CALICE Meeting
DESY 14.02.07

ITEP&MEPhI status report on tile production and R&D activities

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Status of tile production

Tiles for 32 cassettes have been delivered to DESY

Tiles for cassette # 33 are ready

We have good SiPM's for 3 more cassettes

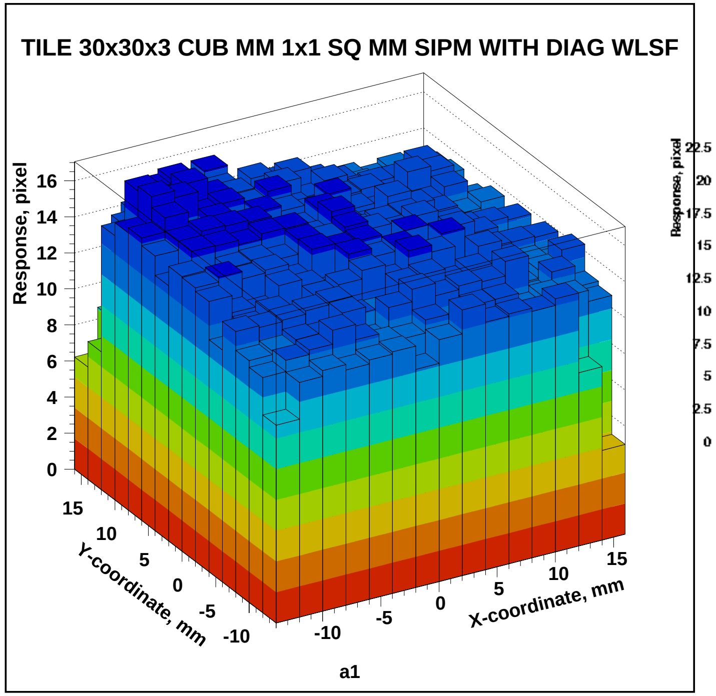
Delivery of SiPM's is going smoothly

We expect all 38 cassettes ready for delivery by the end of March

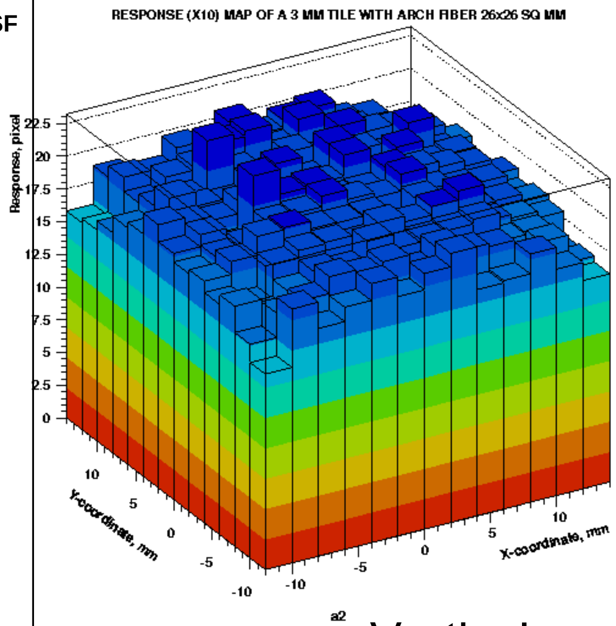
Comparison of WLSF and direct SiPM coupling

Tiles with WLS fiber

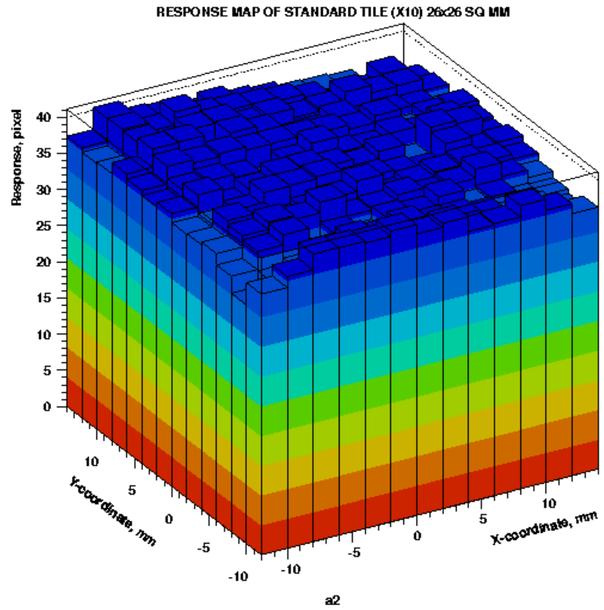
3 mm thick tile with diagonal fiber



3mm thick tile with arch fiber



Standard 5 mm thick tile with arch fiber

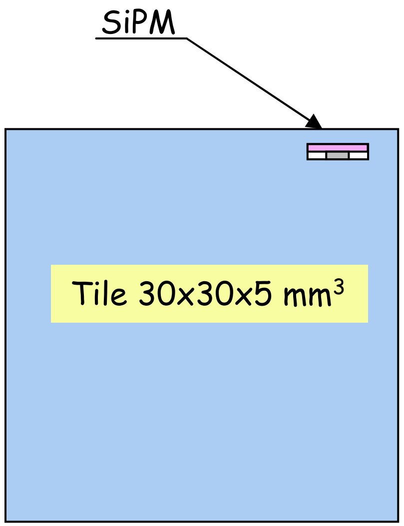


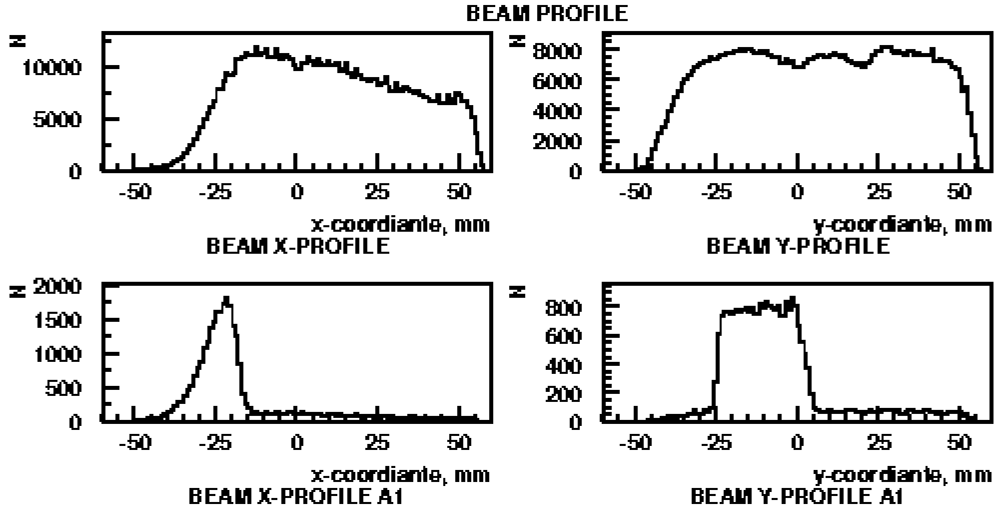
Vertical scale is shown for 1.5MIP

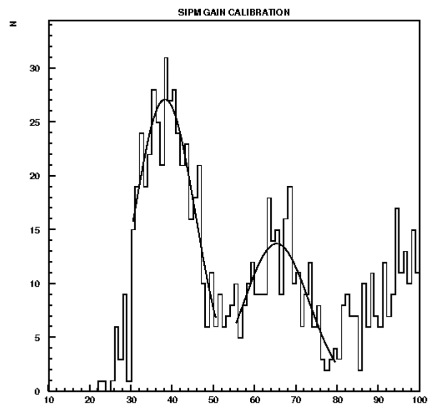
Uniformity is good enough and photo-electron yield is sufficient even for 3mm thick tiles

Tile thickness reduction can save a lot of money (~?/mm) or increase HCAL thickness
However the effect on the energy resolution (sampling fluctuations) should be estimated

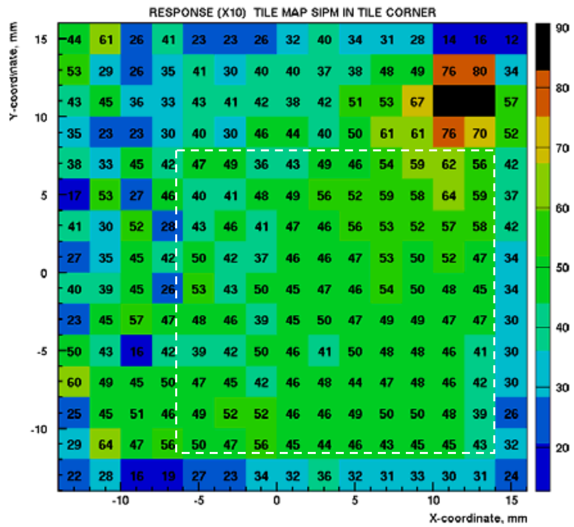
Direct SiPM coupling- desirable to simplify production, but …

