Scintillator HCAL R&D:

direct coupling test with green scintillator

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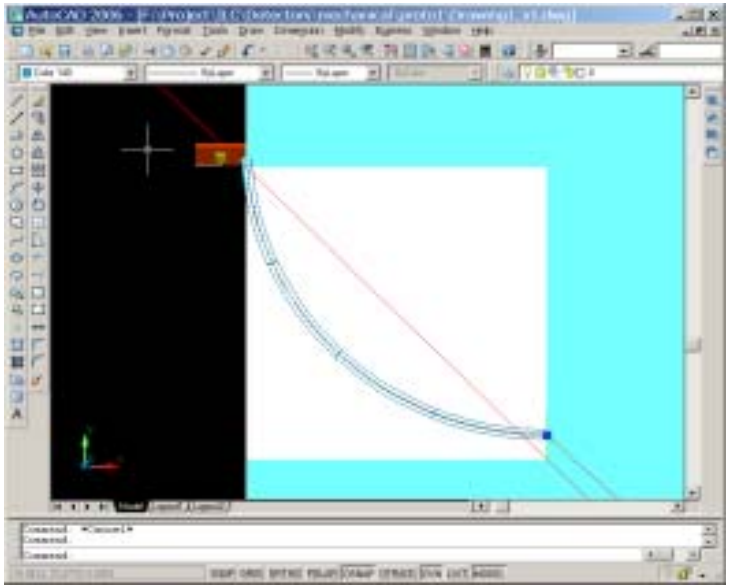
OUTLINE

1. Premises
2. Cosmic test setup
3. Cosmic test results
4. Uniformity test results
5. Summary

Premises

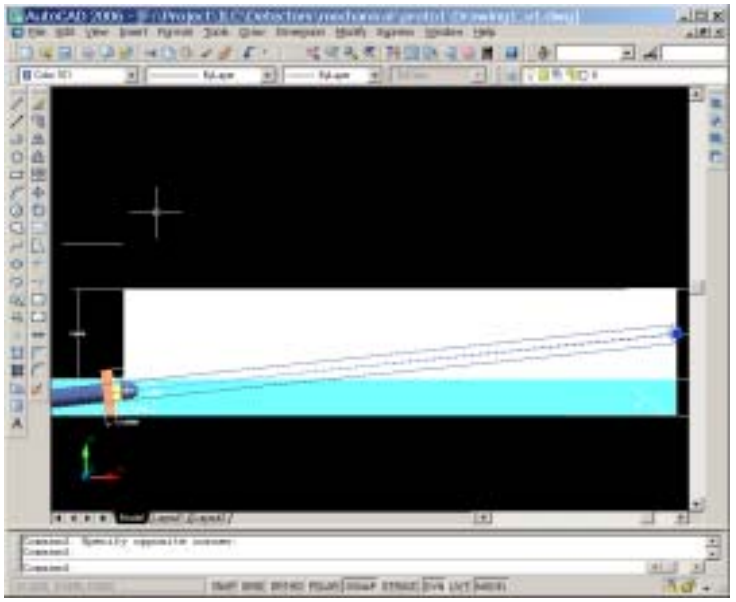
- **Fibreless readout is a part of R&D to optimize the final design. WLS Fiber readout has been extensively investigated.**
- **Possibility of integration(Sensor-PCB-ASIC).**
- **Availability of the SSPM optimized for the green light.**

! WLS fiber readout has been extensively investigated by NICADD and CALICE collaboration

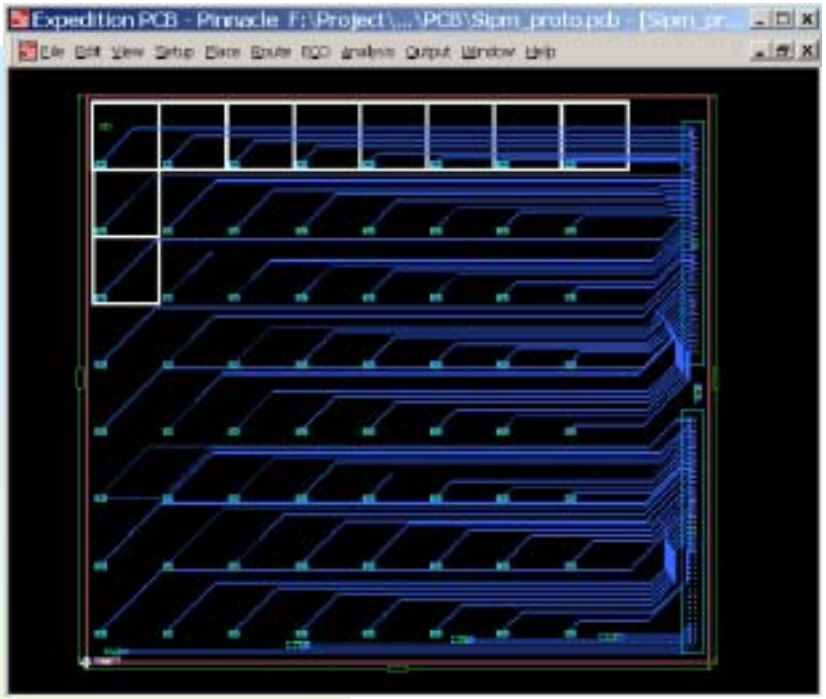


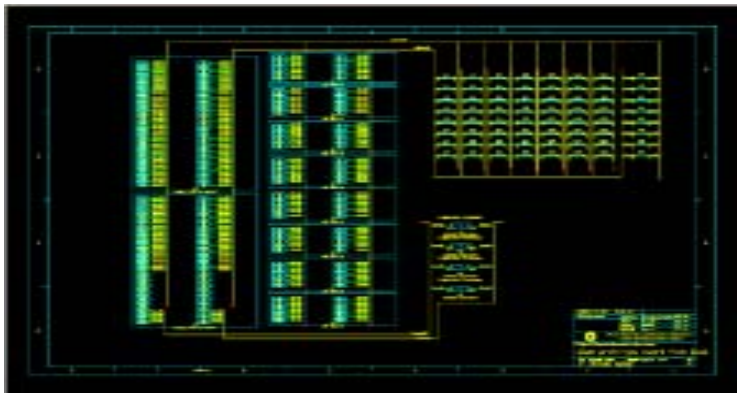
! For the low PDE eff. SSPM (13 % in green) for the WLS readout of blue scintillator, 5 mm. ~ 15 PE.

While this design can work with a fiber-in-cell elements a further simplification in assembly and large-scale production may be possible if direct coupling can be shown to work !



Basic elements of fibreless readout





ASIC

PC Board

Scintillator

Photo-sensor

Parameter	Units	Typical Values	Comments
Peak Sensitivity Wavelength	nm	580	= λ_P
Single photon detection efficiency	%	>20	at λ_P
Operating Voltage	V	30 29.8 - 30.6	= V_R Recommended range
Gain		1.8×10^5	at V_R
Dark current	μA	10	typical at V_R
Capacitance	pF	40	at V_R and readout rate f_R =1MHz
Excess noise factor		<1.05	at V_R, f_R and λ_P
Signal rise time	ns	<2	
Number of micro-cells		~500	
Fill or Geometric Factor	%	>70	

Parameter	Units	Typical Values	Comments
Peak sensitivity wavelength	nm	580	= λ_P
Single photon detection efficiency	%	26 / 13	at λ_P / at 450nm
Operating voltage	V	20.5 19.5 - 20.5	= V_R Recommended range
Gain		1.5×10^5	at V_R using 40ns integration window
Dark current	μA	<18	typical at V_R
Capacitance	pF	~170	at V_R and readout rate f_R =1MHz
Excess noise factor		<1.1	at V_R, f_R and λ_P
Signal rise time	ns	<3	
Number of micro-cells		1700	
Operating Temperature	C°	-40 ... +40	
Storage Temperature	C°	-40 ... +60	
Max. sensor temperature during soldering	C°	110	

