Intnl. Conf. on Particle Physics

The Status of CMS

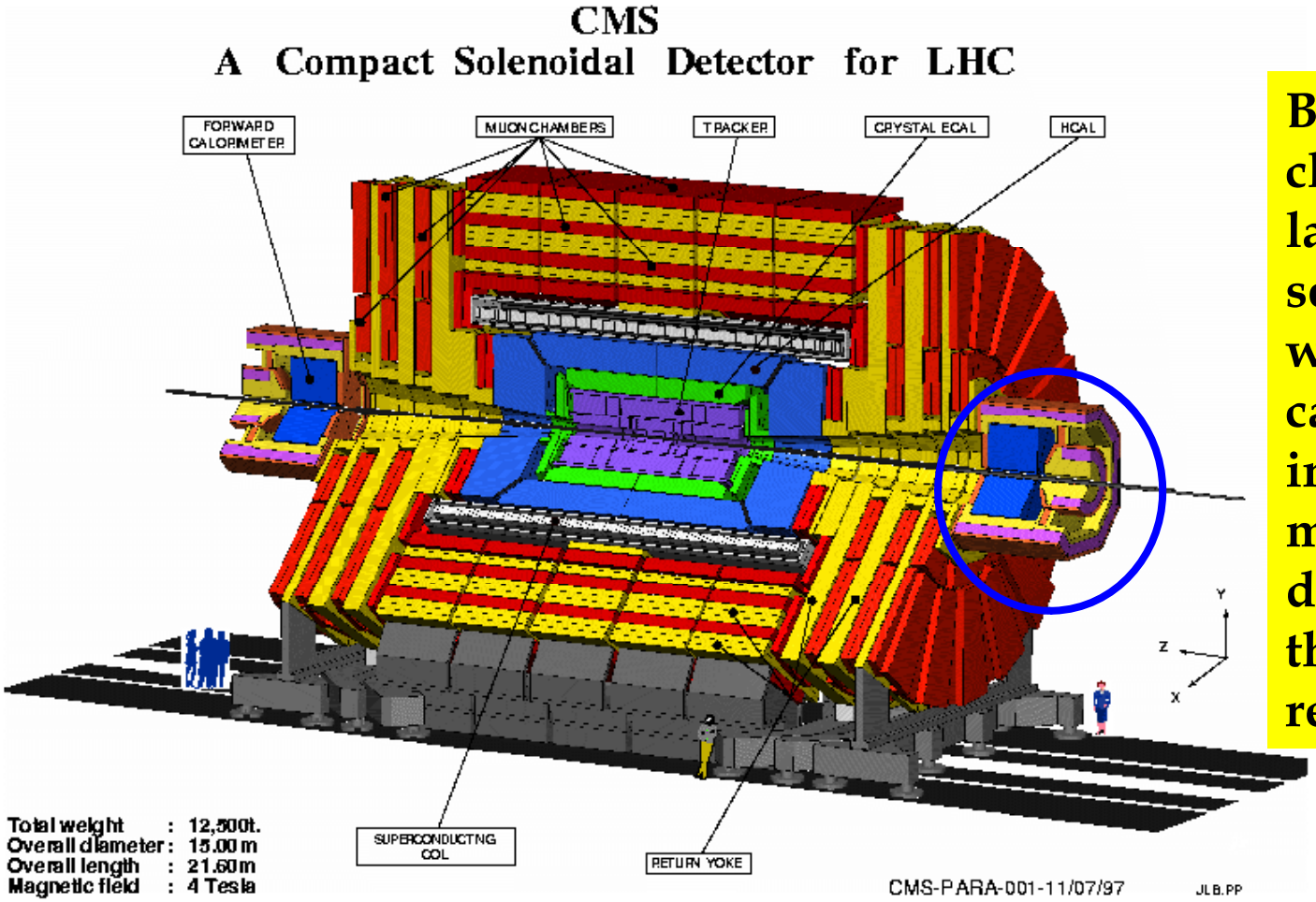
Dan Green

Fermilab

Outline

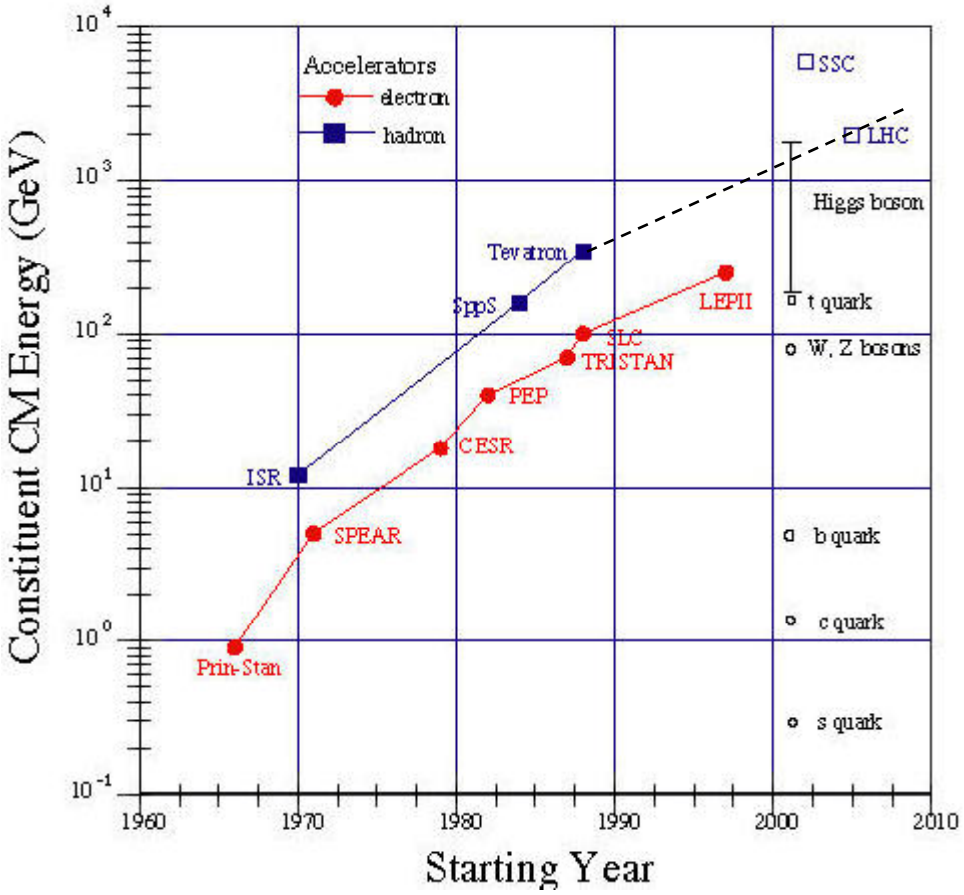
- The Surface Assembly Hall – Magnet Test and Cosmic Rays
- Lowering CMS into the Collision Hall
- Cosmic ray tests in the collision hall
- LHC beam in 2008
- Software and Computing – data and the grid

The Compact Muon Solenoid



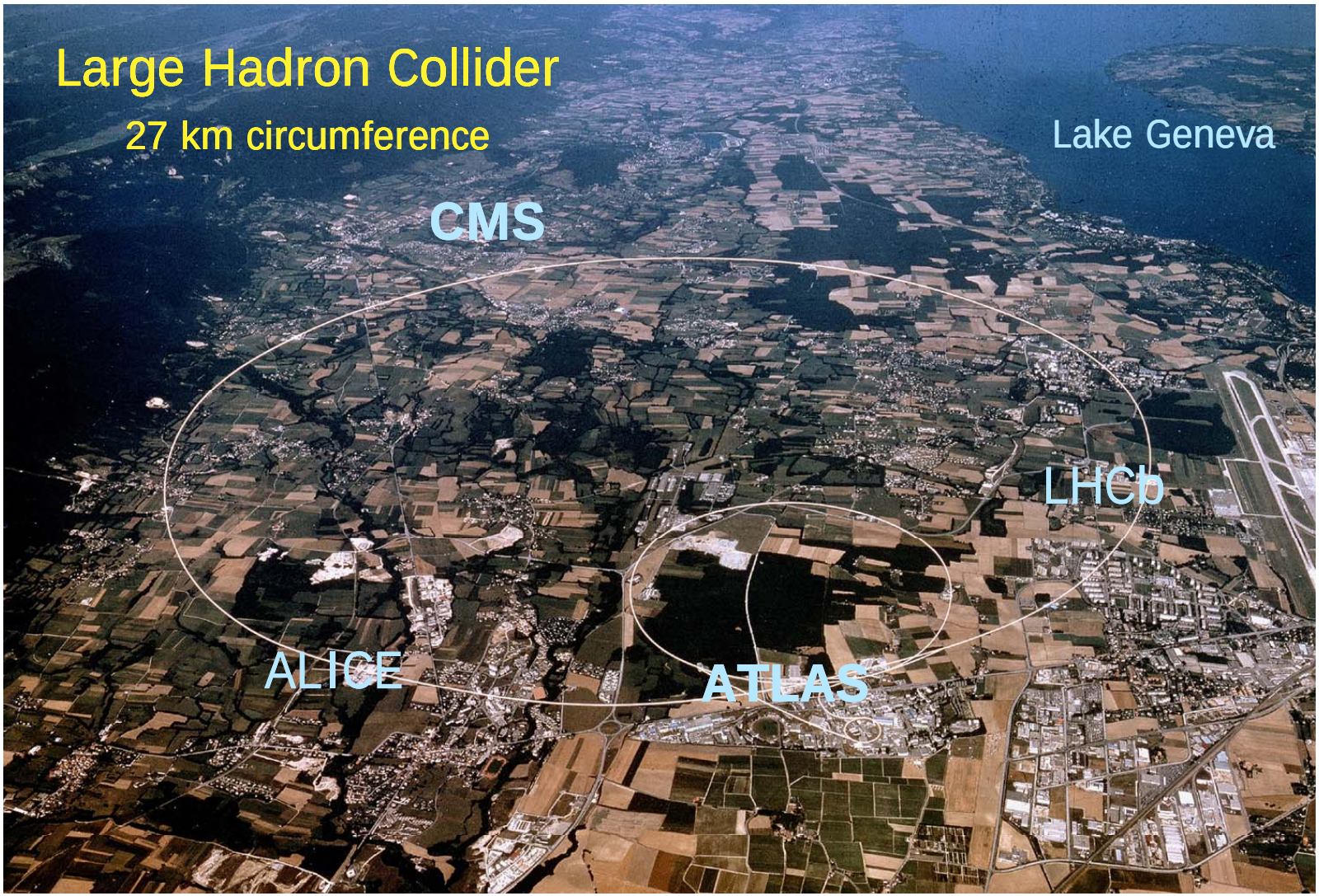
Basic design choice was a large solenoid with calorimetry inside and muon detection in the flux return yoke.

Why the LHC ?



Higher energy means larger mass – up to the TeV mass scale where we know new physics must appear. CMS design follows from the plan to find the SM Higgs boson.

CERN Site

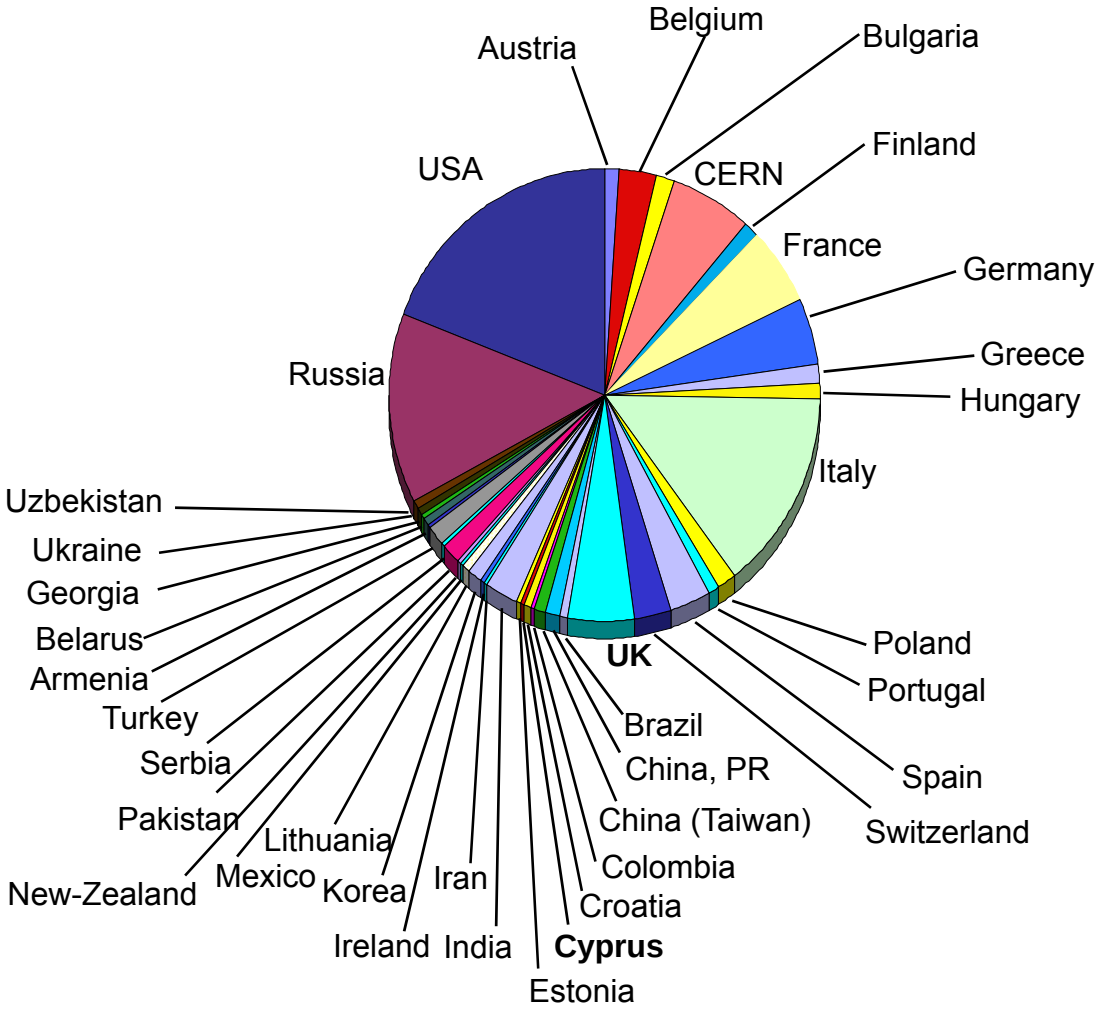

Large Hadron Collider
27 km circumference
Lake Geneva
CMS
LHCb
ALICE
ATLAS

The CMS Collaboration

	Number of Laboratories
Member States	59
Non-Member States	67
USA	49
Total	175

	Nr of Scientific Authors
Member States	1084
Non-Member States	503
USA	723
Total	2310

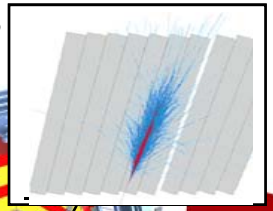
2310 Scientific Authors
38 Countries
175 Institutions

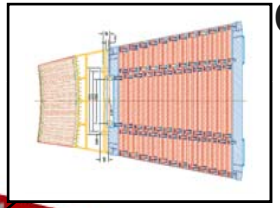


Oct. 3rd 2007/gm

CMS Subsystems

ECAL Scintillating $PbWO_4$ Crystals





CALORIMETERS

HCAL

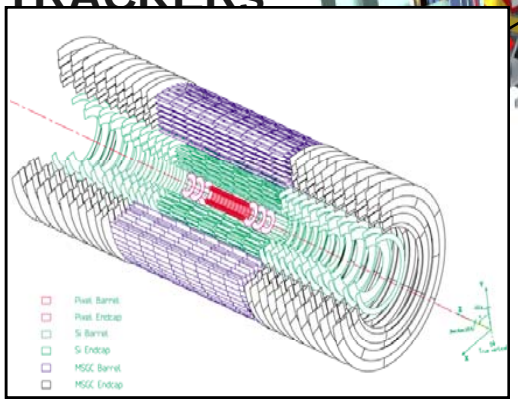
brass Plastic scintillator sandwich

SUPERCONDUCTING COIL

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

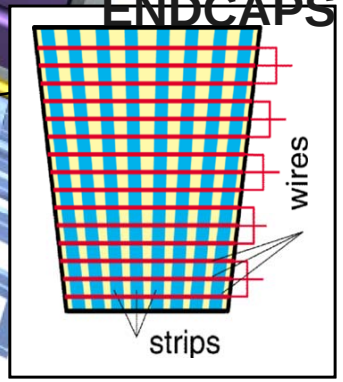
IRON YOKE

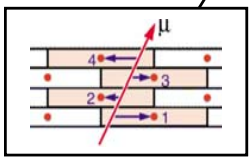
TRACKERs



Silicon Microstrips
Pixels

MUON ENDCAPS





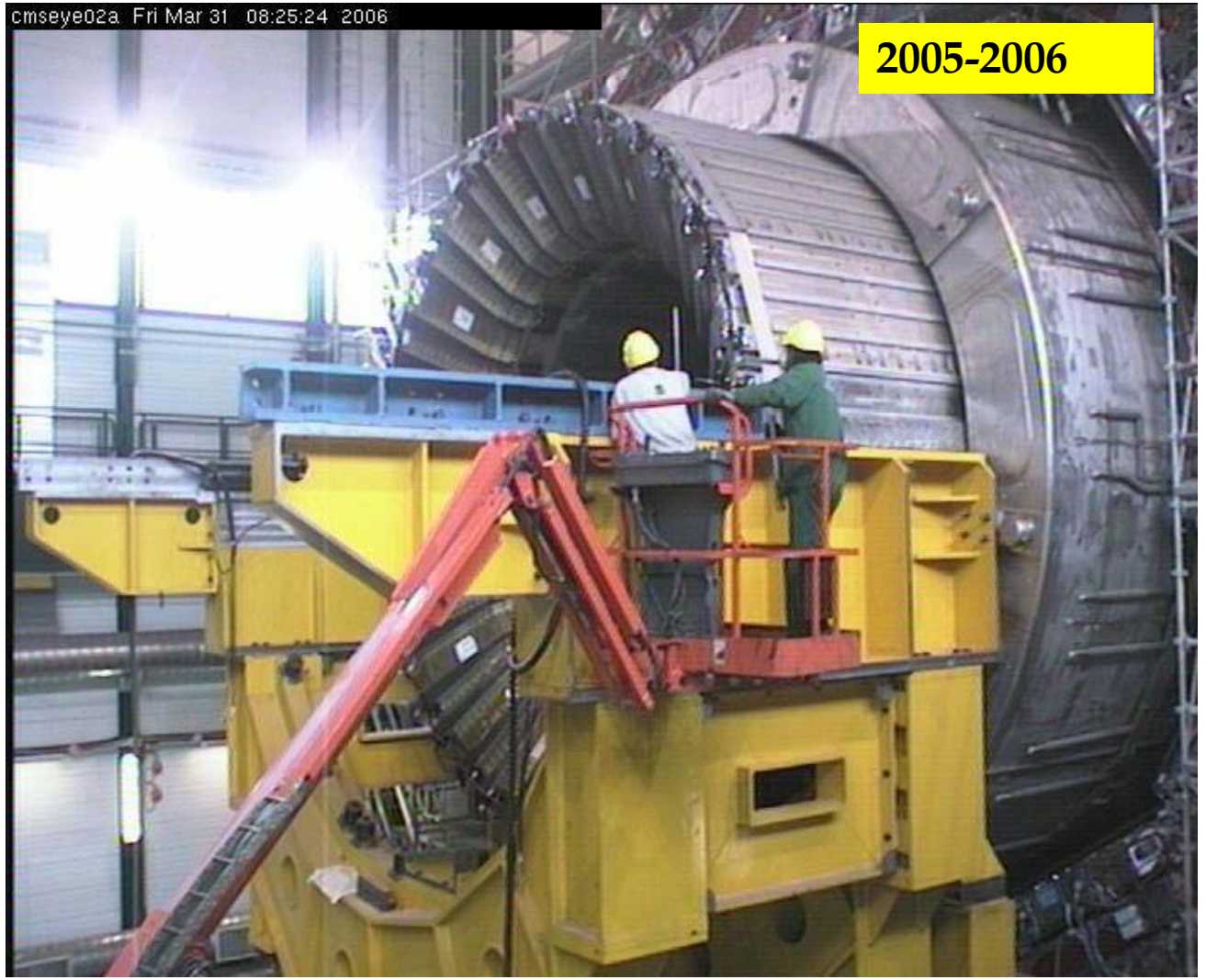
Drift Tube Chambers (**DT**)

Resistive Plate Chambers (**RPC**)

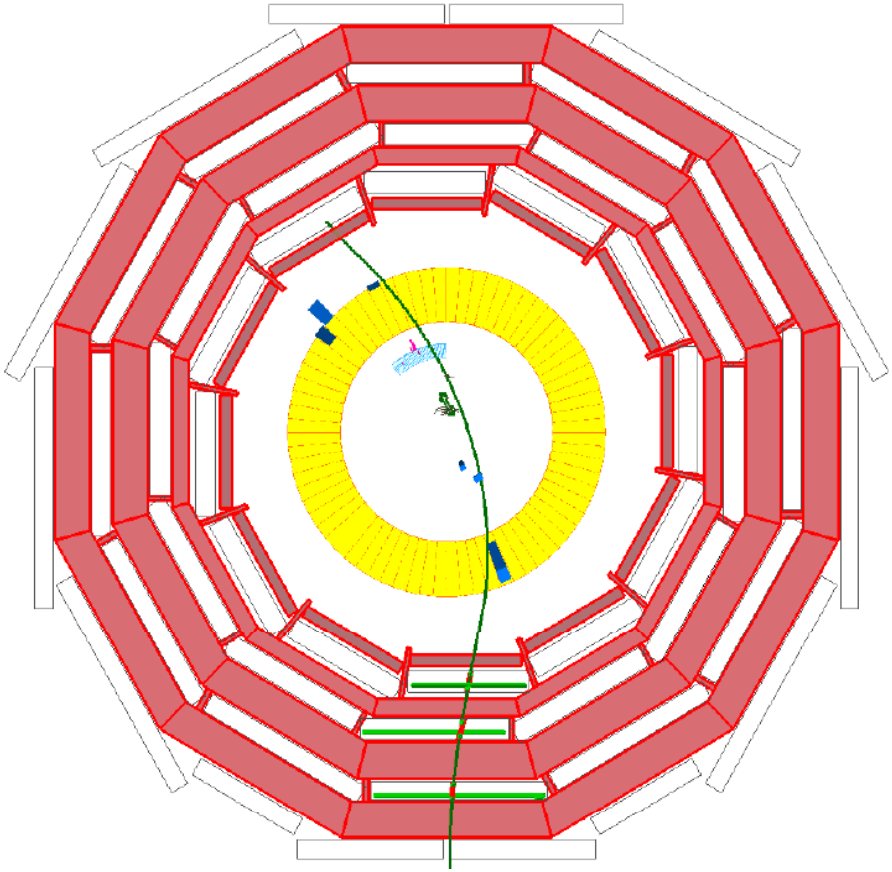
Cathode Strip Chambers (**CSC**)
Resistive Plate Chambers (**RPC**)

