

Investigation of linearity of 3 inch PMT output

November 13th, 2020

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Keio University Nishimura lab.

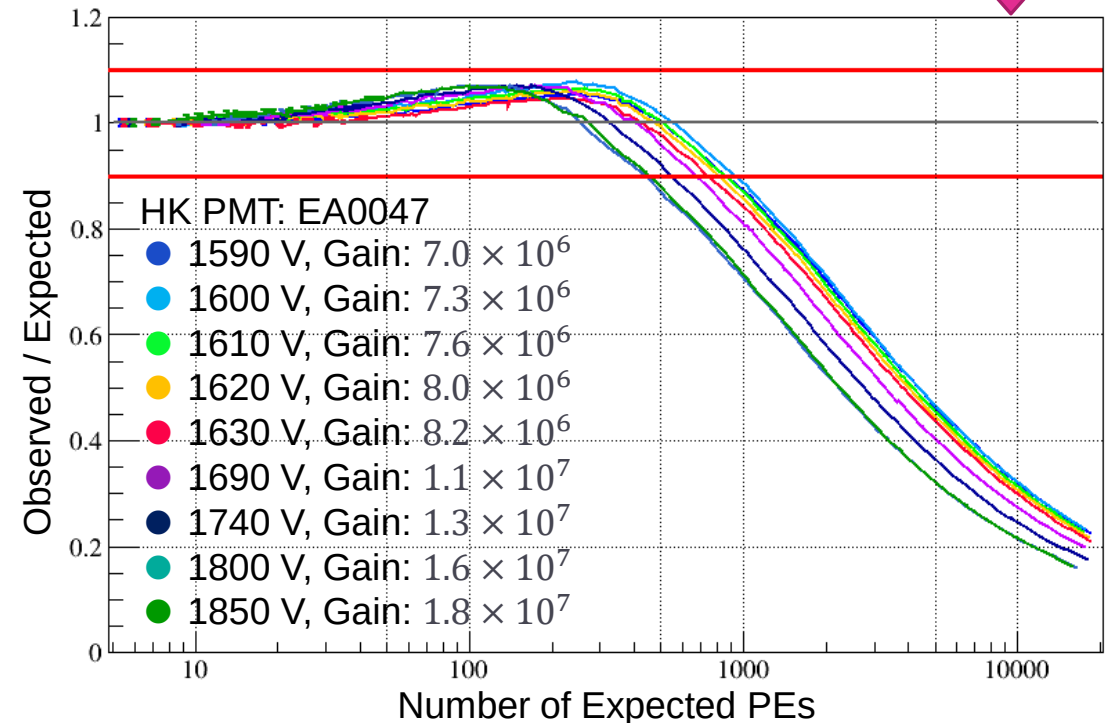
Introduction

The non-linearity was measured in 20" PMT,
but the non-linearity of 3" PMT has not been measured.

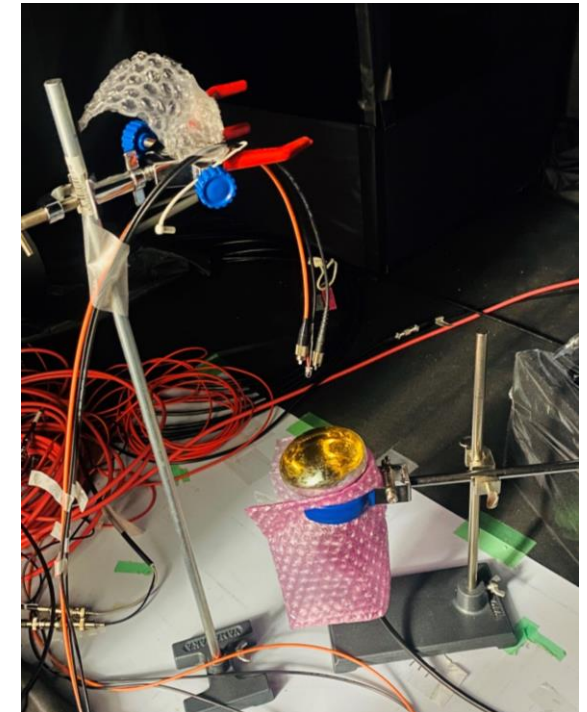
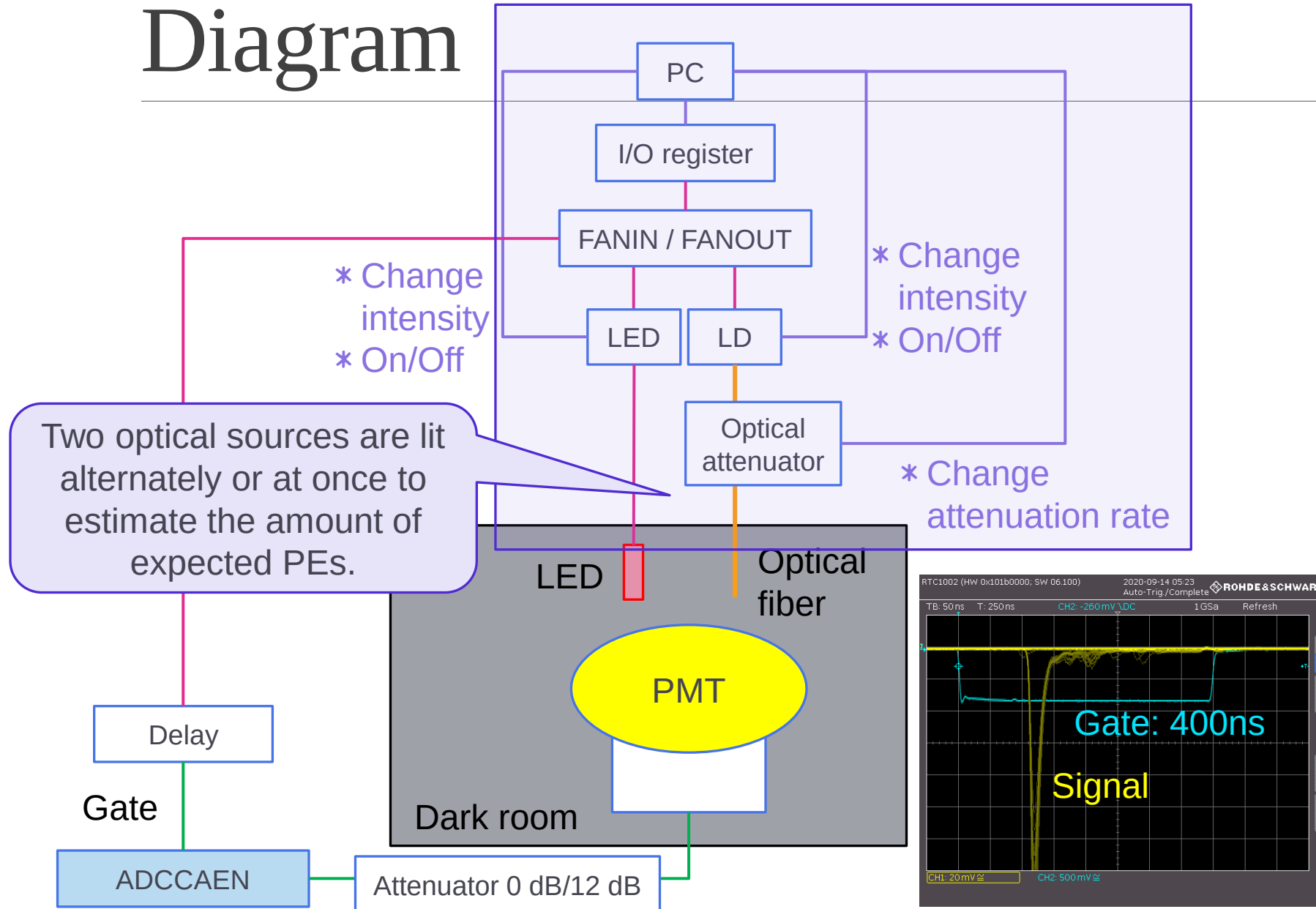
At first, I measured the linearity of 3" PMT(BC0592) at 1080 V.

↓ improvement of estimation

I measured the linearity of
3" PMT(BC0592) at different HV
(*1080 V is HV to be 3×10^6 was
measured by Hamamatsu).

