LCWS08
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Scintillator tile- SiPM systems R&D

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Representing CALICE collaboration

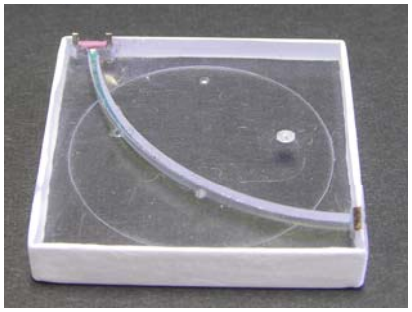
Outline:

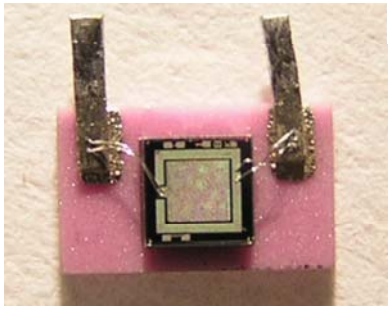
- ✓Measurements of 3 mm and 5 mm thick tiles at ITEP test beam
- ✓Comparison of MRS APD's and SiPM's
- ✓Behavior of irradiated photo-detectors

Measurement of response and efficiency map at proton test beam

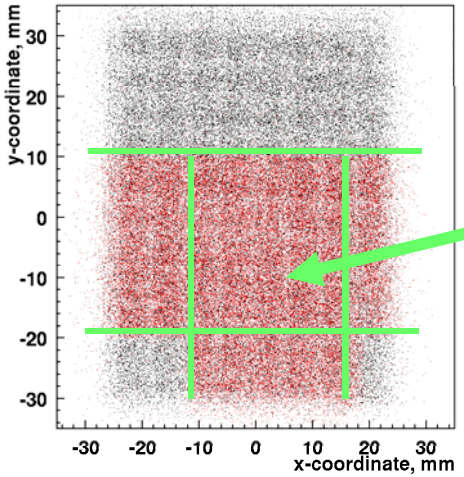
(Very Preliminary!)

1. Tiles and photo-detectors for CALICE HCAL prototype

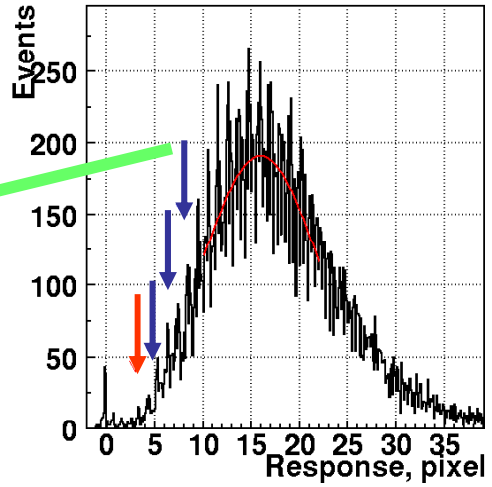




Position of tested tiles in the beam



Response to beam particle



4 tiles of 30×30×5 mm^3 tiles with arc-like 1 mm dia WLS fiber

Readout via 1.06×1.06 mm^2 1156 pixel SiPM from MEPhI-Pulsar

15pixels per MIP working point is chosen as a compromise between wishes to have high detection efficiency and dynamic range as wide as possible

MIP efficiency at various thresholds

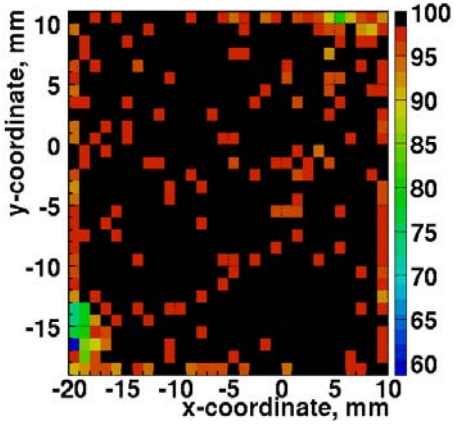
There are two sources of tile inefficiency:

1 – gaps between tiles and dead areas in the tile (volumes of SiPM and mirror at rear fiber end)

2 – inefficiency due to high registration threshold

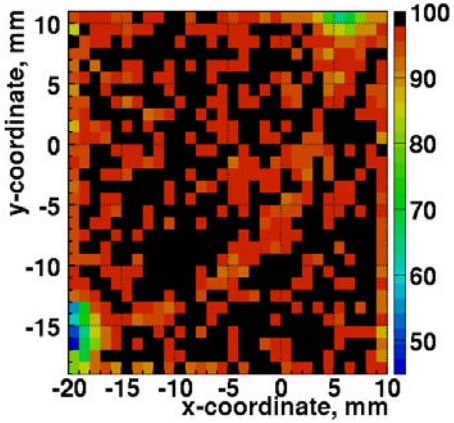
In order to separate these two contributions first we used in the analysis only those events where tile response was higher than 3 pixels (shown with red arrow at response hist). Then we calculated number of events with amplitude higher than 0.3 MIP (0.4 MIP, 0.5 MIP) threshold. These shown with blue arrows at the same hist. The position of response peak was taken as MIP value. Maps of tile efficiency at various thresholds are shown here.

