Systematic Studies of Microchannel Plate PMTs

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- Motivation
- Performance tests
  - magnetic field behaviour
  - time resolution, rate stability
- Lifetime measurements
  - Photonis XP85012, XP85112 and BINP #82

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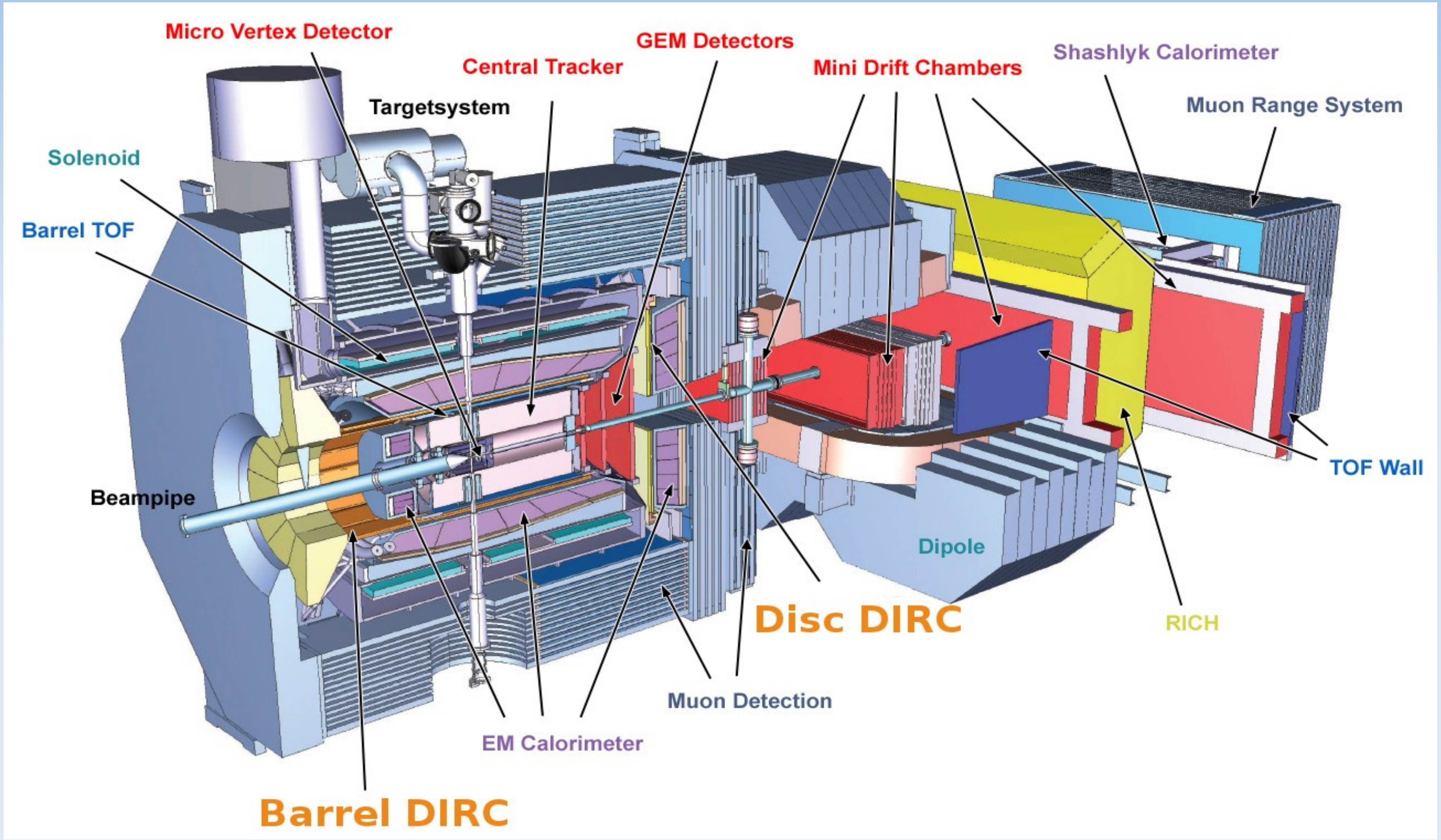
PANDA Experiment

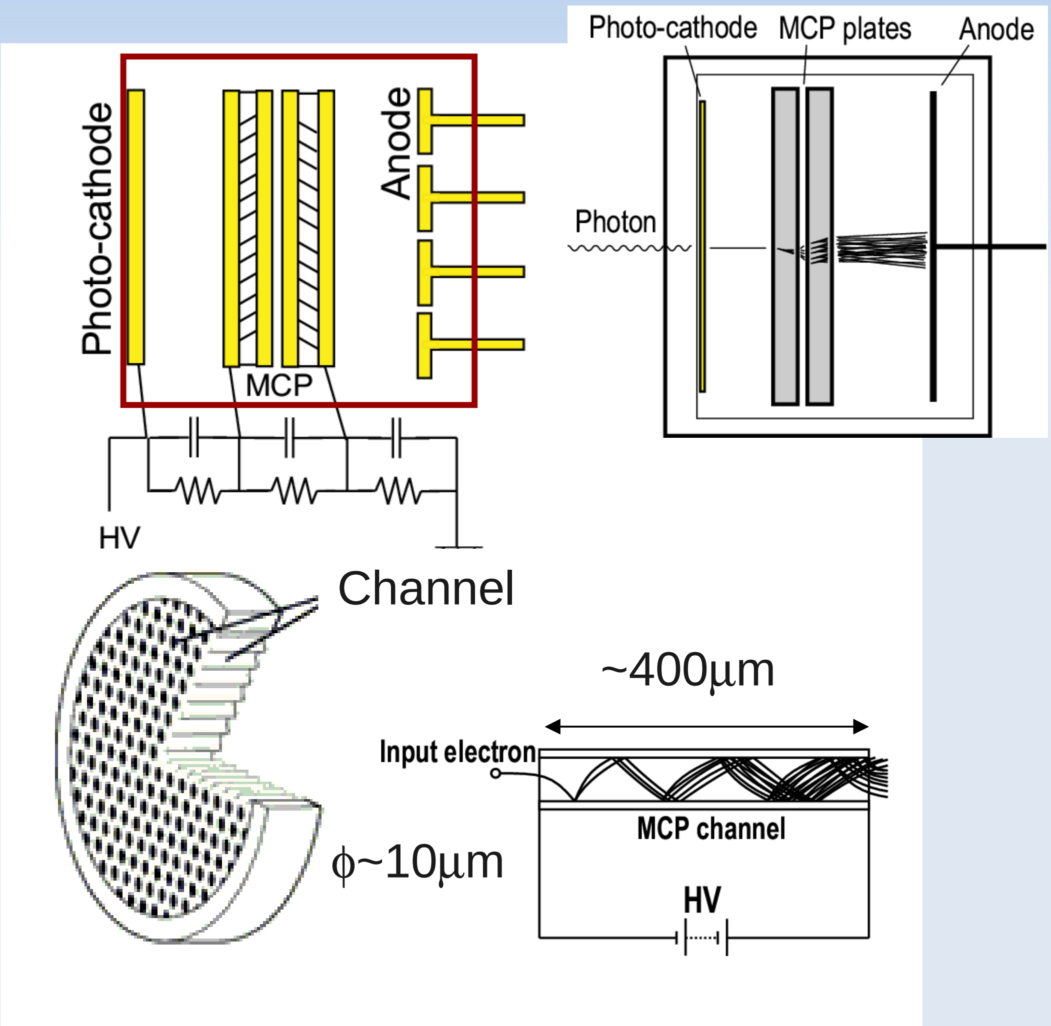


Technical Challenges to Photosensors at the PANDA DIRCs

- Single photon detection inside B-Field
  - high gain in B-fields up to 2 T
- Time resolution < 100 ps for single photons for ToP and/or dispersion correction
- High Photon rates
  - high rate stability (~ 200 up to 2 MHz/cm^2 depending on the positon of the sensor)
  - long lifetime (~ 1 up to serveral C/cm^2/a at full duty cycle)
- Good spatial resolution
  - Multi-Anode PMTs

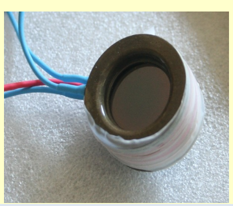
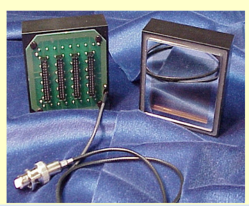
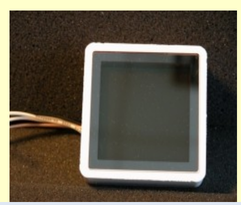
Microchannel Plate PMT

electron multiplication in glass capillaries (∅ ≈ 10-25 μm)



