CMS HCAL Upgrade Plans using G-APDs

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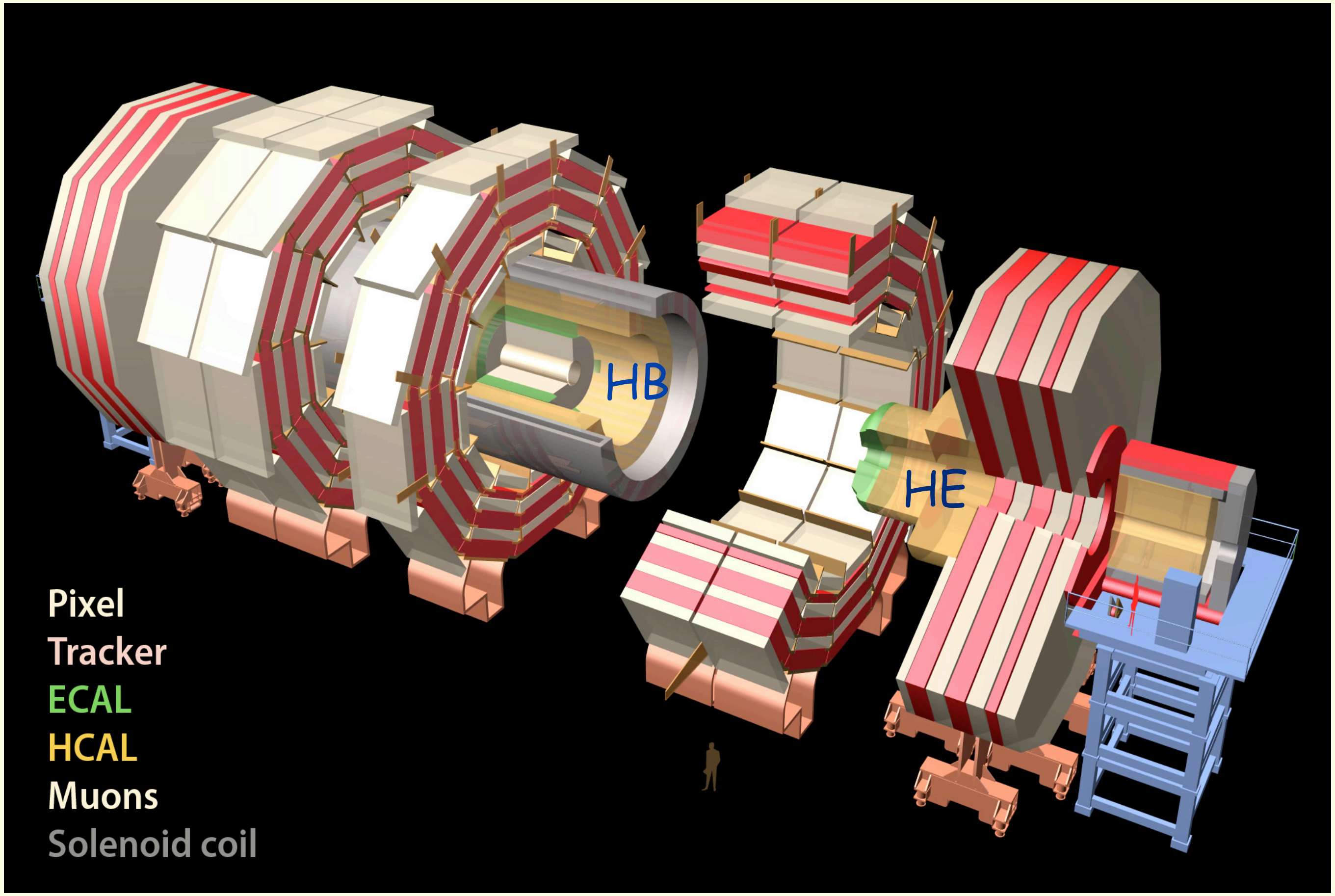
On behalf of the CMS HCAL Collaboration

CMS Hadronic Calorimeter

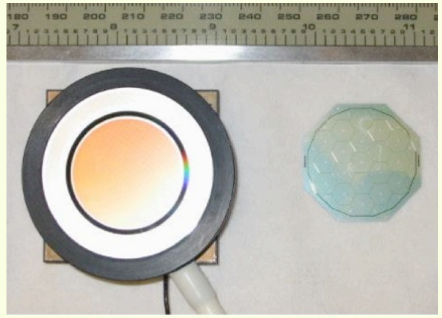


Barrel and Endcap are inside the 4 Tesla magnetic field

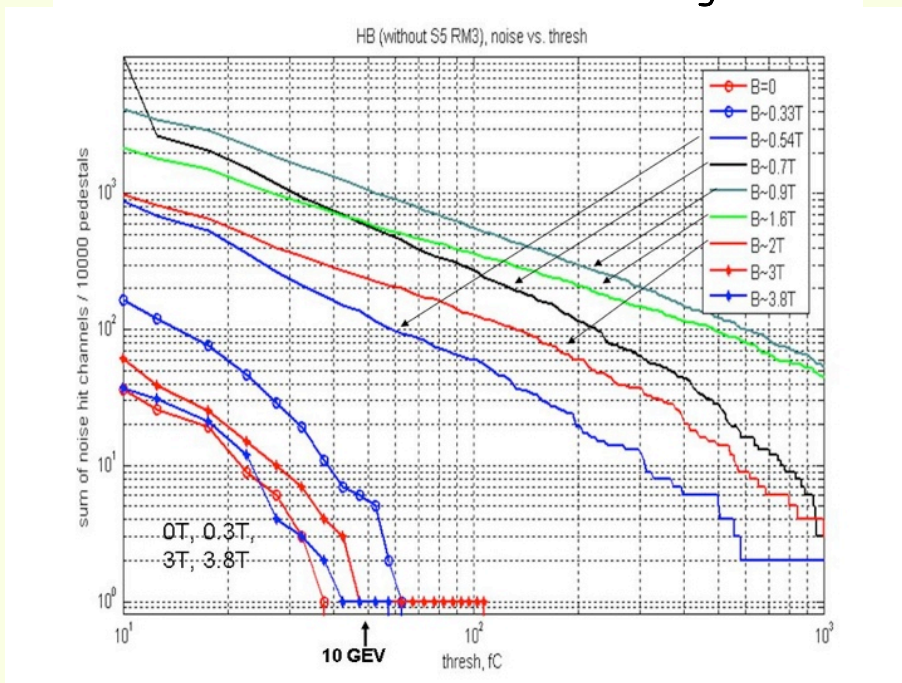
HPD replacement with G-APDs in HO

HPD is the base line photo detector for the CMS HCAL

- PMTs can not operate in high magnetic field
- Low light yield /GeV in the HCAL
- High dynamic range



