Studies of Multianode Photo Sensors

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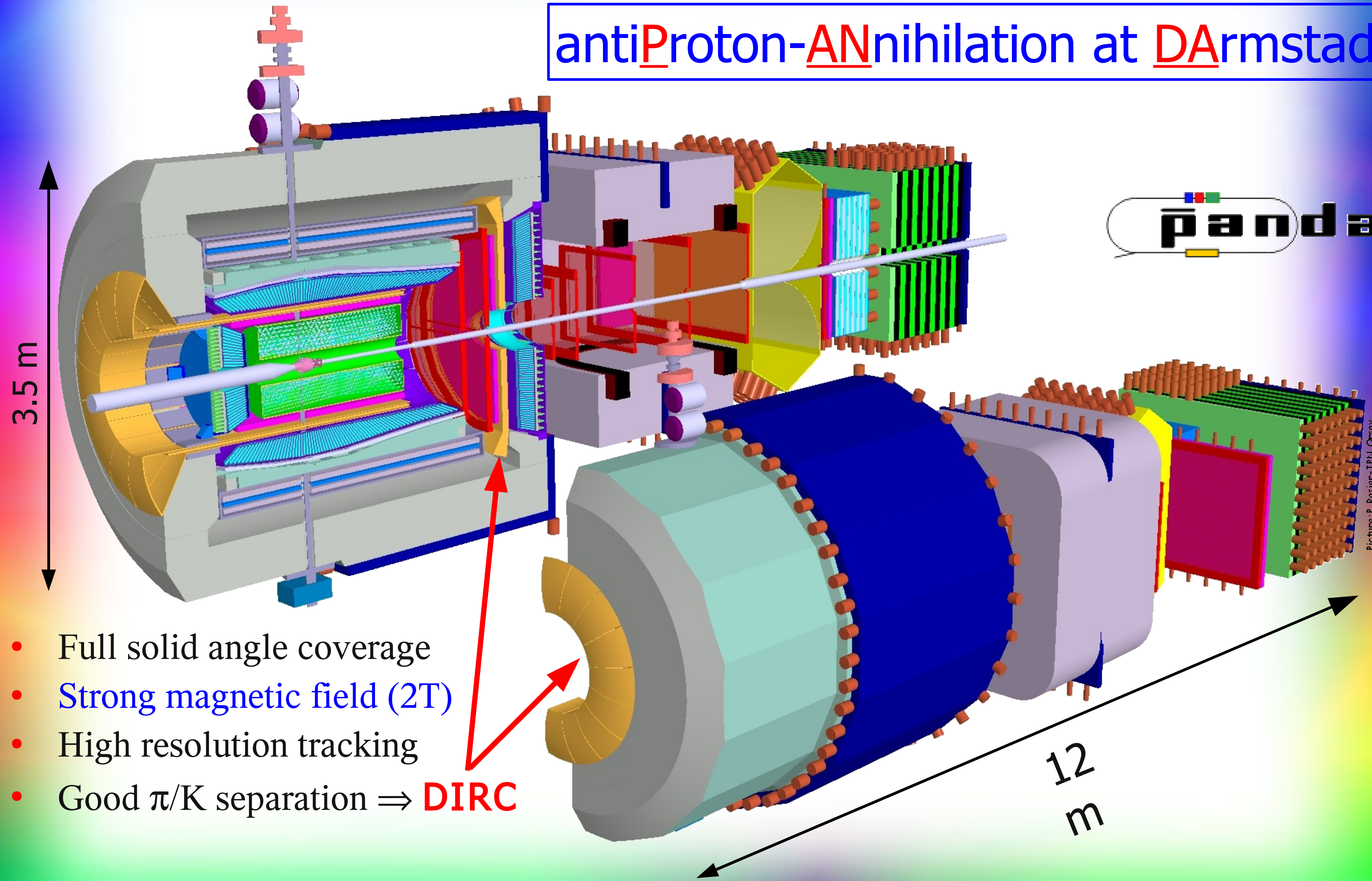
- motivation
- experiences with MCP-PMTs
- first steps and future goals with SiPMs

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

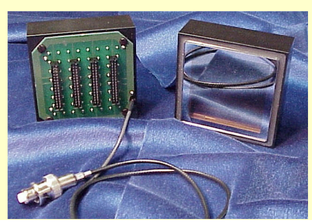
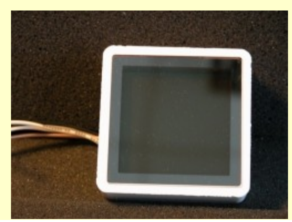
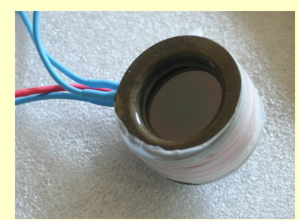
- Single photon detection inside high B-field
  - **high gain** (> $5*10^5$) even in the 2 Tesla magnetic field
- Time resolution to separate π/K with TOP
  - **very good time resolution** of < 50 ps for single photons
- Photon rates in the MHz regime
  - **high rate stability** (rates of several MHz/cm^2)
  - short pulses (< 10 ns) to avoid pile-up
  - **long lifetime**
- Few photons per track
  - **high detection efficiency** $\eta = QE * CE * GE$
    [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
- **micro-channel plate photomultipliers** (MCP-PMTs)
  - problems with lifetime and rate stability
- **Geiger-mode avalanche photo diodes** (SiPMs)
  - problems with noise

Investigated MCP-PMTs

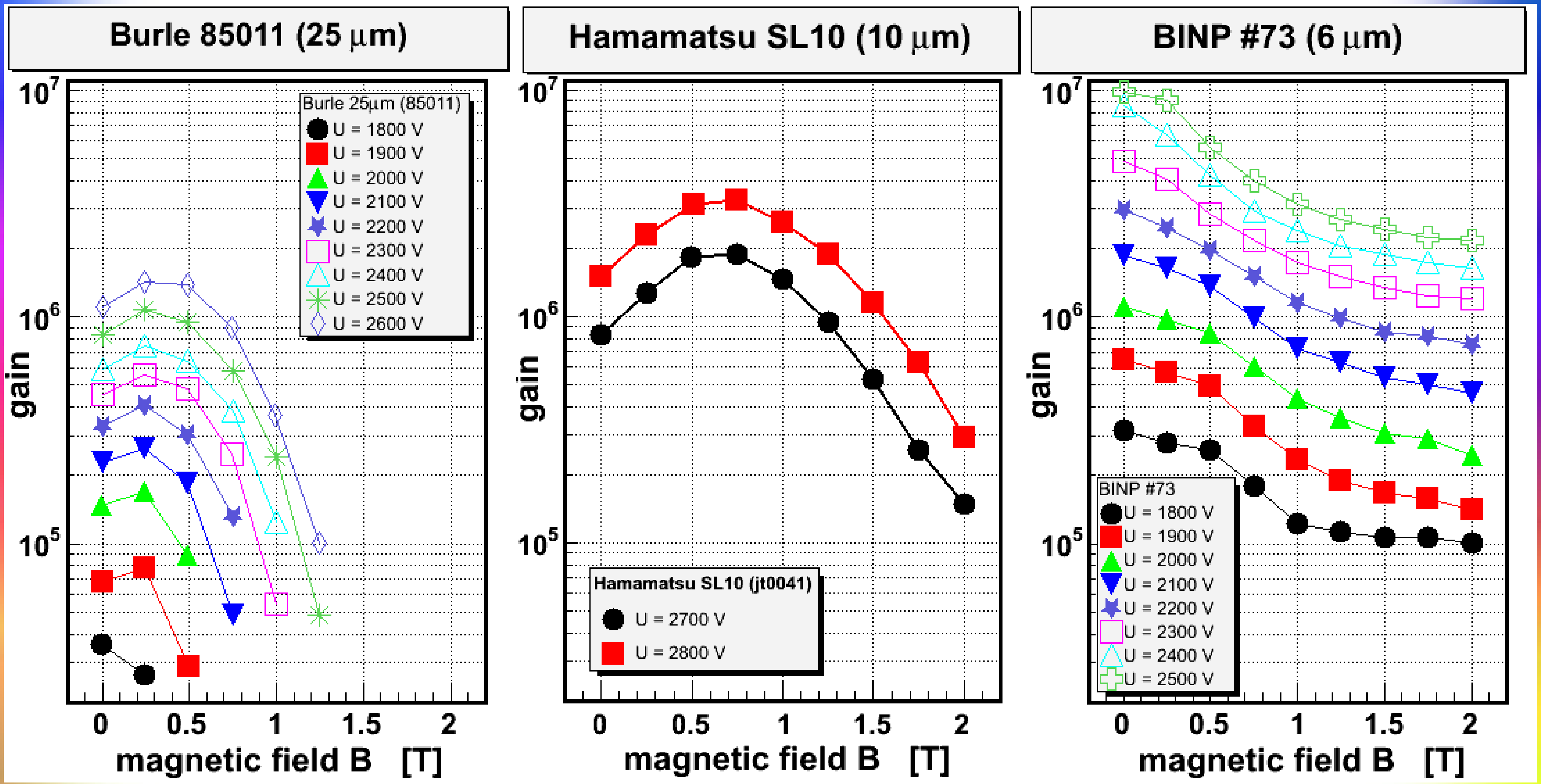
	Burle 85011	**Burle Prototyp**	**BINP**	**Hamamatsu SL10**
pore size (µm)	25	10	6	10
number of pixels	8x8	8x8	1	4x1
active area (mm²)	51x51	51x51	$9^2\ \pi$	22x22
total area (mm²)	71x71	69.5x69.5	$15.5^2\ \pi$	27.5x27.5
active area efficiency	0.52	0.54	0.36	0.61
peak Q.E.	@ 400 nm	@ 400 nm	22% @ 480 nm	20% @ 300 nm
protection layer	none	none	5-10 nm Al_2O_3	none
				

