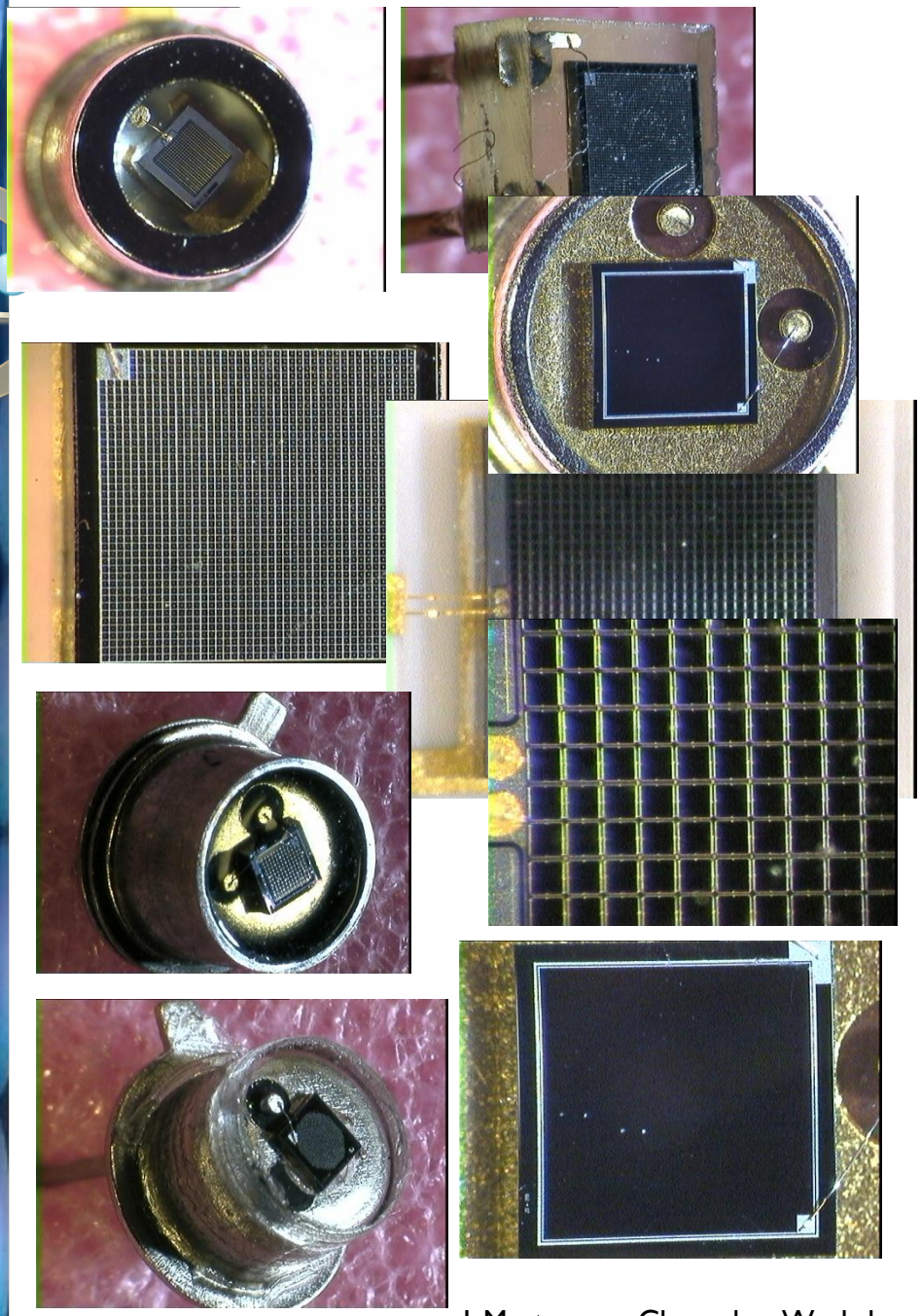
Studies of APD (SiPM) properties

J. Marton
Stefan Meyer Institute
for Subatomic Physics (SMI), Vienna

www.oeaw.ac.at/smi

Outline

- SMI Research Program – interest in SiPMs
- SiPM test equipment at SMI
- SiPM studies performed
- Example for application: Beam profile monitor
- Next steps



Various SiPMs were tested at SMI, e.g.:

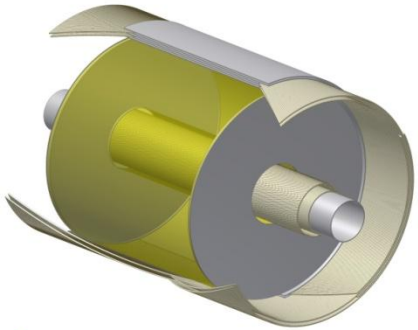
Hamamatsu, 1mm^2, 3 mm^2
Photonique, 1 mm^2
Dubna, 1 mm^2, 3 mm^2
Zecotek, 1 mm^2, 3 mm^2

Different characteristics in

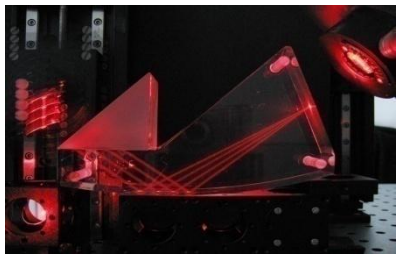
Number of cells (linearity)
Fill factor (PDE)
Q.E. (PDE)
Noise, dark current

SMI Research Program

- Kaon-nucleon interaction: SIDDHARTA at LNF, E17 at J-PARC, FOPI at GSI, AMADEUS at LNF



- Matter-Antimatter (A)symmetry at AD-CERN

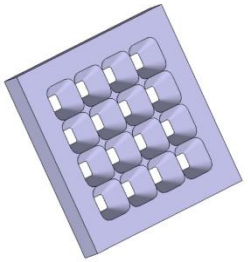


- Research with antiprotons at FAIR (PANDA, FLAIR, AIC)

- Tests of fundamental principles (VIP at LNGS)

Motivations

- Photon detectors for our physics program :
  - Study of the performance of SiPMs for scintillating fiber detectors: FOPI (beam profile monitor), AMADEUS, (scint. fibers as kaon trigger detectors)
  - VIP experiment: possible application in cosmic ray active shielding with scintillation detectors
  - Cherenkov detectors for PID:
  - PANDA, arrays of SiPM for the readout of DIRC
  - Joint activity FP7 HadronPhysics2



Our interest in SiPM Applications

- Low-level light detection and single photon read-out with SiPMs → Cherenkov detectors
- Medium-level light detection in SiPM-coupled scintillating fiber detectors → position sensitive charged particle detection
- SiPMs for fast calorimetry and large dynamic range
- Ultra-fast timing for TOF-applications

SiPMs for Cherenkov detectors

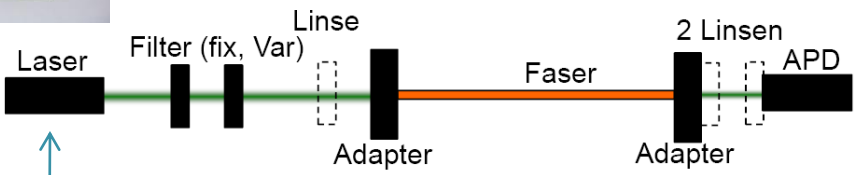
- High photon detection efficiency

  PDE = F·Q·A

  F …. Fill factor
  Q….. Quantum efficiency
  A……probability for avalanche

- High sensitivity for blue light (Q)
- Fast timing performance
- Low cost
- Small size sensors → arrangement in arrays
- Radiation hardness ?
- Insensitive to magnetic fields (given for all SiPMs)

SiPM Test Systems at SMI



Specifications:

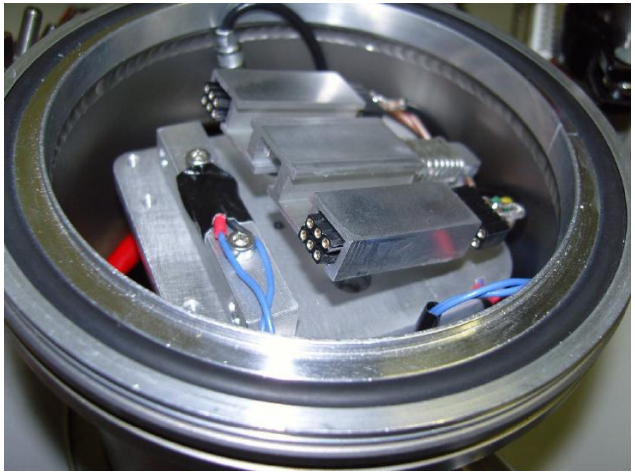
Power (pulse)	1000	mW
Power (Ø max. f)	30	µW
Frequency (max)	1	Mhz
Wavelength λ	407	nm
Pulse duration	32	ps

Black box with optical board („bread board“) and picosecond-laser

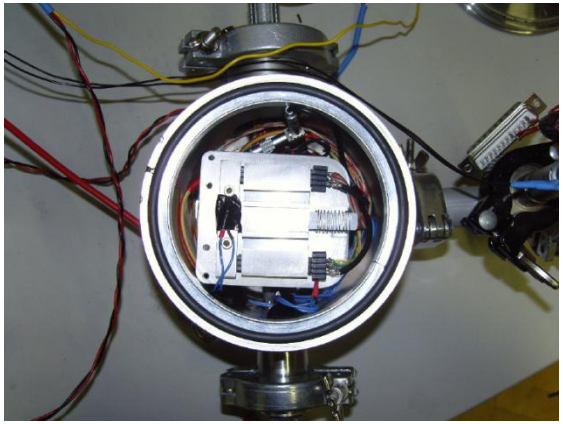
Laser light can be attenuated and fed into optical fiber

Setup at SMI for cooling tests

Vacuum chamber for cooling tests, Peltier cooling, chiller with temperature control.
Light tight, prevents condensation of water vapor



SiPM holder
For 2 devices
cooled by
Peltier



SiPM mounting in the vacuum chamber:
Coupling into laser beam via optical fiber.
Feedthroughs for supply voltages and signal temperature control

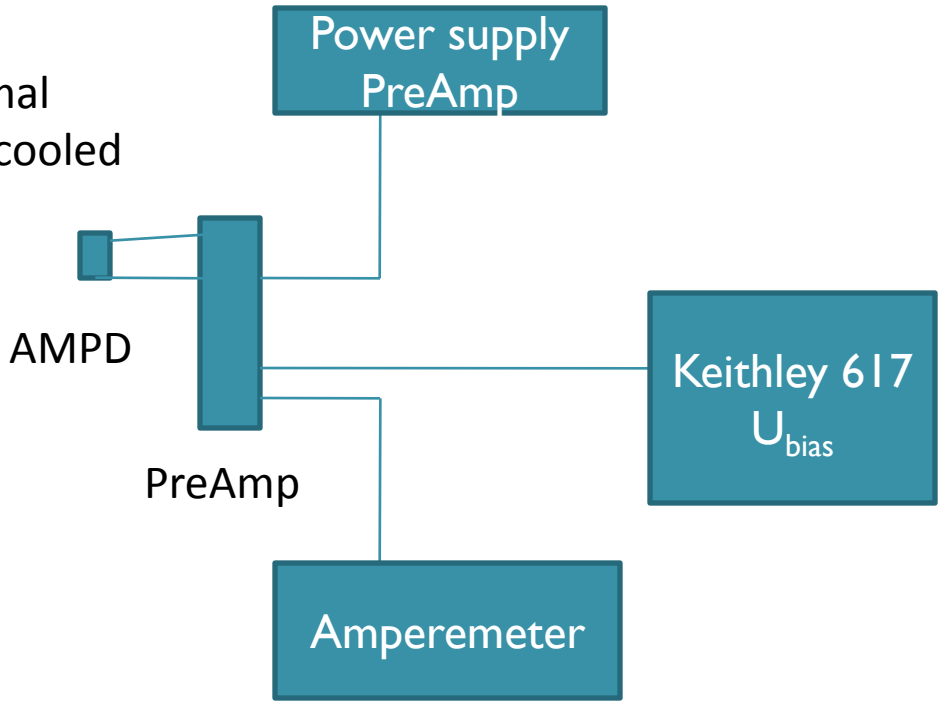
Tests at SMI

- Dark current characteristics as function of V_{bias}, T
- Timing studies with ps laser
- Measurements at different temperatures,

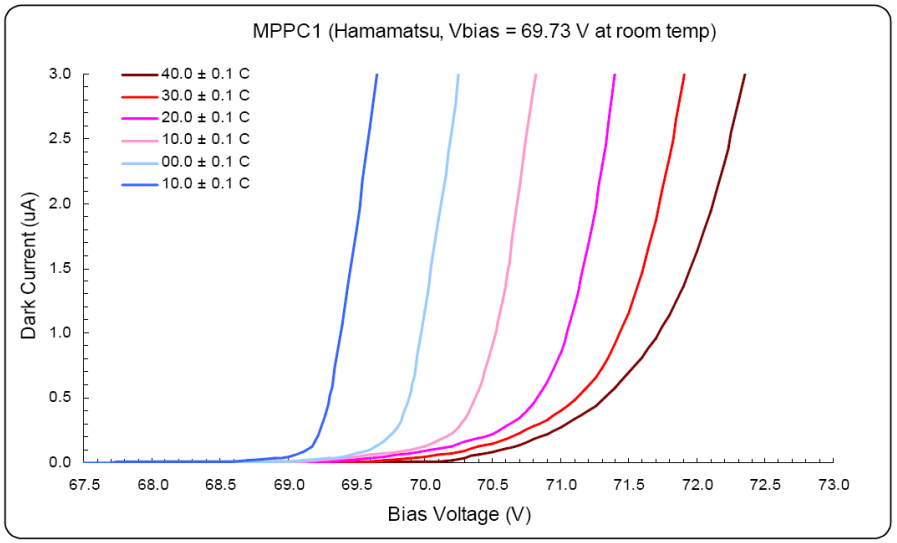
  Peltier cooling down to about -30°C
- Pulse-height and time spectra (CAMAC and VME based DAQ system), gain studies

