HCAL – SiPM upgrade requirements

Workshop in Trieste on June 2-4 2008

HCAL current baseline readout

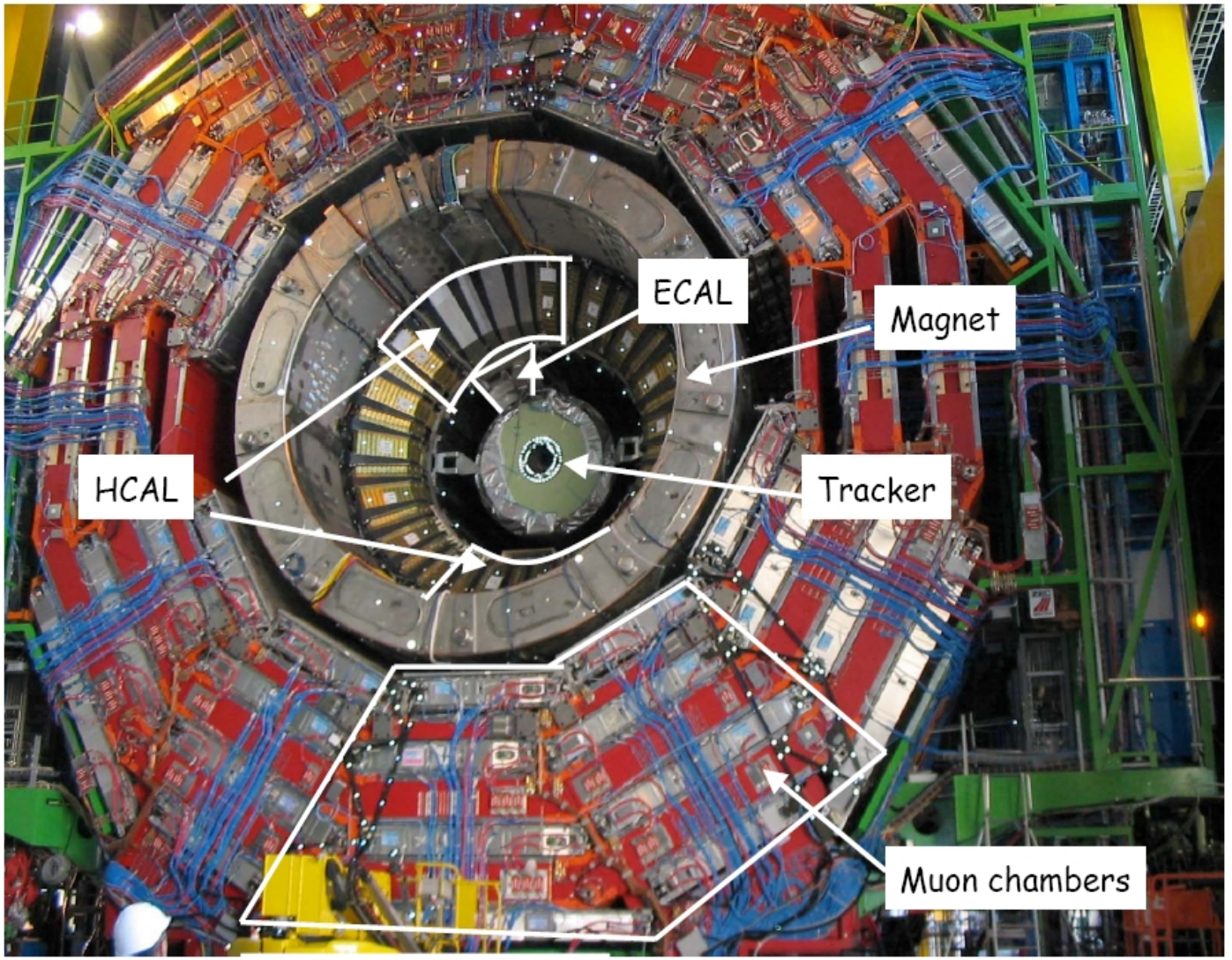
Inside the magnet:

- HB 144 x 19 channel HPDs (16 layers)
- HE 144 x 19 channel HPDs (16 layers)

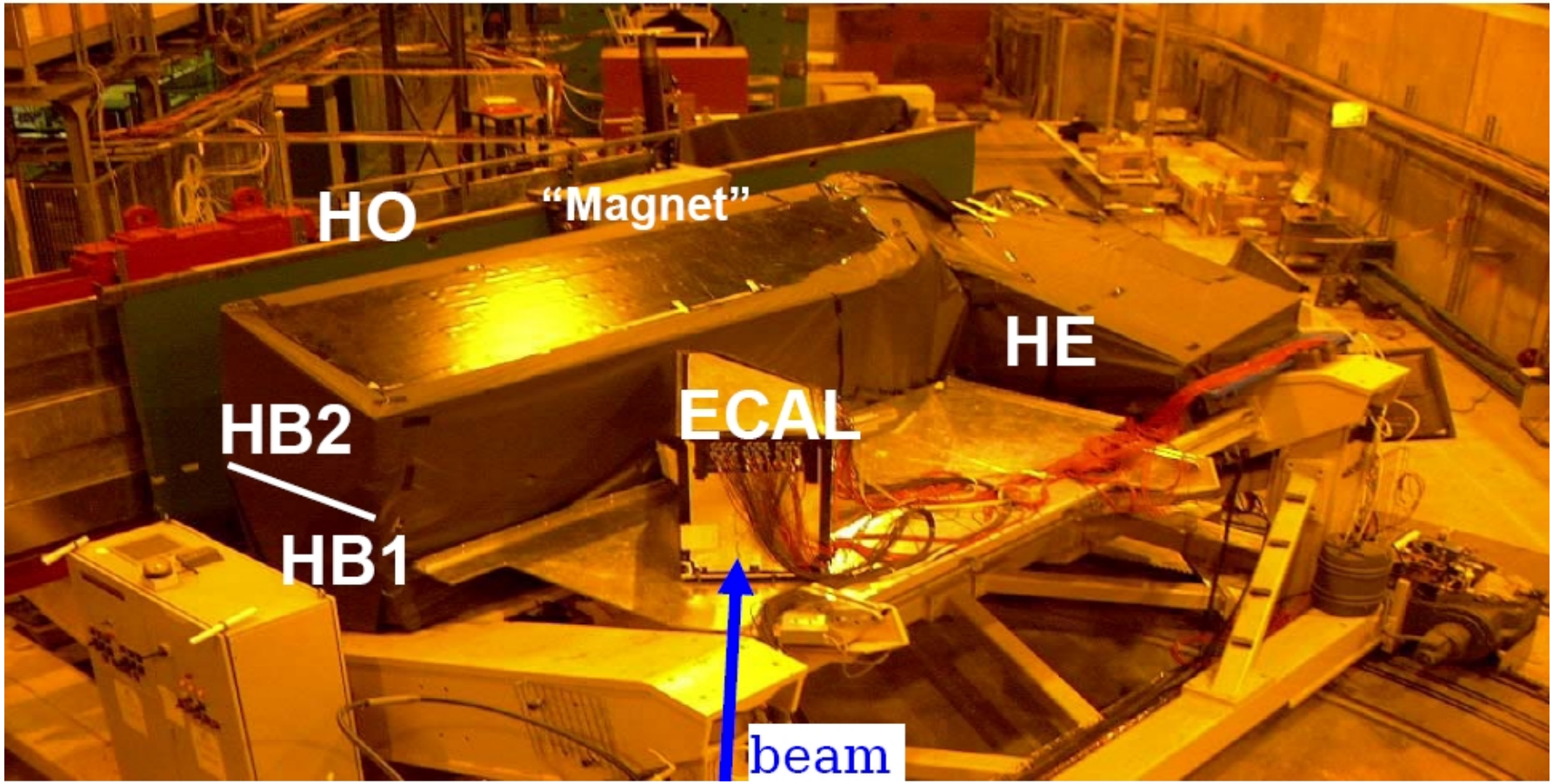
Outside the magnet:

- HO 132 x 19 channel HPDs (1-2 layers)
- HF 1800 one inch PMTs.

CMS Ring YB0

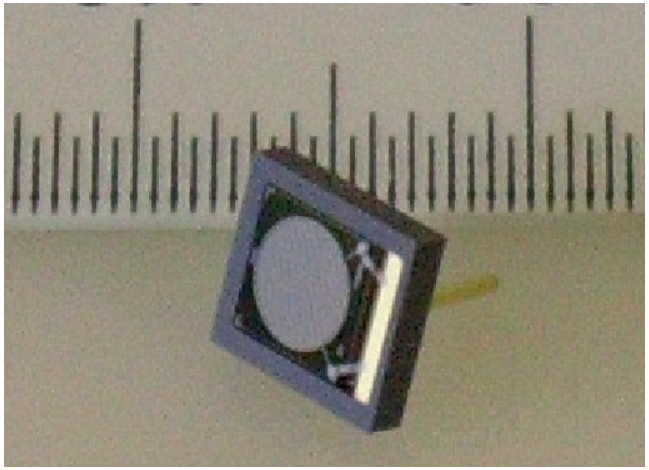


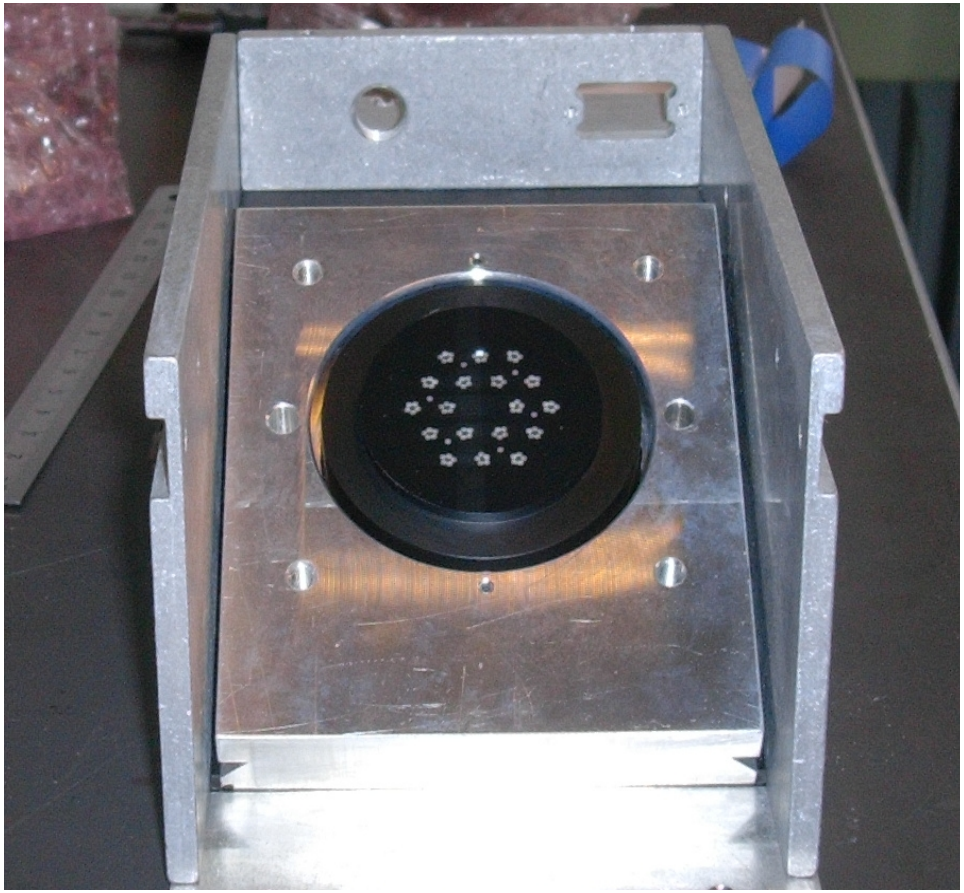
Test Beam setup



- **Due to the cosine effect of the Angle we have lowest light in YB1 (YB0 has 2 layers)**

