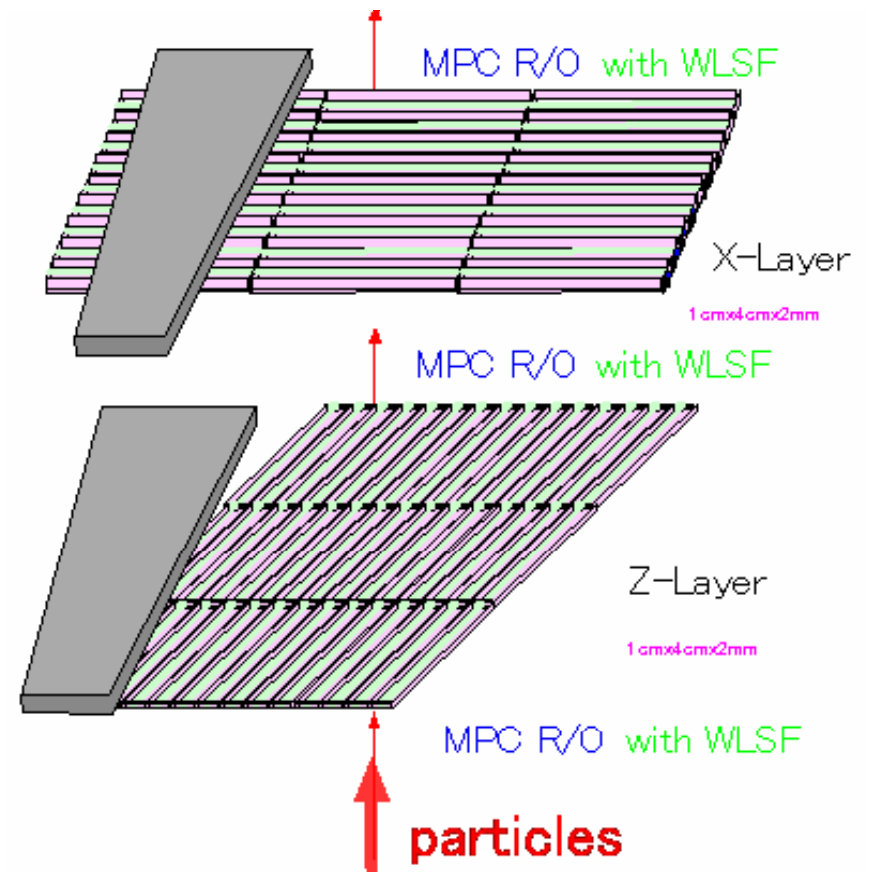
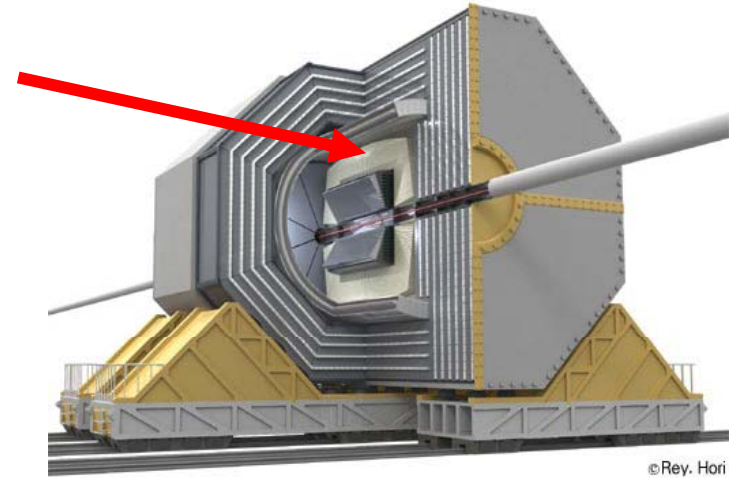


# Results of the Scintillator-ECAL Beam Test in 2007 at DESY

**Oct 21-26<sup>th</sup> 2007 ALCPG meeting @ FNAL**  
**Satoru Uozumi (Shinshu University)**  
***for the GLD Calorimeter Group / CALICE Collaboration***

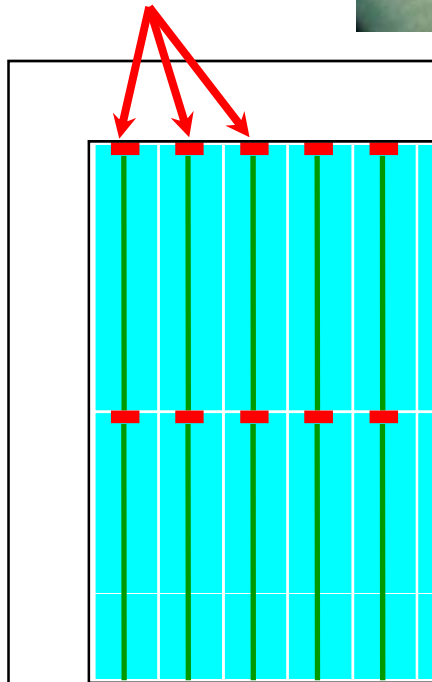
# The GLD Calorimeter

- Sampling calorimeter with W/Pb-scintillator sandwich structure with WLS fiber readout.
  - Scintillator strip structure to achieve fine granularity (strip size  $\sim 1 \times 4.5 \times 0.2$  cm)
  - Full MPPC Readout
    - Huge number of channels ( $\sim 10$ M for ECAL,  $\sim 4$ M for HCAL)
    - Placed inside 3T magnetic field
    - MPPC (Pixelated Avalanche Photodiode from Hamamatsu) is an ideal solution for readout sensor
  - World's first trial to test such type of calorimeter.
    - MPPC is a new photon sensor, does it really work for calorimetry?
- **Beam Test !**



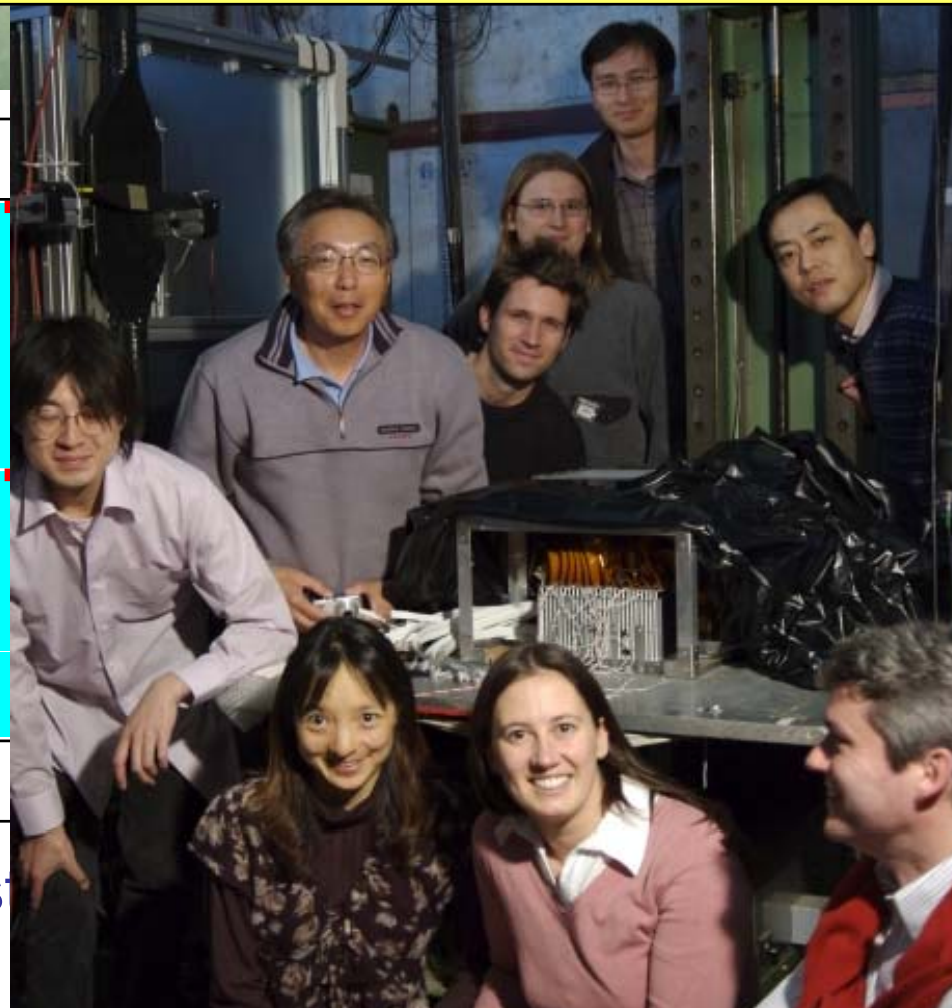
In 2007 Spring beam test has been performed at DESY using 1-6 GeV  $e^+$  beams. People from KNU, Kobe, Shinshu, Tokyo with great help from DESY people

(1600 pixels)



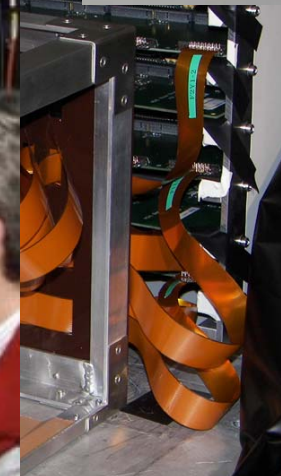
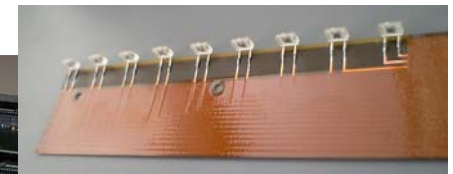
Frame

Scintillator s  
(1 x 4.5 x 0.3)

