Light Yield & Uniformity Measurements of Different Scintillator Tiles with 3rd & 4th Generation Hamamatsu MPPCs

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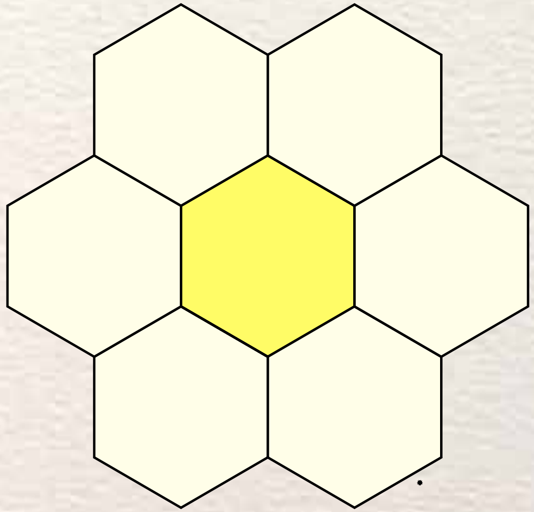
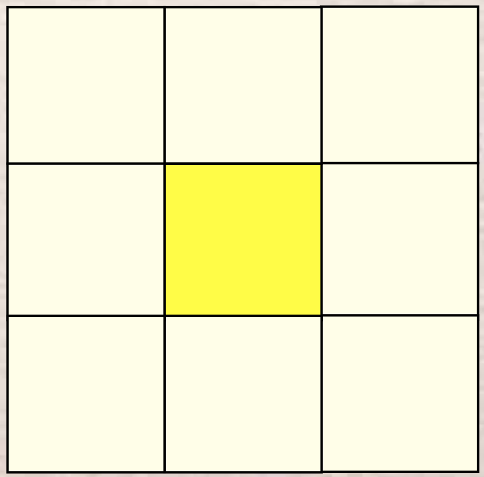
Introduction

- The SiD ECAL uses hexagonal silicon pixels motivated by higher pixel yields from a wafer
- Hexagons are a better approximation to a circle than a square,
  - As for squares larger arrays can be constructed with hexagons without gaps
  - But at the module edges, we have to deal with half hexagons



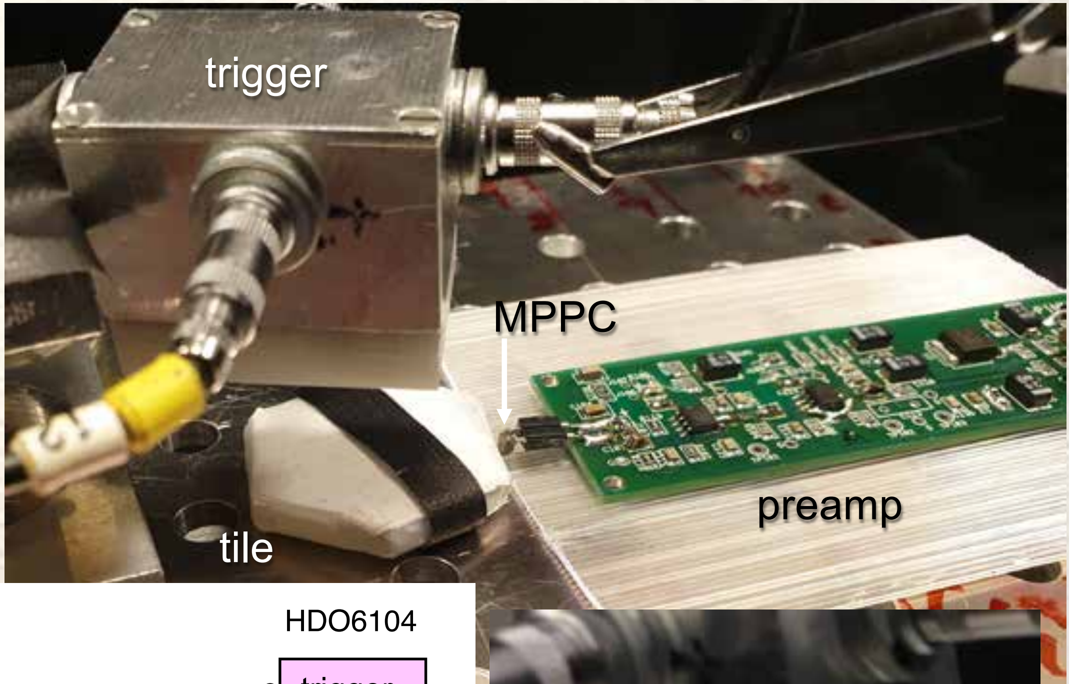
- For EM showers, we expect a better performance for hexagonal cells than for square cells since the first ring around a center tile consists of 6 not 8 tiles and the second ring consists of 12 rather than 16 tiles
  - Better S/N since the energy of less cells is summed

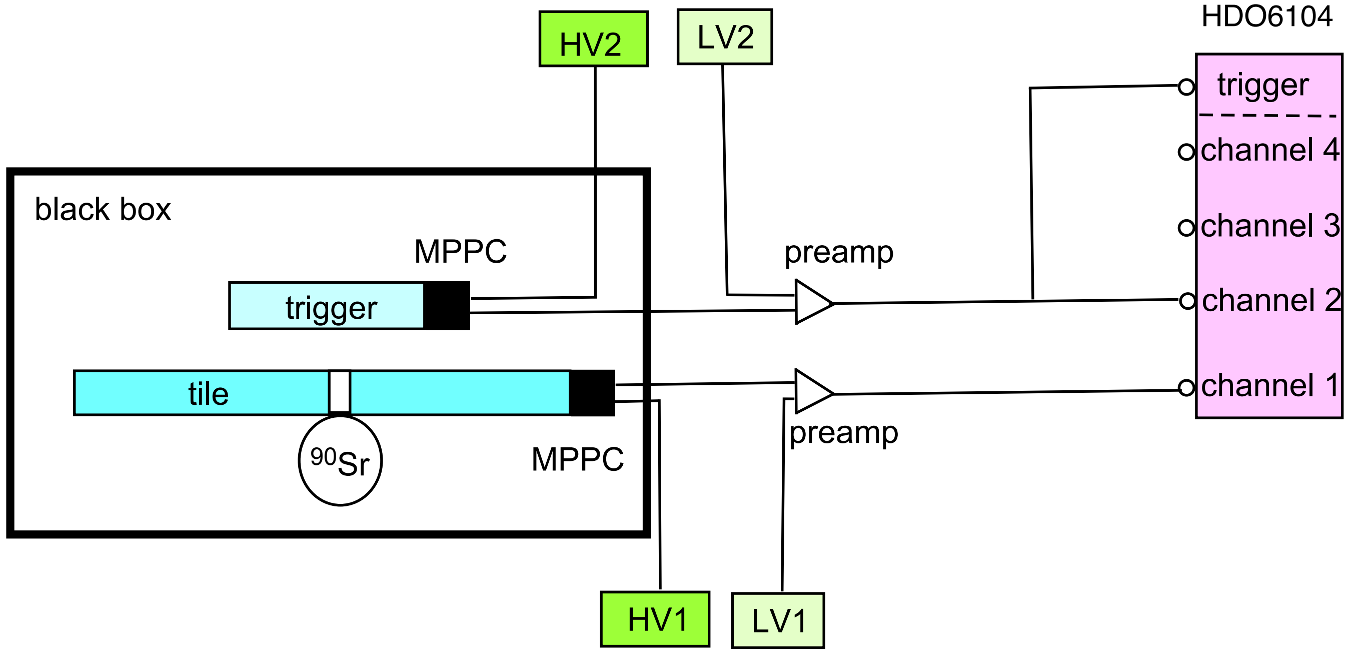


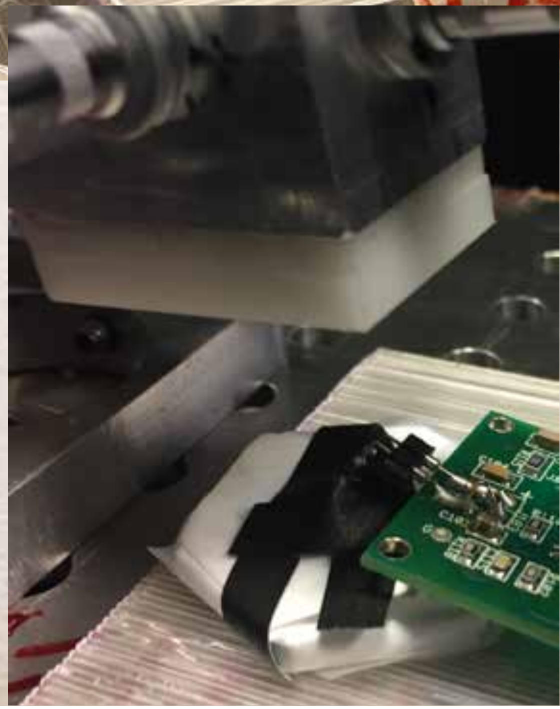
- We started to test the performance of hexagonal tiles with 3 different readout schemes wrt to that of square tiles
- We started to test the 4th generation MPPCs from Hamamatsu

Measurement Setup

- Work in black box
- Use MIP of electrons from ^{90}Sr source
- MPPC is loosely coupled to tile
- Trigger on second tile
- Record 50k waveforms