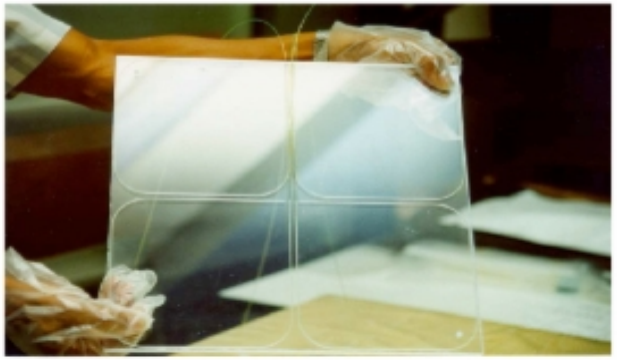
Developed; Custom FBK SiPM



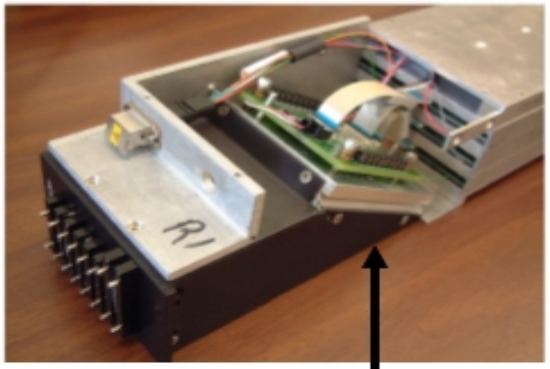


HO with SiPM readout

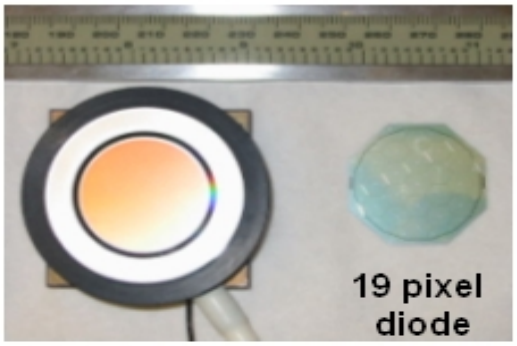
Single layer behind the magnet
4 fibers per tile

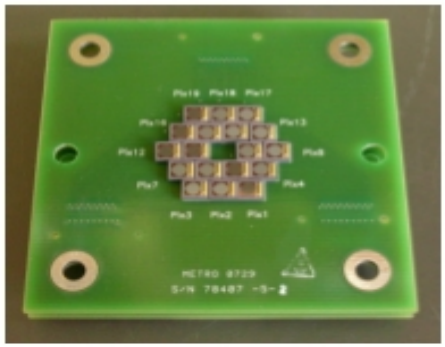


HCAL readout module
4 fibers per tile

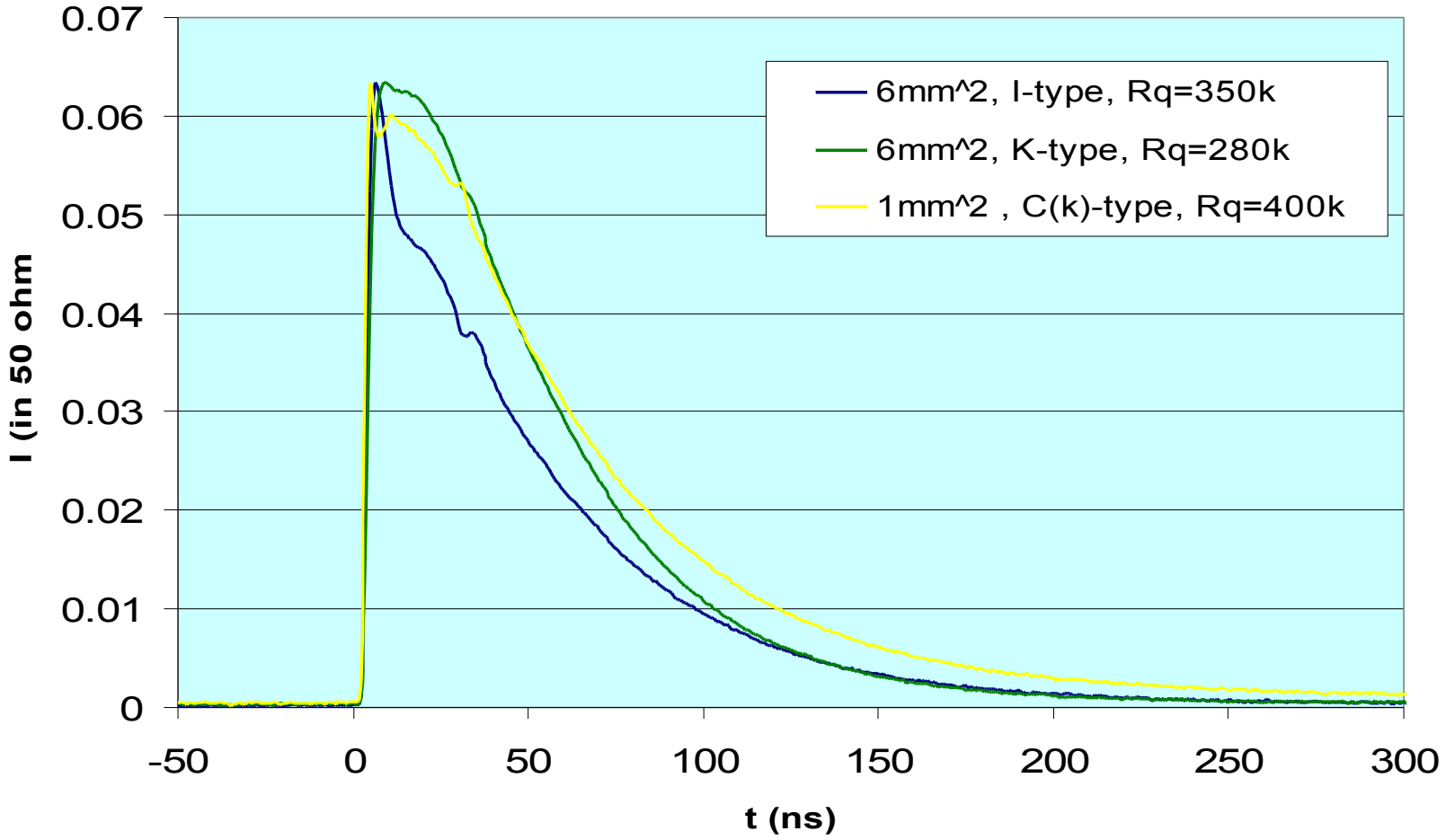


Simple replacement of HPD with SiPMs

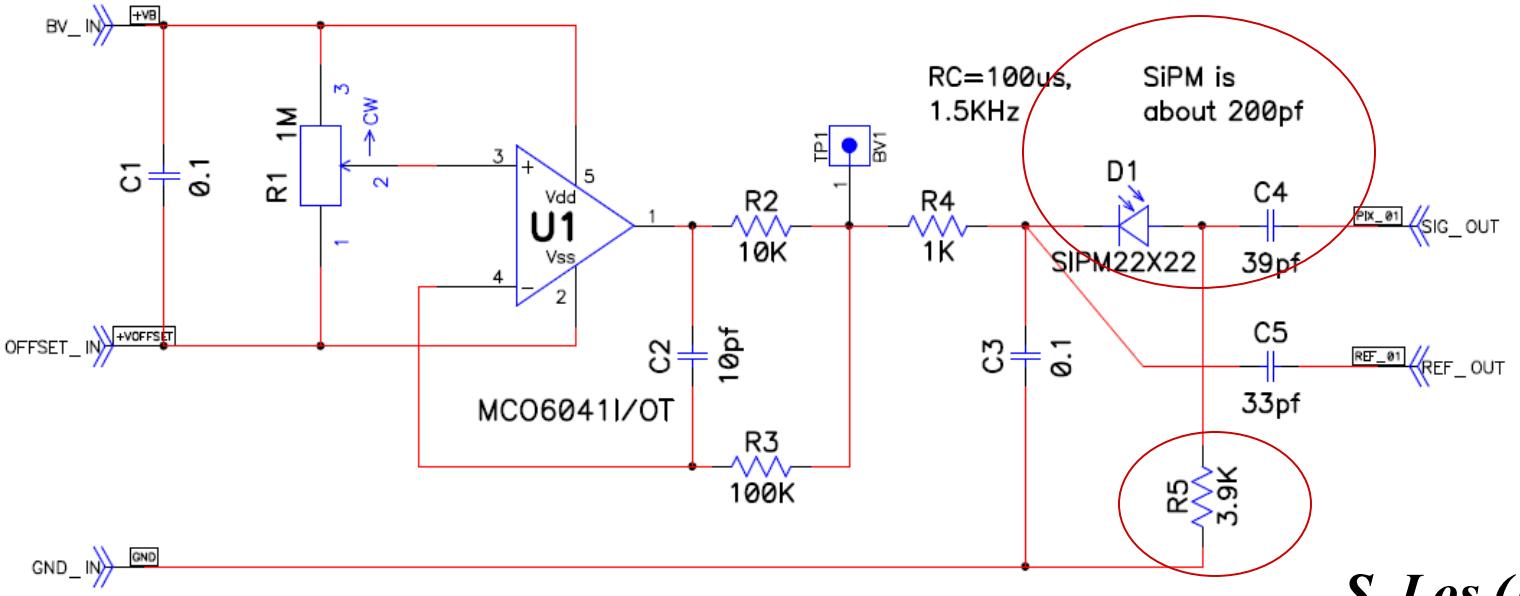




Typical SiPM pulse



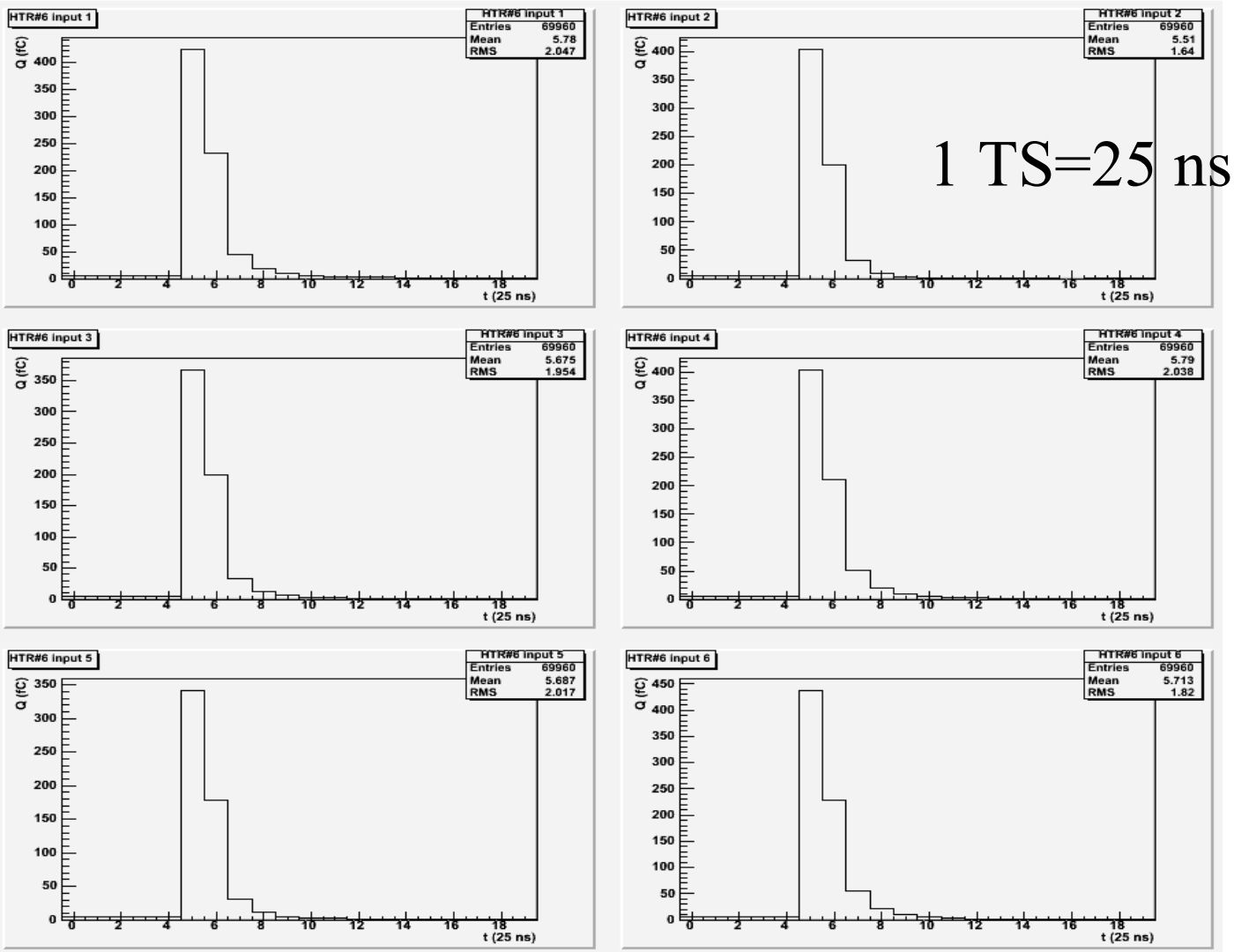
SiPM-QIE Interface Circuit diagram



S. Los (FNAL)

- **To match the gain of the readout we used a factor of 5 lower couple capacitor**
- **Using R5 we hope to shape the pulse shape and cancel the tails**

