# Progress on the Upgrade of the CMS HCAL Front-End Electronics

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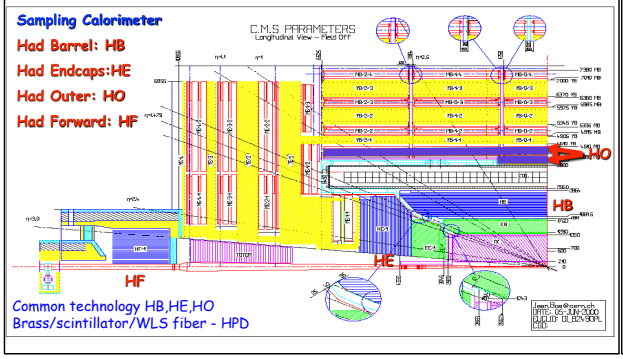
For the CMS HCAL group

## CMS HCAL

**Sampling Calorimeter**
**Had Barrel: HB**
**Had Endcaps:HE**
**Had Outer: HO**
**Had Forward: HF**



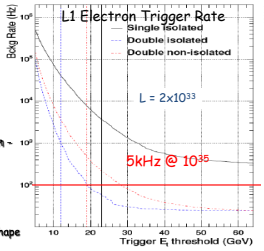

Common technology HB,HE,HO
Brass/scintillator/WLS fiber - HPD

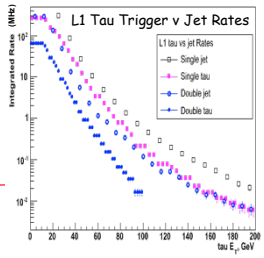
## Calorimeter Trigger

L1 Trigger Rate @ $10^{35}$

**Physics Motivation**

- **High Luminosity run conditions**
  - Maintain detector performance/ resolution
    - Improve triggering
    - Maintain calibration
  - Limit lepton ID degradation / Improve background rejection
    - Lepton Isolation
    - Calorimeter longitudinal segmentation - shower shape, improve resolution (weighting)
  - Extreme pile-up conditions (100-200 pileup evts/X-ing)
    - Need better timing resolution
      - Current HCAL timing based on pulse shape information (2-3ns)



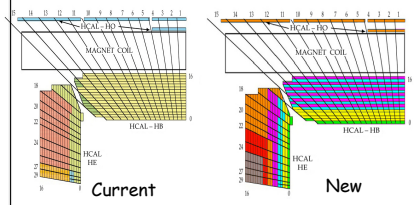

Isolation criteria insufficient at $10^{35}$
Removing Layer 0 from HCAL
Isolation cone improves rejection
--> Longitudinal Depth segmentation

## Front-end Upgrade

### Depth Segmentation

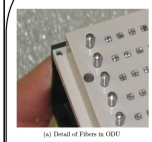
18 Channel RMs

48 Channel HB RMs
32 Channel HE RMs




HB – 3 Depths (Interleaved rear compartment)
- Adds robustness/redundancy
- EODU - Better in terms of SiPM saturation

### New Photo-sensors

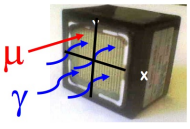


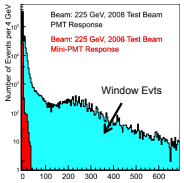
(a) Detail of Fibers in ODU

(b) SiPM Array in RM Detail

HB/HE SiPMs

HF Quad-anode PMT



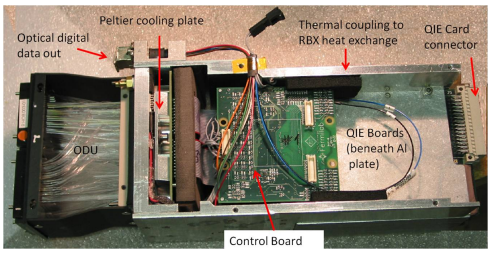

**New photo-detectors**

- SiPM (HB/HE/HO) [see J. Anderson SiPM poster]
  - Replace HPDs with SiPMs
    - Improved performance in B-field
    - Better S/N
  - HB (ODU/EODU) & HE (ODU)
    - Inner Layers - Optical Decoder Unit (ODU) - Optically sum Layers to form towers
      - Outer Layers - Electrical Optical Decoder Unit (EODU) – Optically sum odd [even] interleaved layers then electrically sum output from (odd + even) layer SiPMs
  - HO (ODU) – Drop in replacement of HPD sensor [see J. Freeman HO Upgrade poster]
- 4-anode PMT (HF)
  - Replace thick windowed PMTs with thin windowed/metal can PMTs
  - Multi-anode PMTs with better QE
  - Multi-anode readout (only with new FE electronics, allows rejection of "window interaction" events

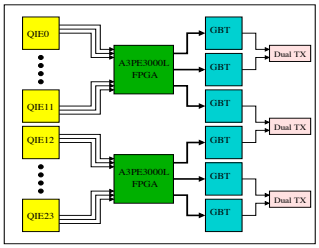
### FE Electronics for HCAL Upgrades

•Installation Plan
- LS1 – HF/HO Photo-sensor replacement,commisson BE μTCA
- LS1.5 – HF FE electronics replacement
- LS2 – HB/HE/HO FE electronics replacement (HB/HE photo-sensor, FE electronics. HO FE Electronics)

•Cost/Schedule Constraints
- Re-use as much of the existing infrastructure as possible
  - Reuse optical data links, H2O cooling, readout boxes
  - Modular FE readout & control units allow for easy replacement of FE electronics
- Radiation Environment (2E12 n/cm$^2$, 100 Gy), B-field: up to 4T

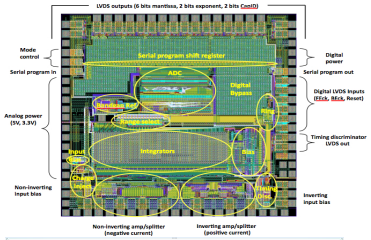


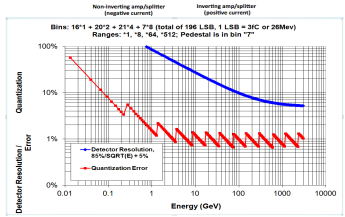

### Block Diagram of HF FE Card




•New/more readout channels
- Increased bandwidth (1.6 Gbps → 4.8 Gbps)
- New QIE ADC with timing (~1 ns resolution) and can be used to readout SiPMs in HB/HE and PMTs in HF.
- New rad hard FPGA – TDC info, data reduction
- GBT chip set
- New FE Controller/Slow Controls module with added redundancy

### QIE10 – ADC chip



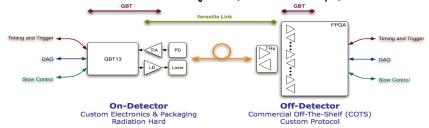

Next Generation QIE (Charge Integrator Encoder)
- Fast, Dead-timeless, floating-point ADC + TDC
- Span 17-bits dynamic range with pseudo-logarithmic, multi-ranging FADC
- Positive (SiPM) or negative (PMT) input current
- 6-bit mantissa, 2-bit exponent, 5 or 6-bit TDC, 2-bit Cap-ID

### FPGA

New 4.8Gbps radiation hard FPGA

### Gigabit Bidirection Trigger & Data Link Project

Common Projects (Joint LHC-Expt)




ngCCM - New FE Electronics Controller
With clock/control data redundancy