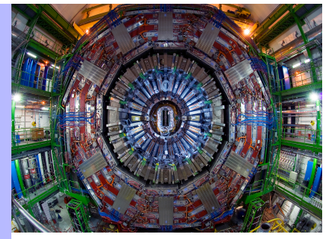
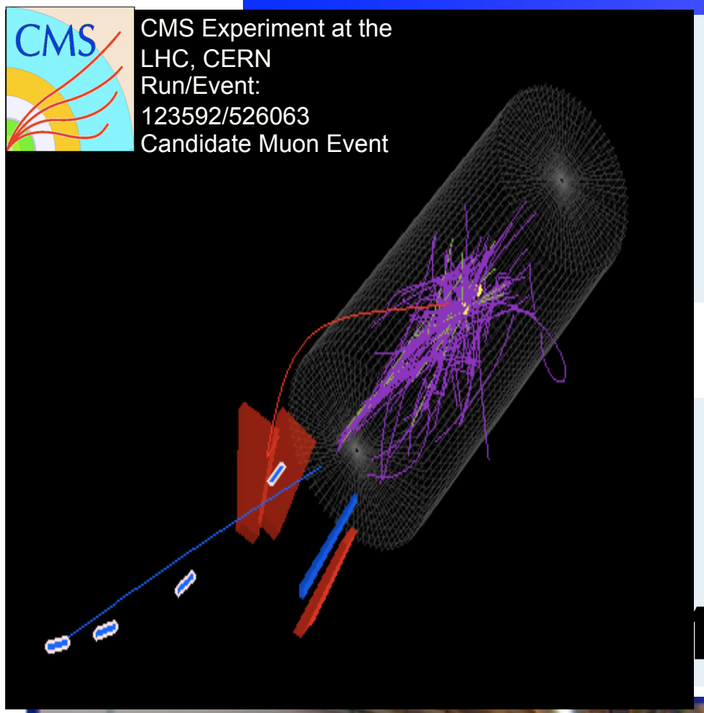


CMS Growing UP



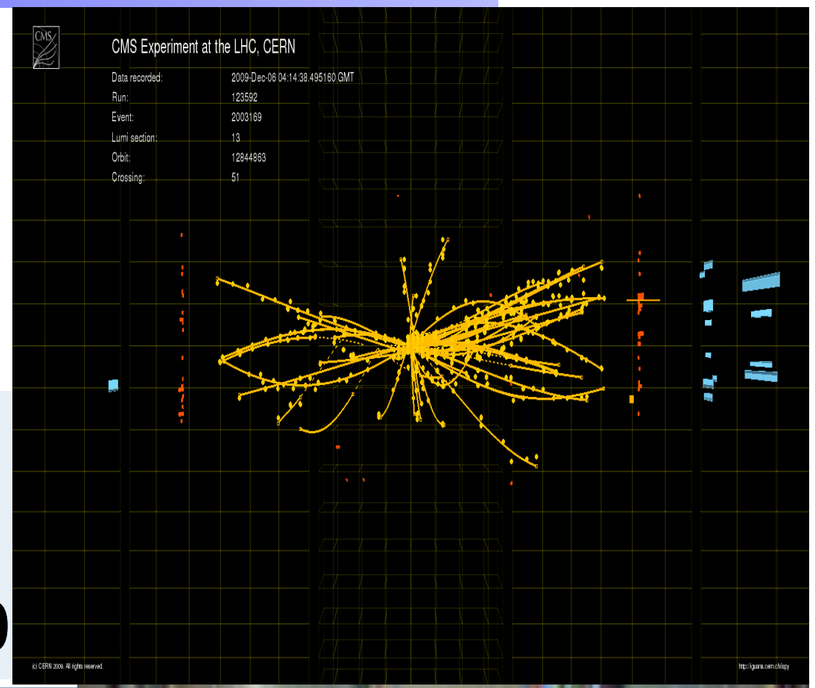
Slawek Tkaczyk

FNAL

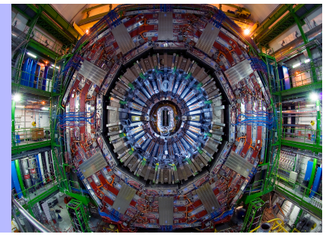
Chris Quigg

Symposium

14-15 December 2009

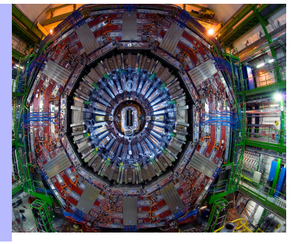


OUTLINE



- Introduction
- Construction
- Commissioning and Operation
  - Cosmic Muons
  - First LHC beams
- Conclusions

Physics Cruxes of Today



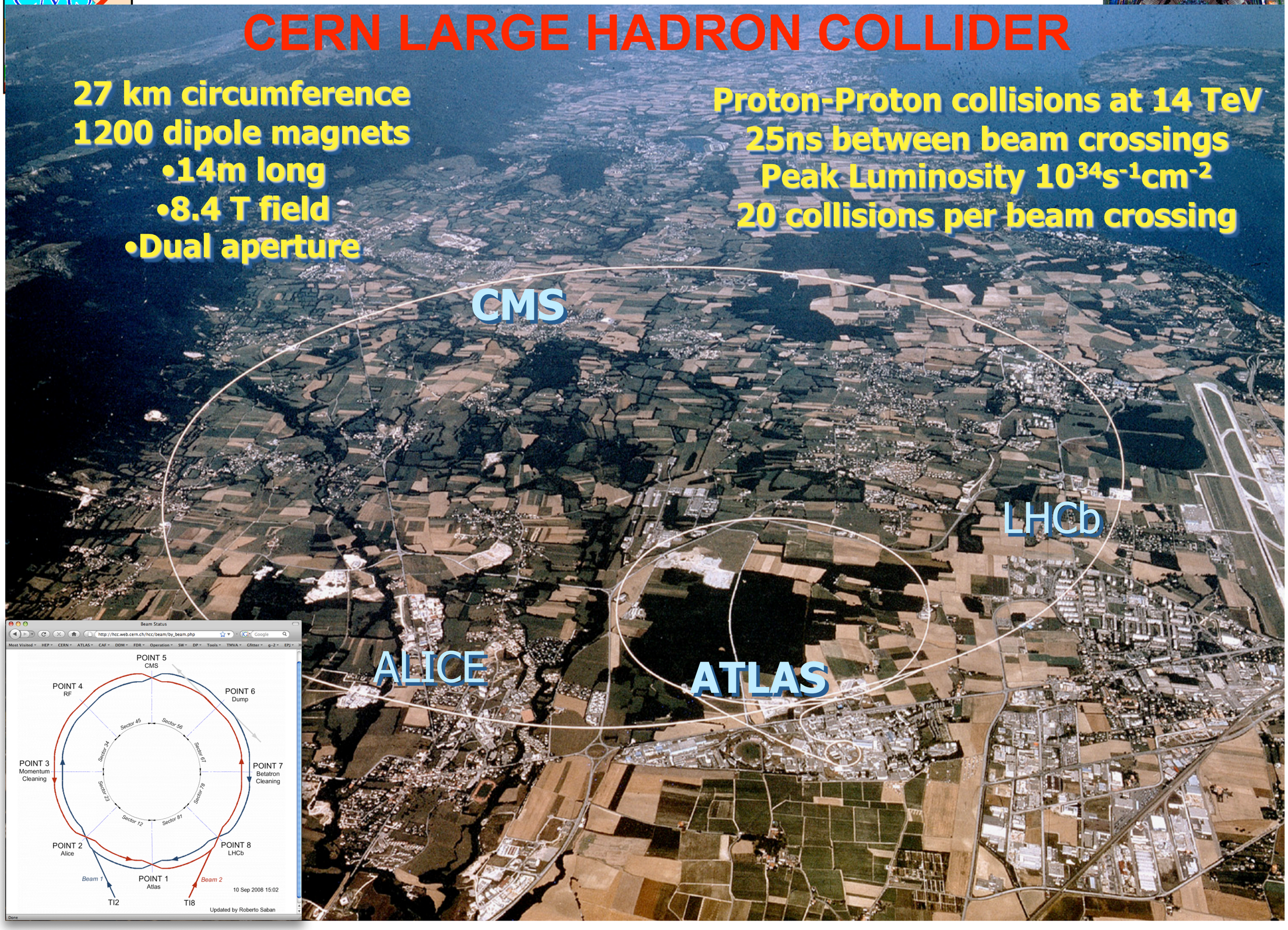
- How do particles acquire mass?
- What is the origin of the spontaneous symmetry breaking?
- Is the Universe super-symmetric?
- What explains dark matter?
- Are there extra dimensions?

- **BIG unsolved questions need POWERFUL apparatus to look for answers!**

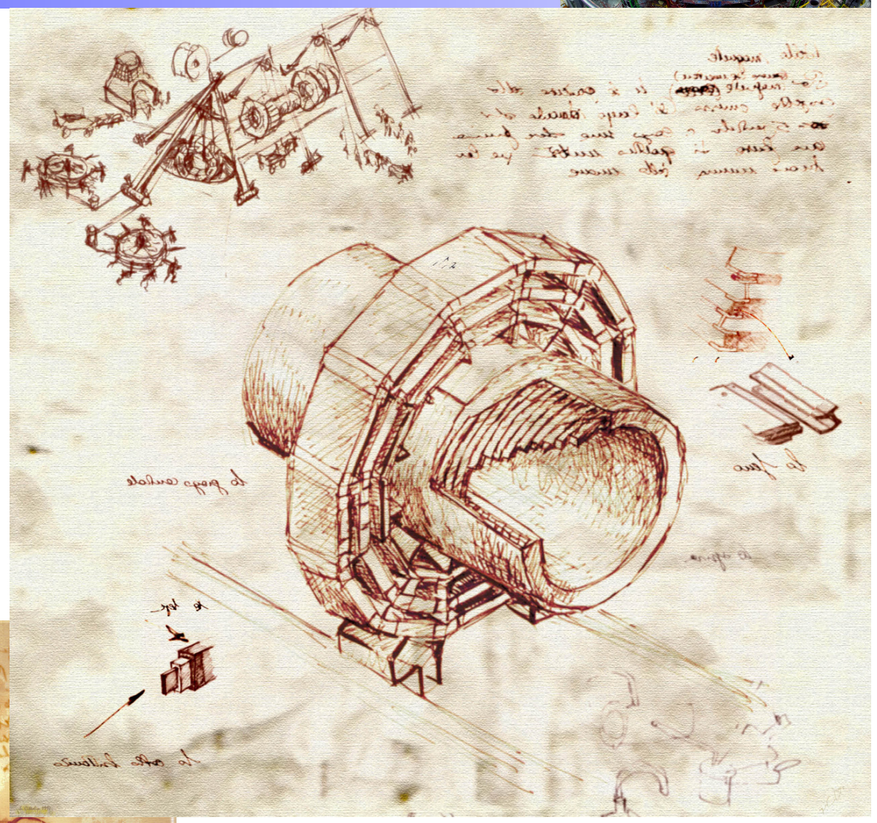
CERN LARGE HADRON COLLIDER

27 km circumference
1200 dipole magnets
- 14m long
- 8.4 T field
- Dual aperture

Proton-Proton collisions at 14 TeV
25ns between beam crossings
Peak Luminosity $10^{34} s^{-1} cm^{-2}$
20 collisions per beam crossing

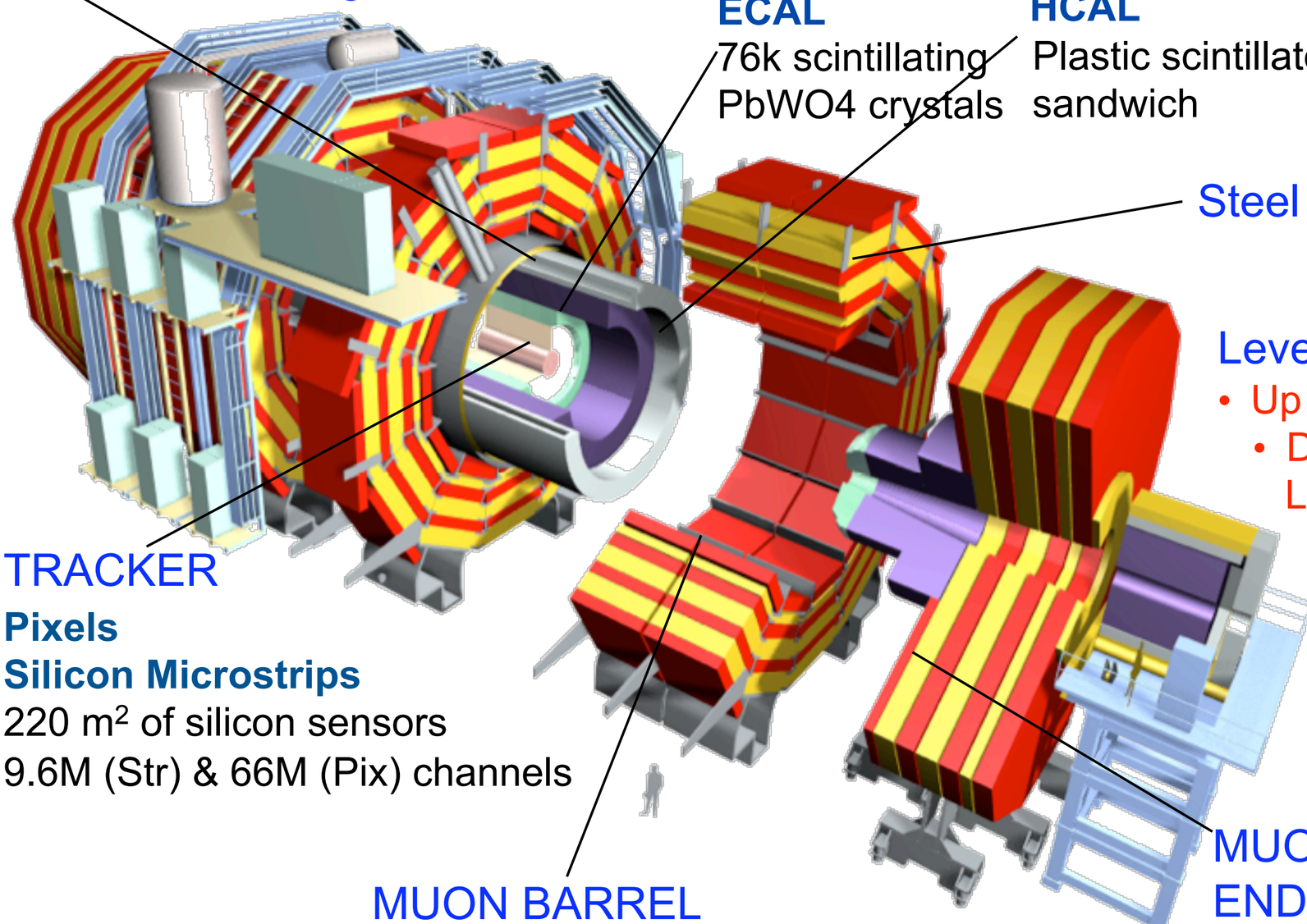


CMS Detector Concept



CMS Concept

CMS Design



Superconducting Coil, 4 Tesla

CALORIMETERS

ECAL
76k scintillating PbWO4 crystals

HCAL
Plastic scintillator/brass sandwich

Steel YOKE

Level-1 Trigger Output
- Up to 100 kHz
  - Directly feeds Higher Level Trigger CPU farm

TRACKER
Pixels
Silicon Microstrips
220 m^2 of silicon sensors
9.6M (Str) & 66M (Pix) channels

MUON BARREL
Drift Tube Chambers (DT)
Resistive Plate Chambers (RPC)

MUON ENDCAPS
Cathode Strip Chambers (CSC)
Resistive Plate Chambers (RPC)

Weight: 1250T
Diameter: 15m
Length: 22m

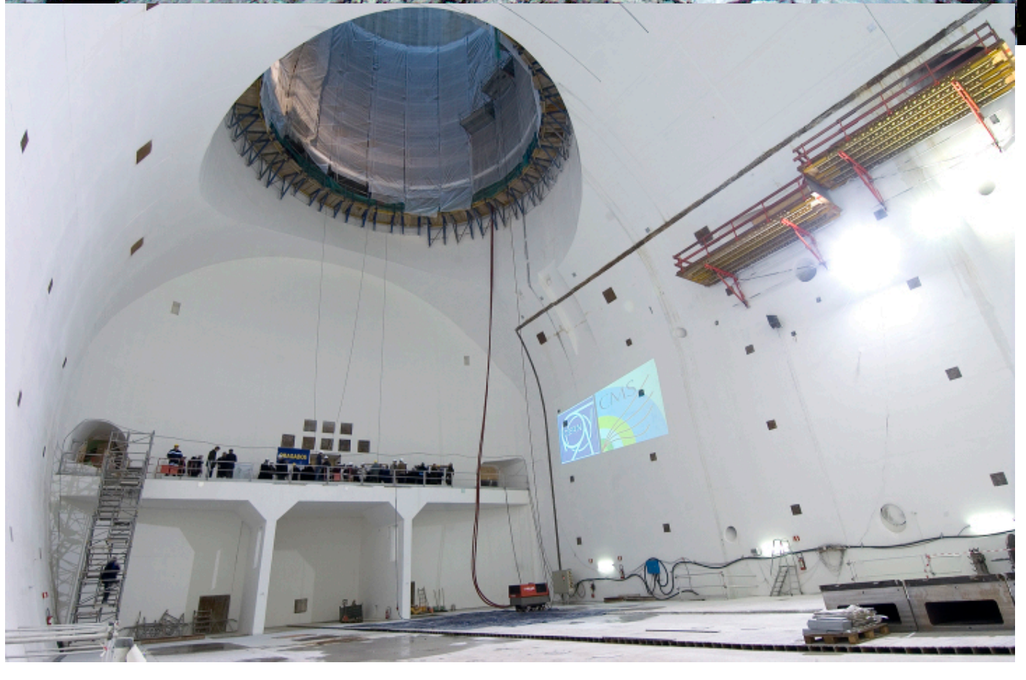
Aerial view of P5 - 1998

Gallo Roman vestiges

Point 5 -Excavation commencement of PM54 shaft - July 09, 1999 - CERN ST-CE

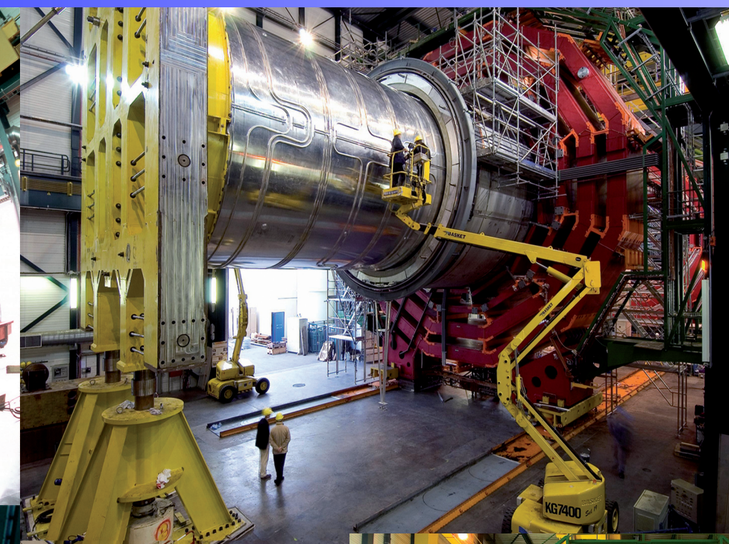
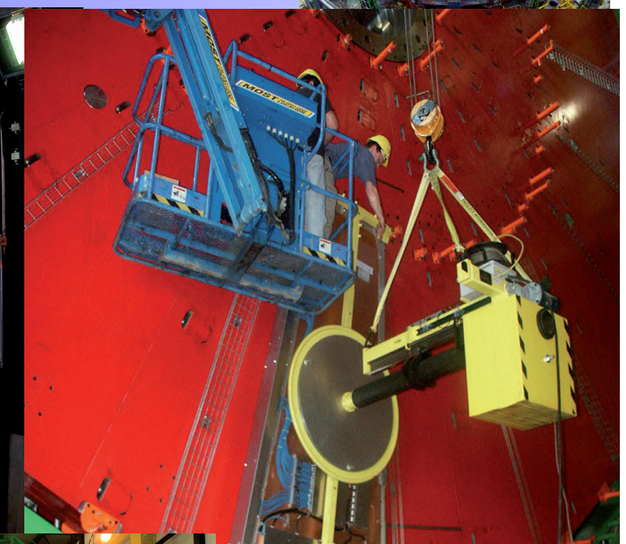
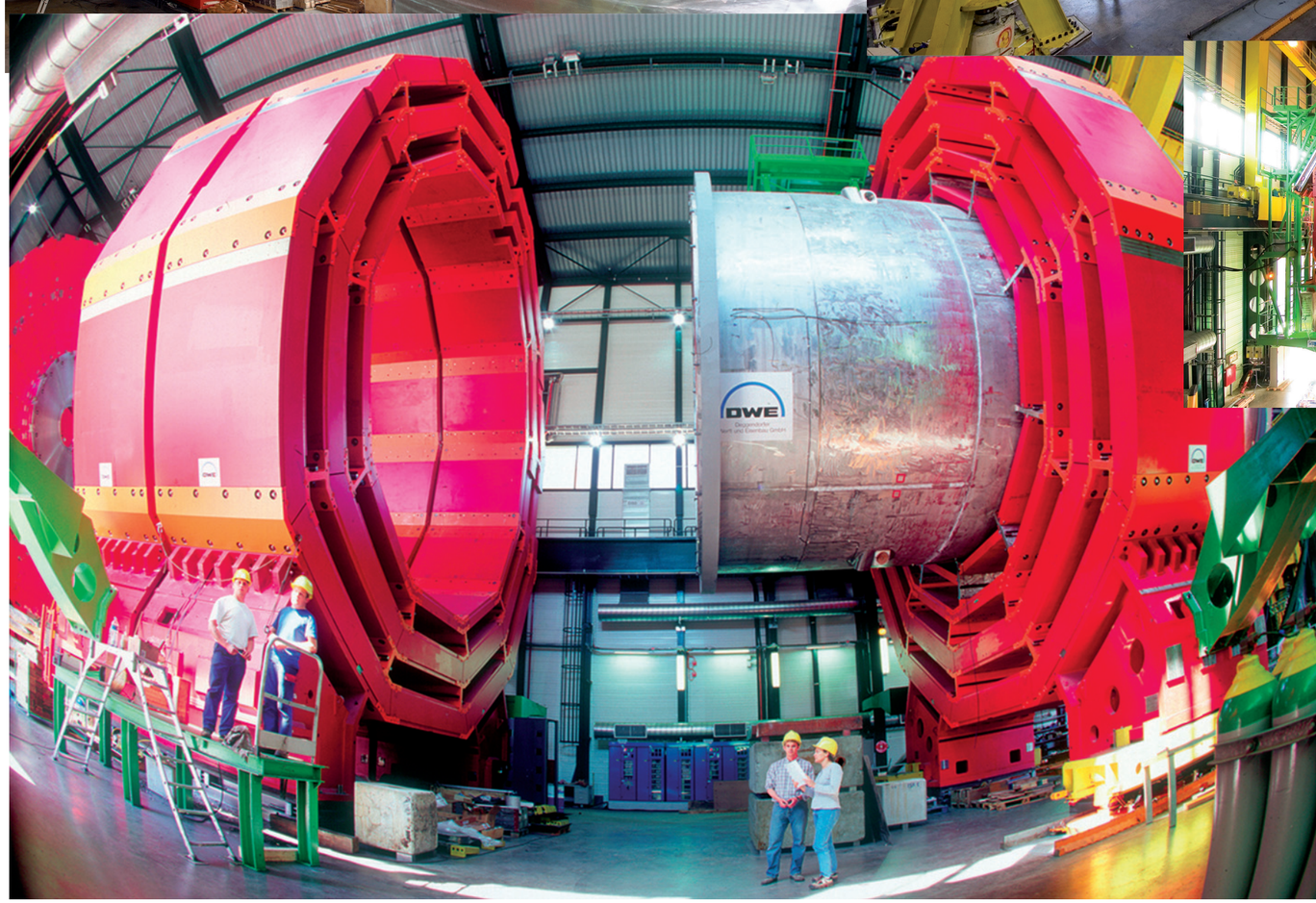
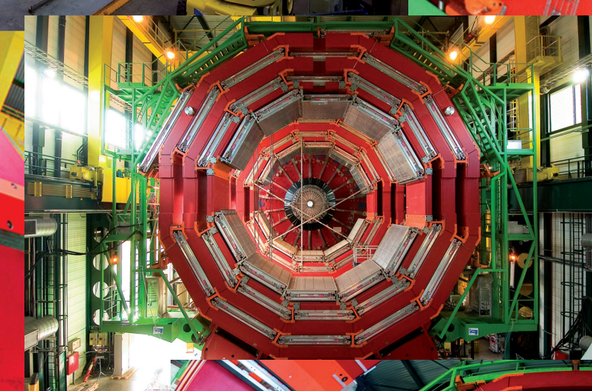
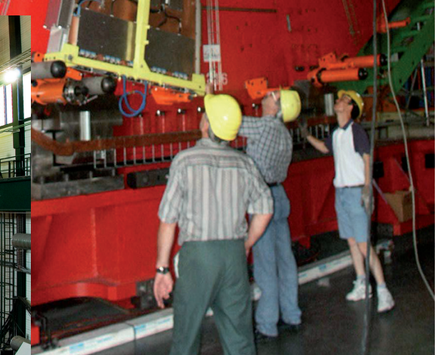
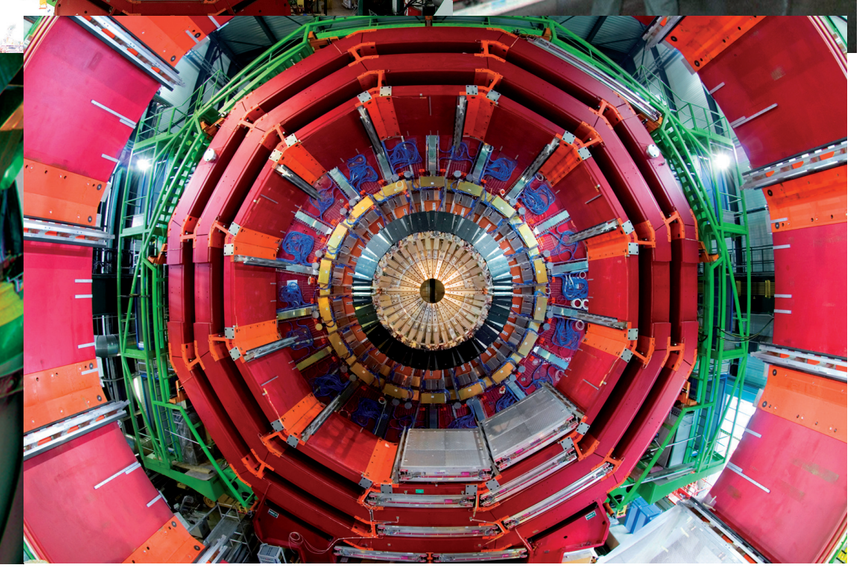
Finishing Point 5

