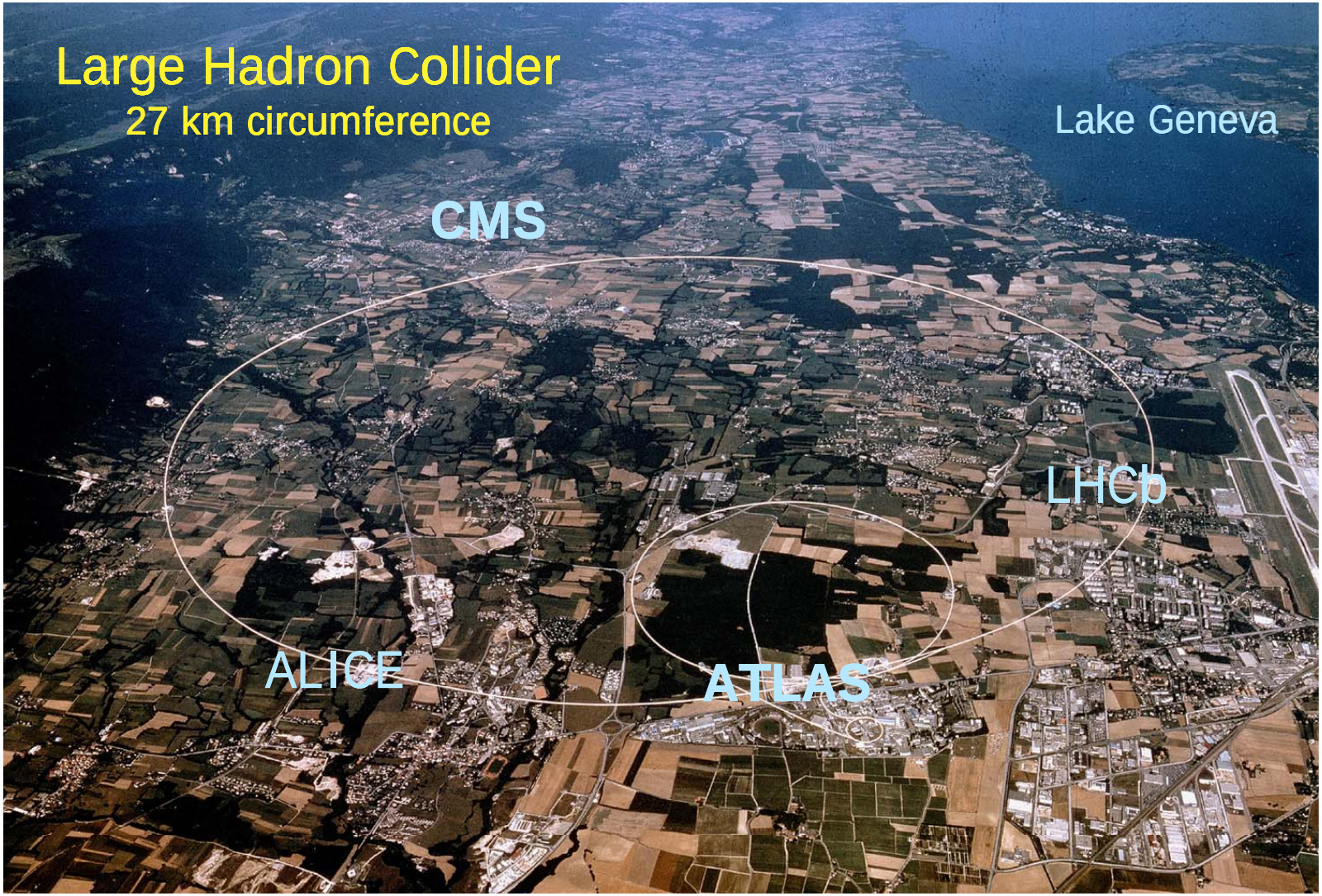
Status of CMS

Nick Hadley
University of Maryland
On behalf of the CMS Collaboration

First USLUO Meeting
Fermilab
October 24, 2008

CERN Site


Large Hadron Collider
27 km circumference
Lake Geneva
CMS
LHCb
ALICE
ATLAS

CMS Collaboration

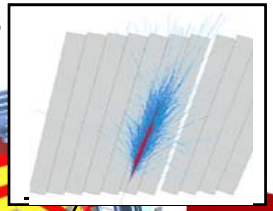
- CMS
  - 39 Countries
  - 181 Institutions
  - 1940 Scientific Authors total
  - 1283 paying M&O share
- USCMS
  - 639 Scientific Authors
  - 442 with Ph.D (34.5%)
  - 197 Graduate Students

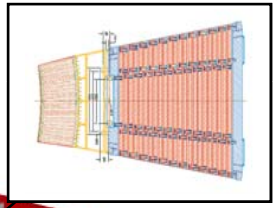
CMS Subsystems

SUPERCONDUCTING COIL

Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

ECAL Scintillating $PbWO_4$ Crystals





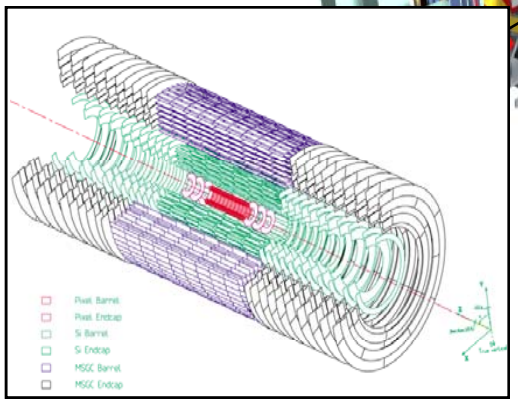
CALORIMETERS

HCAL

brass Plastic scintillator sandwich

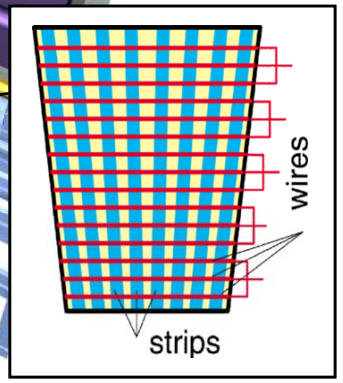
IRON YOKE

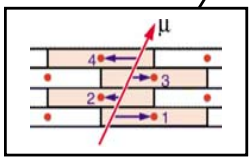
TRACKERs



Silicon Microstrips
Pixels

MUON ENDCAPS





Drift Tube Chambers (**DT**)

Resistive Plate Chambers (**RPC**)

Cathode Strip Chambers (**CSC**)
Resistive Plate Chambers (**RPC**)

MUON BARREL

CMS Detectors

- Magnetic Field: 4 Tesla solenoid + return yoke, outside calorimeters
  - Stored energy 1.6GJ
- Tracker: Silicon pixels and strips, $\sigma/pt = 1.5x10^{-4}\,pt + 0.005$
- EM Calorimeter: $PbWO_4$ crystals, $\sigma/E = 3\%/E + 0.003$, $25X_0$
- Hadronic Calorimeter: Brass+Scintillator (7λ + HO catcher)
  - $\sigma/E = 100\%/E + 0.05$ GeV
- Muon: σ/pt = 1% @ 50GeV to 10% @ 1TeV
  - DT/CSC+tracker, RPC for trigger
- Trigger: L1 (hardware) + HLT (farm)

US Contributions

- **US has major responsibility in many CMS Systems**

- **US led subsystems**
  - **HadronCalorimeter**
  - **EndcapMuons**
  - **Forward pixels**
  - **Trigger•**
- **Systems with strong US participation**
  - **Data Acquisition**
  - **Silicon Strip Tracker**
  - **Electromagnetic Calorimeter**
- **Computing**
- **Physics Analysis**

US Leadership Positions

- Deputy Spokesperson: Bob Cousins (UCLA) since 1/07
- Chair CMS Collaboration Board: Dan Green (FNAL) starting 1/09
- Deputy Physics Coordinator: Joe Incandela(UCSB)
- 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)

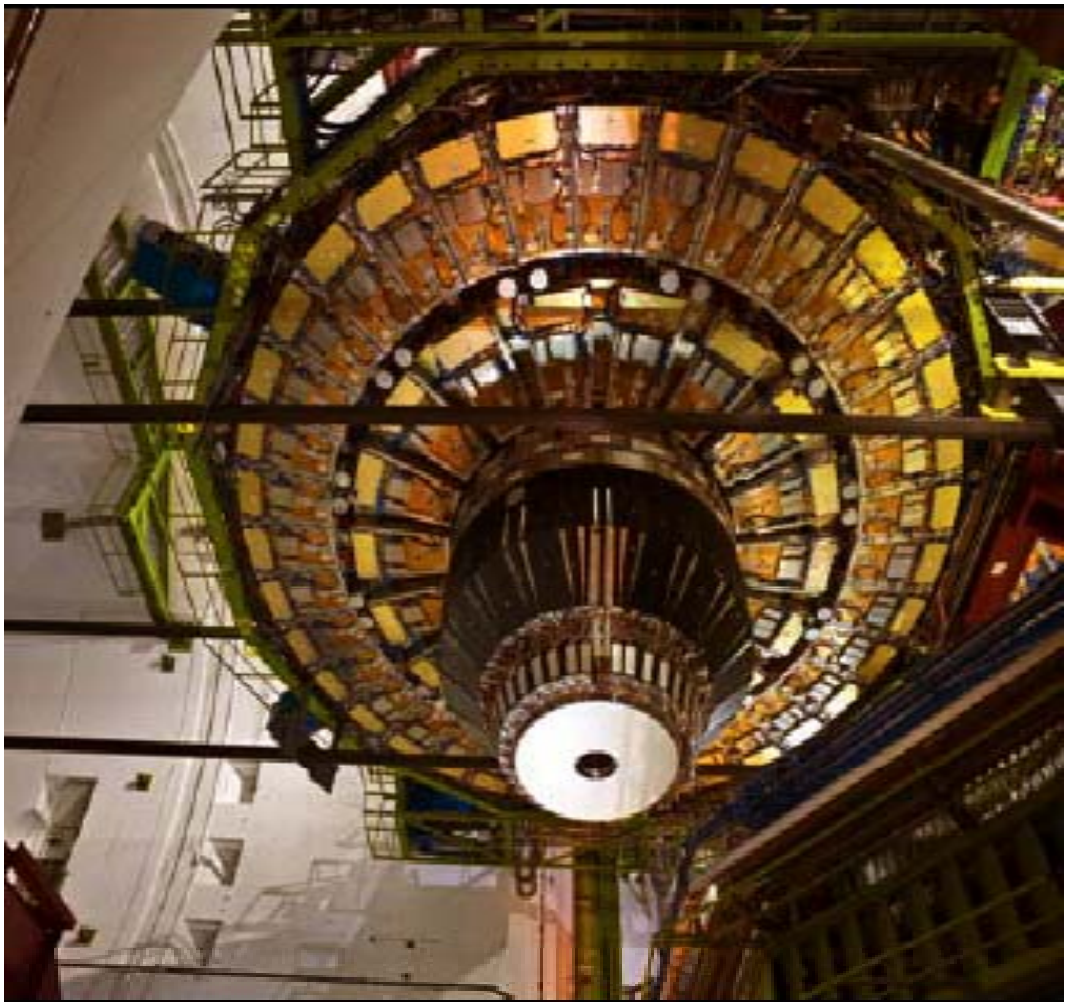
Design

- The iron yoke is built in slices along the beam axis
- Barrel part in 5 wheels
- Central wheel fixed to the solenoid –YB0
- Endcap part 3 disks each end
- 4th disk planned for highest luminosities
- Forward hadron calorimeter on each end
- Detector can be opened along the beam pipe
- Large pieces slide on air pads and grease pads
- Any single detector can be accessed and changed underground
- CMS is the first large HEP detector that has been assembled, cabled and tested on the surface and then brought underground
- Disentangle civil engineering underground from detector construction
- Much less space requirements underground
- Requires doubling some infrastructure on the surface for testing

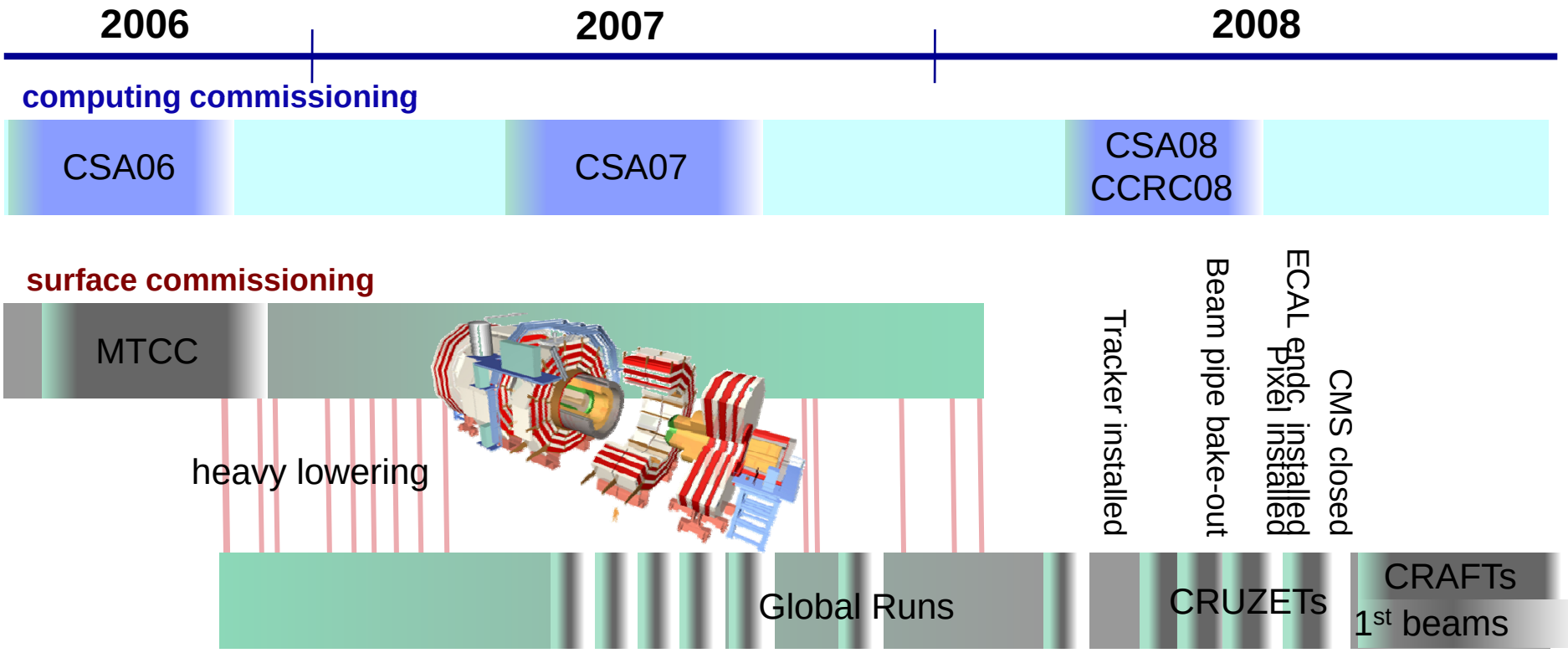
Heavy Lowering

- 13 Heavy Lowerings
- Masses between 400 tons and 1920 tons

- YE1 most difficult: Mass 1430 tons
- Nose of 465 tons out of plane of disk –center of gravity in front of the the plane.