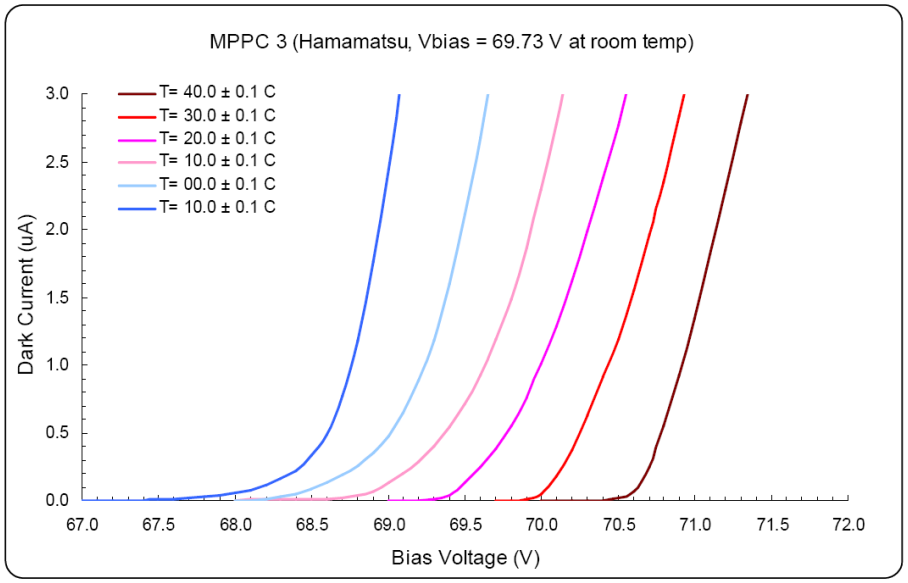
Setup dark current measurements

SiPM in thermal contact with cooled metal holder

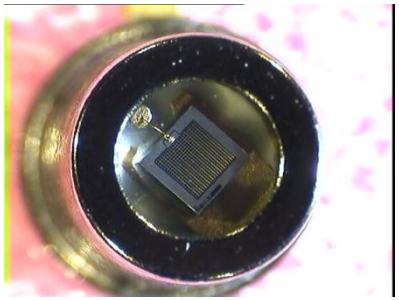


MPPC dark current

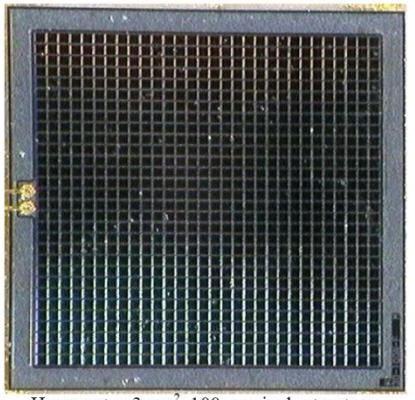




Hamamatsu 1 mm

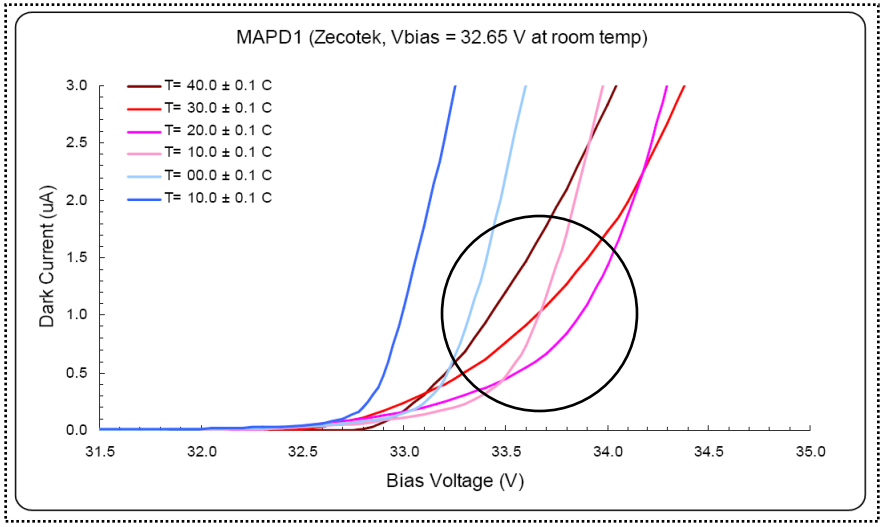


Hamamatsu 3 mm

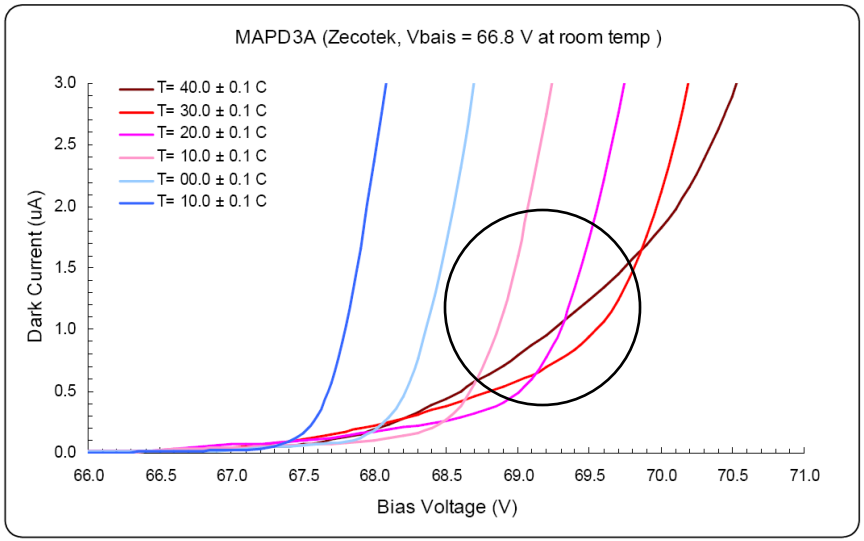


Hamamatsu 3mm^2, 100um pixels structure.

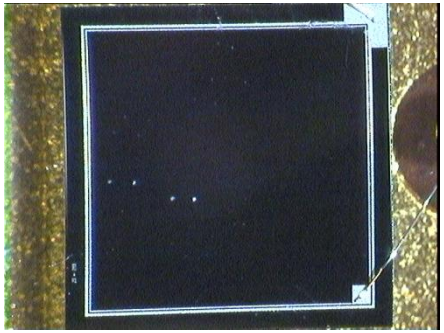
MAPD dark current



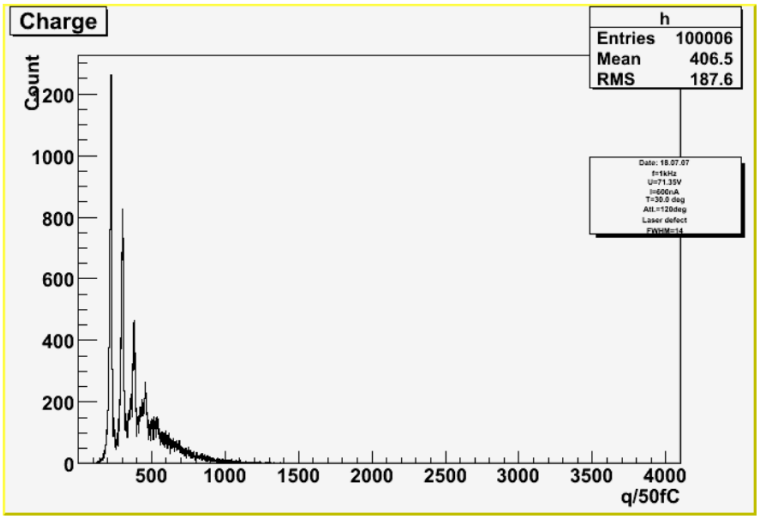
Zecotek 1 mm

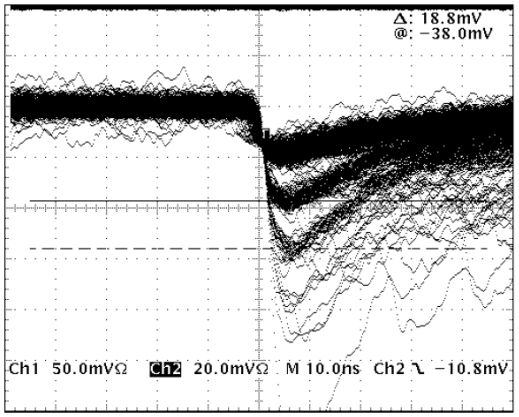


Zecotek 3 mm

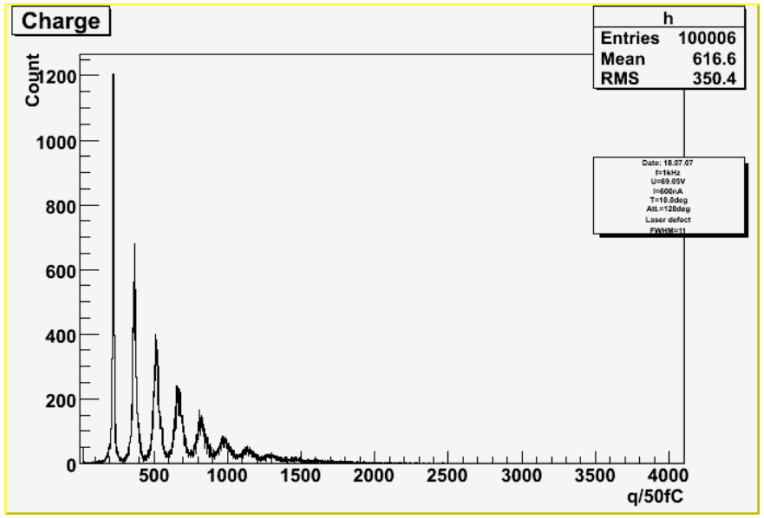


Recorded PH Spectra (VME DAQ)





