SiPM (MMPC) + Scintilliating Fibers

Report from LNF-INFN group

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Prague 22-Feb-2010

MAPD2010 Second G-APD workshop,
WP28 of HadronPhysics2, FP7

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AMADEUS EXPERIMENT

Physics case

Study of the hadronic interactions of K^- in light nuclei at DAΦNE:

Studying the properties of the **$\bar{K}N$ potential** in the nuclear medium

- **Intense theoretical debate** with several different approaches:
  - Variational calculations with phenomenological $\bar{K}N$ potential
  - Chyral SU(3) dynamics by non-perturbative coupled channels
  - 3-body Faddeev calculations
  - etc
- **How deeply is a kaon bounded in a nucleus?**
- A strong attractive potential will allow the formation of **deeply bound kaonic clusters**, with exotic features that would allow to investigate:
  - spontaneous and explicit symmetry breaking of *QCD*
  - Kaon condensation in nuclear matter
  - etc

Experimental program

- DAFNE produces charged Kaons of P~127 MeV coming from Φ decay at rest

- K^- ---> 4He, 3He targets

- **Full acceptancy 4π** spectroscopy in **all formation and decay channels**

$K^-_{stopped} + {}^4He \rightarrow n + n + (K^-pp)$, $(K^-pp) \rightarrow \Lambda + p$

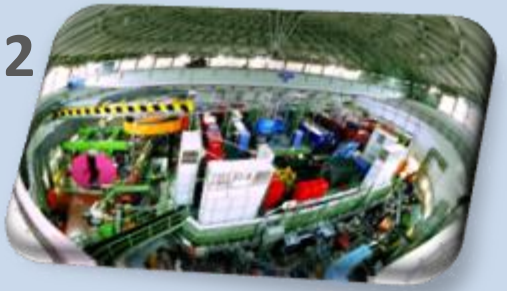
$K^-_{stopped} + {}^4He \rightarrow n + (K^-ppn)$, $(K^-ppn) \rightarrow \Lambda + d$

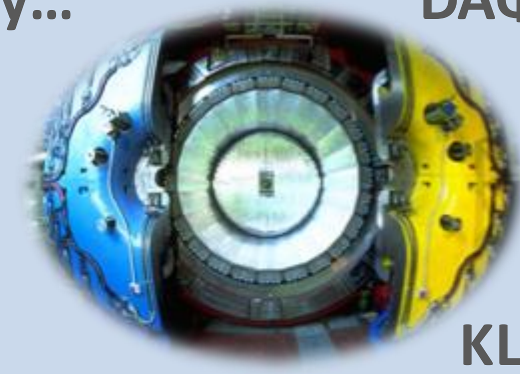
(detected particles)

<u>AMADEUS phase-1</u>: start in 2011/2012 (after KLOE2), study di- and tri – baryon kaonic nuclei and low-energy kaon-nucleon/nuclei interactions

Requirements satisfied by...

DAΦNE2

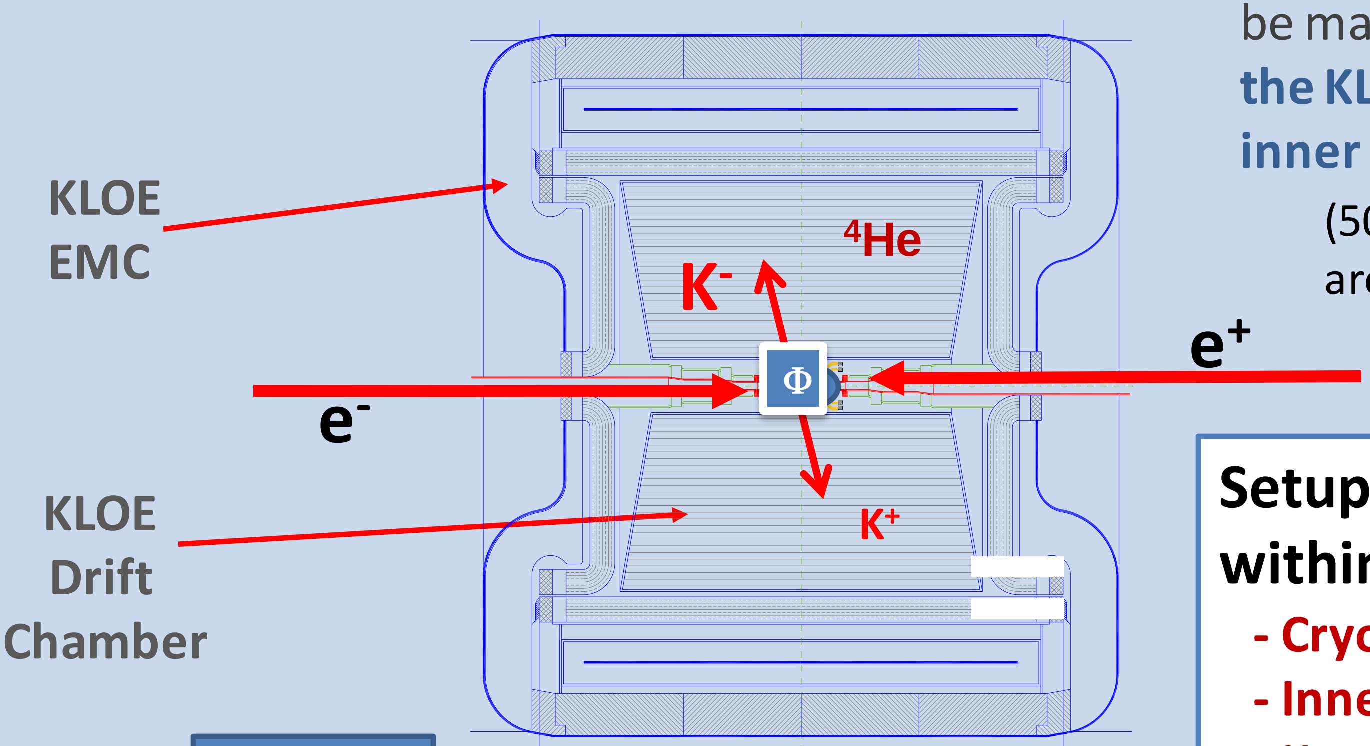




KLOE

Experimental setup

how charged K events looks like nowadays in **KLOE:**



B = 0.6 T

Full acceptance and high precision measurements will be made by **implementing the KLOE detector with an inner AMADEUS setup**

(50 cm. gap in KLOE DC around the beam pipe)

Setup for AMADEUS within KLOE

- **Cryogenic target**
- **Inner tracker**
- **Kaon trigger**

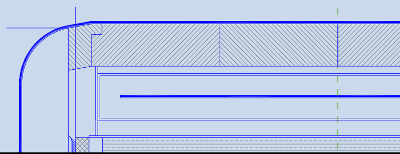
Experimental setup

how charged K events looks like nowadays in **KLOE:**

Full acceptance and high precision measurements will

$K^{-}_{stopped} + {}^{4}He \rightarrow p + (K^{-}pnn)$

$K^{-}_{stopped} + {}^{4}He \rightarrow n + (K^{-}ppn)$

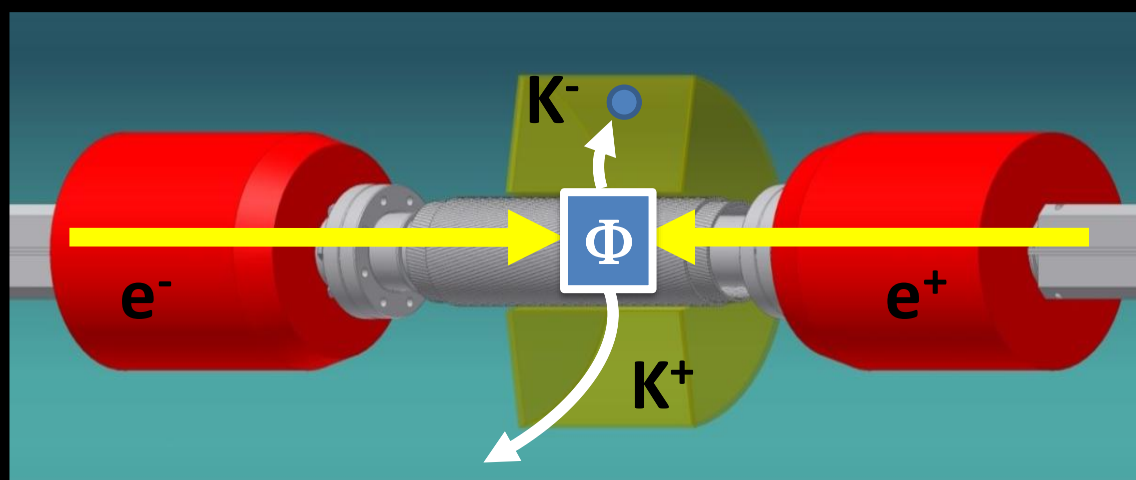


KLOE EMC

e-

KLOE Drift Chamber

how an event will look like in AMADEUS:



Detail of the inner region of the DC

Experimental setup

how charged K events looks like nowadays in **KLOE:**

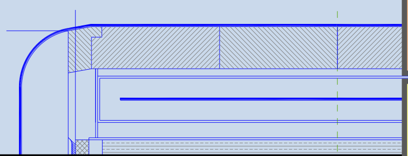
Full acceptance and high precision measurements will

g

n

$$K^-_{stopped} + {}^{4}He \longrightarrow p + (K^-pnn)$$

$$K^-_{stopped} + {}^{4}He \longrightarrow n + (K^-ppn)$$



DC

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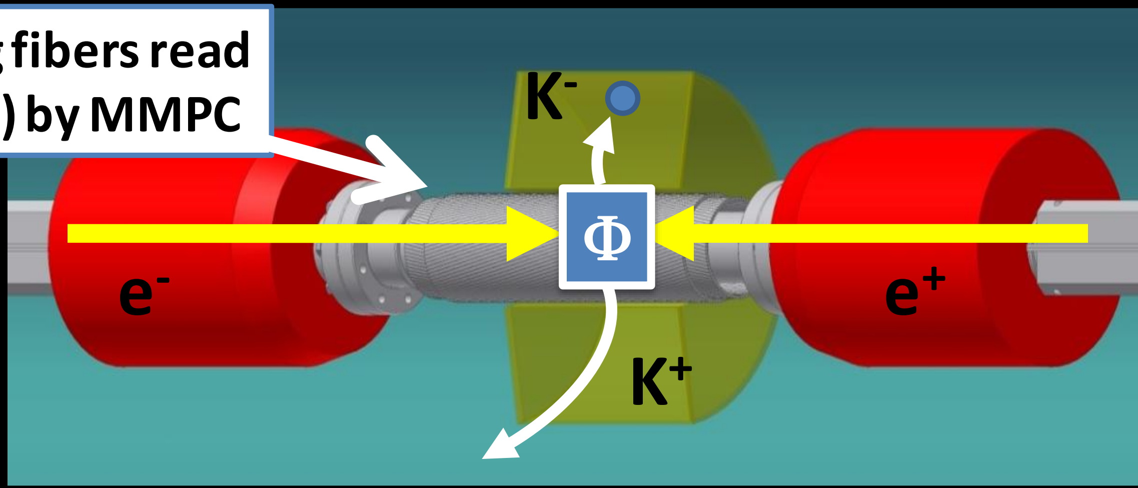
s

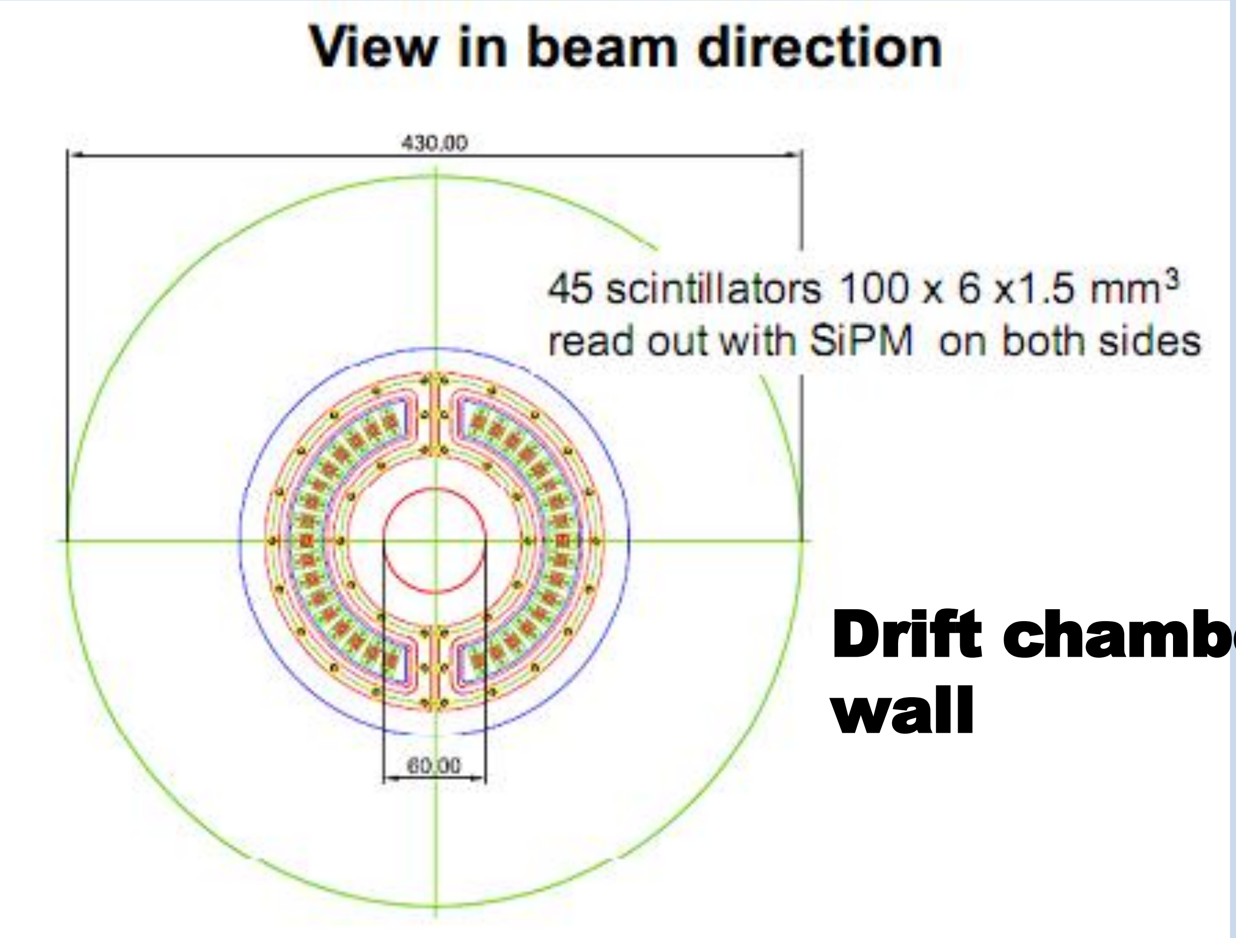
how an event will look like in AMADEUS:

Scintilliating fibers read (both sides?) by MMPC

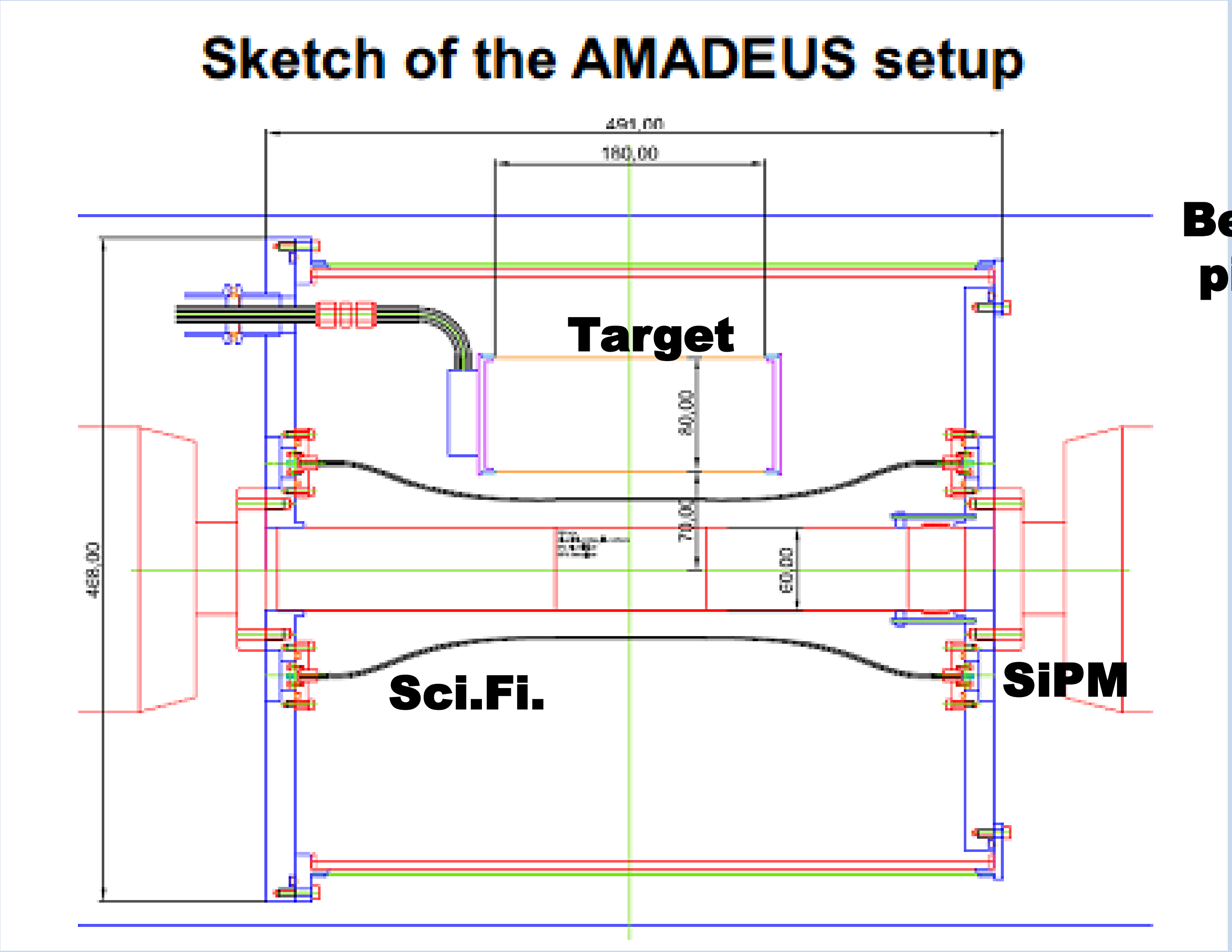


Detail of the inner region of the DC

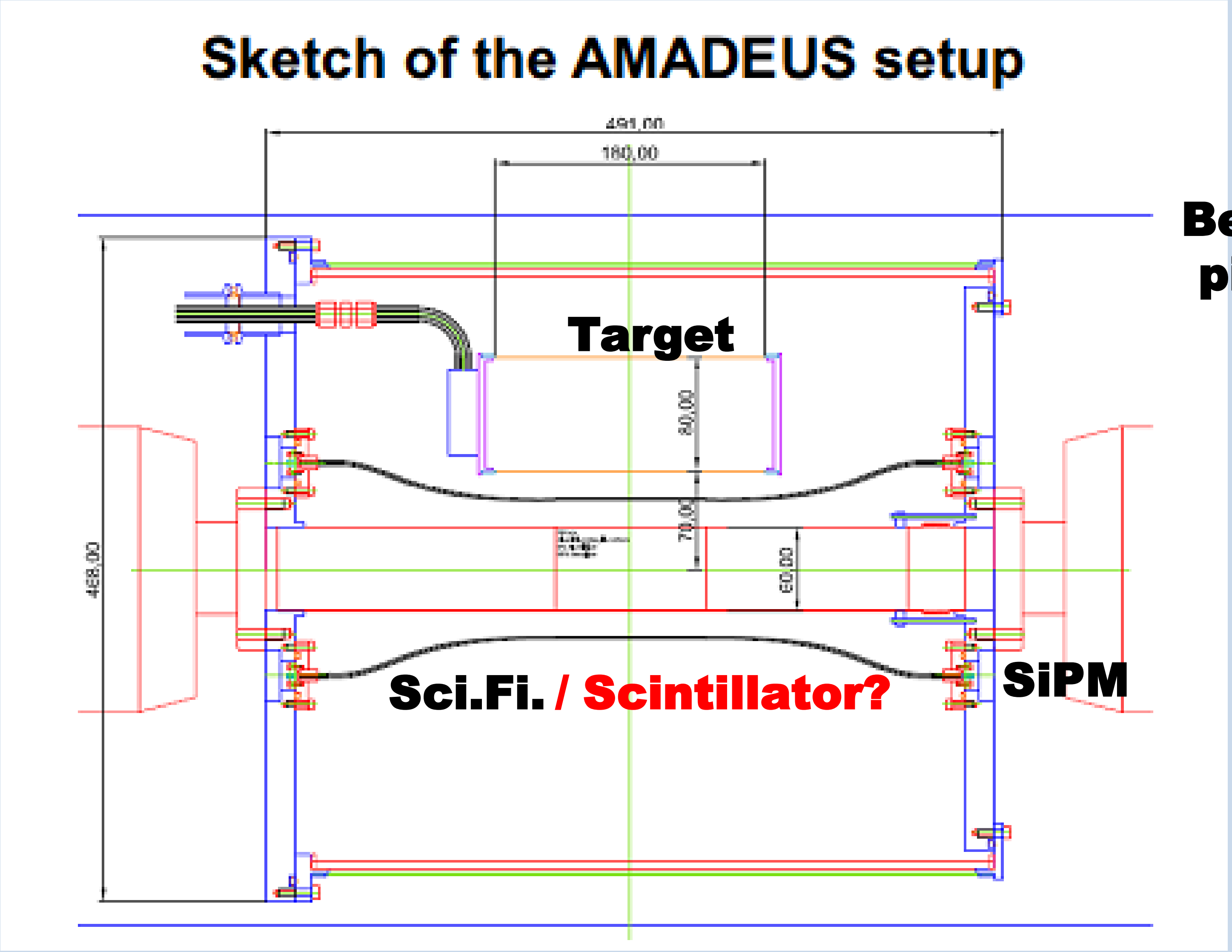
Experimental setup



Experimental setup



Experimental setup



Characterization of SiPM

Characterization of SiPM

Hamamatsu

After a little experience with Photonique...

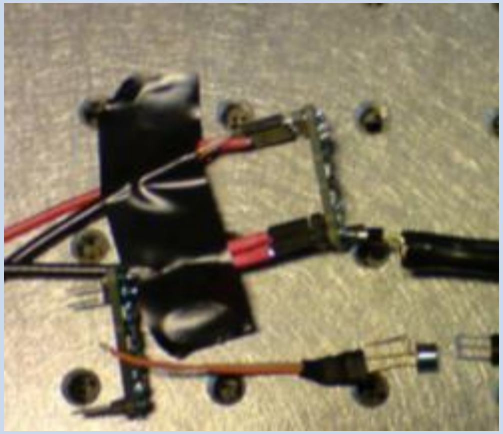
MPPC Hamamatsu S10362-11-050U

efective area 1mm^2

400 pixel

λ = 270-900nm (peak 400nm)

working biases ~ 70 V .



- Array of single Geiger Mode APD.
- Photon counting depending on the PIXEL size
- **Ideal for ScFi coupling (High granularity detector)**
- **Time resolution below 1 ns**
- **Insensitive to strong magnetic fields**
- High gain (>10^6) and quantum efficiency

Characterization of SiPM

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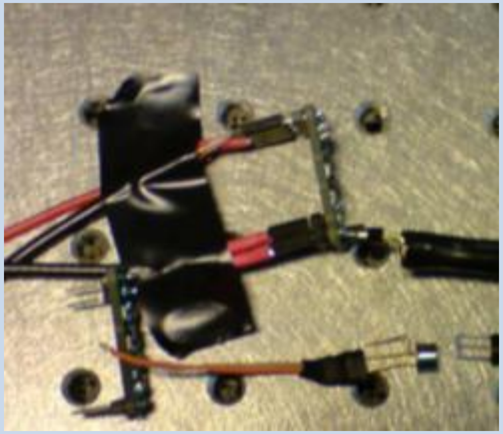
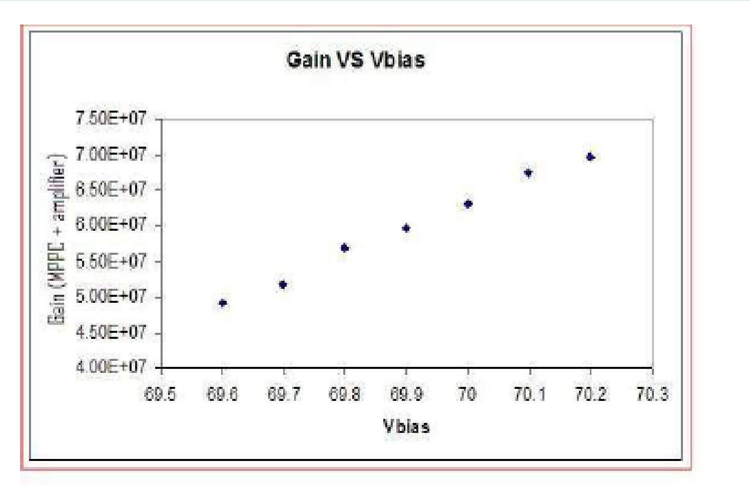




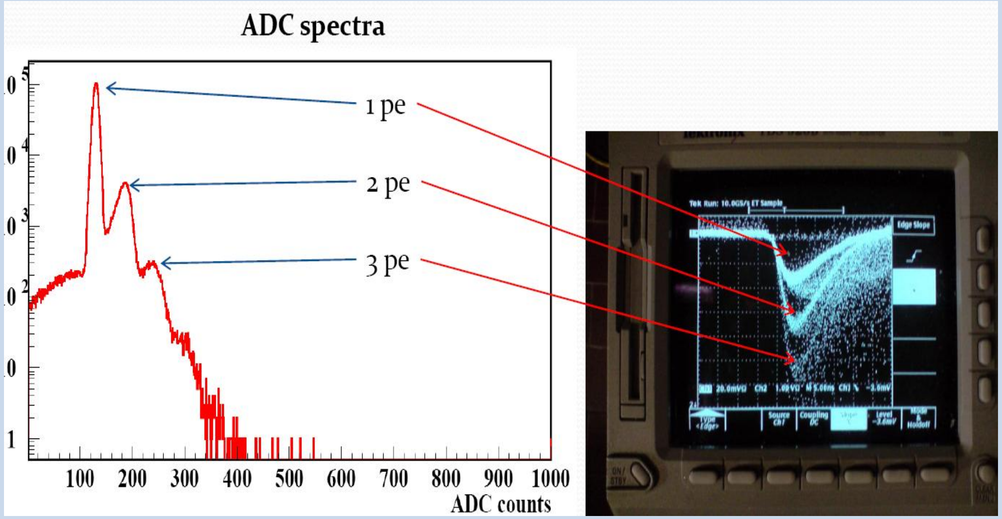
- The Geiger mode of MPPC makes **gain extremely dependent of applied V_{bias}**

-A characterization of this dependency based on the peak distance of intrinsic noise:

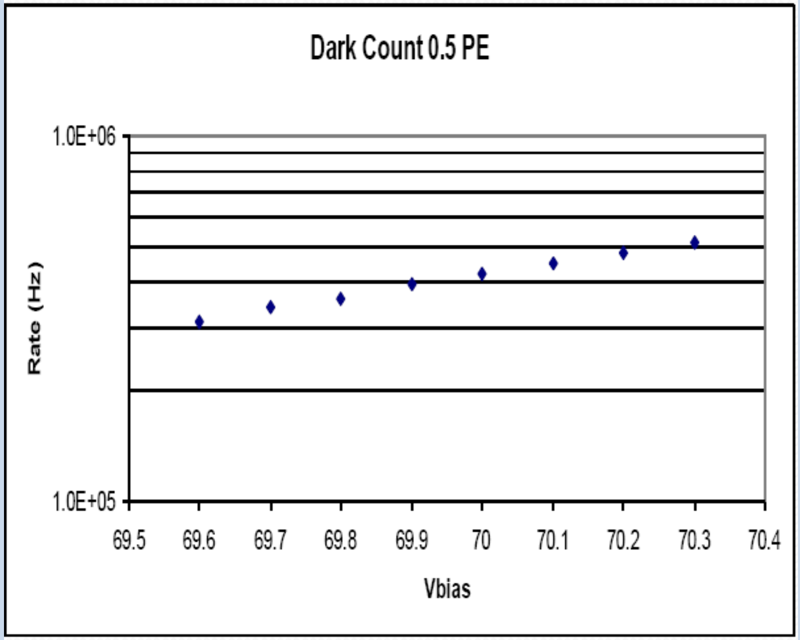
$$G = \frac{\Delta N \times ADC_{conv.rate}}{e}$$

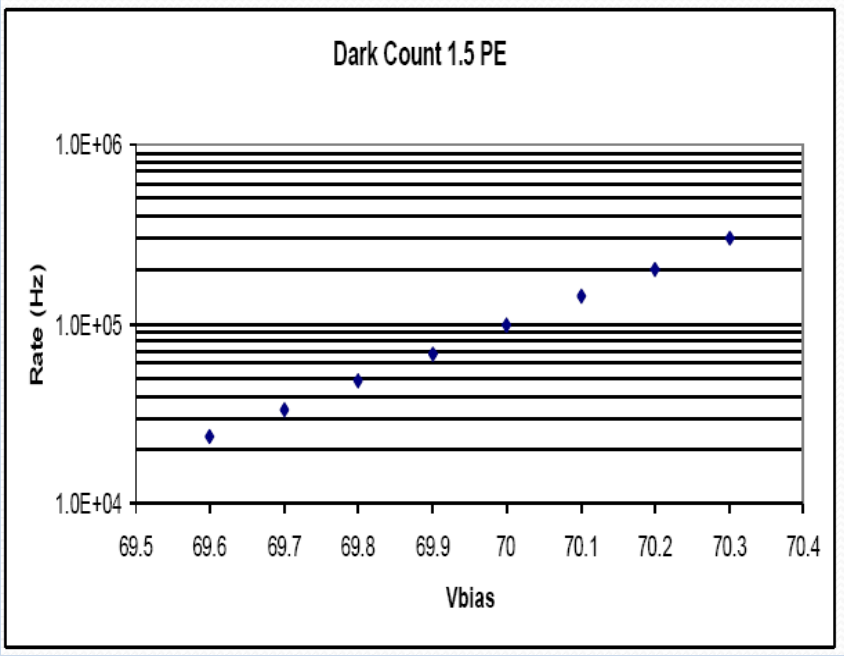
- **For a good behavior stability in the applied voltage with great precision is needed for every single detector**.

Characterization of SiPM



Setting a threshold to 0.5 or 1.5 photoelectrons, dark count rates have been evaluated

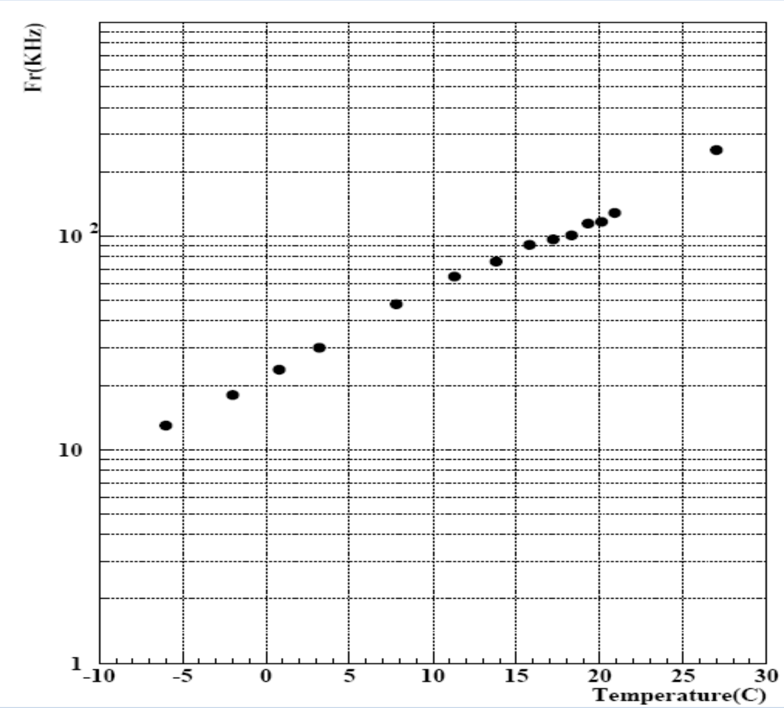




Characterizing MPPC: Dark Count

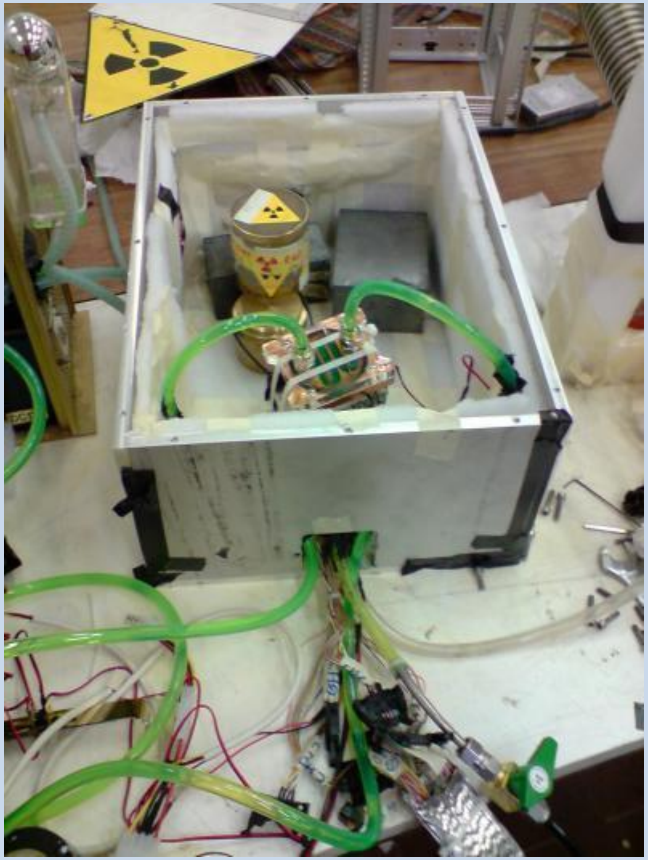
Detectors were cooled down in order to study their behaviour with temperature variations.

