SIPM Developments for CMS

H C A L

Jim Freeman

FNAL

SiPM Upgrades for HCAL

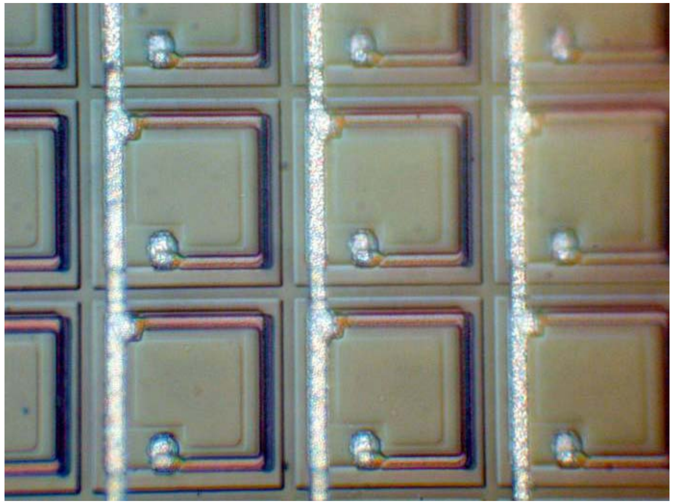
- **Phase I upgrade: Replace HPDs, PMTs with SiPMs**
  - **Larger amplitude signal allows for signal splitting for tdc/adc function**
  - **SiPMs small, can change (increase) depth segmentation, add redundancy**
- **HO upgrade more immediate**
  - **First HCAL application proposed**
  - **HPDs have electron steering issue (angle of B field different than simulations), noise, …**
  - **SiPMs MUCH lower noise**
  - **Greatly improves MIP detection (muons, muon trigger, calibration)**

Silicon Photomultiplier

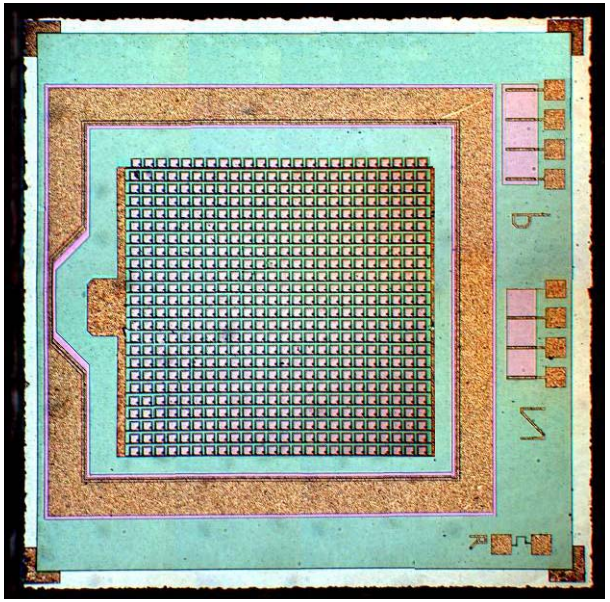
Array of Cells connected to a single output:

Signal = Σ of cells fired

If probability to hit a single cell < 1 => **Signal proportional to # photons**



Pixel size:
~25 x 25 μm^2 to ~100 x 100 μm^2



Array size:
0.5 x 0.5 mm^2 to 5 x 5 mm^2

Silicon Photomultiplier

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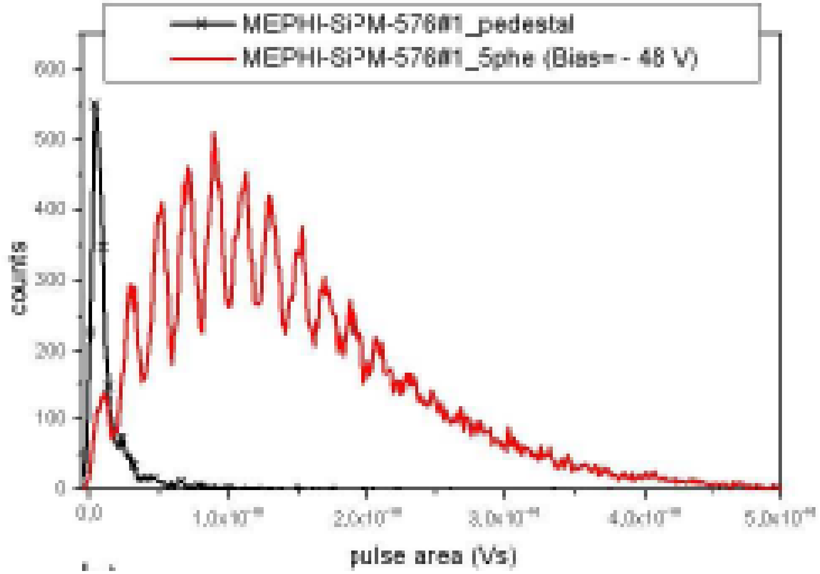
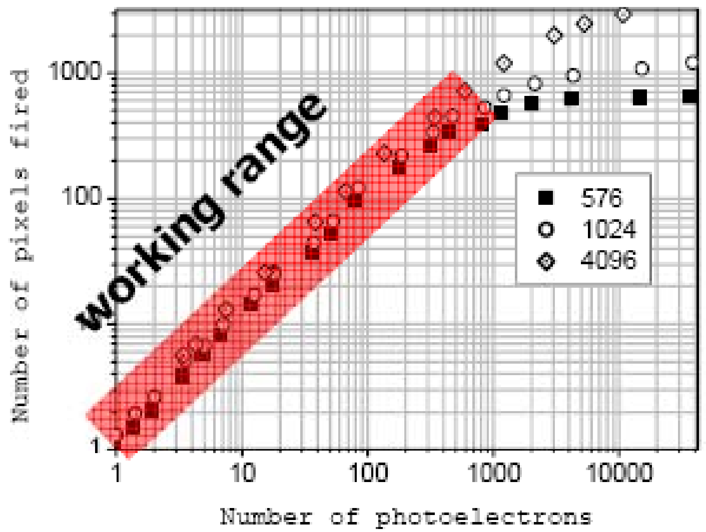
- Single- & multiphoton peaks
- "Self calibrating" photon counter"
- Dynamic range ~ number of pixel
- Saturation for large signals



