Tests of scintillator based fast detector (MTT)

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CMS Upgrade Workshop, 28 October 2009

Links to documentation

Concept:

- CMS-IN note 2007/058

- Upgrade proposal n.07/09:
  http://cmsdoc.cern.ch/cms/electronics/html/elec_web/docs/slhcusg/proposals/proposal_list.htm

- Joint SLHC Trigger-Tracker meeting (19 July 2007):
  http://indico.cern.ch/conferenceDisplay.py?confId=17324

- Trigger Upgrade Workshop (10 April 2008):
  http://indico.cern.ch/conferenceDisplay.py?confId=27925

Simulations:

- Muon Barrel Upgrade Workshop (26 May 2009):
  http://indico.cern.ch/conferenceDisplay.py?confId=59211

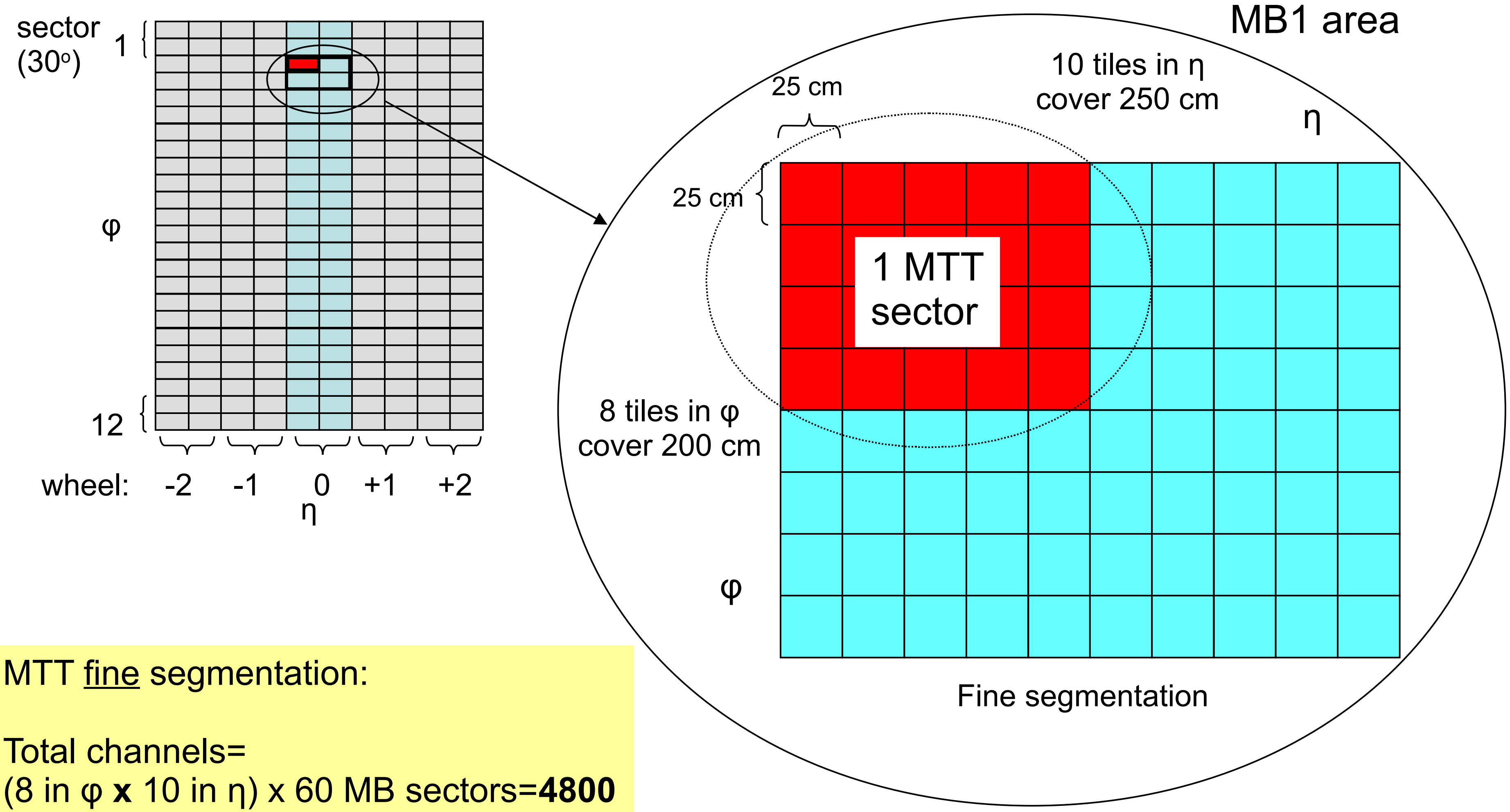
MTT: a reminder

- Muon Track fast Tag:
  - it was initially (2007) proposed as a possible device for:
    - fast selective readout of Tracker (Static Mapping)
