Status of CMS HCAL

Pawel de Barbaro,
University of Rochester,

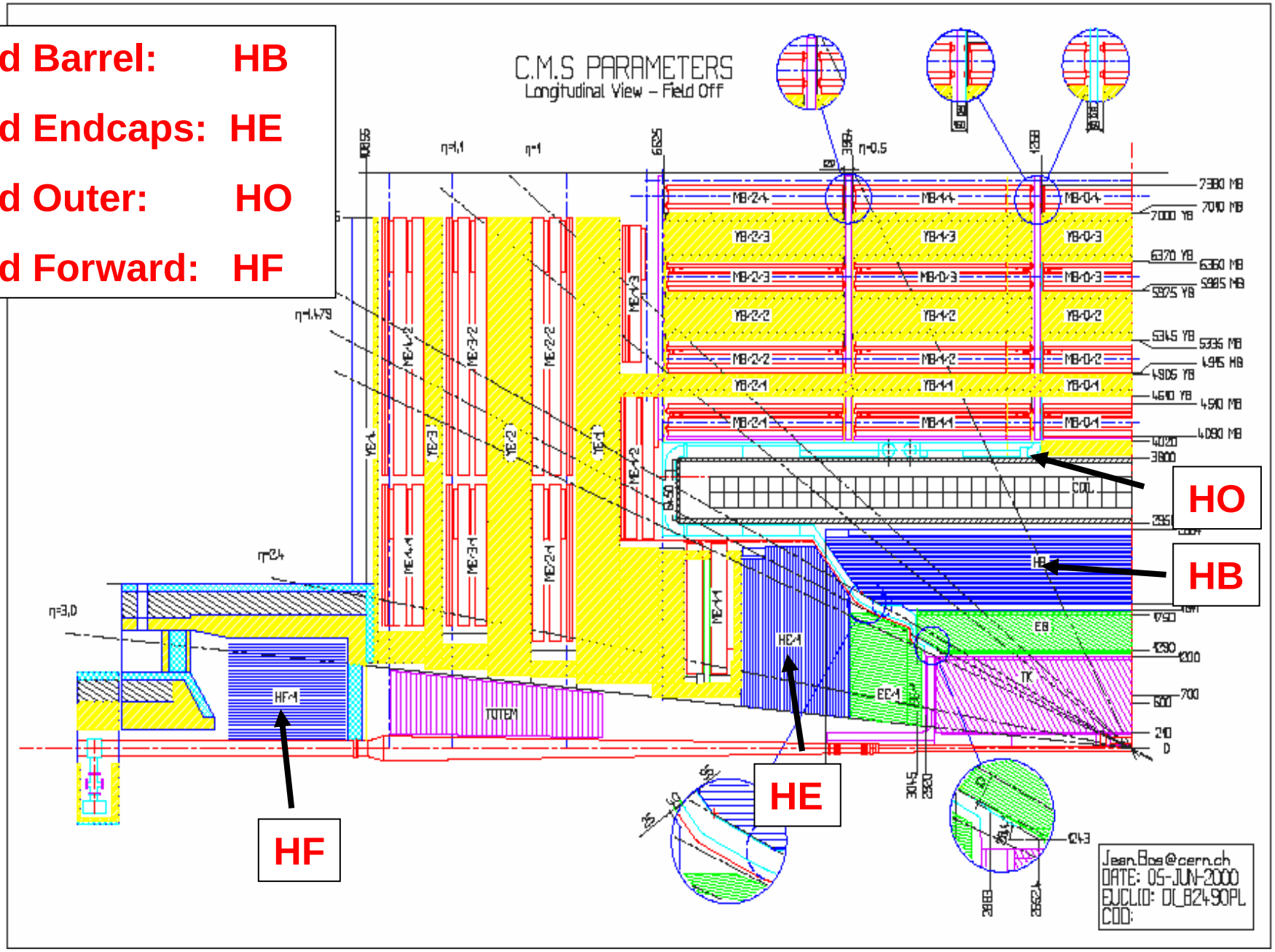
LHC days in Split,
October 2-8, 2006

Had Barrel: HB

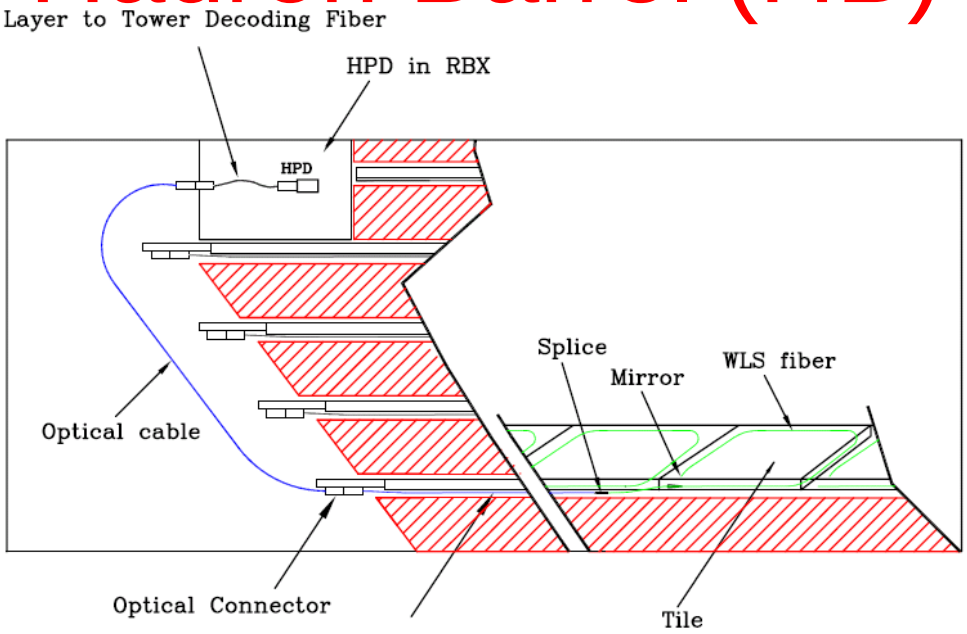
Had Endcaps: HE

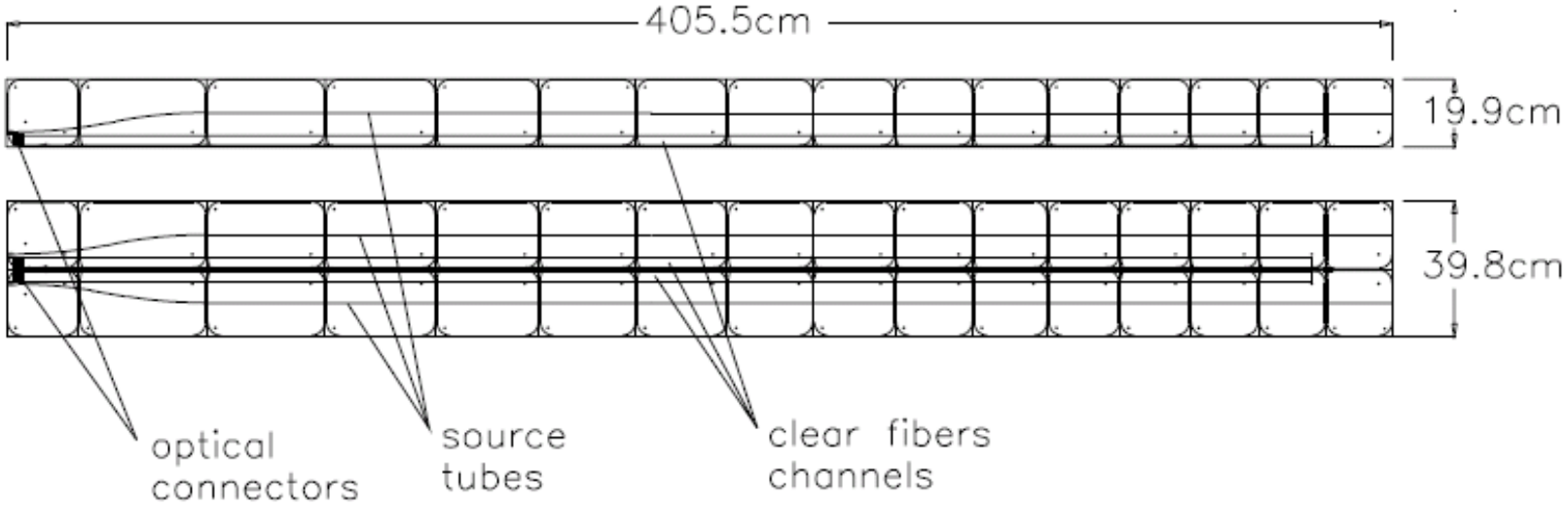
Had Outer: HO

Had Forward: HF



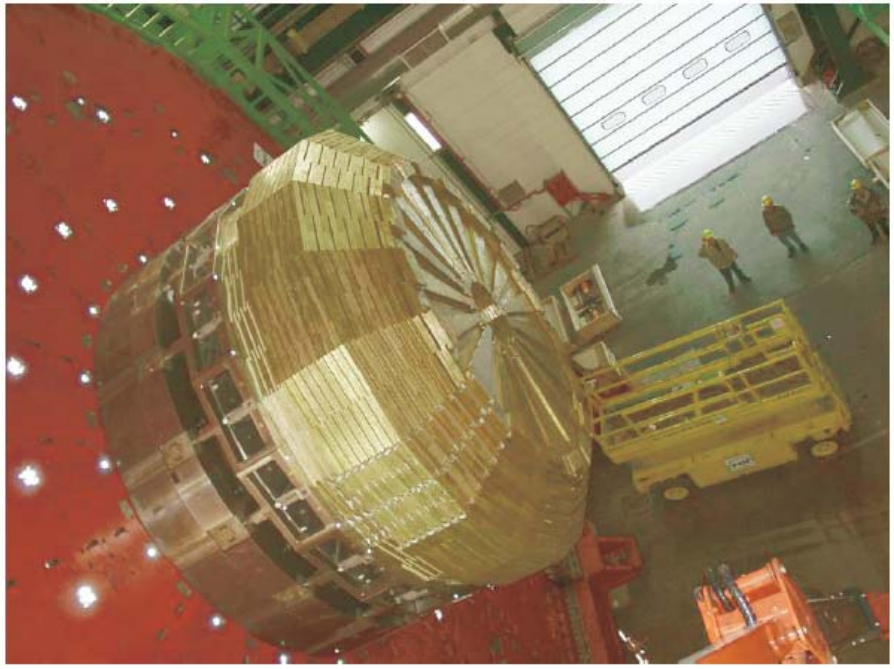
Hadron Barrel (HB)

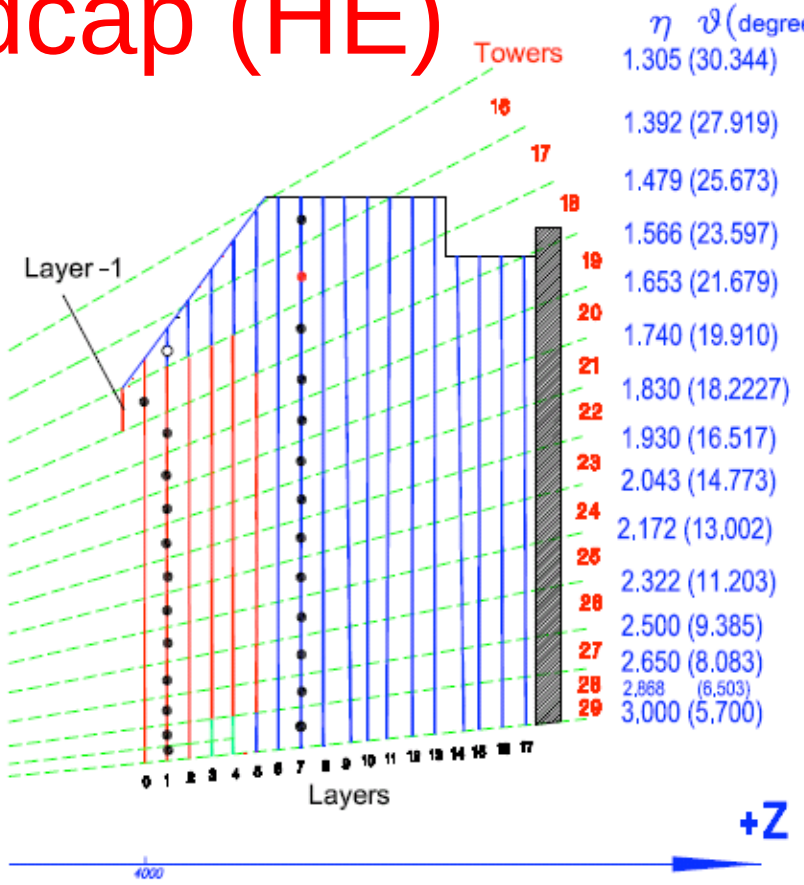


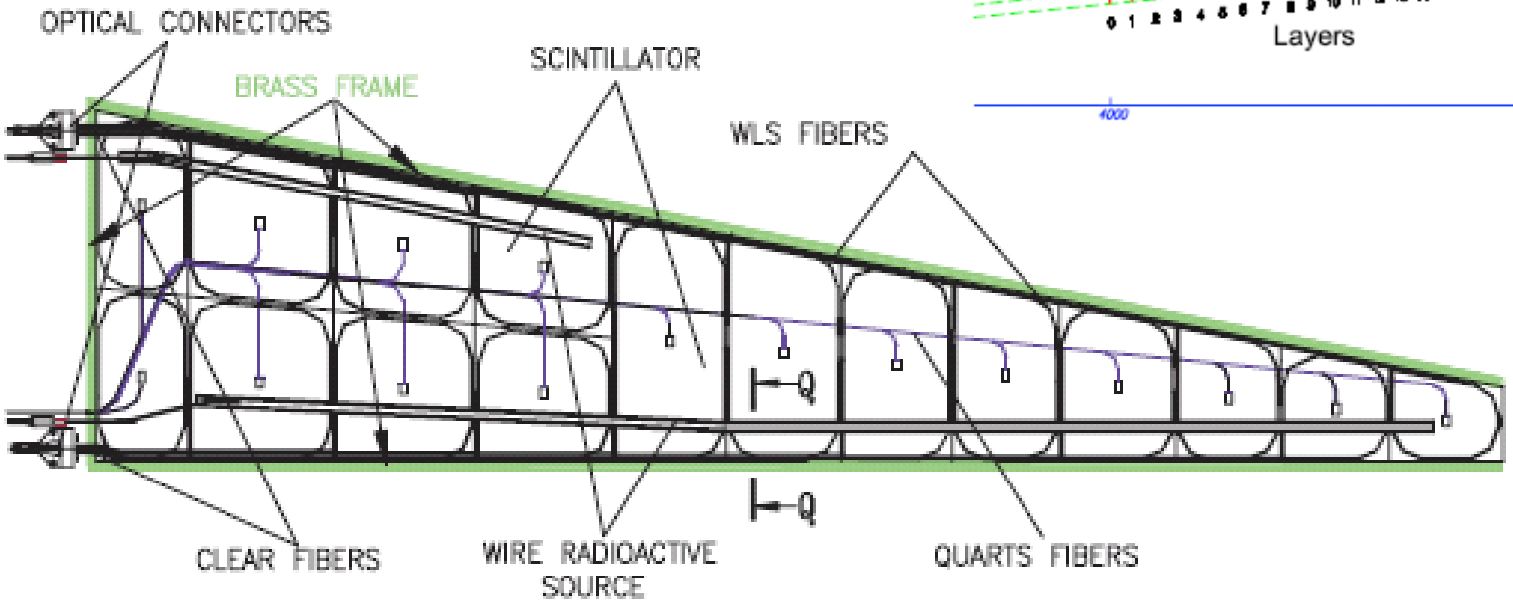


brass/scintillator sampling calorimeter,
with wave-length shifter (WLS) fibers and Hybrid Photodetector (HPD) readout

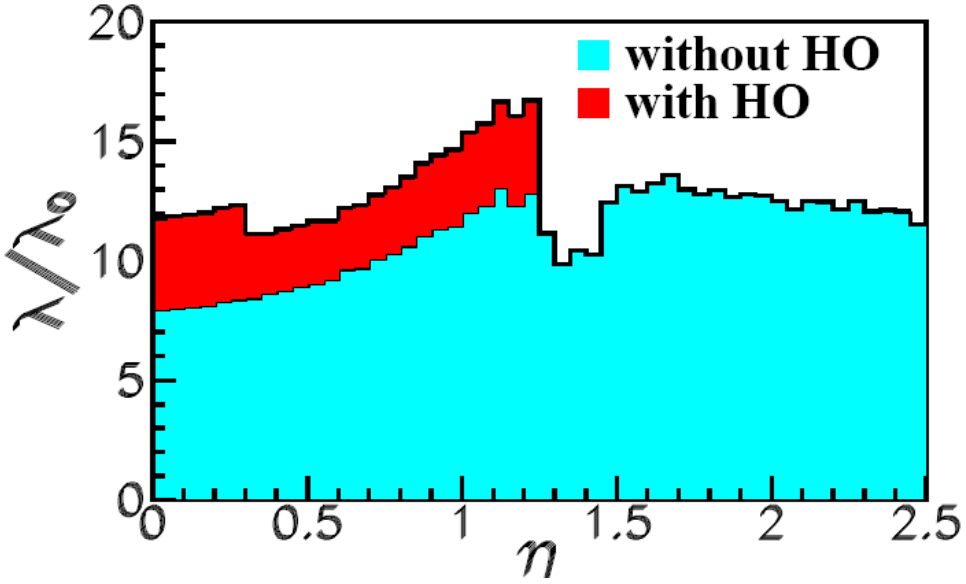
Hadron Endcap (HE)

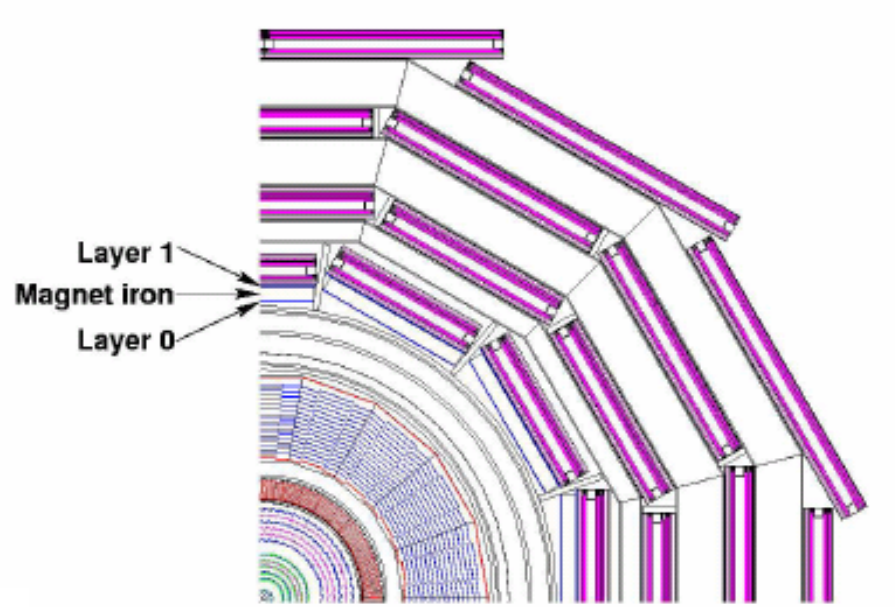


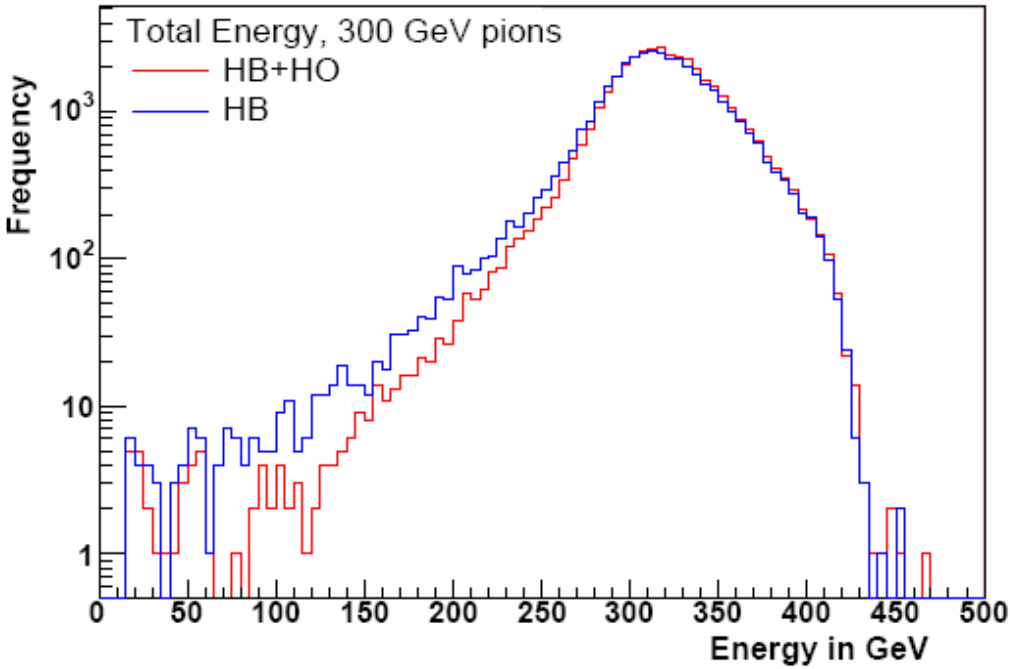


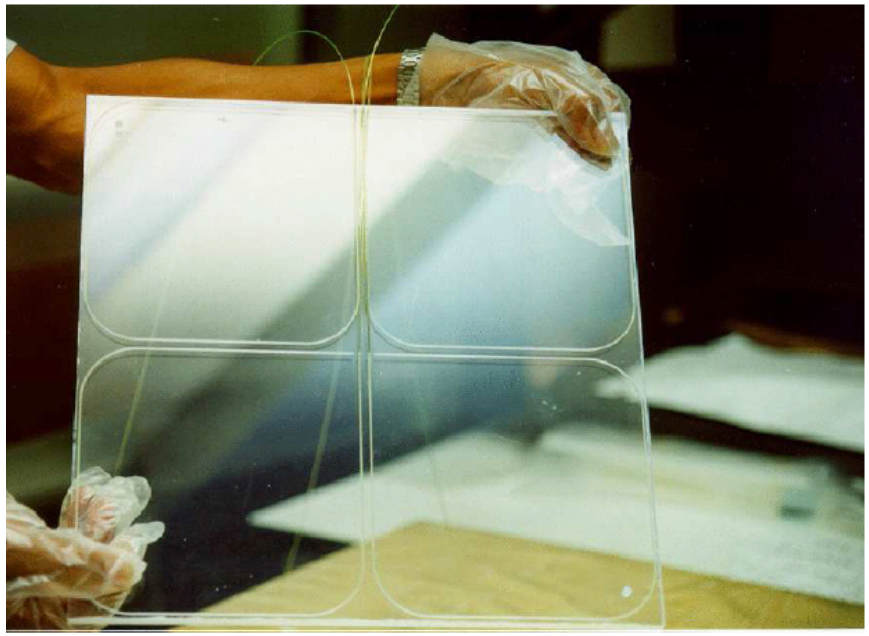


Hadron Outer (HO)

