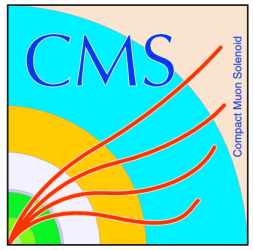
Status of CMS

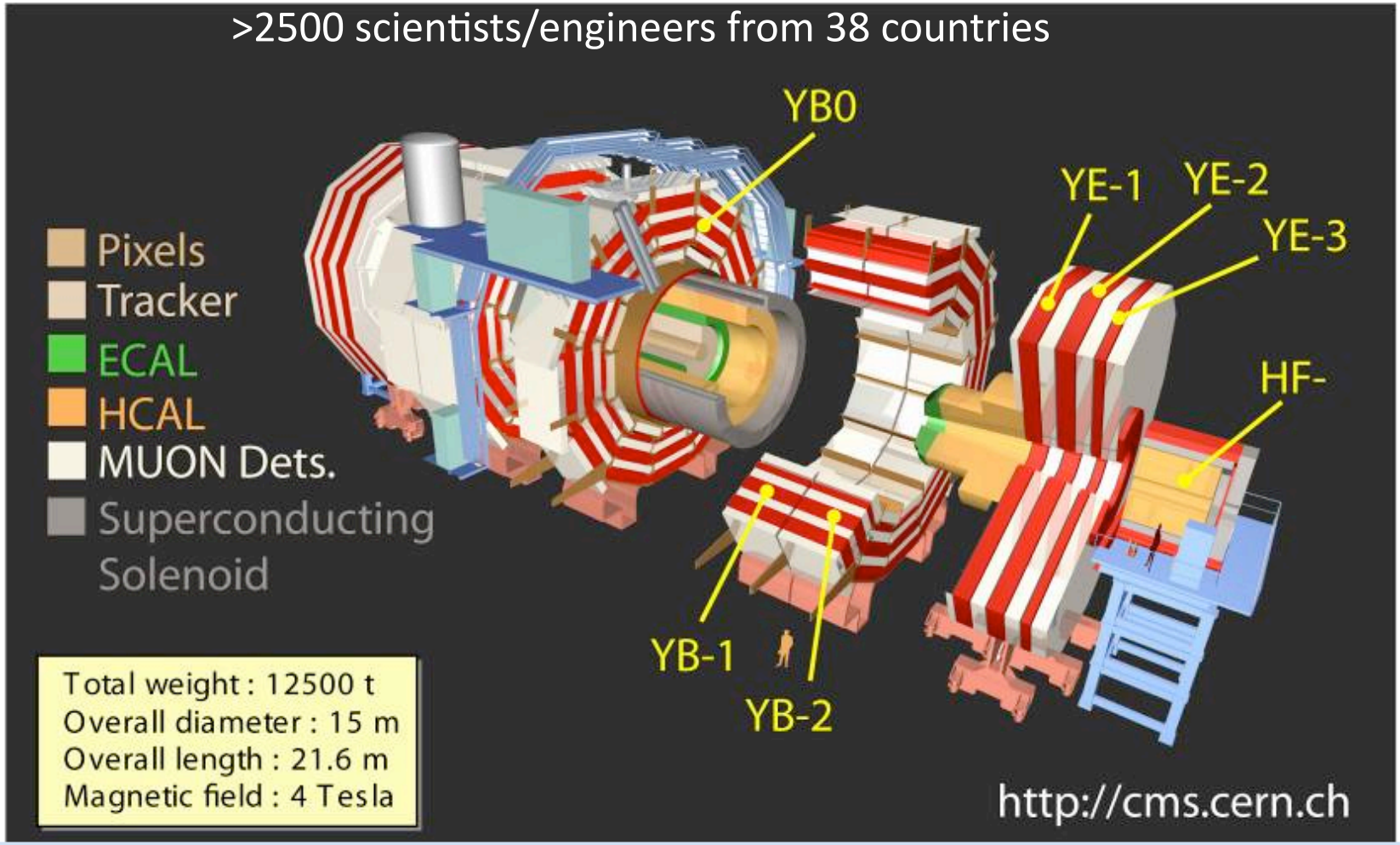


Tulika Bose
(Boston University)

On behalf of the CMS Collaboration

2nd Annual US LHC Users Meeting
Berkeley, California
September 26th, 2009

The CMS Detector



CMS comprises 66M pixel channels, ~10M Si microstrip ch, ~75k crystals, 150k Si preshower ch, ~15k HCAL ch, 250 DT chambers (170k wires), 450 CSC chambers (~200k wires), ~ 500 Barrel RPCs and ~ 400 endcap RPCs, muon and calorimeter trigger system, 50 kHz DAQ system (~ 10k CPU cores), Grid Computing (~ 50 k cores), offline (> 2M lines of source code).

US-CMS Contributions

USCMS:

639 Scientific Authors

431 with Ph.D (35% of CMS)

197 Graduate Students (32% of CMS)

- US has major responsibility in many CMS Systems
- US led subsystems/ systems with strong US participation
  - Hadron Calorimeter
  - Endcap Muons
  - Forward pixels
  - Trigger
  - Data Acquisition
  - Silicon Strip Tracker
  - Electromagnetic Calorimeter
- Computing
- Physics Analysis

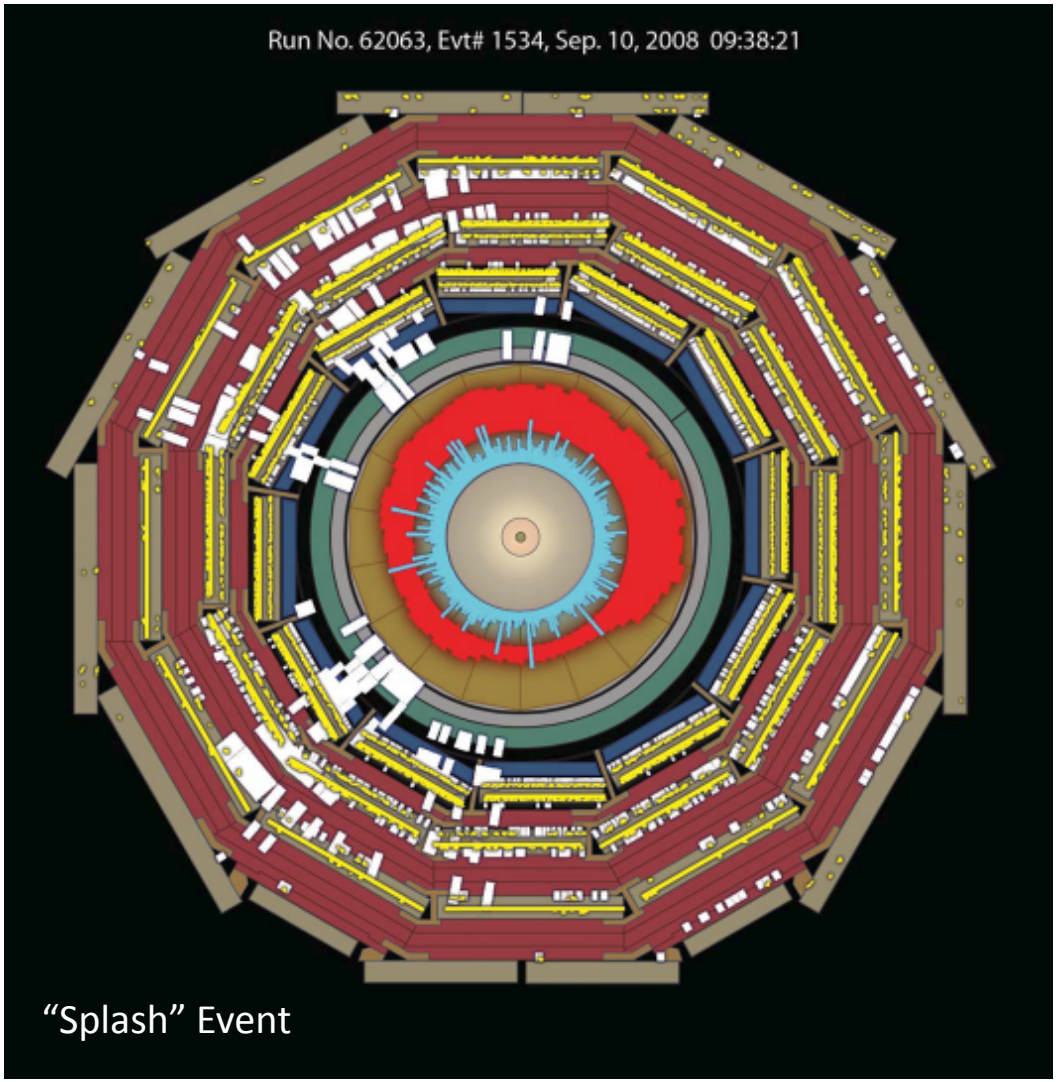
Closure of CMS prior to Beam in 2008

After almost 20 years, from conception, design, construction and commissioning CMS became a working experiment in September 2008

First LHC Beam in 2008

Data-taking with LHC beam.

- **Wed, 10 Sept. 2008**
  - "Splash" events observed when beam (450 GeV, 4×10^9 p) struck collimators 150m upstream of CMS
  - Halo muons observed once beam (uncaptured and captured) started passing through CMS



"Splash" Event

CRAFT

The September 19th incident was followed by a Cosmics Run at Operating Field

CRAFT*: Cosmics Run at Four Tesla

* Operating field of CMS is 3.8T

Wealth of data collected – for ascertaining health and performance of detector, detector cleanup studies (e.g. for alignment - equivalent to >10 pb^{-1}!)

~ 23 papers are in preparation
(to be submitted for publication by ~November)

Continuous Operation of CMS

Ran CMS for 6 weeks (Oct-Nov'08) continuously to gain operational experience, stability of infrastructure.

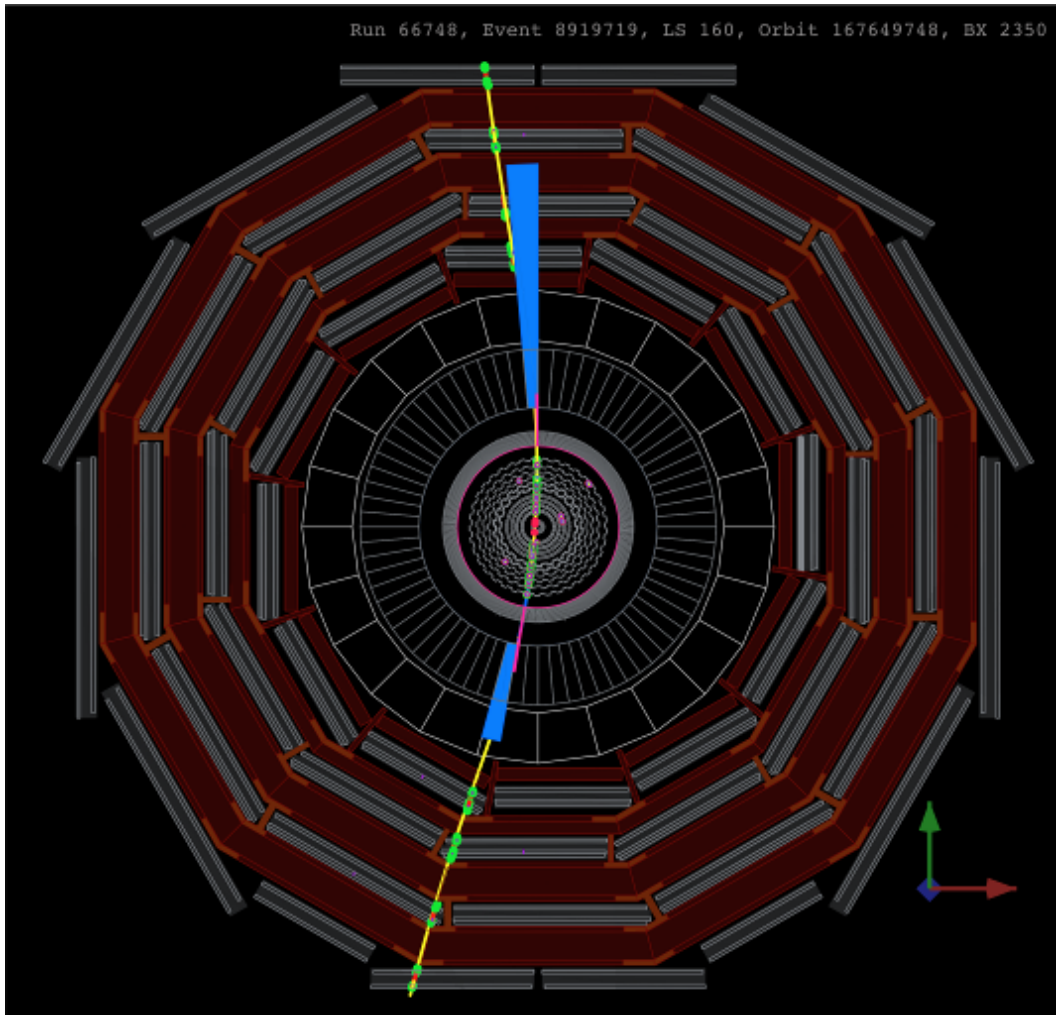
Collected ~300M cosmic events. About 400 TB of data distributed widely.