Noise in HPD due to SEA in the fringe fields



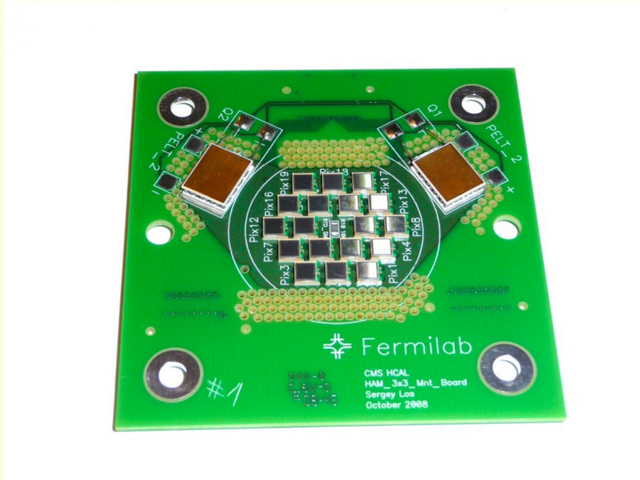
Now widely available G-APDs

PDE: HPD 12% vs G-APD 30% at 520nm
Operation voltage: 8kV vs 90V

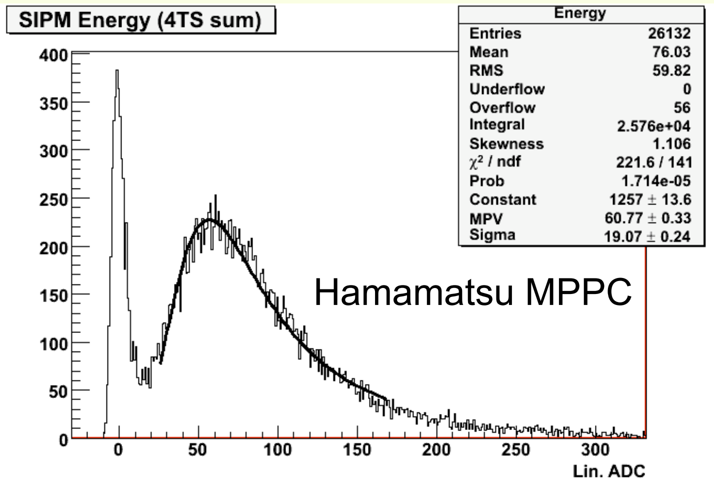
G-APD disadvantage:
Temperature dependance

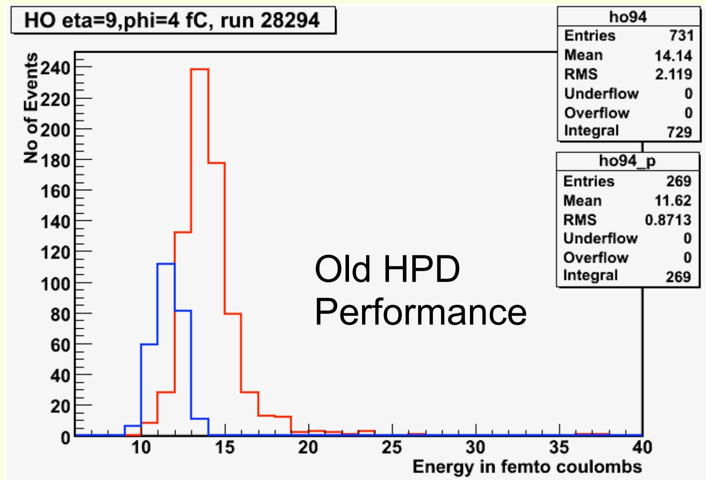
Hcal Outer (HO) replacement

144 G-APDs installed into CMS in April 2009 and now operating.
36 Zecotek 15K/mm^2 3X3mm,
108 Hamamatsu 400/mm^2 3X3mm.



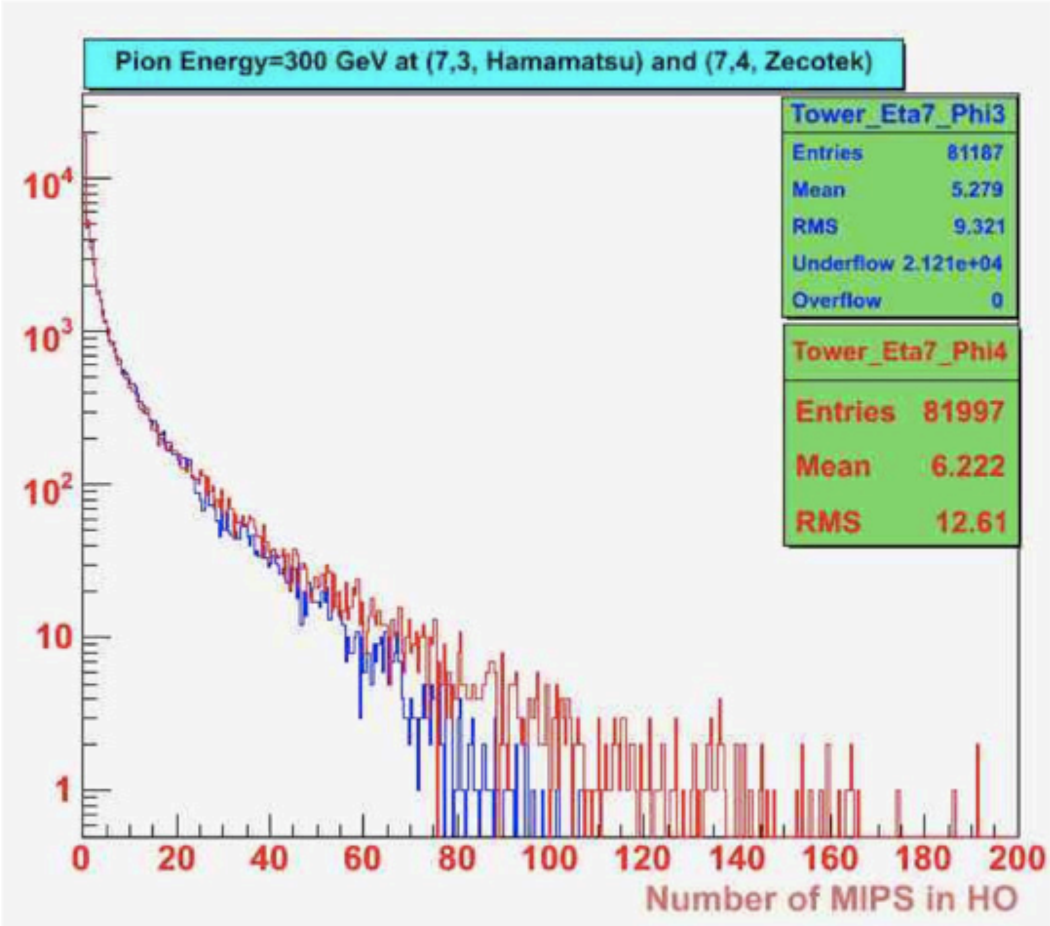
Install ALL HO (~2500 channels) in next shutdown