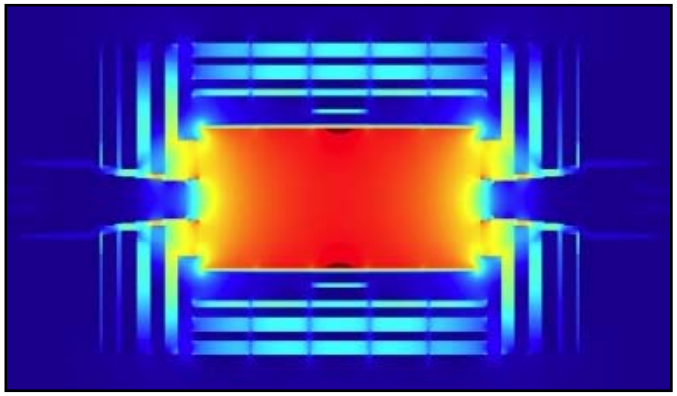
MUON BARREL

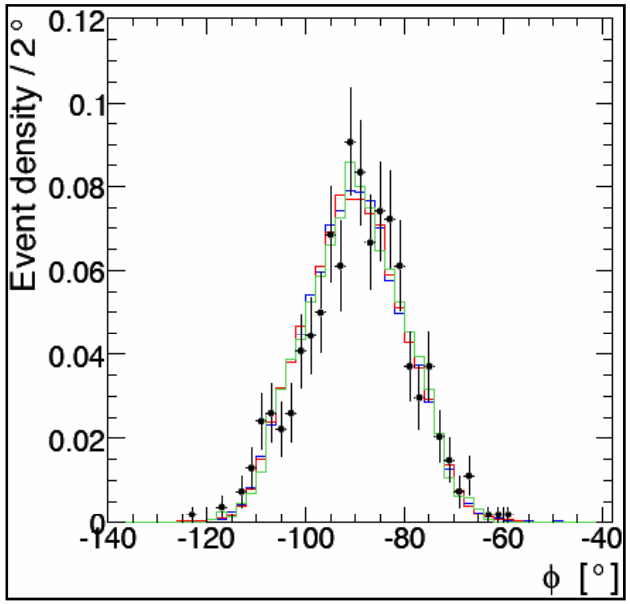
Assembly Hall – SX5



Magnet Test – Fall 2006

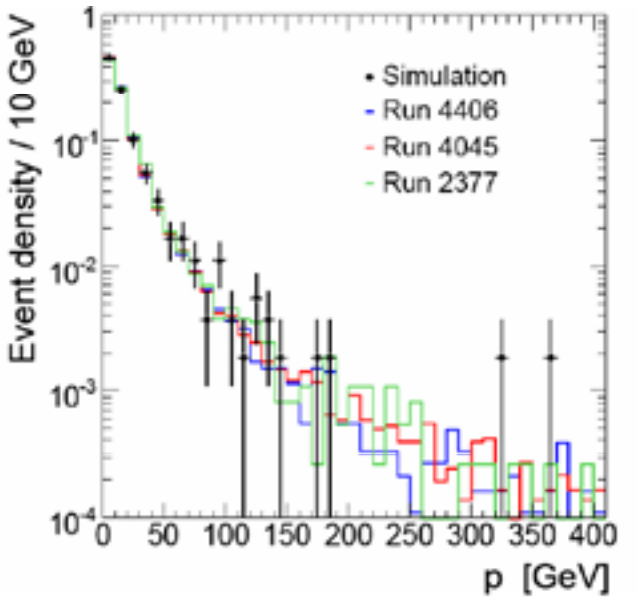


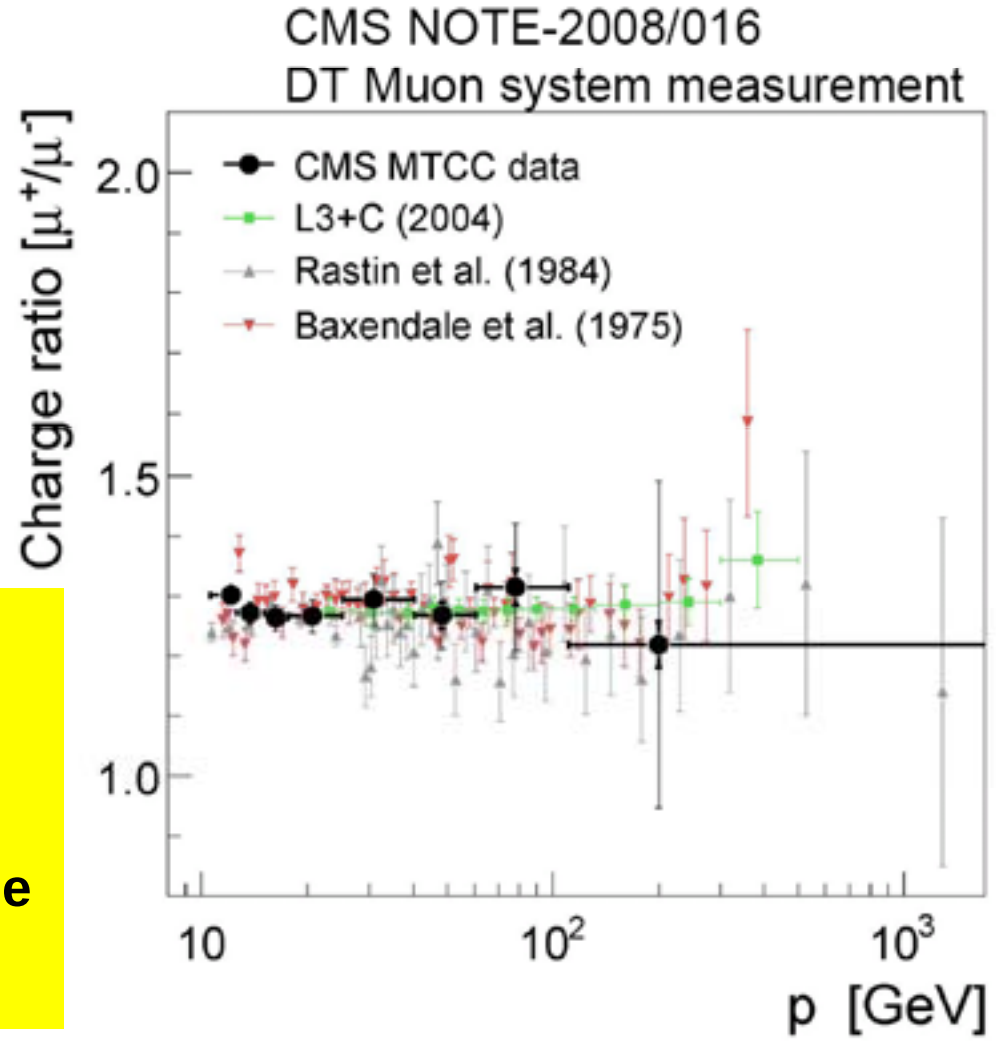




Field map, muon RECO, HCAL readout. Test synchronizing CMS subsystems

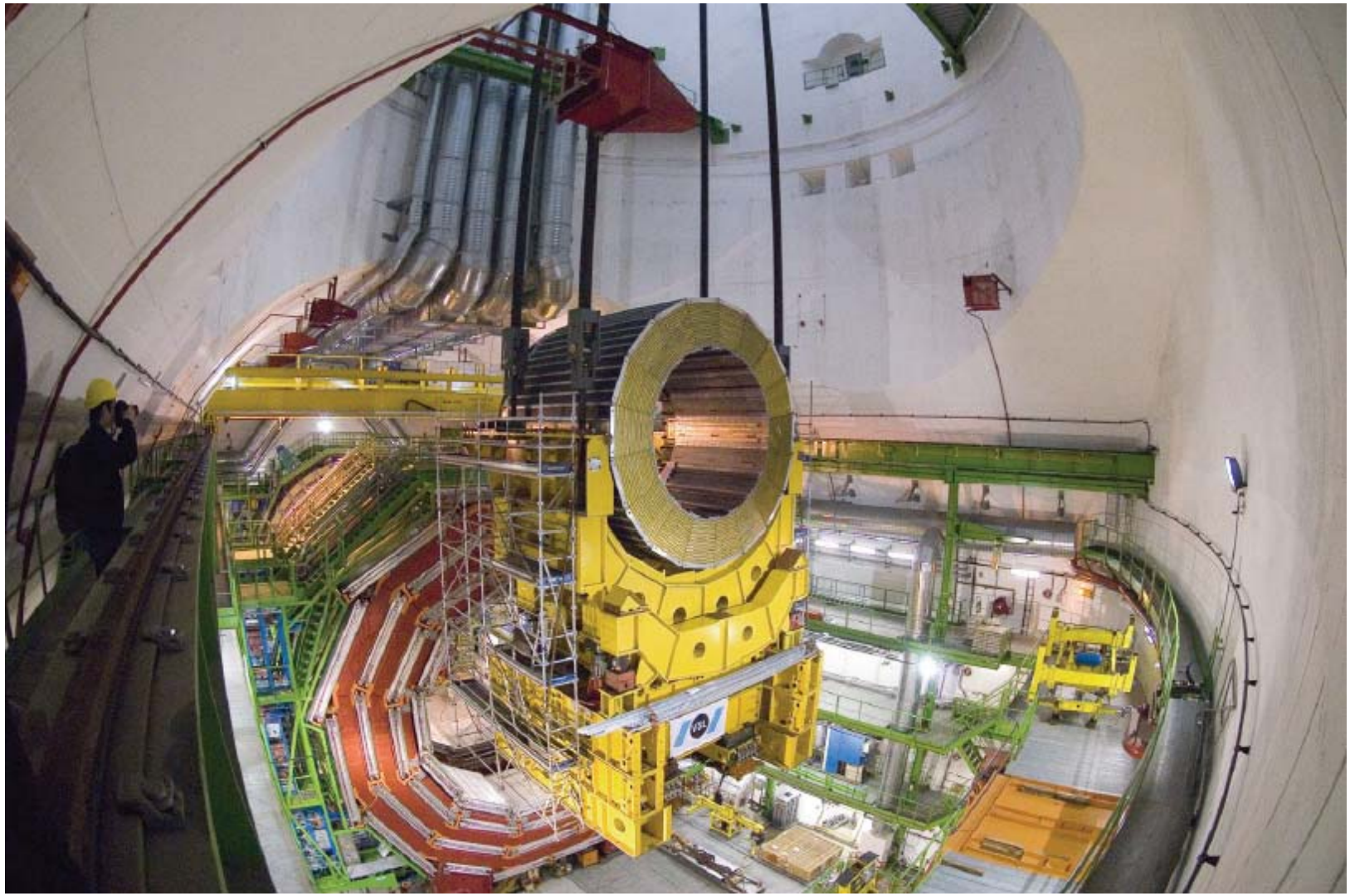
Cosmic Muon - Spectra



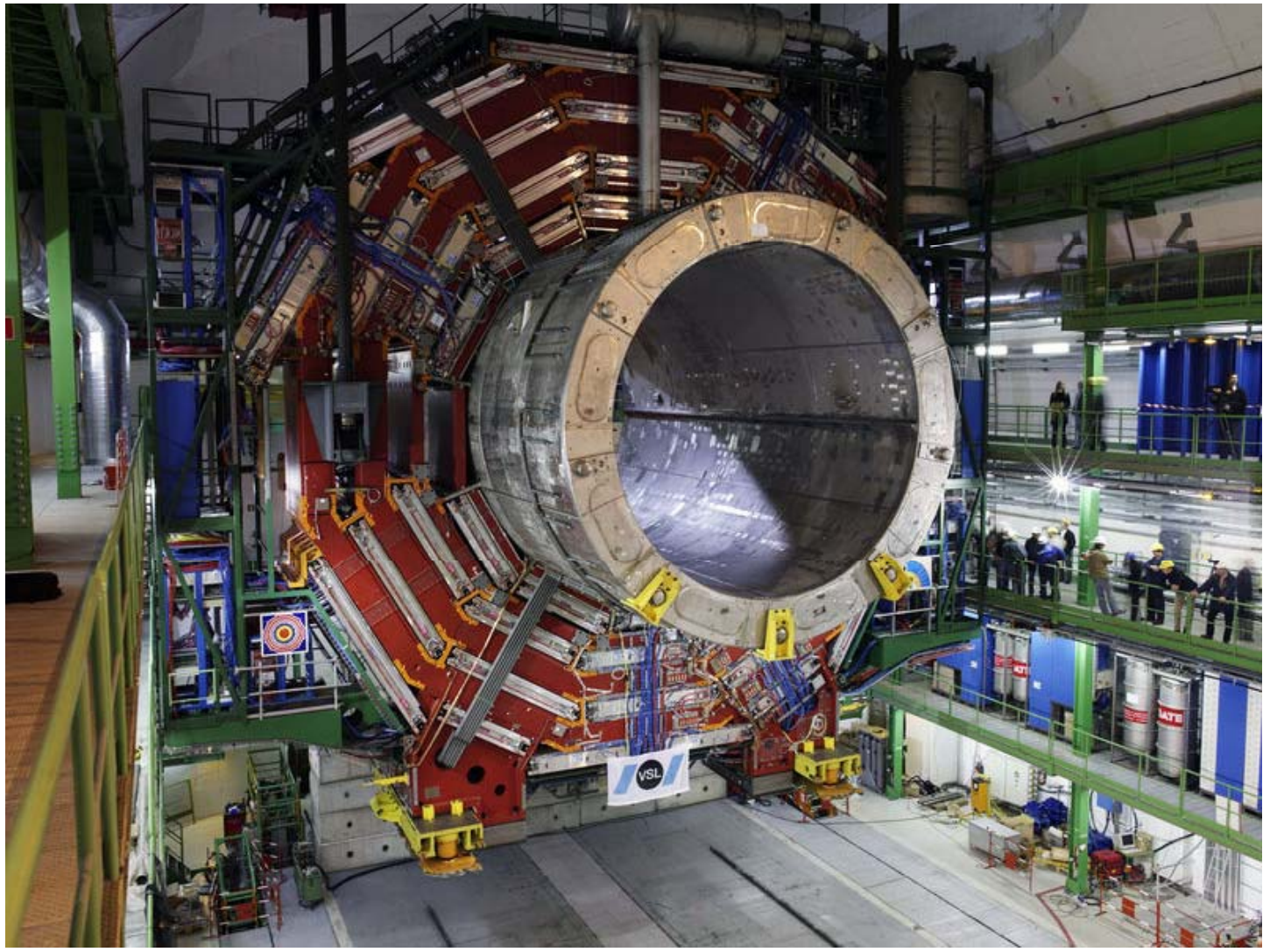


Magnet test: alignment of the muon system. Movement in 3.8 T field tracked. Checked to be "elastic". Extract charge ratio for cosmic rays.

Lowering HB – Feb, 2007

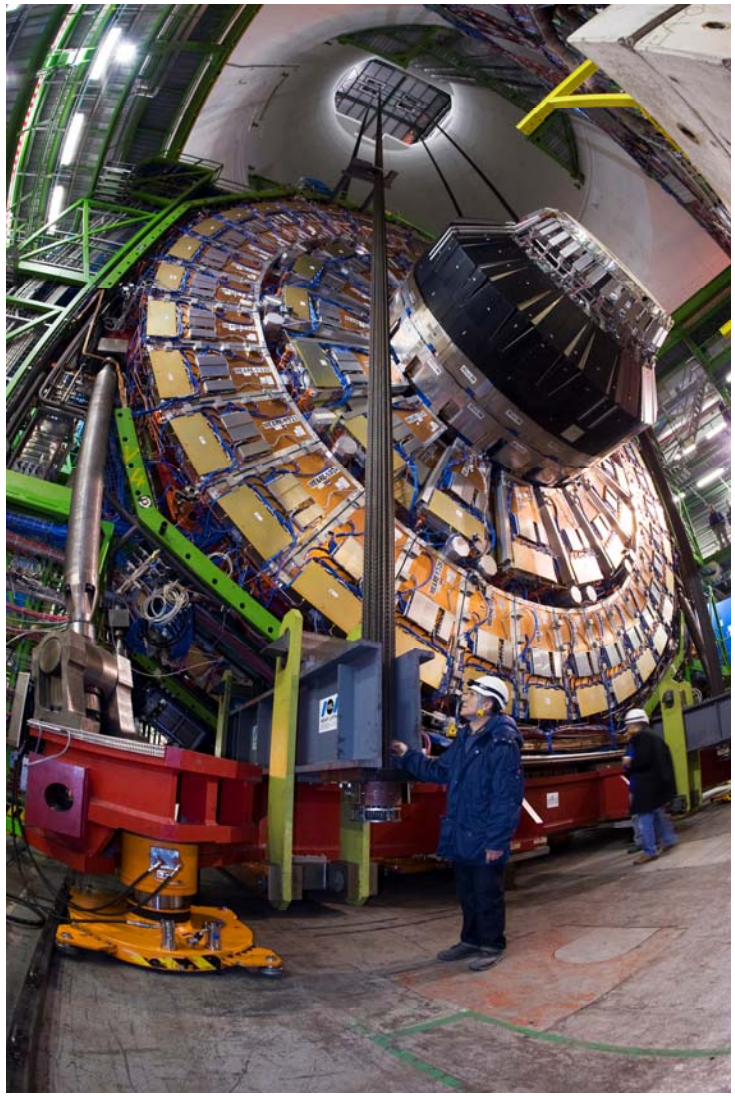


Lowering into Collision Hall

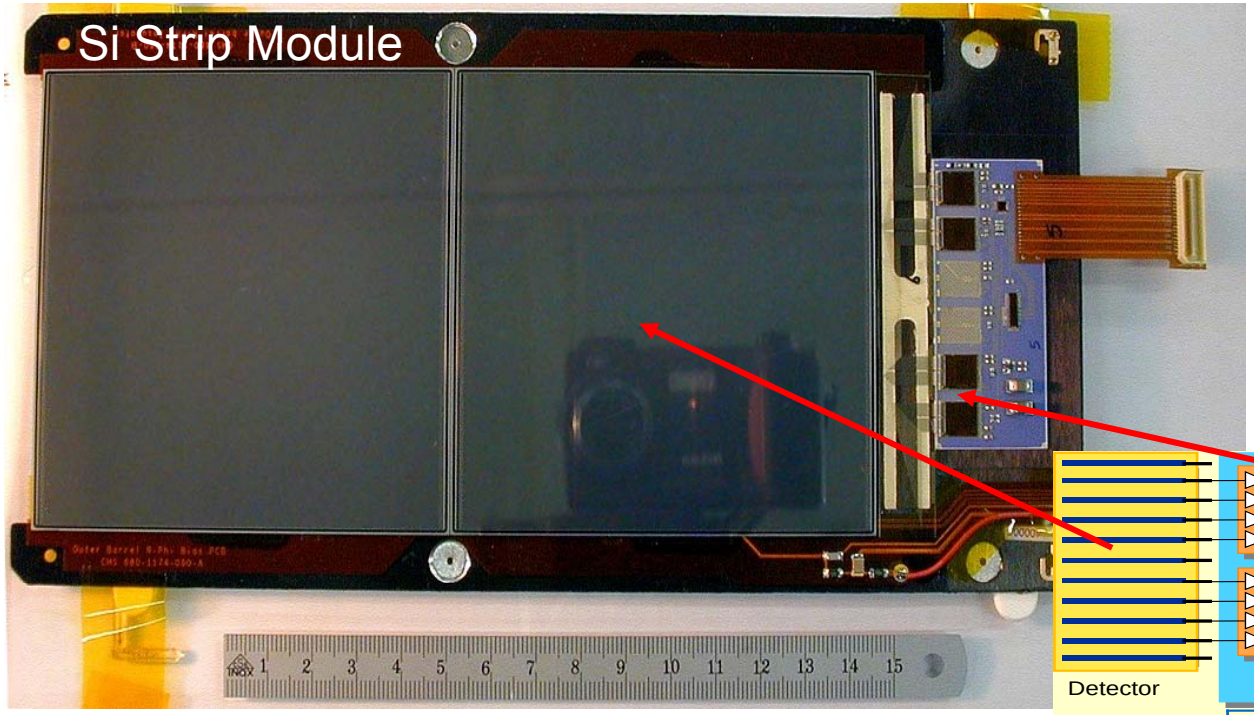


Jan., 2008 - Lowering of YE-1

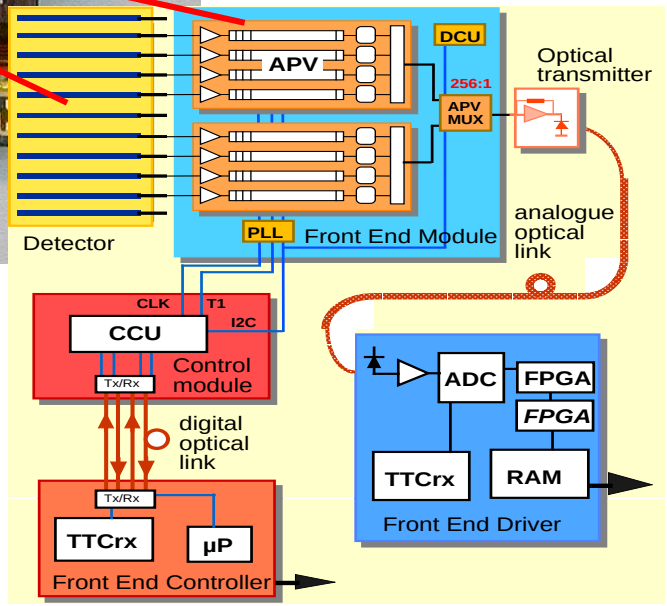
January, 2008 – the last heavy element of CMS is lowered into the collision hall. The silicon strip Tracker, the silicon Pixels and the endcap ECAL remain to be installed.