Efficiency ~ 70% (24/7)

First analyses of these data used s/w release destined for 2008 data-taking & LHC grid infrastructure.

Re-reconstruction and analyses with more advanced versions of the release.

CRAFT08

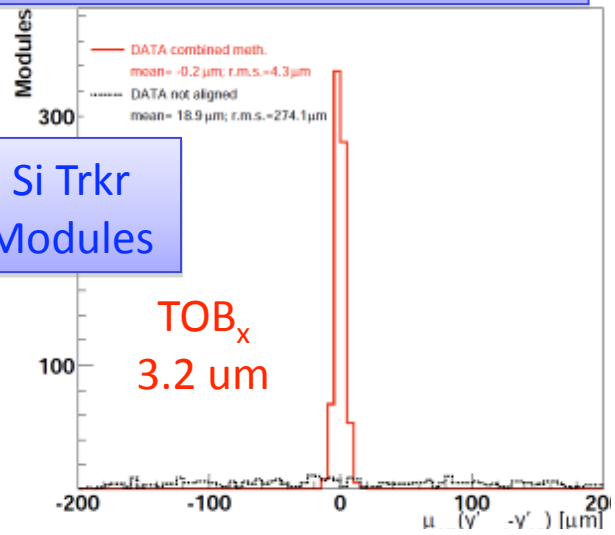


CRAFT08: Results from paper drafts

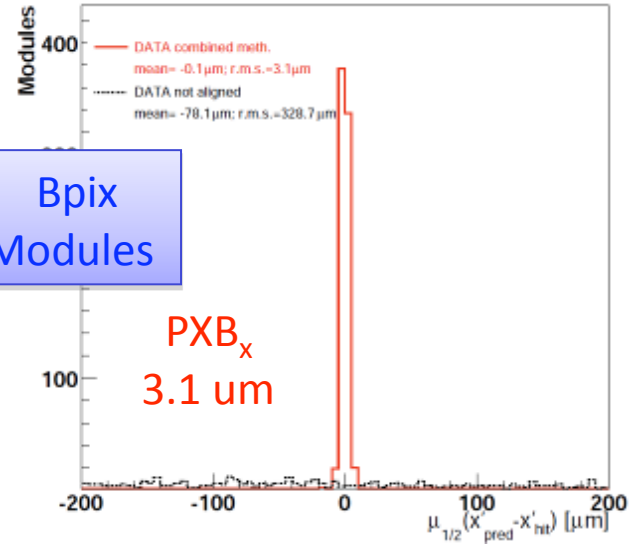
Alignment in Inner Tracker

Distn of Mean Residuals

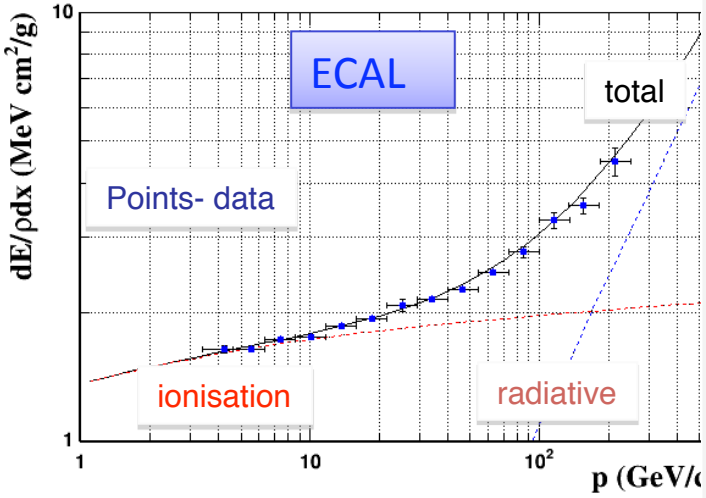
Si Trkr Modules

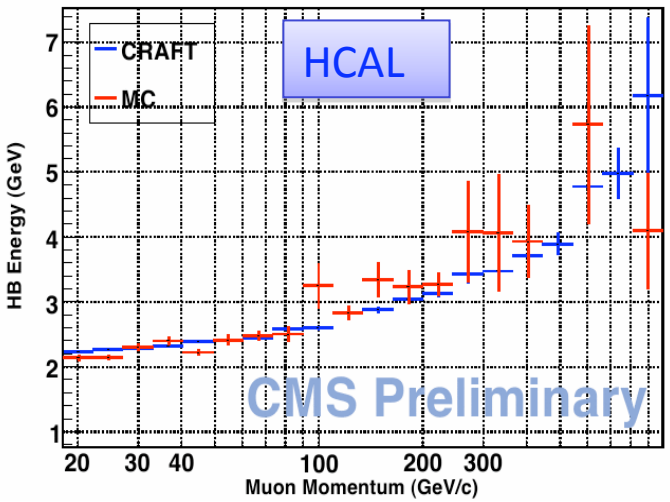


Bpix Modules

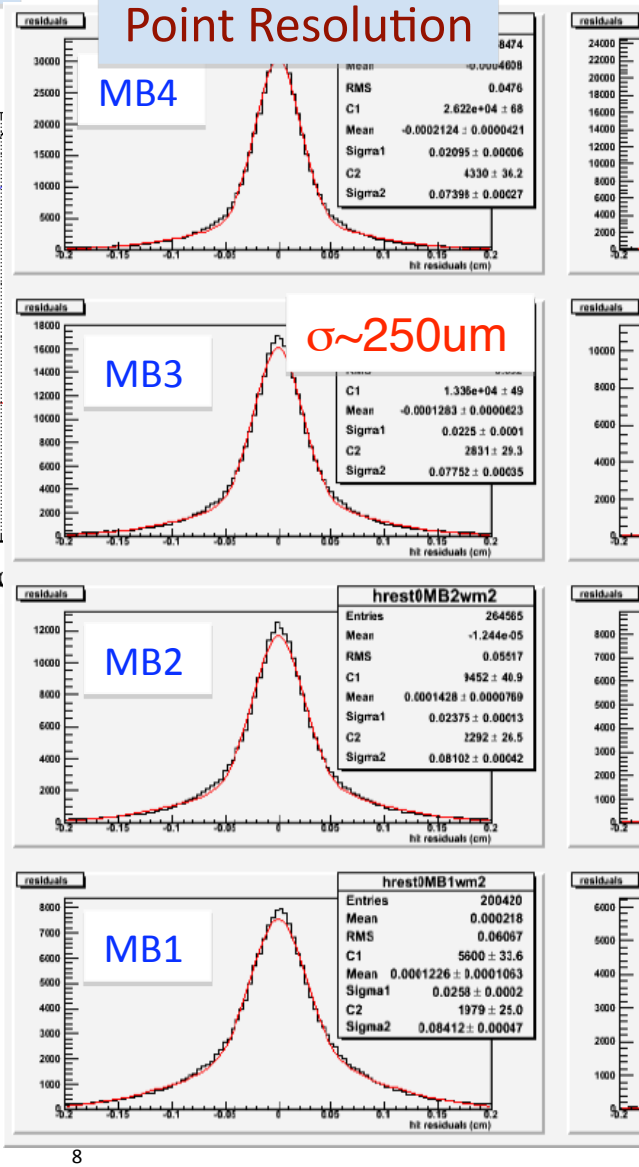


Energy deposited by muons



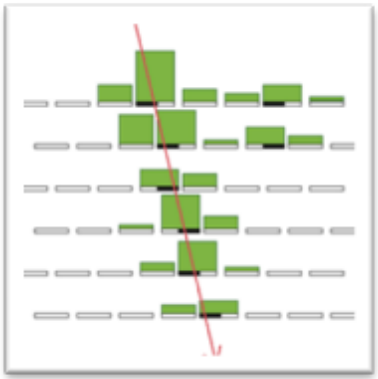


Muon Chambers Point Resolution

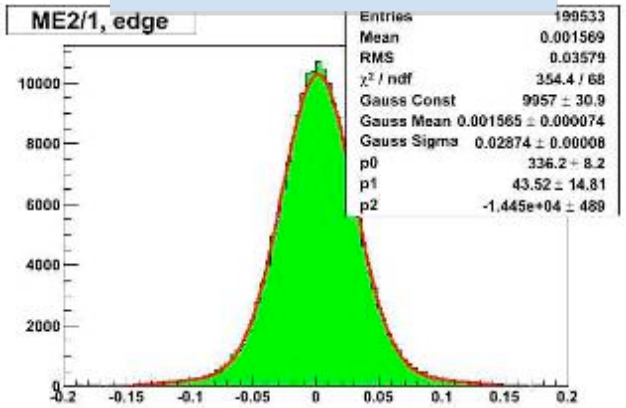


CRAFT08: Results from paper drafts

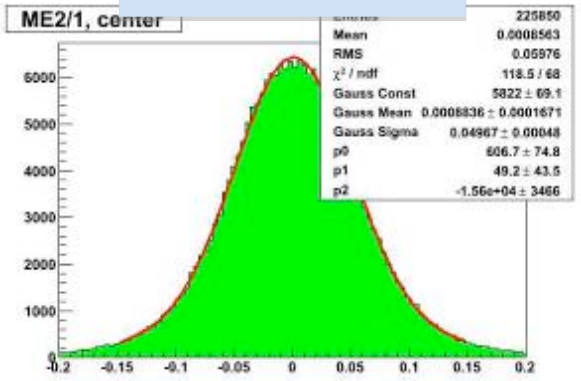
CSC chambers
6 Staggered planes of strips

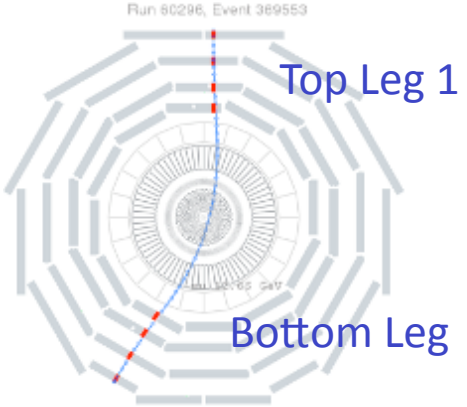


Near the strip edges

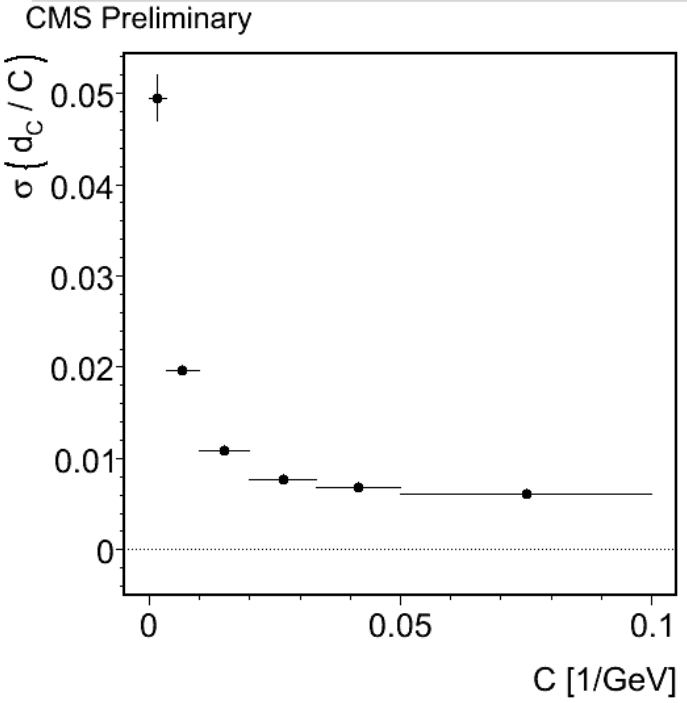


Near the centre





Momentum Resolution <2-leg>



$1/\sigma^2(\text{chamber}) = 3/\sigma_1^2 + 3/\sigma_2^2$

σ(ME2/1) = 161μm (TDR = 150μm)

