Studies of MCP Properties

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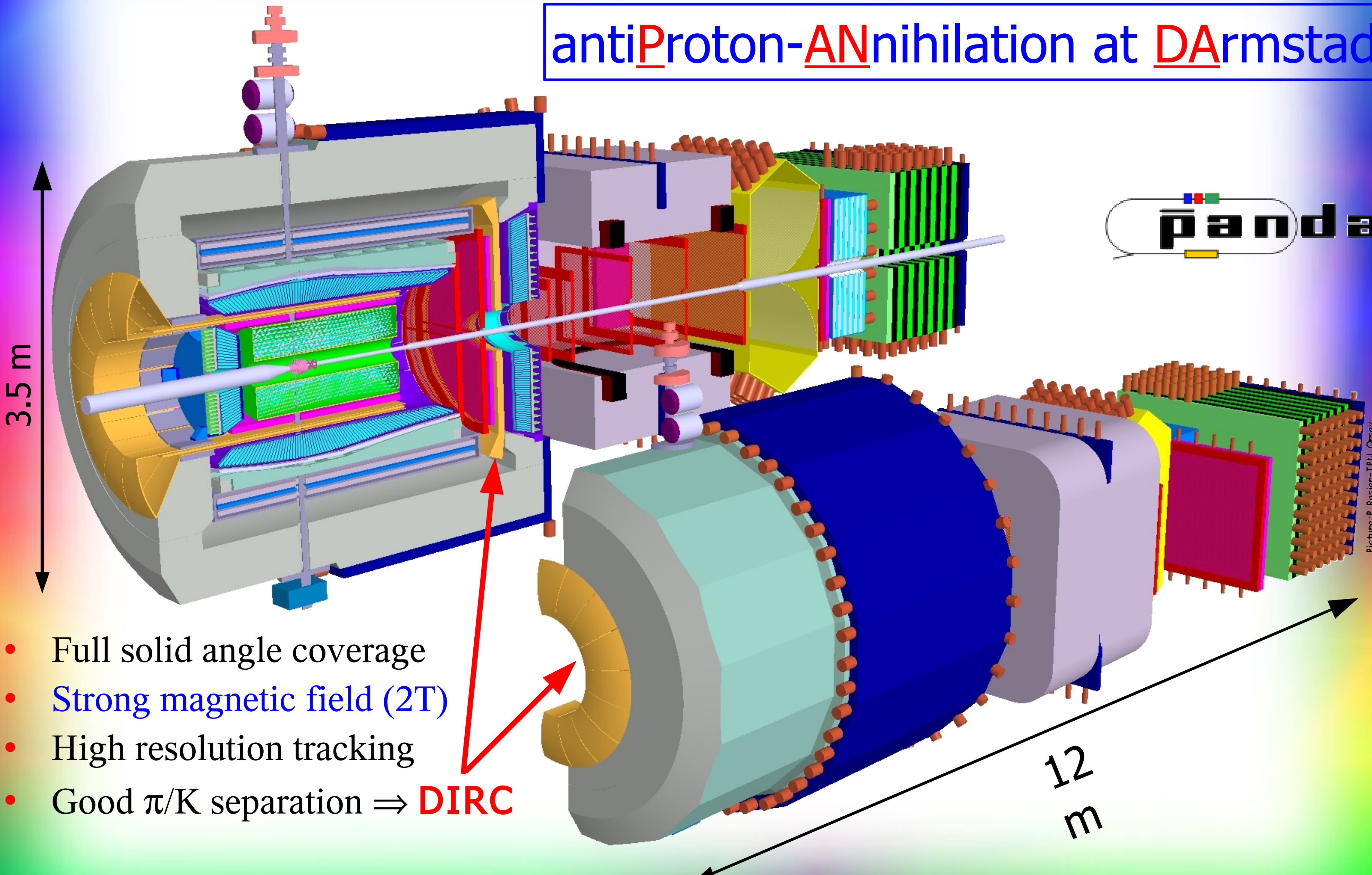
- particle identification with PANDA
- experiences with various MCP-PMTs
  - behaviour in magnetic fields
  - time resolution
  - surface scans
  - rate stability
  - lifetime

PANDA Detector

antiProton-ANnihilation at DArmstadt



- Full solid angle coverage
- Strong magnetic field (2T)
- High resolution tracking
- Good π/K separation ⇒ **DIRC**

Technical Challenges to Photon Sensors

- Single photon detection inside high B-field
  - **high gain** (> $5*10^5$) even in the 2 Tesla magnetic field
- Time resolution to separate π/K with TOP
  - **very good time resolution** of < 50 ps for single photons
- Photon rates in the MHz regime
  - **high rate stability** (rates of several MHz/cm^2)
  - short pulses (< 10 ns) to avoid pile-up
  - **long lifetime**
- Few photons per track
  - **high detection efficiency** η = QE * CE * GE
    [QE = quantum efficiency; CE = collection efficiency; GE = geometrical efficiency]
  - **low dark count rate**

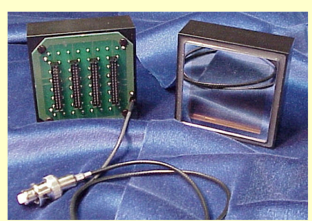
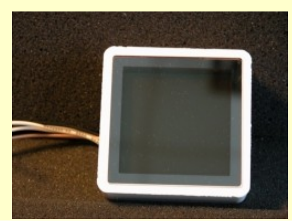
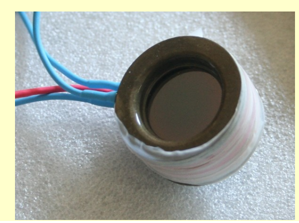
Sensor Candidates

good geometrical resolution over a large surface needed
→ **multi-pixel sensors**

- multi-anode photomultipliers (MaPMTs)
  - (more or less) ruled out by magnetic field
- hybrid photo detectors (HPDs)
  - too bulky
- **Geiger-mode avalanche photo diodes** (SiPMs)
  - noise problematic
- **micro-channel plate photomultipliers** (MCP-PMTs)
  - problems with lifetime and rate stability

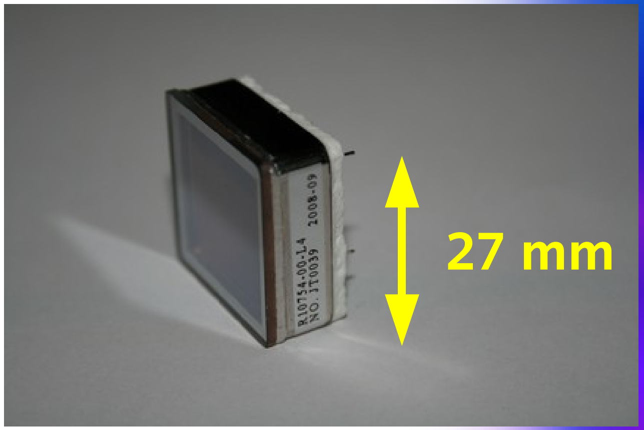
Investigated MCP-PMTs

	Burle 85011	Burle Prototyp	BINP	Hamamatsu SL10
pore size (µm)	25	10	6	10
number of pixels	8x8	8x8	1	4x1
active area (mm²)	51x51	51x51	$9^2\ \pi$	22x22
total area (mm²)	71x71	69.5x69.5	$15.5^2\ \pi$	27.5x27.5
geometrical efficiency	0.44	0.47	0.36	0.61
peak Q.E.	@ 400 nm	@ 400 nm	22% @ 480 nm	20% @ 300 nm
protection layer	none	none	5-10 nm Al_2O_3	none

