Lifetime-Issues of MCP-PMTs

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supported by BMBF and GSI

- Motivation and PANDA Overview
- Characterisation of **Photonis XP 85112 – 9000897**:
  - Dark count rate and time resolution
  - Surface scan and Crosstalk
  - Magnetic field
  - Rate stability
- Lifetime under PANDA conditions
  - PANDAROOT simulation
  - Setup of lifetime measurement and procedure
  - Results of Lifetime measurement of XP 85112:
    - Gain
    - Quantum efficiency and QE-Scans
  - Comparison with other MCP-PMT models
- Summary and Outlook

Detector Overview

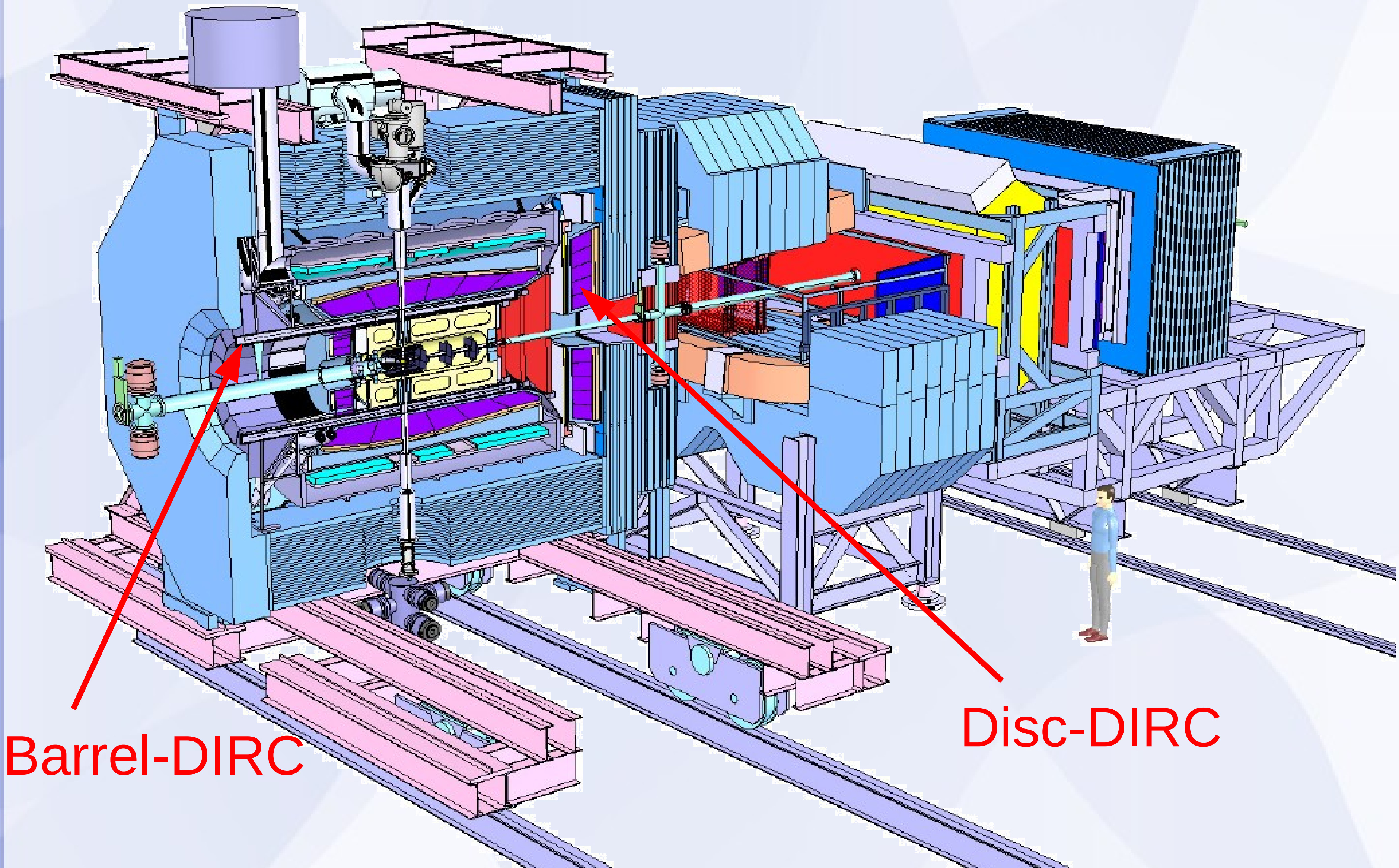


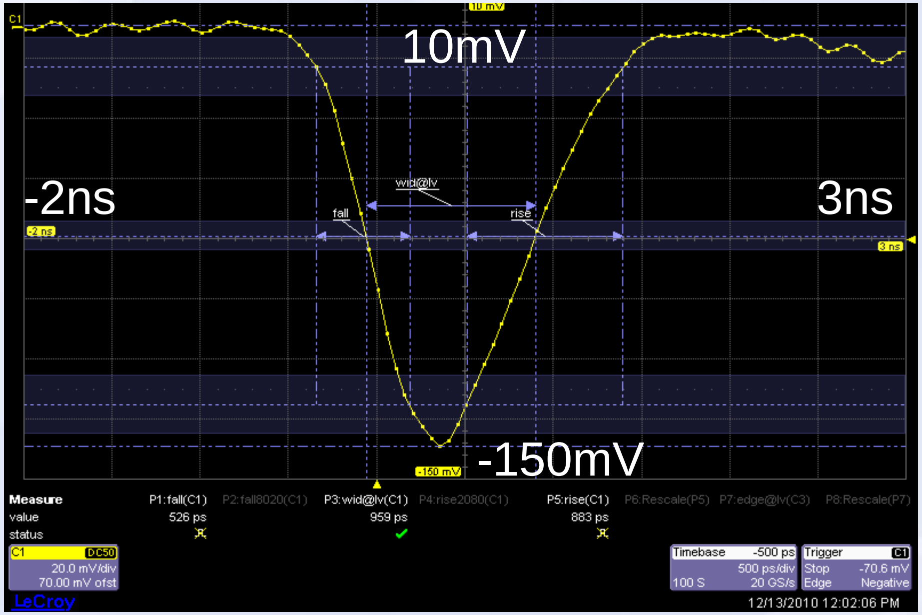
Photo detector requirements

Separation of K and π up to several GeV/c requires:

- B-Field resistance up to 2T (Disc-DIRC)
- Gain > $5*10^5$ for single photon detection
- Good time resolution: $\sigma < 100$ ps
- Good spatial resolution and geometrical efficiency
- High photon rates (~200kHz/cm² (Barrel-DIRC), up to several MHz/cm² (Disc-DIRC))

Characterisation of XP 85112 - 9000897

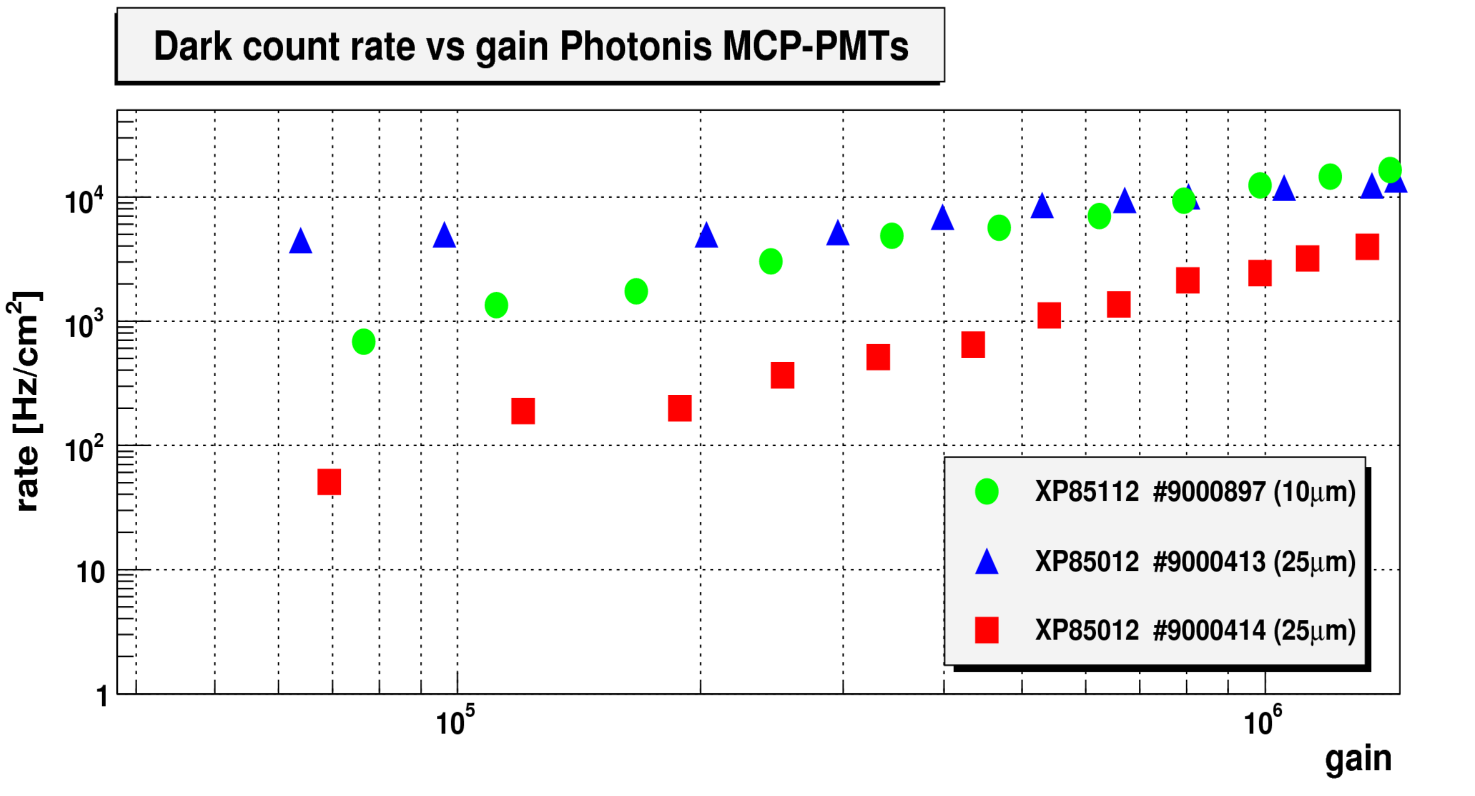
Overview of XP 85112 - 9000897



	Mean (ps)	RMS (ps)
Fall time (90%-10%)	541	90
Width at (50%)	903	110
Rise time (10%-90%)	844	160

pore size (µm)	10
number of pixels	8x8
pixelsize (mm²)	5.9 x 5.9
active area (mm²)	53 x 53
total area (mm²)	59 x 59
geom. efficiency	80%
comments	improved vacuum

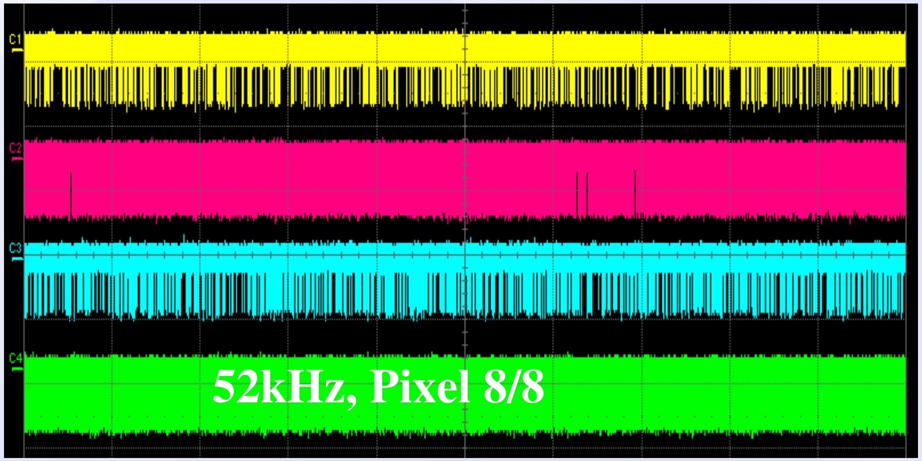
Darkcount of Photonis MCP-PMTs

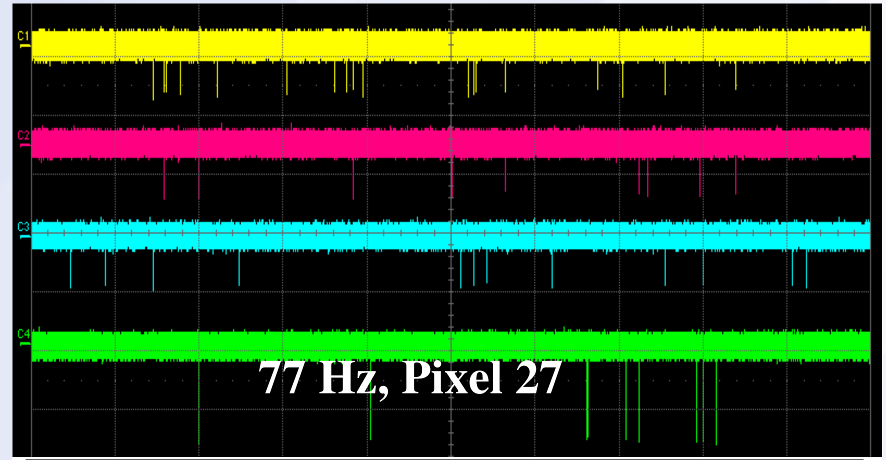


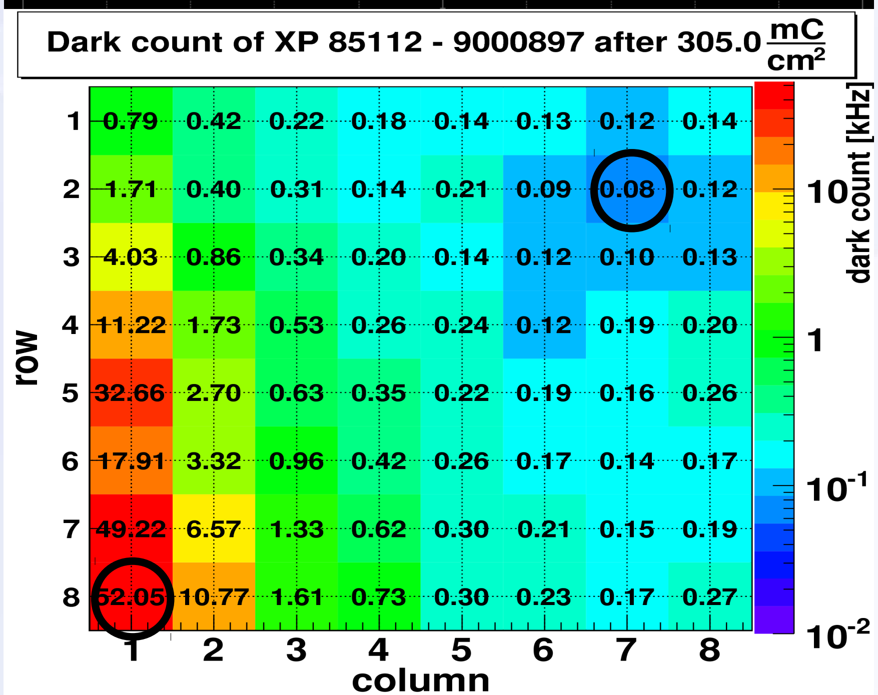
- Darkcount rate (gain 10^6; thresh. 50 mV; ampl. x200)
- Similar slope for both XP85012 models and XP85112