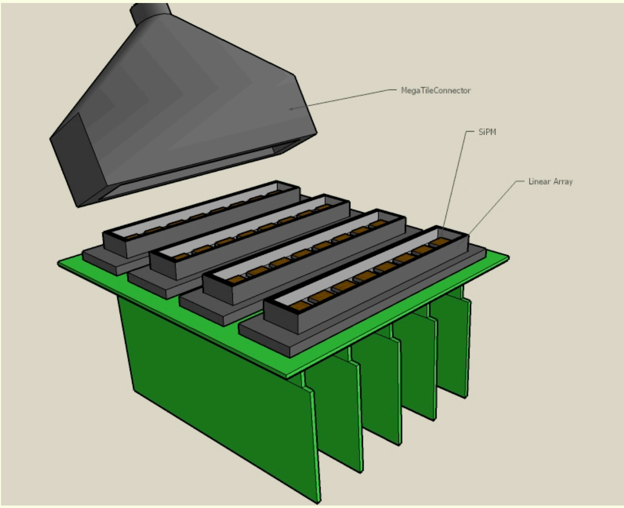


Small saturation

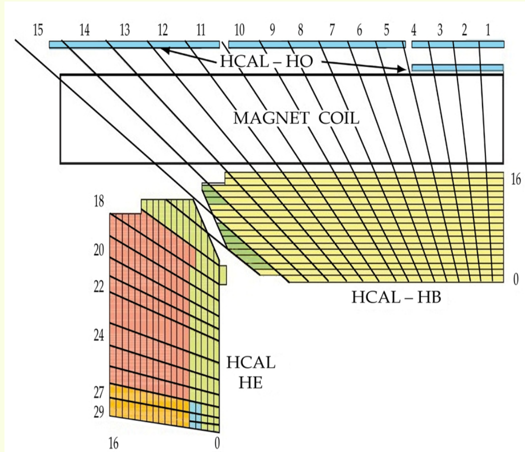
Zecotek/Hamamatsu response to 300 GeV Pions in HO at Eta=7



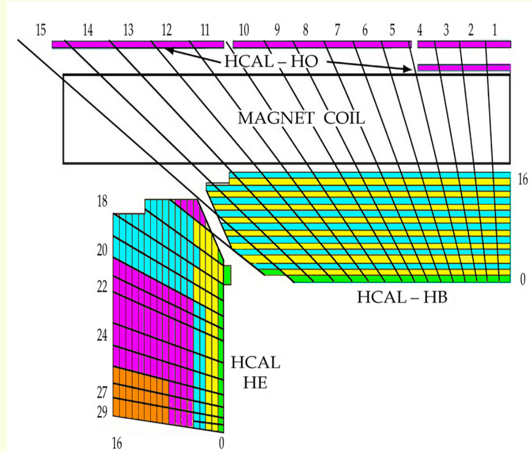
Hcal Barrel/Endcap (HB/HE)

