Design of the CMS-CASTOR sub detector readout system

by reusing existing designs

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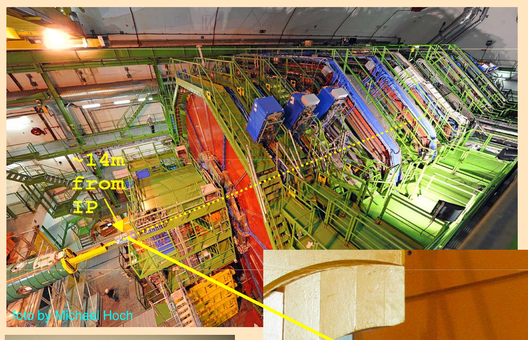
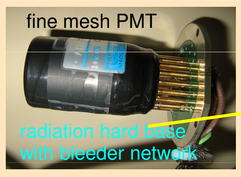
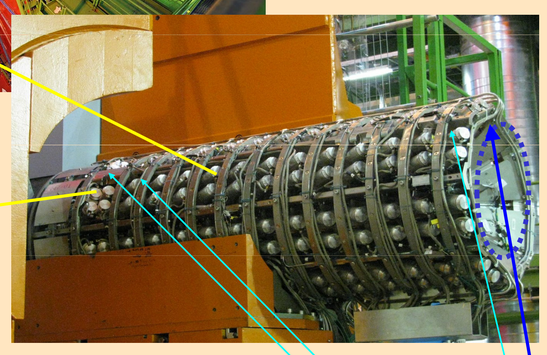
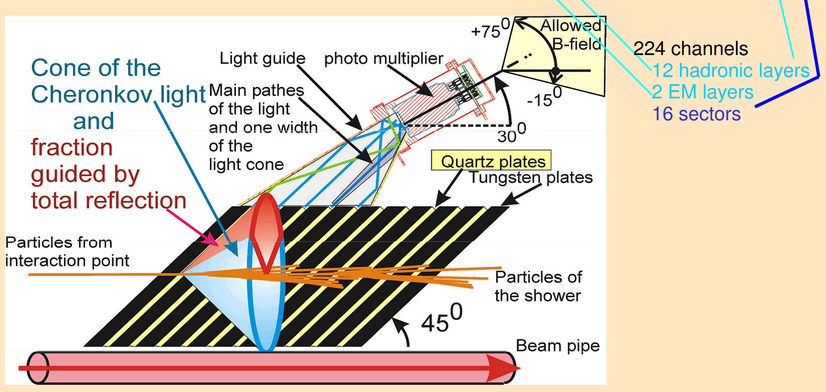


The CASTOR detector

- Forward calorimeter
- coverage: $-5.2 > \eta > -6.6$
- pp physics program
- Heavy ion program







Installed readout components:

- 224 PMT's
  - 7 with no signal
  - 6 effected by HVproblems
- LV Wiener: 8 outputs
- HV CAEN : 148 outputs
- ELMB for temperature monitoring
- 3 front end crates
- LED monitor system
- 38 QIE cards
  - Average noise 2.6 fC
  - (20% higher then calculated)
- HCAL readout and trigger :
  - 5 HTR cards
  - 3 DCCcards
  - 1 TTCf

Initial development resources :
- 1 person for all issues related to electronics
- development time < 2 years

} ->

development strategy : look for similarities and reuse existing designs with none or limited adaptations

Similar sub detector in CMS :

HCAL / **HF(forward):** also Cerenkov light with PMT as sensor

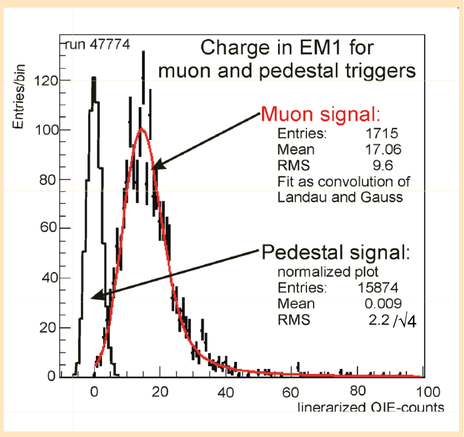
Basic different requirements :
- occupancy per readout unit for CASTOR near 100%
- radiation levels higher in the detector (20 kGy)
- magnetic field in the detector higher
- distance between PMT and front-end chip twice longer.
- higher radiation levels for front-end electronics and power supply

possible CMS front-end chips :
- HCAL / HF(forward) : QIE [7]
  - \+ good bunch crossing separation
  - \+ semi differential input
  - \- dynamic range on the limit
- ECAL: MPGA [1] [3]
  - \- long pulse shaping time=> residue after signal reconstruction effects resolution .
  - \- risk of noise pickup with little means to compensate.
  - \+/- not possible to place the radiation hard MPGA/ADC and Fenix chips on the detector. Less services to the detector if these chips could have been placed
  - \+ bigger dynamic range