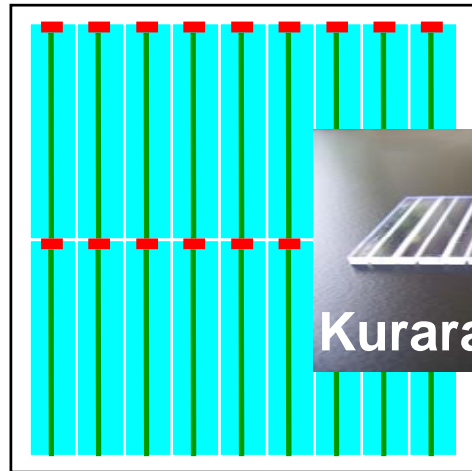


Tungsten  
(3.5 mm thick)

Scintillator layer  
(3 mm thick)



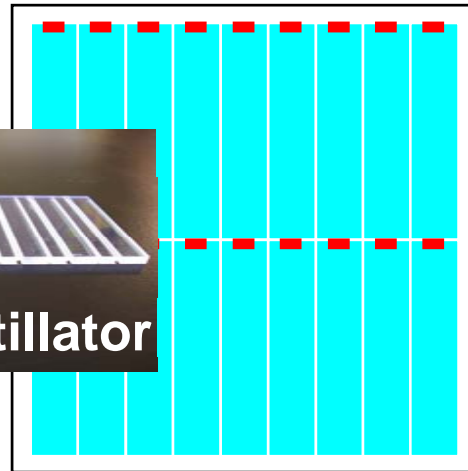
# 3 Types of Modules



Kuraray scintillator

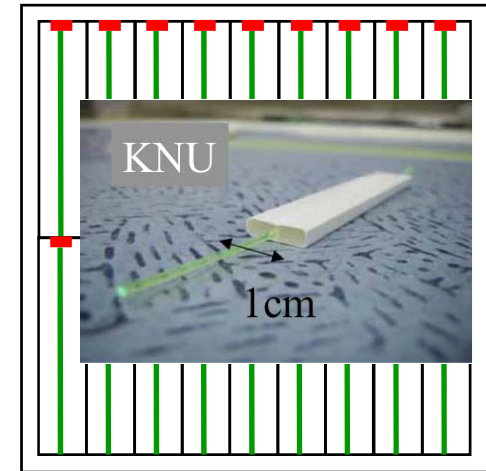
① WLSF readout

13 layers



② Direct readout

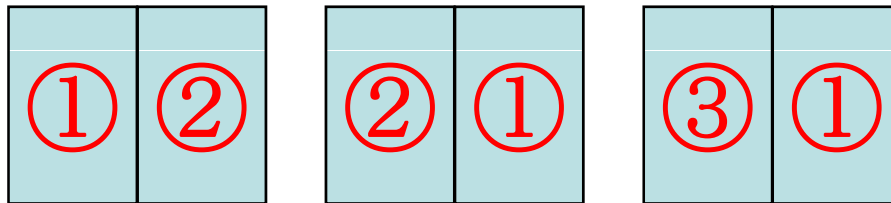
13 layers



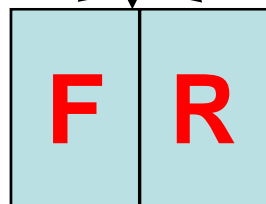
③ WLSF readout

by extrusion technique

13 layers



**Beam** →

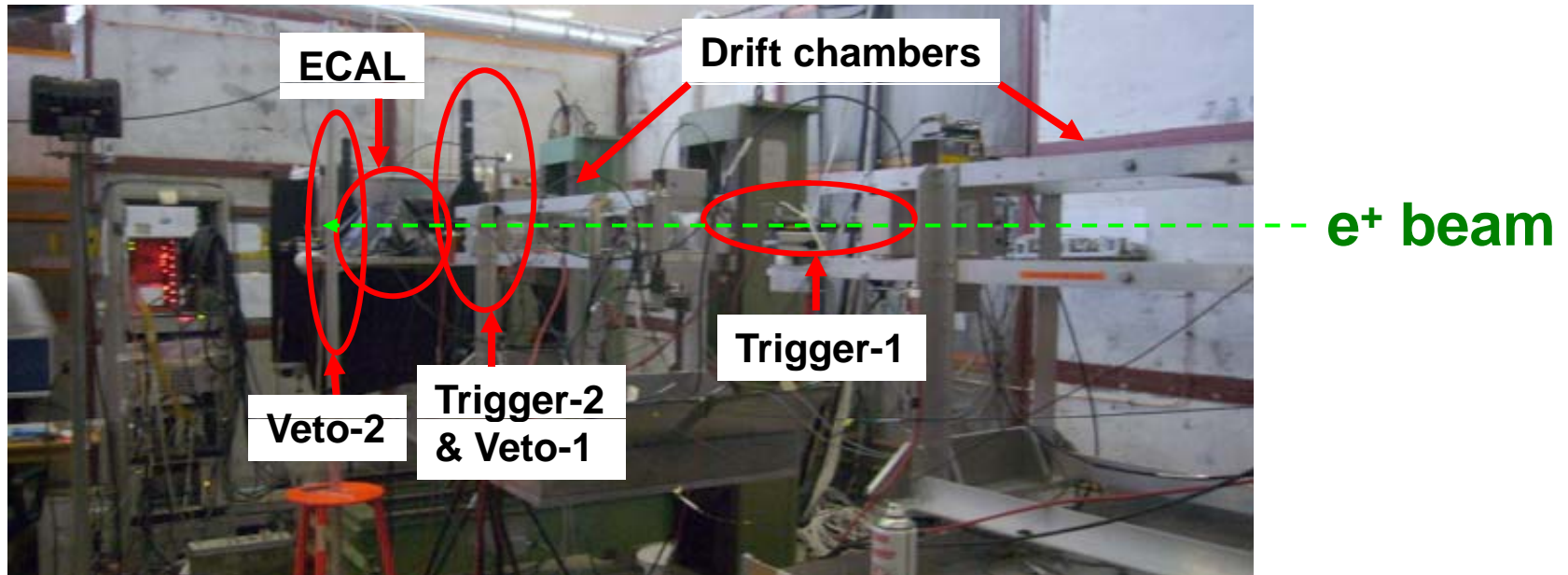
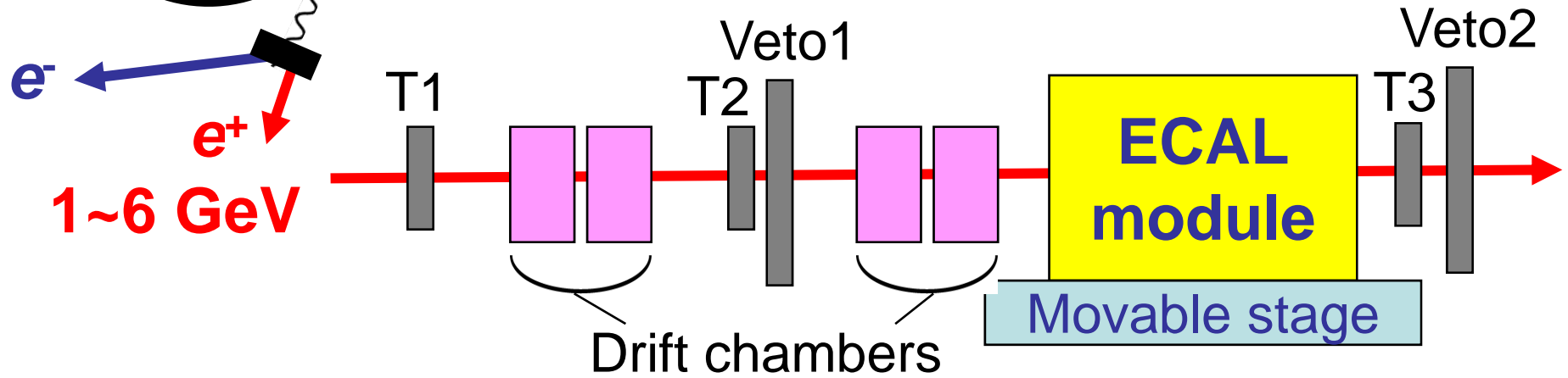


13 + 13 layers

- For ① and ②, well-known Kuraray scintillator is used.
- Extruded scintillator for ③ is very important for cost reduction.



