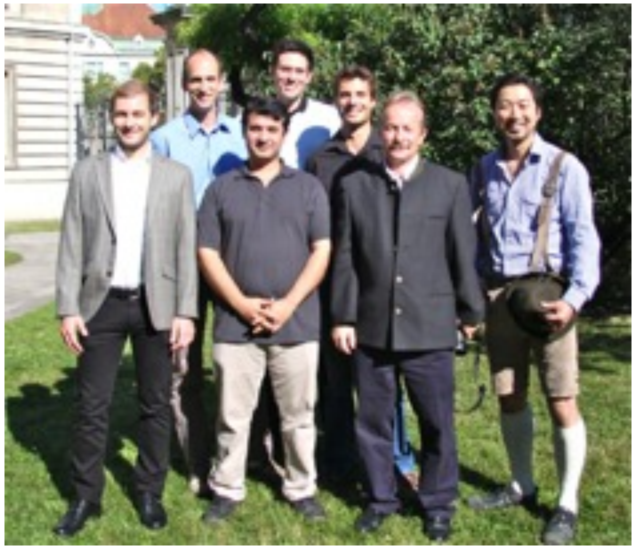
SiPM Project Status in Vienna



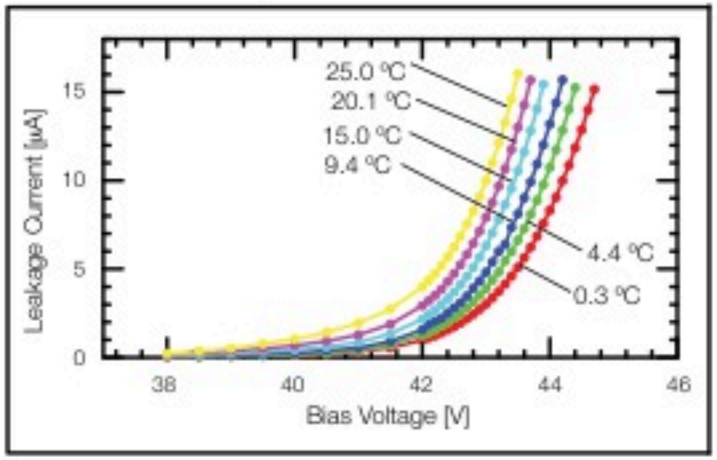
Ken Suzuki <ken.suzuki@oeaw.ac.at>

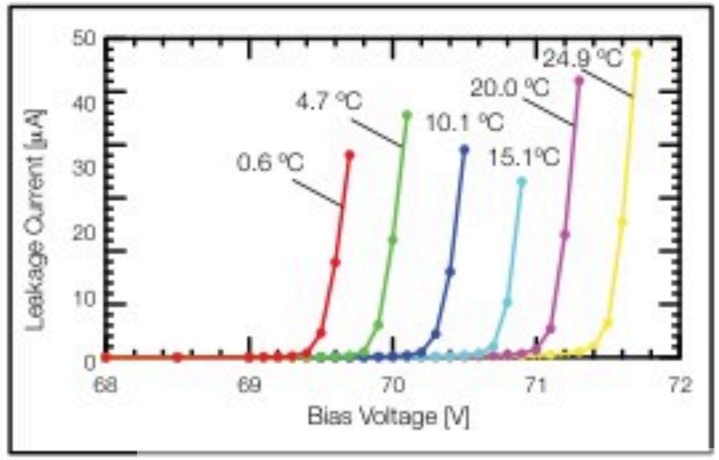
Temperature Dependence!

Photonique SSPM050701

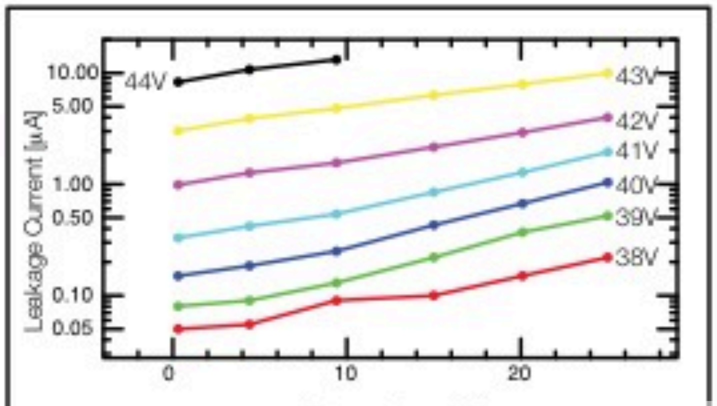
Hamamatsu S10362-11-50U

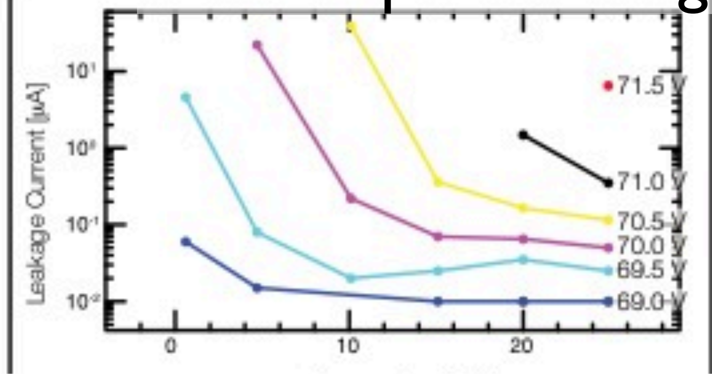
2007





I-temp curve negative!





due to the strong temperature dependence of HPK sensor.

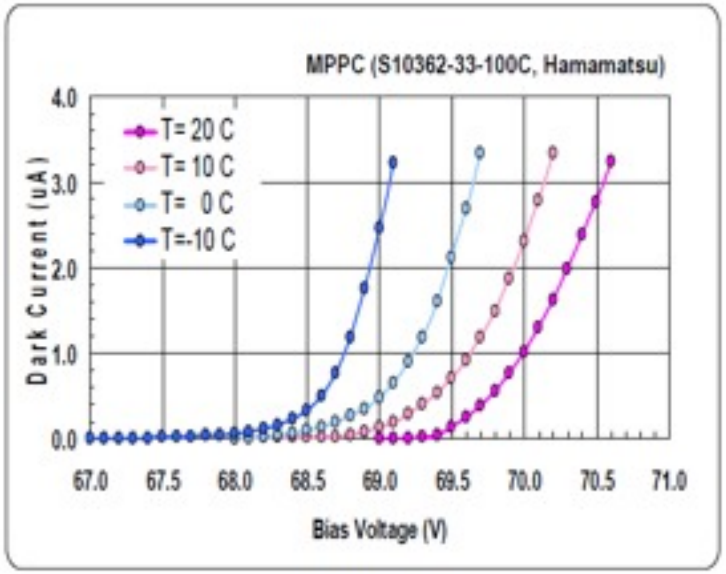
Photonique sensor had also nice features…

. less sensitive to temperature / bias voltage v

. lower operation voltage

. lower noise

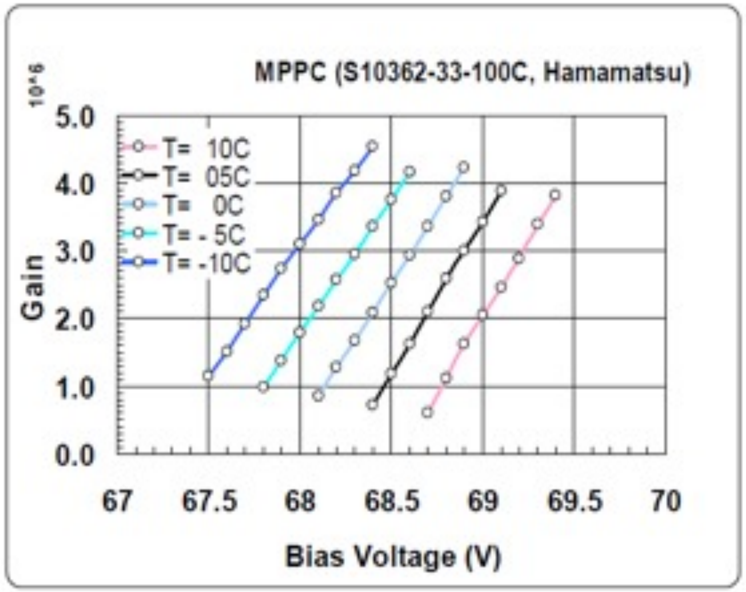
Temperature Dependence!



Δ(darkcount) = ~200% · +10℃ (HPK)

Δ(darkcount) = ~110% · +10℃ (Photonique)

ΔV_{bias} = 56 mV · ℃*

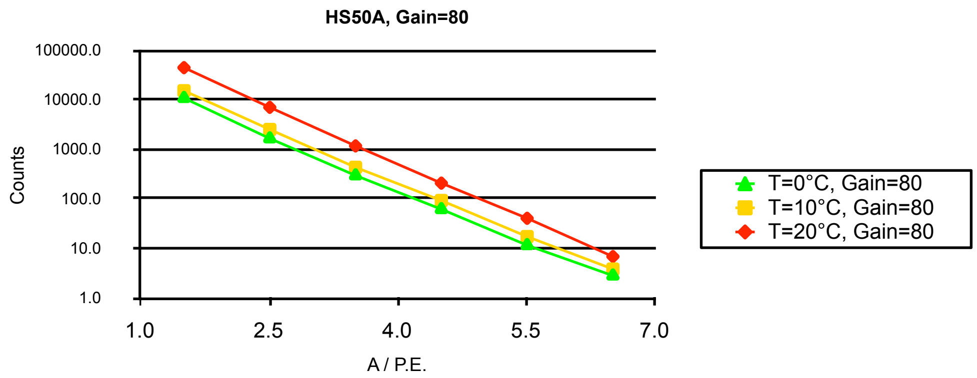


Δgain = ~400% · −10℃

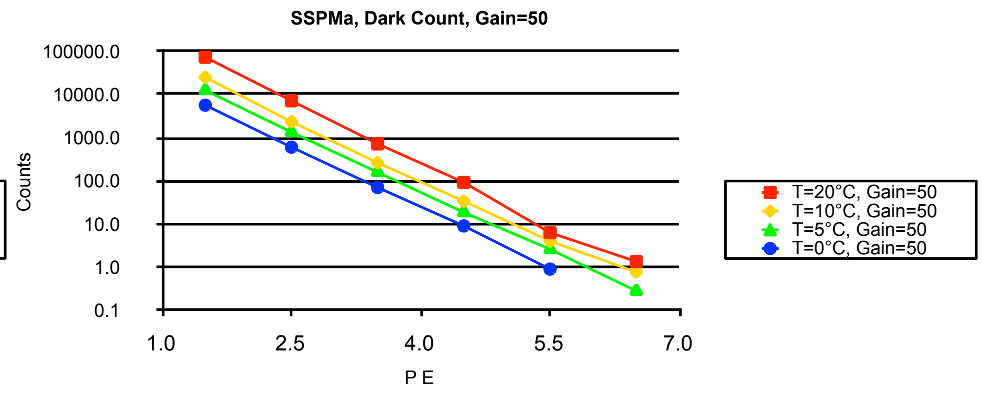
* MPPC catalog

Dark Count

Hamamatsu …-50U

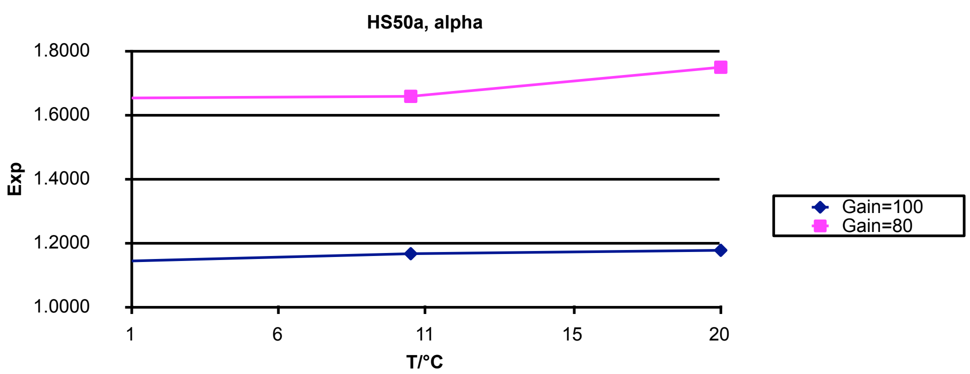


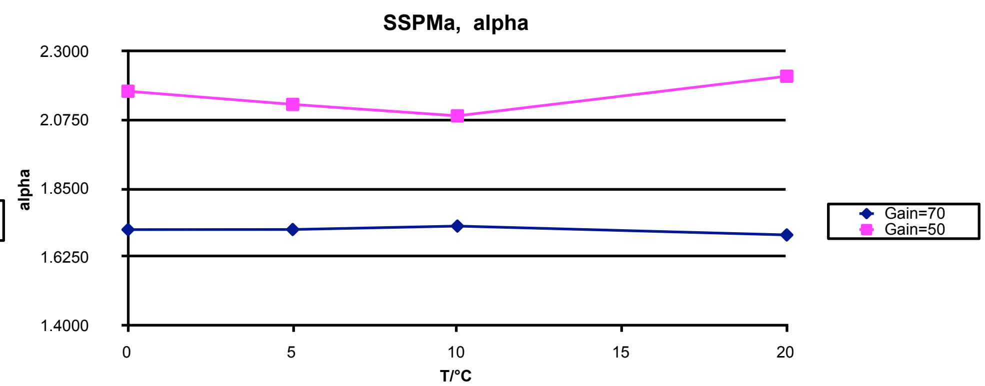
Photonique



Counts ~ exp (-α*A(p.e))

α ~ independent on temperature





to compensate T[°C]-dep.

1: Passive

Measure temperature and gain continuously and calibrate it by adjusting V_{bias}.

Simpler setup/Room temp.

More common approach

Experimental area preferably with some insulation („cave“, UG)

2: Active

Regulate temperature

More complex setup and operation/Can be cooled

Less common? (SMI, HPK)

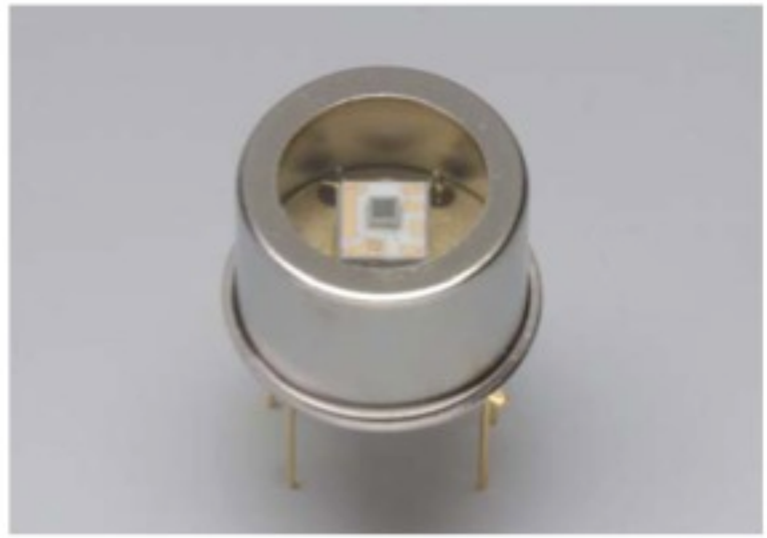
Experimental area nevertheless preferably with some insulation

Would like to keep in mind the option 2 as well

4. TE-cooled type

The S11028 series is a photon counting detector that integrates a 1 × 1 mm MPPC with a thermoelectrically cooler . It also contains a thermistor for temperature monitoring, allowing stable measurement over long periods of time. A temperature controller (C1103-04)* is also provided (sold separately).