1*1 mm^2

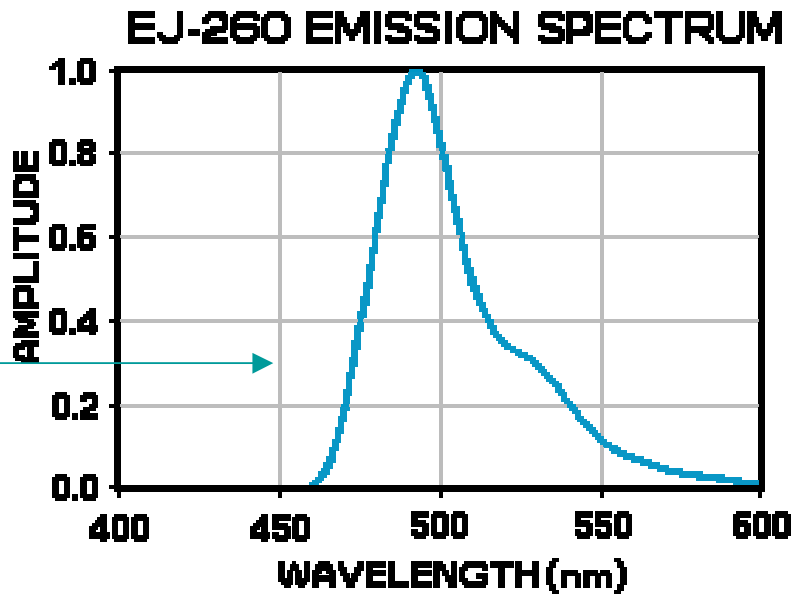
CPTA MOSCOW

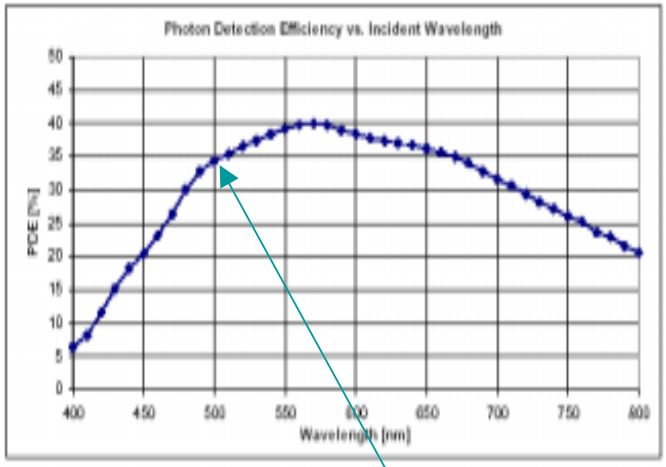
2*2 mm^2

Scintillator and photo-sensors

We used 3*3 cm2 green emission scintillator, wrapped in VM2000, 6.2 mm in thickness, edges cut, not polished, painted in white.

Light Output, % Anthracene	60%
Scintllation effici., photons/1MeV e^-	9,200
Wavelength of max emission, nm	490
Rise Time, nSec	
Decay Time, nSec	
No. of H atoms per cm^3 x 10^{22}	5.21
No. of C atoms per cm^3 x 10^{22}	4.70
No. of electrons per cm^3 x 10^{23}	3.35
Density, g/cc	1.02



