IFR Detector R&D status

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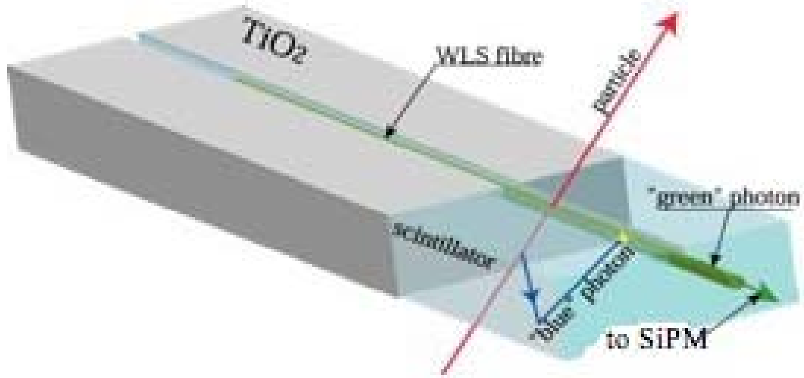
On behalf of the ferrara SuperB group

Detector R&D Workshop, Orsay Feb. 15-18 2008

Detection Technique

Scintillator bars + WLS fibers readout on both ends by Geiger mode APDs



- **Scintillator:**
  - **4 cm** scintillator bars coated with TiO_2
  - Light collection through **WLS fibers**
  - Fibers housed in a surface grove
    or in a embedded hole
- **WLS fibers:**
  - $\phi = $ **1mm** type **Y11(200/300)** (Kuraray) or **BCF92** (Saint Gobain), Attenuation length $\lambda \approx$ **3.5m,** trapping efficiency $\varepsilon \approx$ **5.5%**
- **Photodetectors:**
  - **M**ulti **P**ixel **P**hoton **C**ounters (Hamamtsu), **Si**licon **P**hoto **M**ultiplier (IRST Trento-Italy):
    - **Gain >10^5**, **DE ≈ 40%** (@ 500 nm, MPPC) (DE = Q.E x Fill factor x Avalanche probability)
    - < 1ns risetime
    - Low bias voltage (35V SiPM, 70V MPPC)
    - Dark current rate @ room temperature : **100s of kHz @ 0.5 phe**, few **10s of kHz @ 1.5 phe, few kHz @ 2.5 phe**

detector layout options…

- 2 layouts: time readout, double coord. readout
- Time readout: the azimuthal coord ϕ by the hit bar and polar coord θ by the arrival time of the signal
- Double coord readout: two layers of orthogonal (1.0 cm) scintillating bars provide directly the ϕ and θ coordinates.
- Easier from the point of view of electronics but more complicated for the mechanics

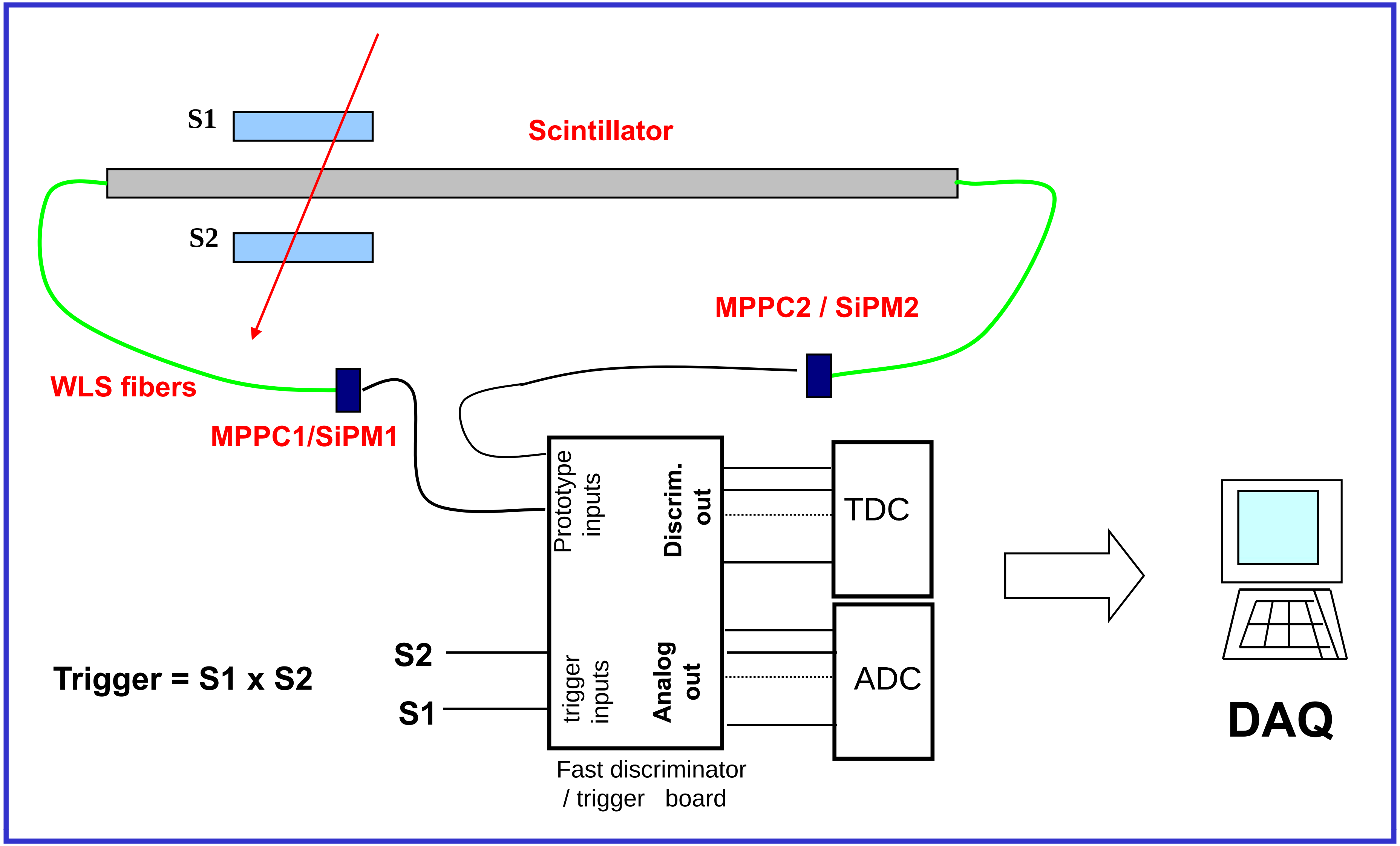
readout options…

- Waiting for simulations of background neutron flux on the detector…

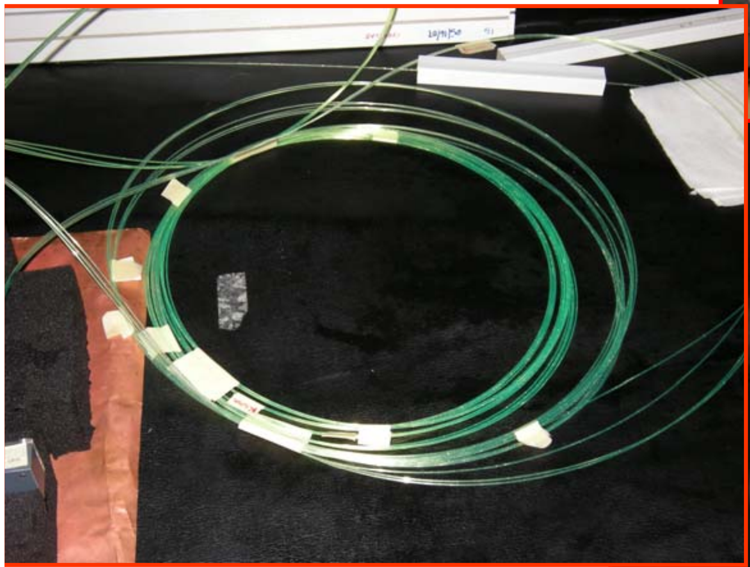
- In the most pessimistic case we have to bring all the photosensors out of the detector :
  - 4m of WLS fiber + 10m of clear fibers
  - Factor ~3 less in number of p.e., to be recovered keeping the same time resolution:
    - Increasing the number of WLS fibers, from 1 to 4, on 2x2 mm^2 SiPM
    - Increasing the fiber's diameter from 1.0 to 1.2 (ordered from Kuraray, expected 2-nd half of Feb.)
    - Playing with fibers position and/or scintillator coating to maximize the light collection