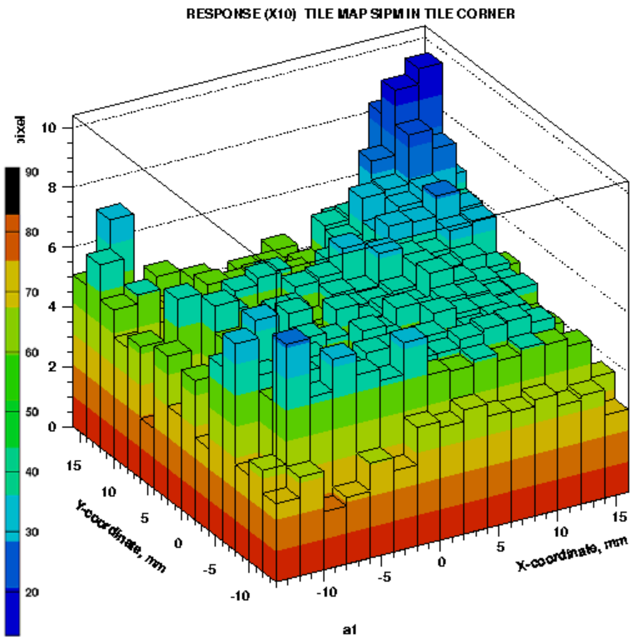






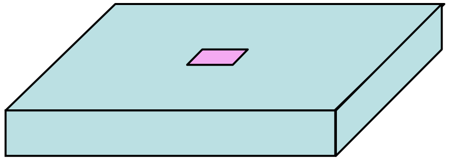
SiPM calibration

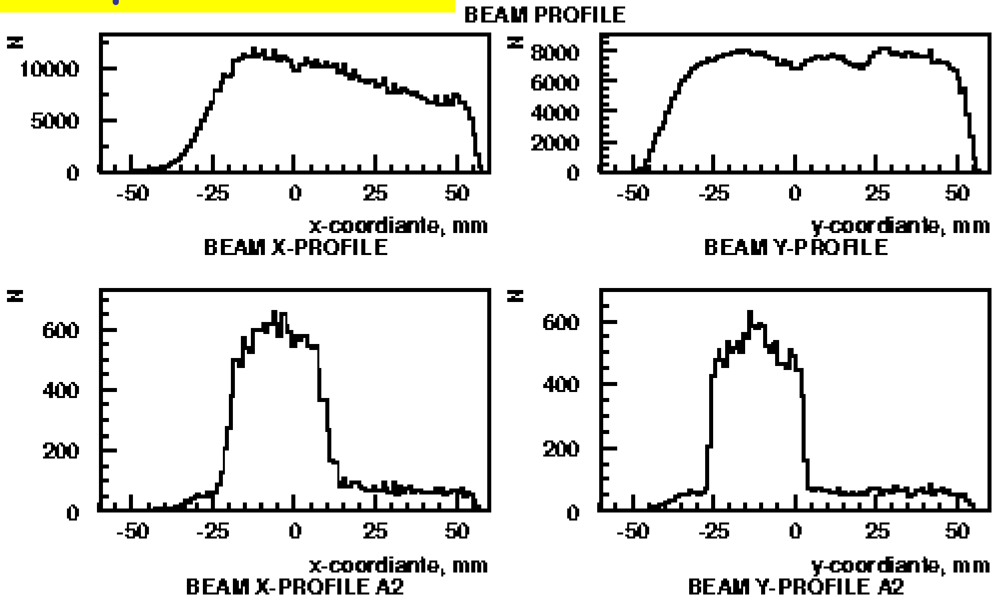


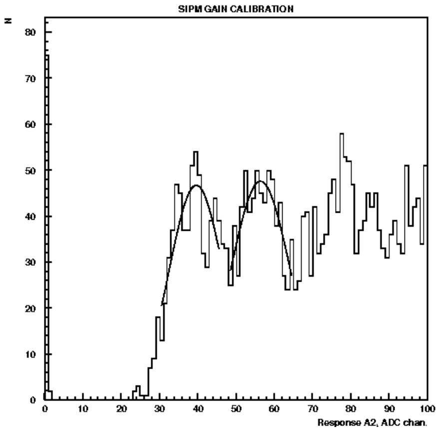


SiPM on top of a tile

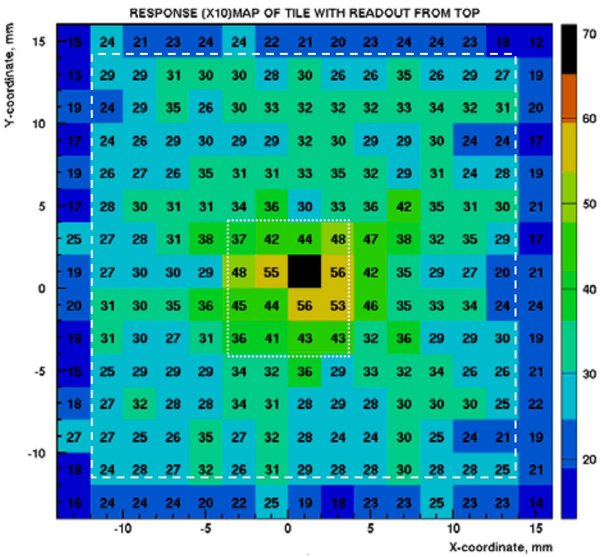
Tile 30x30x5 mm3

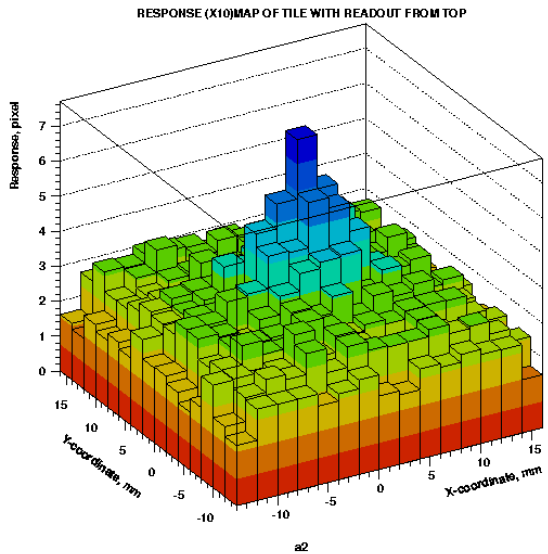






SiPM calibration

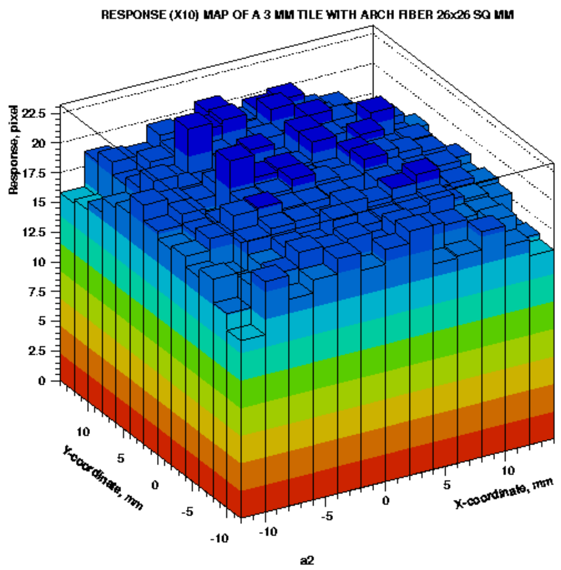




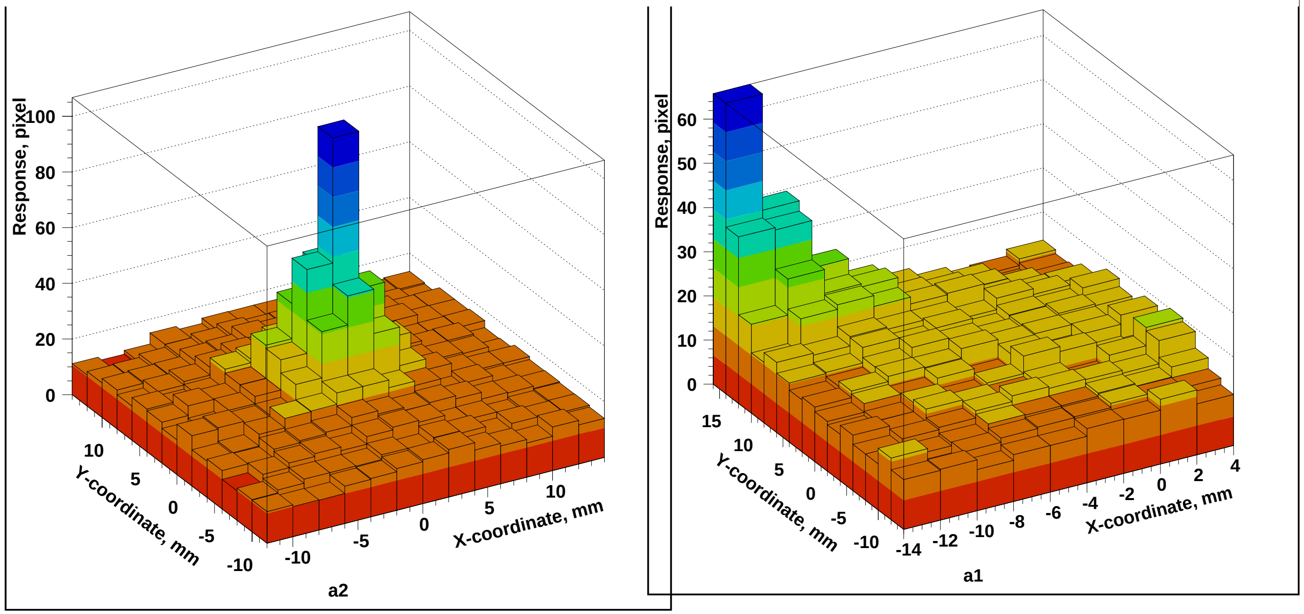
Uniformity is even worse for 3 mm tiles

Uniformity measurements of 30x30x3mm³ tiles at ITEP synchrotron

Arch Fiber&SiPM, 1.5MIP