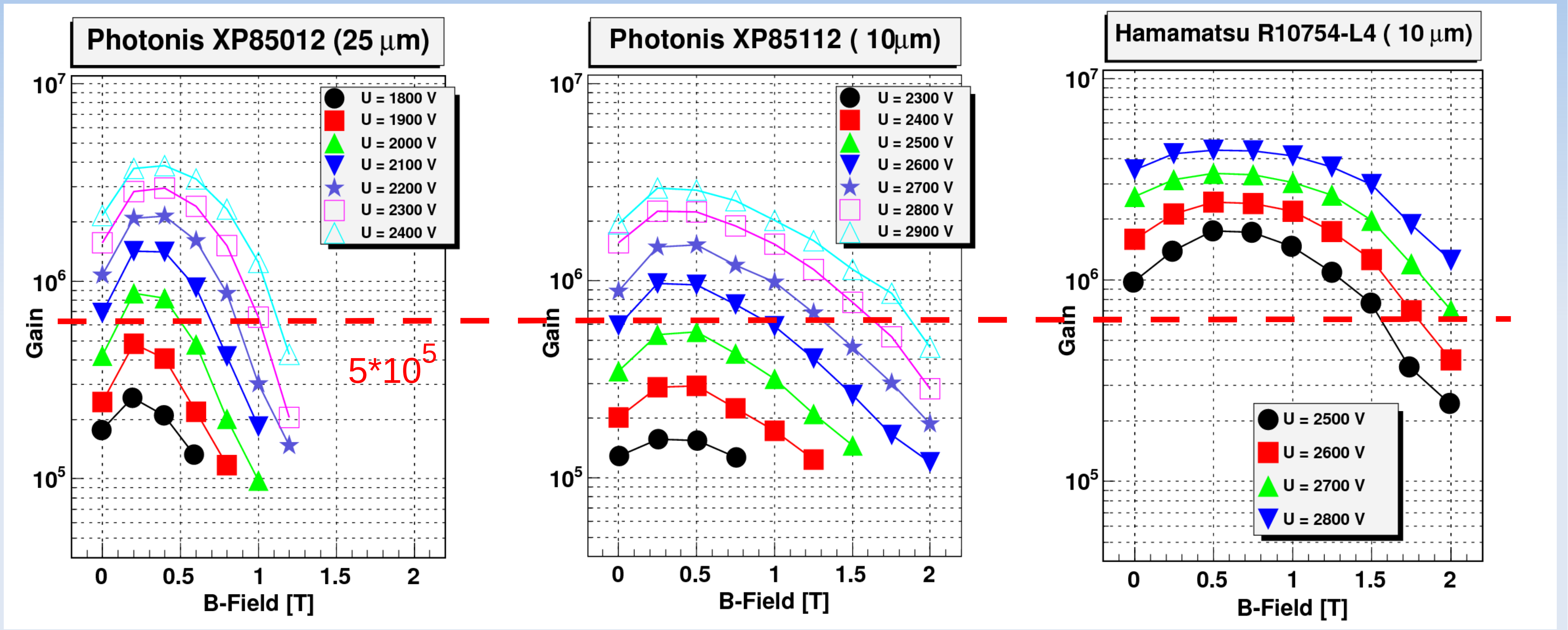
- very fast time response:
  - signal rise time = 0.3–1.0 ns
  - TTS < 50 ps
- high gain:
  - >10^6 with 2 MCP stages
  - single photon sensitivity
- usable in high magnetic fields
- quantum efficiency comparable to that of standard vacuum PMTs
- multi-anode PMTs possible
- caveats:
  - lifetime

Investigated MCP-PMTs

	BINP			Burle-Photonis			Hamamatsu
		XP85011	Prototype	XP85013	XP85012	XP85112	R10754-00-L4
pore size (μm)	6 or 8	25	10	25	25	10	10
number of pixels	1	8x8	8x8	8x8	8x8	8x8	4x1
active area (mm²)	$9^2\ \pi$	51x51	51x51	53x53	53x53	53x53	22x22
total area (mm²)	$15.5^2\ \pi$	71x71	69.5x69.5	59x59	59x59	59x59	27.5x27.5
geom. efficiency (%)	36	52	54	81	**81**	**81**	61
peak Q.E.	22% @ 480 nm	--	--	--	21% @ 380 nm	21% @ 380 nm	20% @ 300 nm
comments	5-10 nm Al_2O_3 protection layer	--	--	larger active area ratio	better vacuum, polished surfaces	better vacuum, polished surfaces	
							

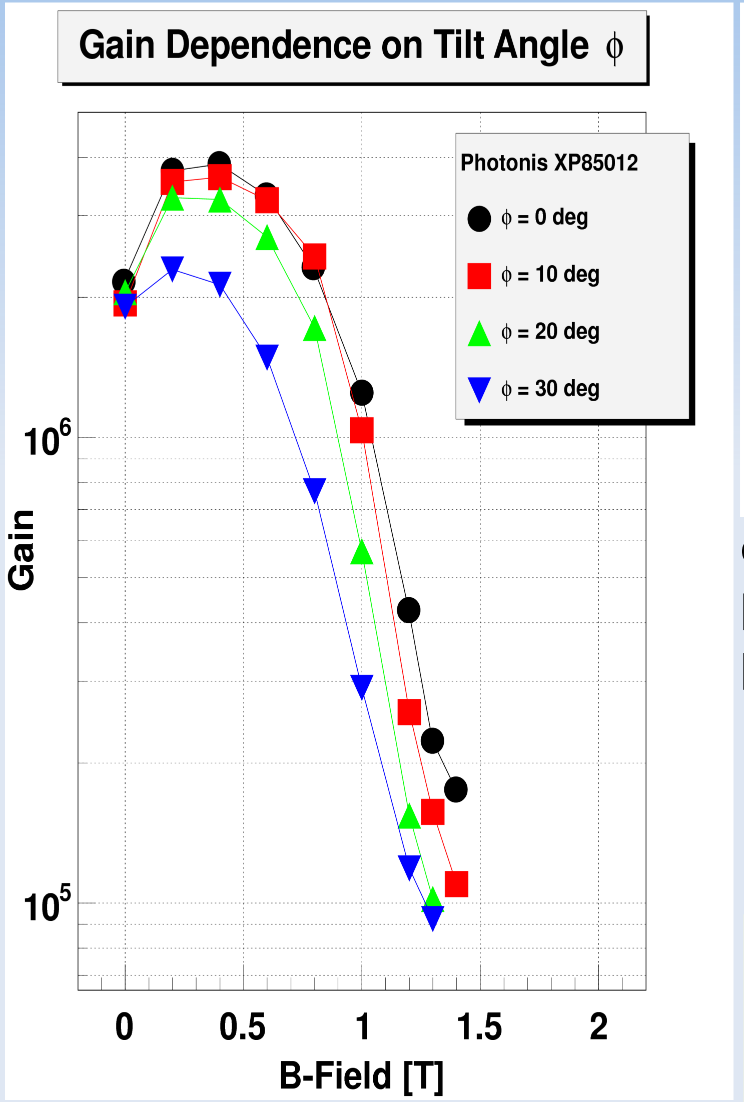
- this work: comparison of several models of MCP-PMTs
  - Photonis XP85012, XP85112 and Hamamatsu R10754-00-L4

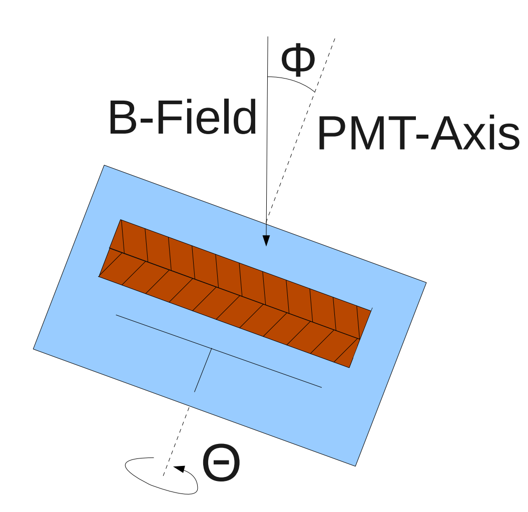
Gain in Magnetic Field



- 25 µm MCP gain breaks down at ~ 1 Tesla
- 10 µm MCP usable up to 2 Tesla

Gain and Direction of B-Field (Φ)

