Progress in Erlangen and Thoughts about Limitations of MCP-PMTs

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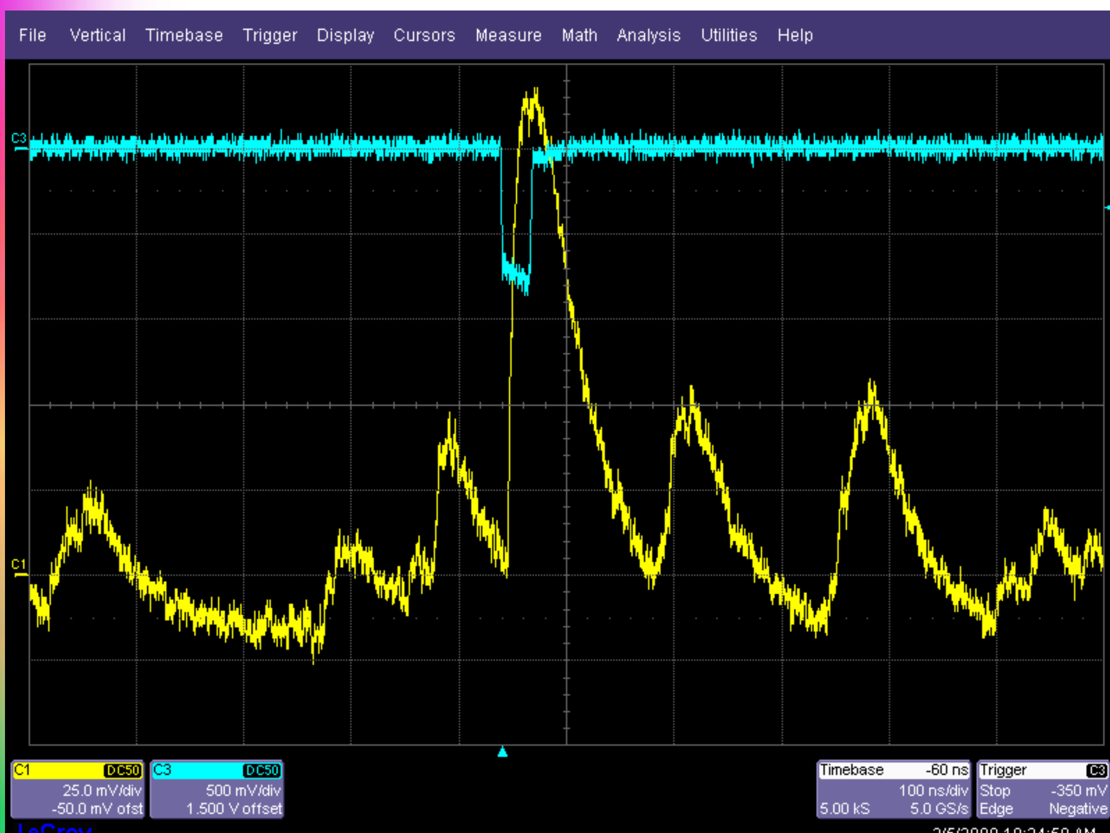
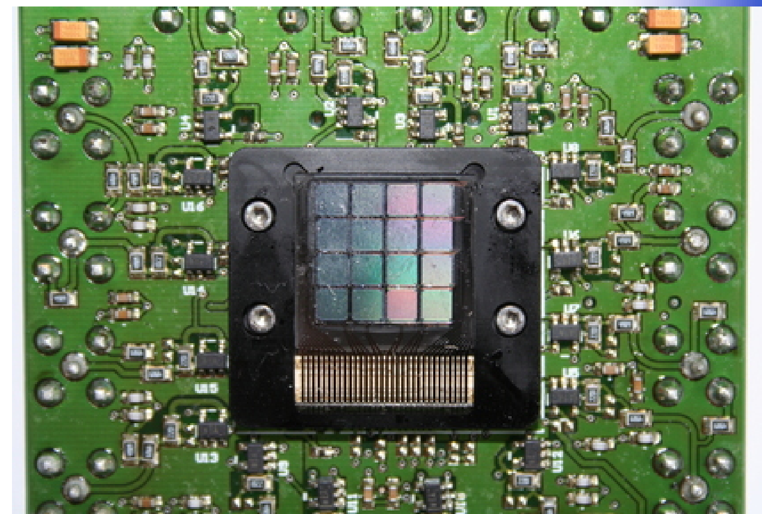
- Status in Erlangen
- Rate stability
- Lifetime
  - limiting factors
  - possible improvements

SensL SPMArray

- active area 12x12 mm^2 with 4x4 channels (3x3 mm^2 SiPMs with 35 µm microcells)
- bias supply and amplification board (x2200 for each channel)

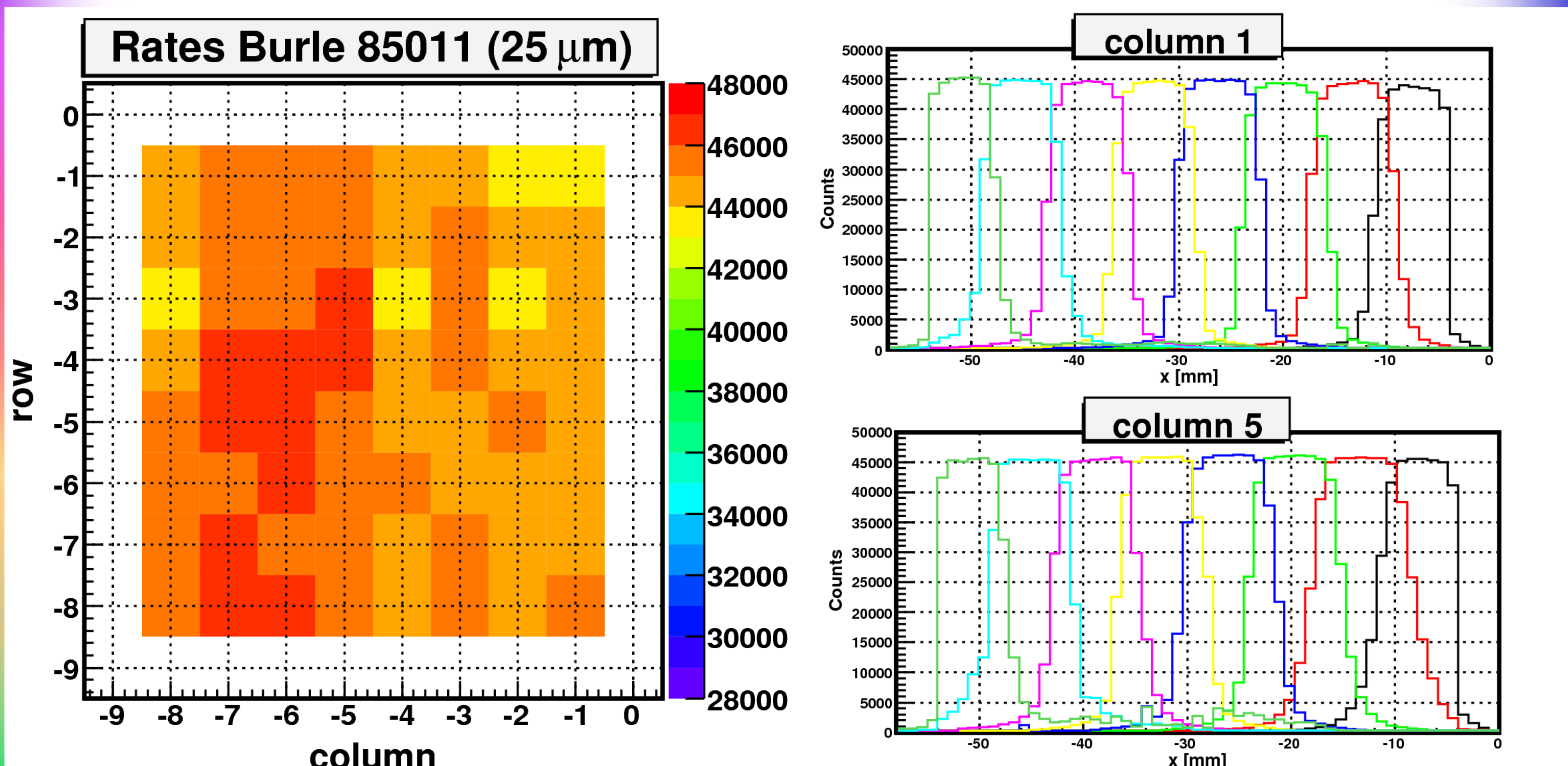




- positive signals
  - fast rise time (<10 ns)
  - width <100 ns
- enormous dark count rate
  - ~10 MHz/channel at room temperature
  - a lot of pile-up