CMS: All Si Tracker

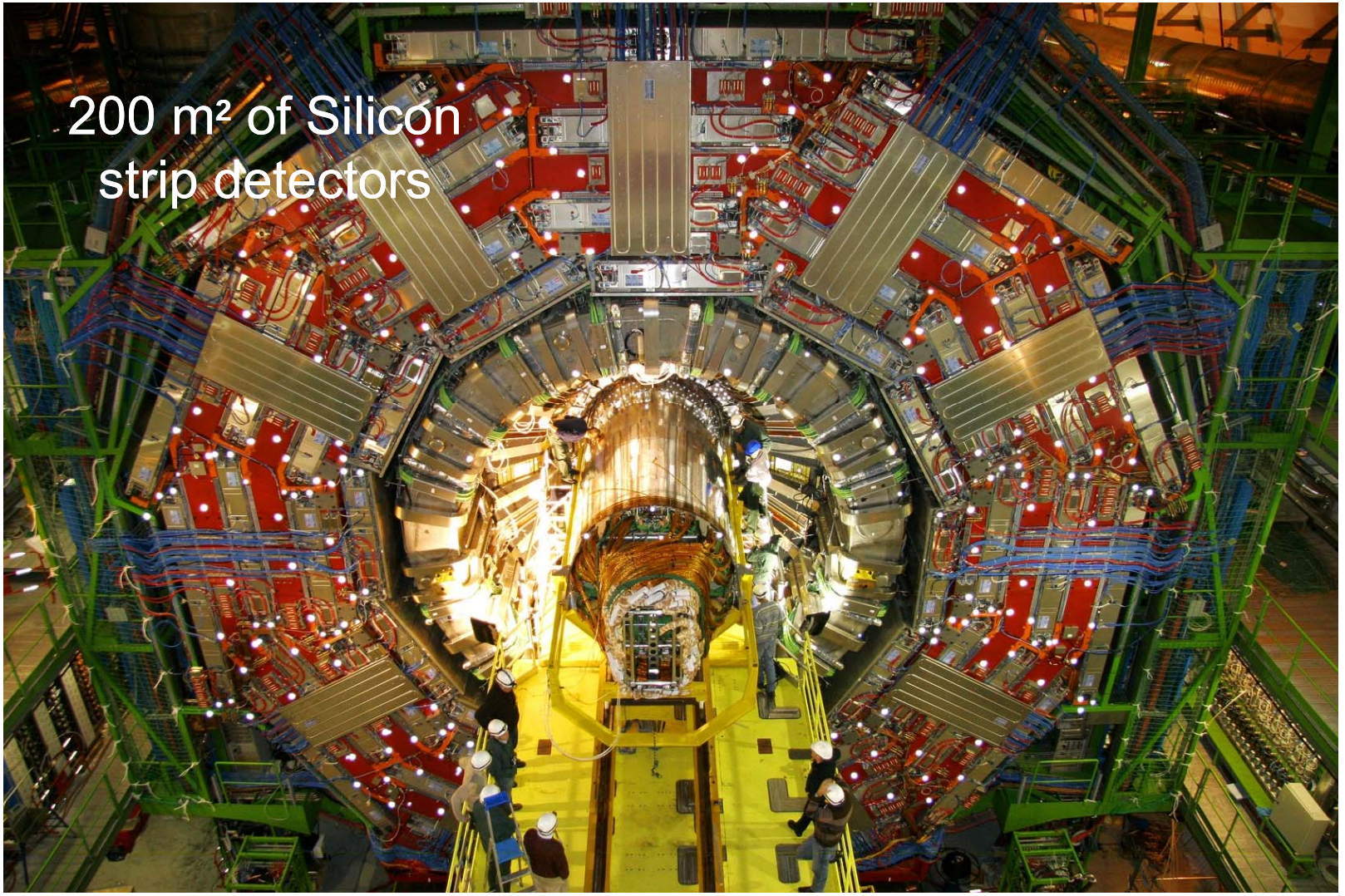


75k chips using 0.25μm technology

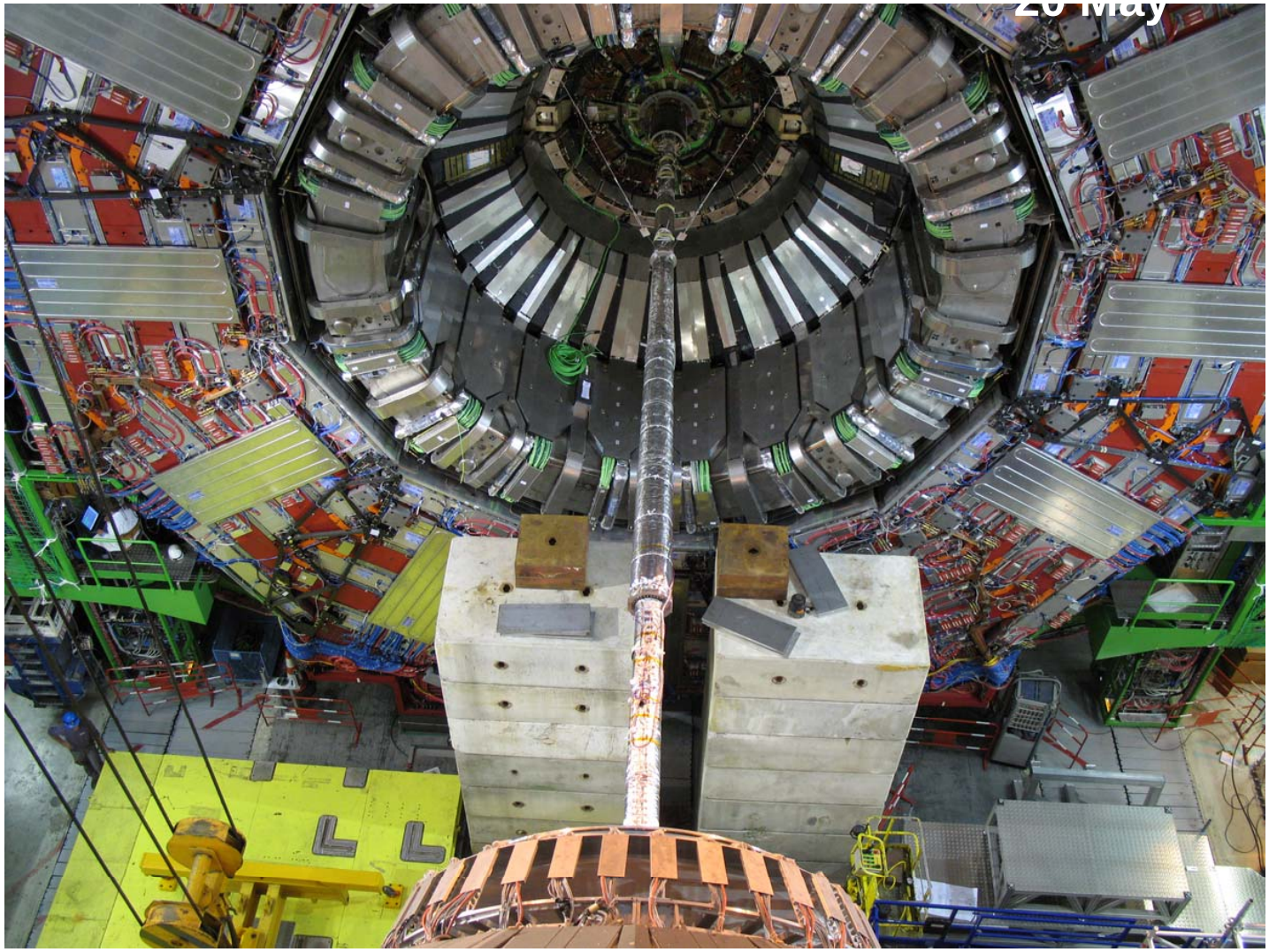


~ 17,000 modules
200 m^2 of high purity silicon sensors
10 M electronic channels

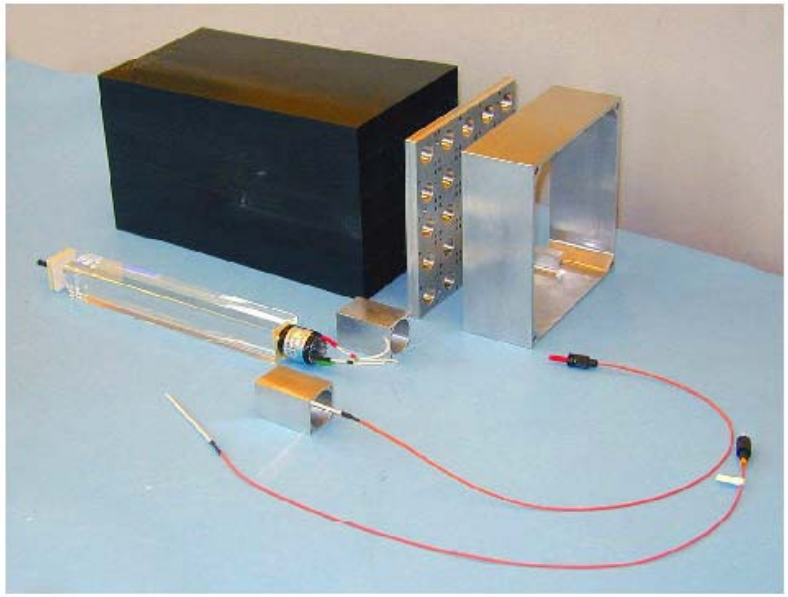
Tracker Insertion (Dec'07)

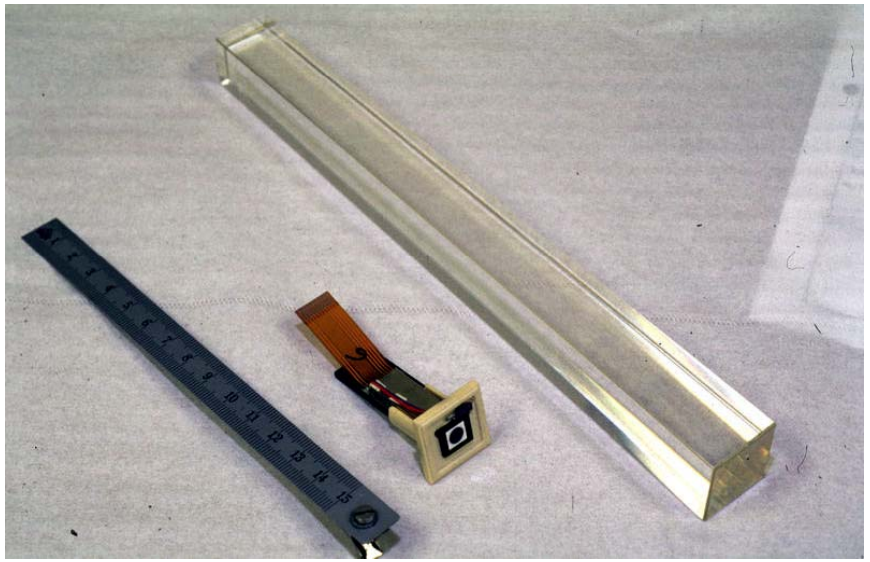


Beam-pipe Installed, May' 08



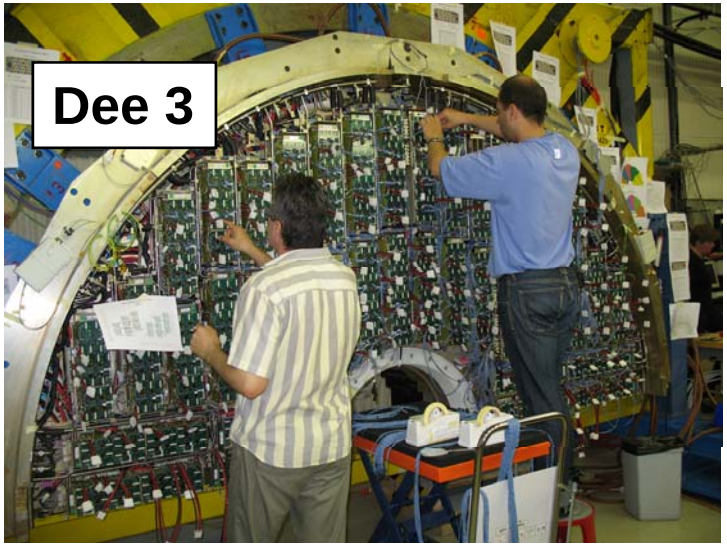
ECAL - PbWO4 Crystals



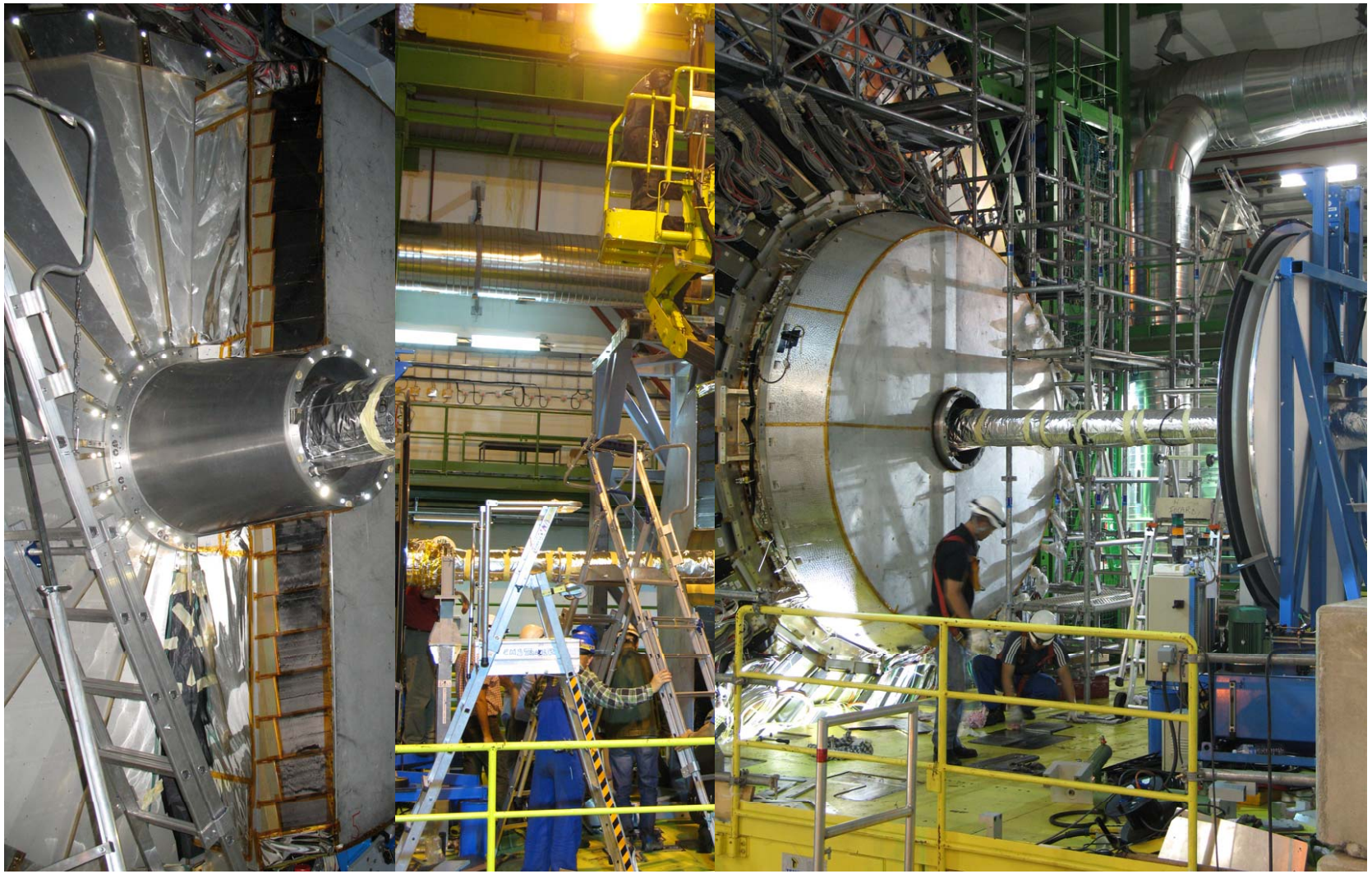


Fully active EM calorimetry. Depth of ~ 20 cm ➔ compact. Radiation hard crystal (SIC), photo transducer (APD) works in 4T field

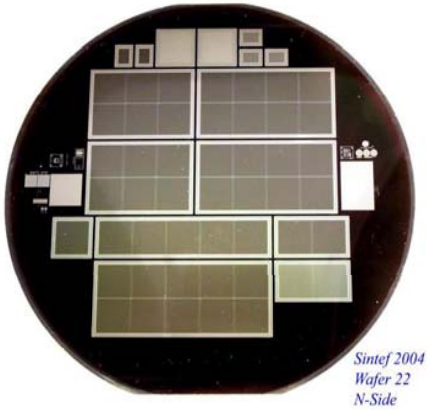
ECAL Endcaps



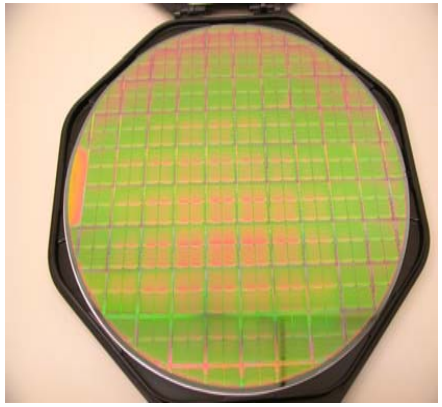
ECAL EE – Summer 2008



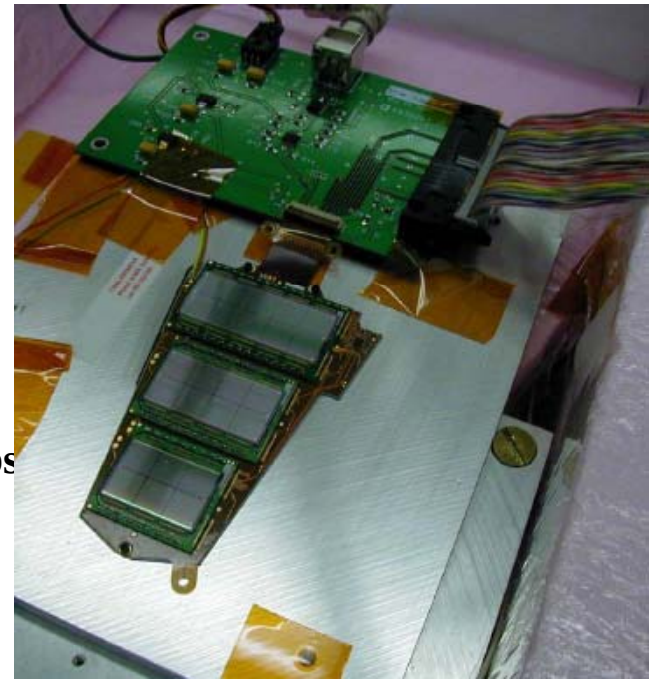
CMS – F Pixels

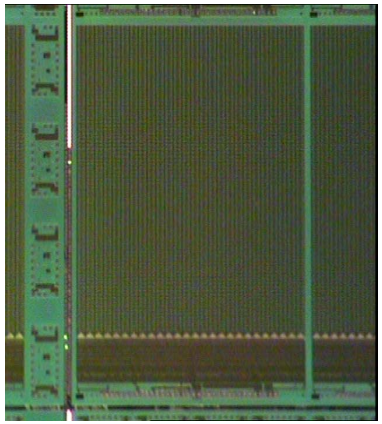


Pixel sensor wafer showing various sizes needed to form “panels”