’08-’09 Shutdown – CMS Activities

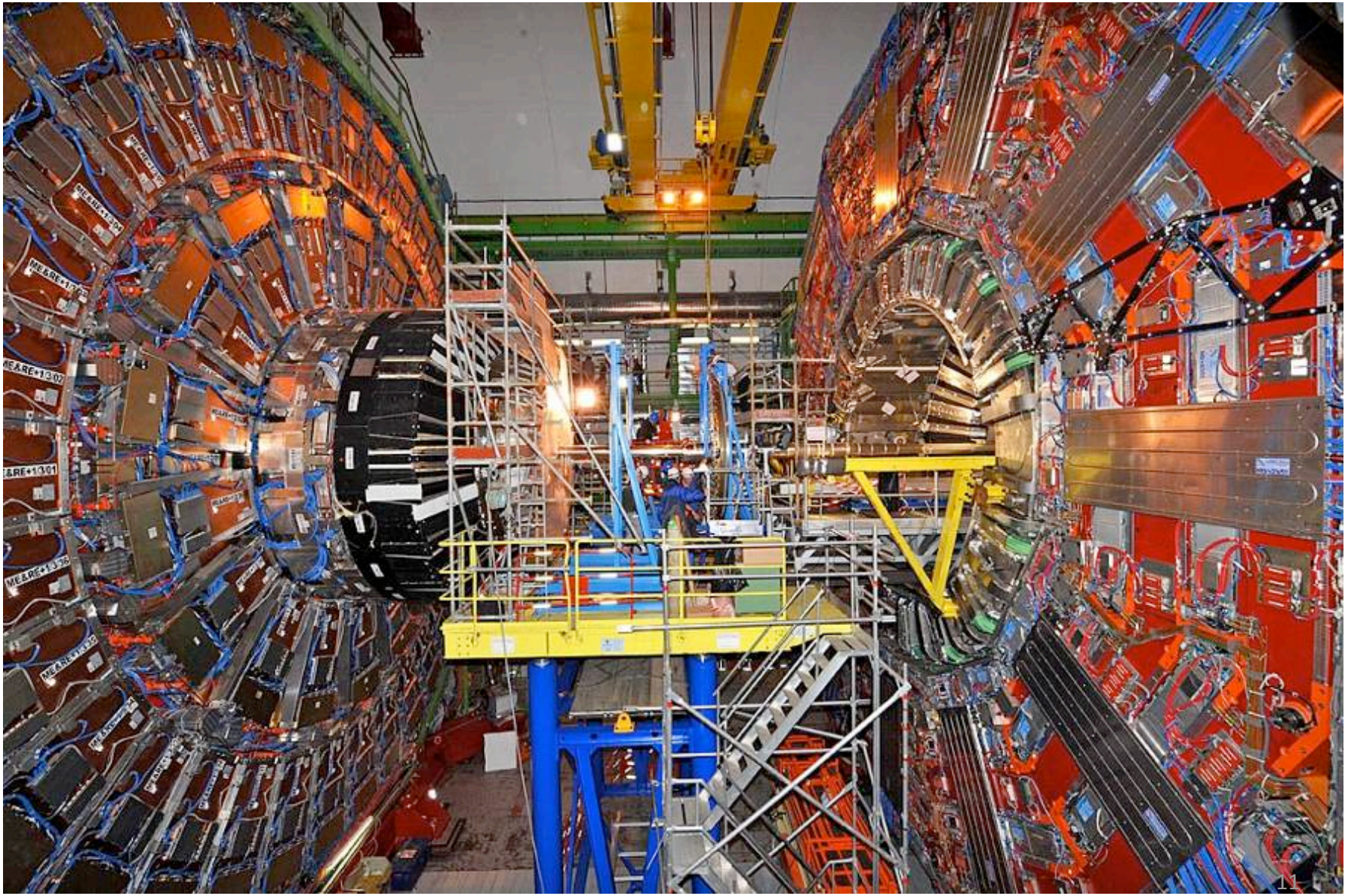
After the cosmics run ended (Nov ‘08), the detector was opened for **carefully selected maintenance, consolidation and repair activities**, as well as the **installation** of the preshower subdetector and CASTOR.

Some highlights:

- Installation and commissioning of the preshower (ES)
- Removal, repair, and re-insertion of the forward pixel system
- Installation of CASTOR ($5.2 < \eta < 6.6$) calorimeter
- Maintenance and (small) repairs involving many sub-systems
- Re-commissioning of CMS – Mid-Week Global Runs and CRUZET interspersed with final maintenance and consolidation activities.
- Preparation of software for 2009 data taking, improving stability & reliability of computing infrastructure, large MC production and analysis at 10 TeV (and 7 TeV)

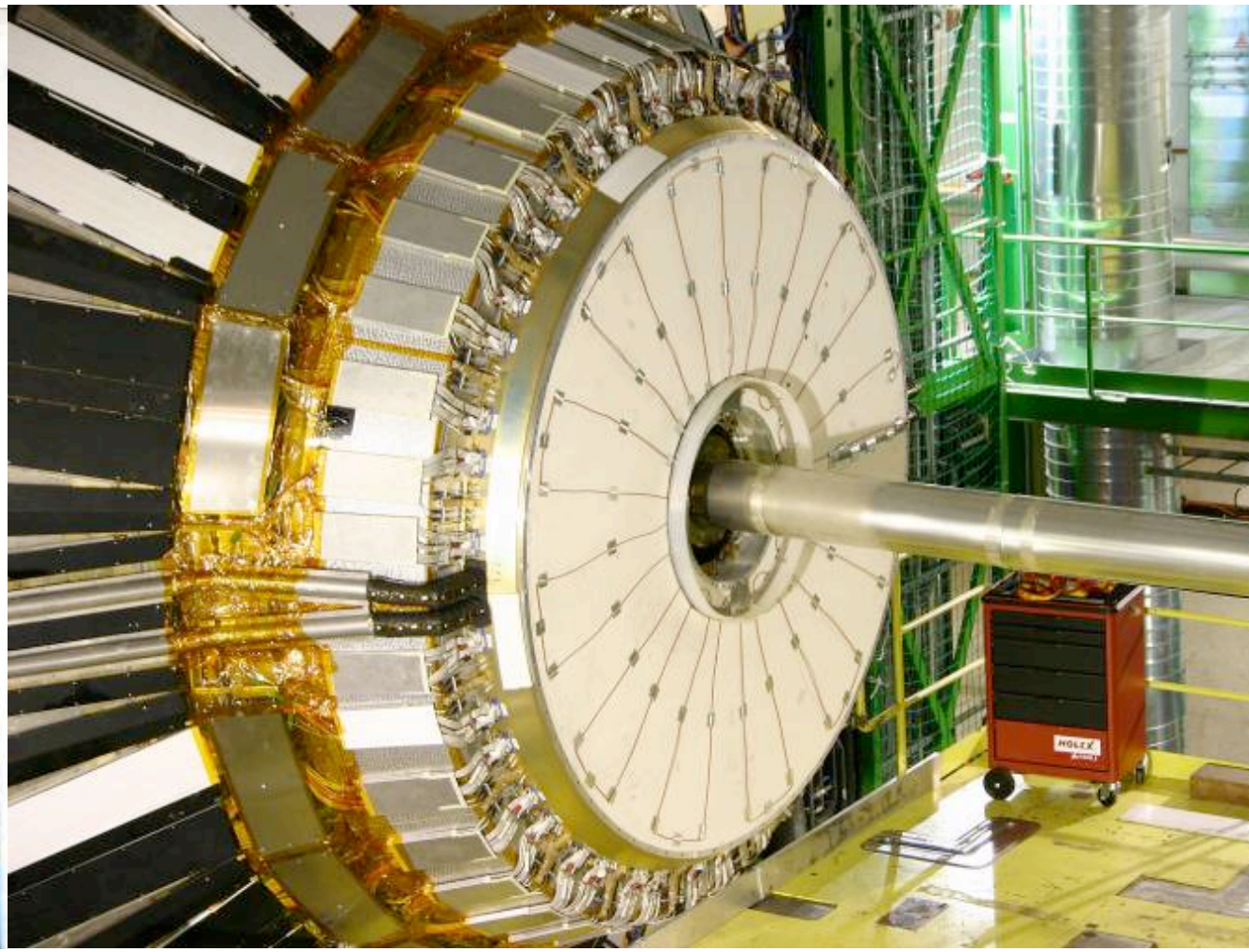
CRAFT09 : Cosmics run at operating field (6 weeks run started end-July)

