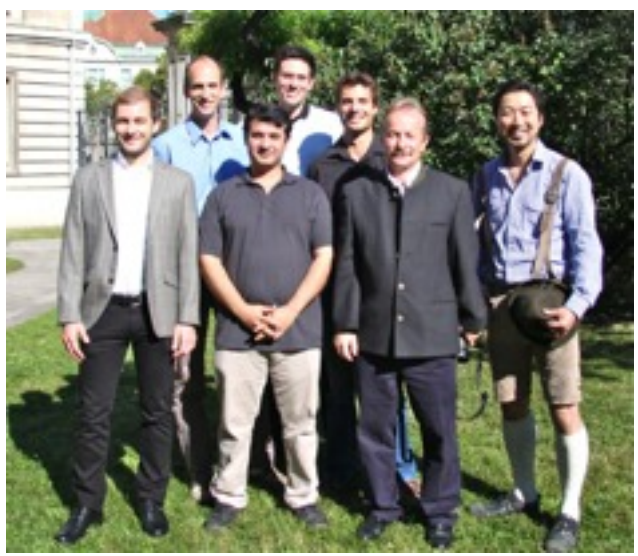
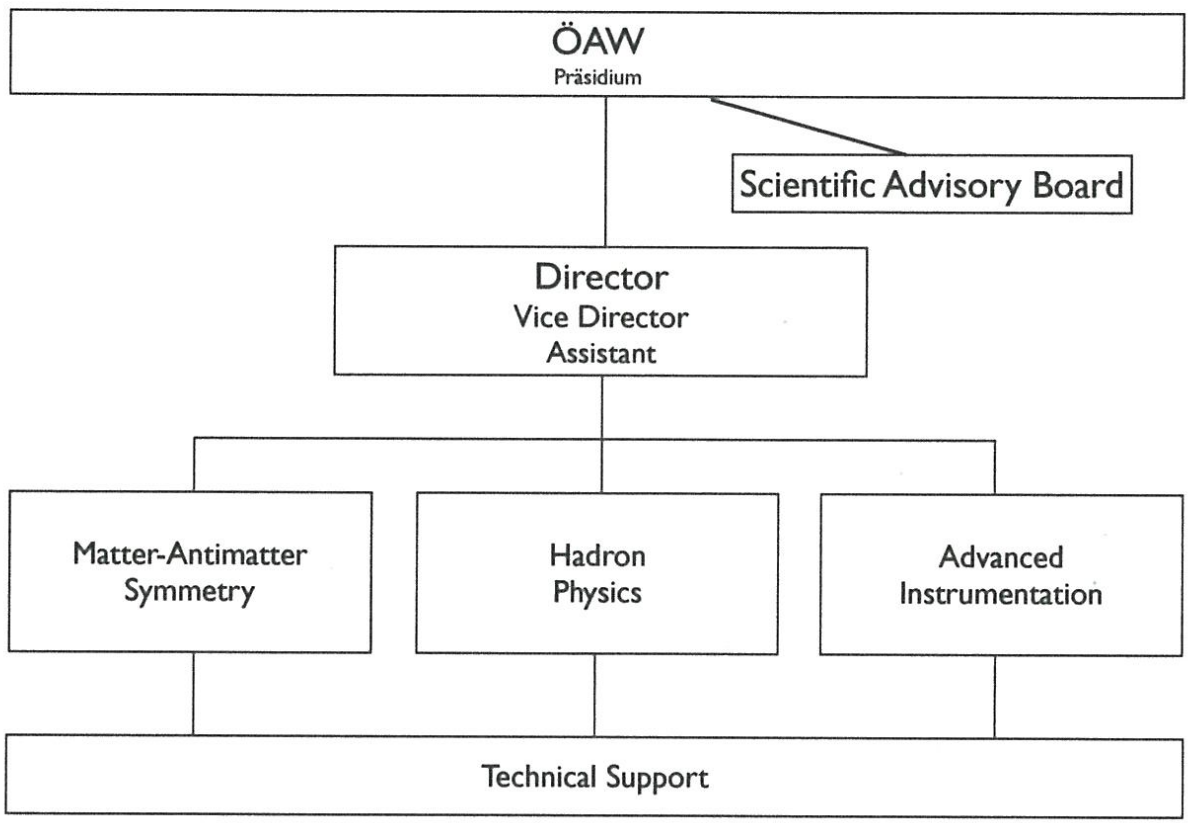
SiPM-Related Projects in Vienna Updates



Ken Suzuki <ken.suzuki@oeaw.ac.at>

Organizational structure

SMI has the following **structure**:



Team

ÖAW Österreichische Akademie der Wissenschaften

Present Members

Johann Marton	Staff
Johann Zmeskal	Staff
Ken Suzuki	Staff
Stefan Brunner	PhD Stuent
Lukas Gruber	PhD Stuent
Albulena Berisha	Diploma Student

Former Members

Stefan Fossati	Work Student
Matthias Schafhauser	Work Student
Gamal Ahmed	PhD Student
Florian Schilling	Diploma Student
Mariana Rihl	Diploma Student

+ Technicians (H. Schneider, L. Stohwasser, D. Stückler)

Publications

- *Since 2007-*
- *7 Publications*
- *1 Ph. D Thesis*
- *4 Diploma Theses*

- *In later session*
  - *Stefan Brunner: ToF-PET*
  - *Lukas Gruber: dSiPM, SciTil*

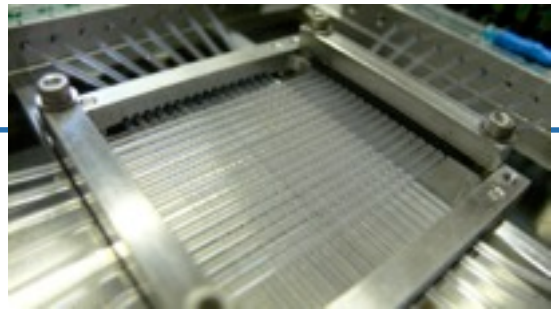
- *In this talk*
  - *A few topics among the rest*

Earlier Projects

- *Beam Profile Monitor with SciFi (2007-2008)*
- *Beamline Veto Counter for π beam (2011)*
- *SiPM Characteristics (2007-2009)*
- *Timing Performance (2009-2010)*
- *w/ Temperature Controll*

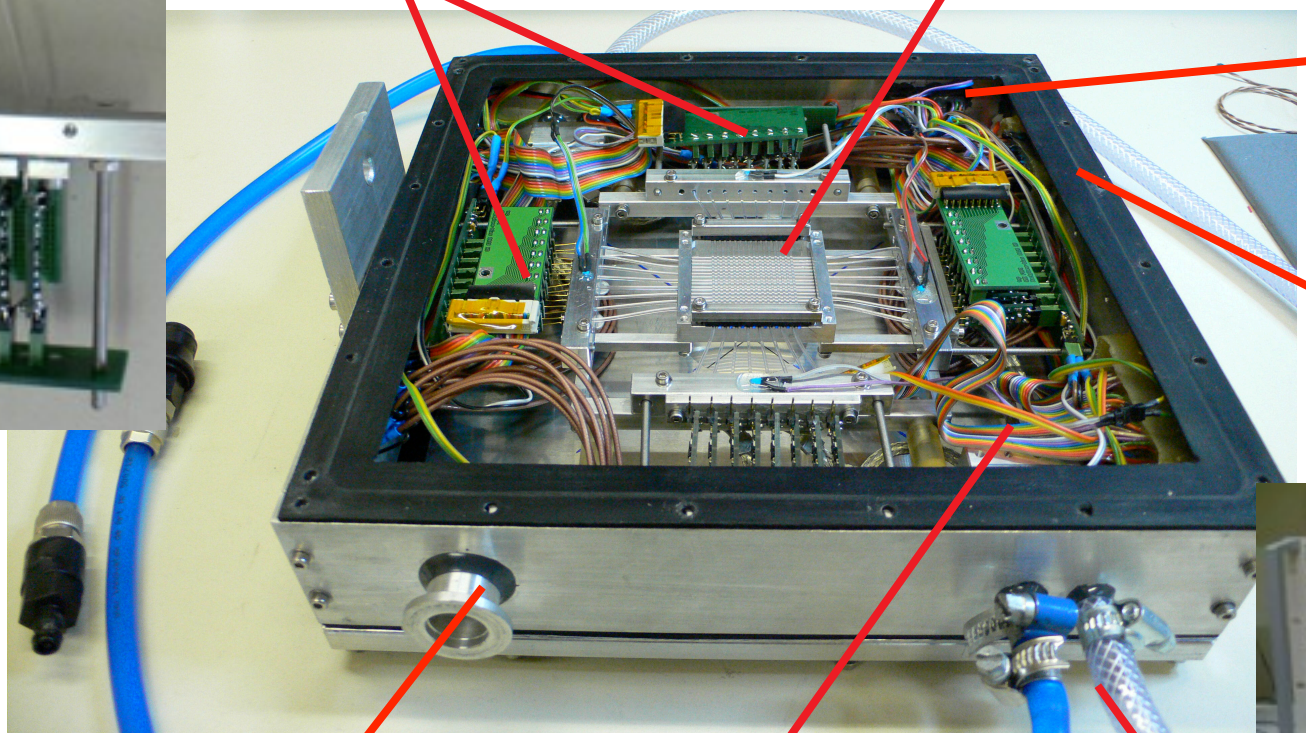
Beam Profile Monitor

KS, M. Schaffhauser, P. Bühler



Scintillating Fiber Grid

SiPM + Amplifier



D-sub 37pin peltier, temp. sensor, amp power

D-sub 37pin bias

to Pump

Peltier Element

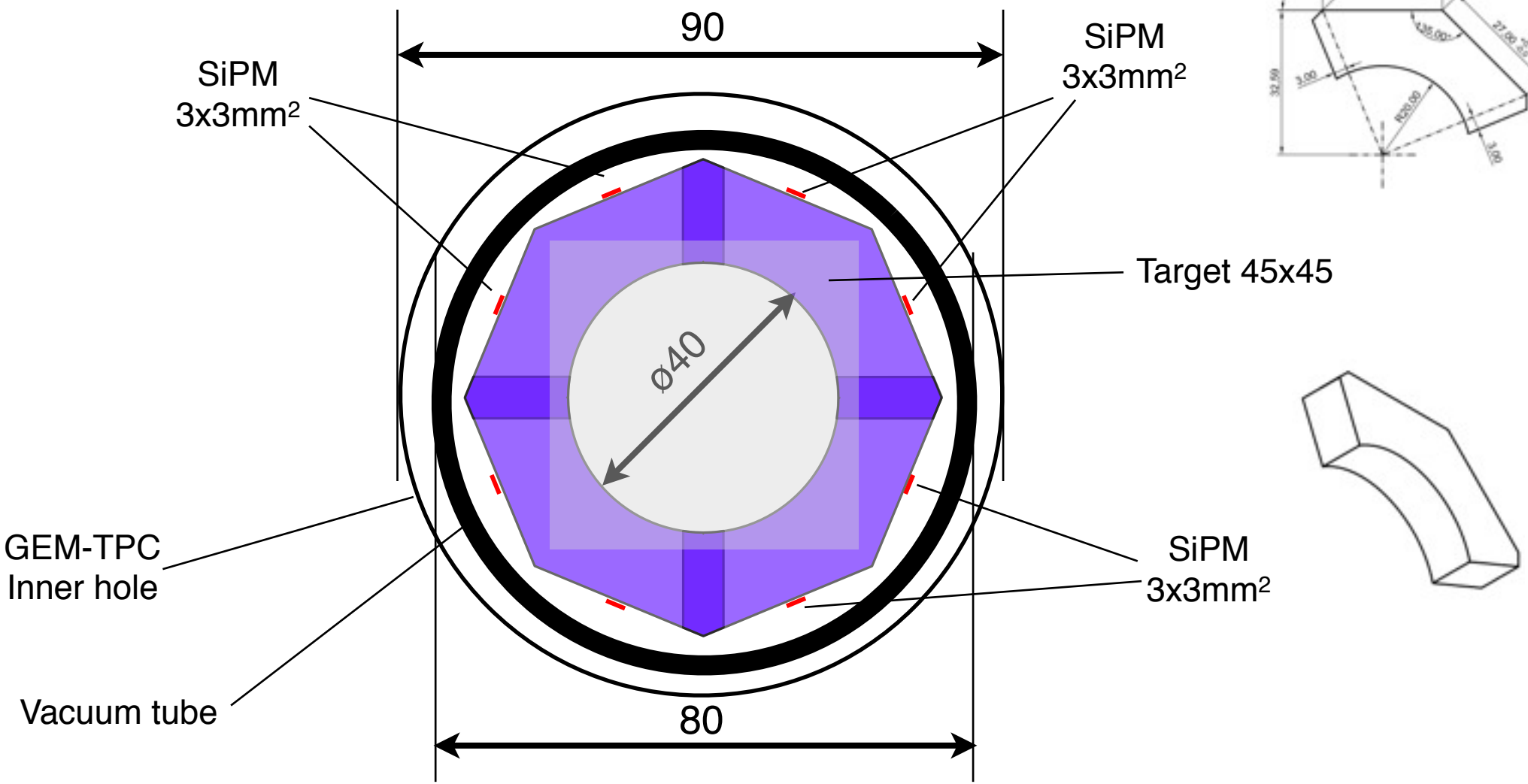
Cooliing Water

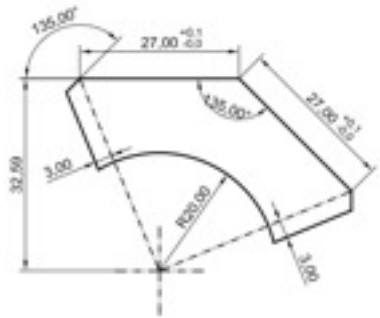
- *Fibre (square 16+16)+SiPM*
- *Blute force readout with conventional technique ⇔ integrated electronics*
- *„custom made“ bias supplier*
- *Remotely retractable into/outof beamline*
- *Good excercise*
- *One of the earliest detector with SiPM used in a physics run (2008)*