Wafer of pixel readout chips

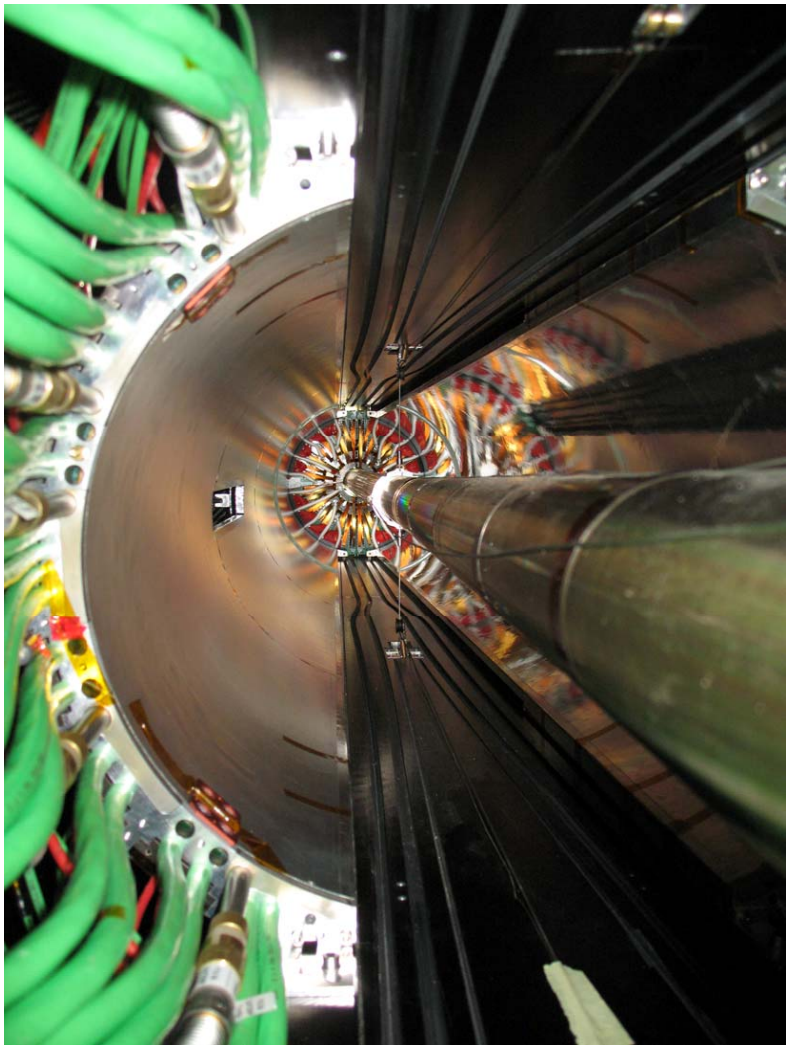




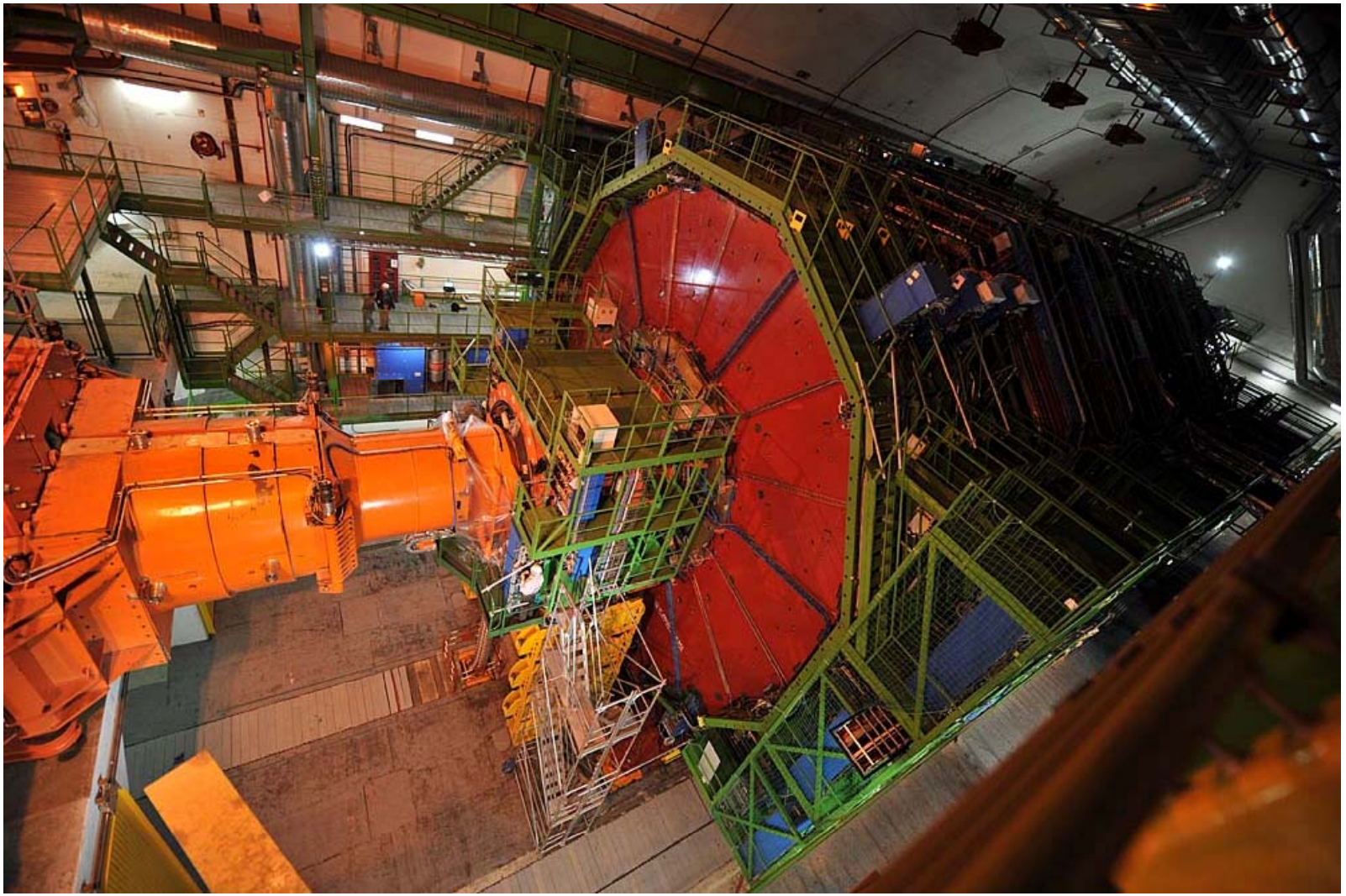
Pixel readout chip: 4160 pixels 100 x 150 μ^2

Bump bonded detectors received from vendors

Barrel Pixels – Aug. 2008



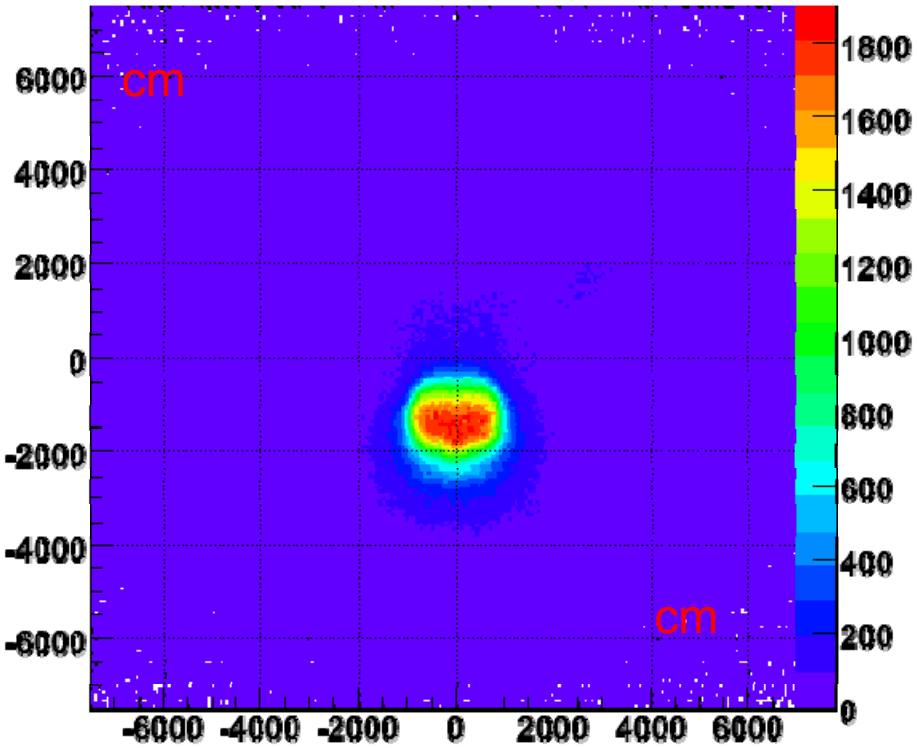
Final Closure – Sept.'08



Muon Chambers - Cosmic Ray Data

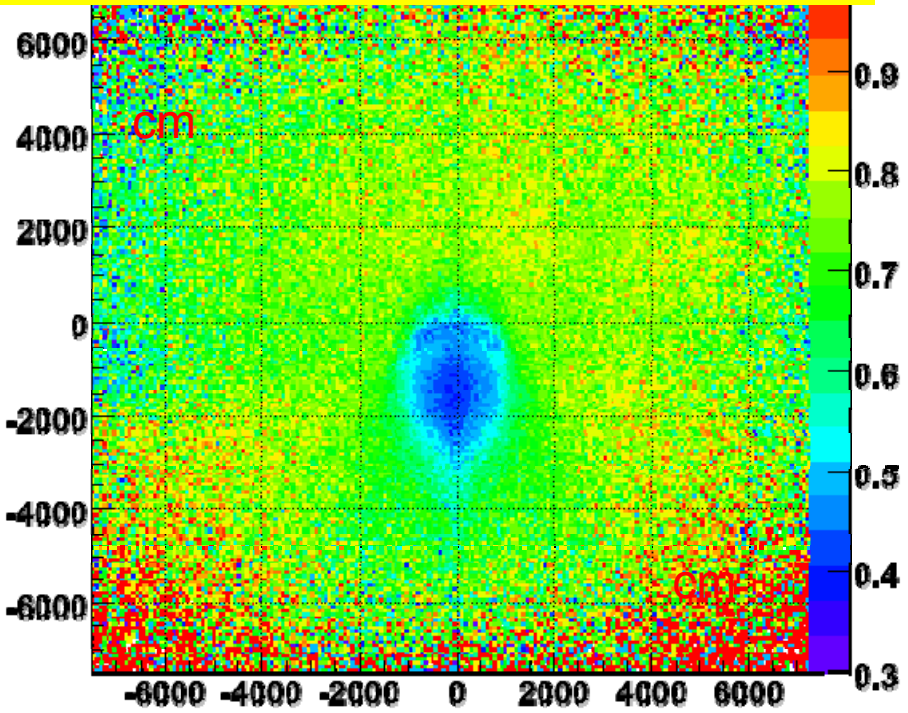
Cosmics tracks extrapolated to the surface

Can clearly see the shaft !

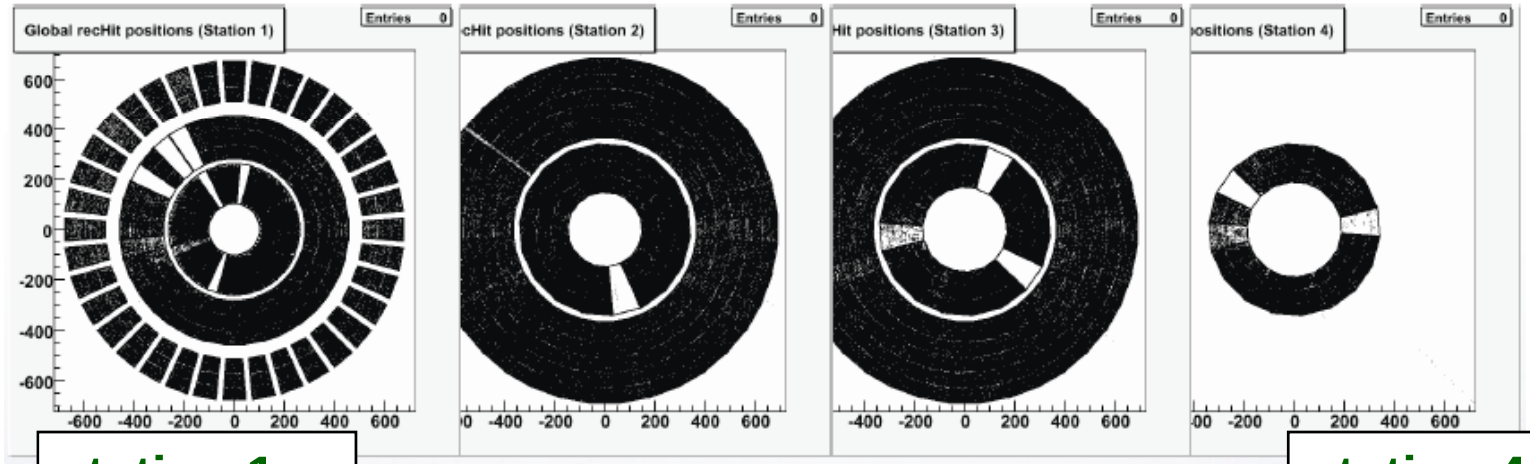


Probability of at least one track segment to be found at bottom if track reconstructed at top

projected to the surface
⇒ shaft muons are softer

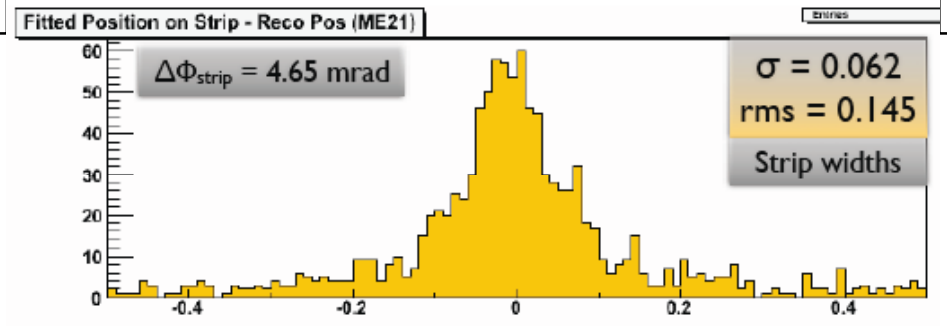


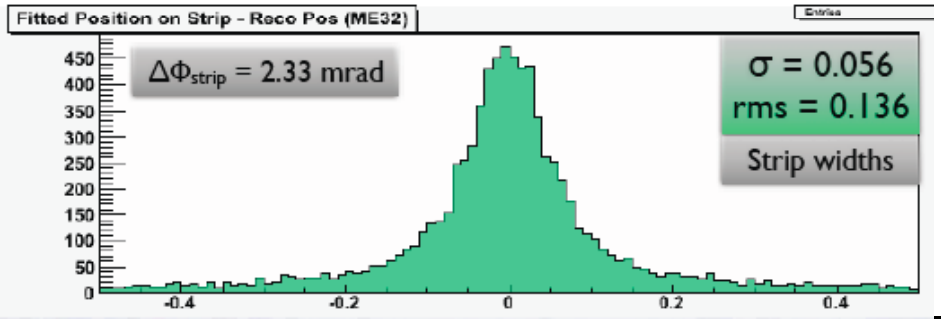
Alignment with Cosmic Rays



station 1

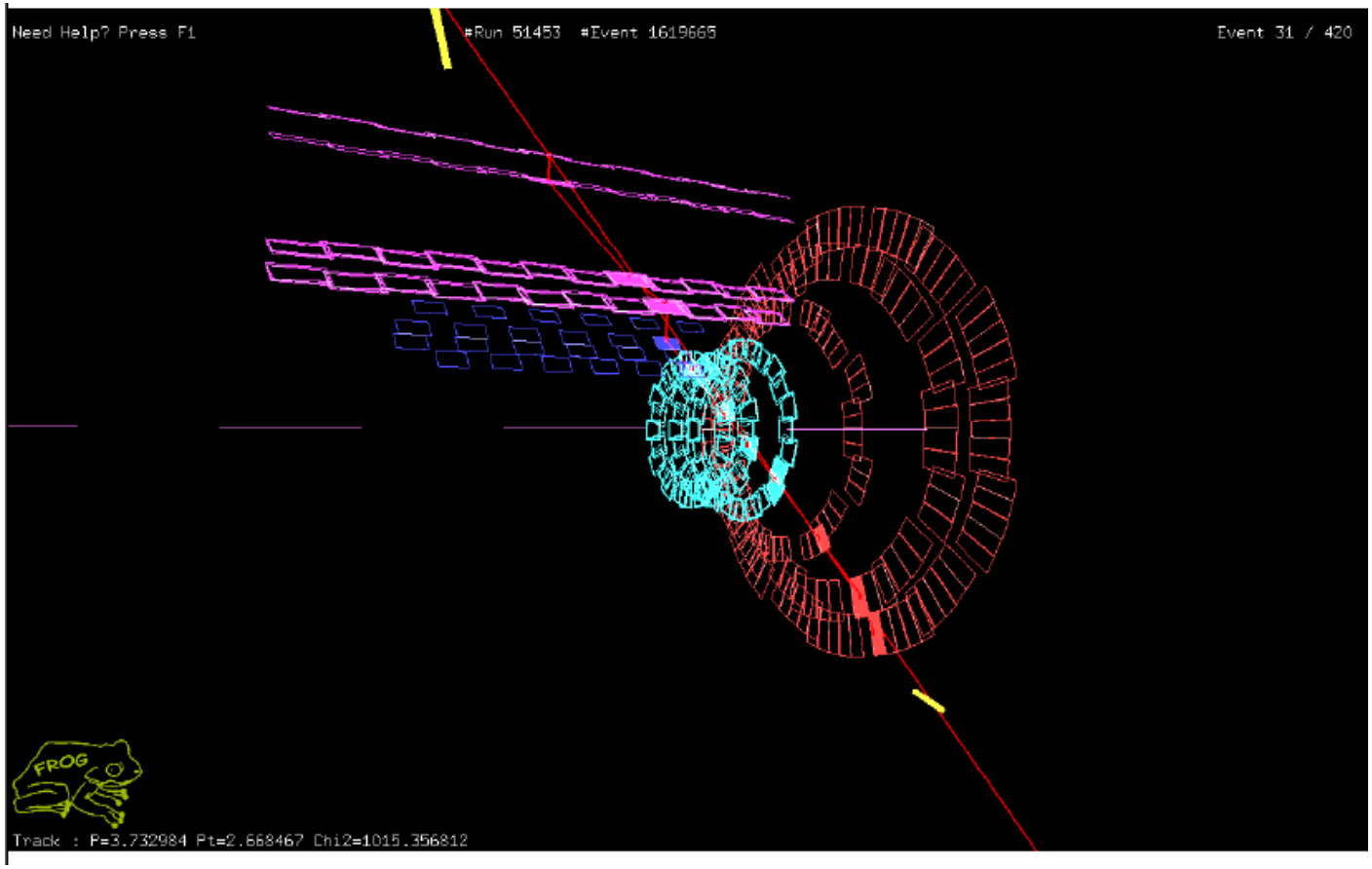
station 4



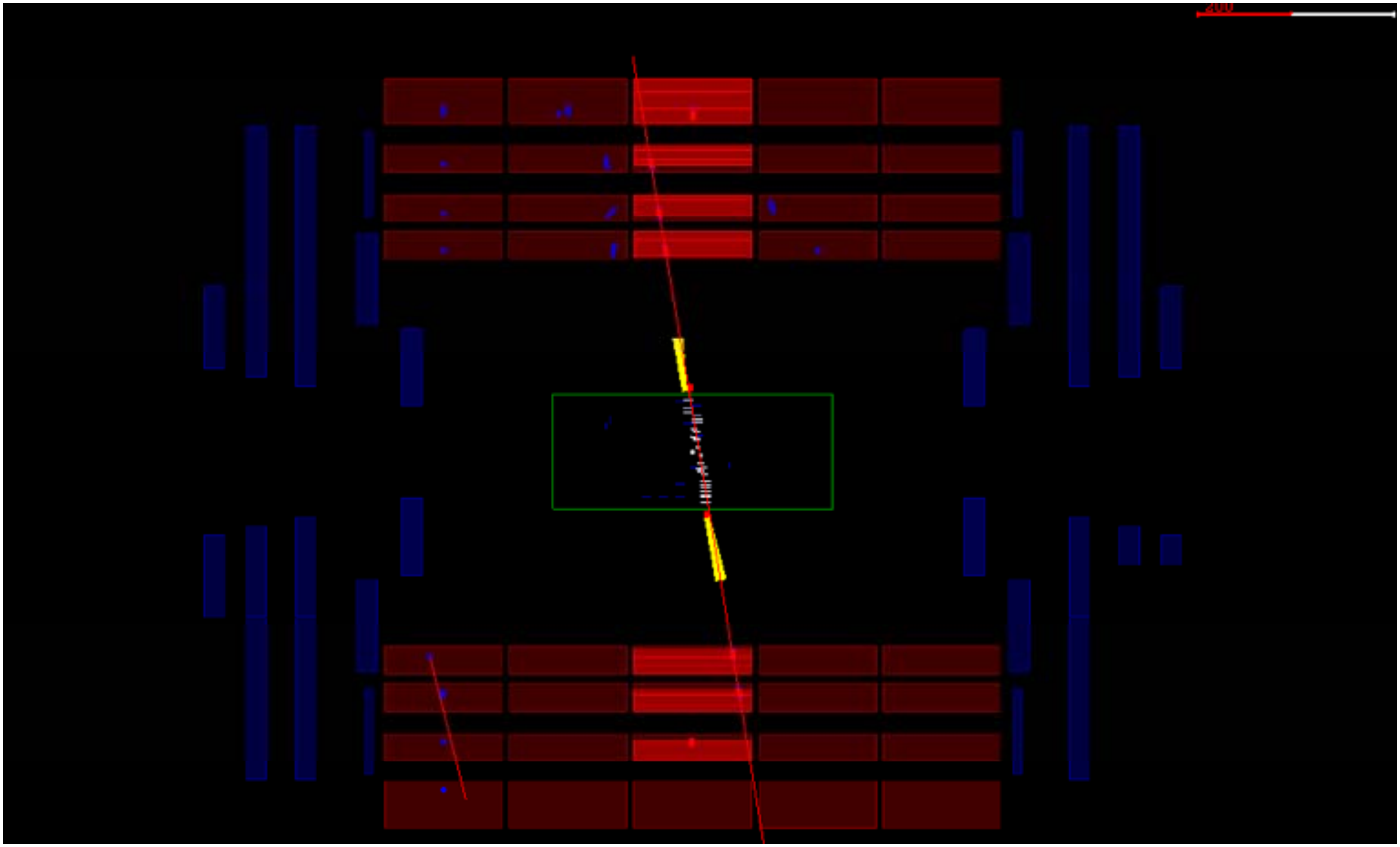


Strip Tracker - Cosmics

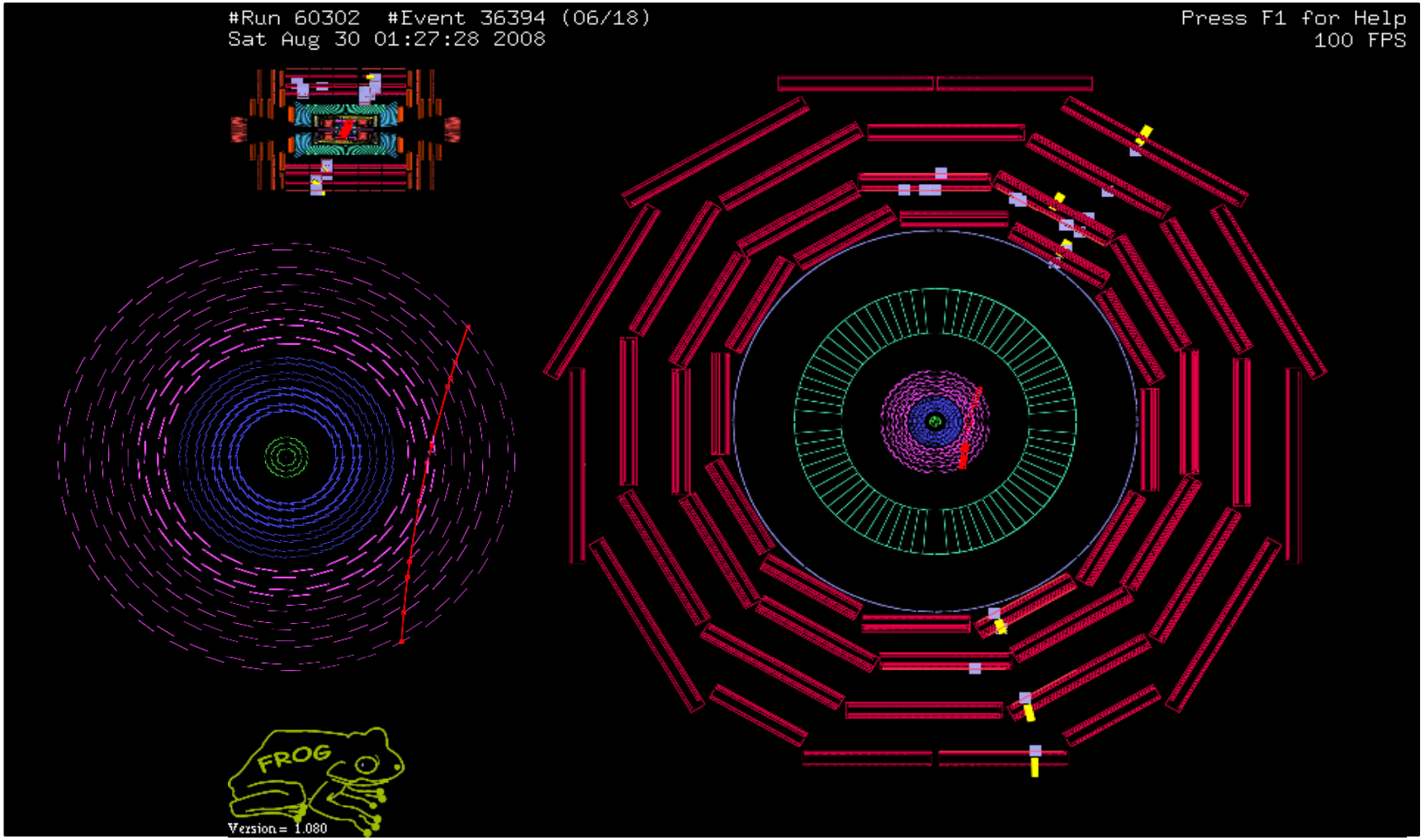
Tracker joined global runs in July, 2008



