R&D in Bologna - Update

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for Bologna IFR group

5th SuperB collaboration Meeting
Pisa, 20 September 2012

Part 1:
Prototype tests

Light collection measurements

Assembly different IFR bar prototypes and study the effect on muon response of:

- WLS fiber glueing
- WLS fiber aluminizing
- Scintillator wrapping
- bar length

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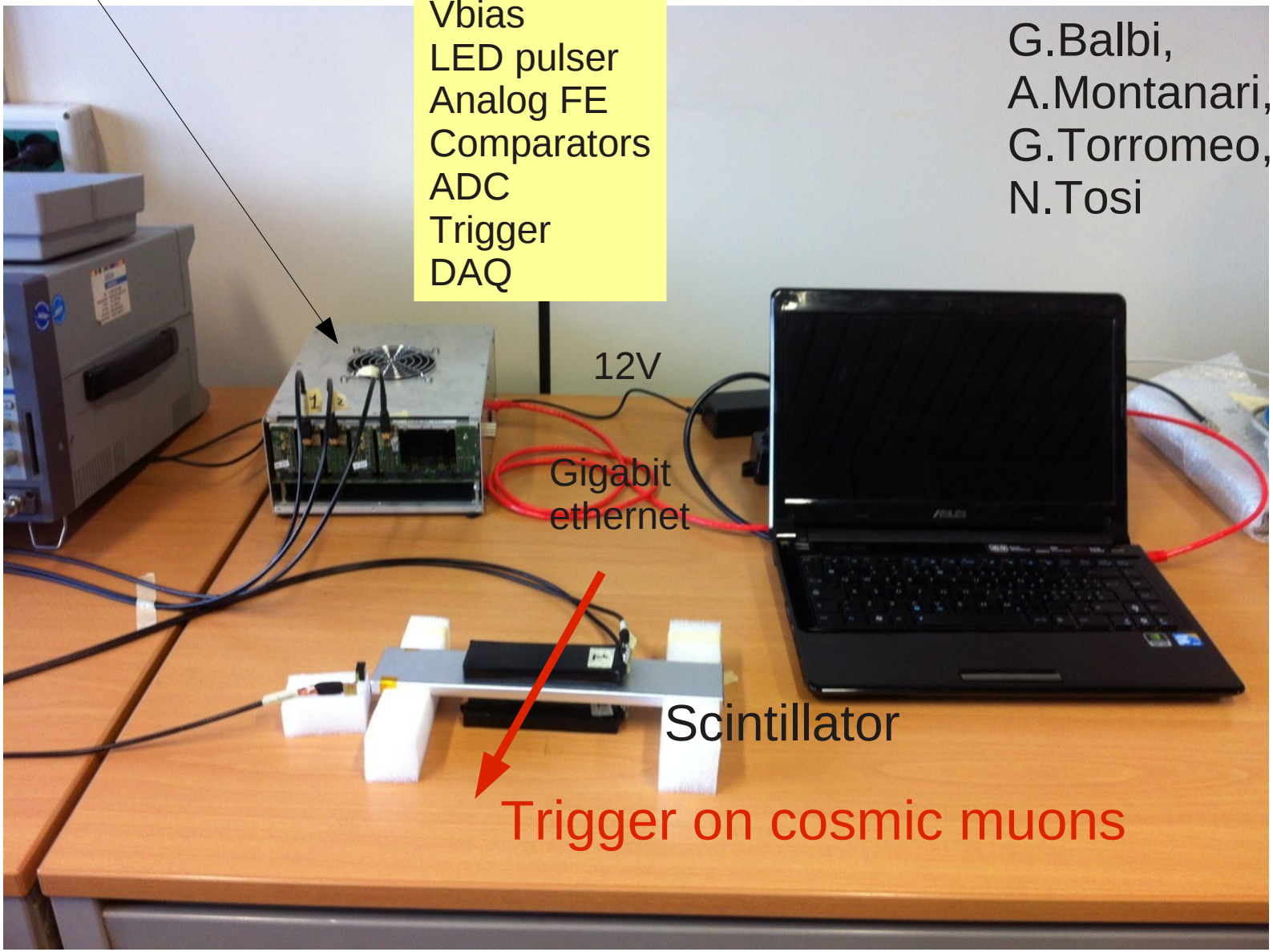
CAVEAT:

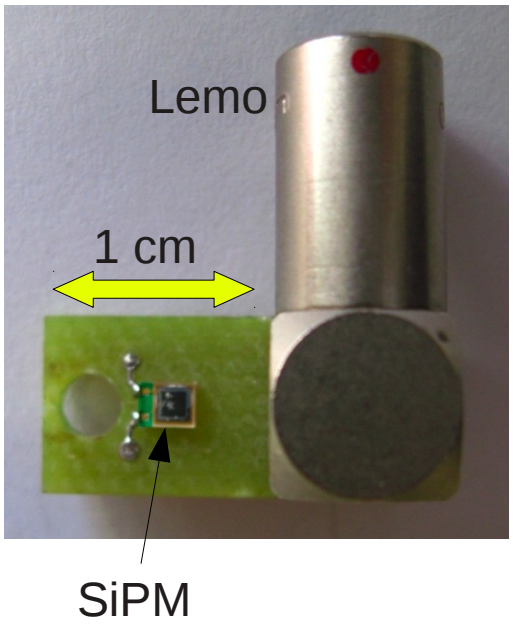
- the absolute figures depend on the type of SiPM used and on the quality of its optical coupling to the fiber
- relatives figures are more relevant

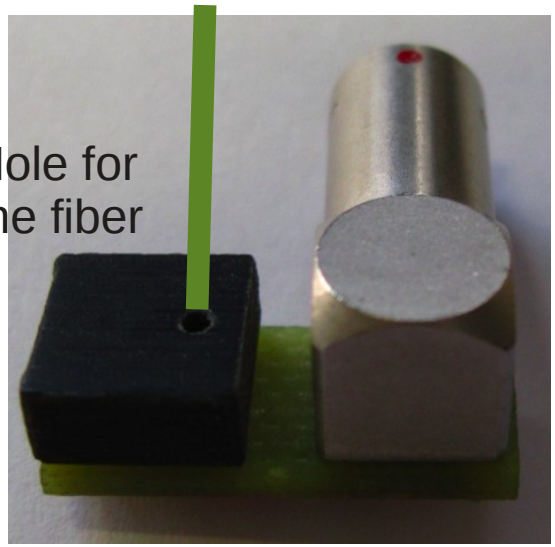
Custom readout and control system

- Versatile system for 8 channels:



SiPM used for tests



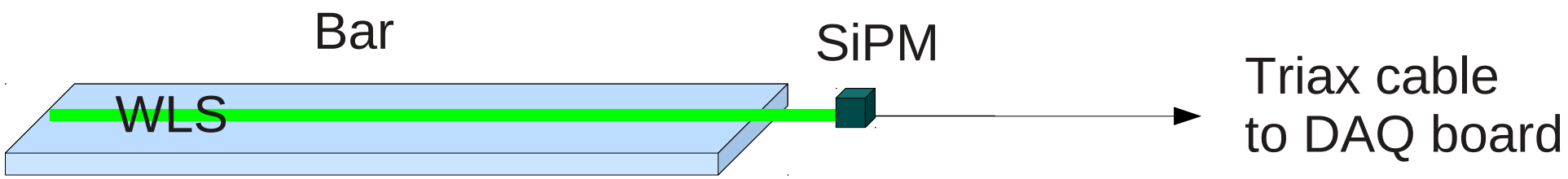


Hamamatsu 1x1 mm^2

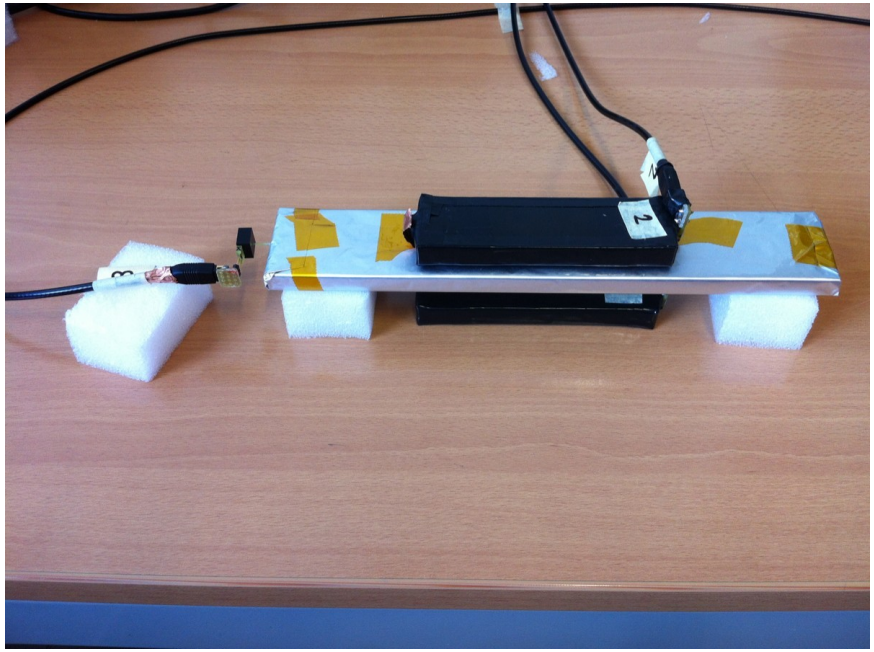
50 μm pixel

Caveat:
not optimized
optical coupling

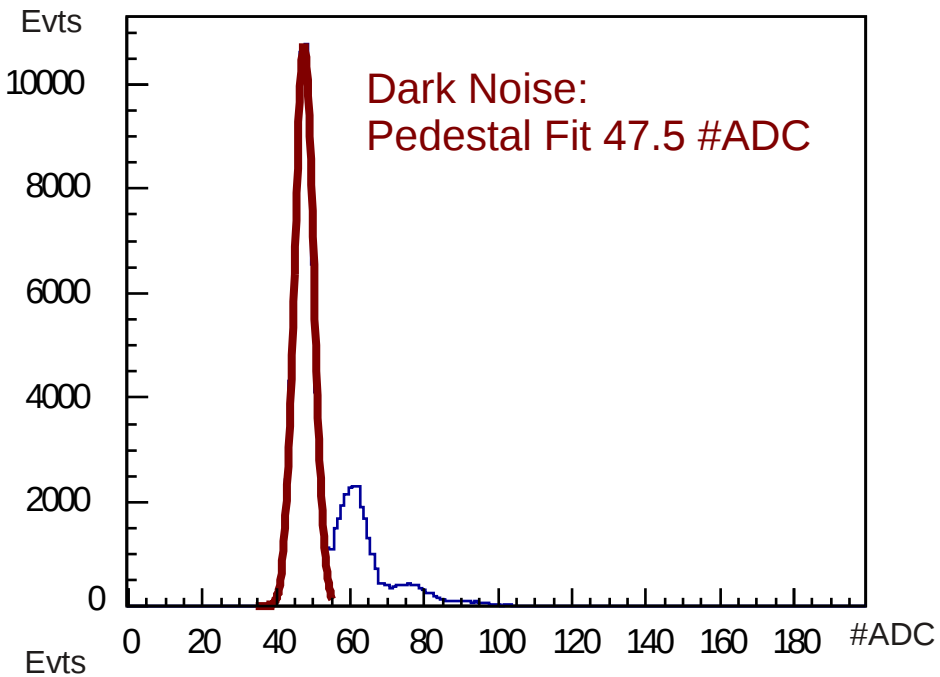
Light collection in short scintillator bar

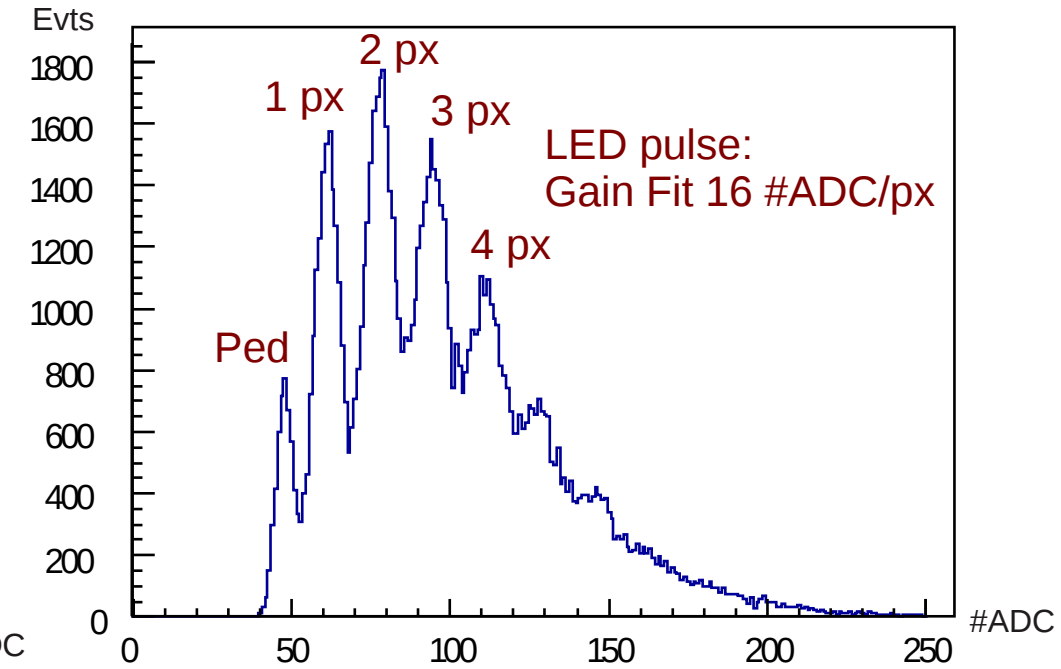


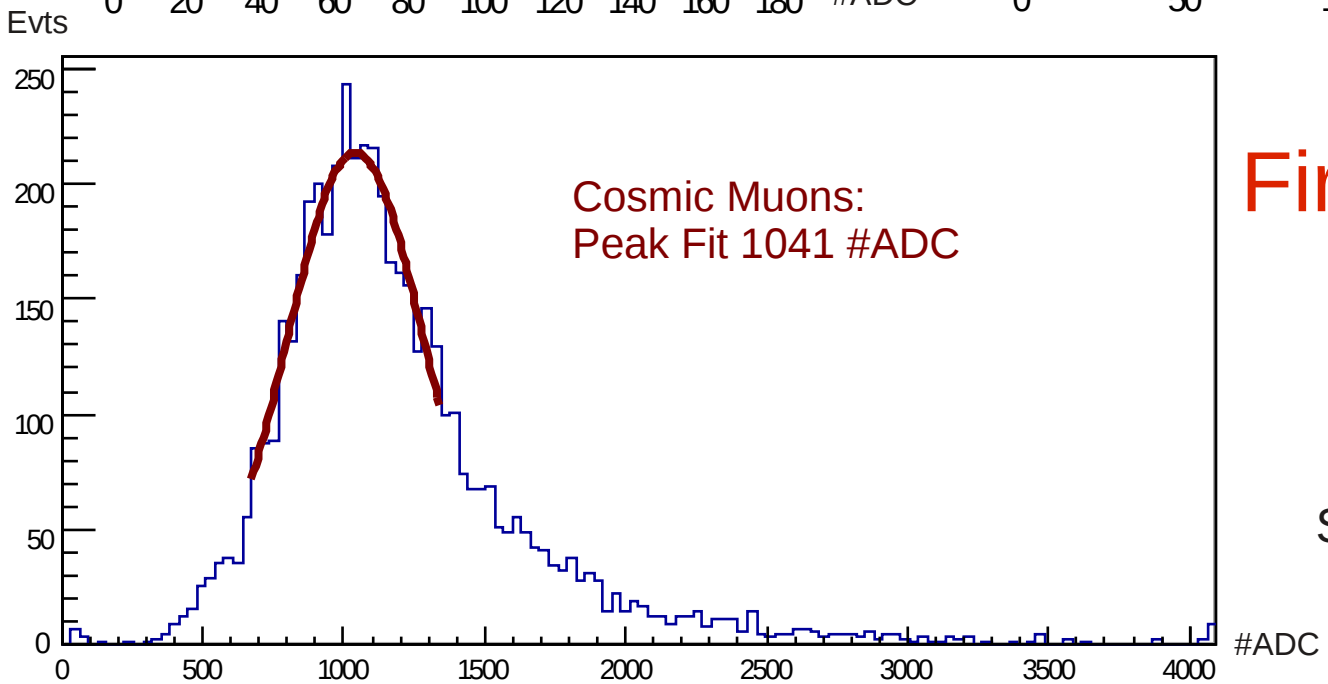
- Fermilab scintillator bar:
  - transverse size: 4.5x1.0 cm^2
  - length: 25 cm
  - one straight groove on top
- WLS: Kuraray 1 mm diameter
  - With and w/o Aluminization
- Aluminum or black wrapping of scintillator



Example: WLS glued + not alumized







Fired pixels for a MIP:

$$\frac{1041-47.5}{16} \simeq 58\ px/\mu$$

Systematic error on fits: ~3 px/μ

Aluminization and scintillator wrapping

New!!