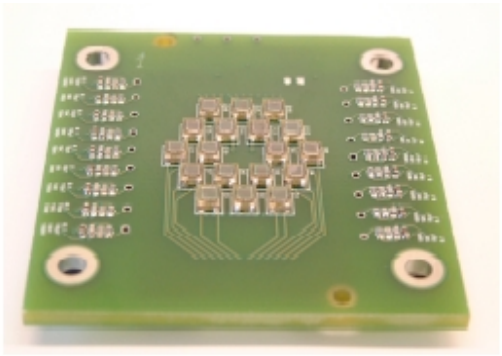
Pulse shape after QIE

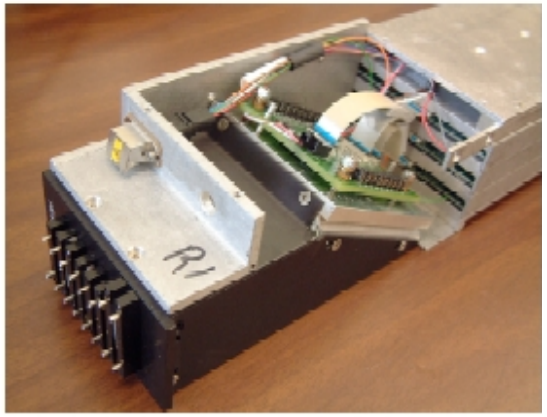


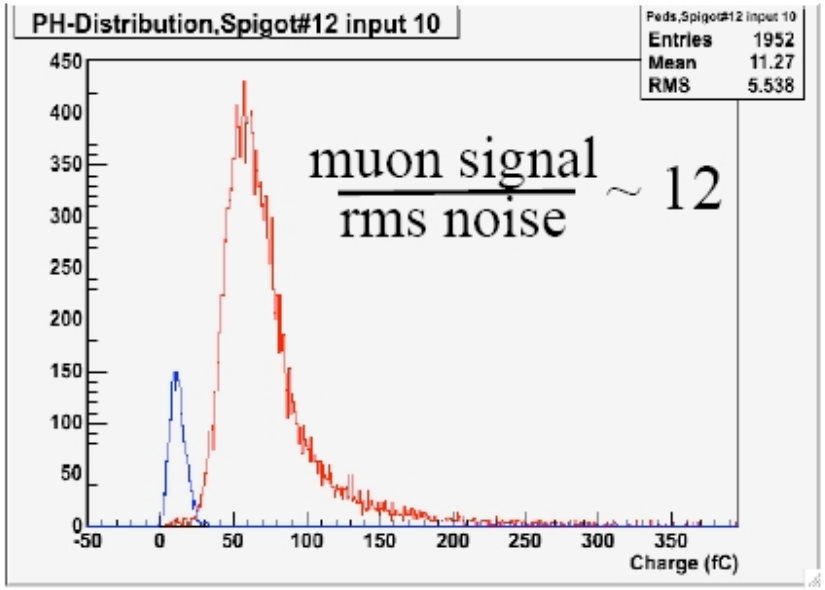
1 TS=25 ns

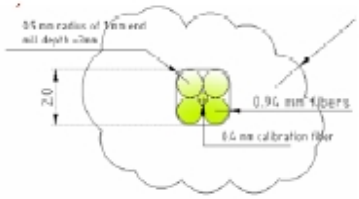
2006 First Test Beam results

2.1 mm x 2.1 mm



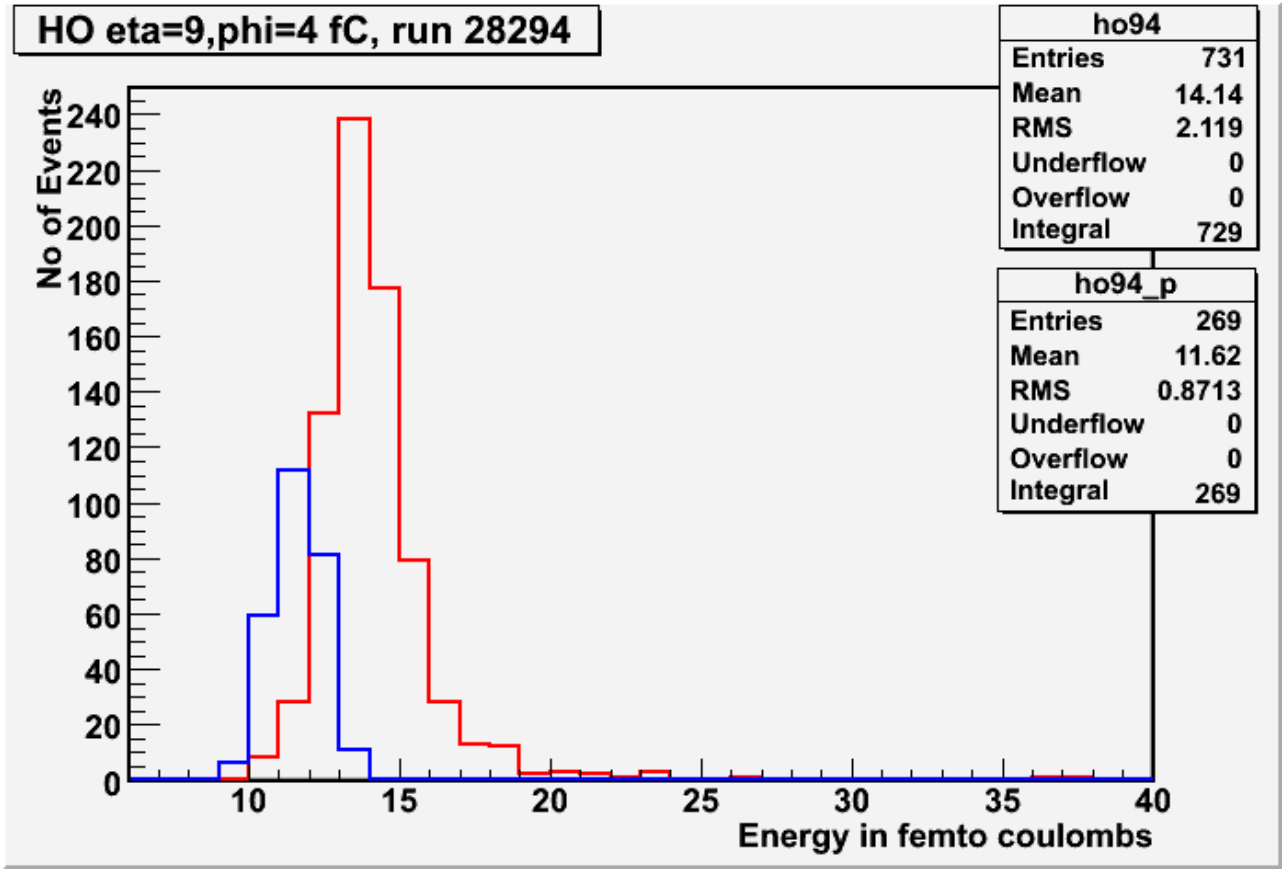






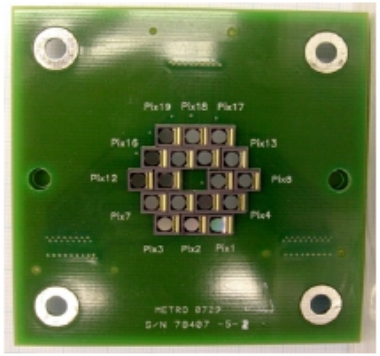
CPTA 2006
1764 pixels

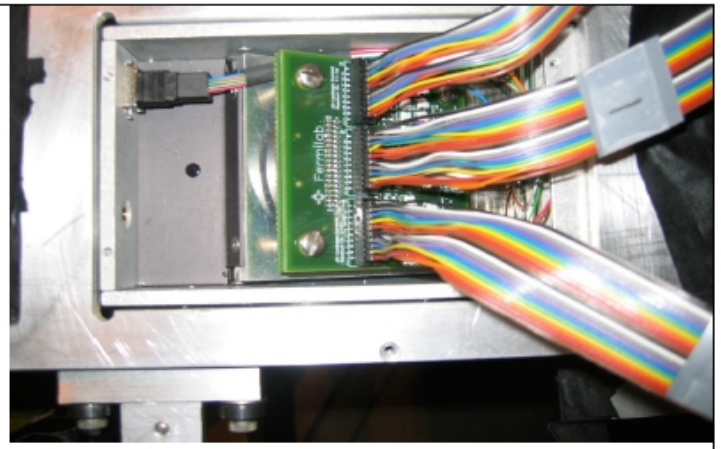
HPD muon in HO YB1

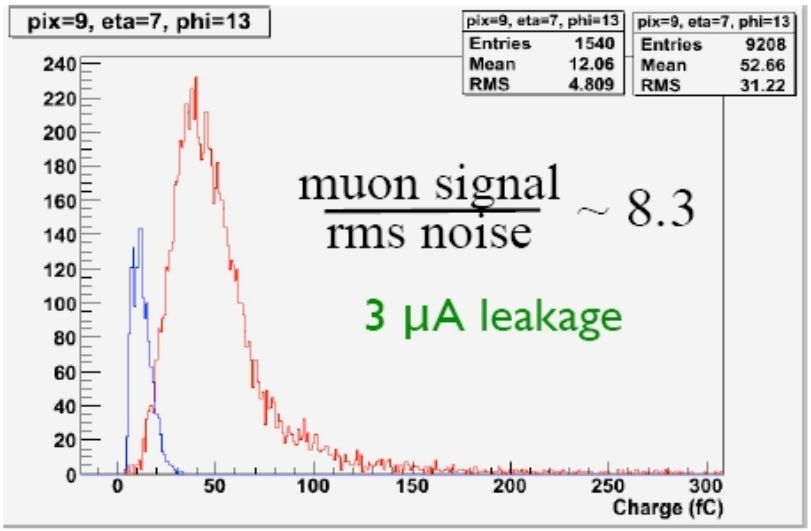


2007 Test beam FBK custom diode

2.8 mm diam.





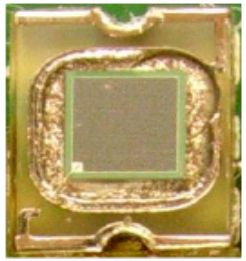


IRST

1250 pixels

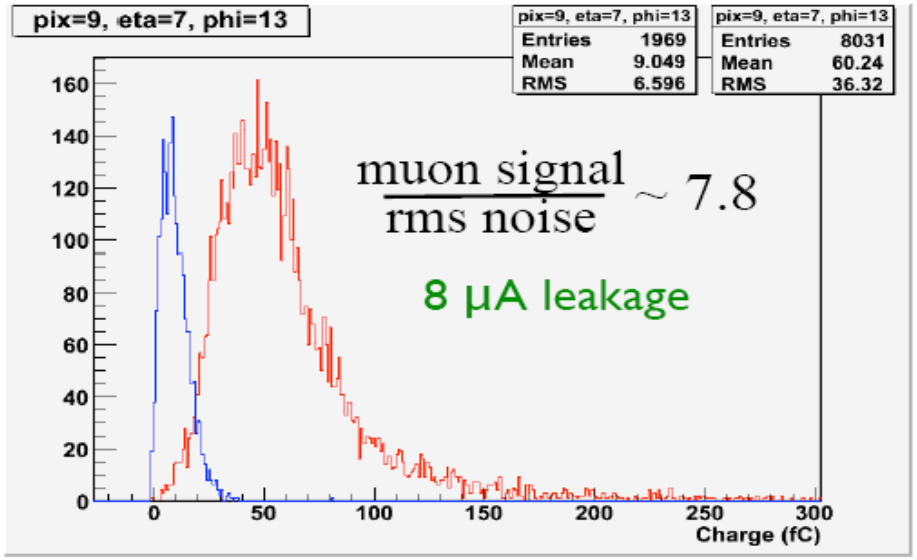
(Used cells)

