D-Egg Golden PMT measurement

Jun 18, 2021
Jul 5 (revised)
Aug 3 rev2

Morii

Golden PMT measurement

Golden PMT are selected to know its detail characteristic as reference sample.
They are expected to use detail calibration work in ice.

Measured 3 items for each PMT at room temperature.

1. Gain measurement
2. Linearity
3. 2D Photo Detection Efficiency

Select 12 PMTS for 3 group, best QE, average QE and worst QE
QE is based on Hamamatsu factory data.

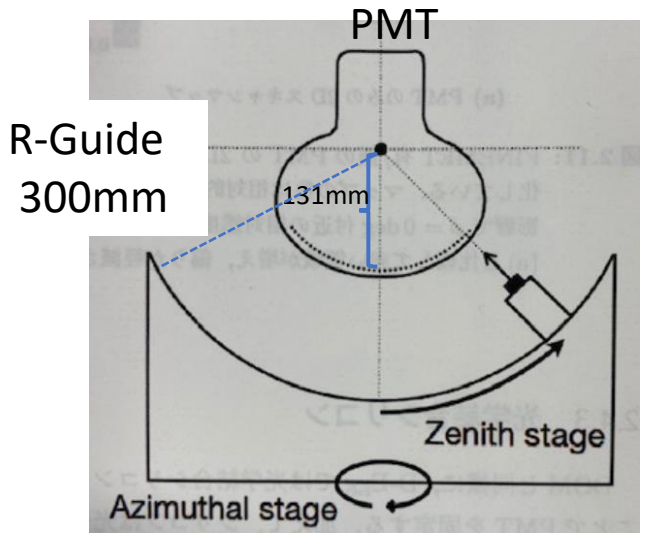
PMT	1st Group (QE)	QE(%)		PMT#	2nd Group	QE(%)
SQ0975	Best	40.7		SQ0967	Best	39.96
SQ0991	Best	40.4		SQ0987	Best	39.86
SQ0657	average	37.0		SQ0953	average	36.99
SQ0866	average	37.1		SQ0797	average	37.01
SQ0428	worst	33.1		SQ0817	worst	33.61
SQ0551	worst	32.9		SQ0775	worst	33.79

Measurement setup

Laser: Hamamatsu c10196 : 400nm pulse width 60ps
Filter: fix 1%
rotation{0.1%, 1%, 5%,10%,50%,100%}
2D scan: azimuth 0~360 degree
Zenith 0~60 degree

Gain and linearity measurement use 2D-scan box, laser output is center.

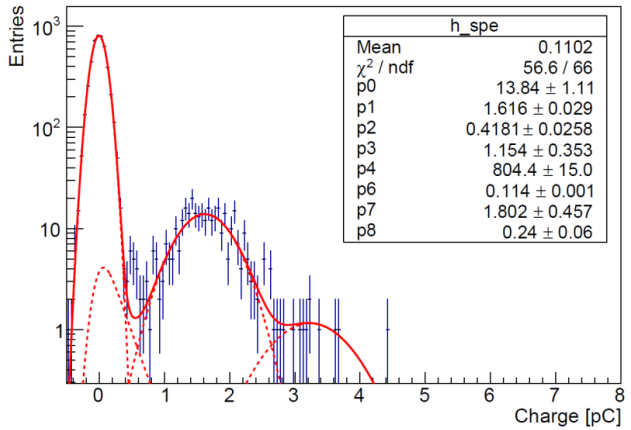
PMT & Rotation stage position



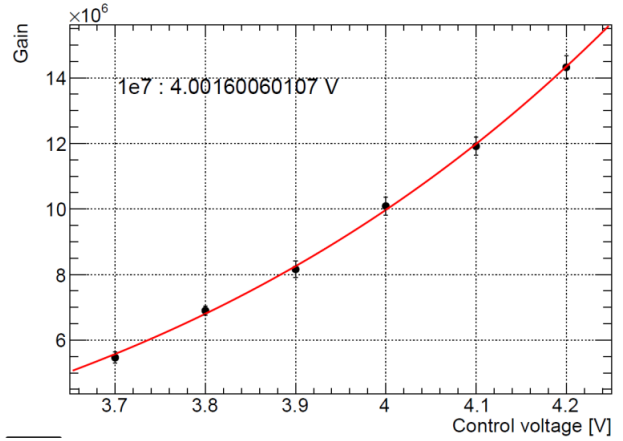
Gain (Room temperature, HV gain=1X10^7)

- spe level laser input with 1%+0.1% filter
- 5000 shot/ one HV point
- Get charge histogram at each HV
- Change HV 5~6 point and draw HV vs Gain curve.
- Get HV at 1X10^7 gain

Ex: sq0975 spe histogram HV=1600V



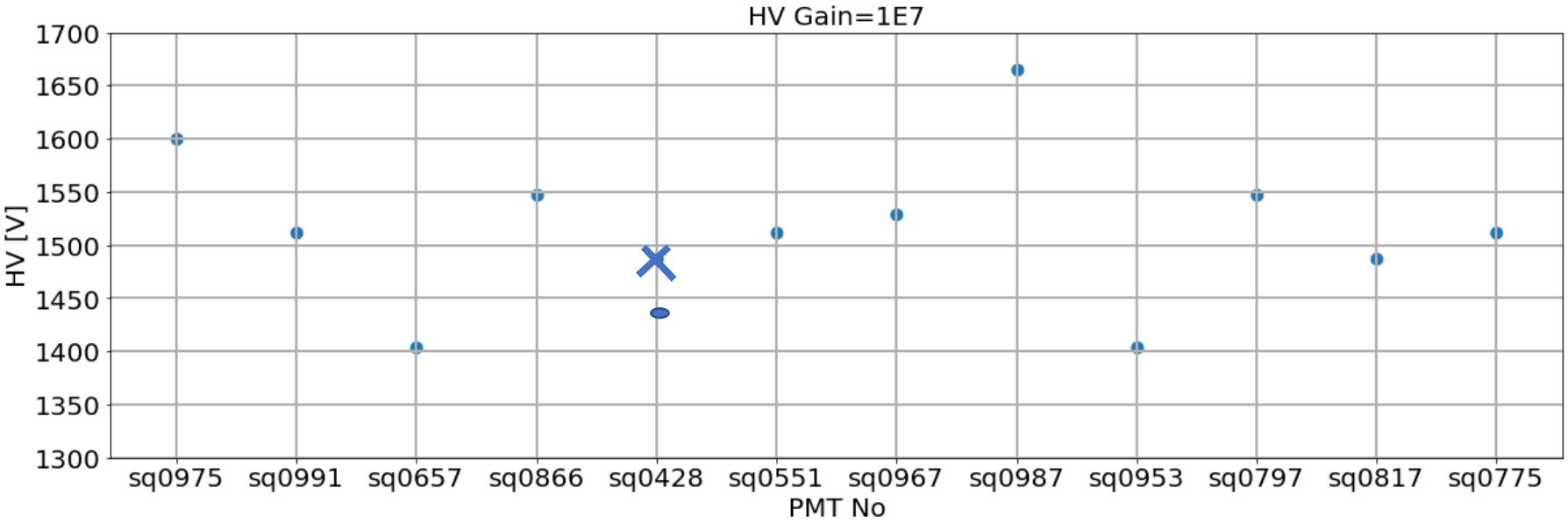
HV vs Gain curve



HV = Control Voltage X 400

All PMT have good gain curve and high voltage at gain = 1X10^7 are between 1400V to 1700V

Other data is in back up



2D Absolute Photo Detection Efficacy measurement

Mesh 4608

Azimuth : 72 (0~360 degree)

Zenith: 64 (0~60 degree)

200 waveform / one mesh point

Intensity : ~20 pe

Measure : Target PMT & reference PMT

Data acquisition time: 44 hours

Calculation method

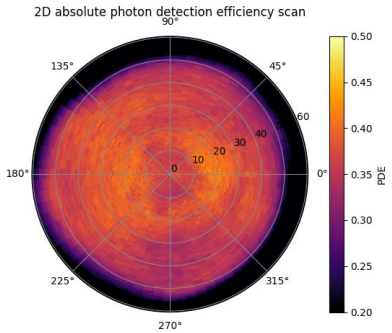
$$PDE_{DEgg}(\Phi,\Theta) = PDE_{ref} \cdot \frac{1}{f_{beamline}} \cdot \frac{\sum charges_{DEgg}(\Phi,\Theta)/gain_{DEgg}(\Phi,\Theta)}{\sum charges_{ref}/gain_{ref}}$$

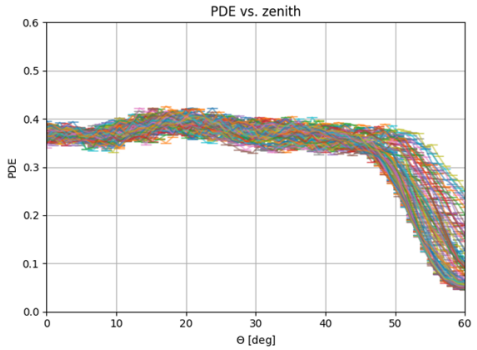
Known parameter: PDE_{ref}=0.263, $Gain_{Degg}$, $Gain_{ref}$

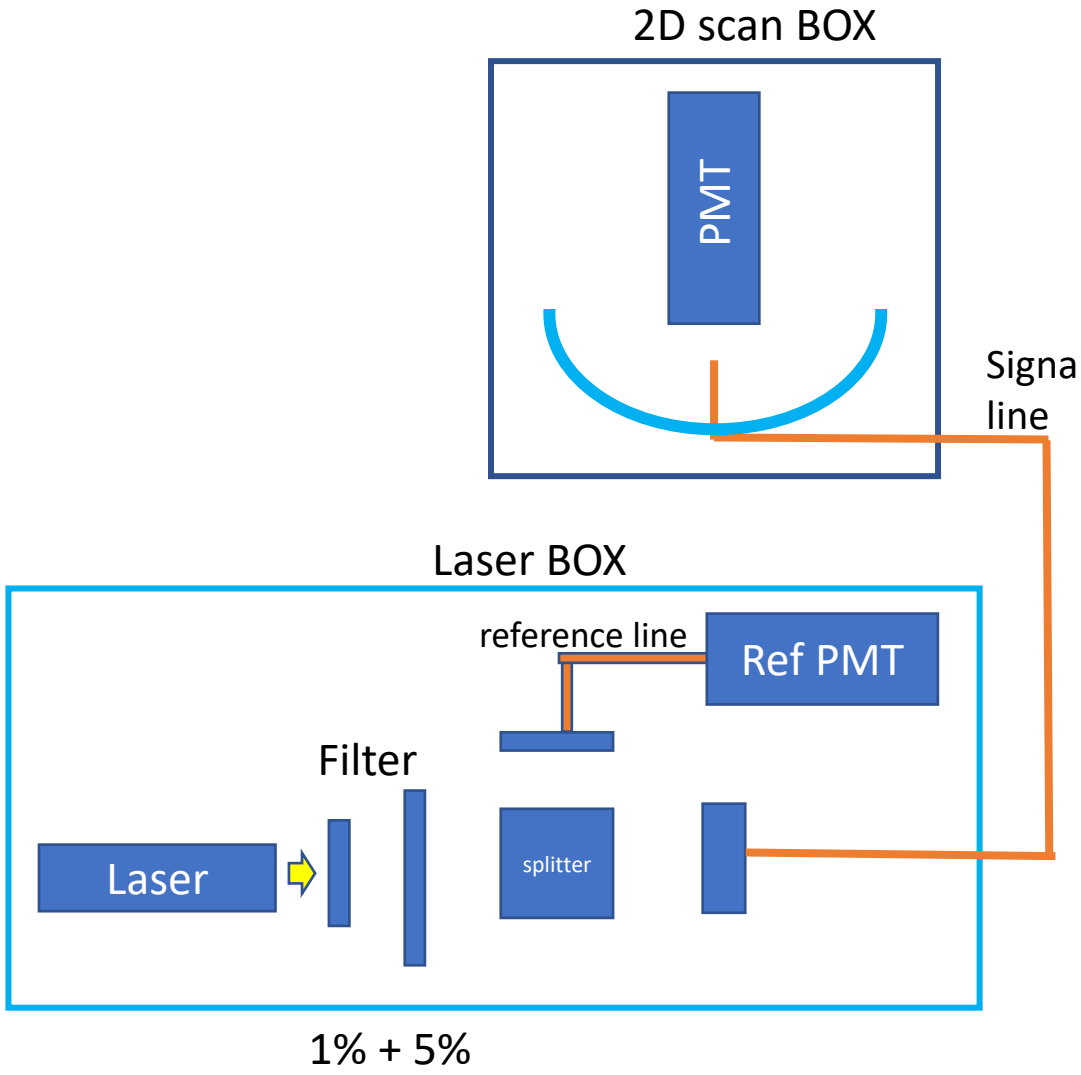
$f_{beamline}$: Signal line/ reference line

calibrated with same reference PMT

very sensitive for optical device alignment

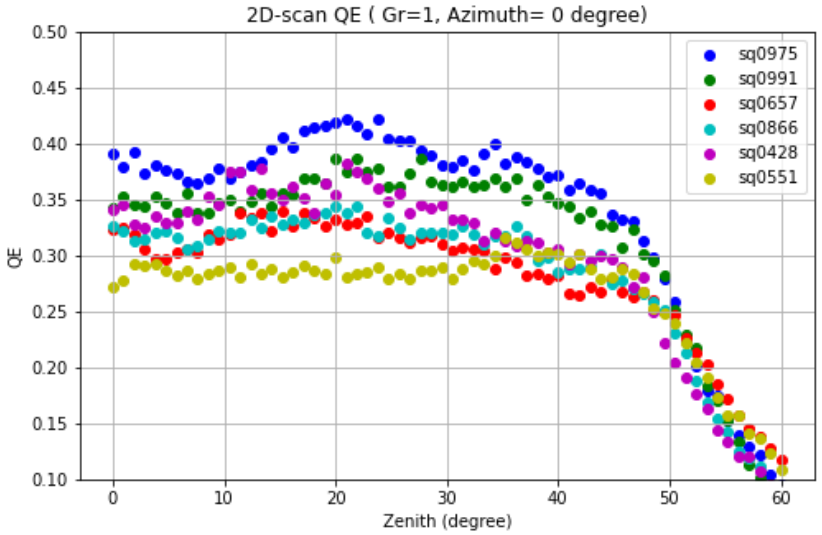




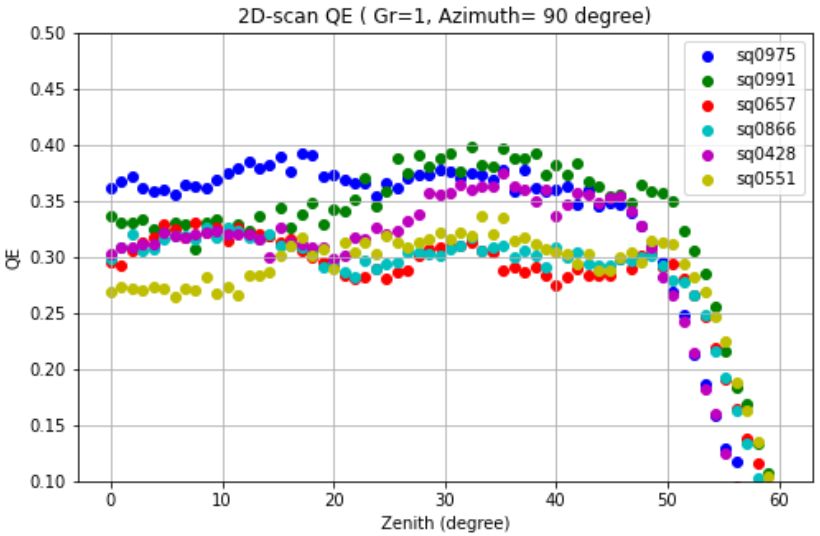


2D Photon Detection Efficiency scan(Golden: Gr1 summary)