Darkcount (2)

305 mC/cm²

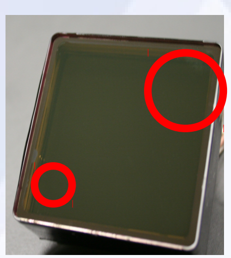






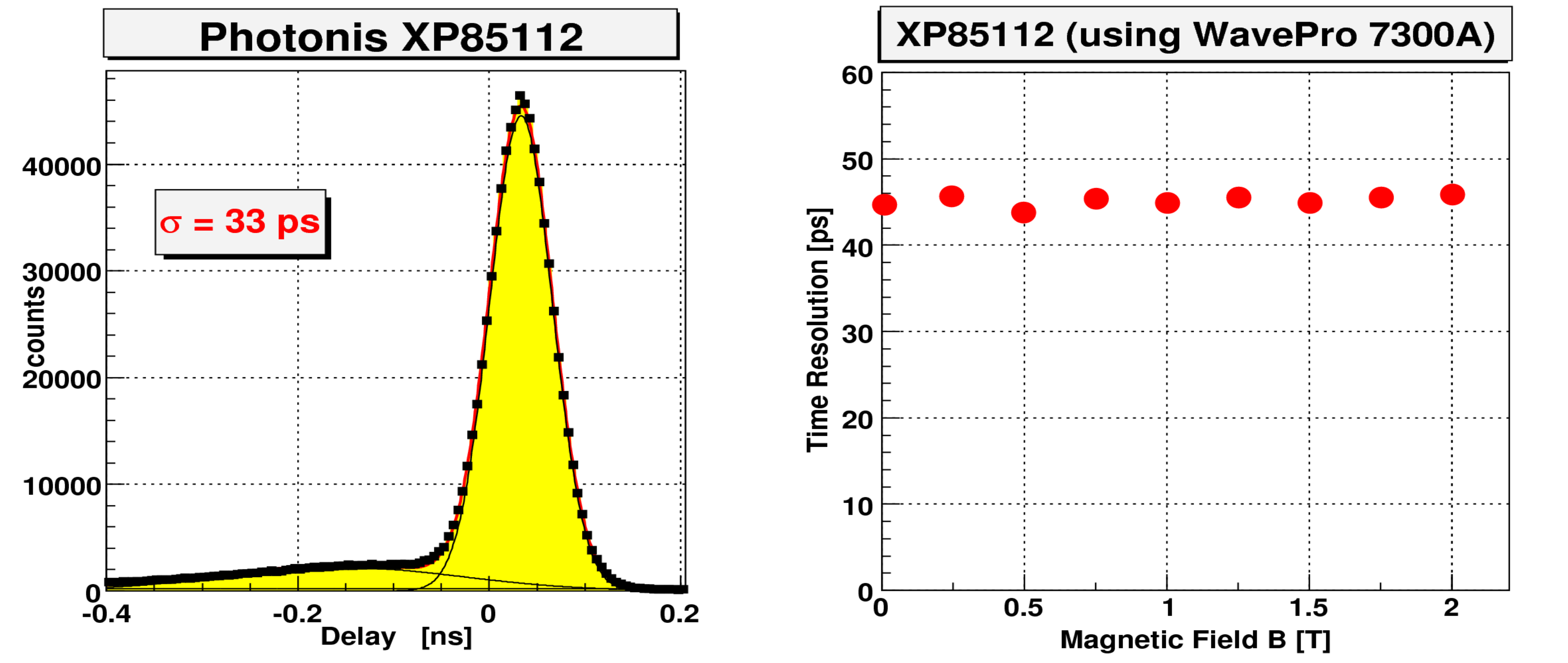
Dark count rate of lower left corner (especially Pixel 81, 71) were tremendously high.

At the beginning: ~1MHz



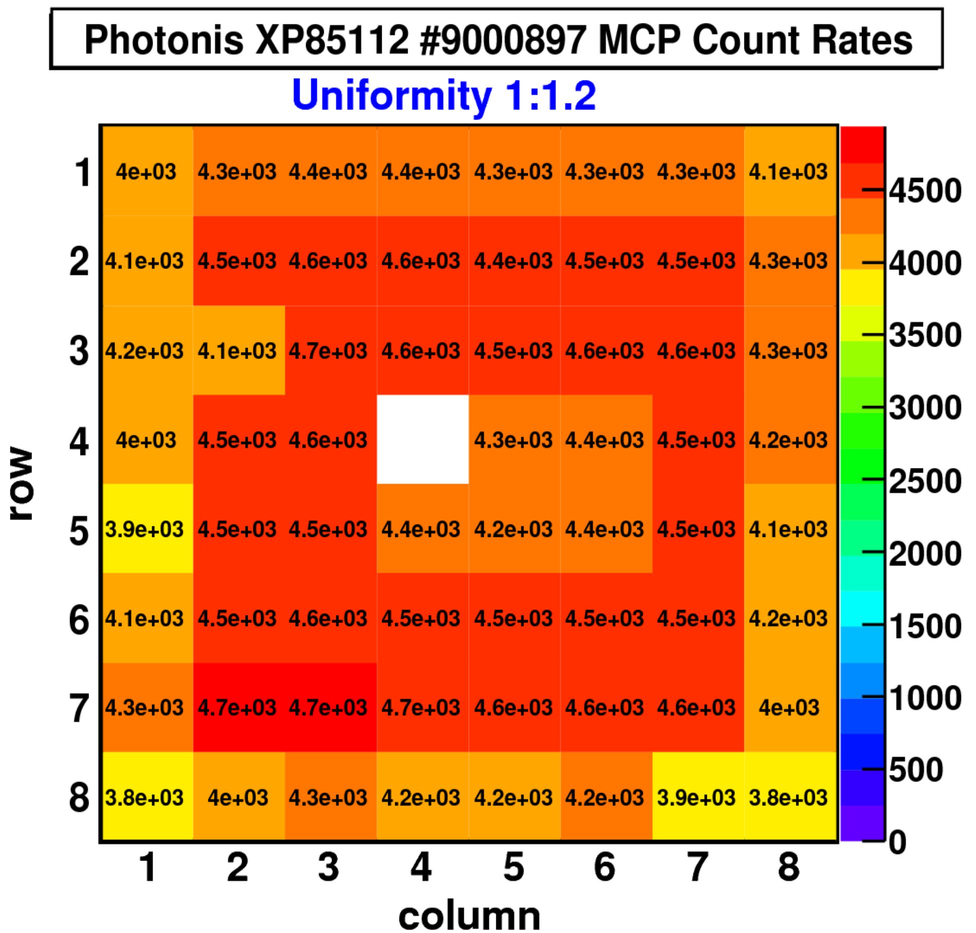
XP85112 Single Photon Time Resolution

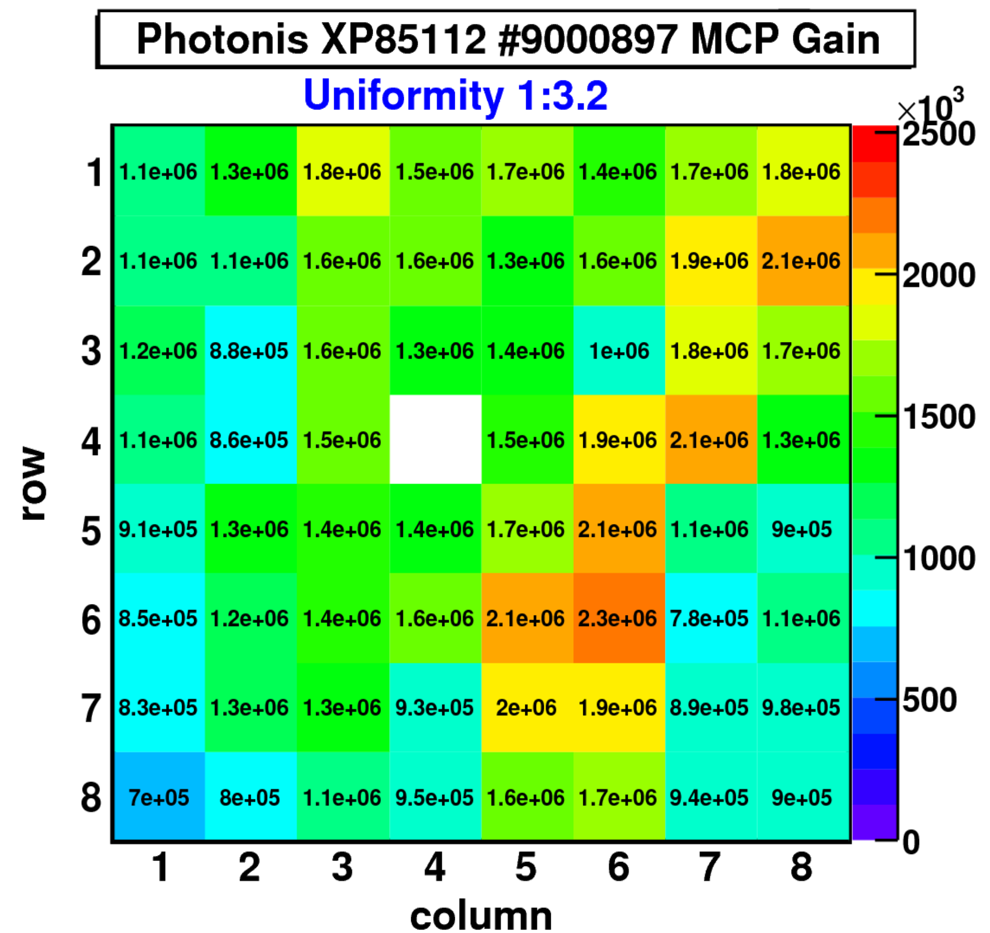
Amplifier Ortec FTA820 (x200; 350 MHz) --- Discriminator Philips Scientific 705



