HadronPhysics2 Project

Overview of the JRA on SiPM

Herbert Orth, GSI Darmstadt, Germany

Call for proposals 4 July 07

Editorial Session for SiPM
Frascati 10/11 Aug. 07

Submission: 15 Sep. 07

Presentations: 28/29 Sept
13 Networking (8)
11 TARI (5)
21 JRA (13)

Steering com. sessions

Revision of Proposals
15 Dec. 07

Writing of Proposal

Subm. to EC 28. Feb. 08

4th July 2007

Seventh Framework Programme

HadronPhysics2

Call for Proposal

The next EU Call for Proposal for Integrated Activities with the instrument of Integrated Infrastructure Initiatives (I3), within the 7th Framework Programme (FP7), will be issued on 17th November 2007 (deadline 15th February 2008).

The Steering Committee set up by the hadron physics community to guide the drafting of a Proposal of an Integrated Activity to be submitted to the European Commission is hereby launching an open call for proposals.

The proposals must comply with the scientific and technical requirements described below, so to optimize and harmonize the selection procedure.

The overall EC contribution is expected to be substantially less than in FP6.

The person who is sending the proposal on behalf of a group (the acting spokesperson) shall also be in charge of orally presenting the proposed activity in a open Plenary Meeting, which shall be held at Laboratori Nazionali di Frascati (LNF) from 28 to 30 September 2007.

► **SCIENTIFIC FRAMEWORK**

Integrating Infrastructure Initiatives

Purpose

Integrated Infrastructure Initiatives (I3) should combine, in a closely co-ordinated manner: (i) Networking activities, (ii) Trans-national access and/or service activities and (iii) Joint research activities. All three categories of activities are mandatory as synergistic effects are expected from these different components.

Size and resources

There must be at least three "legal entities" established in different EU Member States or Associated Countries. The entities must be independent of each other.

Duration

Integrated Infrastructure Initiatives projects are expected to last two to four years.

External reviewing May 08

Rescaling of the work and budgets

Selections

Final Proposal: 22 Aug. 08

Negotiations with EC

Start of Project:
1 Jan. 2009

Budget:
10 M€ requested EC
15 M€ complementing

Midterm Report: Sept. 09
2nd Periodic Report: 15 Nov.11
Final report:
Presentation: 2-3 Dec. 2011
Written: 31. Jan. 2012

(i) Networking activities

These activities **should foster a culture of co-operation in the scientific communities** benefitting from the research infrastructures.

Networking activities should address (not exhaustive list):

- coordination of scientific and technological activities;
- foresight studies of new instruments, methods, concepts and technologies;
- organization of co-operations among theorists and experimentalists with exchange of results and expertise;
- ...

(ii) Trans-national access activities

To provide trans-national access to one or more infrastructures among those operated by participants.

Community financial support should never exceed 20% of the annual operating costs of the infrastructure to prevent it from becoming dependent on the Community contribution and should not include capital investments. This financial support will serve **to provide free of charge access to external users (including travel and subsistence costs)**. Access costs will be defined on the basis of an "**user fee**" relating to the operating costs of the infrastructure.

(iii) Joint research activities

These activities should be **innovative** and **explore new fundamental technologies** or techniques underpinning the efficient and joint use of the participating research infrastructures.

The Joint research activities should address (not exhaustive list):

- higher performance methodologies and protocols;
- higher performance instrumentations, including the testing of components, subsystems, materials, techniques and dedicated software;
- innovative solutions for data collection, management, etc;
- …

The Joint research activities should, on the contrary, NOT address the construction of equipments, major infrastructure updates, or similar.

► **TECHNICAL REQUIREMENTS FOR SENDING THE PROPOSAL**

Interested participants are invited to send a proposal **using the appropriate template (MS Word format)** which can be **downloaded** at

www.hadronphysics2.eu

HadronPhysics2 (n. 227431) *22 August 2008*

SEVENTH FRAMEWORK PROGRAMME

Capacities Specific Programme

Research Infrastructures

Grant agreement for: Integrating Activity - Combination of Collaborative Projects and Coordination and Support Actions

Coordinator: Carlo Guaraldo, LNF Italy

Project acronym: ***HadronPhysics2***

Project full title: ***Study of Strongly Interacting Matter***

Grant agreement no.: ***227431***

Date of preparation of Annex I (latest version): ***22 August 2008***

Date of approval of Annex I by Commission: *(to be completed by Commission)*

Seventh Framework Programme I3 - HadronPhysics2

Midterm Report

on

Matrix Geiger-Mode Avalanche Micro-Pixel Photo Diodes for Frontier Detector Systems

„Silicon Multiplier“

Spokesperson: Herbert Orth, GSI Darmstadt, Germany

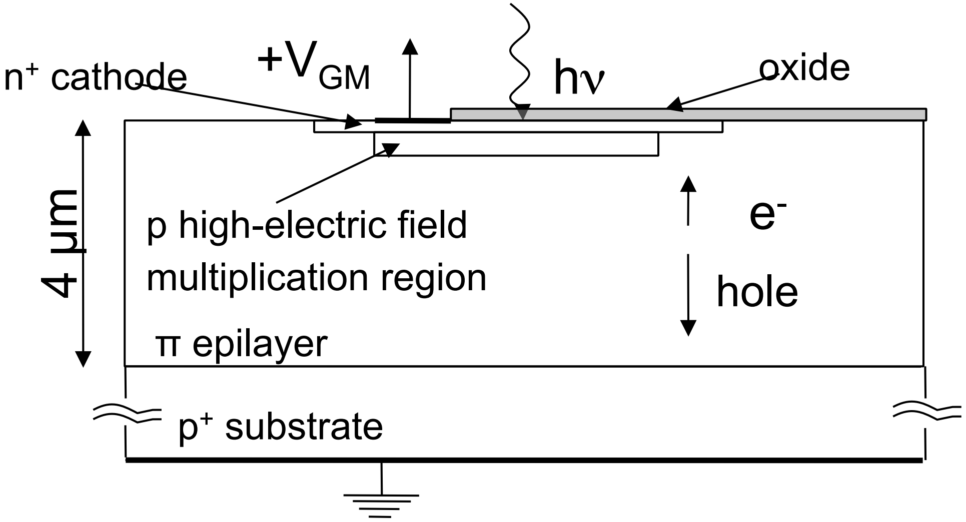
What are Silicon Multipliers?

- **PMT** is a traditional photo sensor of nuclear/hadron physics for more than half a century
  - –legacy device / reliable
  - –new PMTs still actively being developed

- **SiPM** is a newly developed matrix of avalanche photo diodes (APD) operated in Geiger-mode
  - –characteristics of a photon sensor
  - –many advantages over PMT
  - –potential to replace PMT in many applications

Silicon PhotoMultiplier = SiPM
Working principle

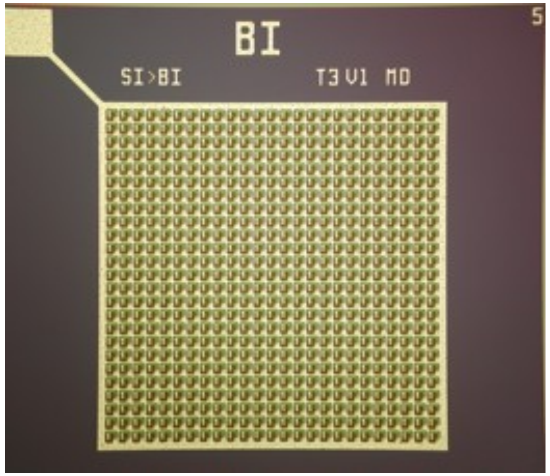
SOLID STATE PHOTODETECTOR➔



- The photon is absorbed and generates an electron/hole pair
- The electron/hole diffuses or drifts to the high-electric field multiplication region
- The drifted charge undergoes impact ionization and causes an avalanche breakdown.
- Resistor in series to quench the avalanche (limited Geiger mode).

SiPM: **Multicell Avalanche Photodiode** working in limited Geiger mode

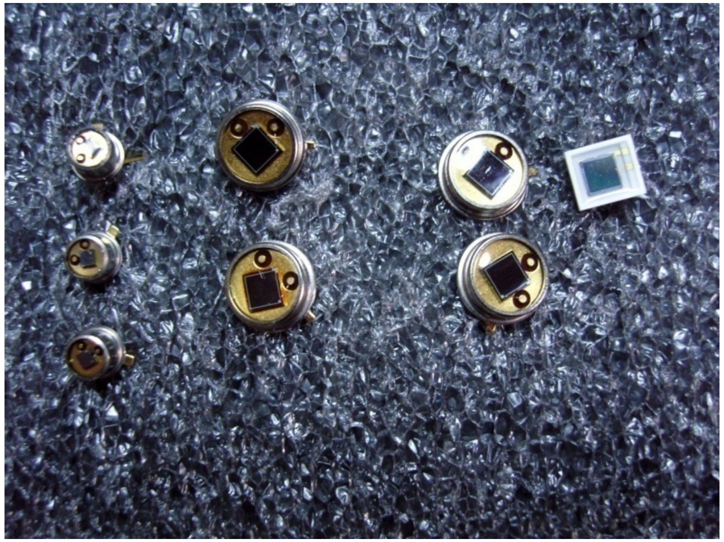
- **2D array of microcells: structures in a common bulk.**
- **$V_{bias} > V_{breakdown}$: high field in mult. region**
- **Microcells work in Geiger mode: the signal is independent of the particle energy**
- **The SiPM output is the sum of the signals produced in all microcells fired.**



Characteristics

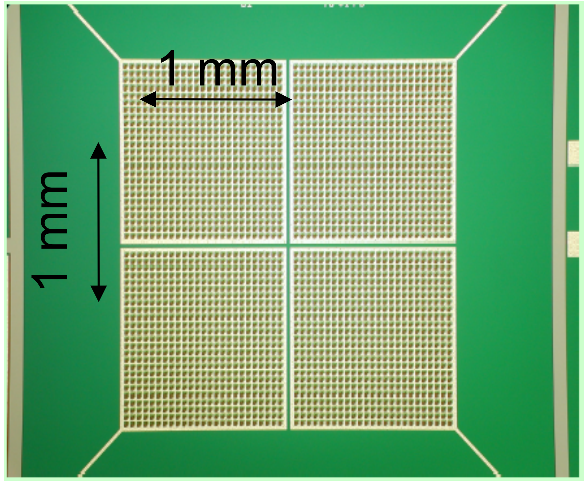
Typical values:

- Gain 10^5-10^6
- Time resolution < 50 ps
- Operating voltage < 100 V
  (at 2-4 V overvoltage $\Delta V = V_{bias} - V_{BD}$)
- Matrix size 1-3 mm^2
- Microcell size 10-100 µm



Dynamic range:

- Determined by the number of microcells and the Photon detection efficiency (PDE).
  Linear while N photons detected <<N of microcells.
  PDE = QE x Pt x GF.
- Increases with overvoltage, but also the noise



Noise:

- $10^5 - 10^6$ per mm^2 sensor at T=25 °C
- $10^4 - 10^5$ per mm^2 sensor at T= 0 °C

Optimization depends on the application

Avalanche Micro-Pixel Photo-Diode for Frontier Detector Systems

Objectives of WP28

Exploiting and further developing the properties of SiPM in a collaborative effort from designer over producer to physics user

The R&D projects:

- **Low level light detection and single photon read-out with SiPM**
- **Detection of medium to high light levels using SiPM-coupled to fiber material**
- **Ultra-fast timing with plastic scintillators using SiPMs**

The focus in more detail

- Development and test of new SiMPs, integrated in arrays which are compatible with the demands of position sensitive detectors (e.g. single photon detectors, scintillating fibre detectors, gamma ray detectors using state-of-the-art crystals like LSO).
- Optimization of the timing performance in the picosecond time resolution range,
- Development and test of the performance as single photon counters.
- Studies of damage effects from ionizing radiation
- Investigation and characterization of the intrinsic and induced noise behavior.
- Development of associated electronics for the supply/readout as well as data acquisition
- Assembly and installation in detector systems working in magnetic fields: characterization of the overall performances and check of the short and long time stabilities on various test beams

Avalanche Micro-Pixel Photo-Diode for Frontier Detector Systems

Participating Institutions

Work package title	Avalanche Micro-Pixel Photo-Diodes for Frontier Detector Systems

Participant number	Organization legal name	Short name	Activity leaders (*in **bold** the spokesperson*)	Person-months (total)
9	Gesellschaft für Schwerionenforschung mbH	GSI	**H.Orth**	12
1	Istituto Nazionale di Fisica Nucleare *INFN Laboratori Nazionali di Frascati* *INFN Sezione di Pisa*	INFN *INFN-LNF* *INFN-PI*	 *C.Curceanu,* *A.Del Guerra*	48 *30* *18*
2	Oesterreichische Akademie der Wissenschaften	OeAW	J.Marton	12
4	Charles University in Prague	CUNI	R.Leitner	12
14	Rheinische Friedrich-Wilhelms-Universität Bonn *Universität Bonn*	UBO *UBO*	 *U.Thoma*	12 *12*
15	Friedrich-Alexander- Universität Erlangen-Nuernberg	FAU	A.Lehmann	6
18	Justus Liebig Universität Giessen	JLU	R.Novotny	6
33	Foundation Bruno Kessler *FBK-irst*	FBK *FBK*	 *C. Piemonte*	
37	Jagiellonian University	UJ	J.Smyrski	12
40	Institutul National de Cercetare-Dezvoltare pentru Fizica si Inginerie Nucleara – Horia Hulubei	IFIN-HH	M.Bragadireanu	60

Other involved institutions	**Activity leaders**	**Person-months**
Paul Scherrer Institut,Villigen (Switzerland)	D.Renker	3
Zecotek Photonics, Zuerich (Switzerland)	Z. Sadygov	12
Joint Institute for Nuclear Research,Dubna (Russia)	A.Olchevski	24
Petersburg Nuclear Physics Institute, Gatchina (Russia)	S.Belostotski	18
Institute for Scintillation Materials, Kharkov (Russia)	B.Gryniov	3
Institute of Nuclear Physics,Moscow (Russia)	F.Guber	6
Institute of High Energy Physics,Protvino (Russia)	V.Ammosov	12

Deliverables

Task	Deliverable	Month of Delivery
Single-photon readout with SiPMs	Design and construction of a 64-pixel prototype matrix	36
SiPM-coupled advanced fiber detectors	Feasibility studies for new detectors with SiPM readout using: a) Crystalline fibers b) Scintillating fibers c) Wavelength shifting fibers	36
Ultra-fast timing for TOF applications	Prototype, radiation hardness and tests in beam	36

Avalanche Micro-Pixel Photo-Diode for Frontier Detector Systems

HadronPhysics2 I3HP/FP7 Kick-off Meeting (6 Feb. 09 H.O. & D.R.)

Avalanche Micro-Pixel Photo-Diodes for Frontier Detector Systems

GSI, 9-10 Feb. 2009, Seminar room C27

Program

Monday morning 9:30-12:30

Welcome, Klaus Peters, GSI

The FAIR accelerator complex, Lars Schmitt, GSI

HadronPhysics2 Project, Overview of the JRA on G-APDs, Herbert Orth, GSI

The Geiger-mode Avalanche Photo detector, Dieter Renker, PSI,

Photonique sensors, David McNally, Photonique SA, Meyrin

Zecotek sensors, Ziraddin Sadygov, JINR Dubna/IP Baku

Front-end electronics for the GAPD, Stefan Ritt, PSI

SiPM technology at FBK, Claudio Piemonte, FBK Trento

ST-Microelectronics sensors, NN

12:30 – 14:00 Lunch

Monday afternoon (14:00-1600)

Cherenkov radiation application, Samo Korpa, University of Ljubljana

Application of G-APDs in Gamma Astronomy, Nepomuk Otte, UCSC

Geiger-mode APDs for the neutrino oscillation experiment T2K, Yury Kudenko, INR Moscow

Application of G-APDs in μSR instrumentation, Alexey Stoykov and Robert Scheuermann, PSI

Study of Radiation Hardness, Iouri Musienko, CERN

Application of MAPDs for Calorimetry and ToF, Alexandr Ivashkin, INR Moscow

Performance of long scintillating fibres read-out with SiPM, Salvador Sanchez, Mainz

16:30 Informaton from the FP7 research goups

Recent progress in SiPM matrices readout and performance, Univ of Pisa, (Maria G. Bisogni, Alberto del Guerra)

Inorganic Scintillating Fibers, University of Giessen (Rainer Novotny)

Prospects for SiPMs at the Crystal-Barrel Experiment, University of Bonn. (C. Wendel, Ulrike Thoma)

The Frascati group activity in testing SiPM related to the AMADEUS experiment, INF-INFN (Catalina Petrascu)

19:30 Workshop dinner

Tuesday morning: 9:30 – 12:30

continuation of: Information from FP7 research groups

Acivities at SMI/Vienna in testing the performance of SiPMs, SMI Vienna (Hans Marton)

G-APD activiities at GSI, GSI Darmstadt, (Andrea Wilms, Herbert Orth)

APD Laser Test Setup, Charles University Prague, (Peter Koyds, Rupert Leitner)

SiPM study and techniques for application in TOF, PNPI Gatchina (Gennady Gavrilov, Stanislav Belostotski)

JINR, Dubna, Alexander Olchevski, Valery Dodokhov

Jagiellonian University, Krakow, Jerzy Smirski

IFIN-HH, Bukarest, Mario Bragadireanu

INP Moscow, Fedor Guber, A. Ivashkin

IHEP Protvino, Vladimir Ammosov

Erlangen plans with SiPM, University of Erlangen, Albert Lehmann

Lunch

Tuesday afternoon: 14:00

INTAS group meeting (1h)

FP7 - Plans for the first project year and sharing of works (2h)

Kick-off Workshop
9-10 Feb. 2009
GSI, Darmsadt

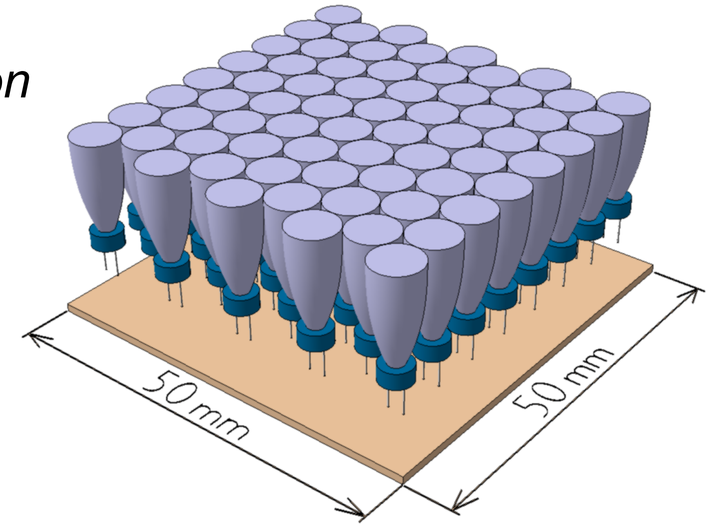
Second SiPM Workshop
21-22 Feb. 2010
Villa Lanna, Prague

https://indico.gsi.de/conferenceDisplay.py?confId=493
https://indico.gsi.de/conferenceDisplay.py?confId=969

T1: Low level light detection and single photon read-out with SiPM

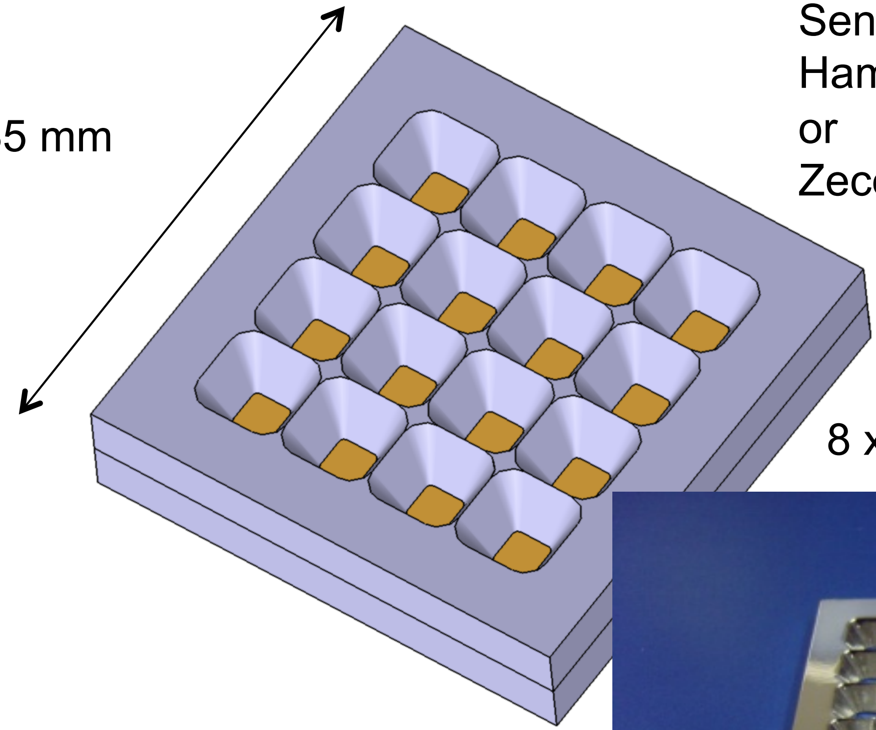
Important parameters of SiMP for very low light level detection:

- *Large PDE (50 %) and large area coverage*
- *small pixel granularity and large pixel size*
- *Fast single photon response for time resolution*
- *Working in high magnetic field*
- *Low sensor noise performance*



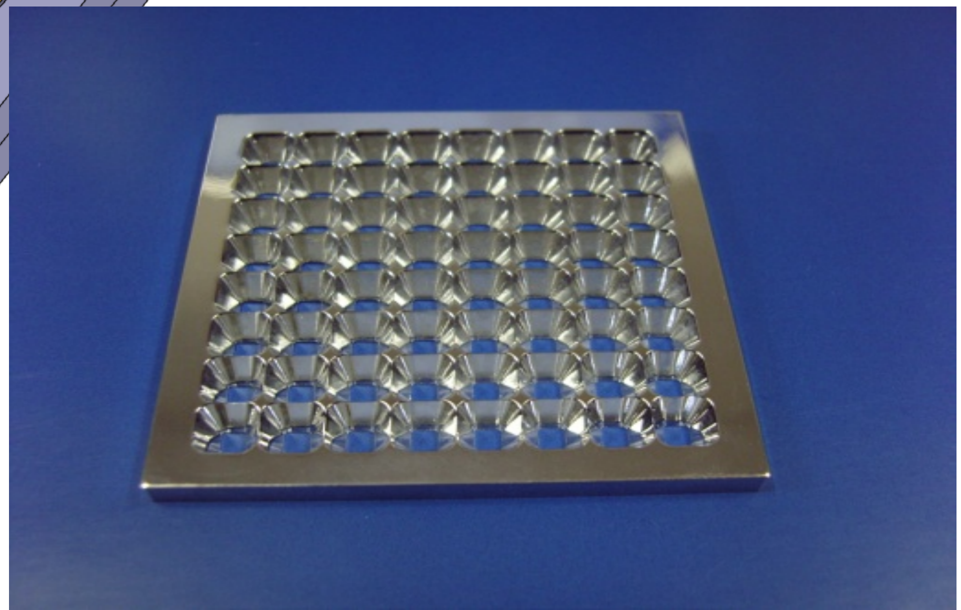
R&D: Large SiPM sensor matrix for coincident photons (e.g. Cherenkov radiation)