PDE distribution VS zenith (Azimuth=0)



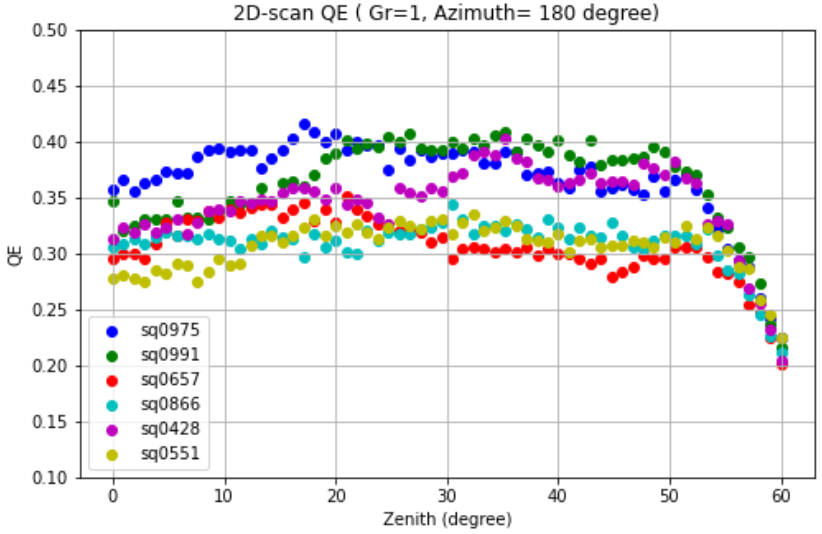
PDE distribution VS zenith (Azimuth=90)



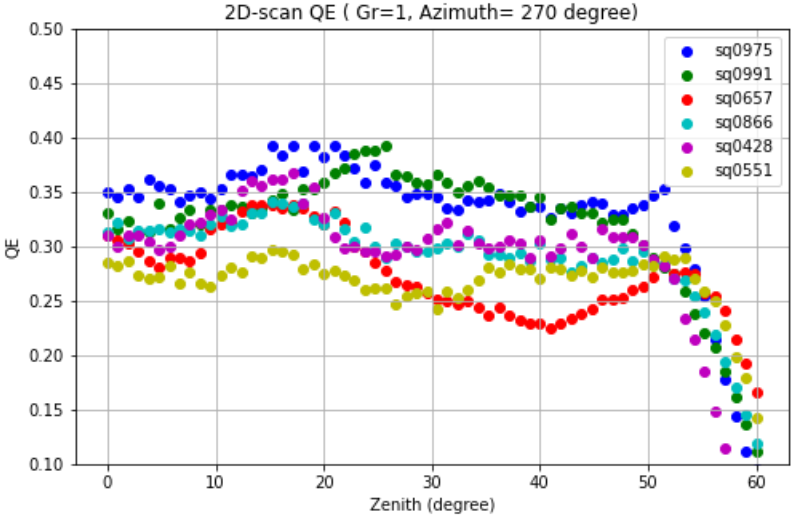
Relatively flat in zenith 0~50°

Small hollow profile in center

PDE distribution VS zenith (Azimuth=180)



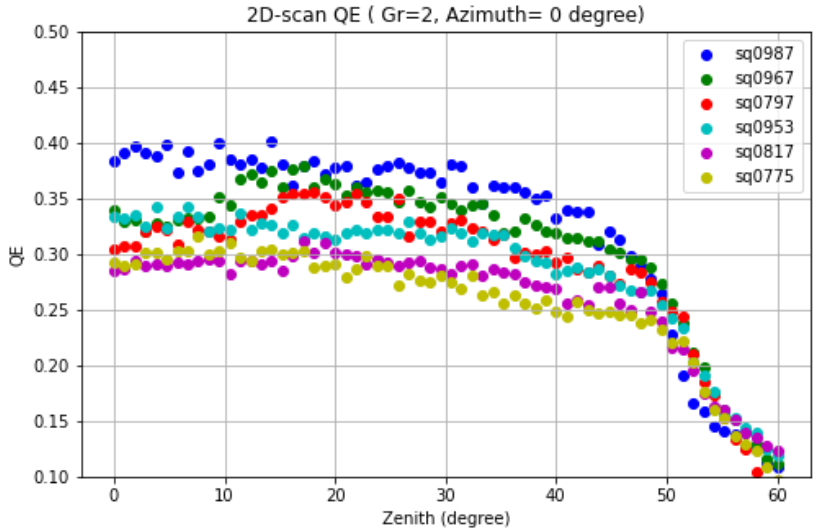
PDE distribution VS zenith (Azimuth=270)



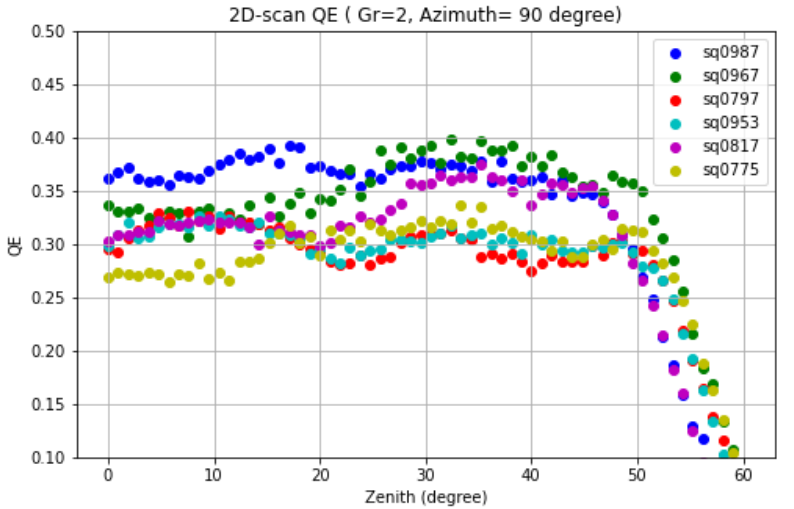
Hollow profile at azimuth=270

2D Photon Detection Efficiency scan(Golden: Gr2 summary)

PDE distribution VS zenith (Azimuth=0)



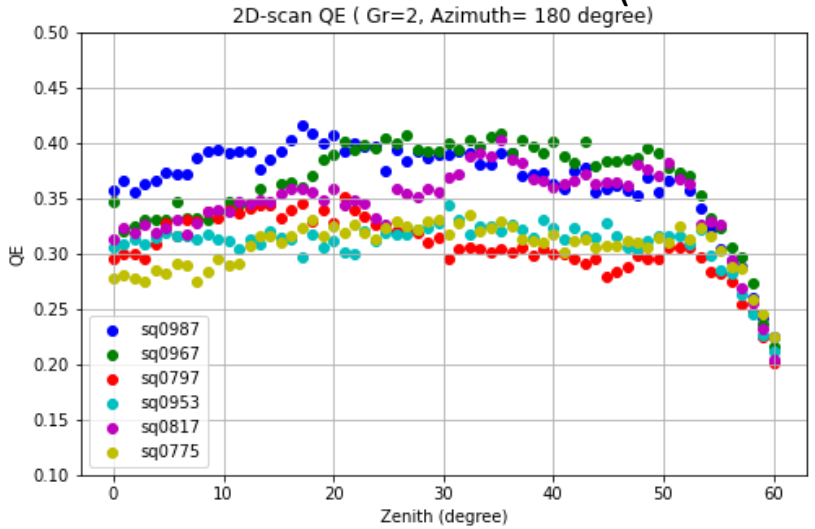
PDE distribution VS zenith (Azimuth=90)



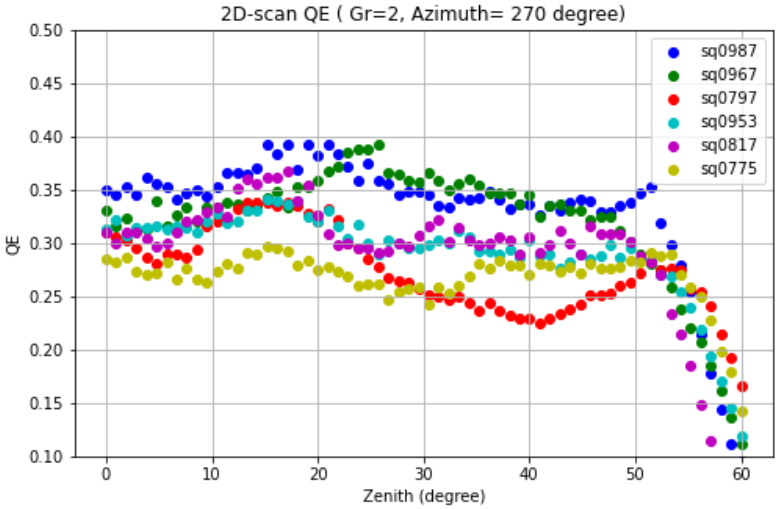
Relatively flat in zenith 0~50°

Small hollow profile in center

PDE distribution VS zenith (Azimuth=180)



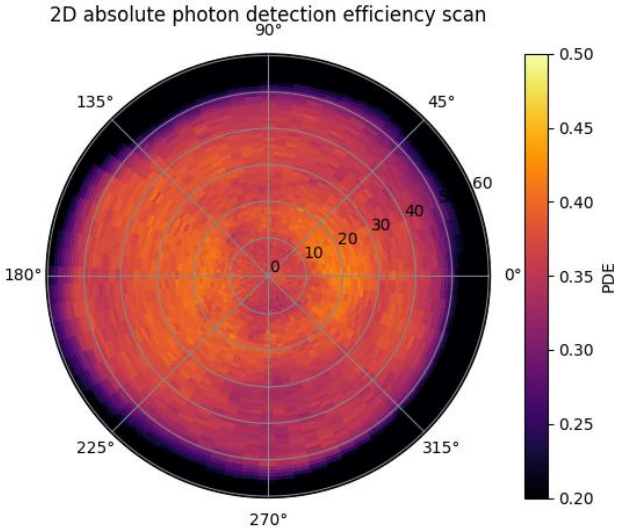
PDE distribution VS zenith (Azimuth=270)

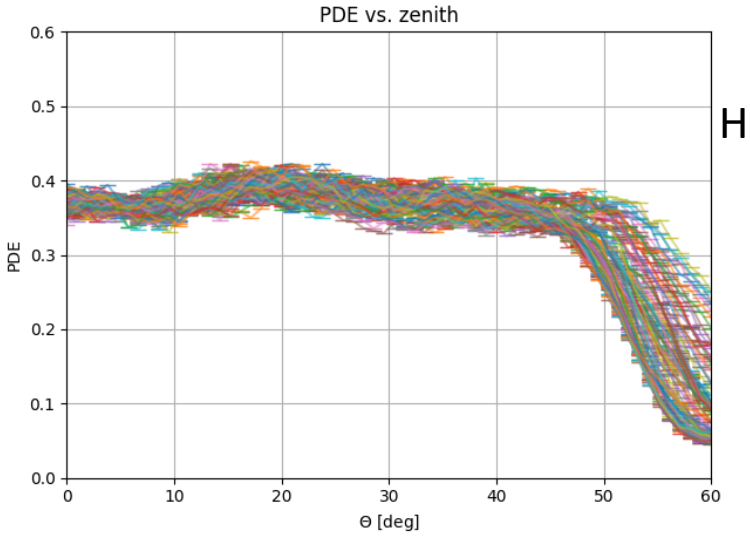


Hollow profile at 270

2D Photon Detection Efficiency scan(Golden 1st Gr :Best)

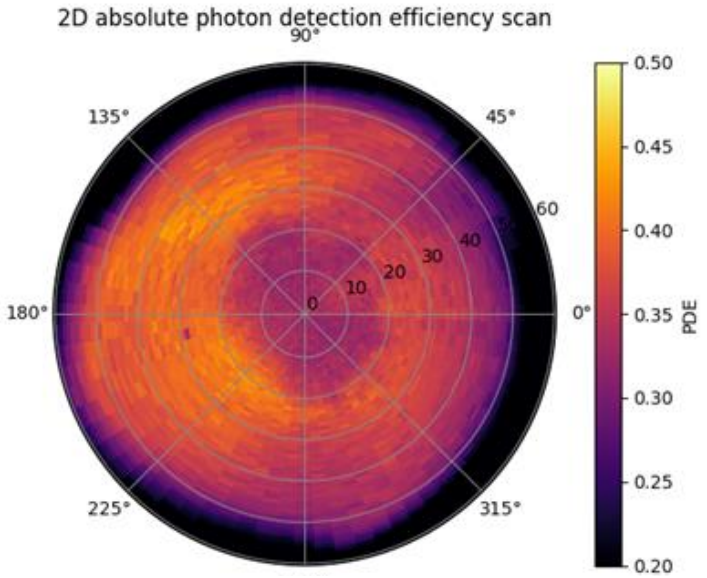
Sq0975(best QE)