1 February 2005



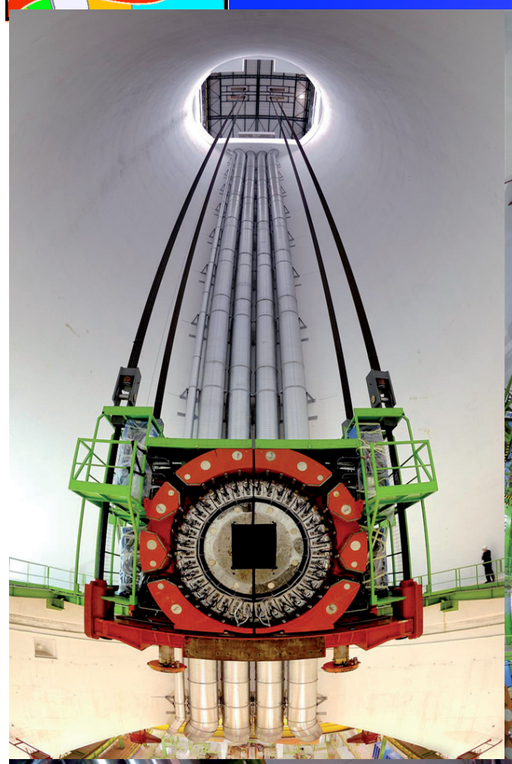
CMS Assembly on Surface

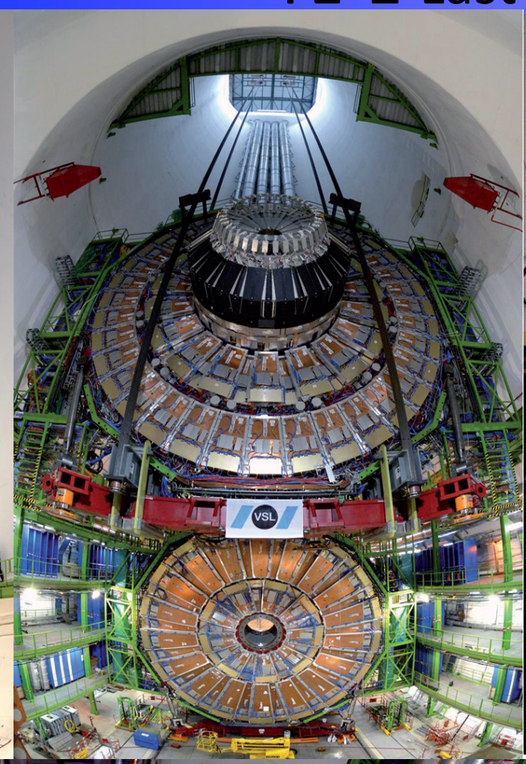


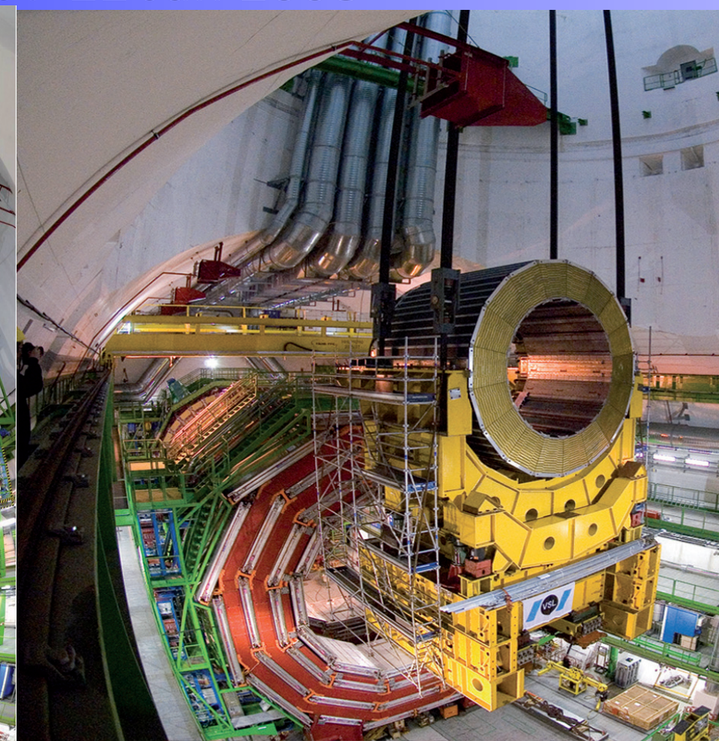







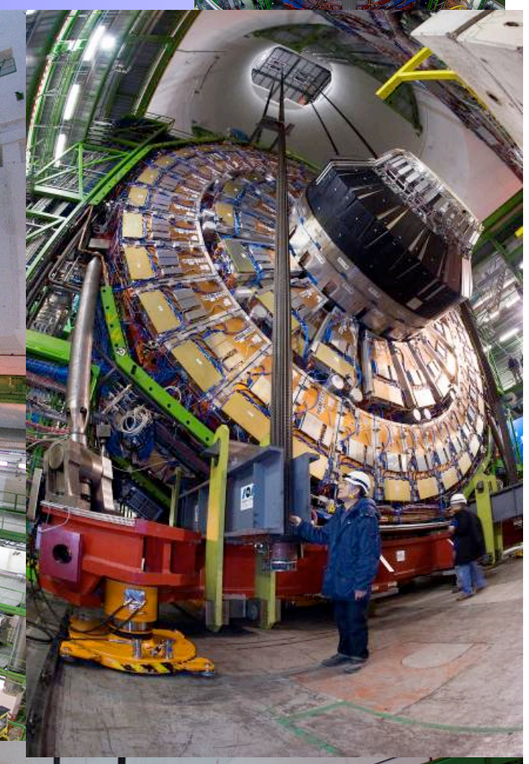
15 Modules Lowered

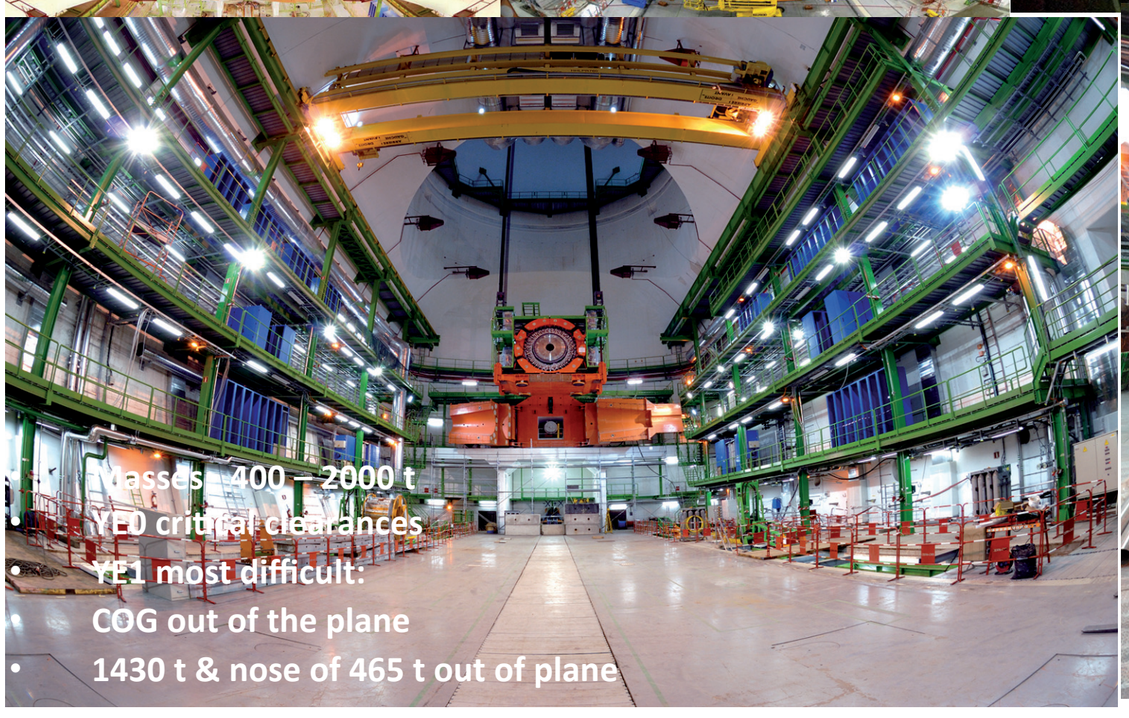
YE-1 Last : 22 Jan 2008



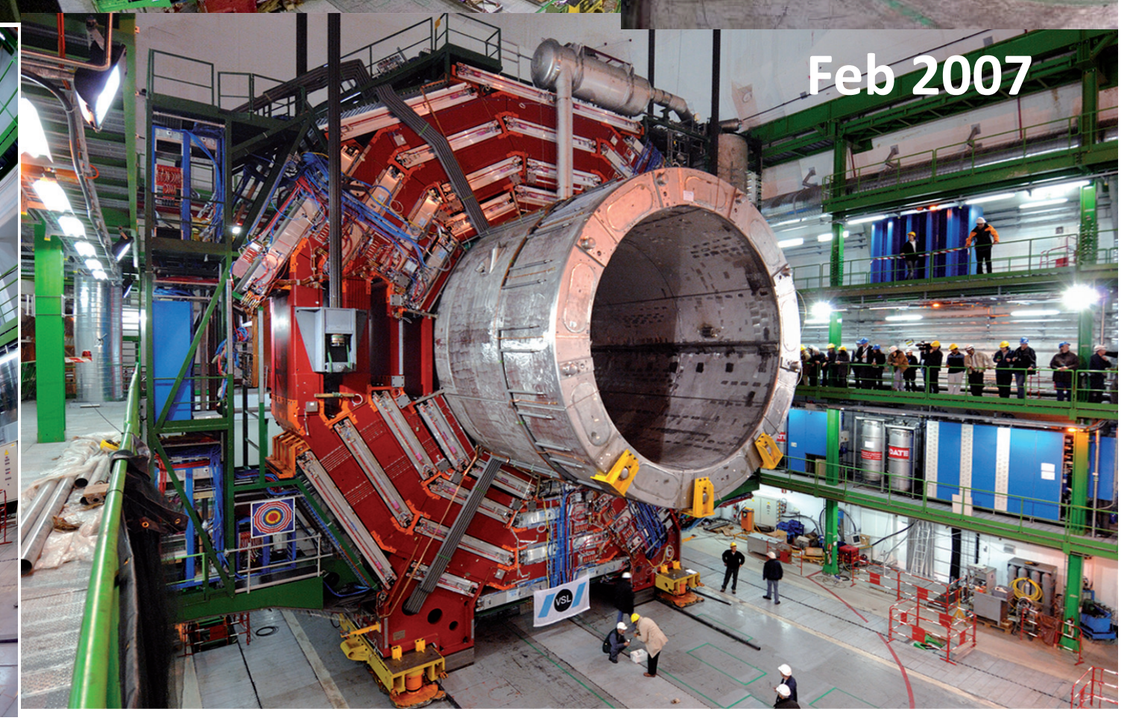




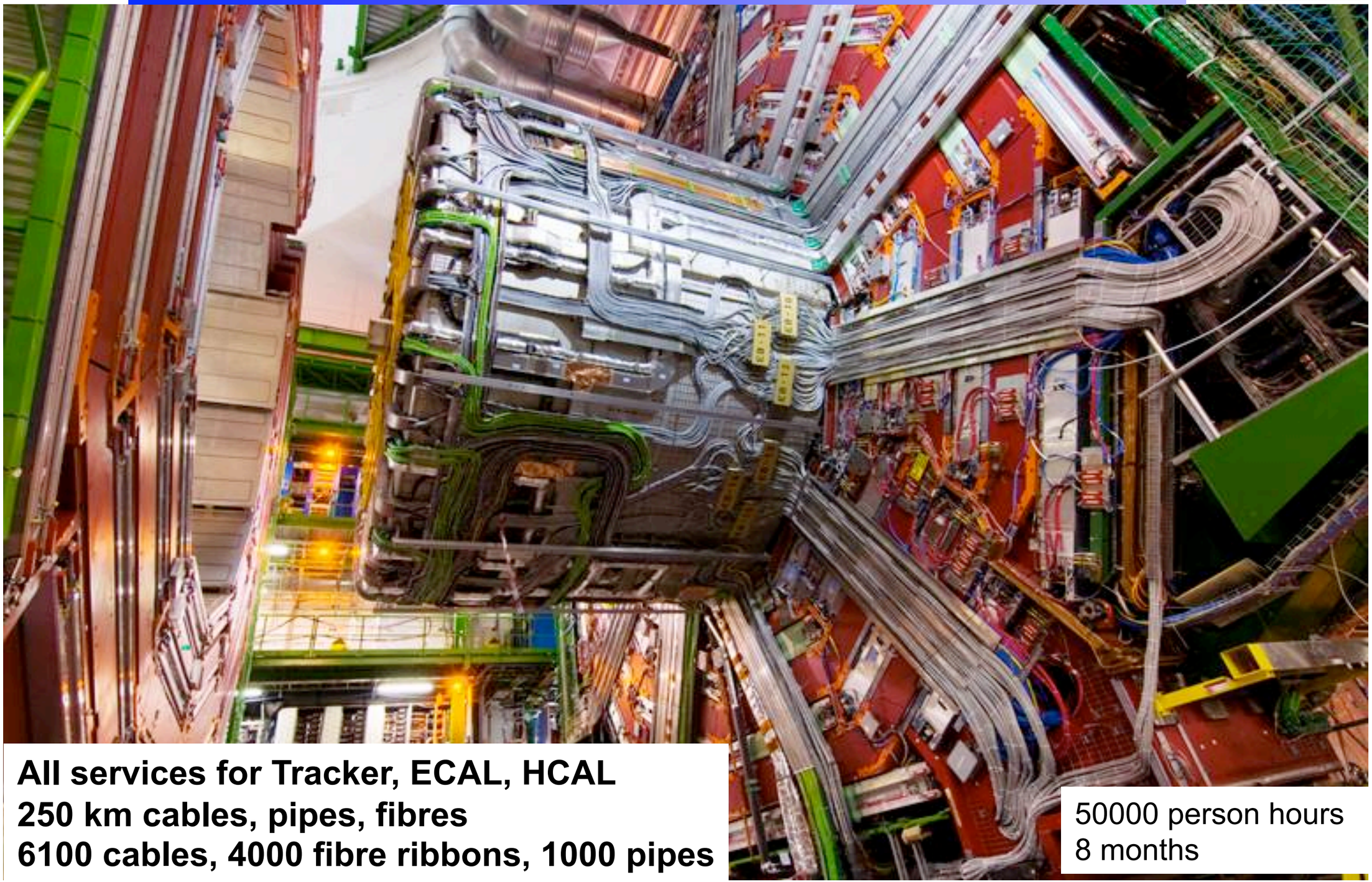




- Masses 400 – 2000 t
- YE0 critical clearances
- YE1 most difficult:
  - COG out of the plane
  - 1430 t & nose of 465 t out of plane



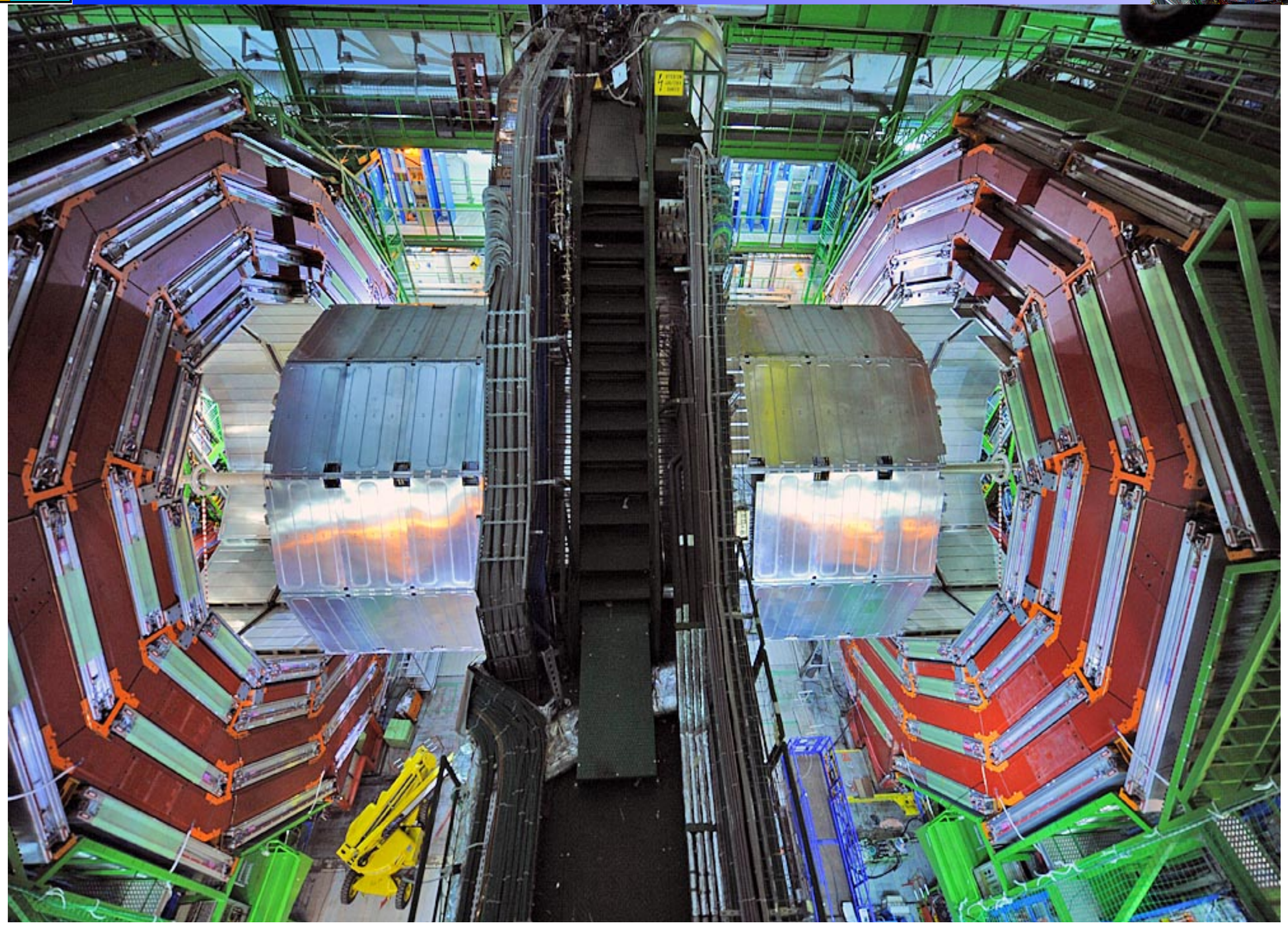
Cabling of CMS



All services for Tracker, ECAL, HCAL
250 km cables, pipes, fibres
6100 cables, 4000 fibre ribbons, 1000 pipes