    - improvement of RPC trigger
    - ghost/fakes suppression in MB1
  - now, in the new Tracker scenarios:
    - it is still possible to send fast muon tag (L0 trigger) to some stage
    - it allows ghost/fake suppression in MB1 for Dynamic Mapping
  - various hardware implementation are under study:
    - new RPC with 2D readout (Bari)
    - scintillator tiles (Aachen, Bologna*)

* Phys.: F.Fabbri, A.M., A.Perrotta

Eng. and Tech: G.Balbi, V.Cafaro, I.D'Antone, V.Giordano, I.Lax, G.Torromeo

MTT detector granularity



MTT <u>fine</u> segmentation:

Total channels=
(8 in φ **x** 10 in η) x 60 MB sectors=**4800**

Total area: 2.0 x 2.5 x 60=**300 m²**

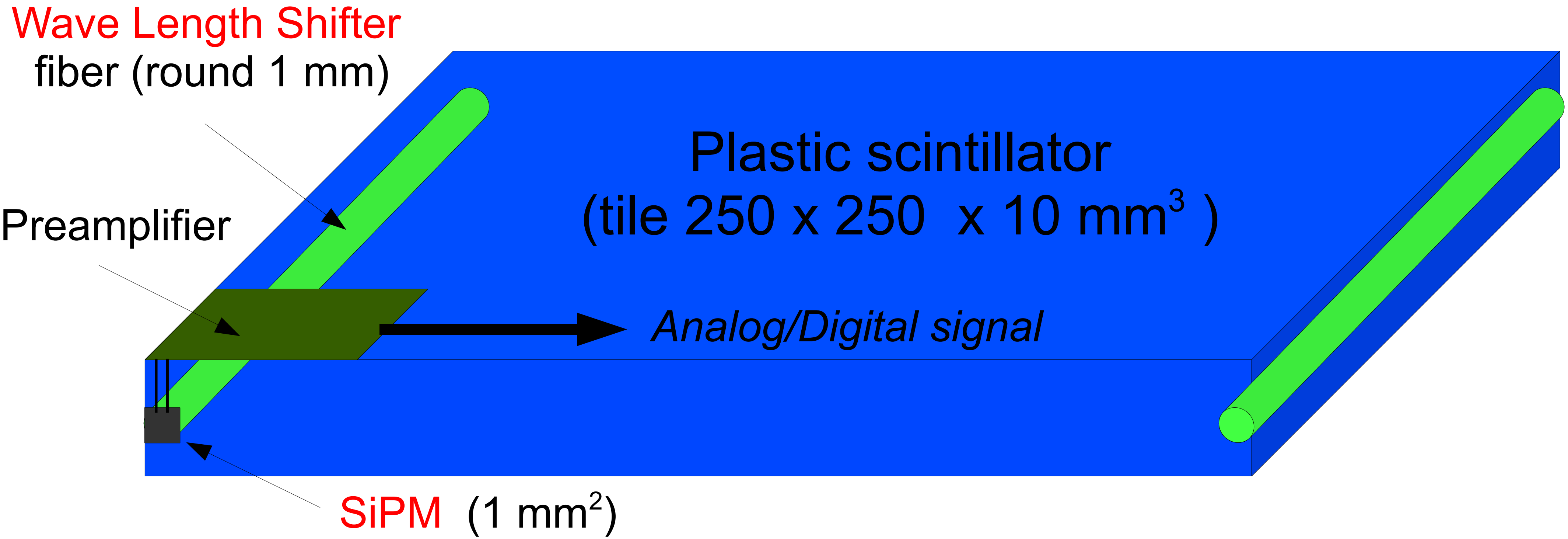
Fast tag + ghost rejection

The optimal fine segmentation for effective ghost rejection needs to be studied with detailed simulation