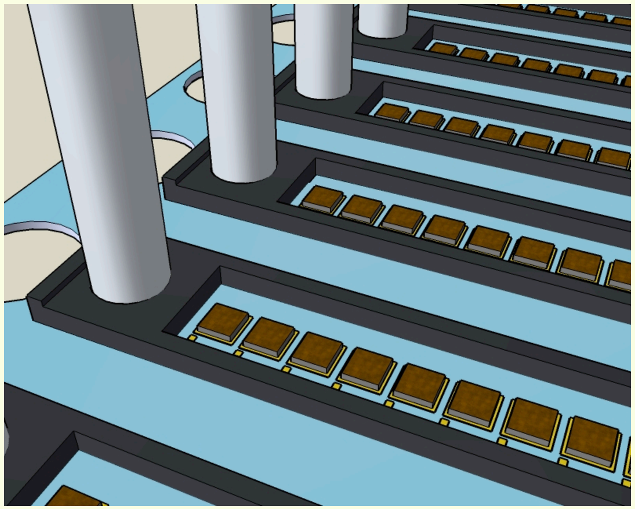


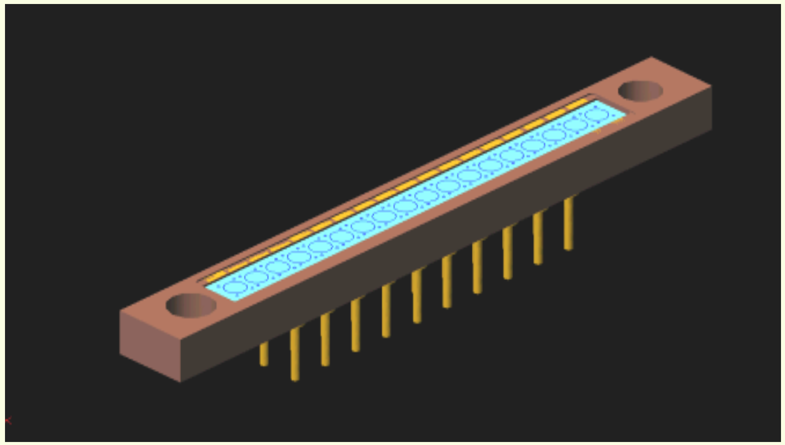
18 Channel RMs



48 Channel HB RMs
32 Channel HE RMs







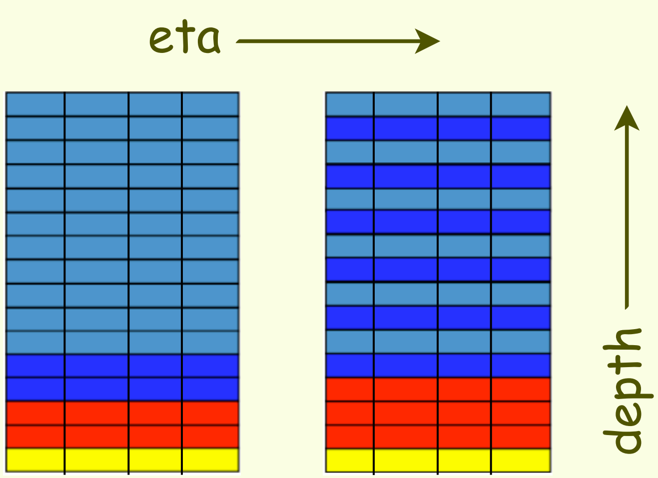
G-APD improvement vs HPD

HPD readout => no segmentation

But fibers are coming from each layer and summed into 1 HPD pixel

PDE: HPD 12% vs G-APD 30% at 520nm
Operation voltage: 8kV vs 90V

disadvantage: Temperature dependance



proposed HCAL towers

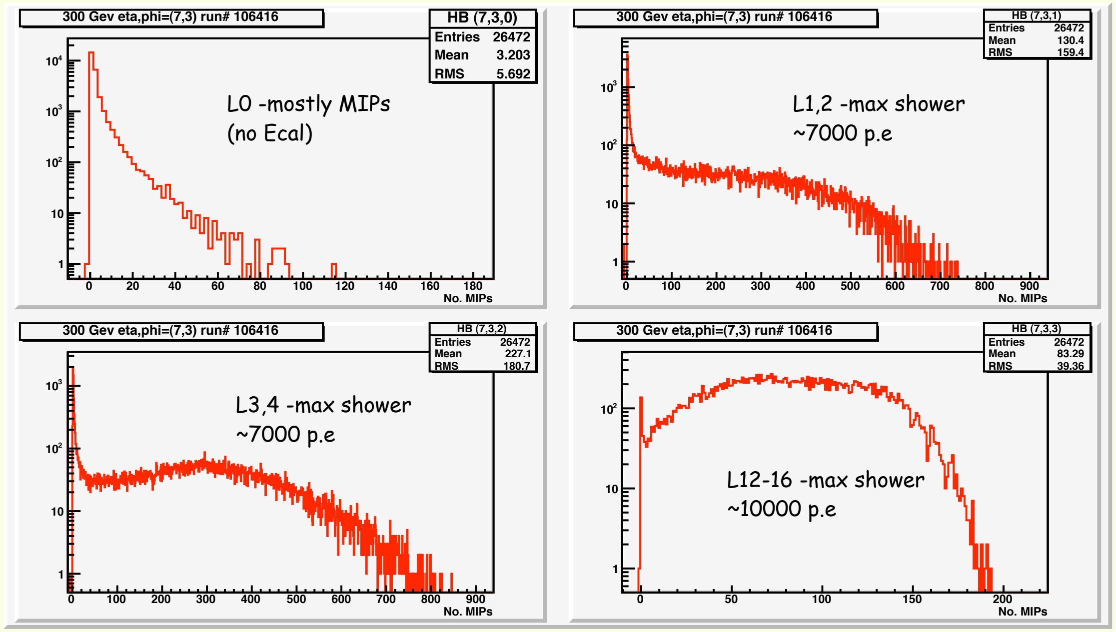
Goal is 4 depth segments:

(a)maximizes resolution by concentrating layers where the energy density is highest

(b)adds redundancy and robustness

Challenges using G-APDs in HCAL

300 GeV pion distributions vs depth in CMS HCAL tower (No ECAL)



1) Very large dynamic range

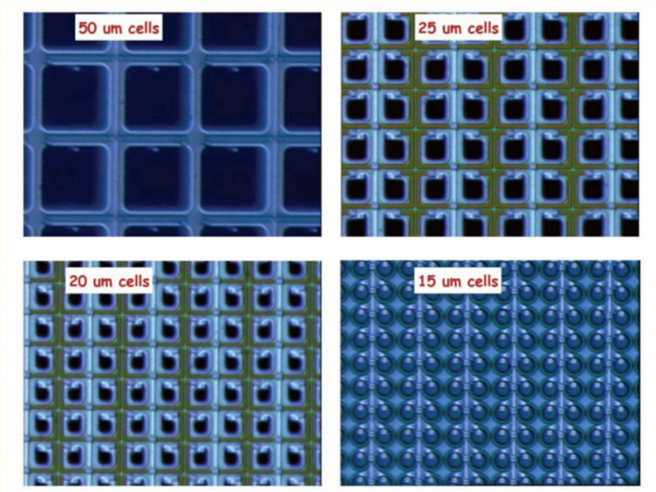
A few p.e. /MIP/layer =2 GeV up to 500 GeV in a few layer from Jet events

2) High occupancy in front layers in SLHC

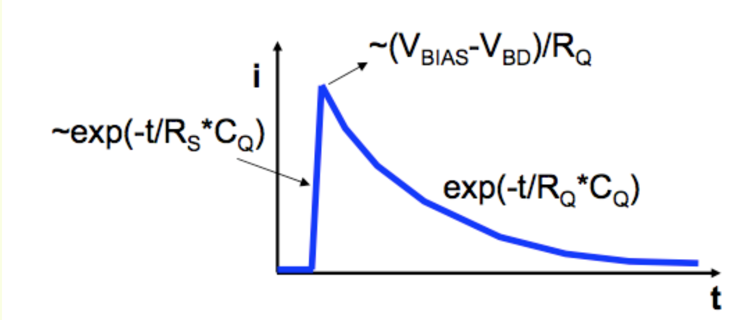
Fast recovery time

3) Radiation hard up to 3E12 1 MeV neutrons/cm2 for 3000 fb-1 (SLHC)

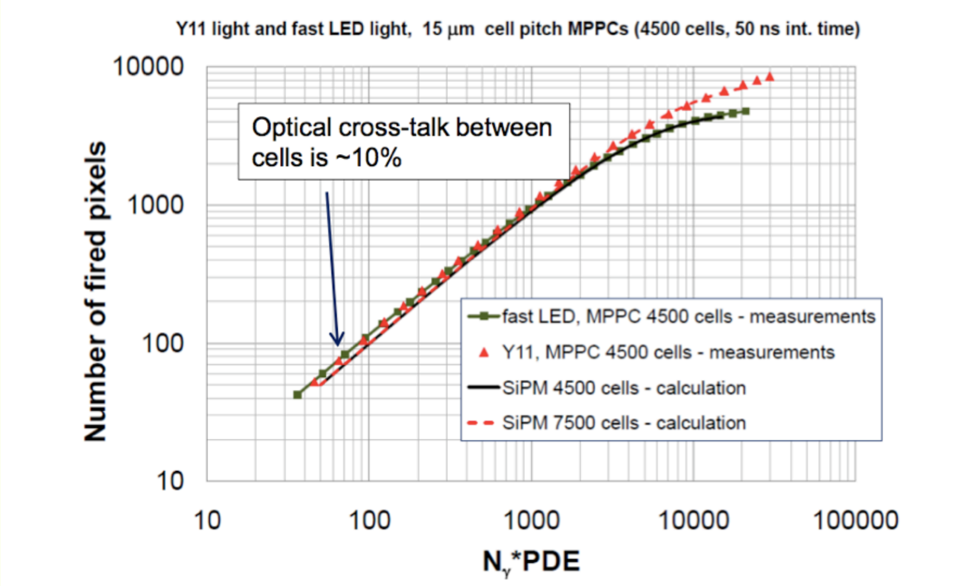
Hamamatsu small cell R&D 2010



Cell recovery for Typical G-APD



Dynamic range increase due to fast cell recovery

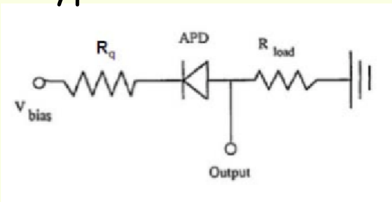


1) Rq is typically 300 kohm (min)