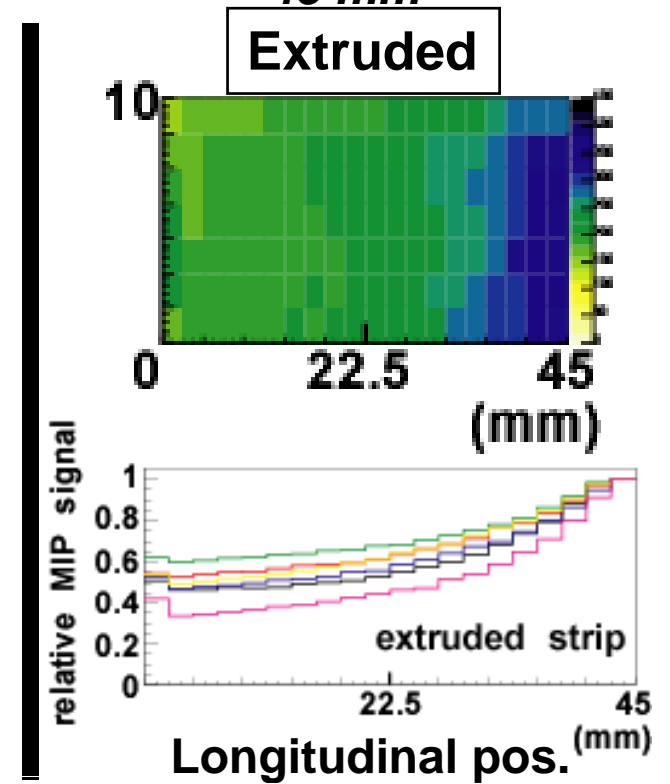
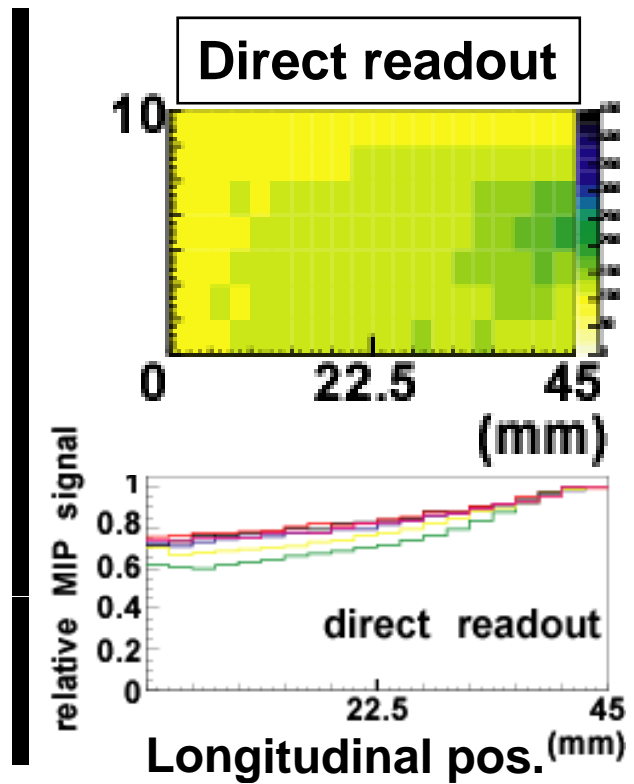
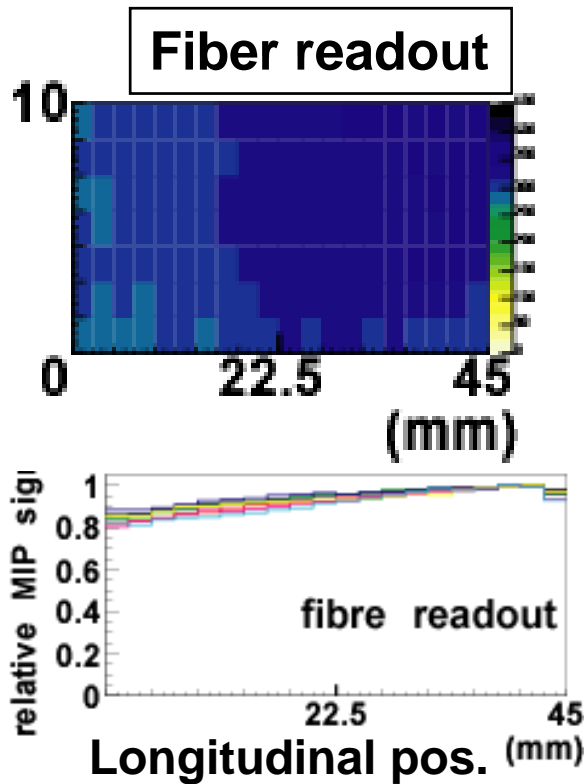
# The DESY beam-test line





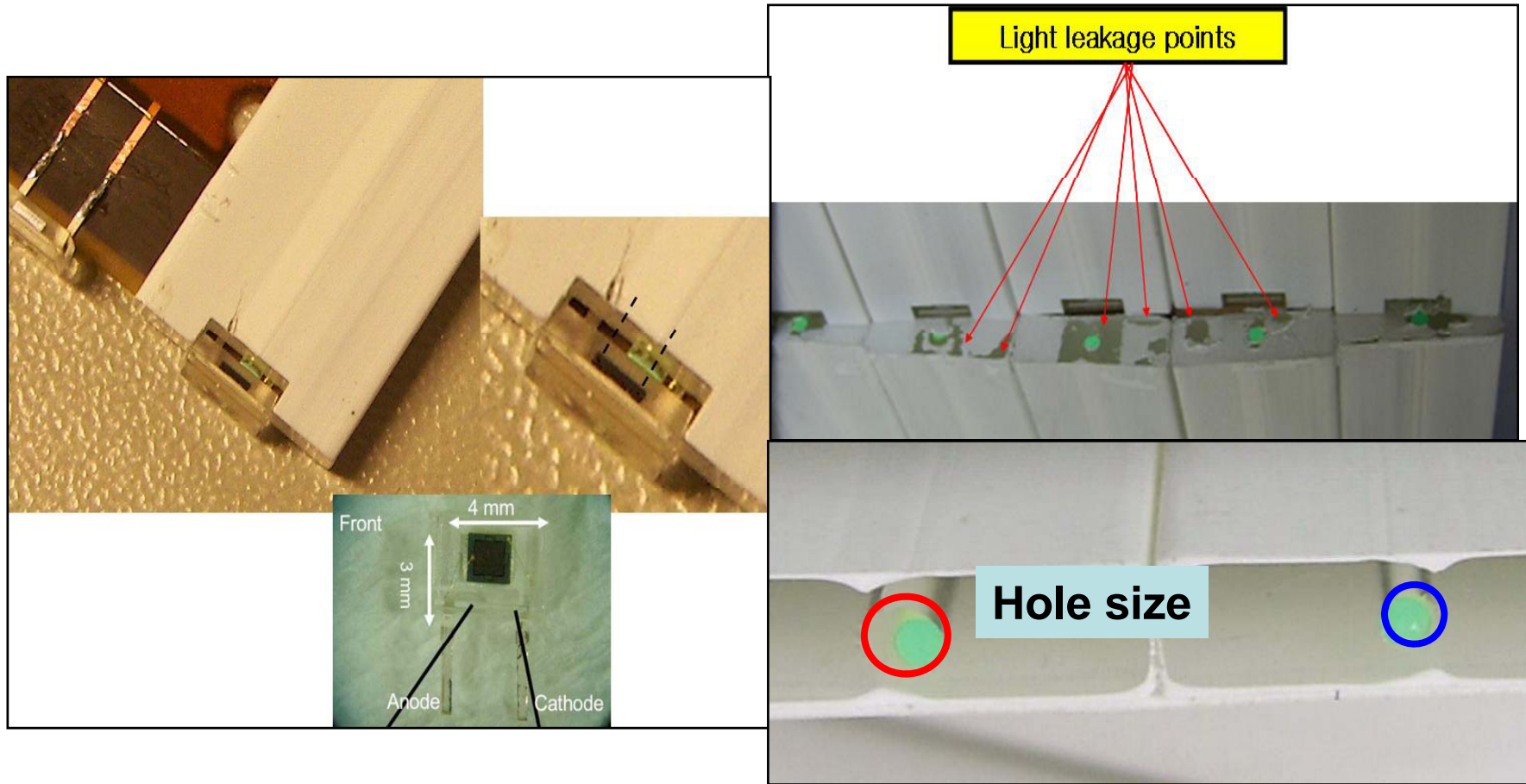
# Uniformity of MIP Response inside Strip

MIP data is taken without tungsten absorbers. 10 mm  45 mm



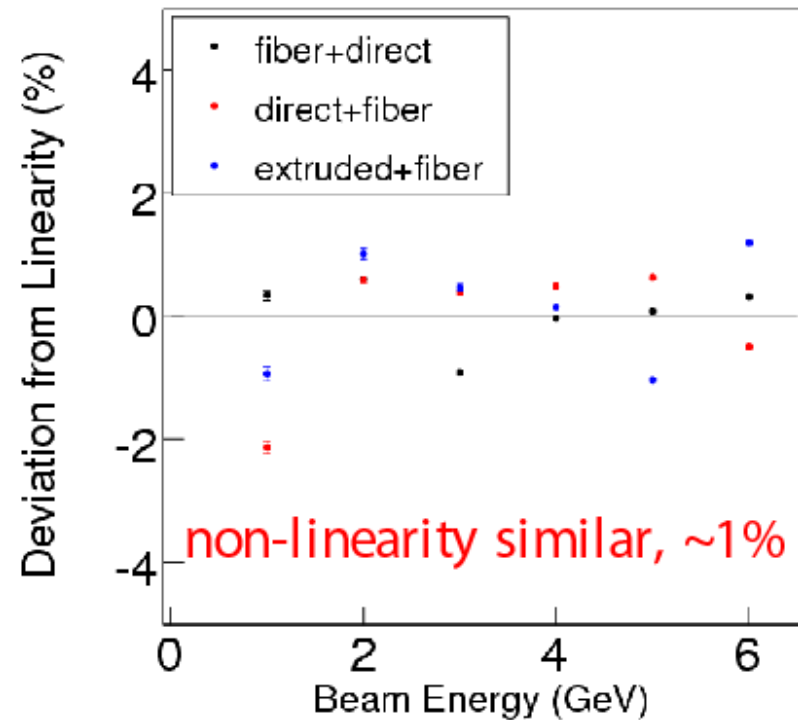
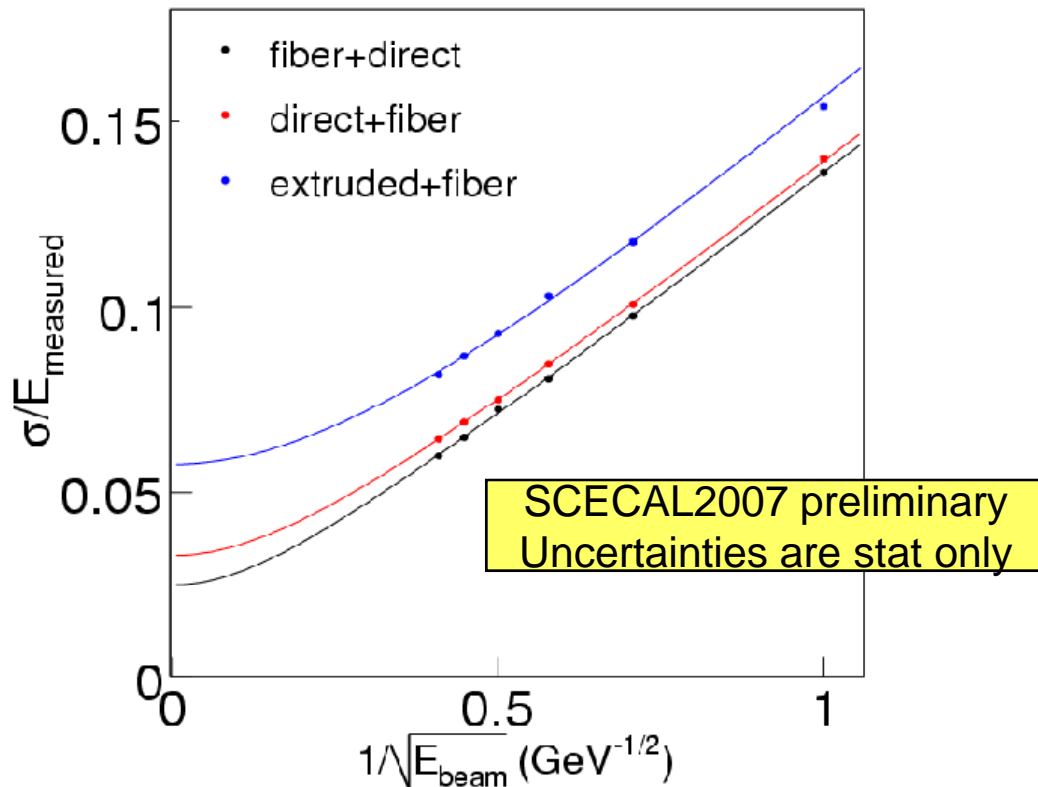
- Kuraray fiber readout strip shows the best uniformity.
- Direct readout strip is a little worse than fiber readout.
- Extruded shows significant non-uniformity (50% light attenuation at strip edge).

