R&D Status of the GLD ECAL and Photon Sensors

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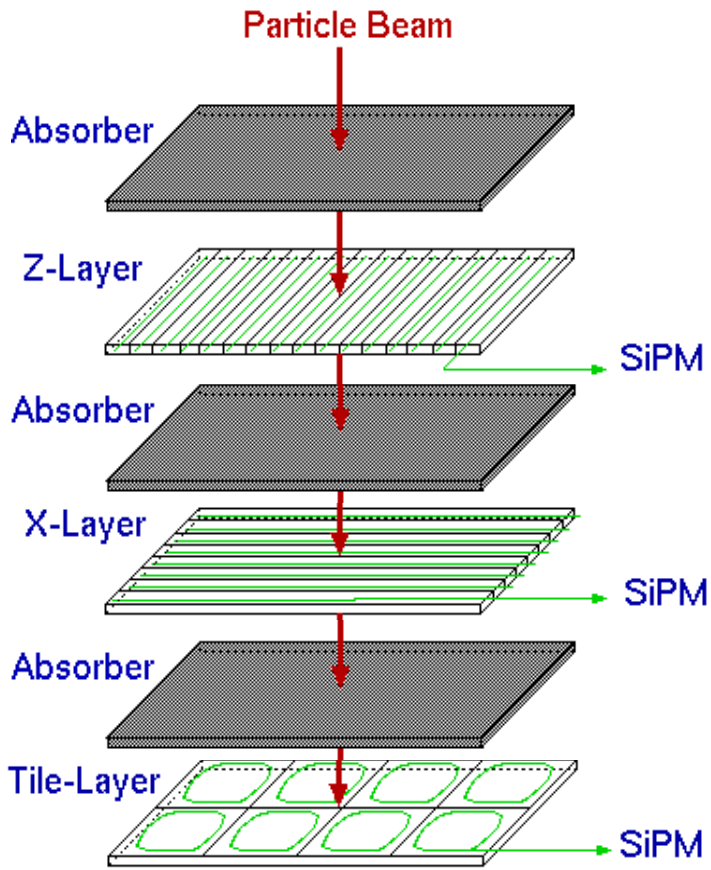
Outline

- ECAL
  - GLD CAL baseline design
  - Scintillator-strip ECAL
  - Other R&D's
- Photon Sensors
  - Russian SiPM / Hamamatsu MPC
  - Measurements of basic properties
- Summary