2007 Test beam CPTA 2x2 mm diode



2.1 mm x 2.1 mm

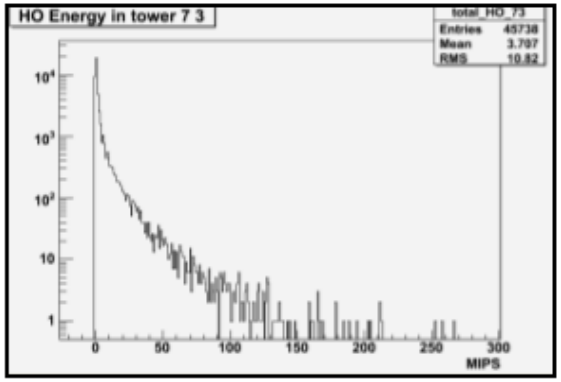
We used light mixer



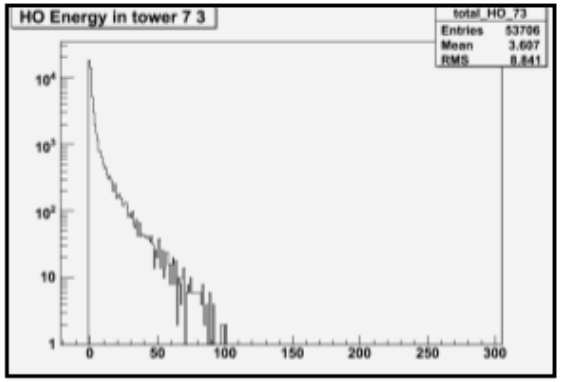
CPTA 2007
1750 pixels

Linear range is worst then HPD

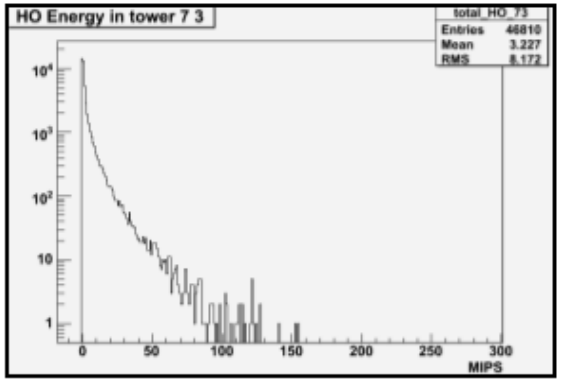
HPD, 300 GeV pions in center tower



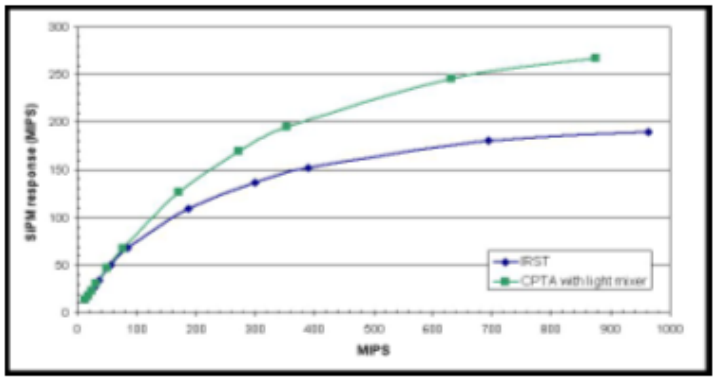
IRST, 300 GeV pions in center tower



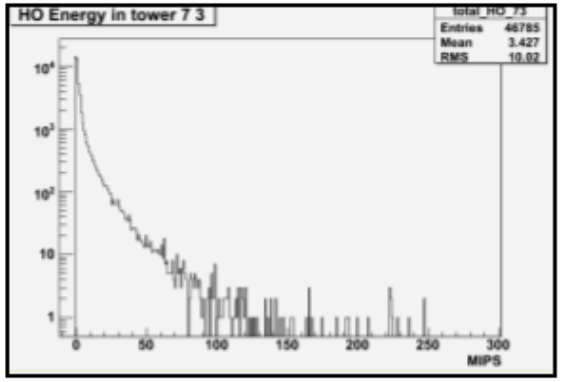
CPTA with light mixer, 300 GeV pions in center tower



Measured Non linearity due to limit # of cells



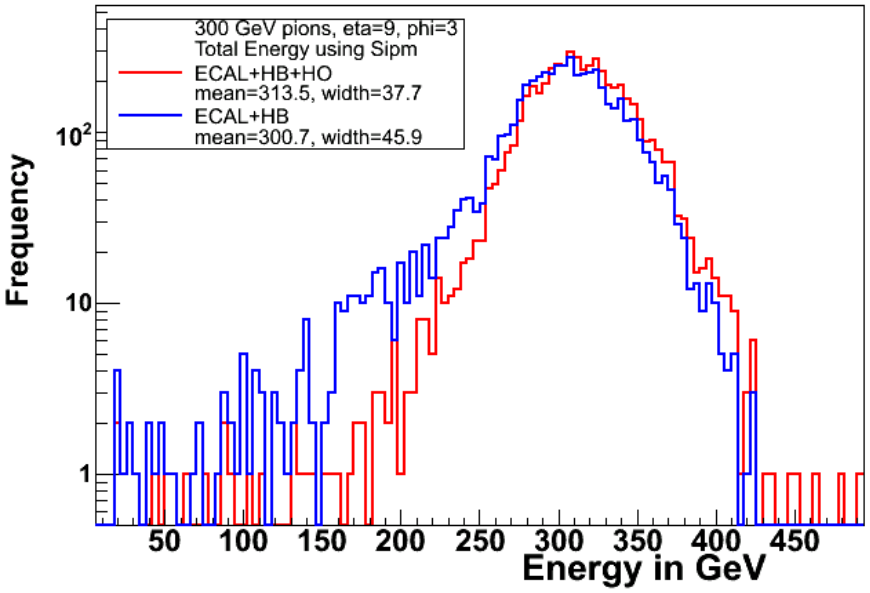
SiPM with Non linearity correction



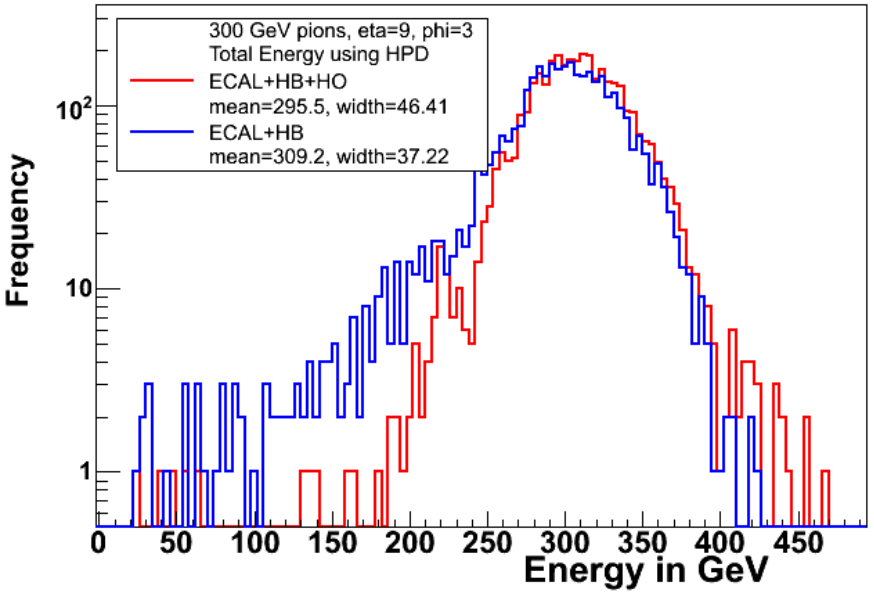
300 GeV pion resolution in 3x3 towers

ECAL + HCAL

SiPM

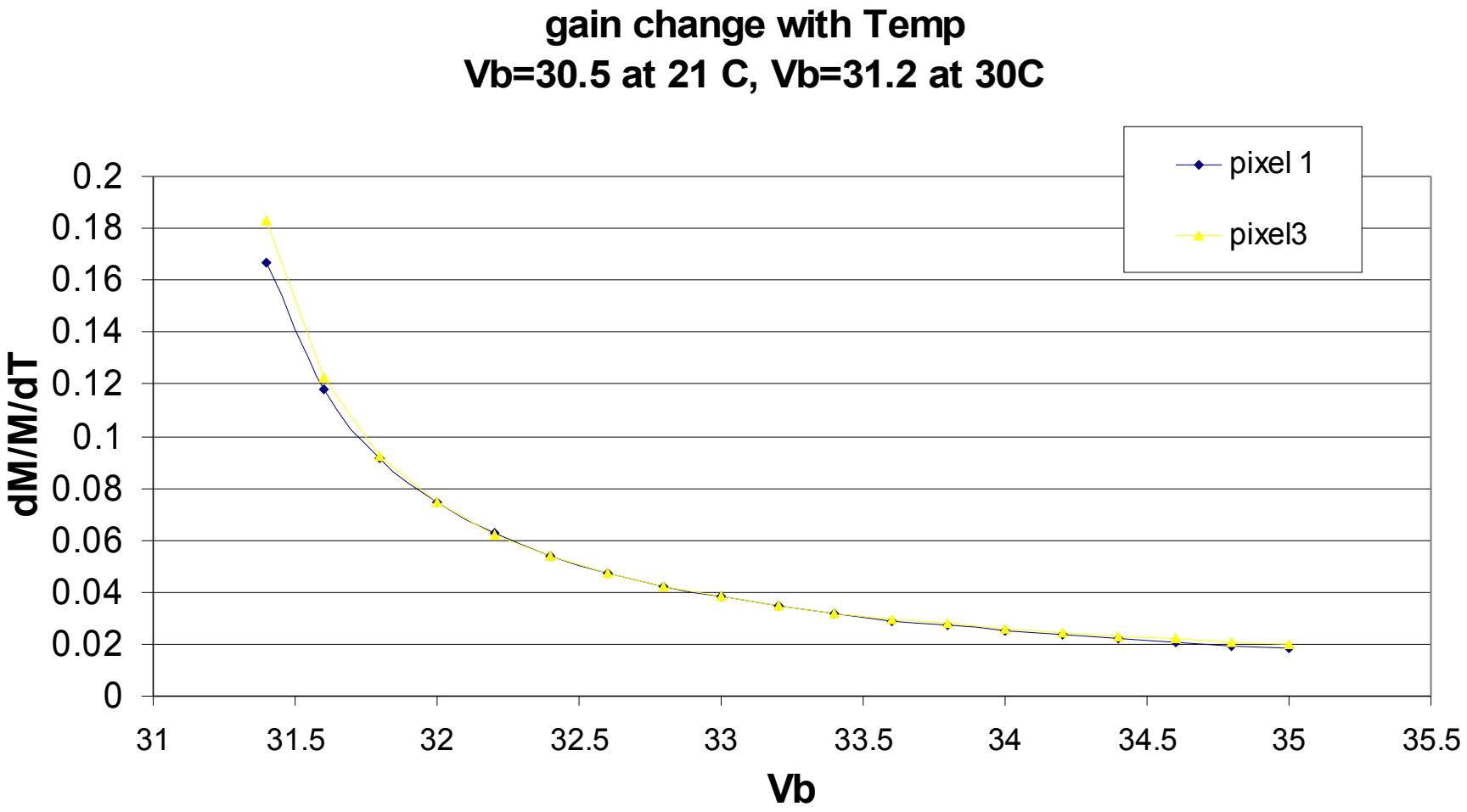


HPD



No indication that late showers give worst resolution as baseline HPD

Measured Temperature coefficient



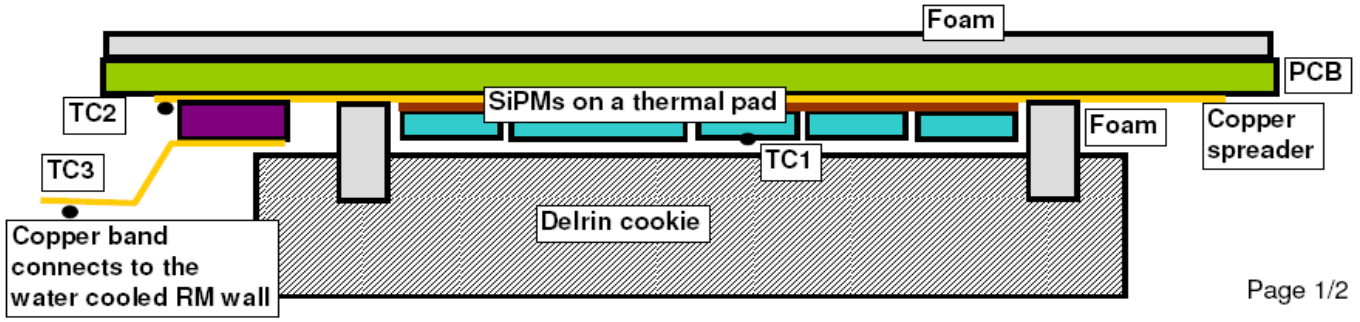
Production Cooling and stabilization

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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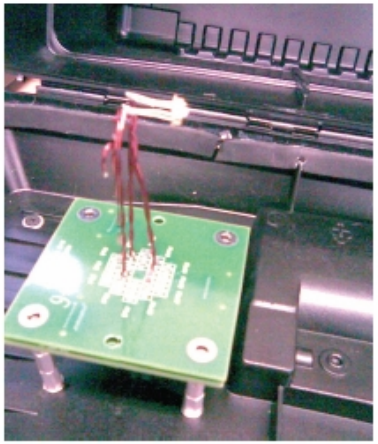
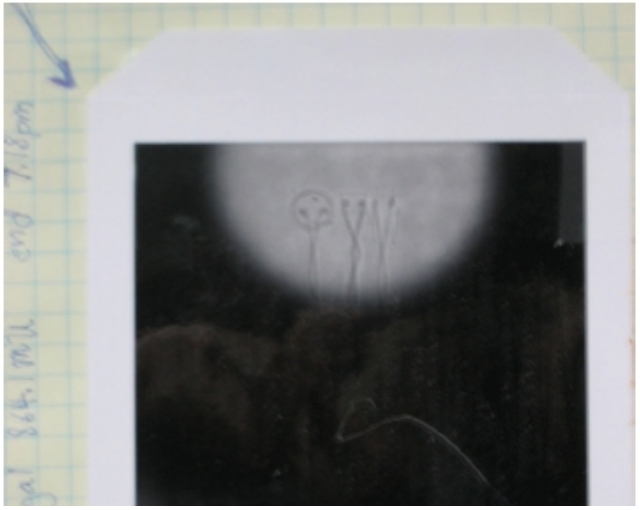
Radiation study in October 2007