* Please see our website: http://jp.hamamatsu.com/



TOC

- A few applications
- Timing performance measurement
- 8x8 martix detector = position sensitive detector with larger sensitive area
- Recovery time/Rate capability measurement

Applications

Experiment at FOPI/GSI,10MHz MIP (=proton) 0.6T
very limited manpower, money, time for R&D

Proton beam at SIS/Cave-B
σ_t=100ps for TOF
Lambda trigger
Forward tracker
Beam halo counter

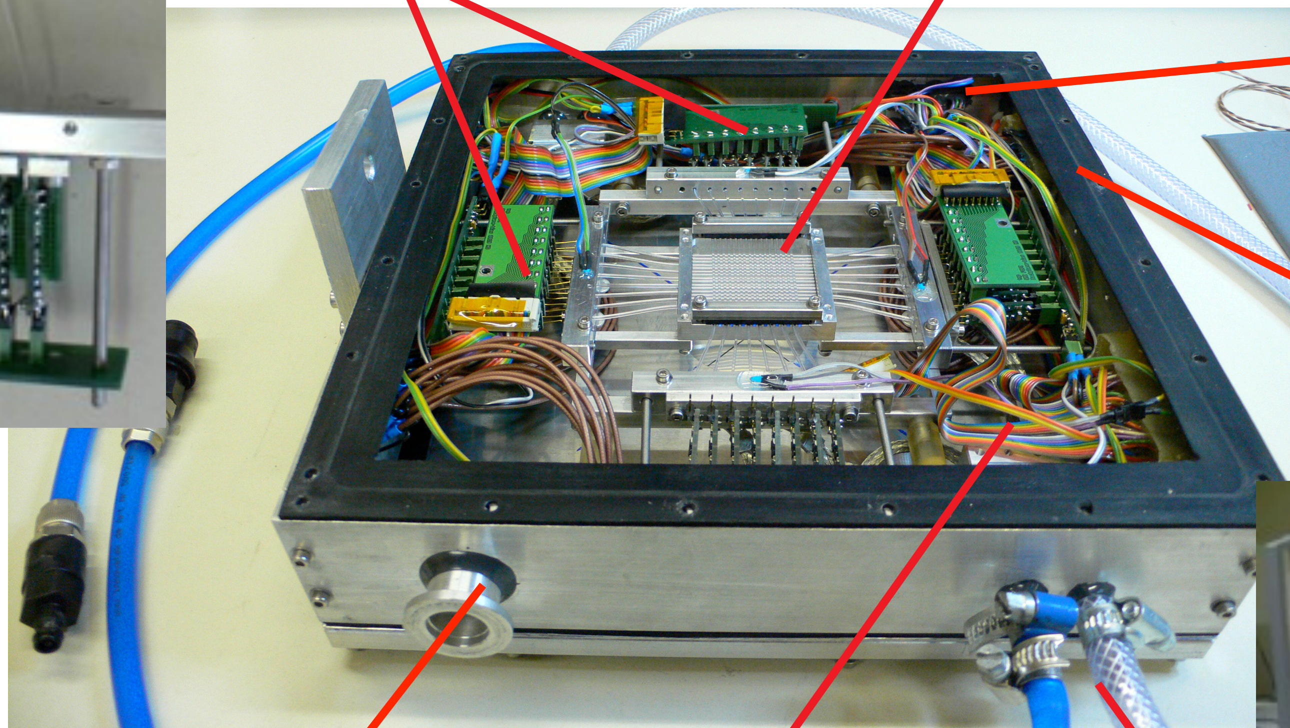
Beam Profile Monitor

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*
- *Good excercise*
- *one of the earliest detector with SiPM used in a physics run (2008)*

FOPI Beam Veto for pion beam

KS, G. Ahmed

Halo2 and Target

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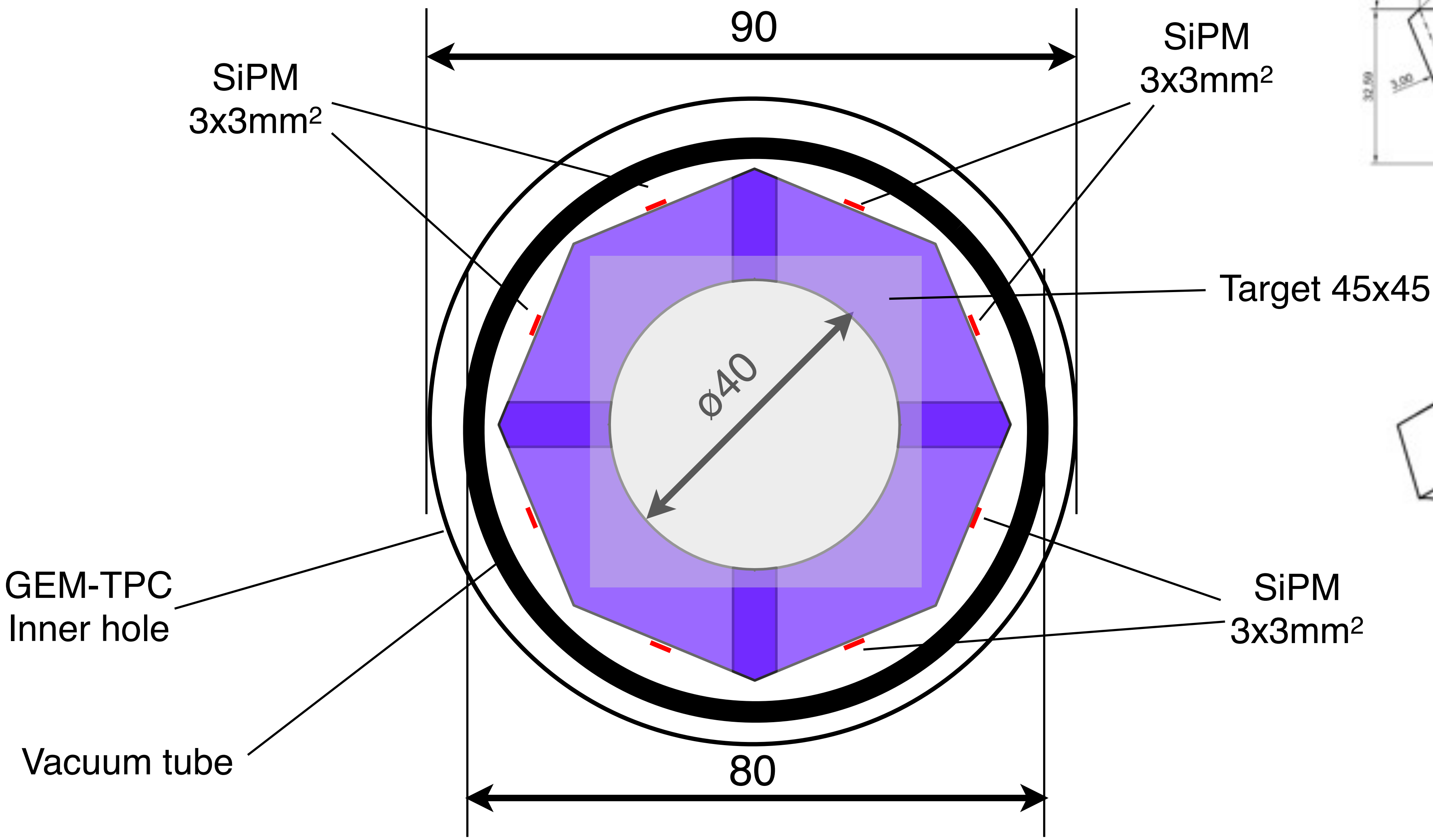
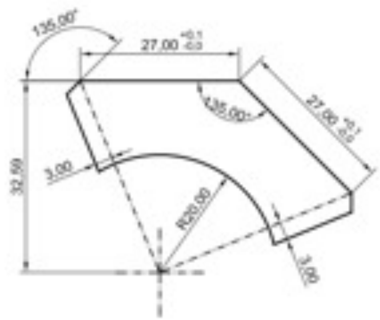
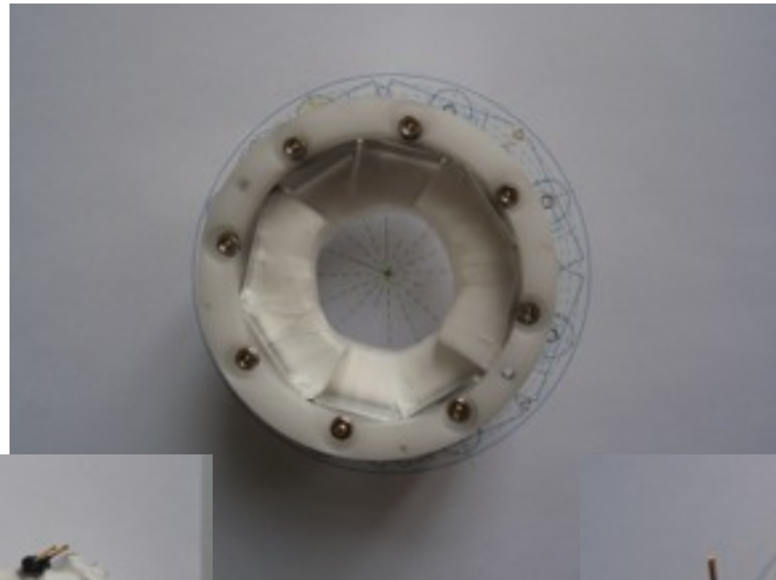
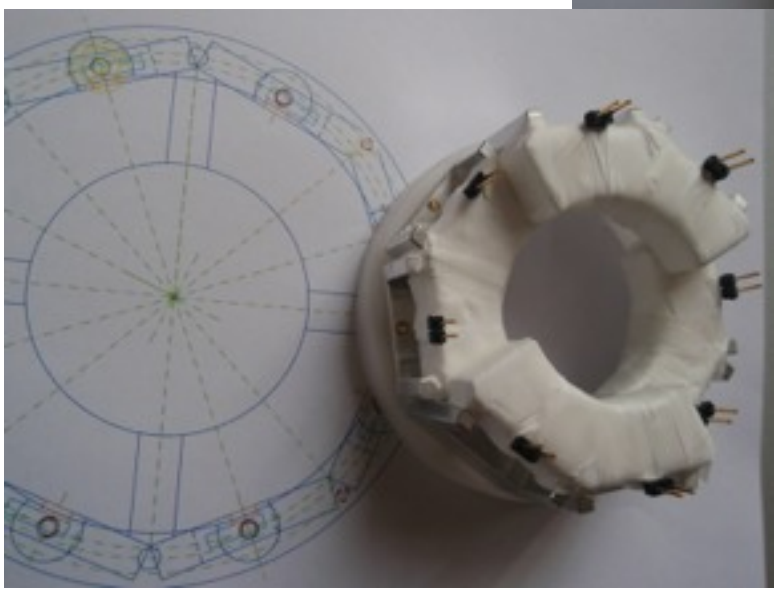
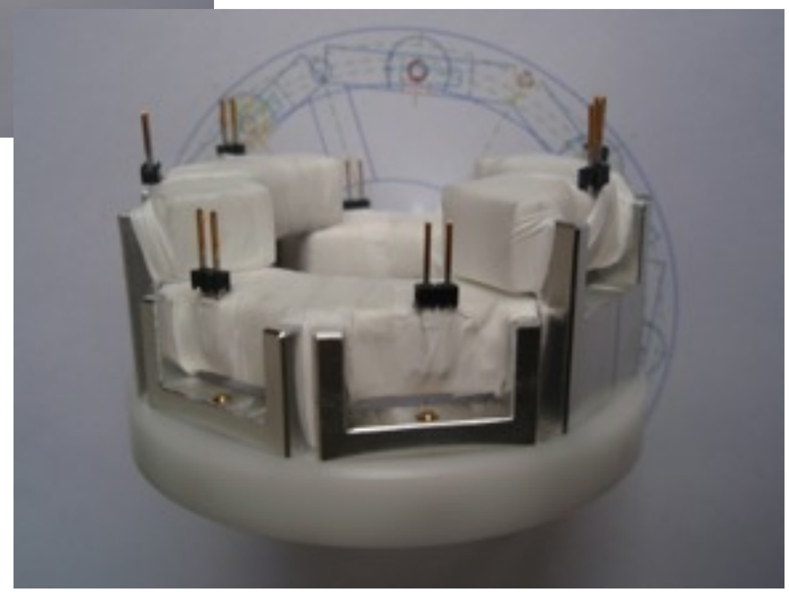




Halo2 (photo)

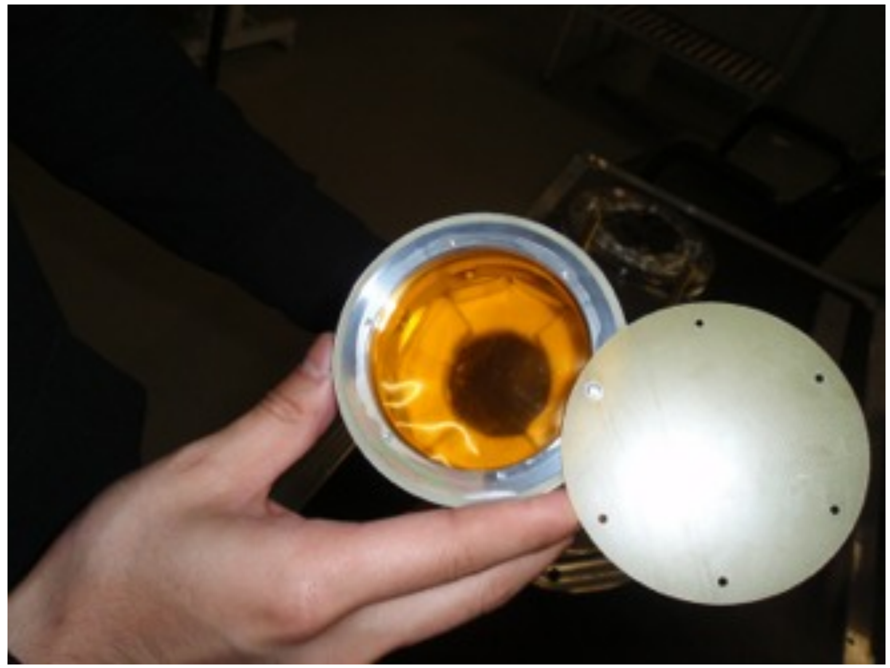






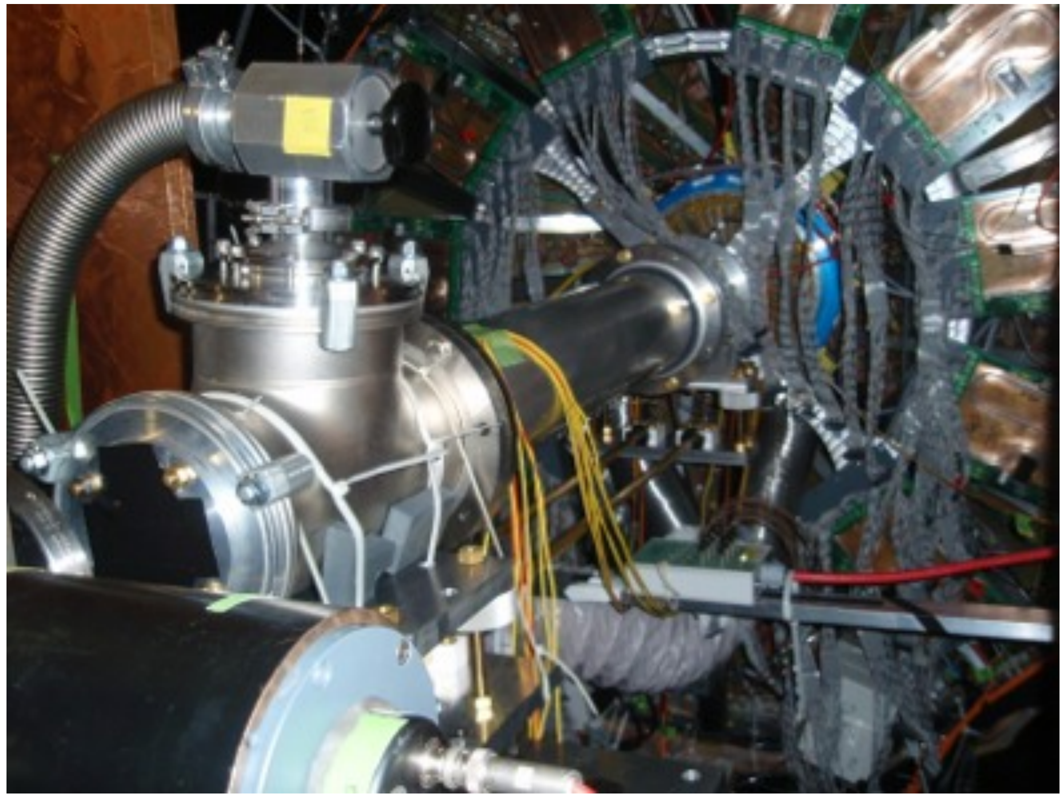
SIPM directly attached to the scintillator with a grease, wrapped with teflon tape

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%*
- *PMT cannot be an option!*

Other applications

- *Cherenkov Fibre detector with SiPM readout*

NIMA628(2011)393

- *Battery driven portable radiation detector!!*
  - *in Japan*
  - *missed a chance to be rich?*
  - *maybe still not too late??*