FOPI Beam Veto for pion beam

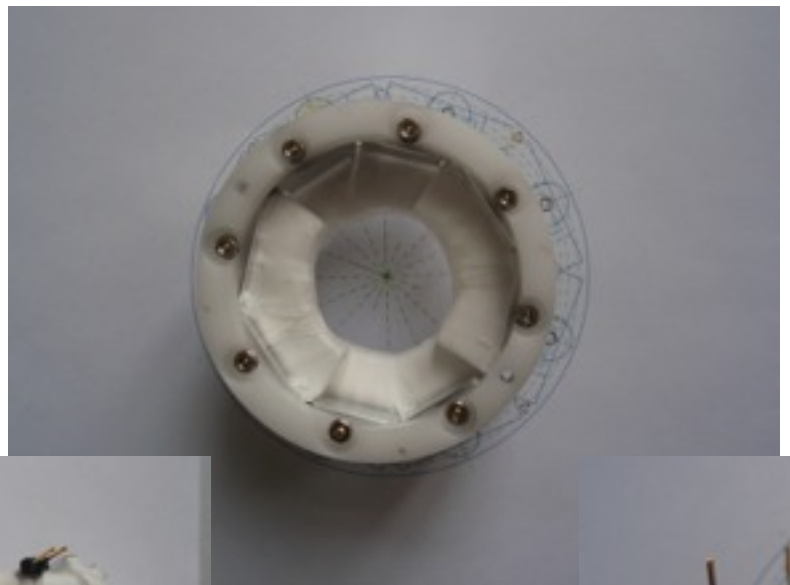
KS, G. Ahmed, J. Zmeskal

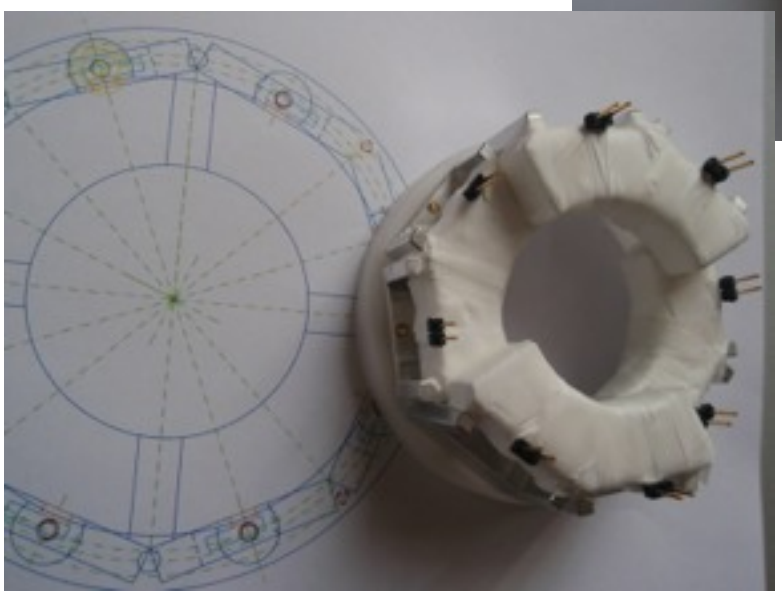
Secondary π beam line





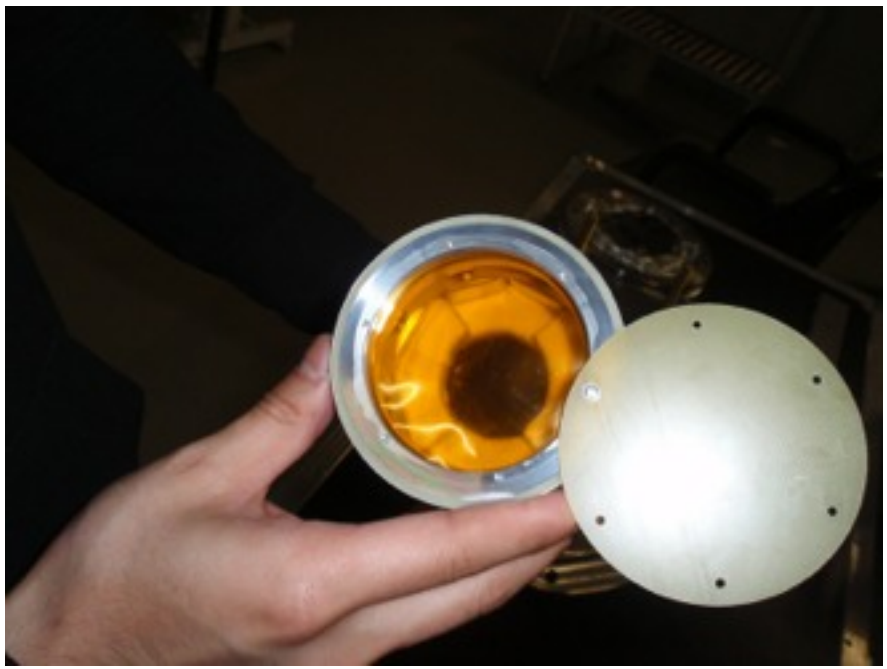
Halo2 (photo)





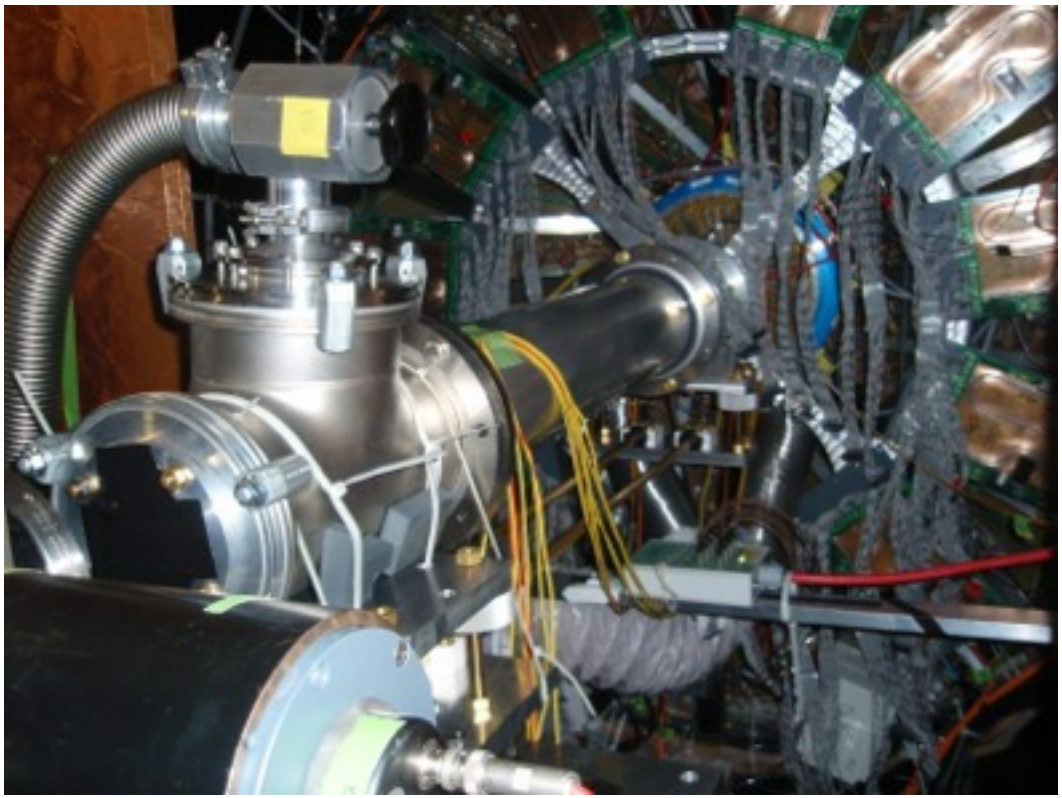
SIPM directly attached to the scintillator with a grease, wrapped with teflon tape

Halo2 (photo)



preamp and cabling in a limited space

Halo2 (photo)



Inserted in FOPI (GEM-TPC, CDC, Magnet)

- *Very large signal ~1V. (scint. could be thinner)*
- *Efficiency ~99.9%*
  - *Massive heat souce (GEM-TPC and RPC) and cooler caused temp. fluct. of >10 ºC/0.5 hr.*
- *PMT cannot be an option!*

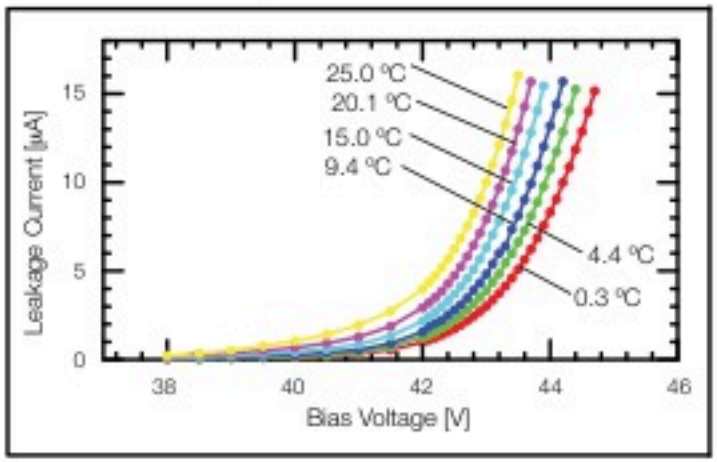
SiPM Characteristics

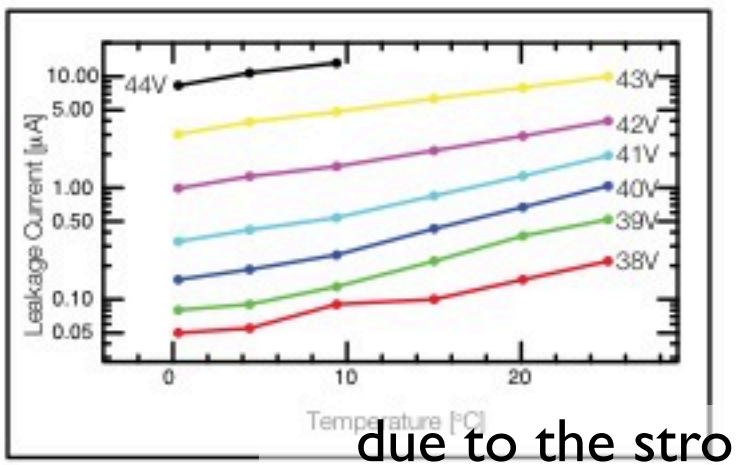
S. Fossati, M. Schafhauser, G. Ahmed, KS, J. Marton

Temperature Dependence!

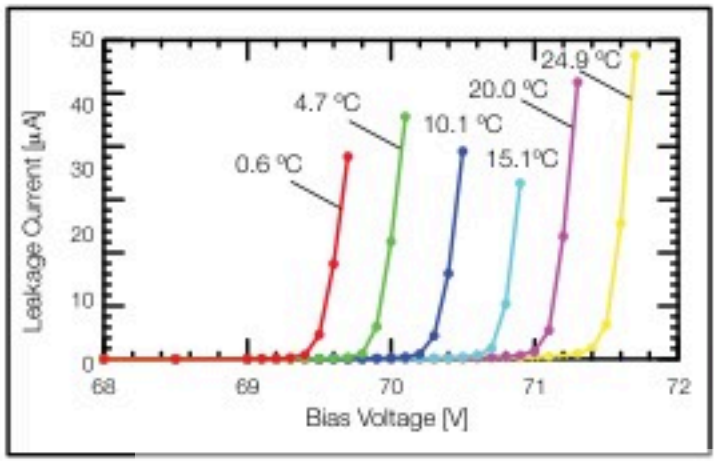
2007

Photonique SSPM050701

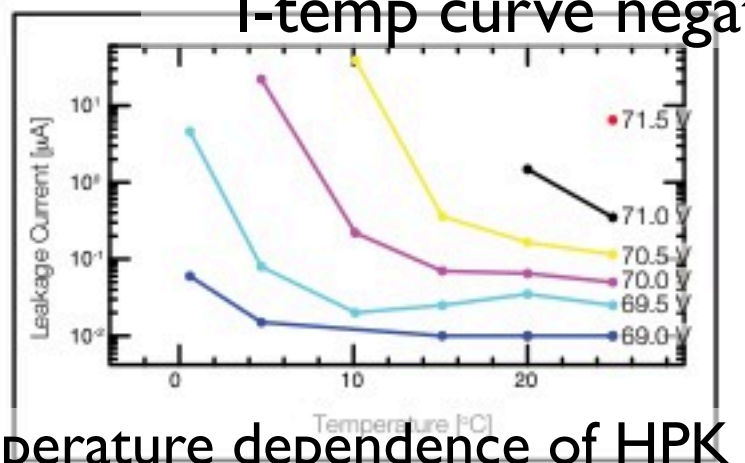




Hamamatsu S10362-11-50U



I-temp curve negative!



due to the strong temperature dependence of HPK sensor.

