CMS Commissioning

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HEPHY Vienna
on behalf of CMS collaboration

30 Sep 2008

4th Conference On Physics at LHC, Split

CMS commissioning overview

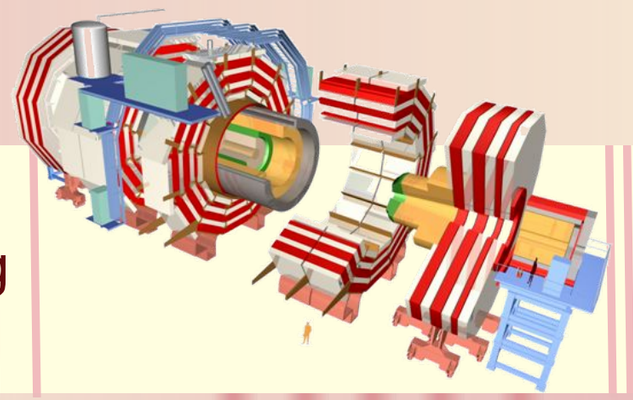
2006 | 2007 | 2008

computing commissioning

CSA06 | CSA07 | CSA08 CCRC08

surface commissioning

MTCC



heavy lowering

CMS closed
ECAL endc. installed
Pixel installed
Beam pipe bake-out
Tracker installed

Global Runs | CRUZETs | Magnet tests 1st beams

underground commissioning

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

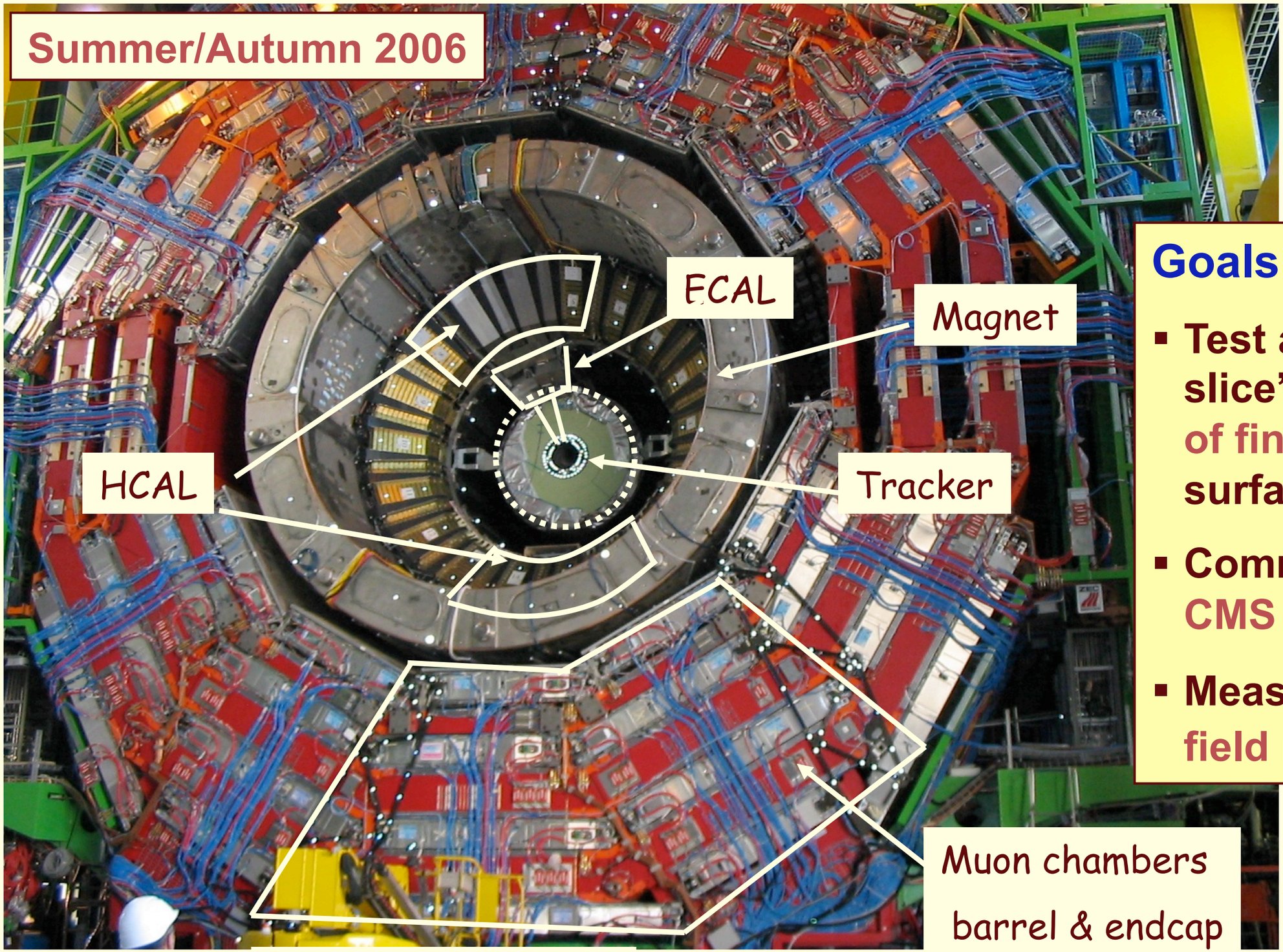
CRUZET – **C**osmic **RU**n at **Zero** **T**esla

First closure on surface

MTCC

Magnet Test and Cosmic Challenge

Summer/Autumn 2006

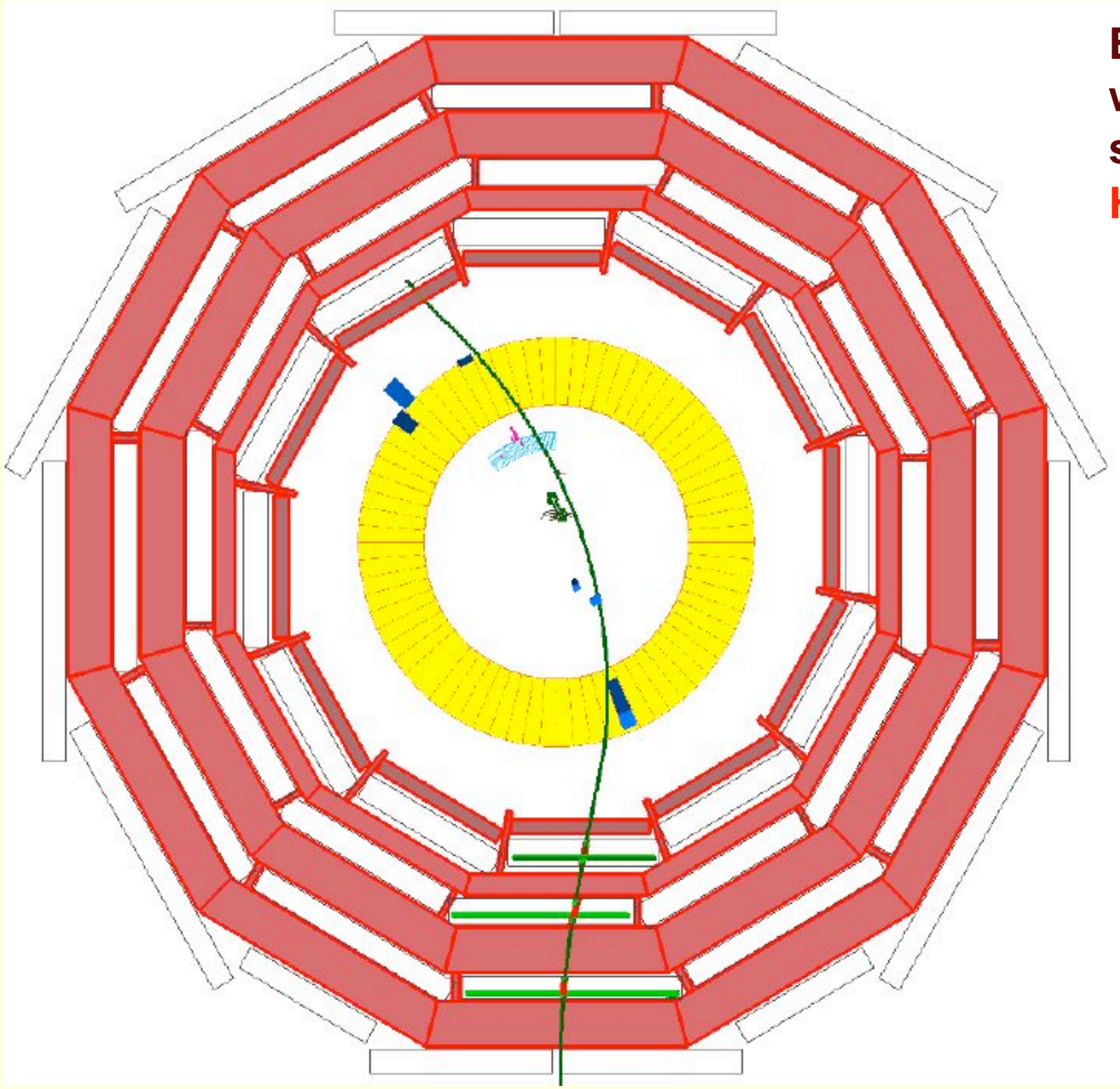


Goals:

- **Test a "vertical slice" of all aspects of final CMS on the surface**
- **Commission the CMS magnet**
- **Measure the magnet field map**

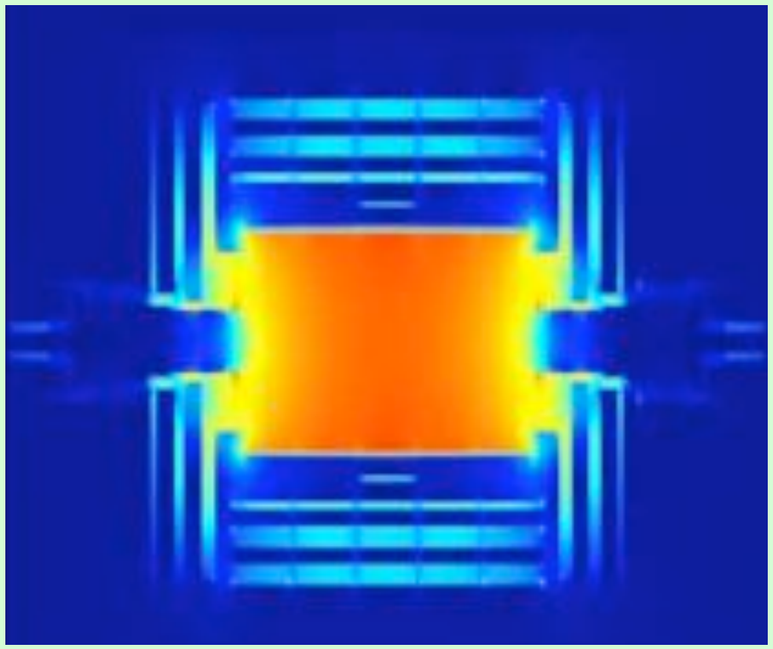
MTCC

Magnet Test and Cosmic Challenge



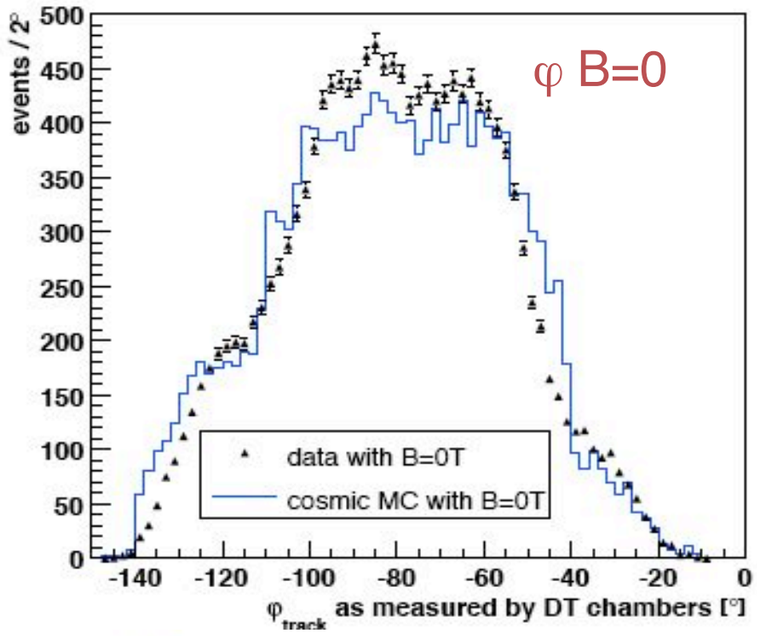
Event display of a cosmic muon with the magnet at 3.8T with signals from Tracker, ECAL, HCAL and Muon DT

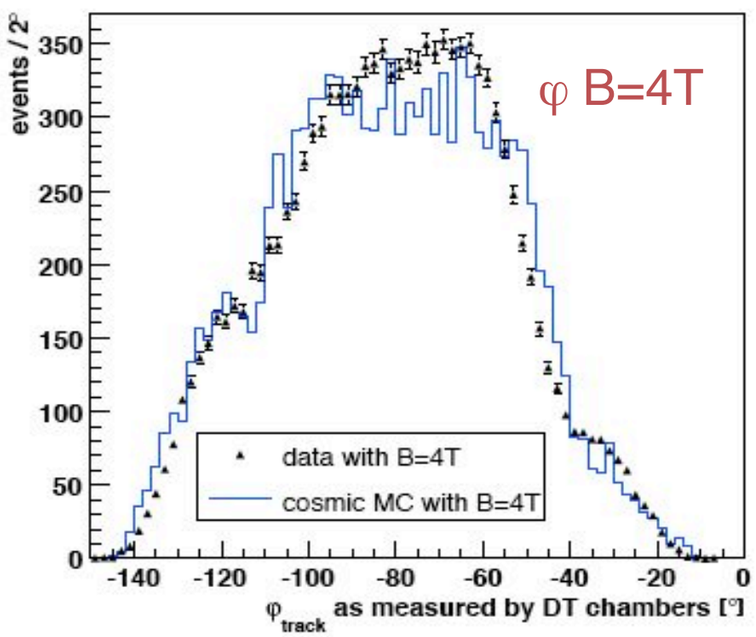
- **Magnet was successfully tested up to 4T**
- **Field maps measured for several working points between 2T and 4T**



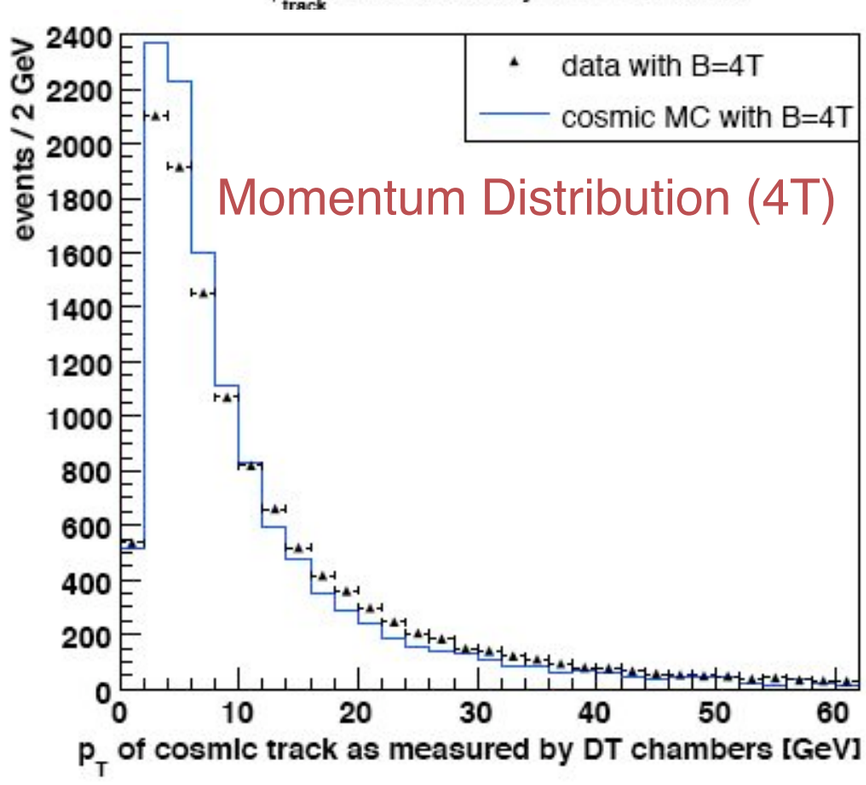
MTCC

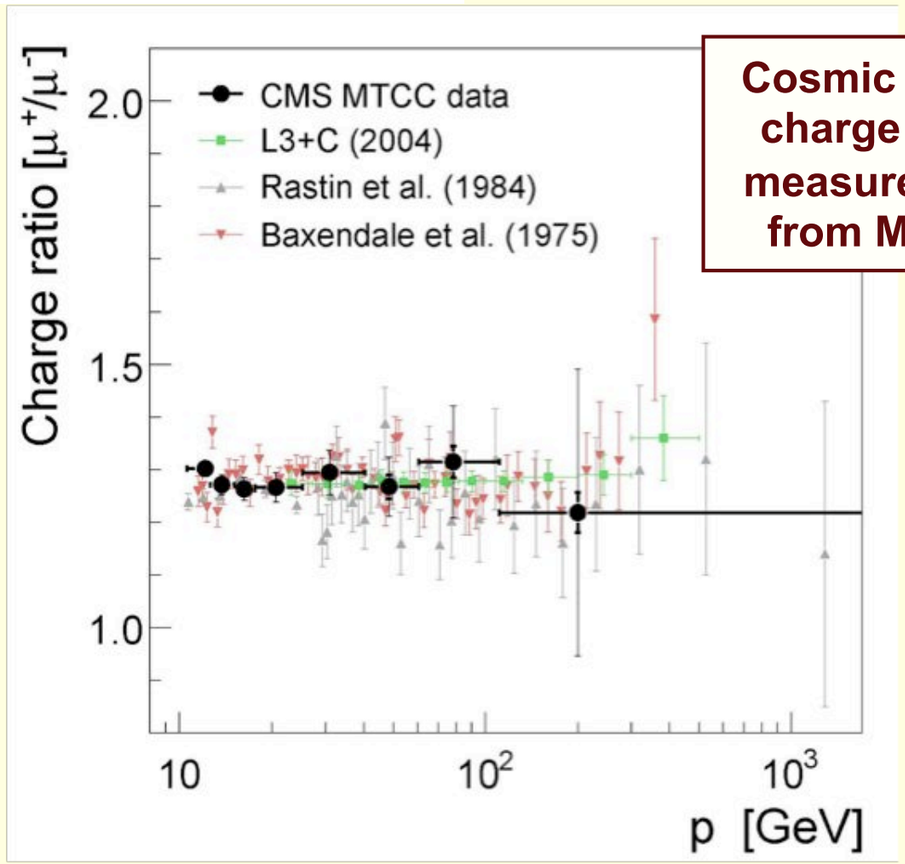
Magnet Test and Cosmic Challenge





Behavior of detectors in the magnetic field was verified using MC and physical observables

