Erlangen Plans with SiPMs

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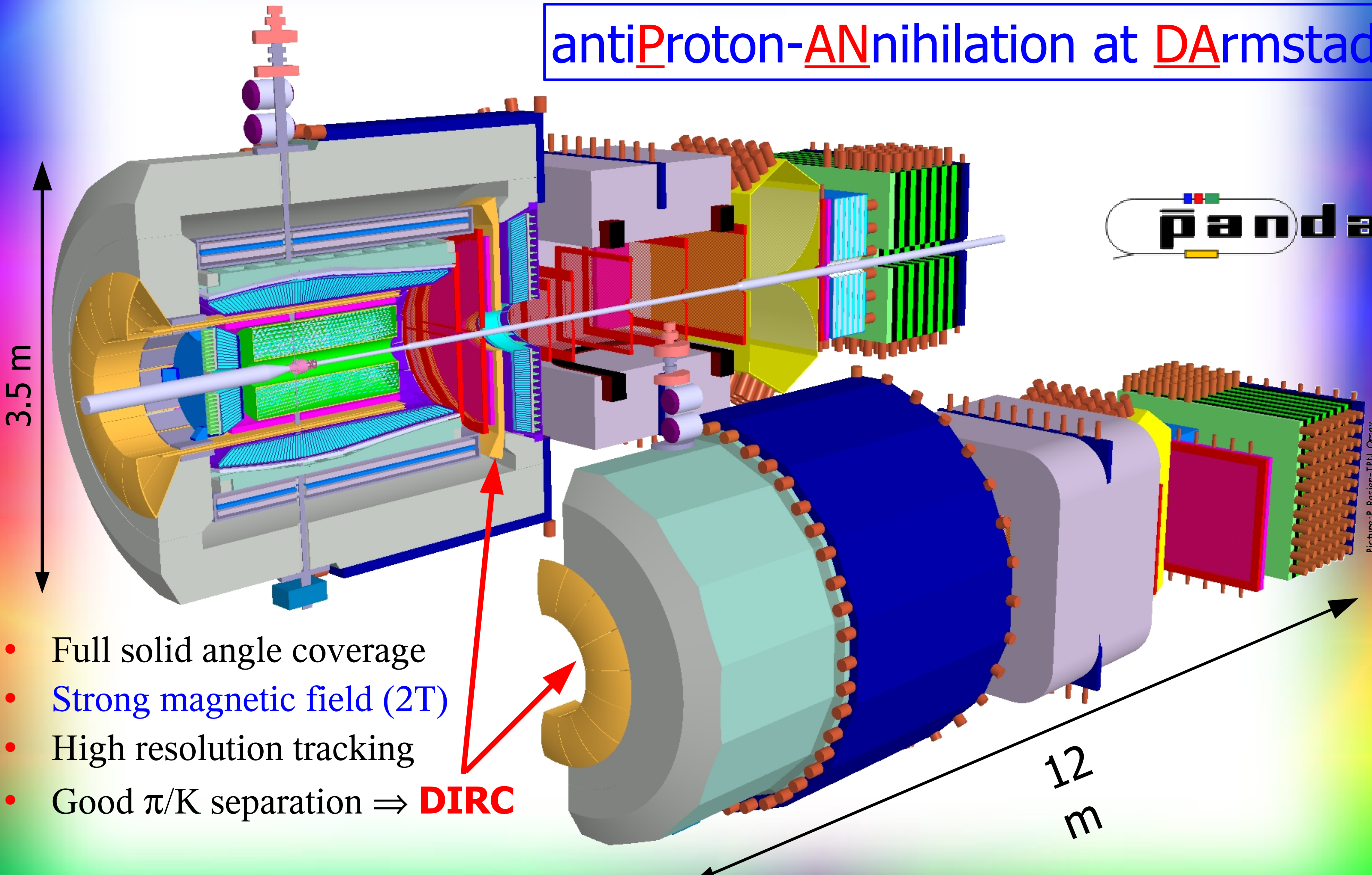
- particle identification with PANDA
- experiences with MCP-PMTs
- first looks at SiPMs
- plans

