CMS HCAL
from commissioning stage to physics

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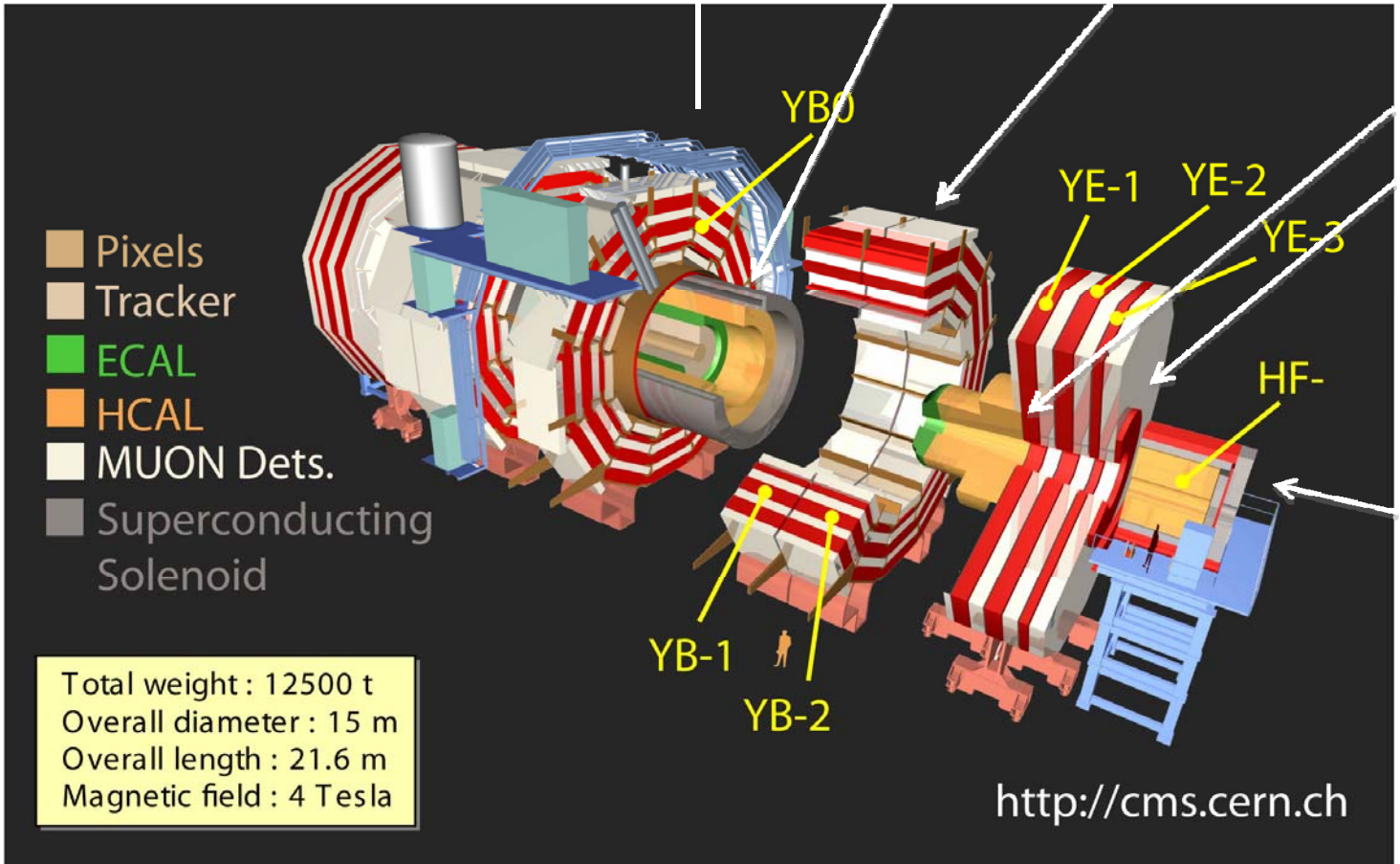
on behalf of HCAL

CALOR 2008
Pavia, Italy,
May 29, 2008

CMS Detector



CMS HADRON CALORIMETER (HCAL)

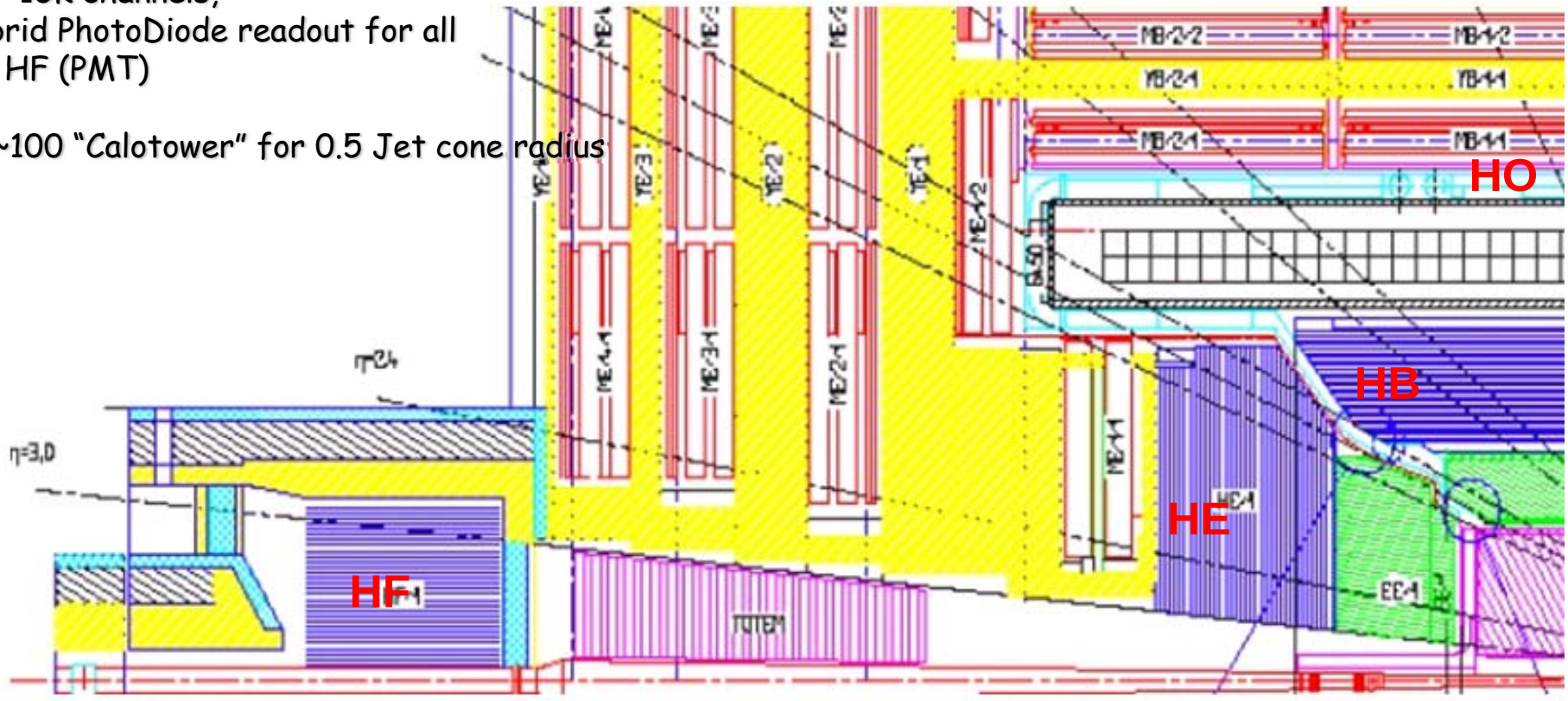
- HCAL Barrel (HB) is 9 meters long, one meter thick and 6 meters in the outer diameter (1.3< |η|) consisting of two half barrels of 18 wedges each made of **brass and scintillator,** with WLS readout.
- The two End Caps (HE) are also made of **brass and scintillator,** with a diameter of 0.8 to 6.0 m.

and a thickness of 1.8 meters.

- HB and HE are inside the 4-tesla solenoid ; **η-φ** segmentation **0.087 × 0.087** (near η = 3.0, doubled.
- The two forward calorimeters (HF) are made of **quarts fibers** imbedded in iron cover 3.0 < η < 5.0.
- Central shower containment in the region |η| < 1.26 is improved with an array of scintillators located outside the magnet in the outer barrel Hadronic calorimeter (HO).
- ~10K channels,

Hybrid PhotoDiode readout for all but HF (PMT)

- ~100 "Calotower" for 0.5 Jet cone radius



CMS Commissioning strategy

on the surface

Before lowering all detectors mounted on the 15 heavy elements were commissioned using

- radioactive sources
- test beams
- cosmic rays

in situ underground cavern

"Global" commissioning runs (using cosmics)

- Inter-synchronize combinations of sub-detectors
- Deploying larger and larger parts of detectors as infrastructure and logistics allow
- Introducing "as-built" and "as-performing" detector into simulations/analysis
- Preparing for 24/7 operation

milestones

- May 5-14, 2008 : Global run with ALL CMS wheels/disks w/o Tracker at zero field for one week. Collected over 30M triggers.
- July 2008: : Global run with ALL CMS wheels/disks with Tracker at zero field for one week. Cosmic run at 4 Tesla, (CMS closed and Field-on)
- HCAL: muons for calibration, muon ID and isolation cut studies, cosmic ray rejection algorithms

HCAL activities 2006-2008

2005/2006:

- Installation and commissioning of hardware and readout electronics on the surface (SX5 assembly hall)
- Initial testing of the HCAL readout with LED and Laser systems
- Relative Calibration of all HCAL towers using radioactive source system
- Participation in MTCC (magnet test and cosmic challenge) data taking

2007

- Lowering of detector elements into underground hall
- Installation of readout and service cables between cavern and underground service cavern
- Establishing power up sequence, timing and calibration procedures

2008

- Full integration of HCAL with CMS system
- Monitoring of HCAL hardware (pedestals, LED)
- Participation in CMS global runs


CMS cavern May 06

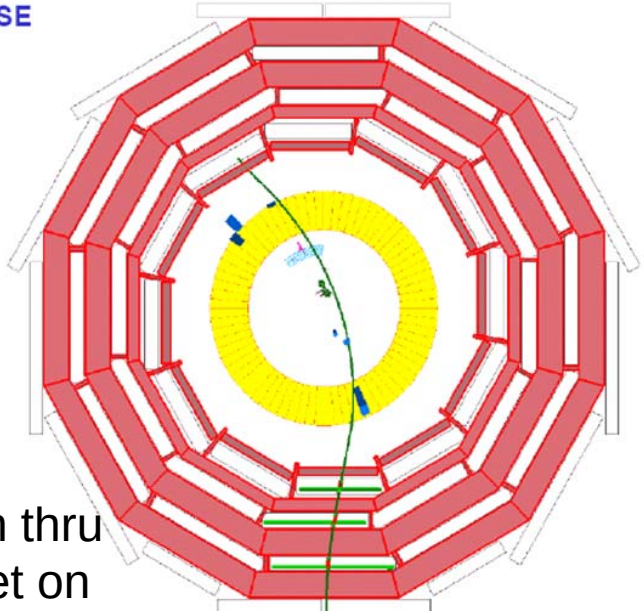

Lowering HB (Feb 07)


CMS at the cavern (15 Dec 07)

Surface activities

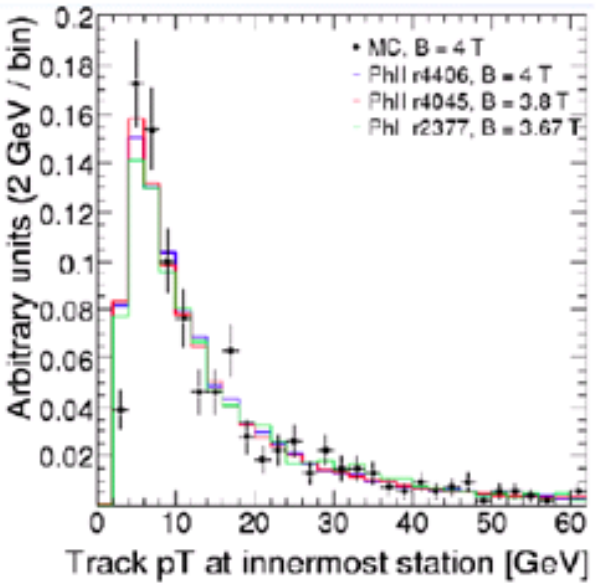
CERN PRESS RELEASE
13 September 2006

The CMS Magnet Test and Cosmic Challenge (MTCC Phase I and II),
(CERN/LHCC 2007-011/G-129, 7 March 2007)



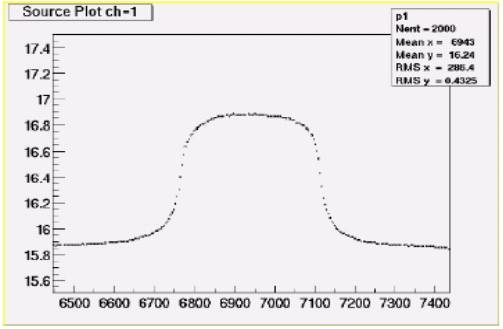
cosmic ray muon thru CMS with magnet on (nov 2006, cms surface hall)

MTCC: on the Surface
Cosmic muons momentum distribution)



Each scintillator tile in every layer is calibrated with a moving wire ^{60} Co 5mCi source.

