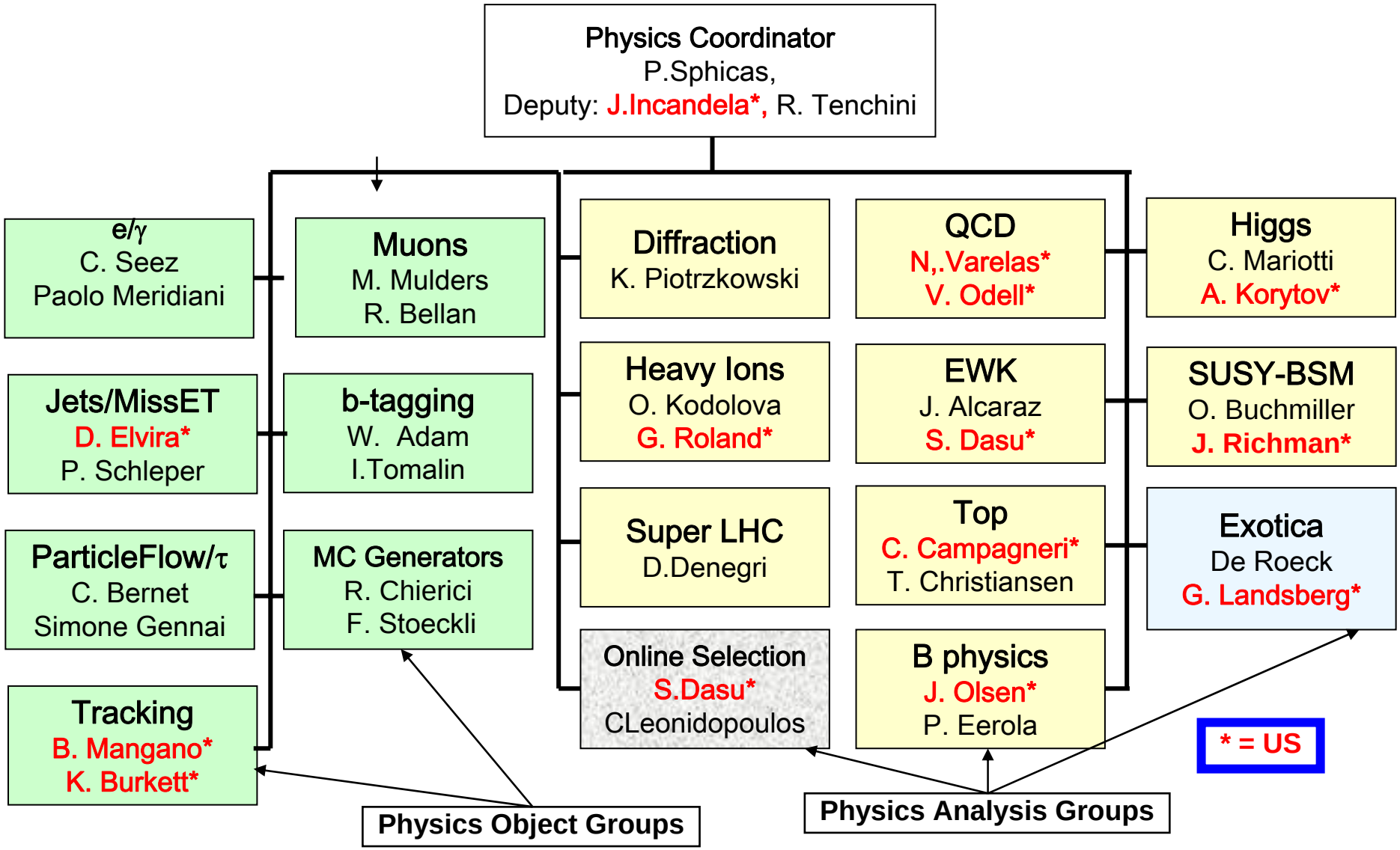


- **Goals reached**
  - **Tier-1 (FNAL) —> Tier-2 50-500MB/s in bursts**

7. Preparations for Physics

- **Strong emphasis on integrationof the efforts of**
  - **groups working on commissioning and understanding the detector (Data Performance Groups or "DPGs")**
  - **groups developing Physics Objects (photons, electrons, muons, taus, jets, missing Et, etc) for analysis ("POGs")**
  - **groups extracting physics (Physics Analysis Groups or "PAGs")**
- **Strong emphasis on what can be done with "early" physics samples of 10 pb^{-1}, 100 pb^{-1}, and 1000 pb^{-1}.**