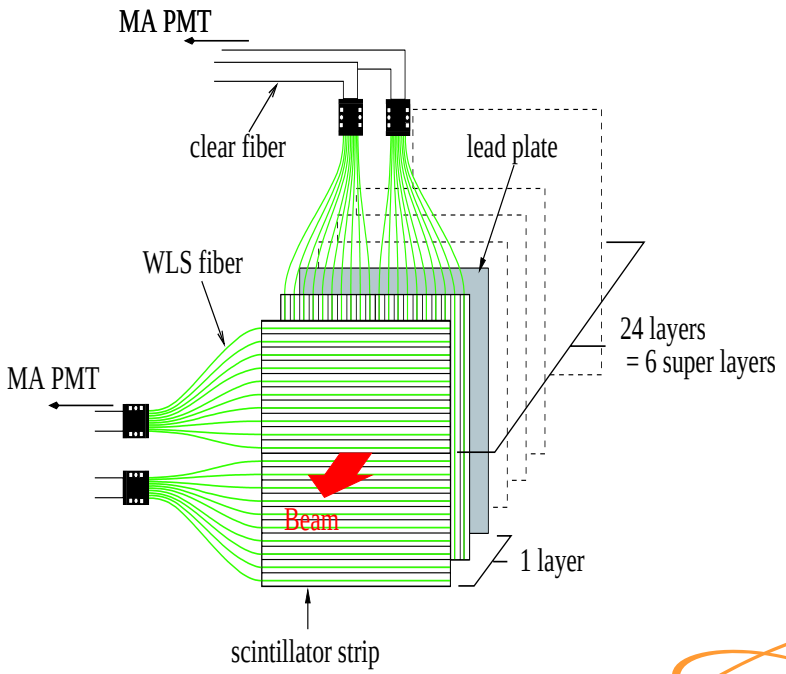
GLD ECAL

- Baseline design
  - Scintillator/absorber sandwich
    - Two orthogonal strip layers
      - Effectively small granularity of 1cmx1cm
    - 4cmx4cm tiles to resolve ghost hits
    - Tungsten as absorber
      - Small Moriere radius
  - WLS fiber
  - SiPM/MPC as photon sensors
  - R_{ECAL} : 2.1 ~ 2.3m



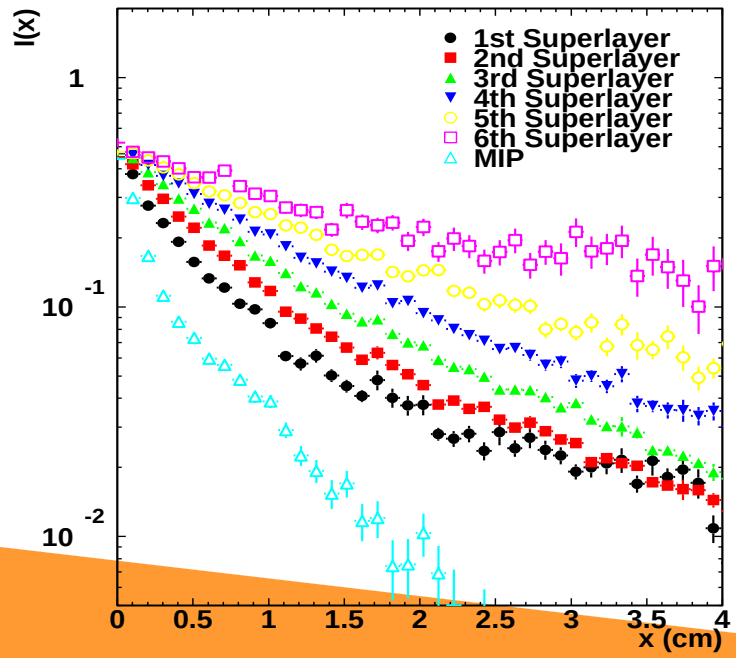
Scintillator-strip ECAL

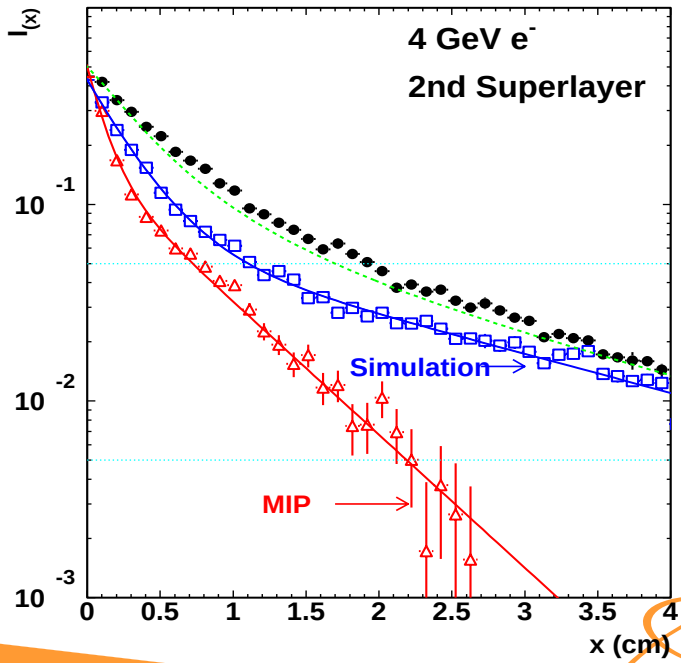
- ECAL test module
  - Lead (4mm thick) + 2 Sci. strip layers (2mm thick)
    - Strip : 1cm x 20cm
  - Multi-Anode PMT
    - Tentatively for beam tests
  - $17X_0$ (24 layers)
  - WLS fiber (Y-11, 1mm-ϕ)
  - Testbeams at KEK PS