Source calibration



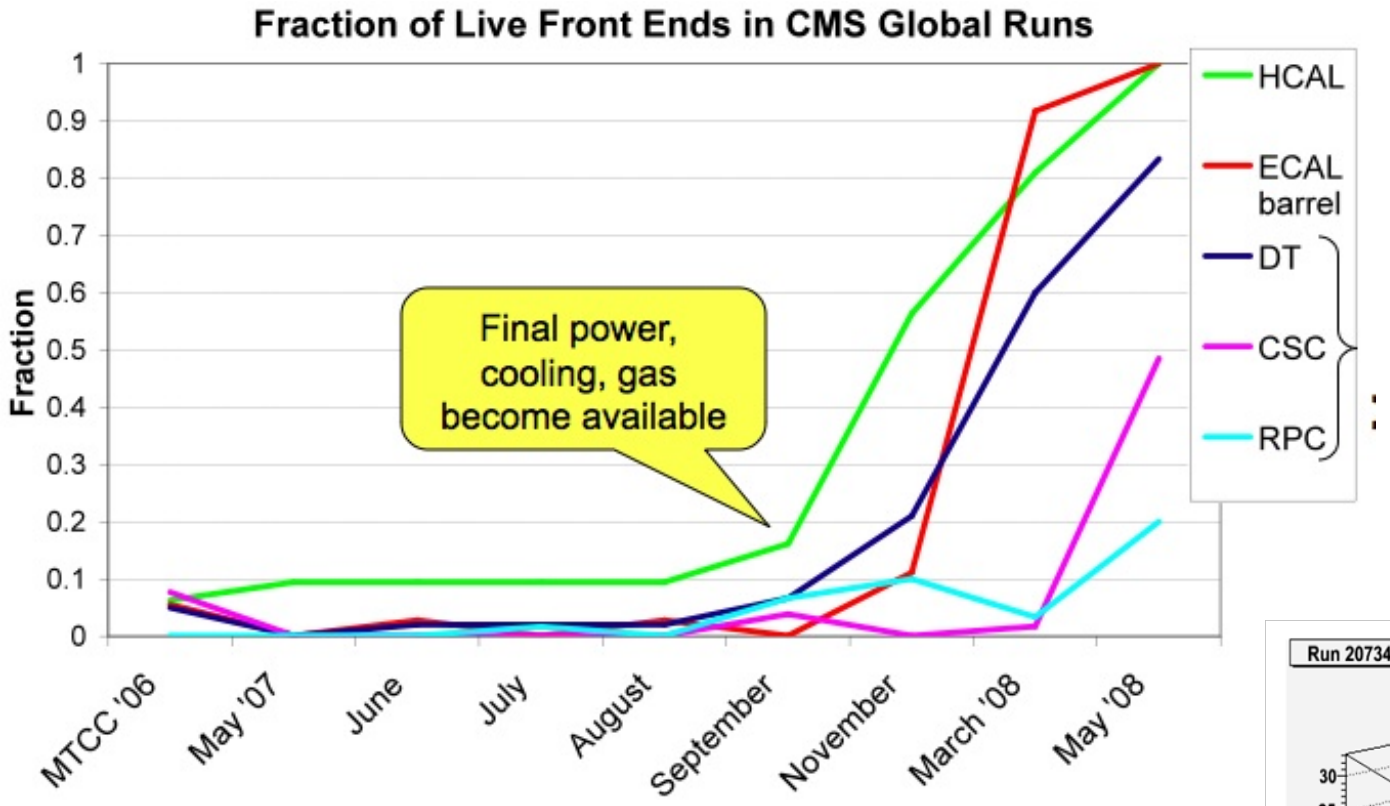
HB/HE pre-calibration to ~ 4%

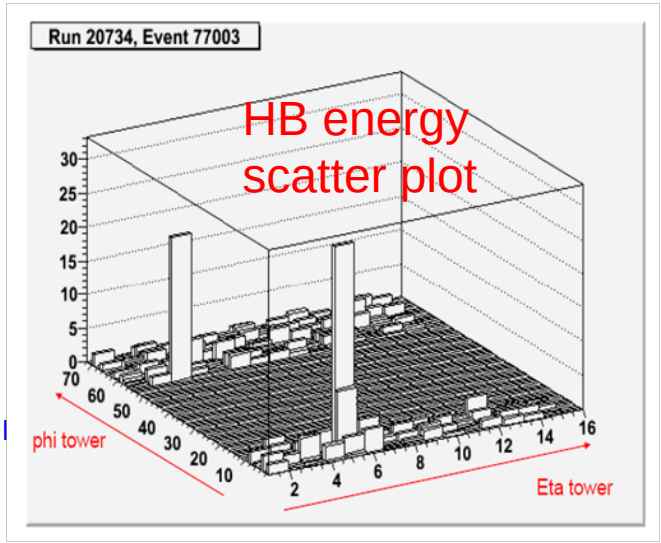
HF pre-calibration to ~ 5%

CMS Global Runs

turning set of commissioned subsystems (HCAL, Muon, ECAL, Tracker)

into fully integrated detector





September 2007 Global Run,

Cosmic ray event triggered by muon track in Drift Tube (DT) Muon

Overview of Cosmic Run at Zero Tesla (Cruzet1, May 5-14, 2008)

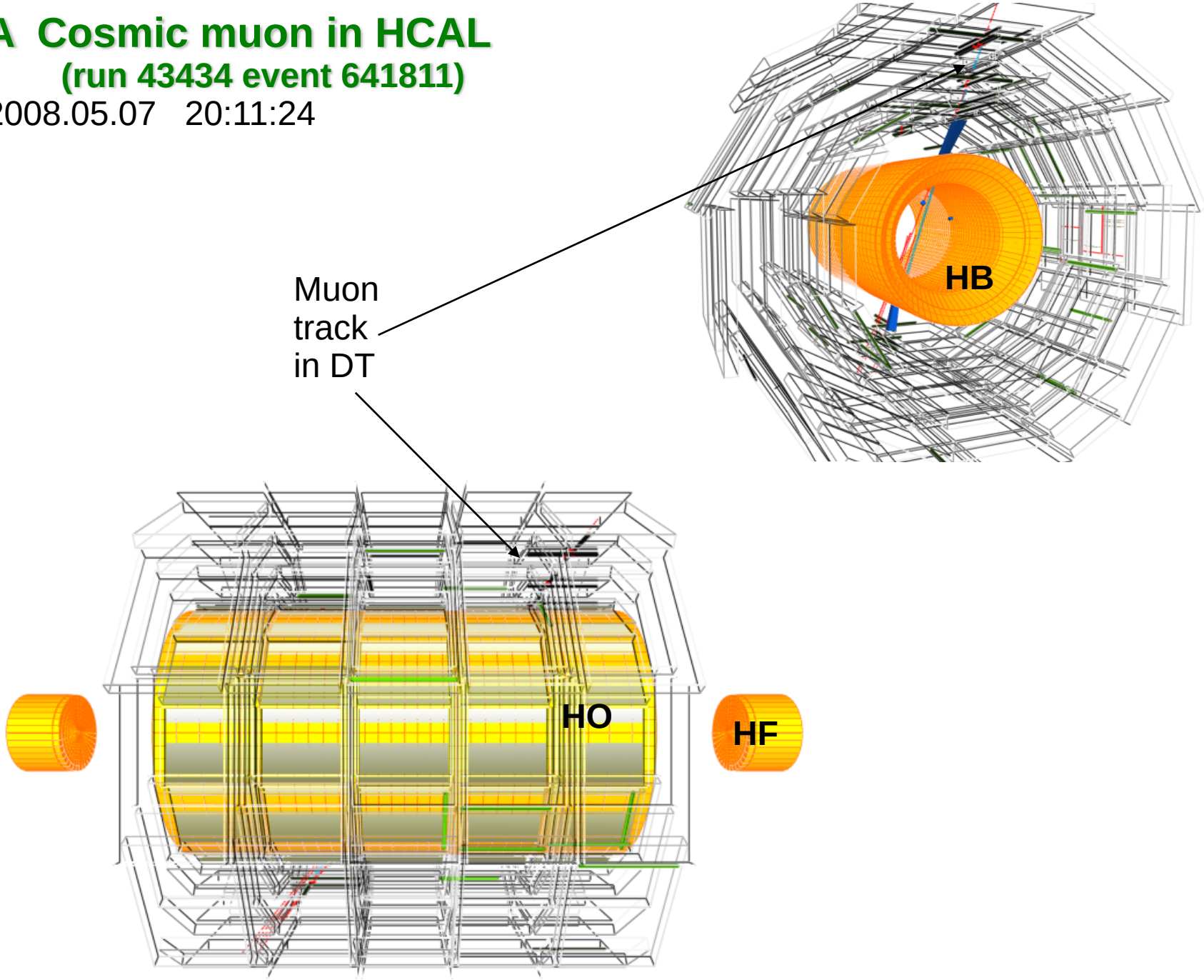
- Operated a substantial fraction of the experiment
  - Level-1 Trigger: all muon triggers, ECAL and HCAL coincidence mip triggers, and calibration triggers including ECAL laser pulsing
  - DAQ and HLT: 177 builder unit and 533 filter unit processors
    - High Level Trigger algorithms run, including filters to select enriched cosmic events plus prototype LHC trigger menu
    - Data streams created from HLT bits from 4 storage managers

- best ever data collected by HCAL subsystem, and in general, most interesting CMS data
- HCAL has collected over 23M good quality events with cosmic ray triggers, all Front End Devices were read out, including HCAL Barrel (HB) , Endcap (HE), Outer (HO) and Forward (HF)
- Factor of 50 larger data set wrt to previous data sets (Sept 2007- March 2008)
- But at the same time, we have learnt lots of lessons
- Plenty of issues to pursue, probably more than we wished for
- next set of slides show data from Cruzet1,

A Cosmic muon in HCAL

(run 43434 event 641811)