# What was happening with the extruded scintillator ?

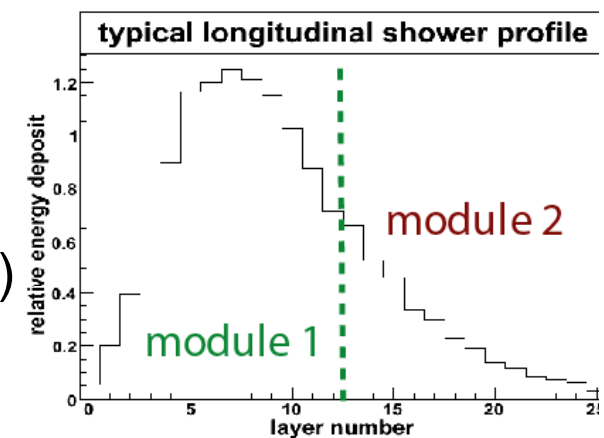


- Some problems were found.
- Production of improved version will be done soon and its performance will be checked at KEK beam test in next month.

# Energy Resolution, Linearity



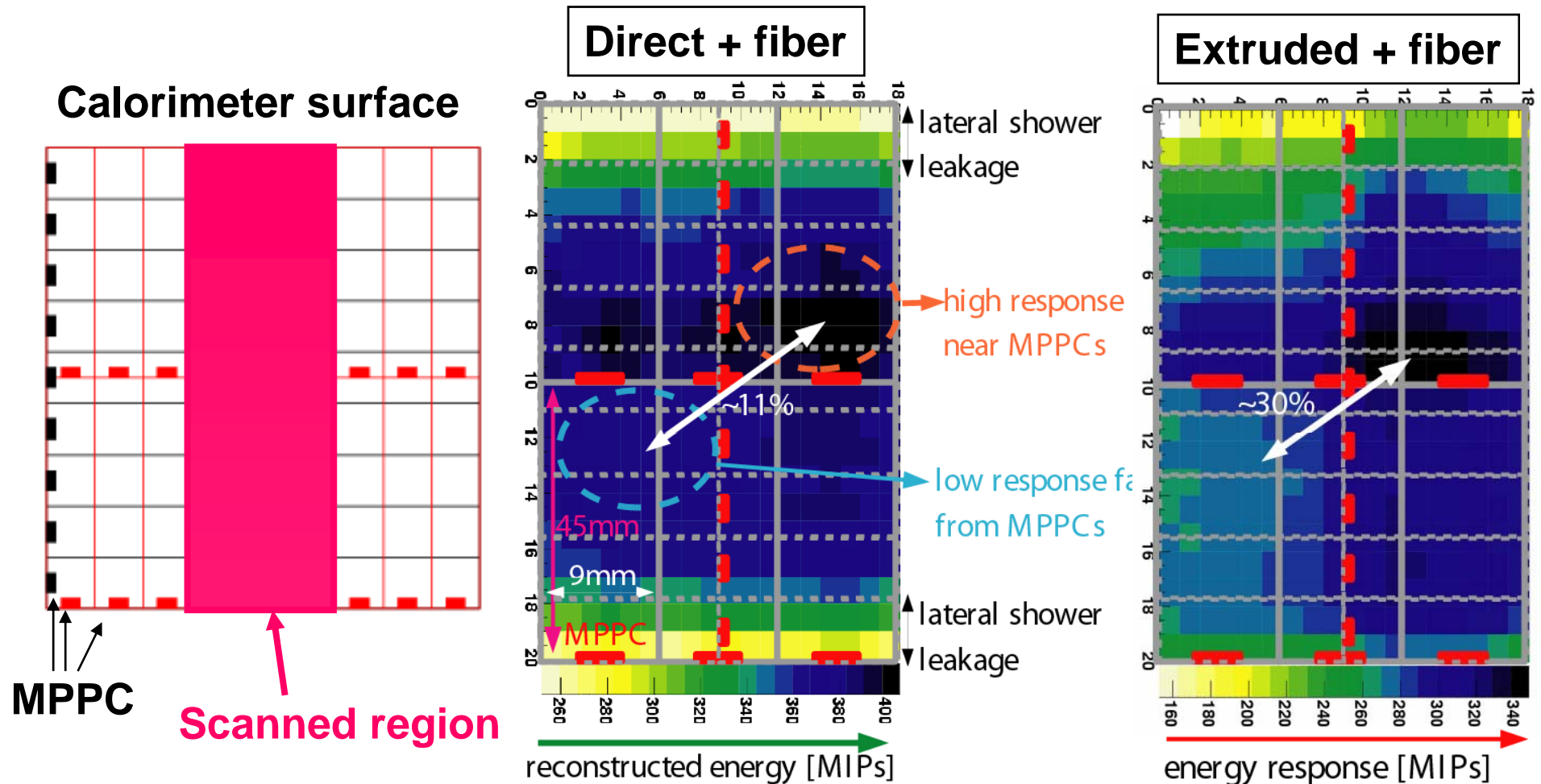
- Energy resolution  $\sim 13\%/\sqrt{E} \oplus 2.5\%$  with fiber+direct config, almost consistent with expectation.
- Significant constant term with extruded + fiber config (Investigating, may due to strip non-uniformity?)
- Deviation from linearity  $< 2\%$ , even without saturation correction of the MPPC response.





# Position Dependence : Response to EM Shower

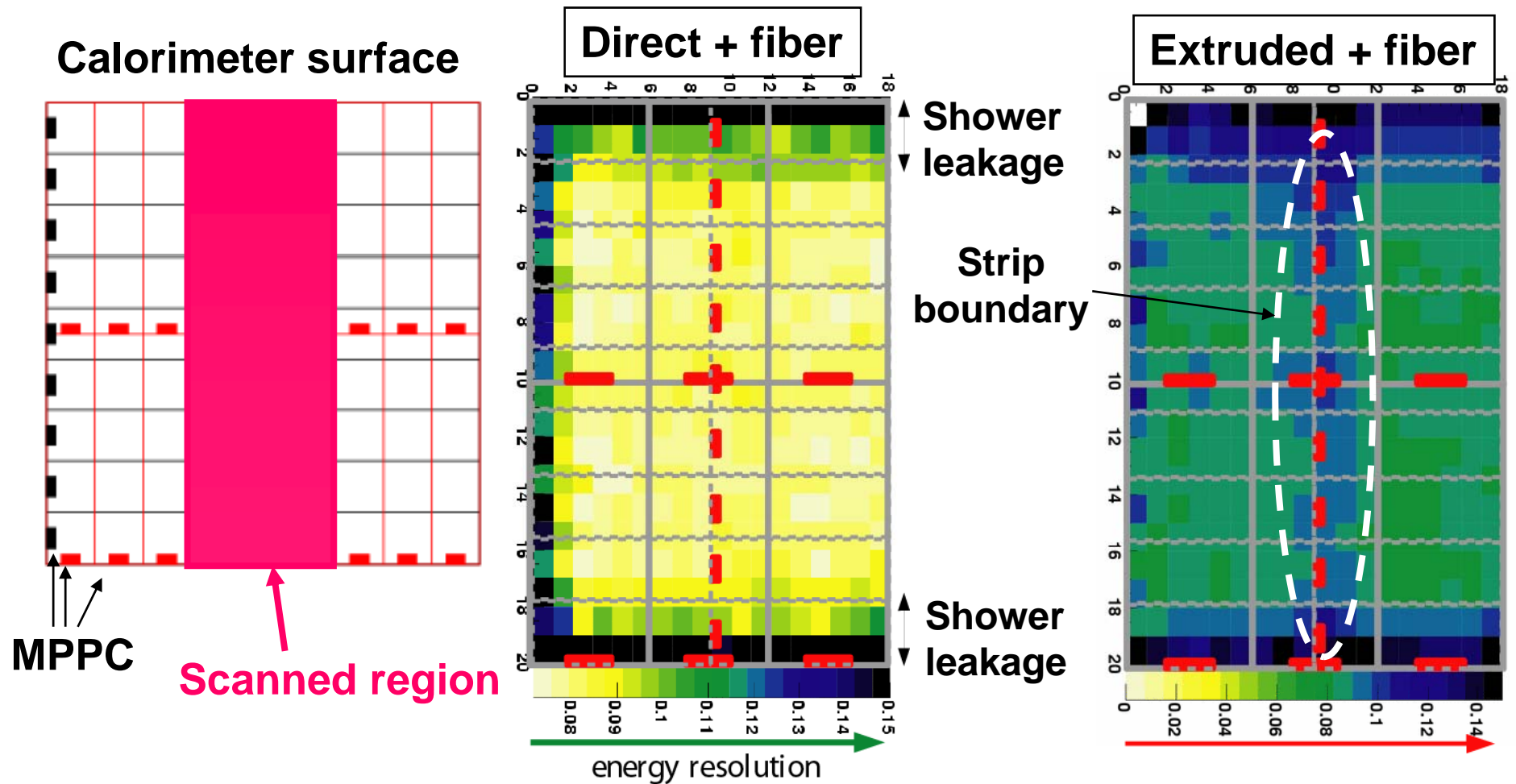
(taken with 3 GeV positron beam)



