

# Properties of the MCP-PMTs for the Endcap Disc Dirc

ERLANGEN CENTRE  
FOR ASTROPARTICLE  
PHYSICS

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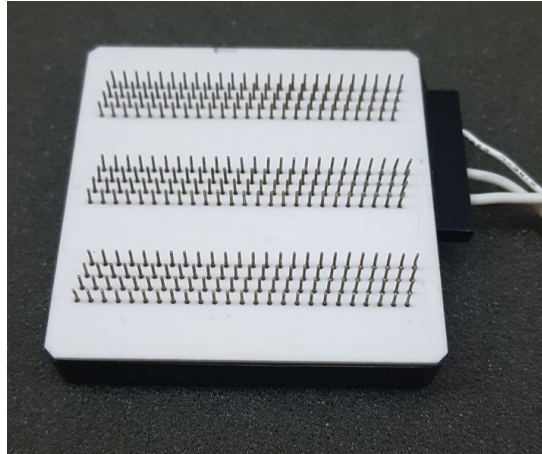
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# Sensors

## Photonis sensors

- 3x100 anode pixels
- MCPs 10  $\mu\text{m}$  pores



Backplane of 943P541

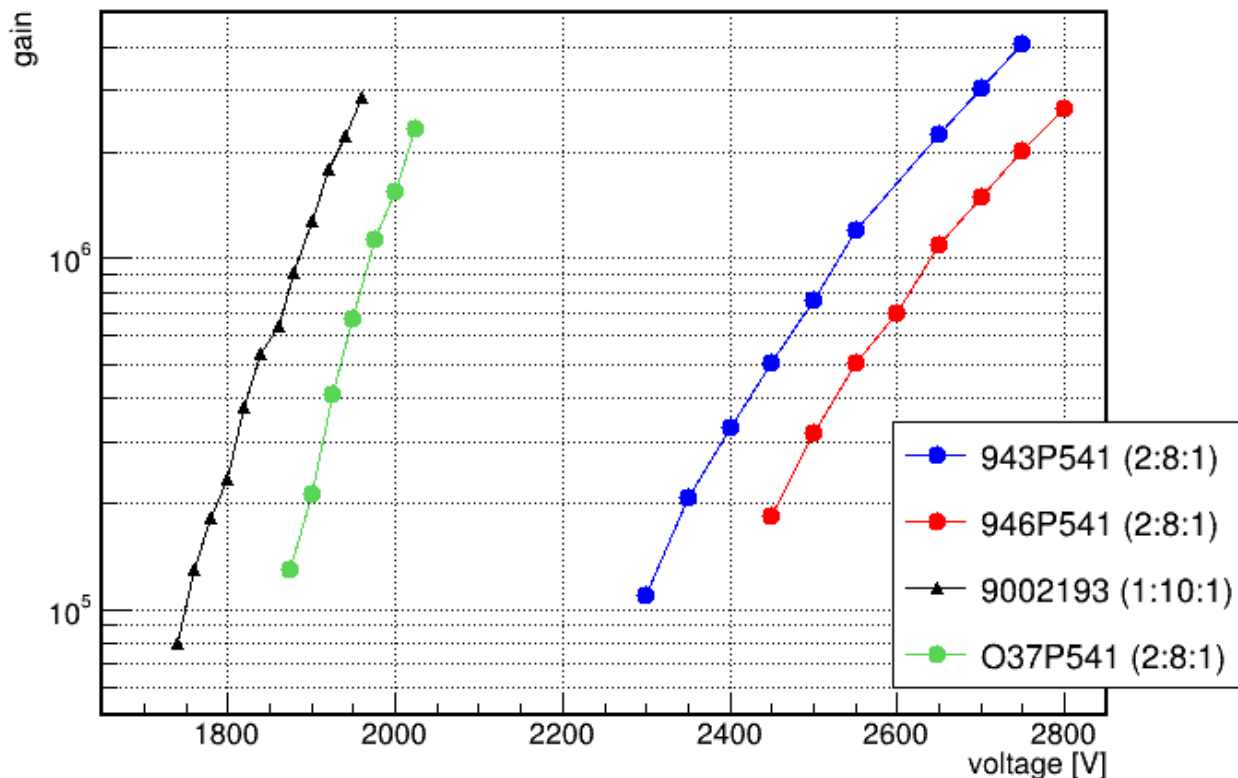
## Tubes:

- ES440 (2017)
  - 943P541 (January 2020)
  - 946P541 (January 2020)
  - O37P541 (December 2020)
  - One more will come
- } Planned to use in  
Endcap Disc Dirc

# Gain curve

- Measured with scope at central region

Gains



Tube	10 <sup>6</sup> gain at
943P541	2550 V
946P541	2650 V
O37P541	1975 V

943P541 and 946P541:

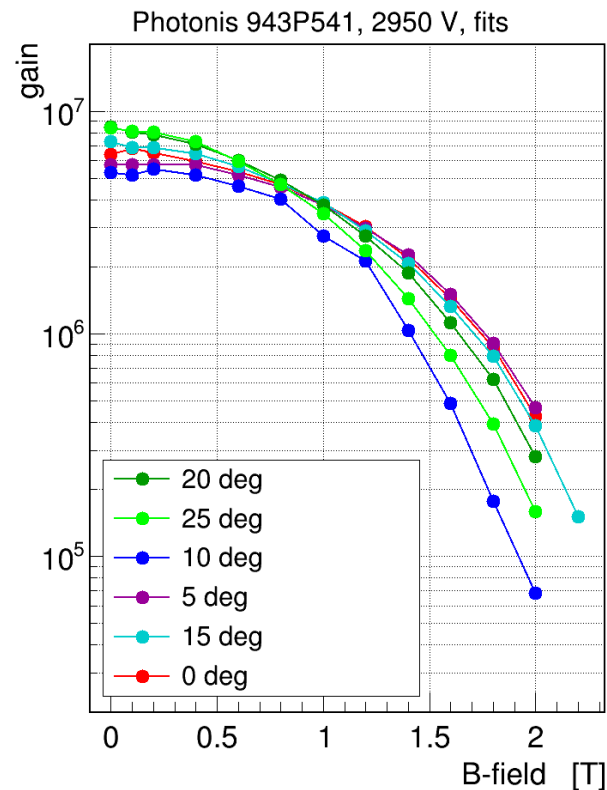
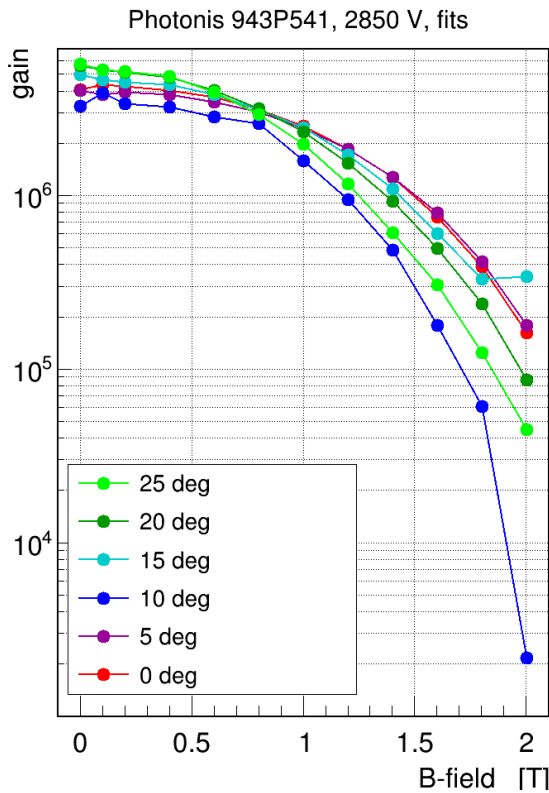
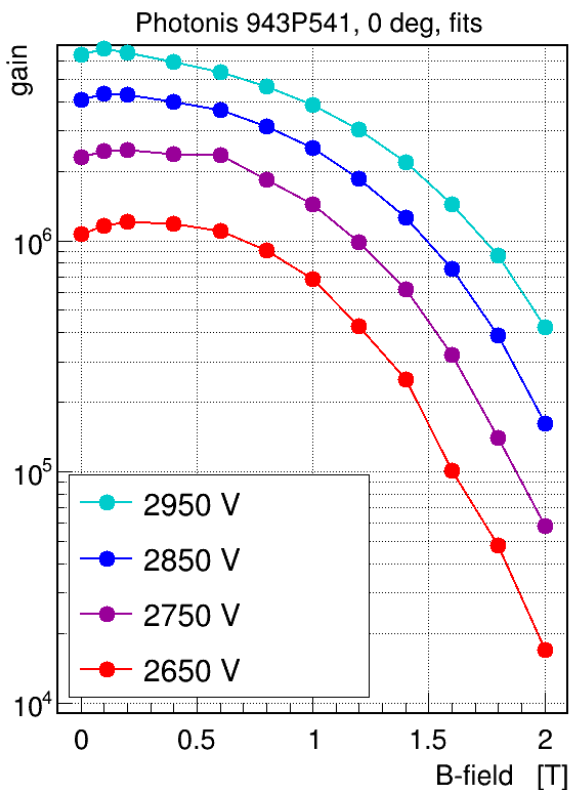
- Less steep
- Higher voltage than O37P541

