CALICE Meeting
Kobe 10.05.2007

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

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Status of tile production

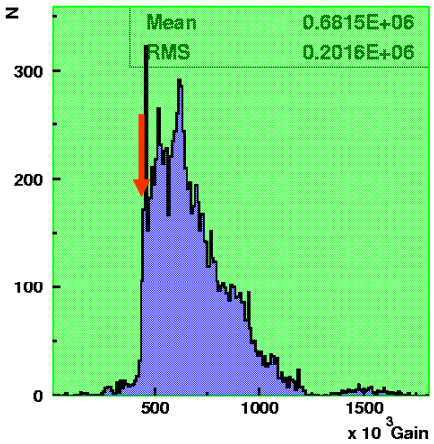
Tiles for 38 cassettes have been delivered to DESY

In case of any problems with them we need a fast feedback

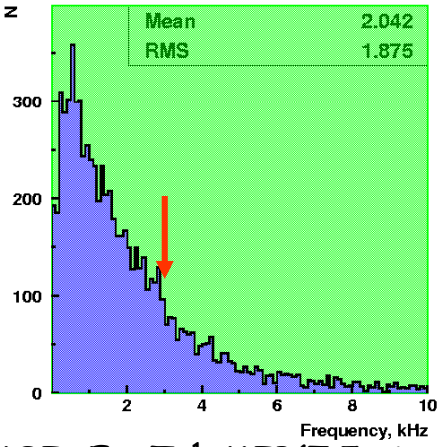
Bad tiles from cassettes # 1-2 were shipped to ITEP and are being repaired

We hope to deliver them back to DESY by mid of May

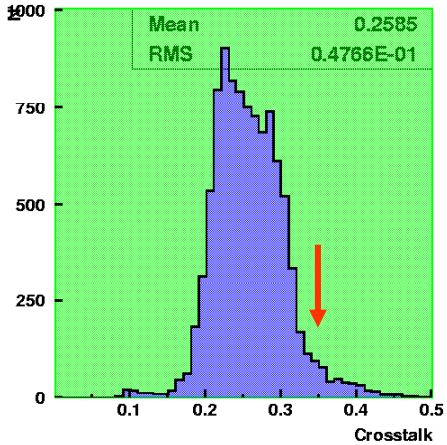
Parameters of ~ 10000 tested SiPM's



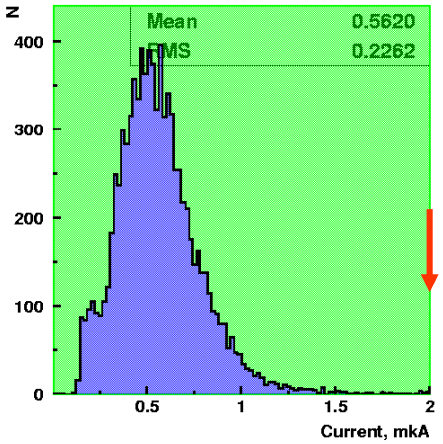
GAIN



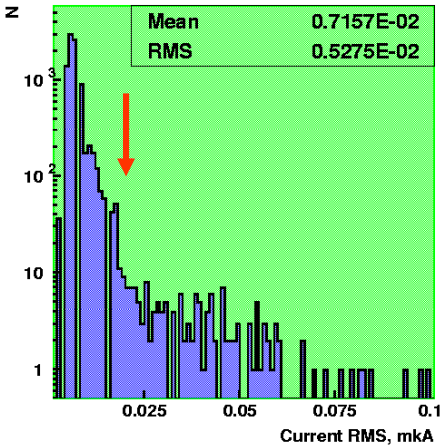
NOISE AT $\frac{1}{2}$ MIP(7.5 pixels)