Direct coupling of 2x2mm² blue MRS APD



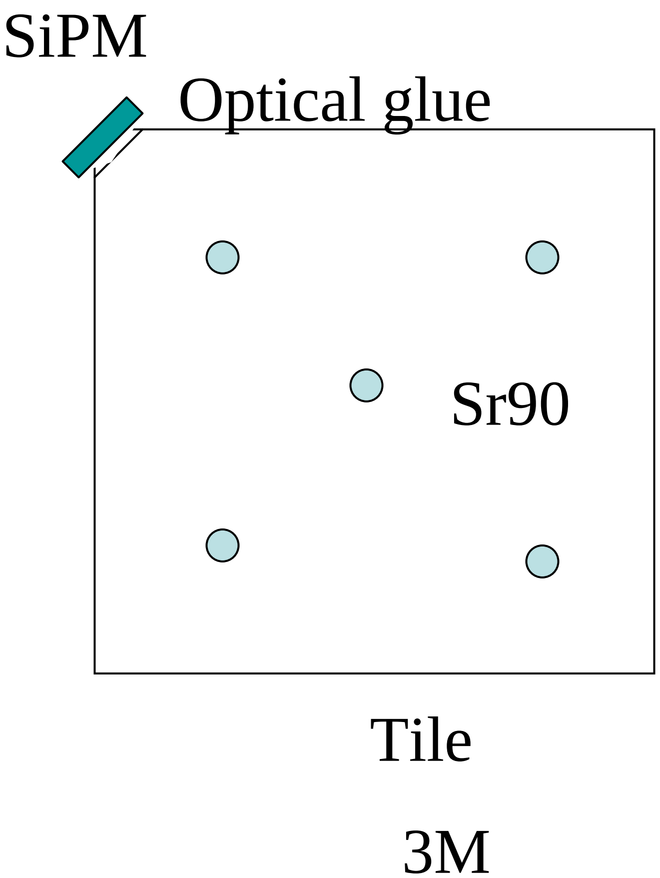
Problems with direct coupling will be more severe for larger size tiles

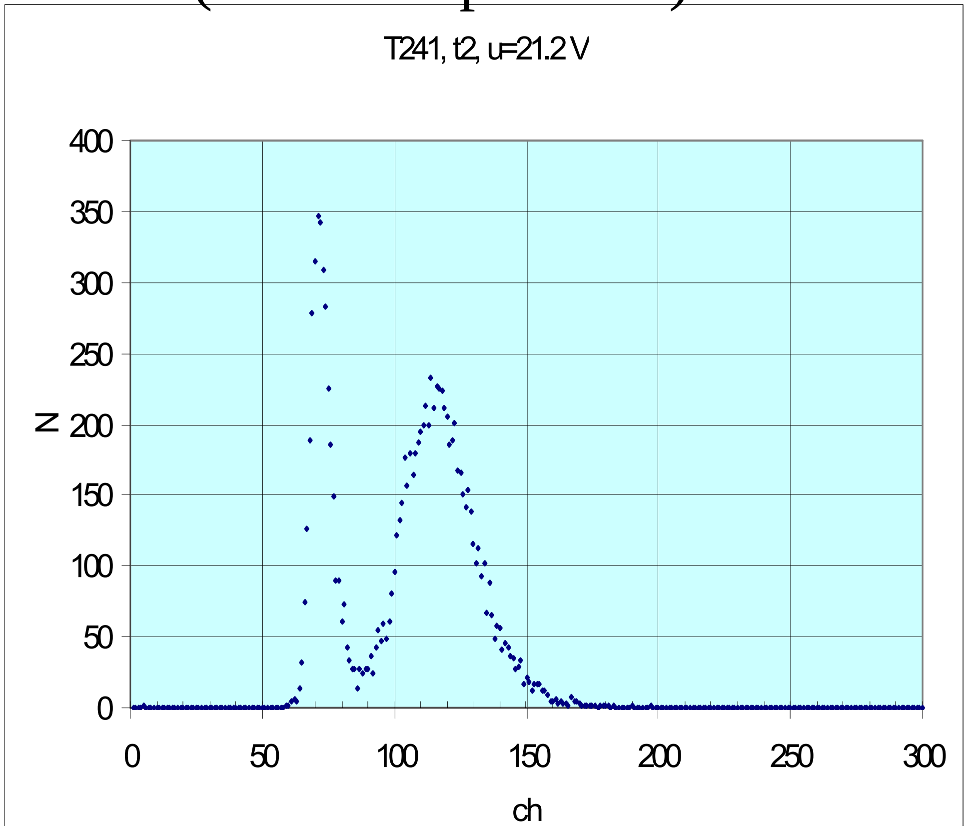
Light yield is sufficient for 3mm thick tiles with glued WLSF and SiPM (~15pix./MIP) and larger area SiPMs (3x3mm²) or MRS APD (2x2mm² blue extended) but noise is too high in these detectors to resolve individual p.e. – bad for calibration

MIP signal for 3x3mm^2 SiPM

Plastic scintillator 30x30x5 mm^3 without WLS fiber and 3x3 mm^2 SiPM assembly was tested at MEPhI (room temperature) with Sr90