O37P541

- Similar to 9002193 (8x8)

# Photonis 943P541

# Gain in B-field

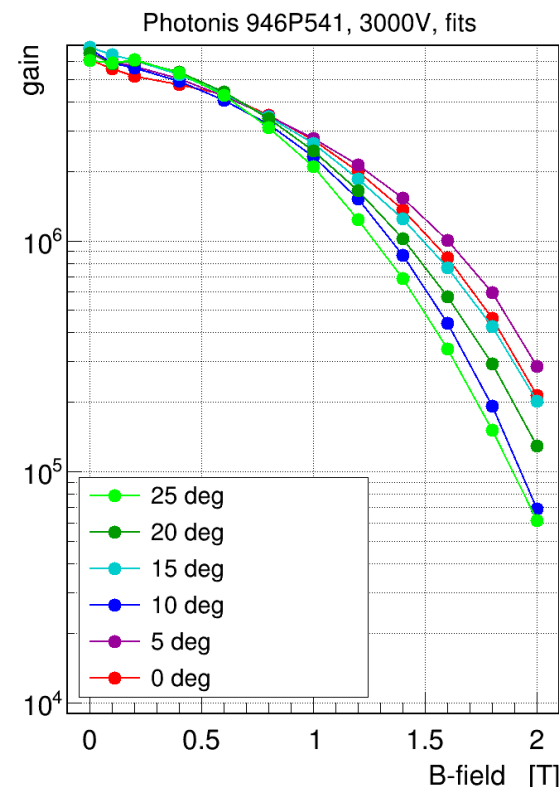
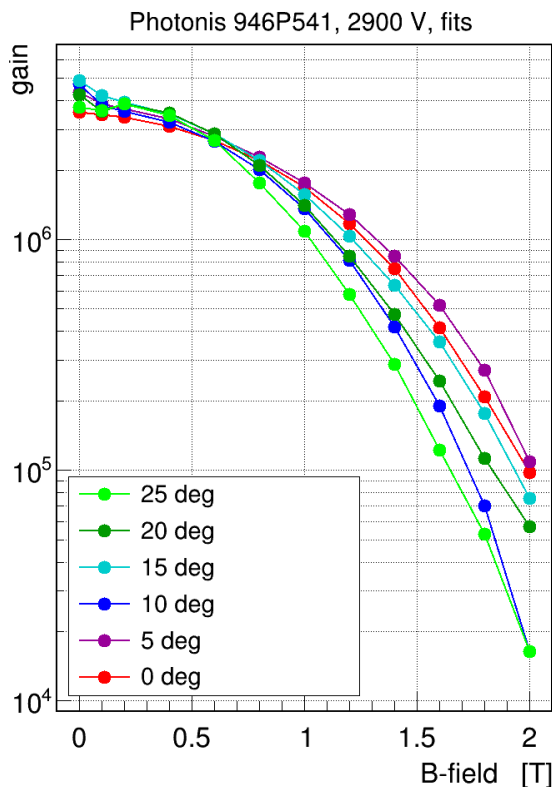
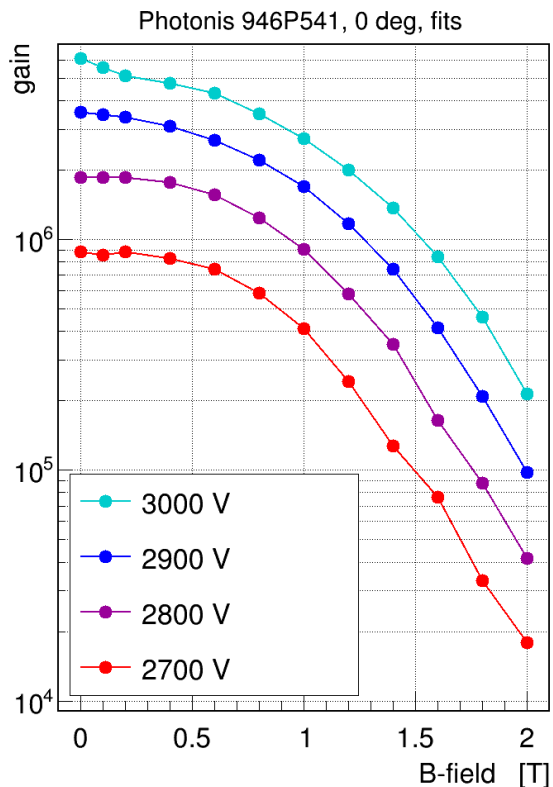


## Gain loss [1/x]:

Tube	0 - 1T, 0°	1 - 2T, 0°	1T, 0 - 20°	2T, 0 - 20°
943P541 (2950 V)	1.8	9.1	1.02	1.5