Installation of the Preshower: Preparation



Installation of the Si Preshower

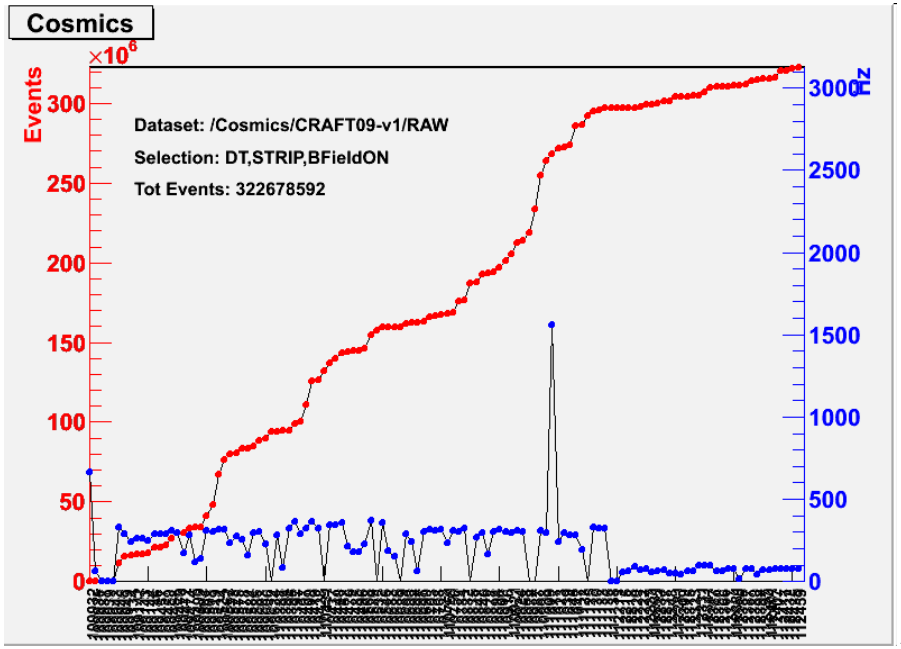
The two separate ES Dees

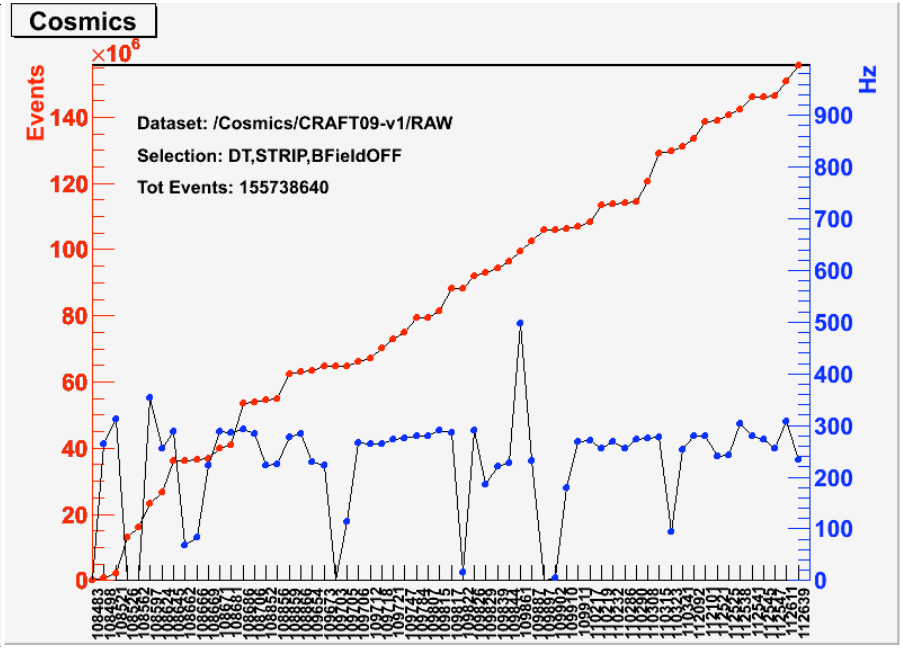


Installation completed in Apr'09

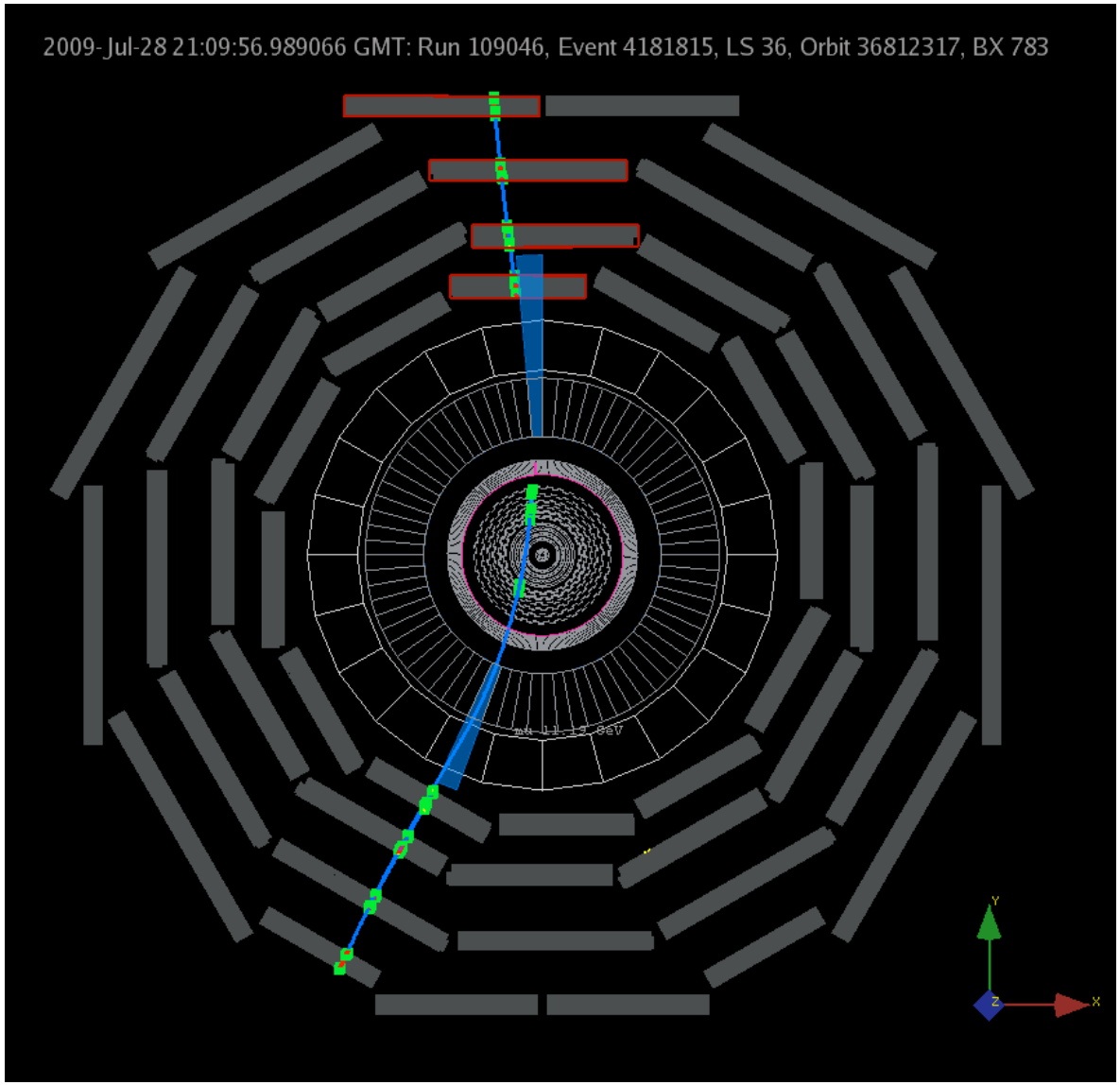
CRAFT09

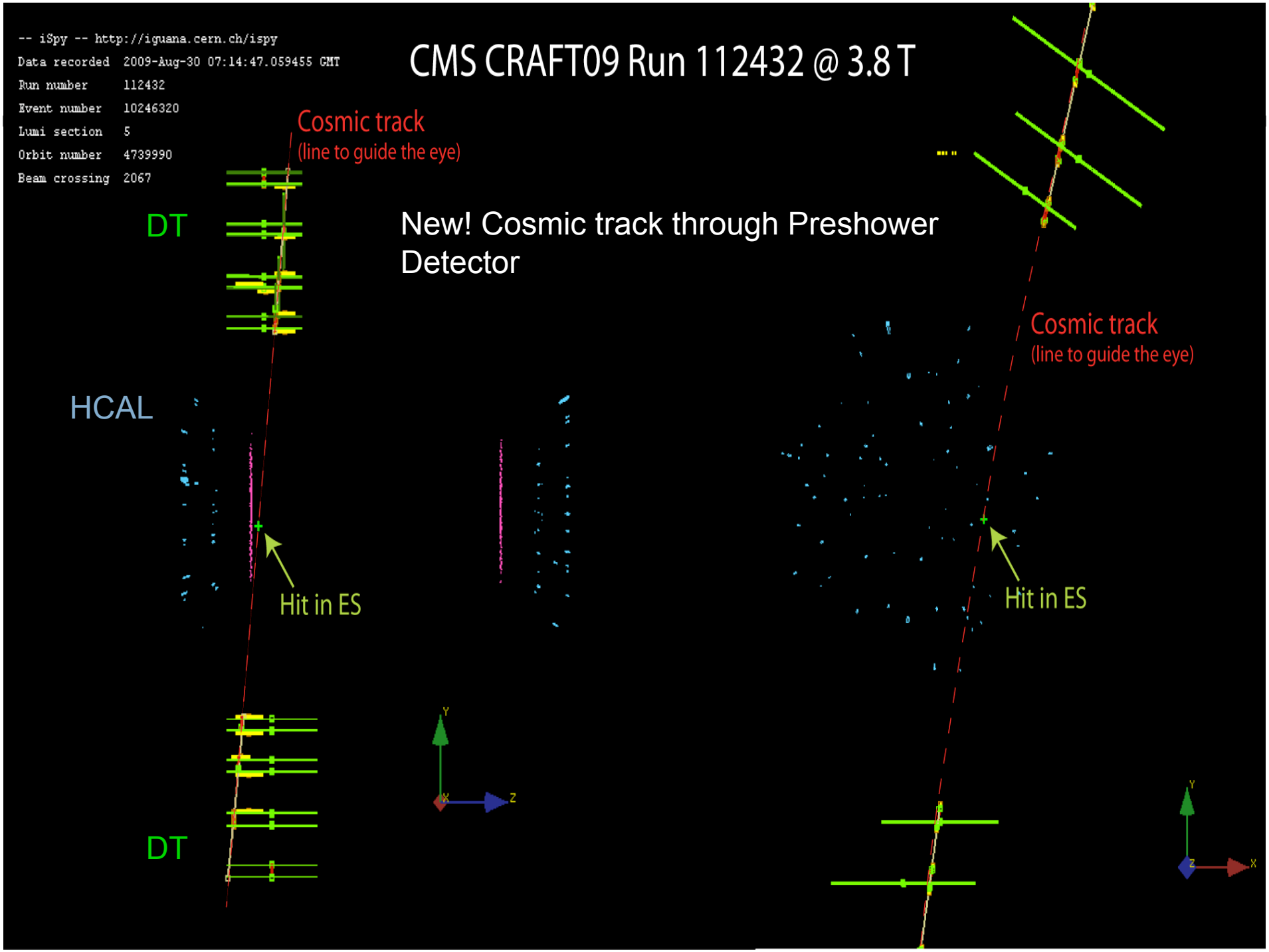
- **CRAFT09:**
  - 40 days from July 23 – Sept.1, 2009 [but with planned downtimes]
  - 320M cosmic triggers with B=3.8T (160M with B=0)





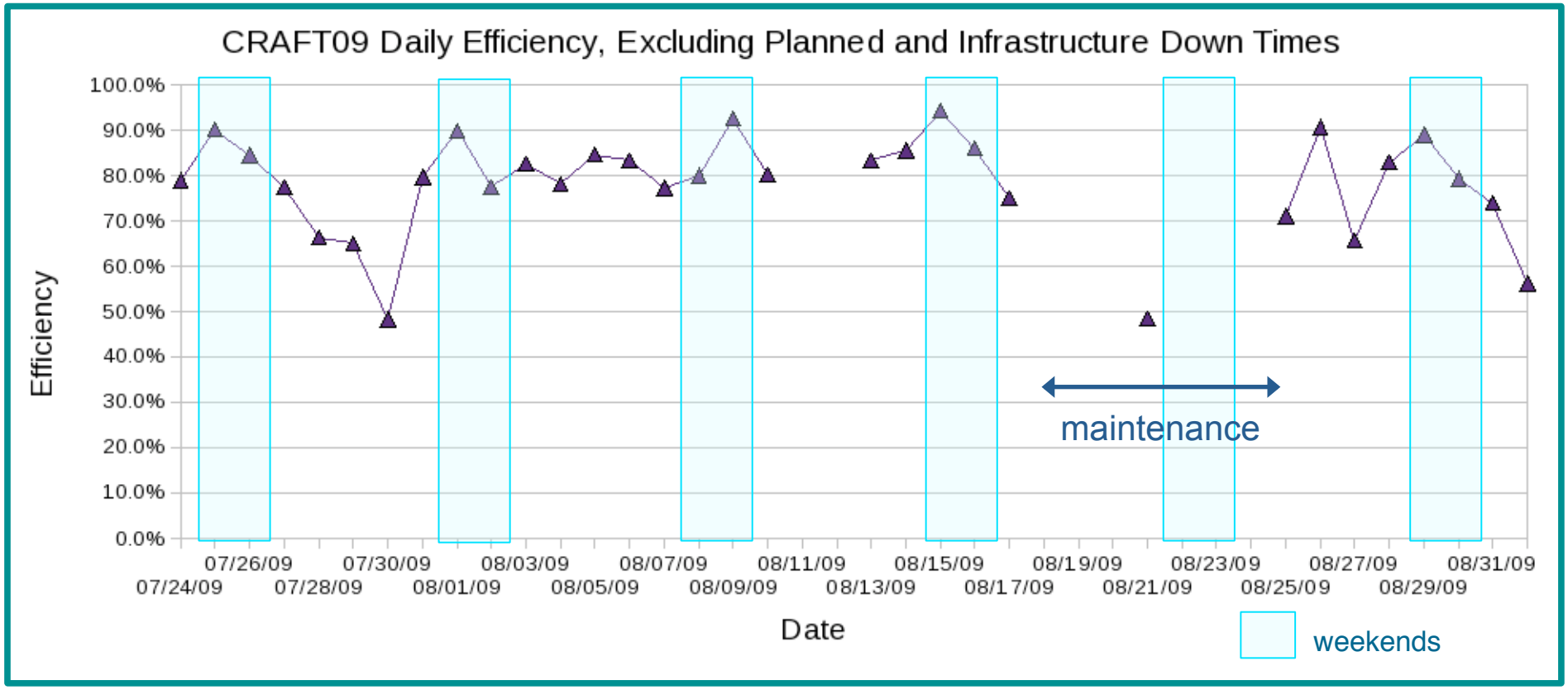
CRAFT09 Cosmic Muon event




-- iSpy -- http://iguana.cern.ch/ispy
Data recorded 2009-Aug-30 07:14:47.059455 GMT
Run number 112432
Event number 10246320
Lumi section 5
Orbit number 4739990
Beam crossing 2067
CMS CRAFT09 Run 112432 @ 3.8 T
Cosmic track
(line to guide the eye)
DT
New! Cosmic track through Preshower Detector
HCAL
Hit in ES
DT
Cosmic track
(line to guide the eye)
Hit in ES