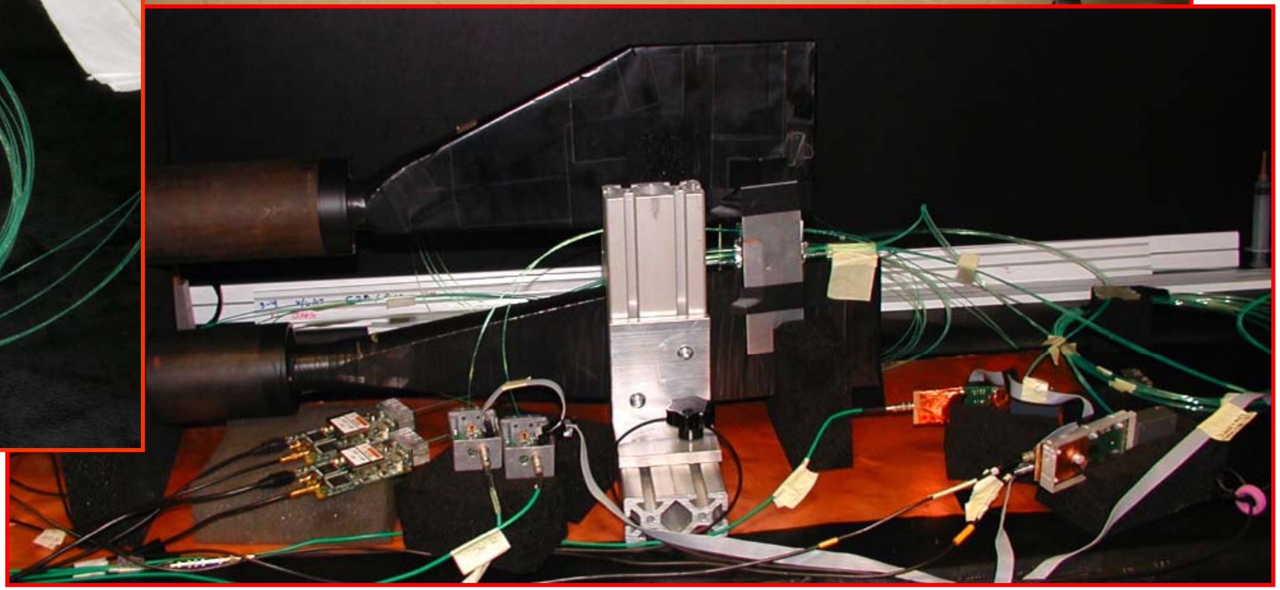
Detector R&D activities in Ferrara

Cosmic ray test setup



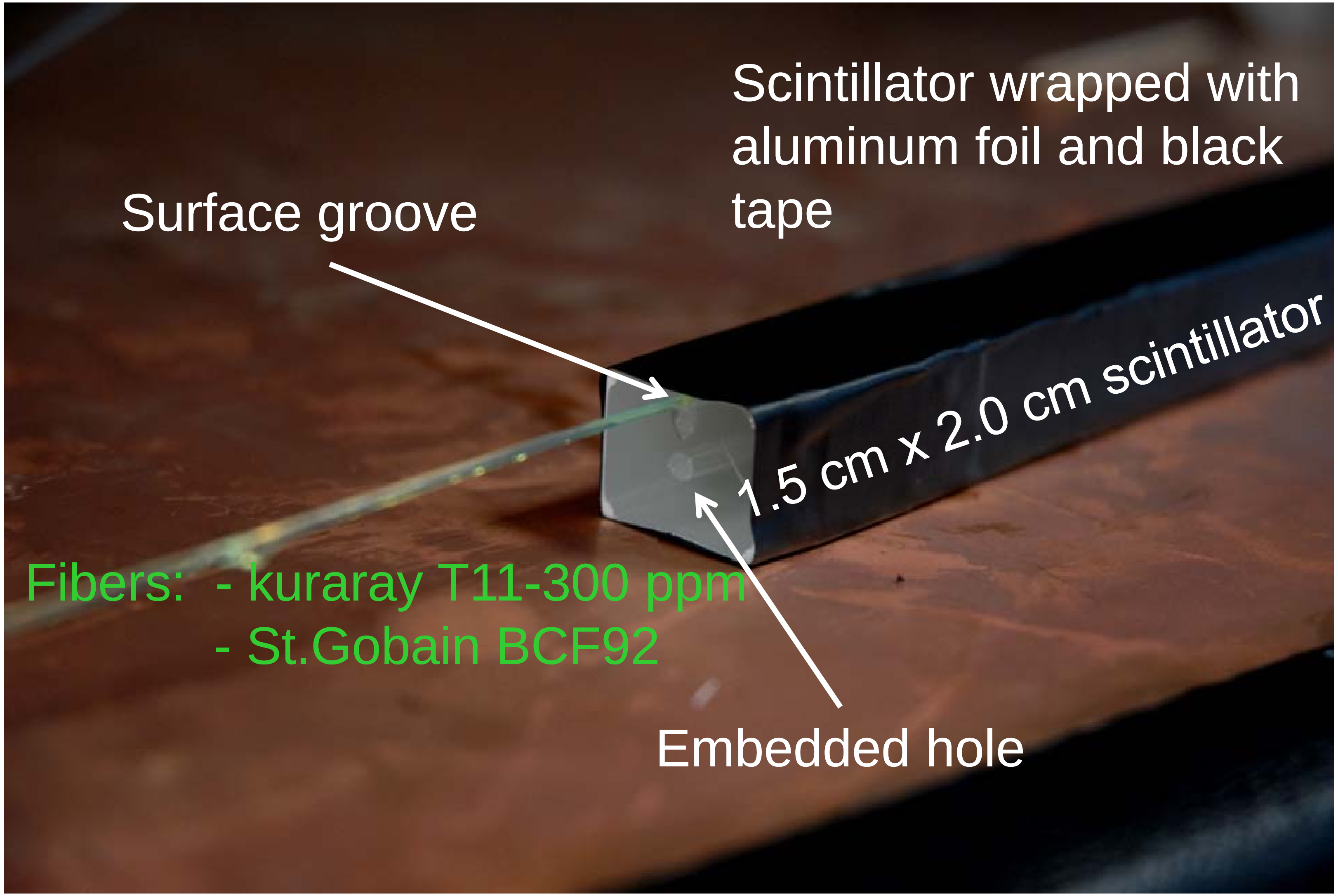
Cosmic ray test setup



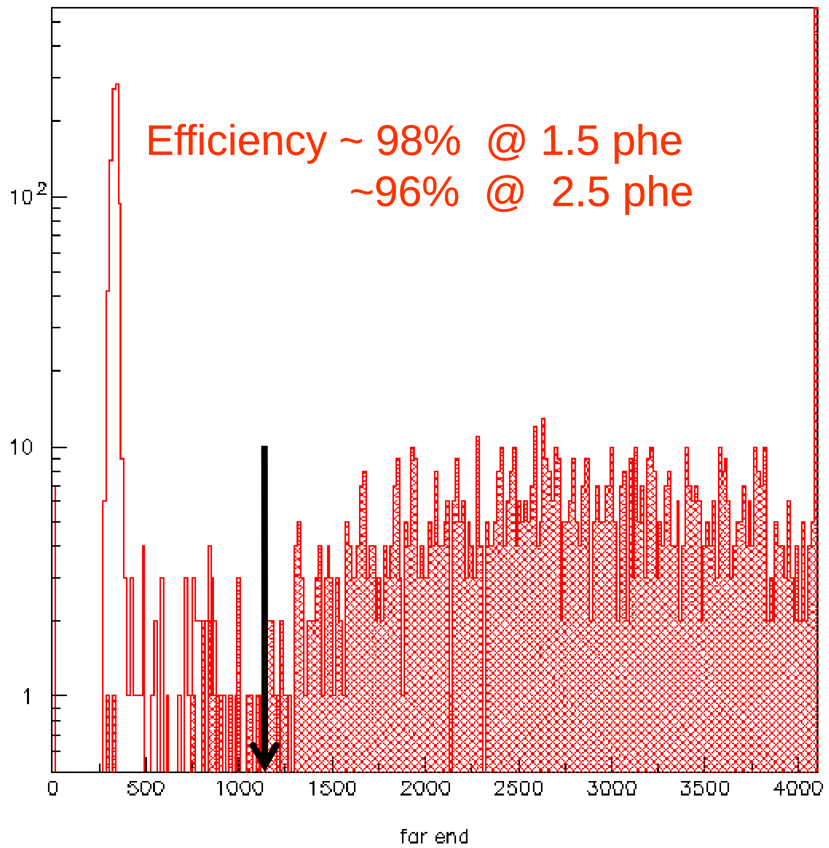


Detection efficiency and timing studies for “on detector readout”