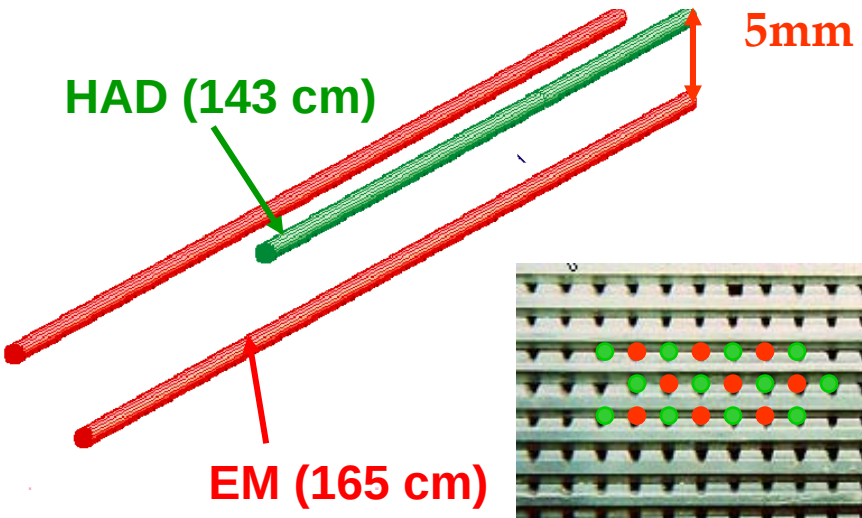








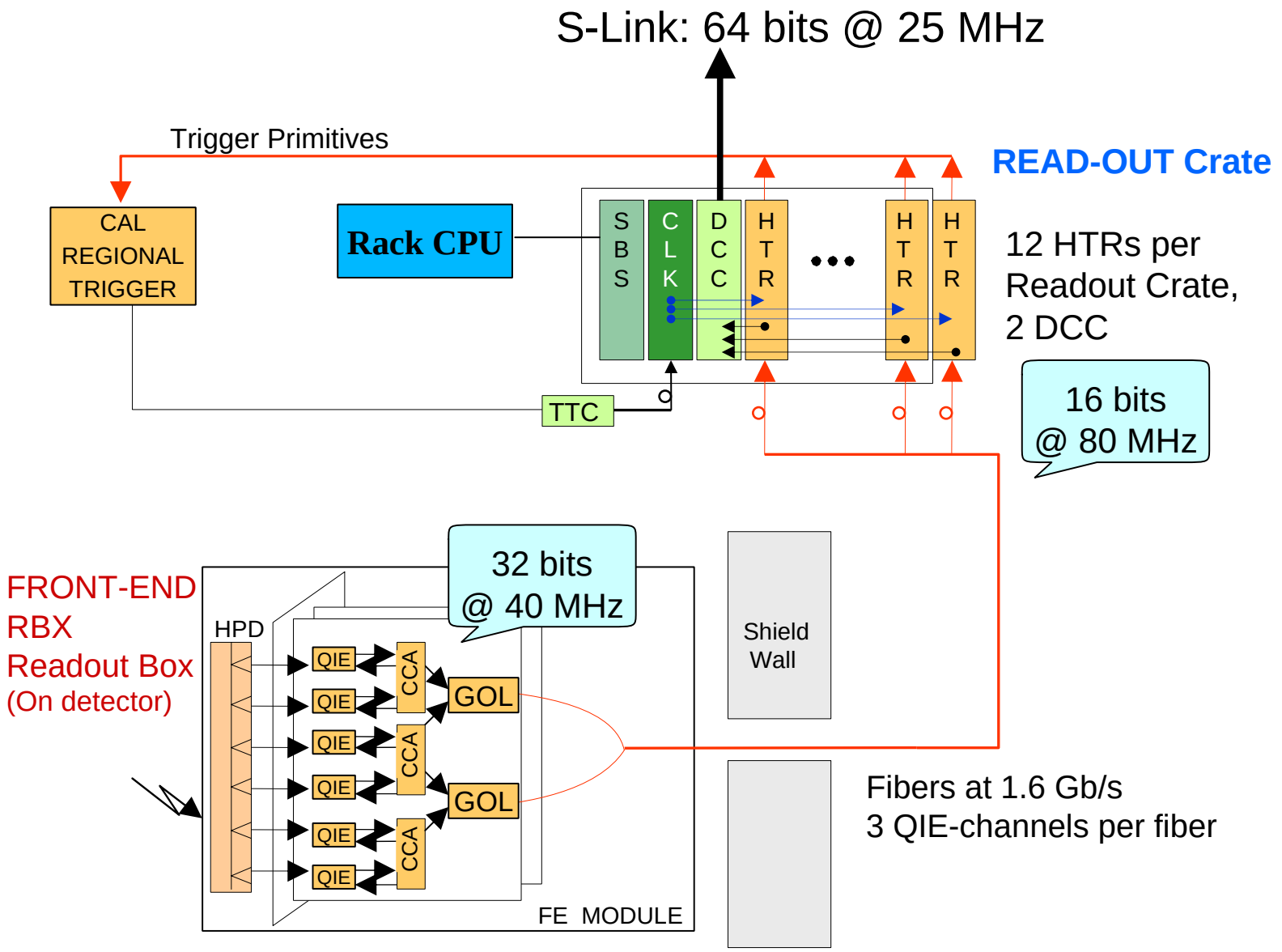
Hadron Forward (HF)



To cope with high radiation levels (>1 Grad accumulated in 10 years) the active part is Quartz fibers: the energy measured through the Cerenkov light generated by shower particles.

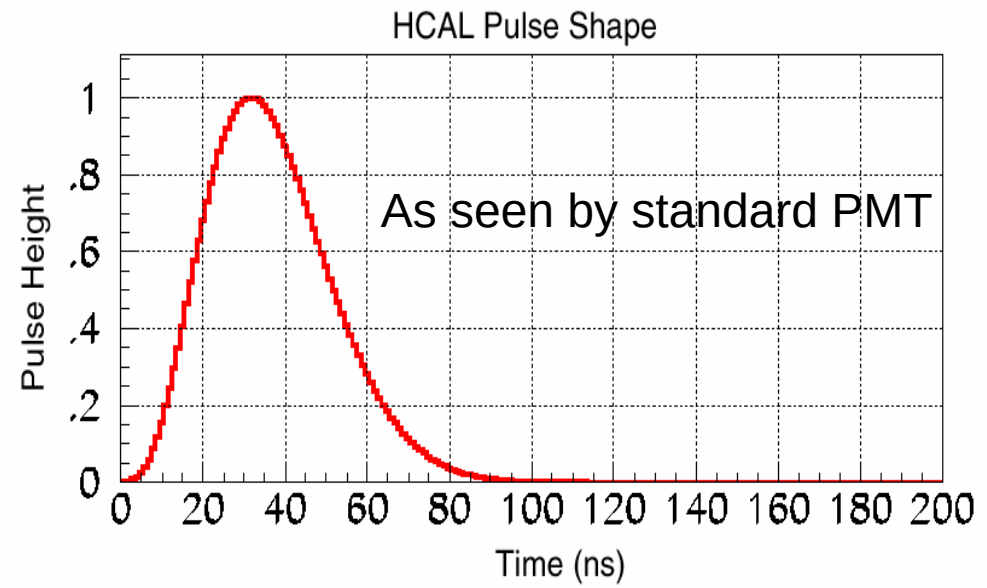
Iron calorimeter
Covers $5 > \eta > 3$
Total of 1728 towers, i.e.
2 x 432 towers for EM and HAD
η x ϕ segmentation (0.175 x 0.175)

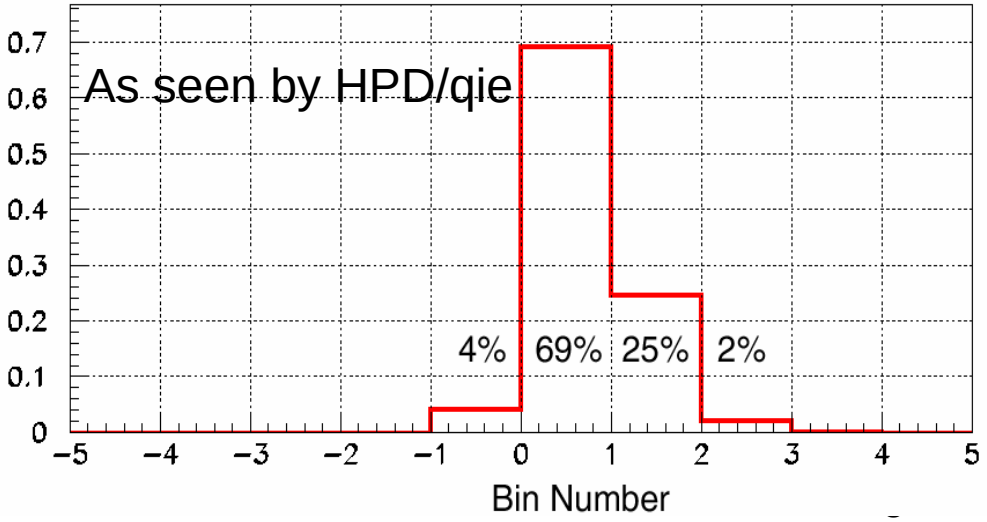
FE/DAQ Electronics



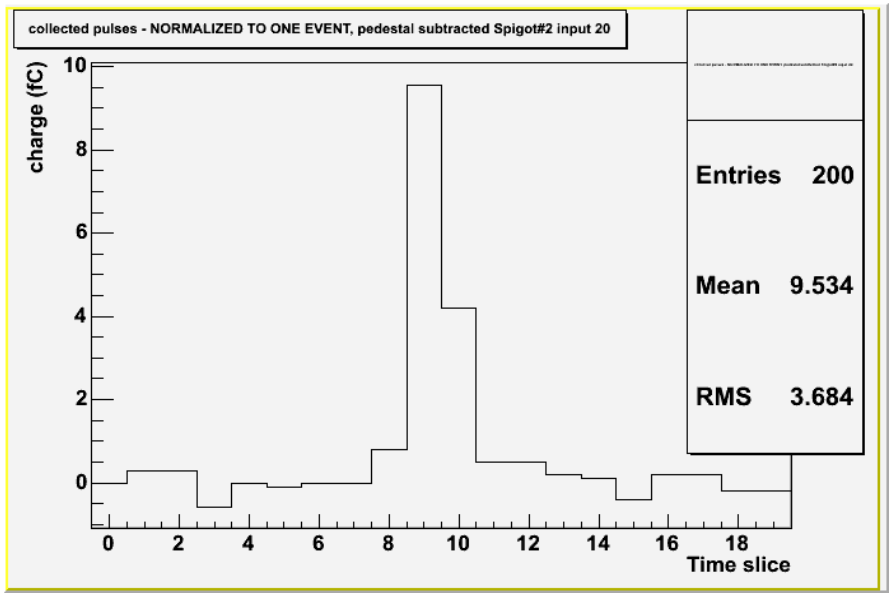
HCAL Pulse

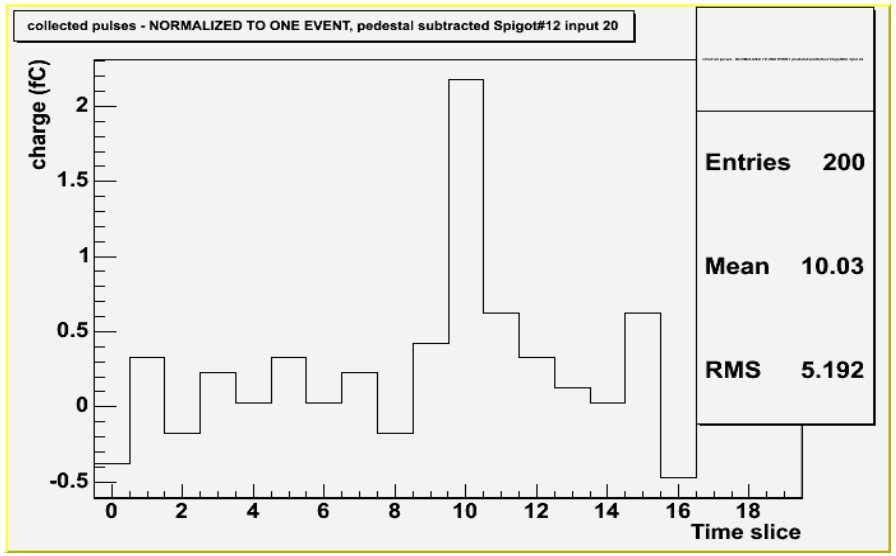
- Nominal HCAL pulse spreads over several 25ns buckets
  - Fraction in bucket is tunable via clock phase adjustment
- Need to recover "event" concept, associate energy to a single crossing (bucket) and report it to the trigger
  - TPG, trigger primitive





Average time (top) = 9.5 t.s



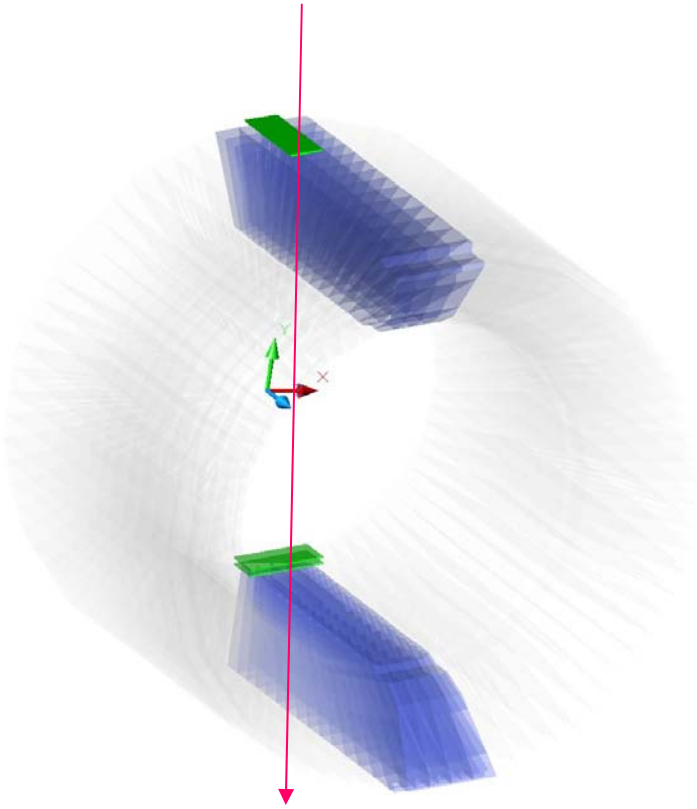


Average time (bot) =10.0 t.s

cosmic ray data taken in summer 2005

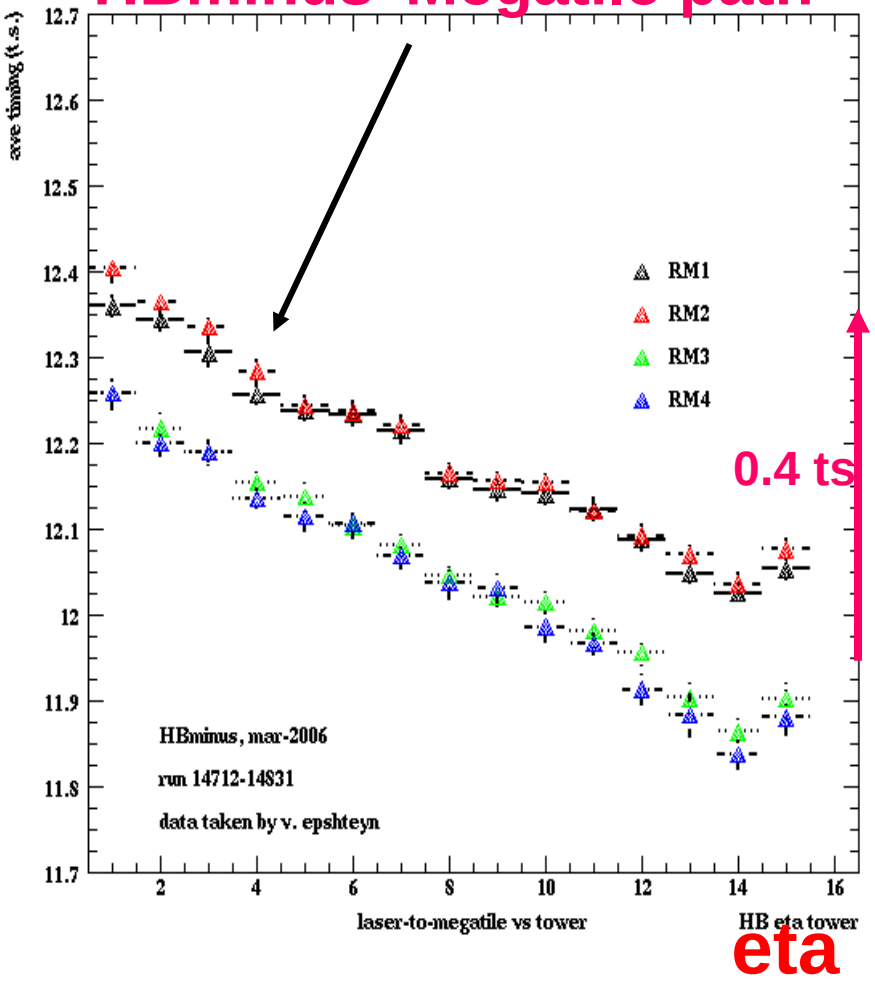
(HB only, external scintillator triggers)

Timing difference between Top and Bottom Wedges is 0.5 t.s ~ 12 ns.