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

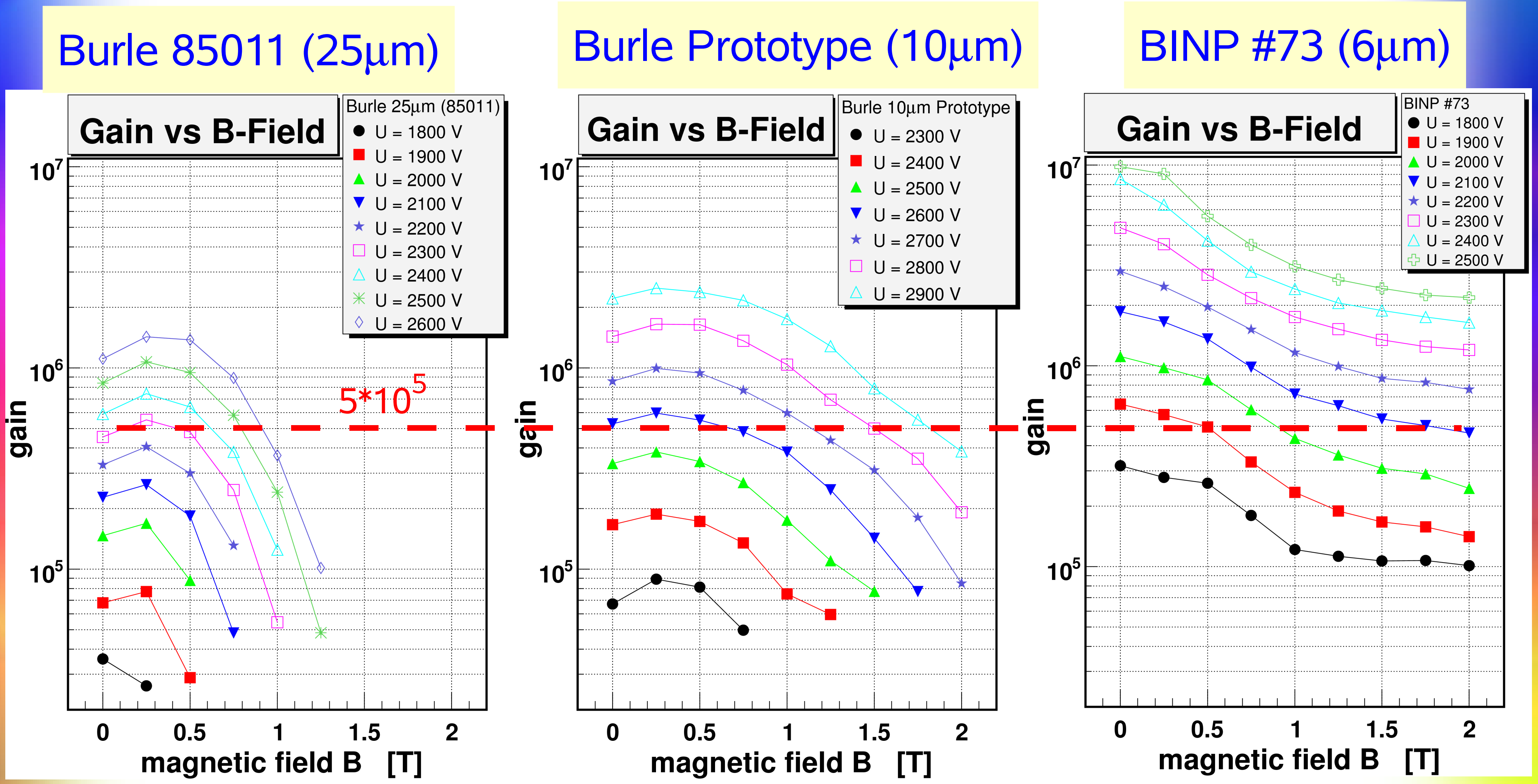
- Single photon detection inside high B-field
  - **high gain** (> $5*10^5$) even in the 2 Tesla magnetic field
- Time resolution to separate π/K with TOP
  - **very good time resolution** of < 50 ps for single photons
- Photon rates in the MHz regime
  - **high rate stability** (rates of several MHz/cm^2)
  - 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)
  - noise problematic