Constraints to detector design

- Limited available space
- Few additional services
- Operation in magnetic field
- Robustness against backgrounds (neutrons,..)
- Fast front-end signal processing
- Possibly, simple and robust design

Idea for light collection and readout



Wave Length Shifter fiber (round 1 mm)

Preamplifier

Plastic scintillator (tile 250 x 250 x 10 mm^3)

Analog/Digital signal

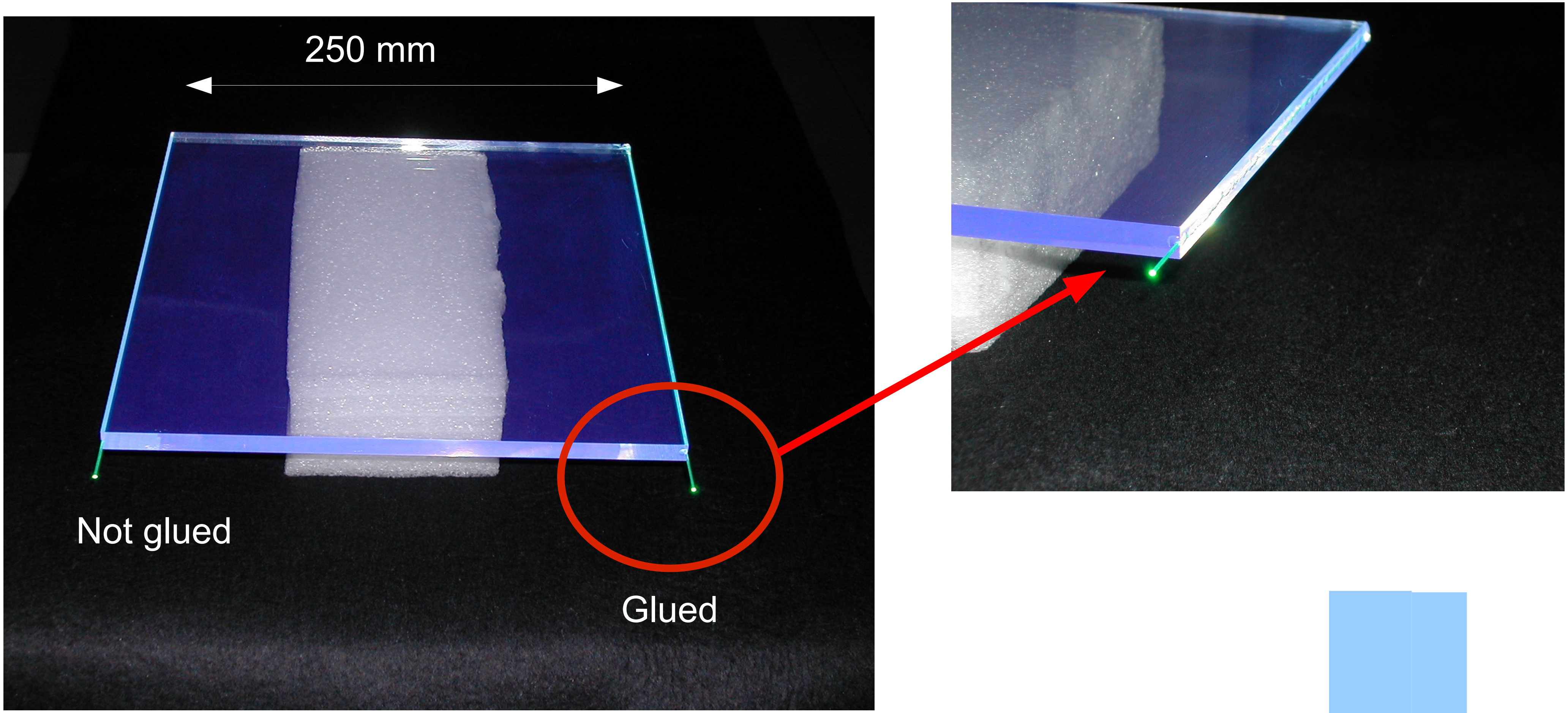
SiPM (1 mm^2)