Large area sensor with light catcher



4 x 4 matrix
Sensors:
Hamamatsu 33-050C
or
Zecotek MAPD-3N

8 x 8 funnelplate Cr-plated brass

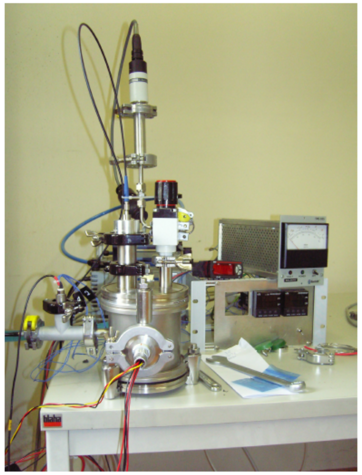


G.M. Ahmed et al.; Application of Geiger-mode photo sensors in Cherenkov detectors; to be published

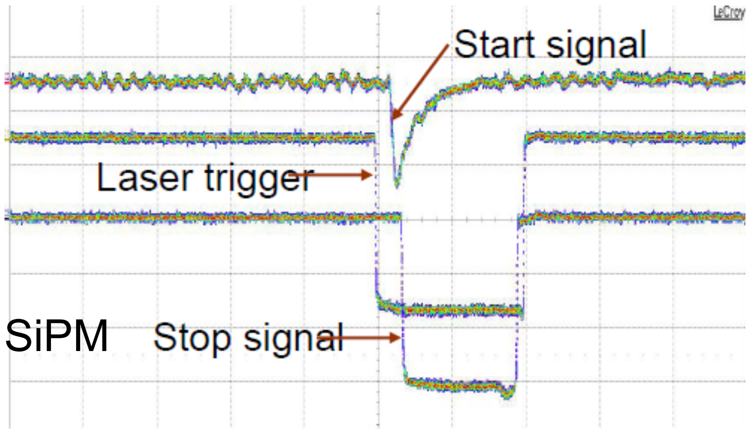
Work at SMI

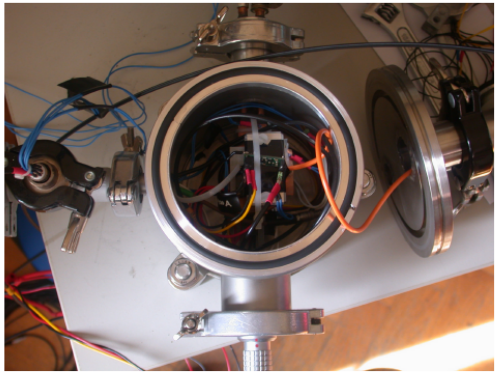
- Position sensitive charged particle detection with scintillating fibers and SiPM readout
- Studies of properties of SiPMs (commercial and prototype devices)
- Timing performance systematic studies as function of overvoltage , temperature and of photon flux
- Cherenkov detectors with SiPM readout: towards timing and position sensitive devices

Test equipment at SMI



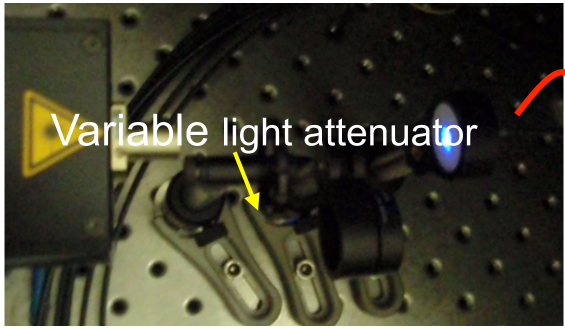
Test bench with insulation vacuum vessel, vacuum pump, Peltier cooling
Bias voltage supply (Keithley), preamp supply voltages
Picosecond laser system @ 408 nm (32ps) for timing tests
Optical bench for laser beam (coupling to optical fiber)
Fast digital oscilloscope
CAMAC/VME DAQ system for TDC, QADC data acquisition

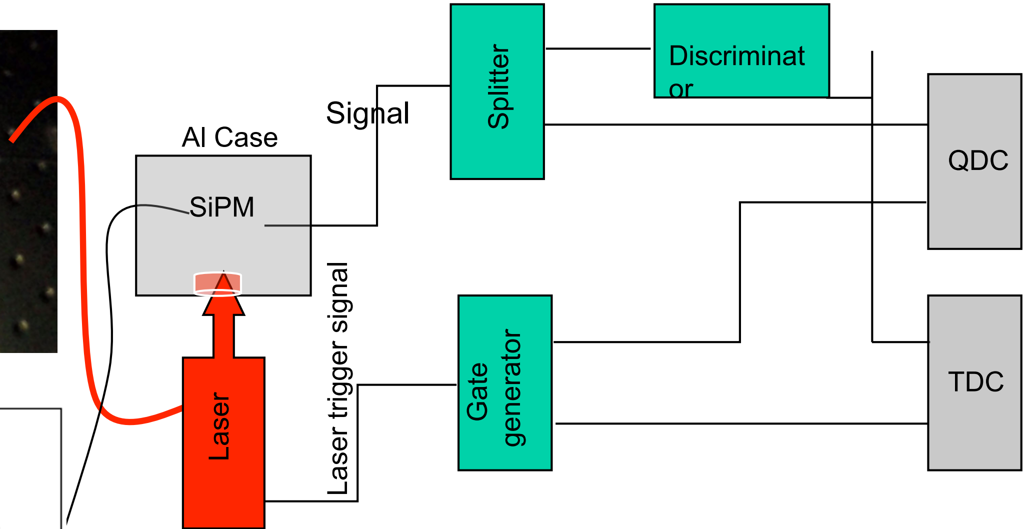


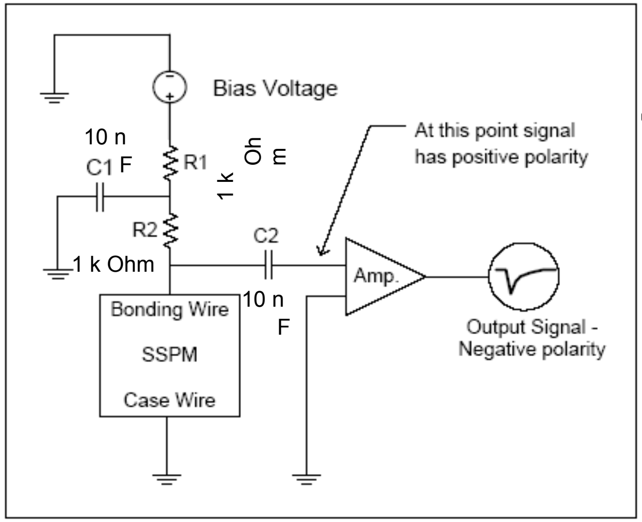


SiPM time resolution measurements

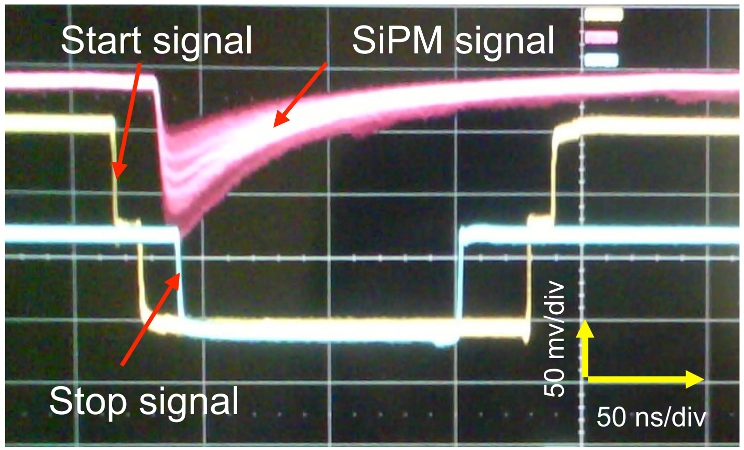
- Time resolution was studied by illuminating SiPM with blue laser light pulse width 32 ps at wave length 408nm.

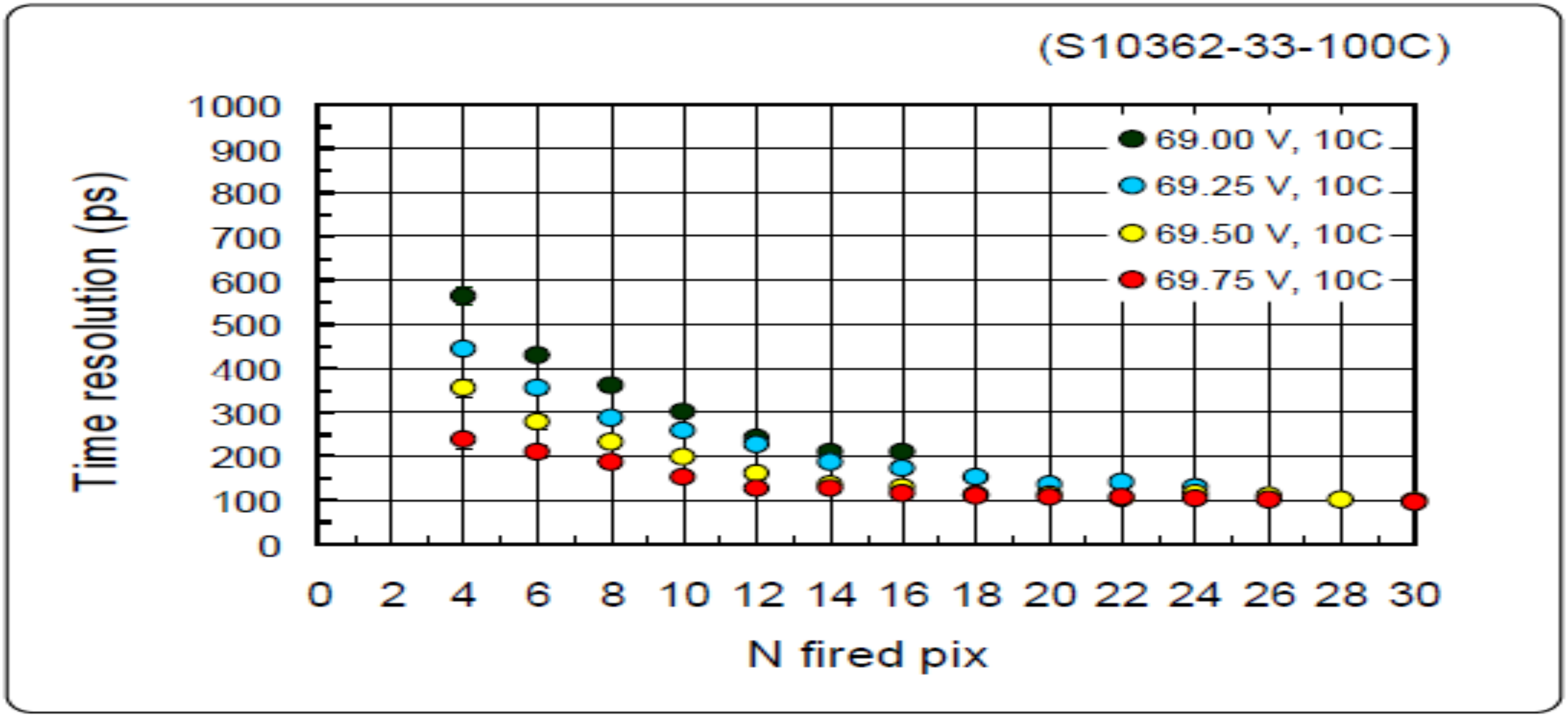






Photonique preamplifier (AMP-0611) (700 ps)





Publications:

G.S.M. Ahmed, P. Bühler, J. Marton and K. Suzuki, "Studies of GM-APD (SiPM) Properties," Journal of Instrumentation 4, 2009, P09004 .

G.S.M. Ahmed, P. Bühler, J. Marton and K. Suzuki, "Study of timing performance of Silicon Photomultiplier and application for a Cherenkov detector", Proc. Int. Conference on Instrumentation, Nuclear Instruments and Methods in print.

G.S.M. Ahmed, P. Bühler, J. Marton and K. Suzuki, "Characterization and application of Geiger-mode silicon Photosensors in radiation detection," presentation at 2010 Symposium on Radiation Measurements and Applications, May 24-28, 2010, Univ. Michigan, Ann Arbor, to be published in Nucl. Instr. Meth. A.

G.M. Ahmed, P. Bühler, M. Cargnelli, R. Hohler, J. Marton, H. Orth and K. Suzuki, "Application of Geiger-mode photo sensors in Cherenkov detectors", Proceedings RICH 2010

Summary of time resolution measurements

- SiPM time resolution improves as a function of the bias voltage and /or the light level at constant temperature.

- SiPM time resolution improves with decreasing operating temperature (>-10 C).

- In this study the best achieved time resolution for MPPC is 33 ± 5 ps, around ~130 p.e. (SiPM limit ?).

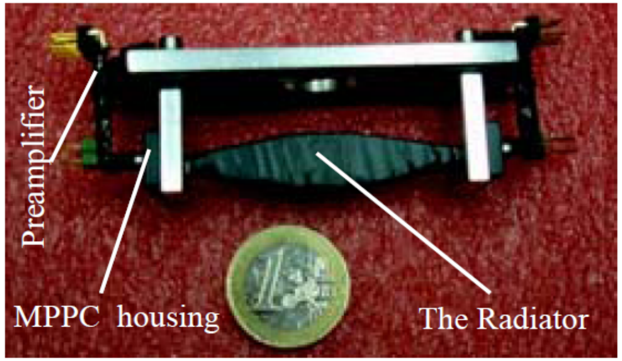
- The best achieved time resolution for MAPD-3N is 70 ± 10 ps.

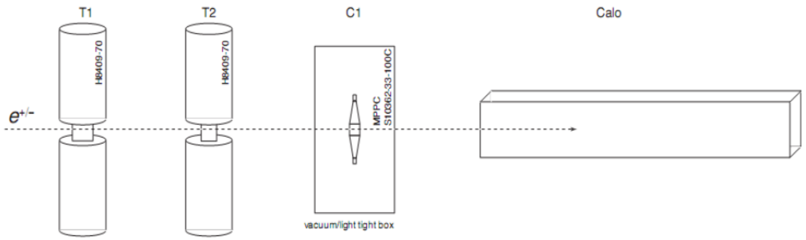
- Time resolution of electronics (Discr., Logics, TDC, DAQ, excluding preamplifier) ~ 20 ps.

- At low light condition, strong dependence on the bias voltage and/or temperature .

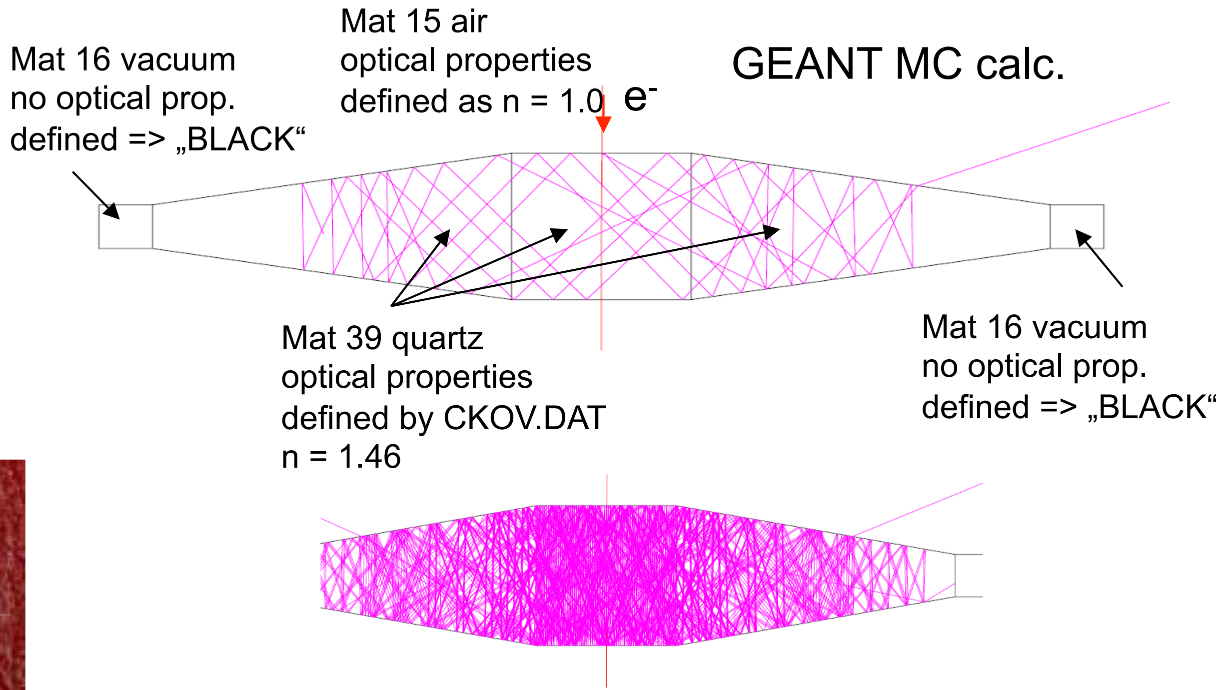
Timing Cherenkov detector

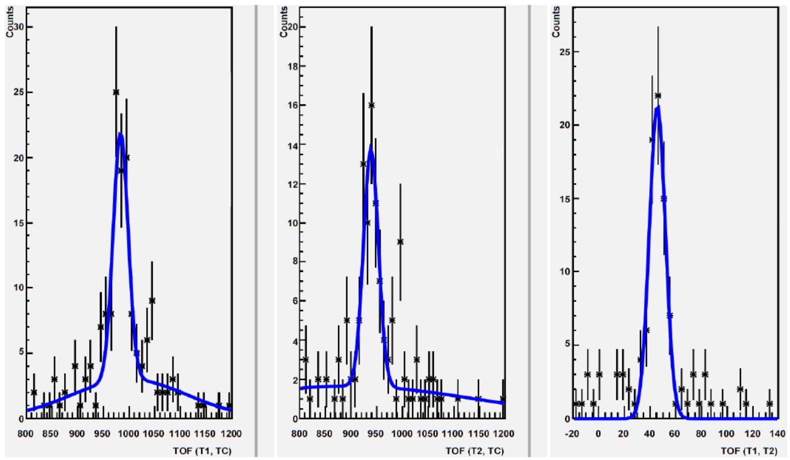
Quarz radiator 10 mm thick,
50 mm lng
Coupled on both sides to
MPPC 3x3 mm

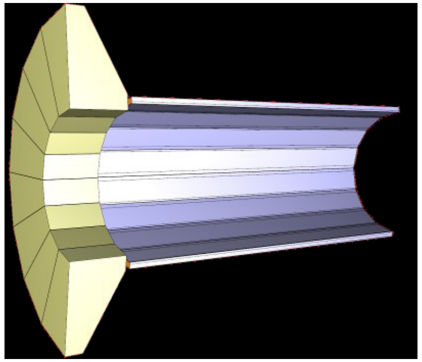




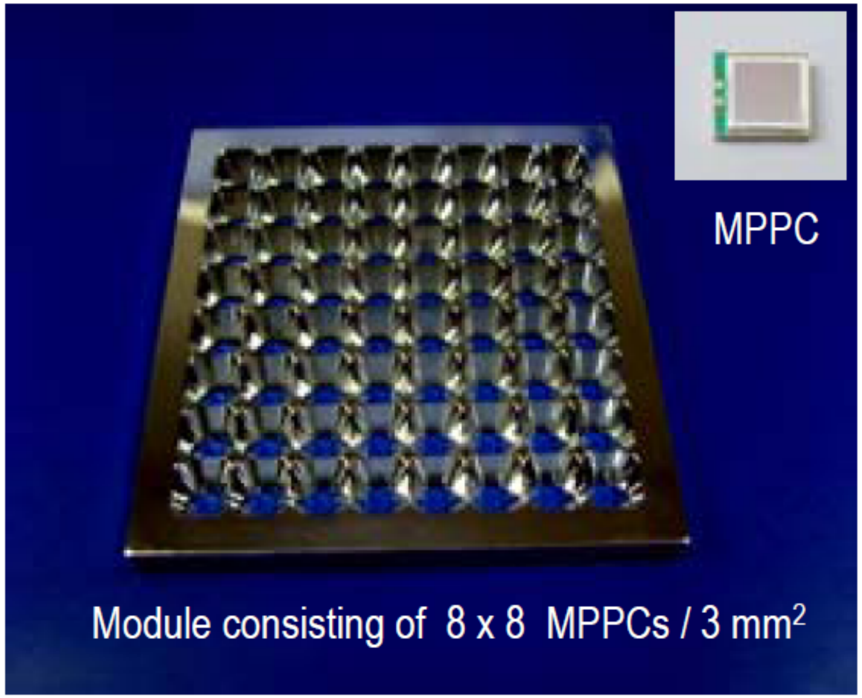
Test at BTF in Frascati with 500 MeV e- beam