- No difference found between
  - Aluminized Mylar wrapping
  - Black (non-reflective?) paper
- But tested fiber had a small piece of aluminum glued at the far end...
  - Effect similar to proper fiber aluminization
  - Was put there to protect fiber end
  - If removed may prove even Al wrapping has similar effect, only smaller due to air gap

    (direct comparison not yet done)

Summary of light collection tests

- Fired pixels per MIP:

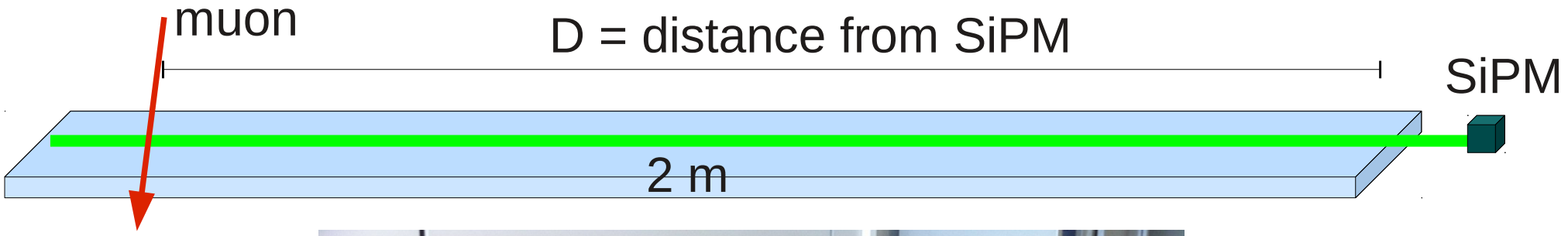
New!!

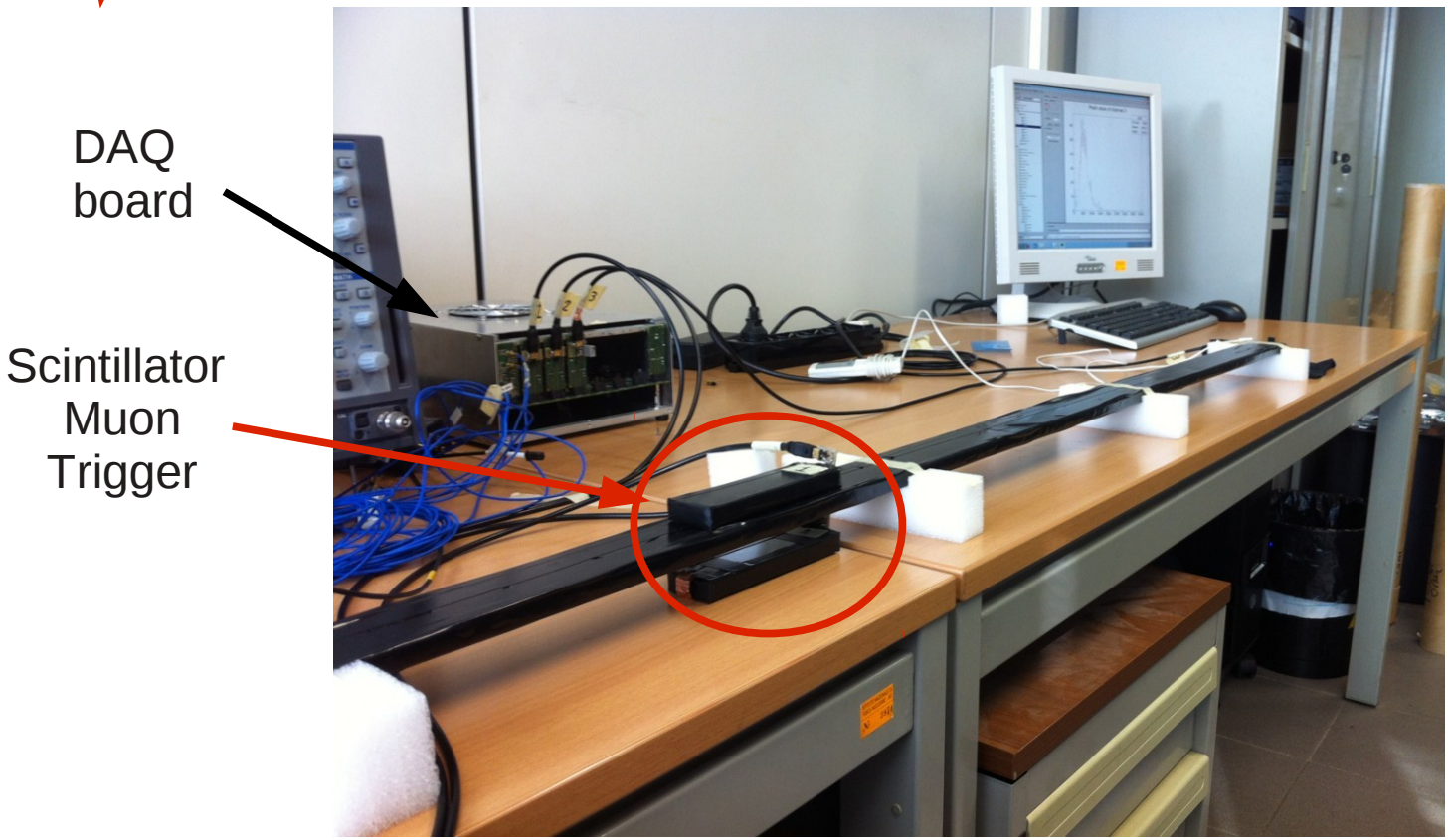
Fiber ends...	Scintillator Wrapping	Not Glued Fiber	Glued Fiber
against wrapping	Black	-	38 ± 3
against wrapping	Al	37 ± 3	-
glued Aluminium	Al	-	58 ± 4
aluminized	Al	46 ± 3	-

Many combinations are missing, some very interesting such as a direct glued vs. not glued fiber, but see next...

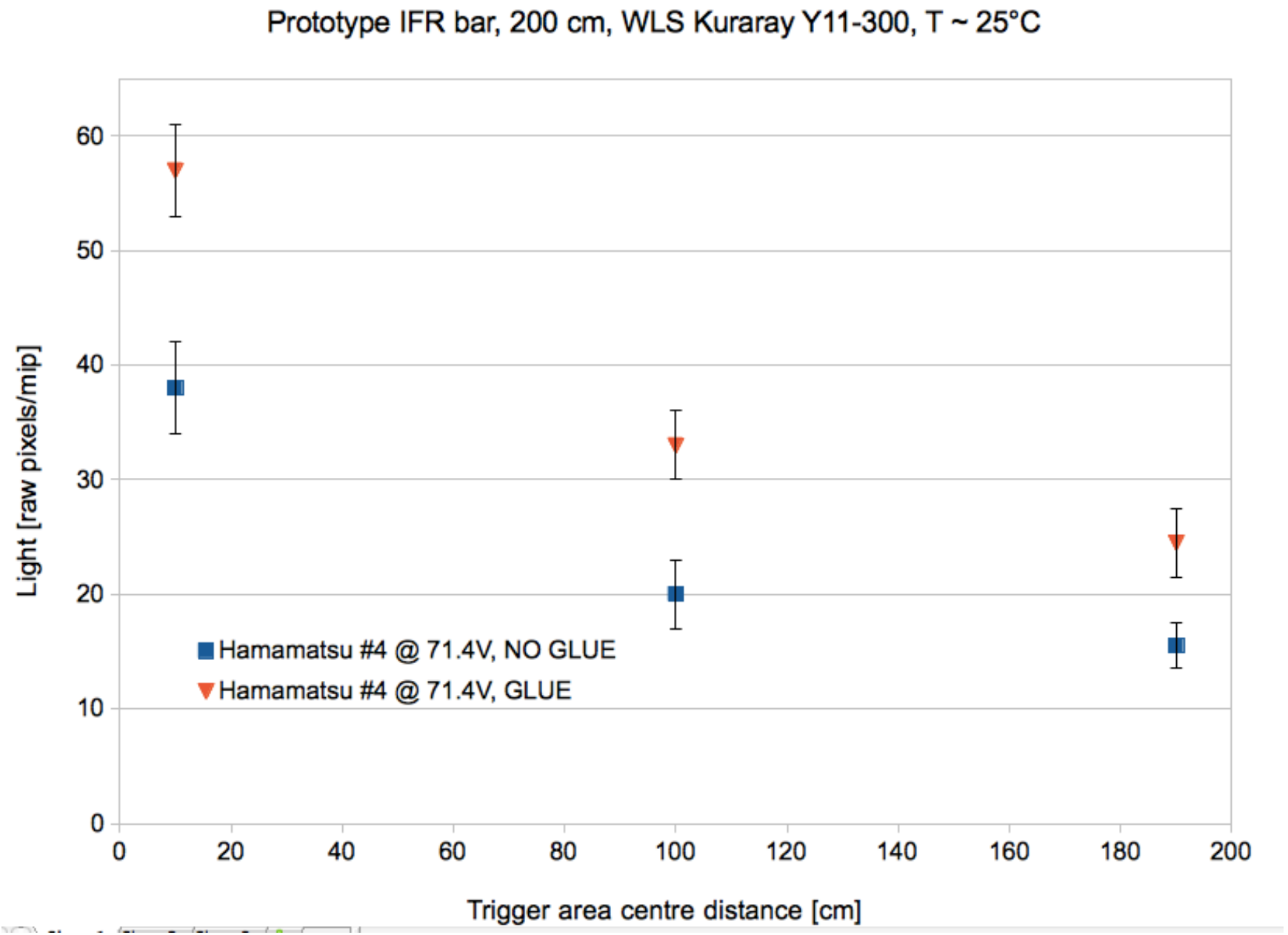
Light collection in long bar

- 2 m bar, WLS Kuraray Y11, T~25^{o} C



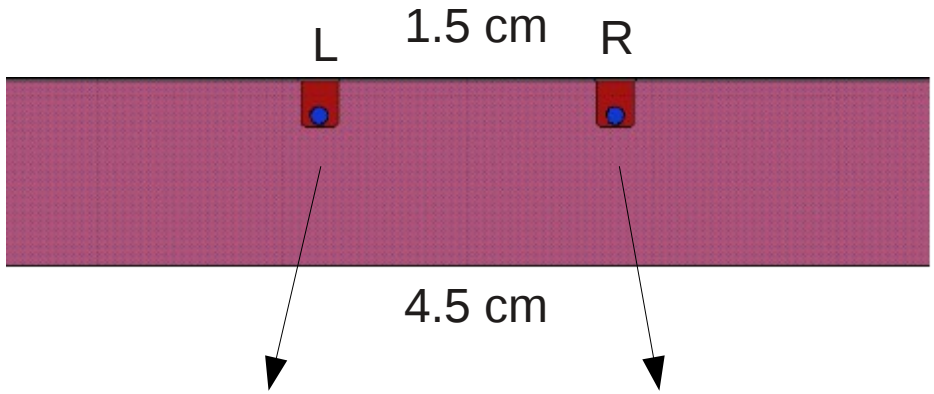


Light collection vs distance



Light from 2 fibers on same scintillator

New!!



27 +- 3 γ 28 +-3 γ

- Measure with 2 Hamamatsu 1x1mm^2, nearly identical efficiency
- Not Glued, not aluminized fibers, but Al wrapped scintillator (matches conditions of single fiber measure)
- Acquired individual spectra, then summed average values

Total = 27 γ + 28 γ = 55 γ = +49% wrt 1 fiber (37)

Conclusion

- Glueing the fiber improves light collection by about 50% (2m long bar)
- Aluminizing or adding some other form of reflector improves light collection in short fiber, additional measurements needed to determine how much
- Attenuation is an issue on long bar
  - more relevant in the blue region of light spectrum
  - Hamamatsu very sensitive to this effect
  - But measure used a single fiber

Part 2:
Simulation

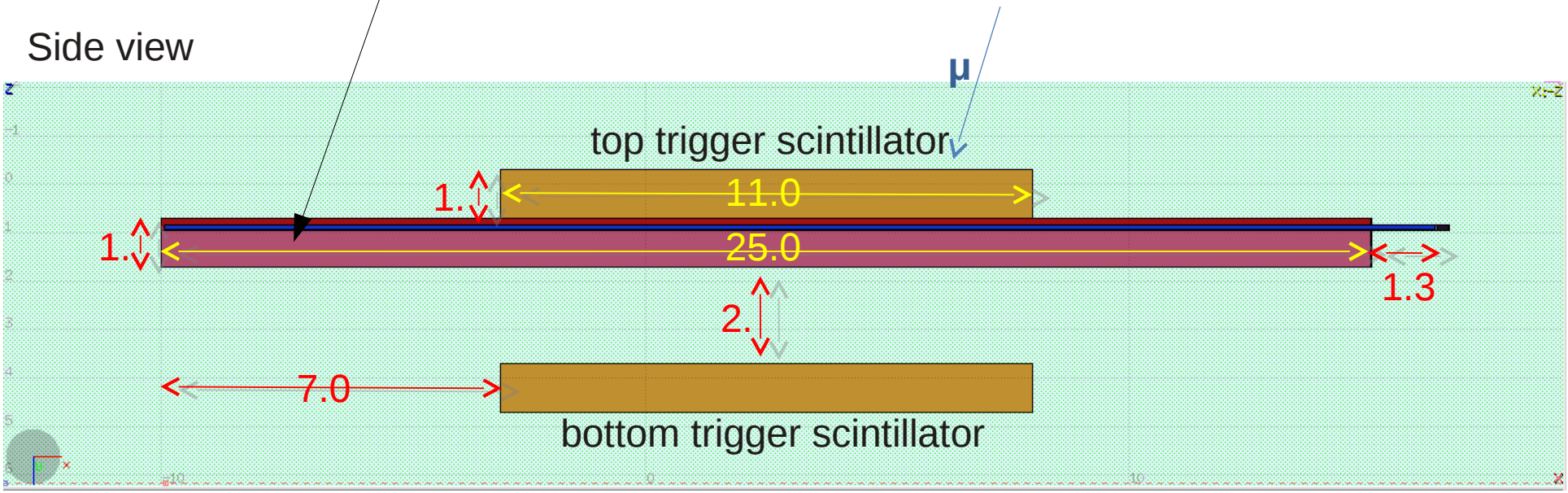
Light collection simulation

Tiziano Rovelli

- setup a detailed simulation of light production, propagation and detection in a prototype of a scintillator bar (FLUKA)
- cross check expected results from simulation with data collected from a real prototype: tune simulation free/unknown parameters
- use simulation setup to study different geometries and optical couplings
- still preliminary results..

