Sezione di Ferrara

IFR Detector R&D status

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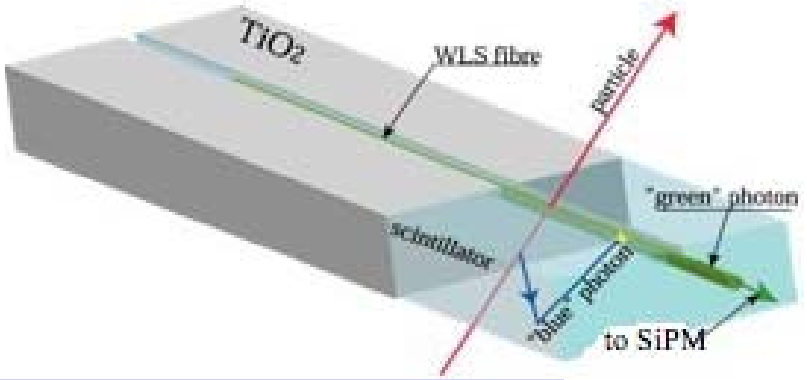
On behalf of the Ferrara SuperB group

SuperB Workshop, Perugia June 16-20 2009

Detection Technique

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

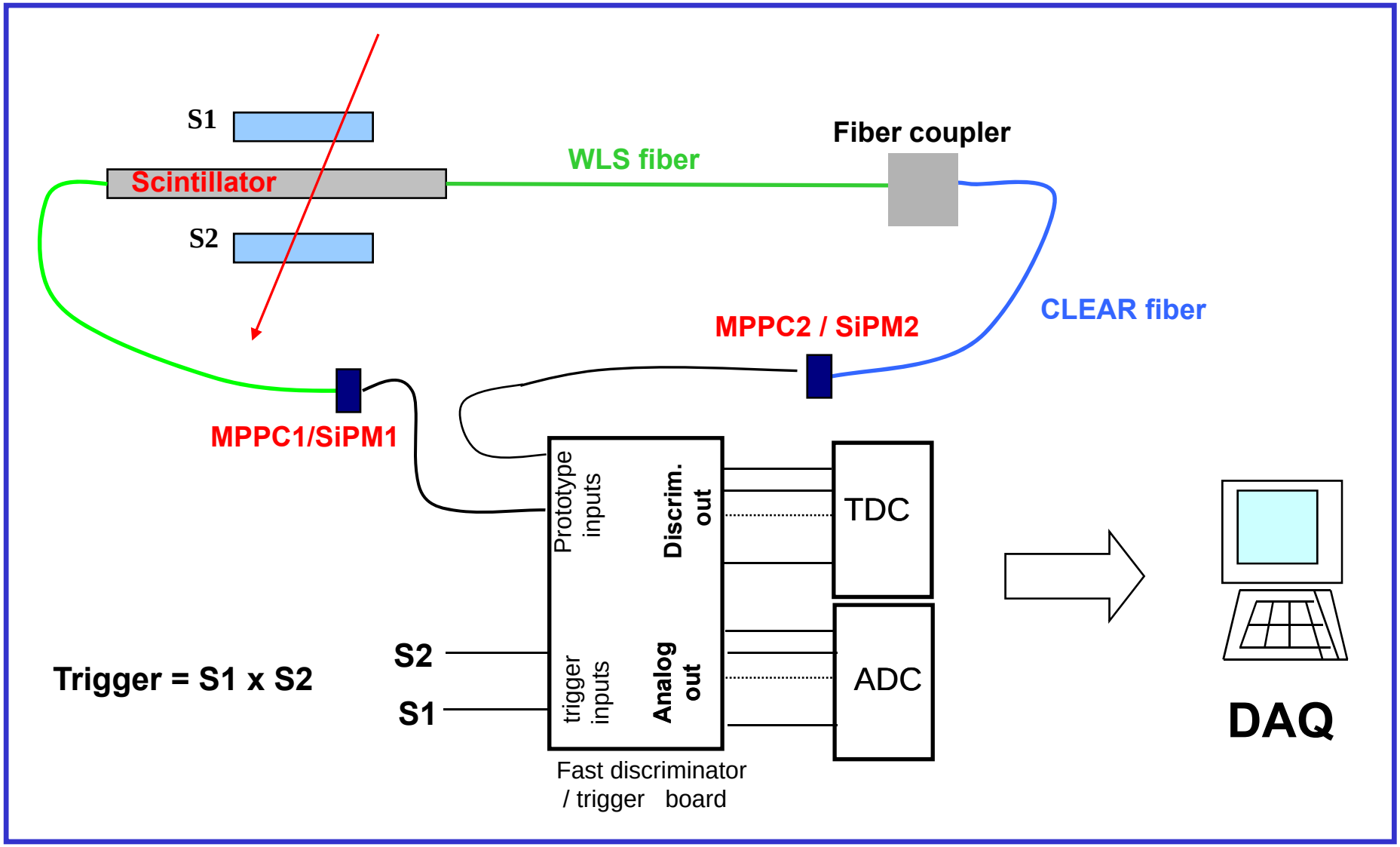


- **Scintillator:**
  - **2x4x400 cm^3** scintillator bars coated with TiO_2
  - Light collection through **WLS fibers**
  - Fibers housed in a surface grove or in a embedded hole
- **WLS fibers:**
  - ϕ = **1.0 or 1.2 mm** type **Y11(200/300)** (Kuraray) or **BCF92** (Saint Gobain), Attenuation length $\lambda \approx$ **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-FBK 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**