Radiation tests at Mass. General Hospital

240 MeV protons

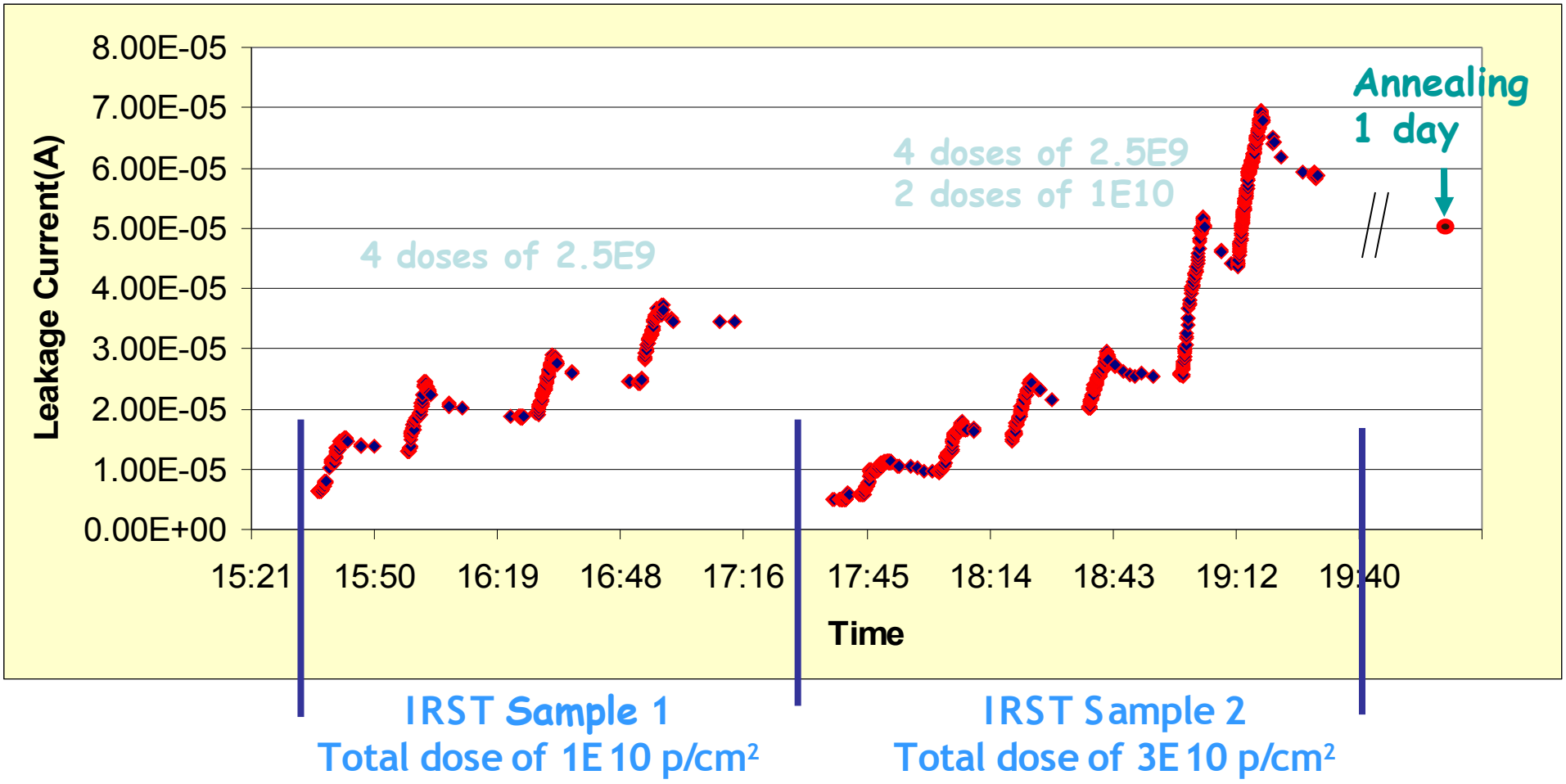
Board no.	SiPM	Fluence (protons per cm^2)
1	CPTA reference	0
1	CPTA 1×1 mm^2	10^{10}
1	HC 3×3 mm^2	10^{10}
1	FBK 1×1 mm^2	10^{10}
2	CPTA reference	0
2	CPTA 1×1 mm^2	3×10^{10}
2	HC 3×3 mm^2	3×10^{10}
2	FBK 1×1 mm^2	3×10^{10}
3	CPTA reference	0
3	CPTA 2.1×2.1 mm^2	10^{10}
3	FBK 2.8 mm	10^{10}
3	FBK single pixel	10^{10}
4	CPTA reference	0
4	CPTA 2.1×2.1 mm^2	3×10^{10}
4	FBK 2.8 mm	3×10^{10}
4	FBK single pixel	3×10^{10}