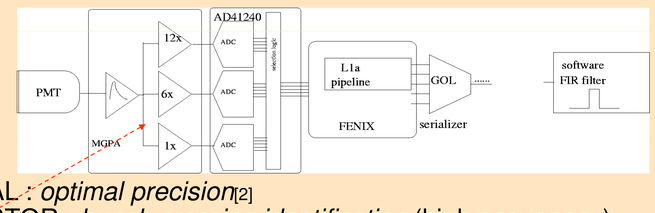
final choice QIE chip

Test beam 2008:

From measurements expected photo electrons on the PMT (dynode type)
- Muon : 9
- Electron : ~ 30 /GeV
- Pion : ~13 /GeV



Signal reconstruction study of the MPGA pulse shape

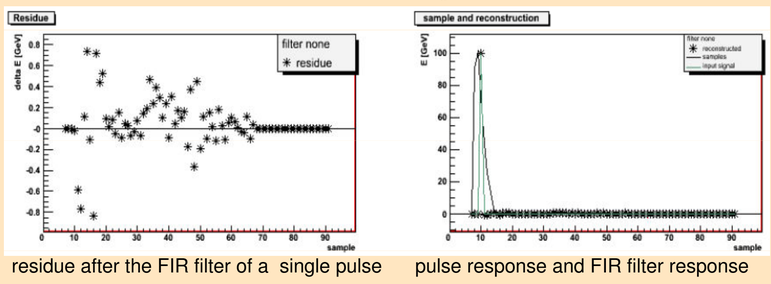


ECAL : *optimal precision* [2]

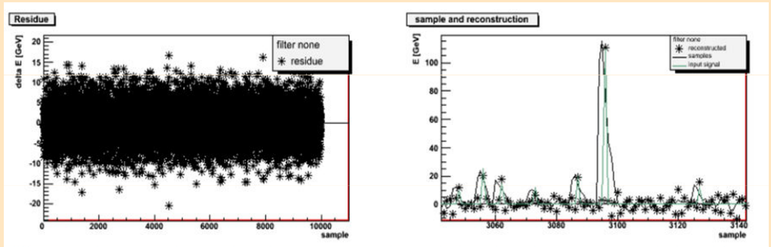
CASTOR : *bunch crossing identification* (high occupancy)

FIR filter response : $x[k]=\sum_{i=1}^{n}(h[i]\times s[k+n-1])$

coefficients determined by : $minimize:(\sum_k x^2[k])$

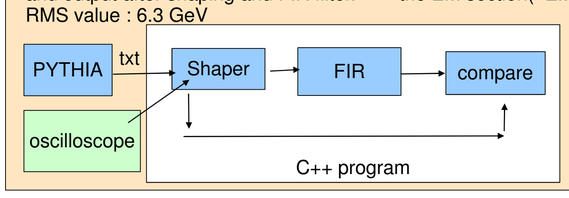


residue after the FIR filter of a single pulse — pulse response and FIR filter response



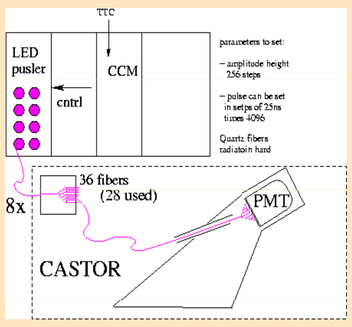
difference between input signal and output after shaping and FIR filter. RMS value : 6.3 GeV

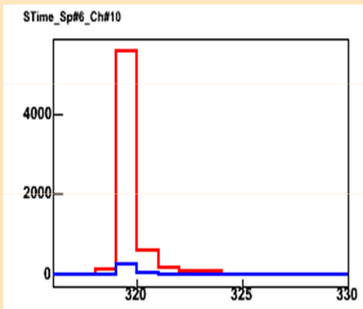
shaped signal and reconstructed signal from the EM section(EM particles, luminosity 10^{32})



effects included :
- time jitter (interaction position)
- electronic noise
- different taps for FIR filter
- 12 bits input signal
- MPGA gain selection

The LED monitoring system



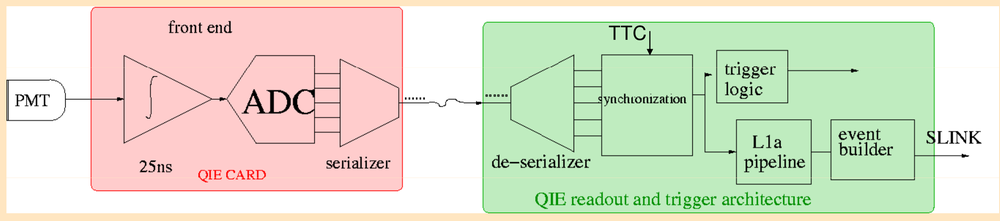


Led pulse signal at PMT voltage 1600 V (red) and 1000V (gain difference 16)