Efficiency at 0.3 MIP threshold



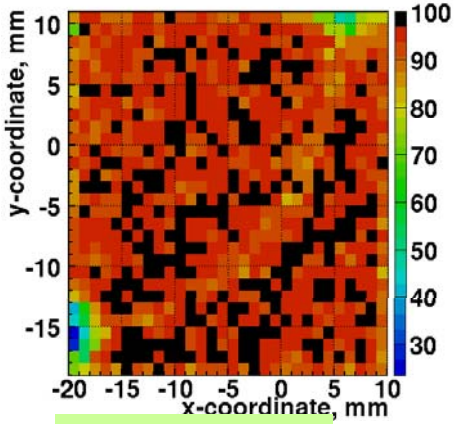
<eff>=0.98

Efficiency at 0.4 MIP threshold



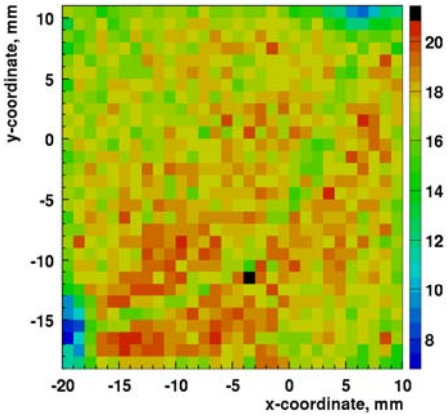
<eff>=0.97

Efficiency at 0.5 MIP threshold



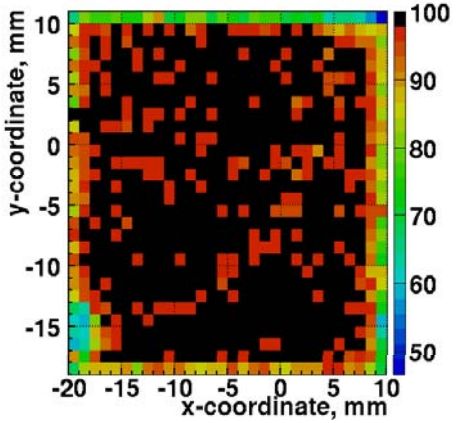
<eff>=0.94

Response map

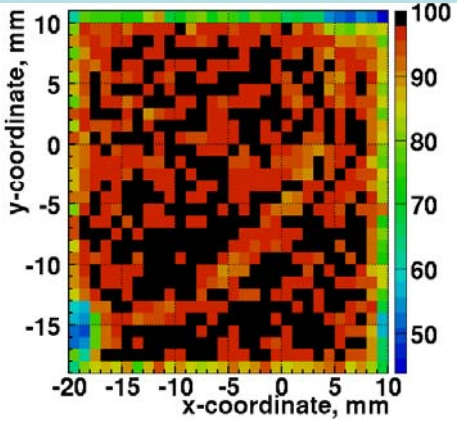


In order to see the total inefficiency due to dead areas and threshold effects we took all events. Because of non perfect track position reconstruction – we had accuracy in particle position Δx ~1mm, Δy~0.5mm – we summed signals from all 4 tiles. The following plots show efficiency maps and profiles at various registration thresholds. One can clearly see the reduction of efficiency near tile edges due to porous structure of reflecting coating and gaps between tiles.

