The Multi-Pixel Photon Counter for the GLD Calorimeter Readout

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Contents

The GLD Calorimeter

- Sampling calorimeter with Pb/W - scintillator sandwich structure with WLSF readout
- Particle Flow Algorithm (PFA) needs particle separation in the calorimeter

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- Fine granularity with strip/tile scintillator

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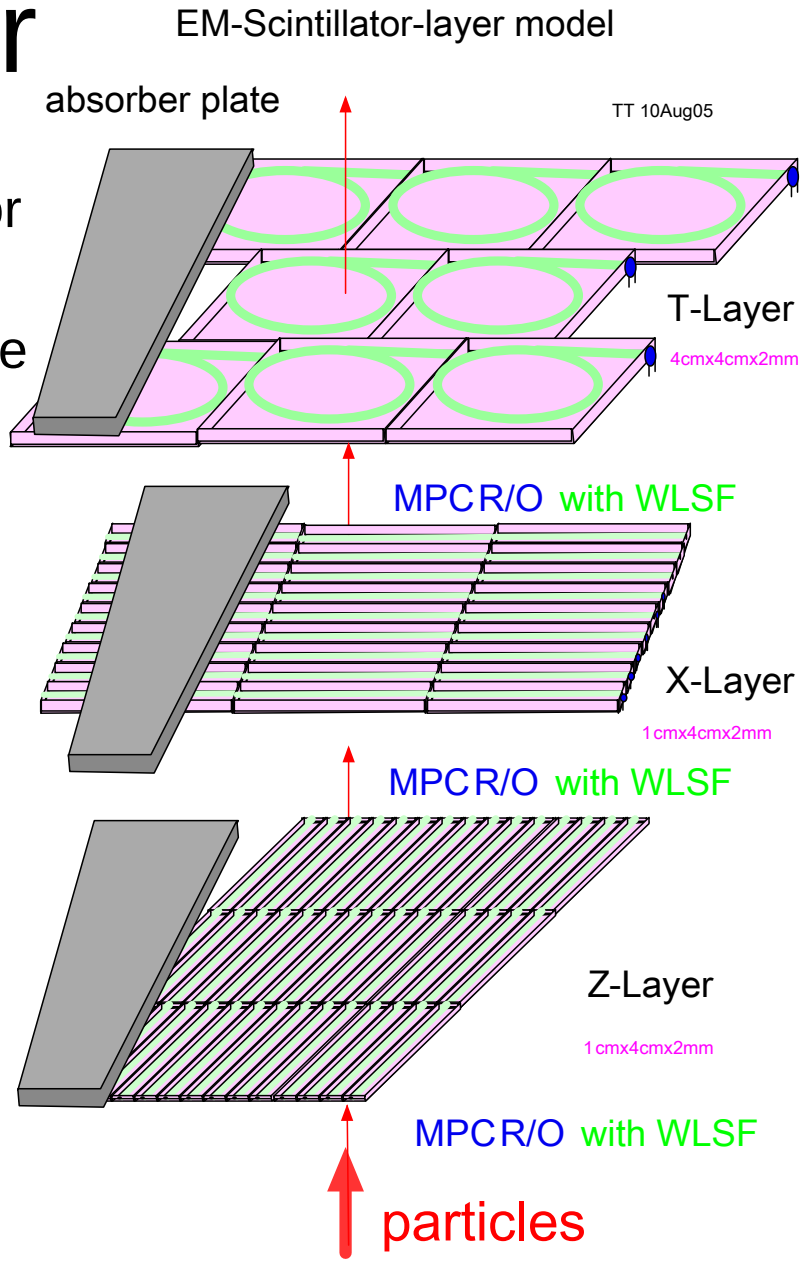
- Huge number of readout channels
  - ~10M (ECAL) + 4M (HCAL) !
  - 10k for muon detector
- Used inside 3 Tesla solenoid

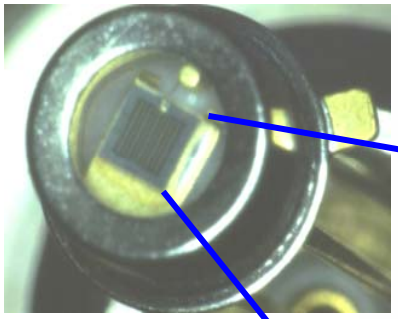
Need new photon sensor which is compact and low-cost, but has enough performance.



The Multi-Pixel Photon Counter … named by Hamamatsu

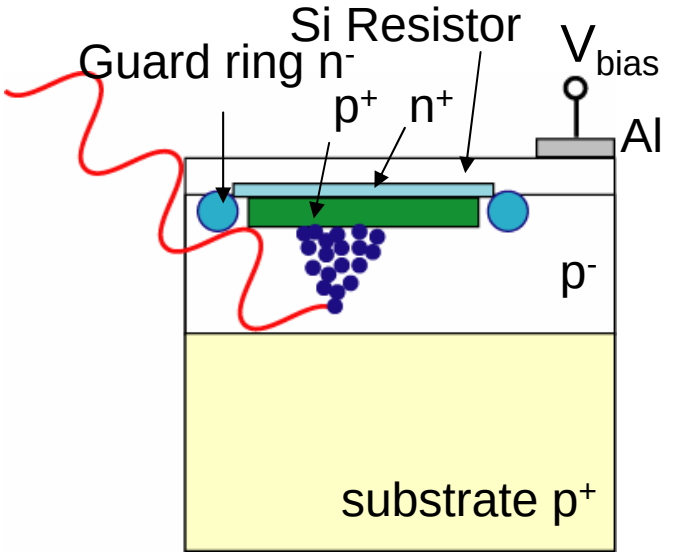
(Silicon Photomultiplier … general name)