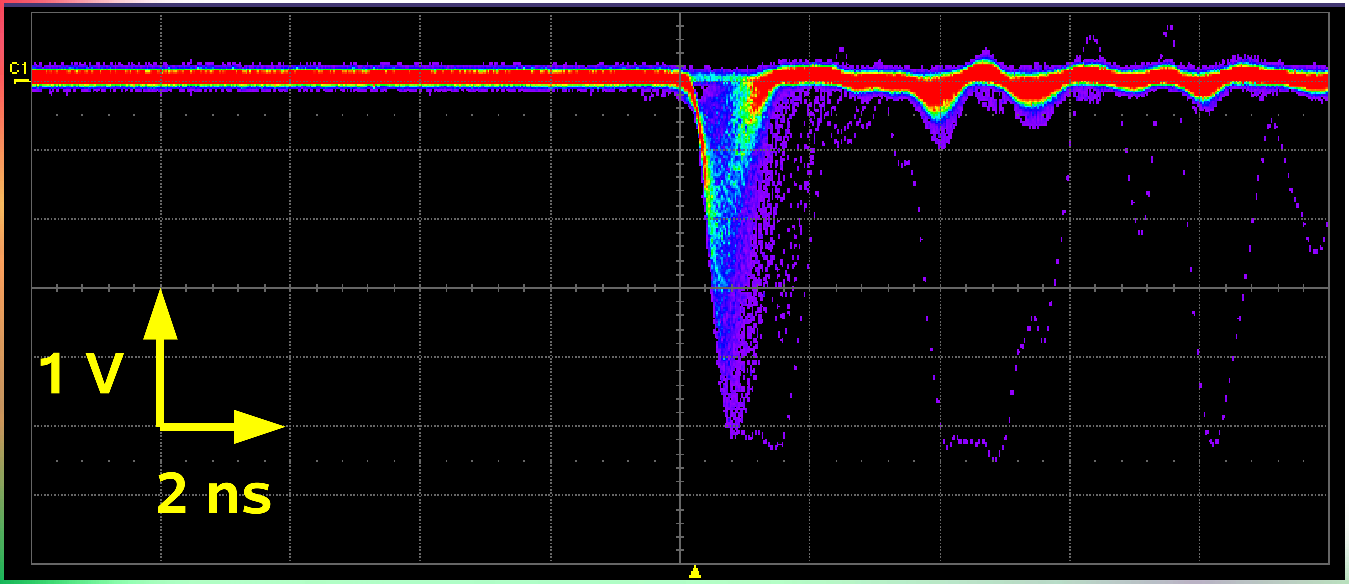





Hamamatsu MCP-PMT (R10754-00-L4)

- first impressions of R10754-00-L4 (= SL10)
  - bulky voltage divider
  - very fast signals (~750 ps FWHM)
  - problems with some standard discriminators
- appears to be rather fragile !!



linear array of 4 pixels with 20x5 mm^2

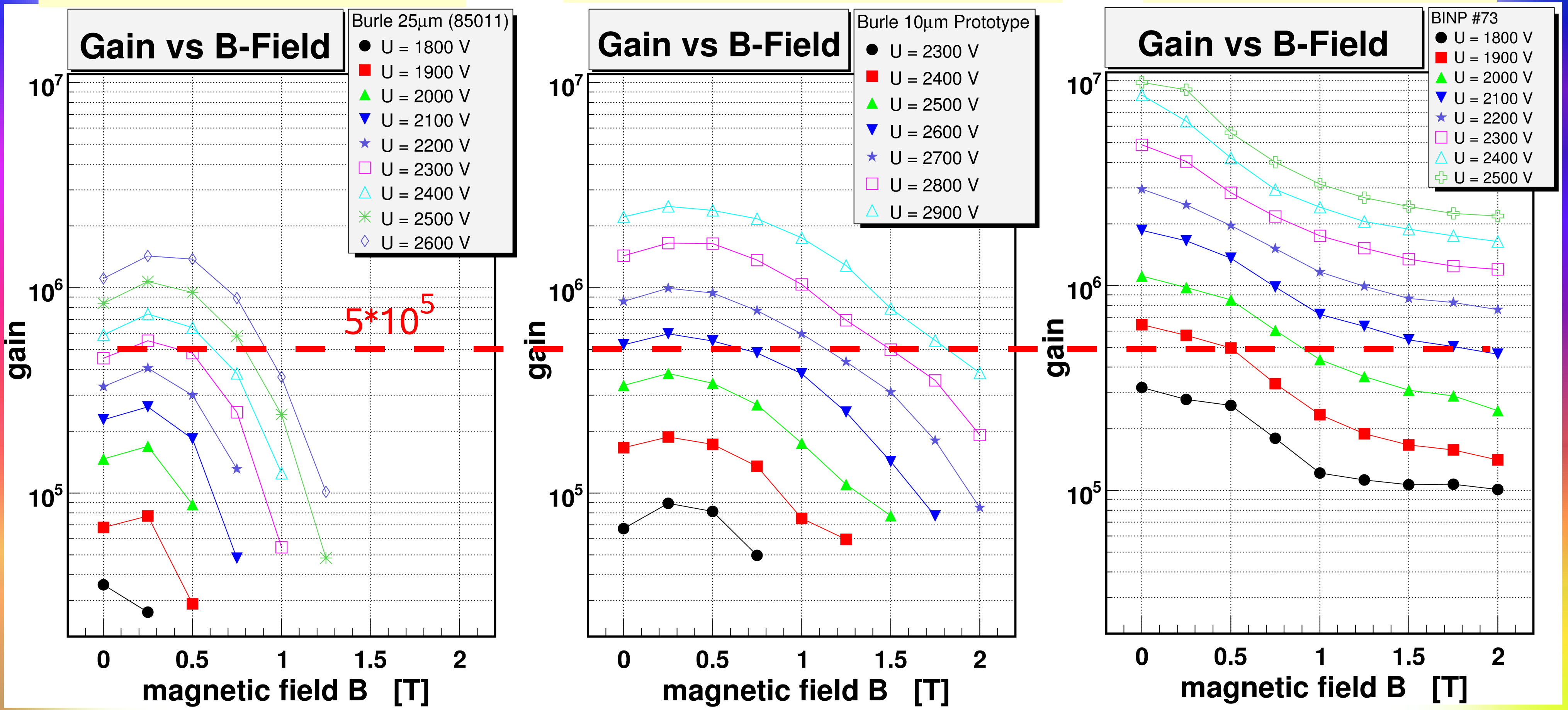


Tools for MCP-PMT Studies

- Light source
  - PiLas light pulser (pulse width 14 ps (σ); λ = 372 nm)
  - light transport through glass fibers, micro lenses and gray filters
- Fast oscilloscope
  - LeCroy WavePro7300 (3 GHz; 20 Gs/s)
  - very useful for precise time resolution measurements
- CAMAC and VME DAQ
- Dipole magnet
  - homogeneous field up to 2.05 T (6 cm pole shoe gap)
- XY-Scanner
- Setup for Quantum Efficiency measurements
  - halogen lamp (λ = 300-800 nm) and monochromator ($\Delta\lambda$ = 1 nm)
  - Si photo diode as reference sensor (Hamamatsu S6337-01)

Gain in Magnetic Field

Burle 85011 (25µm) | Burle Prototype (10µm) | BINP #73 (6µm)