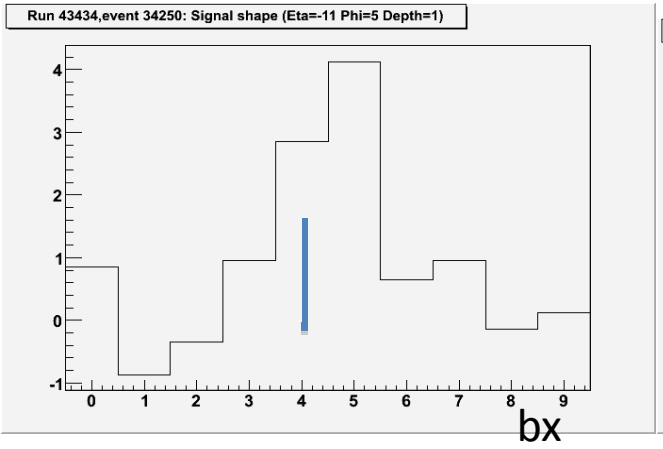
2008.05.07 20:11:24

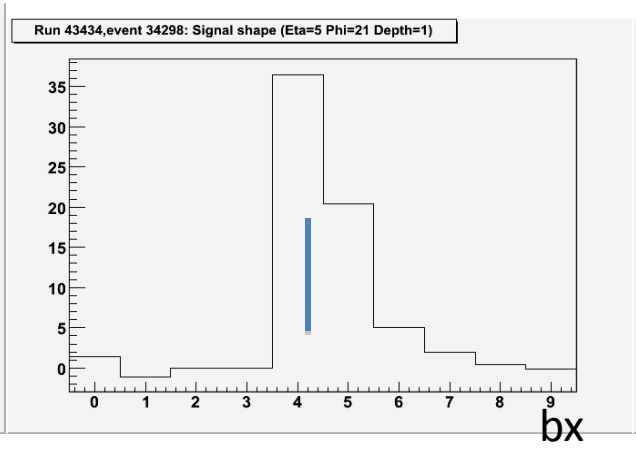


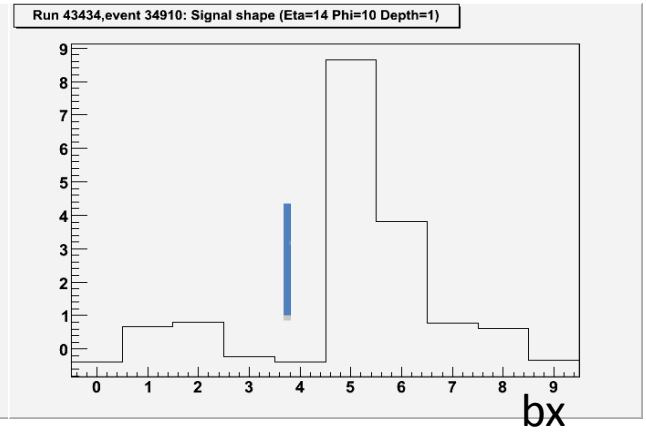
Examples of signals in individual HCAL towers:

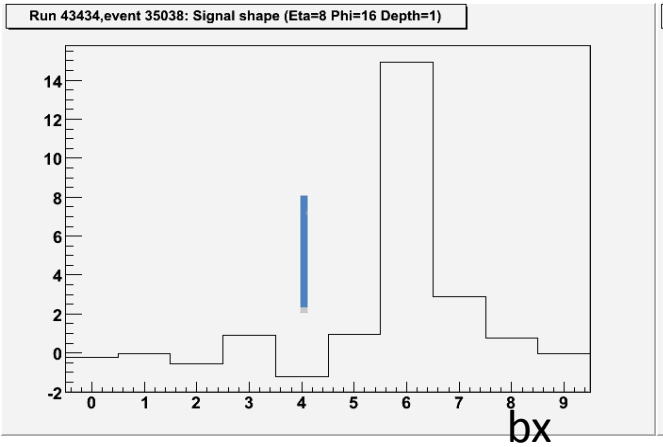
pedestal subtracted ADC counts vs bunch crossing (bx) (0-9)

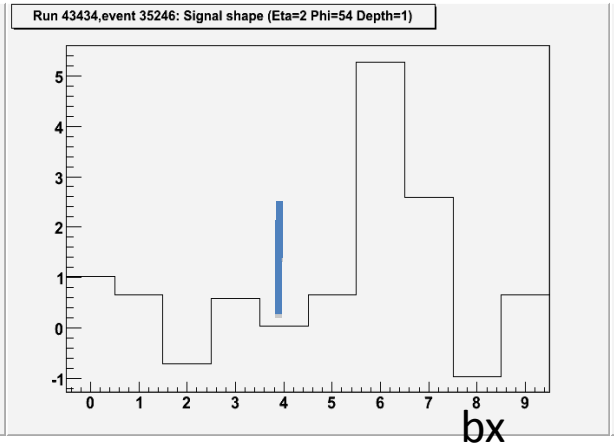
For each trigger, HCAL is reading out information (integrated charge) , for ten bunch crossings. Each bunch crossing is 25ns long.

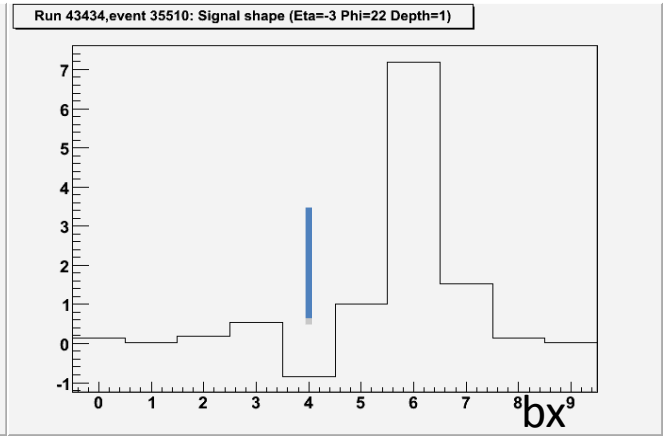




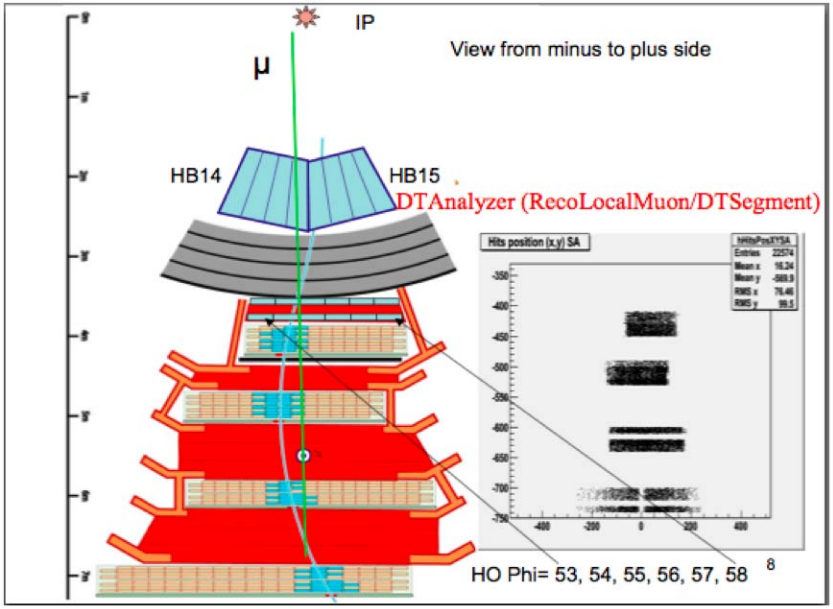


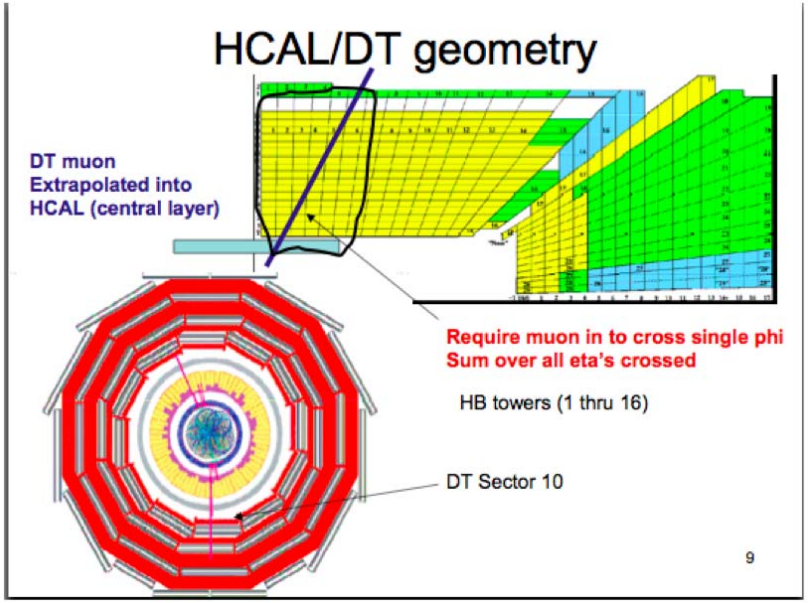


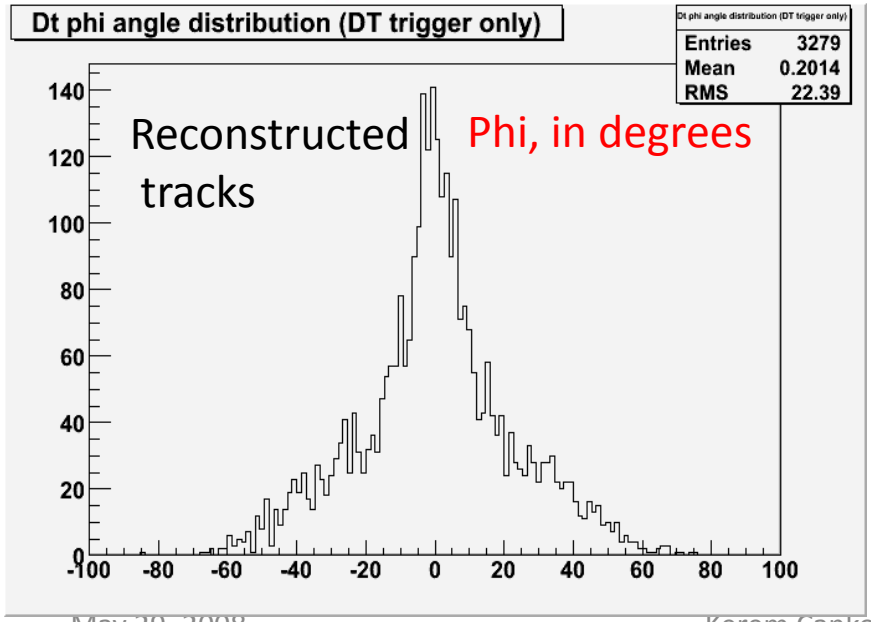


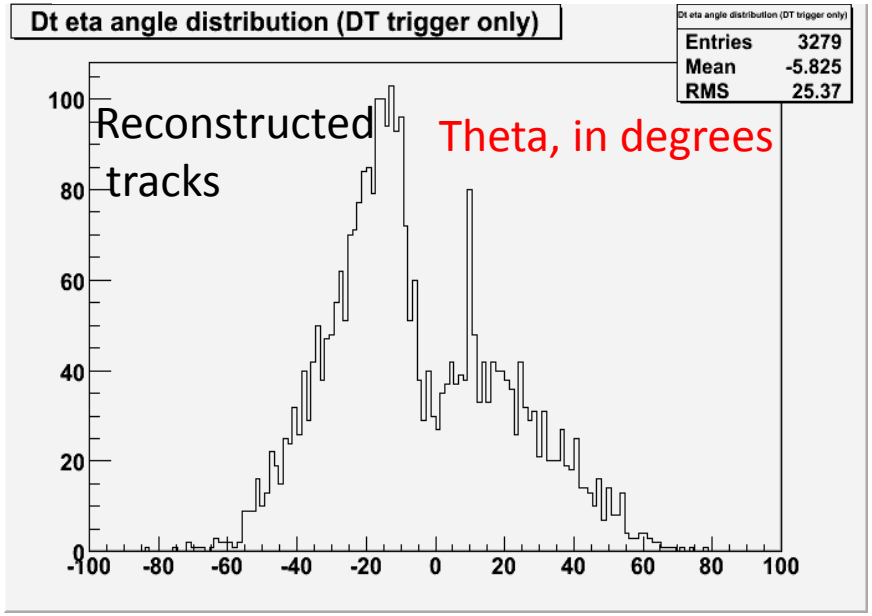


DT track distributions (r43434, DT trigger, 10k events)