Timing performance measurement

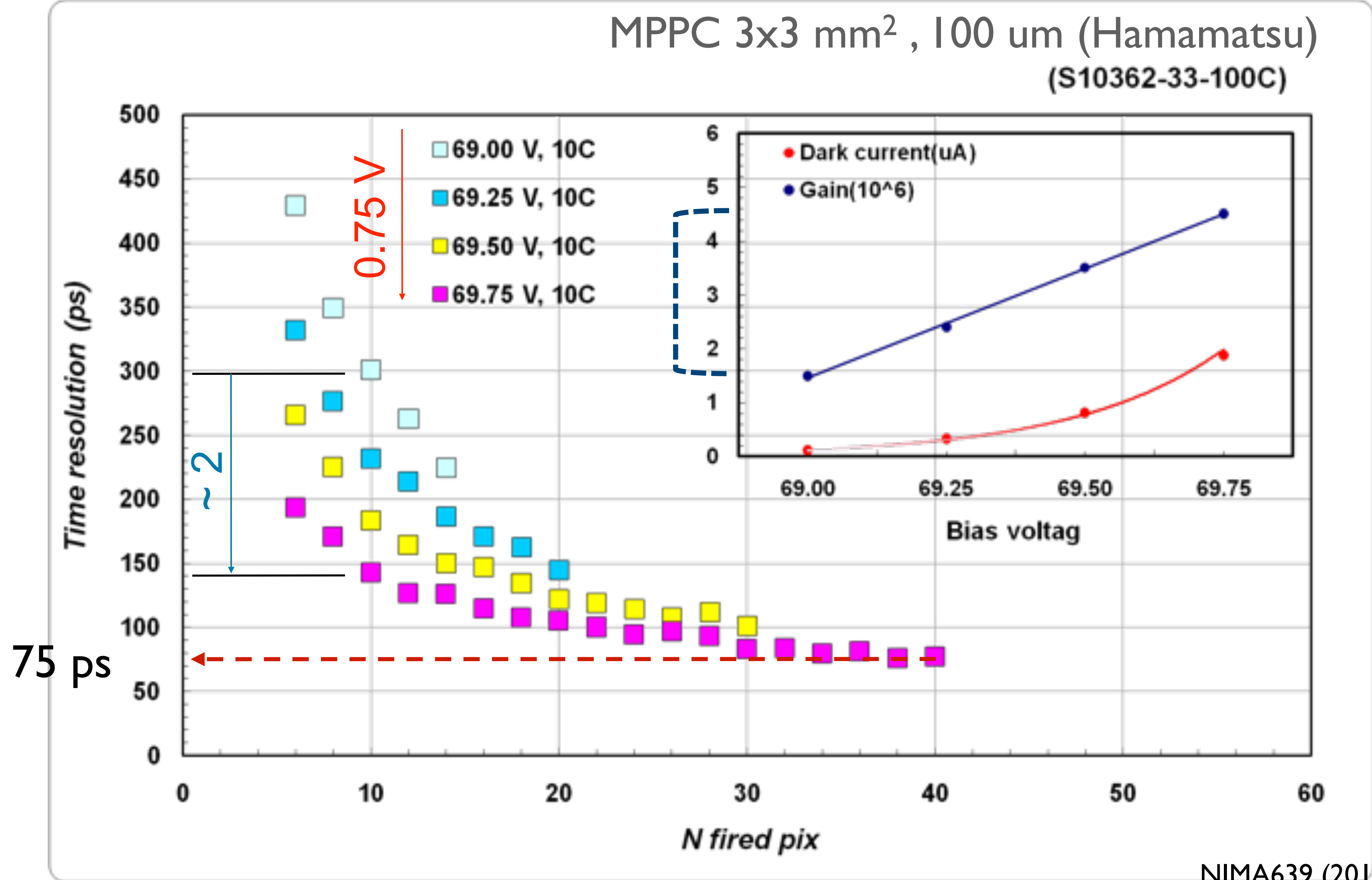
K.S, G. Ahmed, J. Marton

NIMA639 (2011) 107

NIMA652 (2011) 528

Time resolution

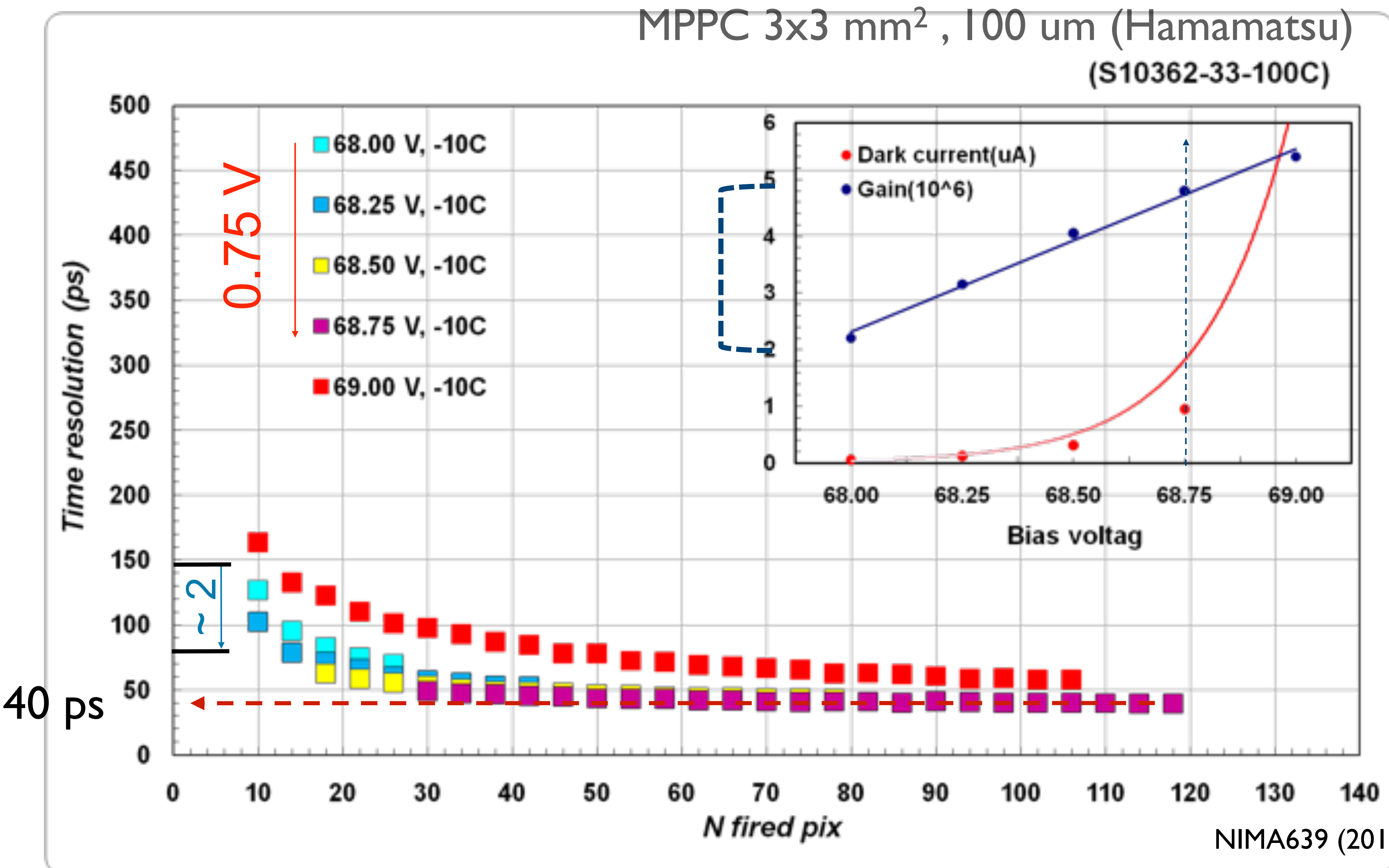
@ +10℃



NIMA639 (2011) 107
NIMA652 (2011) 528

Time resolution

@ −10℃.



NIMA639 (2011) 107
NIMA652 (2011) 528

Array detector: larger area+position sensitivity

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

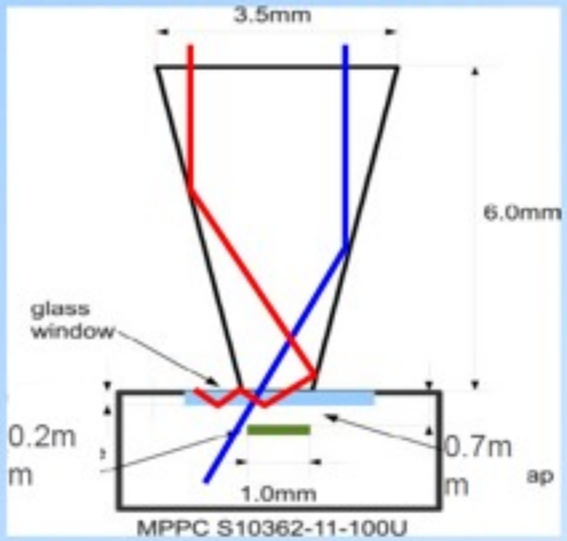
How the others do

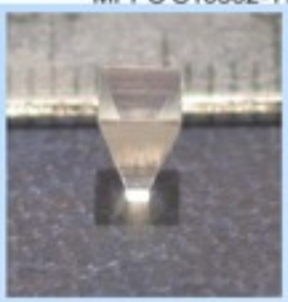
S. Korpar , talk at RICH-2010

Light concentration

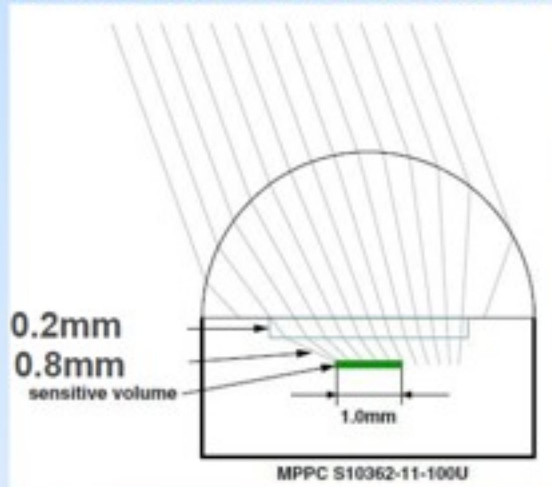
Can be used if light comes within the limited solid angle

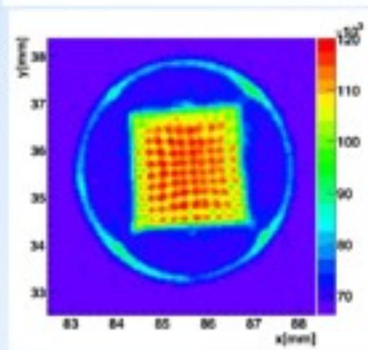
- Winston cones produce large angular spread at the exit surface – photons can miss the active area





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

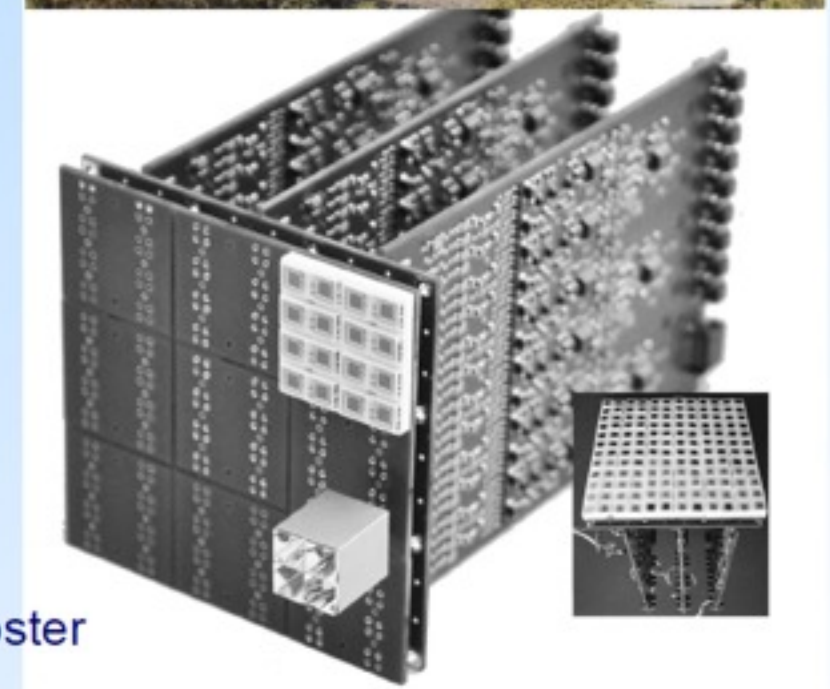




MAGIC

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

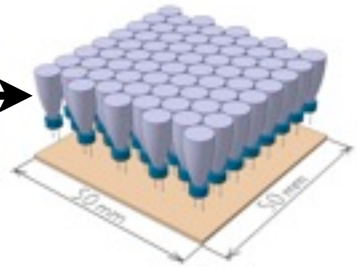
for update look at the previous talk and poster

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*



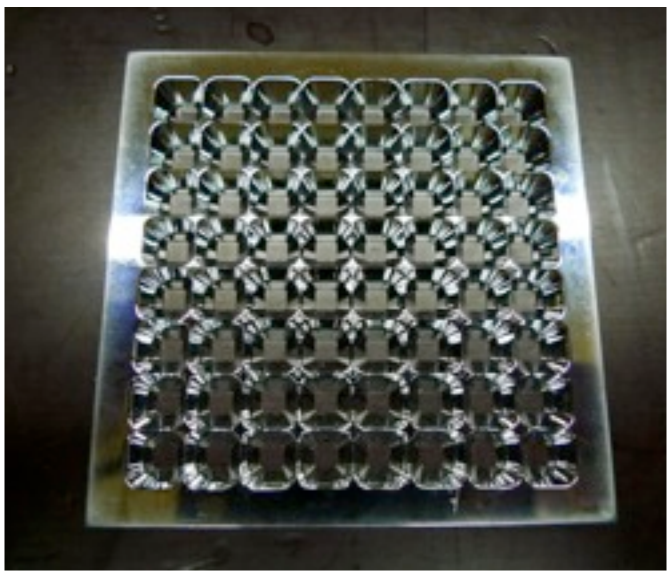


Table 1. Main parameters of the light concentrator.

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 mm^2
Funnel exit aperture	3 × 3 mm^2
Funnel height	4.5 mm
Fill factor (incuding rim)	69 %
Fill factor	93 %
Basic material	Brass
Coating	Aluminum, Chromium

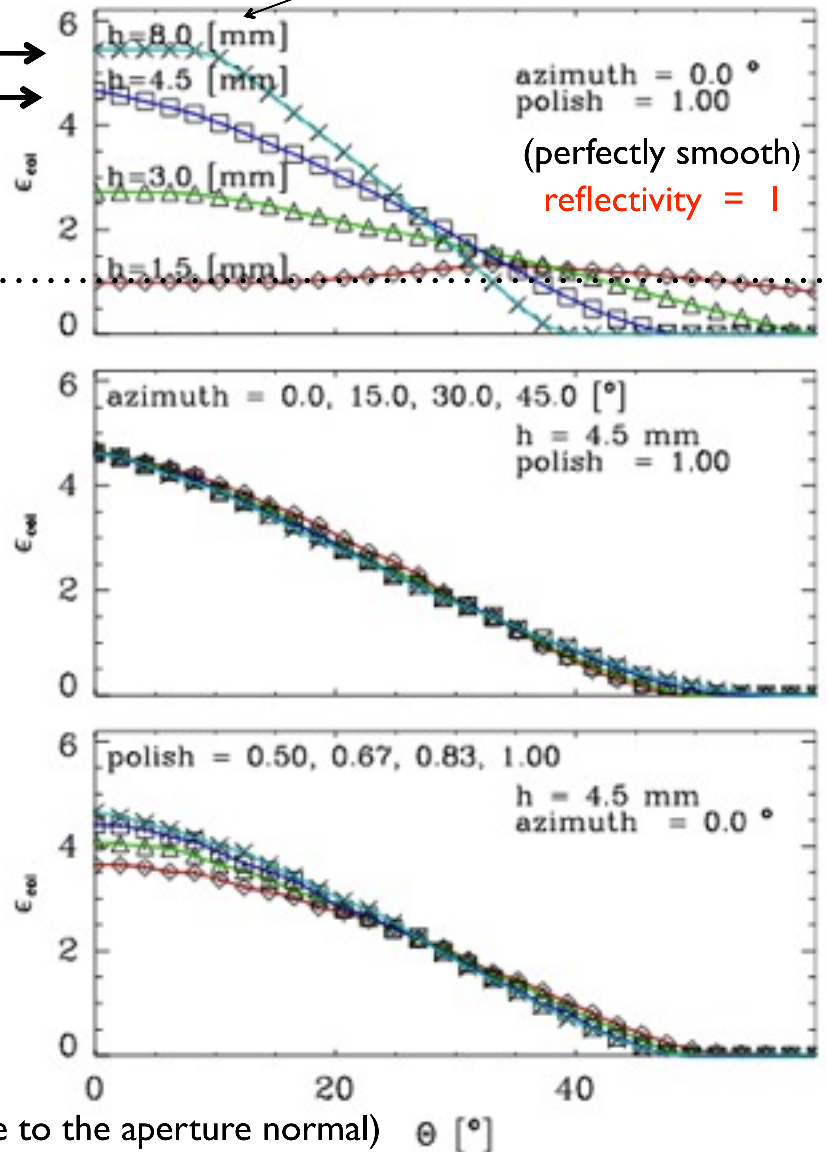
„Geometry optimization“

funnel length

$\varepsilon_{col,max}$ = 100%

ε_{col} = 82%

„concentrate“

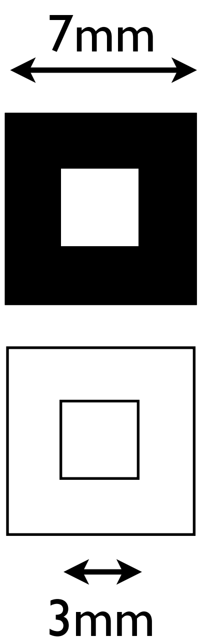


(perfectly smooth)

reflectivity = 1

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

= max for $n_d = N_{phot}$



	ε_{col}
1	19%
5.4	100%

(Angle relative to the aperture normal)