Lateral Shower Profiles

- Lateral shower profiles measured two-dimensionally
  - Integrated lateral shower profiles
    - X=0 : particle incident position
  - Good agreement with MC simulation
    - Taking into account light-leakage and cross-talks evaluated from MIP
    - Reasonable results with respect to granularity and Moriere radius (2.7 cm)





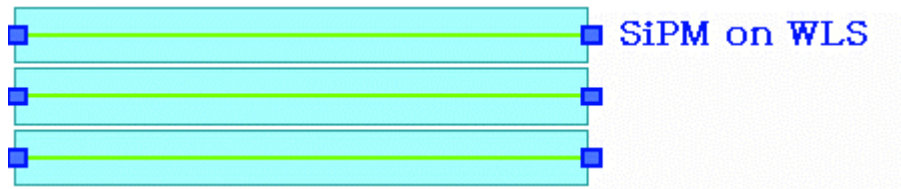
Other R&D's

- Tile-fiber ECAL (4x4 cm^2)
  - Testbeam analysis ongoing
- Scintillator shapes and wrapping materials
  - Light yield, uniformity,…
- Scintillator production with extrusion process
  - DongHee Kim's talk
- Simulation
  - Parameter optimization

New Silicon Photon Sensor

- Micro APD cells in Geiger mode
- Good for scintillator-fiber readout
  - Gain ~ 10^6 (no amplifier needed)
  - Photon counting
  - ~1000 pixels in ~1mm^2
  - Compact, directly attached to fibers at the end of strips/tiles
  - Operation in B-field is possible
  - Good timing resolution

- Originally developed in Russia (SiPM)
- Hamamatsu Photonics started R&D last year

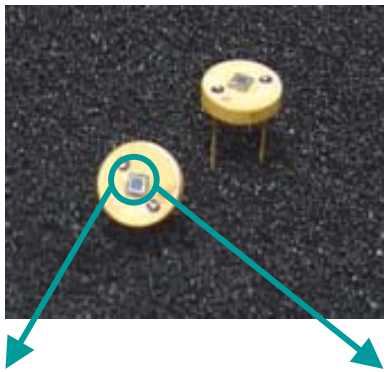


Tests of photon sensors

- Samples
  - Russian SiPM: R1156 (1156=34x34 pixels)
  - Hamamatsu MPC: H100 (10x10 pixels)
  - Hamamatsu MPC: H400 (20x20 pixels)
    - Hamamatsu MPC: H1000 -- coming soon
- Measurements of basic properties
  - Photon counting capability
  - Gain and noise rate
  - Uniformity and efficiency
  - Tests were done at Kobe University and Niigata University

Russian SiPM (Silicon photomultiplier)

