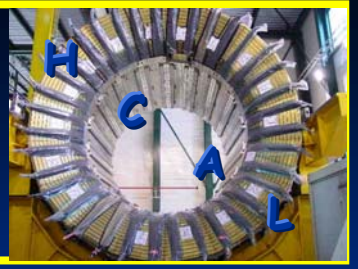
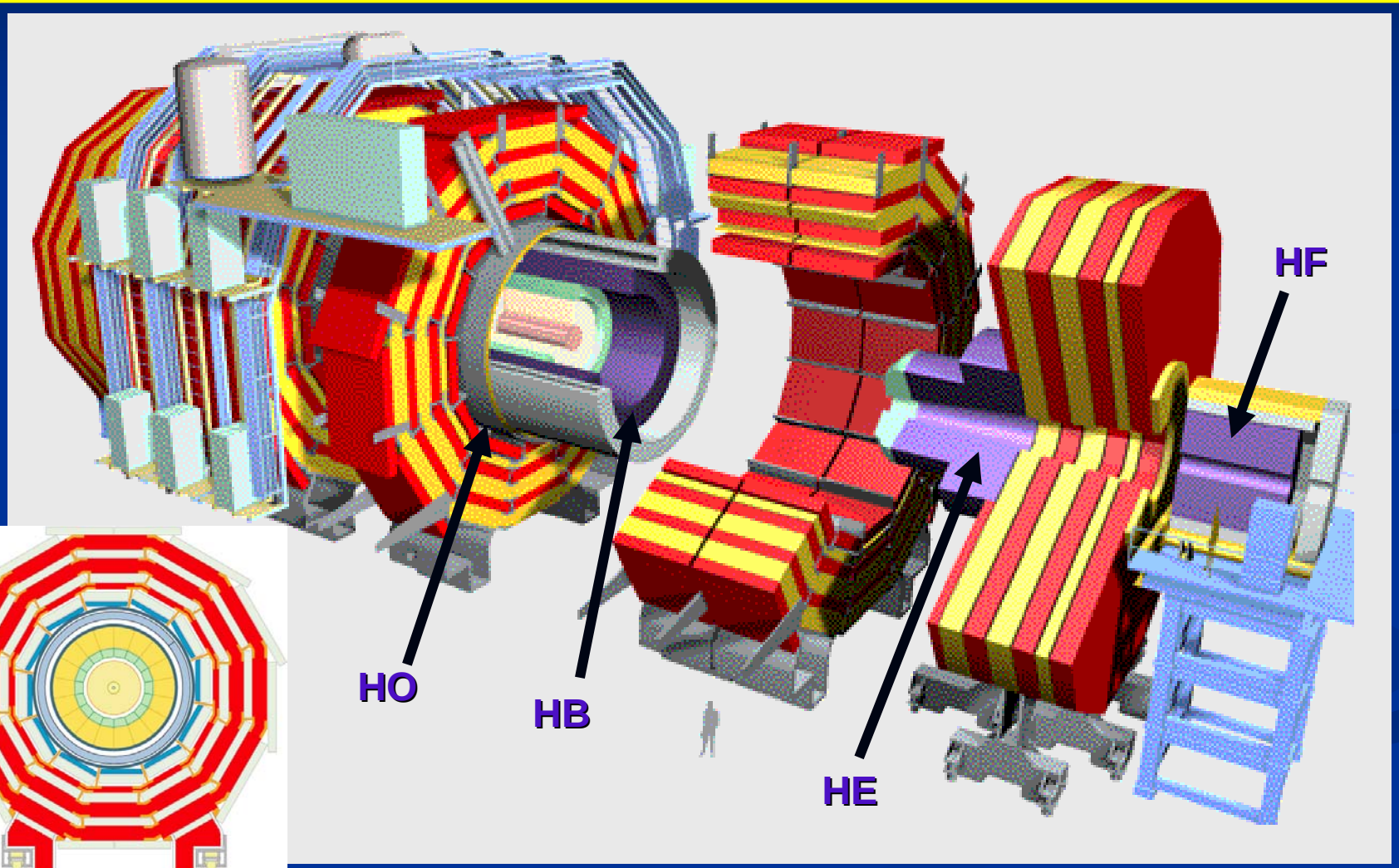
CALOR2006

Overview of the CMS Hadron Calorimeter

Julie Whitmore
Fermilab

CMS Hadron Calorimeter





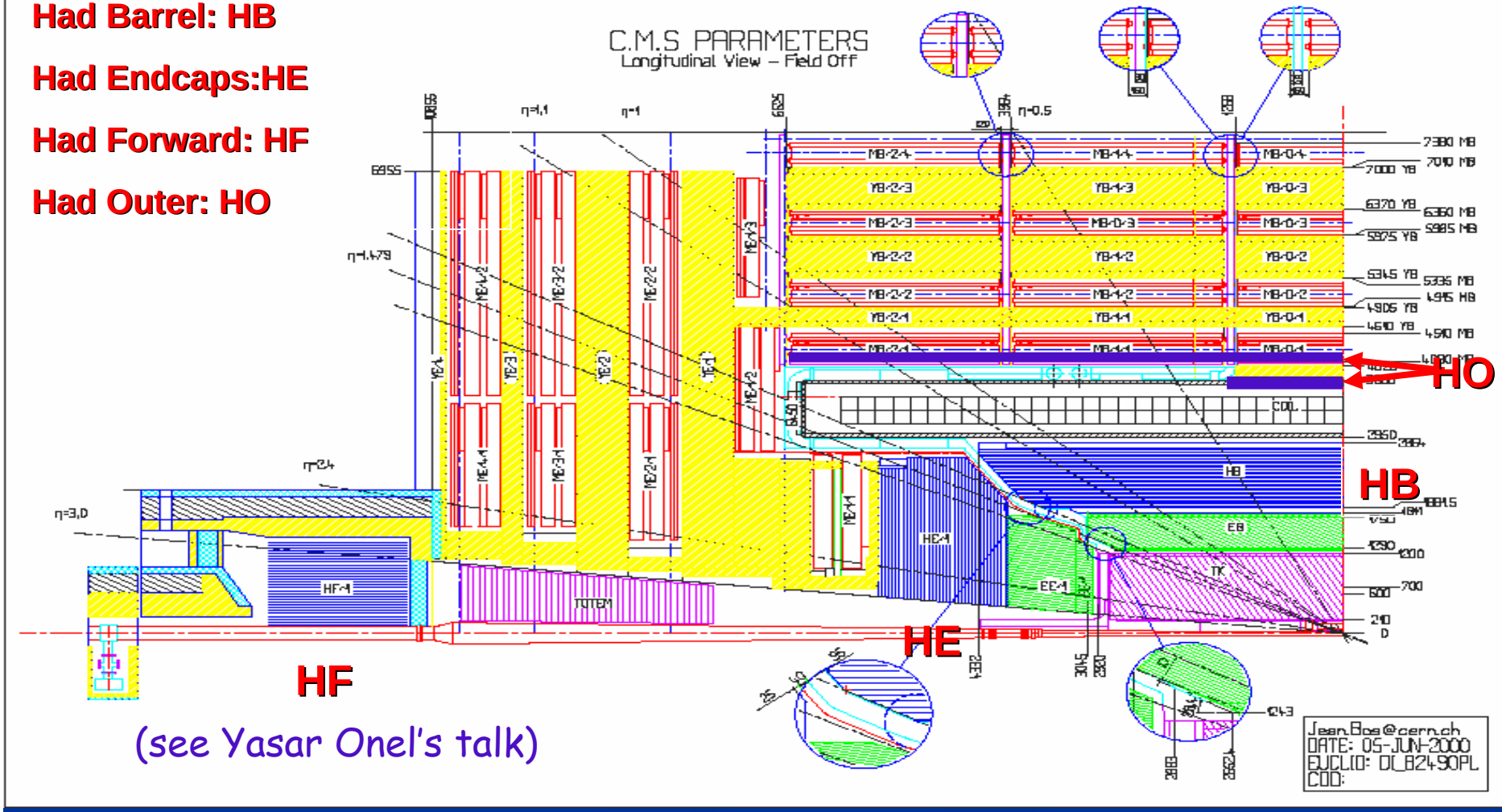
HCAL Subdetectors

Had Barrel: HB

Had Endcaps:HE

Had Forward: HF

Had Outer: HO



(see Yasar Onel's talk)

HCAL Barrel (HB)