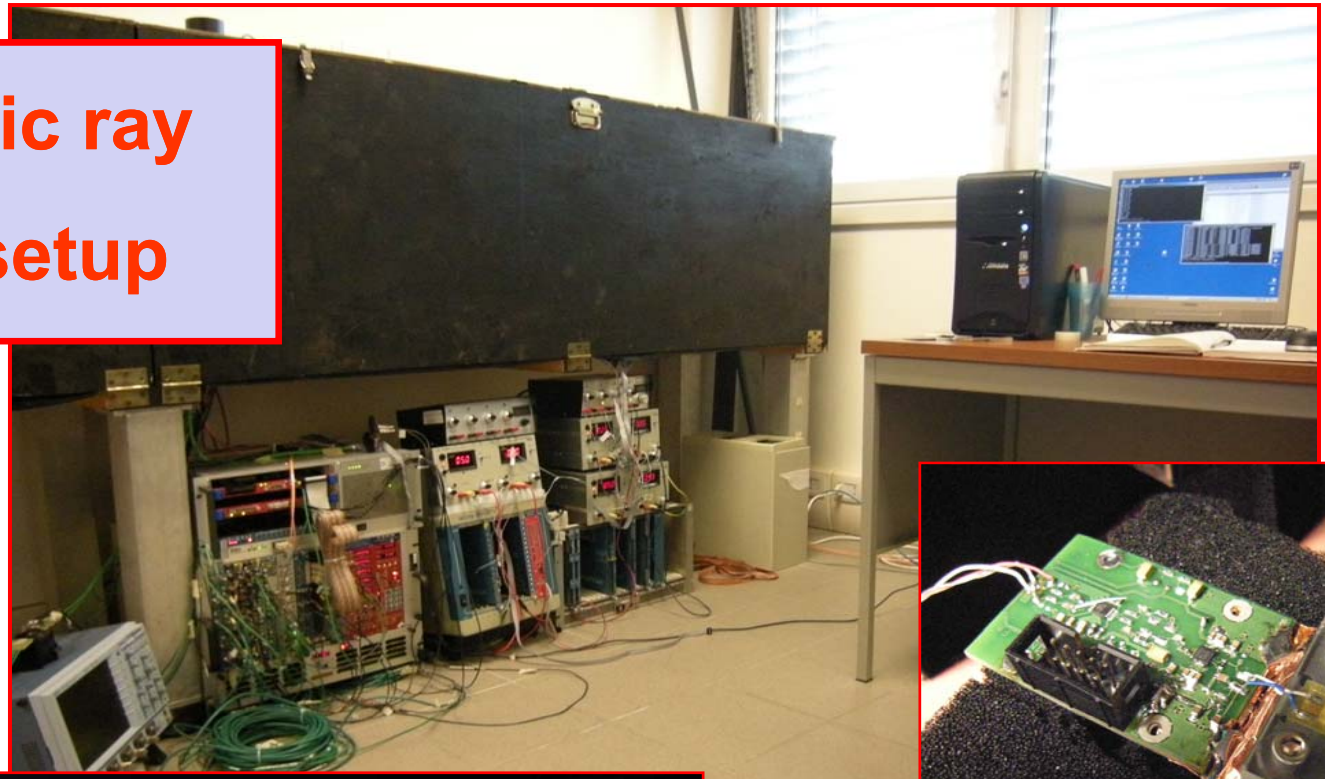
Detector Layout

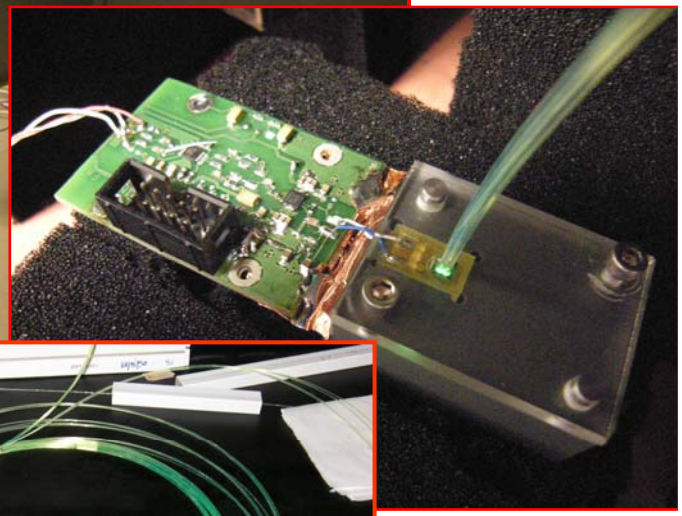
- Combination of 2 layouts: time readout, double coord. readout
- Time readout: azimuthal coord ϕ measured from the hit bar, polar coord θ from the arrival time of the signal
- Double coord readout: two layers of orthogonal (1.0 cm) scintillating bars provide directly the ϕ and θ coordinates. Easier from the point of view of electronics but more complicated for the mechanics
- Number of WLS fibers per scintillator bar under definition
- CLEAR fibers to bring light to photosensors (…see next slides)

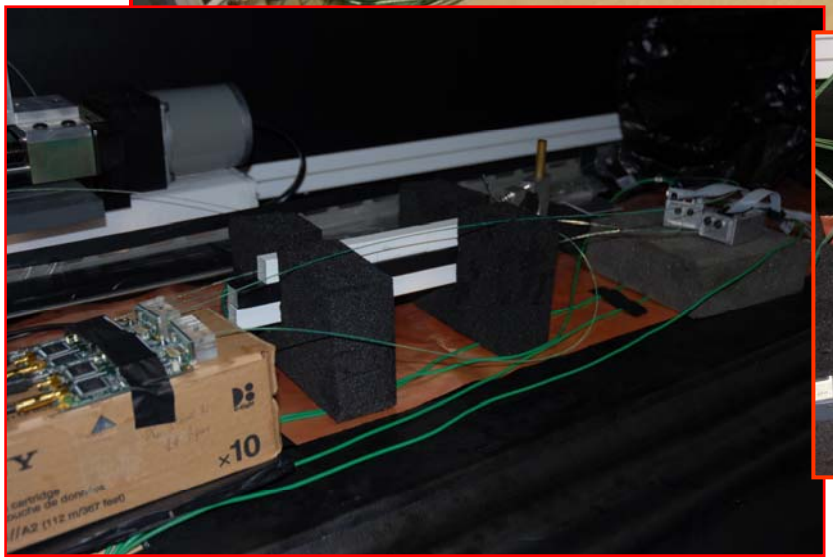
Cosmic ray test setup



Cosmic ray test setup







Update on detector R&D activities in Ferrara

readout options…

- We considered the option of bringing the light signal out of the detector through clear fibers