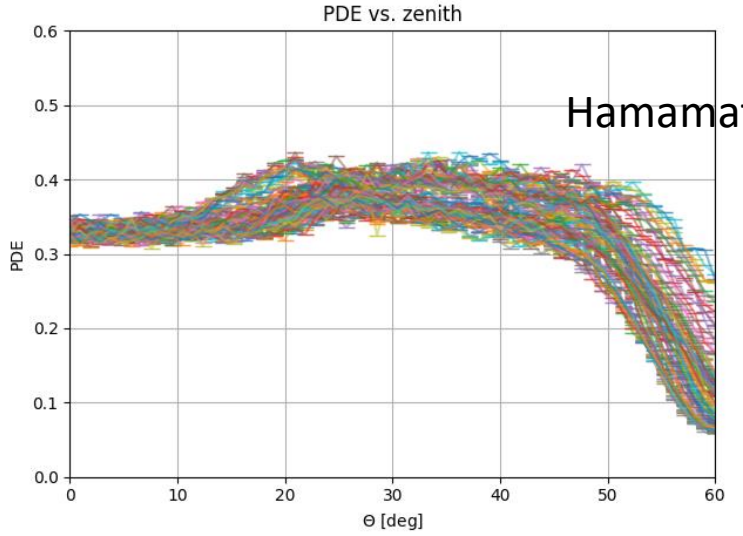




Hamamatsu data 40.7

Sq0991(best QE)





Hamamatsu data 40.4

2D Photon Detection Efficiency scan(Golden 1st Gr: average)

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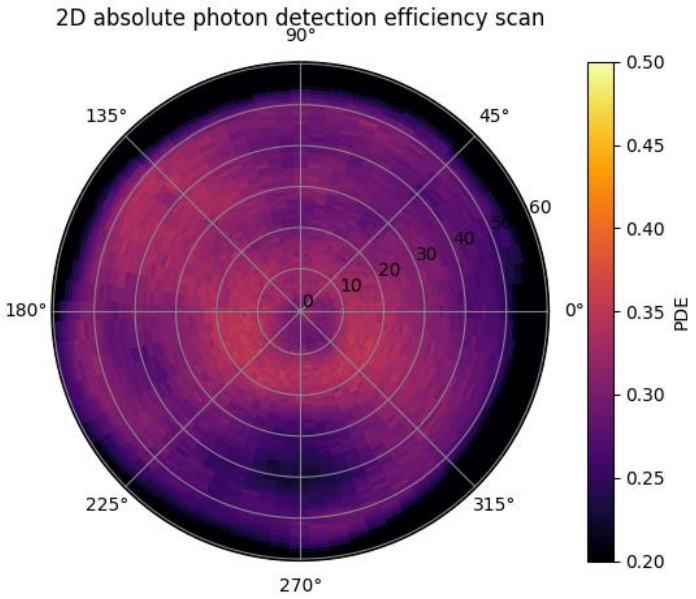
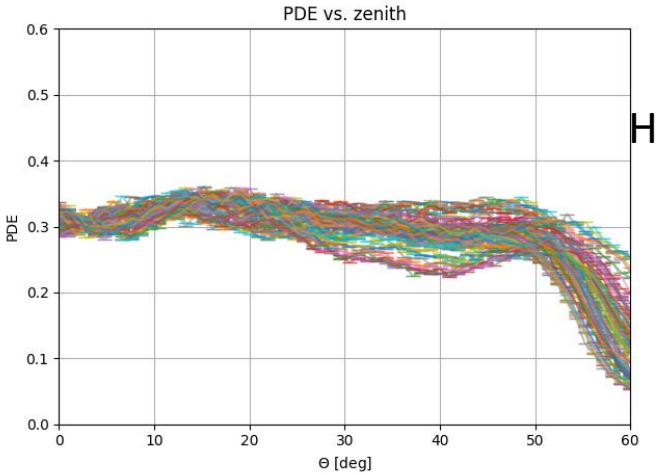
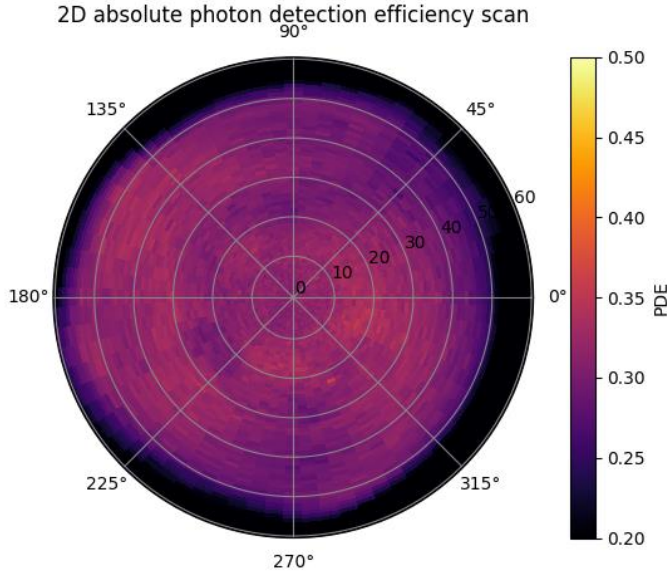
Sq0657(averaged QE)

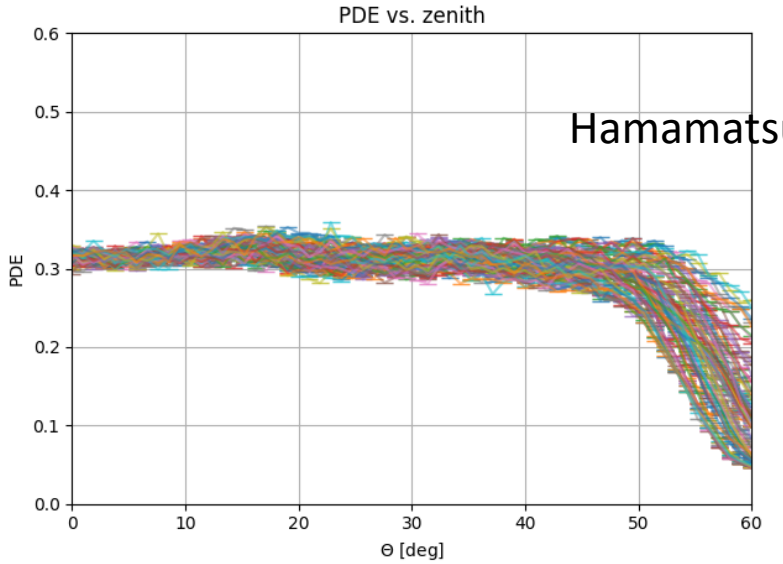




Hamamatsu data 37.0

Sq0866(averaged QE)

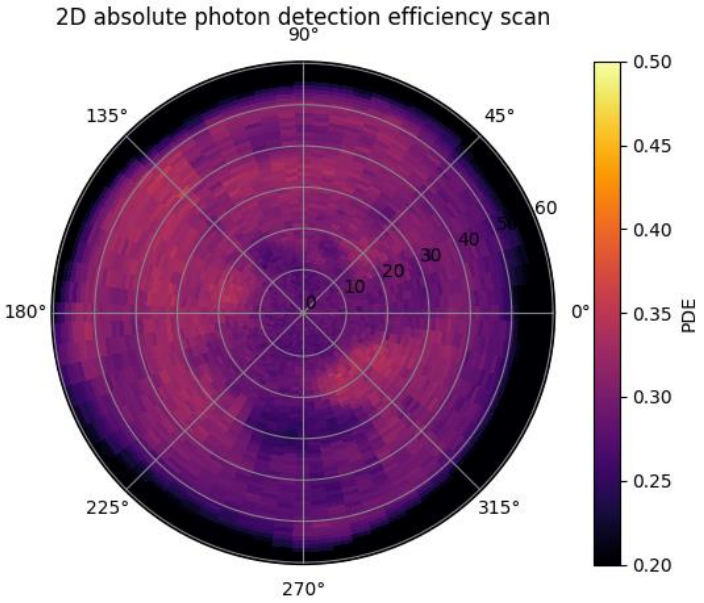


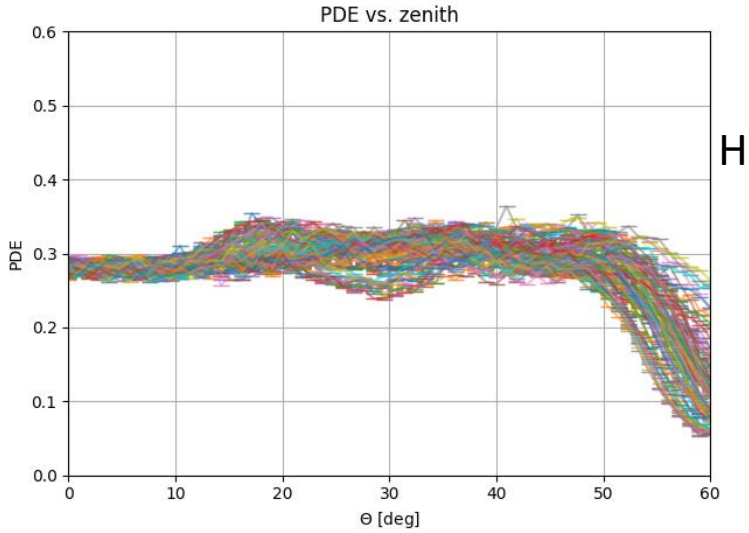


Hamamatsu data 37.1

2D Photon Detection Efficiency scan(Golden 1st Gr: worst)

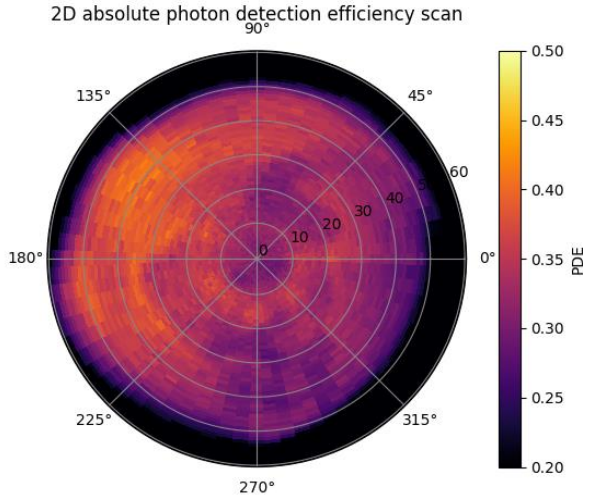
Sq0551(worst QE)

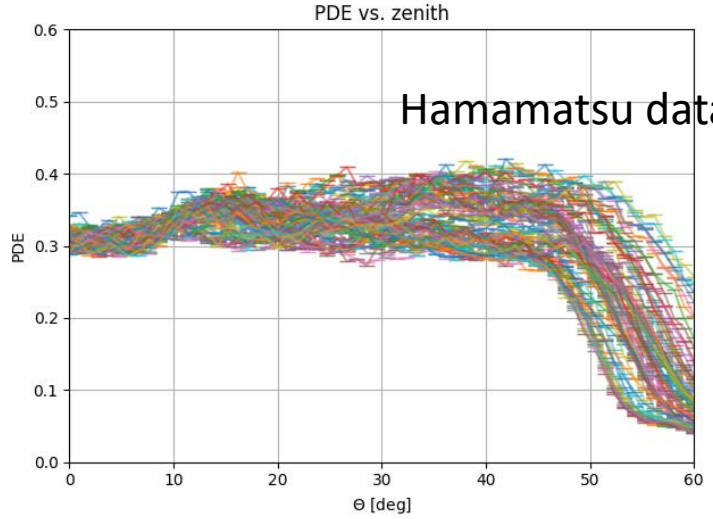




Hamamatsu data 32.9

Sq0428(worst QE)

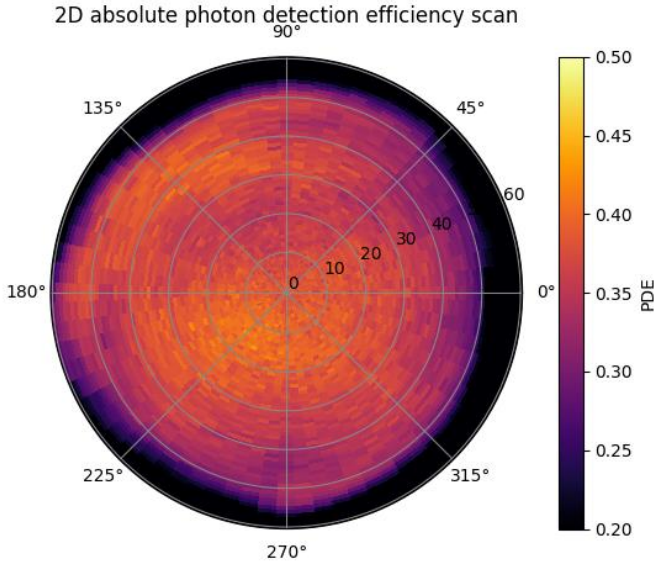


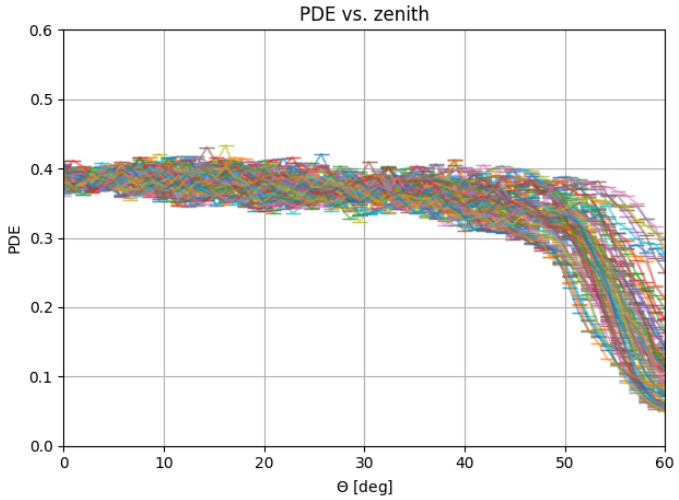


Hamamatsu data 33.1

2D Photon Detection Efficiency scan(Golden 2nd Gr: Best)