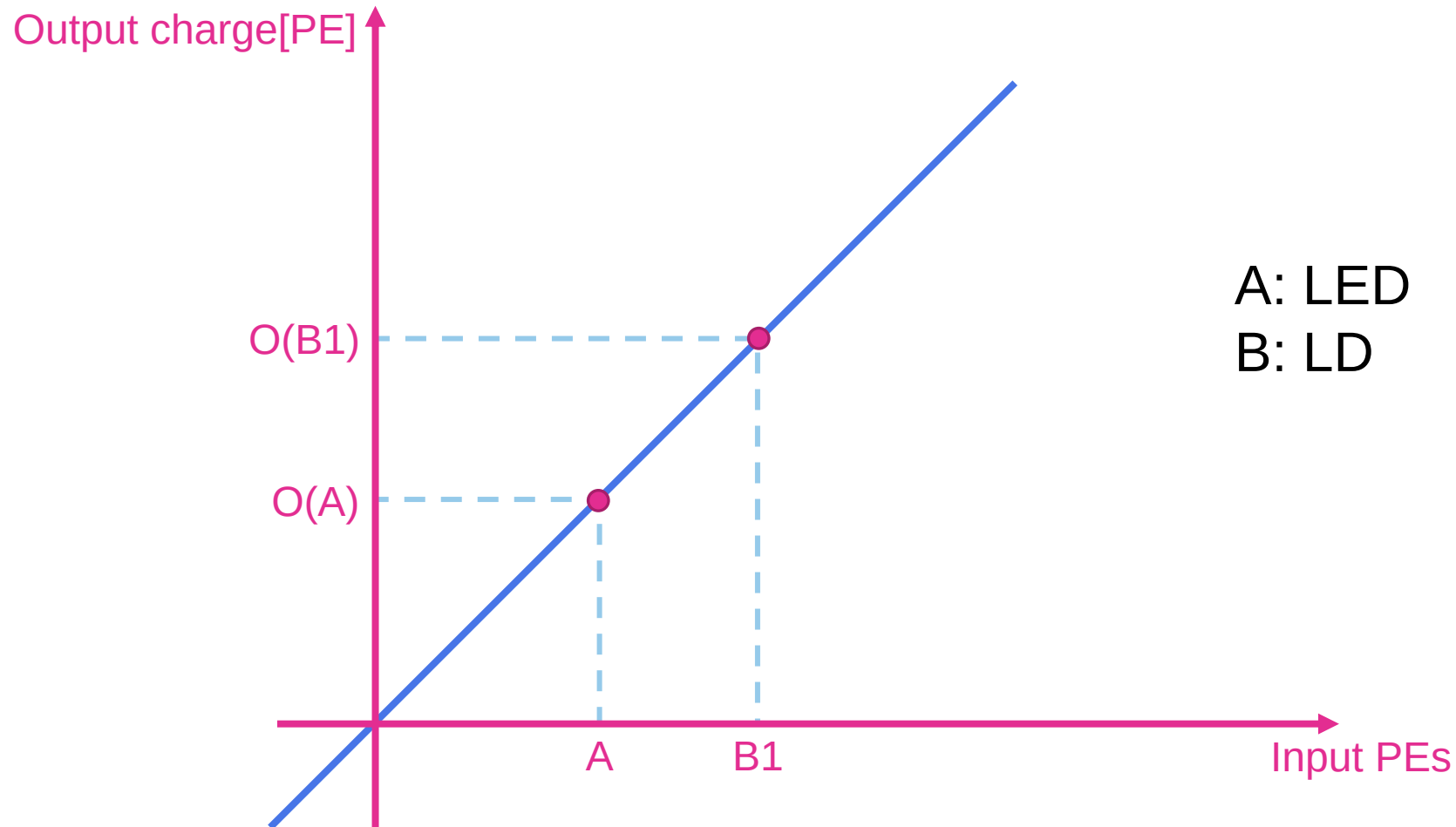


Diagram



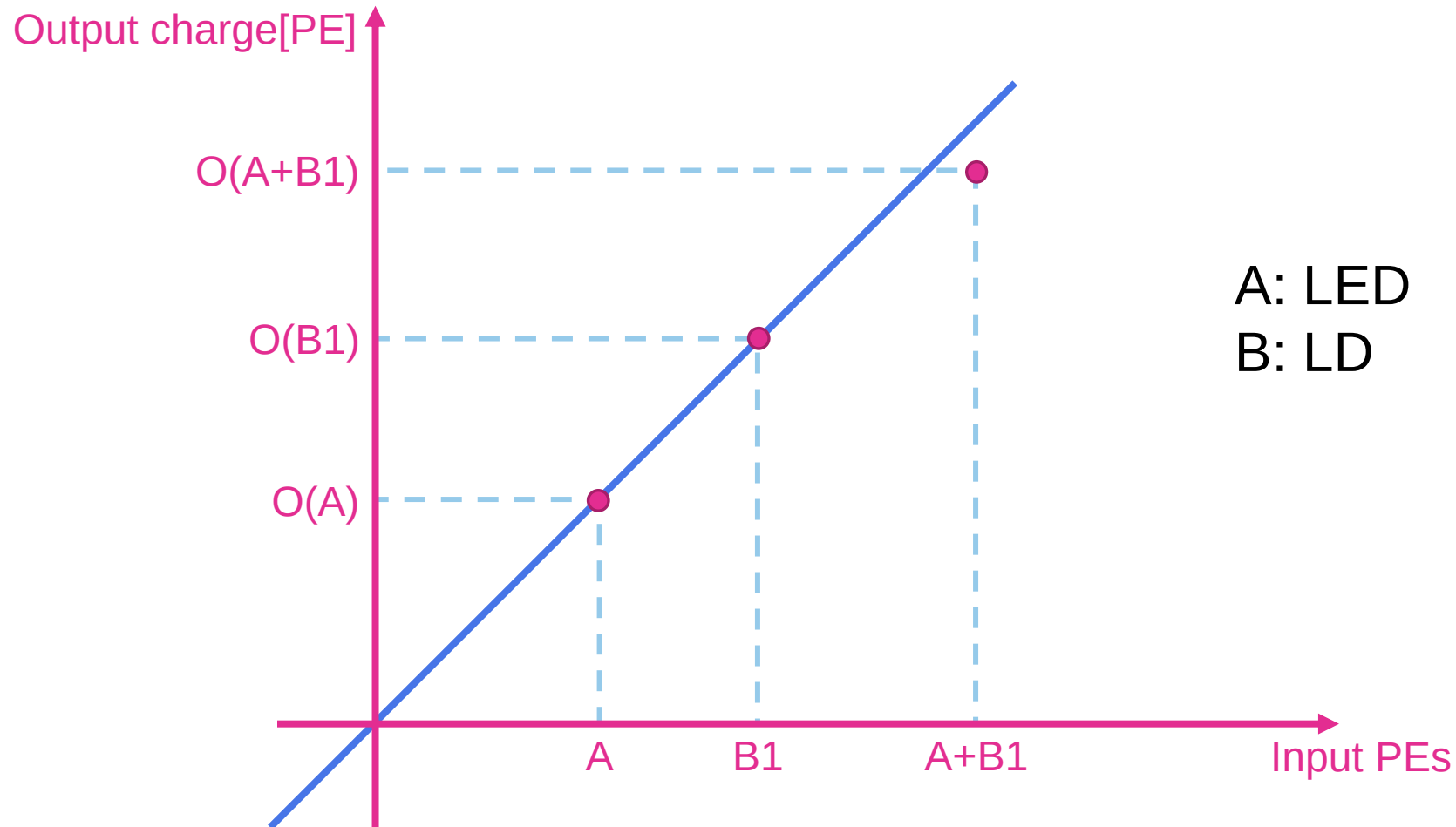
How to Measure the linearity

Measure the linearity between Input PEs and Output charge



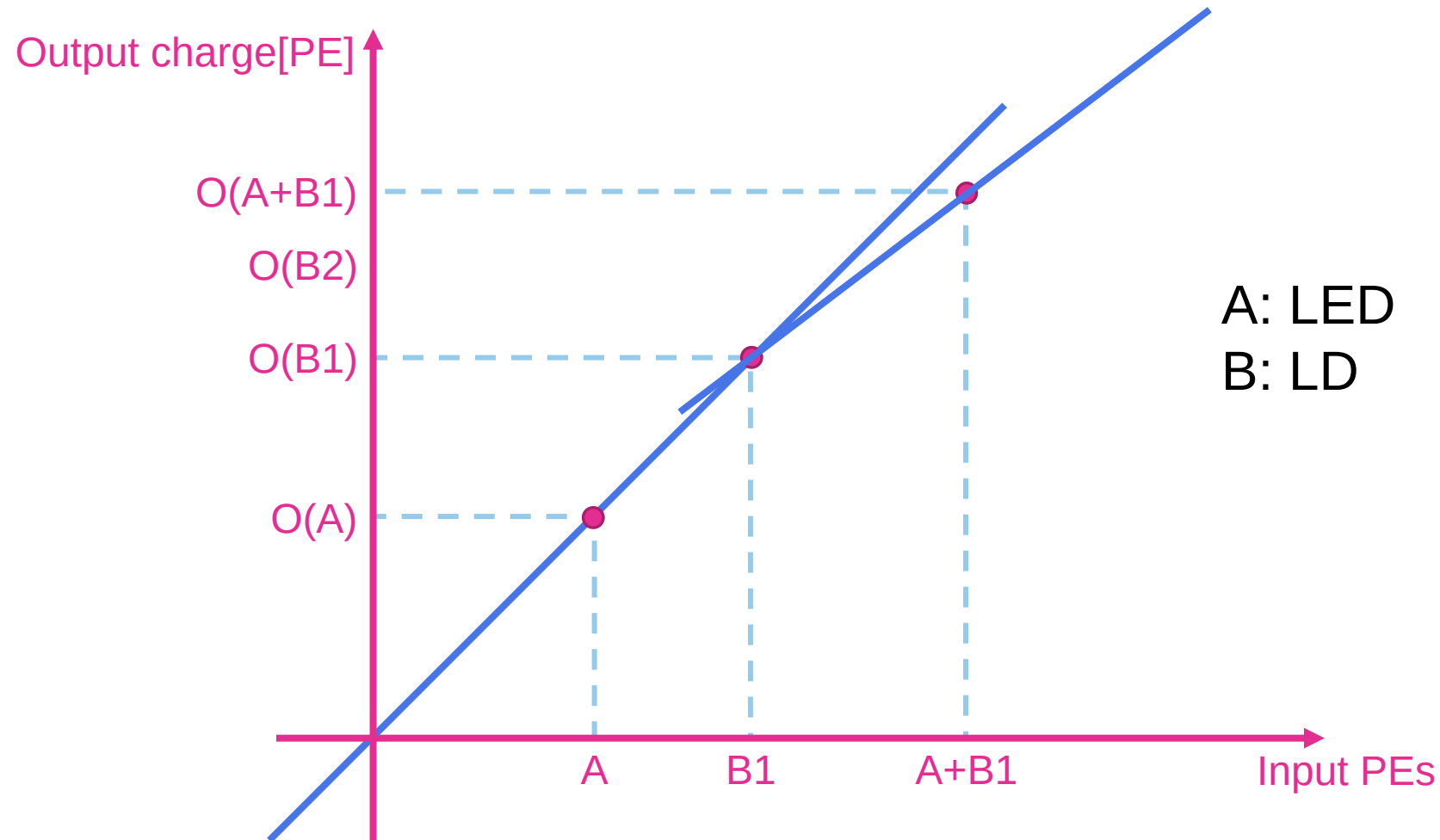
How to Measure the linearity

Measure the linearity between Input PEs and Output charge