Hamamatsu S10362-11-050U



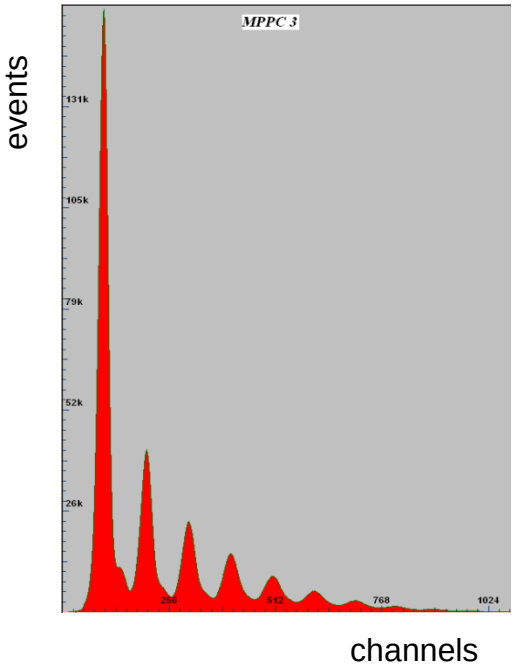
QDC LeCroy 1182
Gate width: 40ns

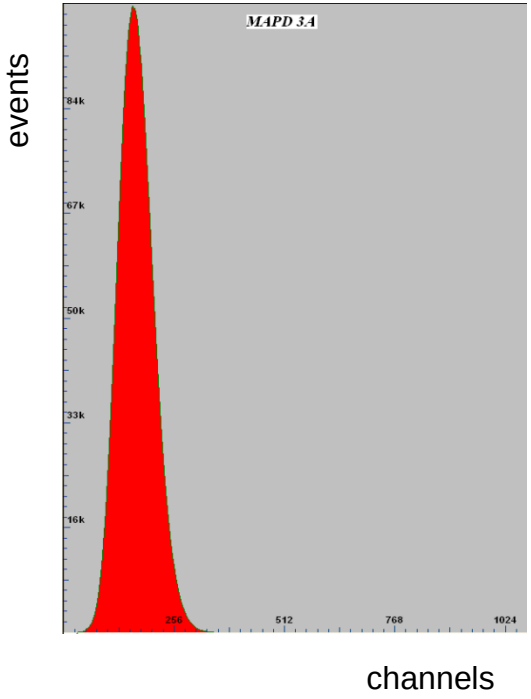
To estimate:
- Gain by charge between peaks

Hamamatsu S10362-11-100U

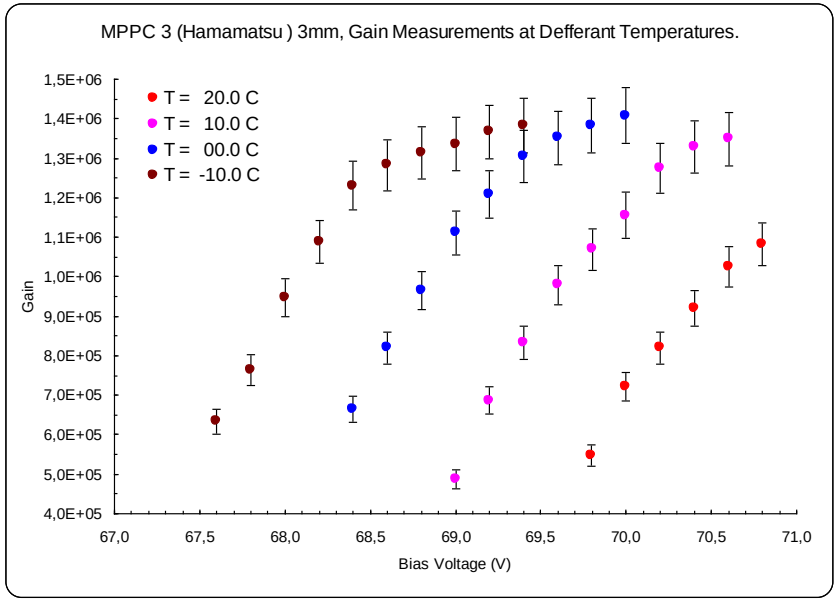
MPPC and AMPD light detection

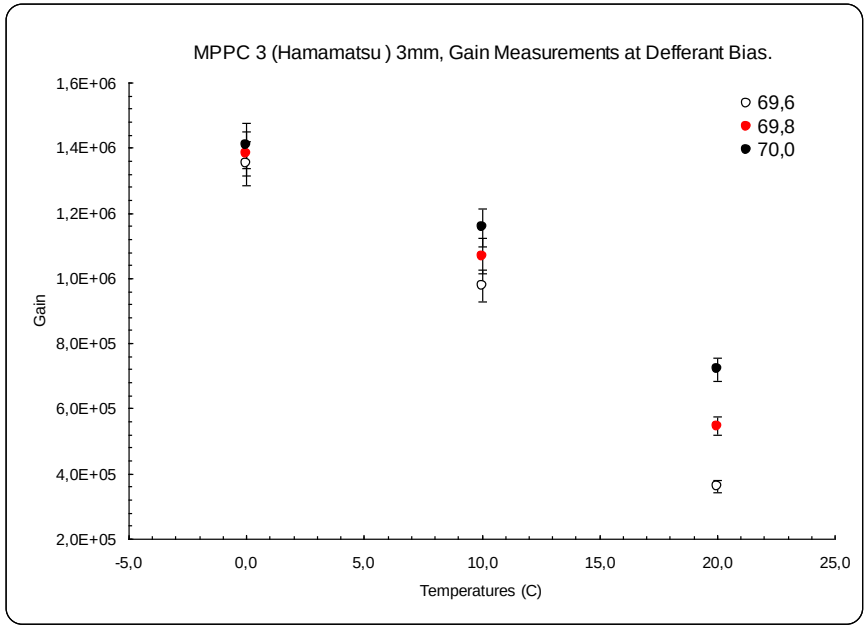
Pulse-Height spectra of 3mm SiPMs (Hamamatsu vs. Zecotek) with laser light