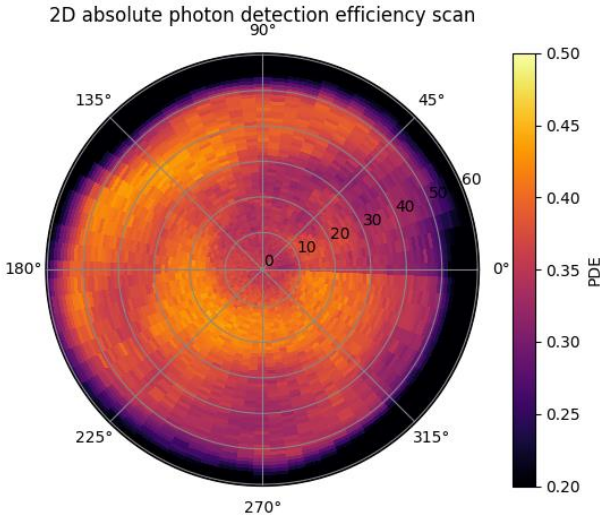
Sq0987

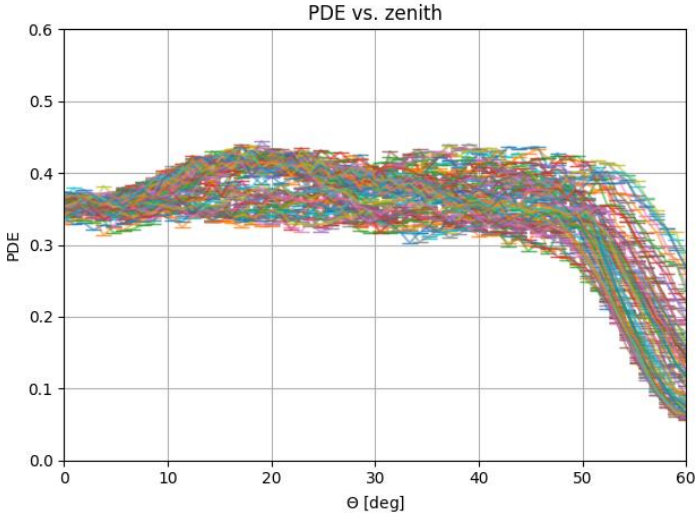




Hamamatsu data
QE:39.9

Sq0967

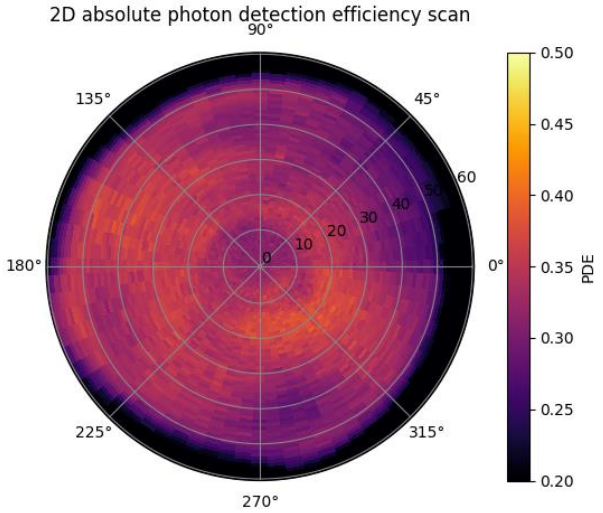


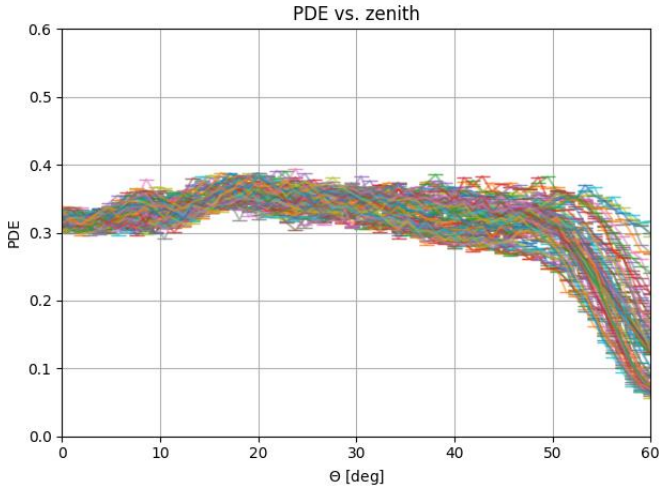


Hamamatsu data
QE:39.9

2D Photon Detection Efficiency scan(Golden 2nd Gr: average)

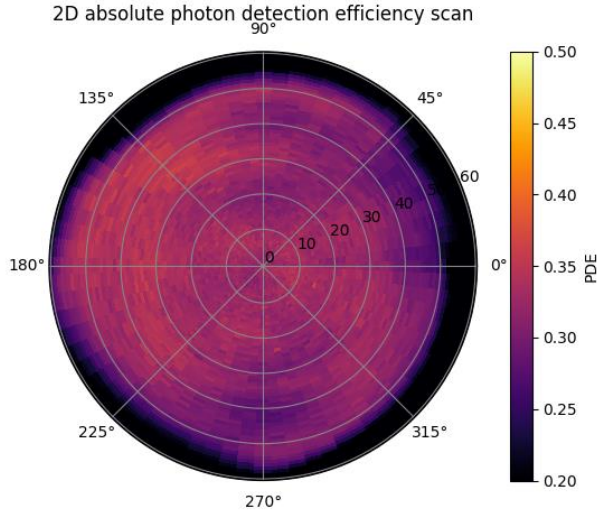
Sq0797

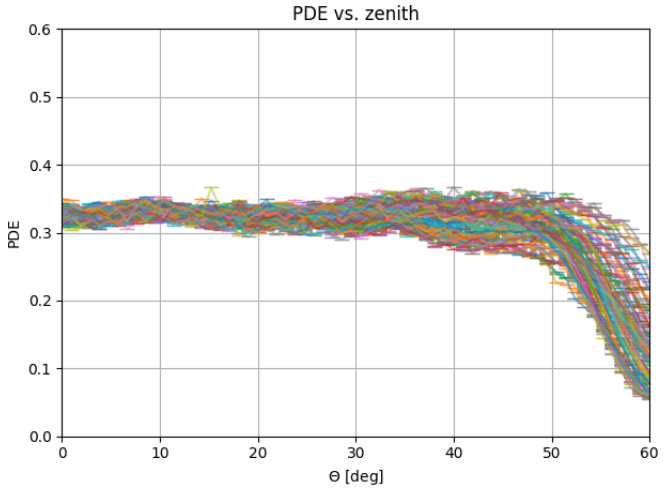




Hamamatsu data
QE:37.0

Sq0953

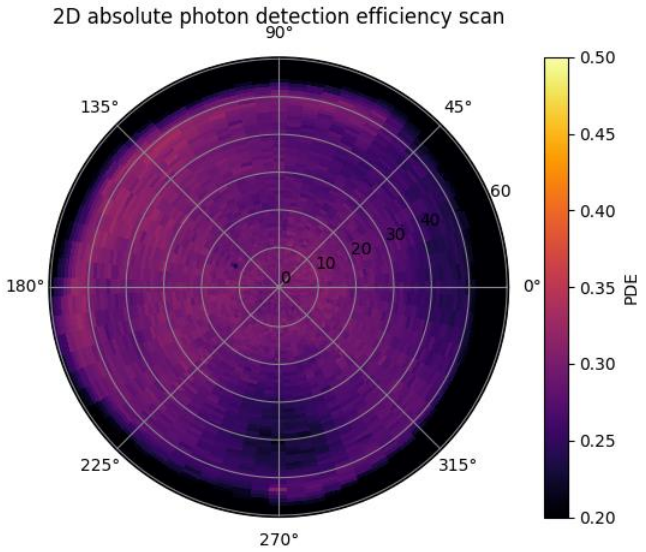


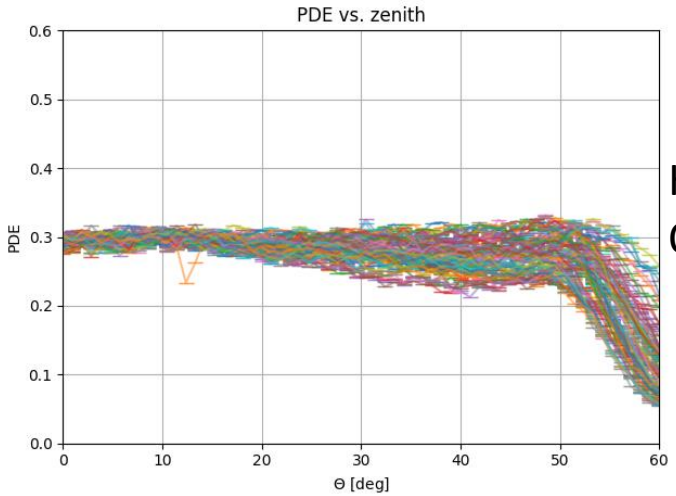


Hamamatsu data
QE:37.0

2D Photon Detection Efficiency scan(Golden 2nd Gr: worst)

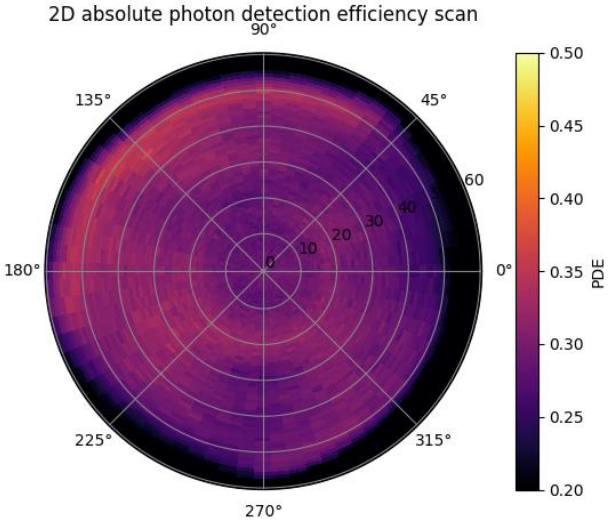
Sq0775

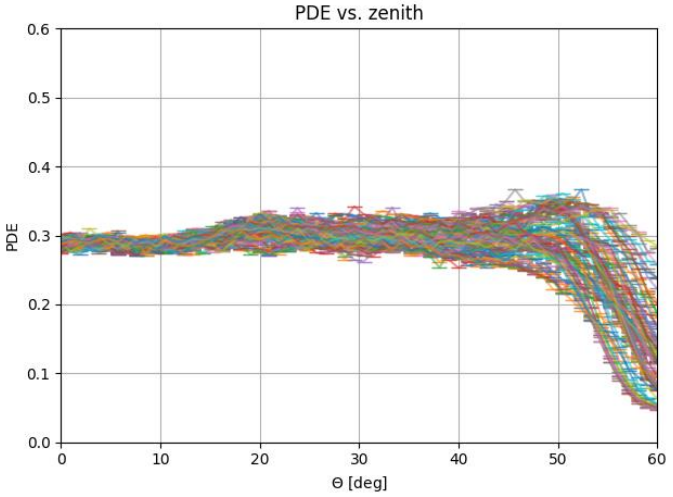




Hamamatsu data
QE:33.8

Sq0817



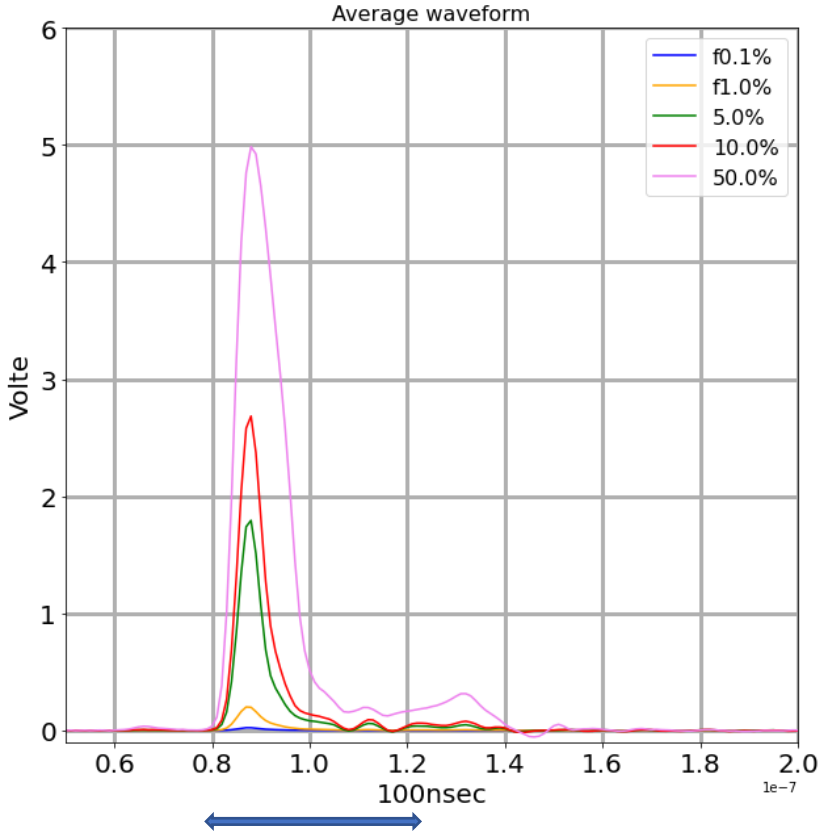


Hamamatsu data
QE:33.6

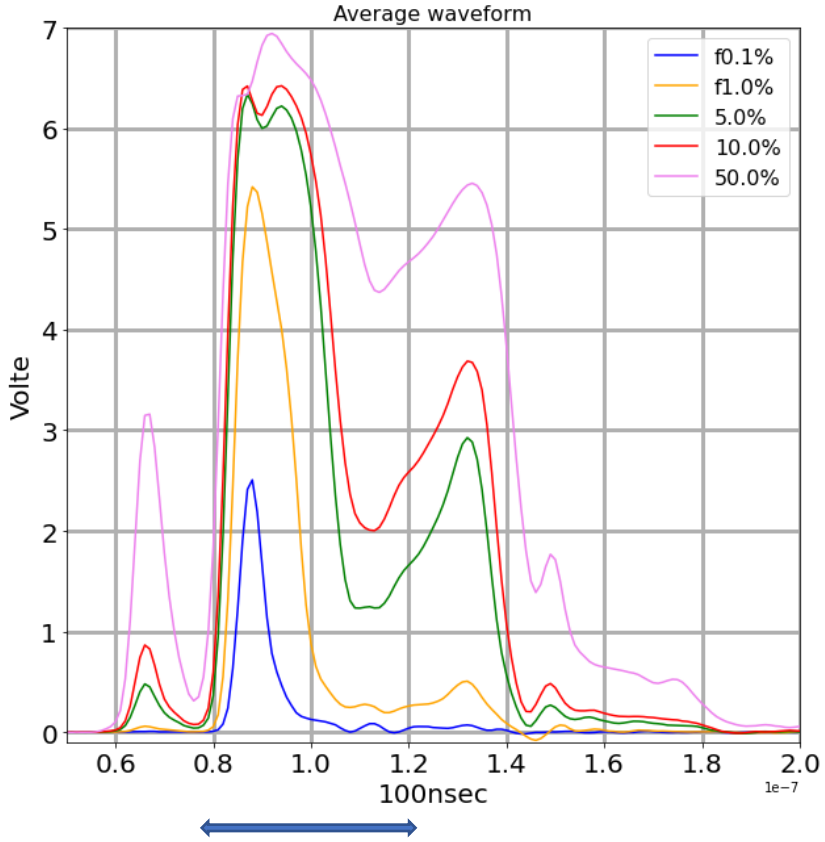
Linearity measurement

- Fix laser intensity, and change Filter 1%+{0.1%,1%,5%,10%,50%} , w/o 1%+{0.1%~50%}
- 1000 waveforms/one filter setting
- Averaged waveform example (sq0987)