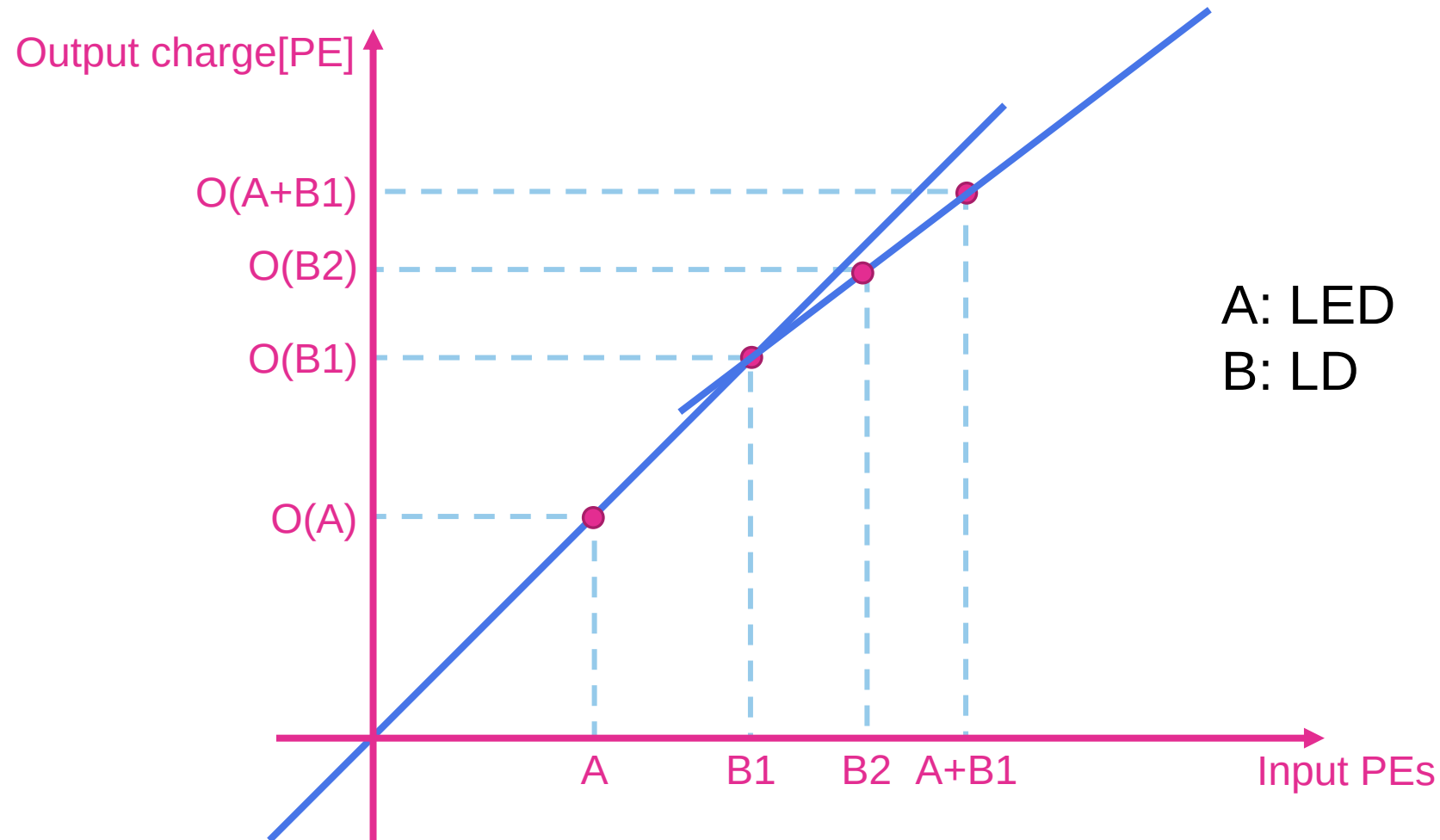
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Measure the linearity between Input PEs and Output charge



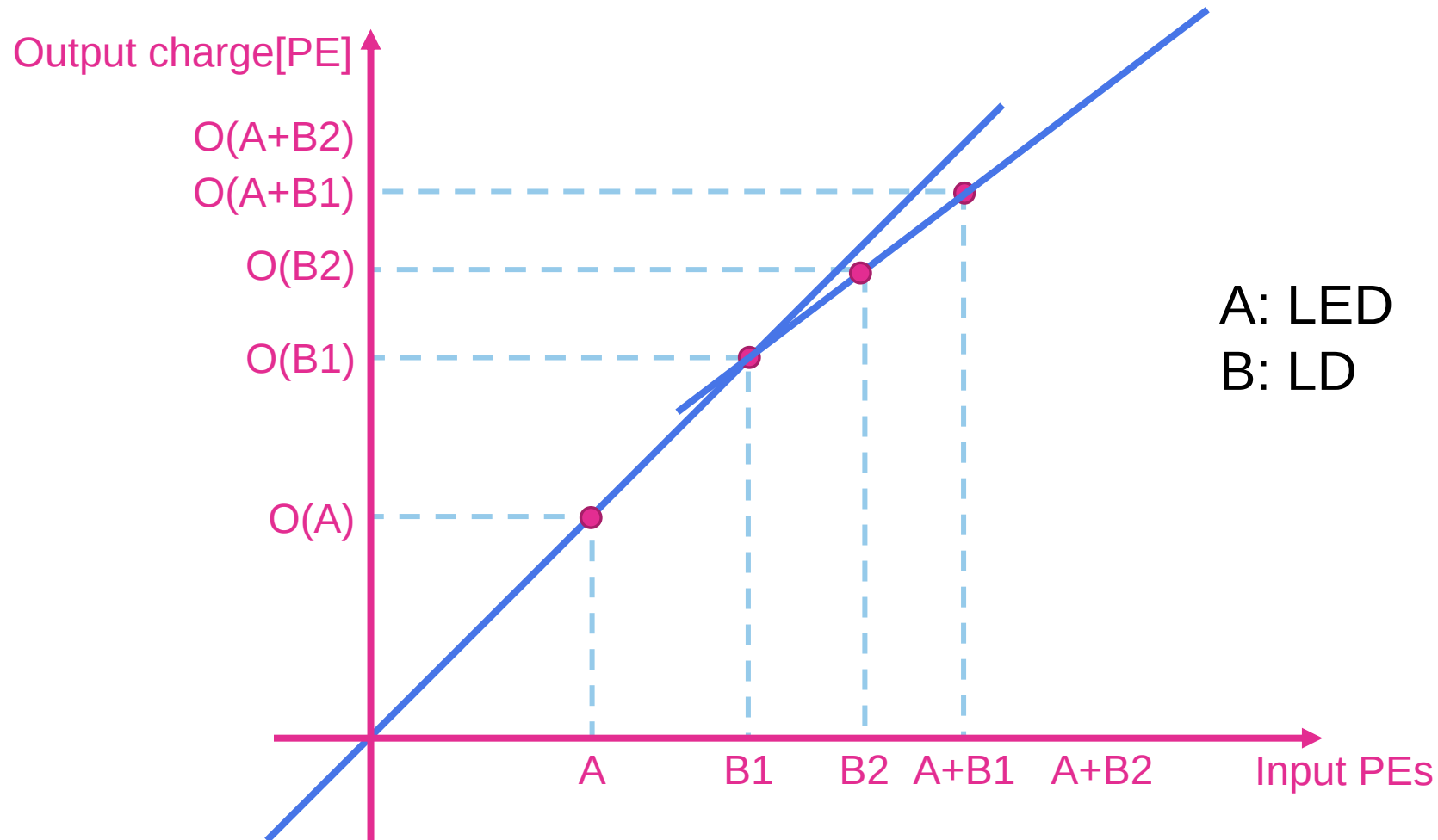
How to Measure the linearity

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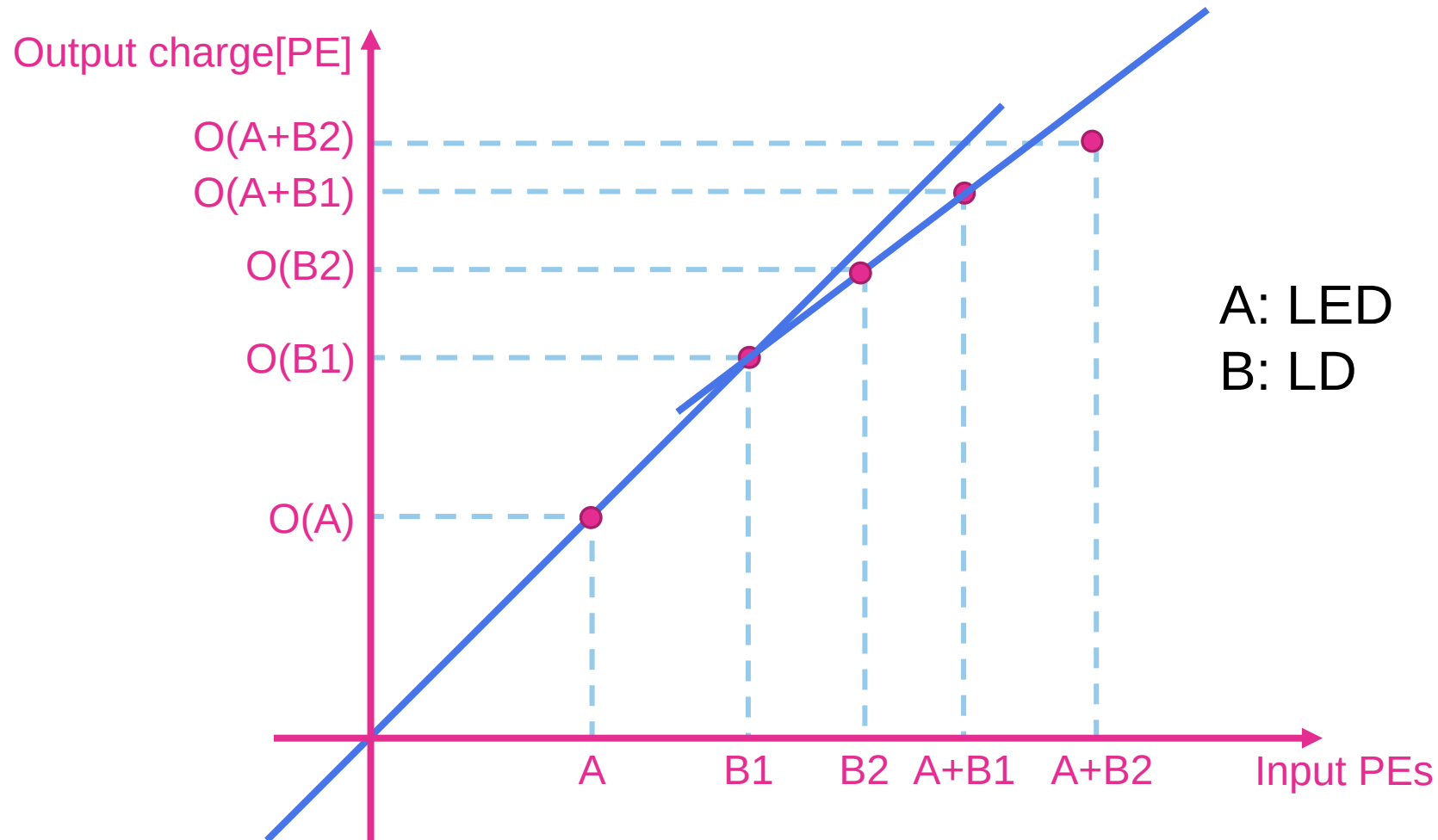
How to Measure the linearity