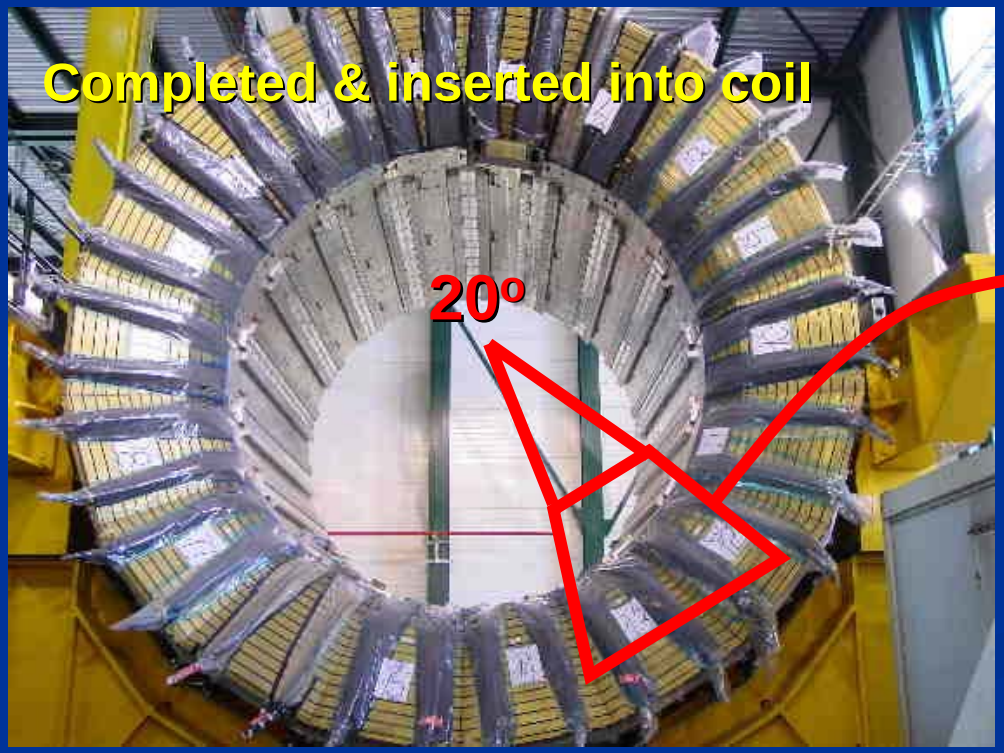
Sampling calorimeter: brass (passive) & scintillator (active)

Coverage: $|\eta|<1.3$

Depth: 5.8 λ_{int} (at $\eta=0$)

π resolution: ~ 90 %/ $\sqrt{E}$

segmentation: $\phi \times \eta =$ 0.087x0.087



HCAL Endcap (HE)

Sampling calorimeter: brass (passive) & scintillator (active)

Coverage: $1.3<|\eta|<3$

Depth: $10\ \lambda_{int}$

segmentation: $\phi \times \eta =$ 0.087x0.087

π resolution: ~ $100\%/\sqrt{E}$

Completed, assembled & installed

HCAL : HO Calorimeter (Outer)

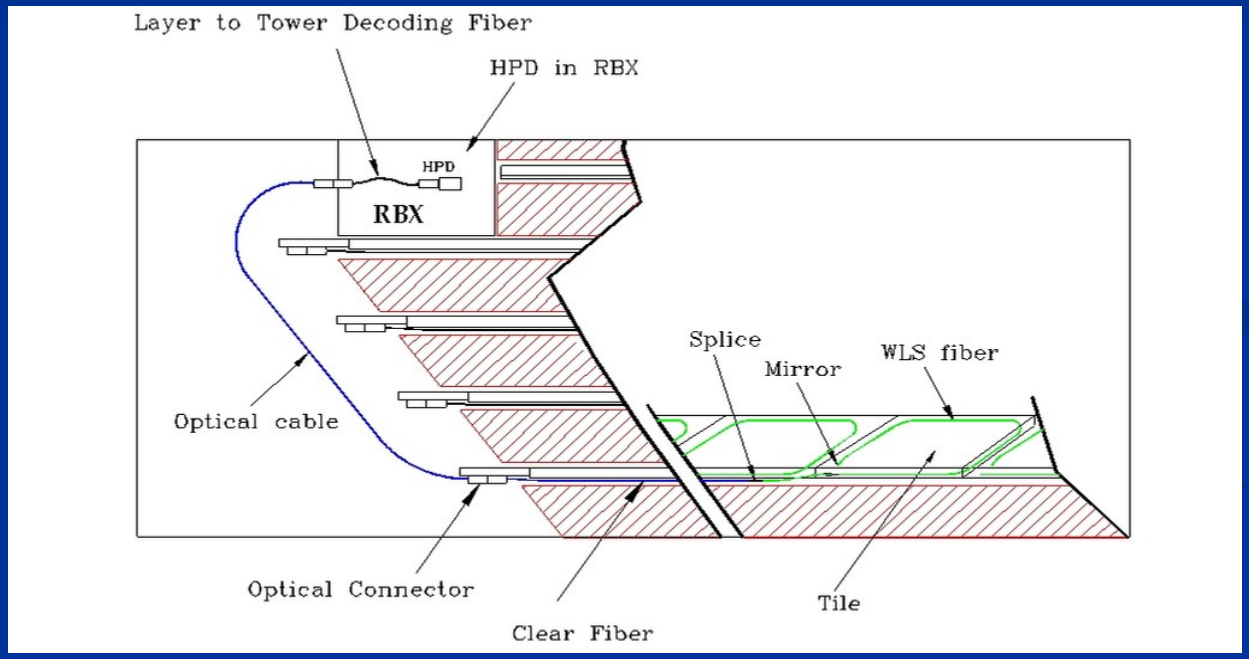
Total number of λ_{int} till the last sampling layer of HB is < 8
HO: 2 scint. layers around first μ layer (extend to~11 λ_{int})

~ 5% of a 300 GeV π energy is leaked outside the HB

HO improves π resolution by ~10% at 300 GeV & linearity

Optical Design for Calorimeters

Common Technology for HB, HE, HO

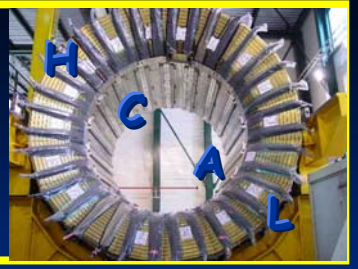



Installing Megatile


Inspecting Tile

FE/DAQ Electronics

S-Link: 64 bits @ 25 MHz



Trigger Primitives

CAL REGIONAL TRIGGER

Rack CPU

READ-OUT Crate

SBS | CLK | DCC | HTR ... HTR | HTR

12 HTRs per Readout Crate, 2 DCC

TTC

16 bits @ 80 MHz

Radiation Environment

FRONT-END RBX Readout Box (On detector)

32 bits @ 40 MHz

HPD

QIE

CCA

GOL

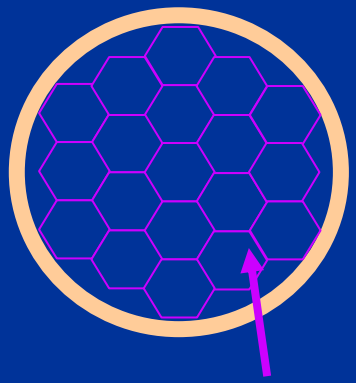
FE MODULE

Shield Wall

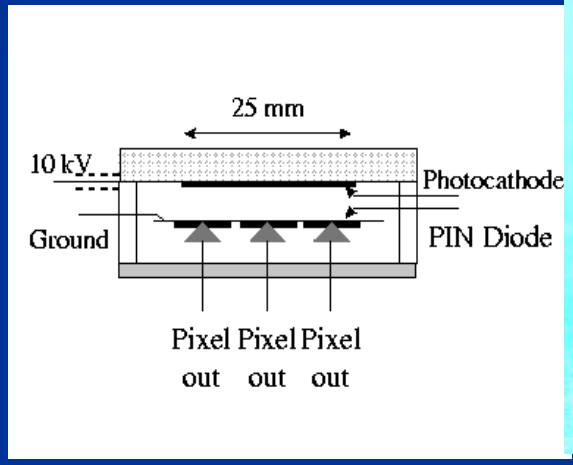
Fibers at 1.6 Gb/s
3 QIE-channels per fiber

HPD

Diode Layout



19 x 5.5mm



Hybrid PhotoDiode photon transducer for HB, HE, HO. Fiberoptic front window, conventional photocathode, pixelated diode (19 channels/device). From DEP, Holland. Need ~ 500 total.