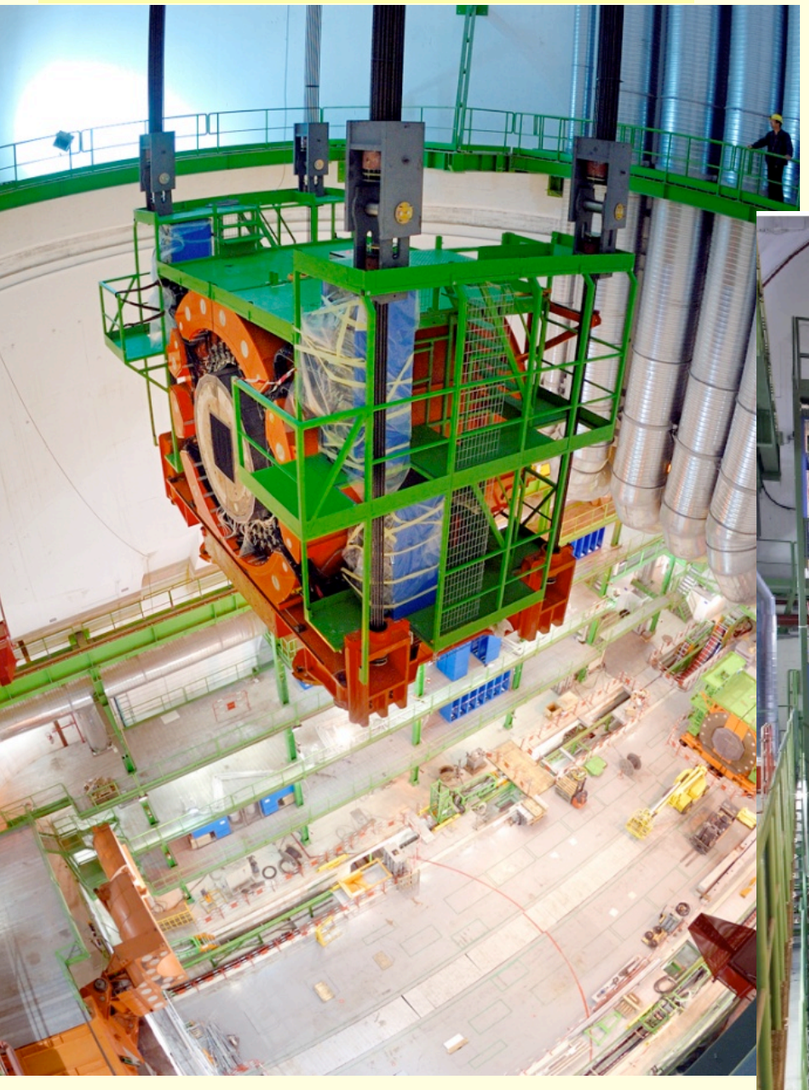




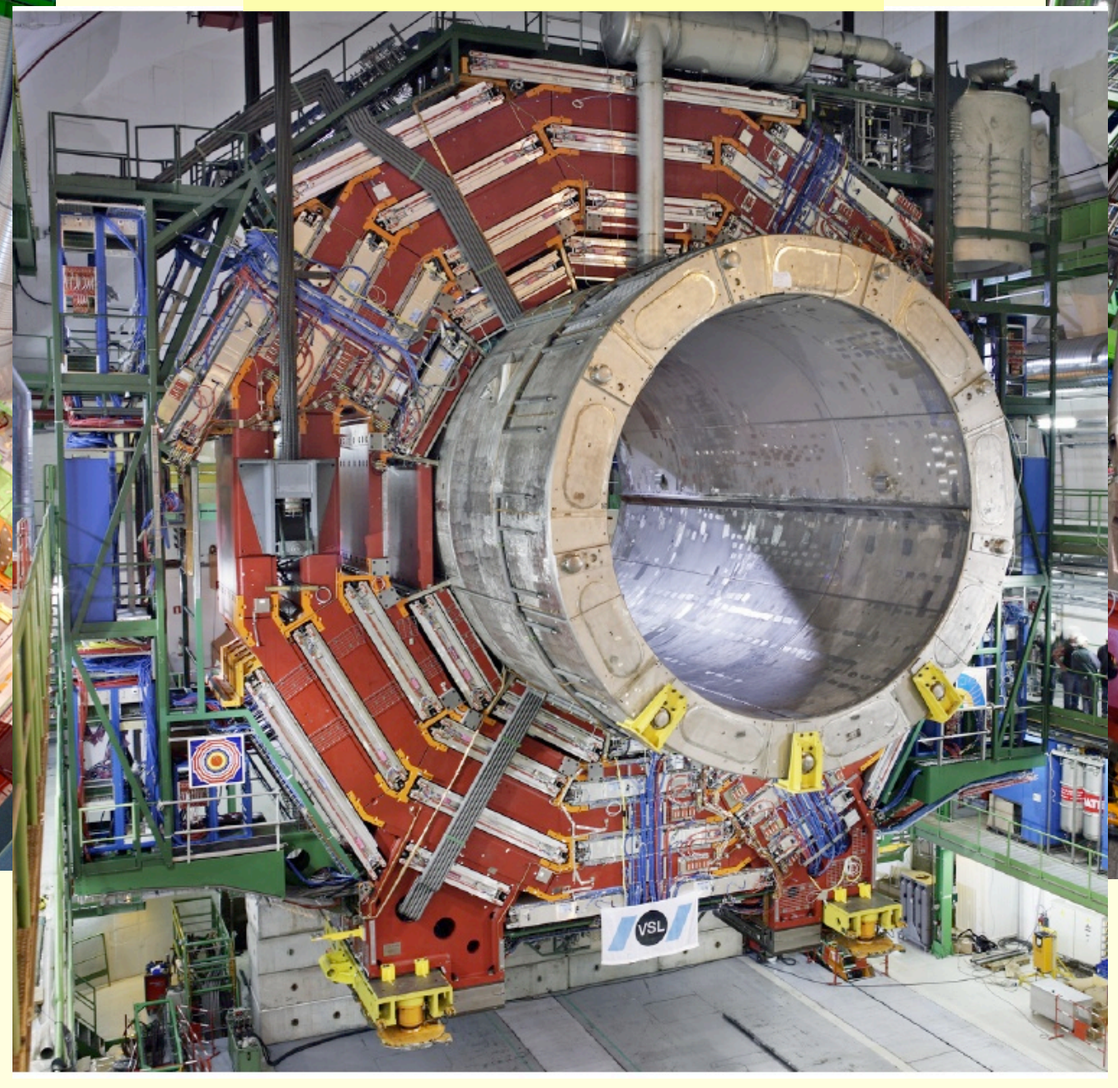
Cosmic muon charge ratio measurement from MTCC

Heavy lowering

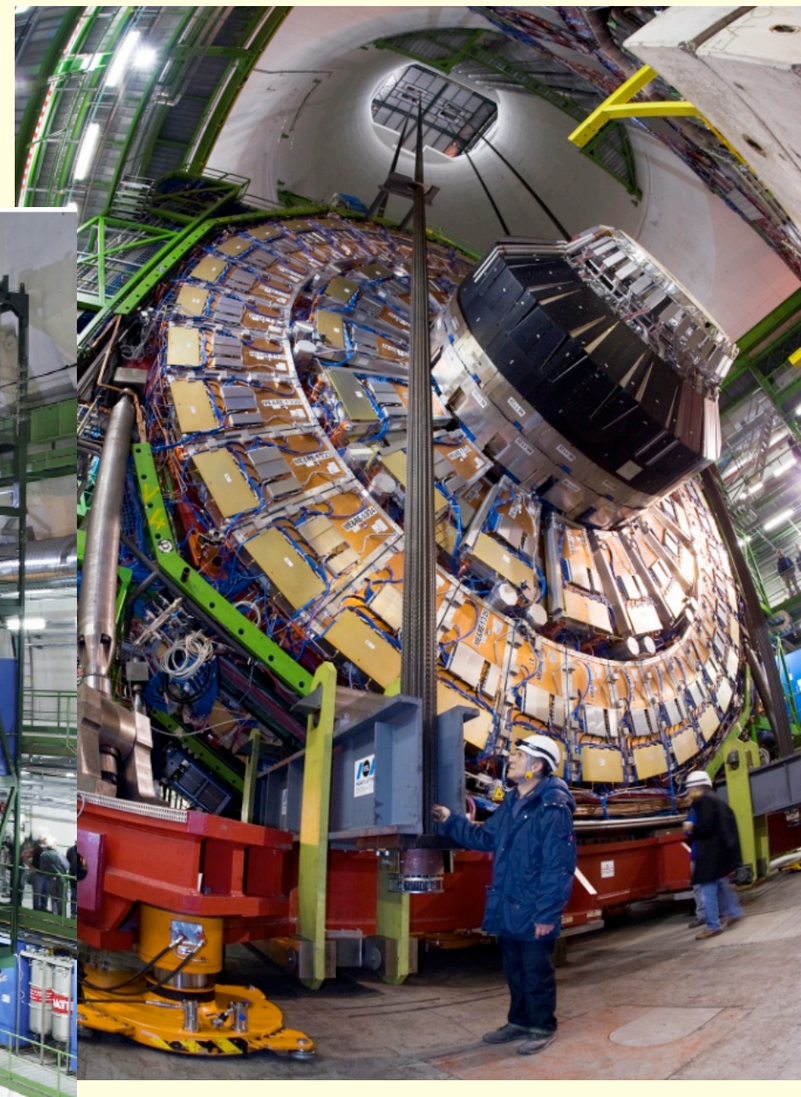
#1 Nov06: HF-



#9 Feb07 YB0



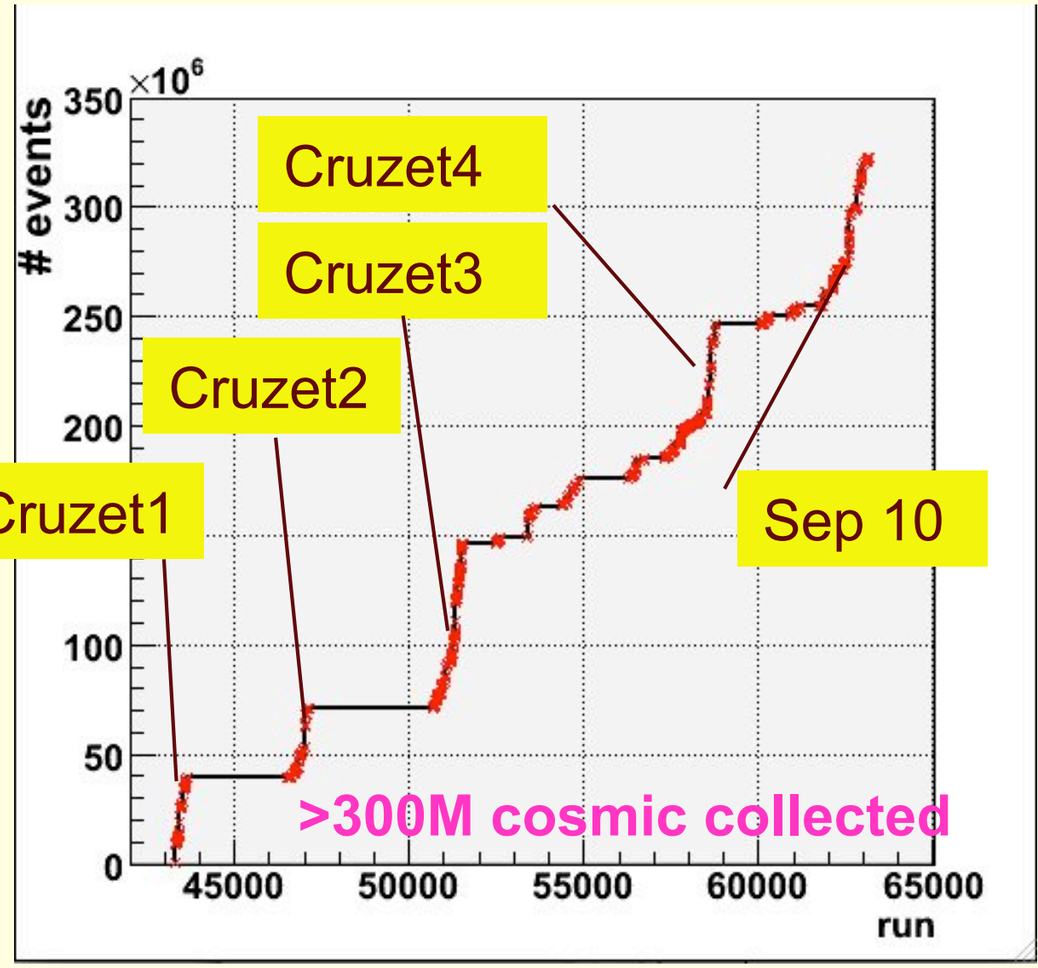
#15 Jan08: YE-1



Global Runs

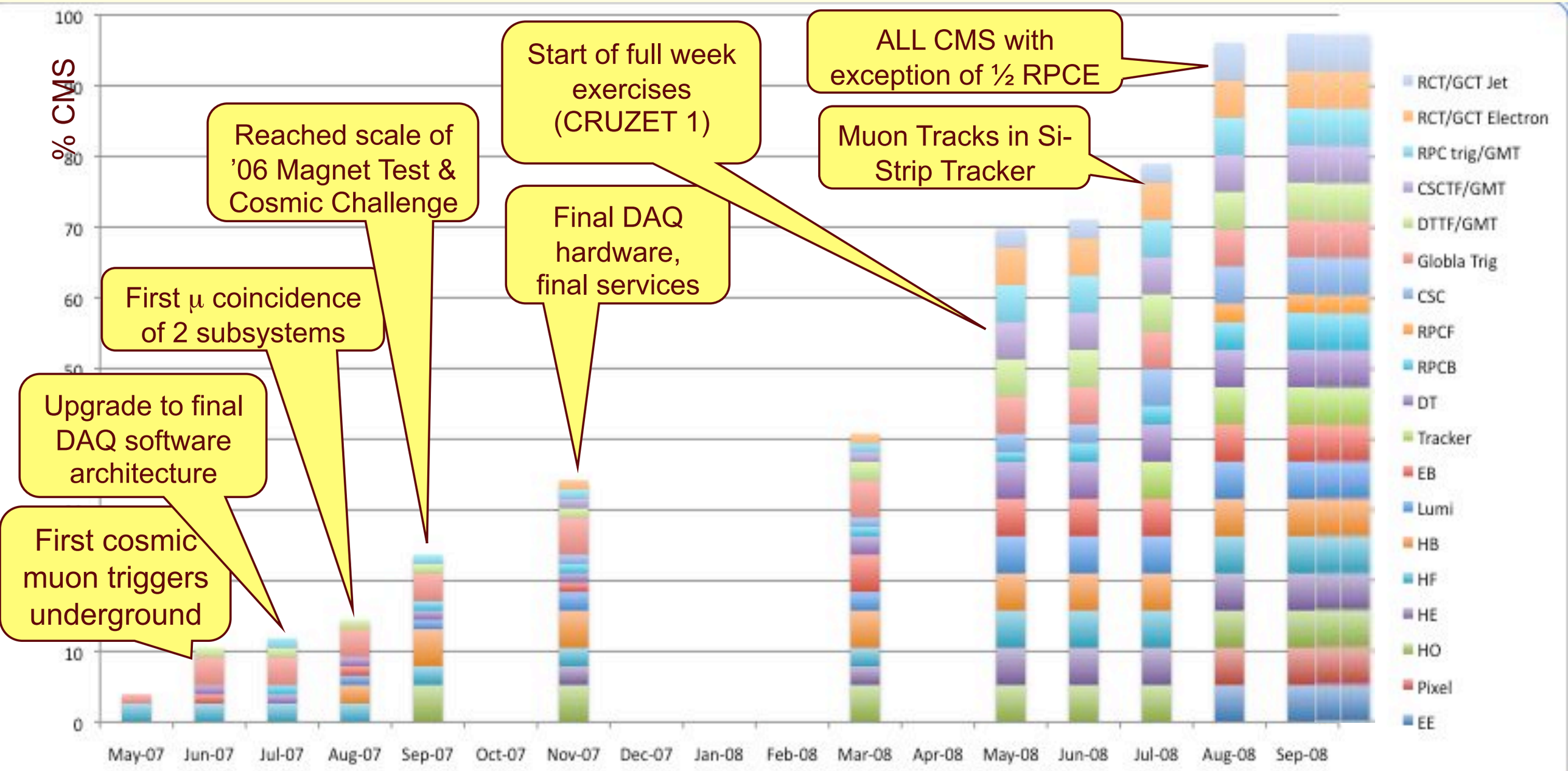
- Started May 2007 - A few days / ~month
- Goals:
  - Integrate parts of CMS into DAQ process as soon as they become available
  - Test the trigger (L1, HLT) and L1 trigger throttling using cosmic and high rate random triggers
  - Introduce 24/7 shift operation and test/develop DQM (Data Quality Monitoring)
  - Exercise data transfer to CAF (CMS Analysis Facility) and Tier 0,1,2, prompt reconstruction, alignment and calibration
  - Use collected data to understand trigger and read out synchronization and detector performance using inter-system correlations
- Global runs have taken place while CMS was being assembled, services installed etc. so every month the complexity of the system or the functionality could be scaled up

- Last 4 months - full week exercises (CRUZETs) with all or large majority of subsystems integrated - achieved more than 8 hours stable running, tested sustained running with LHC trigger rates



Global Runs

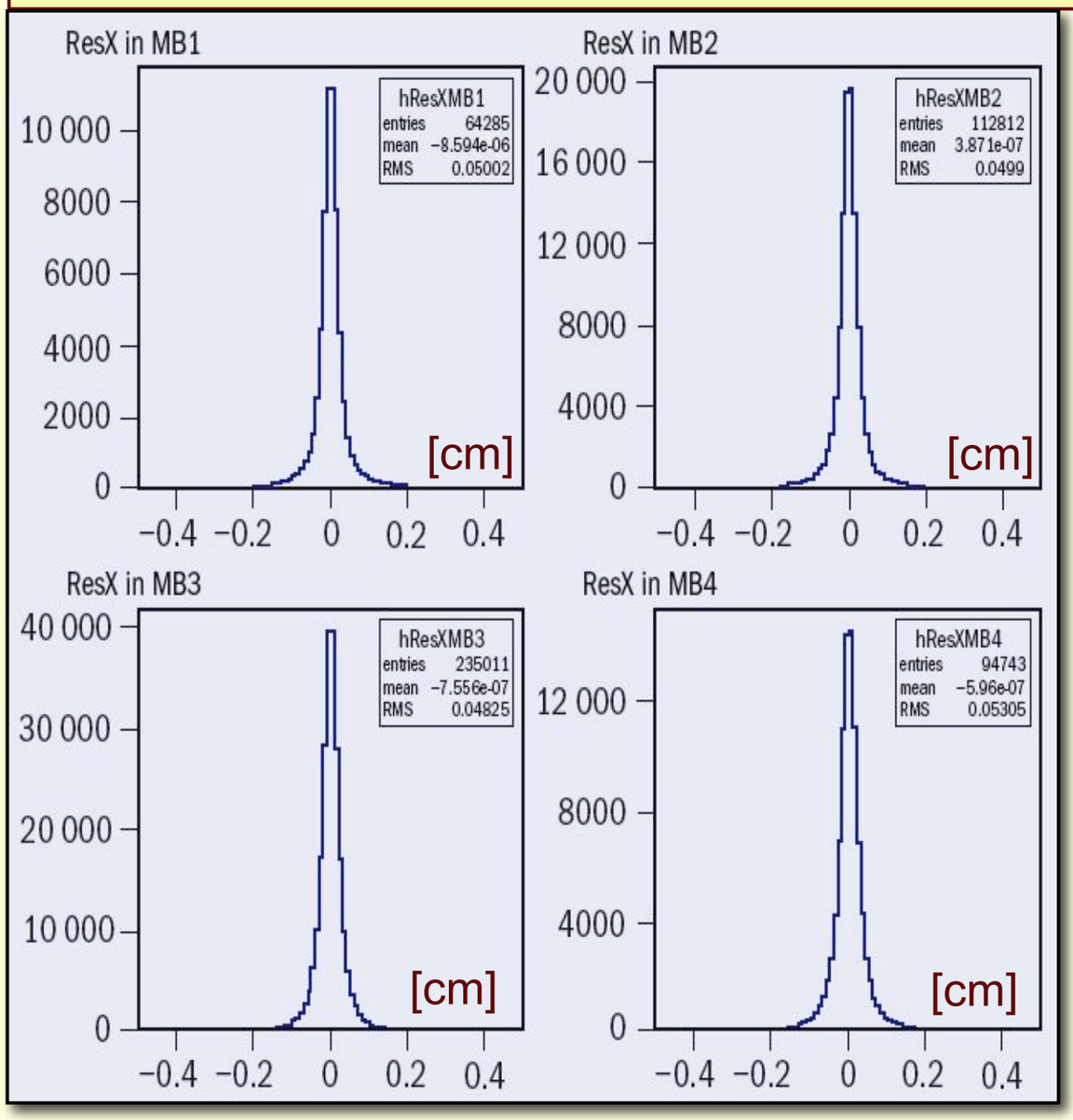
- **Subdetector and trigger considered separately - 19 items, each equally weighted - box size represents approx. fraction included (25%, 50%, 75%, 100%)**
- **With exception of some parts of RPC, all CMS detector and trigger system ready for LHC**



DT

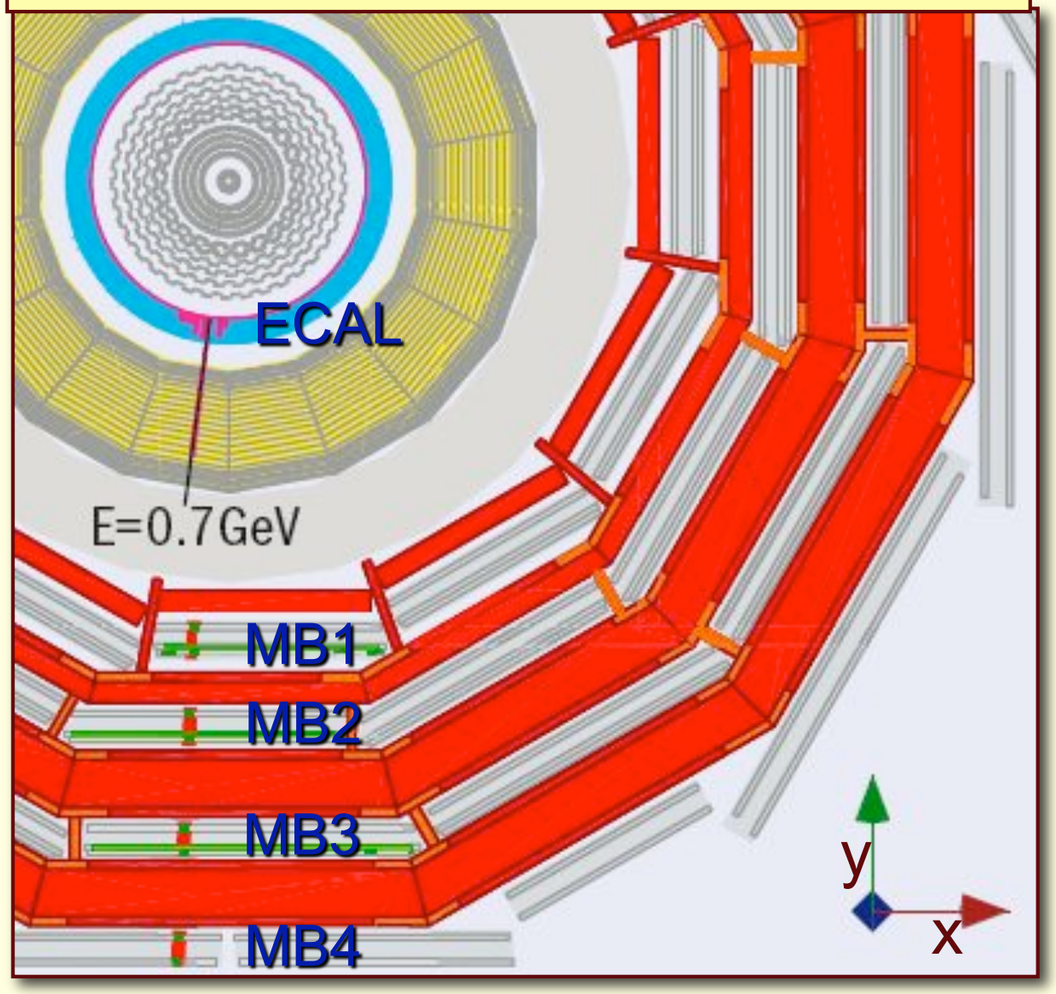
Barrel muon detector:
Drift Tubes

First results from cosmic data: single-hit resolution of barrel drift tubes (DT): < 250 μm