with 1% filter



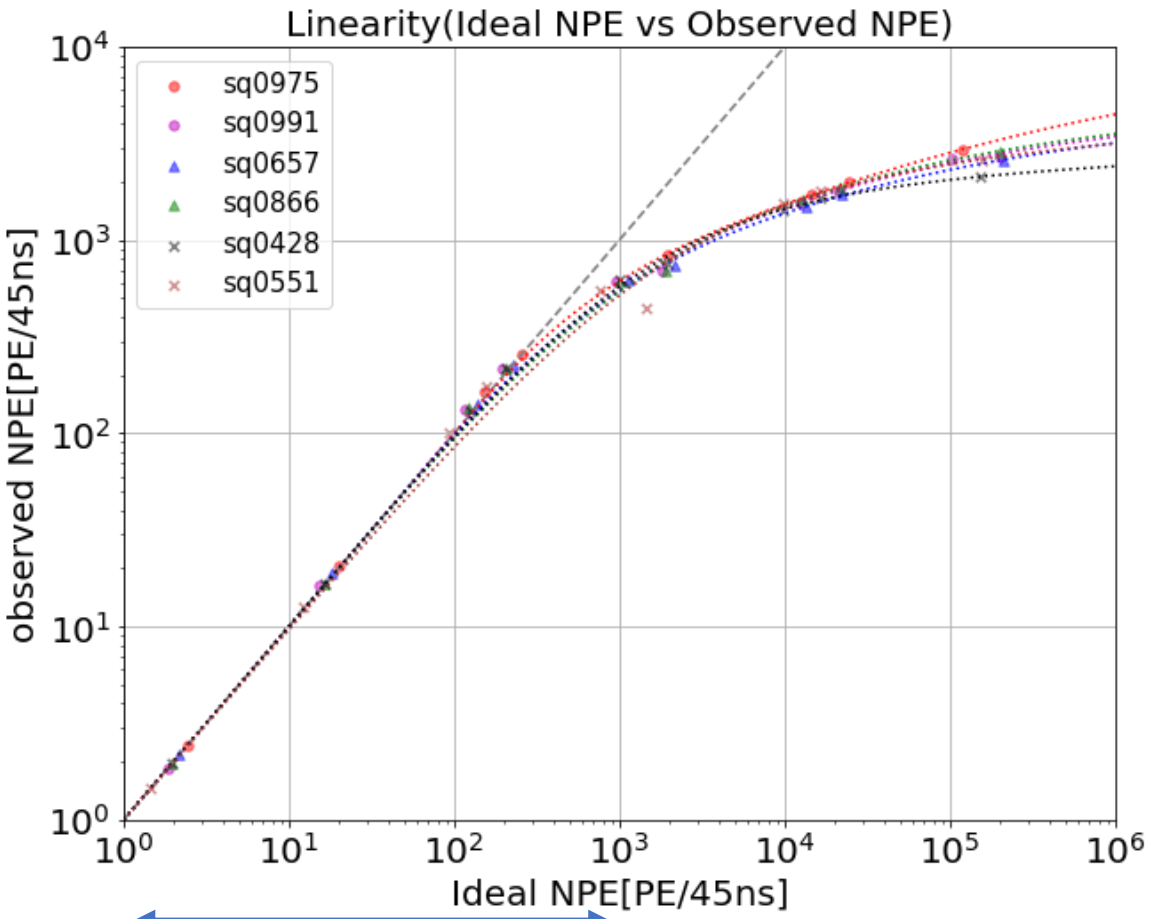
w/o 1% filter



Charge integration :80ns~125ns. Not include pre-pulse and late pulse

Linearity measurement

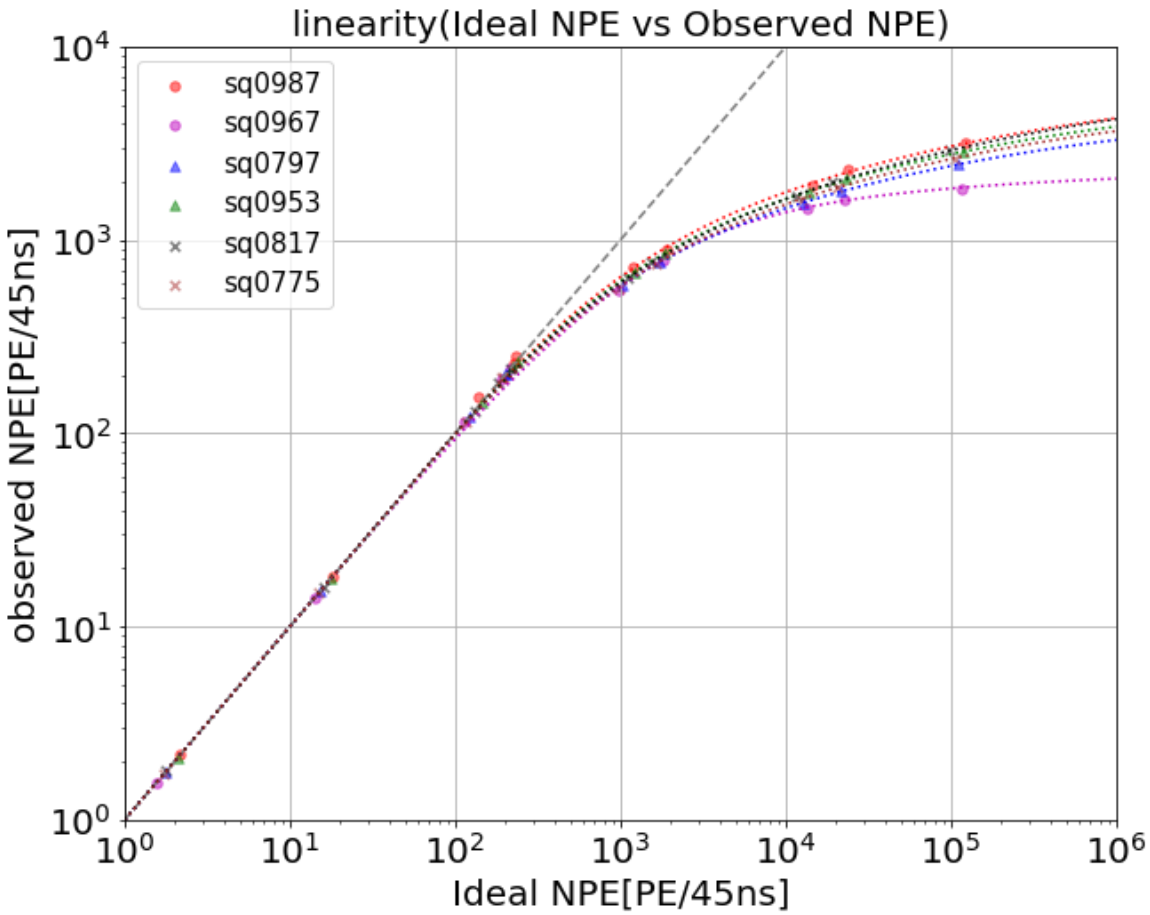
1st Gr



Filter: 1%+{0.1%~50%}

Filter: {0.1%~50%}

2nd Gr

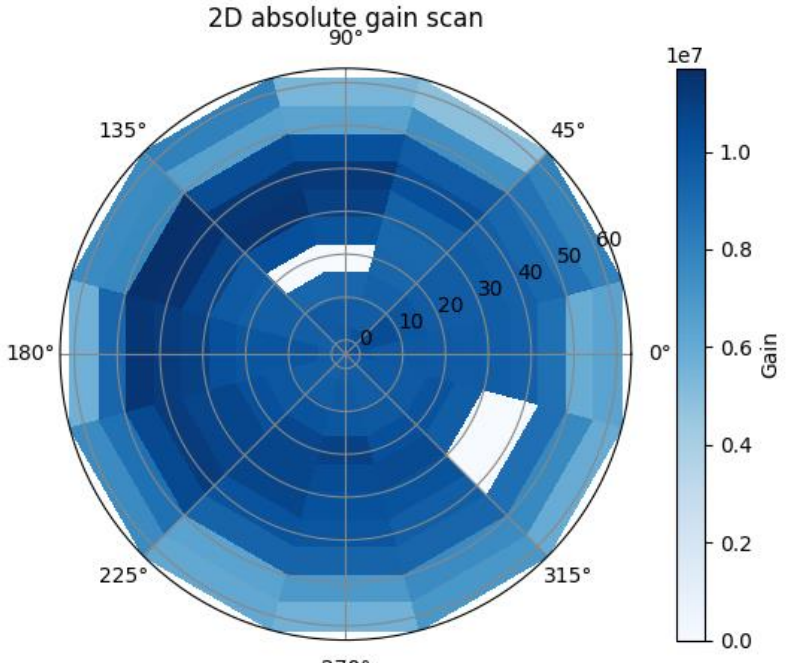


Fitting function

(1./x + (1./p0) * np.log(1. + (x/p1)**3) /np.log(1. + (x/p2)**0.5)) ** -1

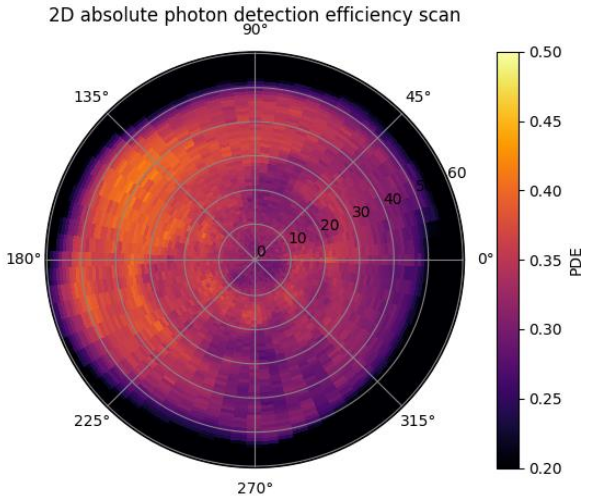
- All PMT is almost same curve, and good linearity below ~300PE
- sq0551(@~1500PE) is dropped. Need to measure again.

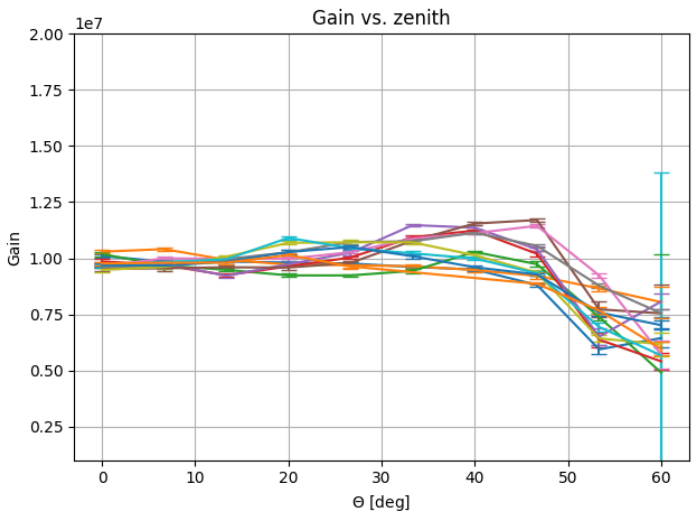
2D Gain map (sq0428: Mesh 12X20)

