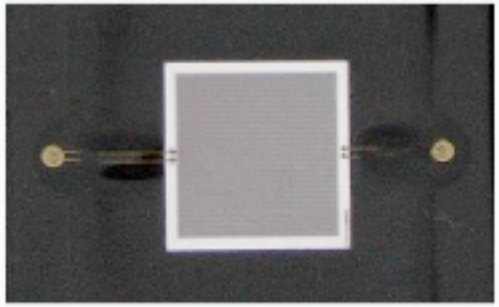
SiPMs: Specifications for HO/HB/HE

J. Rohlf

Boston University

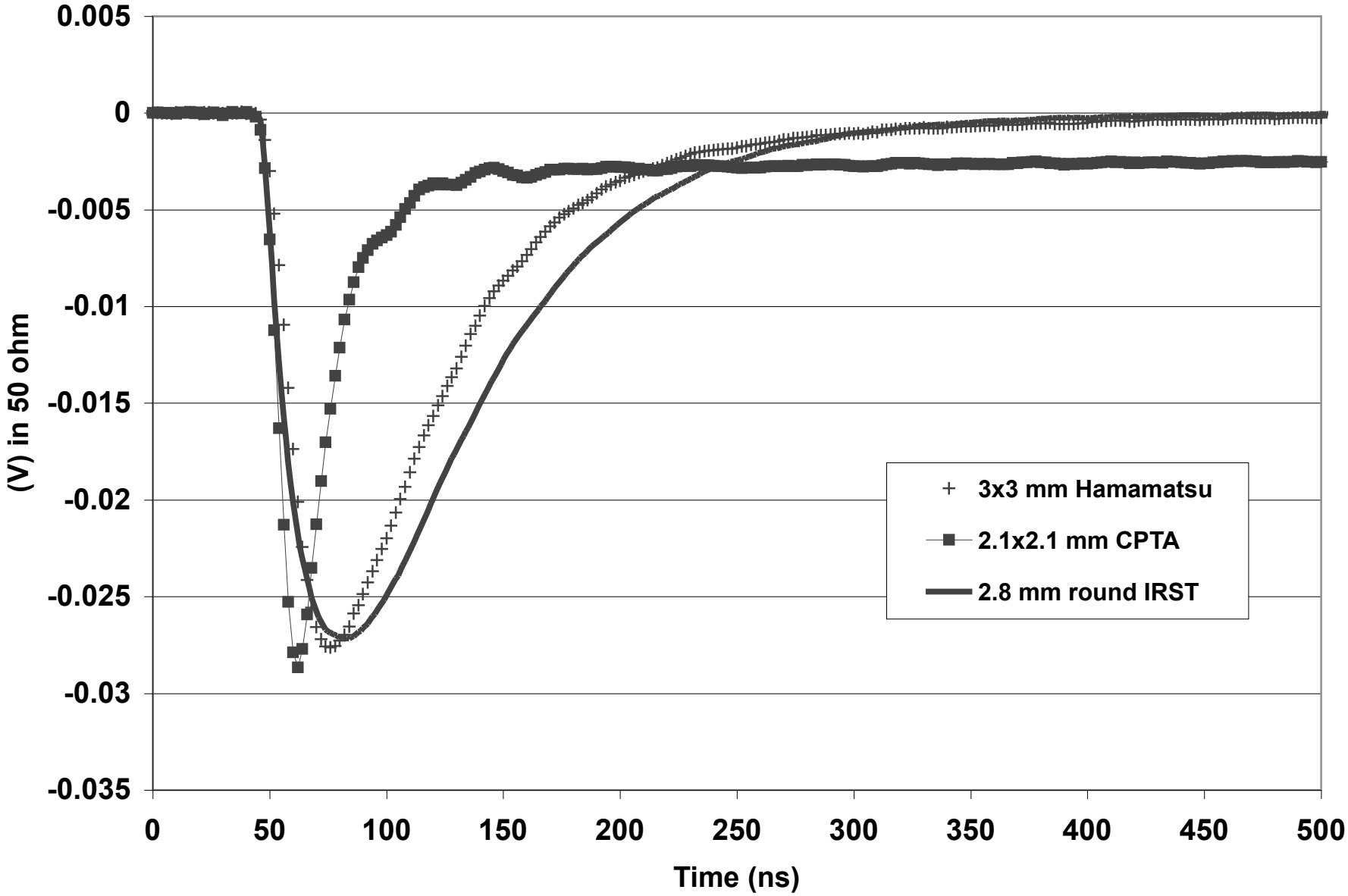
FBK 6.2 mm^2 round

Hamamatsu 9 mm^2 square



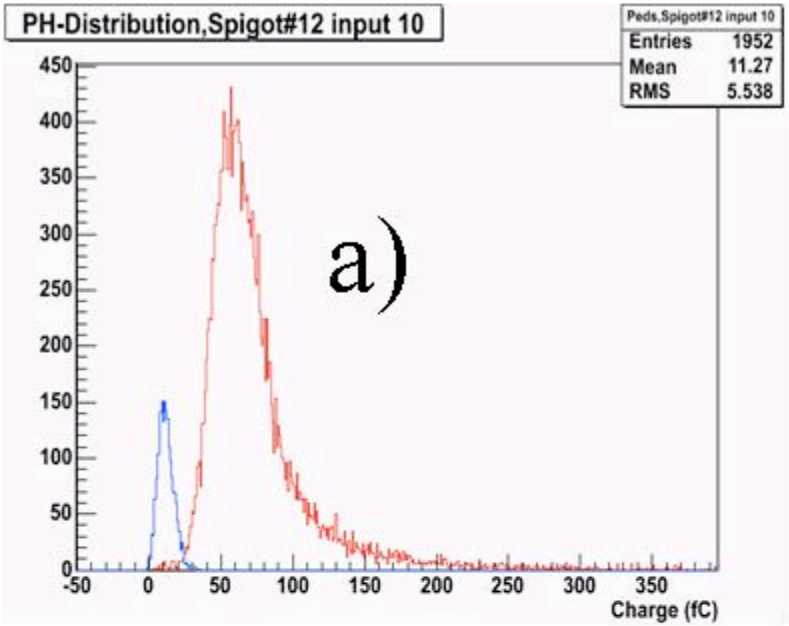
1. Active area
2. Signal/noise
3. Gain variation
4. Operating voltage variation
5. Photon detection efficiency
6. Pulse shape
7. Leakage current after irradiation
8. Radiation damage
9. Saturation due to rate
10. Lifetime
11. Linearity
12. Humidity
13. Stability and range of operation
14. Excess noise factor
15. Insensitive to magnetic field

Requirements for HO SiPMs (Complete Lifetime of CMS including 10 years at 10^{35} $cm^{-2}s^{-1}$), Draft 11 Nov. 2008

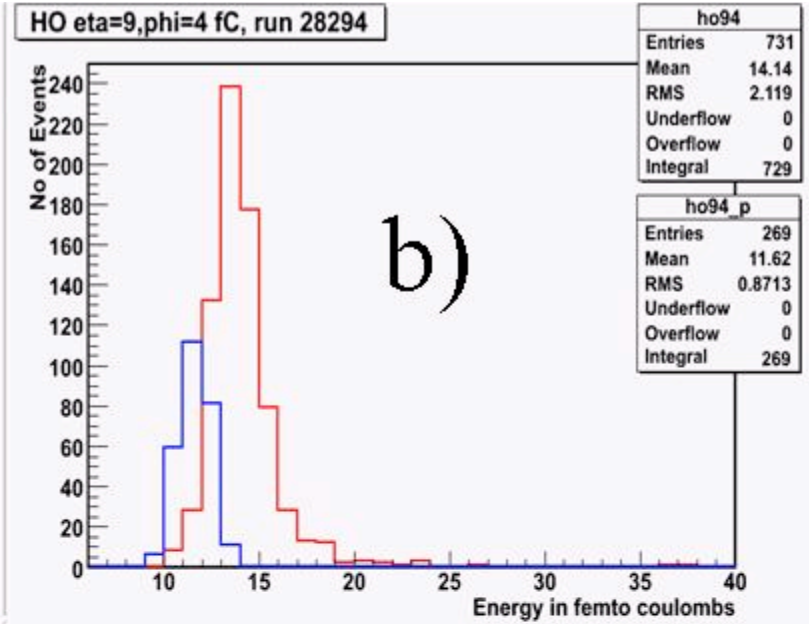

0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
-0.035
(V) in 50 ohm
0
50
100
150
200
250
300
350
400
450
500
Time (ns)
3x3 mm Hamamatsu
2.1x2.1 mm CPTA
2.8 mm round IRST