- 4m of WLS fiber + 10m of clear fibers

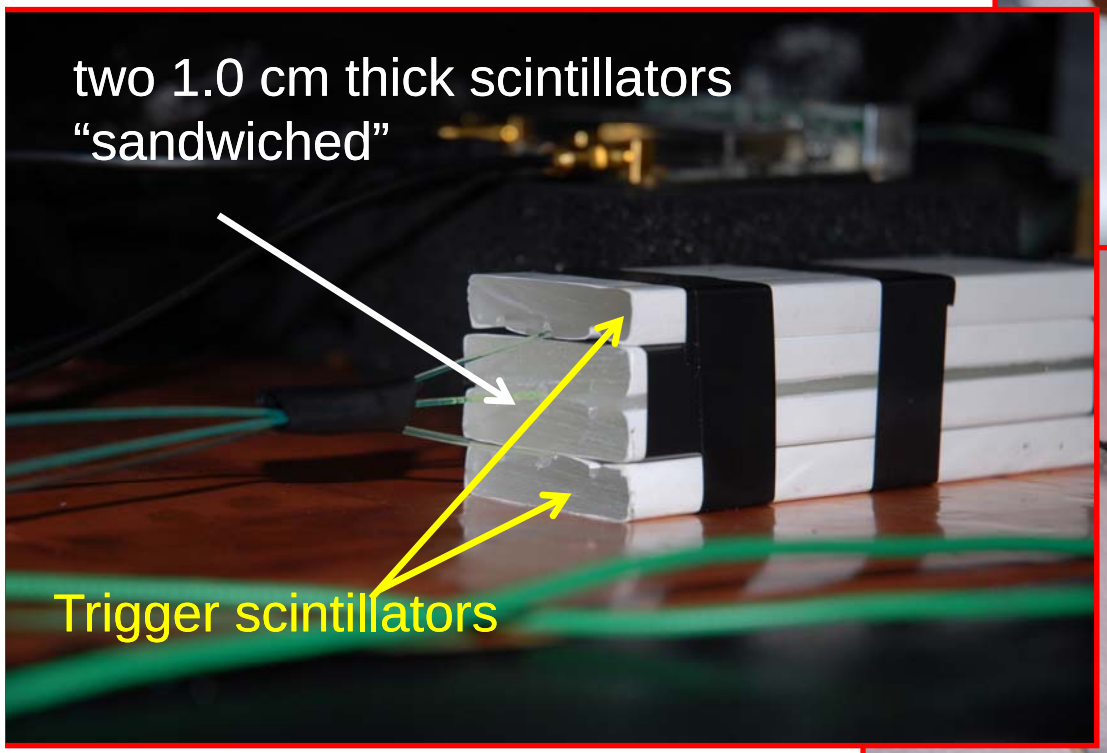
- λ_{att} = 10 m → factor ~3 less in number of p.e., to be recovered keeping the same efficiency and time resolution:
  - Increase the number of WLS fibers, from 1 to 4, on 2x2 mm^2 SiPM and/or 3x3 mm^2 MPPC
  - Increase the fiber's diameter from 1.0 to 1.2mm
  - Play with fibers position and/or scintillator coating to maximize the light collection

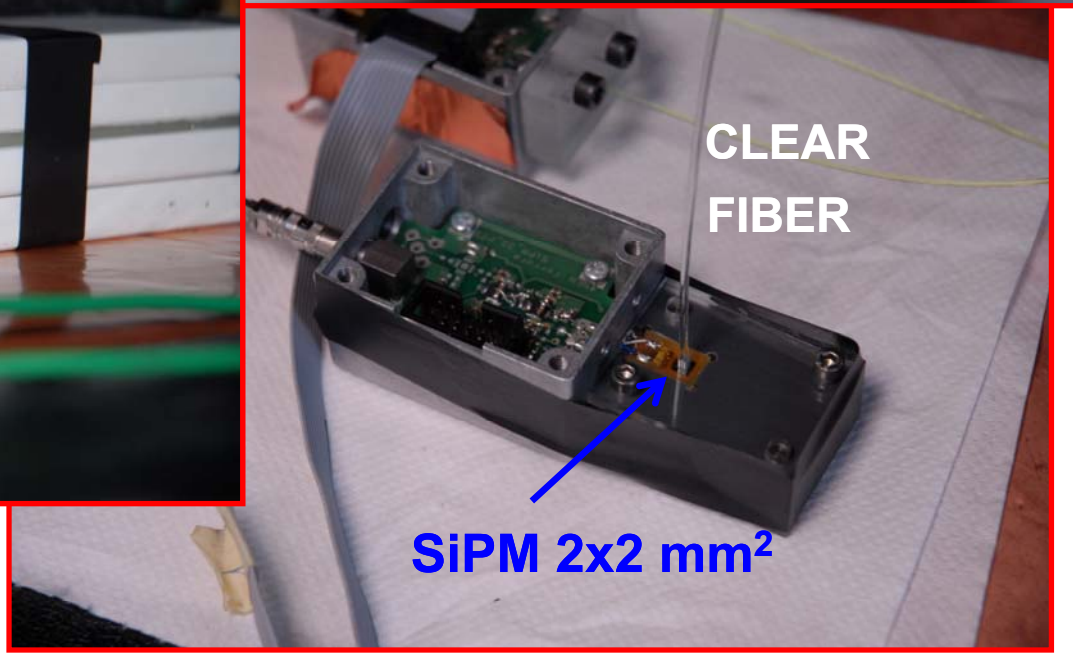
working conditions

- we made several measurements in ~ realistic working conditions
- SiPM: Vbias = 34.0 V, MPPC: Vbias= 71.0V
- Thresholds: 2.5 p.e.
- Fiber length: 4.0m WLS, 1mm diameter , 10.0m CLEAR, 1.5mm diameter
- Scintillator: FNAL “sandwich” of 2 1x4x15 cm^3 scintillator
- 3 grooves with white coating removed on the contact surfaces
- FAR end: ~3.7 m from scintill., CLOSE end: ~0.3m from scint.
- Trigger: 15cm scintillator, readout with 2 MPPC modules (thresholds @ 5 p.e.)