Photonique sensor had also nice features…

. less sensitive to temperature / bias voltage v

. lower operation voltage

. lower noise

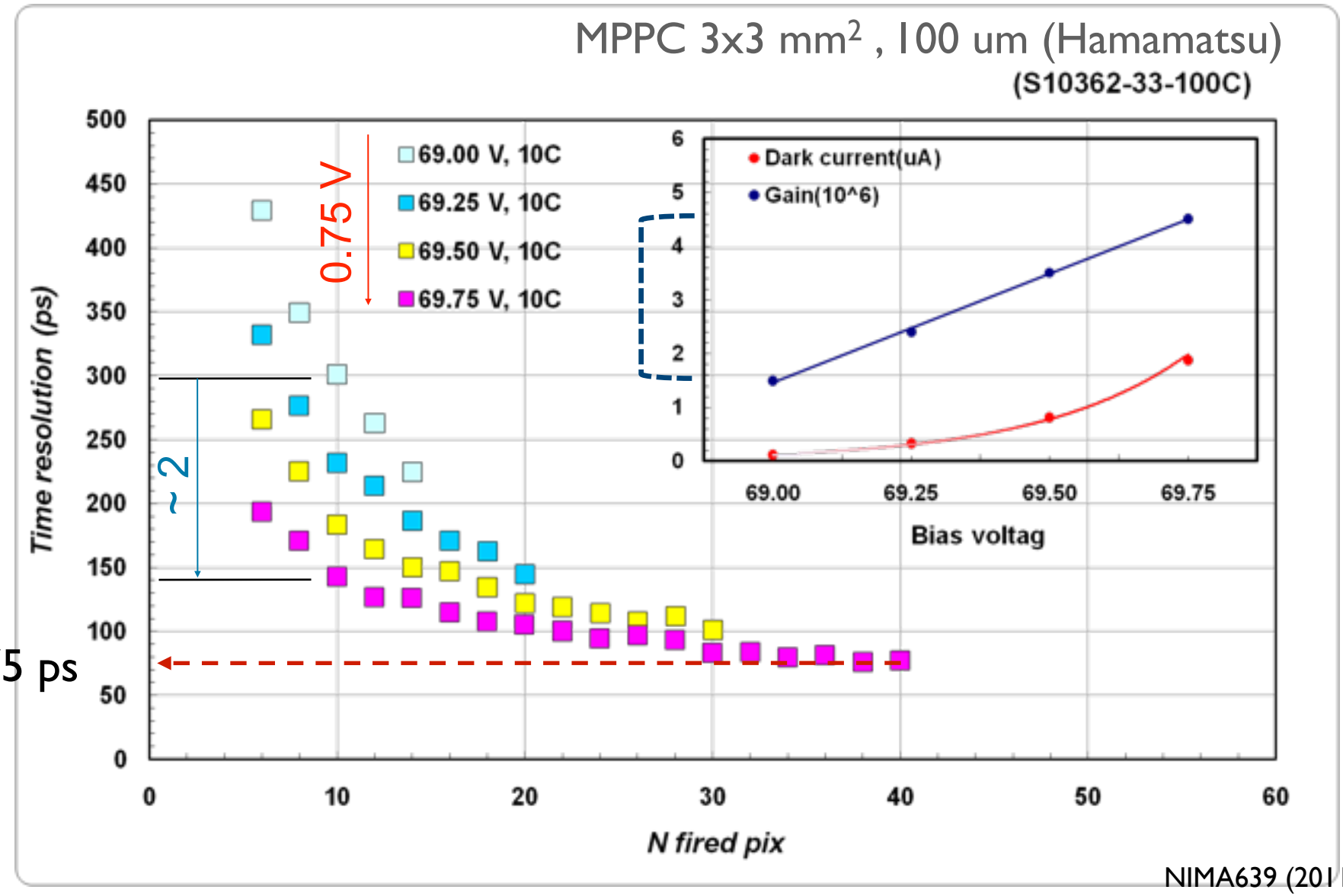
Timing performance measurement

K.S, G. Ahmed, J. Marton

NIMA639 (2011) 107
NIMA652 (2011) 528

Time resolution

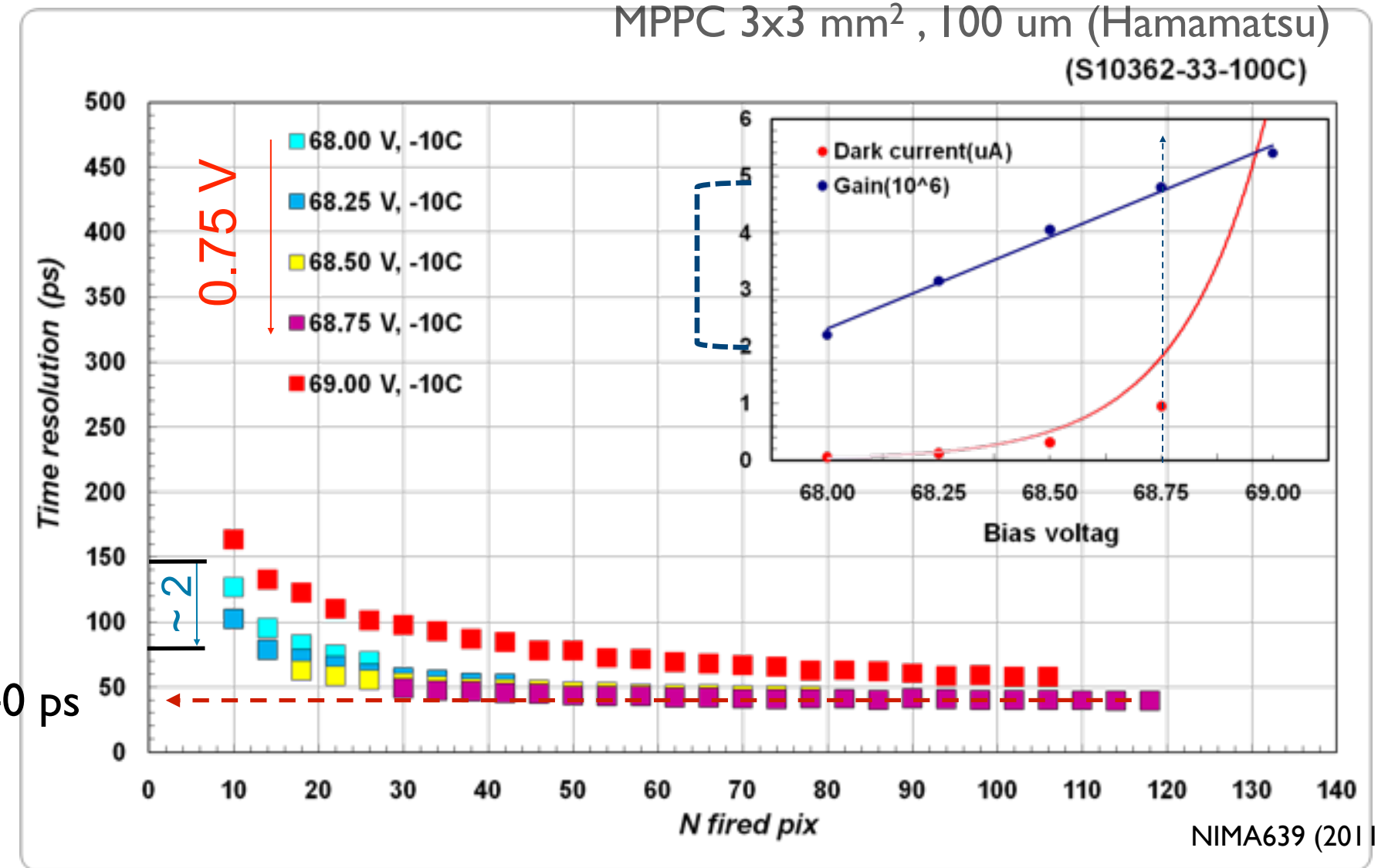
@ +10℃



NIMA639 (2011) 107
NIMA652 (2011) 528

Time resolution

@ −10℃.



NIMA639 (2011) 107

NIMA652 (2011) 528

A Comment

- *Timing resolution improves drastically by operating the device at higher voltage*
- *Due to even more drastic increase of dark noise at high OV, however, one can not operate it at such a regime.*
- *New Hamamatsu MPPC due in a few months*
- *has wider operational voltage = can exploit much improved time resolution!*

„Recent“ Projects

- *SiPM Characteristics*
  - *Rate capability = Recovery TIme Measurement = Double Hit Resolution Measurement*
- *Application*
  - *8x8 Matrix with light concentrator*
  - *SIDDHARTA-2 Active Shield*

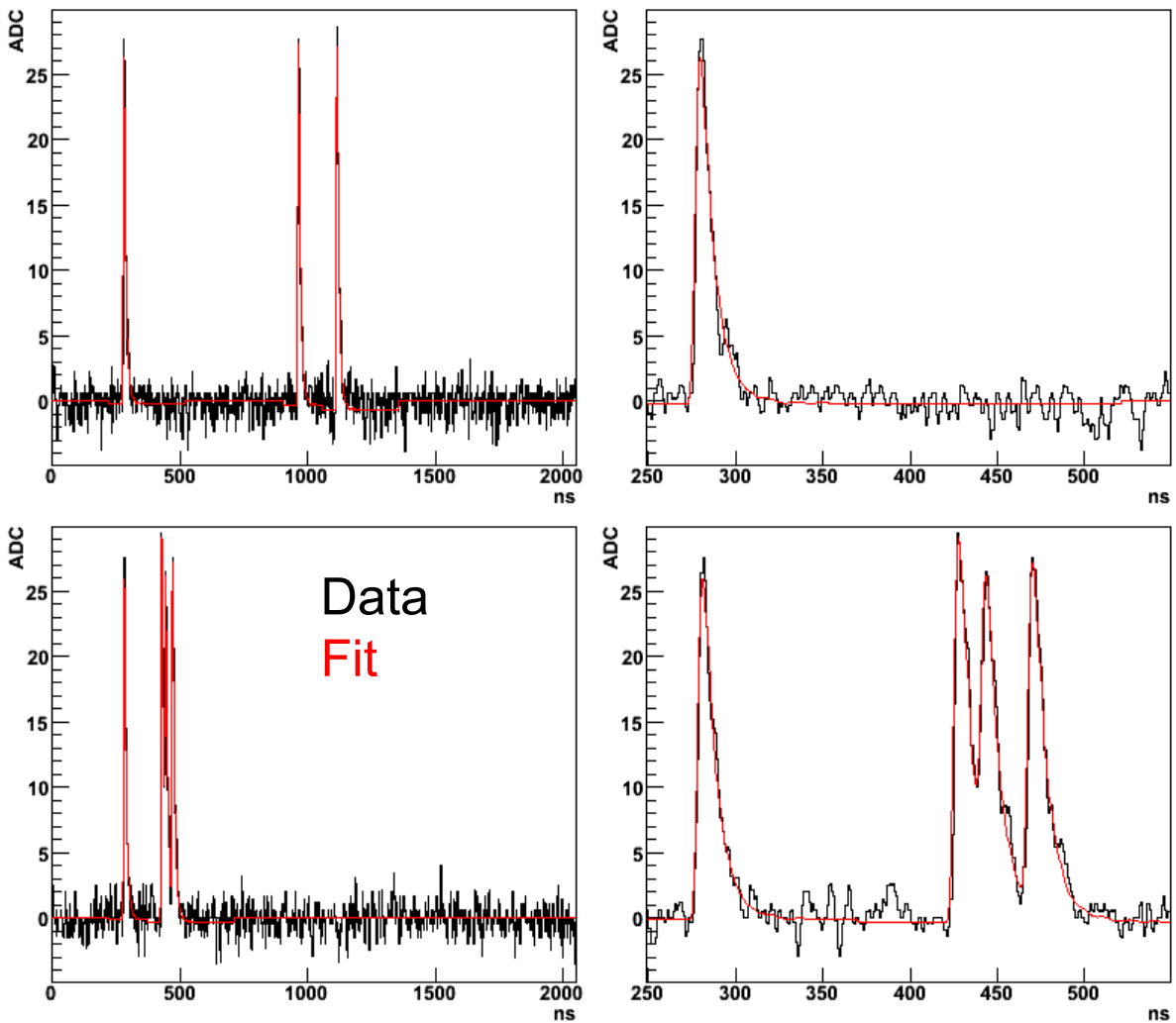
Recovery time measurement

L. Gruber, S. Brunner, KS, J. Marton, A. Scordo, O. Vazquez Doce, A. Romero Vidal

- Rate capability
  - Better or worse than PMT (a few MHz with booster circuit)?
- 1st order approx. inverse proport. to pixel size
  - Hamamatsu 1mm^2 25μm=20ns, 50μm=50ns, 100μm=100-200ns
- For a detector development at AMADEUS (@DAΦNE) environment, want to investigate
  - double hit resolution
  - recovery time

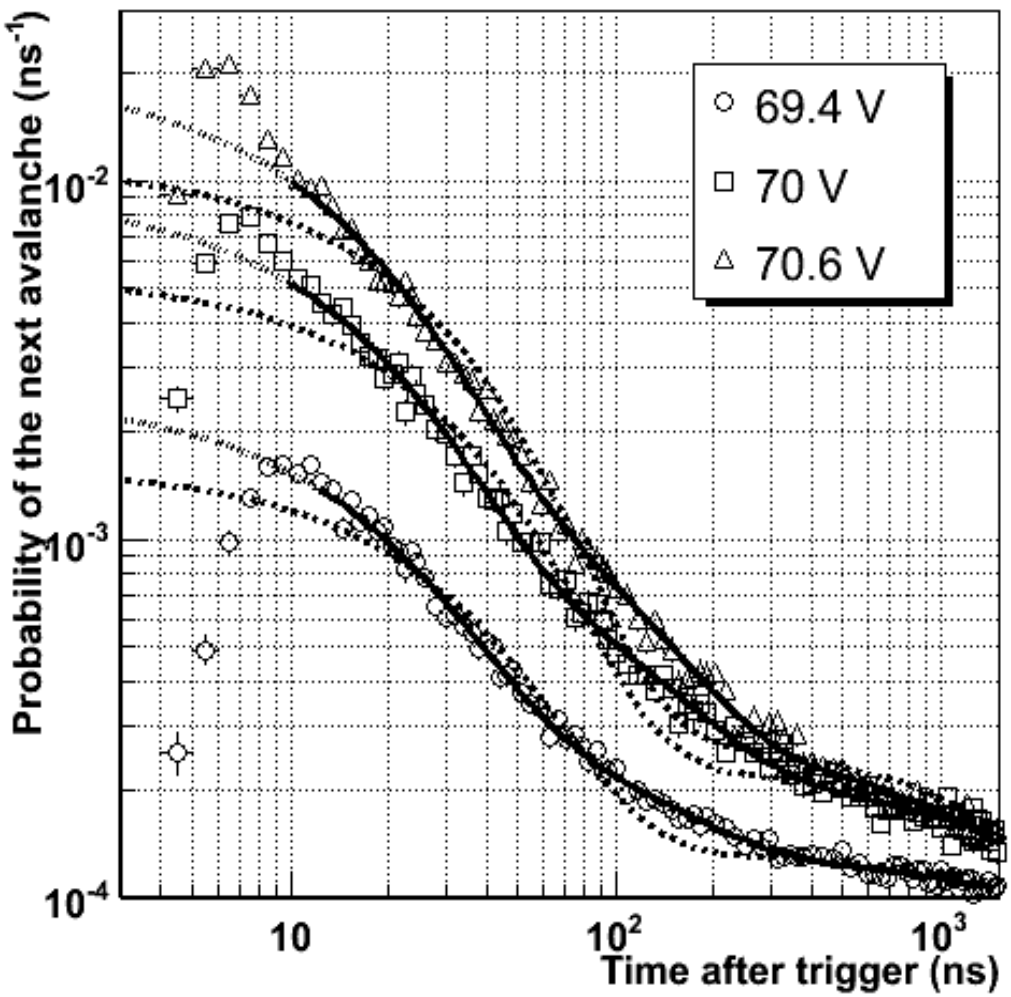
Measuring after-pulsing
Step 1: pulse finding

- MPPC dark noise
  - Self trigger at ~0.2 PE
- Use fast amplifier
- Use 1GHz digitizer
  - CAEN V1729
- Fit waveform with superposition of single avalanche response function
  - Measure response function directly from data