- Number of pixels: 34x34 =1156
- Bias Voltage : 64 ~ 67.5V
- Gain: ~10^6

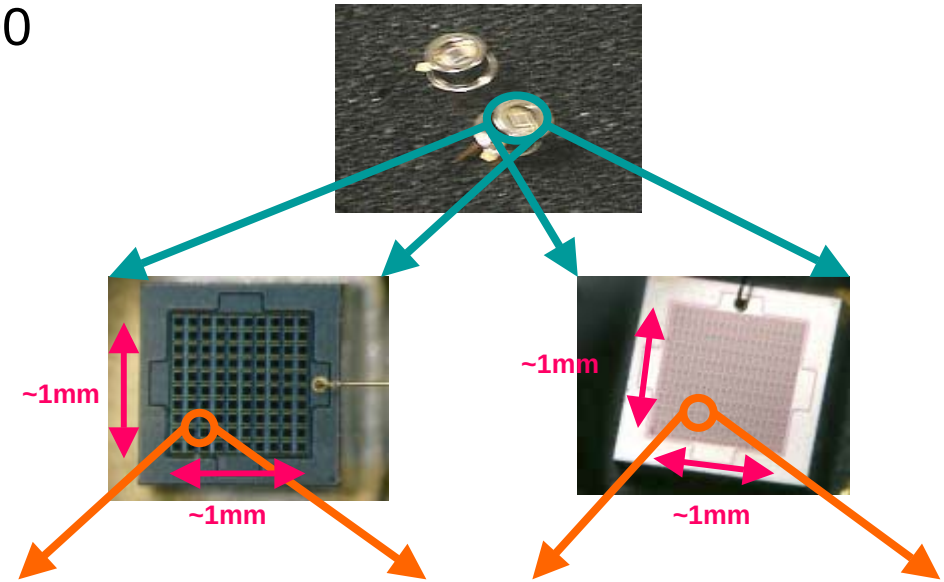


Photoelectron peaks observed

with an oscilloscope (using fast amplifier)

Hamamatsu MPC (Multi-pixel photon counter)

- Number of pixels: 100 and 400
- Bias voltage: 47 ~ 51V
- Gain: 10^6 ~ 10^7
- Now under development
  - Not commercially available



Effective area:

~72.25% for 100 pixel

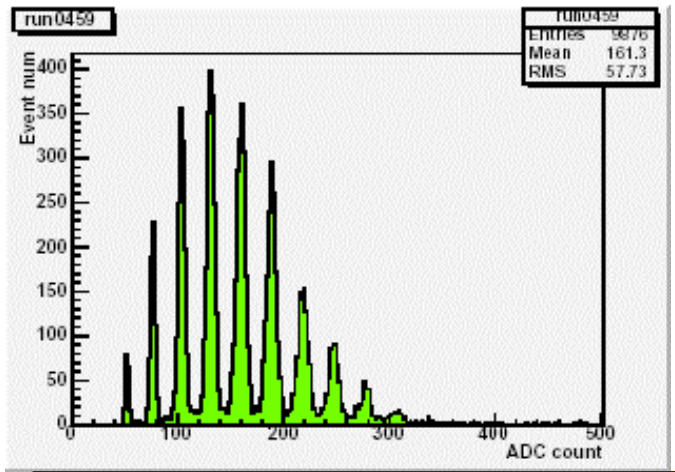
~42.00% for 400 pixel

100 pixel 400 pixel

Photon counting capability

- Up to several photons at room temperature
- H100 is excellent in photon counting

R1156 (V_B=63.2V, T=20C, Amp Used)



H400 (V_B=48.8V T=20C, Amp Used)

H100 (V_B=49.1V, T=20C, no AMP)

More photon counting by H100

- Observed up to 40~60 photon peaks by changing LED light intensity

LED 4.5V×10ns

LED 5.5V×10ns

LED 6.5V×10ns

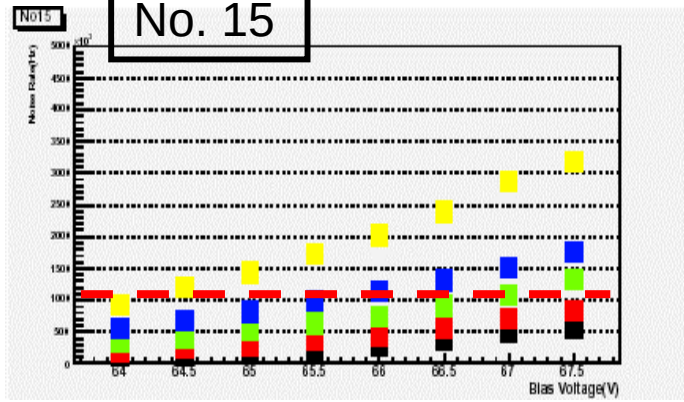
LED 7.5V×10ns

Noise rate measurement (R1156)