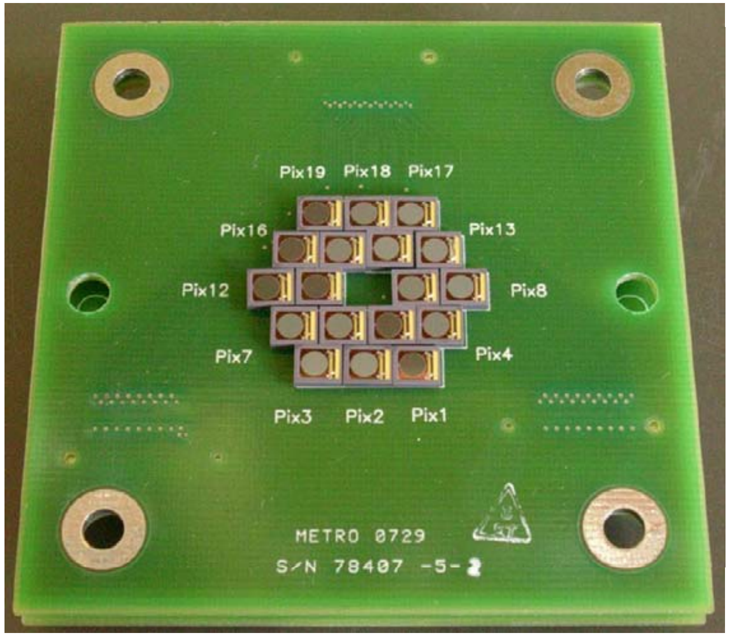


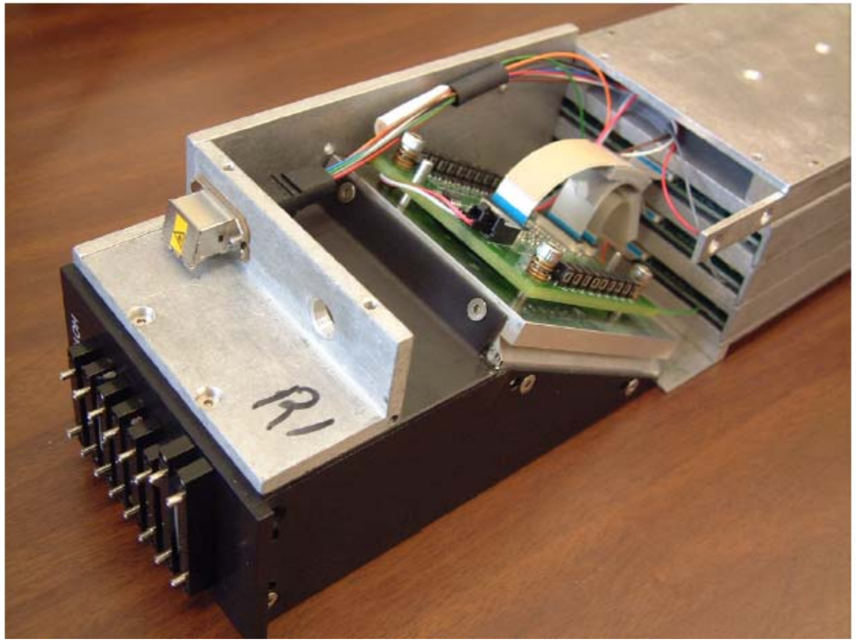
SiPMs for CMS HCAL

- Several different optimizations for the different HCAL applications
  - HO: low rad dose, low dynamic range, low average occupancy, small pixel size → easy!
  - HB/HE: moderate radiation field, large dynamic range, moderate occupancy, medium pixel size → harder
  - HF: high radiation dose, moderate dynamic range, high occupancy, large pixel size → hardest
- Each optimization could (probably will) lead to different SiPM choice