Measure the linearity between Input PEs and Output charge



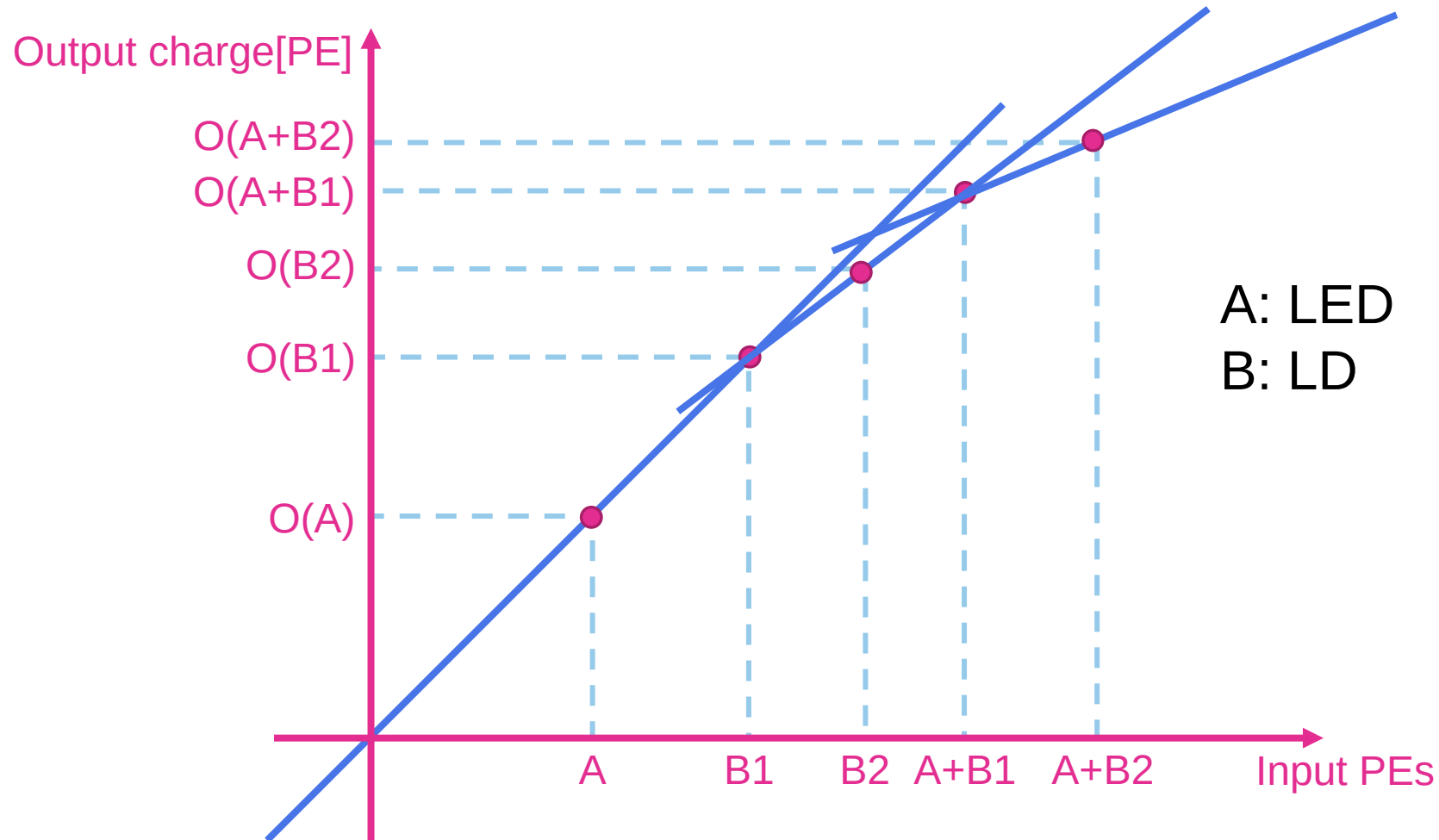
How to Measure the linearity

Measure the linearity between Input PEs and Output charge



How to Measure the linearity

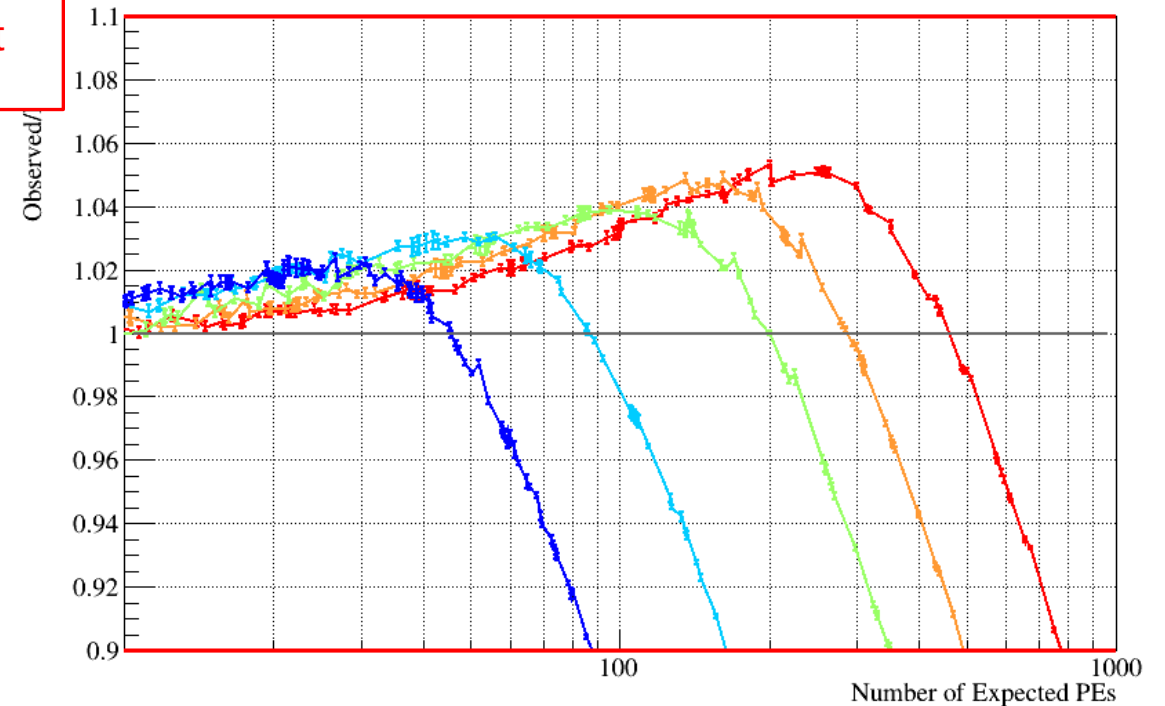
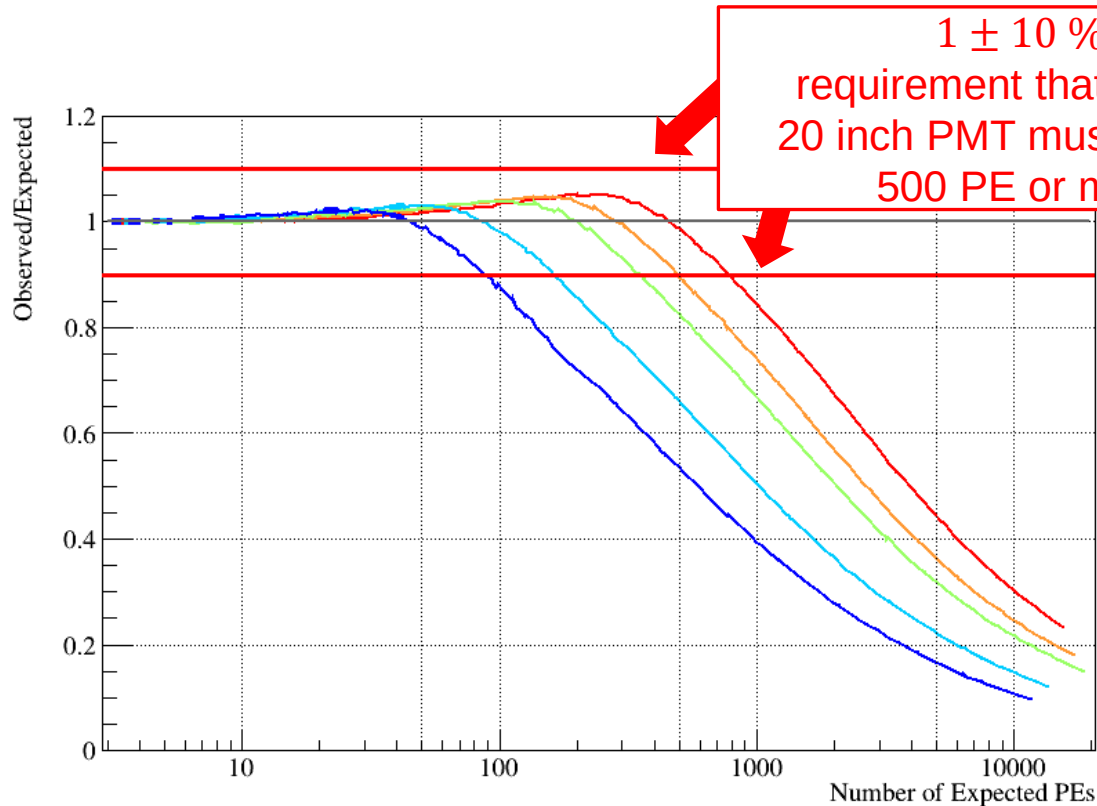
Measure the linearity between Input PEs and Output charge



Non-linearity curve with PE

* Expected PEs vs Observed/Expected in mPMT

- 1080 V, Gain: 3.4×10^6
- 1180 V, Gain: 5.6×10^6
- 1280 V, Gain: 8.3×10^6
- 1380 V, Gain: 1.8×10^7
- 1480 V, Gain: 3.3×10^7