CMS commissioning overview



CMS dictionary:

CSA – **C**omputing, **S**oftware and **A**nalysis challenge

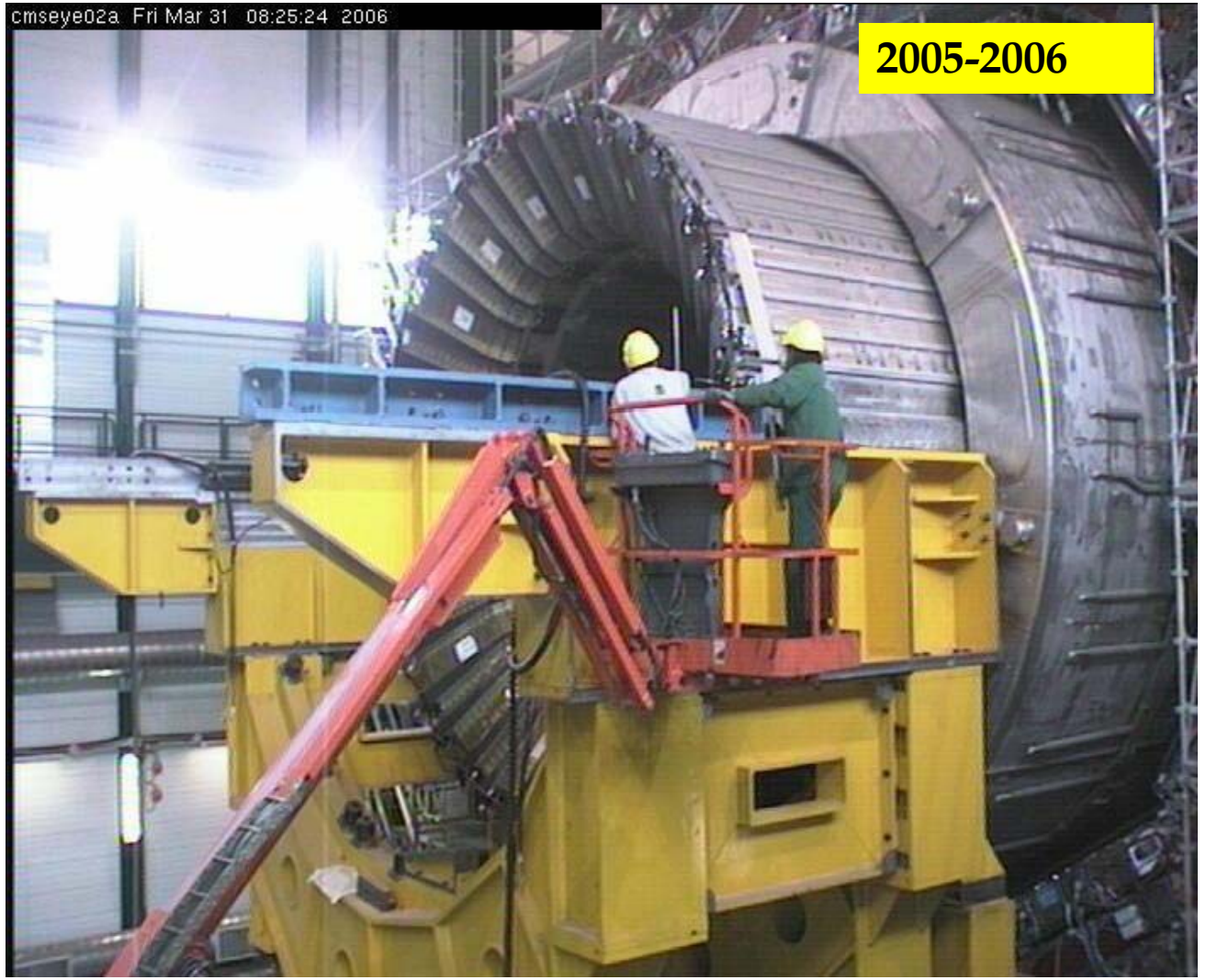
CCRC – **C**ommon **C**omputing **R**eadiness **C**hallenges

MTCC – **M**agnet **T**est and **C**osmic **C**hallenge

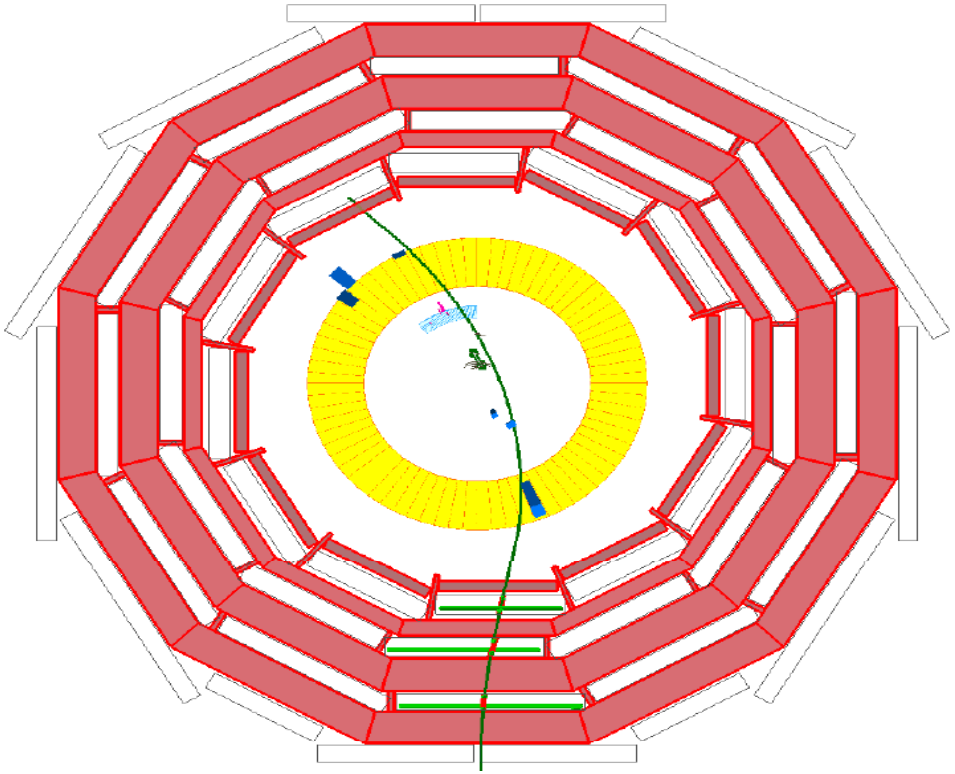
CRUZET – **C**osmic **RU**n at **Zero** **T**esla

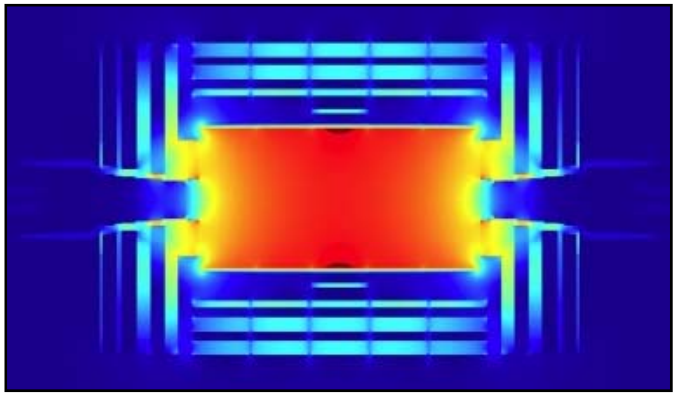
CRAFT – **C**osmic **R**un **A**t **F**our **T**esla