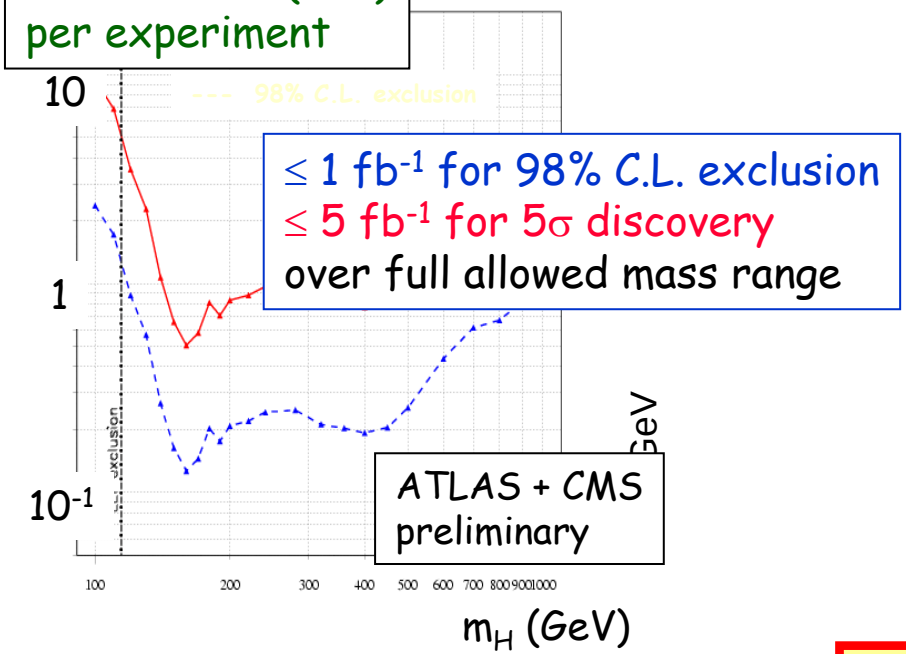
CMS Physics Organization



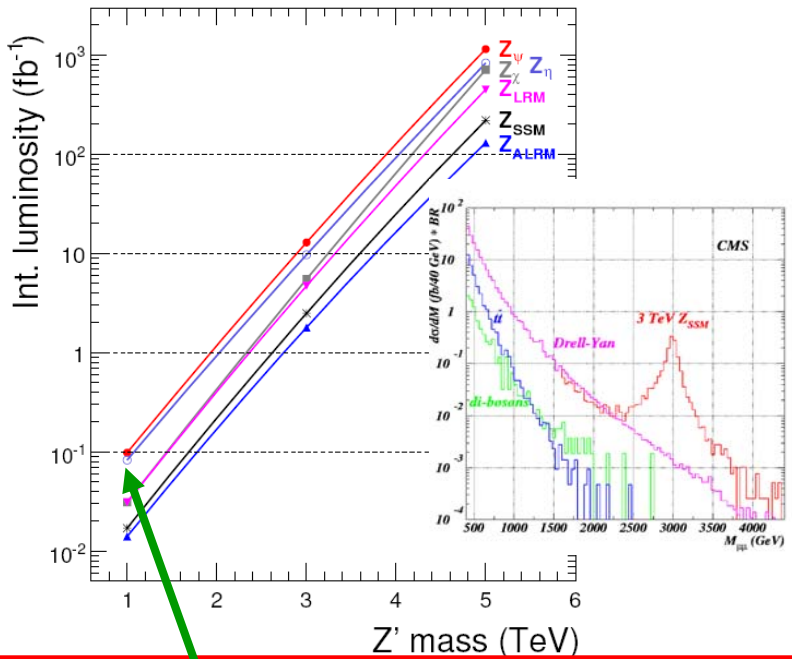
The Excitement of a New Energy Frontier

Channels (examples …)	Events to tape for 100 pb^{-1} (per expt: ATLAS, CMS)	Total statistics from previous Colliders
$W \rightarrow \mu\, \nu$	~ 10^6	~ 10^4 LEP, ~ 10^6 Tevatron
$Z \rightarrow \mu\, \mu$	~10^5	~ 10^6 LEP, ~ 10^5 Tevatron
$tt \rightarrow W\, b\, W\, b \rightarrow \mu\, \nu$+X	~ 10^4	~ 10^4 Tevatron
QCD jets p_T > 1 TeV	> 10^3	---
$\tilde{g}\tilde{g}$ m = 1 TeV	~ 50	---