- time resolution < 35 ps
- **no dependence on the B-field**

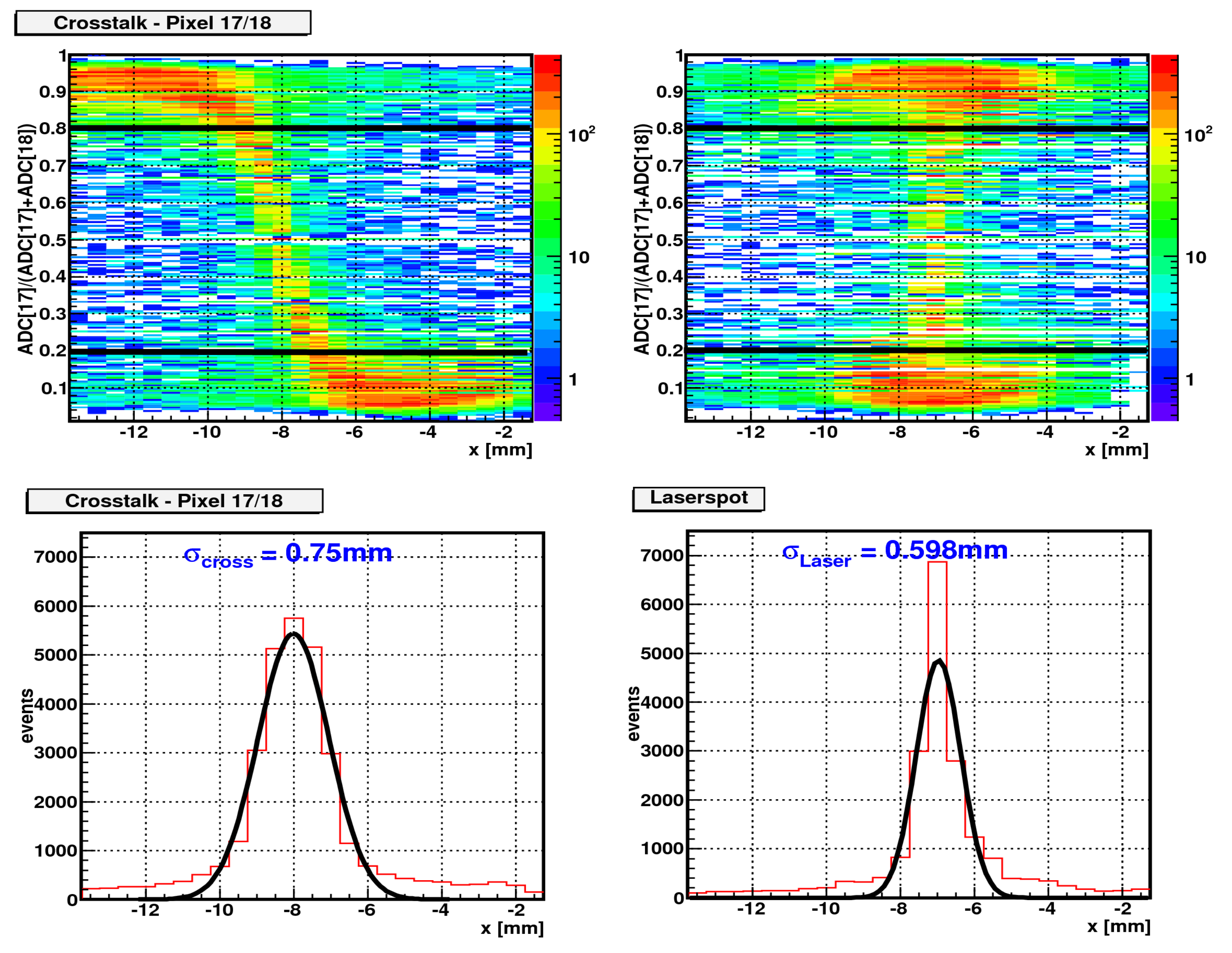
Surface Scan





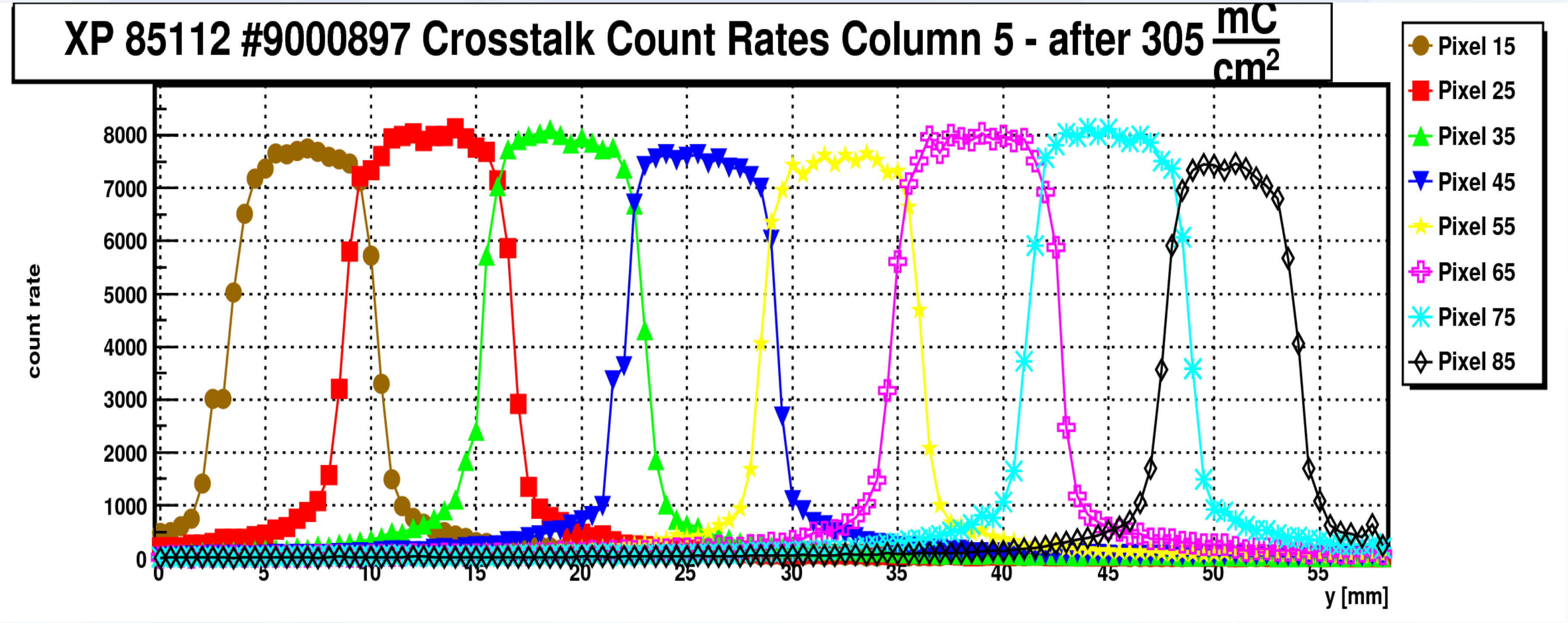
'Bad corner' has a low gain and count rates. Uniformity is better if they are negelcted (Gain: 1:2.94). Voltage: 2.9kV

Crosstalk



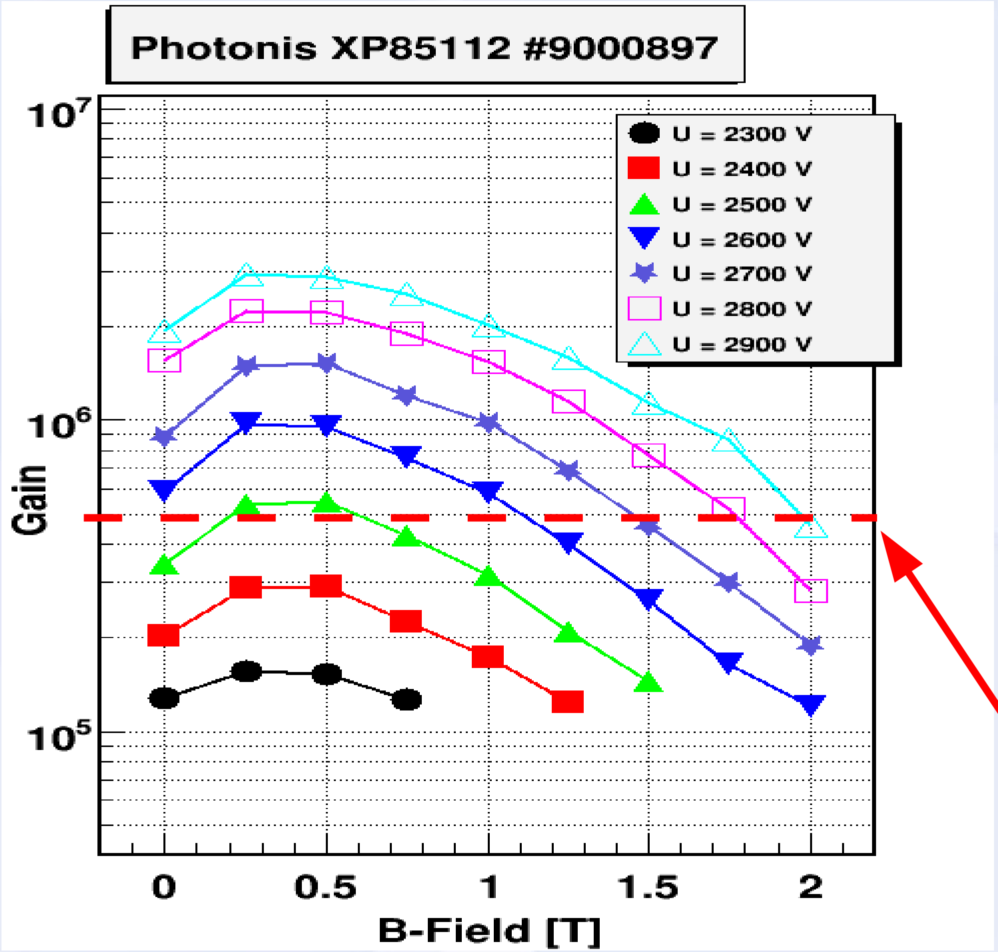
Crosstalk - Pixel 17/18
ADC[17]/(ADC[17]+ADC[18])
x [mm]
Crosstalk - Pixel 17/18
σ_{cross} = 0.75mm
events
x [mm]
Laserspot
σ_{Laser} = 0.598mm
events
x [mm]

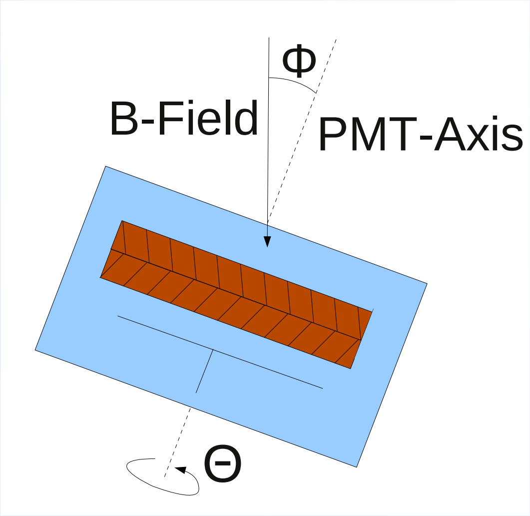
Crosstalk (2)



- Overlap of pixels is mostly dominated by charge sharing and crosstalk
- Crosstalk improved considerably in comparison to the beginning

B-Field measurements



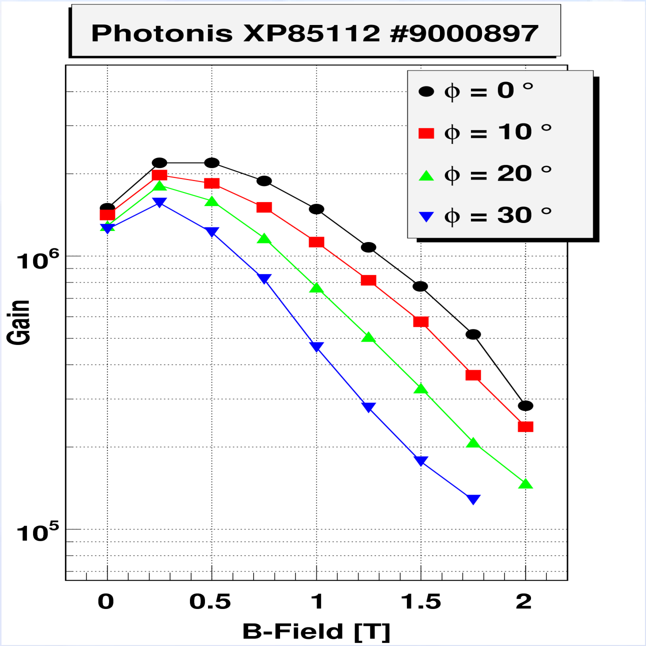


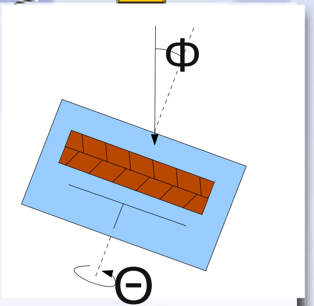
φ = tilt angle between B-field direction and PMT-axis

θ = rotation angle of PMT around B-field direction

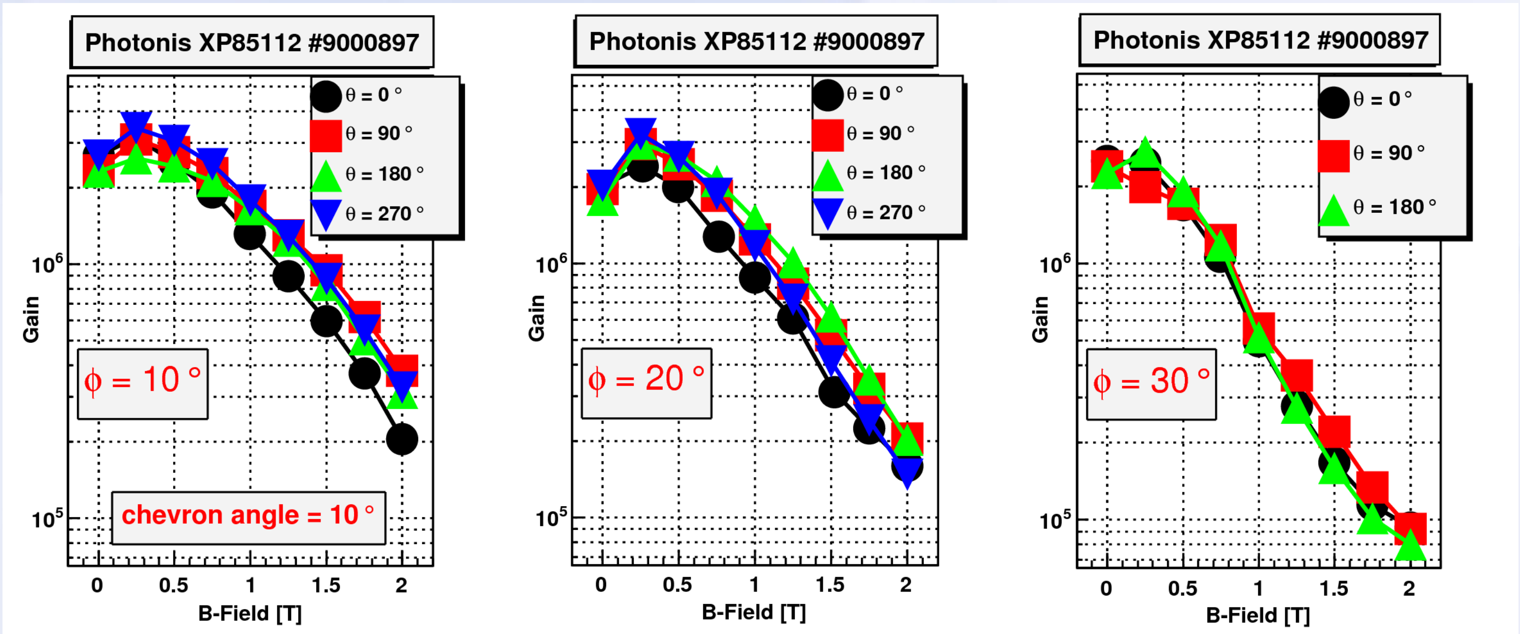
XP 85112 usable up to 2T!

Gain and Direction of B-Field (Φ)

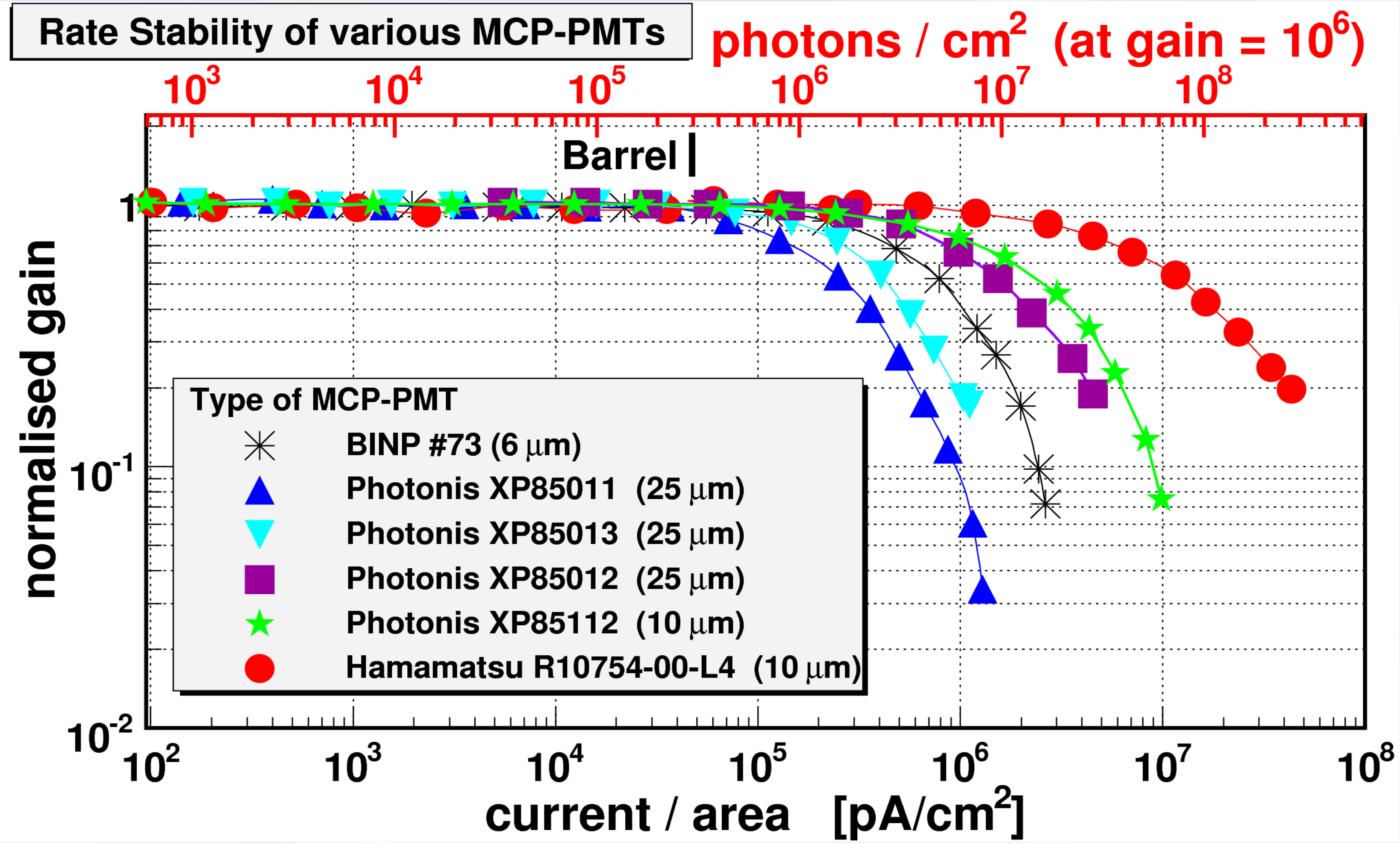




- Gain drops faster with increasing ϕ angle
- Gain slope of XP85112 does not seem to depend on rotation of angle Θ, in contrast to other MCP-PMTs