Prototype setup

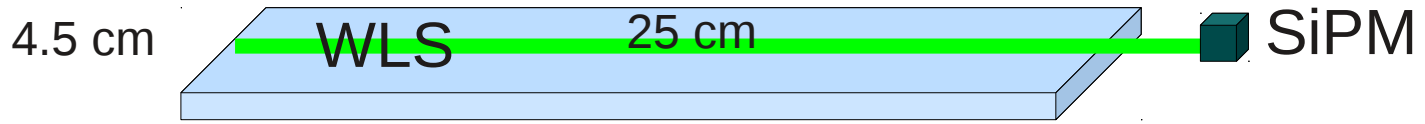
- use FLUKA (version 2011.2.13)
- simulation of bar prototype used to test MIP response (25x4.5x1 cm^3, Al wrapped)



(figures in cm)

Effect of glue and aluminization

- Simulate same geometry as real prototype:



+22%

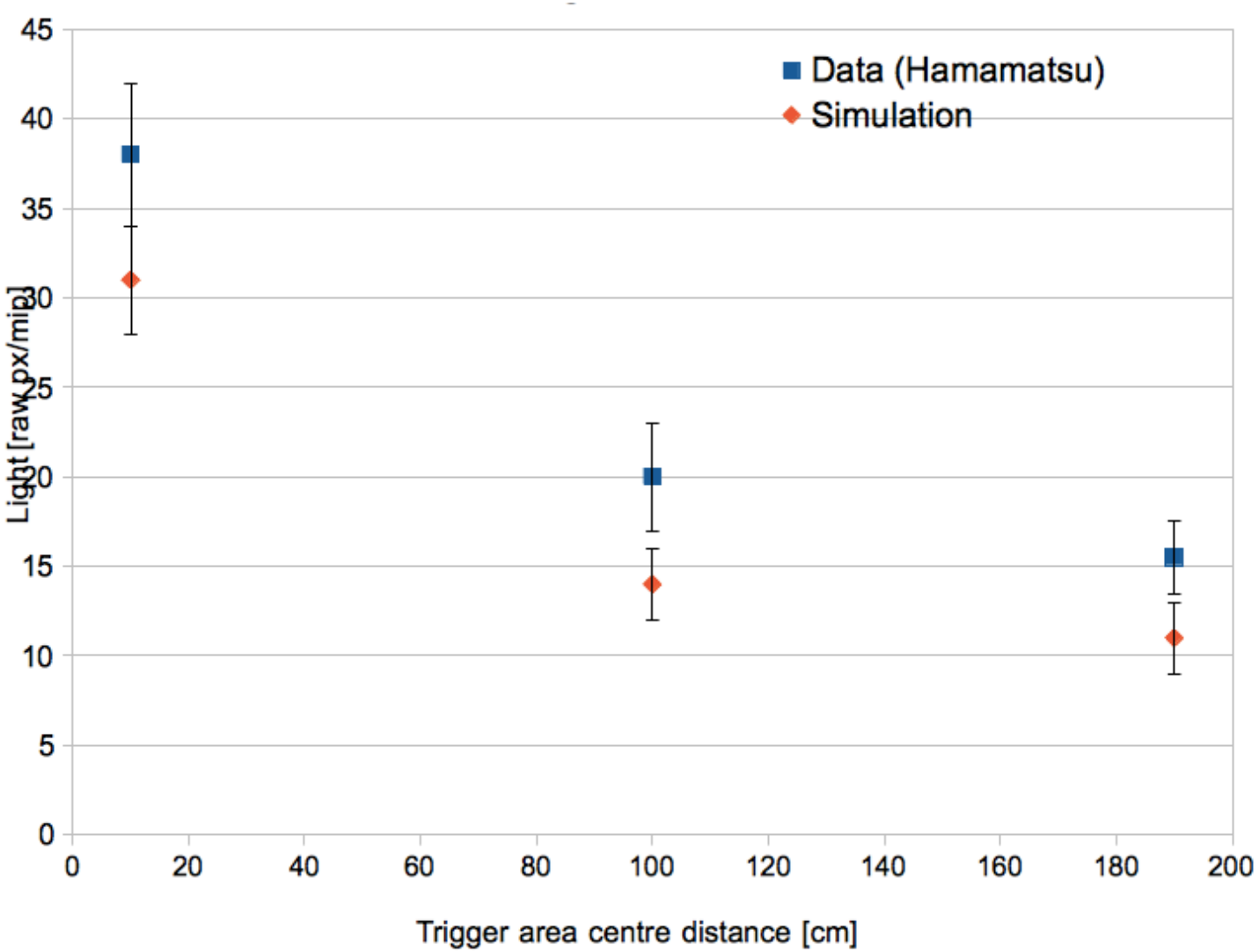
	Wrapping	Not Glued	Glued
Not Aluminized	Al	32 ± 3	39 ± 3
Aluminized	Al	42 ± 3	

+31%

- Good agreement with data (SiPM xtalk not simulated)
- Effect of glueing is underestimated...

Long scintillator bar

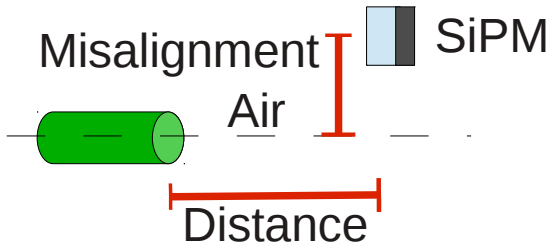
- 2 m bar, WLS Kuraray Y11 NOT GLUED

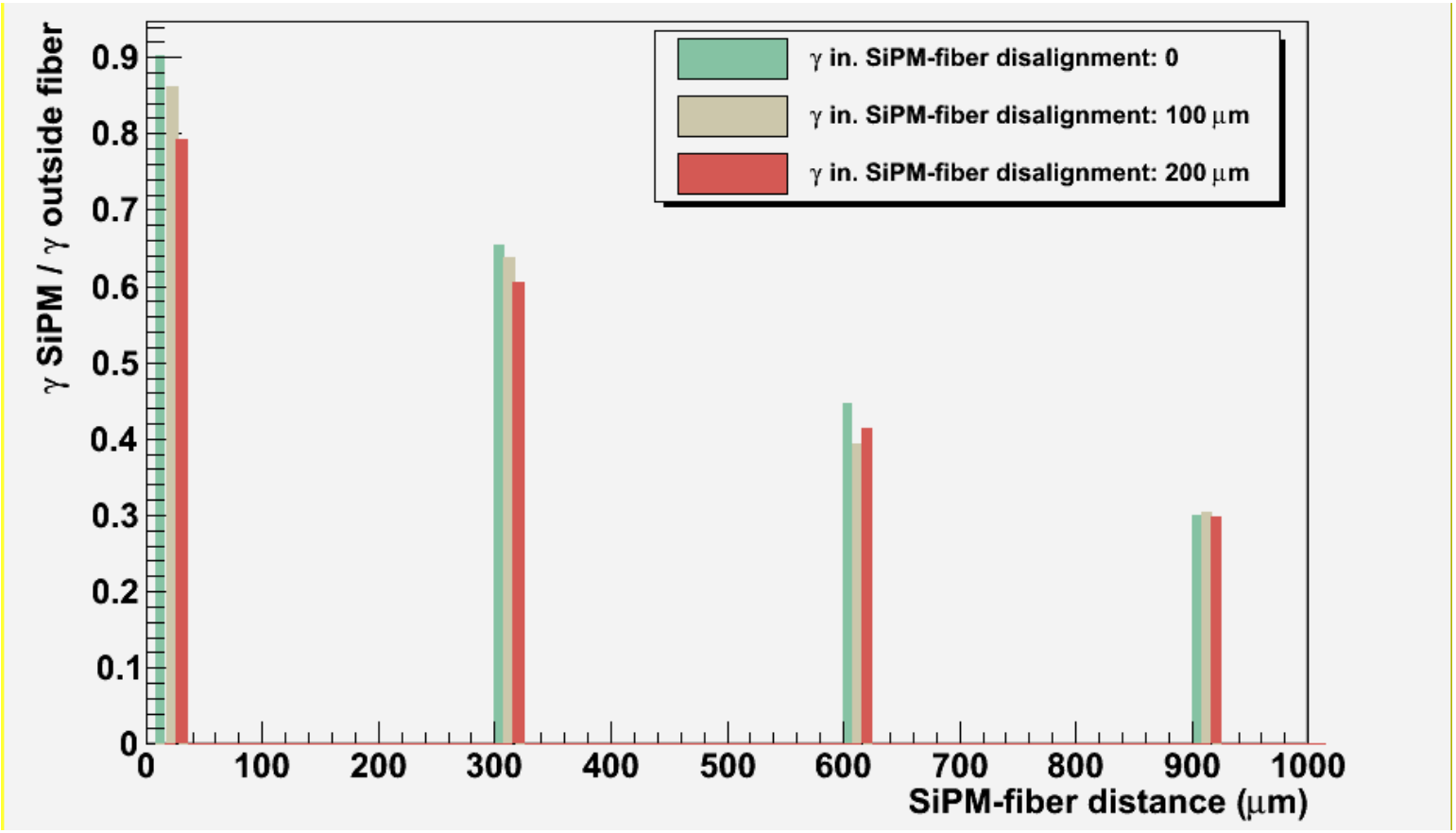


- Behavior is well reproduced

Effect of SiPM distance/misalignment from fiber

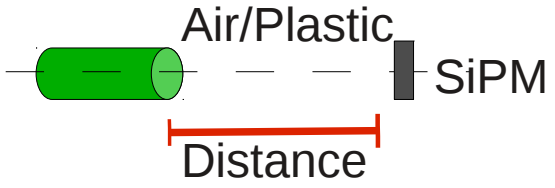
- Ratio =(γ @ SiPM)/(γ @ Fiber) (air in between)
- SiPM in plastic package (300 um)

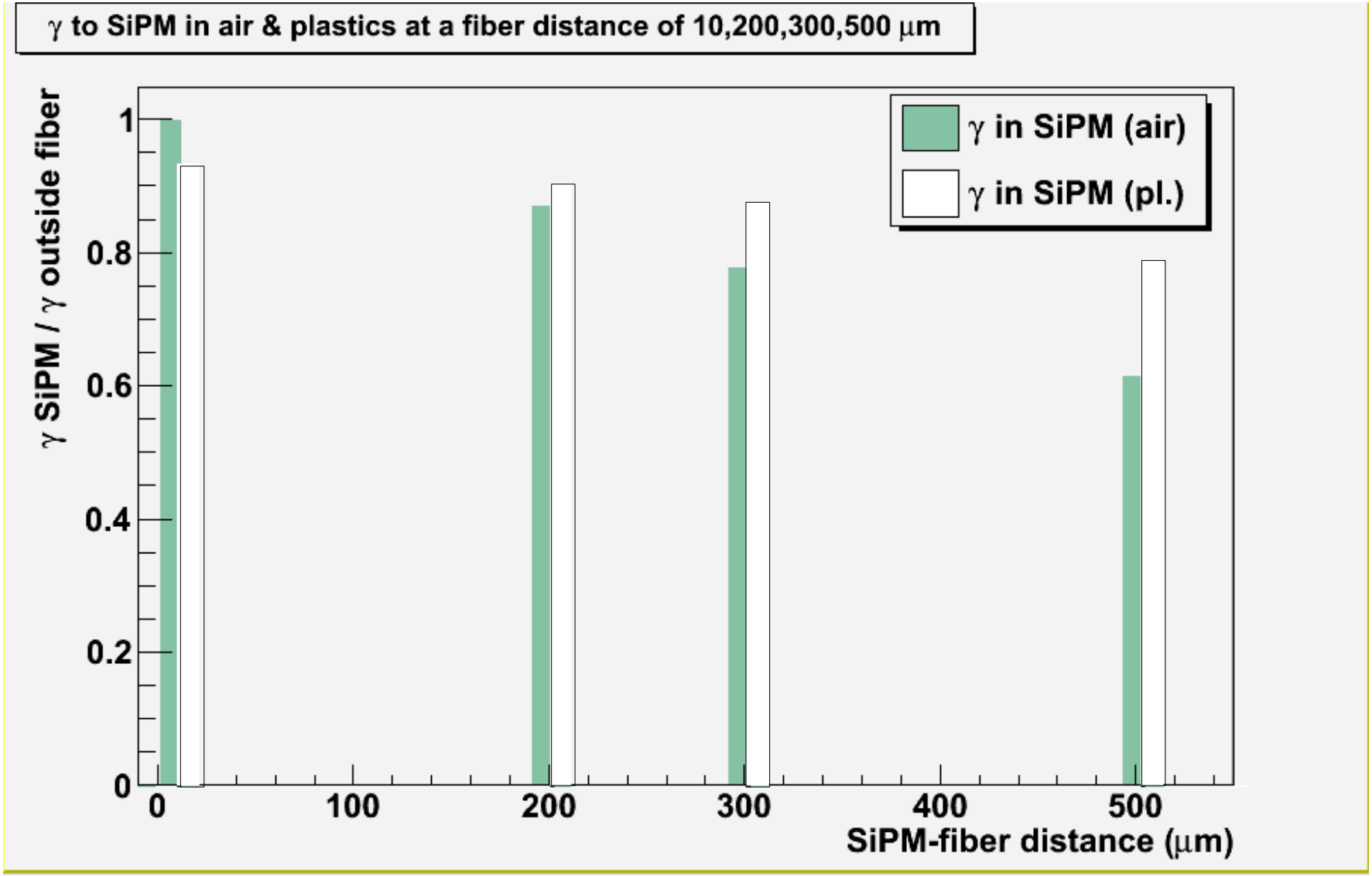




Effect of SiPM plastic package

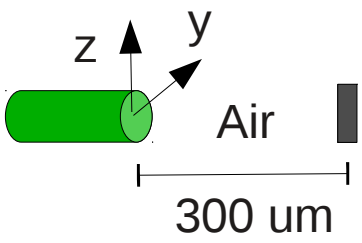
- SiPM perfectly aligned

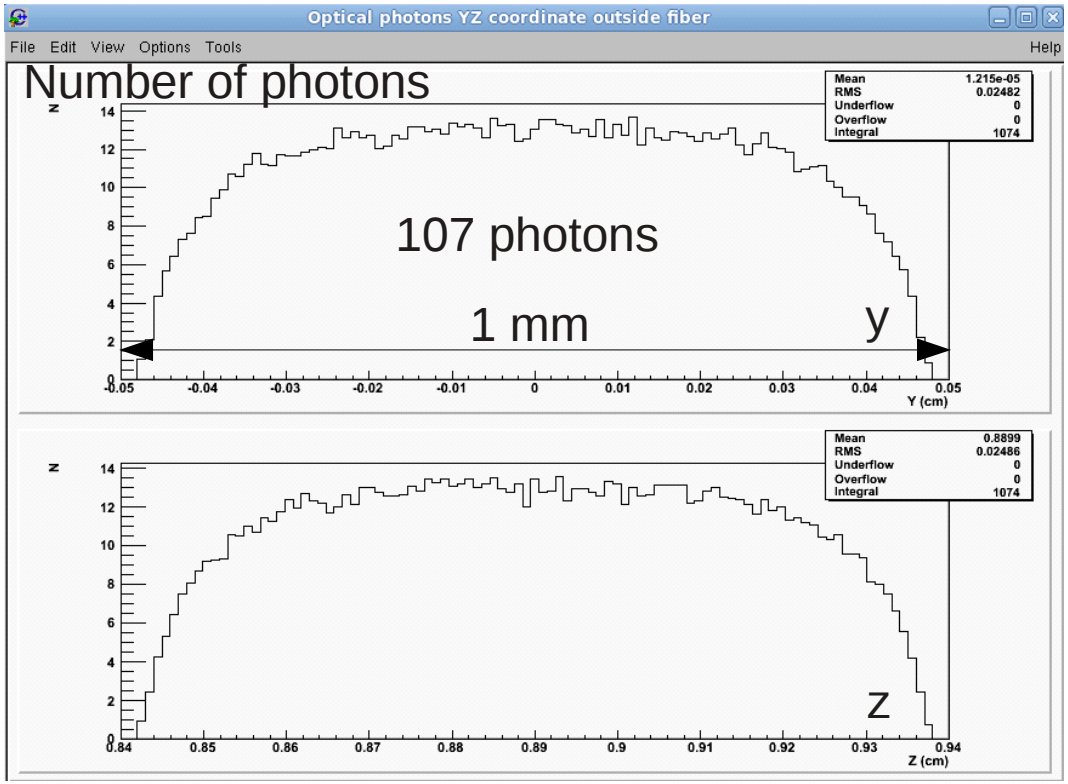




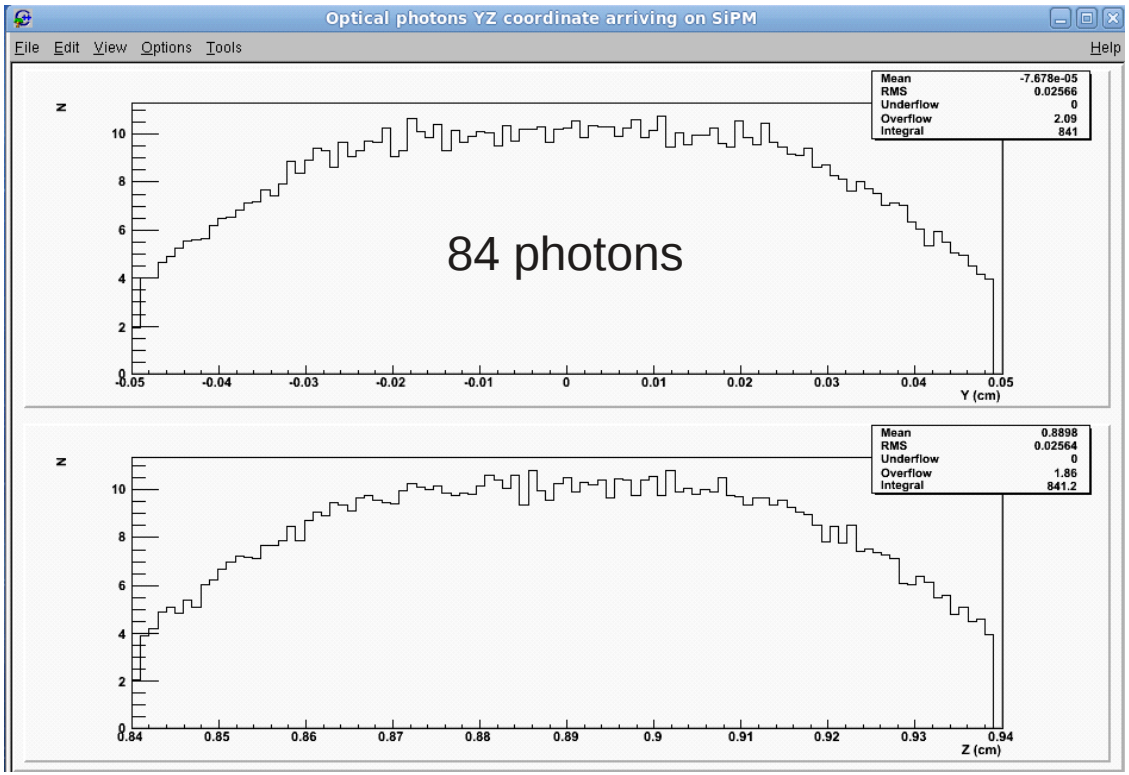
Photon beam profile

- More photons from the center of the fiber
  - Less sensitivity to SiPM misalignment



