SuperB-IFR Detector R&D status

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On behalf of the ferrara SuperB group

Baseline Detection Technique

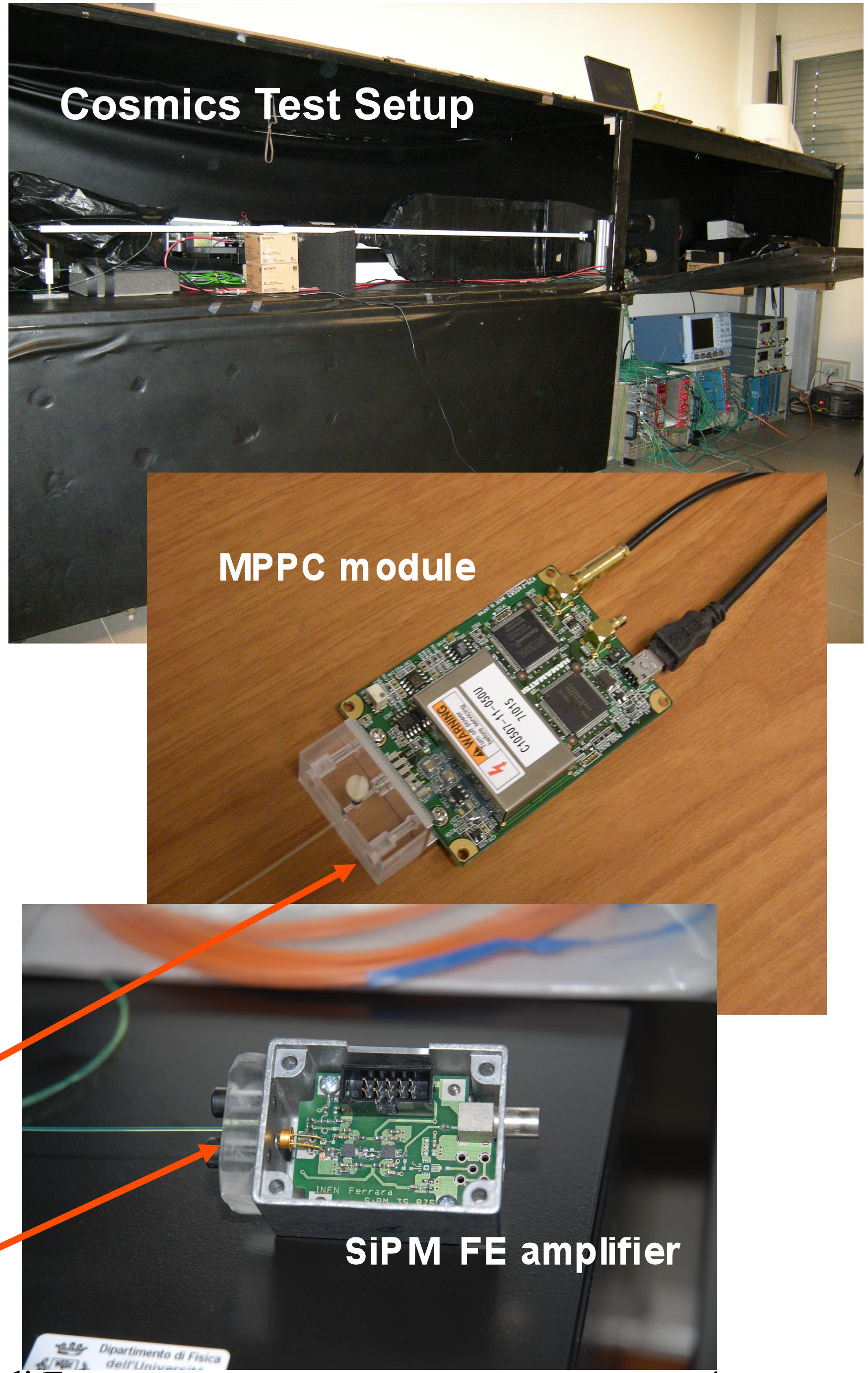
Scintillator bars + WLS fibers readout on both ends by Geiger mode APDs

- **Scintillator:**
  - **4 cm** scintillator bars covered with TiO_2
  - Light collection through **WLS fibers**
  - Fibers housed in a surface grove / embedded hole
- **WLS fibers:**
  - ϕ **= 1mm** type **Y11(300)** (Kuraray) or **BCF92** (Saint Gobain), Attenuation length $\lambda \approx$ **3.5m,** trapping efficiency $\varepsilon \approx$ **5.5%**
- **Fibers readout:**
  - **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**

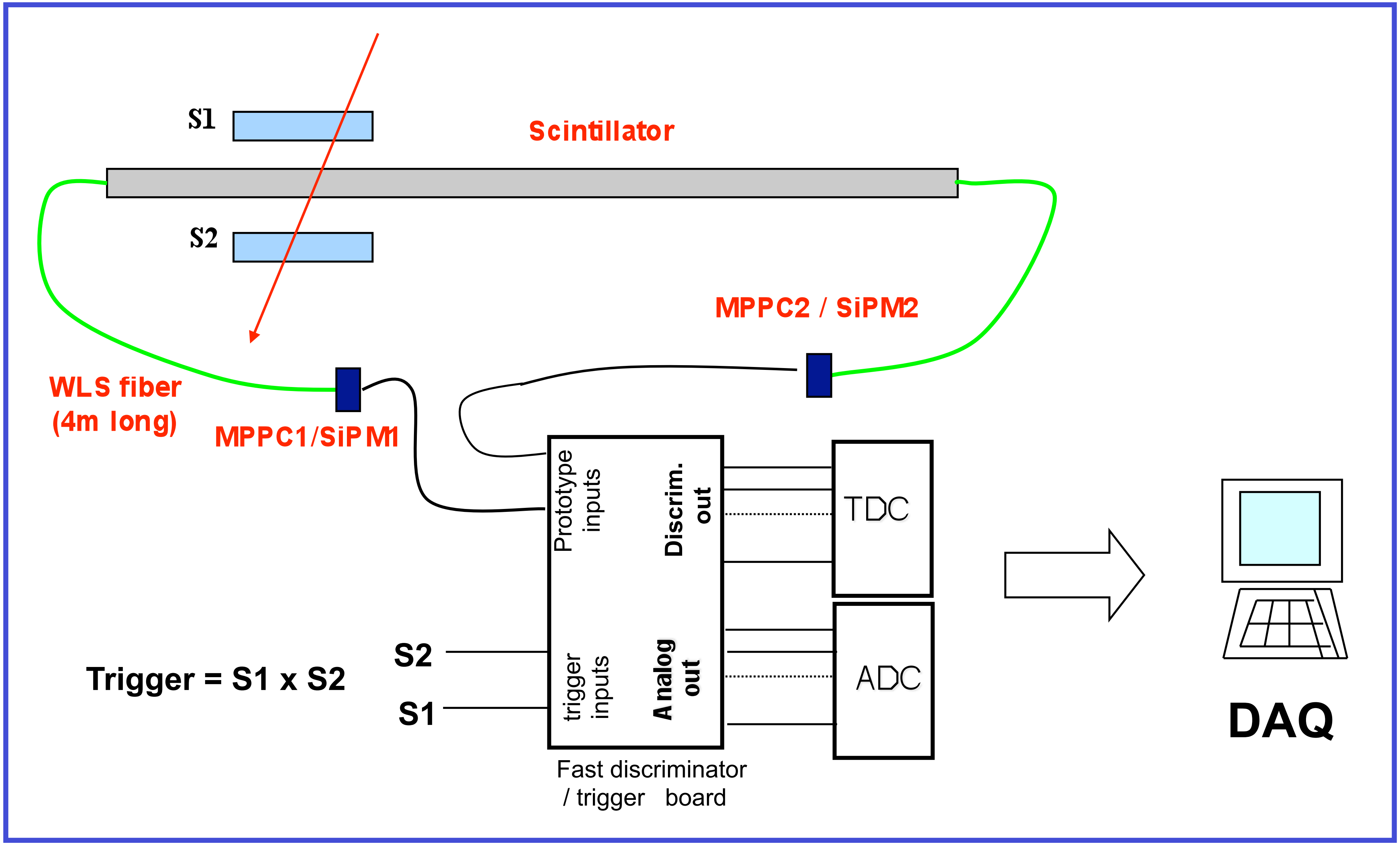
Detector R&D activities in Ferrara

Cosmic ray test setup (I)