6 Channel FE Board

Custom ASICs

Low Voltage Regulator (2 / board) CERN Developed in rad hard process

AD590 Temp Sensor

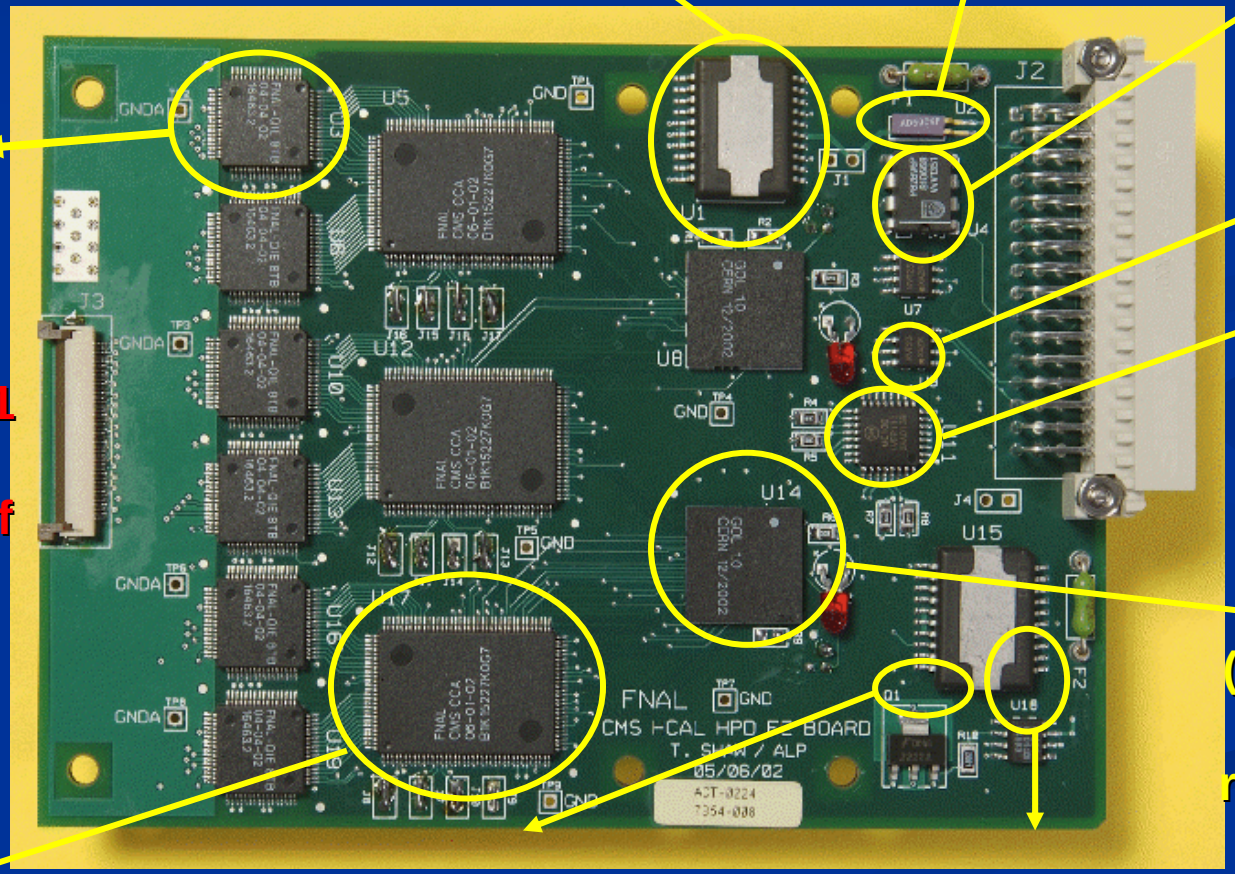
P82B715 I2C Transceiver

QIE (6 / board) Fermilab

Honeywell VCSEL HFE419x-521 (2/board) [back side of board]

MC100LVELT23 LVPECL-LVTTL

MC100LVEP111 LVPECL clock fanout chip



Gigabit Optical Link [GOL] (2 / board) CERN Developed in rad hard process

CCA (3 / board) Fermilab

PZT222A transistor

OP184 bi-polar OpAmp

Clock Control Monitoring

Optocoupler 6N134

LV Regulator (7 total)

RS 485 (2 total)

AD670 8-bit A/D (Analog Devices Tested)

Channel Control

OpAmp OP184

PZT222A Transistor

Clock

ACTEL FPGA

Monitoring

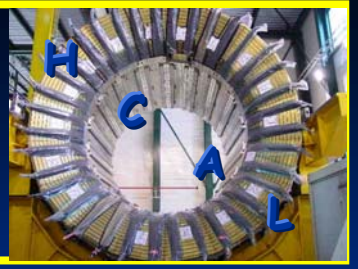
FRAM (Ramtron Tested)

MC100VELT22 CMOS – diff LVPECL (7 total)

Analog MUX ADG 706

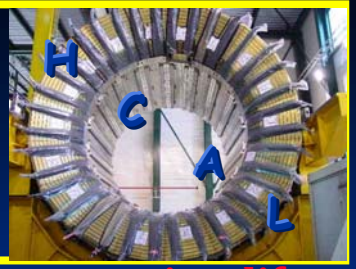
MC100LVEP

QIE Design Challenges

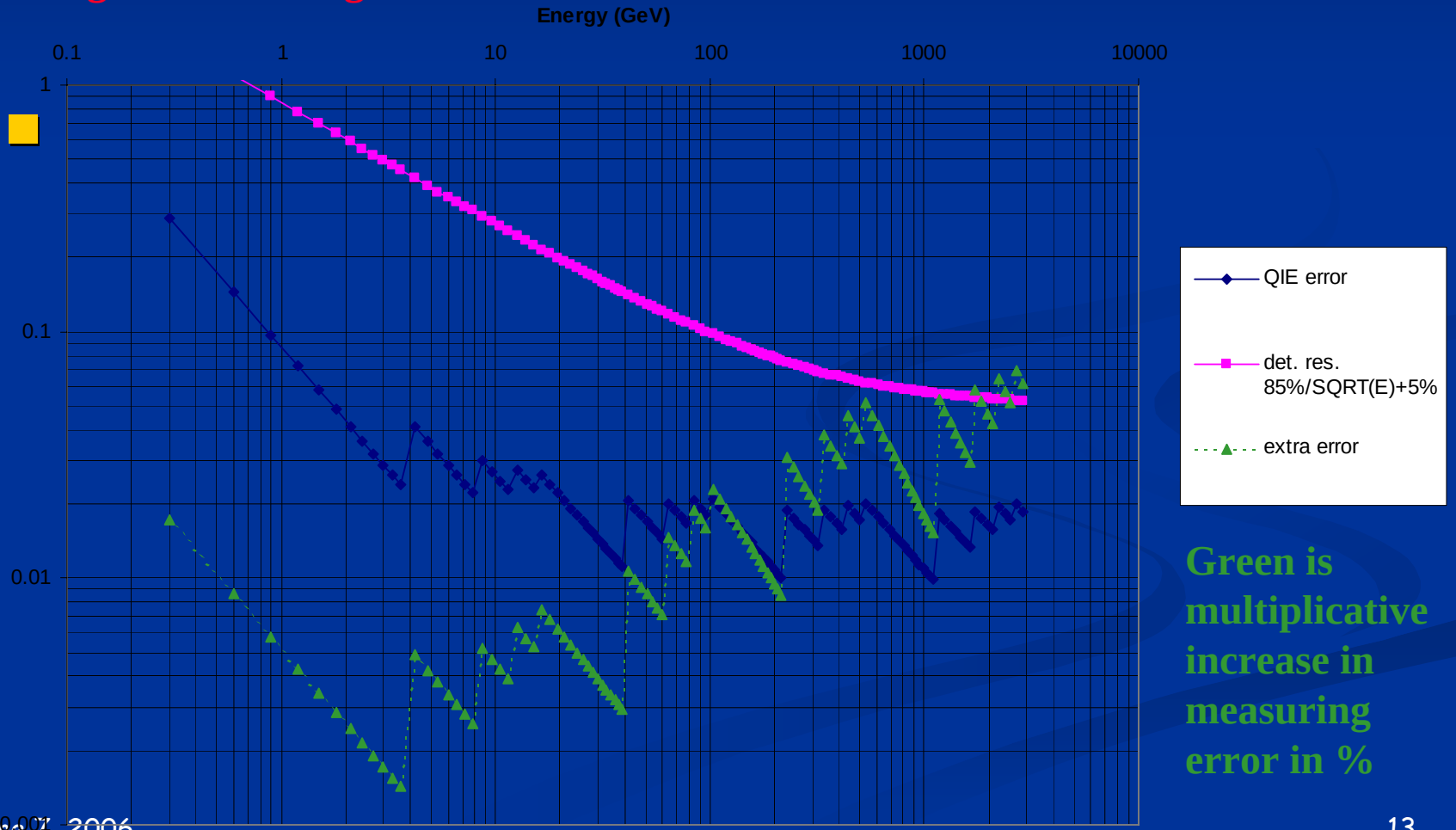


- Must respond to positive and negative inputs (HPDs and PMTs).
- High sensitivity inputs (1 fC/LSB for HPD)
- Wide dynamic range (MIP → 3 TeV [for single time slice])
  - Normal mode: 1 fC – 10 pC
- Very high sensitivity calibration mode (1/3 fC/LSB to track detector response shifts from radioactive source (200 e).
  - Calib Mode: Custom FADC with very low DNL

QIE Flash ADC

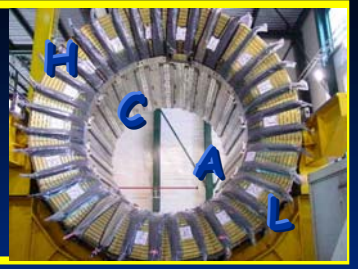


Implementation of a 4-range splitter and a 5 bit non-linear FADC allows to simplify the design while having minimum effect on the detector resolution.