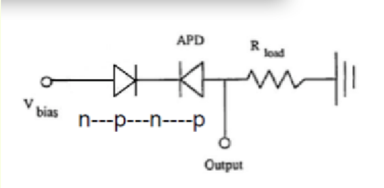
2) R&D wafers from 2009 show
Cd (15 micron) = ~10 fF

"VHD" MAPD from Zecotek

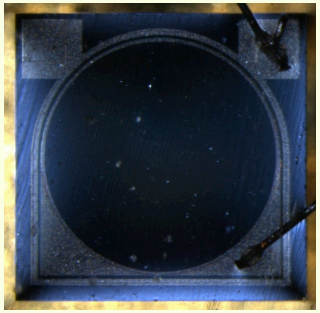
Typical G-APD cell



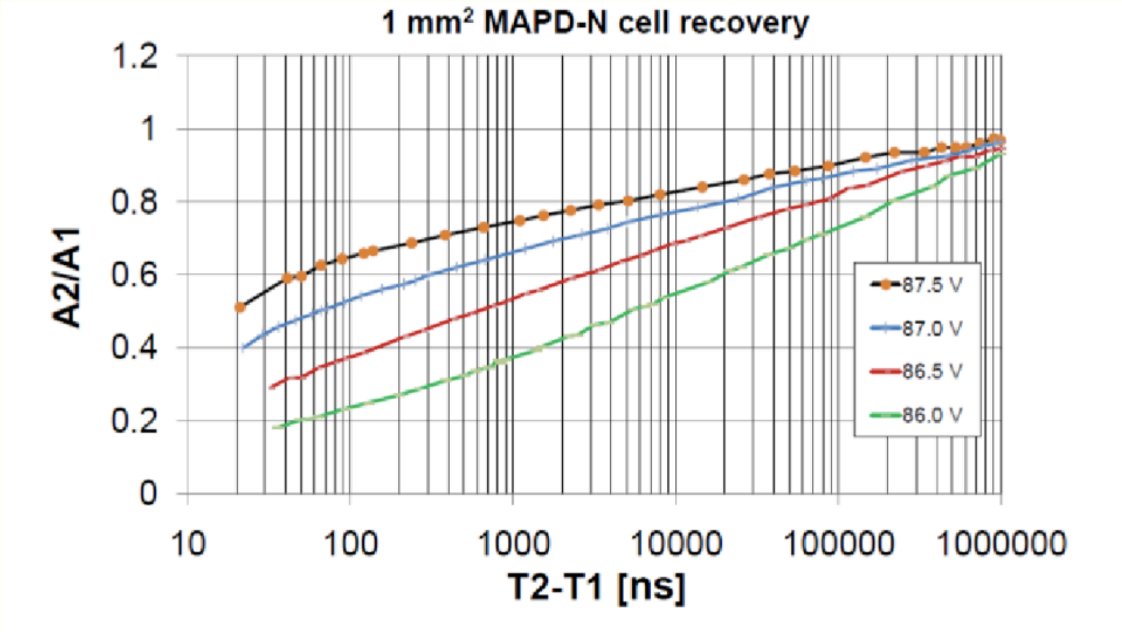
Zecotek MAPD cell



Zecotek (15000 cells/mm^2)



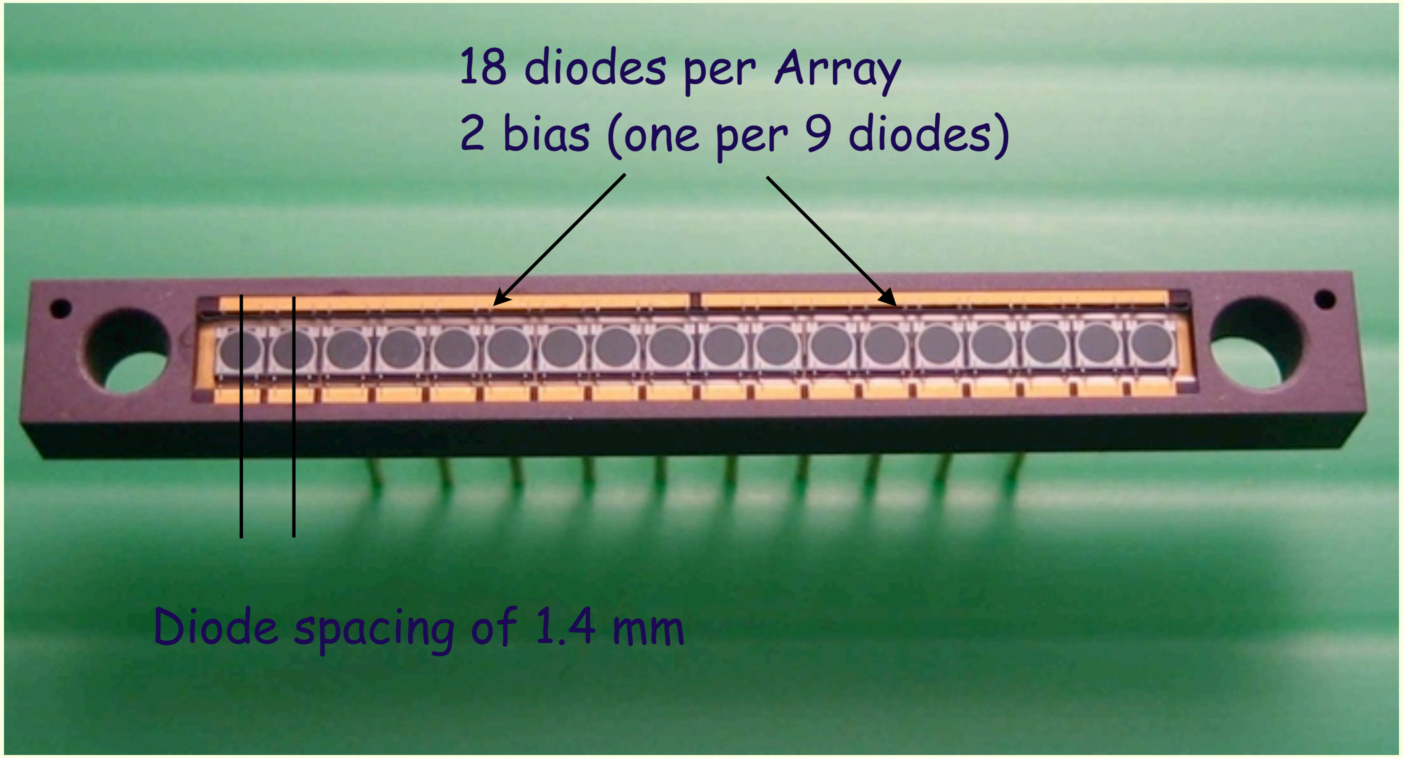
internal Rq
G.F.= high
PDE= 30%



- R&D wafers "on the way" to reduce recovery time !