It was decided to go to 4.5 mm funnel length

Funnel test with laser

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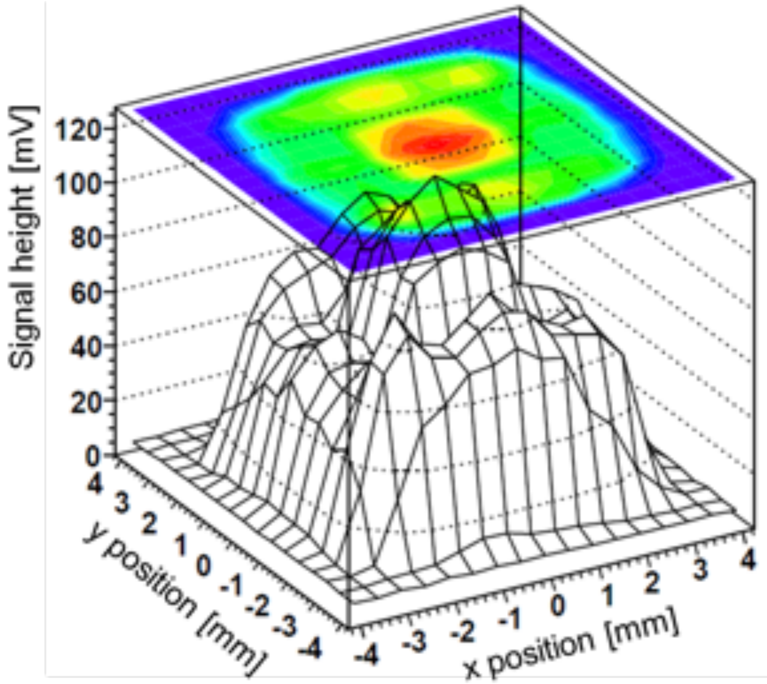
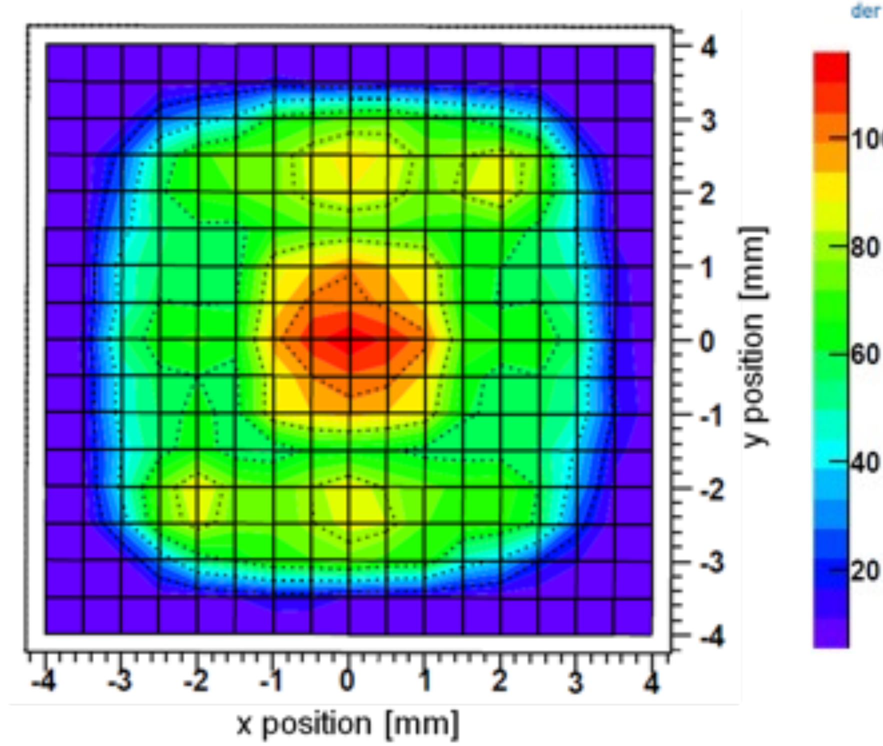
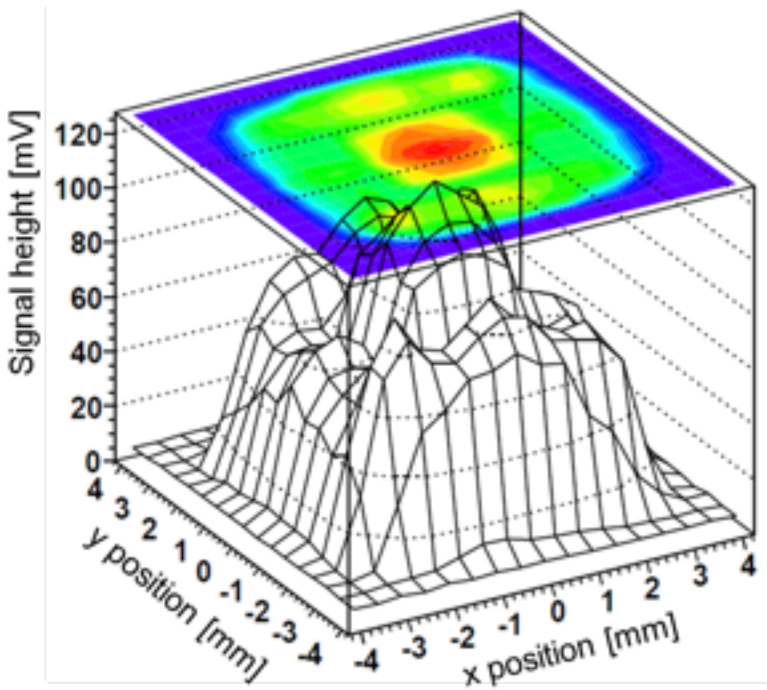
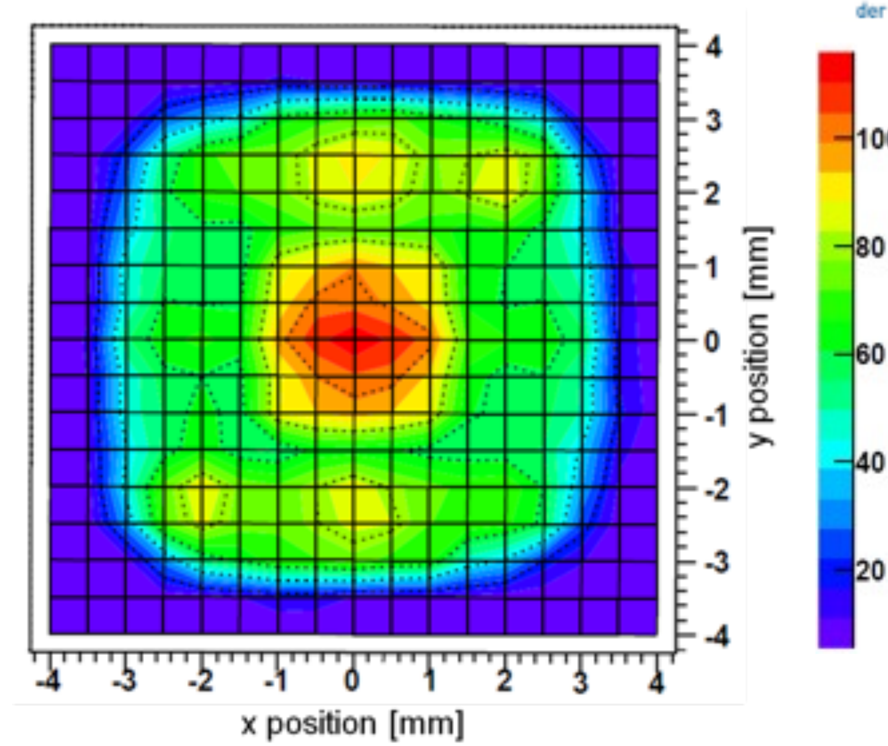




- *the funnel was scanned in two dimensions with a collimated laser (about 1 mm diameter,* Θ *= 0 ± 4°) in steps of 250 μm*

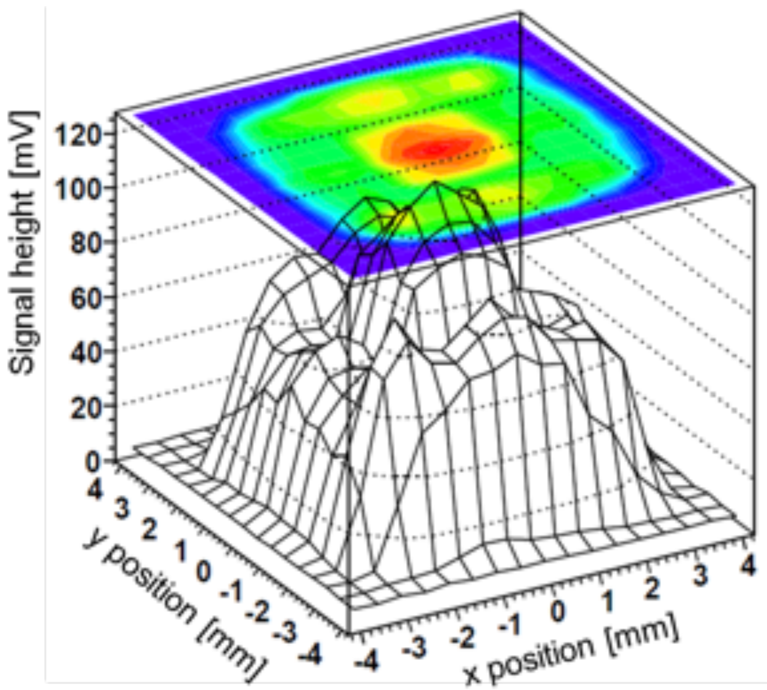
Funnel test with laser

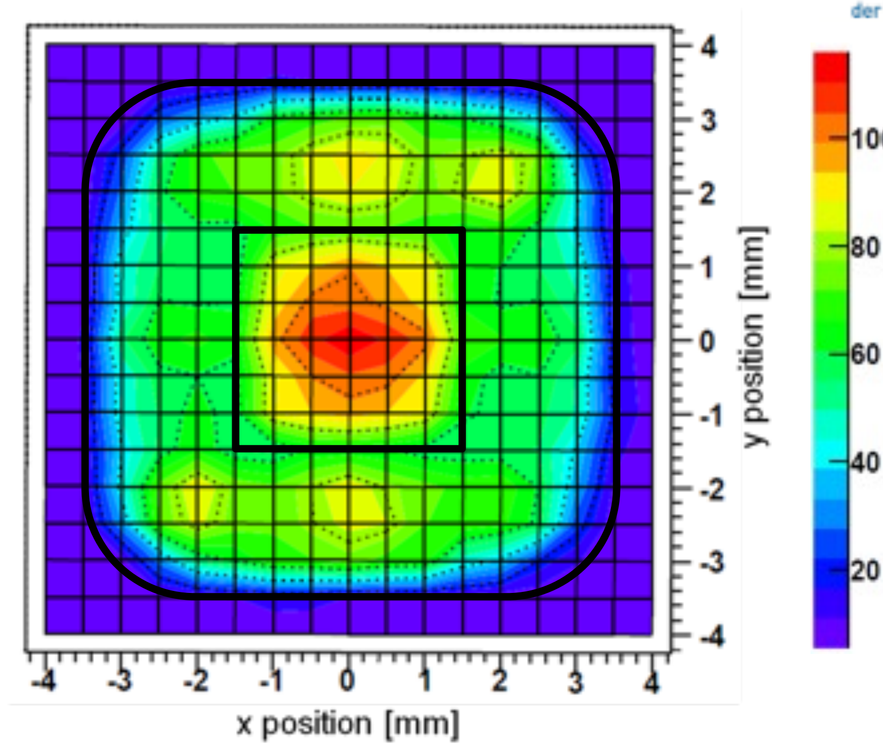




- *the funnel was scanned in two dimensions with a collimated laser (about 1 mm diameter, Θ = 0 ± 4°) in steps of 250 μm*
- *The light concentrator works!*

Funnel test with laser





- *the funnel was scanned in two dimensions with a collimated laser (about 1 mm diameter, Θ = 0 ± 4°) in steps of 250 μm*
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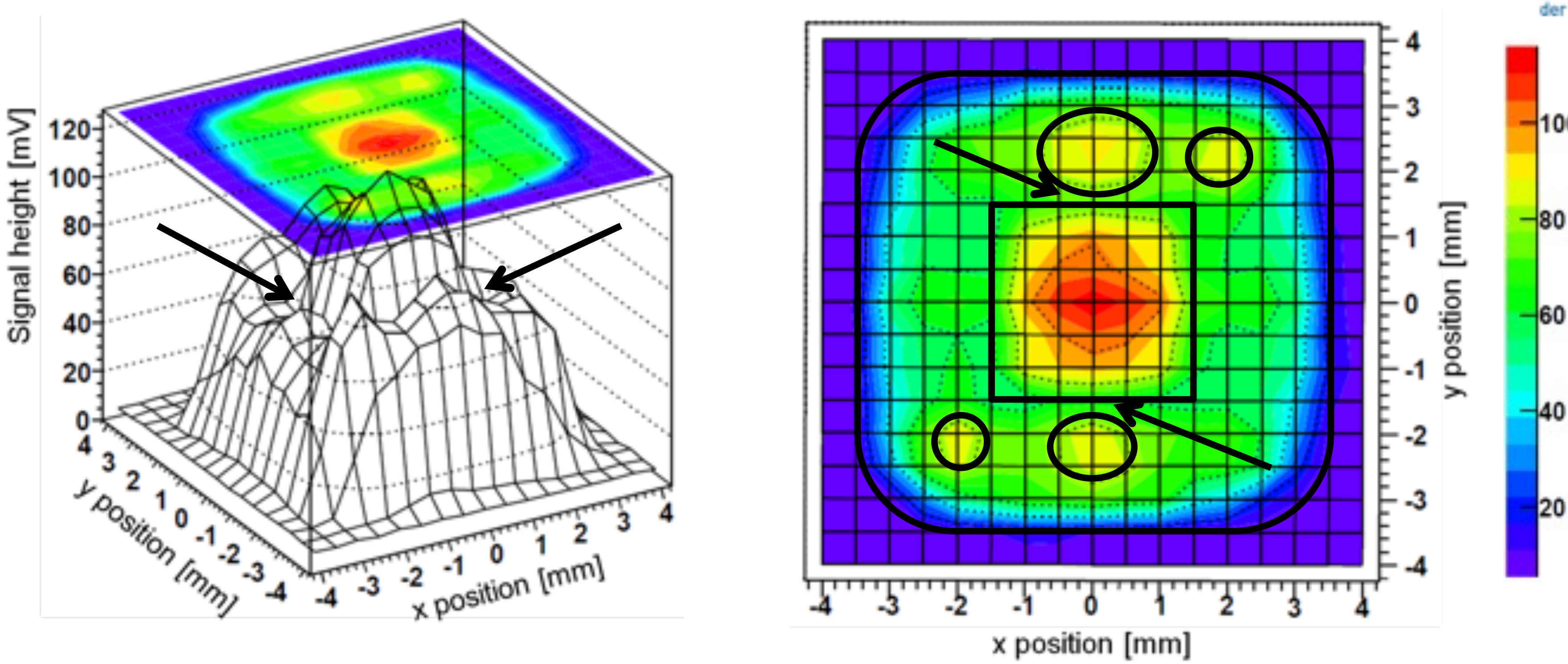
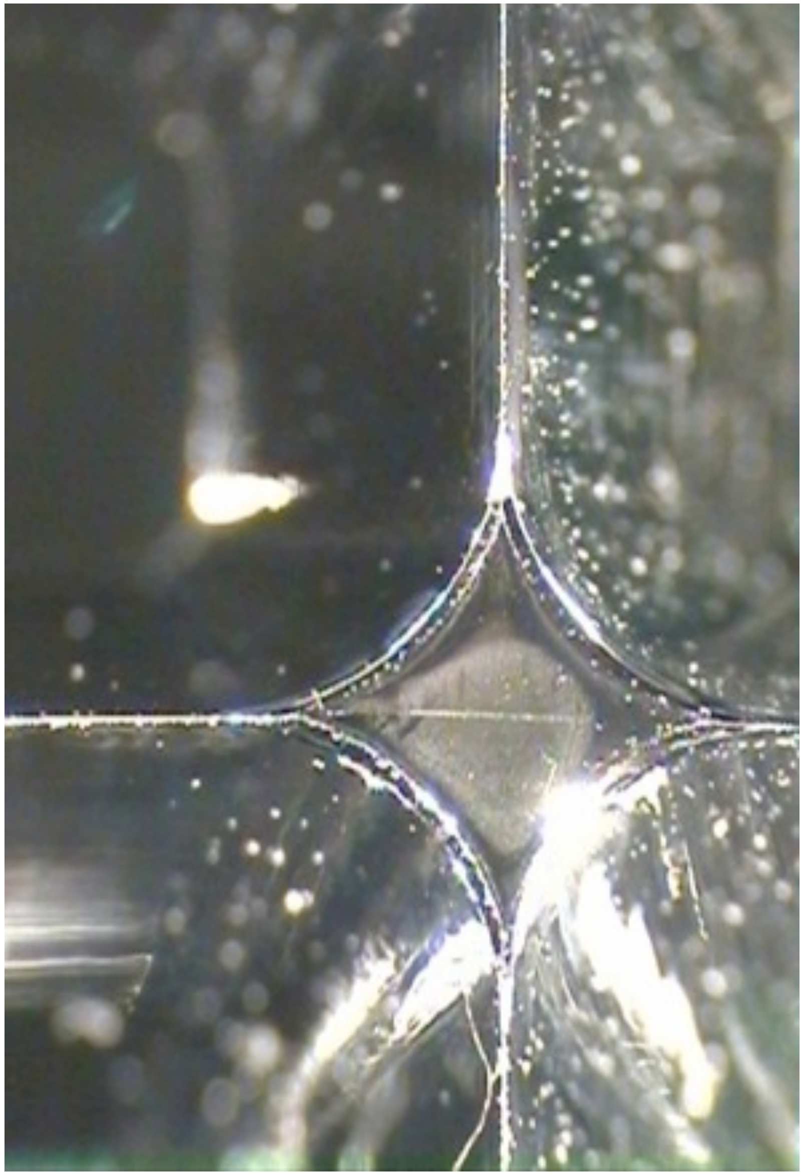
Funnel test with laser