- Commissioning
- Synchronization verification
- Monitor of gain and collection efficiency of PMT
  - $\mu = G \cdot Npe$ G: gain
  - $\sigma = G \cdot \sqrt{Npe}$ Npe : photo electrons
- Signal comparison for different operational gain settings
  - Muon signal 9 pe => for detection PMT gain needed of ~15000 the muon signal is used for calibration of the detector
  - Max signal to detect : 3 Tev => max gain : 2000

CASTOR readout architecture

with two exiting hardware implementation for the backend



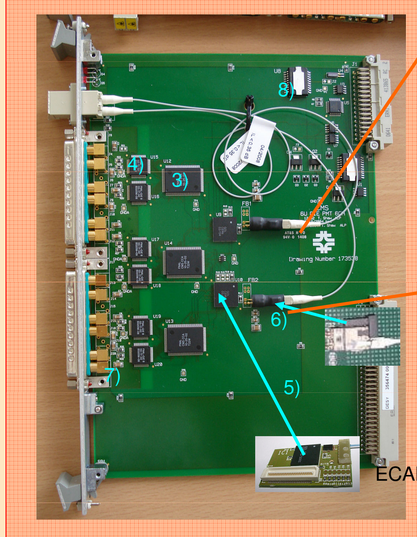
HCAL hardware :
- \+ fully compatible, proven readout path
- \+ reuse of most of the exiting firmware
- \- No solution for trigger path
- \- no hardware available , need to reproduce all the boards

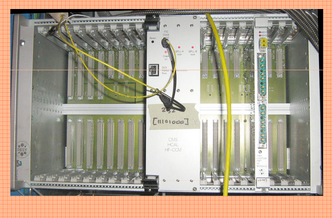
TOTEM/ Pre-shower hardware
- \+ Simple modification optical receiver
- \+ Could join series production VME board
- \- need to modify and write new firmware

Chosen to use TOTEM / pre-shower hardware (under discussion now!)

underestimated firmware tasks

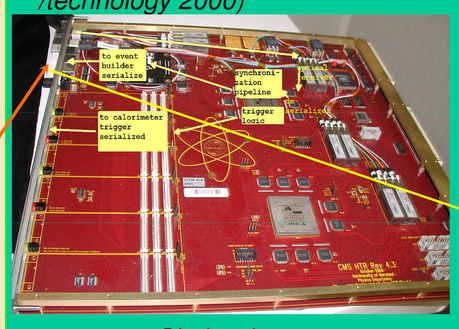
Total 55 QIE boards produced.
QIE card reproduction issues :
1) no need for design changes,
2) needed to redo films
3) sufficient CCA chips (control chips)
4) sufficient QIE chips if one can accept a lower input impedance
5) GOL chips shortage => re-ball GOL chips from defect ECAL-GOH.
6) laser obsolete => package problem => adapt HCAL/ HO mechanics
7) special foot print sub-D connectors
8) bought last radiation tolerant LV regulator from CERN stock



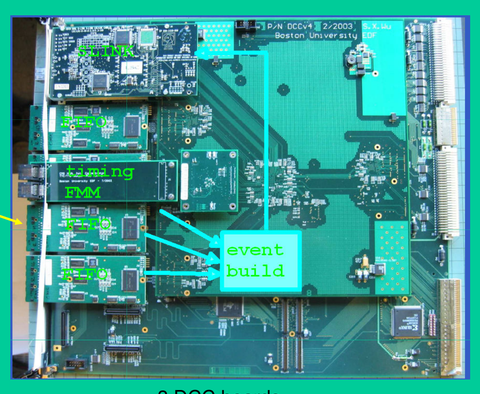


6 crates + backplane produced
10 CCM units produced
both no design changes.
Production organization > 1 month FTE

Functionality split Over different hardware Components (big system /technology 2000)



5 htr boards



3 DCC boards

QIE readout and trigger architecture based on HCAL boards[6]

Comparison between the HCAL readout and trigger architecture and the CASTOR readout and trigger architecture based on the TOTEM/pre-shower FED