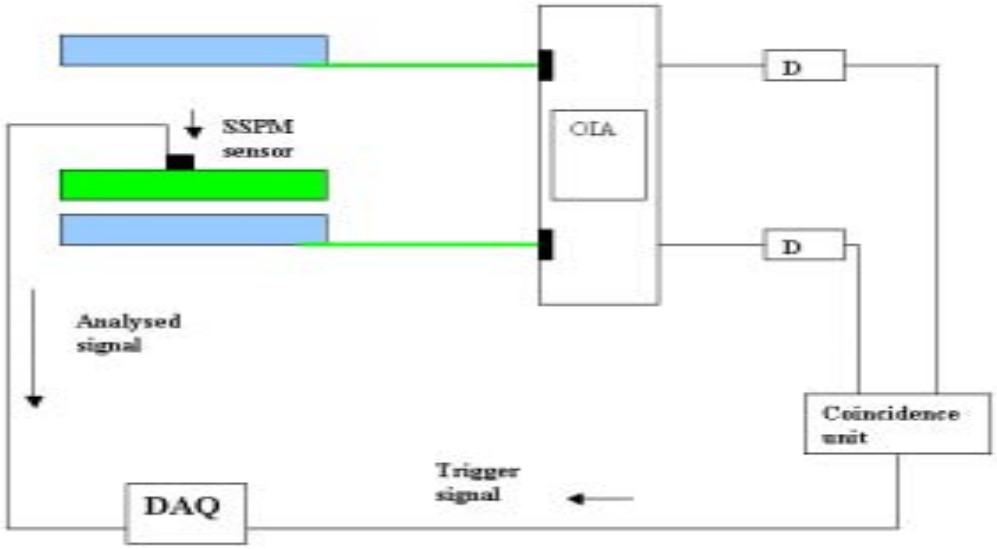


SSPM are of different vendors and characteristics

Cosmic test setup

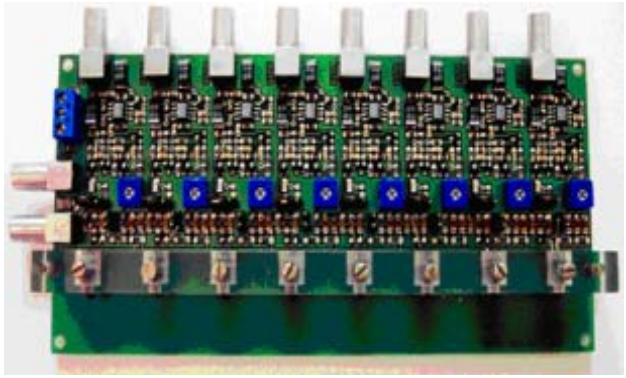
Noise rate at single counter ~ 150 Hz,

Threshold ~5 PE



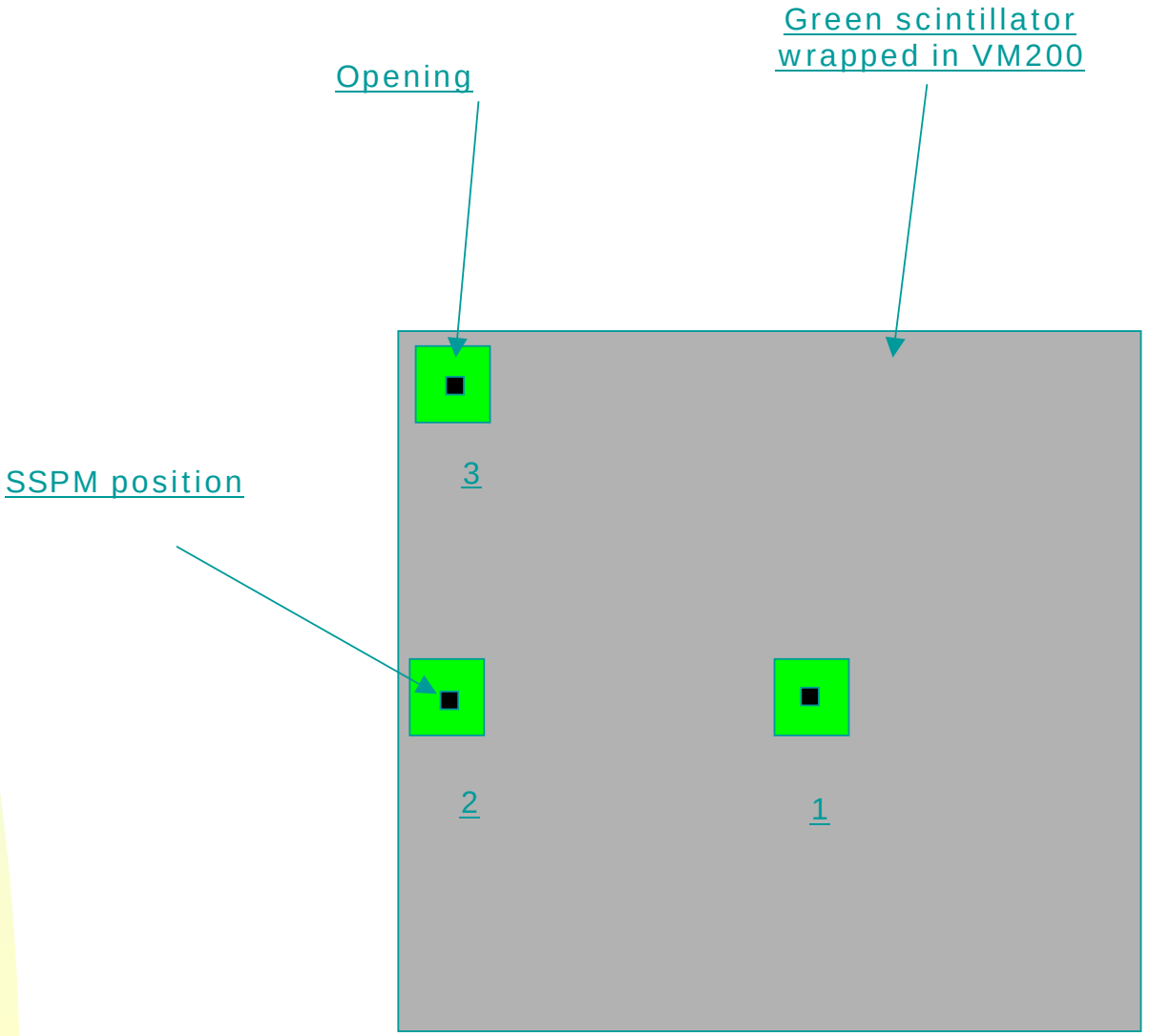
OIA

Magic box



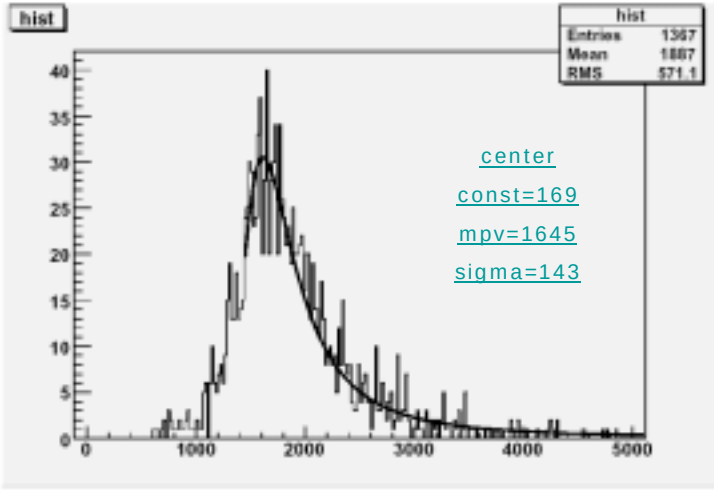
CPTA

Positions of the sensor during measurements

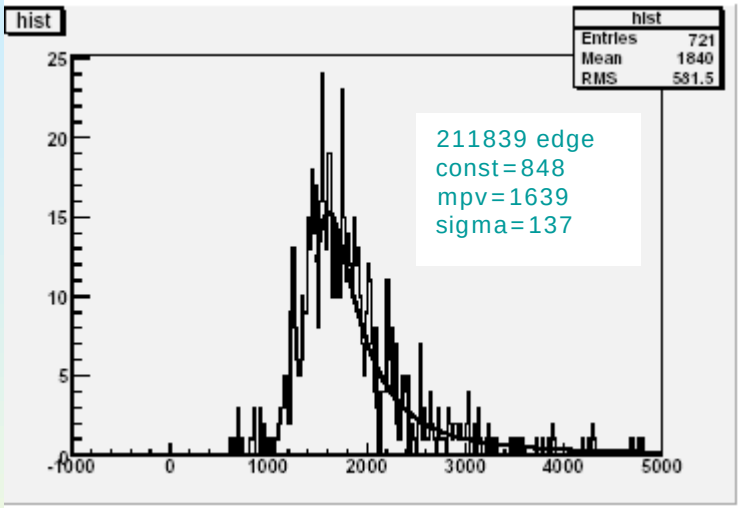


Amplitude distribution for each position.

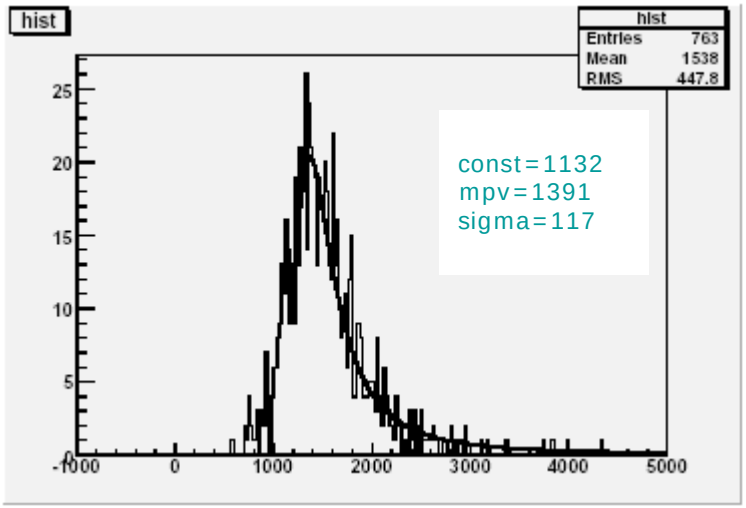
[1], Δ=890



[2], Δ=839



[3], Δ=591



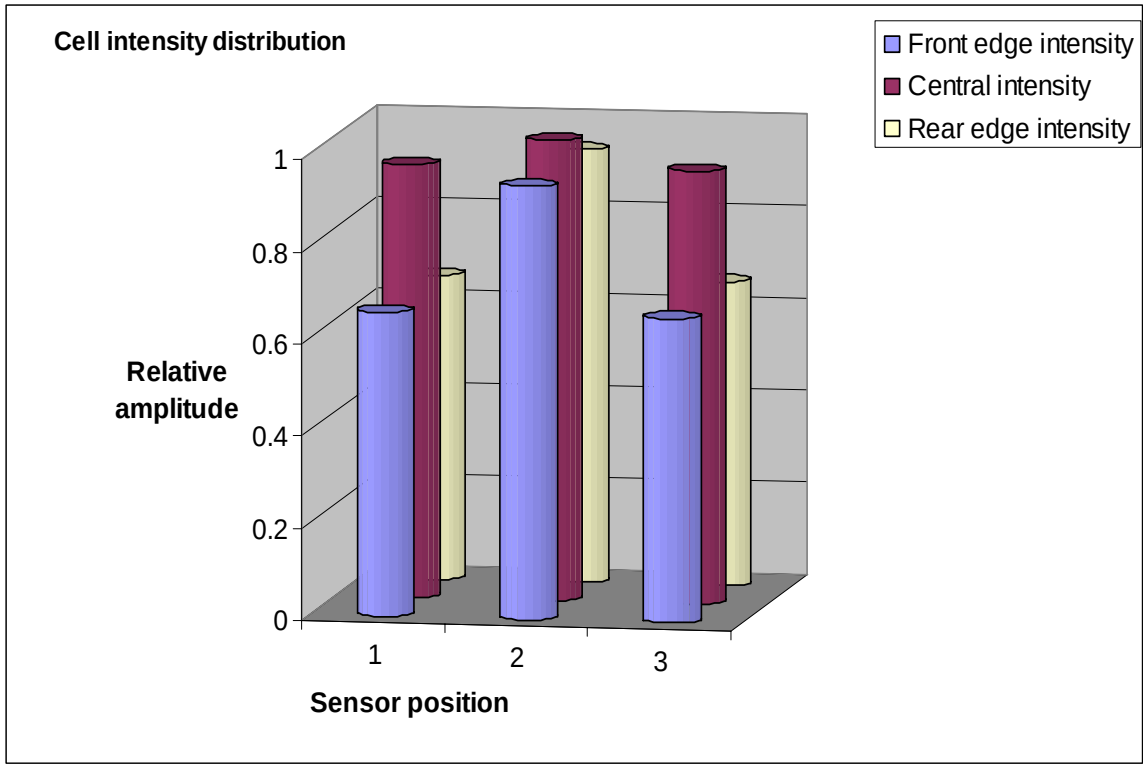
Normalization with fit:

Center - 100%

Edge - 94%

Corner - 66%

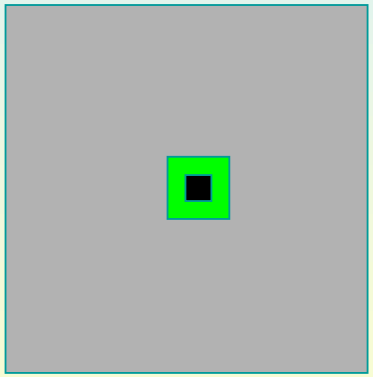
3D distribution of the signal intensity in the green scintillator cell.