- Threshold=-30mV with fast amp (x200): well below single pixel signal
- Bias V: 64 ~ 67.5 V; Temperature: -20, -10, 0, 10, 20 C; Four samples

No. 12

No. 15



1MHz

No. 2

No. 29

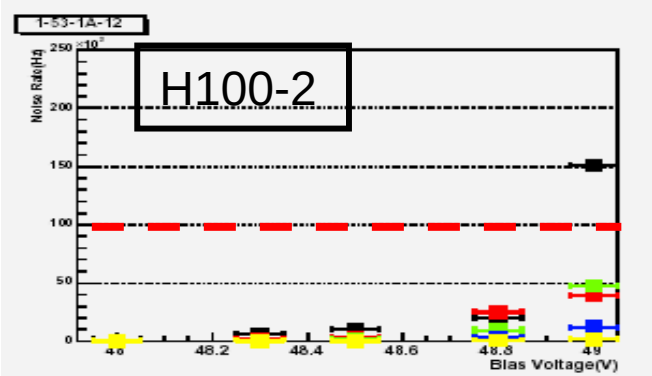
-20C
-10C
0C
10C
20C

Noise rate measurement (H100 / H400)

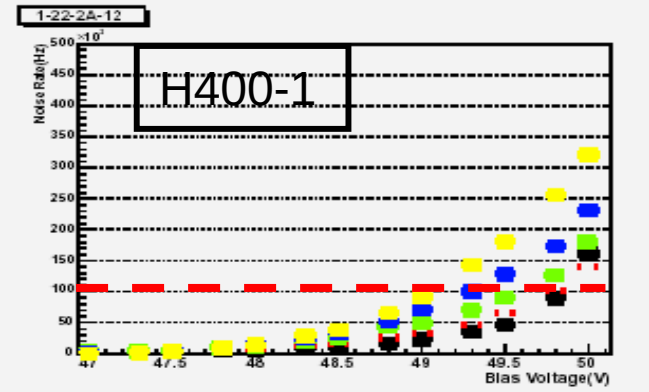
- Threshold=-30mV with fast amp (x200); same condition as R1156
- One order of magnitude less noises than R1156
- H100: More noise rates at lower temperature -> Gain change ?