DT trigger service to other detectors:

m.i.p. signal in ECAL from a cosmic muon triggered by DT

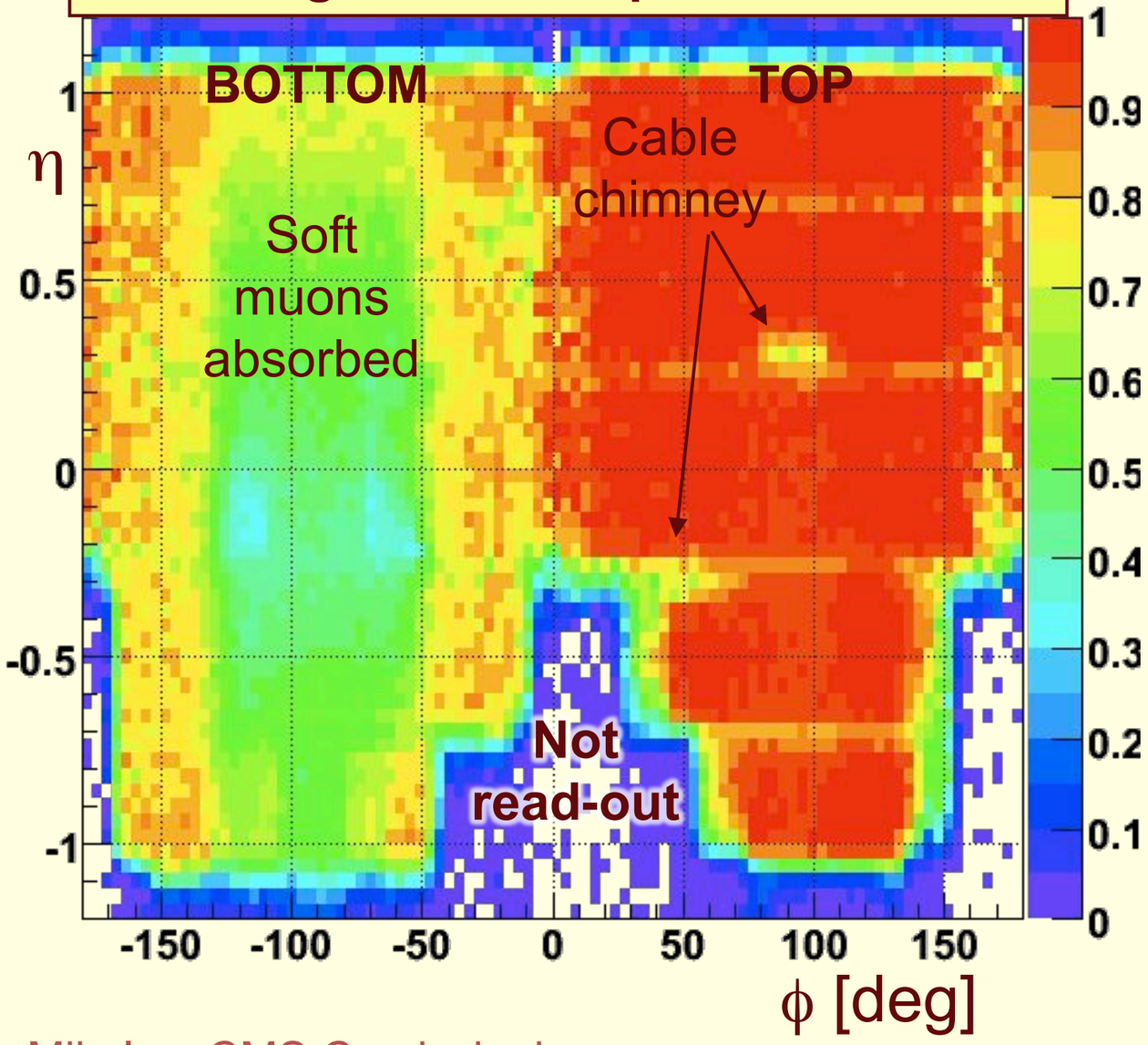


August ‘07 Global Run

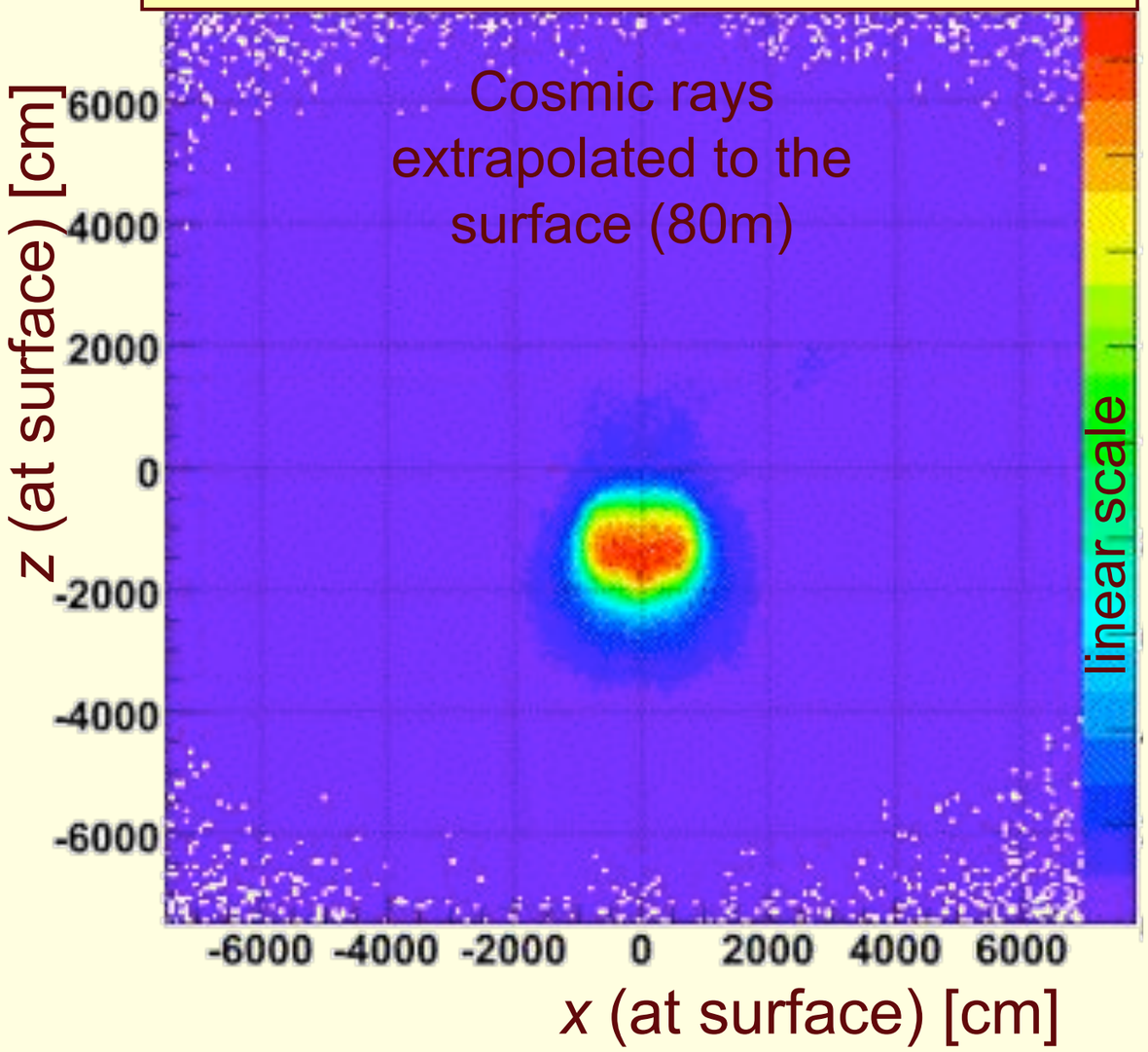
Tag & Probe with cosmics

- TOF-compensated cosmic trigger: di-muon-like signal in DT
- Probe muon trigger and reconstruction

Probability to find at least one segment at the probe side

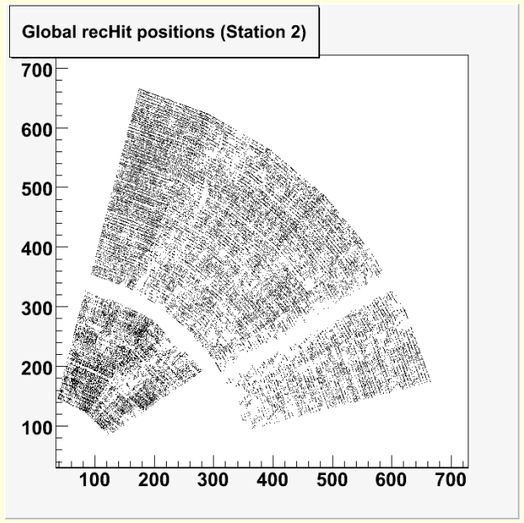


"X-ray" image of the shaft using cosmic rays



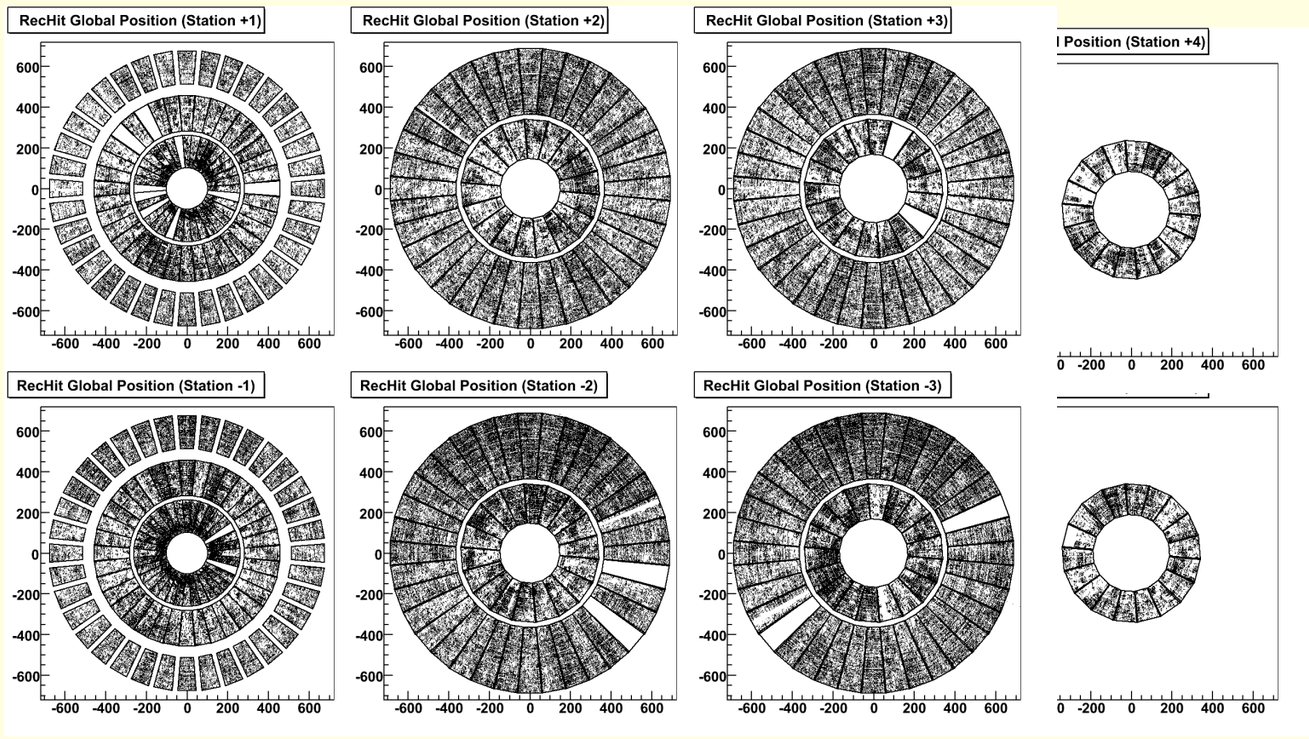
CSC

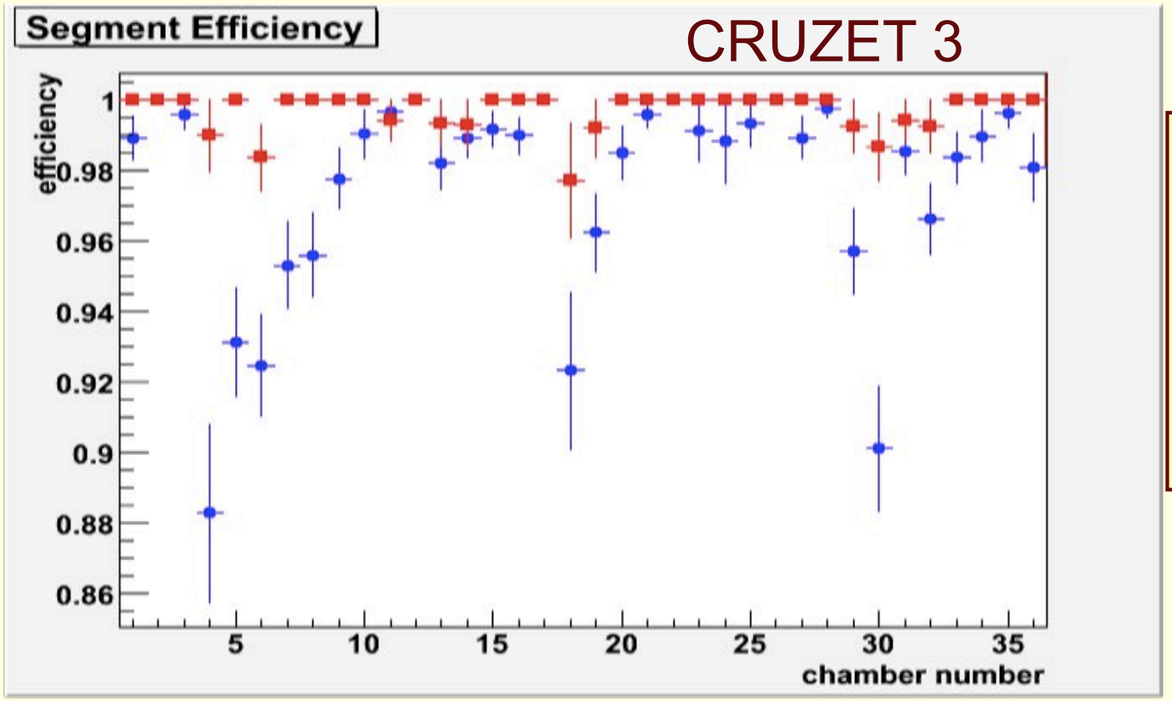
Endcap muon detector: Catode Strip Chambers



Fast commissionig progress from Mar08 to Jul08

97% of chambers operational!
(rest recoverable)



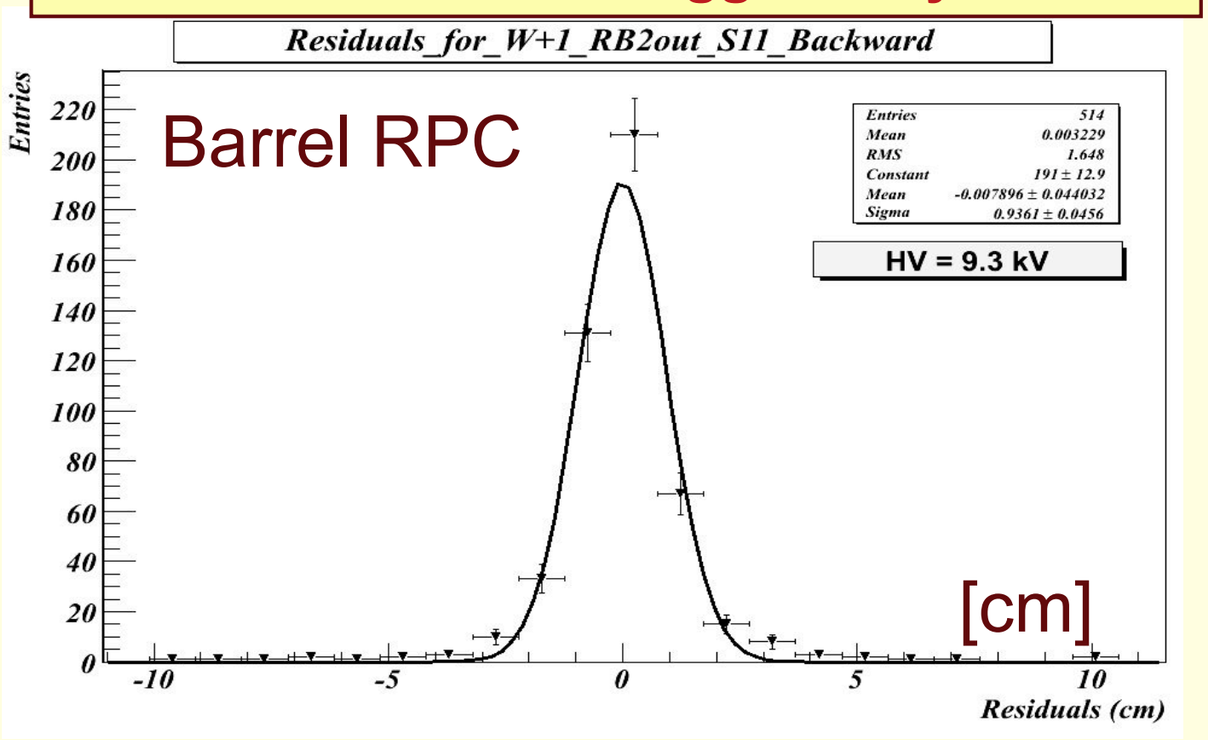


CSC synchronization using Global Run data:

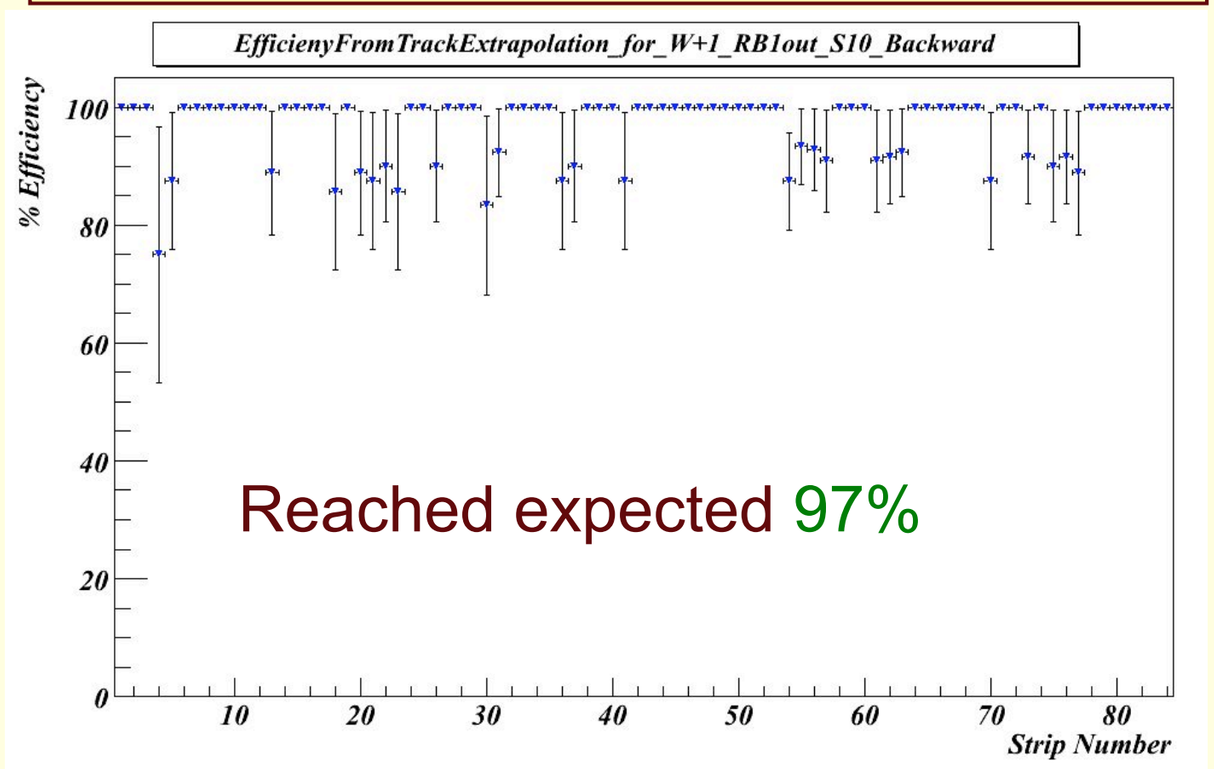
Segment efficiency before and after synchronization