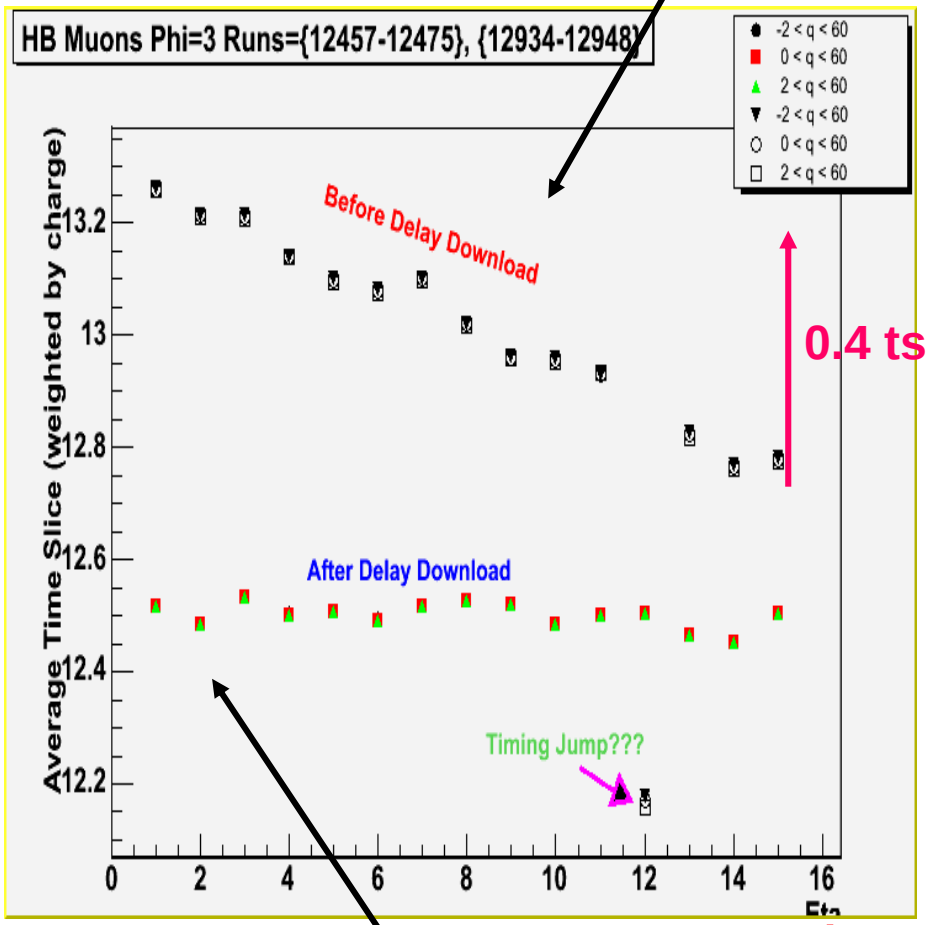


Laser timing (~1 nsec) vs eta tower

HBminus Megatile path



TB2004 muon data test beam



Tower TOF +light path differ by ~ 10 nsec. Laser and test beam agree-> download time delay corrections

HCAL energy calibration strategy

- LED pulsers:

check FE electronics, monitor stability of HPD gain

- Test-beam:

obtain absolute energy scale of HCAL (response to single particles), only few wedges

study response of calorimeter to particles in range of 2 GeV/c -300 GeV/c (linearity and resolution)

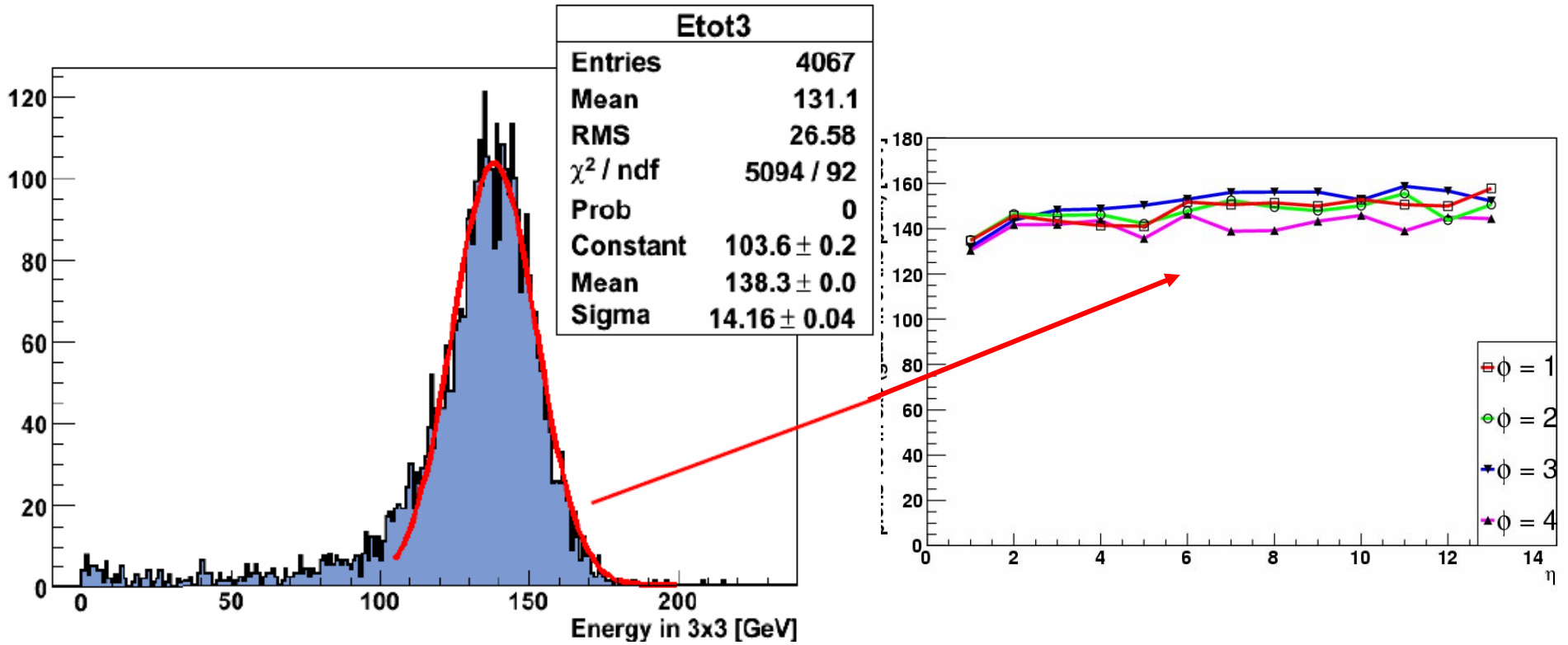
- Wire-sourcing:

obtain relative calibration constants for all HCAL towers

- Cosmic ray muons (mtcc):

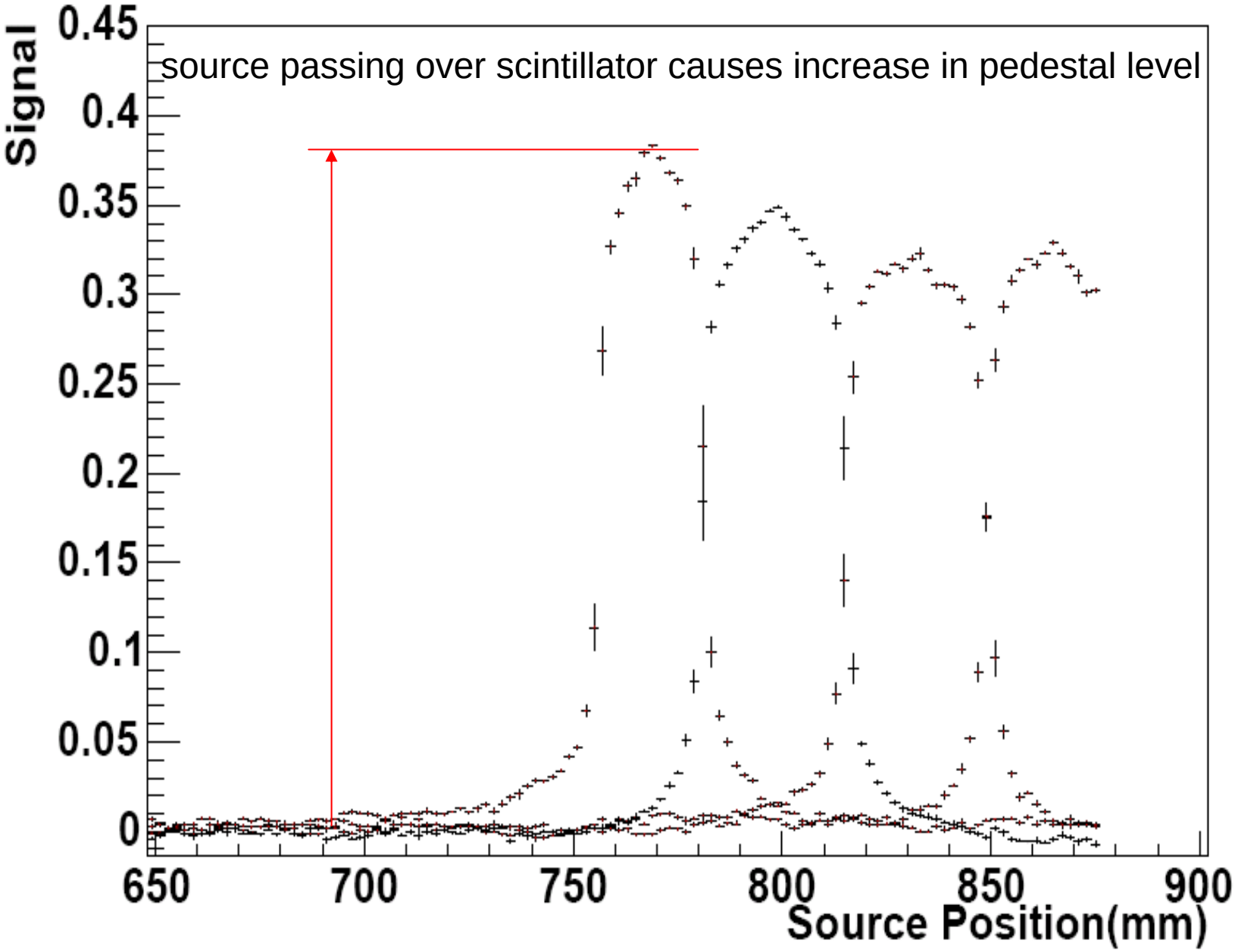
can cosmic ray muons be used to verify calibration of HCAL?

06 Testbeam First results: absolute energy scale (GeV/fC)

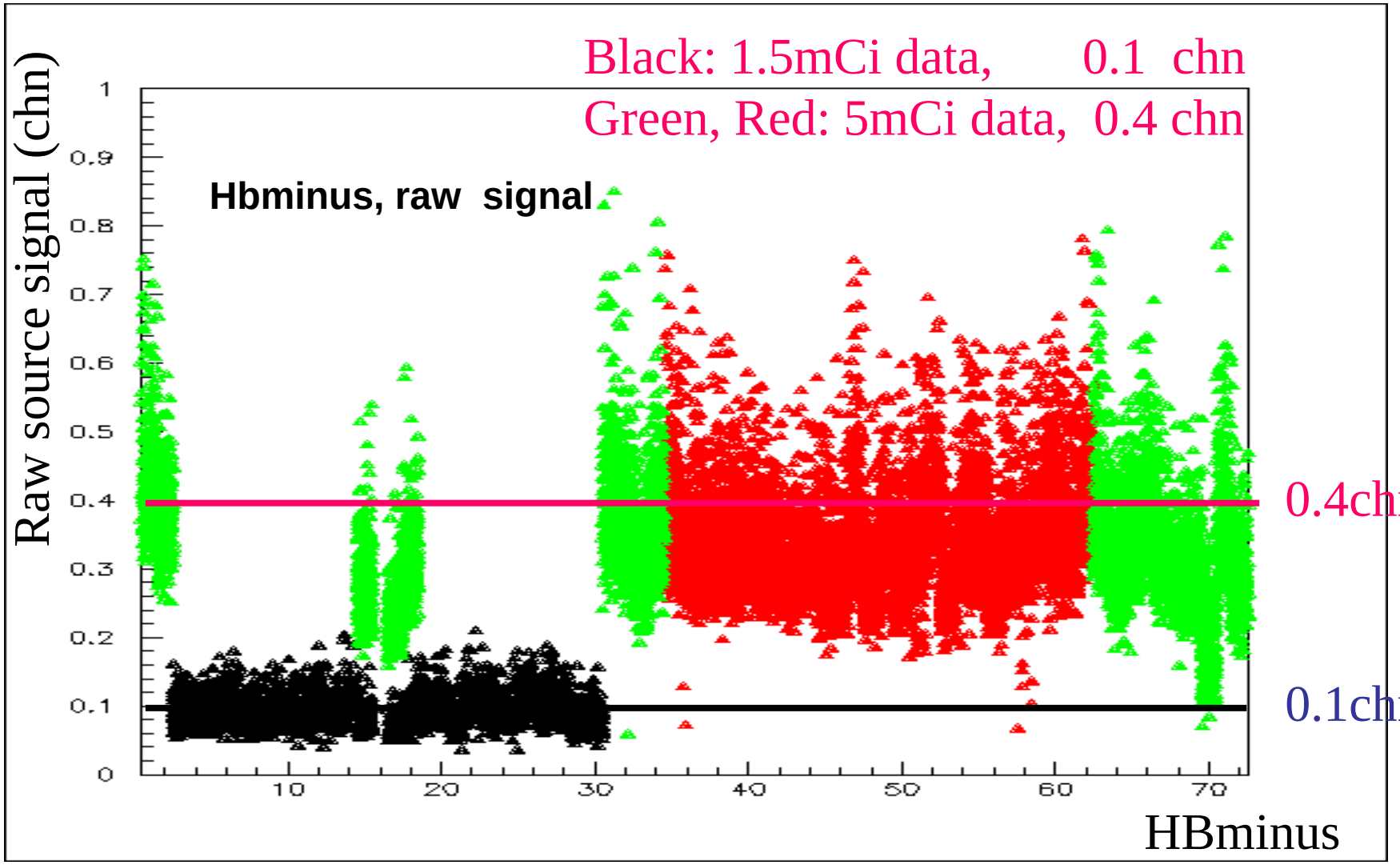


150 GeV pion scan of HB wedge.
3X3 tower sum

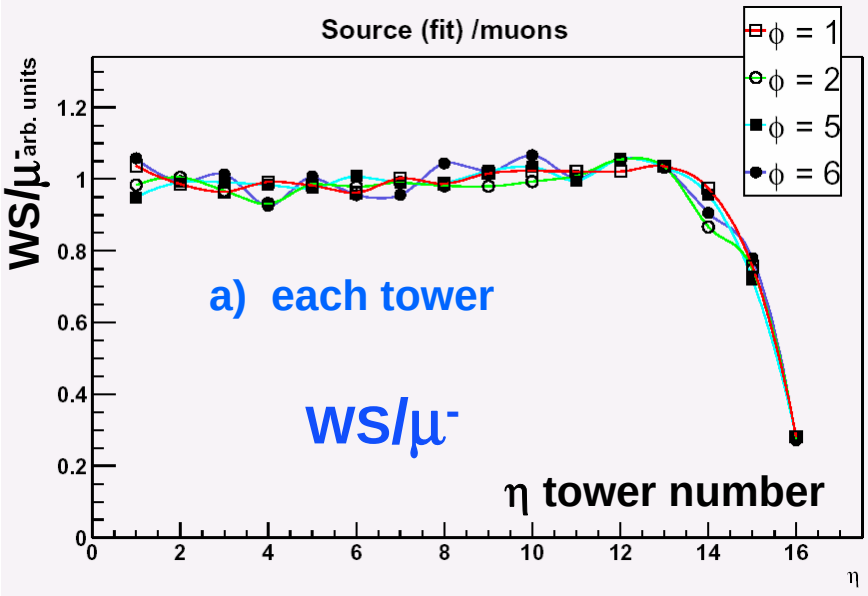
Calibration of HCAL with Co^60 sources

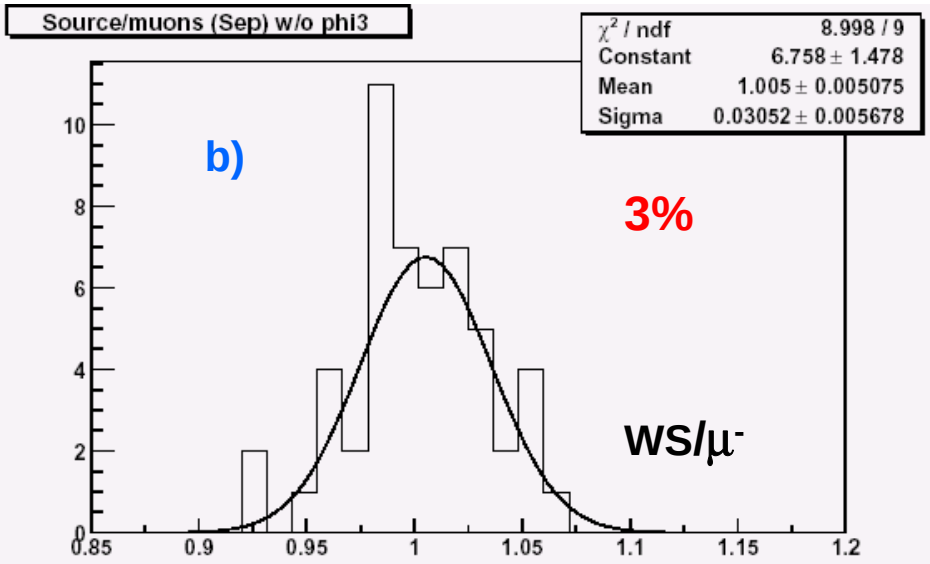


Precision of wire source tower-tower calibration (2%) two different source strengths- 8000 tile measurements

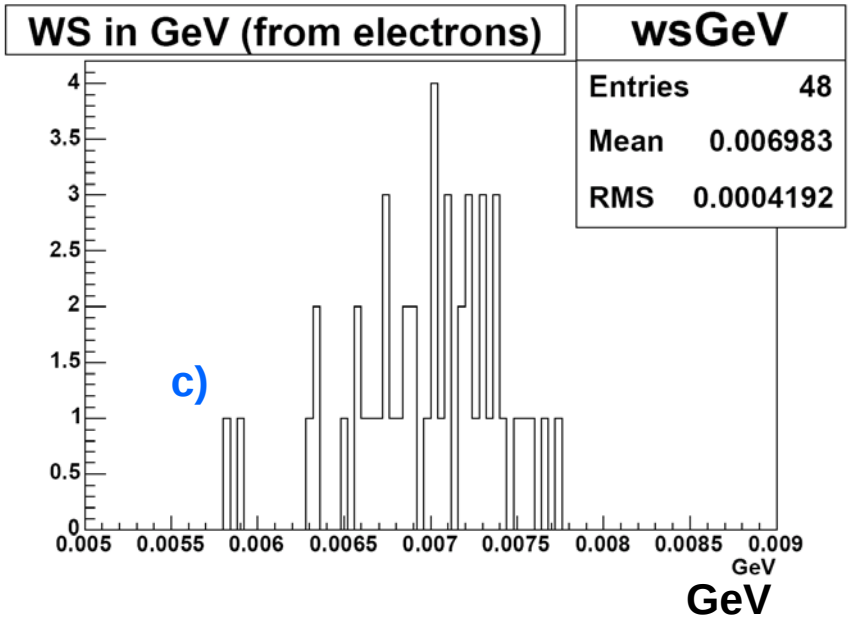


Muons and electrons vs Sources (TB04)



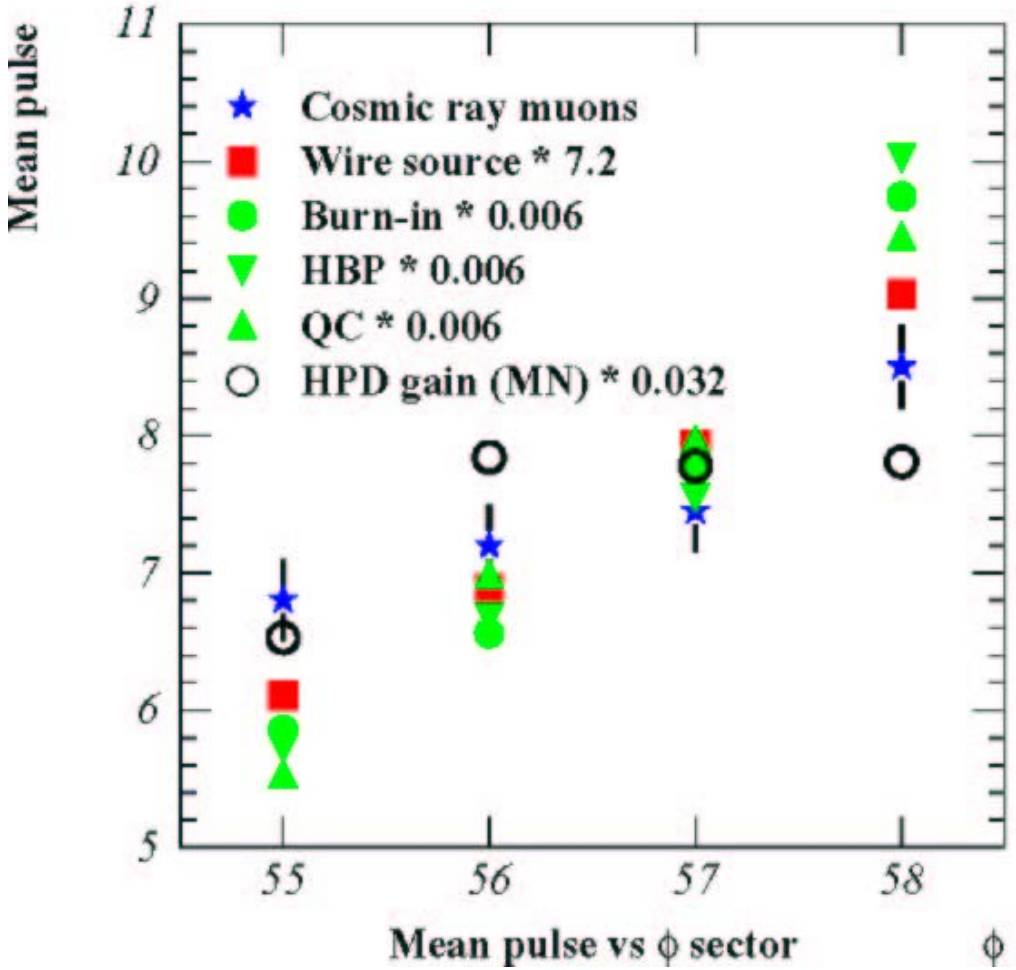


6% - to be improved



HCAL Calibration: Cosmic rays, wire source, LED

Average energy deposition in HCAL versus Phi



cosmic rays (average muon signals)

wire source calibration (re-scaled)

