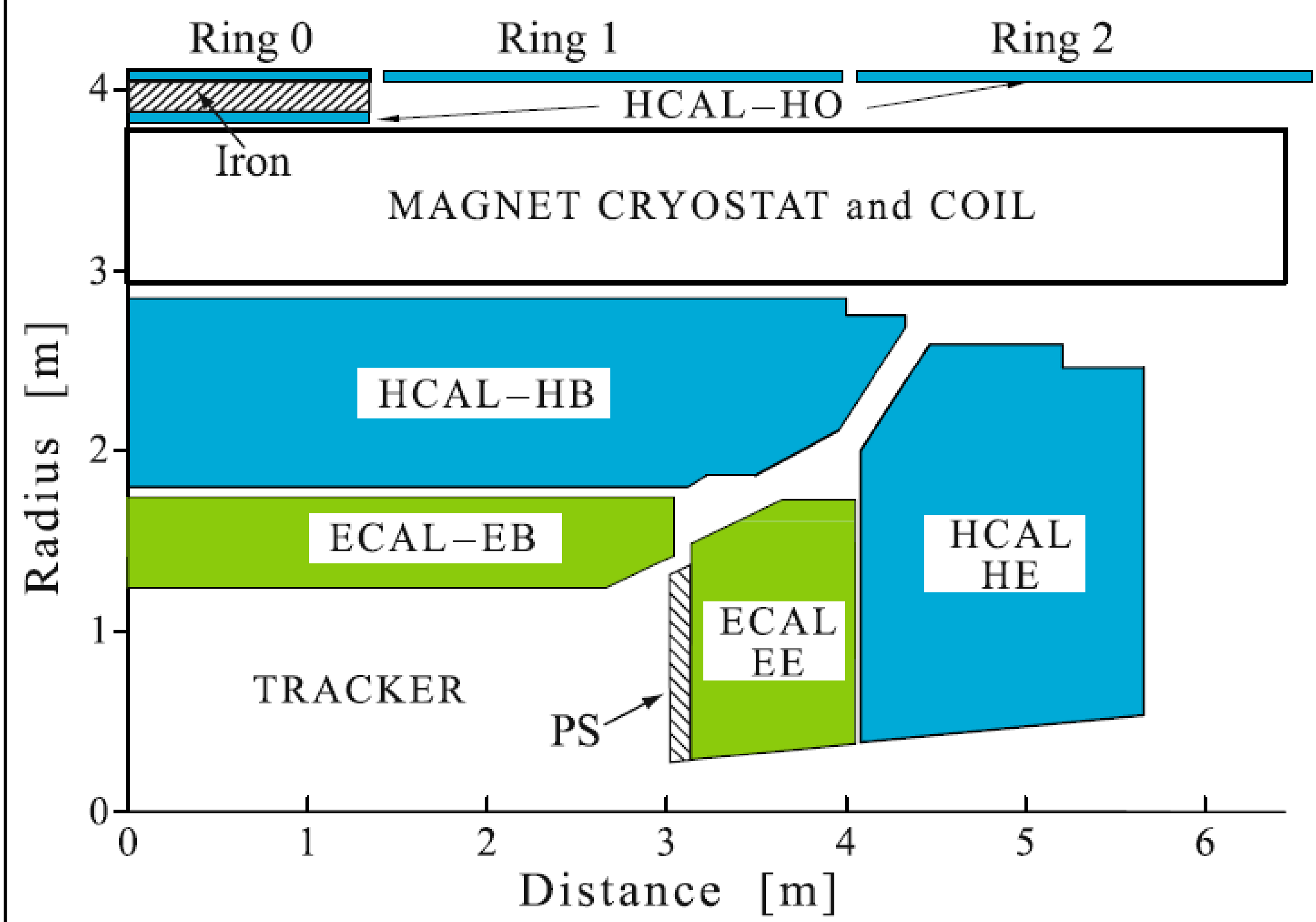


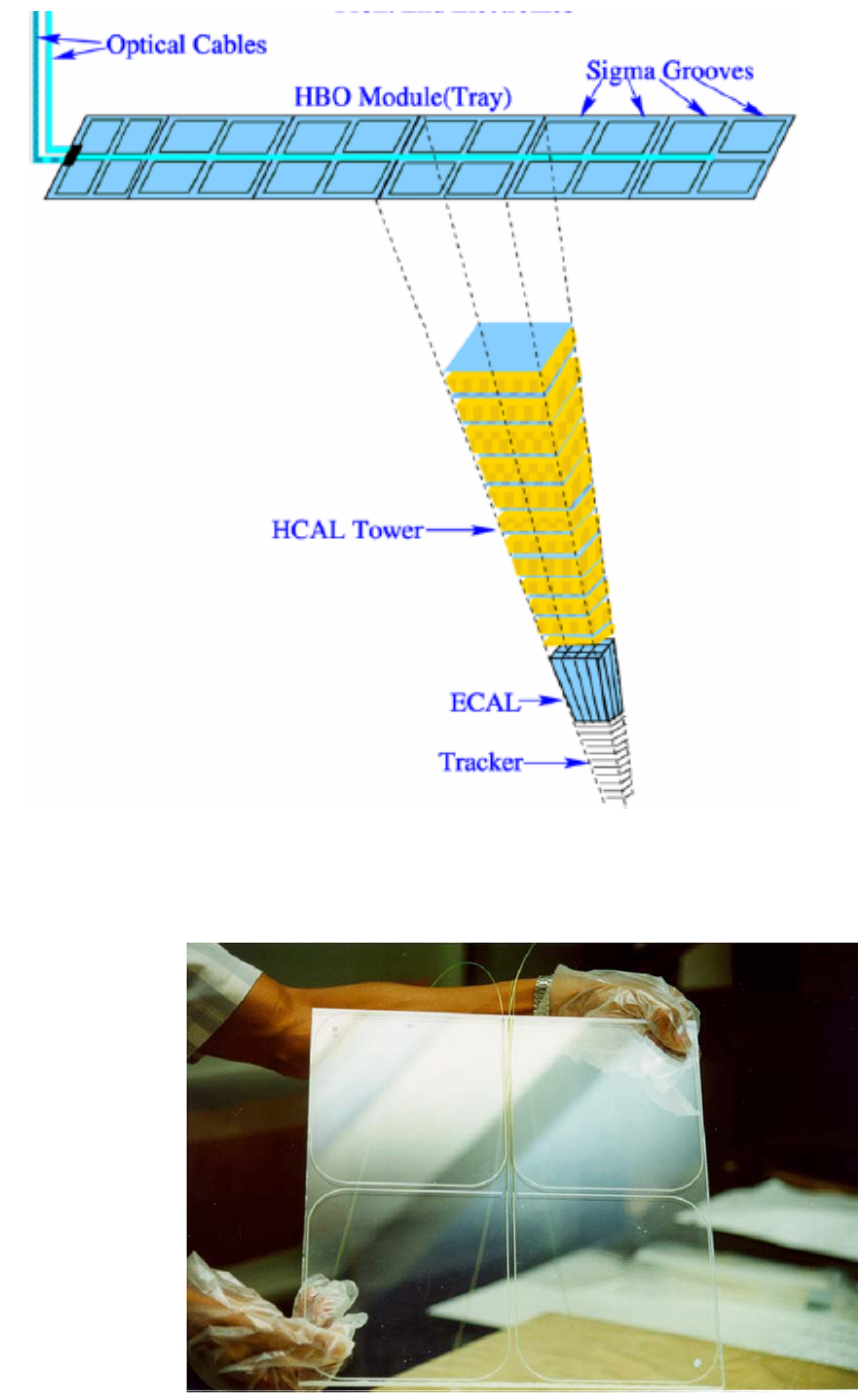
# Progress on the SiPM Upgrade of the CMS Outer Hadron Calorimeter (HO)

Arjan Heering (University of Notre Dame) and Jim Freeman (Fermilab),  
For the CMS HCAL group