Needed $\int$Ldt (fb^{-1}) per experiment



≤ 1 fb^{-1} for 98% C.L. exclusion
≤ 5 fb^{-1} for 5σ discovery
over full allowed mass range



TeV Low lumi 0.1 fb^{-1} : discovery of 1-1.6 TeV possible
High lumi 100 fb^{-1}: extend range to 3.5-4.5

The early physics can be exciting!

8. Luminosity Upgrade: Issues for CMS

- **PHASE 1 to start in 2013 with L= 2-4 × 10^{34} cm^{-2} s^{-1}**
- **PHASE 2 to be decided in 2011 with L=8-10 × 10^{34} cm^{-2} s^{-1}**
- **US-CMS upgrade plan based on the detector needs to run for sustained periods at luminosities well above $10^{34}cm^{-2}s^{-1}$**
- **Issues that must be addressed**
  - **Radiation damage**
  - **High occupancy affecting reconstruction or triggering**
  - **High occupancy that leads to buffer overflows and to problems with link bandwidth**
  - **Pileup creating dead time or affecting trigger**
  - **CMS is accessible, has been designed to be opened, and therefore "easy" to upgrade**
- **Upgrade R&D is now ramping up to deal with collision rates that are well beyond the requirements of the original detectors. Detailed upgrade plans are being developed**

CMS Phase 1 Upgrade

- **An initial plan for CMS is being developed and the corresponding US component of it has been presented to DOE and NSF**
- **Upgrade includes**
  - **Pixel replacement (radiation damage, buffer overflows)**
  - **Hadron Calorimeter – increase longitudinal segmentation to deal with radiation damage and add timing**
  - **Muon**
  - **Trigger/DAQ**
  - **Electromagnetic calorimeter**

A CMS workshop will take place from Nov 19-21 at Fermilab to develop the Phase 1 Upgrade

9. US Leadership Positions in CMS

- **CMS**
  - **Robert Cousins (UCLA): Deputy Spokesperson since 1/07**
  - **Dan Green (FNAL): Chair CMS Collaboration Board starting 1/09**
  - **Joe Incandela (UCSB): Deputy Physics Coordinator**
  - **Trigger Coordinator: W. Smith (Wisc)**
  - **Deputy Run Coordinator: D. Acosta (Fla)**
  - **Deputy Computing Coordinator: P. Mcbride (FNAL)**
  - **Physics Convenors**
    - **Higgs: A Korytov (Fla)**
    - **SUSY; J Richman (UCSB)**
    - **Exotica: G. Landsberg (Brown)**
    - **Top: C. Campagnari (UCSB)**
    - **Heavy Ions: G. Roland (MIT)**
    - **QCD: N. Verelas (UIC), V. Odell (FNAL)**
    - **EWK: S. Dasu (Wisc)**
  - **Detector Project Managers**
    - **HCAL: A. Skuja (Maryland)/J. Spalding (FNAL)**
    - **ECAL: R. Rusack (Minn)**
    - **Endcap Muons: R. Loveless (Wisc)**