LED calibrations at different times

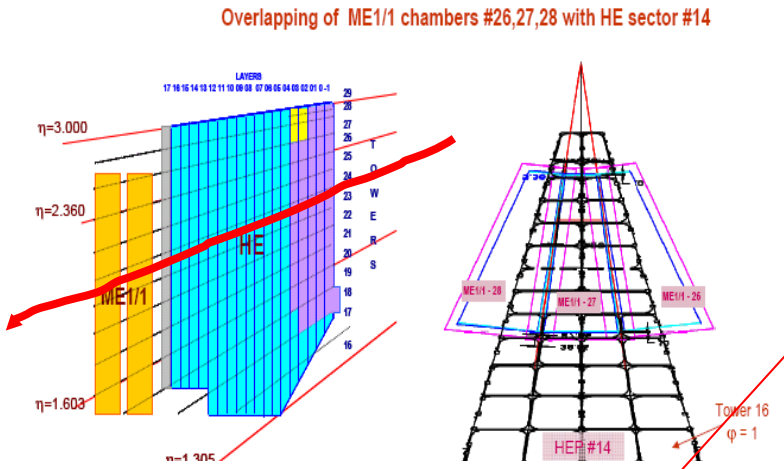
(shown as Burn In, HBP, QC,

HPD gain measurements)

summer 2005 data, HCAL alone,

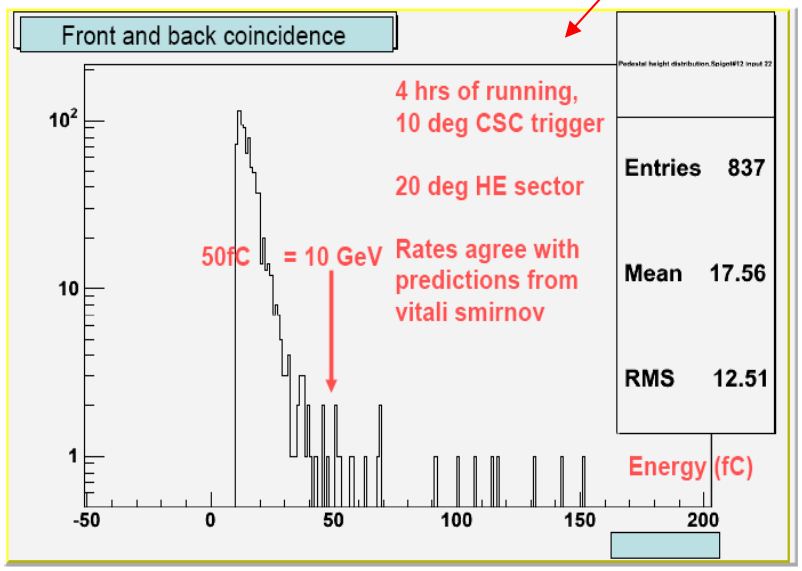
External scintillator trigger

HCAL calibration with cosmic rays, need tracking



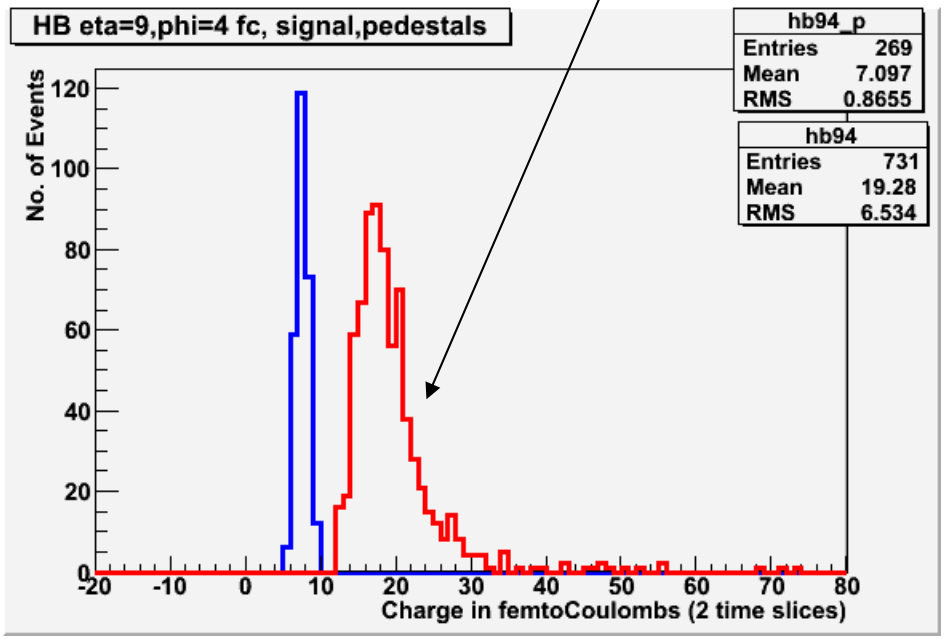
Muon energy spectrum,

signal above 5 fC (1 GeV) required for front and back towers

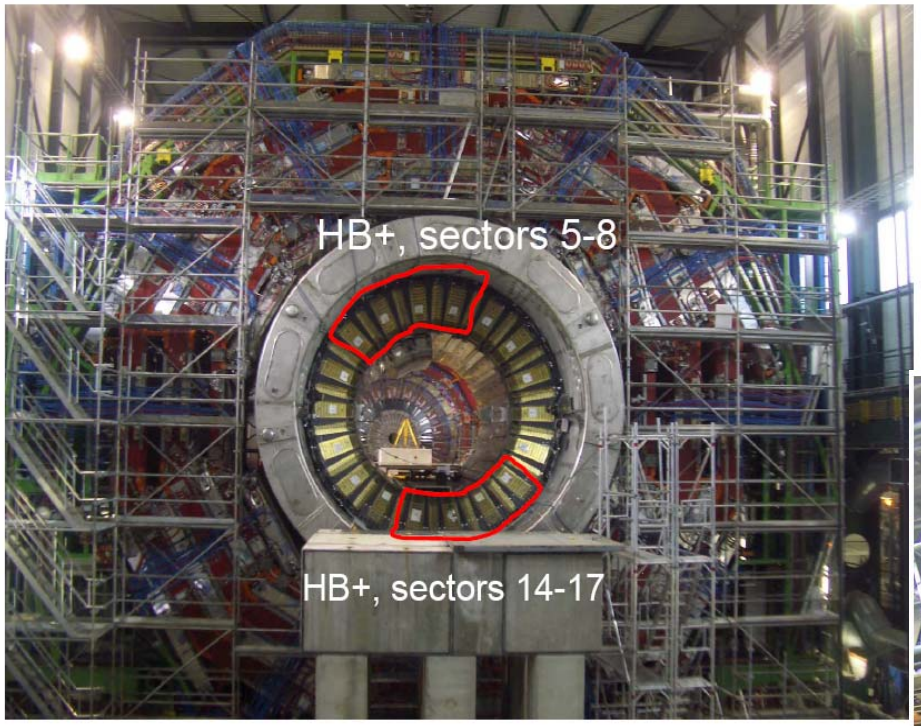


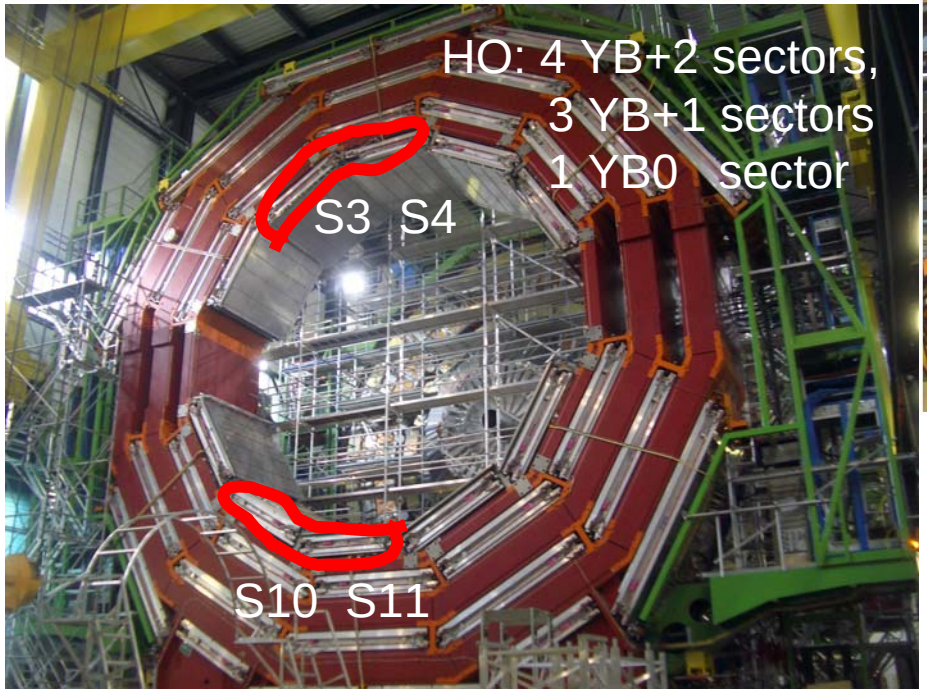
HCAL HE data, triggered on CSC
This plot was done
Without using tracking information:

Result from testbeam calibration
Energy spectrum of muons in HCAL
Muons along tower axis:
1k events/tower gives us ~1% accuracy



Sections of HCAL participating in mtcc

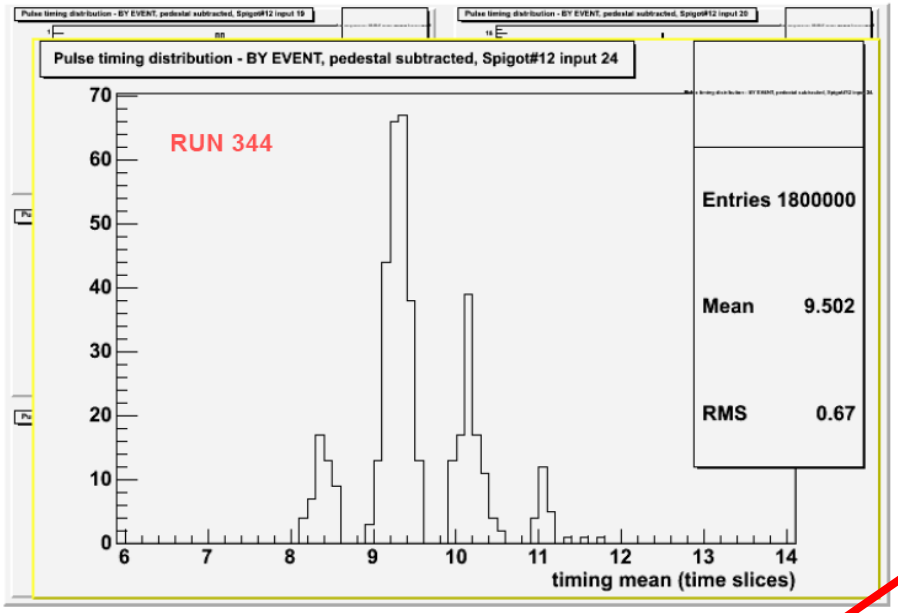


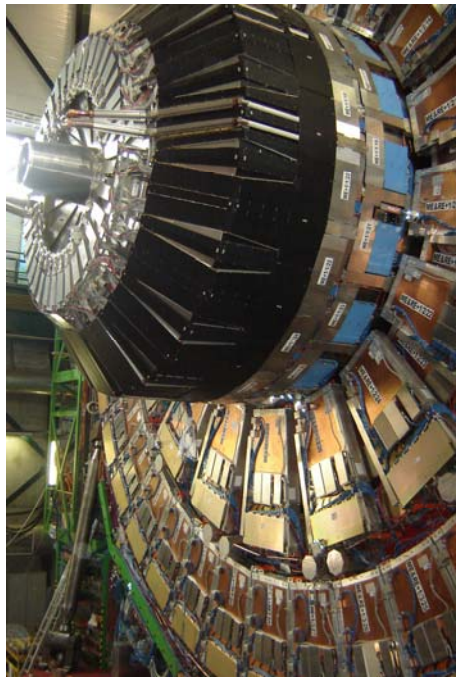


All services: water, N2, LV, HV, DCS, LED and Laser Calibration systems, FrontEnd, DAQ

Synchronizing of HCAL with CSC triggers

Average event time, 5k events passing 10 fC cut
in a single channel of spigot12





In late june, we have cabled up a single, HE+ sector (20deg in phi) to daq in the green barrack

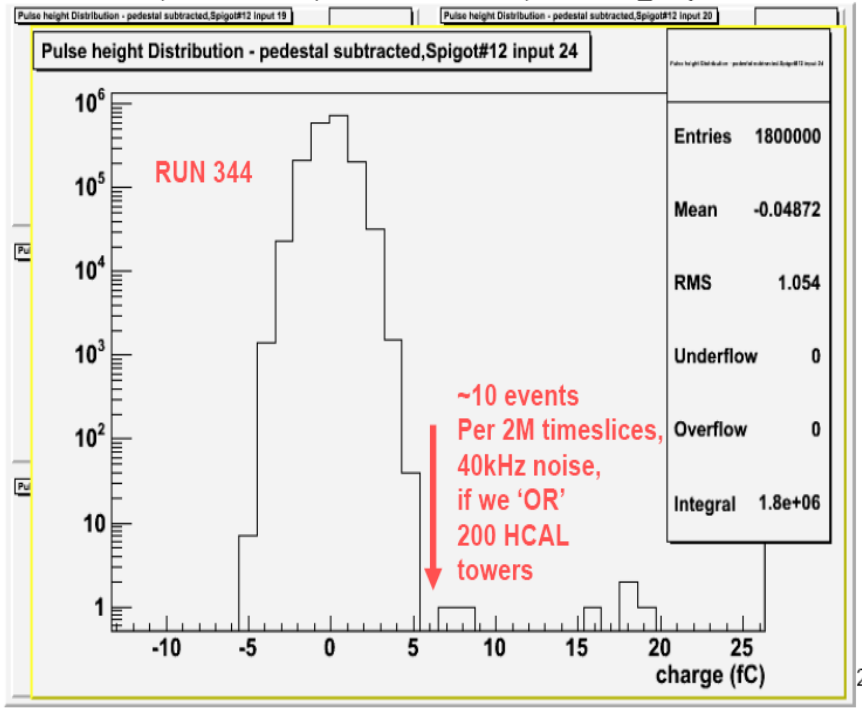
HE muons runs using HCAL local DAQ and CSC trigger
Trigger on ME1/1, chamber 27 (10deg)
Read out HE+, sector 14 (20deg)

Trigger rate ~5Hz,
100k events in less than 5 hrs

Using local daq and CSC trigger (during pre-mtcc CSC/HE run), prior to closing the detector

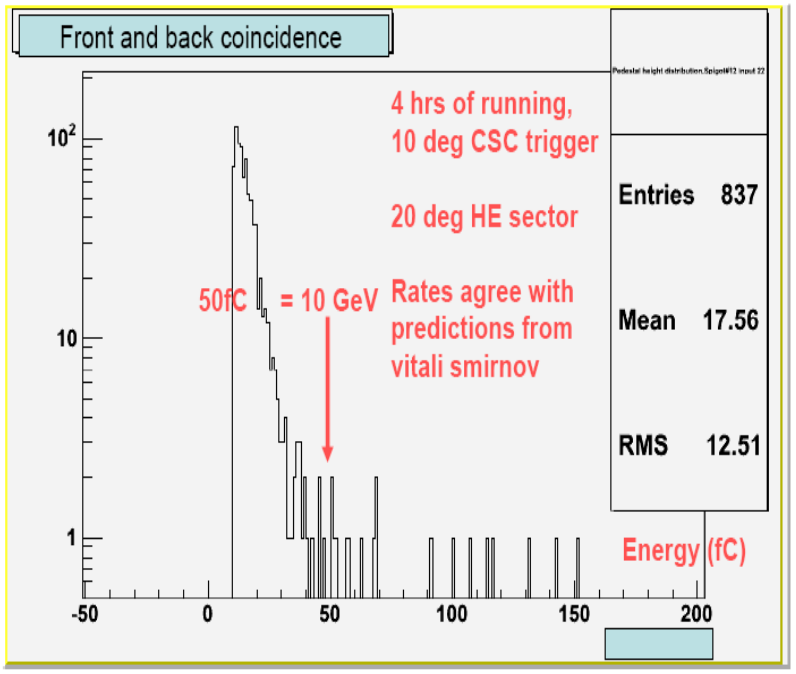
HCAL internal trigger

1.8M entries, 18 qie channels of spigot12
ts1+ts2, rms=1ts, 6 evts> 5fC, average ped. Subtr



Muon energy spectrum,

signal above 5 fC (1 GeV) required for front and back towers

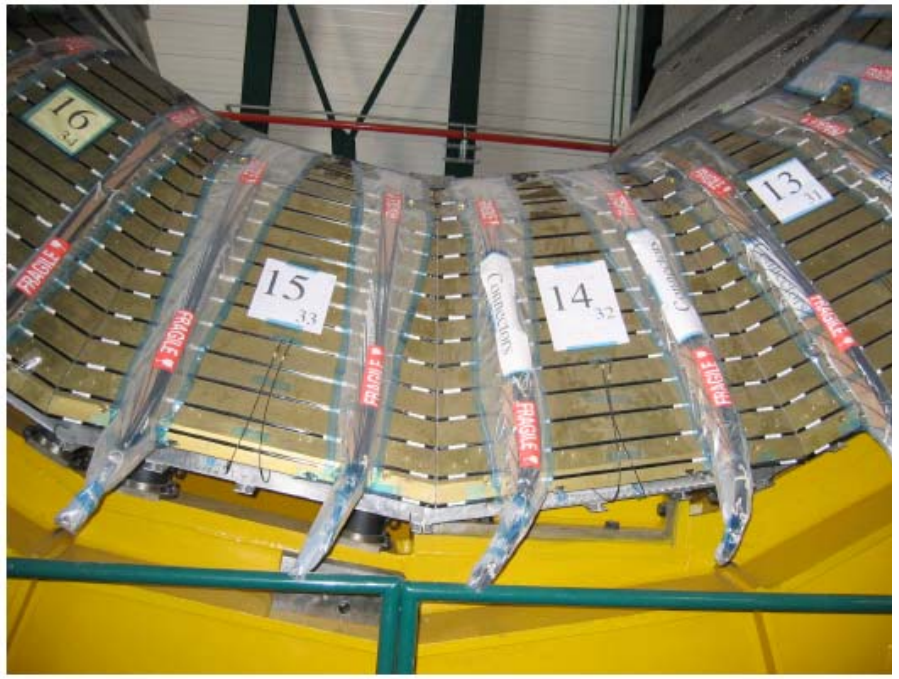


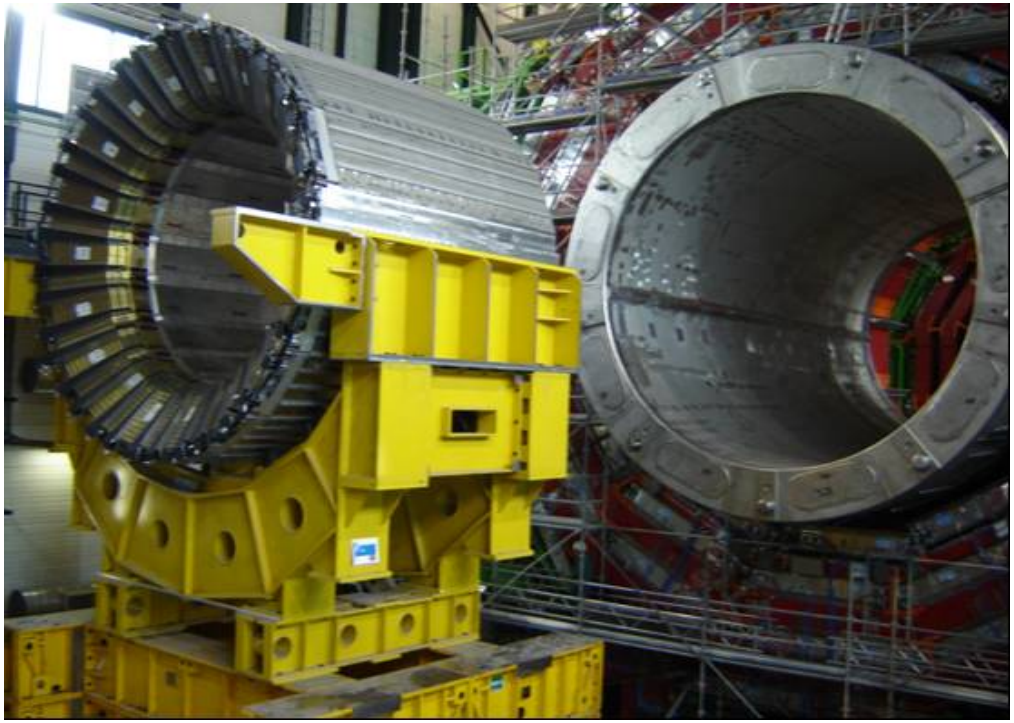
33

Typical ped RMS 1 fC for 2bx sum, muon going thru entire tower has average of ~ 15 fC
We can use average pedestal subtraction
keep running sum of two qie counts for consequitve time-slices
Set threshold 5-10 fC above pedestal
Create OR of HB_top towers above thershold
Create OR of HB_bottom towers
Require AND between TOP and BOTTOM, expect rates ~ 10Hz