Main features:

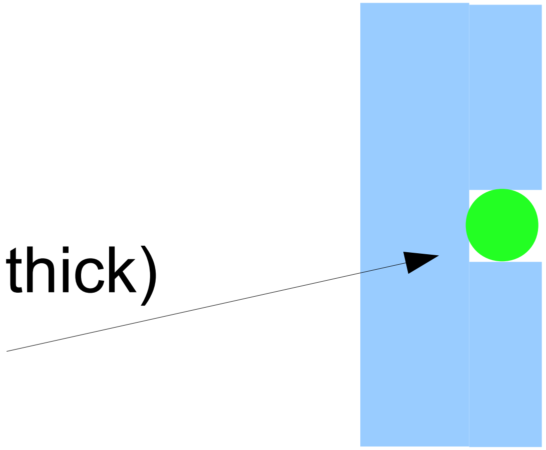
- WLS fiber on one or two sides → easy working
- SiPM on one or both side of the fiber → no clear fibers
- Preamplifier directly mounted near SiPM → compactness
- Local coincidence of at least 2 SiPMs ? → local digital signal ?

Can we collect enough photons with this geometry ??

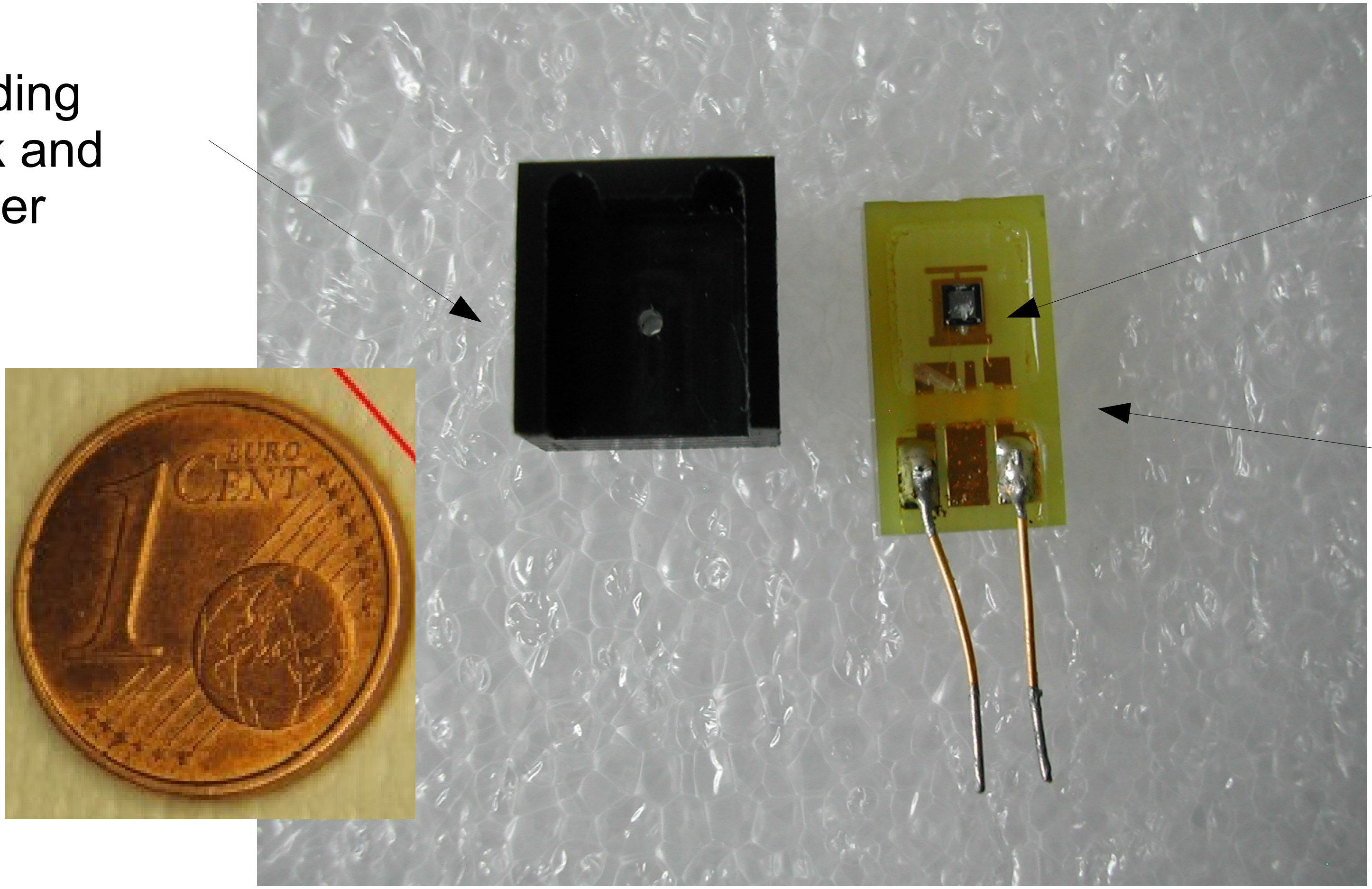
Scintillator tile 250 x 250 x 8 mm^3



Plastic scintillator: Saint Gobain BC408 (8 mm thick)
WLS fiber: Kuraray Y11 (1 mm round)



SiPM from FBK-IRST (Trento)