50000 person hours
8 months

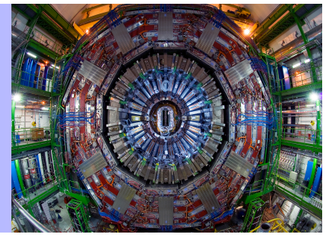
CMS Ready for Closure



CMS Final Closure and Ready for Collisions

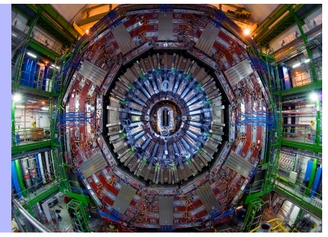
10 Sep 08 – Media Splash Event

CMS Commissioning with Cosmic Muons



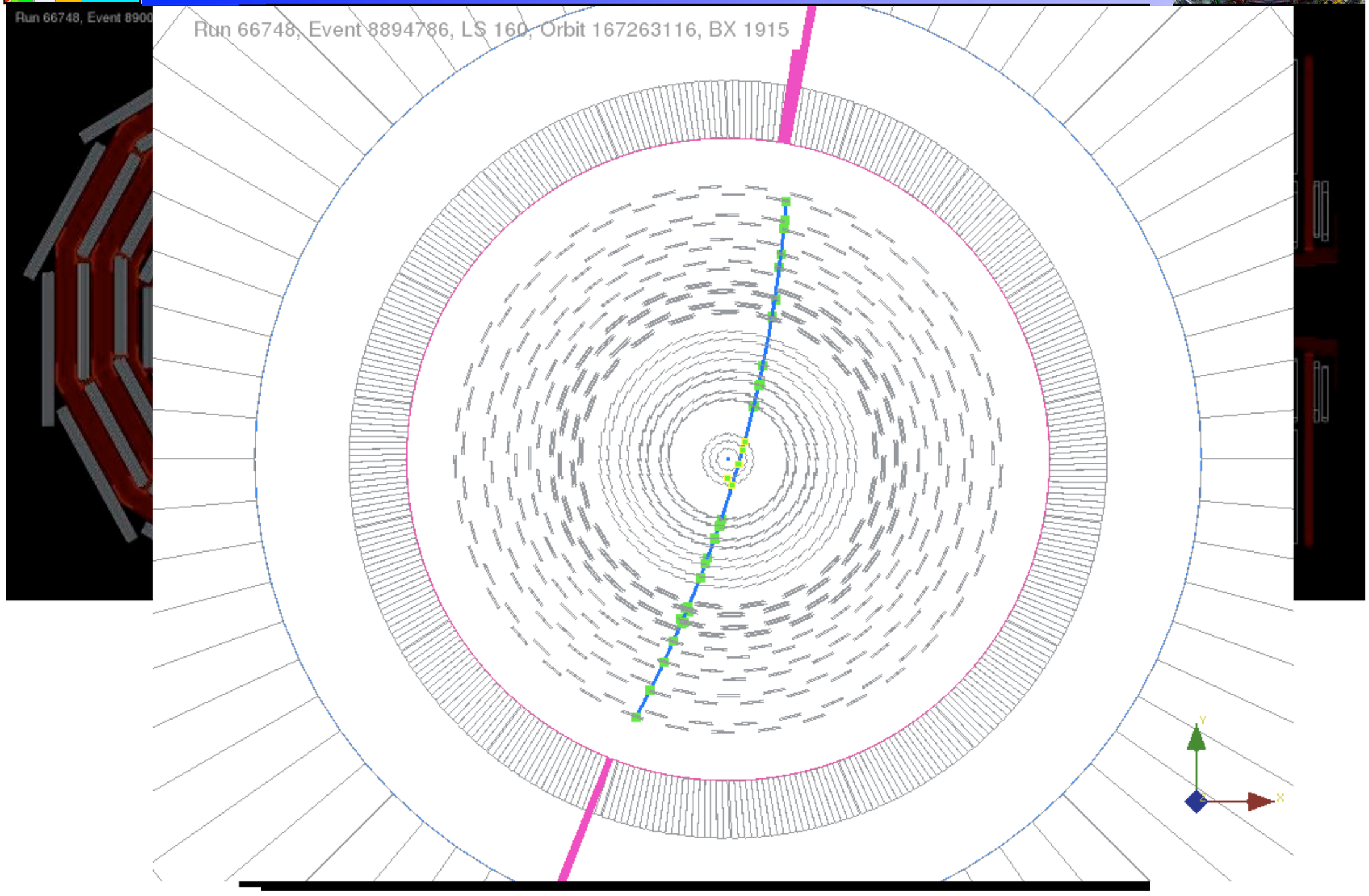
- **Regular Global Run exercises since 2008**
  - Varying frequency
  - Specific goals set
- **Cosmic RUn at ZEro Tesla –CRUZET**
  - Global exercise to accumulate cosmic muon data from entire detector
- **Cosmic Run At Four Tesla-CRAFT**
  - Gain experience in operation of CMS with magnetic field
  - Stability of subsystems and infrastructure
  - Oct 2008 – 23 days ; Aug 2009 – 40 days – leading to beams
- **1 billion cosmic muon events recorded and analyzed!**
  - Data distributed widely
  - Analyses done with advanced versions of the sw releases and using LHC Grid infrastructure
  - Submitted >23 publication from CRAFT

CMS Commissioning

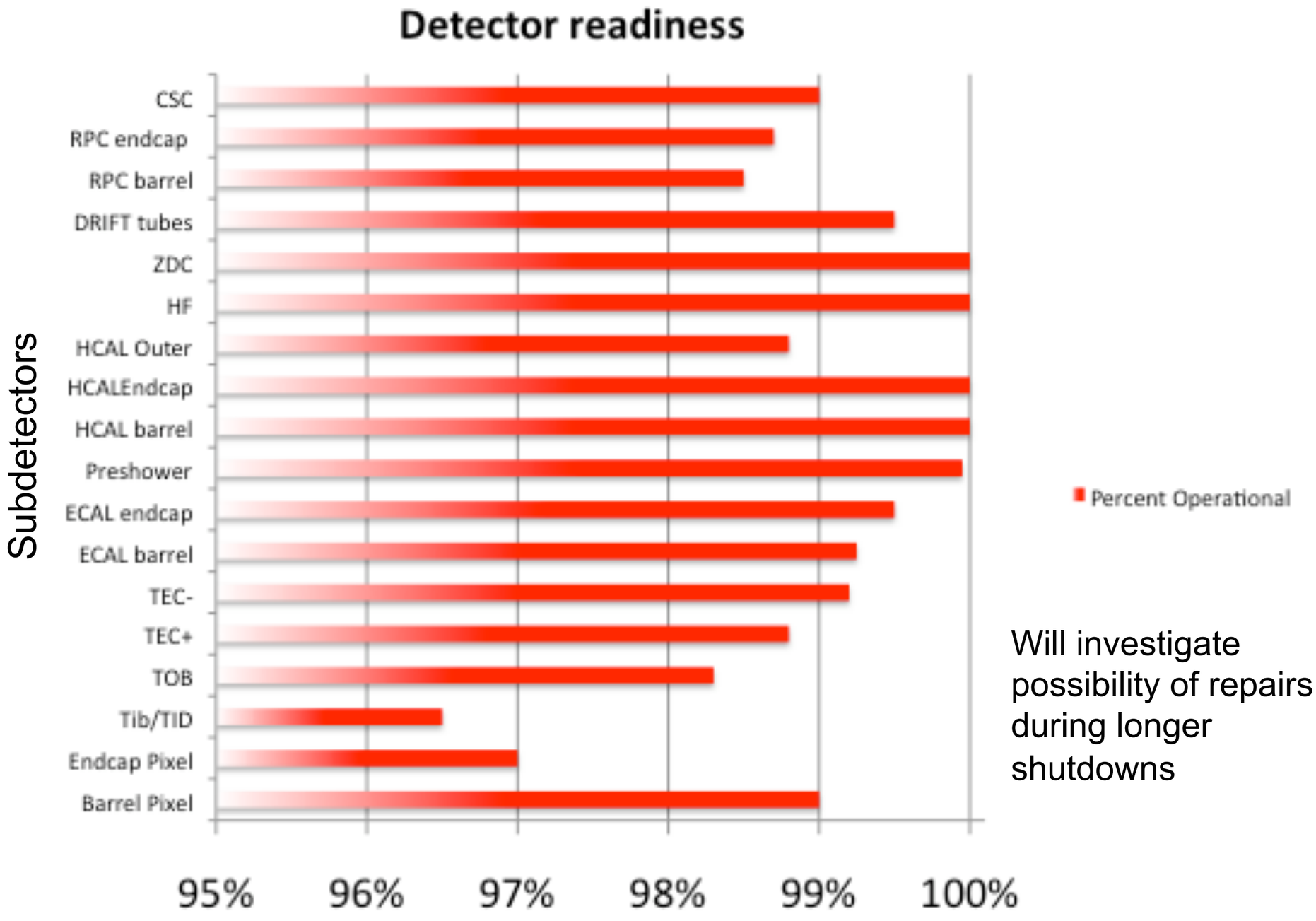


- Conflicting Interests: assembly and integration concurrent with operation
- Commissioning work on single components
  - Check & Repair of hardware components
  - Tuning of firmware and software
  - Local runs for better understanding of noise
  - Calibration and alignment
- Global commissioning: bring whole detector to work
  - Verify integrity of services: trigger, timing, DAQ, DCS
  - Exercise data flow from detector to Tier-2 centers
  - Optimize performance
  - Improve procedures for good running efficiency

From Straight to Bent Tracks

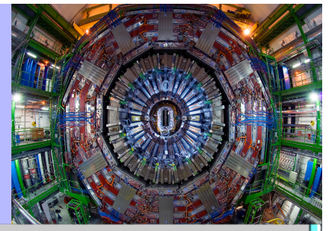


CMS Performance

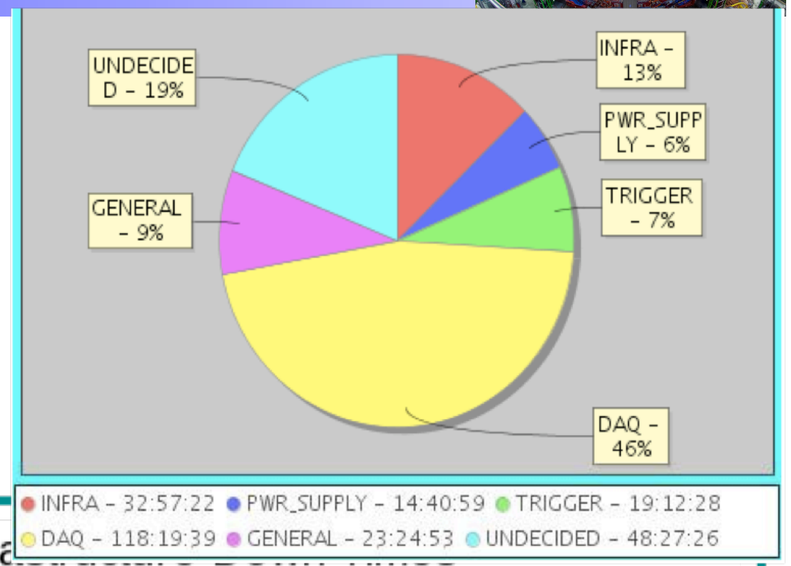


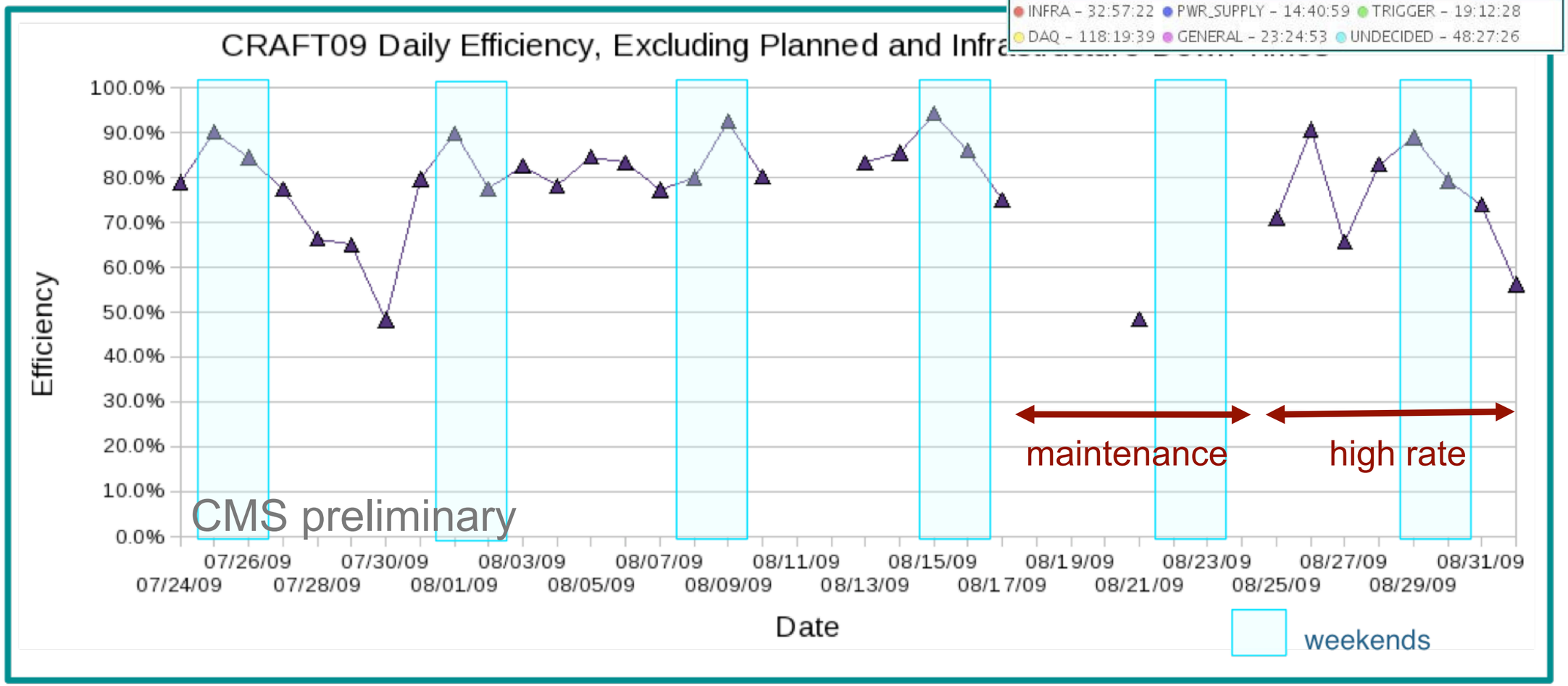
Will investigate possibility of repairs during longer shutdowns

Operational Efficiency in CRAFT2009

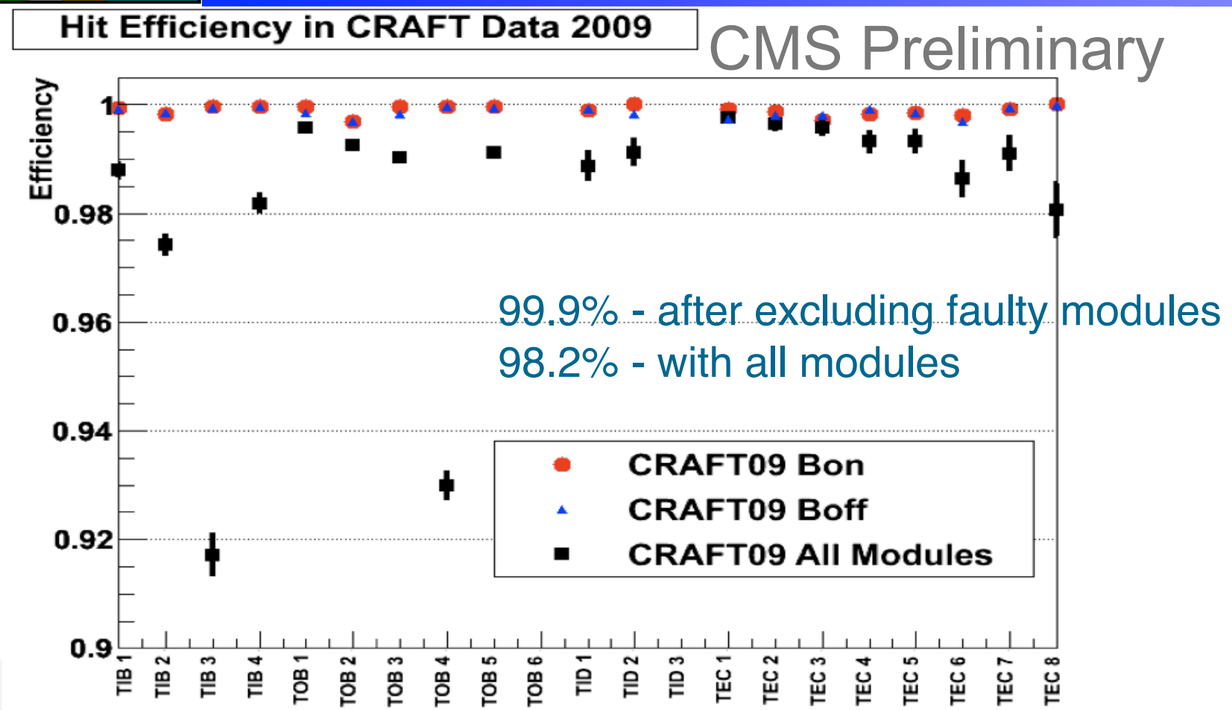


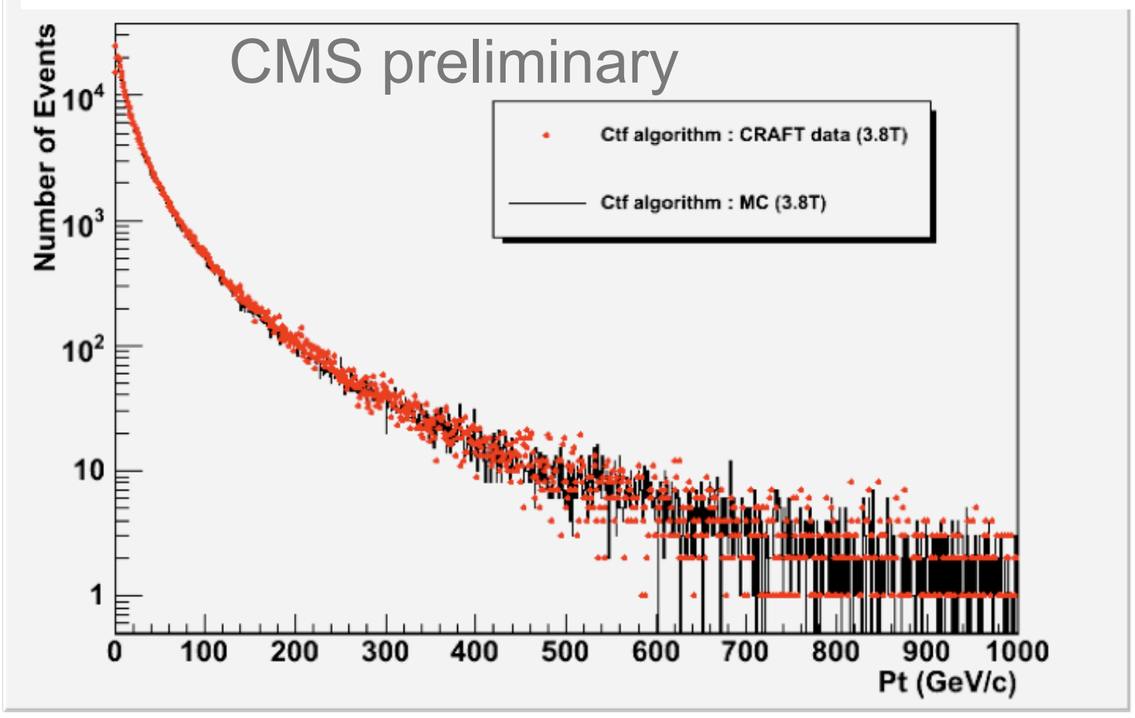
- **Automated Run Time Logger in CRAFT'09**
- **Average efficiency: 71% between 24 July – 1 Sep '09**
- **Weekend effect visible**
- **Human action required to assign cathegory**

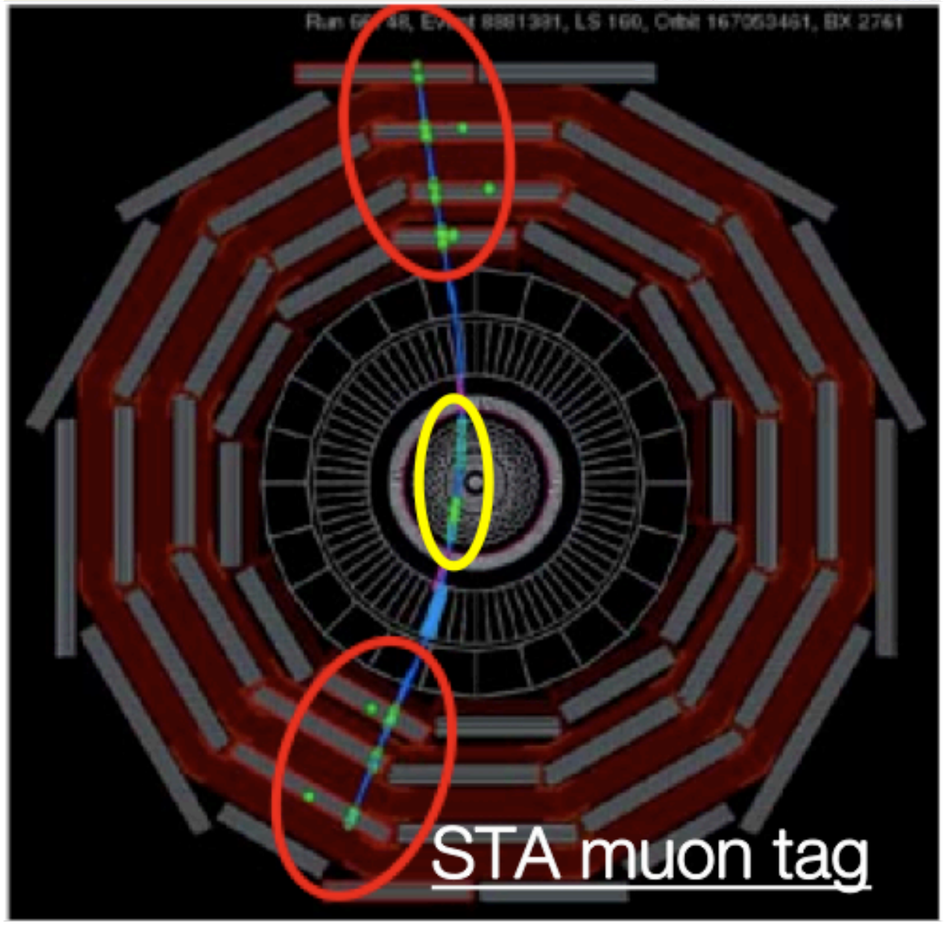




Tracker Performance - CRAFT







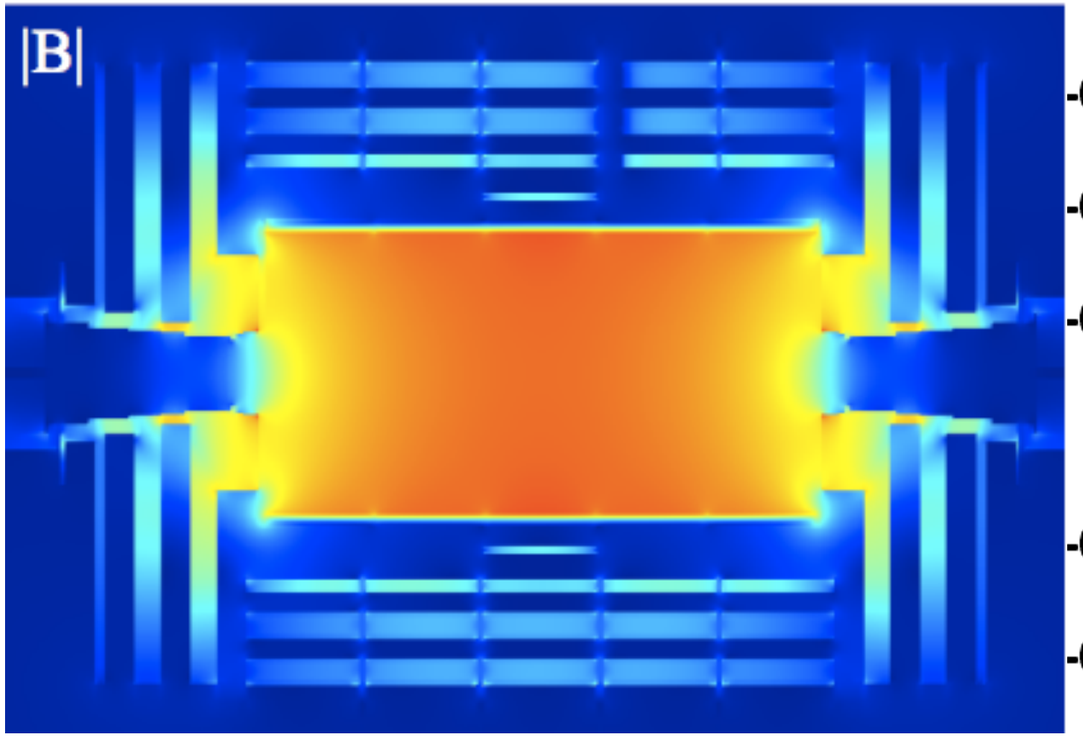
- **Tag muons with tracks reconstructed in the muon chambers**
- **Two algorithms: Combinatorial Track Finding & Cosmic Track Finder**