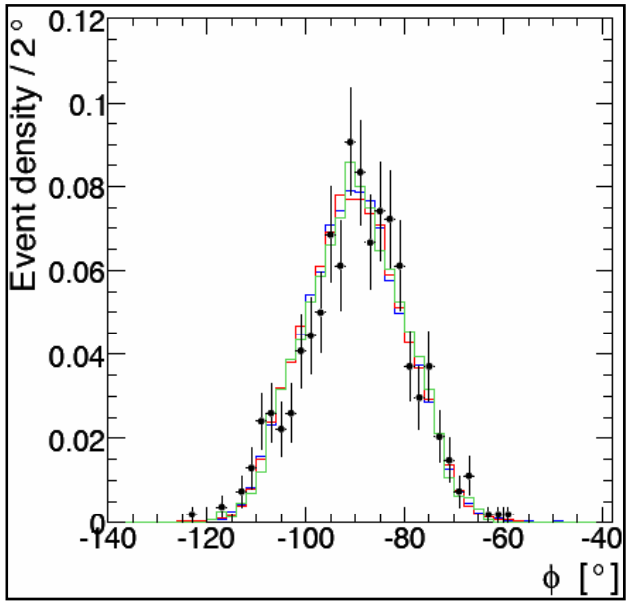
Assembly Hall – SX5



Magnet Test – Fall 2006

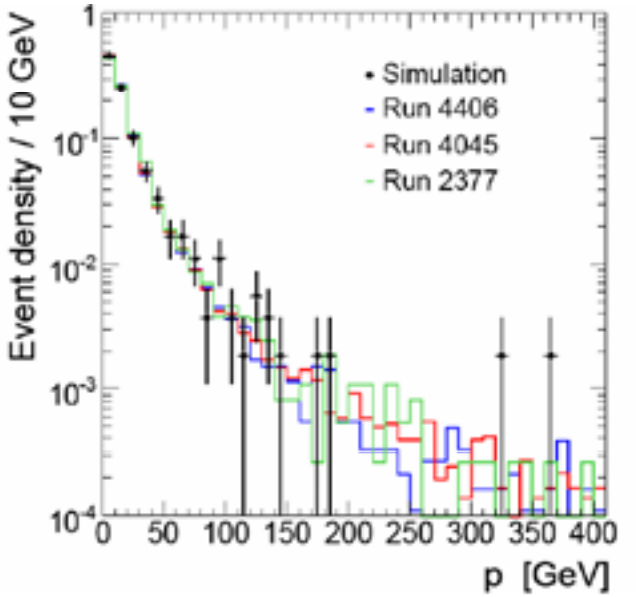




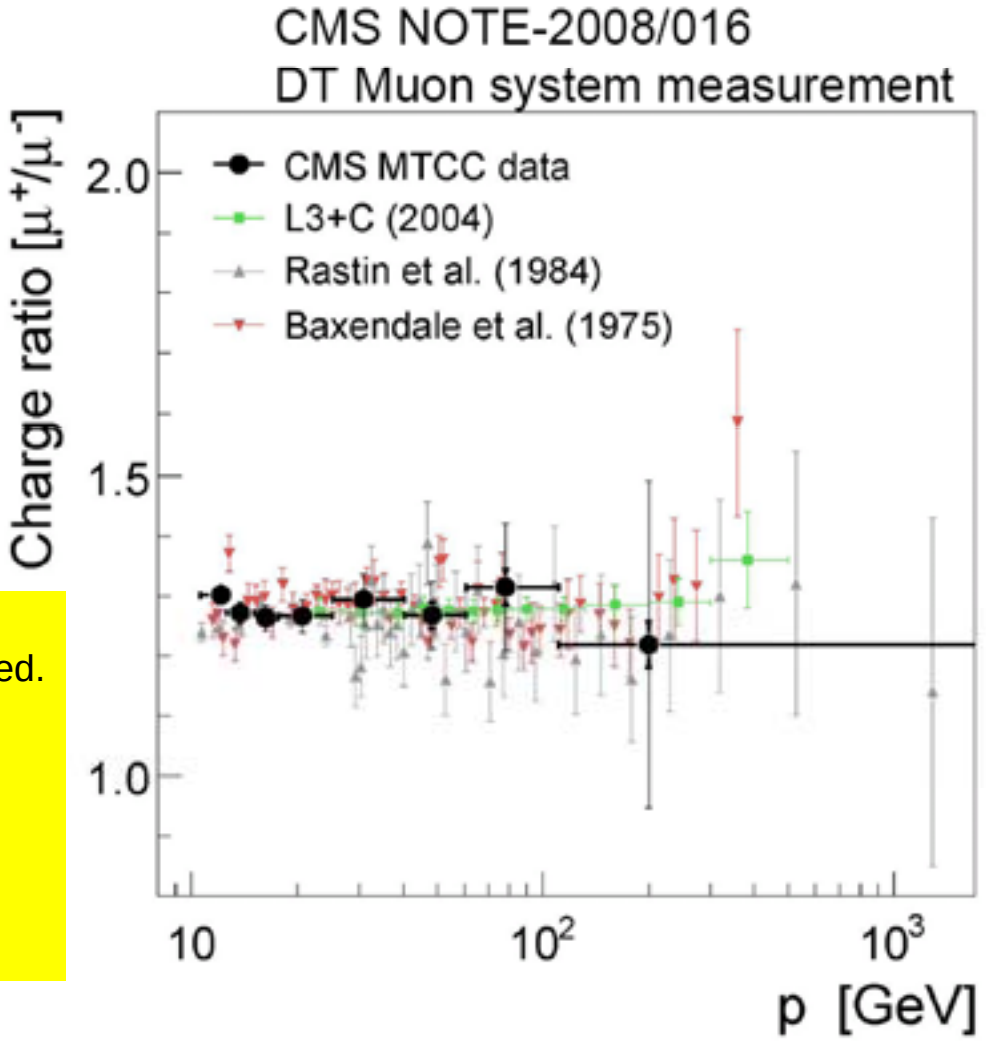


Field map, muon RECO, HCAL readout

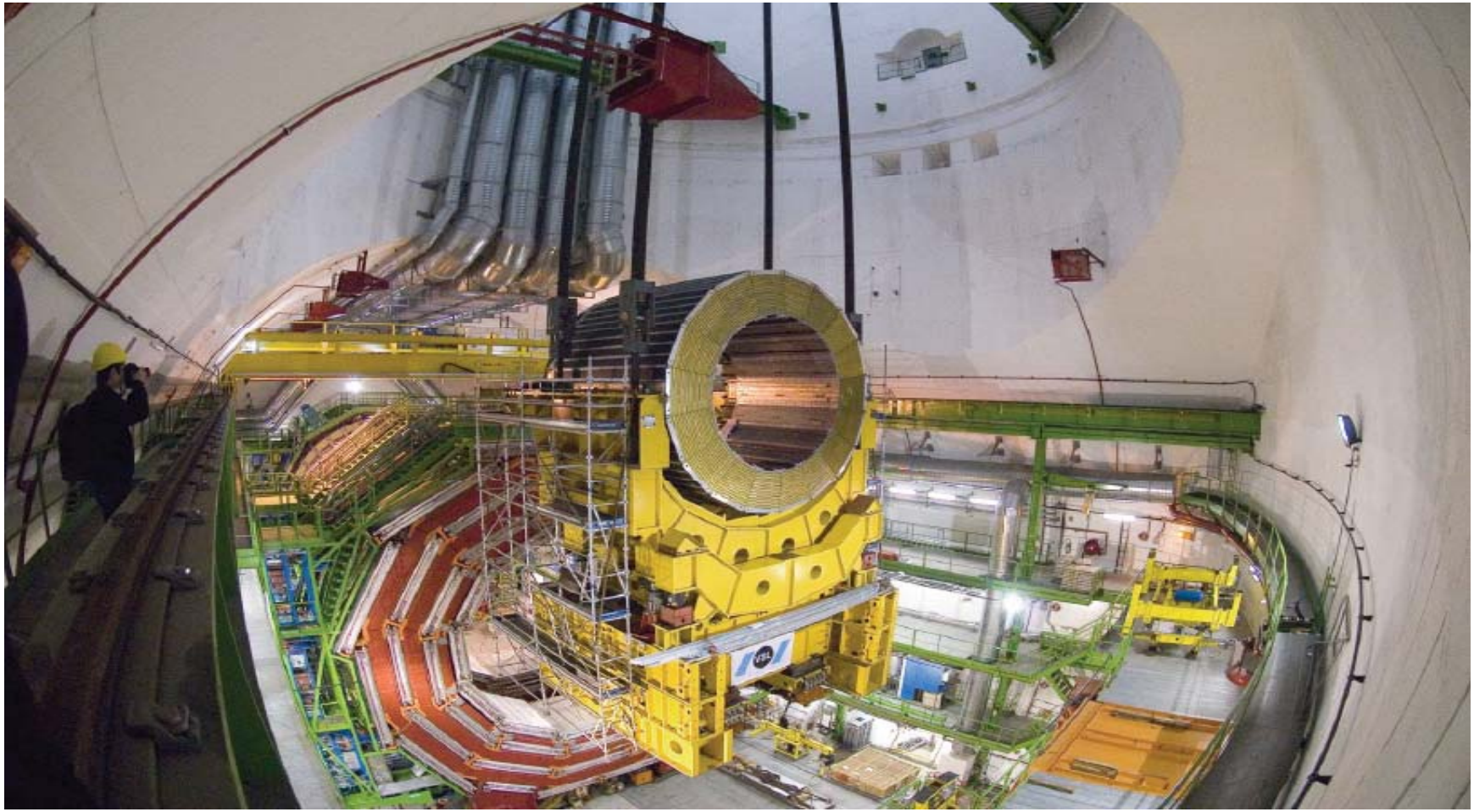
Cosmic Muon - Spectra



- Magnet test: alignment of the muon system. Movement in 3.8 T filed tracked. Check to be “elastic”



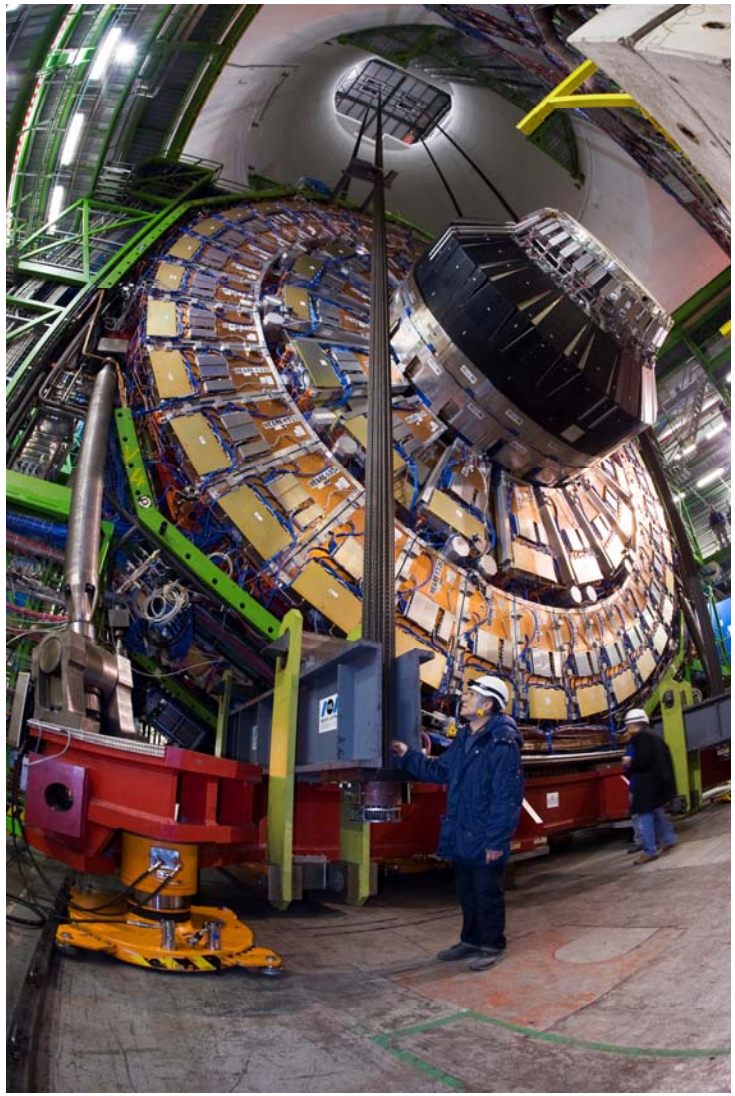
HB – Feb, 2007



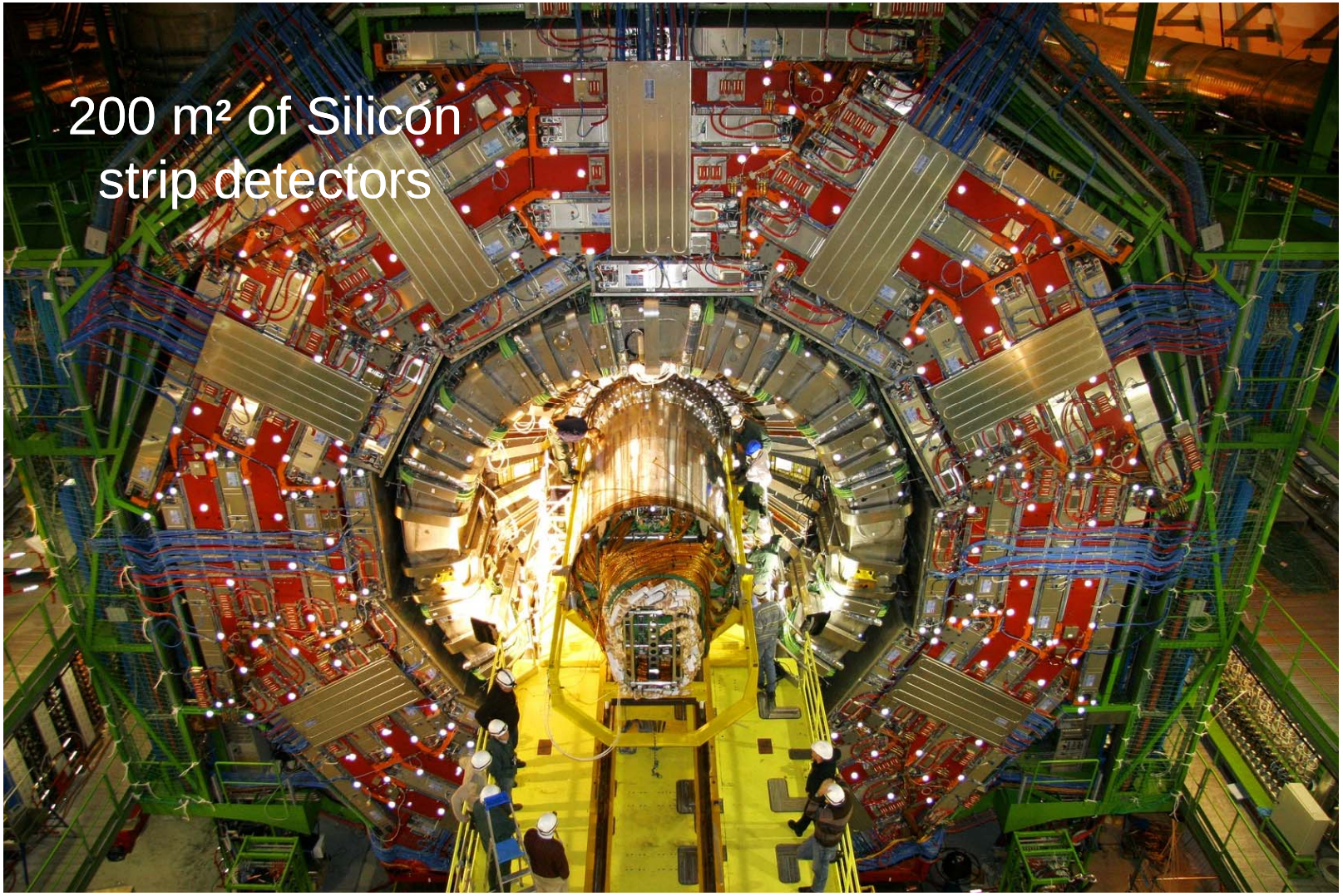
Jan., 2008 - Lowering of YE-1

January, 2008

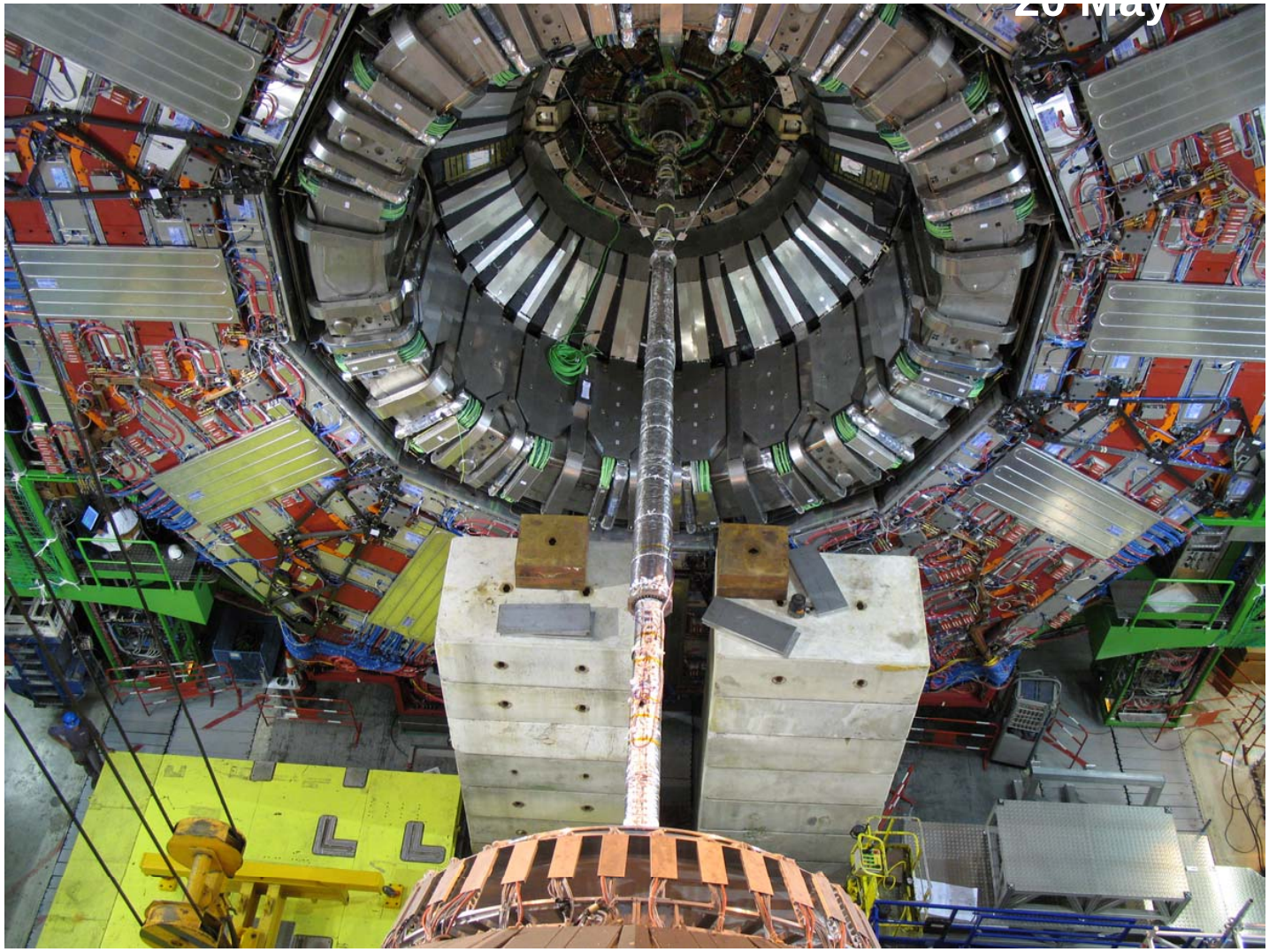
The last heavy element of CMS is lowered into the collision hall. The silicon strip Tracker, the silicon Pixels and the endcap ECAL remain to be installed.