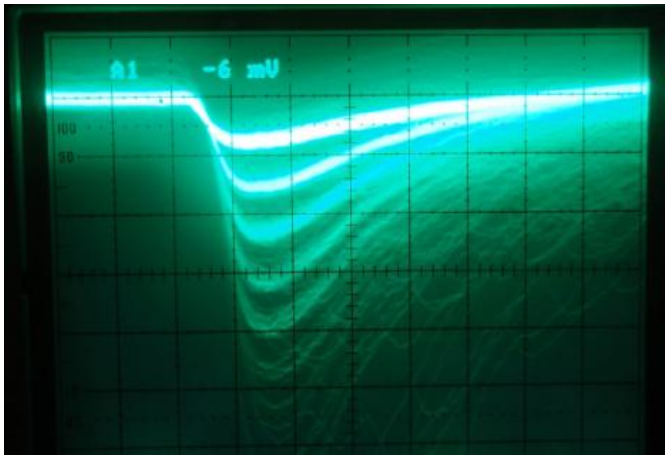


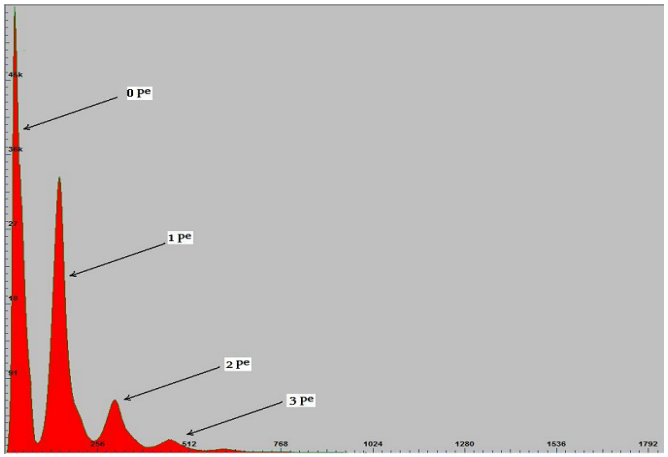
MPPC gain (V_{bias}, T) -- MCA



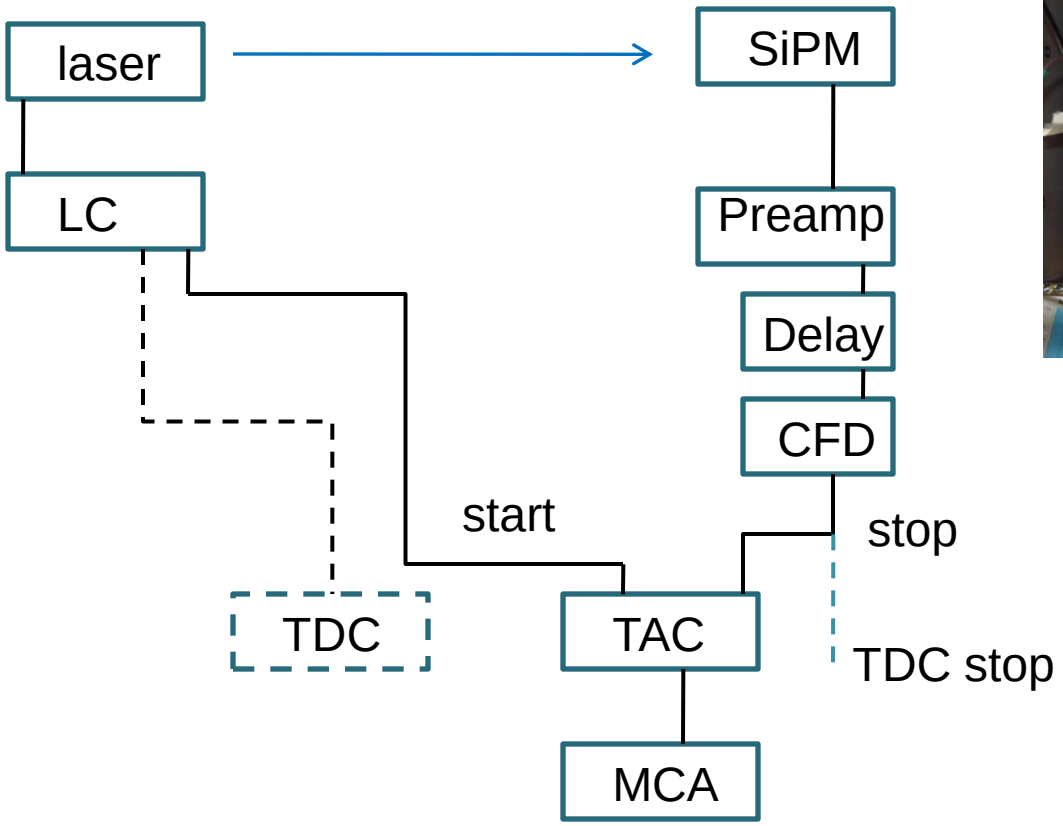


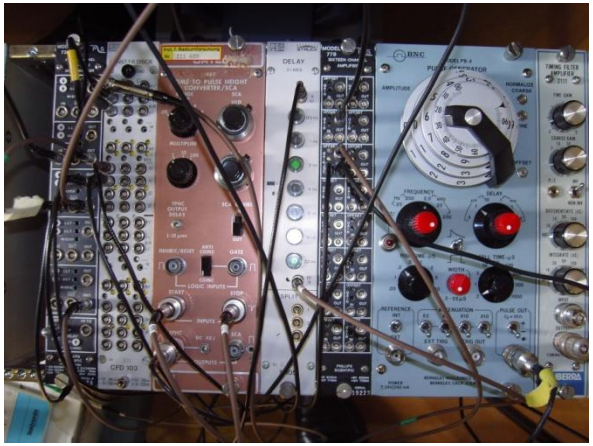
Photon distribution

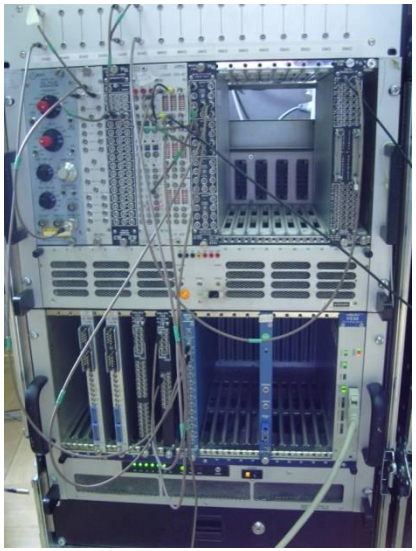




Electronics for timing measurements



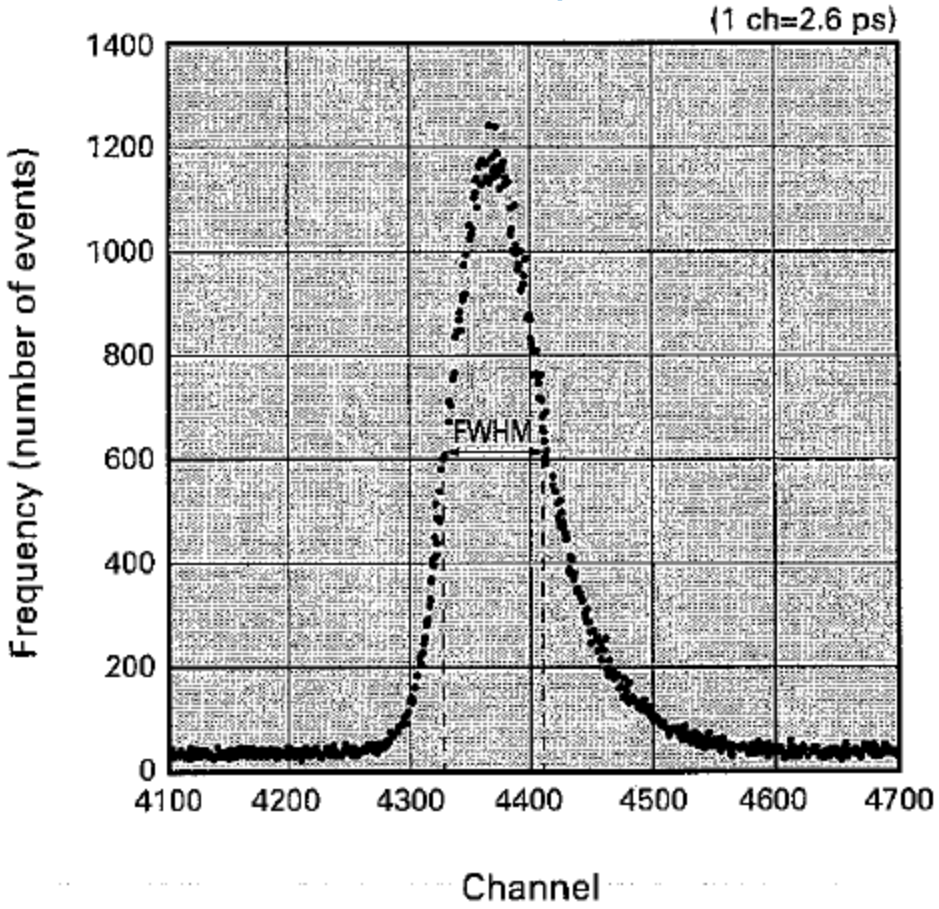




Hamamatsu timing result

From Hamamatsu MPPC booklet

FWHM ~ 250 ps



Tests of timing resolution with TDC

Picosecond-Laser pulsed light source

TDC 25ps/ch

LE discriminator, off-line time-walk correction

Different light intensity, threshold 0.5p.e.