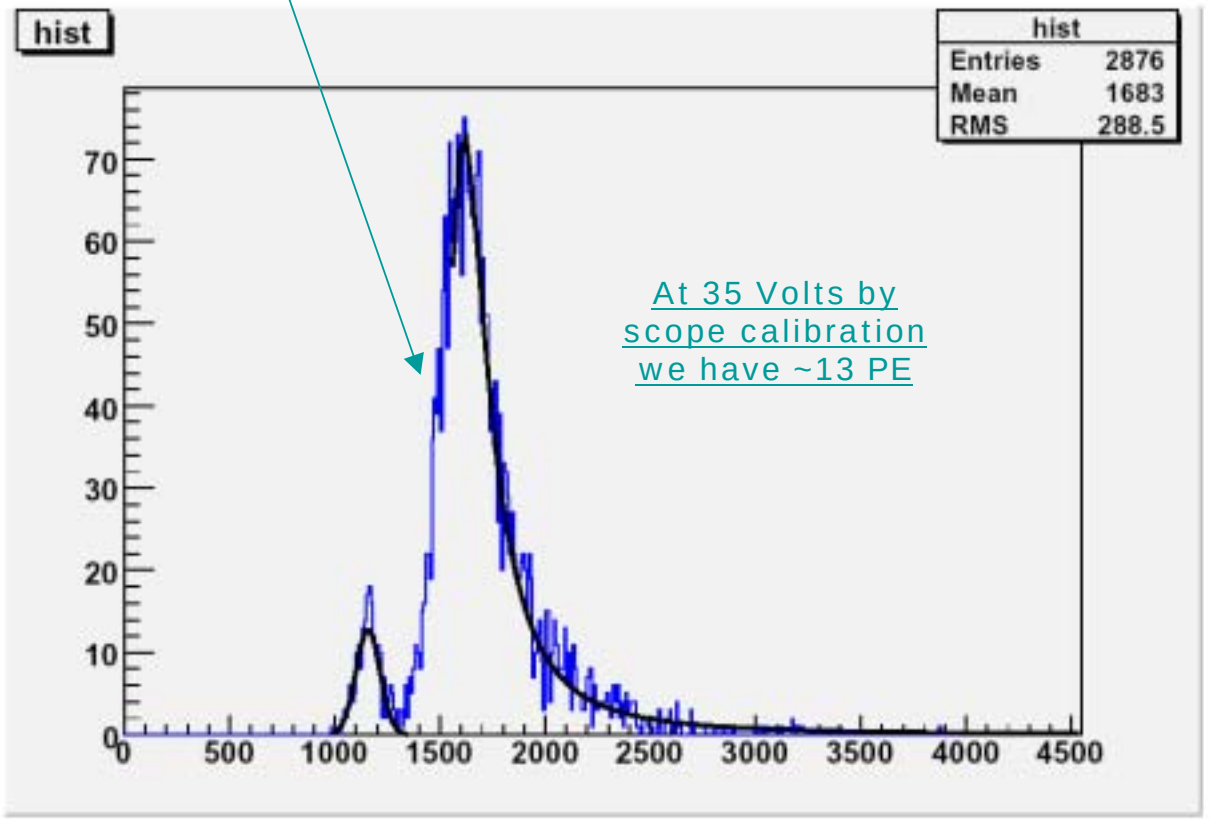


2*2 Cosmic

35 Volts

[1], Δ=238 20 volts
Δ =450 at 35 Volts





At 35 Volts by scope calibration we have ~13 PE

HAMAMATSU

100 pixels

100X100 µm

78% - fill factor

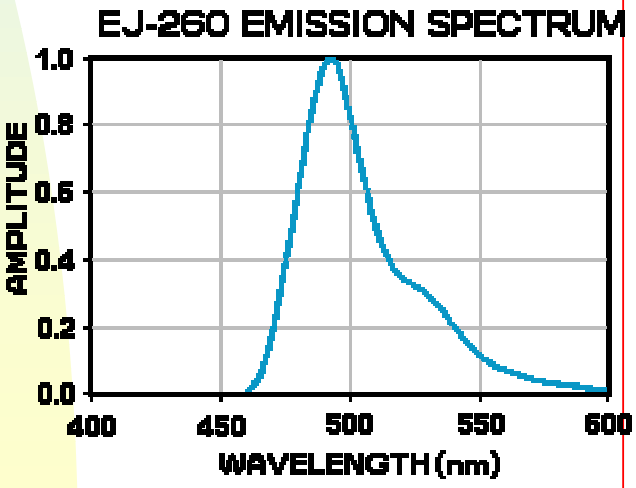
PDE~50%

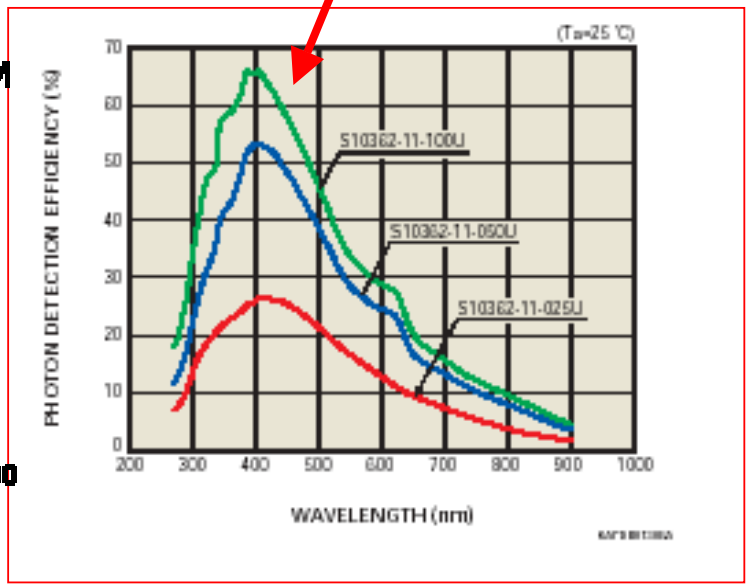
Gain~2.4*10^6

Specifications (Ta=25 °C)

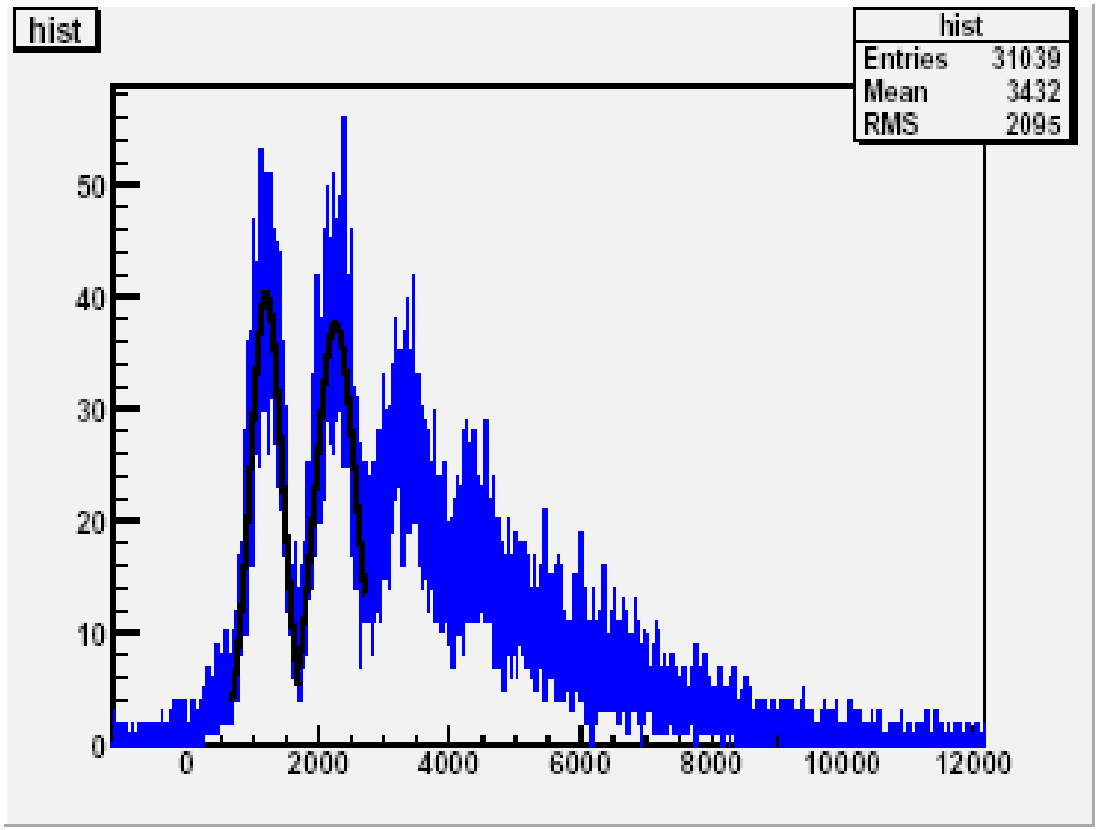
Parameter	Symbol	S10362-11 series			Unit
		-025U, -025C	-050U, -050C	-100U, -100C	
Chip size	-	1.5 × 1.5			mm
Effective active area	-	1 × 1			mm
Number of pixels	-	1600	400	100	-
Pixel size	-	25 × 25	50 × 50	100 × 100	µm
Fill factor *1	-	30.8	61.5	78.5	%
Spectral response range	λ	270 to 900			nm
Peak sensitivity wavelength	λp	400			nm
Quantum efficiency (λ=λp)	QE	70 Min.			%
Photon detection efficiency *2 (λ=λp)	PDE	25	50	65	%
Operating voltage	-	77 ± 10	70 ± 10	70 ± 10	V
Dark count	-	100	270	400	kcps
Terminal capacitance	Ct	35			pF
Time resolution (FWHM)	-	250	220	250	ps
Temperature coefficient of reverse bias	-	50			mV/°C
Gain	M	2.75 × 10^6	7.5 × 10^6	2.4 × 10^6	-

*1: Ratio of the active area of a pixel to the entire area of the pixel.
*2: Photon detection efficiency includes crosstalk and afterpulses.
Note: The last letter of each type number indicates package materials (U: metal, C: ceramic).