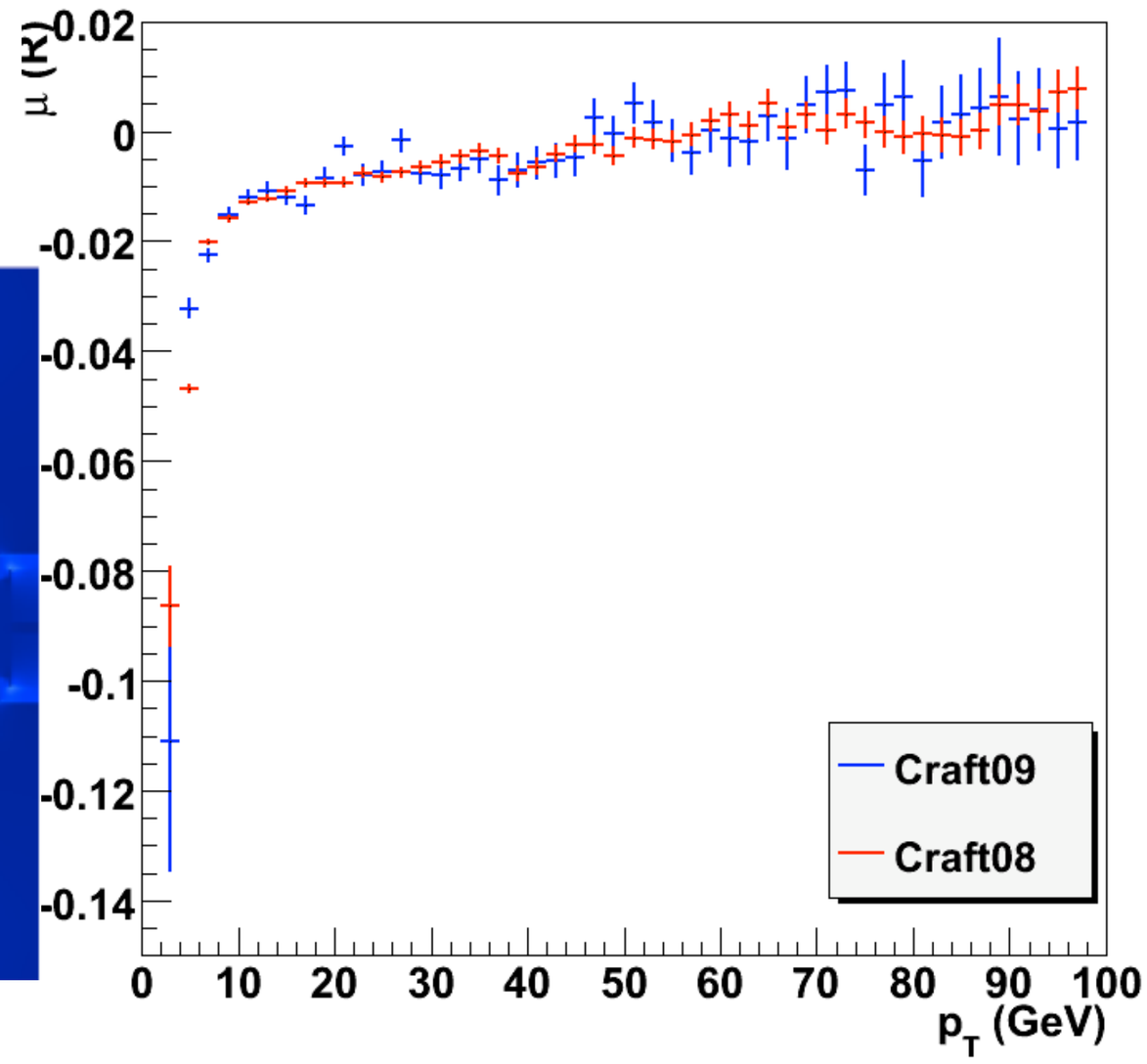
Efficiency (%)	CRAFT 09
CTF	99.8±0.1
CosmicTF	99.8±0.1

CMS Performance

- **Momentum comparison between Standalone and Tracker Muons**
- **Test of B field map**

$$R = \frac{1/p_T^{STA} - 1/p_T^{TT}}{1/p_T^{TT}}$$





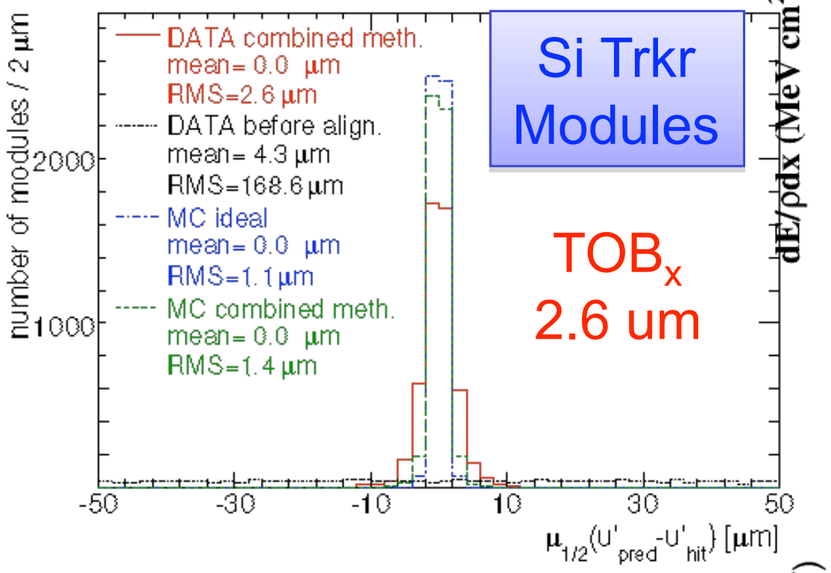
CRAFT 2008 Performance

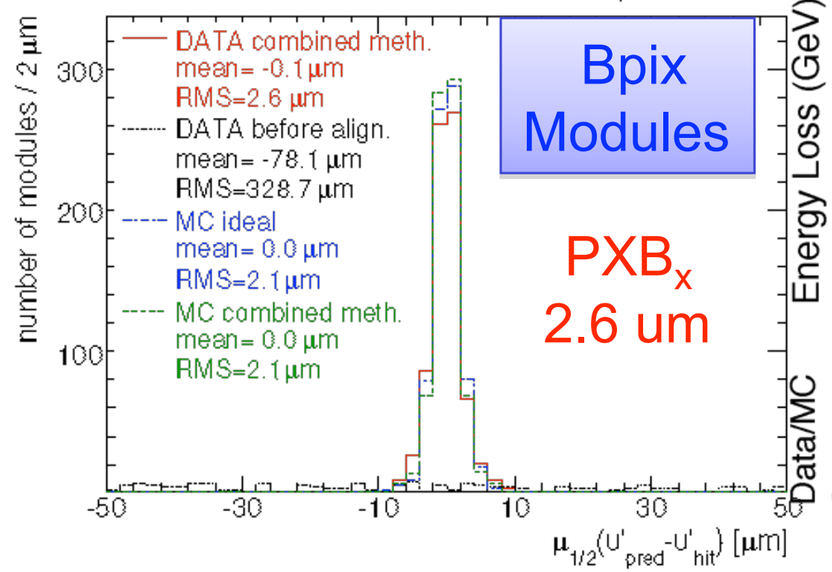
over 23 papers submitted to JINST

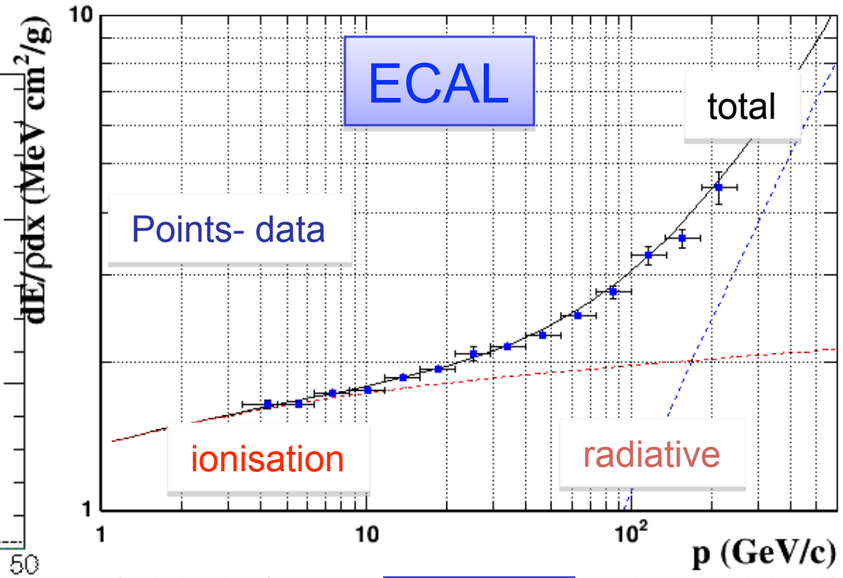
Alignment in Inner Tracker

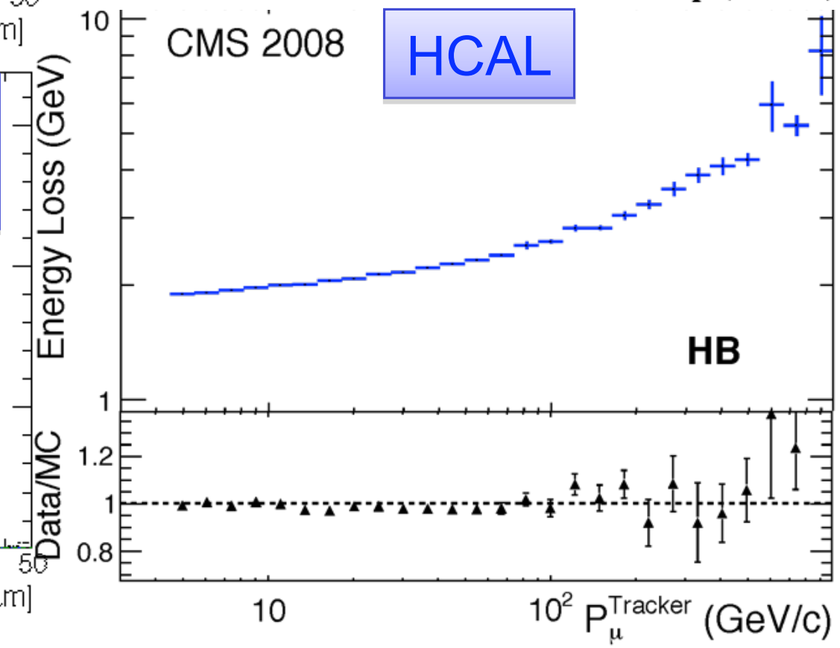
Energy deposited by muons

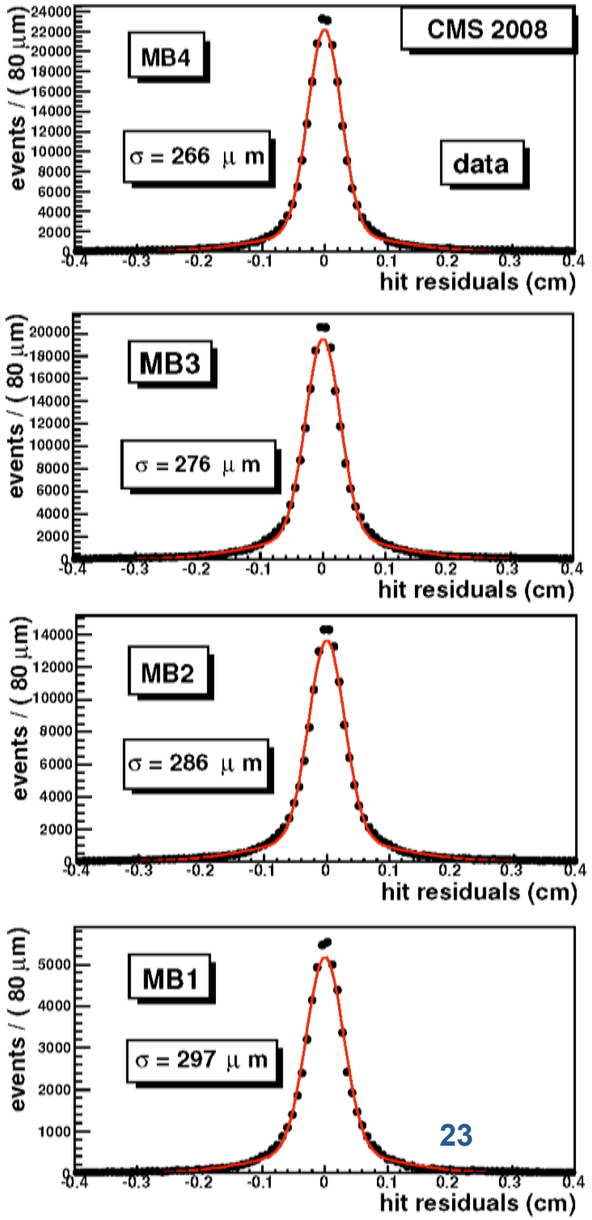
Muon Chambers Point Resolution





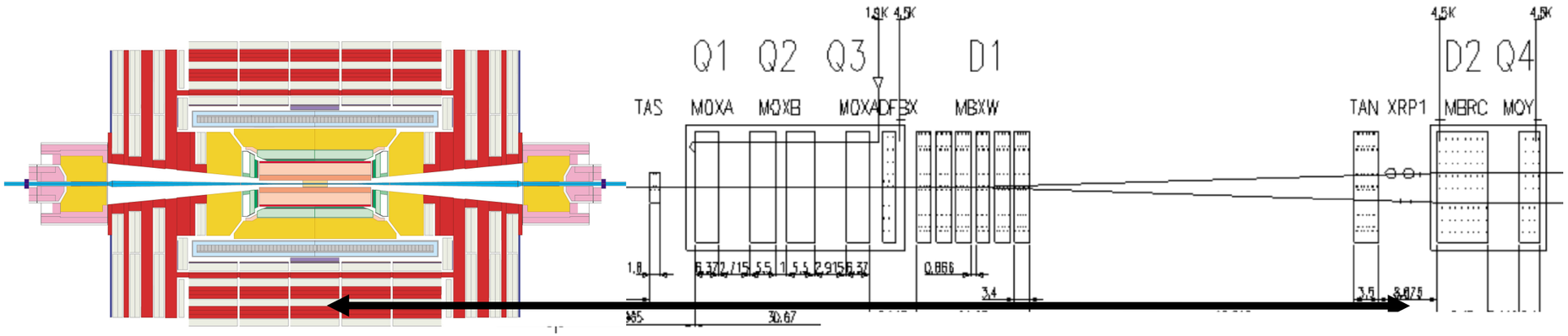


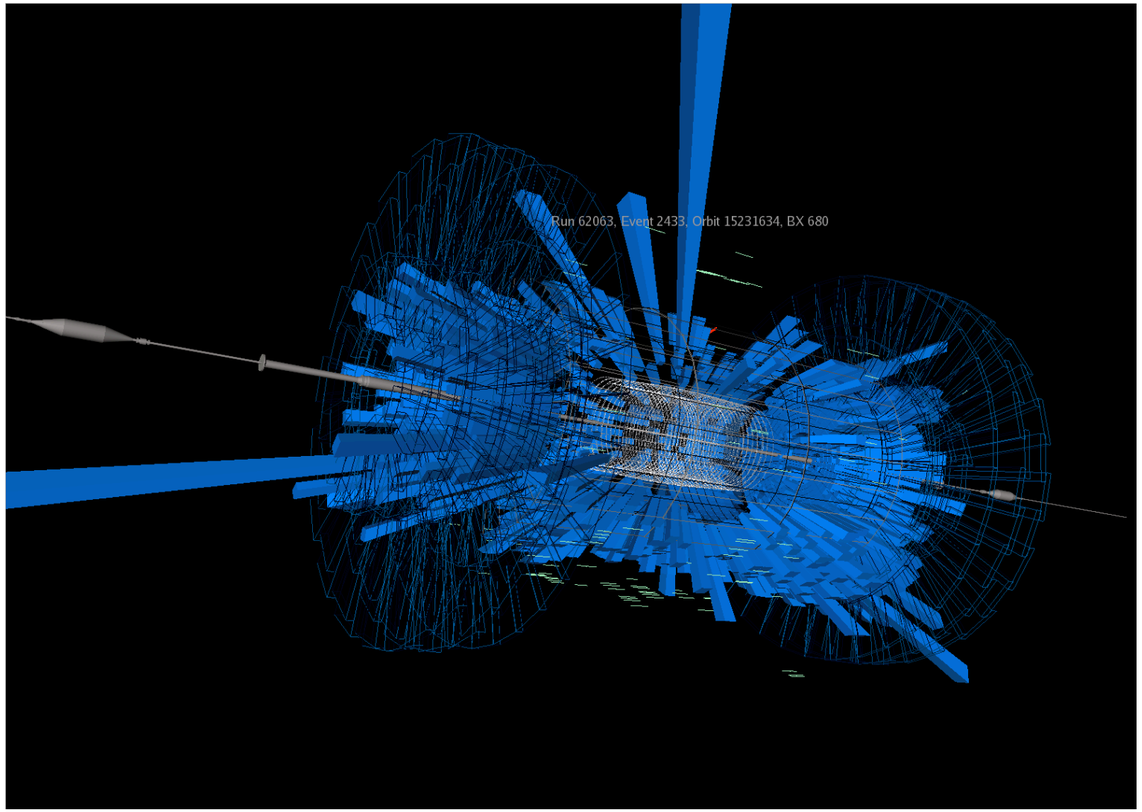


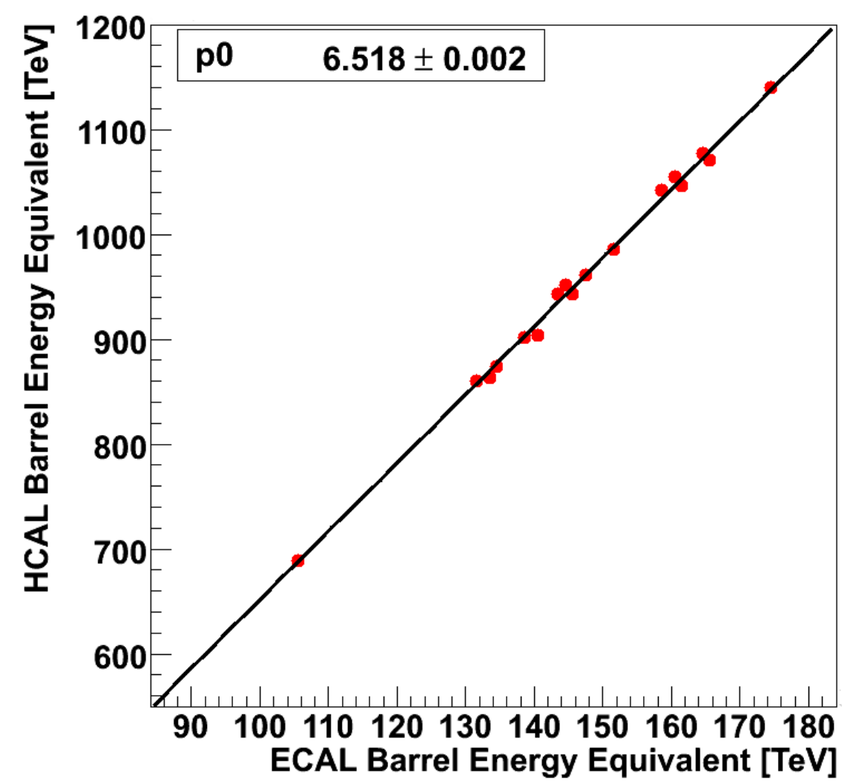


CMS Splash Events

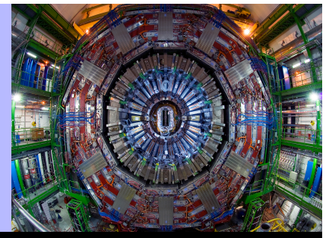
- ~2×10^9 protons @ 450 GeV on collimator 150m upstream of CMS
- Many secondary particles traverse the detectors