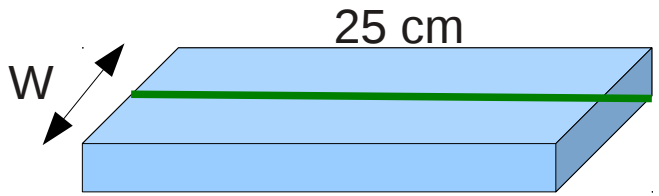


@ fiber output



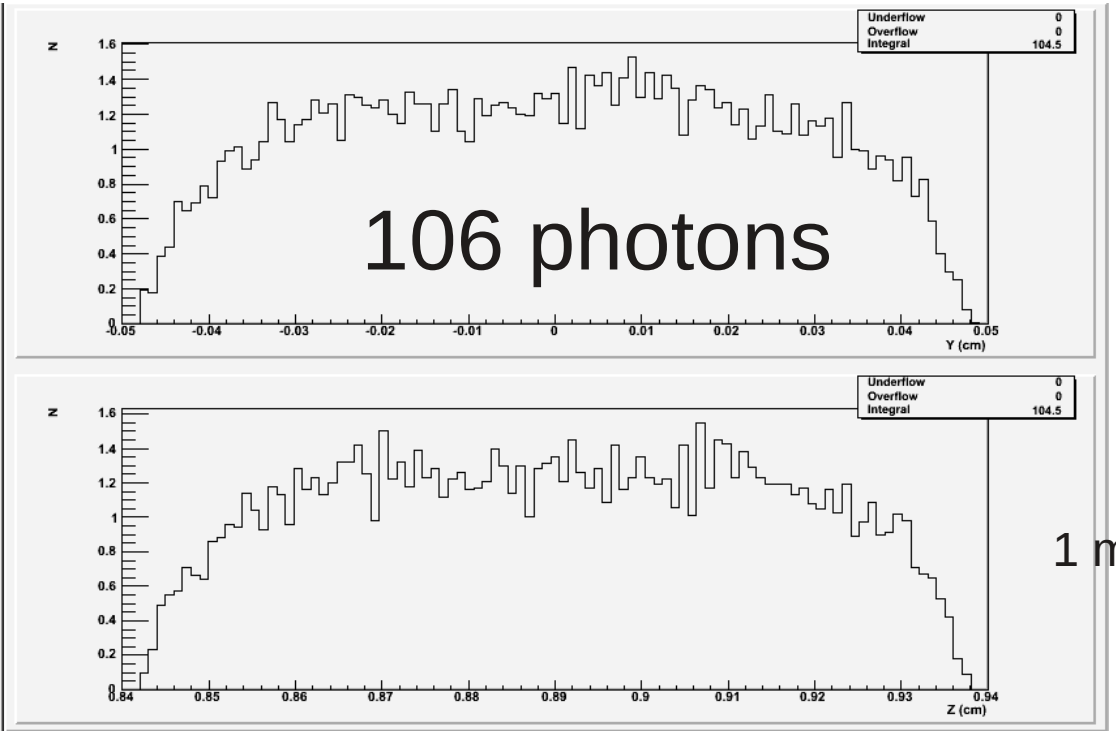
@ 300 um

Light from 1 fiber in 5 and 10 cm wide scintillator

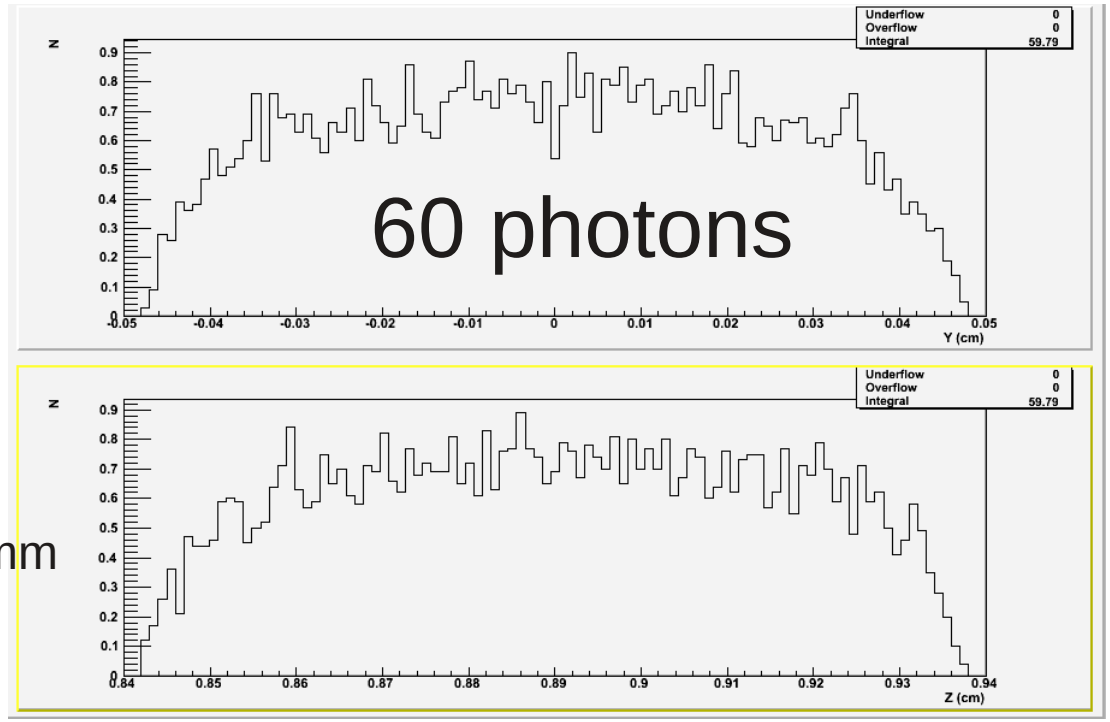


W=5 cm

W=10 cm

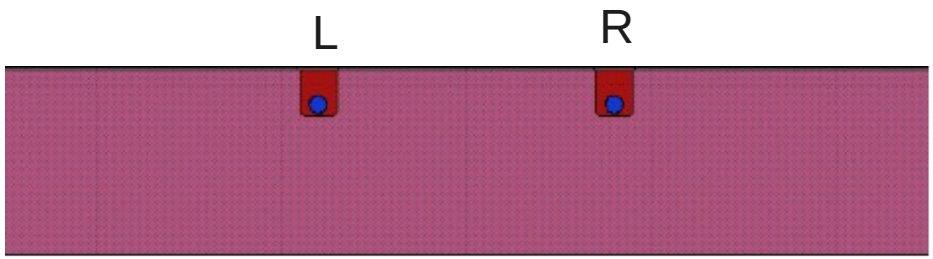


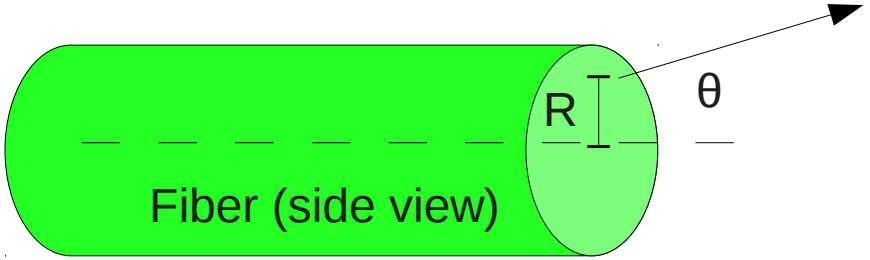
1 mm

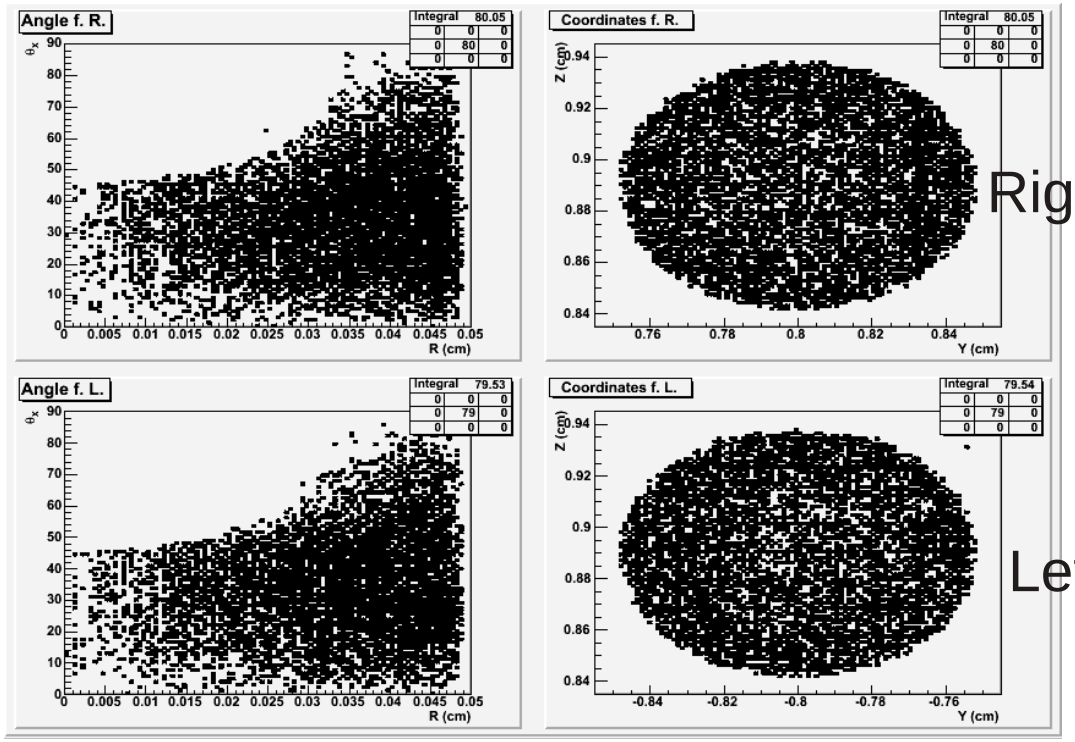


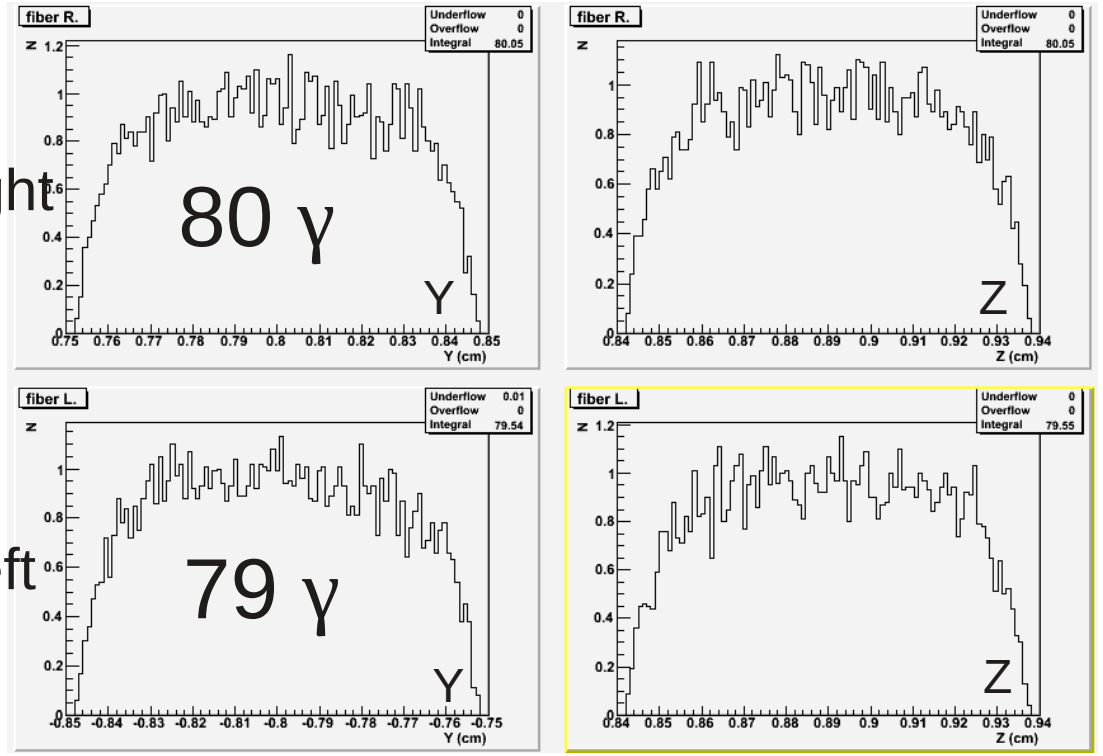
- - 43% of collected light at fiber output in 10 cm wide bar

Light from 2 fibers on same scintillator



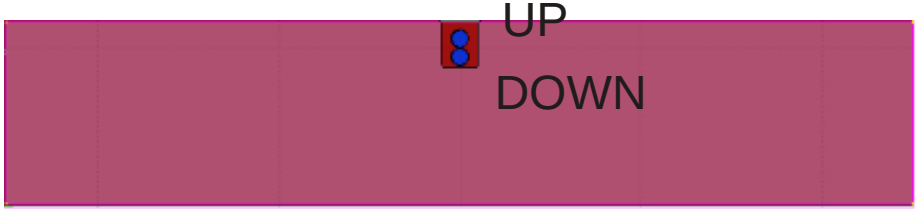


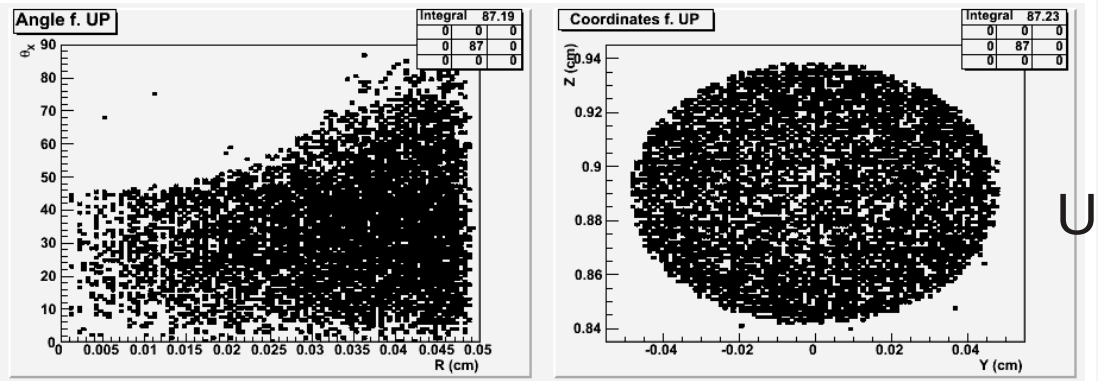




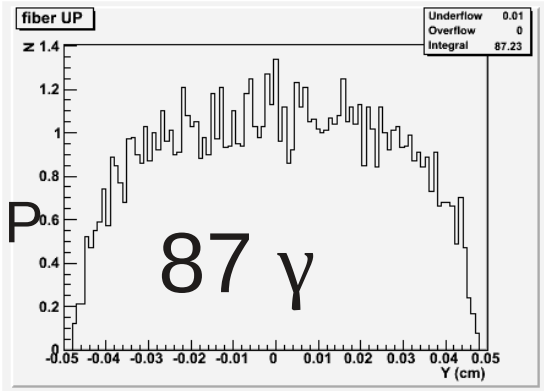
Total = 80 γ + 79 γ = 159 γ = +49% wrt 1 fiber

Light from 2 fibers on same scintillator

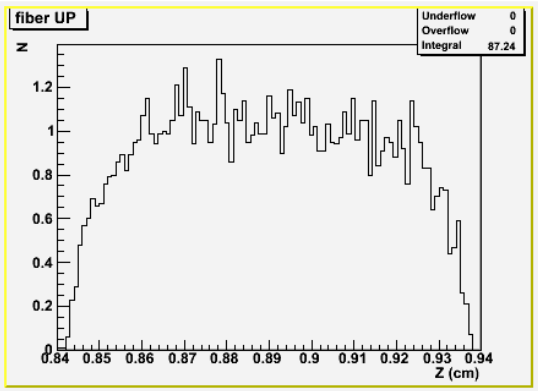




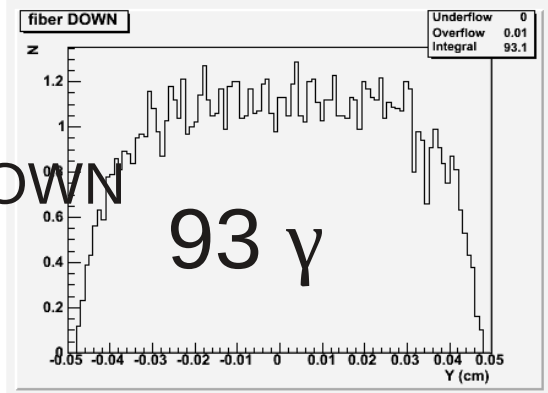
UP



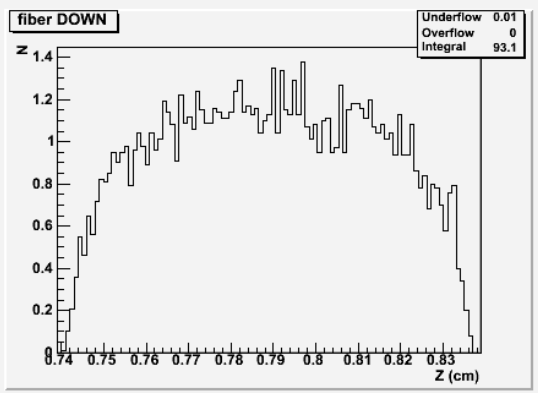
87 γ



DOWN



93 γ



Total = 87 γ + 93 γ = 180 γ = +68% wrt 1 fiber

Conclusion

- First version of simulation was setup

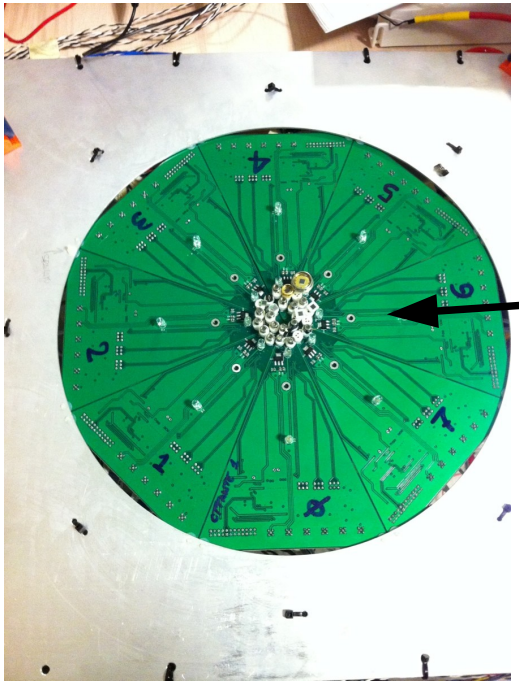
- First tuning done by comparison with real prototype
  - data reproduced at 10-20% level
  - SiPM cross-talk not simulated
  - behavior well reproduced.