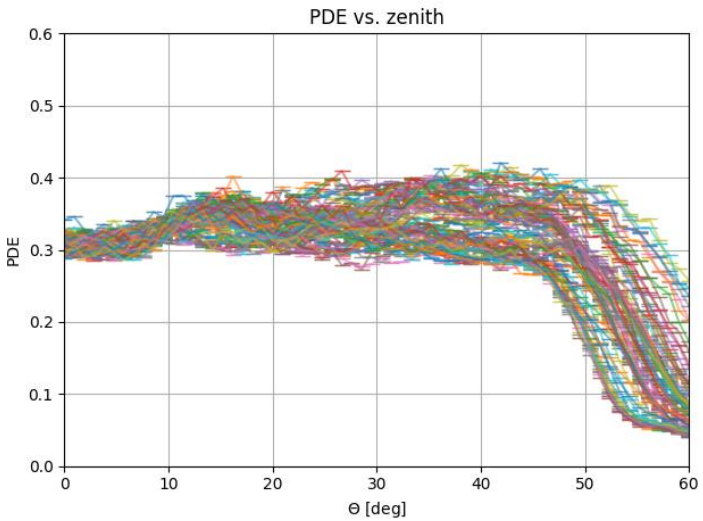


2 white parts
SPE fitting NG

Same profile as
absolute PDE scan







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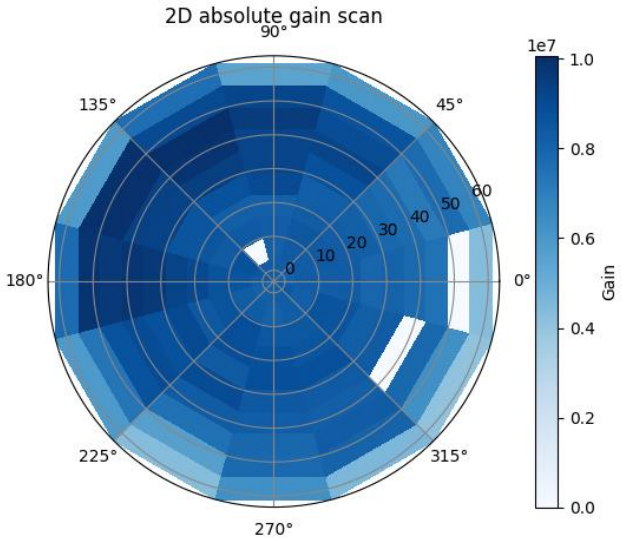
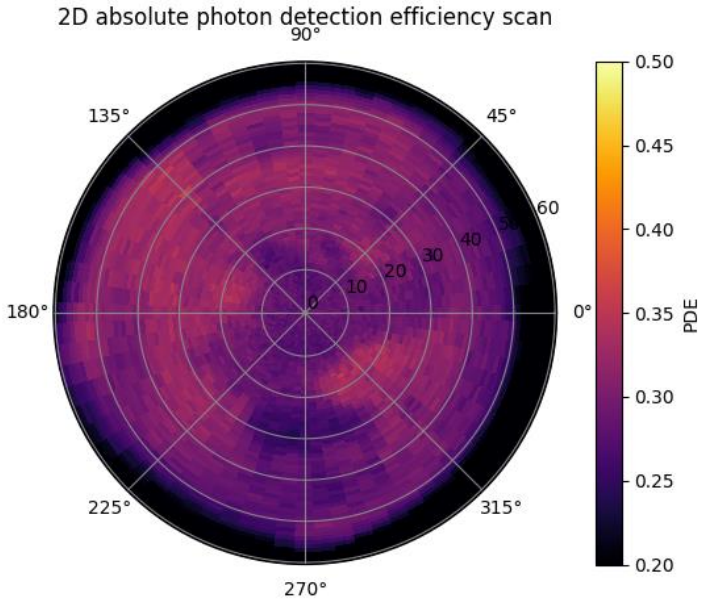
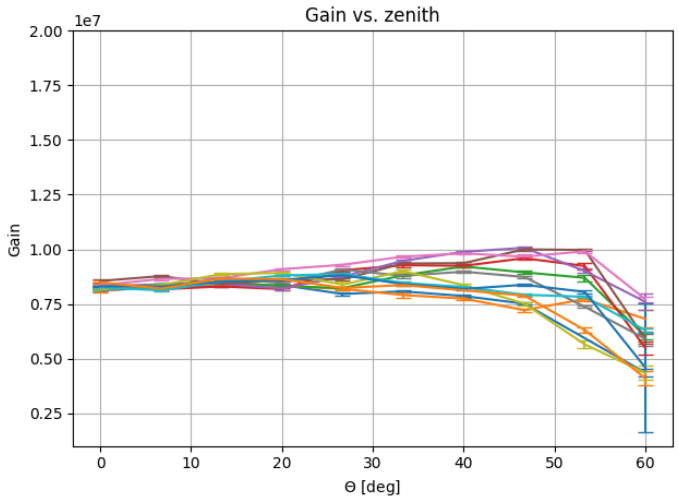
2D Gain map (sq0551: Mesh 12X20)

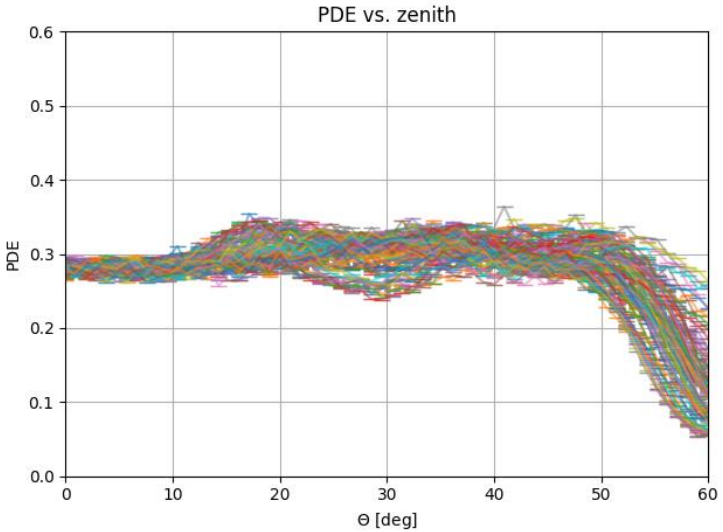


3 white parts
SPE fitting NG

Same profile as
absolute PDE scan







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Summary

- All PMT are good result for operation.
  - HV for @gain $1X10^7$ is in operation range 1400 ~ 1700V.
  - Same type of saturation curve of Input vs observed NPE and keep linearity below 300pe.
  - 2D absolute Photo Detection efficacy is almost flat in zenith angel 0 ~ 50 degree.

- Next step
  - Measure linearity PMT + Main board read.
  - Compare the linearity at low temperature (FAT test) and room temperature (this measurement)

We measured the detail characteristic for these golden PMTS. So expect them to use calibration work or analysis in the ice.

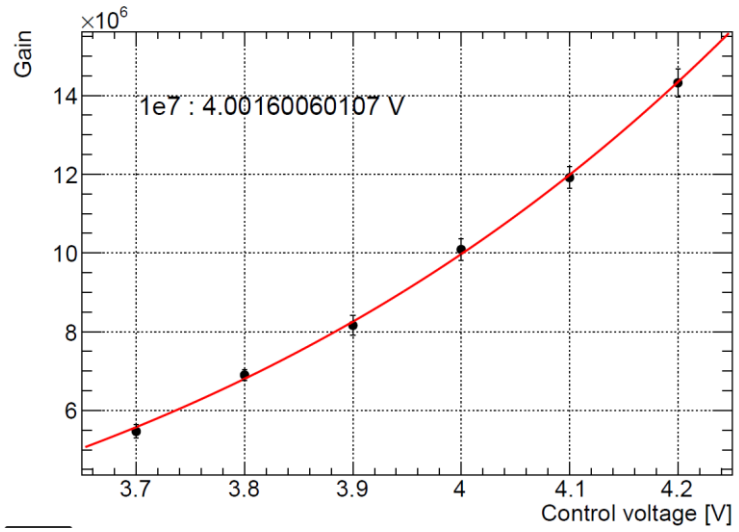
Back up

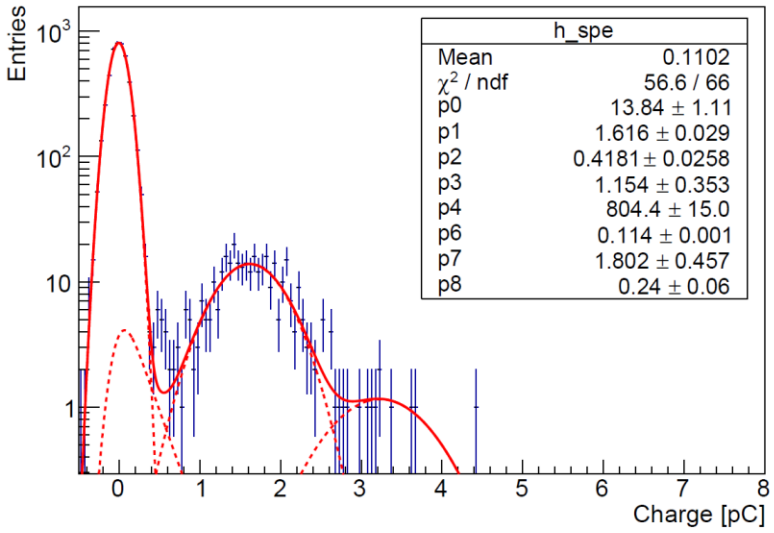
- Gain measurement detail data
- Linearity fitting

Gain (Golden PMT 1st Gr) (Best QE)

Note: HV= Vc x 400 [V]

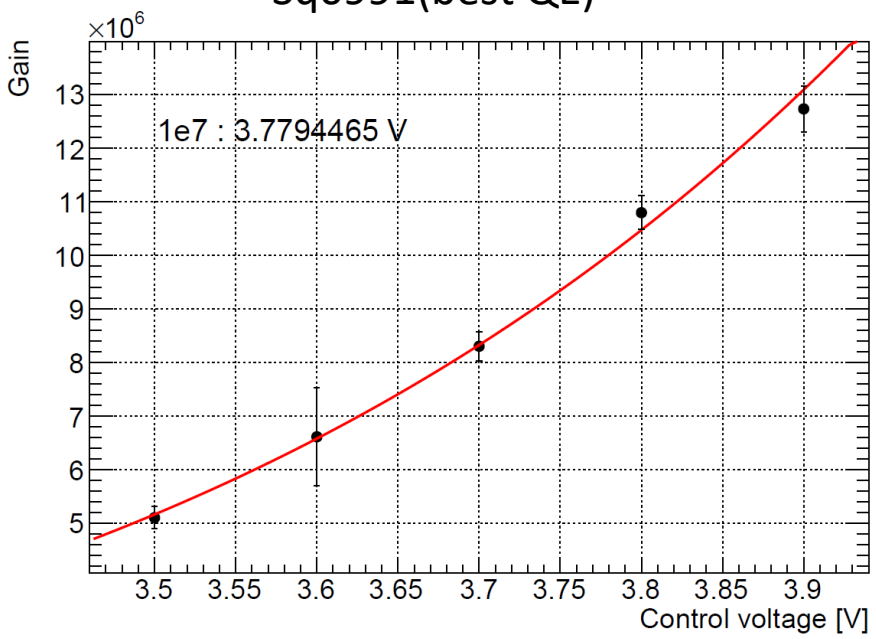
Sq0975 (best QE)

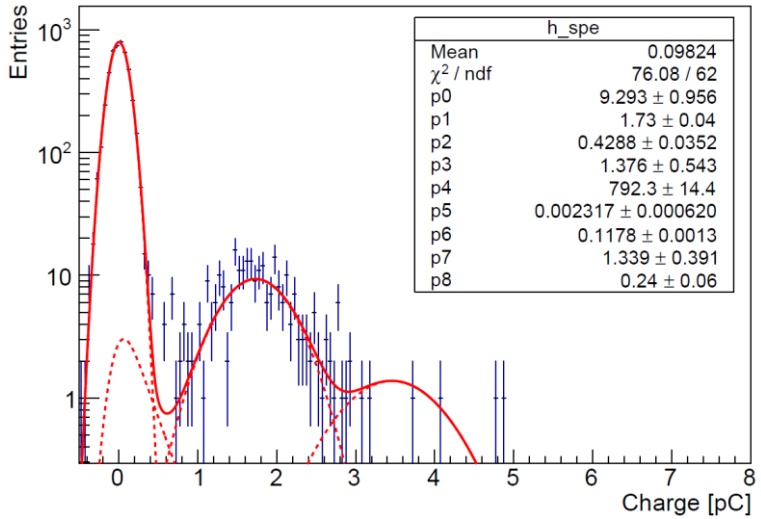




Vc=4.0V

Sq0991(best QE)

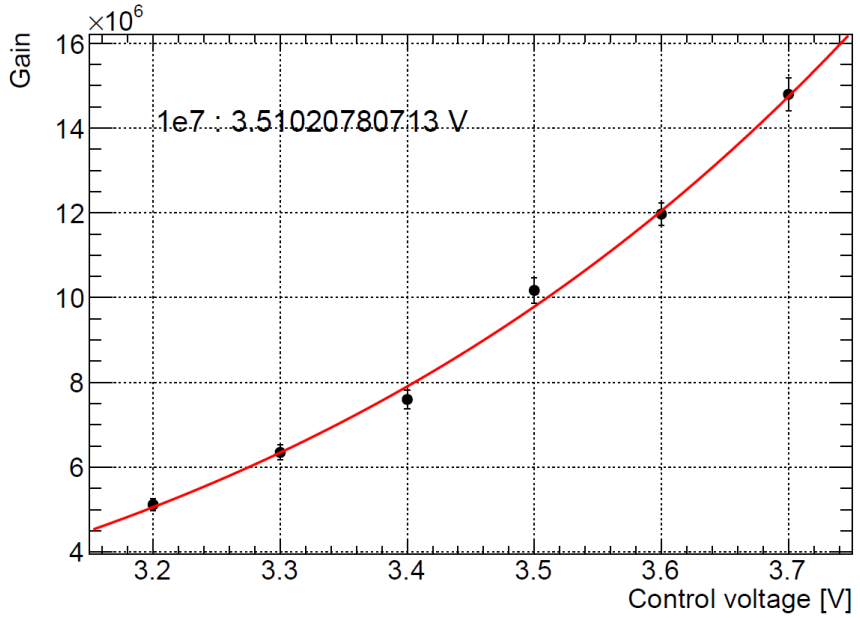


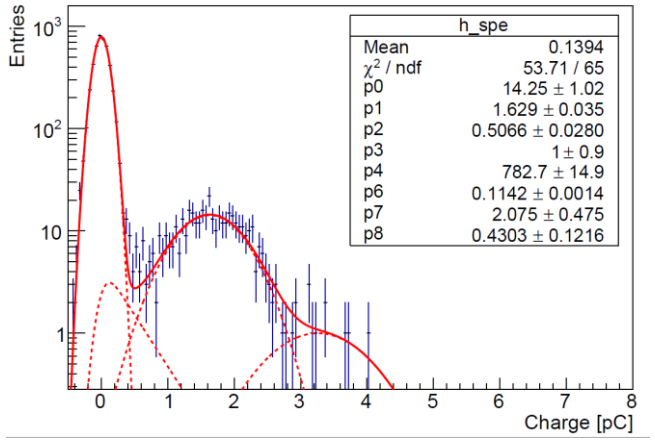


Vc=3.8V

Gain (Golden PMT 1st Gr) (averaged QE)