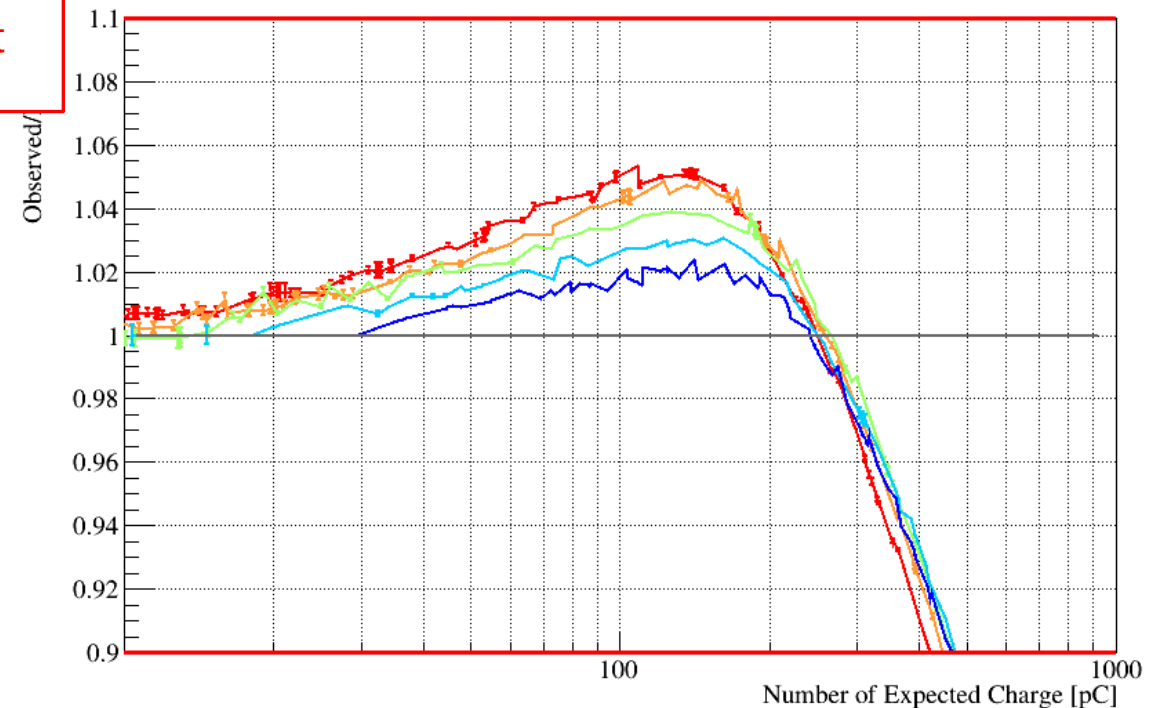
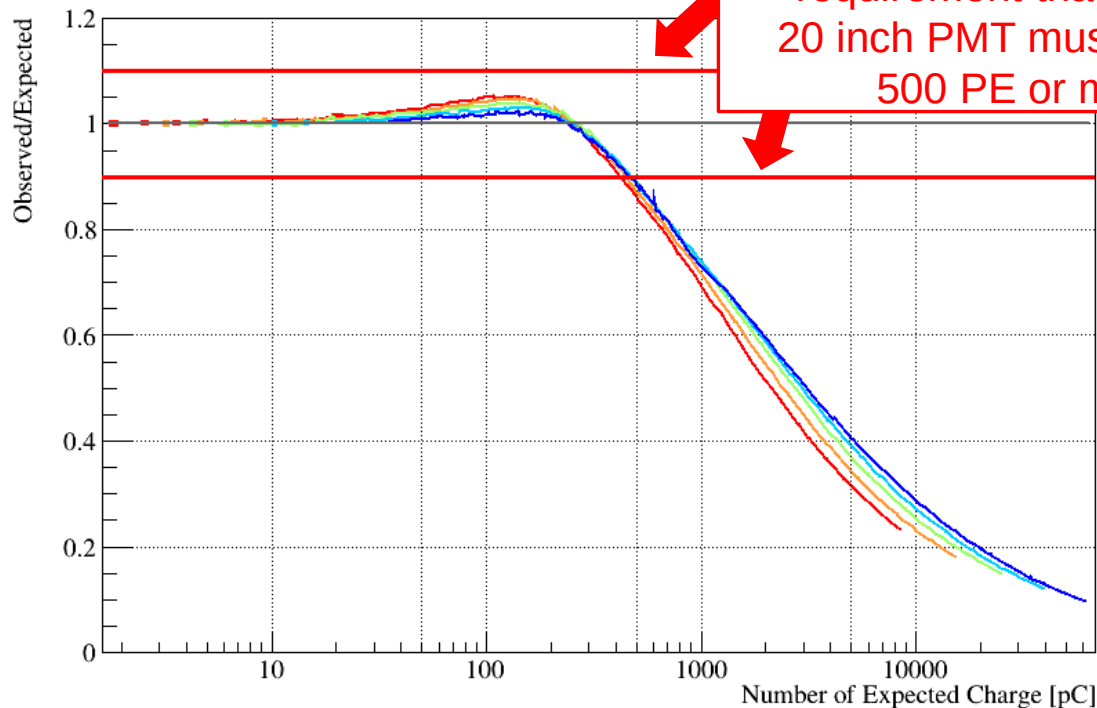


Non-linearity of 3" PMT varied by HV and gain

Non-linearity curve with charges

* Expected charges vs Observed/Expected
in mPMT

- 1080 V, Gain: 3.4×10^6
- 1180 V, Gain: 5.6×10^6
- 1280 V, Gain: 8.3×10^6
- 1380 V, Gain: 1.8×10^7
- 1480 V, Gain: 3.3×10^7



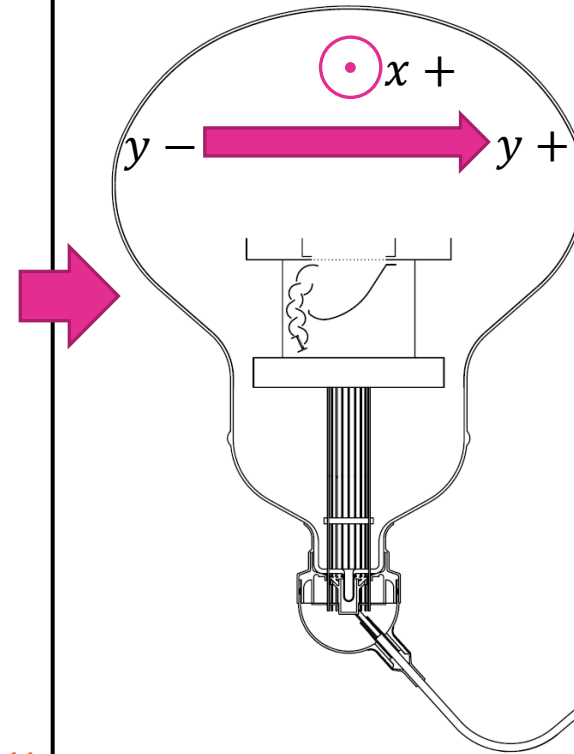
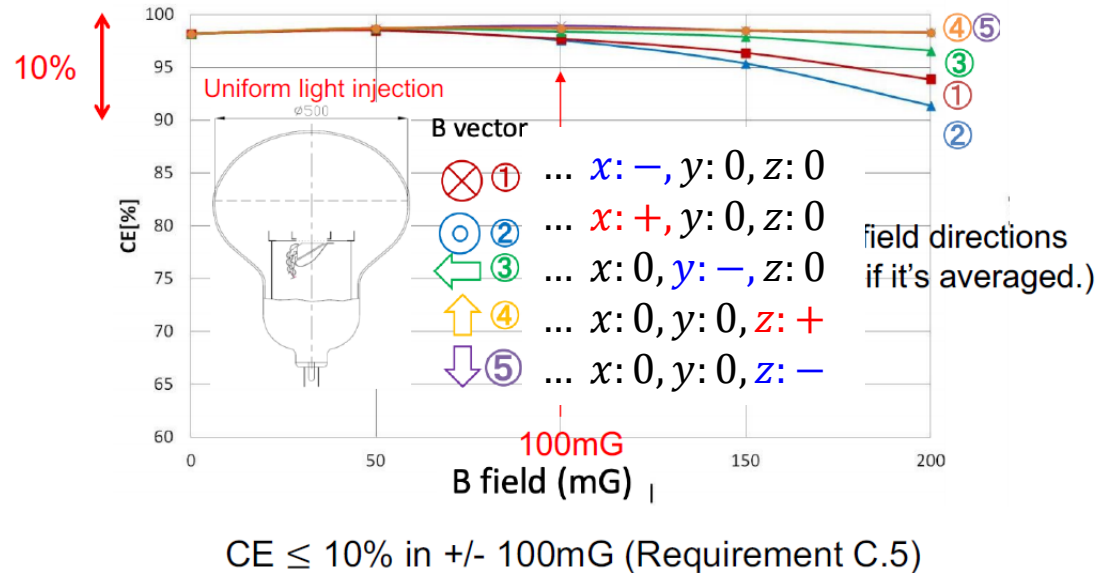
Non-linearity curves of 3" PMT didn't match even if the horizontal axis is charge.

The effect of magnetic field on HK 20'' PMT

*The collection efficiency is affected by magnetic field.

C. Gain Variation in Magnetic Field

Collection efficiency of average on overall 50-cm dia. photocathode calculated by Hamamatsu



It is considered that it is **easily affected** by the magnetic field in the **x-axis** direction and is **not easily affected** by the magnetic field in the **y-axis and z-axis** directions.

'20/Jun/19

ID Box&Line PMT Performance (Nishimura)

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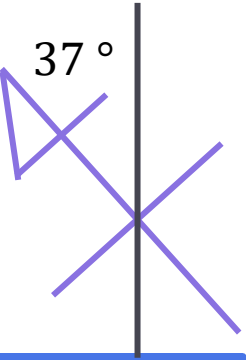
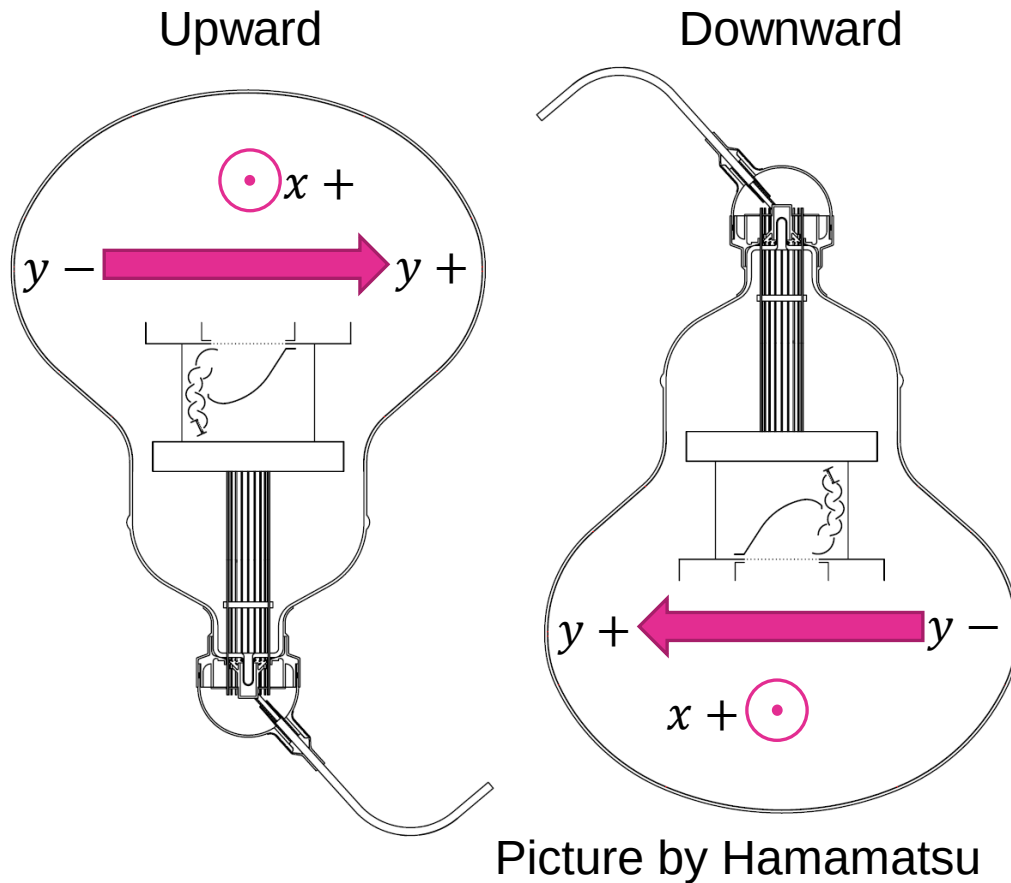
Cited from Nishimura-san's Hyper-Kamiokande ID Box&Line PMT Performance