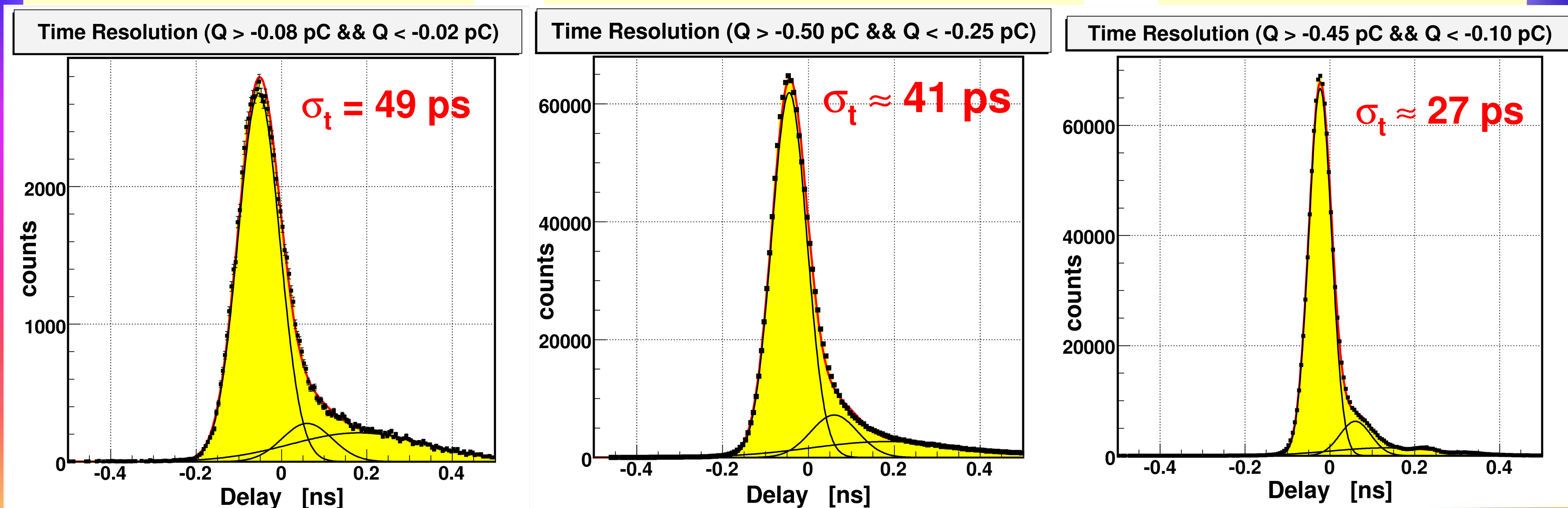


pore size ≤10 µm needed for single photon detection in 2 T field

Time Resolution

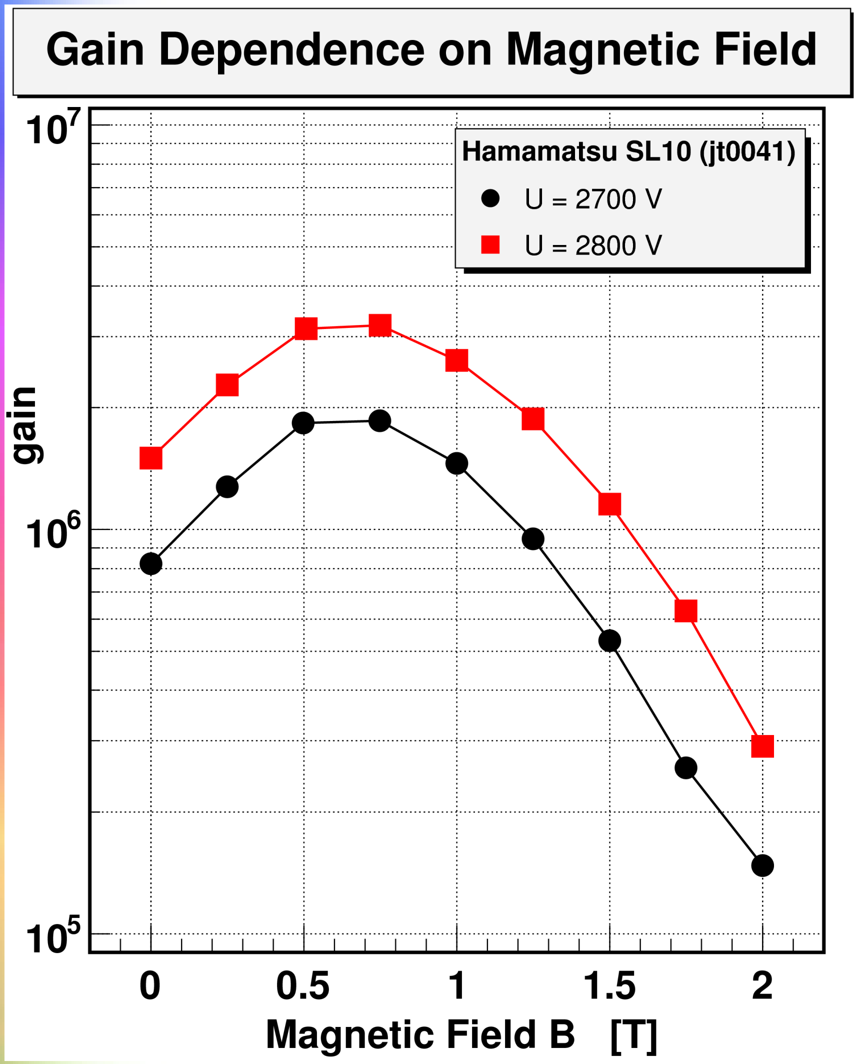
Amplifier Ortec VT120A (x200; 350 Mhz) --- Discriminator LeCroy 821

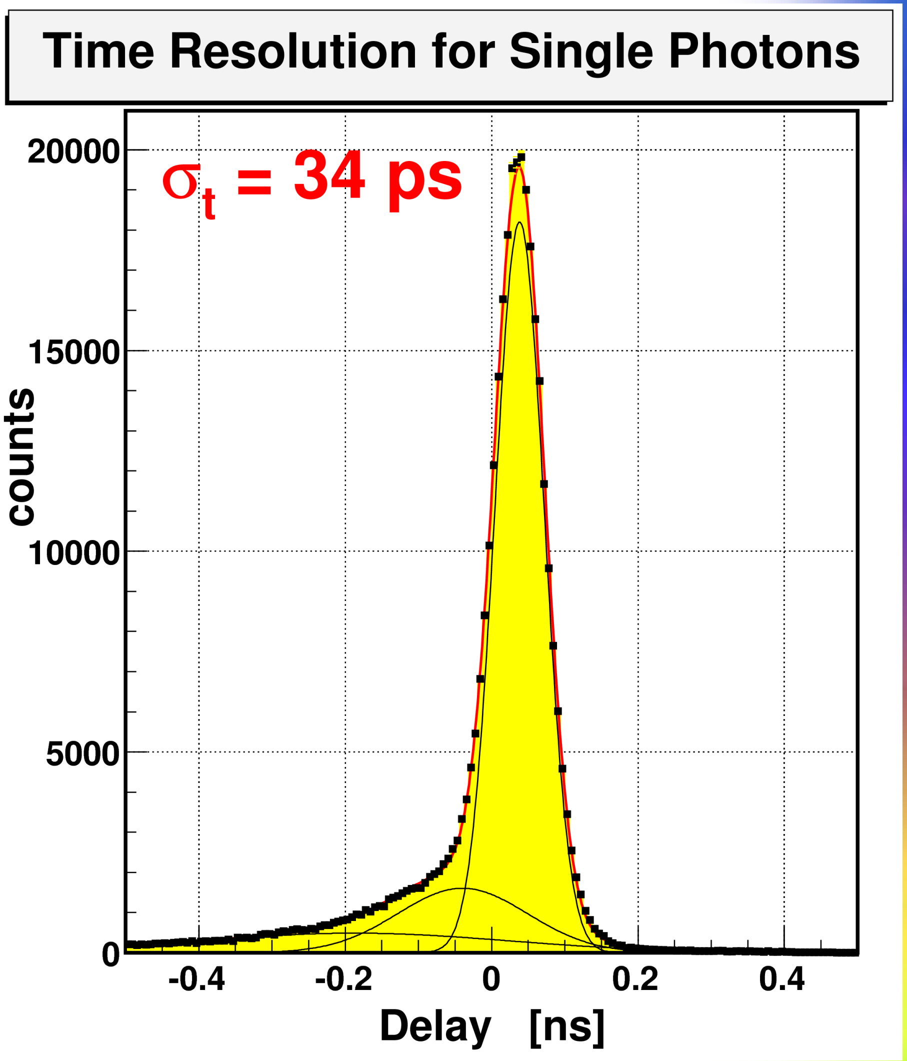
Burle 85011 (25µm) | **Burle Prototype (10µm)** | **BINP #73 (6µm)**



- single photon resolutions corrected for electronics and laser width
  - Burle 85011 (25 µm) **45 ps**
  - Burle Prototype (10 µm) **37 ps**
  - BINP #73 (6 µm) **20 ps**