Muon Cosmic with Tracker

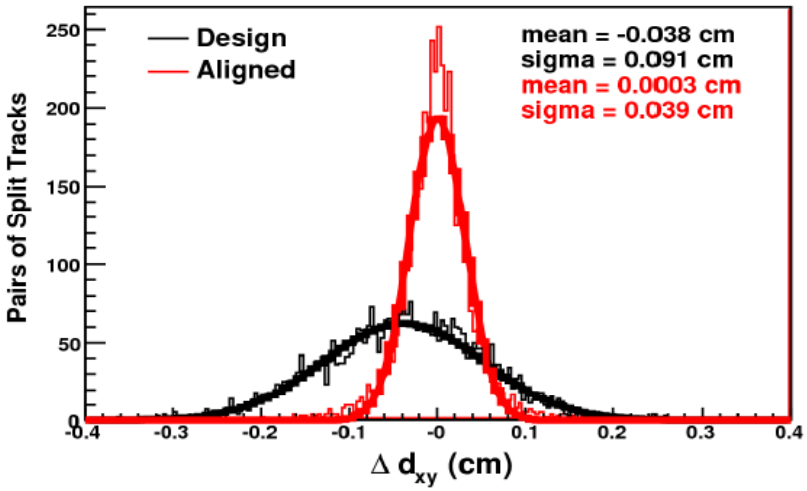


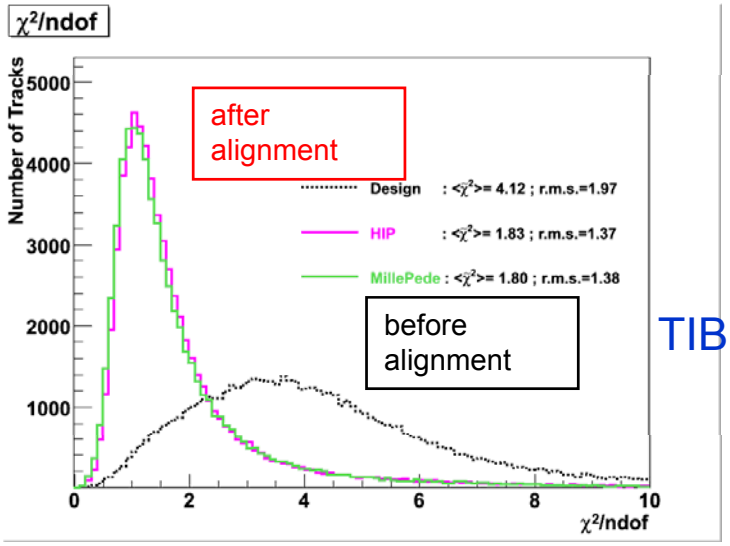
Magnet On Tracker - Muon



Tracker Alignment

CRUZET4





TIB

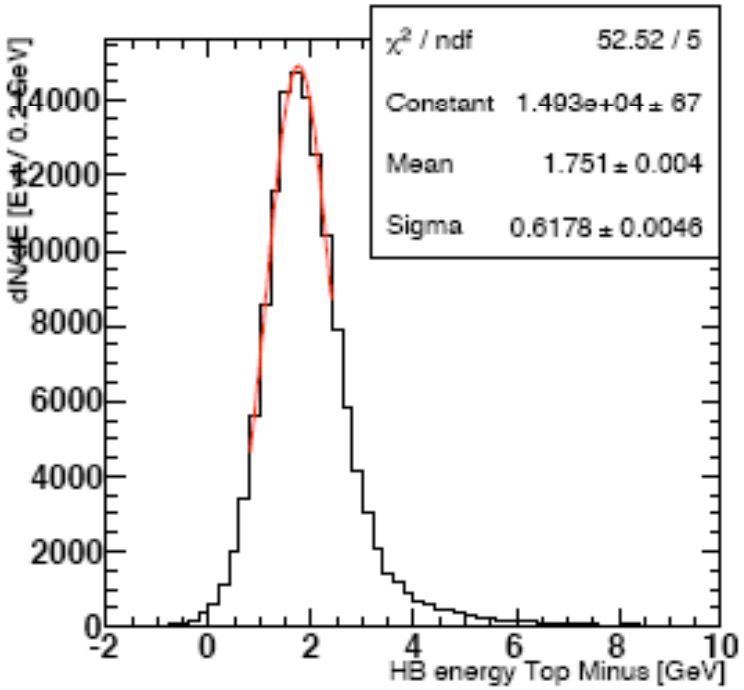
Transverse impact point – using cosmics to align tracker. Aim to have the Tracker pre- aligned using momentum analyzed cosmic ray muons.

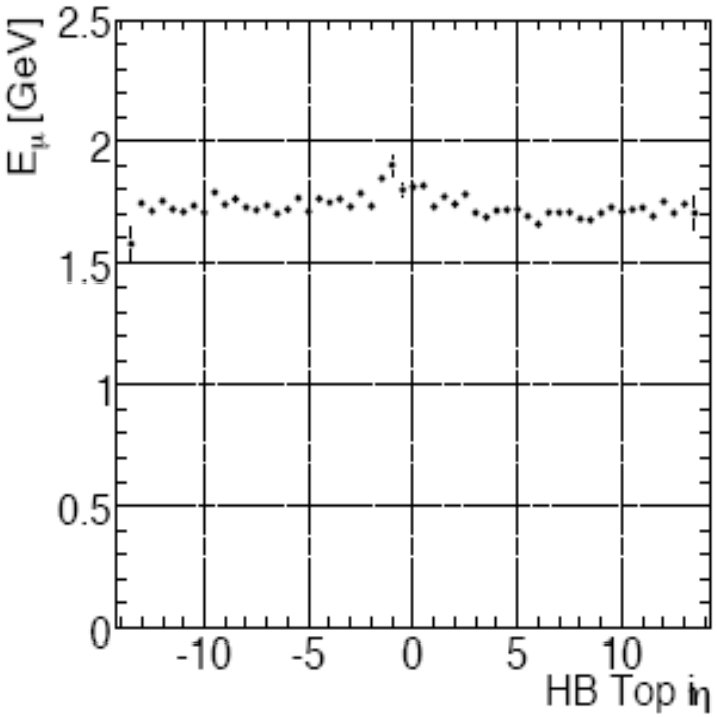
HCAL Calibration – Muons/Sources/Test Beam

Calibration validation: HB-DT (Muons)

Pre-calibration: TB + sourcing data

Validation with cosmic muons



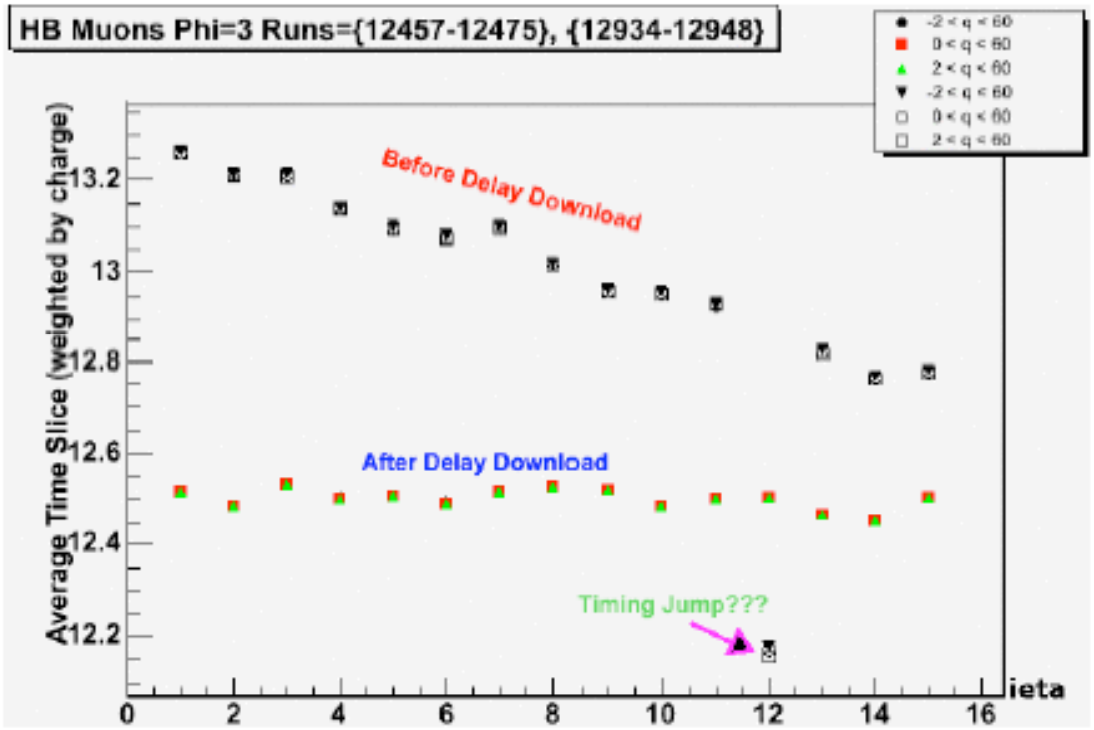


HCAL Timing : Laser – Delay Line Setting

Synchronization: HB

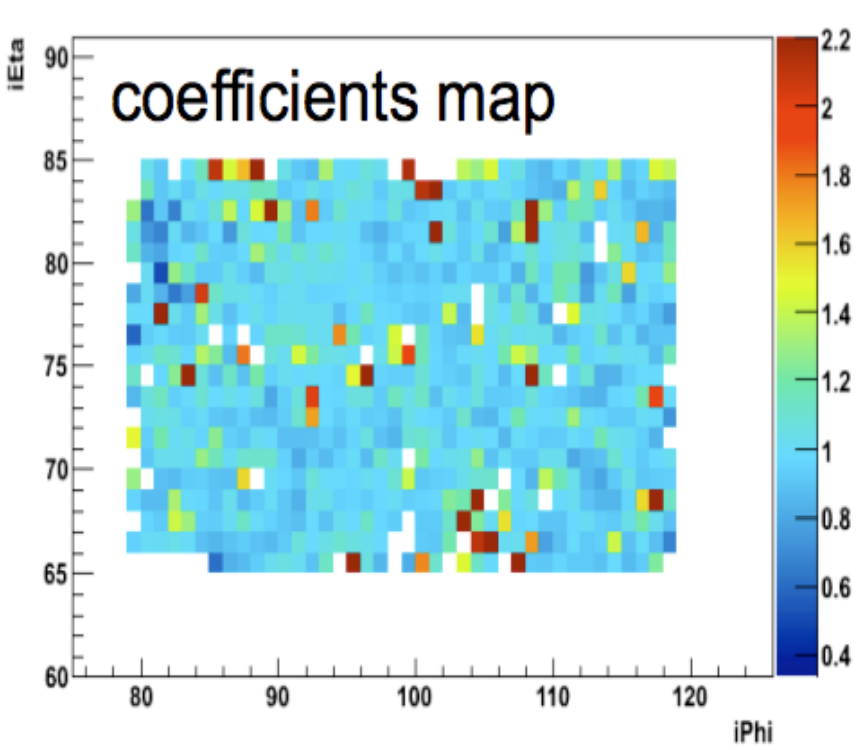
Delay table was measured at TB

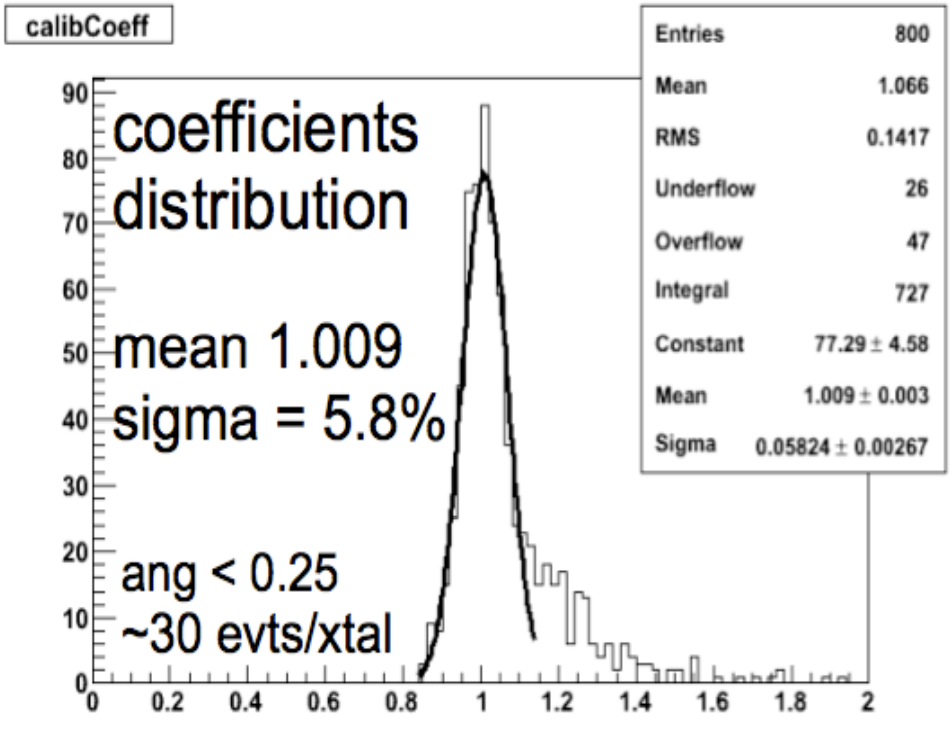
and validated with cosmic muons



ECAL Calibration – Muons and Test Beam

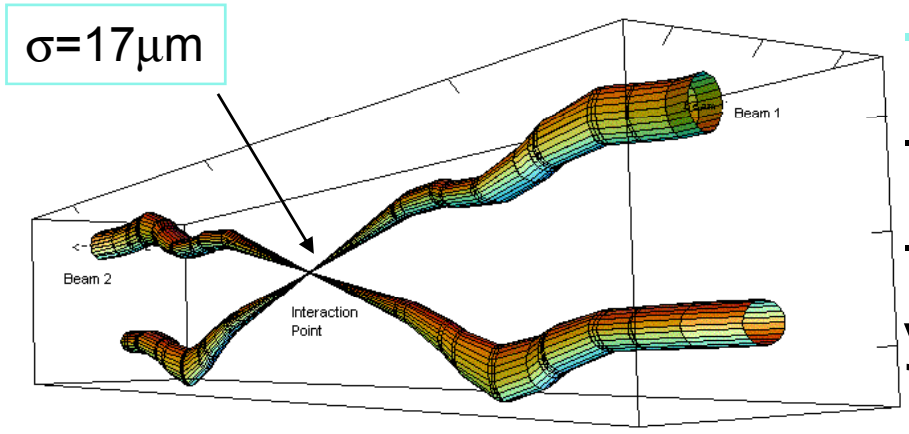
Using pre-calibrated data the spread of the coefficients is convolution of precalibration (<2%) and in-situ precision





LHC Parameters

Nominal LHC parameters	
Beam energy (TeV)	7.0
Number of particles per bunch	1.15×10^{11}
Number of bunches per beam	2808
Stored beam energy (MJ)	362
Bunch spacing (ns)	25
Bunch length (cm)	7.55



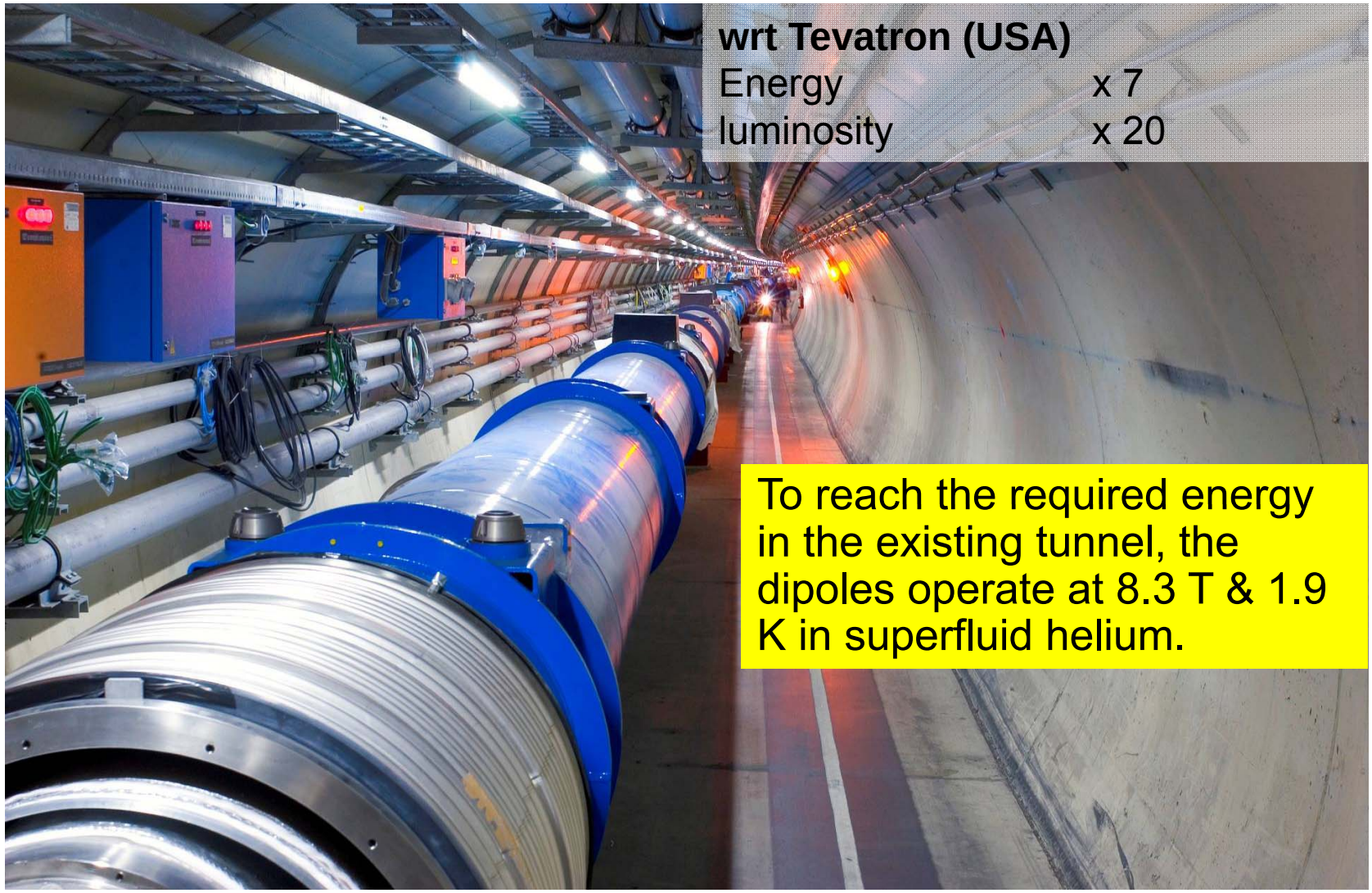
Relative beam sizes around IP1 (Atlas) in collision

- **Crossing angle** = 285 μrad

-Luminosity = 10^{34} cm^{-2} s^{-1}

-Integrated Luminosity per year = 100 fb^{-1}

LHC Accelerator - Dipoles

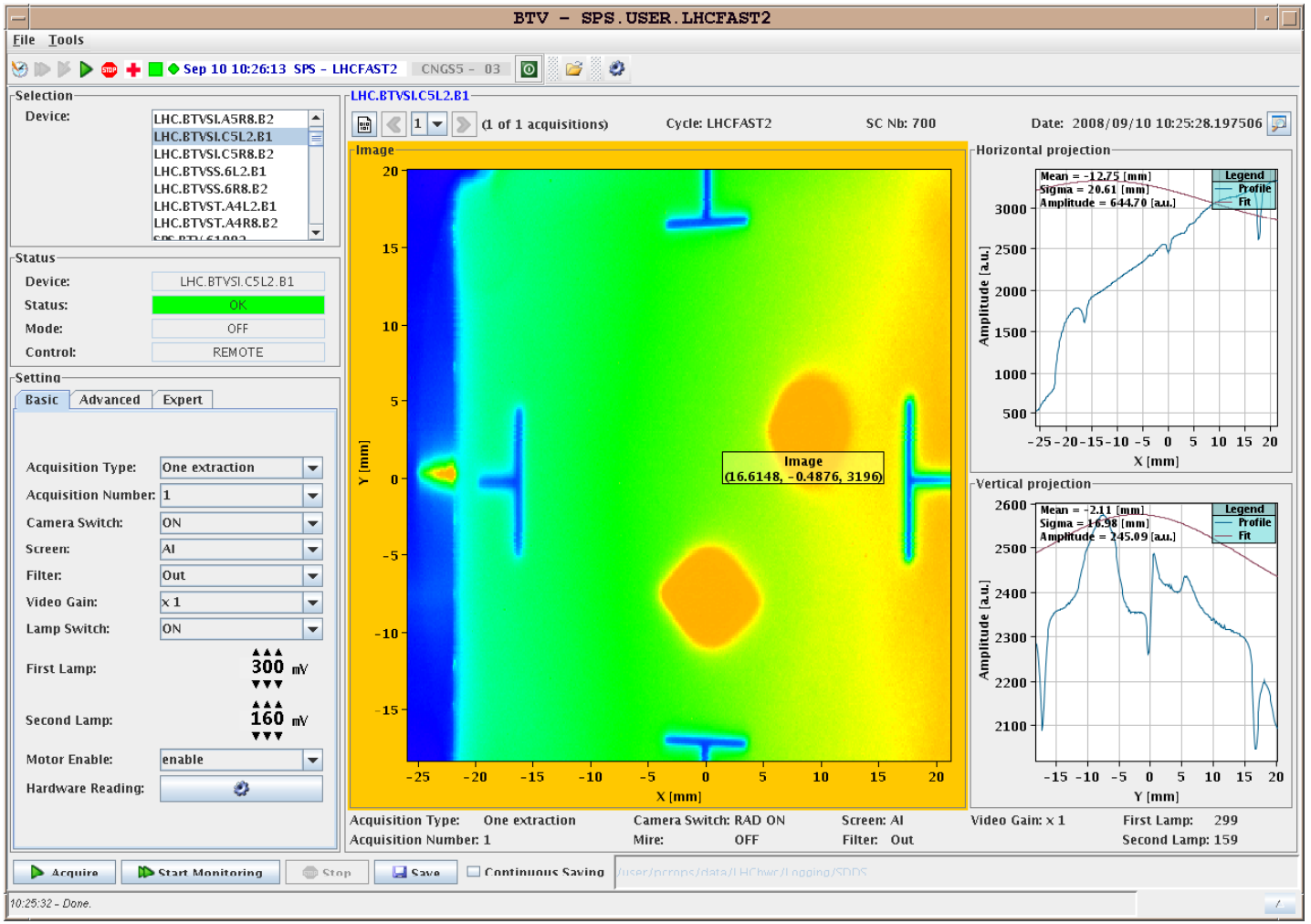


wrt Tevatron (USA)