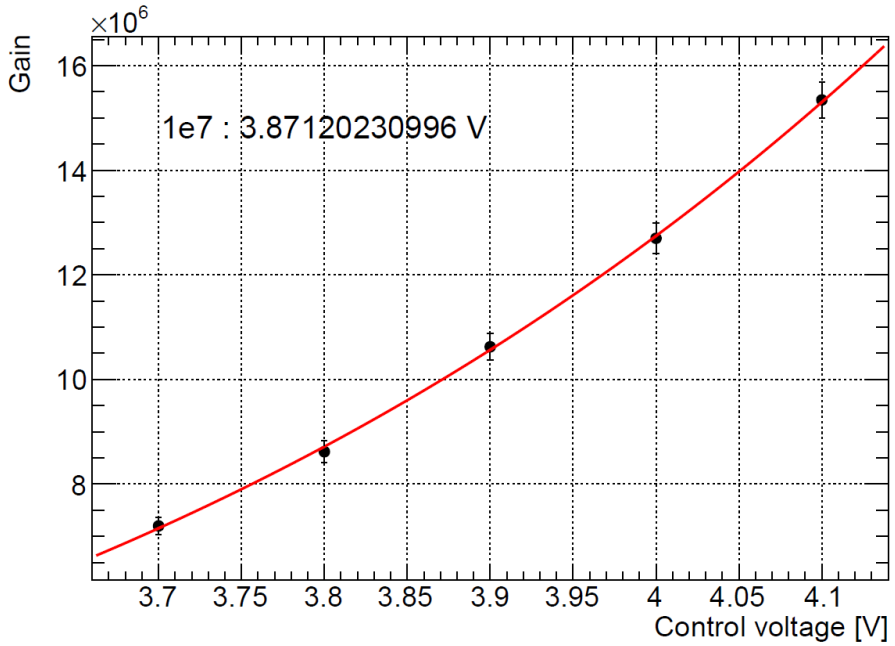
Sq0657 (averaged QE)

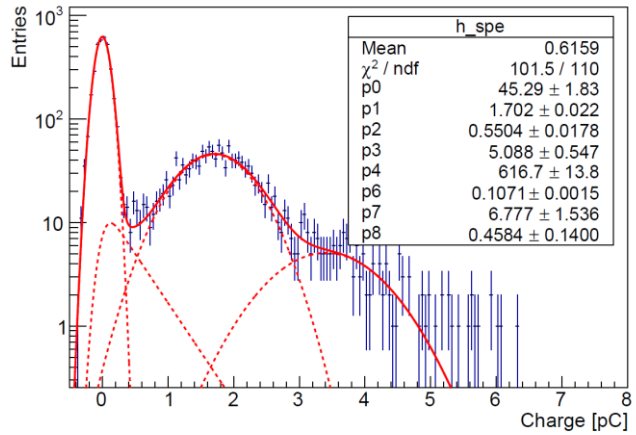




Vc=3.5V

Sq0866(averaged QE)





Vc=3.9V

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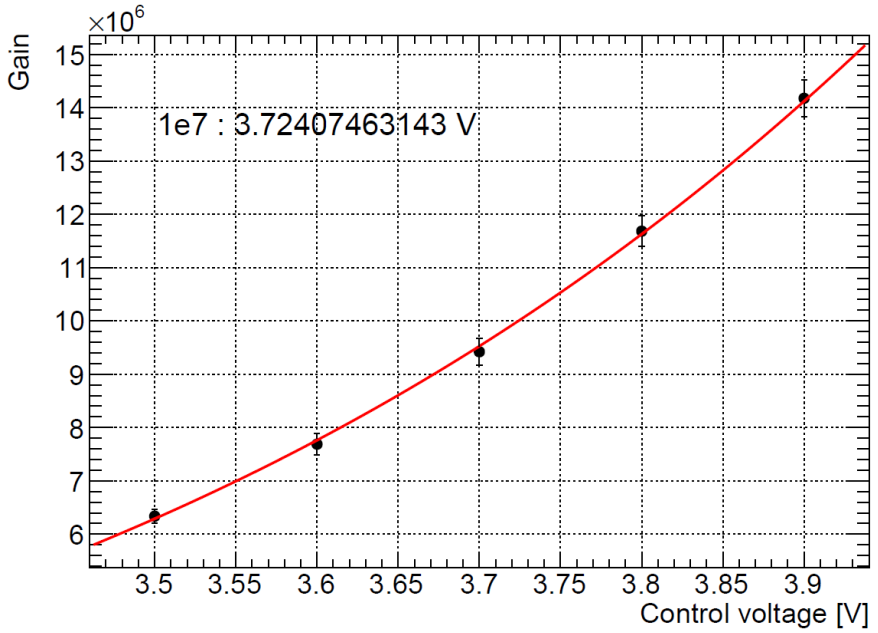
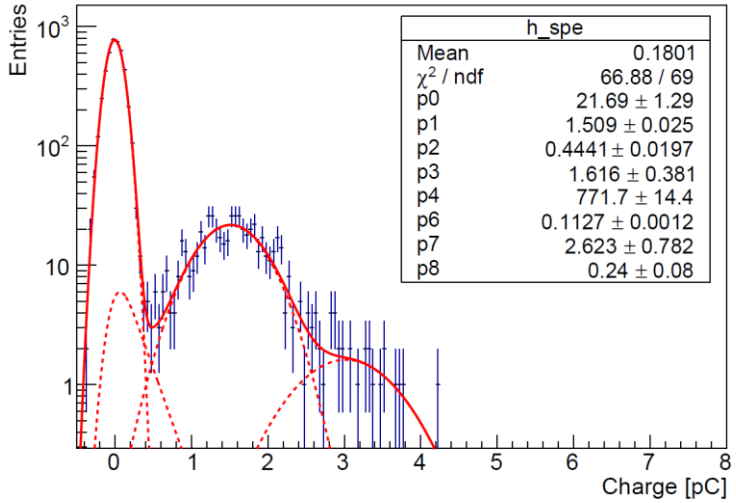
Gain (Golden PMT 1st Gr) (worst QE)

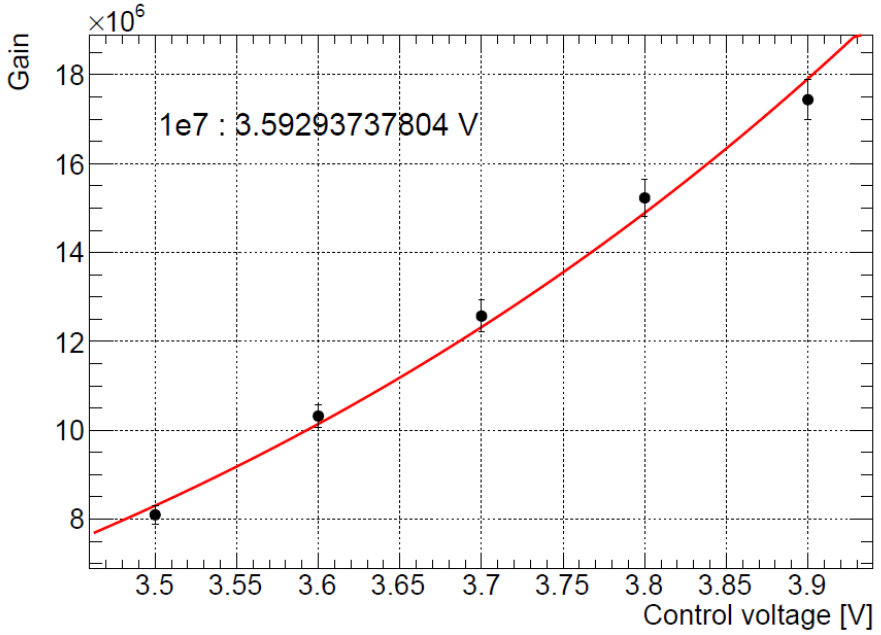
Sq0551

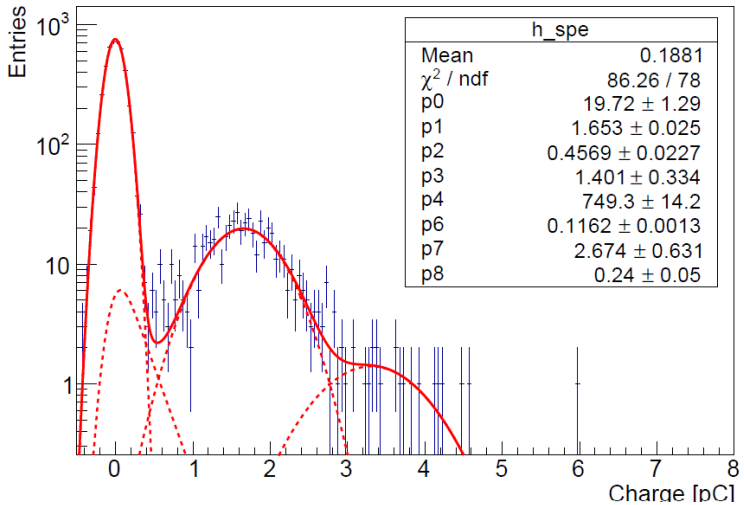




Vc=3.7V

Sq0428

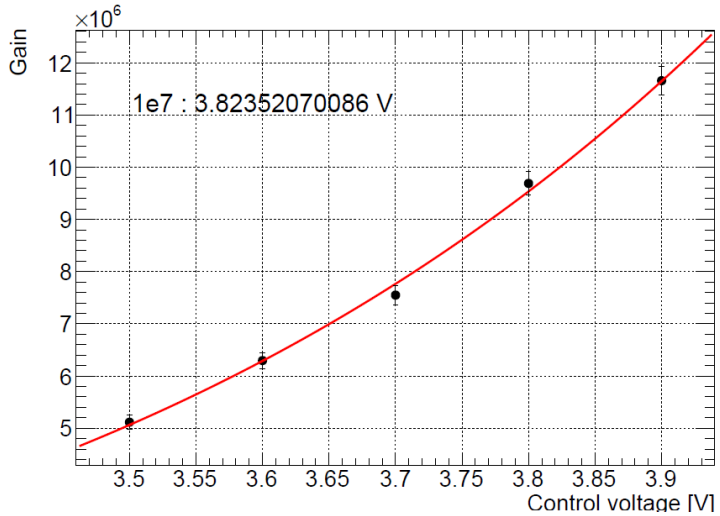


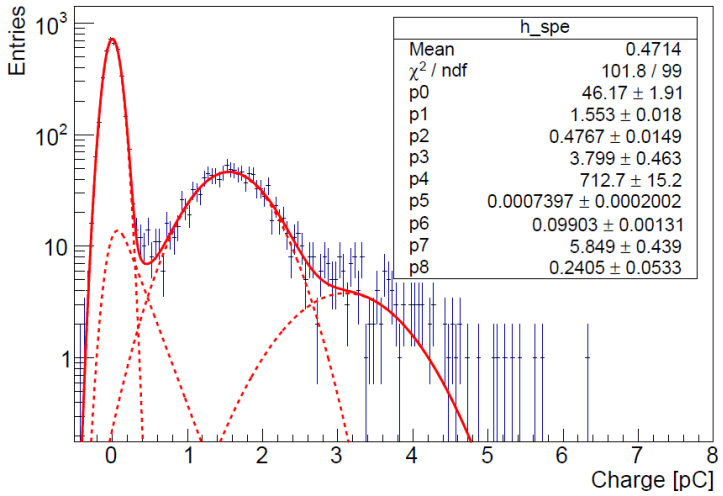


Vc=3.6V

Gain (Golden PMT 2nd Gr) (Best QE)

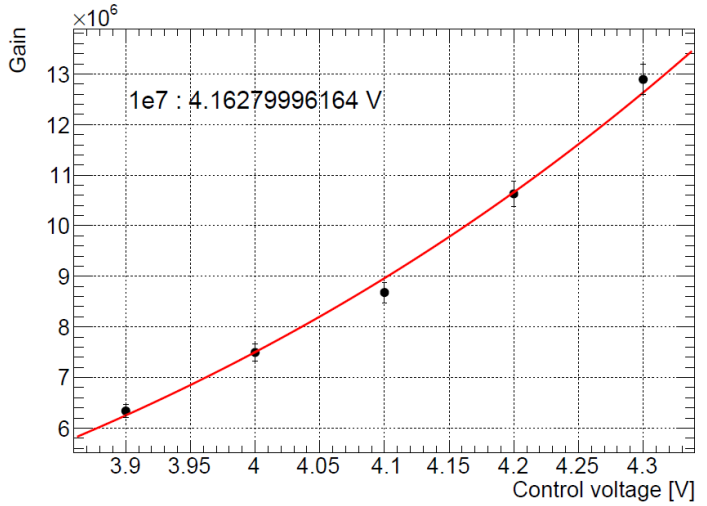
Sq0967 (best QE)

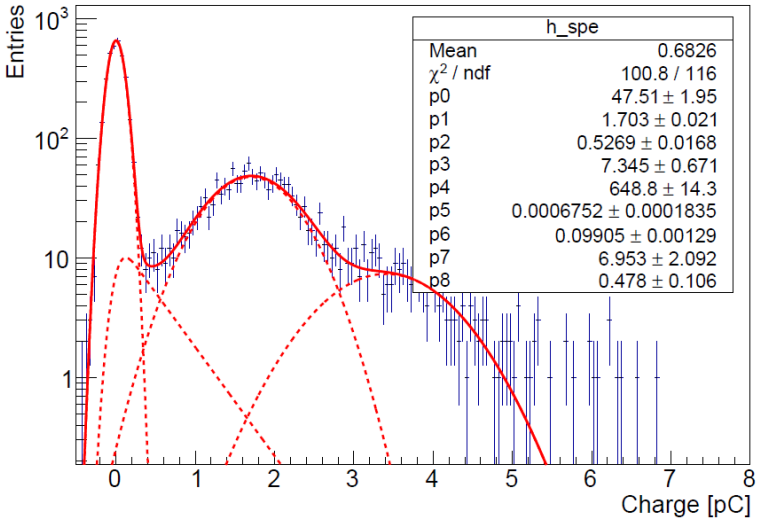




Vc=3.8V

Sq0987(best QE)