Example of resolution studies using Global Run data:

residuals wrt. tracks triggered by DT



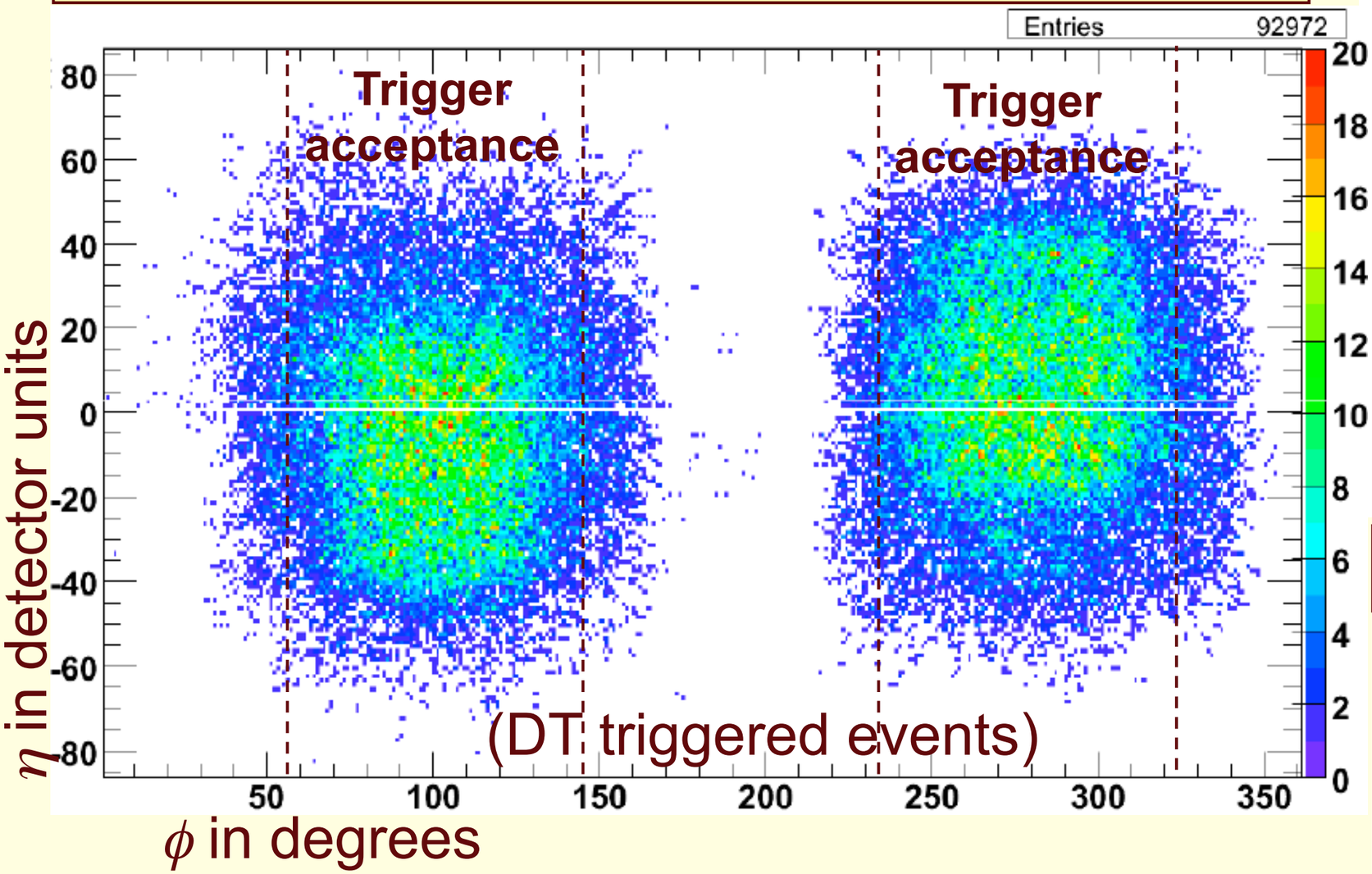
Layer efficiency (in %) using tracks reconstructed in other 5 layers

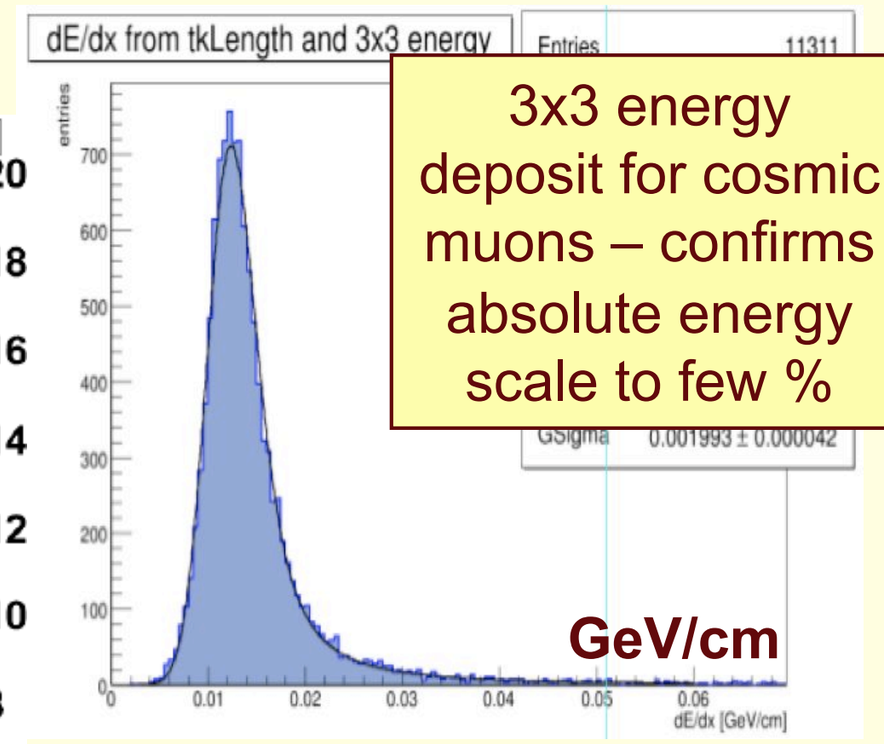


Aug08: full barrel and one endcap integrated

ECAL

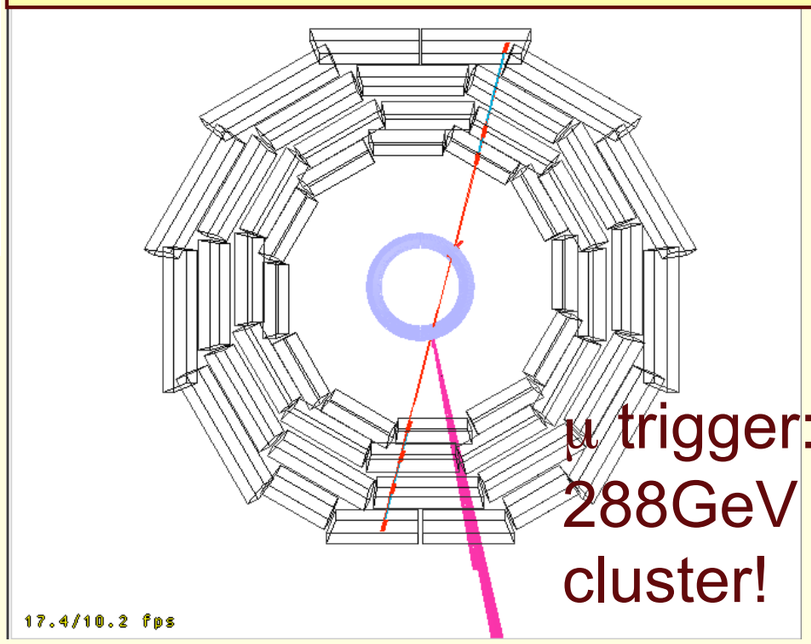
Reconstructed clusters matching muon tracks





3x3 energy deposit for cosmic muons – confirms absolute energy scale to few %

Track-cluster association

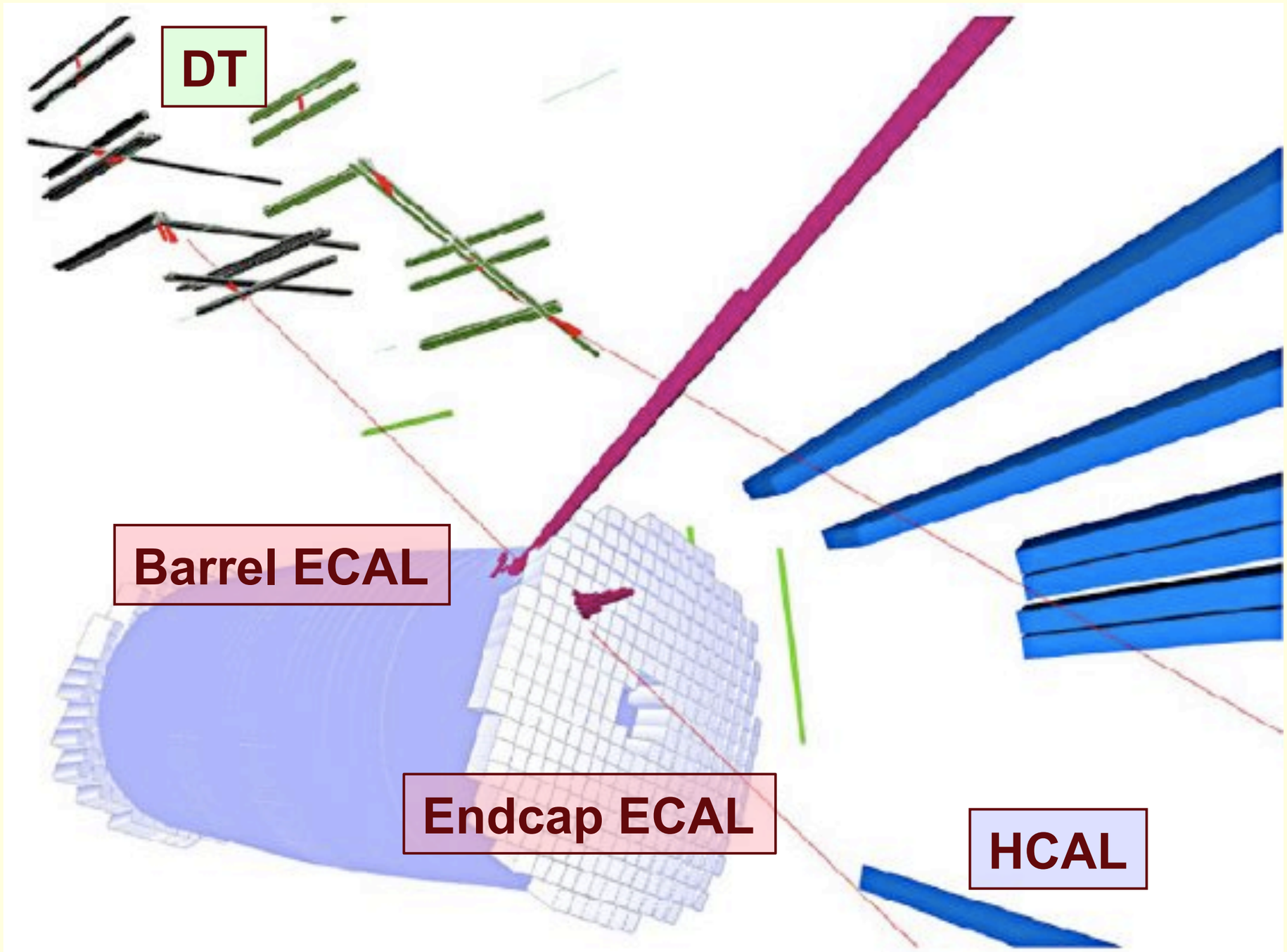


μ trigger: 288GeV cluster!

- **e/γ trigger tested by triggering on m.i.p. signal**
- **synchronized to muon & HCAL triggers**

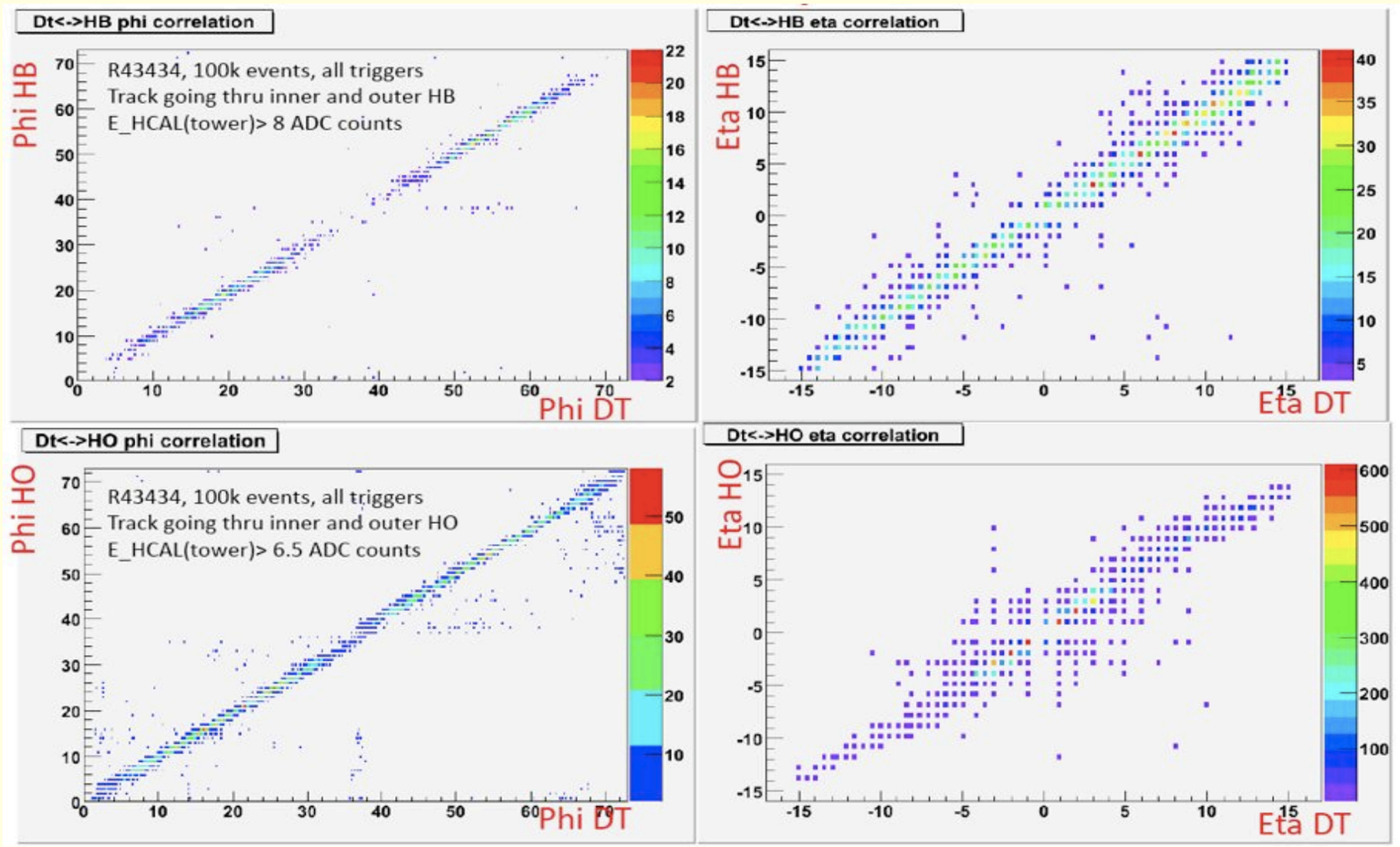
Endcap ECAL

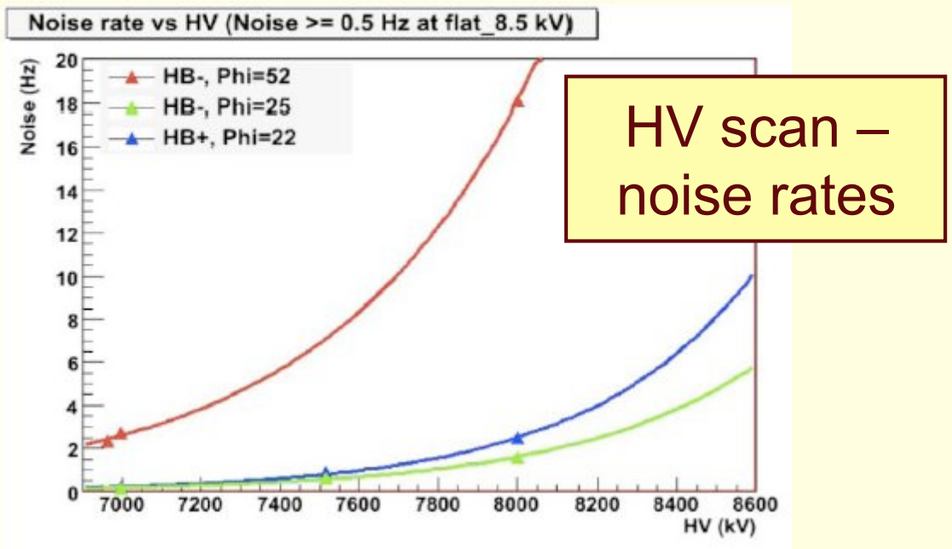
End of Aug08 – Endcap ECAL part of Global Runs



HCAL

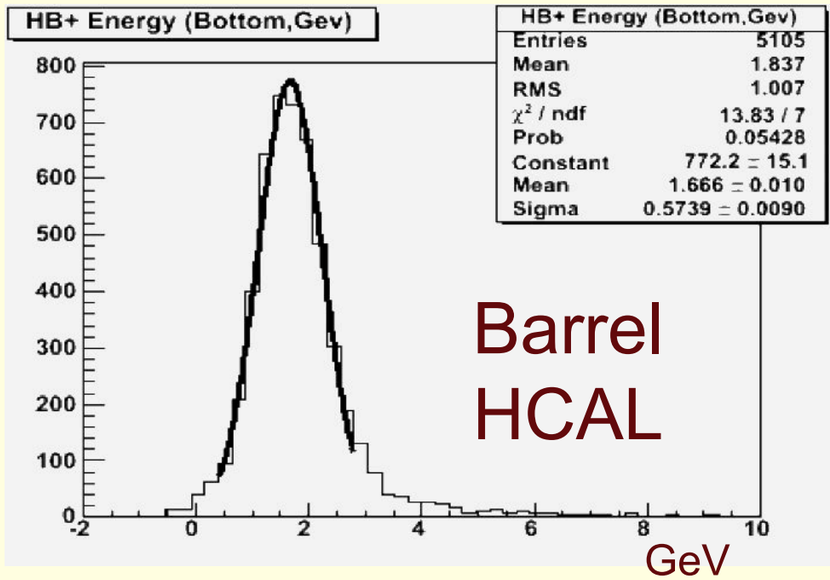
DT vs HB/HO correlations (muon tracks)





HV scan – noise rates

Response to cosmic rays

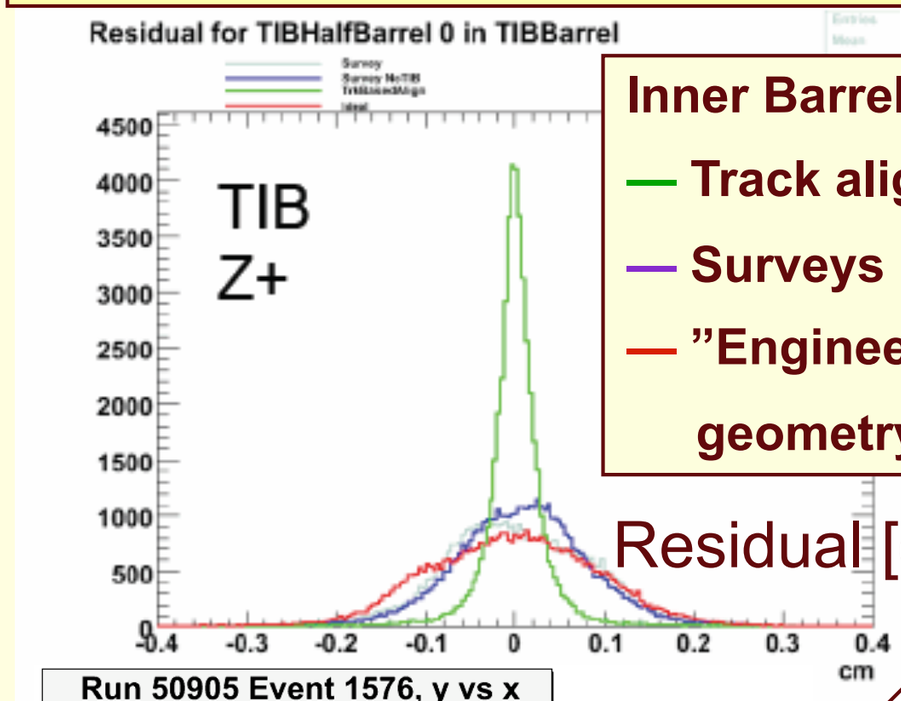


Barrel HCAL

- **Cosmic trigger from coincidence of m.i.p. signals in top and bottom part of HB (synchronized to muon triggers)**
- **HF trigger tested in time before LHC startup**