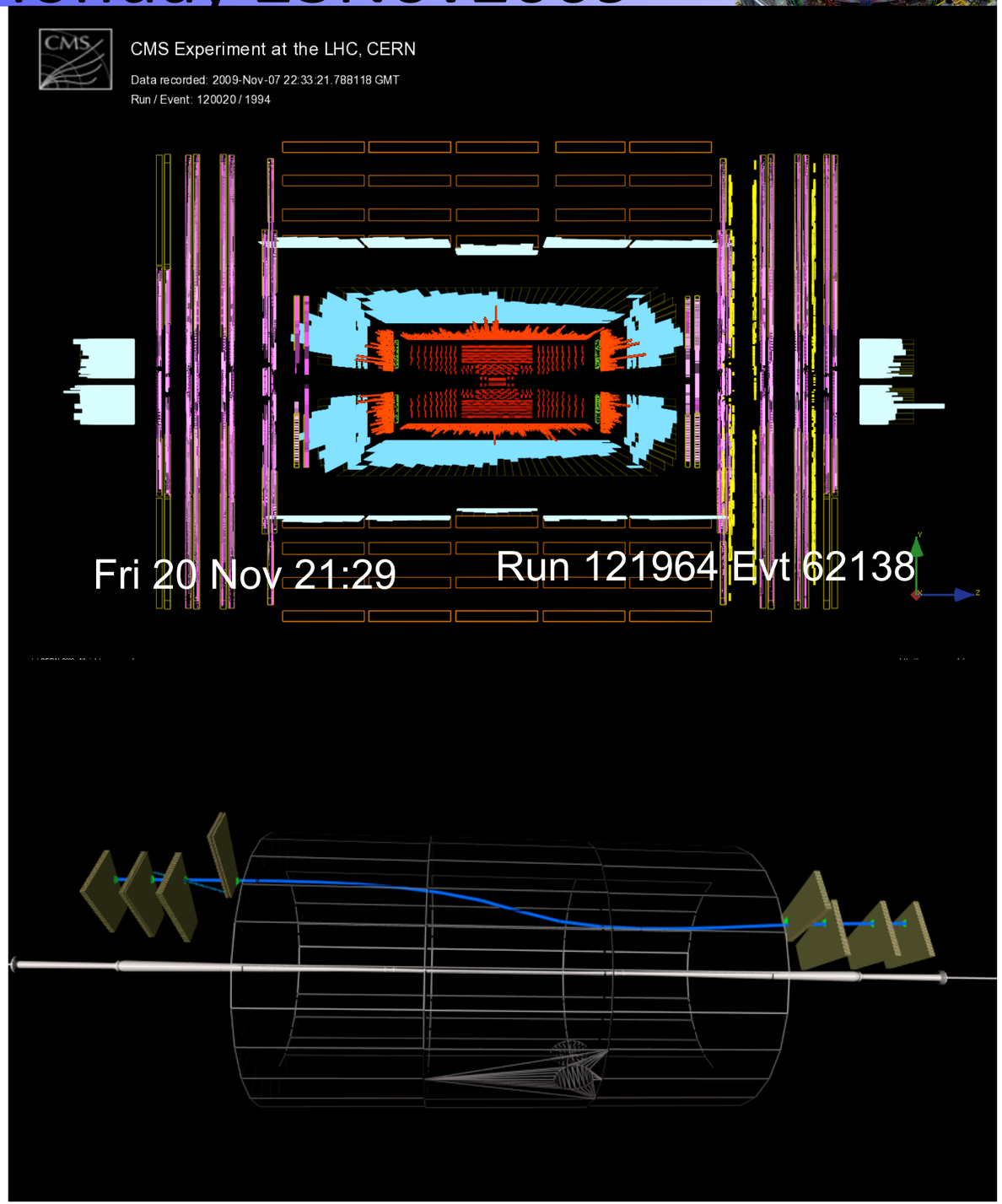




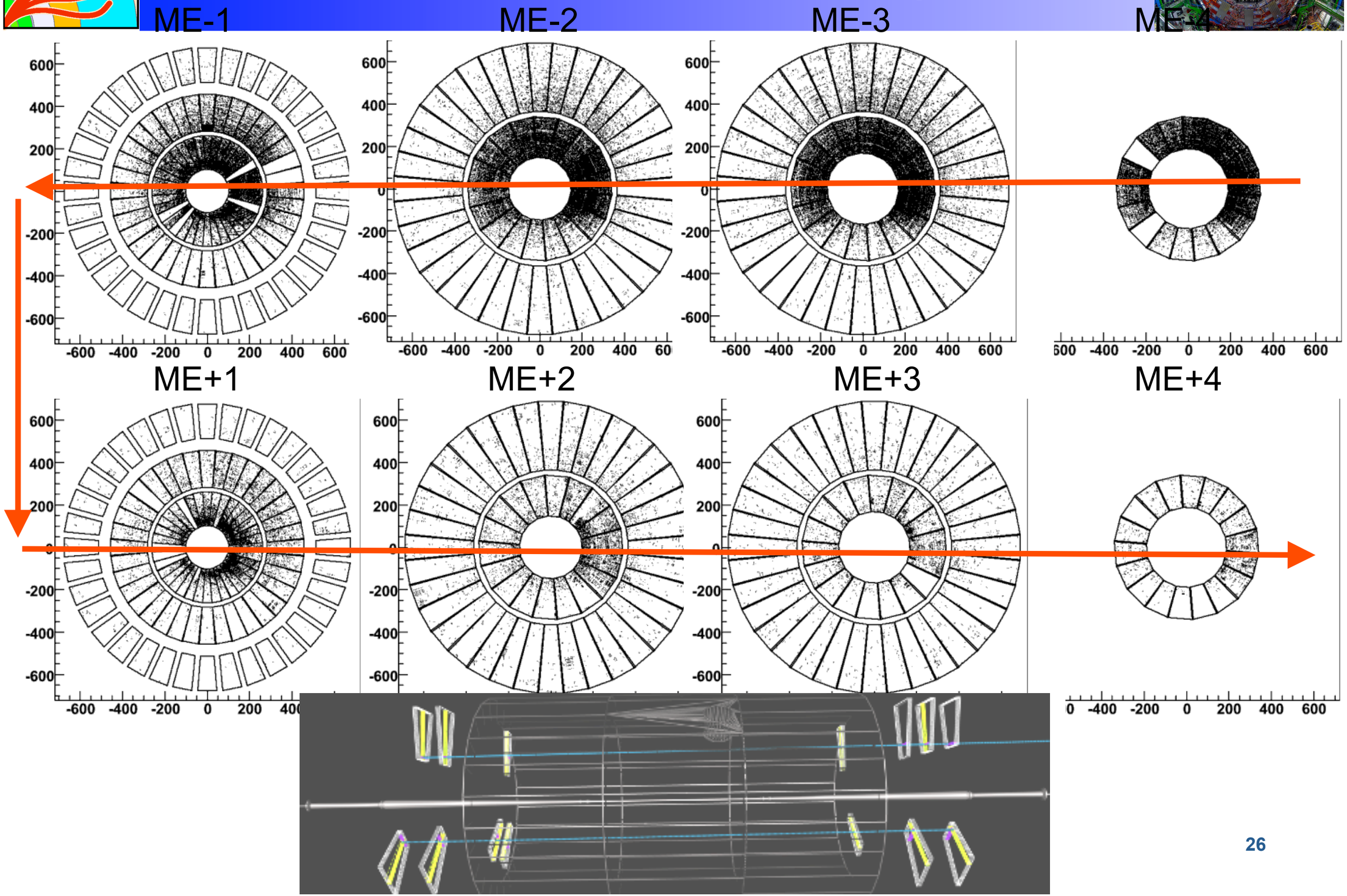
LHC Injects and Circulates Beams
Friday 20Nov to Monday 23Nov2009



- Splashes on both sides on CMS during threading
- Adjust timing of critical trigger parameters
  - Beam Pickup and Beam Scintillators
  - Feedback to LHC on RF cogging
- CMS in special configuration:
  - Calorimeters ON
  - Muon at standby voltages
  - Inner Trk, magnet OFF
- Circulating beams with lifetimes exceeding 5hr
- Accumulation of Beam Halo events

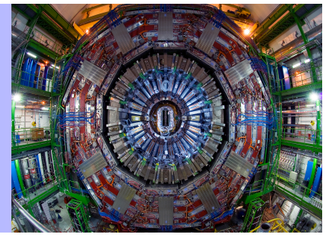


Beam Halo Muons in Endcaps - CSC



2 LHC Circulating Beams

Monday 23Nov2009 - 13:30

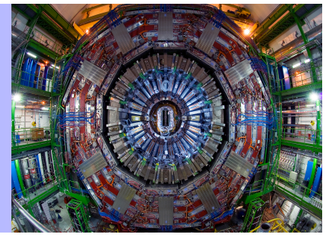


- **Amazing progress in commissioning single beams**
  - **RF capture, Orbit corrections, aperture scans**
  - **Optical dispersion remarkably good**
  - **Beam lifetimes increasing ~10hr**
- **Sunday PM - information of possible simultaneous two beam circulation within 24hr:**
  - **Machine experts advise prudence for sensitive systems close to the beam.**
  - **Machine protection systems, collimators and solenoid compensation not yet fully commissioned.**
  - **Very special CMS configuration: Calorimeters and Muon Systems ON, Tracker Outer Barrel (TOB) ON. Magnet OFF.**
- **Preparations for circulating beams with bunches in the same bucket**

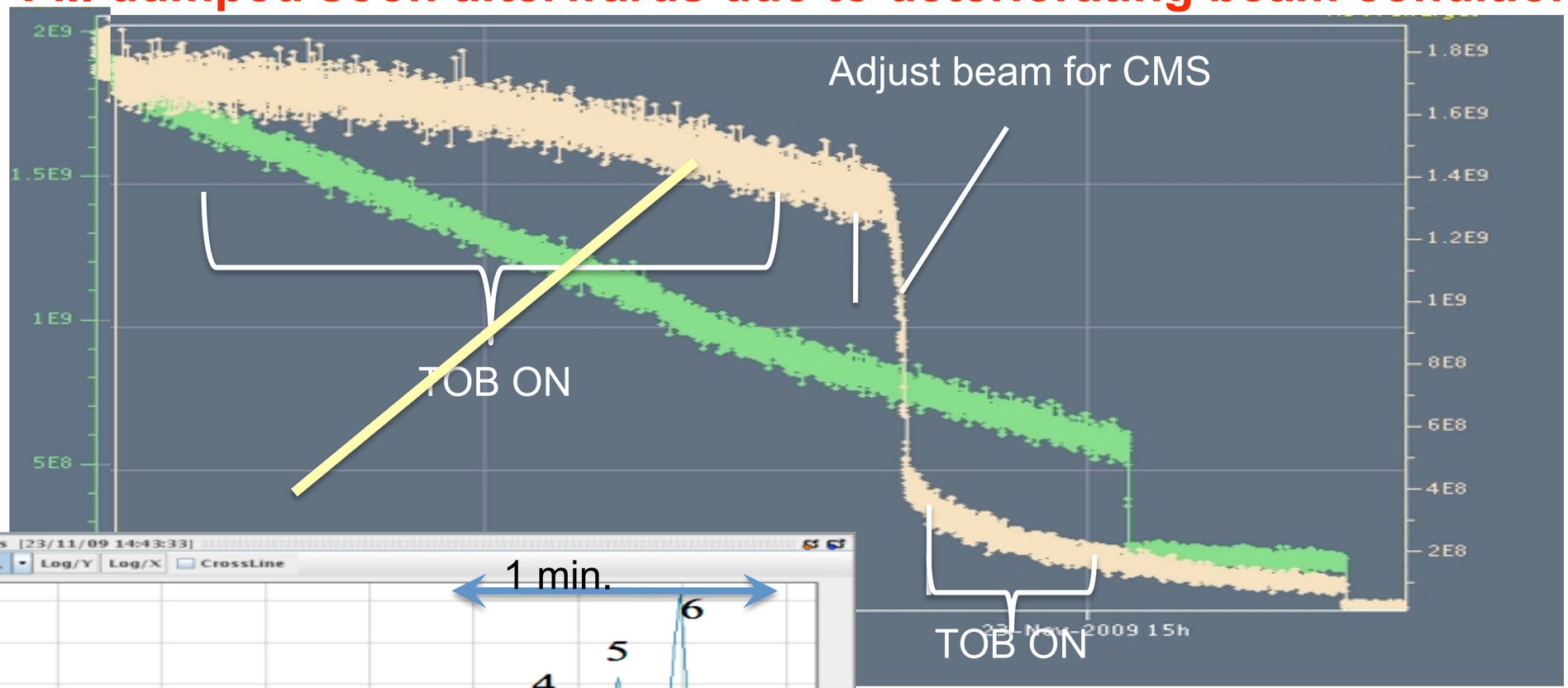
…and a possibility of crossings in CMS and ATLAS

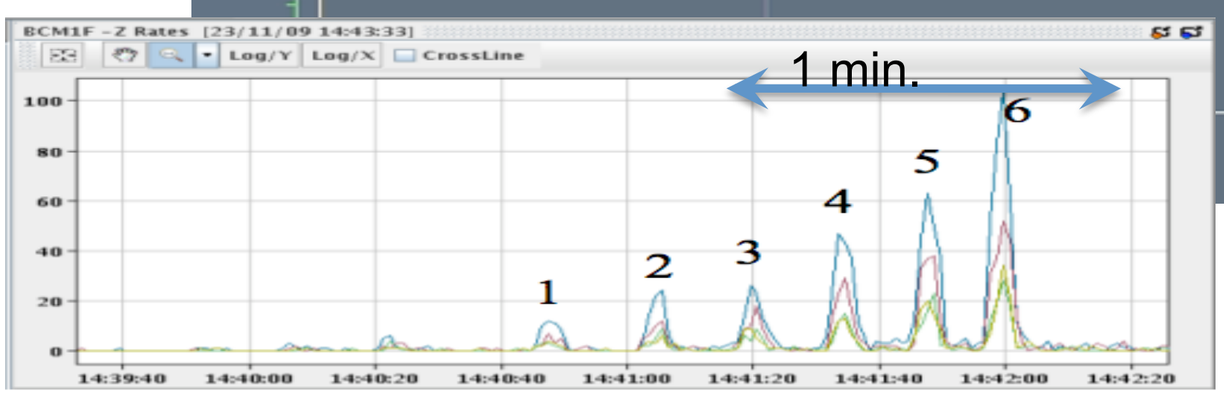
Monday 23 Nov 2009

Afternoon Fill



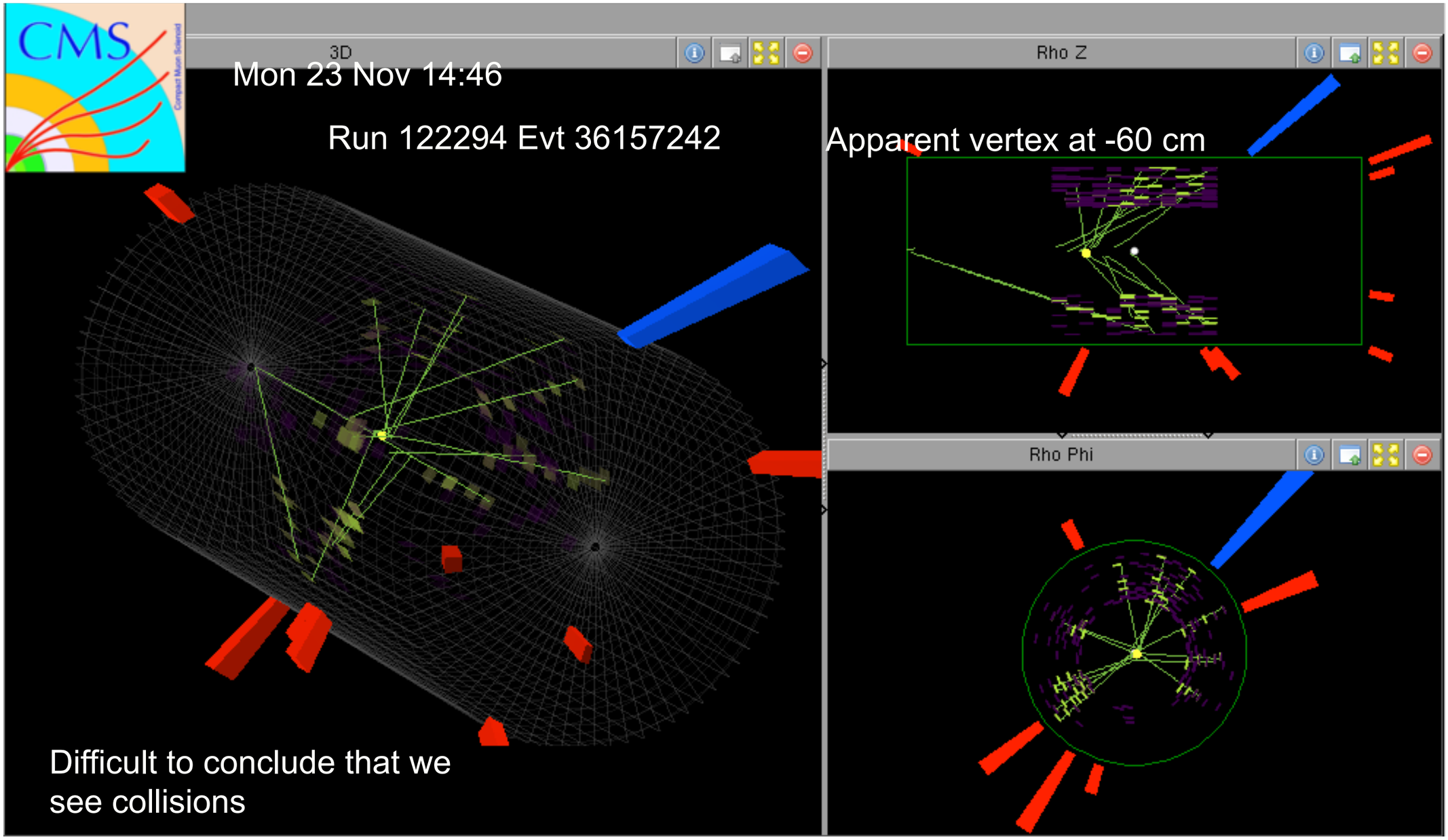
- **Beams were injected at ~13:30 and 'quiet conditions' declared.**
  - **lack of evidence of collisions, LHC ops try steering beams, first at P1 then P5, to bring them 'closer' to each other**
  - **Steering difficulties at P5 provoked large losses in Beam 2.**
  - **Fill dumped soon afterwards due to deteriorating beam conditions.**





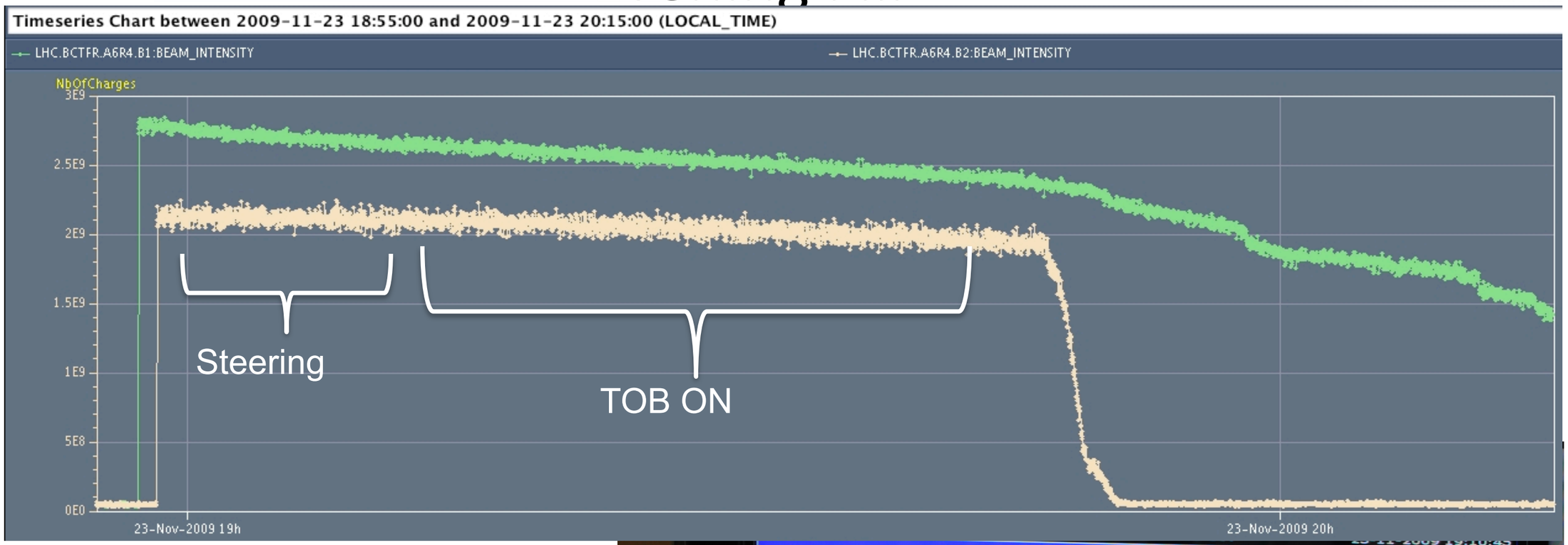
CMS Beam Monitoring sees the losses during the several trims attempted by an operator