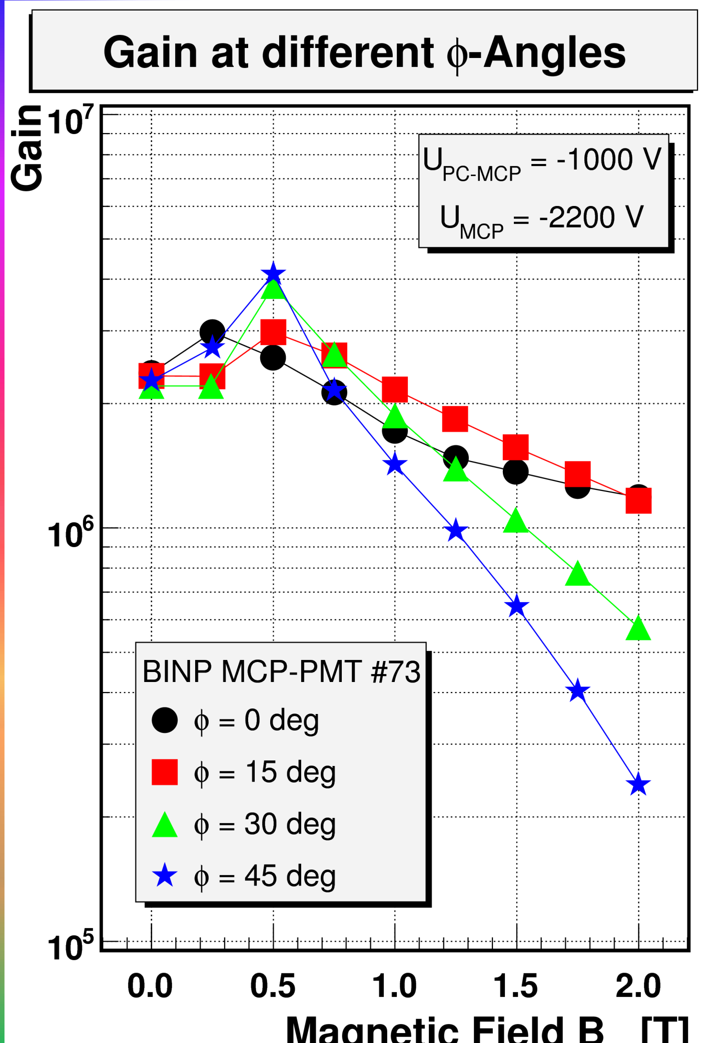
Gain and Time Resolution of SL10

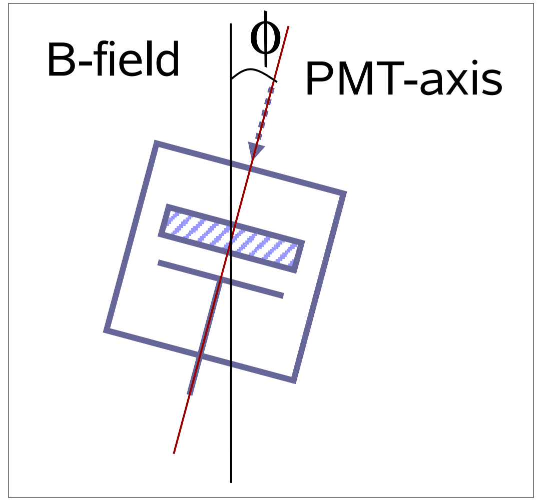




Gain Dependence on B-Field Direction

BINP #73 (6 µm)

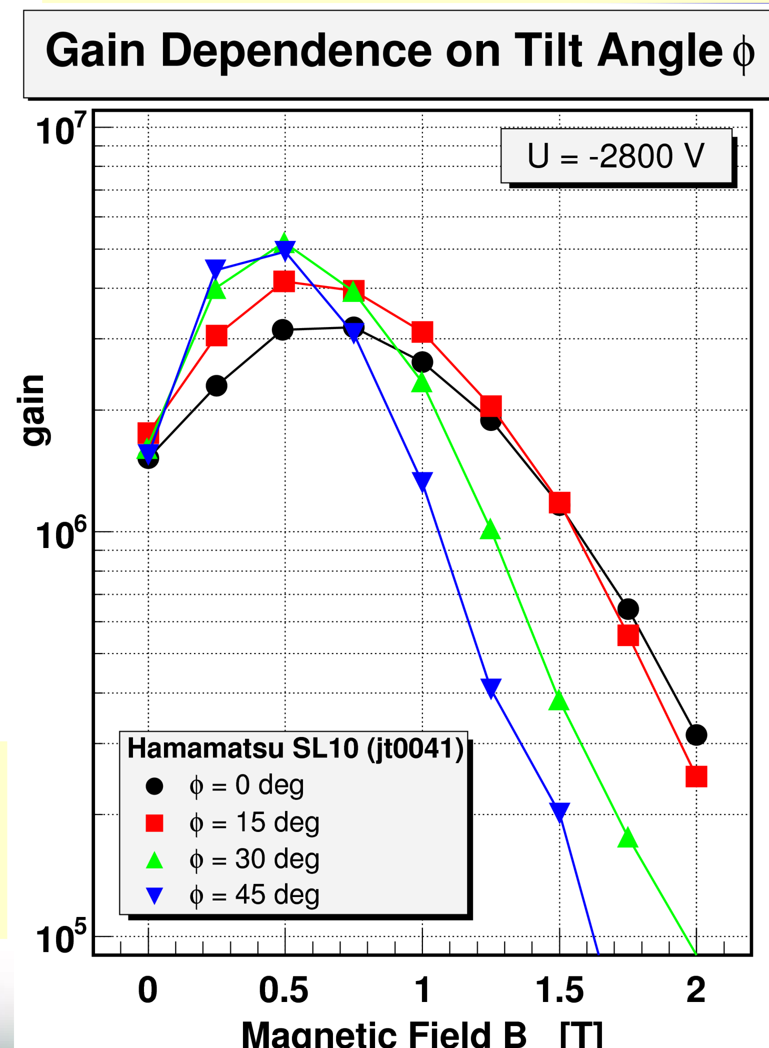




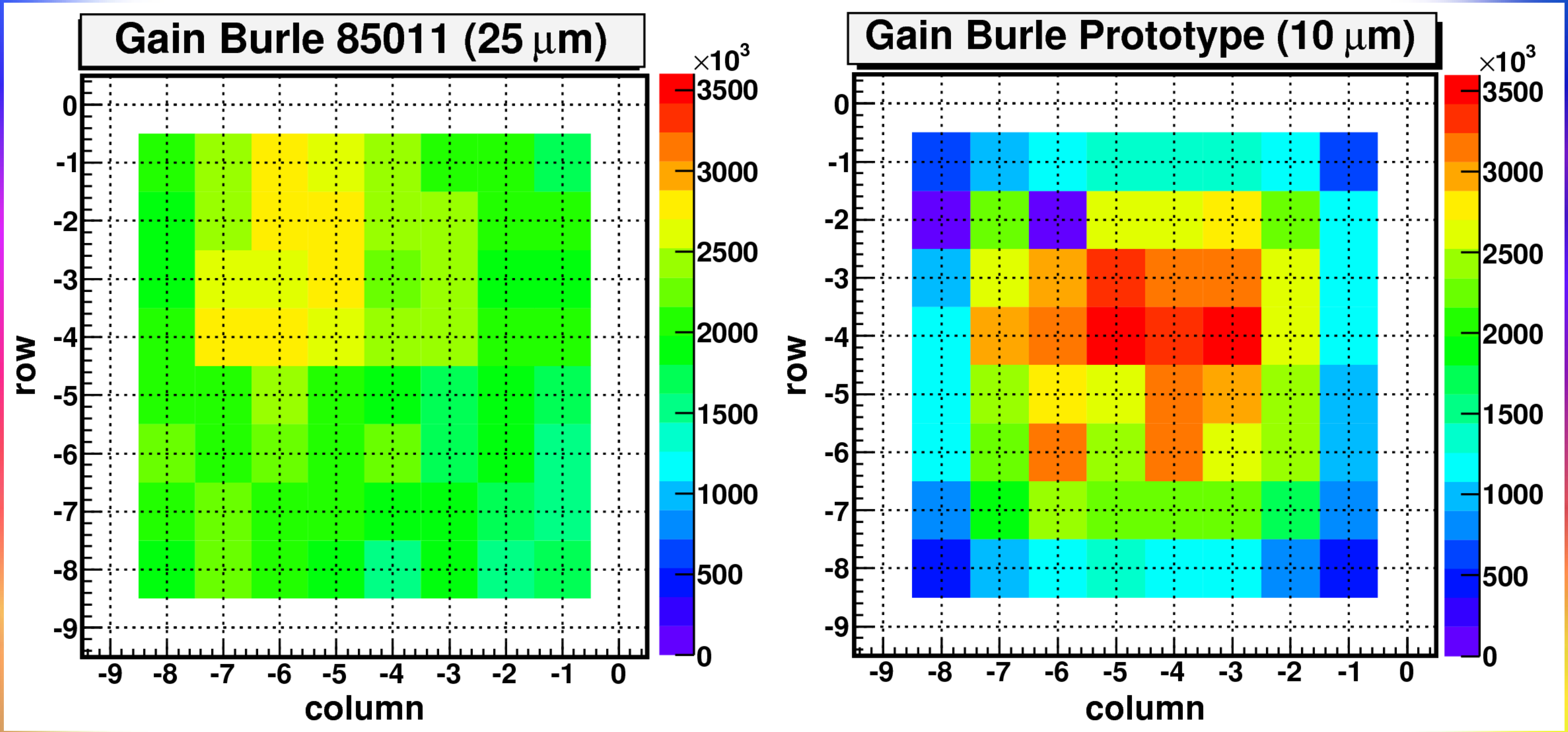
ϕ = angle between magnetic field direction and PMT-axis