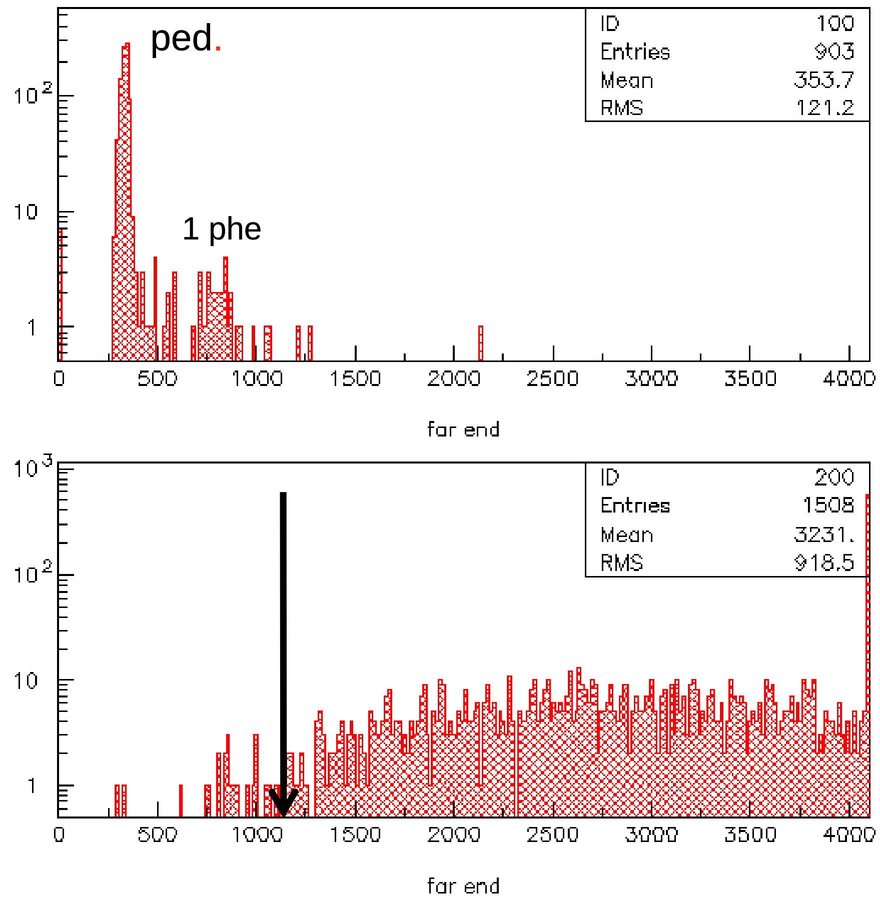
Module prototype



Light yield fiber: Kuraray



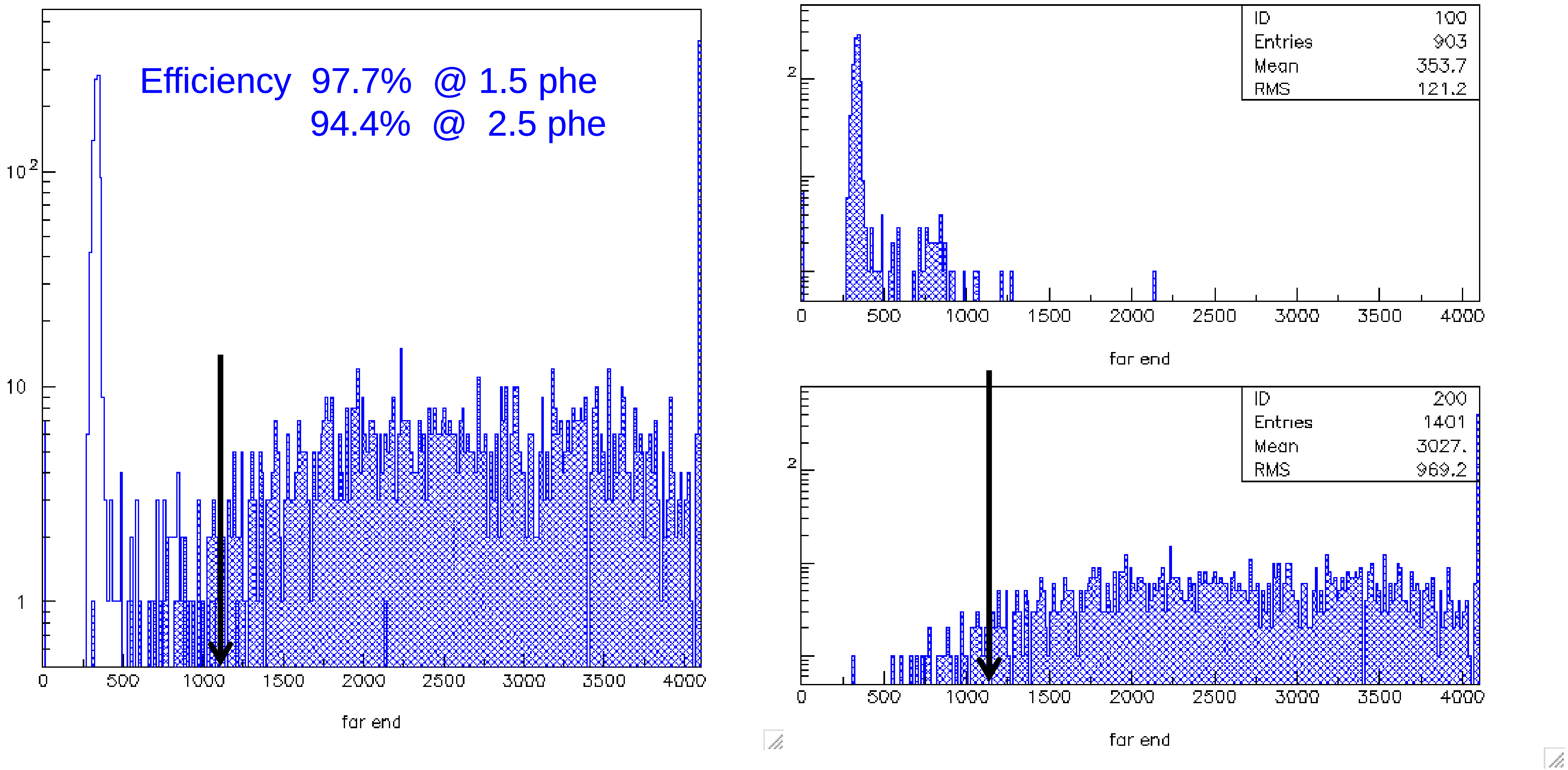
ADC spectrum 350 cm far from the trigger



Separate plots for pedestal and signal

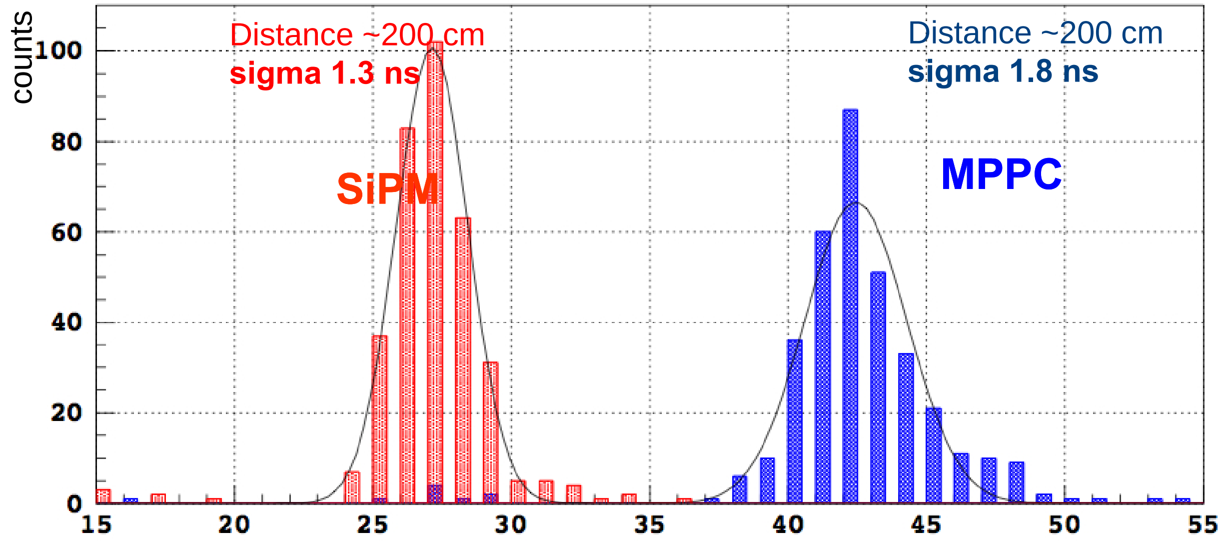
ADC spectra for a kuraray T11-300 fiber about 4 m long in an embedded hole