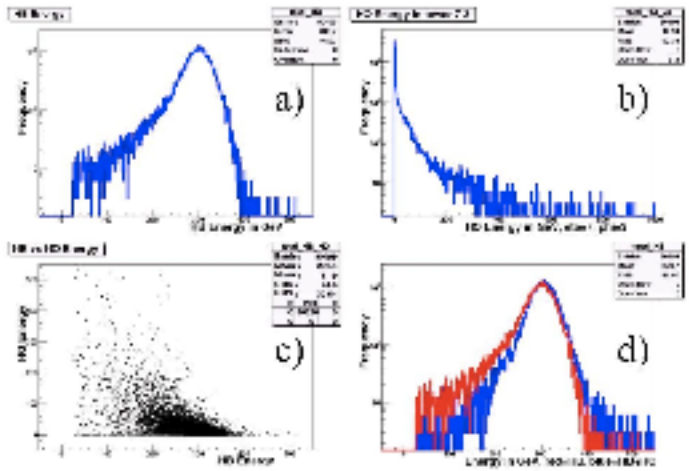
HO Muon signal/noise in H2 test beam

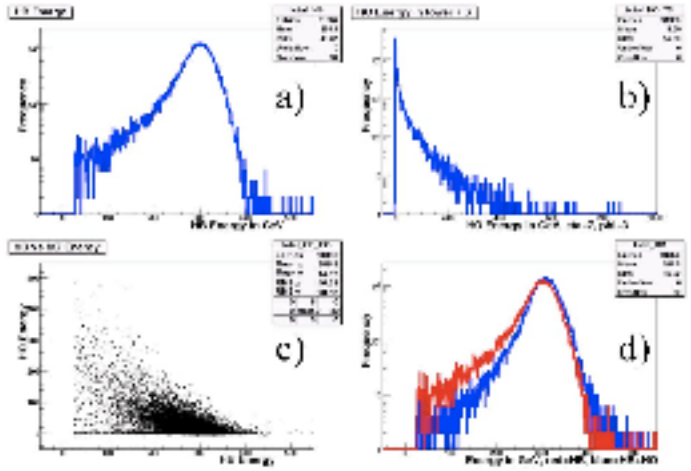
SiPM



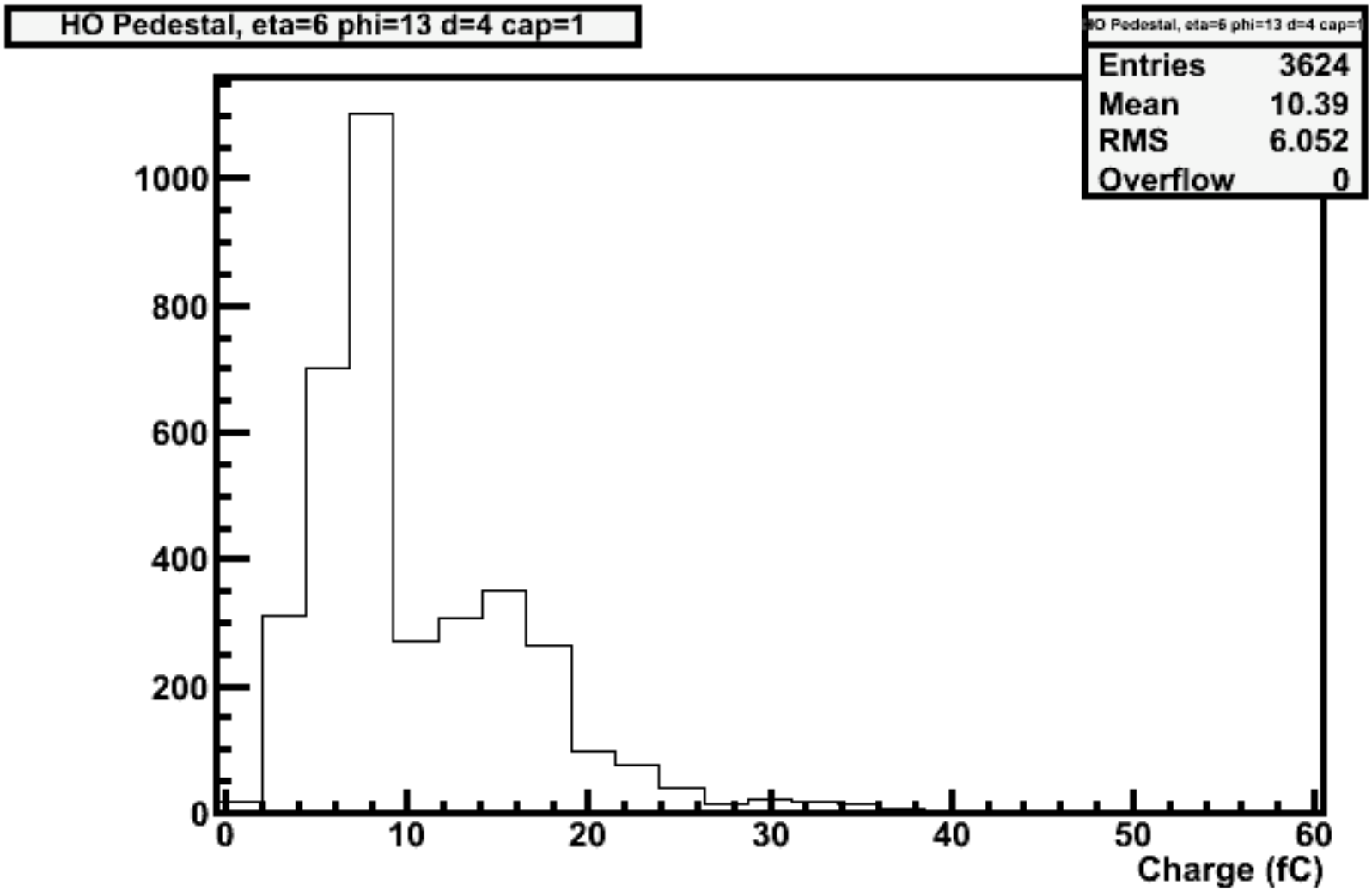
HPD