2020/11/13

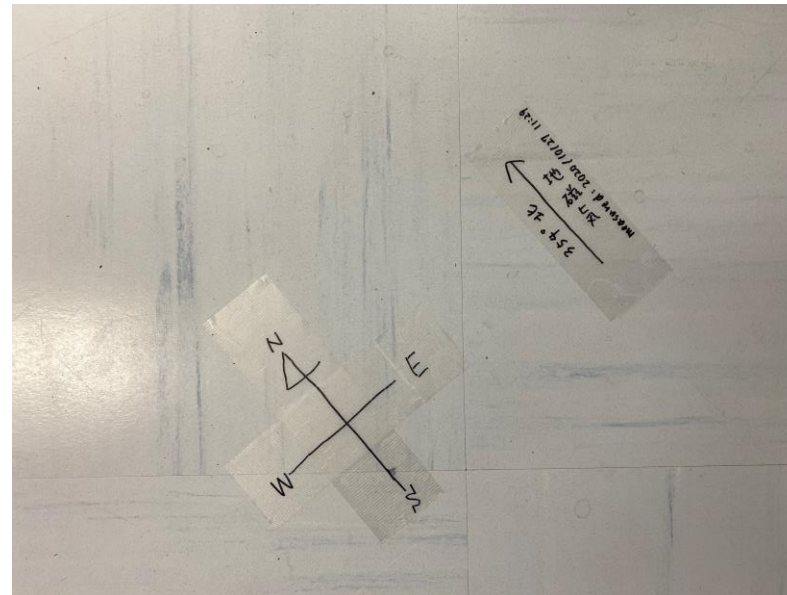
12

The relationship between darkroom and direction

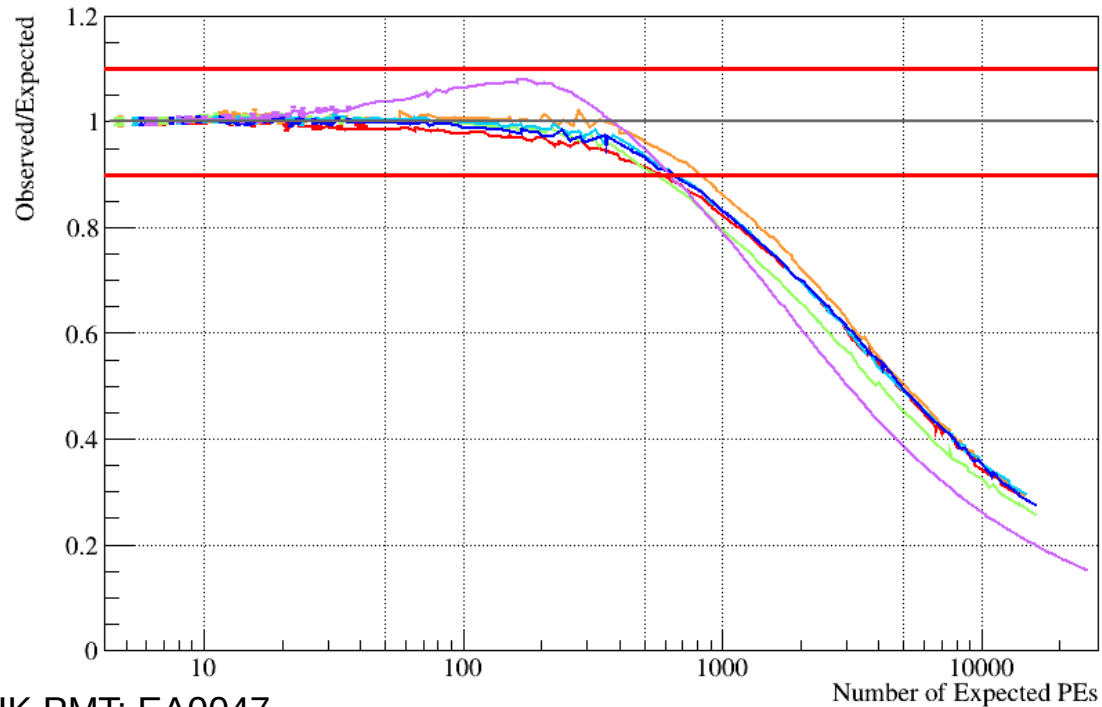
* Measured by changing the orientation of the 20" PMT, considering that it is affected by the geomagnetism.



Laboratory

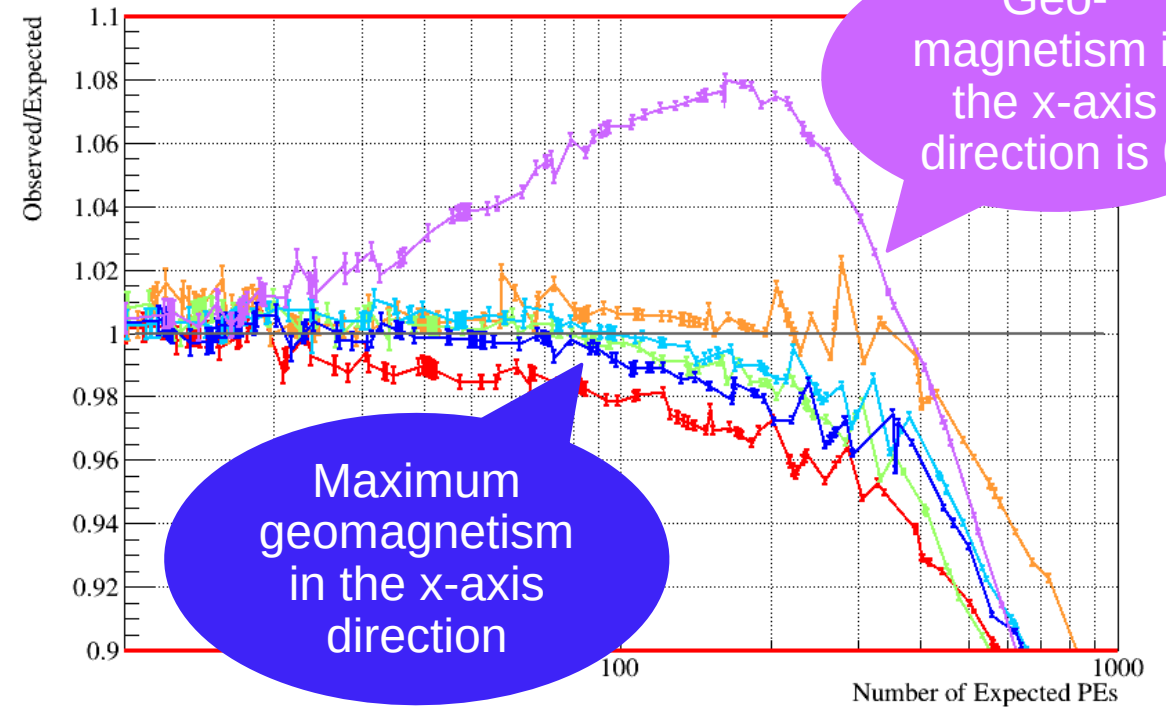


The relationship between geomagnetism and linearity in 20" PMT



HK PMT: EA0047

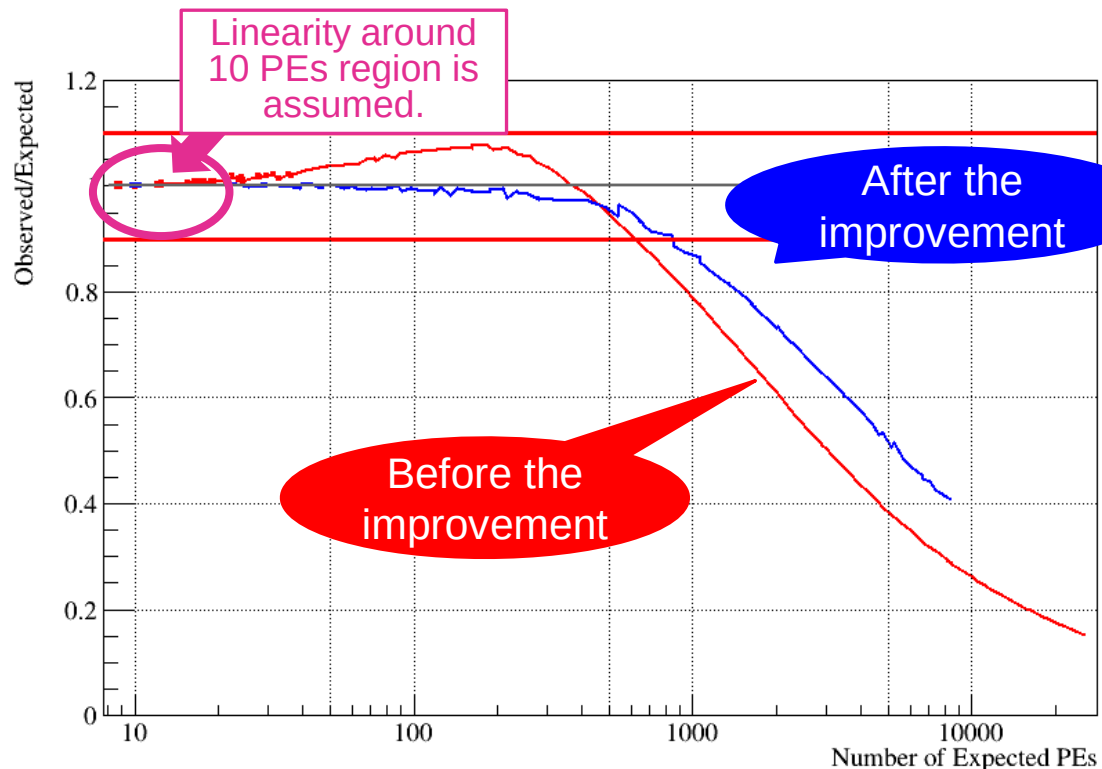
- Downward, y +NW, **x -229 mG**, y 226 mG, z 338 mG, Gain: 9.8×10^6
- Downward, y +SW, **x -226 mG**, y -229 mG, z 338 mG, Gain: 9.4×10^6
- Downward, y +NE, **x 226 mG**, y 229 mG, z 338 mG, Gain: 1.1×10^7
- Downward, y +SE, **x 229 mG**, y -226 mG, z 338 mG, Gain: 1.0×10^7



- Upward, y +W, **x 322 mG**, y 0 mG, z -338 mG, Gain: 1.0×10^7
- Upward, y +N, **x 0 mG**, y 322 mG, z -338 mG, Gain: 1.1×10^7

3 "PMT may also have magnetic field dependence.
A magnetic field shield is available, so it can be evaluated with a low magnetic field.