Replacement of HO HPD with SiPMs

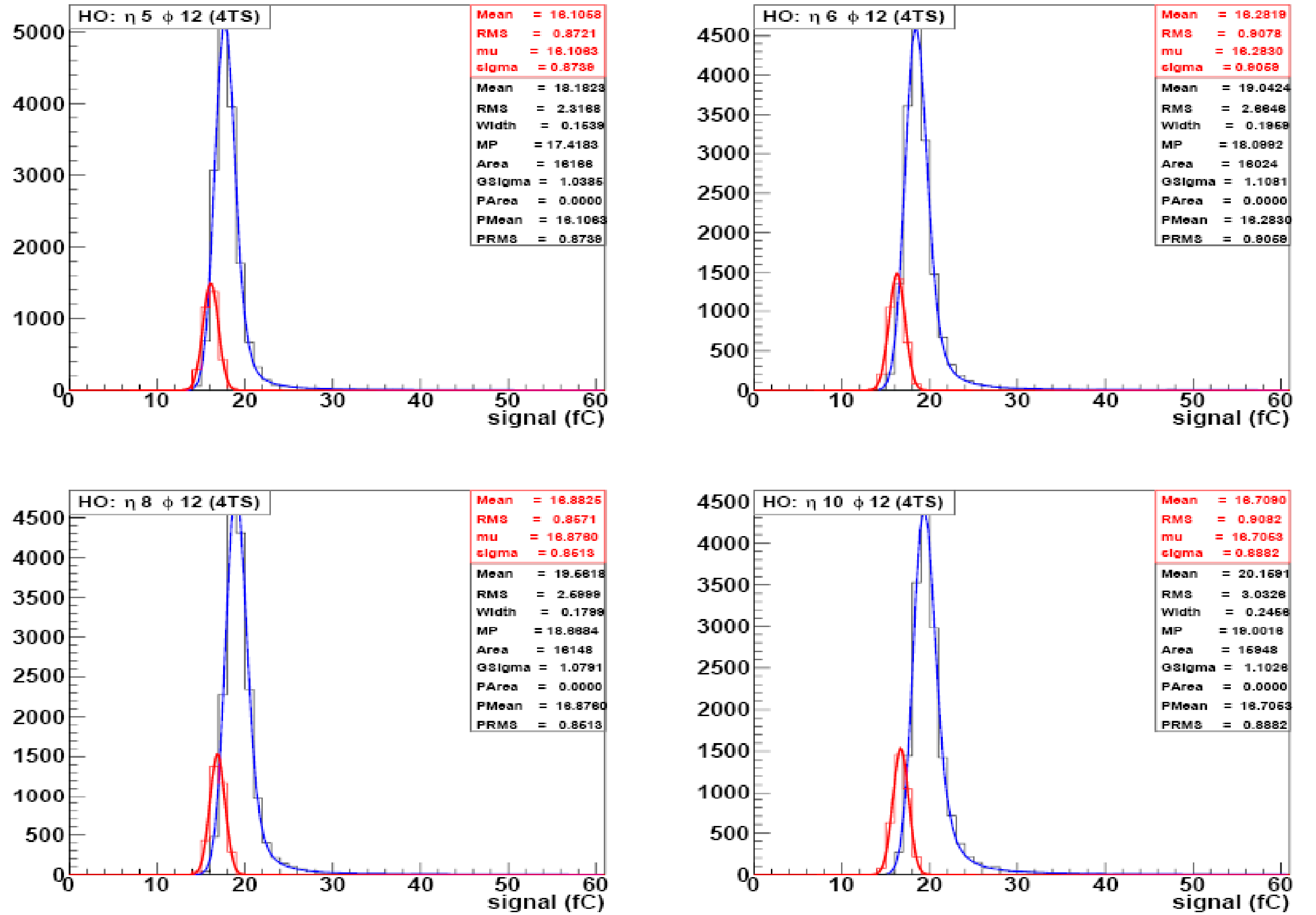
HCAL Readout module





Optical decoder → SiPM → QIE → 1.6Gbit optic link → Counting room

MIP in HO R1 (HPD)