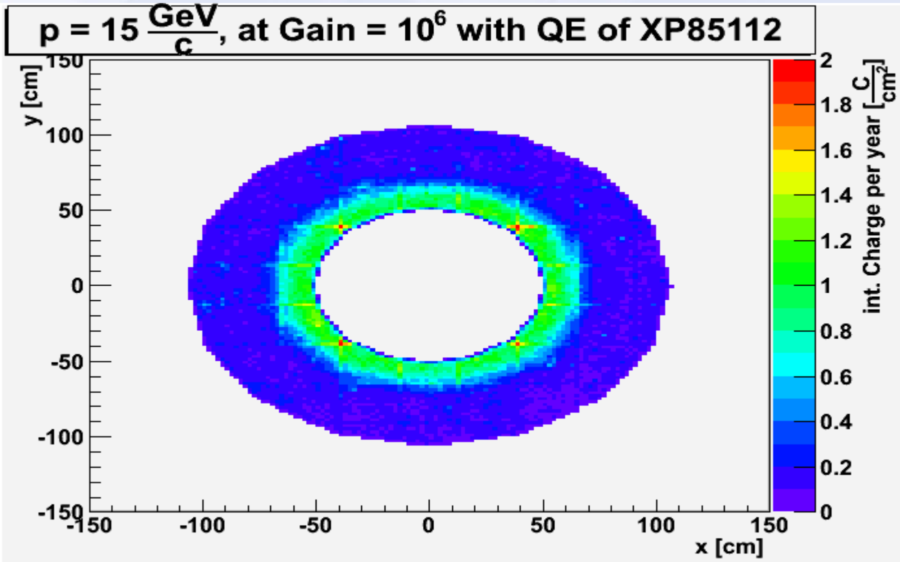
Rate stability

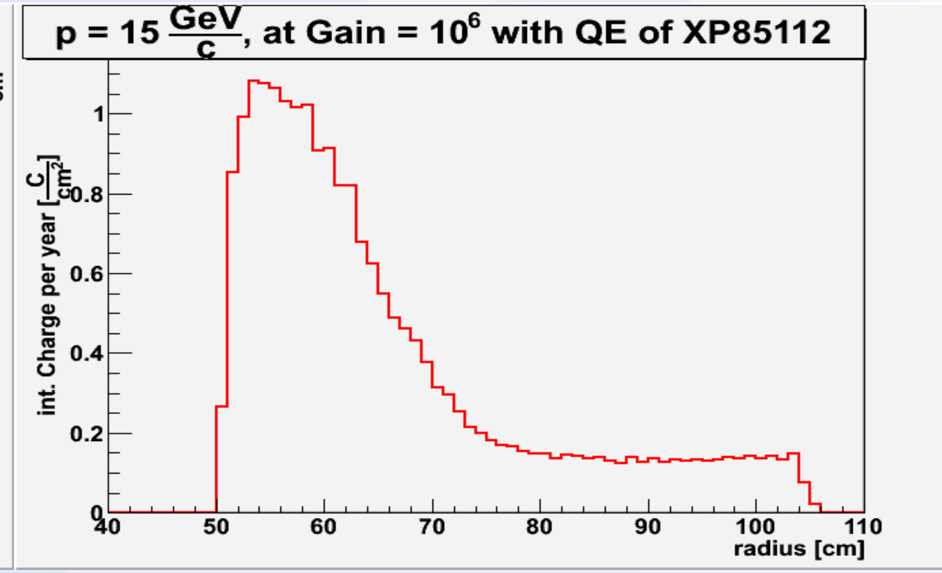


Rate stability is sufficient

Lifetime

Results of PANDAROOT simulation





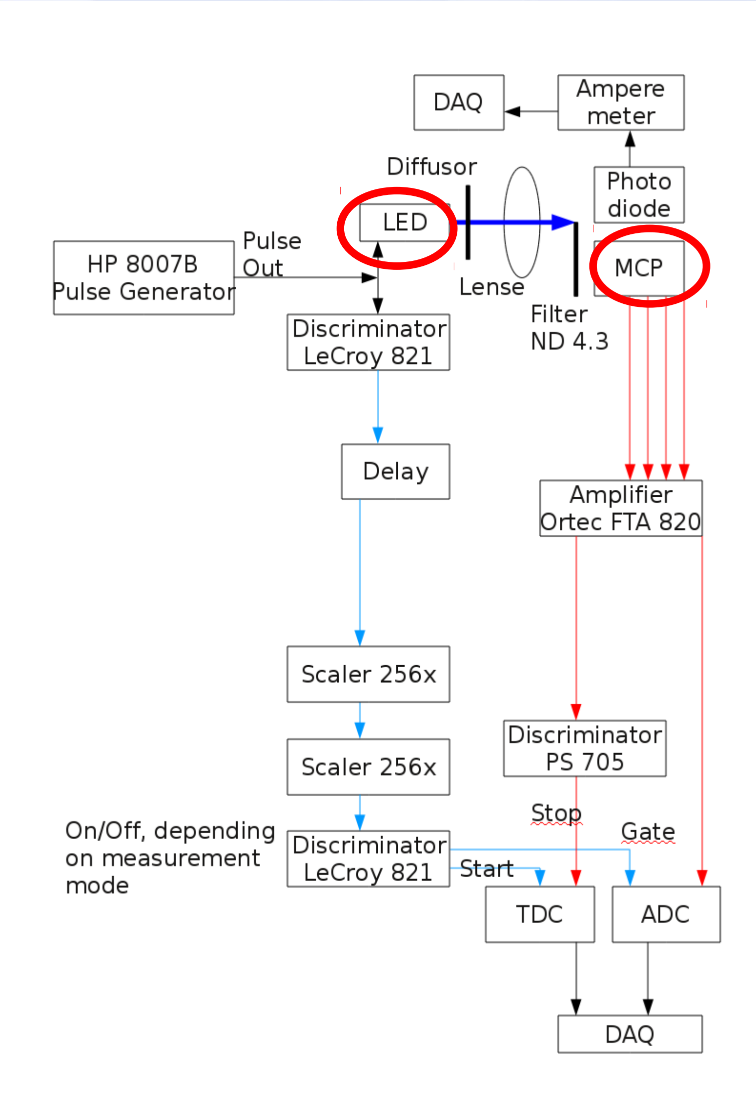
Assumptions:

- PANDA high luminosity mode: $2*10^{32}\,cm^{-2}s^{-1}$
  $\rightarrow$ p-pbar reaction rate: 20MHz
- QE of XP85112
- **1 year of 100% duty cycle!**

results:

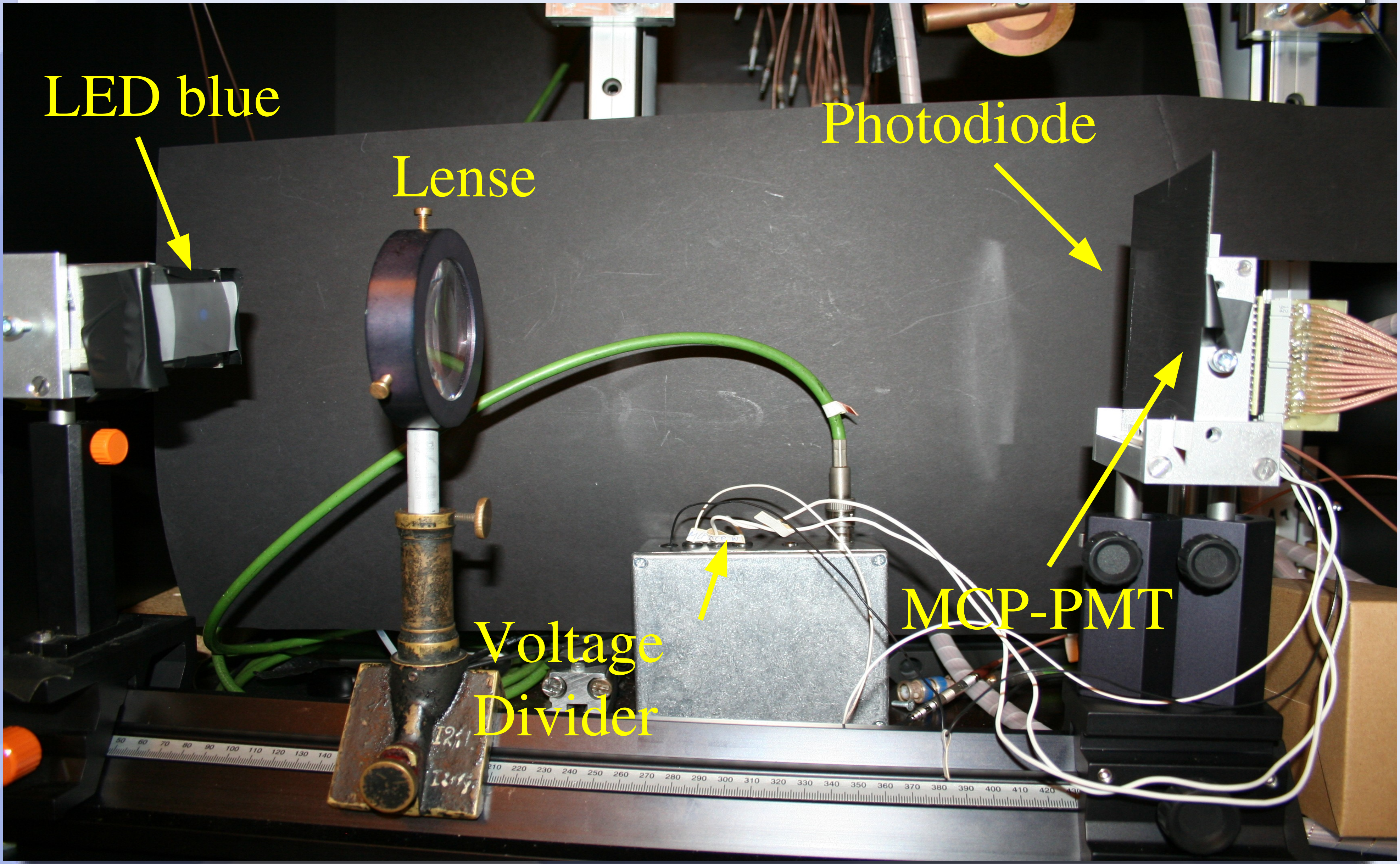
- **Int. Charge is radial dependent**
- $1\,\frac{\mathbf{C}}{\mathbf{cm}^2 * \mathbf{a}}$ at focal plane (~+10% for 5 GeV/c)

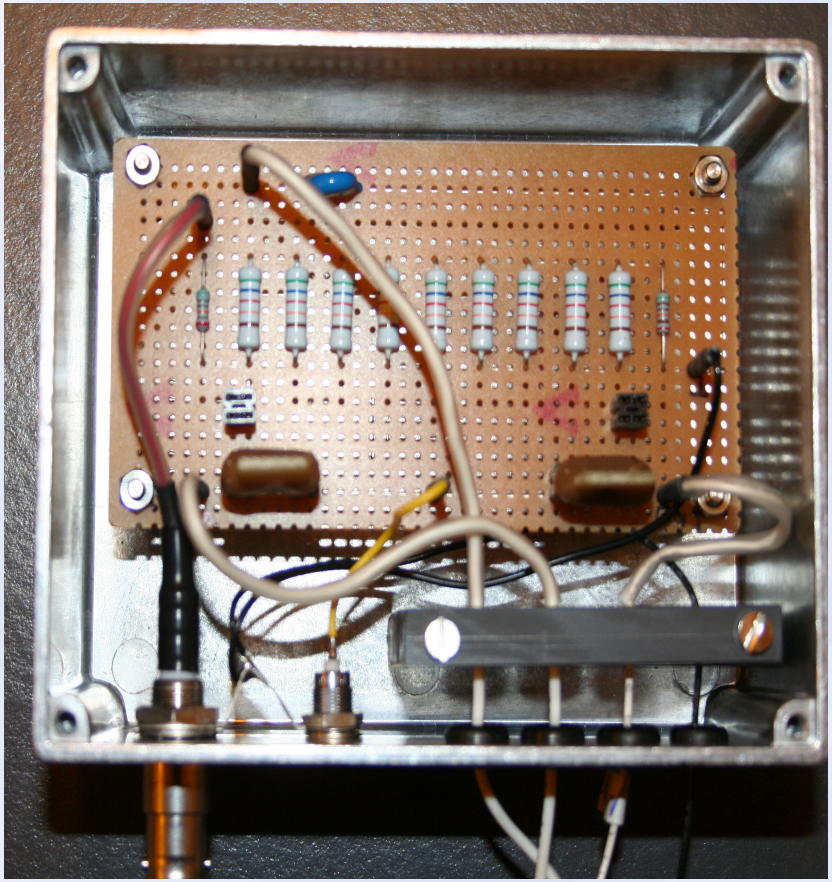
Illumination setup



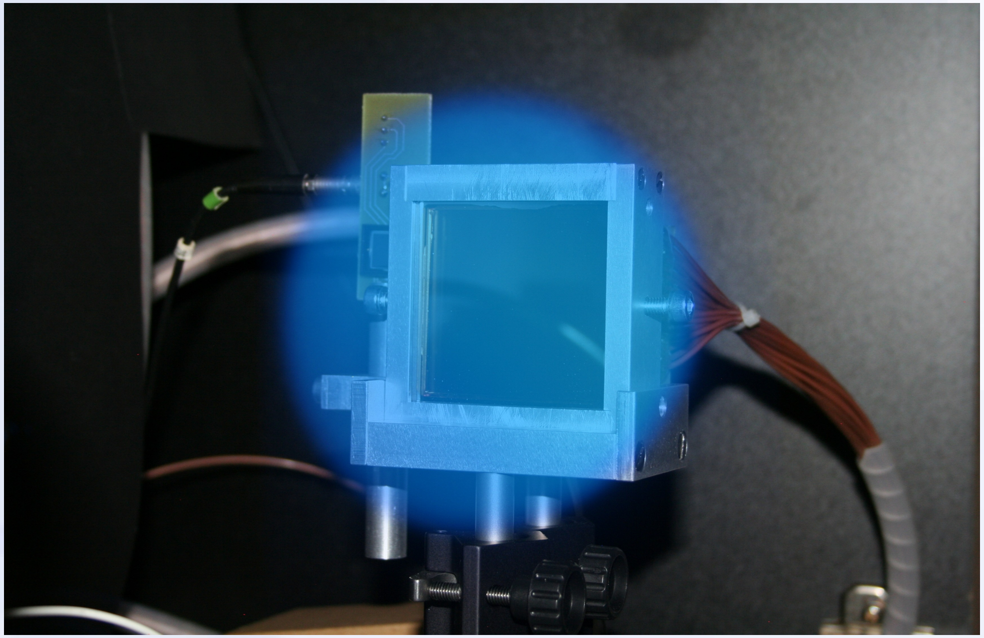
- LED-Lightspot is expanded on whole MCP
- Trigger rate: 272kHz – 500 kHz
- Scaler: event reduction for monitoring
- total voltage: 2.8 kV
- TDC used for crosstalk suppression
- Stability of LED is measured with Photodiode