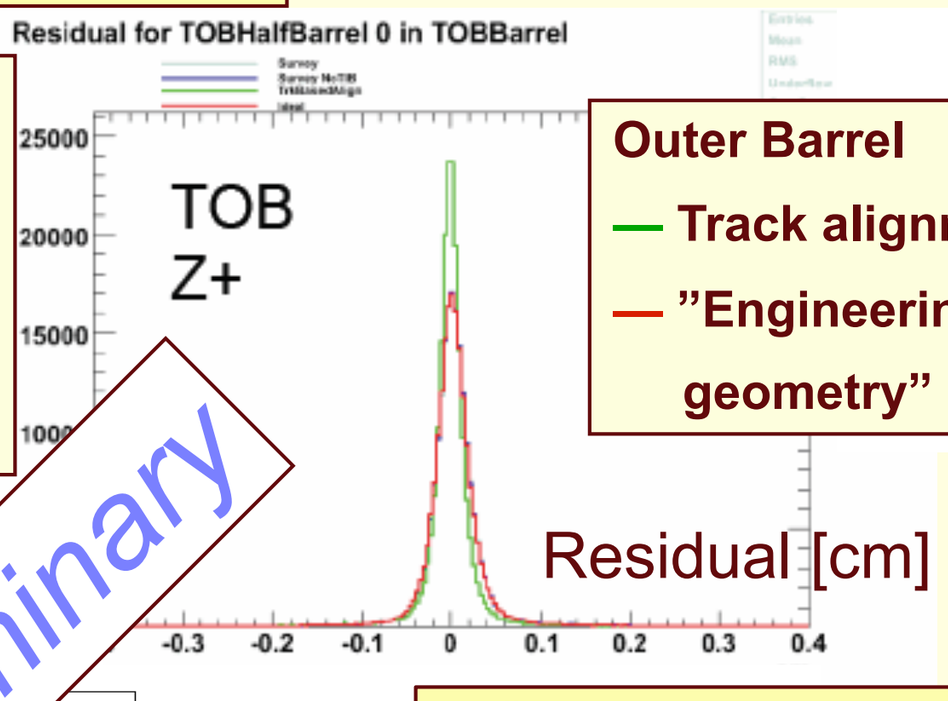
Tracker

Tracker alignment study from July run



Inner Barrel

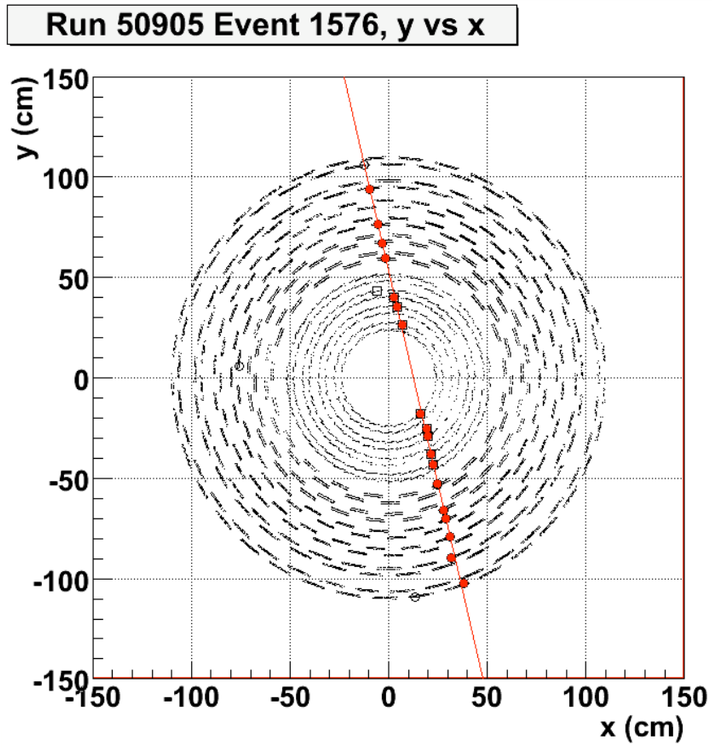
- Track alignment
- Surveys
- "Engineering geometry"

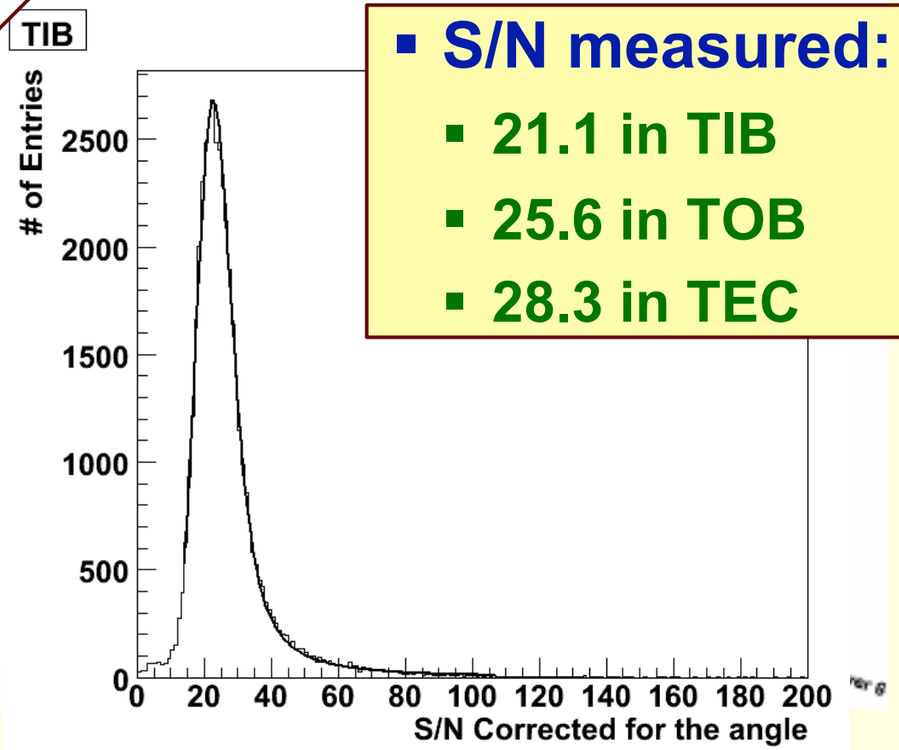


Outer Barrel

- Track alignment
- "Engineering geometry"

Preliminary

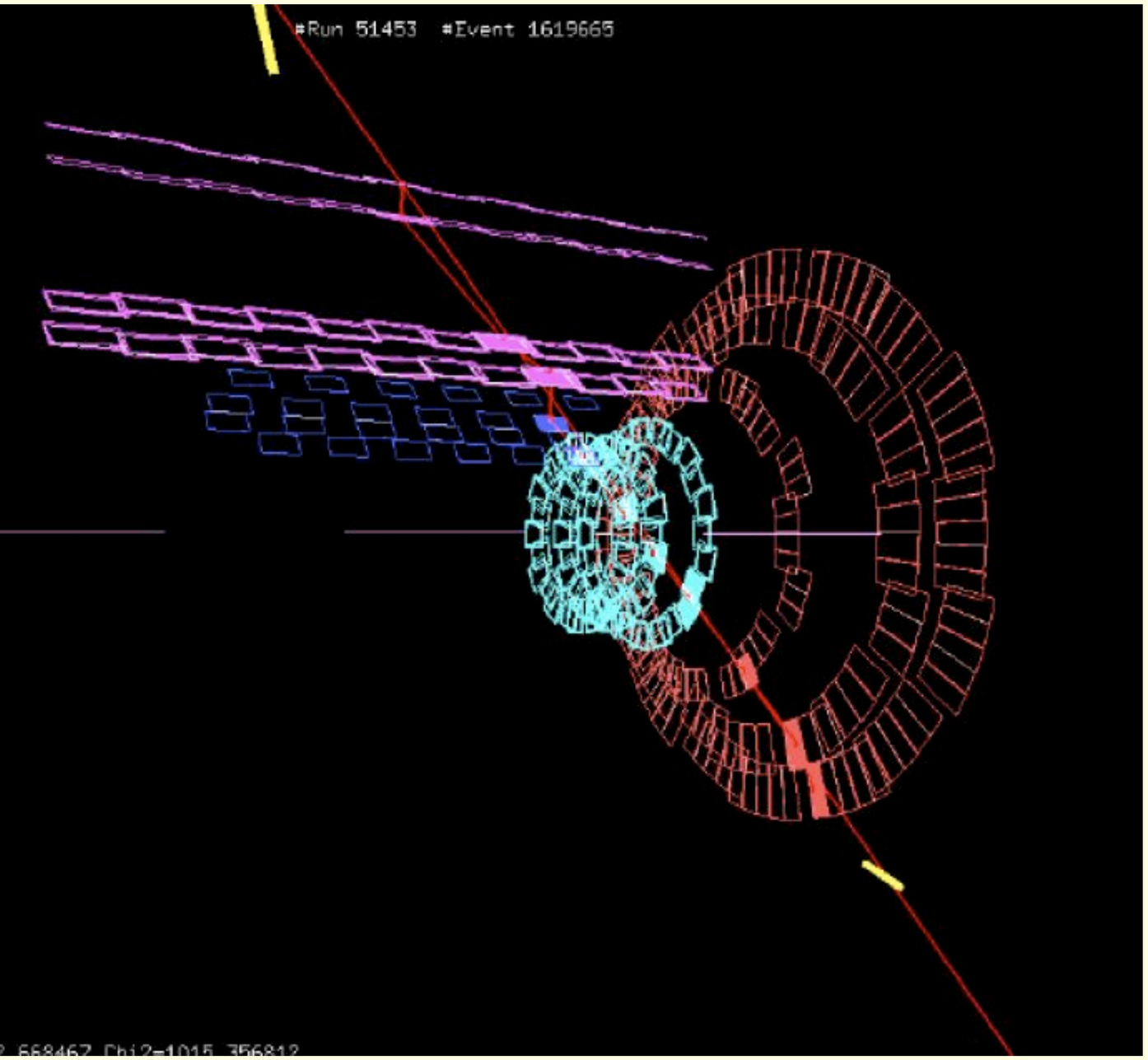




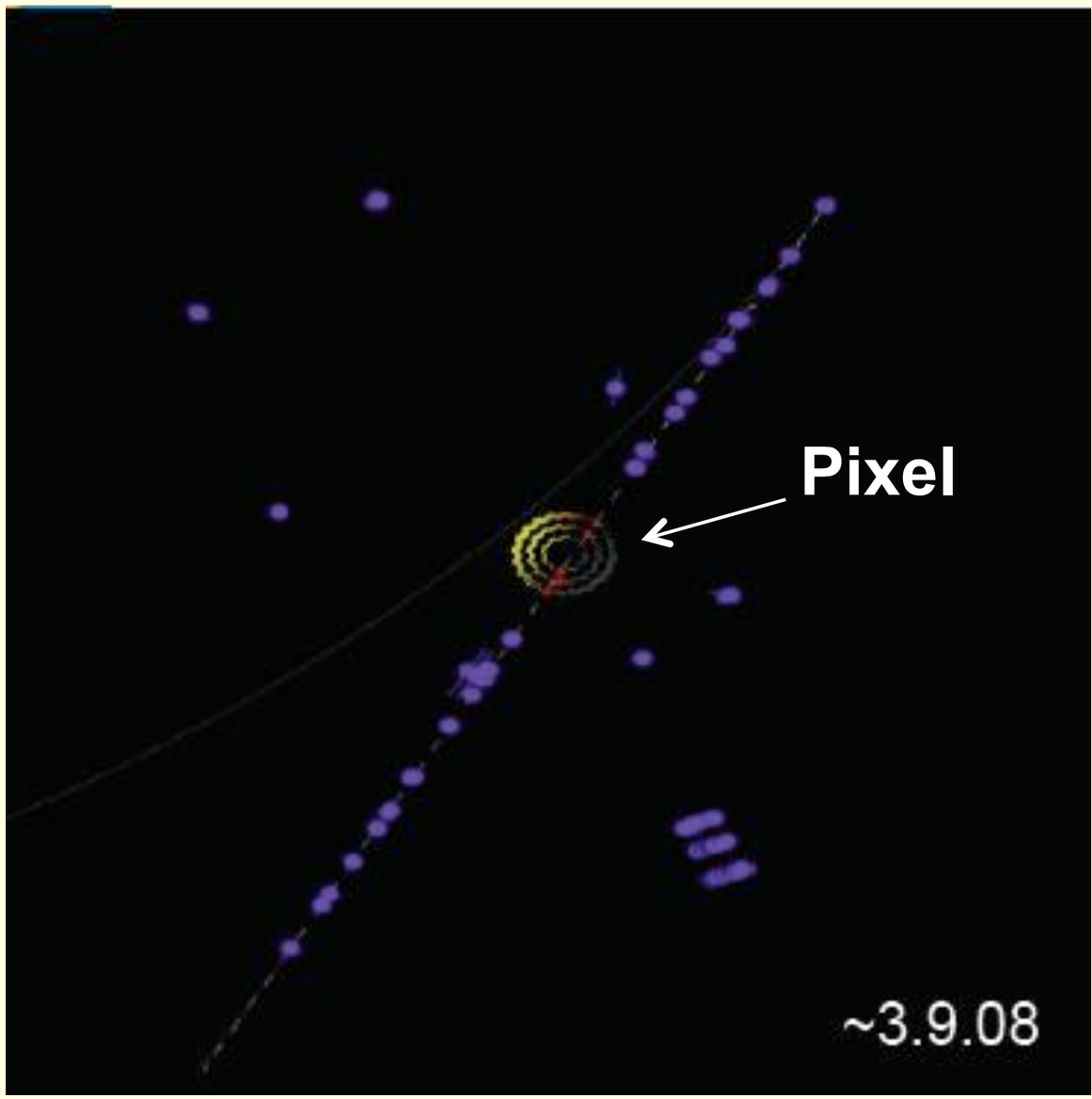
- **S/N measured:**
  - 21.1 in TIB
  - 25.6 in TOB
  - 28.3 in TEC

Tracker/Pixel

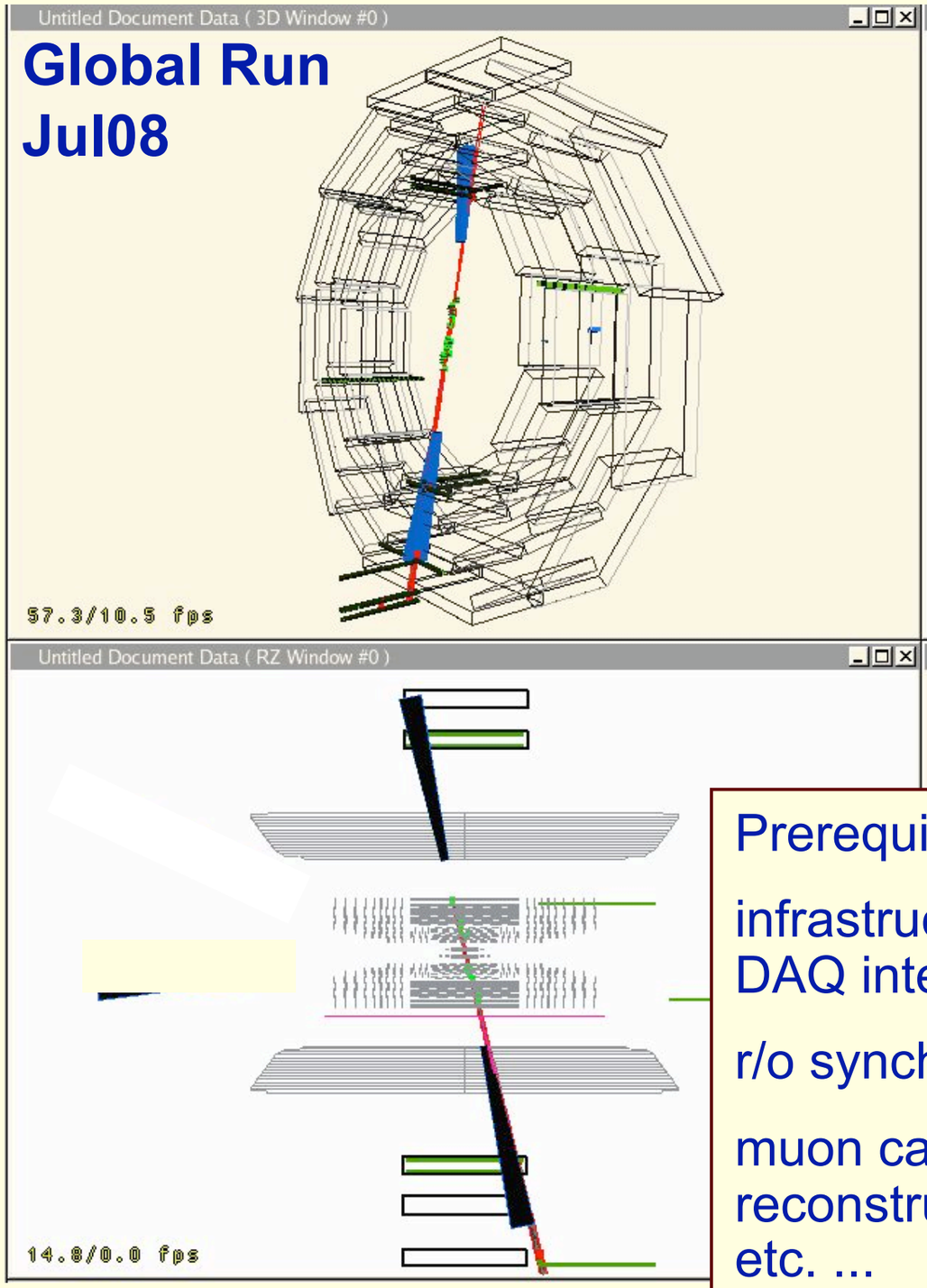
Aug08: all parts of Tracker integrated

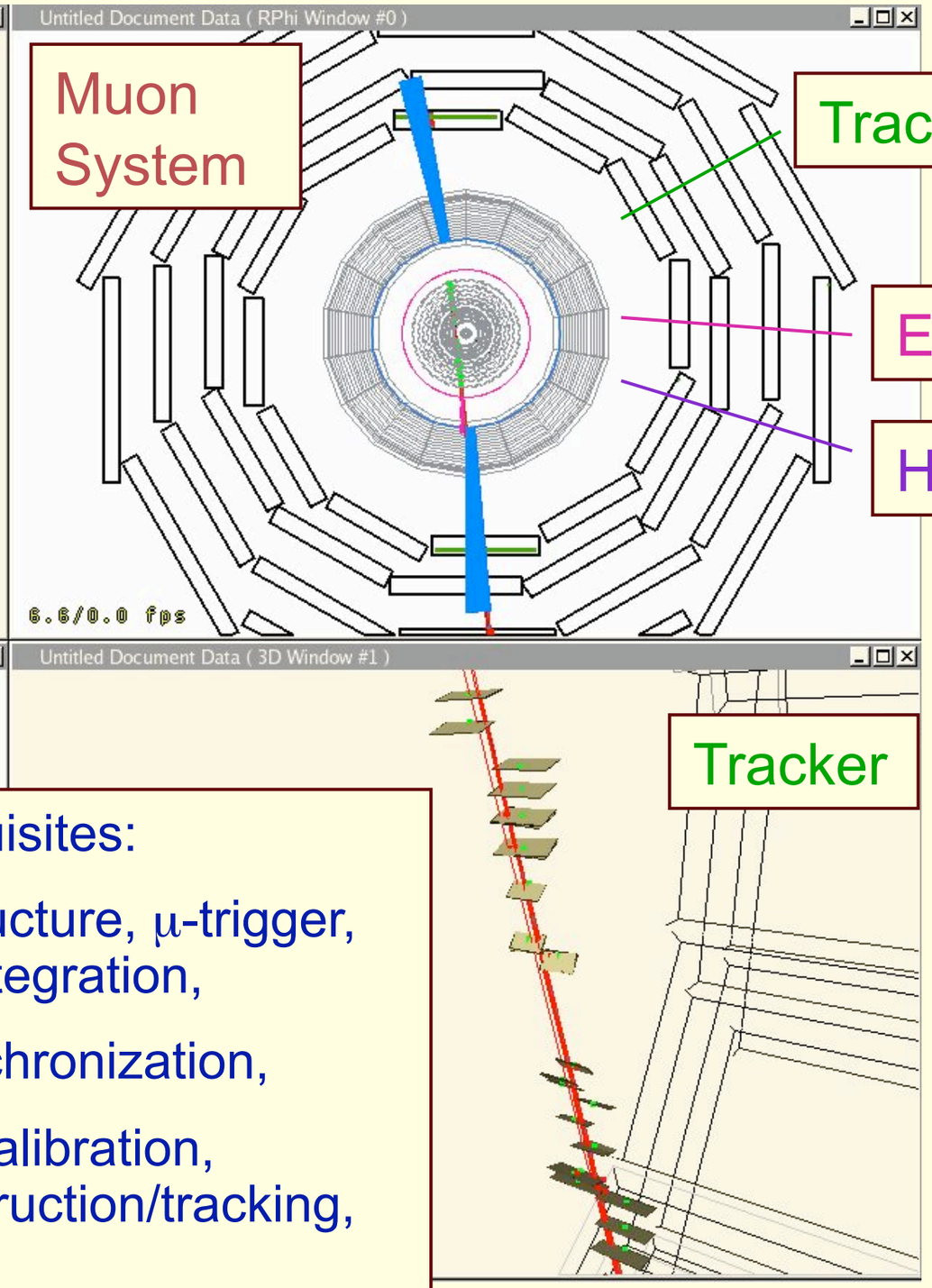


First cosmic tracks with Pixels



Global Tracks: Tracker + Drift Tubes





Prerequisites:

infrastructure, μ-trigger, DAQ integration,

r/o synchronization,

muon calibration, reconstruction/tracking, etc. ...