- ~ 11 % of peak-to-peak-variation with direct+fiber config.
- ~ 30 % variation with extruded + fiber config due to strip non-uniformity.

# Position Dependence : Energy resolution

(taken with 3 GeV positron beam)



- Just a small variation is observed in almost of region.
- Extruded+fiber config shows a little worse resolution around strip boundary.

# Summary

- Scintillator-strip EM calorimeter prototype is built and tested at DESY using 1-6 GeV positron beams.
- Preliminary result proves that the calorimeter is working well !
  - Energy resolution looks reasonable
  - Linearity is excellent even without MPPC saturation correction.
  - Non-uniformity of strip response gives some effects to calorimeter performance.
- Further analysis is ongoing:
  - MPPC saturation correction, etc...
  - Comparison with GEANT Simulation for precise understanding of the data.

# Future Beam Tests

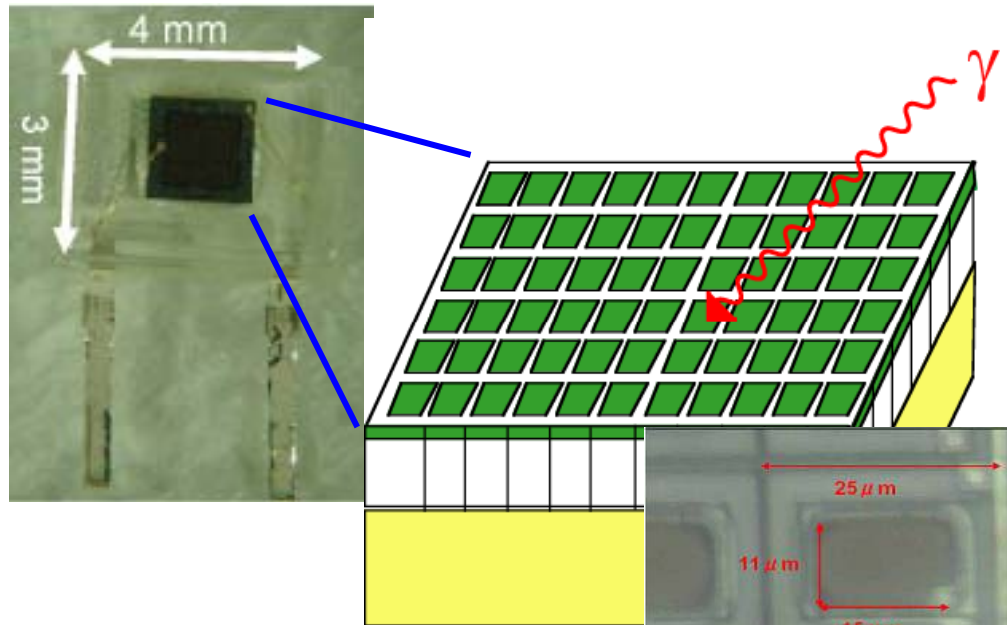
- KEK beam test to check improved extruded scintillator.
  - in Nov 2007 at KEK new electron beamline.
  - Scan strips with MIP to check the response uniformity.
- FNAL beam test in 2008 with larger prototype.
  - Test performance with various (e,K, $\mu$ , $\pi$ ...) beams.
  - Try  $\pi^0 \rightarrow 2\gamma$  reconstruction.
  - Combined test with Analog HCAL.

# Backups

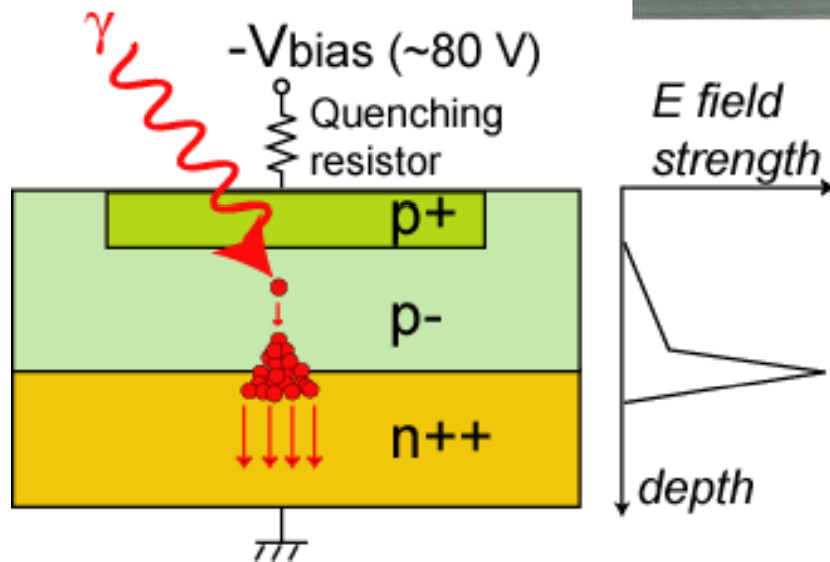


# The Multi Pixel Photon Counter (MPPC)

- A Geiger-mode avalanche photo-diode with multi-pixel structure -



- Belongs to Pixelated Photon Detector family (same as SiPM)
- Manufactured by Hamamatsu Photonics.
- High Gain ( $10^5 \sim 10^6$ )
- Good Photon Detection Efficiency ( $\sim 15\%$  with 1600 pixel)
- Compact (package size  $\sim$  a few mm)
- Low Cost
- Insensitive to magnetic field
- Dark noise exists ( $\sim 100$  kHz)
- Input vs output is non-linear