Light catcher matrix for position-sensitive light detection

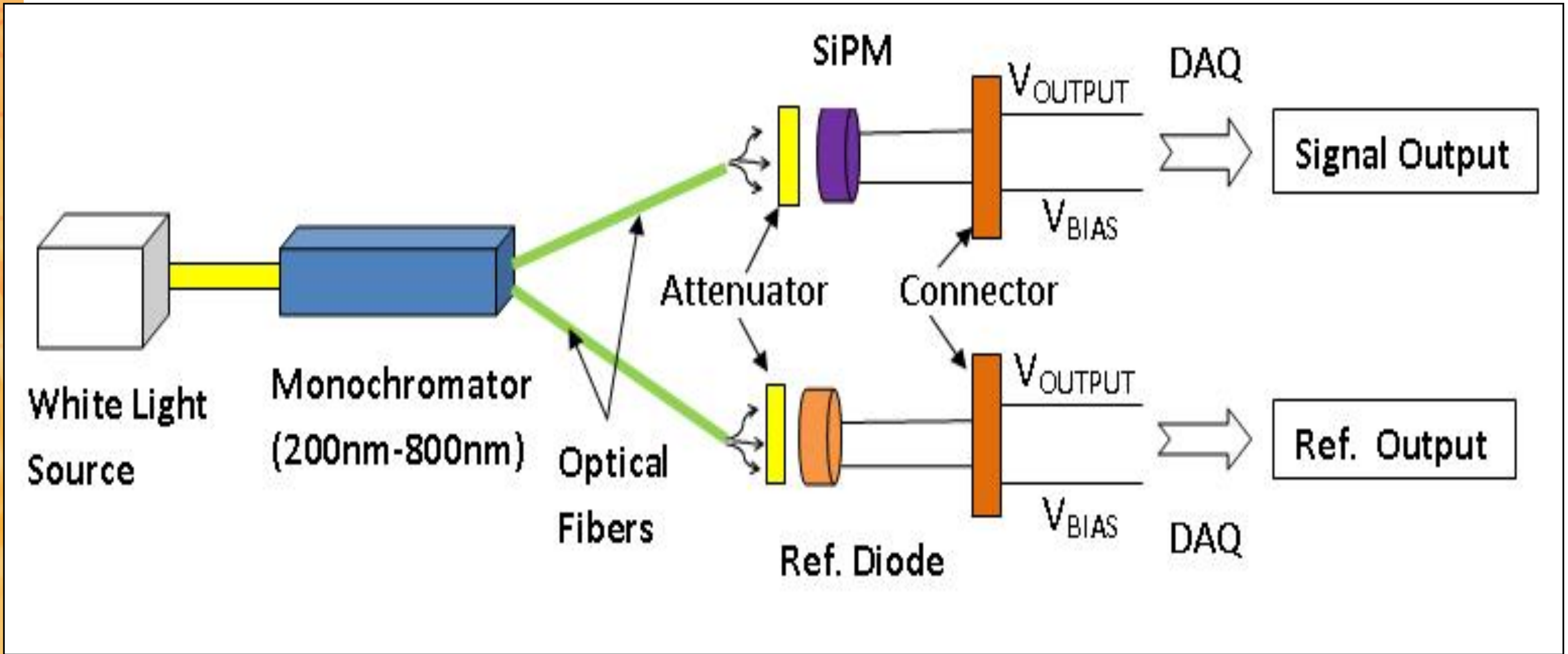


The matrix is designed to fit with SiPMs.
Present version for 3x3 mm MPPC

High PDE (high fill factor)
Good timing at high photon level– but at few photon level?
Cooling easy due to metal frame
Noise to be reduced with cooling
Experience with this device

First preliminary results: Photon enhancement by a factor 2

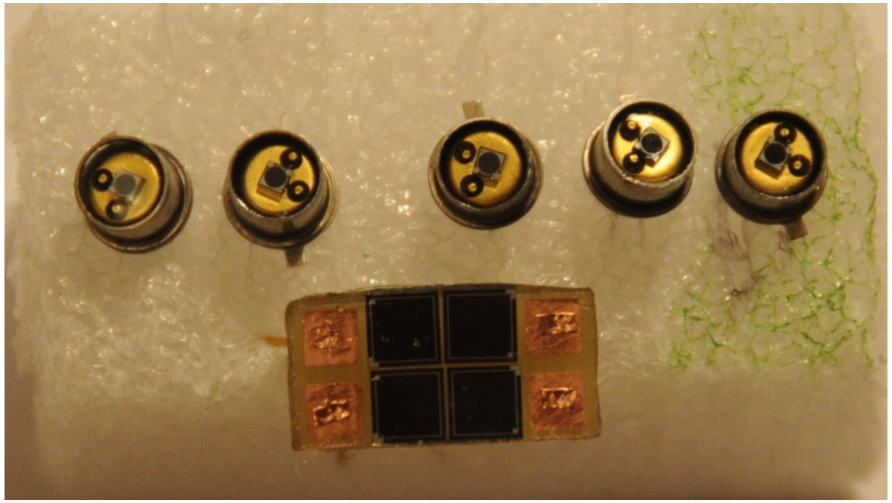
PDE measurements at GSI



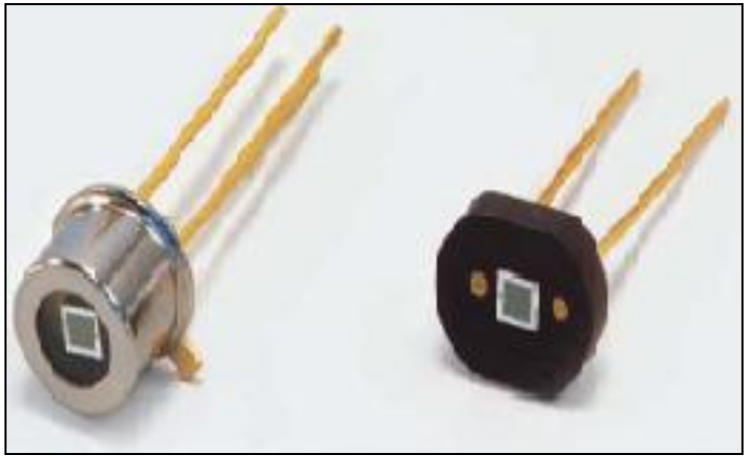
SiPM Sensors

SiPM sensors tested: MPPC from Hamamatsu, MAPD3N from Zecotek

Device	Active Area (mm^2)	Pixel Size (μm)	Pixel Density ($1/mm^2$)
MPPC-11-25	(1×1)	25	1600
MAPD3N	(3×3)	7	15000
MAPD3N	(1×1)	7	15000



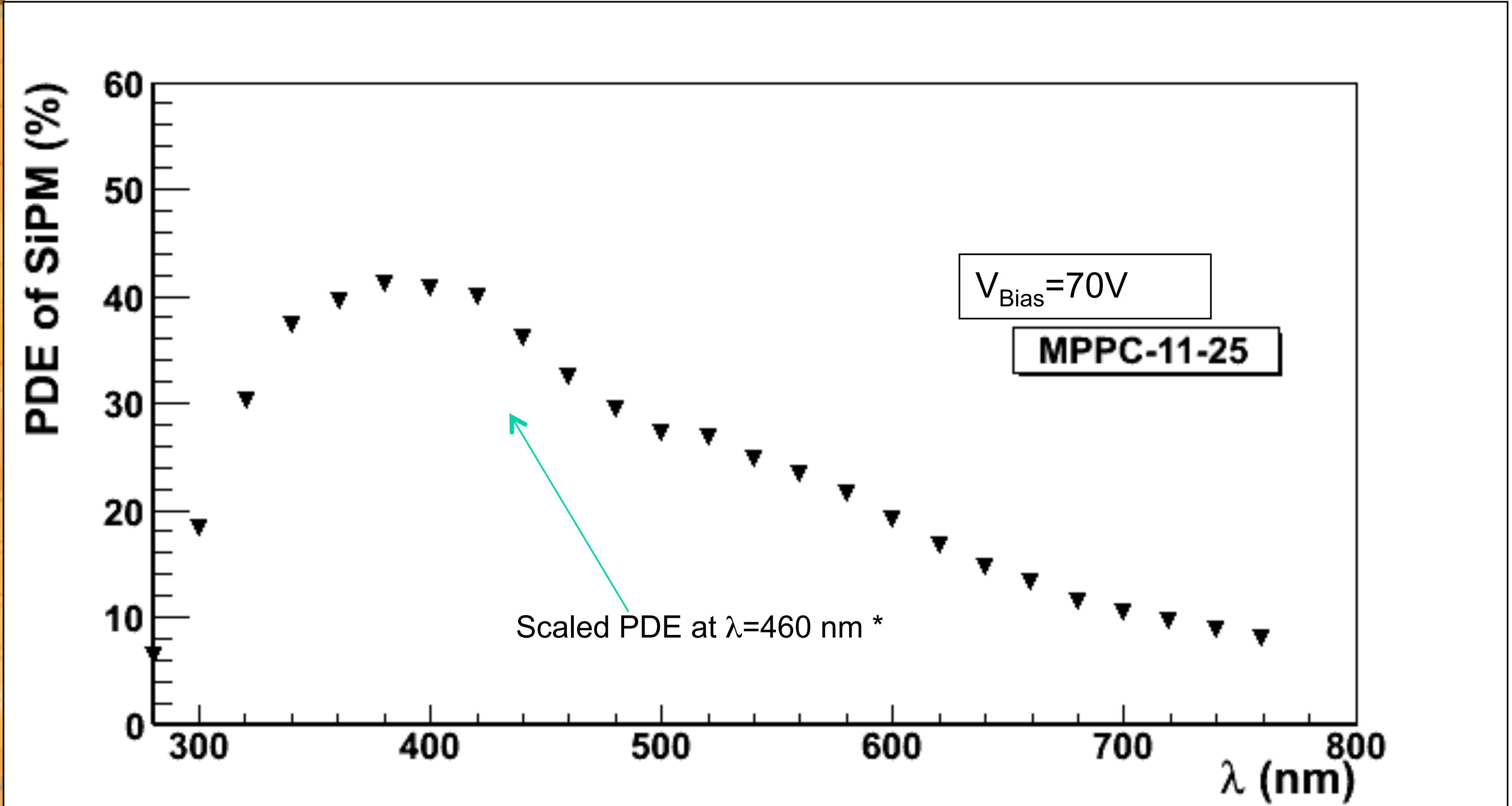
MAPD3N from Zecotek



MPPC from Hamamatsu

Photon Detection Efficiency

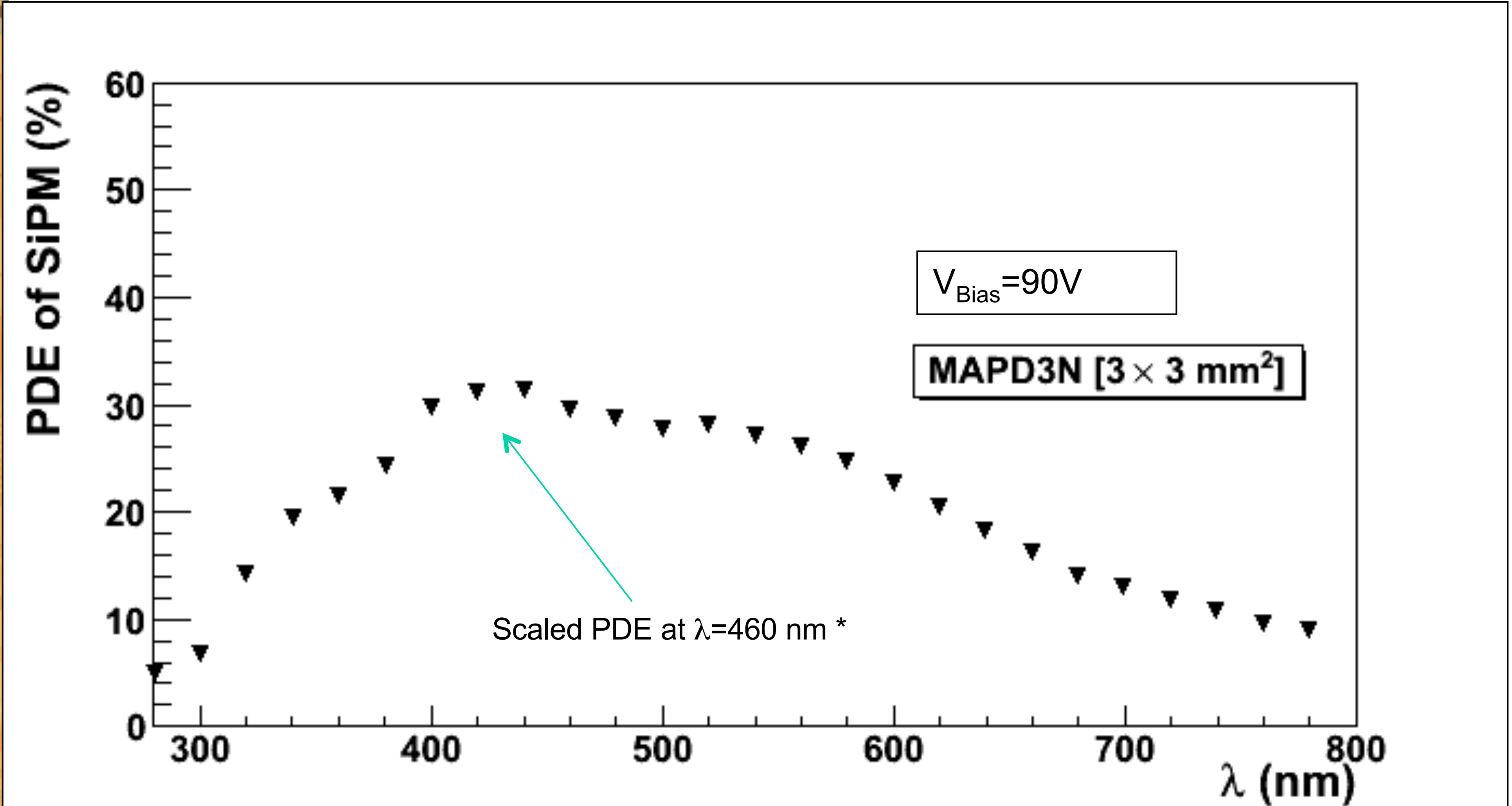
Hamamatsu Sensor MPPC-11-25



* D. Renker, PSI (Private Communication)

Photon Detection Efficiency

Zecotek Sensor MAPD3N [3 × 3 mm²]



* Yu. Musienko, CERN (Private Communication)

Timing and low temperature behavior of SiPM

G.Bisogni[1], G.Collazuol[1], A.Del Guerra[1,2], C.Piemonte[3]
[1] INFN sezione di Pisa, [2]Dipartimento di fisica Universita` di Pisa, [3]FKB-IRST Trento

INFN PISA

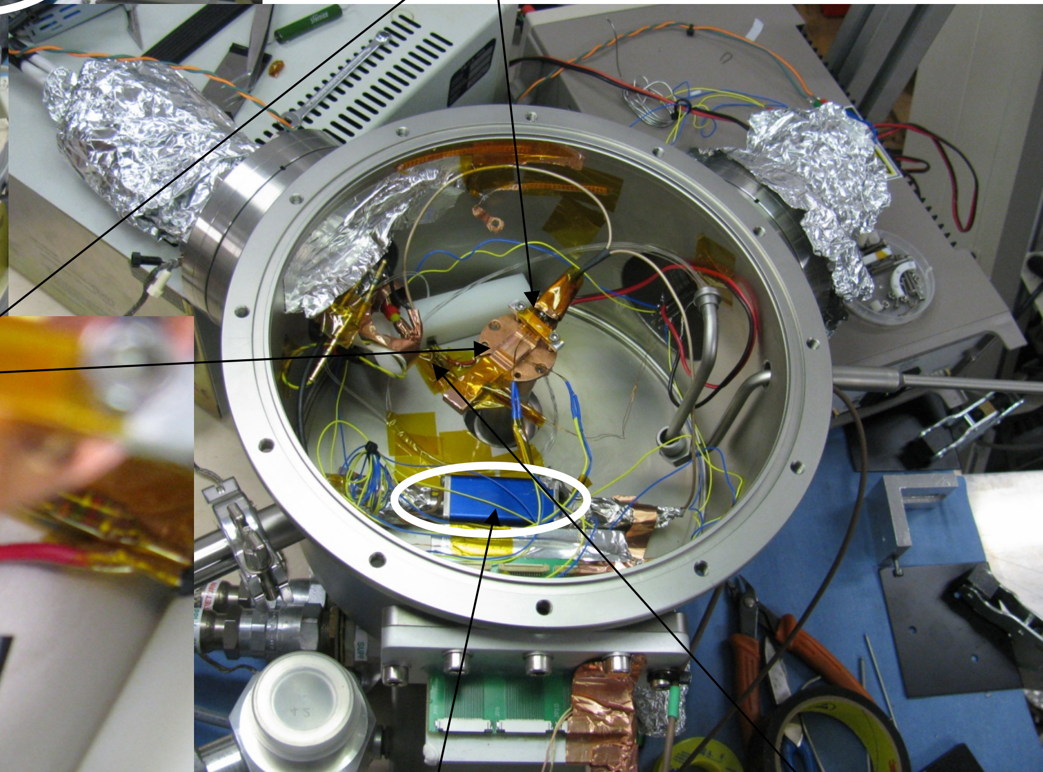
Experimental Setup

Vacuum vessel (P~10^{-3} mbar)

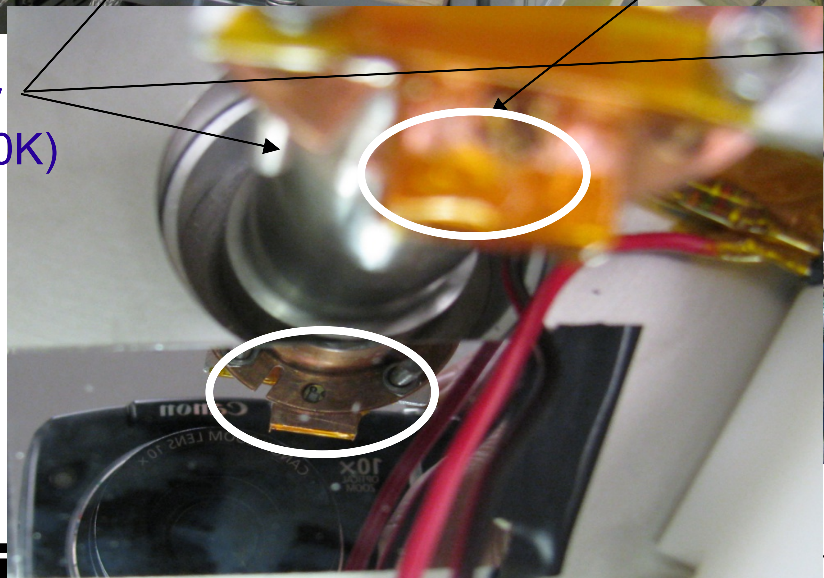
Alogen Lamp

Monocromator (200-900nm)

Quartz filers to
Calibrated Photodiode (outside)
and to **SiPM** (inside vessel)



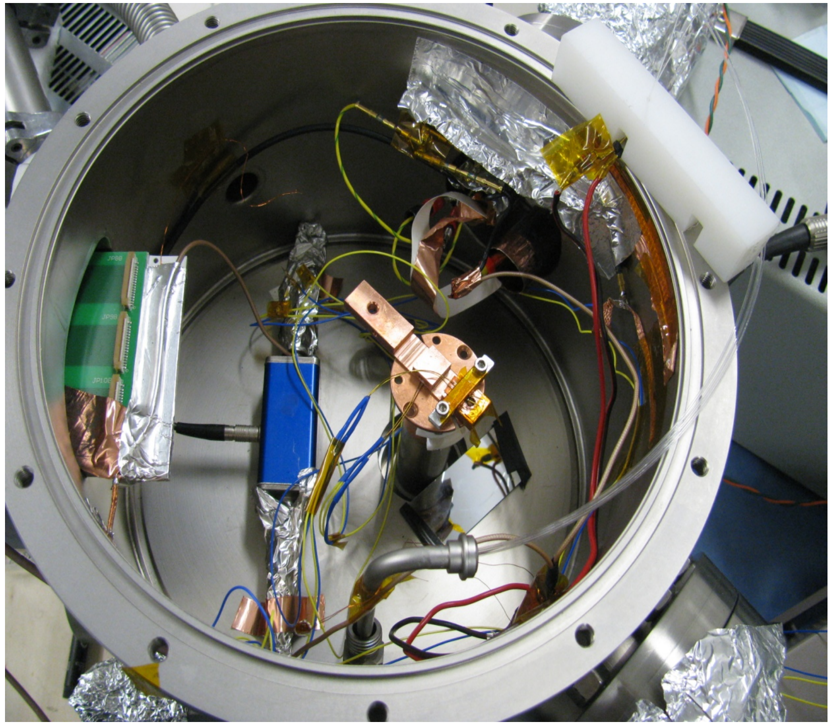
Cryocooler
(50K<T<300K)



Amplifier

UV LED (380nm)
+ fibers to SiPM

Experimental setup



Temperature control/measurement

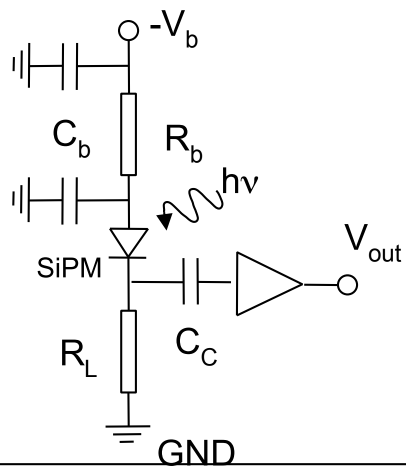
- Cryo-cooler + heating with low R resistor
- thermal contact (critical) with cryo-cooler head: SIPM within a copper rod
- T measurement with 3 pt100 probes
- Measurements on SiPM carried after thermalization (all probes at the same T)
- check junction T with forward characteristic