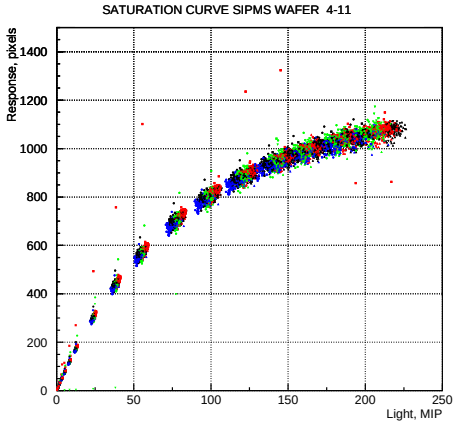
CROSS TALK



SIPM CURRENT

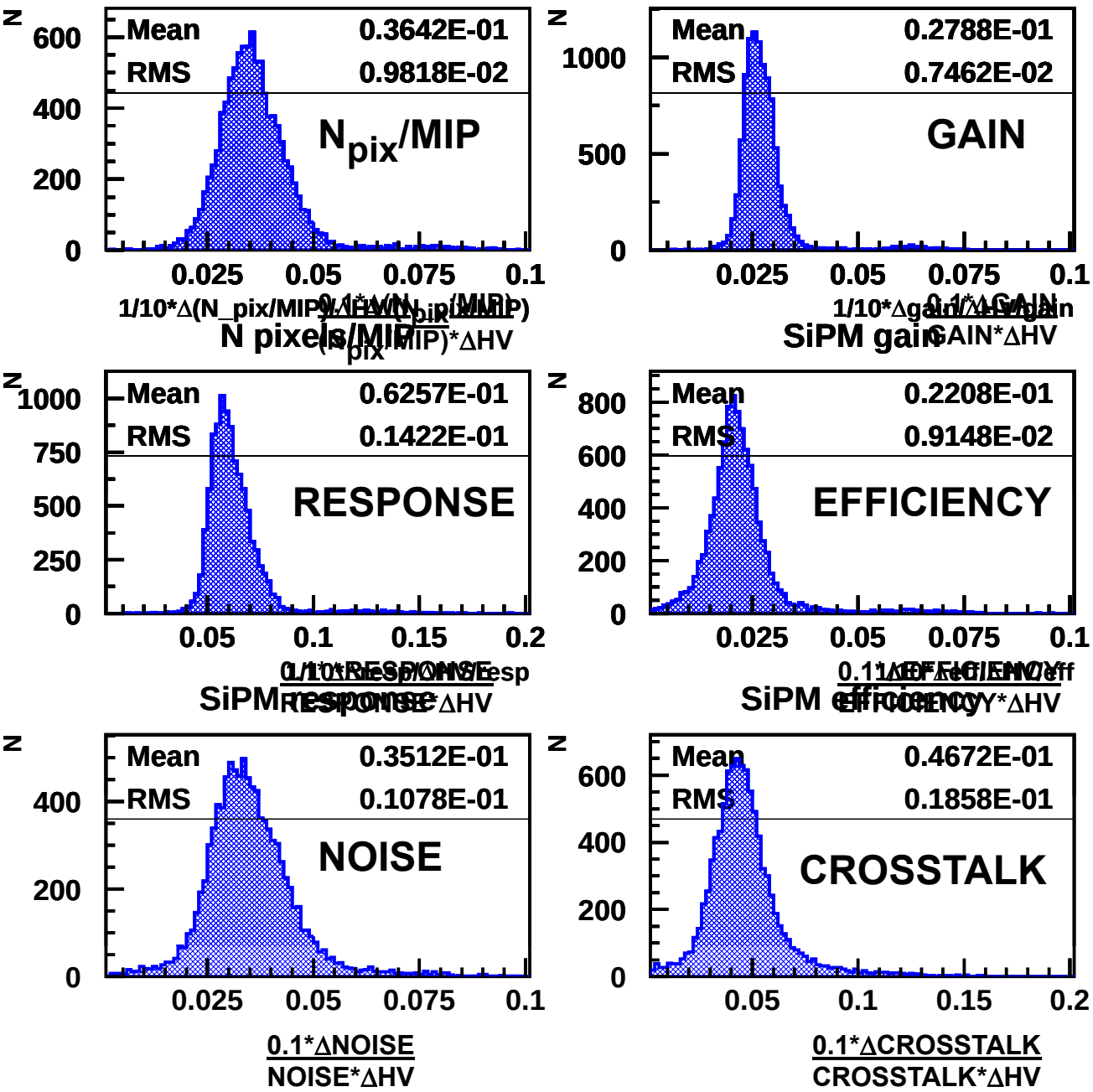


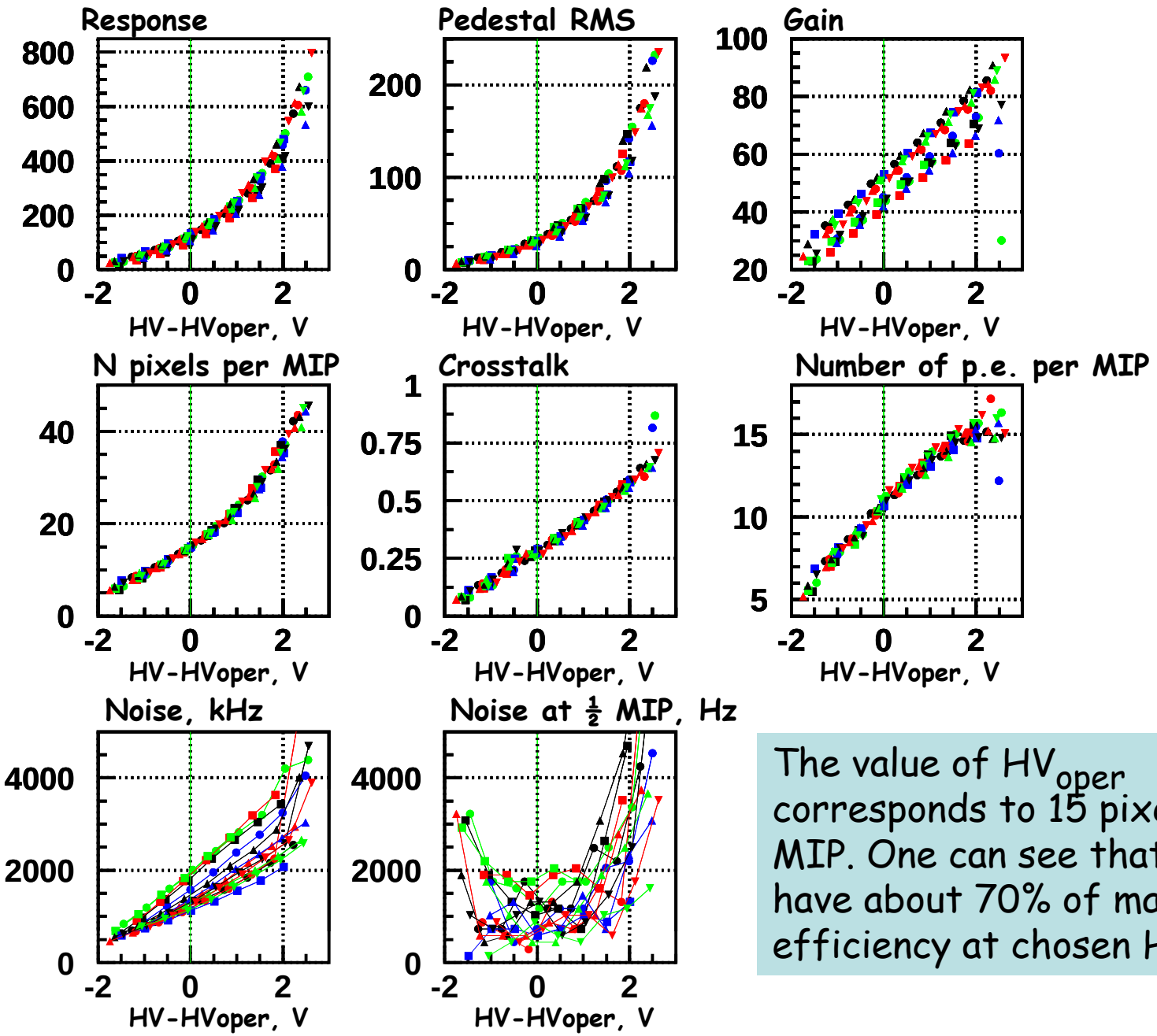
CURRENT STABILITY



SATURATION CURVE

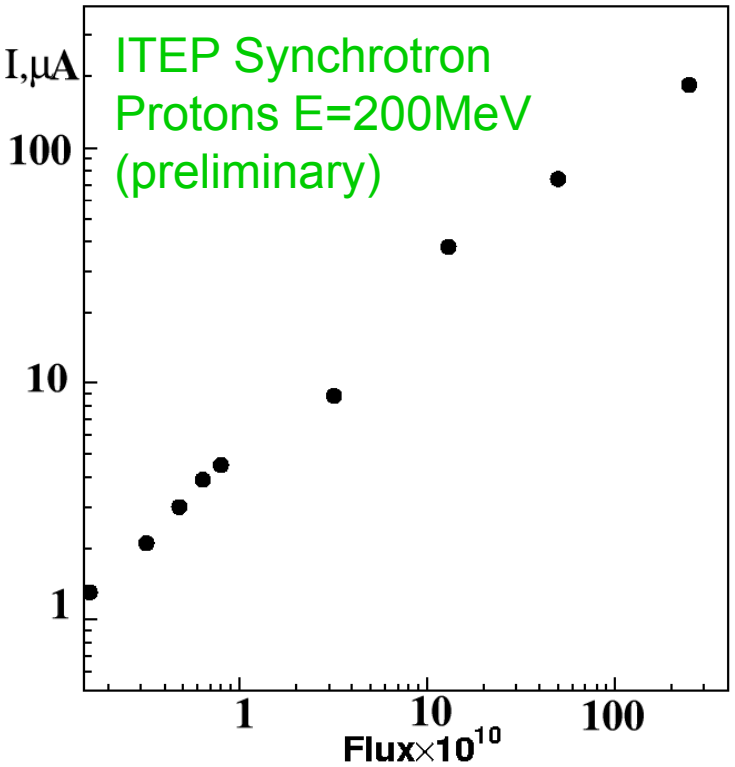
SIPM PARAMETER VARIATION AT 0.1 V HV VARIATION





The value of HV_{oper} corresponds to 15 pixels per MIP. One can see that we have about 70% of maximal efficiency at chosen HV_{oper}.

Radiation damage measurements



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

$\Delta I = \alpha\, \Phi\, V_{eff}\, Gain$, where $\alpha = 6\times10^{-17}$ 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

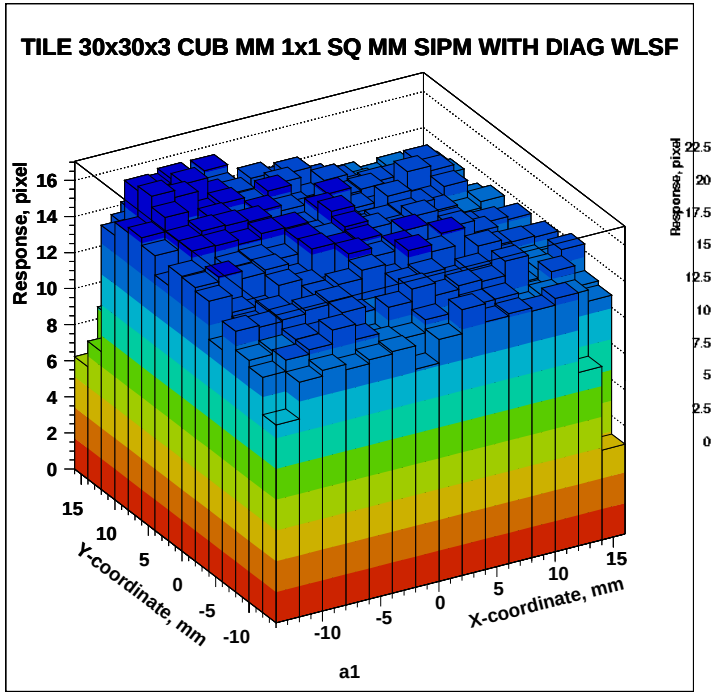
At ILC neutron flux is much smaller than 10^{10}/cm^2 except a small area (R<30cm) around beam pipe