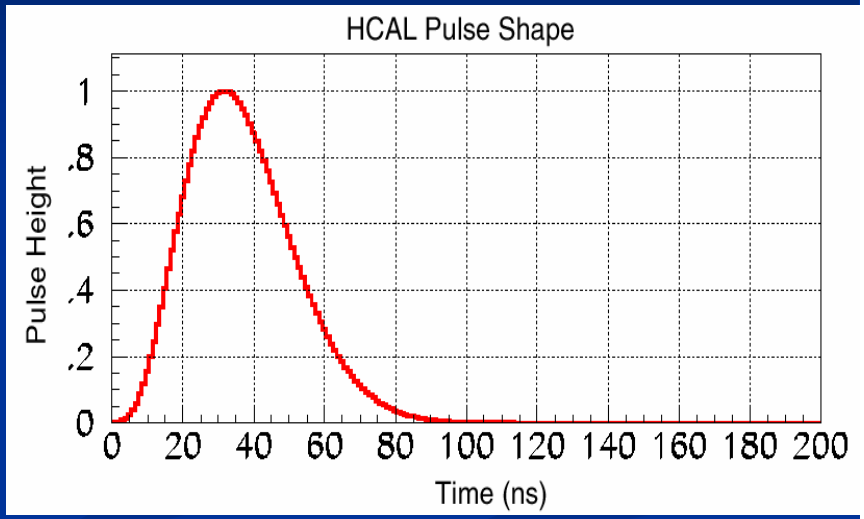


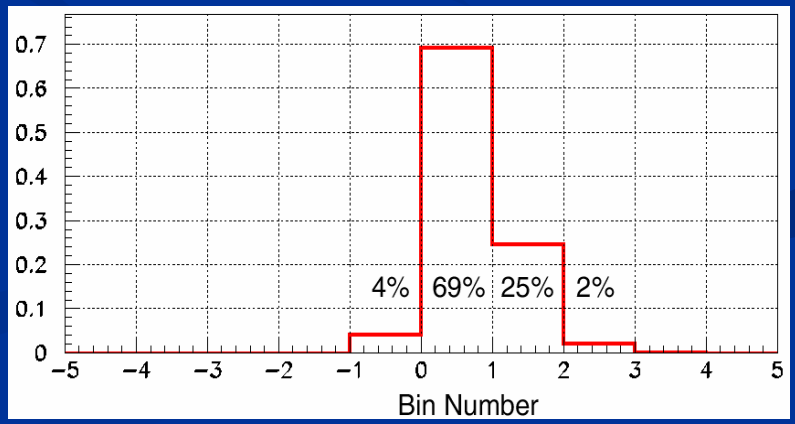
Green is multiplicative increase in measuring error in %

HCAL Pulse



- Nominal HCAL pulse spread 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