Voltage/Current bias/measurement

- Keytley 2148 for Voltage/Current bias/readout

Pulse measurement

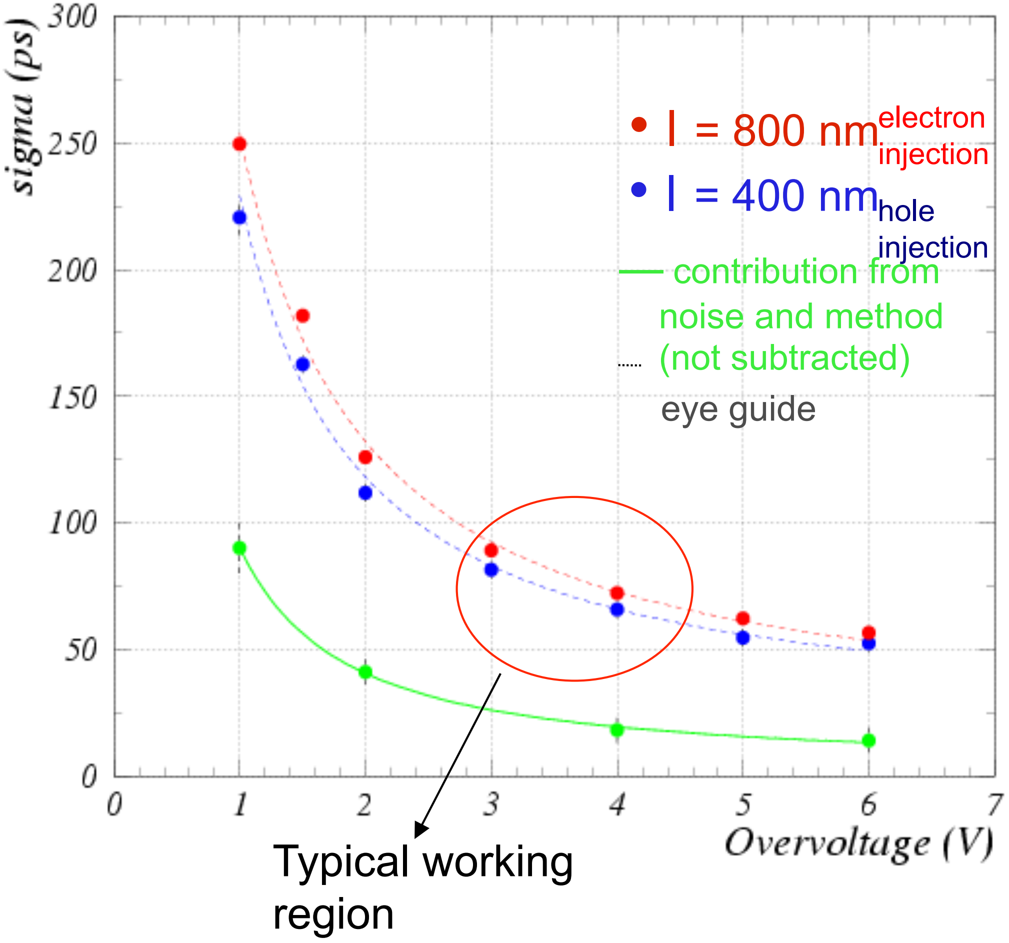
- Care against HF noise → feed-throughts !!!
- Amplifier Photonique/CPTA (gain~30, BW~300MHz)



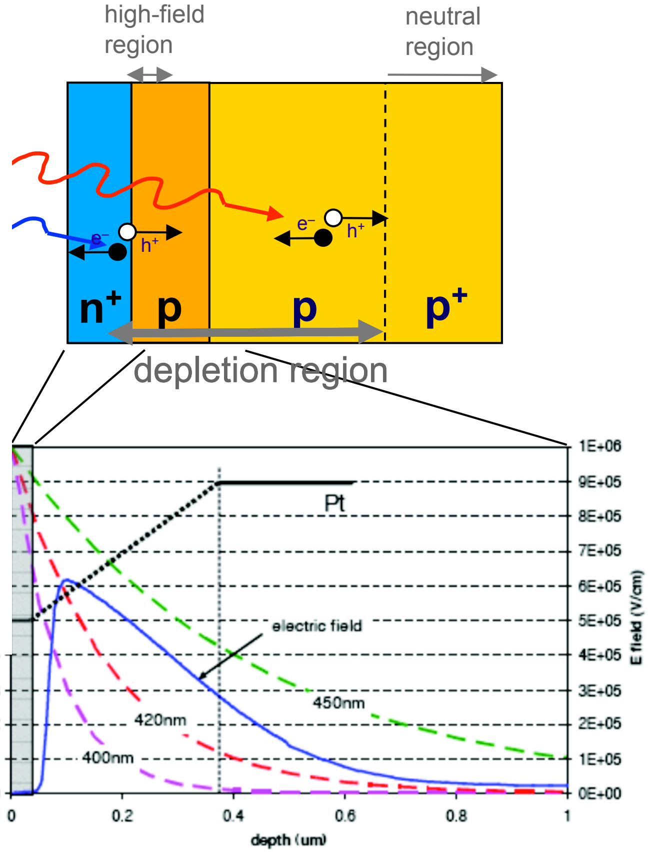
SiPM samples

- FBK SiPM runII – 1mm^2 (Vbr~33V, fill factor~20%)

IRST – single photon timing res. (SPTR)

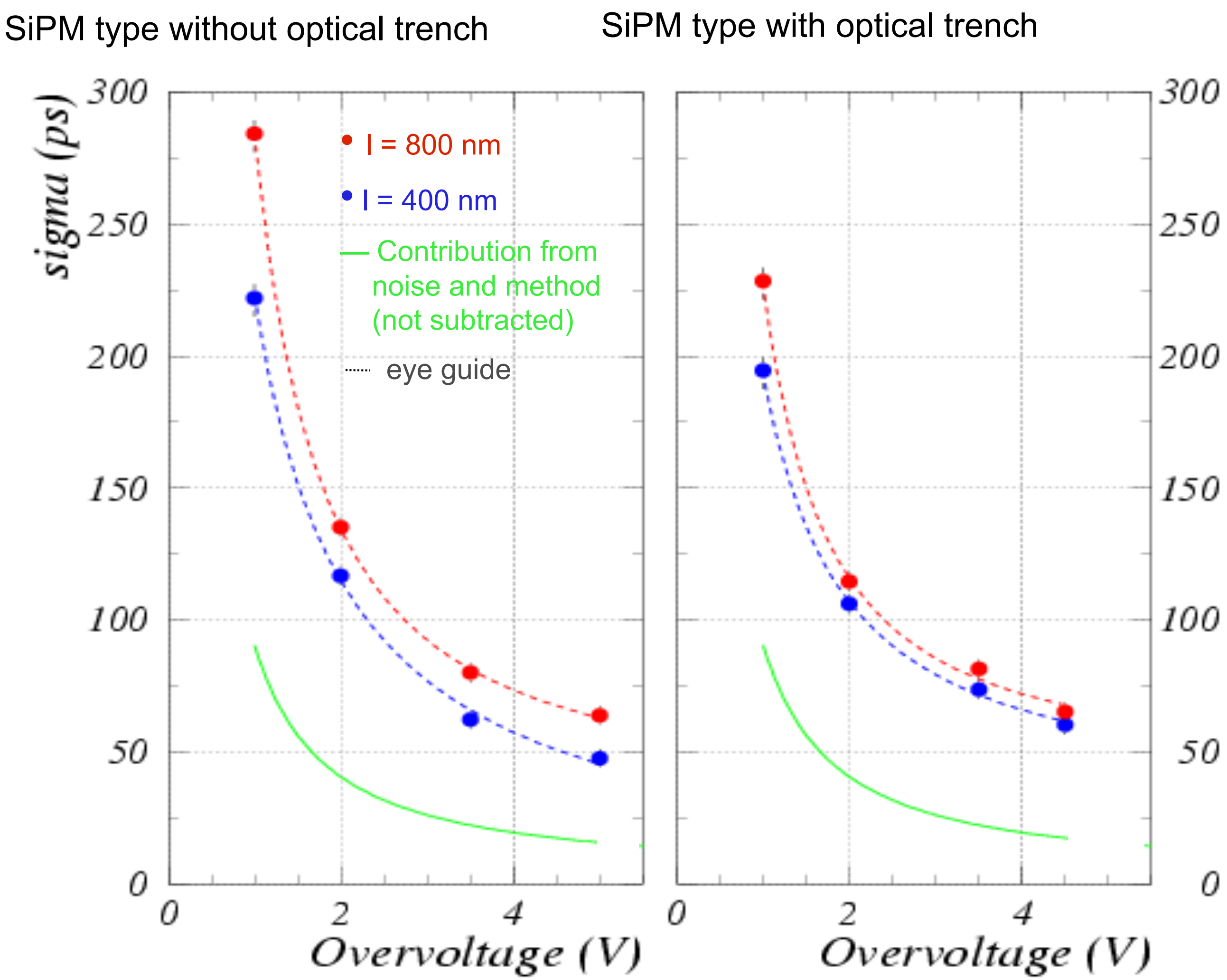


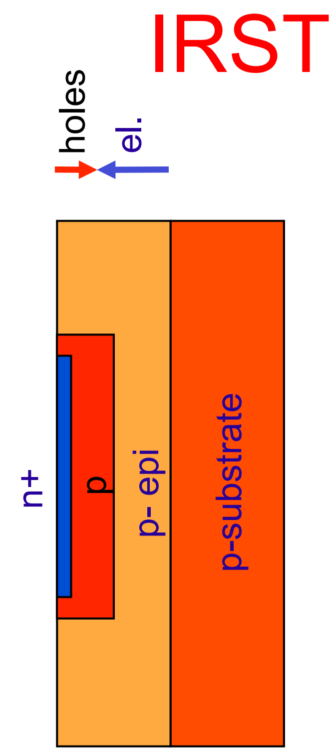
Better resolution for short wavelengths: carriers generated next to the high E field region



G.Collazuol et al NIMA 581 (2007) 461

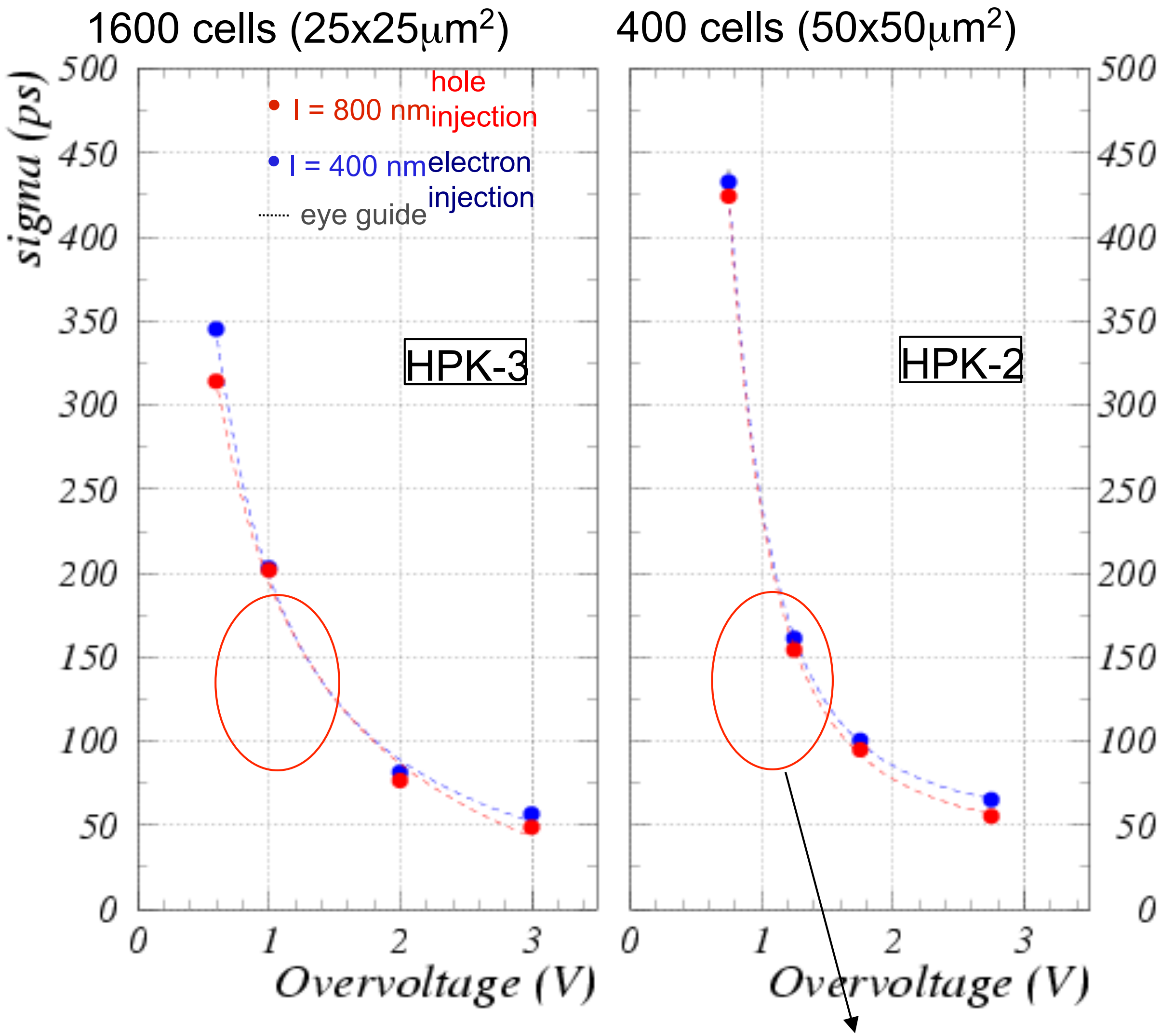
IRST devices (different types)

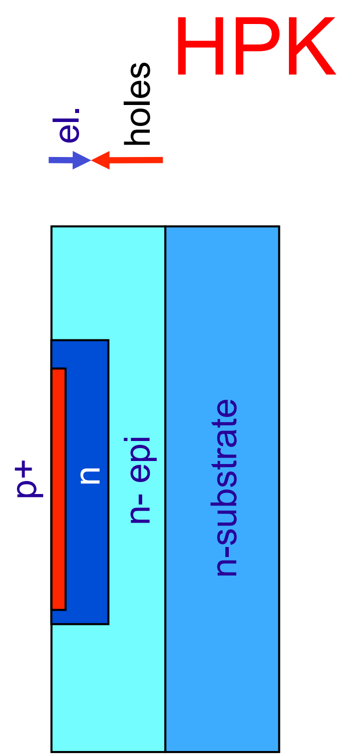




Results in fair agreement for devices with the same structure

Hamamatsu – single photon timing res.





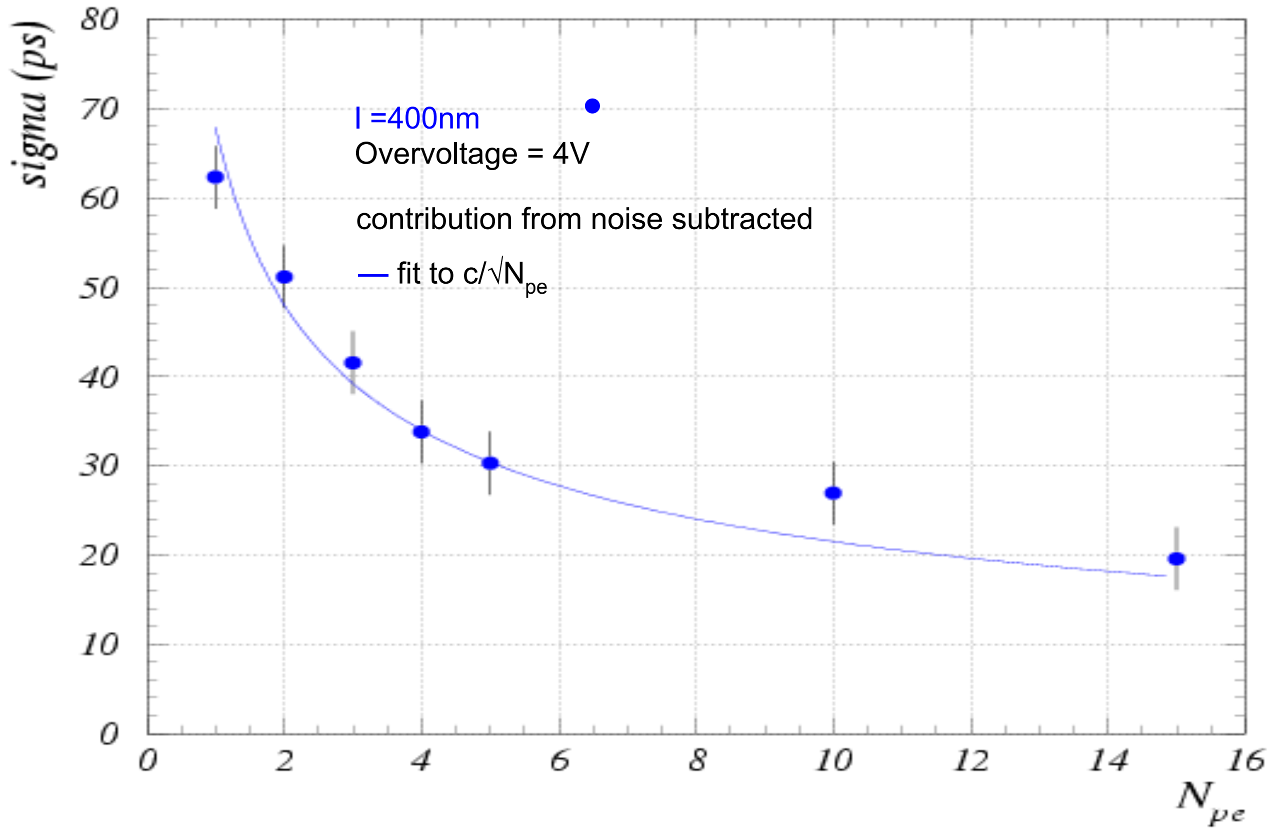
G.Collazuol et al (unpublished)

Suggested Operating range

Timing studies

Dependence of SiPM timing on the
number of simultaneous photons

Poisson statistics: $s_t \propto 1/\sqrt{N_{pe}}$



N of simultaneous photo-electrons

Conclusions

SiPM behave very well at low T, even better than at room T

In the range 100K<T<200K SiPM perform optimally;
→ excellent alternatives to PMTs in cryogenic applications (eg Noble liquids)

- Breakdown V decreases non linearly with T
  → stability of devices wrt T is even better at low T
- Dark rate reduced by orders of magnitude
  → different (tunneling) mechanism(s) below ~200K
- After-pulsing increases swiftly below 100K
- Cross-talk and Gain (detector capacity) are independent of T (at fixed Over-V.)
- PDE higher than at T room at low T for short λ

I just carried on **additional measurements at low T** with short laser pulses for:
- accurately measuring of after-pulsing characteristic time constant(s) vs T
- cross-checking PDE (pulsed vs current method)
- measuring timing resolution vs Temperature (expected to improve at low T)
- checking Gain resolution at low T

Simulations and modeling going on to understand better After-Pulsing and PDE features at low T

We measured also the **excellent SiPM intrinsic timing resolution (<100ps for 1p.e.)**
Recent additional measurements to be analyzed (time to avalanche, different devices, ...)
Simulations and modeling work going on to understand timing data in more detail

Workplan fo Task 1

TASKS/Subtasks	**2009**				**2010**				**2011**			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. LOW LEVEL LIGHT DETECTION AND SINGLE PHOTON READOUT												
1.1 Study of the effect of cooling on noise for different SiPM				1								
1.2 Evaluation of timing with cooled SiPMs				2								
1.3 Setting up a majority logic with single photon threshold												
1.4 Planning a 2-dimensional array						3						
1.5 Study of light concentrator technique and construction						4						
1.6 Construction of a 64 pixel prototype matrix (5x5cm^2)												
1.7 Test in beam												
1.8 Planning of matrices with higher PDE >30 %												

Milestones:
1 Report on cooling of SiPM's
2 Evaluation of timing properties of cooled SiPM's performed
3 Design of a two-dimensional array performed
4 Design of a light concentrator module performed

T2.1: SiPM-coupled advanced scintillating fiber detector

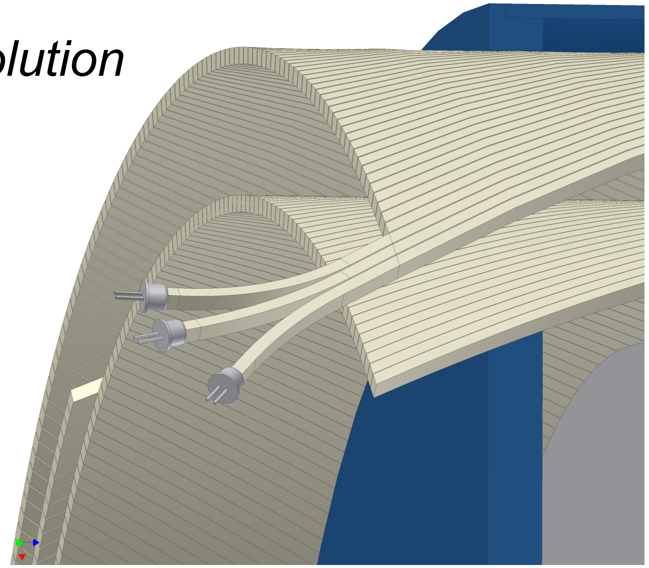
Important parameters of SiMP for low light level detection:

•*Large pixel area for high PDE (> 30 %)*

•*Medium granularity for good linearity and without saturation*

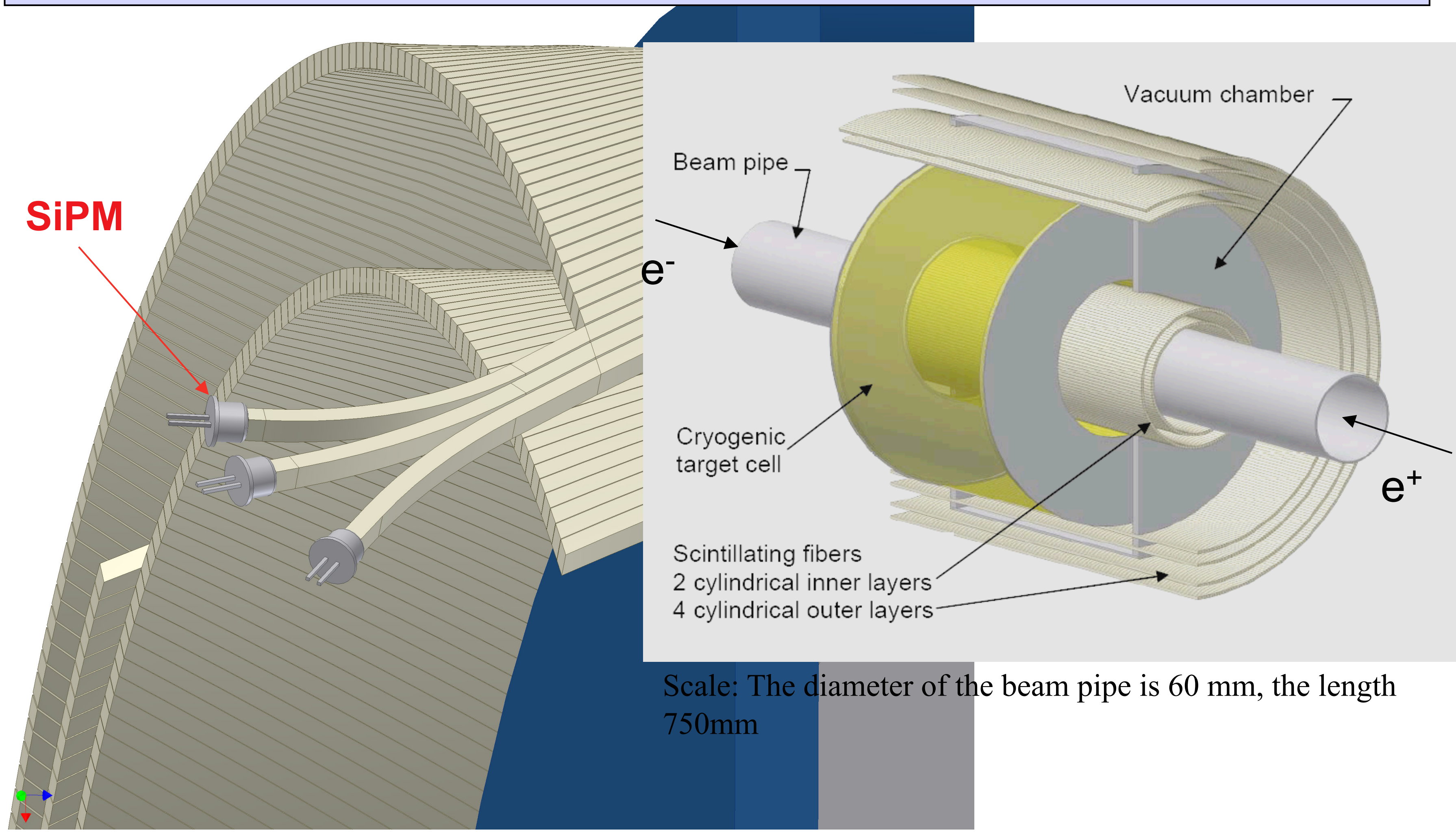
•*Fast single photon response for good time resolution*