- **Burle 85013:** as 85011 but with a better active area efficiency (81% of a total area of 59x59 mm^2)
- **Burle 85012:** as 85013 but with improved vacuum → better lifetime

Tools for Sensor 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 (Δλ = 1 nm)
  - Si photo diode as reference sensor (Hamamatsu S6337-01)

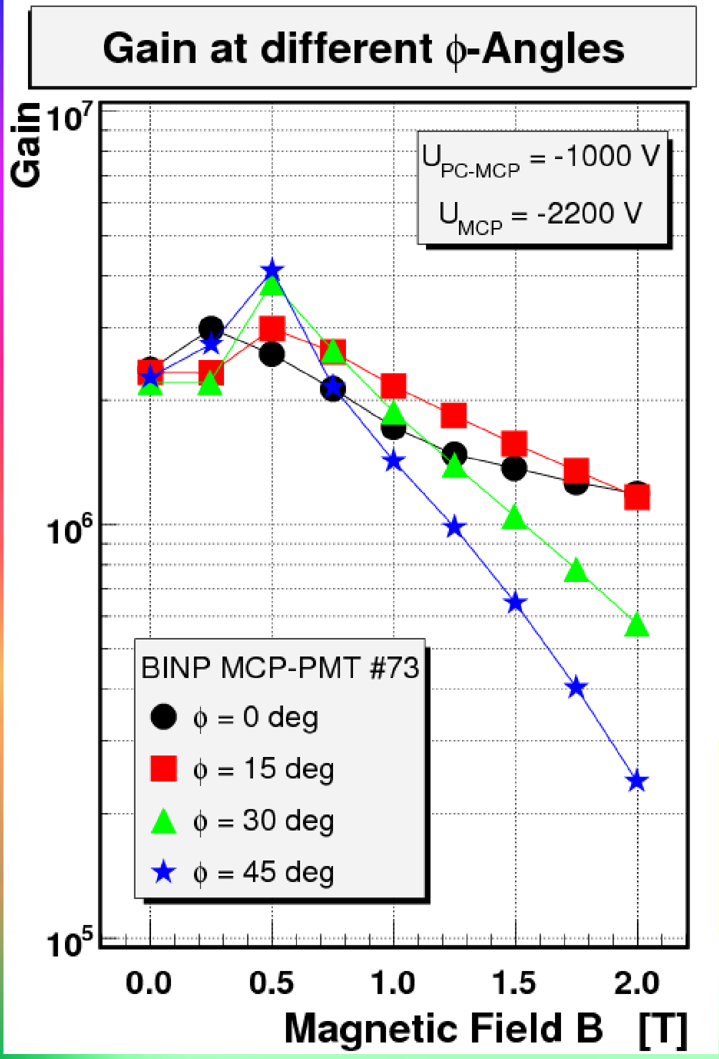
MCP-PMT Gain in Magnetic Field

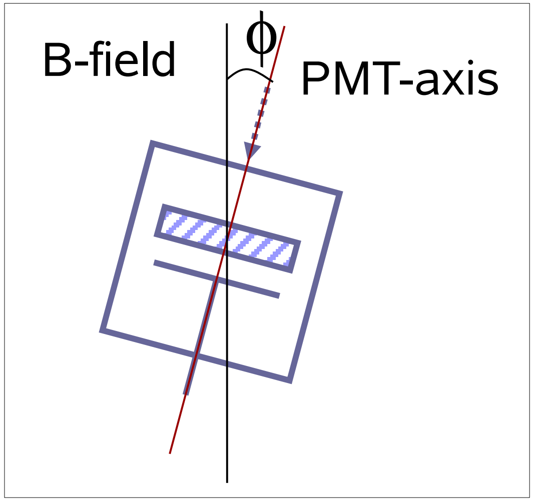


pore size ≤10 μm needed for single photon detection in 2 T field

Gain Dependence on B-Field Direction

BINP #73 (6 µm)