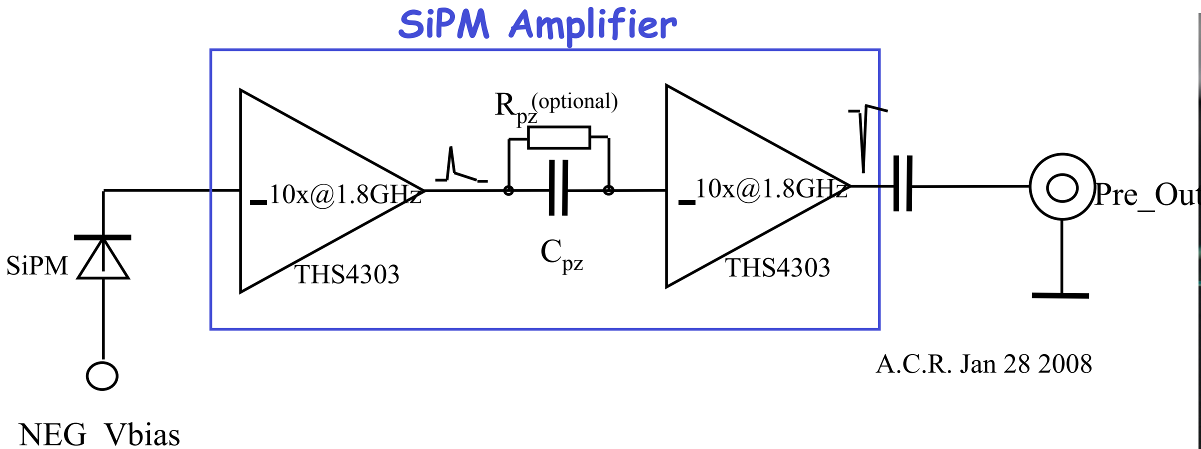
- **Tests with cosmics**
- **scintillator: 1.5cmx2.0cm, with one embedded hole (one fiber)**
- **Same scintillator with a surface groove**
- **WLS fibers: Saint Gobain BCF92, and kuraray T11 – 300ppm**
- **ϕ = 1mm, ≈ 4m long**
- **Fibers Readout:**
  1. MPPC *"plug and play"* module (Hamamatsu), 1.2mm active area
  2. SiPM with custom FE amplifiers

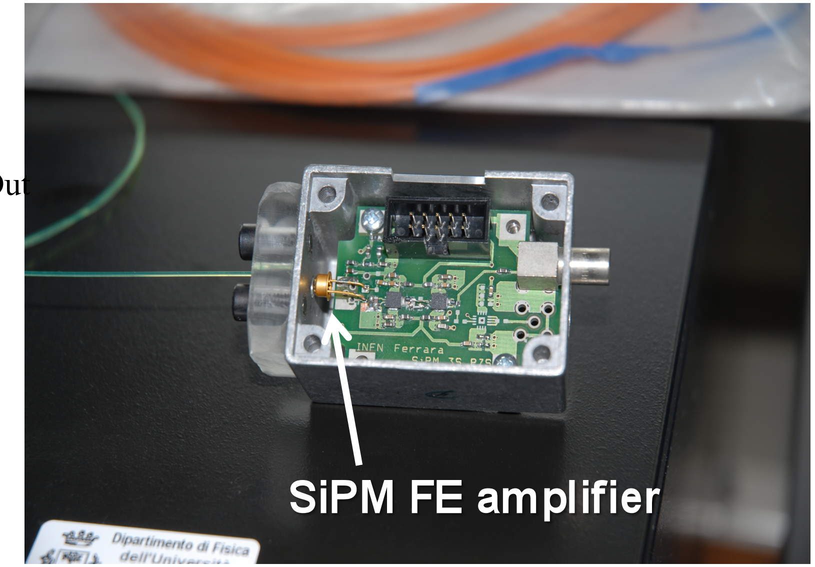


Cosmic ray test setup (II)



Front End Electronics: SiPM Amplifier



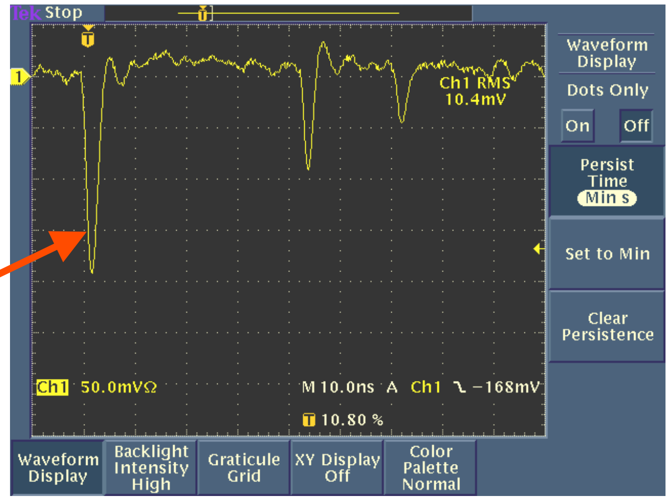


- **The MPPC modules comes with (unknown) FE electronics**

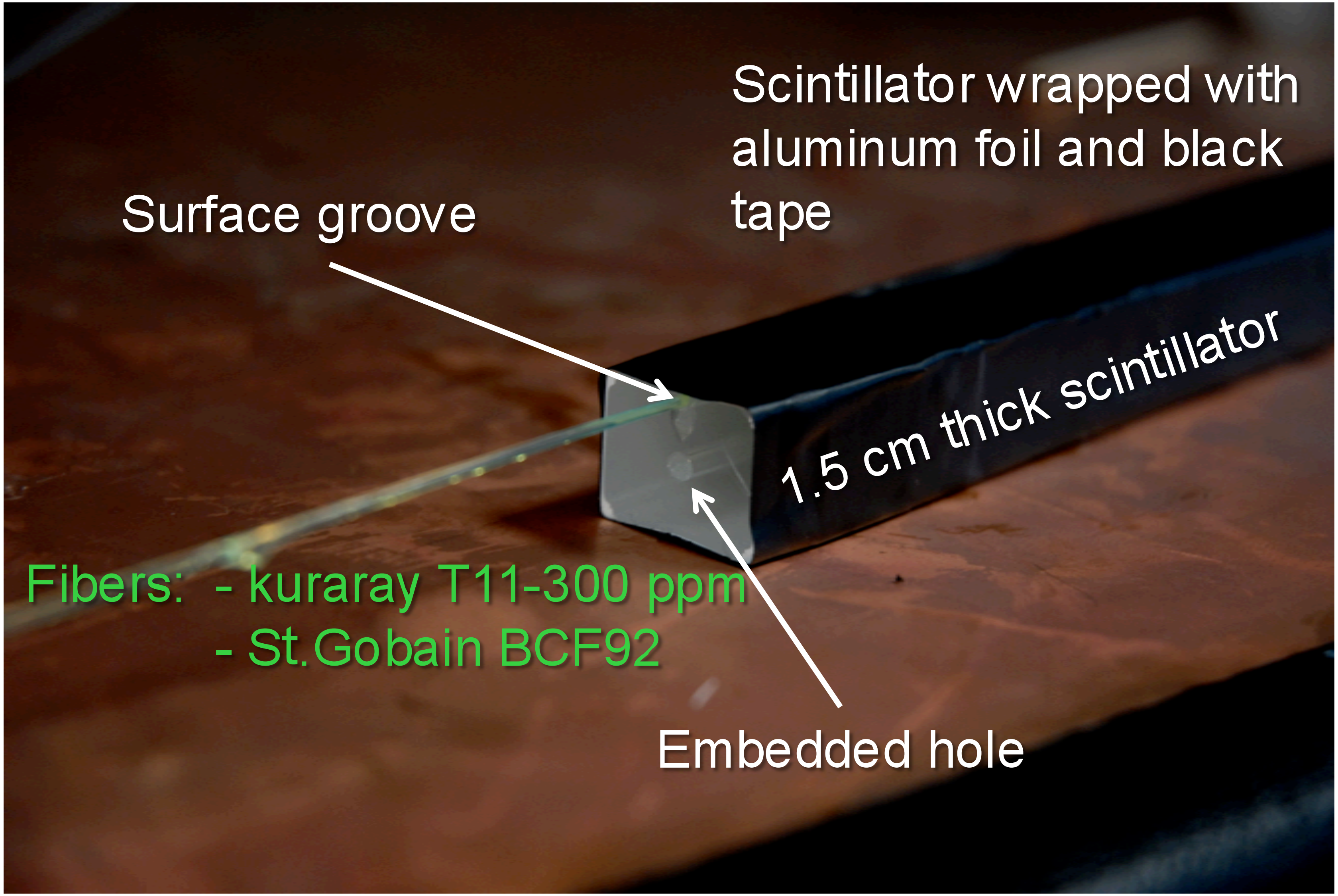
- **For the SiPM devices a prototype amplifier has been developed based on commercial Texas Instrument THS4303 fast amplifier**

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

- **The combination with a fast / low jitter discriminator board can give < 1ns time resolution**