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

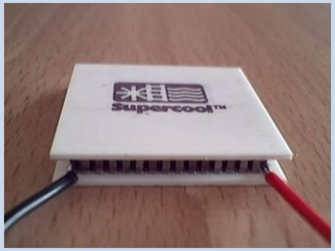


Dark count 1 p.e signal is reduced by a factor 20!

Cooling system



Peltier cell

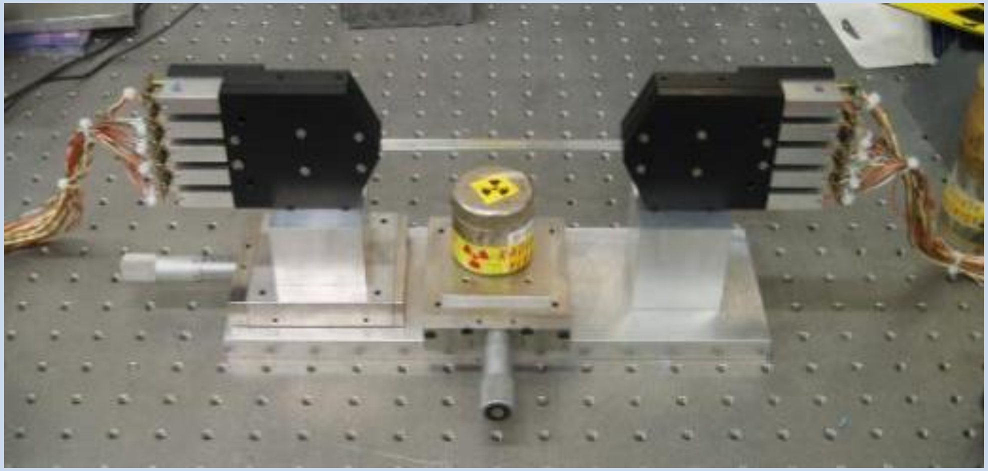


SiPM+Scintillating Fibers

SiPM+Scintillating Fibers

New mechanical support for
5 ScFi read from both sides
10 MPPC + readout card

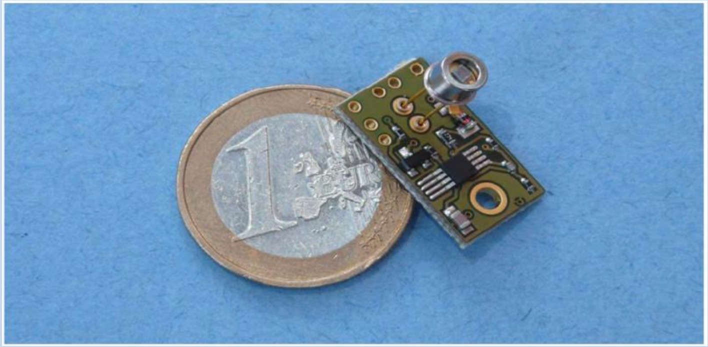
Precission support for
efficiencies studies



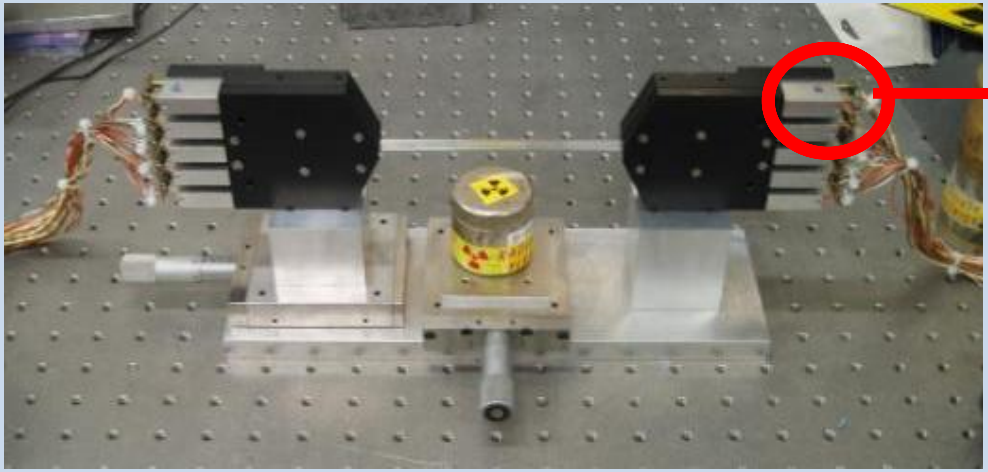
Instrumented fibers:

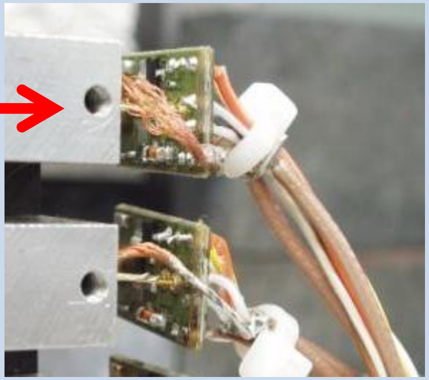
-Saint Gobain BCF- 10 single cladding:

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



SiPM+Fibers: ELECTRONICS



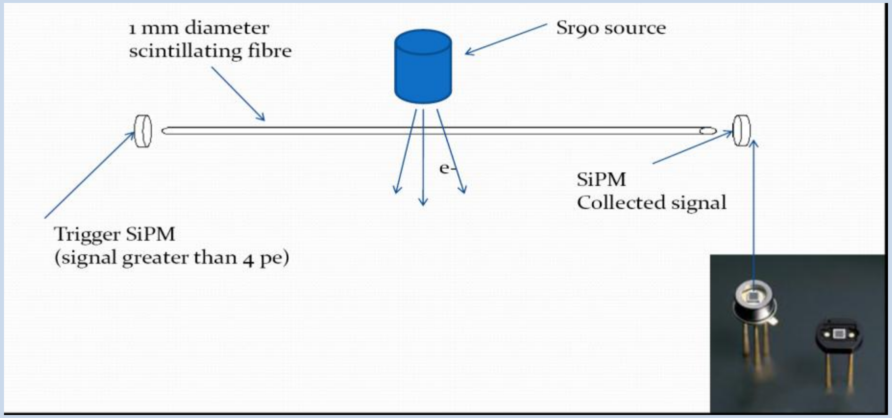


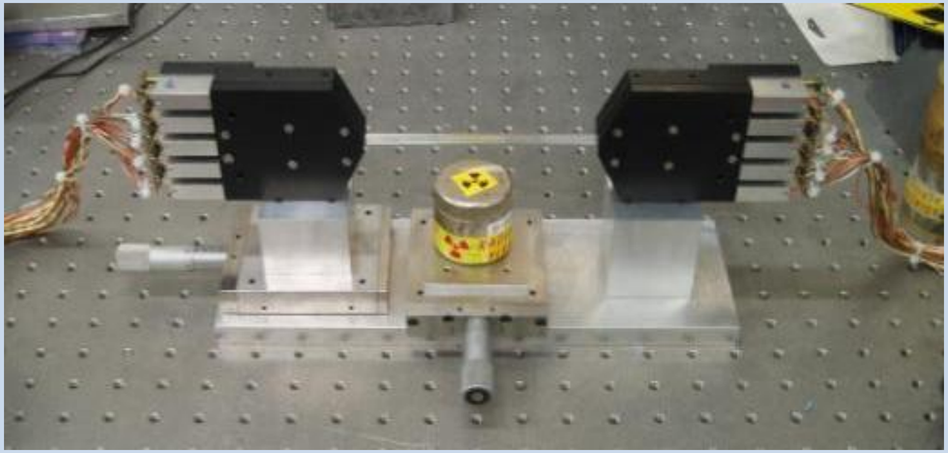
Electronics: New NIM modules providing:

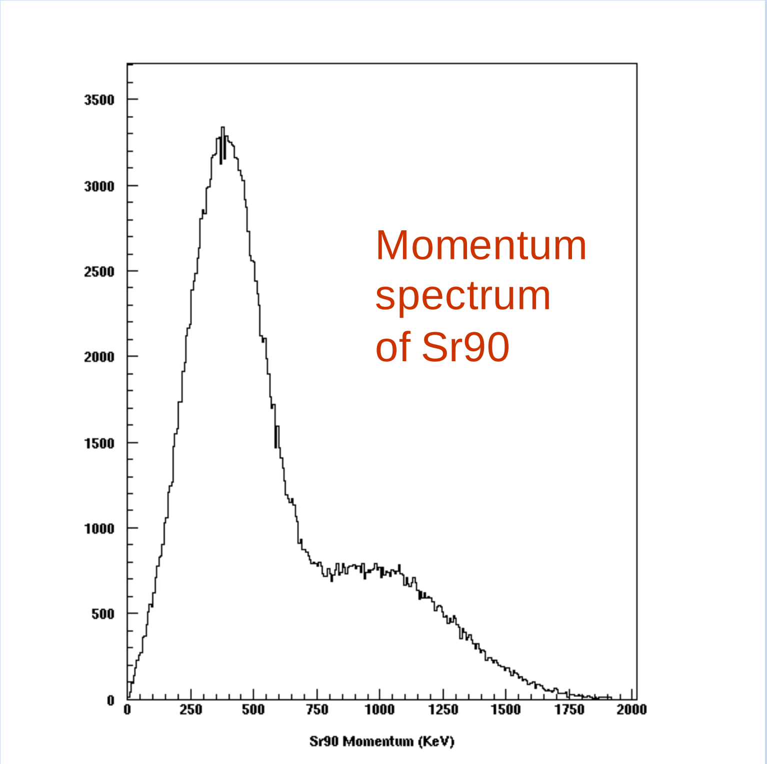
- Variable V_{bias} for 5 channels with a **stability for nominal voltages below 10 mV**
- 2 output / channel:
  - -Amplified (x25-x50-x100) signal
  - -Discriminated signal (variable threshold)

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

SiPM+Scintillating Fibers





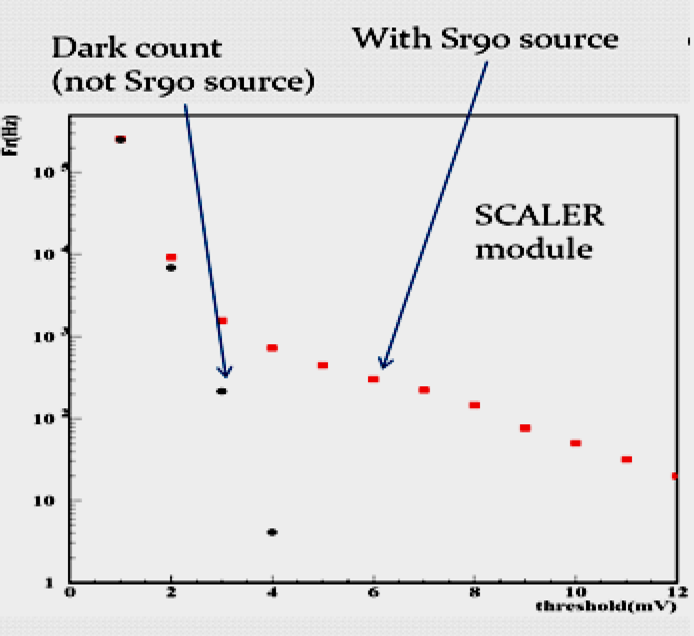


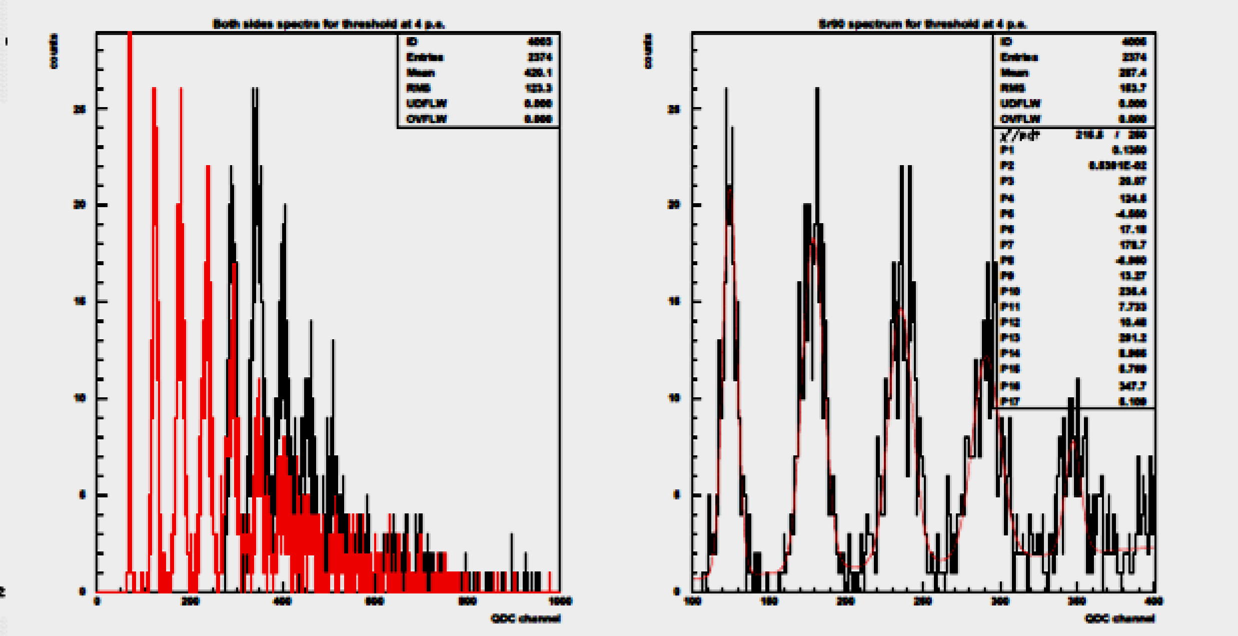
A scintillating fiber is activated by a beta Sr90 source

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

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

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

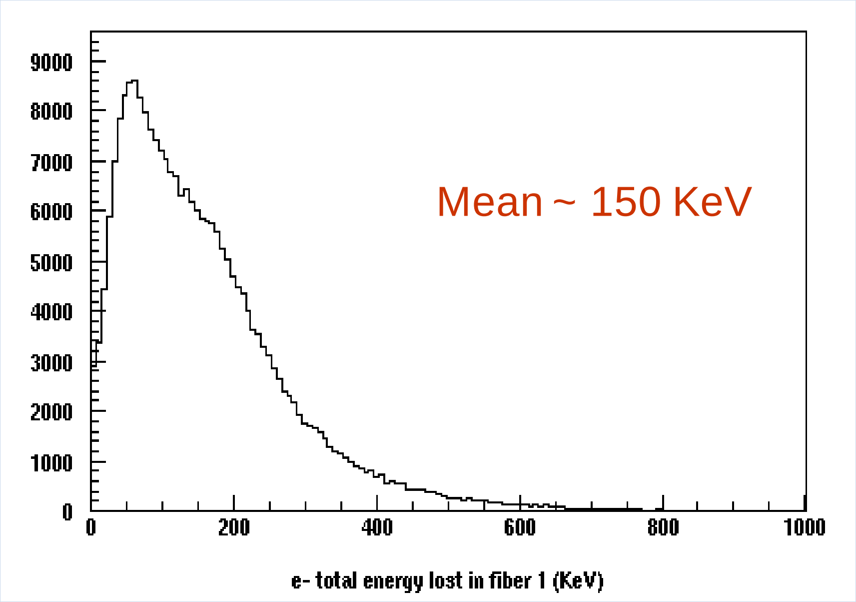
* No cooling is needed in this case!!!!