HB Installation status

Barrel wedges assembled into half-barrels,
Instrumented with scintillators
and Front-end readout boxes,
Inserted into the magnet for mtcc





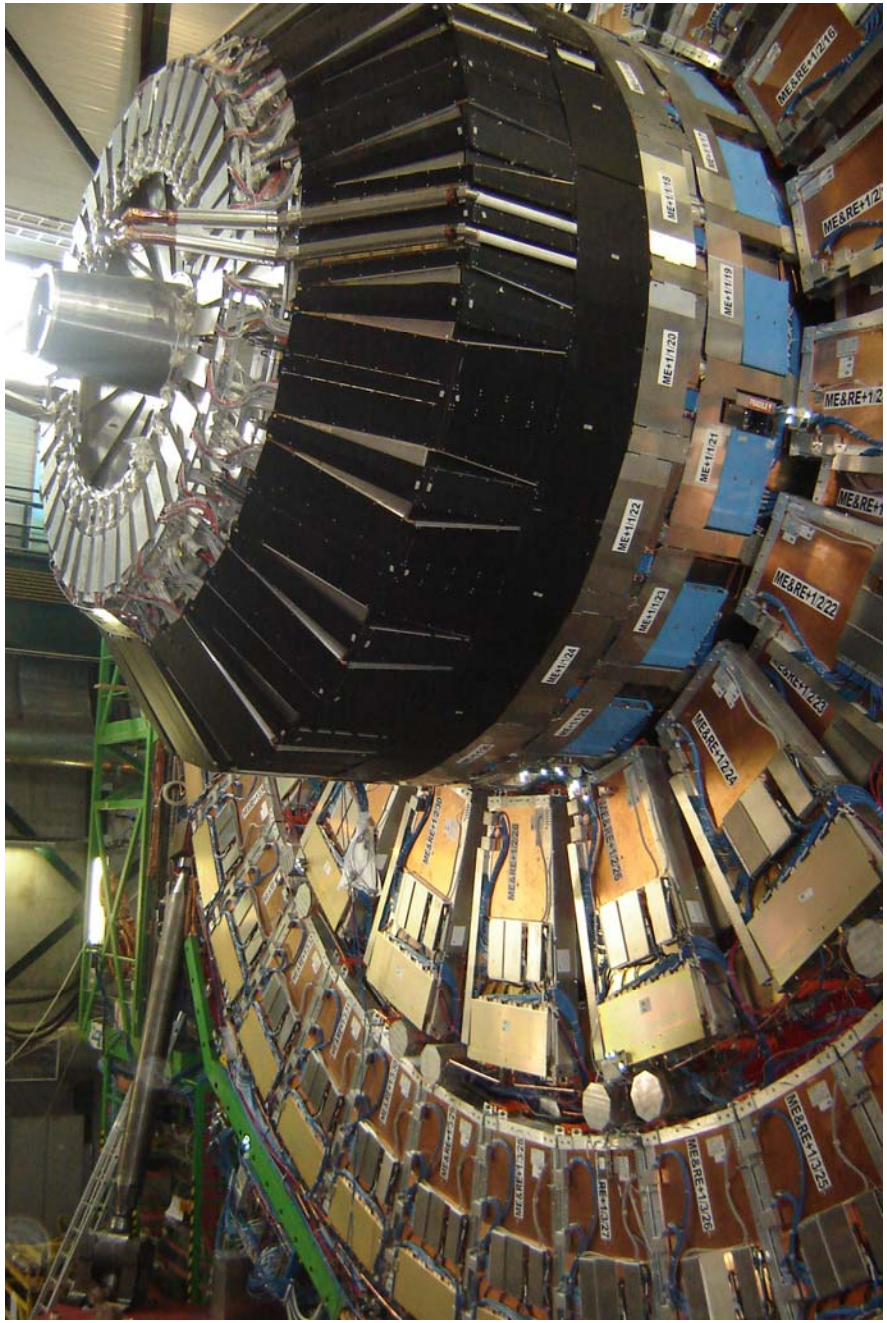
after mtcc HBs will pulled out of magnet

ECAL Barrel SuperModules will be installed into it

HB+EB half-barrels will be lowered into the underground separately from magnet and re-inserted underground

HE Installation status

- both Endcaps fully installed and cabled up to the on-detector patch panels
- HE will be lower as integral part of YE disks,
- cabling from patch panels to service hall is in progress)

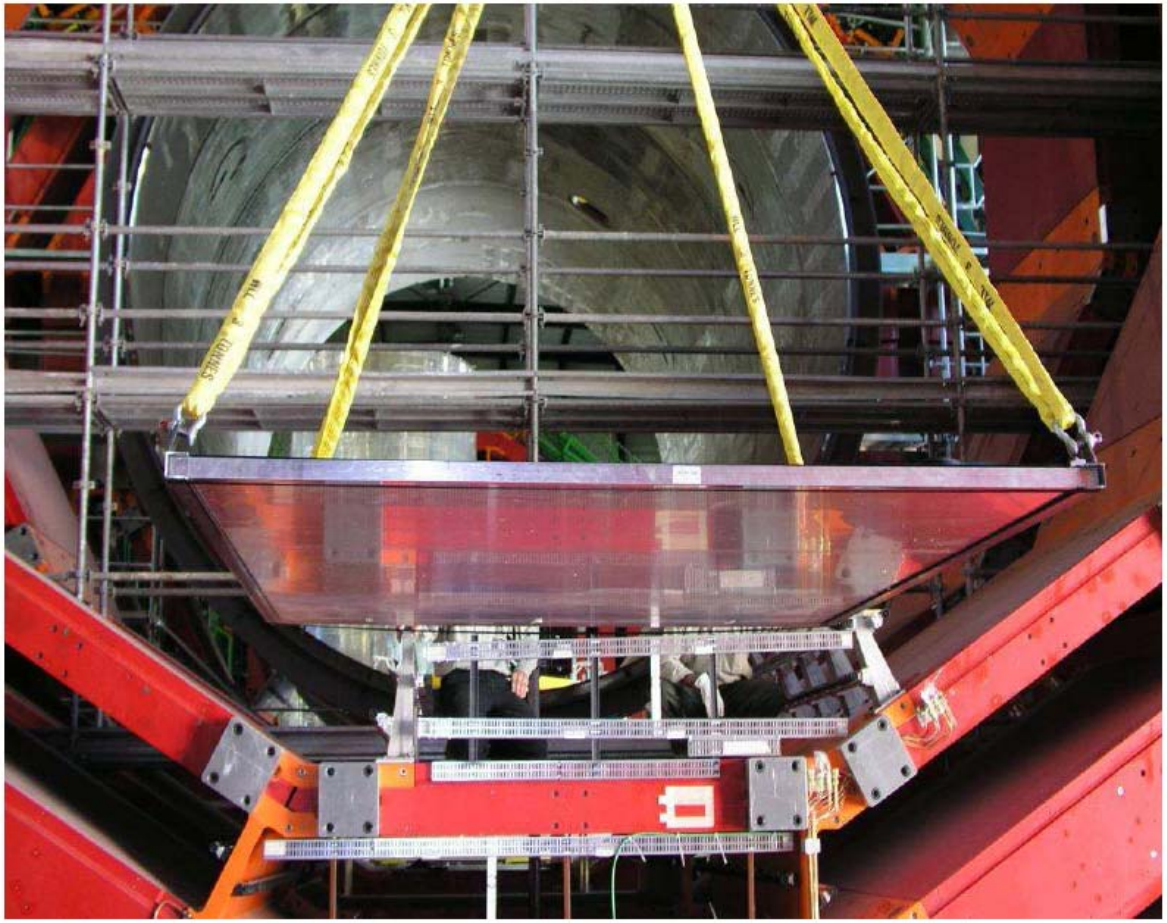


HF installation

- Two HFs fully assembled and commissioned, ready to be lowered to the uderground hall (ux5)

HO installation

- HO scintillators will be installed into five YB disks
  - Only YB+2 is fully installed right now
- Next two disks (YB+1, YB0) will be completed in Nov/Dec 2006
- Remaining two by March 2007



HPD x-talk problem in HO

1.we have identified and understood the problem:

x-talk is due to mis-alignment of HPD with respect to B field

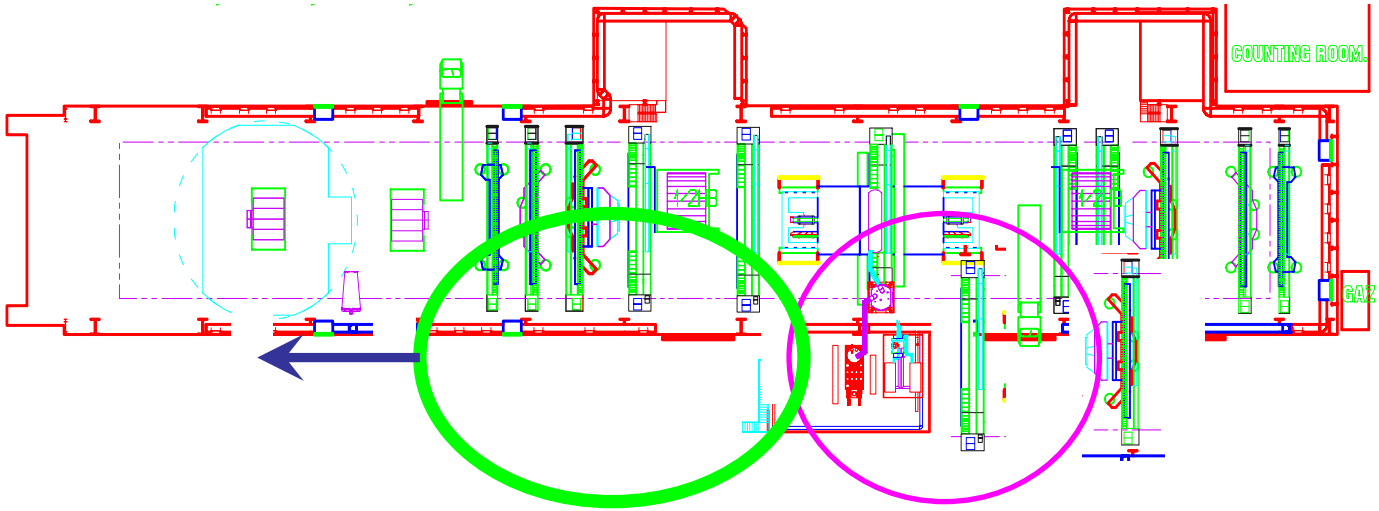
2. we have outlined possible solutions:

a) repositioning of RBXes in z

b) re-shaping Bfield by introducing soft-iron wedges

c) replacing HPDs with SiPM (for 2008)

Post-mtcc period:



Open –end first, since muon installation here is the critical path

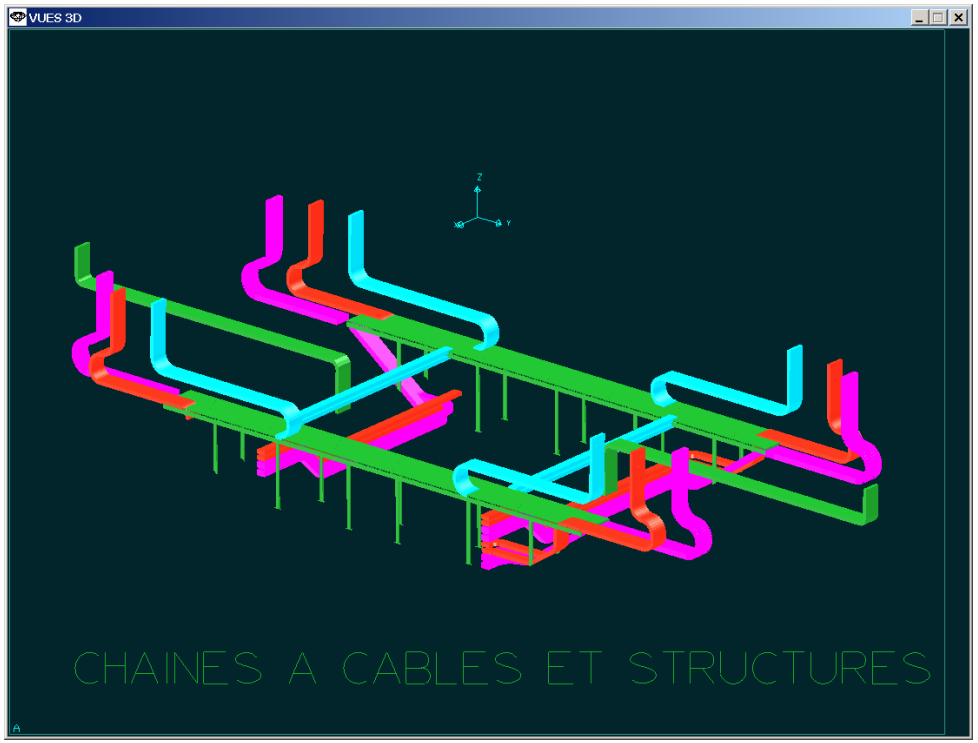
Completion of YB0 DT/RPC and HO work is first priority

Aim to lower YB0 ~2 months after opening magnet

Thereafter, aim to work on YB-1 and YB-2 simultaneously

Lower YB-1,-2 and endcaps in one programme after end Feb 07

Start commissioning work in UX5 march 07



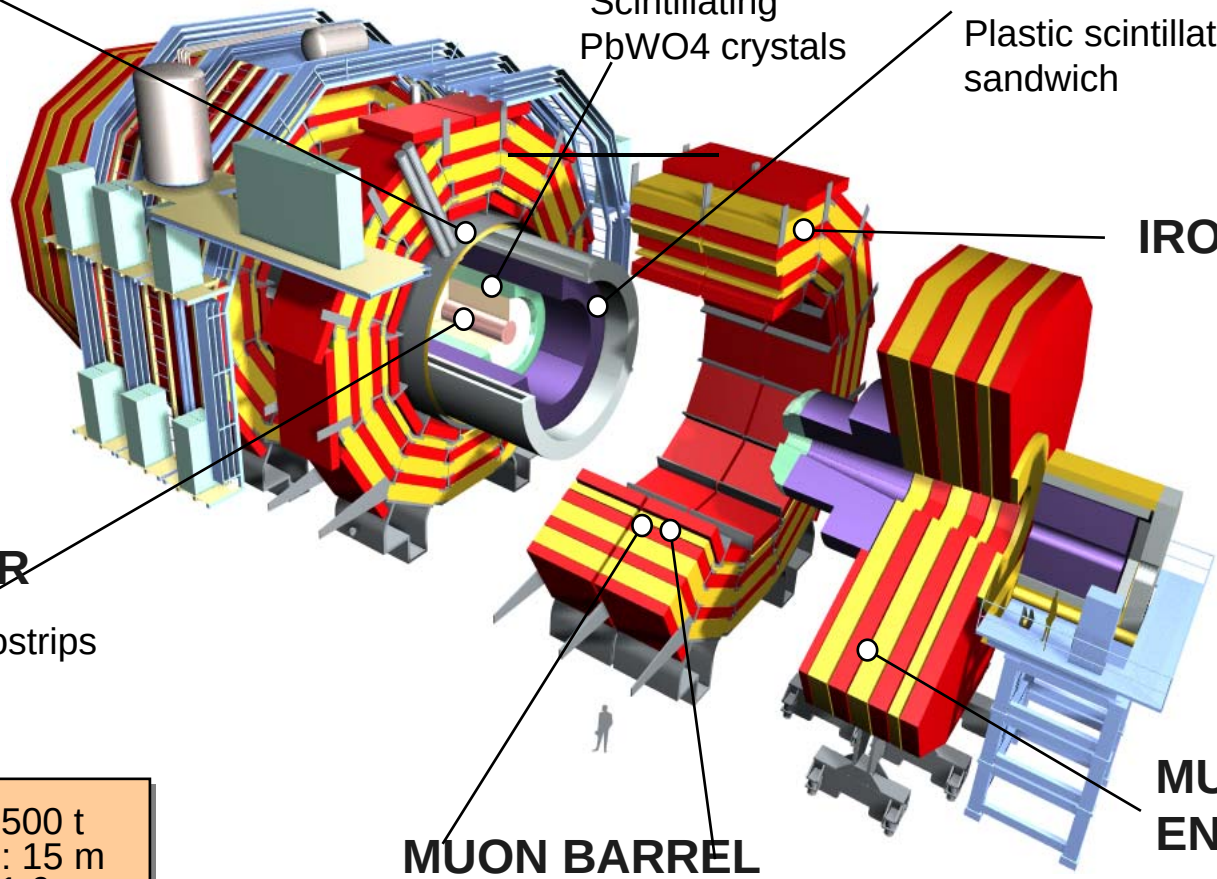
summary

- >10 years of work on HCAL, from early R&D, engineering desing, production of absorber, scintillator panels, readout electronics
- Installation of HCAL is almost complete, commissioning and calibration underway
- HCAL (HF) will be first cms detector to be lowered, Oct 2006
- Ready to go underground !


caffe bar · ROMANA

Back-up slides

The CMS Detector

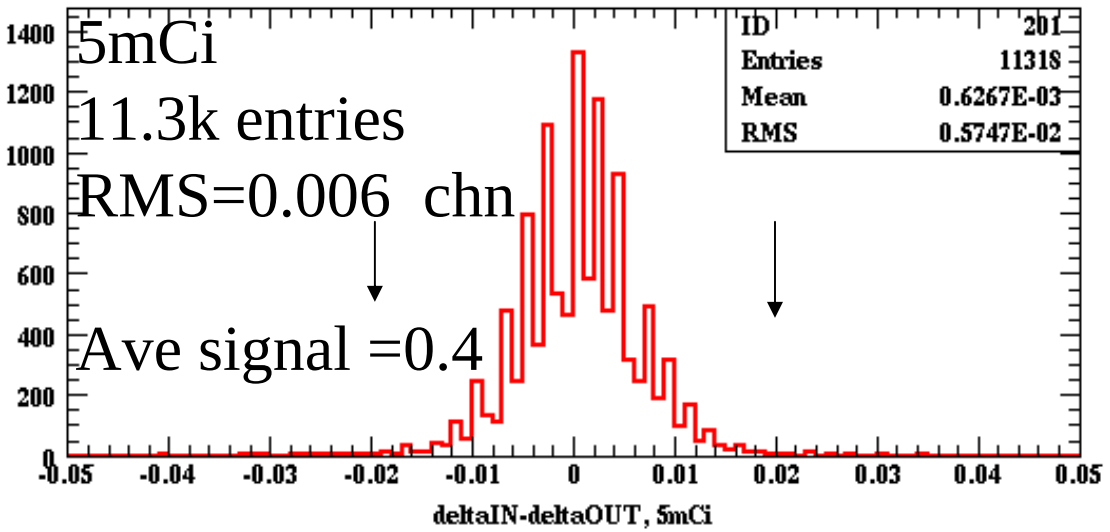


Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

Accuracy of Co-60 radioactive source calibration

RMS of difference
~ 0.006 channels
This is an absolute signal uncertainty,
not a relative error

Single tile relative error:
1.5% for 5mCi data



Statistical error of calibration constants for HCAL towers using weighted sum of individual tiles

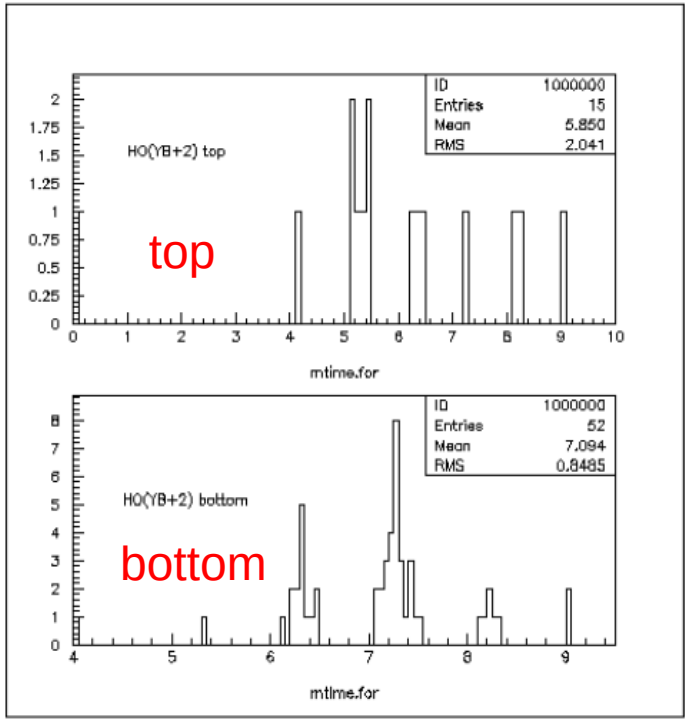
5mCi data,
Relative error on singal for towers = 0.6%

relative difference of tower calibration constants,
using 50 Gev pion weights
(all pions vs pions-mip-in-ecal).