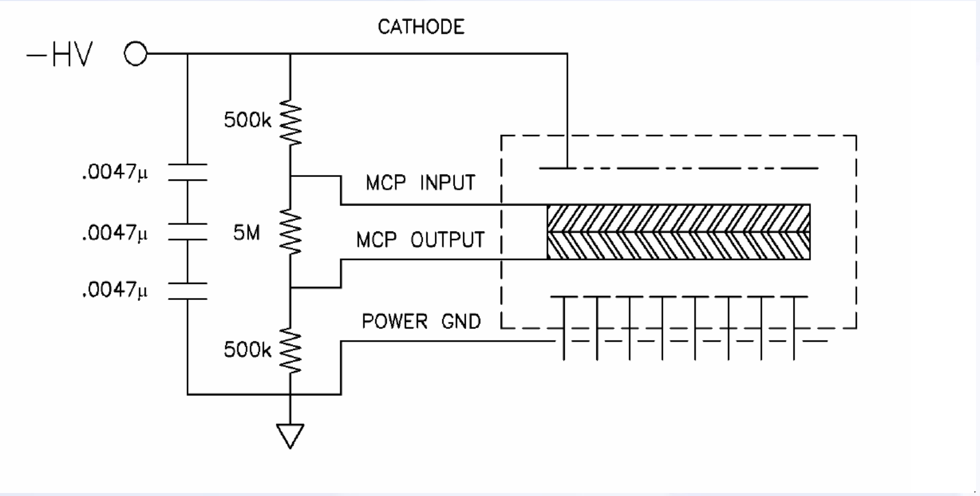
Setup – Photonis XP85012 and XP85112





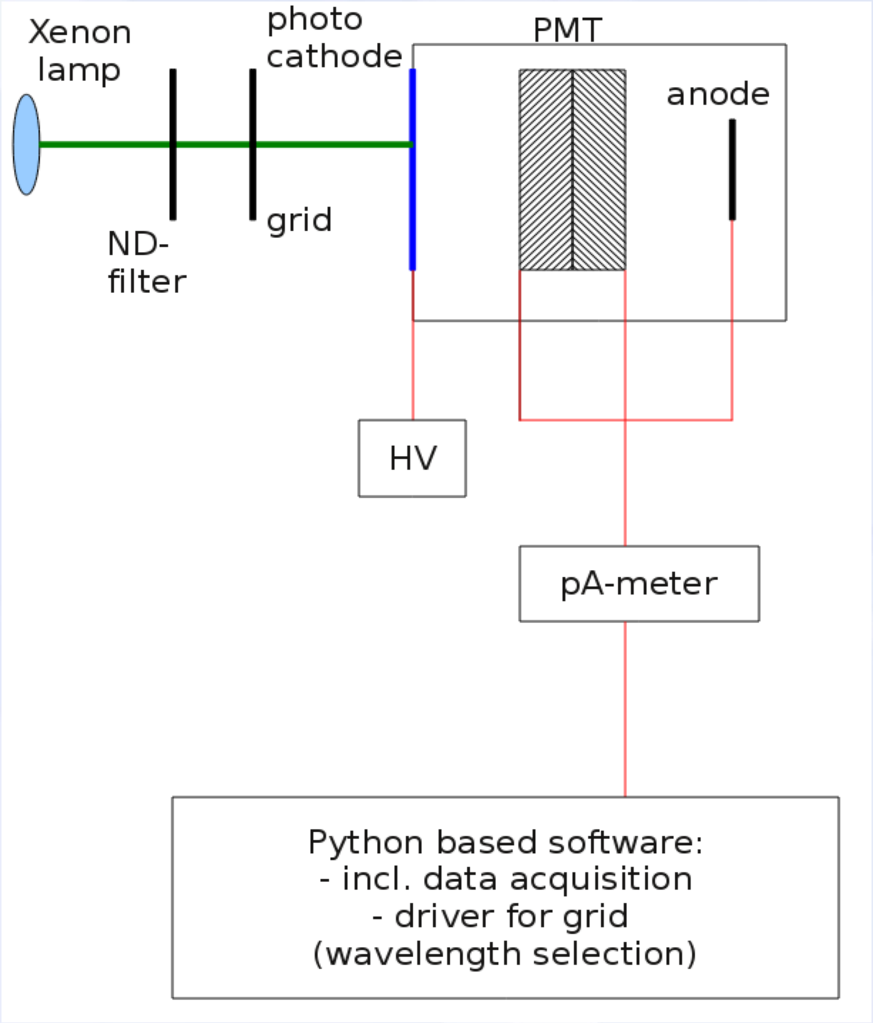
Lightspot of LED for Illumination





Voltage-Divider

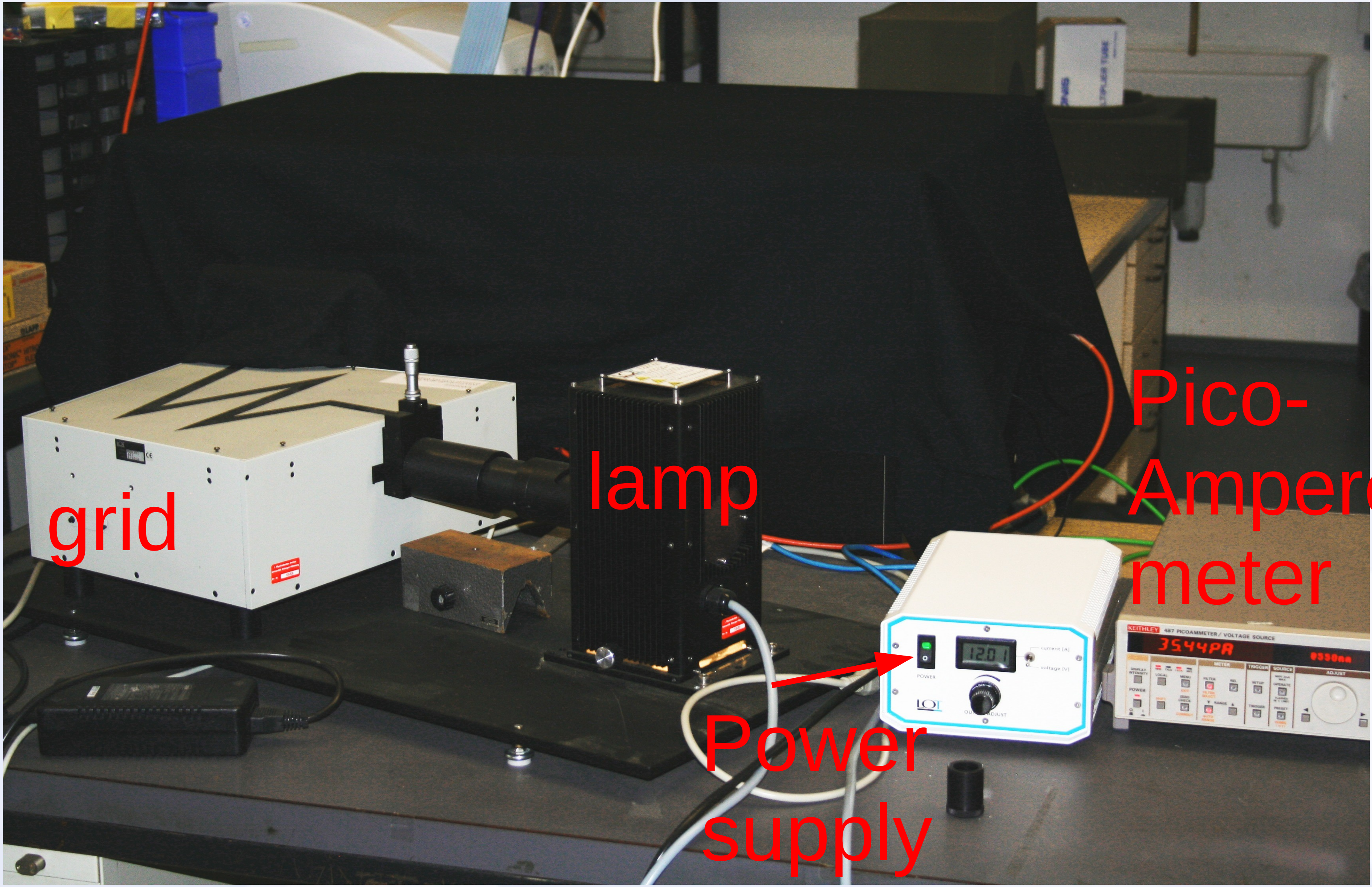
Quantum Efficiency measurement



Kalekin et al., PMT characterisation for the KM3NET project, NIMA 626-627 (2011), p. 151-153

- Wavelength is selected by a grid, $\Delta\lambda = 1\text{nm}$
- Calibrated Photodiode Hamamatsu S6337-01 for measuring lamp spectra
- Xenon lamp for high resolution at blue and UV range
- MCP and anode are shorted and current is measured