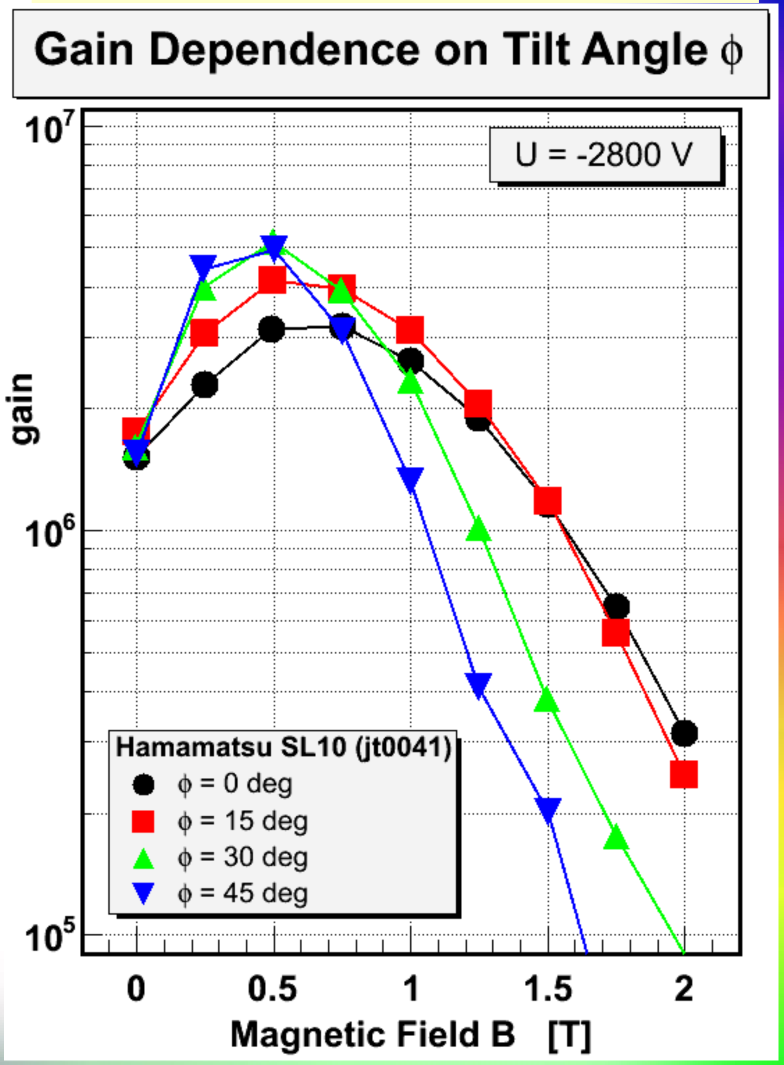




ϕ = angle between magnetic field direction and PMT-axis

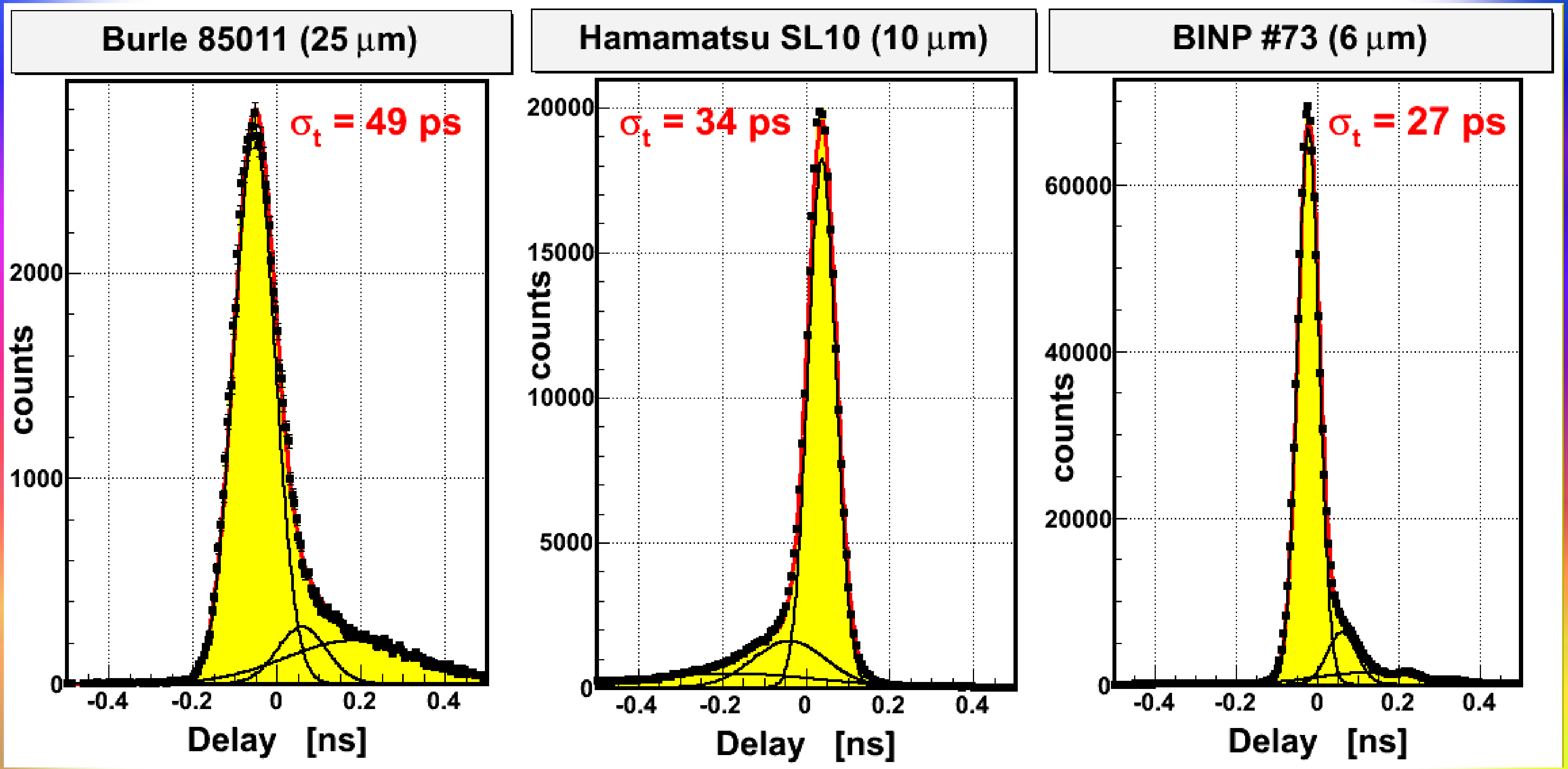
Significant gain drop at large magn. fields and ϕ-angles

Hamamatsu SL10 (10 µm)



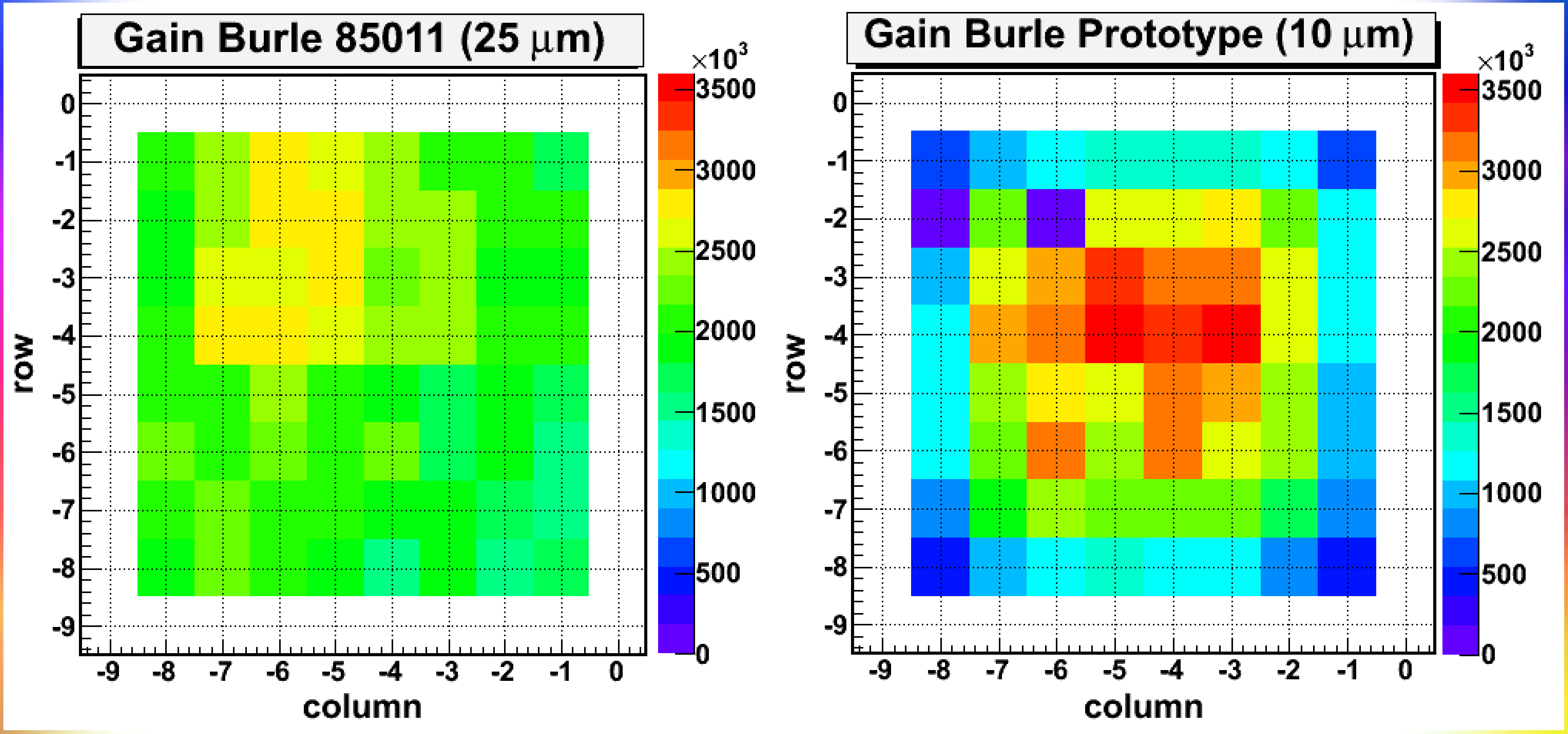
MCP-PMT Time Resolution

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



- best single photon resolution corrected for electronics and laser width obtained with BINP #73 (6 µm): **20 ps**