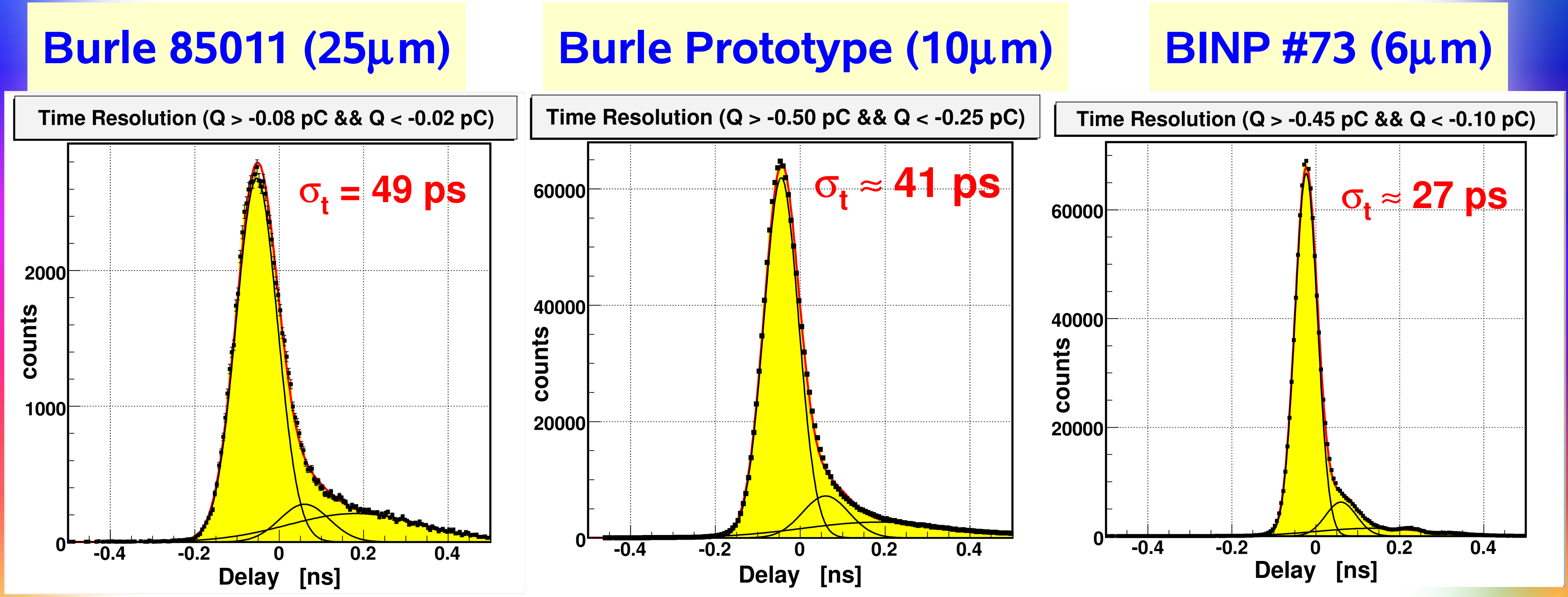
MCP-PMT Gain in Magnetic Field



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

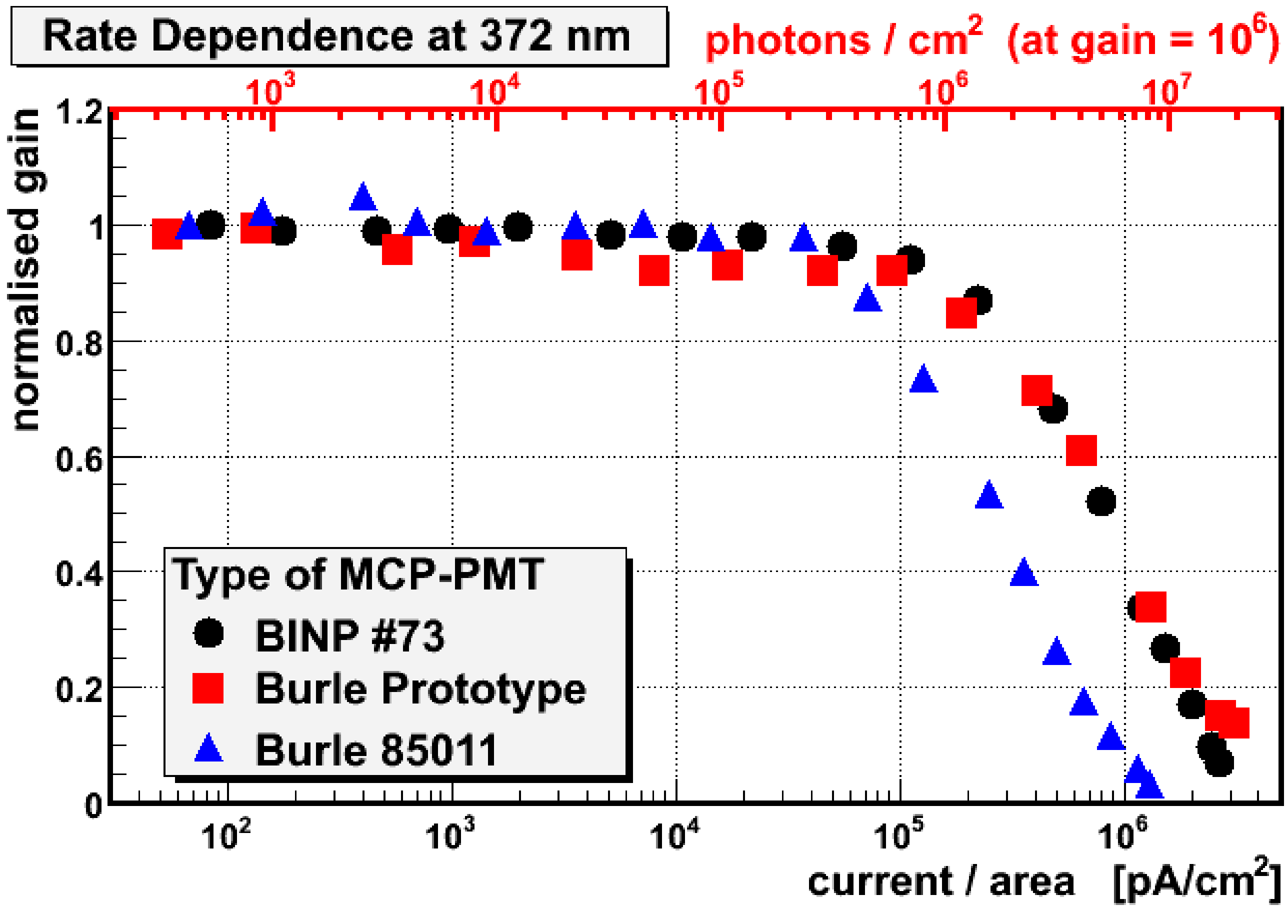
MCP-PMT Time Resolution

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



- 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**

MCP-PMT Rate Stability



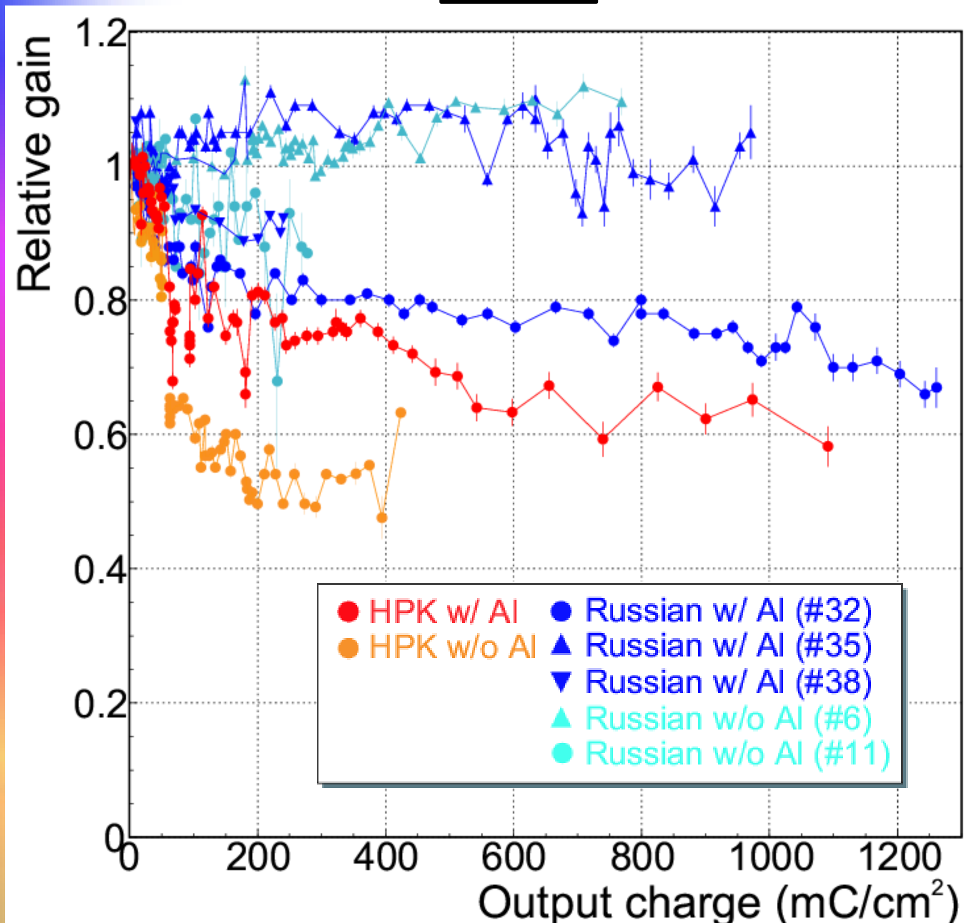
- **usually stable operation to about 1 MHz/cm² photons**
- dark count rates typically several kHz/cm²