A candidate Event-Afternoon Fill

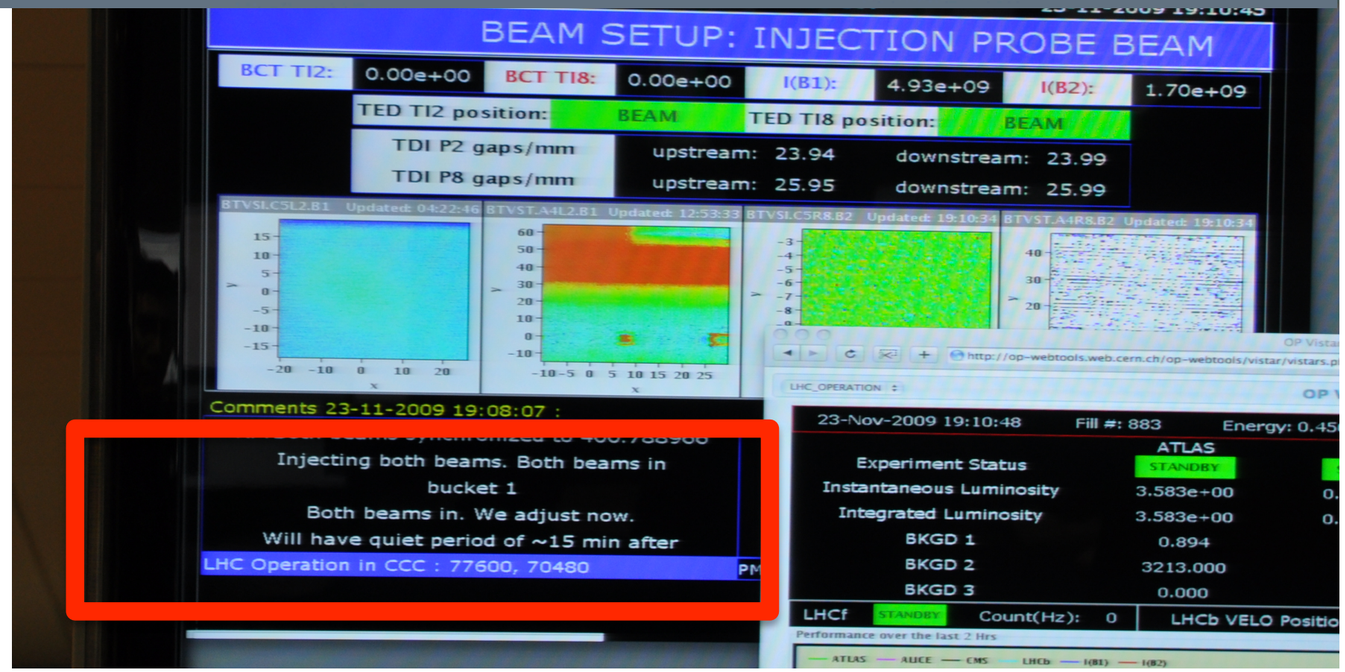


Monday 23 Nov 2009

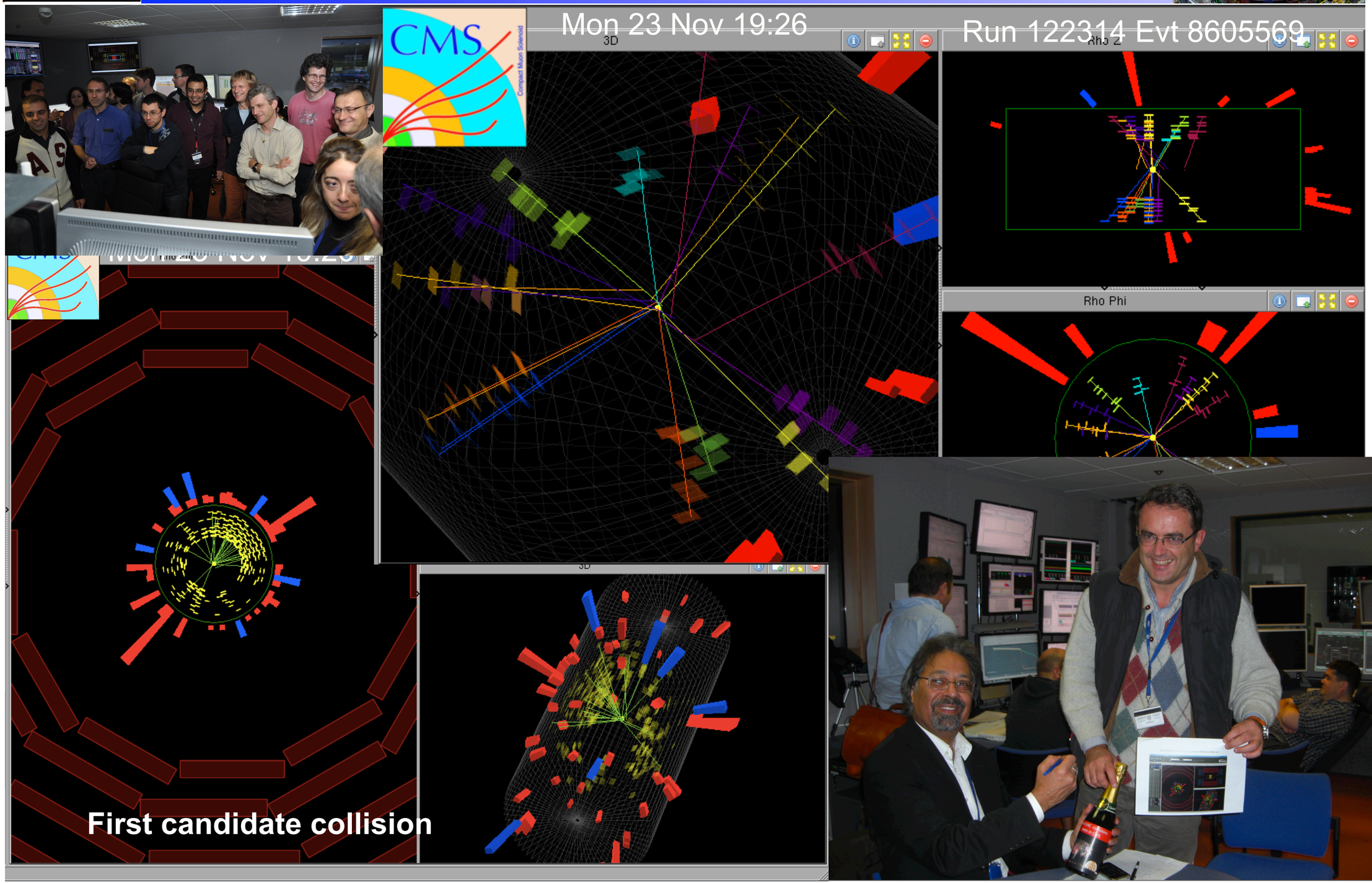
Evening Fill



- **After successful steering at P5: crossing beams.**
- **Collisions seen shortly after!**



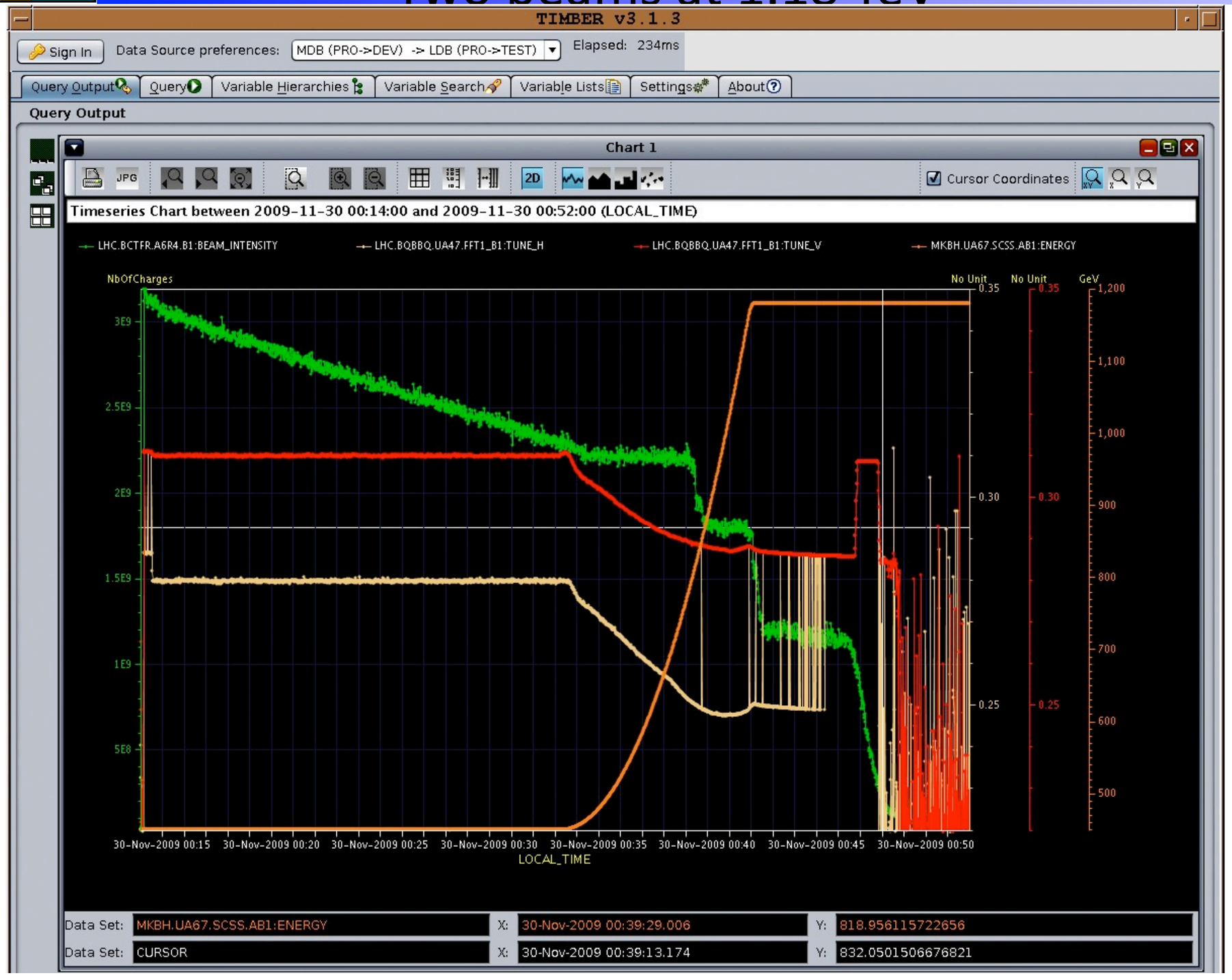
A First Event – Evening Fill



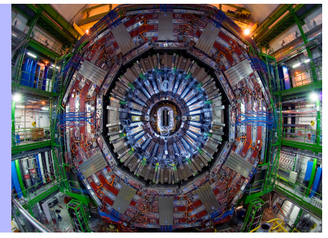
Thank you LHC Team!

30 Nov 2009

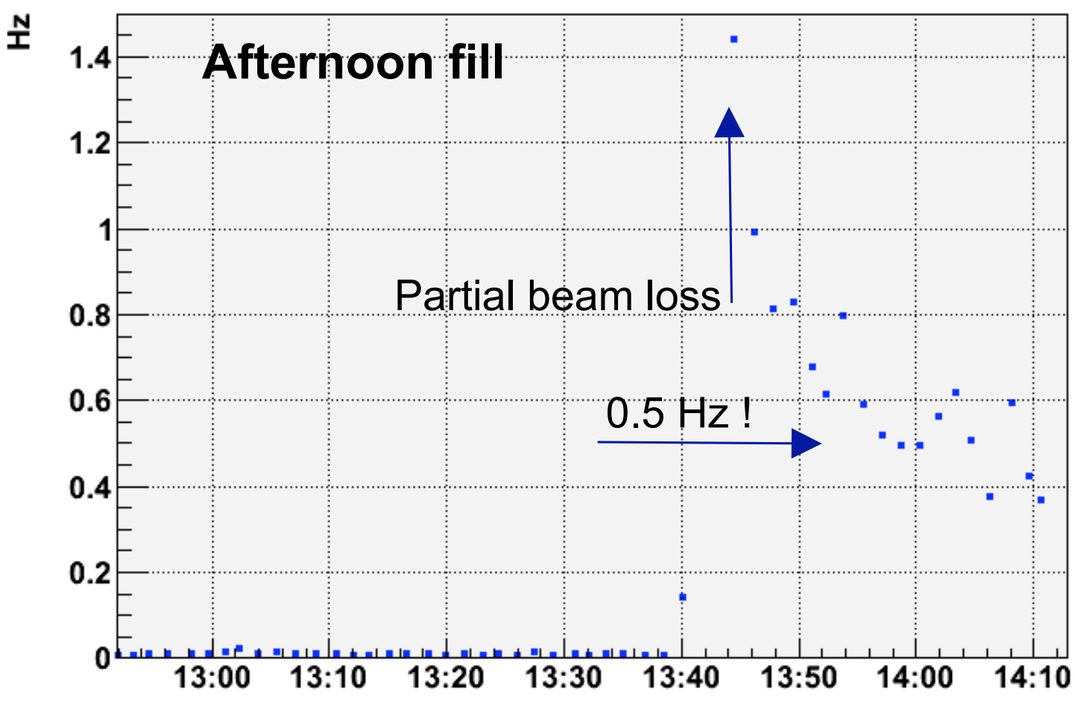
Two beams at 1.18 TeV

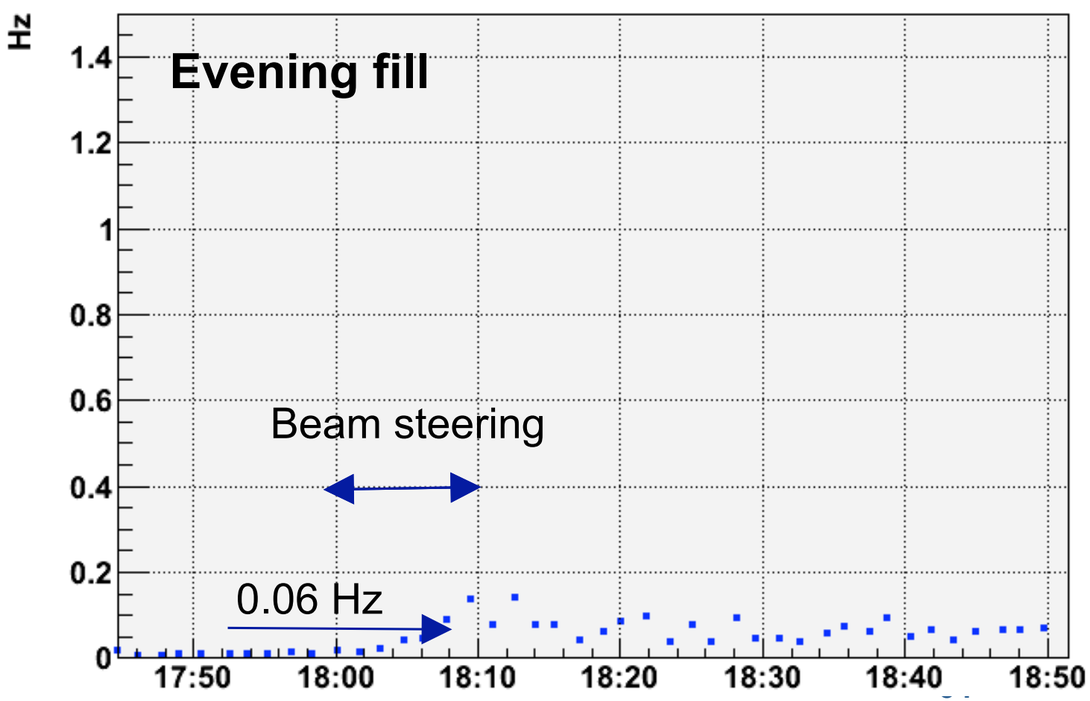


CMS Trigger configuration

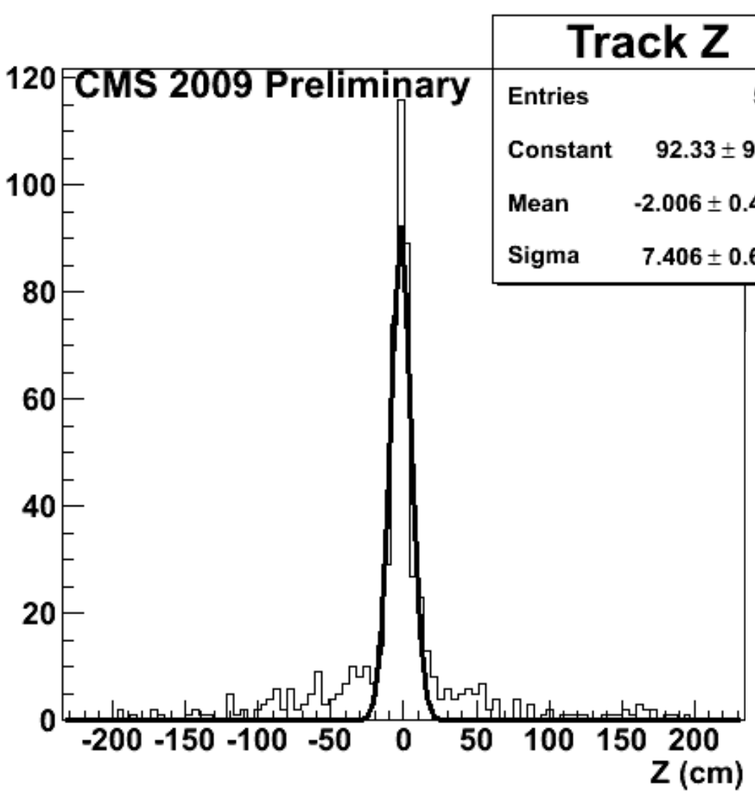


- **Beam Pickups timed in with splash events**
- **Beam Scintillators timed in with single beams**
- **<u>L1:</u> trigger on Beam Pickups, record decisions of min. bias triggers**
- **<u>High Level Trigger:</u> Select events with L1 min. bias decisions in a +- 2bx window around BPTX or with activity in calorimeters**





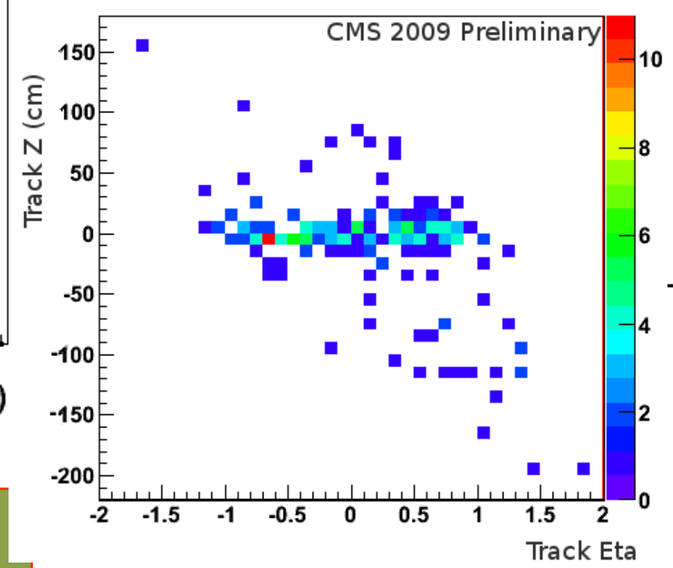
Prompt Track Information
Evening Fill



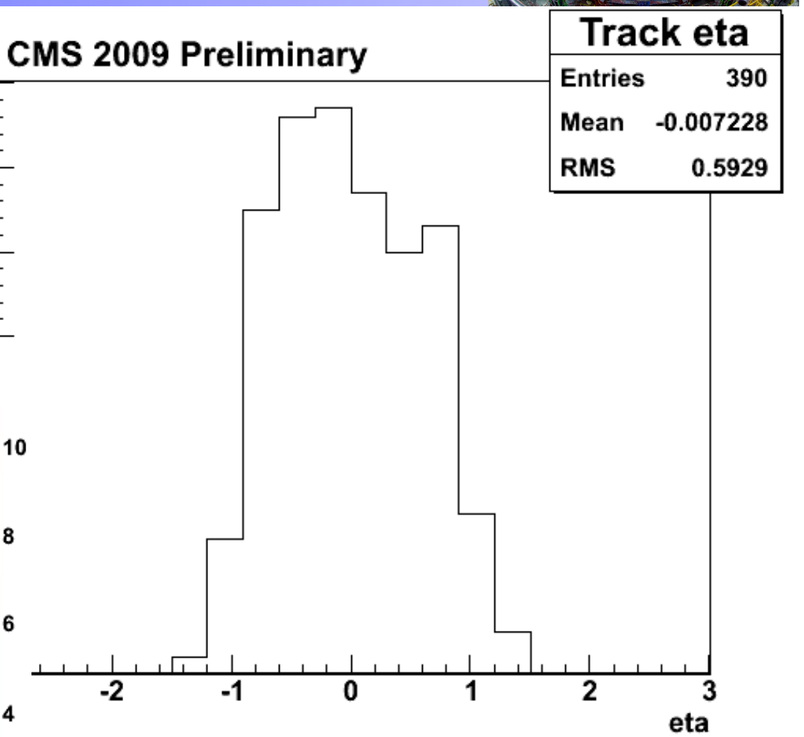
Collisions close to the center

All tracks with > 6 hits and $\chi^2 < 10$

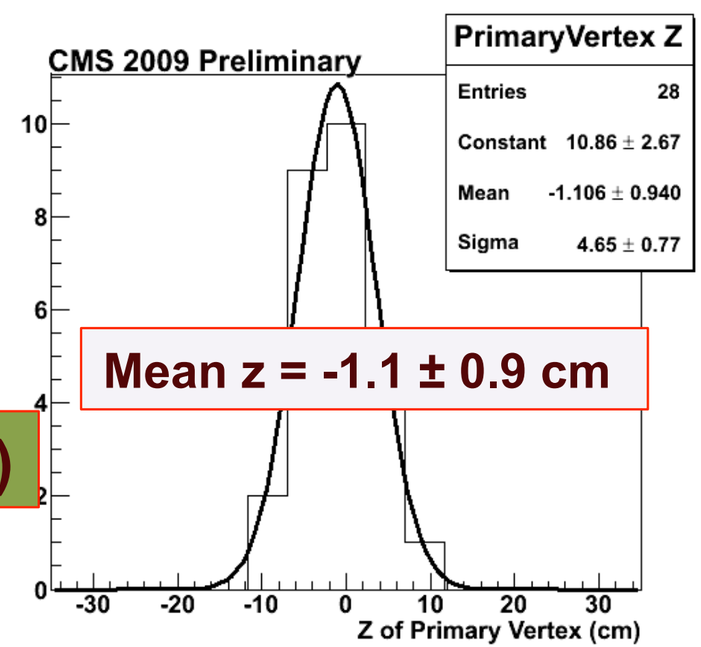
CMS 2009 Preliminary
Uncorrected Distribution



Events triggering BSC and having at least 3 tracks



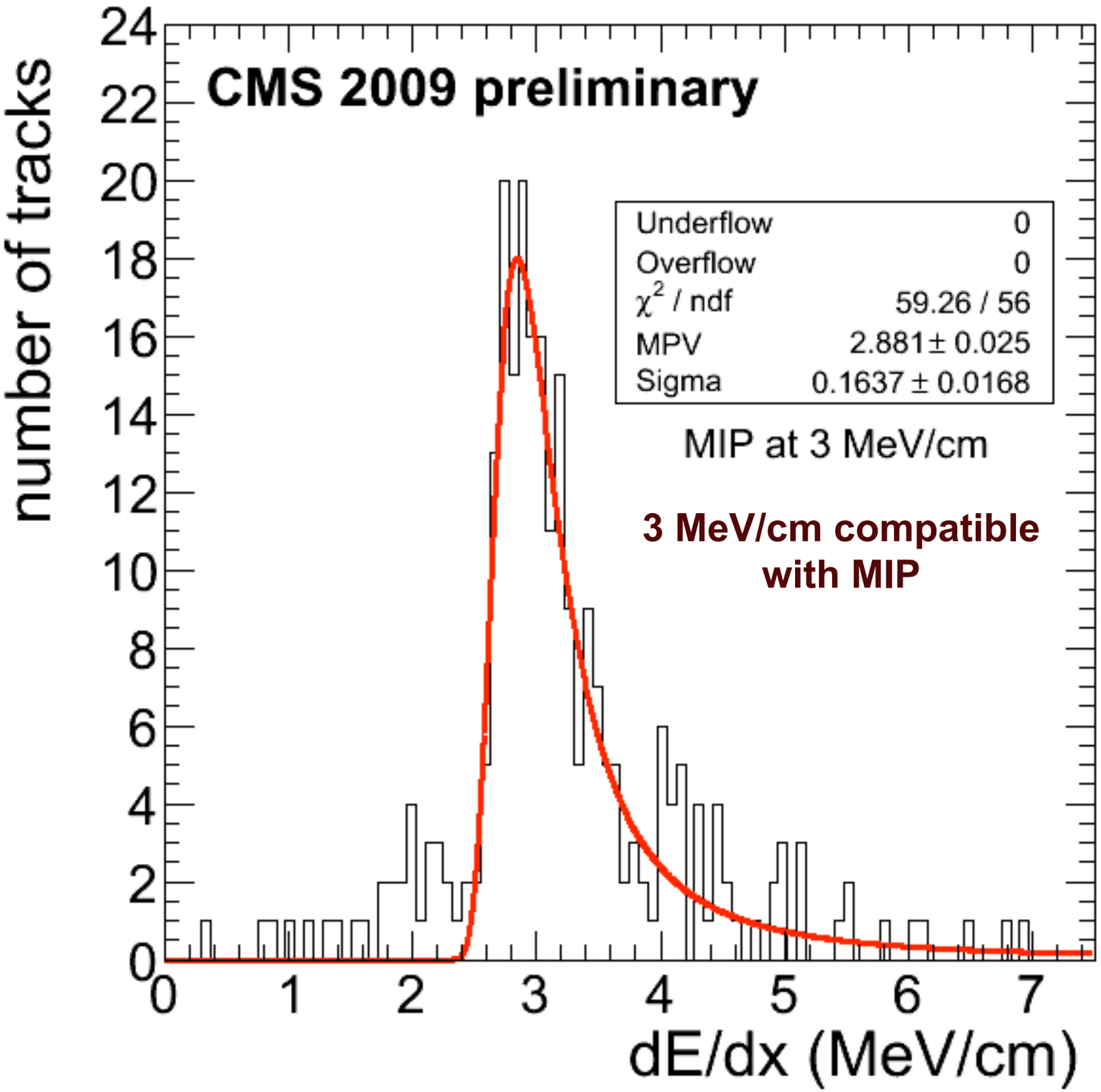
Clean vertices (≥ 3 tracks)



Mean z = -1.1 ± 0.9 cm

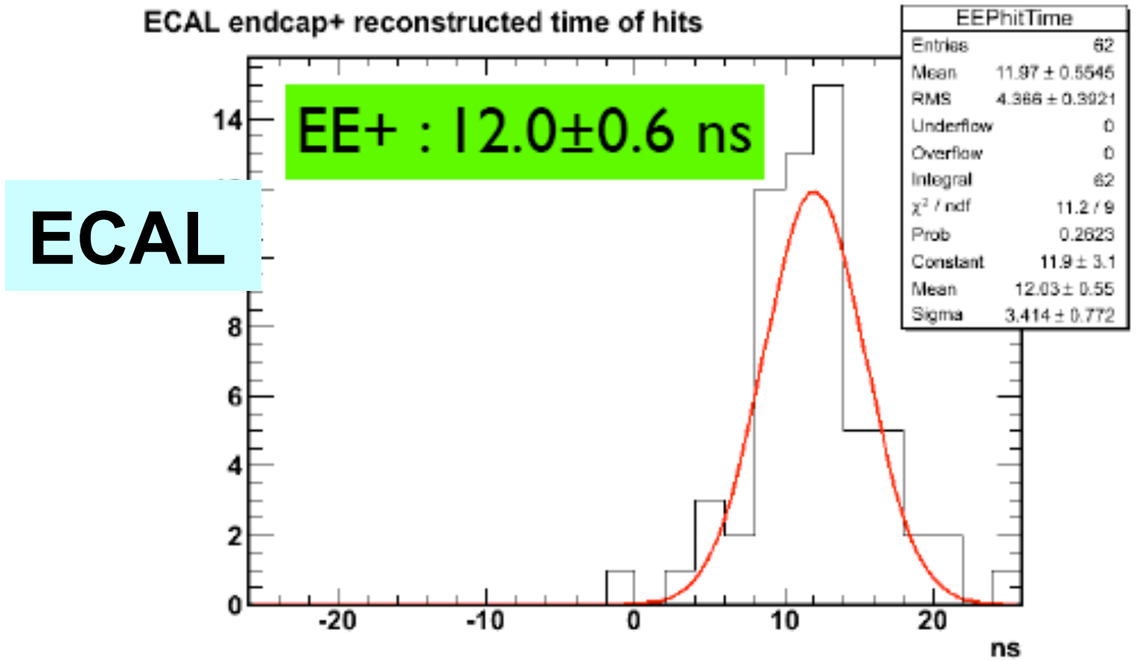
Beam gas or wall interactions or collisions far away from center?