SiPM- tile assembly

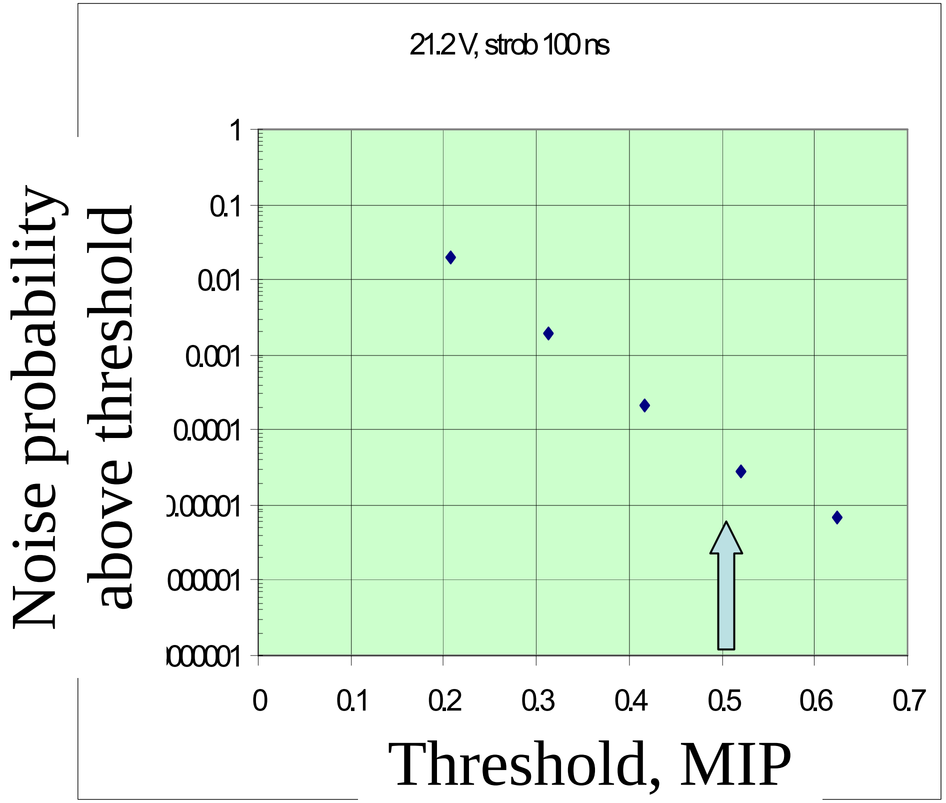


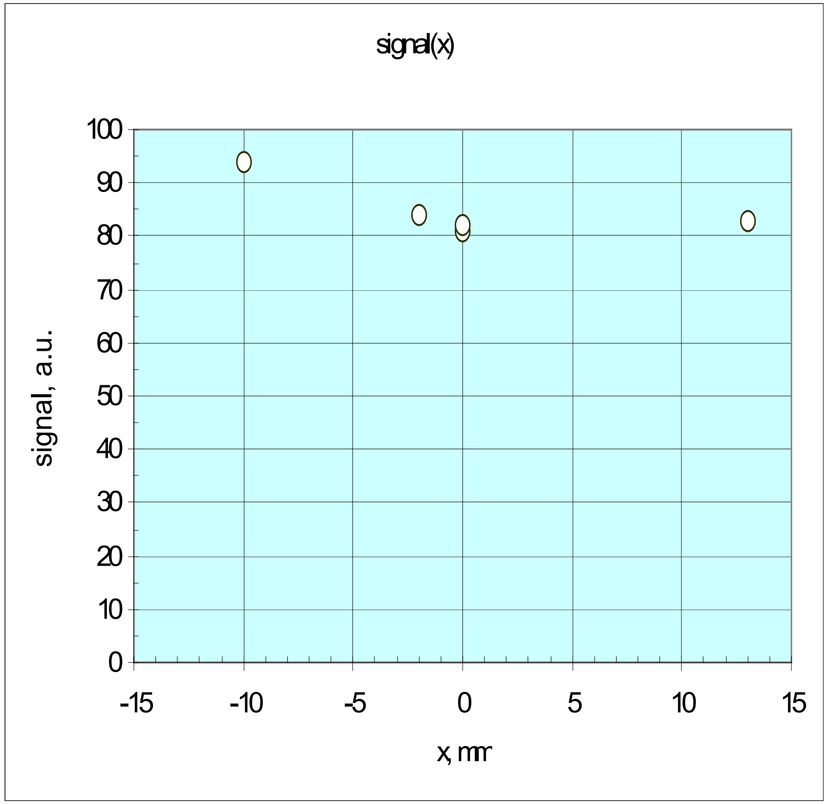


Efficiency of light registration appr18%

Appr. 30 fired pixels/MIP

Noise probability & Light Collection Uniformity for 3x3 mm^2 SiPM-tile assembly



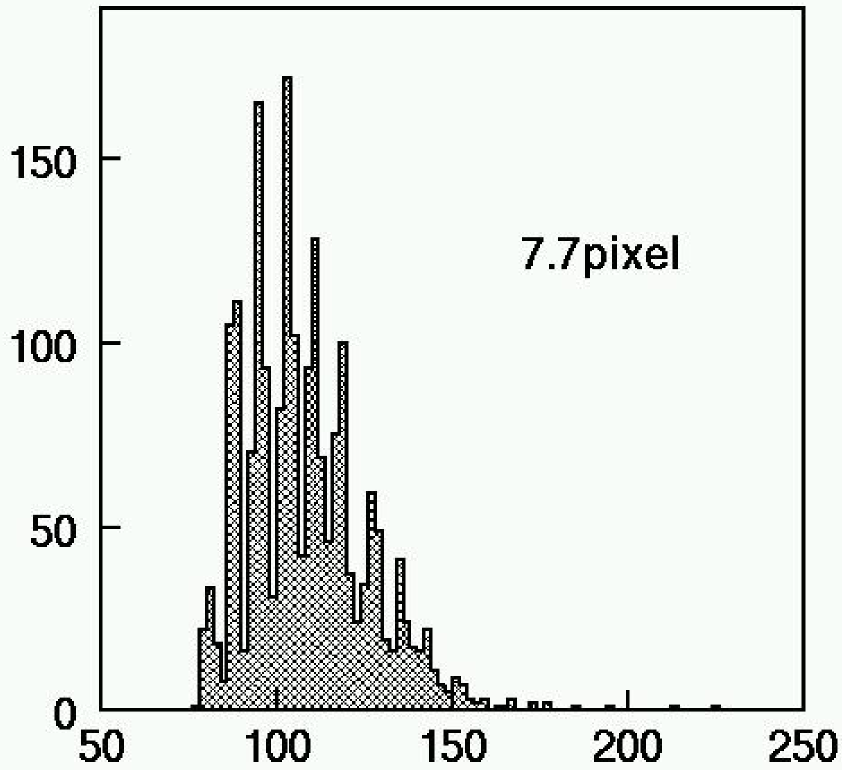


$3*10^{-5} * 8000=0,24$ events/prototype

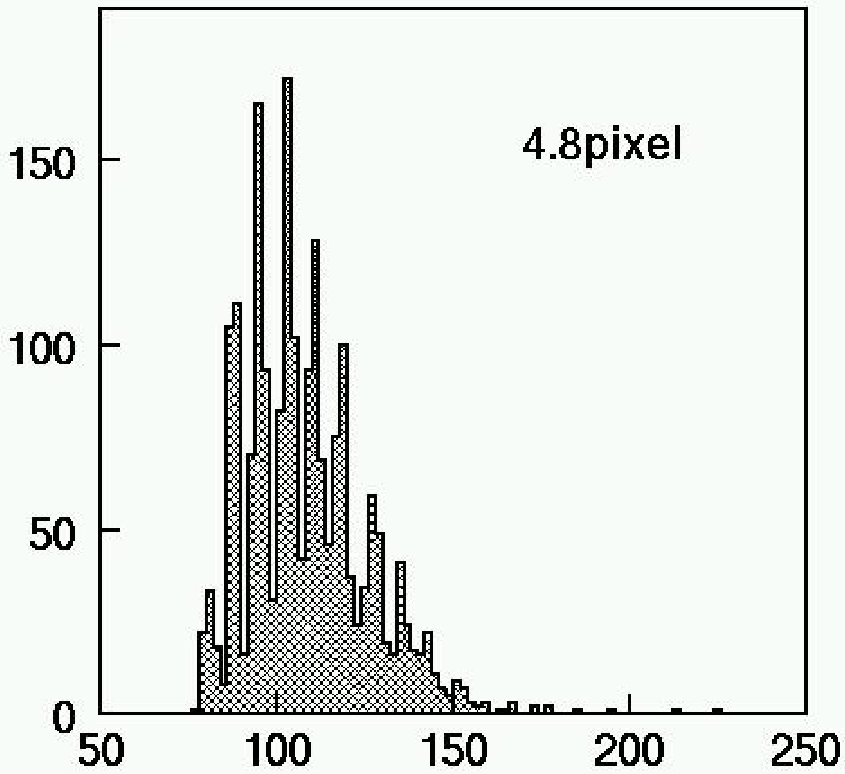
Absence of individual p.e. peaks is a serious drawback for calibration