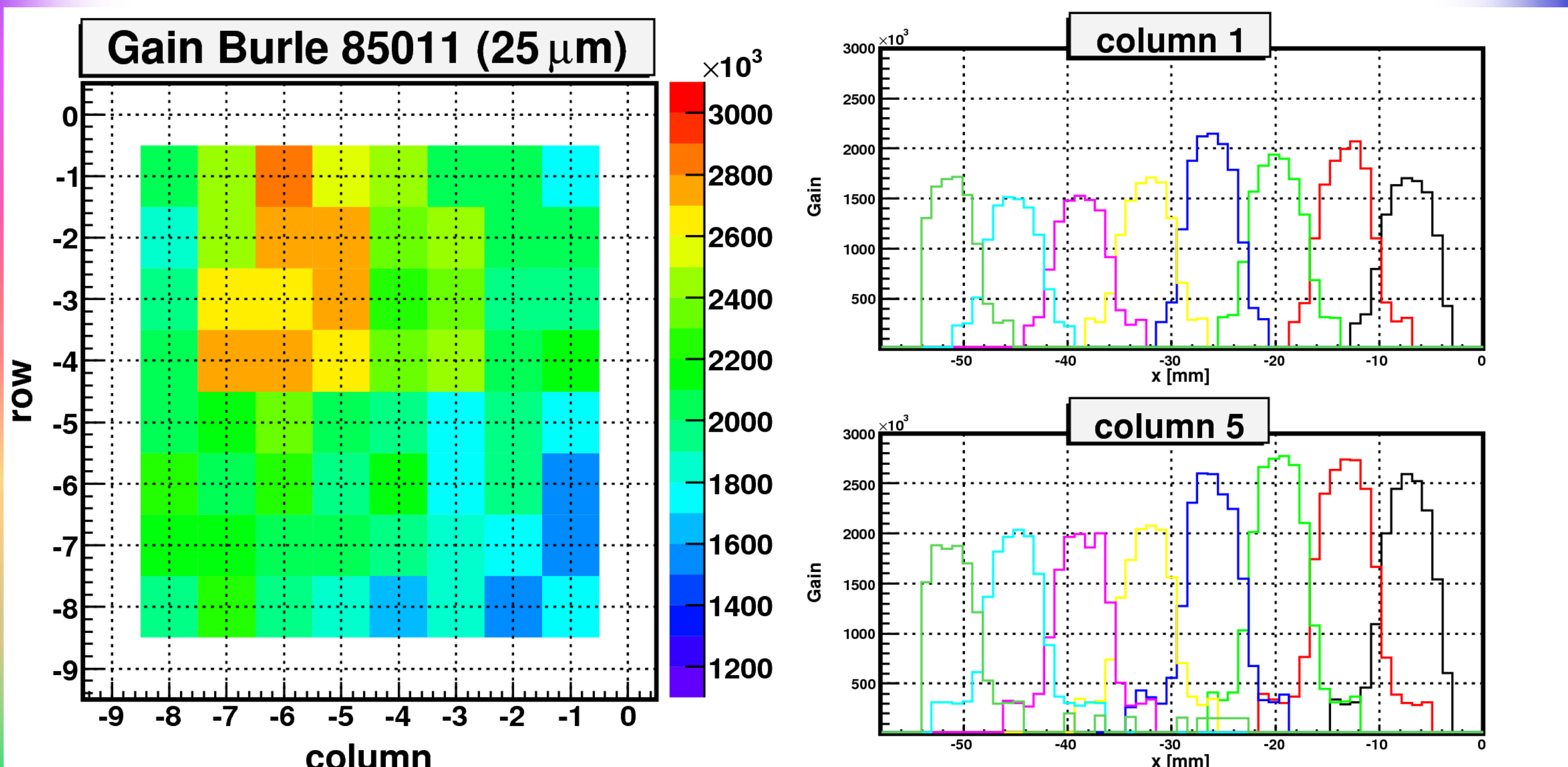
Surface Scans of Burle 25 μm **(Rates)**

- rather **uniform response** of the individual channels
- but **significant crosstalk** between the channels

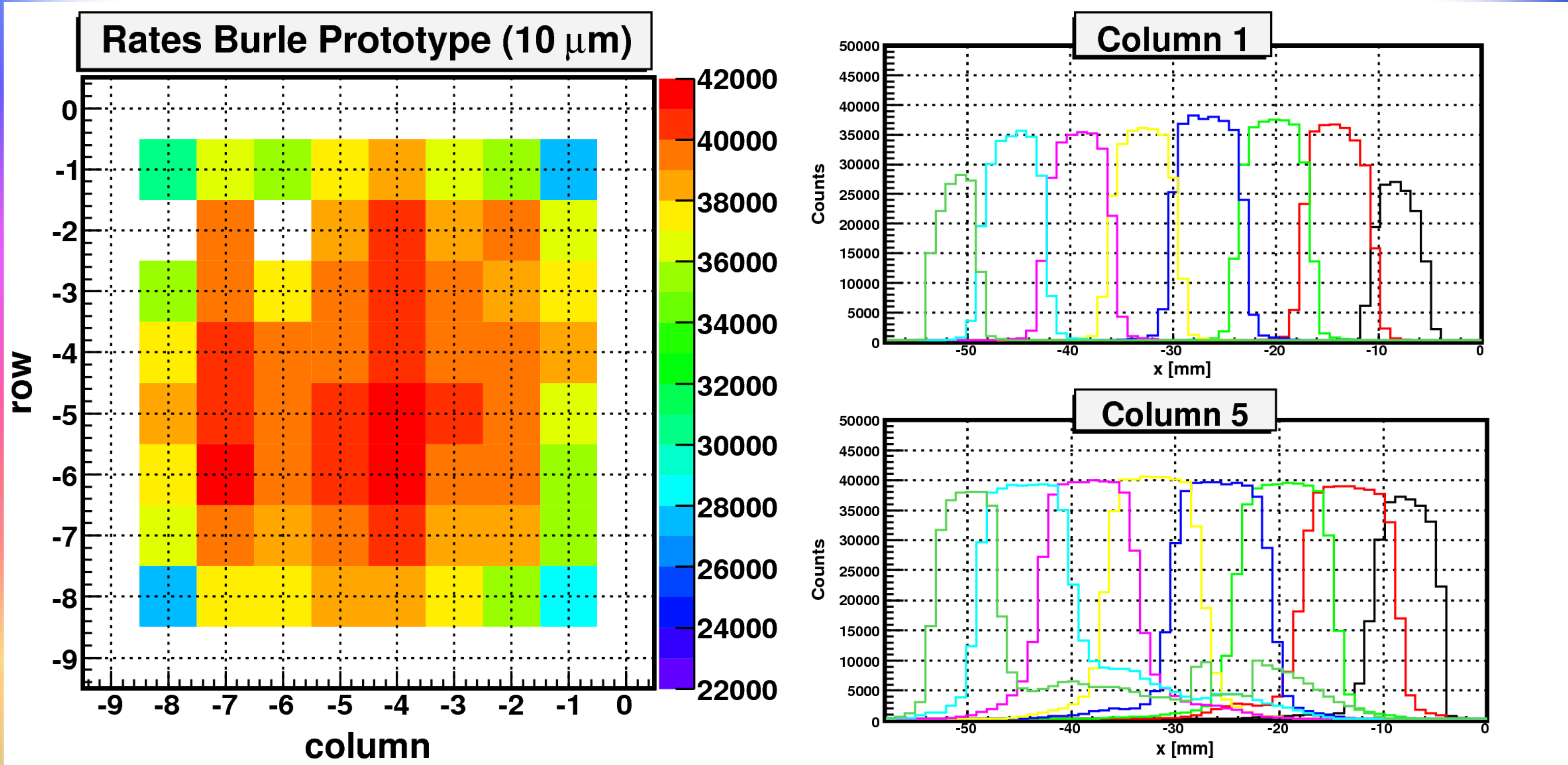


Surface Scans of Burle 25 μm (**Gain**)

- **significant gain variations** of almost factor 2 (1.5 to $2.8*10^6$) between channels



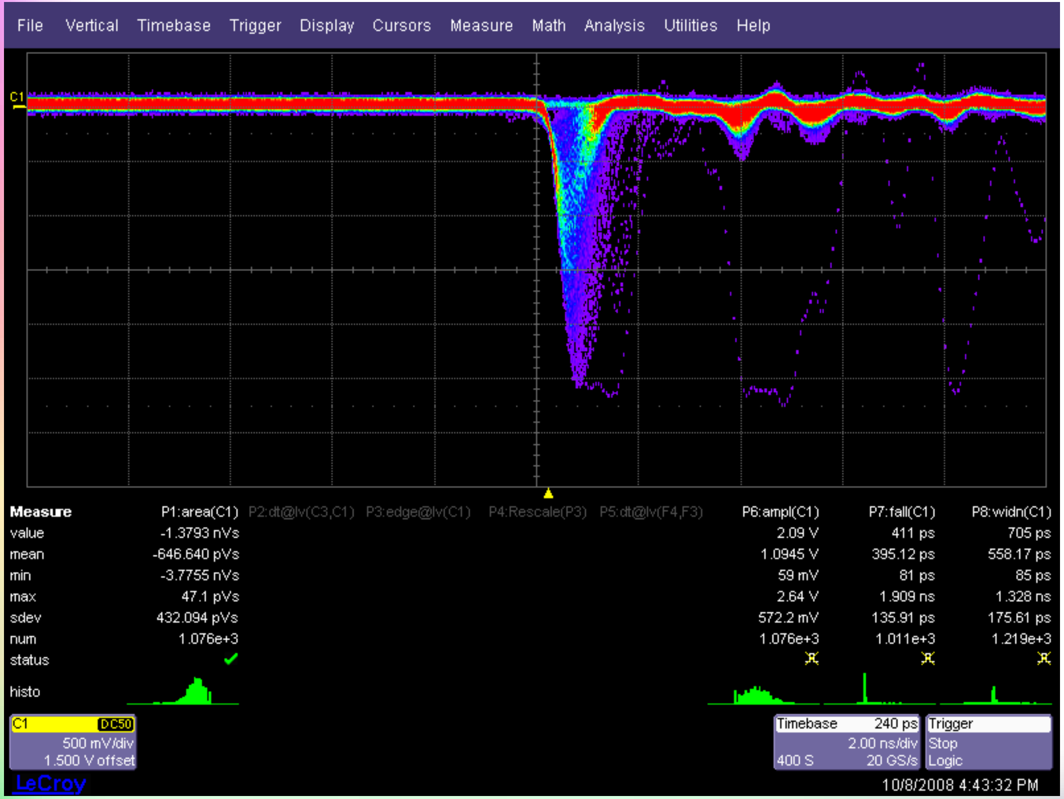
Surface Scans of Burle 10 µm (**Rates**)