Significant gain drop at large magn. fields and ϕ-angles

Hamamatsu SL10 (10 µm)



Surface Scans of Burle MCPs (**Gain**)

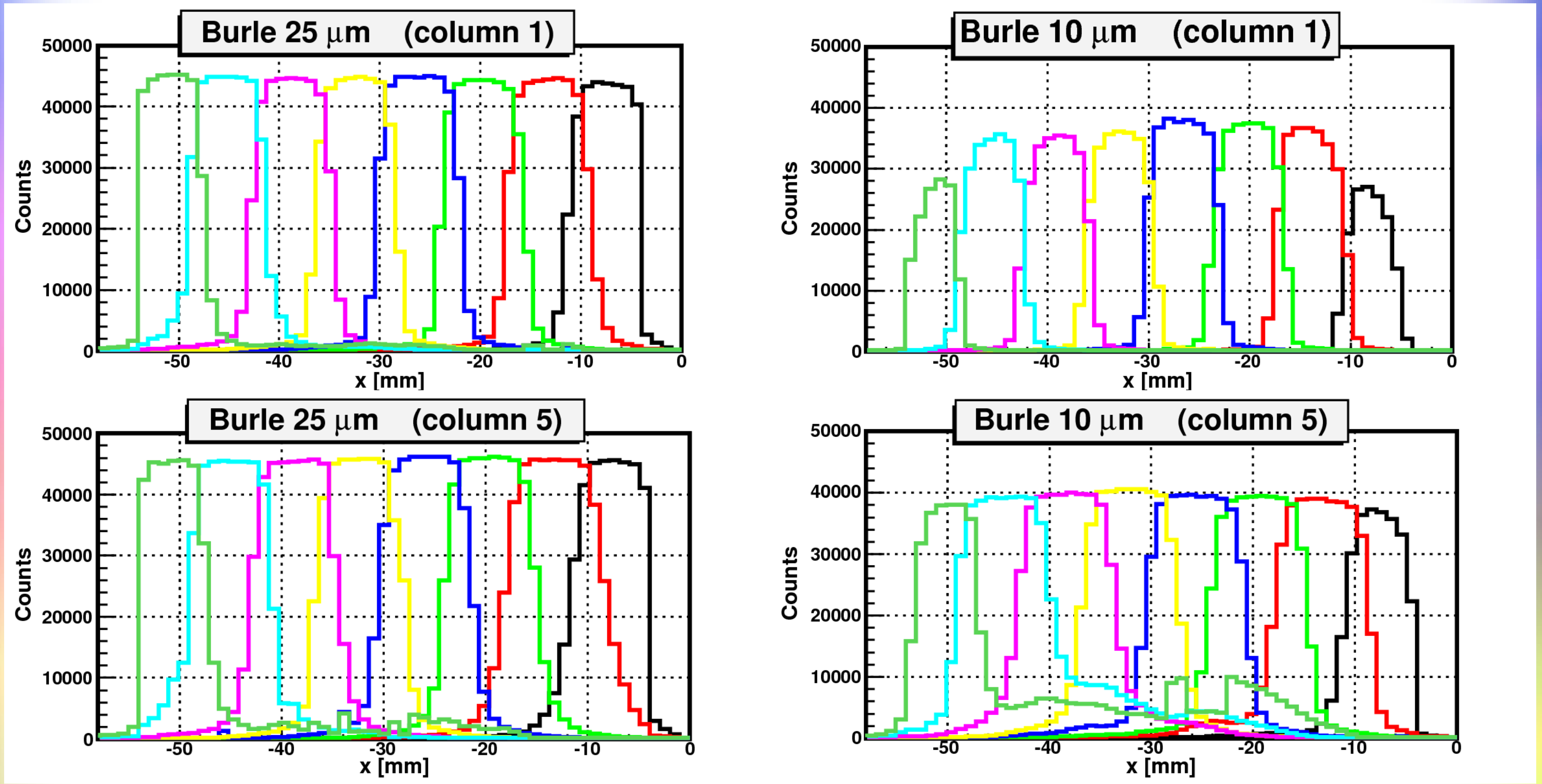


- ***Burle 25 µm:*** **almost x2 gain variations** (1.5 to $2.8*10^6$) in channels
- ***Burle 10 µm:*** **very strong gain fluctuations** (0.5 to $3.5*10^6$!!)

Surface Scans of Burle MCPs (**Crosstalk**)

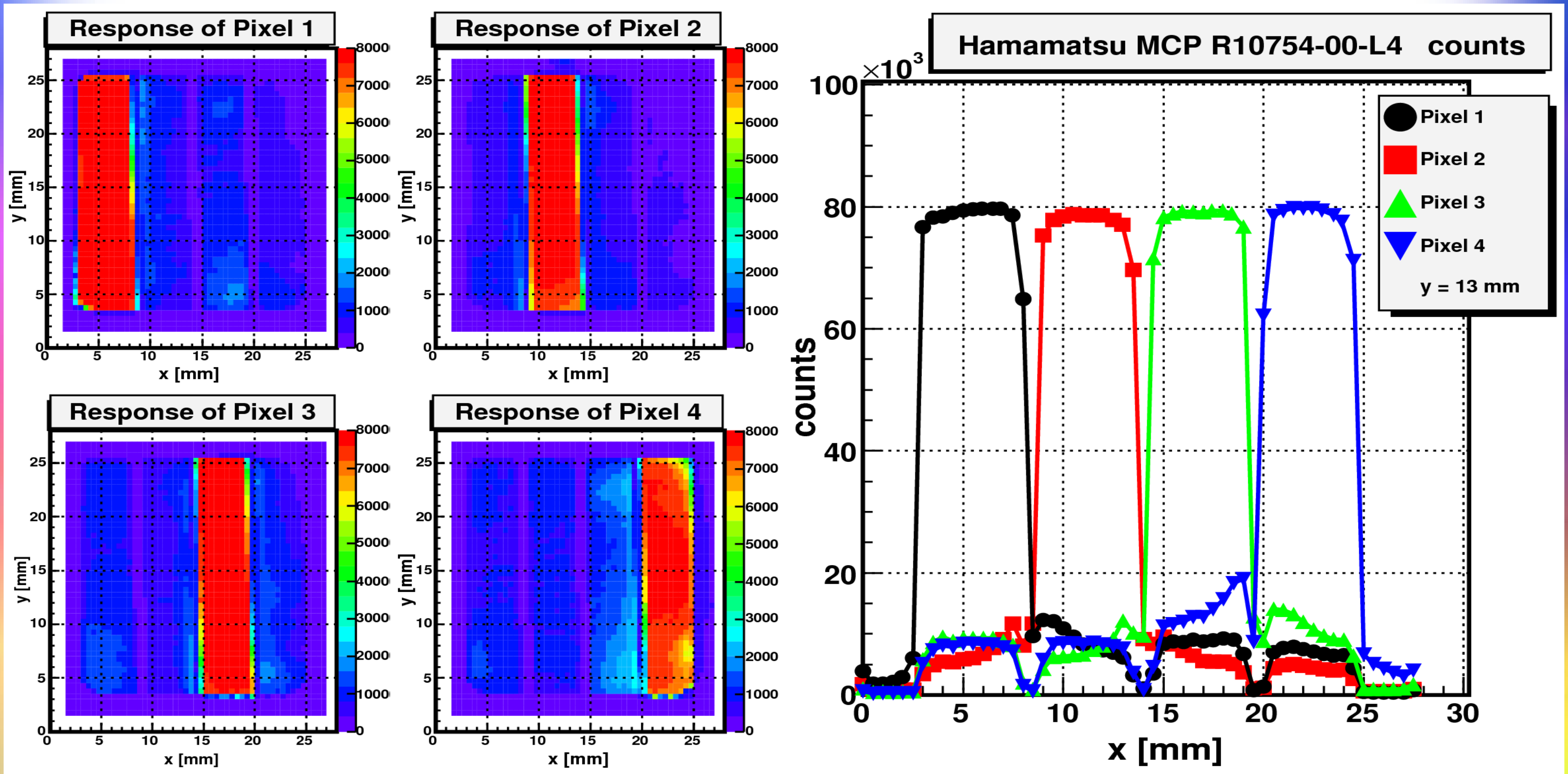
Burle 85011 (25 μm)