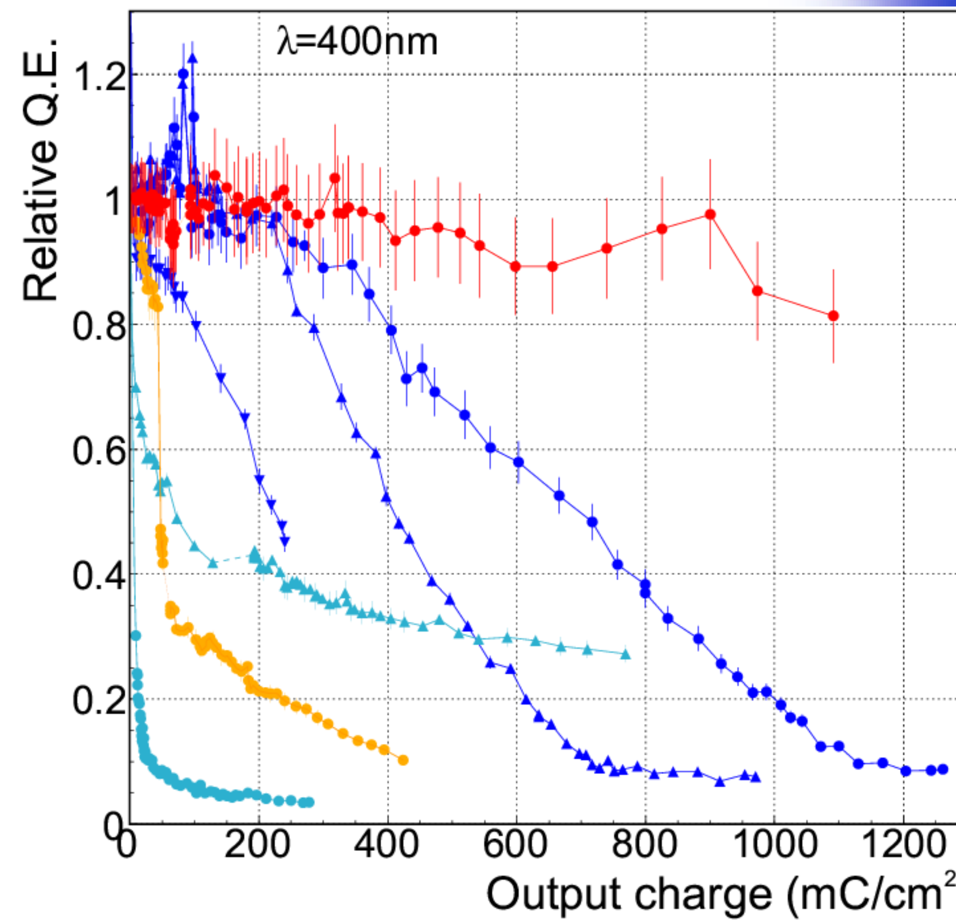
MCP-PMT Lifetime

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

Overview of Sensor Performances

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

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

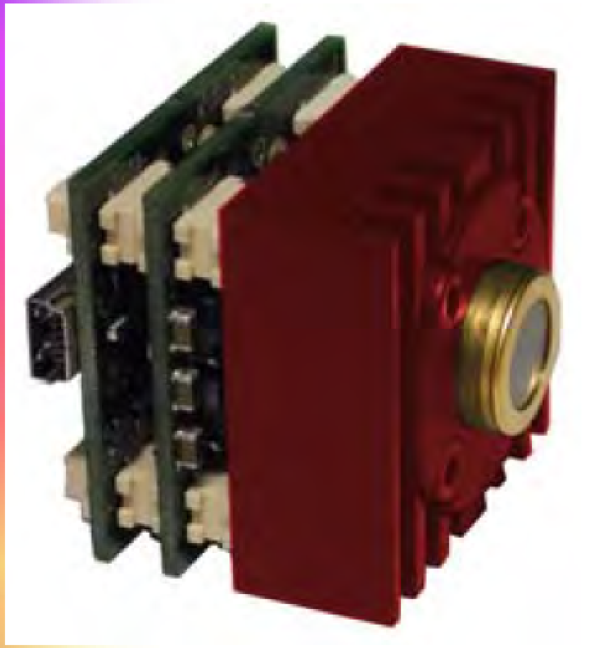
SiPMs for PANDA DIRC?