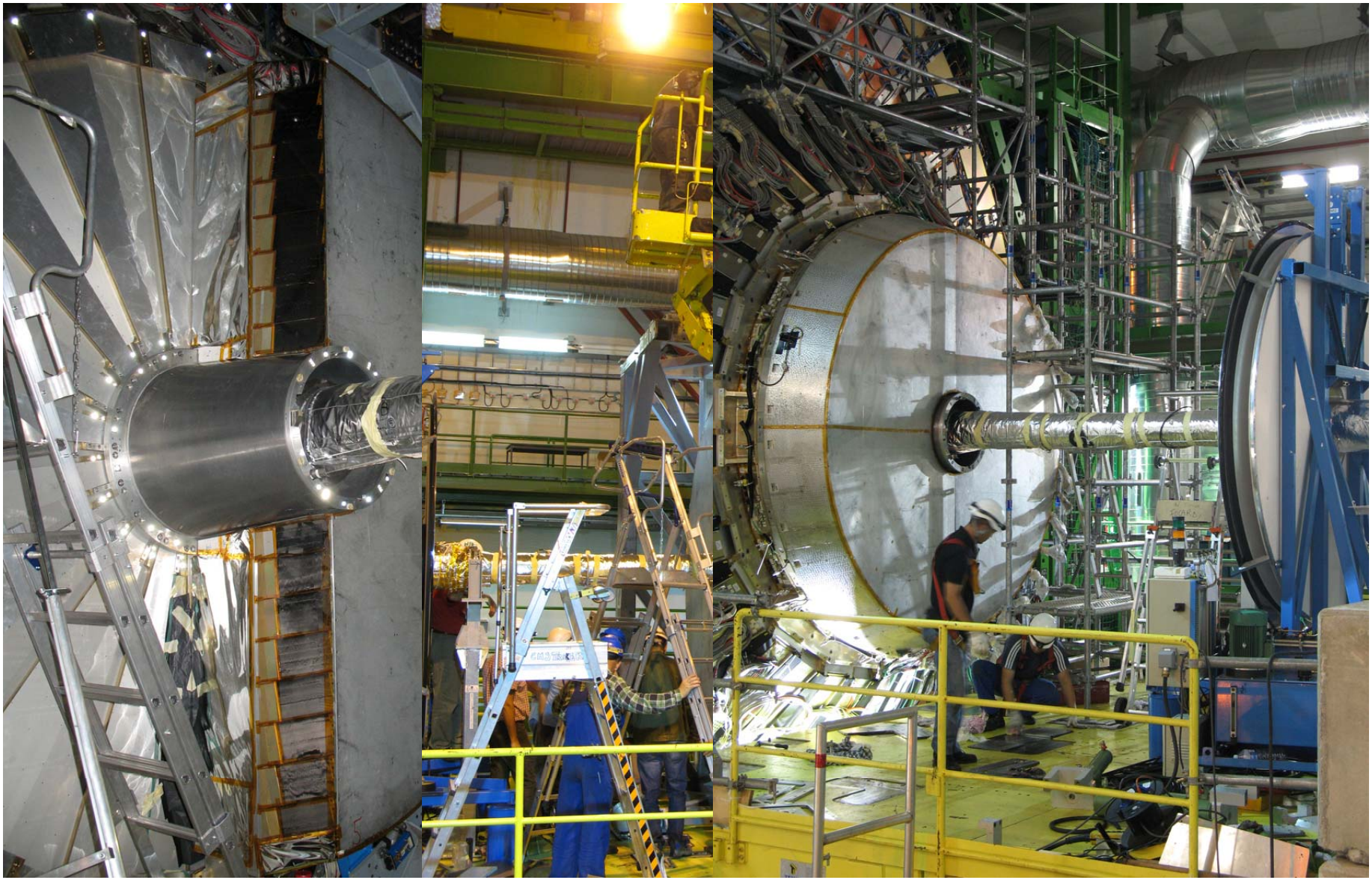
Tracker Insertion (15 Dec'07)