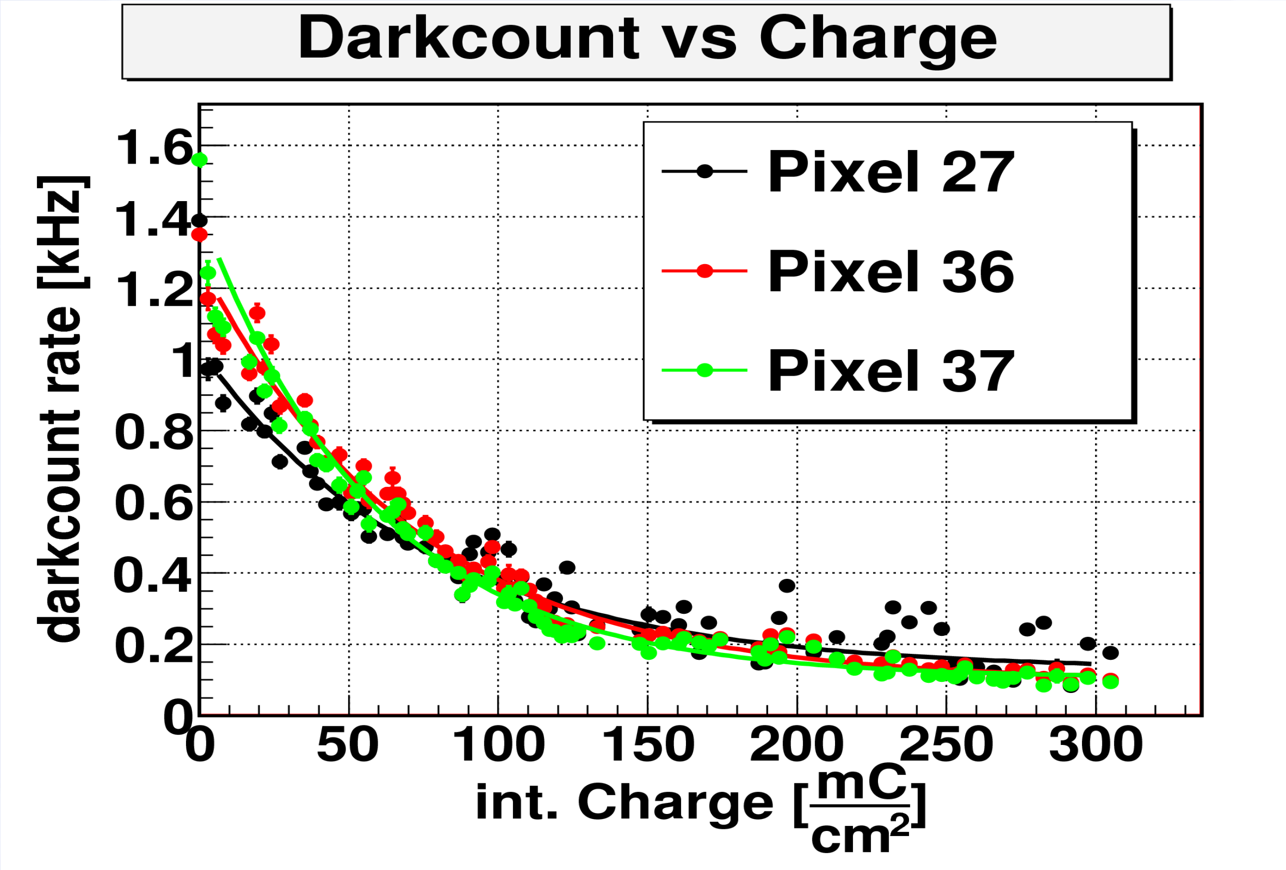
Quantum efficiency setup



procedure of lifetime measurements

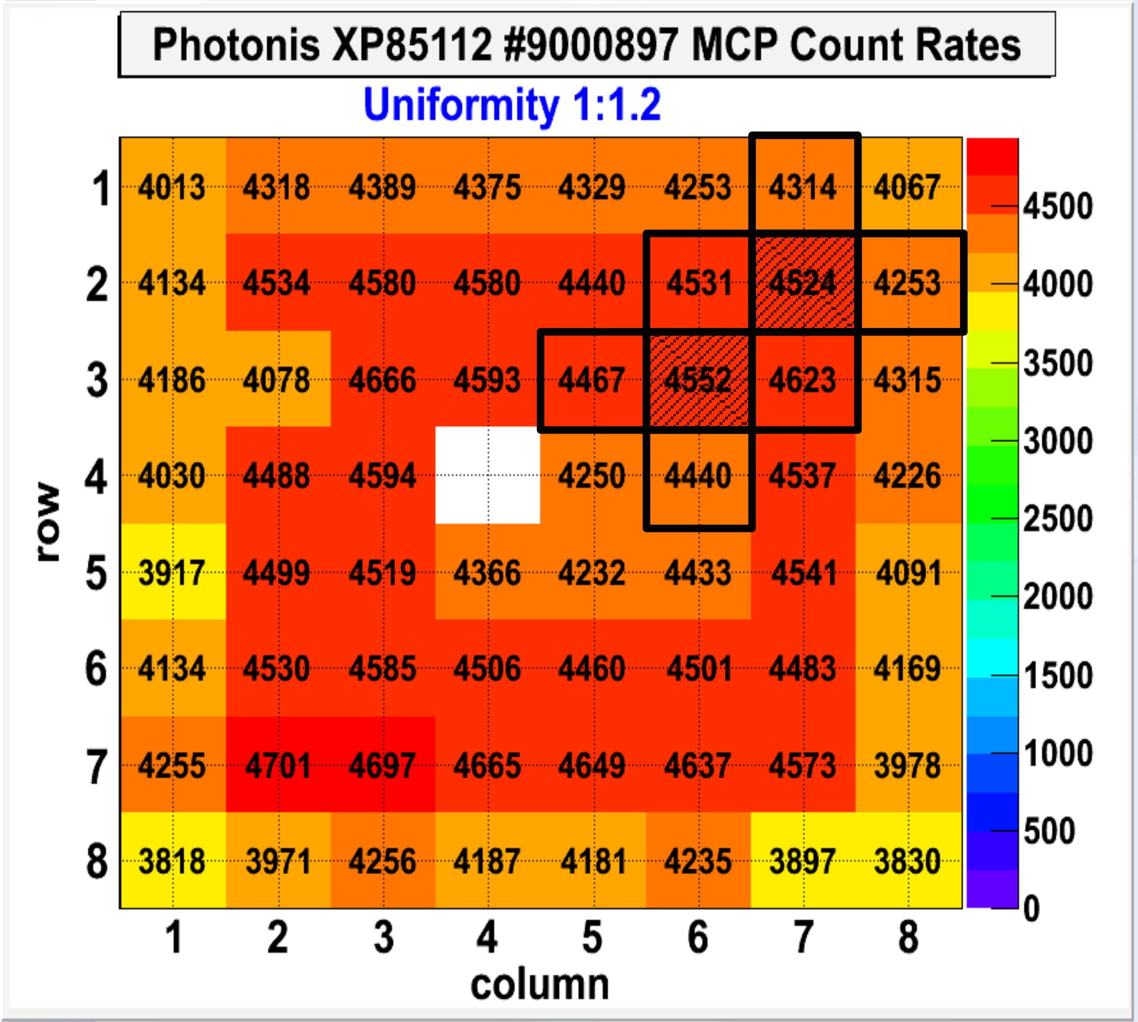
- Permanent illumination and monitoring
- Procedure (every 1-3 days):
  - Measuring **Gain** with different methods:
    - **Center of charge**
    - **Crosstalk suppressed:** read-out of 8 ADC and TDC channels to cut-off coincident signal
  - Measurement of **dark count rate**
  - **Quantum efficiency** measurement
- Every 2-3 weeks: **QE measurement (QE-Scan)** at 16 points on the whole detector (4x4grid)

Dark count rate



Dark count rate decreases with higher int. Charge for all pixels and saturates (~100 Hz)

Crosstalk suppression for Gain measurement

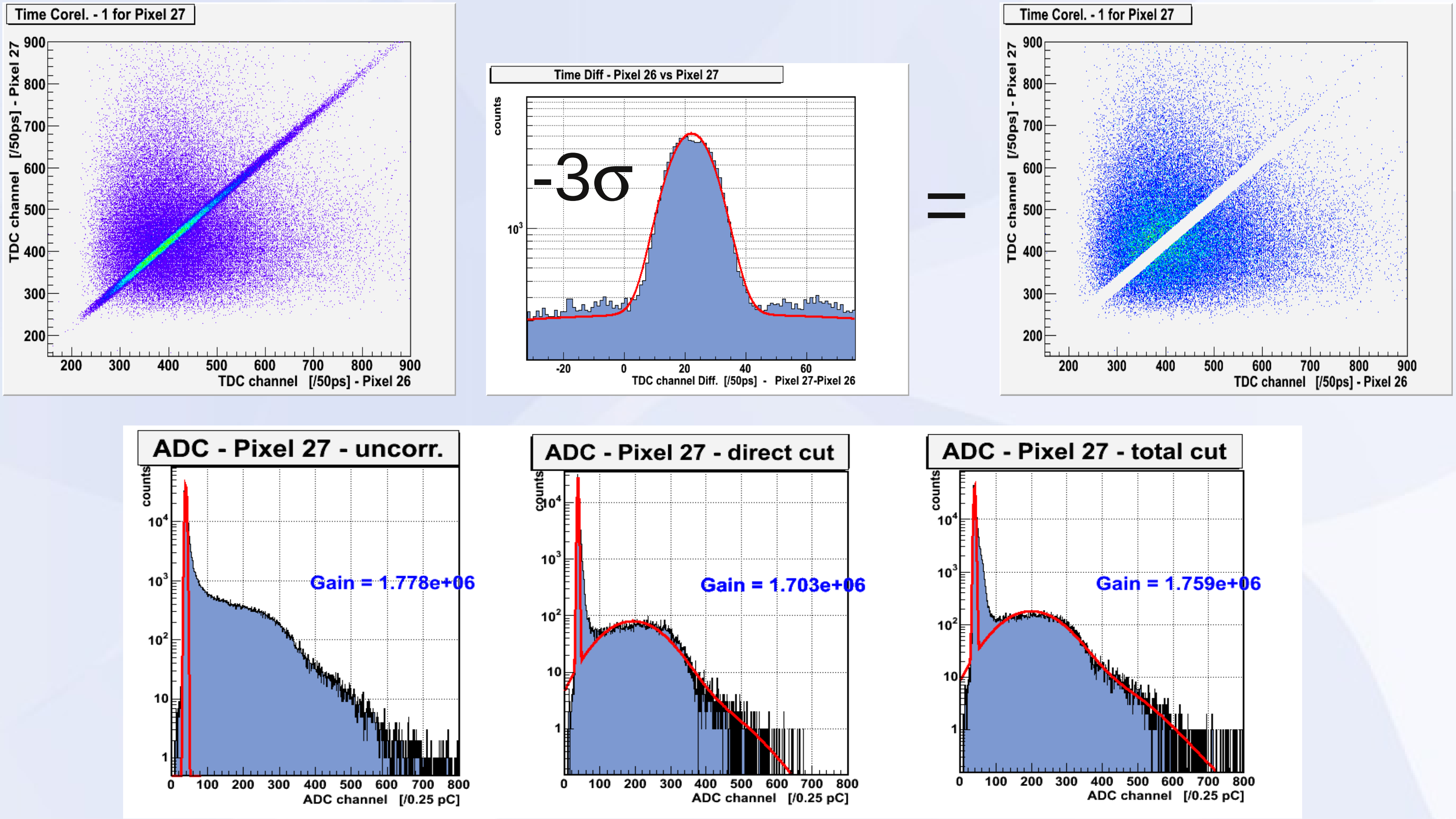


Read-out of 8 Channels,
2 Possibilities:

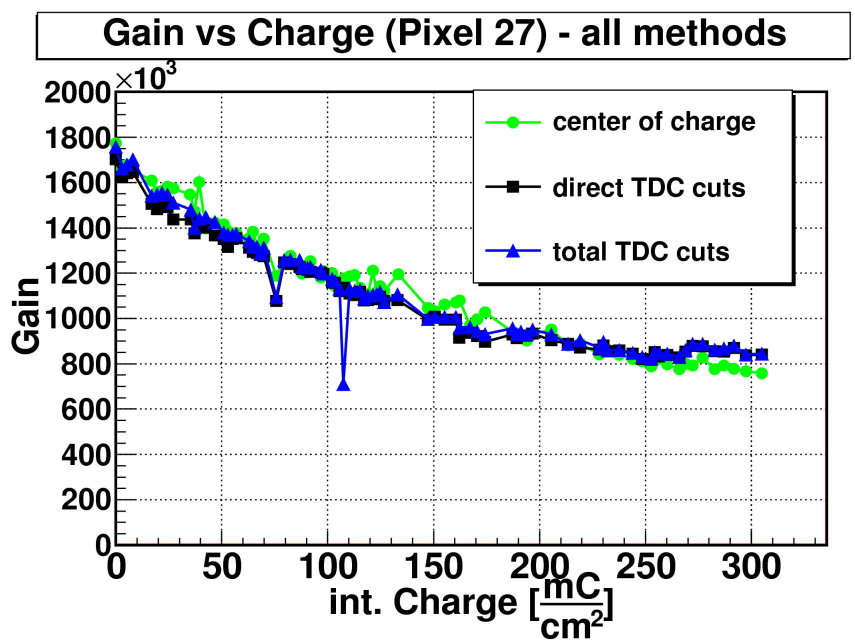
- ”**Direct cut**”: Events with signals in surrounding pixels are neglected
- ”**Total cut**”: Coincident signals induced by charge sharing are neglected

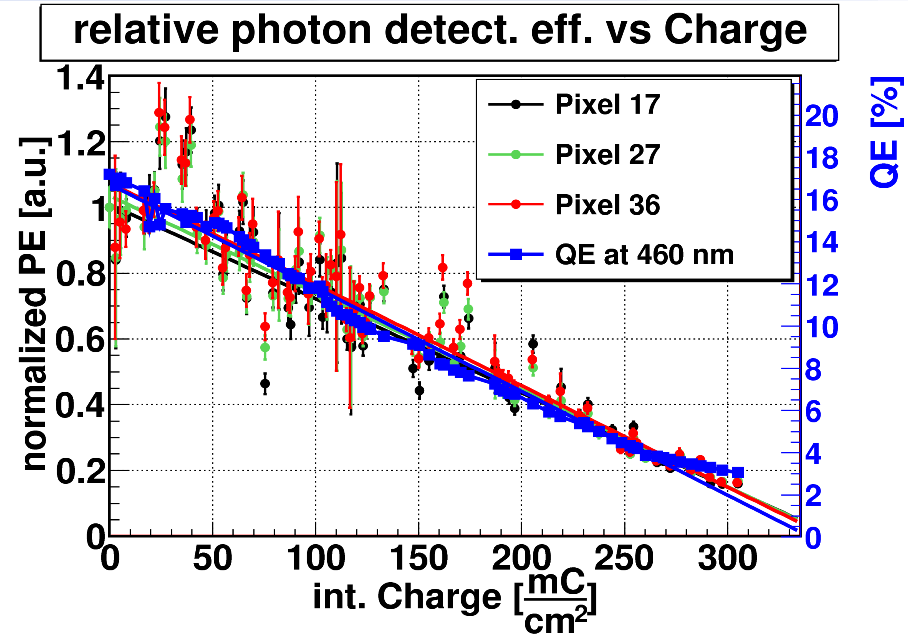
Crosstalk suppression (2)

Charge sharing results in coincident TDC signals ("Total cut"):



Gain and rel. Photon det. eff.