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

SiPM+Fibers: **Montecarlo 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



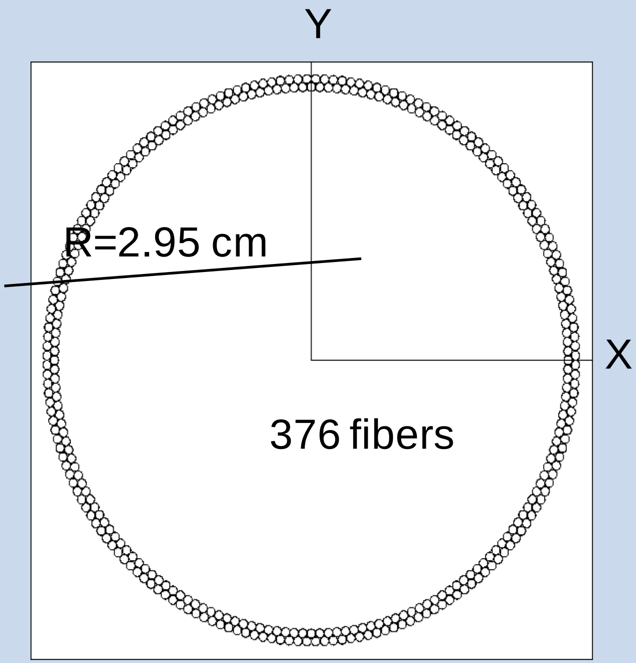
Comparing with experimental data:

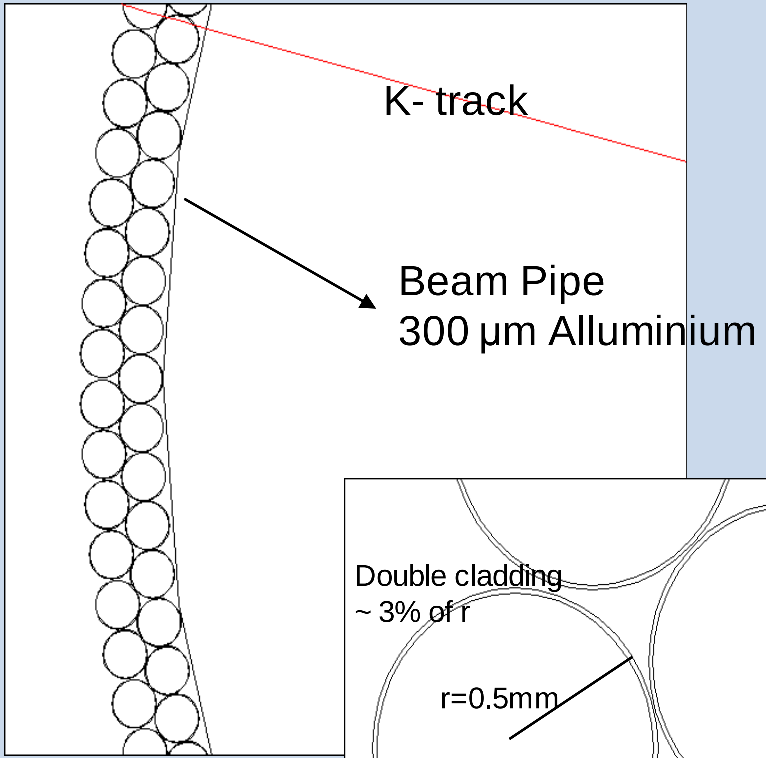
Mean energy loss ~ 150 KeV	600 photons (~4000 ph/MeV)
Nominal trapping efficiency ~ 4%	24 photons
Attenuation length ~ 2.2 m (1/e)	22 photons (30 cm)
Q.D.E. ~ 50 %	11 photons
Reading 1 size	5/6 photons

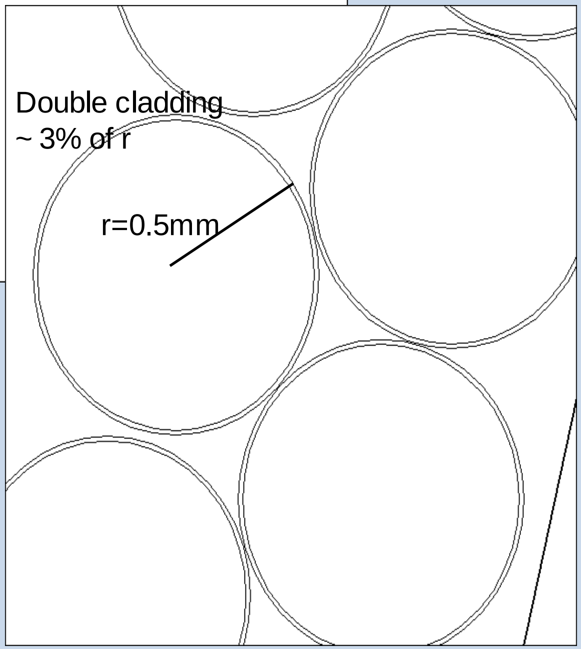
Consistent with lab tests

SiPM+Fibers: **Montecarlo simulations**

AMADEUS trigger







Setup consists in 2 layers of 70 cm scintillating fibers BCF-10 multicladding.

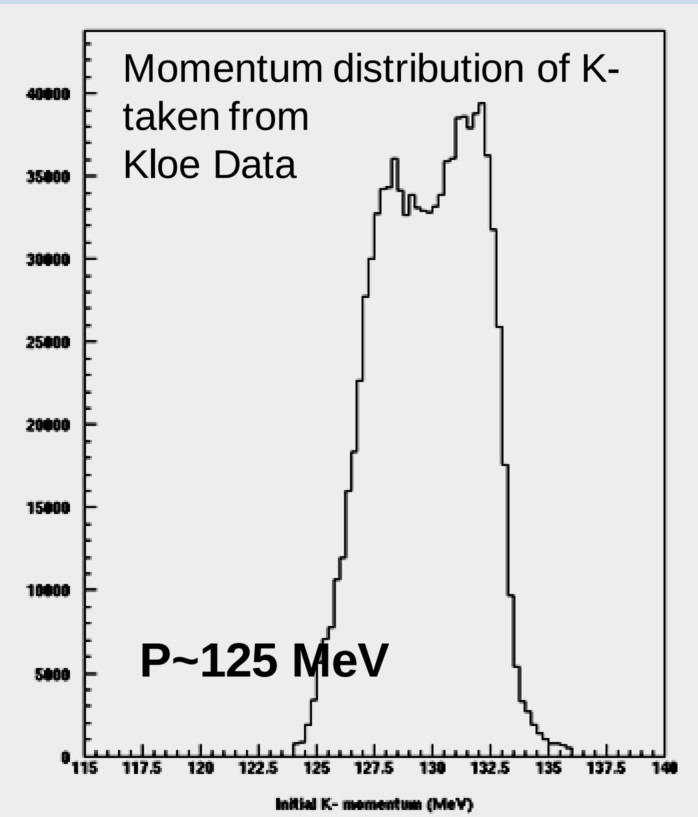
Beam Pipe is an alluminium tube with radius r=2.95 cm and 300 μm thickness.

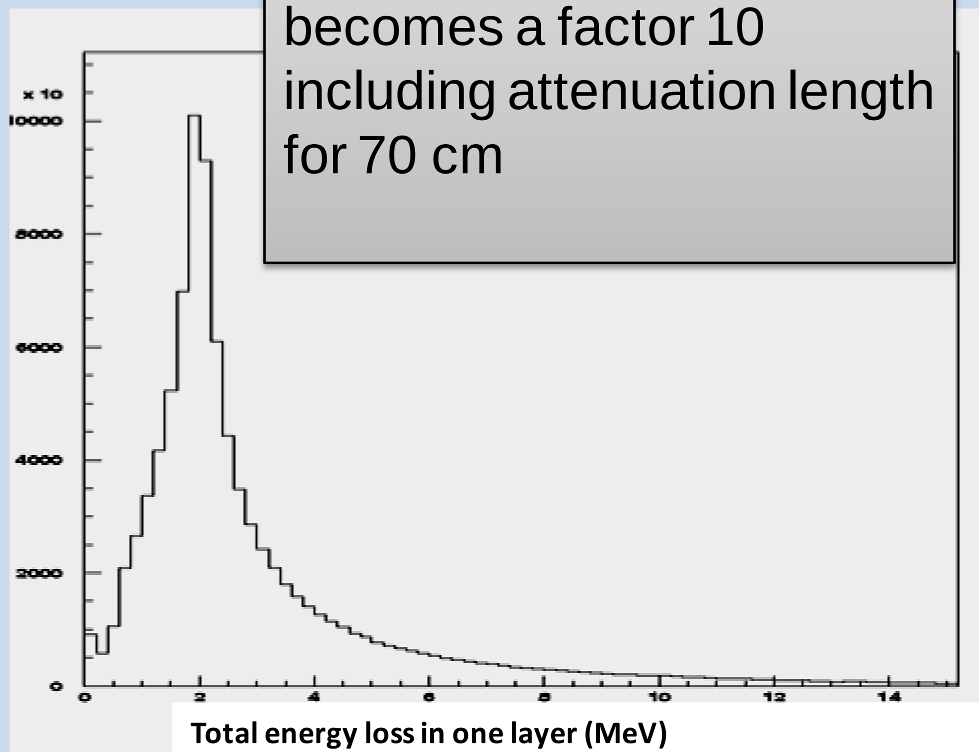
SiPM+Fibers: Montecarlo simulations

Passage of Kaons

In each layer energy loss by Kaons is ~ 2 MeV

This means a factor 13 more than Sr90 e- wich becomes a factor 10 including attenuation length for 70 cm

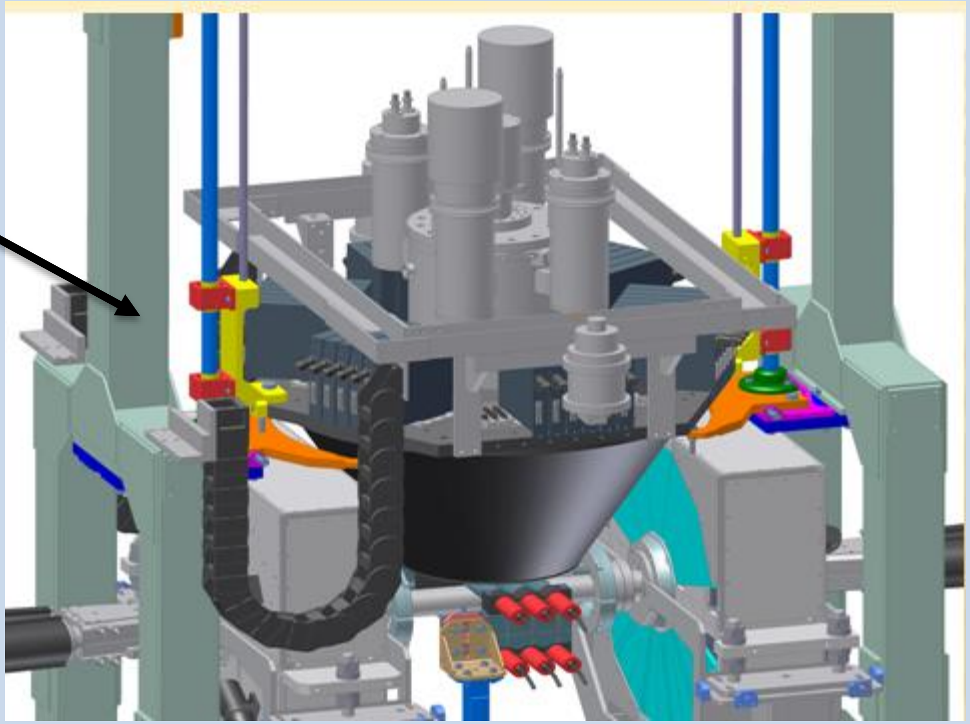




Test @ DAΦNE

Test @ DAΦNE
Siddharta experiment

SIDDHARTA setup



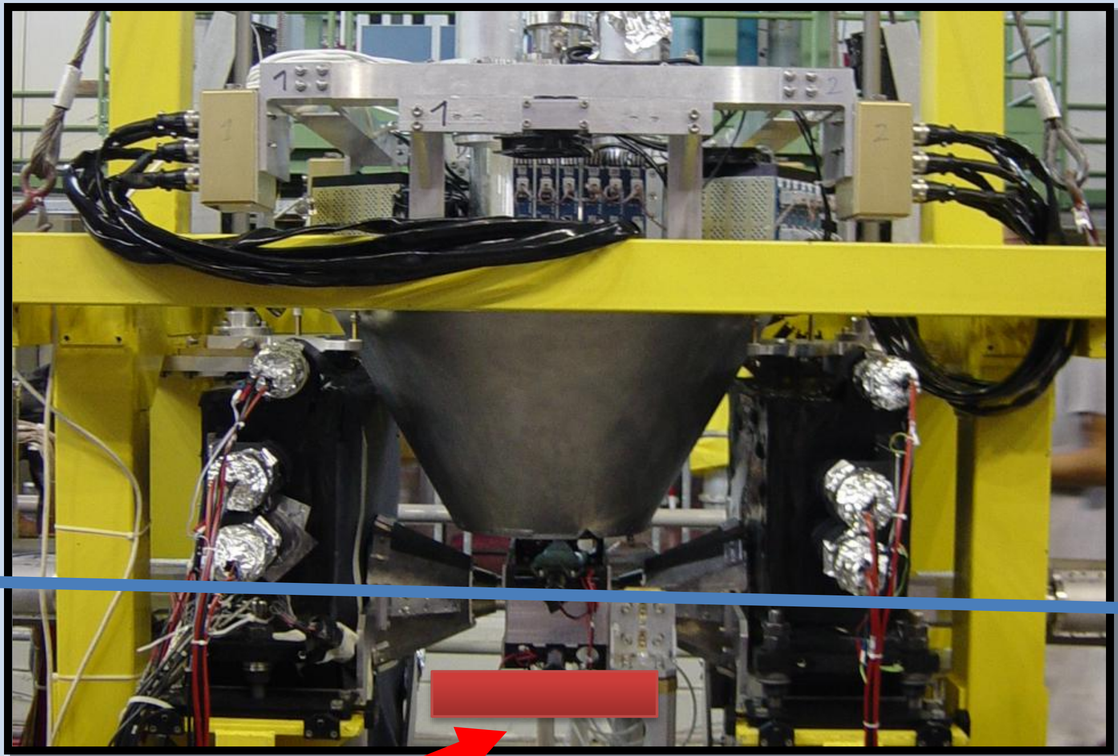
DAΦNE
beam pipe

Experimental setup

Trigger system

tests installation at DAΦNE

SIDDHARTA setup



DAΦNE
beam pipe

Our test setup

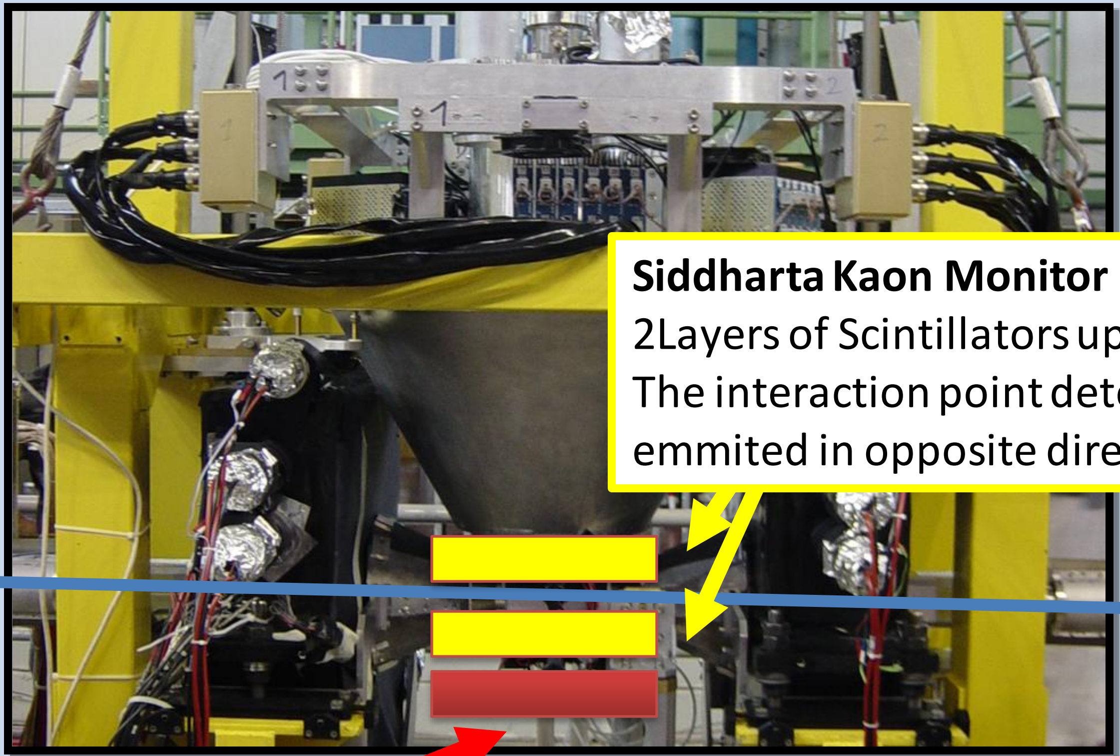
Experimental setup

Trigger system

tests installation at DAΦNE

SIDDHARTA setup

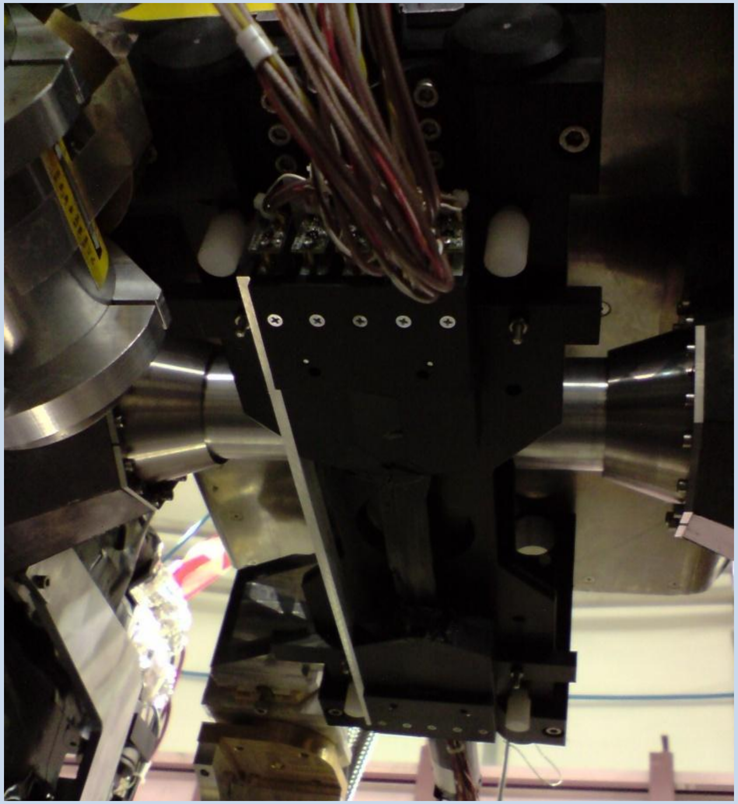
DAΦNE
beam pipe



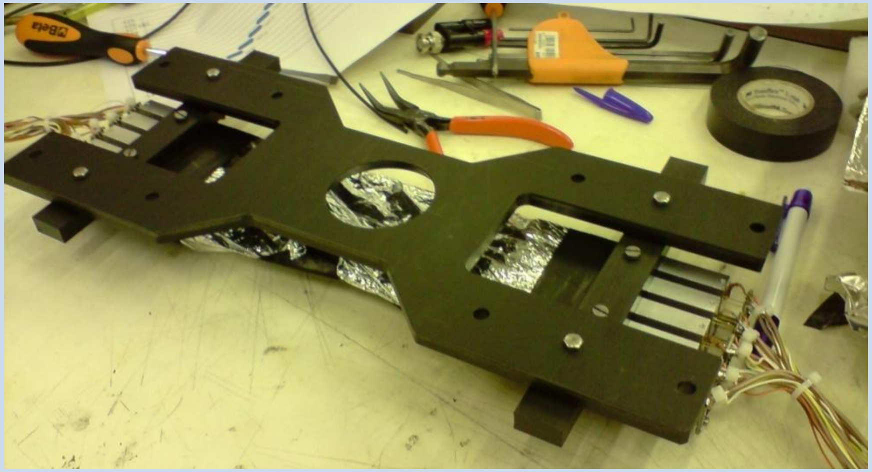
Siddharta Kaon Monitor
2Layers of Scintillators up&down
The interaction point detecting K+ K-
emmited in opposite directions