The setup


WLS and CLEAR fiber are coupled mechanically, no splicing
WLS
CLEAR

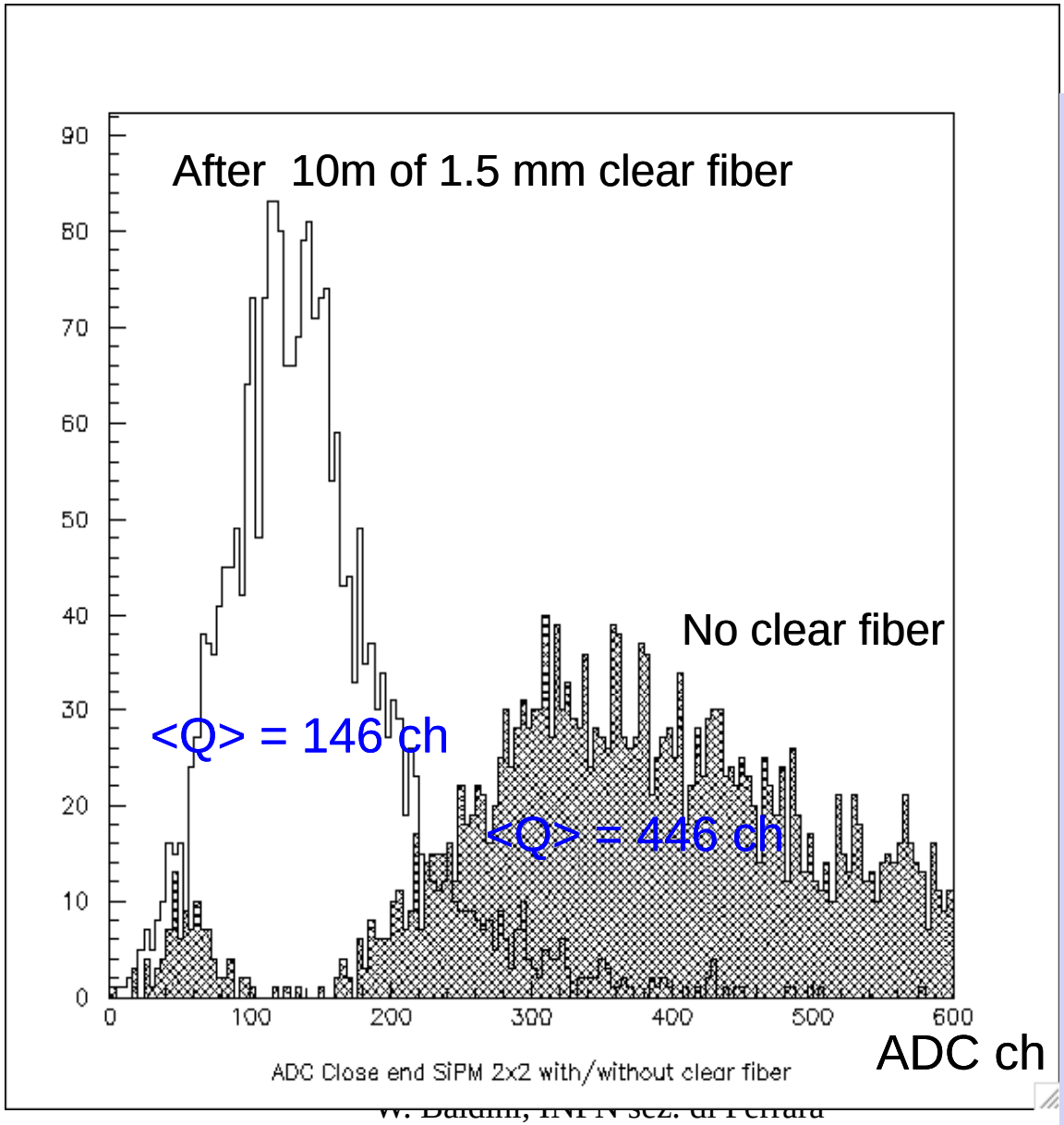

two 1.0 cm thick scintillators "sandwiched"
Trigger scintillators


CLEAR FIBER
SiPM 2x2 mm²

Measurements

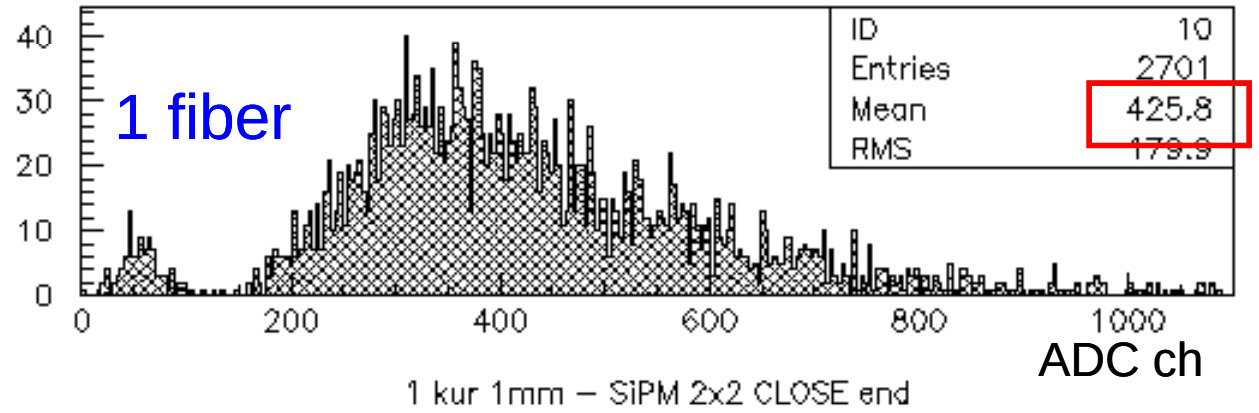
- Light loss in the CLEAR fiber (+ coupling with WLS)
- relative light yield of 1,2,3 fibers (WLS+CLEAR) on both, close and far ends of the WLS fibers
- Compared light yield of kuraray vs Saint-Gobain fibers
- Compared signal of SiPM 2x2mm^2 and MPPC 1x1mm^2 (Tried also MPPC 3x3mm^2: too noisy)
- WLS fiber in central vs lateral groove