# Photonis 946P541

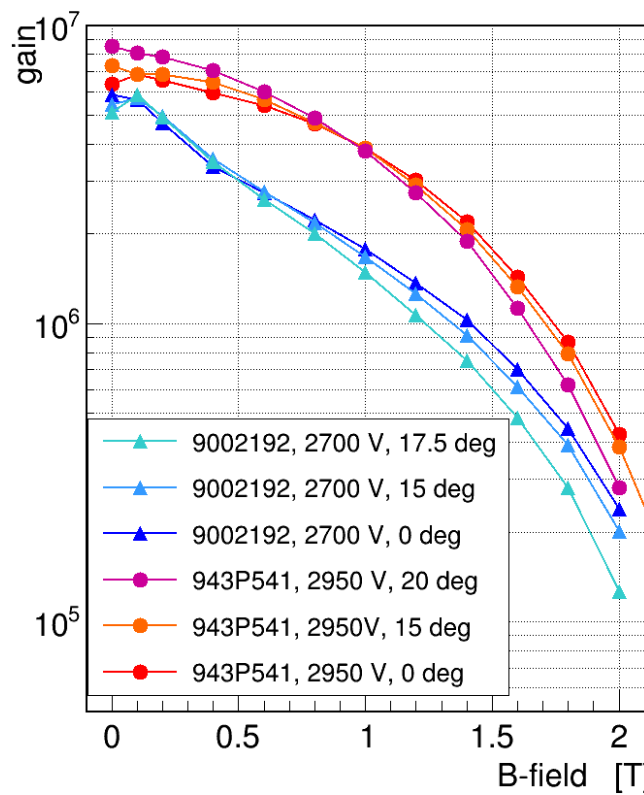
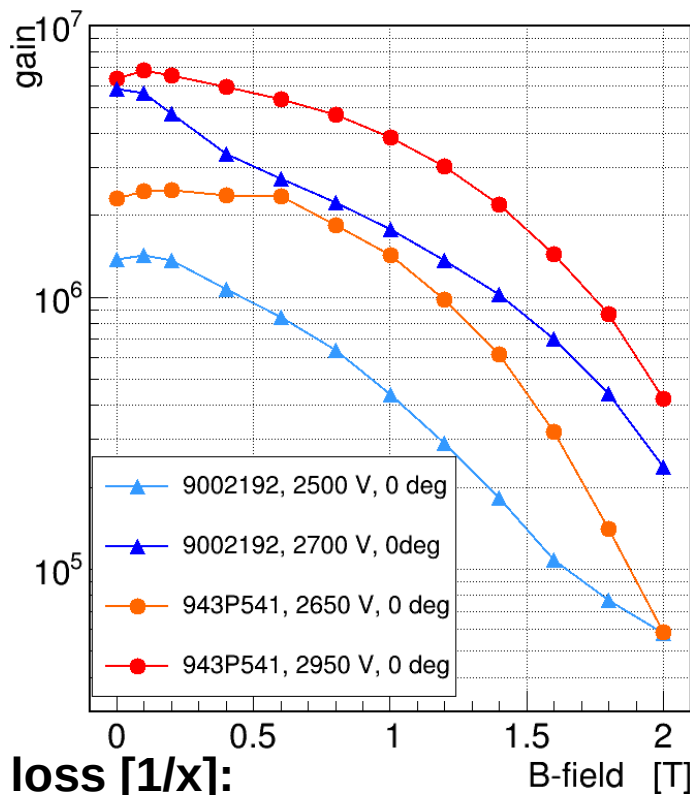
# Gain in B-field



## Gain loss [1/x]:

Tube	0 - 1T, 0°	1 - 2T, 0°	1T, 0 - 20°	2T, 0 - 20°
946P541 (3000V)	2.2	12.7	1.1	1.7

# Comparison with 9002192 (8x8)

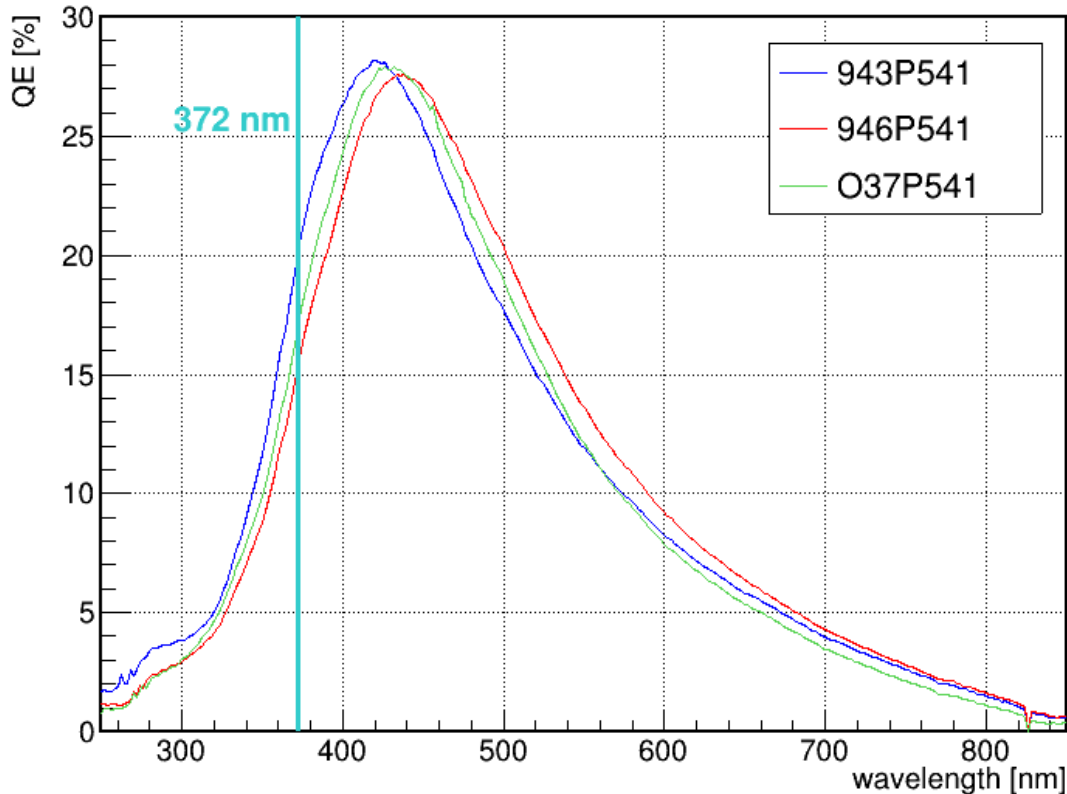


Gain loss [1/x]:

Tube	0 - 1T, 0°	1 - 2T, 0°	1T, 0 - 15°	2T, 0 - 15°
943P541 (2950 V)	1.8	9.1	1.0	1.1
9002192 (2700 V)	3.3	7.4	1.05	1.2