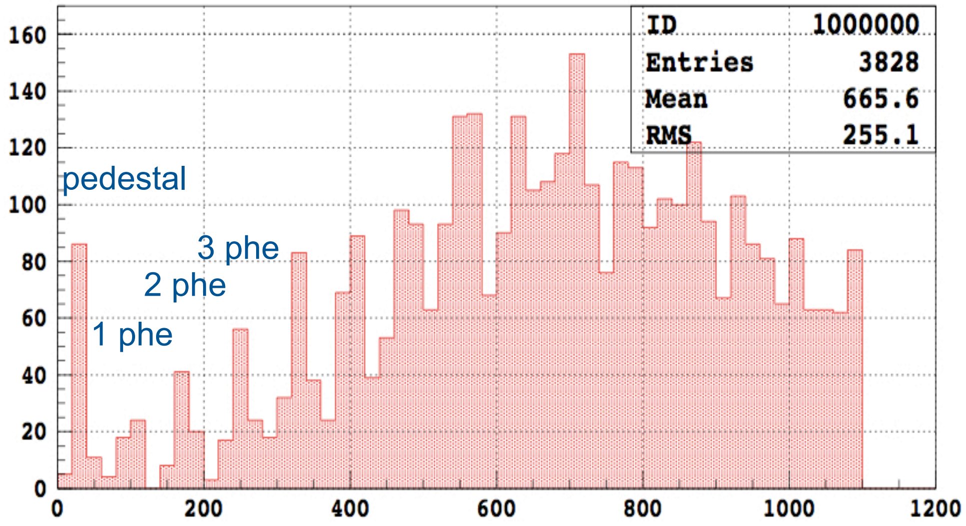
Module prototype



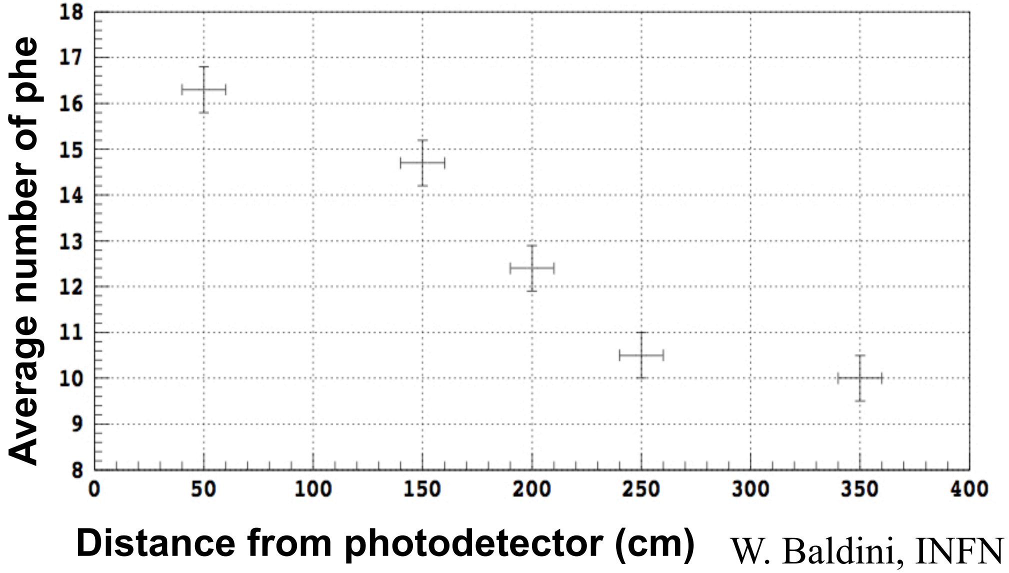
Detection efficiency studies

Light Yield   fiber: Saint-Gobain

ADC spectrum for MPPC 350 cm far from the trigger



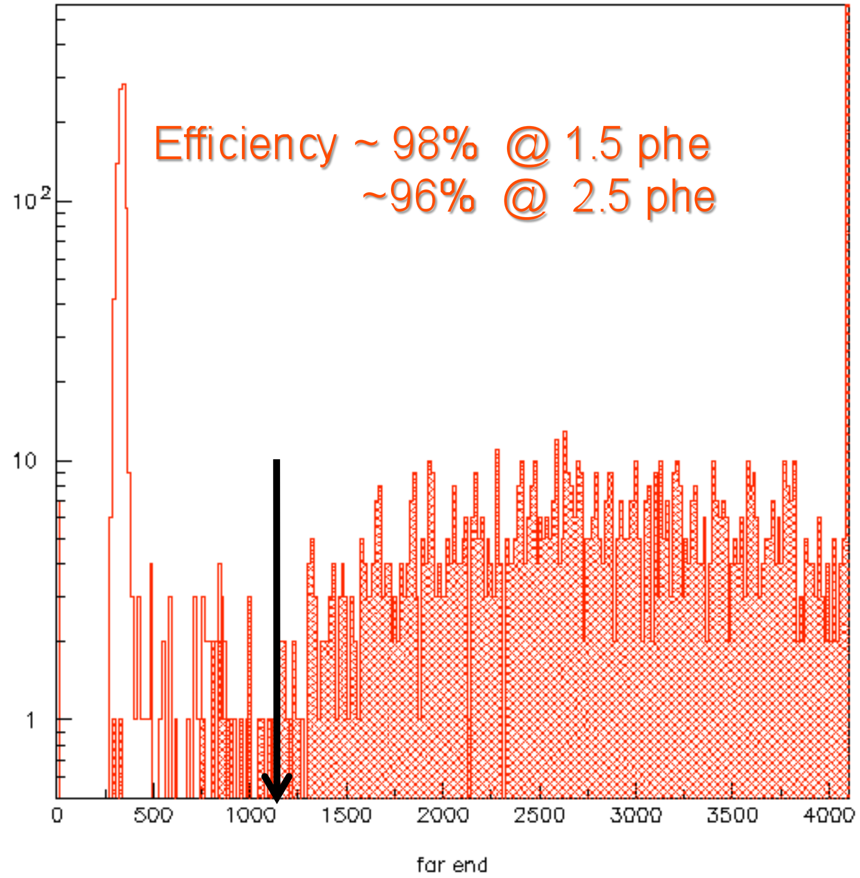
Average number of phe:
~ 9 at maximum distance (~4m)



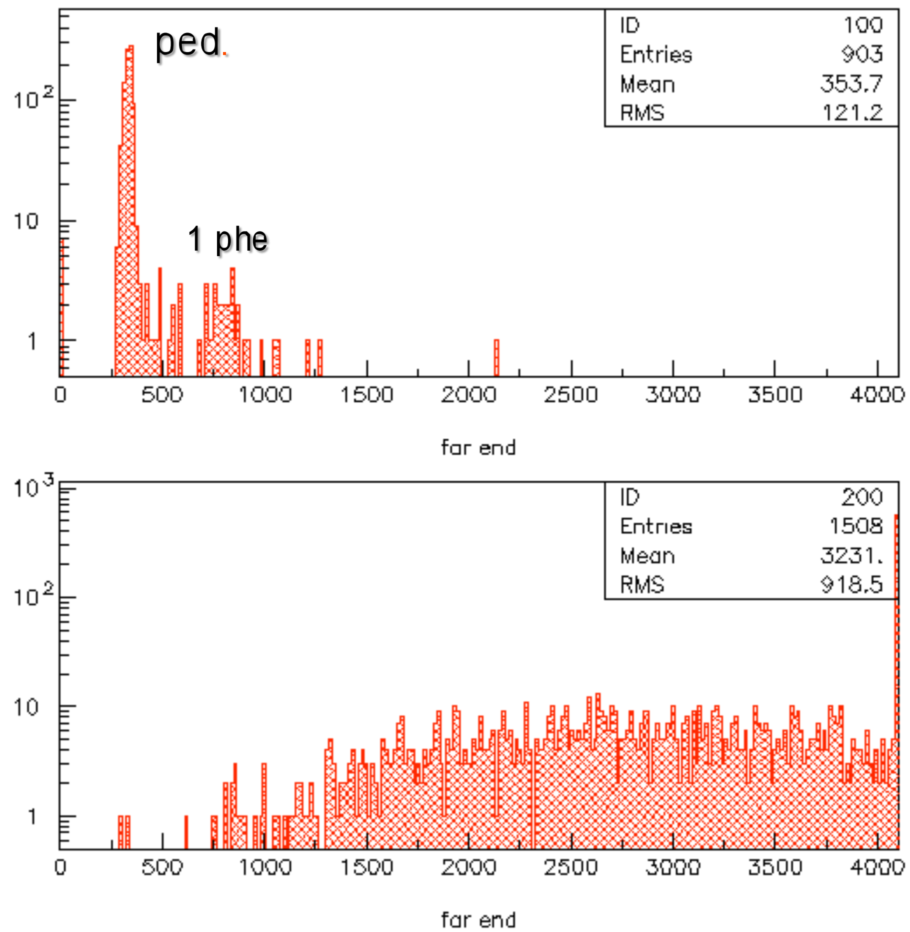
Detection efficiency:

- ~96% @ 1.5 phe
- ~94% @ 2.5 phe

Light yield   Fiber: Kuraray



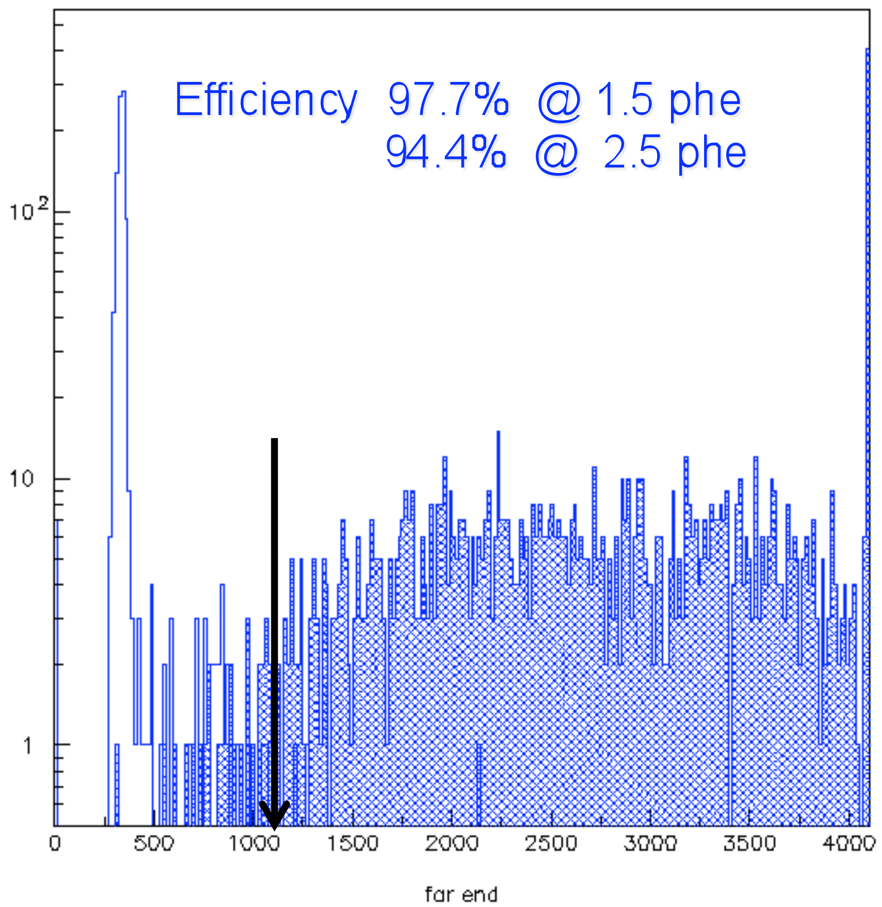
ADC spectrum 350 cm far from the trigger

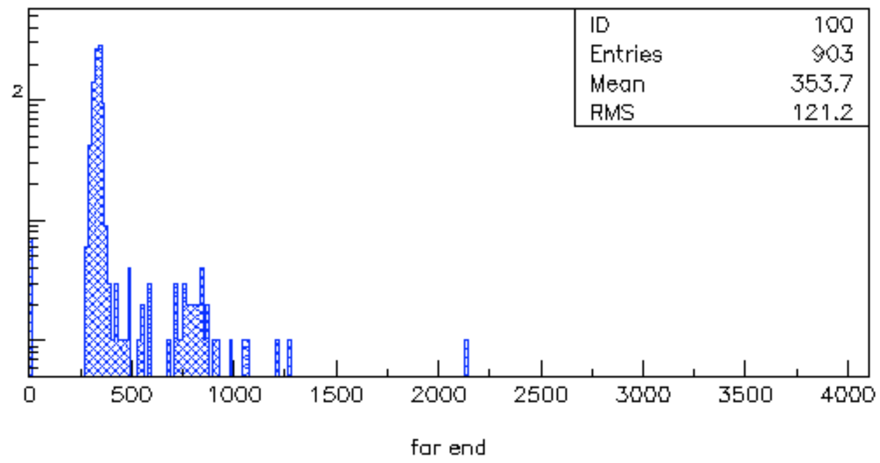


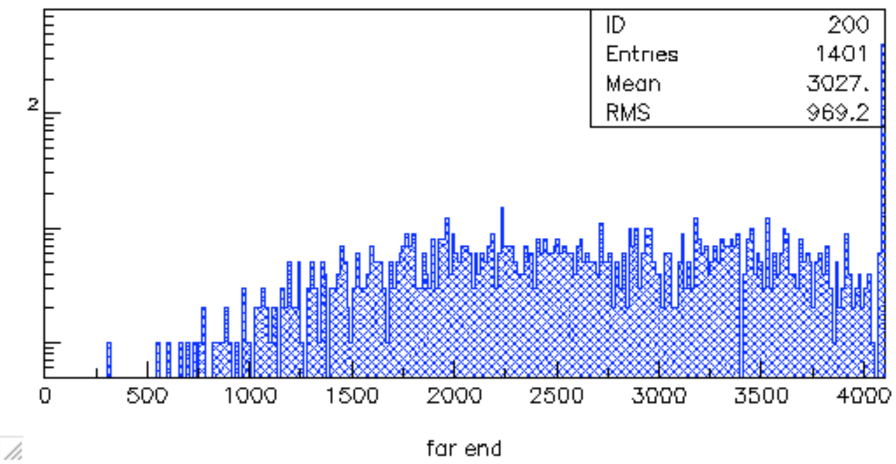
Separate plots for pedestal and signal

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

Light yield fiber kuraray

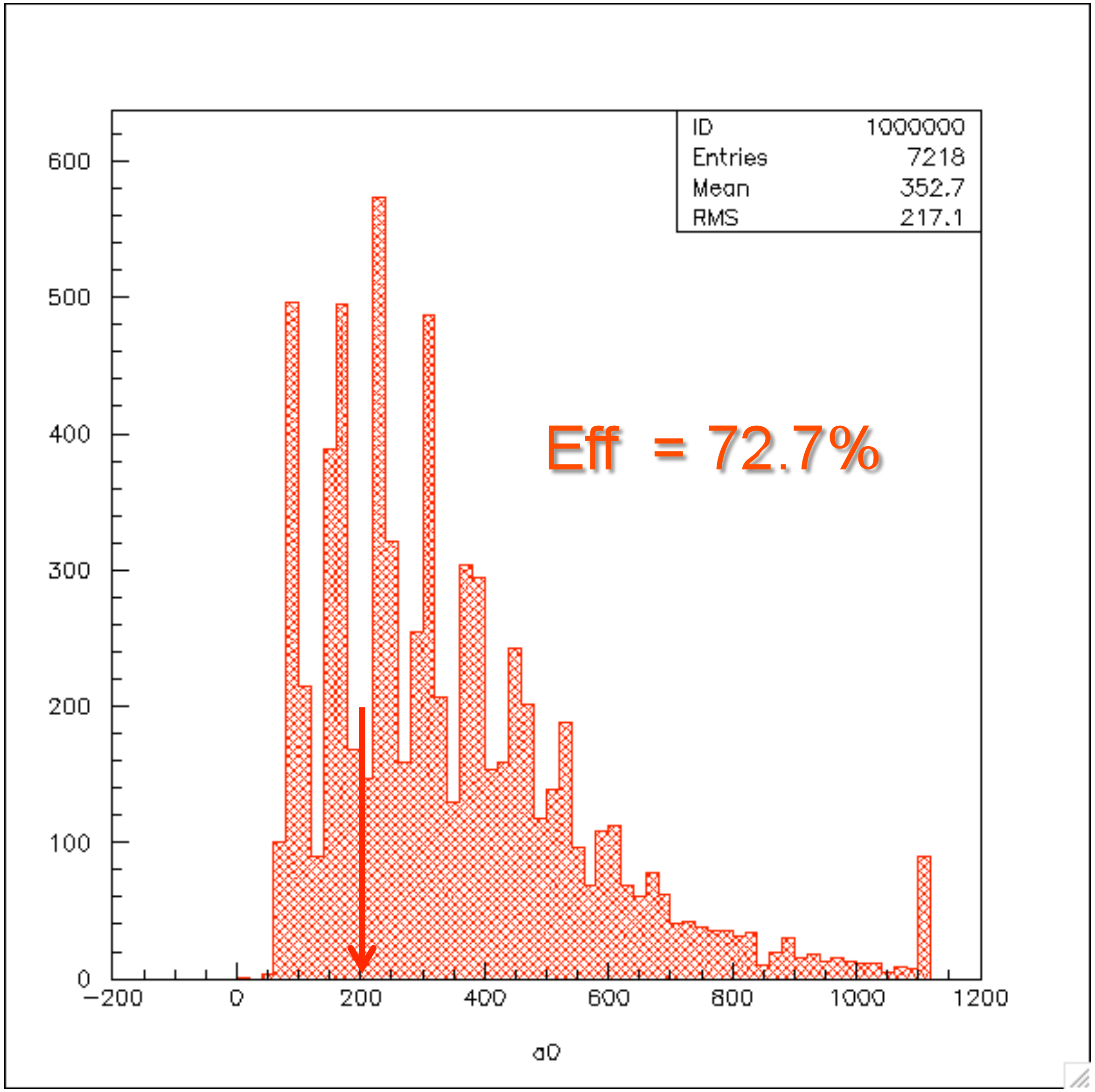






ADC spectra for a kuraray T11-300 fiber about 4 m long in a surface groove

Thinner scintillator



- 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
- At least 1.5 cm scintillator Is needed