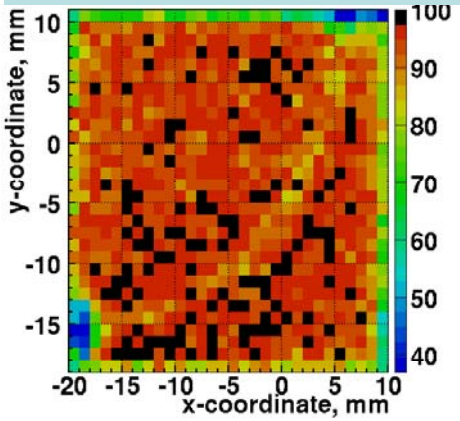
Efficiency at 0.3 MIP threshold



Efficiency at 0.4 MIP threshold

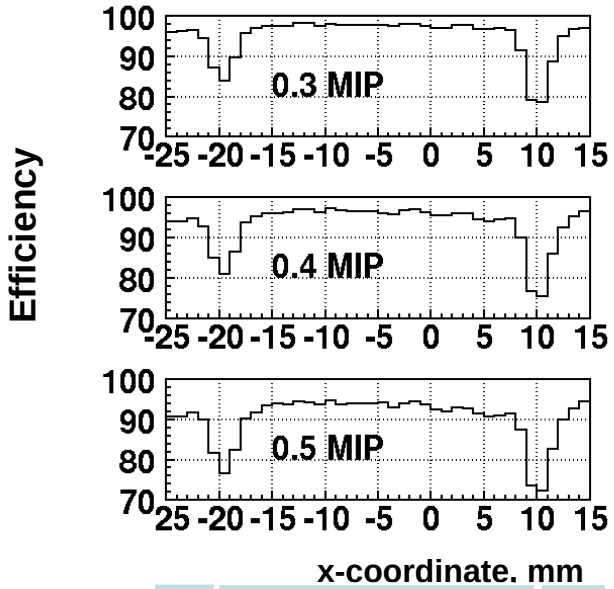


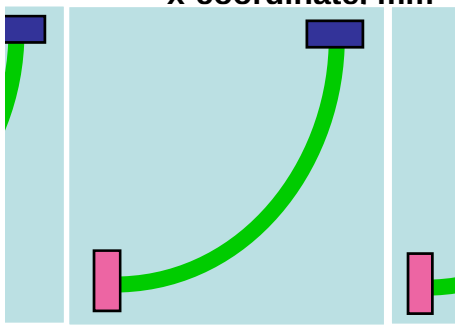
Efficiency at 0.5 MIP threshold



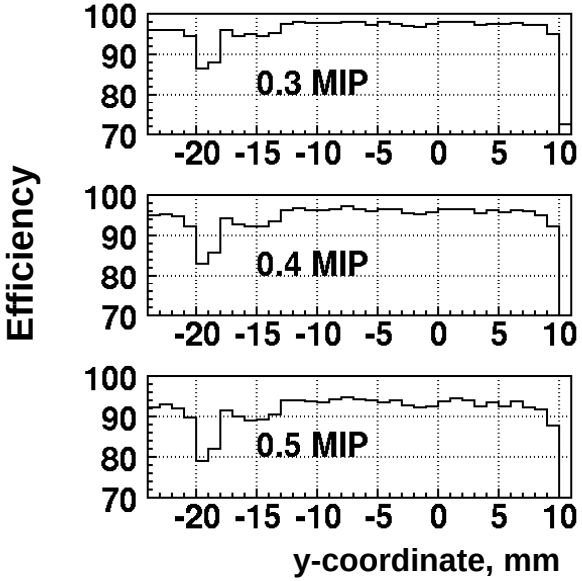
Profiles of MIP registration efficiency

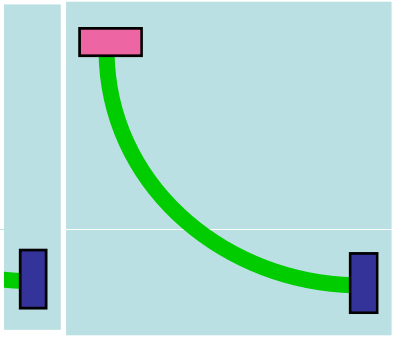
X-profile





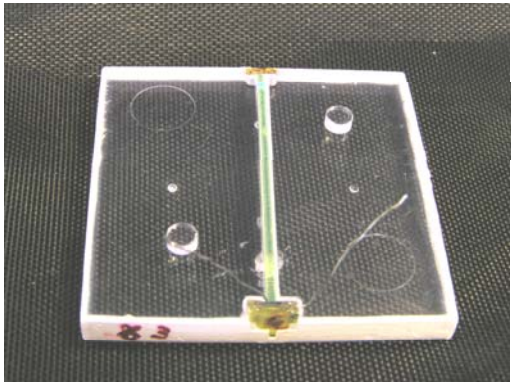
y-profile

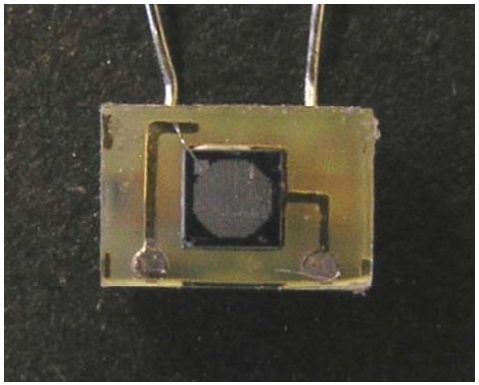


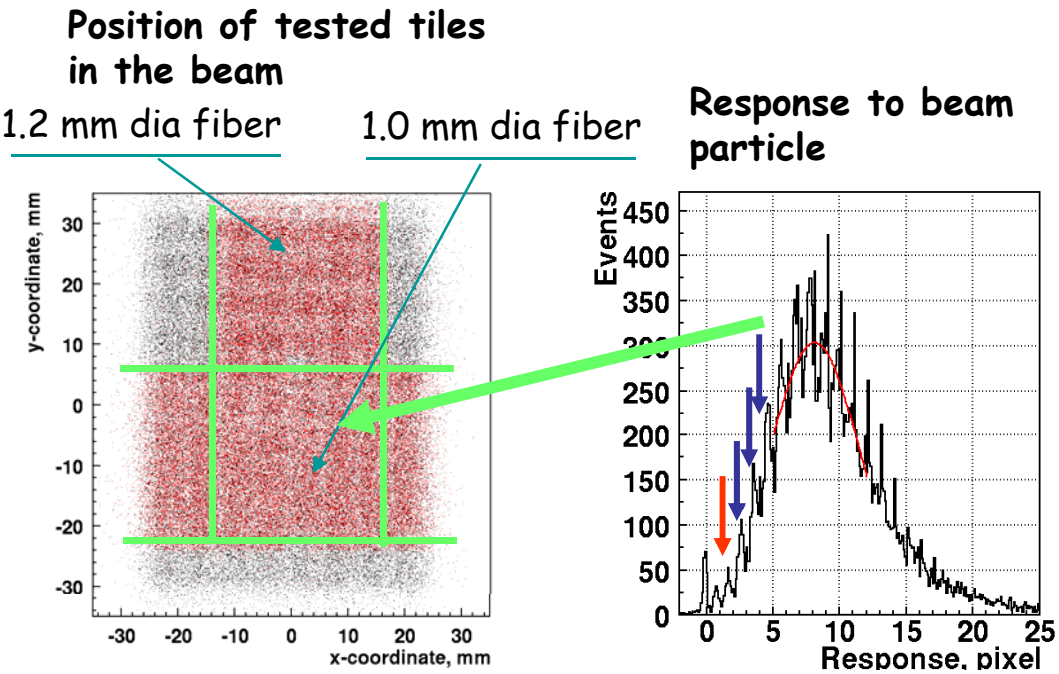


Results on response uniformity and tile efficiency will be used in CALICE test beam data analysis

2. Tiles and photo-detectors for EUDET prototype







4 tiles of 30×30×3 mm^3 tiles with 1(1.2) mm dia WLS fiber

Readout via 556 pixel MRS APD from CPTA

Fiber and photo-detector are glued in the tile

Working point for these tiles is chosen MIP=10 pixels, this corresponds to ~15% PDE

MIP efficiency at various thresholds

Again, we looked first using only events with tile response higher than "noise" threshold . And then we calculated efficiency at 0.3 MIP (0.4 MIP, 0.5 MIP) threshold (blue arrows at tile response hist).