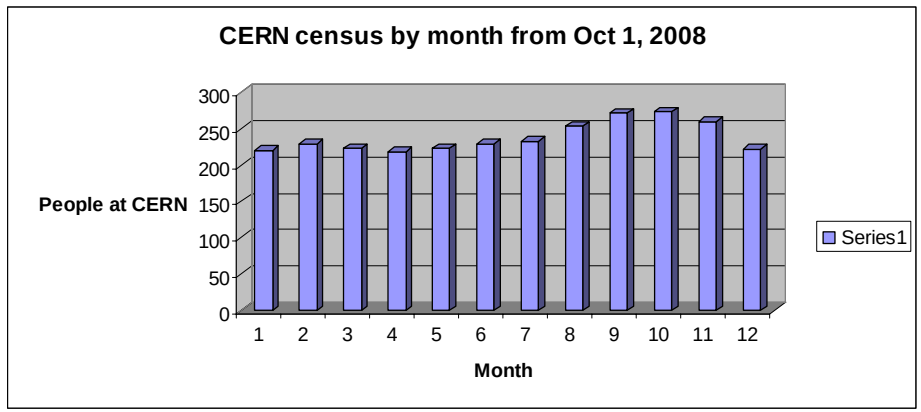
USCMS in the CMS Collaboration

- **CMS**
  - 39 Countries
  - 181 Institutions
  - 1940 Scientific Authors total
  - 1283 paying M&O share
- **USCMS**
  - 639 Scientific Authors
  - 442 with Ph.D (34.5%)
  - 197 Graduate Students
- **US CMS full time people at CERN**
  - 26 Professors
  - 16 Scientists
  - 57 Post Docs
  - 86 Graduate Students
  - 24 Professionals
  - 4 Technicians
  - 4 staff
- **217 total**

There is a very large US full-time community at CERN.

There is a large transient component as well

This creates special problems that are rather new for the US program



Summary

- After 20 years of planning and an incredible “finishing kick” in July, CMS was closed and ready for first beam
- During the limited beam, collimator “splash events” and circulating beam “halo events” were recorded and are being analyzed to extract all possible information on the detector
- After the shutdown, a month of highly successful Cosmic Running with the CMS Solenoid on at 3.8T was completed and analysis is already in full swing
- A thoughtful, focused and flexible plan of improvement is planned for the remainder of the shutdown
- CMS is continuing to prepare for the physics analysis of the early runs
- Upgrade planning and R&D are in full swing
- A large US community, about 1/3 of total is resident at CERN, while the remaining 2/3 is actively engaged from the US
- We eagerly await first collisions!!!!

Backups

Elective activities

•Non-critical repairs which allow untried routine maintenance procedures to be tested, (especially if work area will acquire activation)

• Non-critical new installation, repairs or improvements which can be done off the critical path.

• Non-critical new installation, repairs or improvements not subject to ALARA which require a long shutdown.