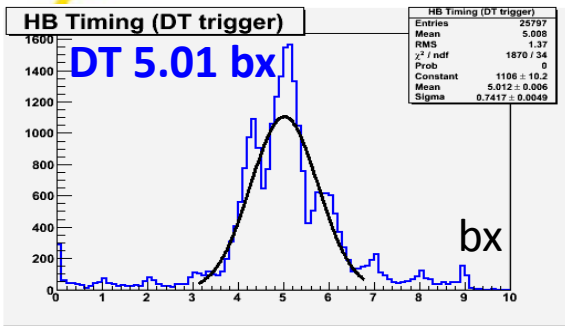


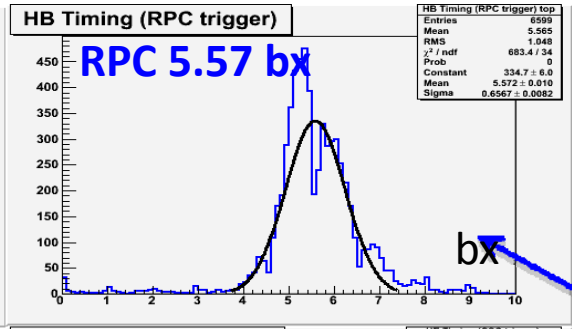
Mean HCAL signal time, wrt to L1A trigger

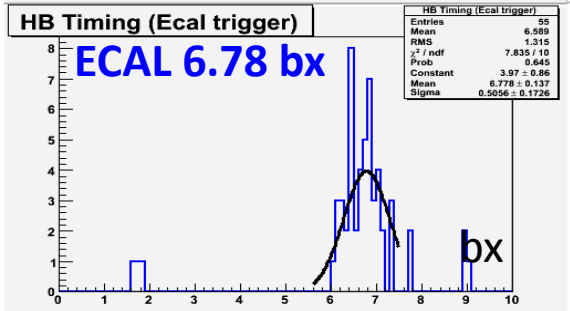
1bx= bunch crossing= 25ns

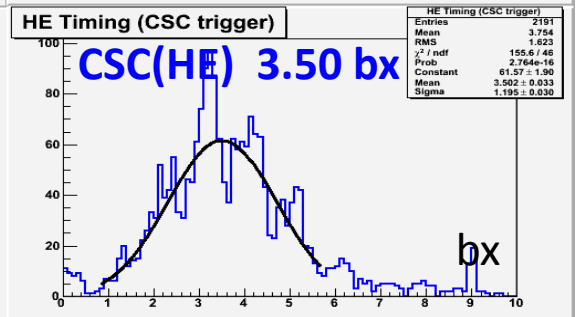
HCAL timing:

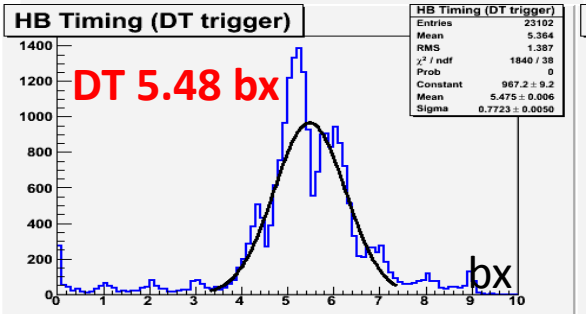
Top vs bottom

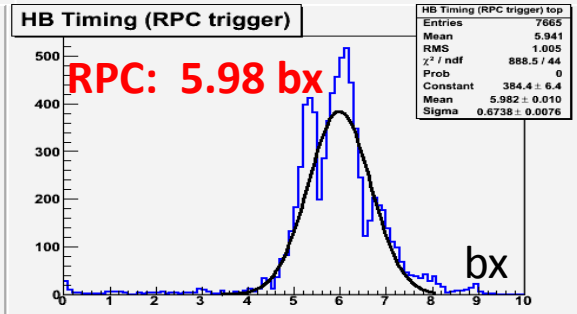


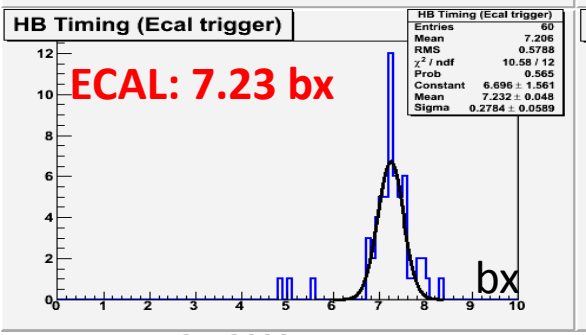


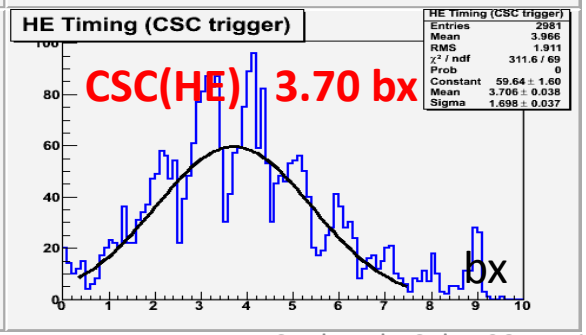








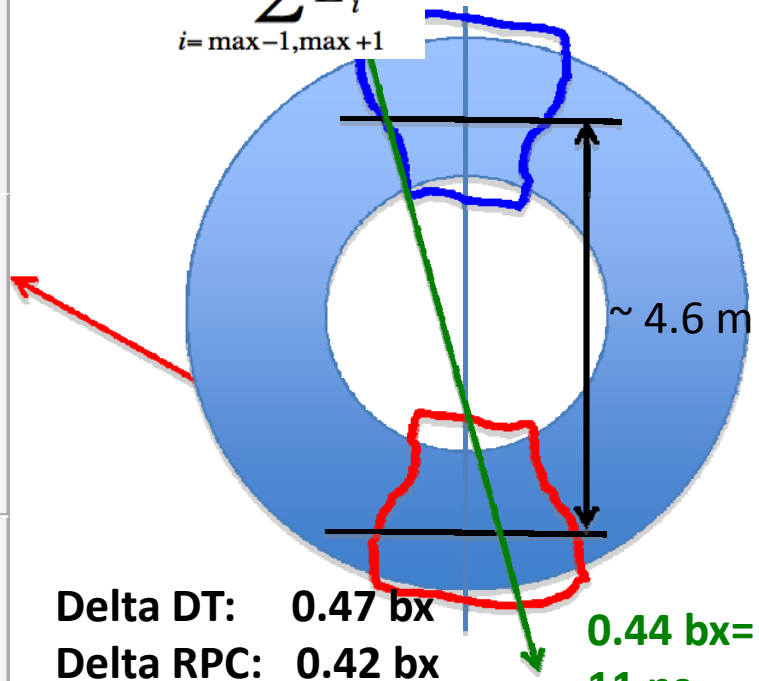




Muon Time of Flight

$$t_\mu = \frac{\sum_{i=\max-1,\max+1} E_i * i}{\sum_{i=\max-1,\max+1} E_i}$$

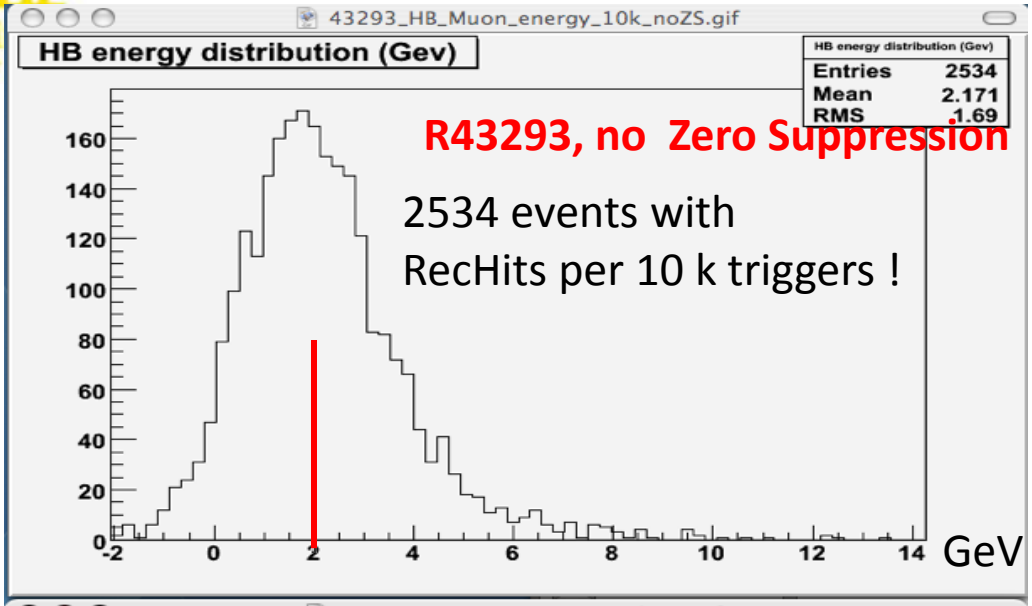
Note:
HCAL delays corrections
As a function of eta
not loaded yet

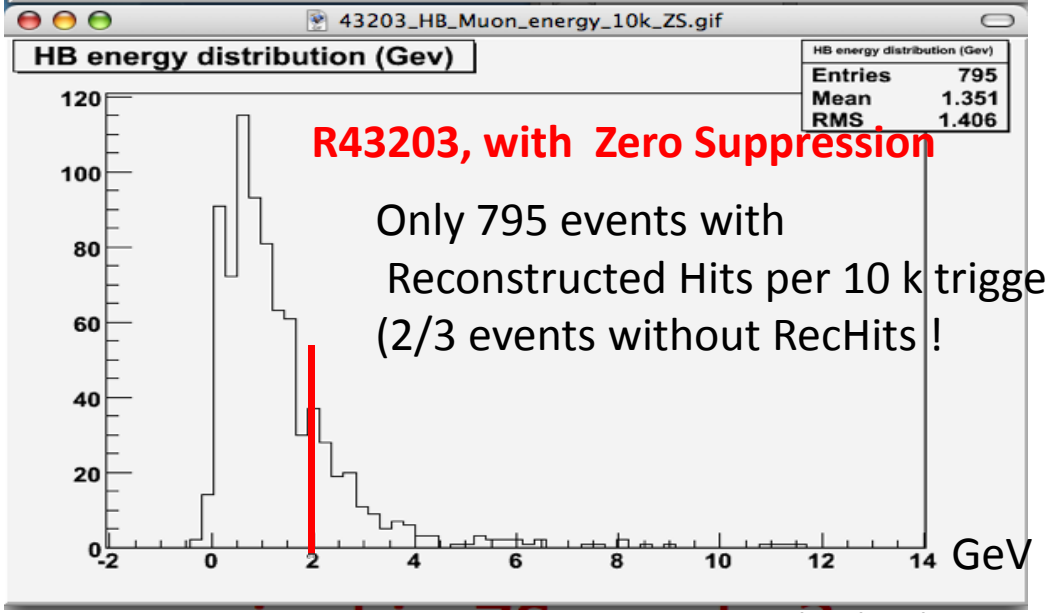


Delta DT: 0.47 bx
Delta RPC: 0.42 bx
Delta ECAL: 0.45 bx
Delta CSC: 0.20 bx
(HE data, smaller separation)

0.44 bx= 11 ns= 3.3 m

Can muons survive ZeroSuppression mode?





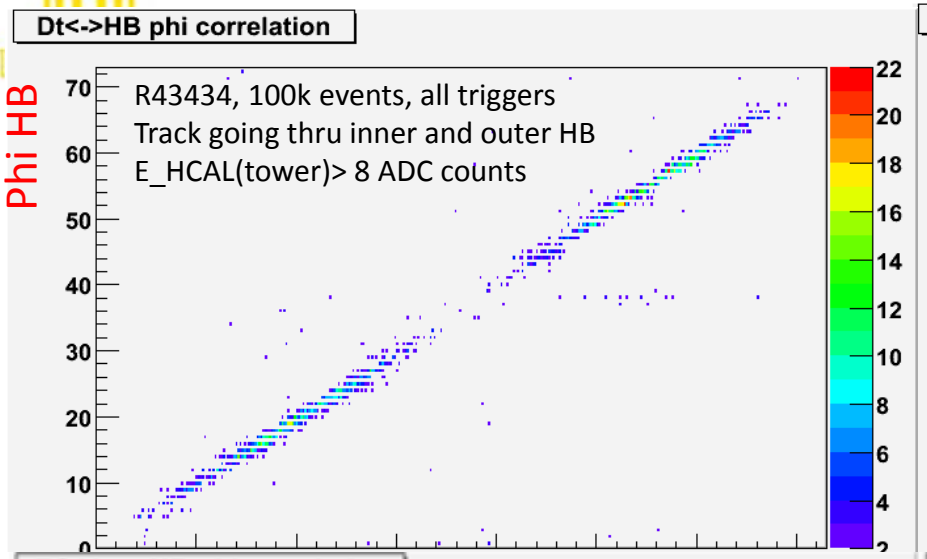
- Muon energy summed over all towers crossed by DT track (10 bx sum)
- Not corrected for angle of incidence
- No threshold on energy in HCAL (unbiased distribution) !