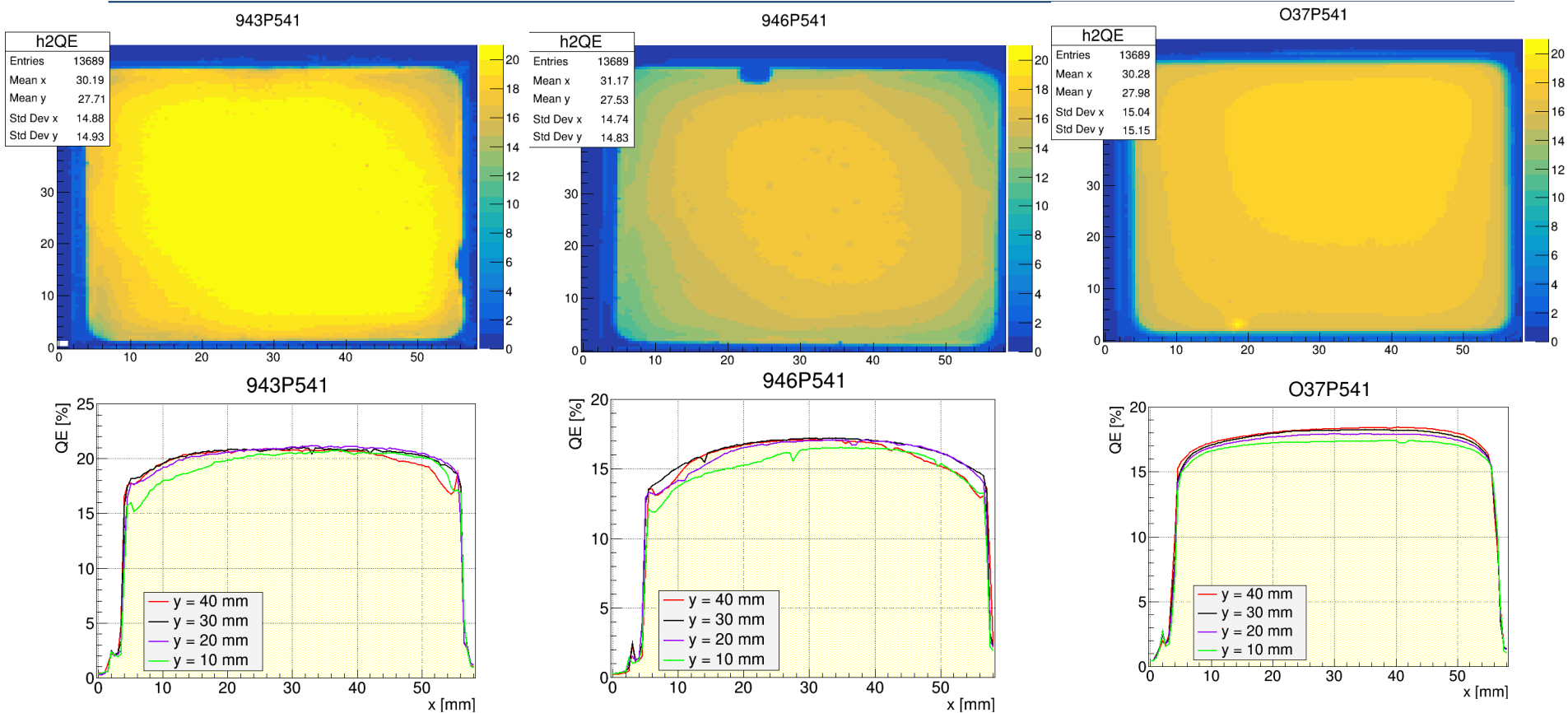
# Spectral QE

spectral QE



- Measured at position 57
- Peak at ~430 nm
- Peak QE ~28%

Tube	Peak QE	At $\lambda$
943P541	28.2 %	420 nm
946P541	27.6 %	438 nm
O37P541	27.9 %	426 nm



Tube	Max QE (at $\lambda = 372$ nm)	Peak QE
943P541	21%	28.2 % (420 nm)
946P541	17%	27.6 % (438 nm)
O37P541	18.5%	27.9 % (426 nm)

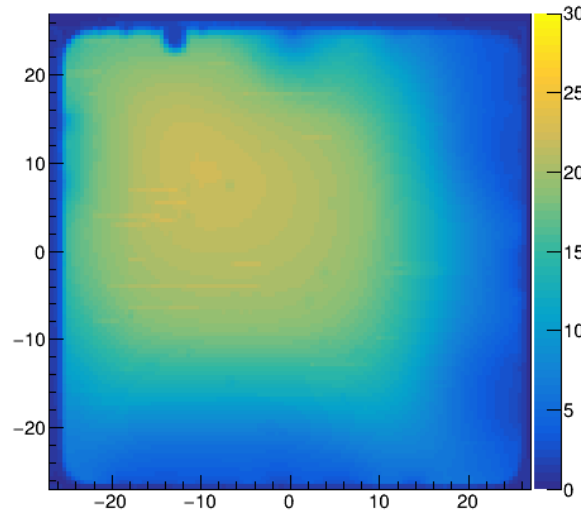
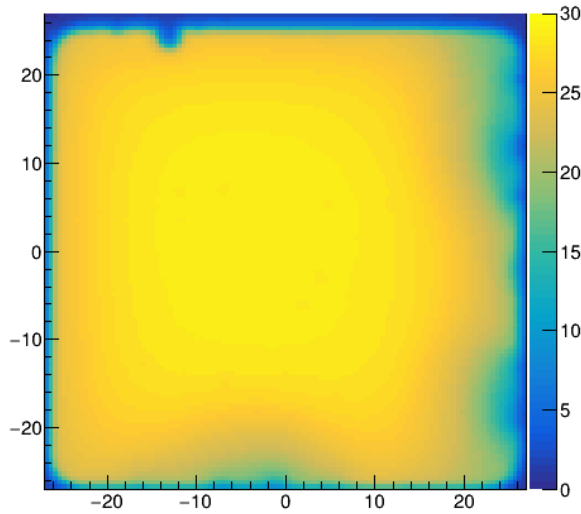