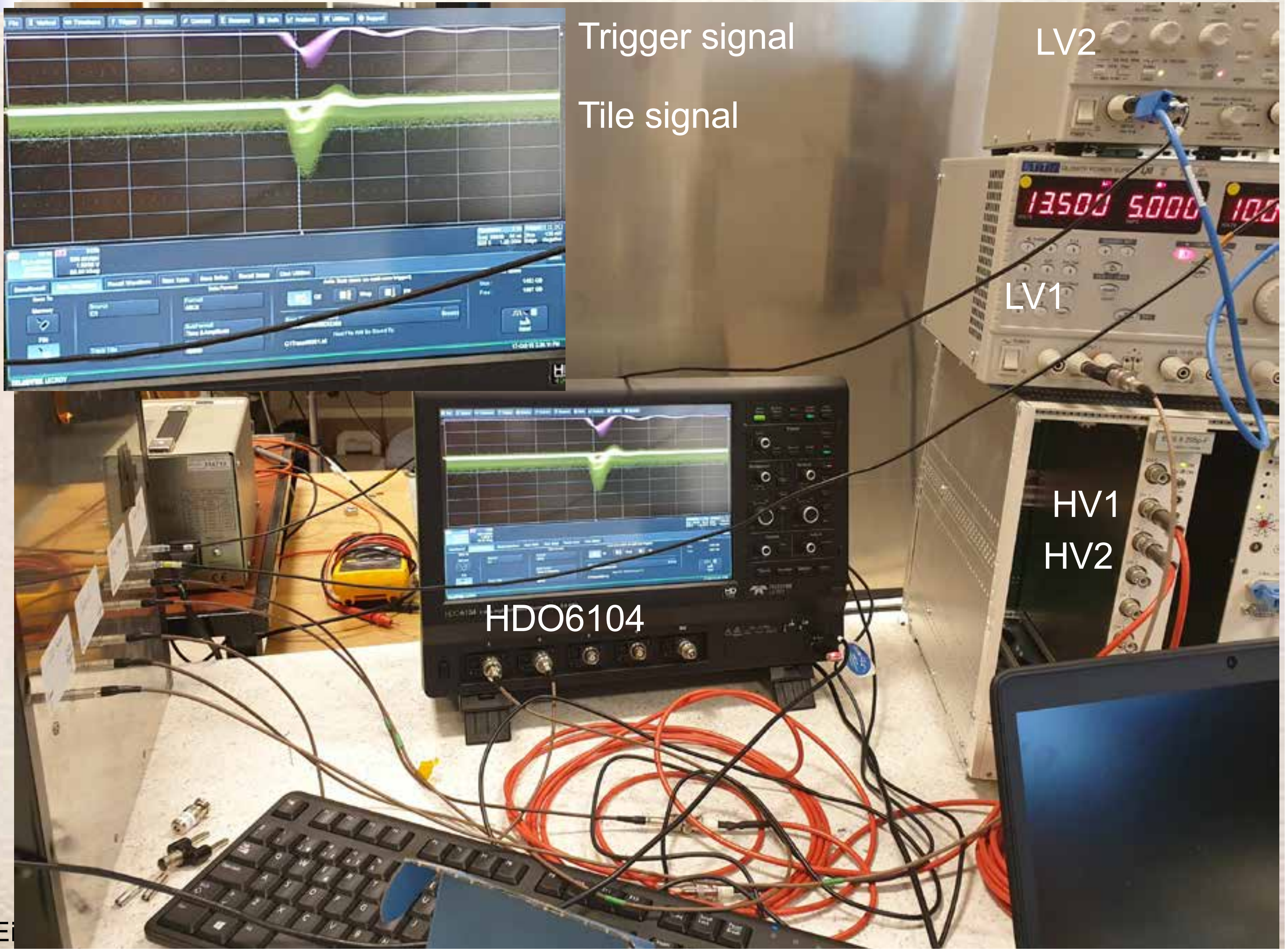






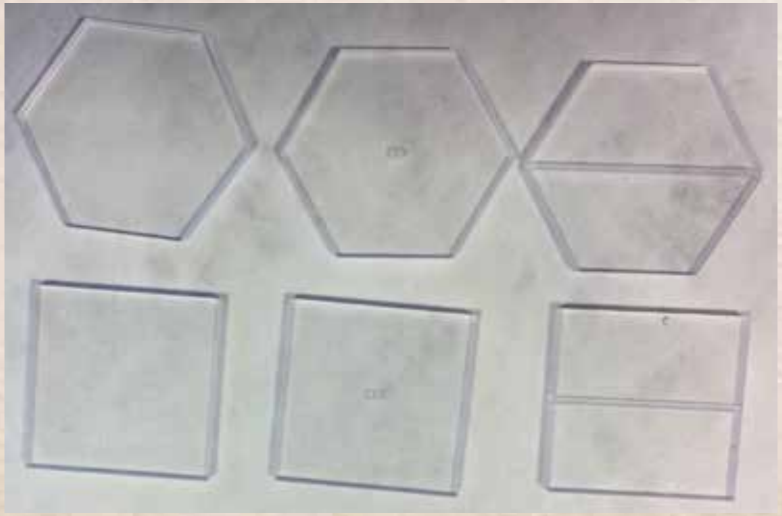
Signal Recording

- Take 50k wave-forms in a run
-



Tile Layouts

- Our machine shop produced 9 hexagonal-shaped tiles (a=1.86 cm) and 9 square-shape tiles (3 cm × 3 cm), which have the same area, thickness 3 mm
- Scintillator material is from St Gobain (Bicron) BC404
- We use 3 different readout schemes
  - Via Y11 fiber inserted into a groove located in the middle of the tile
  - Via a dimple in the center
  - Via coupling to a corner/side



	BC-400	BC-404	BC-408	BC-412	BC-416
Light Output, % Anthracene	65	68	64	60	38
Rise Time, ns	0.9	0.7	0.9	1	-
Decay Time, ns	2.4	1.8	2.1	3.3	4
Pulse Width, FWHM, ns	2.7	2.2	~2.5	4.2	5.3
Light Attenuation Length, cm*	160	140	210	210	210
Wavelength of Max. Emission, nm	423	408	425	434	434
No. of H Atoms per cm^3, $(x10^{22})$	5.23	5.21	5.23	5.23	5.25
No. of C Atoms per cm^3, $(x10^{22})$	4.74	4.74	4.74	4.74	4.73
Ratio H:C Atoms	1.103	1.1	1.104	1.104	1.11
No. of Electrons per cm^3, $(x10^{23})$	3.37	3.37	3.37	3.37	3.37
Principal uses/applications	General purpose	Fast counting	TOF counters, large area	Large area	Large area, economy

Tile Wrapping and Readout

- Tiles on top and bottom are wrapped with 2 layers of Tyvec paper
- Use 2 layers of Teflon tape on sides
- Readout hole in Tyvec is 1 mm
- Green fiber is Y11 from Kuraray
- For readout we use the Hamamatsu MPPC S13360-3025 as well as 4th generation MPPCs: S14160-1315 , S14160-3015 and S14160-3010

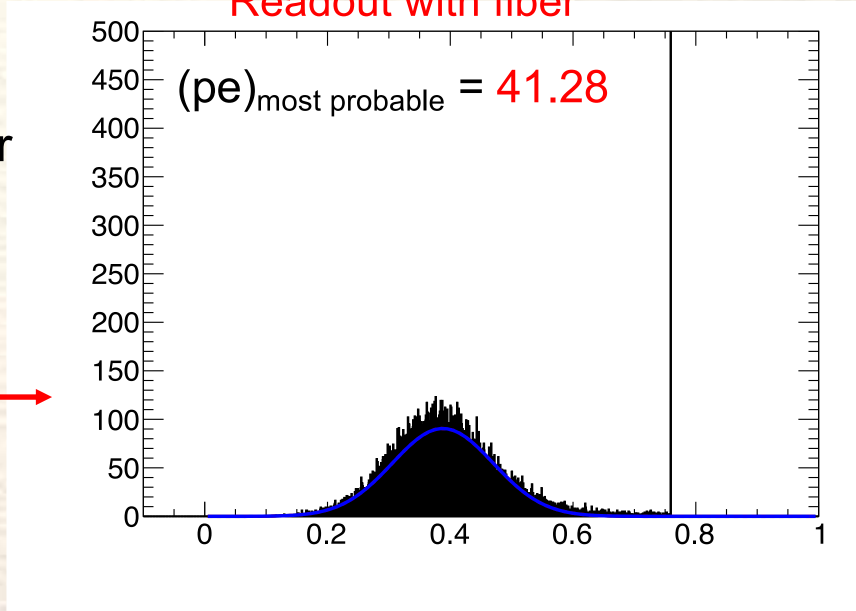
S14160-1315

S13360-3025

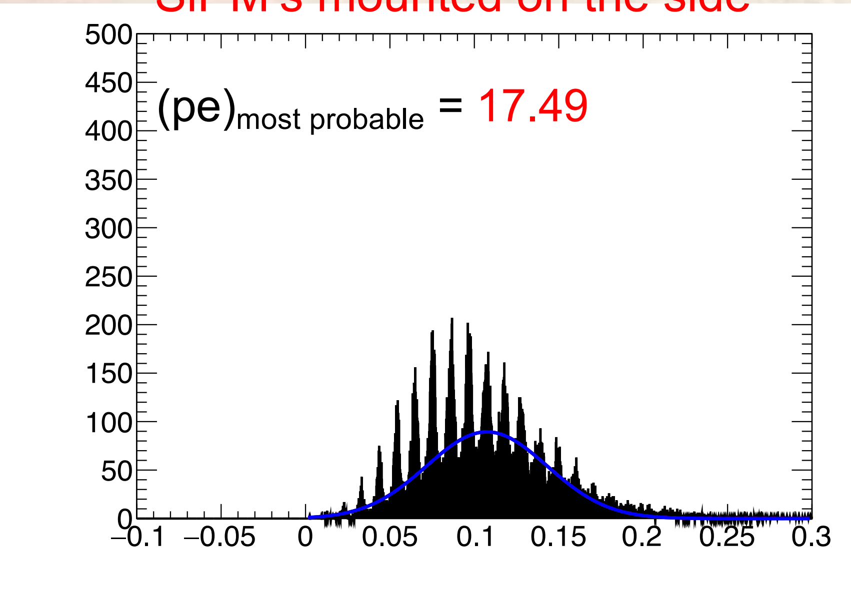
Comparison of the 3 Readout Schemes

- Hexagonal tiles read out with 3x3mm^2 MPPC
- For side and center readout, use 1 mm hole, fiber is at a corner also 1 mm
- Measure center position of tile
  - For readout with fiber
  - For readout on the tile center
  - For read on the tile side
- Measure high light yields