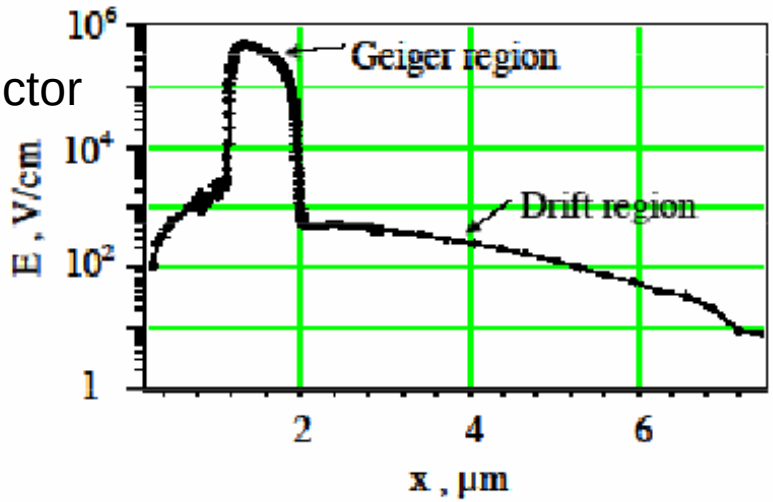
is a novel type semiconductor photon sensor



We have the MPPC samples with:

- 400 pixels
- 1600 pixels





The MPPC performance

	PMT	MPPC
Gain	~10^6	10^5~10^6
Photon Detection Eff.	0.1 ~ 0.2	0.1~ 0.4
Response	fast	fast
Photon counting	Yes	Great
Bias voltage	~ 1000 V	30 ~ 70 V
Size	Small	Compact
B field	Sensitive	Insensitive
Cost	Expensive	Low ($1~10?)
Dynamic range	Good	Determined by # of pixels
Long-term Stability	Good	Unknown
Robustness	decent	Unknown, maybe good
Noise (fake signal by thermions)	Quiet	Noisy (order of MHz)

The MPPC looks feasible for the GLD Calorimeter readout!

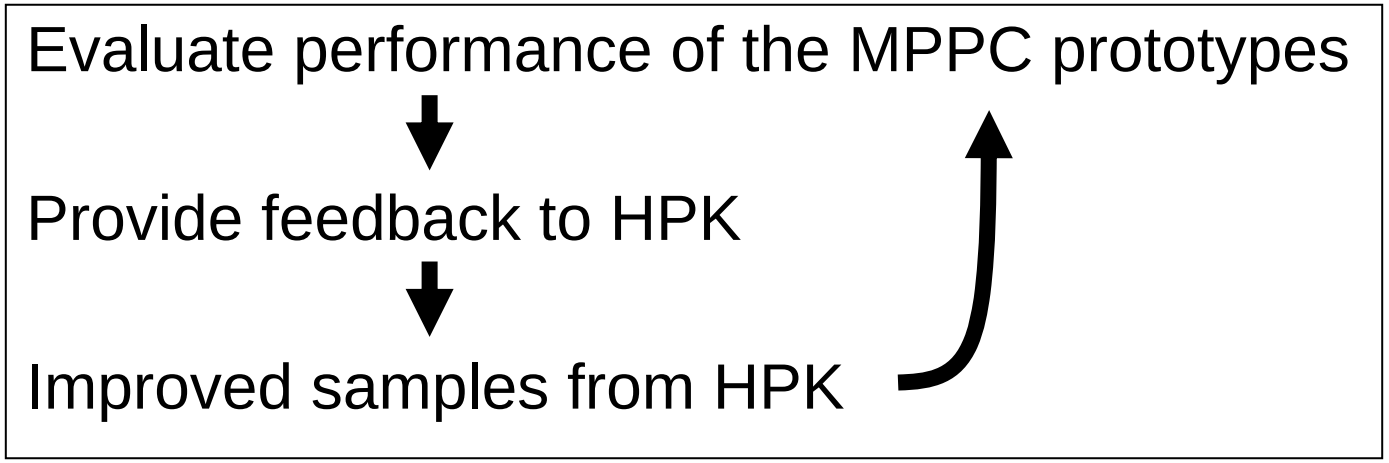
Required performance for the GLD Calorimeter

- Gain: ~ Best to have 10^6 , at least 10^5
- Dynamic range: can measure ~1000 p.e.
  - satisfactory to measure EM shower maximum
  - need > 2500 pixels
- Photon Detection Efficiency ~ 30 %
  - to distinguish MIP signal
- Noise rate : ~ 1 MHz (threshold = 0.5 p.e.,
  threshold =1.5 p.e is also acceptable)

- good uniformity, small cross-talk
- Timing Resolution ~ 1 nsec
  - Necessary for bunch ID, slow neutron separation
- Sensor area: 1.5 x 1.5 mm
  - suitable for 1.5 mmϕ fiber
- Should be stable against bias voltage / temperature / time

R&D Status @ GLD Calorimeter

- The MPPC performance looks feasible for the GLD calorimeter readout, but still not sufficient.
- Need study and improvement of the fundamental property to achieve our goal.
- Now we are measuring performance of latest 400 / 1600 pixel MPPC prototypes provided by Hamamatsu.
- Based on its results, we provide feedback to Hamamatsu to have improved sample.