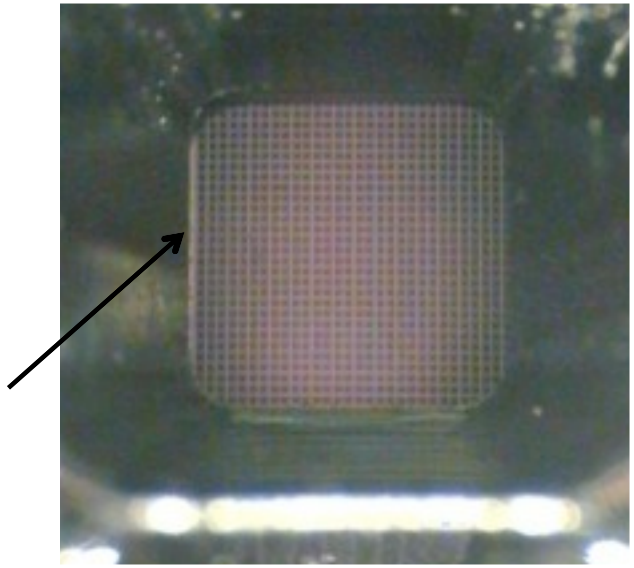


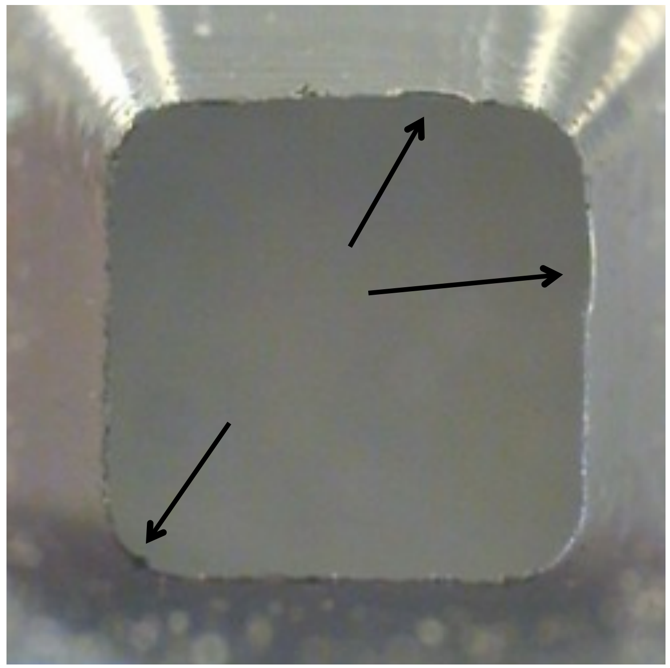
- *the funnel was scanned in two dimensions with a collimated laser (about 1 mm diameter, Θ = 0 ± 4°) in steps of 250 μm*
- *The light concentrator works!*

- "Eff. dip": fabrication, non-uniform coating quality?
- Inefficient bands at the edge of the funnel
- No real plateau in the center: beam size
- Redo with a finer collimator (15μm pin hole), finite angle

Some pictures







Efficiency simulations

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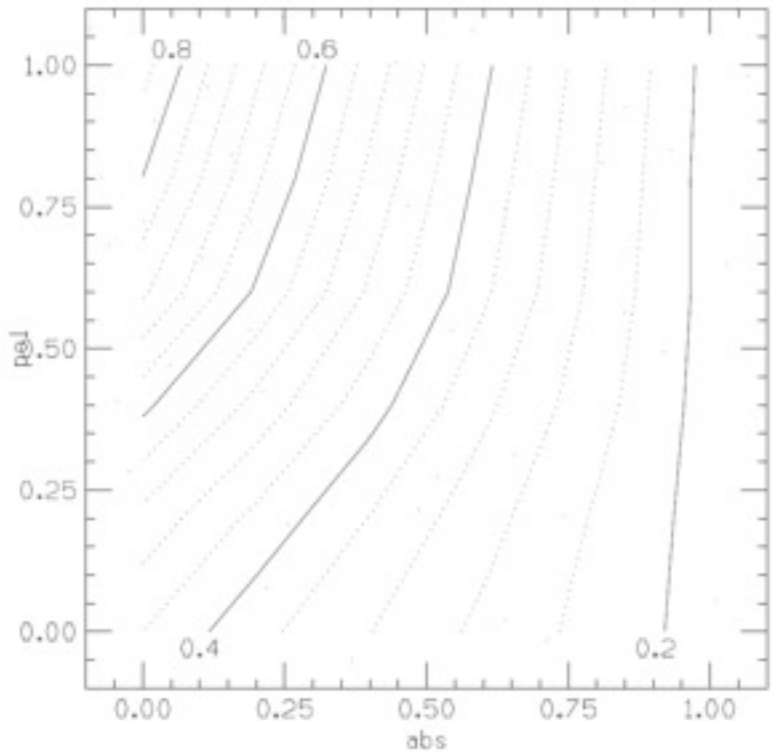
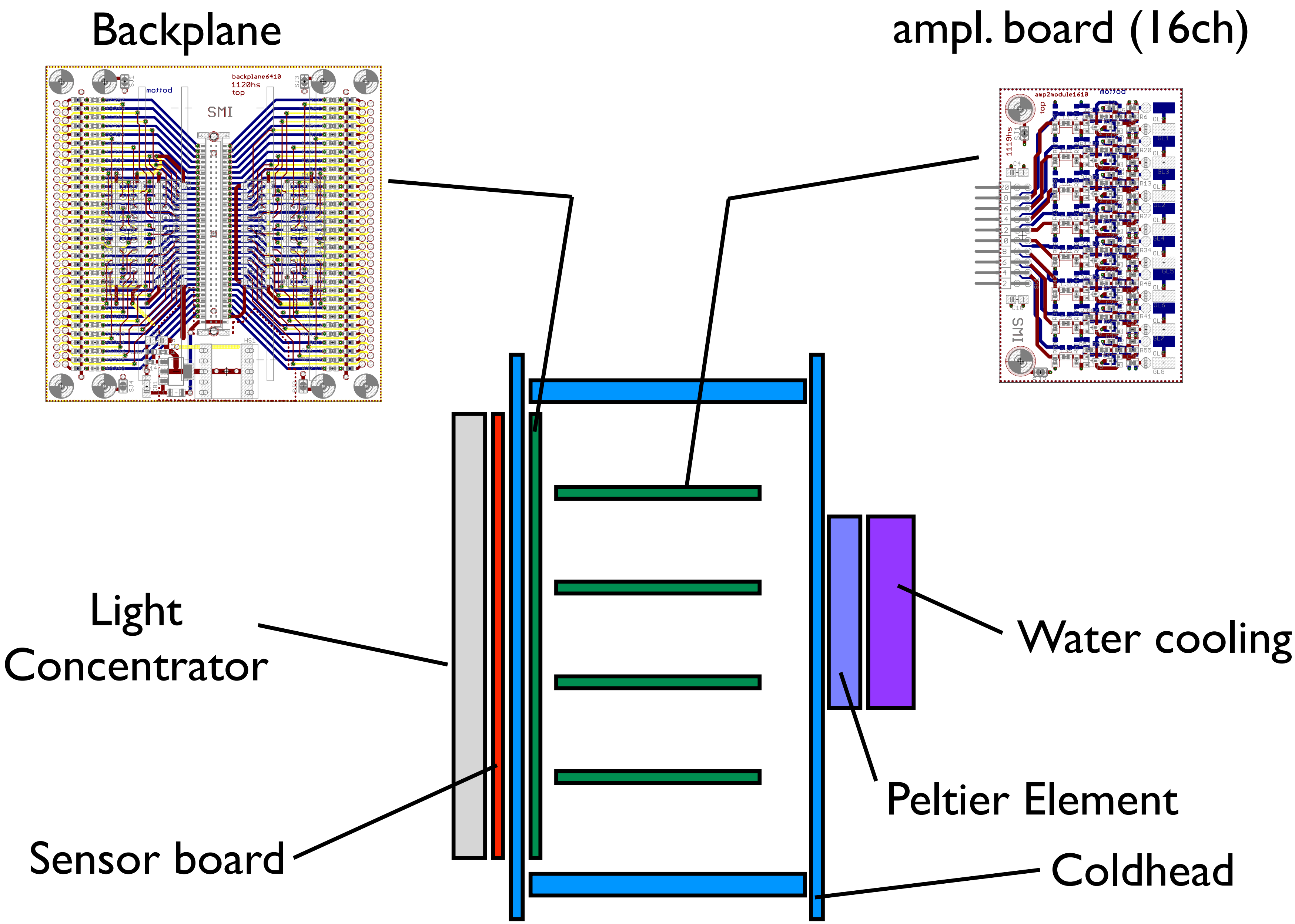
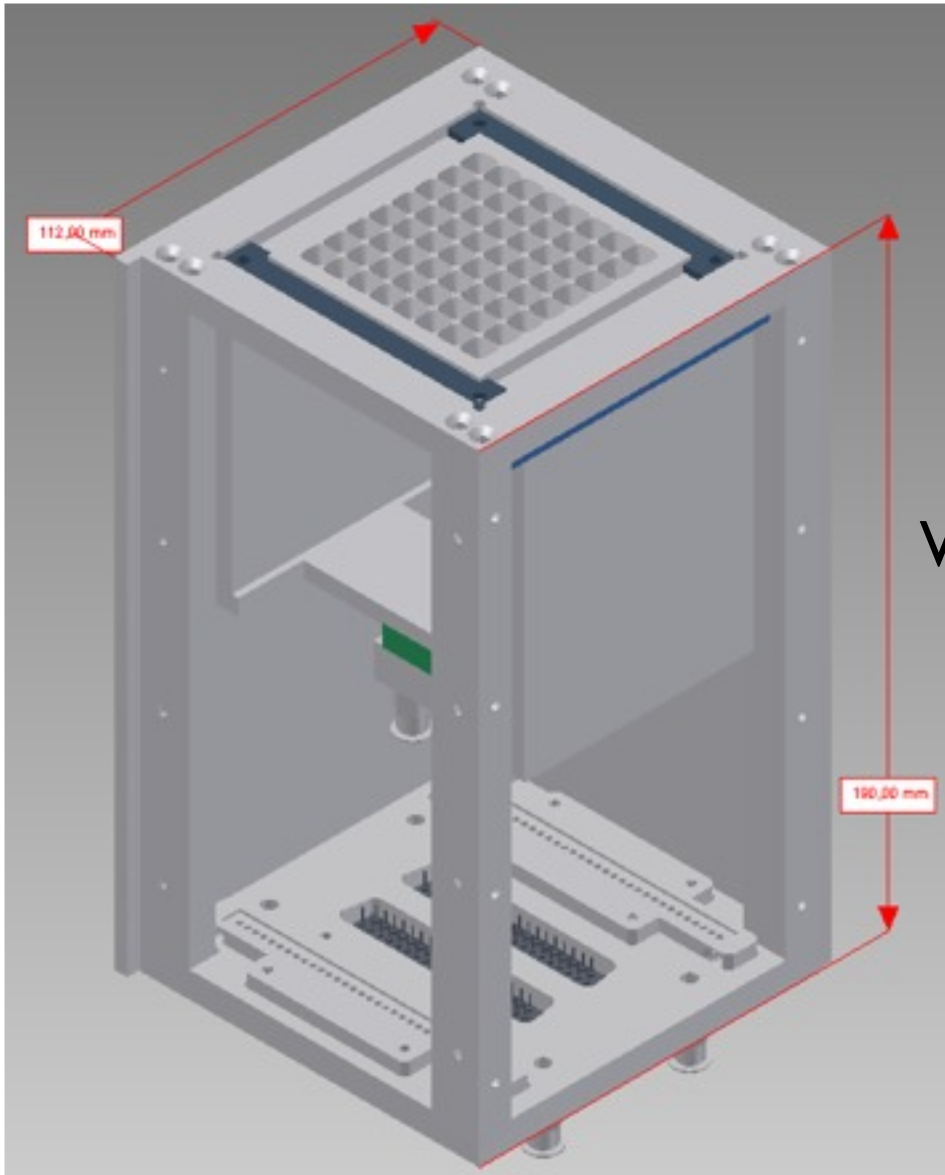


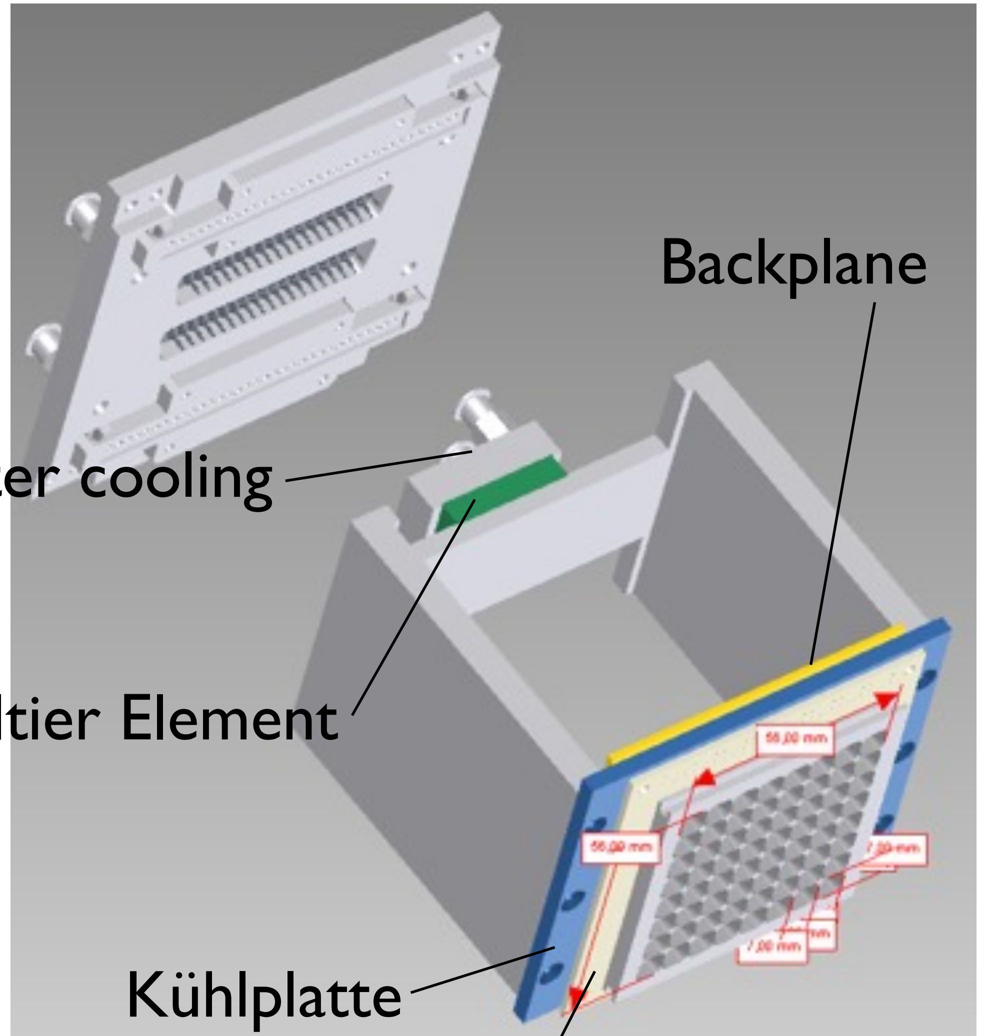
- *The factor polish has only a minor influence on the outcome, in contrast to the absorption coefficient.*
- *At a reflection coefficient of 0.55 (Chromium at 400 nm) and for a reasonable surface roughness (polish = 0.8), we find an average light collection efficiency of about 50% for 4.5 mm funnel length and* Θ *= 0°.*

Prototype Design (side view)