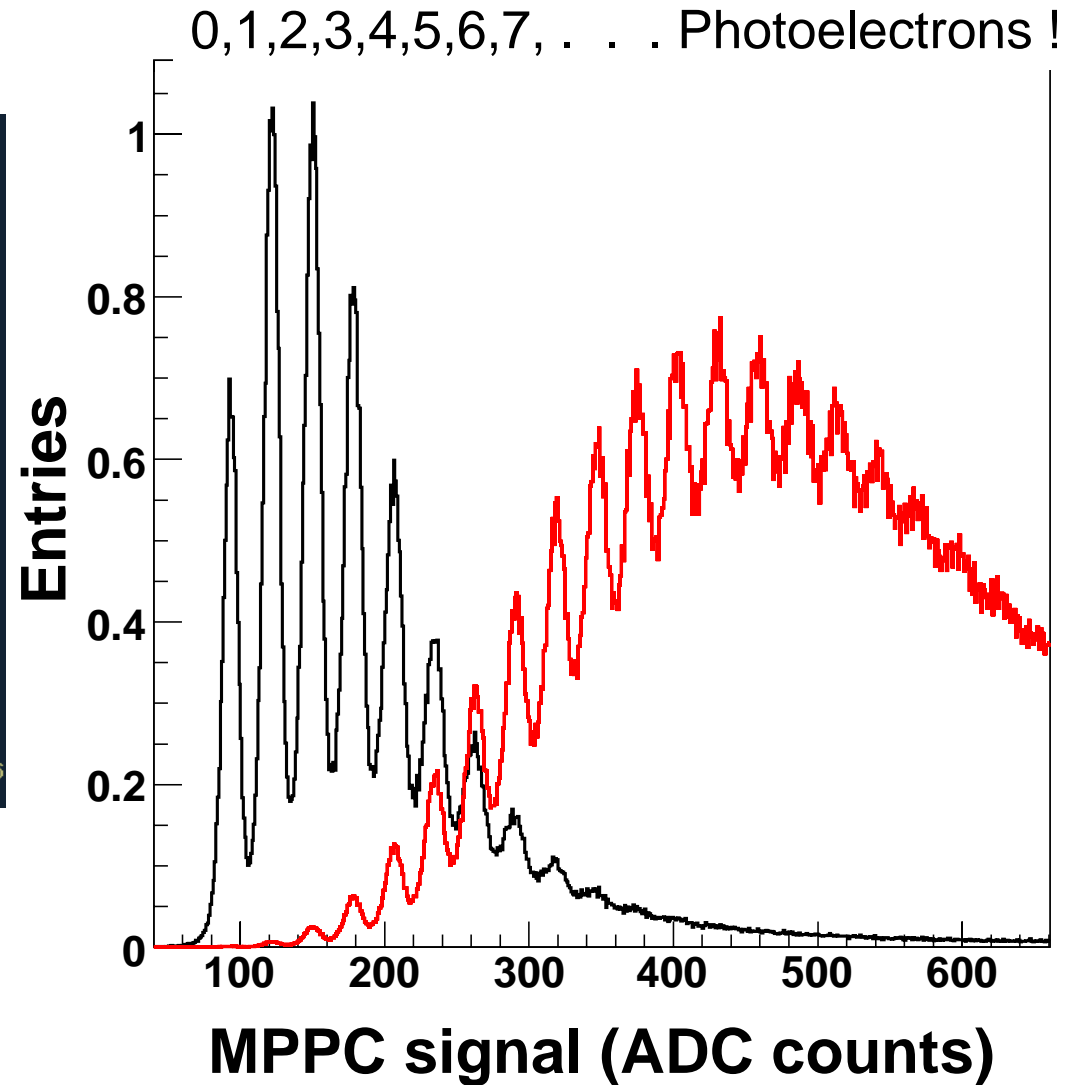
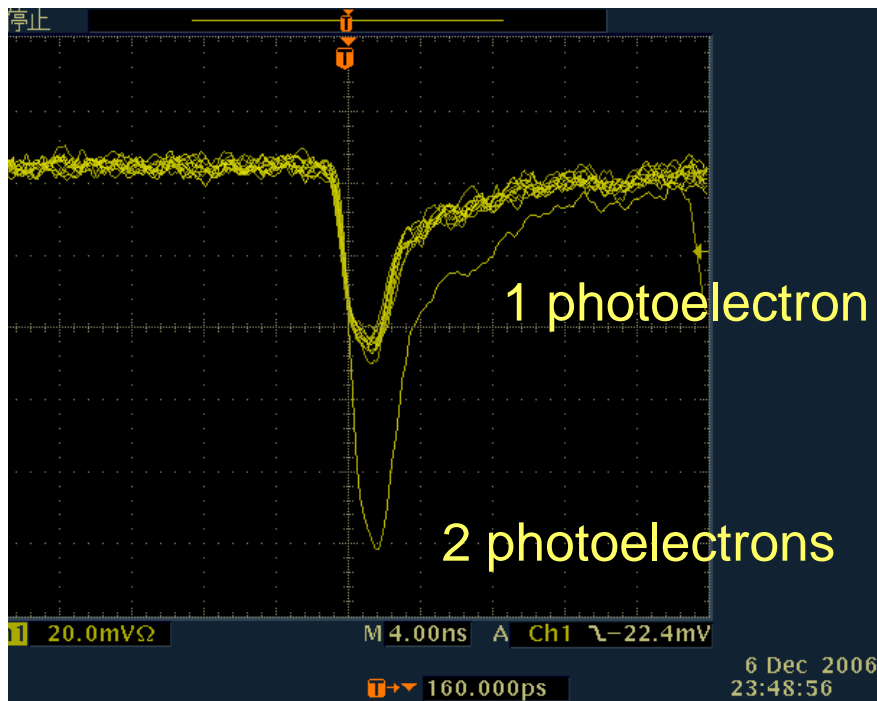
We are developing and studying the 1600-pixel MPPC with Hamamatsu for the GLD calorimeter readout.

## The MPPC has lots of advantages

	Photomultiplier	MPPC
Gain	$\sim 10^6$	$10^5 \sim 10^6$
Photon Detection Eff.	0.1 ~ 0.2	$\sim 0.2$ for 1600 pix. MPPC
Response	fast	fast
Photon counting	Yes	Great
Bias voltage	$\sim 1000$ V	$\sim 70$ V
Size	Small	Compact
B field	Sensitive	Insensitive
Cost	Very expensive !	Not very expensive
Dynamic range	Good	Determined by # of pixels
Long-term Stability	Good	Unknown
Robustness	decent	<b>Unknown, presumably good</b>
Noise (fake signal by thermions)	Quiet	Noisy (order of 100 kHz)

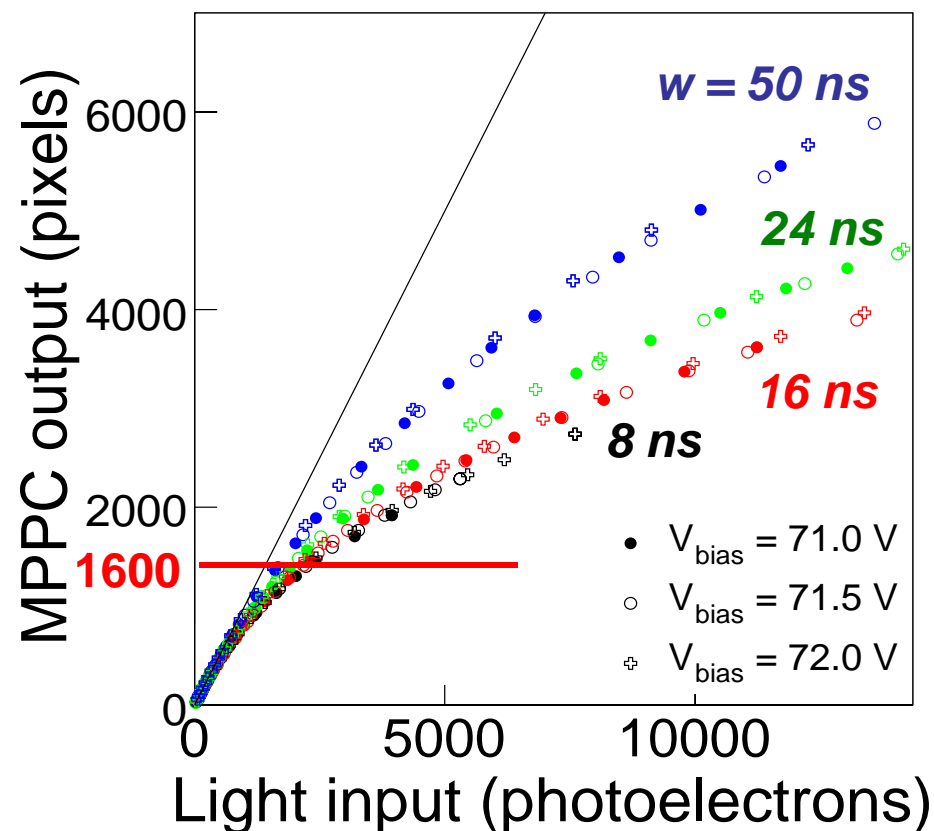
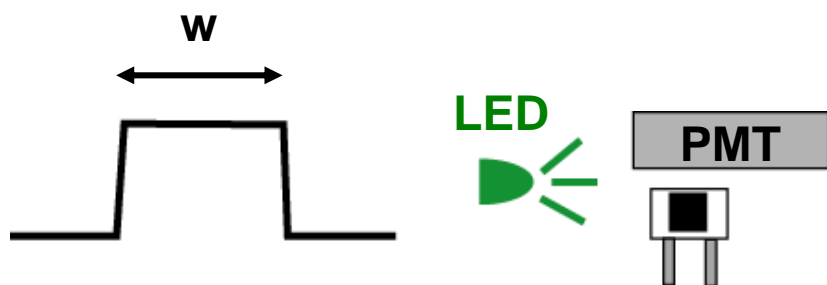
The MPPC is a promising photon sensor,  
and feasible for the GLD Calorimeter readout !

# Excellent photon counting ability



# Response Curve

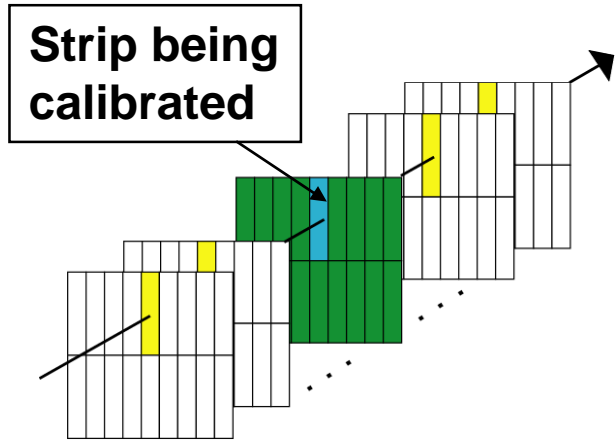
Response curves measured with various width of LED pulses



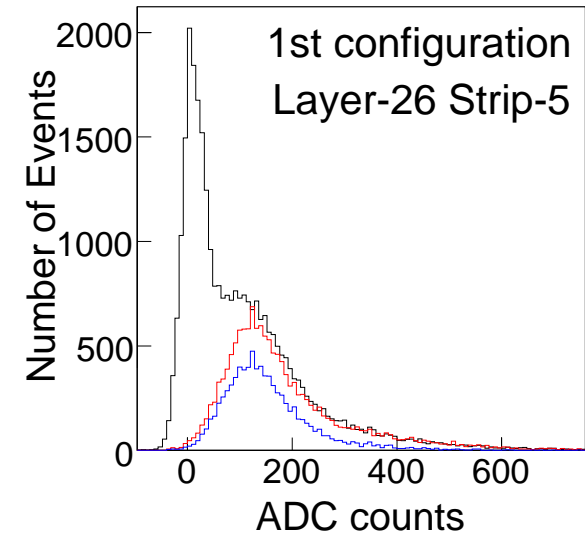
- Linearity of 1600 pixel MPPC is not limited by number of pixels thanks to quick recovery !
- No significant influence from changing bias voltage.
- Time structure of the light pulse gives large effects in non-linear region.
- Knowing time structure of input light is important.