# Photonis ES440 (3x100)

# QE problem

June 2018

January 2021



No continuous illumination  
Uniform drop in QE

- no microleaks
- More investigation

Max QE	ES440
2018	29%
2021	22%

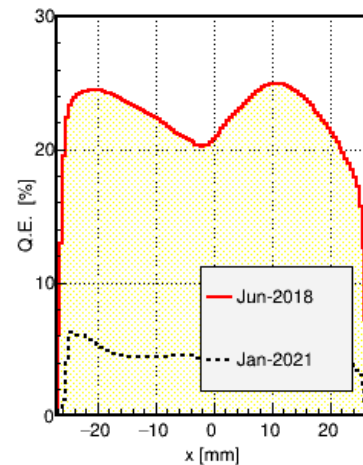
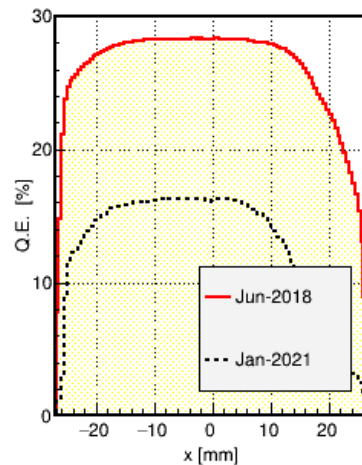
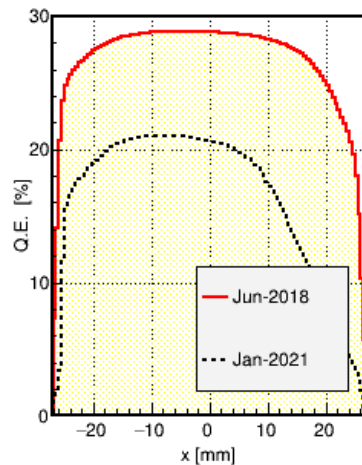
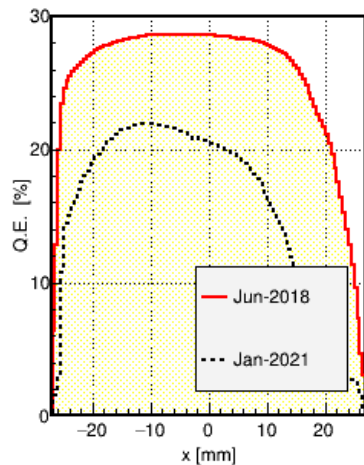
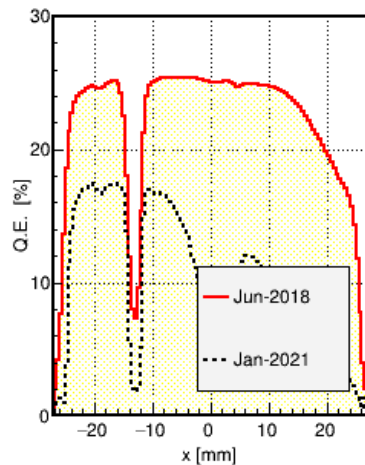
y = 24 mm

y = 12 mm

y = 0 mm

y = -12 mm

y = -24 mm



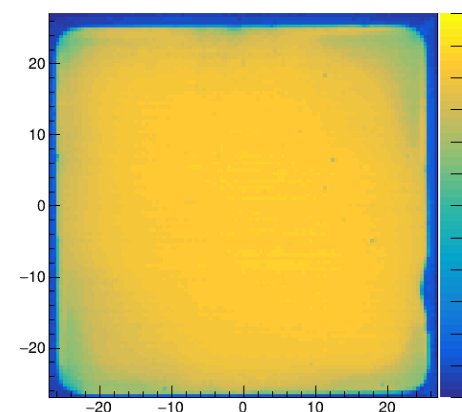
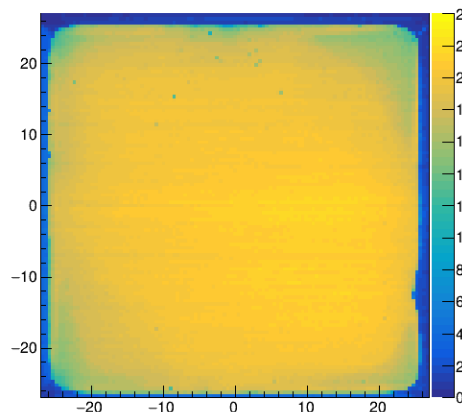
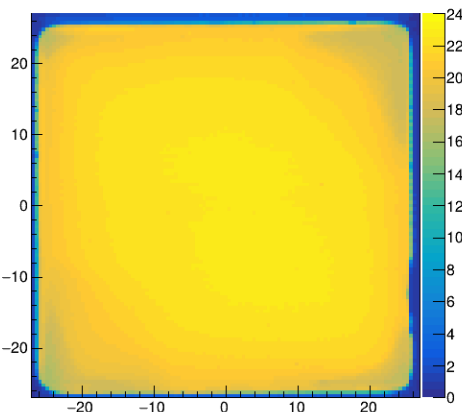
# Photonis 943P541

# QE problem?

QE 943P541 Jan 2020

QE 943P541 Dec 2020

QE 943P541 Feb 2021



<b>Max QE</b>	<b>943P541</b>
2020	22.5%
2021	21%

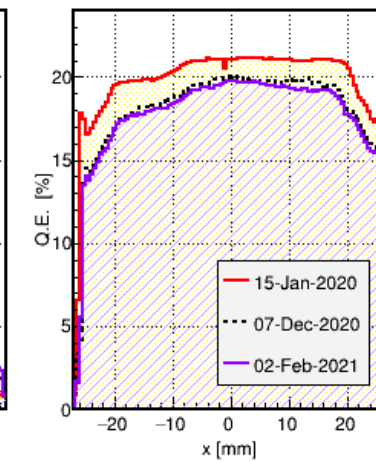
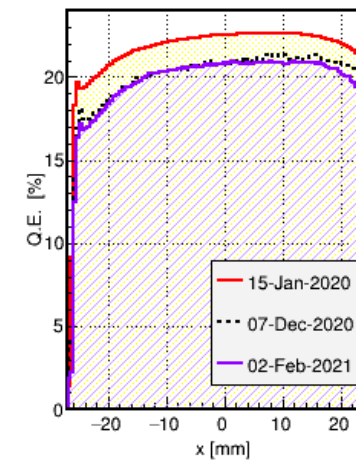
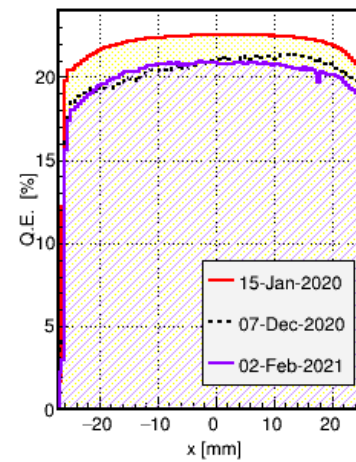
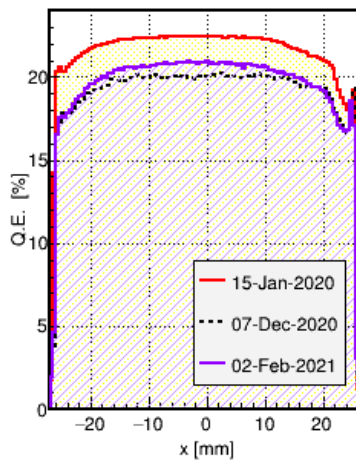
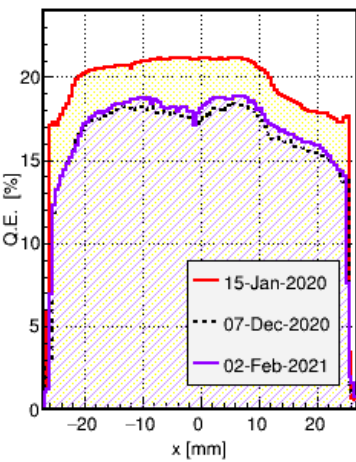
y = 23 mm