HAMAMATSU single-electron calibration



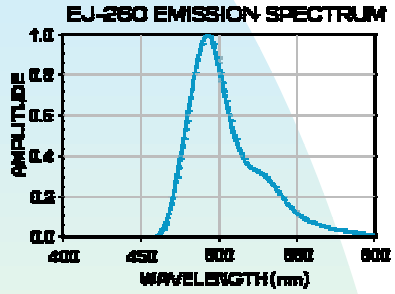
Signal from cosmic

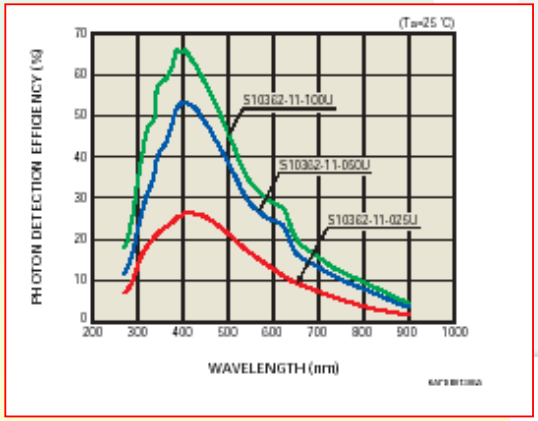
[2] Δ =2608

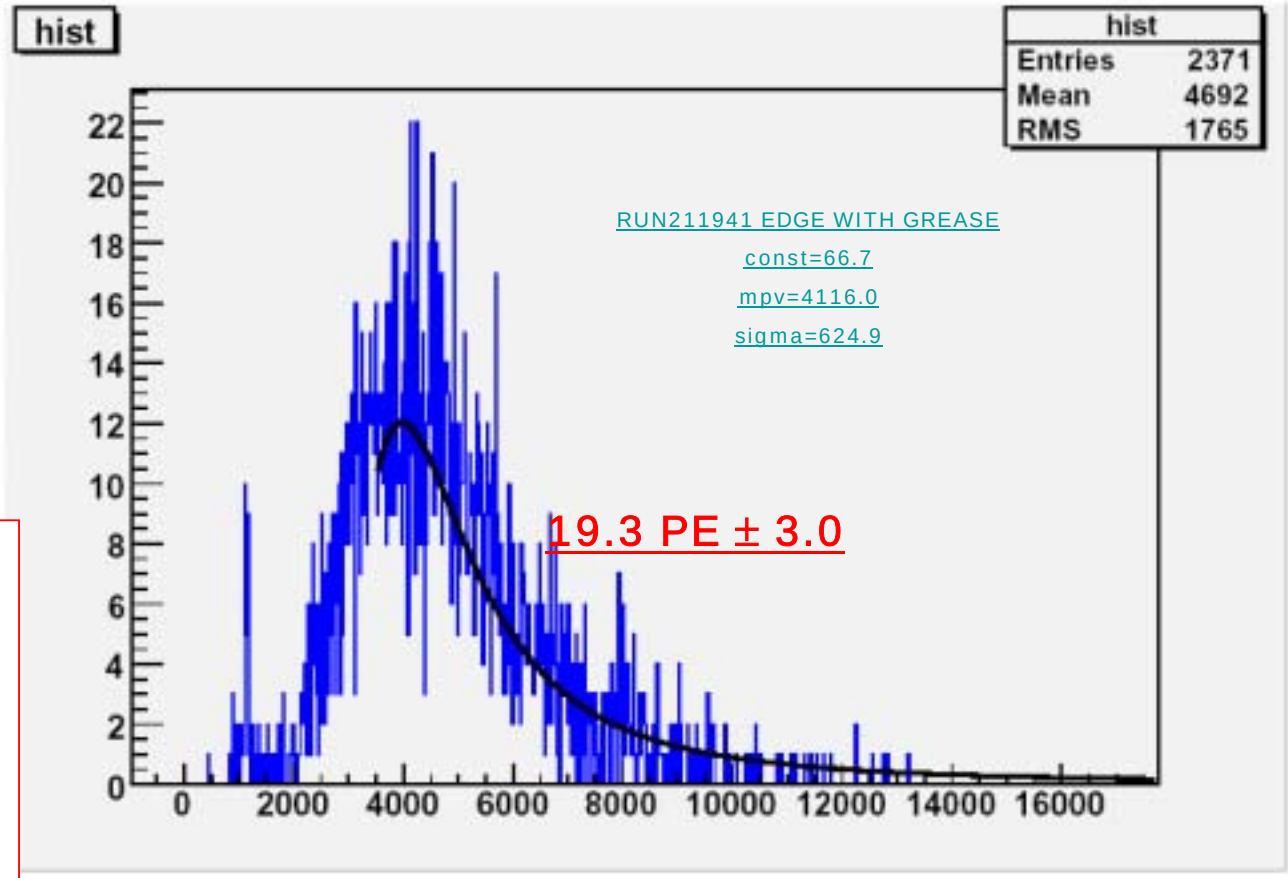
Scintillator - 6.2 mm

Edge position

Optical grease



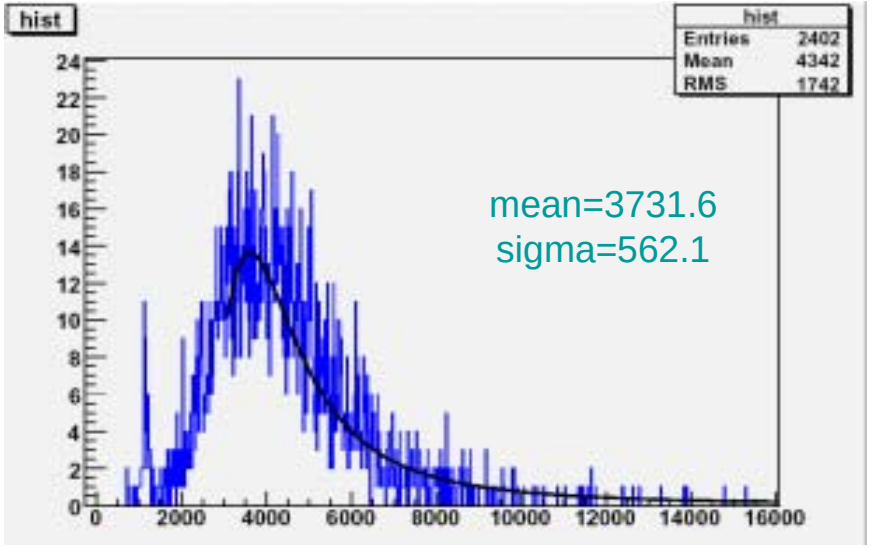




PDE at 500 nm ~ 45%

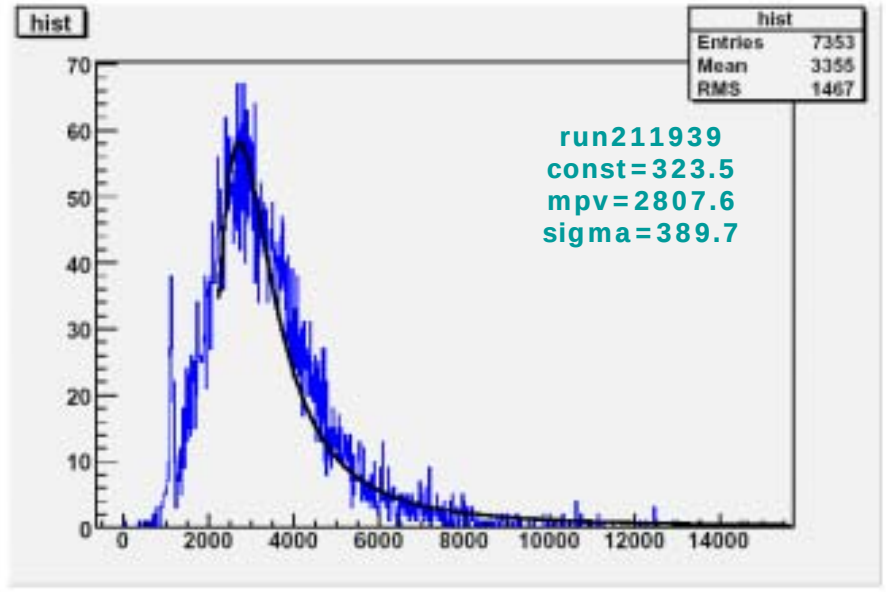
HAMAMATSU cosmic(optical grease vs. no grease)