Photo-electron yield for direct MPPC coupling to 30x30 mm^2 tiles

5 mm thick tile, MPPC at side center

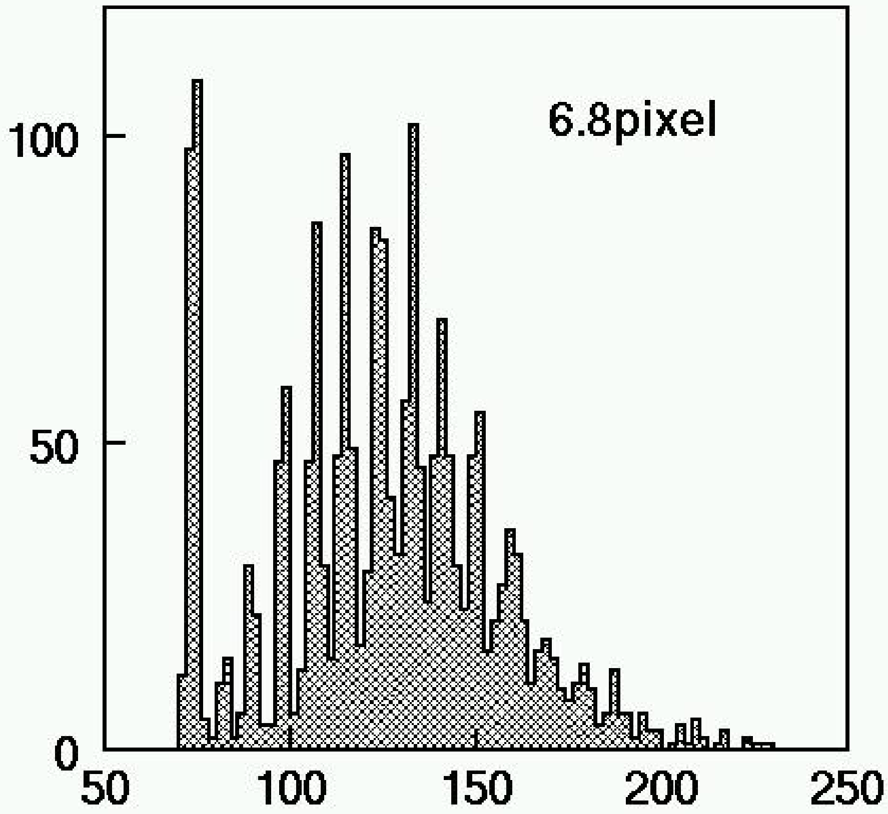


3 mm thick tile, MPPC at side center



Gluing increases photo-electron yield for 5 mm thick tiles

MPPC in tile corner



Glued MPPC in tile corner

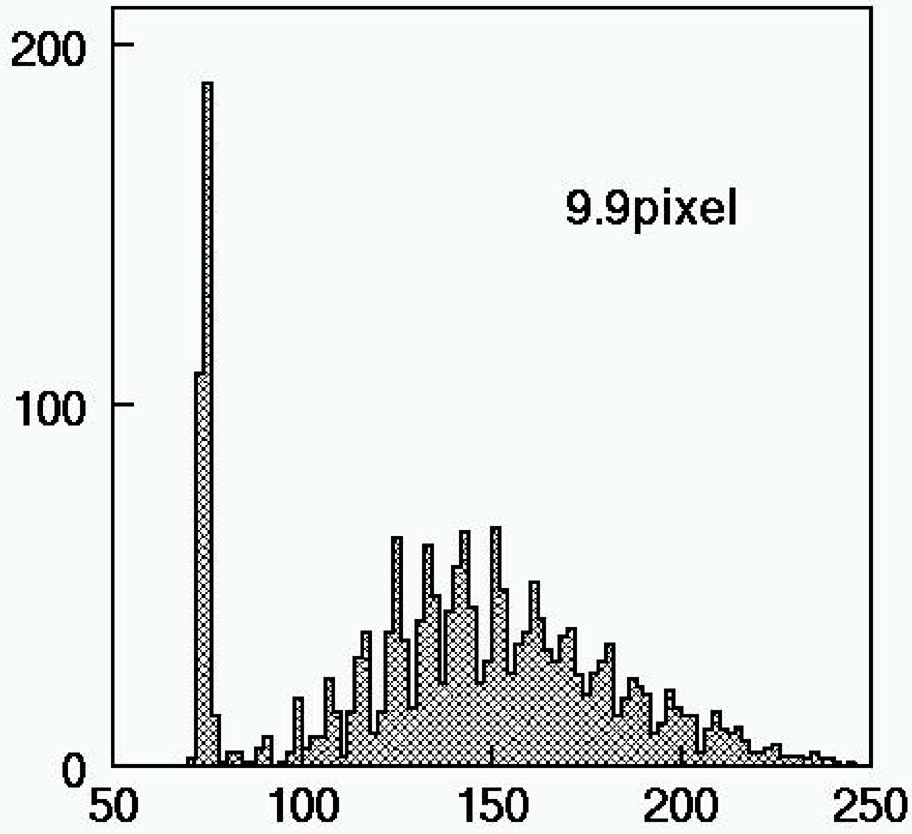
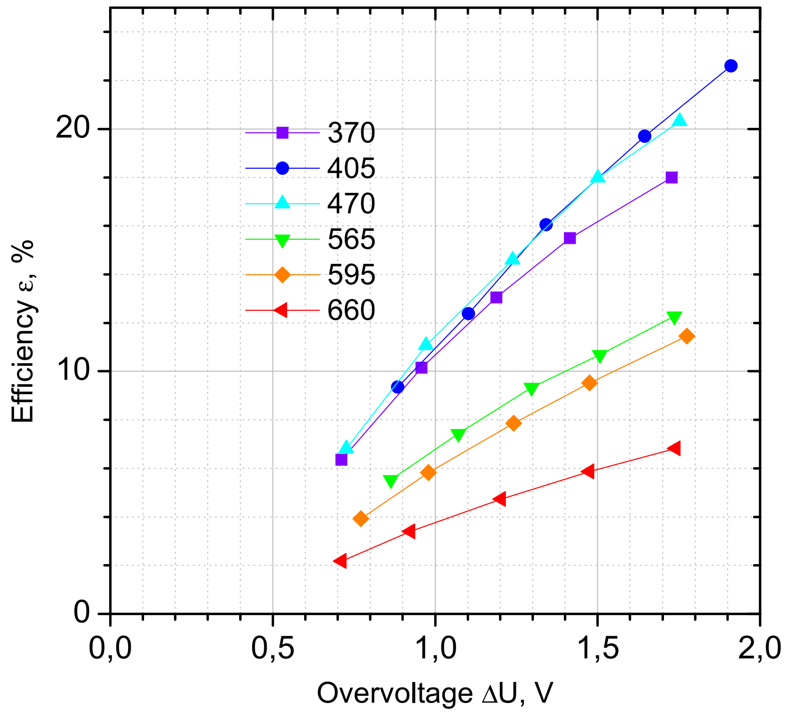
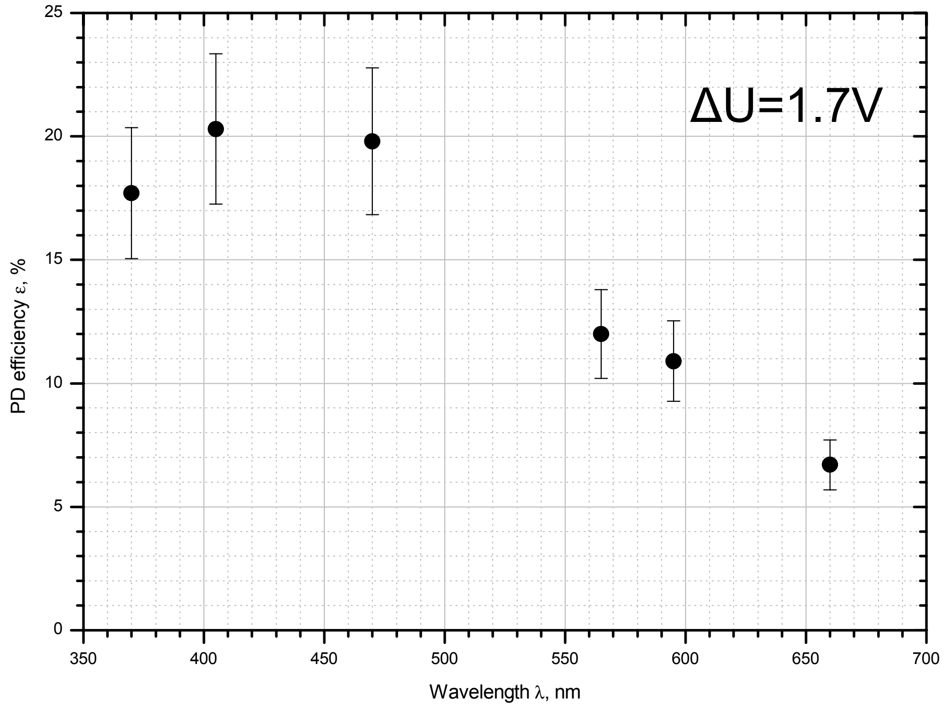