Burle Prototype (10 μm)



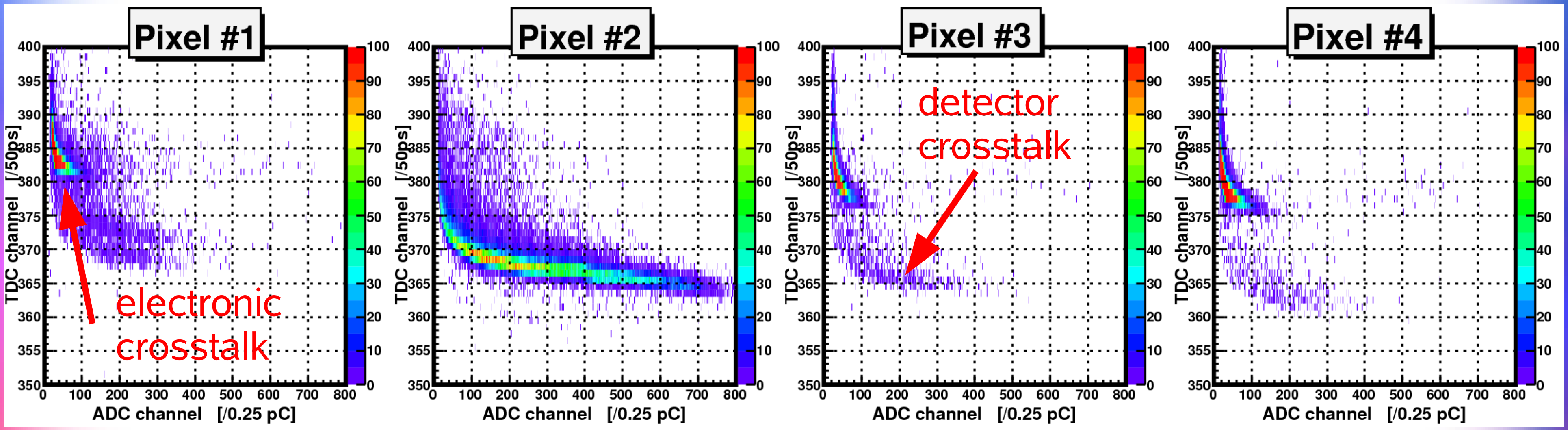
- ***Burle 25 μm:*** rather homogeneous response, but significant crosstalk
- ***Burle 10 μm:*** less homogeneous response and even more crosstalk

Surface Scans of SL10 (**Count Rates**)

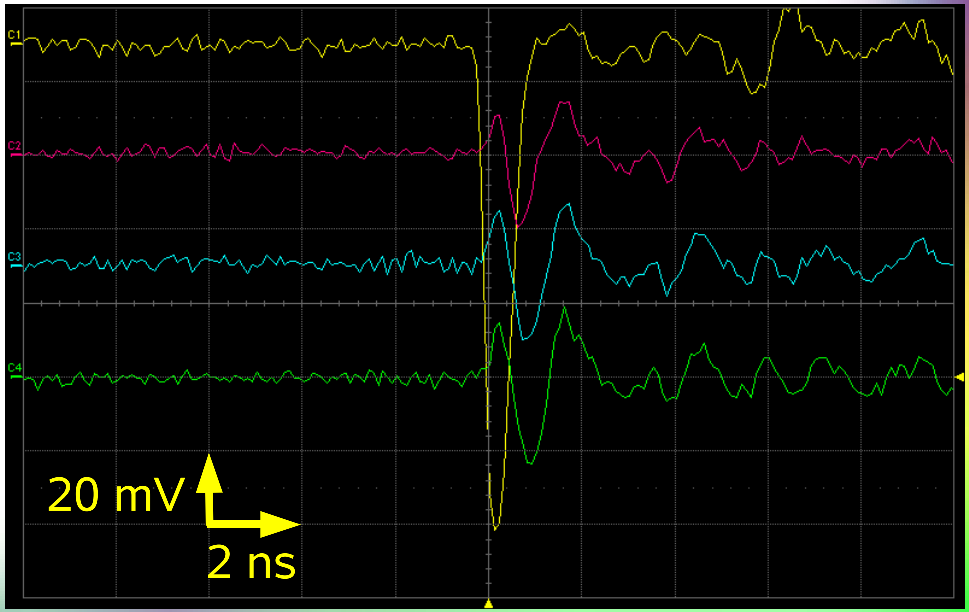


- very **homogeneous response** of the individual channels
- significant **crosstalk** between the channels