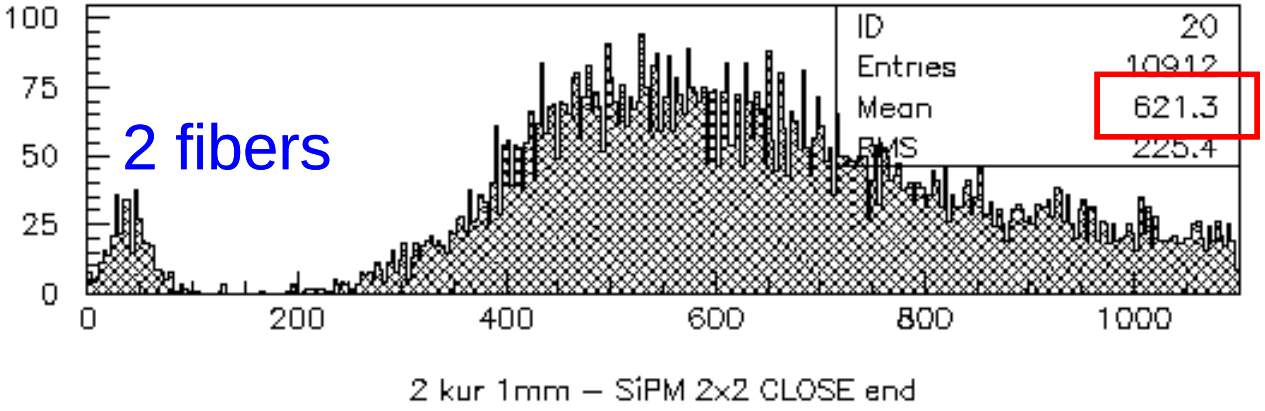
Light loss in the CLEAR fiber

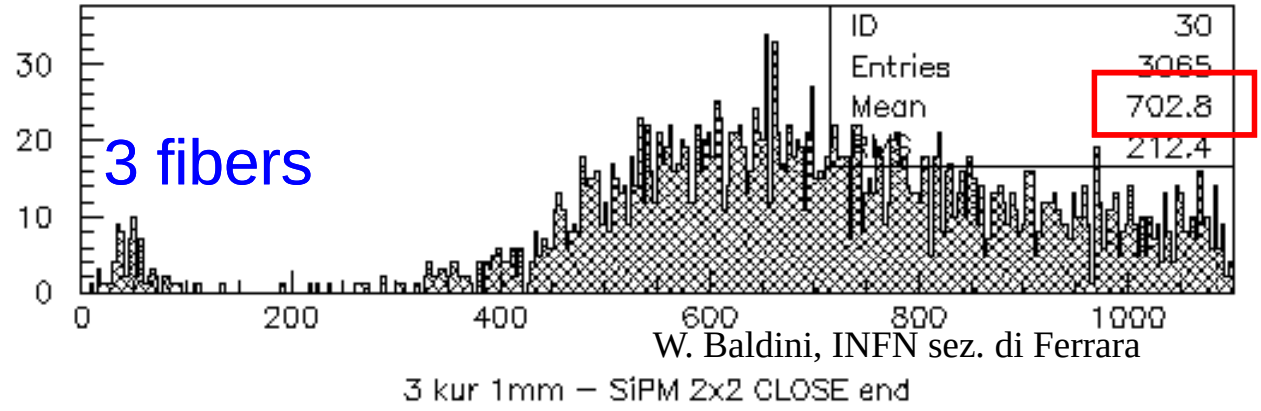


- WLS and clear fiber are coupled mechanically, no splicing
- We expect roughly a 10% coupling loss
- L= 10m, att length $\lambda = 10$m
- $A_{exp} = A_{coupl}\ e^{-\lambda/L} \sim 0.9 * 0.37 \sim 0.33$
- A_{meas}=146/446 = 0.33
- This confirm our estimate for the fibers coupling loss

1 vs 2 vs 3 kuraray fibers on the close end





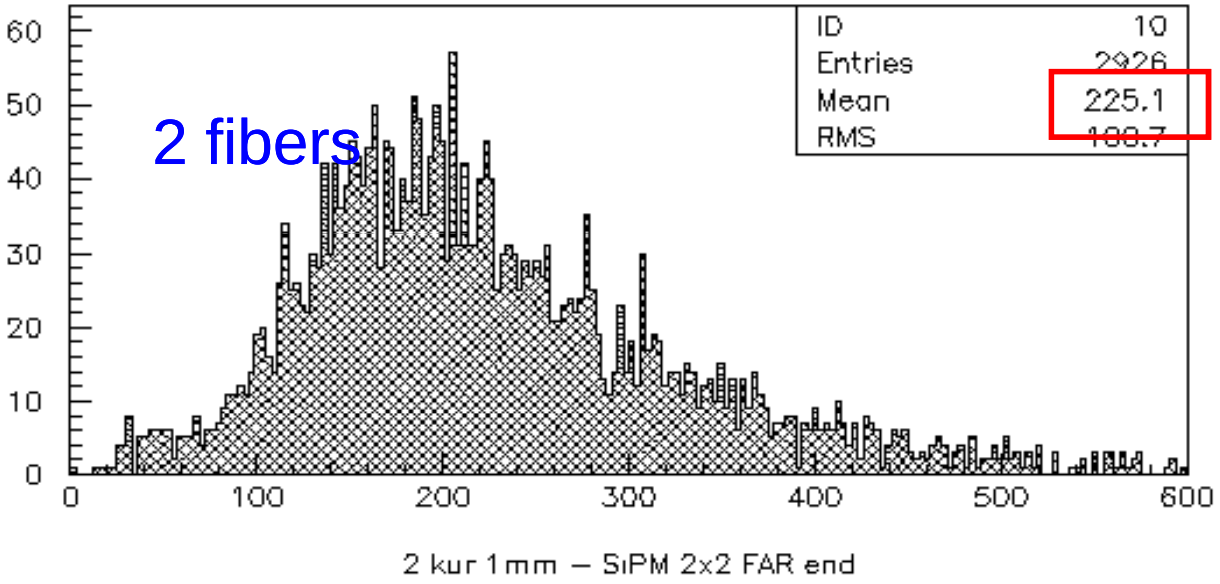


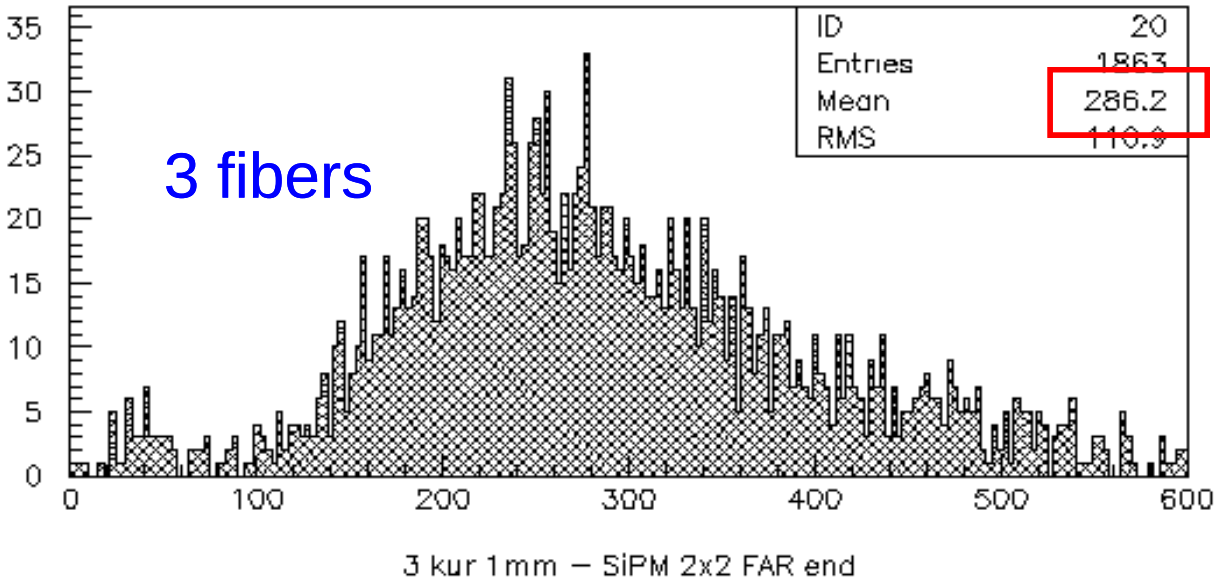
R2/1 = 1.46

R3/1 = 1.65

With 3 fibers we gain only 13% more signal….