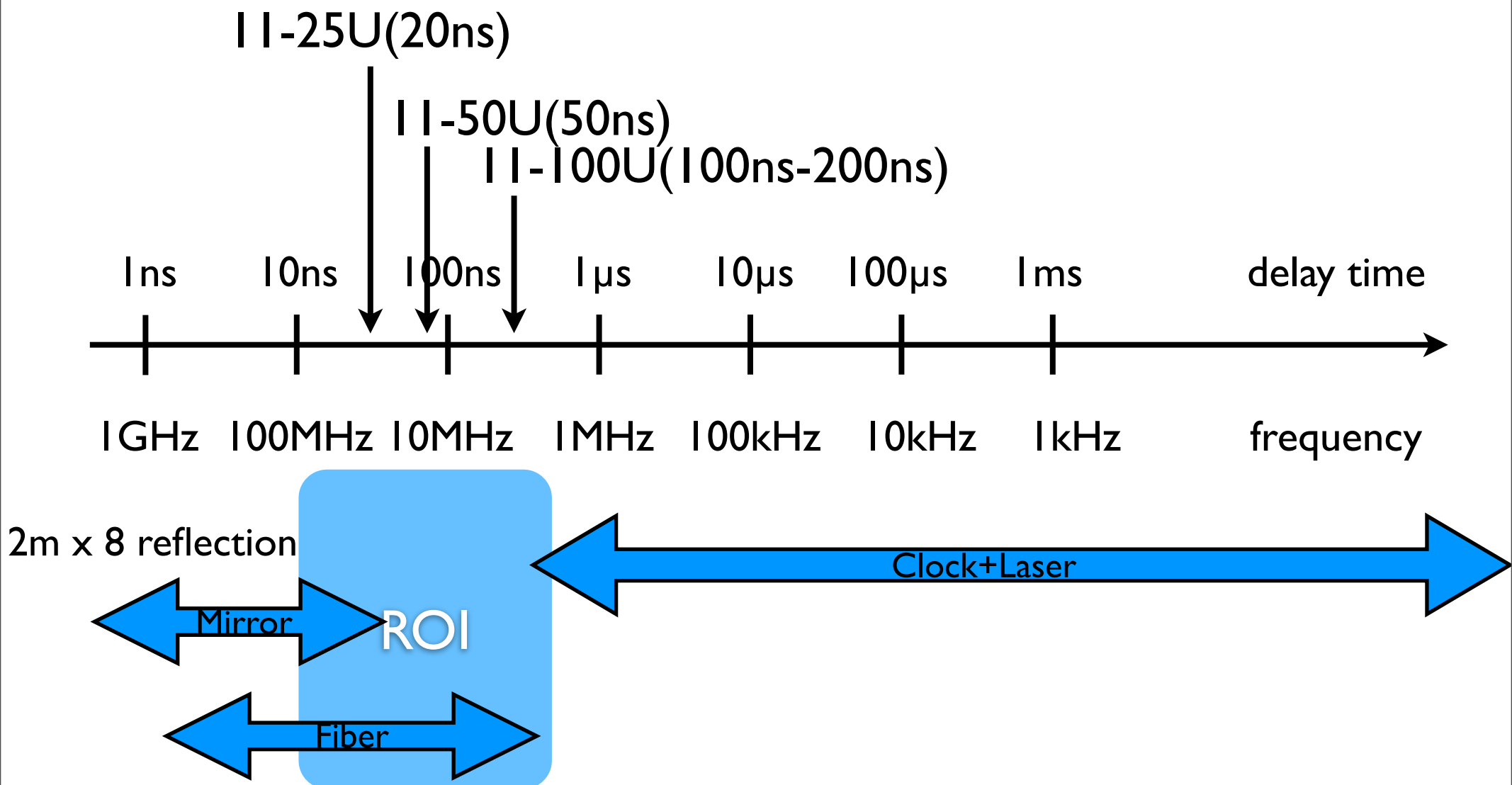


Measuring after-pulsing
Step 3: fit timing distribution

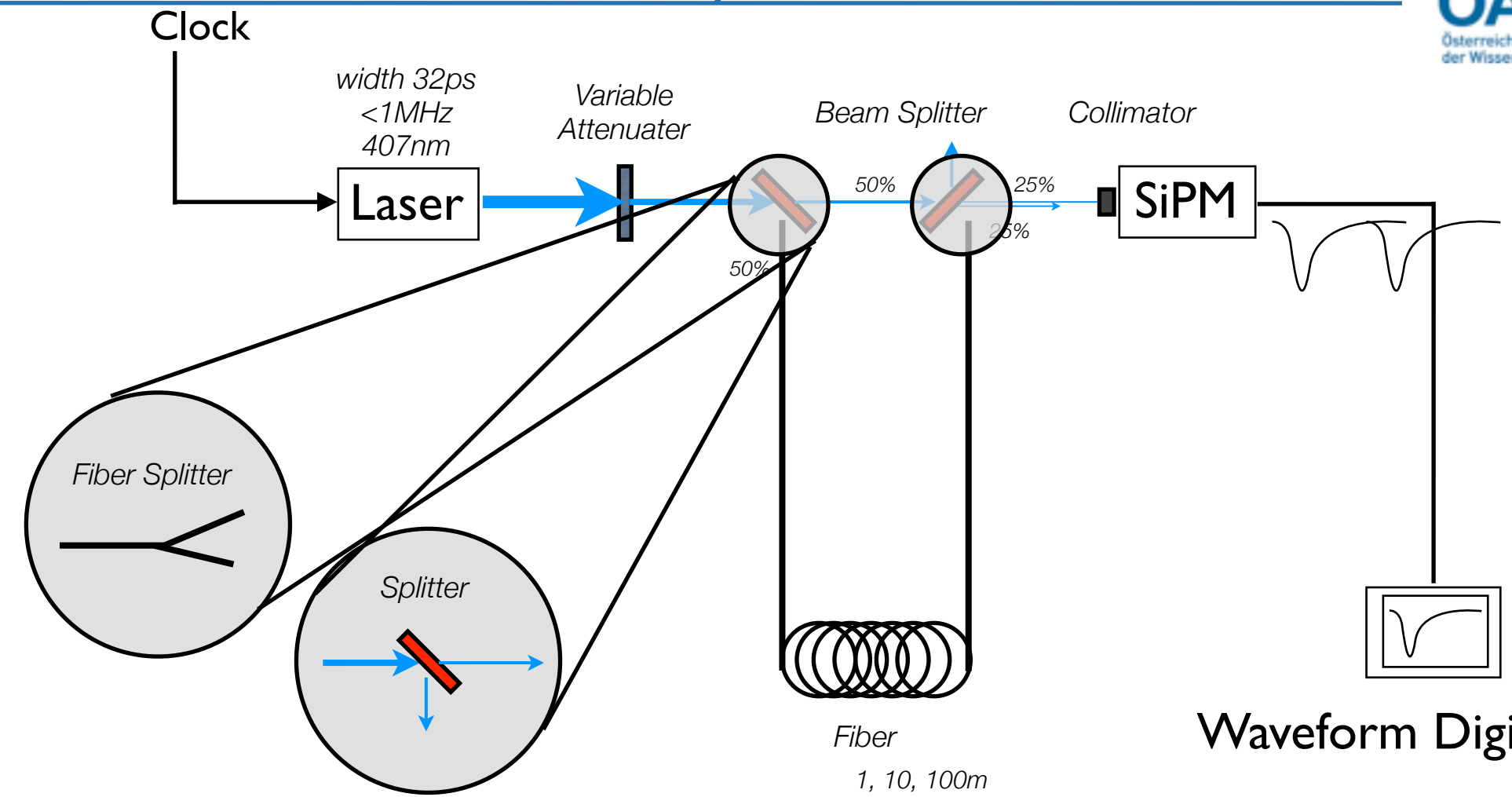
- Distribution of first pulse arrival time can be expressed with a few parameters
  - Probability and time constant + Dark Noise rate
    - 1 exponential function does not fit well
    - 2 exponential function is best
  - Issue: distortion of the distribution in the 1st 10 ns
    - Pulse finder inaccurate when gain is low
    - Effect estimated by simulation



Delay time range



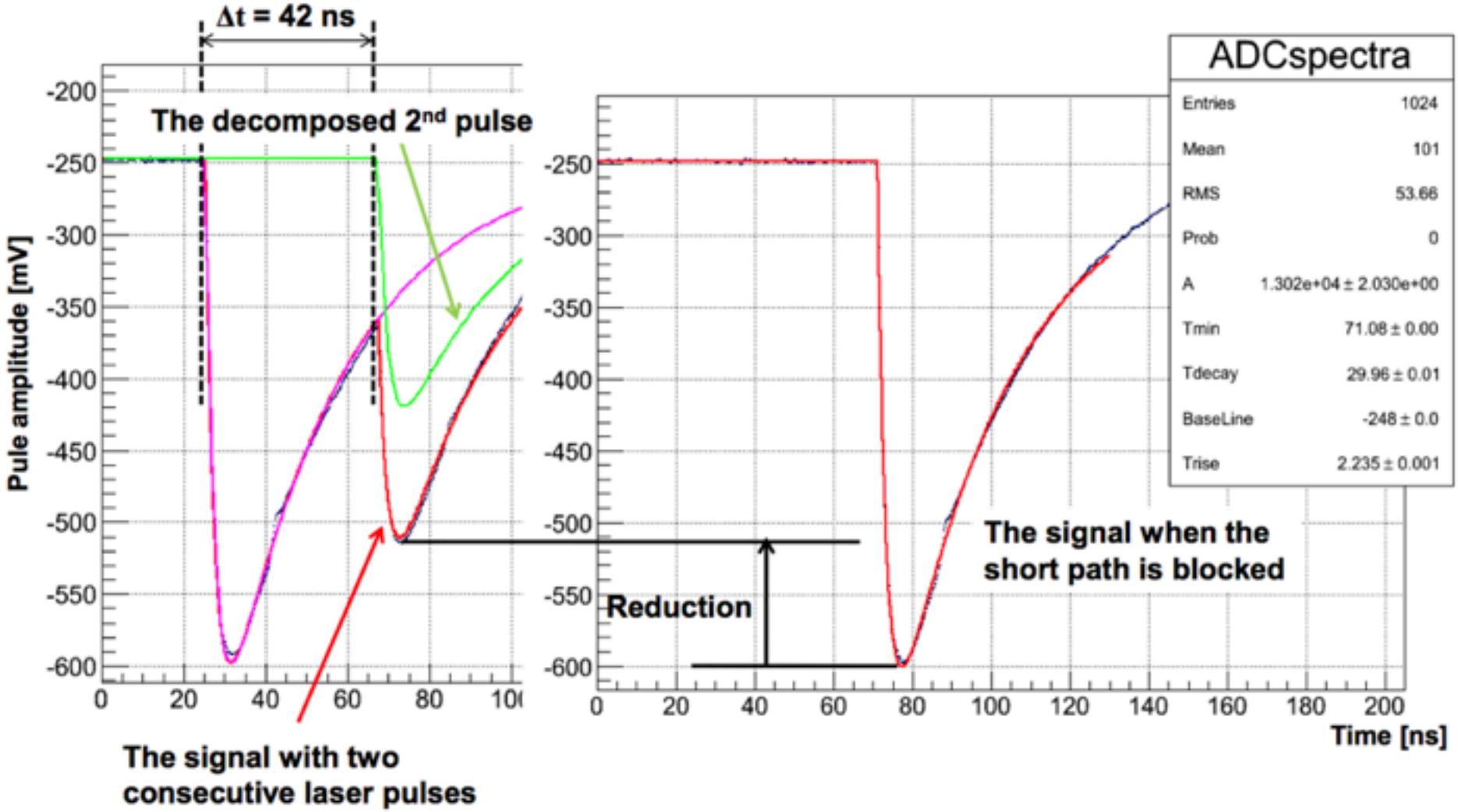
Setup



Well focused beam on a single pixel

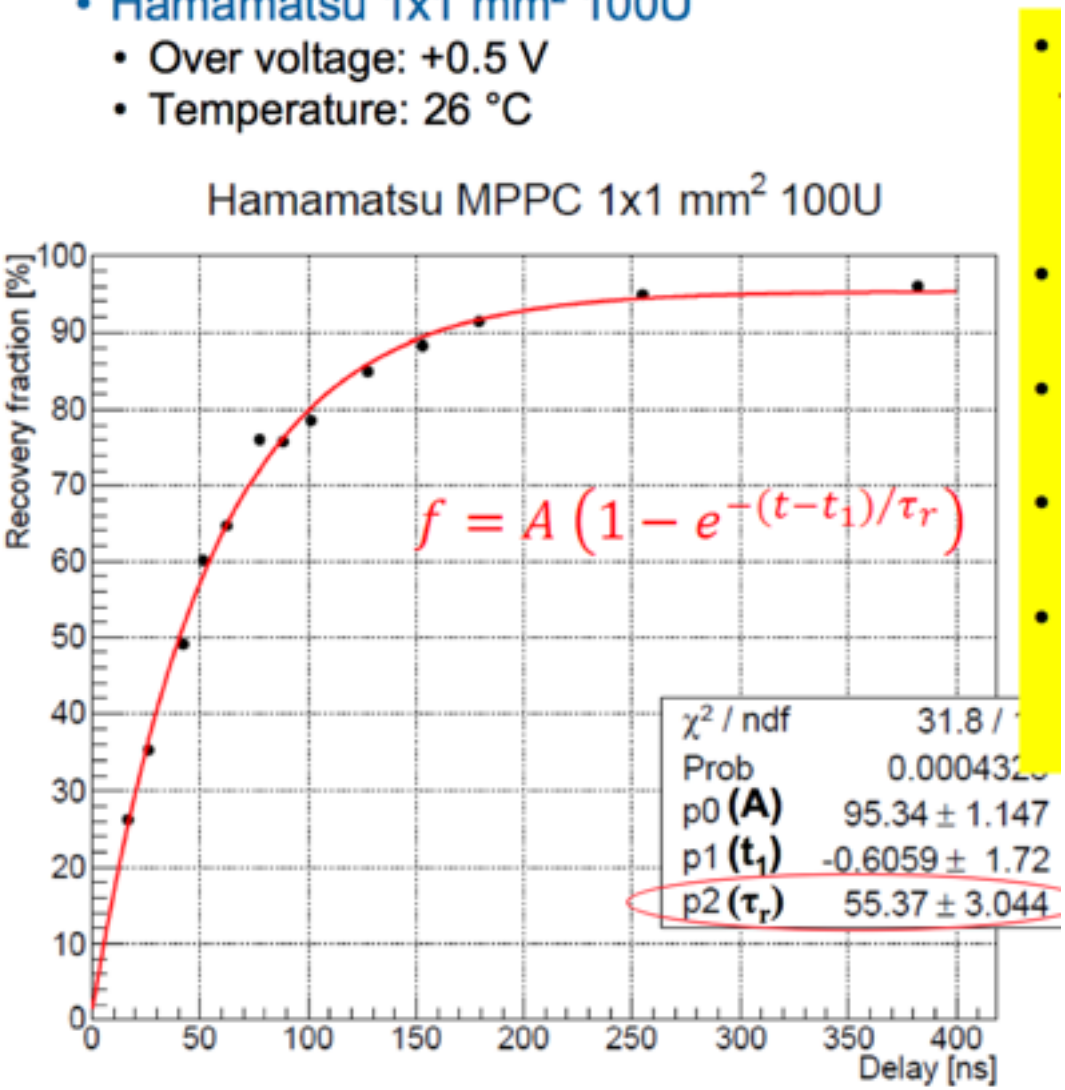
or **Full illumination**

Waveform Digitizer 5GS/s (DRS4 chip - CAEN V1742)



L. Gruber ÖPG Tagung, Graz, 18 – 21 Sept. 2012

- Hamamatsu 1x1 mm² 100U
  - Over voltage: +0.5 V
  - Temperature: 26 °C

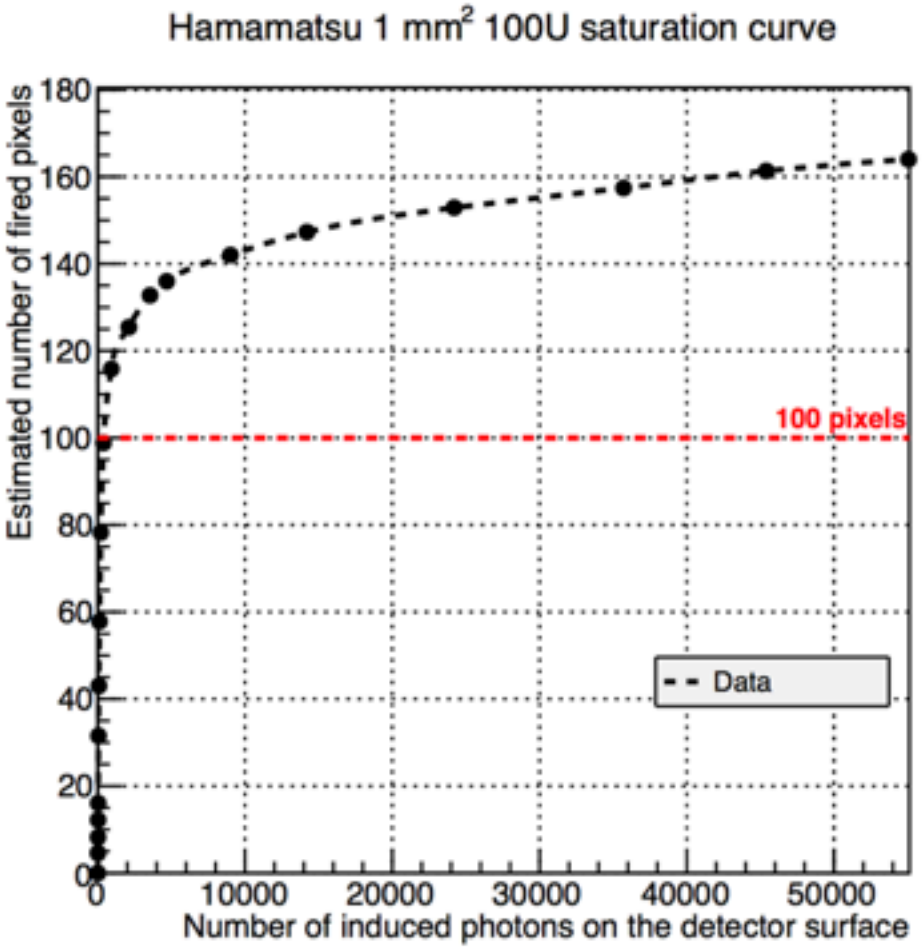


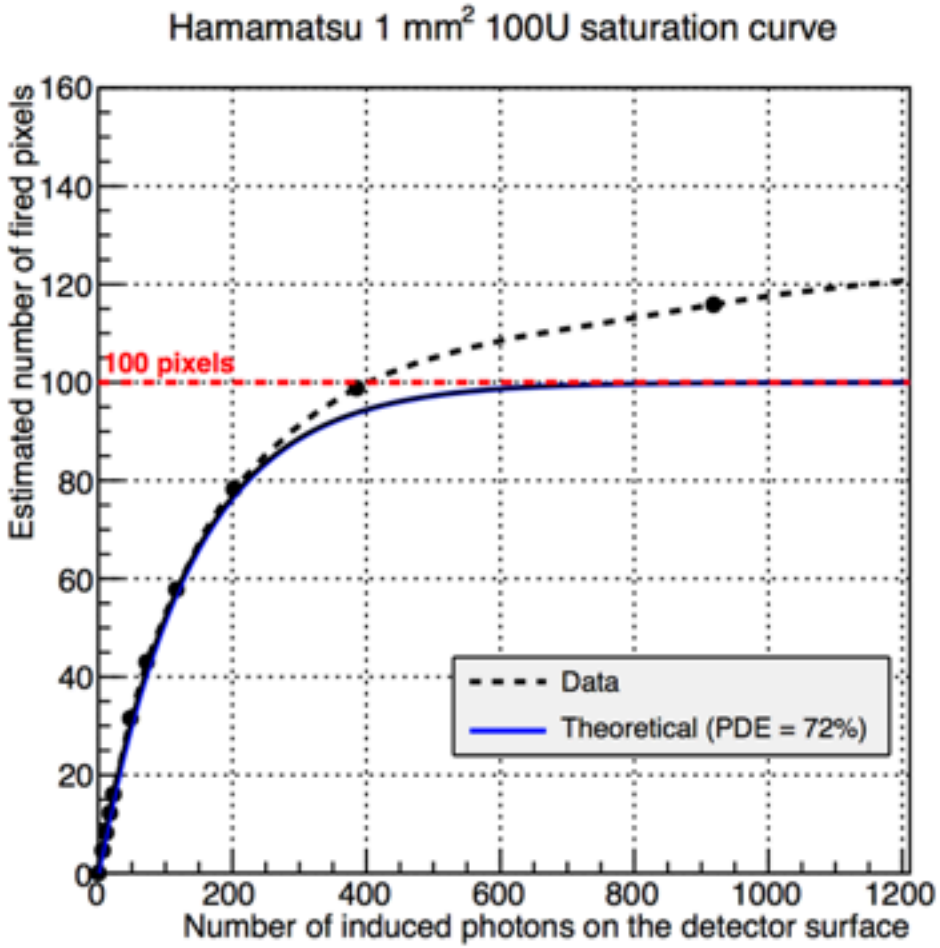
L. Gruber ÖPG Tagung, Graz, 18 – 21 Se

Status

- *MC Simulation that includes*
  - *cross talk*
  - *after pulse*
  - *dark noise*
- *Fitting with MC for each parameter condition*
- *Global Fit to data with different conditions (OVs)*
- *Paper in preparation*