Computing and Software Challenges

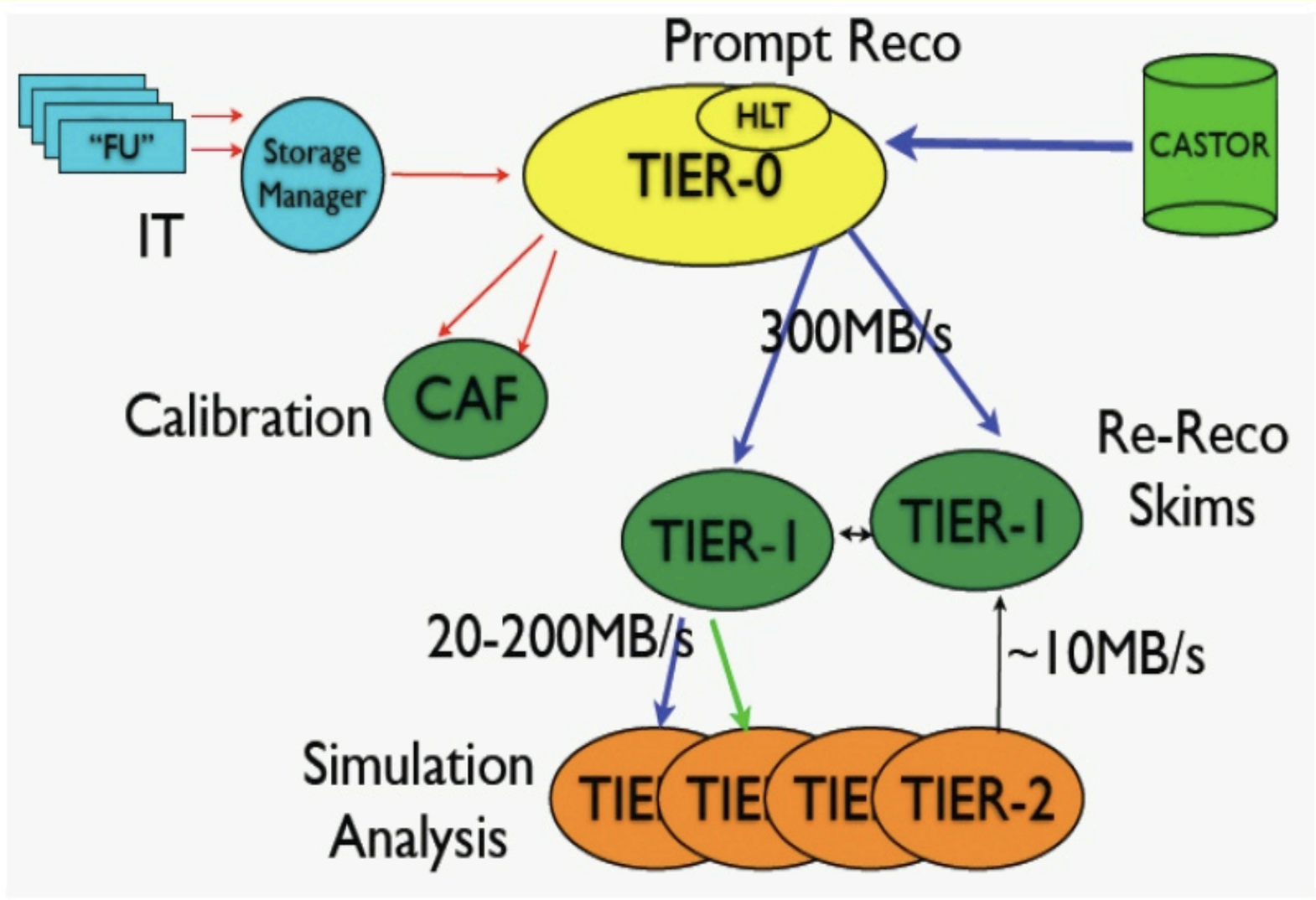
- **Test preparedness to deal with LHC data taking and analysis workflow**
- **Full fledge exercise carried out in May 2008 using simulated data**

Computing challenge:

Data transfer, reconstruction concurrent with other LHC experiments to test GRID

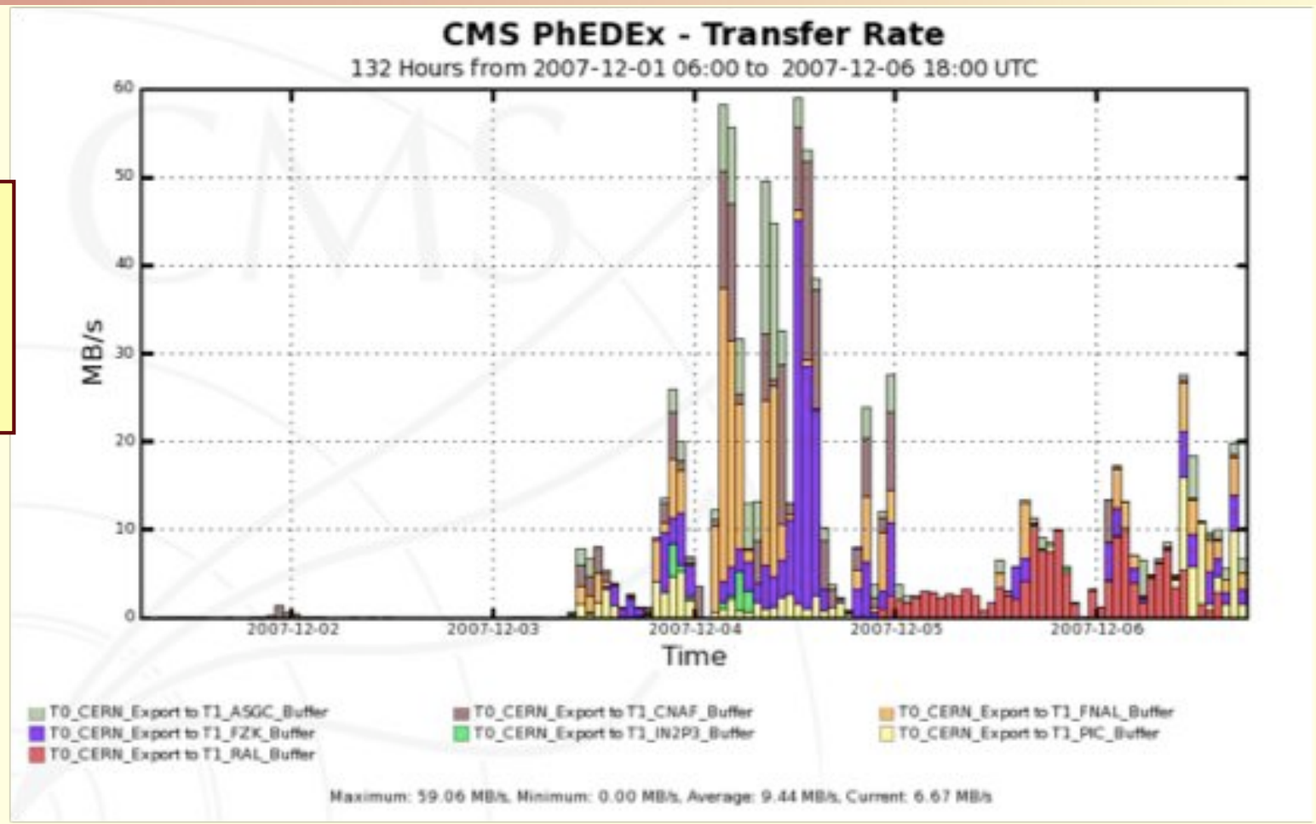
At the same time:

- Complete & deploy physics analysis tools
- Vertical integration from Detector Performance Groups to final physics plots
- Commission "physics analysis paths" from Tier-0 to Tier-1 & Tier-2
- Perform analysis as if it was real data flow



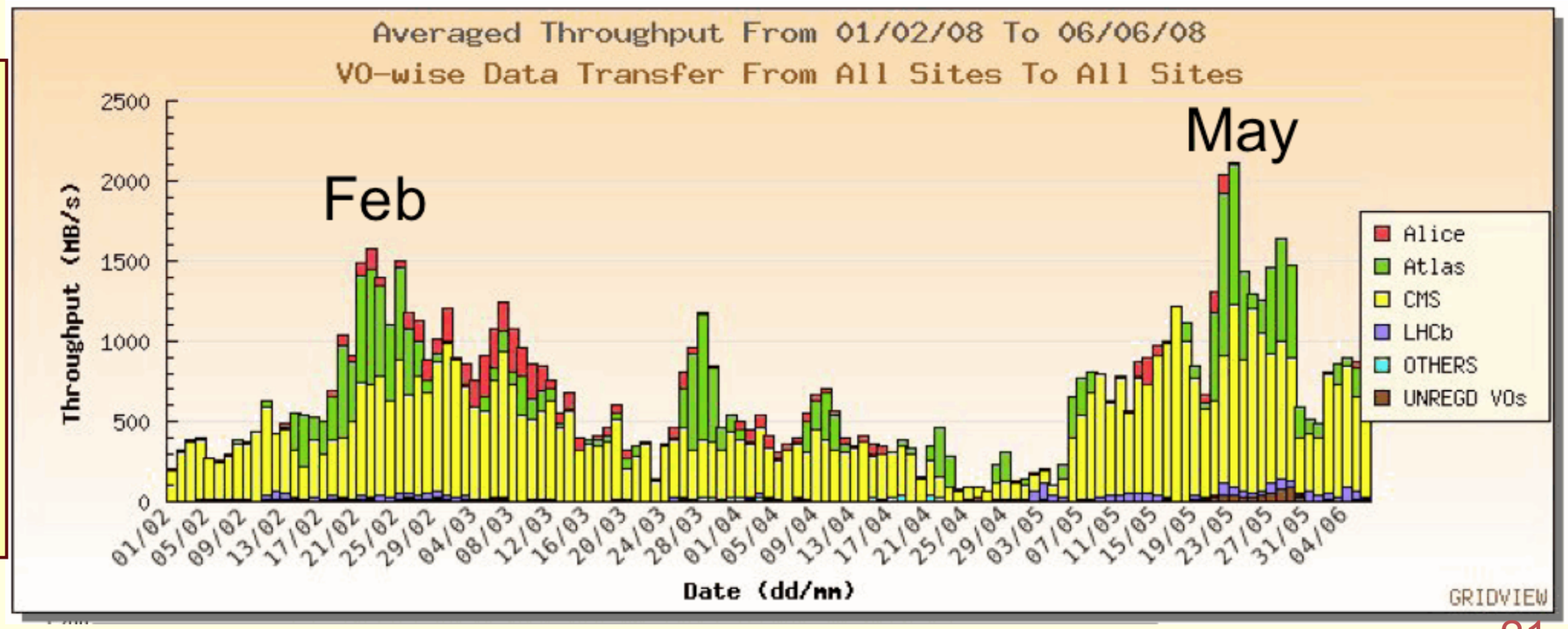
Computing and Software Challenges

Transfer rates during
Global Commissioning Runs
(different colors – different Tier 1's)



Transfer rates during
a CERN wide
Computing Challenge
(different colors – different experiments)

CMS exceeded the target export rate of 600 MB/s



CSA08

Computing, Software and Analysis Challenge

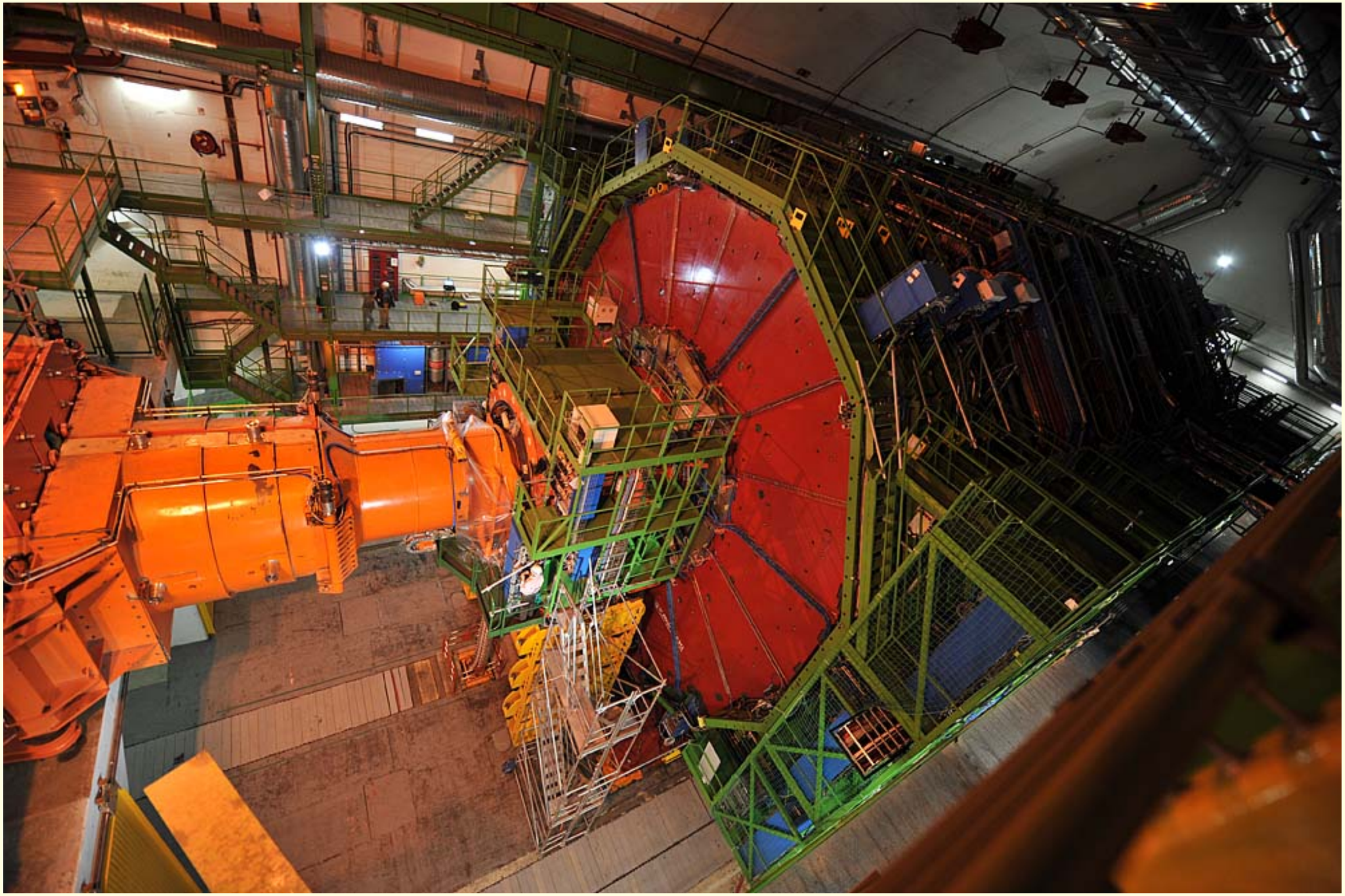
Alignment and Calibration tasks during CSA08:

- **ECAL Calibration**
  - ϕ symmetry
  - π^0 calibration
  - $Z \rightarrow ee$
- **HCAL Calibration**
  - ϕ symmetry with noise subtraction
  - Isolated-track calibration
  - Di-jet balancing ($\rightarrow$ flat response in η)
  - HO ("Outer HCAL") calibration for muons
- **Muon Calibration**
  - T_0 calibration
  - v_{drift} calibration
- **Si-Tracker Calibration**
  - Strip *dE/dx*
  - Strip Lorentz angle calib.
  - Pixel Lorentz angle calib.
- **Tracker Alignment**
  - Various tracking algorithms
    - on min-bias, muons p_T>5 GeV & 11 GeV, cosmics, di-muons
- **Muon System Alignment**
  - Global tracks
  - Muon-system standalone

Multiple samples: min-bias, noise, QCD jets, cosmics, J/ψ, Z, ...