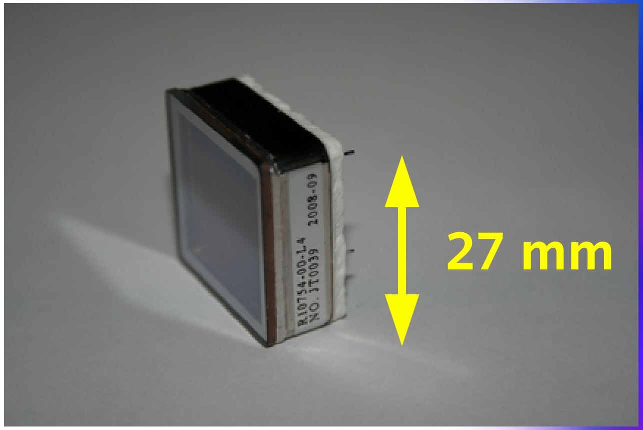


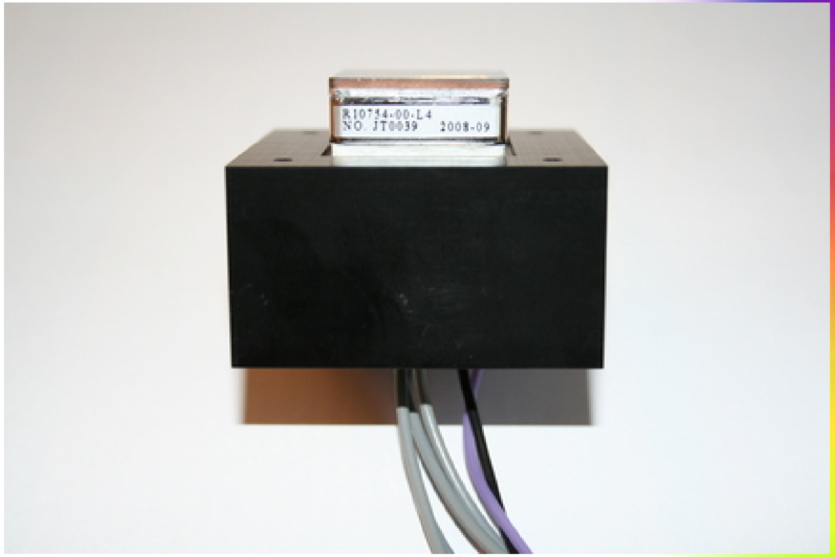
- **less uniform response and more crosstalk** than with 25 µm device
- **very strong gain fluctuations** (variation from 0.5 to 3.5×10^6 !!)

Hamamatsu MCP-PMT (R10754-00-L4)

- first studies of R10754-00-L4 (= SL10)
  - very fast signals (~750 ps FWHM)
  - problems with some standard discriminators
  - time resolution 30-40 ps

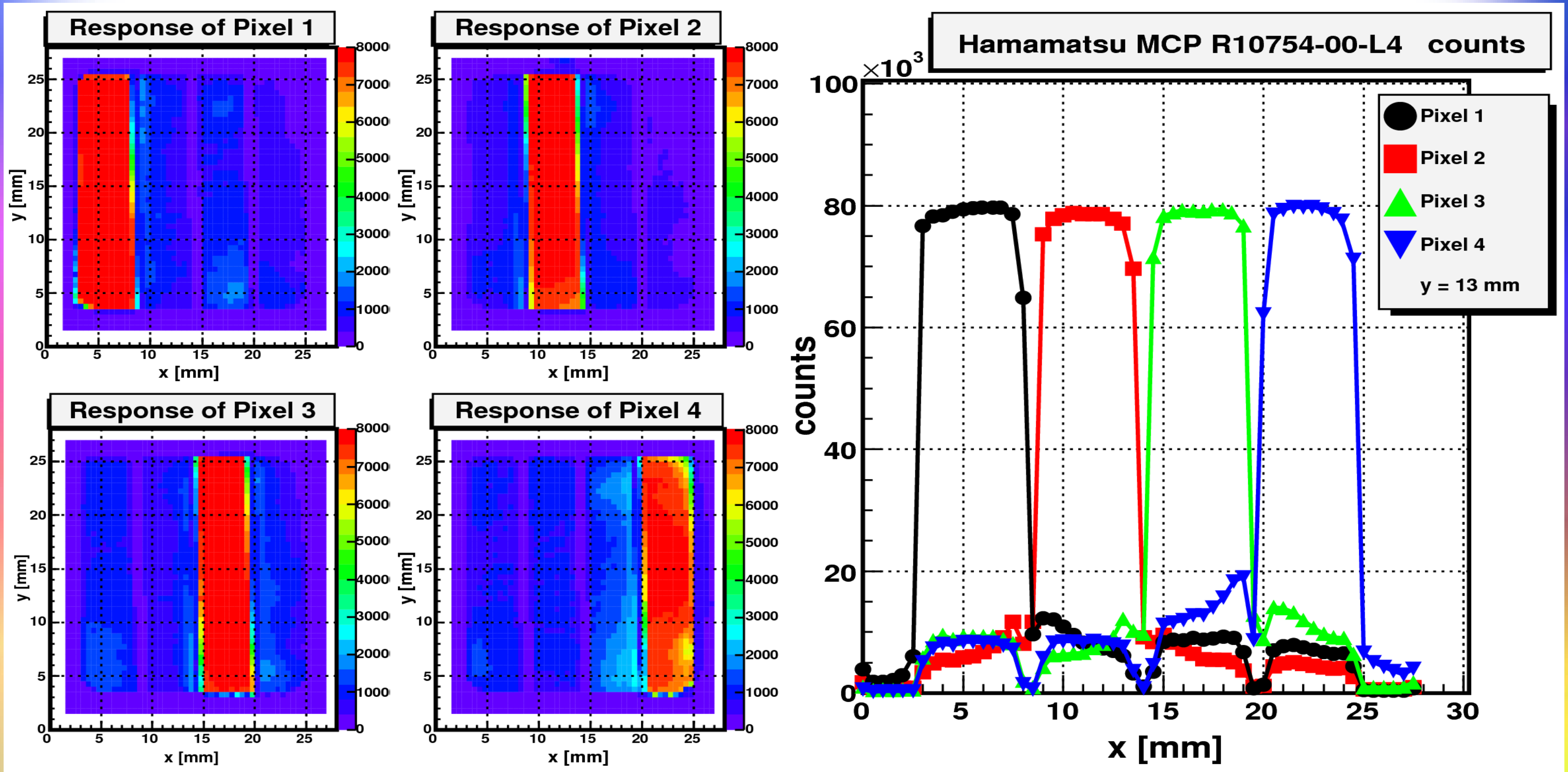






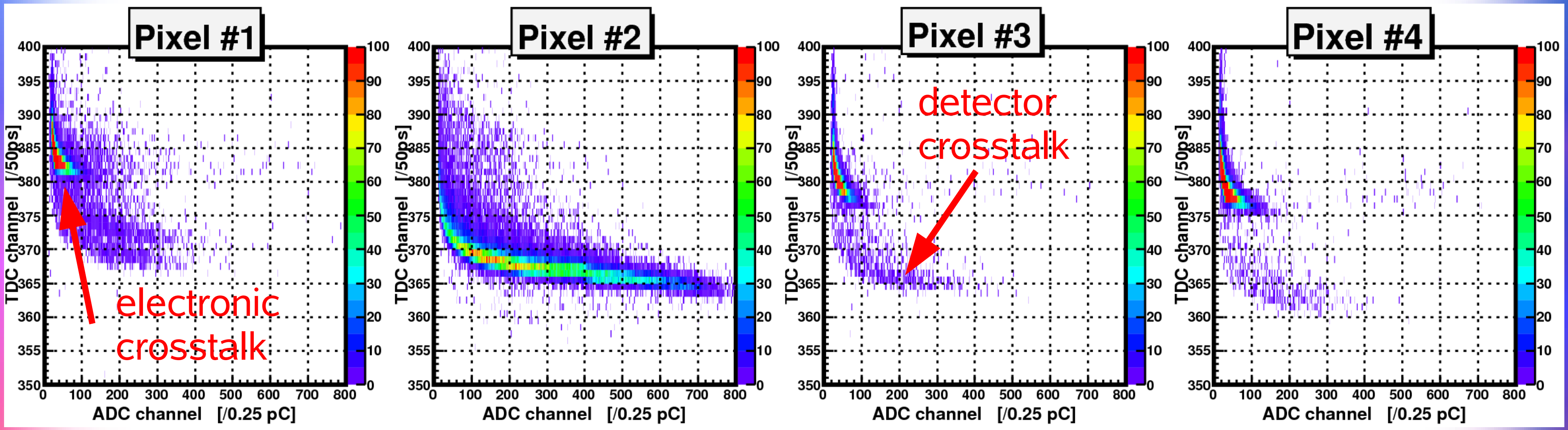
linear array of 4 pixels with 20x5 mm^2

Surface Scans of SL10 (Count Rates)

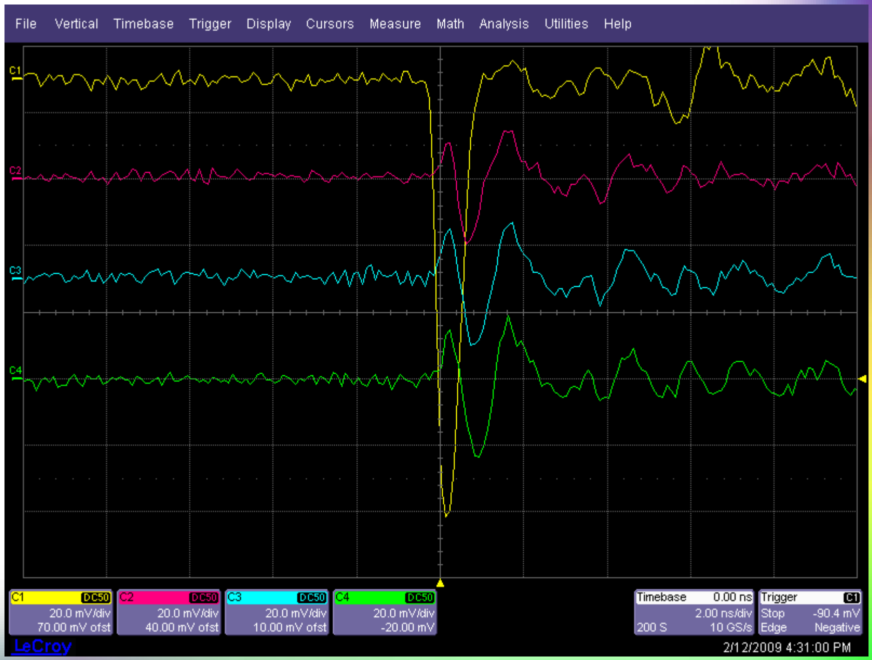


- very good **uniform response** of the individual channels
- but **crosstalk** between the channels