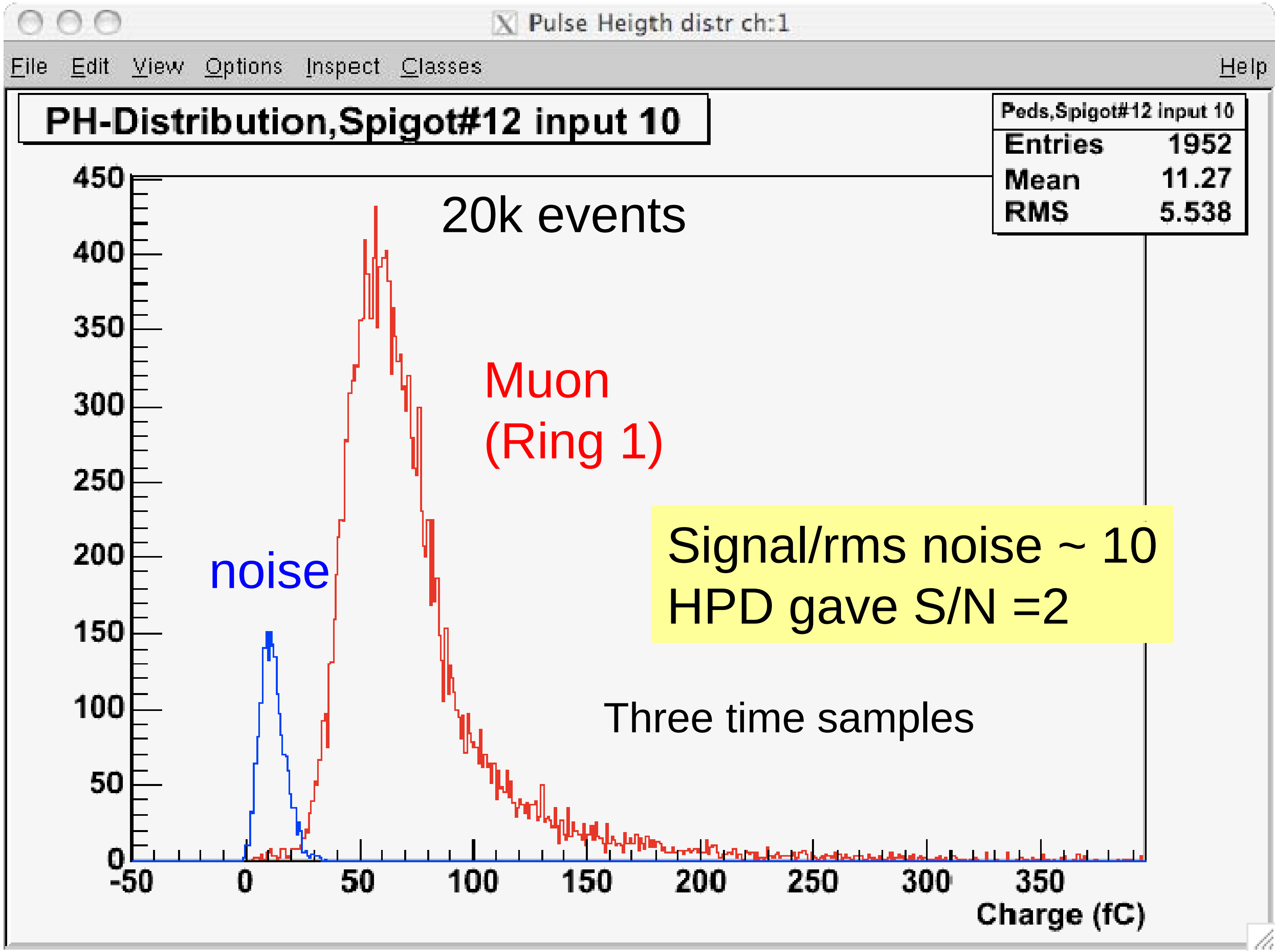
- Pedestal subtracted signal varies from 1.59 to 2.66 fC for η=5 to 10.

9th October, 2006
Calibration meeting

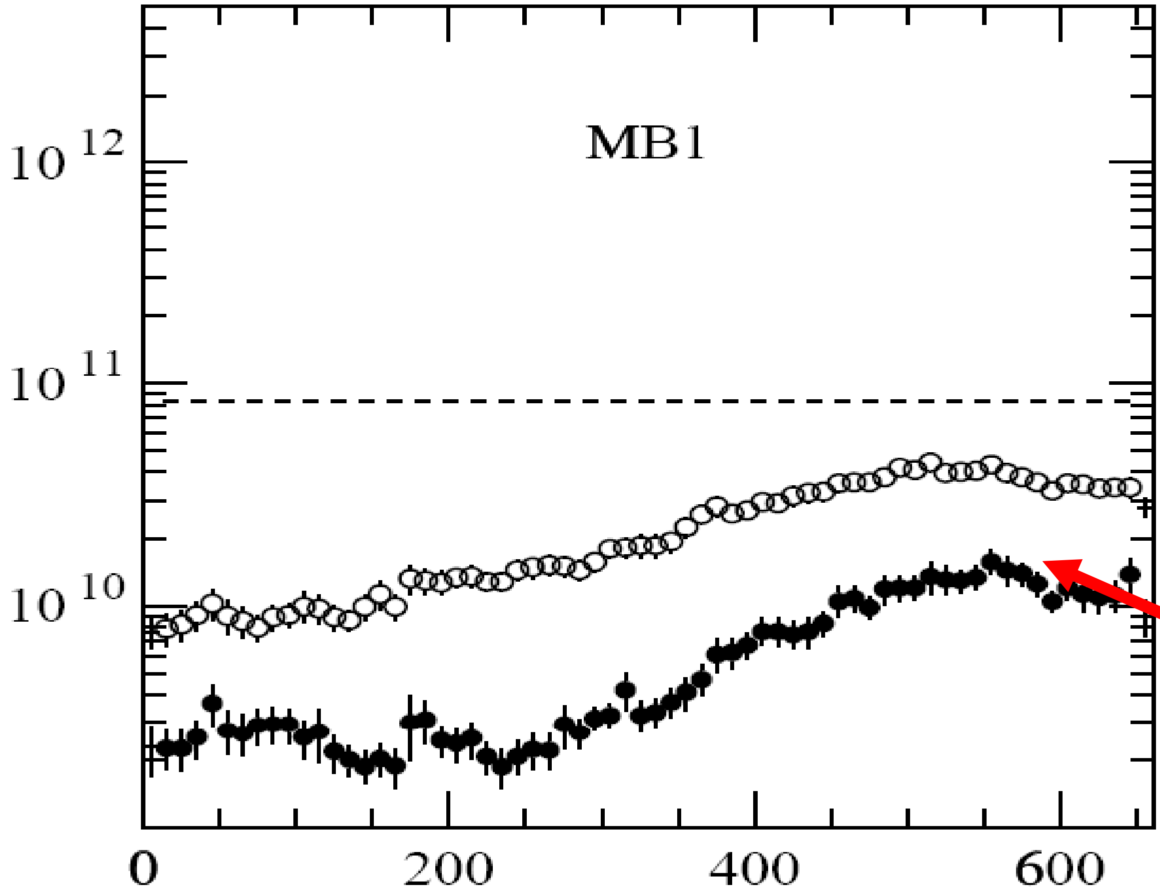
TB2006 : Calibration of HO Towers using 150 GeV Muons (page 7)