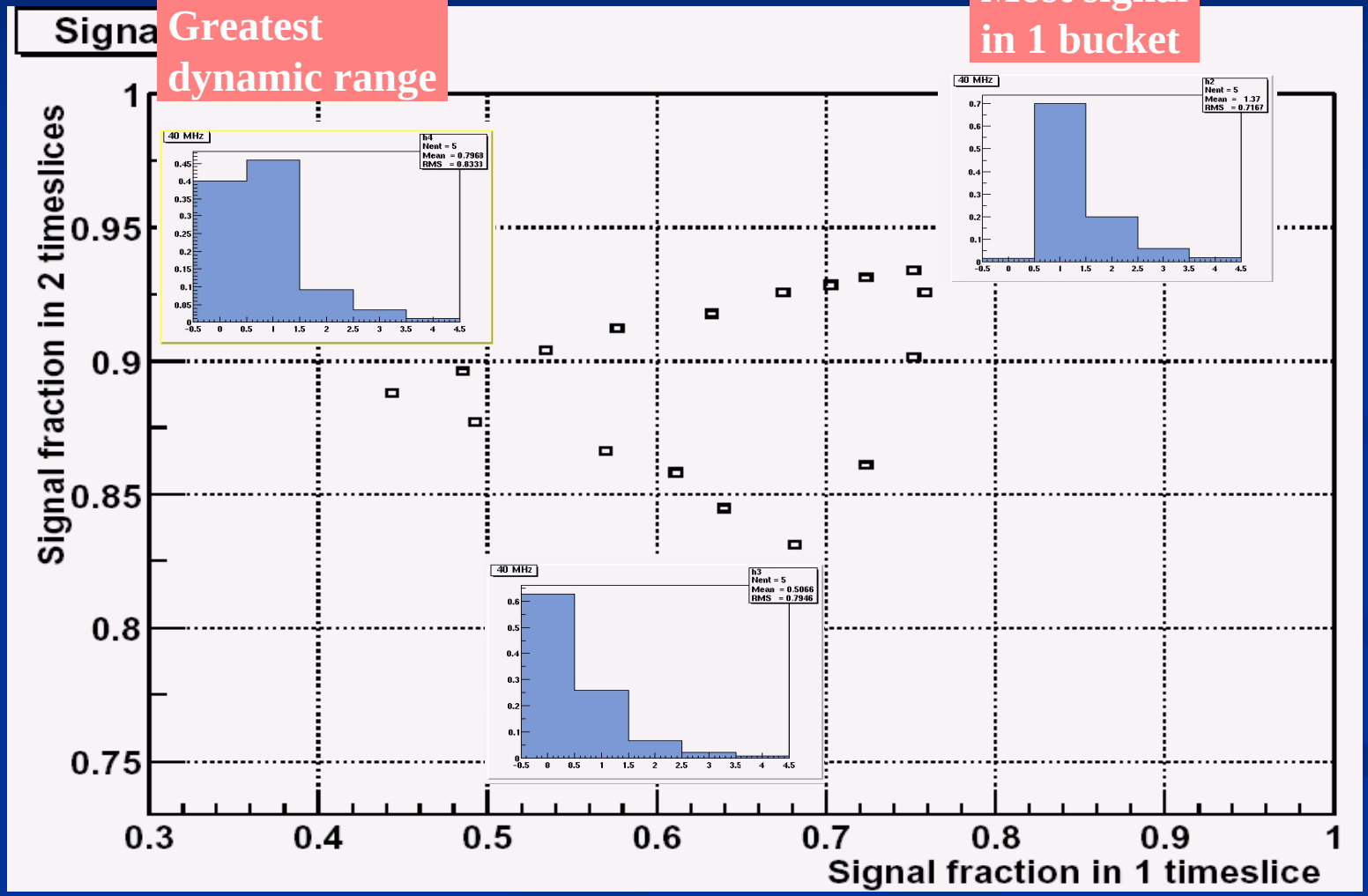




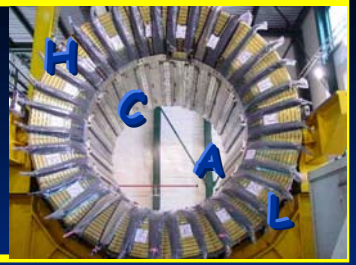
Choice of phase relative to pulse

Greatest dynamic range

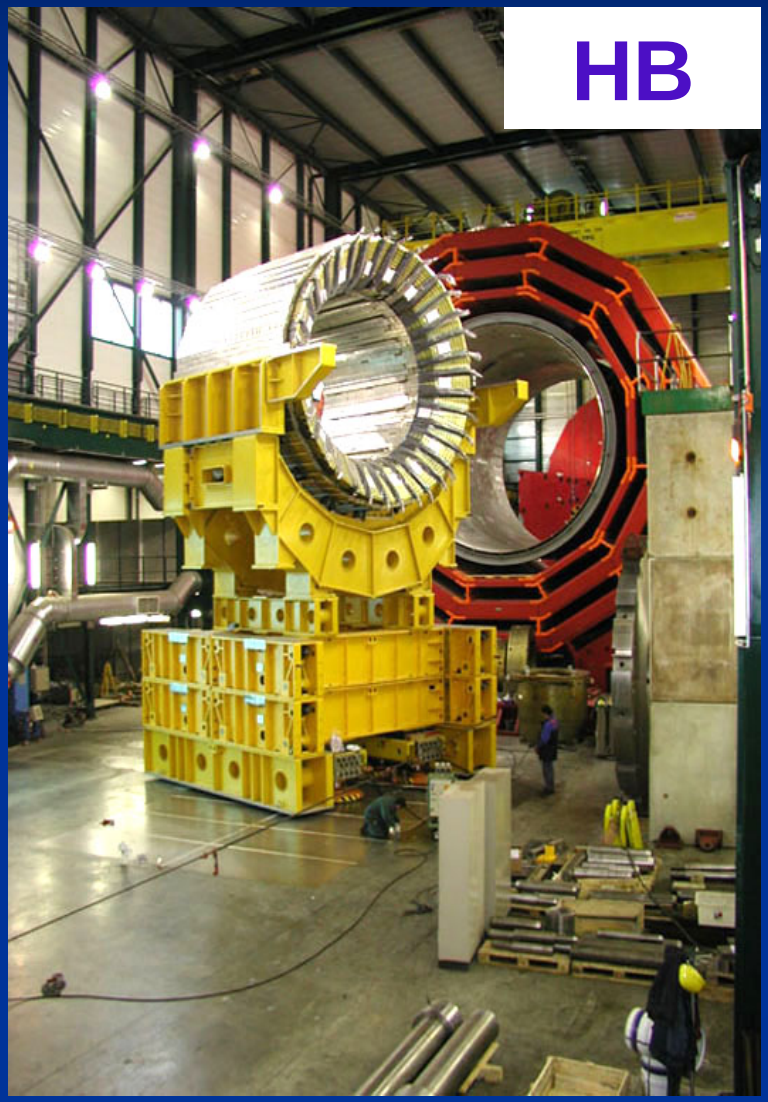
Most signal in 1 bucket



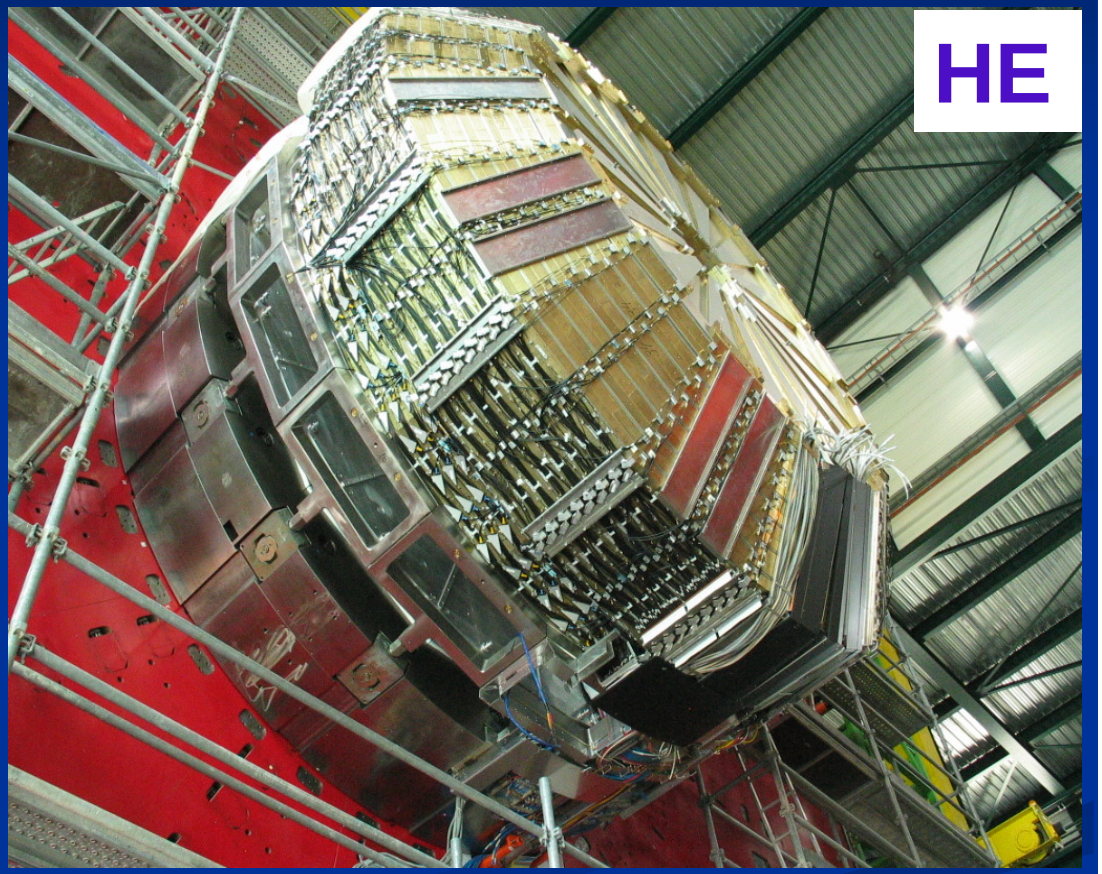
HCALs Complete



HB

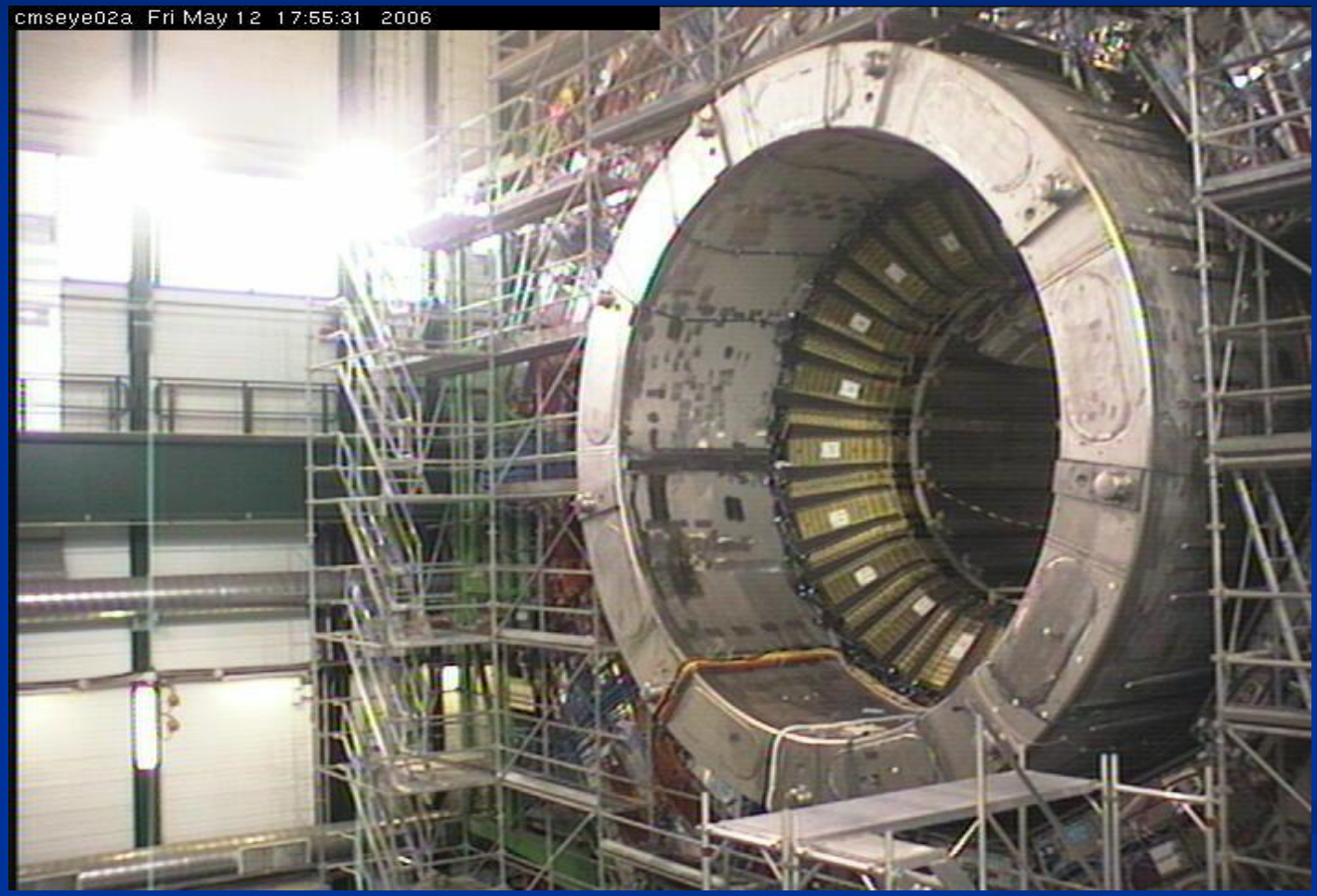


HE

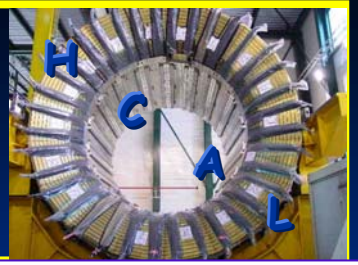


HB+ Insertion

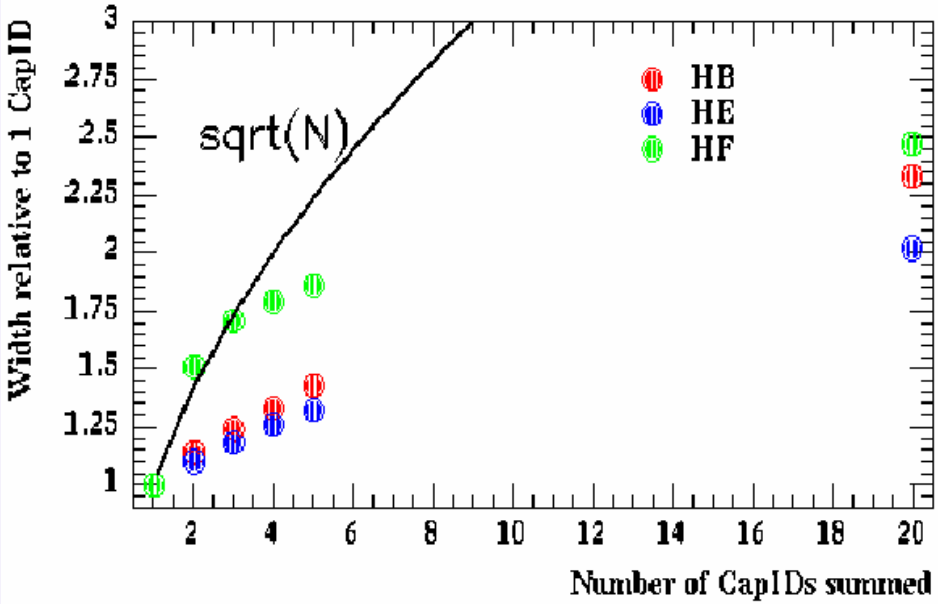
SX5 Now



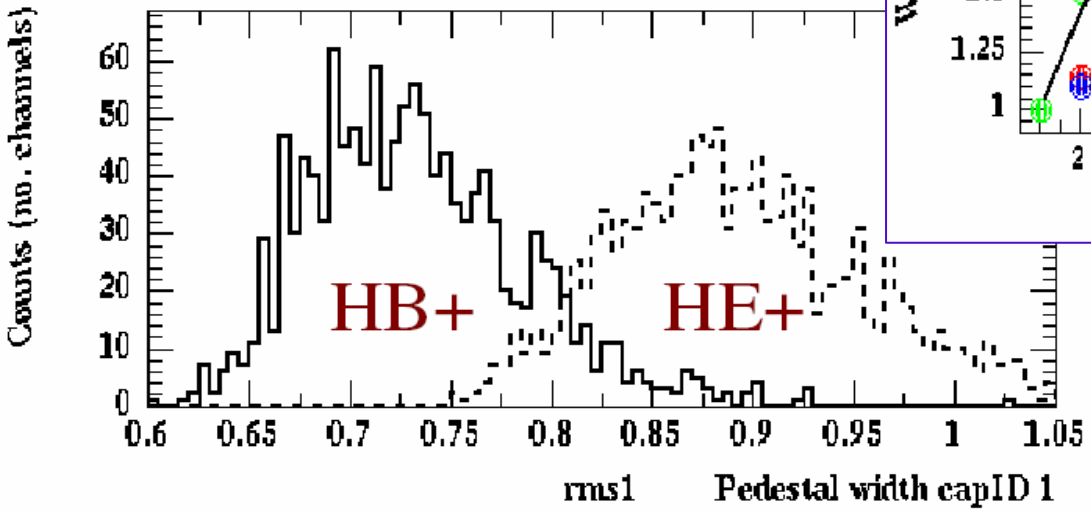
HCAL Pedestals



Pedestal RMS v. Slices Summed

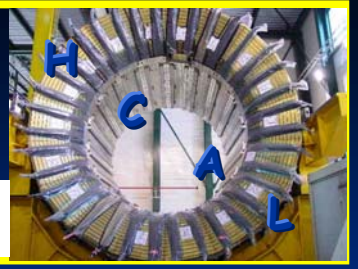


Pedestal RMS Distribution



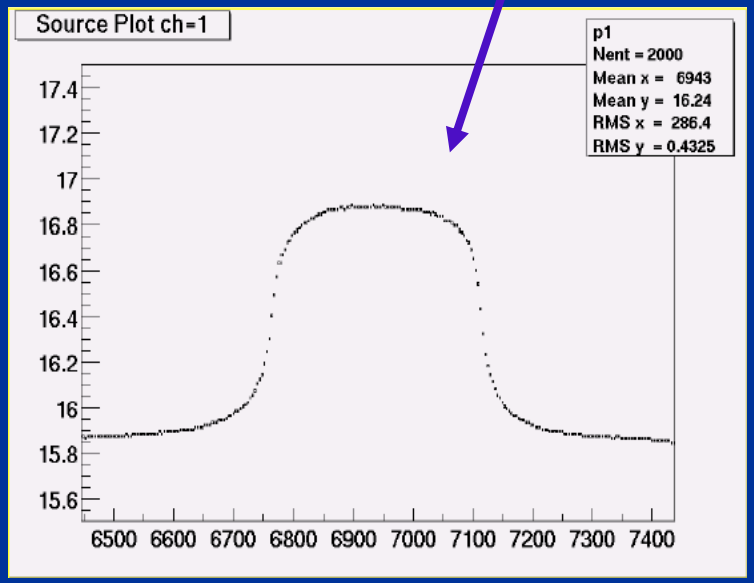