The result of the circuit improvement of 20" PMT

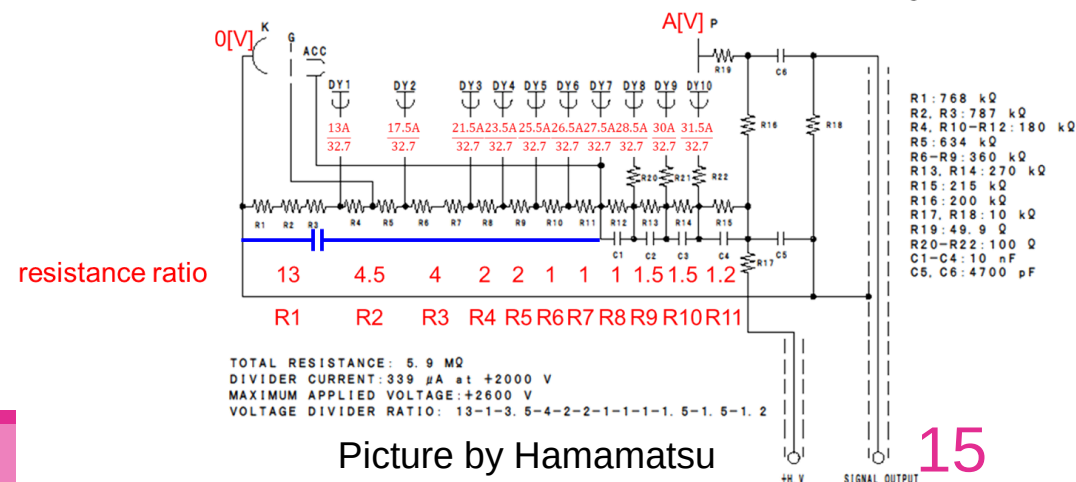
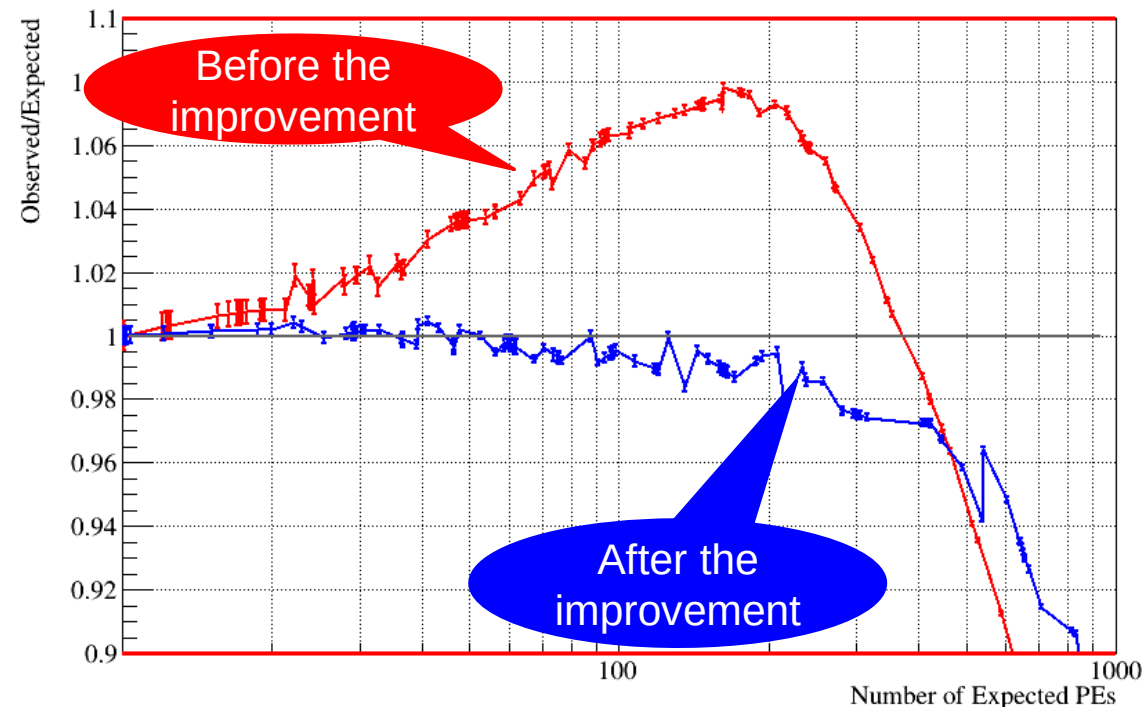


HK PMT: EA0047, 1690 V, PEs

● Before the improvement, Gain: 1.1×10^7

● After the improvement, Gain: 1.1×10^7

3" PMT may be improved in a similar way.
3" PMT and circuits for +/- HV were ordered,
so it can be improved.



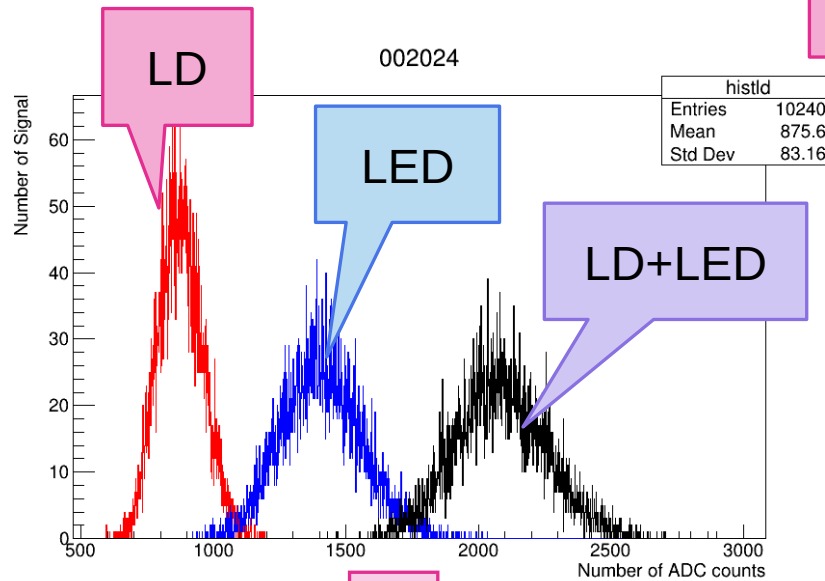
Conclusion

- * Data of linearity of 3" PMT with improved estimates from the first measurement is in root file format.
- * The measured non-linearity varied by HV and gain.
- * Magnetic field would affect non-linearity of 3" PMT too.
It can be evaluated with a low magnetic field by a magnetic field shield.
- * Possibly improve the bleeder circuit of 3" PMT(+HV and -HV)

Backup

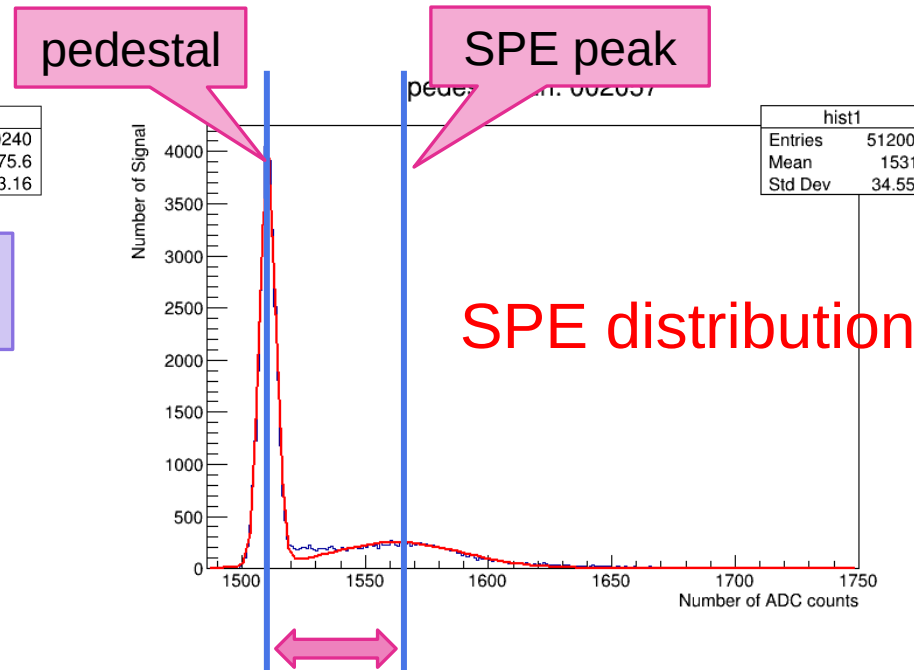
Data taking and analysis

* Calculating the mean from the histogram.