[1] Δ =2608



GREASE/NO GREASE = 1.5 ± 0.2

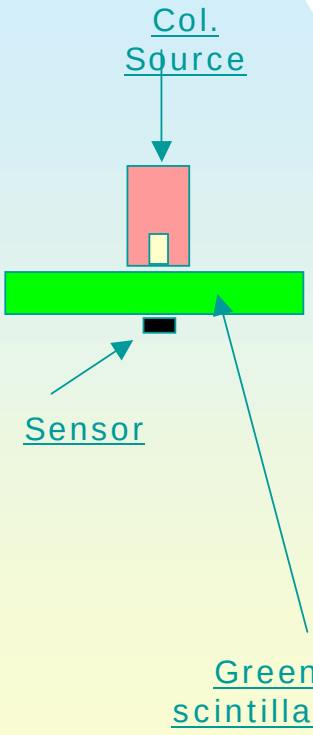
[1] Δ =1684

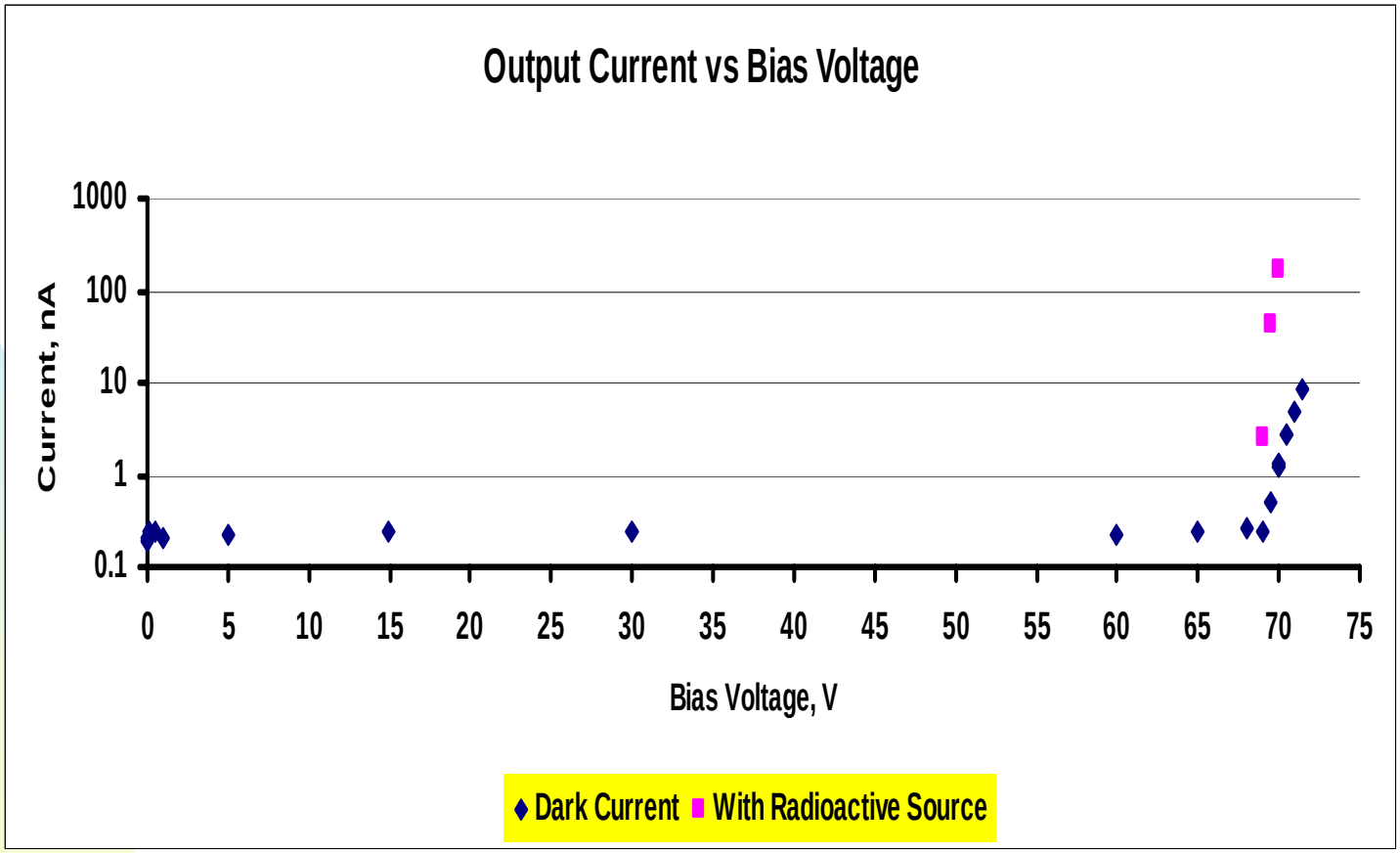


Cosmic test overview

- SSPM (CPTA) and HAMAMATSU have been tested.
- Absence of single electron separation for SSPM (CPTA) creates problems for calibration (for the setup we use).
- The best (expected) result came from HAMAMATSU with 100 pixels.
- Optical coupling through the grease improves results by 50 %.
- Uniformity test is necessary.

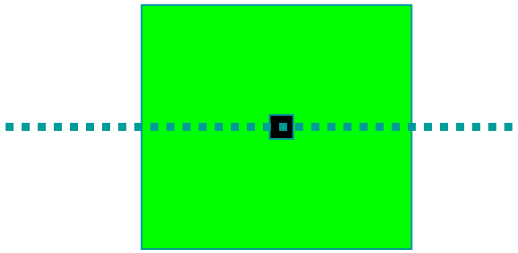
D.C. measurements with radioactive source Sr^{90}