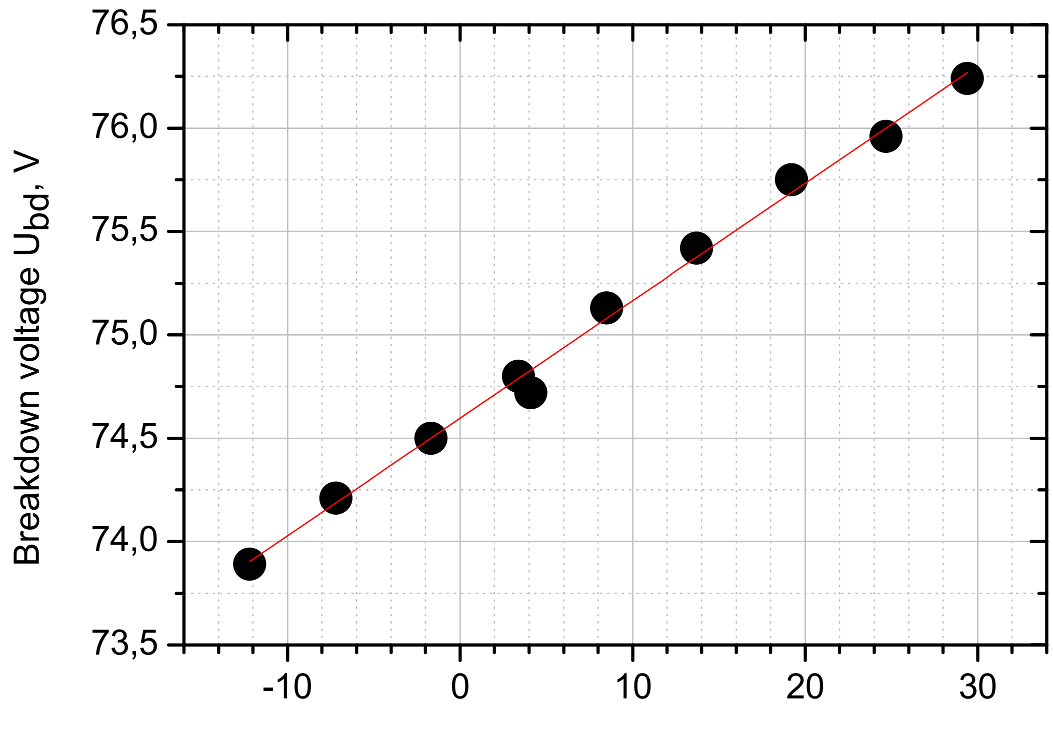
Photo-electron yield is too small for 60x60 mm^2 tiles (~2p.e. without gluing)

MPPC Studies

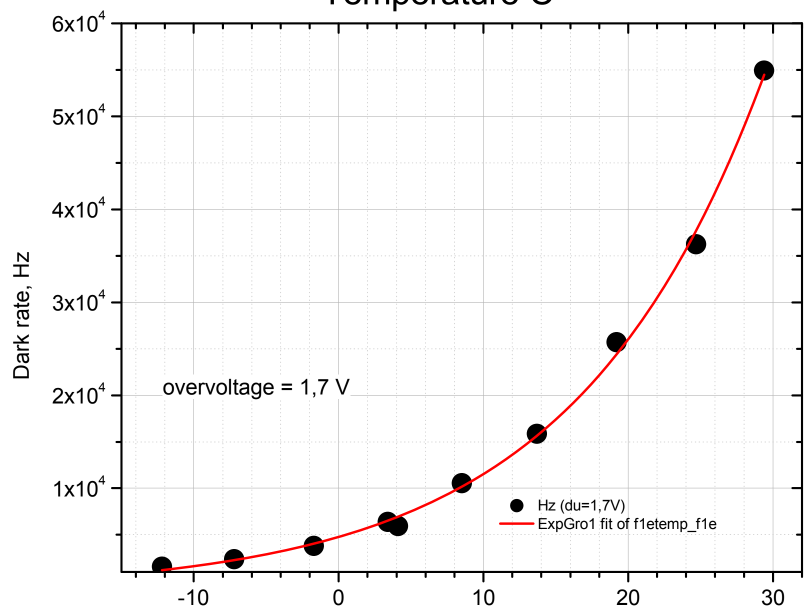




PDE agrees well with the MPPC specification



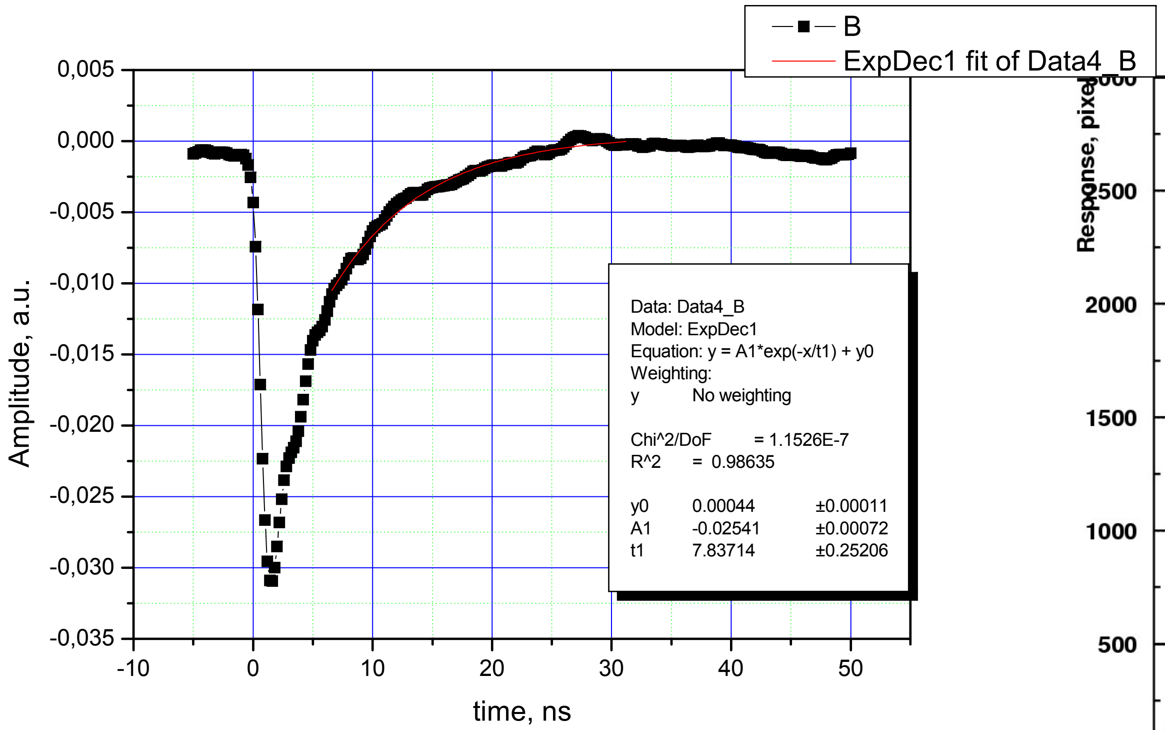
Breakdown voltage U_{bd}, V
76,5
76,0
75,5
75,0
74,5
74,0
73,5
-10
0
10
20
30
Temperature C

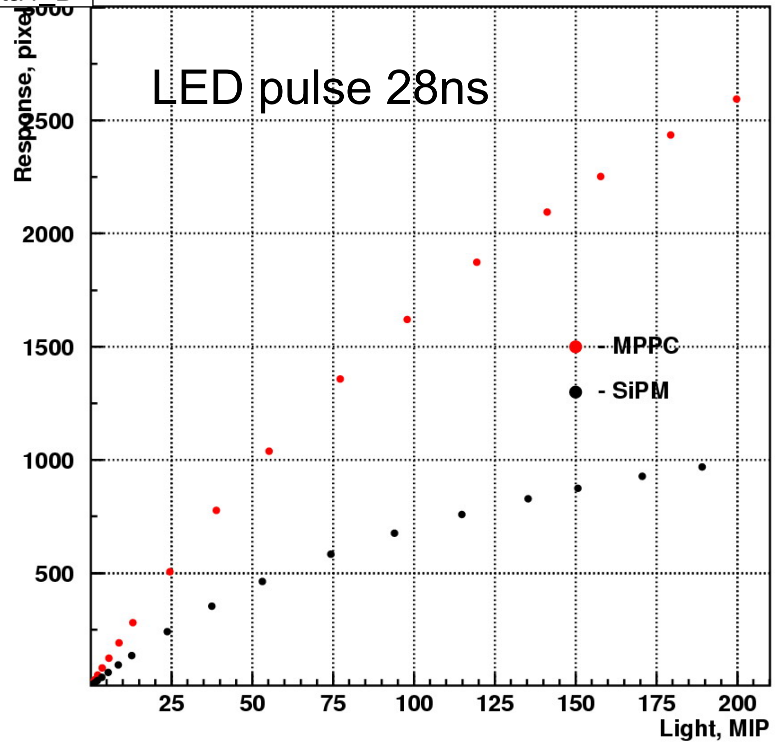


Dark rate, Hz
6x10^4
5x10^4
4x10^4
3x10^4
2x10^4
1x10^4
overvoltage = 1,7 V
Hz (du=1,7V)
ExpGro1 fit of f1etemp_f1e
-10
0
10
20
30