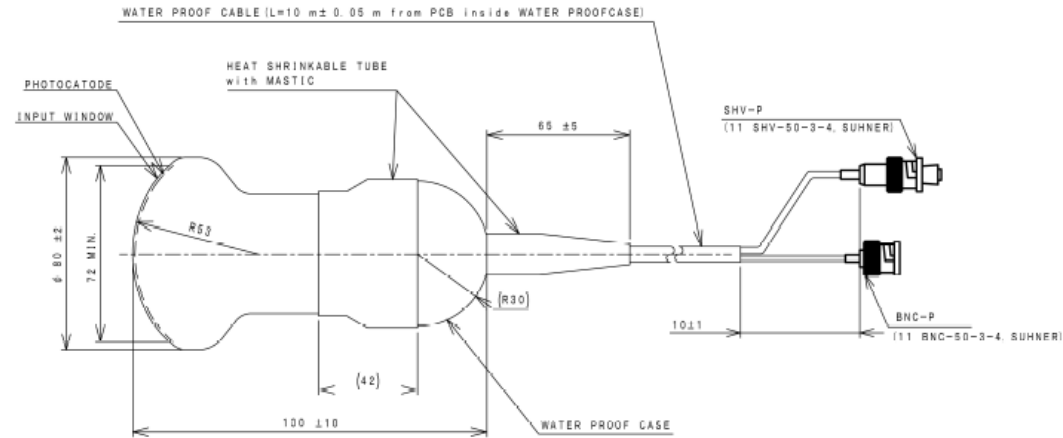
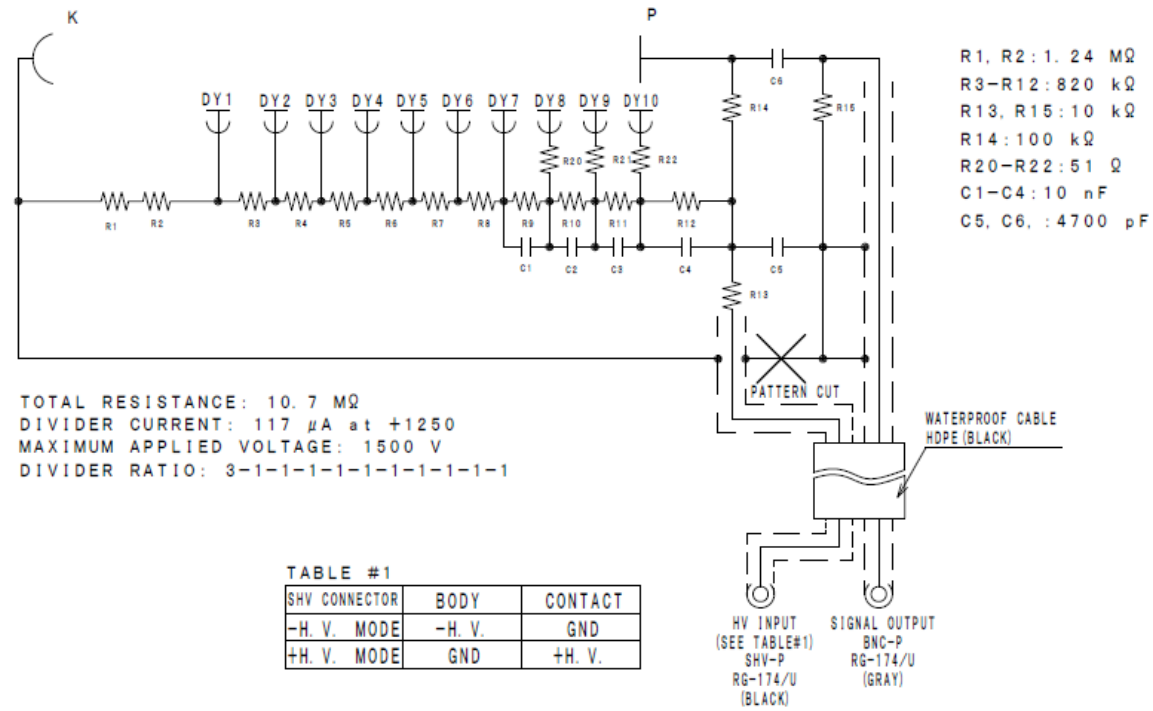
mean values

* Fitting 2 gaussian to SPE distribution



1PE

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R14374-Y013

DIMENSIONAL OUTLINE AND VOLTAGE DIVIDER CIRCUIT

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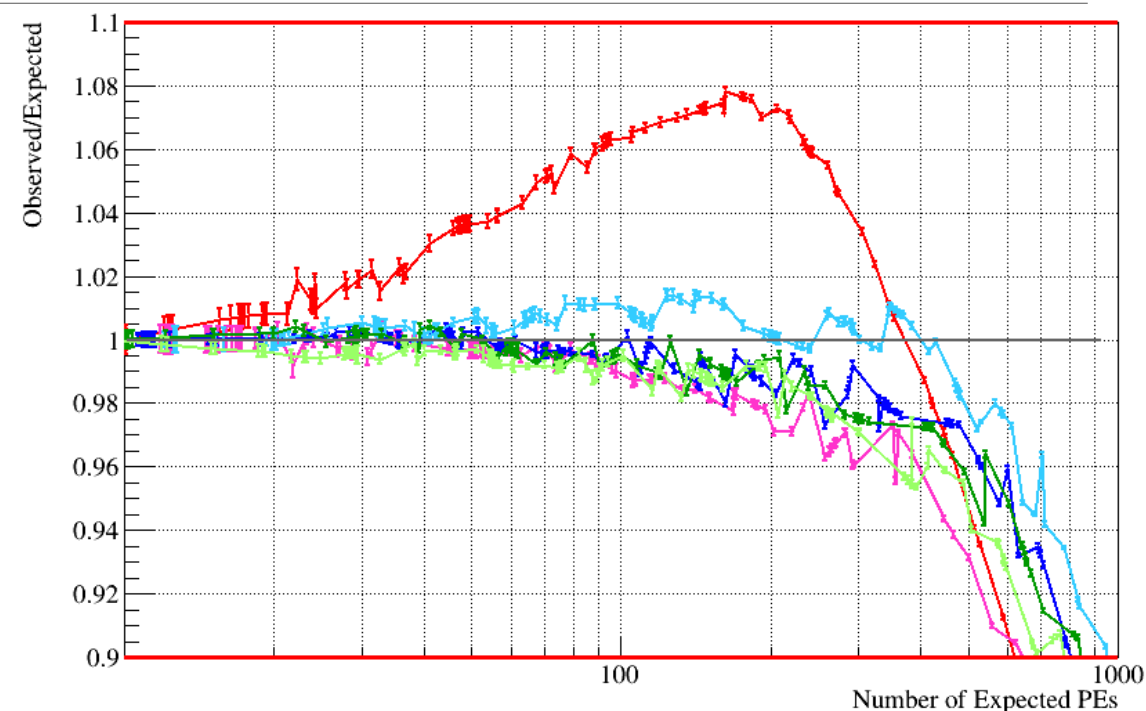
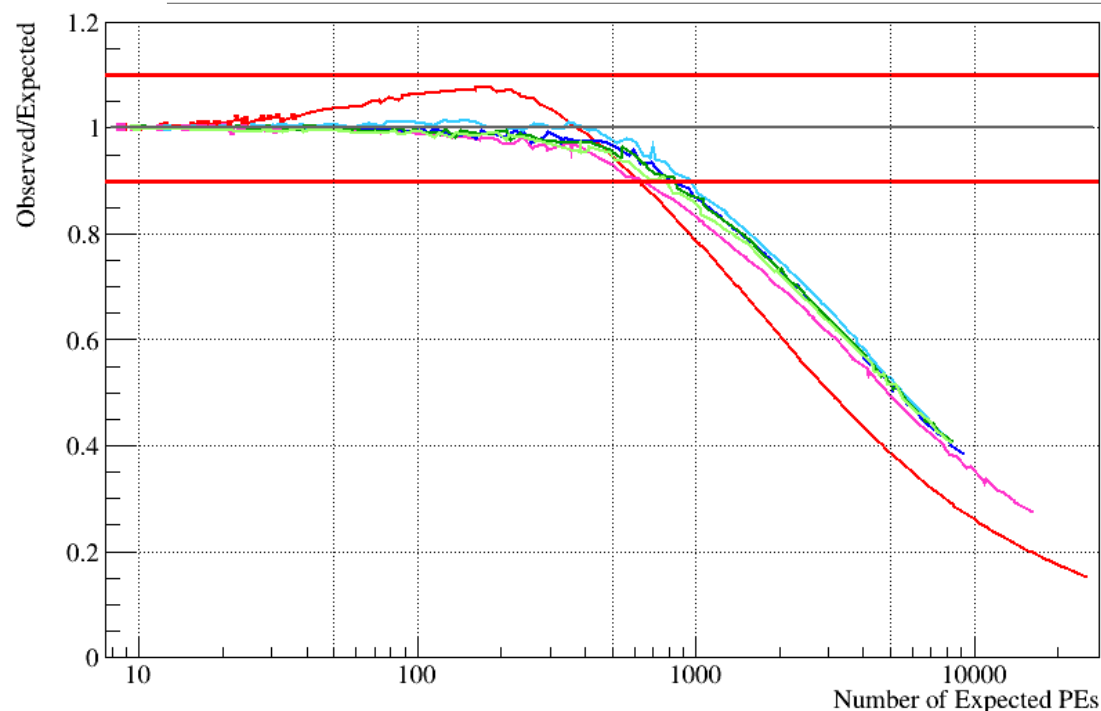
UNIT : mm

DATE: 09. Sep. 2020

The values of 3'' PMT

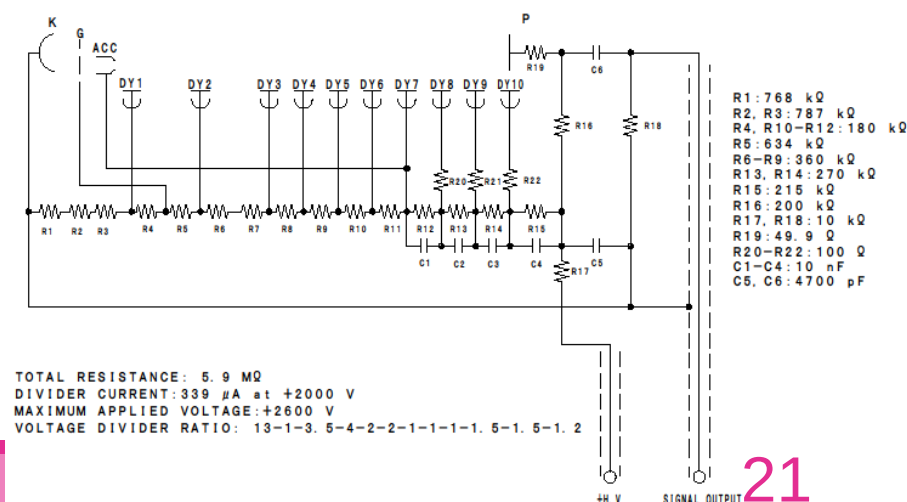
HV / V	Gain / 10^6	Upper limit assuming linearity / PE	Max of deviation	PE at 0.1 loss
1080	3.37	5.81	1.053	771.4
1180	5.64	6.70	1.049	491.4
1280	8.34	4.22	1.039	352.0
1380	18.0	6.20	1.030	163.1
1480	33.1	5.48	1.024	87.1

The effect of the magnetic field of the improved circuit



HK PMT: EA0047, 1690 V, PEs

- Before the improvement, Upward, $y + N$, Gain: 1.1×10^7
- Before the improvement, Upward, $y + W$, Gain: 1.0×10^7
- 10 nF from K to dynode2 and from dynode2 to dynode7, Upward, $y + N$, Gain: 1.1×10^7
- 10 nF from K to dynode2 and from dynode2 to dynode7, Upward, $y + W$, Gain: 9.8×10^6
- 10nF from K to dynode7, Upward, $y + N$, Gain: 1.1×10^7
- 10nF from K to dynode7, Upward, $y + W$, Gain: 1.0×10^7



The improved circuit is unlikely to be affected by the geomagnetism.