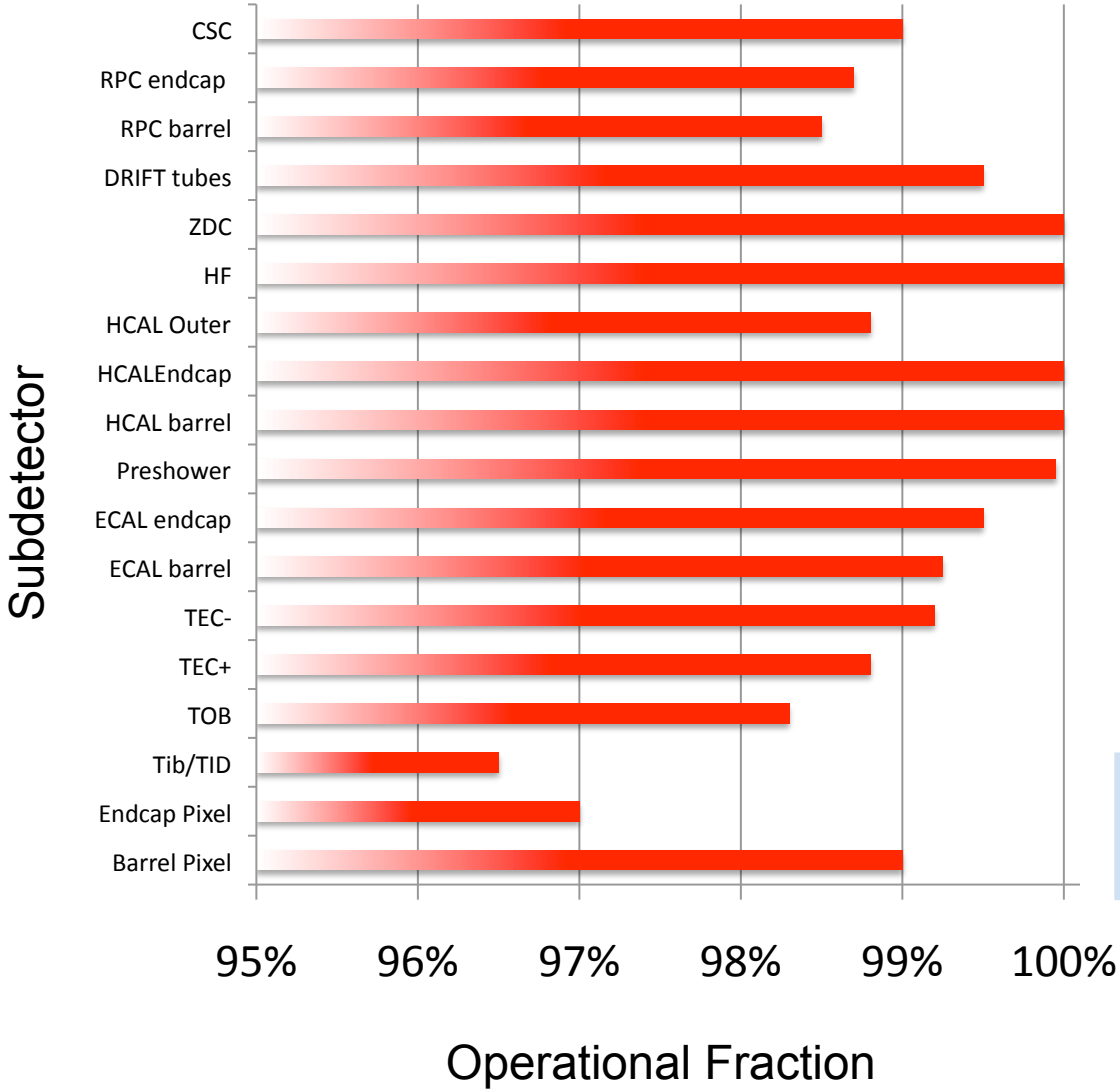
CRAFT09 Data Taking Efficiency

RunTimeLogger (RTL) was developed and deployed in CRAFT09.
RTL keeps track of details of data taking efficiencies and causes of down times systematically



Average CRAFT09 (24 July – 1 Sept. 2009) Efficiency: 71%
Without disruptions or testing: > 80%
Note: quiet weekend days operation indicates efficiencies > 90%, consistently

Detector Status in CRAFT09



- Percent of front-end electronics operational

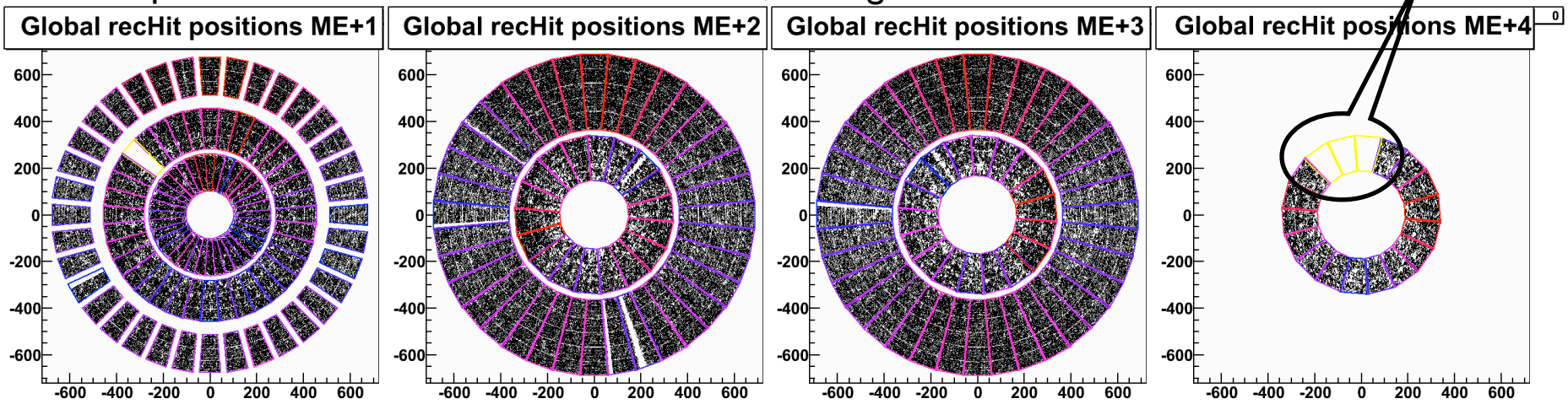
Example occupancy plots on next slides

CSC data: rechit positions:
global y vs x (in cm) in each station

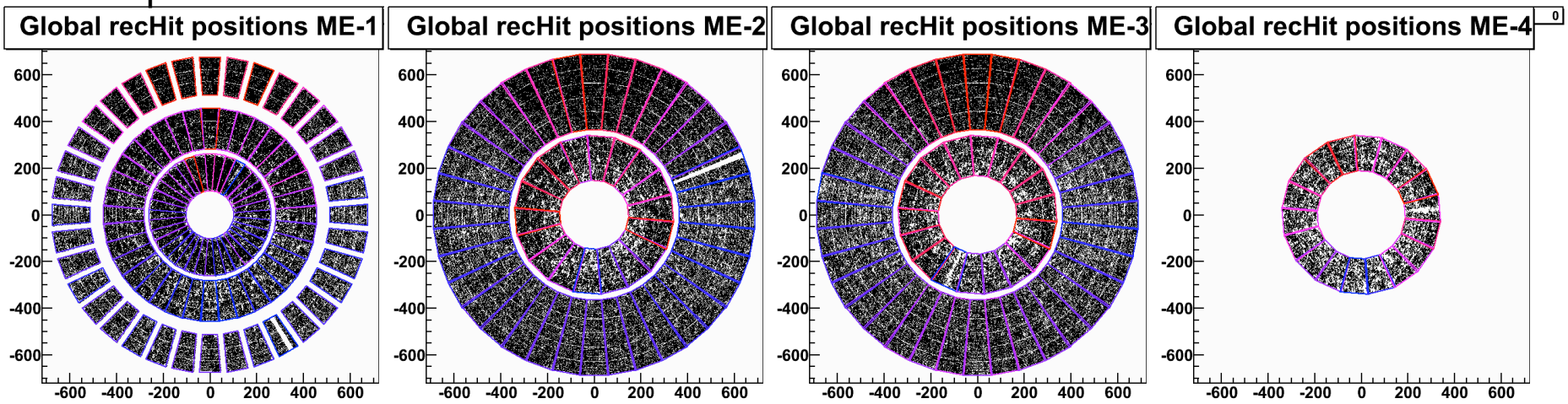
Low voltage off for development

+z endcap

Run 110508, 11 Aug 2009



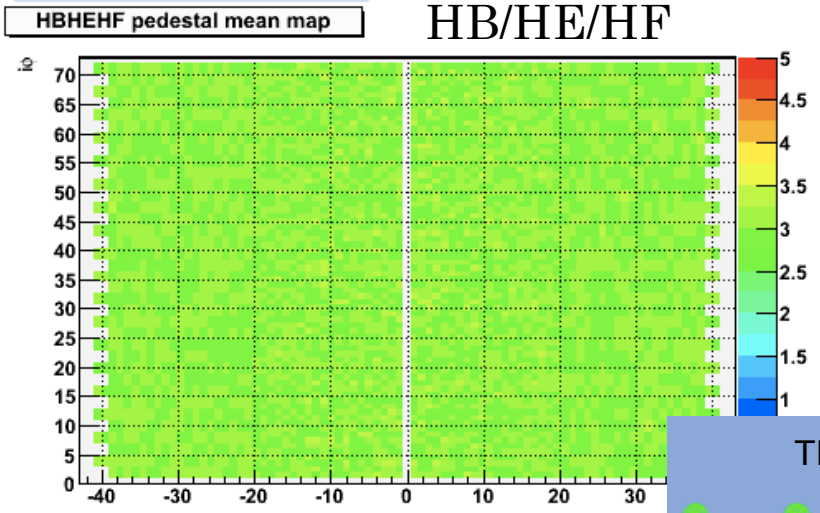
-z endcap



99% of chambers delivered data in CRAFT09 (cf. 96% in CRAFT08)