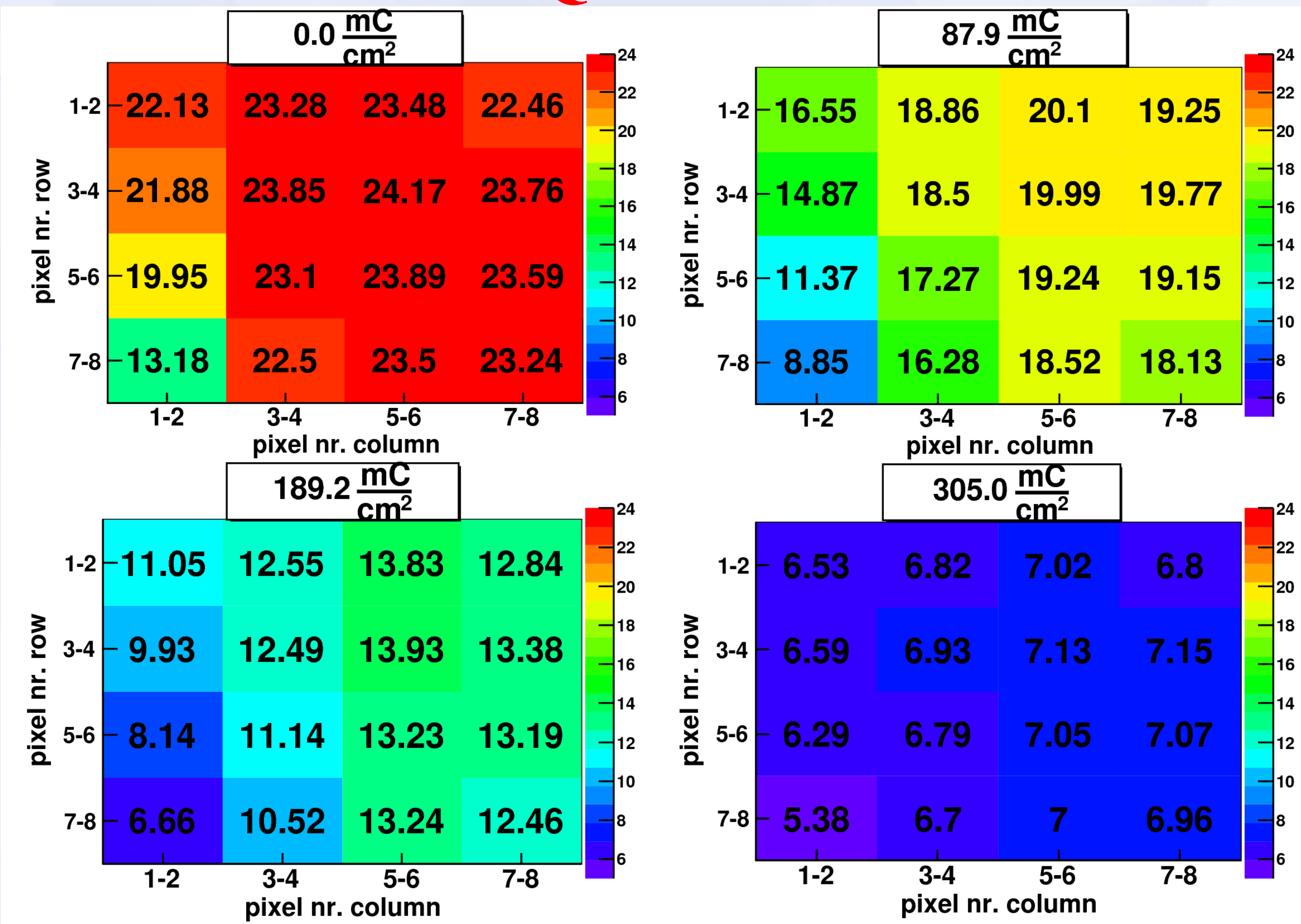




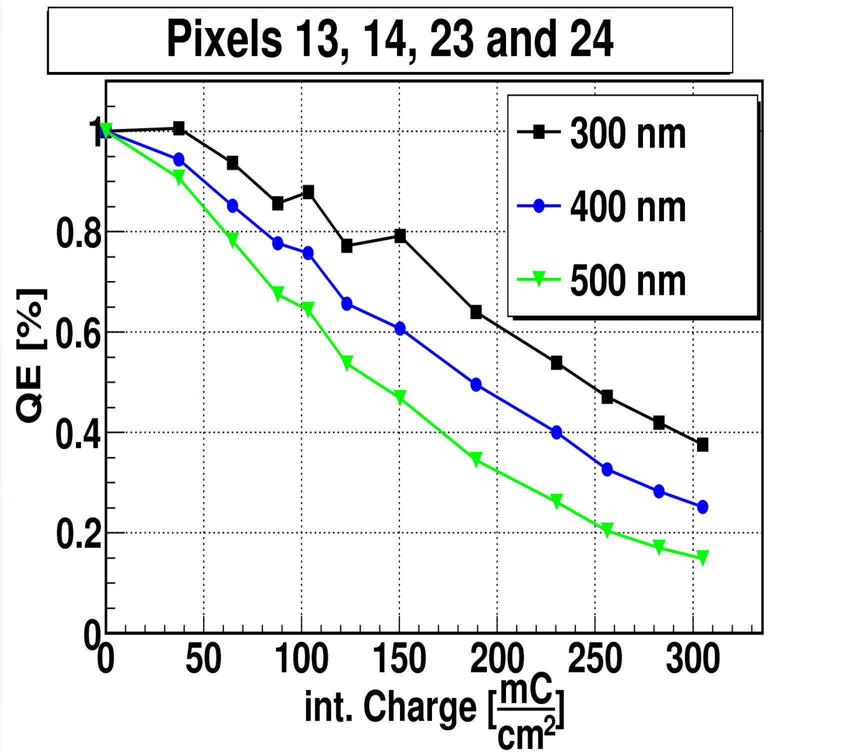
- Gain drops by ~50% at 305 mC/cm²
- ”total cut” and ”direct cut” result in same Gain, center of charge is a bit higher
- Linear extrapolations of rel. Photon det. eff. and QE are similar

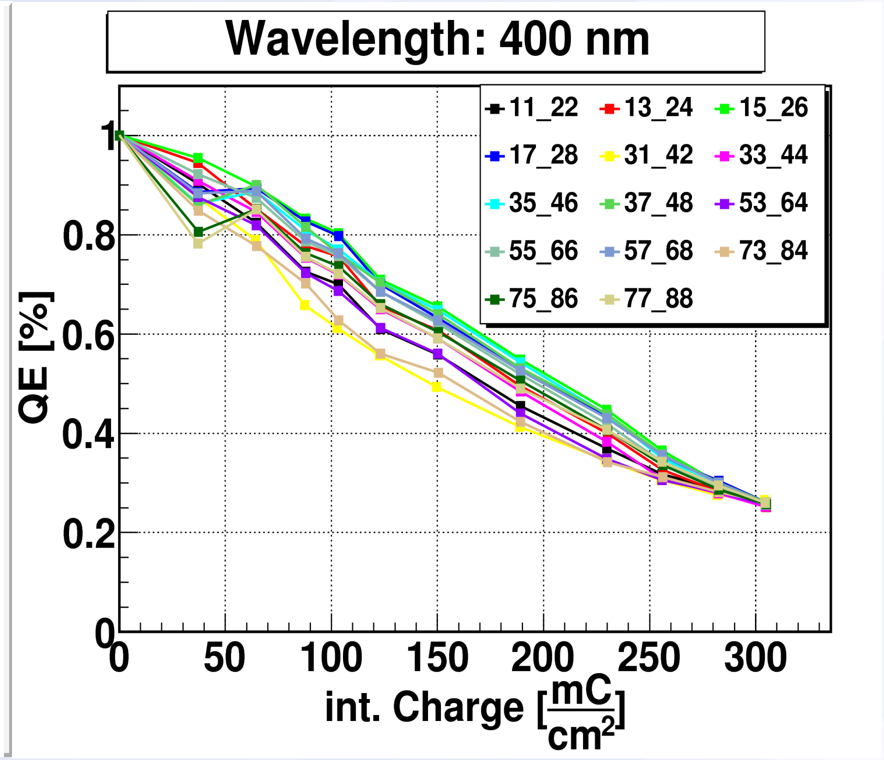
$\Rightarrow$ collection efficiency unaffected by illumination

QE Scans


0.0 mC/cm²
pixel nr. row
pixel nr. column
1-2 3-4 5-6 7-8
22.13 23.28 23.48 22.46
21.88 23.85 24.17 23.76
19.95 23.1 23.89 23.59
13.18 22.5 23.5 23.24
87.9 mC/cm²
16.55 18.86 20.1 19.25
14.87 18.5 19.99 19.77
11.37 17.27 19.24 19.15
8.85 16.28 18.52 18.13
189.2 mC/cm²
11.05 12.55 13.83 12.84
9.93 12.49 13.93 13.38
8.14 11.14 13.23 13.19
6.66 10.52 13.24 12.46
305.0 mC/cm²
6.53 6.82 7.02 6.8
6.59 6.93 7.13 7.15
6.29 6.79 7.05 7.07
5.38 6.7 7 6.96
24 22 20 18 16 14 12 10 8 6

QE Scans (2)

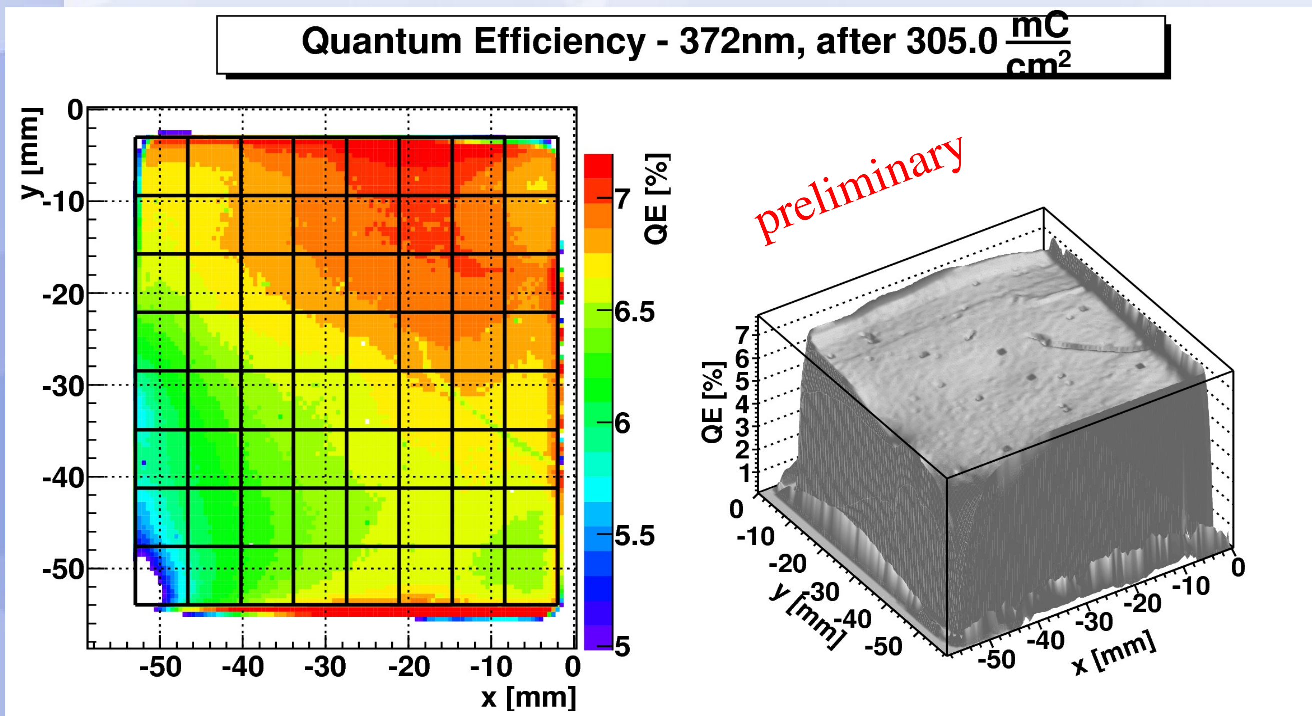




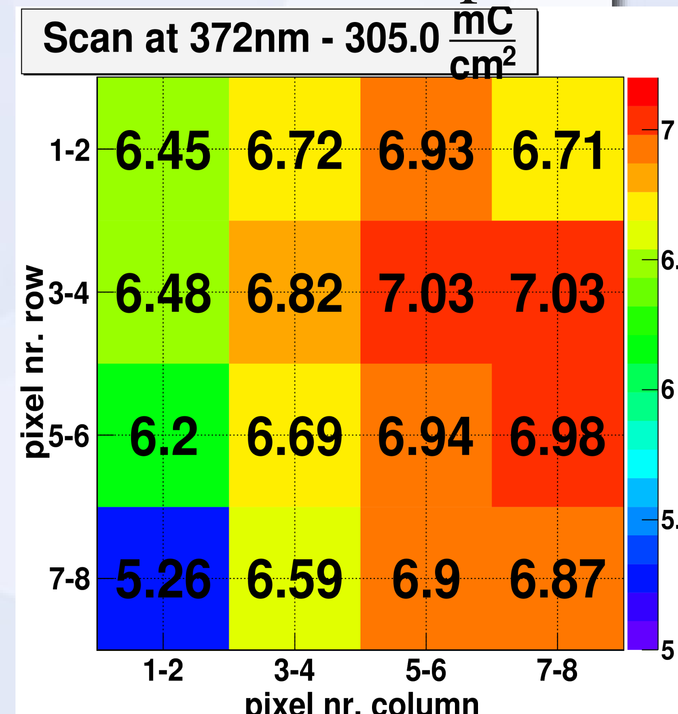
- Faster decrease of higher wavelengths can be measured for all pixels
- The relative loss for a given wavelength is quite similiar for all pixels

QE-Scan with PiLas-Laser

Laser

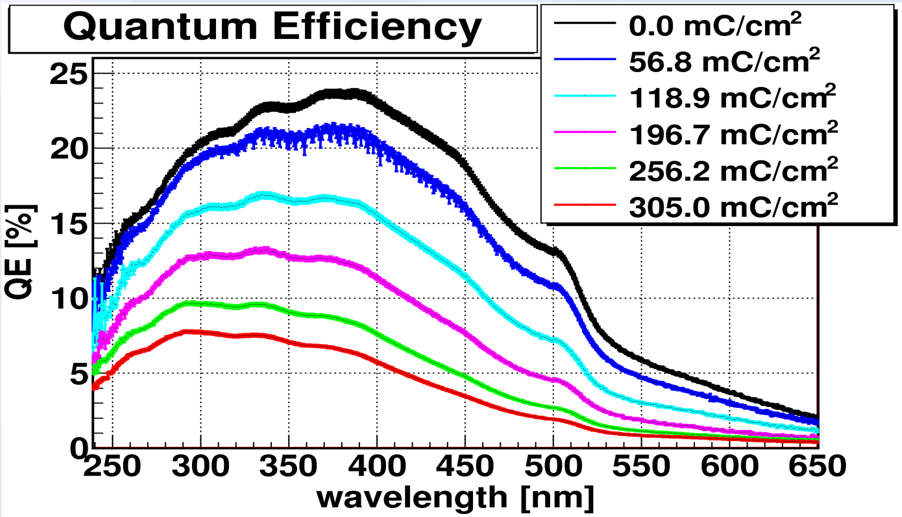


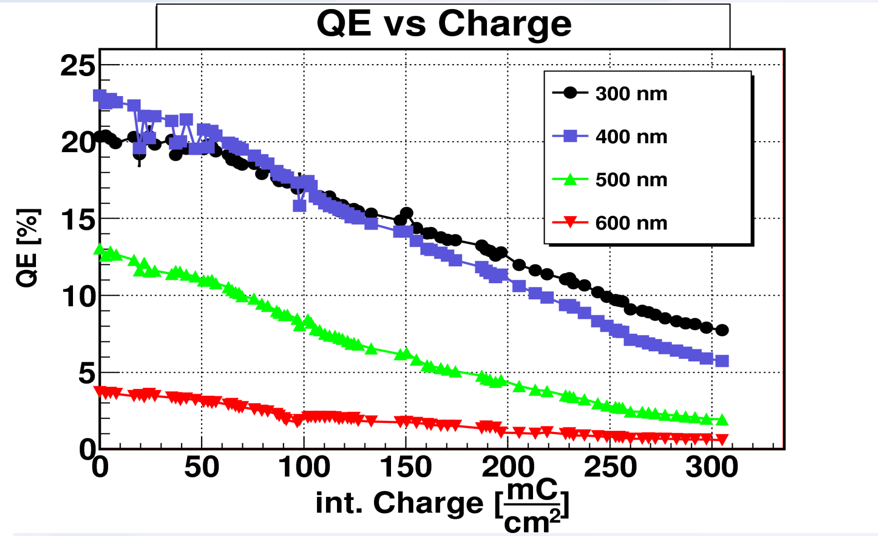
Xenon-lamp

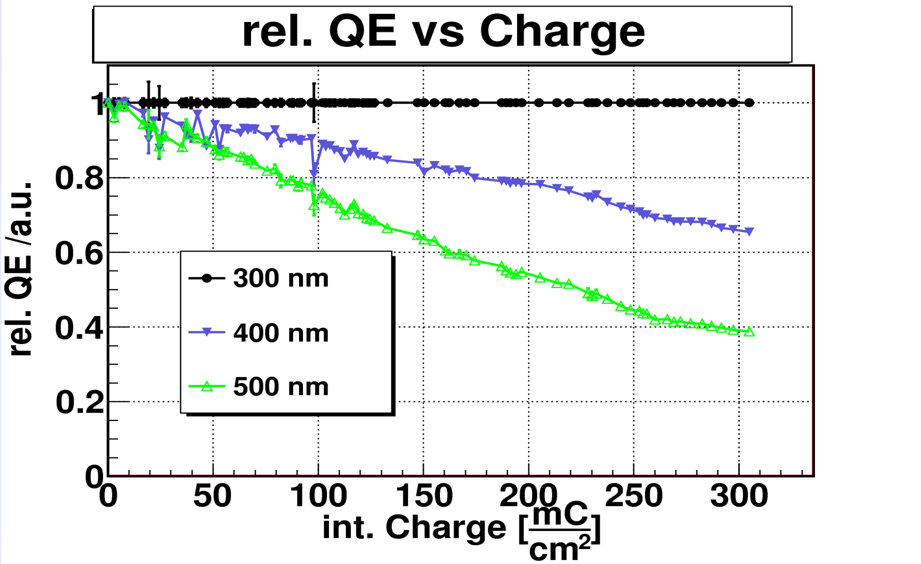


- Pulse frequency: 100kHz, no attenuation
- Laser stability: ~2%
- Stepsize: 0.5mm, both directions (Spotsize: Ø < 0.5mm)
- QE is anti-correlated to dark count rate!