- From the point of view of the detection efficiency we have a certain degree of freedom in choosing the type of fiber and its positioning in the scintillator (embedded hole or surface groove)

- The scintillator has to have a thickness of at least 1.5 cm. With 1.0 cm the efficiency at 1.5 phe is only 73%

- We can now proceed to analyze the time behaviour….

Time resolution studies

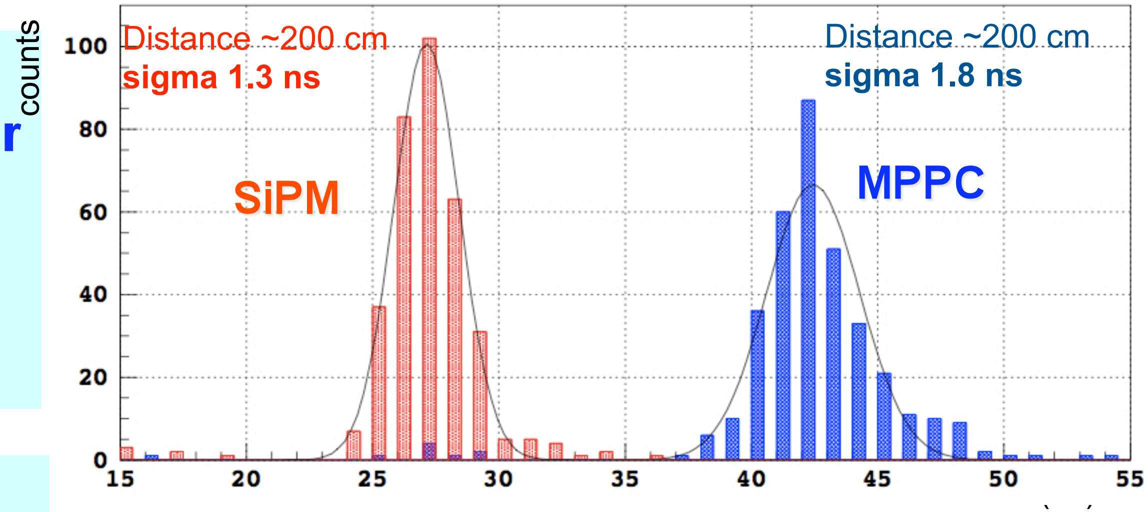
Time resolution first results

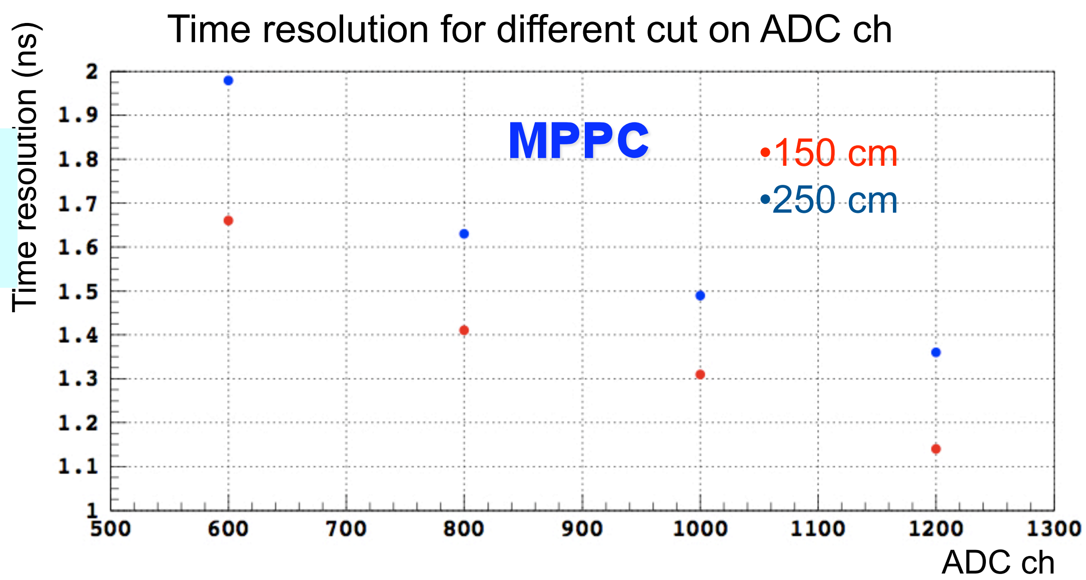
- For these first measurements **no constant fraction discriminator** was used because we wanted to understand how the time resolution depends on the strength of the signal

- 15 cm scintillators has been used in the trigger

- Time measured with respect to the trigger signal (common start)

- A single hit TDC was used





Time resolution studies update

- time resolution studies are ongoing using fast discriminator board with programmable thresholds

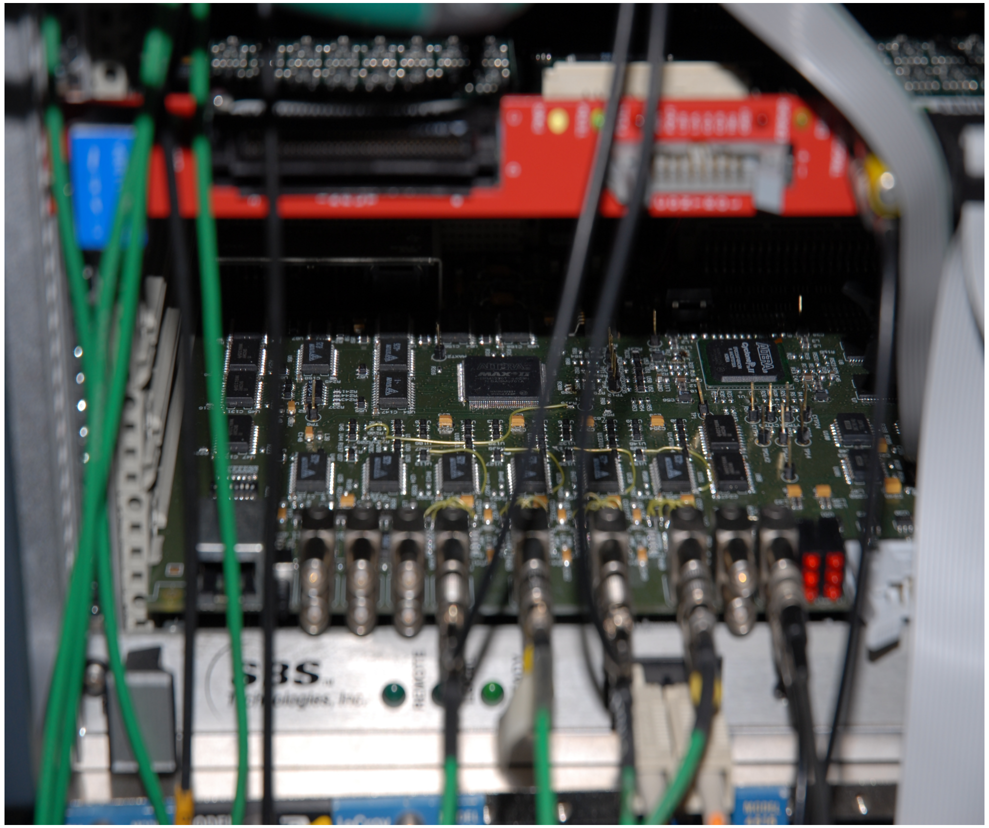
- for each input the board provides outputs at different thresholds

- The idea is to use a high (2.5 p.e.) threshold to reduce noise and a lower threshold to have precise timing