MPPC fast decay time indicates small R and fast recovery time

This leads to double signals from one pixel during a long pulse

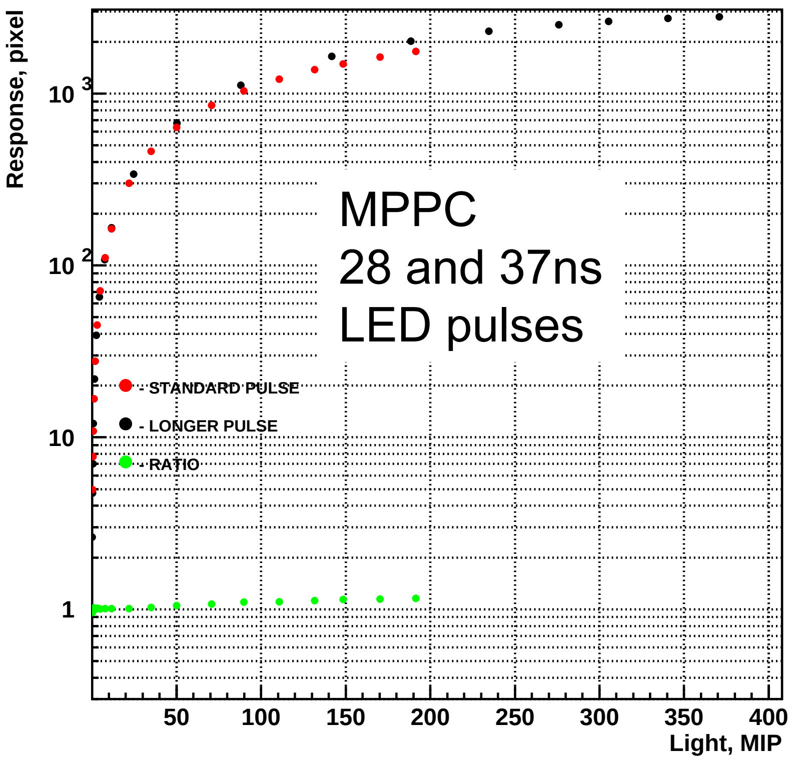


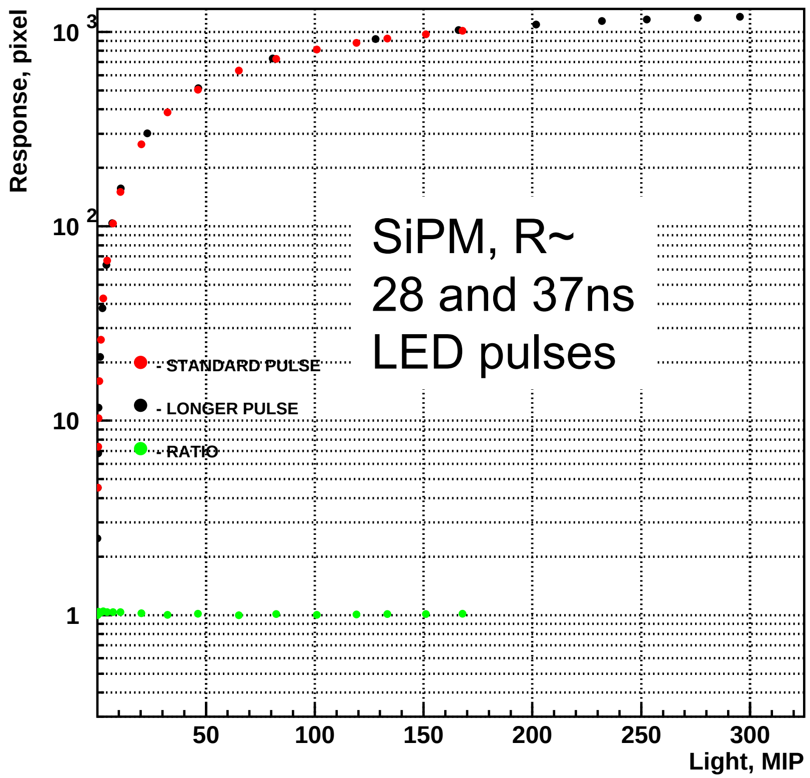


Measurements at DESY and ITEP give 7-9 p.e./MIP for direct MPPC (1600pix) readout of 5mm thick 30x30mm^2 tiles and ~5p.e./MIP for 3mm thick tile

MPPC do not provide enough p.e. for direct readout of 3x30x30mm tiles
Photo-electron yield is even smaller for larger tiles (~2p.e. for 60x60x5mm^3 tile)

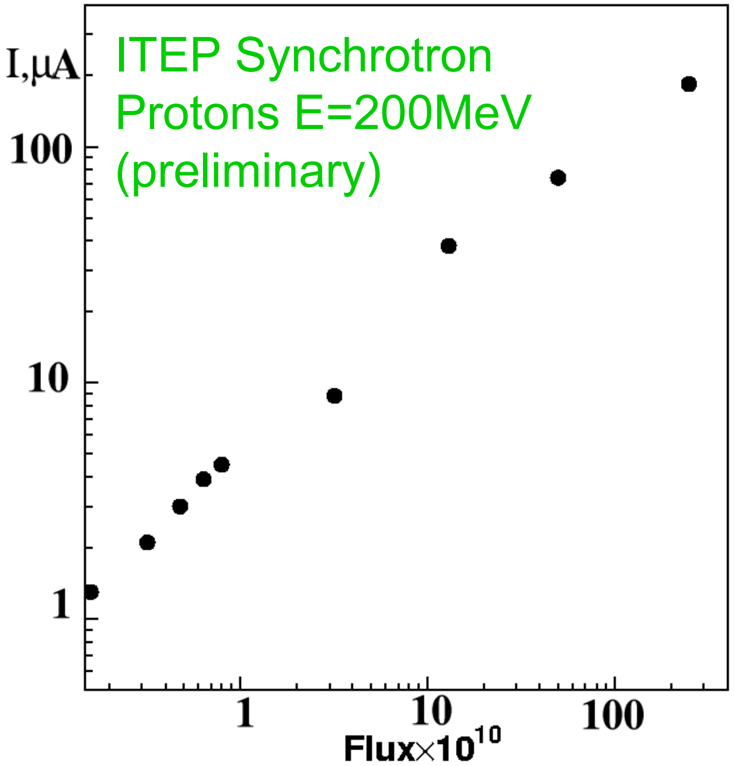
MPPC saturation curve dependence on pulse length create problems for calibration





Larger size MPPC can be adequate for direct tile readout since noise is not a limiting factor
However long term stability and radiation hardness should be demonstrated

Radiation damage measurements



Dark current increases linearly with flux Φ as in other Si devices:

$\Delta I = \alpha\, \Phi$ Veff Gain, where $\alpha = 6 \times 10^{-17}$ A /cm

Veff ~ 0.004mm^3 determined from observed **ΔI**
looks a bit too high
(since it includes SiPM efficiency)
but not completely unreasonable

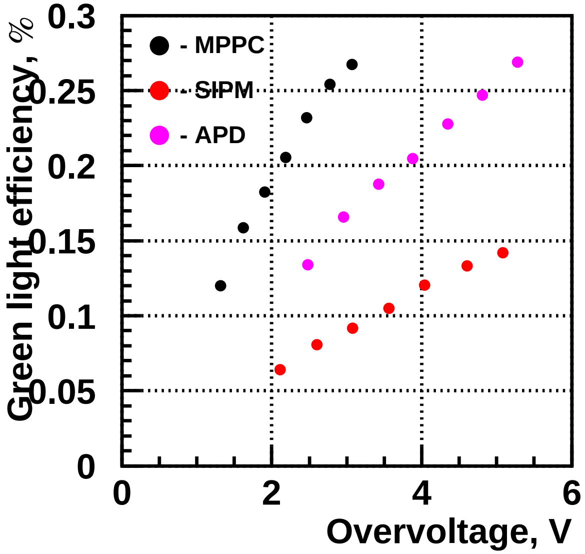
Since initial SiPM resolution of ~0.15 p.e. is much better than in other Si detectors it suffers sooner:
After **Φ**~10^{10} individual p.e. signals are smeared out