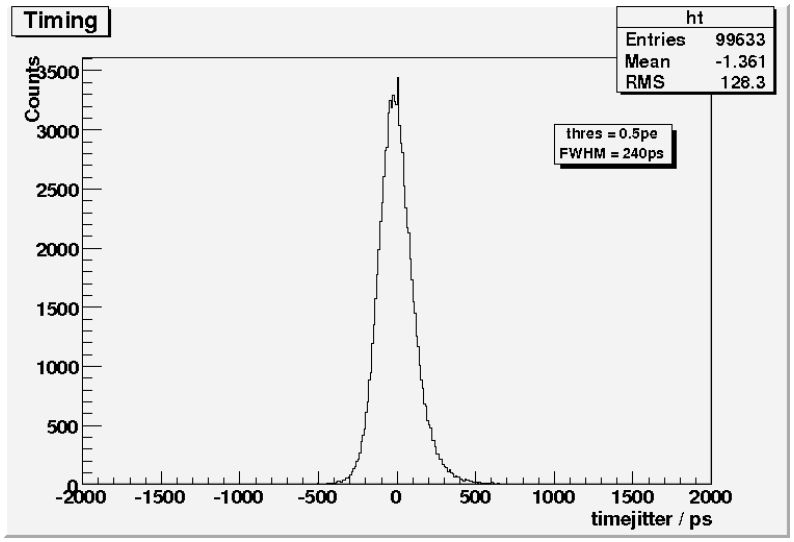
→ Better timing performance with more light

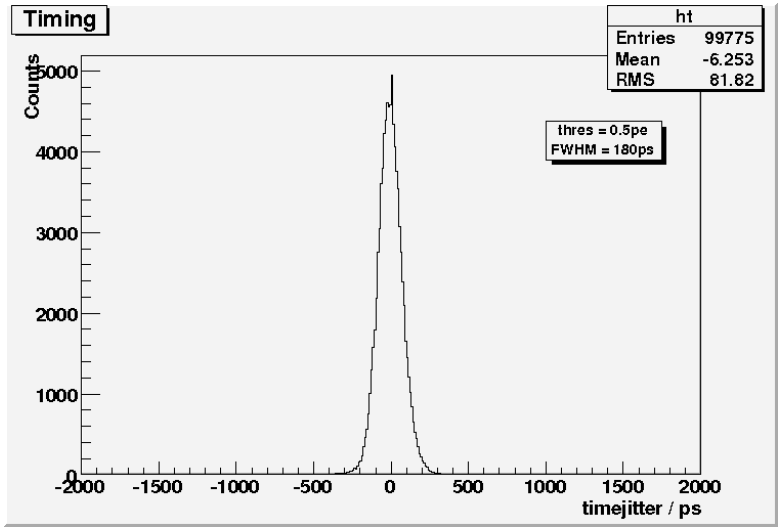
Mean: 10 photon

σ=102 ps = 240 ps FWHM

Mean: ~15 photon

σ=77ps =180 ps FWHM

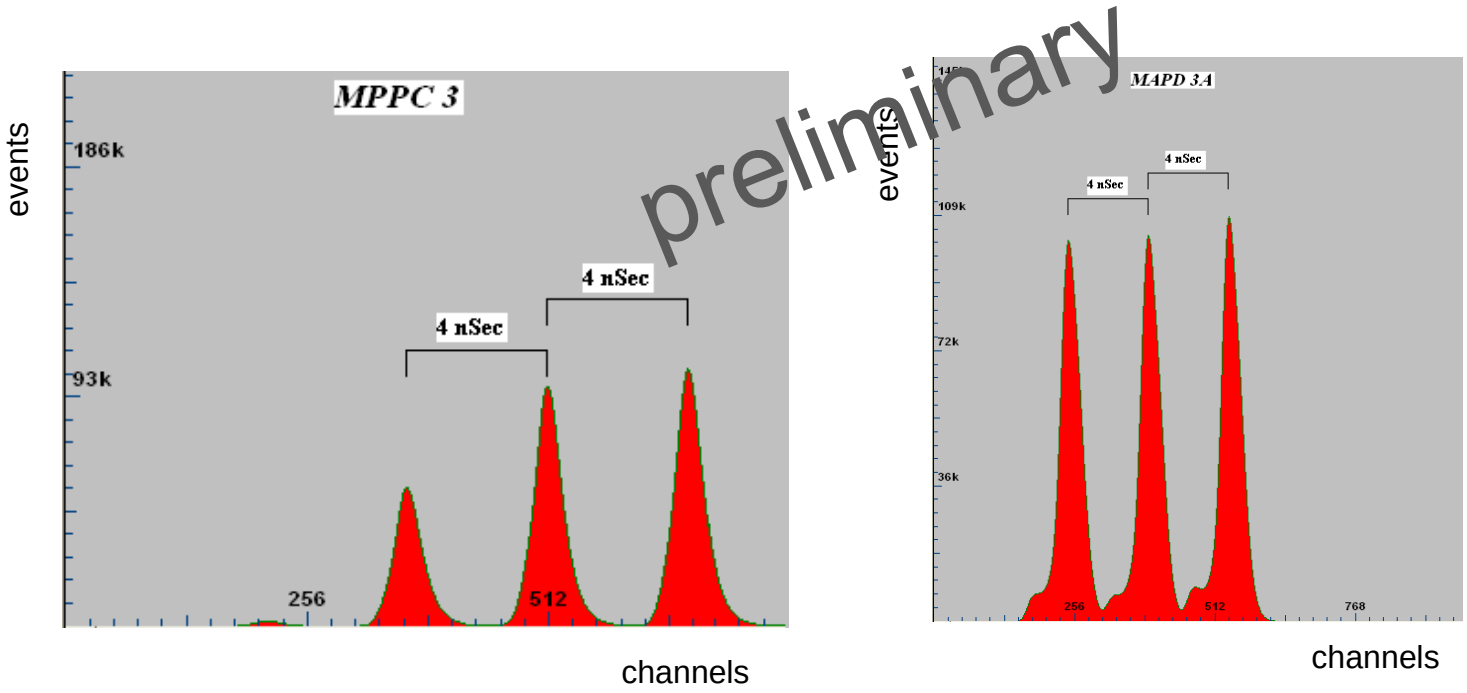




Hamamatsu 100U AMPD (HS 100)

MPPC and MAPD timing

Timing spectra, peaks are separated by equidistant delays of 4ns
preliminary data