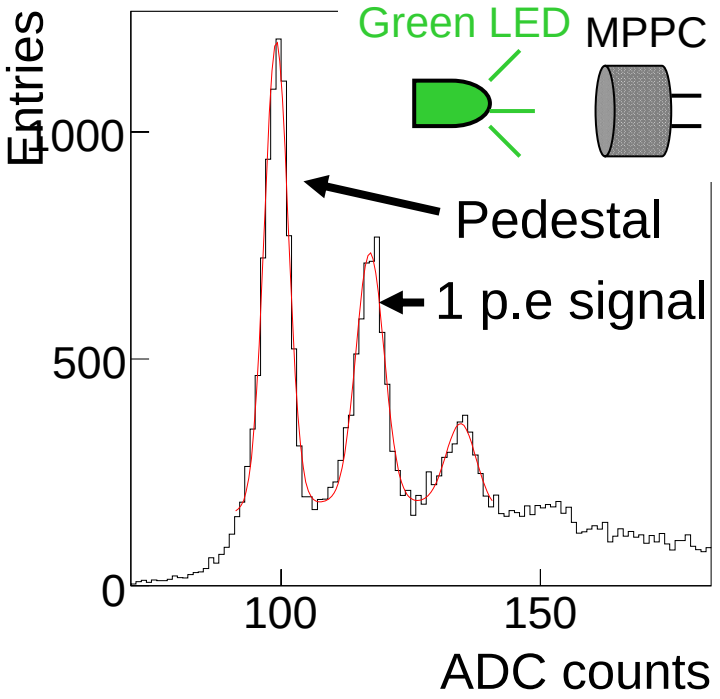


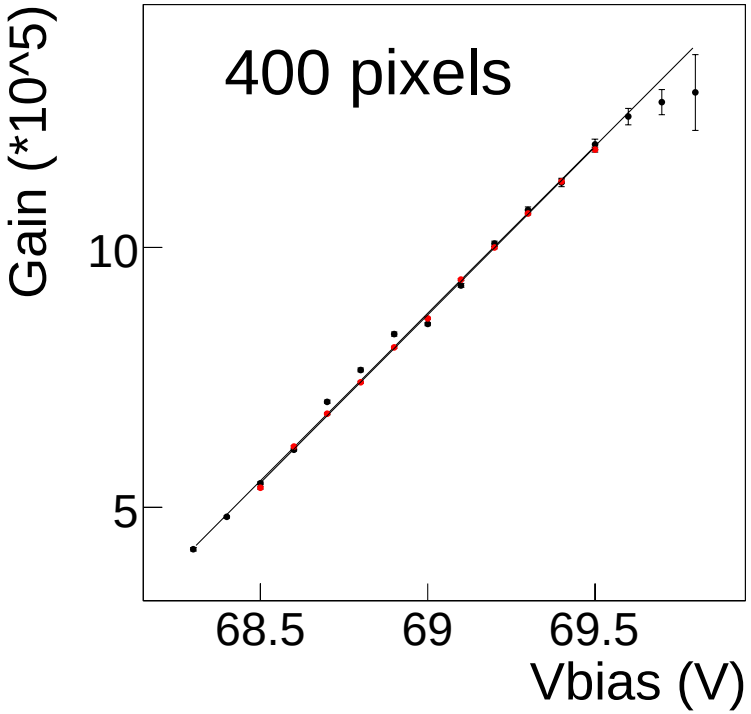
Current Results of R&D with the 1600 pixel prototype

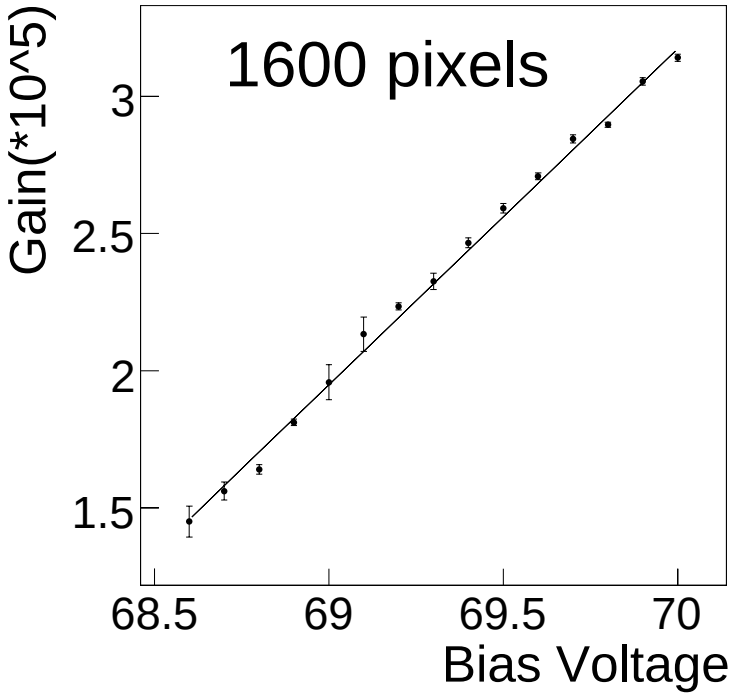
- Gain
- Noise Rate
- Microscopic Laser Test