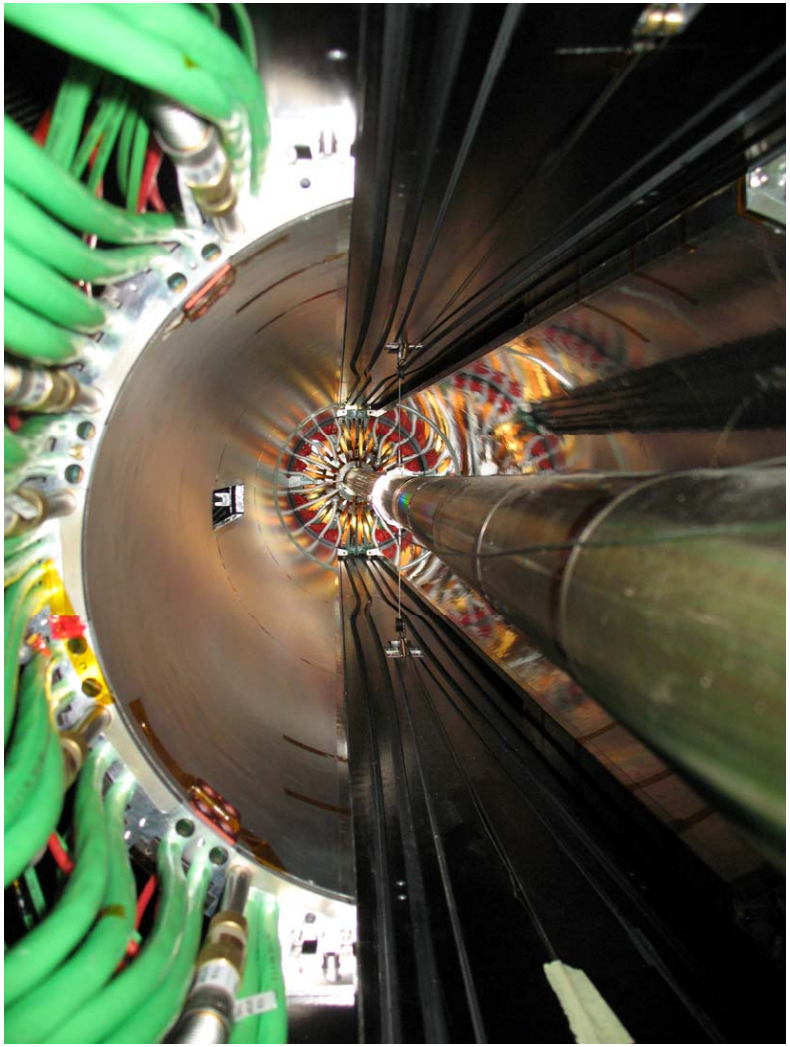
Beam-pipe Installed, May' 08



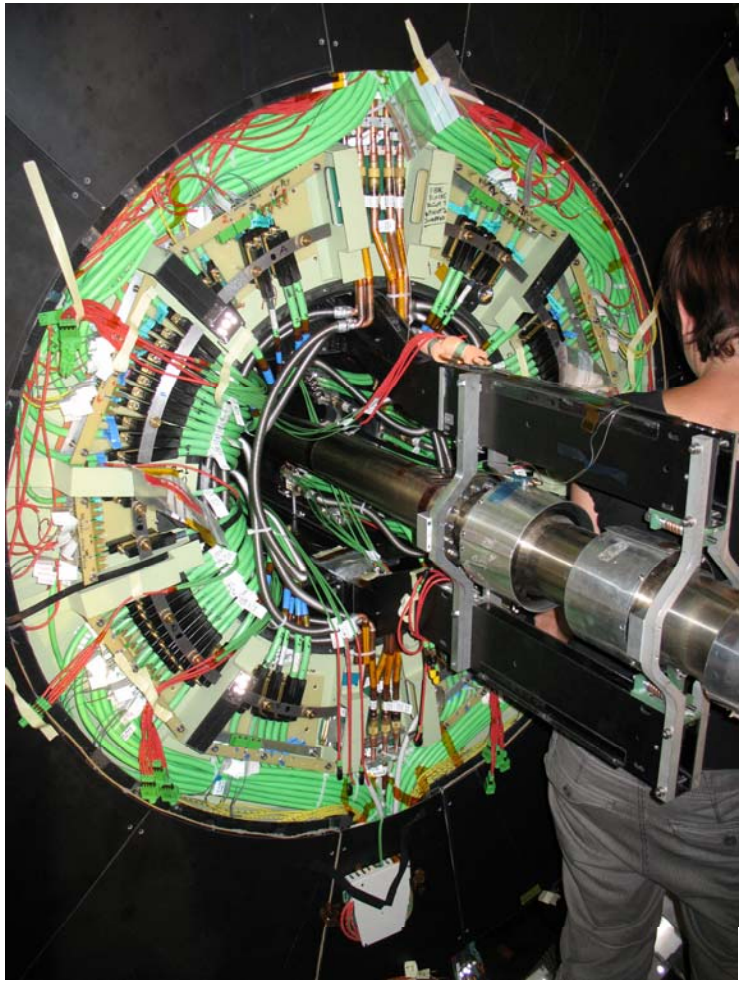
ECAL EE



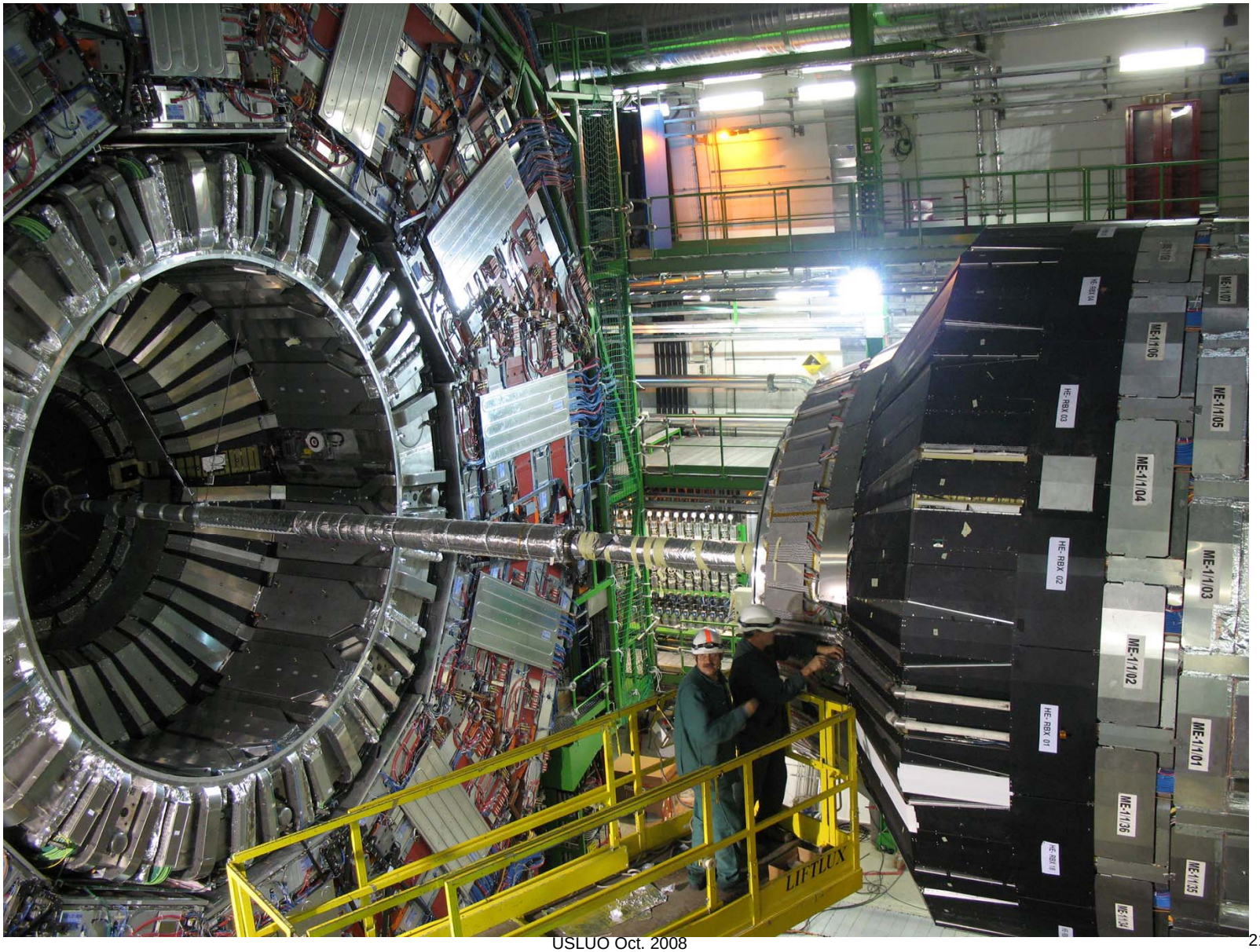
Barrel Pixels



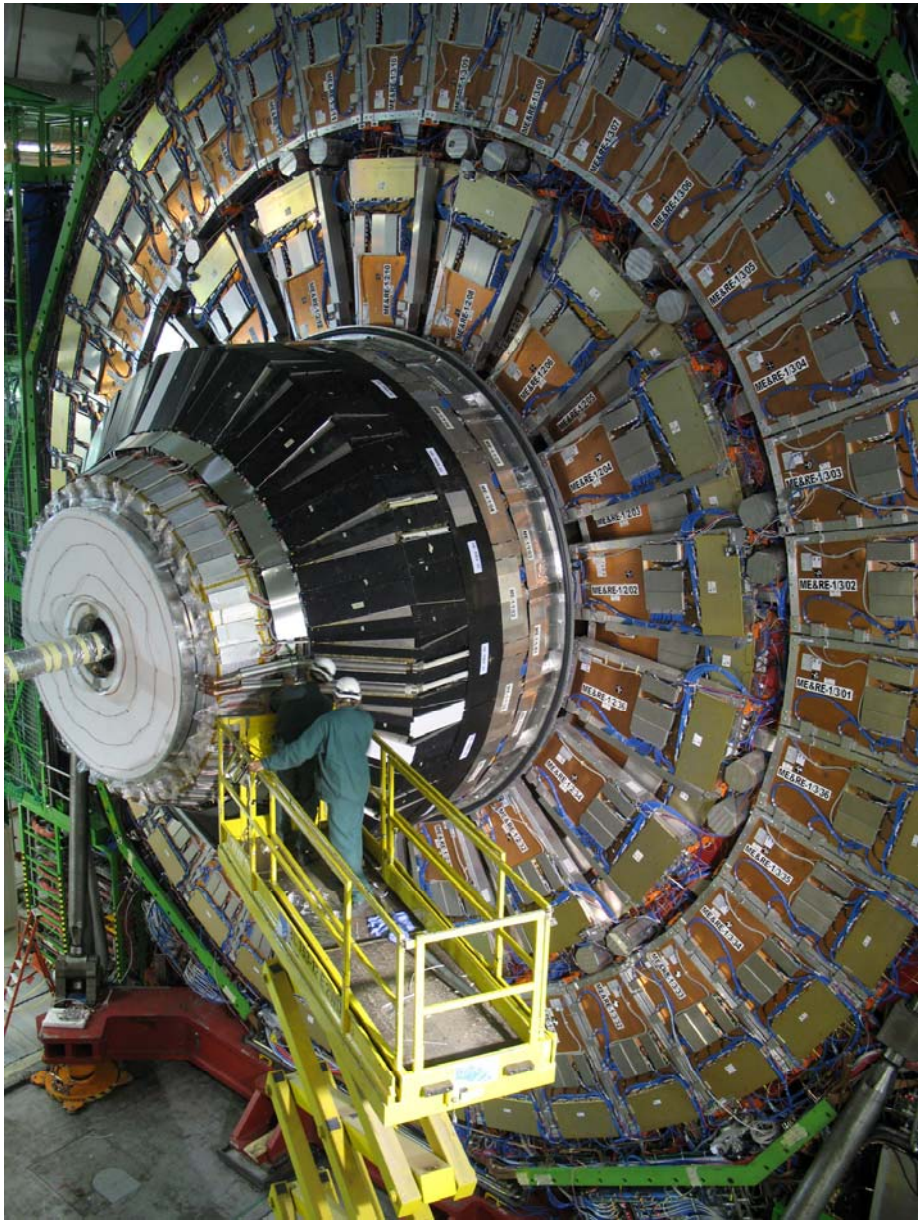
Forward Pixels

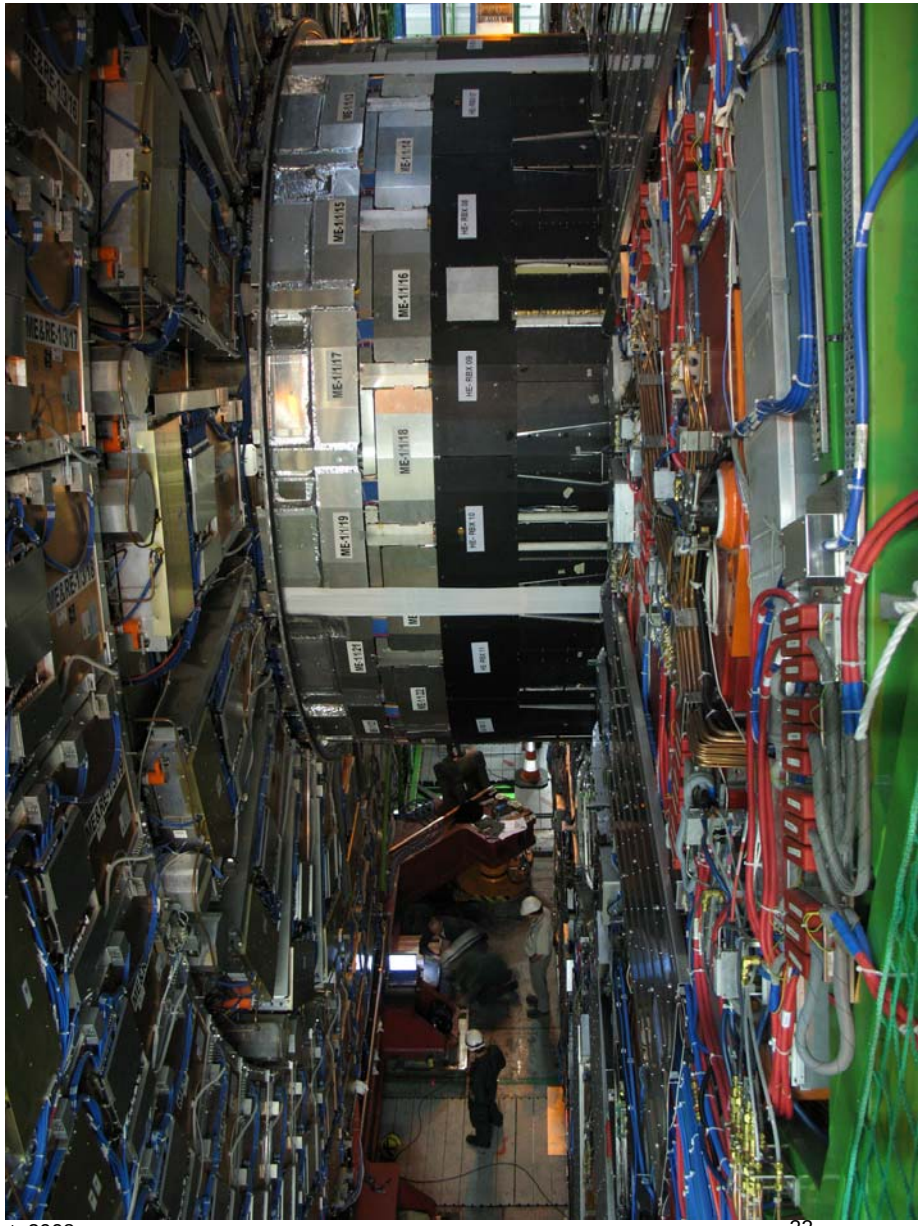


Minus End before Closure

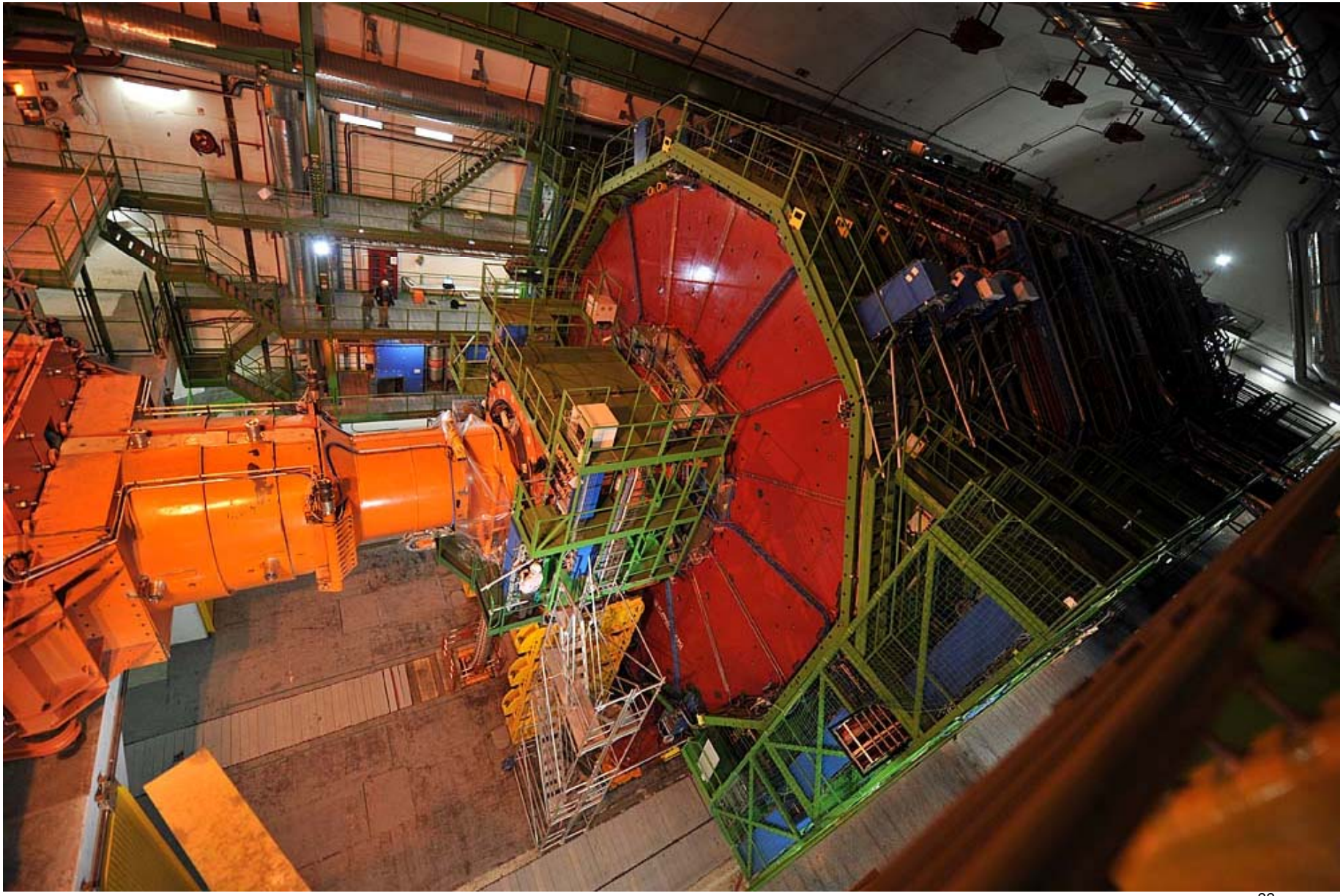


Minus End & Closure



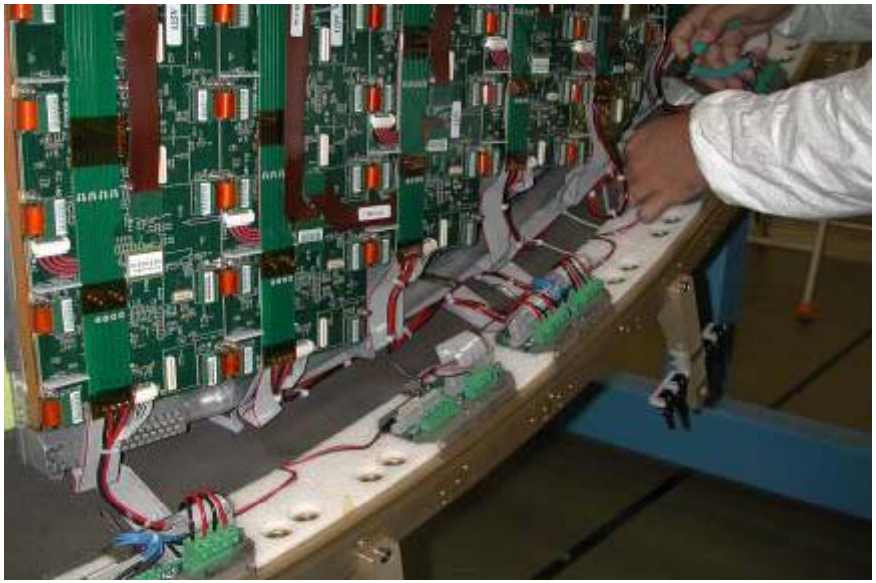


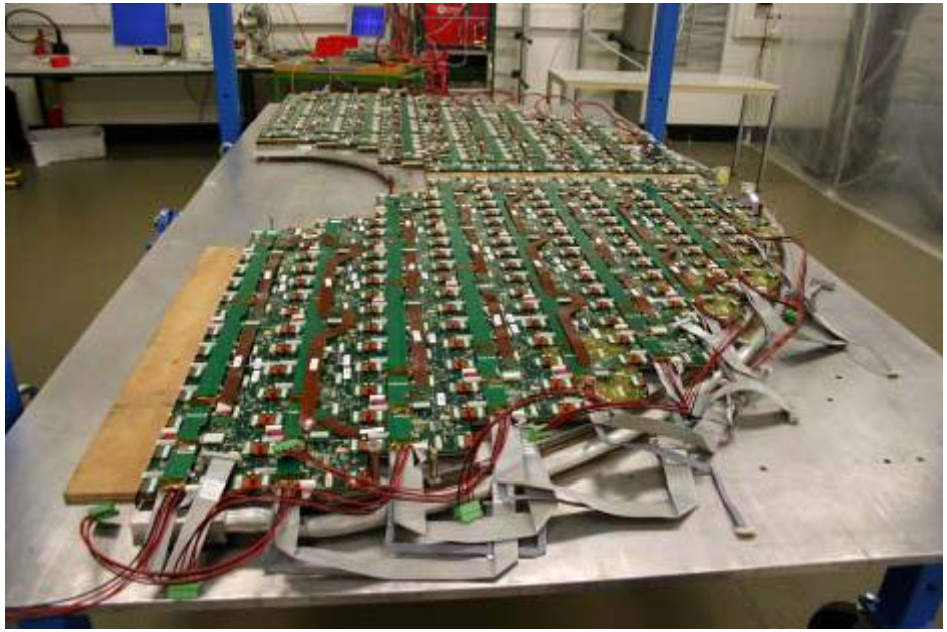
Final Closure

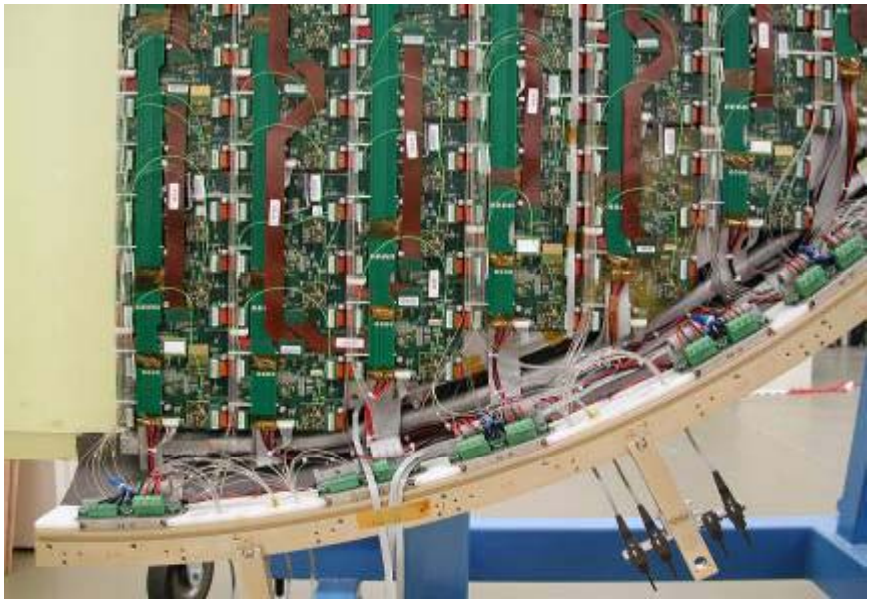


ECAL ES: Preshower Progress (1)