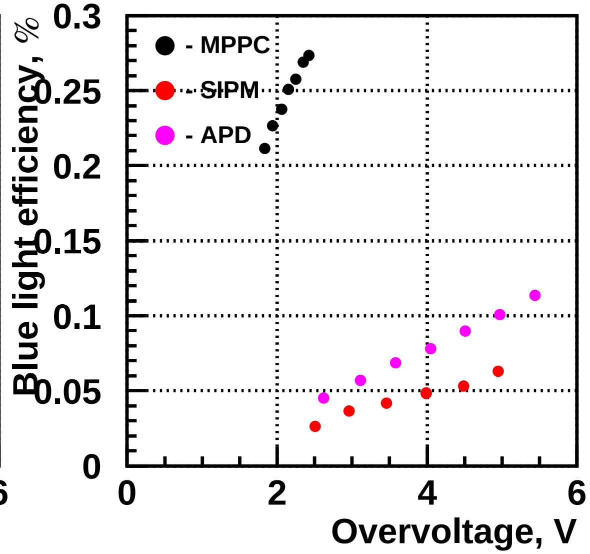
However MIP signal are seen even after **Φ**~10^{11}/cm^2

At ILC neutron flux is much smaller than 10^{10}/cm^2 except a small area (R<50cm) around beam pipe

→ Radiation hardness of SiPM is sufficient for HCAL

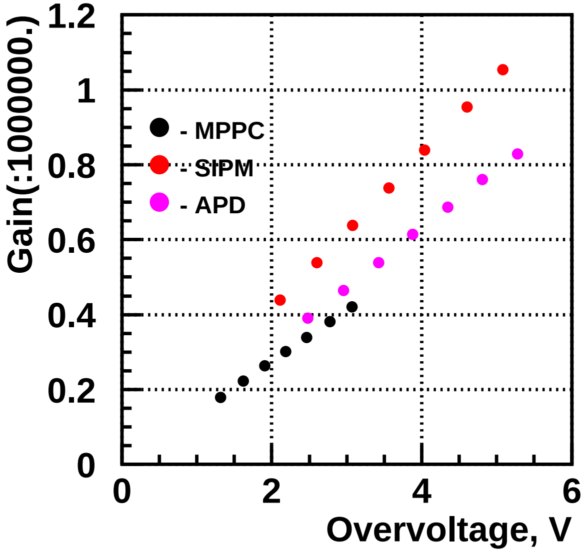
Comparison of different Multipixel Geiger Photo Diods (MGPD)

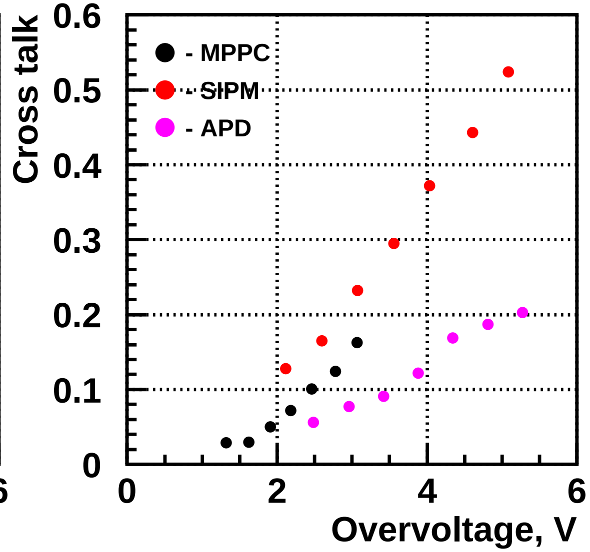




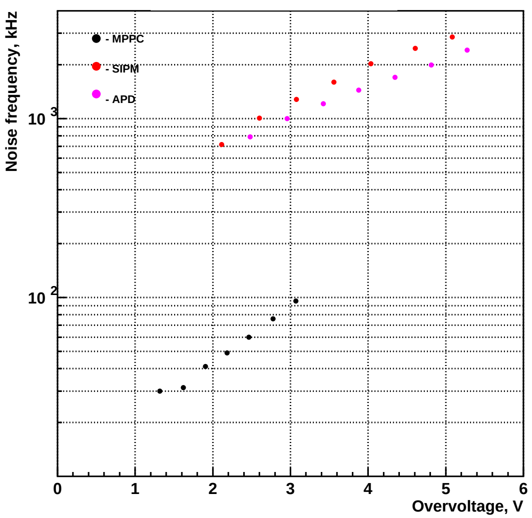
MGPD were illuminated with Y11 (green) and scintillator (blue) light

Efficiency was normalized to MPPC one





Noise frequency

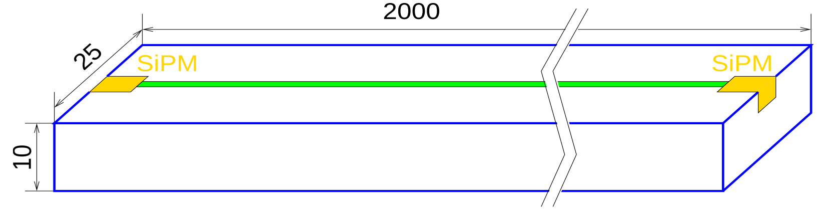


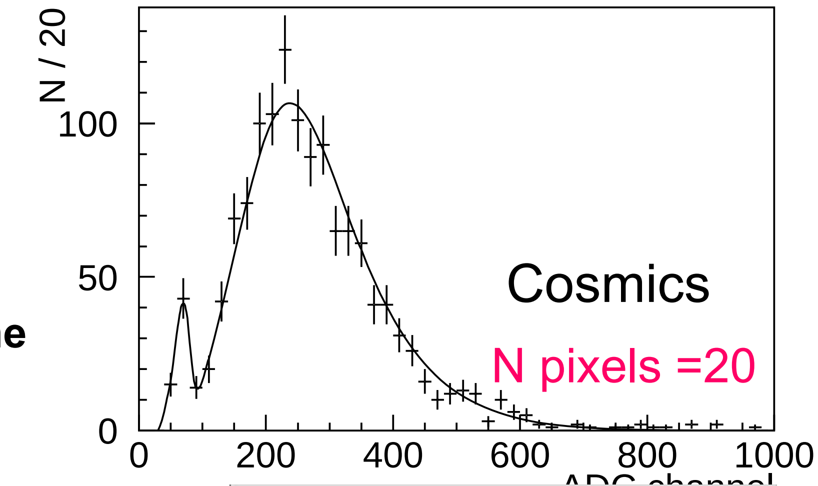
Conclusions

Scintillator tile calorimeter with WLSF and SiPM readout is a viable option for ILC HCAL but industrialization is needed for several hundred times larger system

Scintillator strips with WLSF and SiPM readout can be used for ILC muon system

Tests of 2 m long strip at ITEP

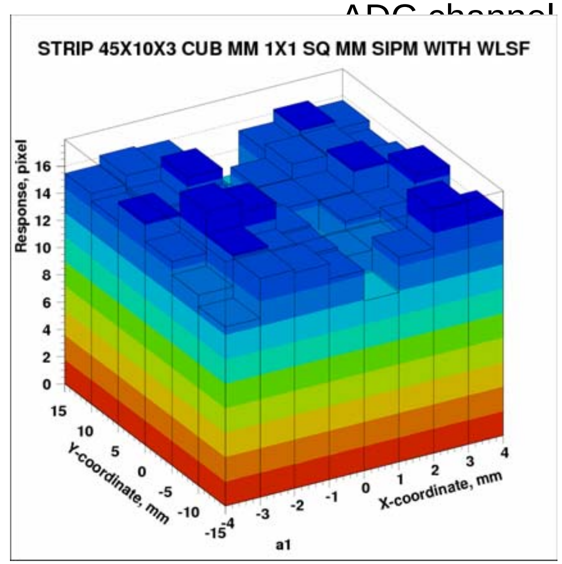




Position along strip can be determined from time measurements: ΔT~2ns leads to ΔX~25cm
(**ΔT~2ns** was already achieved)

Thin scint. strips with WLSF+SiPM readout provide sufficient light and uniformity (~6%) for last layers of EM calorimeter
(approach tested extensively by Japanese groups)

Uniformity measurements for $3x10x45\ mm^3$ strip with WLSF and SiPM readout



Summary

ILC HCAL prototype is the first (and successful!) large scale (~10^4) application of novel photo-detectors – SiPMs
Among 4536 channels in cassettes 3-23 only 1.1% are dead (soldering problems) and 1.1% show long discharges
(reason for long discharges was understood, will be fixed in next SiPM version)
Within errors situation is stable in time

Scintillator tile calorimeter with WLSF and SiPM readout is a viable option for ILC for analog and semi-digital approaches, but a lot of industrialization is required
The same technique can be used for ILC muon system and
last layers of ECAL

Possibility to use direct MGPD coupling is still to be demonstrated
(uniformity and p.e. yield)

The field is developing very fast. Photo-detector properties improve every year.
The final choice of the Photo-detector depends on the overall optimization

Selection between Analog, Digital or Semi-Digital approaches depends on the outcome of the test program at CERN and FNAL