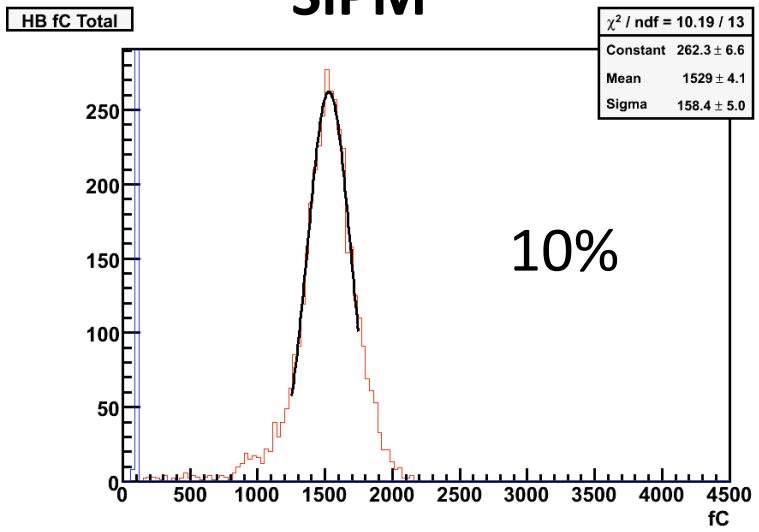


SiPM easy to calibrate because of single PE peak



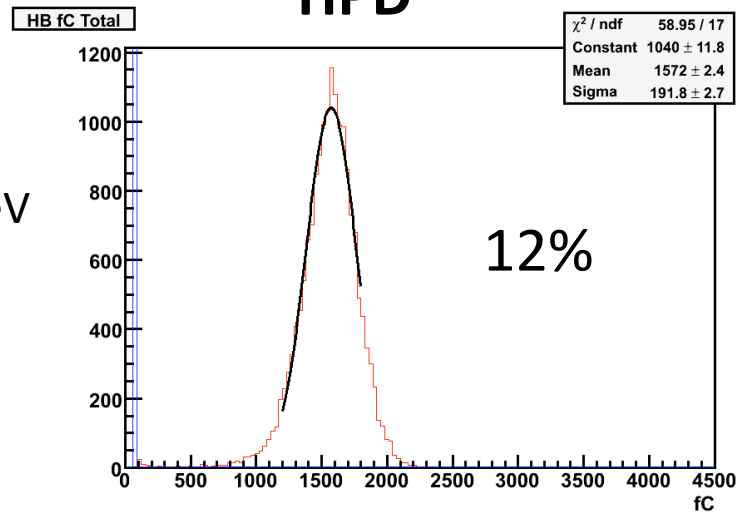
MAPD by Zecotek, 40k pixels per mm^2, 9 mm^2 (360k pixels)