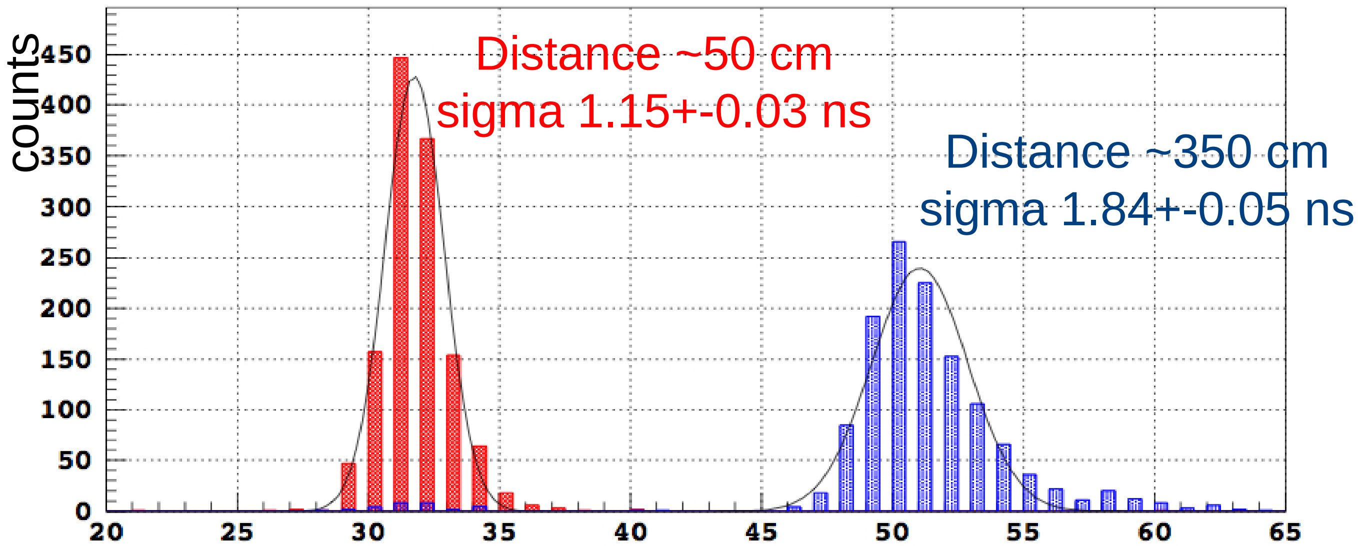
Light yield fiber kuraray

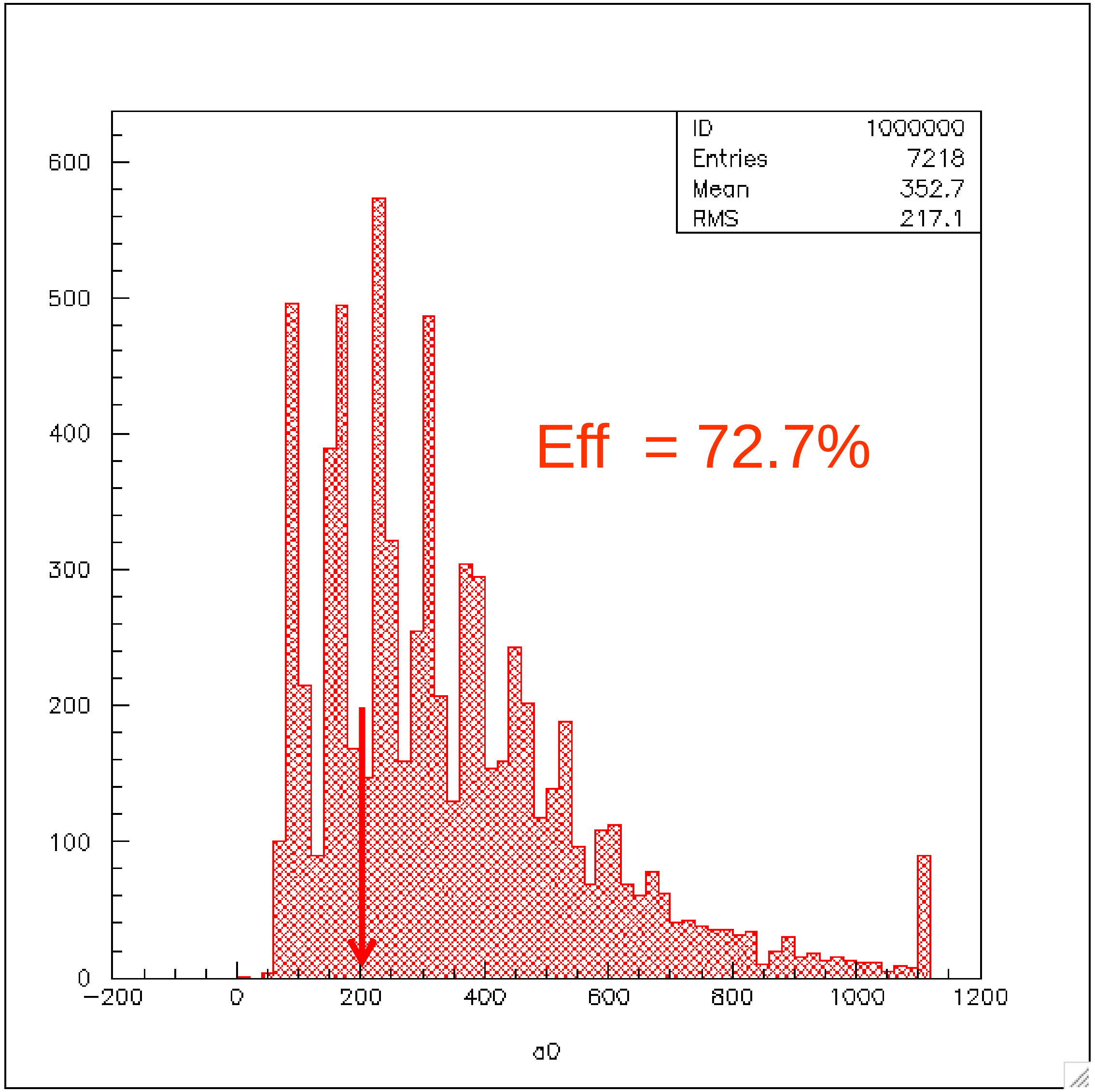


ADC spectra for a kuraray T11-300 fiber about 4 m long in a surface groove

Time resolution Saint-Gobain fiber

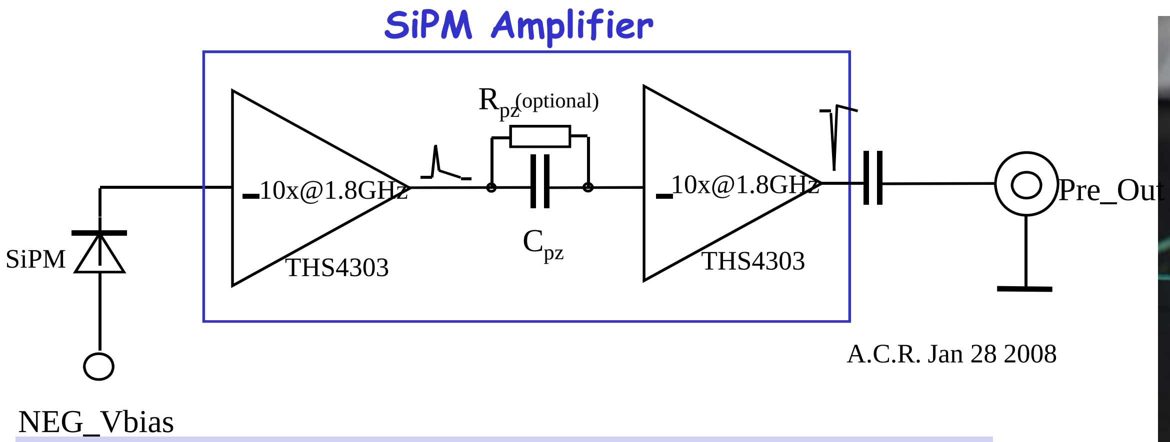


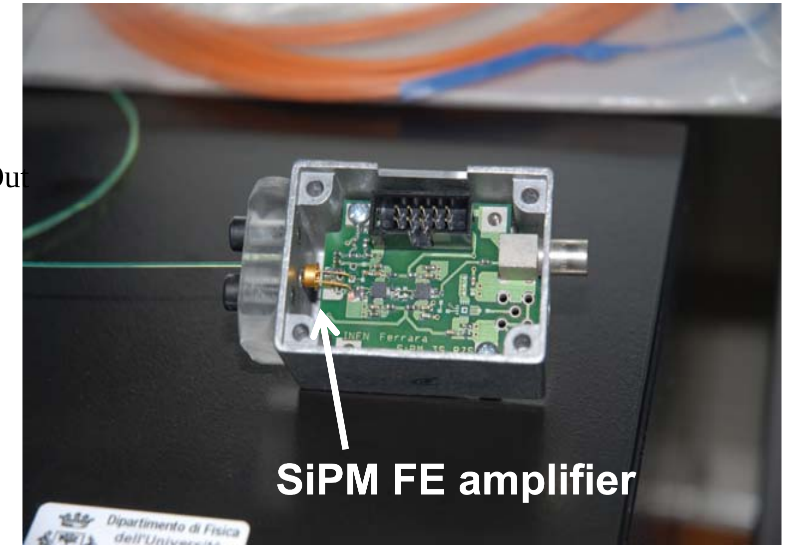




- 1.0 cm scintillator and Saint-Gobain fiber on a surface groove
- Low light yield at the far end (~ 4 m)
- Detection efficiency less that 73% @ 1.5 phe

Front End Electronics

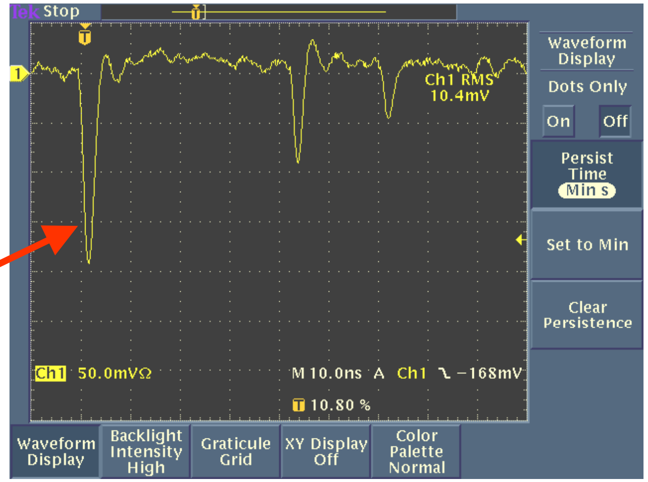




- The MPPC modules comes with (unknown) FE electronics

- For the SiPM devices a prototype amplifier has been developed based on commercial Texas Instrument THS4303 fast amplifier

- The idea is to preserve as much as possible the very fast leading edge of the SiPM signal (~ 200psec) to minimize the time spread

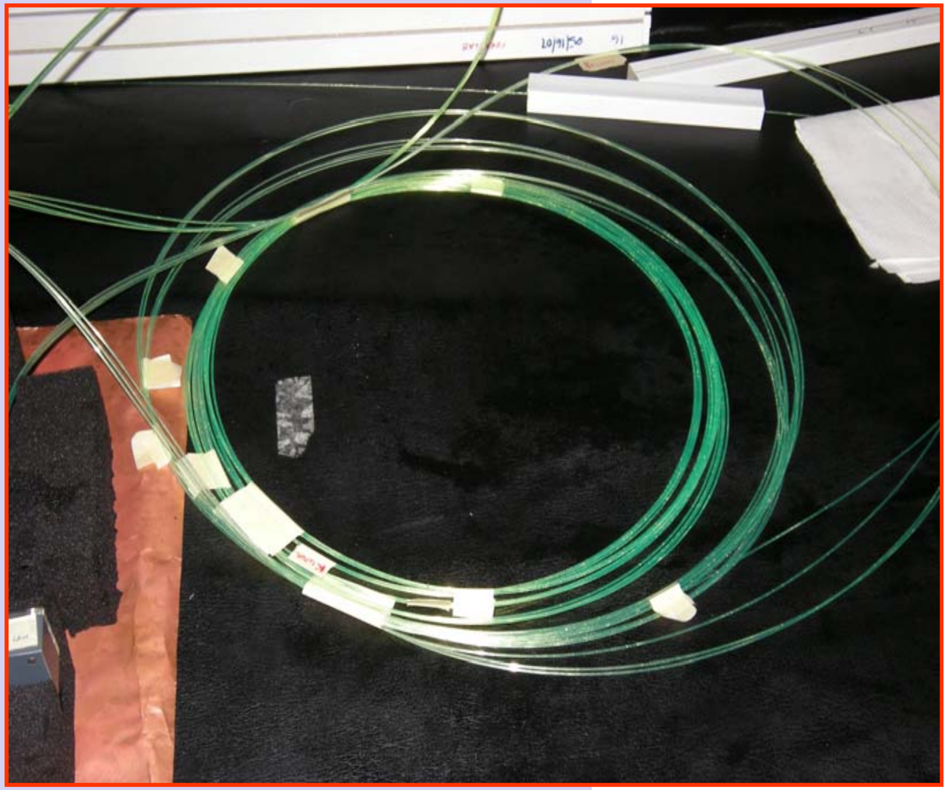


Latest studies for “out of detector readout”

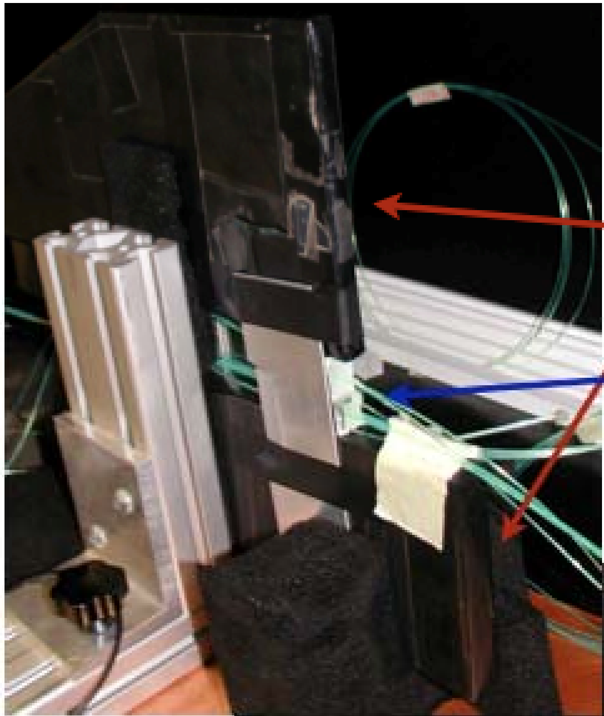
- In this case we have to bring the light signal out of the detector, in a lower radiation region
- we have considered 10m of clear fiber

□ $\lambda_{att} = 10$ m → ~ factor 3 less number of p.e.

- Several measurements are ongoing:
  - 4 WLS fibers/scintillator on 2x2 mm^2 SiPM (Hamamatsu 3x3 mm^2 ordered)
  - Various FE amplifiers
  - Kuraray and Saint-Gobain fibers
- <u>two 1cm scintillators</u> "sandwiched"