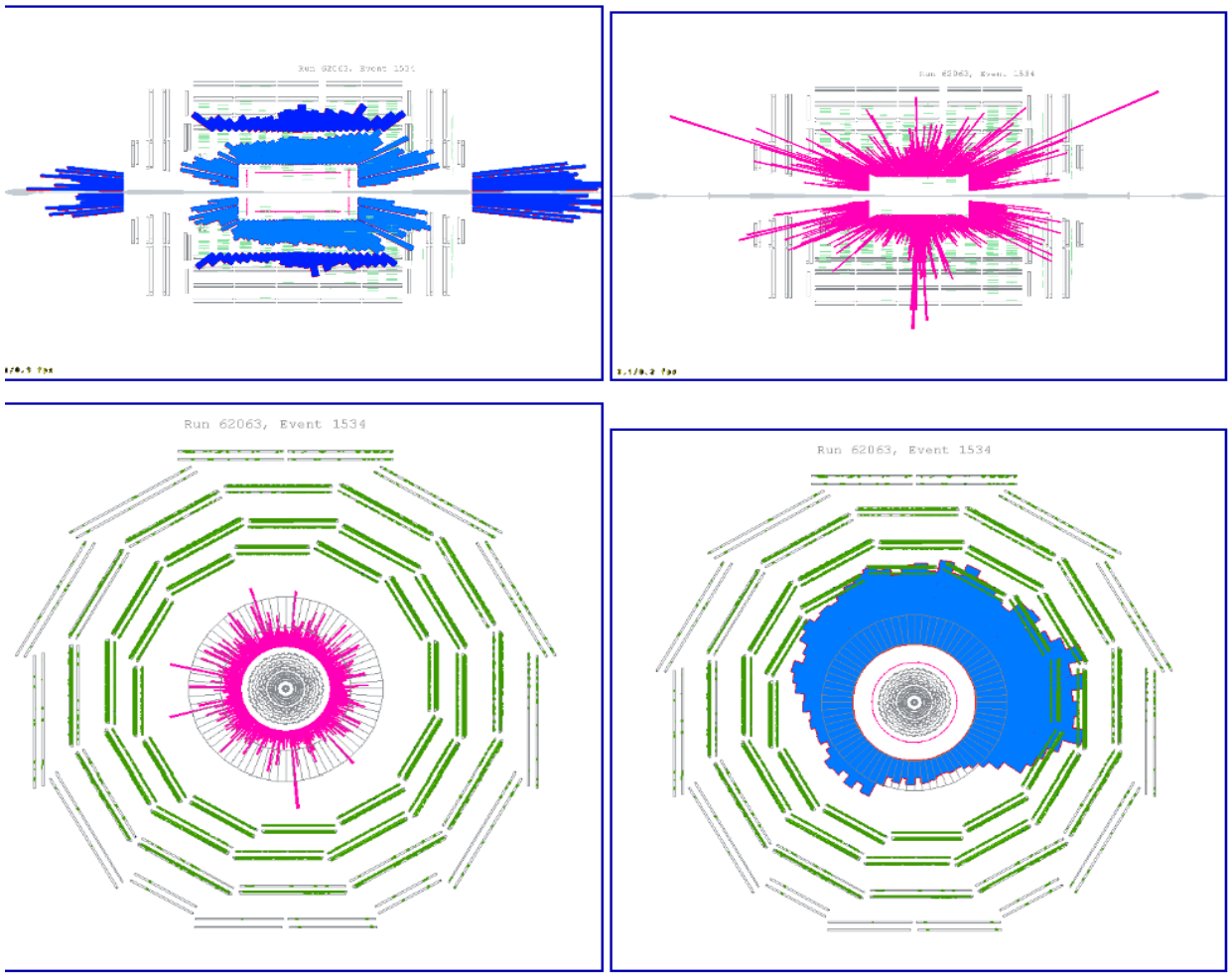
all subject to availability of resources after highest priorities satisfied

•All CMS systems (except BCM!) have made intervention requests.
see TCM 09 Oct : http://indico.cern.ch/conferenceDisplay.py?confId=42919
-priority, required configuration and resources for each are being discussed in TCM/TIG, MTP,EB,MB meetings.
-final decisions on priority and time allocation once we have a sound framework planning (many activities can be don e parasitically to CP)