- Needed (4288) micromodules assembled and tested
- About 500 ladders assembled and stress-tested (~520 required)
- Ladders mounted, cabled and tested on 3 of 8 absorbers. All channels (~50k silicon strips) operational.
- 1 of 8 fully connected to outer drum (vertical) including spliced optical fibre bunches







ECAL ES: Preshower Progress (2)

First stuffed absorber now inside an environment-controlled tent (in the old "TIF")

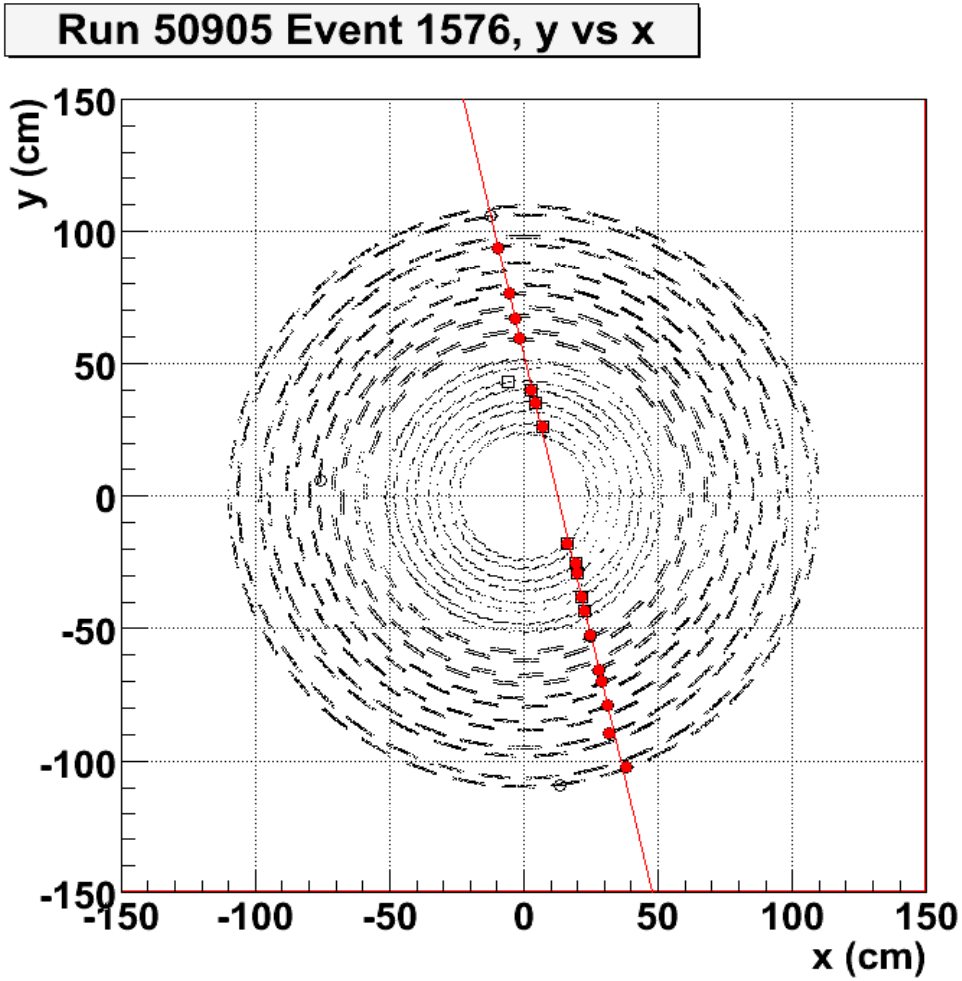
Starting full tests with final off-detector electronics, DAQ software etc.

Will cool to -15 degrees and re-test etc.

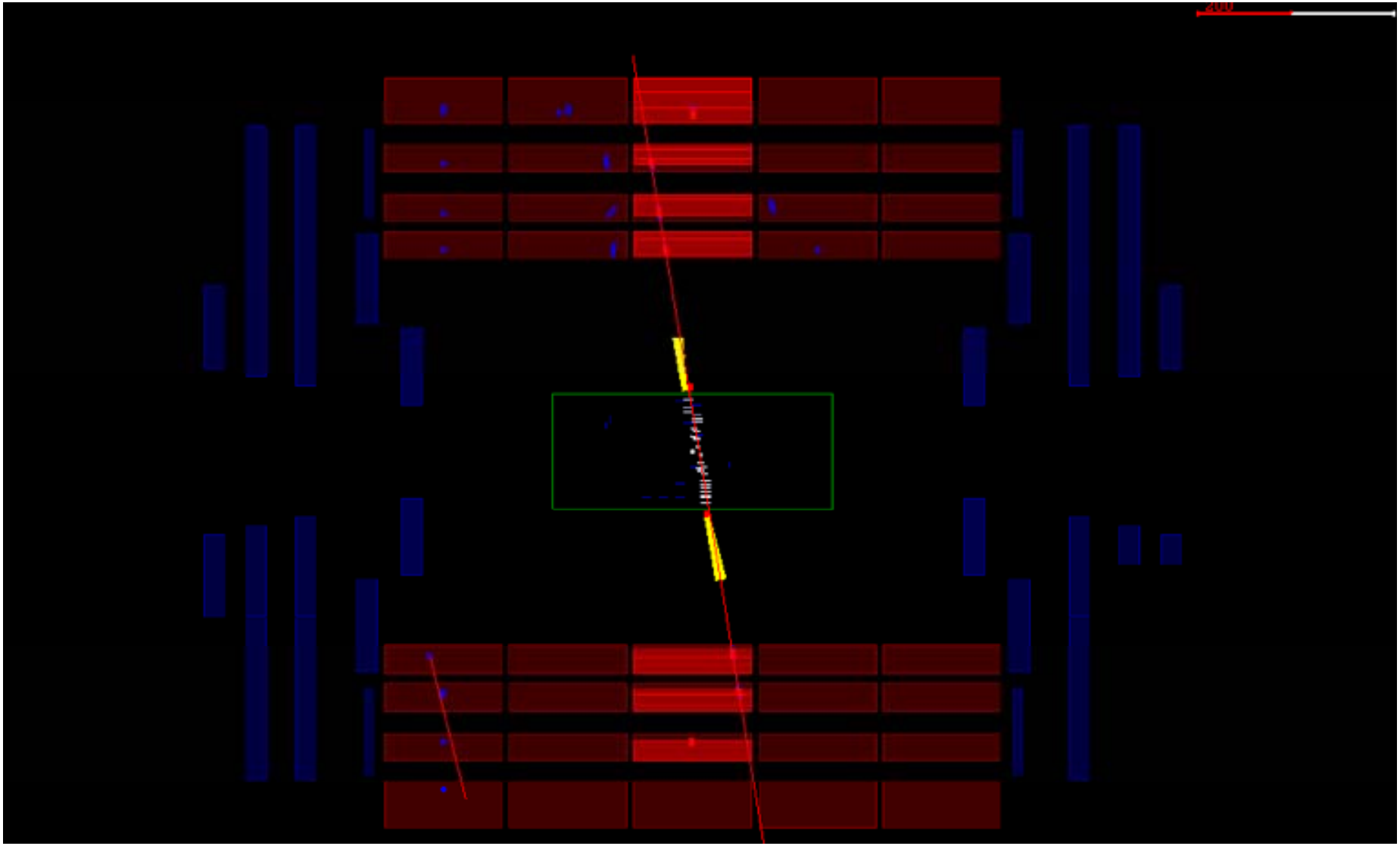
Target: get ES 'ready for installation' by the end of 2008.

Members of the ES team prior to moving the absorber into the tent

CRUZET3: Cosmic Rays in the Tracker



CRUZET4: Events



Recent CMS Progress

- **CMS low luminosity Detector ready: includes pixels, Si strip Tracker, barrel and endcap crystals ECAL, HCAL (barrel, endcap and forward), Muons (DTs, CSCs and RPCs), Level-1 Trigger, 50 kHz DAQ**
- **Solenoid**: The coil is operational at 3.8T in final configuration.
- **Tracker**: The full Si Tracker and the full pixels detector have been installed, commissioned and are operational.
- **ECAL**: Both ECAL endcaps installed, commissioned and operational.
- **In situ Commissioning.**
  - 24/7 run made mid-August (CRUZET4) with the whole experiment switched on.
  - Currently 24/7 runs with magnet on (CRAFT)
- **Software & Computing Infrastructure:** The final releases for data taking deployed. Simulation of the 10 TeV datasets has started.
- **Preparation for physics** consolidating the analyses for up to 100 pb^{-1}.

First Beams

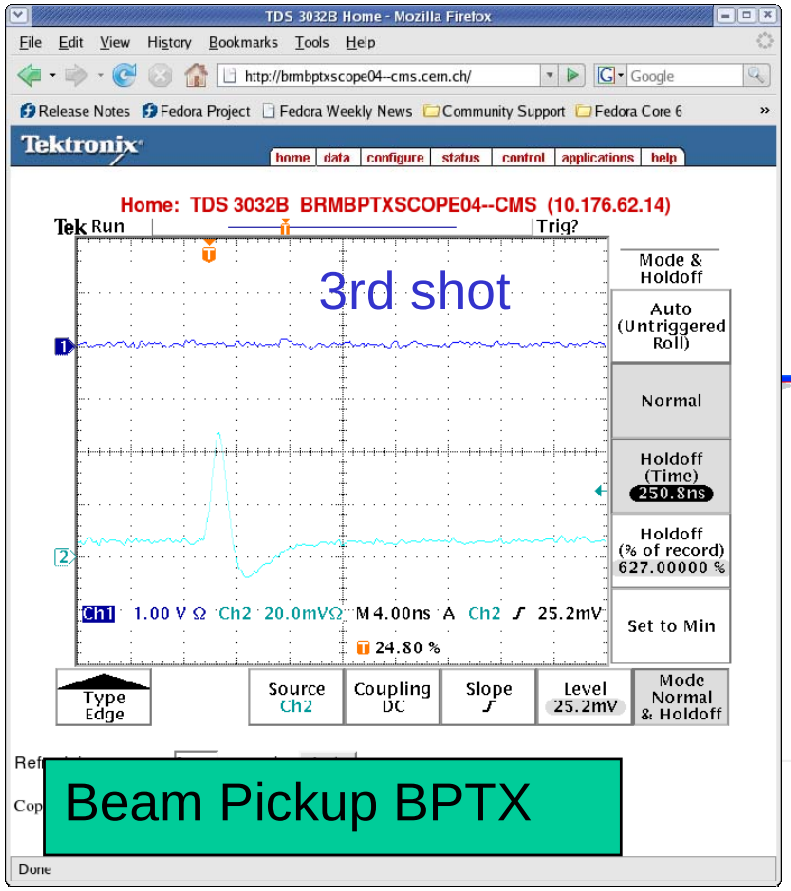
After almost 20 years of design and construction CMS started taking data with LHC beams.