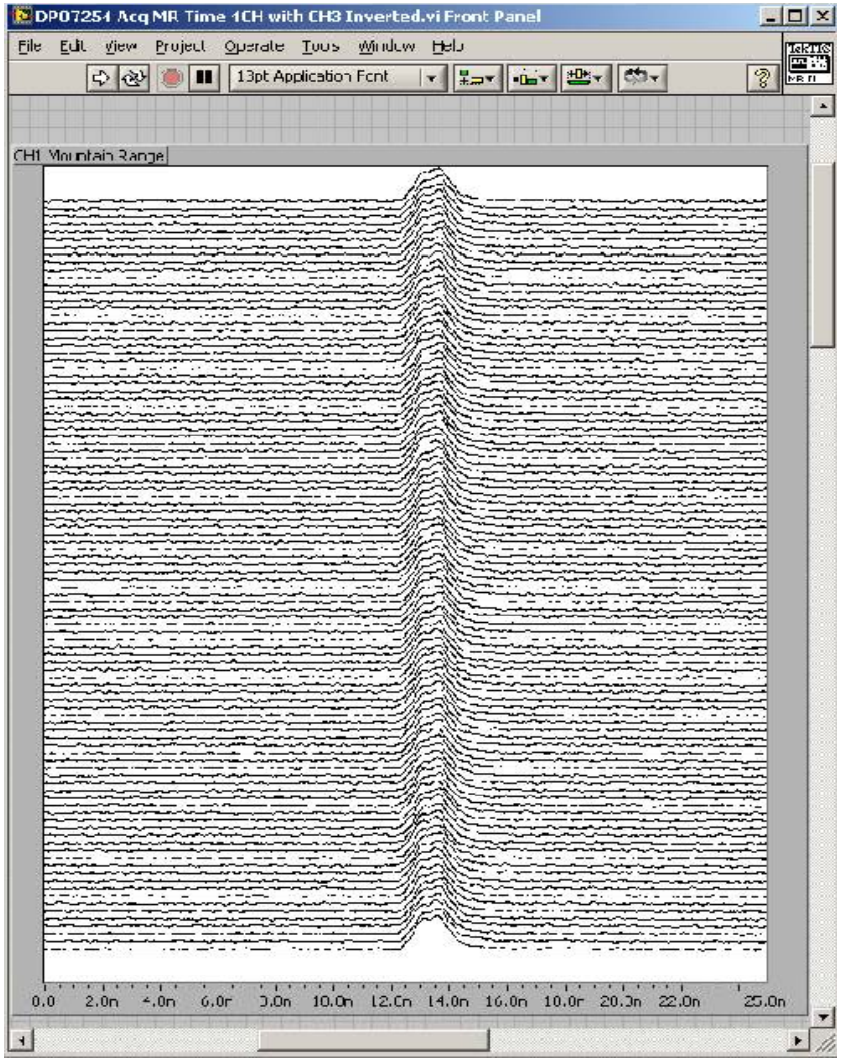
Energy	x 7
luminosity	x 20

To reach the required energy in the existing tunnel, the dipoles operate at 8.3 T & 1.9 K in superfluid helium.

Beam 1 – 1st and 2nd Turns

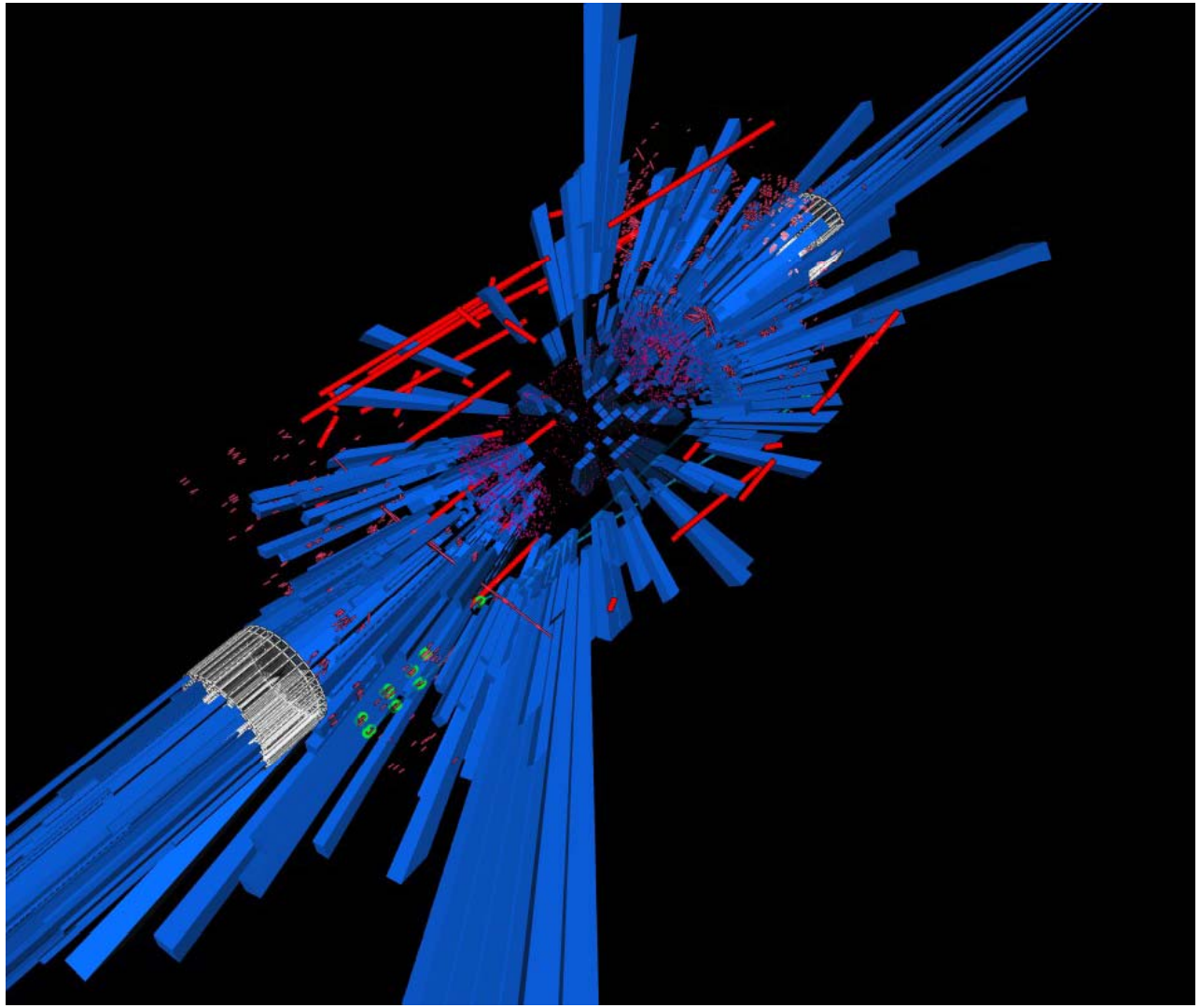


Beam 2 – RF Captured

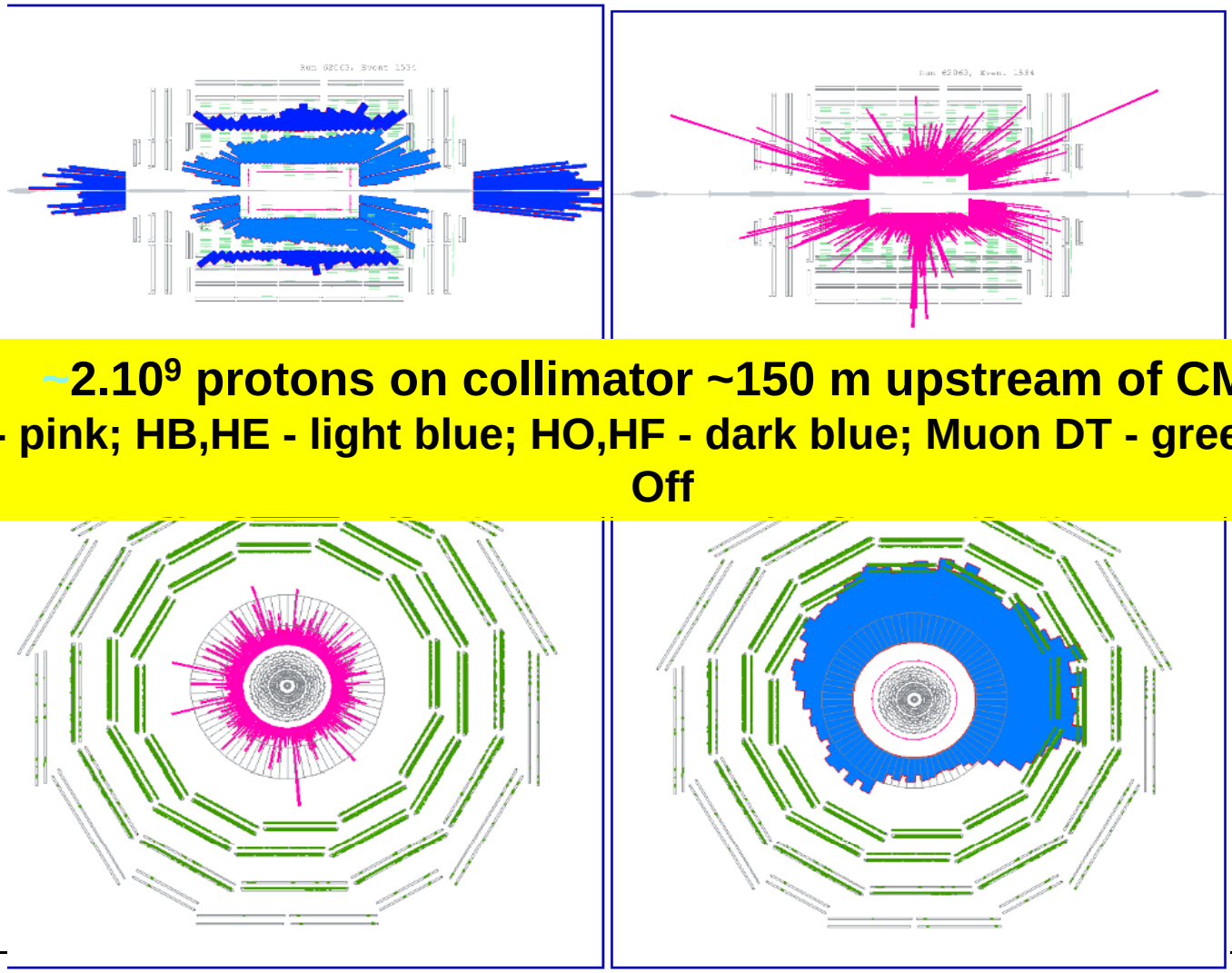


LHC injected beam in Sept., 2008. Beam r.f. phase tuned to capture circulating beam.

Collimator Spray in CMS



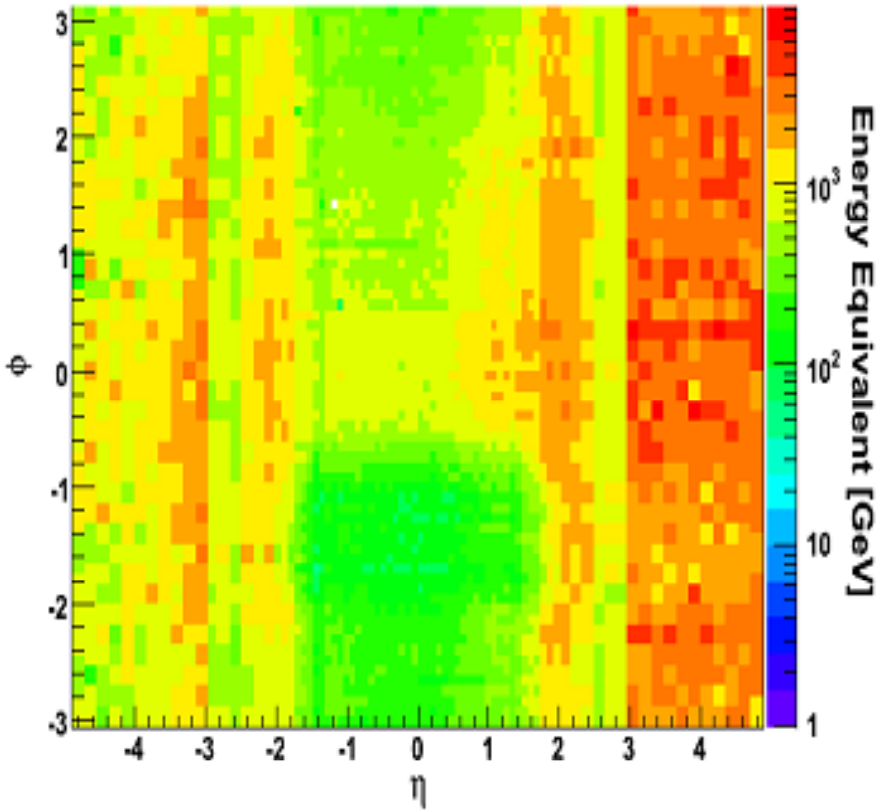
First Events: Collimators Closed

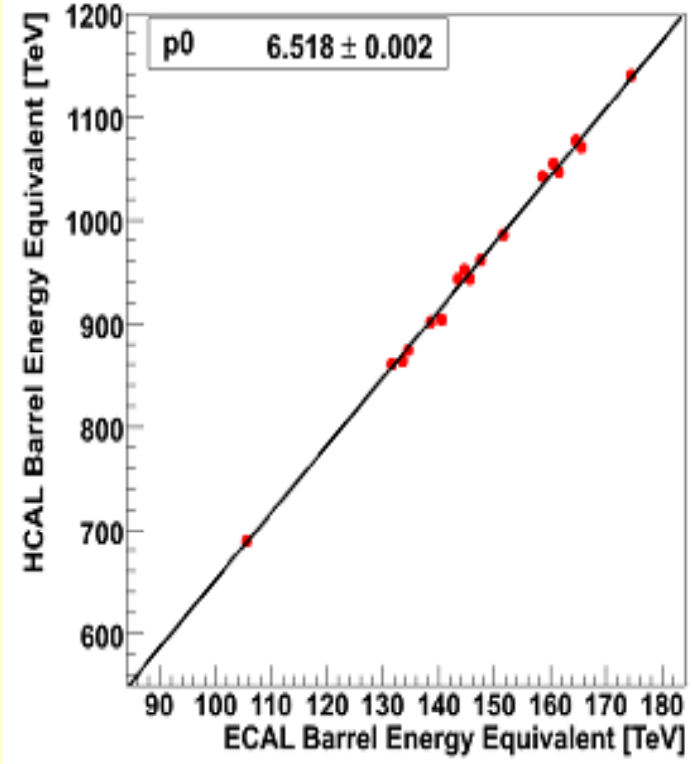


~2.10^9 protons on collimator ~150 m upstream of CMS

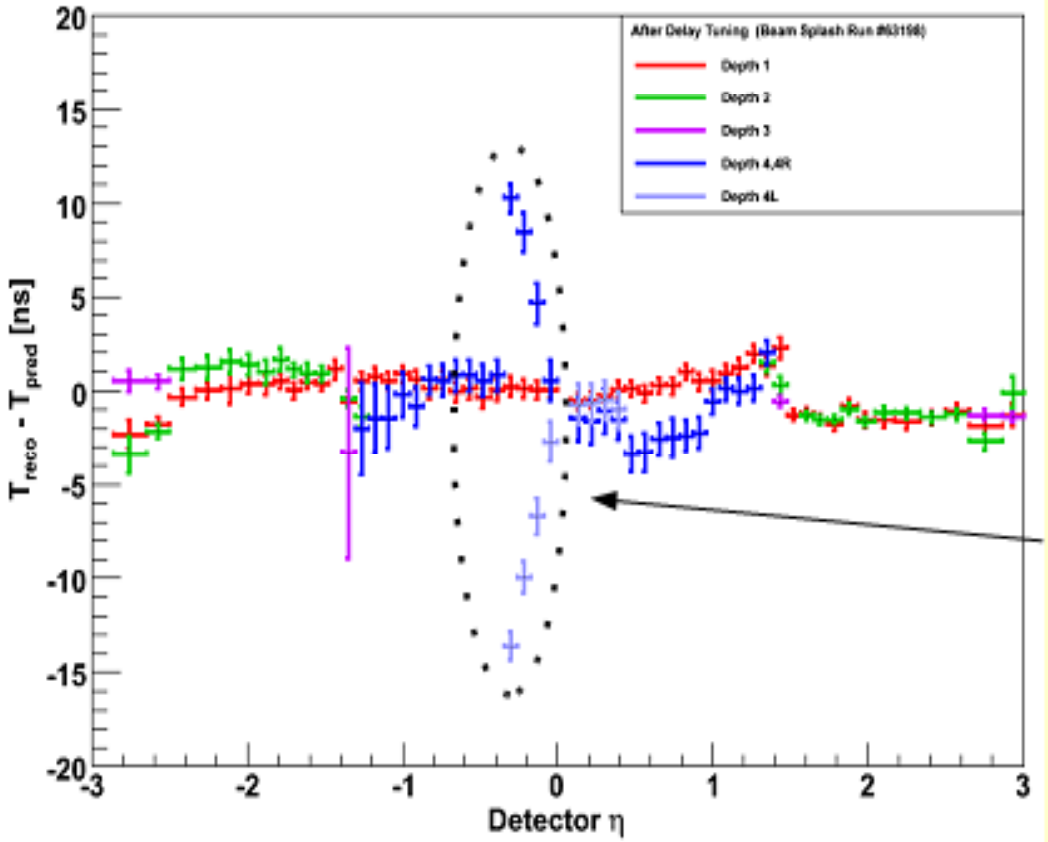
ECAL- pink; HB,HE - light blue; HO,HF - dark blue; Muon DT - green; Tracker Off

Energy in HCAL, ECAL





HCAL Timing with Spray



Sign error in delay file generation since identified and fixed

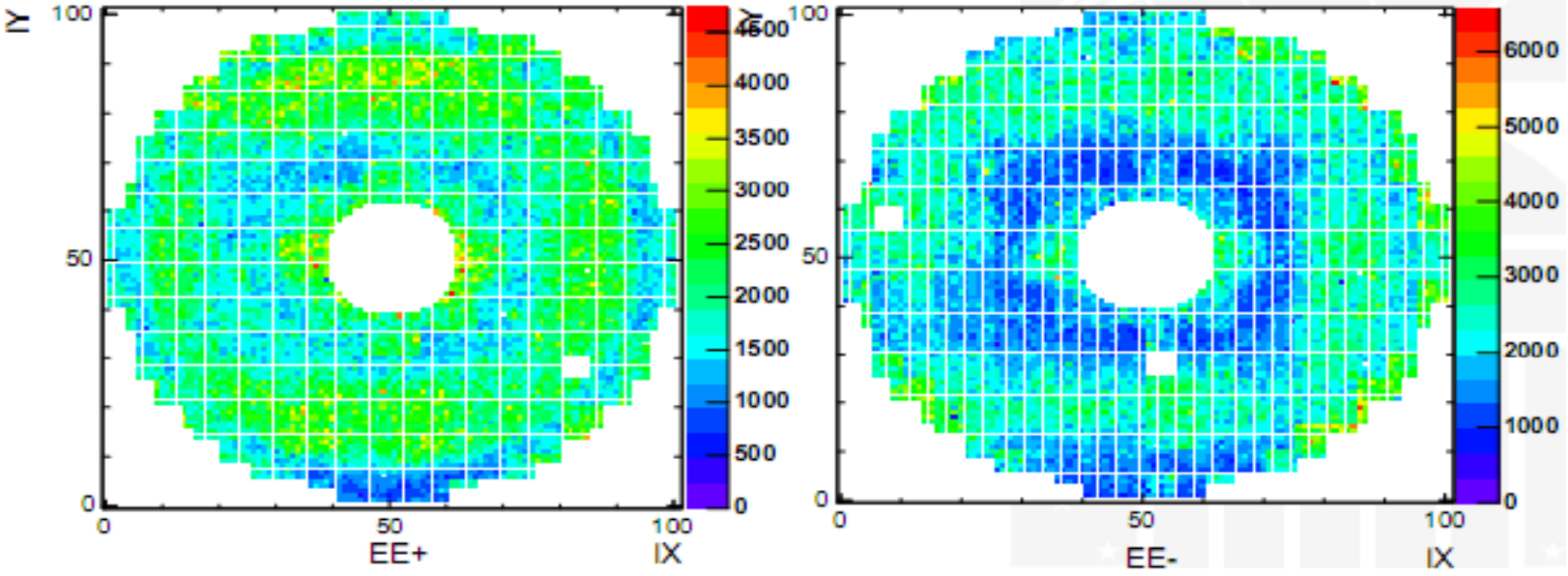
- Tuning results confirmed by beam splash on 18/9
- Single-beam-splash leaves some systematic effects uncorrected

ECAL Endcap

first LHC beam

Sept 10. Beam hits collimator. Produces a splash of muons through detector.