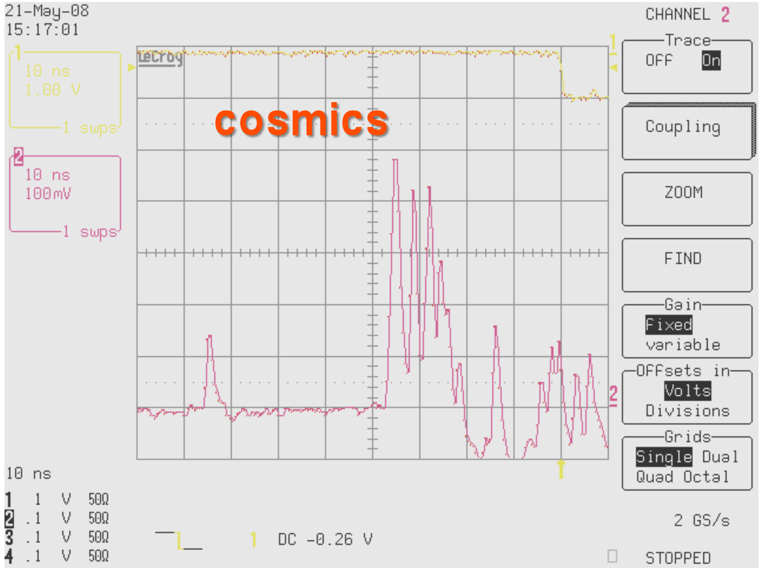
- 5 cm scintillators has been used in the trigger to have a precise time reference

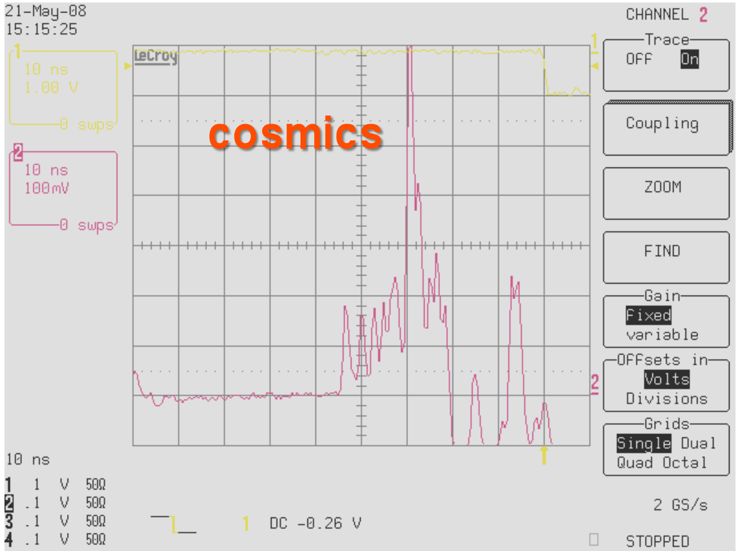
- A Multi-hit TDC (caen 1190A) is now used

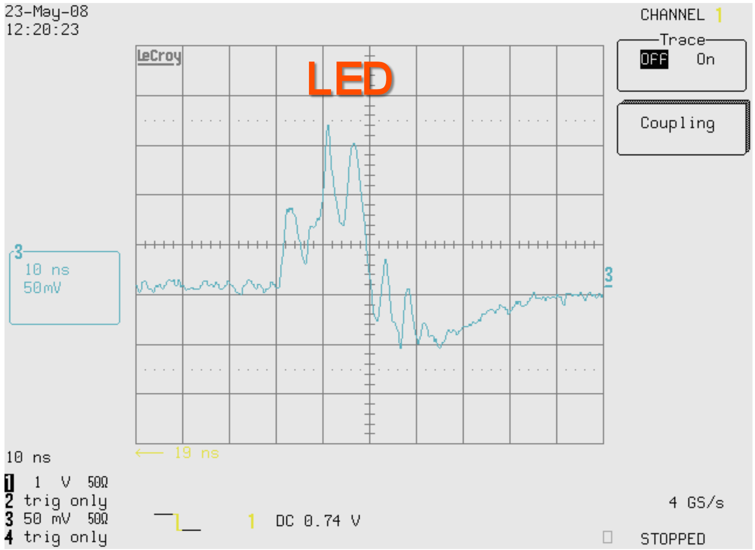
- SiPM signal shows multiple hits, not easy to deal with….

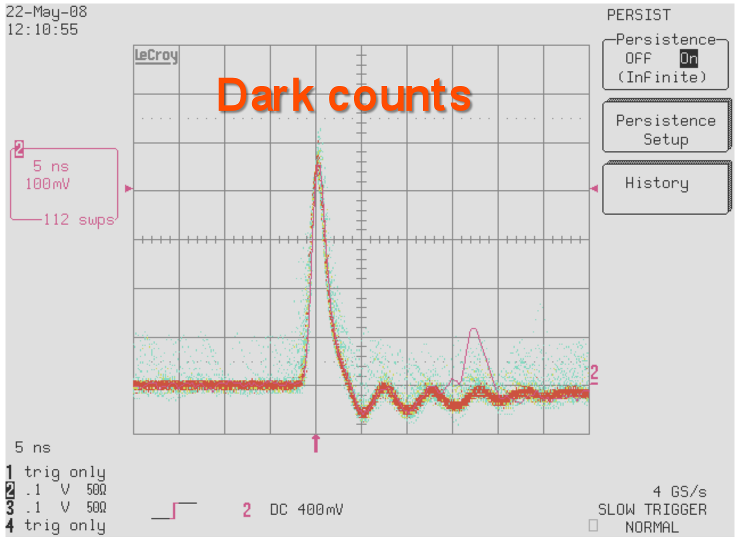


A sample of signals…..



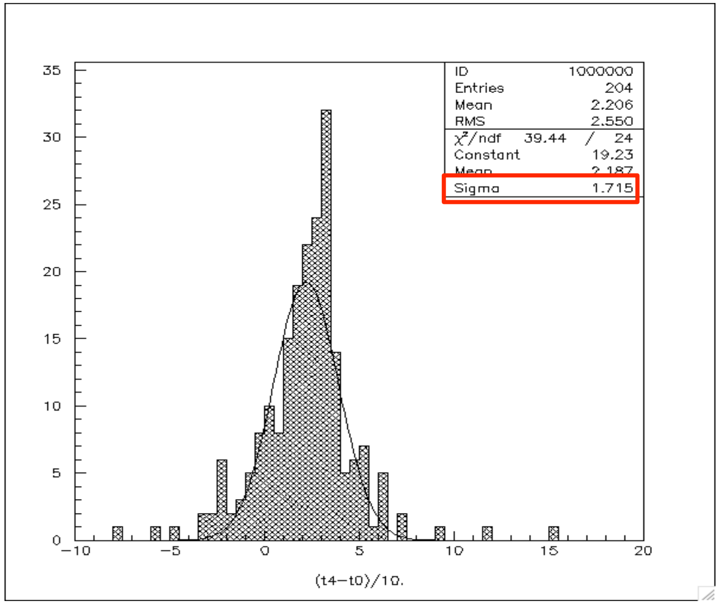


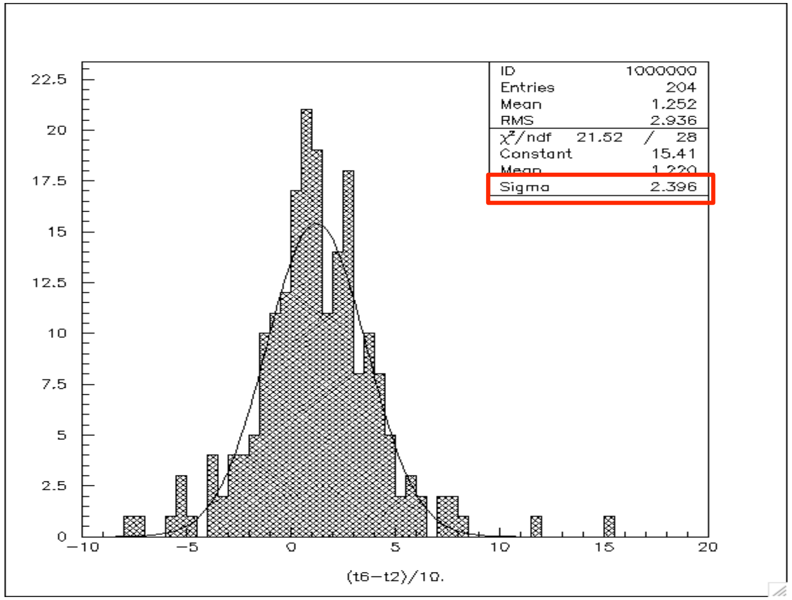




This peculiar signal shape is related to the external light signal…..

So what we get is…..





- Time distributions (especially at high thresholds) show peaks due to the shape of the signal

- fitting the main peak only we obtain better that 1 ns resolution ….