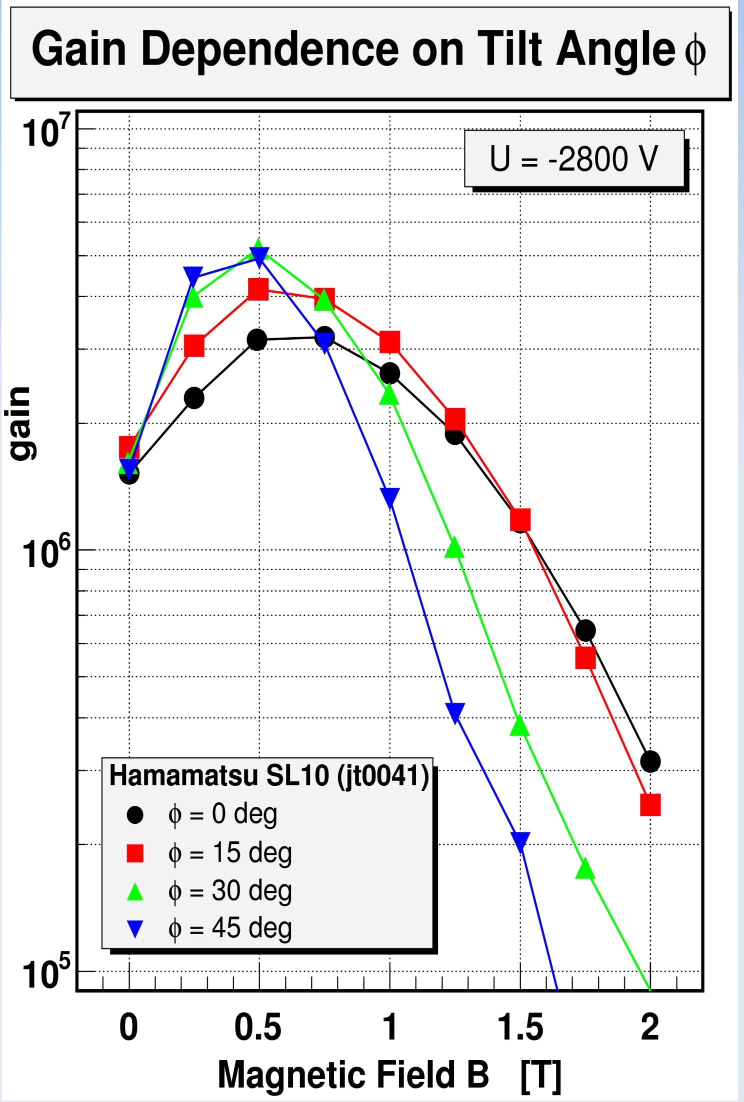




Φ= tilt angle between B-field direction and PMT-axis

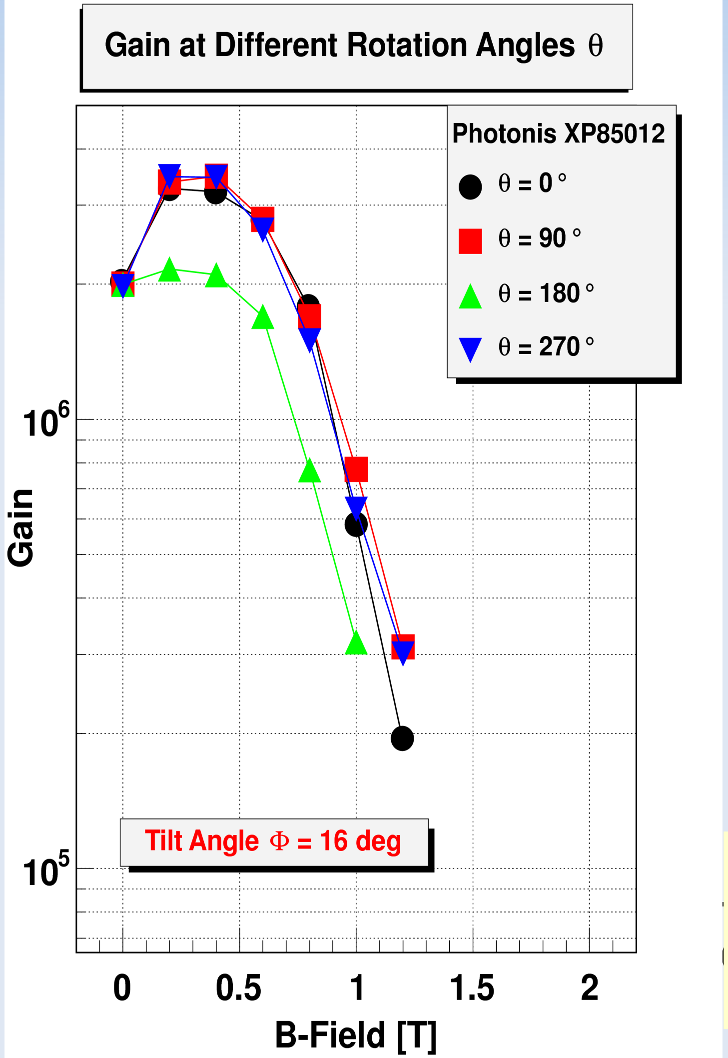
θ = rotation angle of PMT around B-field direction

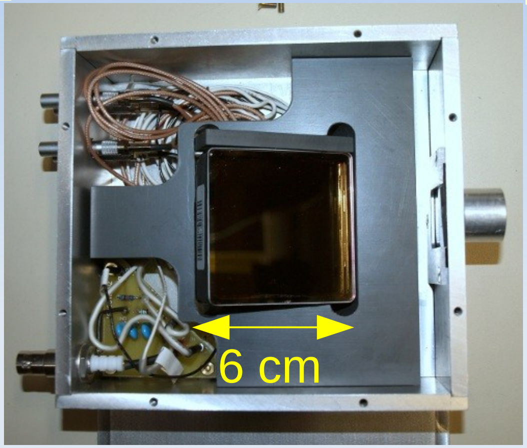
Significant gain loss at high B-field and large Φ-angles



Gain and Direction of B-Field (θ)

Photonis XP85012 (25 μm)

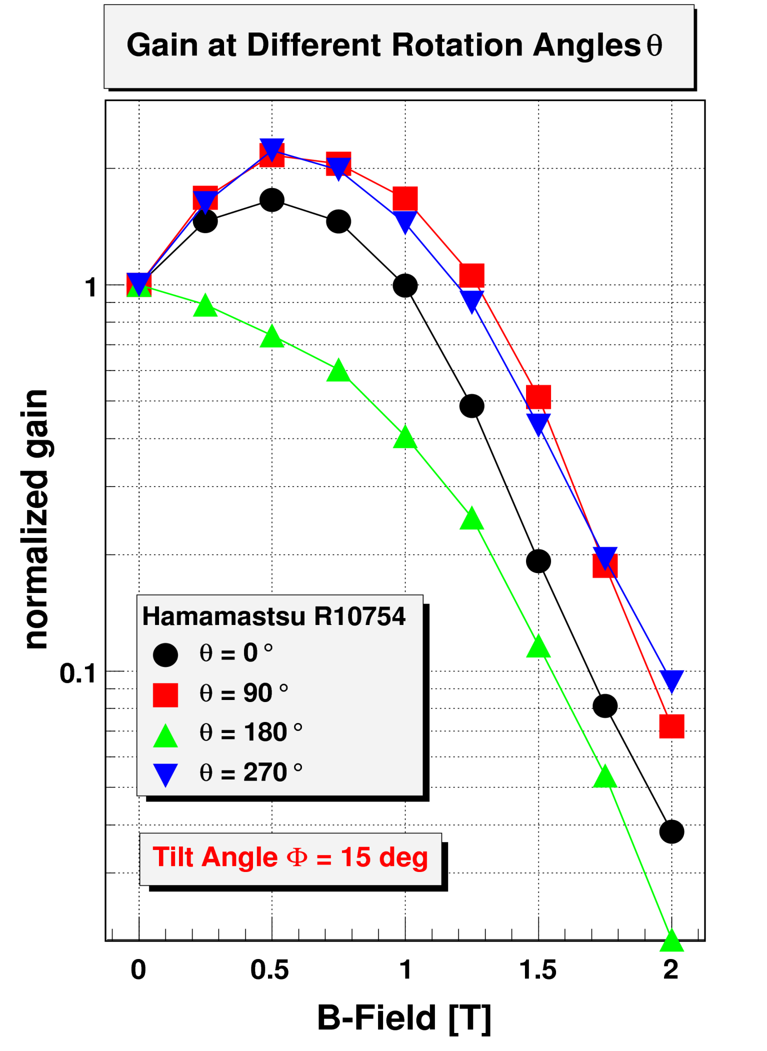




PMTs built with some ferromagnetic material → rotation and tilting of PMT inside B-field with special inserts in alubox