y = 12 mm

y = 0 mm

y = -12 mm

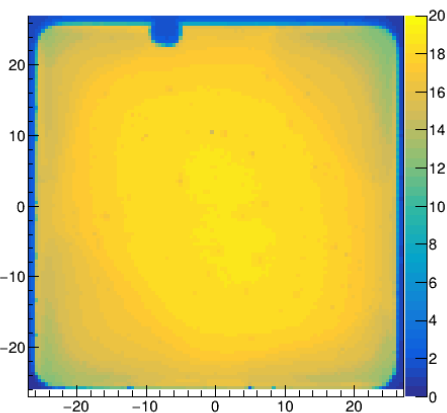
y = -23 mm



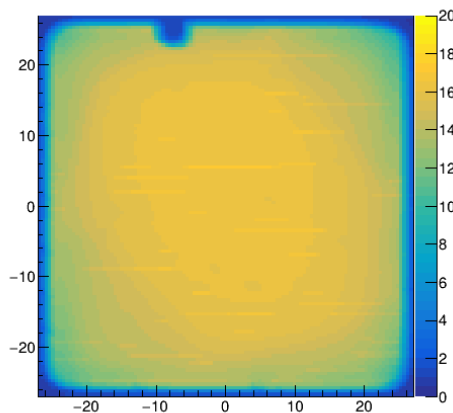
# Photonis 946P541

# QE problem?

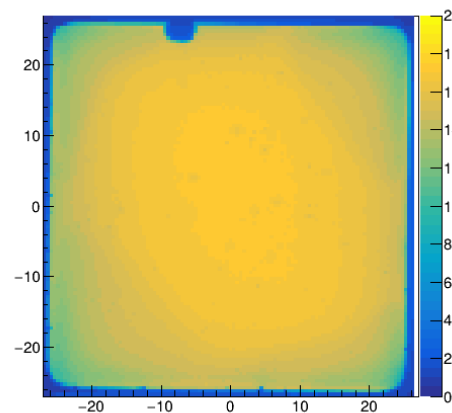
QE 946P541 Jan 2020



QE 946P541 Jan 2021

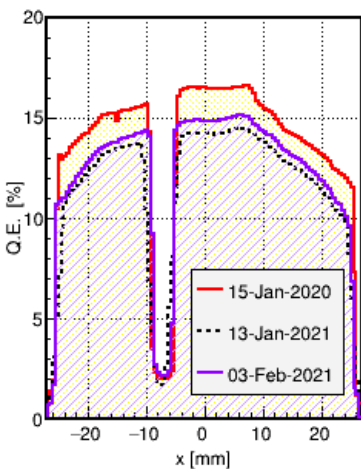


QE 946P541 Feb 2021

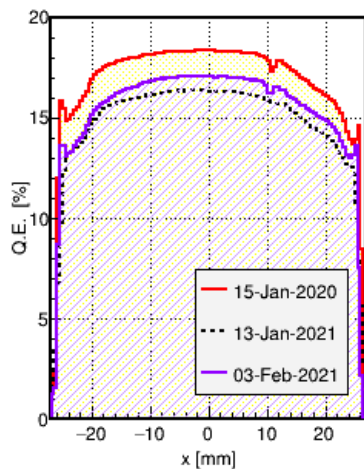


<b>Max QE</b>	<b>946P541</b>
<b>2020</b>	<b>18.5%</b>
<b>2021</b>	<b>17%</b>

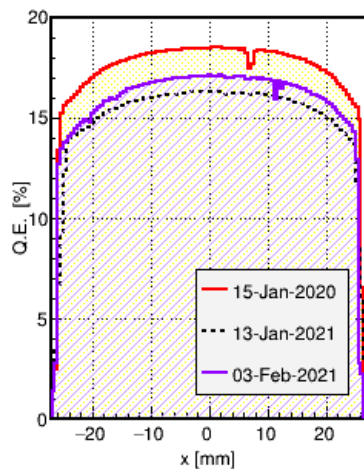
y = 24 mm



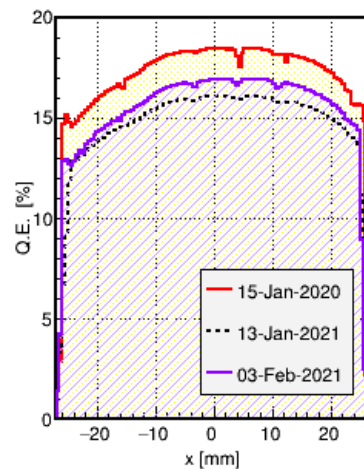
y = 12 mm



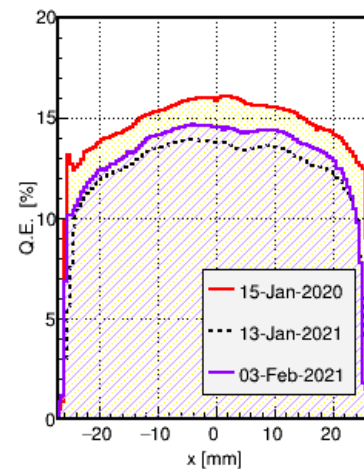
y = 0 mm



y = -12 mm



y = -24 mm

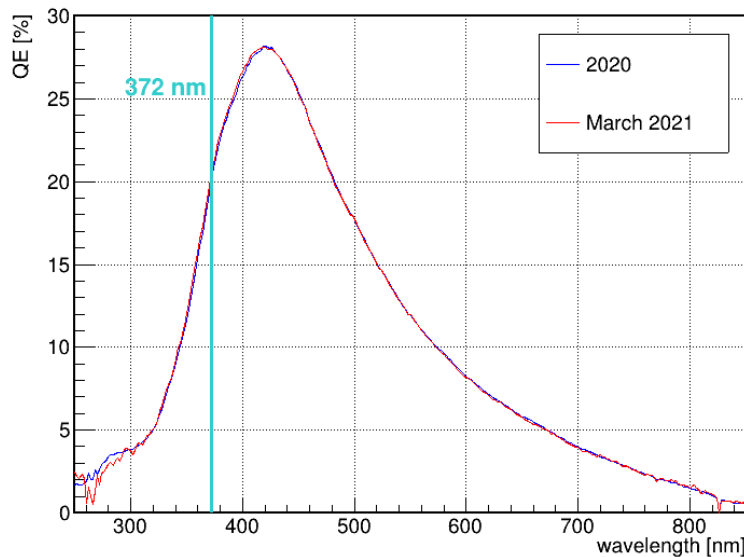


# QE problem?

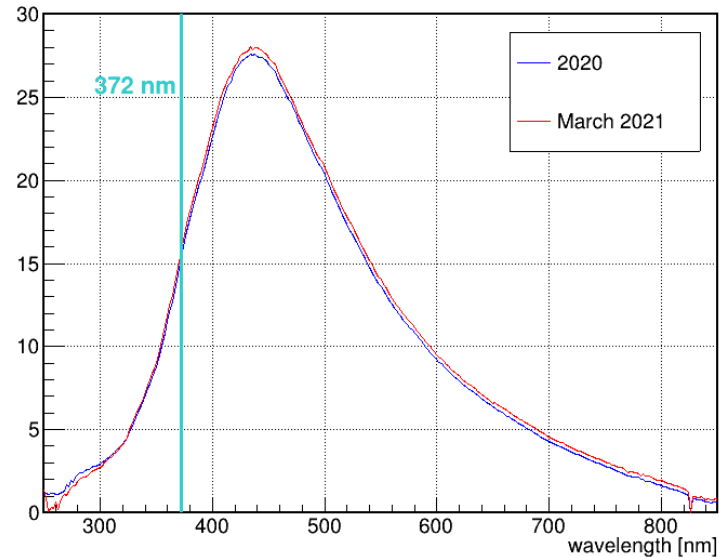
Max QE (Scan)	943P541	946P541
Jan 2020	22.5%	18.5%
Dec 2020/ Jan 2021	21.5%	16.5%
Feb 2021	21%	17%