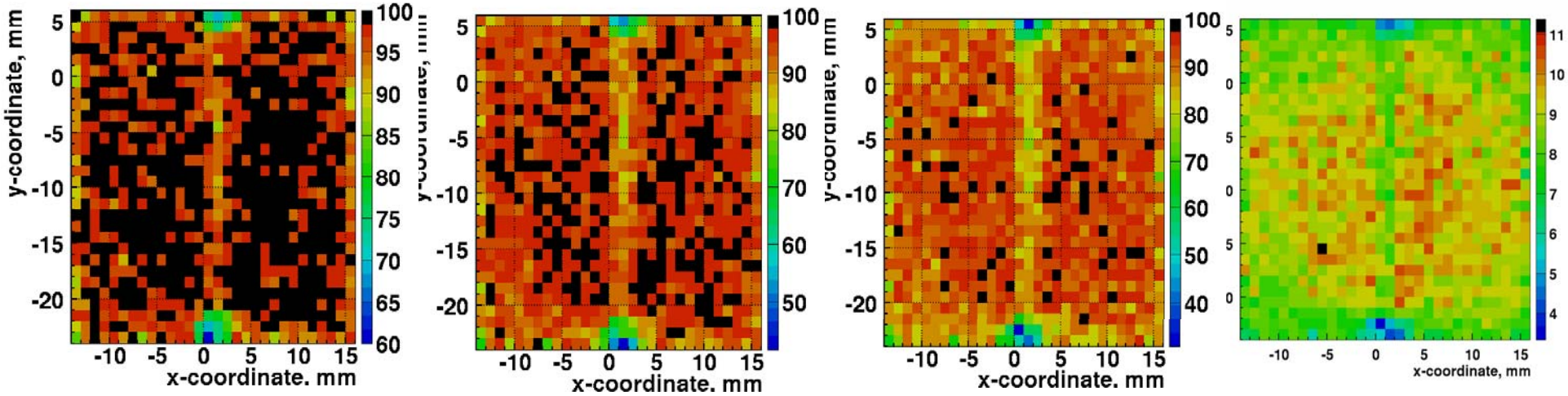
MIP value for this tile was 8 pixels – it is less than we intended to have but might be easily increased with higher bias voltage.

Efficiency at 0.3 MIP threshold

Efficiency at 0.4 MIP threshold

Efficiency at 0.5 MIP threshold

Response map



<eff>=0.96

<eff>=0.94

<eff>=0.90

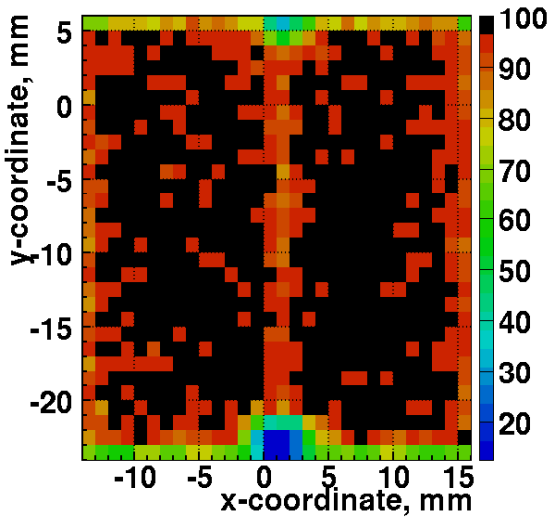
Efficiency is small because tile has only 8p.e./MIP instead of 10p.e.

Distributions of tile efficiency for all events

Drop of efficiency near tile edges is clearly seen especially at the top edge where gap between tiles was 200 μ.

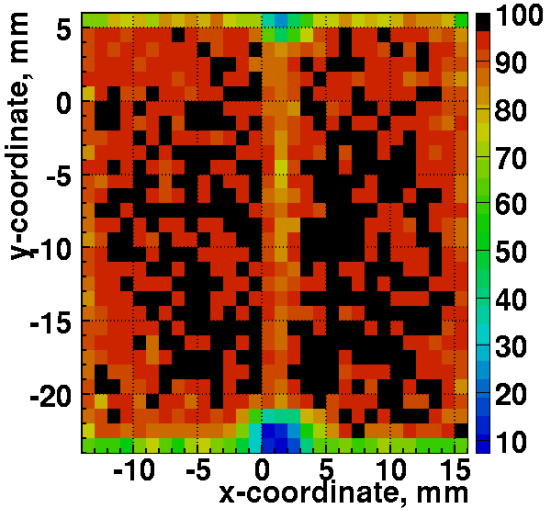
Drop of efficiency at the bottom edge is due to absence of a tile below