HCAL Source Calibration

(See Mayda Velasco's Talk)

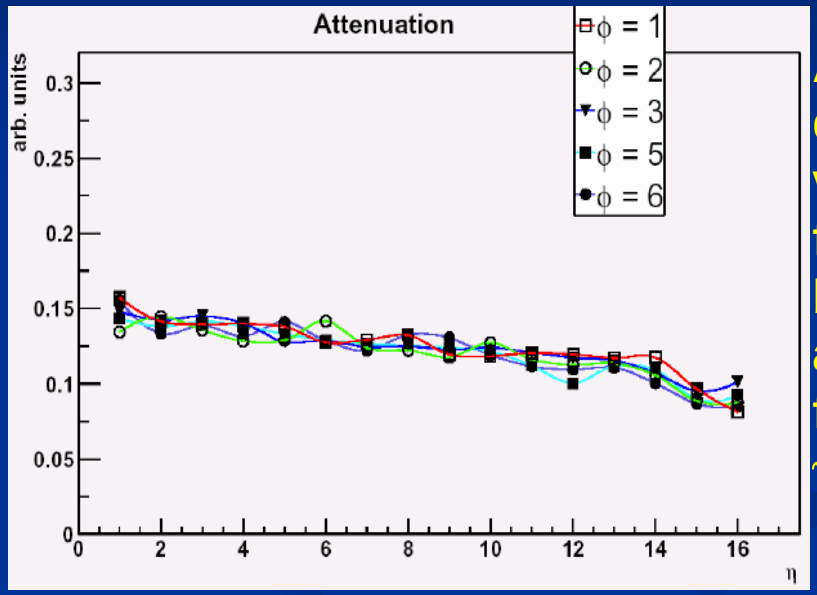


Each Scintillator tile in every layer is calibrated with a moving wire ^{60}Co 5mCi source.

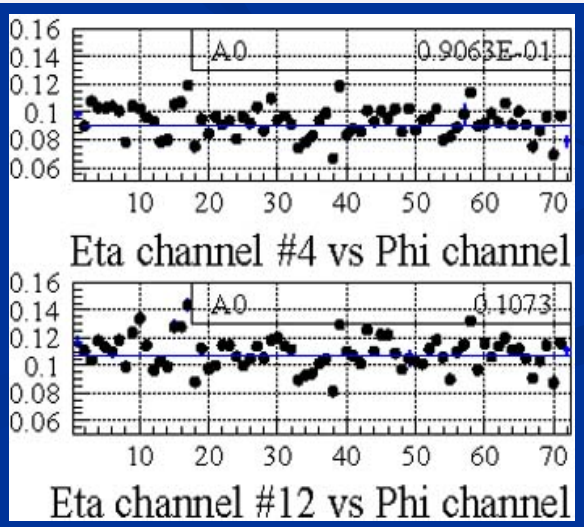
Response of a scintillator tile as the radioactive source passes by it.



HB/HE pre-calibration to ~ 4%

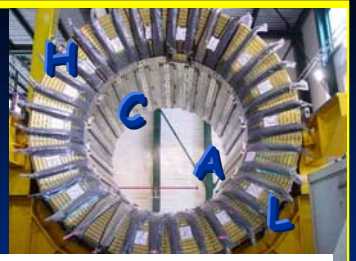


Attenuation due to variation of fiber length between tile and HPD as function of η (HB).

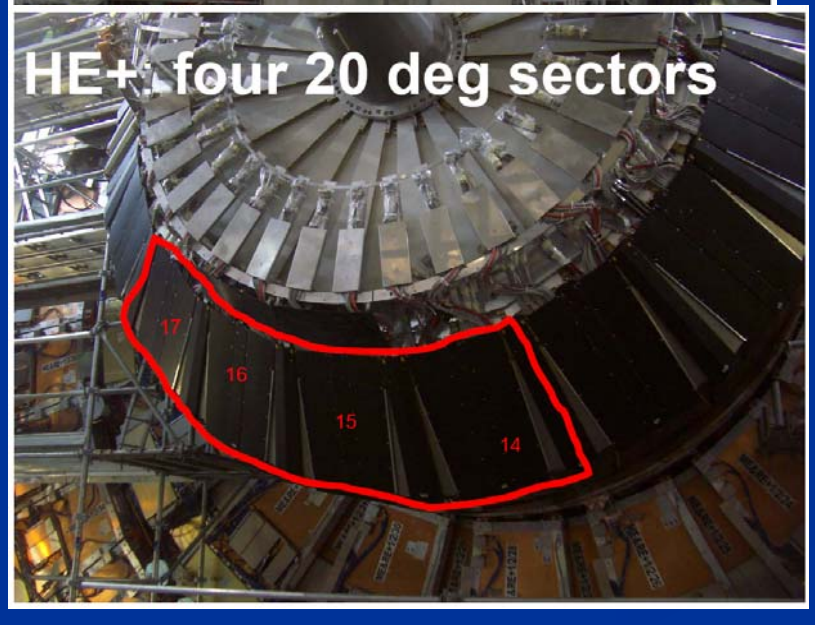


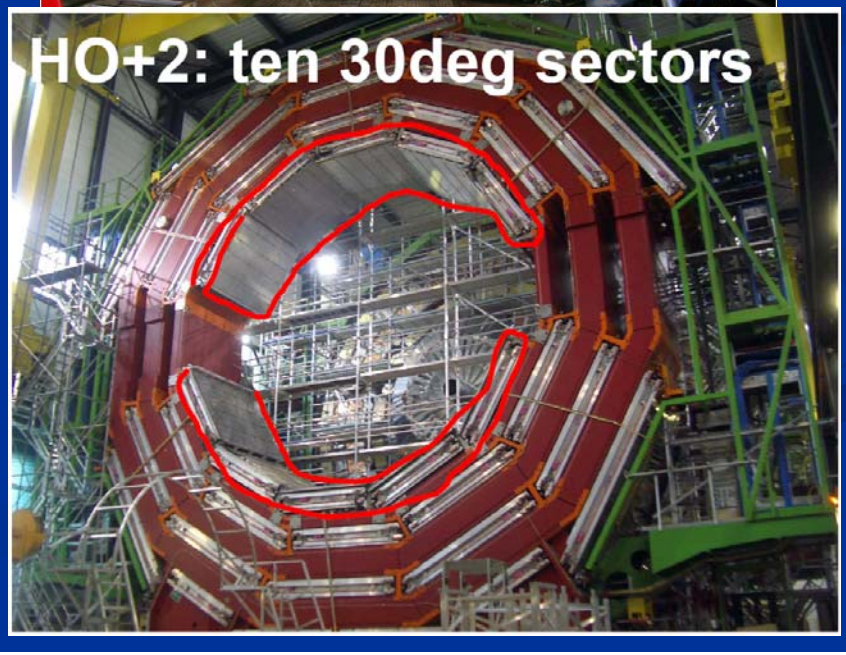
Scatter around A0 gives the calibration coeff: Tile response x gain of HPD