Quantum eff. and rel. QE

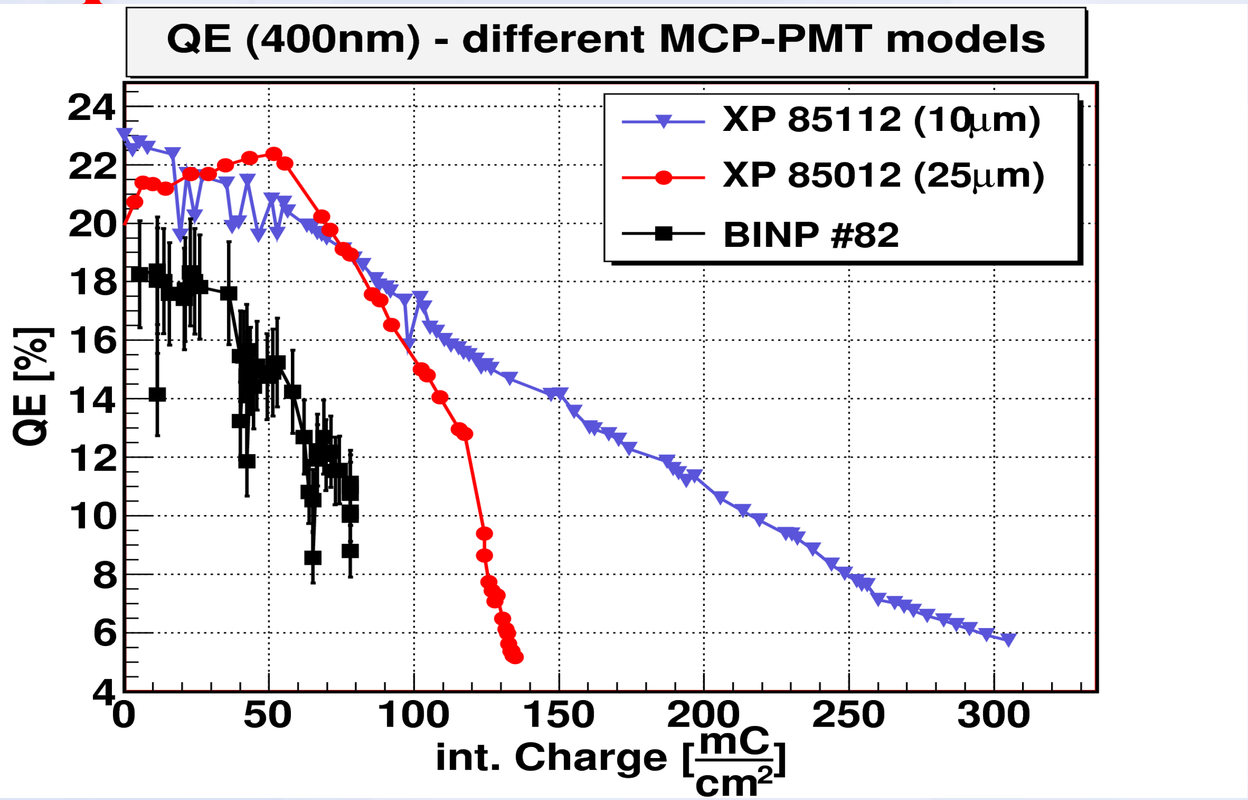






Rel. QE drops faster for higher wavelengths => absolute Maximum shifts to lower values

Comparison with other MCP-PMTs



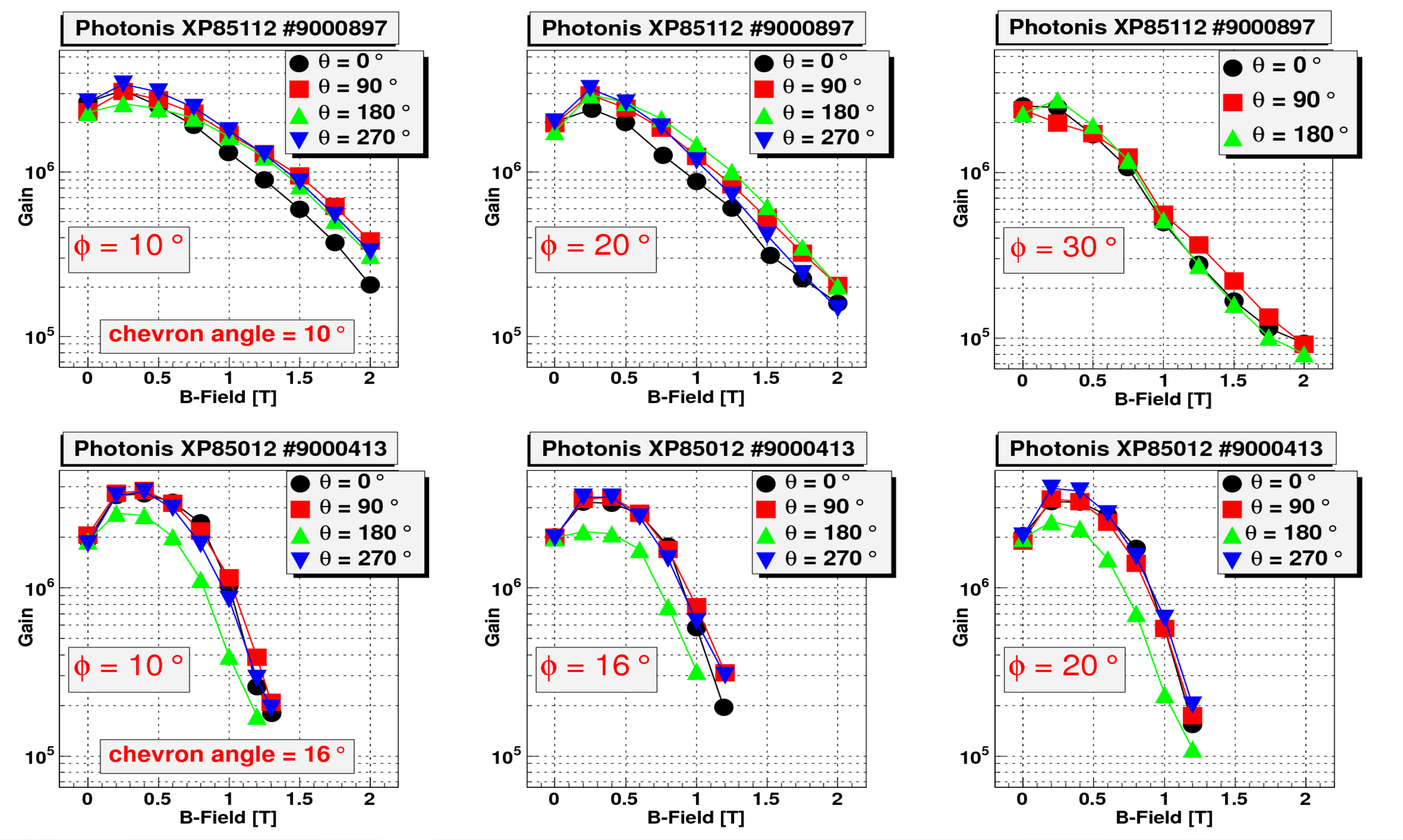
- Later models perform better in lifetime issues
- QE of XP85012 increased at the beginning, cannot be observed with any other MCP-PMT so far

Summary and Outlook

- **Results of XP85112 after 305mC/cm²:**
  - Performance sufficient in terms of rate stability, time resolution, and magnetic field immunity
  - Gain (-50%) and QE (460nm, -80%) dropped extremly
  - Lifetime of XP85112 still not sufficient for PANDA requirements ($1\frac{\mathbf{C}}{\mathbf{cm}^2 * \mathbf{a}}$, 100% duty cycle)
- **On the other hand:**
  - Lifetime upgrades of Photonis MCP-PMTs ongoing
  - Recent developments of Hamamatsu SL10 seems promissing:
    - ($2-3\frac{\mathbf{C}}{\mathbf{cm}^2}$!! T.Mori et al., Lifetime-extended MCP-PMT, NIMA 629, p. 111-117, 2011)
    - Measurement of 2 models of the new SL10 imminent (4x4 and 4x1)

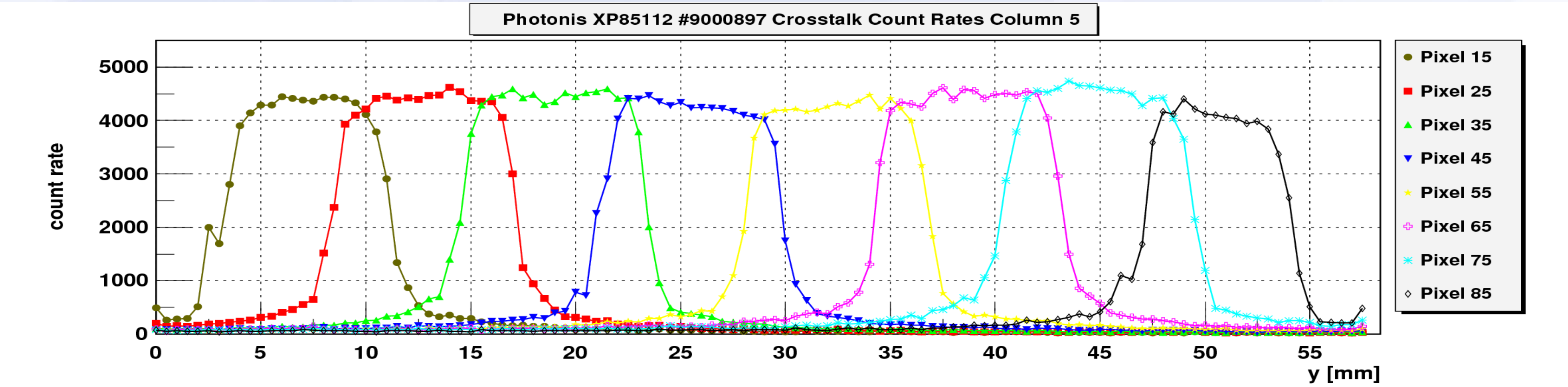
Backup

Gain and Direction of B-Field (θ)

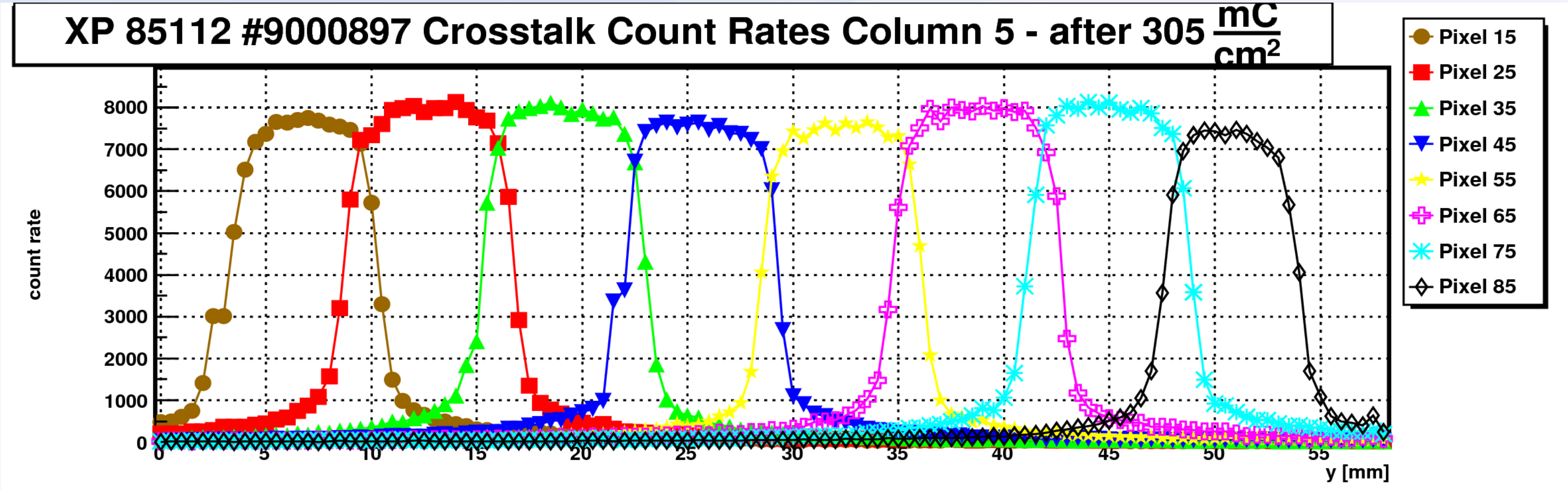


- Gain slope of XP85112 not depended on rotation angle theta, but that of XP85012 is (mostly at chevron angle)

Crosstalk



Photonis XP85112 #9000897 Crosstalk Count Rates Column 5
count rate
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
40
45
50
55
y [mm]
Pixel 15
Pixel 25
Pixel 35
Pixel 45
Pixel 55
Pixel 65
Pixel 75
Pixel 85



XP 85112 #9000897 Crosstalk Count Rates Column 5 - after 305 $\frac{mC}{cm^2}$
count rate
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
40
45
50
55
y [mm]
Pixel 15
Pixel 25
Pixel 35
Pixel 45
Pixel 55
Pixel 65
Pixel 75
Pixel 85