0.3 MIP threshold



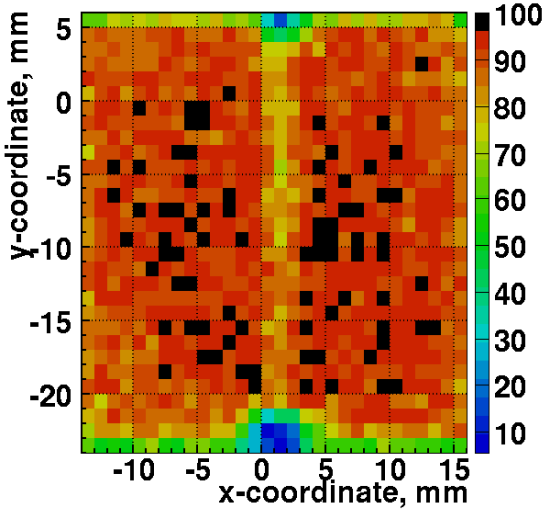
<eff>=0.94

0.4 MIP threshold



<eff>=0.91

0.5 MIP threshold

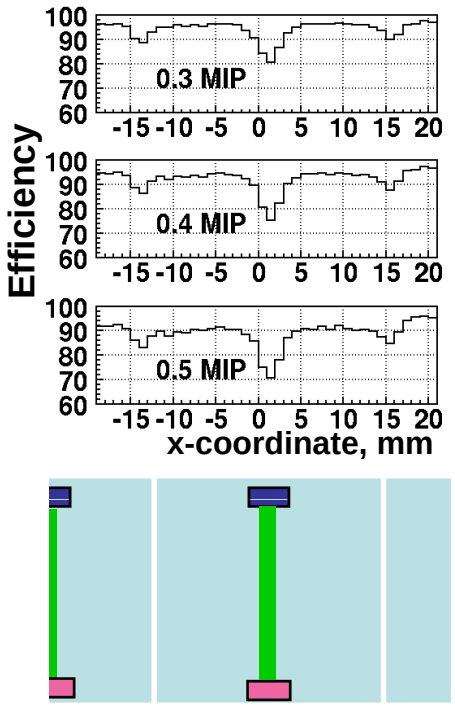


<eff>=0.88

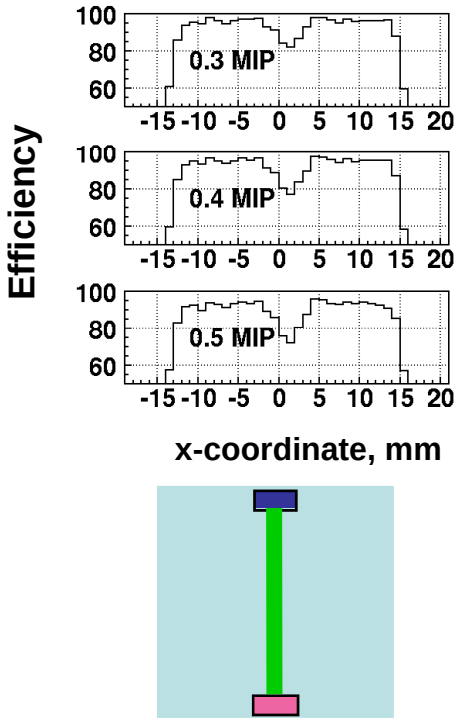
In order to increase efficiency we will increase p.e. yield from 8 to 11-12p.e./MIP
Expected efficiency ~ 95% at 0.4MIP threshold
SiPM (MRS APD) with 798 pixels will be developed to increase dynamic range

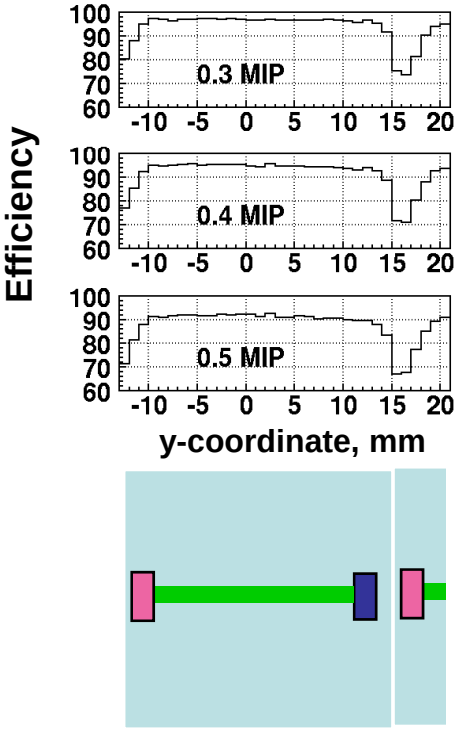
Profiles of tile response averaged over one coordinate

1 mm dia WLS fiber



1.2 mm dia WLS fiber





Comparison of MEPhI SiPM's and CPTA MRS APD's

More than 10000 SiPM's have been tested during CALICE prototype production

Several hundreds MRS APD's were tested during this year

The following parameters of photo-detectors at the working point have been compared:

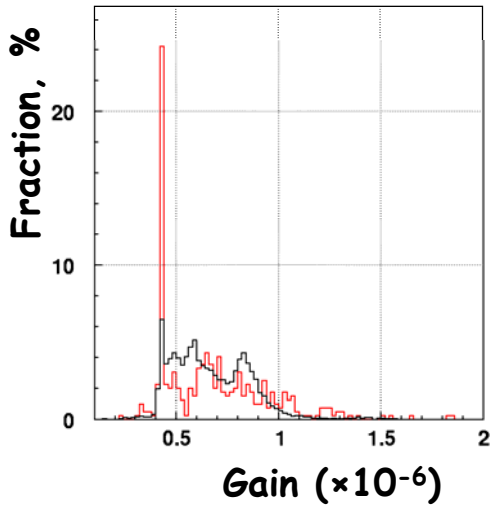
- ✓ Gain
- ✓ Cross talk
- ✓ Noise frequency at zero level
- ✓ Noise frequency at $\frac{1}{2}$MIP threshold
- ✓ Current
- ✓ Current stability

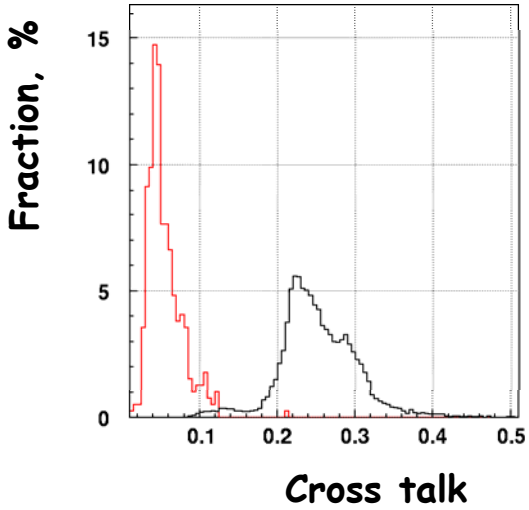
Working point for SiPM's was taken as 15 pixels per MIP in 30×30×5 mm^3 tile with arc like WLSF - chosen for tiles in CALICE HCAL prototype