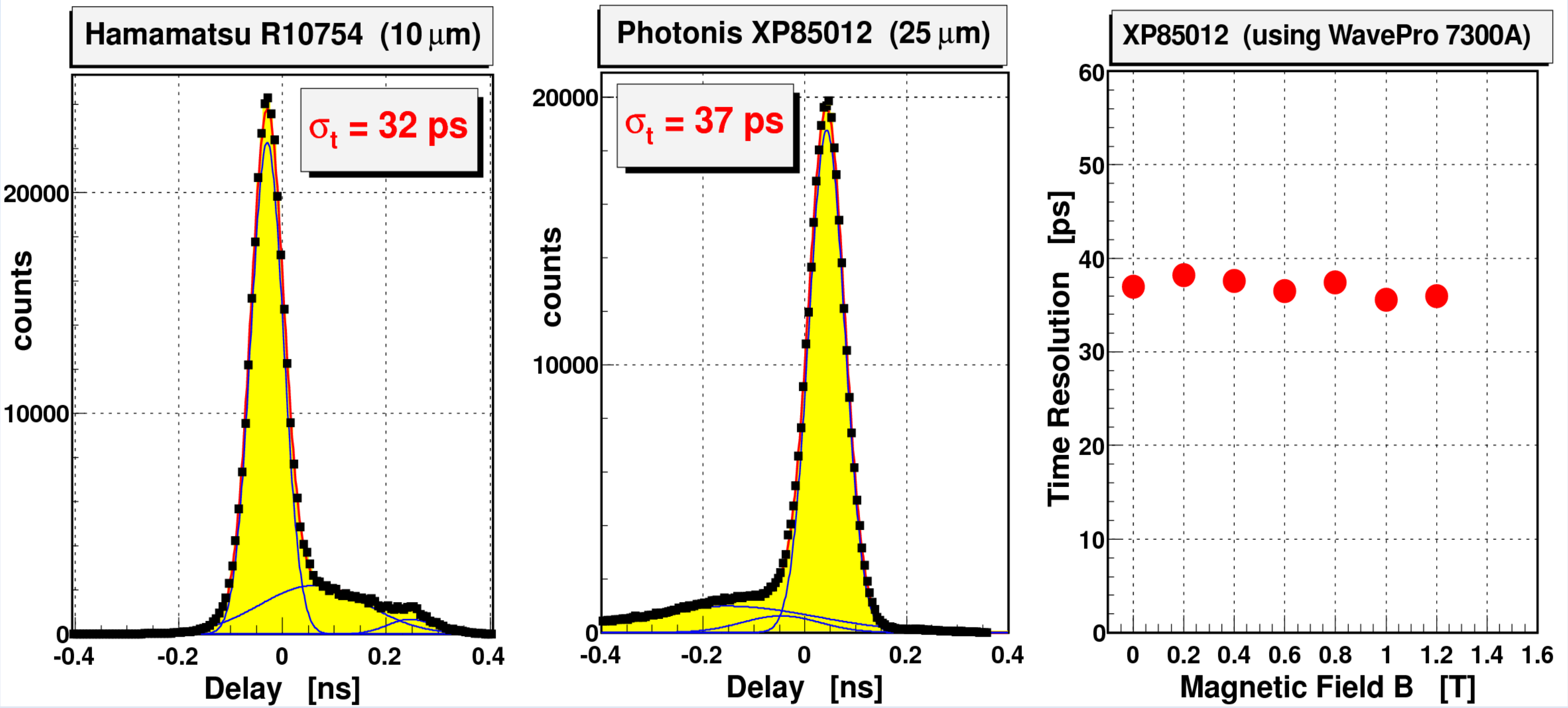
gain slope changes rapidly when pores point along B-field

Hamamatsu R10754 (10 μm)



Single Photon Time Resolution

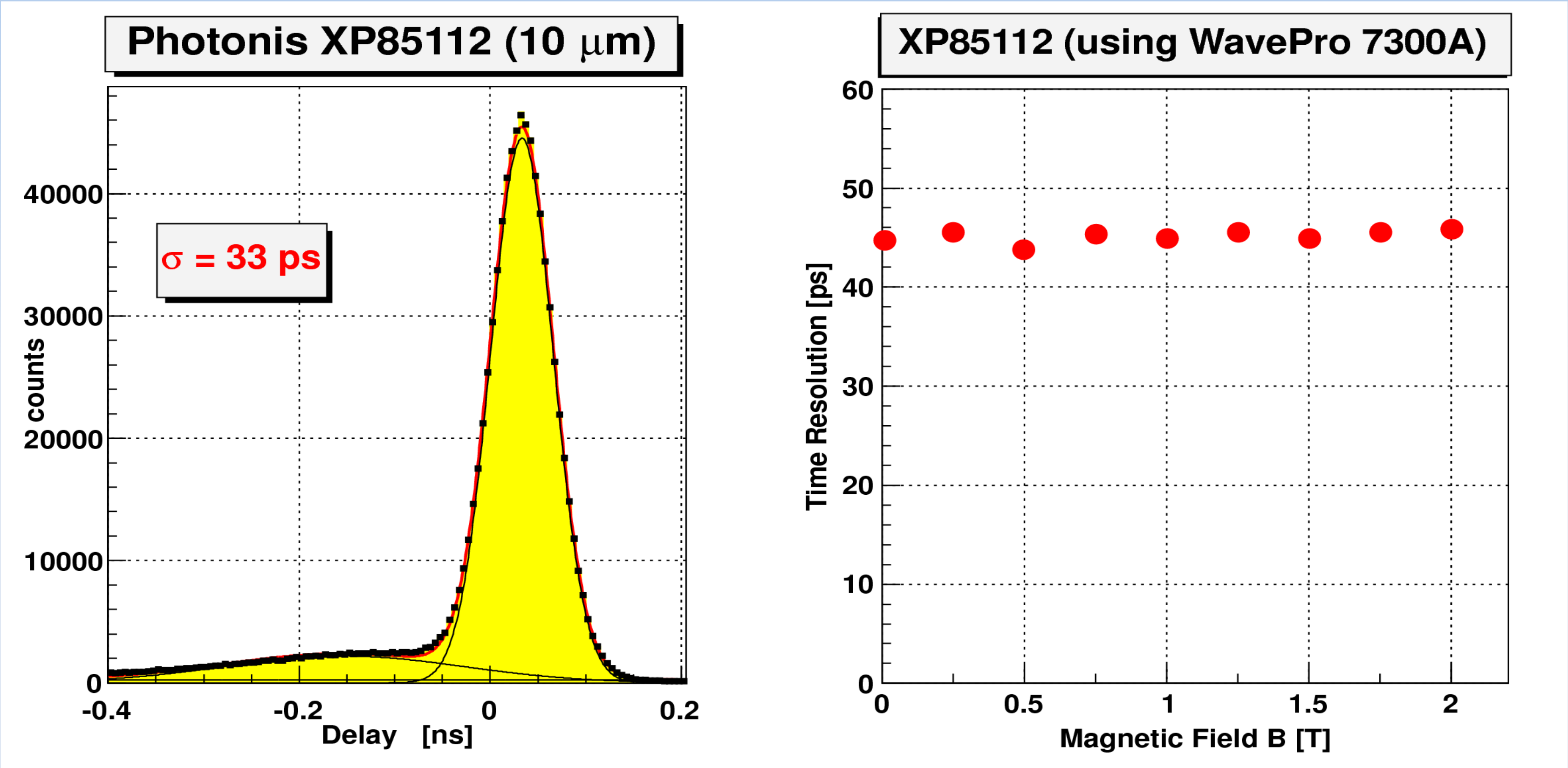
Amplifier Ortec FTA820 (x200; 350 MHz) --- Discriminator Philips Scientific 705