RMS for 5.0mCi data is 1.5%

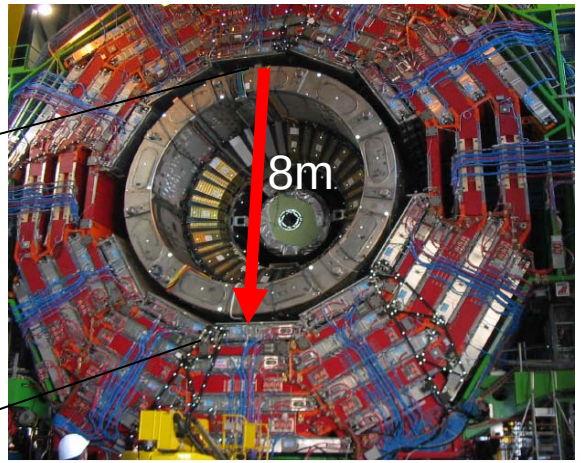
HCAL timing wrt to DT trigger

HO,YB+2 top vs bottom

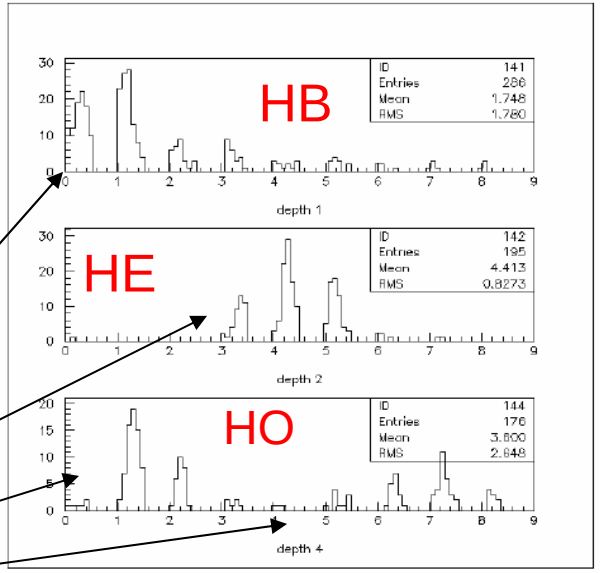


Top: 5.85 bx
Bottom: 7.08 bx

Distance ~ 8m or 25ns



Timing of HB, HE, HO, r2242



Cable lenths:

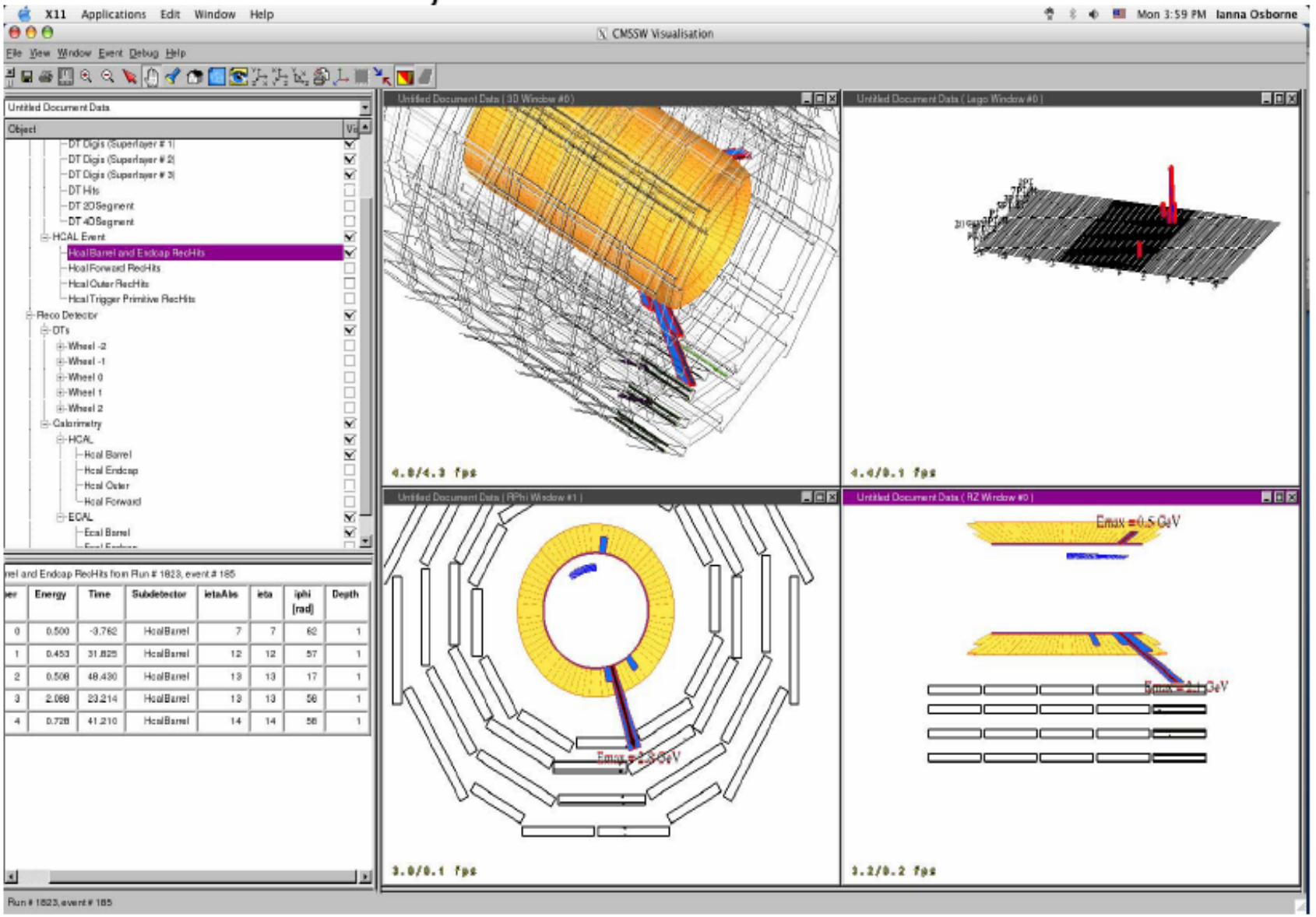
Extra 17m for HE
Extra 35m for HO(YB2)

Pipeline delays:
HB, HE, HO(yb0,yb1) =81

HO(yb2) =79

Difference in timing caused by extra cable lengths between detectors and daq in green barrack. This can be corrected by adjusting pipeline delay in HTRs

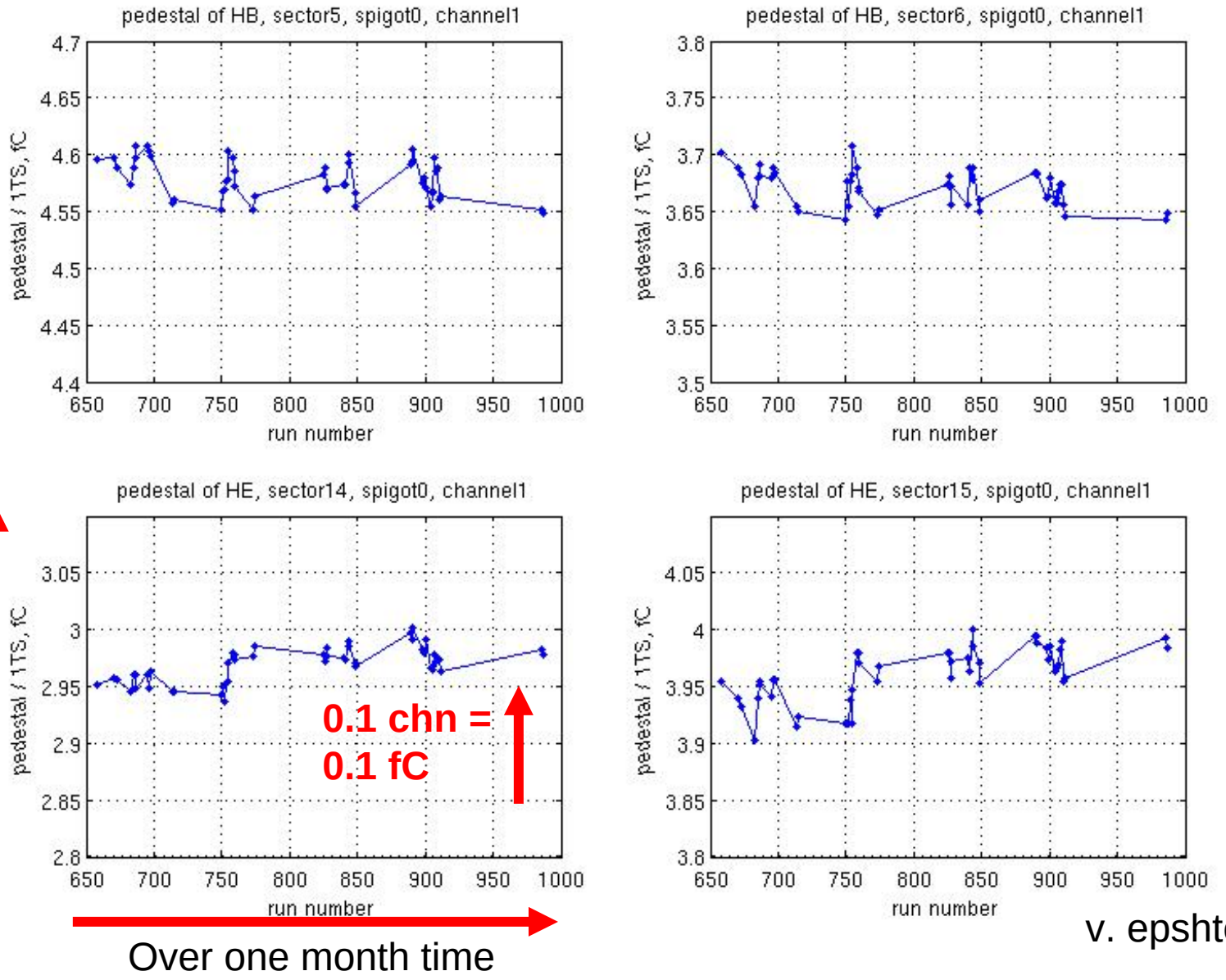
R1823, muon in DT and HB



	Energy	Time	Subdetector	ietaAbs	ieta	iphi [rad]	Depth
0	0.500	-3.762	HcalBarrel	7	7	62	1
1	0.453	31.825	HcalBarrel	12	12	57	1
2	0.508	48.430	HcalBarrel	13	13	17	1
3	2.089	23.214	HcalBarrel	13	13	58	1
4	0.728	41.210	HcalBarrel	14	14	58	1

Pedestal stability vs time

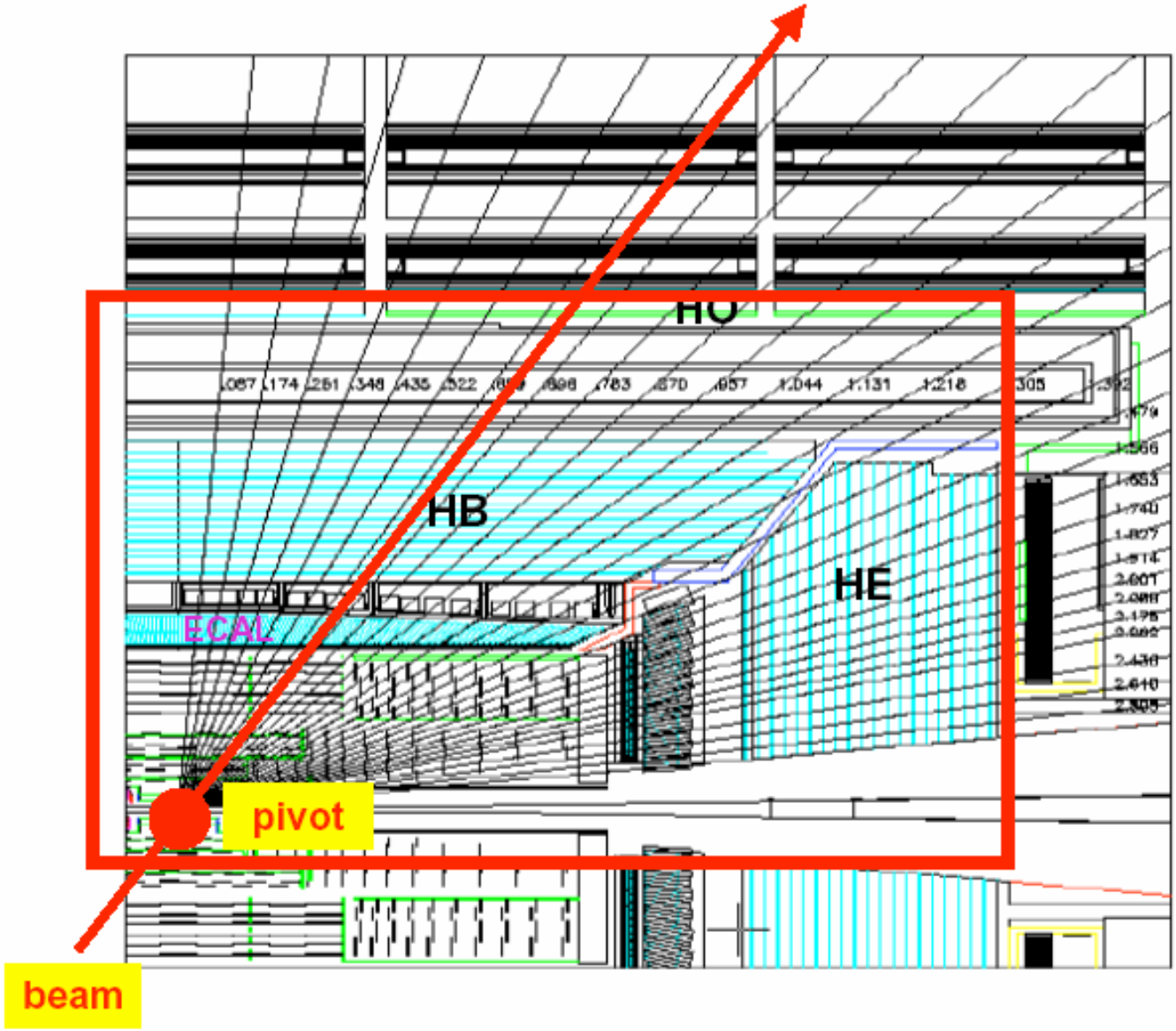
(using local DAQ)



v. epshteyn

HCAL+ECAL 2006
testbeam setup in H2

CMS Geometry at H2



Pivot of table
= IP at LHC

A phi slice of
CMS HCAL

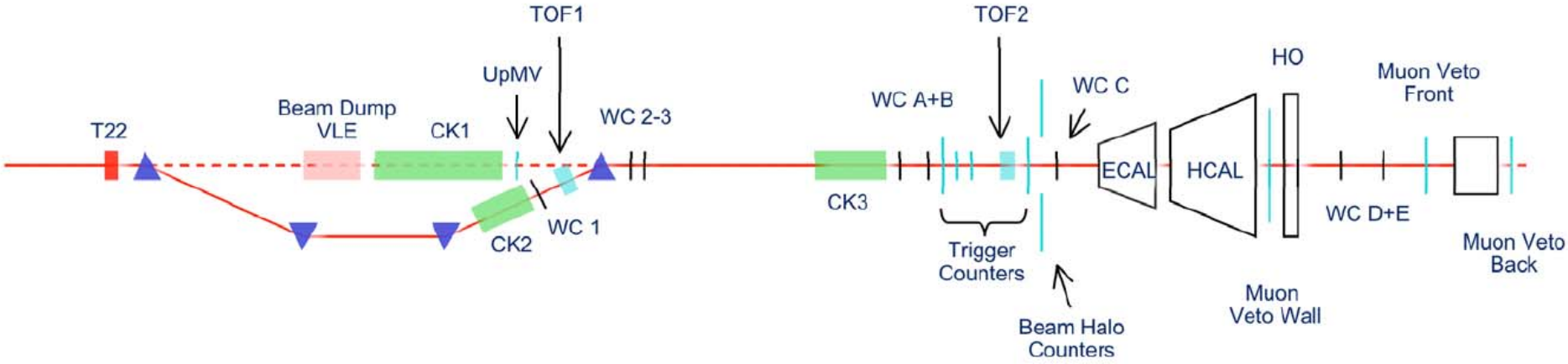
HB: 2 wedges
8 ϕ segments
$\Delta\phi$ = 40deg.

HE: 4 ϕ segments
$\Delta\phi$ = 20 deg.

HO: Ring 0, 1 and 2.

ECAL: SM9

Beam Clean-up and P-ID



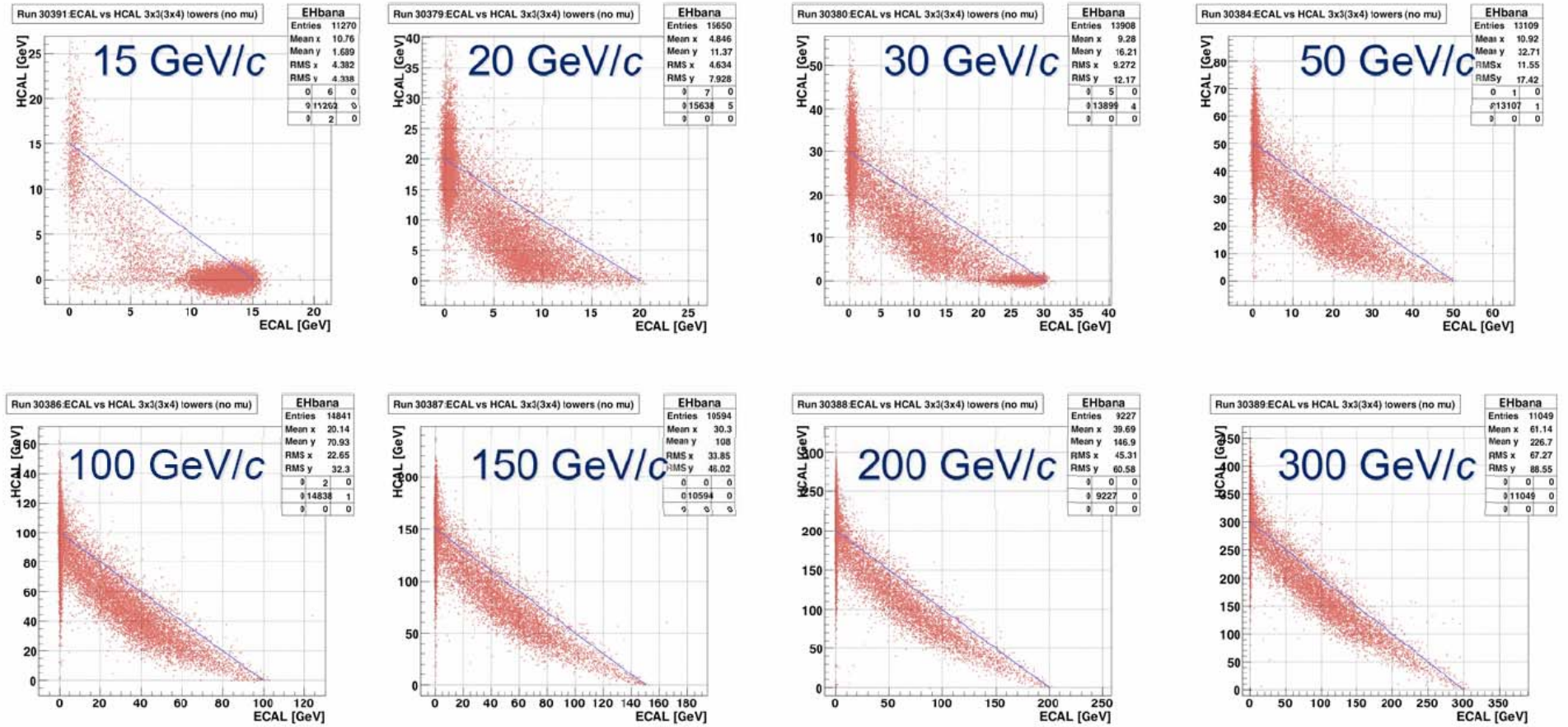
Removing Interaction in beam line:

Single particle in	S1,S2,S4
No wide angle secondaries	BH (beam halo counters, 7x7cm hole)

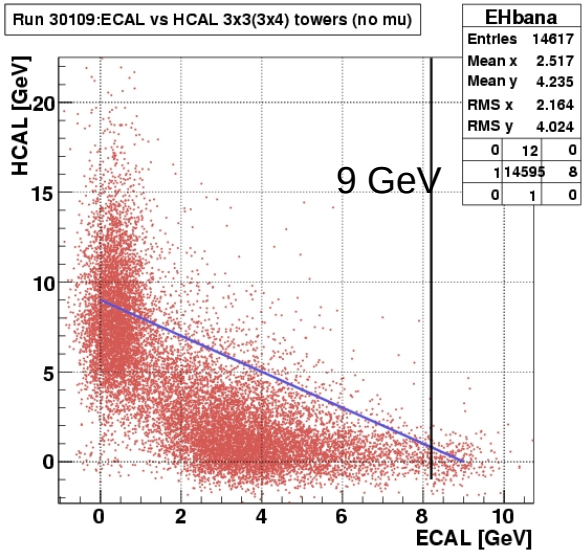
Particle ID:

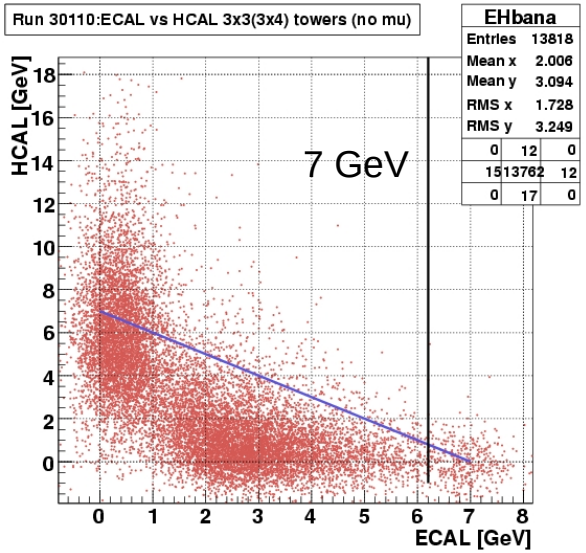
electrons:	CK2 (on) for p<9GeV, CK3(on) for p<3GeV
muons:	Muon Veto front/back, Muon Vero Wall
protons:	CK3 (off) and TOF for 1-9GeV
kaon:	TOF for p<4GeV and CK3 (on) & not-proton
pion:	rest.