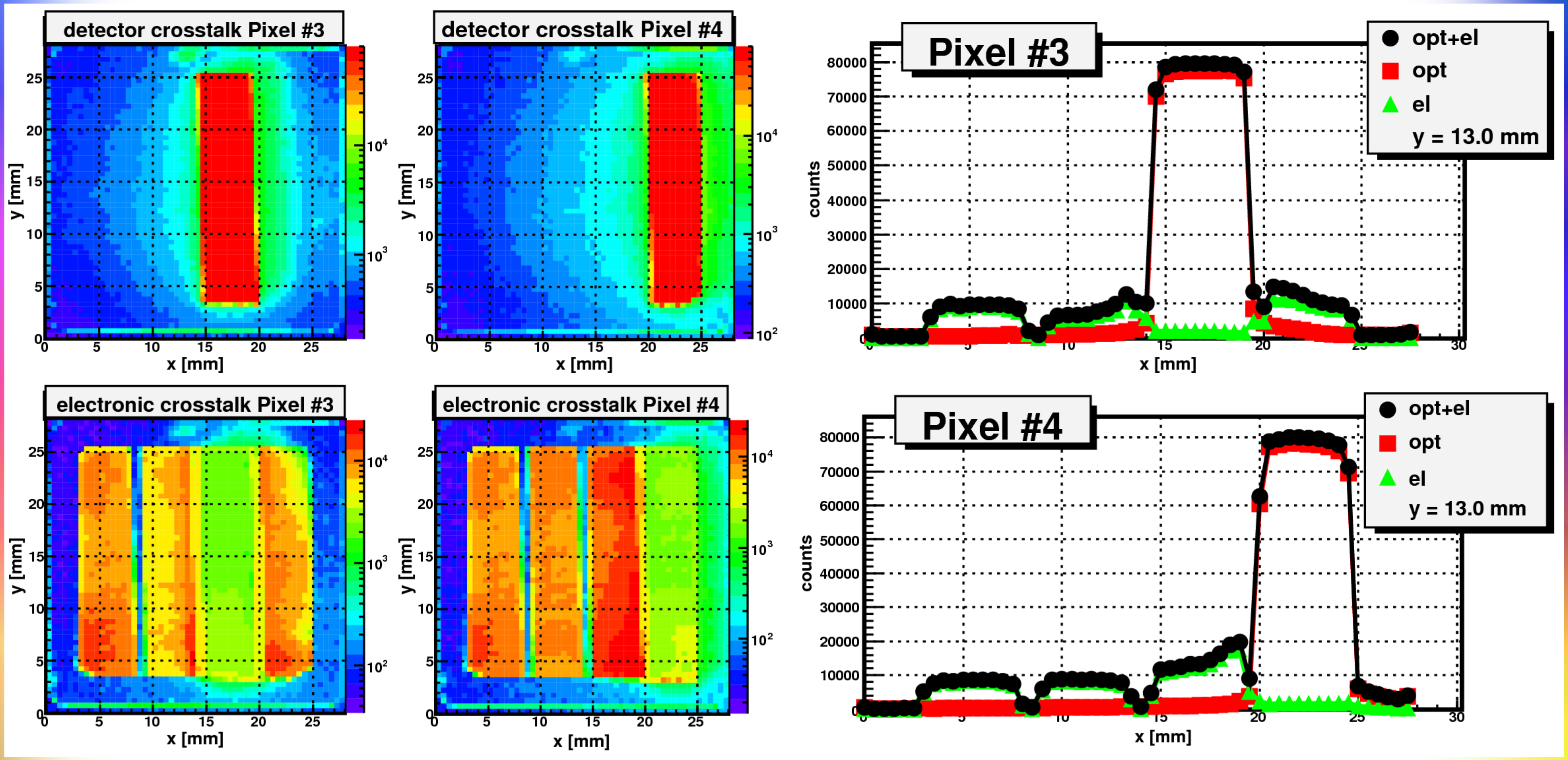
Surface Scans of SL10 (Crosstalk I)



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

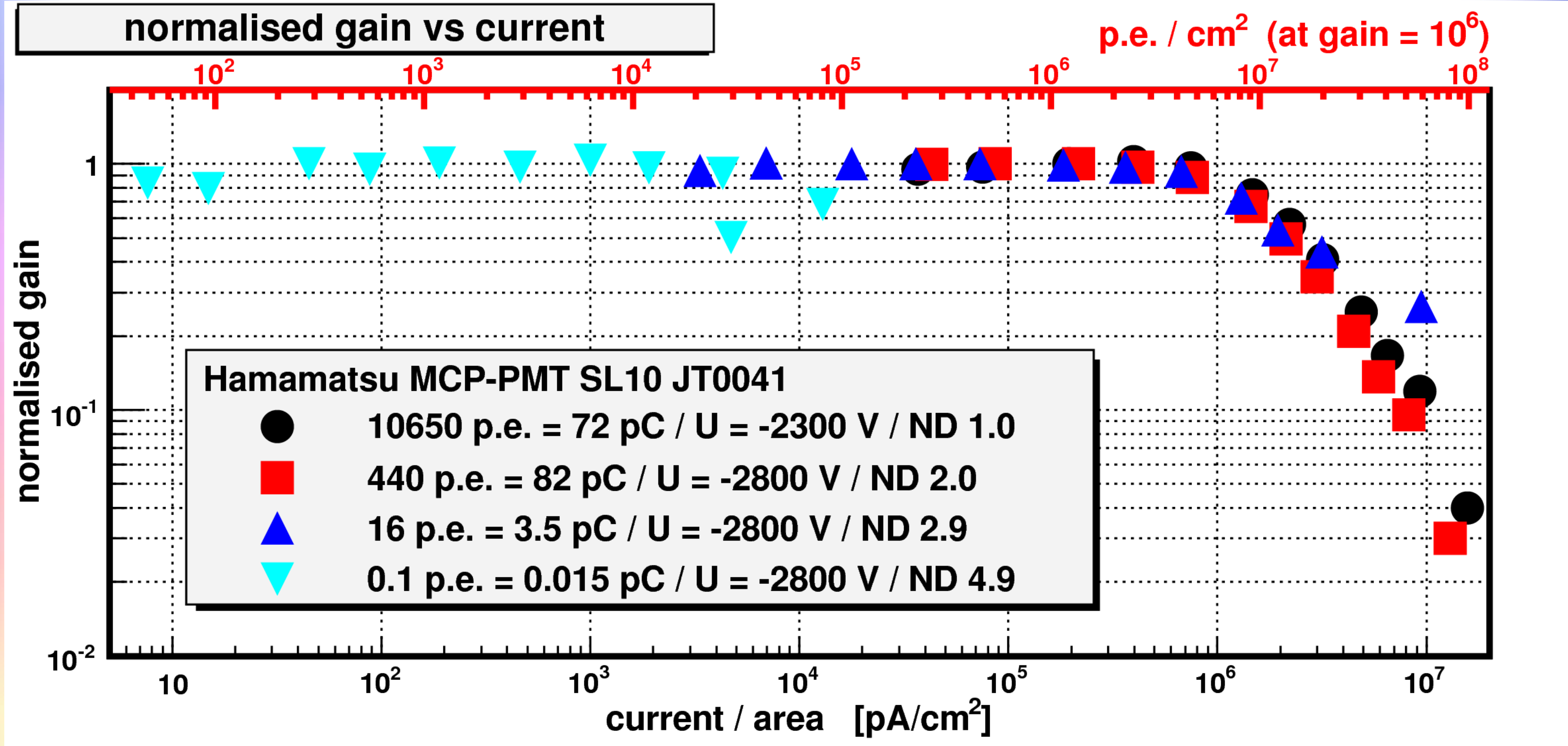


Surface Scans of SL10 (Crosstalk II)



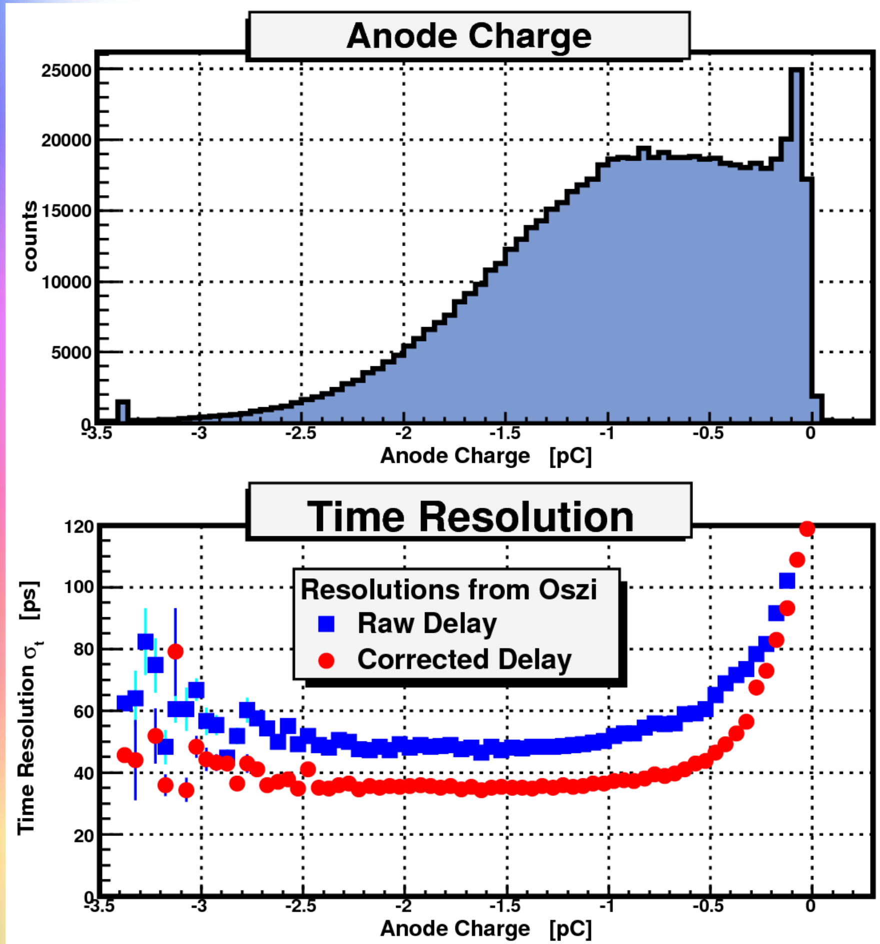
- most of the crosstalk signal is probably caused by voltage divider
- **real channel crosstalk** inside the detector is **small**