H100-1

0.1MHz



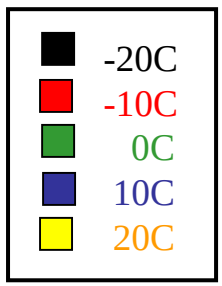
-20C
-10C
0C
10C
20C

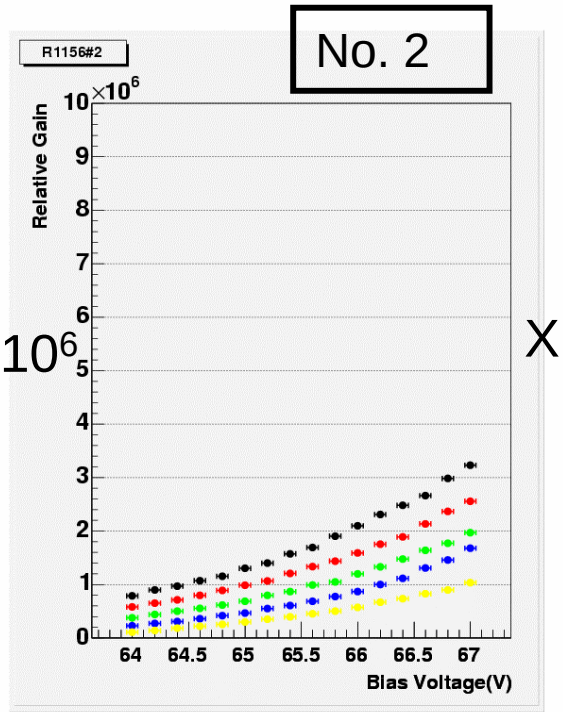


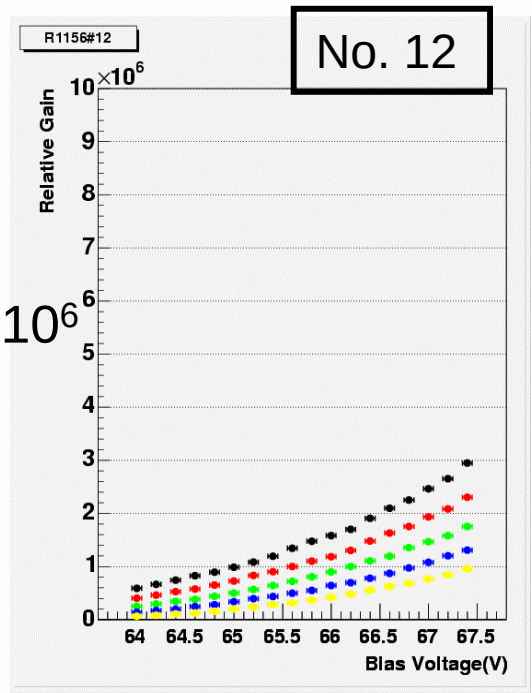
H400-2

Gain measurement (R1156)