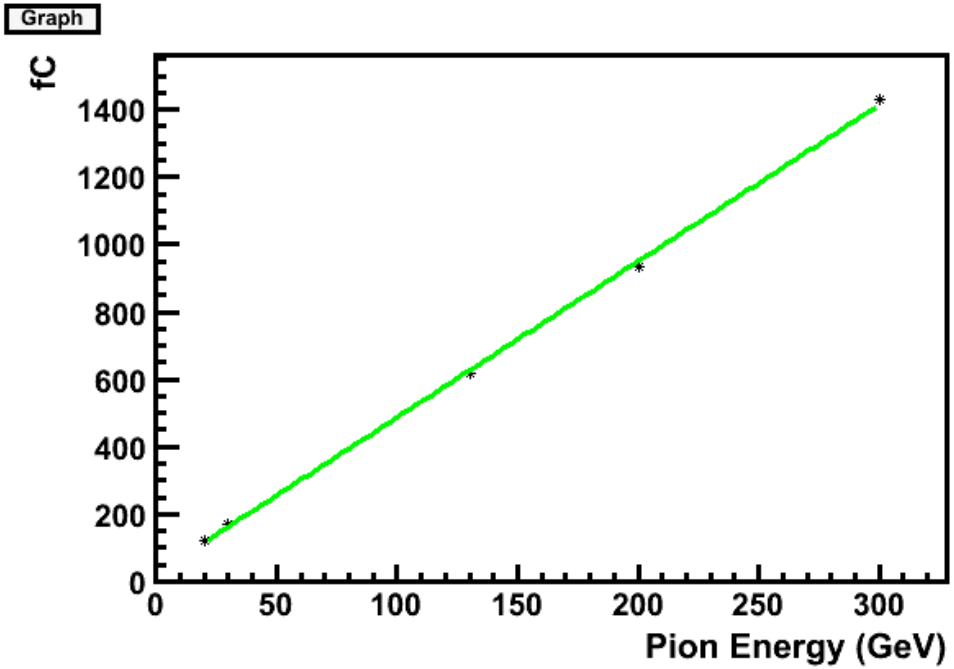
SiPM



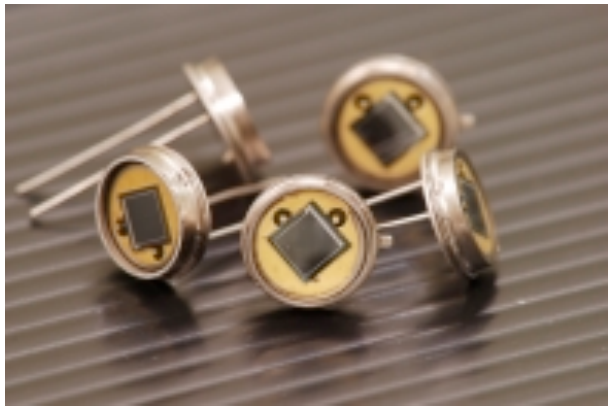
300 GeV pions

HPD





SiPM Linearity



M. Huhtinun, A global radiation test plan for CMS electronics in HCAL, Muons and Experimental Hall (Dec. 1999)

Fluence (cm^{-2}) for 10 LHC years, x 10^7 s at 10^{34} cm^{-2} s-1

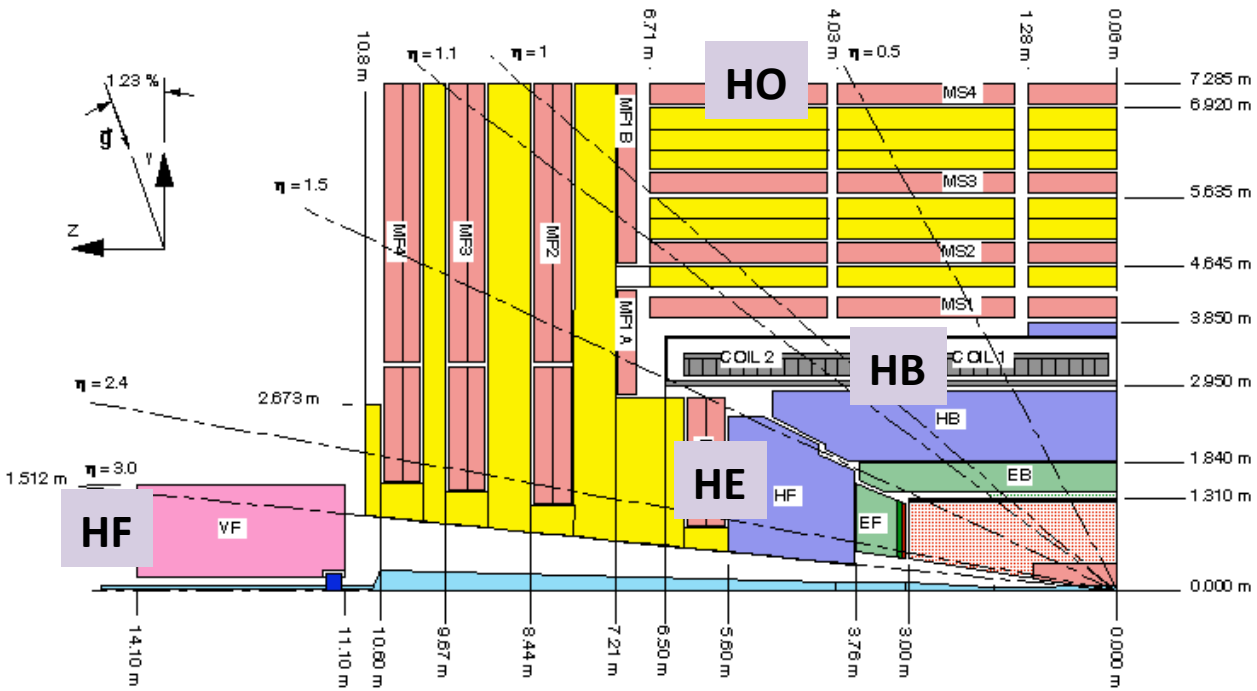
	Neutron F				Ch. Had. F	Max. TID
	Total	E>100keV	2-20MeV	E>20MeV	E>5MeV	Rads/10y
HCAL:						
Barrel FEE box	$3.1 \cdot 10^{11}$	$1.3 \cdot 10^{11}$	$4.3 \cdot 10^{10}$	$2.4 \cdot 10^{10}$	$2.7 \cdot 10^{8}$	190
Endcap FEE box	$6.5 \cdot 10^{10}$	$2.8 \cdot 10^{10}$	$5.2 \cdot 10^{9}$	$2.8 \cdot 10^{9}$	$1.6 \cdot 10^{8}$	71
Muon chambers:						
Barrel MB1	$2.3 \cdot 10^{10}$	$6.4 \cdot 10^{9}$	$8.0 \cdot 10^{8}$	$1.2 \cdot 10^{9}$	$2.7 \cdot 10^{7}$	12
MB1, Z=0-400		$2.9 \cdot 10^{9}$				5
MB1, Z=400-660		$1.1 \cdot 10^{10}$				22
Barrel MB4	$2.9 \cdot 10^{10}$	$6.3 \cdot 10^{9}$	$1.0 \cdot 10^{9}$	$3.4 \cdot 10^{8}$	$7.1 \cdot 10^{6}$	10
Endcap ME1/1	$8.7 \cdot 10^{11}$	$2.2 \cdot 10^{11}$	$3.6 \cdot 10^{10}$	$5.4 \cdot 10^{10}$	$1.8 \cdot 10^{9}$	740
ME1/1, R=100-150		$6.2 \cdot 10^{11}$				1780
ME1/1, R=170-270		$1.1 \cdot 10^{11}$				530
Endcap ME1/2	$3.0 \cdot 10^{10}$	$5.6 \cdot 10^{9}$	$6.9 \cdot 10^{8}$	$7.3 \cdot 10^{8}$	$2.3 \cdot 10^{7}$	25