- time resolution < 40 ps
- no dependence on the B-field

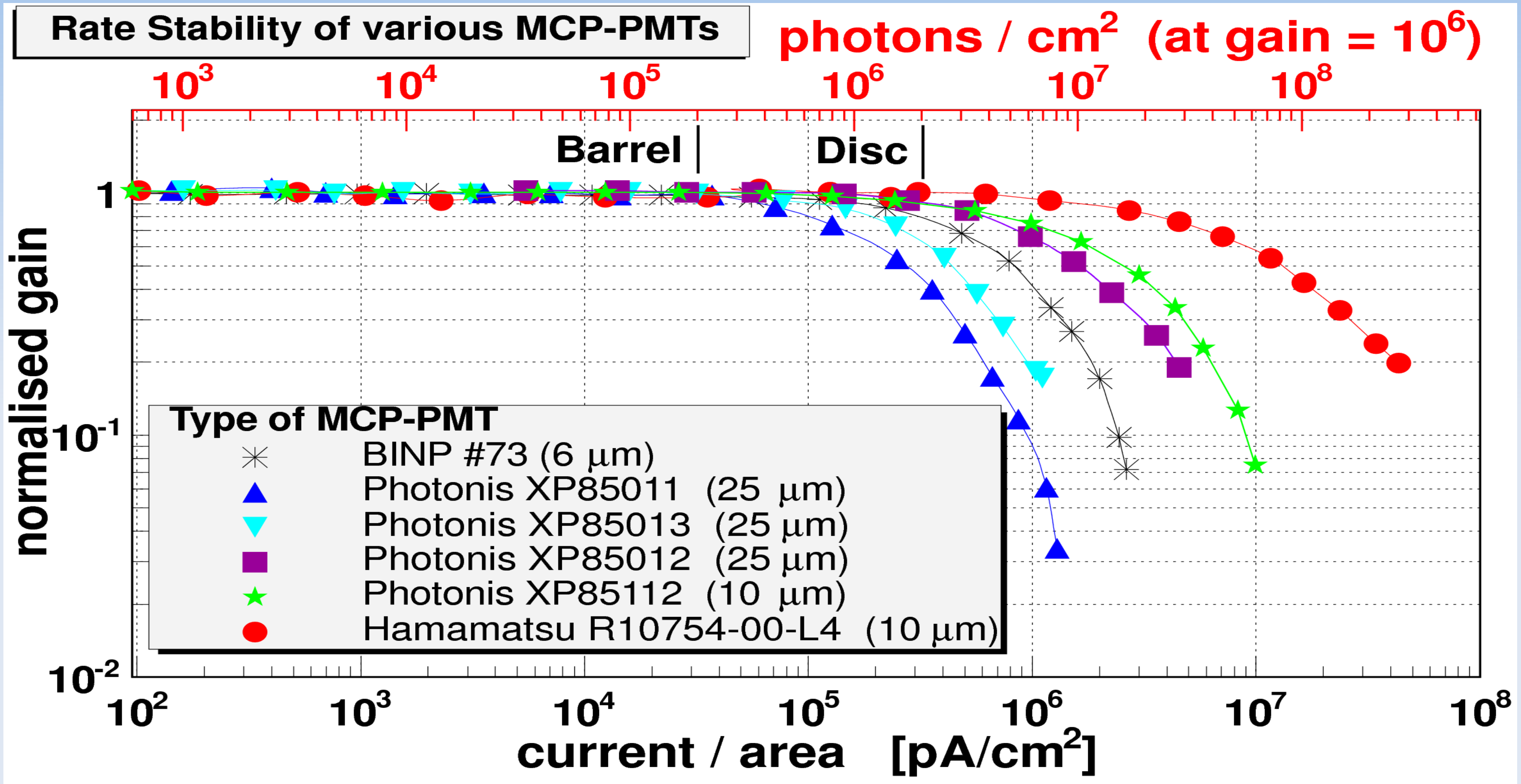
XP85112 Single Photon Time Resolution

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



- time resolution < 35 ps
- also no dependence on the B-field, but a worse time resolution due to more noise at the test hall (FZ Juelich)

Rate Stability of various MCP-PMTs

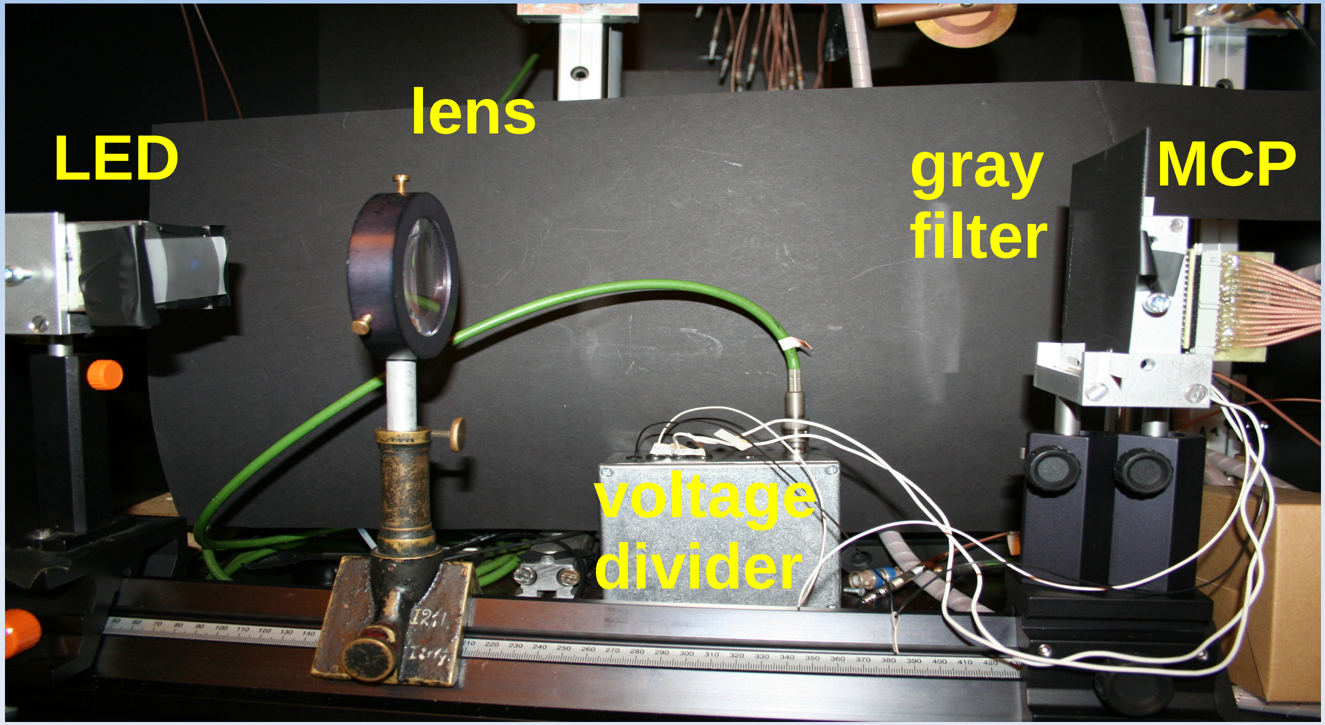


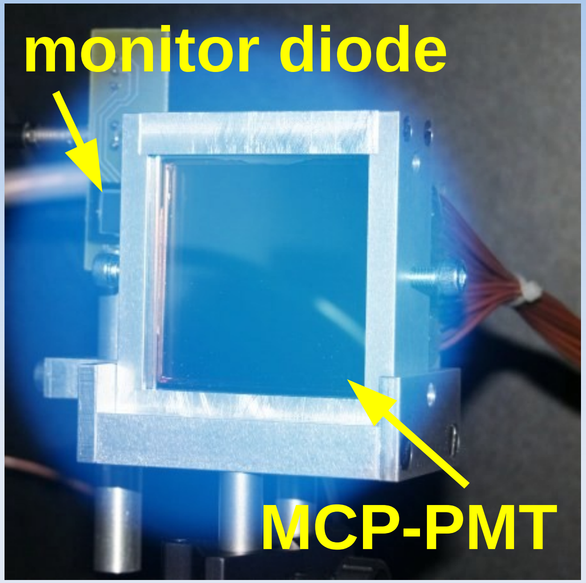
- XP85112 (10μm) and XP85012 (25μm) stable up to ~ 2 MHz/cm^2 s.ph.
- Hamamatsu R10754 stable up to ~ 7 MHz/cm^2 s.ph.

How to Measure MCP Lifetime

- Continuous illumination
  - 460 nm LED at 272 kHz rate attenuated to single photon level
  - ~0.4 photo electrons (ph.e.) per pixel → ~3.5 mC/cm^2/day
- Permanent monitoring
  - record MCP pulse heights at highly prescaled rate using CAMAC DAQ
  - measure LED light intensity using the current of a photo diode
- [Ir]regular quantum efficiency (Q.E.) measurements
  - 250–650 nm wavelength band with 1 nm monochromator resolution
  - measure current of calibrated reference diode [Hamamatsu]
  - measure current of shorted (2 MCPs and anode) MCP-PMT
- Analysis
  - calculate Q.E. from current ratio of MCP-PMT and reference diode
  - extract gain and number of ph.e. from pulse height spectra