Funny Observation





Array detector: larger area+position sensitivity

L. Gruber, S. Bruner, M. Rihl, KS, M. Cargnelli,
P. Bühler, J. Marton, H. Orth

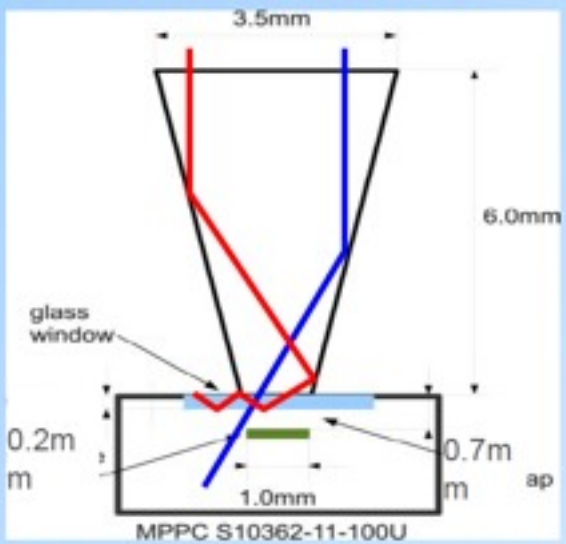
How the others do

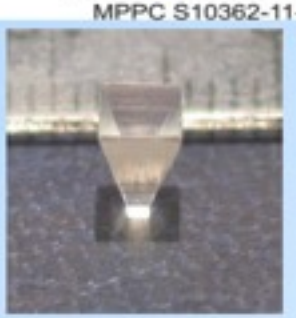
S. Korpar , talk at RICH-2010

Light concentration

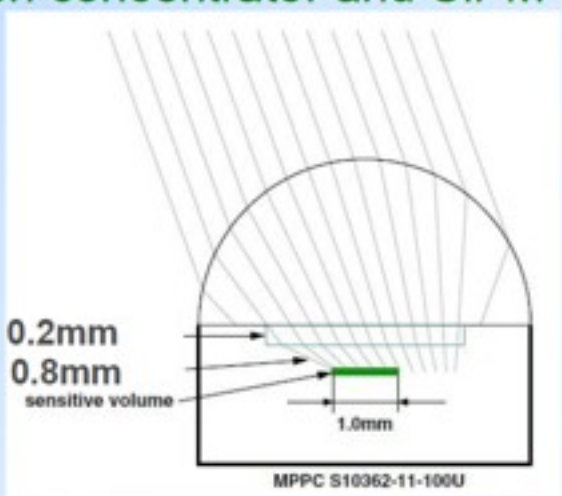
Can be used if light comes within the limited solid angle

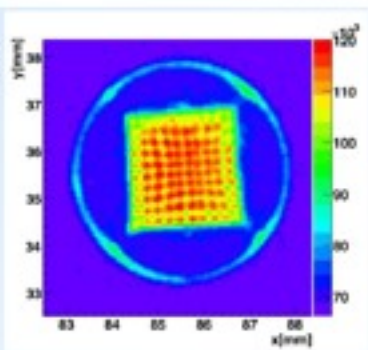
- Winston cones produce large angular spread at the exit surface – photons can miss the active area





- hemispherical light concentrators give better results with large spacing between concentrator and SiPM

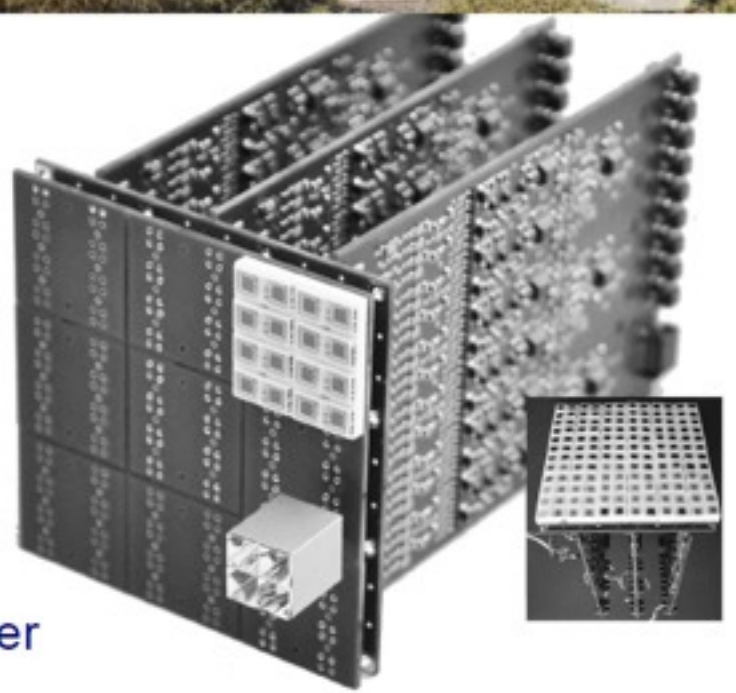




MAGIC

FACT project

- SiPM based module for camera for a Cherenkov telescope (DWARF: Dedicated multi Wavelength AGN Research Facility)
- 144 SiPMs + Winston cones
- 36 electronic channels



T. Krähenbühel (ETH Zurich) @ PD09

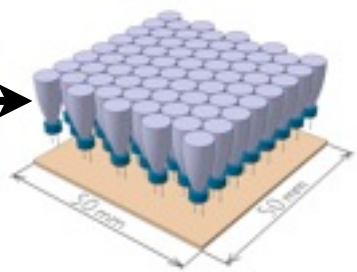
for update look at the previous talk and poster

Our approach

- *It consists of 64 regularly arranged pyramid-shaped funnels with round edges and has been designed to be used with an array of 3 x 3 mm² SiPMs.*

- *The funnels were produced by electro-erosion.*

- *Simple geometry*
- *Robust* ⟷
- *Easy to fabricate*



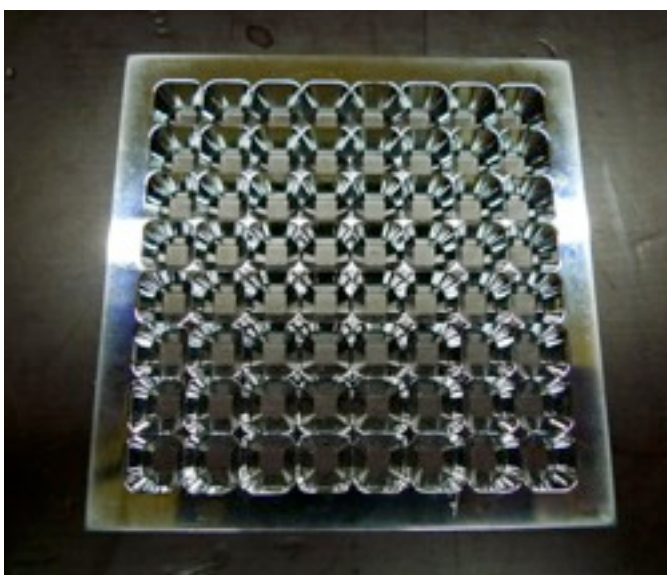
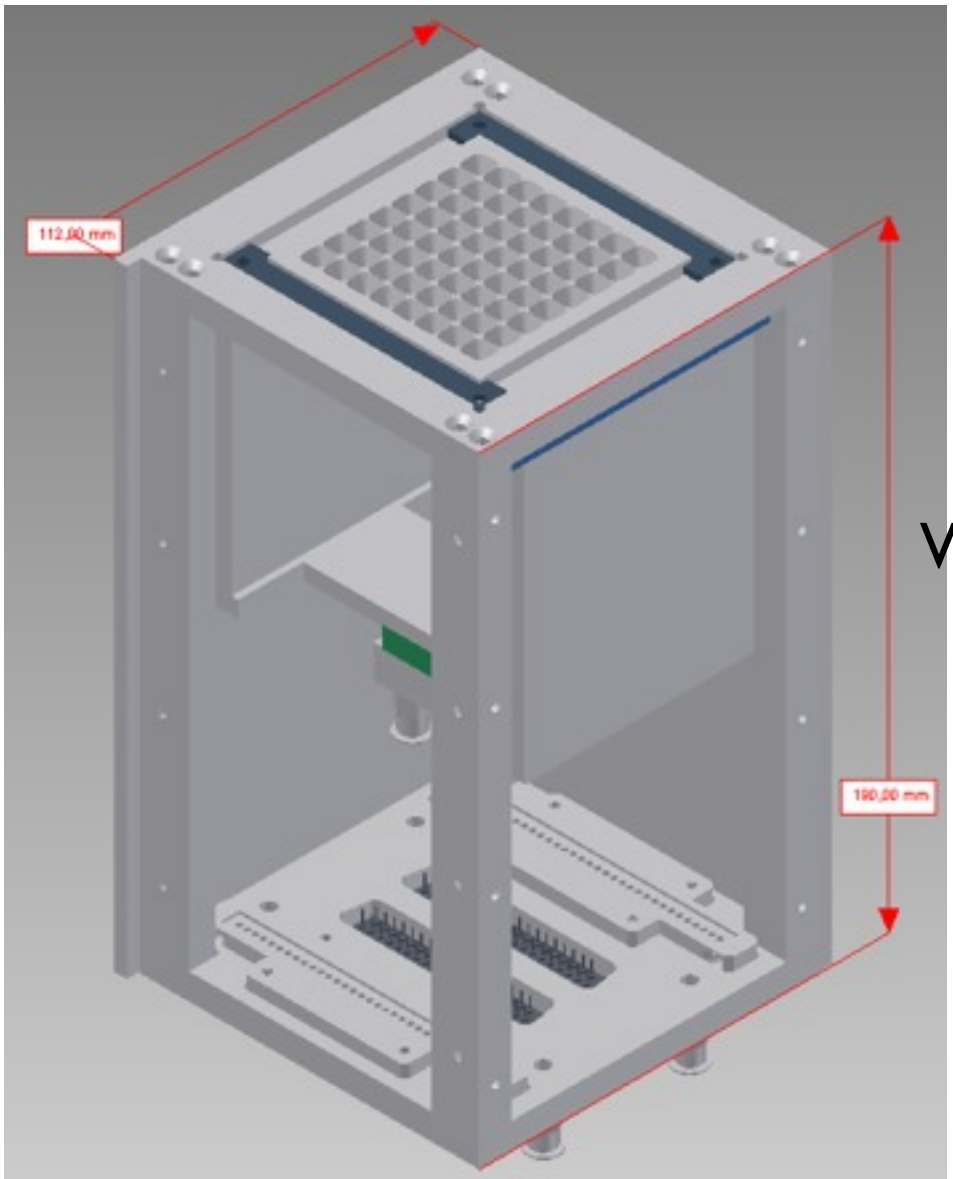
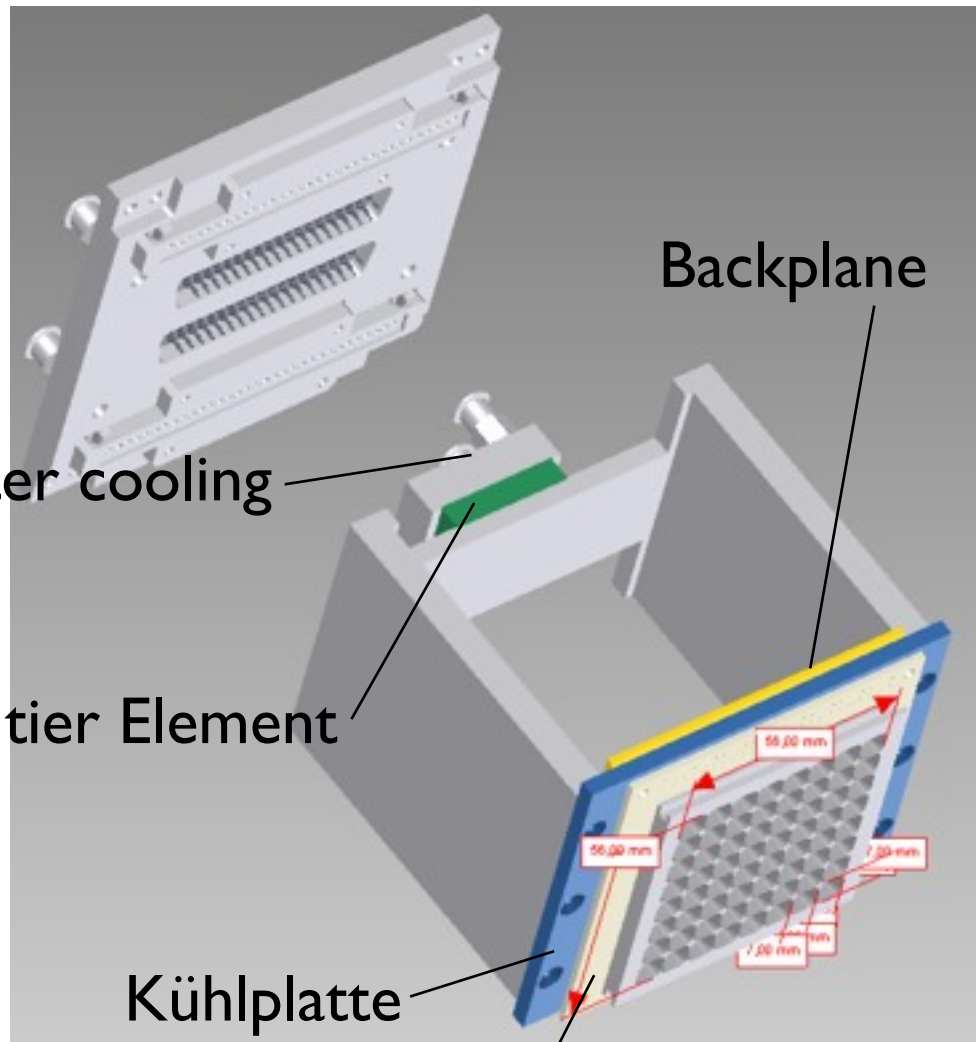


Table 1. Main parameters of the light concentrator.