Occupancy Plots

Pedestal maps

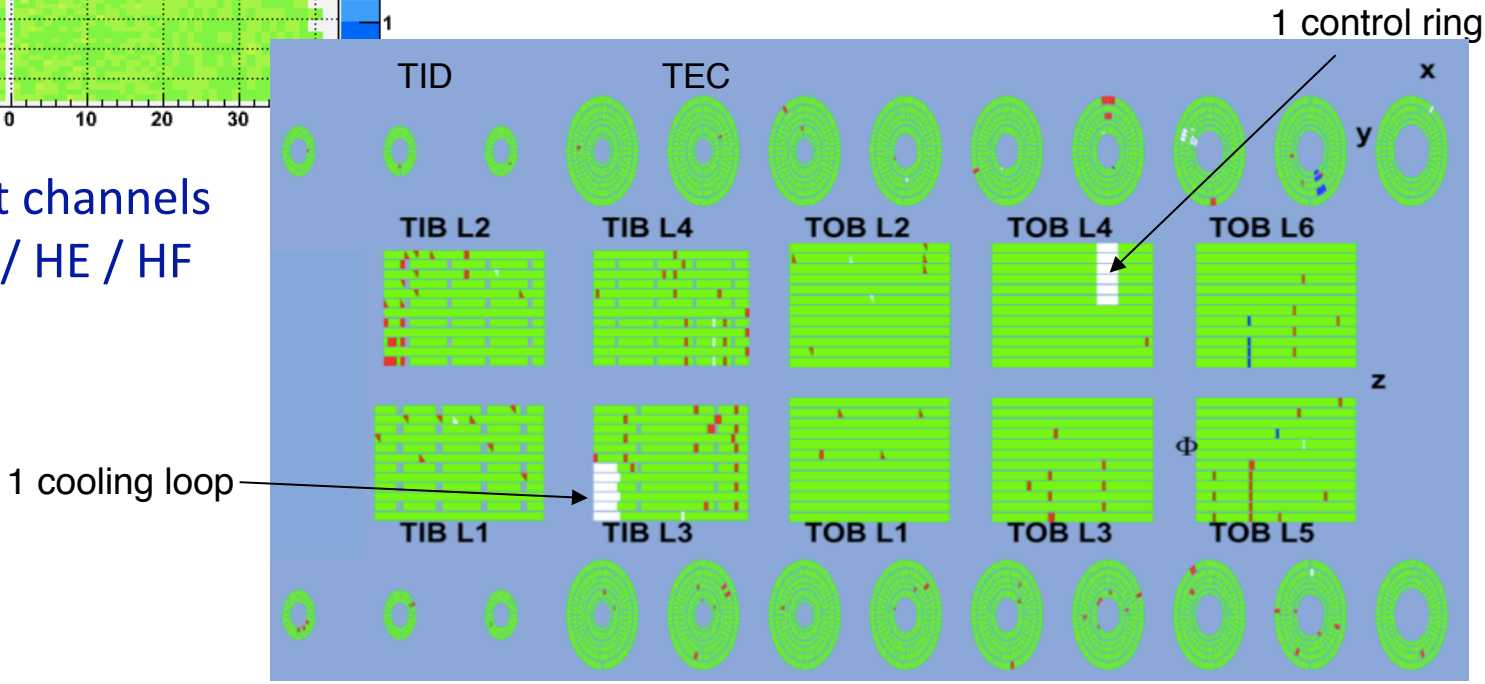


100% of readout channels available in HB / HE / HF

Operational Fraction of Tracker

- Strip Tracker : 98.1%
- Pixels : 98.5%

Hit finding efficiency of Barrel and Endcaps layers and disks after masking of faulty modules: ~99.9% average



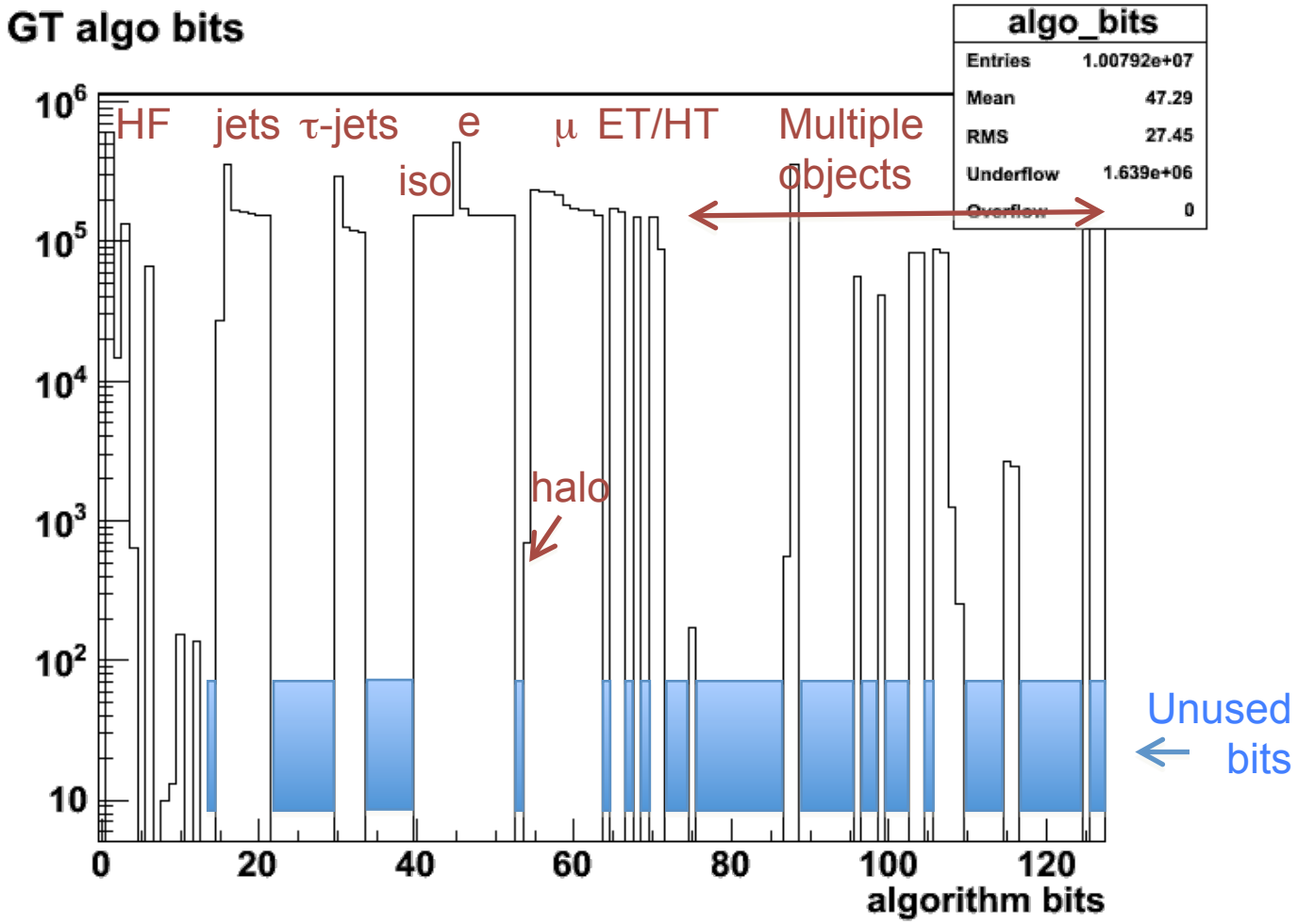
Strip map : working modules (green), disabled (white), not read-out (red), other (mainly missing HV blue)

All L1 Trigger Algorithms used

DT, CSC, RPC muon triggers with cosmic timing

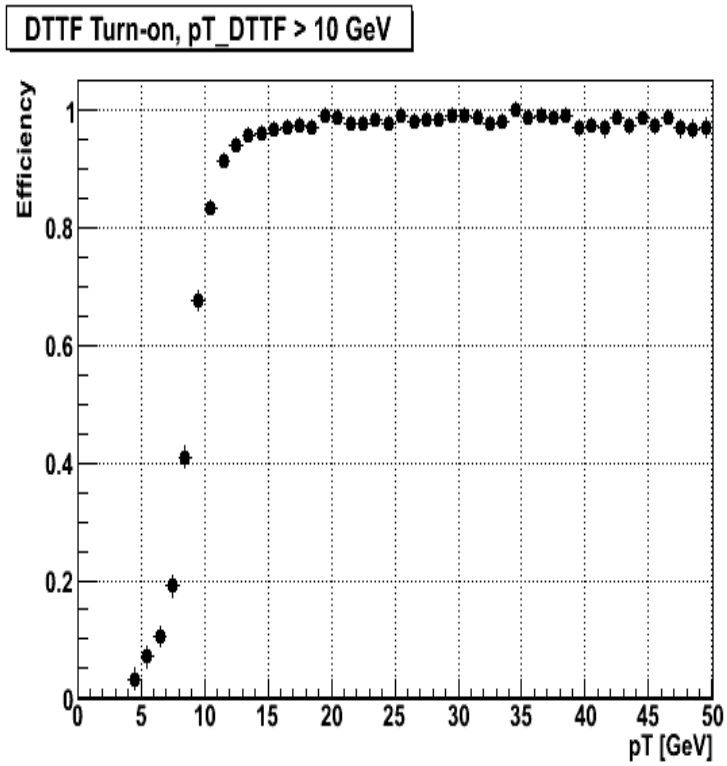
Also used: LHC timing and pointing roads in muon trigger

ECAL & HCAL based triggers with very low thresholds (e.g. L1_EG1, L1_Jet6)



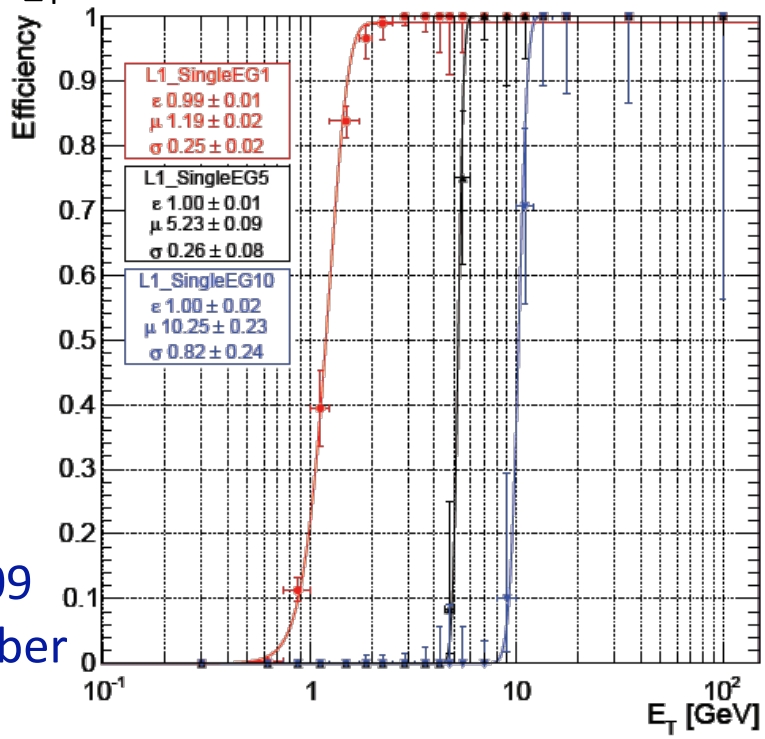
L1 Trigger Efficiencies

DT Track Finder candidates efficiency vs p_T (threshold 10 GeV)



L1 E-gamma trigger efficiency turn-on curve

- Measurement using muon brems in crystals
- Muon triggered events, requiring muon associated to ECAL e.m. cluster
- Plot efficiency of L1SingleEG1, 5, 10 trigger as function of electromagnetic cluster E_T



ECAL endcap+ trigger was commissioned in CRAFT09
Commissioning of endcap- to be concluded in October

High Level Trigger

- In 2009, developed "lean" trigger menus & focused on specific luminosity scenarios