Some picture of the last setup

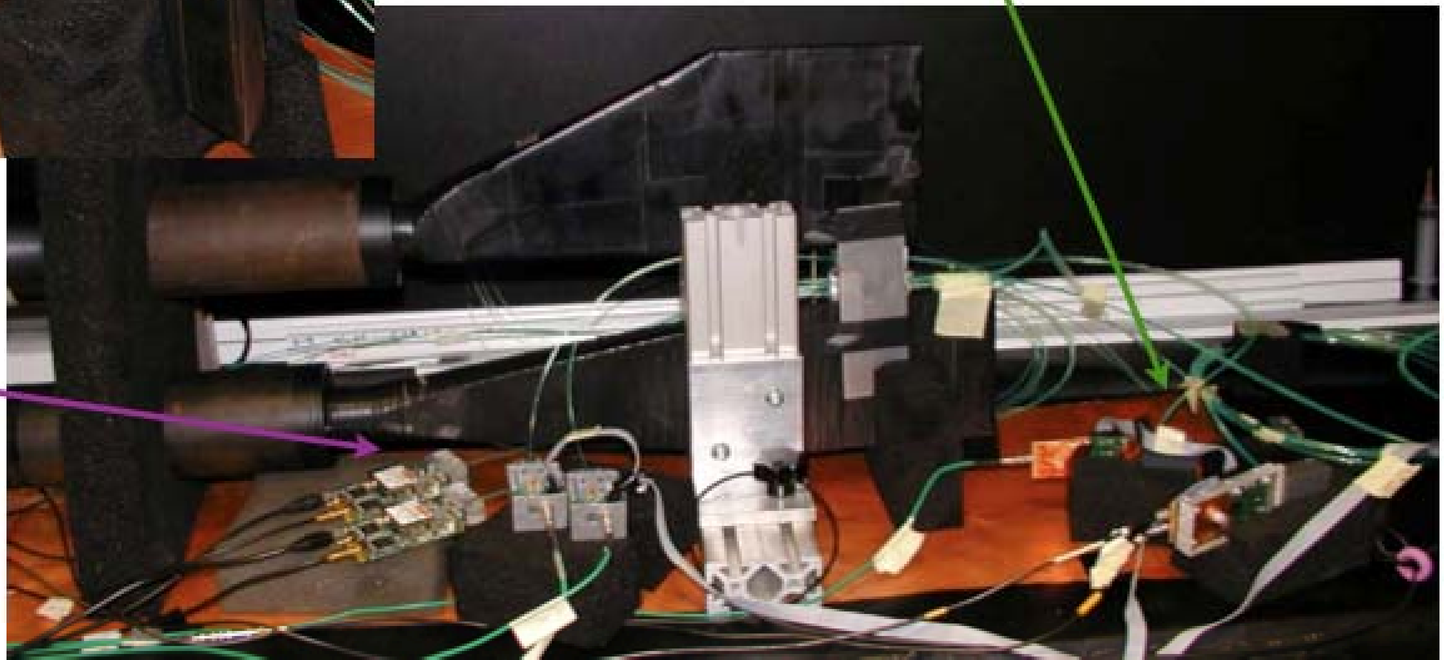


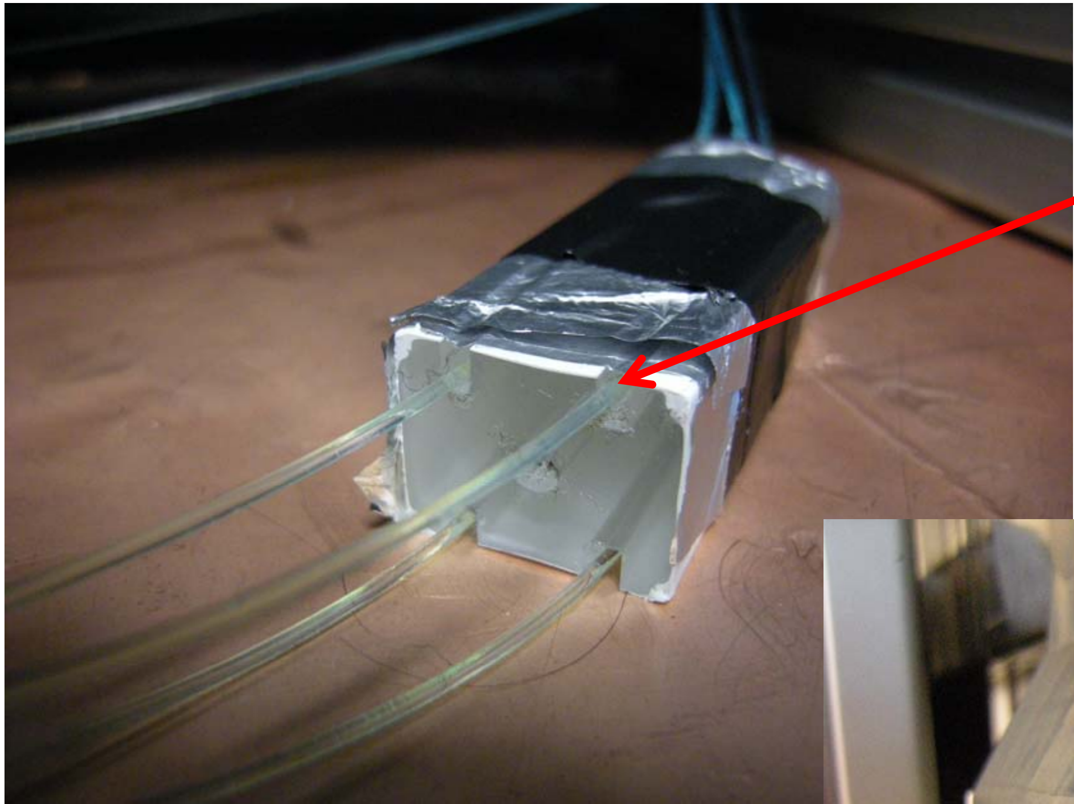
scintillators with PMTs as fast trigger

2 5-cm long 2-cm high scintillators with different combinations of fibers.

4 fibers readout by 2x2 mm2 SiPM

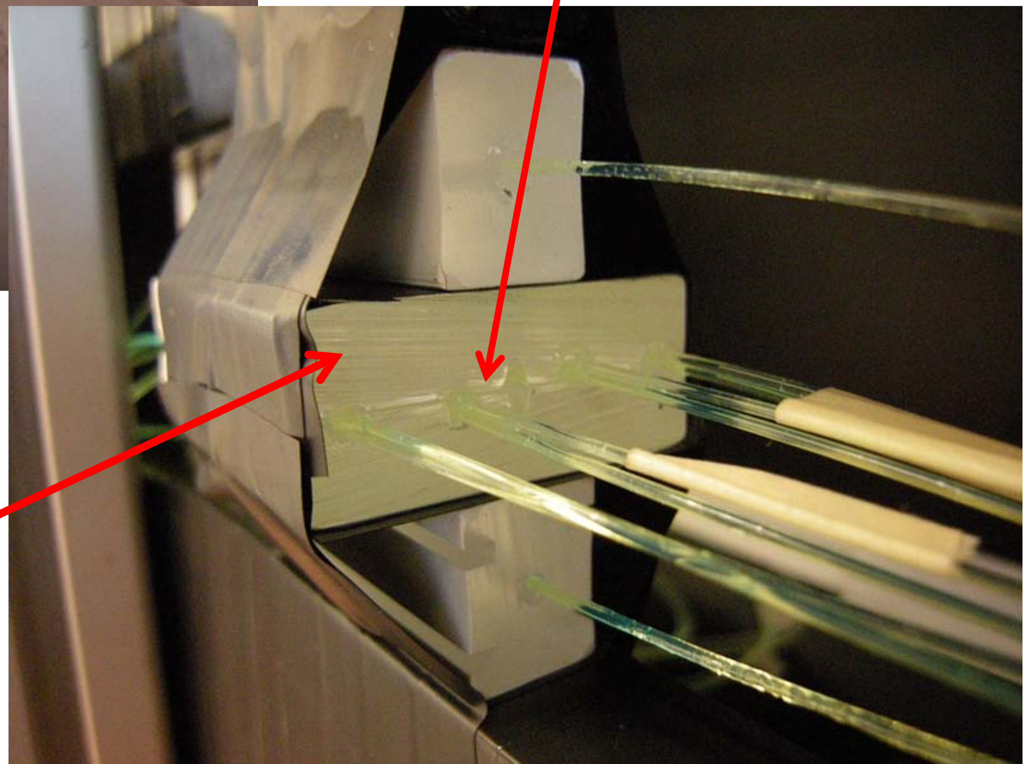
1 fiber readout by 1x1 mm2 SiPM/MPPC





4 fibers kuraray OR saint gobain

8 fibers kuraray AND saint gobain



Two sandwiched scintillators 1cm thick

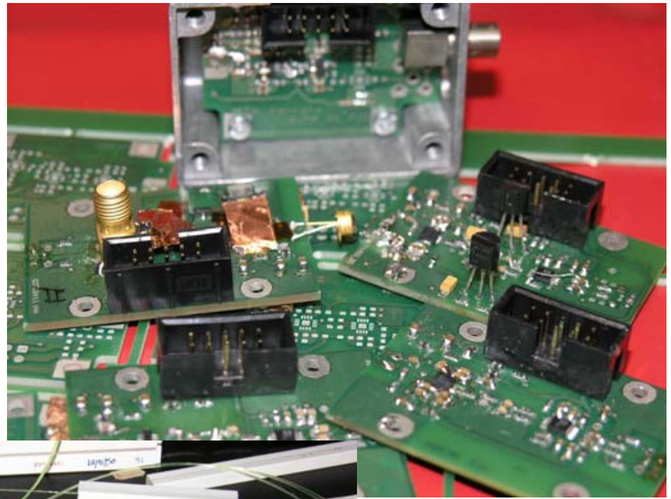
In some more detail…

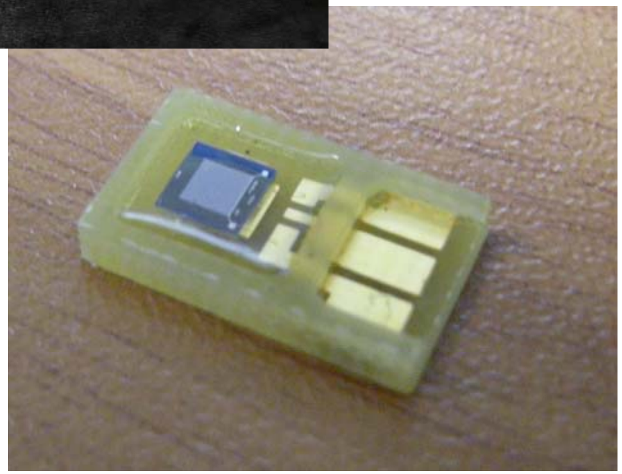
- We tried many combinations of FE amplifiers (for complete description see Roberto Malaguti’s talk) with different gain/BW combinations:
  - Texas instruments
  - Analog device

- Various fiber’s length: 3,4,5 m of both, Bicron and Kuraray

- SiPM with active area 2x2 mm^2 (waiting for Hamamatsu 3x3 mm^2)

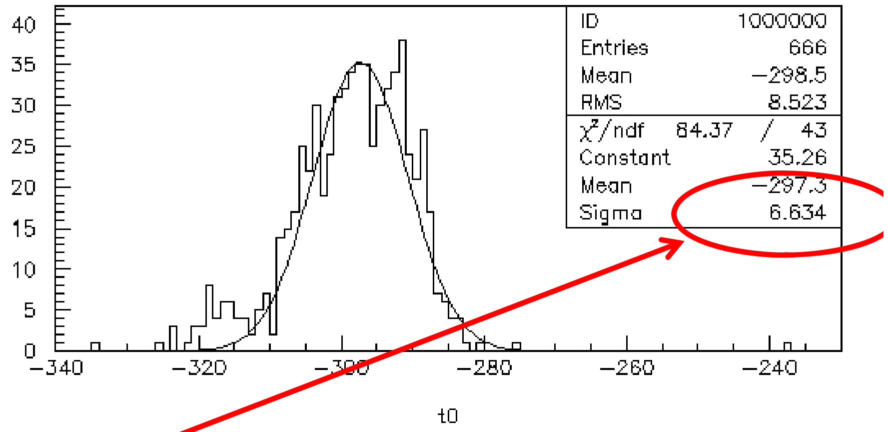
- We concentrated our efferts (for the moment) on the optimization of the time resolution