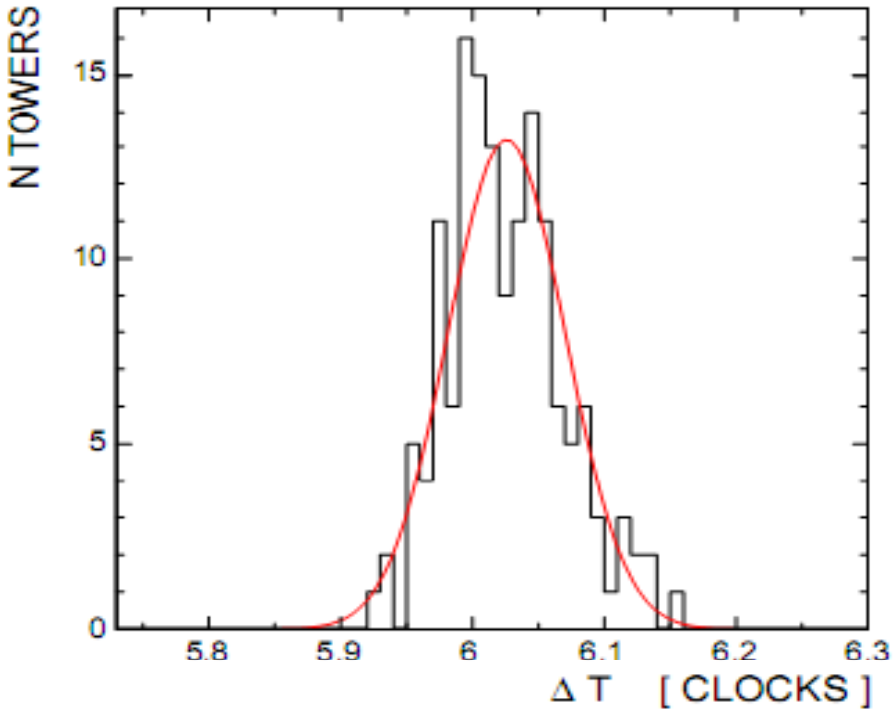
Energy deposition in EE from 20 beam events



ECAL Timing with Spray

beam timing

distribution of T_{MAX} for dee4 towers



Good timing for individual DEEs:

DEE4: $\sigma = 1.1\ nsec$

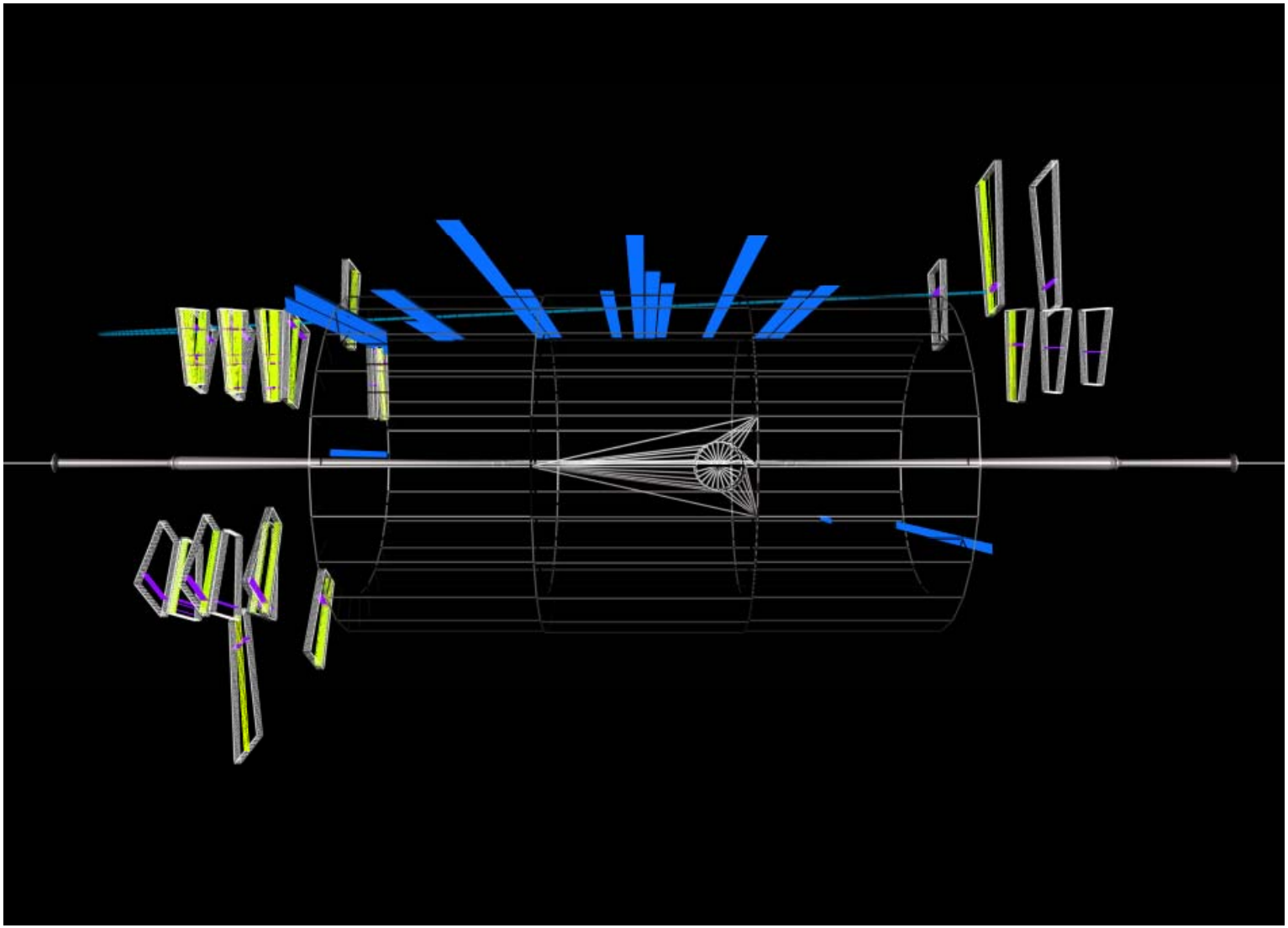
DEE3: $\sigma = 2.0\ nsec$

DEE2: $\sigma = 1.5\ nsec$

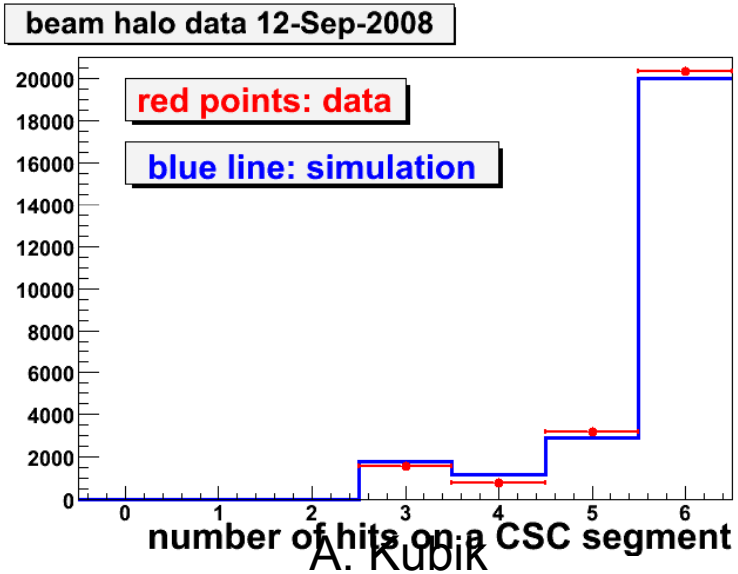
First beam demonstrated very good timing of EE

Possible to do $< 1\ nsec$

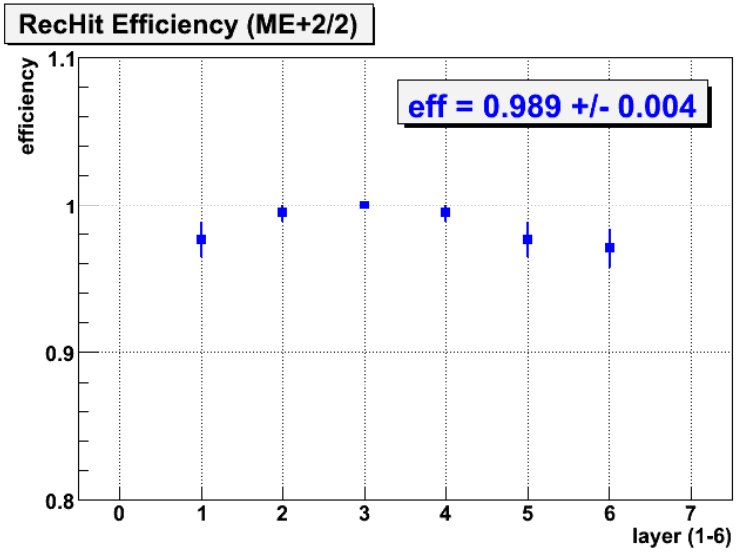
Beam Halo Events



Software is Ready – Muon RECO



A. Kubik
(Northwestern)



Use the collimator splash to set timing. Use the halo muons to test the reconstruction software and extract the detection efficiency.

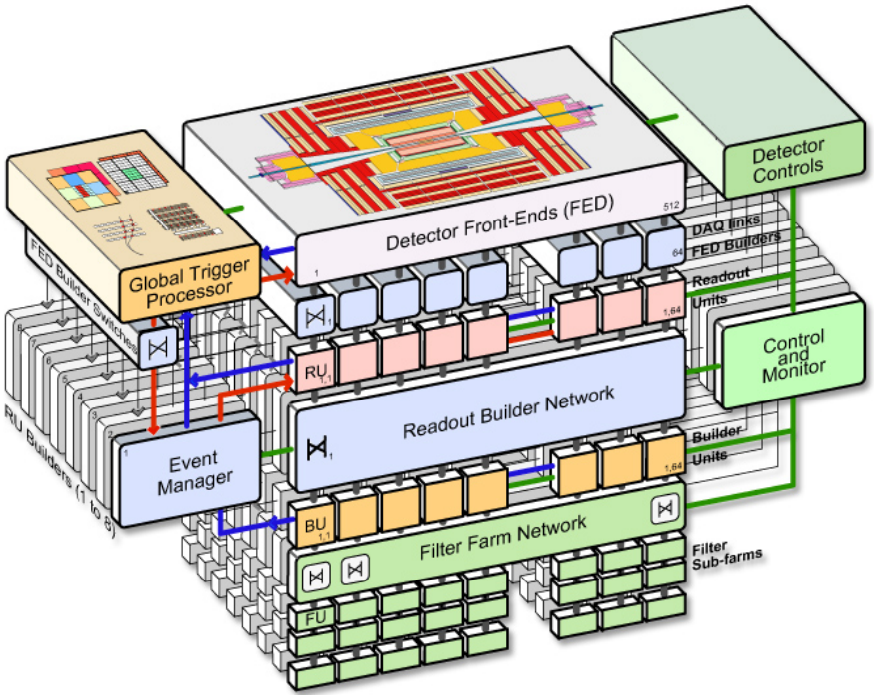
CMS DAQ and Trigger System

Trigger Tables are Defined

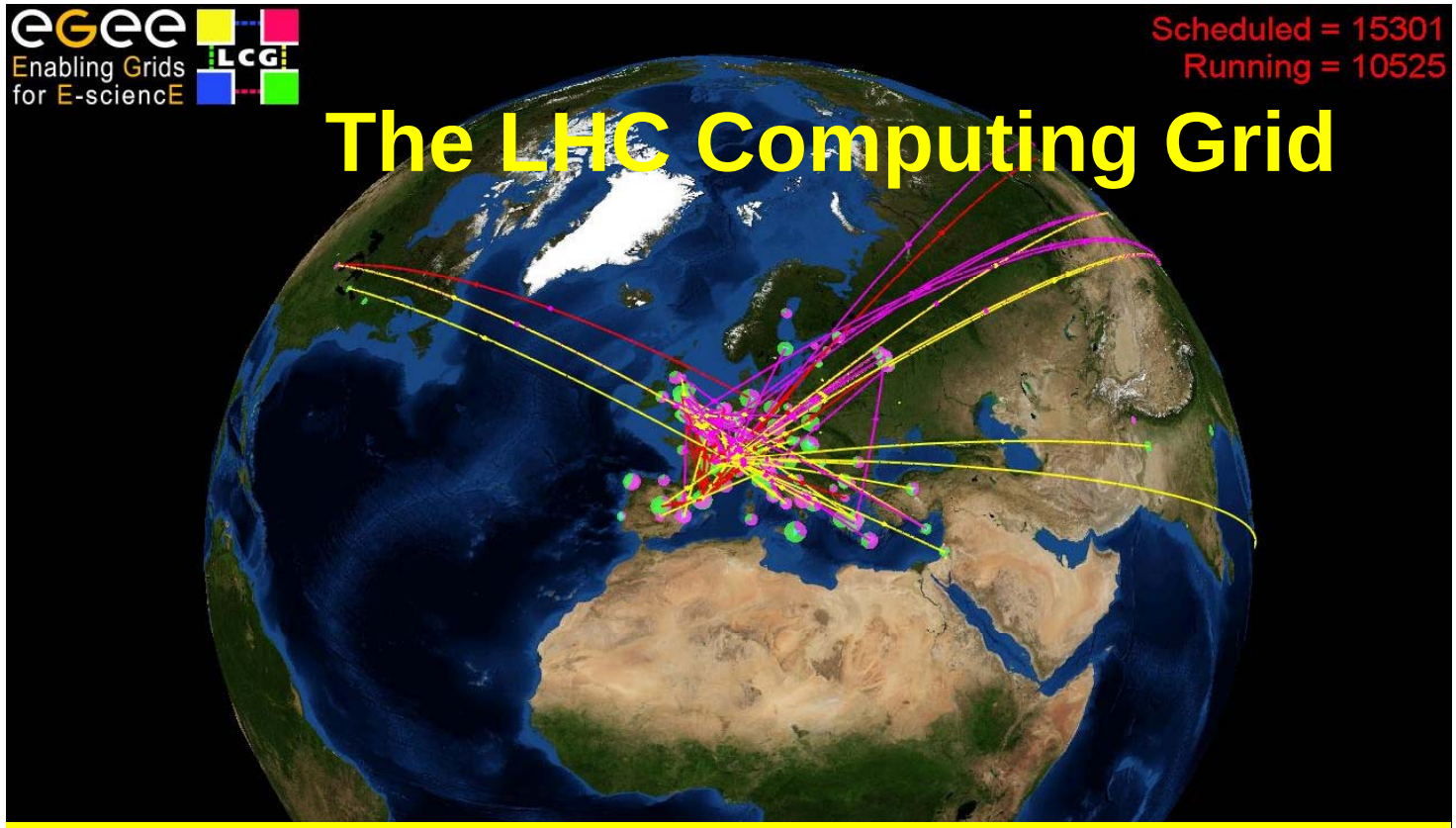
Trigger on "minbias" for LHC startup

Data Quality and Trigger Monitoring are in place

DAQ at ~ 50 kHz has been "stress tested"



CMS Computing and Software



Experiments will produce about 15 Million Gigabytes of data each year (about 20 million CDs!)

~~Tests done of data transfers from T1 -> T2 -> T3 in 2007 at full rate. The grid is ready.~~

CCRC/CSA Workflows

Prompt Reconstruction

TIER-0

CASTOR

CAF

Calibration
Express-Stream
Analysis

600MB/s

50-500MB/s

TIER-1

TIER-1

TIER-1

Re-Reco
Skims

50-500MB/s

~20MB/s

Simulation
Analysis

TIER-2

TIER-2

TIER-2

TIER-2

CCRC08

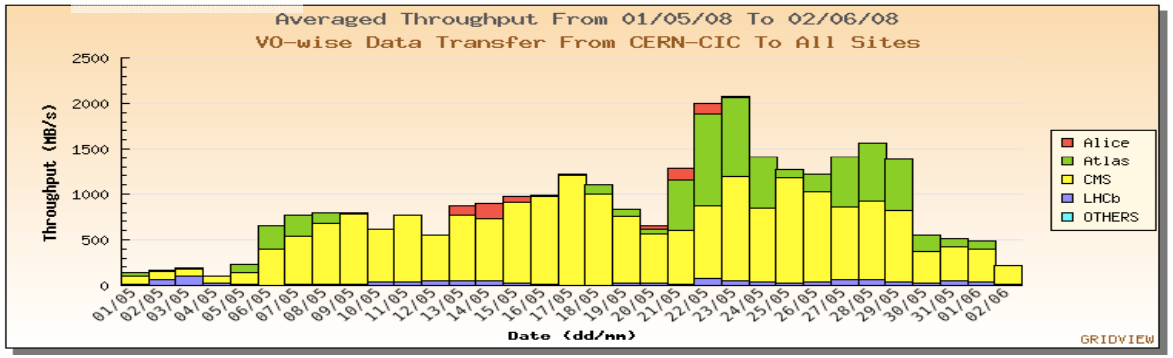
For CMS the CCRC08 was successful

Demonstrated all key use case performances of T0, CAF, T1, T2 infrastructure

Some results:

- **Data export CERN-T1 > 600MB/s**
- **Re-reconstruction and skimming run at all T1 sites**
- **Physics analysis jobs successfully run at 62 sites**

1 GB/s _



Demonstrated successful DPG/ALCA/Physics activities, and at the same time, stress tested the computing infrastructure with real and artificial load.

T0 -> T1 -> T2 (US Example)

T0 at CERN, T1 at Fermilab as US CMS national center,

T2 at UCSD, Caltech, UFlorida, Wisconsin, MIT, Nebraska and Purdue as regional US CMS centers. (+ Brazil + China ?)

Remote Operations in CMS

The LHC is a discovery machine so we must be ready on "day one". Practice data transfer and data quality monitoring and remote data analysis – using "global runs". RO in many sites means more of CMS is engaged

Summary

- The CMS magnet, MB and HCAL were tested in the Surface Hall in 2006
- After lowering into the Collision Hall all the CMS subsystems were aligned, calibrated and synchronized using cosmic rays.
- LHC beam was successfully used to set timings and confirm RECO algorithms.
- Data transfers and analysis models have been exercised
- We will take 300 M cosmic ray events in Oct.-Nov. in preparation for the 2009 run.
- We are ready for multi-TeV LHC collisions.

Muon System Alignment

Alignment constants for all CRUZET geometries submitted (including CSC movements during closure)

DT:

- chamber alignment within wheels (incl. survey)
- wheel-to-wheel alignment under validation

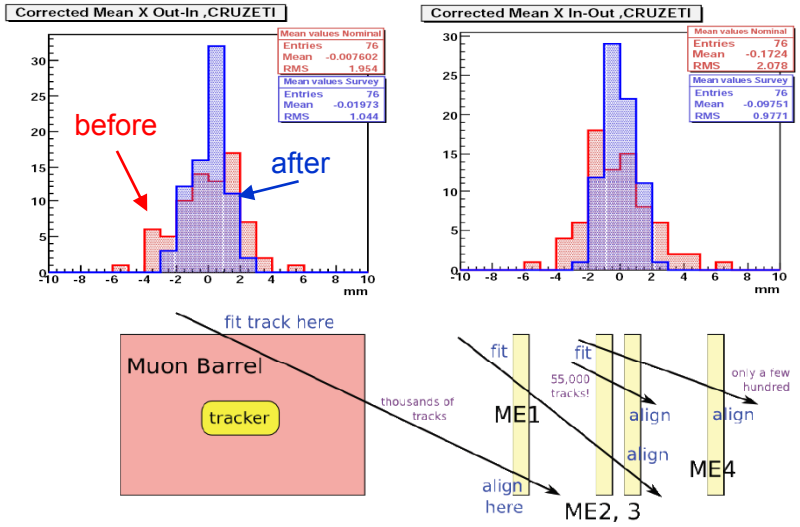
CSC:

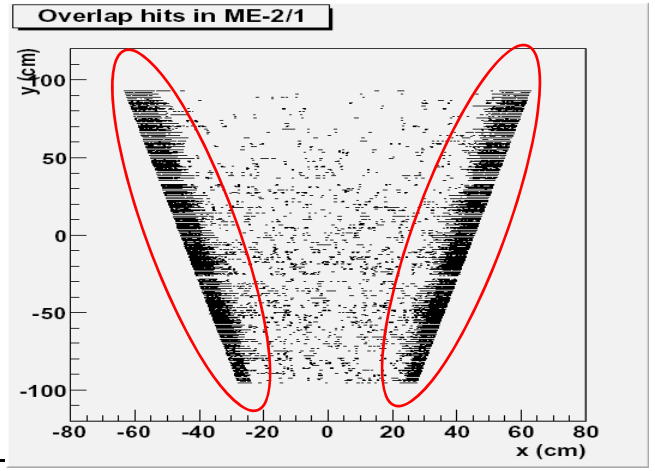
- wheels aligned relative to barrel using cosmics under shallow angle
- presently, using beam halo tracks in chamber overlap regions for chamber alignment within endcap wheels

Statistics:

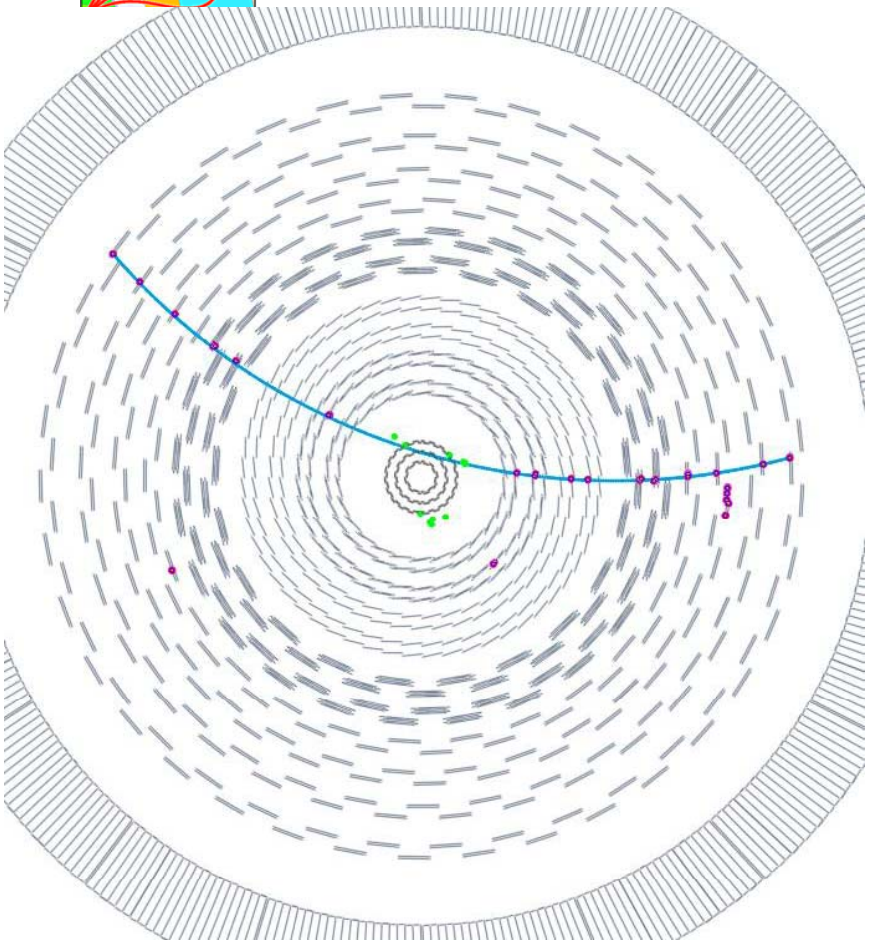
- 120000 alignment tracks in beam halo overlaps stream
- 32 M muon standalone cosmics

DT: Local X displacement
before & after internal chamber alignment





Tracking in CRUZET/CRAFT



First goal has been to provide as many tracks as possible for the **calibration and alignment** of the tracker.