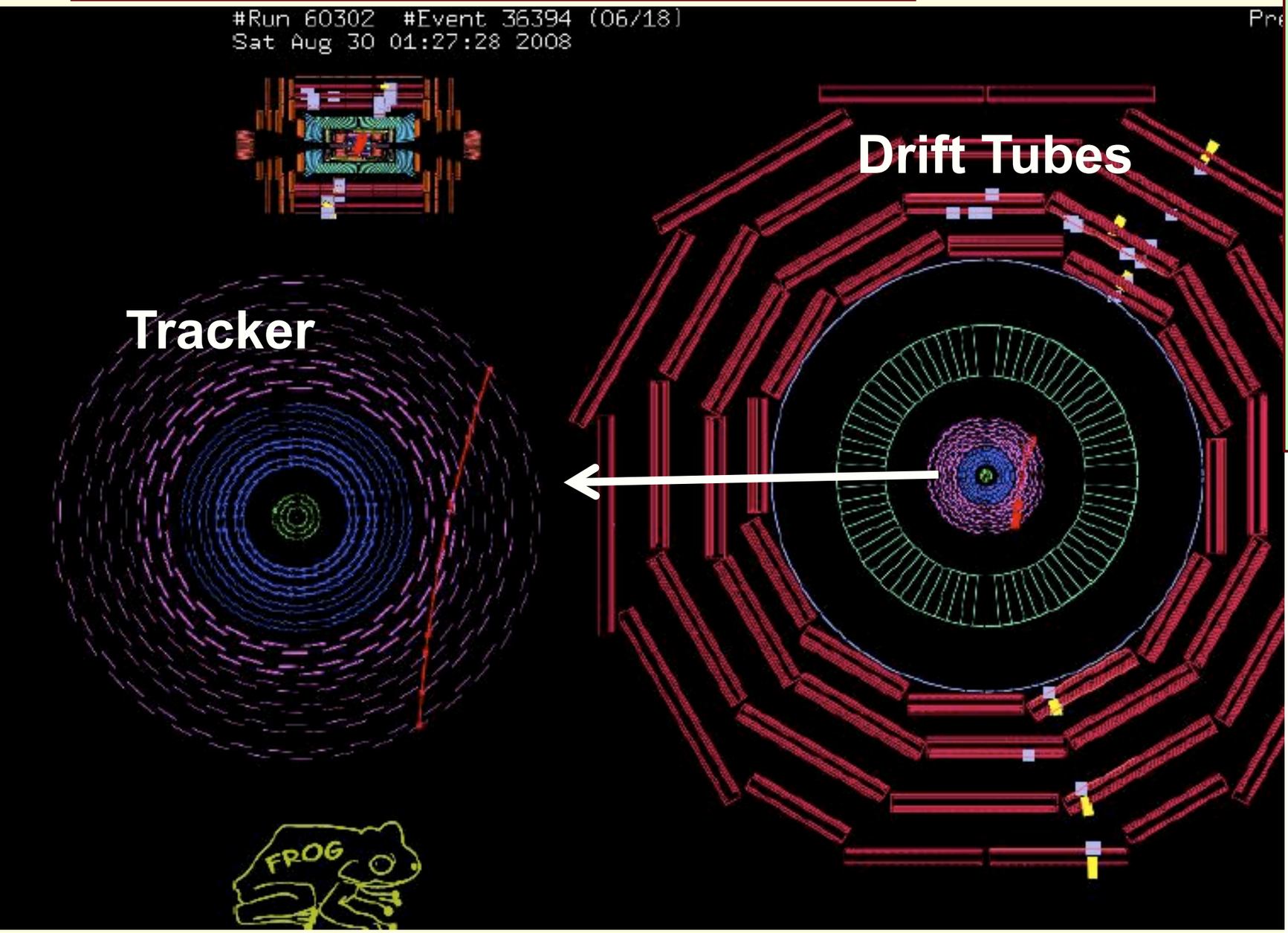
2 Scenarios: 1 pb^{-1} and 10 pb^{-1}

Final Closure

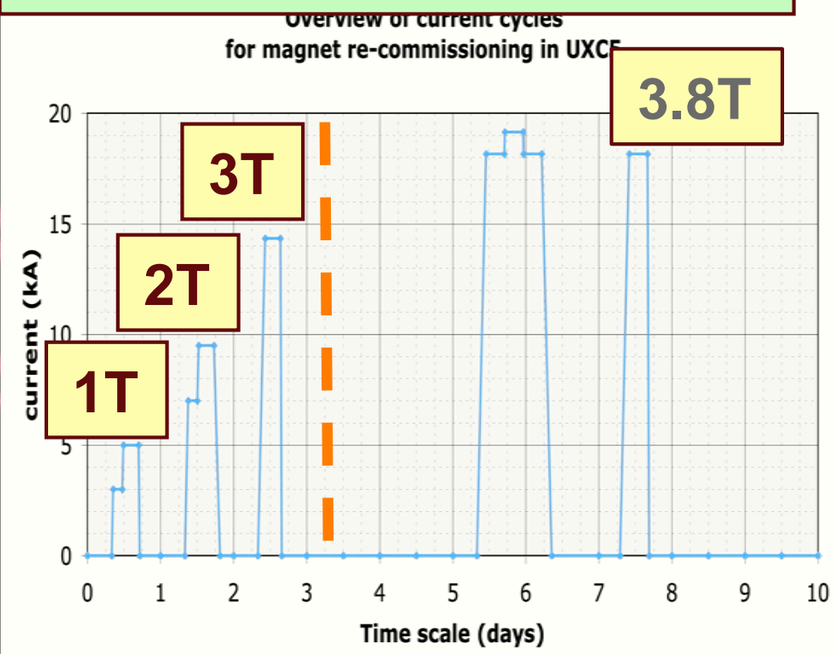


Underground Magnet Test

Event display from Magnet Test

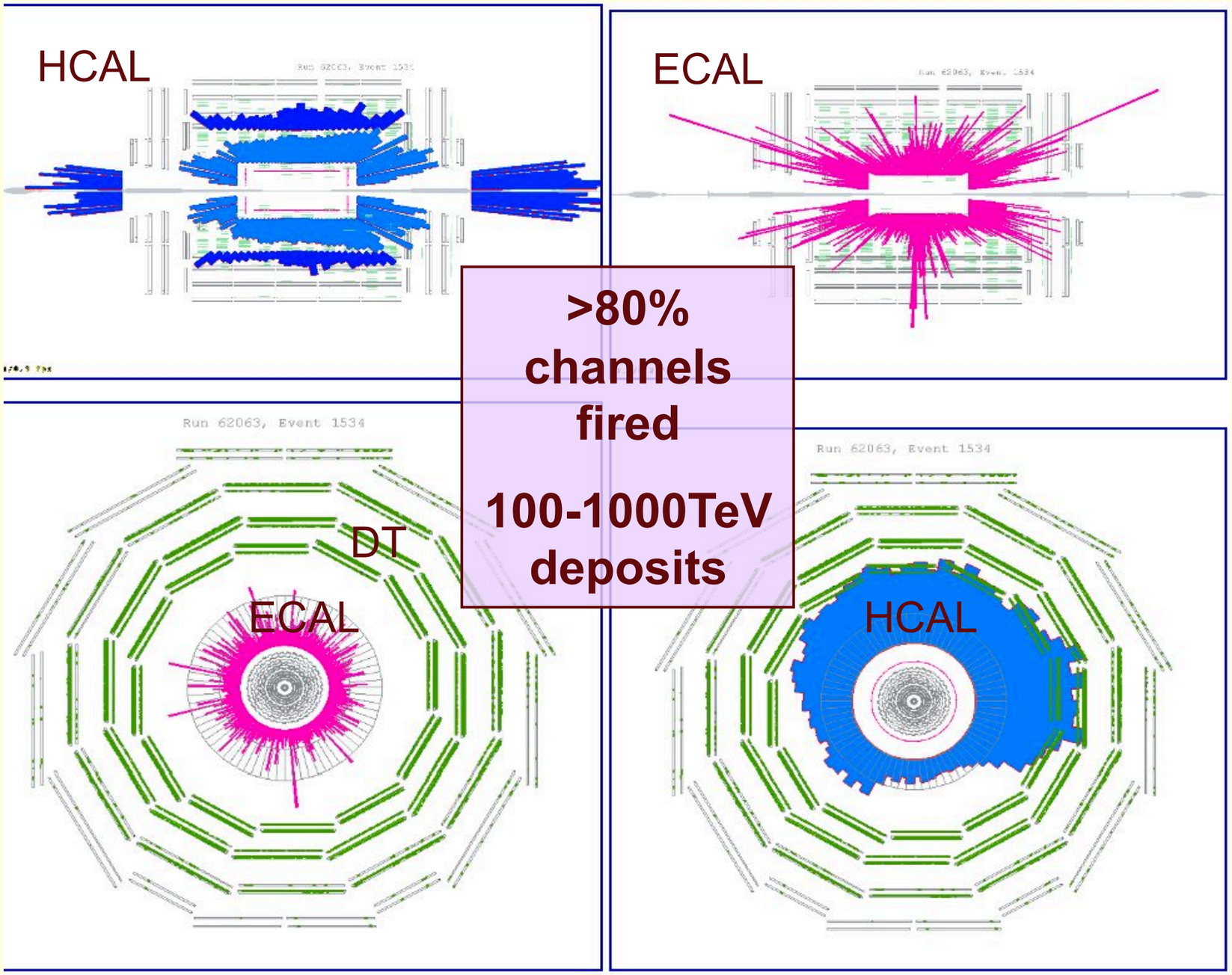


- **Magnet test interrupted due to beam operations**
- **Reached 3T – no effects in HCAL**
- **Unforeseen fringe field effects on surrounding mechanics – being addressed**



First beam: splash events

Beam shots (~2x10^9 p) on collimator ~150 m from detector

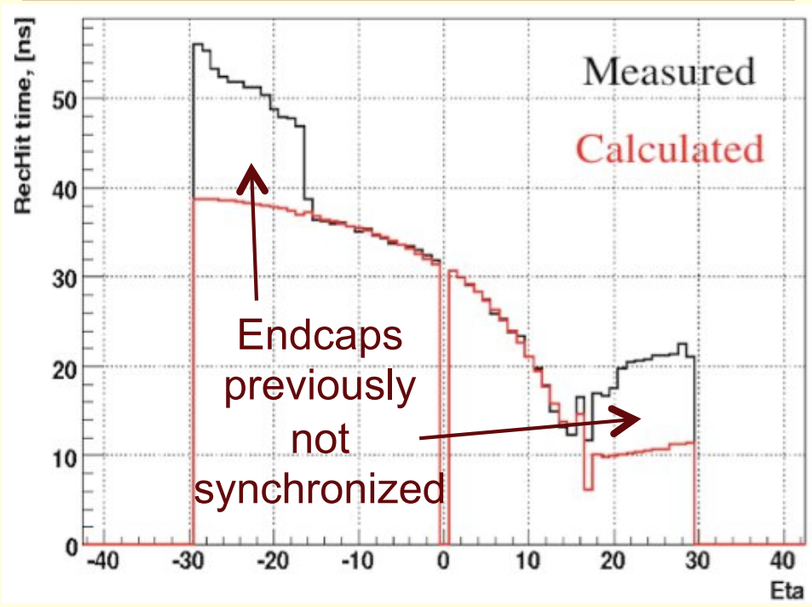


>80% channels fired

100-1000TeV deposits

Beam triggers (BPTX, BSC) correctly timed in to CSC and HF triggers

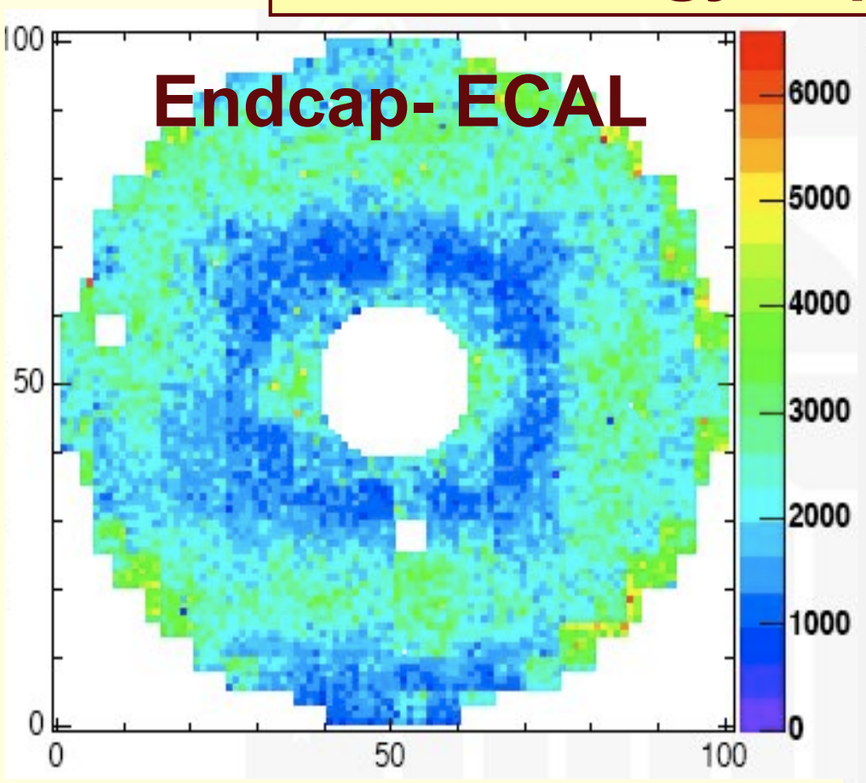
Example of synchronization of HCAL

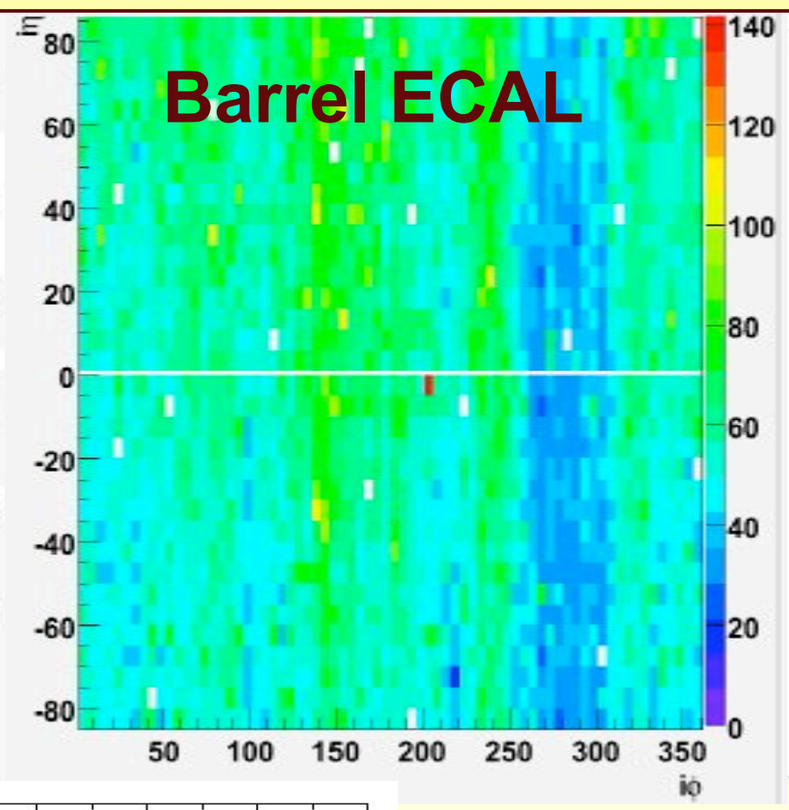


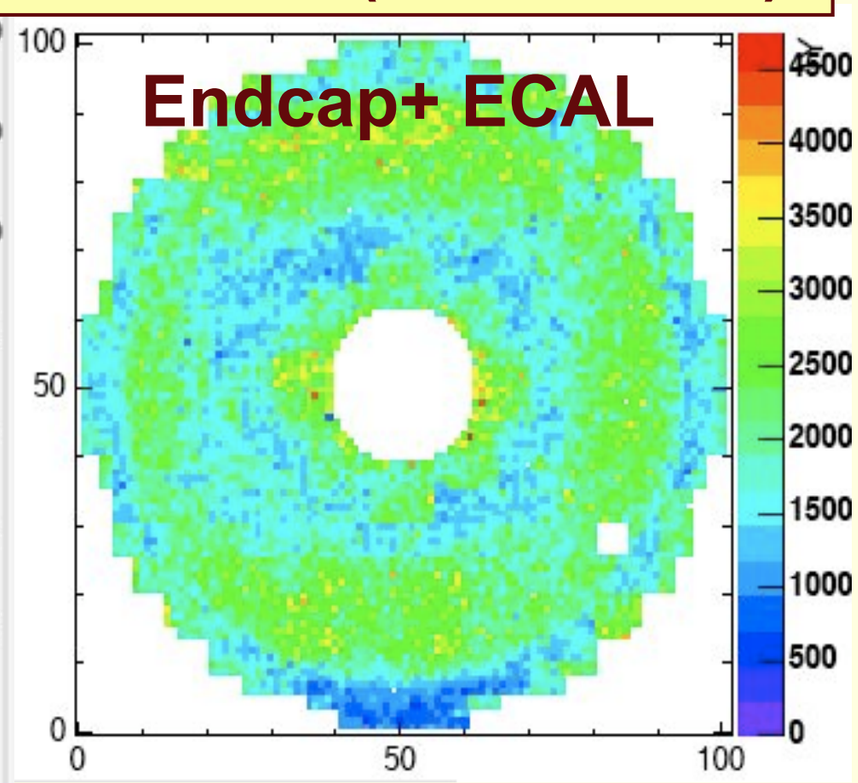
First beam: splash events

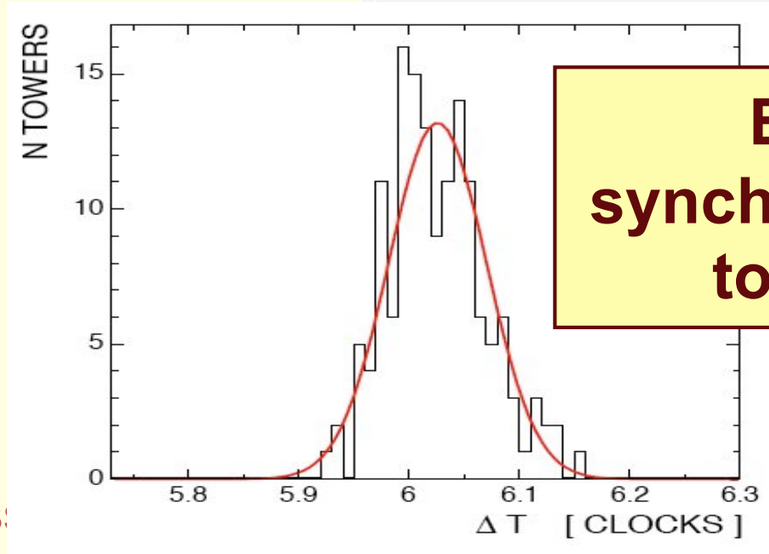
ECAL - use splash events to study occupancy, synchronization and bad channels

ECAL energy deposits in splash events – beam 1 (from + side)



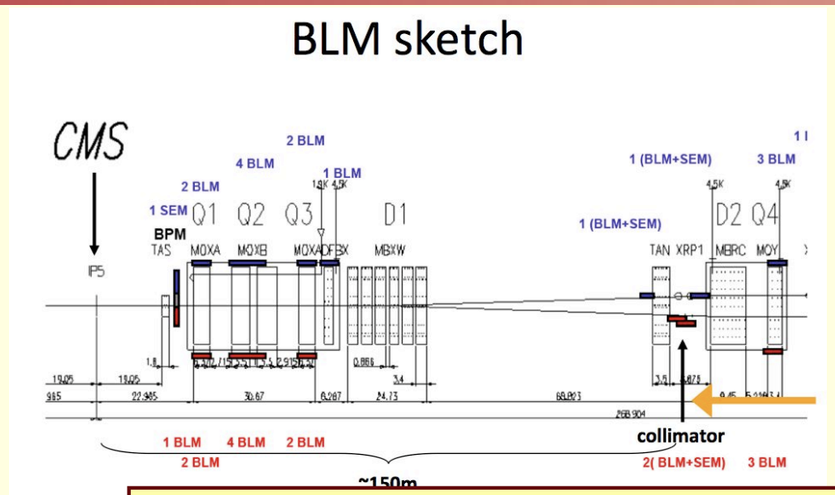






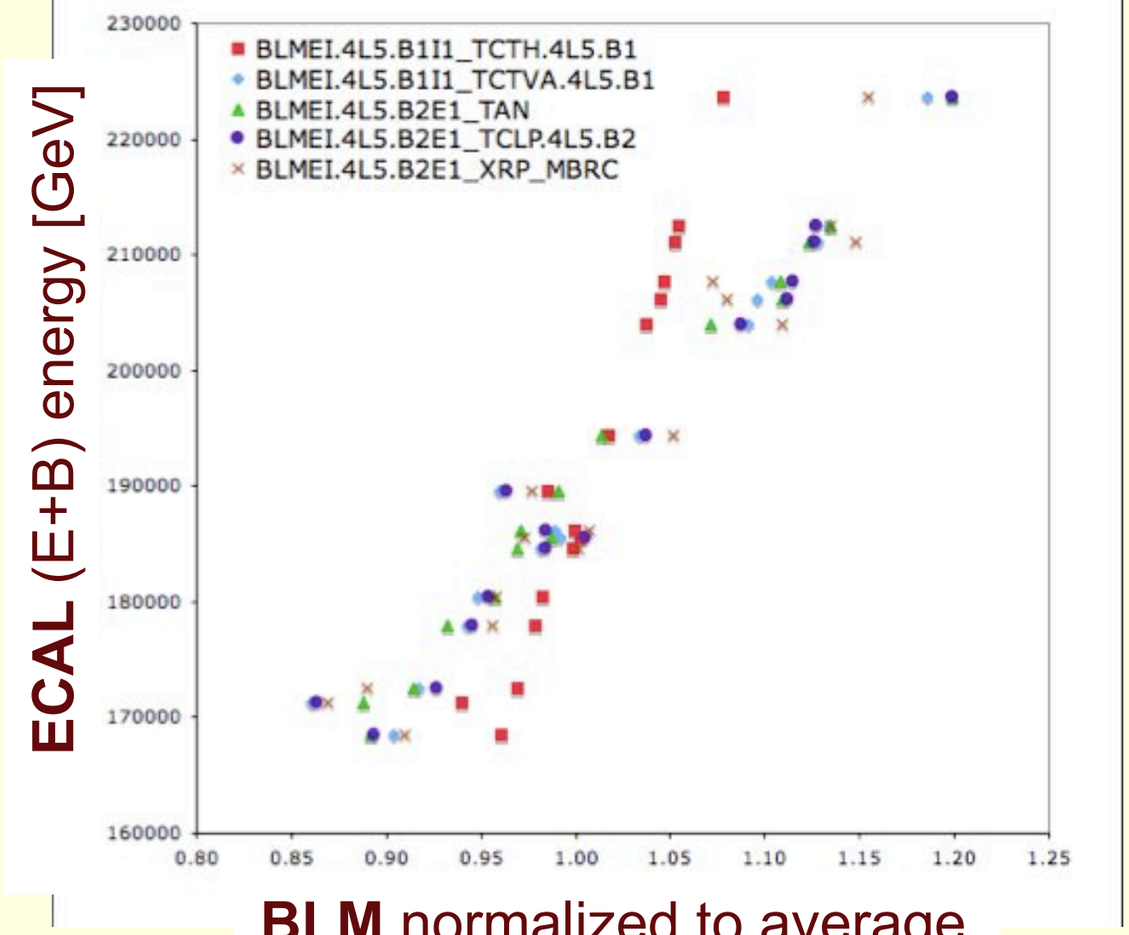
ECAL synchronization to ≤ 2 ns

First beam: splash events

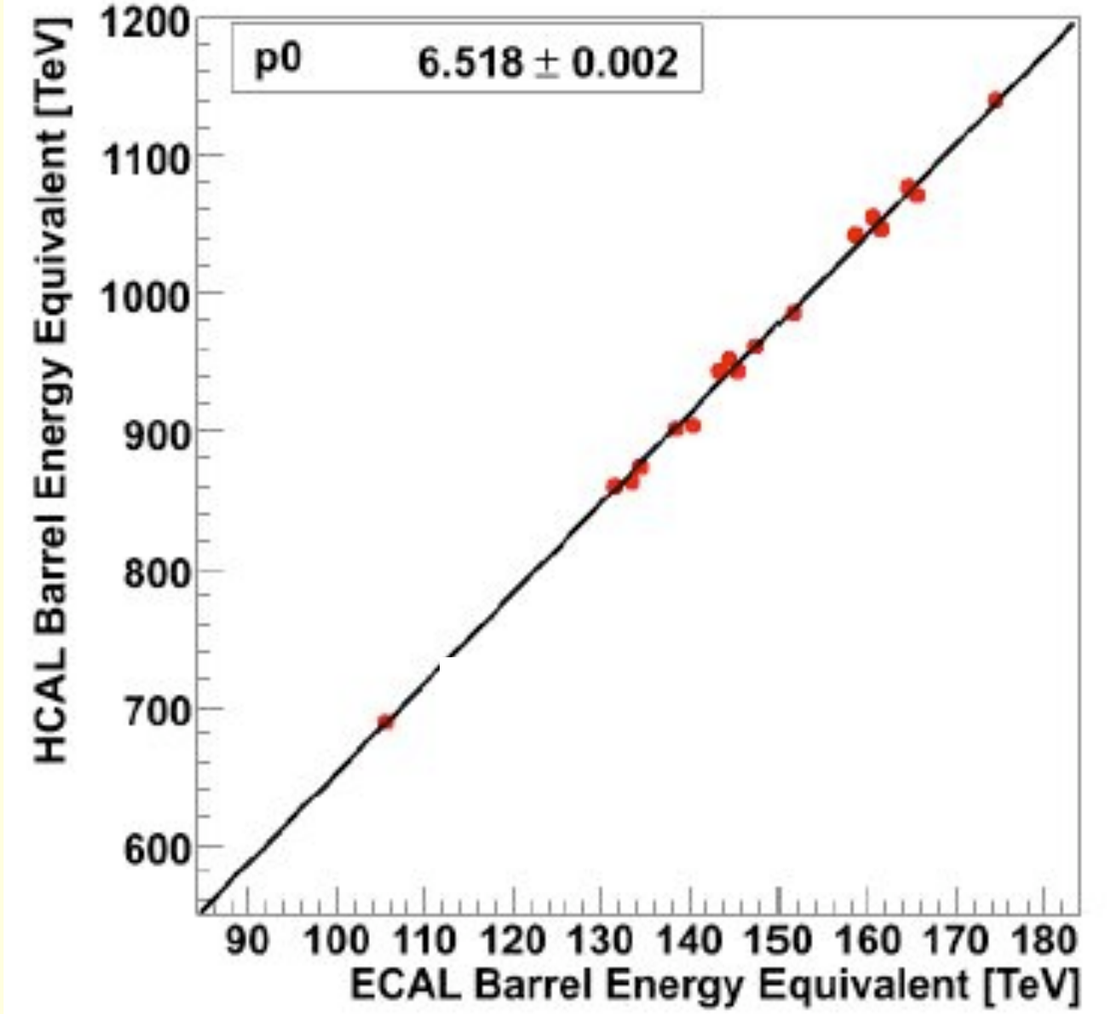


Correlation between signal in Beam Loss Monitors (BLM) and energy deposits in ECAL and HCAL from first collimator shot session