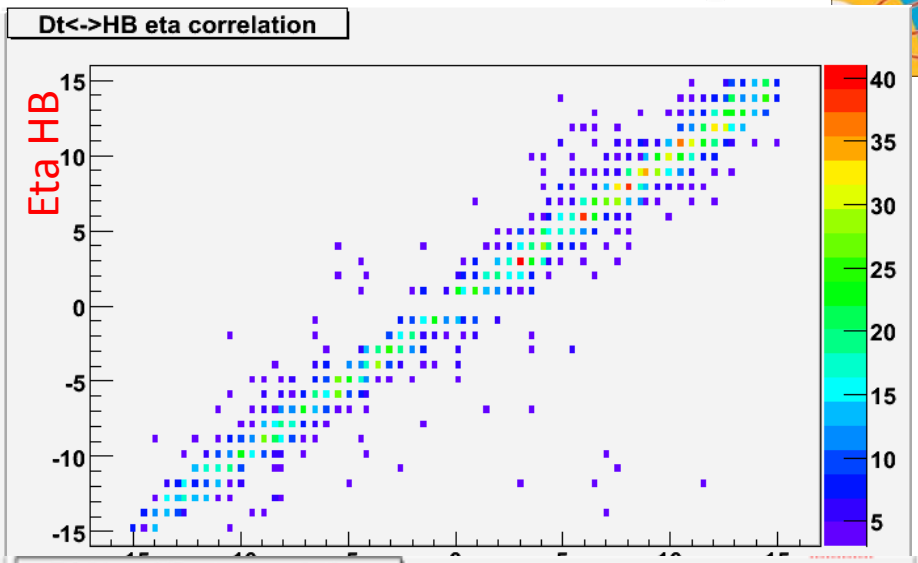
Caveat:

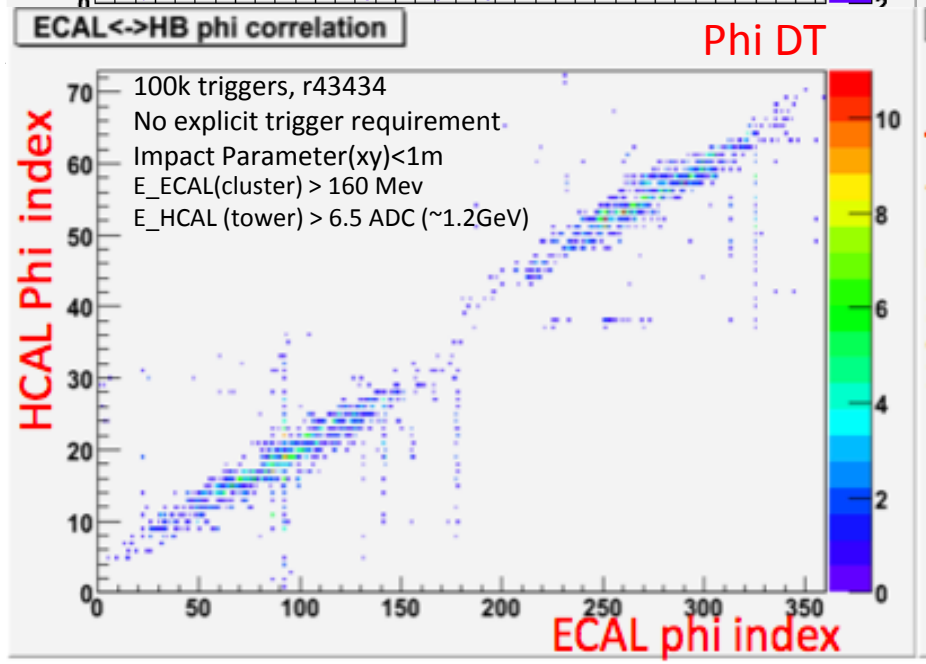
muons from pp collisions will originate from IP, They will deposit energy only one tower

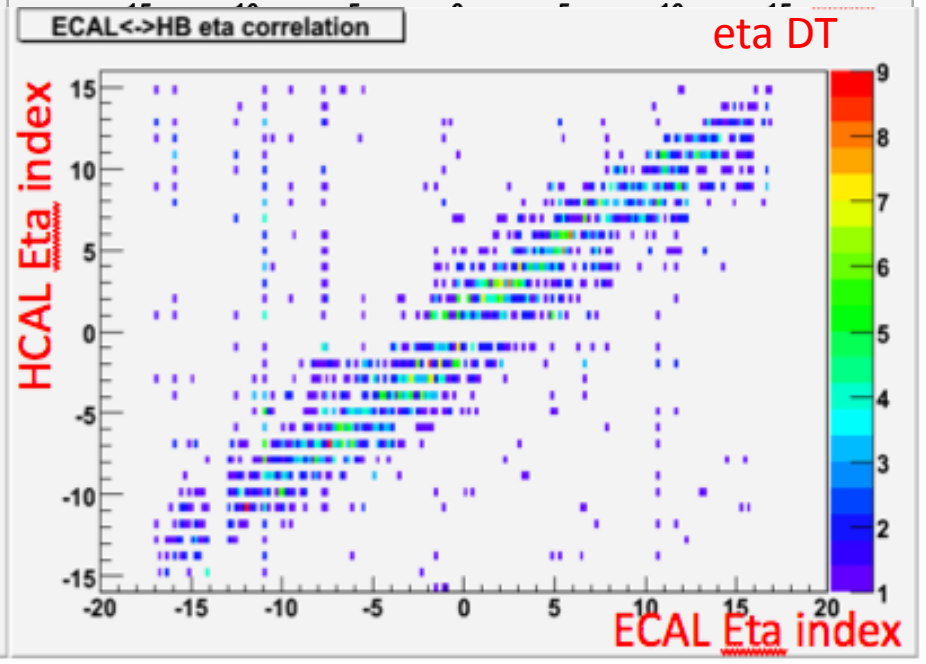
cosmic ray muons have large Impact Parameter, They deposit energy in multiple towers

Muon DT and ECAL vs HCAL: eta and phi

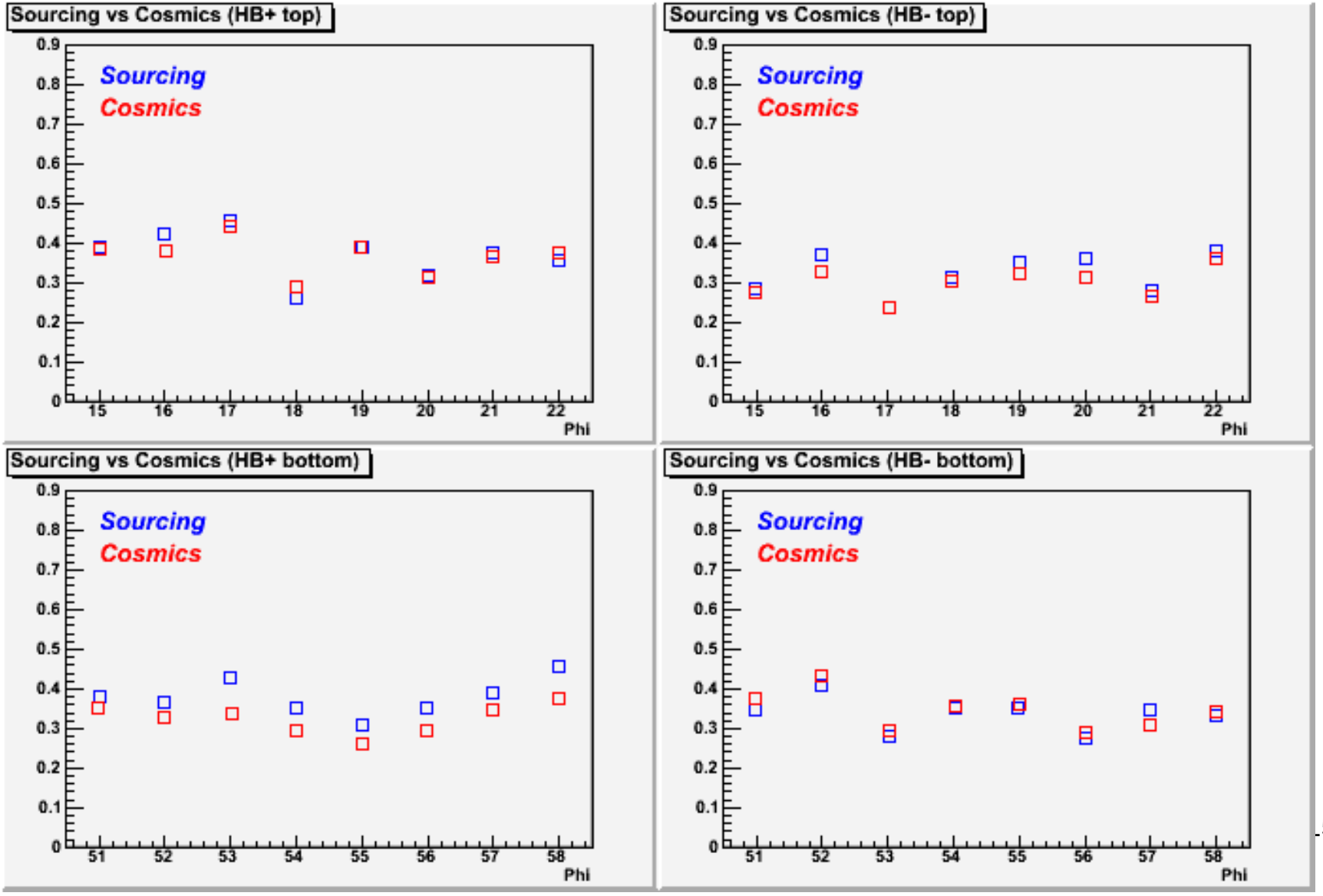








Muon Signal average (linearized adc counts/25) and wire source averages (normalized at arb. scale)

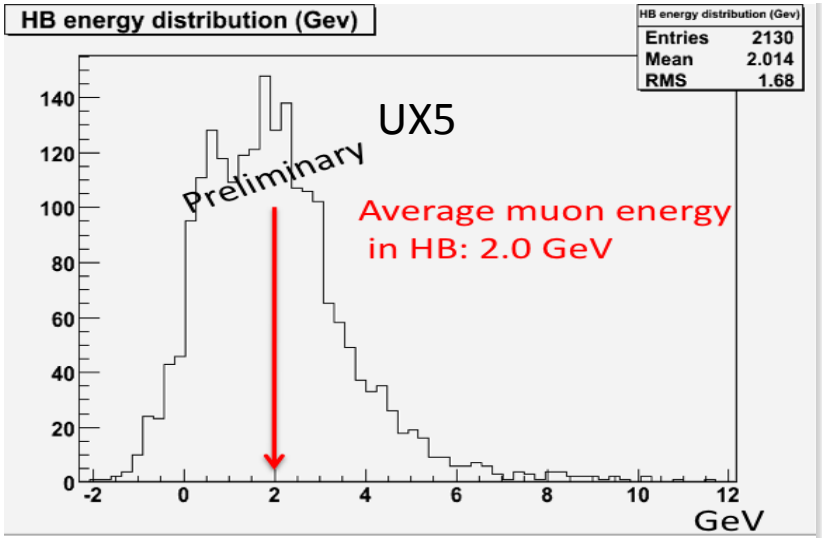


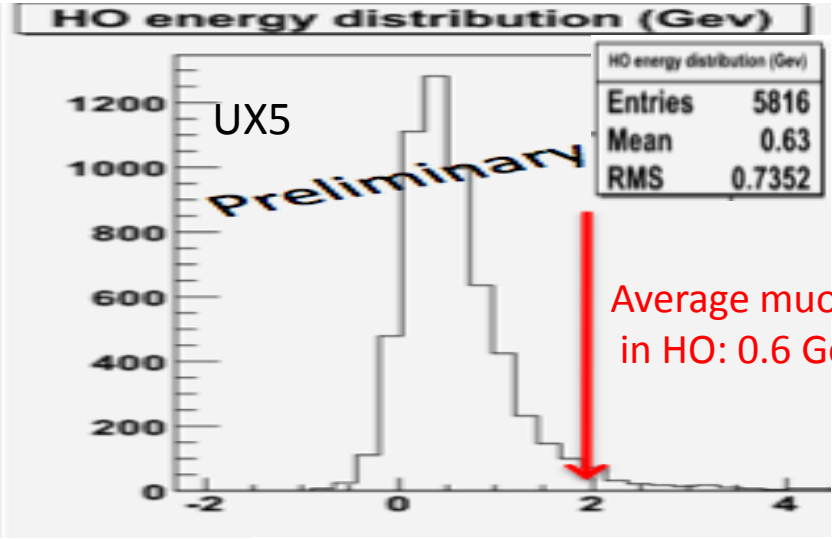
Cosmic muons (UX5) vs Test Beam comparison (preliminary):