Holding block and fiber

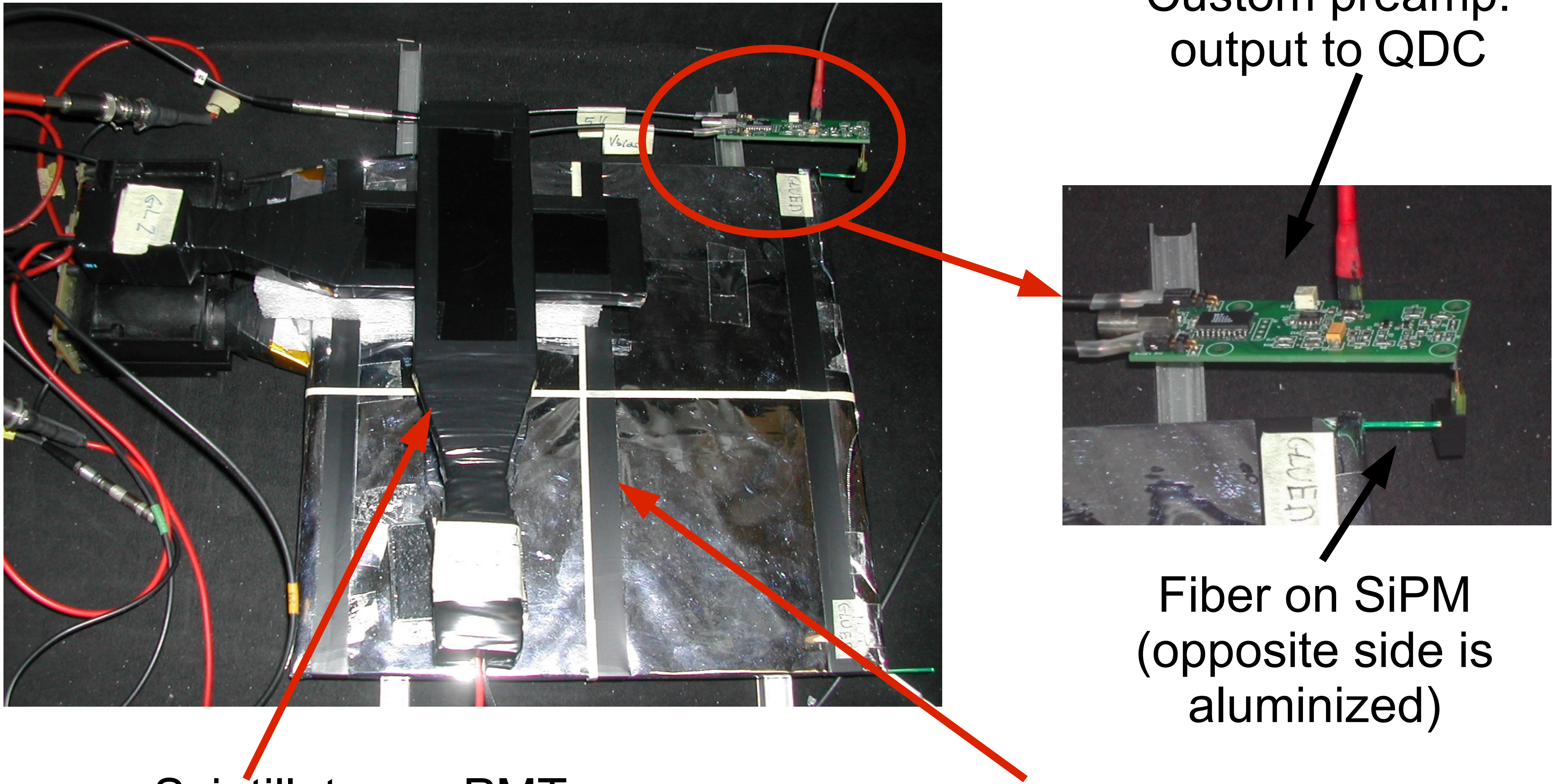
SiPM

Packag

Joint research program with INFN

Active area:	1x1 mm^2
Number of pixels:	400
Pixel size:	50x50 μm^2
Breakdown voltage:	~30 V

Custom WLS-SiPM coupling