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

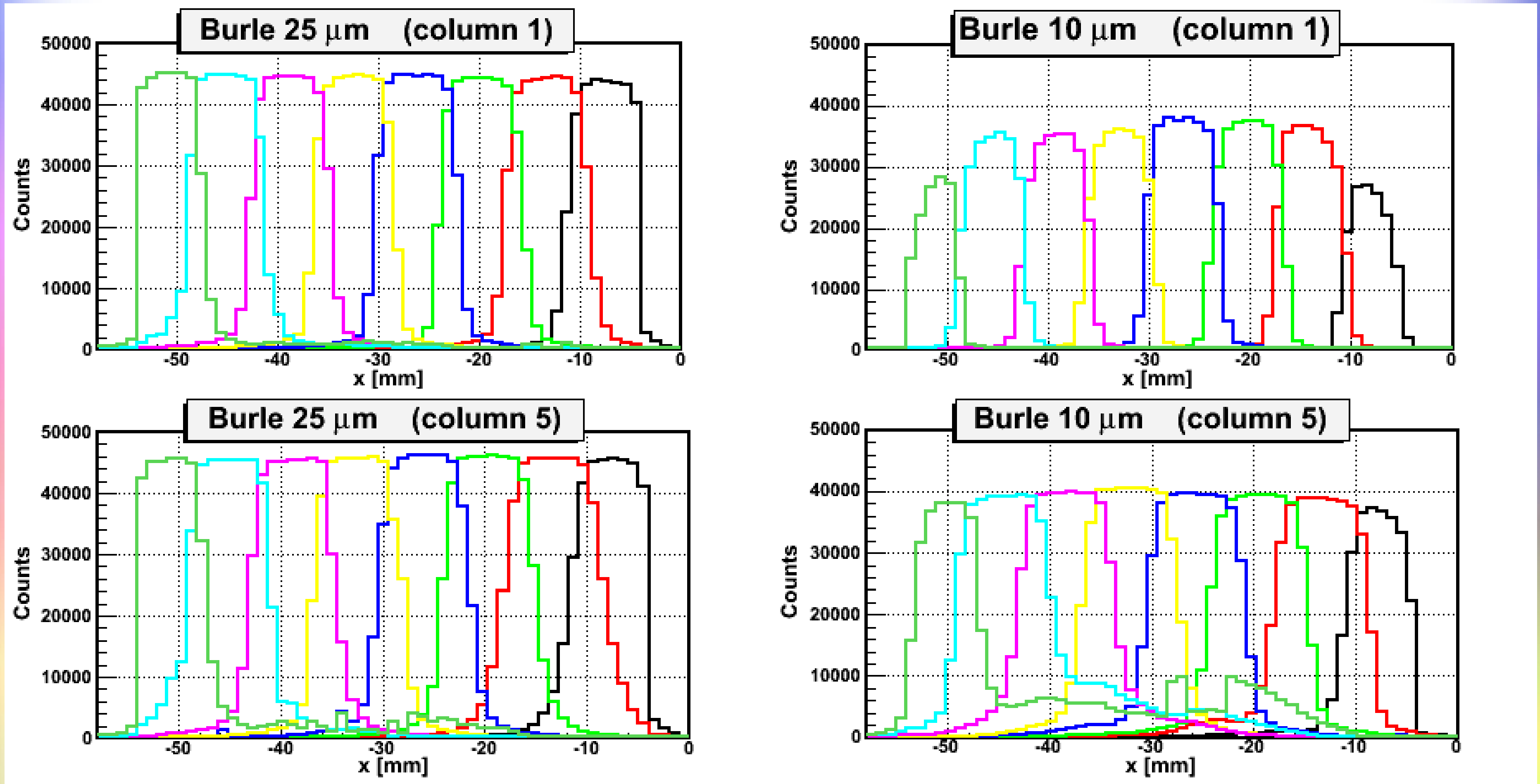


- ***Burle 25 μm:*** **almost x2 gain variations** (1.5 to $2.8*10^6$) in channels
- ***Burle 10 μm:*** **very strong gain fluctuations** (0.5 to $3.5*10^6$!!)

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

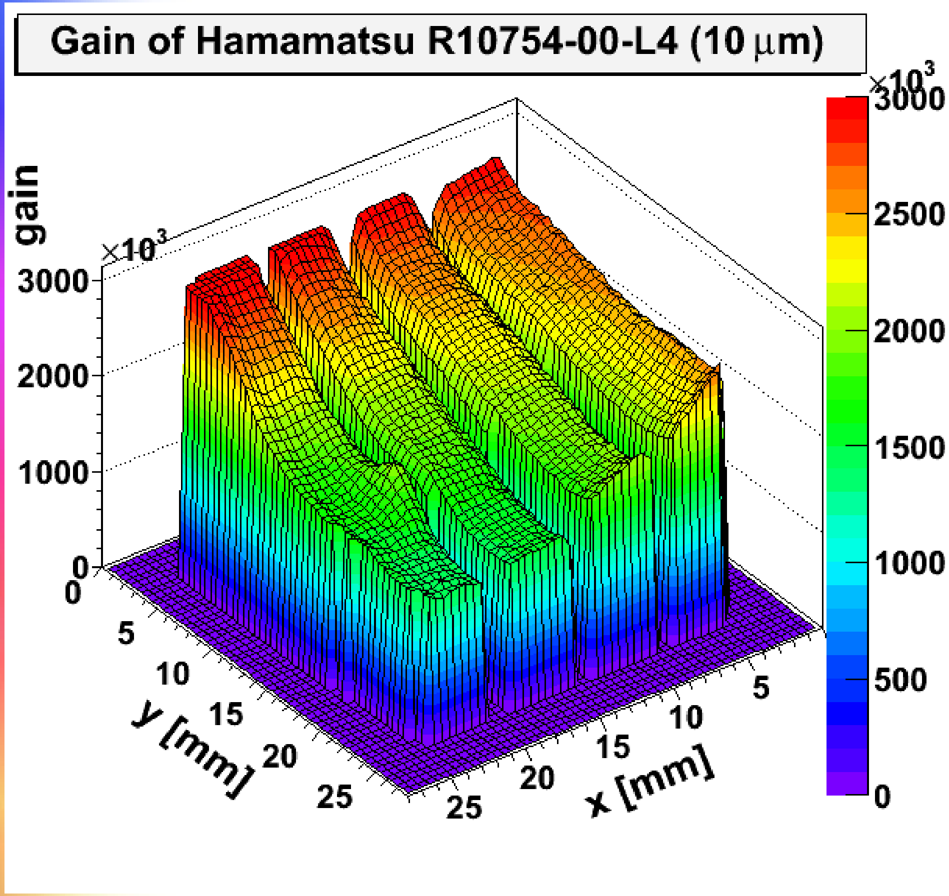
Burle 85011 (25 µm)

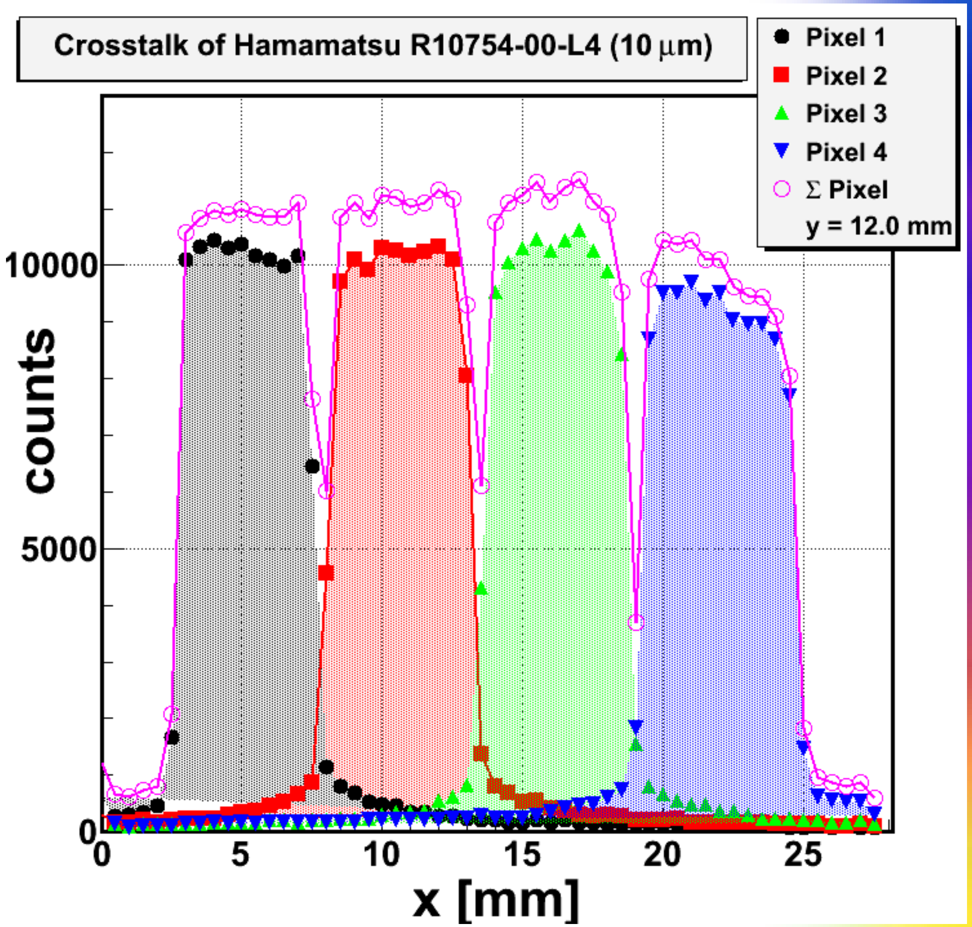
Burle Prototype (10 µm)