→ Radiation hardness of SiPM is sufficient for HCAL

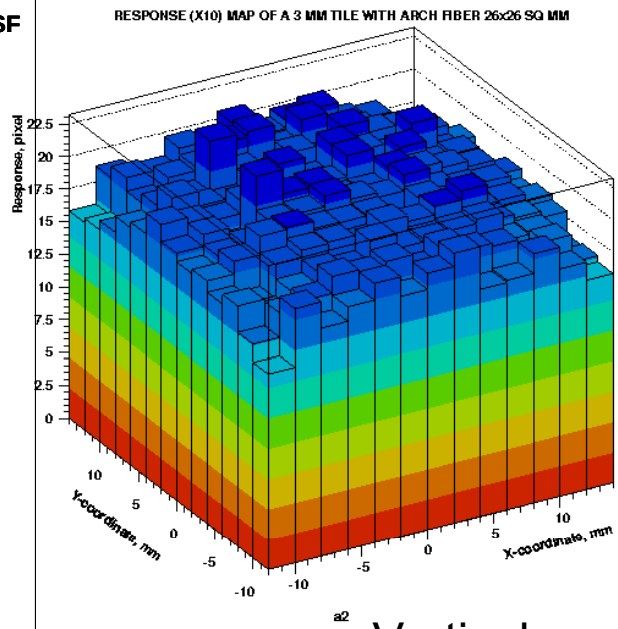
Comparison of WLSF and direct SiPM coupling

Tiles with WLS fiber

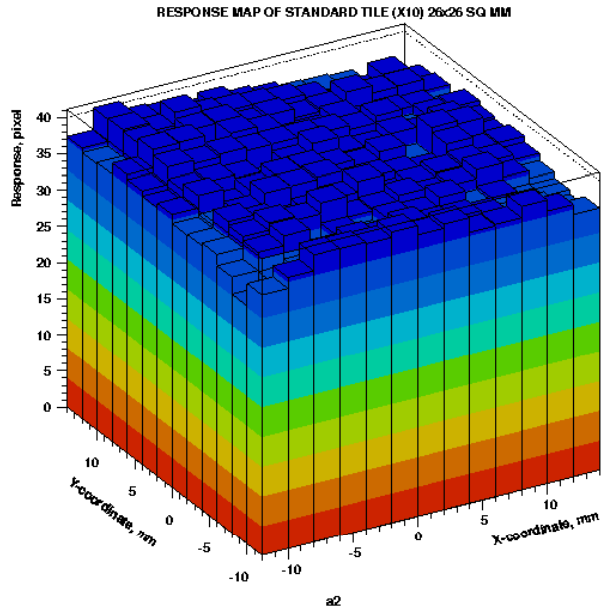
3 mm thick tile with diagonal fiber



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

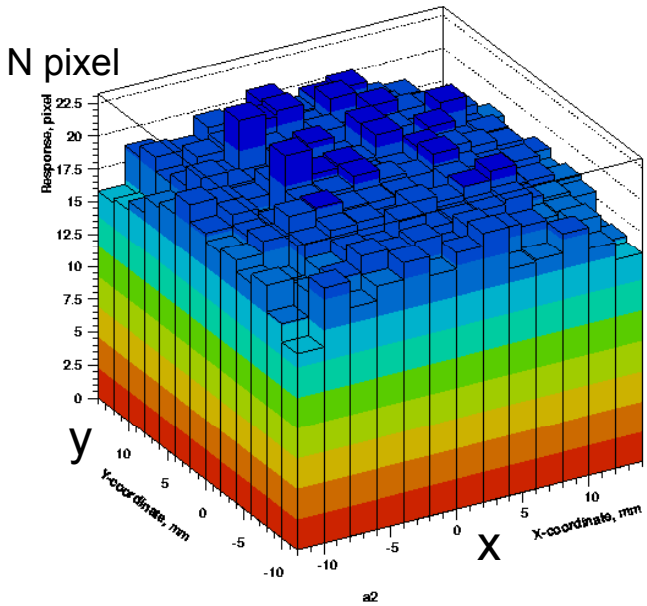
Tile thickness reduction can save a lot of money (~?/mm) or increase HCAL thickness
However the effect on the energy resolution (sampling fluctuations) should be estimated

Tile thickness can be reduced to 3 mm (saves a lot of money)

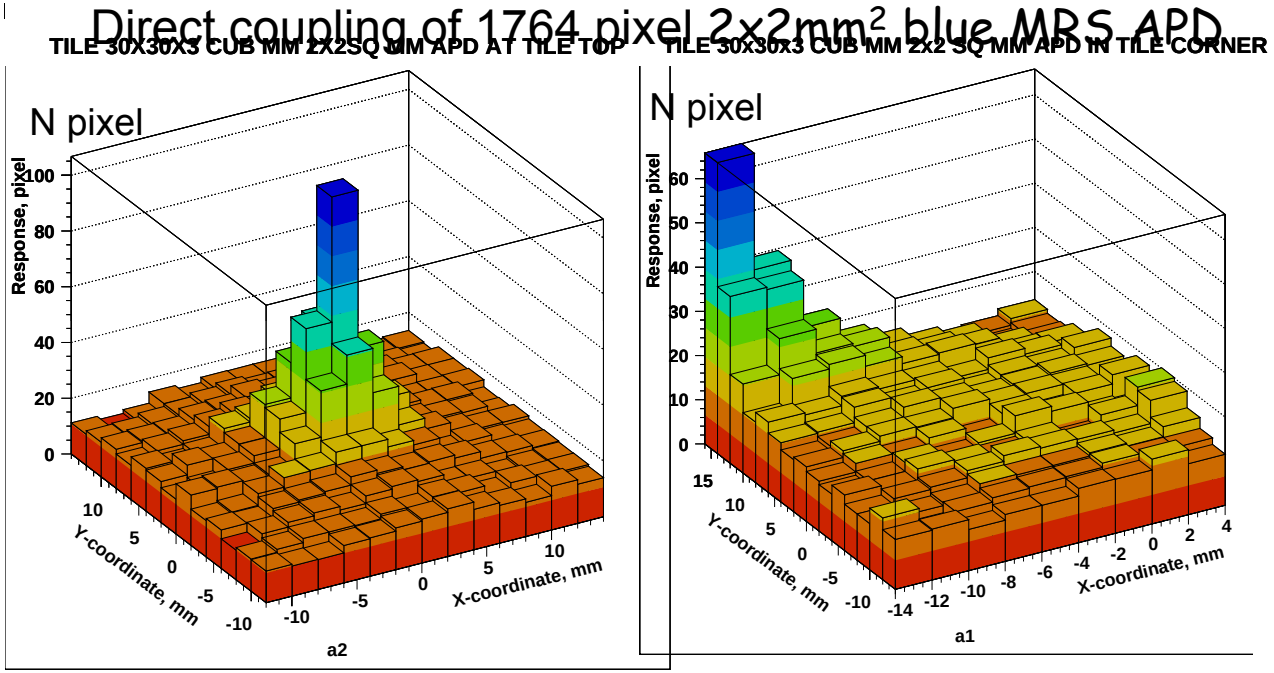
Response uniformity is good for tiles with WLS fibers even for thin tiles and problematic for direct SiPM coupling which is easier for fabrication

Uniformity measurements of 30x30x3mm^3 tiles at ITEP synchrotron

Arch fiber&SiPM 1.5MIP



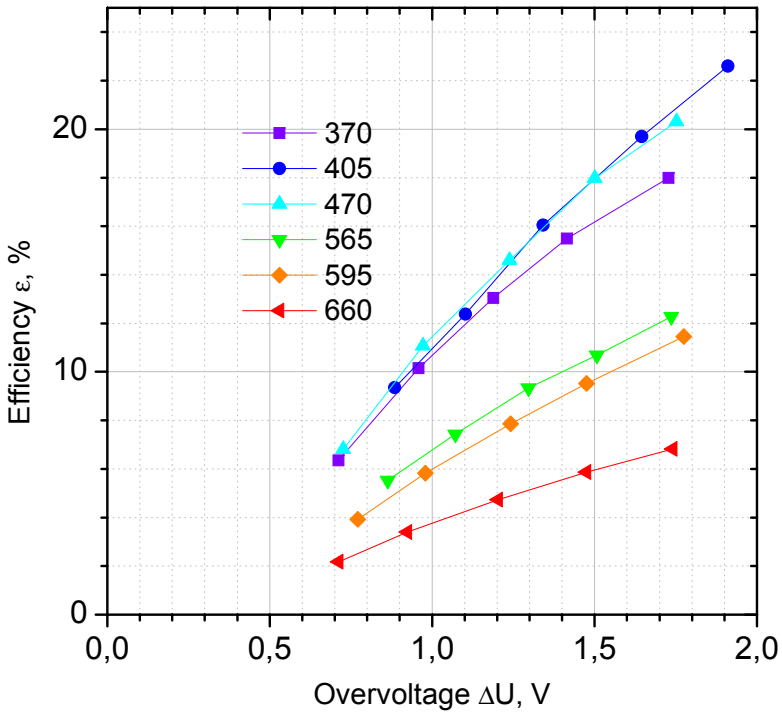
Direct coupling of 1764 pixel 2x2mm^2 blue MRS APD