- The first peak gives the correct time, we are working on algorithms to extract that informarion from all kinds of signals…

- Signal shape doesn't depend on bias voltage, possible temperature effects will be investigated

Next steps

- Complete the timing studies
- Spread of gain/dark noise for more SiPM (we have now about 20 devices)
- Study of temperature behaviour

Conclusions

- Detection efficiency studies show that:
  - Kuraray fibers give little more light wich translates into an efficiency a few % higher, but always better than 94%
  - The fiber placed in a surface groove (instead of the embedded hole) gives an efficiency just about 1-2 % lower
- Timing resolution studies are ongoing, the time response of the SiPM is very fast and signals shows multiple peaks due probably to different arrival times of photons.
- Various strategies are under study to detect the correct time

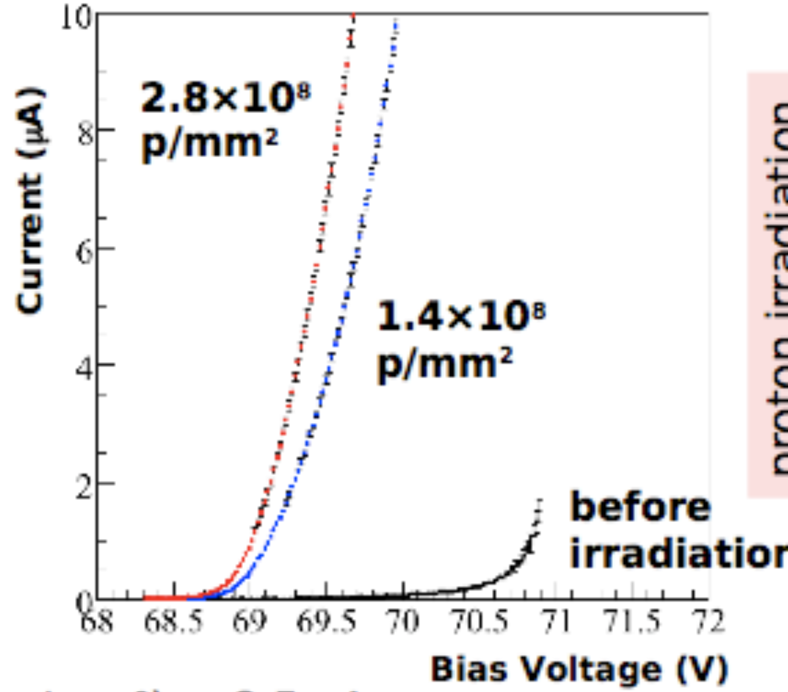
SPARE SLIDES

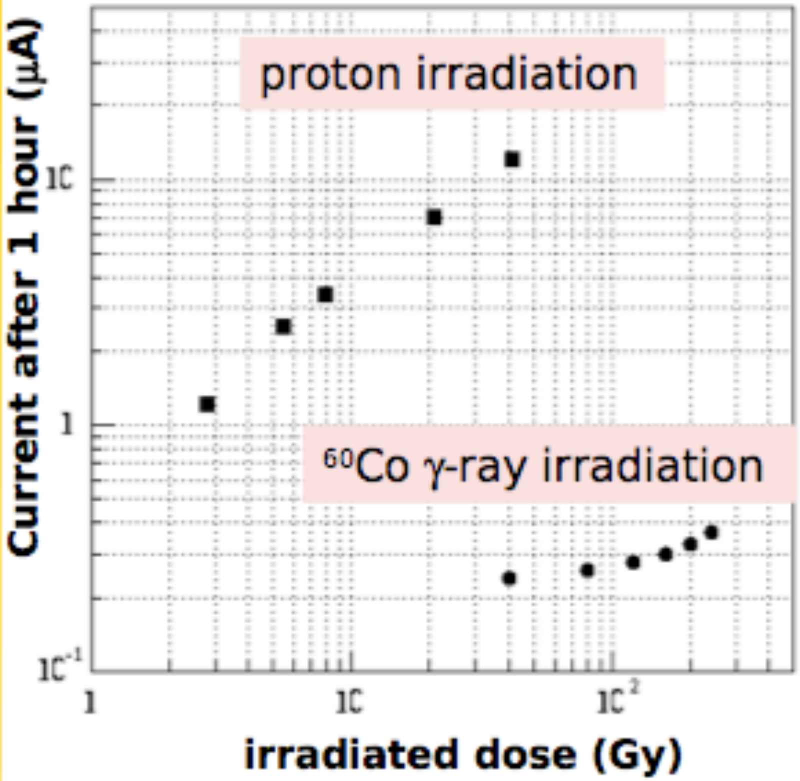
Damage comparison

Damage effect …
almost the same for protons and neutrons

2.3×10⁵ p/mm²/s (130 Gy/h)