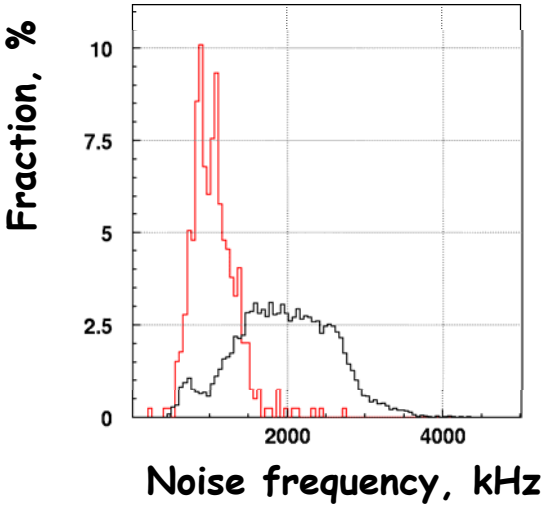
For MRS APD's it was 10 pixels per MIP in 30×30×3 mm^3 tile with glued in straight WLSF as a compromise between wishes to have high MIP registration efficiency and dynamic range as wide as possible

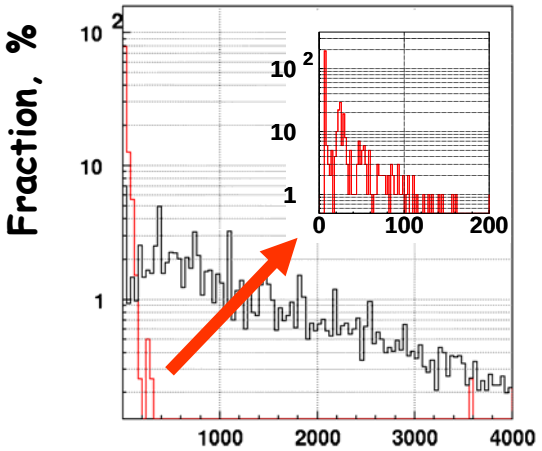
Distribution of parameters for MEPhI SiPMs (black) and MRS APDs (red)

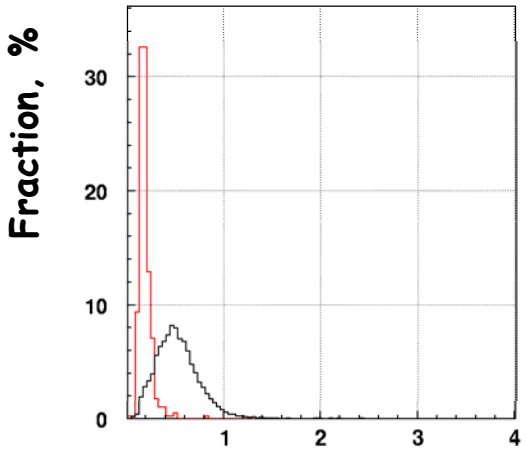
(normalized to 100%)