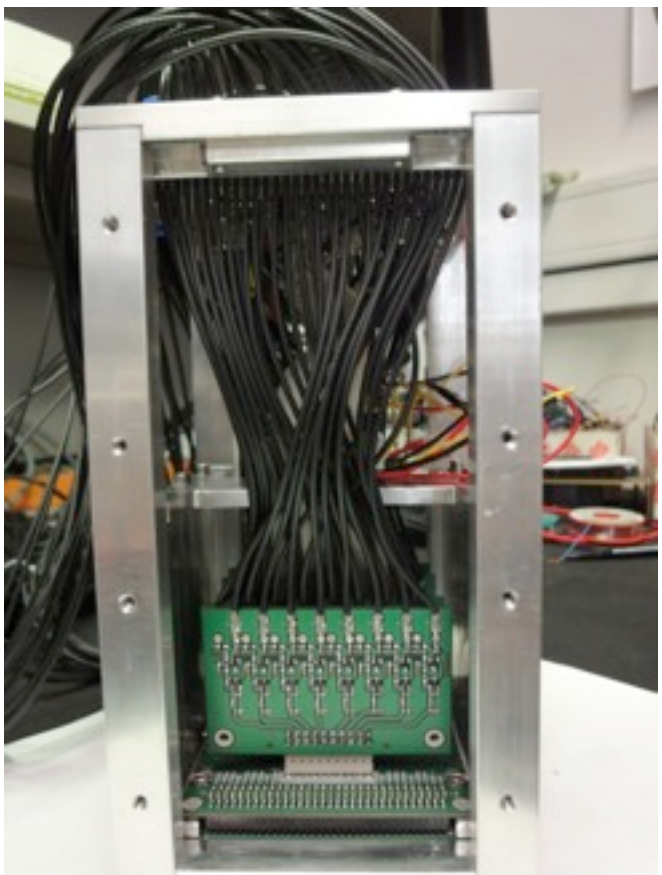
Parameter	Design value
Dimensions (L x W x H)	65 mm × 65 mm × 4.5 mm
Detection area	56 mm × 56 mm
Number of cells (funnels)	64
Funnel entrance aperture	7 × 7 mm²
Funnel exit aperture	3 × 3 mm²
Funnel height	4.5 mm
Fill factor (incuding rim)	69 %
Fill factor	93 %
Basic material	Brass
Coating	Aluminum, Chromium

Prototype Design

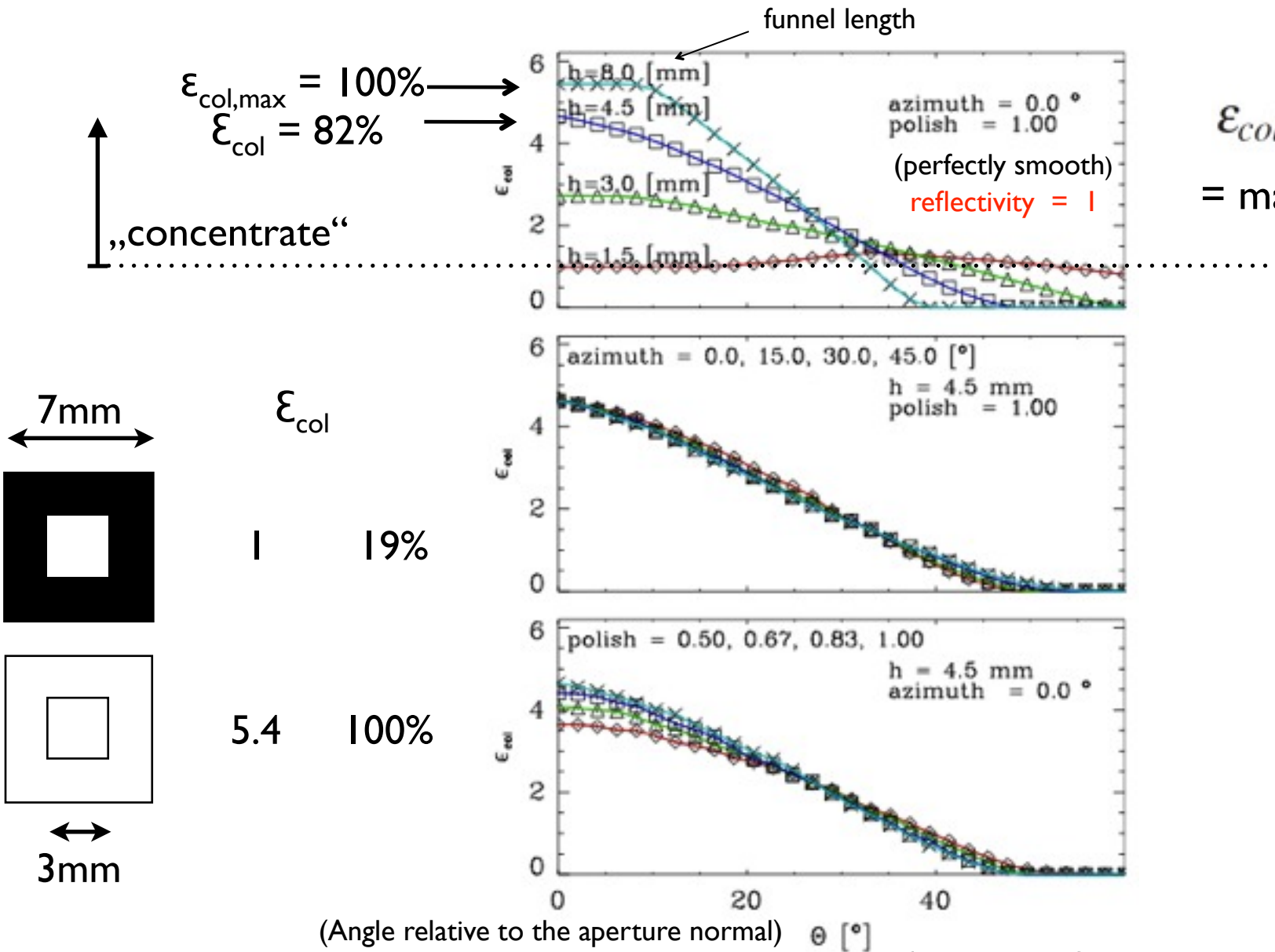




Prototype photos



„Geometry optimization“

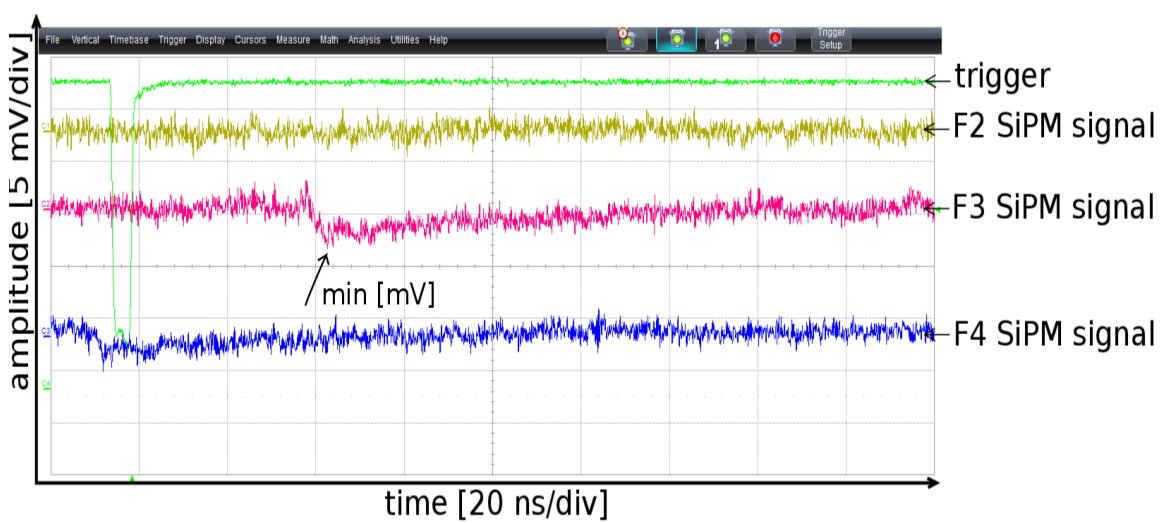


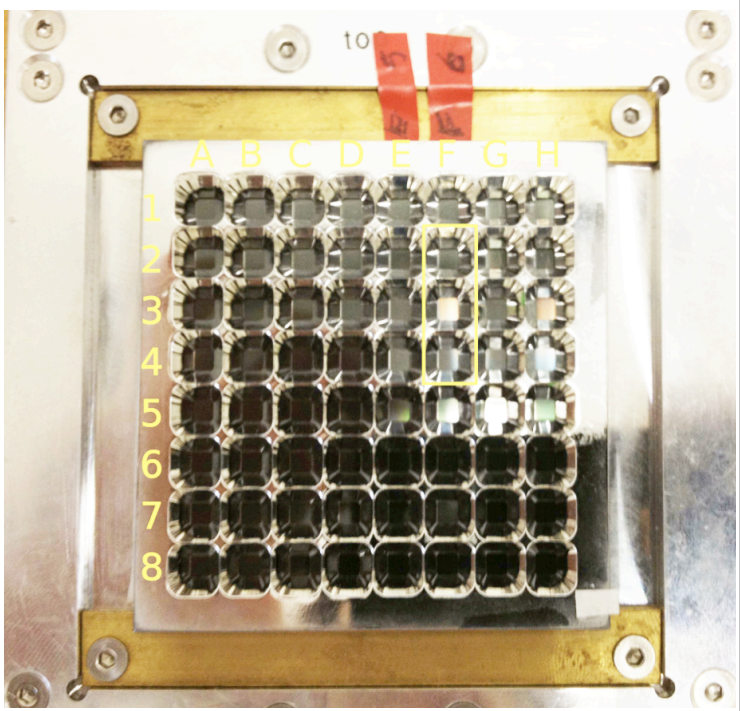
$$\varepsilon_{col} = n_d / N_{phot}$$

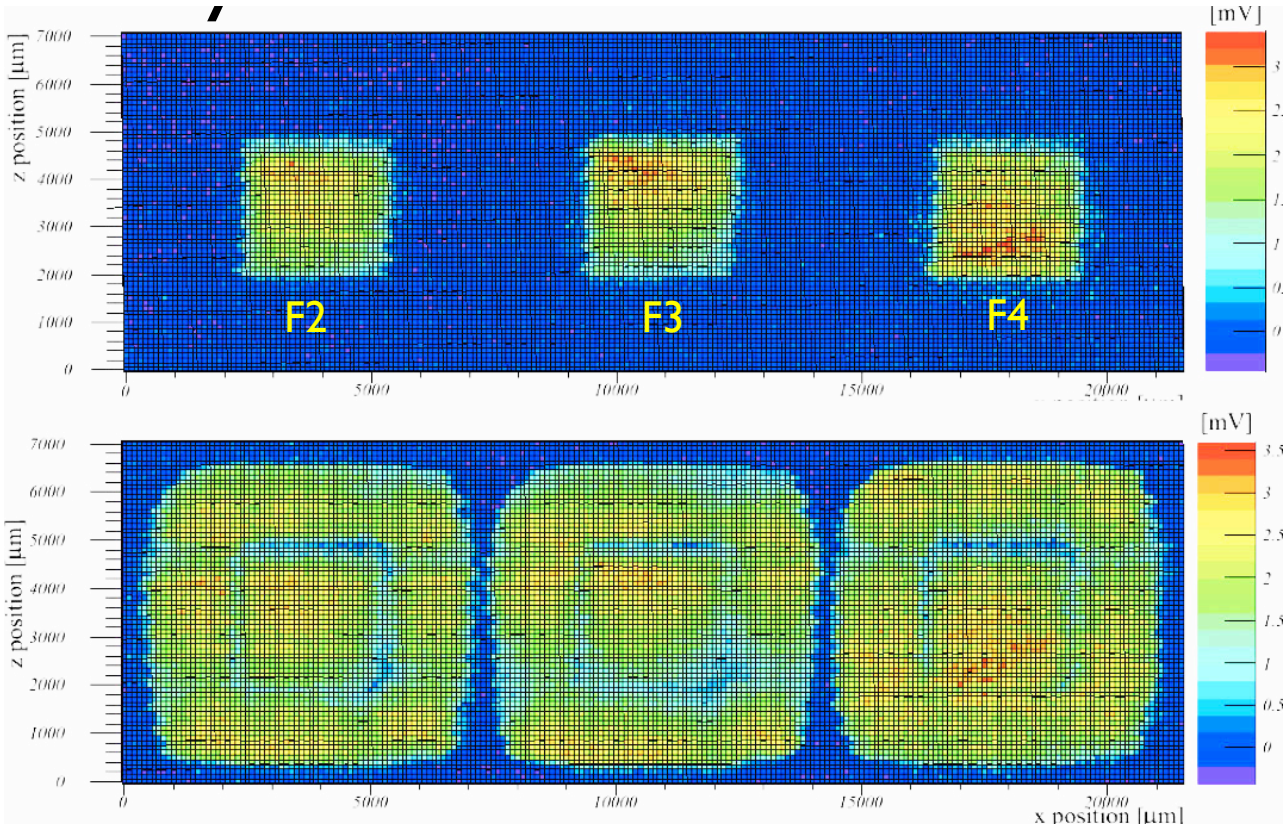
= max for $n_d = N_{phot}$

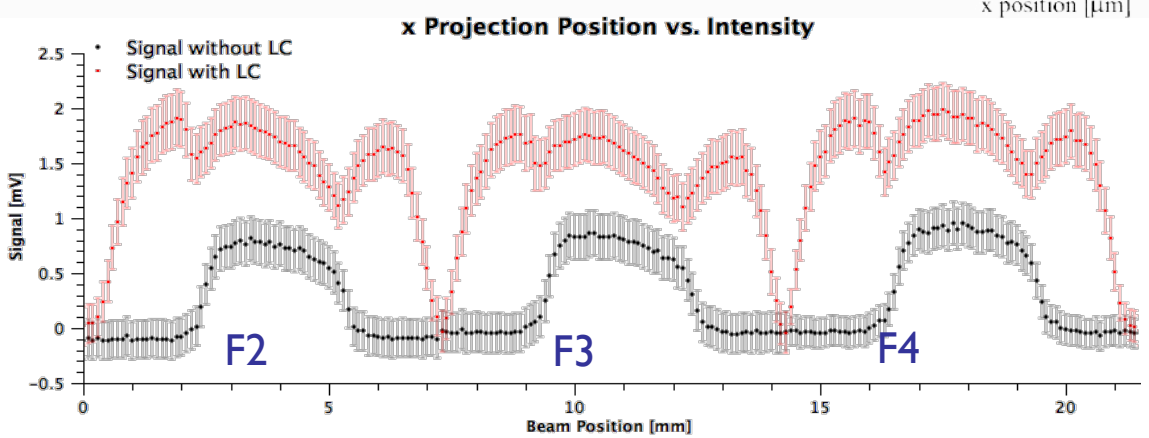
It was decided to go to 4.5 mm funnel length

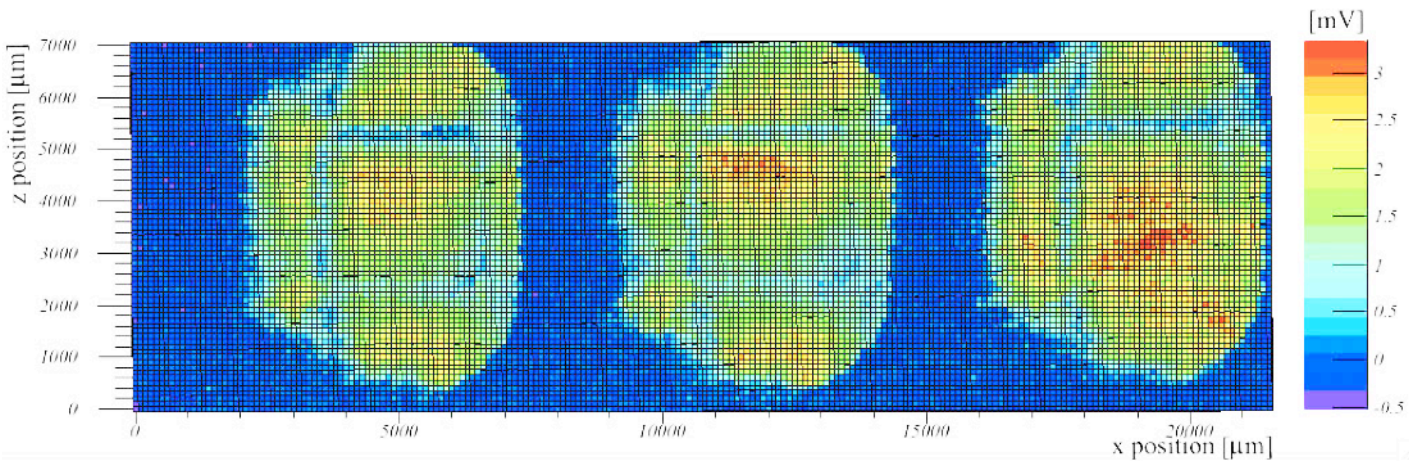
- *two dimensional scan of 3x 7x7 mm^{2}surface with 100 μm step size = 15k points*
- *One scan takes ~10 hours ~one night*
- *100 μm spot (1~4 cells)*