2 vs 3 fibers kuraray on far end

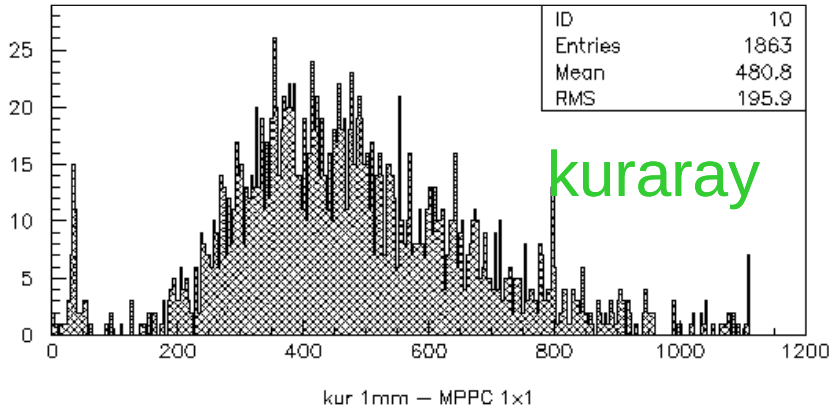


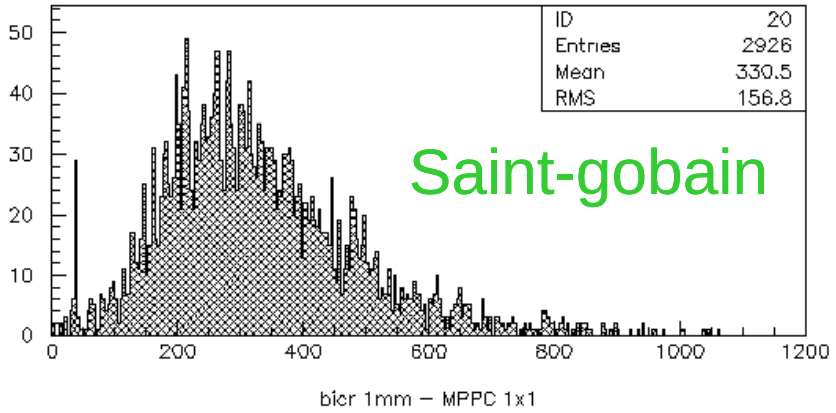


On the far end the gain is higher

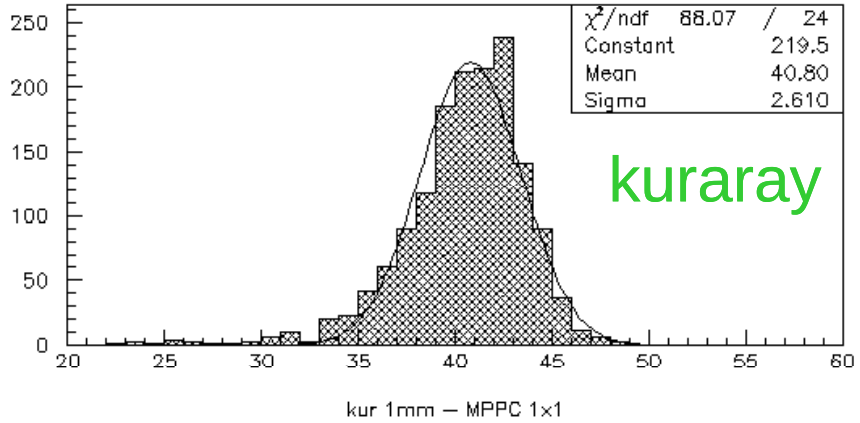
Kuraray vs bicron

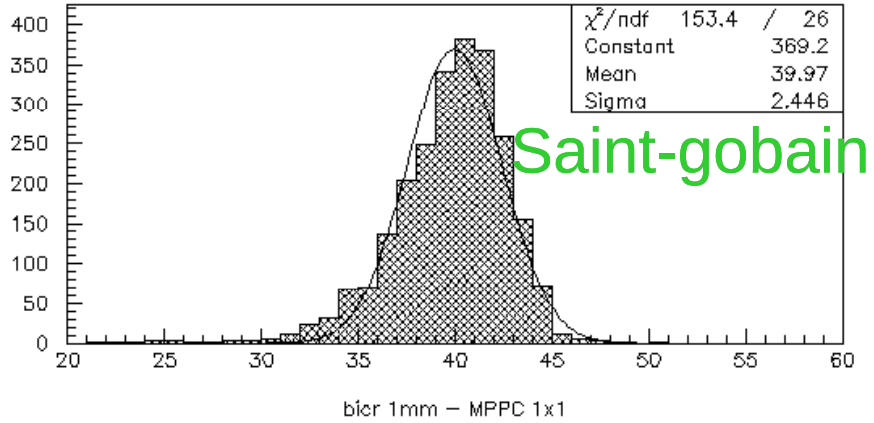
ADC





TDC

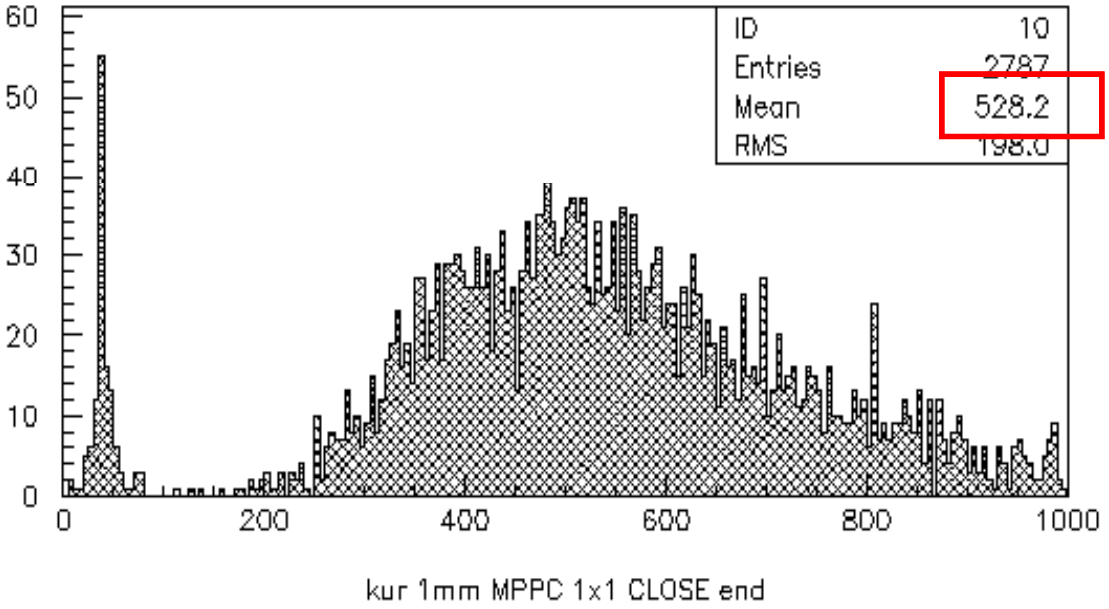


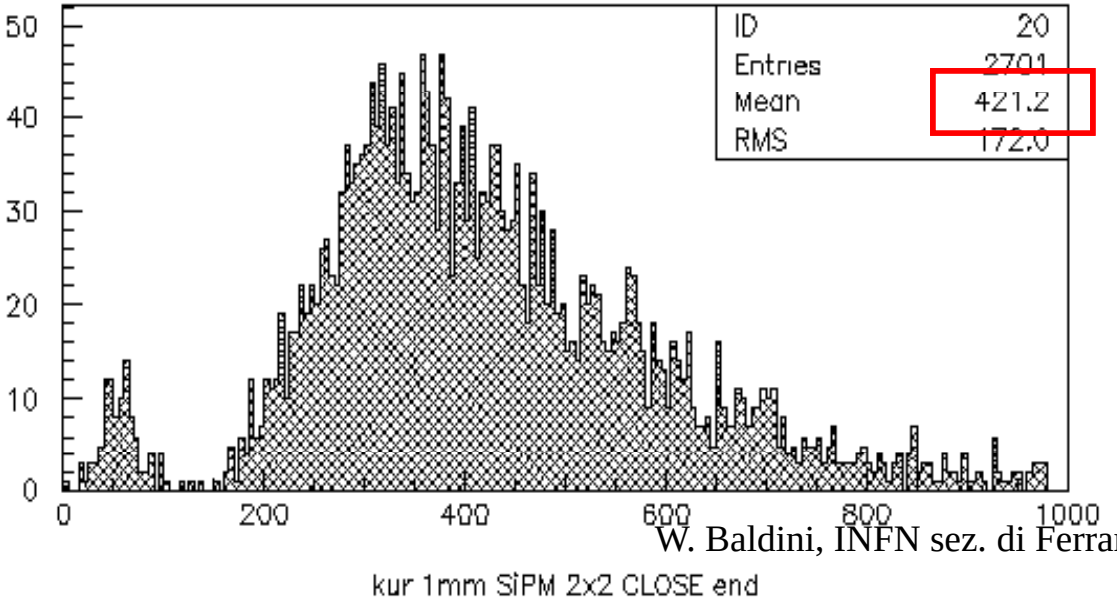


Saint-Gobain Light Yield is ~ 30% lower than Kuraray, but Bicron has a better time response (as shown at the Orsay workshop)