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

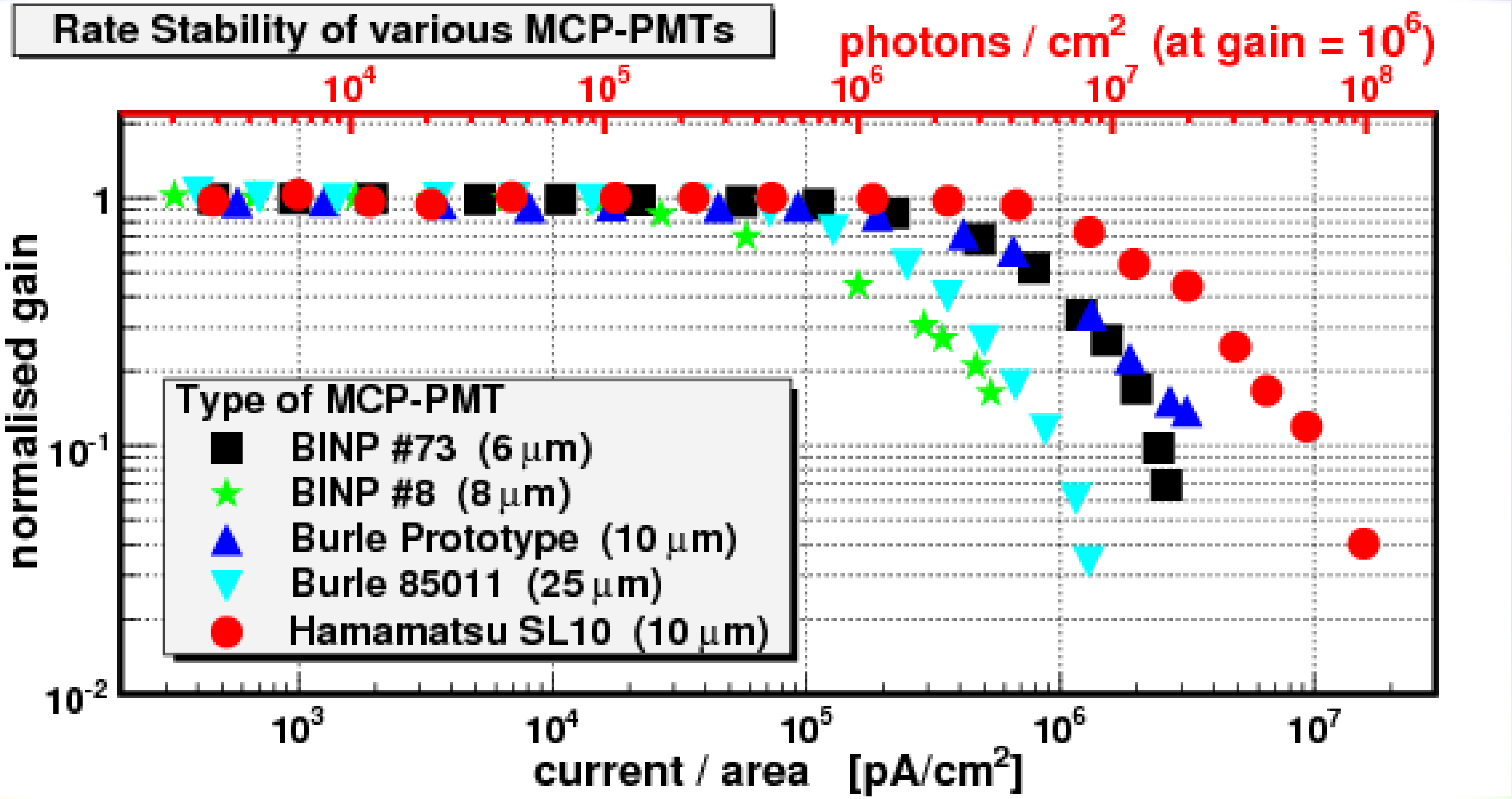
Surface Scans of SL10 (Gain, Crosstalk)





- ***Gain:*** not very uniform even across the individual pixels
- ***Crosstalk:*** rather moderate with specially designed voltage divider

Rate Stability

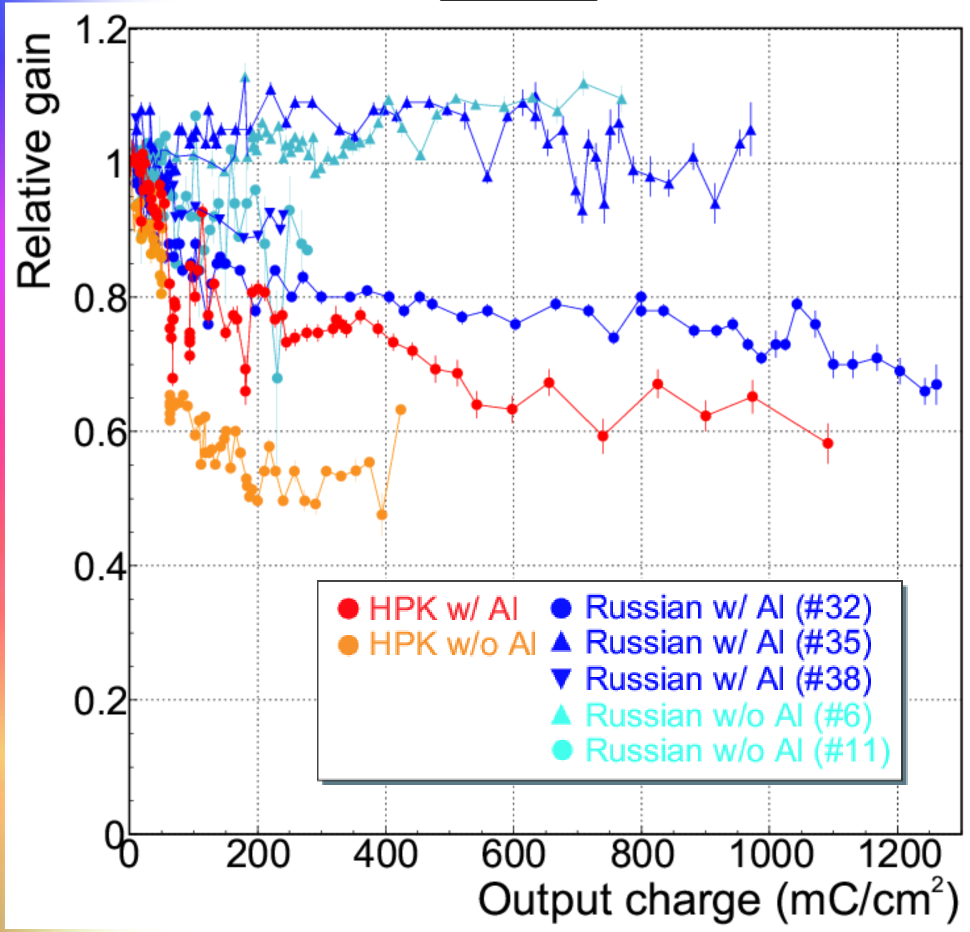


- usually stable operation to about 1 MHz/cm^2 photons
- **Hamamatsu SL10 stable up to 5 MHz/cm^2** (at gain 10^6)

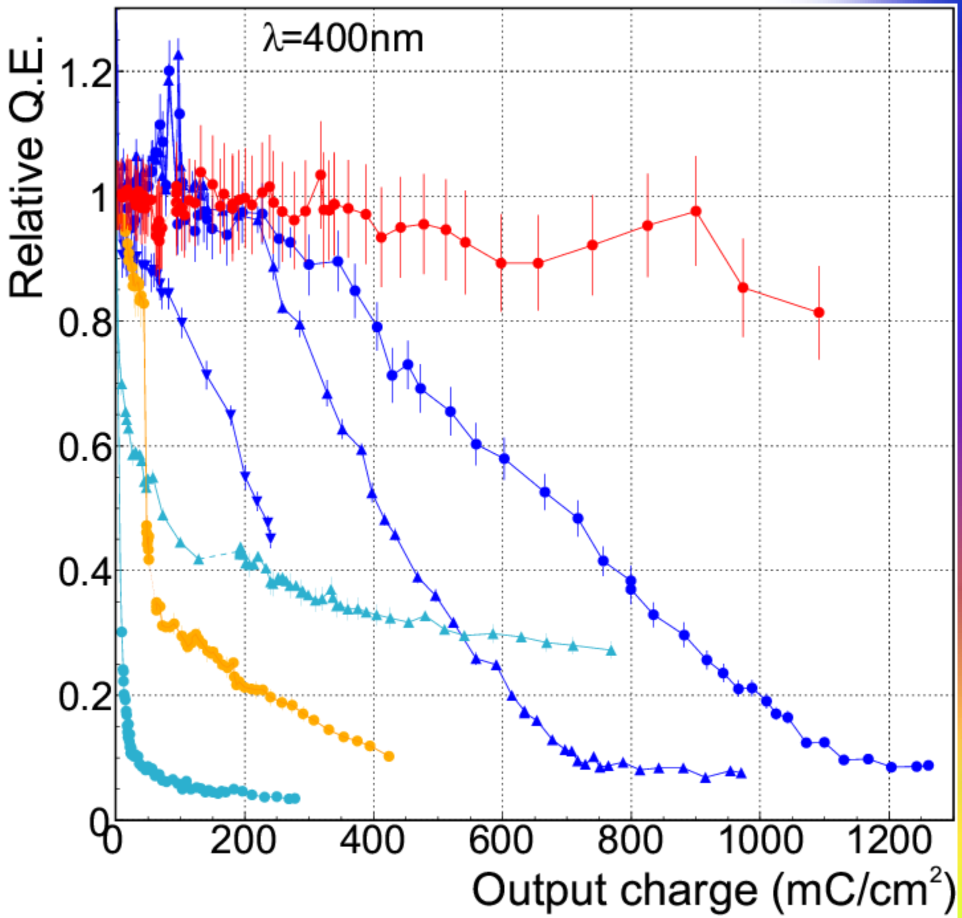
MCP-PMT Lifetime

T. Ohshima (Nagoya)
Talk at SLAC 2006

Gain



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

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	**< 1**	**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

SiPMs for PANDA DIRC?