Gain vs Bias Voltage

- Typical Gain ~ 5-12 x 10^5 (400 pixels),
  1.5-3 x 10^5 (1600 pixels)
- Need precise control of bias voltage to have stable gain

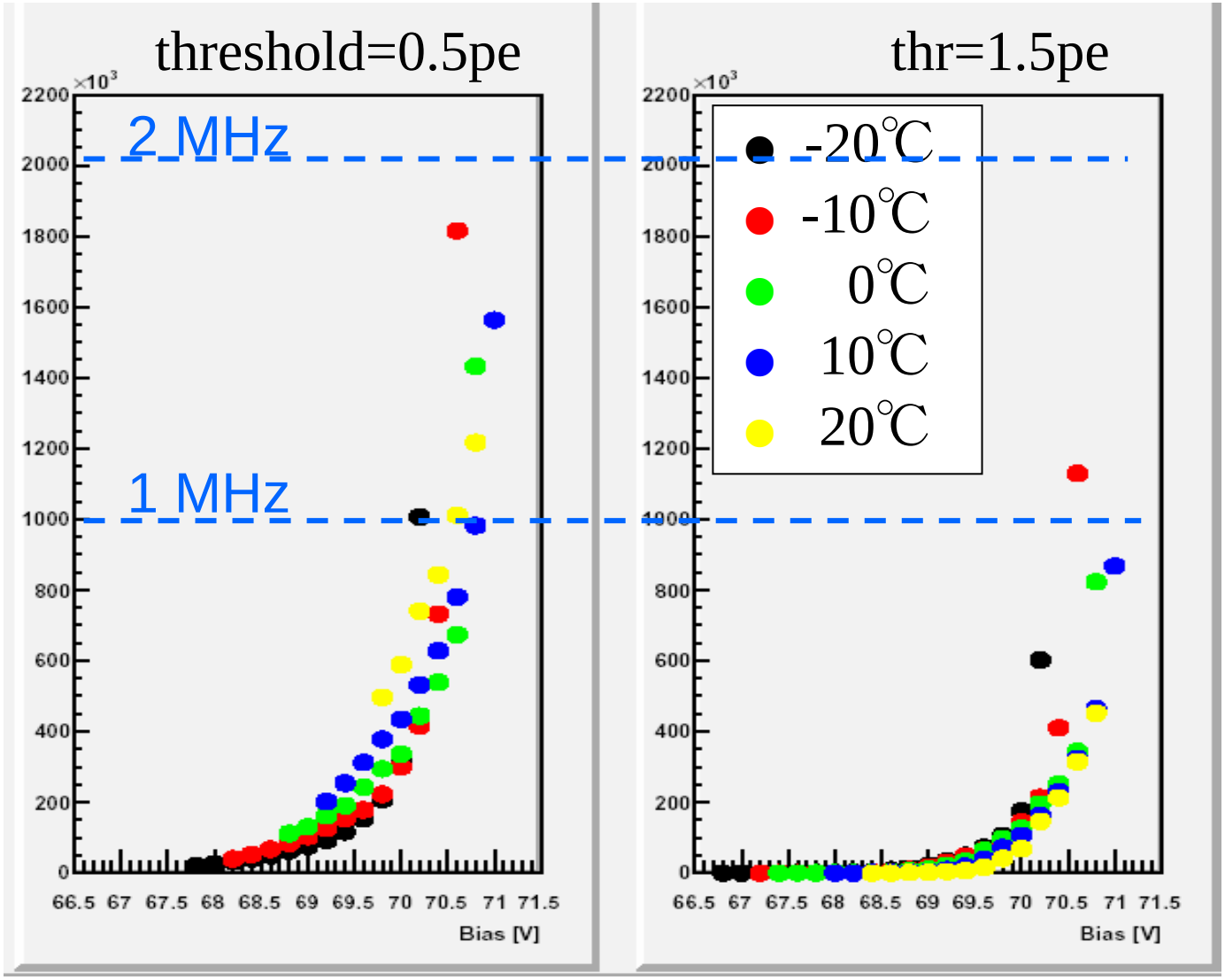


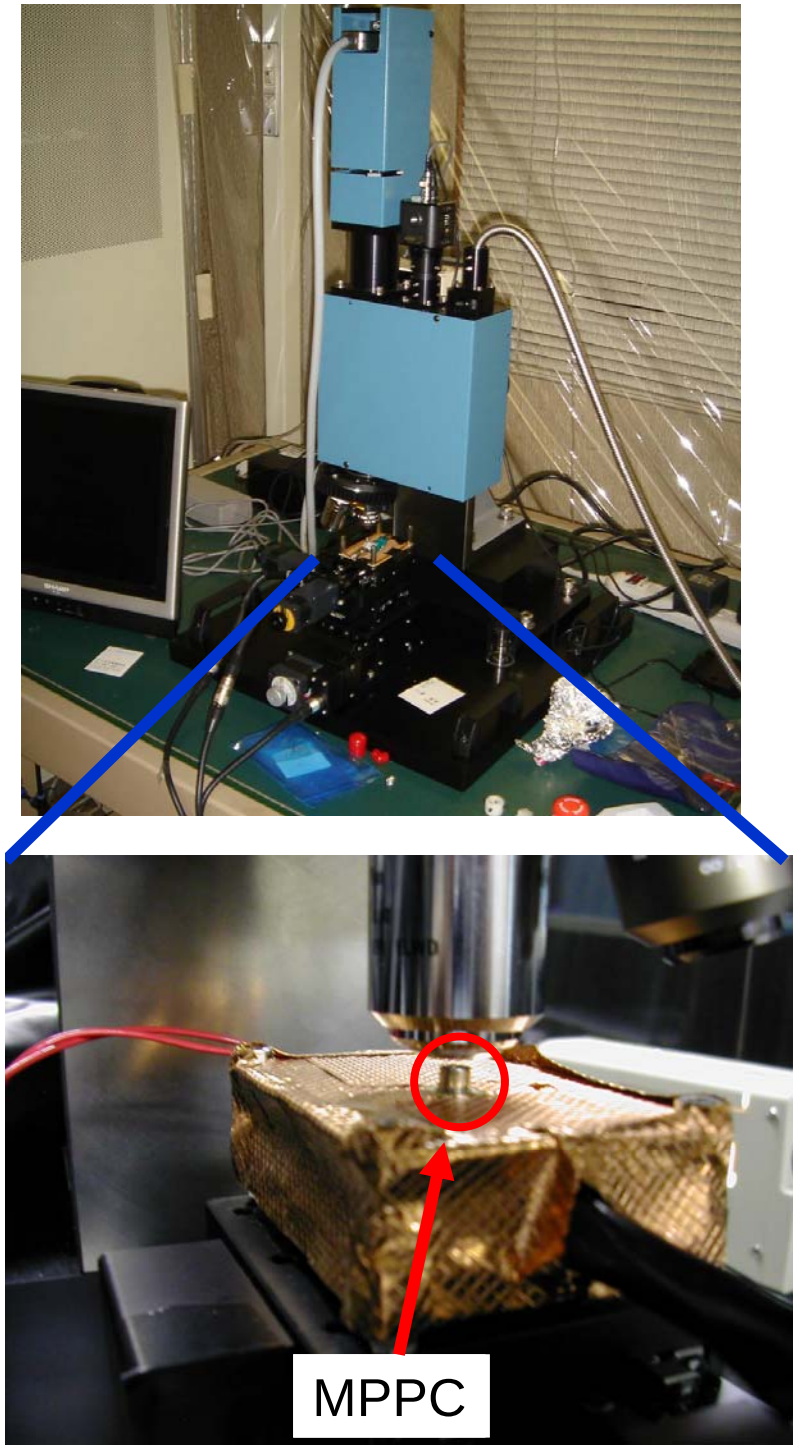




Noise (Dark Counting) Rate (1600 pixels)

Count rate of dark noises above threshold
(>0.5 / 1.5 photoelectrons)





Laser Bench Test of 1600 pixel MPPC

It is important to understand pixel-by-pixel / inside-pixel variation of the performance.

↓

Need of the pin-point light source

The microscopic laser system launched at KEK in Mar 2006

- YAG Laser (λ = 532 μm) with microscope
- Pulse width ~ 2 nsec
- Laser spot size ~ 1 μm
- Moving stage pos. resolution ~ 0.02μm
- Can perform precise pinpoint scan with the well-focused laser

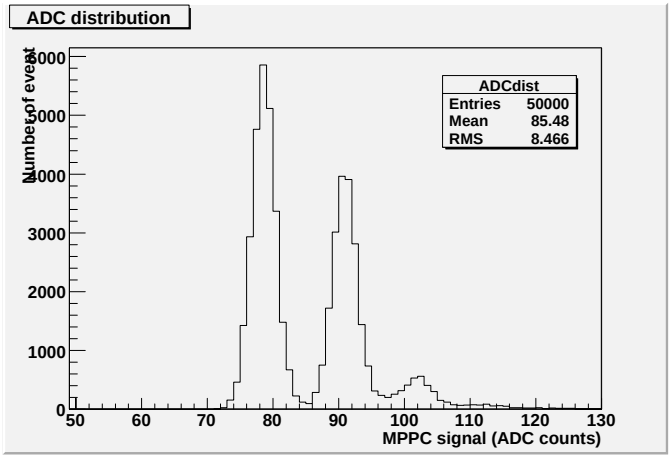
Results are yet preliminary !