Endcap ME1/3	$1.2 \cdot 10^{10}$	$2.3 \cdot 10^{9}$	$3.4 \cdot 10^{8}$	$1.7 \cdot 10^{8}$	$4.7 \cdot 10^{6}$	7
Endcap ME2/1	$2.2 \cdot 10^{11}$	$6.0 \cdot 10^{10}$	$9.8 \cdot 10^{9}$	$1.7 \cdot 10^{10}$	$2.8 \cdot 10^{8}$	190
Endcap ME2/2	$2.8 \cdot 10^{10}$	$5.7 \cdot 10^{9}$	$9.2 \cdot 10^{8}$	$1.1 \cdot 10^{9}$	$3.3 \cdot 10^{7}$	22
Endcap ME3/1	$2.2 \cdot 10^{11}$	$6.5 \cdot 10^{10}$	$1.0 \cdot 10^{10}$	$1.7 \cdot 10^{10}$	$2.8 \cdot 10^{8}$	220
Endcap ME3/2	$5.9 \cdot 10^{10}$	$1.5 \cdot 10^{10}$	$1.9 \cdot 10^{9}$	$1.5 \cdot 10^{9}$	$1.2 \cdot 10^{7}$	53
Endcap ME4/1	$2.0 \cdot 10^{11}$	$8.1 \cdot 10^{10}$	$1.4 \cdot 10^{10}$	$2.4 \cdot 10^{10}$	$5.5 \cdot 10^{8}$	300
Endcap ME4/2	$1.3 \cdot 10^{11}$	$4.2 \cdot 10^{10}$	$5.7 \cdot 10^{9}$	$6.2 \cdot 10^{9}$	$6.8 \cdot 10^{7}$	90
Exp. Hall:						
Block House Z=25 R=3	$3.3 \cdot 10^{11}$	$1.8 \cdot 10^{11}$	$1.3 \cdot 10^{11}$	$9.2 \cdot 10^{10}$	$2.7 \cdot 10^{9}$	920
HF shield. Z=12 R=3	$2.0 \cdot 10^{11}$	$1.0 \cdot 10^{11}$	$5.6 \cdot 10^{10}$	$3.5 \cdot 10^{10}$	$1.5 \cdot 10^{9}$	330
Above barrel Z=3 R=10	$6.9 \cdot 10^{10}$	$1.6 \cdot 10^{10}$	$6.2 \cdot 10^{9}$	$2.1 \cdot 10^{9}$	$2.9 \cdot 10^{7}$	43
Cavern wall Z=18 R=10	$1.9 \cdot 10^{11}$	$8.4 \cdot 10^{10}$	$5.0 \cdot 10^{10}$	$3.1 \cdot 10^{10}$	$8.2 \cdot 10^{8}$	620