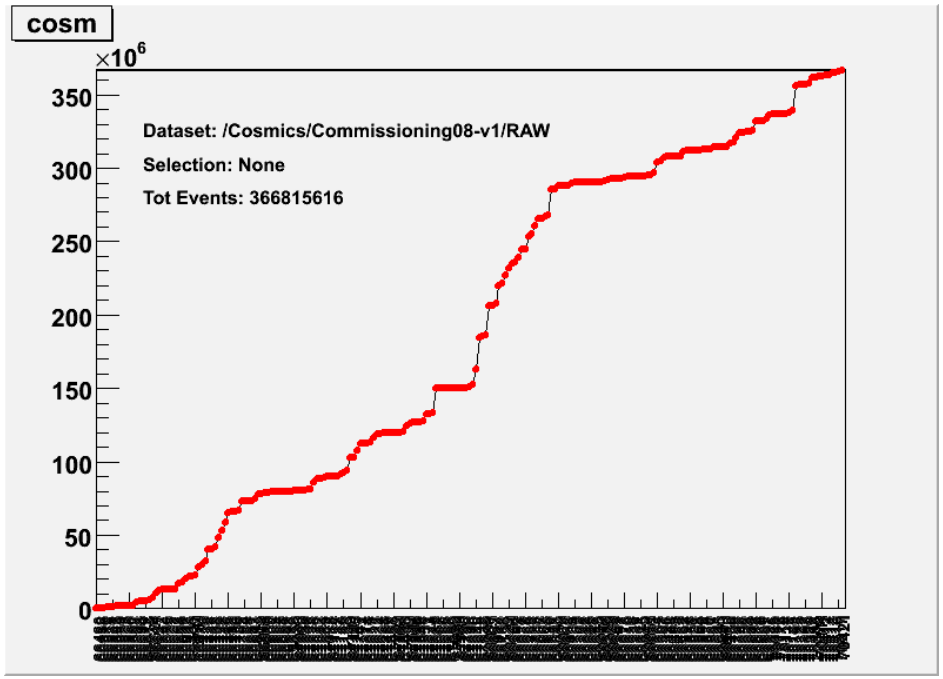
First Events: Collimators Closed

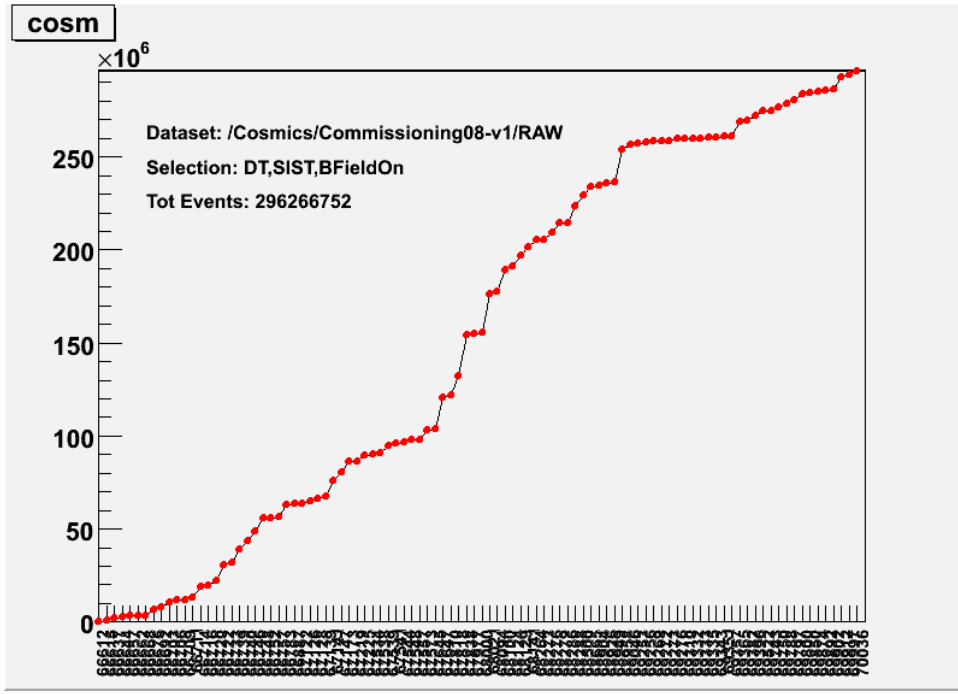
~2.10^9 protons on collimator ~150 m upstream of CMS