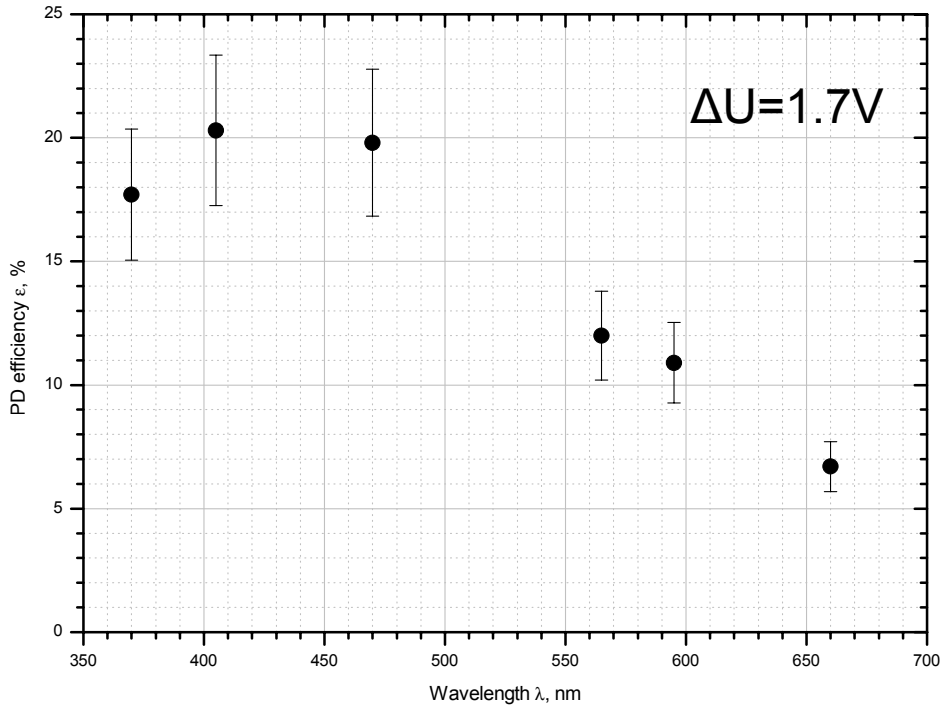


Problems with direct coupling will be more severe for larger size tiles

Light yield is sufficient for 3mm thick tiles with glued WLSF and SiPM (~14pix./MIP) and larger area SiPMs (3x3mm^2) or MRS APD (2x2mm^2 blue extended) but noise is too high in these detectors to resolve individual p.e. – bad for calibration

MPPC Studies





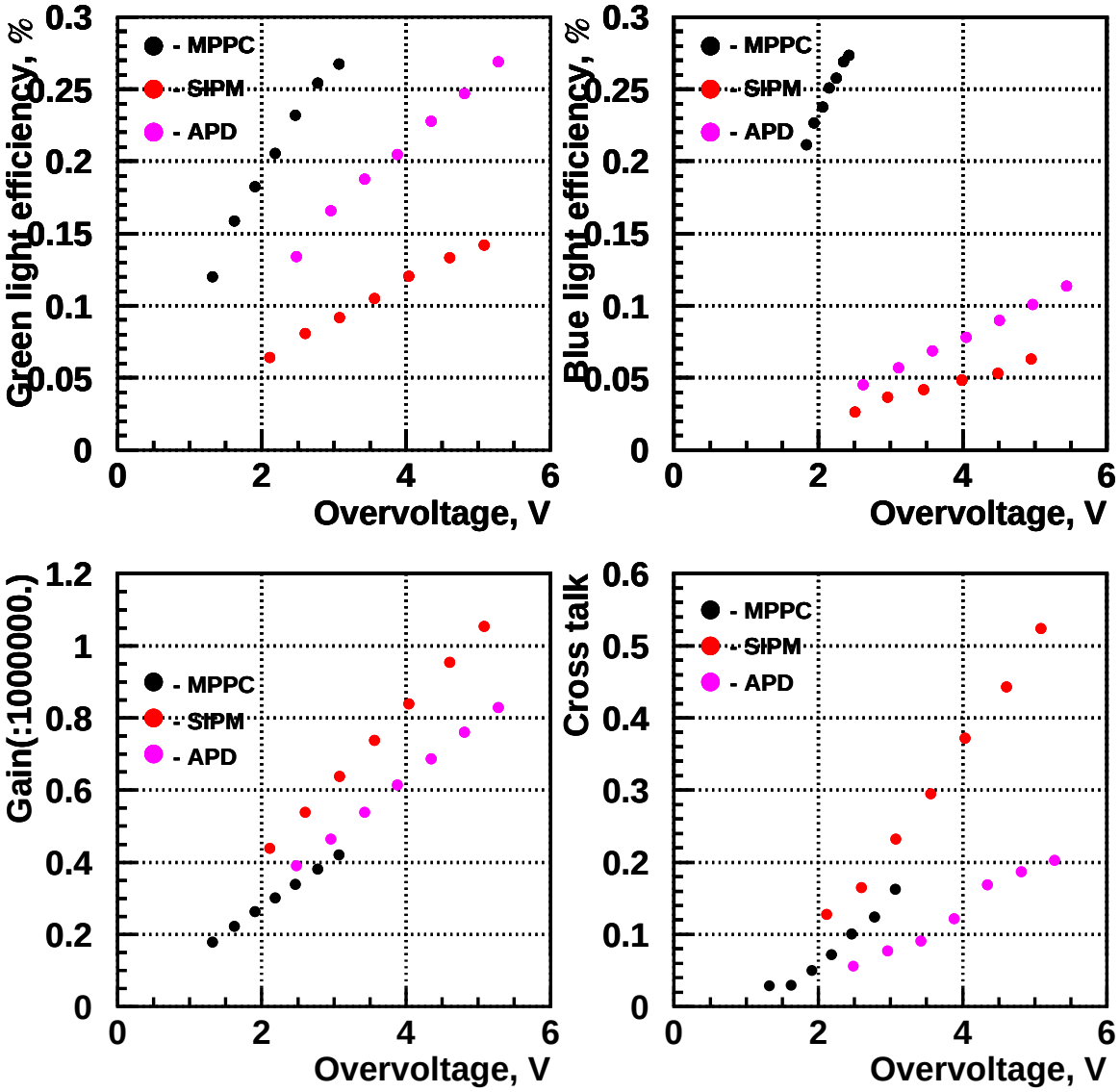
PDE agrees well with the MPPC specification

Recently low noise blue sensitive MPPC with high PDE were developed by HPK

Comparison of different Multipixel Geiger Photo Diods (MGPD)

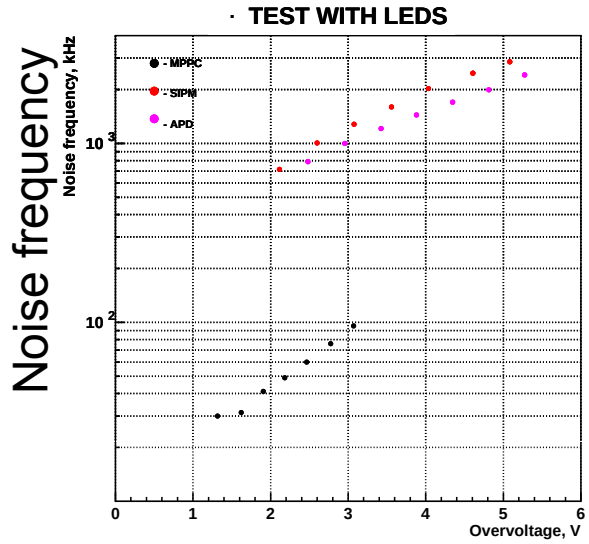
(MPPC(1600 pix), SiPM (1156 pix), MRS APD(656pix))