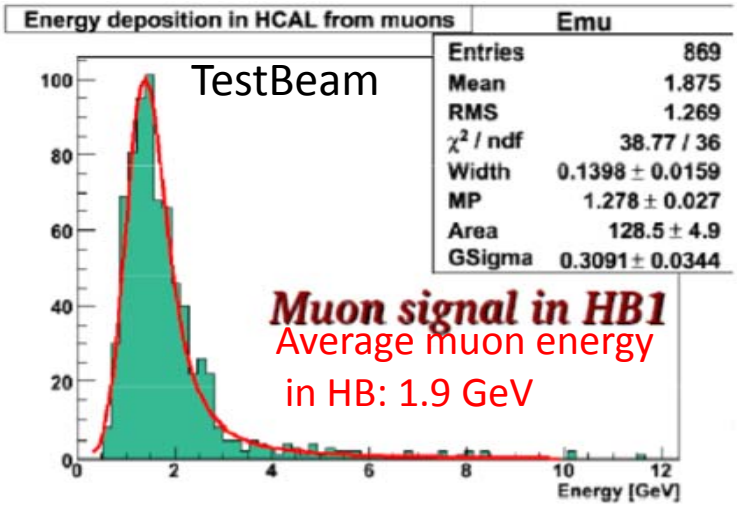
not corrected for angle of incidence

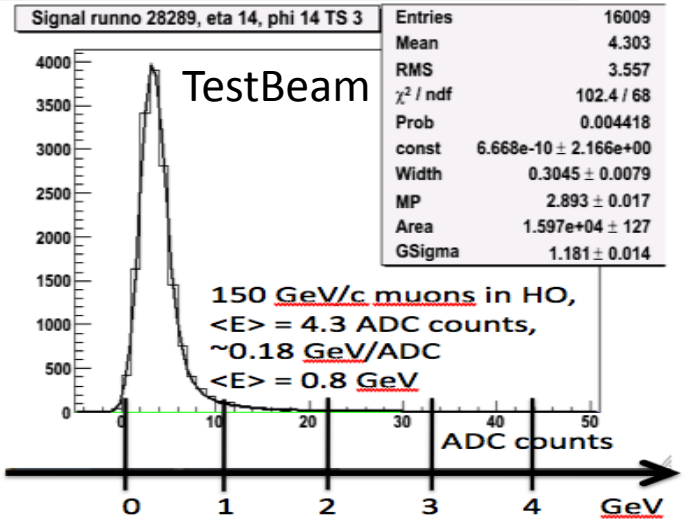
UX5: energy defined using multiple towers, 10 bx sums