SLHC radiation Requirements (10 year)

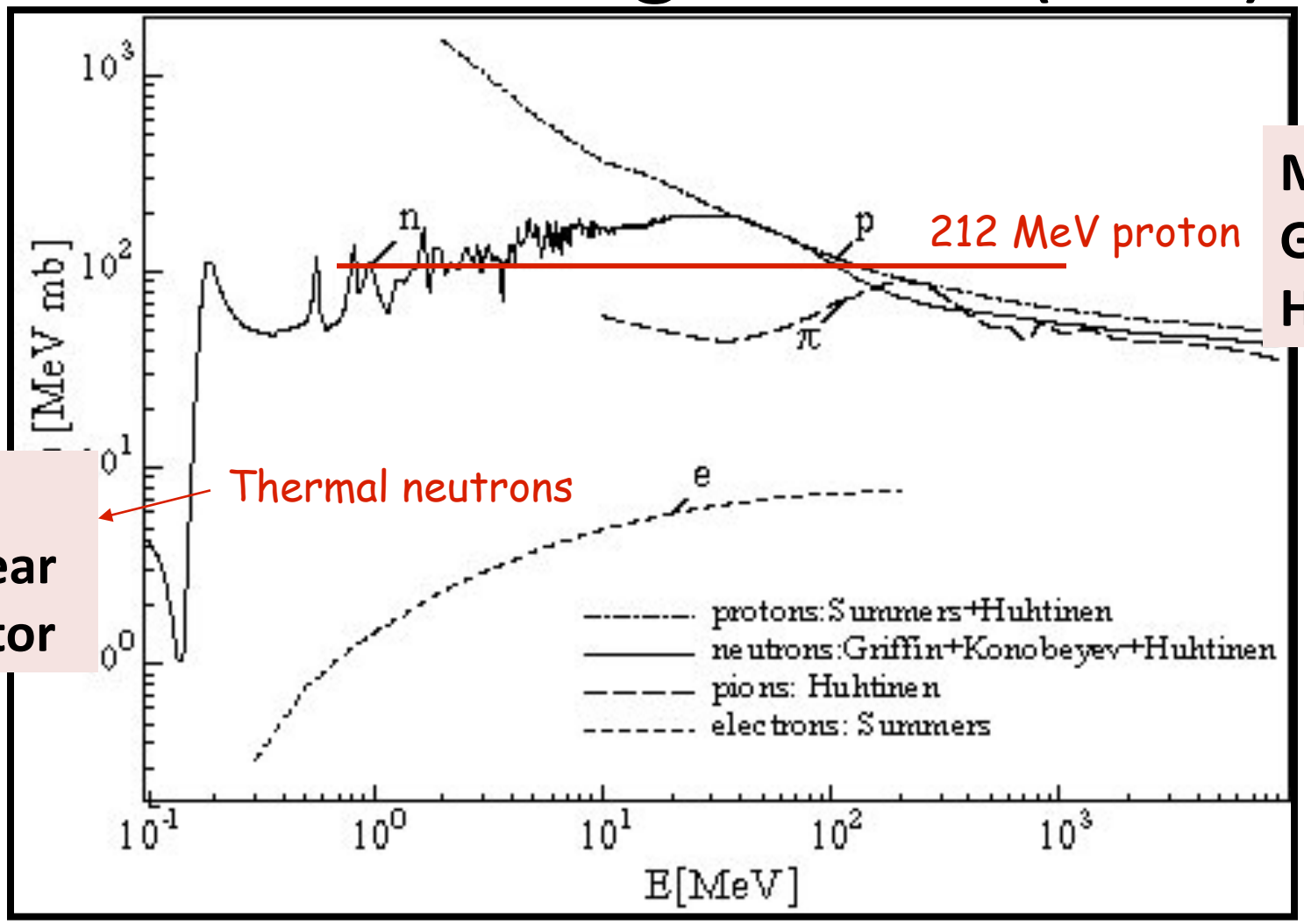
HO: 10^{11} cm^{-2}

HB: 10^{12} cm^{-2}

HE: 3×10^{11} cm^{-2}



Silicon damage factor (NIEL)