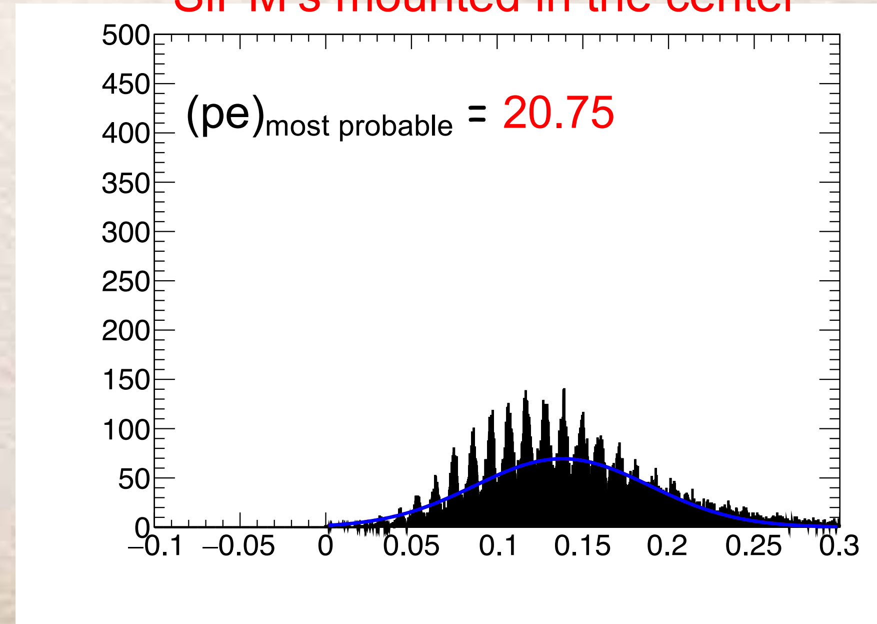
Readout with fiber



SiPM's mounted on the side

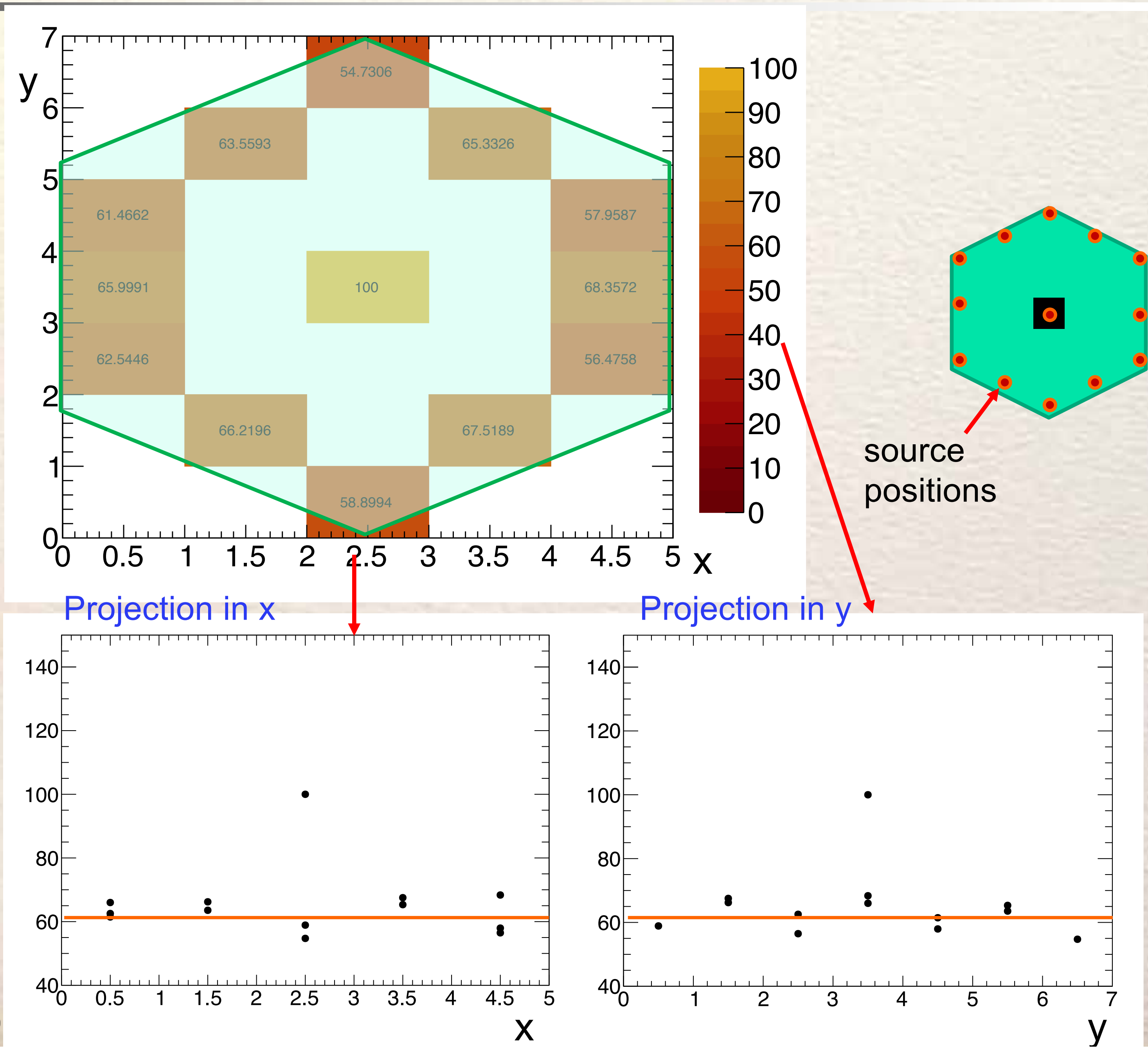


SiPM's mounted in the center



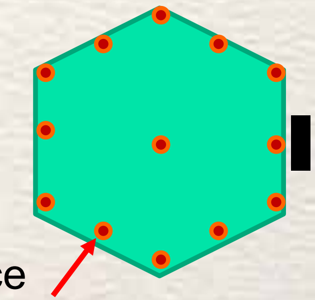
Uniformity Measurement of Center-mount MPPC

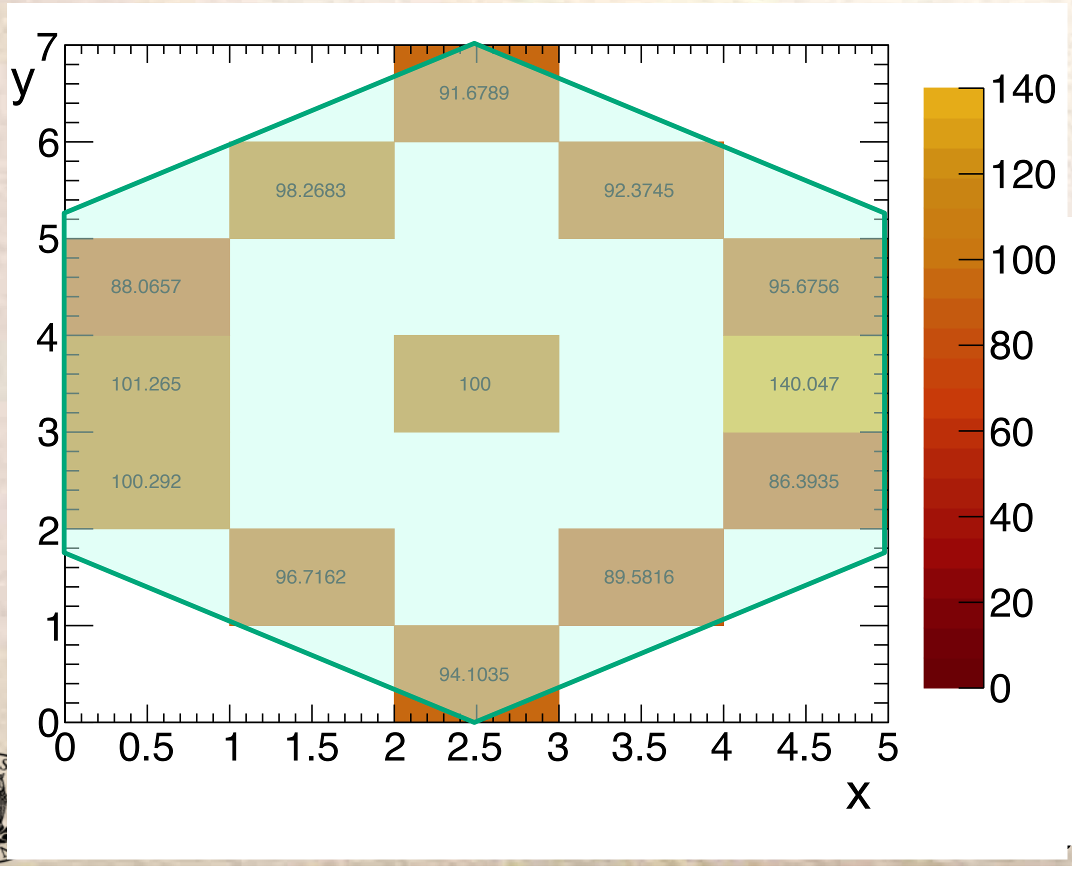
- Center point sees 1.68 times more light wrt average
- Excluding light yield at tile center center, tile center, all other mean light yield is (62.4 ±1.4)% wrt center LY
- Uniformity within ~ ±6% except for value at the center
- Need to enlarge dimple!