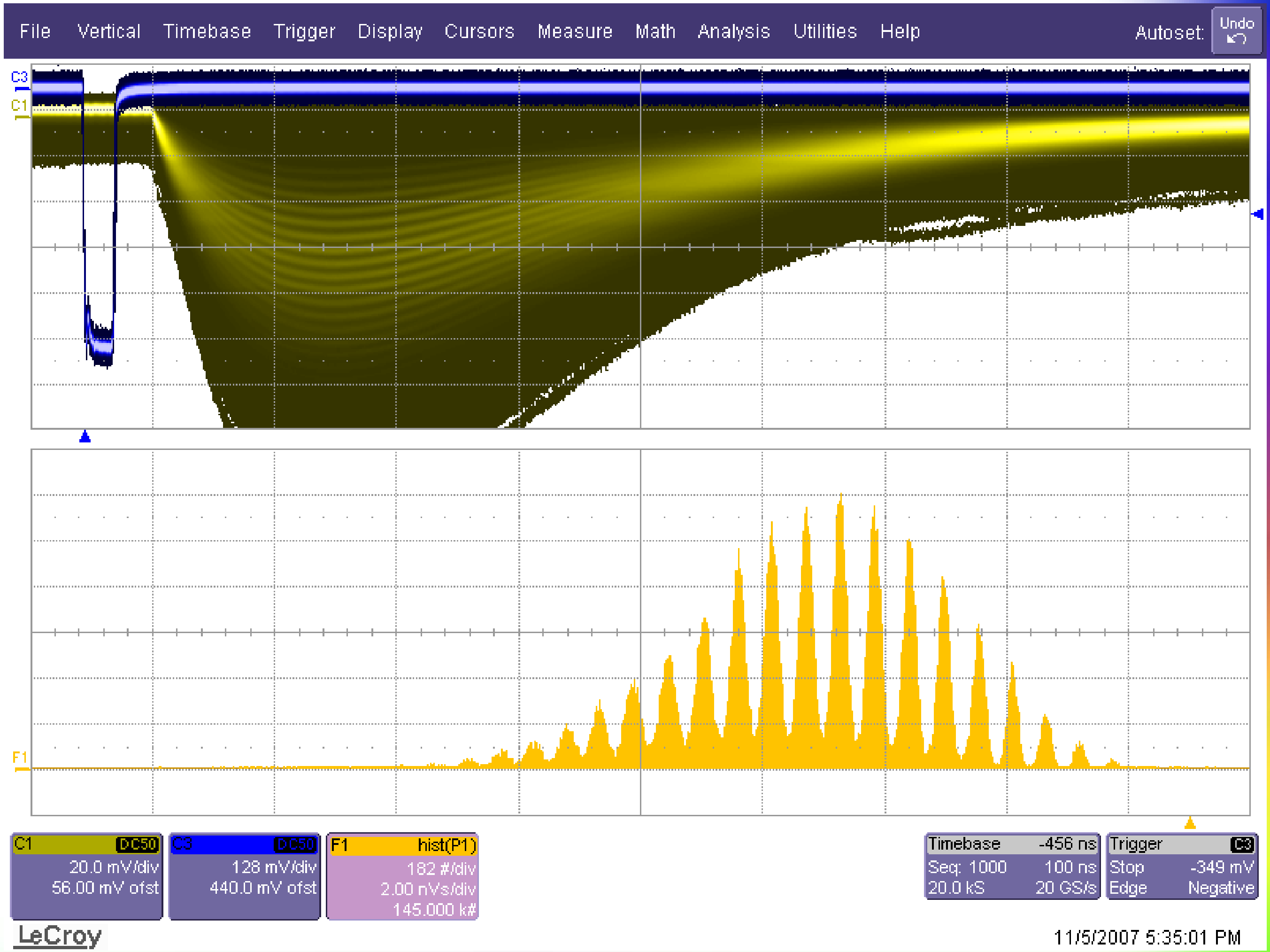
- Advantages compared to MCP-PMTs
  - probably higher rate stability
  - higher quantum efficiency
  - probably longer lifetime

- Disadvantages compared to MCP-PMTs
  - low geometrical efficiency
  - worse time resolution
  - behaviour in radiation environment?
  - **enormous dark count rates at room temperature**
  - very expensive because coverage of large area necessary

SensL SPMMini (1x1 mm^2)