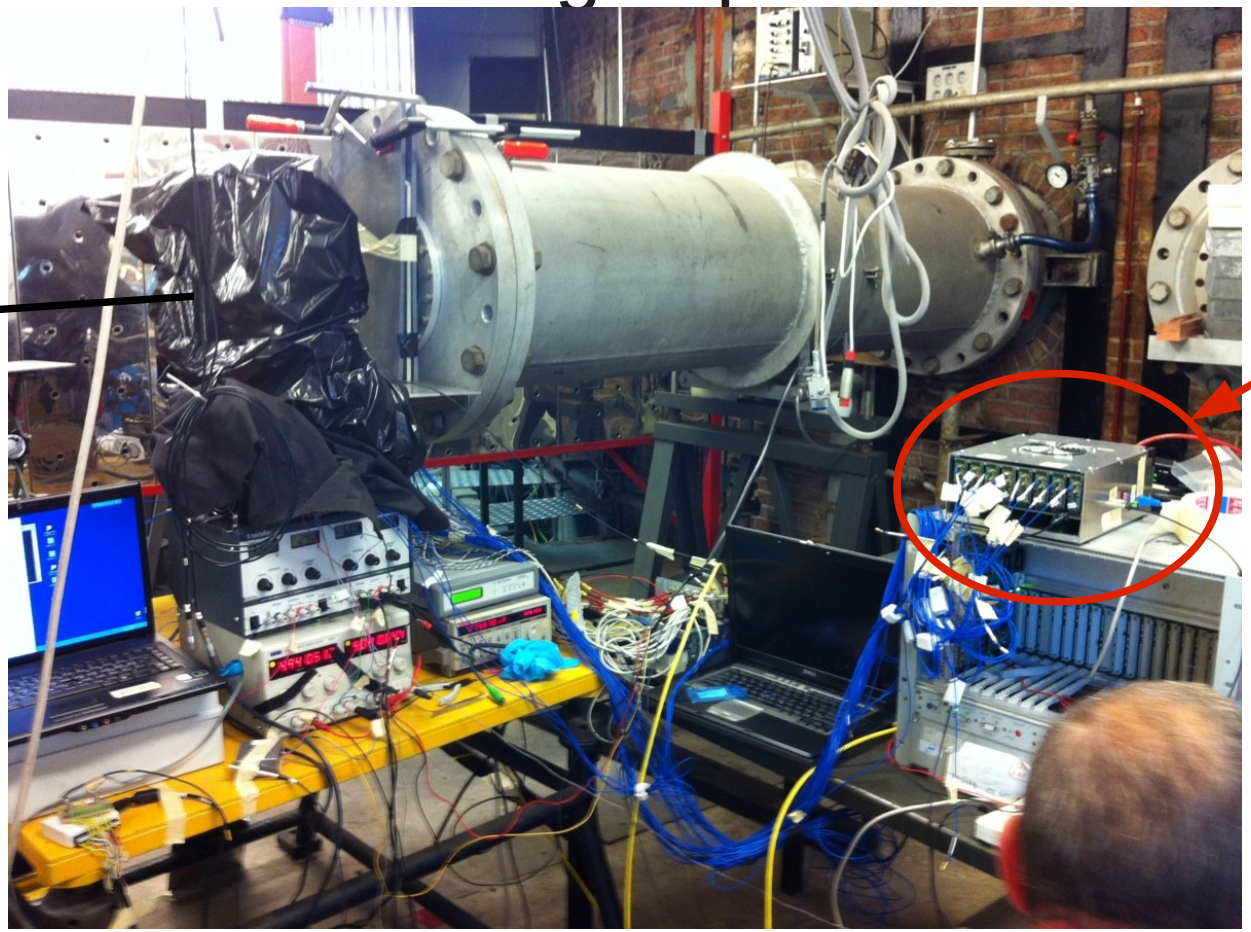
Part 3:
Neutron irradiation test

Setup at Gelina facility

- Low energy neutrons (peak at ~40 meV)
- Total fluence ~2 x 10^{10} n/cm^2
- Measure dark rates and charge spectra

A.M., N.Tosi

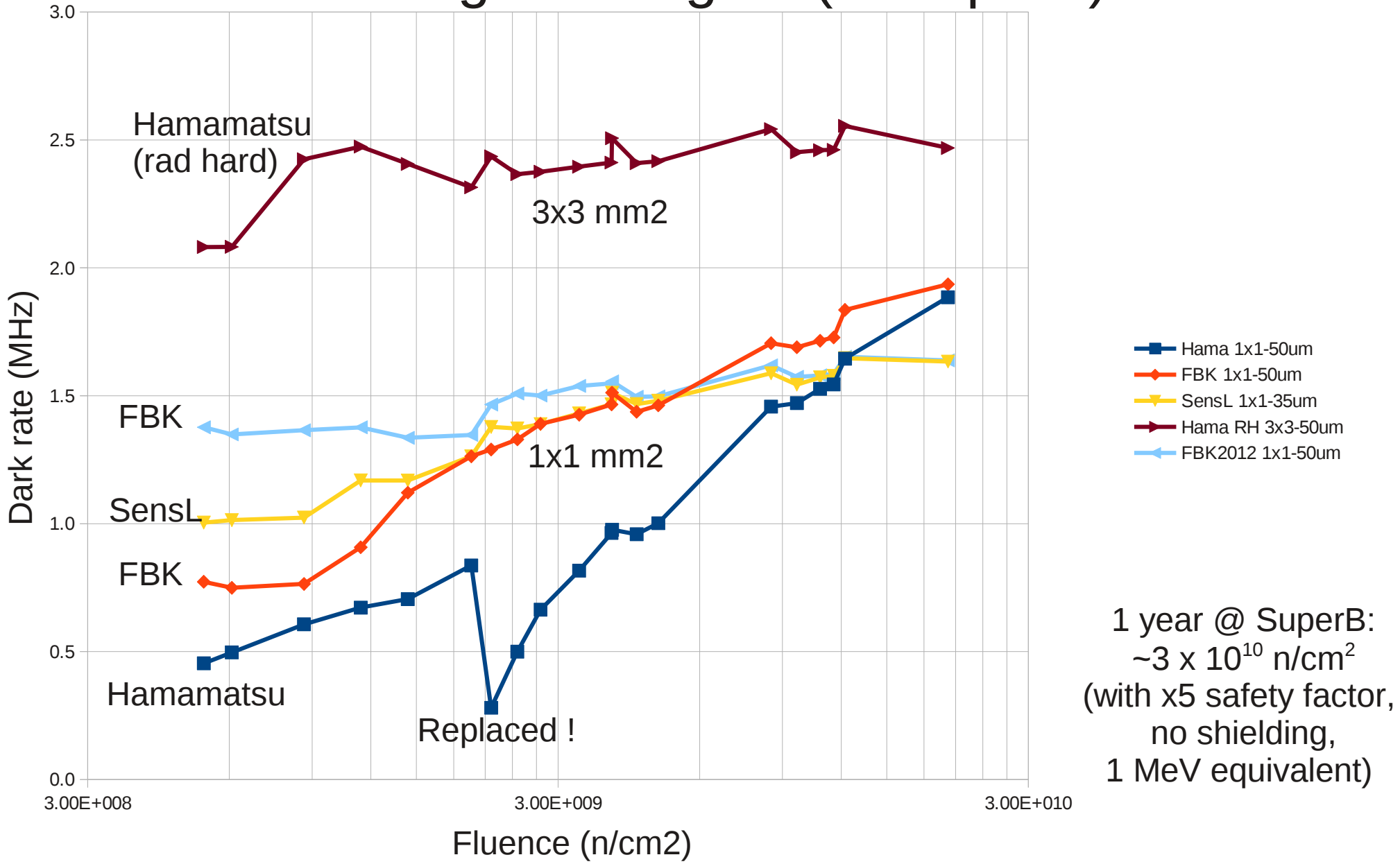




DAQ board

Dark rate vs neutron fluence

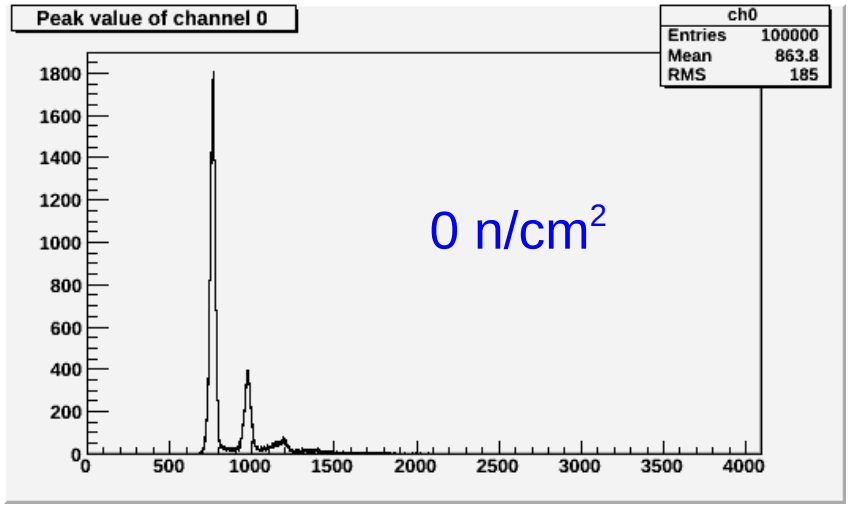
- Threshold on integrated signal (>1.5 pixel)

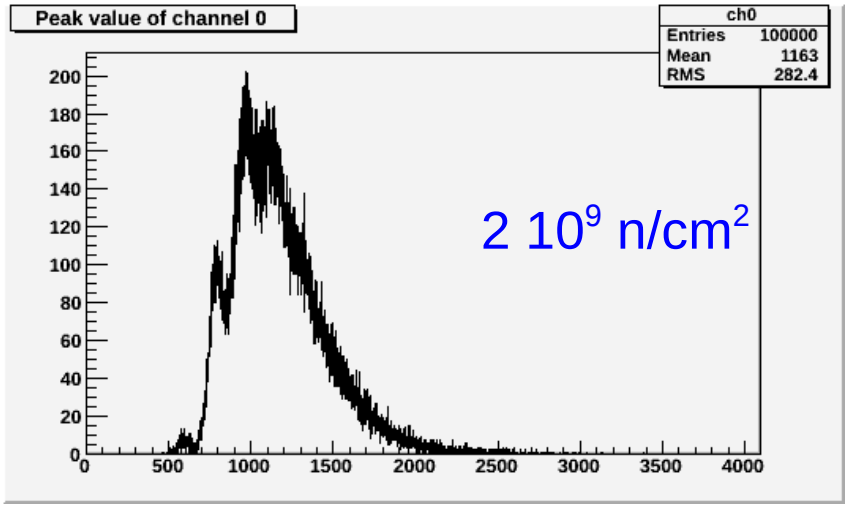


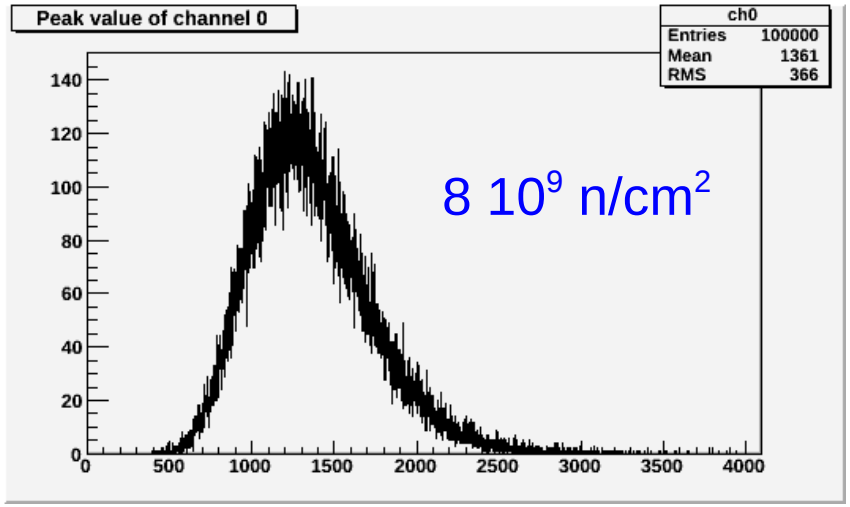
1 year @ SuperB:
~3 x 10^{10} n/cm^2
(with x5 safety factor,
no shielding,
1 MeV equivalent)