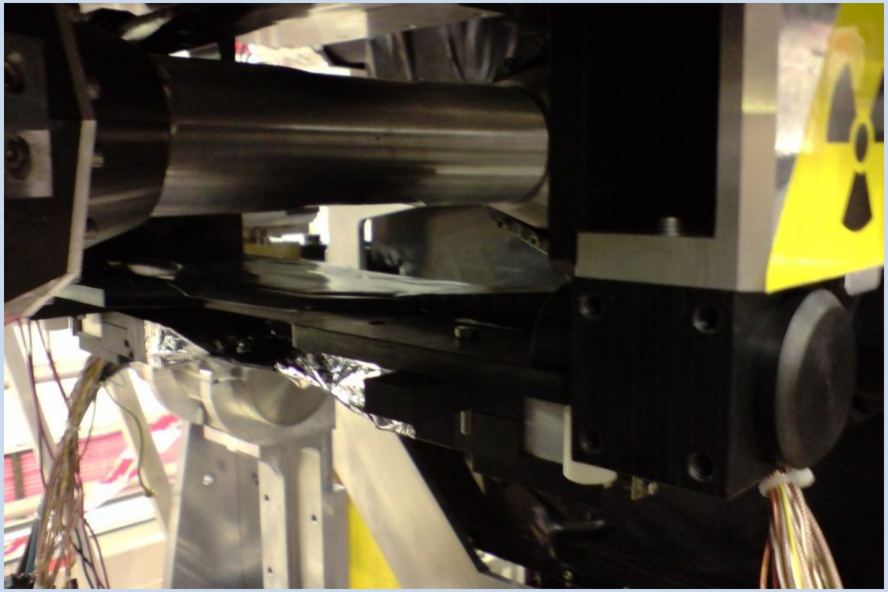
Our test setup

Trigger system tests: installation at DAΦNE



Installation of AMADEUS trigger test setup in DAΦNE 2009





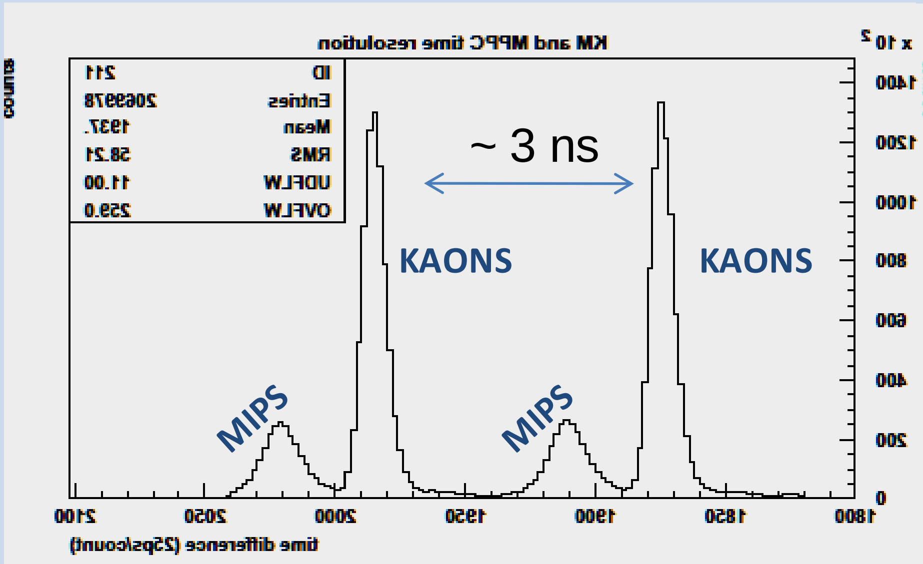
Trigger system tests: installation at DAΦNE

- 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

↓

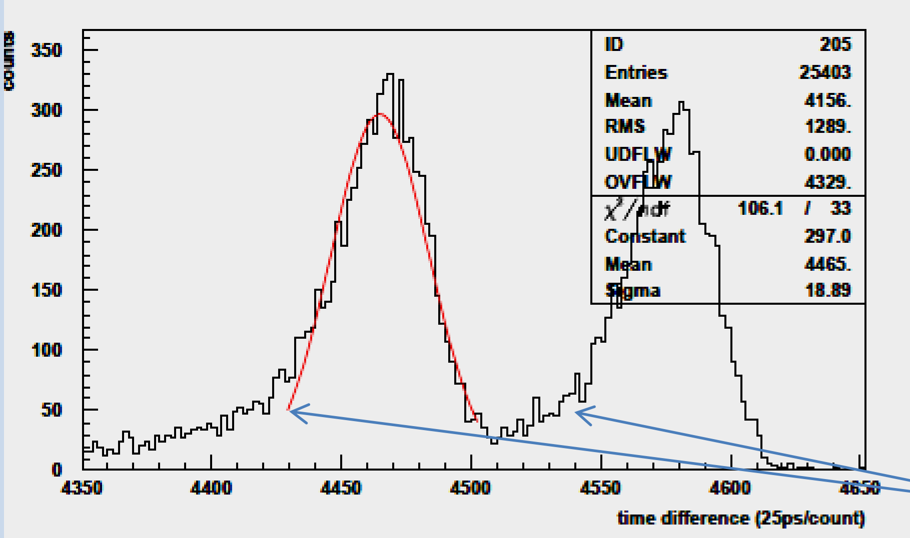
New data taking on DAFNE with new DAQ (including KM)

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

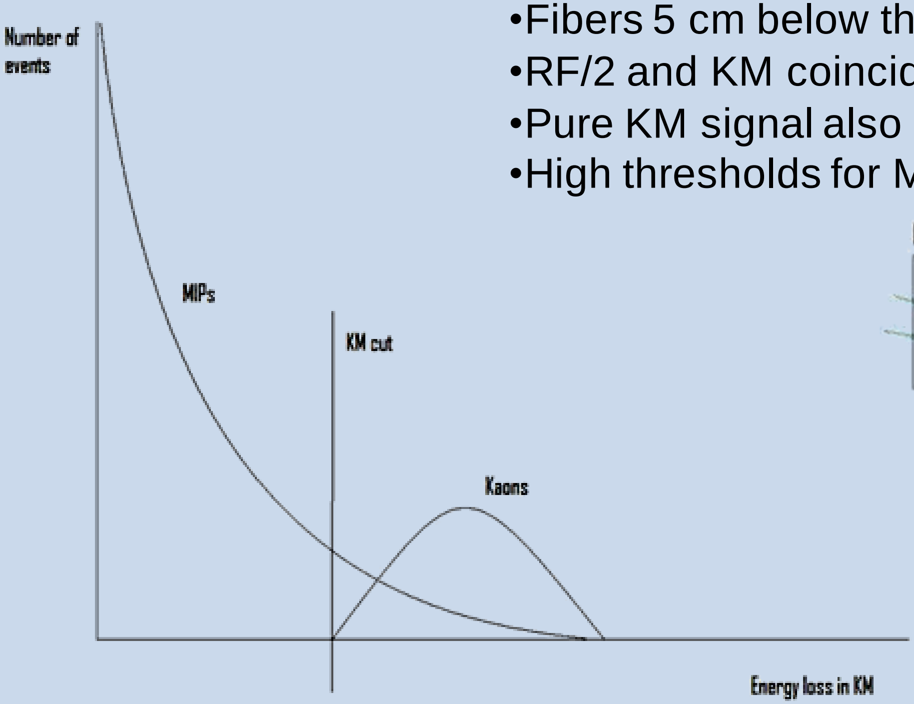
- TDC working in Common Stop (RF/4)

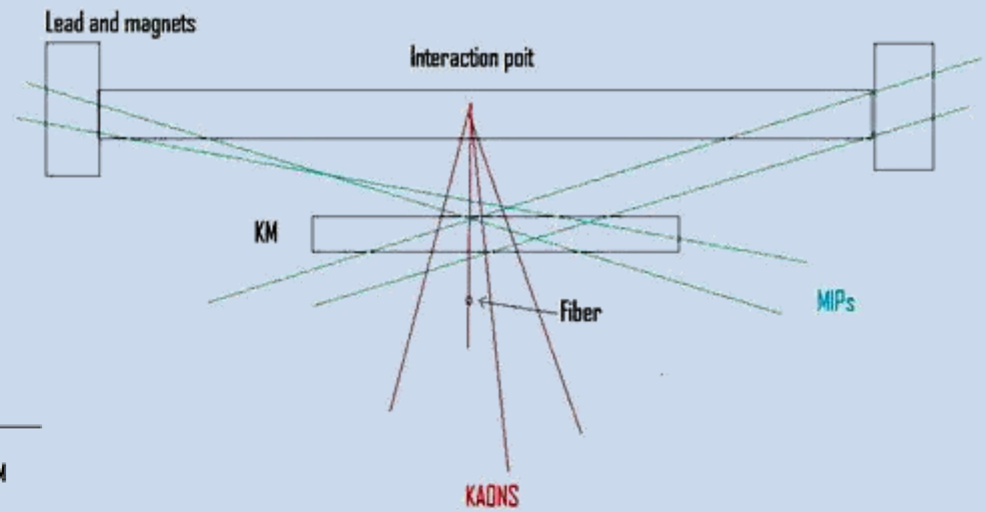
Achieved best single peak resolution around 500 ps

Missing MIPS

Results with Kaon Monitor

- 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.)



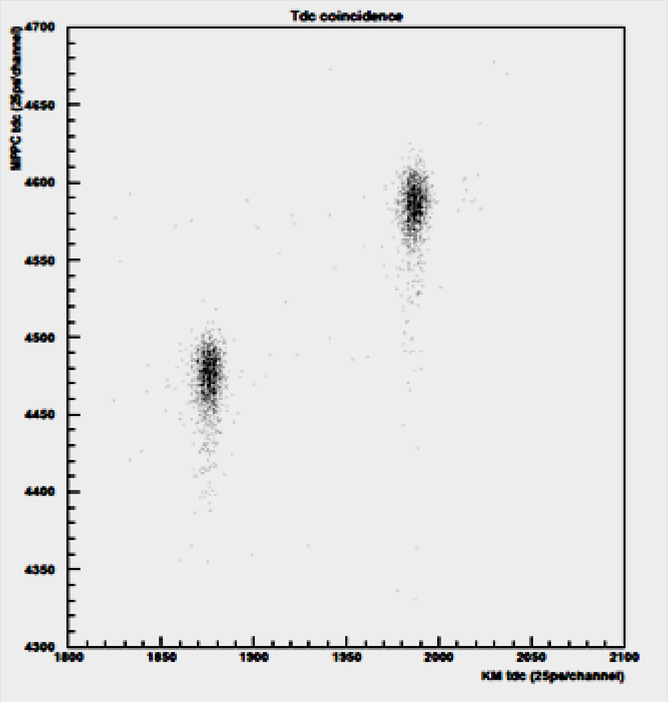


MIPs of high energy tail comes from E.M. Shower wich occurs in lead bricks placed as shielding just before interaction region

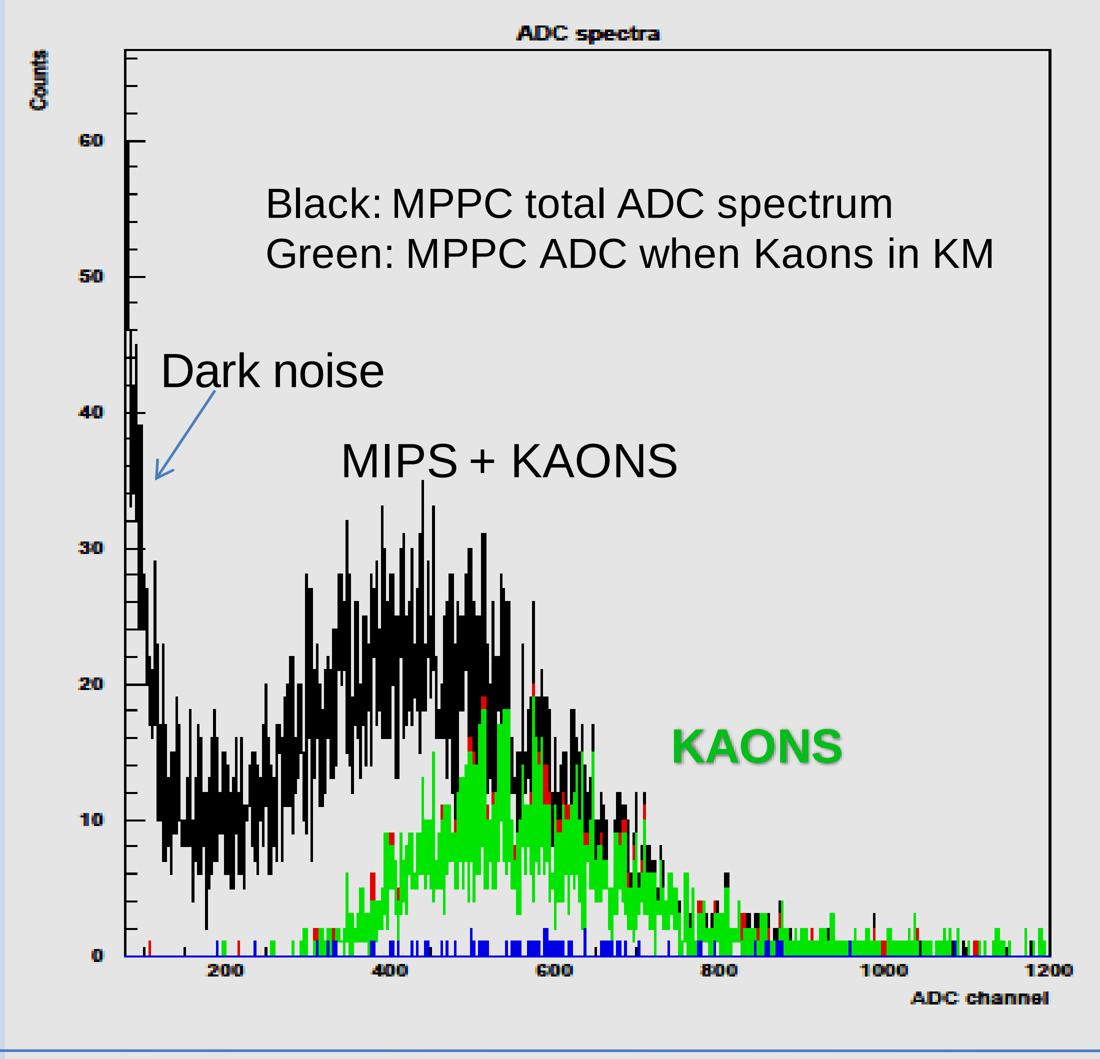
This particles pass with low angle in KM (losing more energy) but not in fibers