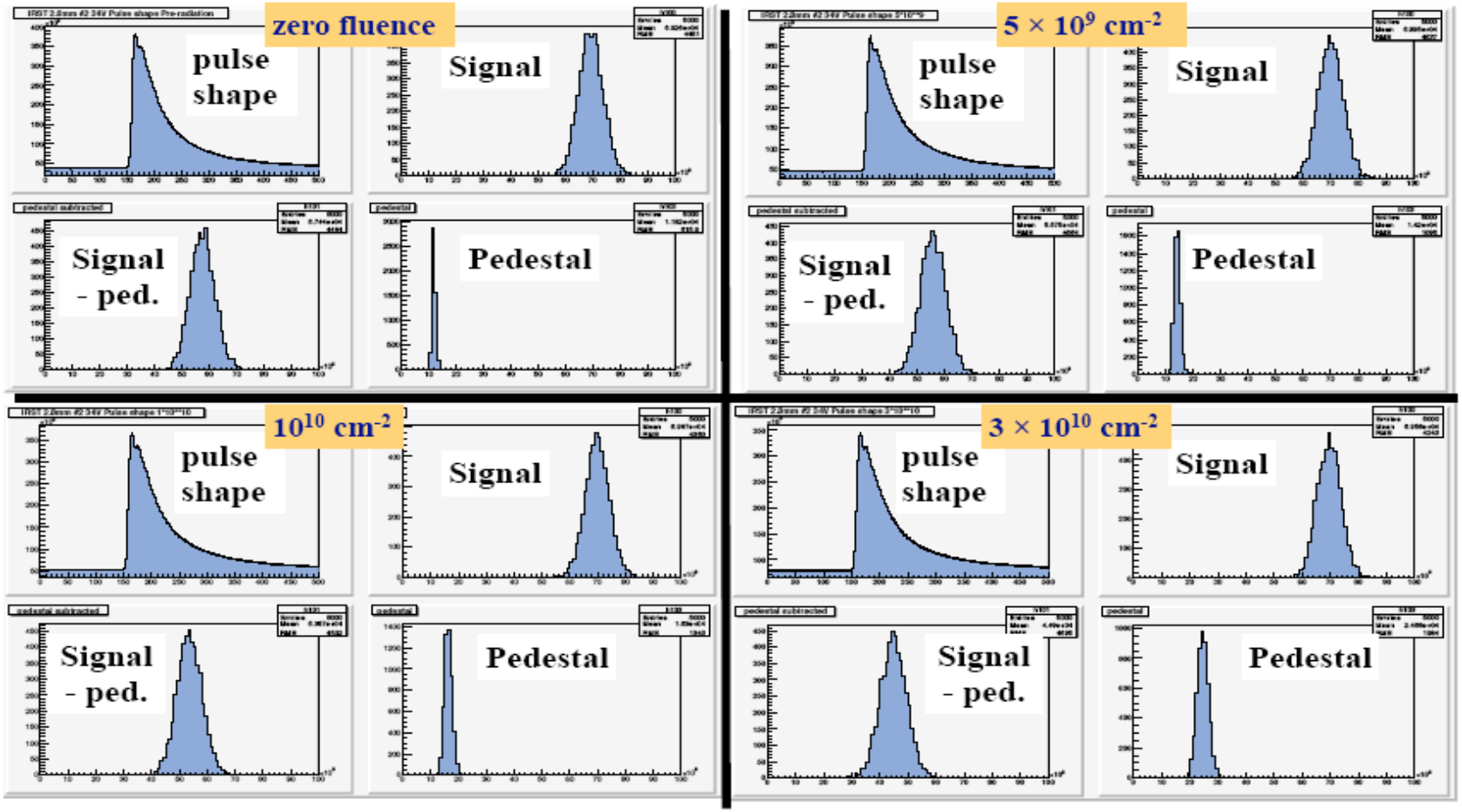
Radiation damage for 240 MeV Protons

Custom 6 mm2 FBK SiPM

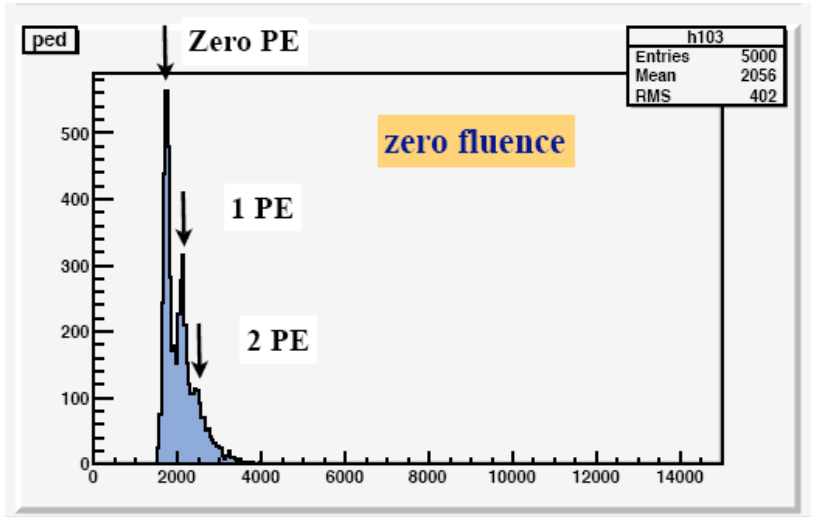


Scope traces during radiation

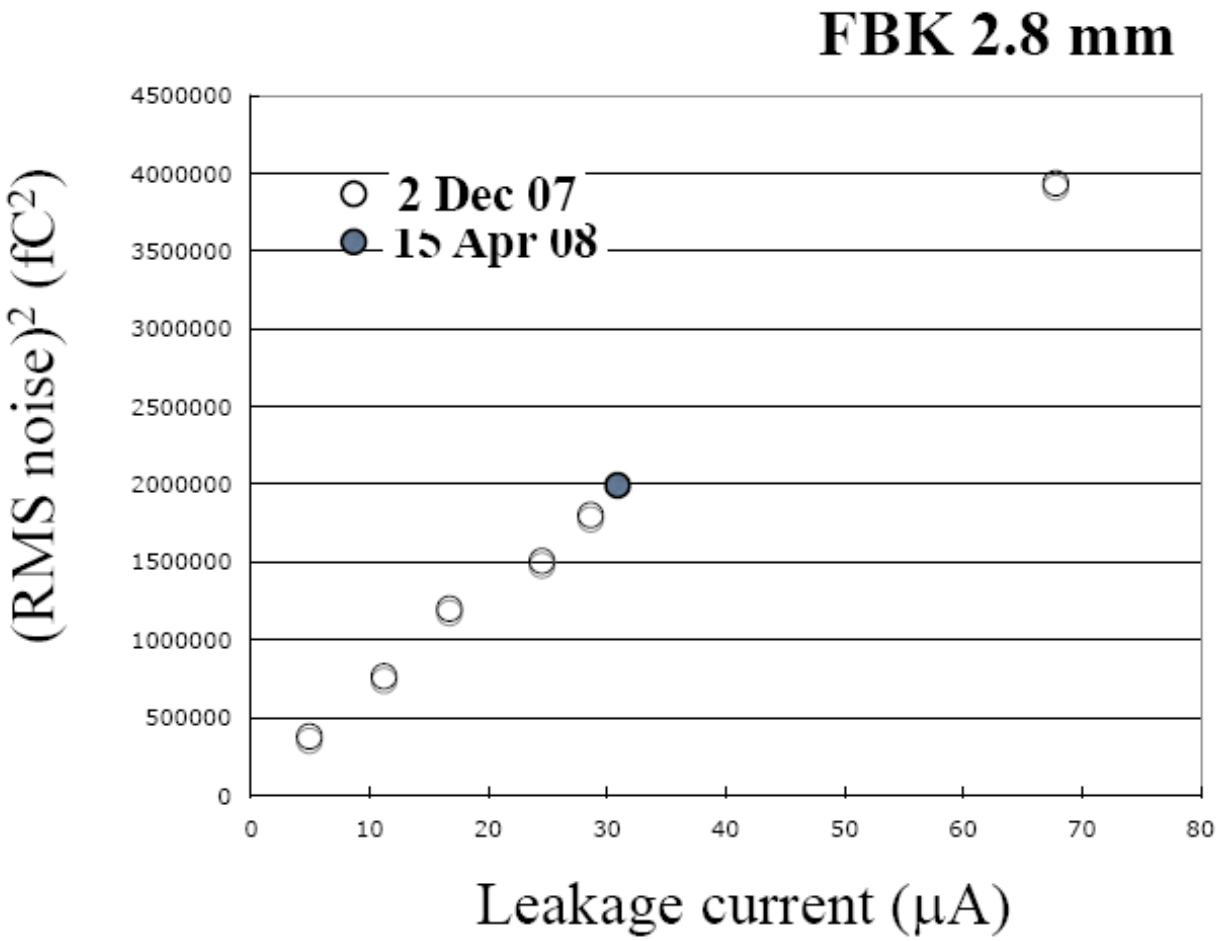
FBK 2.8 mm



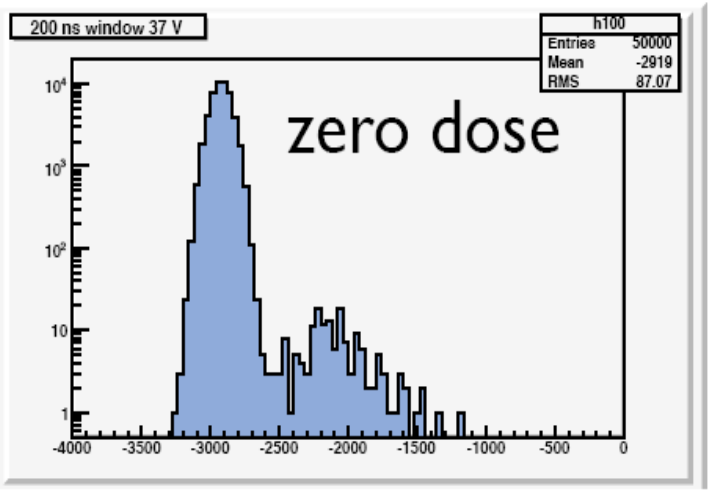
1mm^2 diodes

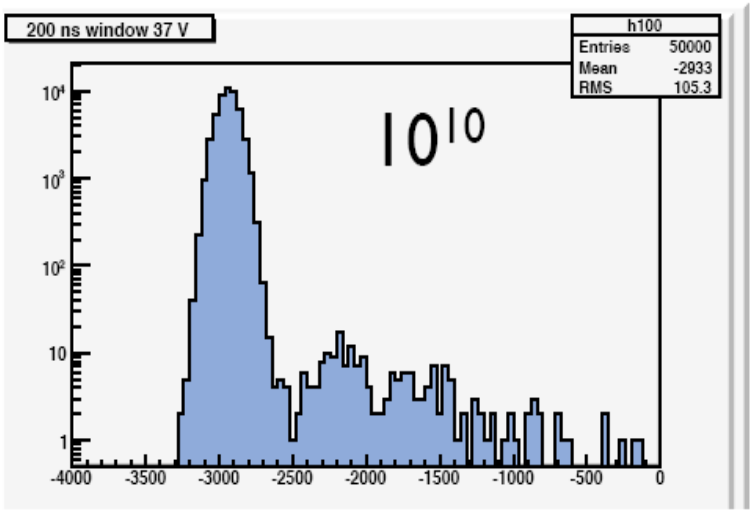

ped
Zero PE
h103
Entries 5000
Mean 2056
RMS 402
zero fluence
1 PE
2 PE
ped
2 PE
1 PE
3 PE
h103
Entries 5000
Mean 2810
RMS 719.8
5 × 10^9 cm^-2
Zero PE

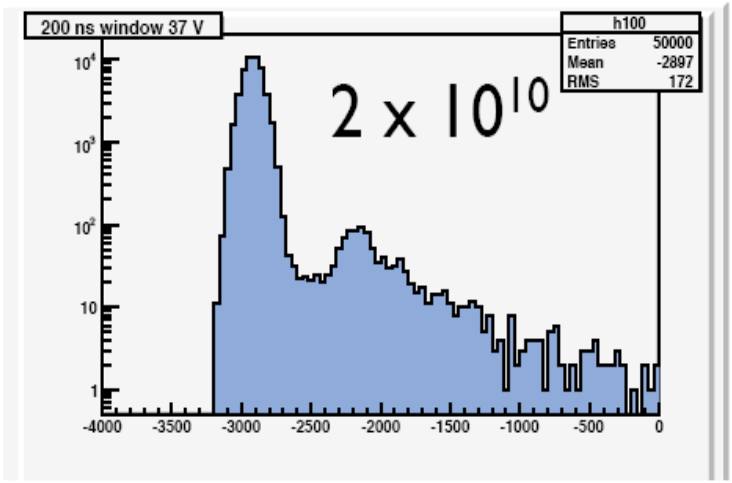
I_leakage vs Ped_rms

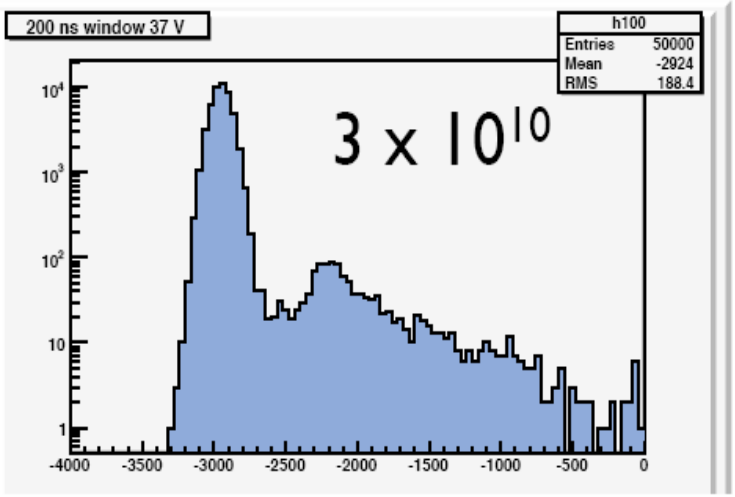


FBK single cel single PE (pedestal distributions)



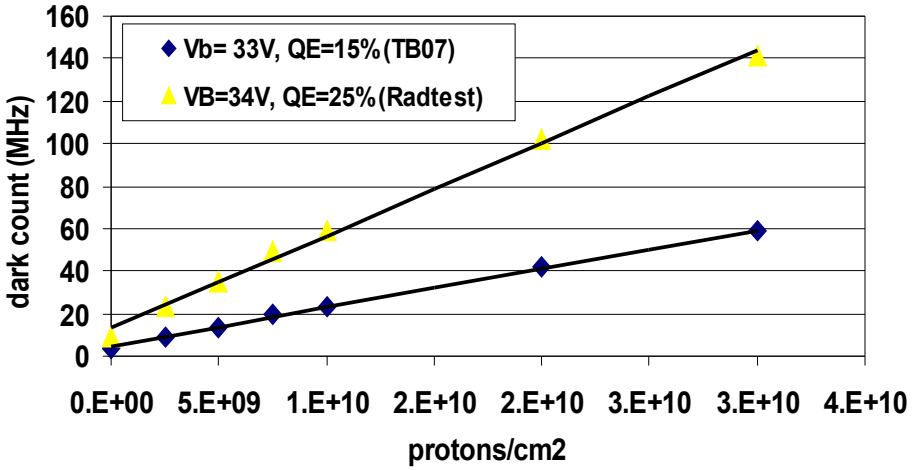




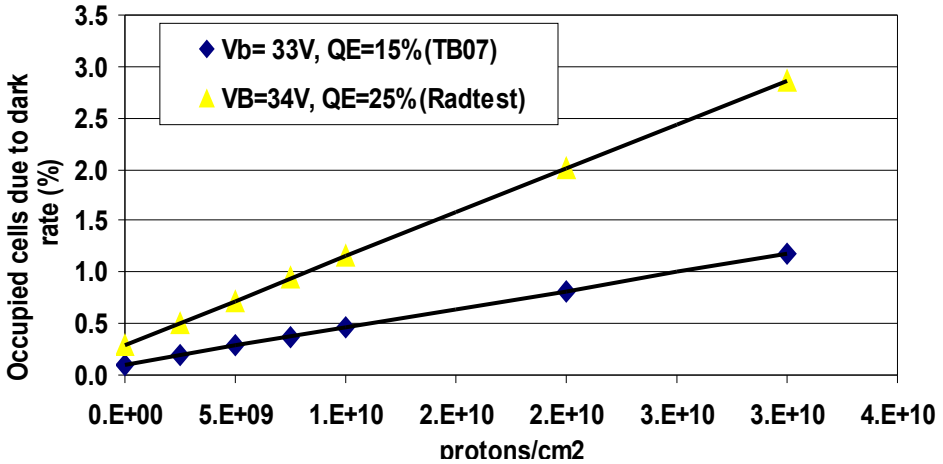


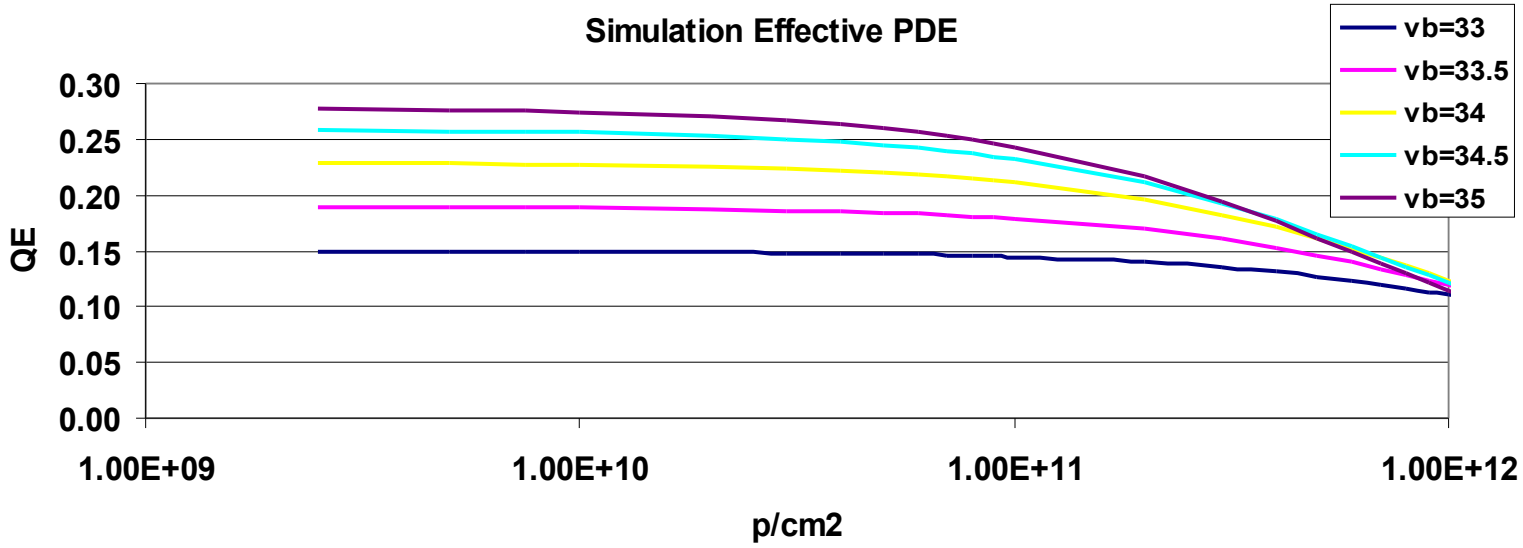
Damage and QE (one day annealing) T=27 degree C