Prototype Design



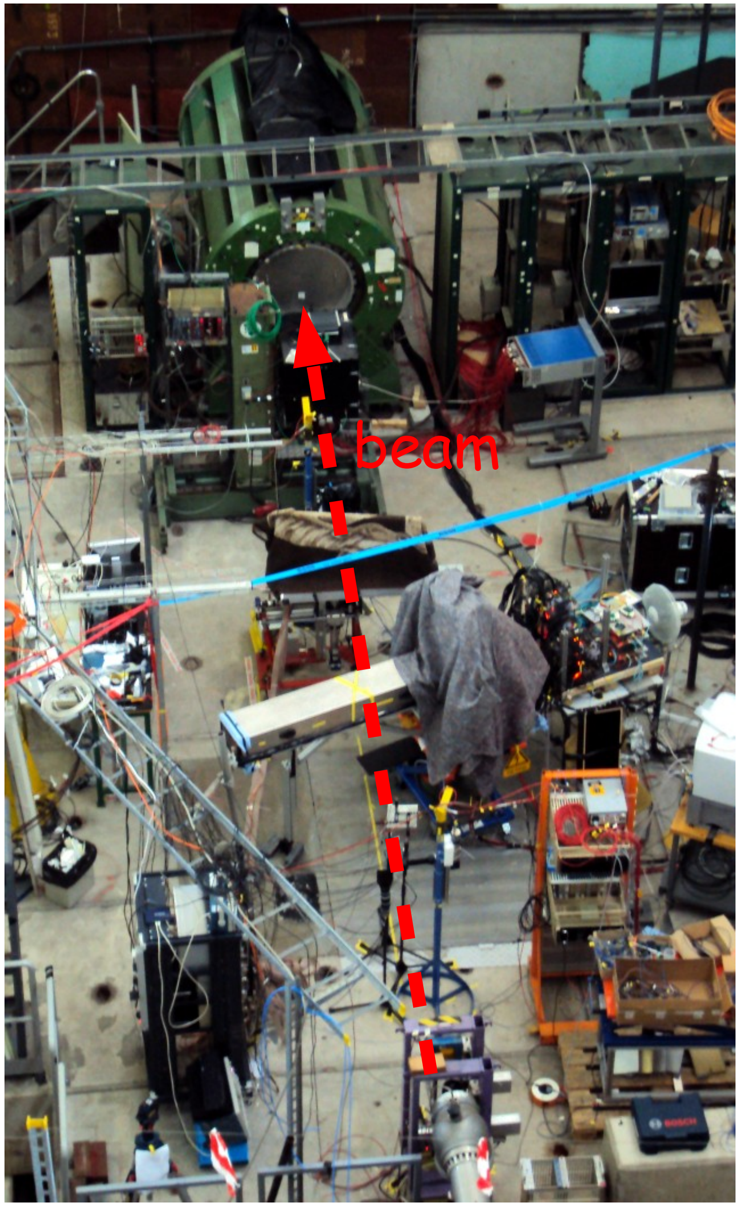


Prototype photos

CERN beam time

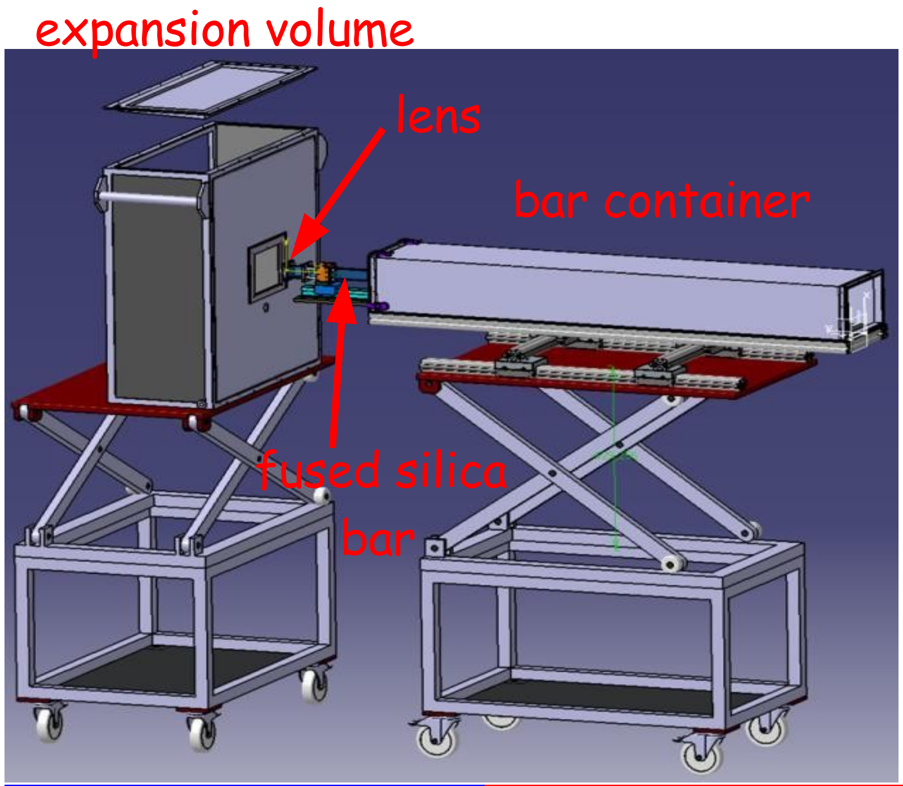
July 9-21, 2011

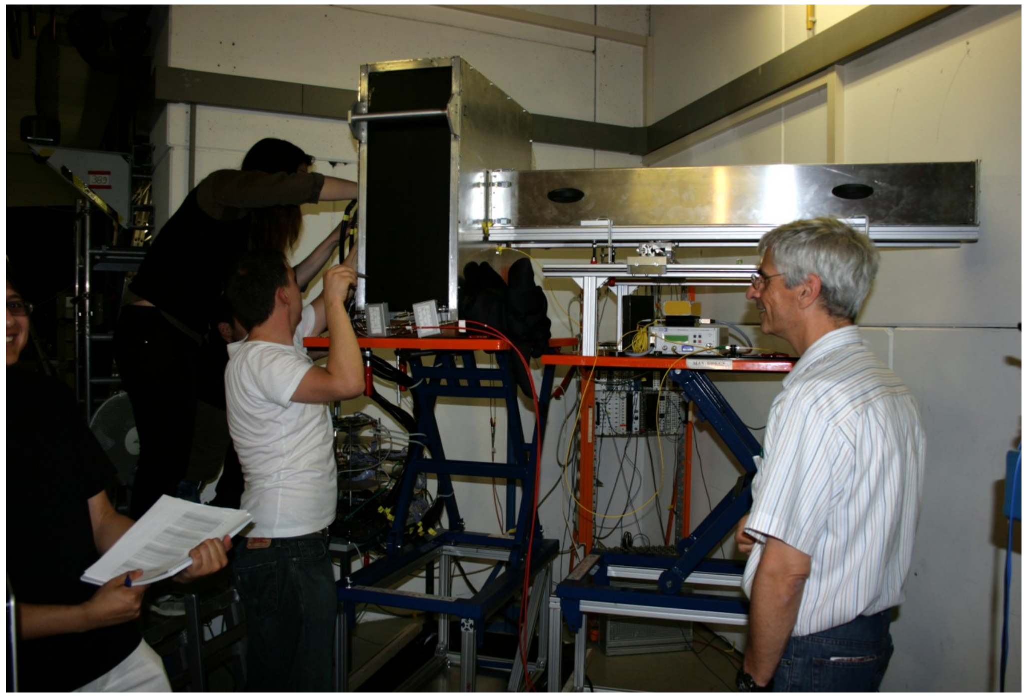
- T9 test beam facility
- 24h beam
- mixed beam either electron- or pion-rich
- beam momentum changeable from 1.5 – 10 GeV/c
- beam focus adjustable



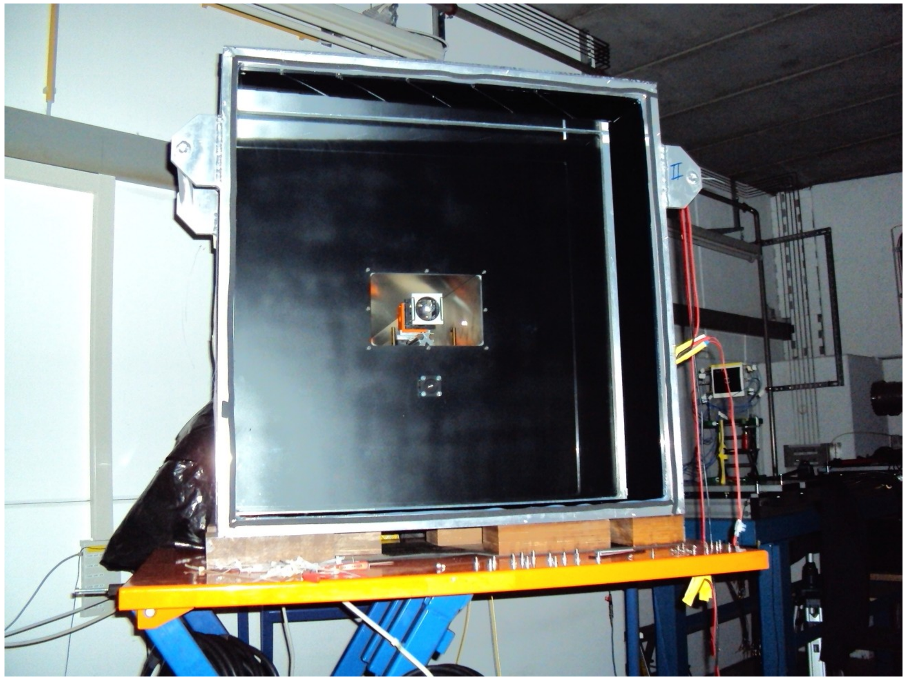
Prototype layout (i)

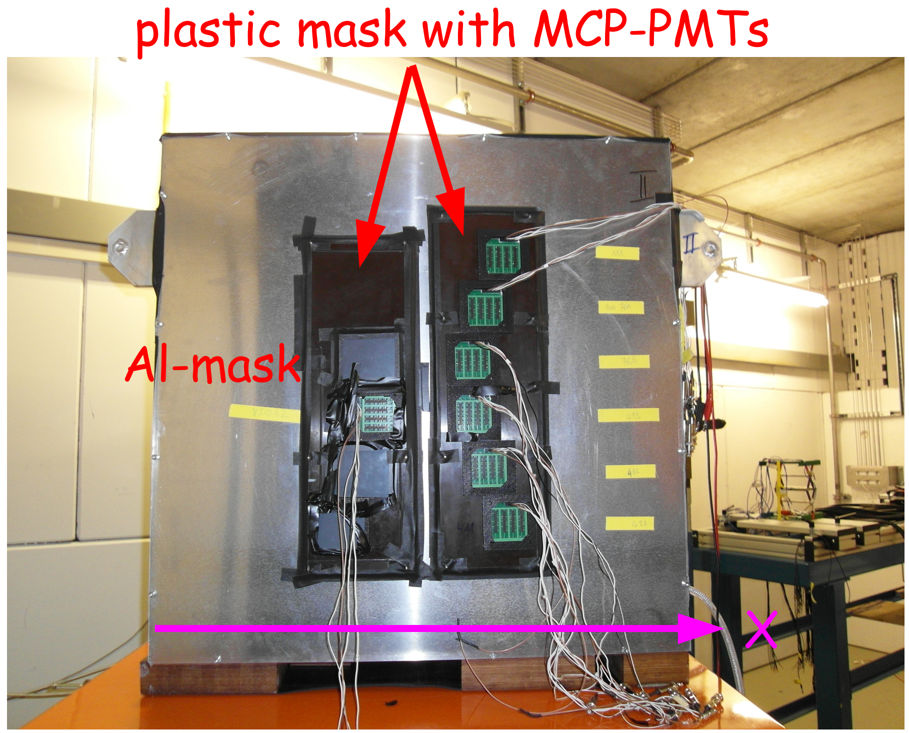
- Bar container (aluminum, 200x300x1500 mm)
- Fused silica bar (35x17x800 mm, Lithotec)
- Fused silica lens (f = 250 mm)
- Expansion volume (aluminum, 800x800x300 mm); filled with 190 liter
  Marcol 82 oil; 2 windows (float glass)





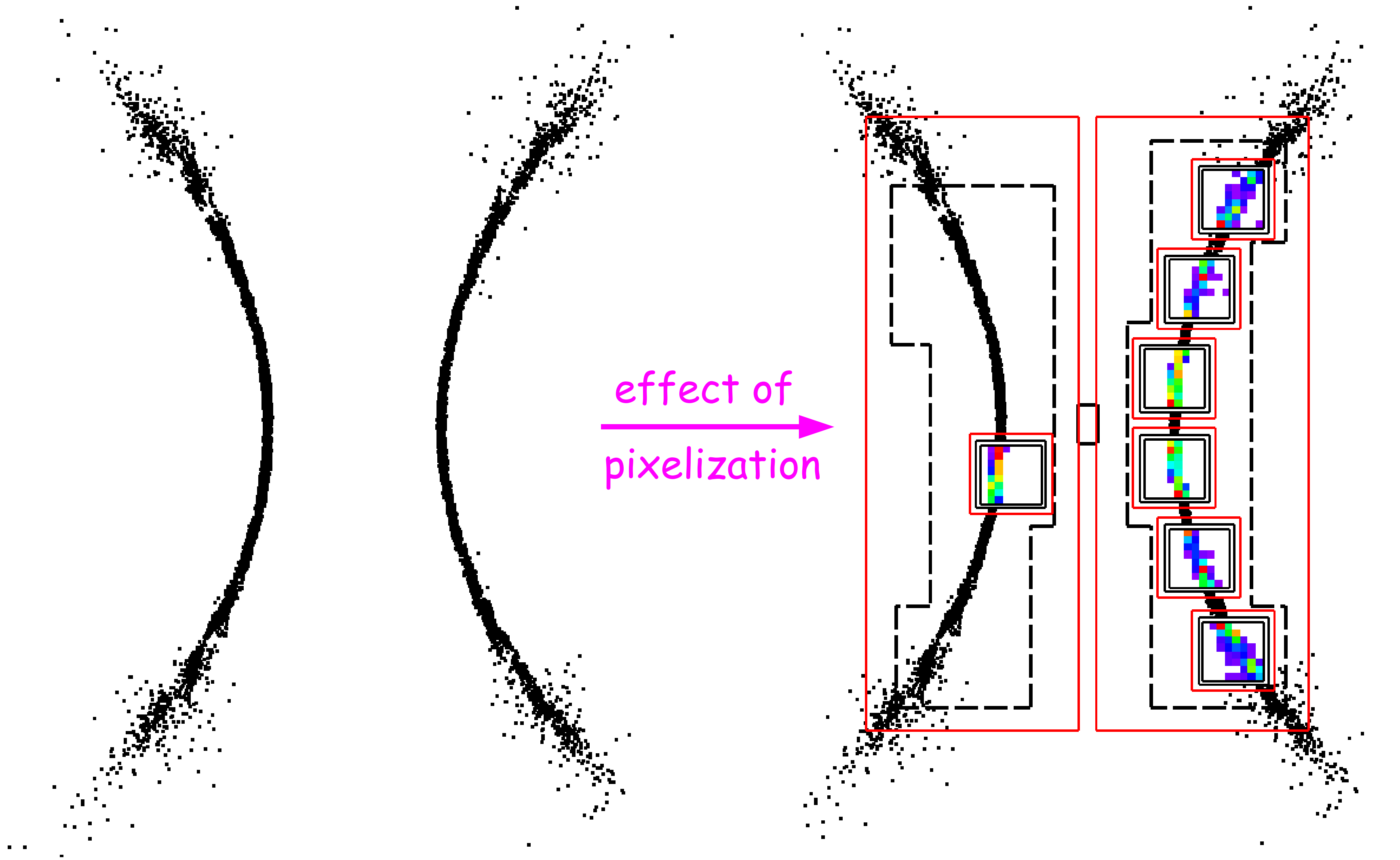
Prototype layout (ii)



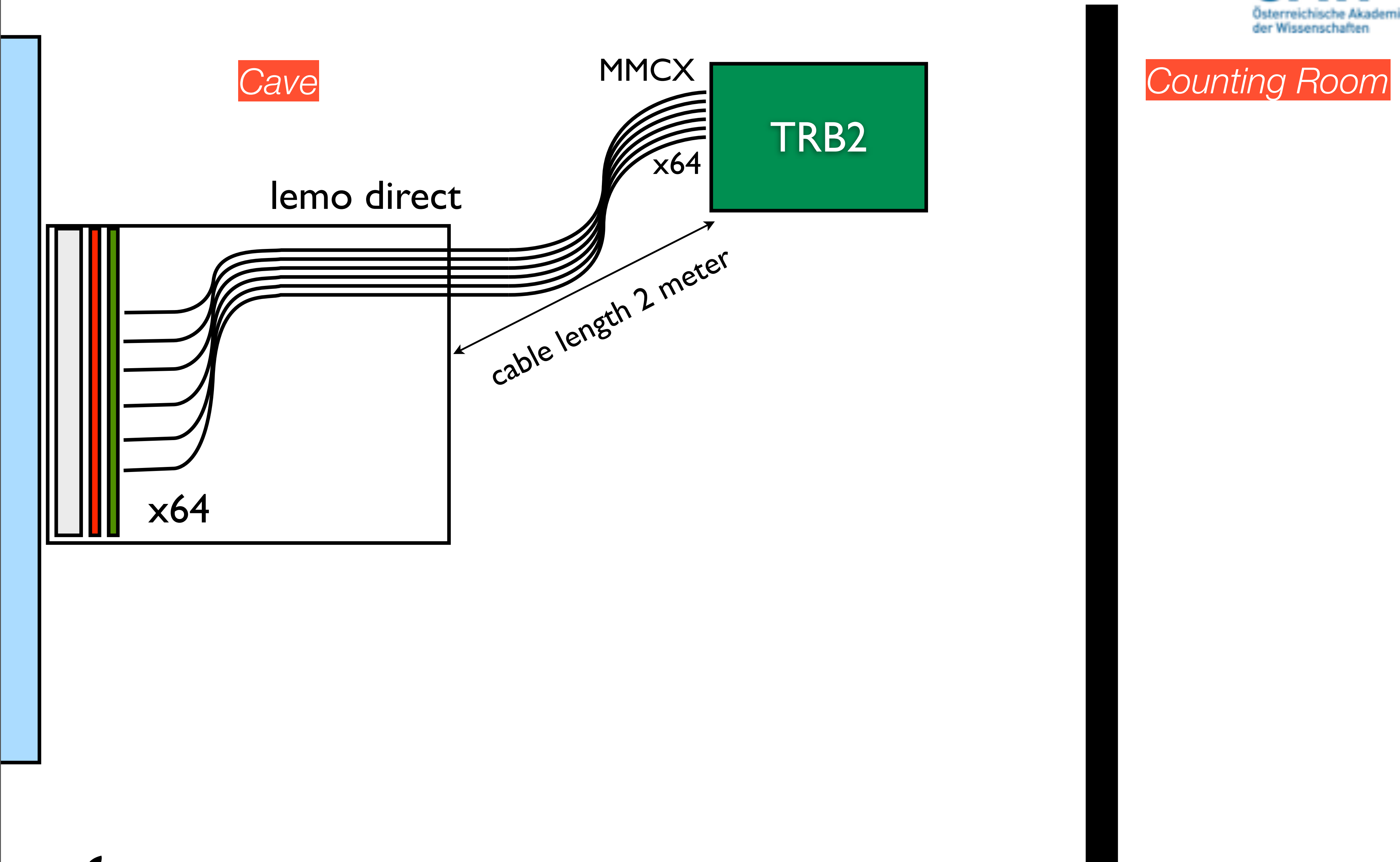


- 2 plastic masks for the detector (up to 10 mm movable in X)
- Aluminum mask for a specific incidence angle of the particle (30°)
- 9 different PMTs tested
  - 7x Photonis XP85012 (MCP-PMT)
  - 1x Hamamatsu H8500 (MA-PMT)
  - 1x Hamamatsu SL10 (MCP-PMT)