Seema Sharma
TIFR

MIP in HO R1 (SiPM)



Muon Fluence LHC lifetime



N fluence at MB1, Muon TDR (Mika)

n/cm2, E>100 KeV LHC lifetime. Max dose ~ 1E10.**

Expose SIPM to 3E10

Proton Irradiation

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Board	*SiPM*	V_b (V)	*Fluence* (cm^{-2})
1	CPTA 4.8 mm^2 reference	36	0
1	CPTA 1.0 mm^2	34	10^{10}
1	HC 1.0 mm^2	70.5	10^{10}
1	FBK 1.0 mm^2	33.5	10^{10}
2	CPTA 4.8 mm^2 reference	35	0
2	CPTA 1.0 mm^2	34	3×10^{10}
2	HC 1.0 mm^2	70.5	3×10^{10}
2	FBK 1.0 mm^2	33.5	3×10^{10}
3	CPTA 4.8 mm^2 reference	35	0
3	CPTA 4.8mm^2	37	10^{10}
3	FBK 6.2 mm^2	34	10^{10}
3	FBK single pixel	37	10^{10}
4	CPTA 4.8 mm^2 reference	35	0
4	CPTA 4.8 mm^2	37	3×10^{10}
4	FBK 6.2 mm^2	34	3×10^{10}
4	FBK single pixel	37	3×10^{10}