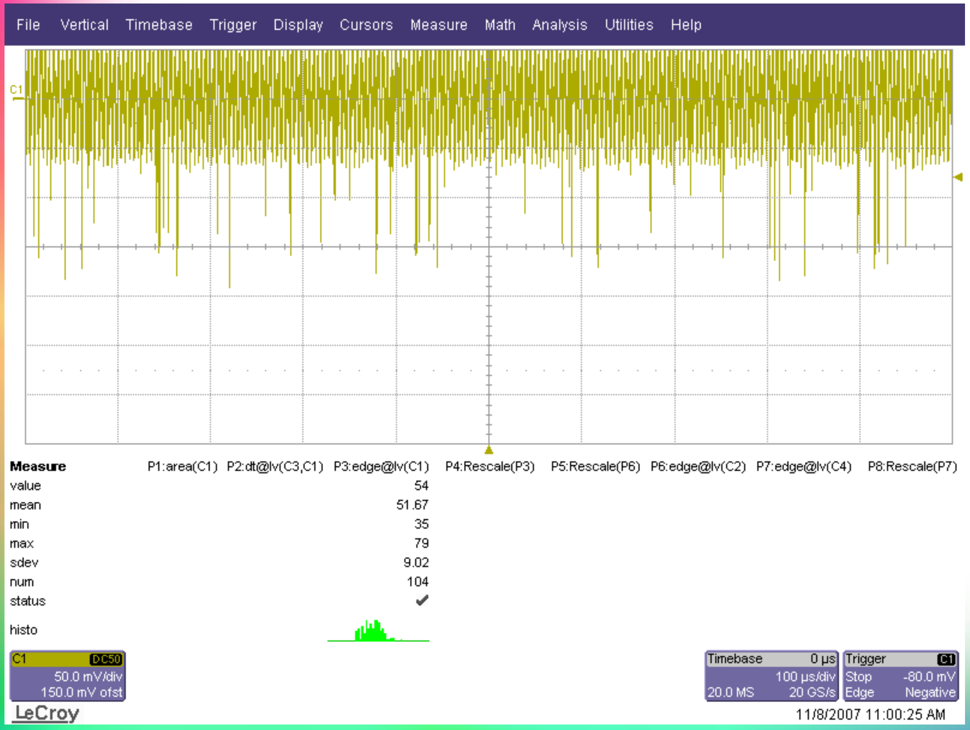
- Advantages compared to MCP-PMTs
  - higher rate stability
  - higher quantum efficiency
  - significantly longer lifetime
- Disadvantages compared to MCP-PMTs
  - still rather low geometrical efficiency
  - worse time resolution
  - behaviour in radiation environment?
  - **enormous dark count rates at room temperature**
  - very expensive (coverage of large area)

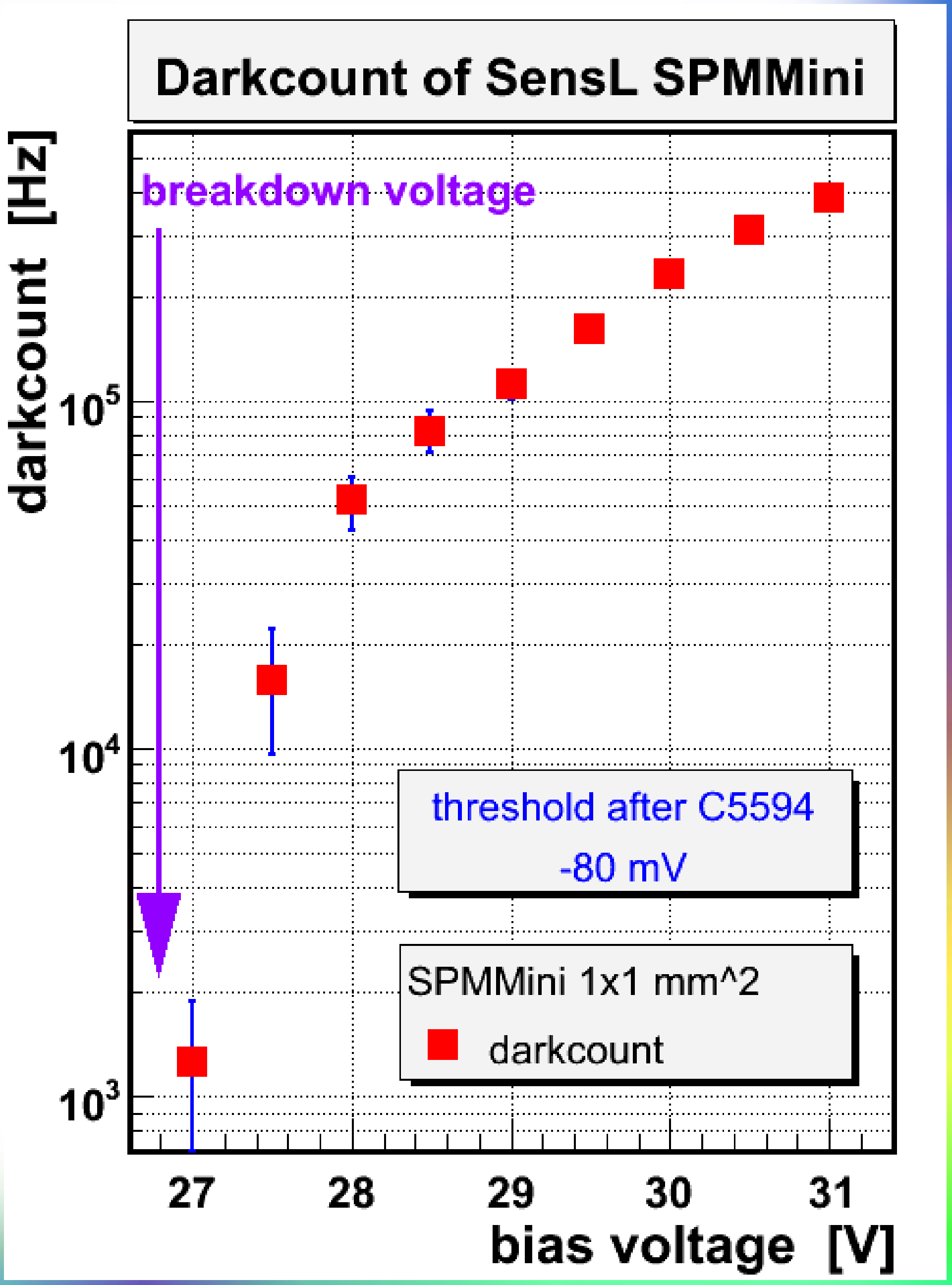
SiPMs available in Erlangen

- SensL SPM
  - SPMMini (only test module)
    - 1x1 mm^2 with Peltier-Cooling
  - SPMArray
    - active area 12x12 mm^2 with 4x4 channels
      (3x3 mm^2 SiPMs with 35 µm microcells)
- Hamamatsu MPPC
  - S10362-11-025U; S10362-11-050U; S10362-11-100U
    - 1x1 mm^2 MPPCs with 25, 50 and 100 µm microcells
  - S10985-025C; S10985-050C
    - active area 6x6 mm^2 with 2x2 channels
      (3x3 mm^2 MPPCs with 25 and 50 µm microcells)

SensL SPMMini (Dark Count)