## CMS Hadron Calorimeter



## HO Design

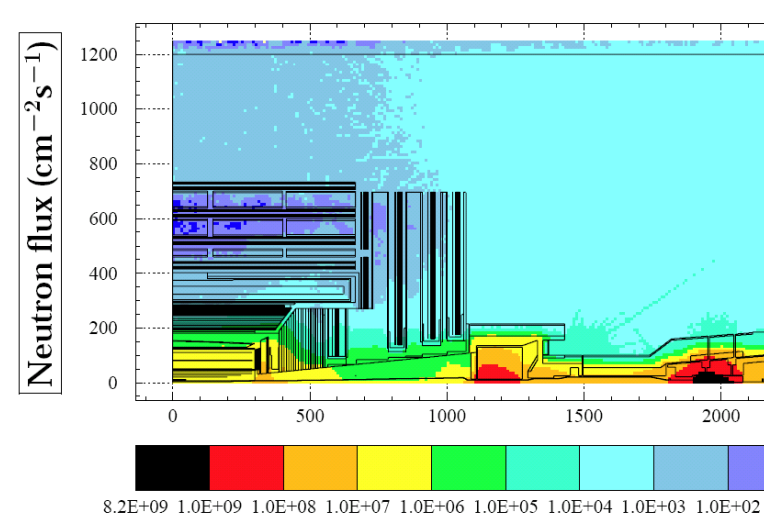


- “Tail catcher” for the barrel calorimeter.
- Correct missing  $E_T$  and jets particularly in Ring 0.
  - Useful for muon identification.
  - HO is in projective towers that match the inner calorimeter.
  - Made of scintillator/wavelengthshifting fiber.

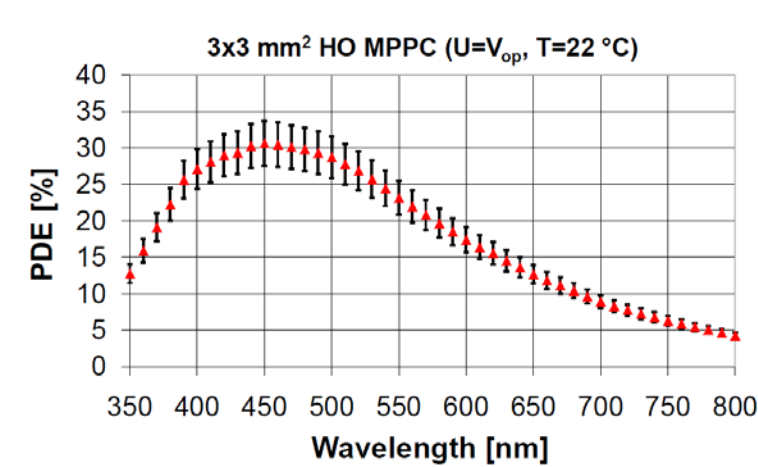
## SiPM Choice

- Important requirements were
- Rad. tolerance to  $5E11$  neutrons ( $>100$  KeV) /  $cm^2$
  - Dynamic range sufficient for HO (2500 pes)
  - Pulse recovery time
  - Leakage current
  - Photon detection efficiency
  - Temperature dependence of gain
  - Source capacitance
- 3000 Hamamatsu 3X3 mm 50 micron MPPCs are in the system

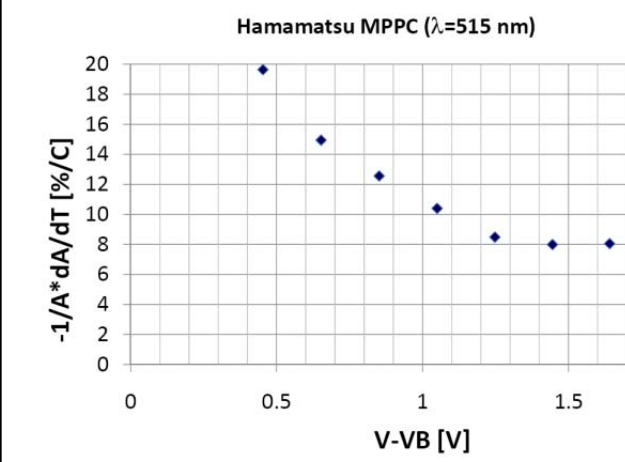
Simulated Neutron field in CMS.  $E > 100KeV$