ECAL- pink; HB,HE - light blue; HO,HF - dark blue; Muon DT - green; Tracker Off



CRAFT statistics

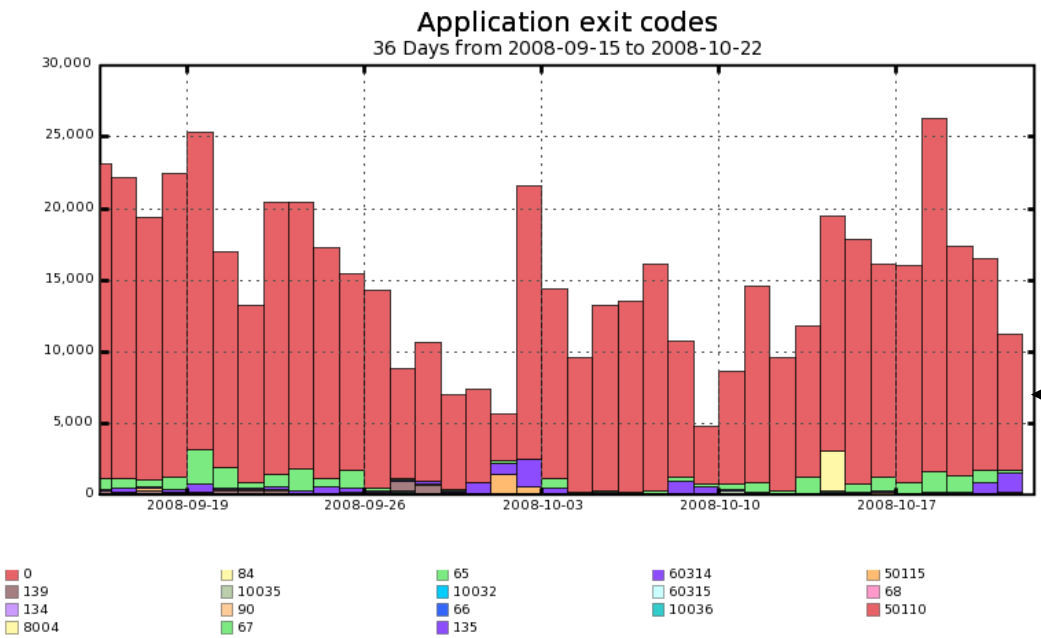




- 360 M-cosmic events all over
- 290 M-cosmic events with DT / B-magnet / StripTK in
  - about 3% have Tracks into it

Tier-2 MC Production Metric

- **CMS has been running grid enabled MC production for 5 years**
  - This month CMS achieved the nominal rate of more than 100M ev./month
  - **35 Tier-2s contributed worldwide**
  - **seven U.S. Tier-2 are top performers**
  - **<1 FTE US effort to run the system**



20k jobs /d
~ 6-10k batch slots

Development of a replacement plan

2013 Pixel Replacement/Upgrade Discussion Meeting

Thursday 09 October 2008
from 09:00 to 18:50
Europe/Zurich
at CERN (17-1-007)

Description: PW for file uploads: pixmeet

EVO PW: pixmeet

Thursday 09 October 2008

09:00 Welcome (10') (Slides)
09:10 CMS Tracker Upgrade Program (10') (Slides)
09:20 BPIX Options for Phase 1 (15') (Slides)
09:35 Fpix scenarios (15') (Slides)
09:50 Beam Pipe Bake-out & Pixel Re-Installation (10') (Slides)
10:00 break

10:10->*11:10* COOLING

10:10 CO2-Cooling : Possibilities & Properties (15') (Slides)
10:25 Cooling Loops for a 3 or 4 Layer CO2 Cooled BPIX (05') (Sli
10:30 CO2 R&D at FNAL (10') (Slides)

11:10->*12:10* MECHANICS&GEOMETRY

11:10 Possible Geometry for a 3 or 4 Layer Pixel System (05') (Slides)
11:15 First thoughts about a CO2 Cooled BPIX Mechanics (05') (Slides)
11:20 BPIX Integration: Lessons learned (05') Stefan Koenig (*Paul Sc*
(Slides)
11:25 Panel material studies (10') (Slides)
11:35 Layout optimization (10') (Slides) Harry Cheung (*Fermi National*
12:10 Lunch break

13:30->*14:30* POWER,CABLES,DCS

13:30 Power cables: Status & Constraints (10') (Slides) Wilhelm Bertl (*PSI*)
13:40 First Results from a On-Chip 2:1 Step Down Converter (10') (Slides) Beat Meier (*ETHZ*)
13:50 Power studies (10') (Slides) Simon Kwan (*Fermilab*)

14:30->*15:30* READOUT

14:30 Phase I Pixel ROC (10') (Slides ; more information) Hans-Christian Kaestli (*PSI*)
14:40 Very low power links through micro twisted pairs (10') (Slides) Beat Meier (*ETHZ*)
14:50 AOH replacements (10') (Slides)

15:30->*16:30* SENSORS&MODULES

15:30 BPIX Sensors: Production, Testing and Qualification (10') Tilman Rohe (*Nuclear and Particle Physics Department*)
(Slides)
15:40 Low Mass modified BPIX modules: Design & Fabrication (05') (Slides) Stefan Koenig (*Paul Scherrer Institut, 5232 Villigen PSI, Switzerland*)
15:45 BPIX Module Qualification (10') (Slides) Andrei Starodumov (*Labor fur Hochenergiephysik*)
15:55 FPIX Sensors R&D (10') (Slides) Gino Bolla (*Purdue University*)
16:05 FPIX Material reduction & Module Development (10') (Slides) Kirk Arndt (*Purdue*)

16:30->*17:30* SOFTWARE&COMMISSIONING

16:30 Lessons from Commissioning (10') (Slides) Anders Ryd (*Cornell University*)