3 different algorithms were used during CRUZET III-IV and CRAFT:

- an ad-hoc algorithm for cosmic reconstruction: **CosmicTF**

- Two algorithms (designed for tracking in collisions) adapted to cope with cosmics: **CTF** and **RS**

All three algorithms reconstructed tracks during both **BON** and **BOFF** runs with comparable performance.

Tracking in CRUZET/CRAFT

CosmicTF algorithm has always had an higher efficiency in collecting good measurements respect to the other 2 algorithms, as expected from MC.

	CRUZET 4	Monte Carlo
CTF	84.8%±0.3	82.77%±0.08
RS	84.8%±0.3	84.78%±0.08
Cosmic	91.6% ± 0.2	88.77%±0.08

Nevertheless it has been very useful to run all 3 algorithms because:

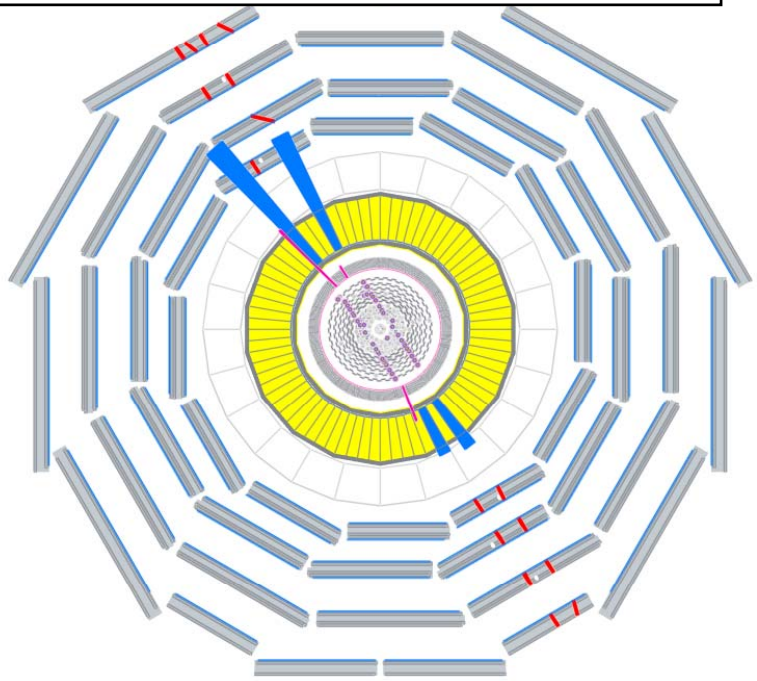
- One tracking approach can be used to debug the others

- The versions of CTF and RS for cosmic reconstruction share most of the code designed for collisions: ~same pattern recognition, same final fit.

~90% of software for tracking in collisions has already been used during cosmic runs

Tracking for CRUZET/CRAFT

Not-null pattern recognition was already run on real cosmic data



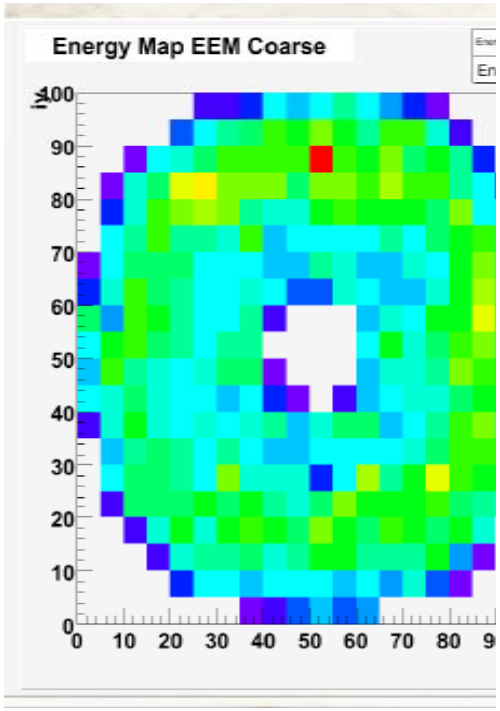
Next step: select muons pointing very close to center of CMS and try to reconstruct them **seeding the track reconstruction from the innermost layers**, as we do for collisions on MC.

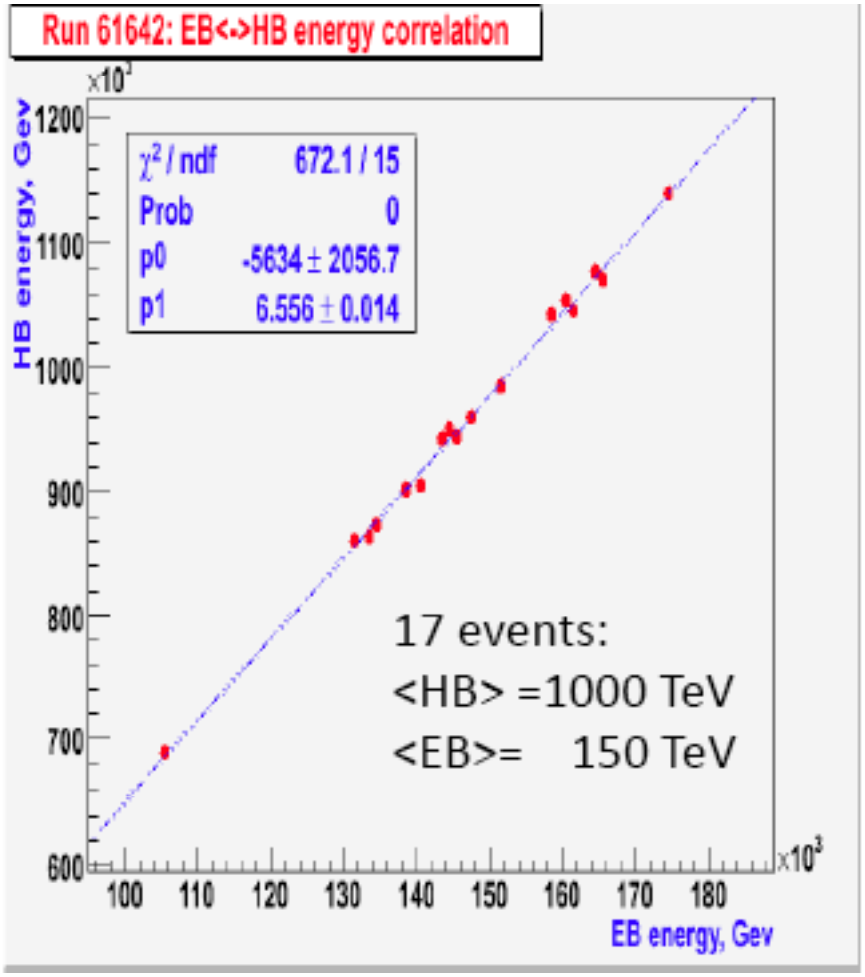
We can test 100% of the reconstruction sequence which is expect to be used for LHC collisions….before spring 2009

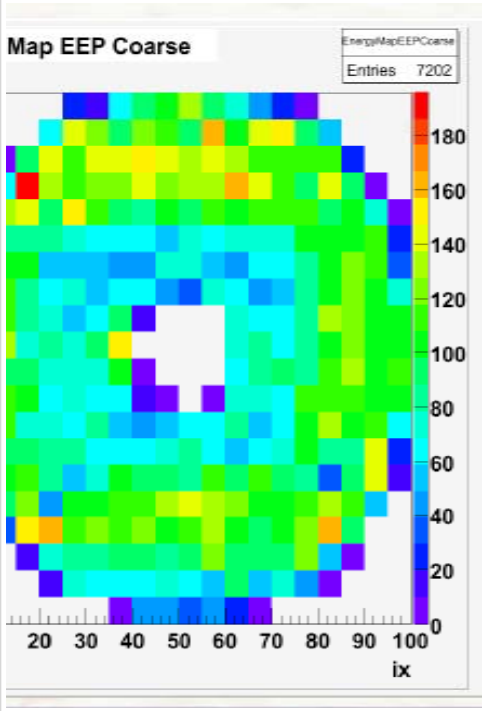
Details given in Tracker DPG report by D.Contardo:

http://indico.cern.ch/materialDisplay.py?contribId=40&sessionId=22&materialId=slides&confId=41026

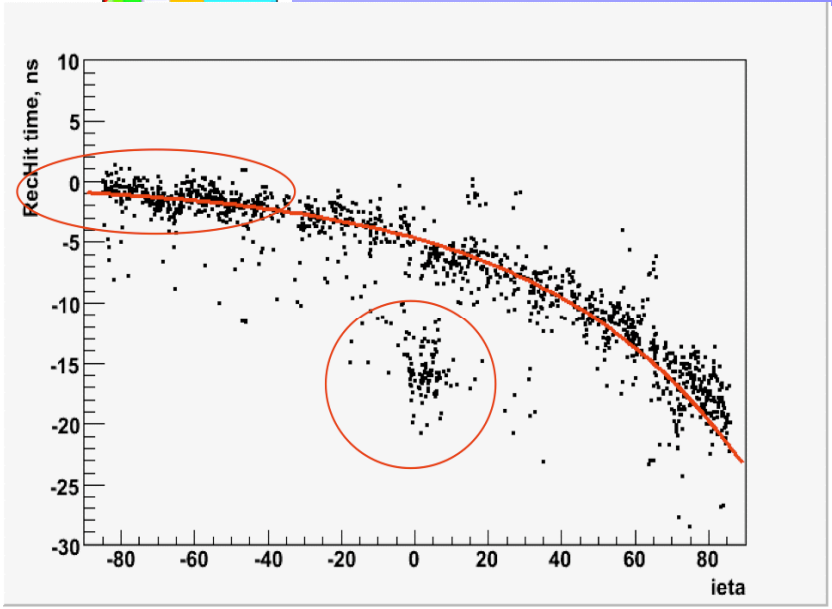
Correlating E in HCAL and ECAL







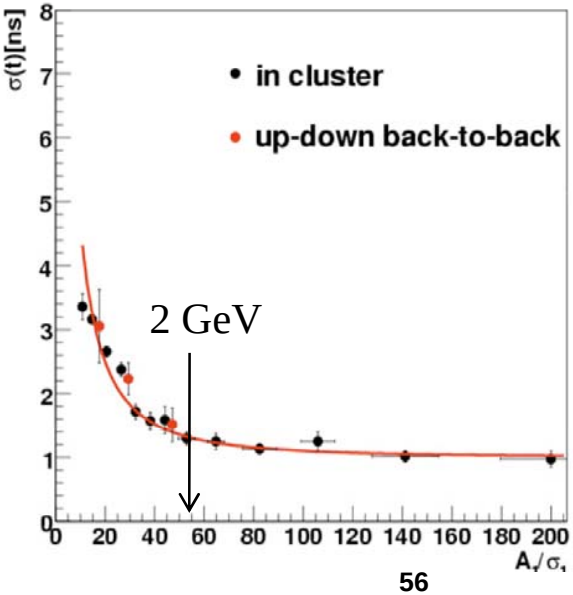
More on timing



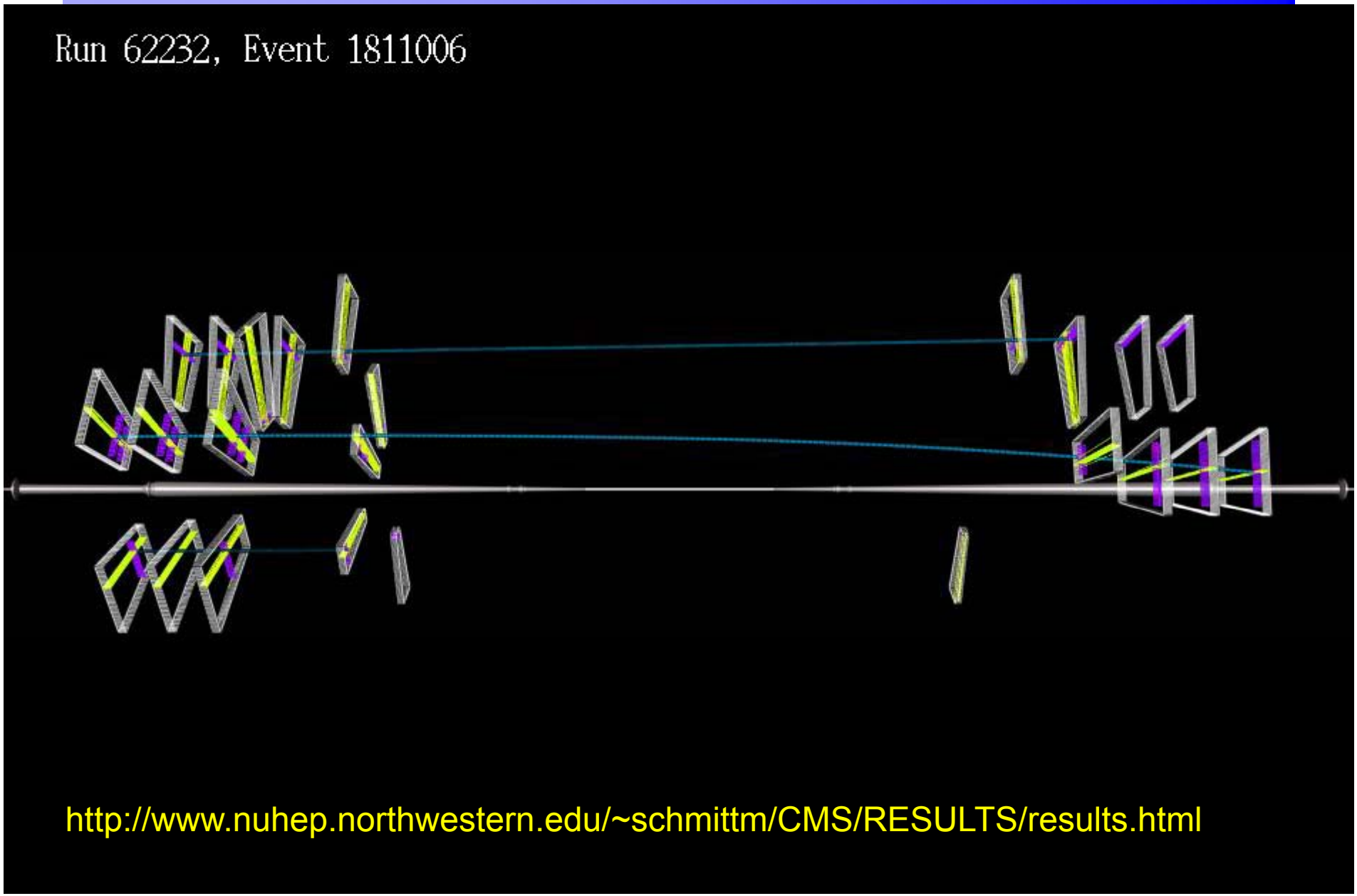
- In beam dump events channels ~10 ns early:
  - Isolated channels
  - not always the same across events
  - In central region (low |η|)
  - Studies ongoing

Time reco: ongoing effort with contribution from exotica group:

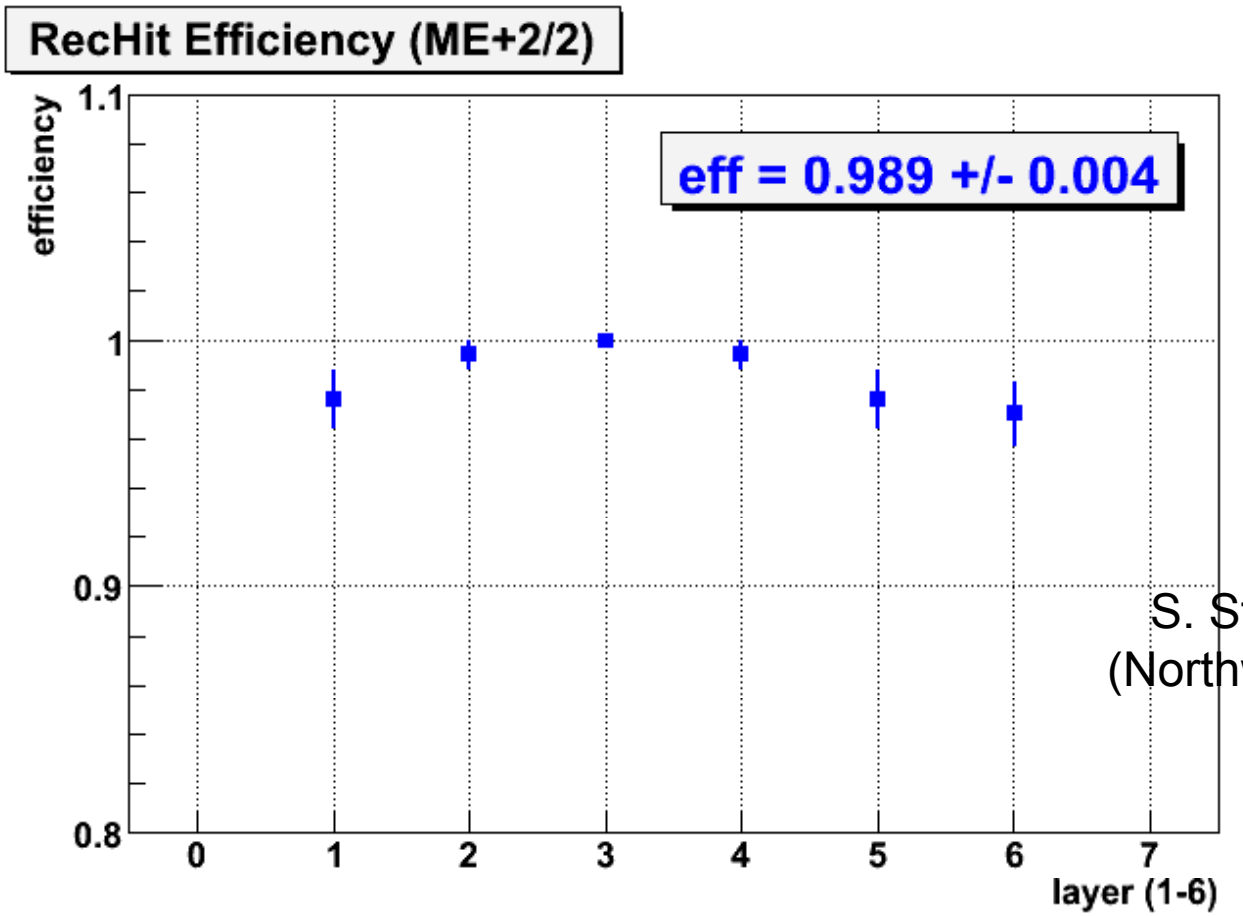
- **Re-deploy weights for time measurement with ECAL**
- **Extend reconstruction to large interval around nominal time, using**



3-Muon Event in the CSC's



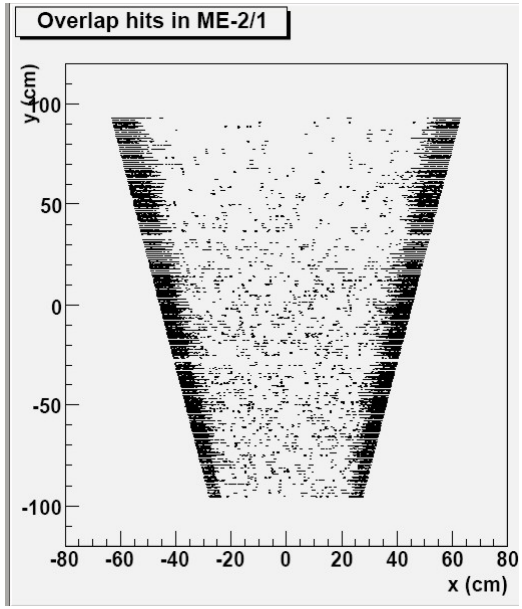
Efficiency to obtain a recHit in each given layer, for all chambers in ME+2/2

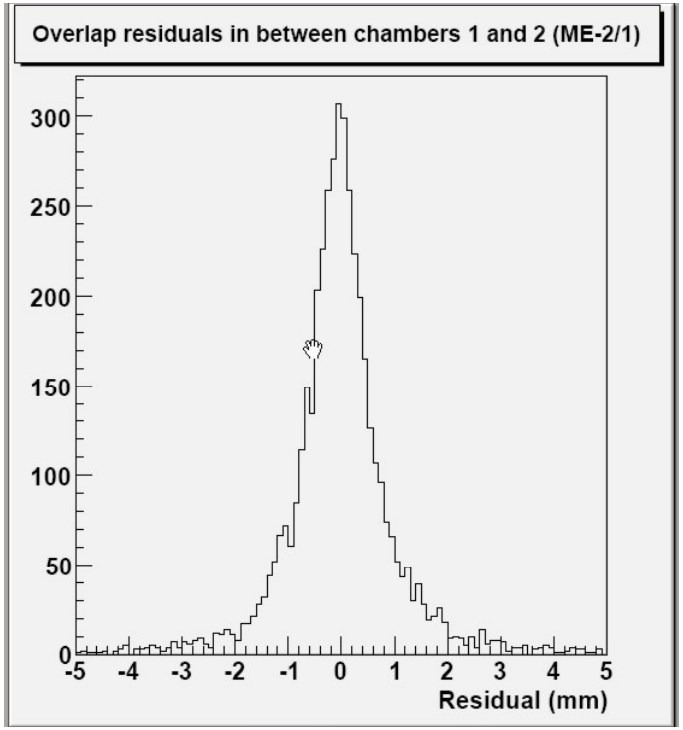


S. Stoynev
(Northwestern)

Track Based Alignment

J. Pivarski (Texas A&M)





Use simultaneous solution of fits to residuals from overlapping regions to align chambers to each other (For details, see alignment meeting Wednesday)