- Gain : ~10^6
- Gain is higher at lower temperature

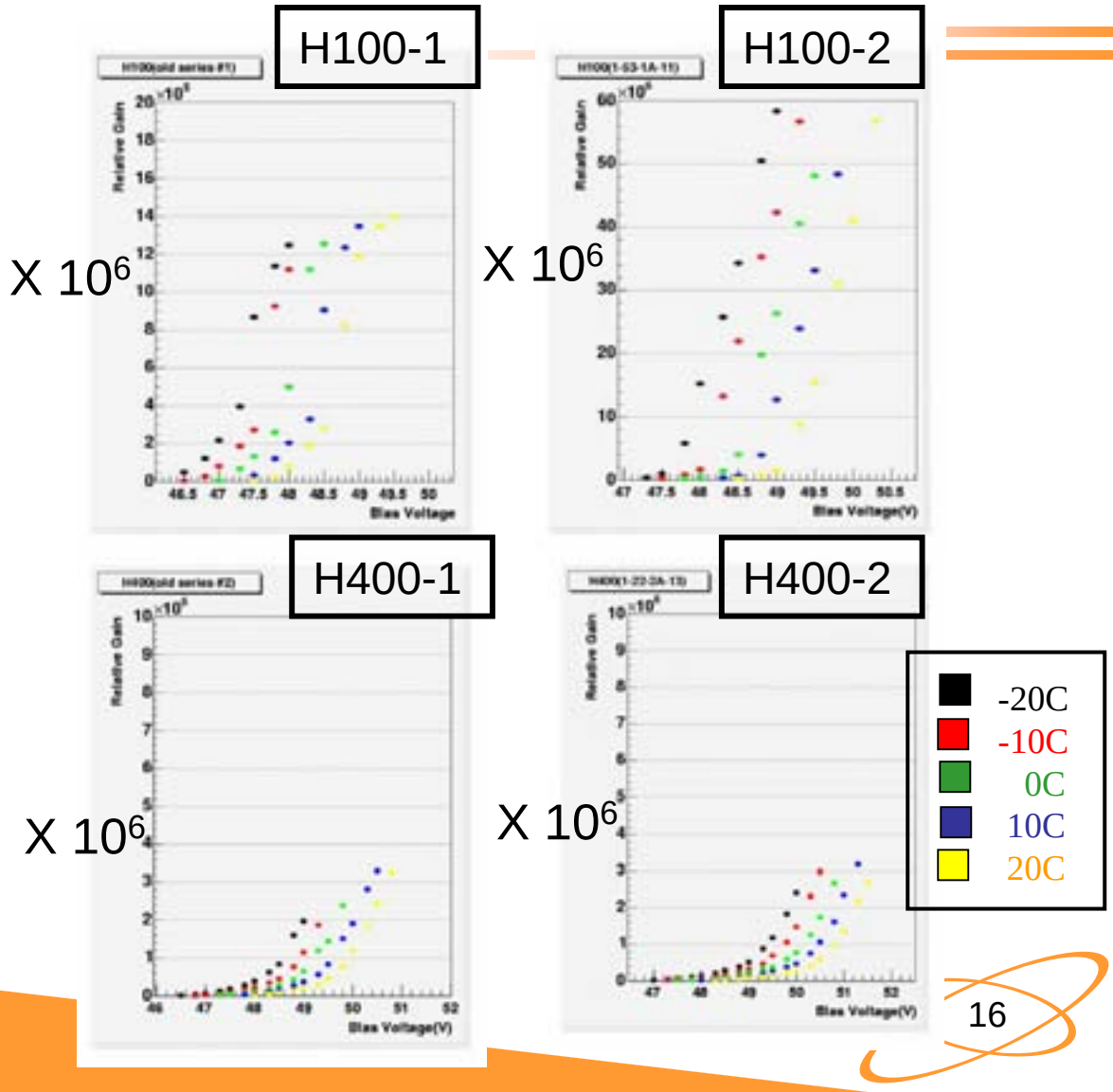






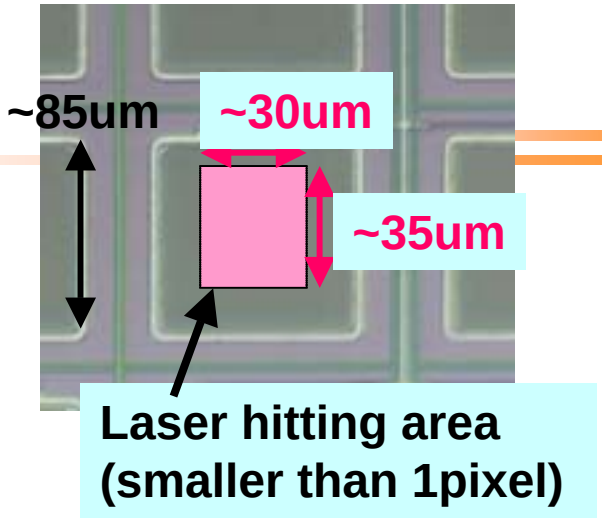
Gain measurement (H100 / H400)

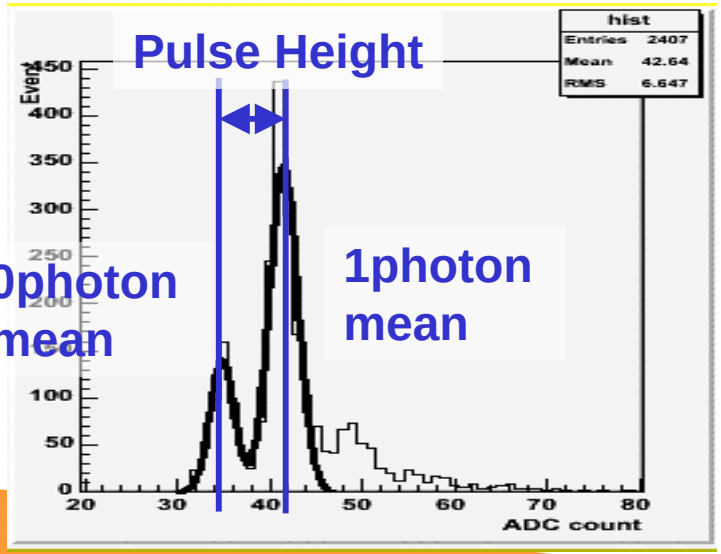
- Gain(H100) is larger than Gain(H400)
  - Gain(H100): ~10^7
  - Gain(H400): ~10^6
- Gain variation is very sensitive to bias voltage
  - Accurate voltage control will be necessary for stable operation