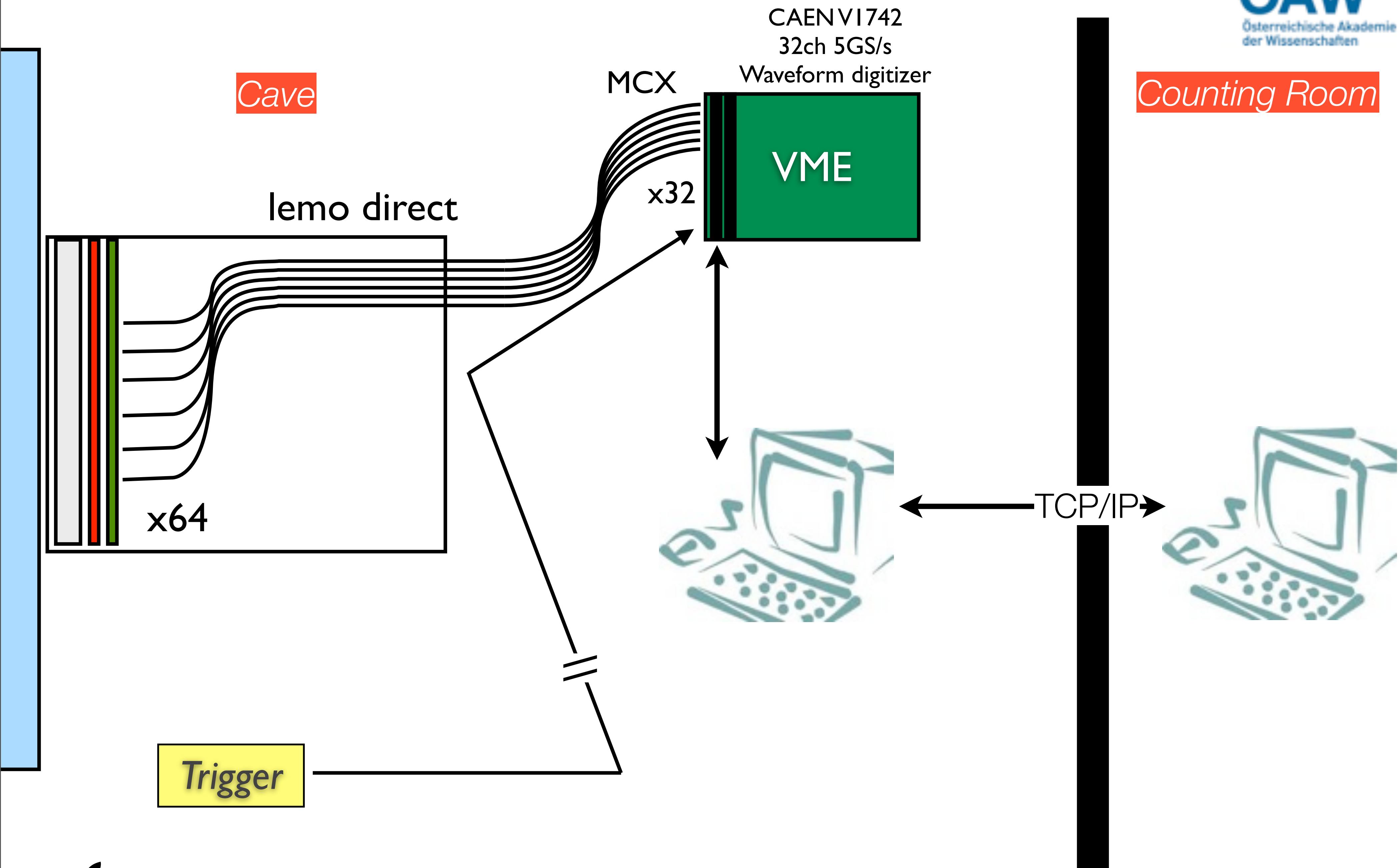
Simulation (drcprop)



Readout (plan A)



Readout (plan B=stand alone)

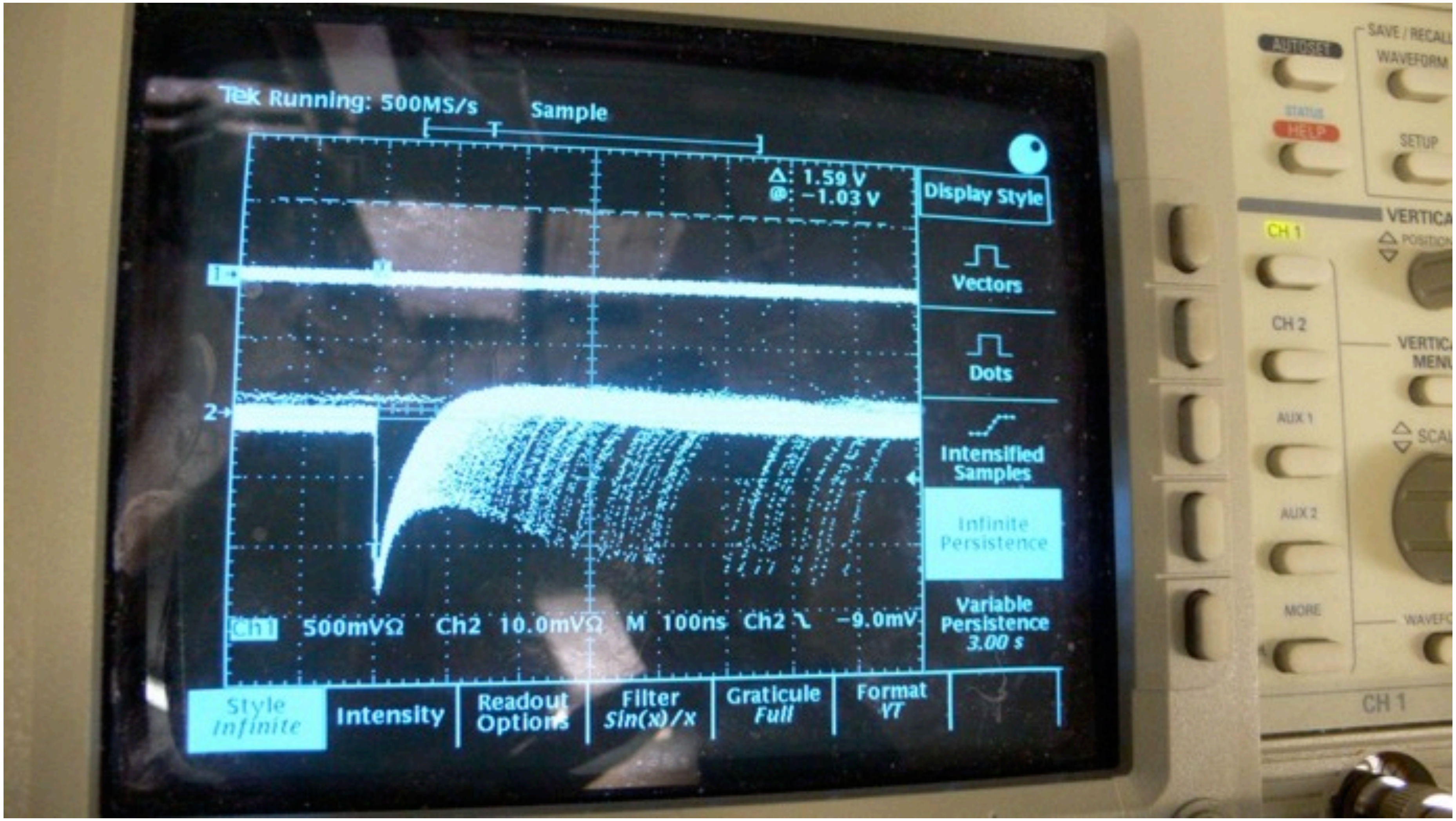


- *A full 64 channel prototype built and powered*
- *and tested in PANDA DIRC test setup*
- *Data taken with TRB (timing of both rising and falling edge) and CAEN V1742 (waveform digitizer 5GS/s)*
- *Dark noise(!) restricted the whole DAQ rate (TRB)*
- *Analysis preliminary*
  - *Saw (hopefully) a Cherenkov peak on timing spectrum with very bad S/N. No ring image*
  - *Waveform analysis*
- *Need to reduce dark noise!*

Recovery time measurement

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

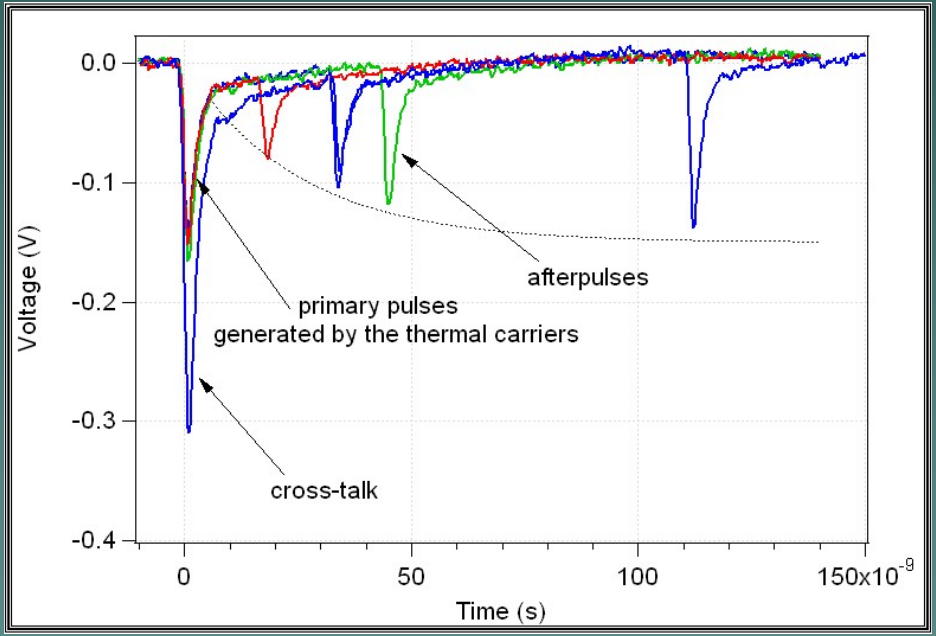
- For a detector development at AMADEUS (@DAΦNE) environment, want to investigate
    - double hit resolution
    - recovery time
- Rate capability (in general)
    - Better or worse than PMT (a few MHz with booster circuit)?


Tek Running: 500MS/s Sample
Δ: 1.59 V
@: −1.03 V
Display Style
Vectors
Dots
Intensified Samples
Infinite Persistence
Variable Persistence 3.00 s
Ch1 500mVΩ Ch2 10.0mVΩ M 100ns Ch2 ⌄ −9.0mV
Style Infinite
Intensity
Readout Options
Filter Sin(x)/x
Graticule Full
Format YT
AUTOSET
SAVE / RECALL
WAVEFORM
SETUP
HELP
VERTICAL
CH 1
CH 2
AUX 1
AUX 2
MORE

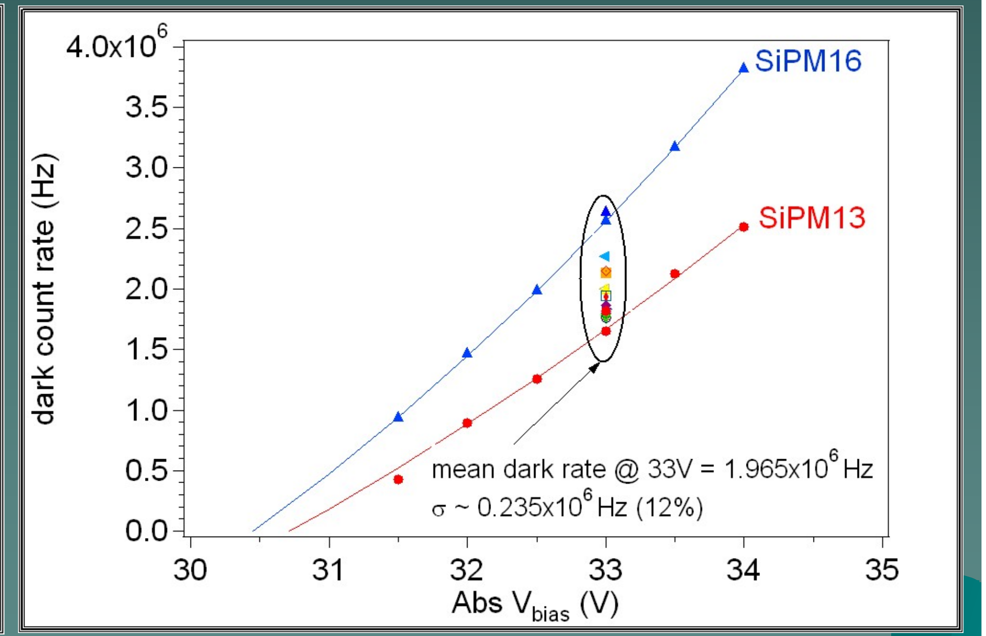
PIF@PSI 2007

Dark count rate (DCR)

- The main source of the SiPM noise - the dark signals
- Mechanisms generating these signals:
  - thermal generation of the carriers– the main source
  - afterpulses – carriers trapped during one avalanche and when they released, they trigger a new avalanche
  - optical cross-talk – "hot carrier luminescence": ~ 30 photons are emitted during an avalanche of 10^6 carriers (A. Lacaita et al., IEEE TED, Vol. 40, nr.3, 1993)