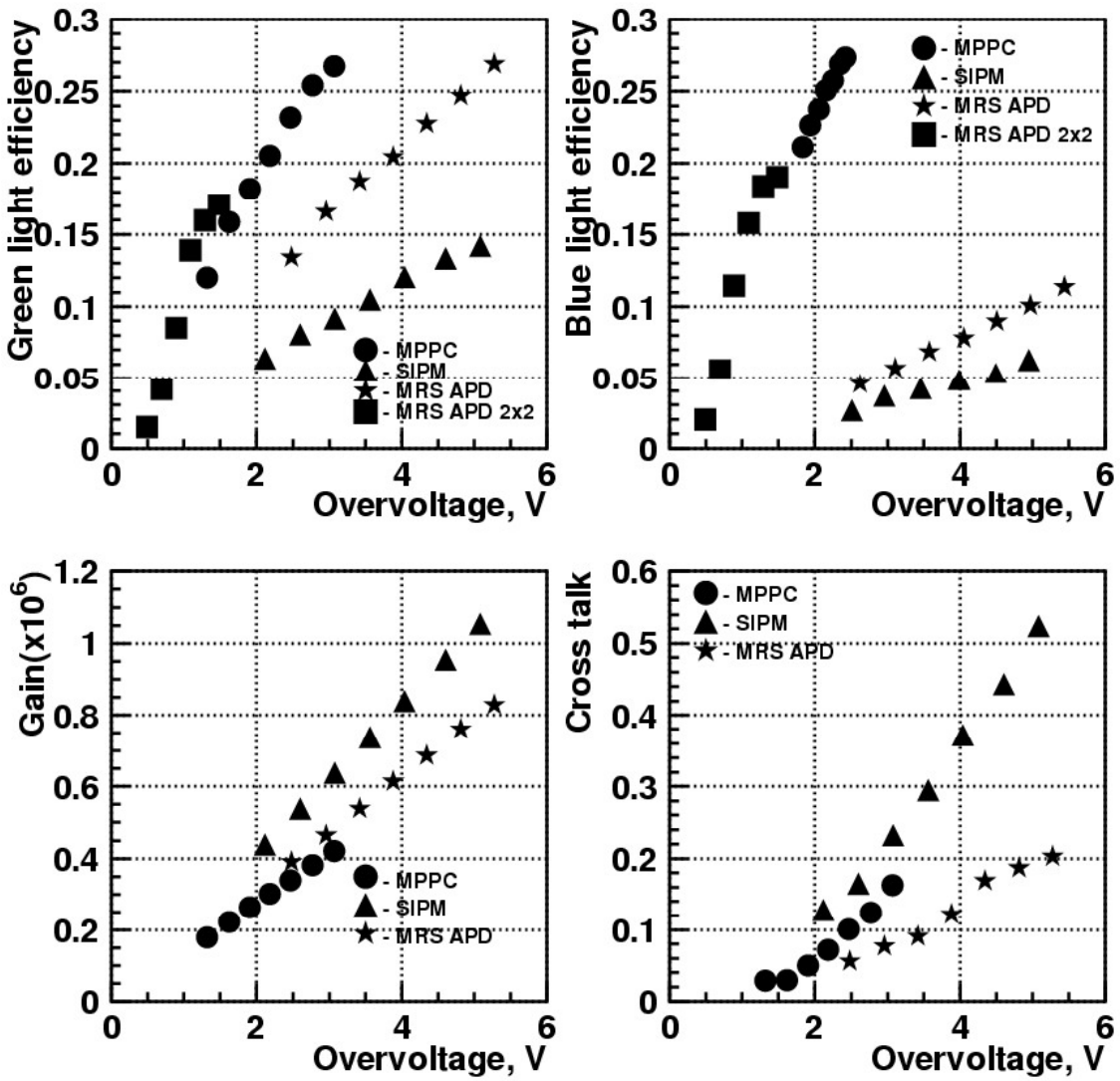
TEST WITH LEDS



MGPD were illuminated with Y11 (green) and scintillator (blue) light Efficiency was normalized to MPPC one

MRS APD with 25% larger efficiency already exist.

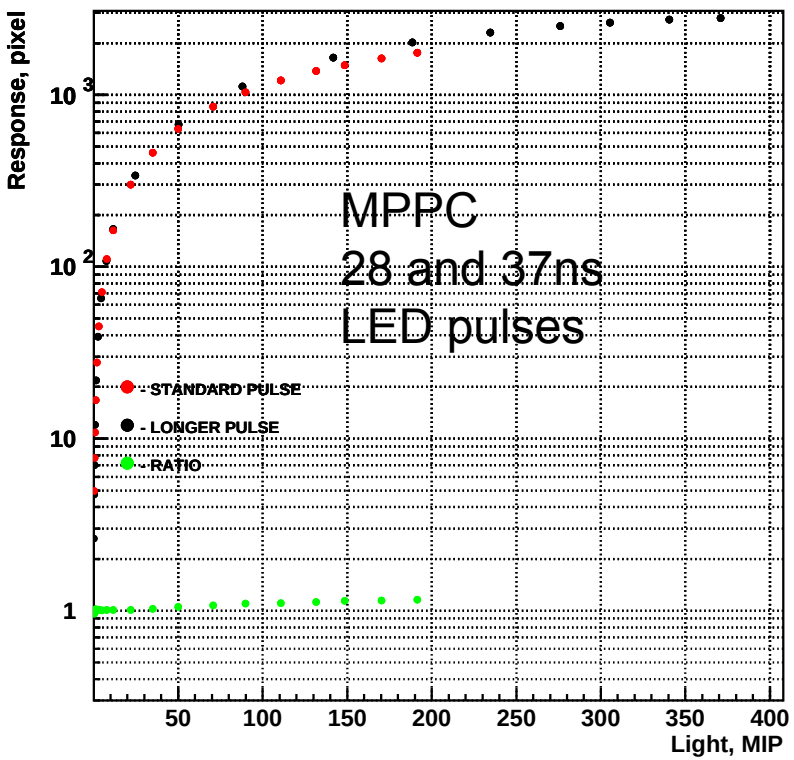


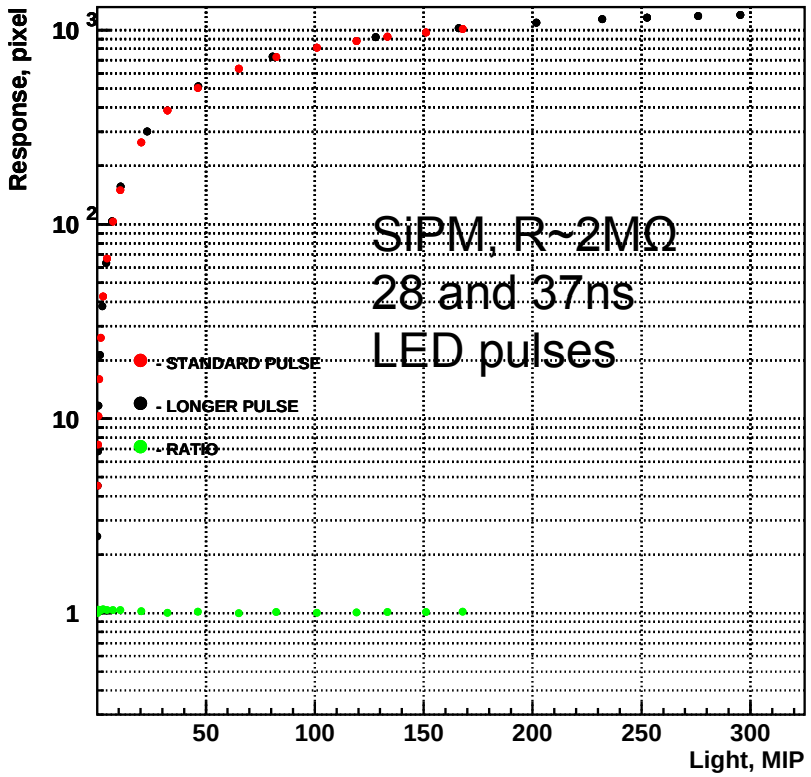

Green light efficiency
Overvoltage, V
- MPPC
- SIPM
- MRS APD
- MRS APD 2x2
Blue light efficiency
Overvoltage, V
- MPPC
- SIPM
- MRS APD
- MRS APD 2x2
Gain(x10^6)
Overvoltage, V
- MPPC
- SIPM
- MRS APD
Cross talk
Overvoltage, V
- MPPC
- SIPM
- MRS APD