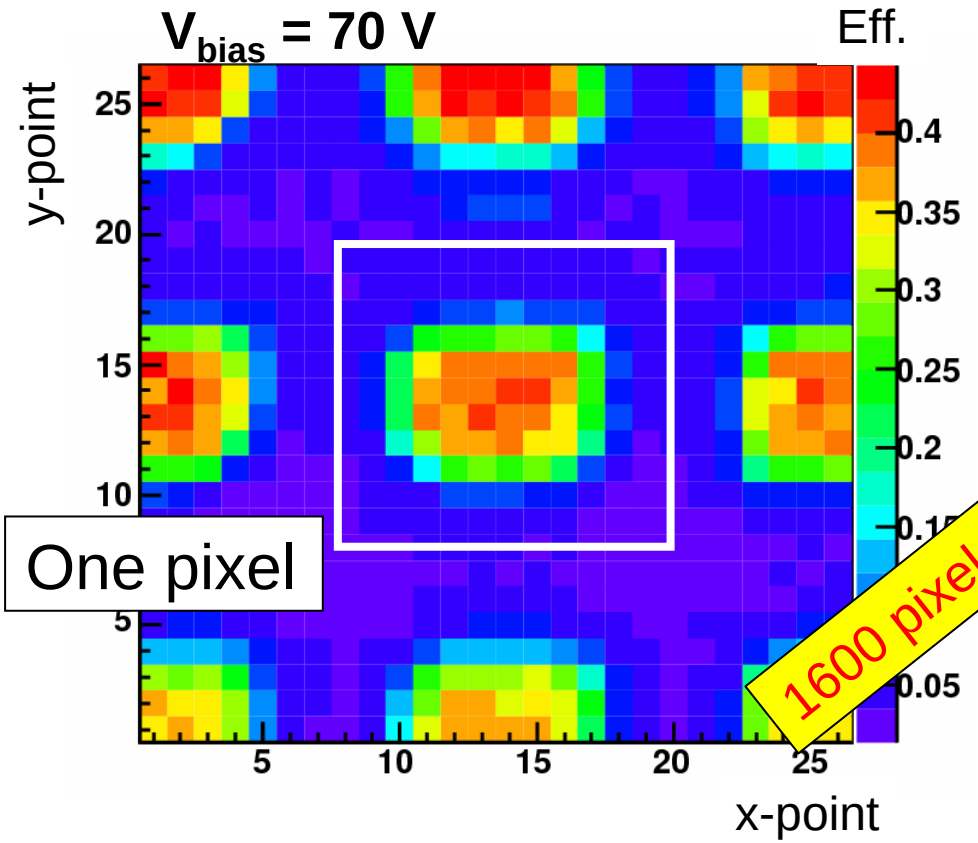
Scan within a pixel
- Detection Efficiency -