•*Working in high magnetic field*



R&D: Prototype for Amadeus central fiber tracker

AMADEUS fiber tracker within KLOE



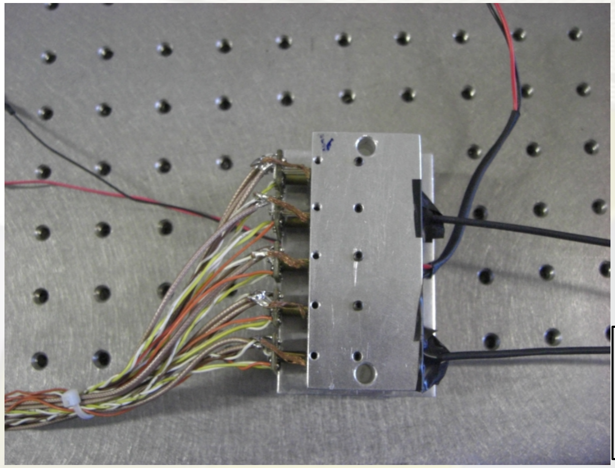
Scale: The diameter of the beam pipe is 60 mm, the length 750mm

Trigger and tracker systems coupled to SiPM

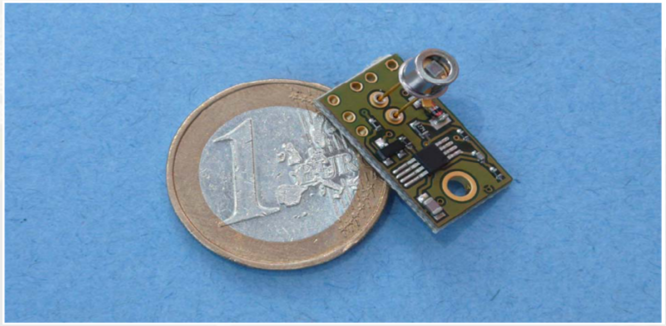
Work at LNF

Characterizing SiPM : HAMAMATSU S10362-11-050U

Experimental setup (we did tests on Photonique as well)



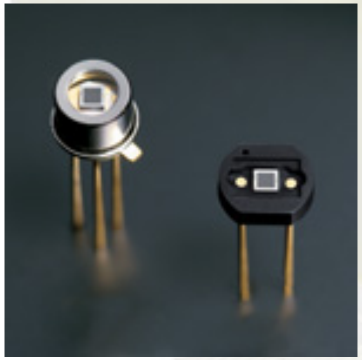
Scintillating fibers
Bicron BCF-10 (blue)

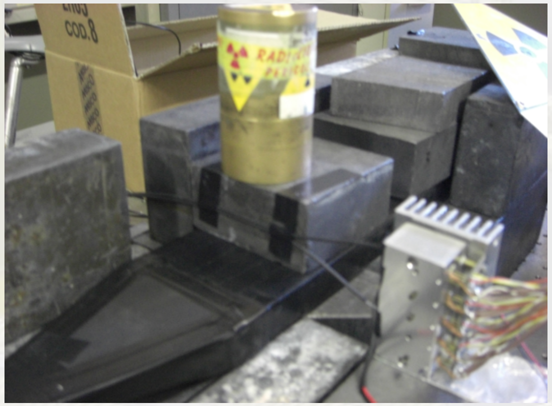


Pre-Amplifiers (X 100)

5 Channles HV power supply (stability better than 10 mV)

SiPM (HAMAMATSU U50) (400 pixels)
Operating voltage ~70V



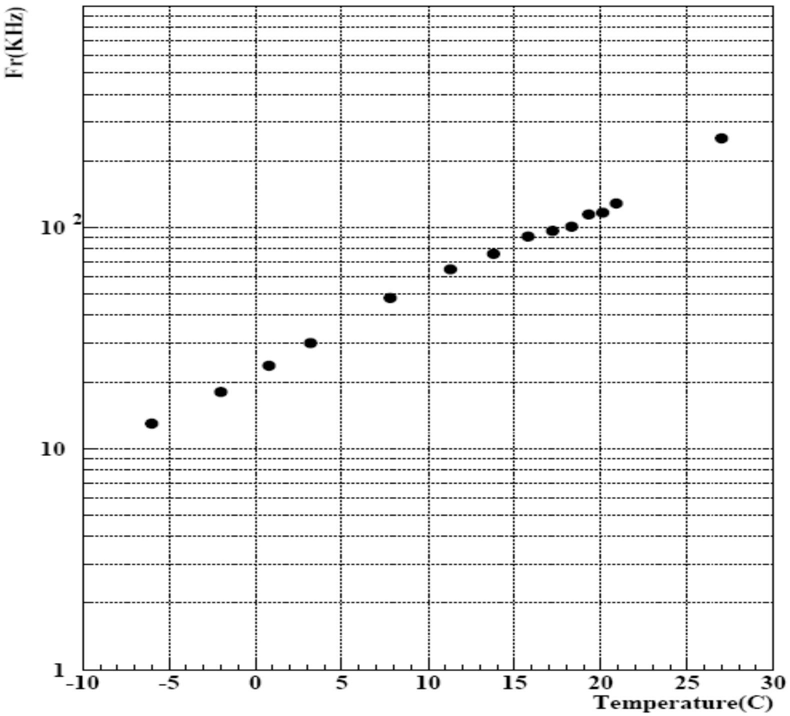


- Sr90 beta source (37 MBq)

Characterizing MPPC: Dark Count

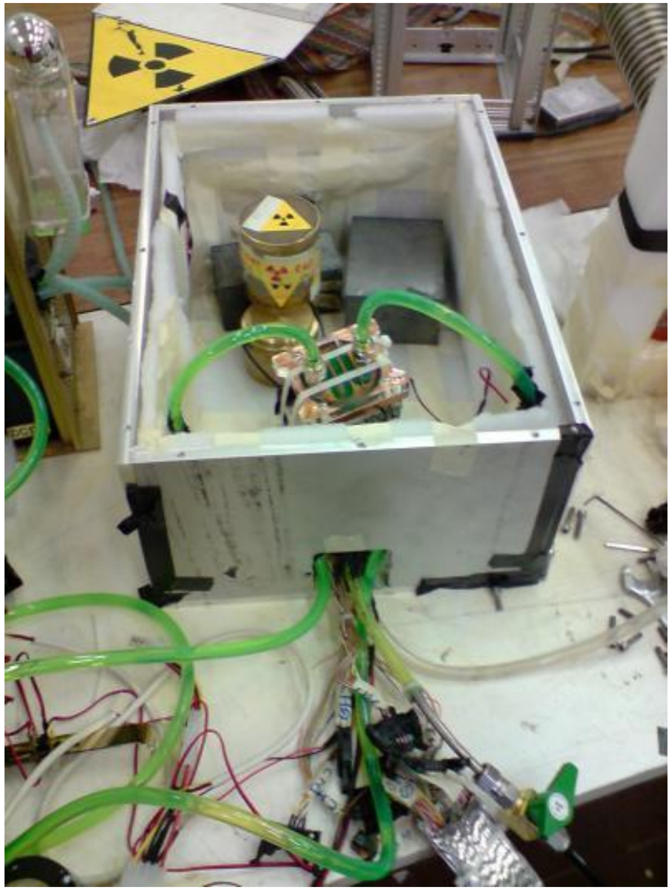
Detectors were cooled down in order to study their behaviour with temperature variations.

A scan of the 1 p.e peak rate is reported



Dark count 1 p.e signal is reduced by a factor 20!

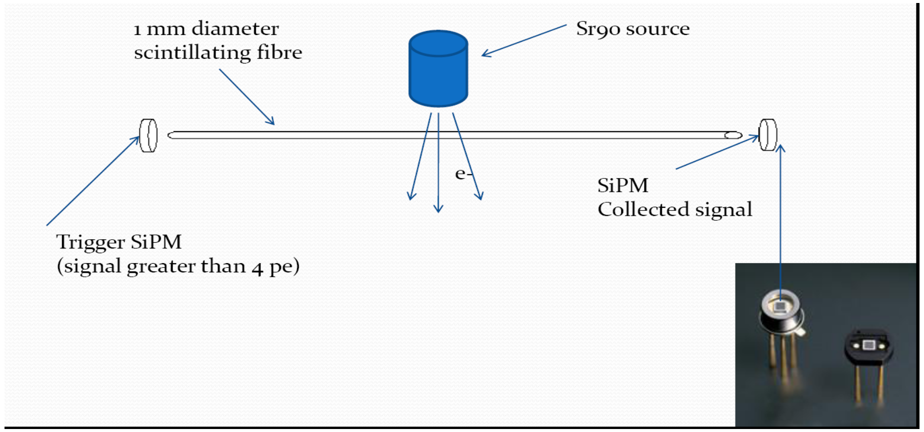
Cooling system

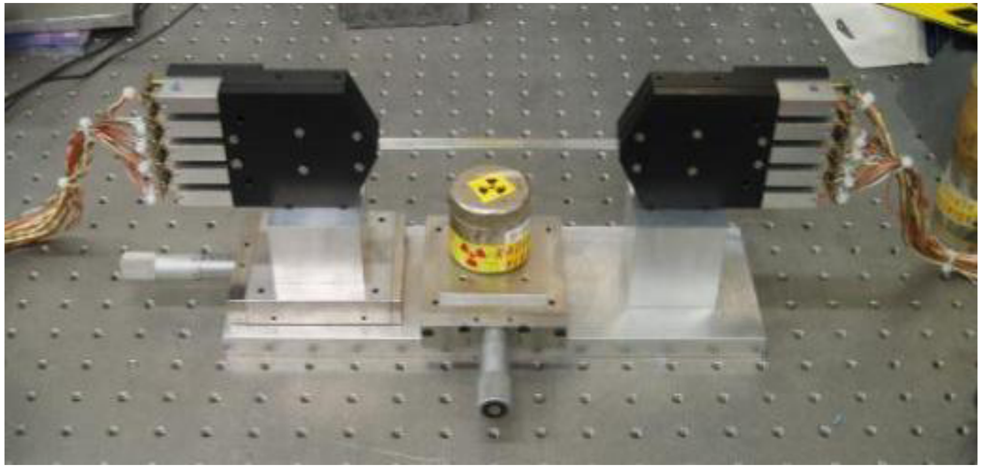


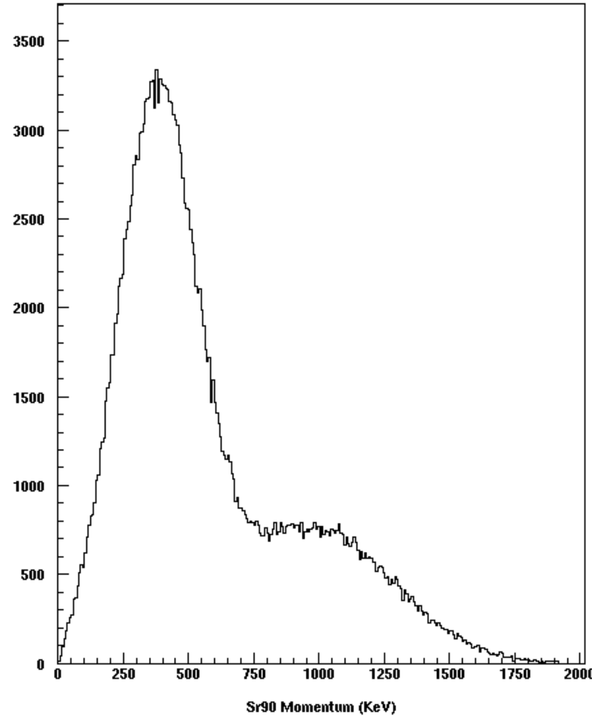
Peltier cell

Work at LNF

Characterizing SiPM: reading scintillating fibers







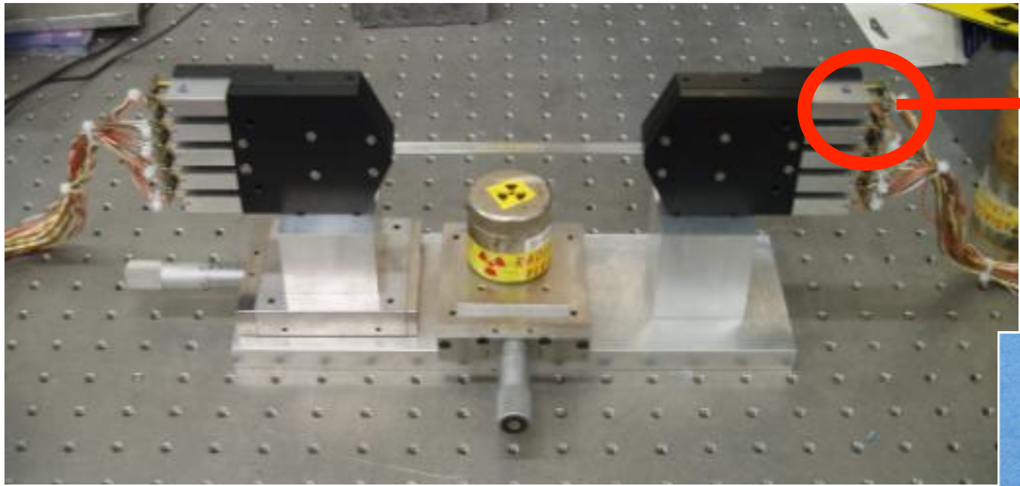
Setting the threshold for the SiPM used as trigger, most part of dark count is eliminated.

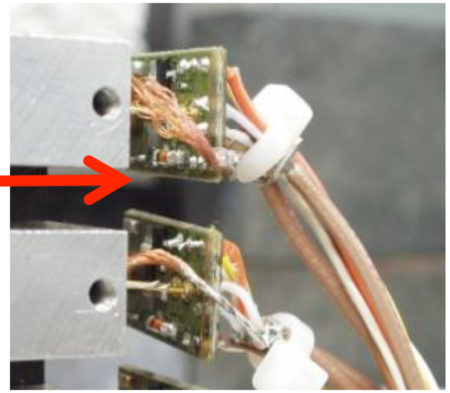
In this way spectra due only to the source can be observed

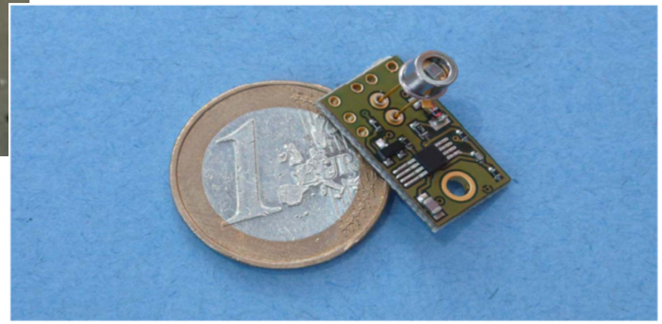
A scintillating fiber is activated by a beta Sr90 source

Both ends are coupled to detectors; one is used as trigger

SiPM+Fibers: ELECTRONICS







Electronics: New NIM modules providing:

- Variable V_{bias} for 5 channels with a **stability for nominal voltages below 10 mV**
- 2 output / channel:
  - -Amplified (x25-x50-x100) signal
  - -Discriminated signal (variable threshold)

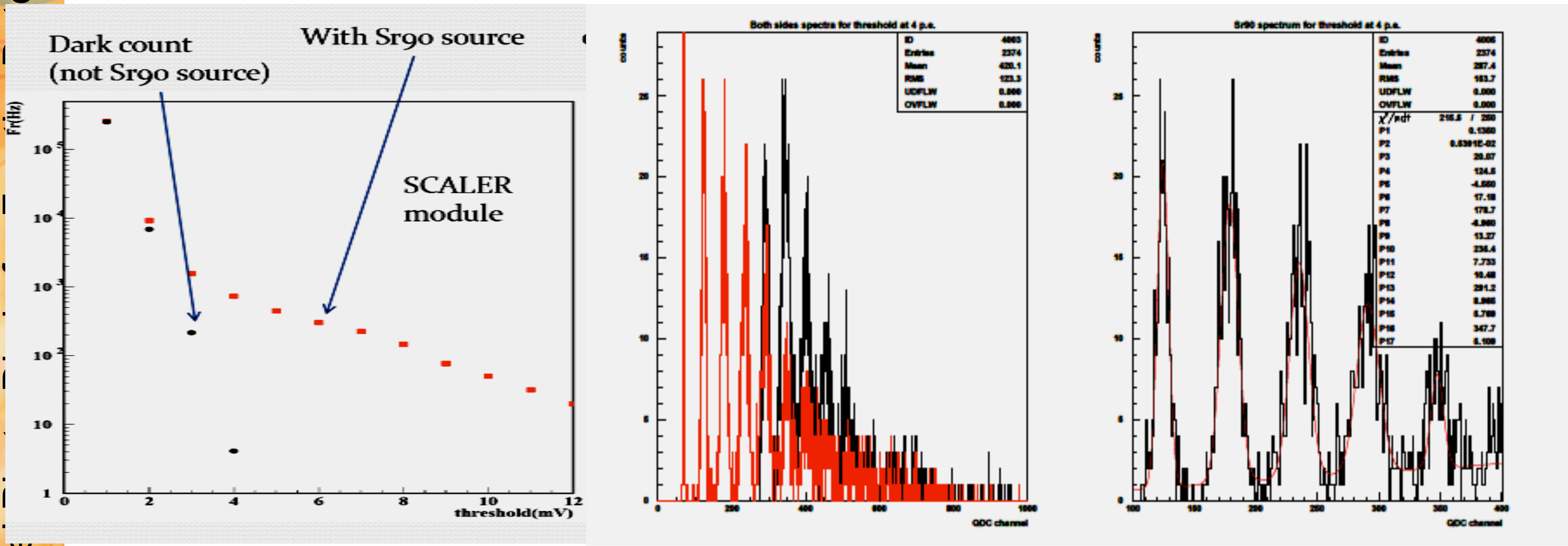
Designed by G. Corradi, D. Tagnani, C. Paglia

Instrumented fibers:

-Saint Gobain BCF- 10 single cladding:

-Emission peak 432 nm
-Decay time 2,7 ns
-1/e 2.2 m
-4000 ph./MeV

SiPM+Scintillating Fibers



* Studying rates with and without the beta source, it turned out that starting from the 4th p.e. Peak, dark count contribute is negligible

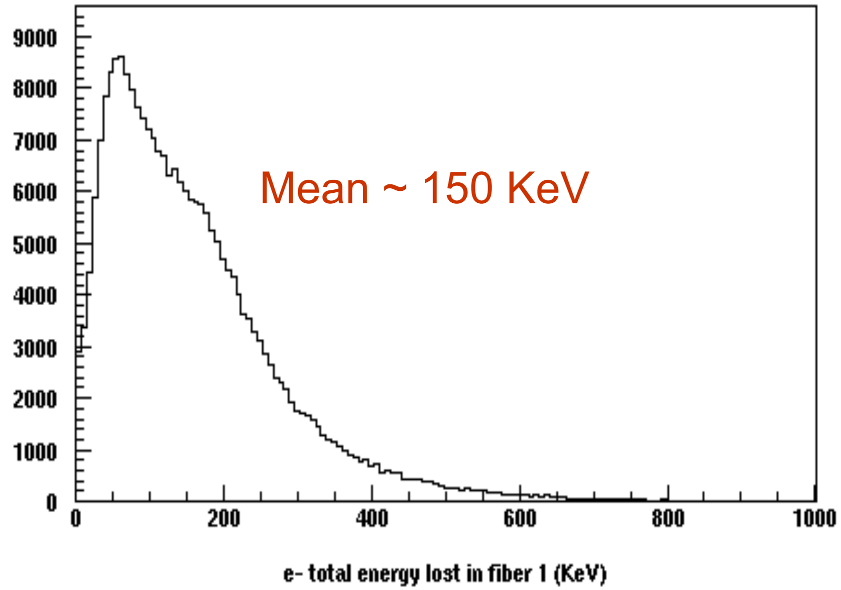
* No cooling is needed in this case!!!!

* With 4 p.e. threshold, main peaks of Sr90 are of 4 and 5 photoelectrons.