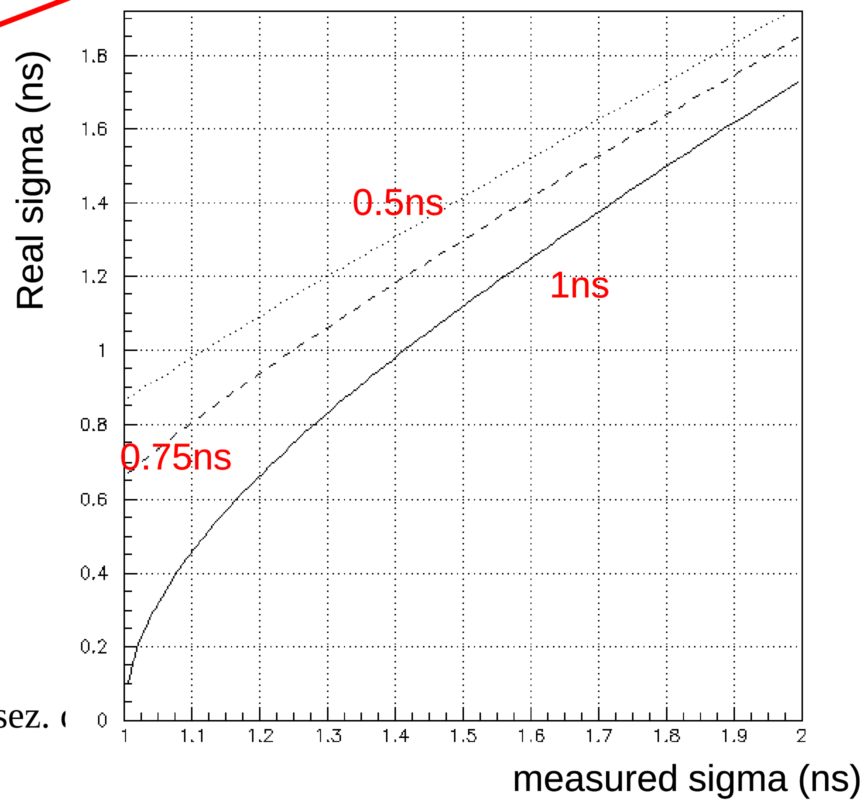




So.. Let's start from the trigger

- The trigger is given by the coincidence of two scintillators: S1, S2, to select vertical cosmics
- The reference time T_0 is given by scintillator S2. S1 has a time spread of ~0.66 with respect to S2
- The T_0 time spread is then about 0.4 - 0.5 nsec so the actual time resolution is expected to be roughly 0.1 nsec lower



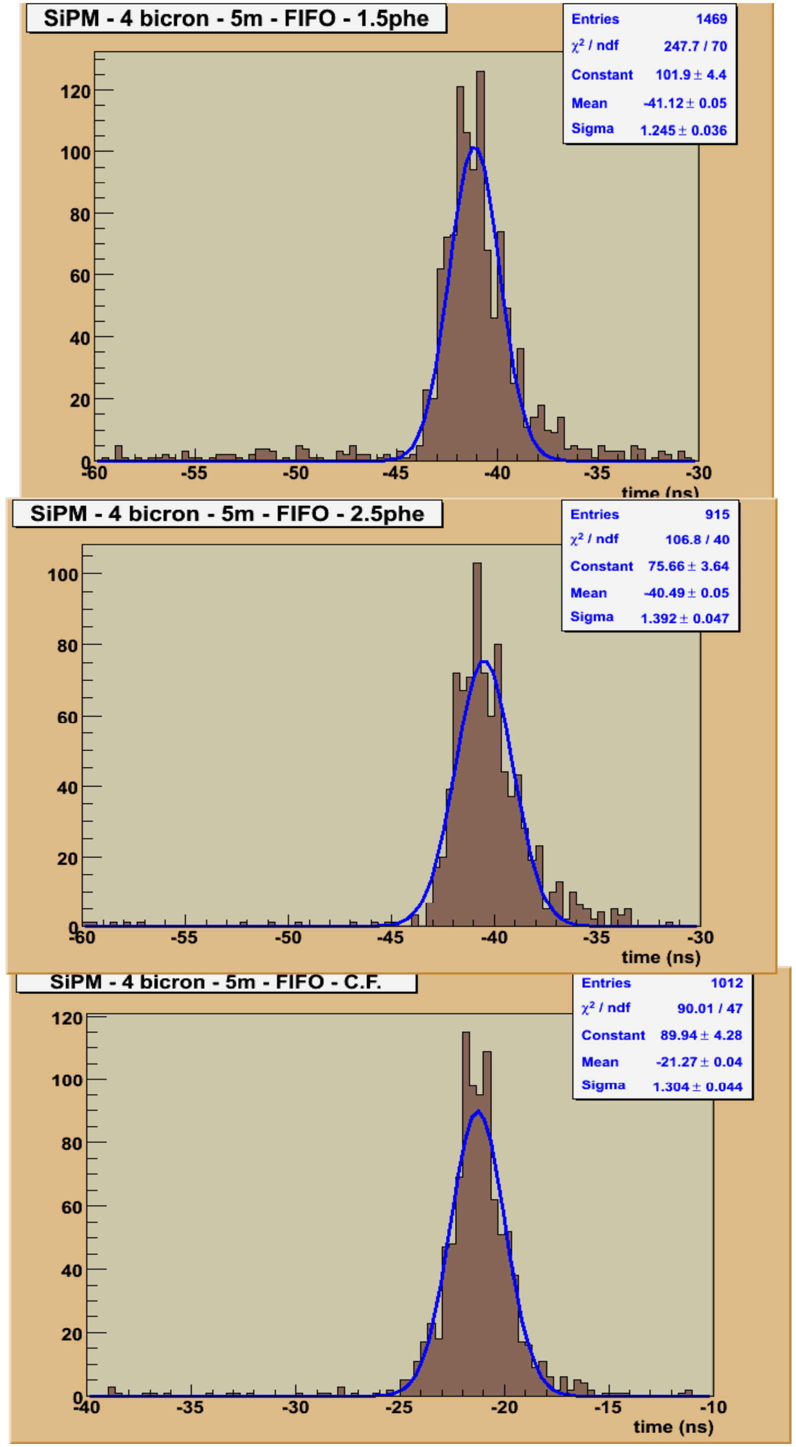


• Our best results (for the moment) have been obtained with Saint-Gobain fibers

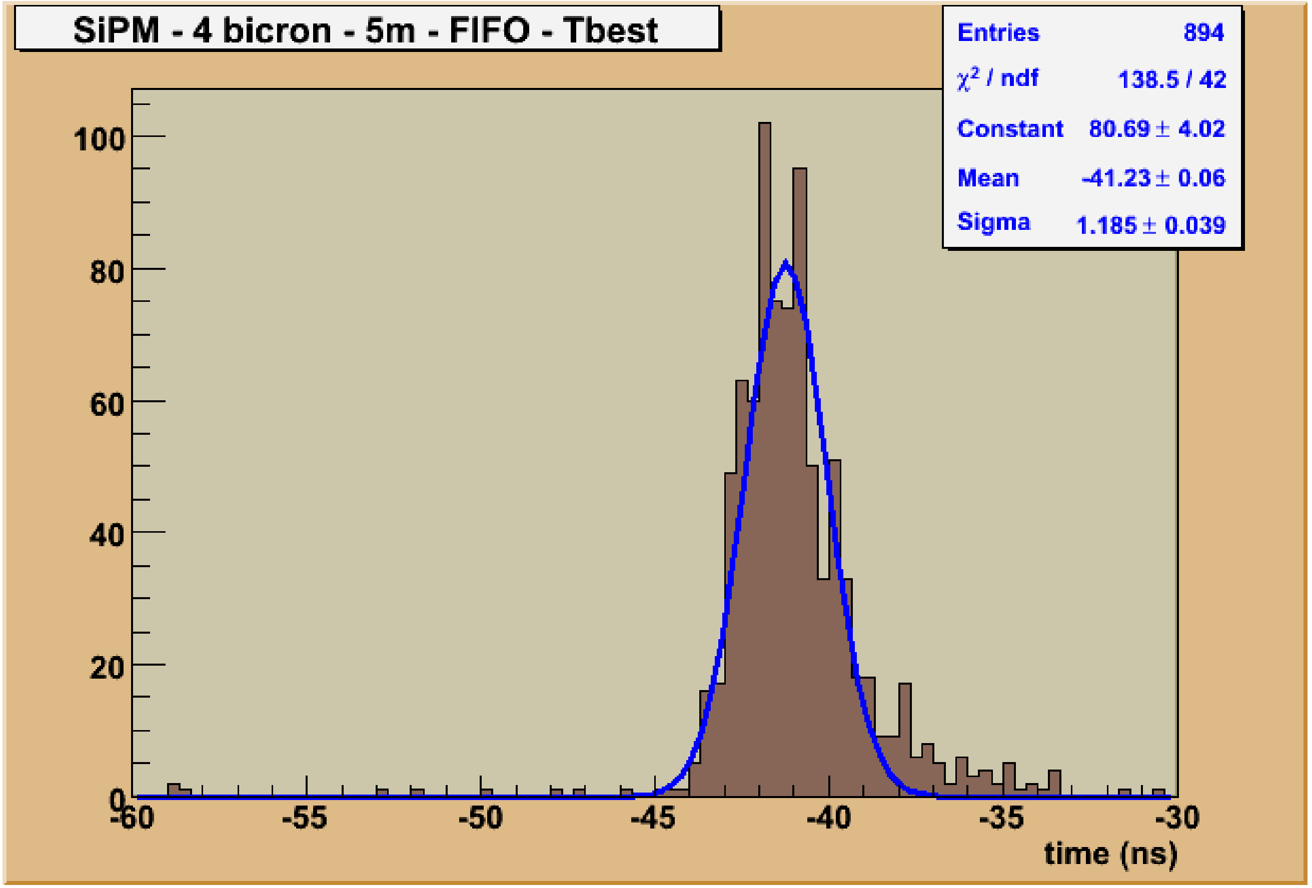
• 1.5 and 2.5 phe thresholds

• we tried with CF discriminator but no clear improvement was seen

•A Fan In / Out was taken out but results are better with it (it filters some high frequency noise? See next slides)



If we plot the time distribution of the 1.5 phe corresponding to 2.5 hit (Tbest) we obtain a promising 1.2 nsec resolution



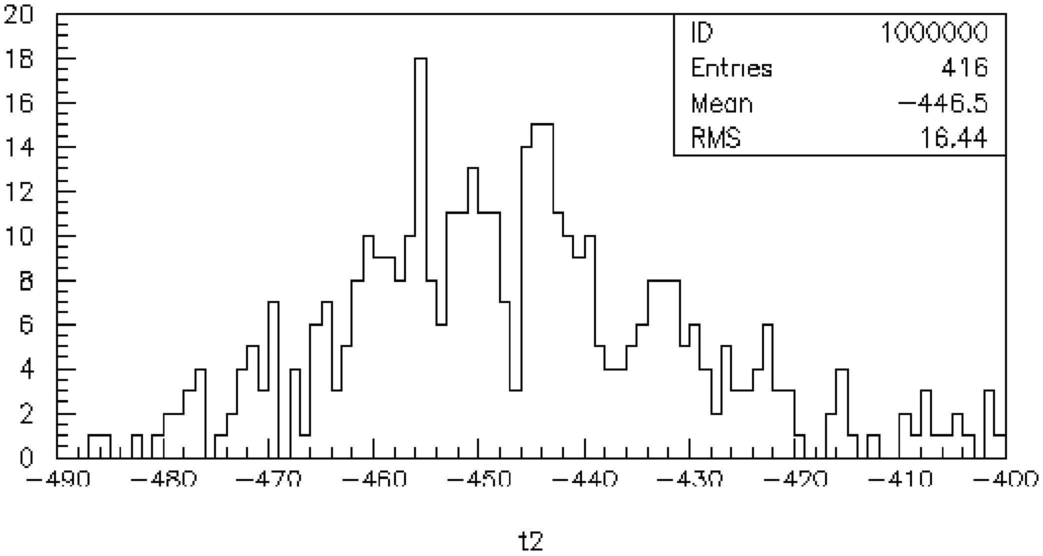
• Time resolution is limited by a clear ~1 nsec “multipeak structure” ….