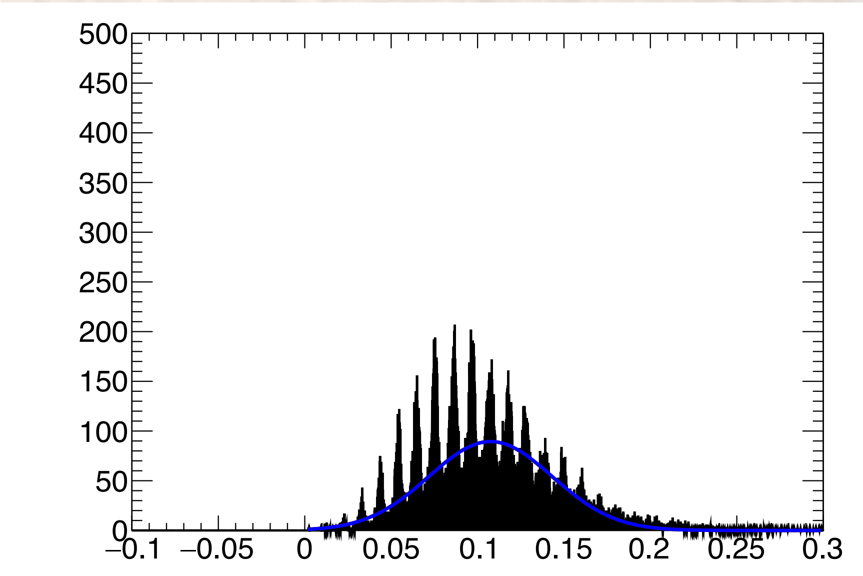


Uniformity Measurement of Side-mount MPPC

- Mean value of fitted Gaussian for each position is divided by the light yield measured at the center position
  - Note the increase in the number of PE's in the right most bin near MPPC
- Most probable light yield at the center position $(pe)_{most\ probable}$ =17.5 pe
- Excluding point near MPPC, average relative light yield is (94.5±5)%



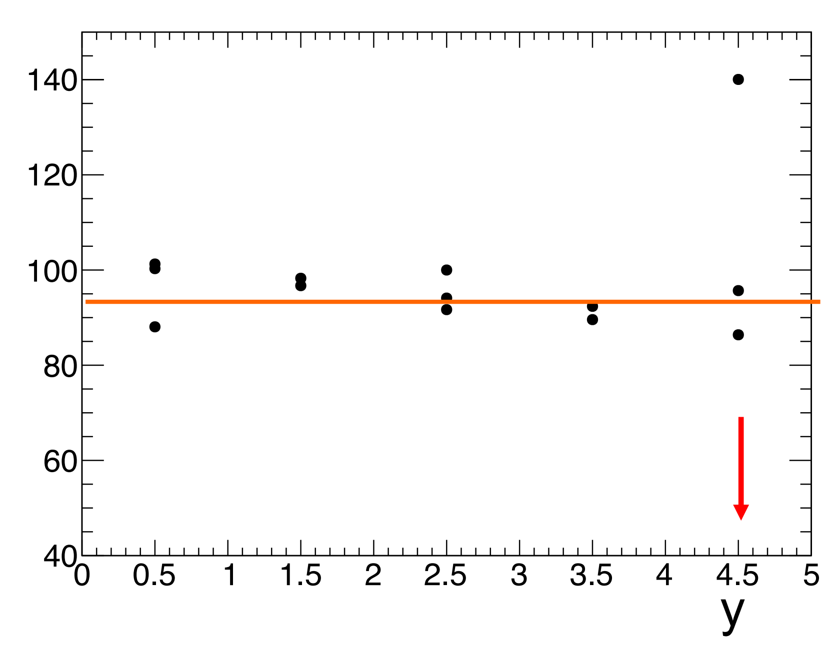




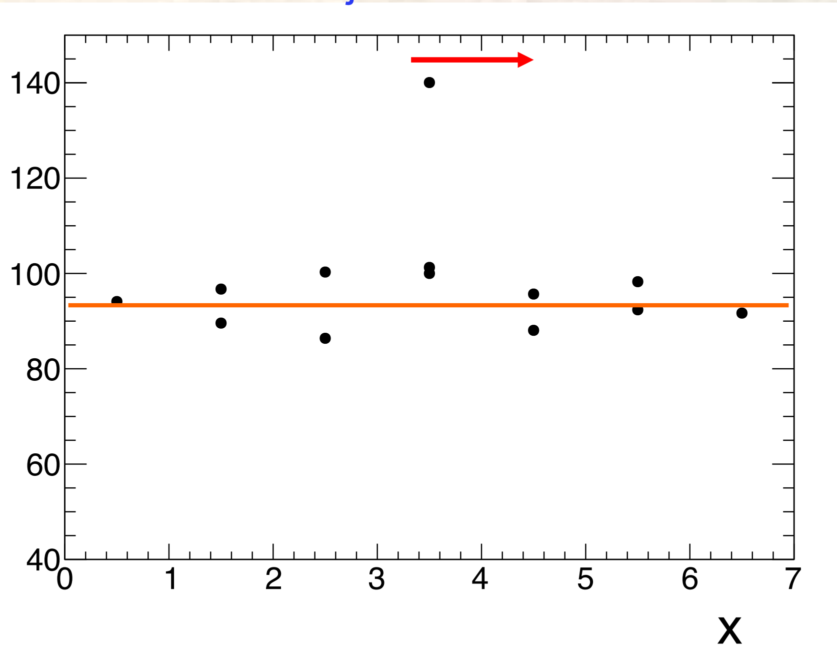
Uniformity Measurement of Side-mount MPPC

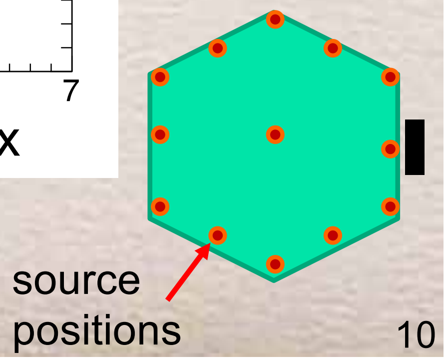
- Position at readout position is enhanced by 1.48 wrt average value
- Except for left edge position near the MPPC, uniformity within < ±7%
- We will perform more checks