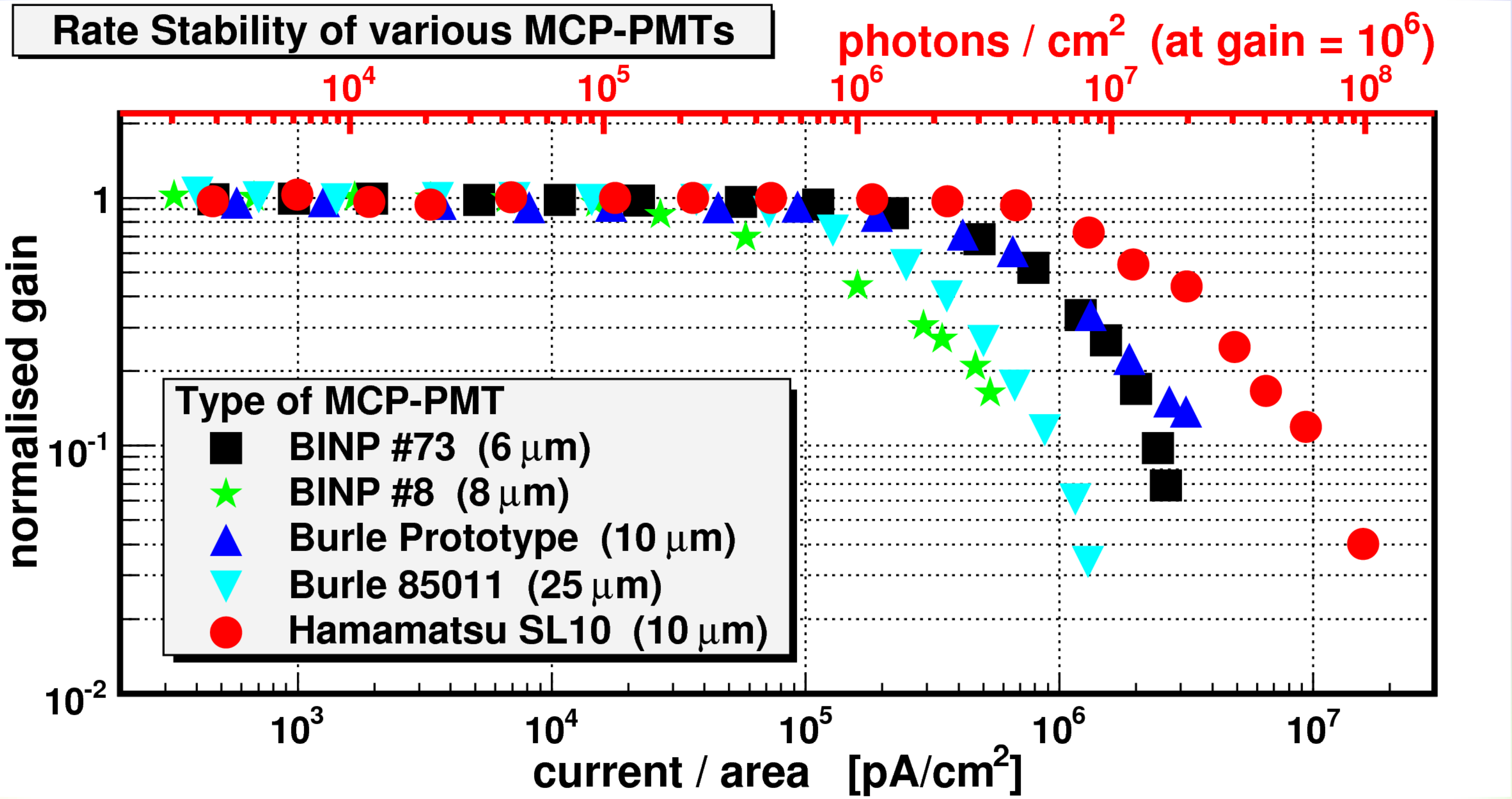
Crosstalk of SL10



- two components in timewalk distributions
  - crosstalk inside detector
  - electronic crosstalk
- separation of components possible
- electronic crosstalk probably from voltage divider



Rate Stability



- usually stable operation to about 1 MHz/cm^2 photons
- **Hamamatsu SL10 stable up to 5 MHz/cm^2** (at gain 10^6)

Overview of Sensor Performances

	DIRC required	MaPMT	**MCP-PMT**	SiPM
Gain at 0 T [* 10^6]	> 0.5	1 to 10	**1 to 10**	0.5 to 1
Gain at 2 T [* 10^6]	> 0.5	**0**	**> 0.5**	> 0.5
Time resolution [ps]	< 50	150	**< 50**	100
Rate stability [MHz/cm^2]	5 – 10	10	**5**	
Darkcount rate [kHz/cm^2]	< 10	~ 0.01	**2**	**10000**
Crosstalk behaviour	low	okay	**moderate**	
Lifetime [C/cm^2]	50 – 100		**> 3.5**	

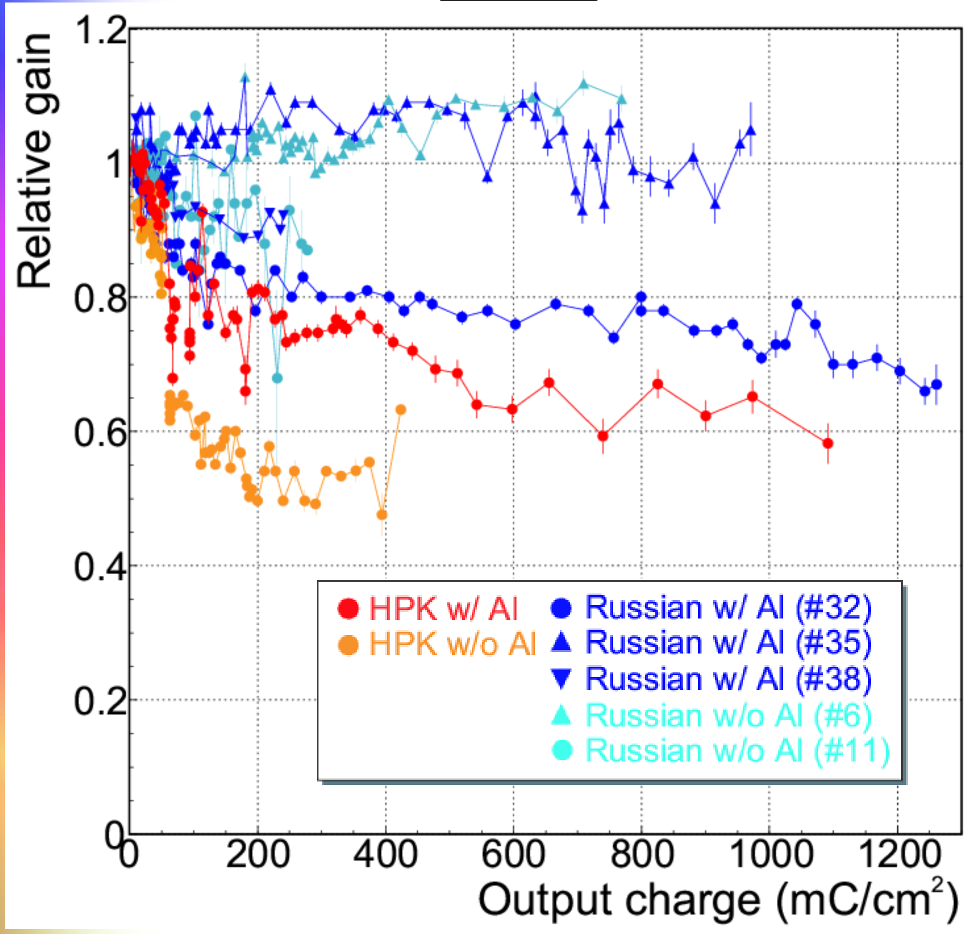
- currently there is no sensor fulfilling all requirements of the PANDA DIRCs

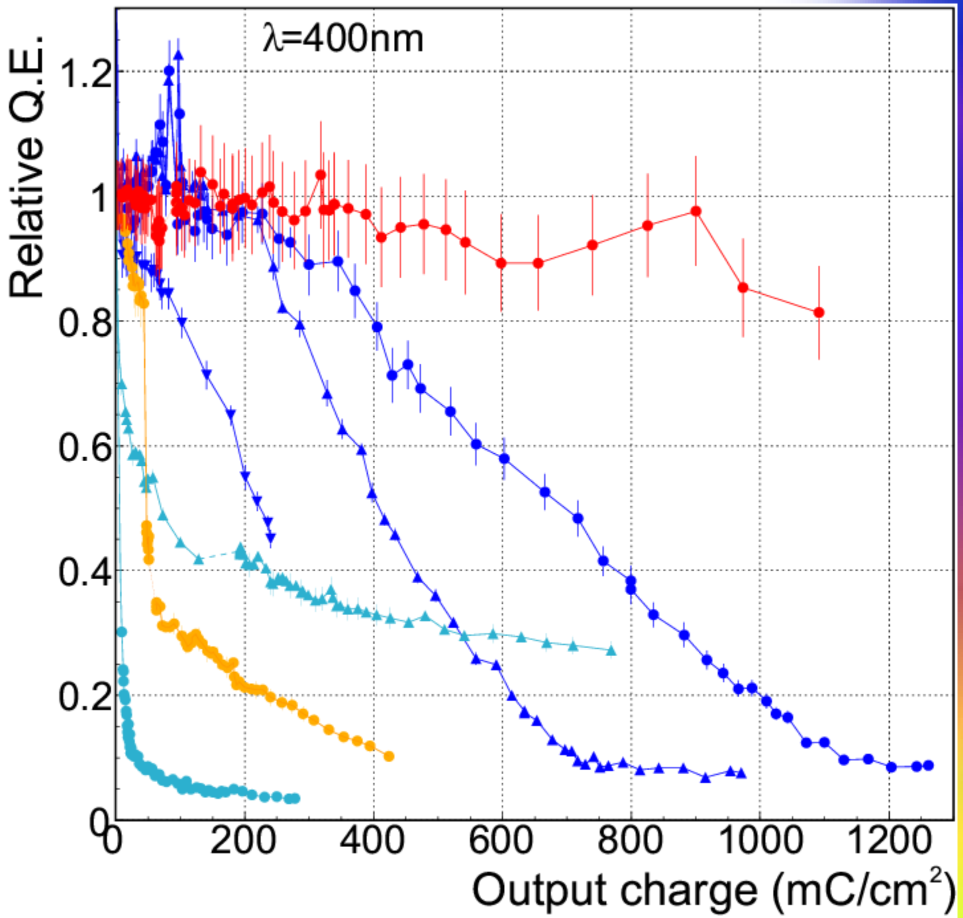
Lifetime (1)