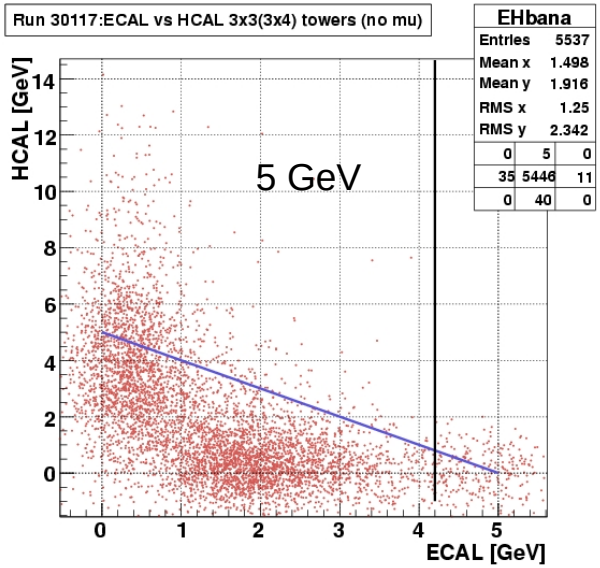
Bananas

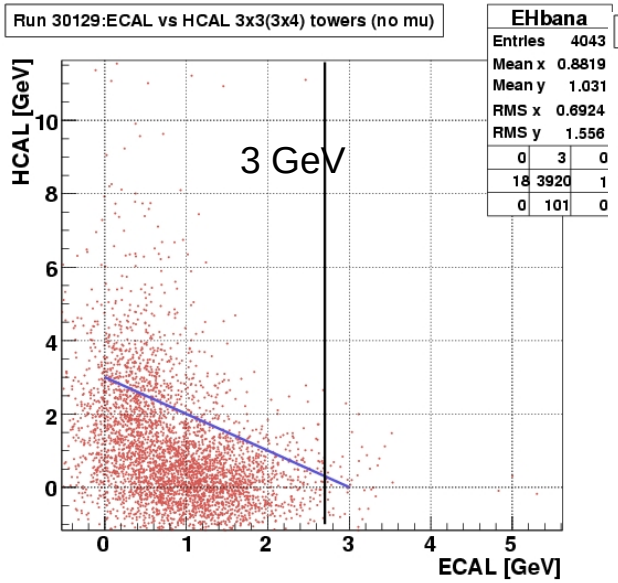

Run 30391:ECAL vs HCAL 3x3(3x4) towers (no mu)
EHbana
Entries 11270
Mean x 10.76
Mean y 1.689
RMS x 4.382
RMS y 4.338
15 GeV/c
HCAL [GeV]
ECAL [GeV]
Run 30379:ECAL vs HCAL 3x3(3x4) towers (no mu)
EHbana
Entries 15650
Mean x 4.846
Mean y 11.37
RMS x 4.634
RMS y 7.928
20 GeV/c
HCAL [GeV]
ECAL [GeV]
Run 30380:ECAL vs HCAL 3x3(3x4) towers (no mu)
EHbana
Entries 13908
Mean x 9.28
Mean y 16.21
RMS x 9.272
RMS y 12.17
30 GeV/c
HCAL [GeV]
ECAL [GeV]
Run 30384:ECAL vs HCAL 3x3(3x4) towers (no mu)
EHbana
Entries 13109
Mean x 10.92
Mean y 32.71
RMSx 11.55
RMSy 17.42
50 GeV/c
HCAL [GeV]
ECAL [GeV]
Run 30386:ECAL vs HCAL 3x3(3x4) towers (no mu)
EHbana
Entries 14841
Mean x 20.14
Mean y 70.93
RMS x 22.65
RMS y 32.3
100 GeV/c
HCAL [GeV]
ECAL [GeV]
Run 30387:ECAL vs HCAL 3x3(3x4) towers (no mu)
EHbana
Entries 10594
Mean x 30.3
Mean y 108
RMS x 33.85
RMS y 46.02
150 GeV/c
HCAL [GeV]
ECAL [GeV]
Run 30388:ECAL vs HCAL 3x3(3x4) towers (no mu)
EHbana
Entries 9227
Mean x 39.69
Mean y 146.9
RMS x 45.31
RMS y 60.58
200 GeV/c
HCAL [GeV]
ECAL [GeV]
Run 30389:ECAL vs HCAL 3x3(3x4) towers (no mu)
EHbana
Entries 11049
Mean x 61.14
Mean y 226.7
RMS x 67.27
RMS y 88.55
300 GeV/c
HCAL [GeV]
ECAL [GeV]

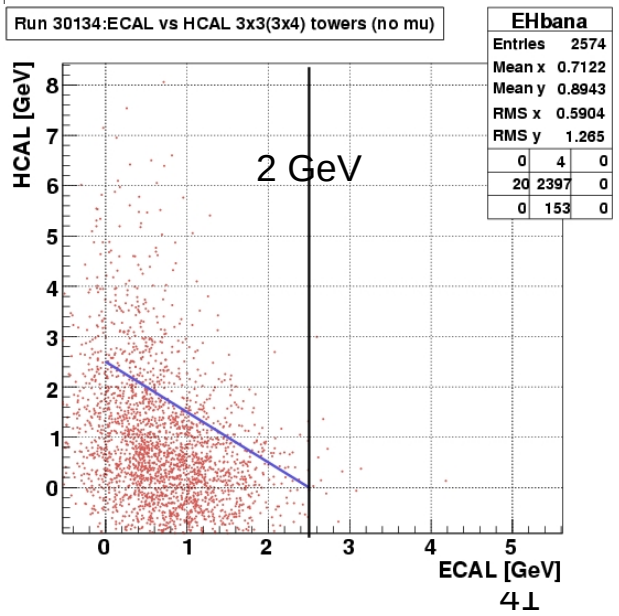
More Bananas



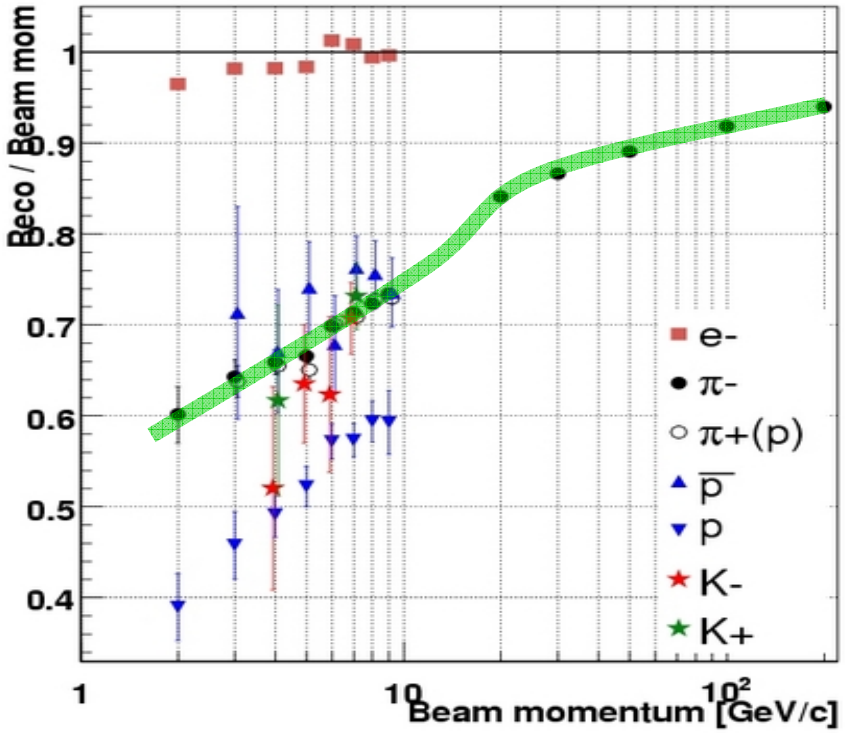


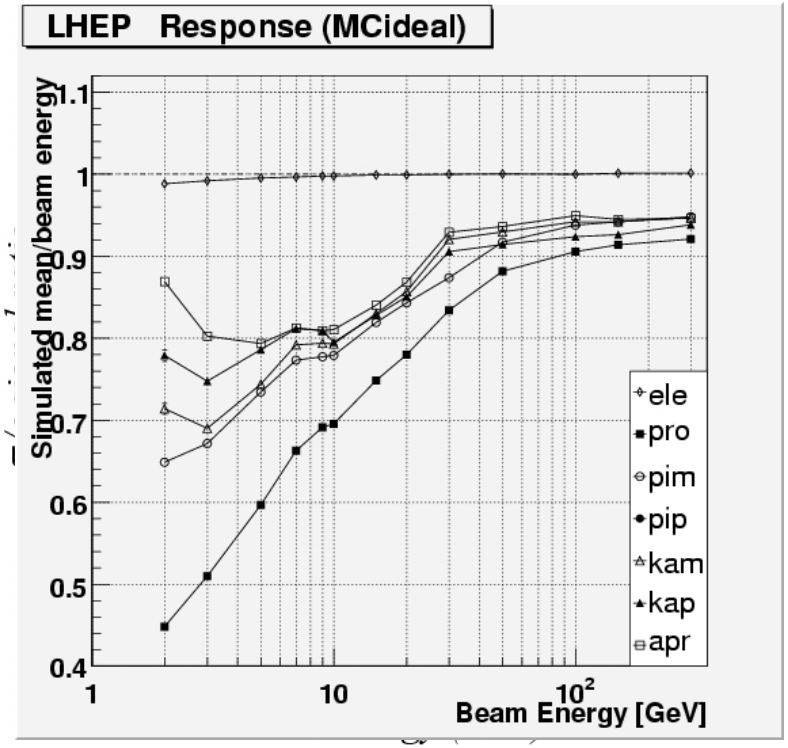






ECAL+HCAL Response - MC

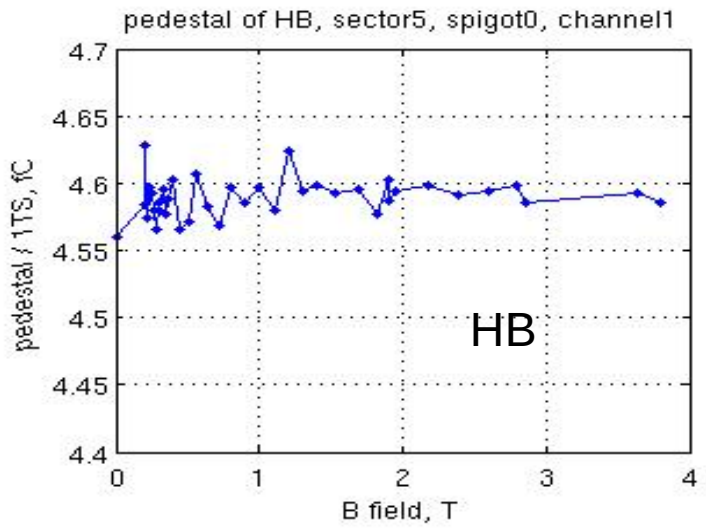


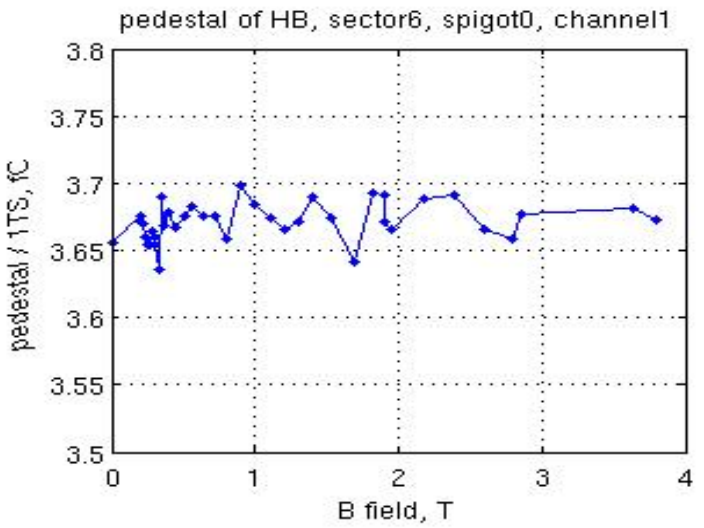


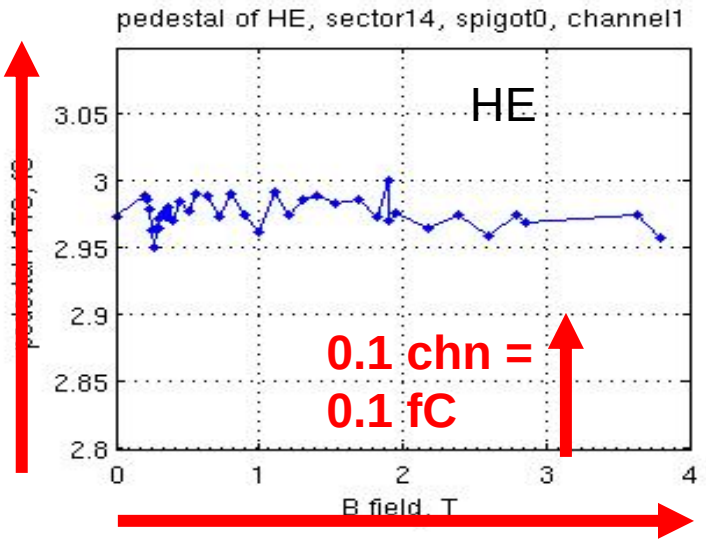
•For the first time, we have a complete set of low energy data for pions, kaons and (anti)protons for the combined ECAL+HCAL. These data are essential to correctly estimate the jet response of the CMS calorimeter system. We need to tweak G4 prior to first data taking.

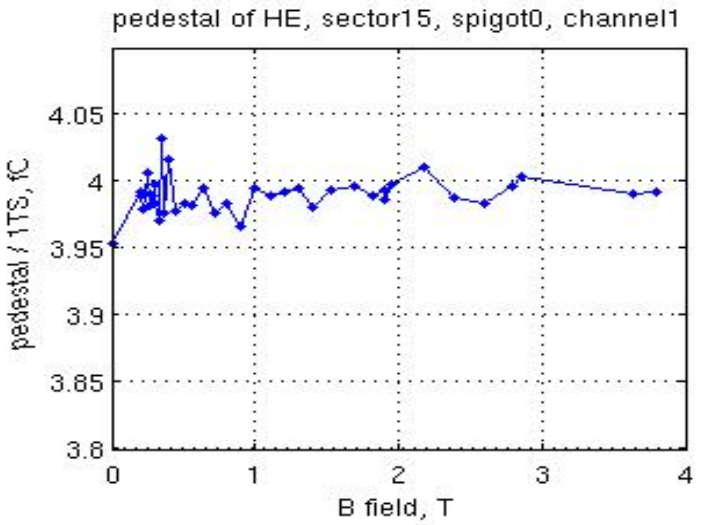
Pedestal stability vs Bfield

(data taken during ramp-up)







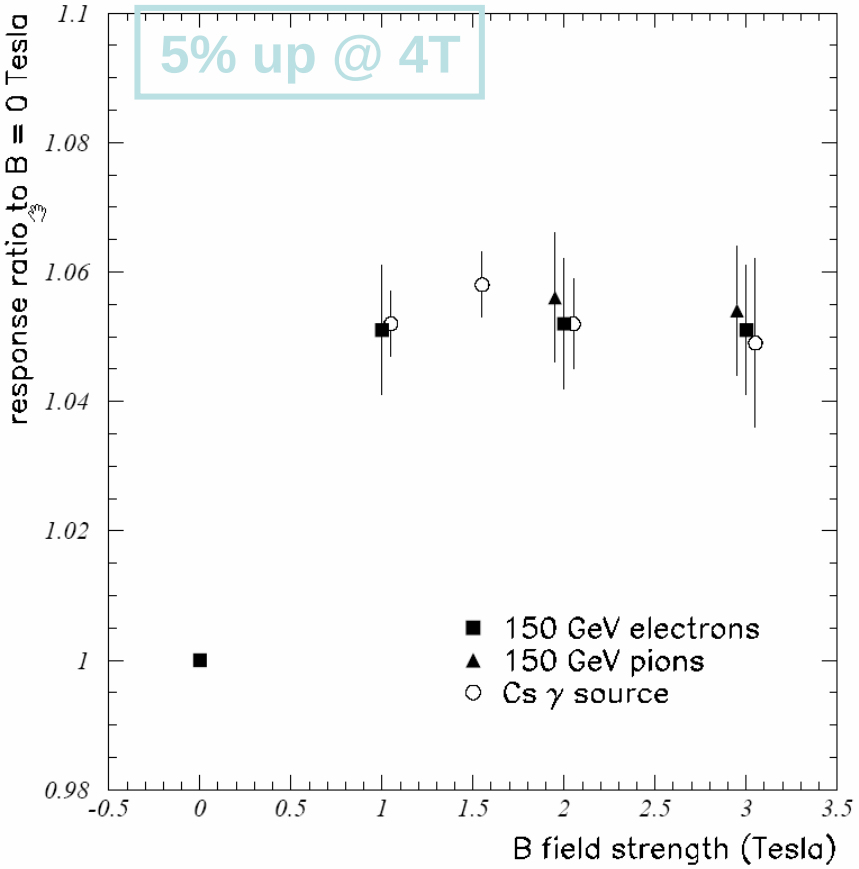


ped/1ts (fC)

0 to 4 Tesla, no shift at all

Holding Calib in Field

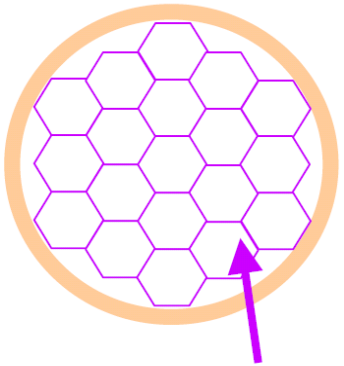
#1 Scintillator brightening



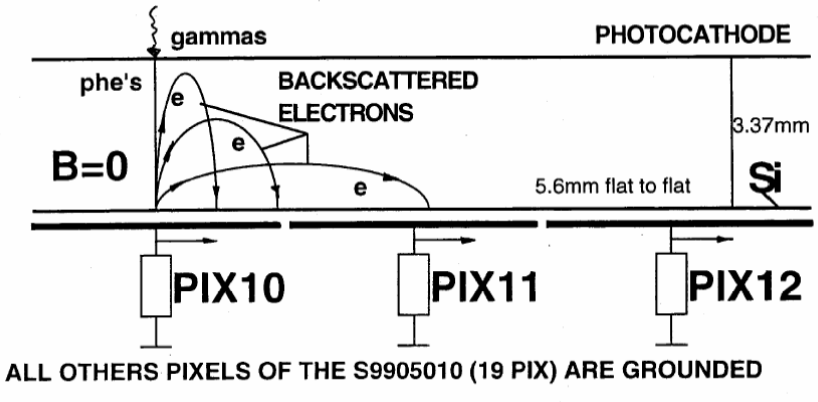
More light output in B-field

#2 HPD pixel cross talk due to electrons backscatter

10% up @ 4T



19 x 5.4mm

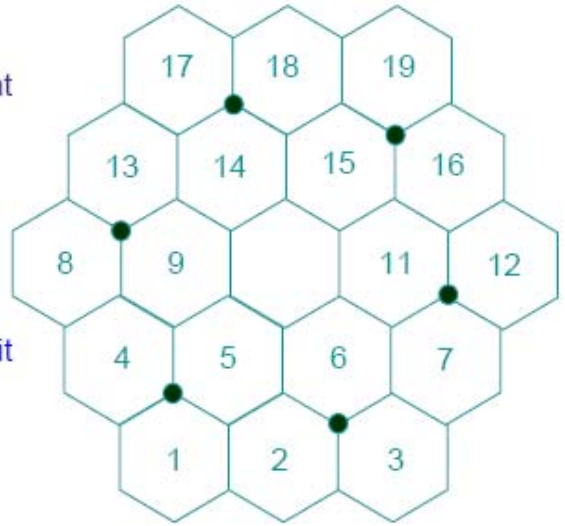


ALL OTHERS PIXELS OF THE S9905010 (19 PIX) ARE GROUNDED

No cross talk in B-field
e- trapped along B-field line.