HCAL in Magnet Test/Cosmic Challenge

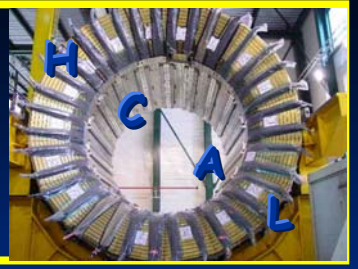


MTCC - July 2006





MTCC Goals



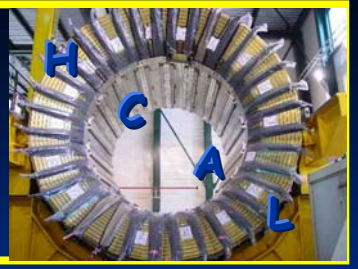
CMS general

- Magnet commissioning and mapping (First operation of the magnet)
- Integration Plan Validation (First closing of the detector)
- Sub-Detector technical verification. Test Alignment system. (First operation in 4T field)
- Check entire detector-electronics-DAQ-CPT chain

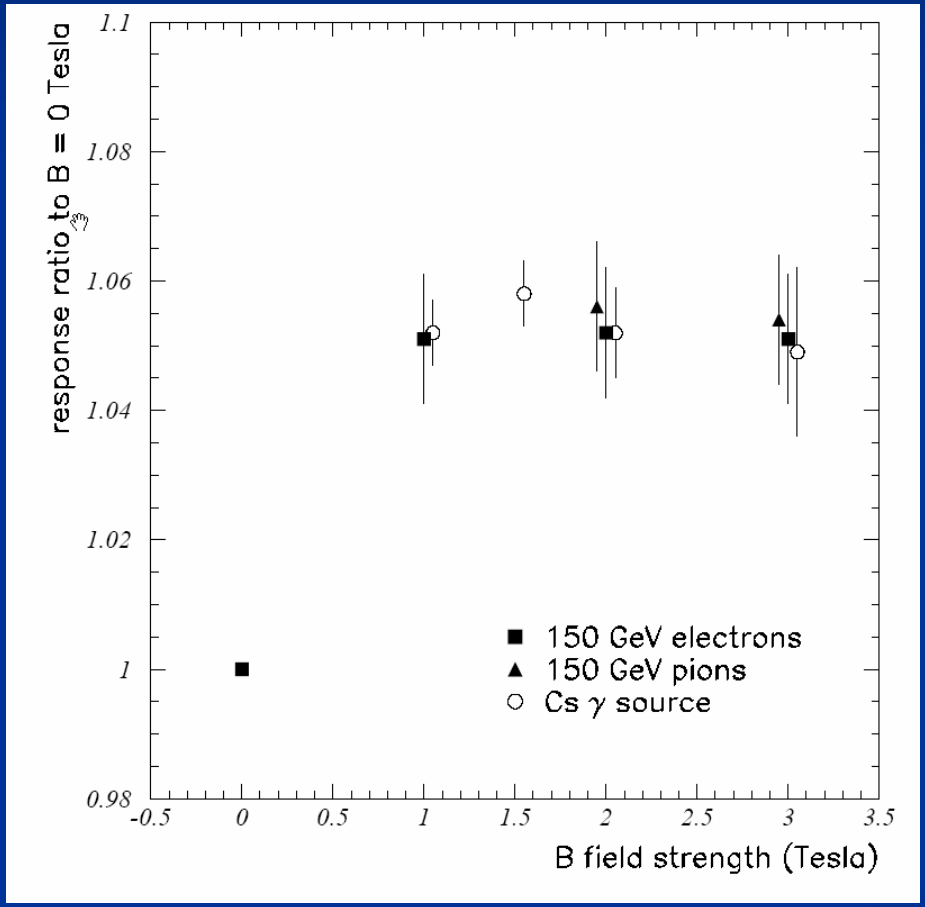
HCAL Specific

- Cable and close detector.
- Study HB/HE gap.
- Operate the calibration system in 4T field. (wire sourcing).
- Measure scintillator brightening effect in 4 T field.
- Confirm no pixel x-talk in HPD (proximity focussing).
- Process data through complete software chain.
- Reconstruct muons with proper calibration constants.

B-field effects

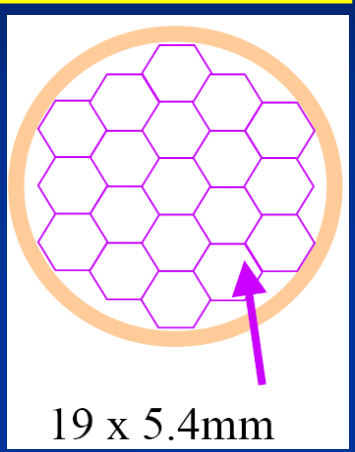


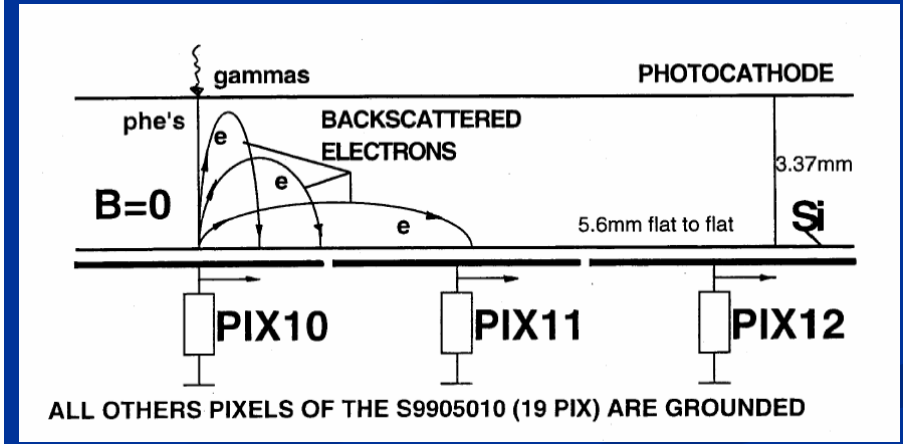
Scintillator brightening



More light output in B-field.

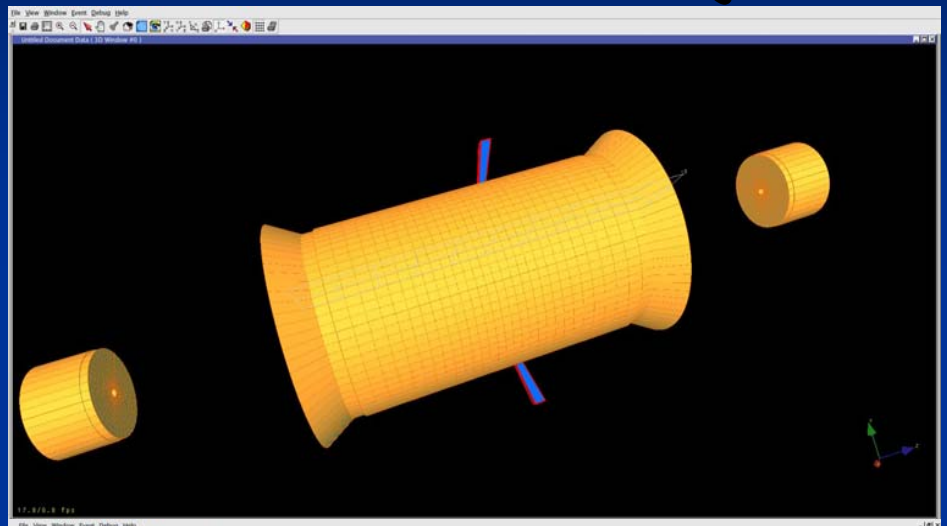
HPD pixel cross talk due to electrons backscatter