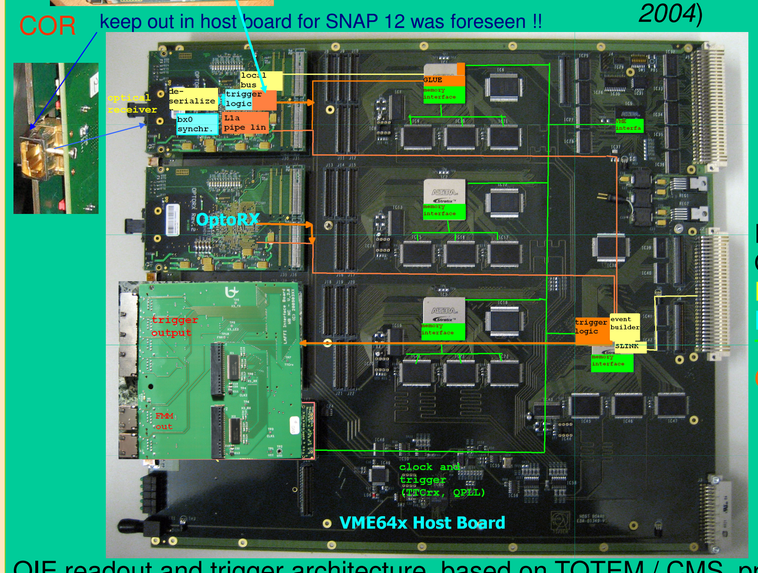
NGK : 800 MB/s , obsolete =>AFBR-742BZ , 2500MB/s

[5] From NGK optrx => snap 12 package optorx simple design change and lay-out change

Hardware components serve different functionalities (small system /technology 2004)

COR

keep out in host board for SNAP 12 was foreseen !!

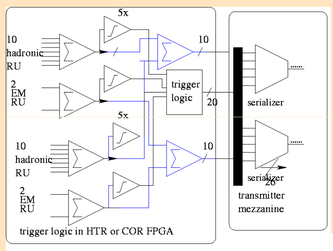


4 host boards
7 optical receivers

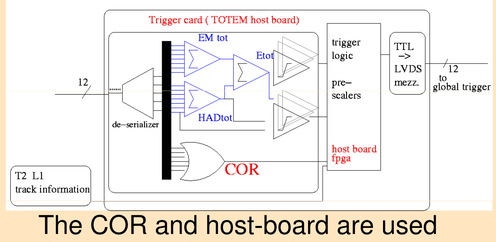
Firmware based On :
- Pre-shower code
- HCAL code
- TOTEM code
- CASTOR code

QIE readout and trigger architecture based on TOTEM / CMS pre-shower boards [4]

Trigger bit generator



In the FPGA of the COR the energy in a sector is calculated. To reduce the data the energies of 3 sectors are summed together.
Hadronic energy has to be added over 12 readout units but could not be fitted In the existing hardware .
The energy information and trigger bits will be sent to the trigger card via 4 optical links on a mezzanine(to be designed)



The COR and host-board are used for an other functionality

The trigger card calculates the total energy.
The total energy as well sector energies are compared to different thresholds.
Optional: tracker information from TOTEM T2 can be used.

The firmware for the project is not finished in time so there are no results to report. For this reason the HCAL readout and trigger boards are installed and project implementation is under discussion

Reusing exiting designs experience :

- Lower risk
- Time gain ? Less development time but a lot of time needed to find hardware that best satisfies the requirements.
- Requirements have to be adapted to the hardware.
- More time lost with production in respect to a new design
  - preparation (ordering specific component)
  - obsolete components force design changes
- The host-board is a good example of a reusable design:
  - design as it was indented to be a multi purpose design
  - prepared for standard components (SNAP 12 package)

What is helpful to be more efficient when reusing a existing design ?
- Access to full documentation and production files
- Detailed design specification, like internal bus clock speed
- Use general components, (second source supplier), check commercial lifetime
- To make a design multi purpose one has to implement more then what is necessary for the initial requirements. More bandwidth , bigger FPGA … (Who will pay this ?)

[1] Raymond, M ; Crooks, J ; French, M ; Hall, G The MGPA electromagnetic calorimeter readout chip for CMS, 9th Workshop on Electronics for LHC Experiments,
[2] Brunelière, R; Zabi, Alexandre Reconstruction of the signal amplitude of the CMS electromagnetic calorimeter CMS-NOTE-2006-037; 2006
[3] M. Hansen for the ECAL frontend workgroup: The New Readout Architecture for the CMS ECAL 12th Workshop on Electronics For LHC and Future Experiments, Valencia, Spain, 2006
[4] Antchev G - TOTEM Collaboration. The TOTEM front end driver, its components and applications in the TOTEM experiment Topical Workshop on Electronics for Particle Physics
[5] Vichoudis, P ; Reynaud, S A multi-channel optical plug-in module for gigabit data reception 12th Workshop on Electronics For LHC and Future Experiments 2006
[6] CMS HCAL : http://cmsdoc.cern.ch/cms/HCAL/document/CountingHouse/
[7] Lazic, D CMS Hadron Calorimeter Readout Group. Beam tests of CMS HCAL readout electronics 9th Workshop on Electronics for LHC Experiments 2003