Dark Count

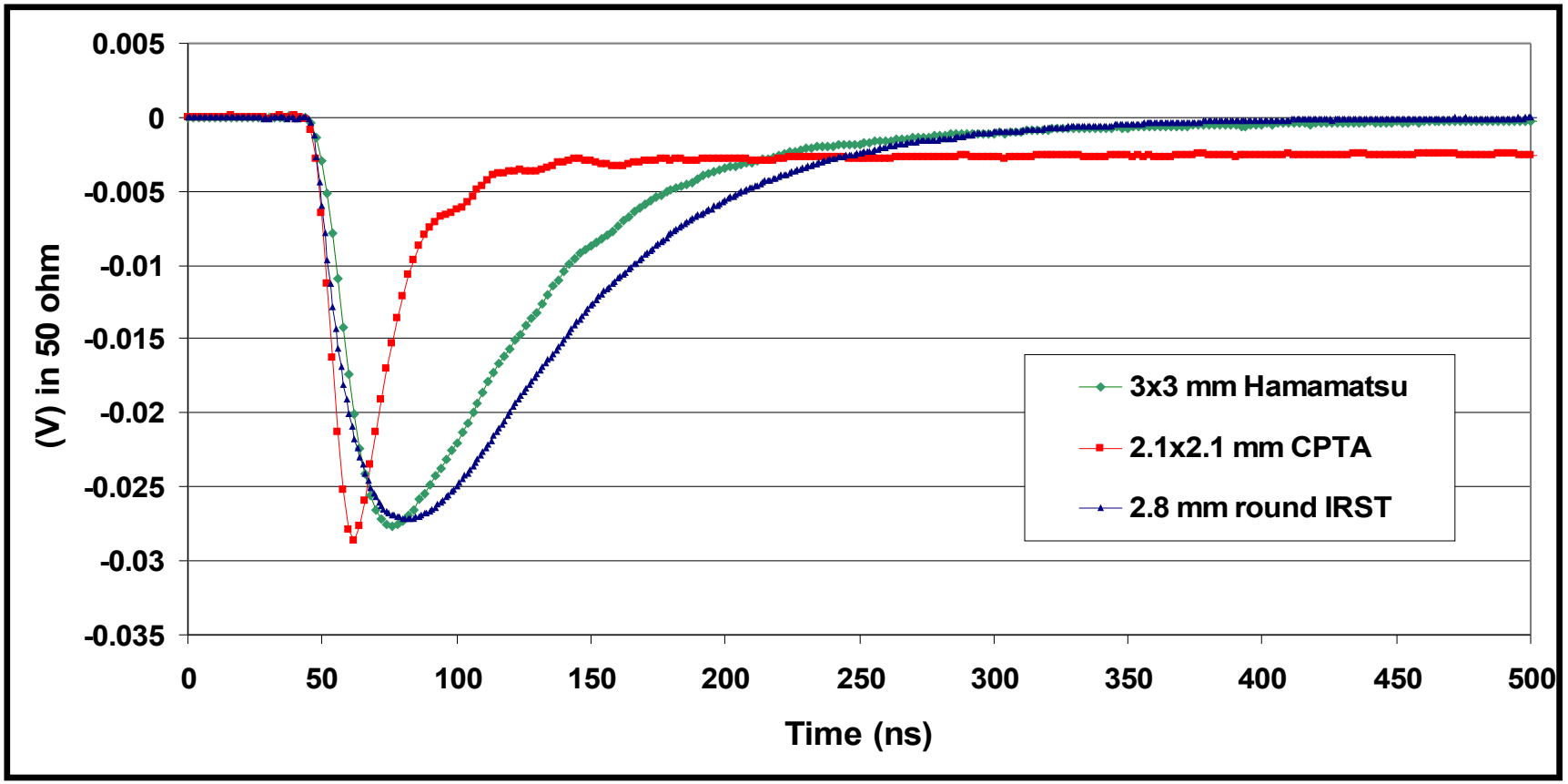


PDE loss due to high darkcount (cell recovery =500 ns)