# MIP Calibration

- MIP data for strip-by-strip energy calibration is taken without absorber.

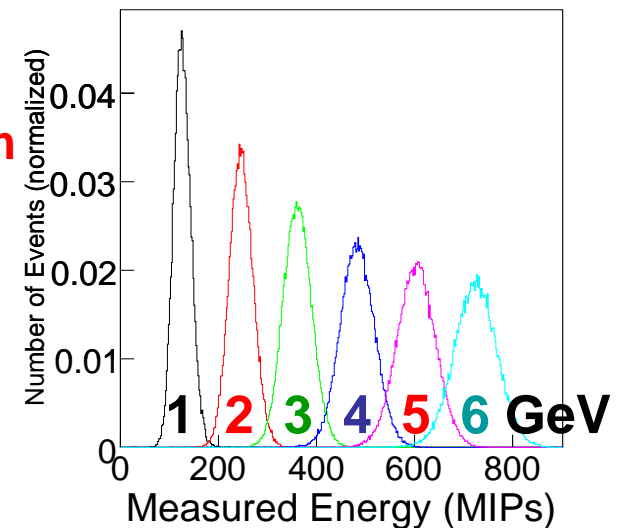
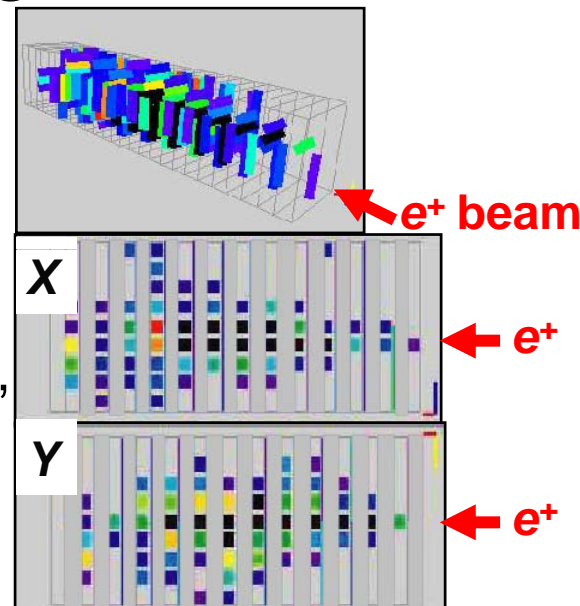


**Black ... Quality cuts only**  
**Red ... Yellow strips have non-pedestal signal**  
**Blue ... Green strips have no signal**



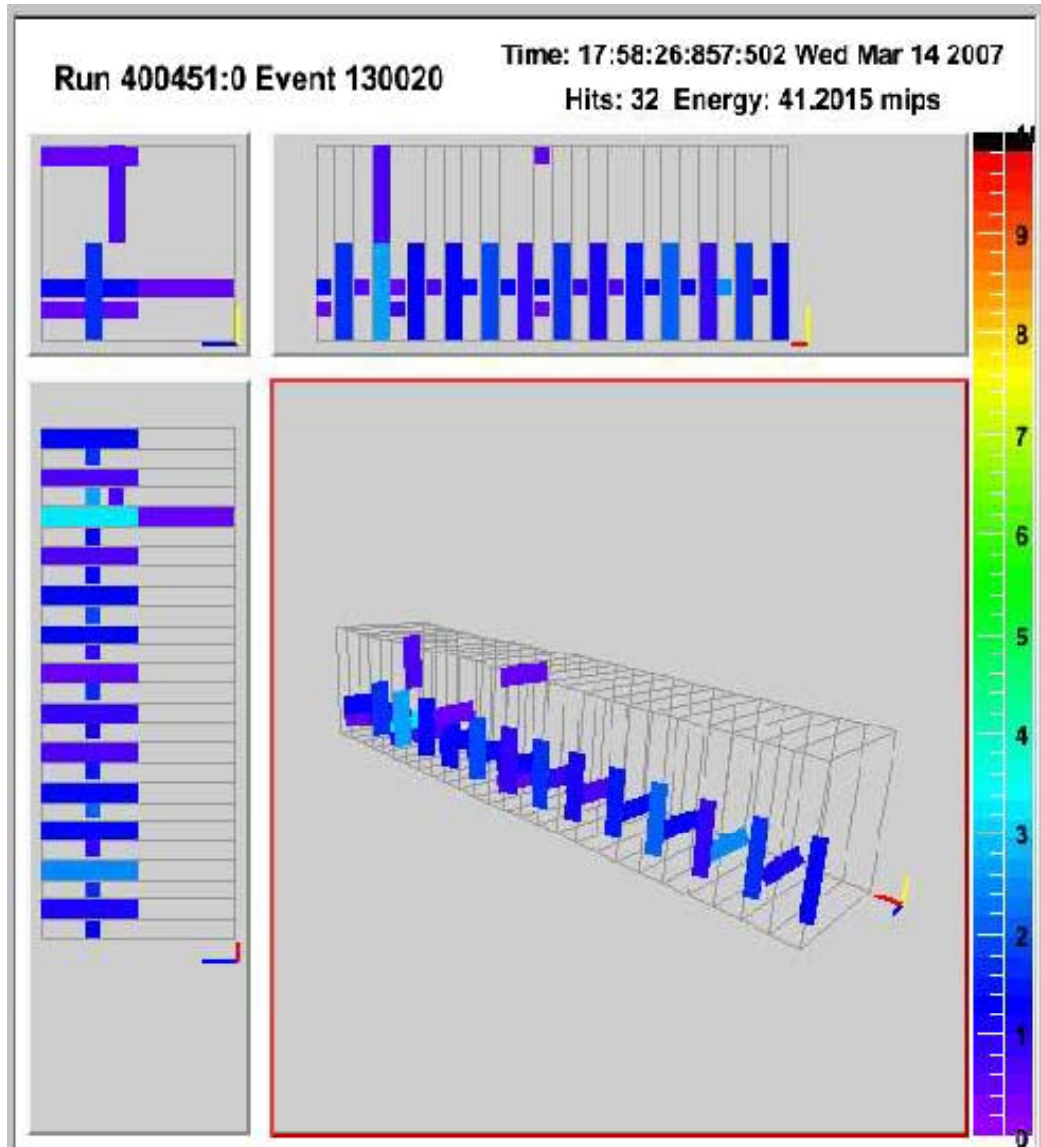
## Electromagnetic Shower Events

- Shower events taken with absorber and 1-6 GeV  $e^+$  beams.
- Signal from all the channels are summed after calibration, and energy spectra are obtained.





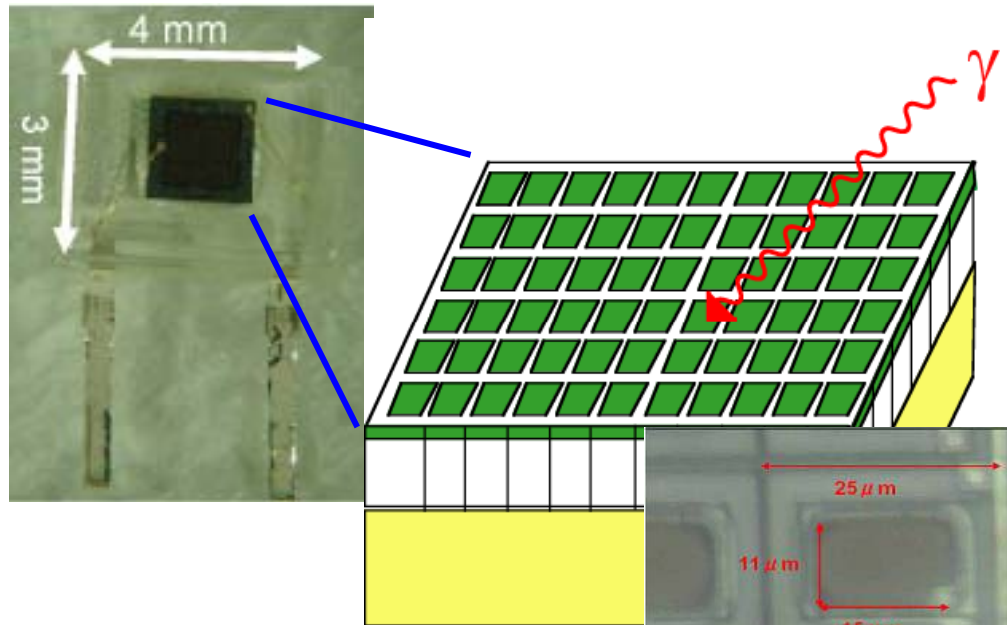
# MIP Response Calibration



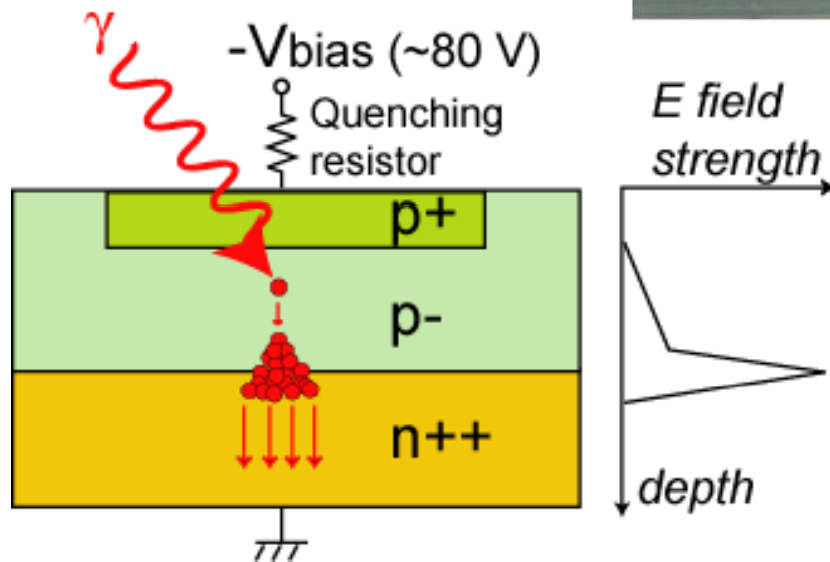
- Calibrate response of each strip using MIP signal.
- Positron beam events taken **without** tungsten.
- Center of all the strips has been scanned.