Monte Carlo Simulations

Geant3 simulations were done in order to understand how many p.e. should be left by Kaons in DAΦNE

Simulation af a fiber+Sr90 source



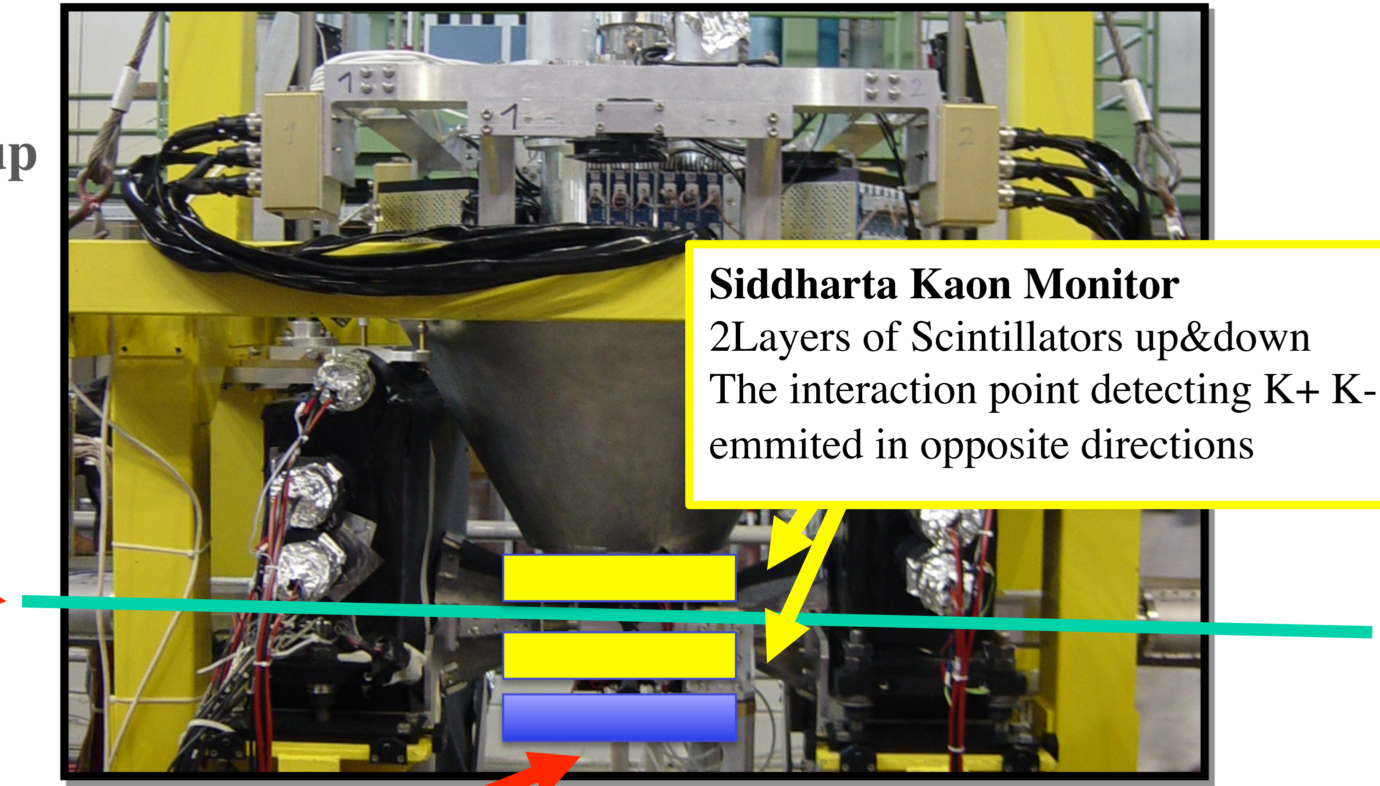
Comparing with experimental data:

Mean energy loss ~ 150 KeV	600 photons (~4000 ph/MeV)
Nominal trapping efficiency ~ 4%	24 photons
Attenuation length ~ 2.2 m (1/e)	22 photons (30 cm)
Q.D.E. ~ 50 %	11 photons
Reading 1 size	5/6 photons

Consistent with lab tests

Tests installation at DAΦNE

SIDDHARTA setup



Trigger system tests: installation at DAΦNE

• Time difference between MIPs and Kaons is ~ 1 ns

•Time difference in AMADEUS will be much less (~ 300/400 ps) because trigger will be placed just around the beam pipe

•High timing resolution is needed!!!!

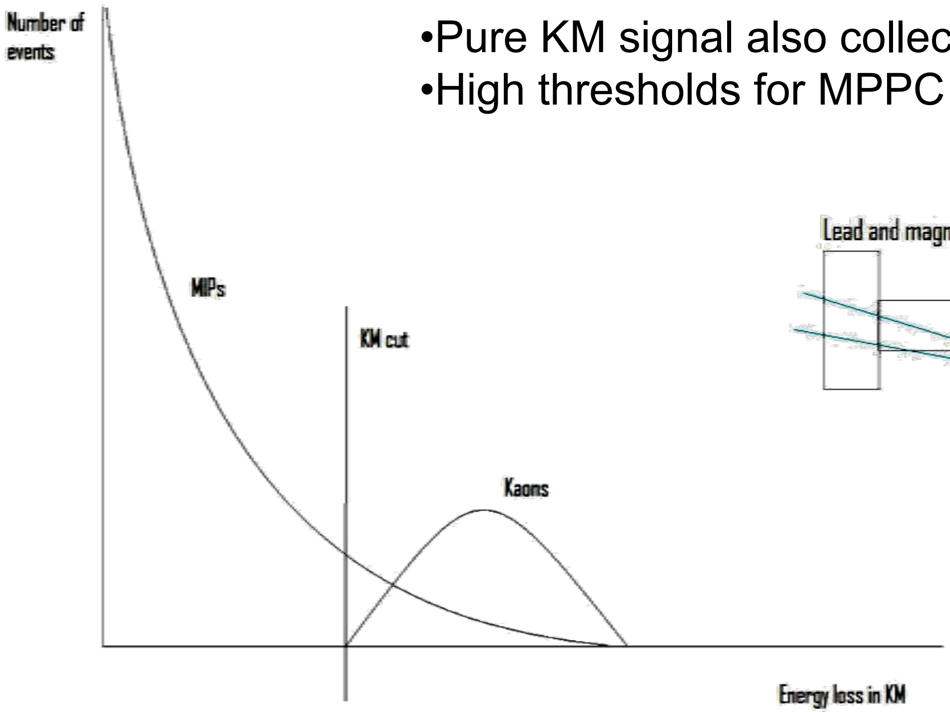
•TDC spectra are needed to understand behaviour of MIPs and Kaons on fibers

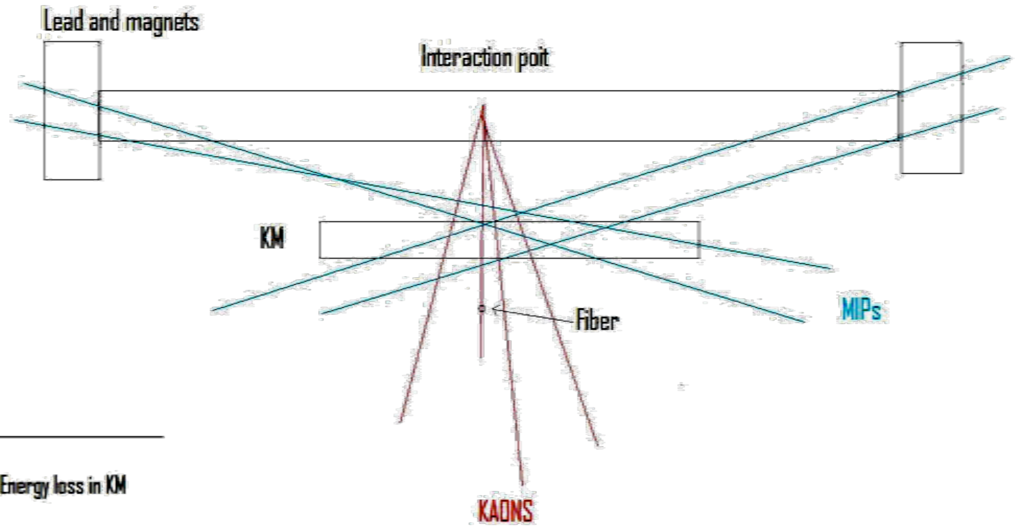
•SIDDHARTA Kaon Monitor can be used as reference

Data taking on DAFNE including KM

MIPs and Kaons

- KM scintillator at 6 cm from Interaction point
- Fibers 5 cm below the lower scintillator
- RF/2 and KM coincidence as gate and stop
- Pure KM signal also collected
- High thresholds for MPPC (above d.c.)

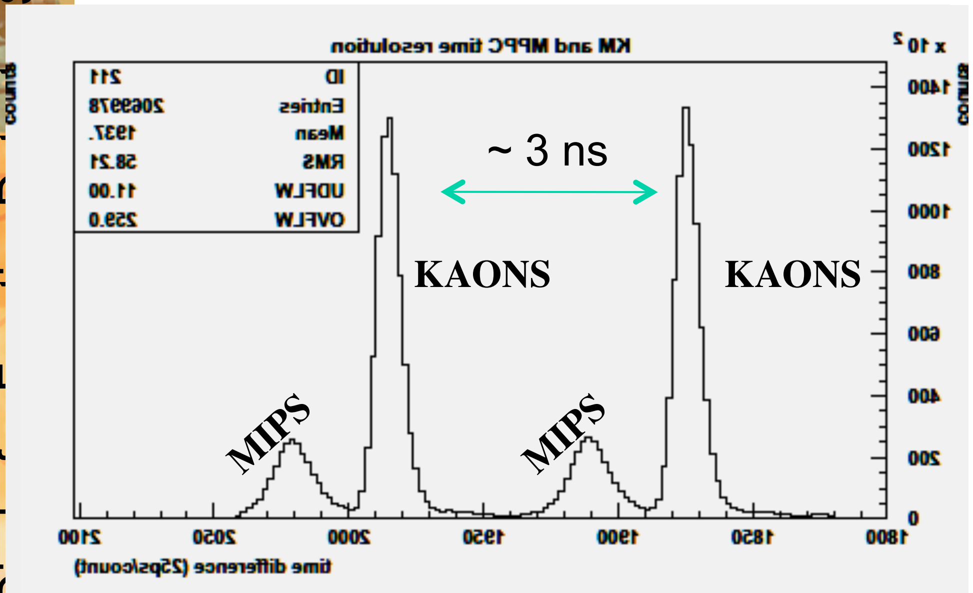




MIPs of high energy tail comes from E.M. Shower which occurs in lead bricks placed as shielding just before interaction region

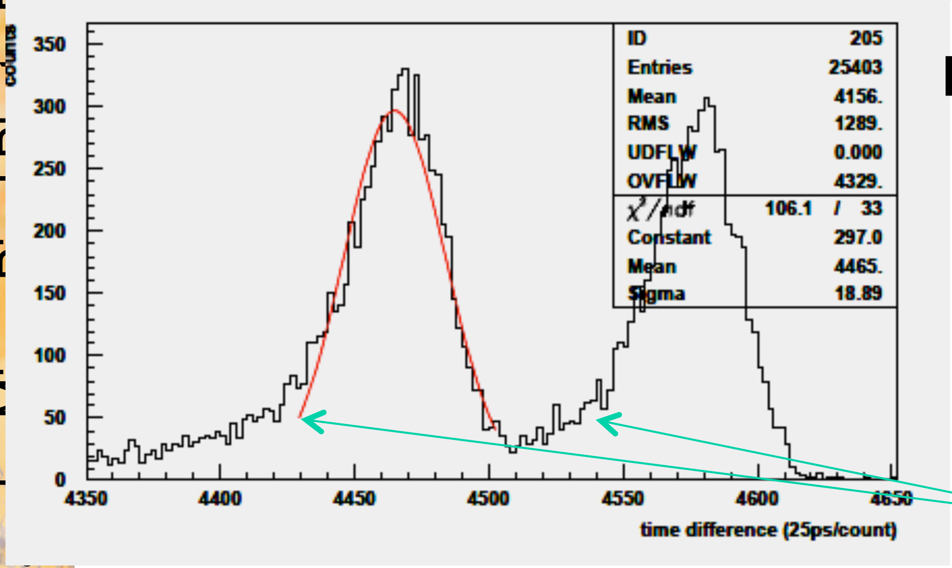
This particles pass with low angle in KM (losing more energy) but not in fibers

Results with Kaon Monitor



Kaon Monitor TDC (upper/lower coincidence)

- TDC working in Common Start (RF/2)
- Single peak resolution~ 100 ps
- MIP/K separation ~ 1 ns



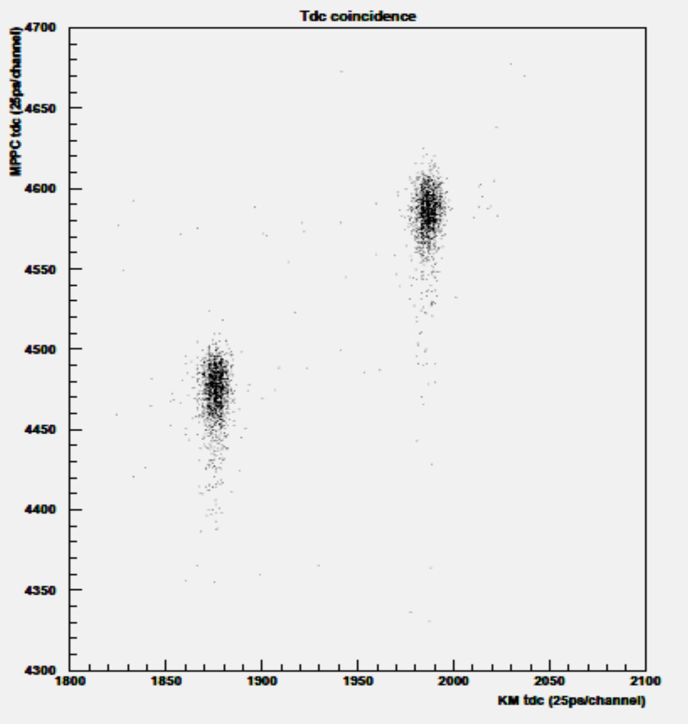
MPPC tdc spectra

- TDC working in Common Stop (RF/4)

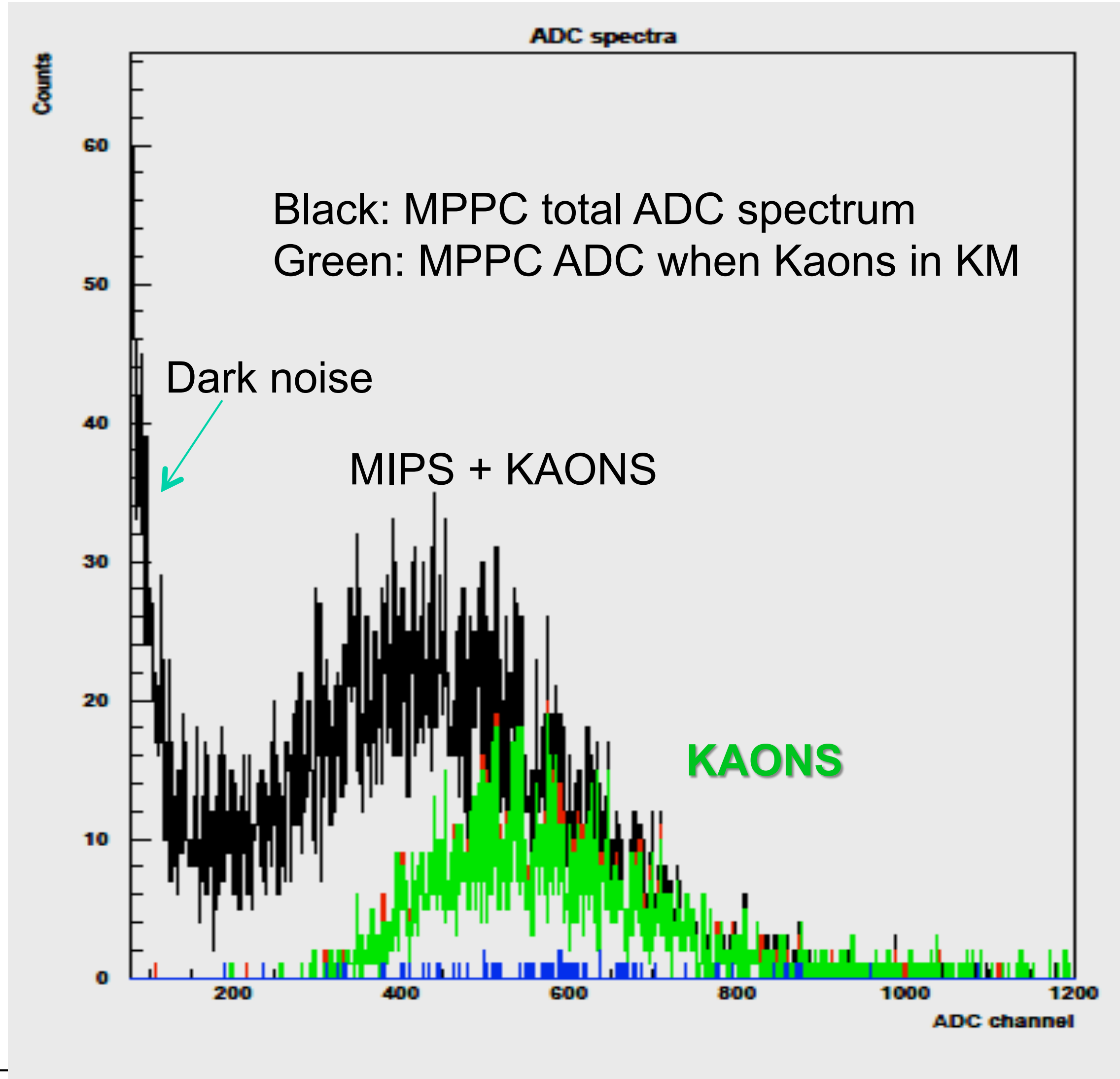
Achieved best single peak resolution around 500 ps

Missing MIPS

Results with Kaon Monitor



Time correlation between MPPCand KM



T2.2: SiPM for fast calorimetry

Important parameters of SiMP for high light level:

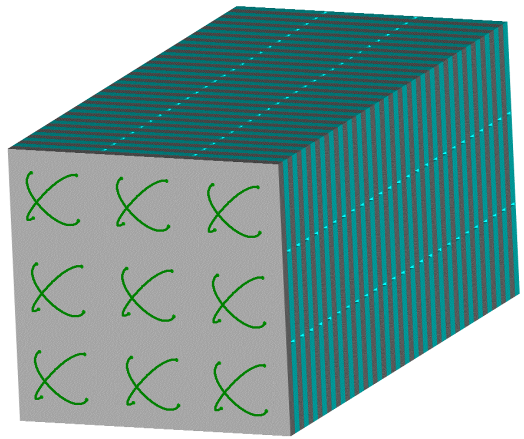
•*Small sensor area with high PDE (30 %)*

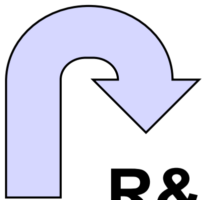
•*Large pixel number for good linearity and avoiding saturation*

•*Fast response for good time resolution*

•*Working in high magnetic field*

•*Sensor noise uncritical*

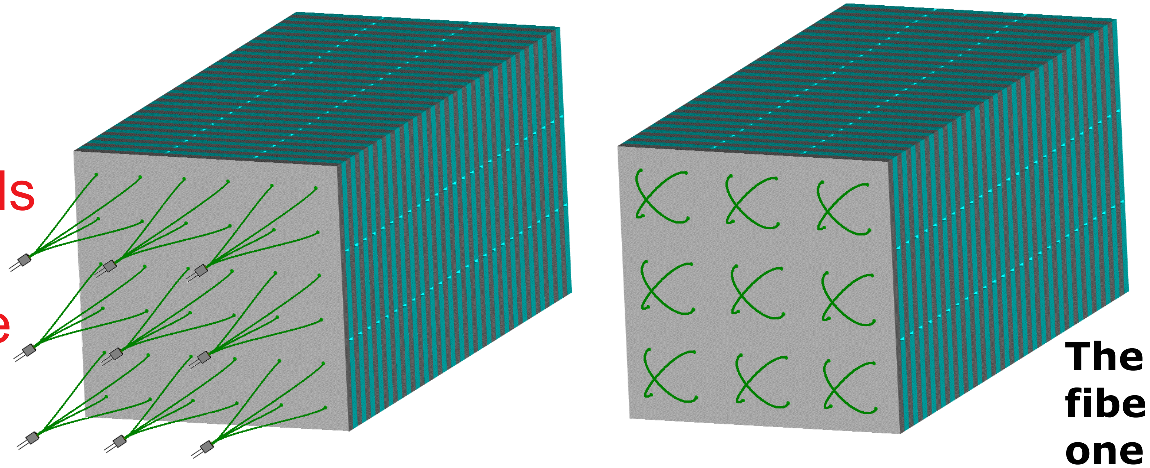




R&D: SiPM for Shashlik modul in COMPASS

Construction of prototype "Shashlik" module with SiPM

9 SiPMs per module



Parameters of the prototype "Shashlik" module for COMPASS.

Transverse size	100 x 100 mm^2
Number of the layers	20 (25)
Polystyrene scintillator thickness	4.0 mm
Lead absorber thickness	4.0 mm
Number of holes per layer	6 x 6
Holes spacing	16.6 mm
Holes diameter in Scintillator/Lead	1.2/1.3 mm
WLS fibers per module	18 x 0.6 m ≈ 11m
Diameter of WLS fiber	1.0 mm, (1.2 mm)
Diameter of fiber bundle	3 mm, (3.5 mm)
Effective radiation length X0	11.5 mm
Effective Moli`re radius RM	20 mm
Active length	160mm /14,5.X0 (200mm/18 XO)
Number of SiMP per module	9

The outputs of 4 fibers are joined into one channel hence we have the grid with 33 x 33 mm cell. Each cell is optically isolated from others. Such calorimeter structure provides good resolution for a few gamma-events in particular the possibility to identify effectively the photons from π^0 decay.