- No difference between December/January and February
- No difference in spectral QE
  - Possibly problem of first scan
  - will be observed further
- ES440 at the moment in Gießen

spectral QE 943P541



spectral QE 946P541

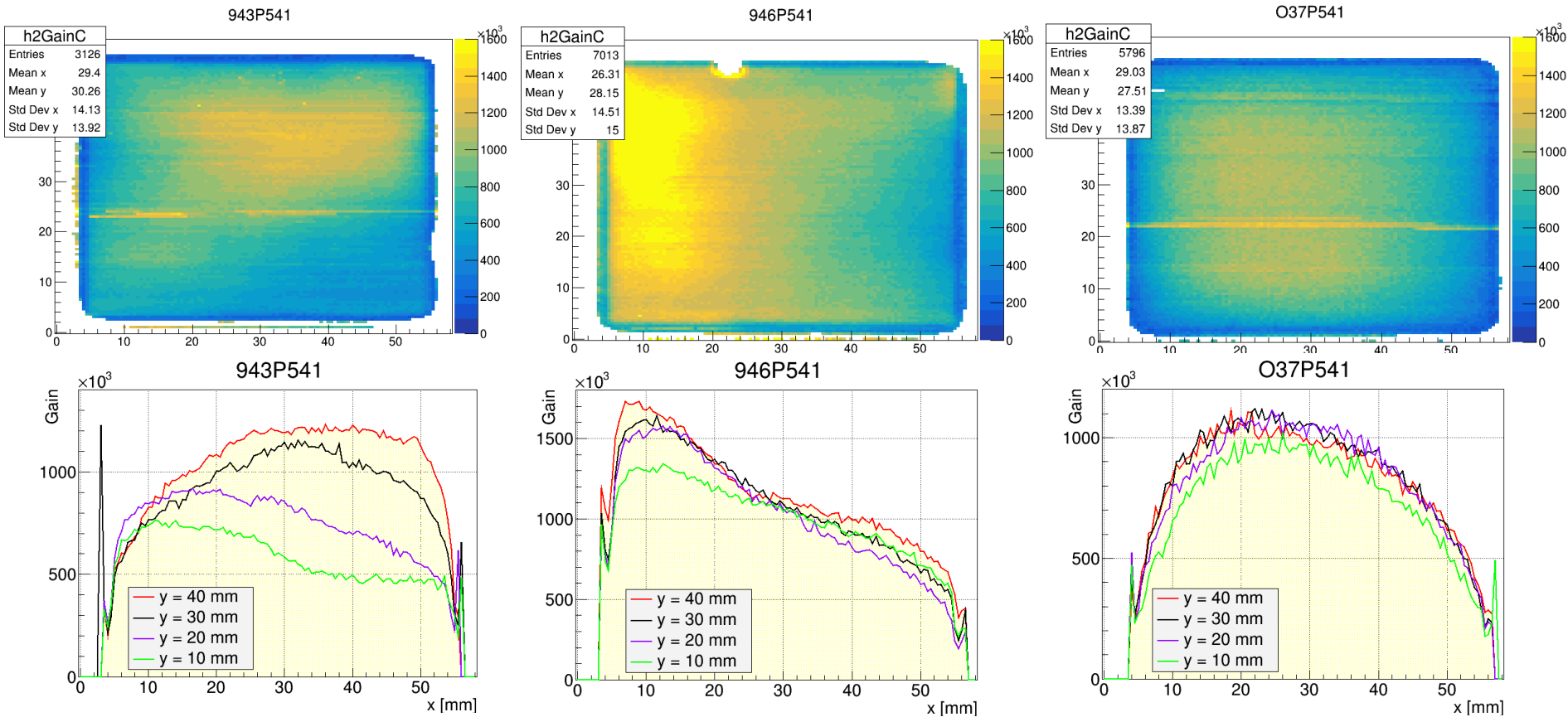


# Gain scans



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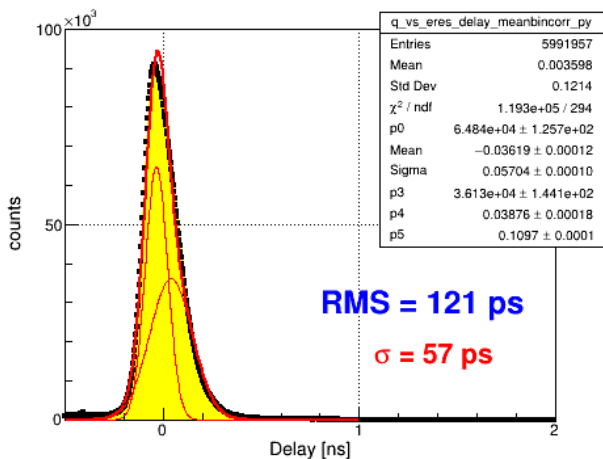
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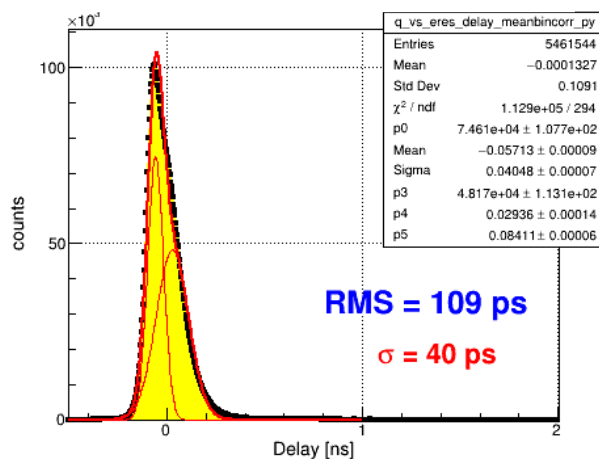
Tube	Max Gain	at
943P541	$1.4 \cdot 10^6$	2650 V
946P541	$1.6 \cdot 10^6$	2550 V
O37P541	$1.1 \cdot 10^6$	2000 V