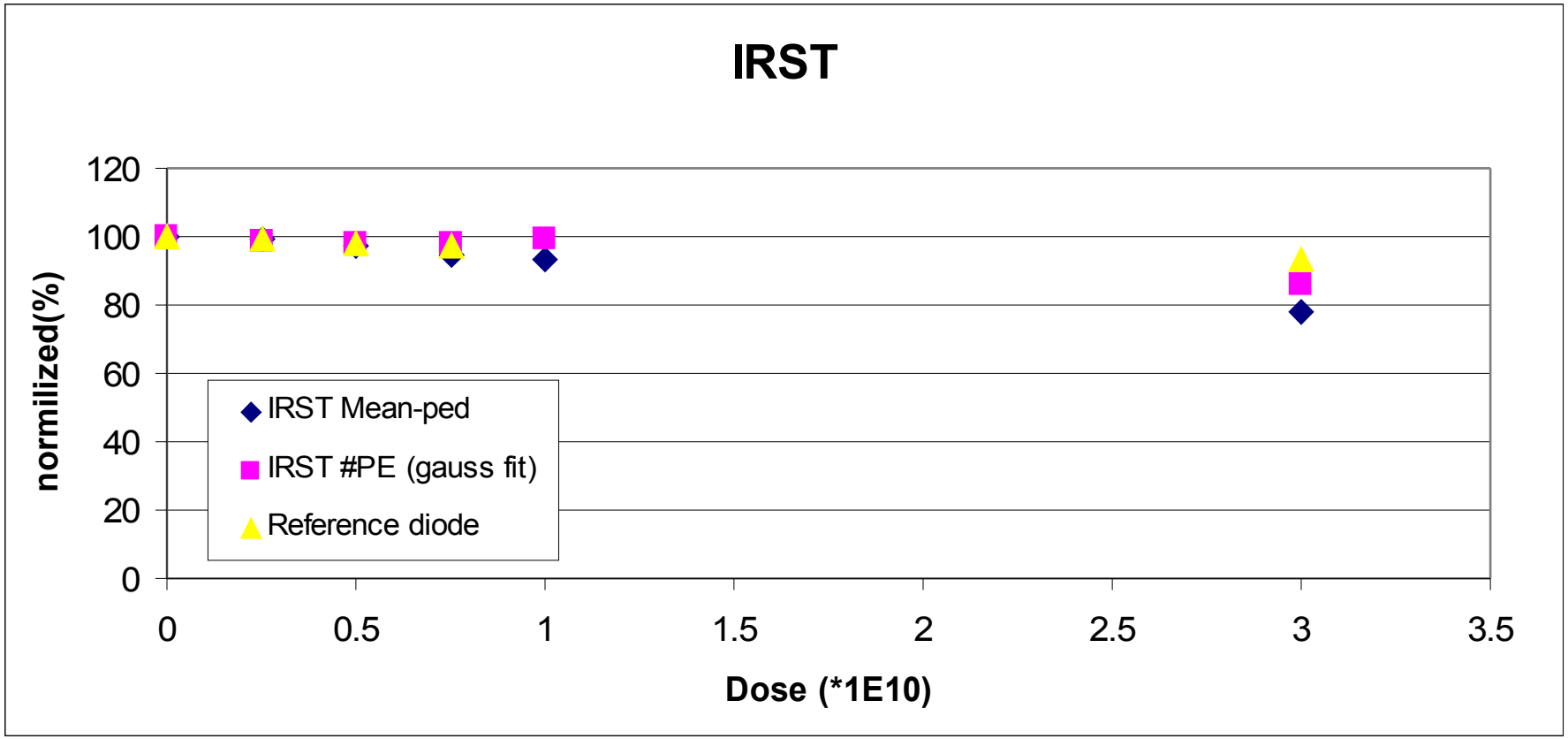




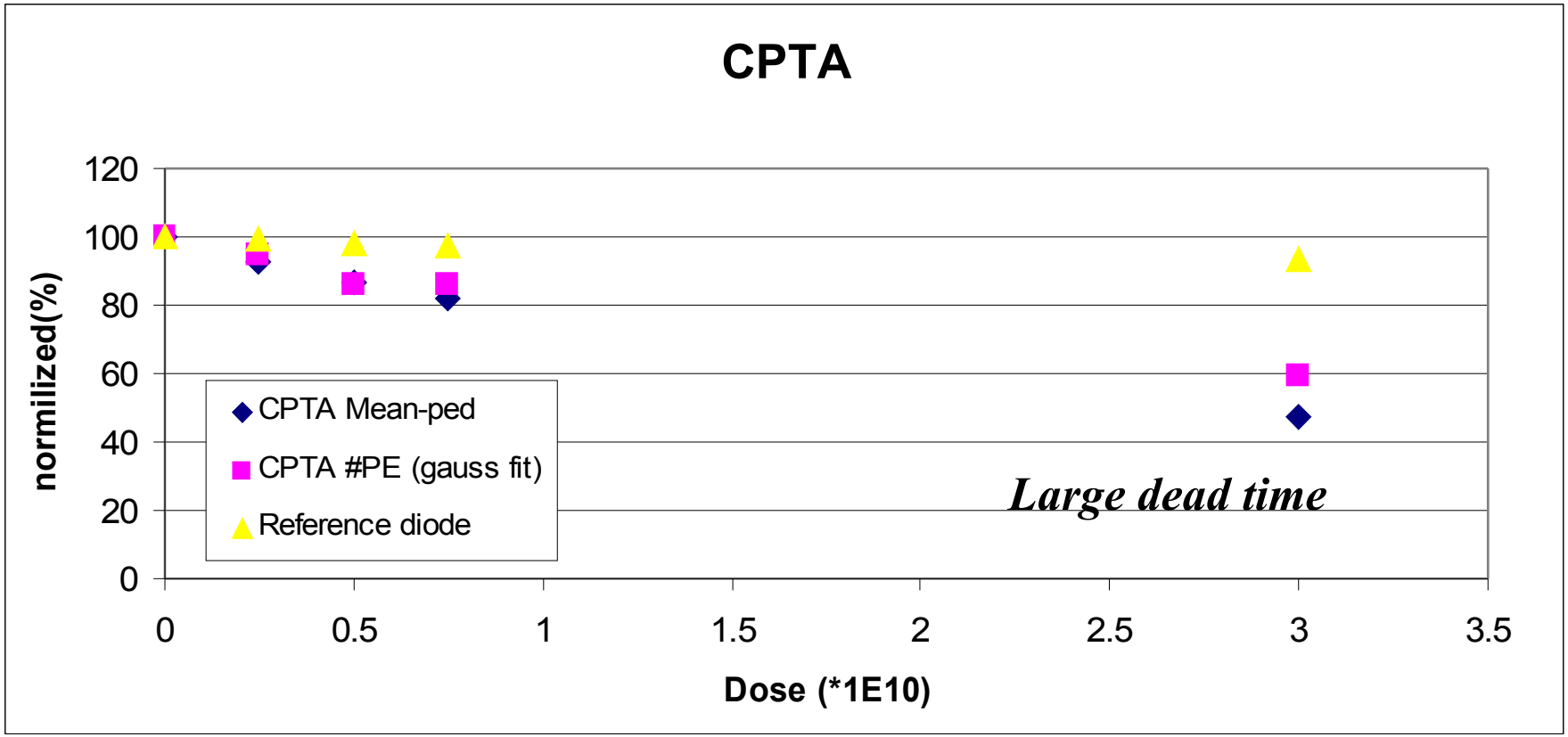
Dead time of micro cells



Signal –Pedestal during radiation



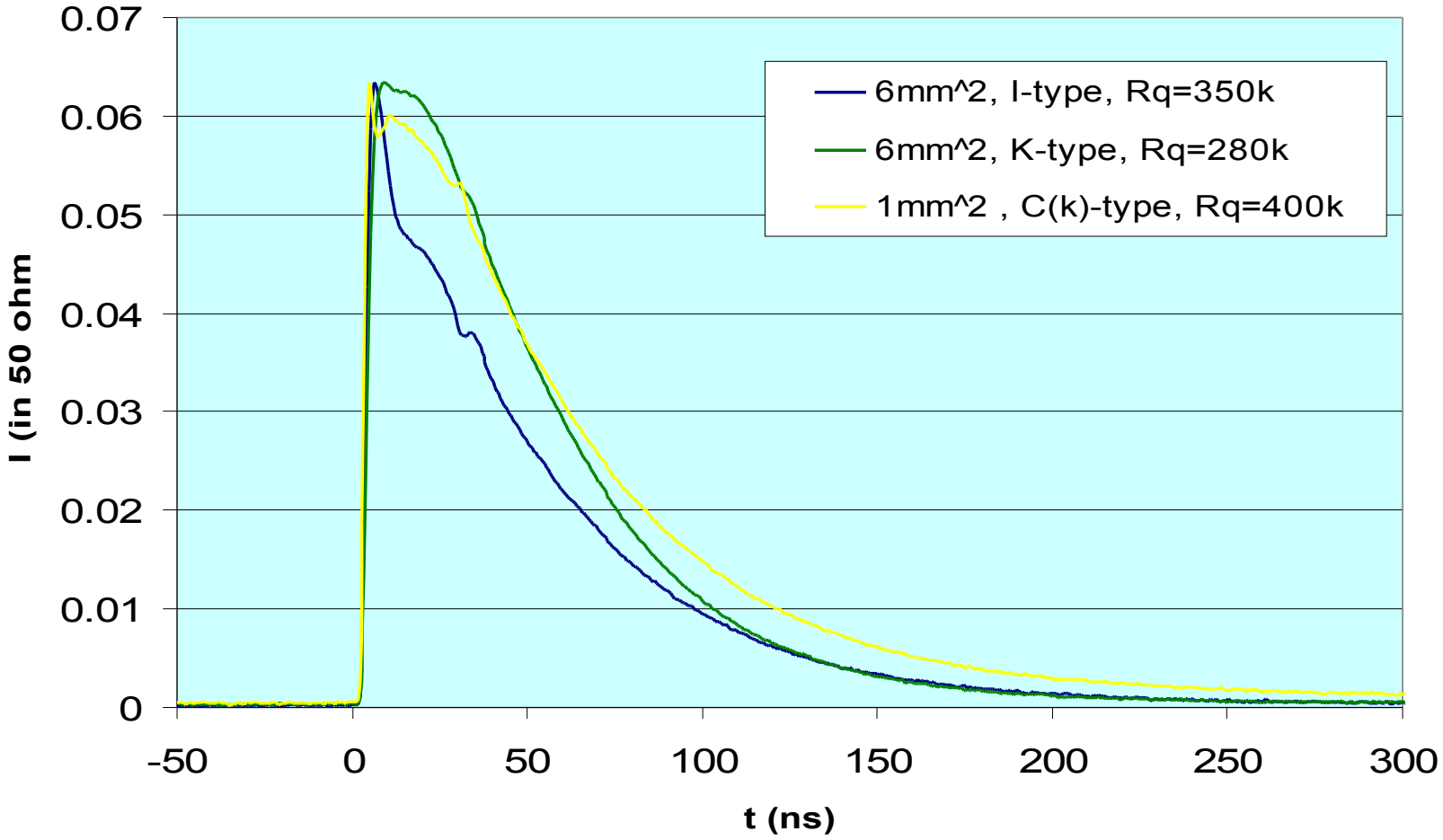
Signal –Pedestal during radiation



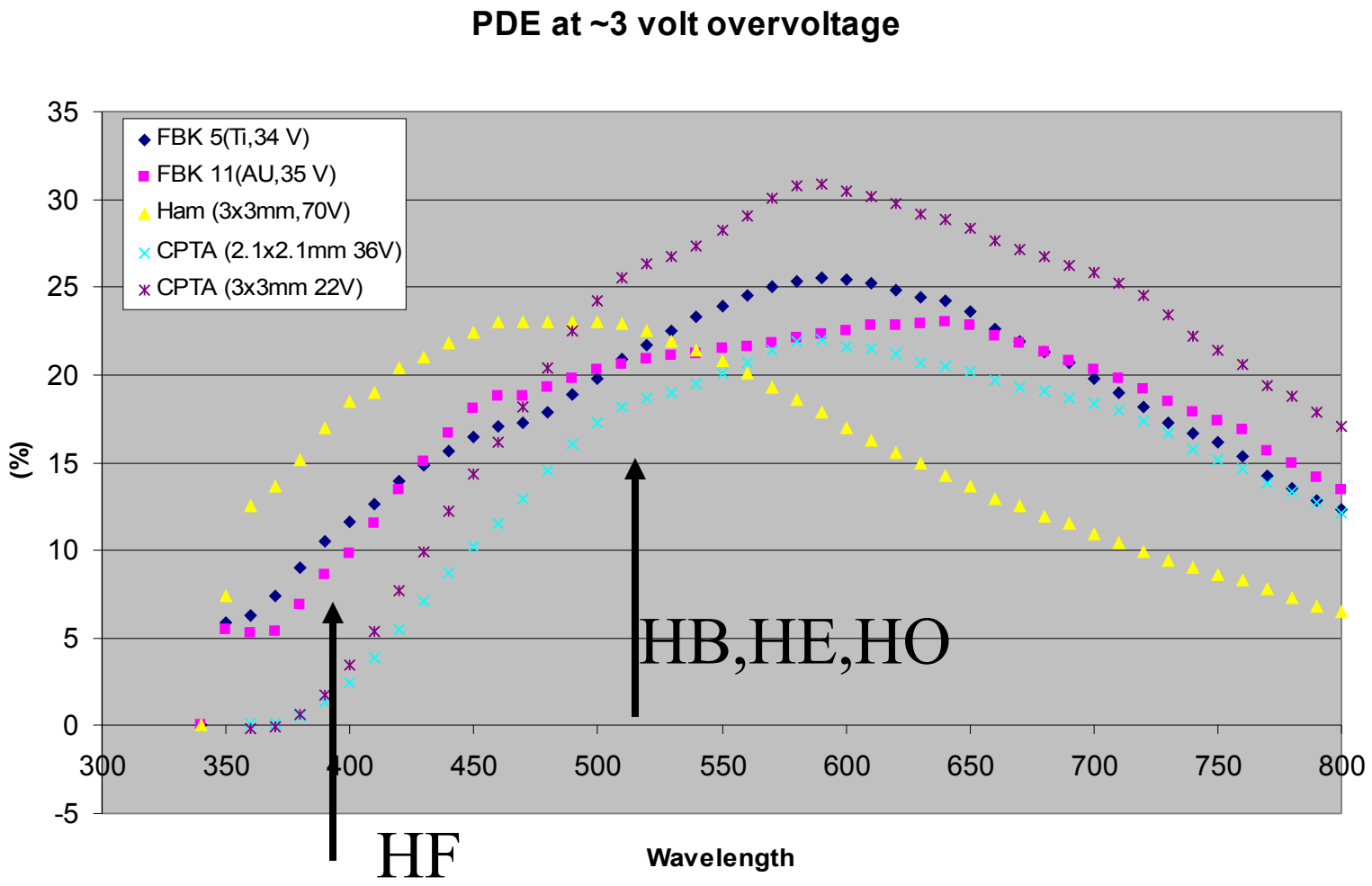
Radiation levels in HCAL

- HB – 10^{10} n/cm^2/ CMS Year
- HE – $3 * 10^{10}$ n/cm^2/ CMS Year
- HO – 10^{9} n/cm^2/ CMS Year
- HF – 10^{11} n/cm^2/ CMS Year

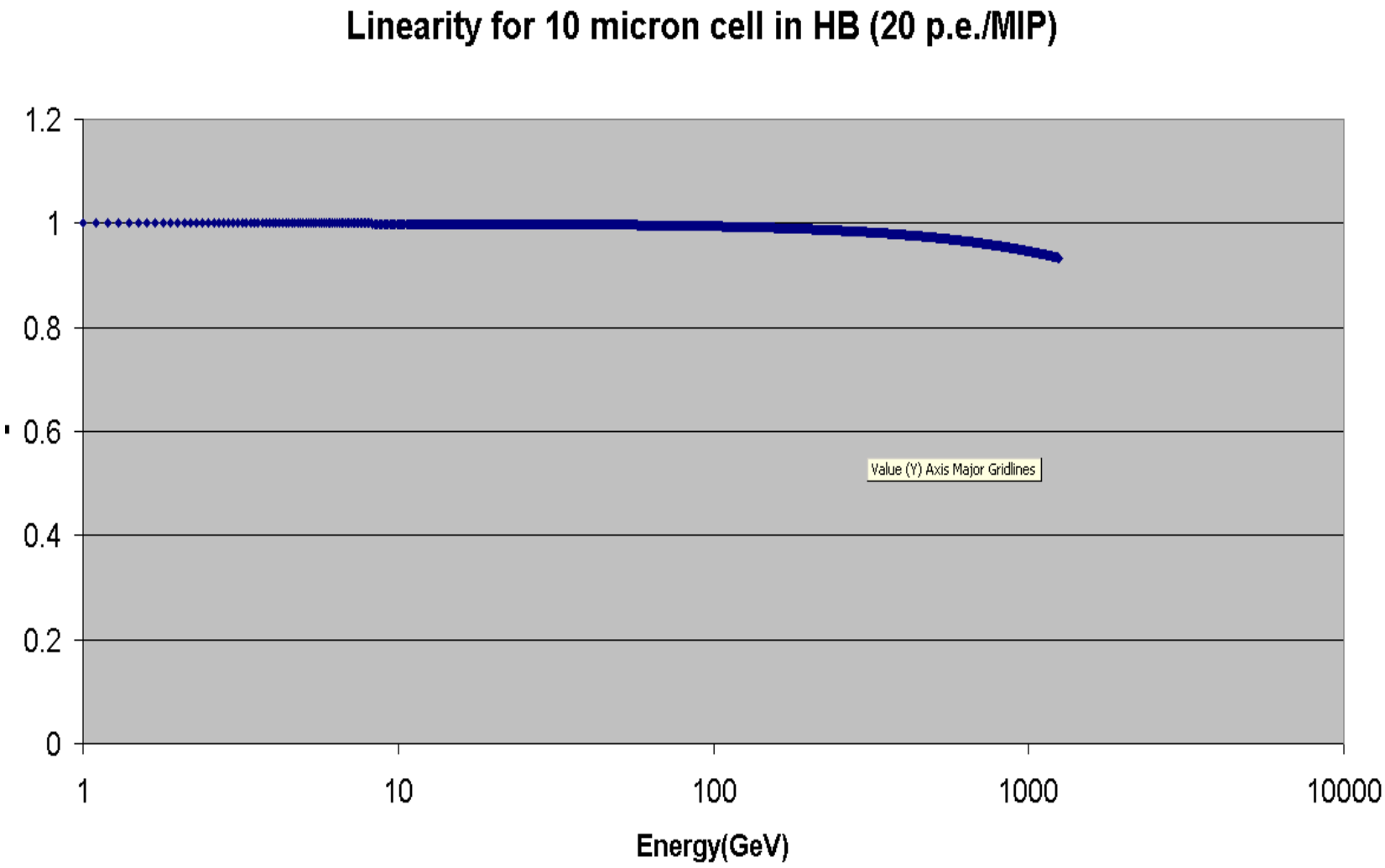
Dead time shorter??



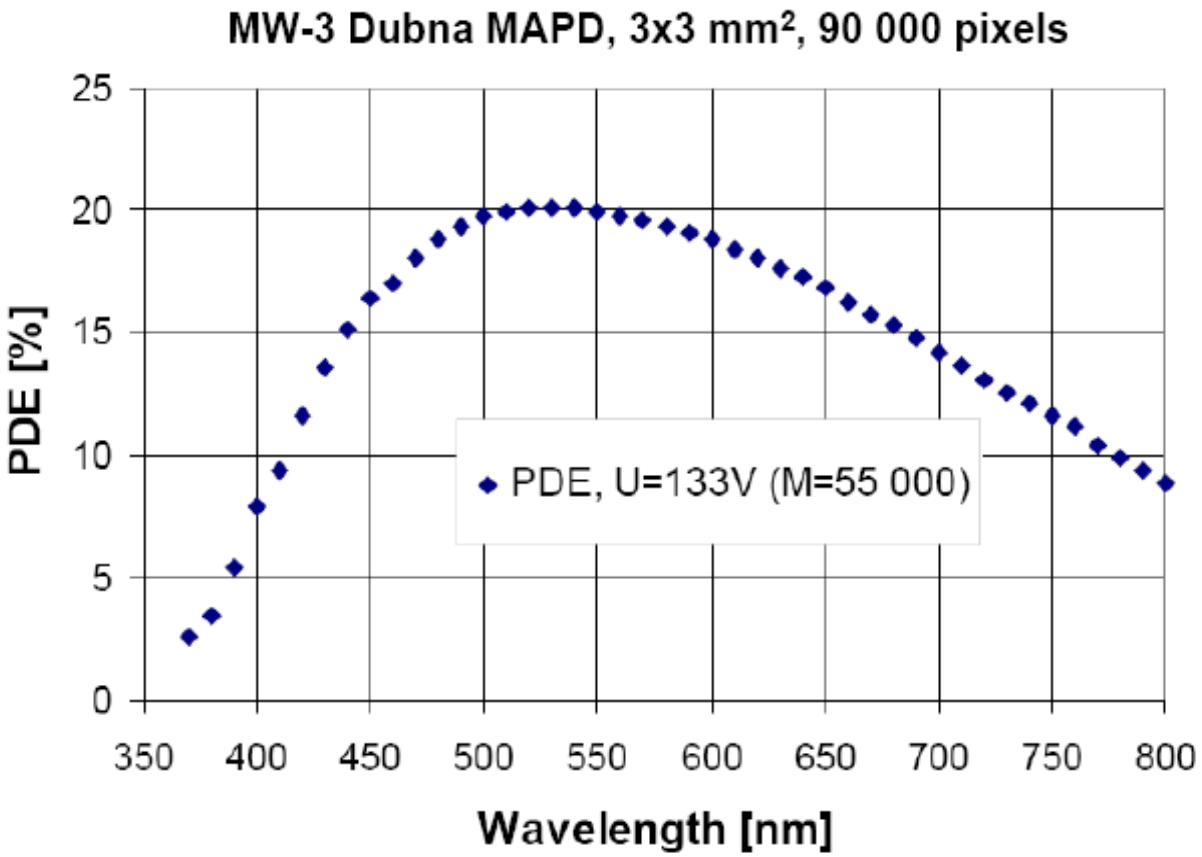
PDE vs Company



Smaller cells vs Linearity (deadtime!)



New devices with 10 micron cells



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