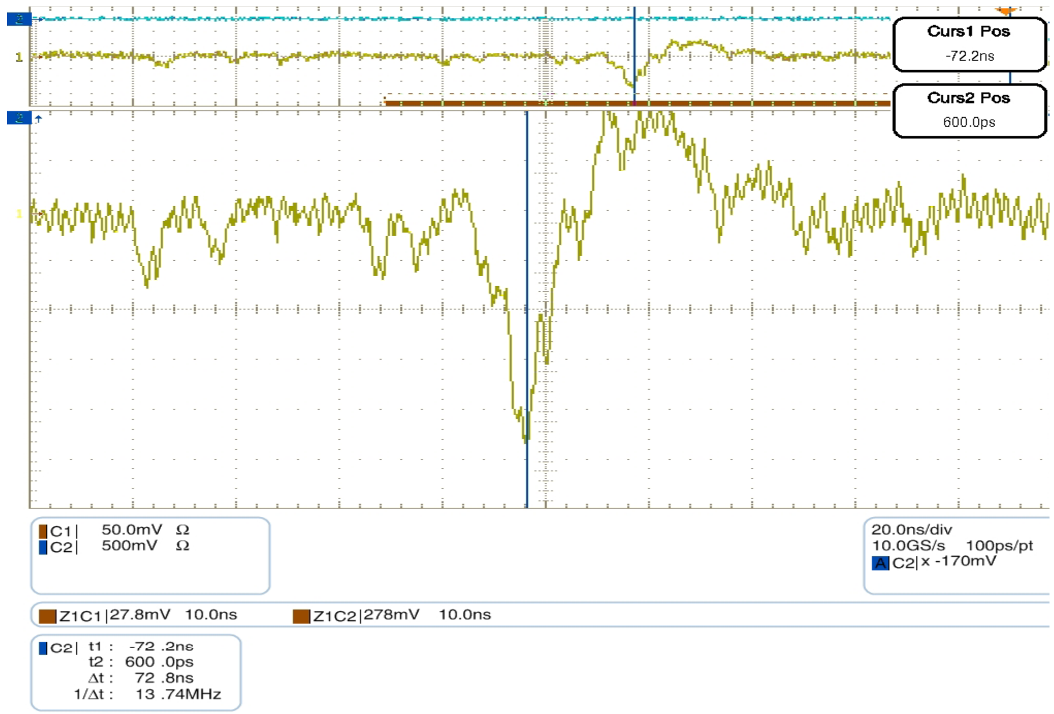
•This regularity is suspect and might be due to ~1 GHz noise (mobile phone - wireless??) summing up to the signal…

•Intrinsic discrete (phe) signal structure would give closer peaks (< 0.5 nsec)

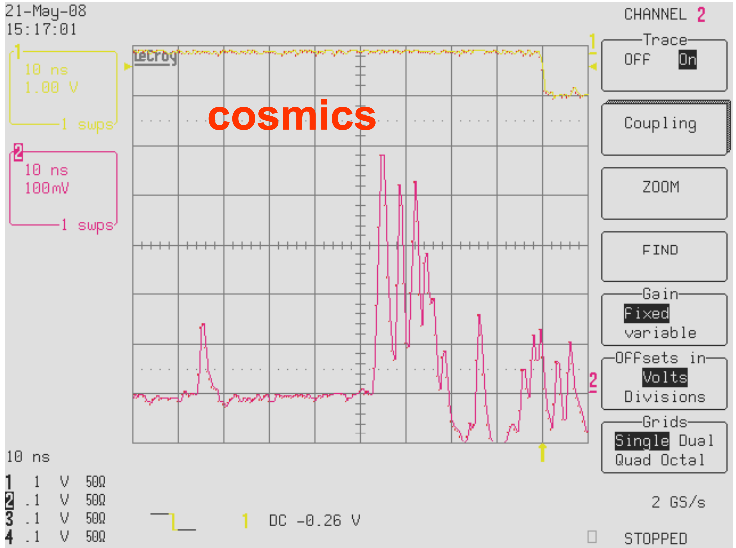
• Also SiPM multiple hit structure is present but peaks time distance is > 1.0 nsec (see next slide)

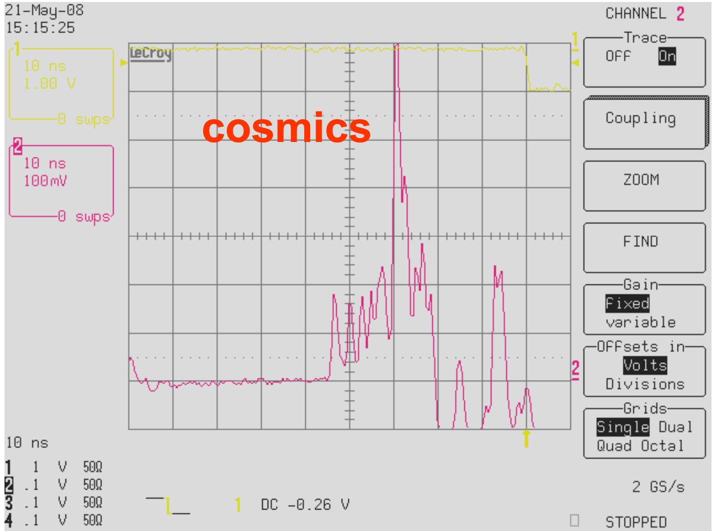
• better shielding / grounding

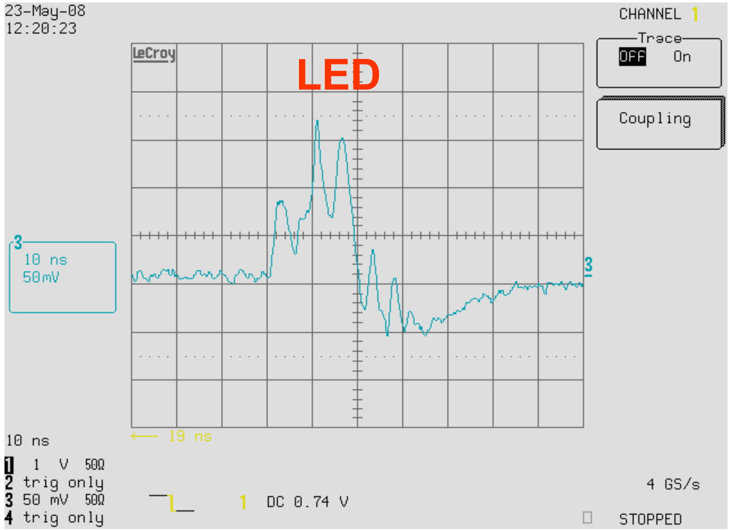


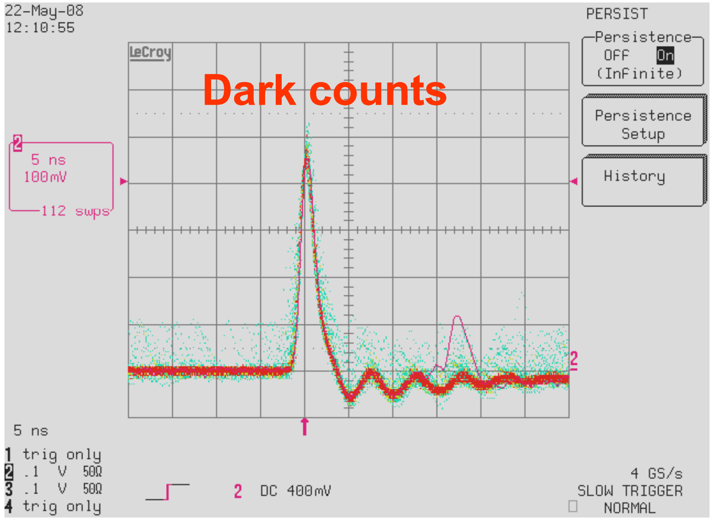


A sample of signals…..









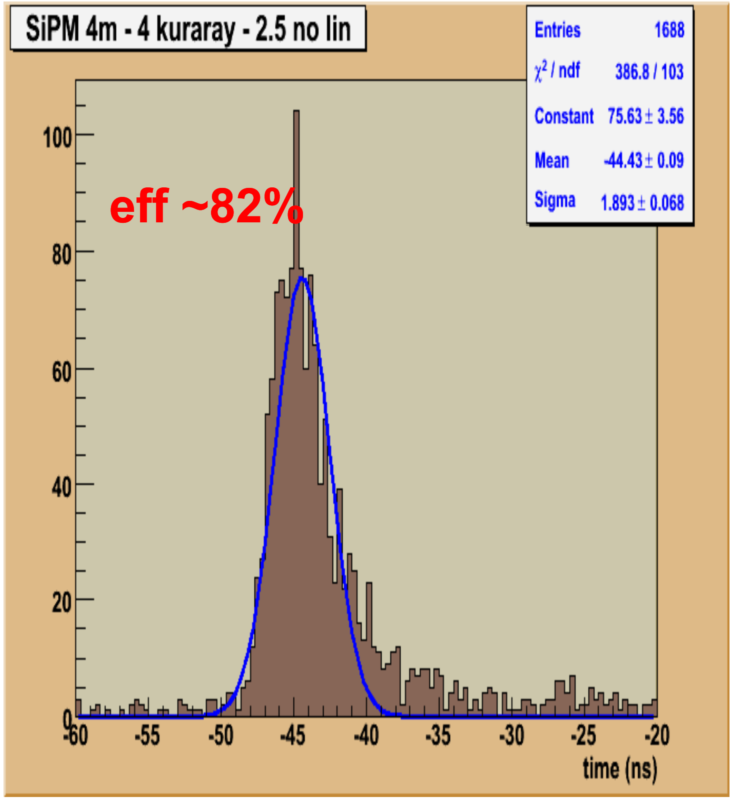
This peculiar signal shape is related to the external light signal…..