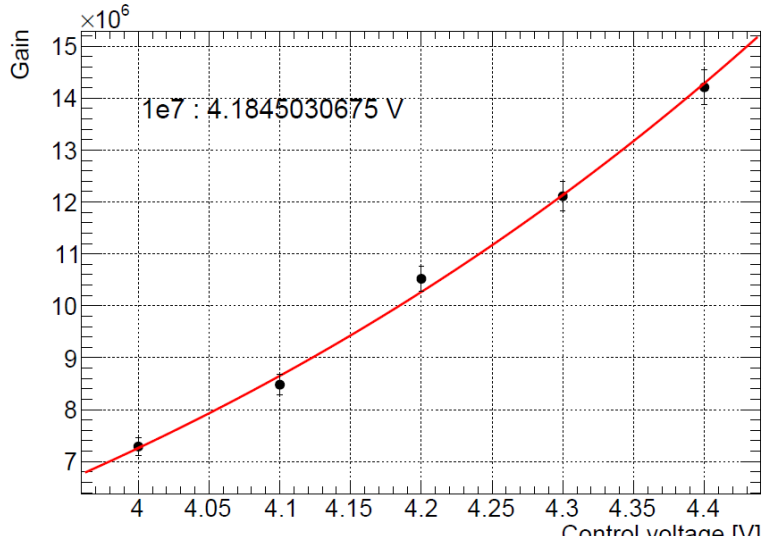


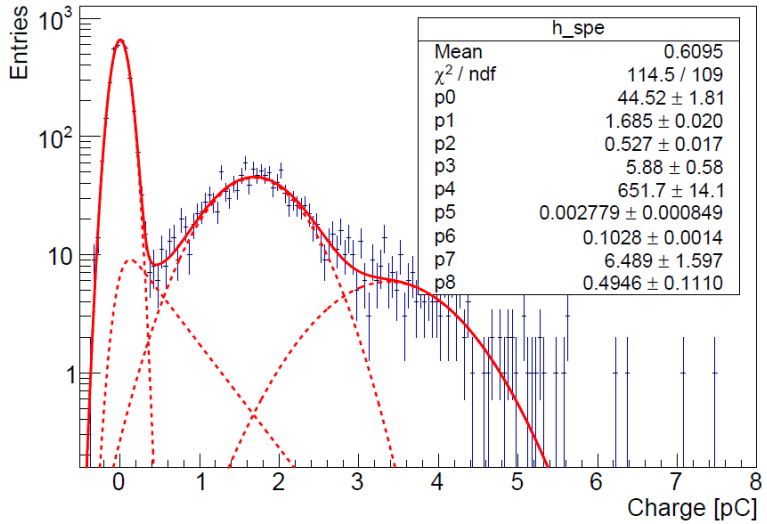


Vc=4.2V

Gain (Golden PMT 2nd Gr) (Average QE)

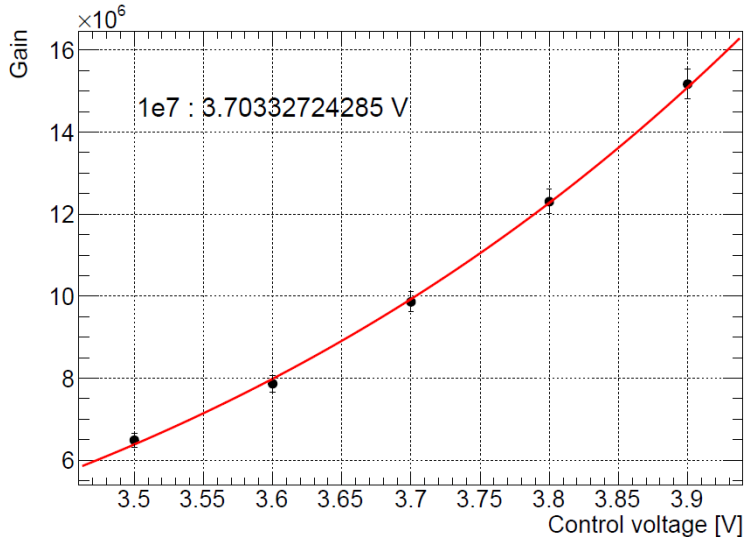
Sq0953 (average QE)

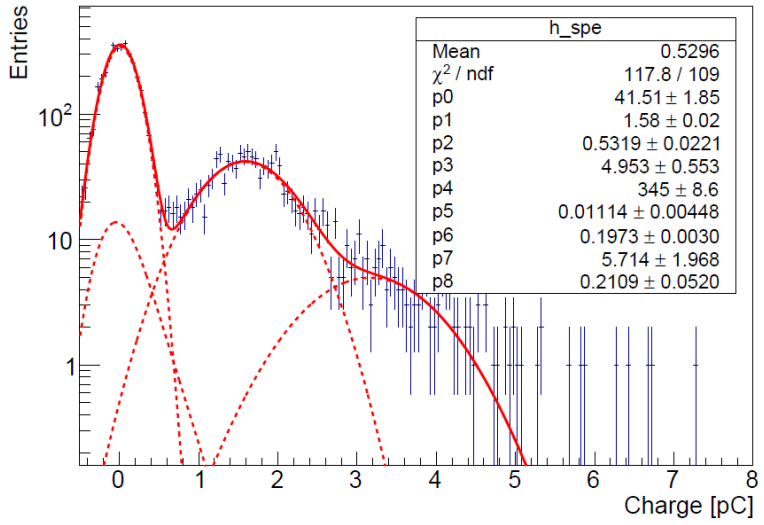




Vc=4.2V

Sq0797(average QE)

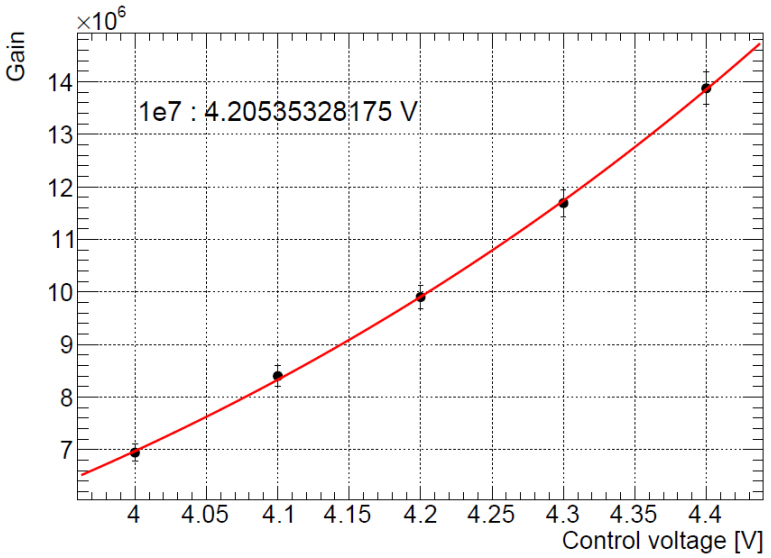


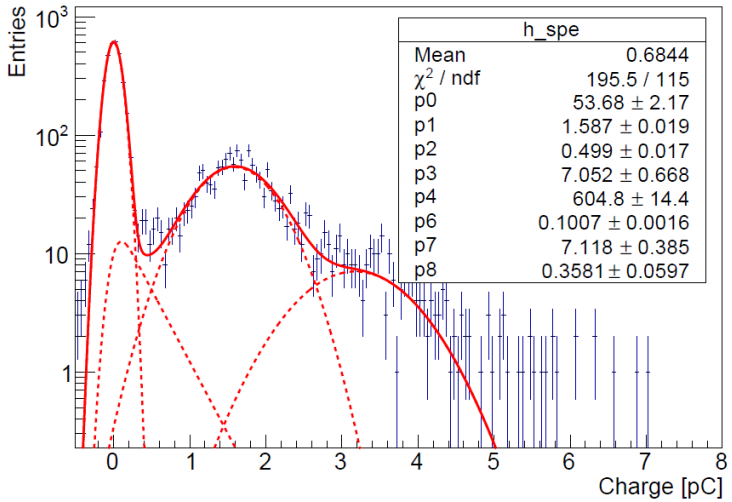


Vc=3.7V

Gain (Golden PMT 2nd Gr) (low QE)

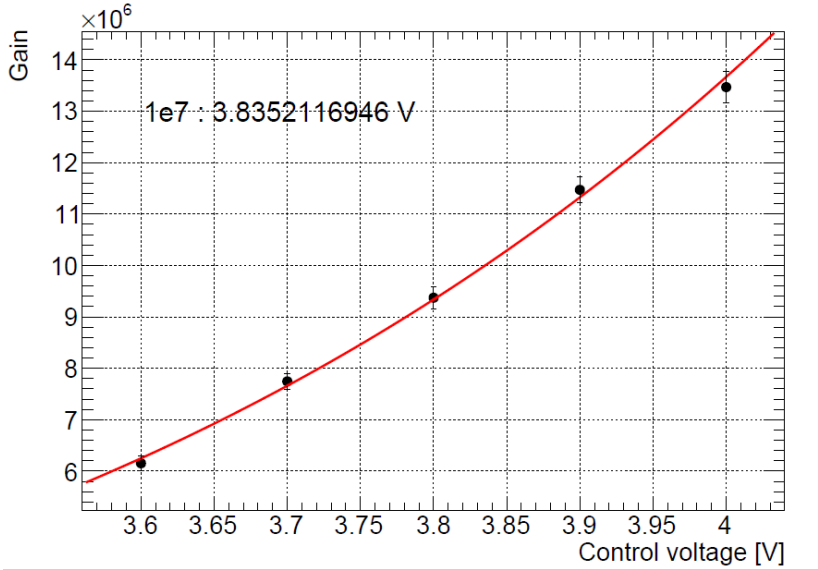
Sq0817 (low QE)

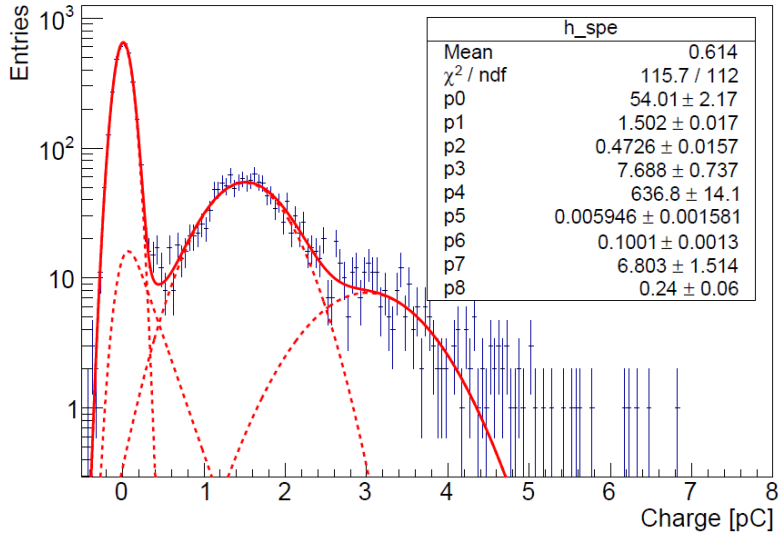




Vc=4.2V

Sq0775(low QE)

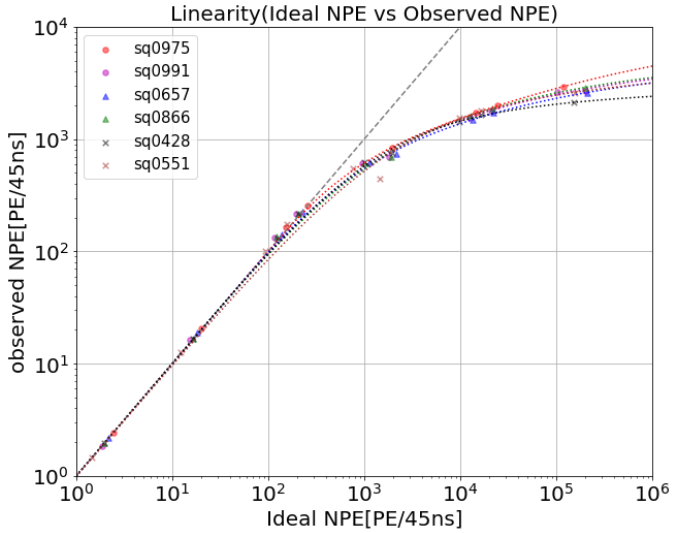


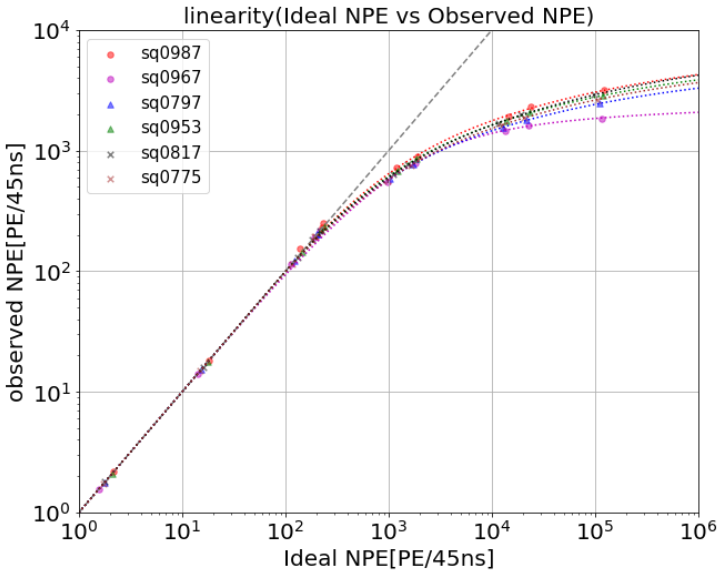


Vc=3.8V

Linearity fitting function

(1./x + (1./p0) * np.log(1. + (x/p1)**3) /np.log(1. + (x/p2)**0.5)) ** -1





	p0	p1	p2
sq0975:	[87313	228	142644]
Sq0991:	[46472	74.8	19074]
Sq0657:	[43498	102.7	23332]
sq0866	[48345	46.5	15568]
Sq0428:	[22619	41.5	1698]
Sq0551:	[47479	0.015	794.5]

	p0	p1	p2
sq0987:	[59425	168.1	32187]
Sq0967:	[17632	21.20	505.6]
Sq0797:	[43643	136.5	23163]
Sq0953:	[53356	148.5	29210]
Sq0817:	[65054	133.9	44713]
Sq0775:	[51408	110.5	27154]