Test module: electronics (“wrong” amplifier + Peltier-Cooling) attached

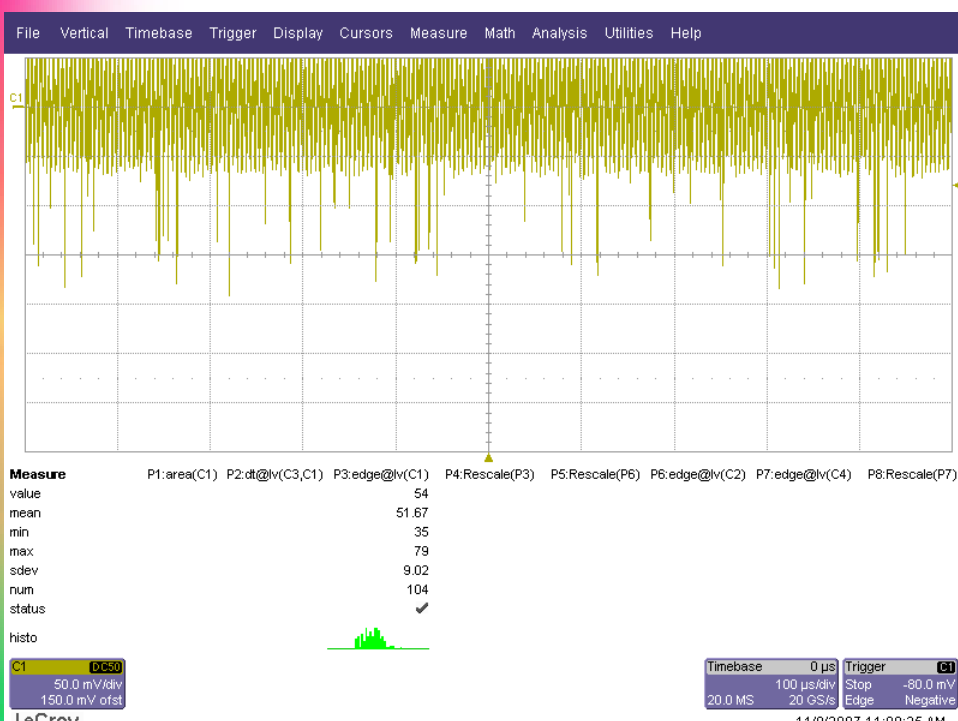


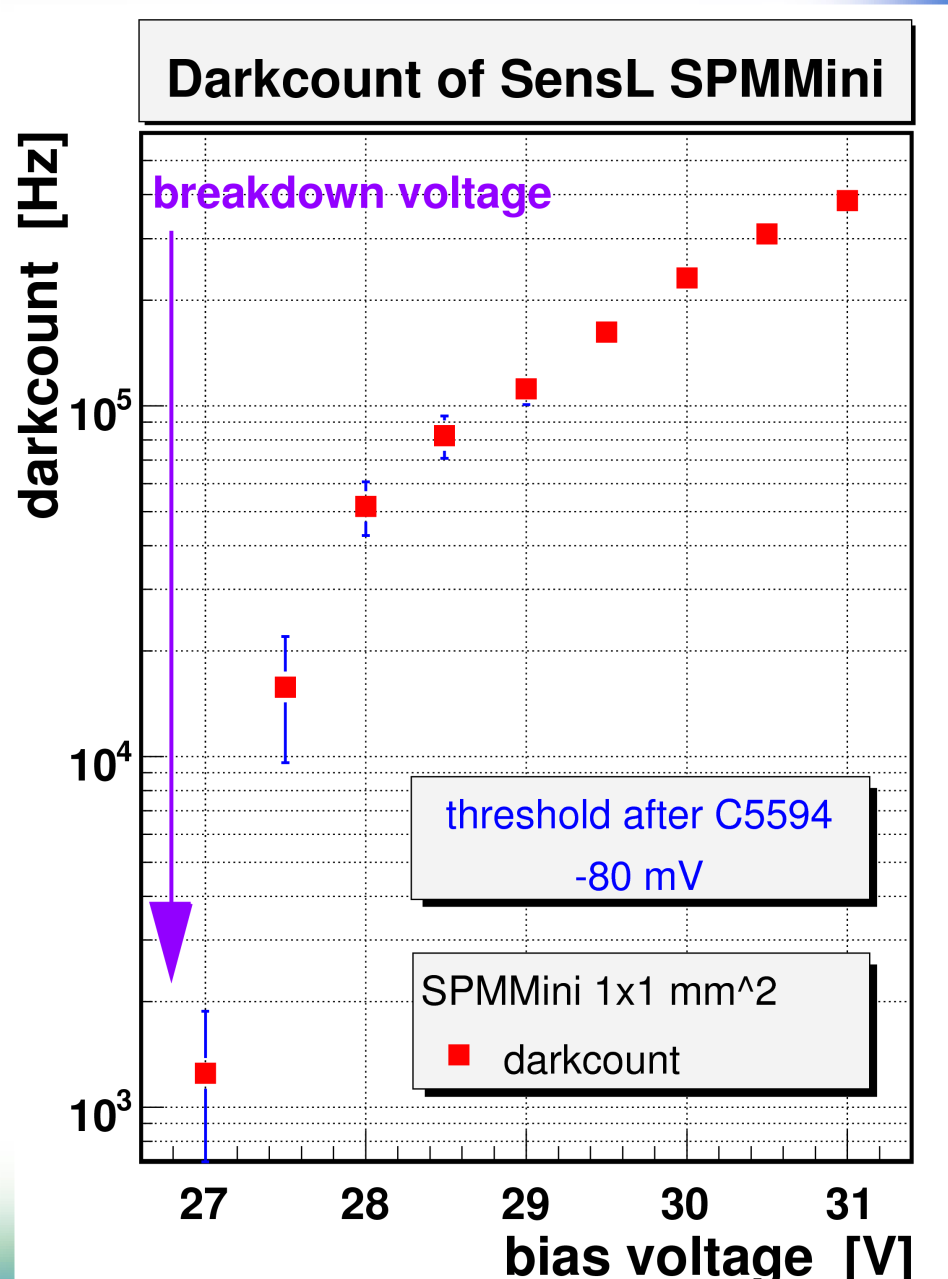


very long signals (~300 ns width, >1 µs long)