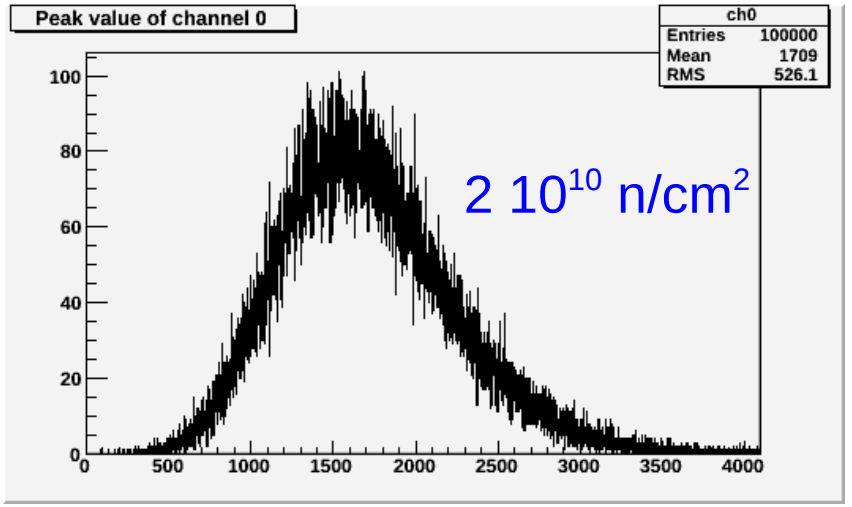
Charge spectra: example 1

- Hamamatsu 1x1 mm2, 50 um pixel



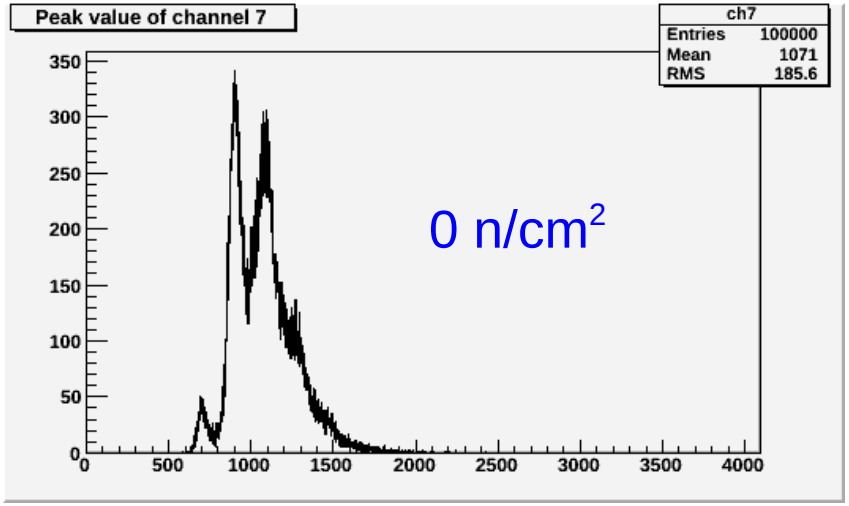


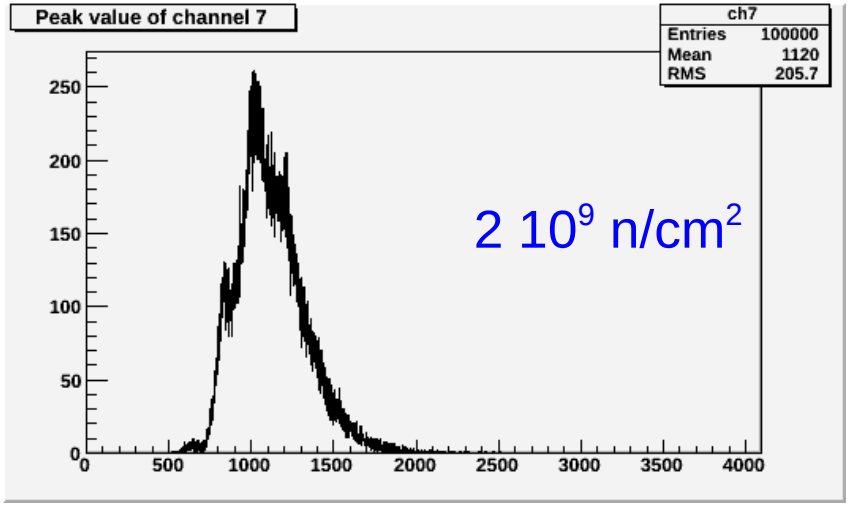


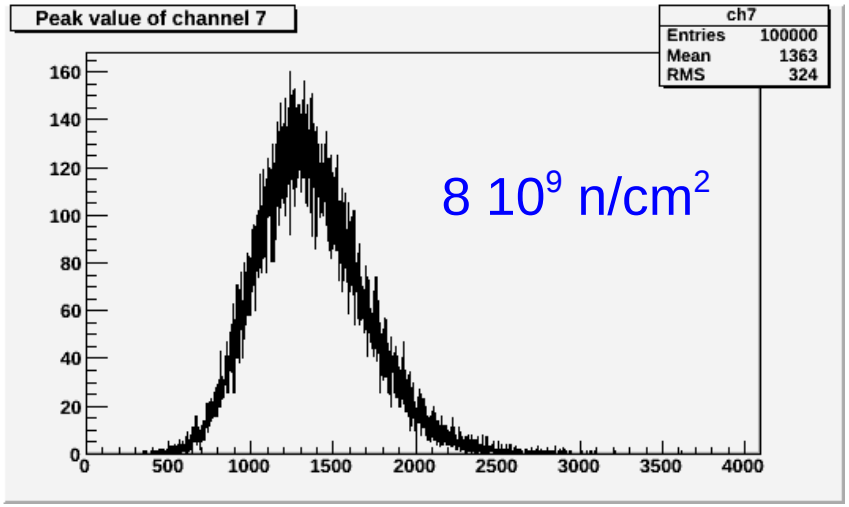


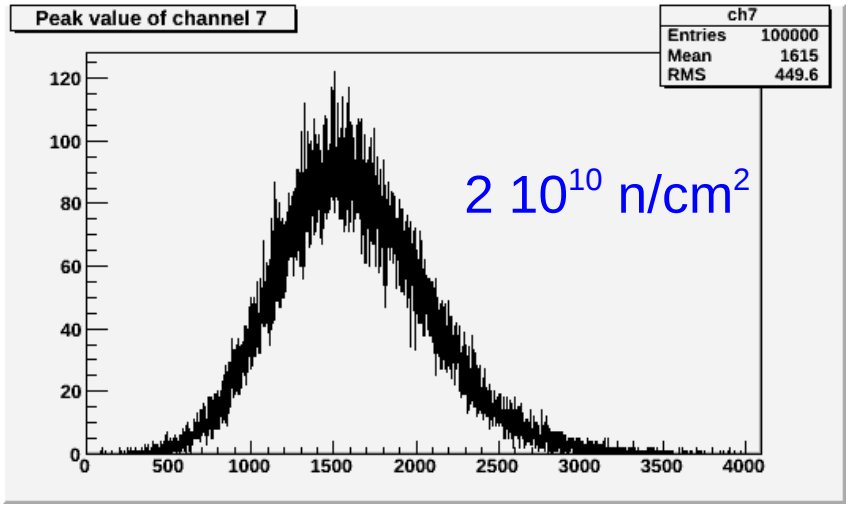
Charge spectra: example 2

- FBK 2012 1x1 mm2, 50 um pixel



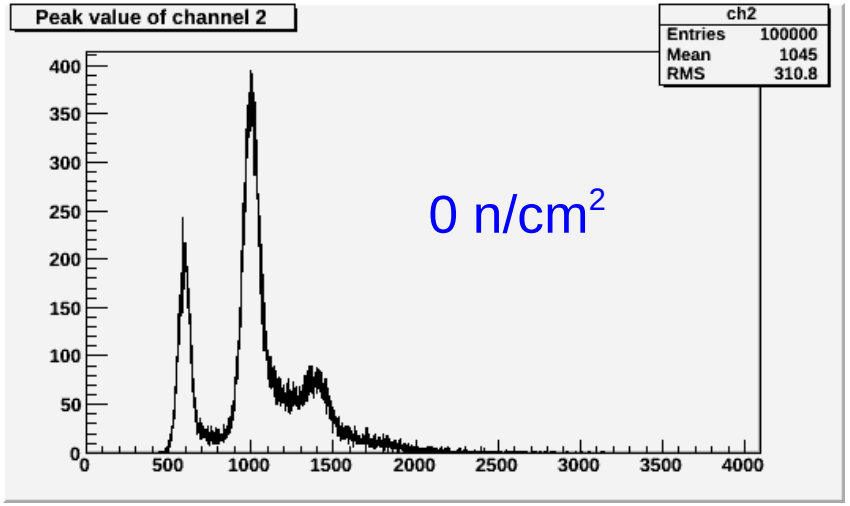


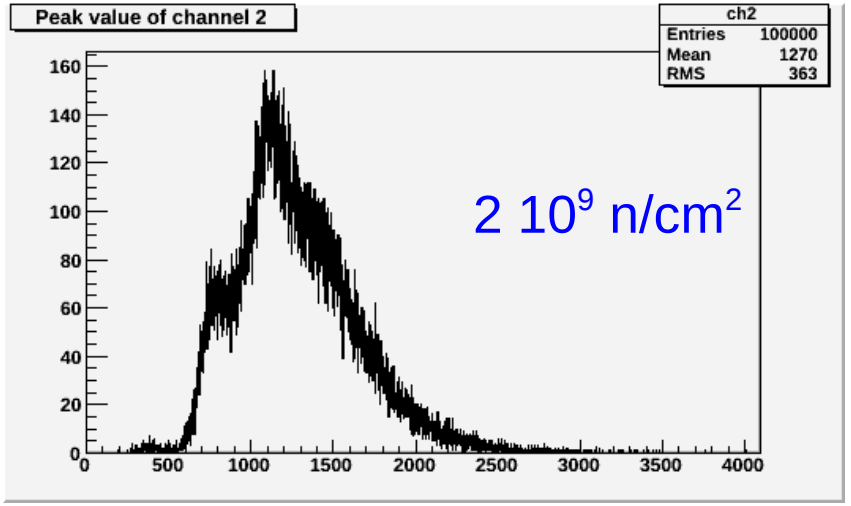


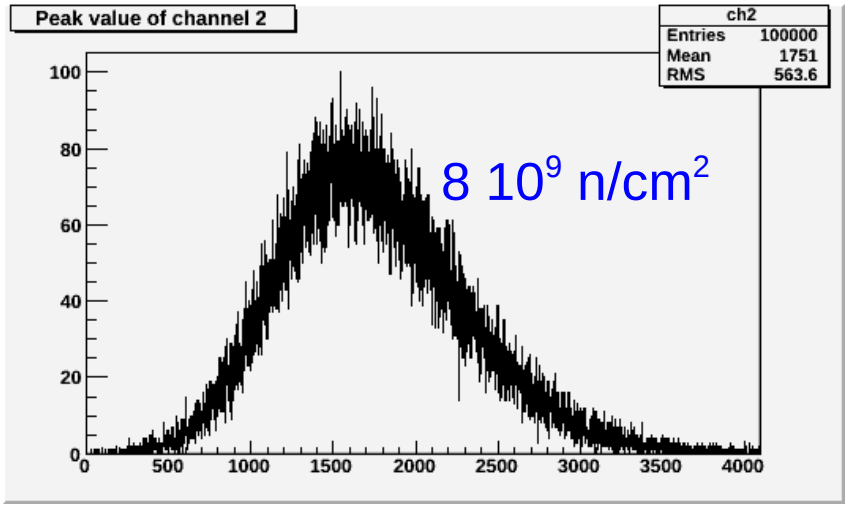


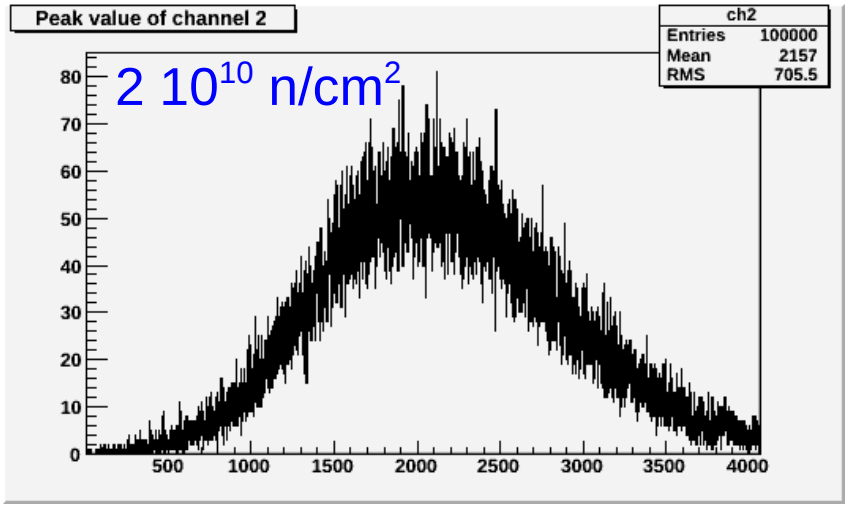
Charge spectra: example 3

- FBK 2008 1x1 mm2, 50 um pixel

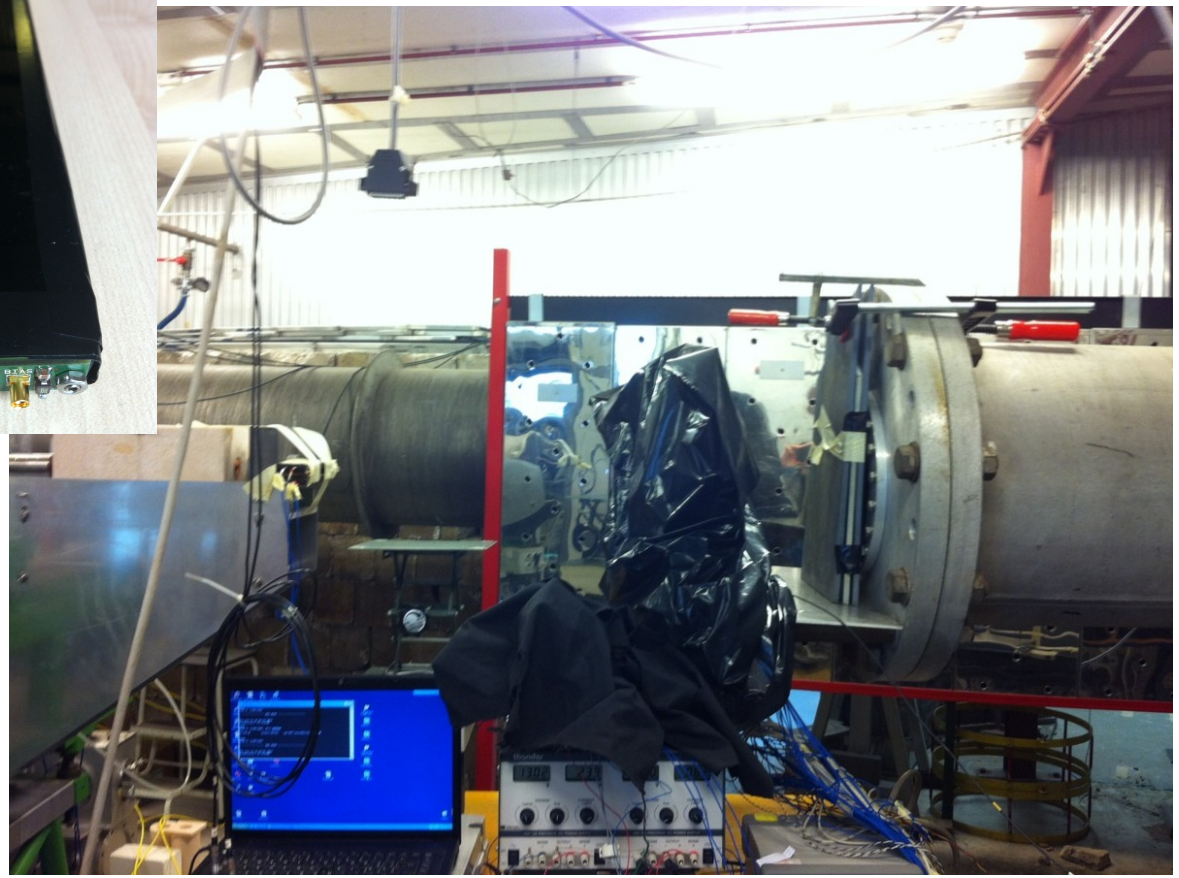








Scintillator irradiation



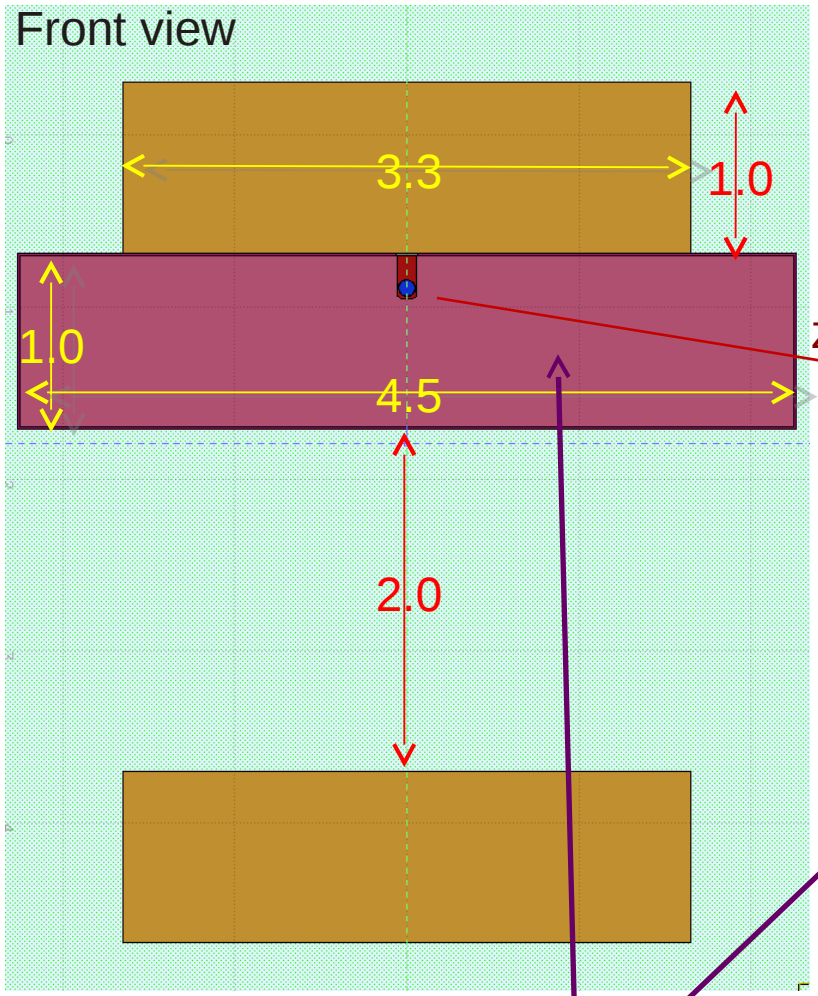
- 2 prototype bars (WLS w/ and w/o glue)
- Irradiated with ~2 x 10^{10} n/cm^2 (~6x10^8 1Mev eq.)
- NO measurable effect (preliminary)