Tests at DAFNE

Results with Kaon Monitor



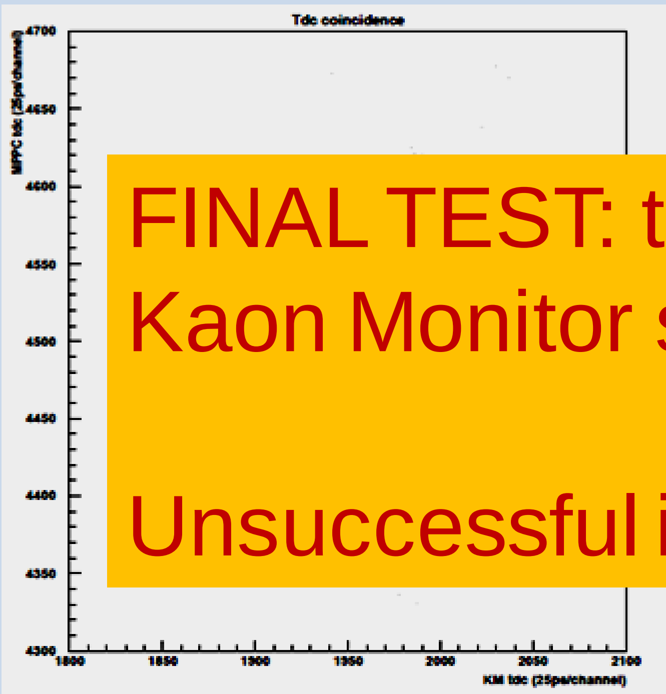
Time correlation between MPPCand KM



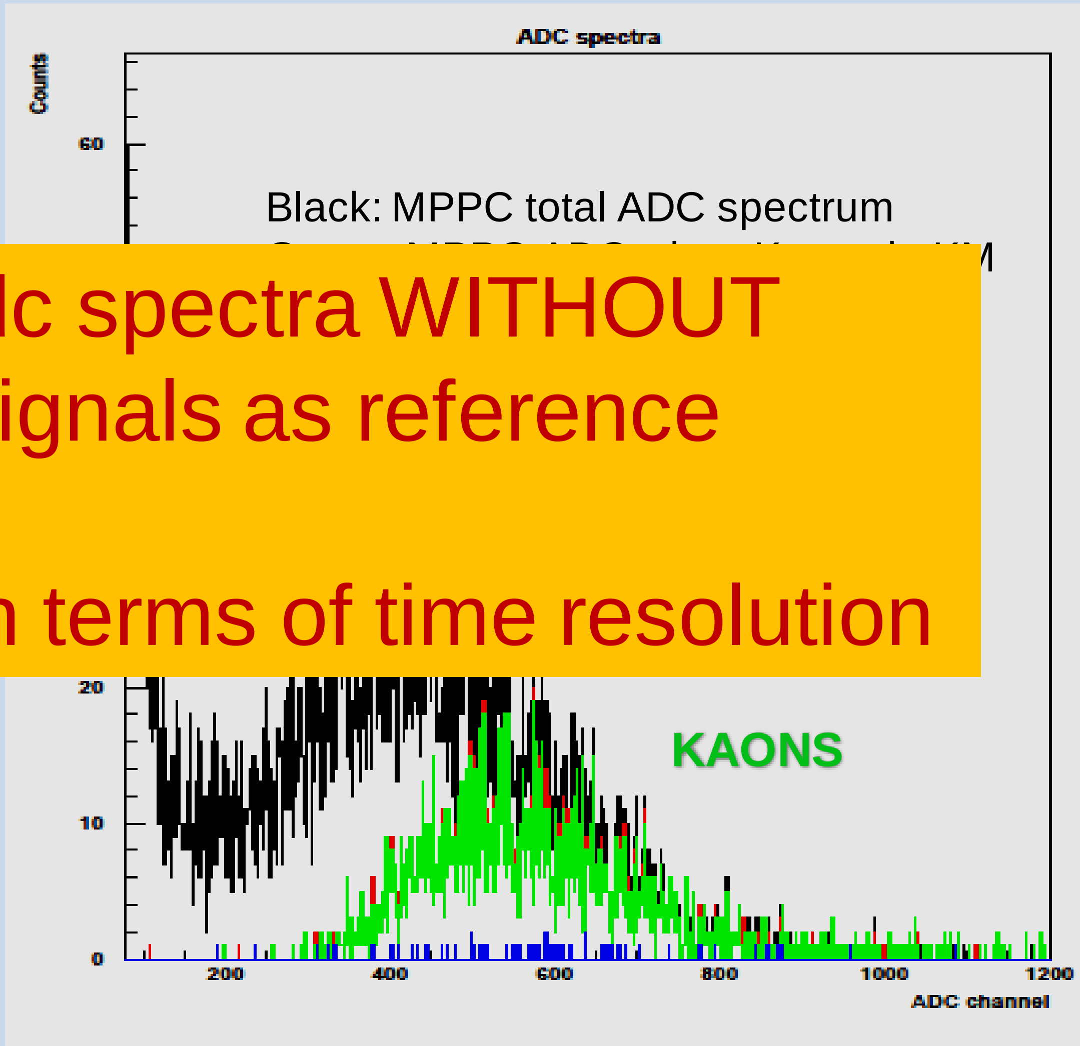
Results with Kaon Monitor

FINAL TEST: tdc spectra WITHOUT Kaon Monitor signals as reference

Unsuccessful in terms of time resolution



Time correlation between MPPCand KM



TIME RESOLUTION STUDY @ Roma3 University

TIME RESOLUTION STUDY @ Roma3 University

- Test of electronic and DAQ chain
- Test of detectors

Objective: know the limit in time resolution using a ~1 fs rise time Laser

TIME RESOLUTION STUDY @ Roma3 University

Instrumentation:

- » LabView + CAEN A2818
- » VME modules
  - Tdc VME 16CH/25ps/multihit/CAEN V1290N
  - QDC VME 16Ch/CAEN V792N
  - Controller VME CAEN V2718 Conet-VME Bridge

Res ≤ 30 ps
(without detector)

TIME RESOLUTION STUDY @ Roma3 University

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Res ≤ 30 ps
(without detector)

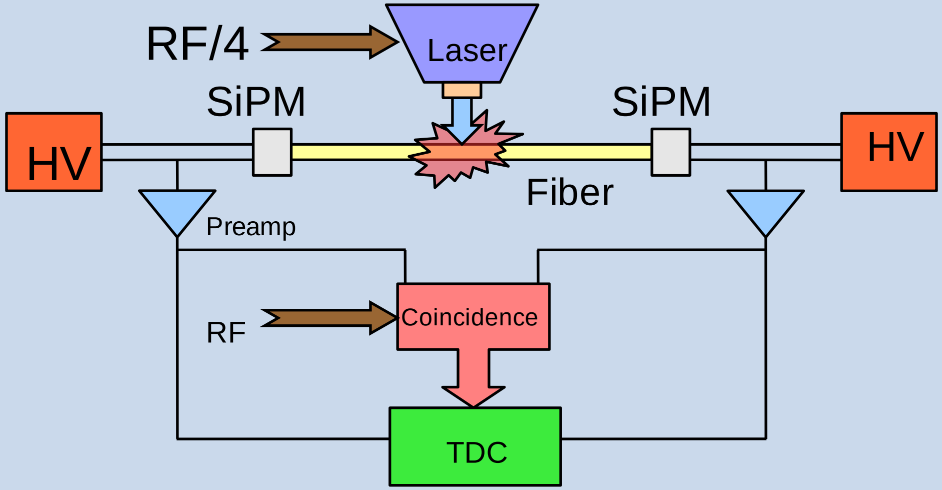
+ Constant Fraction Discriminator
+ SiPM response

Res ≤ 40 ps

TIME RESOLUTION STUDY
@ Roma3 University

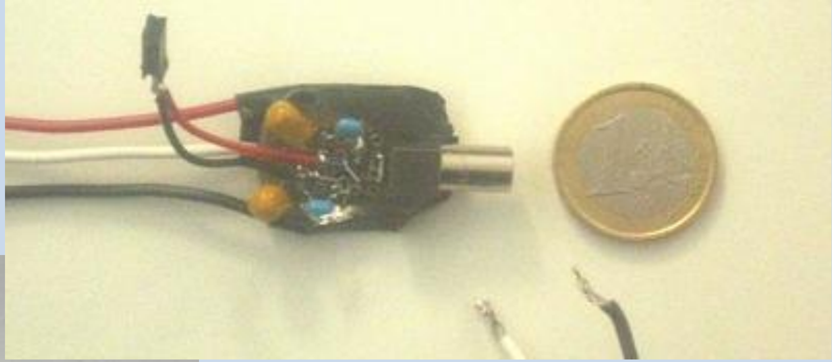
- Single scintillating fiber illuminated by Laser beam
  Instrumented both sides with SiPM
  Time difference **Res ≤ 300 ps**

- **Siddharta-like test:**
  -Simulation of the RF/4 (radiofrequency signal used during siddharta tests) with a 90 MHz NIM signal
  -Sincronous laser at 1 kHz
  Res ≤ 800 ps

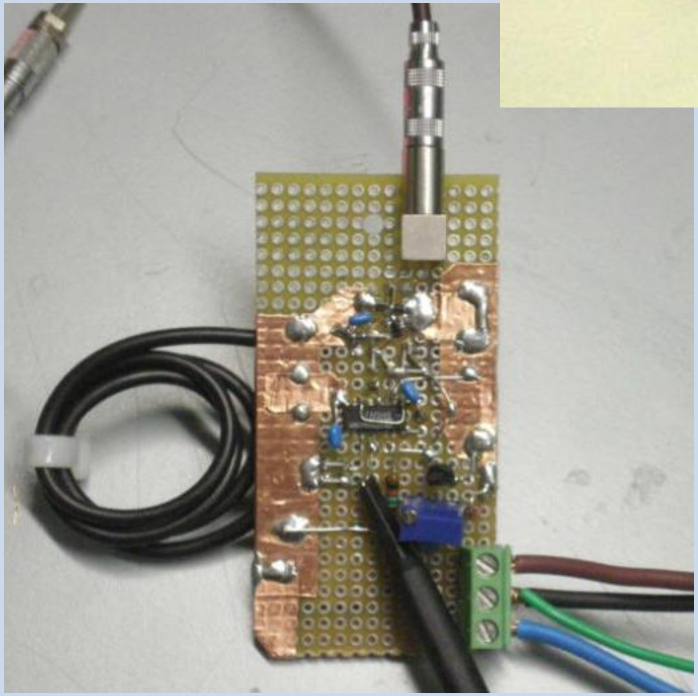


TIME RESOLUTION STUDY
@ Roma3 University

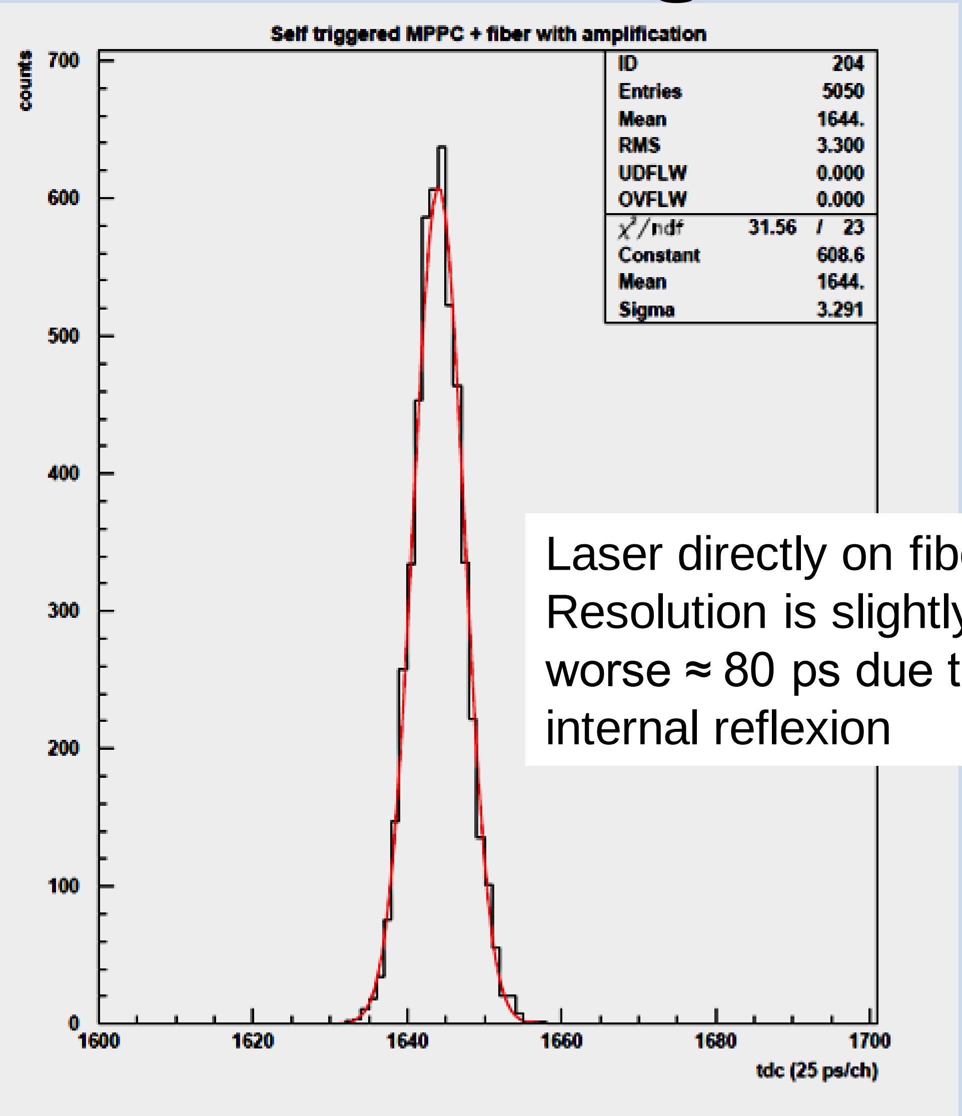
New electronics -> Pre-amp



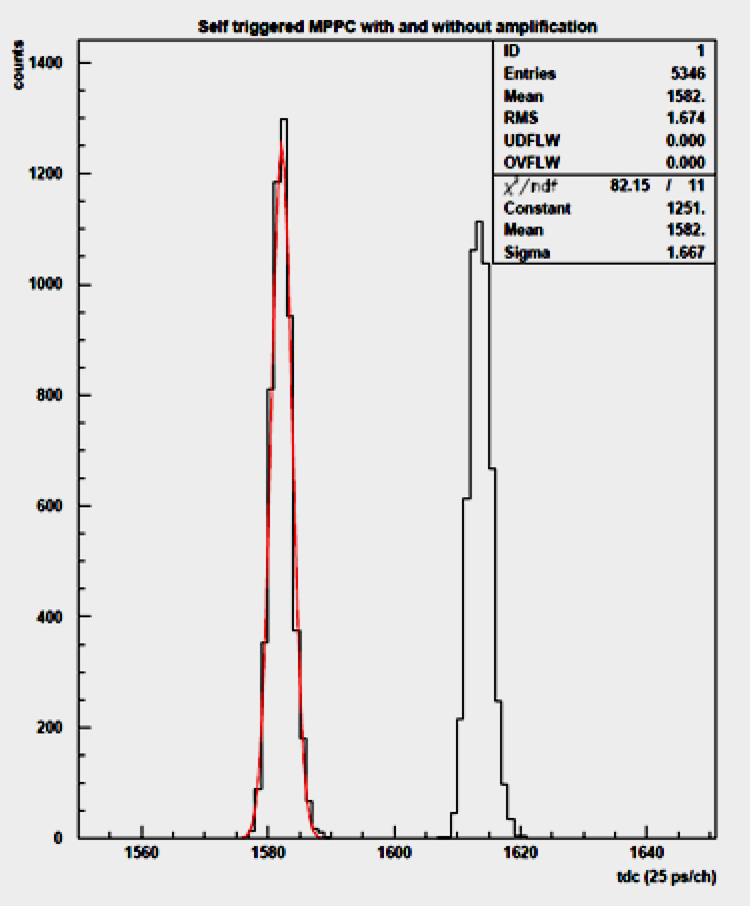
- **Transinpedance preamplifier**
  - **5mV per single photoelectron**
  - **Gain 1KOhm**
  - **Bandwidth 200 Mhz**
- **Discriminator**
  - **constant fraction**
  - **2ns delay**
- **HANDMADE!**



TIME RESOLUTION STUDY
@ Roma3 University



Laser directly on fiber: Resolution is slightly worse ≈ 80 ps due to internal reflexion



Laser directly on SiPM; 1 Khz
Res ≈ 40 ps

Amplificator is not worsening!