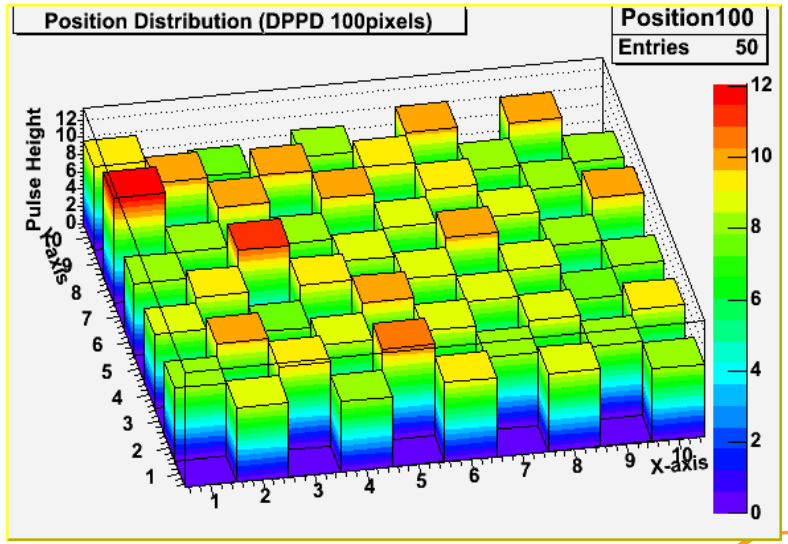


Uniformity

- Measured uniformity for half (50) pixels of H100
  - Laser is irradiated in the central region of the pixels
- PH deviations: 10% in RMS

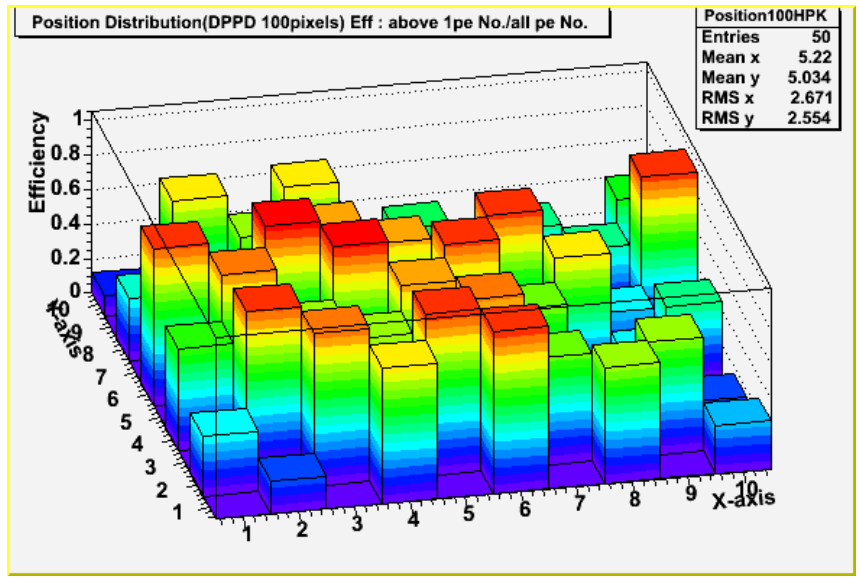






Efficiency measurement

- Efficiency was measured as
  (# of□1photon events) / (# of all events)
- Low signal efficiency at the sensor edge
- Good efficiency in the central region



Fraction of□1photon events

Summary

- GLD ECAL design: Scintillator-strips and tiles
  - Scintillator-strip ECAL works as expected
  - Needs optimization (for PFA) with MC simulation
- Tested new silicon photon sensors
  - Russian SiPM and Hamamatsu MPC
  - Hamamatsu MPC is promising
    - Still a lot of things to check:
      - Linearity, cross-talk, overall efficiency, long-term stability, …
    - Close communication between Hamamatsu and users is important for better performance and production use