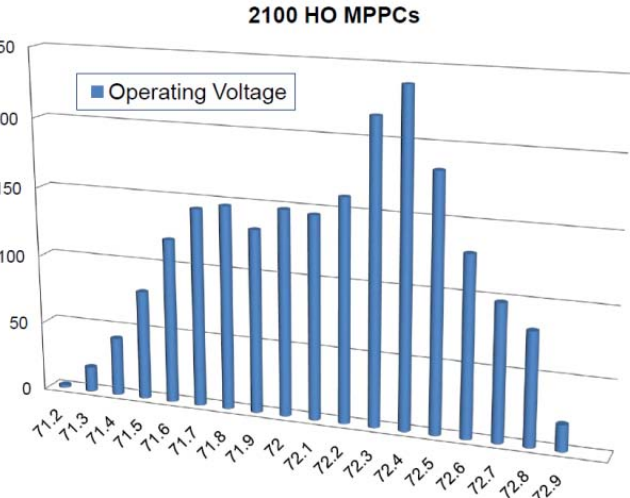
MPPC PDE vs. wavelength



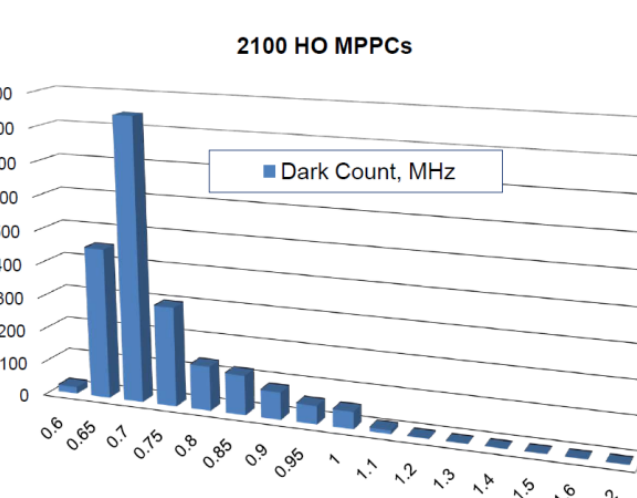
MPPC Gain dependence vs temperature



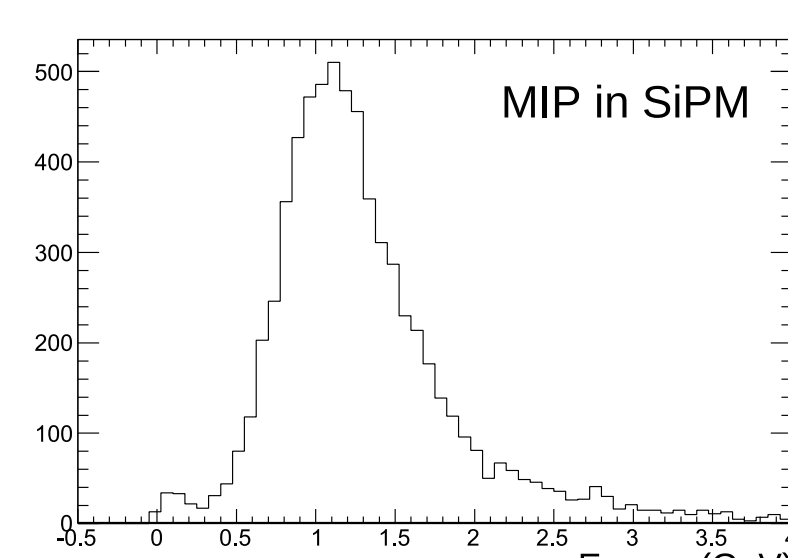
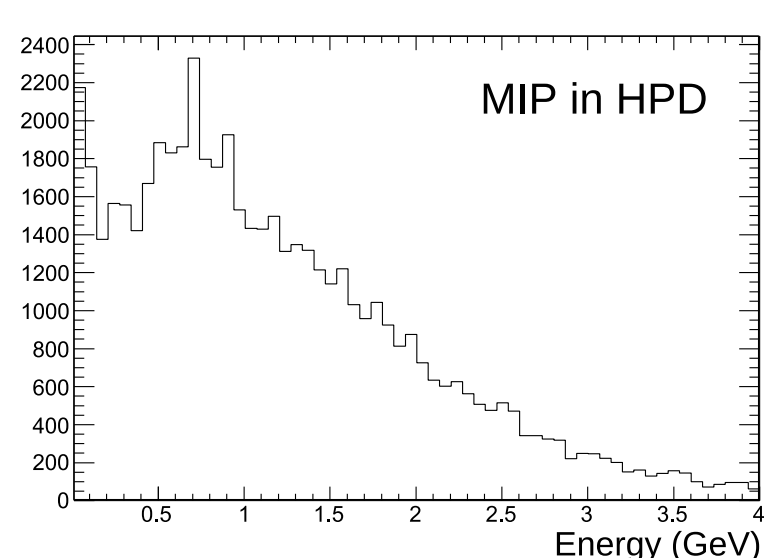
MPPC Operating Voltage (2100 devices)