Conclusion

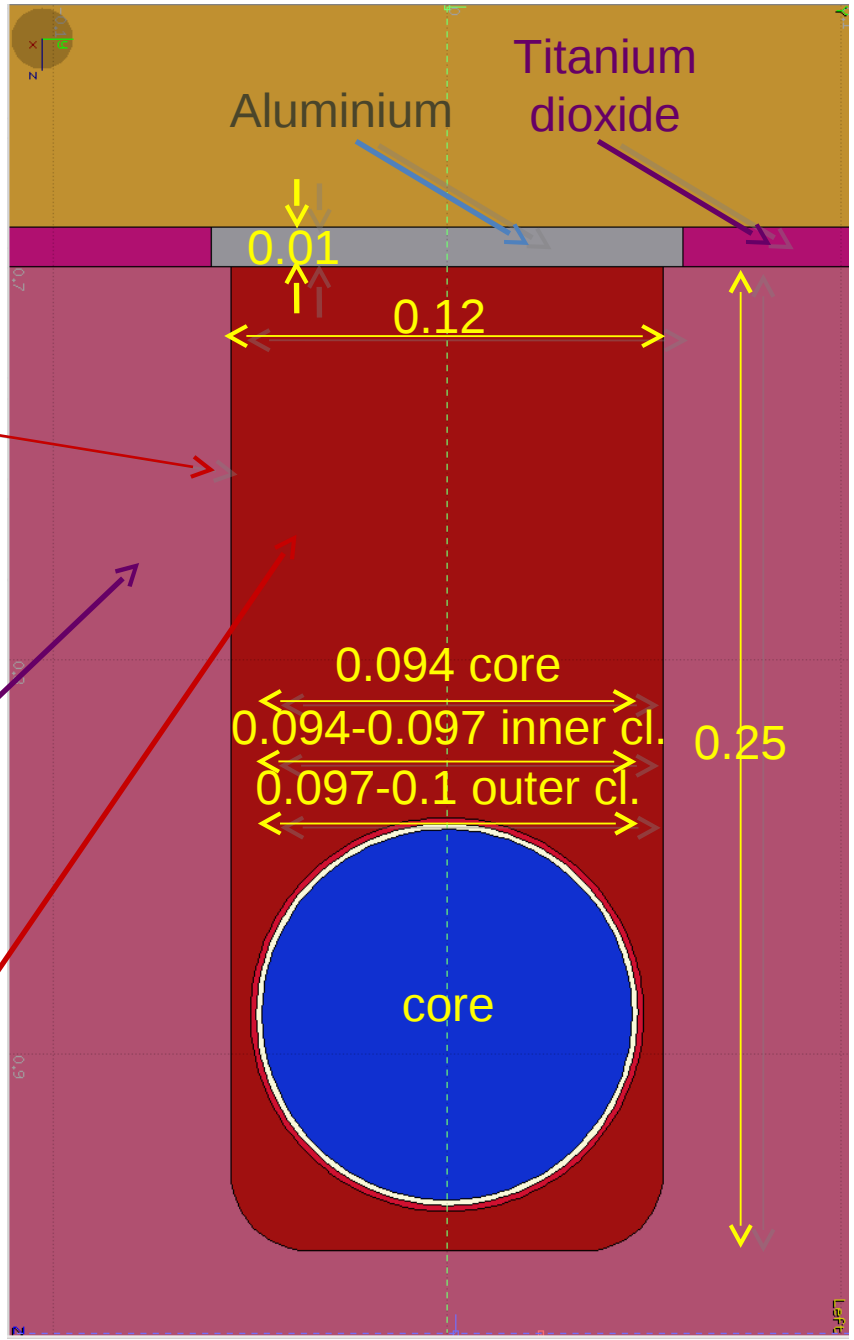
- Very preliminary results
- Single photon capability (calibration) lost after few 10^9 n/cm^2
- Scintillator, fiber and glue not affected

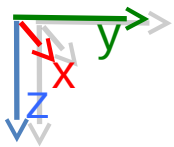
Backup slides

Prototype setup



zoom

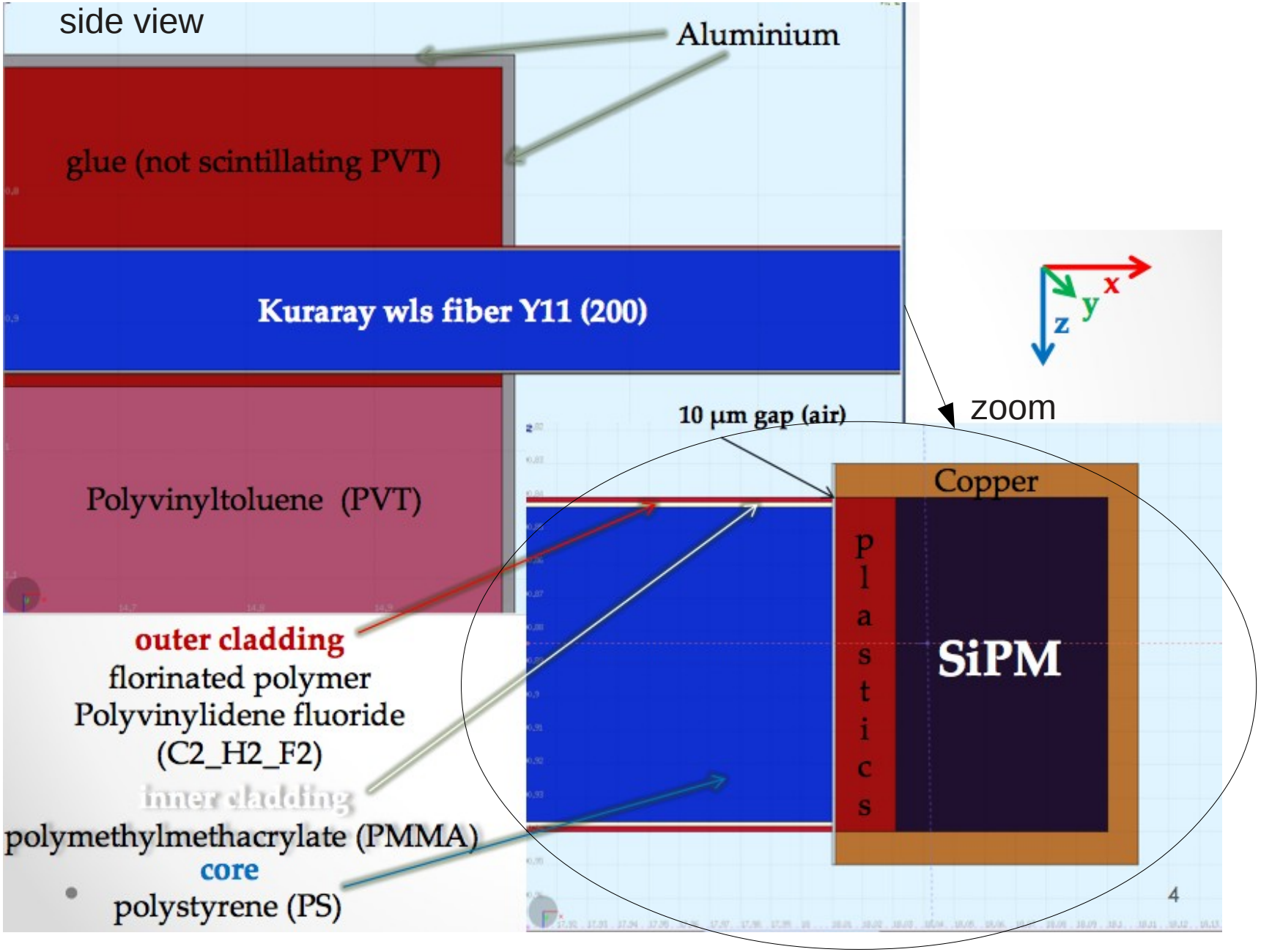




Polyvinyltoluene (PVT)

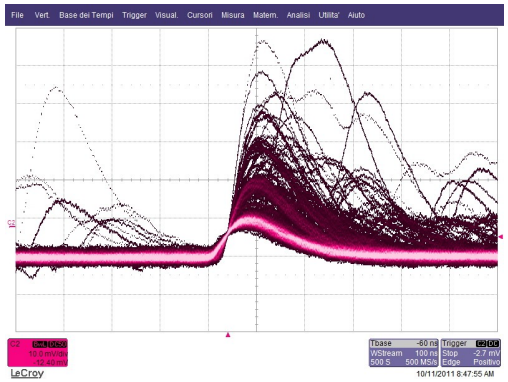
glue (not scintillating PVT)

Prototype setup



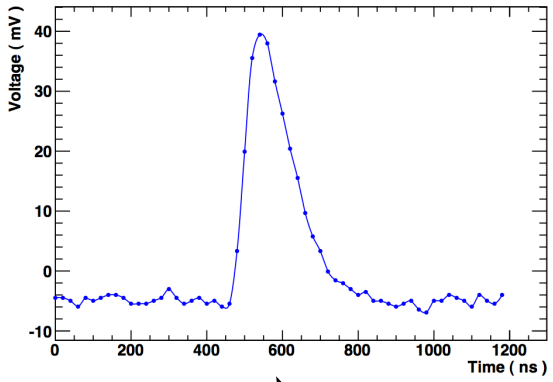
Integrated charge measurements

Slow shaper on scope

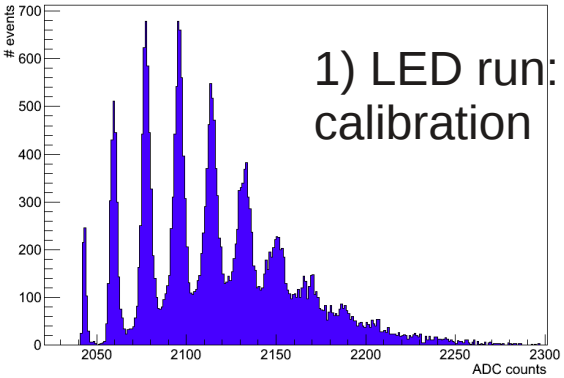


Peaking time ~70 ns

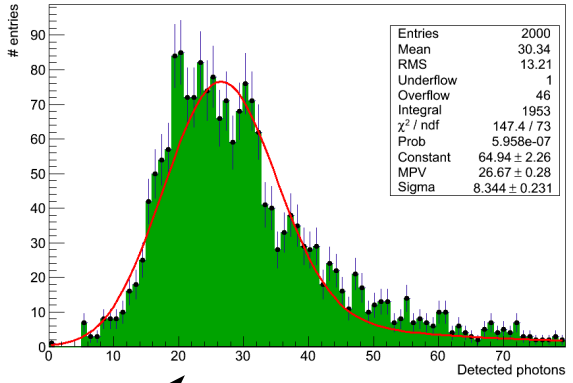
Digitized (50 Msps)



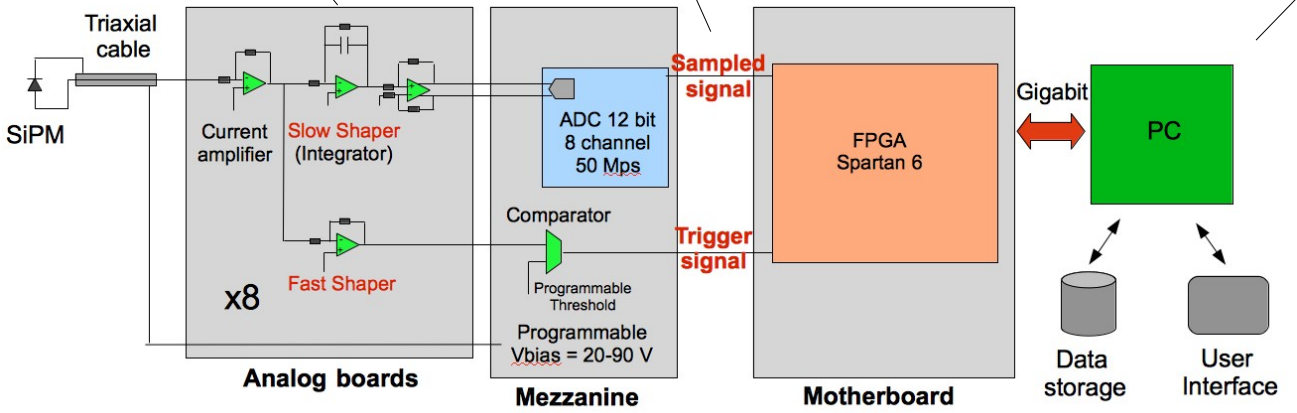
charge spectrum



1) LED run: calibration



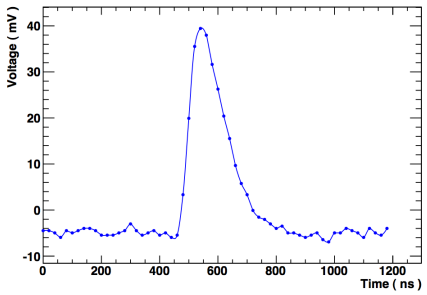
2) Muon run: MIP response



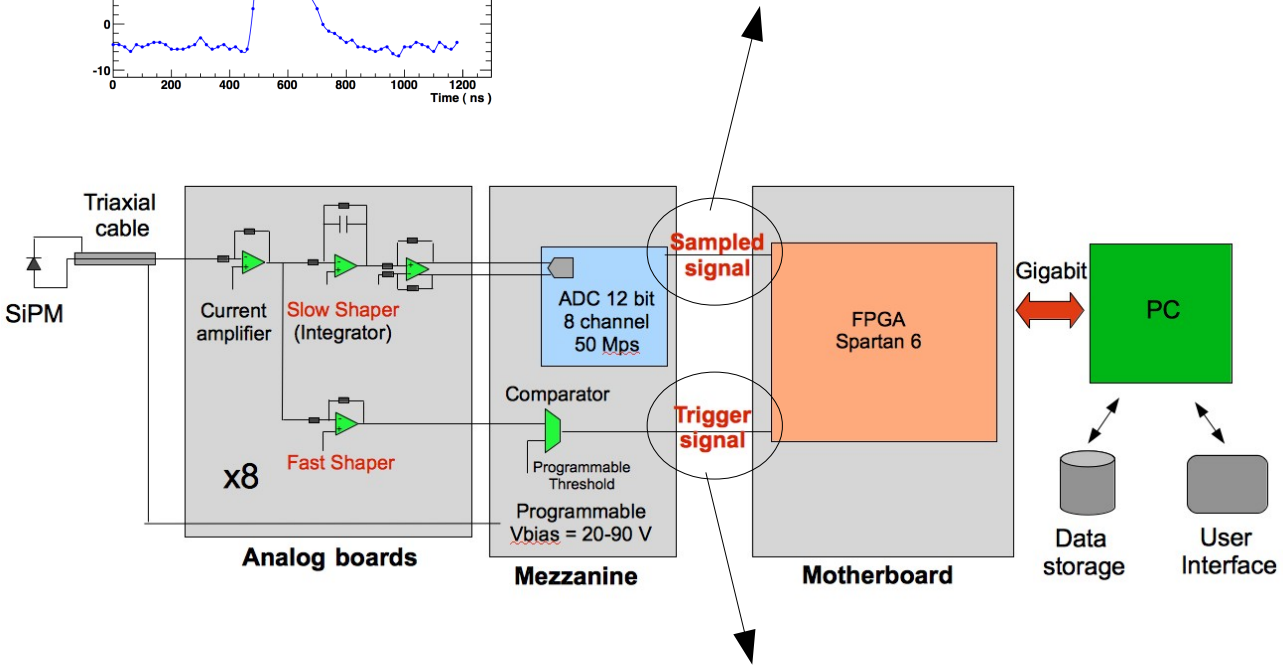
Dark Noise rate measurements

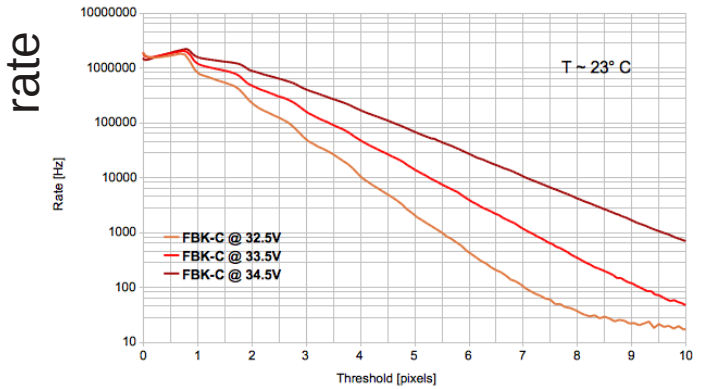
A)

Slow shaper



Threshold (fw) on integrated signal
Peaking time ~70 ns
Trigger counters
Threshold calibrated with LED runs