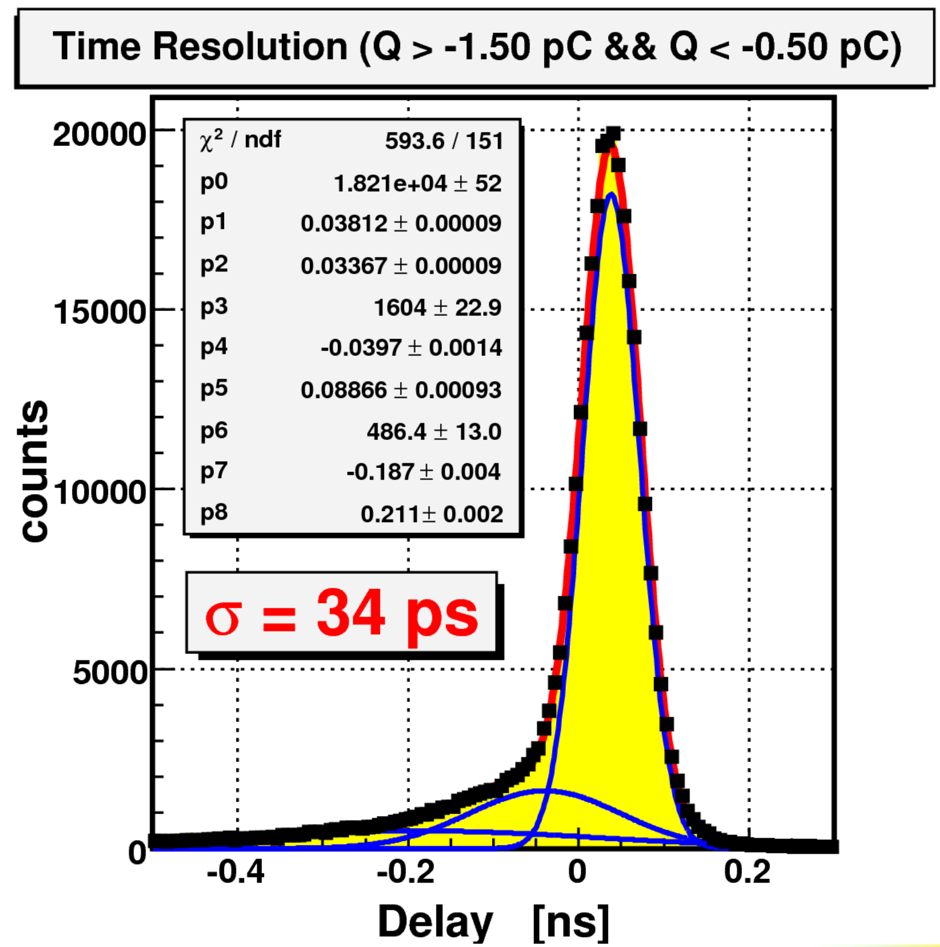
Rate Behaviour of SL10



- same response from 0.1 to 10^4 photons / sec → gain only depends on anode current
- **stable gain up to 5 MHz single photons per cm^2** (for 10^6 gain)

Single Photon Time Resolution of SL10





- **excellent time resolution of <35 ps for single photons**
  - measured with oscilloscope
  - Philips Scientific 705 discriminator and Ortec FTA820 amplifier (x200)

Reminder of MCP Performances

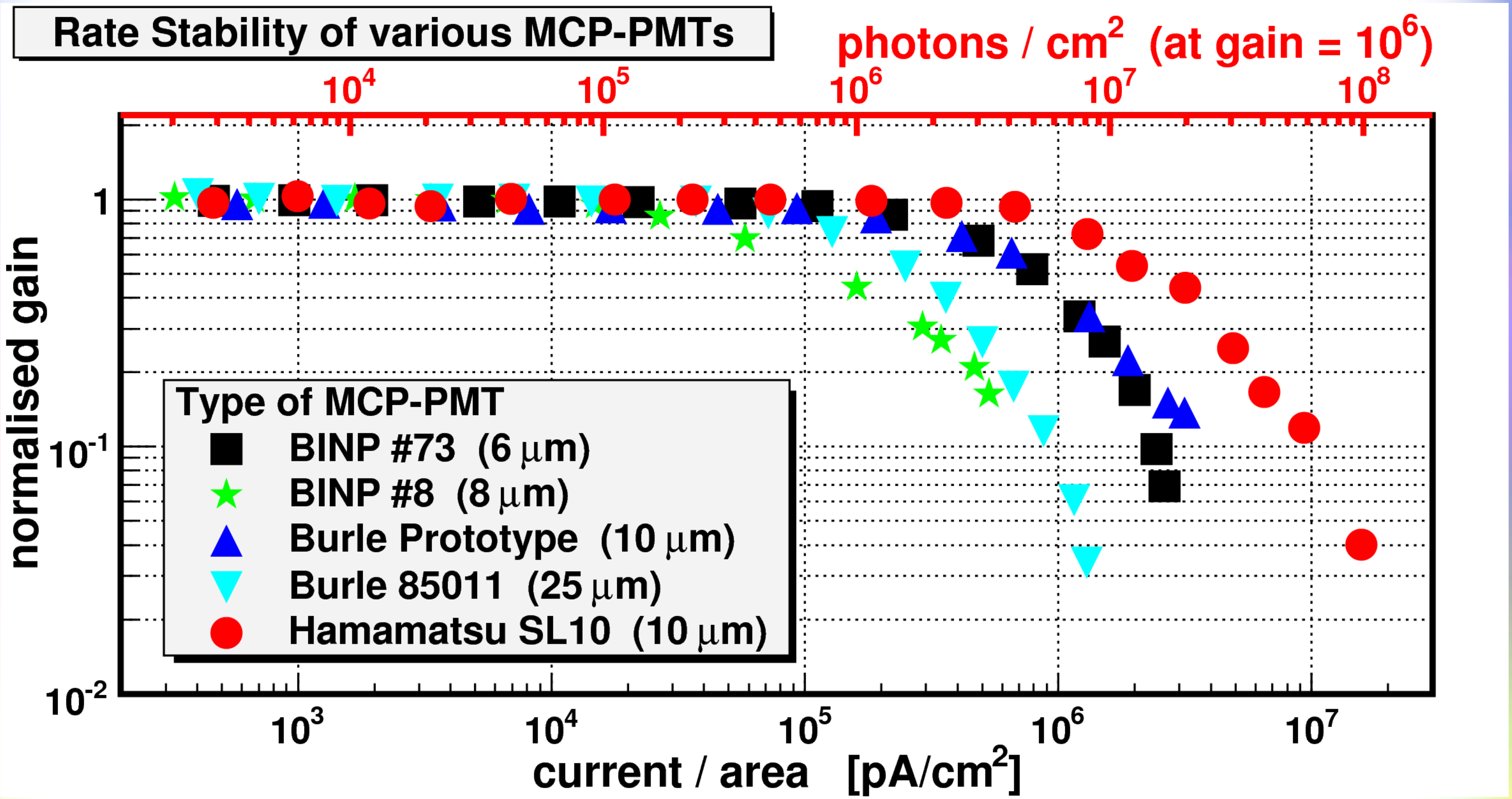
- **positive** for application in PANDA DIRC
  - gain >10^6 → single photon detection okay
  - time resolution <50 ps for single photons
  - with pore size of ≤10 µm usage in B-field >1 Tesla possible
  - dark count ~10 kHz/cm^2 probably okay
- **negative** for application in PANDA DIRC
  - single photon rate stability only up to ~1 MHz/cm^2 (except SL10)
  - maximum lifetime only ~1-2 C/cm^2
    - defined as 30% loss of Q.E.
    - SL10 probably better

Expected Rates and Charges

- Assumptions for simulation (A. Britting)
  - 10 pions per annihilation (5 charged and 5 neutral)
  - phase space distribution
  - $2*10^7$ annihilations
  - photon spectrum from 200 to 1000 nm
  - quantum efficiency (Q.E.) of BINP MCP-PMT
  - collection efficiency 100%
  - reflectivity 0.995

	total rate	anode rate (after Q.E.)	integrated anode charge
	[MHz/cm^2]	[MHz/cm^2]	[C/cm^2/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

Rate Stability of Different MCP-PMTs

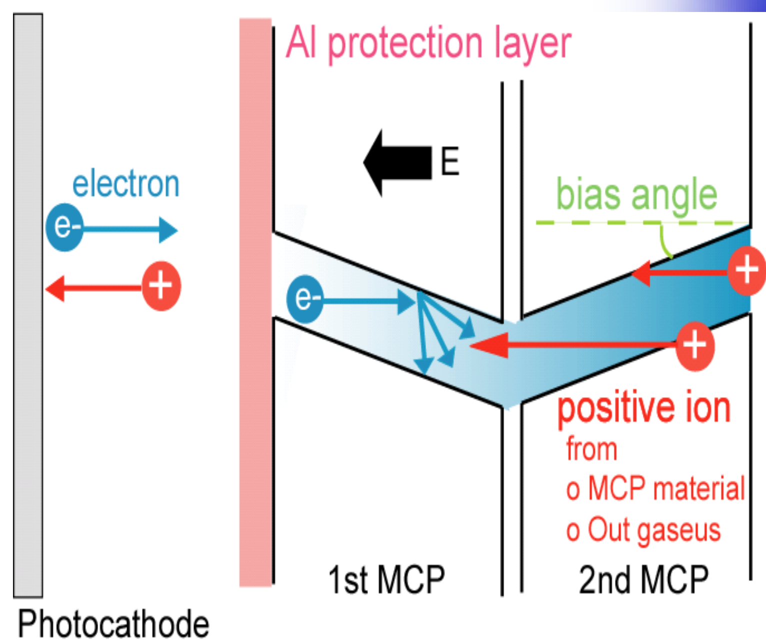


- quite different rate stability for each type of MCP-PMT
- Hamamatsu SL10 stable up to about 5 MHz/cm^2