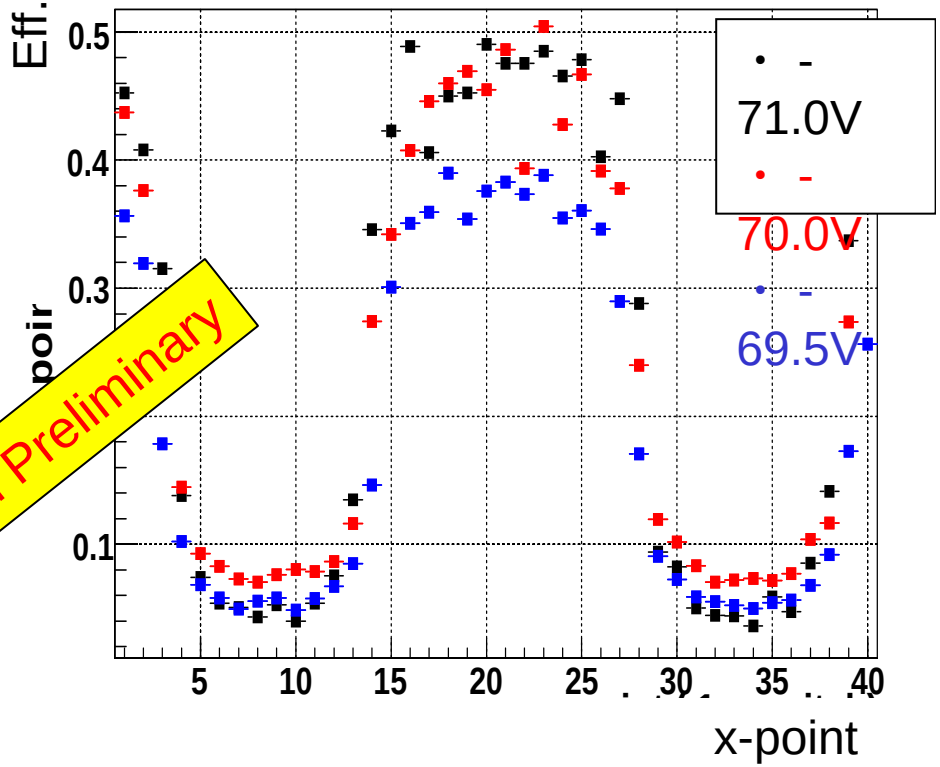
$$Eff = \frac{N_{>=1p.e.}}{N_{All}}$$

← Num. of >= 1 pix. fired events

← Num. of all events



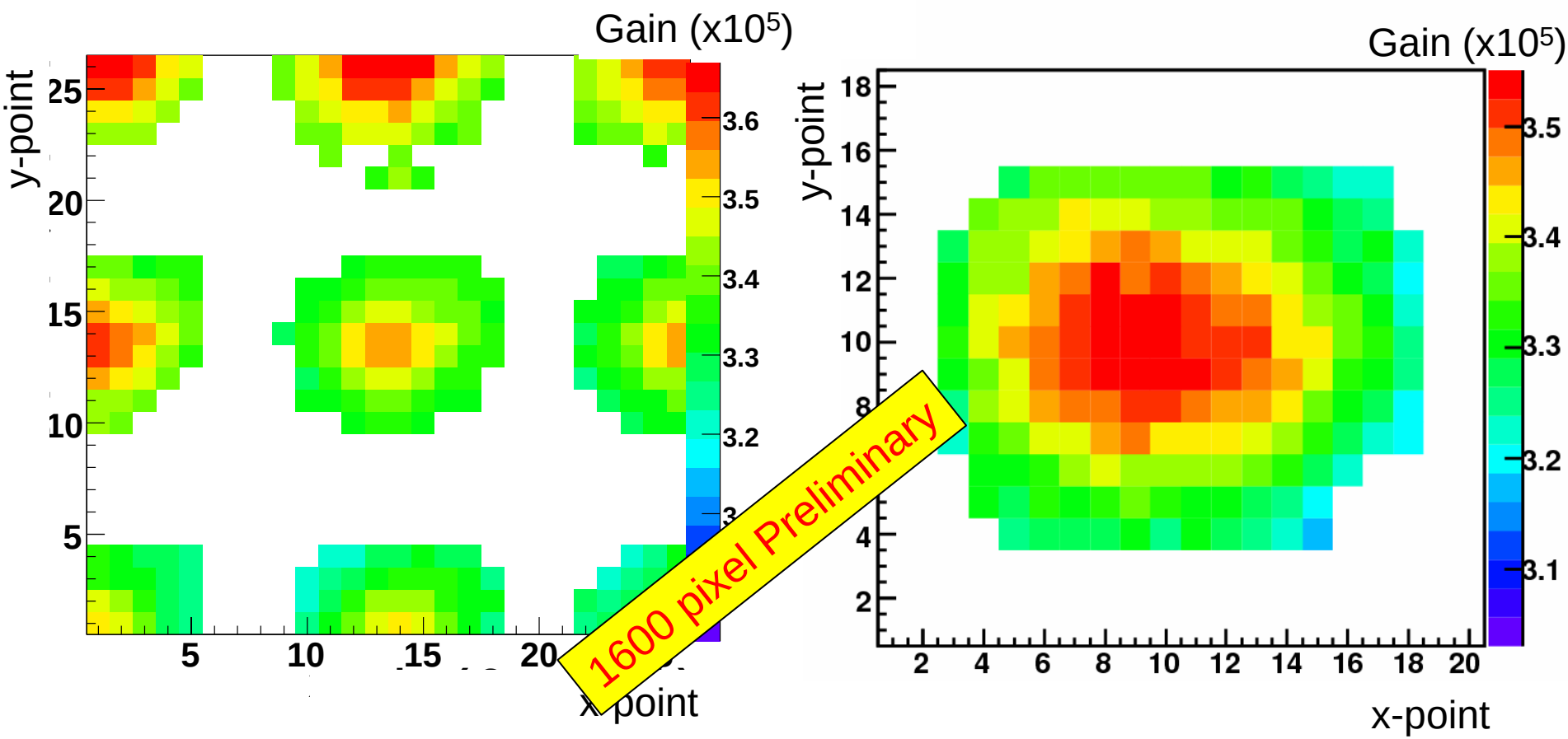




1600 pixel Preliminary

- **Geometrical acceptance within a pixel ~ 20%**
- **Variation within an active region ~ 7-13%**

Scan within a pixel
- Gain -



- **Center part have higher gain**
- **Gain Variation inside sensitive region ~ 2-3 %**

Summary & Plans

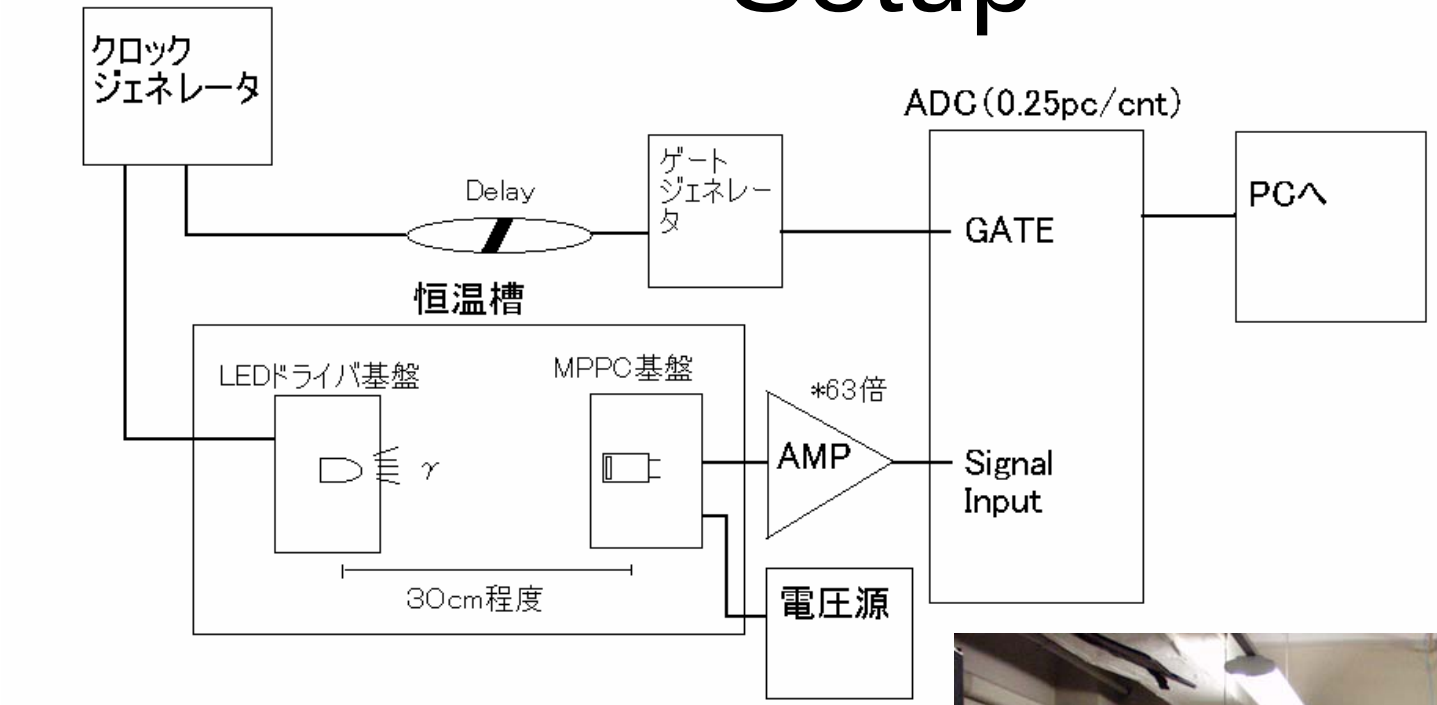
- MPPC is a great device, and feasible for the GLD calorimeter readout.
- Extensive R&D is ongoing collaborating with the Hamamatsu Photonics.
- We still have lots of things to do in a short term:
  - Need more study of the fundamental properties (Photon Detection Efficiency, Linearity, etc)
  - Stability, Robustness, B-field tolerance
  - Time resolution
  - Device-by-device variation
  - More test with microscopic laser
- We may have next improved MPPC samples soon from HPK
- Current target is a beam test of EM calorimeter prototype with the full MPPC readout (next talk).
  ~500 MPPCs necessary, we will have them by the end of this year.