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(1600pix) do not provide enough p.e. for direct readout of 3x30x30mm^3 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

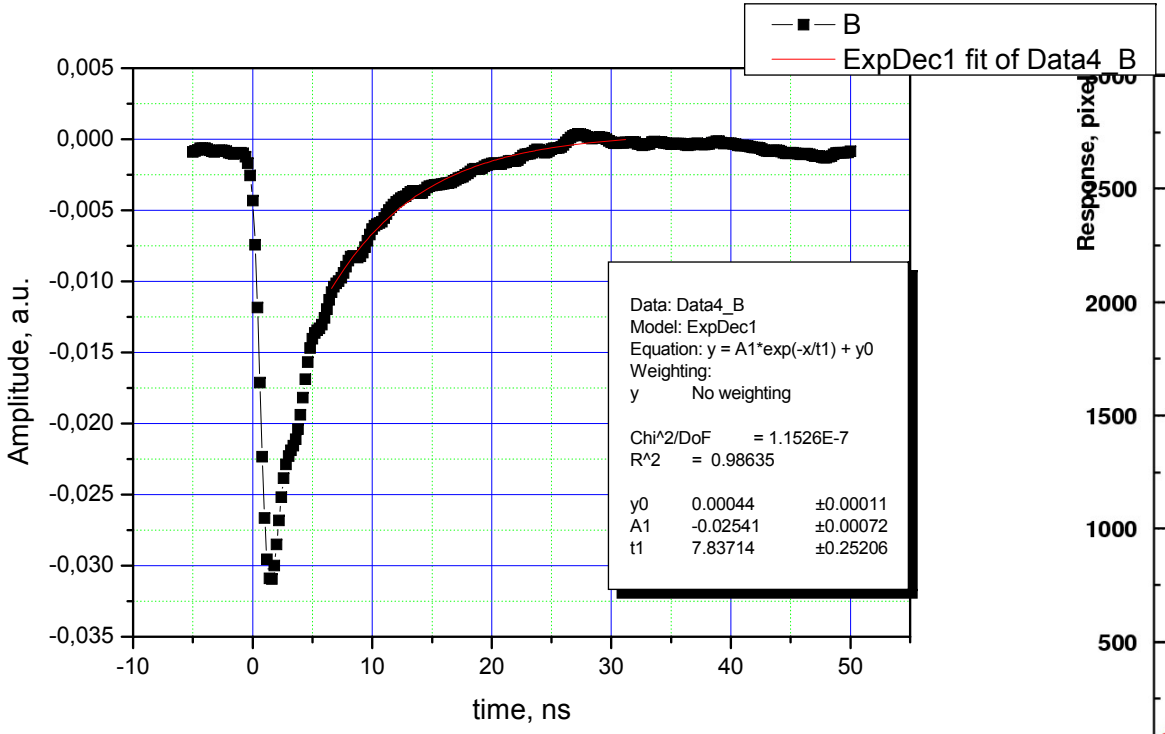


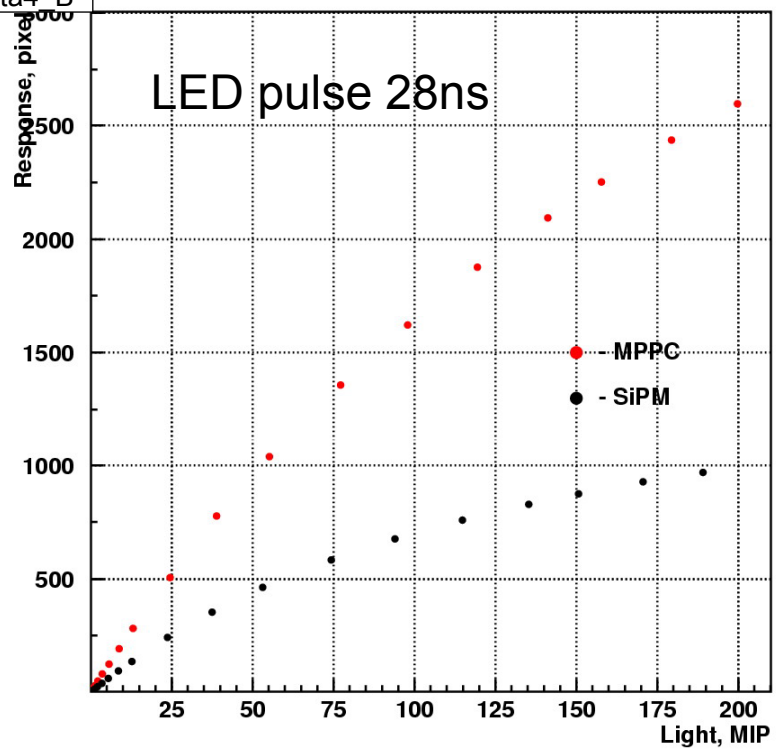


Larger size MPPC could be adequate for direct tile readout
since noise is not a limiting factor. Better scintillator and gluing could also help
However long term stability and radiation hardness should be demonstrated

MPPC fast decay time indicates small R and fast recovery time

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



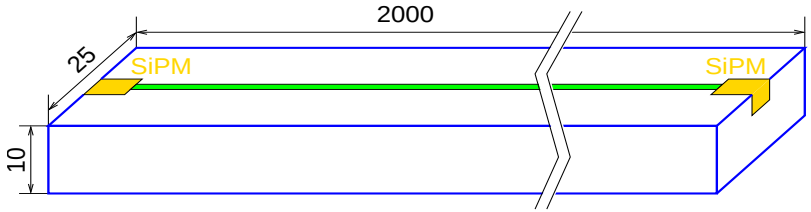


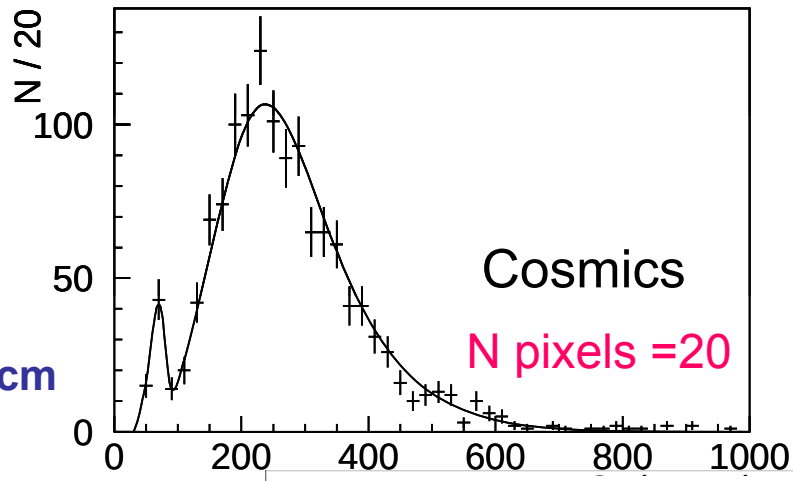
First Conclusions

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:

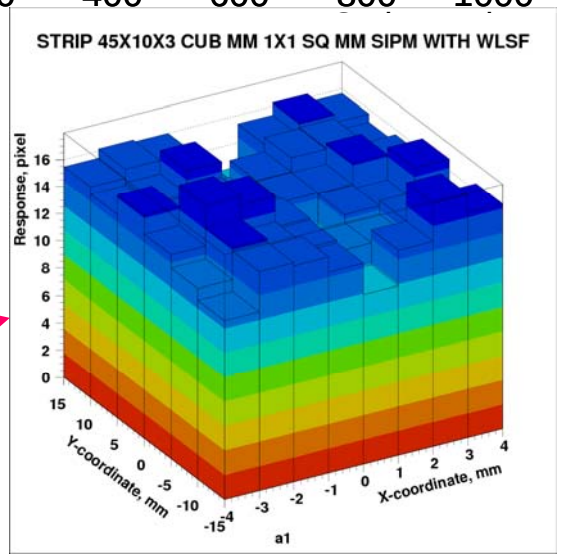
Achieved time resolution ΔT~2ns leads to ΔX~25cm

More experience will be gained from TCMT tests

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

(approach is extensively tested by Japanese groups)

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



Further R&D Activities

Coupling of tiles to PCB

Coupling of SiPMs to tiles

Ageing studies

Industrialization of SiPM production

Development of large size (9mm x 1.8mm) SiPMs for direct readout (1500 pixels 40x40μm^2)

Development of blue sensitive SiPMs

Summary

8 thousand scintillator tiles with WLS fibers and SiPM have been produced and carefully tested.