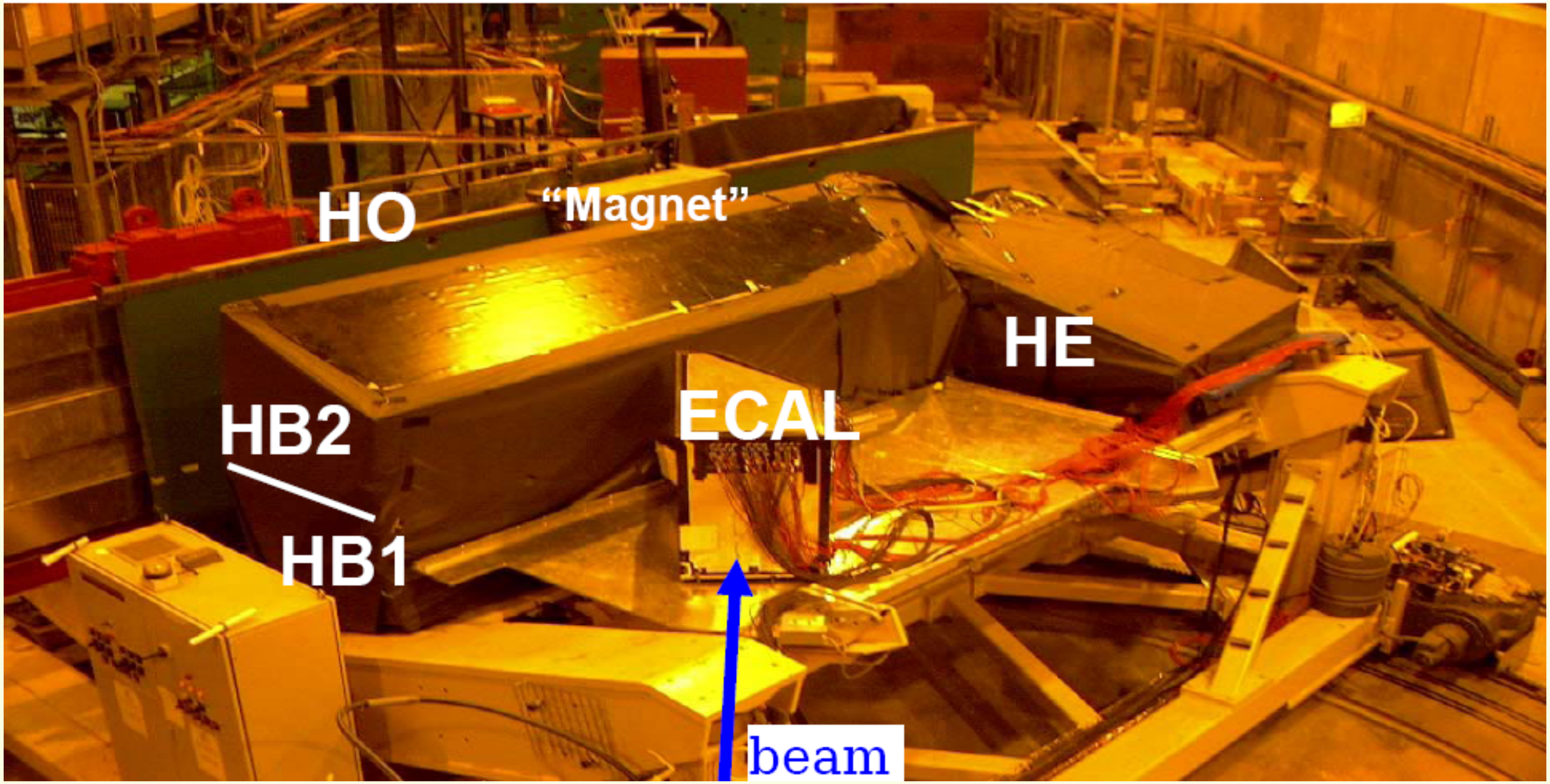
18 channel MAPD Array

CERN: 20 pin package by Kyocera (fine Ceramics, Germany)
MAPD assembly and potting at Zecotek



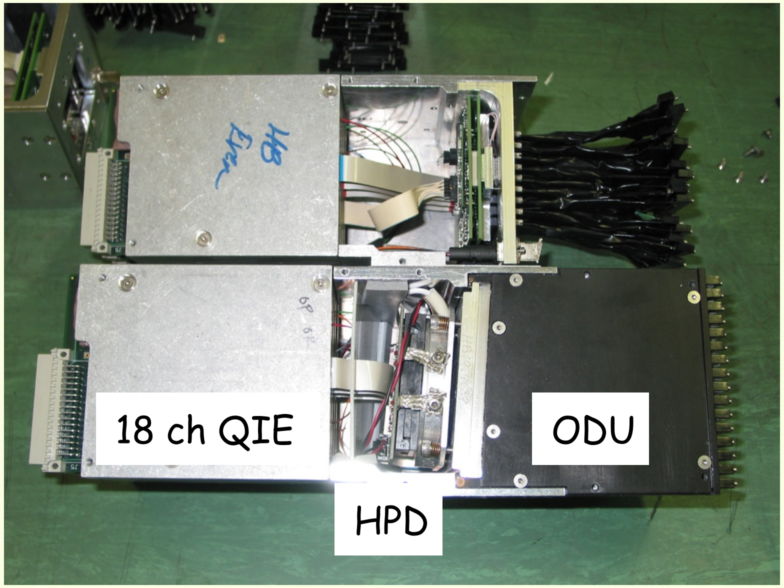
Total diodes needed = 100k =~ 5000 Arrays