Projection in X



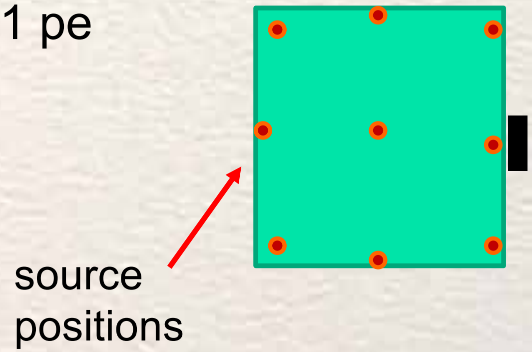
Projection in Y

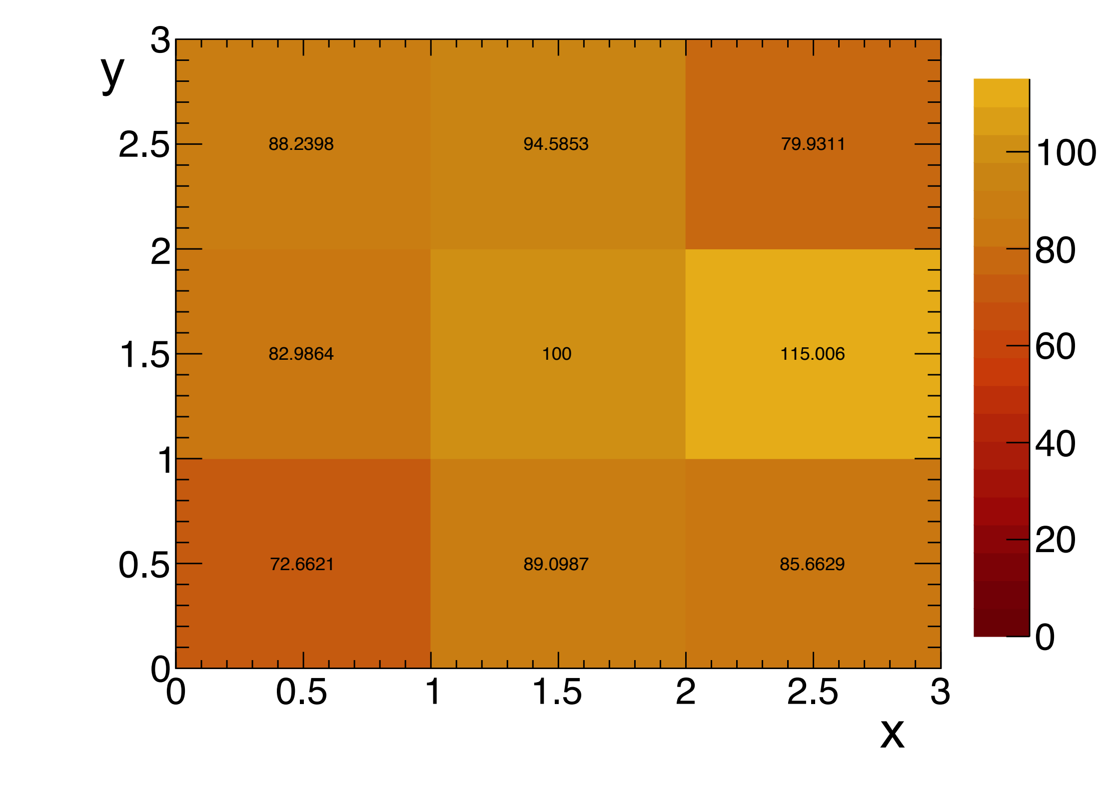


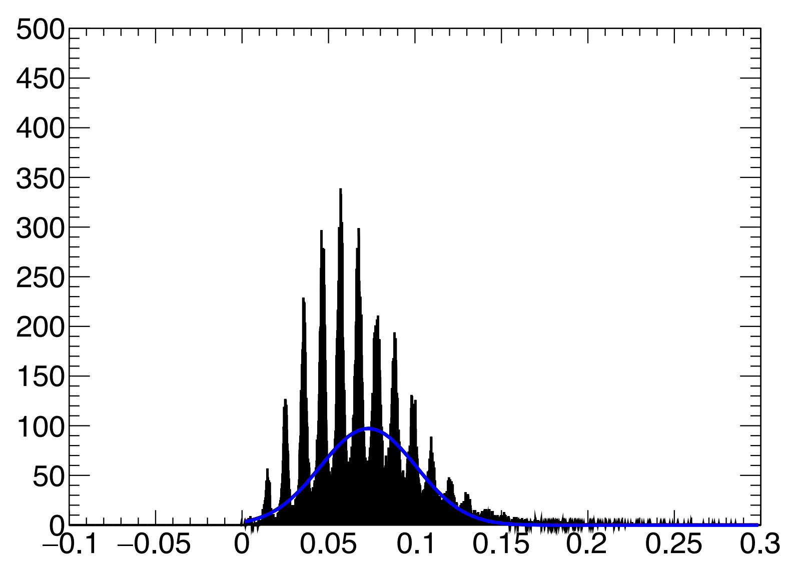


Uniformity of Square Tile with MPPC on Side

- Mean value of fitted Gaussian for each position is divided by the light yield measured at the center position
  - Note the increase in the number of PE's in the right most bin near MPPC
- Most probable light yield at the center position $(pe)_{most\ probable}$ =7.91 pe
- Average relative light yield is (86.7±2)%





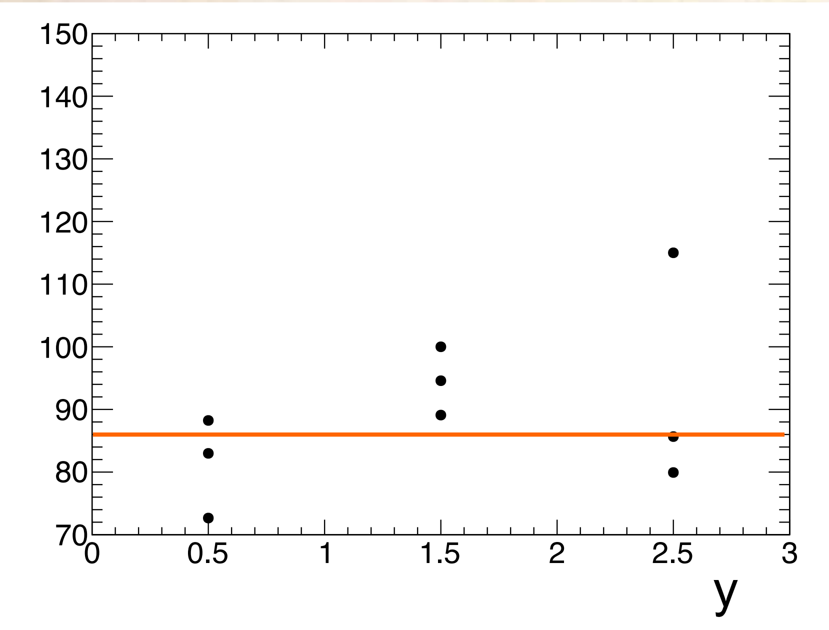


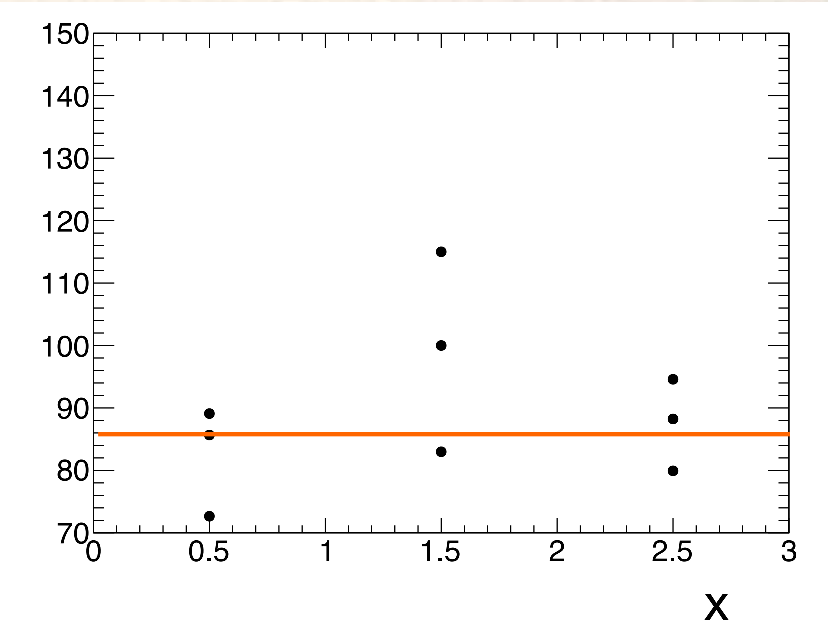
Uniformity Measurement of Side-mount MPPC

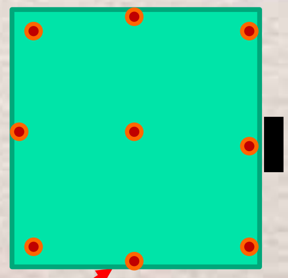
- Position at readout position is enhanced by 1.33 wrt average value
- Except for left edge position near the MPPC, uniformity within ~ ±13%
- Will perform further checks

Projection in X

Projection in Y







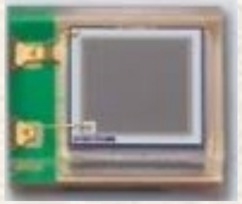
source positions

Properties of 4th Generation MPPCs S14160

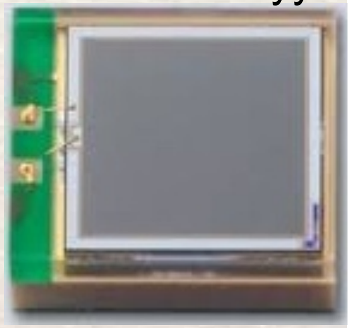
- We received 8 MPPCs from Hamamatsu (2 of each type)

MPPC	S14160-1310	S14160-3010	S14160-1315	S14160-3015
Sens. area	1.3 x 1.3 mm^2	3 x 3 mm^2	1.3 x 1.3 mm^2	3 x 3 mm^2
Pixel size	10 μ	10 μ	15 μ	15 μ
# pixels	16675	90000	7296	40000
V_b	~43	42.1	42.5	42.2
Dark rate	120 kHz	700 kHz	120 kHz	700 kHz
gain	1.8x10^5	1.8x10^5	3.6x10^5	3.6x10^5
C at Vop	100 pF	530 pF	100 pF	530 pF

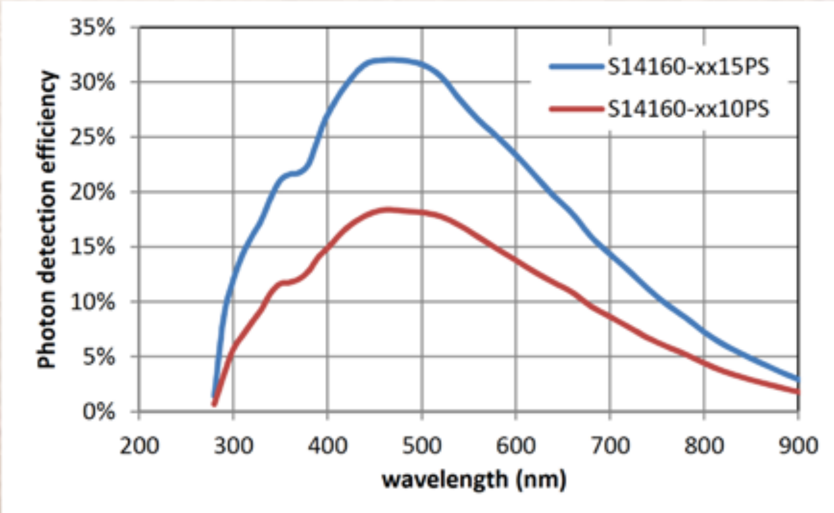
S14160-13yy



S14160-30yy

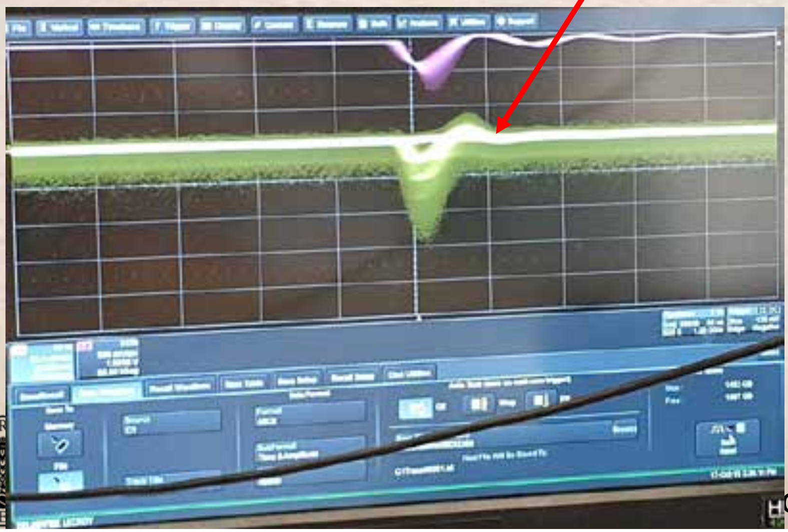


- Photodetection efficiency is highest for green light from Y11 fiber
- BC404 has maximum wavelength at 408 nm
- Photon detection efficiency of 10 μm pixel is about half of that of the 15 μm pixel sensors