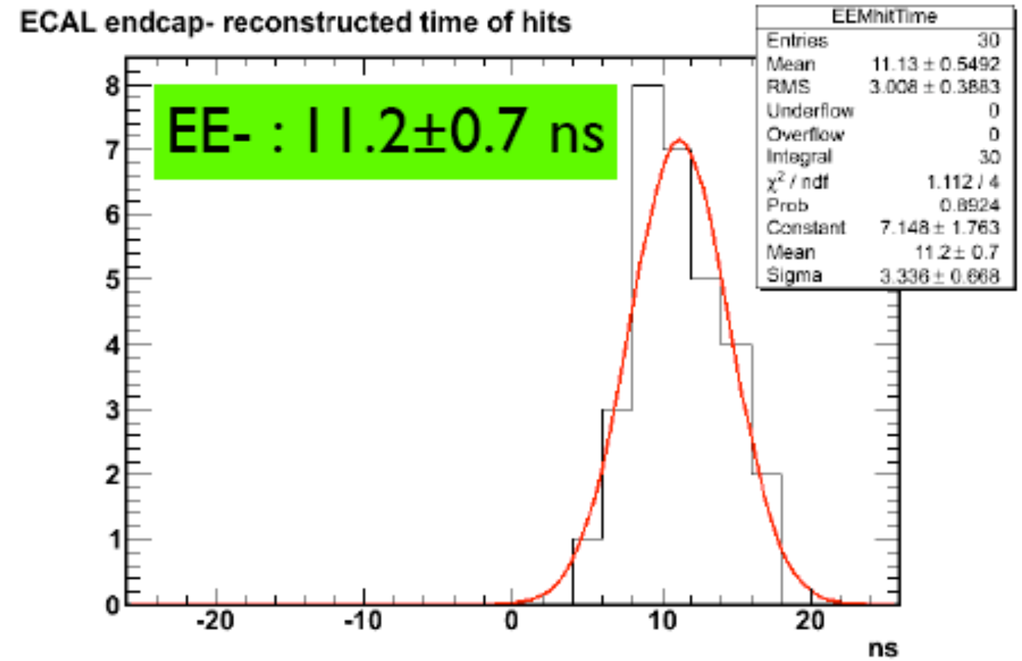
Track Energy Loss



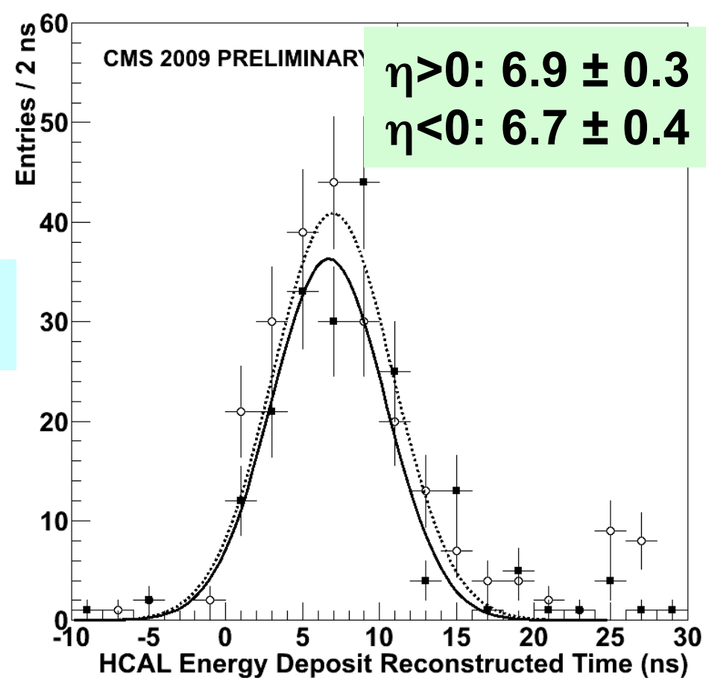
- **Loose quality track selection**
- **Upper tail from low momentum tracks (no B-field)**

Calorimeters timing in collision data





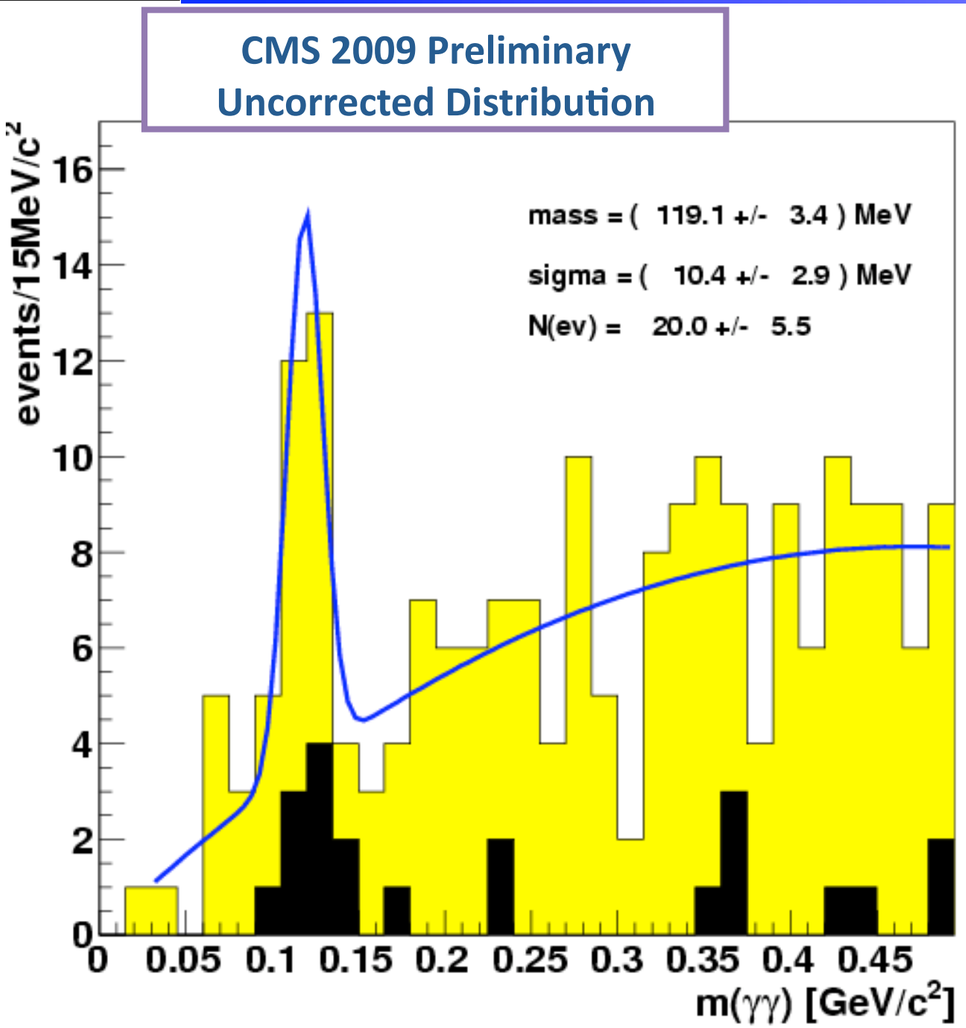
ECAL

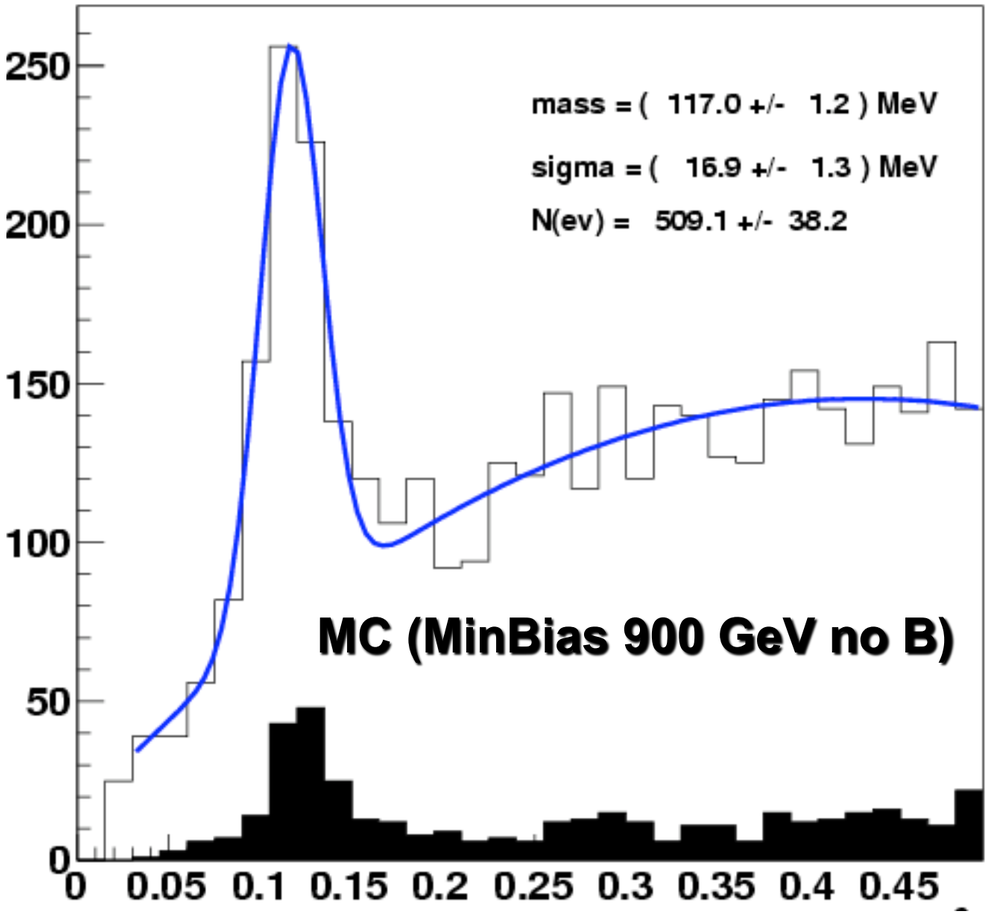


HCAL

Signal timing on "plus" and "minus" sides of ECAL and HCAL consistent with collisions
(phase wrt bunch clock is arbitrary)

First diphoton resonance in CMS

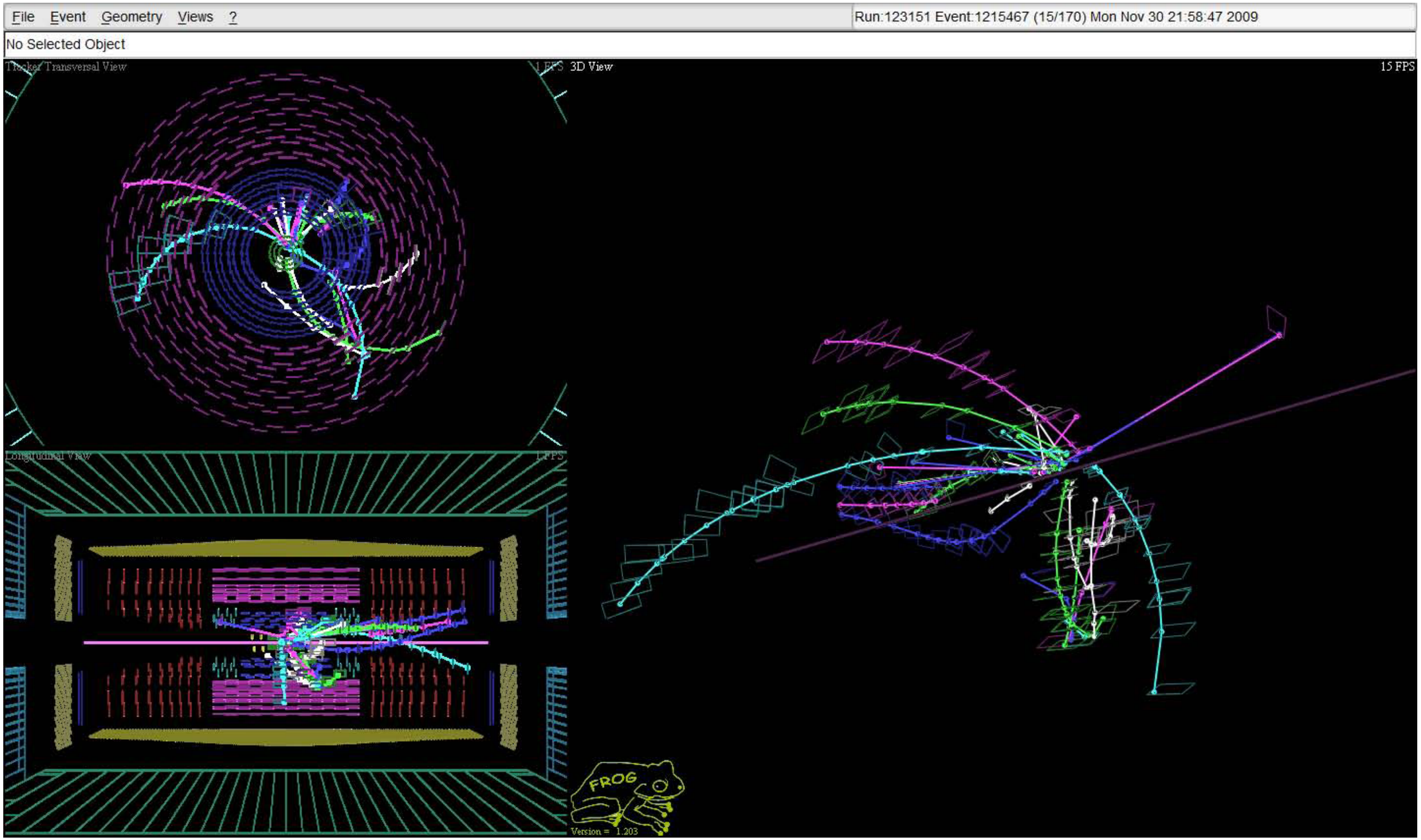




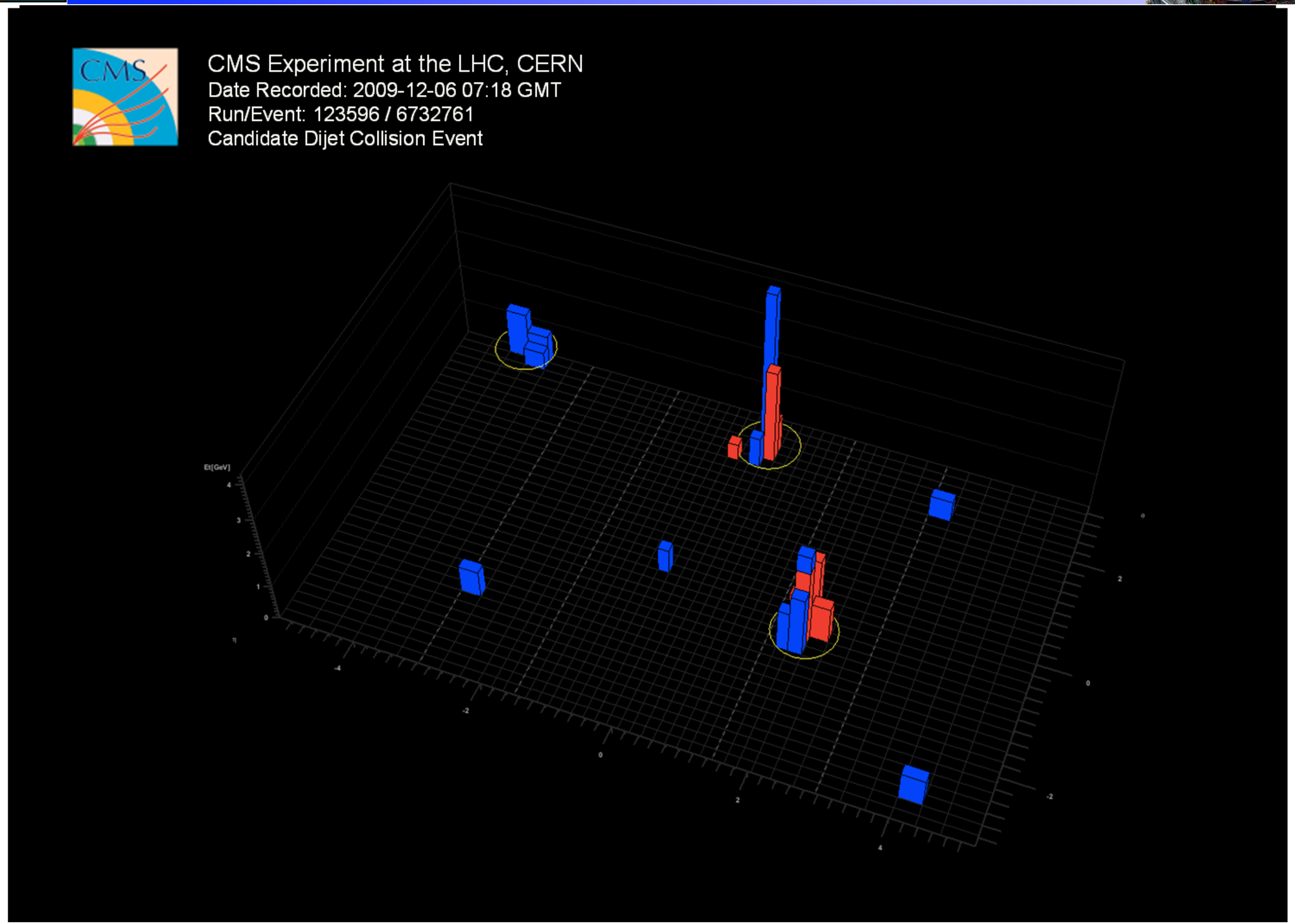
- $M(\pi^0)$ is lower in both data and MC
- Mostly due to the readout threshold (100 MeV/Crystal).
- Conversions: part of the energy is deposited upstream of ECAL.
- Event timing is consistent

First Event with Magnet ON

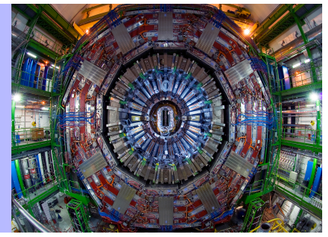
Nov 30 2009



Dijet Candidate Event



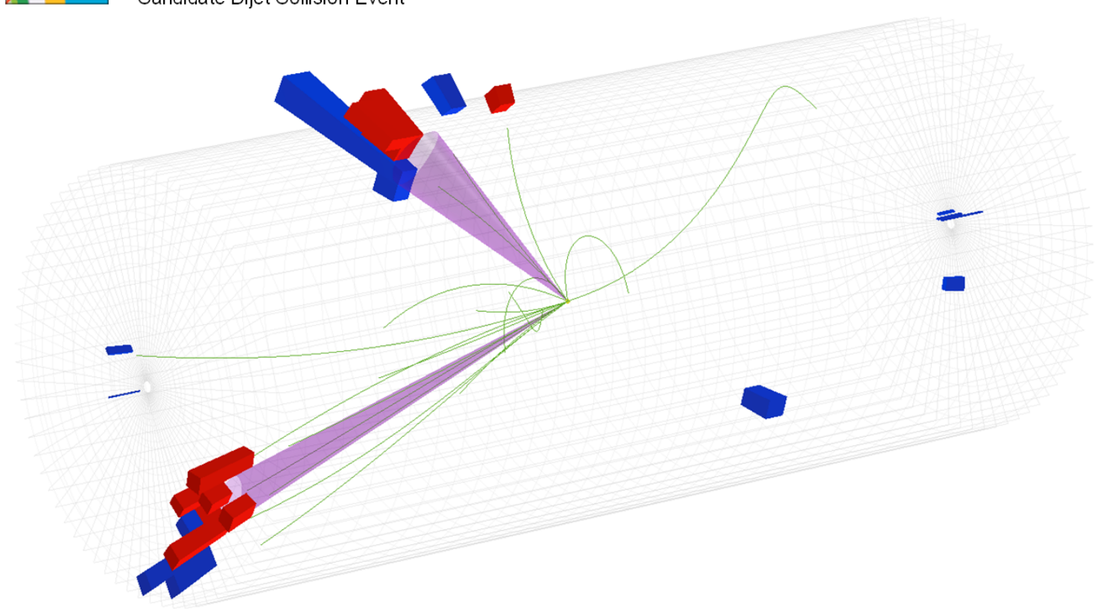
Dijet Candidate Event



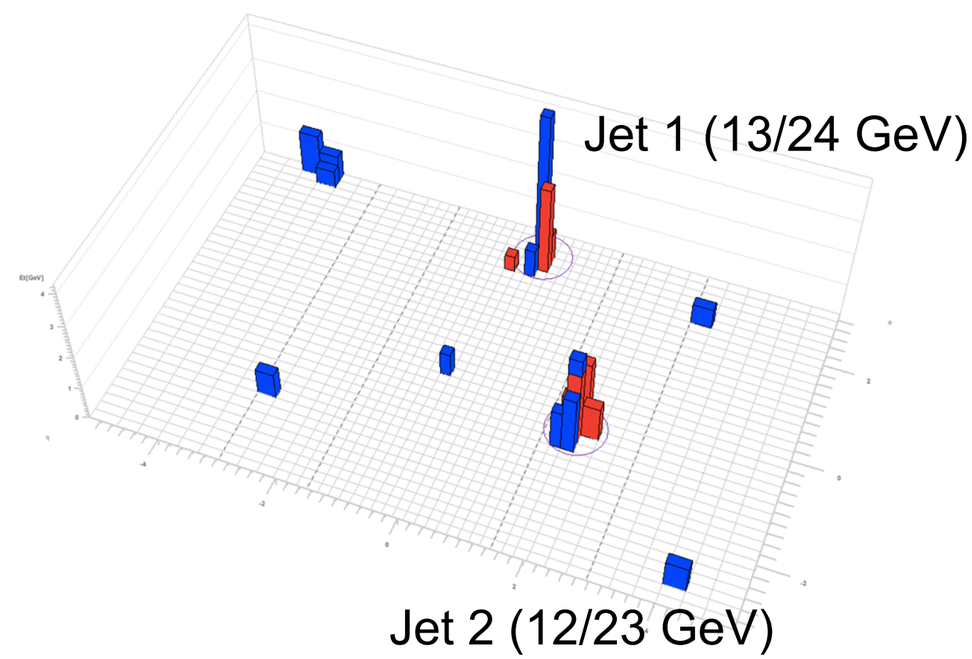
Anti-K_T algorithm with cone size R=0.7

	Jet 1	Jet 2
Corrected p_T (GeV)	24	26
η	0.3	2.0
ϕ	2.5	-0.7
EM Energy Fraction	0.5	0.6