CERN H2 Test Beam Setup up to 300 GeV

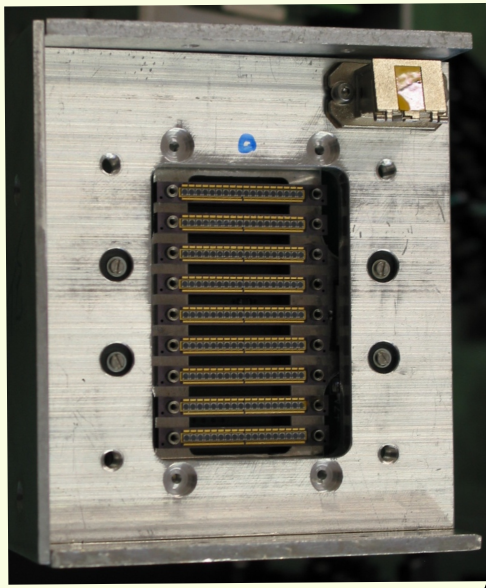


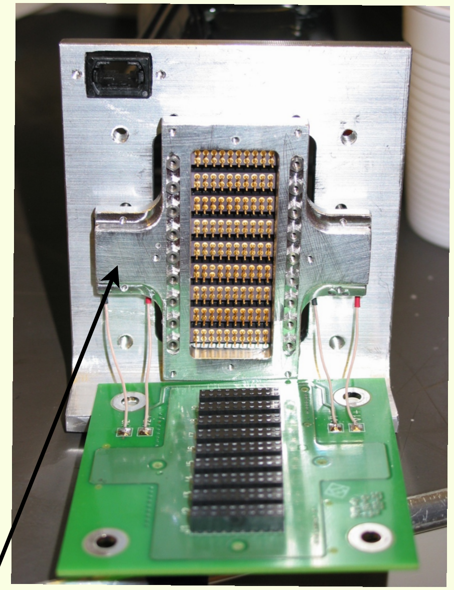
This year we expect real ECAL Supermodule and good data on the advandages of the depth segmentation.

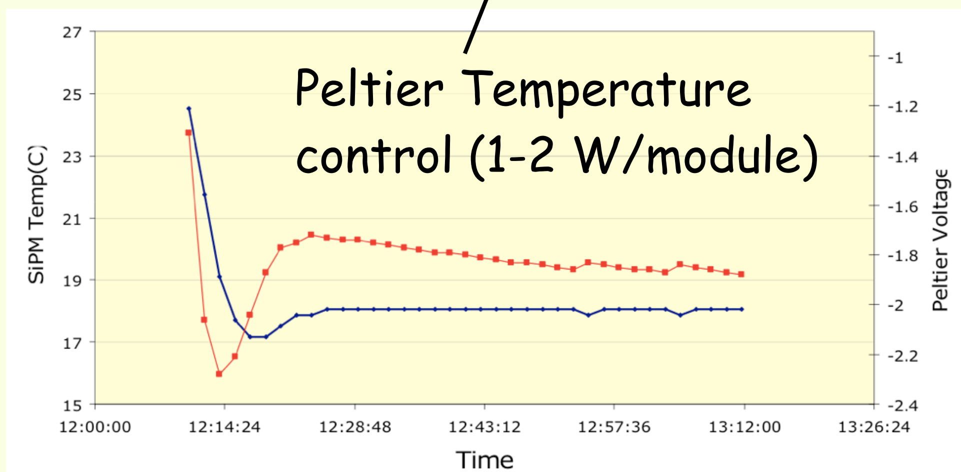
Prototype Module



Bottom: HCAL HPD R-Module
Top: GAPD R-Module





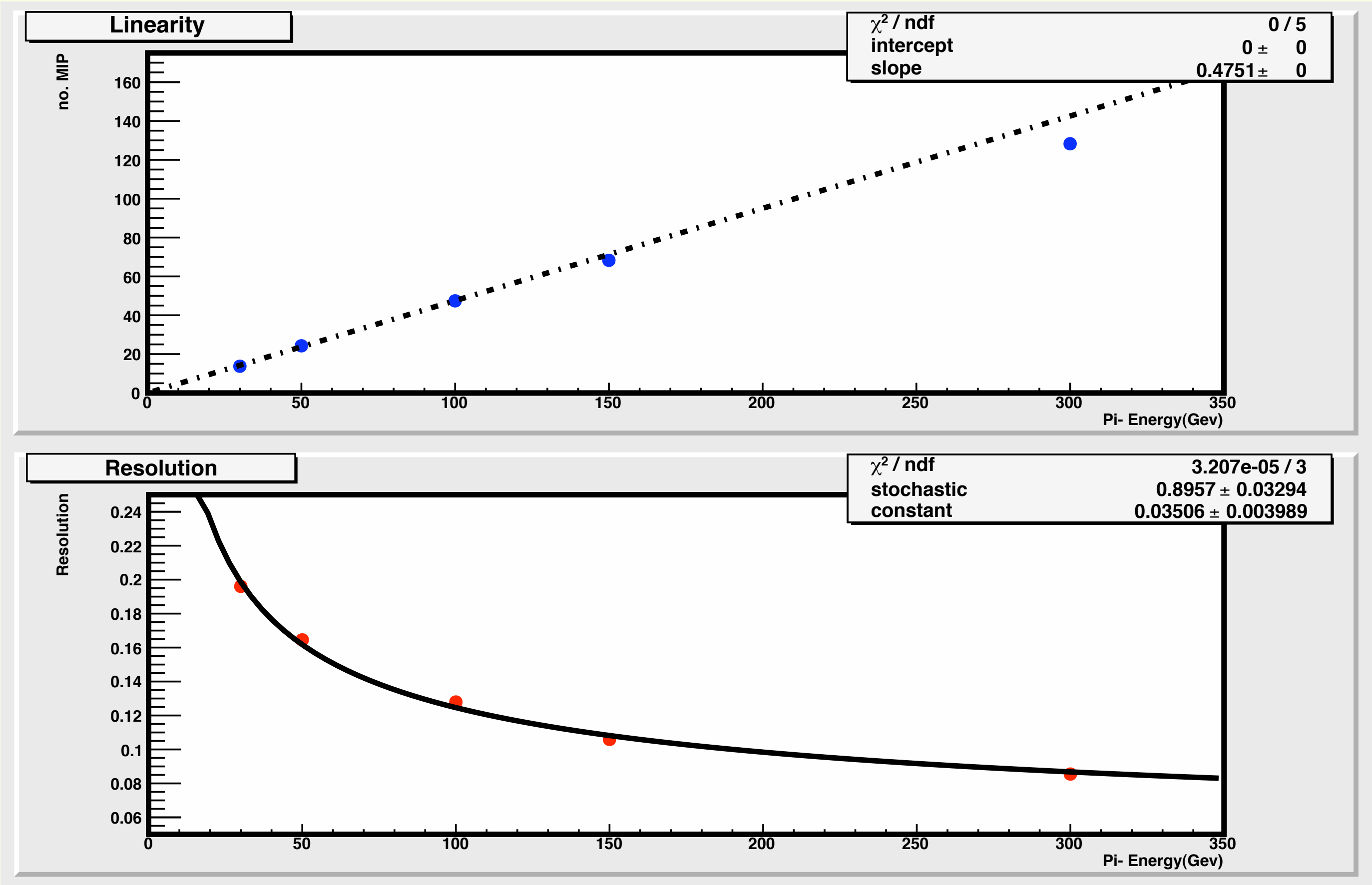


Peltier Temperature control (1-2 W/module)