Test of HPD alignment wrt to Bfield

The HO RMS have a special alignment
check fiber 6 intersections of 3 pixels
this fiber can be pulsed independently
From the regular calibration fiber

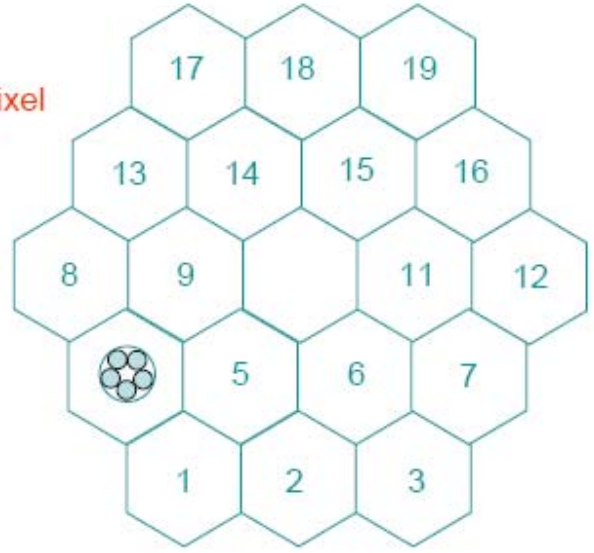


In good alignment we find an even split
Of the charge between the 3 pixels

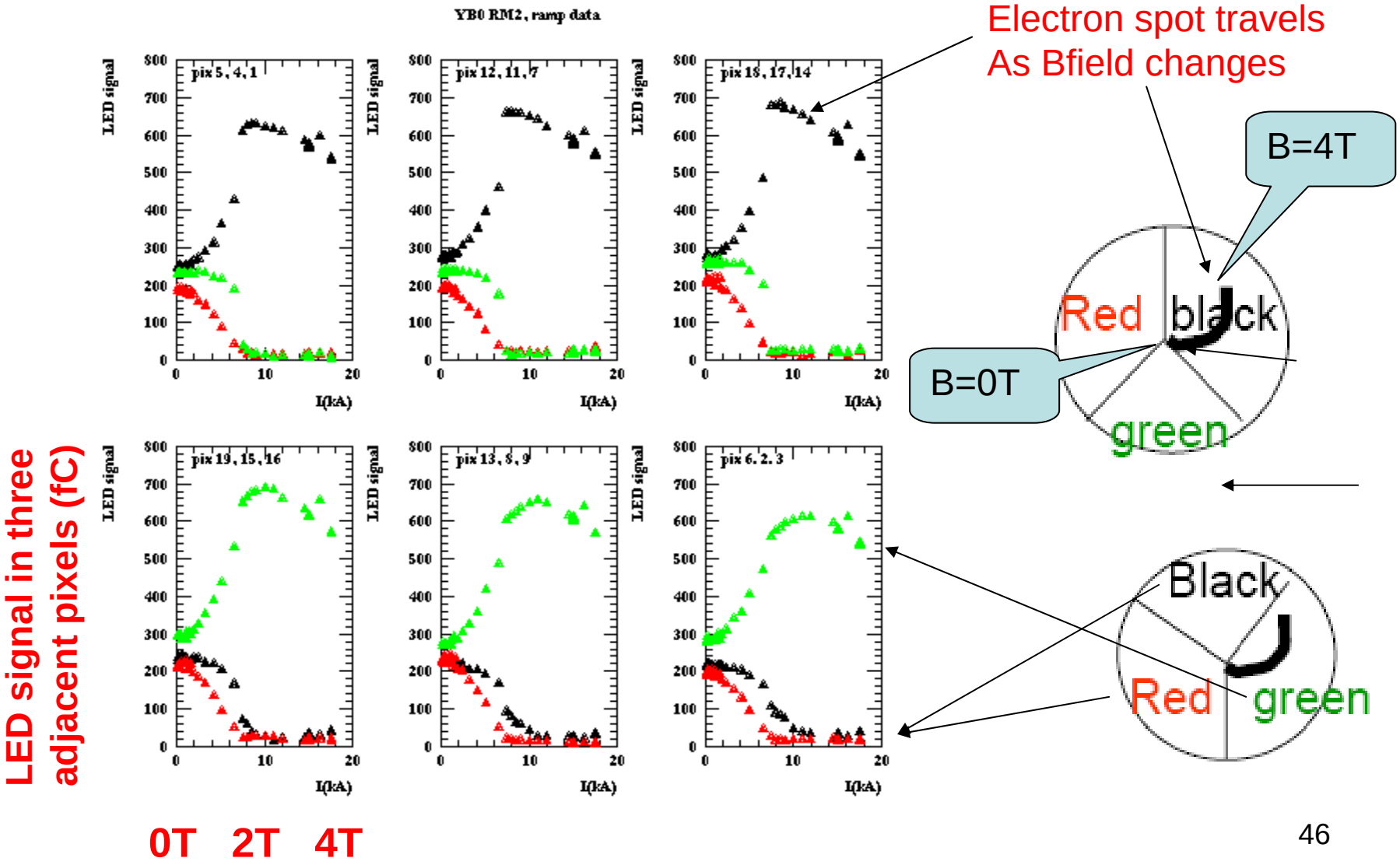
On Pixel LED runs! With 1 fiber per pixel

All pixels (shown only one) have a
calibration fiber randomly distributed
in a 3mm holes

Pixel size is 5.4 mm

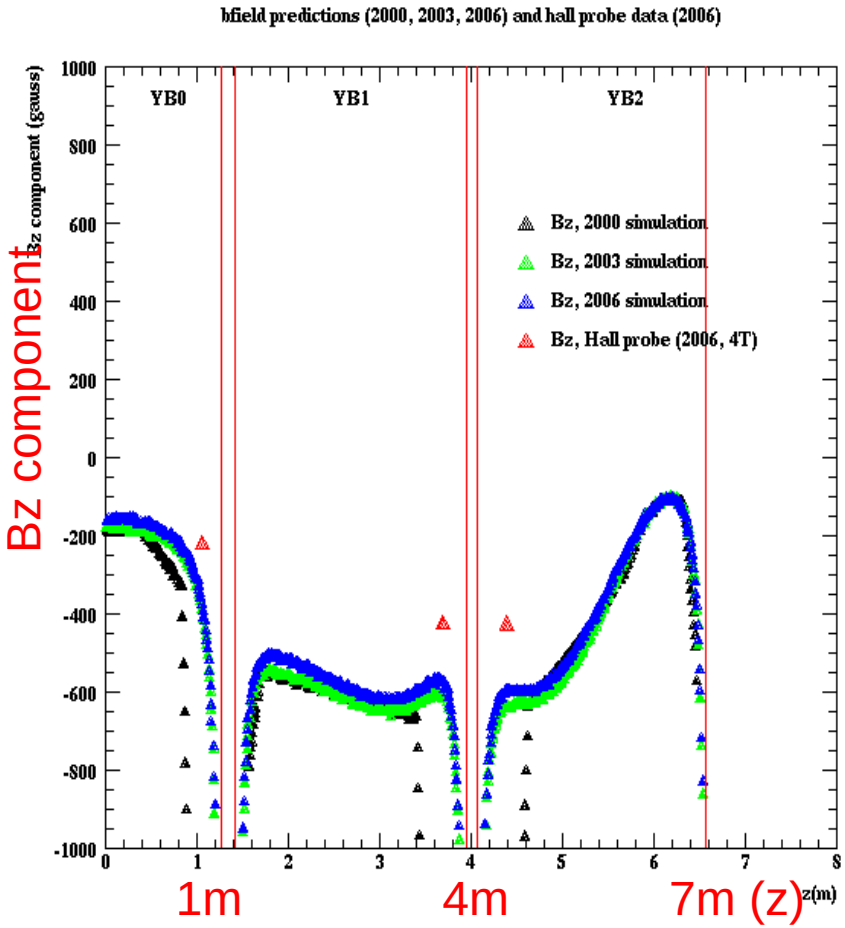


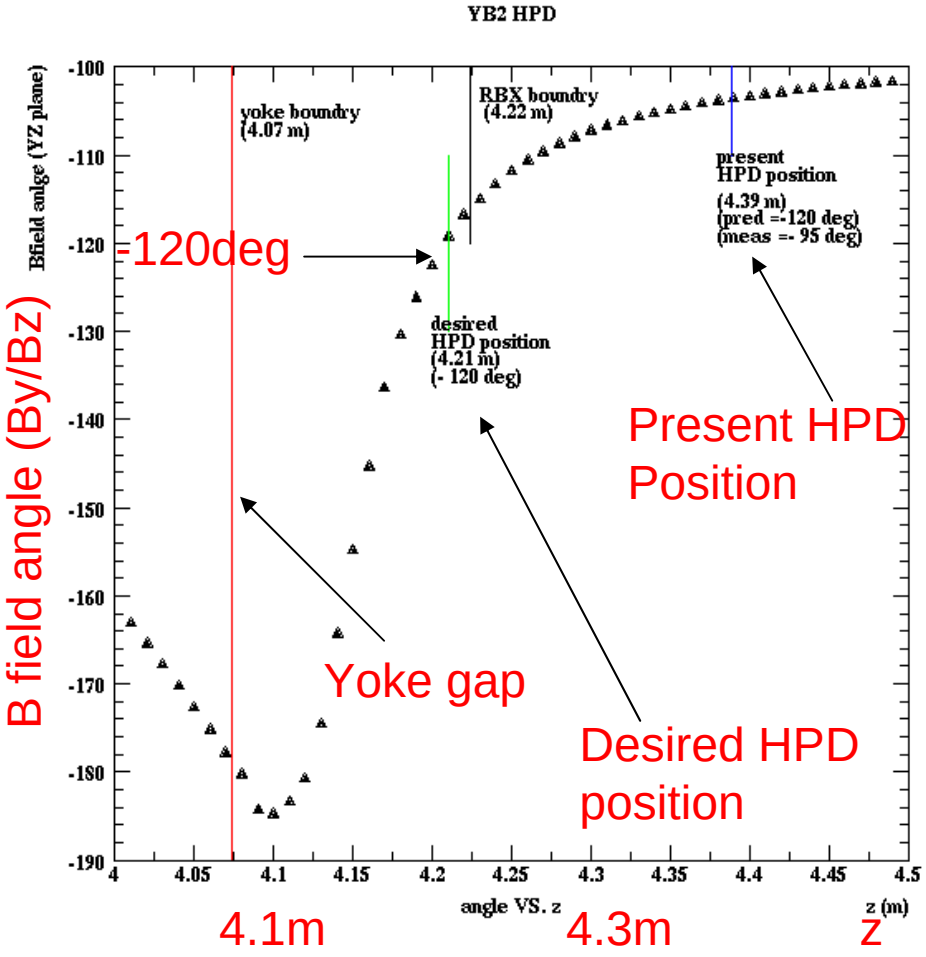
HO xtalk data, YB0/rm2, combined 3.0T and 3.8T ramp-up data

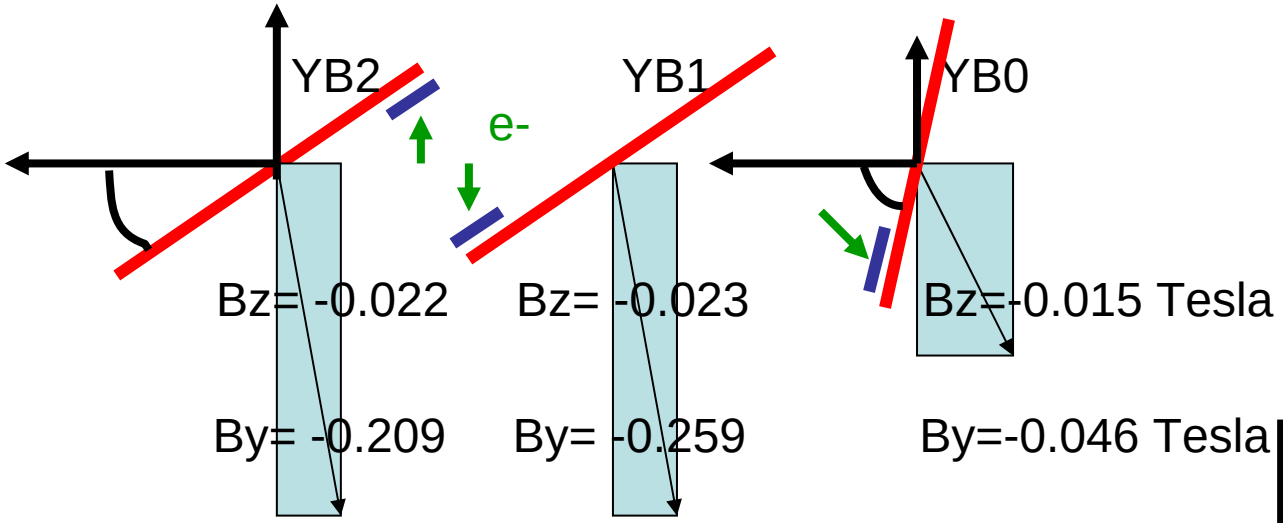


question: do we fully understand Difference between Bfield calculation and Hall probe measurement (slava)

Possible solution:
move RBX into the region where B field is ll to E field







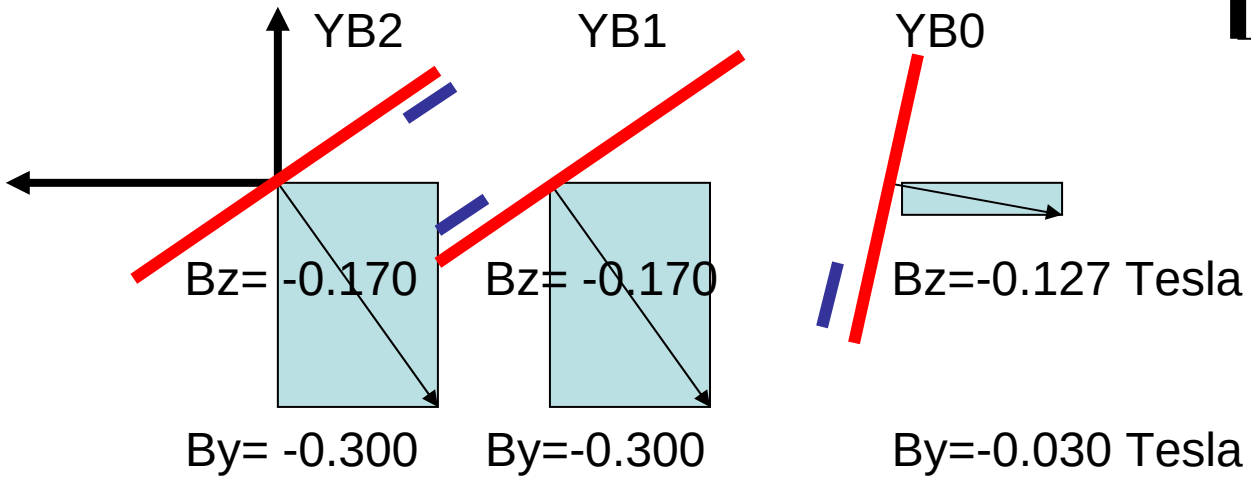
Measured B field

HPD alignment according to Predictions,

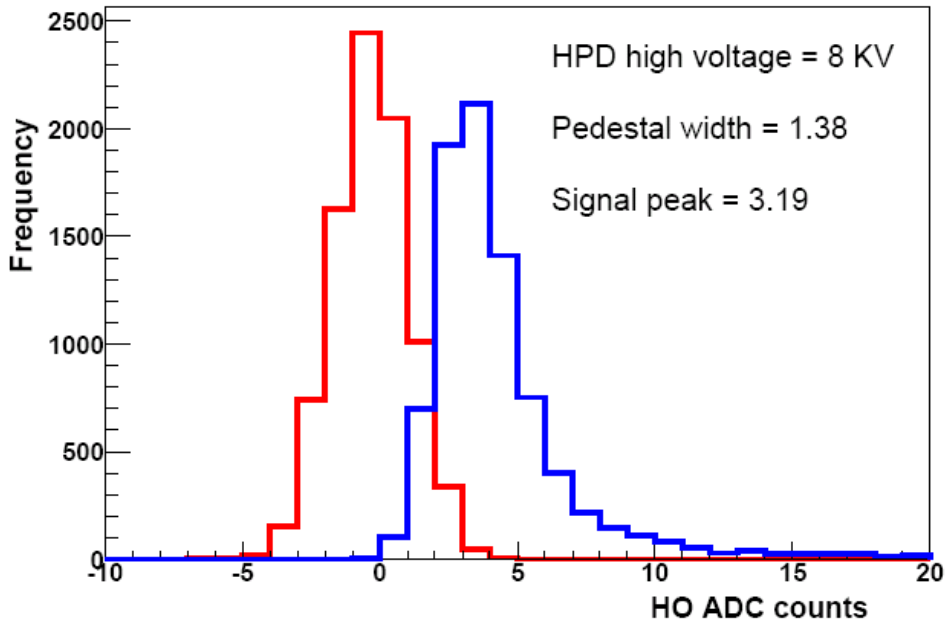
	YB+2	YB+1	YB0
data	96	95	108
pred	120	120	165

Angles (in degrees, wrt to +z axis)

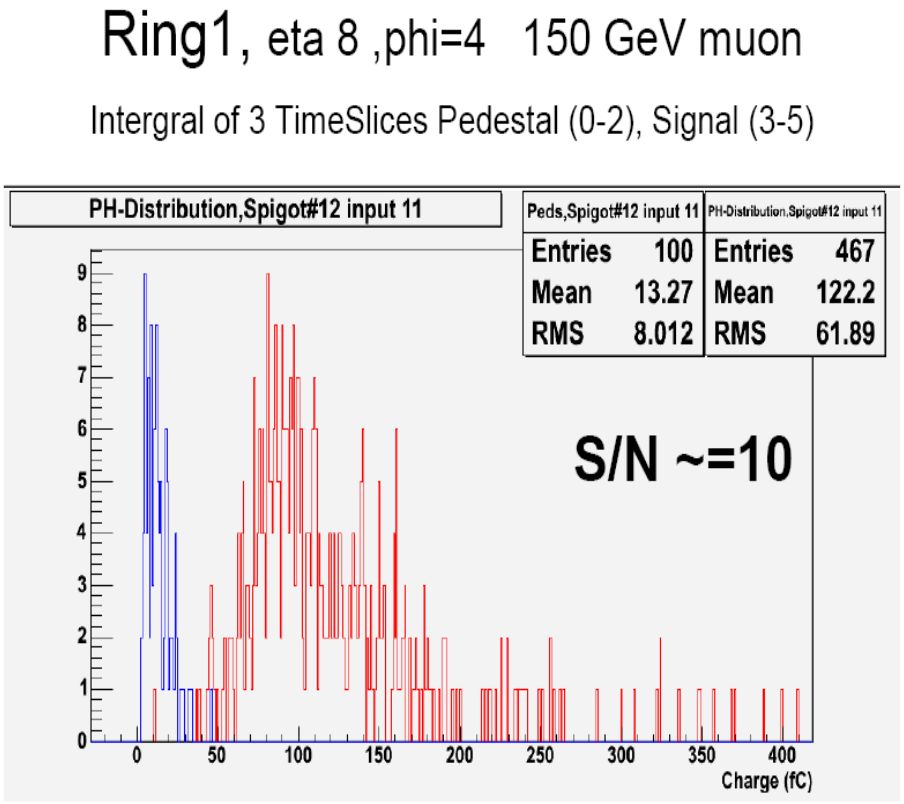
Predicted B field



Other option?
Silicon PhotoMultiplie (SiPM)



HPD Results from 2004 HCAL testbeam



SiPM Results from 2006 HCAL testbeam

Can soft iron wedge (26.5mm by 50mm) help to re-shape the field ?