TB: energy defined using single tower, 2 bx sums

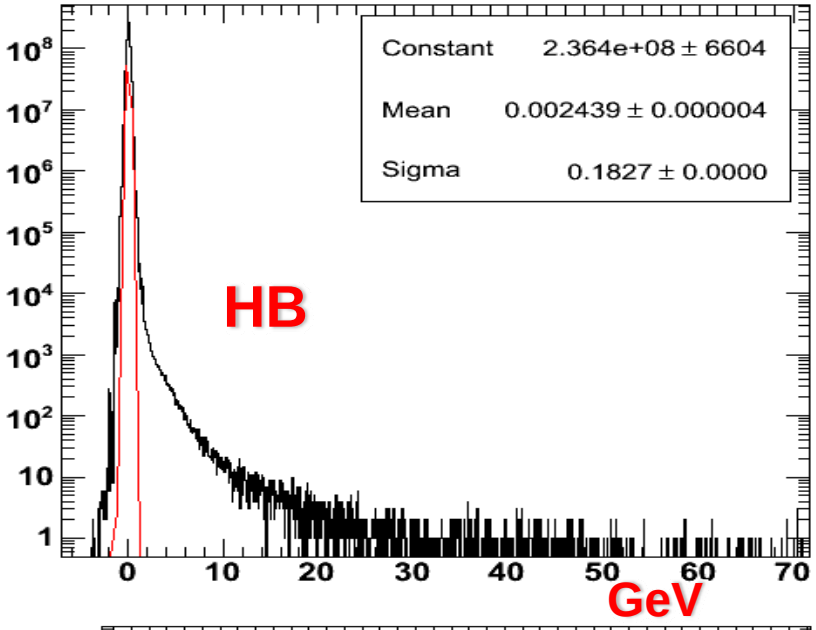


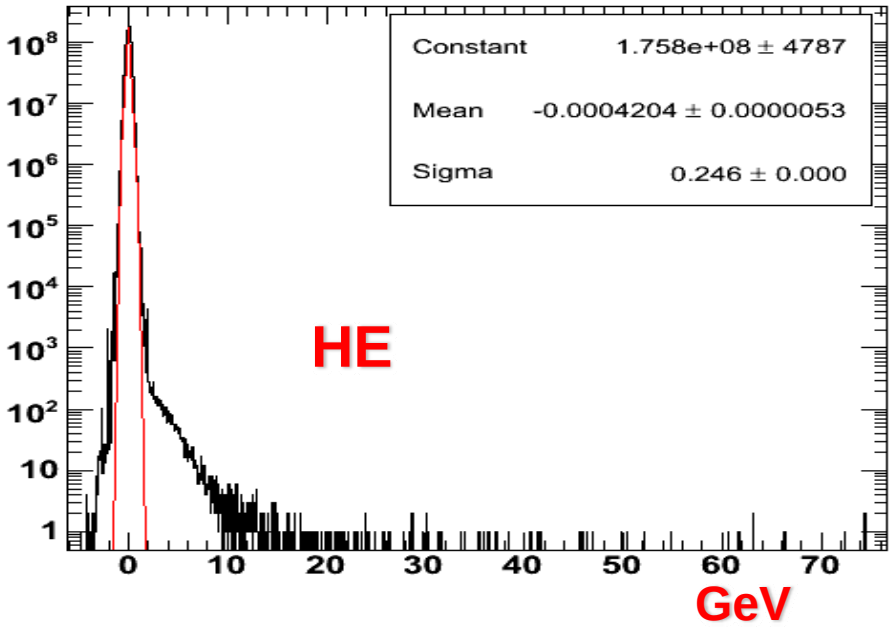


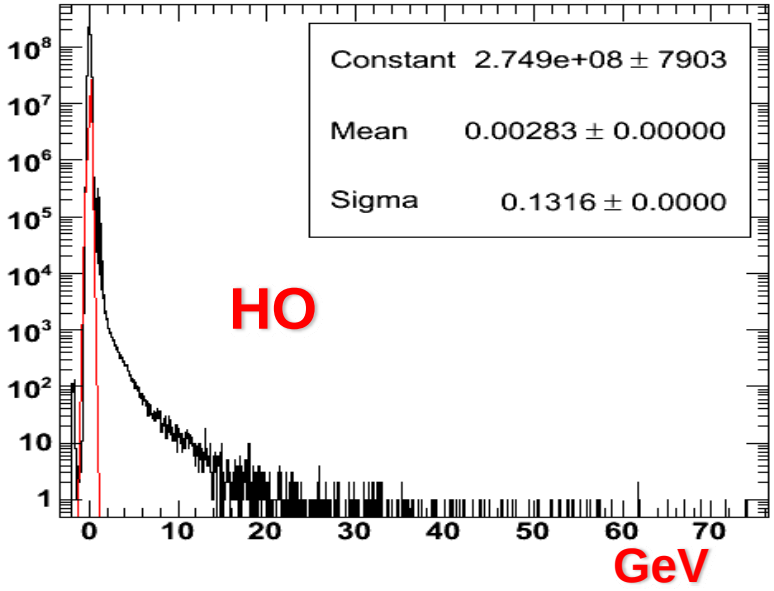


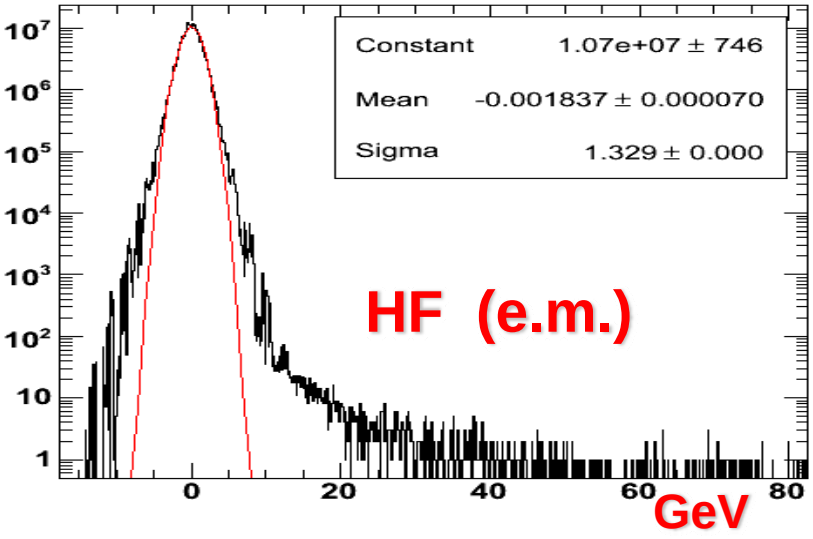


reconstructed energies from muon trigger Cosmic runs

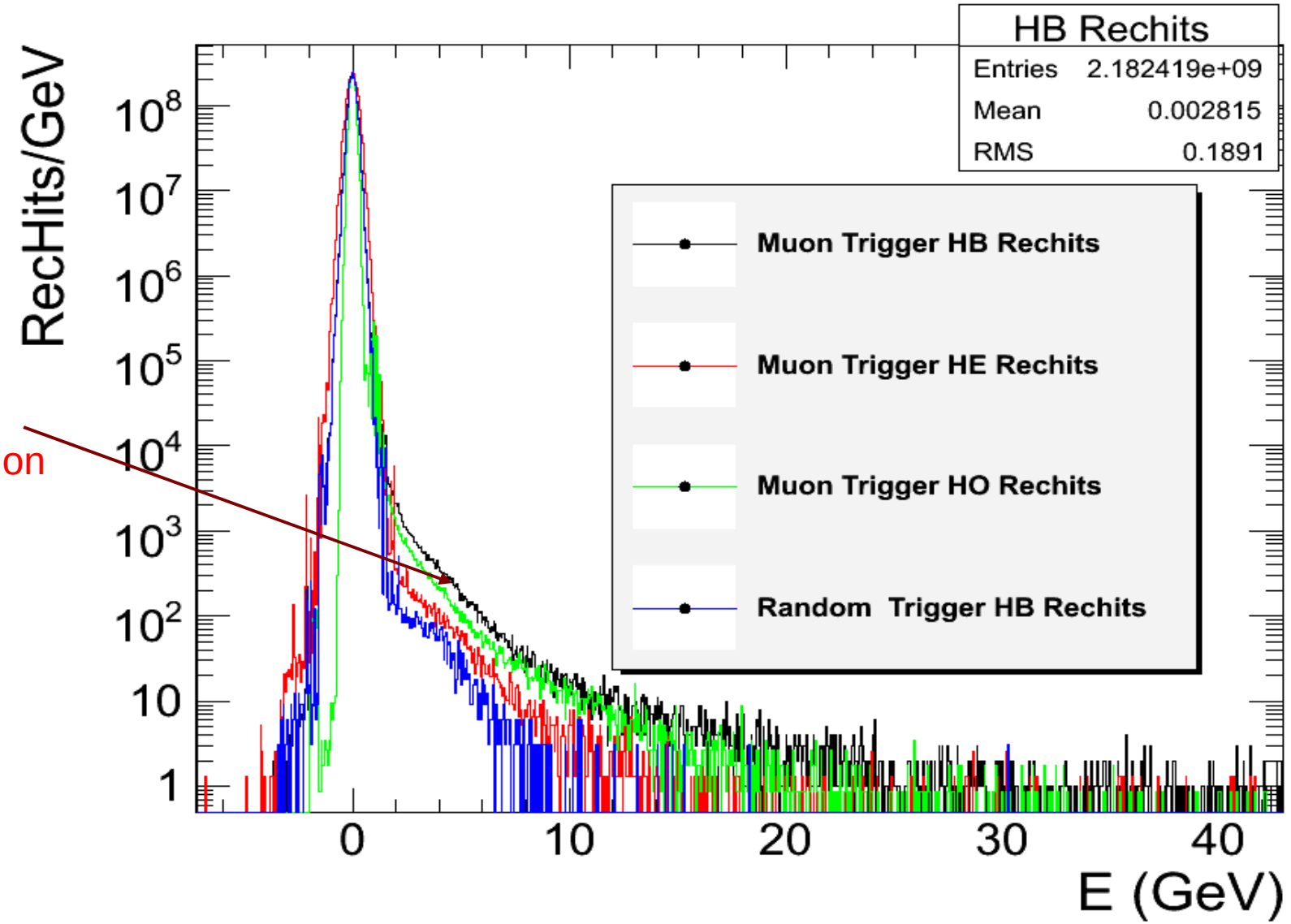




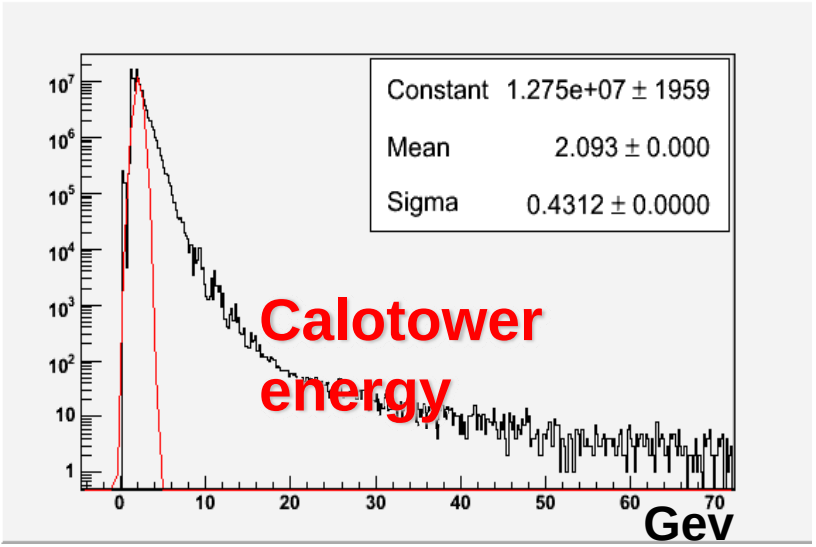


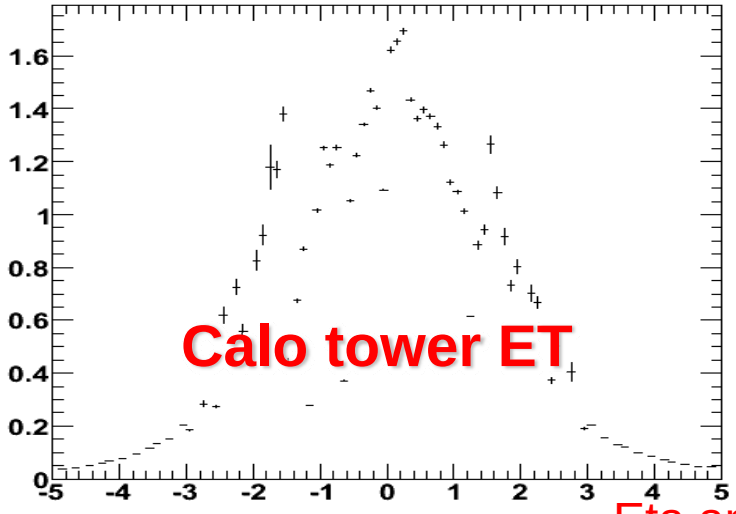


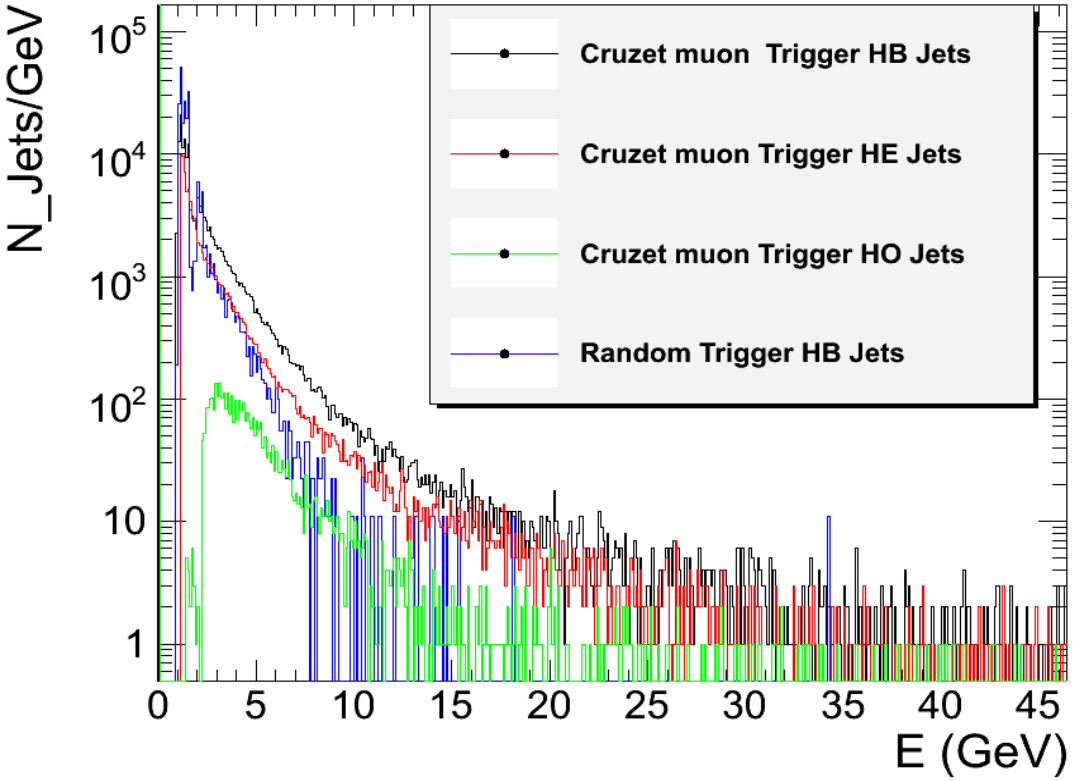
muon trigger vs Random trigger Cosmic runs



reconstructed Jets from muon trigger Cosmic runs







icon alg. **Radius 0.5**

Fake Jets cleaning studies is going on

Conclusion

- HCAL Calorimeter is fully installed and commissioned

- Hcal is timed in wrt DT,RPC, CSC and ECAL during Global runs

- DT/HCAL and ECAL/HCAL phi&eta correlations are good, trigger studies still going on. All triggers will be further aligned

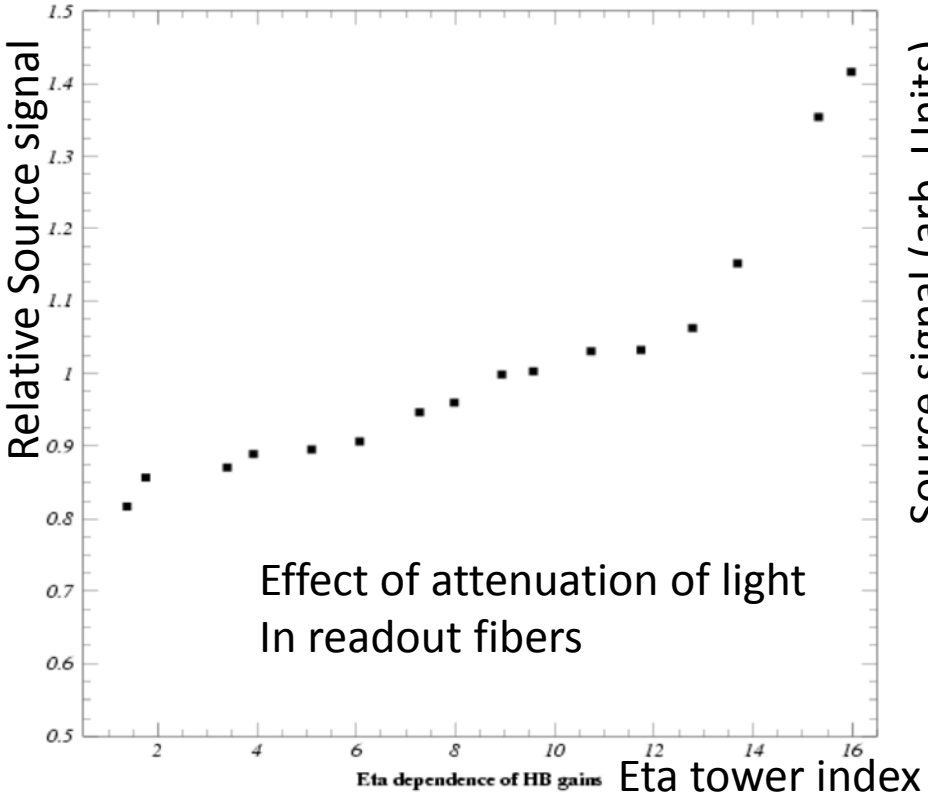
- HCAL calibration in situ, muon ID and isolation cut, cosmic ray rejection algorithms studies are going on

Back-up slides

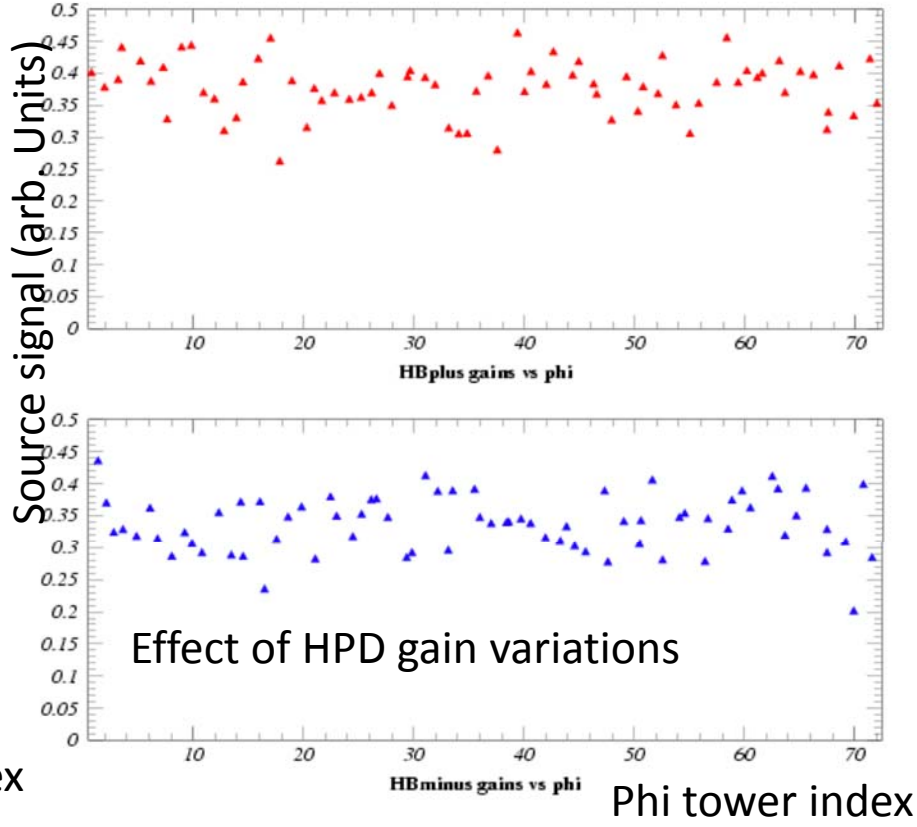
Relative calibration of HCAL (2005/06)