TIME RESOLUTION STUDY
@ Roma3 University

- Single scintillating fiber illuminated by Laser beam

  Instrumented both sides with SiPM

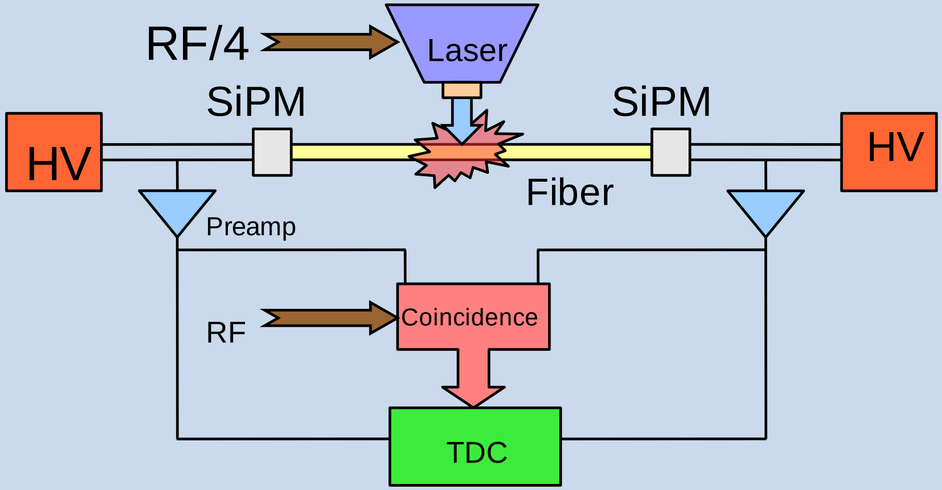
  Time difference **Res ≤ 300 ps** ⇒ **Res ≤ 80 ps**

- **Siddharta-like test:**

  -Simulation of the RF/4 (radiofrequency signal used during siddharta tests) with a 90 MHz NIM signal

  -Sincronous laser at 1 kHz

  Res ≤ 800 ps ⇒ **Res ≤ 200 ps**



NEXT STEPS

- New LARGER setup with eventual New electronics:
  - Evaluate tracking capabilities
  - More channels in less space: Evaluate cross talk
  - Remote Vbias control
  - **Temperature Feedback vs V.bias - > gain fixed**

- Test Hamamatsu arrays x4
  - we have adquired **S10984-050P** Array type (1 × 4 ch)
    Active area: 1 x 4 mm, pitch: 50 um)
    COMMON ALIMENTATION

- Simultation of daphne interaction region:
  - Energy release -> AMOUNT OF LIGHT for KAONS in fiber

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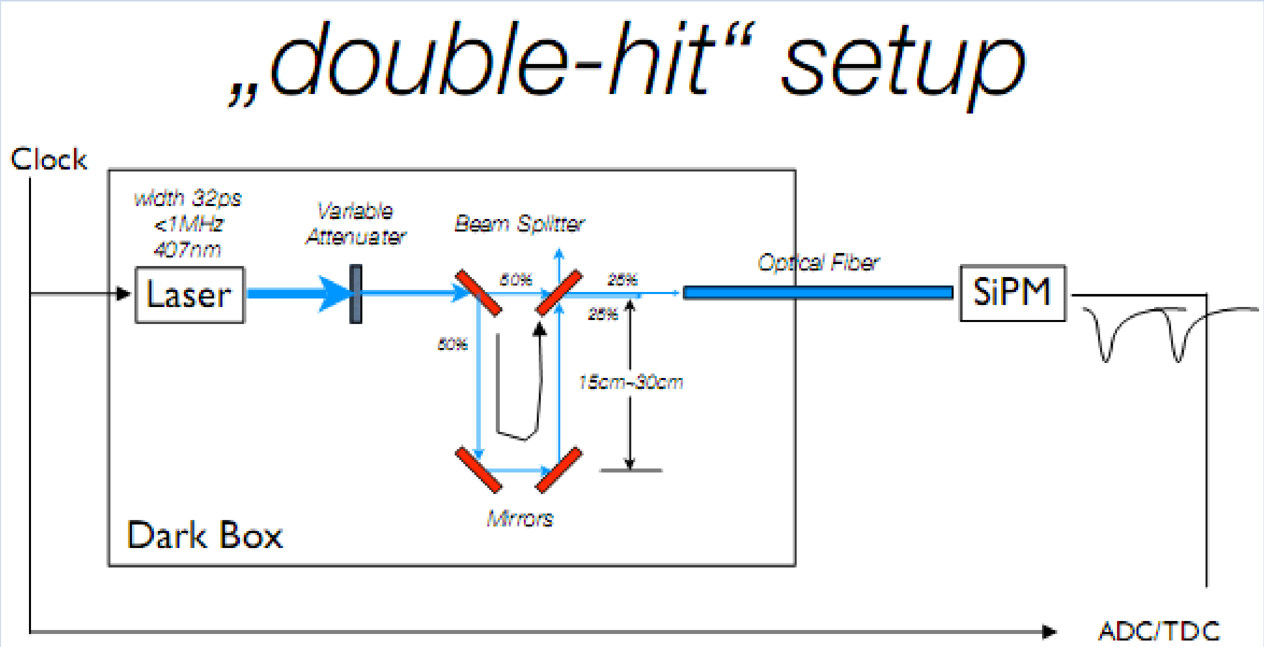
  - Energy release -> AMOUNT OF LIGHT for KAONS in fiber

- **Time resolution test @ Vienna with laser and black box**

- **PSI test for Energy deposit in the scintillating fiber**

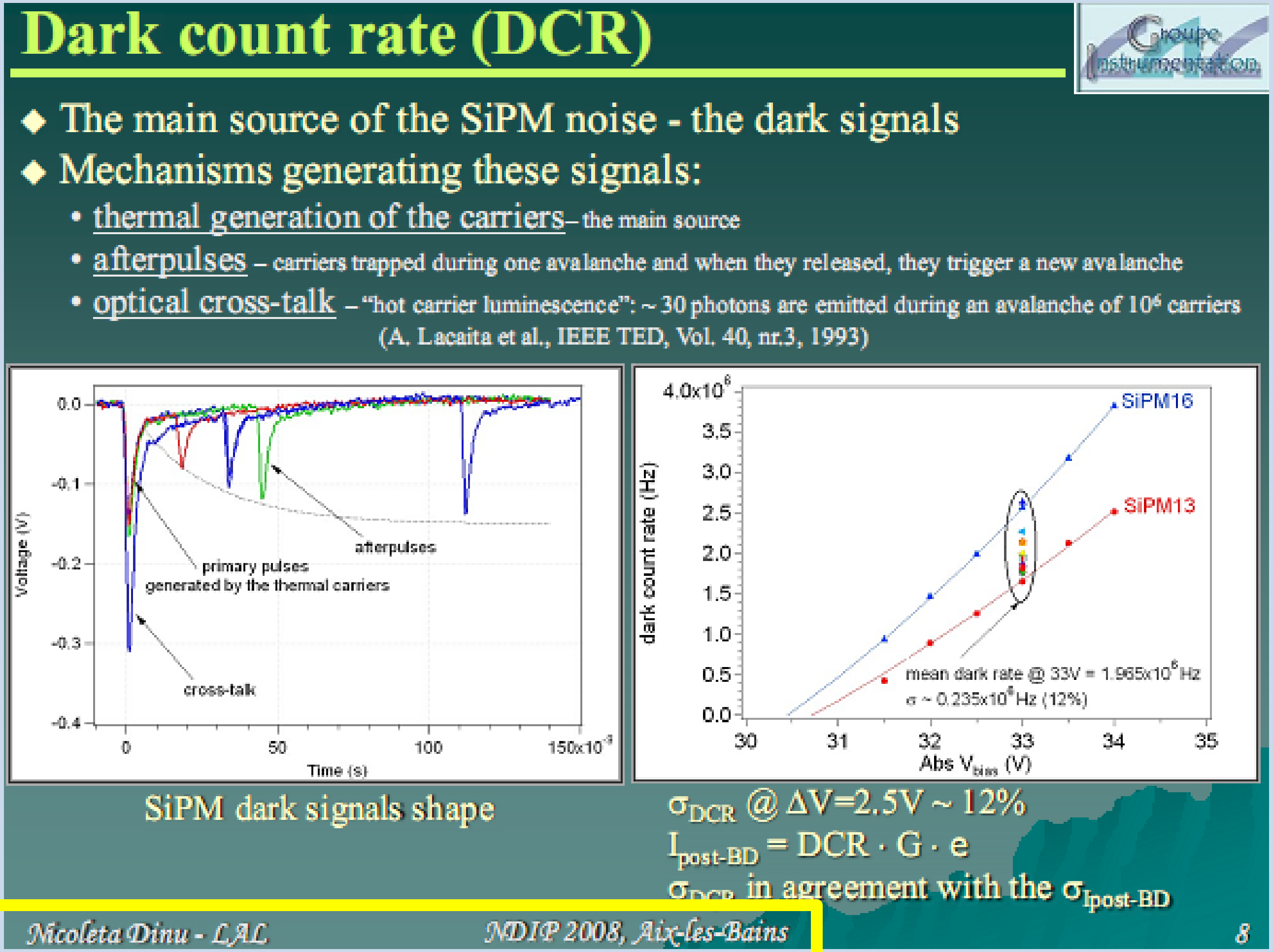
Time resolution test with LASER@VIENNA



© by Ken Suzuki

- Picosecond Laser system
- Wavelenght 407nm
- With mirrors possibility to split signal with 0.5 - 4.0 ns delay (blackbox is ~1m)

Time resolution test with LASER@VIENNA



After-pulsing effect test

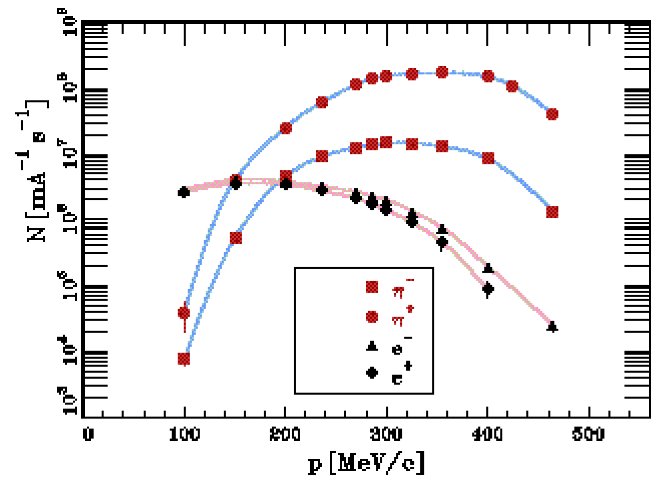
Capaciter not full recharged when 2nd pulse arriving gettin smaller signal

PSI test beam

piM1 beam line: high resolution pion beam line with a momentum range between 100 and 500 MeV/c
The pion momentum can be determined from a hodoscope made of 64 scintillators strips, located at the intermediate focus.
Electrostatic separator built at CERN ("2 m" type), which can reduce the proton contamination in a pi+ beam from 400% to about 5% at 300 MeV/c momentum.

Table 1 : Characteristics of the piM1 beam line

Total path length	21 m
Momentum range	100-500 MeV/c
Solide angle	6 msr
Momentum acceptance (FWHM)	2.9 %
Momentum resolution	0.1 %
Dispersion at focal plane	7 cm/%
Spot size on target (FWHM)	15 mm horizontal
	10 mm vertical
Angular Divergence on target(FWHM)	35 mrad horizontal
	75 mrad vertical



Pion an electron fluxes in piM1

Figure gives the measured particle fluxes for the standard beam-line tune as a function of momentum with an uncertainty of 10% at the peak of the yield curves.
The flux of muons is 100 times smaller than the corresponding pion flux at momenta around 300 MeV/c, and falls more slowly than for the pions toward low momenta.

THANK YOU

(but...)

Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH)
WP28- SiPM

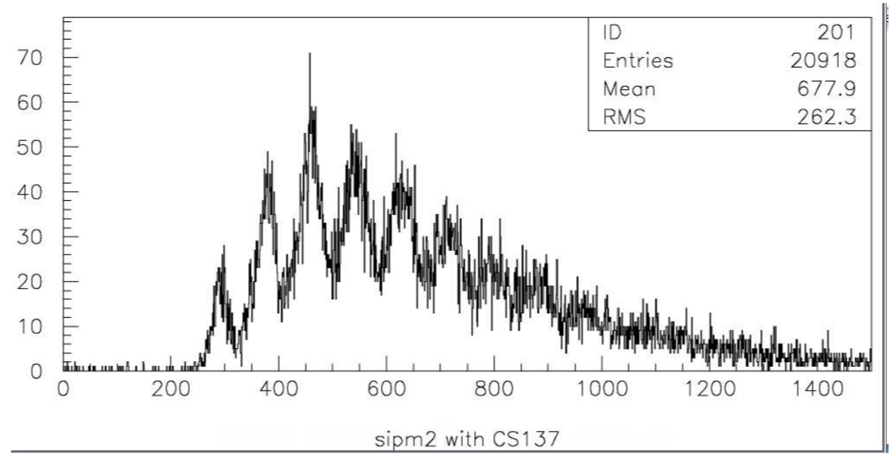
•During 2009, to avoid the overlapping of tasks, we reinforced our key electronics infrastructure : 2x Keithley 2400 SourceMeters (9.250 Euro), VME crate and modules (28.000 Euro), oscilloscope and logic analyzer (17.500 Euro)

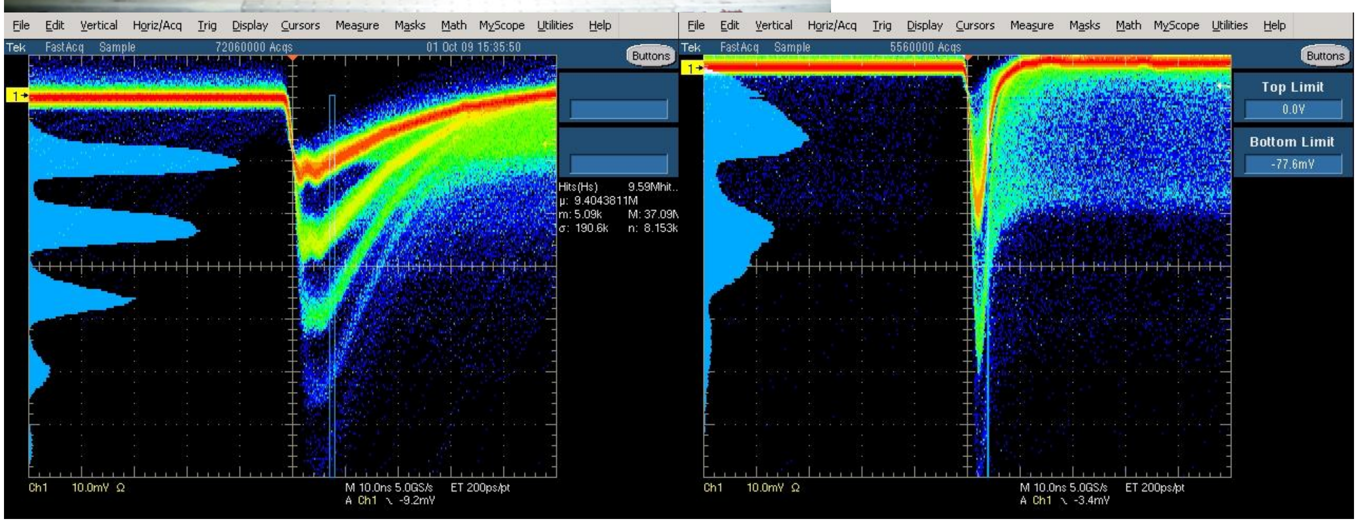
•Altera (Cyclone II FPGA) and Analog Devices (Blackfin processor) development boards (1.000 Euro)

<u>If needed:</u>
Clean room: 15 m^2 (Cleanliness Class 1.000)
(Certification at the end of February 2010)
Costs: 41.000 Euro
Additional 50 m^2 experimental area

To be shared with WP24-JointGEM Activity

Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH)
WP28- SiPM



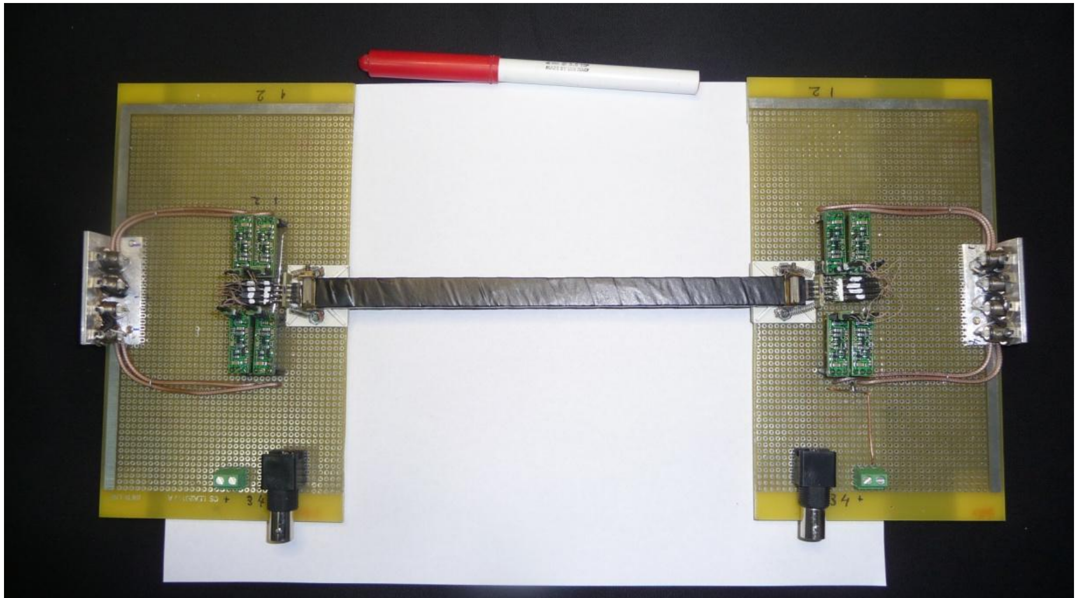


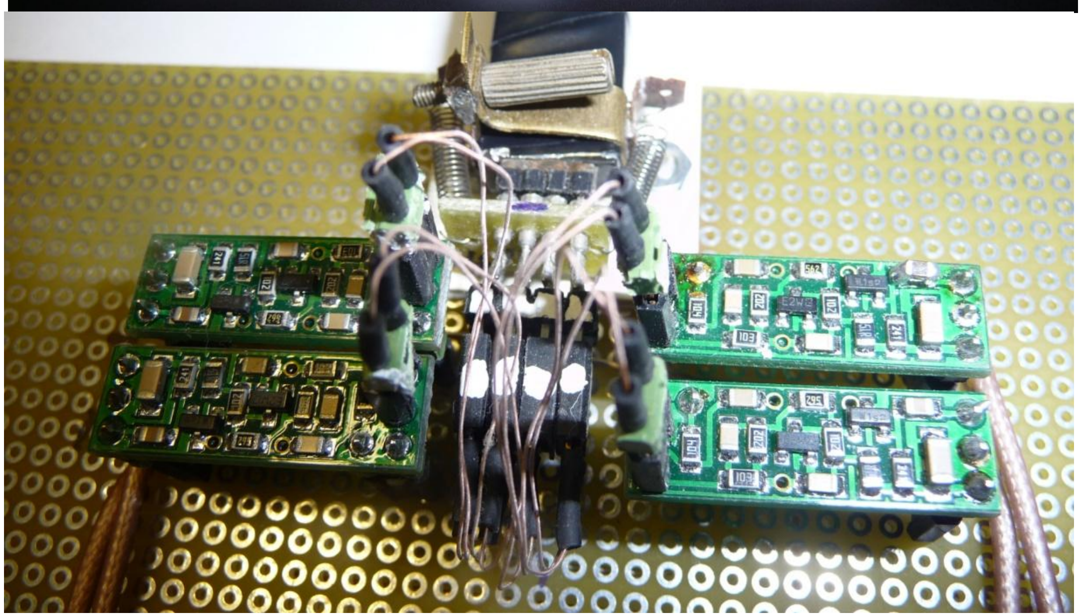
<u>Autumn 2009</u>: Small SiPM setup (fiber) now used for educational purposes

– <u>Radiation Monitor Payload Subsystem of European Student Moon Orbiter (ESMO) mission in collaboration with ESA</u>

Hamamatsu (S10362-11-100C) vs. Photonique (SSPM-050701GR-TO18)

Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH)
WP28- SiPM





Setup based on 2 Photonique 4 element arrays and 6x12x200 mm scintillator under test in IFIN.