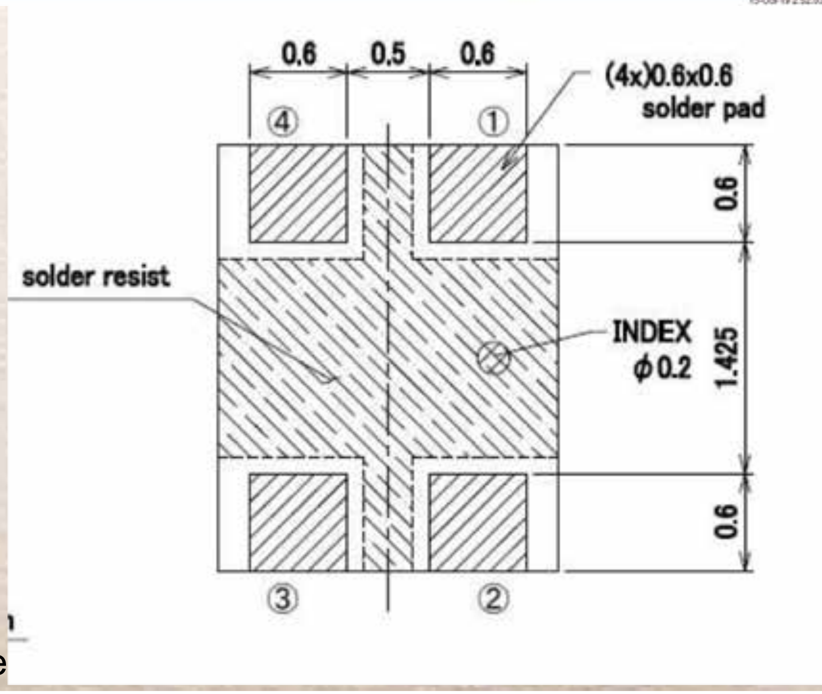


Experience with S14160 MPPCs

- Waveform of S14160-1315 sensor at V_b=43.33 V and T=25°C
- Clearly see individual photoelectrons
- Solder joints are rather touchy in 3 S14160-13 sensors, solder pads detached from sensor
- Our electronics engineer could fix two S14160-1310 sensors
- I ordered 4 new MPPCs

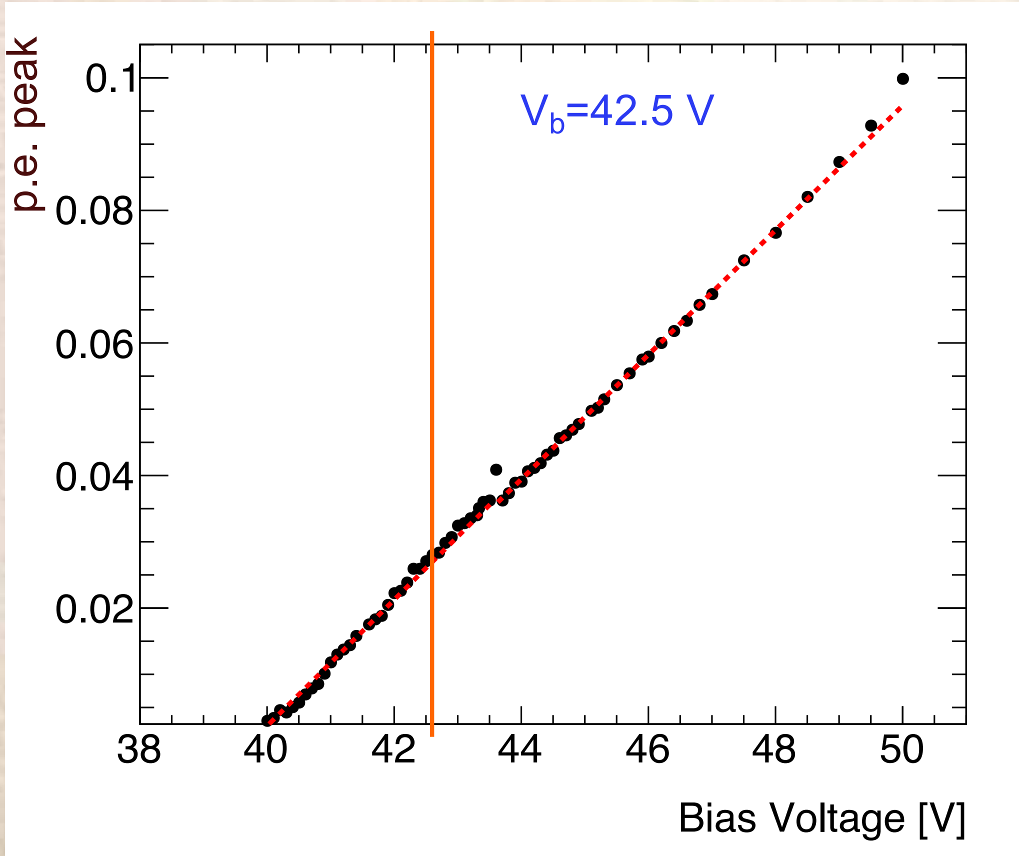


S14160-1315

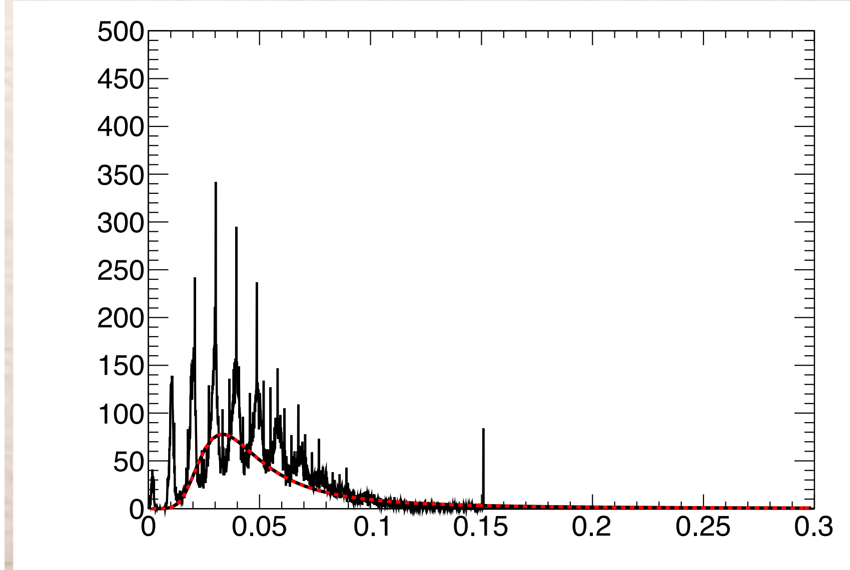


Voltage Scan with S14160-1315

- Use ^{90}Sr source on hexagonal tile with fiber read out by S14160-1315
- Determine peak of photoelectron distribution from fit with a Landau distribution, determination of most probable value would have been better
- Two linear regimes? Break of linearity at around 43.6 V
- Breakdown voltage: ~39.8 V