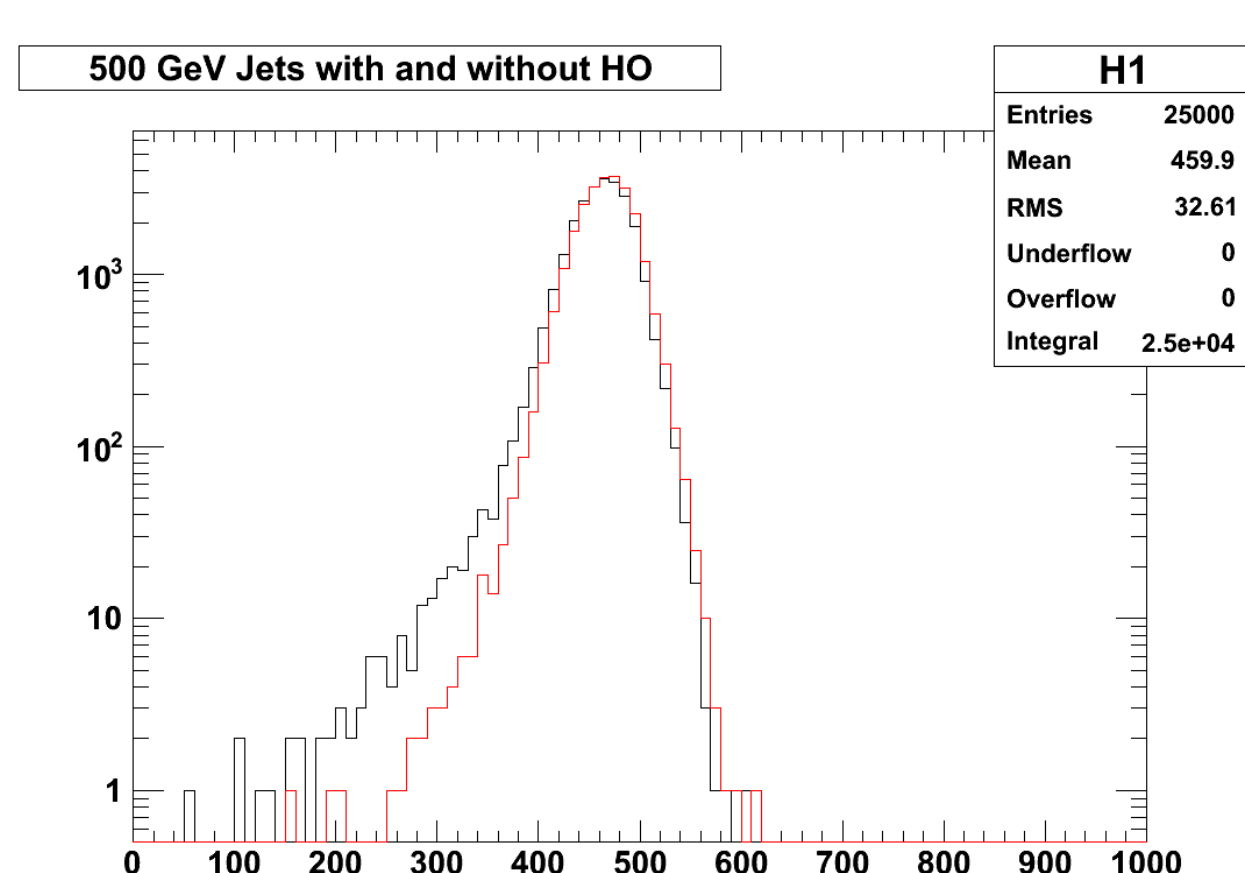
MPPC Dark Count (2100 devices)