SiPM dark signals shape



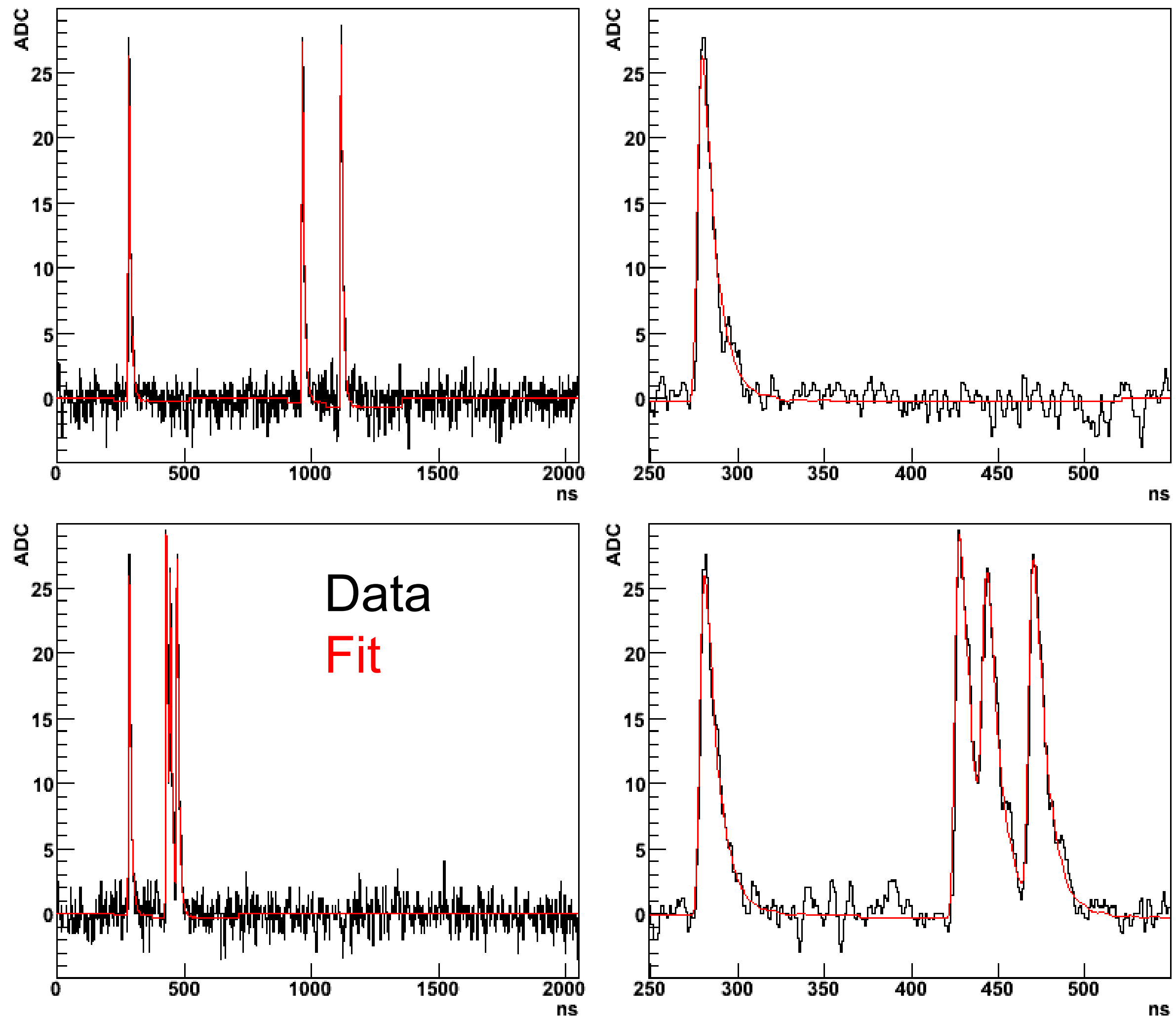
σ_{DCR} @ $\Delta V=2.5V \sim 12\%$

$I_{post\text{-}BD} = DCR \cdot G \cdot e$

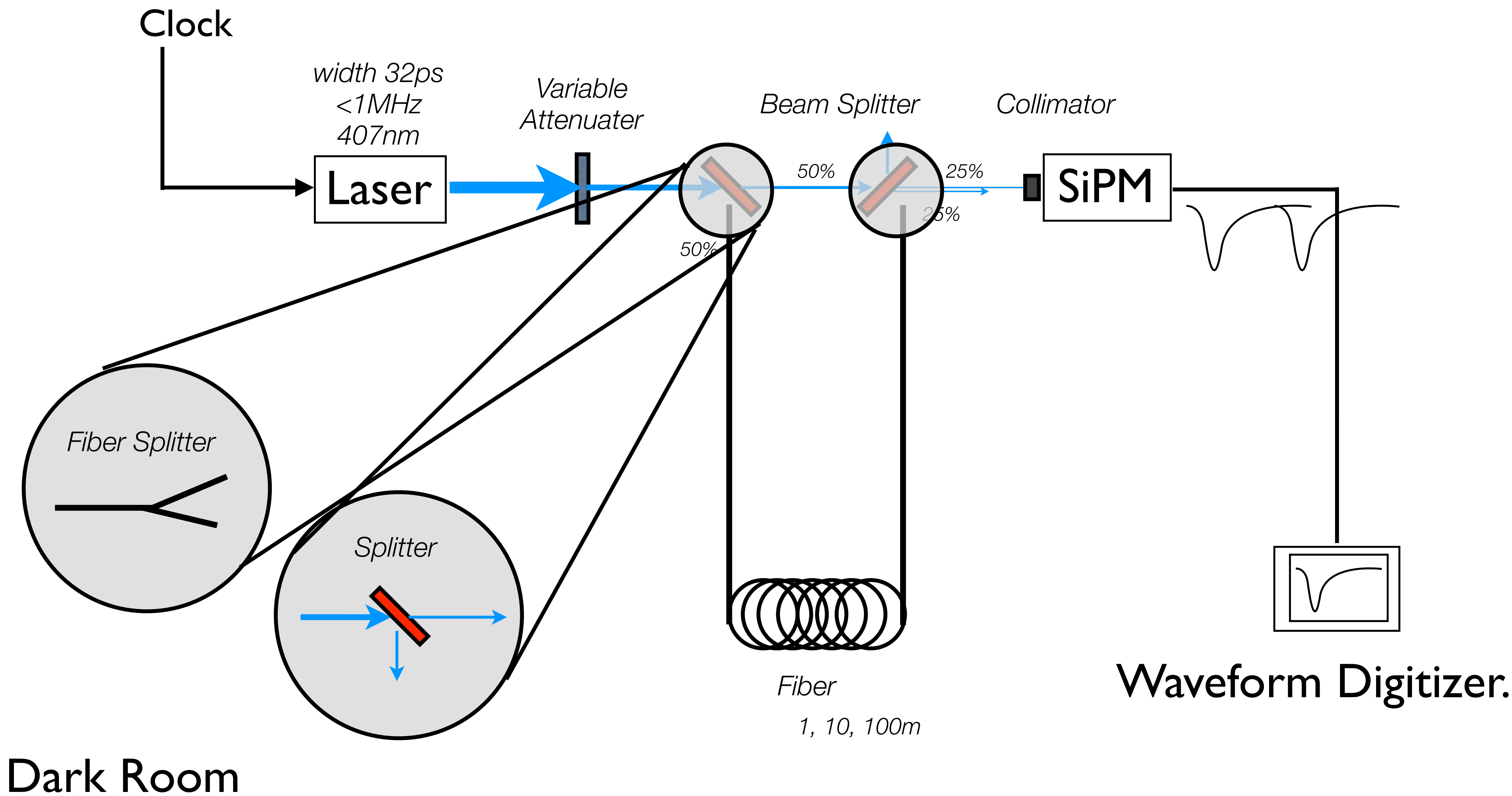
σ_{DCR} in agreement with the $\sigma_{Ipost\text{-}BD}$

Measuring after-pulsing Step 1: pulse finding

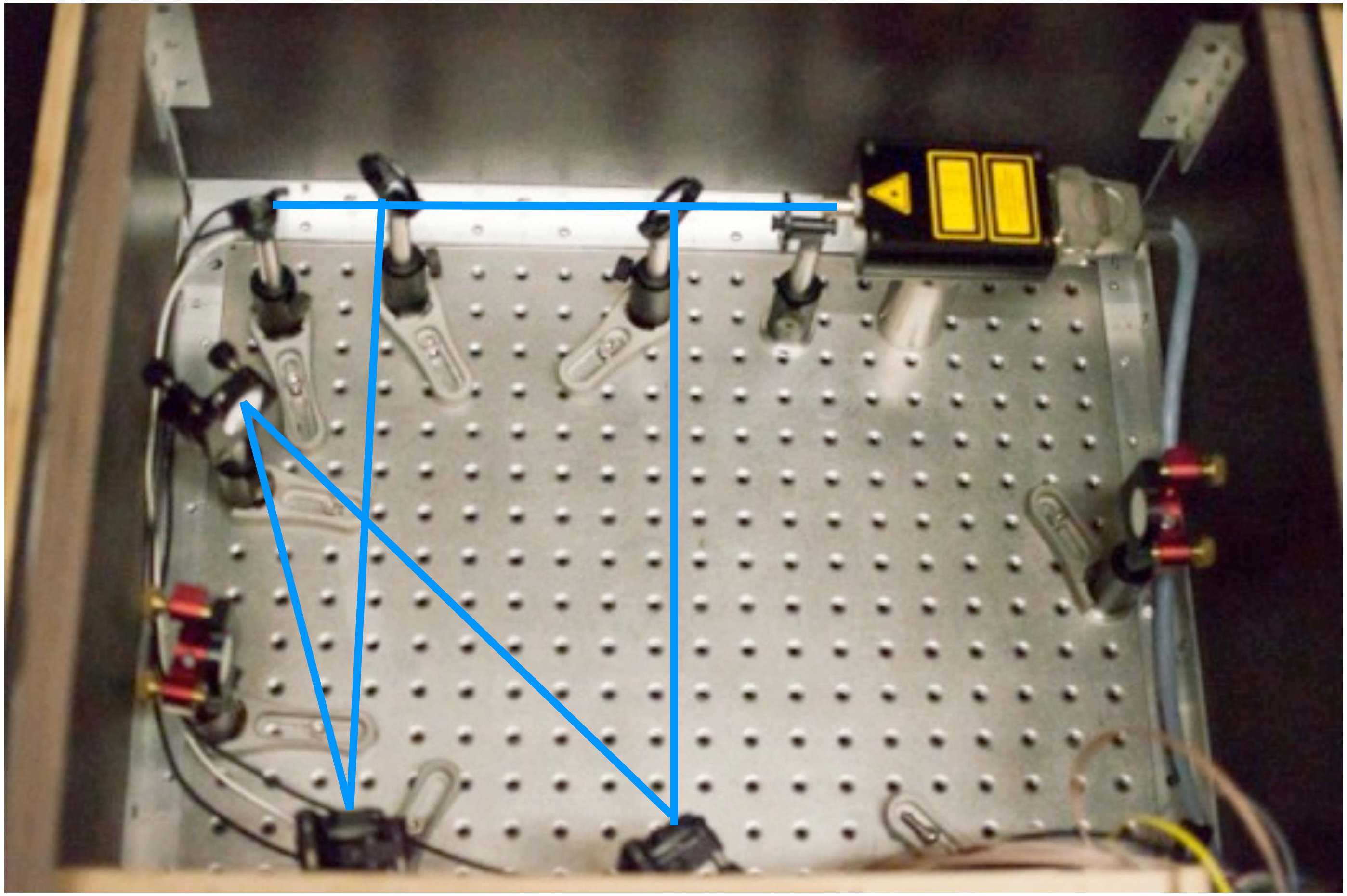
- MPPC dark noise
  - Self trigger at ~0.2 PE
- Use fast amplifier
- Use 1GHz digitizer
  - CAEN V1729
- Fit waveform with superposition of single avalanche response function
  - Measure response function directly from data



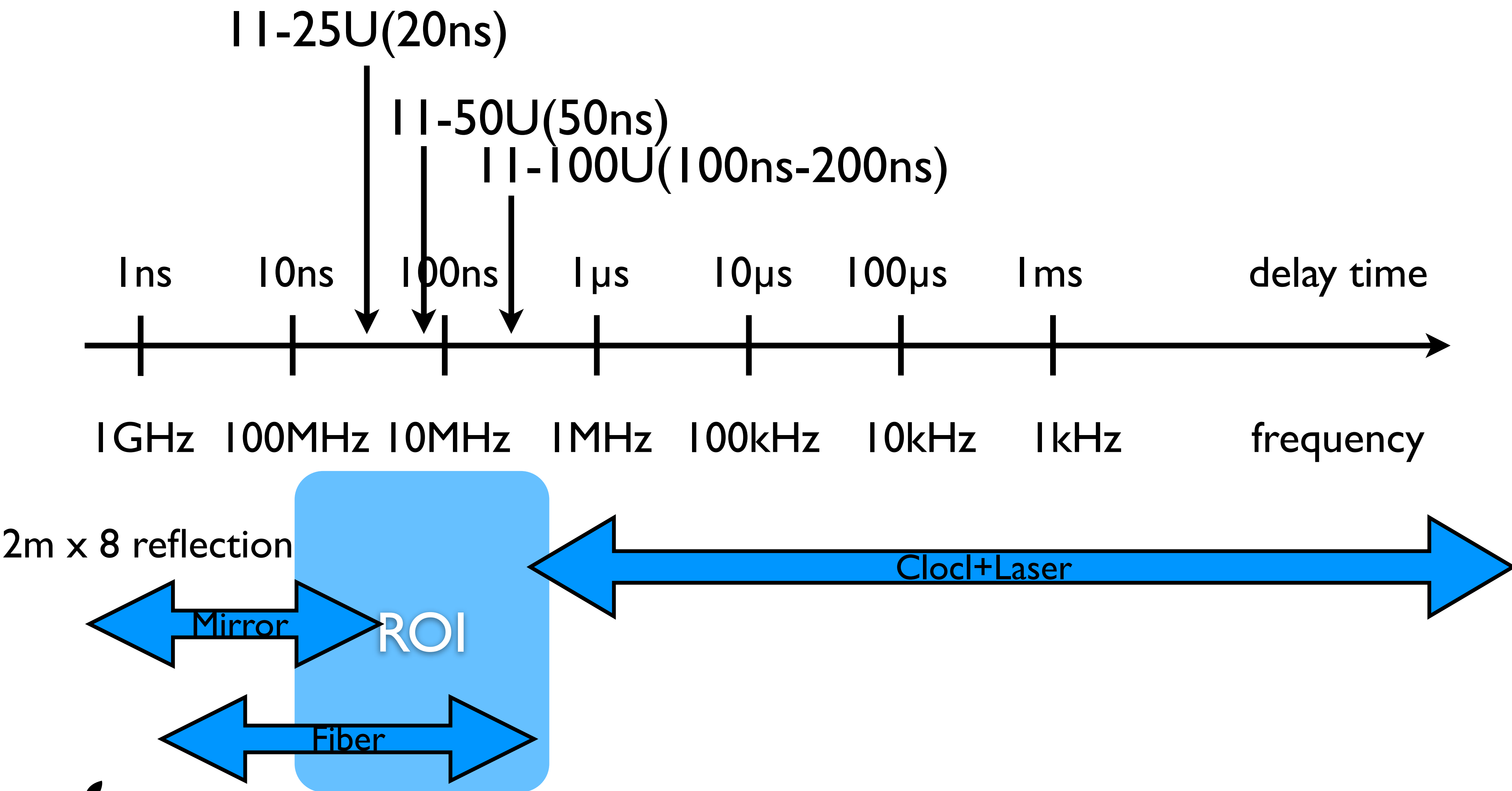
Setup



Clock
width 32ps
<1MHz
407nm
Laser
Variable
Attenuater
Beam Splitter
Collimator
50%
25%
25%
50%
SiPM
Fiber Splitter
Splitter
Fiber
1, 10, 100m
Waveform Digitizer.
Dark Room

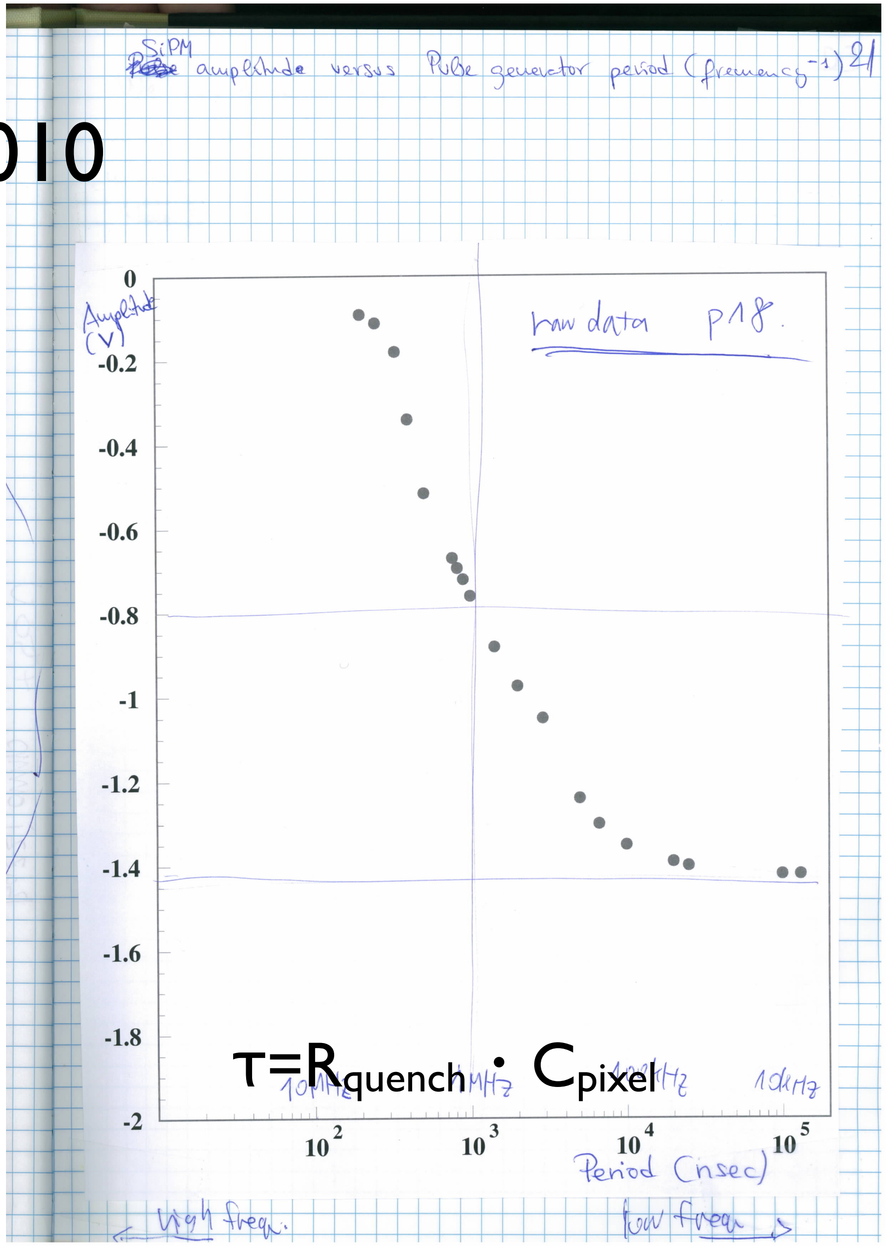


Delay time range



Clock+Laser Test

2010



$\tau = R_{quench} \cdot C_{pixel}$

Recovery times of
Sensor
Ampl.
Light source
are convoluted here

start to see a rate effect already at >100kHz

Systematic Measurement

- *Next trial at LNF in November*
- *We vary*
  - *Delay time*
  - *Sensors with different pixel sizes*
    - *Hamamatsu 1mm^2 25μm=20ns, 50μm=50ns, 100μm=100-200ns*
    - *!prop pixel size=capacity. R different?*
  - *Temperature? (which R and C is influenced by)/ Voltage*

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*