σ<250 ps

σ<400 ps

An Example for the Application of SiPMs : Beam-Profile Monitor for FOPI

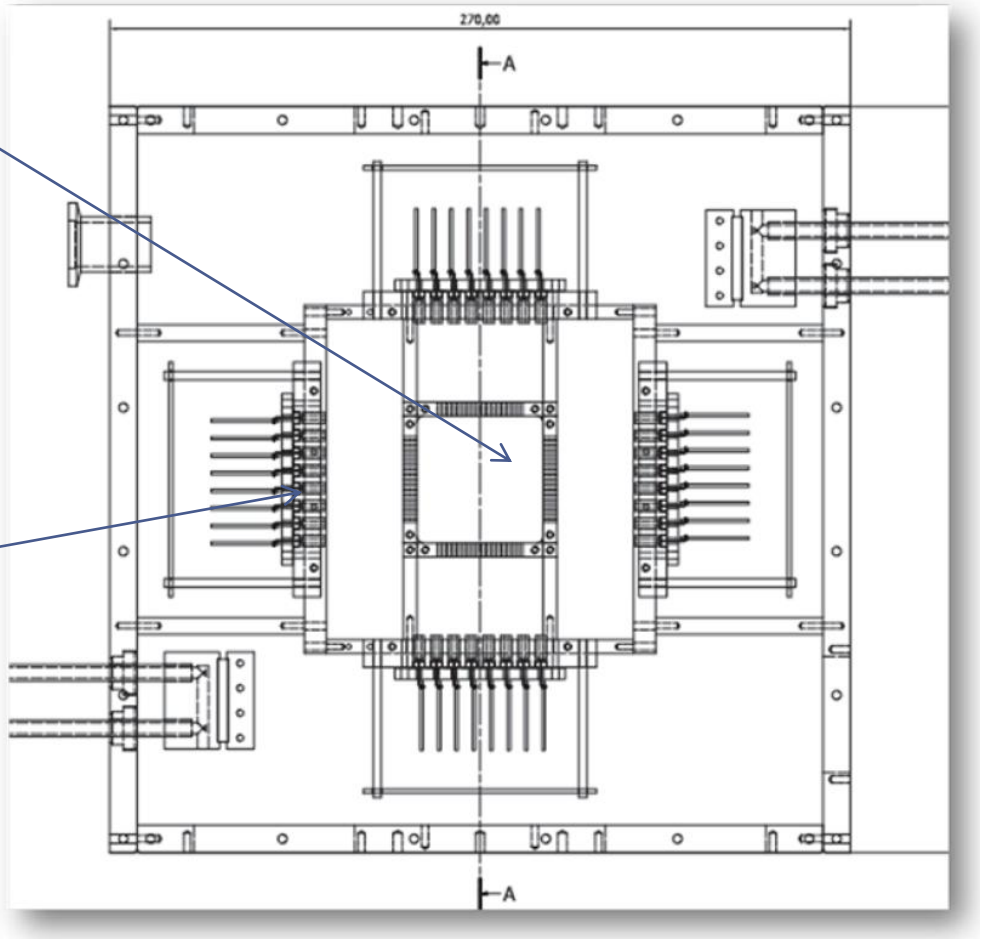
K. Suzuki, P. Bühler, S. Fossati, J. Marton, M. Schafhauser and J. Zmeskal, "Development of SciFi/CheFi detectors with SiPM readout", Proc. New Developments In Photodetection 2008", Aix-les-Bains, France, Nuclear Instruments and Methods in Physic Research A, in print.

- Monitor of proton beam
- Good position resolution ~1mm
- 1 grid consisting of 2 layers of scintillating fibers 1mm
- Resistant to magnetic field of FOPI (0.6 T)
- High rate capability (>1 MHz)