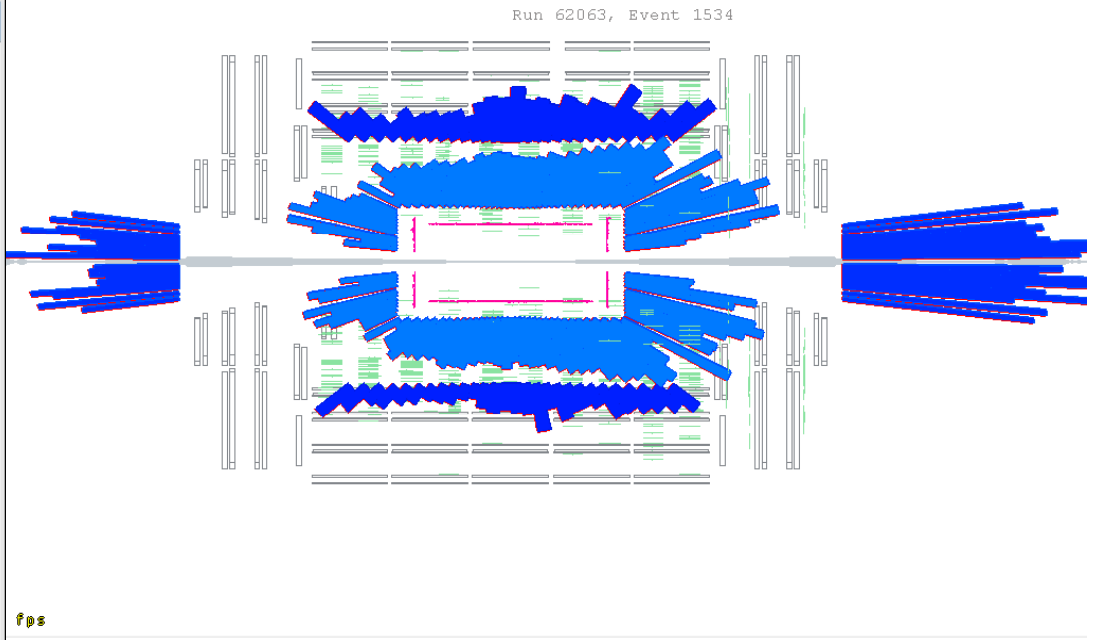
(Congratulations to the Machine)

- **Sun/Mon, 7-8 Sept.**
  - **Single shots of Beam 1 (clockwise via ALICE) onto collimator 150m upstream of CMS, ~ 1 hour**
  - **Large CSC events require CSC FEDs to be taken out of readout… (later solved, and CSCs go to reduced HV for subsequent dumps)**
  - **Allows synchronization of BPTX trigger (good prep for Wed.)**
- **Tues, 9-Sept**
  - **20 shots of Beam 1 onto collimator 150m upstream of CMS**
- **Wed., 10 Sept.**
  - **Nice splash events observed when beam onto collimators (as before), 100-1000 TeV observed in ECAL-HCAL**
  - **Halo muons observed once beam started passing through CMS**

First Events: Collimators Closed

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

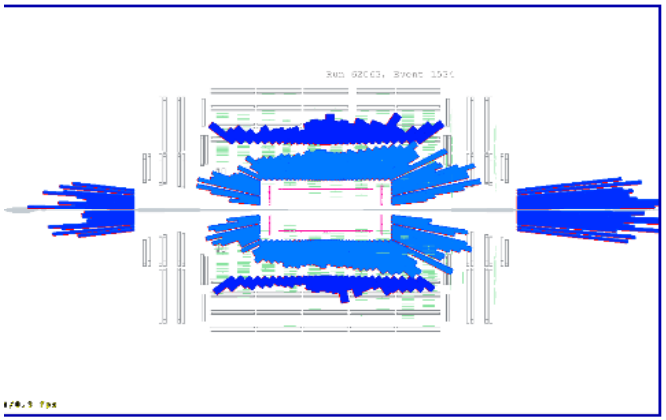


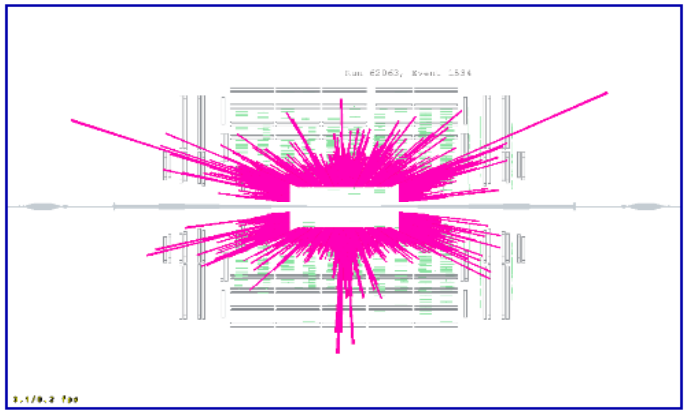


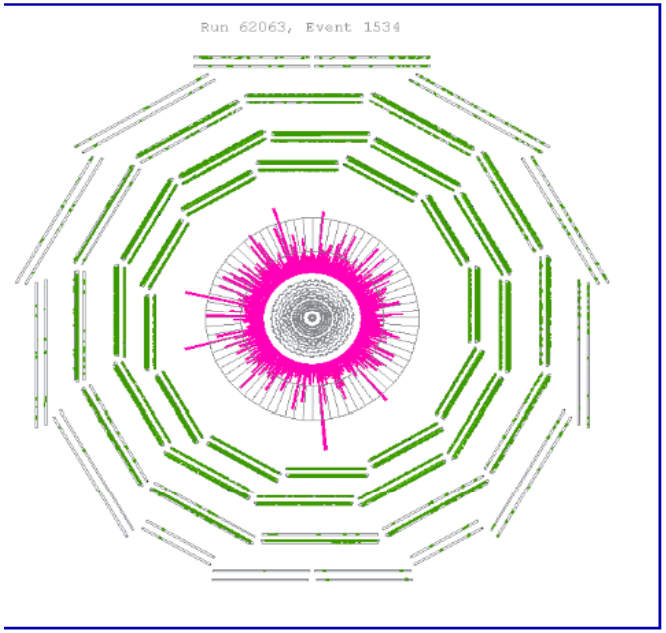
First Events: Collimators Closed

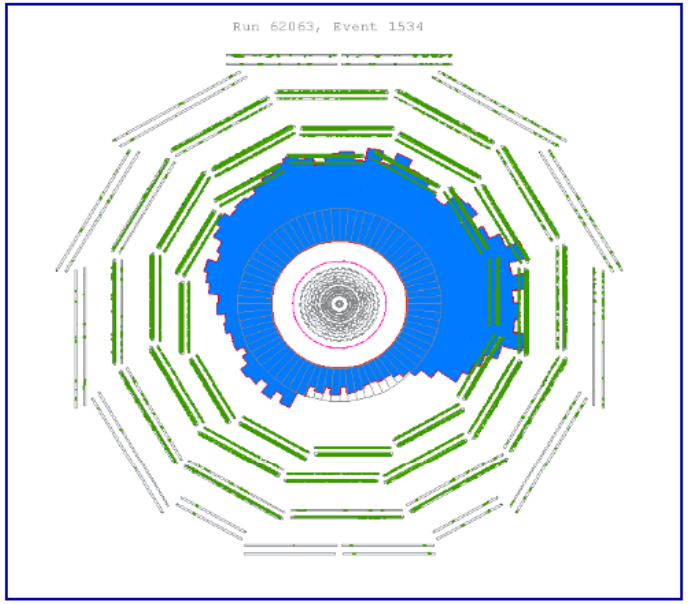
~2.10^9 protons on collimator ~150 m upstream of CMS