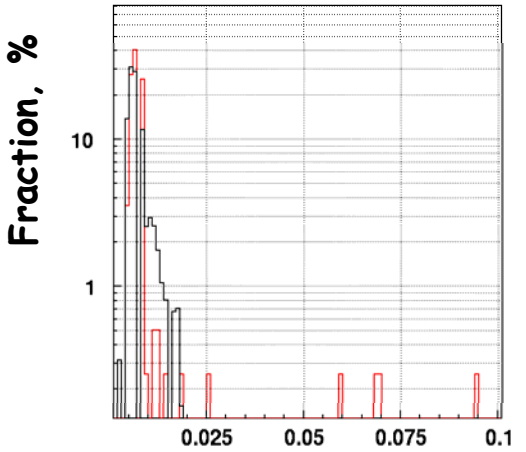




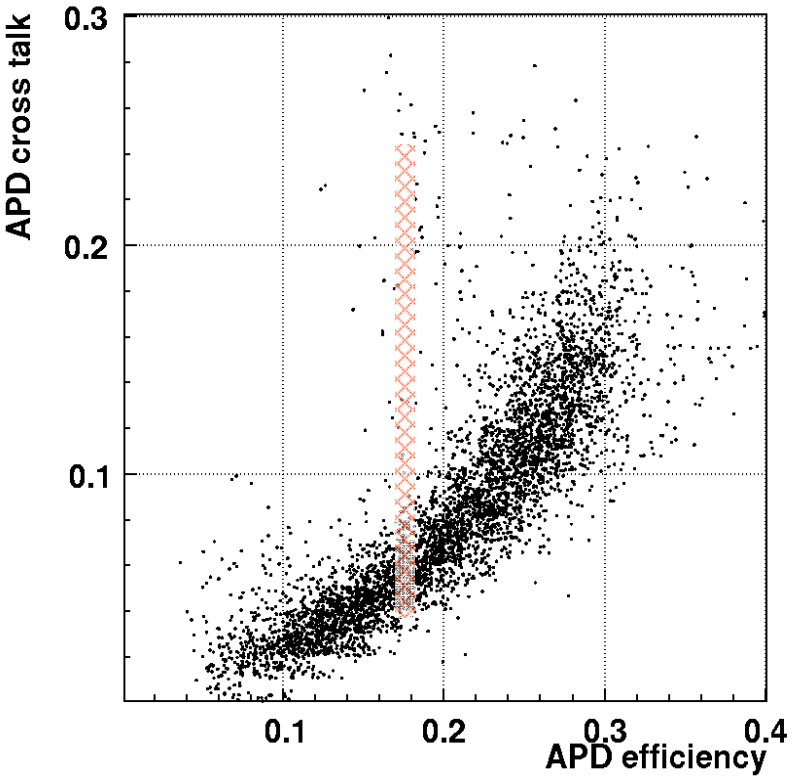


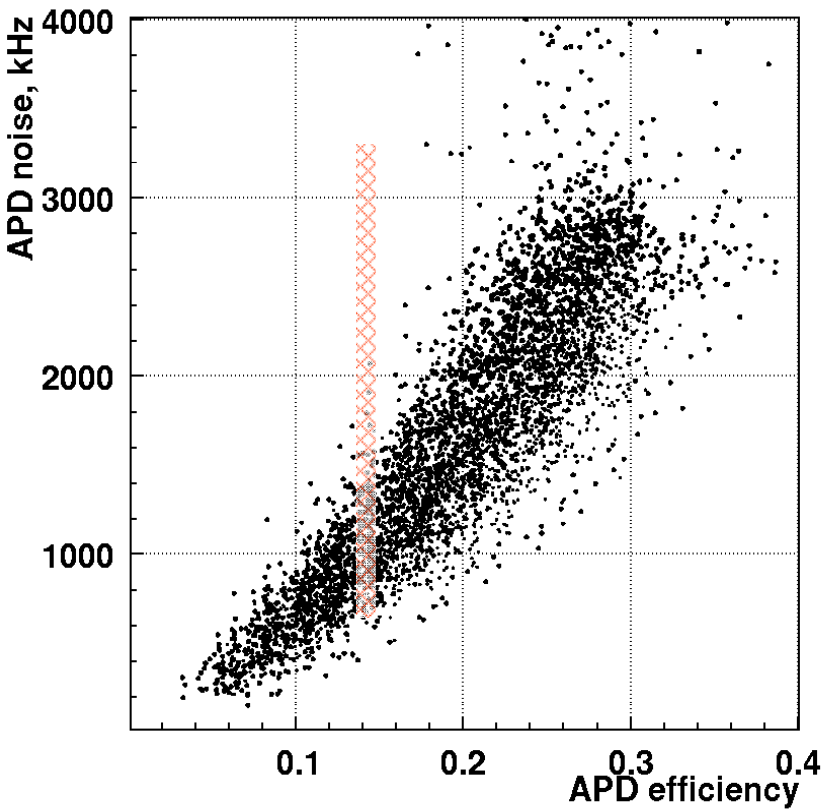






X-talk and noise frequecy vs photo-detector efficiency for tested MRS APD. Hatched area shows 15 ± 1% range of efficiency chosen for working point.

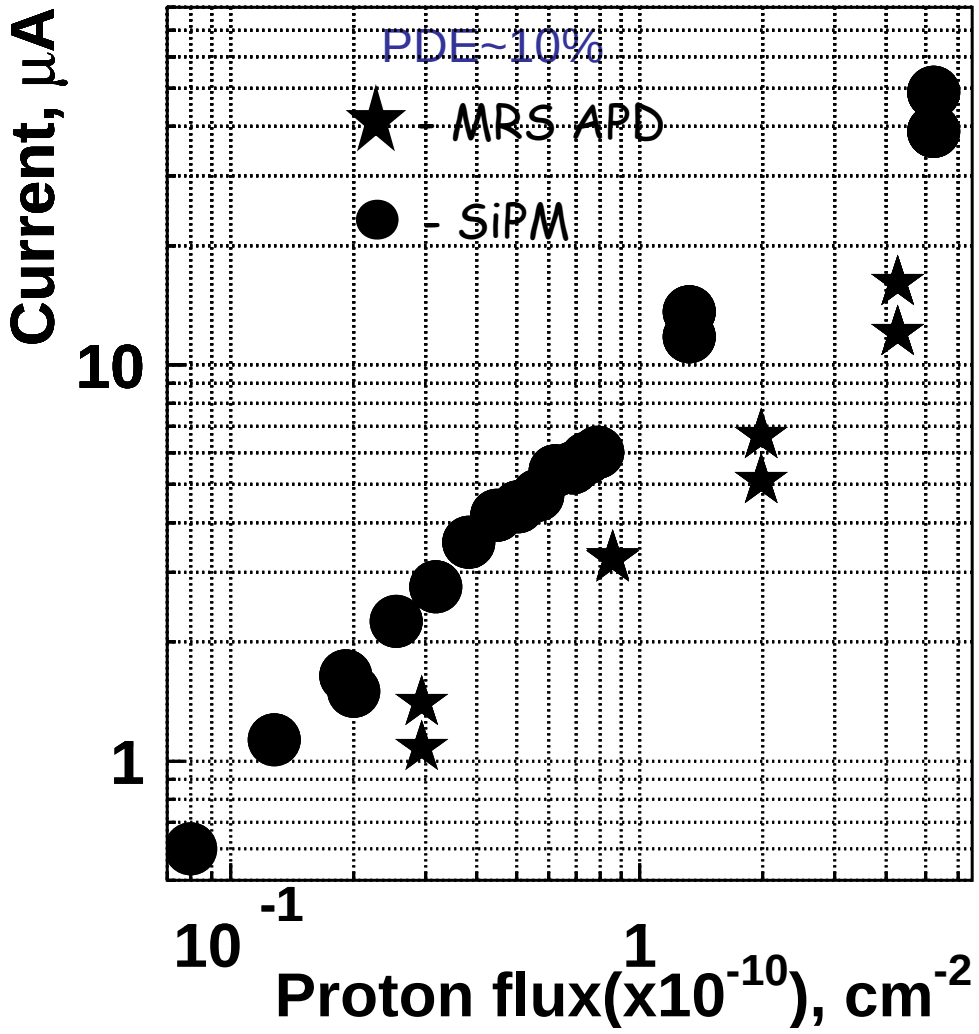




CPTA MRS APD is much better than MEPhI SiPMs used in CALICE AHCAL
They satisfy the requirements for the next prototype