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**

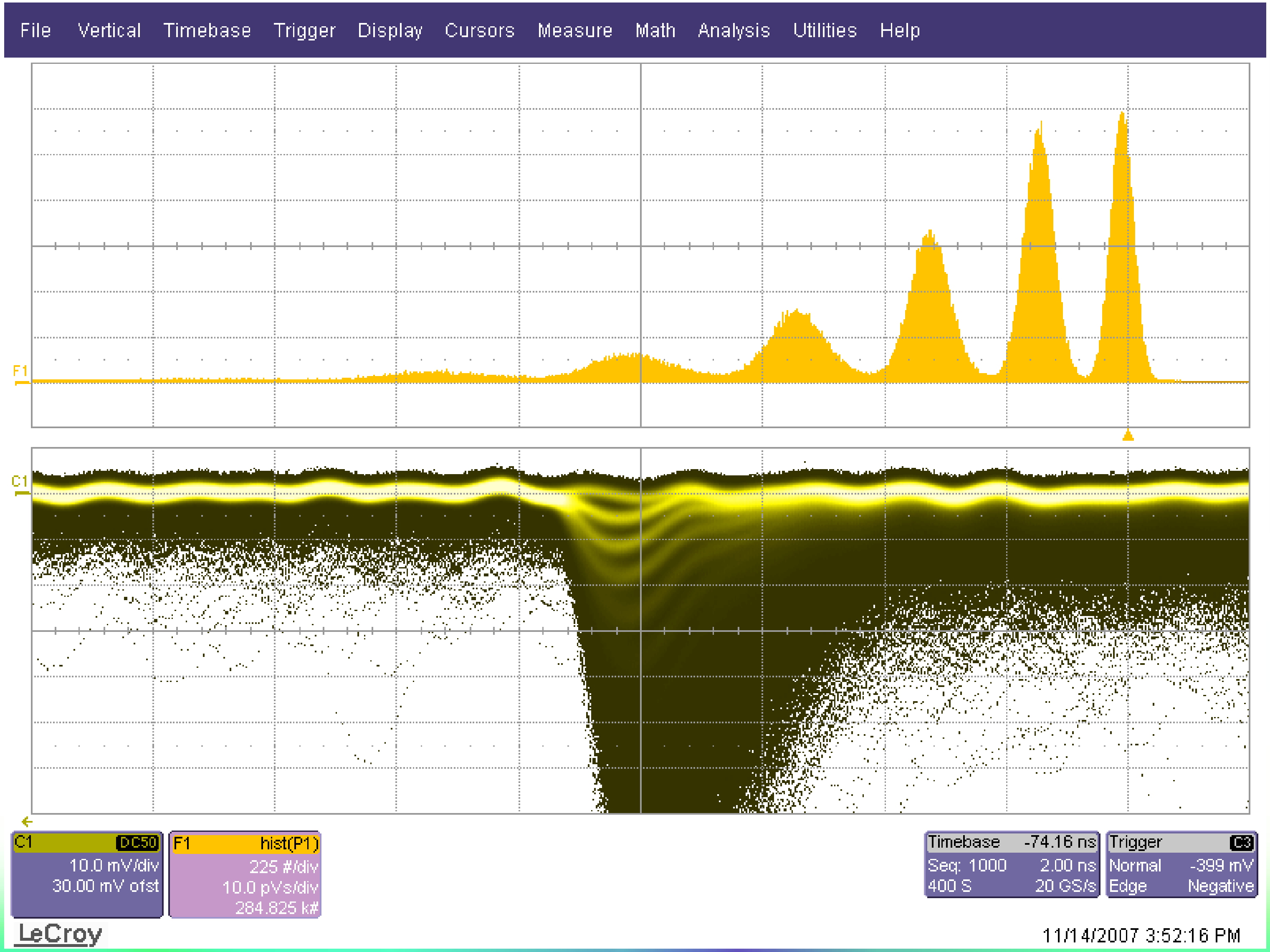




Hamamatsu MPPC (S10362-11-050U)

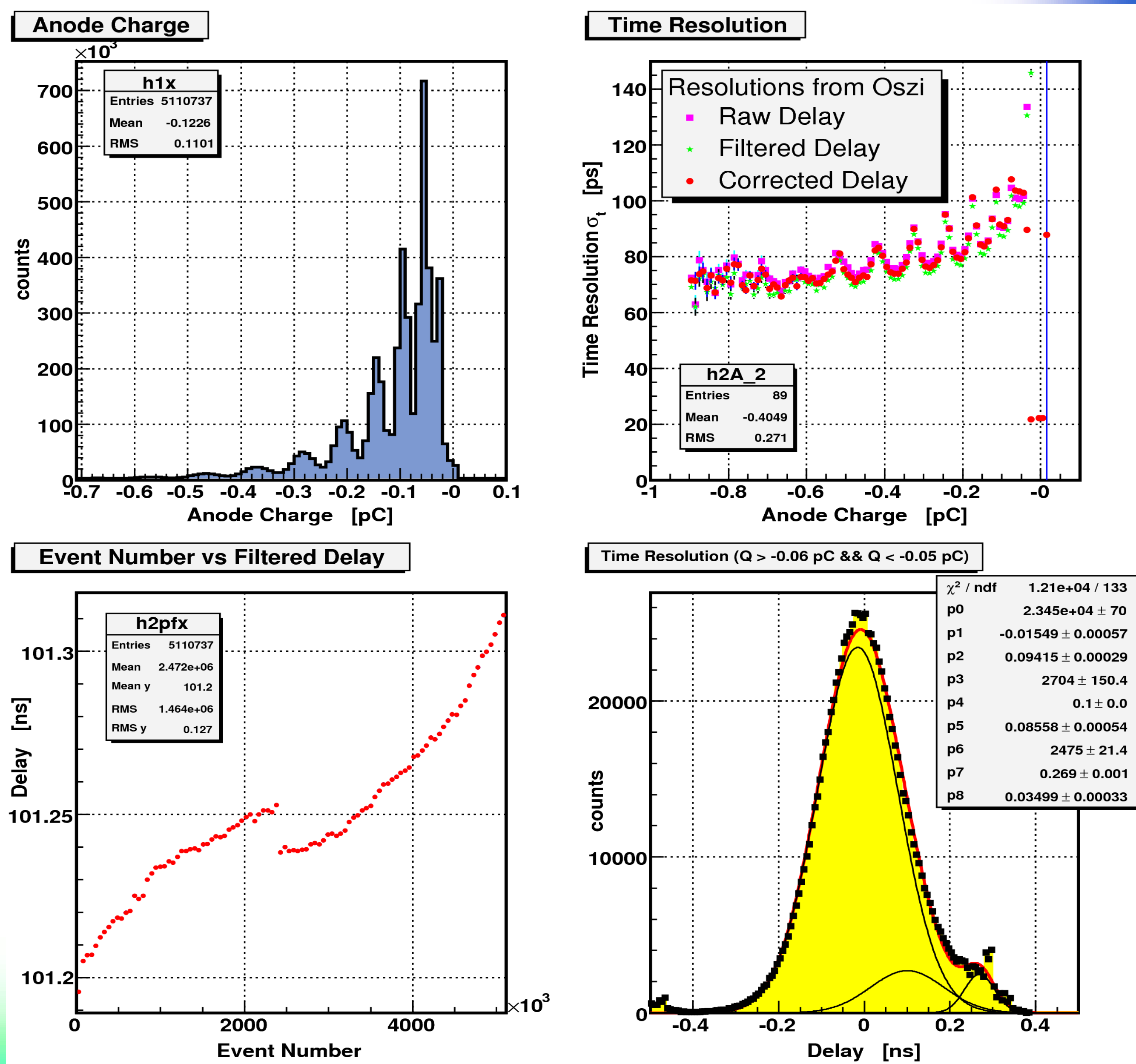
50 μm pixels module: 1x1 mm^2; amplification with VT120A (200x)

very short signals (~2 ns width)