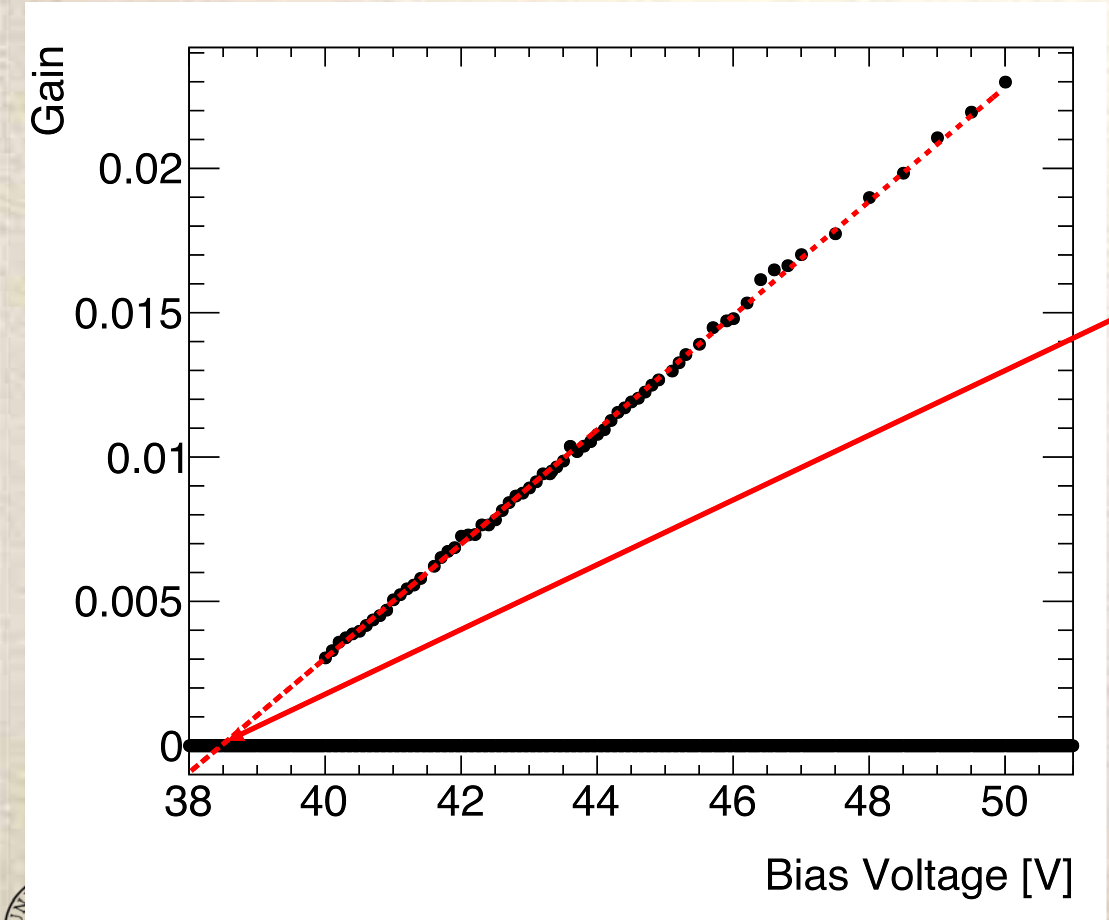


T=25°C -26.4°C

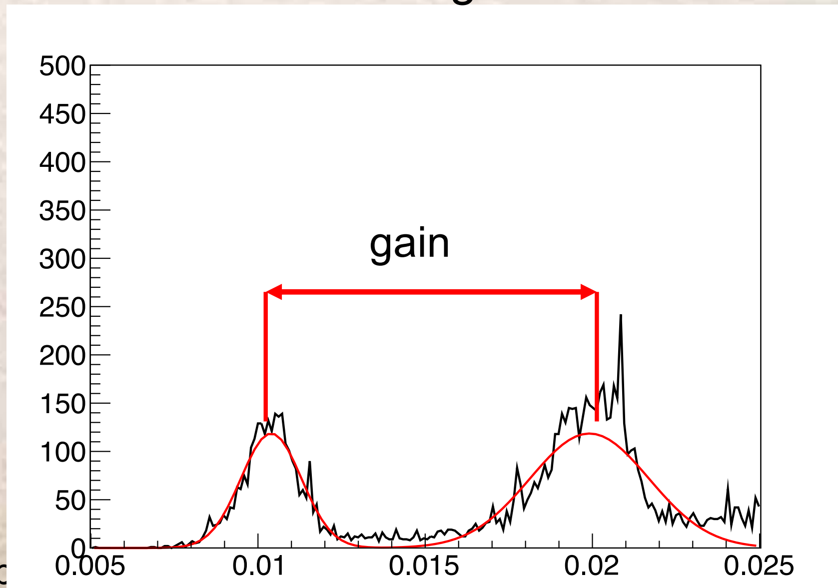


Gain versus Reverse Bias Voltage

- Determine gain from the distance between two adjacent photoelectron peaks
- Gain can be fitted with linear dependence, slope = 0.00198/V
- Deviations from line may come from small temperature fluctuations

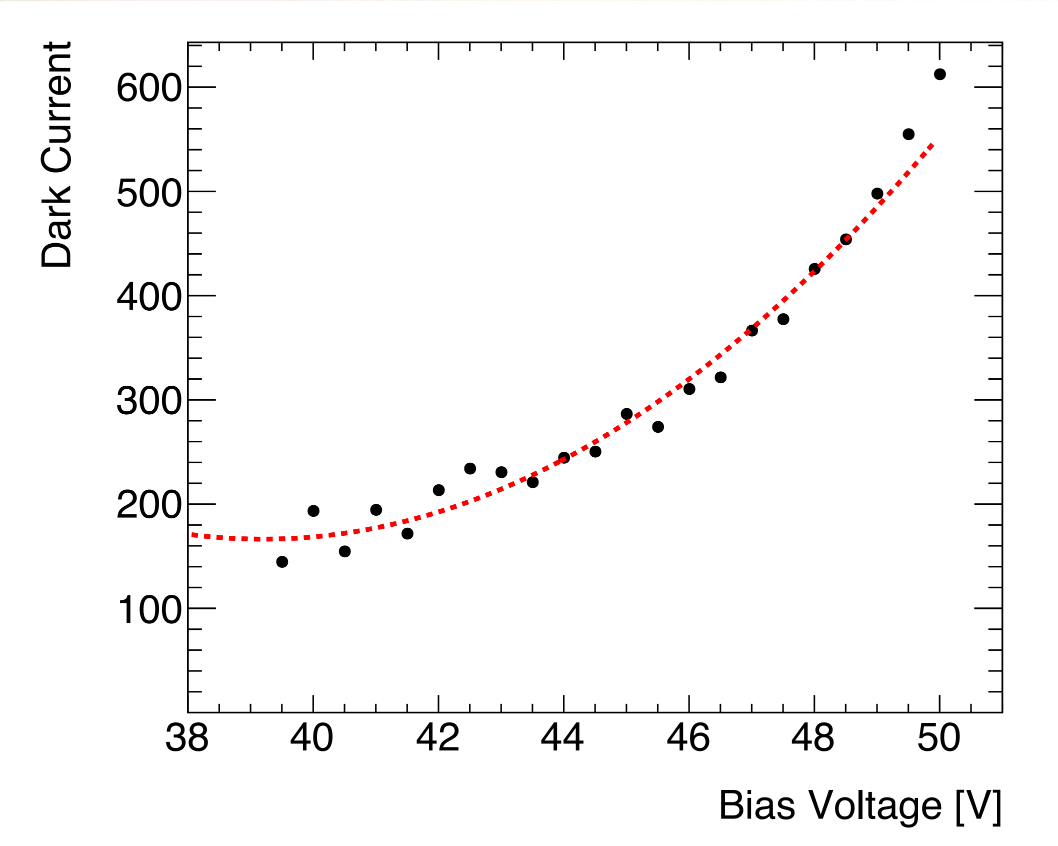


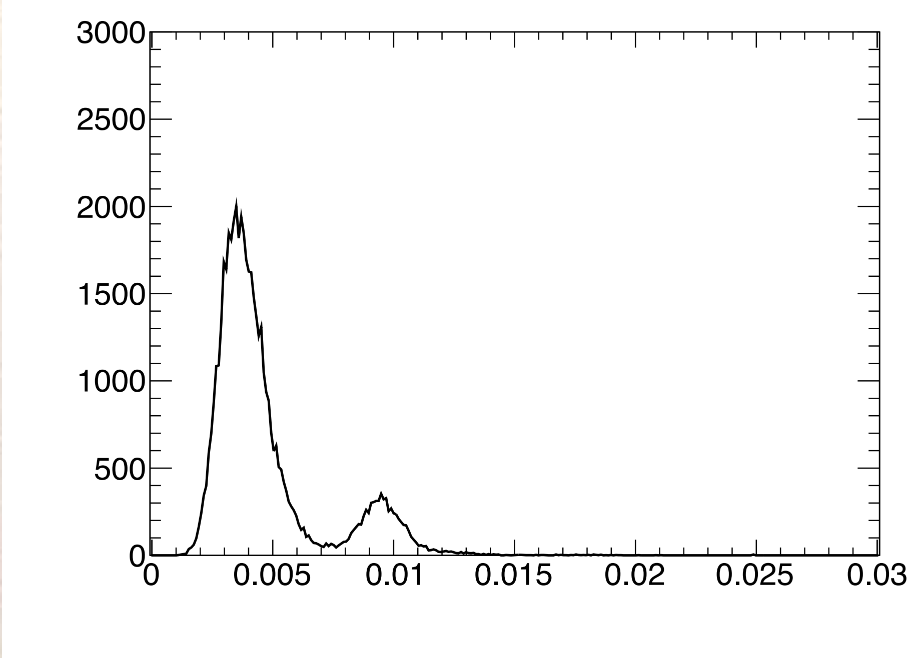
- Slope corresponds to 12375/V assuming C=100 pF
- At nominal V_b=42.5 V: G=5.3x10^5
- Breakdown voltage V_{break} =38.5 V
- I did not see signal at 39.3 V



Dark Current vs Reverse Bias Voltage

- Determine dark current from integral of waveform without source
- Dark current increases rapidly with increased reversed bias voltage
- Fit is second-order polynomial