- HCAL Barrel has over 33 thousand individual scintillator tiles, 2592 readout channels, 16(in eta)x72(in phi) readout towers
- Full readout system was calibrated using 1-4mCi Co-60 radioactive source system
- Achieved relative calibration of all towers at the level of 3%

Source signal vs eta tower,

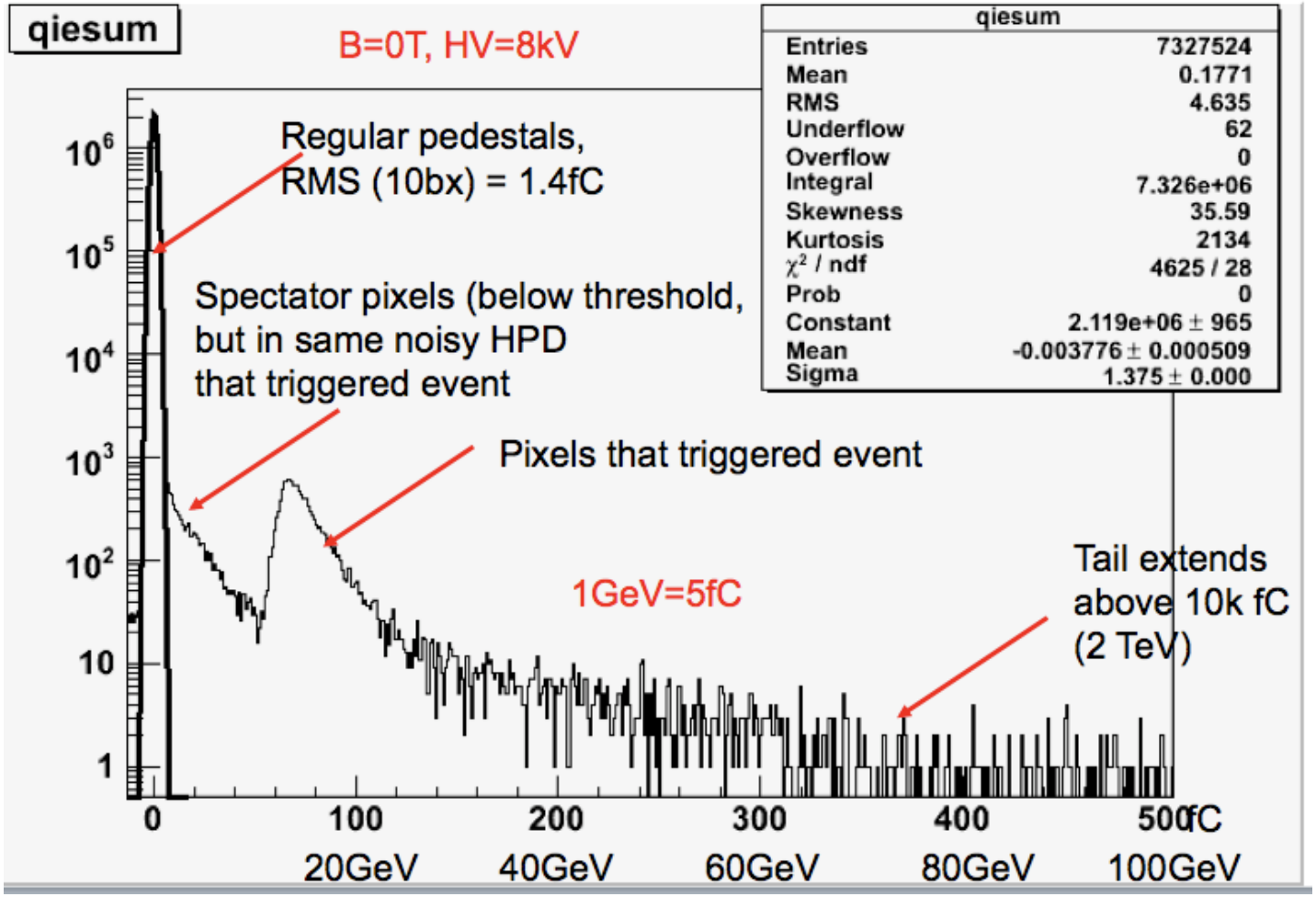


Source signal vs phi tower

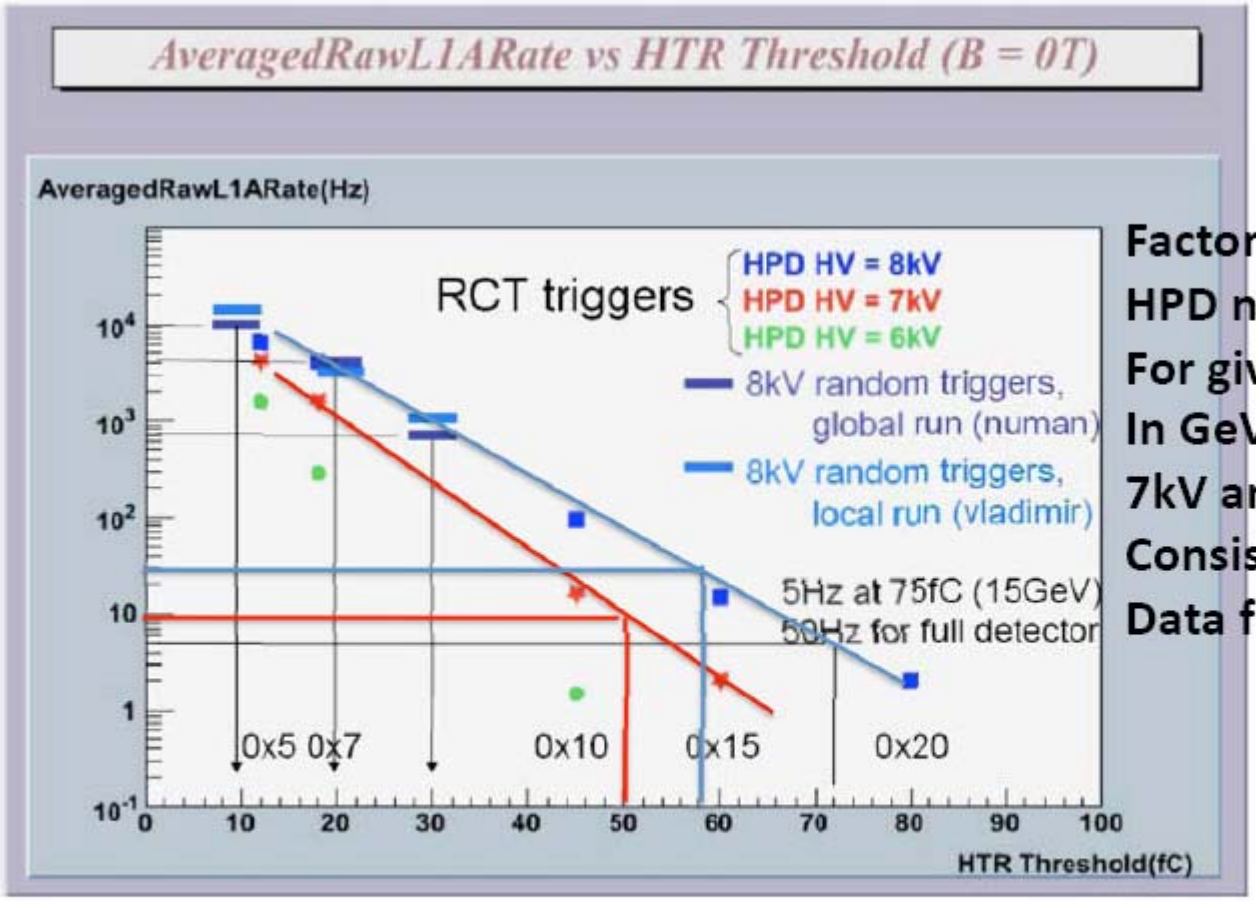


HPD noise (discharges) (2007)

Noise Pulse spectrum 13k triggers at 60 fC, threshold 31 HPDs (496 pixels), rate ~15Hz



HPD noise rates vs threshold and



Factor of 3 in HPD noise rates For given Threshold In GeV between 7kV and 8kV is Consistent with Data from mtcc

Figure 15: HCAL trigger rates using GLOBAL_OR of 448 HCAL Towers (~10% of detector), as a function of threshold (fC) and High Voltage on HPDs. Nominal operation voltage is 8kV. At 8kV, 10fC is equivalent to approximately 2 GeV energy. Data was taken at B=0T.

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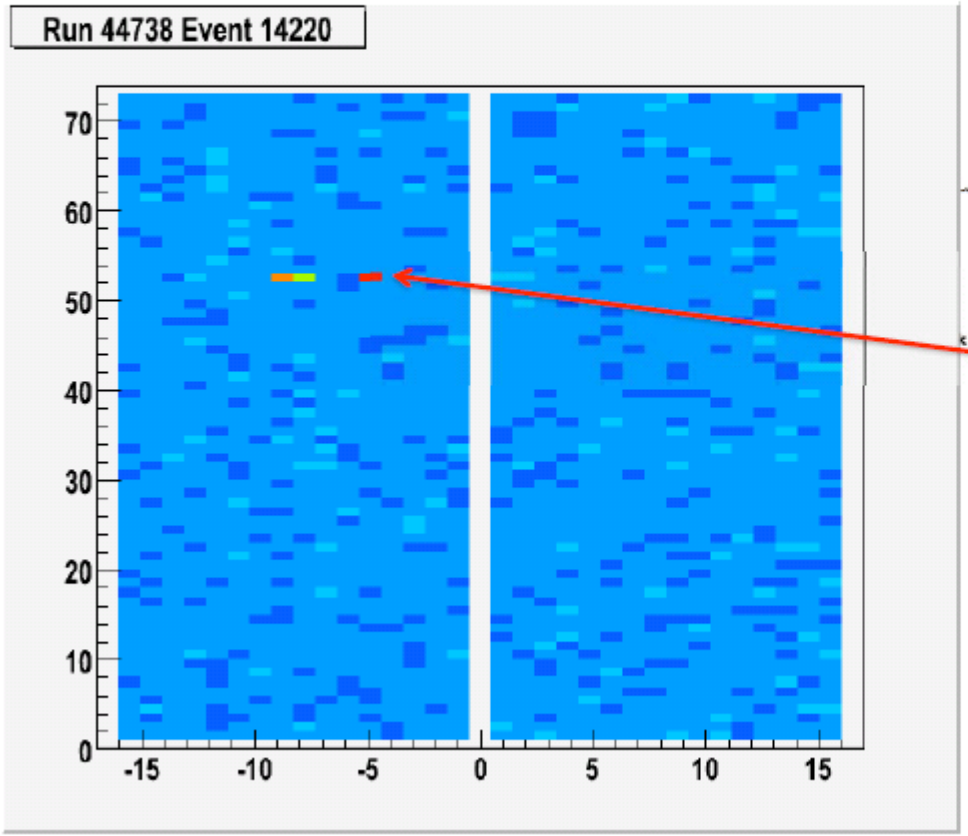
Example of event from phi=-52 (RM type 3)

look like HPD discharges, not light leaks

(events are multi-bx, multi-pixel, clustered inside HPD)



These 3 pixels correspond to Eta 5, 8 and 9