# Time resolution

943P5410

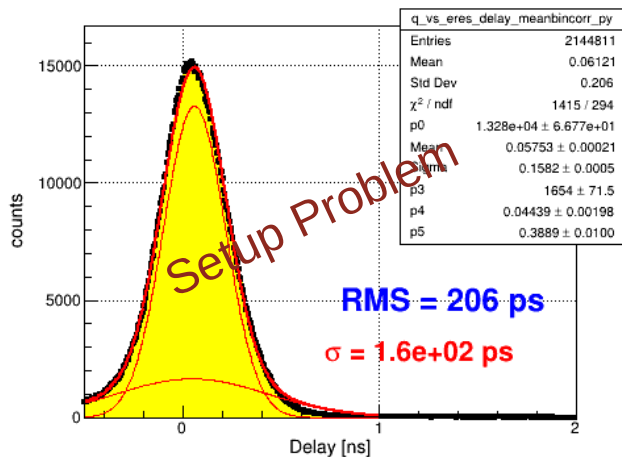


946P541



Tube	RMS in ps	$\sigma$ in ps
943P541	121	57
946P541	109	40
O37P541	206	160

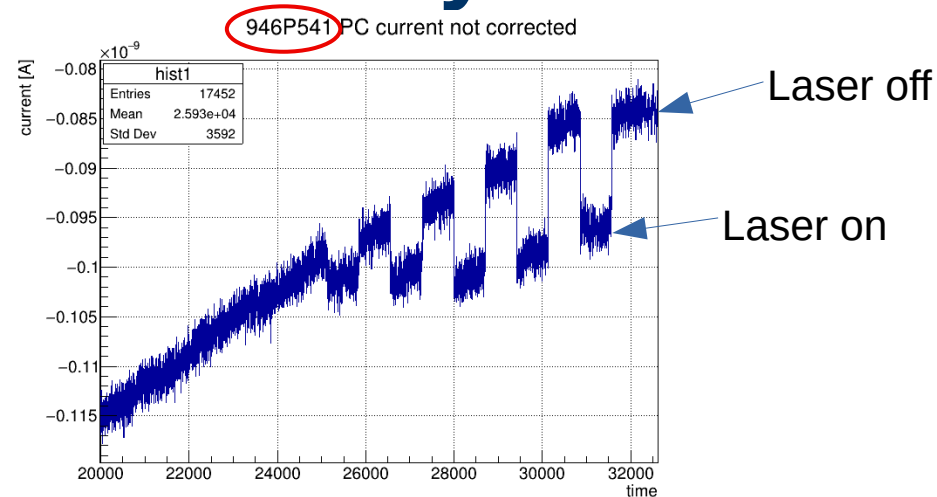
O37P541



- Measured at one central pixel
- Provisory setup:  
Not ideal for measuring one pixel with the scope
- O37P541: bad signals  
→ high value due to setup
- Soon boards for better measurements

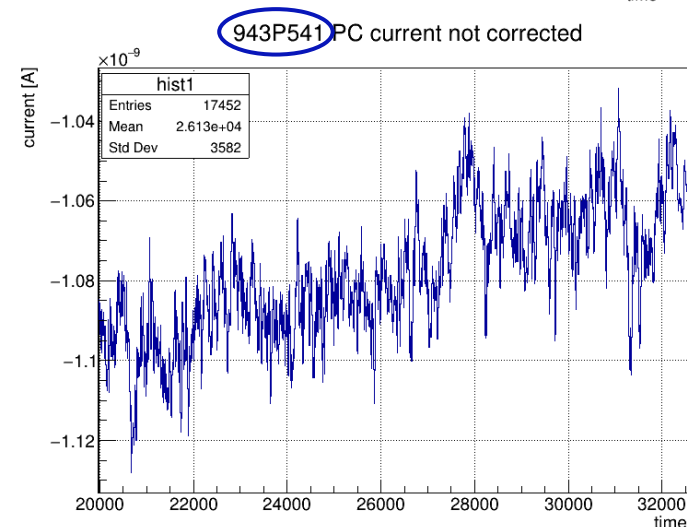
# Collection efficiency

Tube	CE
943P541	??
946P541	~95%
O37P541	~100%



## 943P541:

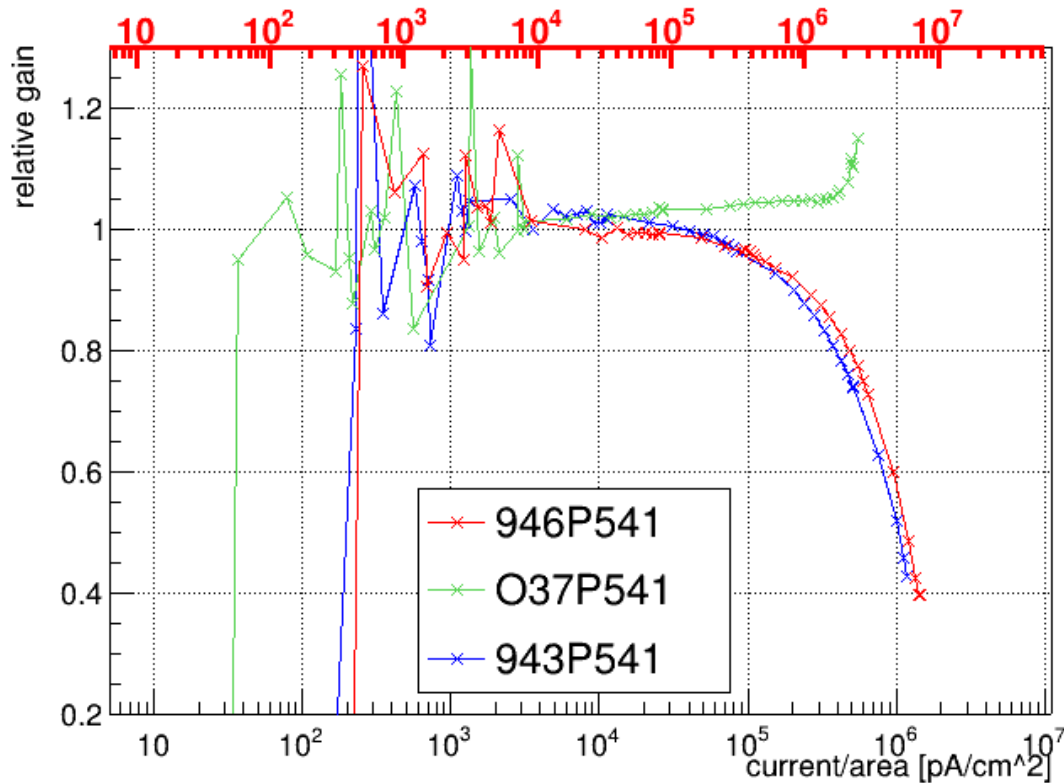
- High dark current
  - factor 10 higher than 946P541
  - consistent with QE measurement
- High fluctuations of dark current
  - CE not measurable



# Rate capability whole tube, current measurement

Relative GAIN (averaged & corrected)

photons / cm<sup>2</sup> s (at gain = 10<sup>6</sup>)



- 943P541 and 946P541:  
90% relative gain at 10<sup>6</sup> Hz/cm<sup>2</sup>
- O37P541:  
strange effect:  
high anode currents at certain  
photon rate (~200 μA)  
→ Increase of relative gain
- Will be measured with pulse  
mode soon



## Summary

Tube	$10^6$ gain at	Peak QE	Max QE (@372 nm)	Peak Gain	RMS	CE
943P541	2550 V	28.2% (@420 nm)	21%	$1.4 \cdot 10^6$ (@2650 V)	121 ps	??
946P541	2650 V	27.6% (@438 nm)	17%	$1.6 \cdot 10^6$ (@2550 V)	109 ps	~95%
O37P541	1975 V	27.9% (@426 nm)	18.5%	$1.1 \cdot 10^6$ (@2000 V)	206 ps	~100%

### O37P541:

- $10^6$  gain at low voltage, different slope
- High anode currents at high illumination rates

### 943P541 and 946P541

- Lower gain loss in magnetic field (than Photonis 9002192)
- Possible problem with QE