Device types and doses from proton irradiation study. Dec 2007

Proton Irradiation 3E10

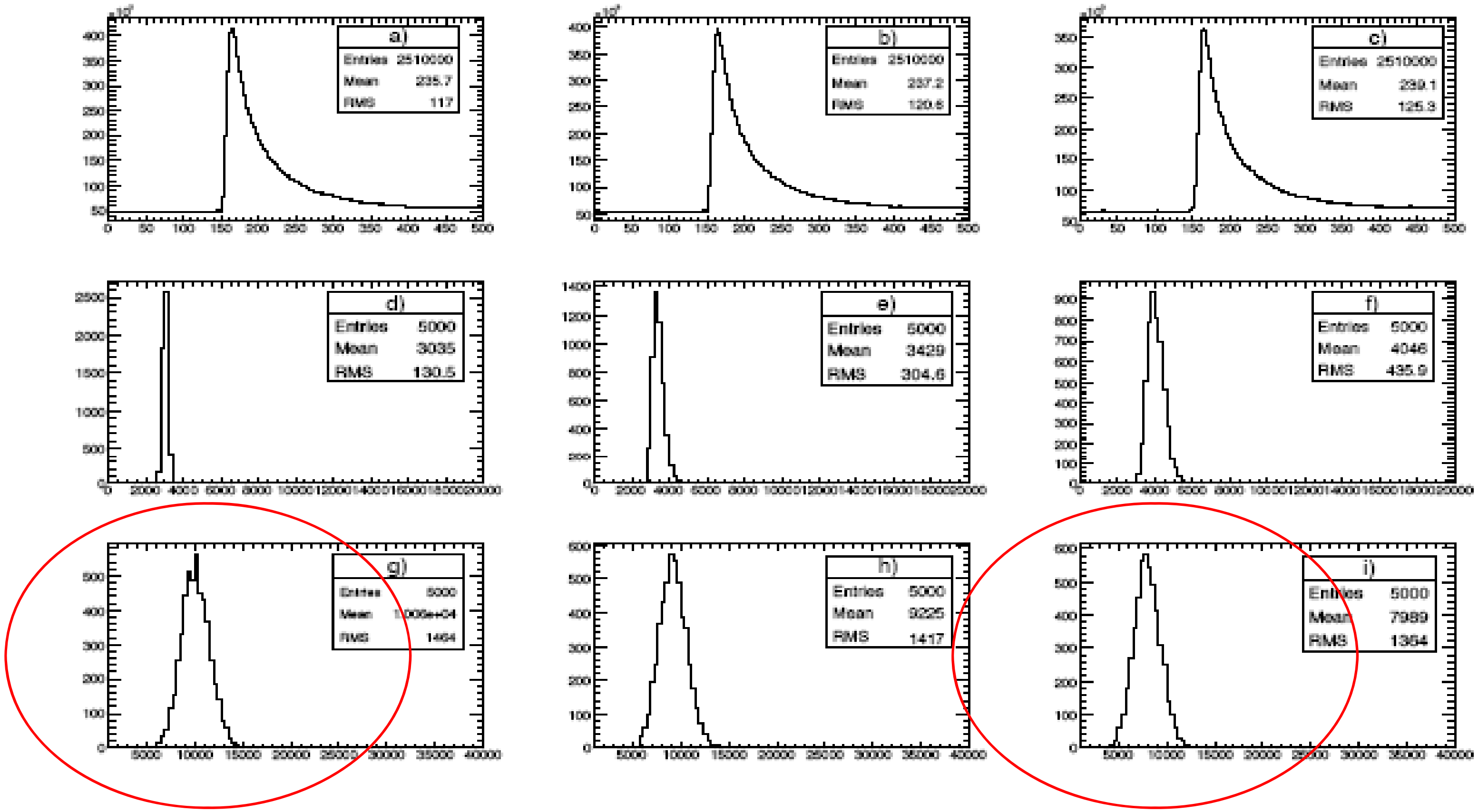

Fig. 19. FBK 6.2 mm^2 at $V_\mathrm{b} = 34$ V on board 4: pulse shape a) before irradiation, b) after 10^{10} cm^{-2}, and c) after 3×10^{10} cm^{-2}; noise distribution d) before irradiation, e) after 10^{10} cm^{-2}, and f) after 3×10^{10} cm^{-2}; and signal distribution in response to LED g) before irradiation, h) after 10^{10} cm^{-2}, and i) after 3×10^{10} cm^{-2}.

Proton Irradiation

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Table 7
Measured properties of the FBK 6.2 mm^2 SiPMs. The bias voltage was 34 V.

Board	*Fluence* (cm^{-2})	I_b/A ($\mu A/mm^2$)	MF (fC/PE)	n_{PE}/F	S/S_0
3	zero	1.2	400	180	1
3	2.5×10^9	2.2	410	170	1.00
3	5×10^9	3.3	420	170	0.97
3	7.5×10^9	4.2	400	170	0.94
3	10^{10}	5.6	420	170	0.93
3	15Apr08	2.6	400	170	0.96
4	zero	0.7	340	170	1
4	2.5×10^9	1.5	340	170	0.99
4	5×10^9	2.7	350	150	0.97
4	7.5×10^9	4.5	340	170	0.94
4	10^{10}	7.9	330	160	0.93
4	3×10^{10}	10.1	340	140	0.77
4	15Apr08	4.6	320	170	0.92

Silicon Photomultiplier in Strong Magnetic Field

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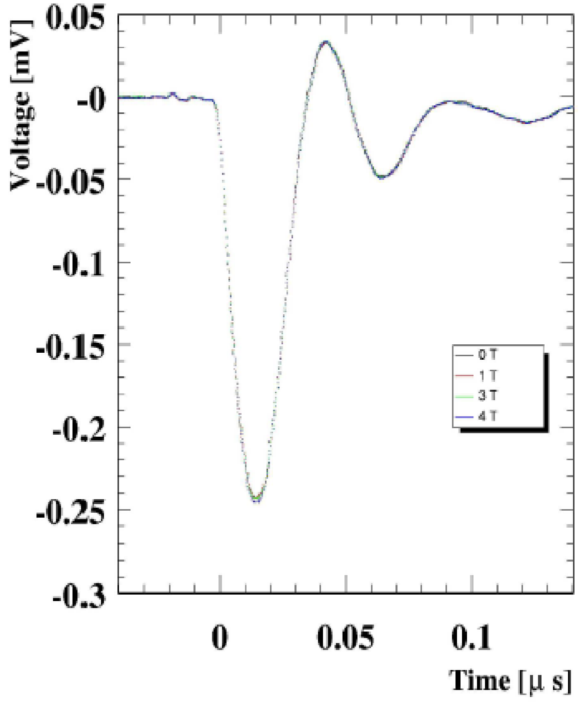

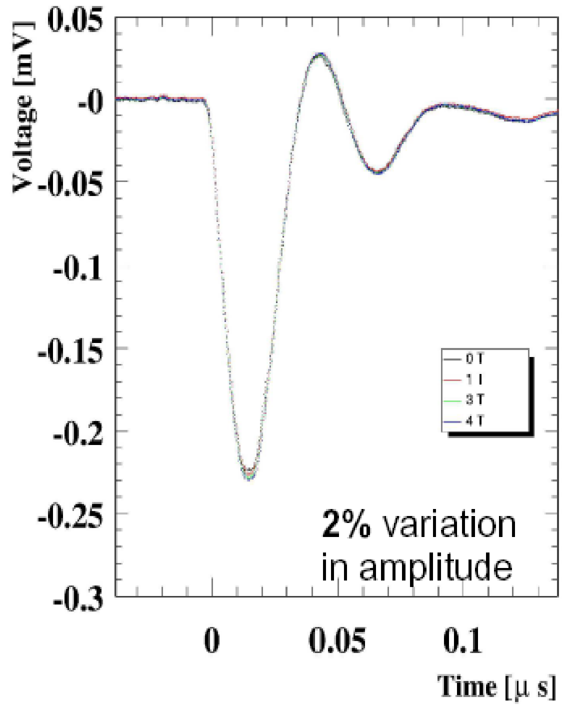

Test of SiPM in Strong Magnetic Field up to 4 Tesla (Amplitude of SiPM signal in magnetic field with different orientations) (CALICE Meeting, DESY, 30.01.2004)