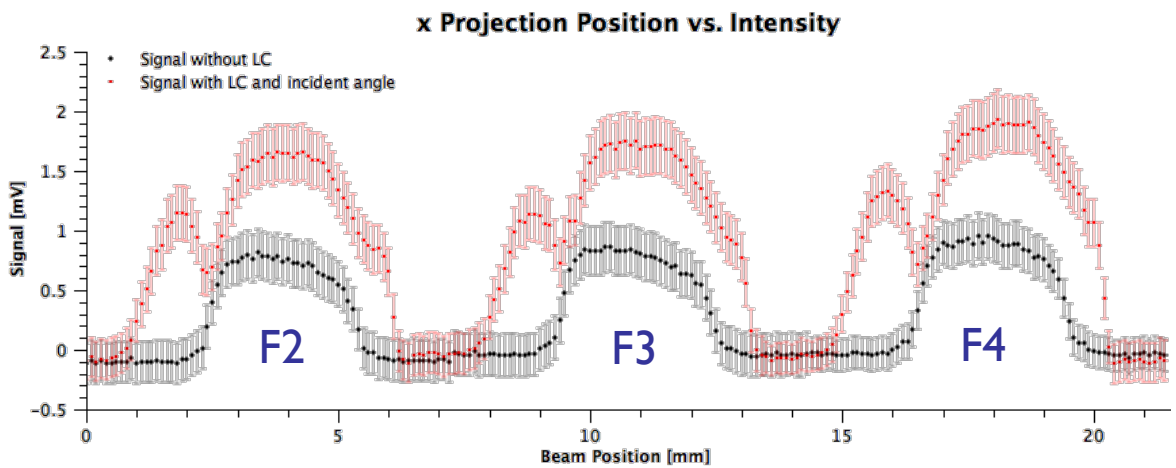





[mV]
z position [µm]
F2
F3
F4
[mV]
z position [µm]
x position [µm]


x Projection Position vs. Intensity
Signal without LC
Signal with LC
Signal [mV]
F2
F3
F4
Beam Position [mm]

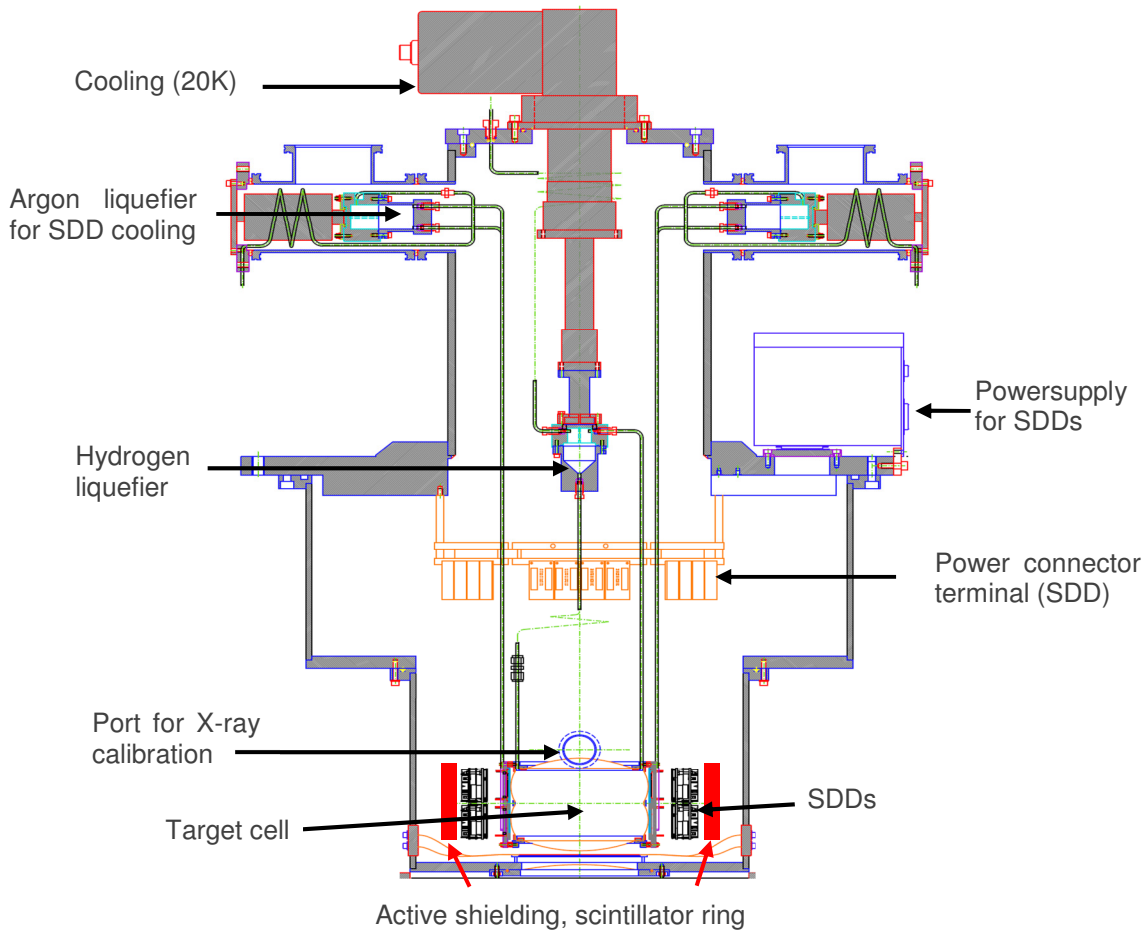

[mV]
z position [µm]
x position [µm]


x Projection Position vs. Intensity
Signal without LC
Signal with LC and incident angle
Signal [mV]
Beam Position [mm]
F2
F3
F4

SIDDHARTA-2
„Active Shield“

F. Schilling, J. Zmeskal

- Veto a charged-particle event that penetrate through SDD
- FBK Sensor



SciTil / dSiPM

L. Gruber, S. Brunner, J. Marton, K. Suzuki

TOF-PET

S. Brunner, A. Hirtl, L. Gruber, J. Marton, K. Suzuki

Outlook

- *SiPM Array*
  - *Evaluation of the light concentrator with laser*
    - *with better collimated beam, finite incident angle*
  - *Digesting the CERN data*
  - *Readout electronics!*
    - *incl. temperature regulation*
  - *Noise*
    - *Improving cooling system?*
- *Recovery time / Rate capability test*
  - *Next month (November) test at LNF*

Spare Slides

Lukas

Position sensitive SiPM detector for Cherenkov applications

- *L. Gruber[1,2], G. Ahmed[1], S. E. Brunner[1,2], P. Bühler[1], J. Marton[1], K. Suzuki[1]*
- *[1]Stefan Meyer Institute for Subatomic Physics (SMI), Austrian Academy of Sciences, 1090-Vienna, Austria*
- *[2]Faculty of Physics, Vienna University of Technology, 1040-Vienna, Austria*

Summary

- *A prototype of a position sensitive photo detector with SiPM readout has been built and tested.*

- *The detector module consists of an array of 8 x 8 SiPMs (Hamamatsu 3 x 3 mm^2), an array of suitable light guides (light concentrator) and in-house built preamplifier boards.*

- *First measurements showed that the prototype detector is working very well. The light concentrator clearly increases the acceptance of the detector.*

- *The Chromium-plated light concentrator partly shows inhomogeneous behavior due to fabrication defects and inhomogeneous surface quality. The Aluminum-plated module is used for further measurements because of better performance.*

- *It was shown that the measurements are in good agreement with the simulations.*

Hans

Test equipment at SMI

Test bench with insulation vacuum vessel, vacuum pump, Peltier cooling

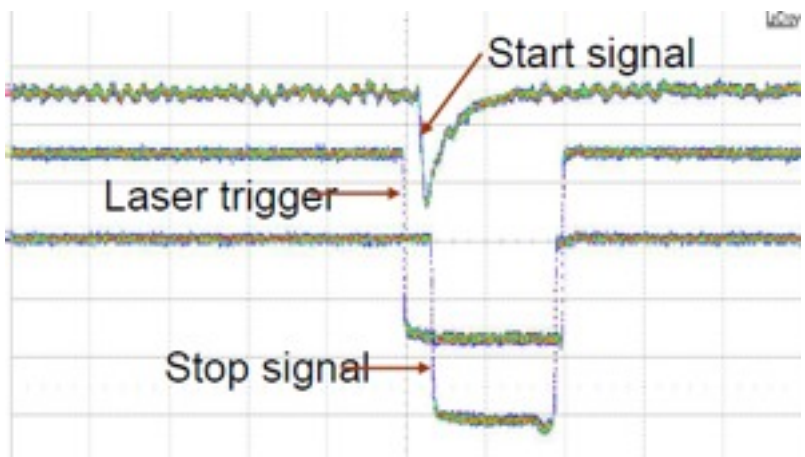
Bias voltage supply (Keithley), preamp supply voltages

Picosecond laser system @ 408 nm (32ps) for timing tests

Optical bench for laser beam (coupling to optical fiber)

Fast digital oscilloscope

CAMAC/VME DAQ system for TDC, QADC data acquisition



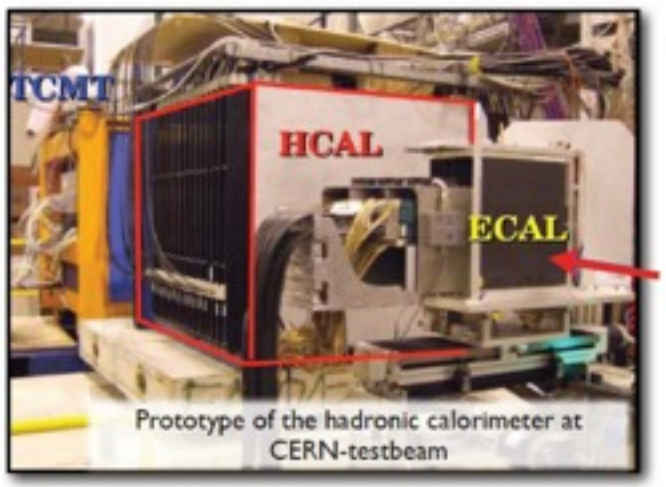
SiPM

Calorimetry

CALICE - first large system experience

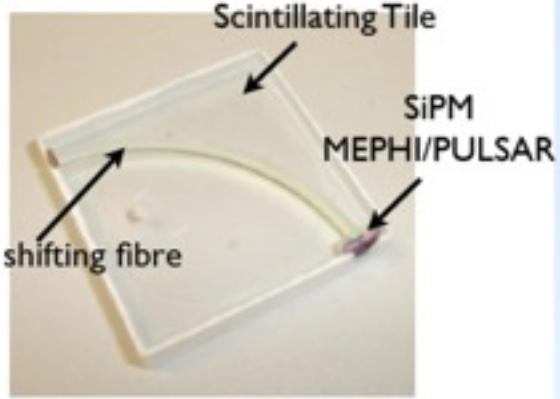
- only 20 bad channels in 3 years of testing – mostly mechanical problems

CALICE: Calorimeter for the Linear Collider Experiment



Prototype of the hadronic calorimeter at CERN-testbeam

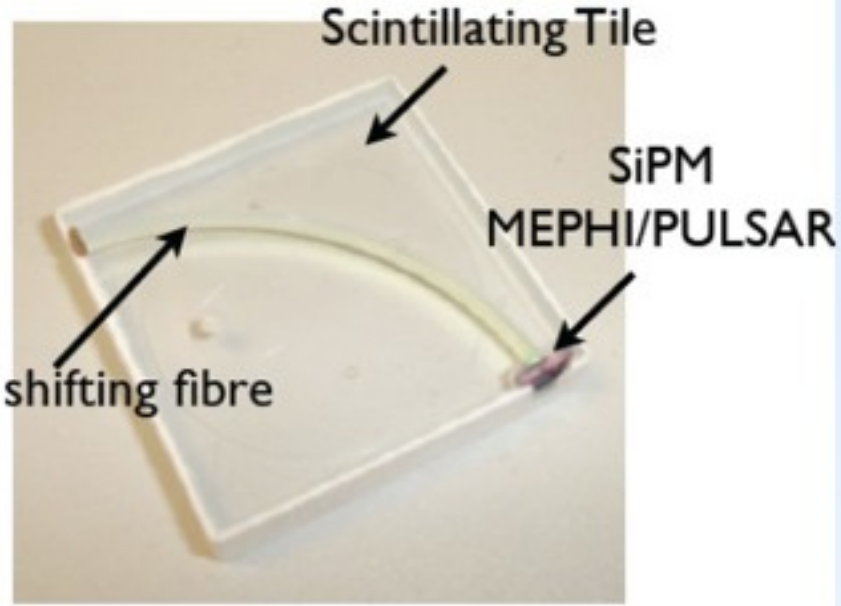
~ 7600 SiPMs



Wavelength schifting fibre
blue → green (highest sensitivity of sensor)
+ response uniformity

- Several producers/sensor types
- Which sensor ist best for the application?
- Characterisation is needed

A. Tadday (CALICE)@PD09



Calorimetry for fast neutrons ?

Radiator:

- plastic scintillator (no PSD)
- Organic liquid scintillator (PSD, but difficult to handle)
- New organic crystalline scintillator (PSD, high light output, e.g. potassium dihydrogen phosphate KDP; 9,10-diphenylanthracene DPA, sizes??)

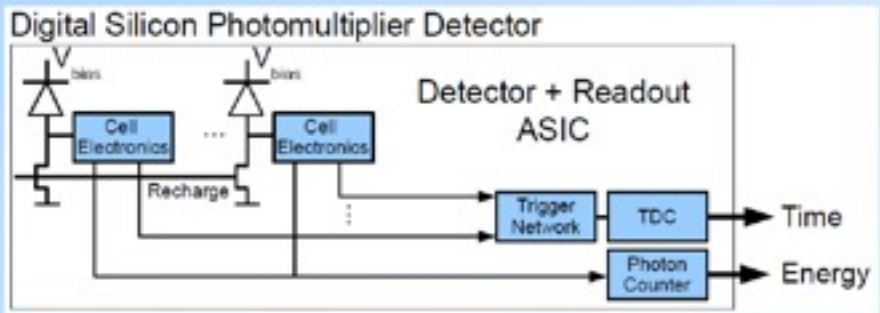
DPA … 20.000 photons/MeV, fast

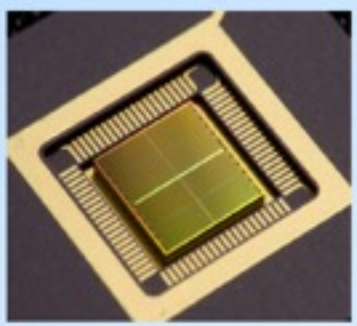
New developments

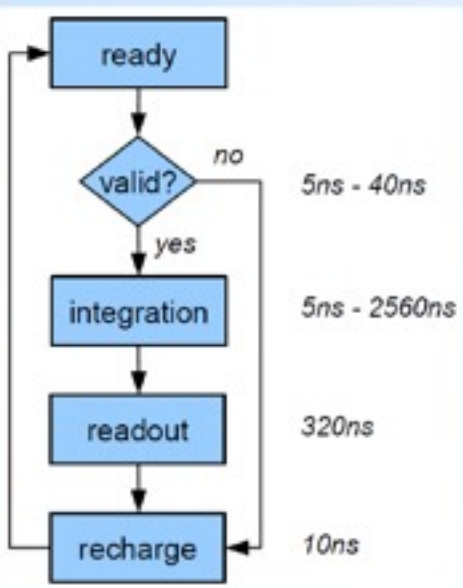
dSiPM - Digital SiPM (Philips)

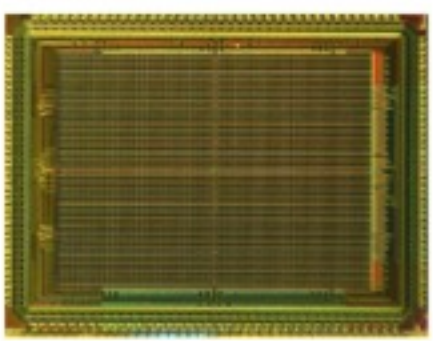
Signal from each pixel is is digitized and the information is processed on chip:

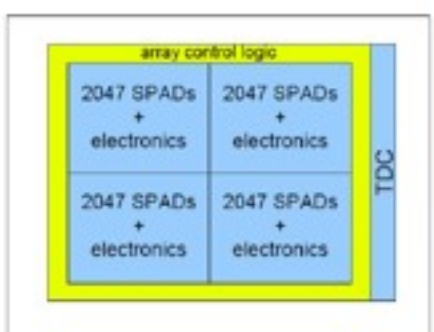
- time of first fired pixel is measured
- number of fired pixels is counted
- active control is used to recharge fired cells
- 4 x 2047 micro cells
- 50% fill factor including electronics
- integrated TDC with 8ps resolution









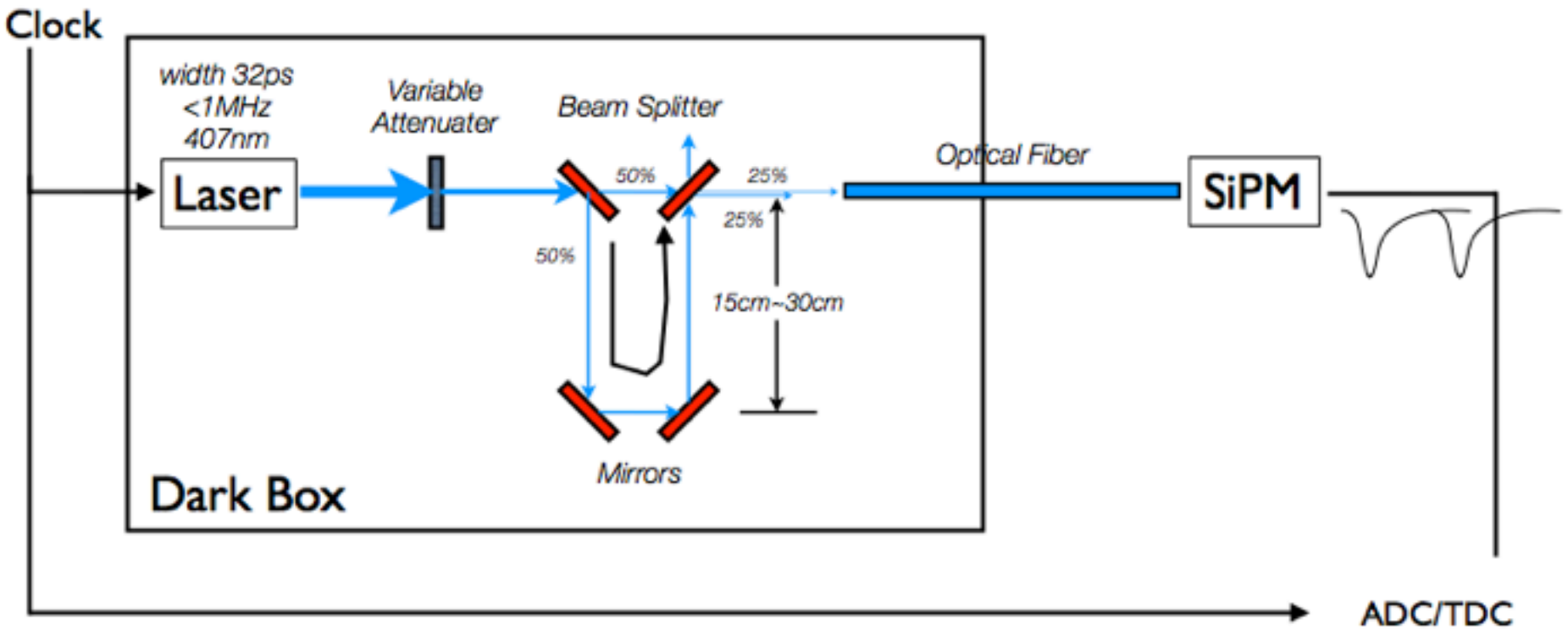


T. Frach (Philips) @ IEEE2009

Current work and future plans

- *Test of different Preamplifiers, effect on the timing performance*
- *Instrumentation of light-catcher Cherenkov module, start with MPPC, other sensors?*
- *Tests with Cherenkov light (e.g. aerogel radiator)*
- *Test with double laser pulse*

„double-hit“ setup



Ken Suzuki

Perspectives for HP-3

- *High light level regime*
- *TOF for PANDA*
- *Application in Calorimetry or neutron detection*

Ken

Remark: Definition of

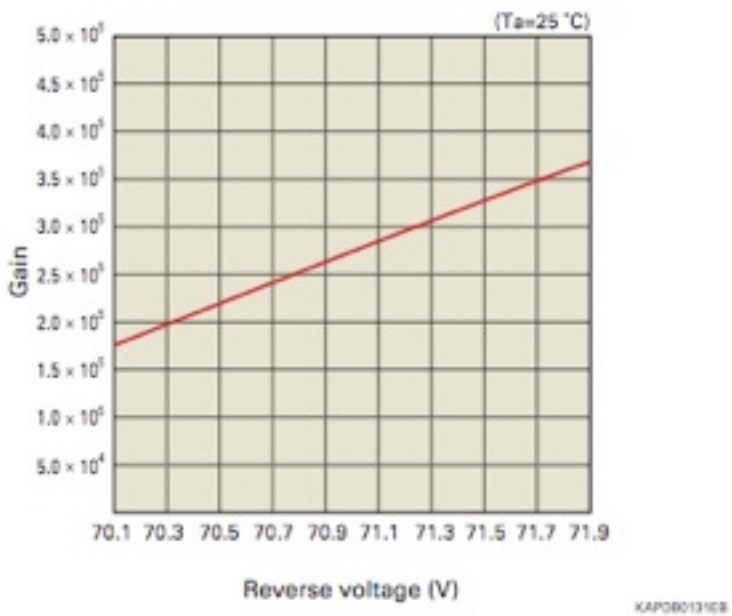
3-4 Gain characteristic

■ Gain linearity

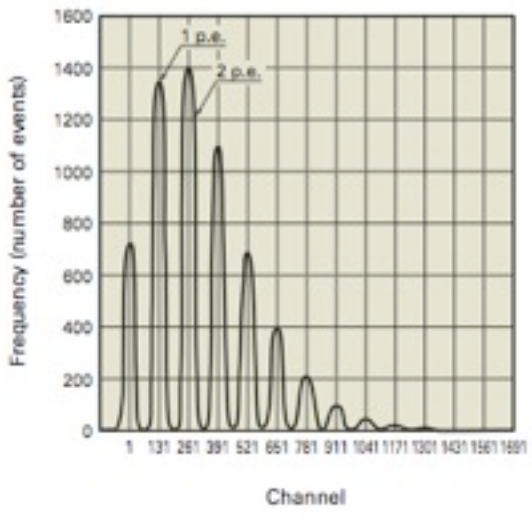
The MPPC gain has an excellent linearity near the recommended operating voltage.

[Figure 5] Gain vs. reverse voltage

(a) S10362-11-025U/C



[Figure 4] Frequency distribution example of output charge



$$\text{Gain} = \frac{\text{Number of channels between 2 peaks} \times \text{ADC conversion rate}}{\text{1 electron charge}}$$

Alternative: using current (over estimate)

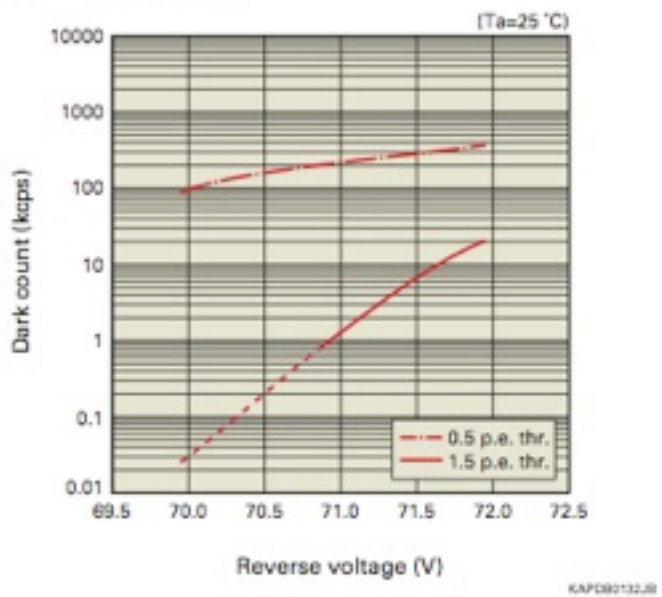
Simple(?) dark count

ÖAW
Österreichische Akademie der Wissenschaften

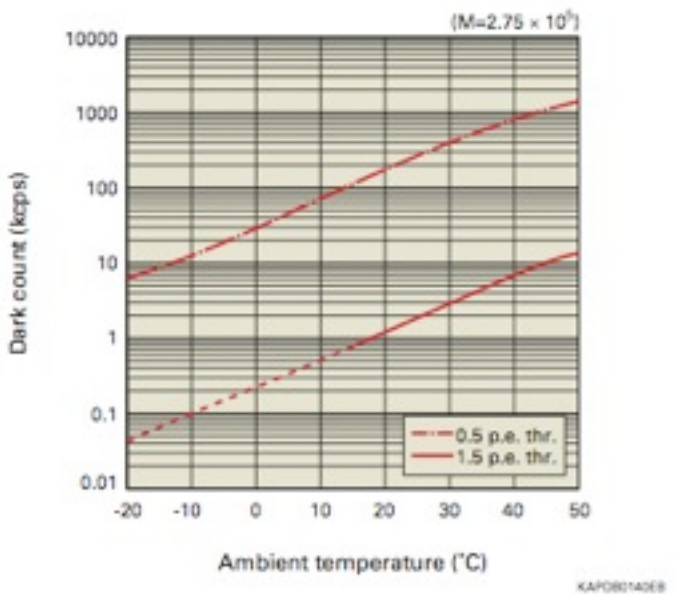
3-6 Dark count rate

Measurement examples of dark count rate are indicated below.

[Figure 10] Dark count vs. reverse voltage
(a) S10362-11-025U/C



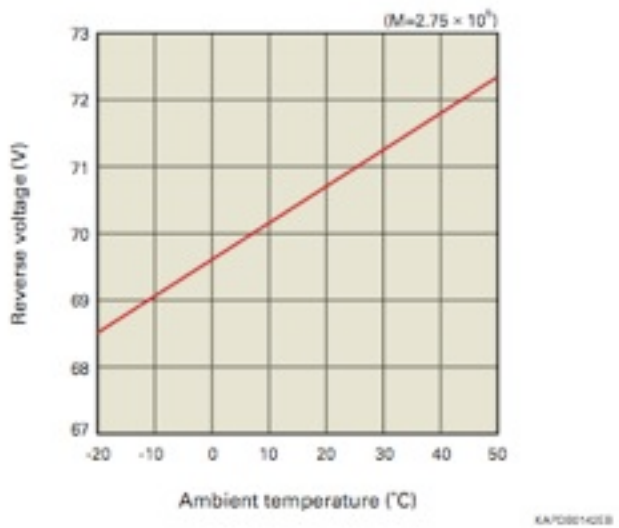
[Figure 11] Dark count vs. ambient temperature
(a) S10362-11-025U/C



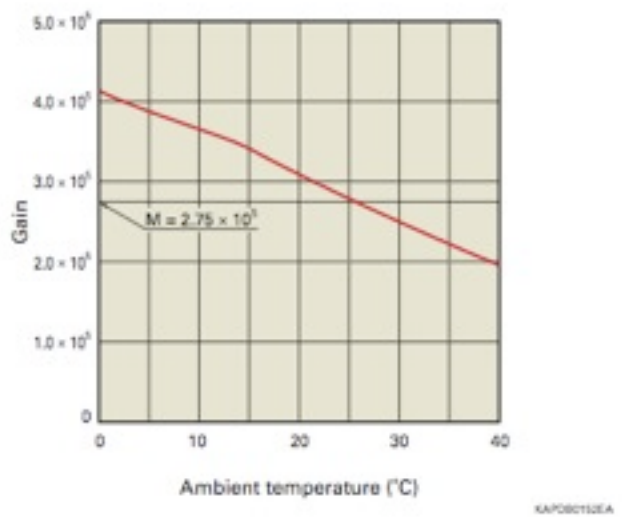
In order to define „p.e.“, gain has to be measured

Simple(?) measurement

[Figure 6] Reverse voltage vs. ambient temperature
(a) S10362-11-025U/C



[Figure 7] Gain variation vs. temperature (at constant voltage)
(a) S10362-11-025U/C



Gain kept constant

Marking Problem

- *Color coding (like resister)*
  - *side*
  - *<10 colors clearly distinguis*
  - *against scratch, fading*

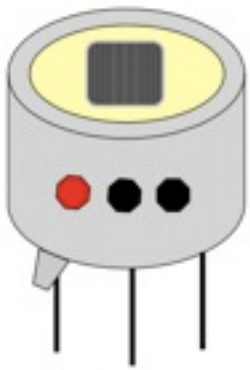


Fig (a) HAMAMATSU 1-100

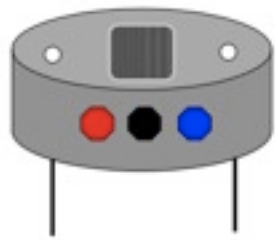
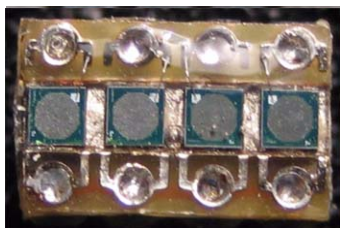
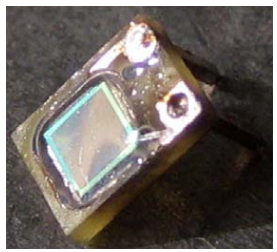
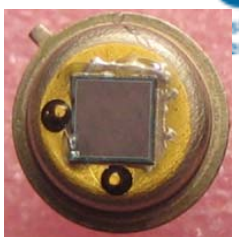


Fig (b) HAMAMATSU 1-50

- *pants*
  - *a sheet of paper with 2(3) holes inserted from bottom*
  - *can read from top / bottom, can be printed*

APD Size

Model Name	SSPM_0701BG	ASS_0604_02	SSPM_0611B4	SSPM_0604BE
Effective Area	1mmx1mm	1mmx1mm	2mmx2mm	3mmx3mm
Price	€ 110	70€/ch	€ 200	€ 350
P.D.E.	40%@560nm 15%@450nm	⇐	25%@440nm	8%@420nm
Gain	$4x10^5$	⇐	$6x10^4$	$4x10^5$
N_{pixel}	550	⇐	1700	8100
Dark Current	10μA	⇐	<10μA	<30μA
Signal Risetime	<0.7ns	⇐	<0.7ns	<10ns
Capacitance	40pF	⇐	160pF	300pF

Which APD?

Producer	Photonique	Hamamatsu	Hamamatsu	SensL	Russian
Model Name	ASS_0604_02	S10362-50U	S10362-100U	SSPMMicro 1000X01A3	MP3D
Effective Area	1mmx1mm	1mmx1mm	1mmx1mm	1mmx1mm	1mmx1mm
Price	70€/ch	€ 100	€ 100	?€	?€
P.D.E.	15%@450nm 40%@560nm	50%@400nm 38%@500nm	65%@400nm 46%@500nm	0.15 @400nm 1 @500nm	9%@460nm 22.5%@640nm
Gain	$4x10^5$	$7.5x10^5$	$2.4x10^6$	$1.1x10^6$	$6.2x10^5$
N_{pixel}	550	400	100	620	1024
Dark Current	10μA	270kcps	400kcps		Noisy
Signal Risetime	<0.7ns			<5ns	
Time resolution	<70ps	92ps	105ps		
Pixel Recovery Time				<20ns?	7μs
Excess Noise Factor	<1.2				
Capacitance	40pF	35pF	35pF		