Mass General Hospital

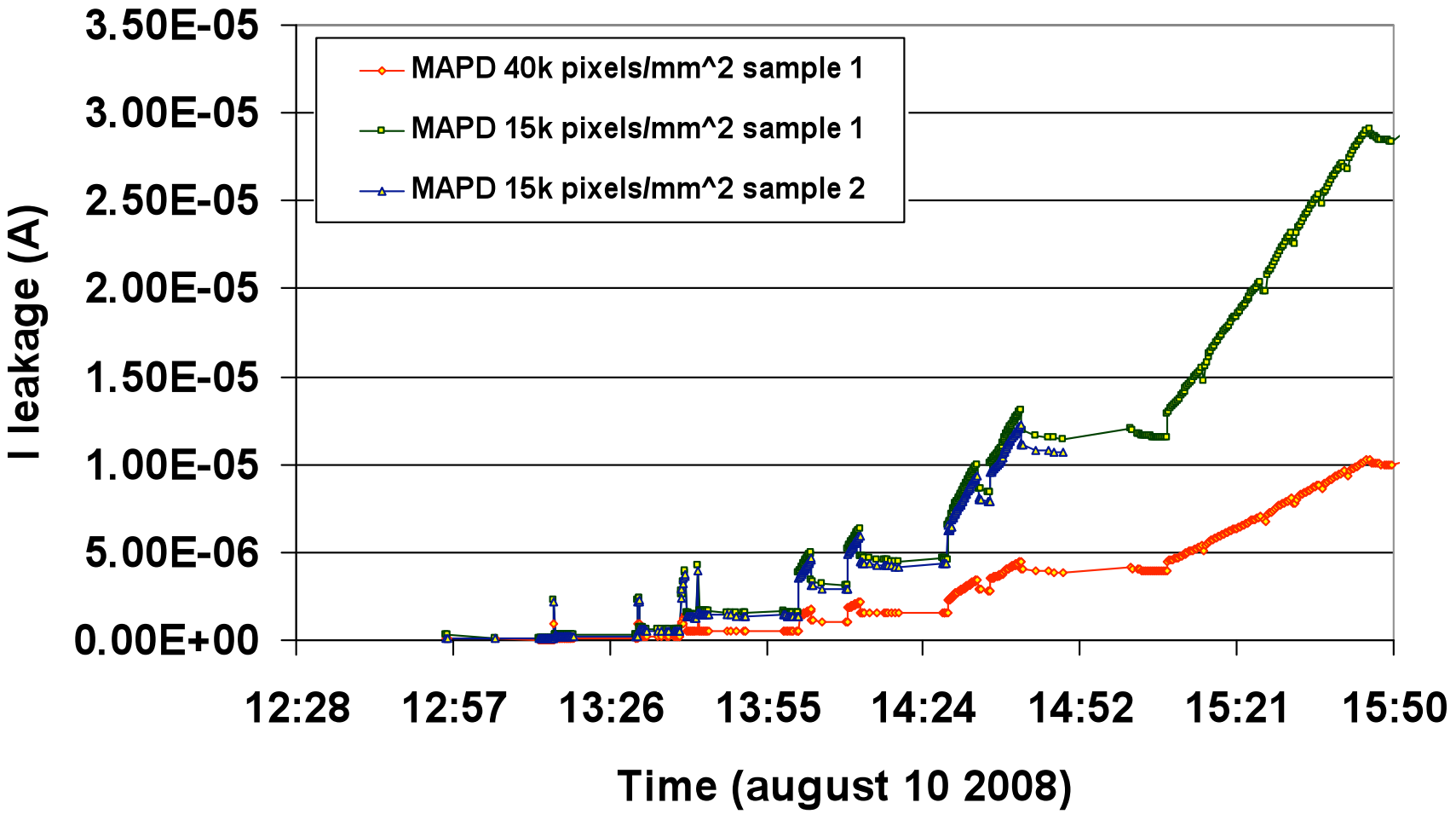
MIT Nuclear Reactor

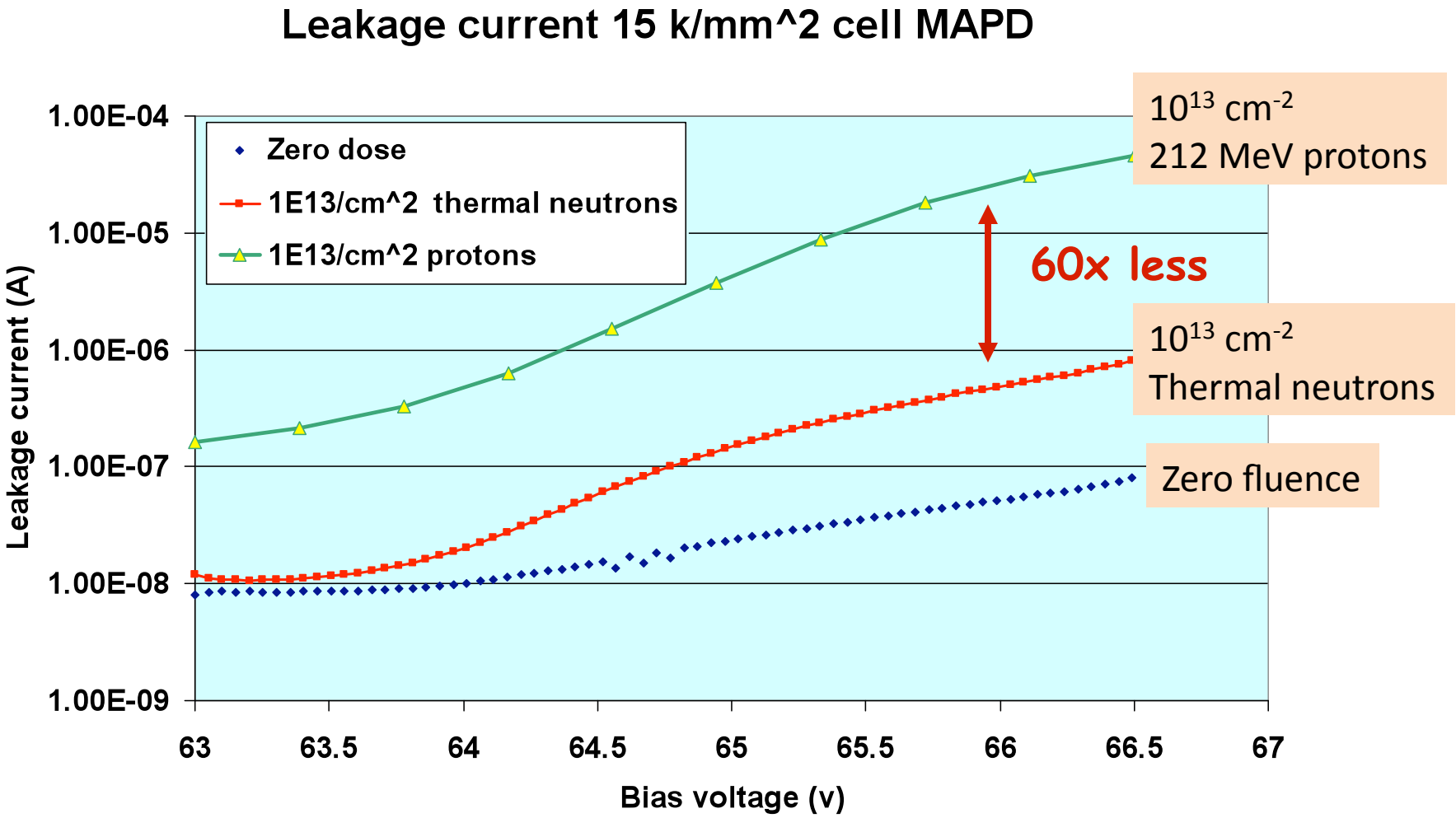
60 MeV protons: 10^{11} cm^{-2} = 140 Gy (14 krad)