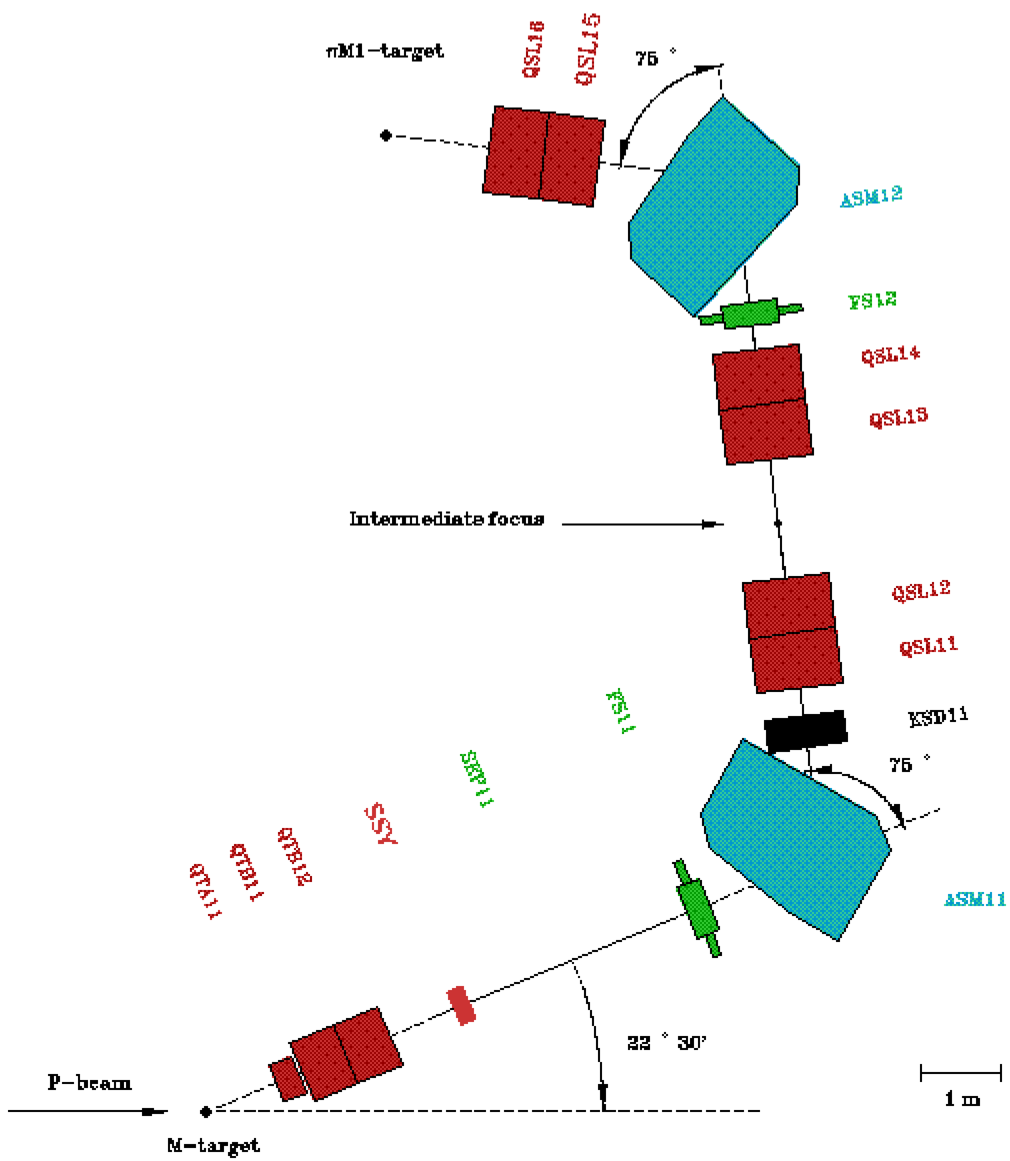
- Main goal logical correlation between groups of “fired “ opposite cells in order to reduce (eliminate?) the thresholds in amplitude;

-Second type of array (Hamamtsu – S10984) to arrive soon (ordered by Frascati at the end of 2009);

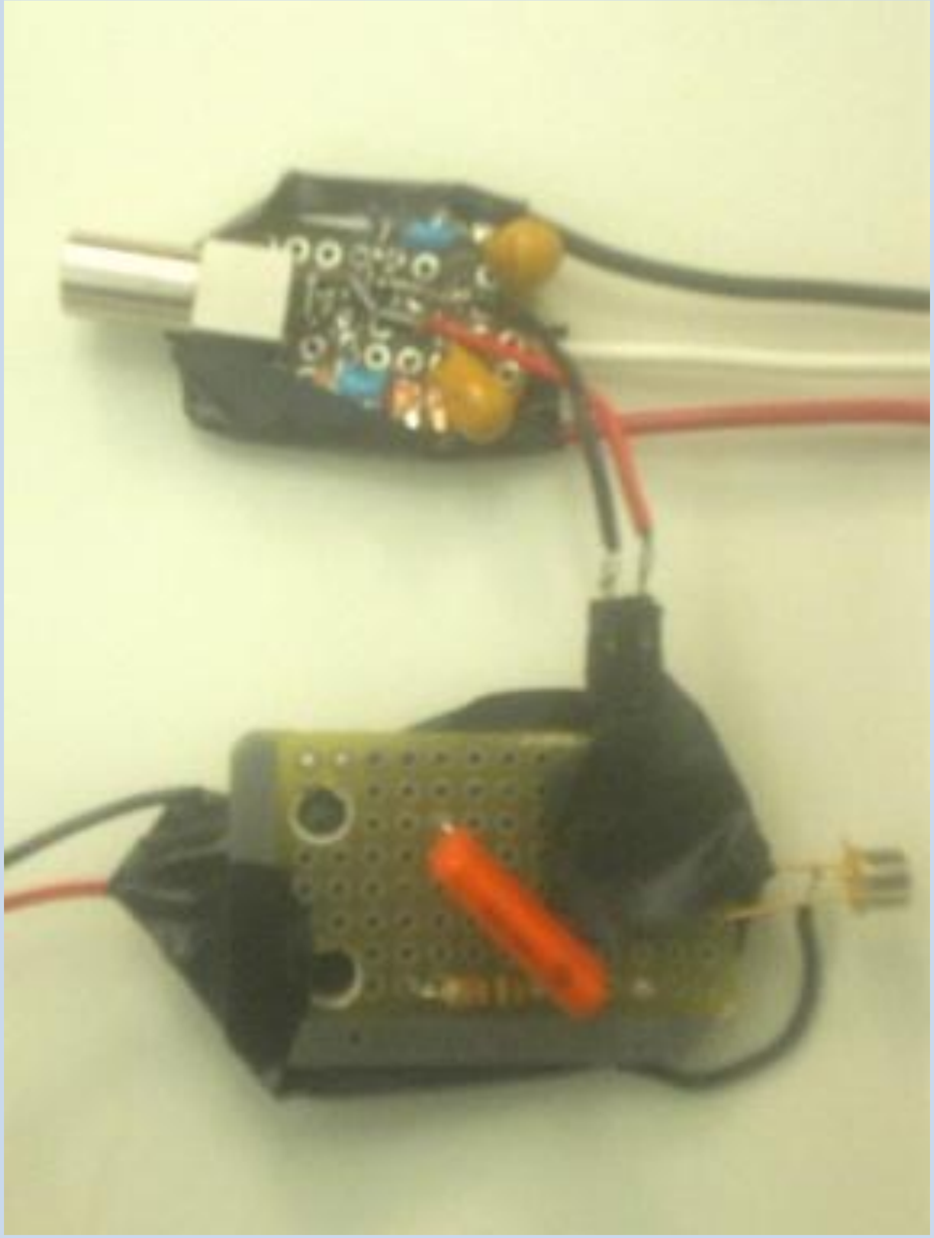
Testing in Frascati @ DAFNE-Beam Test Facility to be scheduled until summer holidays.

SPARE

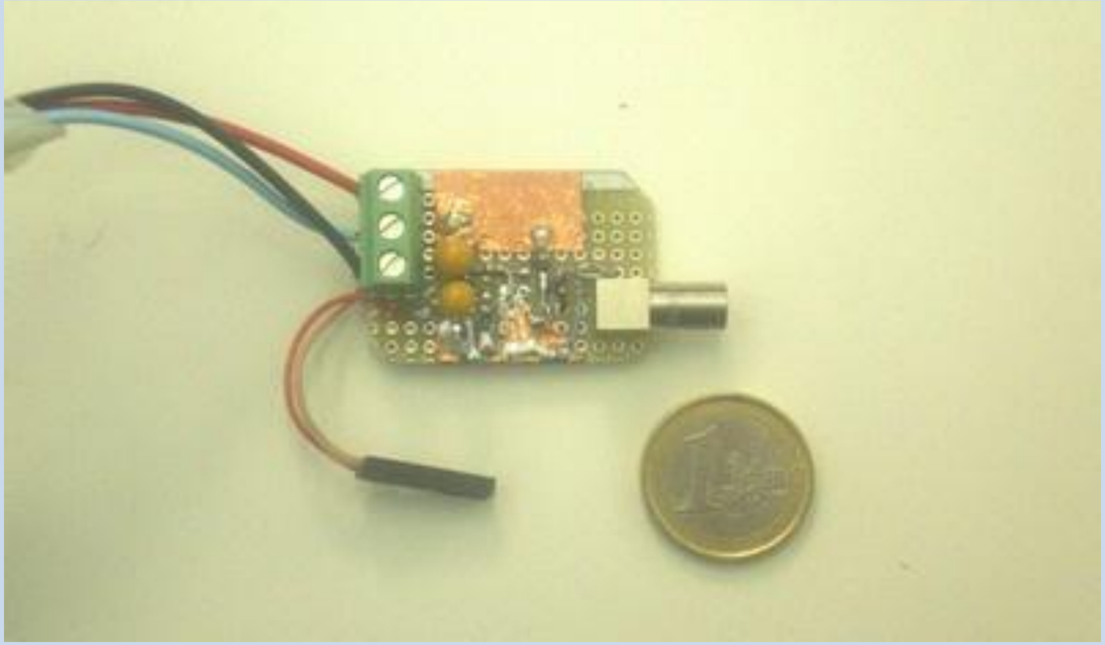
πM1



πM1−target
QSL16
QSL15
75 °
ASM12
FS12
QSL14
QSL13
Intermediate focus
QSL12
QSL11
KSD11
FS11
SHP11
SSY
QTB12
QTB11
QTA11
75 °
ASM11
22 ° 30'
1 m
P−beam
M−target

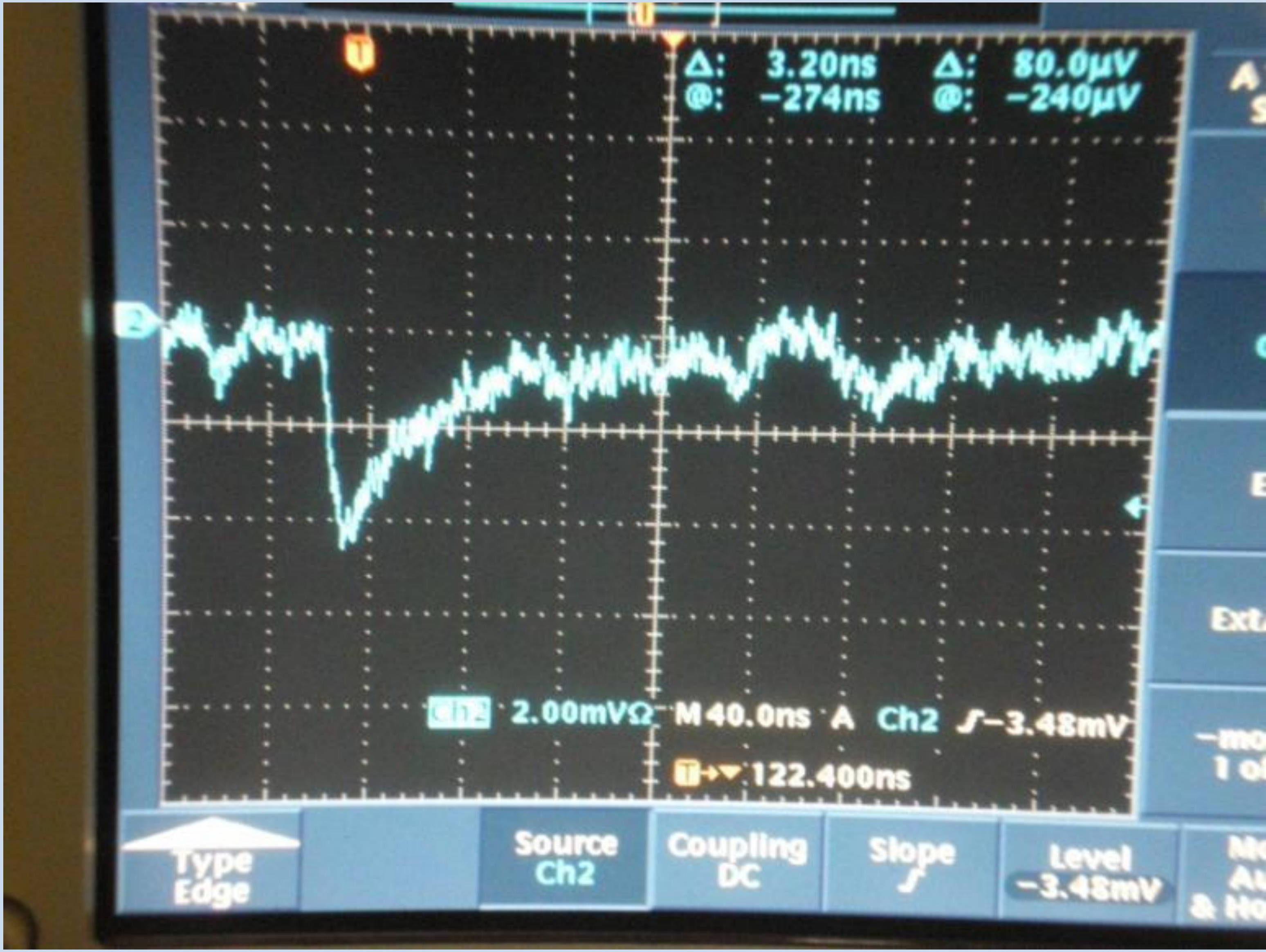


Elettronica di supporto



Per simulare la radiofrequenza di DAΦNE si è reso necessario un convertitore TTL NIM che preleva un segnale TTL, fruibile da qualunque unità logica (es: una FPGA) e lo converte nello standard NIM.
Garantito per uno clock di **100MHz**.

Costruito con una pinza e un saldatore!



Δ: 3.20ns
@: −274ns
Δ: 80.0µV
@: −240µV
Ch2 2.00mVΩ M 40.0ns A Ch2 ∫ −3.48mV
122.400ns
Type Edge
Source Ch2
Coupling DC
Slope
Level −3.48mV

Conclusions

AMADEUS @ DAΦNE

- **Trigger is a crucial point and some preliminary indications are coming from test setup in DAFNE**
- **Achieved best single peak resolution around 300 ps**
- **Final test of feasibility is undergoing**
- **Simulation of K and MIPS on test setup are undergoing**

First publications:

- A. Scordo et al. “Silicon PhotoMultipliers(SiPM) for the AMADEUS trigger system” Proc. XLVII International Winter Meeting on Nuclear Physics; Bormio(Italy), 26-30 January 2009
- M. Bazzi et al. “Scintillating fibers read by Multi Pixel Photon Counter as trigger system for AMADEUS experiment at DAΦNE; AMADEUS technical note IR-1 29/09/2009