Summary of results

Type of electronics		Time resolution (ns)			Efficiency (%)		
		bicron 3m	bicron 5m	kuraray 4m	bicron 3m	bicron 5m	kuraray 4m
old	2.5 phe	-	1.3/1.5	1.9	-	73	88
new fast	2.5 phe	1.2/1.3	1.3	2.3(?)	89	70	-
new fast FIFO	2.5 phe	1.1	1.4	-	76	72	-
	1.5 phe	1.0	1.25	-	79	77	-
	best T	0.9	1.2	-	75	70	-
	C.F.	1.1	1.3	-	79	76	-
new slow no FIFO	2.5 phe	1.2	-	-	69	-	-
	1.5 phe	1.15	-	-	83	-	-
	best T	1.1			69	-	-

Efficiencies…

- With this new setup also efficiency studies are ongoing…
- We just implemented a CAEN ADC (V792) instead of a LeCroy 1182 which had some problems…
- For the moment efficiencies are calculated only through the TDC and are rather low: ~ 80%
- With the V792 we will have more informations on the signal and will help to investigate…



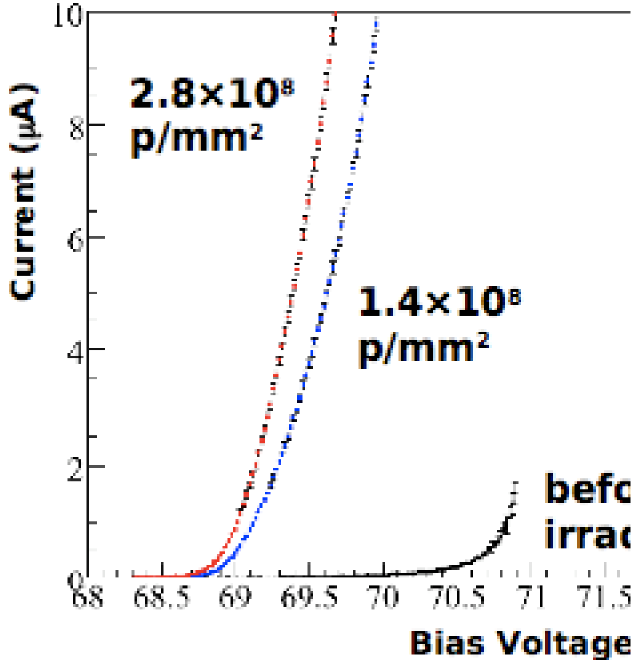
Radiation effects….

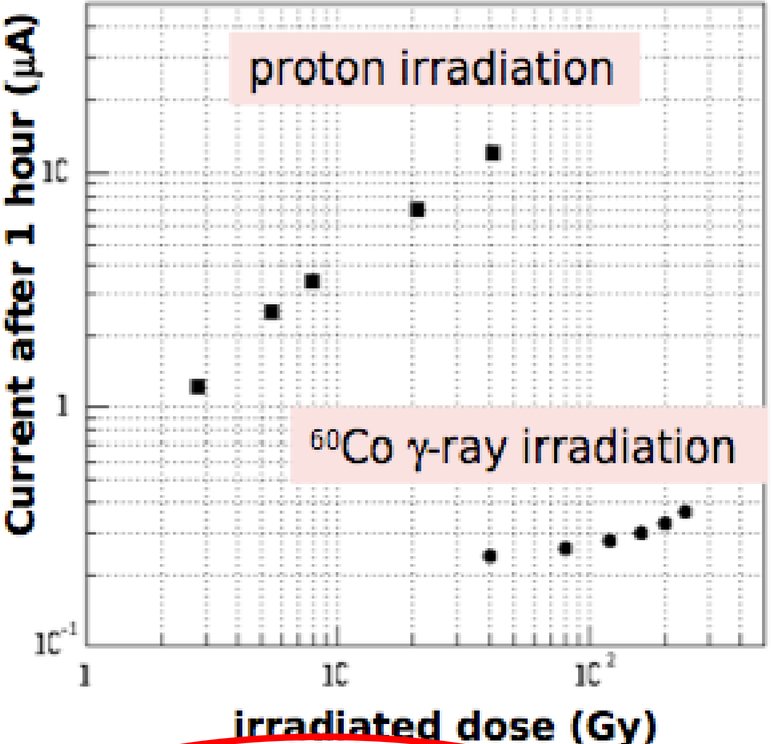
Damage comparison

Damage effect ...
almost the same for protons and neutrons

2.3×10^5 p/mm²/s (130 Gy/h)

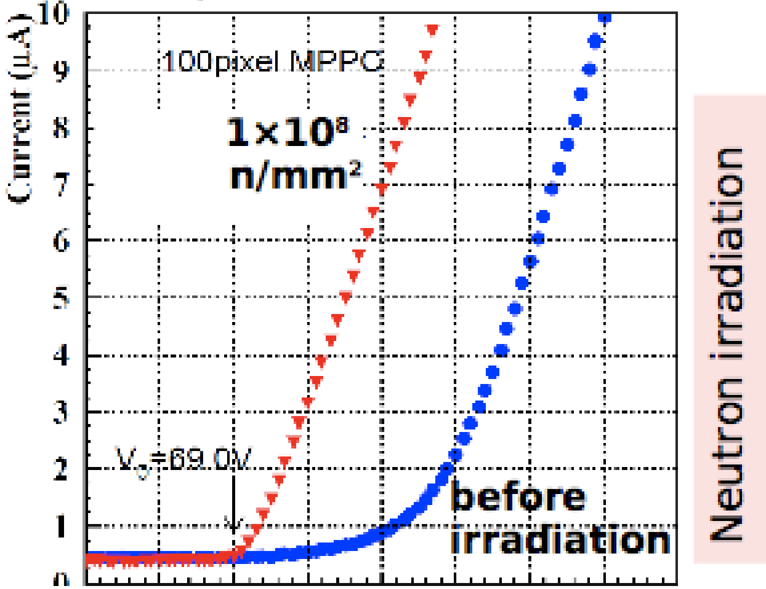
I_{leak} @ (V_{op}, 1.4×10^8 p/mm²) =





4.2×10^5 n/mm²/s

I_{leak} @ (V_{op}, 1.0×10^8 n/mm²) = 8.5 µA



Damage effect ...
1~2 orders larger with protons than γ-ray irradiation

VERY Rough background estimate

- Flux ~ 1.6 x 10^9 n/s over 4π, from bending magnets (d ~10-12 m from IP) @ L = 7×10^{33} cm^{-2} s^{-1}
- → ~ 1.3 neutrons / sec * mm^2 → ~250 n/sec*mm^2 (2 sources and a factor 100 in luminosity)
- damage begins around 10^8 neutrons, this means a lifetime 10^8 / 250 = 4 x 10^5 sec…
- Of course this is a very rough estimate, more precise simulations needed….

Next steps

- Measurements with the “2cm” thick scintillator (just started, no results yet)
- More realistic conditions (4.0 cm large instead of 1.5cm)
- Measurements with 4 x 1.2 mm WLS and 1.5 mm clear fibers
- Repeat measurements with hamamatsu 3x3 MPPC (better Detection efficiency)

SPARE SLIDES

APDs vs Geiger mode APDs

- **APD:**
  - For BaBar R&D was considered the model RMD #S0223:
    - G>1000
    - QE=65% (>530 nm)
    - 5ns risetime
    - High bias voltage (1850V) → difficult to stabilize
    - G very sensitive to V and T variations

$$\left\{ \begin{array}{l} \frac{\Delta G}{G} = 75 \cdot \frac{\Delta V}{V} \\ \frac{\Delta G}{G} = 17 \cdot \frac{\Delta T}{T} \end{array} \right.$$

  - Hamamatsu APDs have lower gain (few 100), bias voltage 400- 500 V

Geiger mode APDs:

- **MPPC (Hamamatsu), SiPM (FBK- IRST)**
    - G >10^5
    - DE ≈ 40% (530nm) (DE = Q.E x Fill factor x Avalanche probability)
    - ~ 1ns risetime
    - ≈ 10 times less sensitive to V and T variations

$$\left\{ \begin{array}{l} \frac{\Delta G}{G} = 7 \cdot \frac{\Delta V}{V} \\ \frac{\Delta G}{G} = 1.3 \cdot \frac{\Delta T}{T} \end{array} \right.$$

    - Low bias voltage (30-70V)
    - Dark current rate @ room temperature : { 100s of kHz thr = 0.5 phe; 10s of kHz if thr = 1.5 phe }

Dear Eugenio,
I pulled some numbers of neutron rates at BaBar and compared them to LHC CMS projected rates. They are similar ! The technique to estimete BaBar rates was as follows:

1. Use two neutron counter rates on opposite side of BaBar.
2. Calibrate them with a Pu237 neutron source to correct their efficiency.
3. Assume, naively I should say, that the there is a single source coming from radiative Bhabhas striking
some region between Q3&Q4. Its position was worked out from the two counter rates assuming assuming
the spherical propagation.
4. Using this spherical model, I estimate a rate of ~1.6x10^9 Hz going into 4pi for a BaBar luminosity of
7x10^33.
5. From there I can estimate rates at various detector faces in BaBar and compare them to the CMS rates.
I have no way to verify that these rates are correct. However, Chris O'Grady told me that a rate of DCH
FPGA resets was consistent with my flux estimate on the DCH face, if he uses some LHC R&D data.
6. Finally, Roberto Fasso from SLAC radiation group calculated energy spectra of these neutrons at BaBar
using Fluke program. Assuming 4-9 electrons striking Cu or Fe flange, they are typically 1-2 MeV neutrons.
I include his simulated spectrum.
7. Finally I compare BaBar rates with the LHC EMC estimated rates in the region of main tracking detectors.
I include CMS numbers from their internal note. The rates are similar within a factor of 10.
8. Last but not necessarily the least. Every neutron ends its life with a few Gammas of a few MeV. That is
a final additional background.

I think the way to proceed is to estimate the neutron flux at the likely major source, which is, according to Mike's picture, about 10-12 meters from IP (the first major bend). It can be shielded, of course. However, not along the beam line pointing back to BaBar. This will act as a port hole in a nuclear reactor fuming neutrons back. So one should estimate the rate there assuming a spherical radiation of neutrons, and calculate what will be coming into BaBar assuming spherical geometry.

Jerry