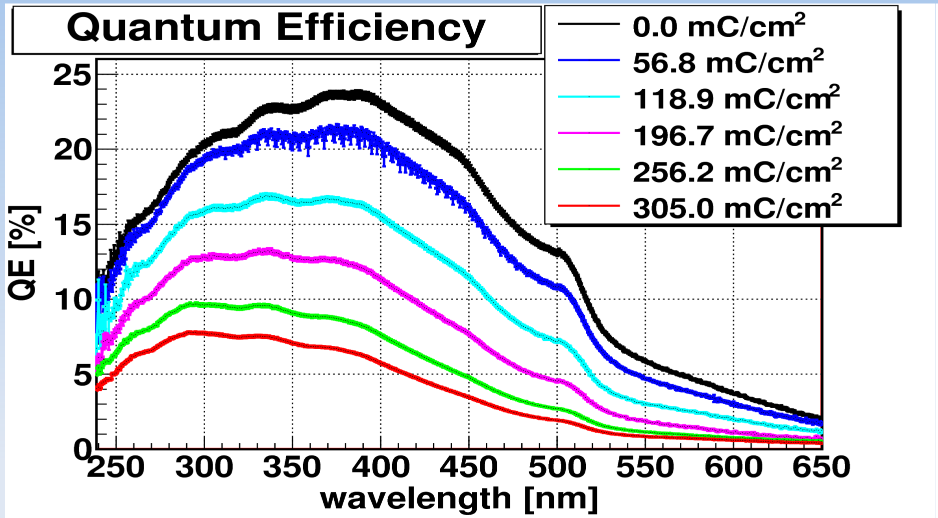
Setup for Illumination

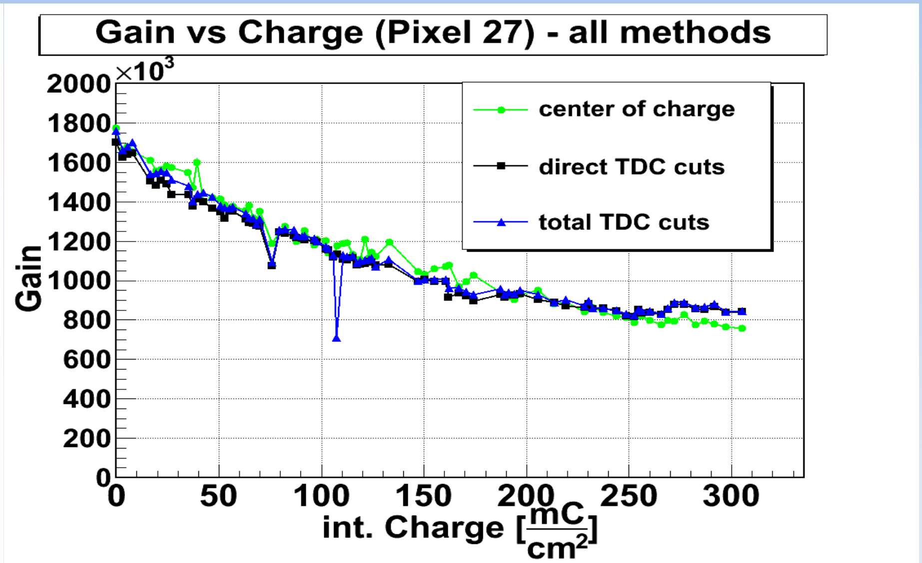


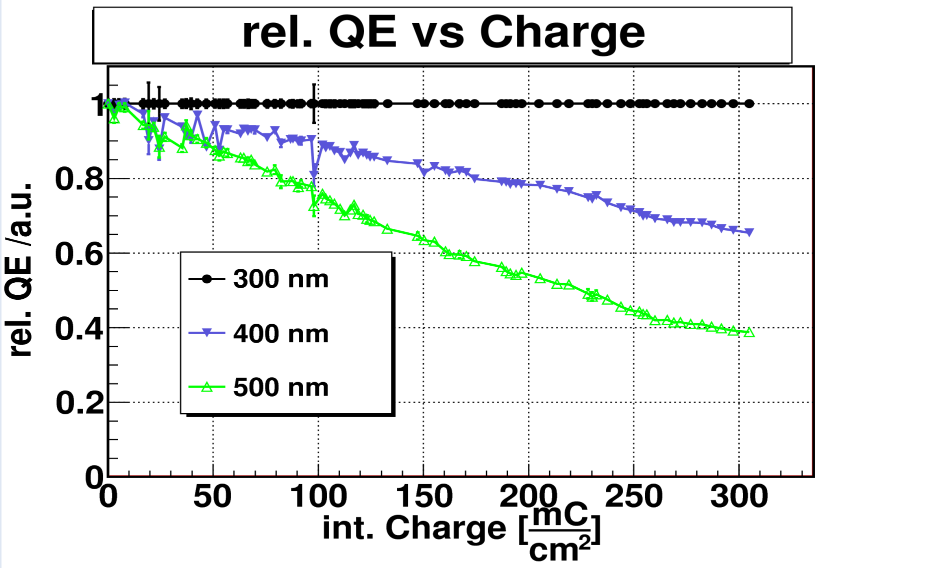


- importance of solid and repeatable setup (often taken apart)
- lens creates roughly parallel light of the LED spot
- homogeneous illumination of whole MCP (blue area of light) and monitor diode

Quantum Efficiency and Gain Photonis XP85112

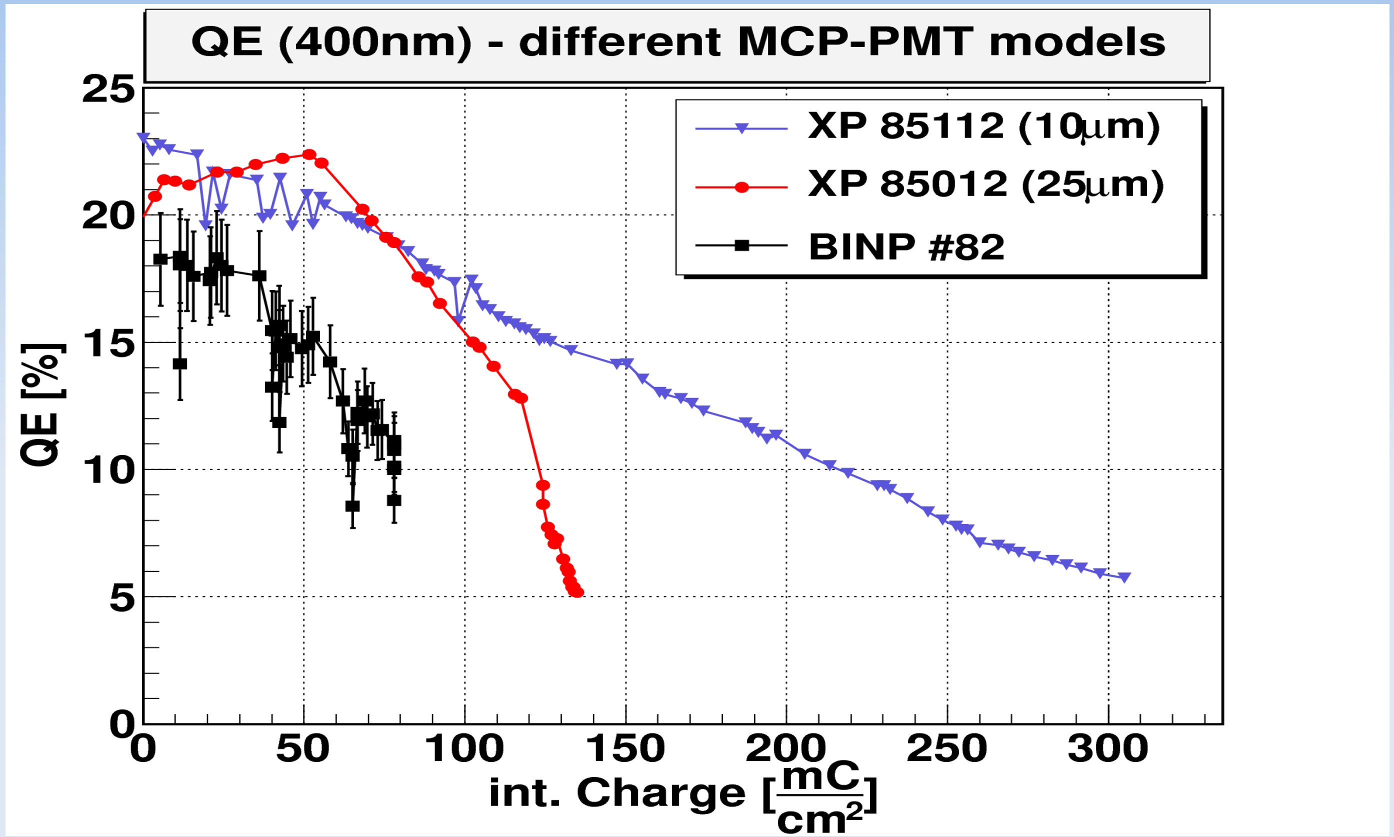






- rel. QE drops faster for higher wavelengths => absolute Maximum shifts to lower values
- Gain drops ~ 50% after 305 mC/cm²

Comparison with other MCP-PMTs



- newer models show improvement of lifetime, but minimum 1 C/cm^2/a required for Barrel-DIRC
- QE of XP85012 increases at the beginning; not observed with any other MCP-PMT so far