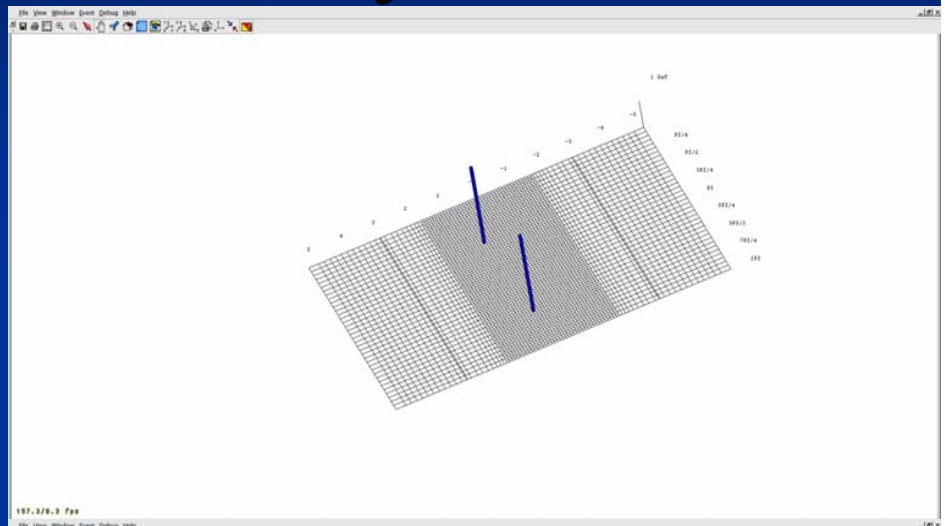


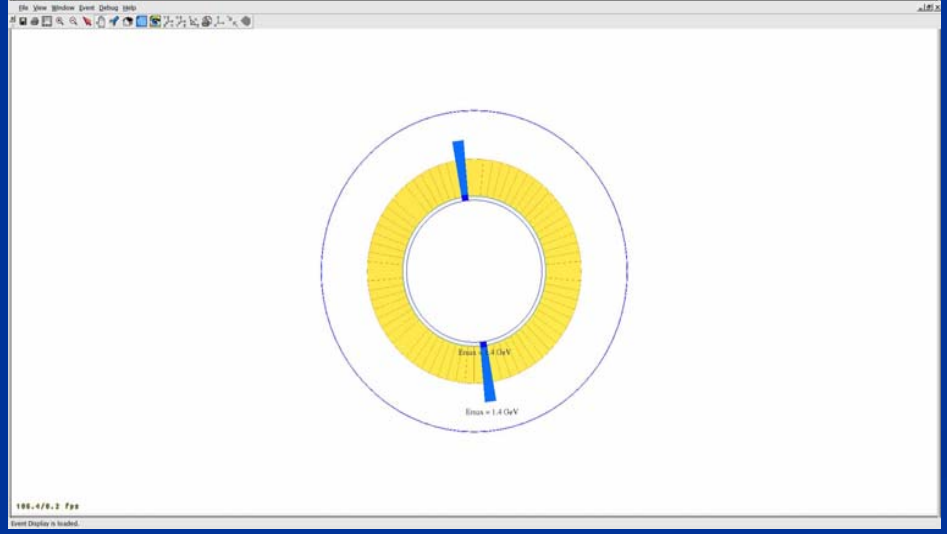


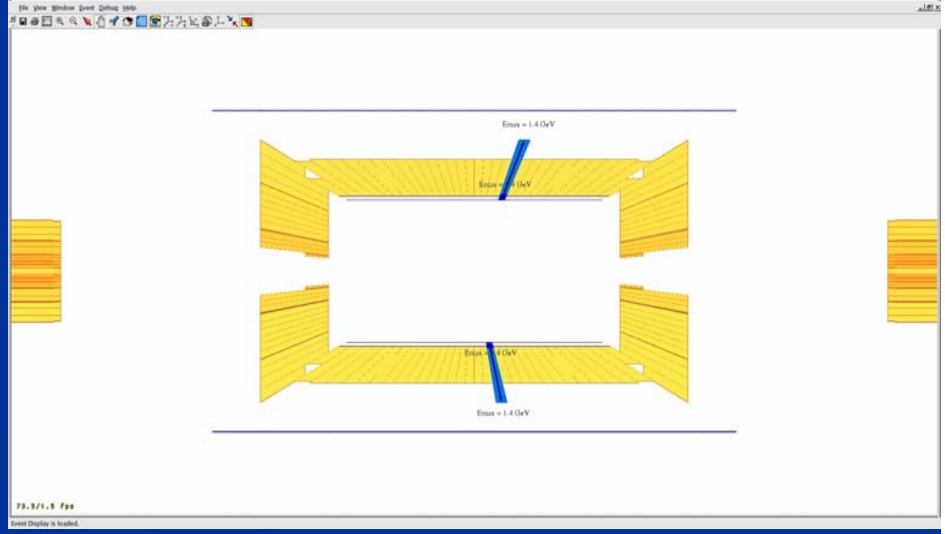
No cross talk in B-field
Electrons are trapped along B-field line.

HCAL muons at SX5 (no B-field)

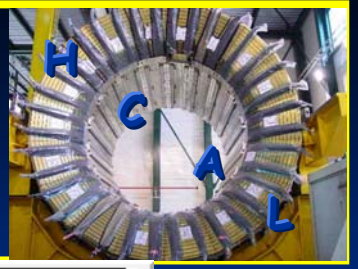


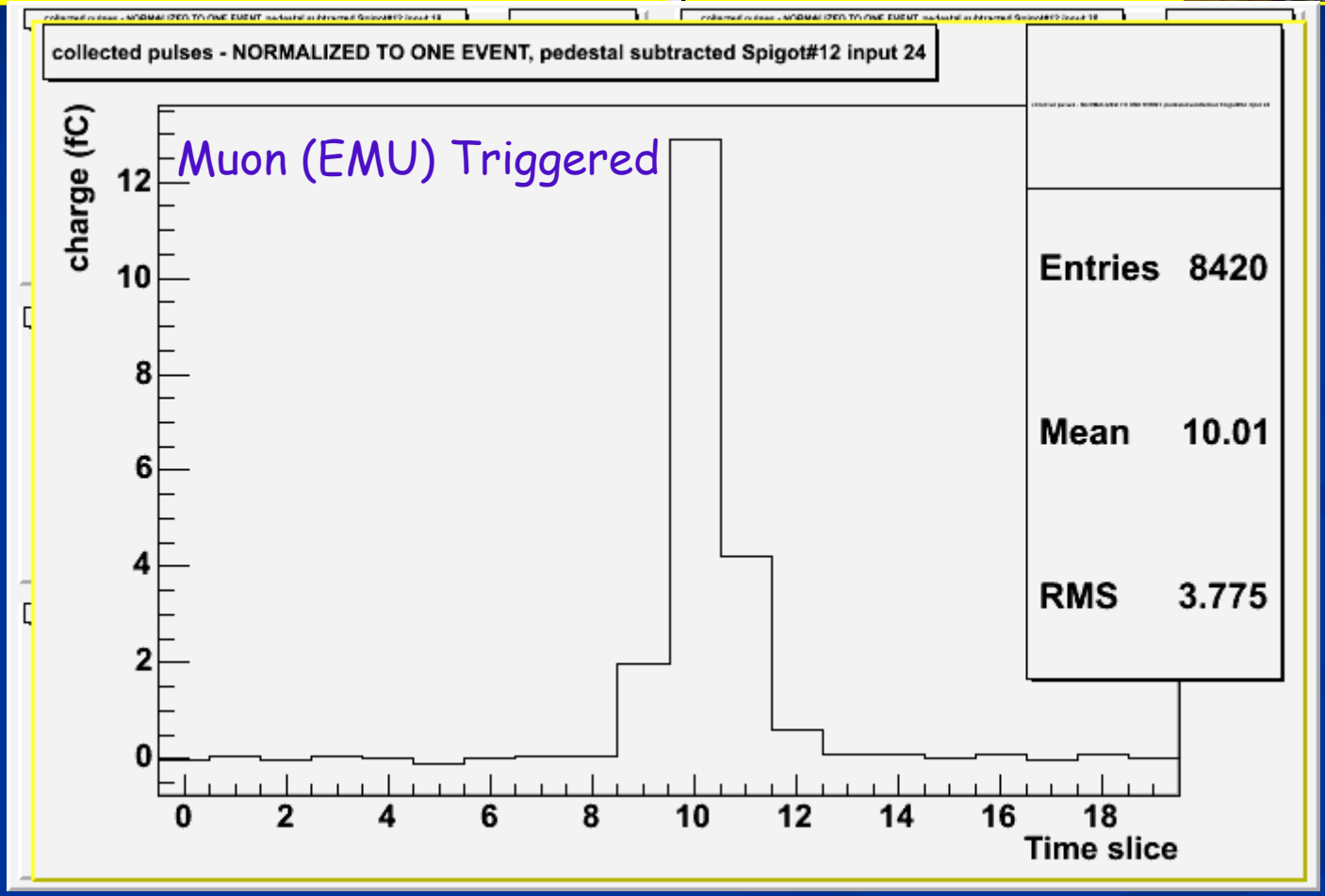






MTCC: Muon Pulse Shape





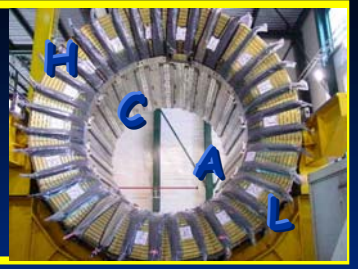
Events above 10 fC,
corrected for trigger jitter
(max time-sliced forced to ts=10)

HCAL in Test Beam

Late July – mid Sept 2006

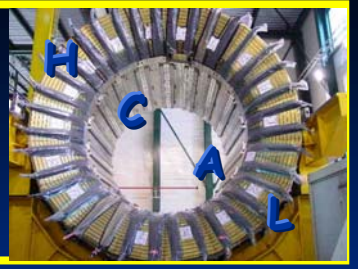
(TB2004 - See Jordan Damgov's Talk)

TB2006



- Goal
  - Measure performance of real CMS calorimeter. (2-300GeV) with real ECAL SuperModule and real ECAL readout
  - System test of combined ECAL+HCAL system.
  - Real-life input data for the development of calorimeter software
  - Calibrate radioactive source with beam (HCAL) again to repeat TB2004.
  - Study low energy beam data - improvements
    - e/μ/π/K/P separation - Cerenkov + TOF + μVeto + …
    - Cleaner beam (reduce/tag interactions in beam line)

Conclusions



- HCAL SX5 commissioning is almost done. HB/HE/HF source calibration completed. A calibration at the ~ 4% level exists for (HB/HE) and 5-7% for HF.
- HCAL Trigger electronics burn-in/integration nearing completion in Building 186 staging area. Move to USC55 underground area 6/06.
- We need to exercise DB and DAQ systems.
- The MTCC will establish systematic shifts measured separately on the bench to hold the preliminary calibration.
- TB2006 must confront G4 incisively (see Jordan Damgov's and Anwar Bhatti's talk).
- HCAL must perform a "calibration challenge".