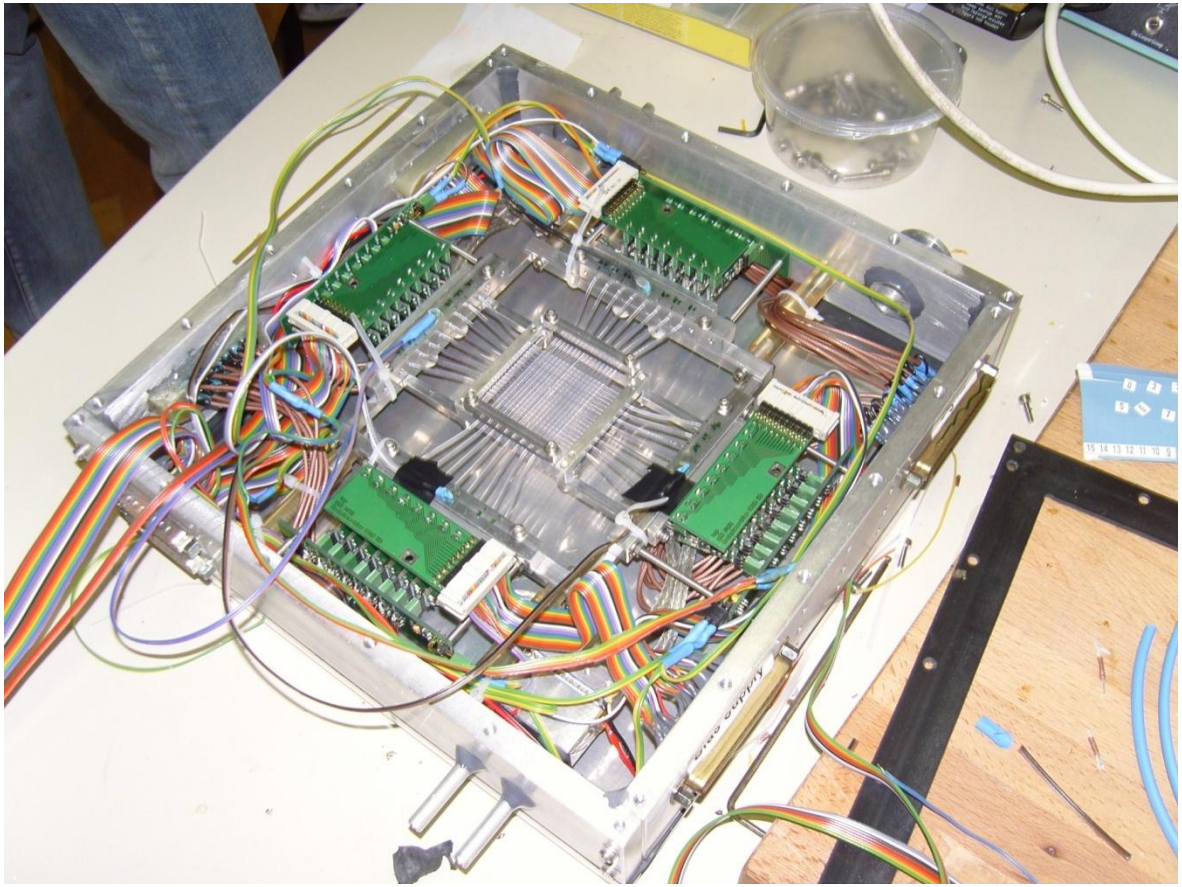
Beam Profile Monitor - Design

2 Layers of scint. fibers X-Y

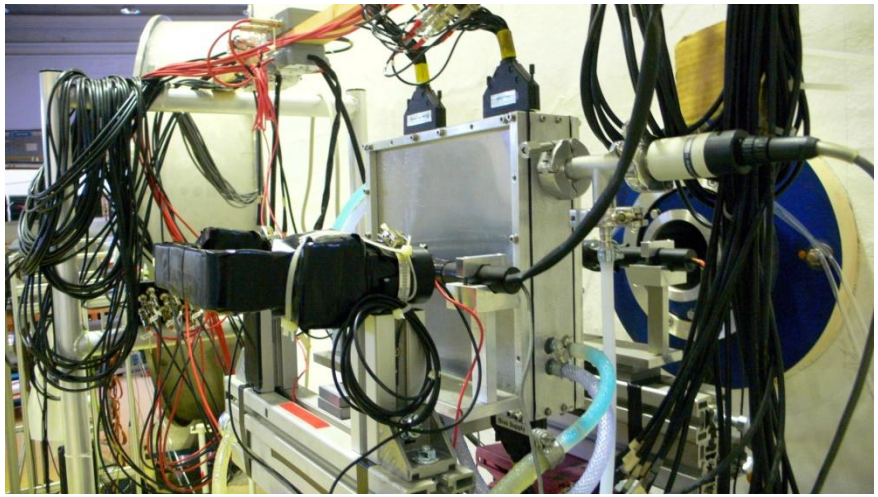
Readout with SiPMs

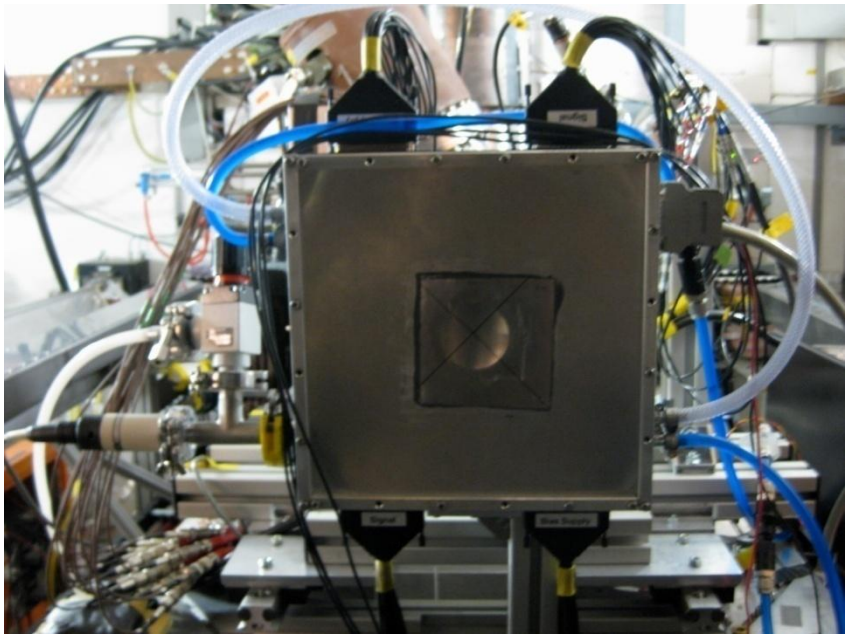


Beam Profile Monitor

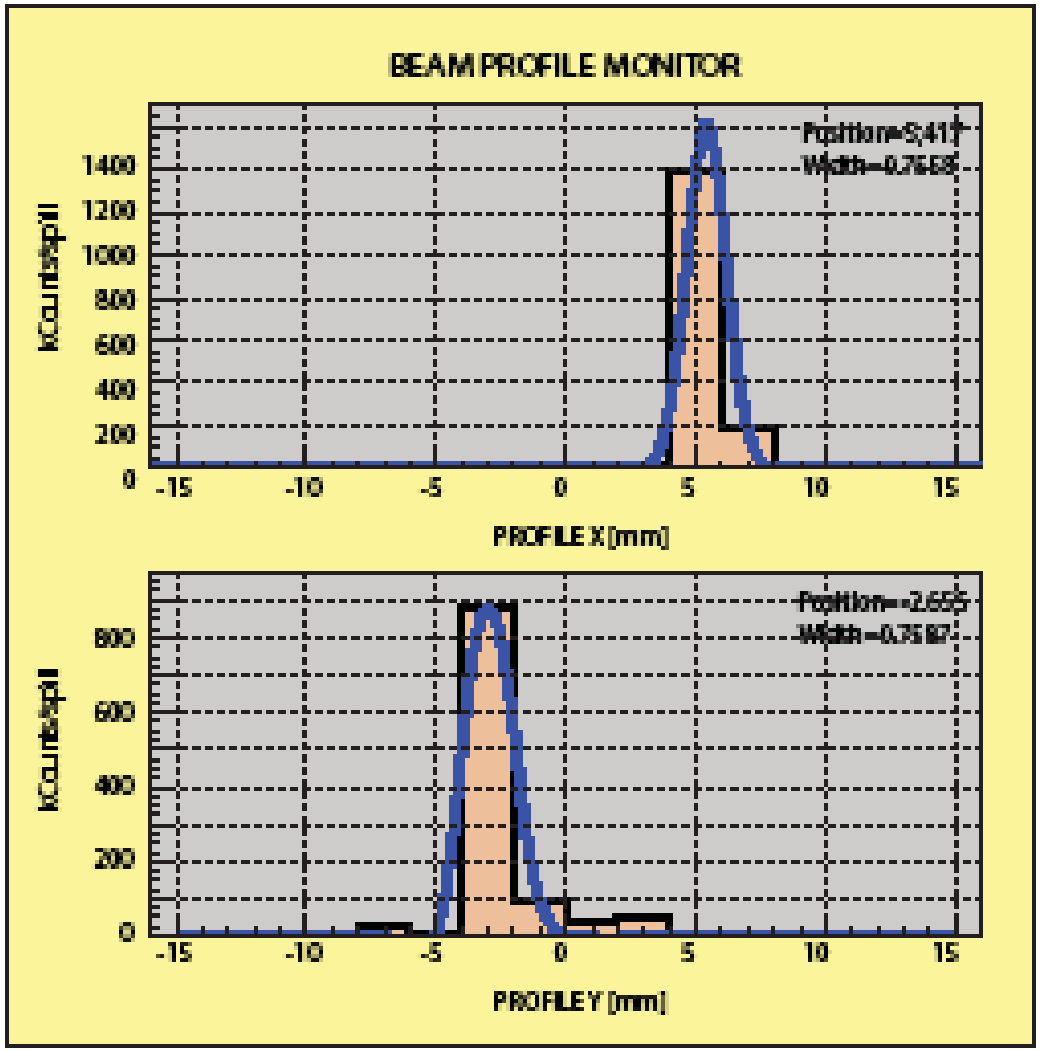


Installation at GSI-FOPI





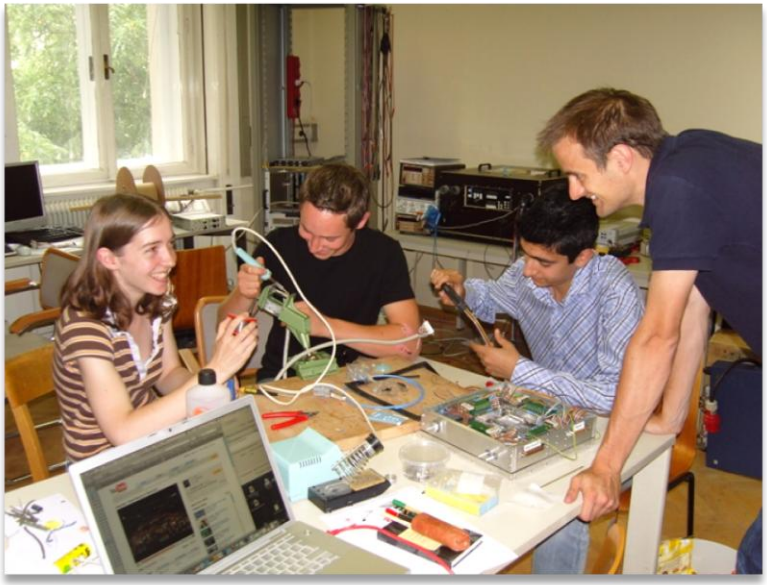
Beam profile measurement



Next steps

- Characterization of SiPMs to be continued
- SiPM array development (joint activity FP7)
- Cherenkov detectors with fast timing
  - Prototyping
  - Tests at BTF at LNF
- Scintillating fiber detector for AMADEUS
  - Prototyping
  - Rate capability tests
- Development of an anticoincidence shield for VIP with scintillators read out with SiPMs

Team @ SMI



Gamal Ahmed

Paul Bühler,

Matthias Schafhauser,

Ken Suzuki,

Johann Marton

technicians (3) and students

Thank you for your attention

Dark count rate with Peltier cooling

Gain kept constant by adjusting the bias voltage