## Performance



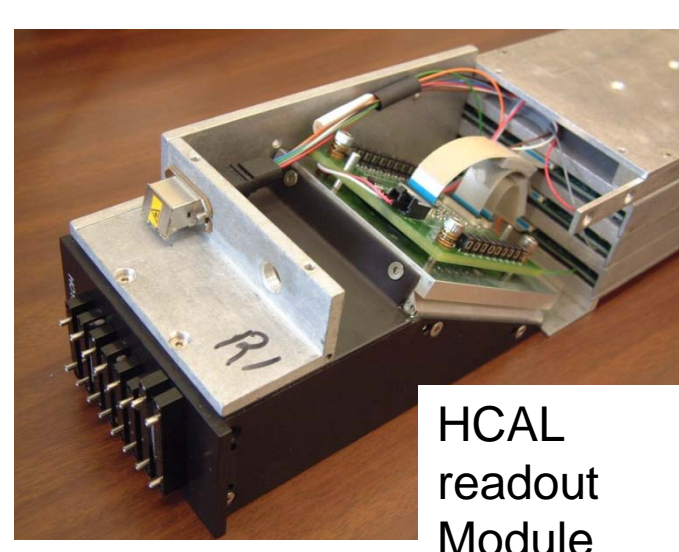
Minimum ionizing tracks in HO for HPDs, left, and SiPMs, right. S/N for SiPM is  $> 20/1$



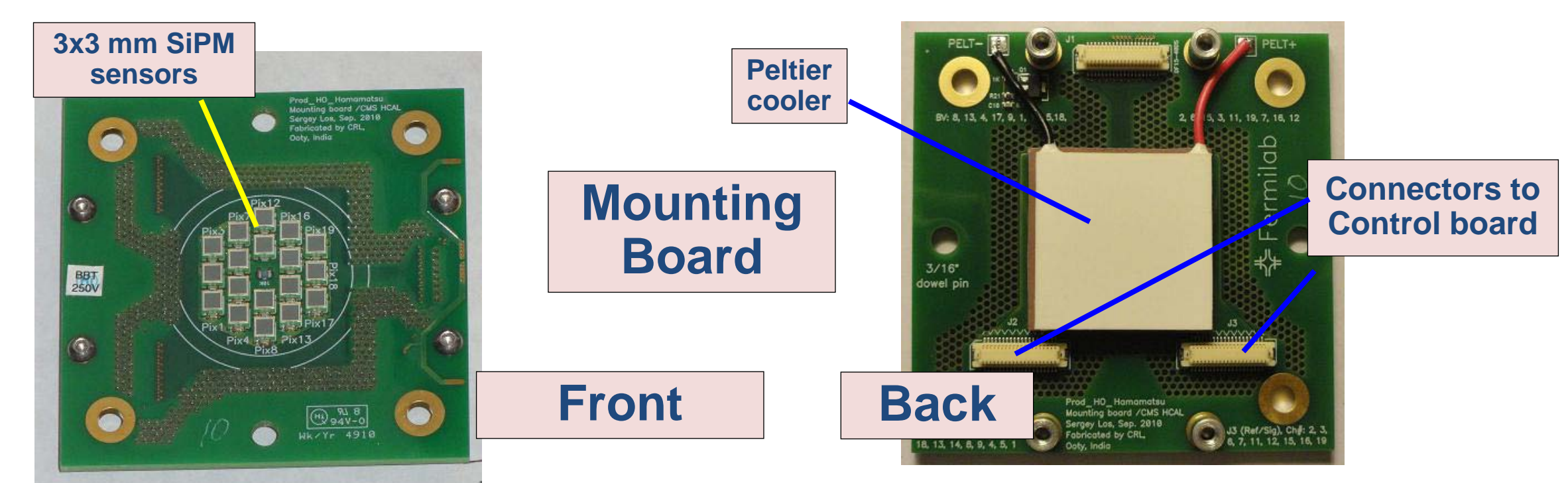
Simulated Jet response for 500 GeV Jets. Curves are with/without HO energy added to Jet. HO makes important improvement to missing  $E_T$

Design criteria were for a “drop-in” replacement of the HPDs with the SiPM system.