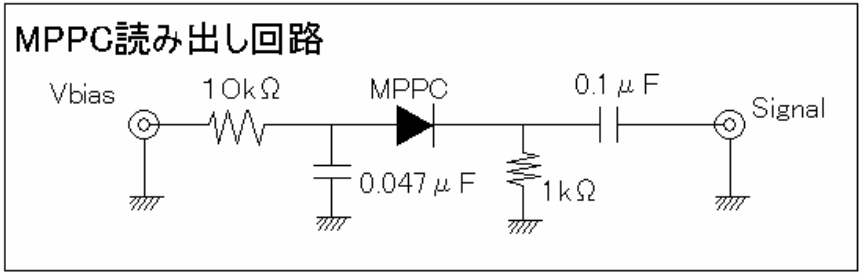
Backups

(*) Multi-pixels

	PMT*	MCP-PMT*	HPD*	APD*	MPPC (SiPM)
HV	1kV	1kV	8kV+300V	300V	50V
Gain	10^6	10^6	10^5	10^2	10^6
Noize	<10Hz	<10Hz	??	Very Sensitive	1MHz
B Filed	NA	OK	OK	OK	OK
Price/channel	$25	$60	---	$30	$10
QE	15%	8%	8%	70%	10~20%
R&D	No	marginal	necessary	Marginal	**necessary**

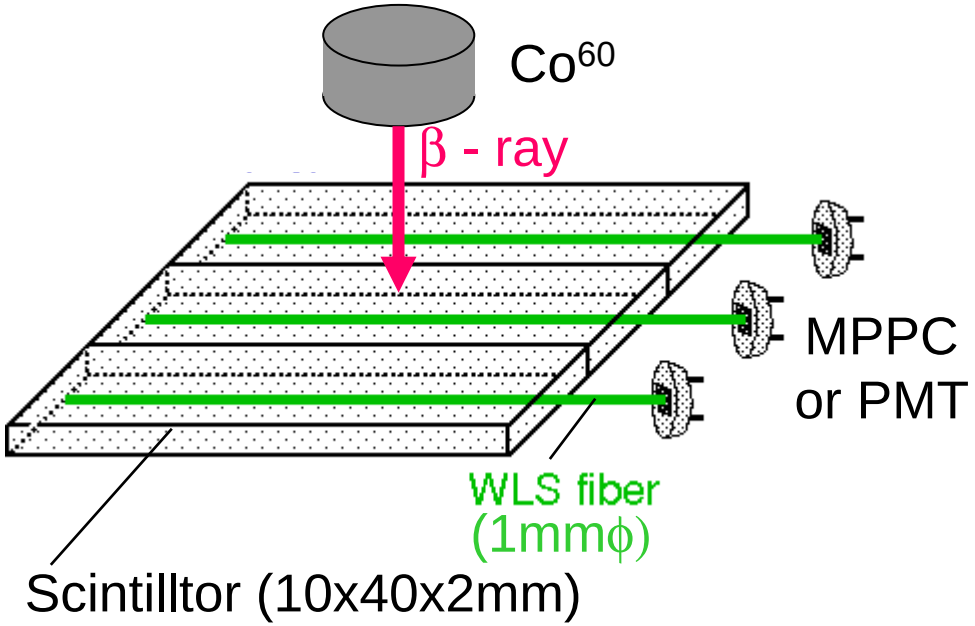
Setup


クロック
ジェネレータ
Delay
ゲート
ジェネレータ
ADC(0.25pc/cnt)
GATE
PCへ
恒温槽
LEDドライバ基盤
MPPC基盤
γ
*63倍
AMP
Signal
Input
30cm程度
電圧源


MPPC読み出し回路
Vbias
10kΩ
MPPC
0.1μF
Signal
0.047μF
1kΩ

β-ray test (in 2005)

- Practical test with Scintillator & WLSF
- Compare performance with PMT



Preliminary result

Device	# of p.e. detected	# of photons from fiber
MPPC (100 pix)	**6.1±0.7 (pixels)**	**28±10**
PMT	**5.8±0.5 (p.e.)**	**29±6**

MPPC performance is comparable with PMT for the practical use.