Novel deep micro-well MAPD with super high pixel density and their applications

Anfimov Nikolay

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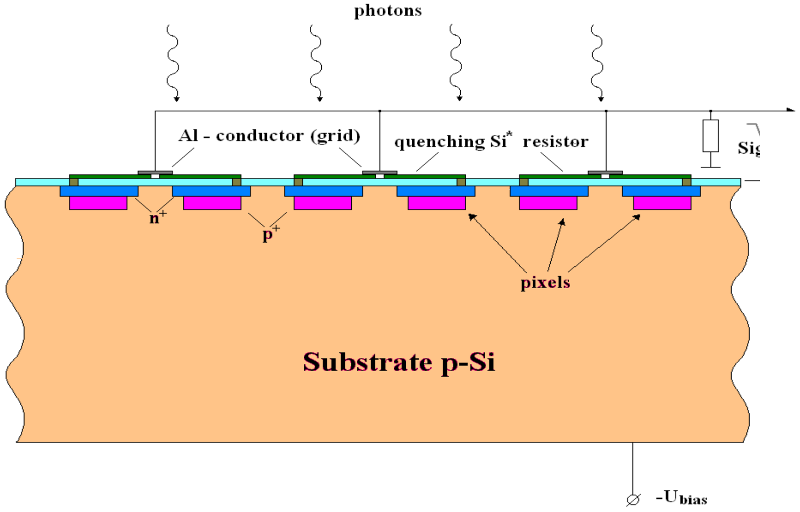
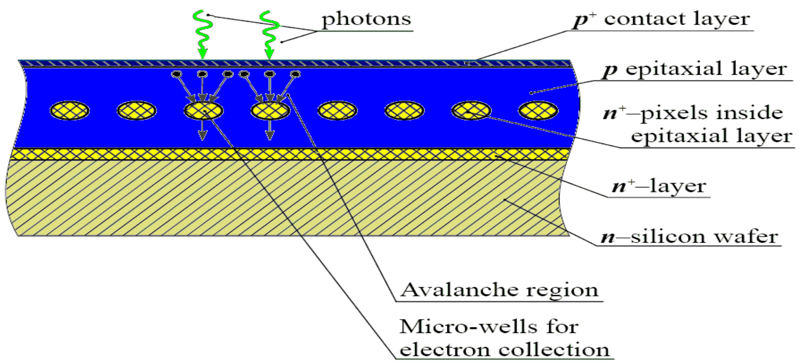
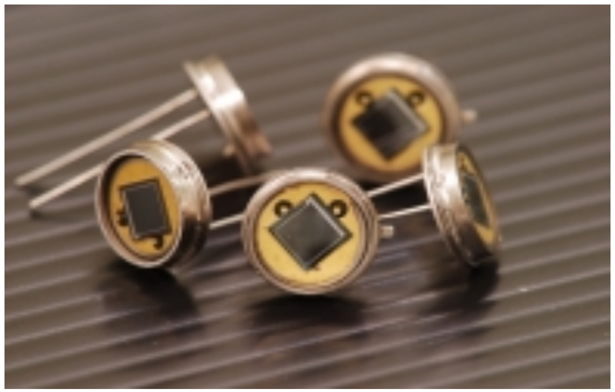
DLNP, Joint Institute for Nuclear Research,
141980, Joliot-Curie 6, Dubna, Russia.

Two basic constructions of MAPDs





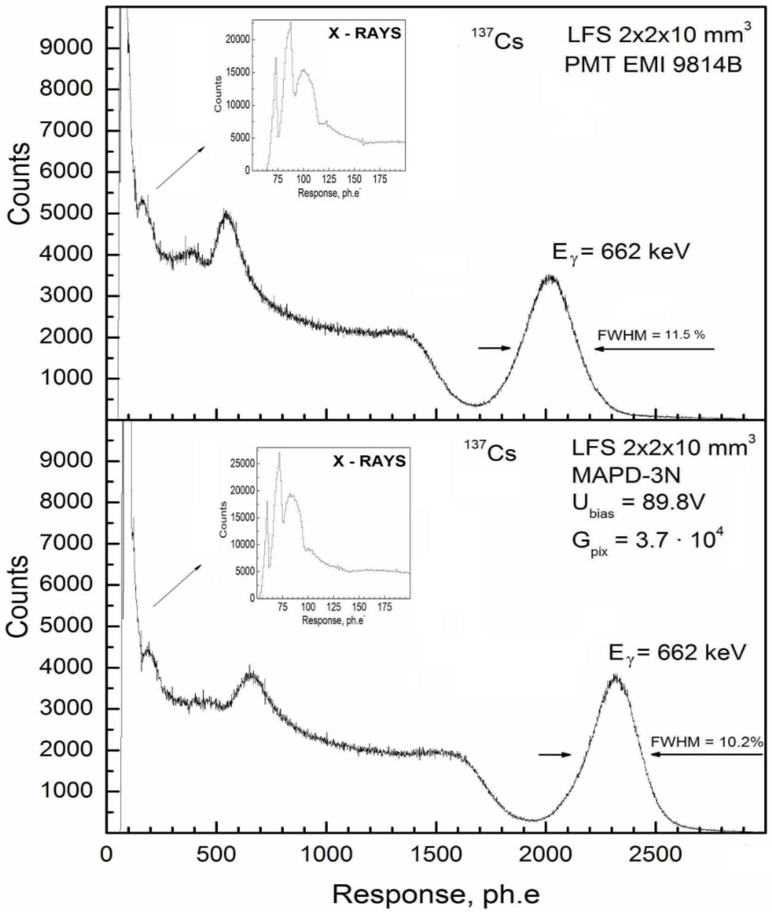


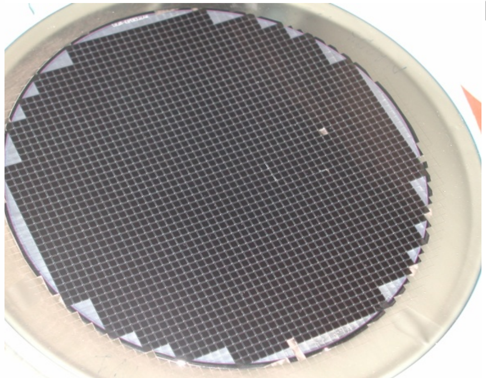
Main Features of DMW-MAPD:

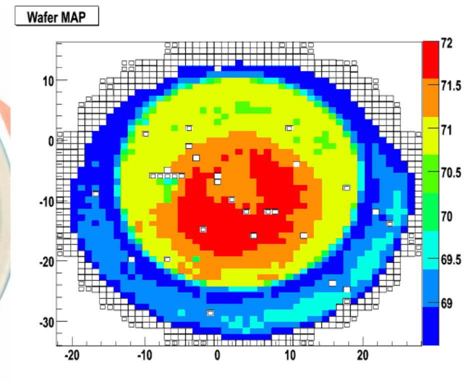
- High Dynamic Range (pixel densities of up to 40000 mm^{-2})
- Photon Detection Efficiency up to 30 %
- Gain up to 10^5
- Better radiation hardness
- Insensitivity to magnetic field.
- Compact and rigid
- Low voltage supply (<100 V)

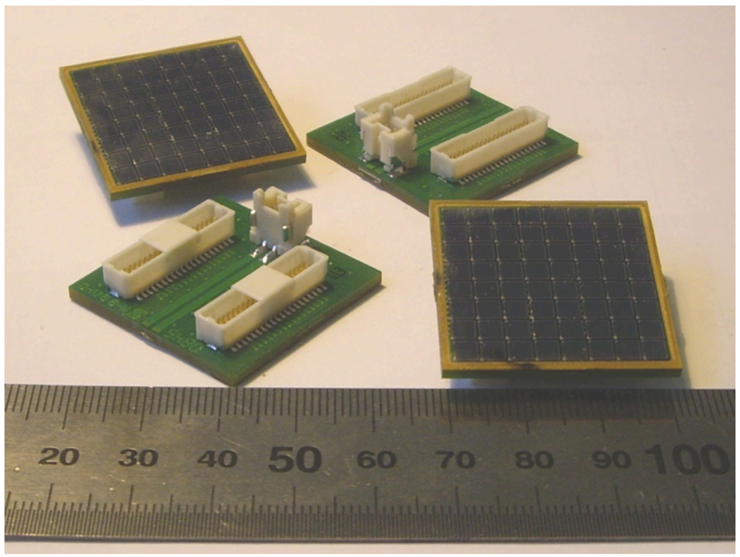
- Drawbacks:
- Temperature dependence
- High dark rate (> 0.5 MHz/mm^2)
- Large Recovery time.

Sensor Matrices from Zecotek/Dubna









EM - Calorimetry

Insensitivity to magnetic field;

High dynamic range ~ 10^5 ph.e.

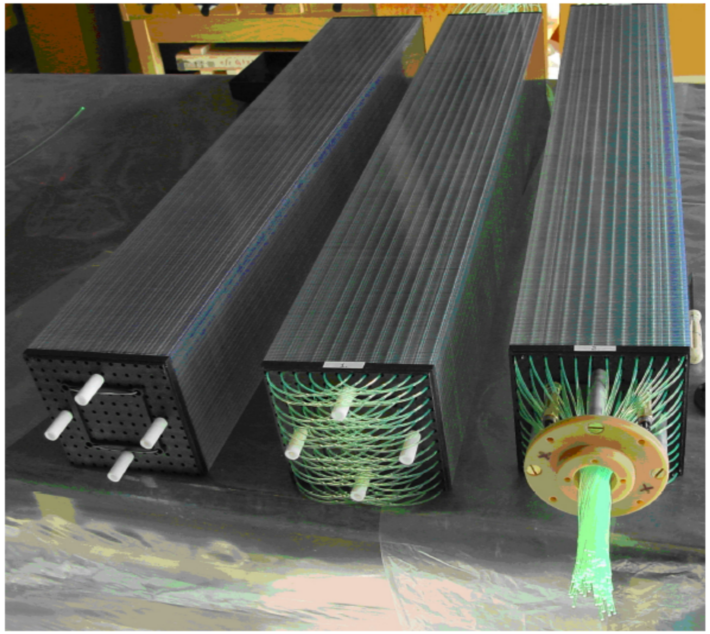
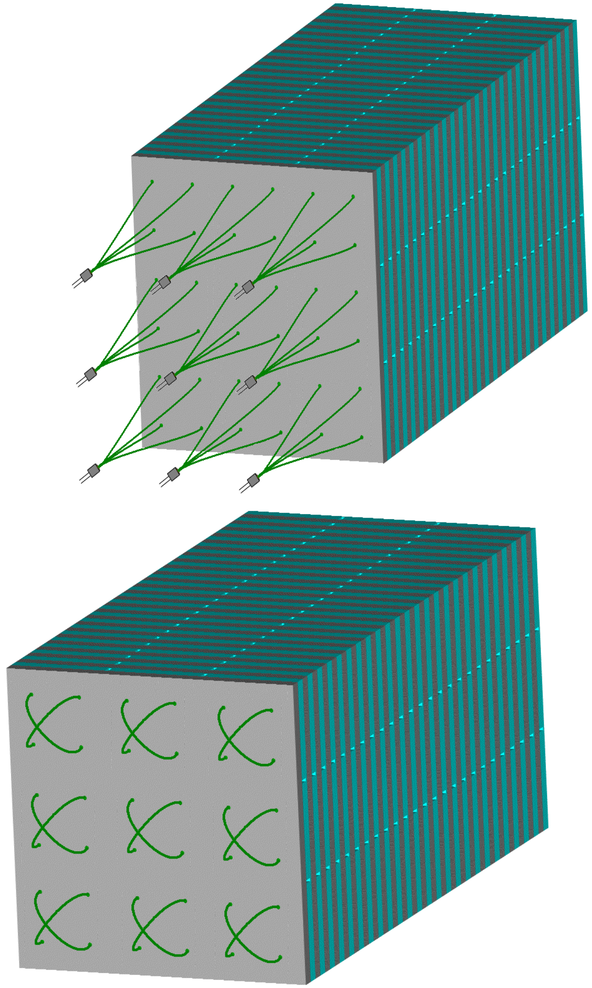
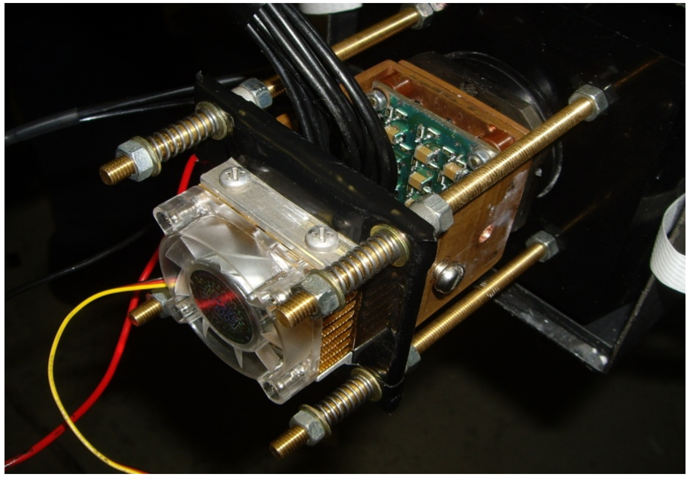


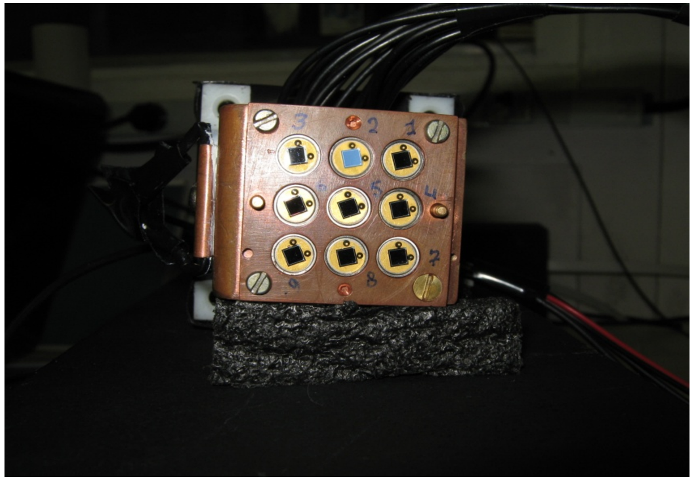
Fig. 1. The Shashlyk modules at different stages of assembly

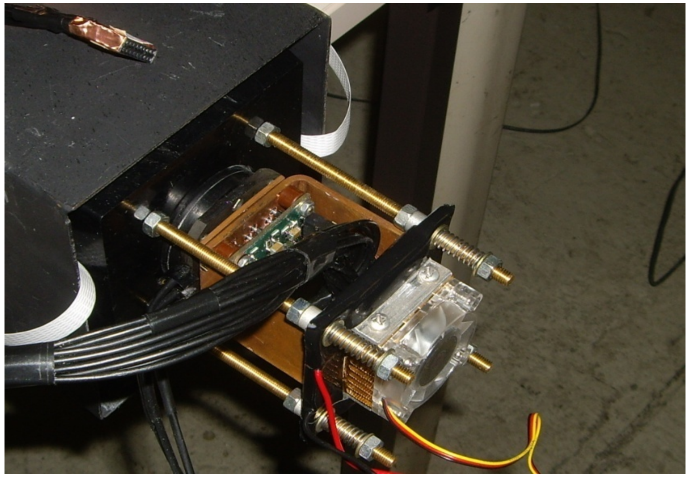


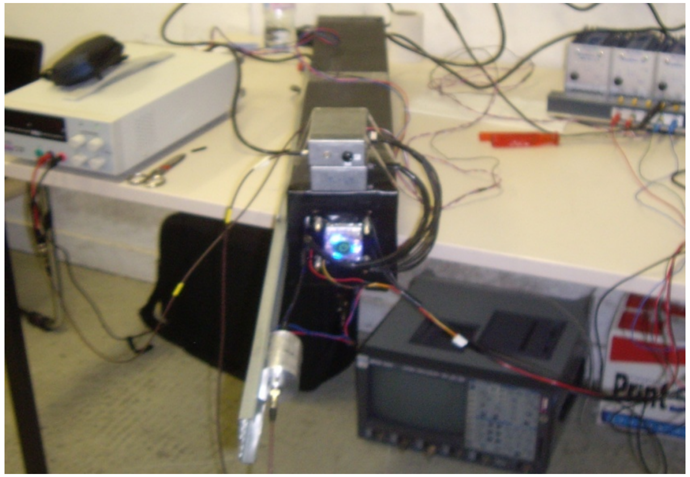
EM - Calorimetry

- General view of the optical head with 9-MAPD mounted on a shashlik module



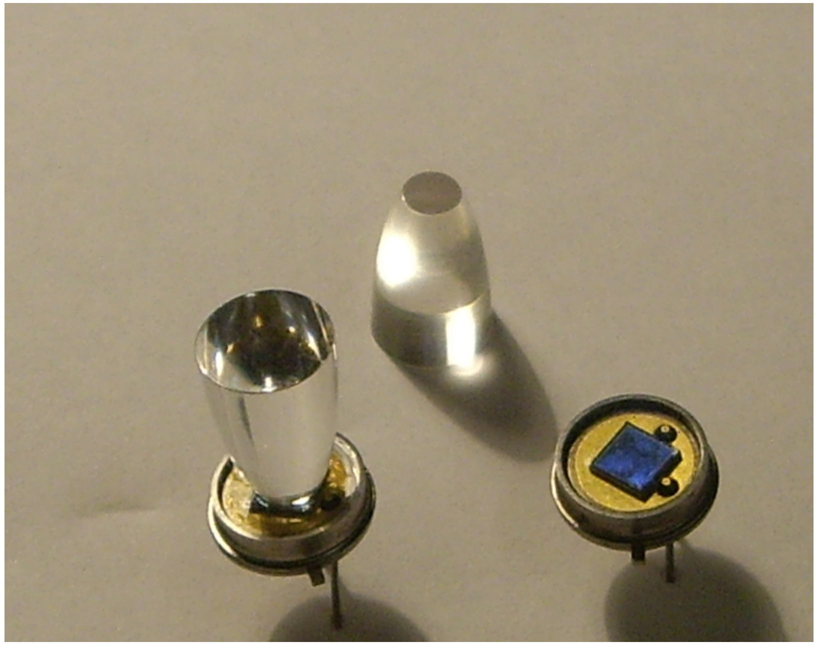


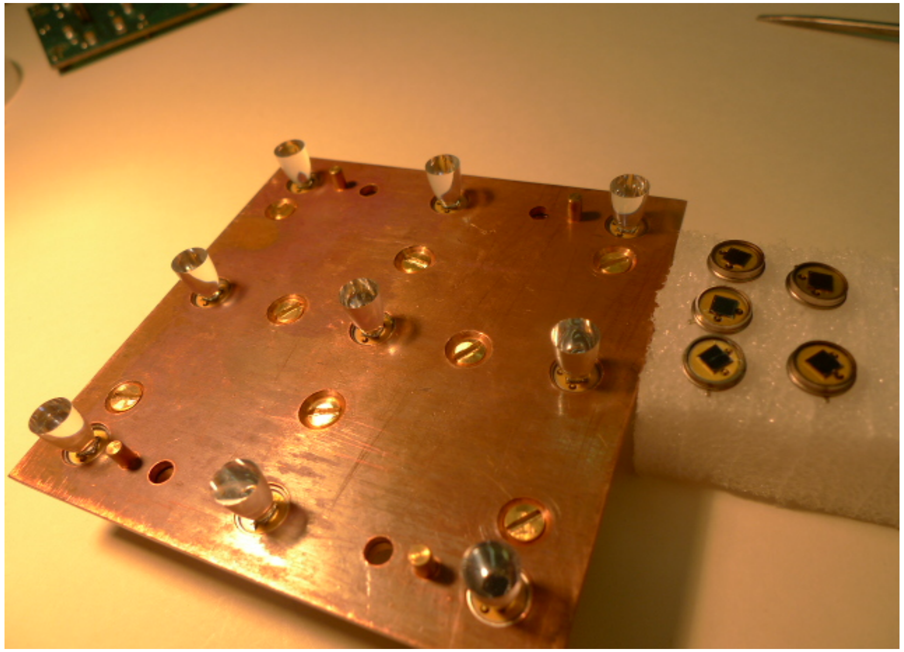




EM - Calorimetry

- Winston's cones allow to collect more light from fibers





Increase of MAPD sensitive area

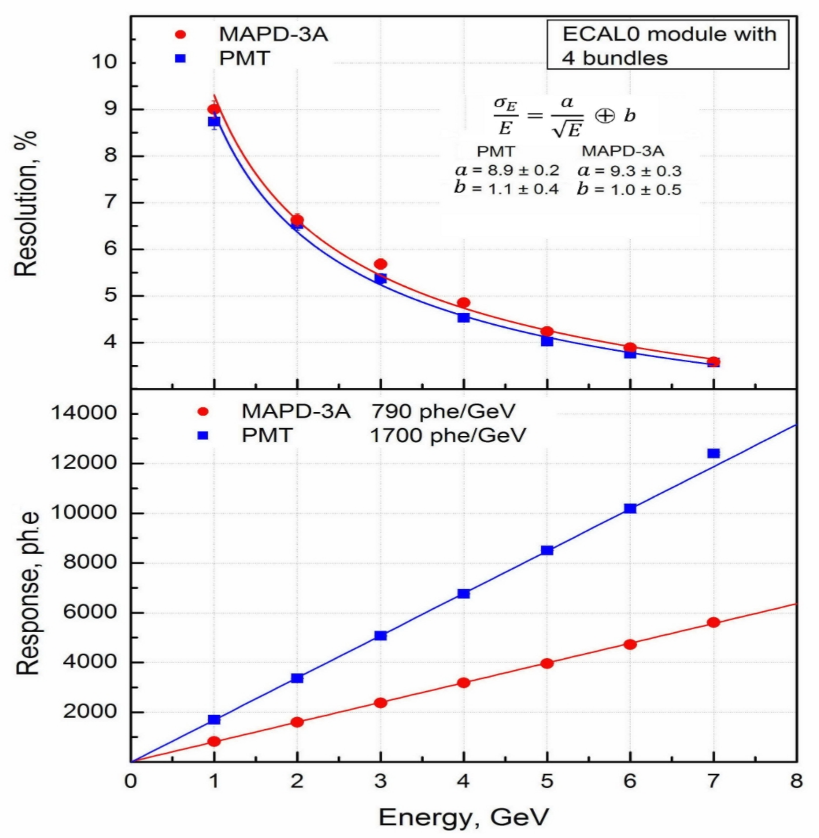
EM - Calorimetry

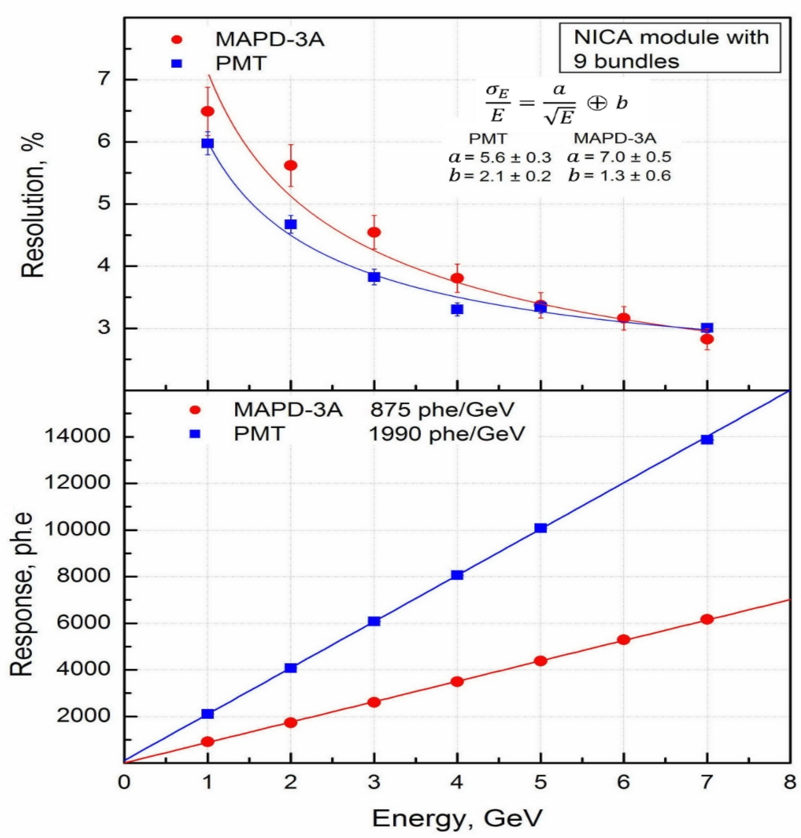
- Parameters of the tested modules:

ECAL0 – 4 bundles	NICA – 9 bundles
Scintillator – 4 mm	Scintillator - 1.5 mm
Lead - 2 mm	Lead - 0.275 mm
Distance between scintillators – 2.36 mm	Distance between scintillators – 0.35 mm
Number of pair – 66 pcs.	Number of pair – 300 pcs.
Size of plates - 121.0×121.0 mm^2	Size of plates - 109.7×109.7 mm^2
Radiation length – 16.4 mm	Radiation length, X_0 – 34.9 mm
Total length – 420 mm (25 X_0)	Total length – 555 mm (15.9 X_0)
Moliere radius – 35 mm	Moliere radius – 59. 8 mm
Number of fibers – 64 pcs	Number of fibers – 144 pcs
Number of bundles – 4 pcs	Number of bundles – 9 pcs
Diameter of fibers – 1.2 mm	Diameter of fibers – 1 mm
Bundle diameter – 6.5 mm	Bundle diameter – 6 mm

EM - Calorimetry

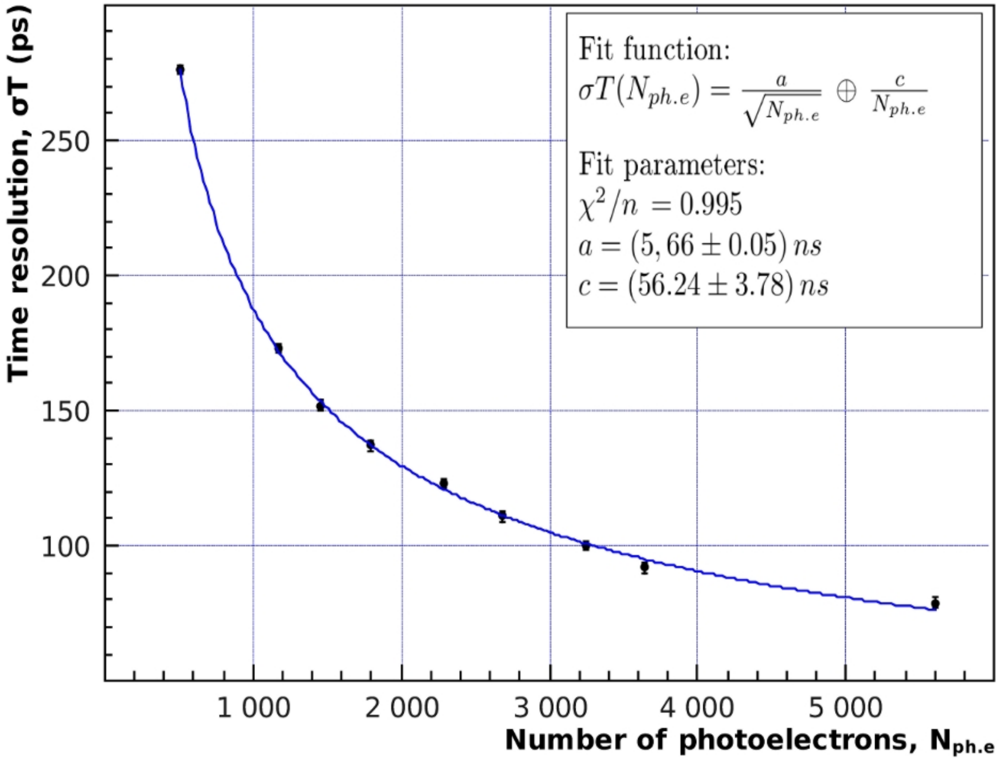
- Energy resolutions for two different modules
- MAPD readout in comparision with PMT readout

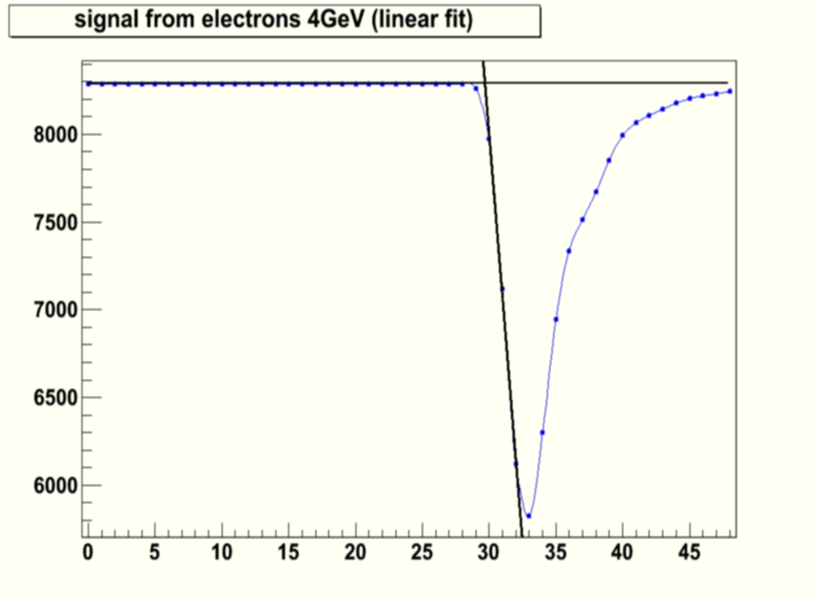




EM - Calorimetry

- Time resolution of one channel (bundle) MAPD-3N



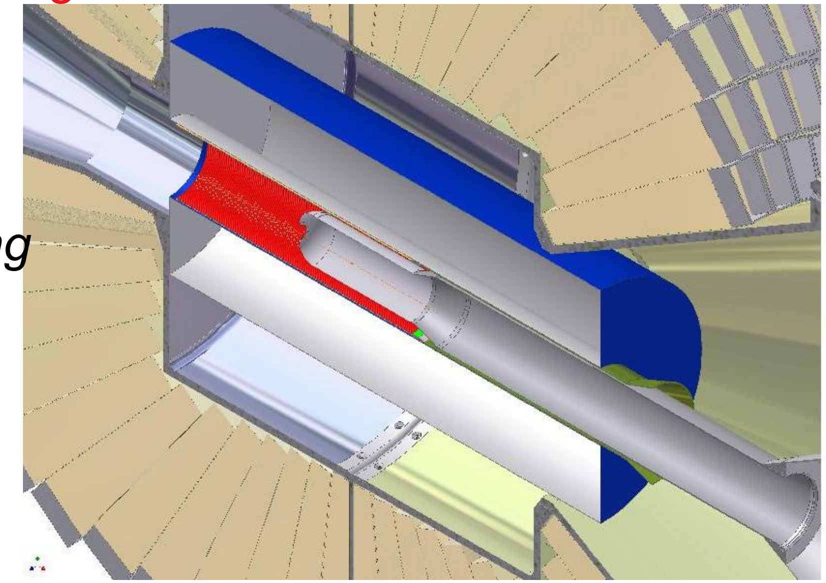


Sampling ADC 100 Mhz
1.6V/14-bit

T2.3: Photon read-out of crystalline fibers with SiPM

Important parameters of SiMP coupled to inorganic fibers:

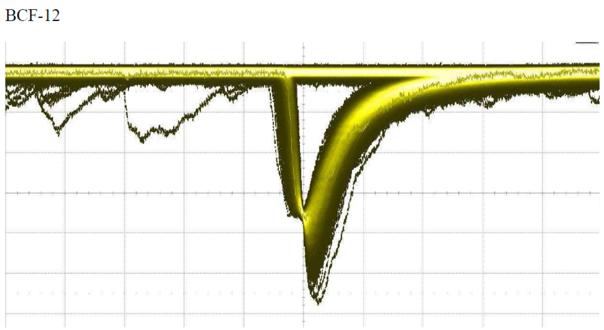
- *Small sensor area high PDE (>30 %)*
- *High granularity for good linearity*
- *Fast single photon response for good timing*
- *Working in high magnetic field*
- *Noise performance uncritical*



R&D: prototype for timing/trigger detector inside Crystal Barrel at ELSA

Closely together with WP21 SciFI

Some tests with inorganic scintillating fibers



BCF-12

At first we used the BCF-12 plastic scintillator fibre which we took already at the tests with the LED pulse.

LYSO

The second one was a transparent LYSO:Ce with a size of 1 x 1 x 50mm. This material is emitting a blue light like the BCF-12.

YAG

The third material was a YAG:Ce ($Y_3Al_5O_{12}:Ce$) with a size of 1 x 0,8 x 50mm. This scintillator is emitting a yellow light.

Workplan fo Task 2

TASKS/Subtasks	**2009**				**2010**				**2011**			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2.1 Evaluation of available SiPMs for SciFi readout												
2.2 Tests of different fiber materials				5								
2.3 Optimization of SiPM coupling to the fibers						6						
2.4 Beam tests: Radiation hardness, aging, rates, etc.												
2.5 Data analysis and results of feasibility study												
SCINTILLATING FIBERS												
2.6 Evaluation of available SiPMs for SciFis				7								
2.7 Optimization of fiber coupling to SiPM												
2.8 Construction of small prototype												
2.9 Development of readout system						8						
2.10 Tests of small prototype detector												
2.11 Analysis of results of feasibility study												
WAVE-LENGTH SHIFTING FIBERS												
2.12 Survey and ordering of available samples of SiPM												
2.13 Optimization of SiPM and material						9						
2.14 Construction of electronics for read-out												

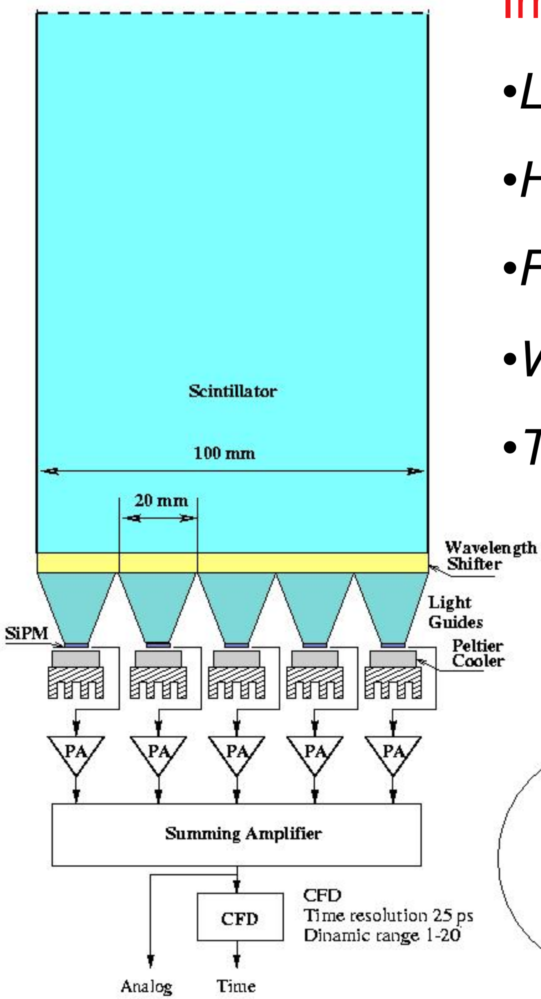
Workplan fo Task 2 (cont.)

TASKS/Subtasks	**2009**				**2010**				**2011**			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2.15 Test of small prototype												
2.16 Test data analysis and report												

Milestones of task 2

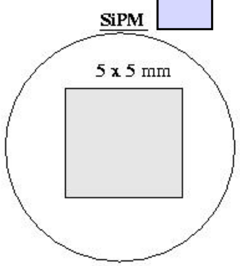
5 Test of different fiber materials performed
6 Efficient light coupling in small dimensions obtained
7 Evaluation of SiPM's for SciFi's performed
8 Readout system, end of development methodology and work plan
9 Design of a small prototype module performed

T3:Ultra-fast timing with plastic scintillators for TOF applications using SiPMs



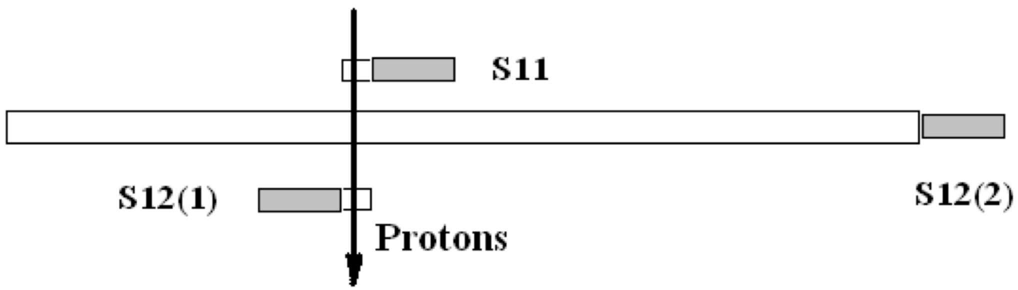
Important parameters of SiMP:

- *Large area for high PDE (>30 %)*
- *High granularity for good linearity*
- *Fast single photon response for extreme time resolution*
- *Working in high magnetic field*
- *Temperature stabilization*

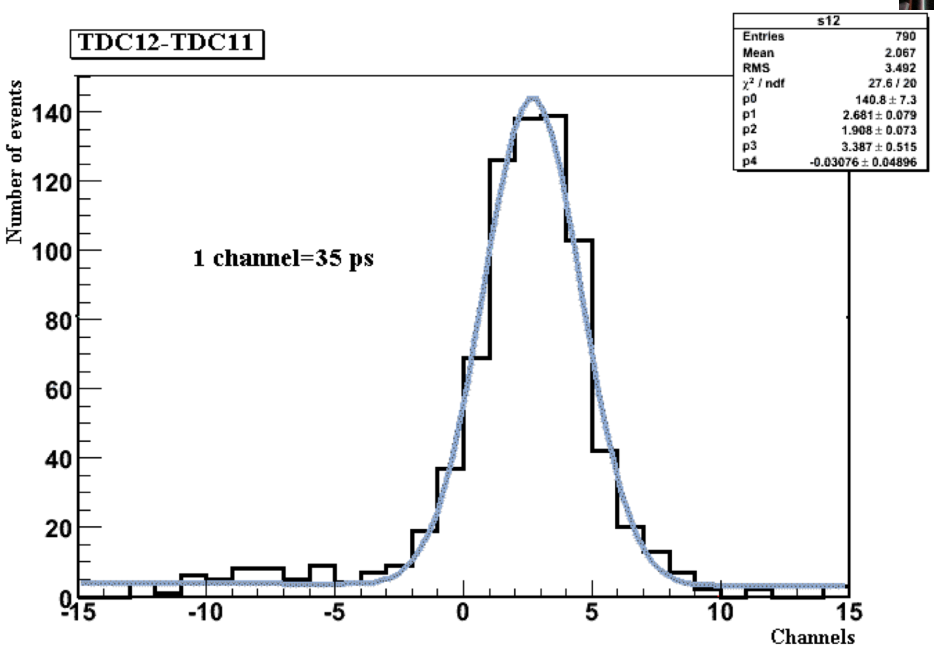


R&D: prototype of SiPM-coupled scintillator slab for TOF wall

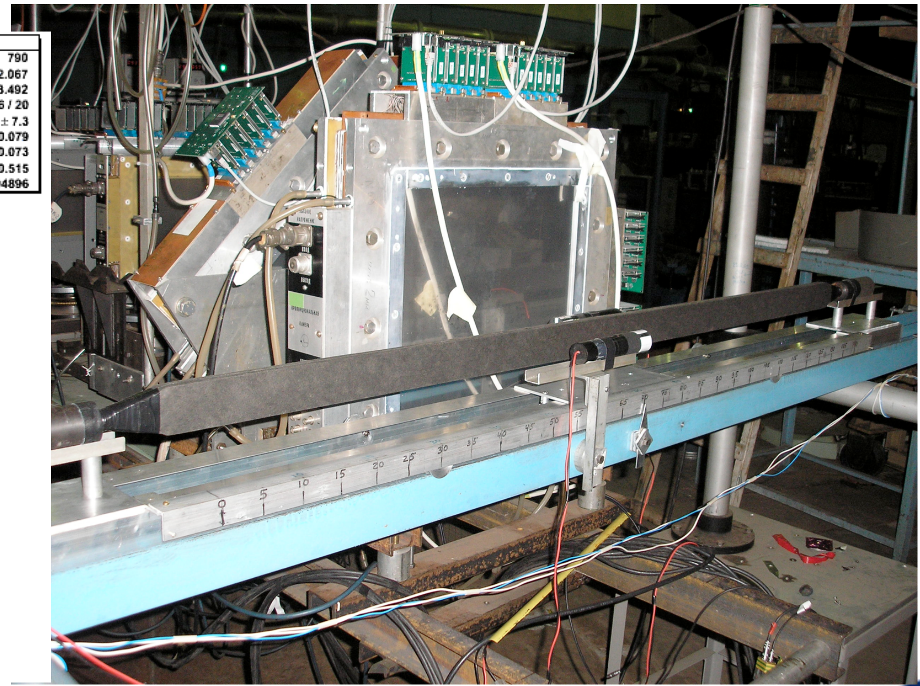
TOF measurements at PNPI in beam



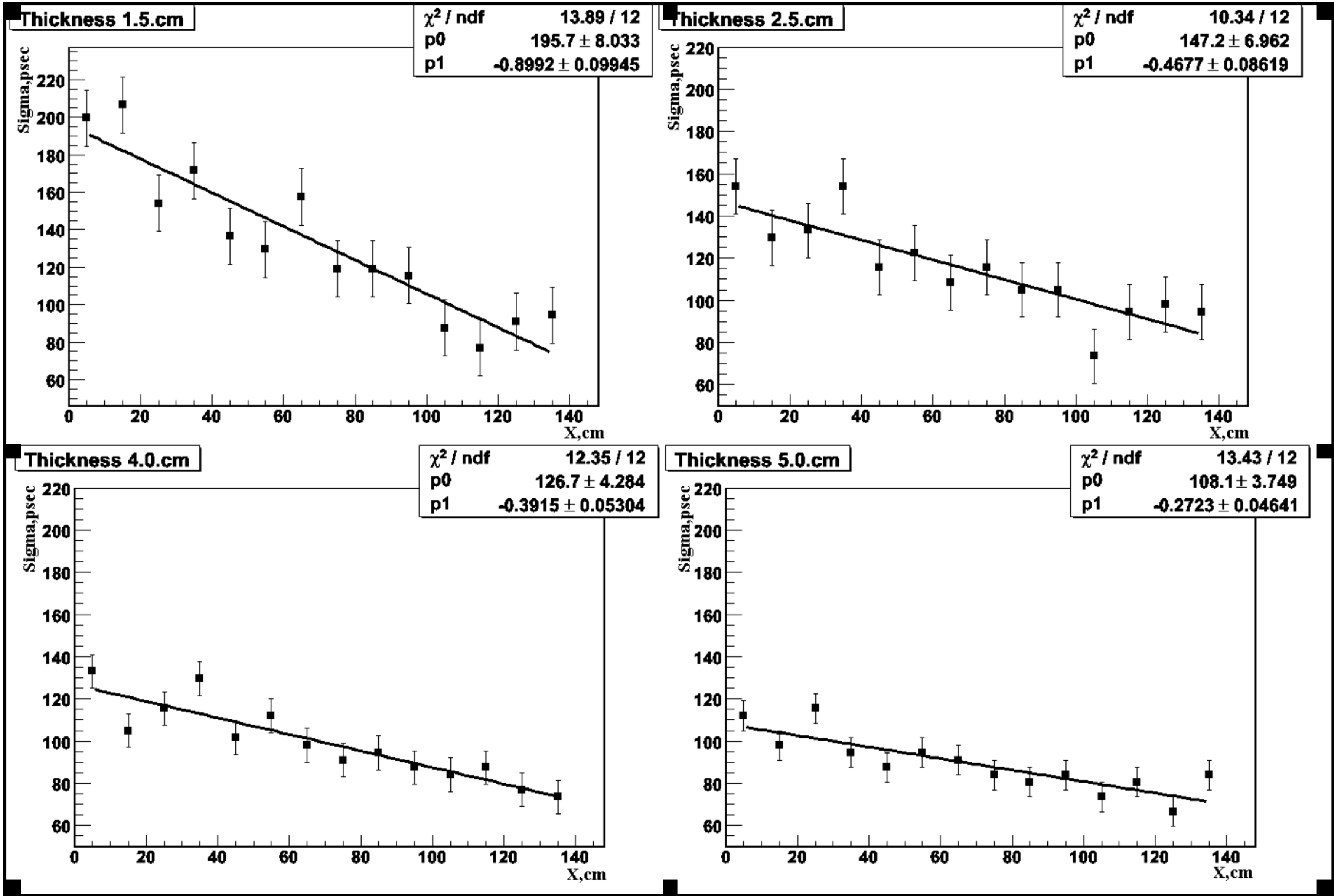
Set-up



Time resolution



Results of TOF measurements with unilateral readout of large Scintllator pannels using PMTs



Workplan fo Task 3

TASKS/Subtasks	**2009**				**2010**				**2011**			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
3. ULTRA-FAST TIMING WITH PLASTIC SCINTILLATORS FOR TOF APPLICATIONS												
3.1 Monte-Carlo simulations on scintillator structure, geometry ,time resolution, etc.												
3.2 Design of fast read-out electronics and realization												
3.3 Tests with cosmics and Sr^{90} source												
3.4 Study the functionality on operating conditions (temperature, dark rate, thresholds, etc)								10				
3.5 Construction of a prototype												
3.6 Prototype tests at the PNPI 1 GeV proton beam												
3.7 Evaluation of results and report												

Milestones

10 Study of varying operation conditions for TOF pannel performed

Summary

This JRA investigates the unique capabilities of Silicon Multipliers guided by different case studies:

Detection of very low light levels	**Cherenkov Radiation**
Detection of low to medium light levels	**Fiber Readout**
Detection of high light levels	**Calorimetry**
Ultra fast time resolution	**TOF**

- The proposed tasks of WP28 have been performed and the milestones achieved.
- The results give us better insight to the SiPM sensor both the benefits and the deficiencies.
- We expect to learn much more during the second half of the project.
- The development of prototype detectors using SiPMs progresses.

The project should be continued within HadronPhysics3