Note: TDC sensitivity is 1 ns and trigger scintillator is 15cm, this is just to compare the two fibers. Measurements are done at the close end (30cm)

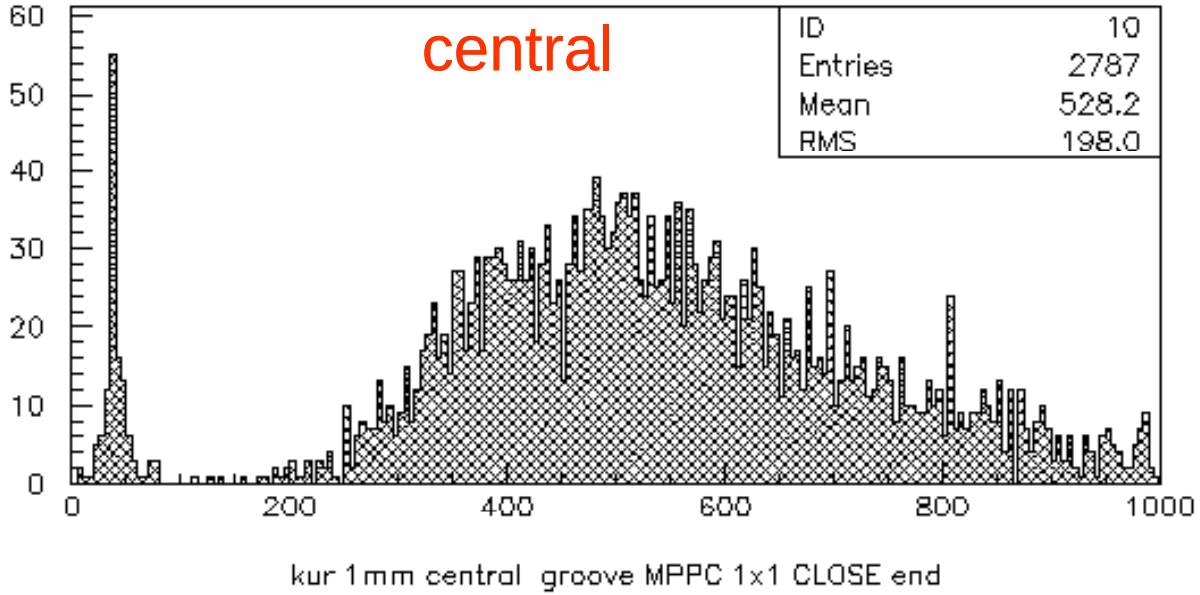
MPPC 1x1 vs SiPM 2x2

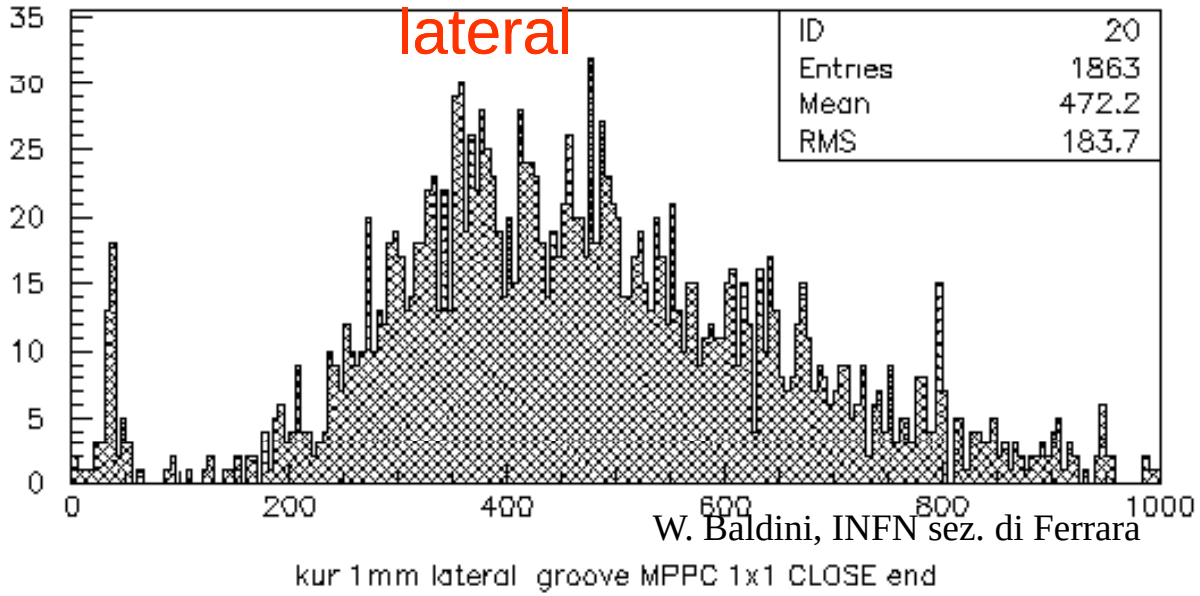




- MPPC – Hamamatsu has a ~20% higher gain
- This depends on working voltage
- Working voltage is a trade off between gain and dark counts rate…