- The system has
- Local temperature sensing and stabilization (Peltier and software feedback correction voltage)
  - Hardware under-temperature protection
  - Leakage current measurement
  - Bias voltage generation (CW from LV volt supply)



## System Design

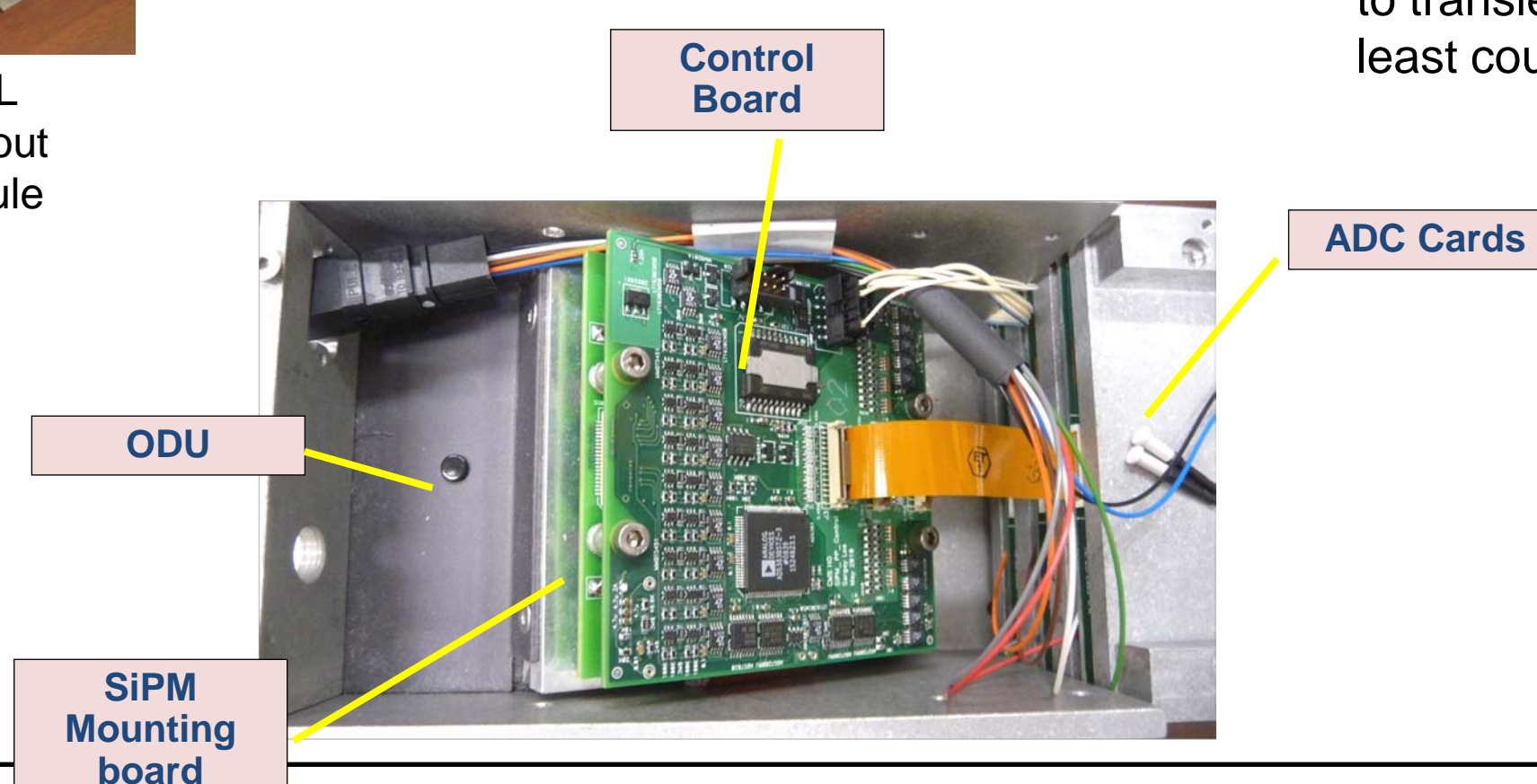
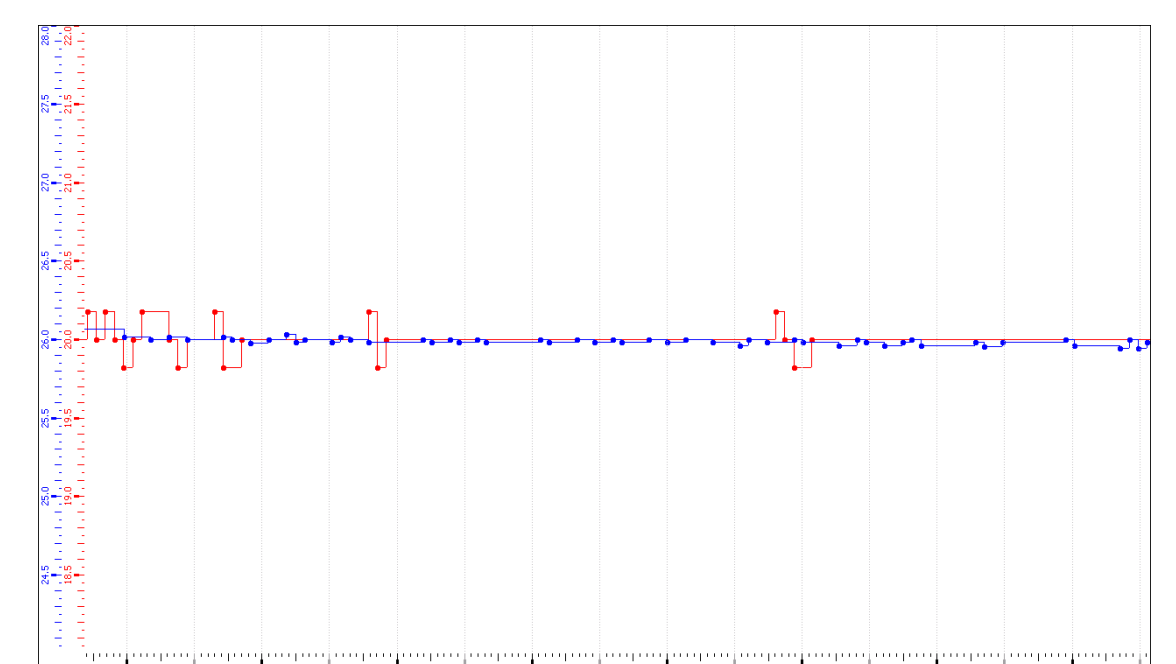