Lifetime Measurements in Nagoya

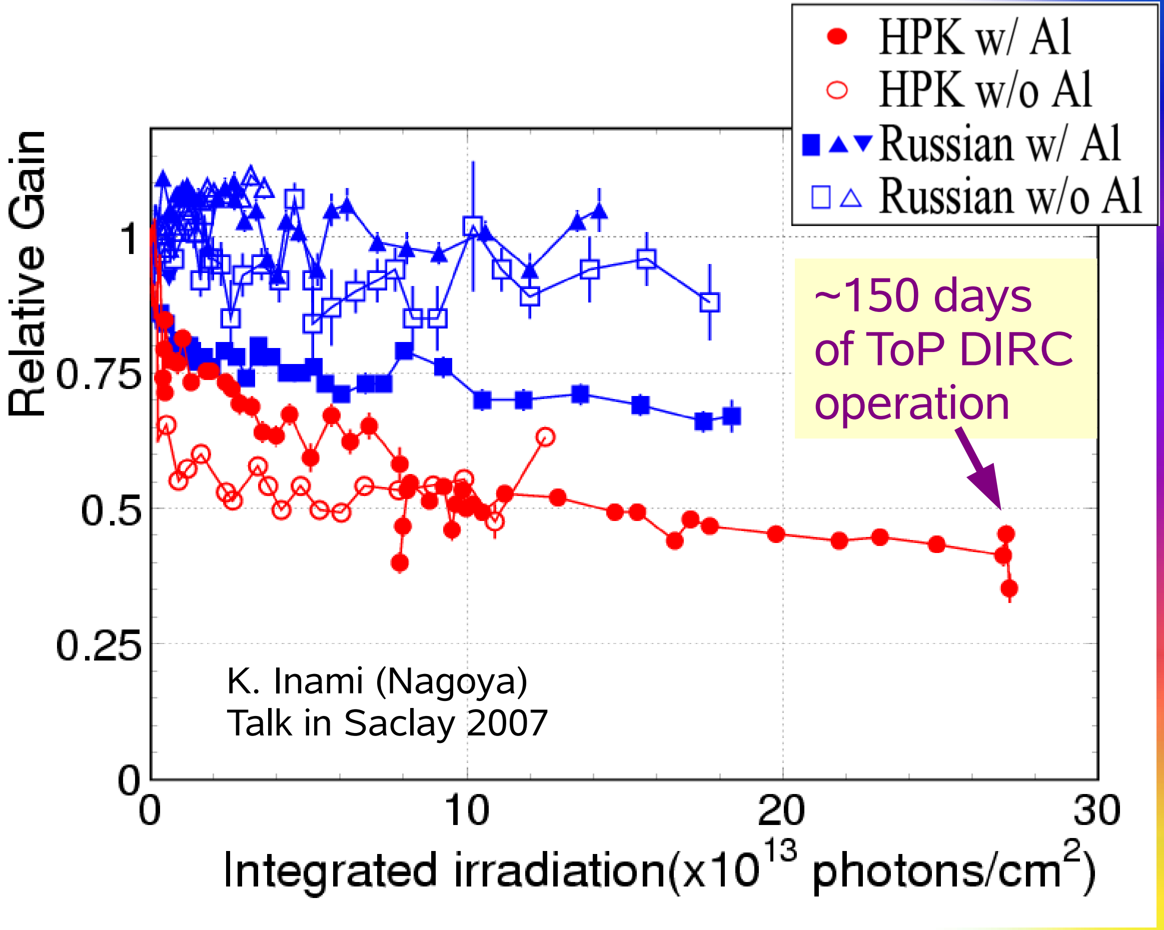
K. Kishimoto et al., NIM A564 (2006) 204

	HPK (x2)		Russian (x5)	
Al protection	**O**	**X**	**O**	**X**
Correction eff.	**37%**	**65%**	**40-60**	**55-60 %**
Effective area	11mm$^\phi$		18mm$^\phi$	
Gain	1.9x10^6	1.5x10^6	3~4x10^6	
TTS	34ps	29ps	30~40ps	
Photo-cathode	Multi-alkali (NaKSbCs)			
Quantum eff. at 400nm	21%	19%	16-20%	
Bias angle	13deg		5deg	



Lifetime – Gain

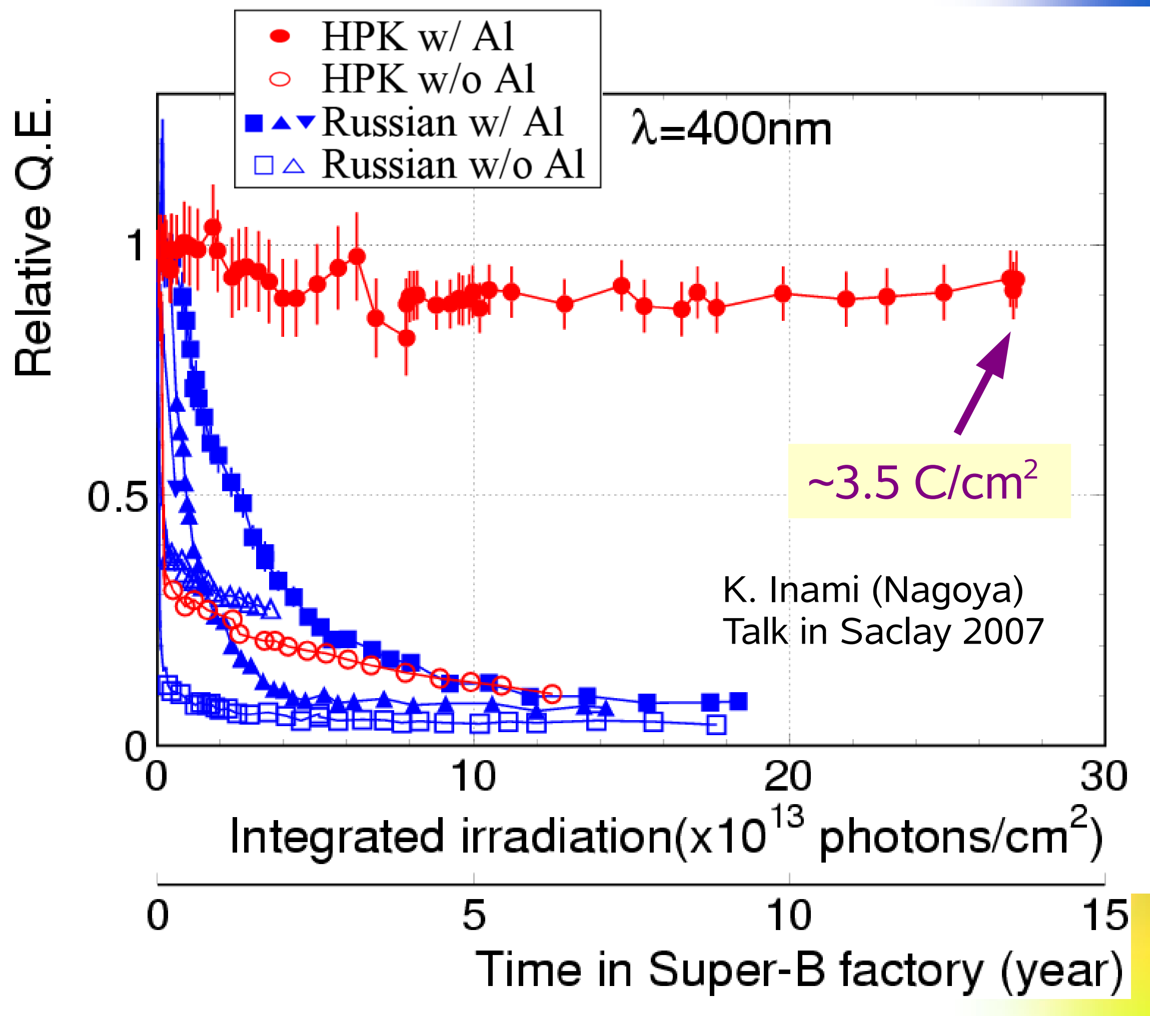
- fast drop at beginning ($< 10^{13}$ photons/cm^2)
- only slow drop later ($> 10^{13}$ photons/cm^2)
- maximum drop to 40% after $27*10^{13}$ phot/cm^2
- gain can be recovered by increasing HV (up to a certain extent)



unclear what the gain would be after 10 years of PANDA operation (~10x more integrated irradiation)