200 MeV protons: 10^{11} cm^{-2} = 60 Gy (6 krad)

212 MeV
Proton beam
At MGH

Zecotek MAPD leakage current up to $1* 10^{13}$ p/cm^2

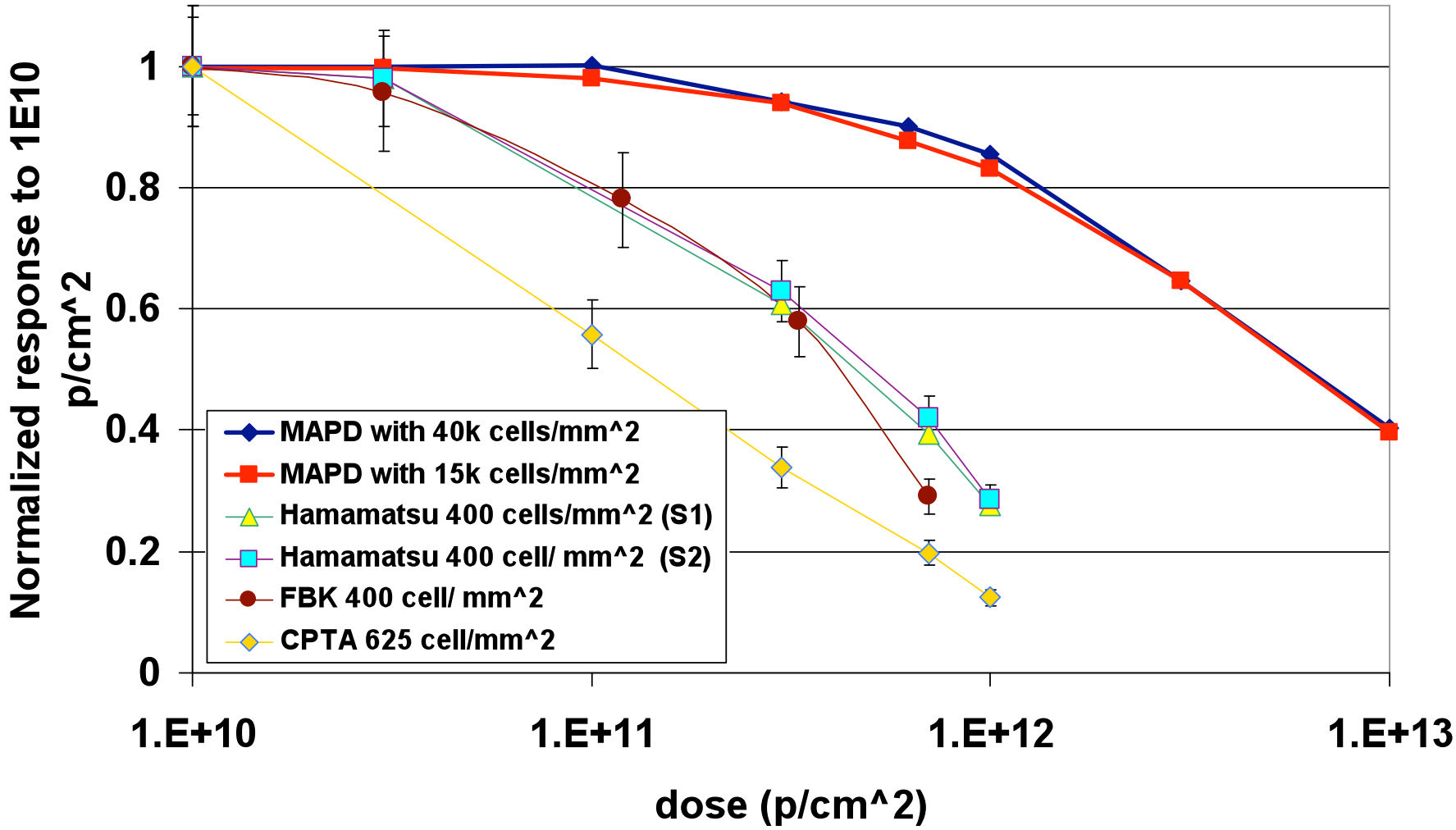




Both proton and thermal neutron damage anneals x2 measured on Oct. 16, 2008

Reported at IEEE, Dresden, Oct. 2008

Response vs. fluence



Summary

We have 2 good SiPM candidates for HO:
Hamamatsu and FBK (50 μ pixels)

We have 1 good SiPM candidate for HB/HE:
Zecotek (5 μ pixels)