SiPM Issues

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Adjust recovery time (specify to vendor)

Thermal stabilization (control temp)

Radiation hardness (evaluate)

Dynamic range (pixels)

Each Issue is being studied

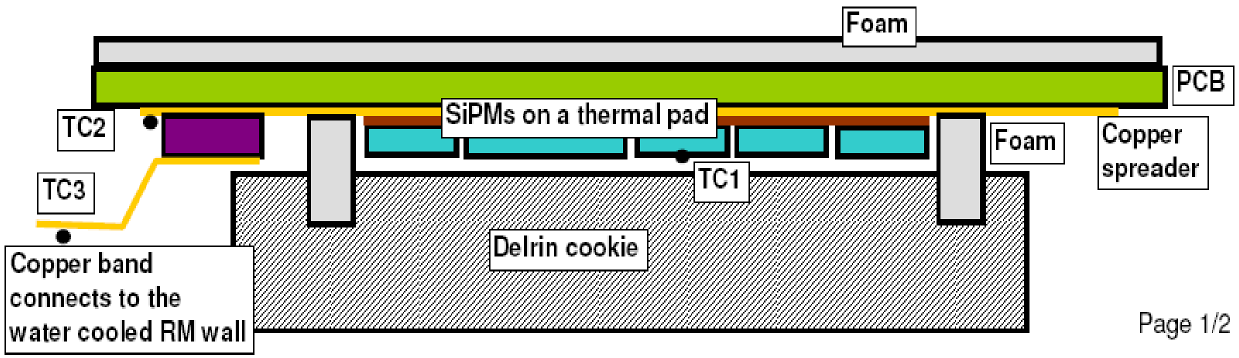
Interface card with thermoelectric cooling

SiPM Cooling with the Thermoelectric Coolers for HCAL/CMS

S.Los Jan. 11, 2008

Thermal conductivity	$W \times m^{-1} \times K^{-1}$	Range
Copper	400	
Aluminum	238	
Silicon	150	
Ceramic (Al_2O_3)	16	16-40
Glass	1.4	
Fiberglass	1	
Delrin	0.375	
Silicone Ceramic filled	1.4	
ZnO thermal grease	0.8	
Polyurethane foam	0.03	
Air	0.025	

Thermal resistance		K/W
Delring cookie	(10mm thick, 32mm ∅)	33
Ceramic body of SiPMs	(1.5mm thick, 28mm ∅)	0.15
Thermal Pad	(0.2mm thick, 28mm ∅)	0.23
Copper Spreader	(0.1mm thick, 30mmWx50mmL)	42
2 oz copper fill	0.07mm thick, 40mmx40mm)	36
Aluminum spreader	(1mm thick, 30mmWx50mmL)	7
Copper strap (heat sink)	(1mm thick, 12mmWx40mmL)	8
PCB radial loss resistance	(1.6mm rhick, 32mm ∅, 10mm	62
Back foam pad	(1mm thick, 75mmx75mm)	6
Back foam pad	(2mm thick, 40mmx40mm)	42



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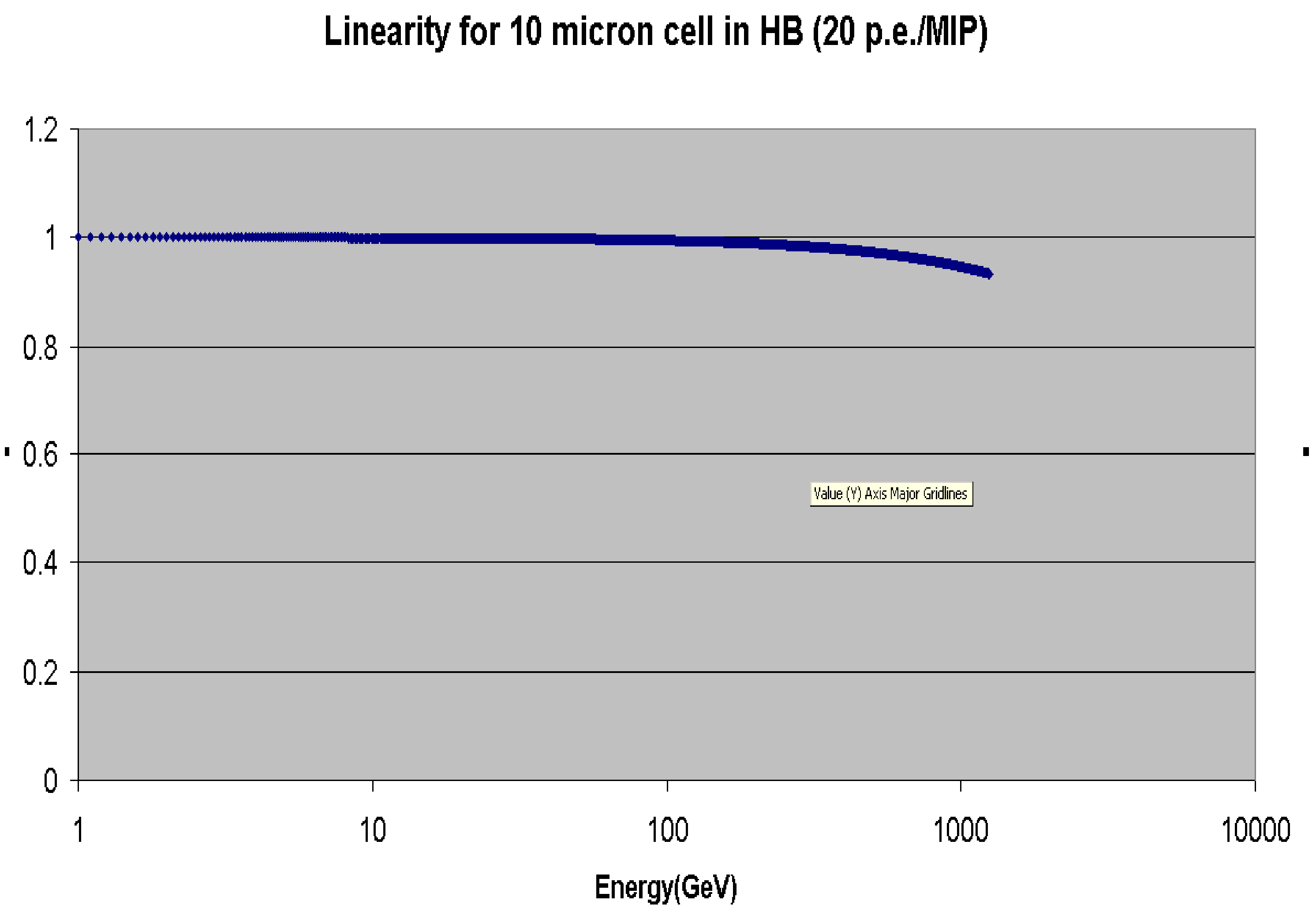
Simulation of HB SiPM with 10 μm pixels (90K pixels)