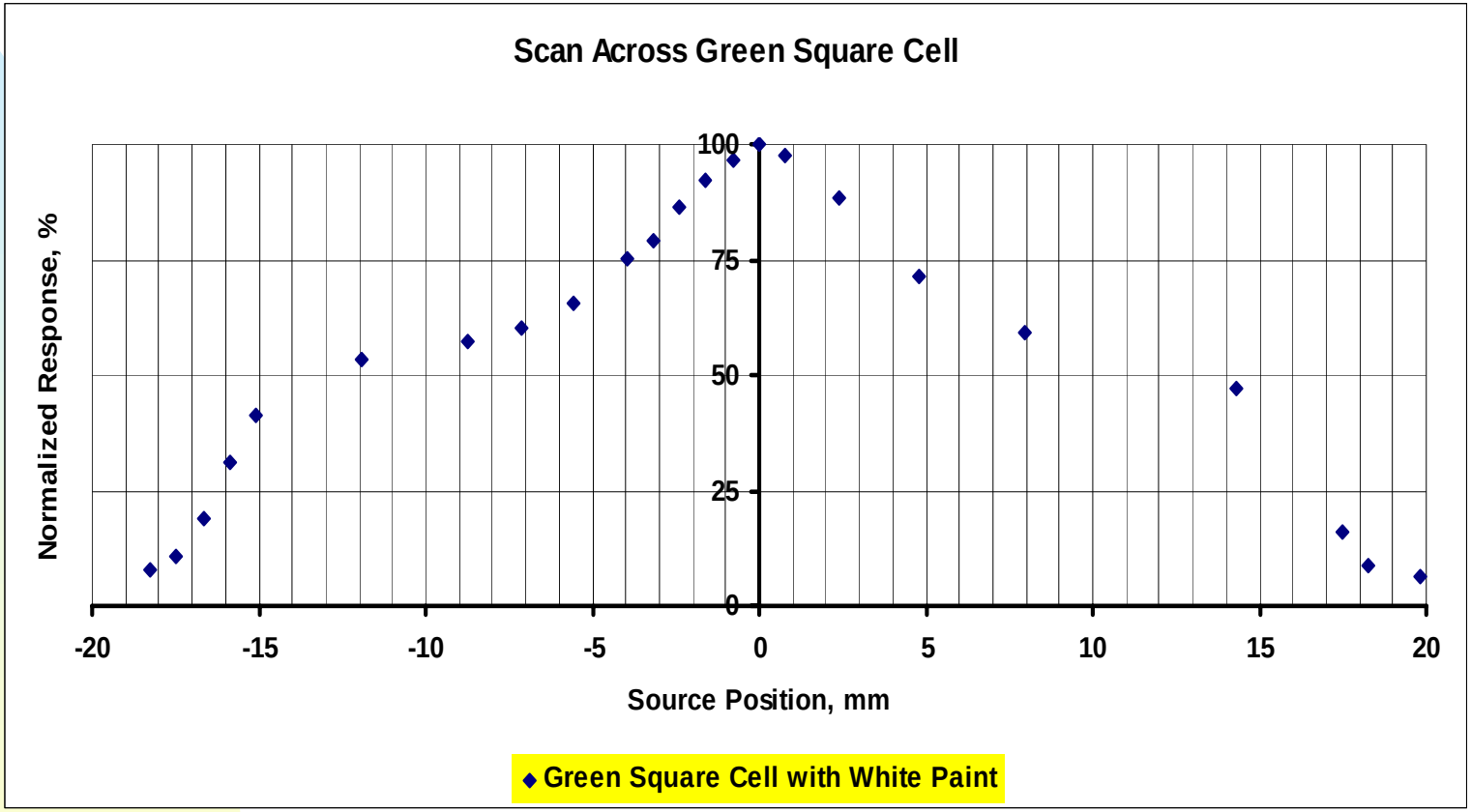




Signal /Background~130

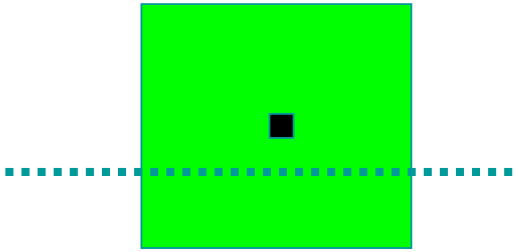
Scan test

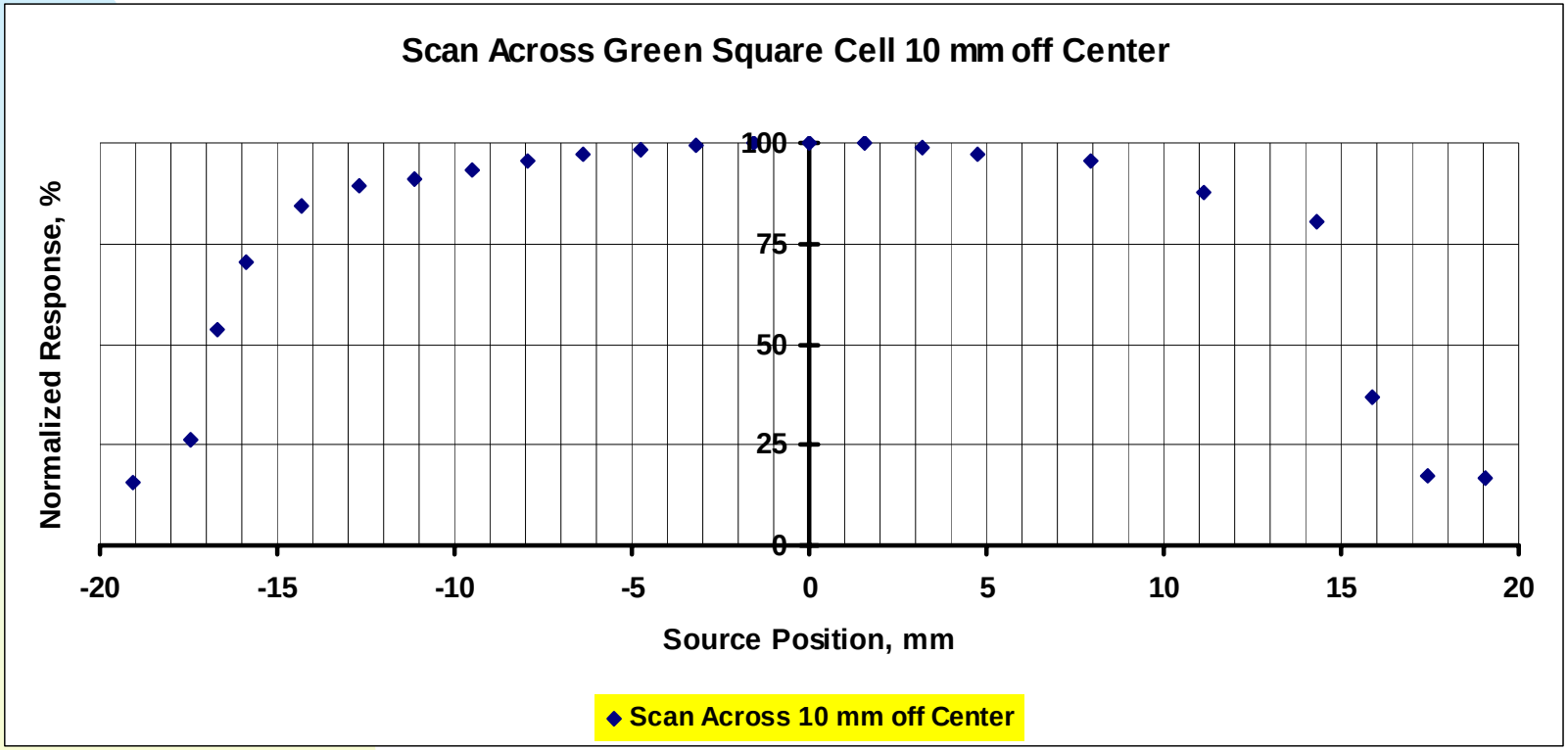




37% non uniformity

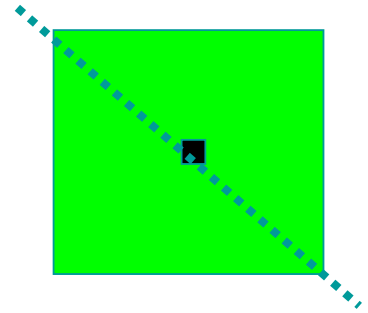
Scan test

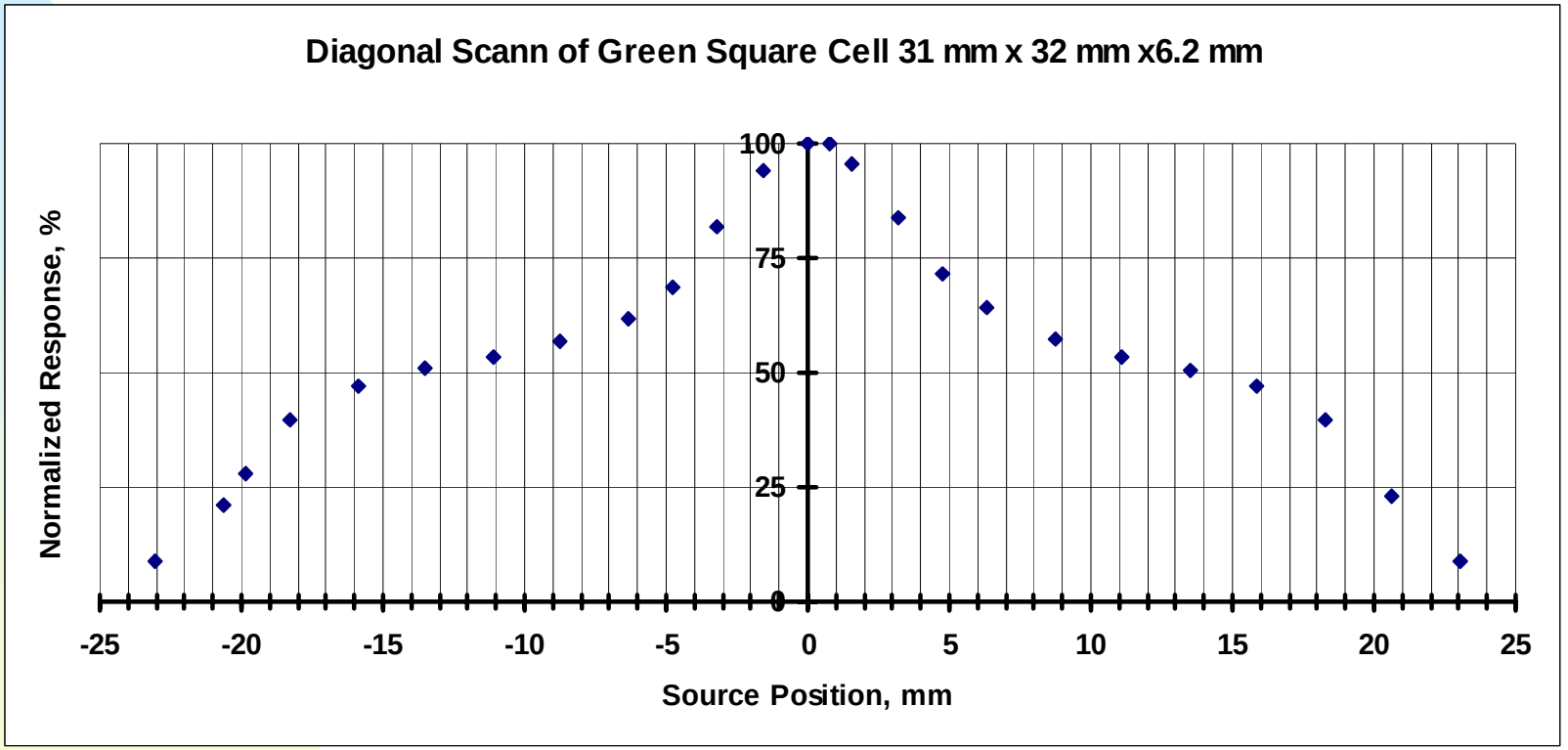




20% non uniformity

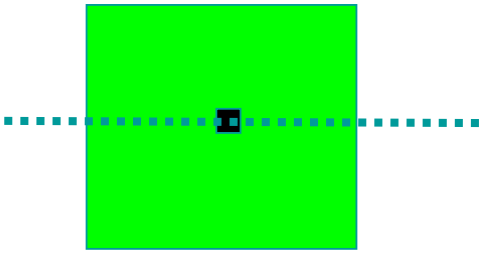
Scan test



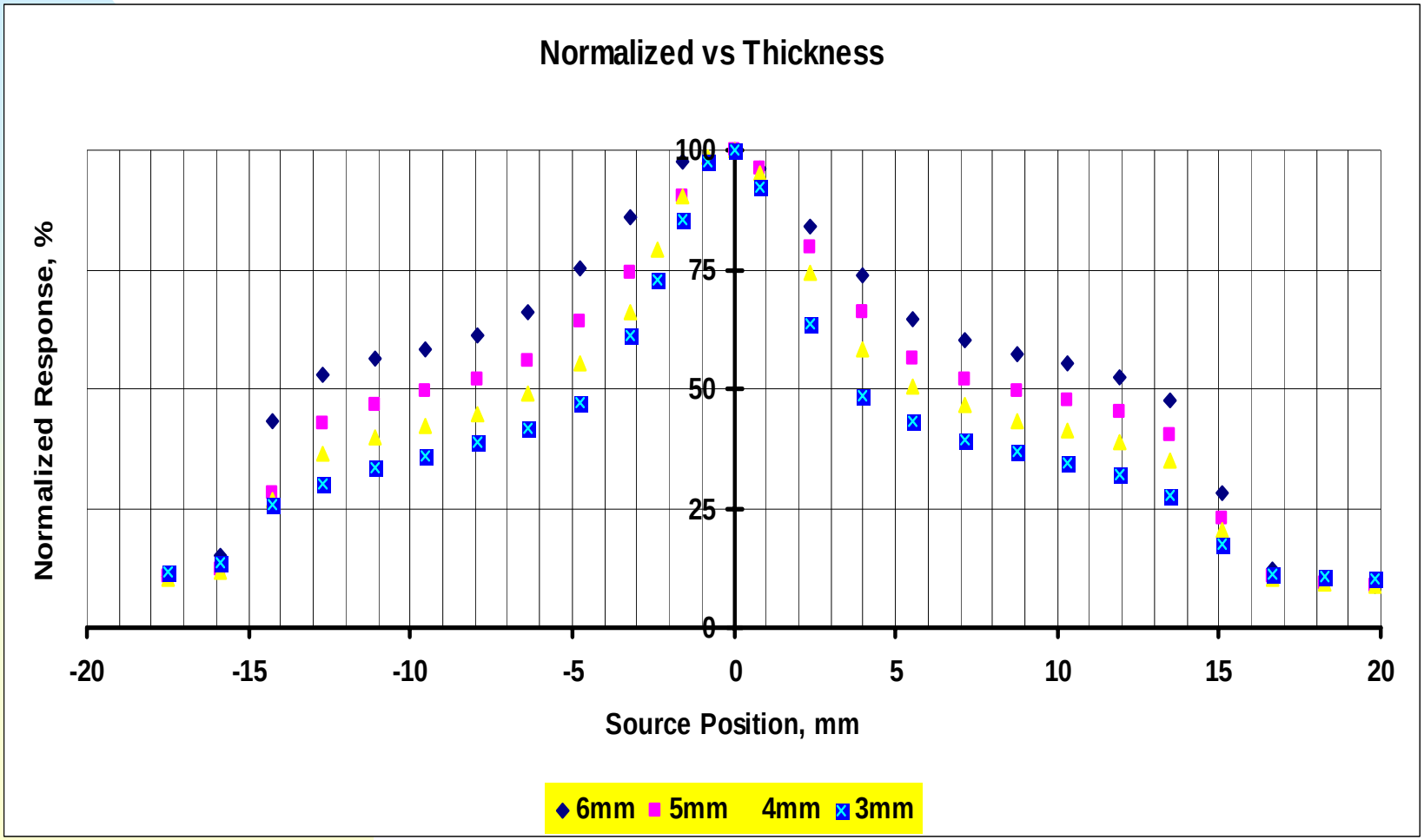


40% non uniformity

Comparative scan test



Thickness impact



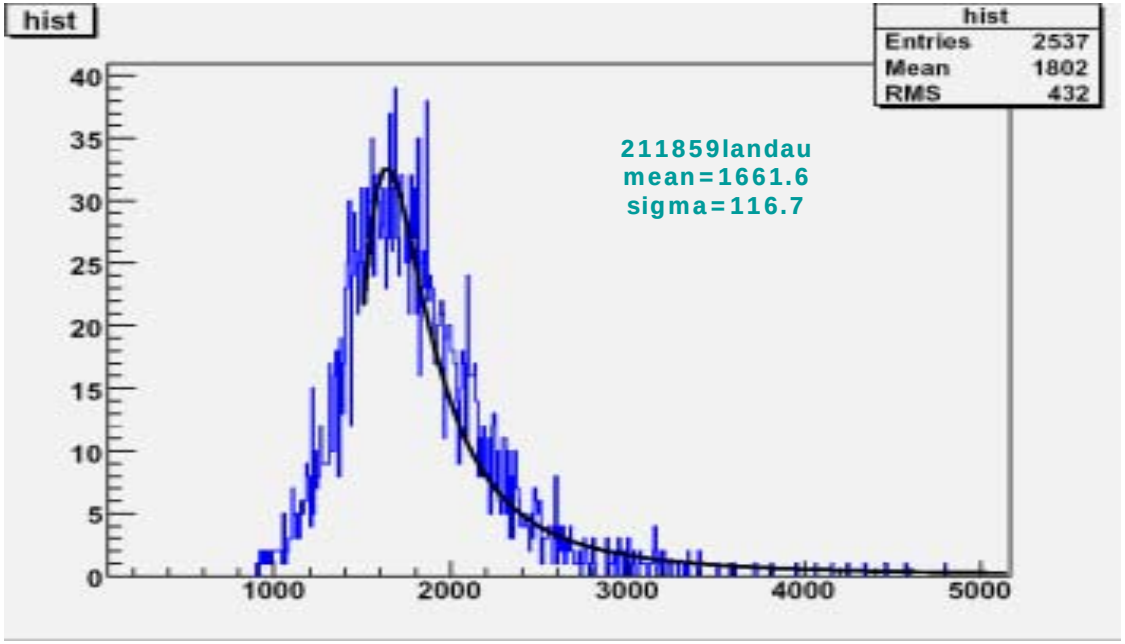
~40% non – uniformity for 6 mm

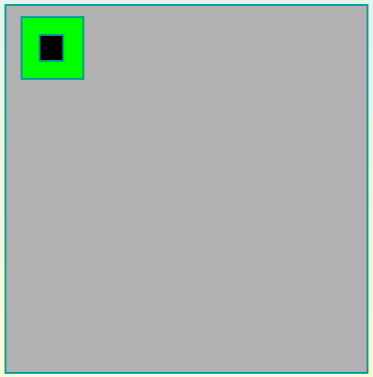
~75 % non – uniformity for 3 mm

Summary

- Direct coupling between green scintillator and SSPM looks promising ~ 19 PE for the sensor of 100 pixels.
- Uniformity scan shows applicability of the method, ~ 40 % non-uniformity from center to edge for 6 mm thick green scintillator.
- Non-uniformity increases when thickness decreases.
- Optical coupling(cement, no cement) still an issue.
- More R&D is necessary

Cross – reference test at the corner with a new trigger(replaced trigger scintillators)





[3], Δ=511

Conclusion - the result is consistent

[3], Δ=591

Previous measurement

HOW to get PE from calibration

1PE in PHYSICS mode is 154.9 ADC counts