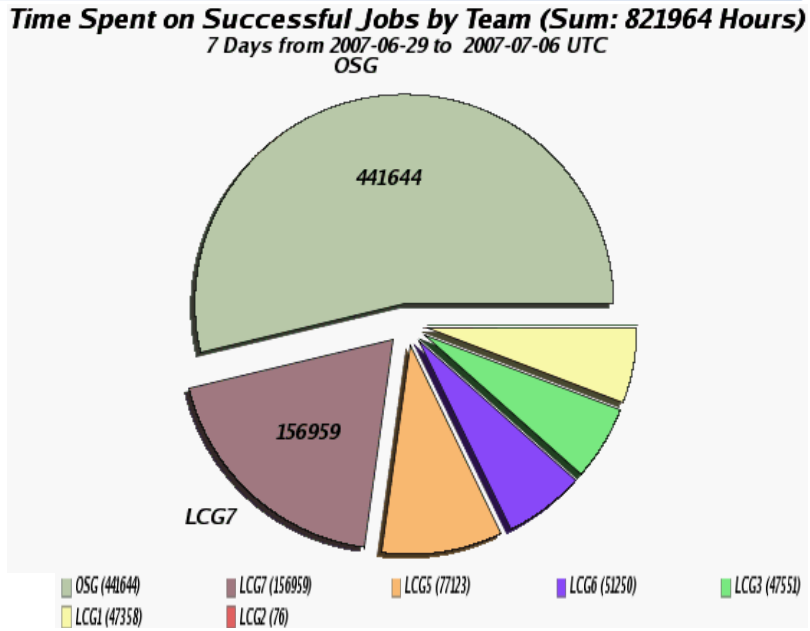
17:30->*18:30* SCHEDULES

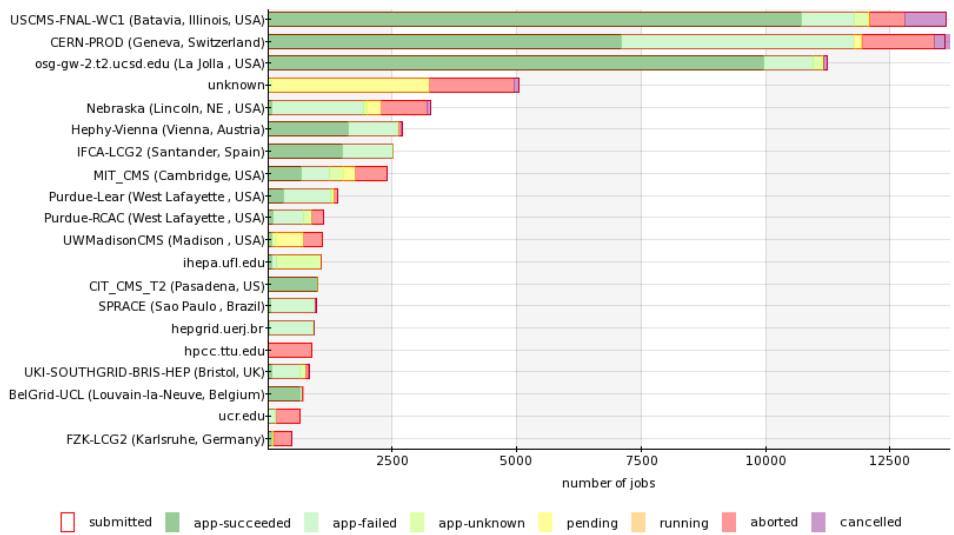
17:30 Schedules for various BPIX replacement/upgrade scenarios (15') Roland Horisberger (*PSI*)
17:45 Schedules for FPIX scenarios (15')

- **Development of layout is allowing to proceed to :**
  - **Conceptual design**
  - **Small prototyping**
  - **Full scale prototyping**

US Computing Sites

- **US sites are working well and ramping up**
  - **Contributing both to central simulation (upper plot) and user analysis (lower plot)**
  - **OSG Providing more than nominal 35% US share for simulation**
  - **Computing Commissioning program ramping functional Tier-2s for analysis**
    - **7 Strong Tier-2s at US Universities**





Assembly of ECAL Endcap Dees