I_{leak} @ (V_{op}, 1.4x10^8 p/mm²) = 6.7 μ

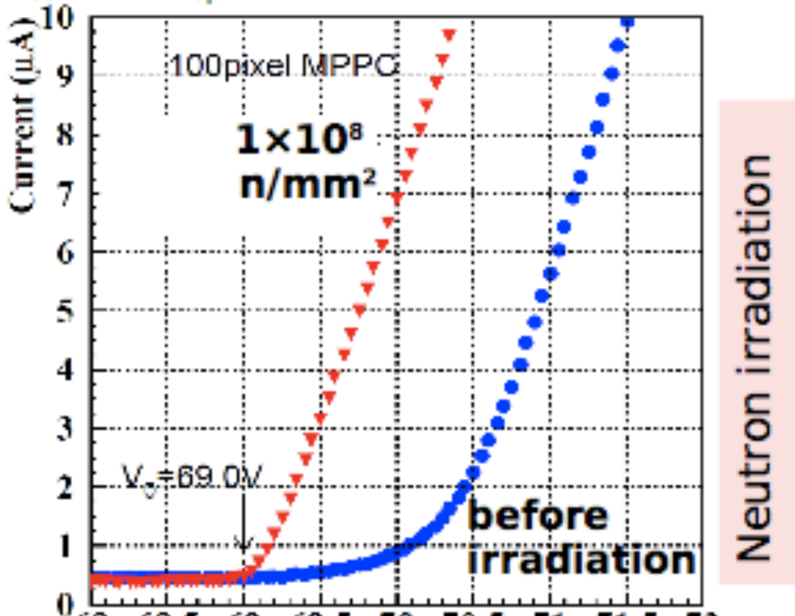




Damage effect …
1~2 orders larger with protons than γ-ray irradiation

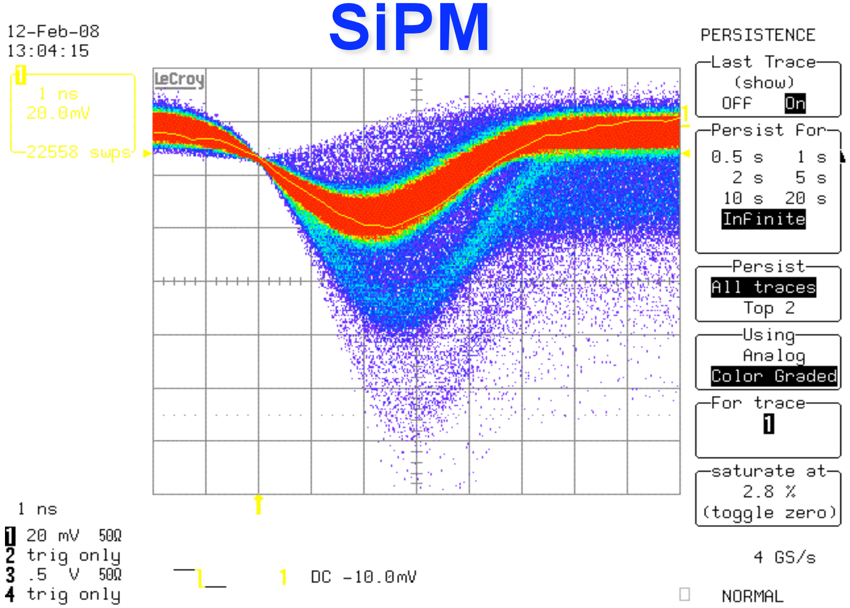
4.2×10⁵ n/mm²/s

I_{leak} @ (V_{op}, 1.0x10^8 n/mm²) = 8.5 μA

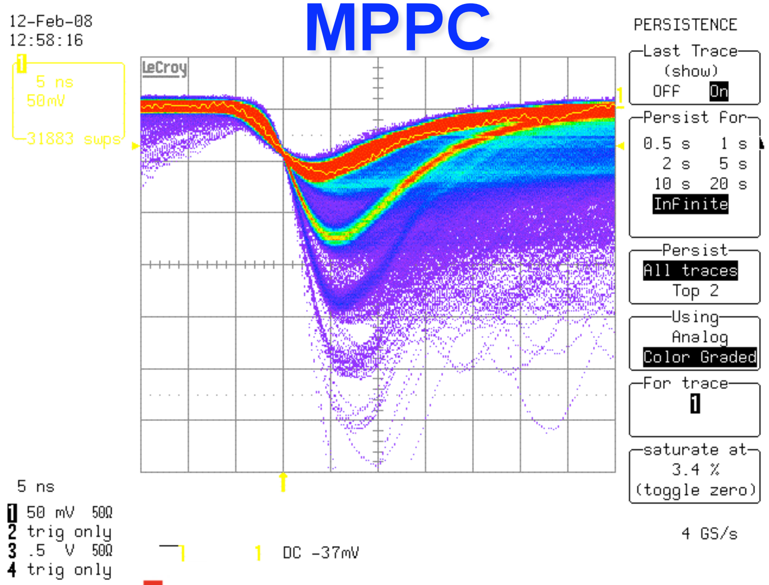


Geiger mode APDs

SiPM



MPPC

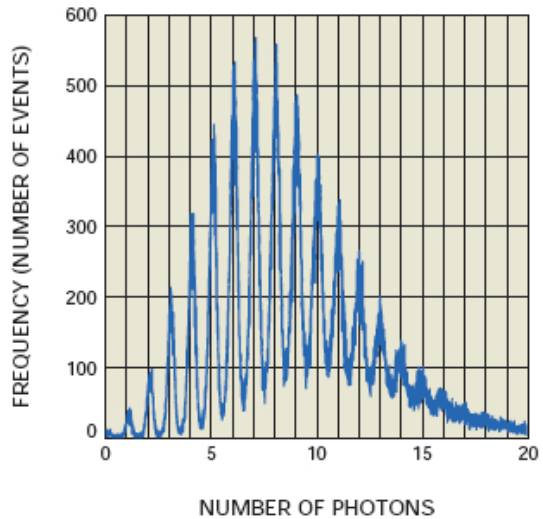


- Avalanche photodiodes operated a few Volts above the breakdown voltage

- Dark count rate too high for large active areas → matrices of small (~ 50μm) cells in parallel

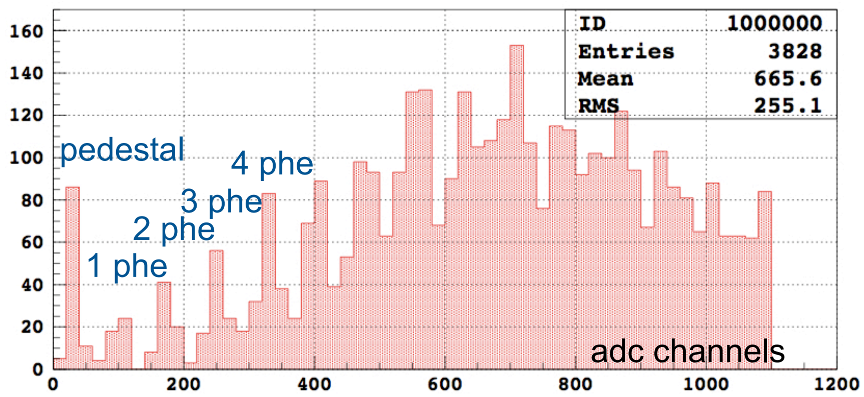
- A single cell signal for each photon

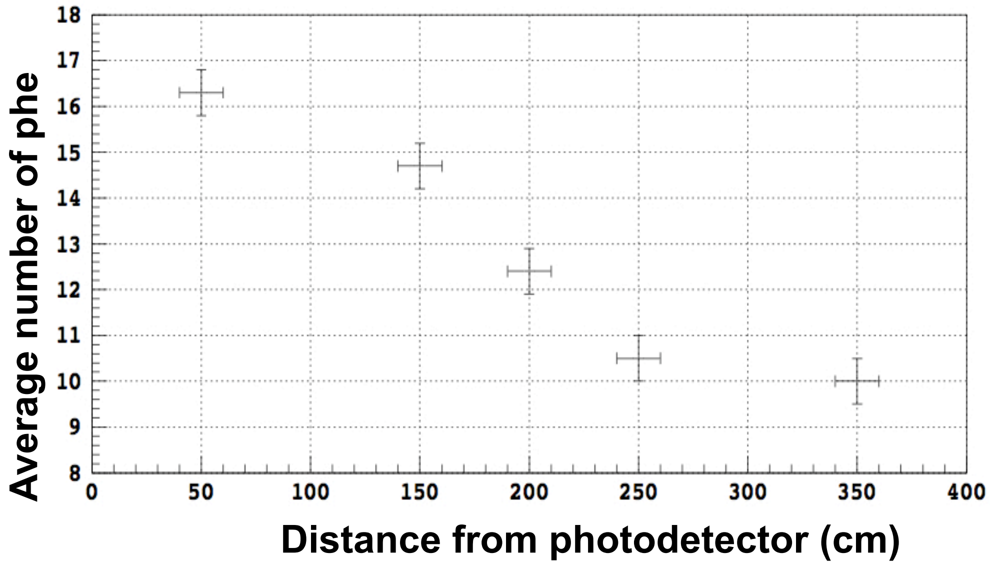
Pulse height spectrum when using charge amplifier (S10362-11-025U, M=2.75 × 10^5)



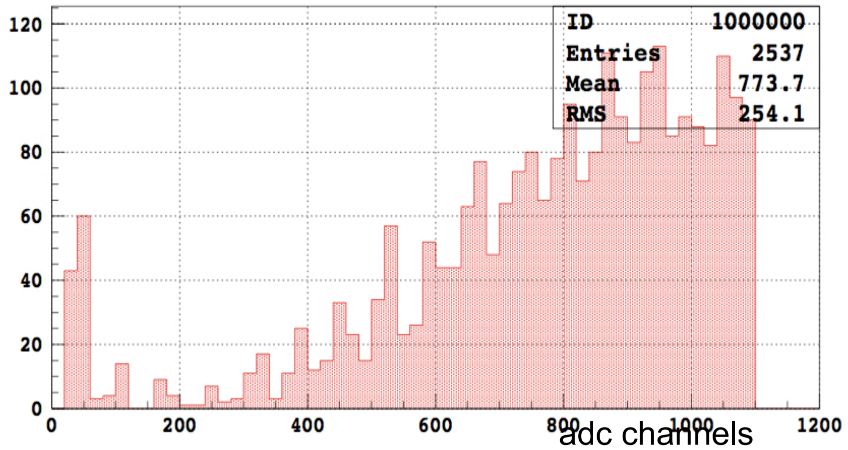
Light Yield fiber: Saint-Gobain

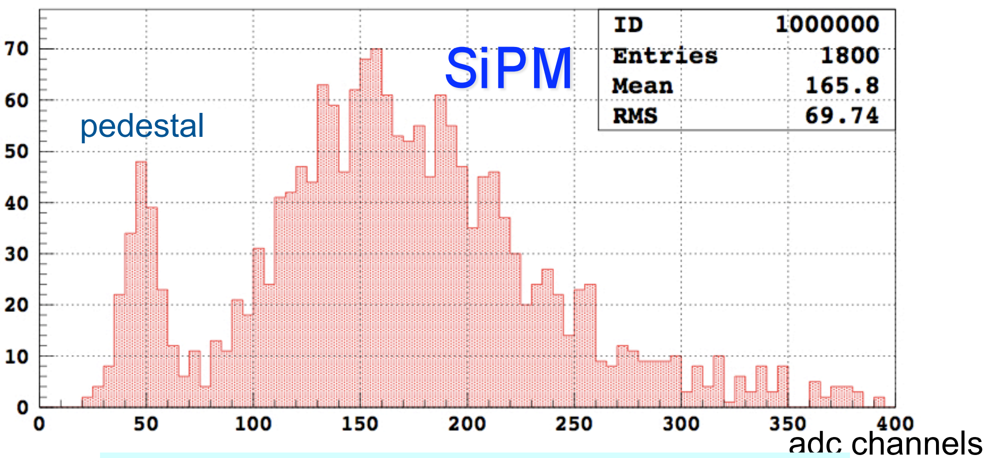
ADC spectrum for MPPC 350 cm far from the trigger





ADC spectrum for MPPC 50 cm far from the trigger





Average number of phe: ~ 9 at maximum distance (4m)

ADC spectrum from SiPM 200 cm far from the trigger

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 → $\frac{\Delta G}{G} = 75 \cdot \frac{\Delta V}{V}$, $\frac{\Delta G}{G} = 17 \cdot \frac{\Delta T}{T}$
  - 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 → $\frac{\Delta G}{G} = 7 \cdot \frac{\Delta V}{V}$, $\frac{\Delta G}{G} = 1.3 \cdot \frac{\Delta T}{T}$
    - 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