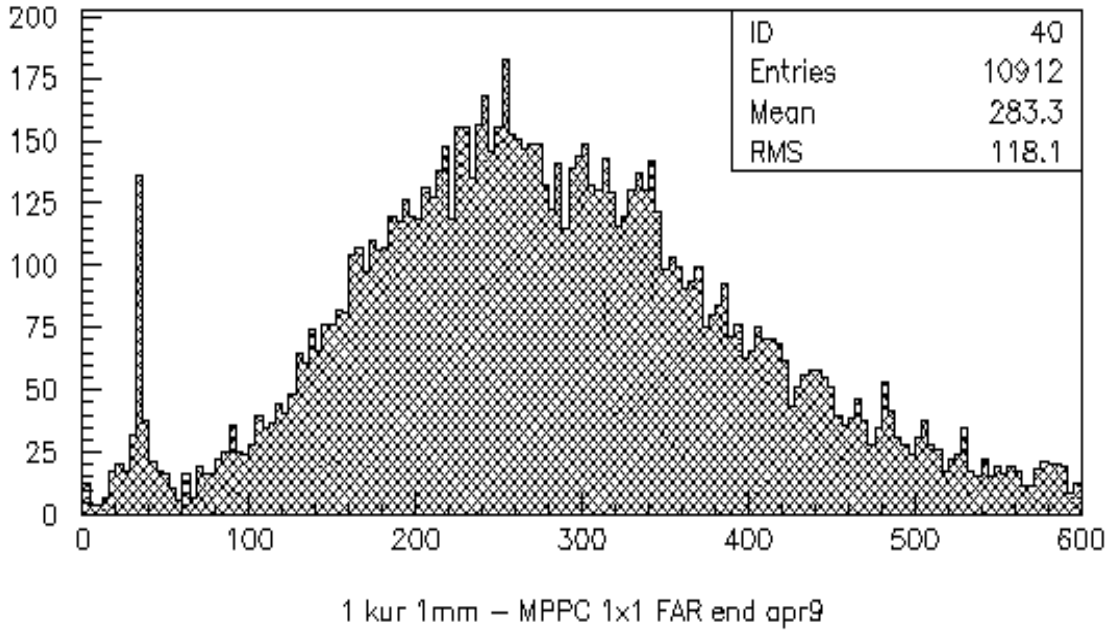
Central vs lateral groove

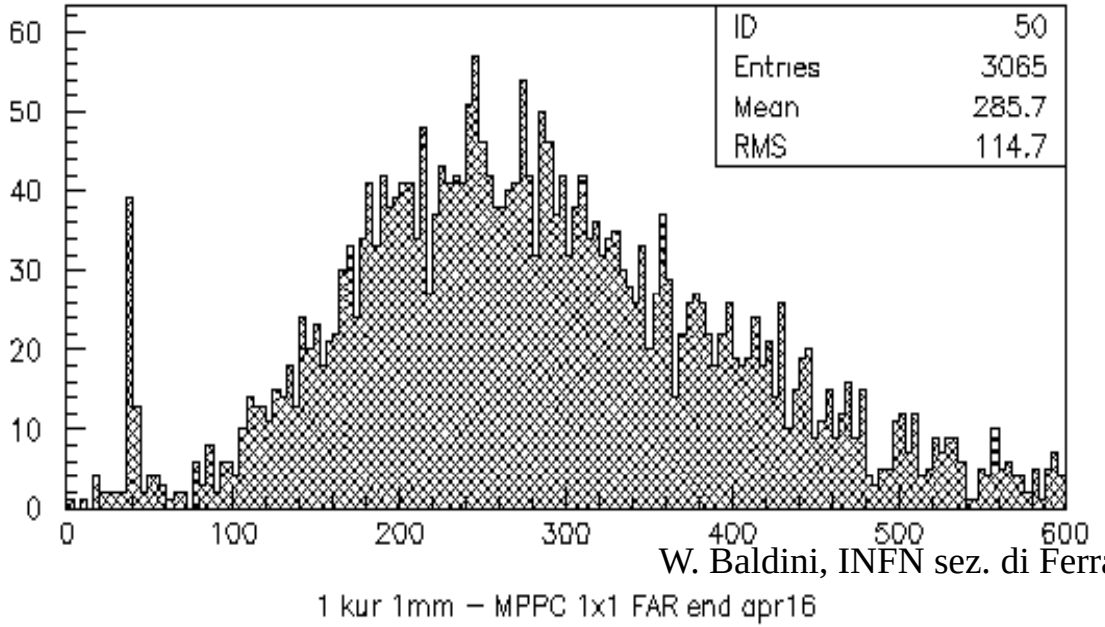




Also position of the groove counts for ~10% of light

Stability





stability of conditions checked during the measurements: stable within few %

Some preliminary conclusions…

- Measured Light Yield in ~realistic conditions: 2 cm thick scintillator (actually 2x 1cm sandwitched…) , 4m WLS fibers, 10m CLEAR fibers on 2x2 mm^2 SiPM
- In the CLEAR fiber the light loss is the expected factor 3
- Light collection does not increase linearly with number of fibers, with 3 fibers we gain a factor 1.65
- Saint gobain (better time resolution) have a 30% lower Light Yield
- preliminary results of SiPM/MPPC radiation tests (see G. Cibinetto/ D.Pinci talks) show that moderate radiation reduces significantly the signal
- So...
- To bring the light signal out of the detector looks very “inefficient” (and also expensive)
- Photodetectors should be properly shielded on the detector
- Simulations/studies of neutron flux on the detector is very important

Next steps…

- Fix number/type of WLS fibers to obtain high efficiency AND the desired time resolution (here MC studies should tell us…) for time readout option
- Same, but no time resolution constraints for the double coord. option
- Photodetectors and on detector electronics shielding studies