Radiation hardness of SiPMs

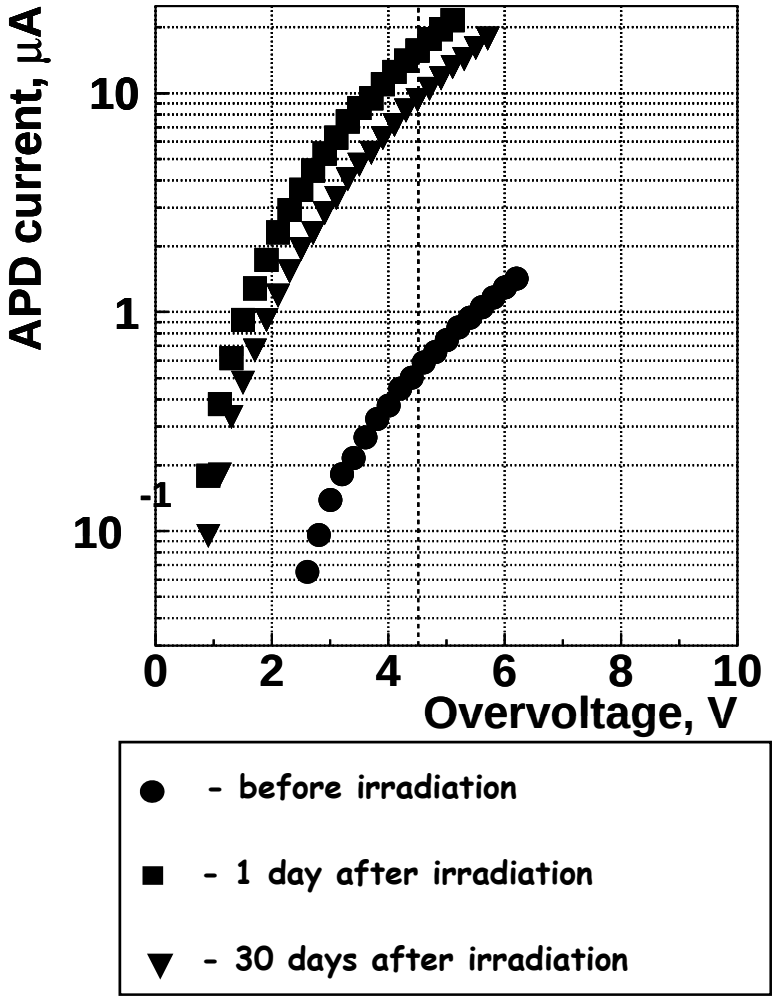
Comparison of radiation damage of MRS APD and SiPM with low energy protons



MRS APD has better rad. hardness at the same PDE

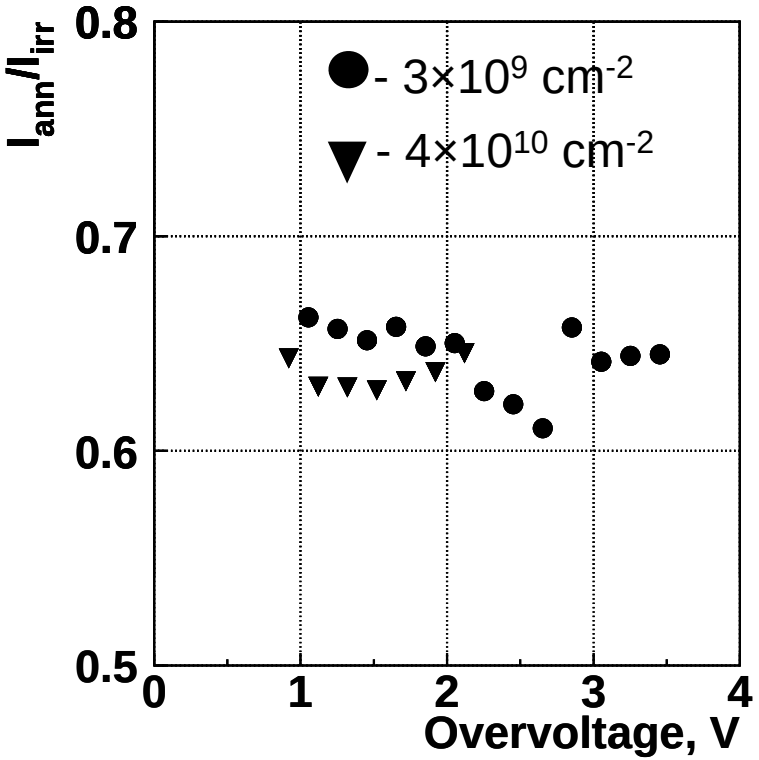
However at higher PDE
CPTA and MEPhI SiPMs are similar

Annealing of MRS APD



Fluence 3×10^9 /cm-2 protons

Annealing does not depend on fluence nor overvoltage



Conclusions

3 mm thick tiles with WLS fiber and CPTA SiPM look adequate for the next prototype

The response uniformity is goon enough

The efficiency is expected to be quite high

Radiation hardness is somewhat better for CPTA SiPMs in comparison with MEPhI SiPMs