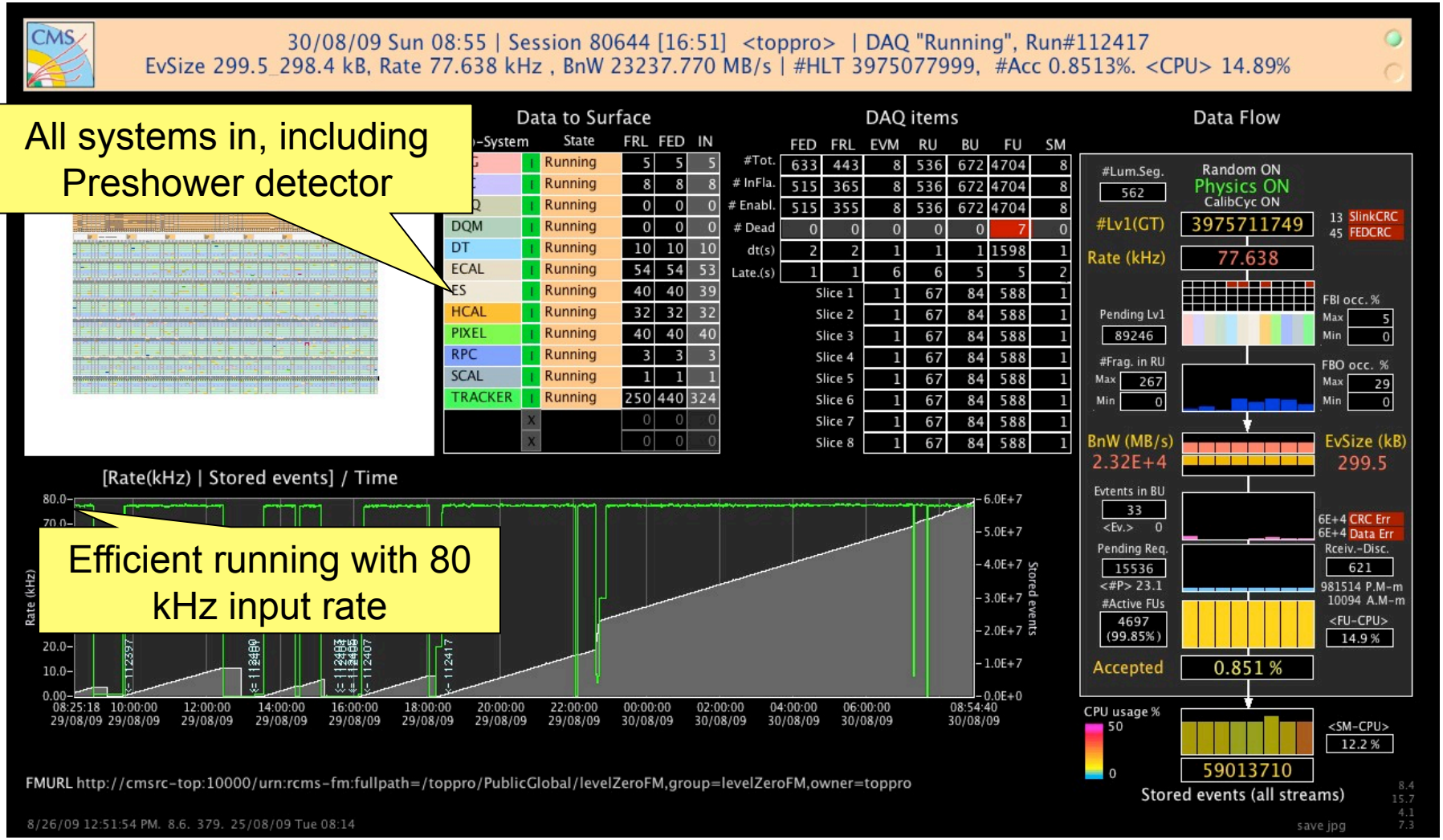
- L=8E29: collision menu for Day 1
  - startup detector calibration, relaxed isolation criteria, etc., 71 total paths
  - Trigger rates: L1: 6 kHz, HLT: 138 Hz (without AlCa paths)
  - **Successfully deployed (+ commissioning triggers) during CRAFT09**

- L=1E31: designed for higher luminosity MC studies
  - ideal detector calibration, high-p_T triggers, 94 total paths
  - Trigger rates: L1: 9 kHz, HLT: 145 Hz (without AlCa paths)

- Totals include physics, alignment/calibration, commissioning, monitoring paths

These menus will be re-optimized for 7 TeV collisions once new MC samples are available

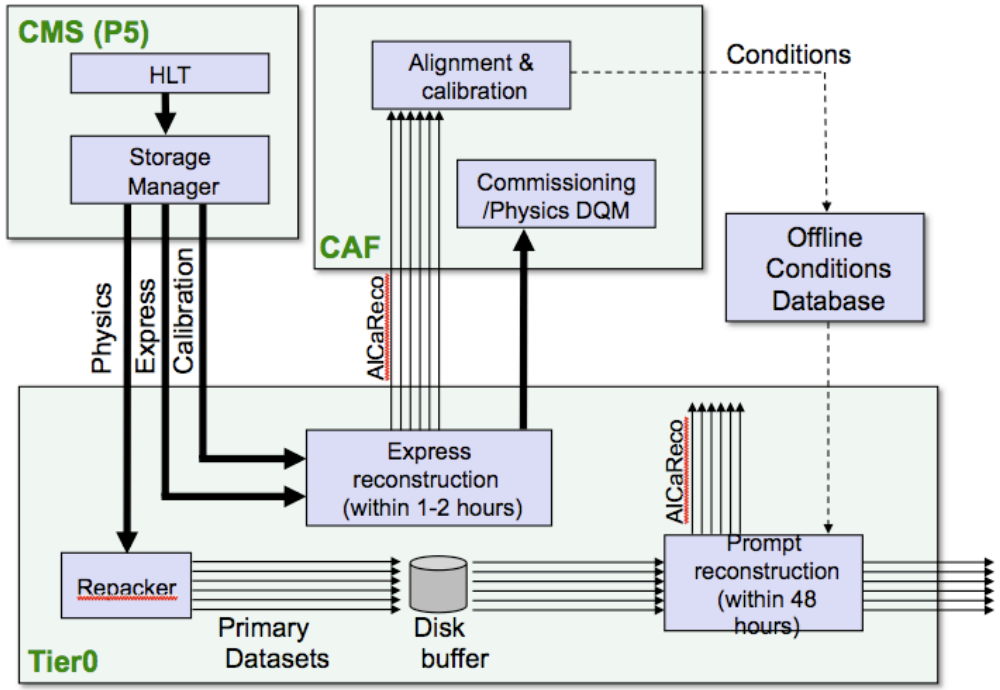
CRAFT09 Data Acquisition



- ~1 kHz cosmics / calib + 80 kHz randoms
- ~15 hours, ~ 4 10^9 events

Tier-0 Processing

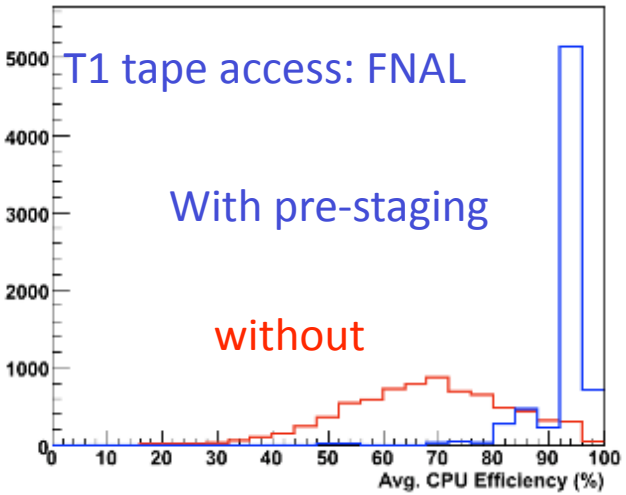
- Tier-0 processing ran smoothly through CRAFT09
  - Repacking
  - Prompt Reconstruction
  - AlCaReco production
- New functionality tested
  - pause mechanism to allow data to be buffered at T0 for 48 hours before prompt reconstruction



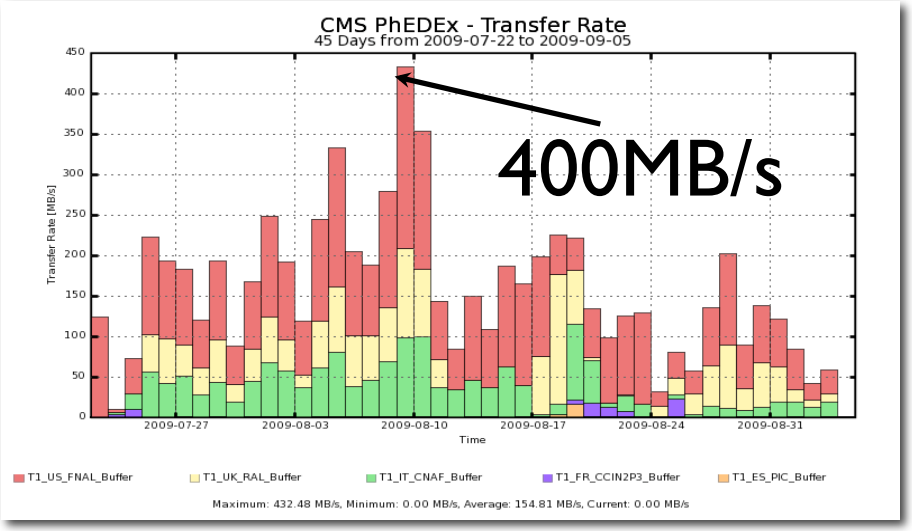
- Express stream worked well
  - latency to deliver data to CAF typically <1 hour
- CRAFT09 has demonstrated routine/prompt operation of alignment and calibration procedures
- New constants fed via Conditions DB into reconstruction of the same runs used to calculate the constants

Tier-1

- Tier-1 traffic during CRAFT was custodial transfers to RAL and CNAF
  - Additional copy of the data to FNAL
    - Quite successful
- Preparing for CRAFT09 re-reconstruction at Tier-1 sites
- STEP09 reasonably well conducted (Scale Test for Expt. Programme)
  - Data recording with other LHC experiments
  - Data Transfers
  - T1 tape access, Analysis at T2



CPU Efficiency

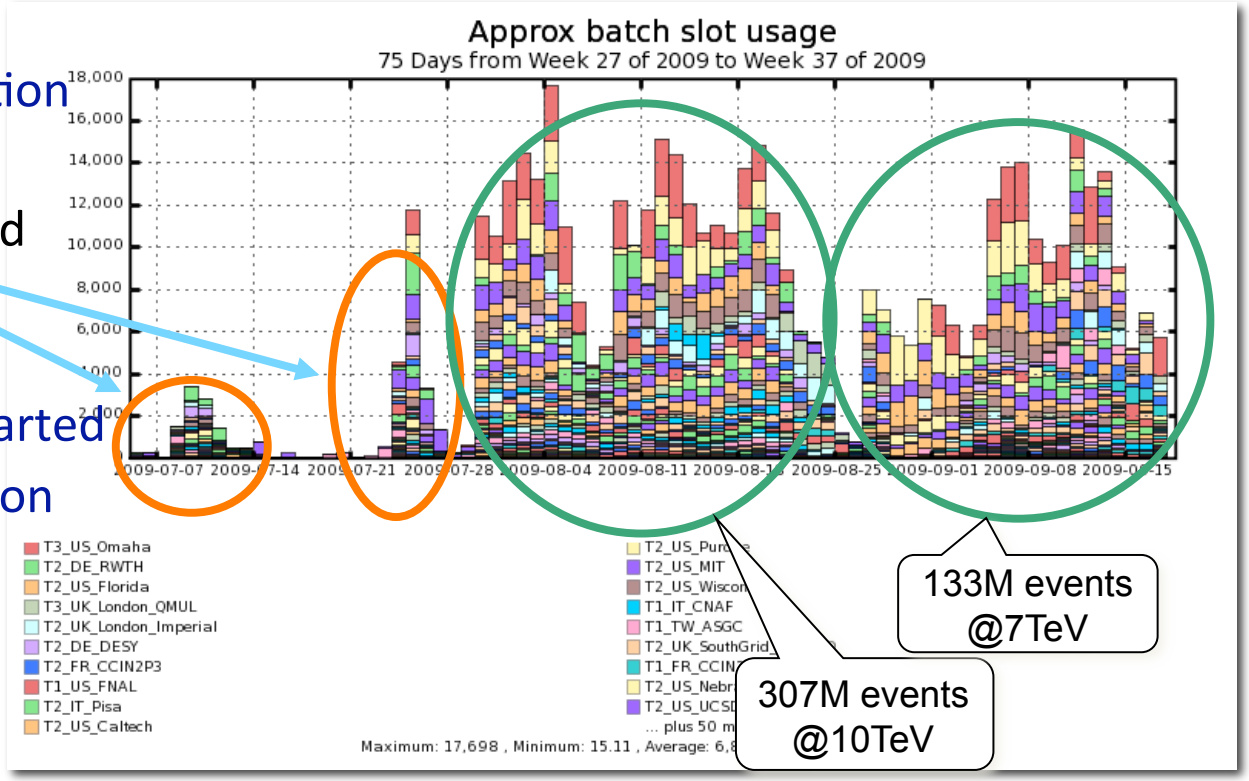


Summer'09 MC production

Pre-production of MC generation in July.

- ~15M events produced within few days

Summer'09 MC production started on July 29, when pre-production validation finished.



Large number of resources could be grabbed and used efficiently at the Tier-2 sites

The US Tier-2 sites have been extensively used for both simulation and analysis processing.

Readiness of Software

CMSSW 3

The 2009 release being used for CRAFT and MC @ 10 TeV (and 7 TeV) from August and later for LHC beam.

Includes (amongst other features)**:**

- input from CRAFT08, analysis exercises
- GEANT4 and ROOT major updates
- Data mixing and pileup
- Realistic detector (input from CRAFT08, analysis exercises)
  - dead/noisy channels
  - track corrected jets, MET
  - new version of Physics Analysis Toolkit
- Integration of heavy-ion simulations and reconstruction

Improving Workflows – make automatic e.g. prompt calibration etc.