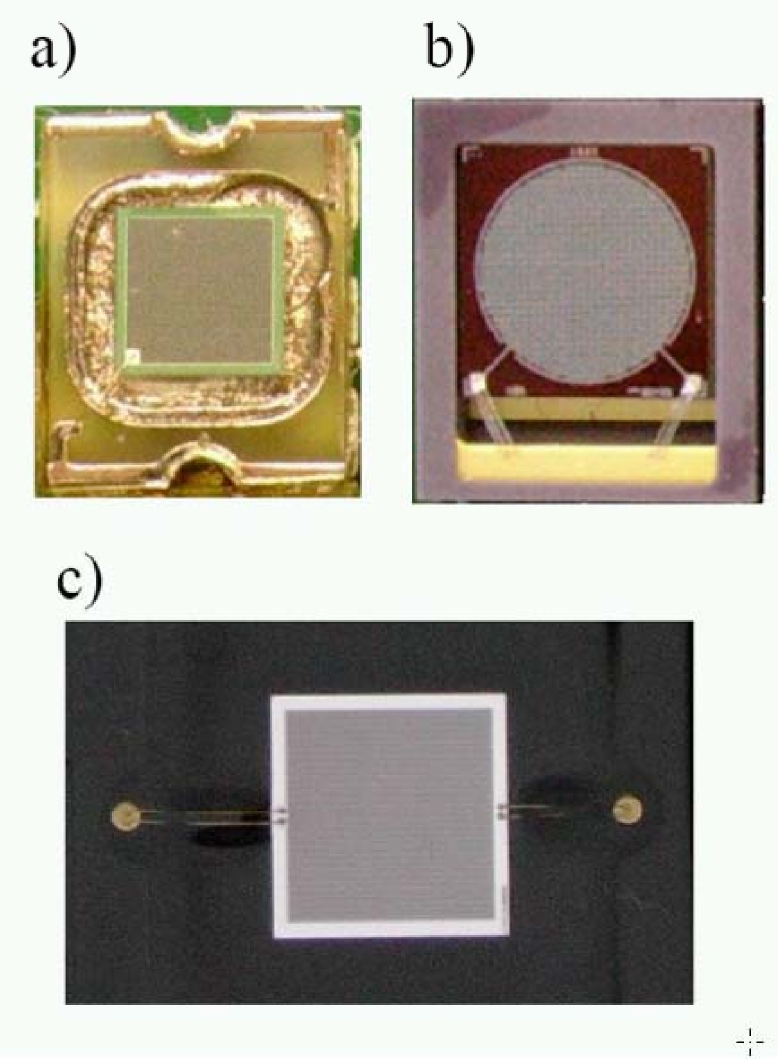


SiPM Plan

HCAL

- Have established methodology for proton irradiation
- Recently exposed diodes to thermal neutrons (MIT reactor) OK results, under evaluation
- Ongoing testbeam program: Right now. HB Sipms (3X3mm, 4 μm cells, 360K pixels – Zycotek, PDE = 20%)
  - HO RM, thermal-electric cooling, voltage setting, current readback (final system for HO)
- Will irradiate full HO RM in August (protons 3E10)

SiPM Device Plan



Plan:

Follow vendor developments, especially on large area and large pixel devices

Watching new development on GaS SiPM. Potential to be very rad-hard

Purchase and evaluate options

Proton, neutron radiation tests

Finalize choices for SiPMs 2009