4 modules = 4x9 =36 Arrays

eta,phi,depth coverage = 4x4x4

2009 TB data with 15k cells/mm2 array's

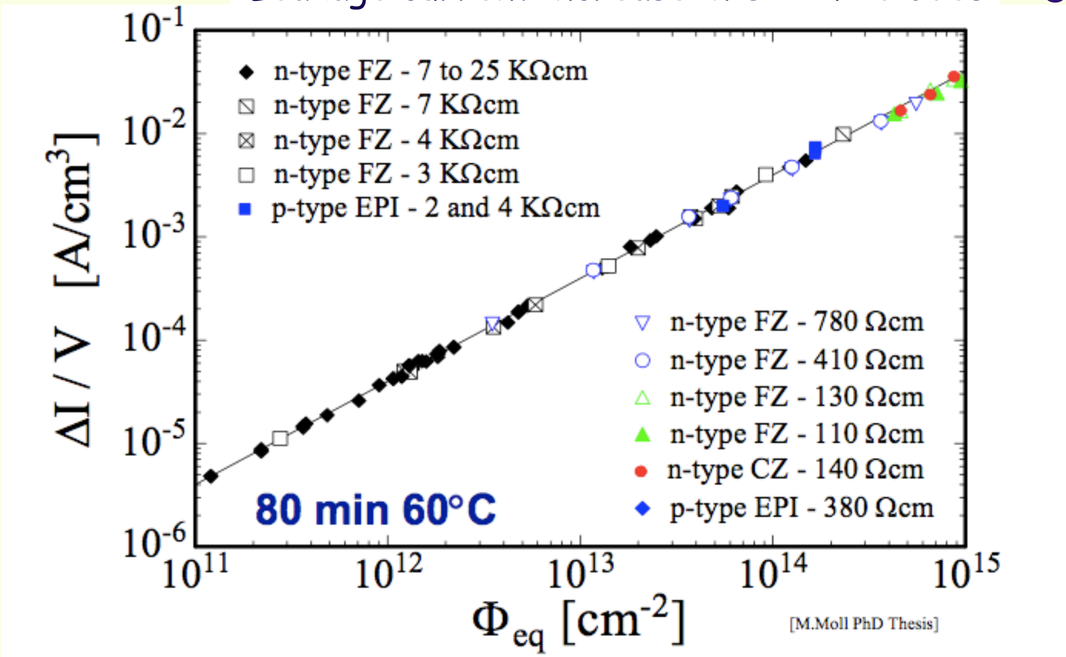


Repeat measurement in 2011 with fast HPK and other companies

GM-APD Radiation Damage

eq. 1 Mev neutrons

Leakage current increase in Si-PIN diodes



Similar damage seen in GM-APDs

slope= 4E-17 A/cm

V= cell size * d_{epi} (few microns)

Due to high gain we can see the current increase in Si as single p.e. counts:

Dark Count = 1/q * V * Φ * slope * G.F. * $P_{(V)}$

high dose ==> MHz noise /cell

Amplitude during irradiation

230 MeV proton radiation at Massachusetts General Hospital in 2008

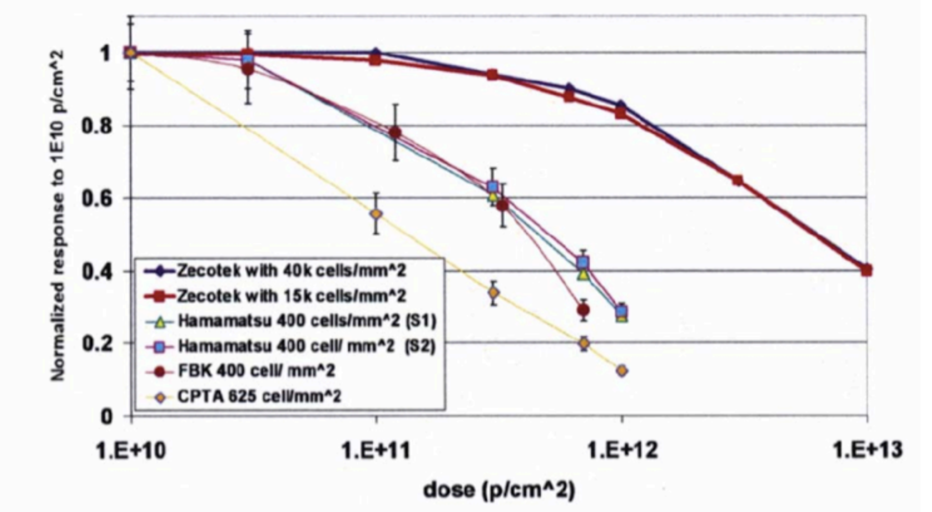
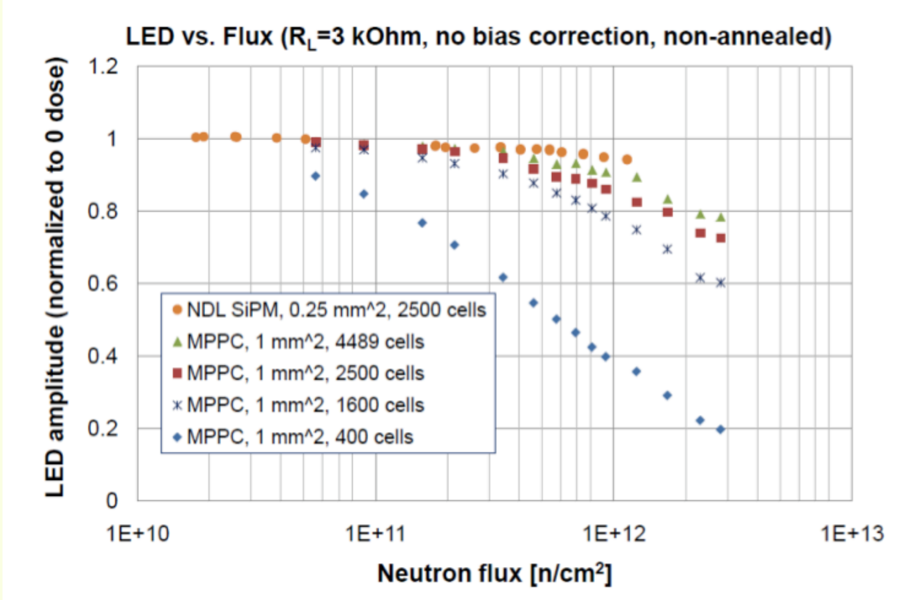


Fig.11. Response vs. radiation fluence for different samples and manufacturers (gain was corrected for voltage drop over the series resistor).

24 GeV backscattered protons (neutrons) radiation at CERN PS 2010



Conclusion

Great improvements have been made in the development of silicon based small cell size SiPMs or GAPDs.

More companies have shown interest in making large dynamic range devices. Also samples from: FBK (italy), Ketek (Germany), NDL (China), CPTA (Russia)

R&D will continue to study these devices for operation in CMS SLHC.