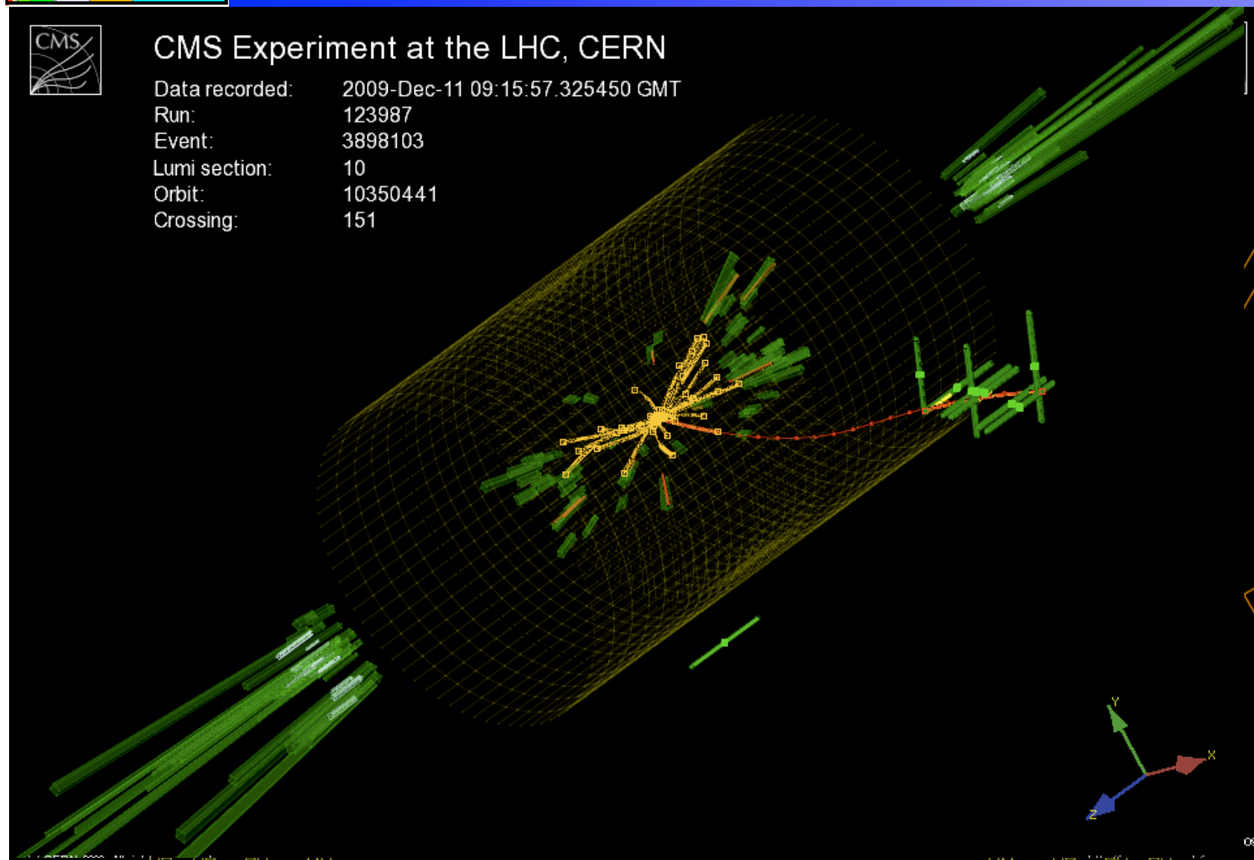
CMS Experiment at the LHC, CERN
Date Recorded: 2009-12-06 07:18 GMT
Run/Event: 123596 / 6732761
Candidate Dijet Collision Event

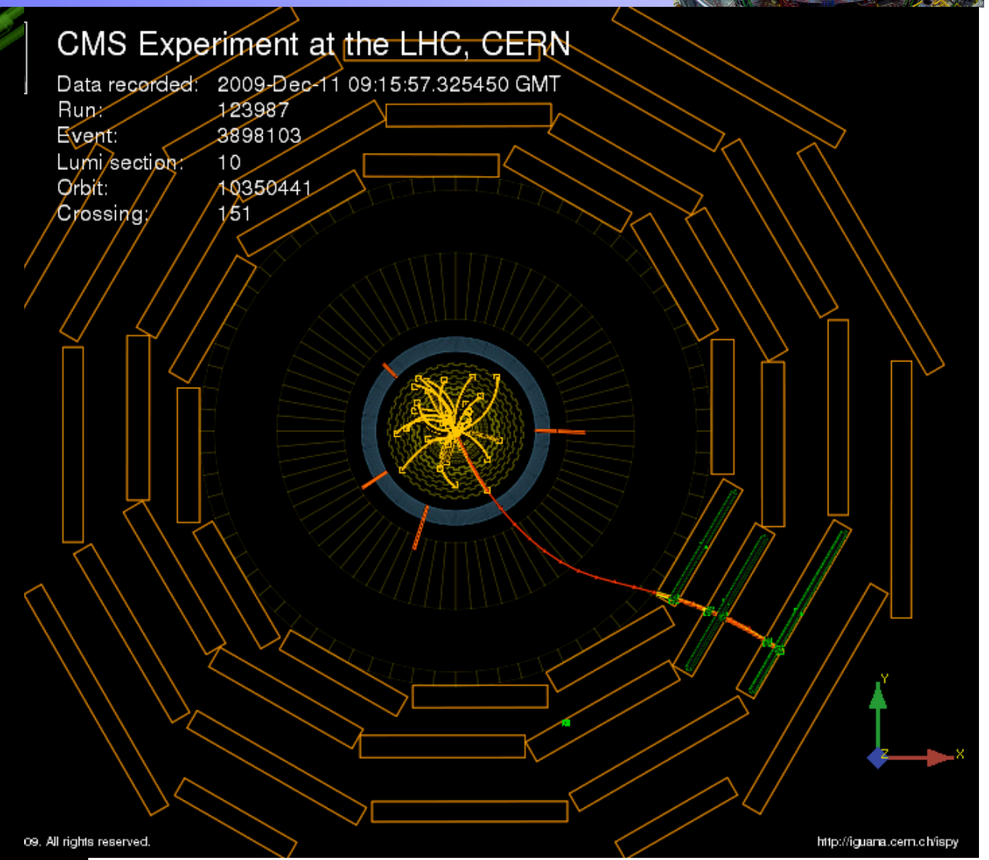


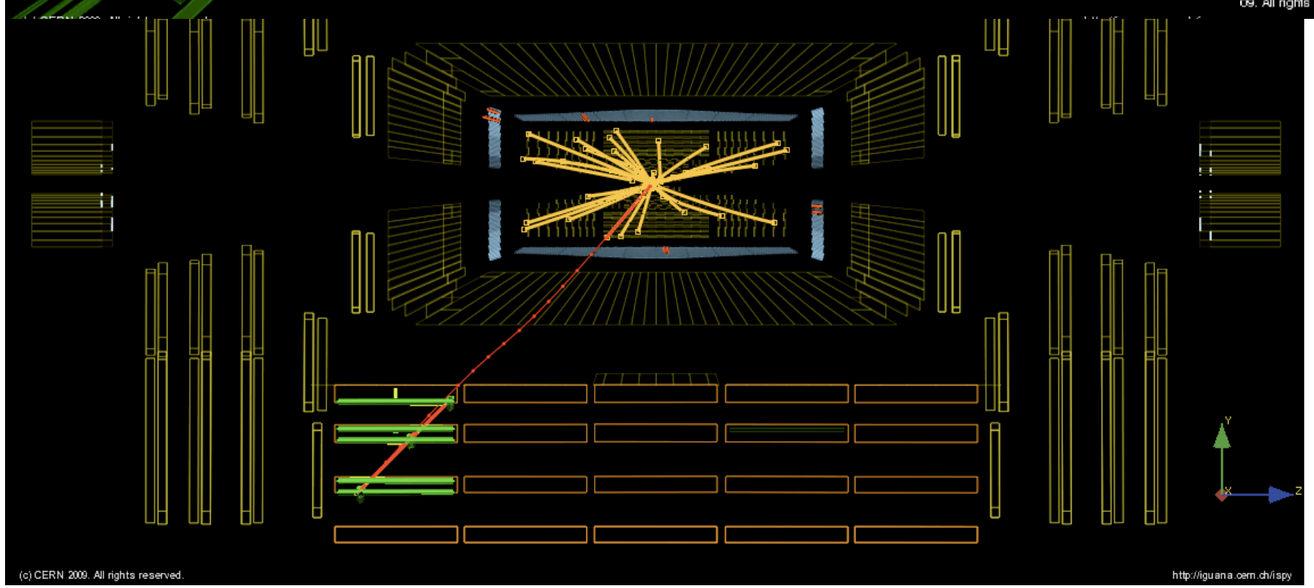
CMS Experiment at the LHC, CERN
Date Recorded: 2009-12-06 07:18 GMT
Run/Event: 123596 / 6732761
Candidate Dijet Collision Event



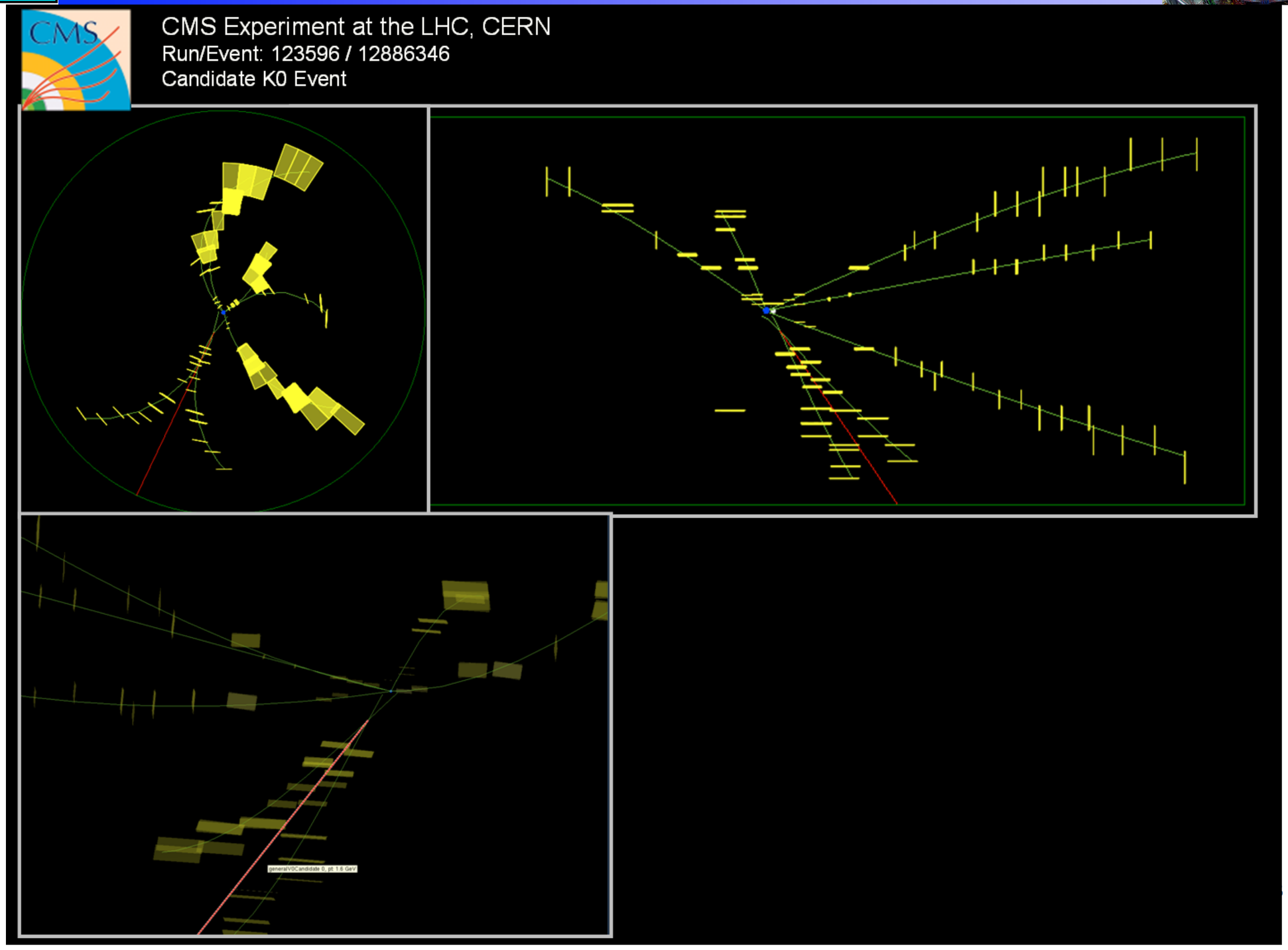
Barrel Muon Candidate



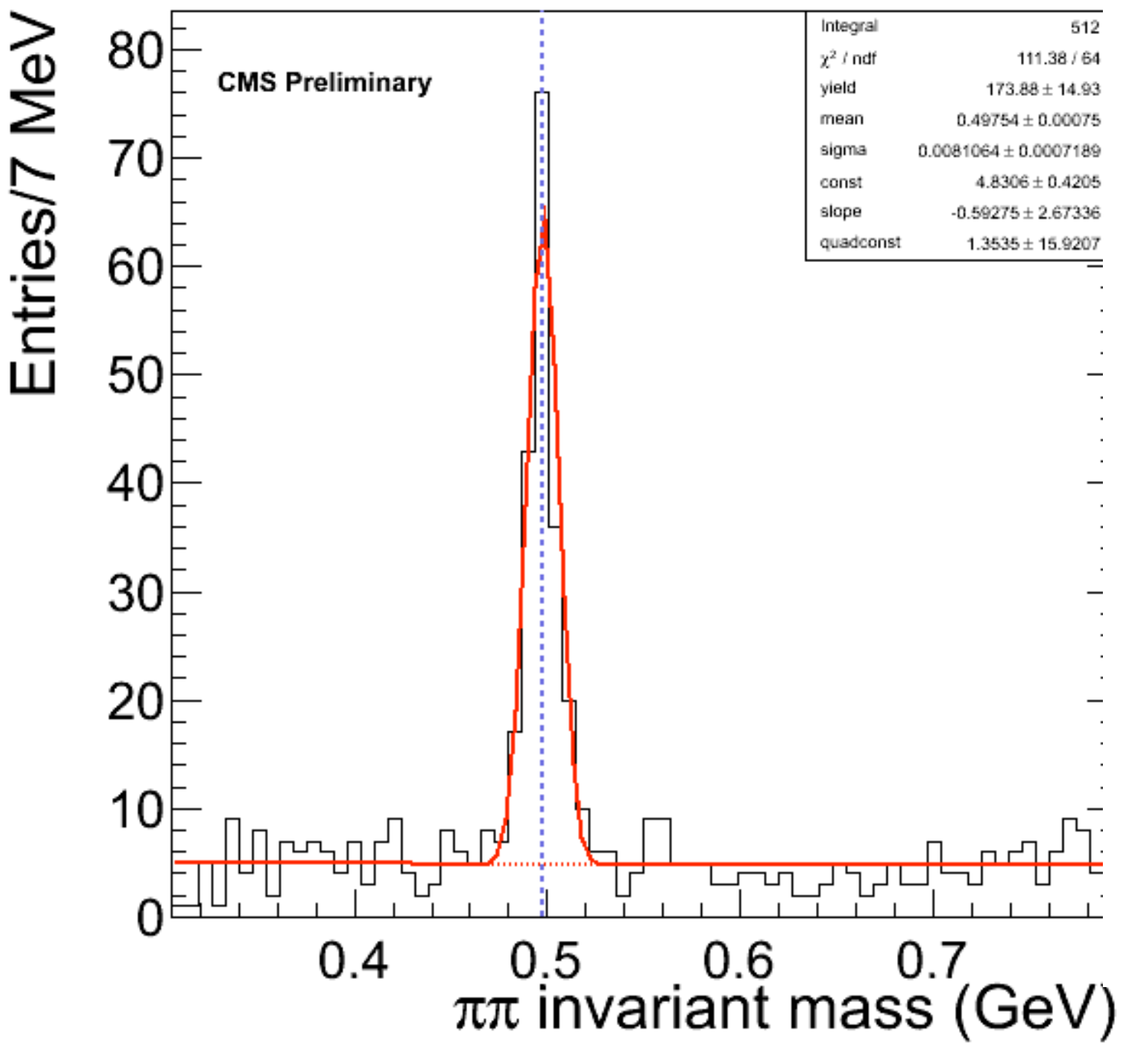


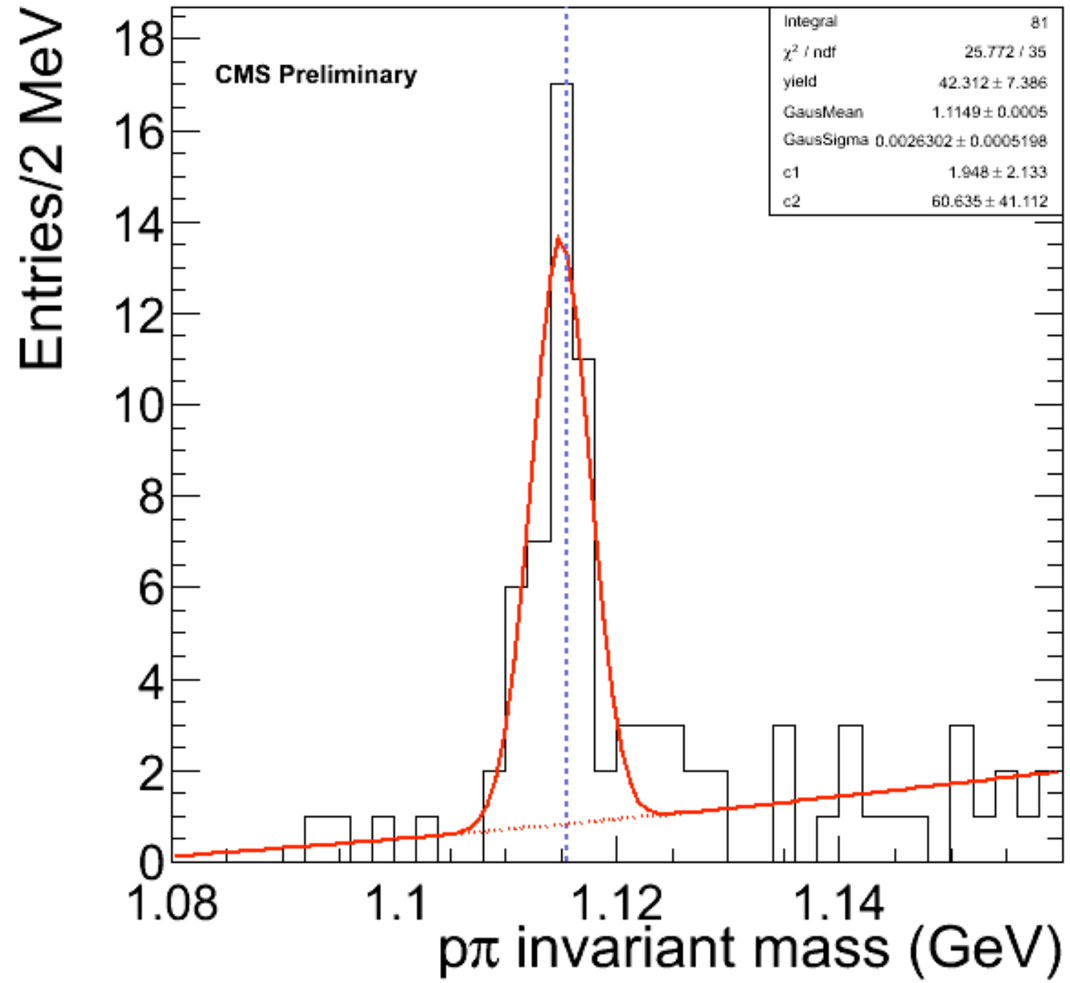


Ks Candidate Events

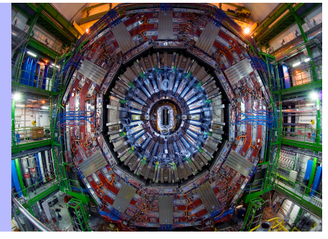


Ks and Lambda Events



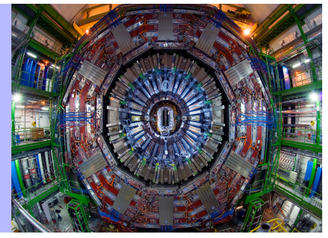


CMS Near Term Plans



- **Exploit the collisions at 0.9, 2.36, 7 TeV and any lumi**
- **Commission detector with first beams**
- **Understand its performance, calibrations, alignment, efficiencies and resolutions**
- **Optimize trigger selection and rates**
- **Target First Physics: Measure particle spectra, jets, PDF, Standard Model processes, W/Z, top's, and VV,…**
- **Tune underlying event and pile-up effects**
- **Start exploring huge physics potential of LHC**

Conclusions



- CMS Construction is over
- Commissioning with beams progresses rapidly
- LHC's leaps in energy and luminosity present enormous exploration opportunities
- Excitement of Discoveries is arriving!