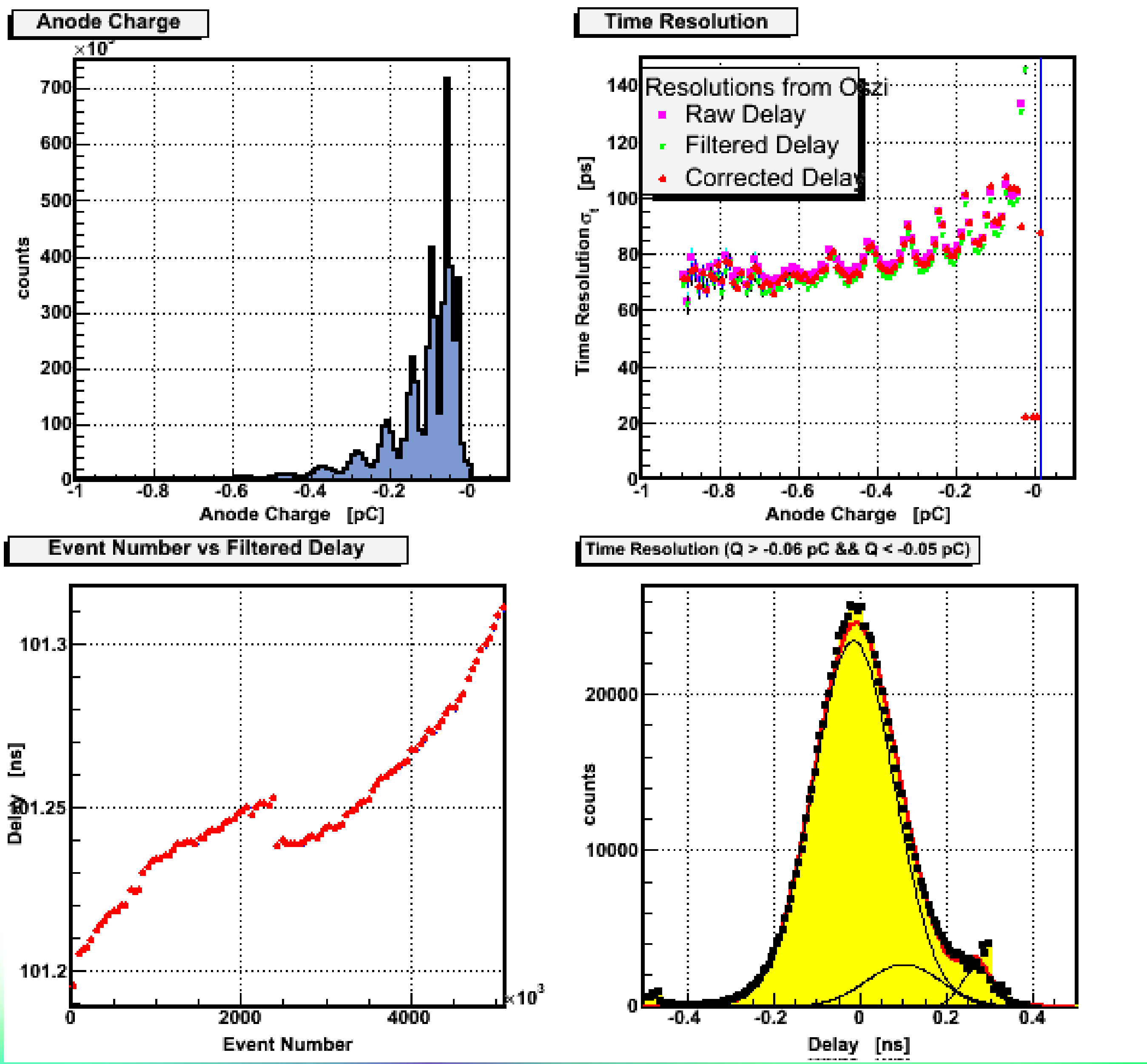
- Size of SPMMini: 1x1 mm^2
- 920 pixels
- Test module with readout electronics and Peltier cooling
- **Dark count cooled >100 kHz**



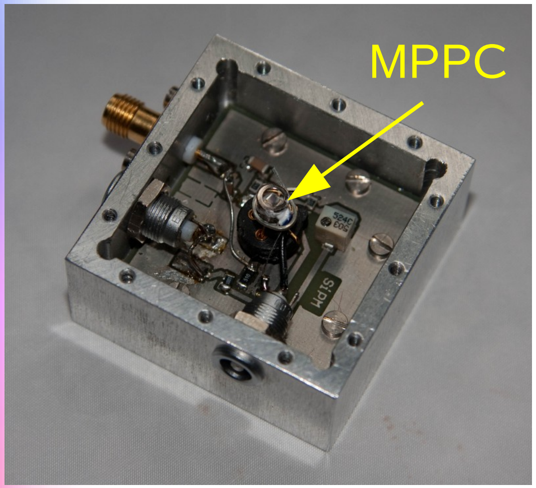


Hamamatsu MPPC (Time Resolution)

- Hamamatsu MPPC (S10362-11-050U)
  - 50 µm pixels
  - area: 1x1 mm^2
- self-designed readout circuit
- amplification factor x6300
- measured with oscilloscope
- **single photon time resolution ~100 ps**