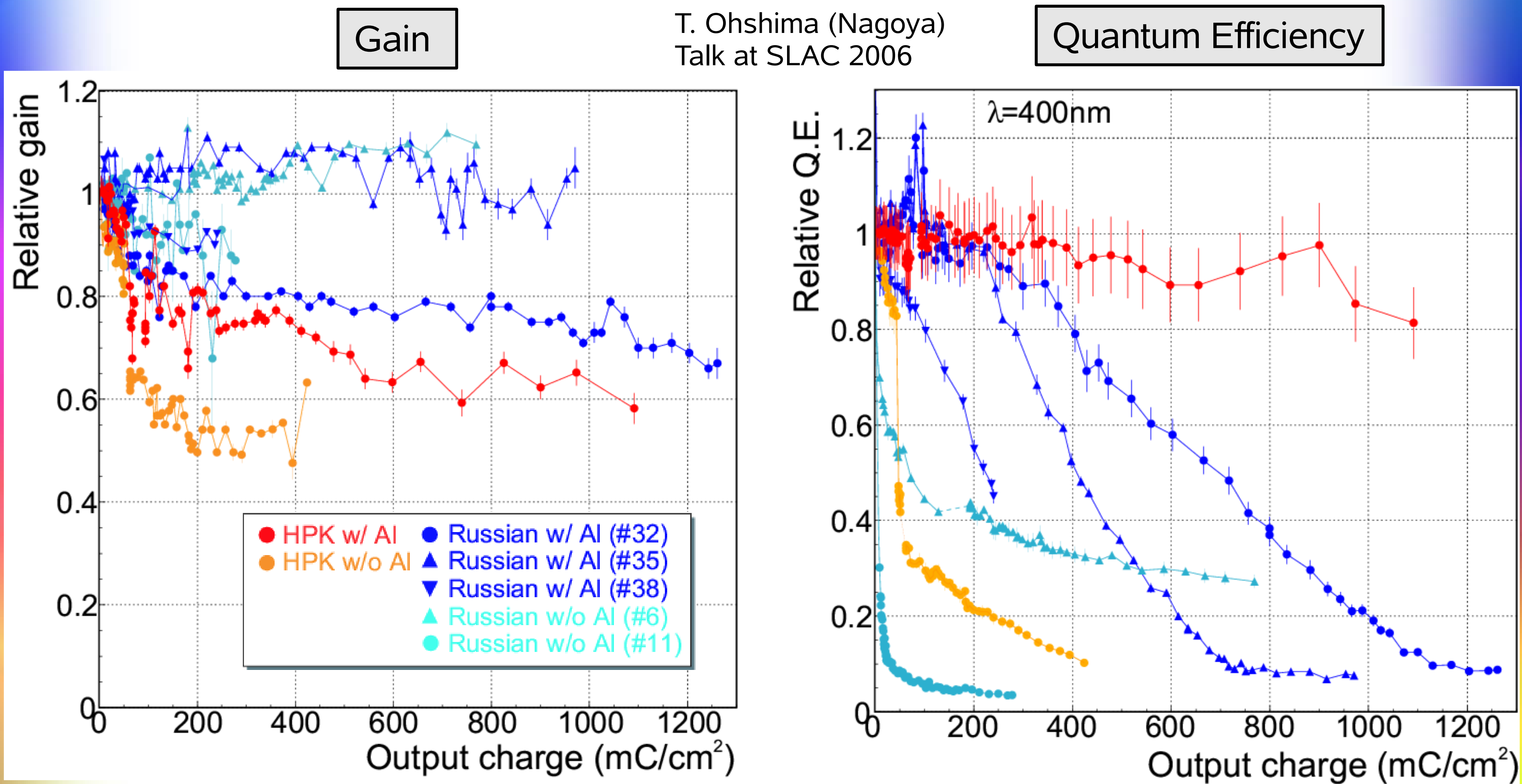
Lifetime – Quantum Efficiency

- Q.E. of Russian MCP-PMTs drops very fast
  - better with Al-layer but lifetime still much too short for PANDA
- Q.E. of HPK MCP-PMT wo Al-layer drops fast as well
- Q.E. of HPK MCP-PMT with Al-layer remains almost constant



only 10% Q.E. drop of HPK MCP with Al-layer after ~3.5 C/cm^2

Q.E. and Gain vs Anode Charge

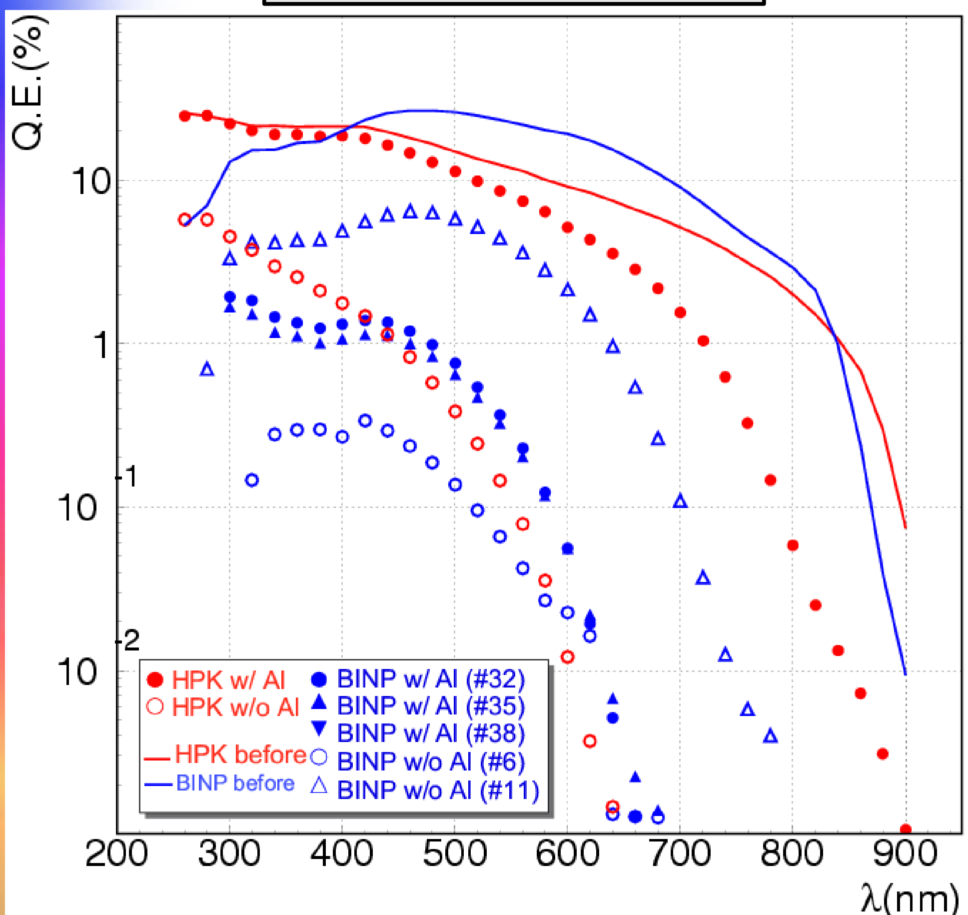


- gain of some BINP MCPs appears quite robust
- but Q.E. of BINP MCPs drops to 50% after ~0.5 C/cm^2 charge

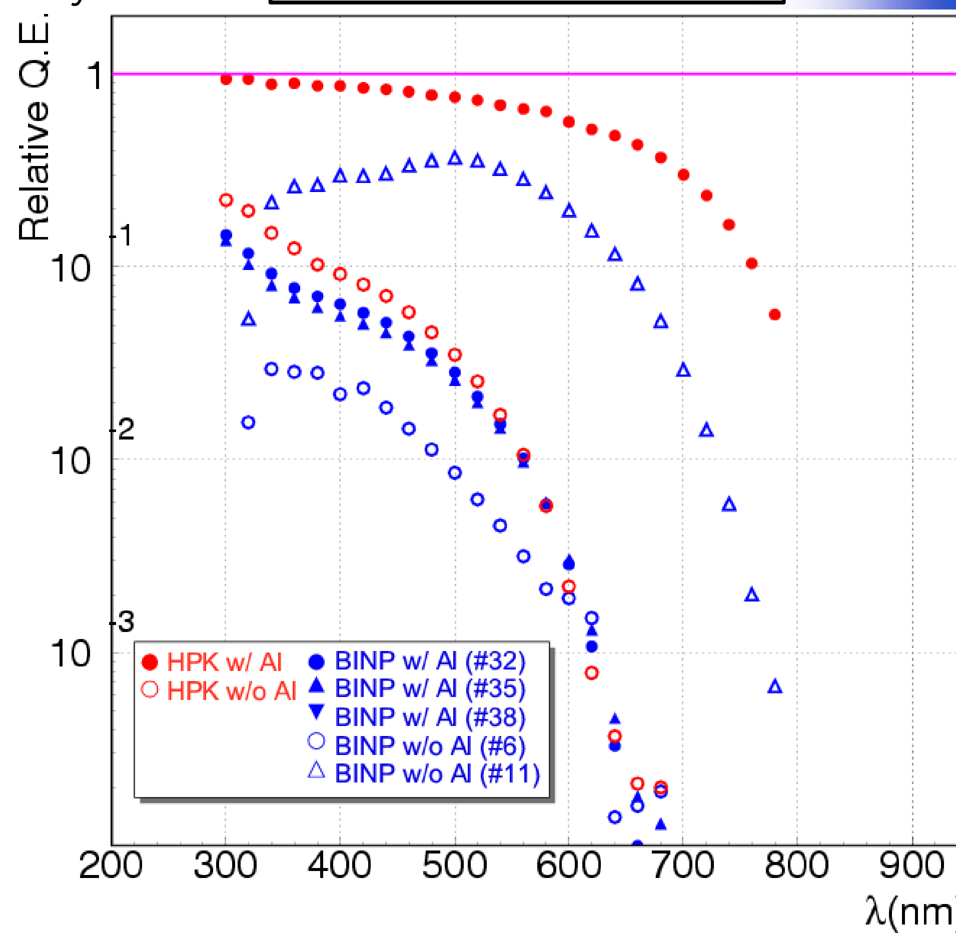
Lifetime – Q.E. vs Wavelength

K. Inami (Nagoya)
Talk in Saclay 2007

Q.E. after lifetime test



Q.E. ratio: after/before

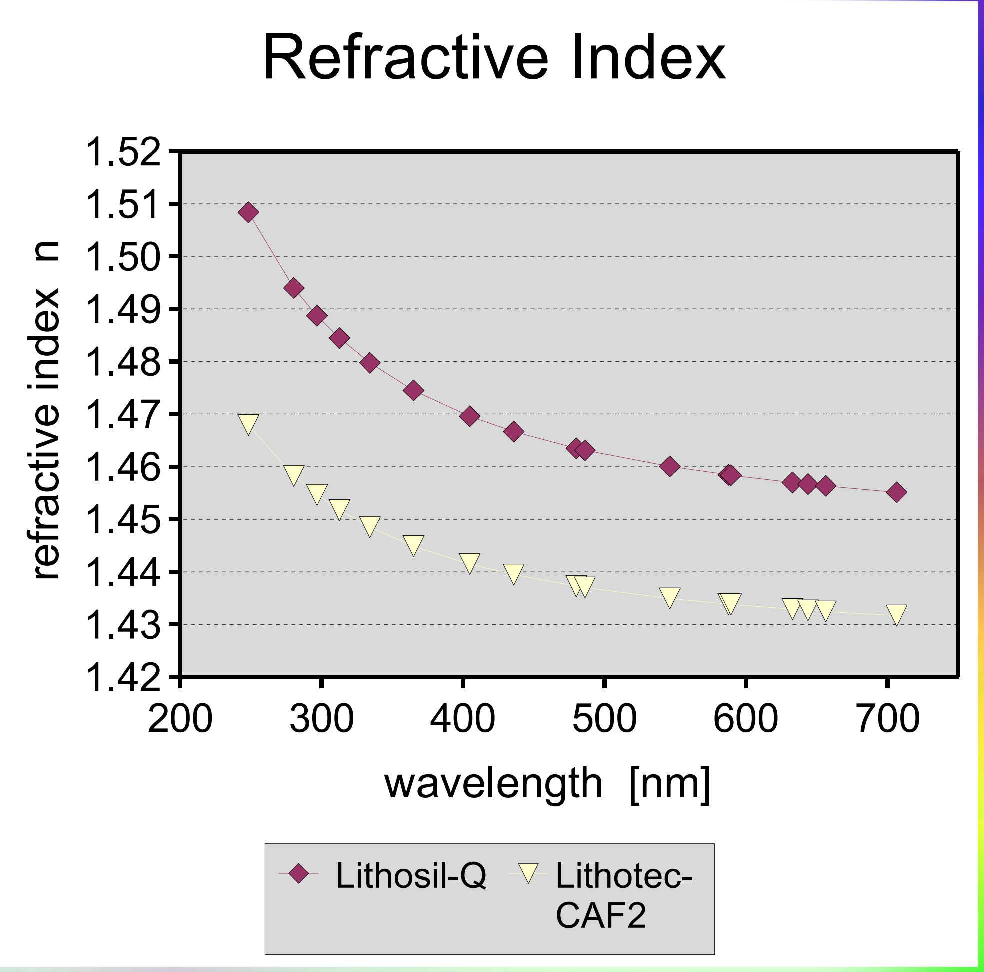


- large Q.E. drop at longer wavelenghts
- **less aging problems with UV sensitive photo cathodes**