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

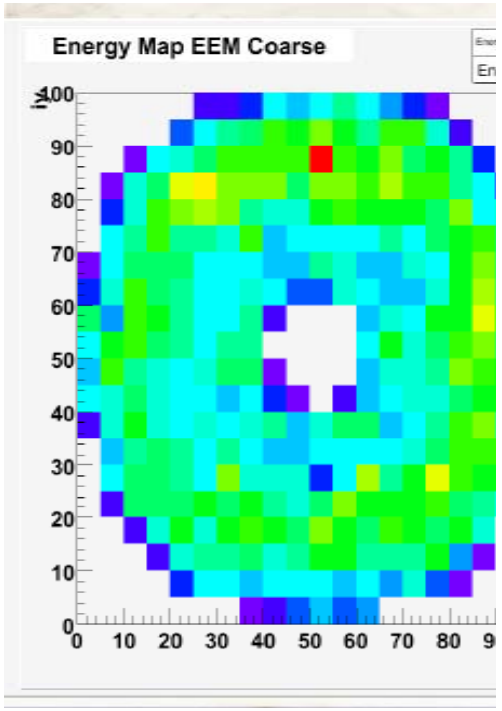


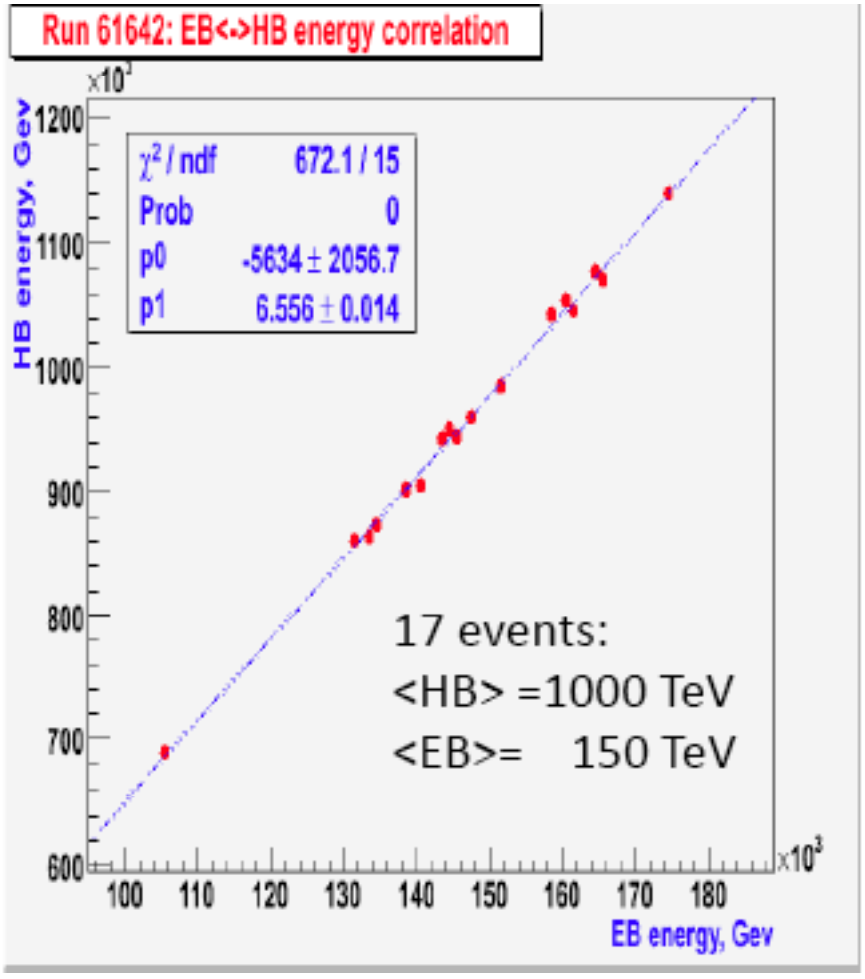


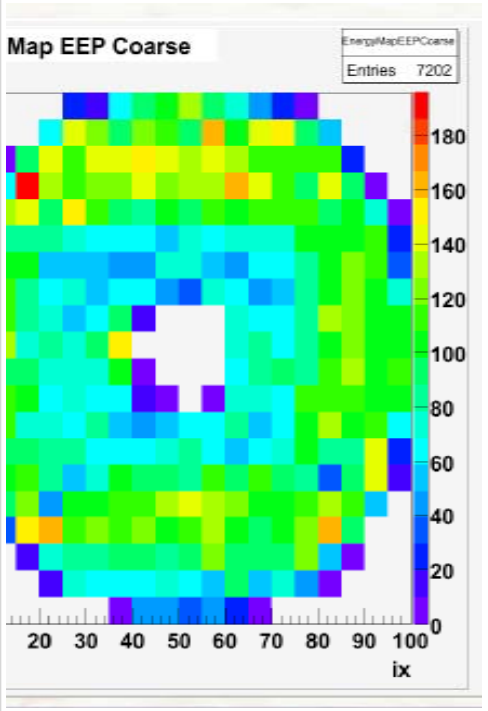




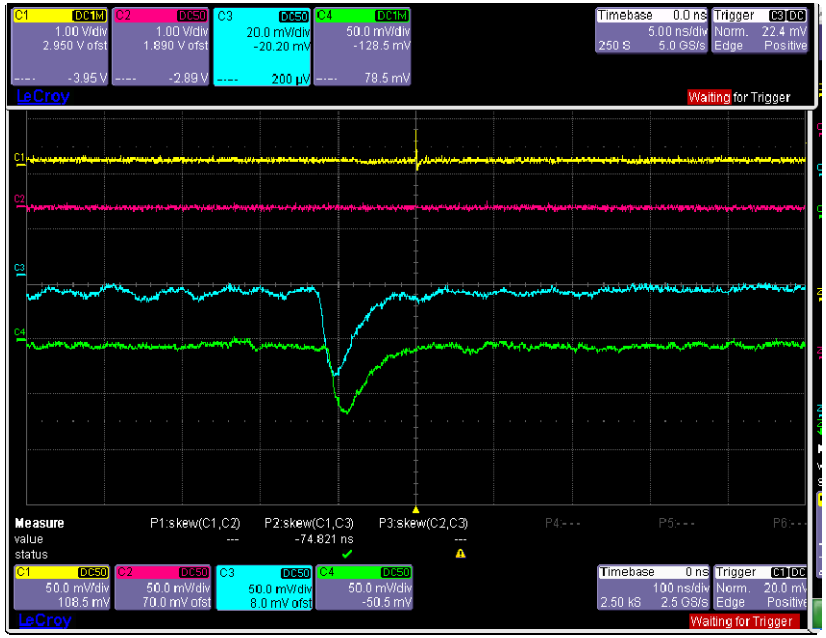
Beam Dumped in Collimator



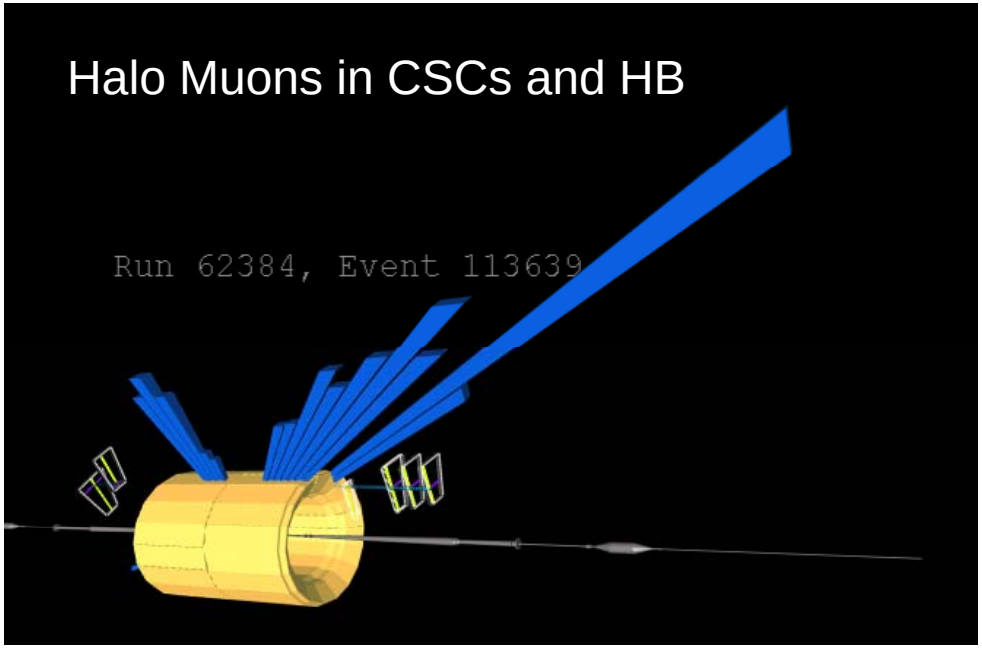




First Events: Beam going through CMS

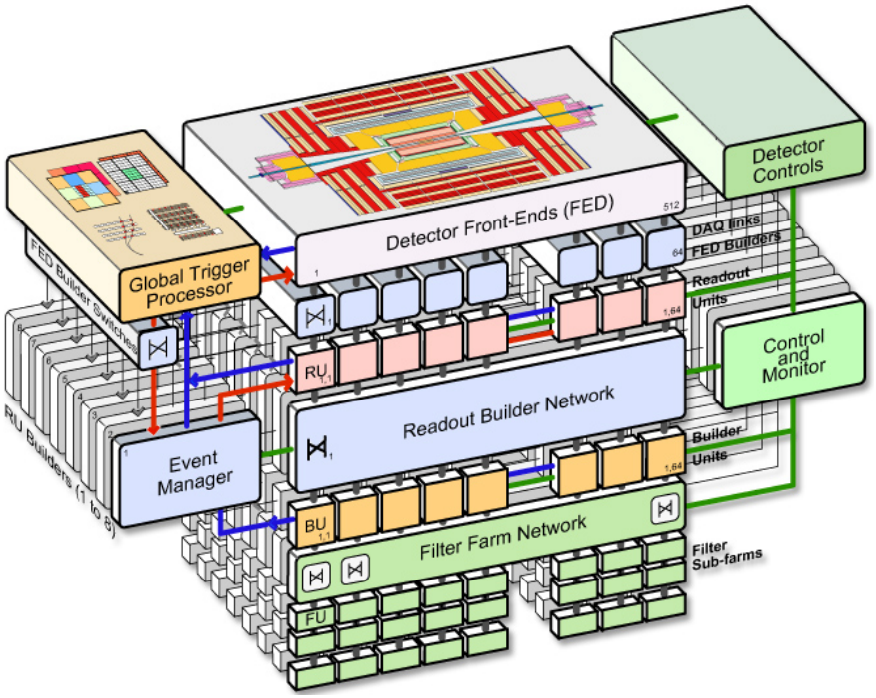


Beam Pickup (ch1) CMS Beam Condition Monitors (ch 3, 4)



CMS DAQ and Trigger System

- Trigger Tables are Defined
- Trigger on "minbias" for LHC startup
- Data Quality and trigger Monitoring are in place
- DAQ at ~ 50 kHz has been "stress tested"



Tier-1 Facility at FNAL

- The FNAL Tier-1 has reached the end of the 4 year procurement ramp
  - Meeting the obligations of the U.S. to CMS Computing and providing analysis resources for the LPC
  - The remaining equipment is primarily analysis computing for the LPC which will be available this month and in production before the run

FNAL Tier-1 and LPC Summer 2008	CPU T1	5.5MSI2k	Tier-1 Processing Nodes
	CPU LPC	240 Nodes	Dedicated to Local Analysis
	Disk T1	2.0PB	dCache (1600MB/s IO)
	Disk LPC	0.5PB	Dedicated to Local Analysis
	Network	15Gb/s	CERN to FNAL
	People	30FTE	Includes Developers and Ops

  - The baseline in 2009 is the Tier-1 facility to go to maintenance for CPU (replace nodes) and continue to grow for analysis
  - Target: disk at ~ one third of CMS requirements for Tier-1 Capacity

Tier-2 Facilities in the US

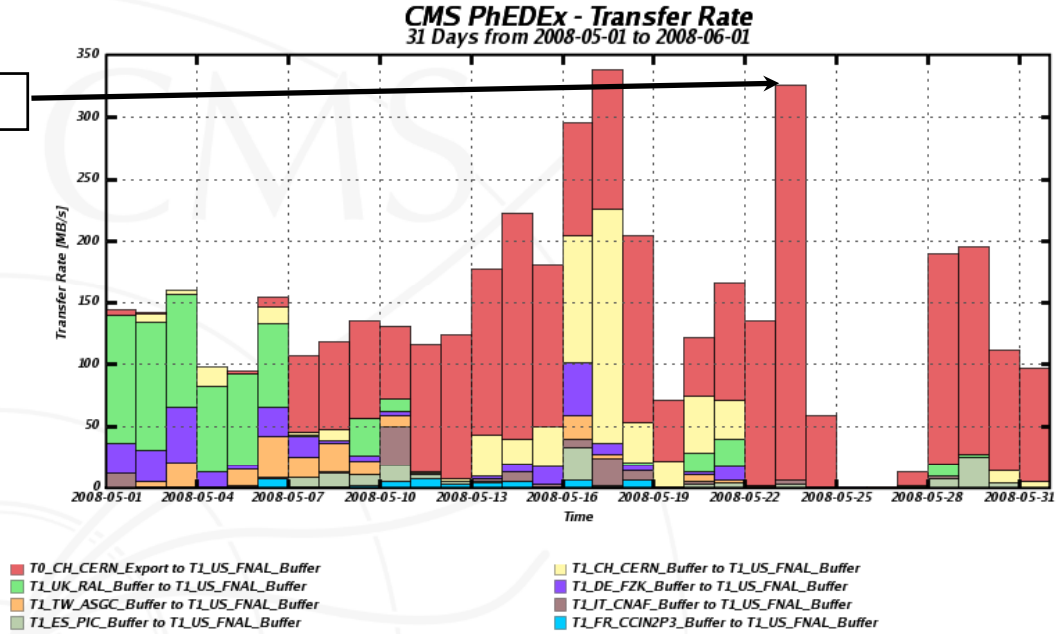
- The US Tier-2s have been extensively used for both simulation and analysis processing.
- The goal is for all the US Tier-2 sites to reach the nominal capacity in 2008
- All US Tier-2s met the milestone
  - T2_US_Caltech, T2_US_Florida, T2_US_MIT, T2_US_Nebraska, T2_US_Purdue, T2_US_UCSD, T2_US_Wisconin
  - The Tier-2 sites well prepared for the start of data taking and simulated event production for start-up

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

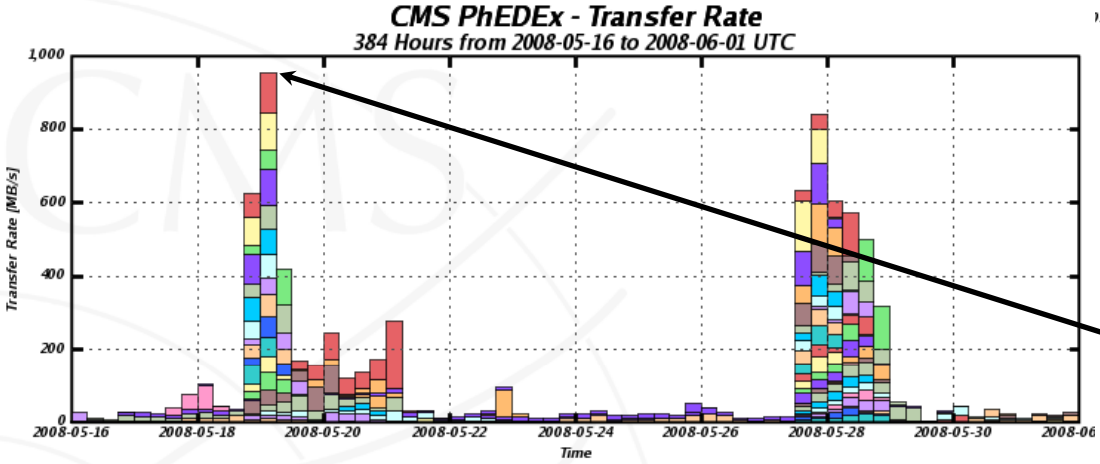
Use of the T1 Facility

- The Tier-1 Facility Performed very well during the two Challenges
  - Transfers

300MB/s from CERN



Import Metrics met Transfer metric for FNAL from CERN was 168MB/s averaged over 3 days.



Export Metrics Exceeded
FNAL exported to
31 Tier-2 sites
peak rate reached 950MB/s

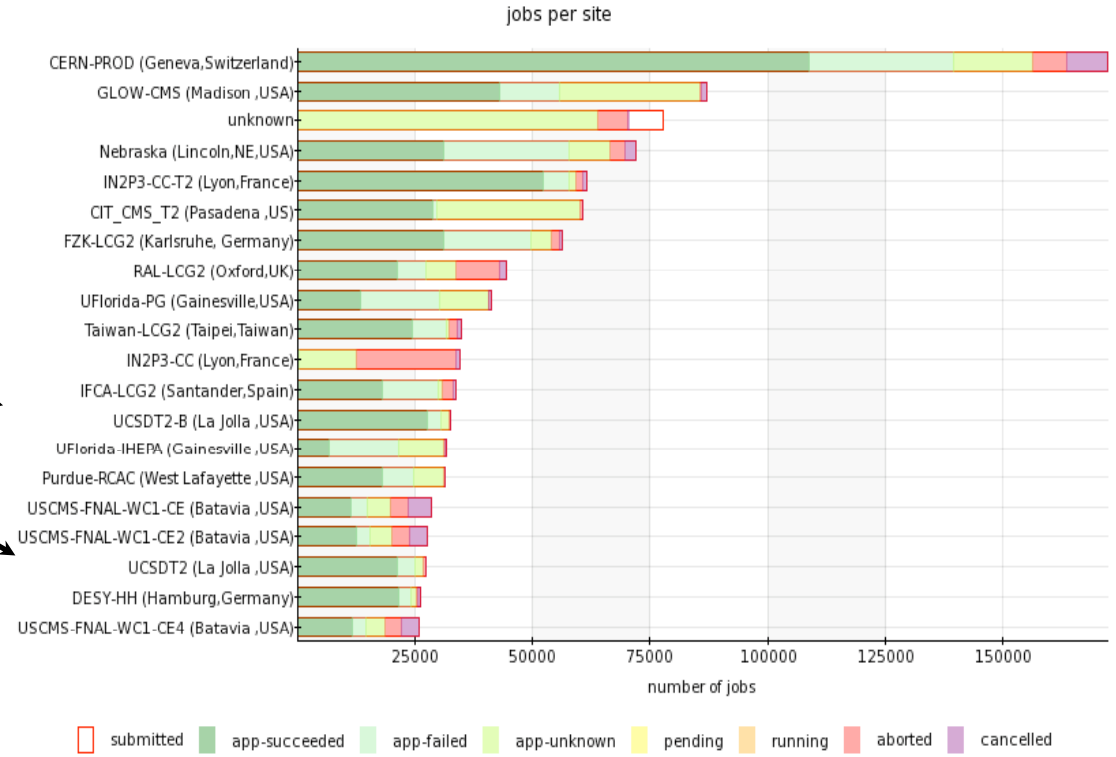
950MB/s from FNAL

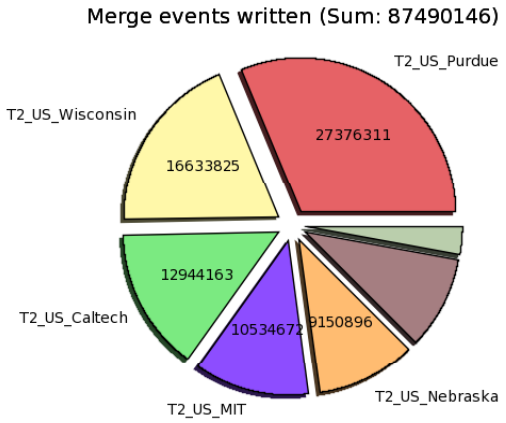
Tier-2s

- US Tier-2s Performed well during the 2008 challenge

Analysis
Jobs Submitted in May
Top 25 Sites

US Tier-2 Sites





US Sites produced almost half the MC produced at Tier-2 centers before and during the challenge
- Good balance of site usage

Offline Status

- **Global runs have been an excellent test-bed for preparation and testing of the offline workflows**

- **Prompt reconstruction at Tier-0**

- **Reconstruction software supports several different configurations**
  Cosmics, beam-halo, pp collisions - with/without B-field

- **CRUZET data have been reprocessed several times to benefit from improved calibrations and alignments**

- **A first working Offline DQM infrastructure has been deployed and used during Global Runs**

Remote Operation Centers

The LHC is a discovery machine and we need to be ready on "day one". Remote Operations Centers allow more of CMS to be engaged. Data transfer and data quality monitoring and remote data analysis tested in cosmic and beam runs. Centers at Fnal and DESY. DQM shifts in progress.

Shutdown Plan

- **Until mid-November, take 300 million events of cosmic ray data at 3.8T with all detectors included in the run**
- **Maintenance of the cooling system will then begin, followed by a program of carefully selected repairs, interleaved with installation of the Preshower.**
- **CMS will then be closed up and returned to a state of cosmic data-taking with and without the magnet on, well before the re-start of the LHC.**

Conclusions

- CMS was ready for first LHC beam
- Practically all detectors fully integrated
  - Missing channels at few % level or less
  - Synchronization at few ns level or better
  - One RPC endcap to be integrated
  - Pre-shower to be installed
- Magnet operational at 3.8T underground
- Trigger ready and synchronized to ~1 bx
  - Fine tuning to be done with beam
- DAQ shown to be capable of handling startup LHC data
  - Final High Level Trigger farm to be commissioned
- Alignment and calibration workflows in place
- Offline SW and data handling ready for beam, monitoring and prompt analysis in operation