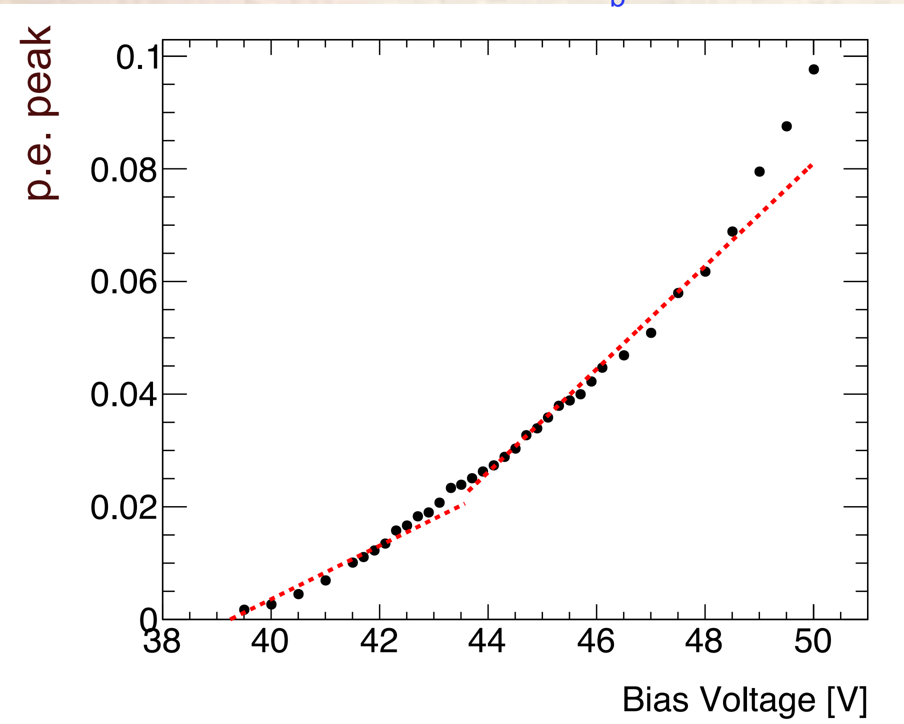




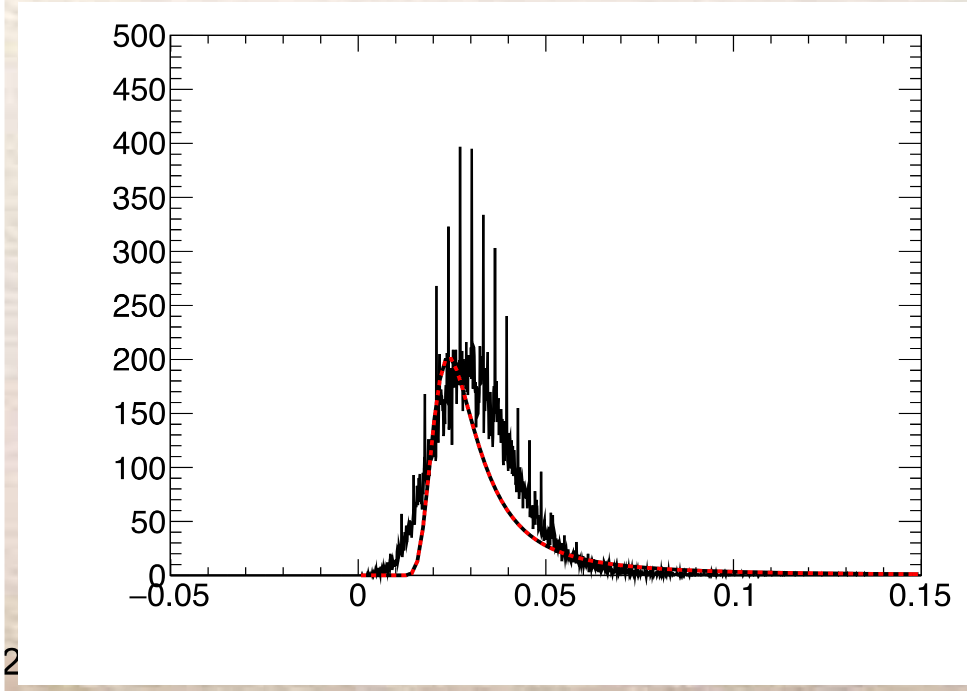
Voltage Scan with S14160-3010

- Use ^{90}Sr source on hexagonal tile with fiber read out by S14160-3010
- Determine peak of photoelectron distribution from fit with a Landau distribution, which does not give a good description of the MIP distribution and peak position
- Dependence is not linear, fit shows 2 linear sections, which are not a good fit
- Gain determination needs to be redone
- Breakdown voltage is V_{break}~39.3 V

Recommended V_b=43.3 V

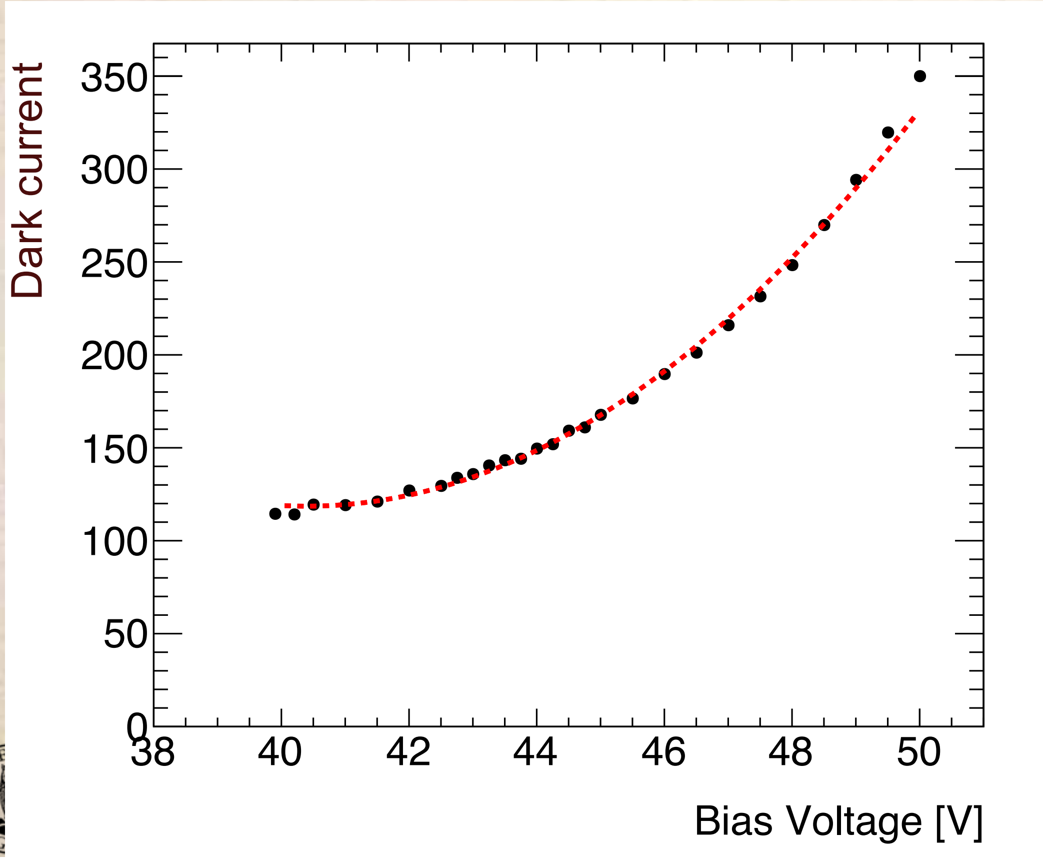


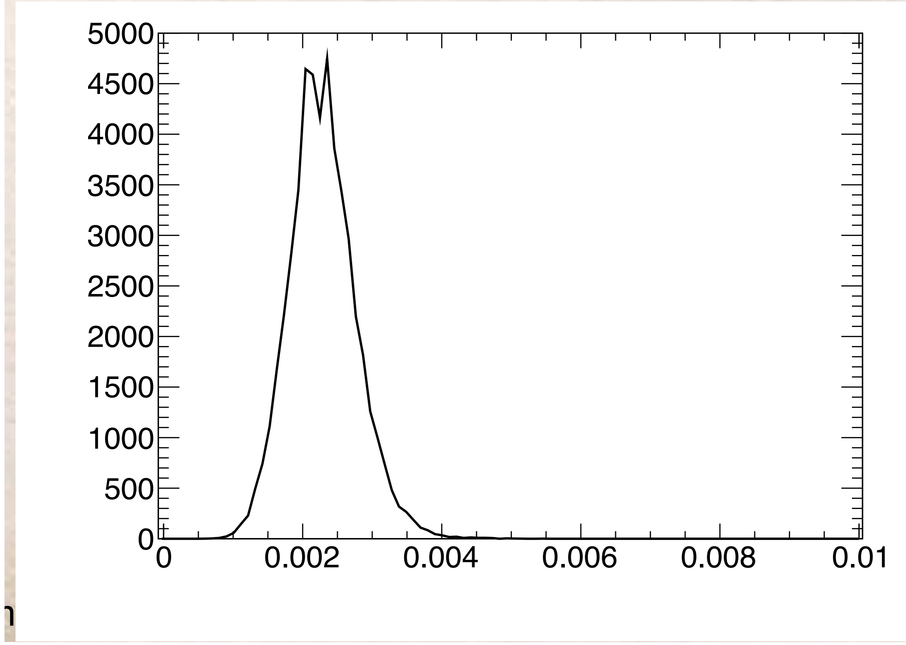
T=25.4°C



Dark Current vs Reverse Bias Voltage

- Determine dark current from integral of waveform without source
- Dark current increases rapidly with increased reversed bias voltage
- Fit is second-order polynomial
- Dark current for S14160-3010 is lower than that for S14160-1315, (I don't understand this) needs to be checked





Conclusions

- Readout of hexagonal tiles look promising
- Performance of hexagonal tiles with center-mount readout
  - Uniformity within ±6% except for center position
  - Dimple was too small to insert MPPC fully, ➔ light yield in the center is 1.68 times larger than the average ➔ need to enlarge dimple and redo measurements
- Performance of hexagonal tiles with side-mount readout
  - Uniformity within ±7% except for position close to MPPC
  - No dimple ➔ light yield near MPPC is 1.48 times larger than the average
- Performance of square tiles with side-mount readout
  - Uniformity within ±13% except for position close to MPPC
  - No dimple ➔ light yield near MPPC is 1.33 times larger than the average
- First test of 4th generation MPPCs, 14160 series
  - Gain of S14160-1315 is linear with V_b between 40 and 50 V
  - Dark current increases rapidly with V_b
  - Fixed S14160-1310 MPPC seems to work

Outlook

- Improve mounting of MPPC to tile
- Measure performance of square tiles read out with fiber-mount and center-mount
- Repeat measurements of hexagonal tile with center-mount and side-mount readouts using proper-size dimples
- Measure gain, breakdown voltage, dark current and after-pulsing of all S14160 sensors
- Measure linearity, response of recorded pixels versus number of input photons with light pulser
- Study temperature dependence of S14160 sensors
- Study light yield of hexagonal tiles for different wrappings