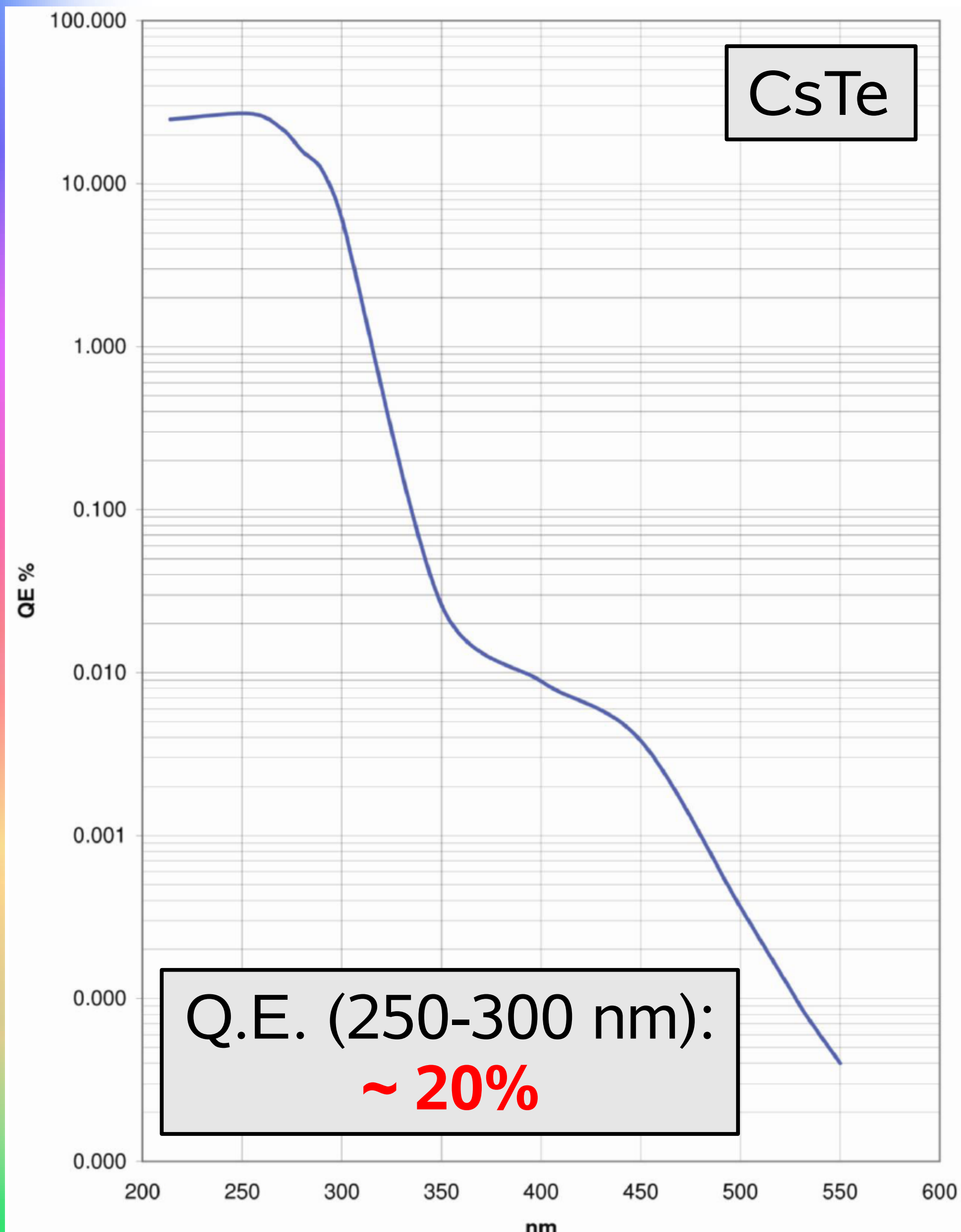
Scenario for PANDA-DIRCs

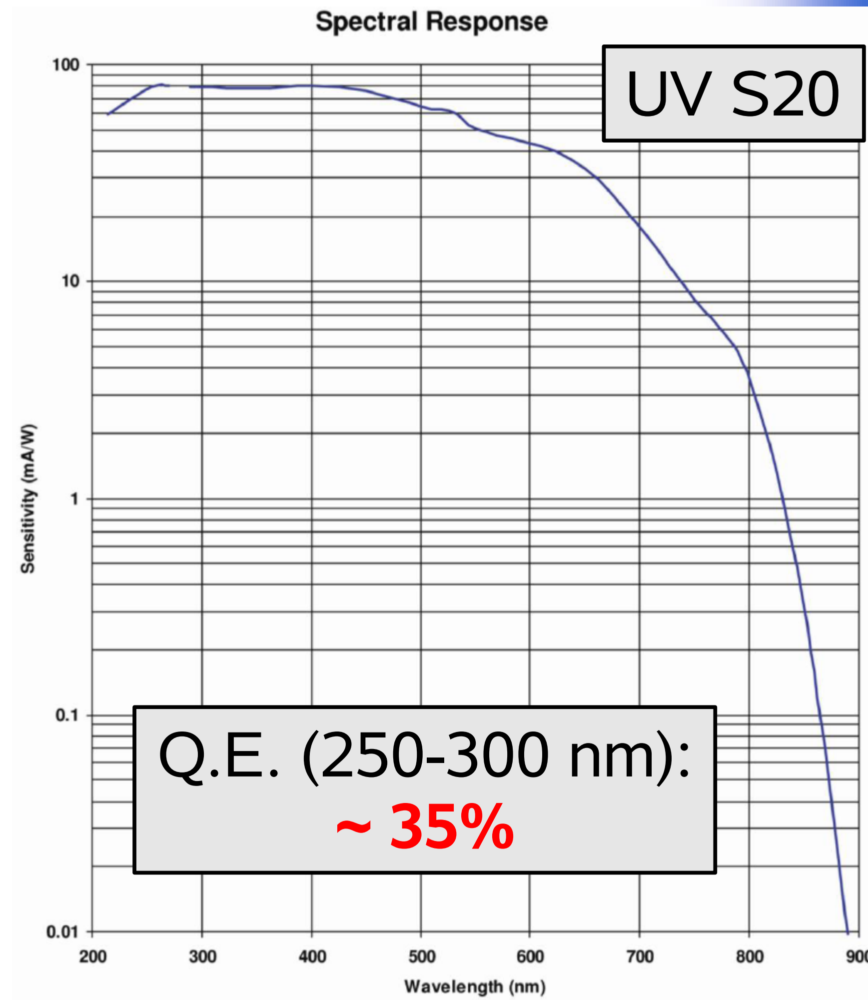
Use a narrow band of UV photons (e.g. 250-300 nm)

- disadvantage
  - dispersion problematic
  - but dispersion in narrow UV band is comparable to the dispersion of the total visible range
- advantage
  - **more photons per nm**
  - **longer lifetime** of UV photo cathode (e.g. CsTe)



Q.E. of UV Photo Cathodes





	mA/W	%QE		mA/W	%QE		mA/W	%QE		mA/W	%QE
214nm	58.6	34.0	300nm	78.8	32.6	532nm	59.4	13.8	750nm	8.22	1.4
254nm	79.4	38.8	350nm	78	27.6	550nm	50.3	11.3	800nm	3.57	0.6
270nm	80.4	36.9	400nm	80.4	24.9	600nm	43	8.9	850nm	0.32	0.0
280nm	0	0.0	450nm	75.3	20.8	650nm	33.2	6.3	900nm	0.004	0.0
290nm	79.3	33.9	500nm	63.9	15.8	700nm	22.3	4.0			

Photon Rates in UV Range

- Alexander's simulations
  - assumptions as above (slide #13)
  - quantum efficiency of CsTe photocathode

	anode rate (after Q.E.) [MHz/cm²]		integrated anode charge [C/cm²/year] at 10^6 gain	
	full spectrum	250-300 nm	full spectrum	250-300 nm
Barrel-DIRC				
at upstream rim	8.5	1.4	43	7.1
at readout plane	0.24	0.04	1.2	0.2
Endcap DIRC				
TOP	2	0.29	10	1.5
focussing	0.8	0.12	4	0.59

Summary and Outlook

- maybe we should put some thoughts upon using a narrow UV band as an option for the PANDA DIRCs
- immediate future in Erlangen
  - finalize analysis of Burle MCP surface scans
  - more studies with Hamamatsu SL10 (magnetic field behaviour)
  - investigate behaviour of Hamamatsu large area SiPMs
- mid term future
  - set up test stand for lifetime measurements
    - requires tools for Q.E. measurements (monochromator + calibrated reference photo diode)
    - laser pulser with 10-100 MHz repetition rate
  - set up test stand to investigate cooled SiPMs
  - investigate SL10 with protection layer
  - investigate diamond dynode PMTs