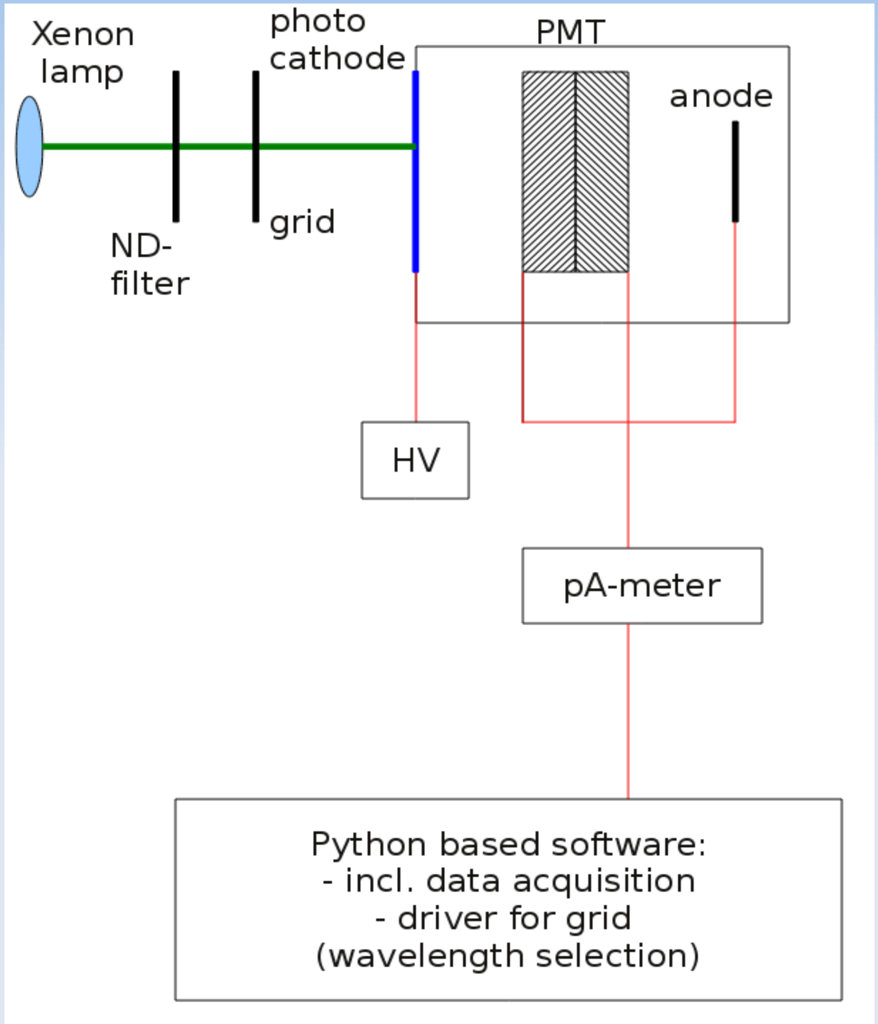
Summary and Outlook

- Photonis models XP85012 (25 µm), XP85112 (10 µm) and the Hamamatsu R10754 (10 µm) show very good performance in rate stability and time resolution, but magnetic field immunity of the 25 µm device only up to about 1 Tesla
- Lifetime result for XP85112 improved, but still not enough for the Panda DIRCs (at least 1 C/cm^2/a required for Barrel-DIRC)
- Simultaneous lifetime measurement of three devices planned
  - Photonis XP85112 which was developed for higher lifetime
  - 2x Hamamatsu R10754X with protection layer

  ($2-3\,\frac{\mathbf{C}}{\mathbf{cm}^2}$ T.Mori et al., Lifetime-extended MCP-PMT, NIMA 629, p. 111-117, 2011)

Thank you for your attention!

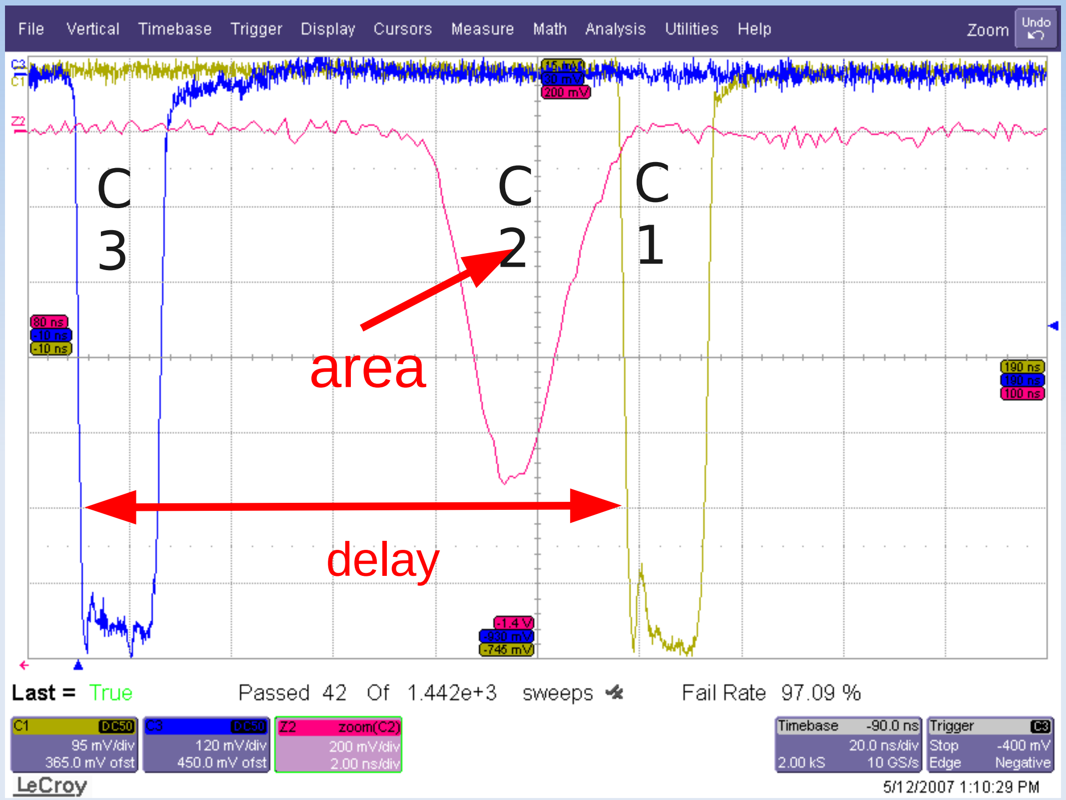
Quantum Efficiency measurement



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

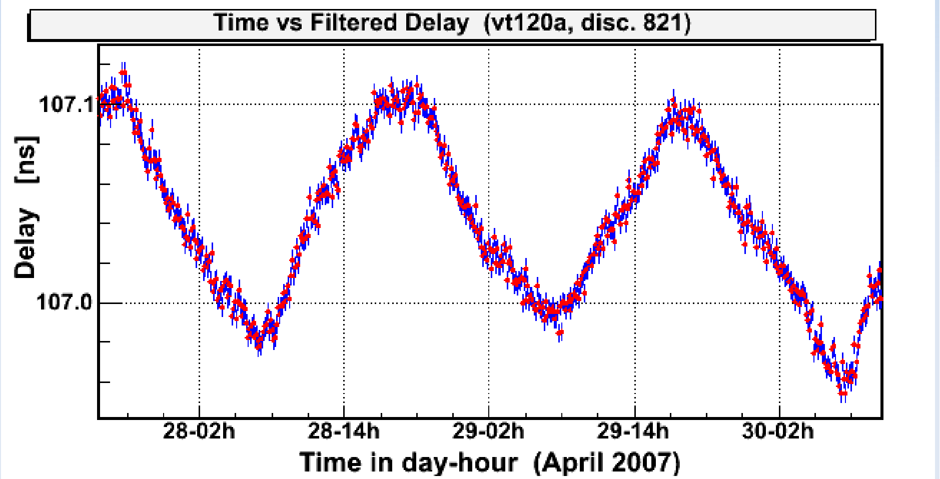
- Wavelength is selected by a grid, $\Delta\lambda$ = 1nm
- Calibrated Photodiode Hamamatsu S6337-01 for measuring lamp spectra
- Xenon lamp for high resolution at blue and UV range
- MCP and anode are shorted and current is measured

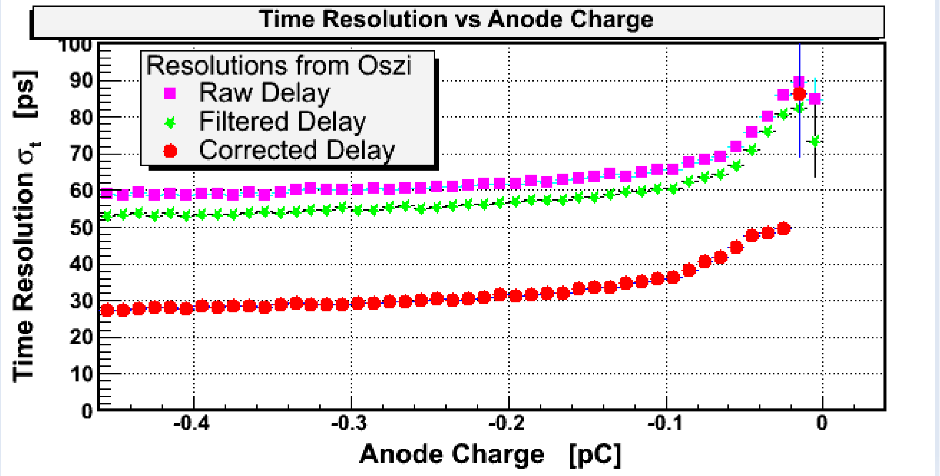
Time Resolution Measurements



- 3 GHz / 20 Gs oscilloscope
- measure area (C2)
- measure delay of PiLas reference pulse C3 to MCP pulse C1 ⇒ jitter ≡ time resolution