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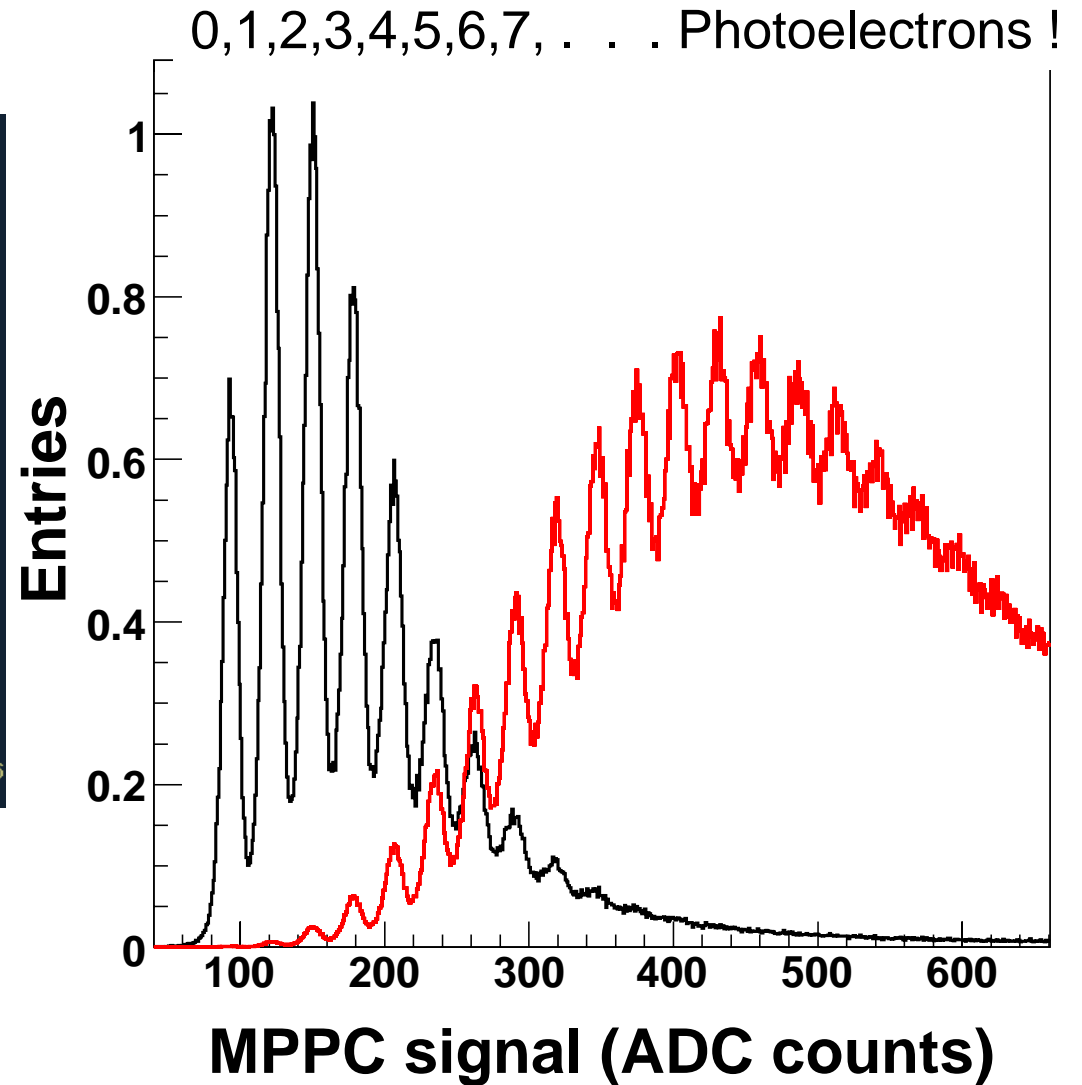
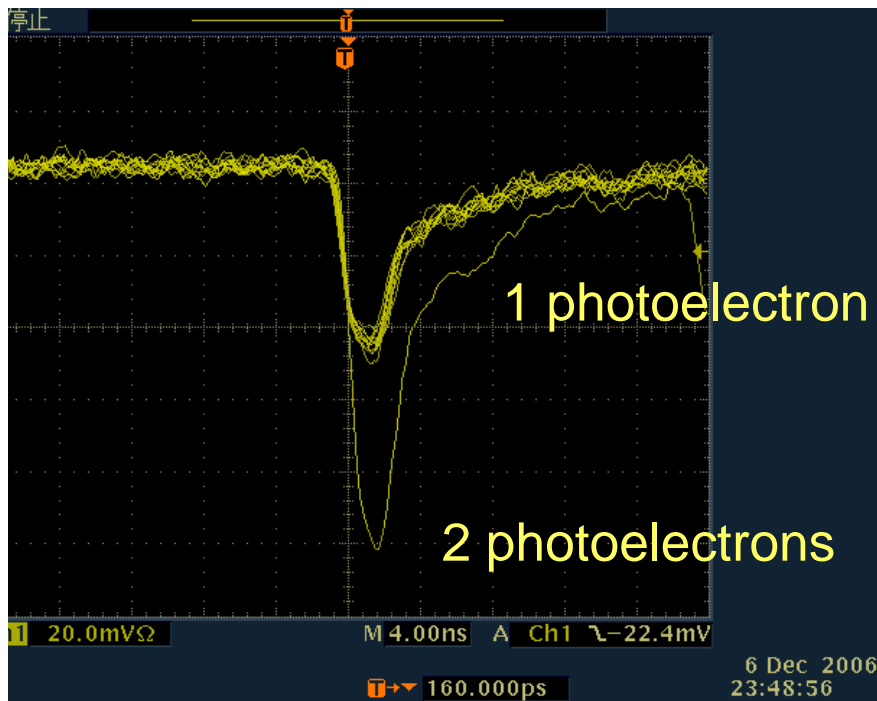
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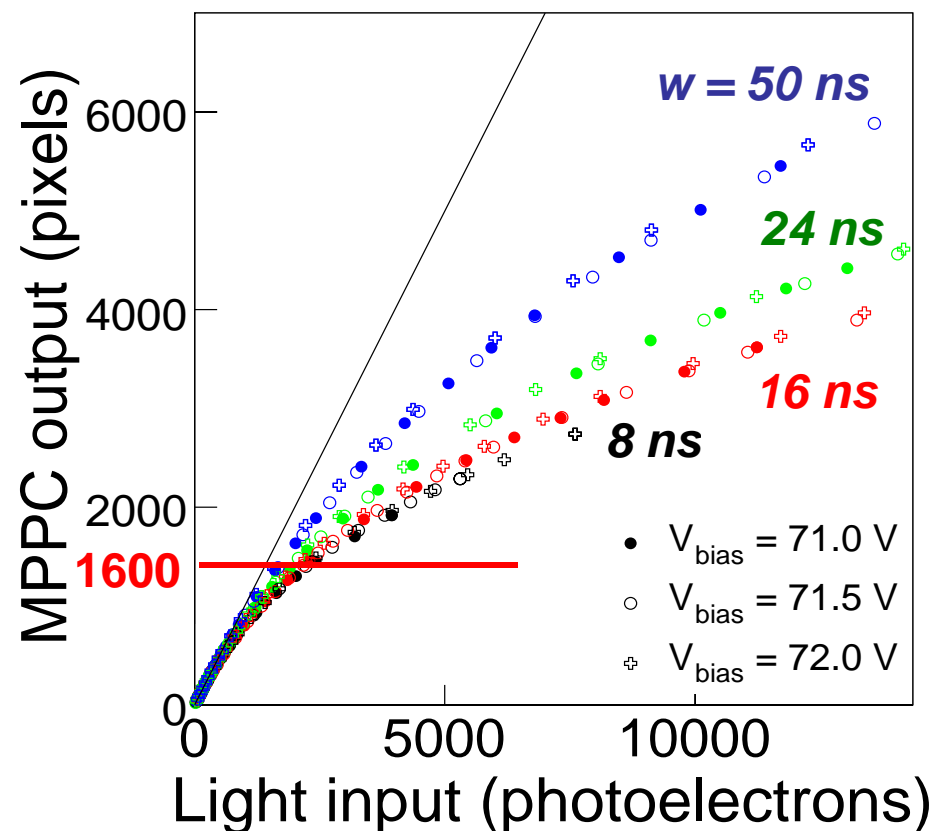
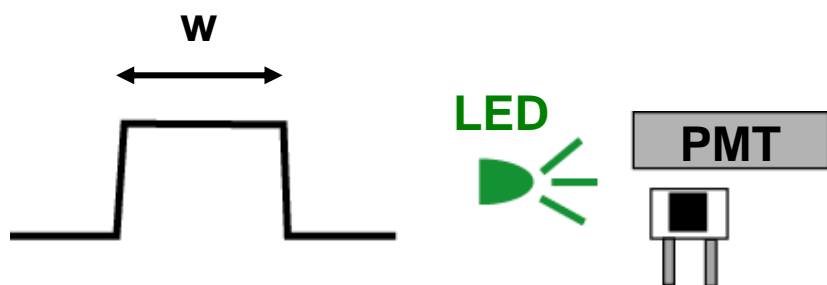
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