Scintillator tile calorimeter with WLSF and SiPM readout is a viable option for ILC for analog and semi-digital approaches.
The same technique can be used for ILC muon system

A lot of industrialization is required and we are working on this

Ideas for Tile – PCB and SiPM-tile connection are being tested

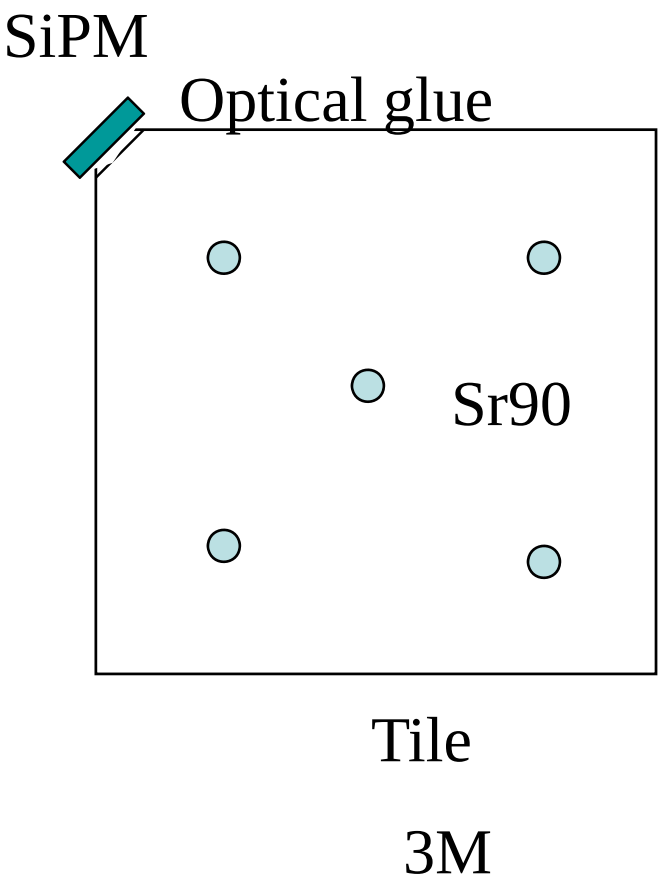
Possibility to use direct MGPD coupling is still to be demonstrated (uniformity and p.e. yield)

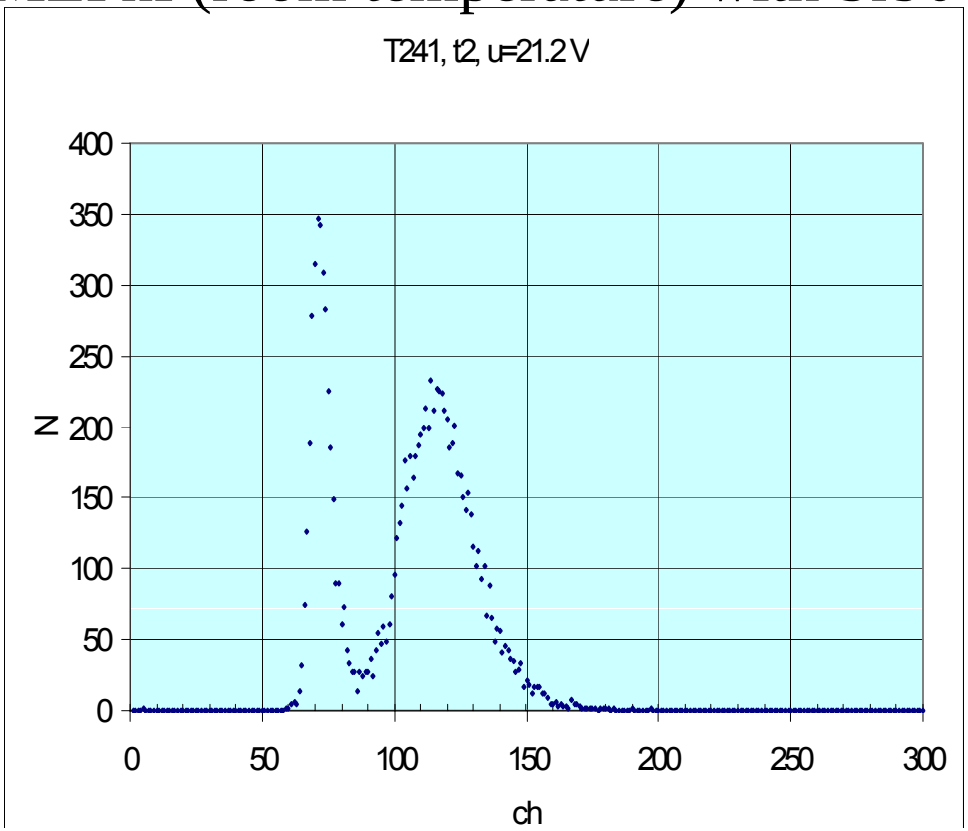
The field is developing very fast. Photo-detector properties improve every year.
We are working on MGPD industrialization and new MGPD types
The final choice of the Photo-detector depends on the overall optimization