Gain

T. Ohshima (Nagoya)
Talk at SLAC 2006

Quantum Efficiency





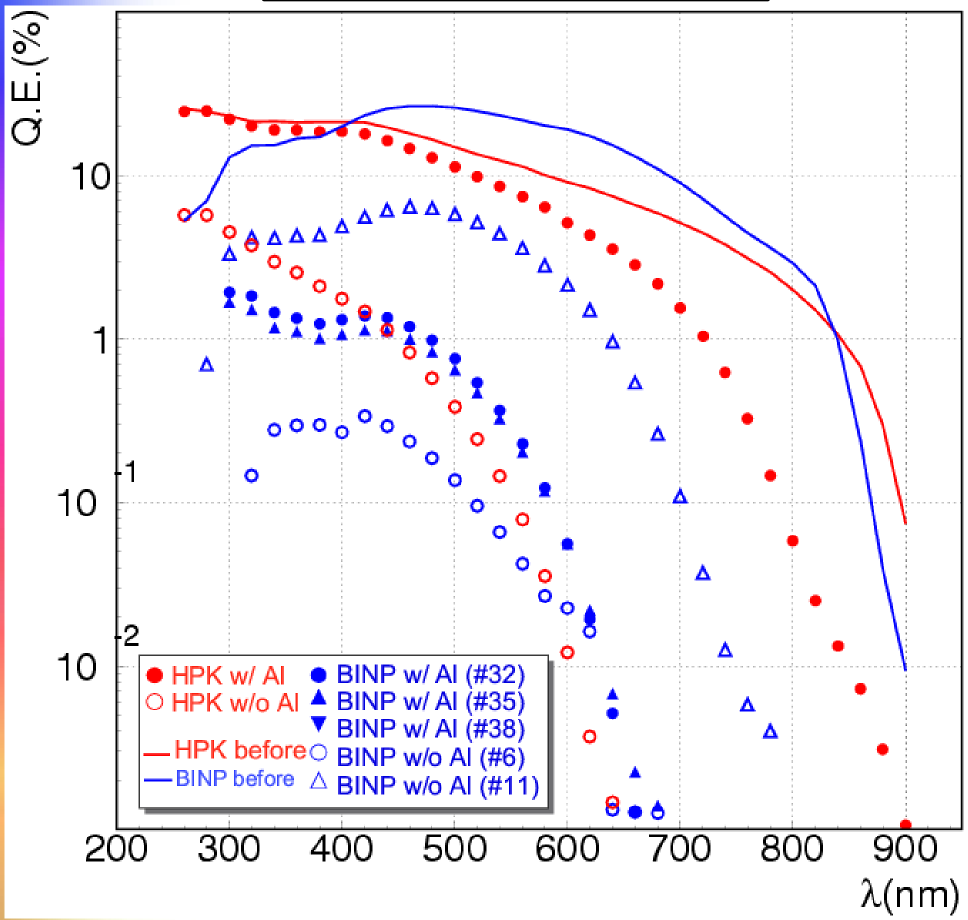
- fast gain drop first and almost constant later
- Q.E. of HPK w Al-protection almost stable up to 3.5 C/cm^2

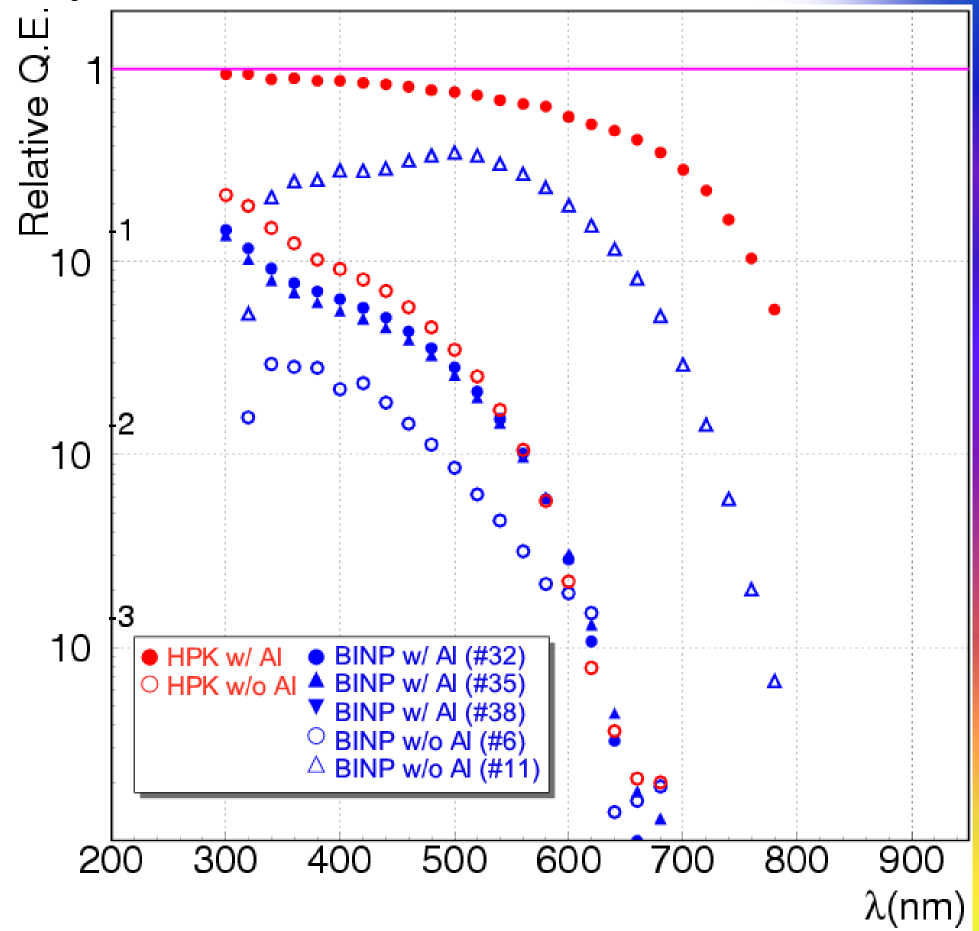
Lifetime (2)

Q.E. after lifetime test

K. Inami (Nagoya)
Talk in Saclay 2007

Q.E. ratio: after/before





- large Q.E. drop at longer wavelengths
- **less aging problems in UV region** (UV sensitive photo cathodes?)

Conclusions

- expected rates and anode charges of the PANDA DIRCs:

	total rate	anode rate (after Q.E.)	integrated anode charge
	[MHz/cm²]	[MHz/cm²]	[C/cm²/year] at 10^6 gain
Barrel-DIRC			
at upstream rim	*60*	*5.6*	*28*
at readout plane	1.7	**0.16**	**0.8**
Endcap DIRC			
TOP	19	**1.9**	**9.6**
focussing	7.5	**0.76**	**3.8**

- MCP usage probably possible for Barrel DIRC
- lifetime issue is very critical for Endcap DIRC
  - Could we use only photons of a narrow UV band?
  - alternative sensors?