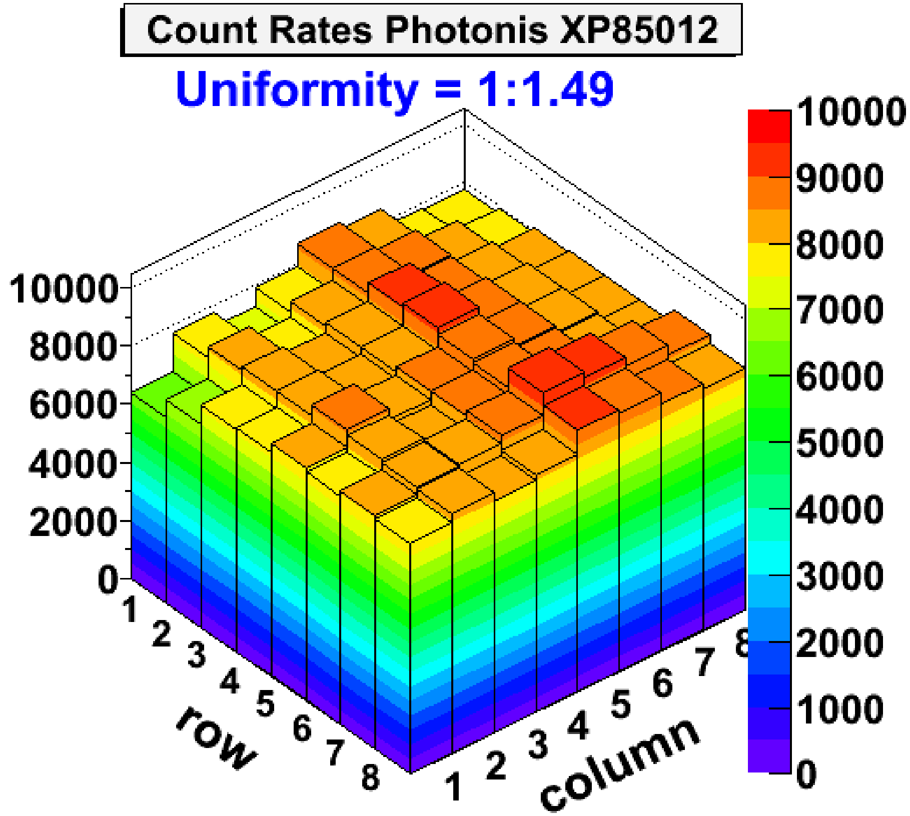
- timewalk to be corrected for
  - sampling noise of oszilloscope
  - longterm drifts in delay

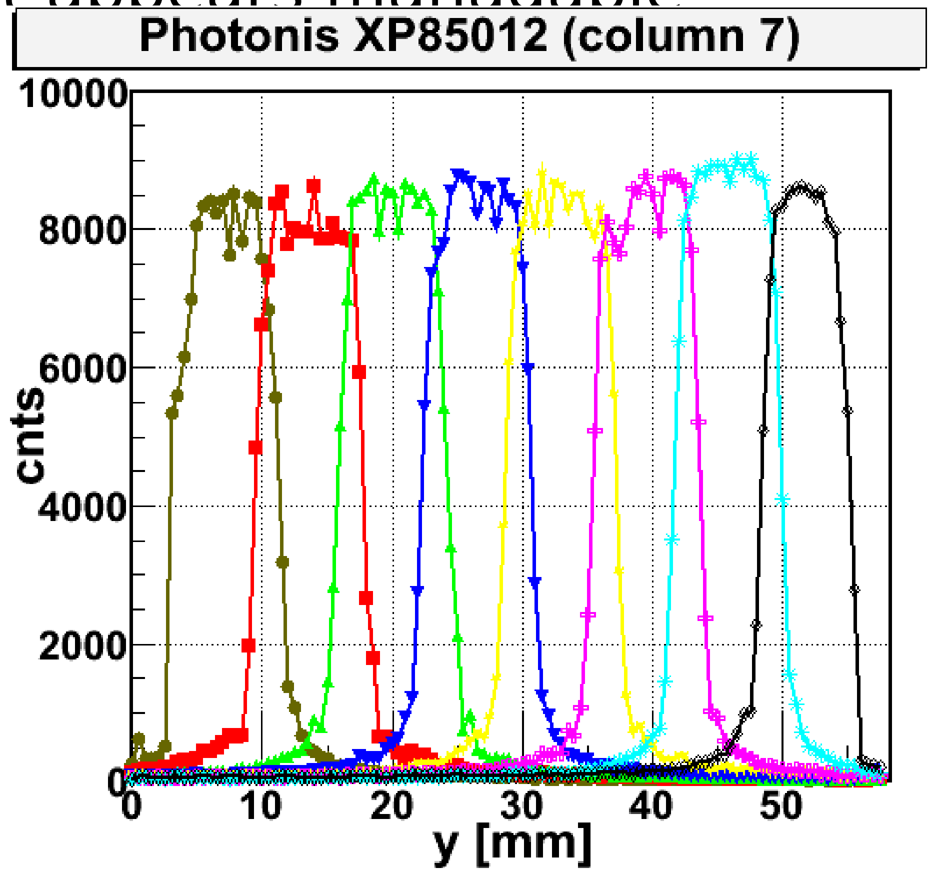




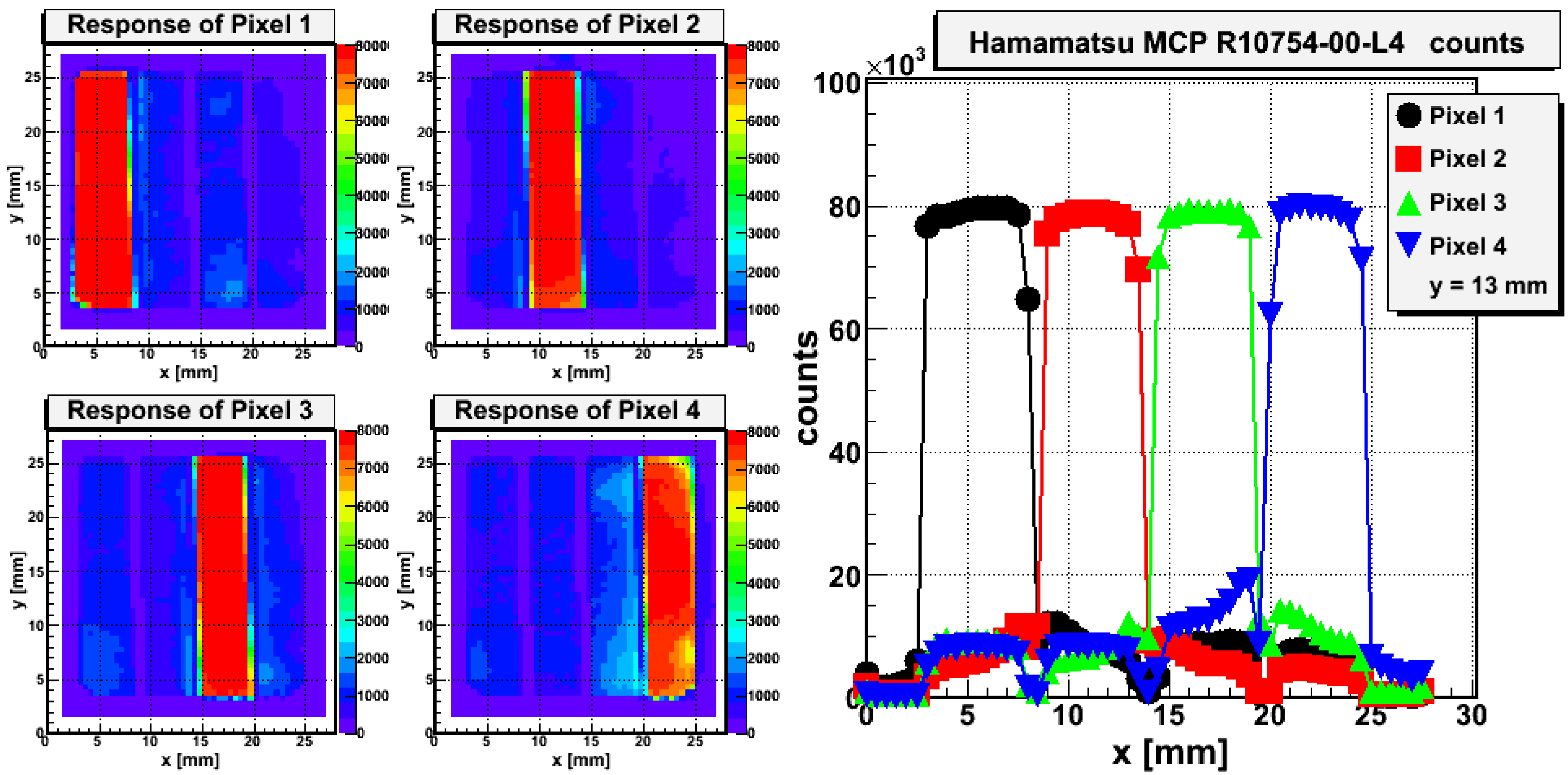
Homogeneity and Crosstalk of Photonis XP85012

- fairly flat response with **factor 1.5 variations** between pixels
- crosstalk is clearly visible but appears managable





Homogeneity and Crosstalk of Hamamatsu R10754-00-L4



- very **homogeneous response** of the individual channels
- significant **crosstalk** between the channels: can it be reduced?