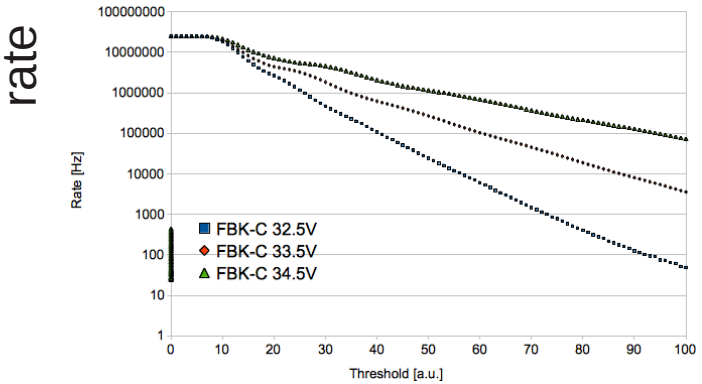


number of pixel

B)

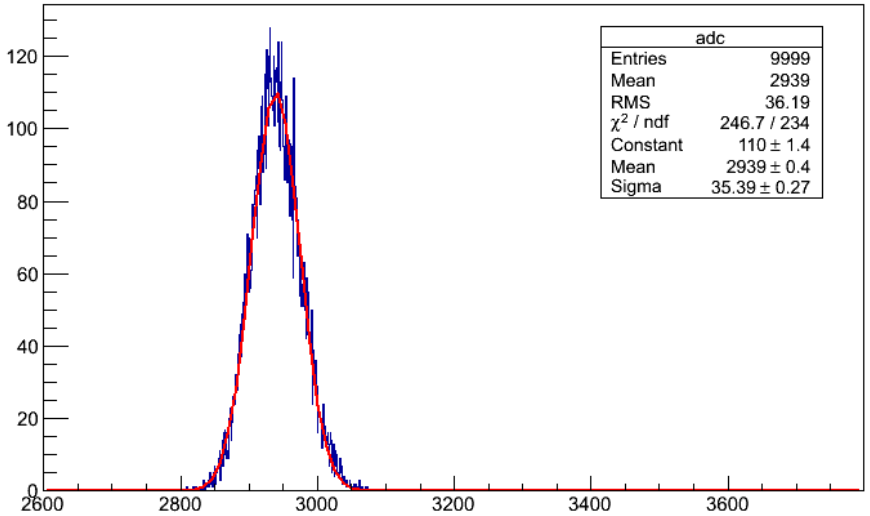
Fast shaper

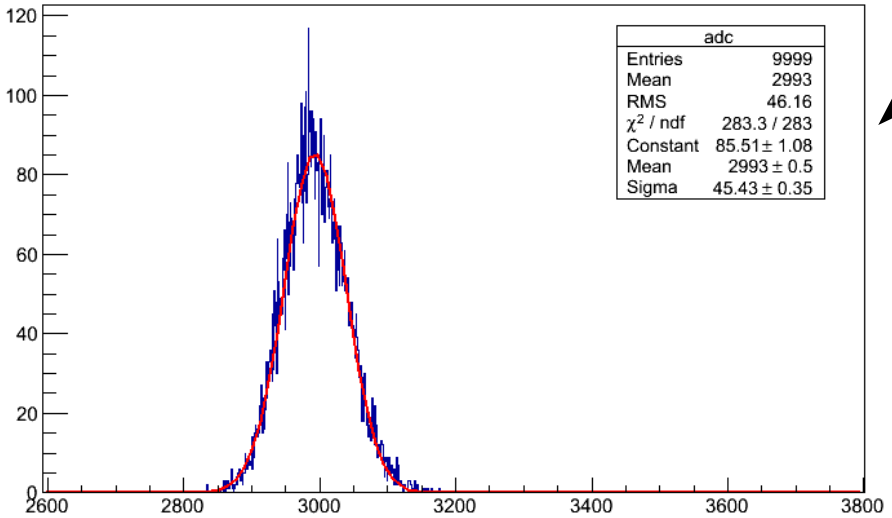
Threshold on comparators
Deadtime ~40 ns (fw limit, can be reduced to ~10 ns)
Trigger counters
Threshold not calibrated



arbitrary units

Correlated Noise effect



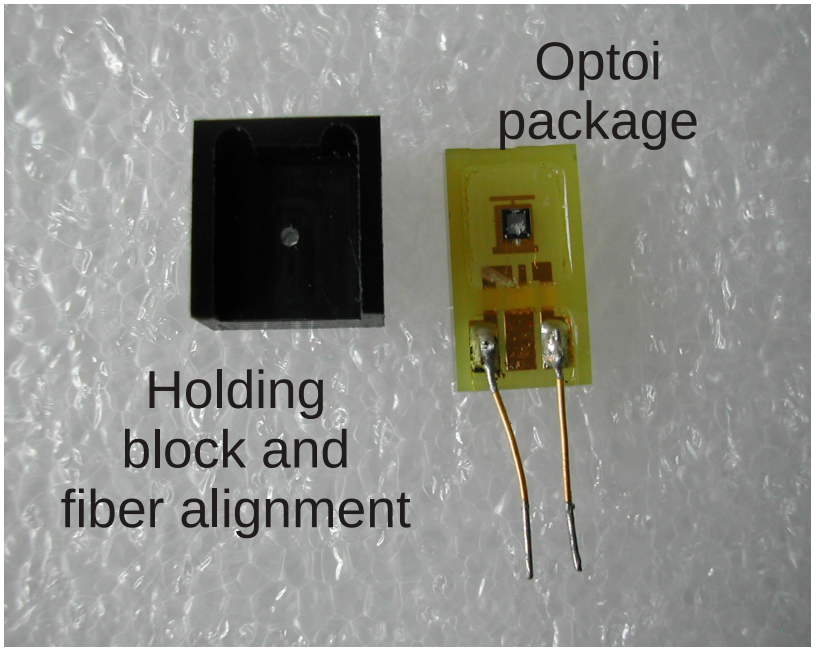


- Use Toy MC to generate 53 detected photons with Poisson statistics
- Apply 20% crosstalk + afterpulse
- Measure:

  (2993-2681)/5=62

  fired pixels !!

SiPM from Bologna



FBK 1x1 mm^2

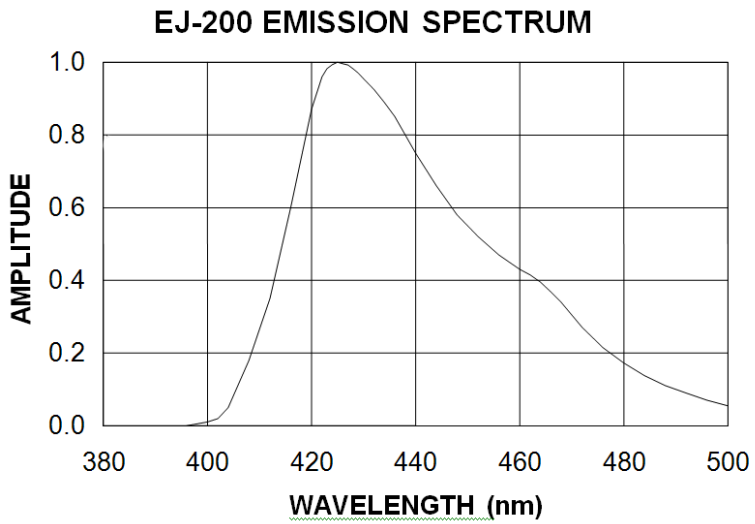
old 2008 sample, model C,

..not state of the art..

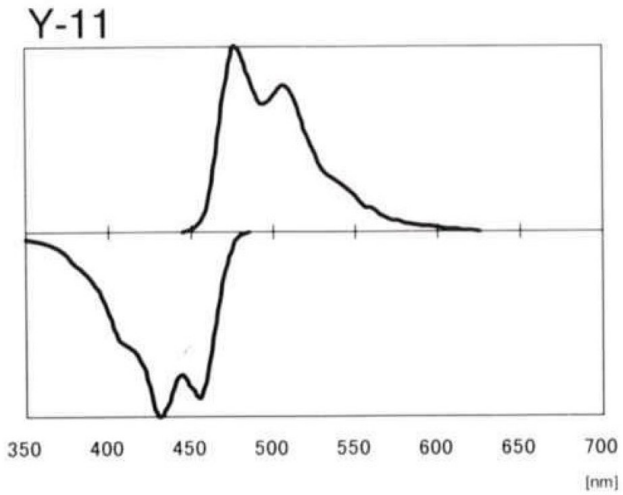
50 μm pixel

Caveat:
not optimized
optical coupling

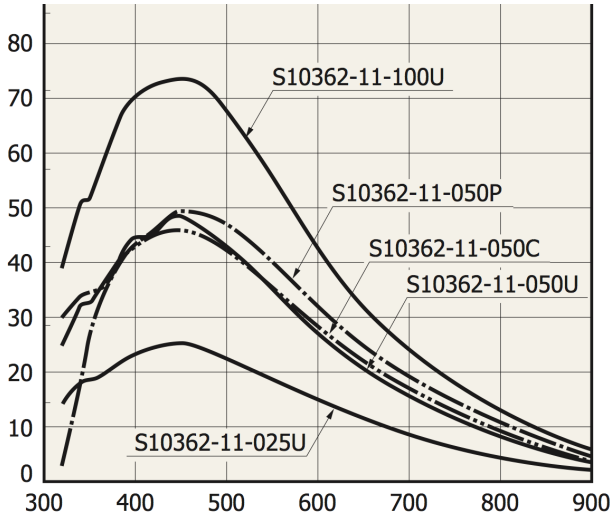
Emission/Absorption spectra



Scintillator: EJ 200



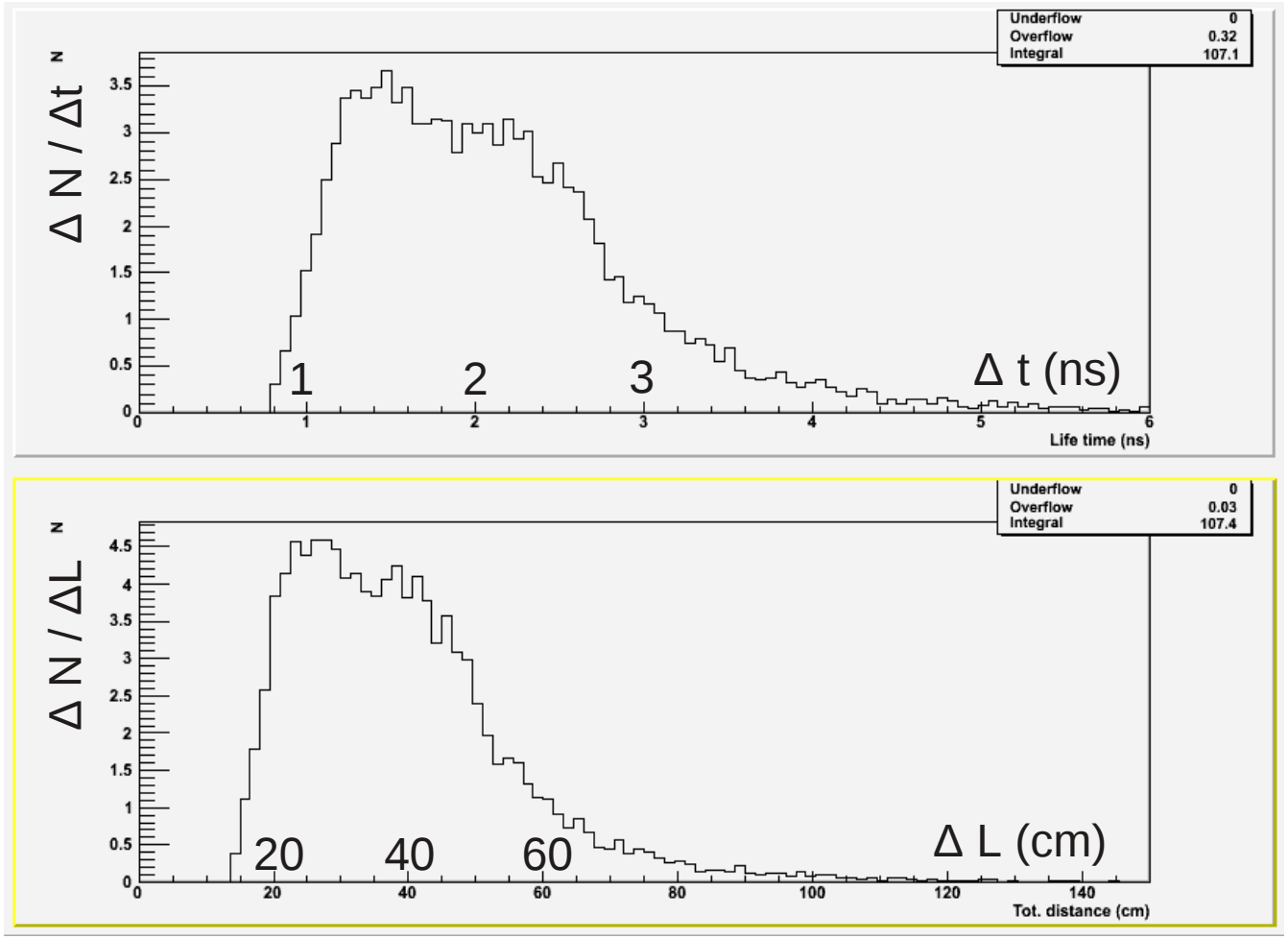
WLS fiber: Kuraray Y11



SiPM: Hamamatsu

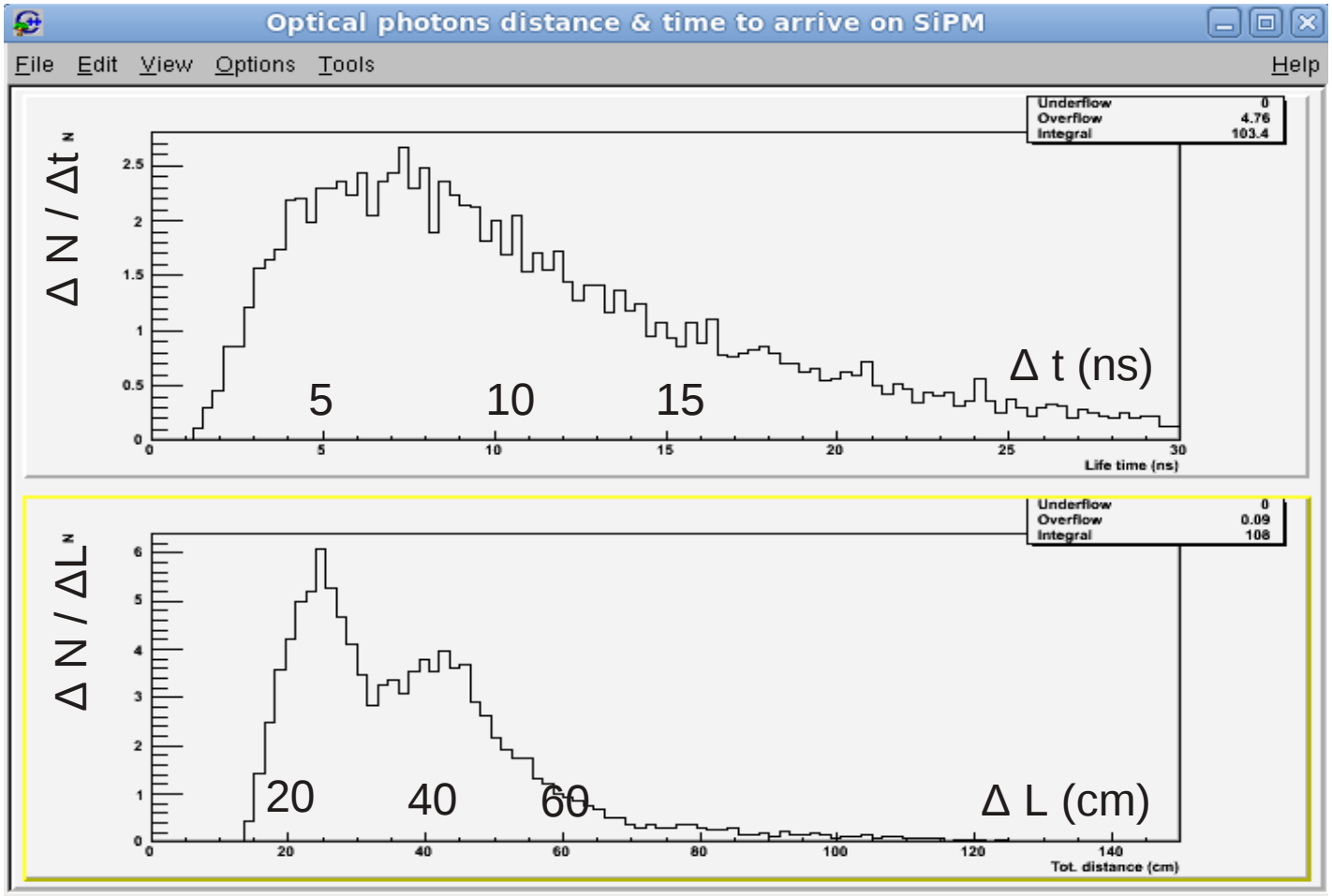
Photons arrival times

- If scintillator and WLS fiber decay times are NOT simulated:



Photons arrival times

- Adding decay times simulation:
  - scintillator: τ = 2 ns
  - WLS fiber: τ = 7.5 ns



Photons detected by SiPM

- About 100 detected photons/MIP
  - simulation not yet tuned