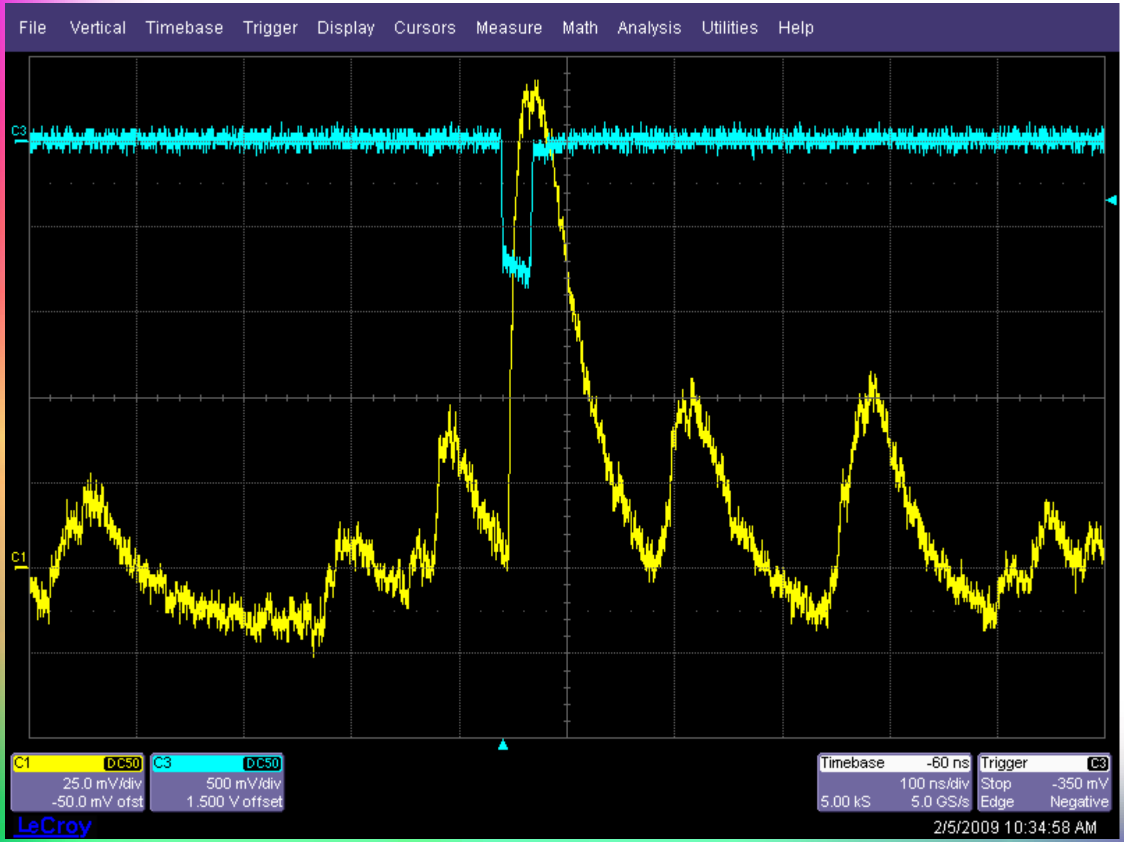
Time Resolution

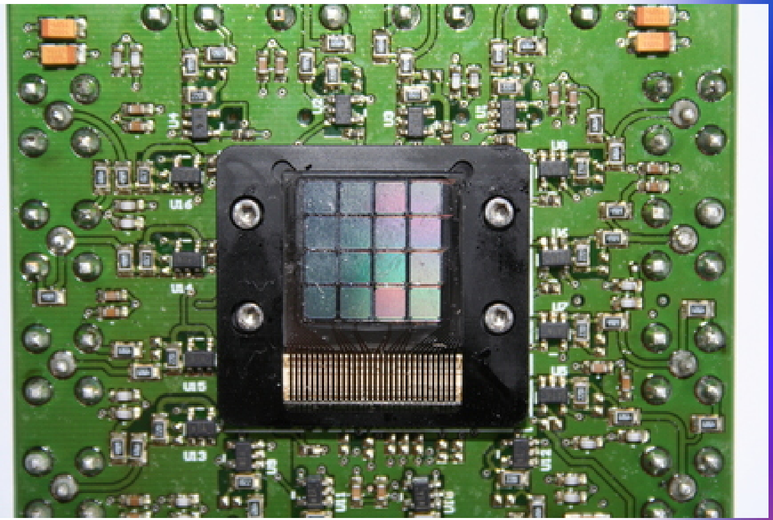
- Hamamatsu MPPC (S10362-11-050U)
  - 50 µm pixels
  - area: 1x1 mm^2
- self-designed readout circuit
- amplification factor x6300
- measured with oscilloscope
- **single photon time resolution ~100 ps**



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

Plans with SiPMs

- performance measurements for different SiPM models
  - setup existent
  - single photon time resolution
  - behaviour at high event rates
  - lifetime

- **reduction of dark count rates**
  - sensor cooling
  - setup has to be built

- behaviour in high radiation environments