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

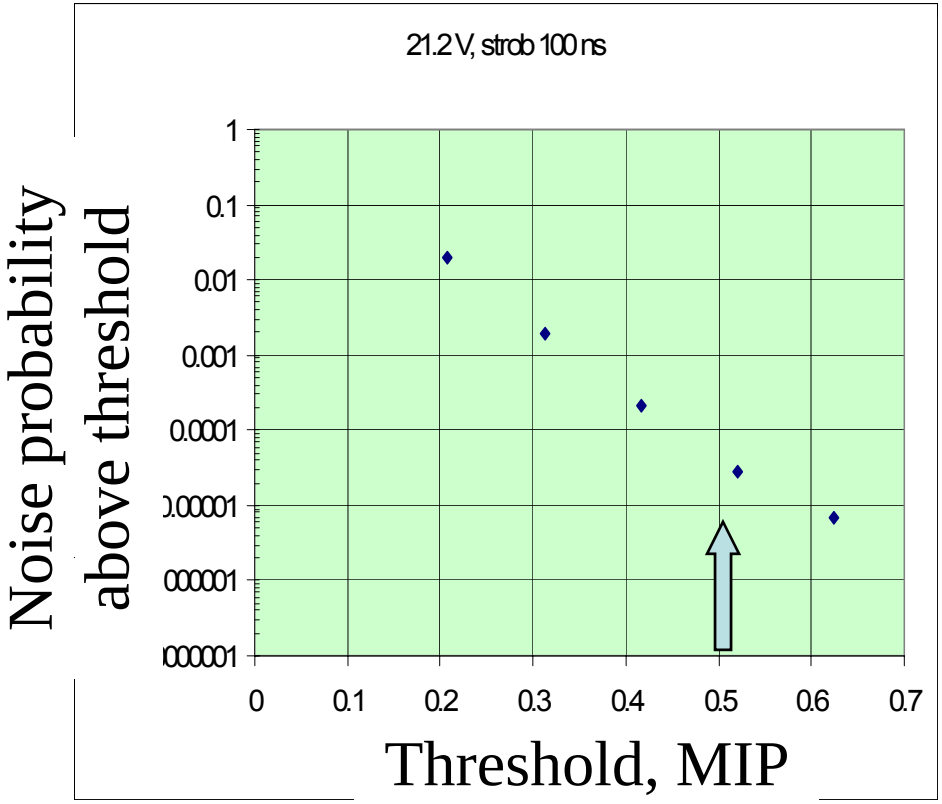


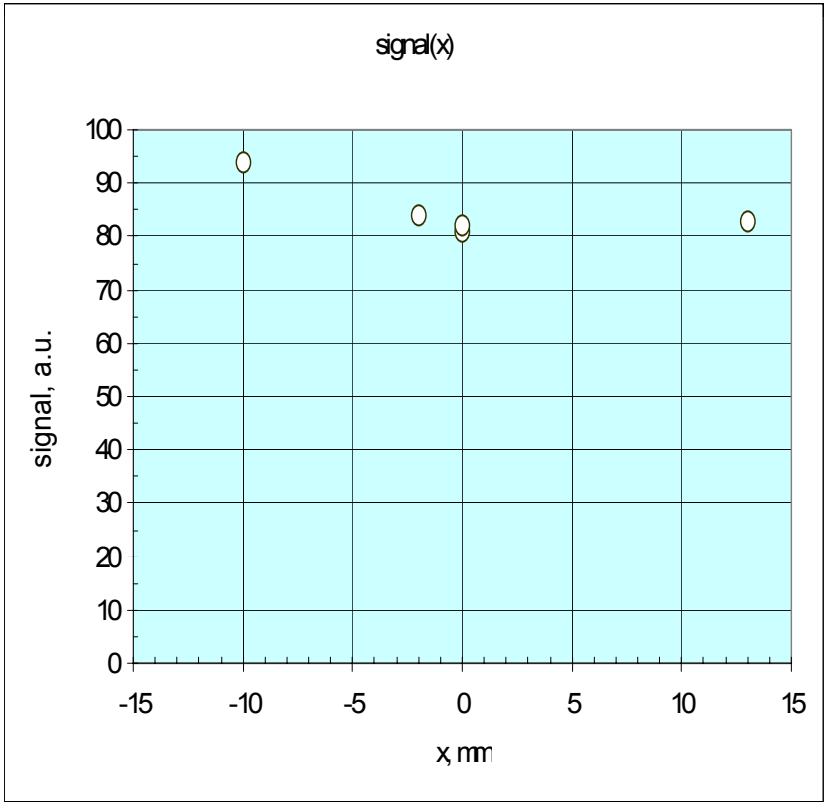


Efficiency of light registration appr18%

Appr. 30 fired pixels/MIP

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

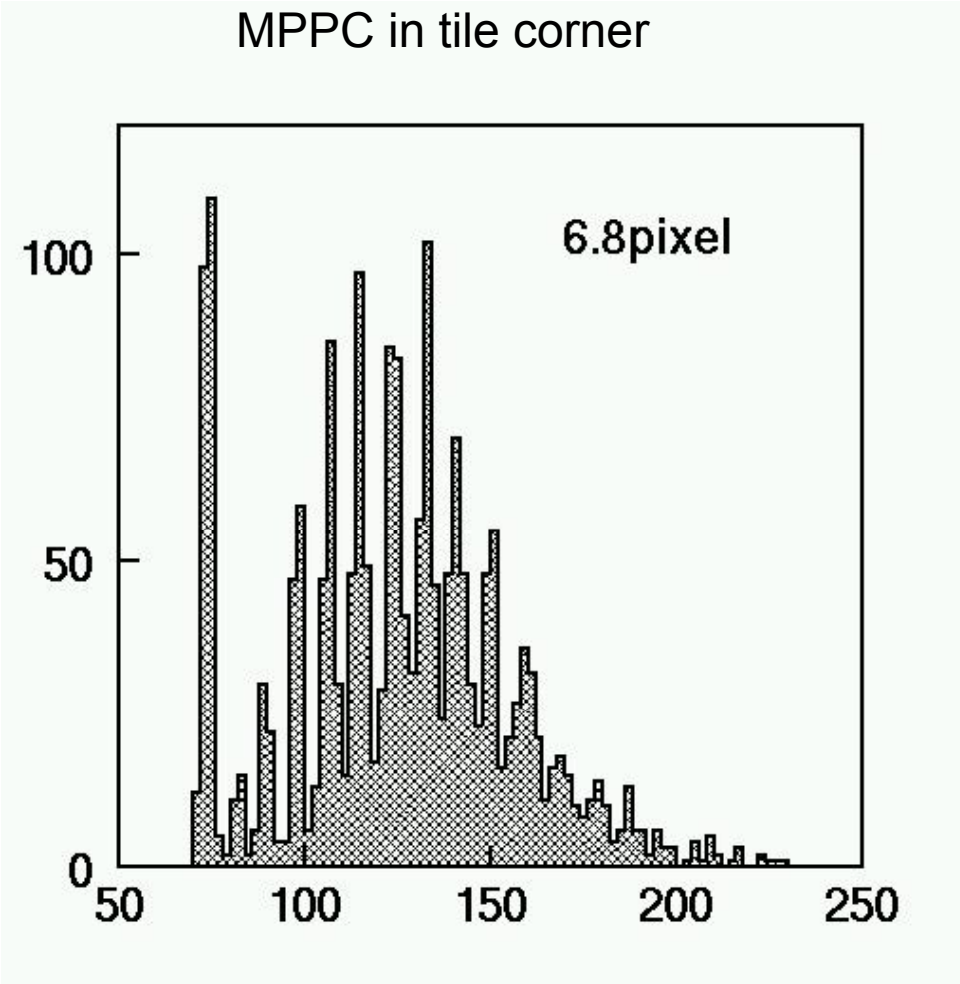




$3*10^{-5} * 8000=0,24$ events/prototype

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

Gluing increases photo-electron yield for 5 mm thick tiles



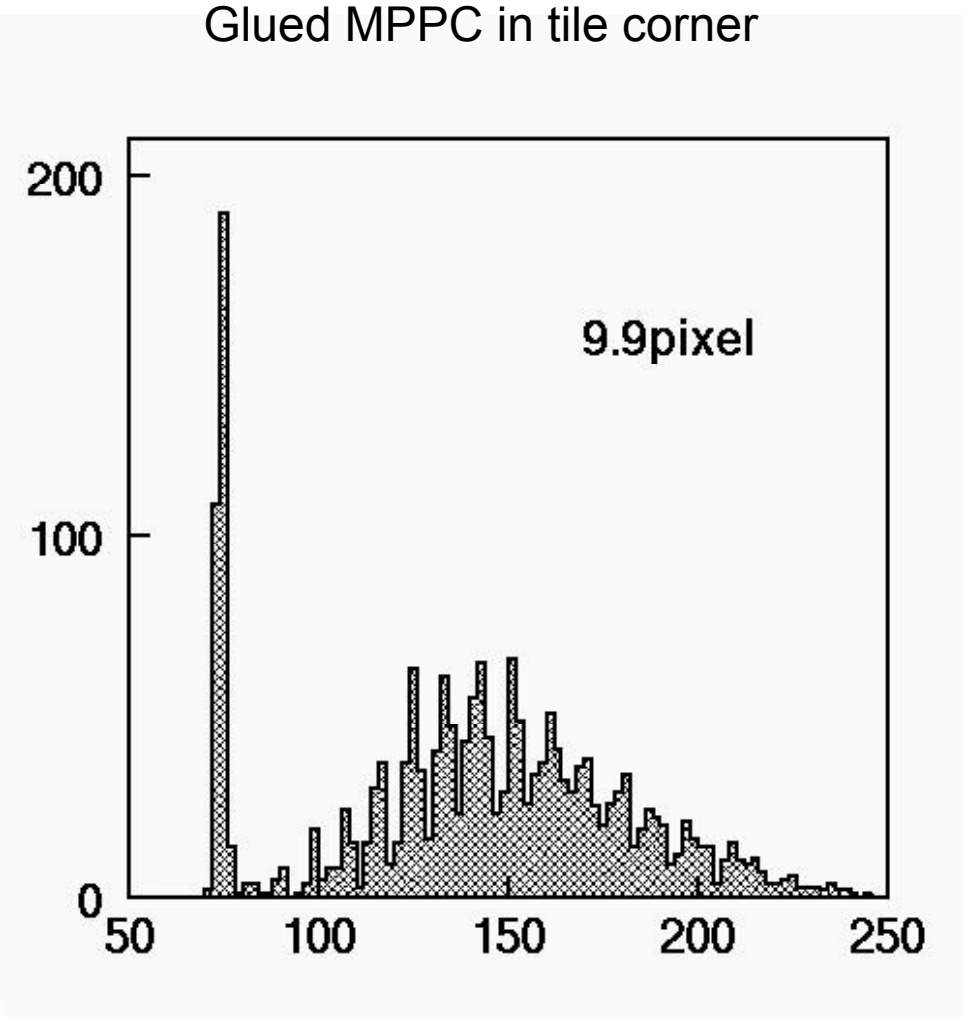


Photo-electron yield is too small for 60x60 mm^2 tiles (~2p.e. without gluing)