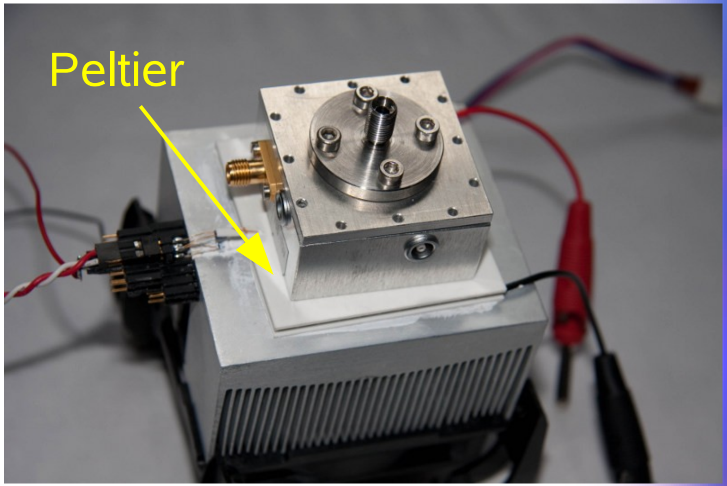


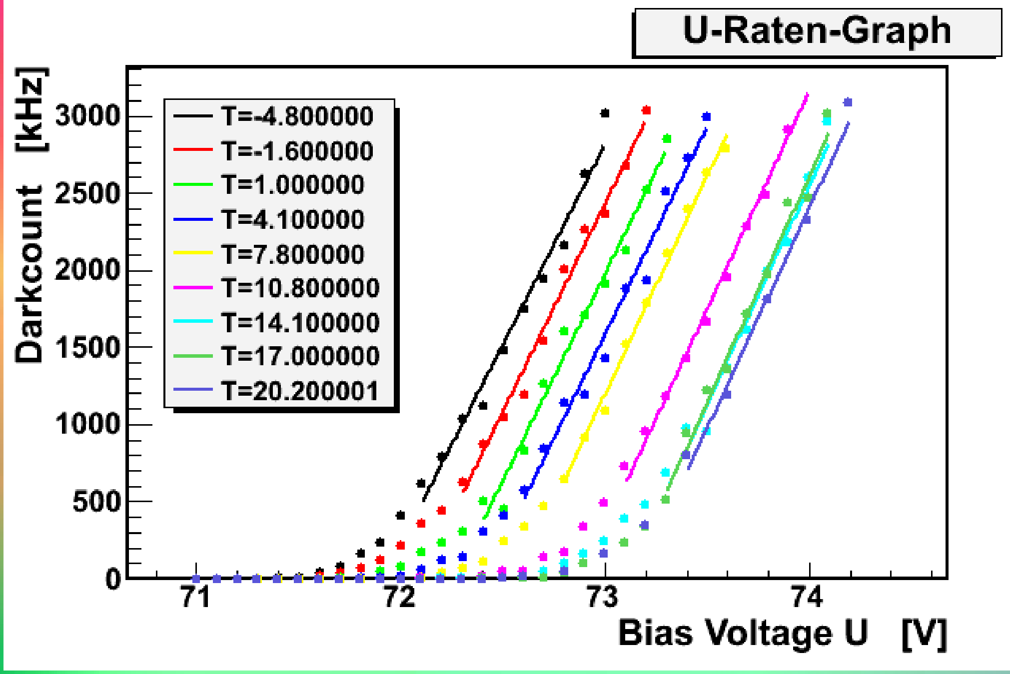
First Measurements with Cooled MPPC

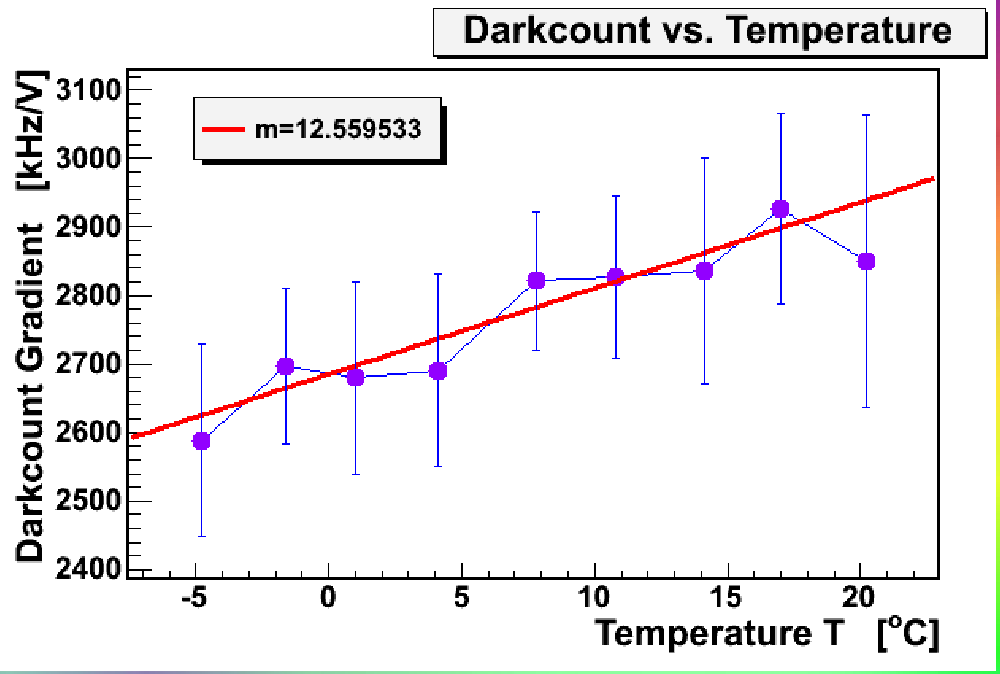


Hamamatsu MPPC S10362-11-050U

Cooled with 5x5 cm^2 Peltier element at air → probably not very efficient

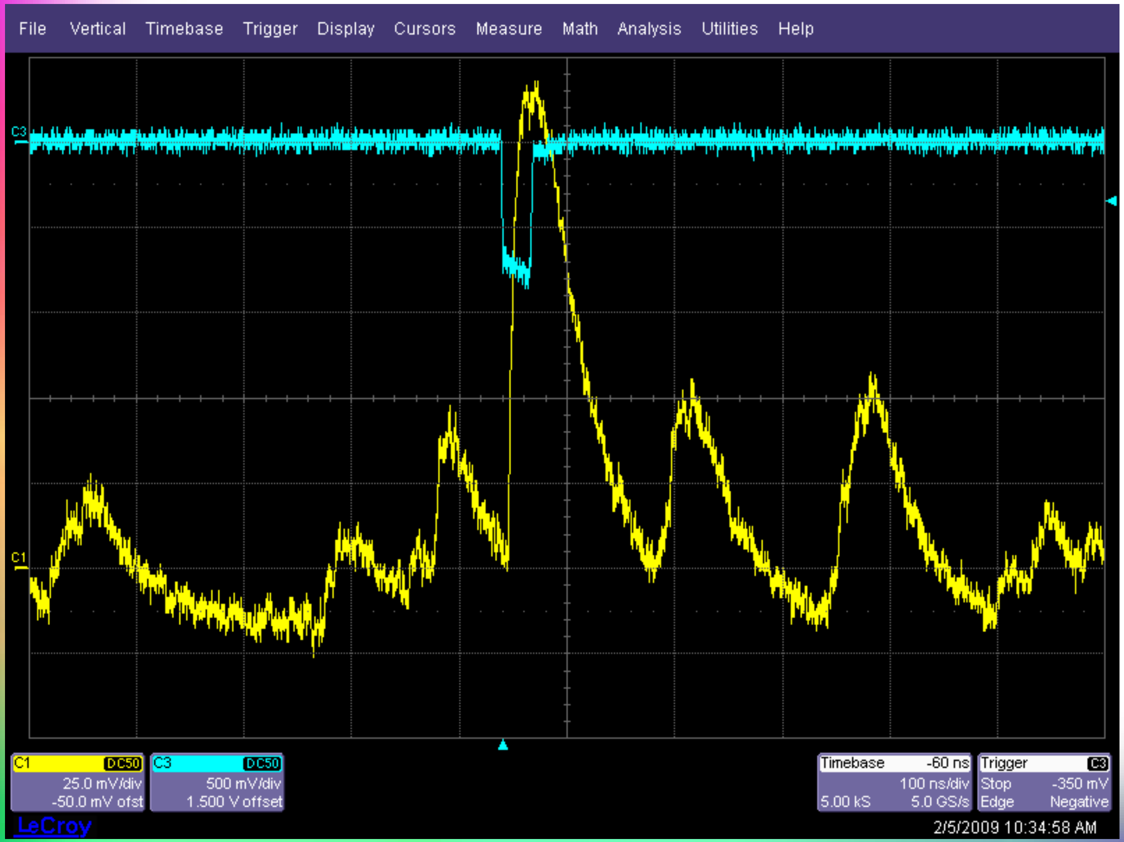


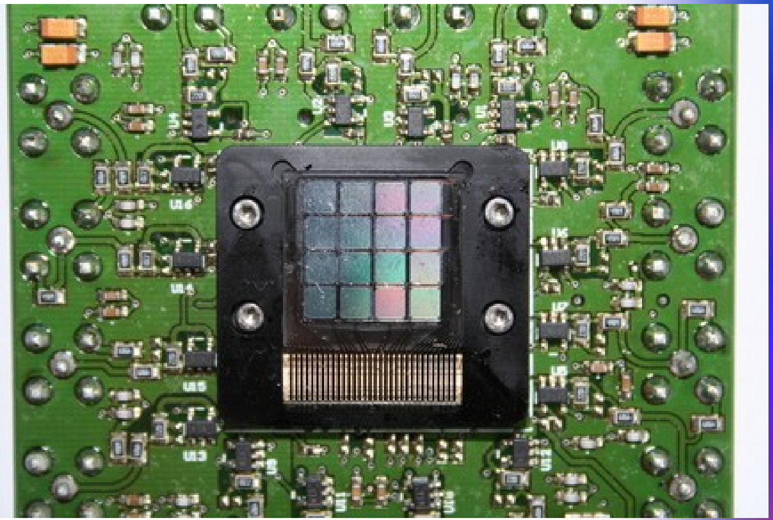




SensL SPMArray

- 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)

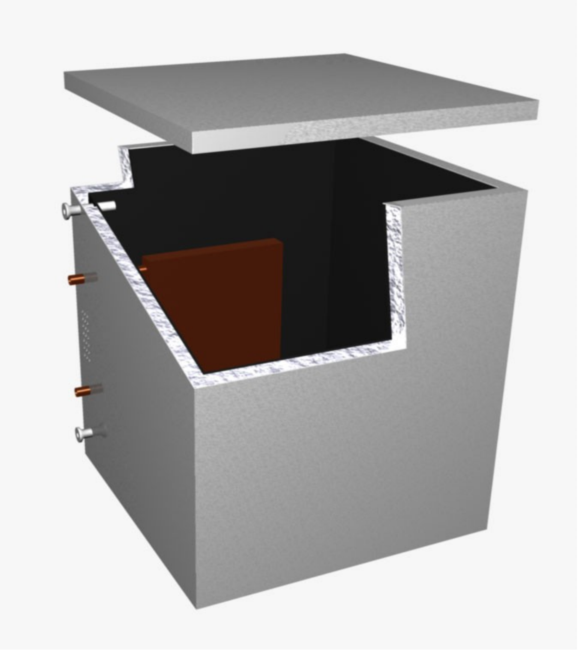




- positive signals
  - rise time ~10 ns
  - width ~100 ns
- enormous dark count rate
  - **~10 MHz/channel at room temperature**
  - a lot of pile-up

Construction of a Cooling Box

- Size: ~60x60x60 cm^3
  - large enough for XY-scans of multi-pixel SiPMs
  - vacuum insulated panels
  - cooling medium: dry gas



- Thermostat ministat 230-cc
  - temperature: **-40 ... 200 °C**
  - temp. constancy: 0.02 K
  - sucking and forcing pump
  - cooling power:
    - 0.38 kW @ 0 °C
    - 0.05 kW @ -40 °C
  - external temperature control

Plans with SiPMs

- performance measurements for different SiPM models (especially large area devices)
  - most of the equipment exists
  - single photon time resolution
  - behaviour at high event rates
  - lifetime

- **reduction of dark count rates**
  - sensor cooling inside large box (also usable for XY-scans)
  - ***setup is currently being built***