“Physics Commissioning”

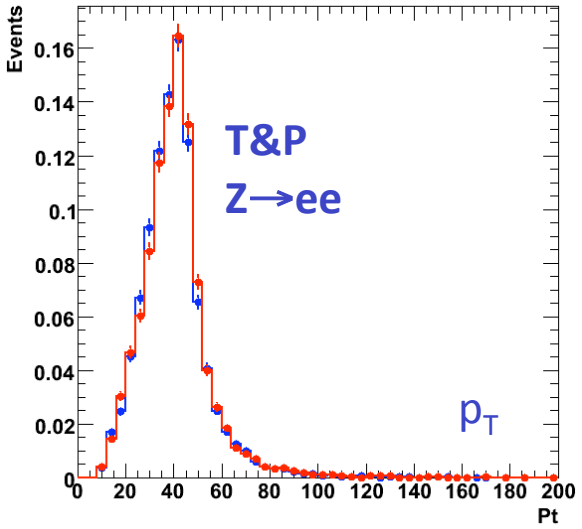
Physics: Progress

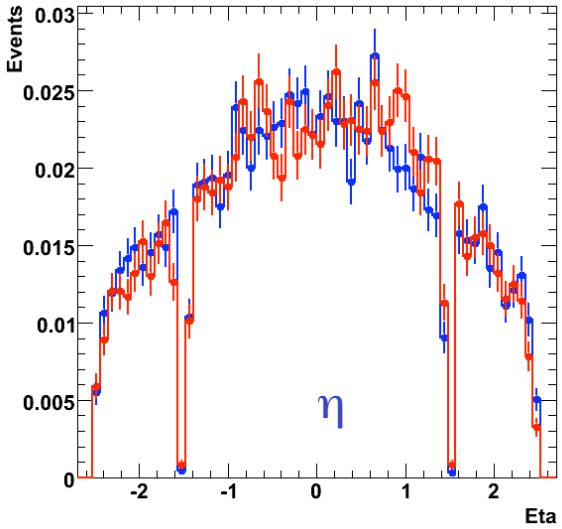
- **Analysis "marathon".** Completed analyses with CMSSW_2 (@ 10TeV), in order to move onto CMSSW_3
- Total of ~50 analyses from the marathon
- All analyses concentrated and in most cases included methods that would be applicable with real data (for $10pb^{-1}$ to 200 pb^{-1})
- **Next step:** Early look at CMSSW_3_X data.
  - First Data Monte Carlo at 10 TeV (FDMC-10) production complete!
  - FDMC-7 started. These will be the samples we will use to compare our "models" to the data

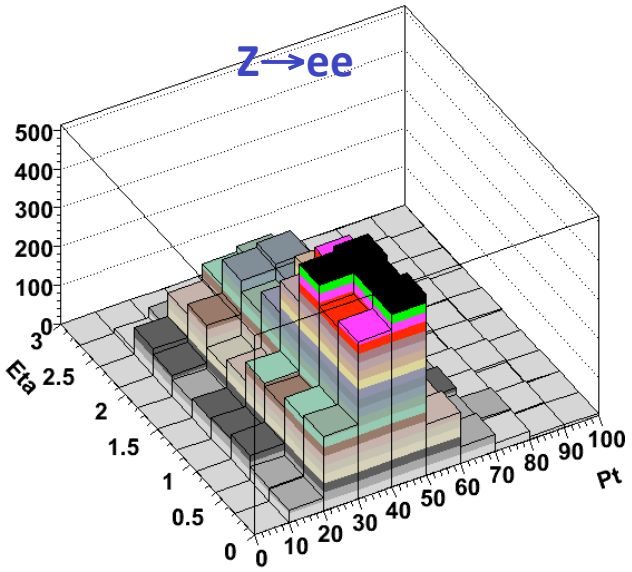
Data-driven Methods: physics objects ID

Already two years ago, developed Tag and Probe (T&P): identify a physics object in an unbiased way in order to study efficiencies.

e.g. Z→ee events: one tight electron (tag); the other can be a probe, provided the invariant mass of the pair is ≈M_Z







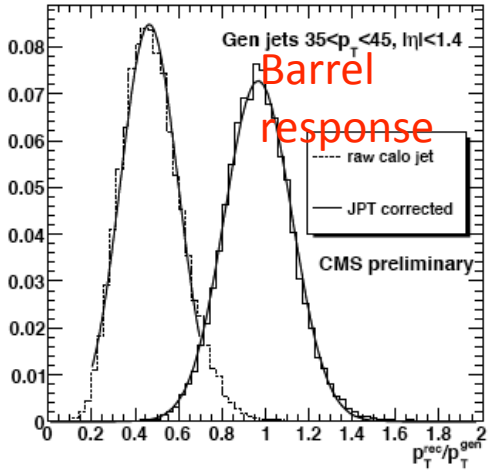
Efficiency from T&P: 94.36±0.24
Efficiency from MC truth: 94.63±0.24

} **for 10 pb^{-1} at 14 TeV**

Preparation for Physics Analysis: 10 TeV

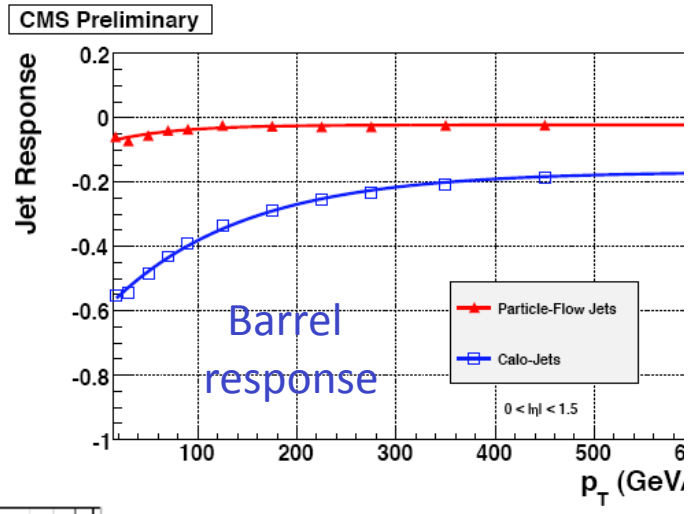
Example: Use of Tracks in Reconstructing Jets

Jets+Tracks (JPT)

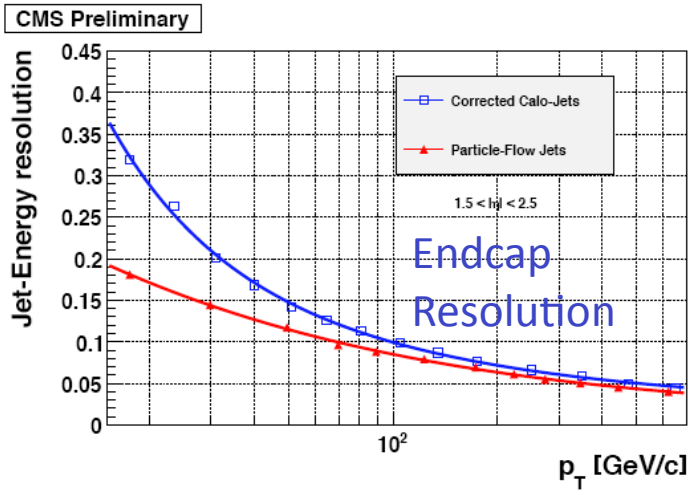


Barrel response

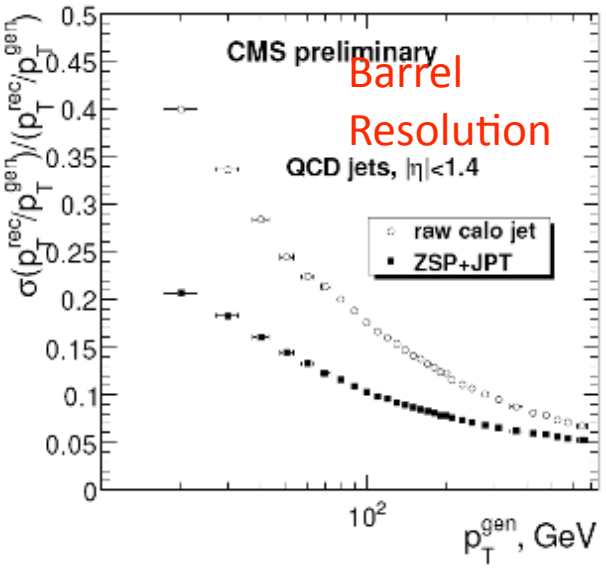
"Particle Flow"



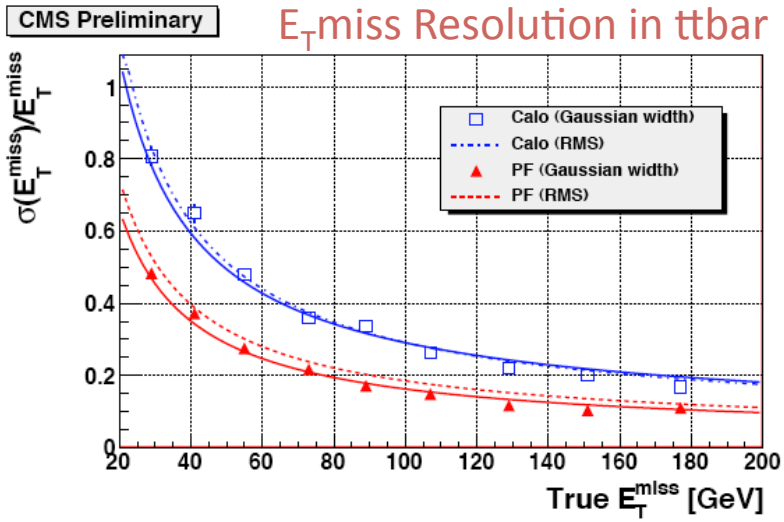
Barrel response



Endcap Resolution



Barrel Resolution



$E_T$miss Resolution in ttbar

Early Physics Program Outline

- Detector commissioning – much already done using cosmics/testbeam,..
- Early beam: splash events, first collisions at injection energy, then at 7 TeV
  - Detector synchronization, alignment with beam-halo events, minimum-bias events. Earliest in-situ alignment and calibration
- Early beam - collisions, up to 10-20 pb^{-1} @ 7 TeV
  - Commission trigger, start "physics commissioning" – "rediscover SM":
    - Physics objects; measure jet and lepton rates; observe W, Z, top
    - Reference measurements for heavy-ion program
    - And, of course, first look at possible extraordinary signatures…

Early Physics Program Outline

- 7 TeV, 10's of pb^{-1} measure S.M., start searches
  - Approx per pb^{-1}: 3000 $W \rightarrow l\,\nu$ ($l = e,\mu$); 300 $Z \rightarrow ll$ ($l = e, \mu$); 5 ttbar $\rightarrow \mu$+X
    - Improved understanding of physics objects; jet energy scale from $W \rightarrow j\,j'$; extensive use (and understanding) of b-tagging
    - Measure/understand backgrounds to SUSY and Higgs searches
  - As data accumulates higher, look for excesses from SUSY & Z' resonances.

- Collisions at the higher energy: extend searches
  - Explore a larger part of SUSY and resonances
  - **~1000 pb^{-1} entering Higgs discovery era**

- Late 2010: One month of Pb+Pb collisions at 4 TeV
  - Study hot QCD matter

Conclusions & Outlook

- During the Fall 2008 LHC beam & cosmics run, the sub-detectors, online, offline, computing and analysis systems all performed well.
- The ensuing shutdown included broad maintenance activities and a program of carefully selected repairs interleaved with installation of the preshower
- A lot of VERY useful information has been extracted from the CRAFT08 data. Plan to publish ~25 papers by ~November.
- The CMS detector was closed in mid-July. CRAFT09 was successfully run in August. First results indicate a performance equal to, or better than, that in CRAFT08.
- The software and computing systems have been exercised by generating and distributing MC samples (500 M Fullsim evts) to update 10 TeV "physics analyses" and soon 7 TeV "physics analyses" AND to get familiar with the latest version of CMS software (CMSSW_3).
- **CMS is ready and eager for beam!**