“Mounting Board” has 18 SiPM array (match HPD) and Peltier on back side

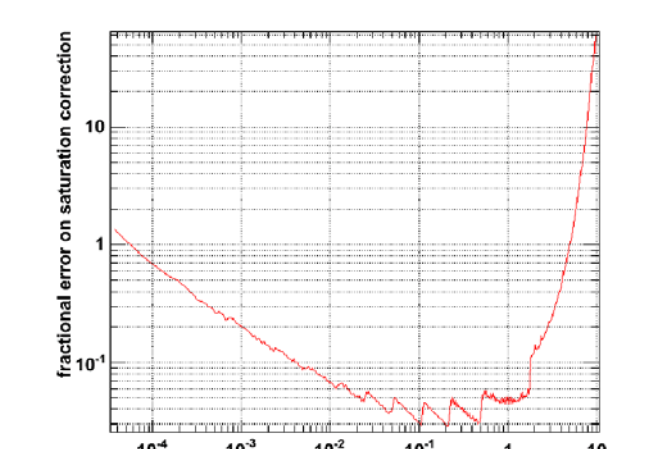
Control Board Parameter	Hamamatsu 3x3 mm
Maximum DAC set BV	100 V
BV resolution	25 mV
BV current limit (per diode)	100 $\mu$ A
Maximum measurable leakage current	40 $\mu$ A
Leakage current resolution	10 nA
Diode grounding resistor	4.99 kOhm
Temperature resolution	0.018 C

## Control Board Major Design Parameters

Temperature response to transient. Stable to least count (0.02 C)



Simulated fractional error vs number pe's per micro-pixel. Includes ADC binning. Useable to  $\sim 5000$  pe's



## Schedule

CMS made an initial installation during the spring of 2009, replacing  $\sim 10\%$  of the HO HPD's.

This initial trial has been successful, and CMS is preparing to replace all of the HO HPD's during the next long LHC shutdown, foreseen in 2013.

### Tentative LHC Schedule