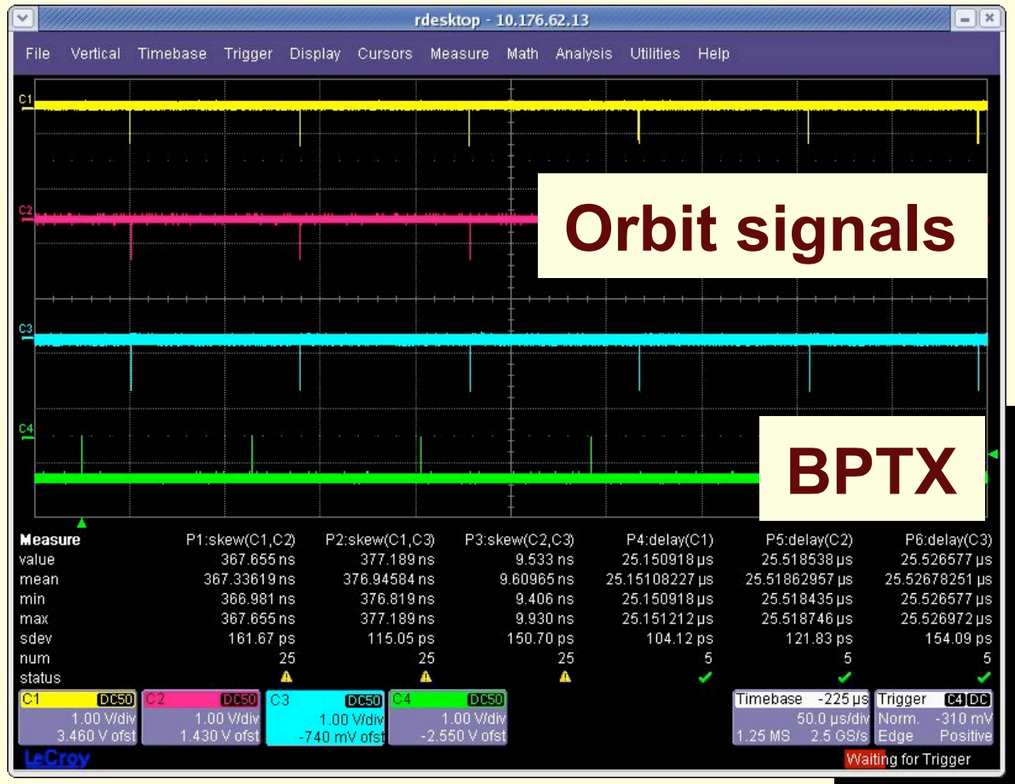
ECAL – BLM correlation



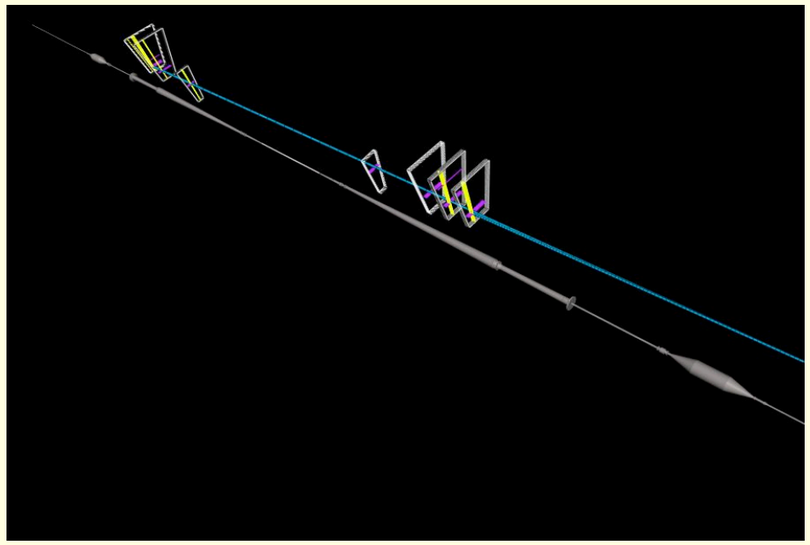
HCAL – ECAL correlation

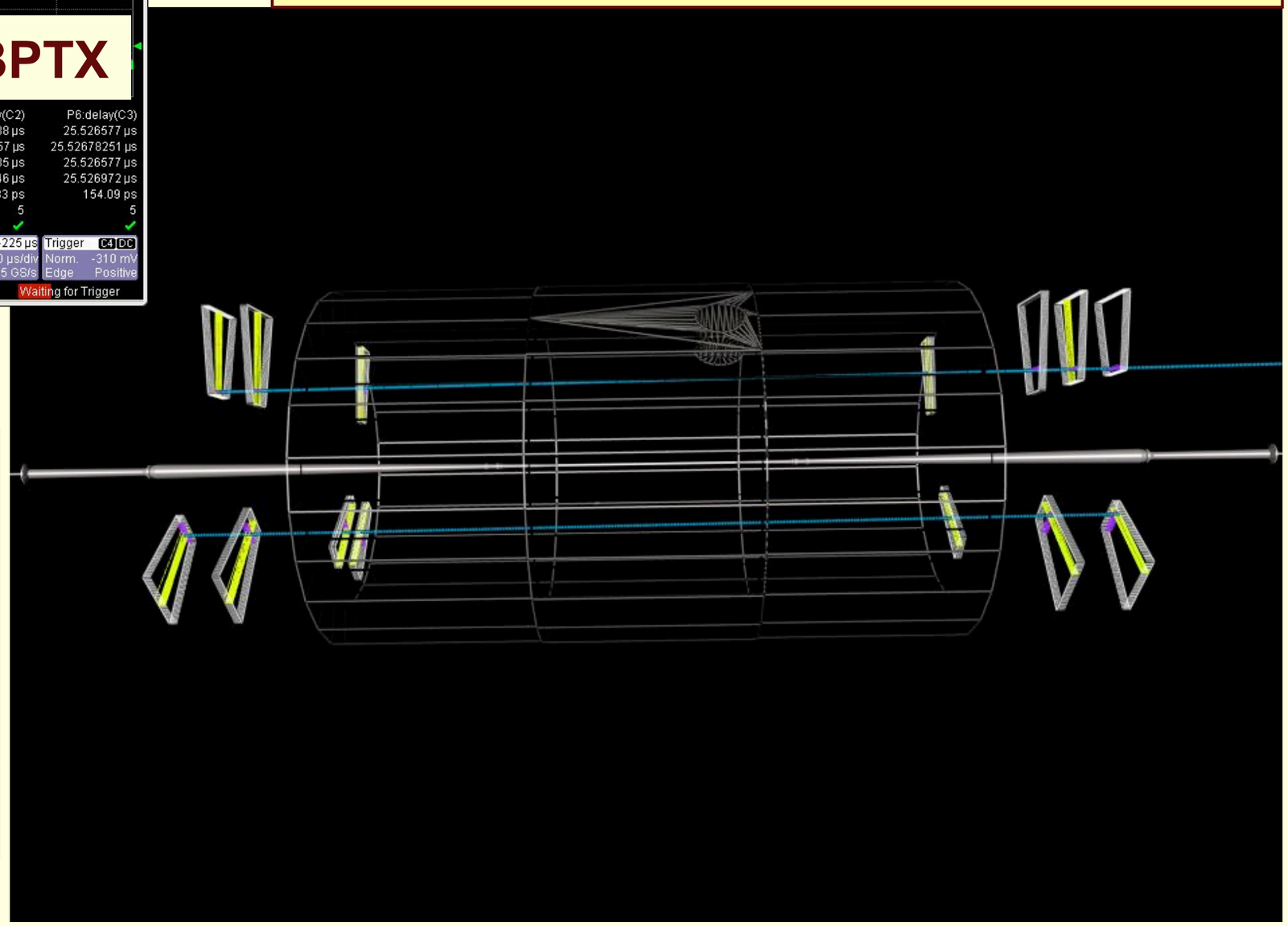


First orbiting beam



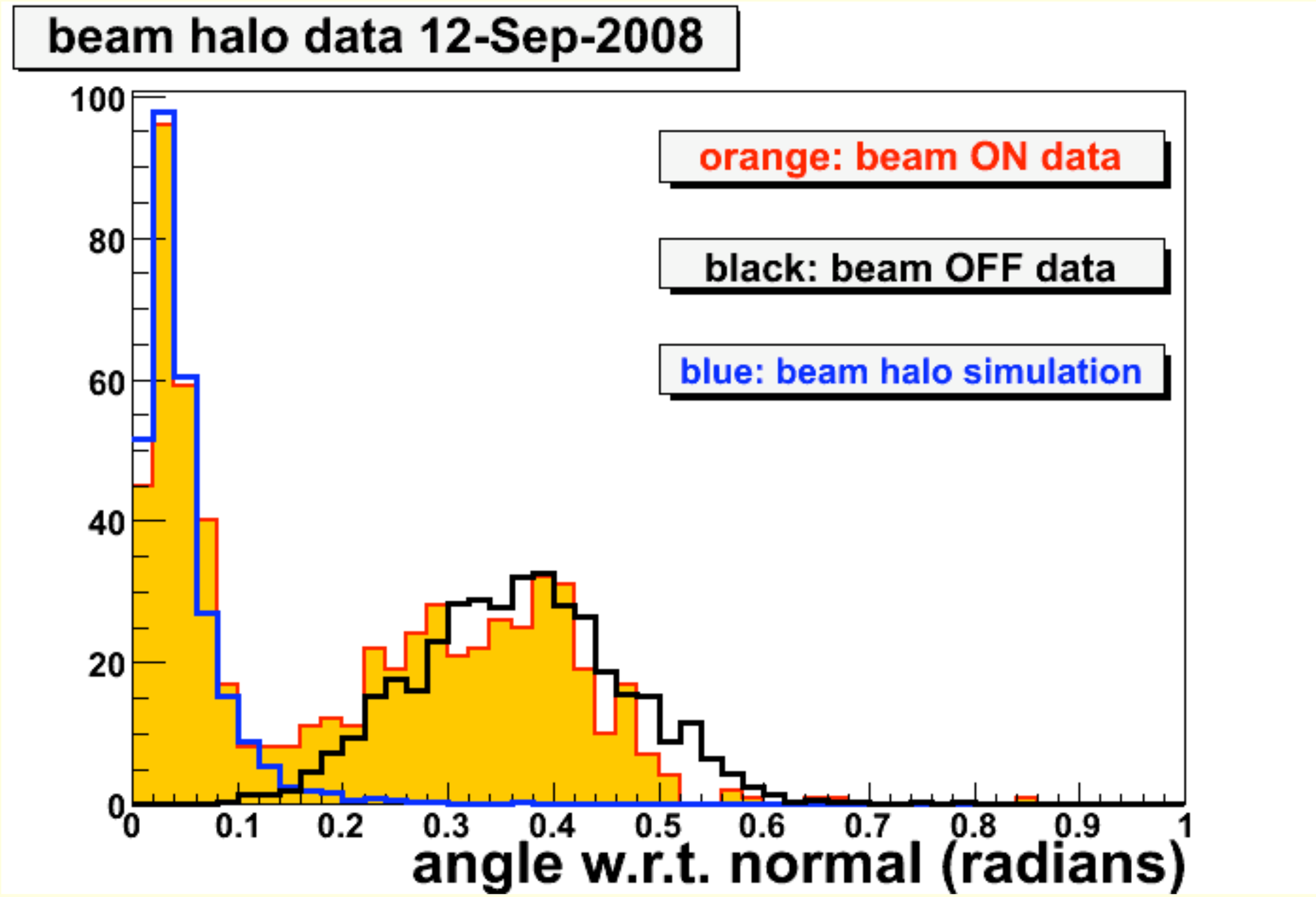
Examples of beam halo events detected by endcap muon chambers (CSC)





RF captured beam

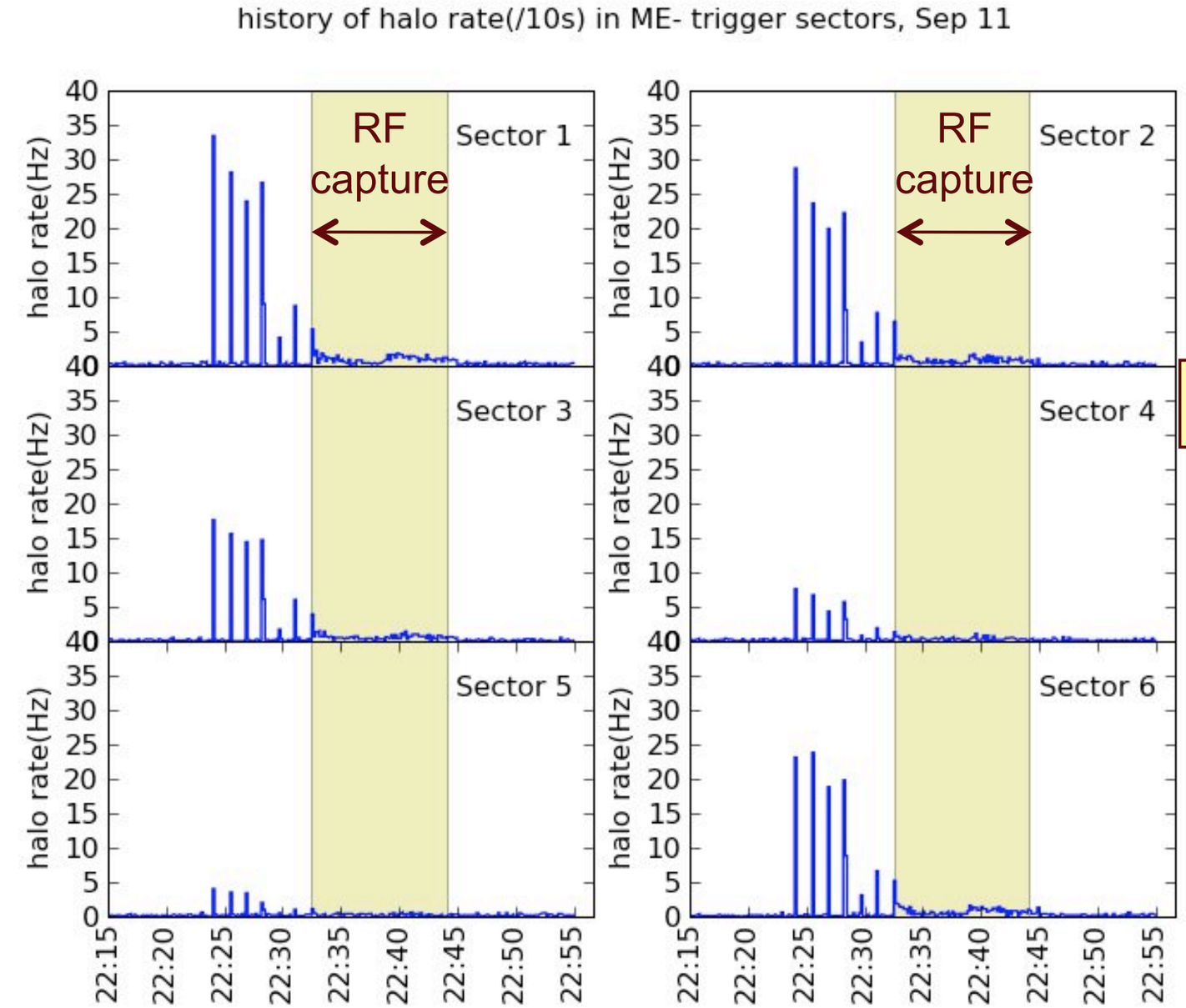
Comparison of CSC beam data with cosmic and halo MC

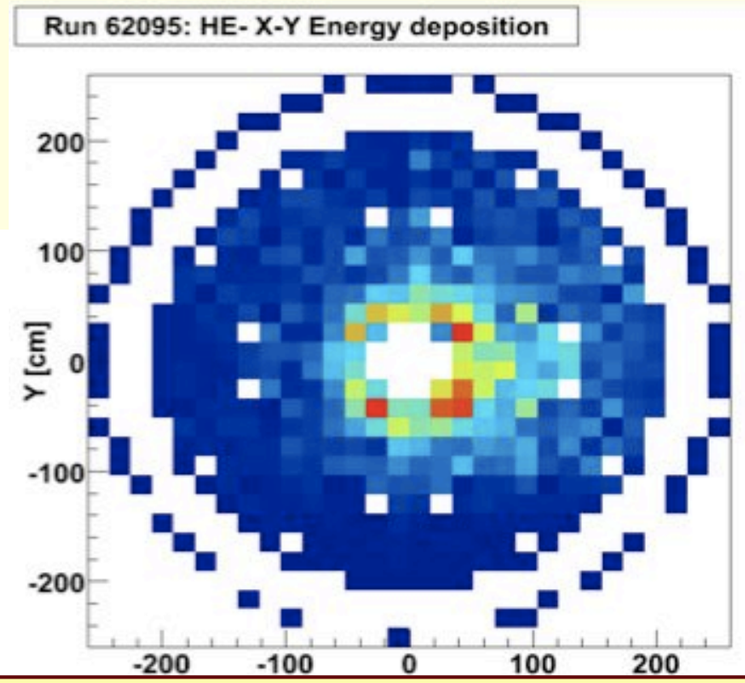


RF captured beam

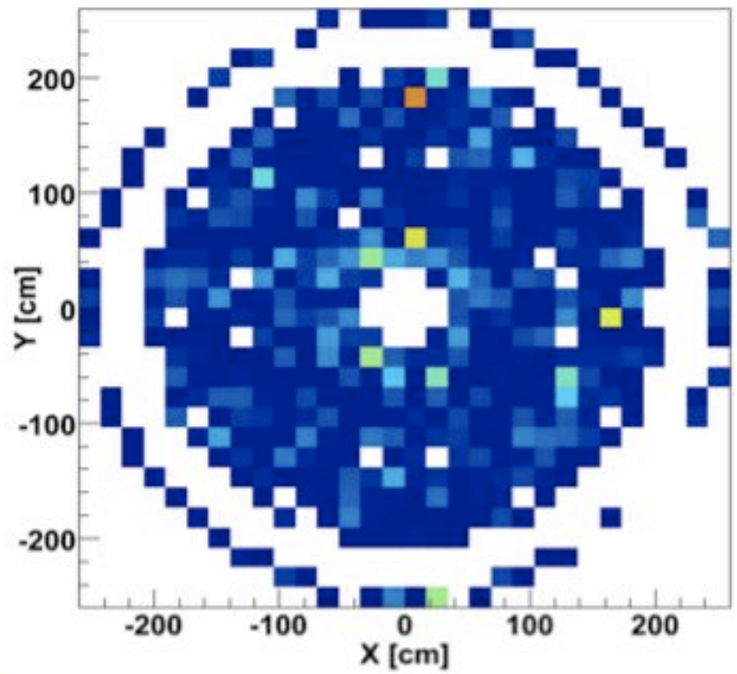
Studies of cleanness of captured beam

CSC halo trigger rates vs. time





HCAL endcap energy deposits



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 shown to work on surface**
  - **Underground magnet commissioning to be finished in next weeks**
- **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**
- **Efforts concentrate now to achieve smoother, more automatic operation and consolidate monitoring and workflows**