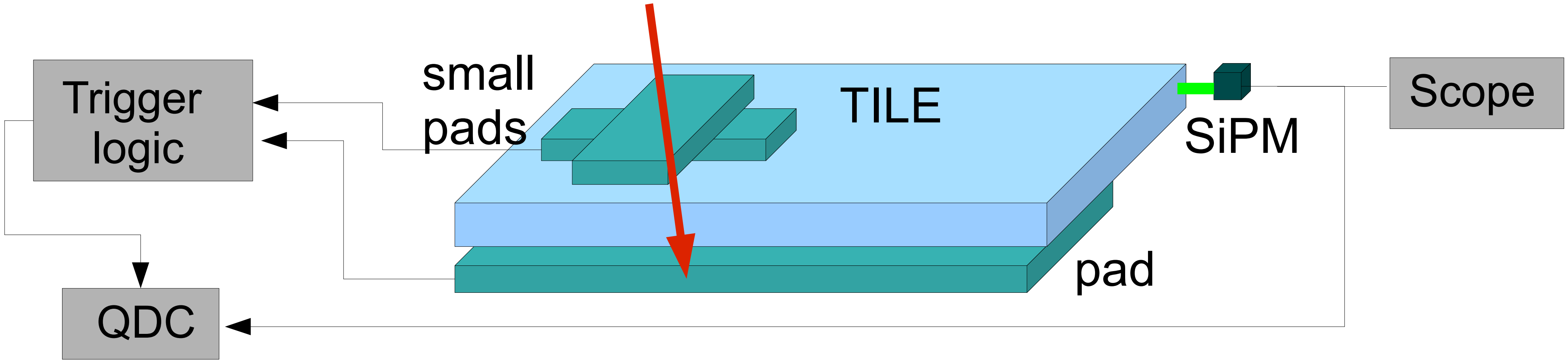
Custom preamp:
output to QDC

Fiber on SiPM
(opposite side is
aluminized)

Scintillators + PMT
for external cosmic muon trigger
(~16 events/min)

Packaged tile
(with aluminized mylar)

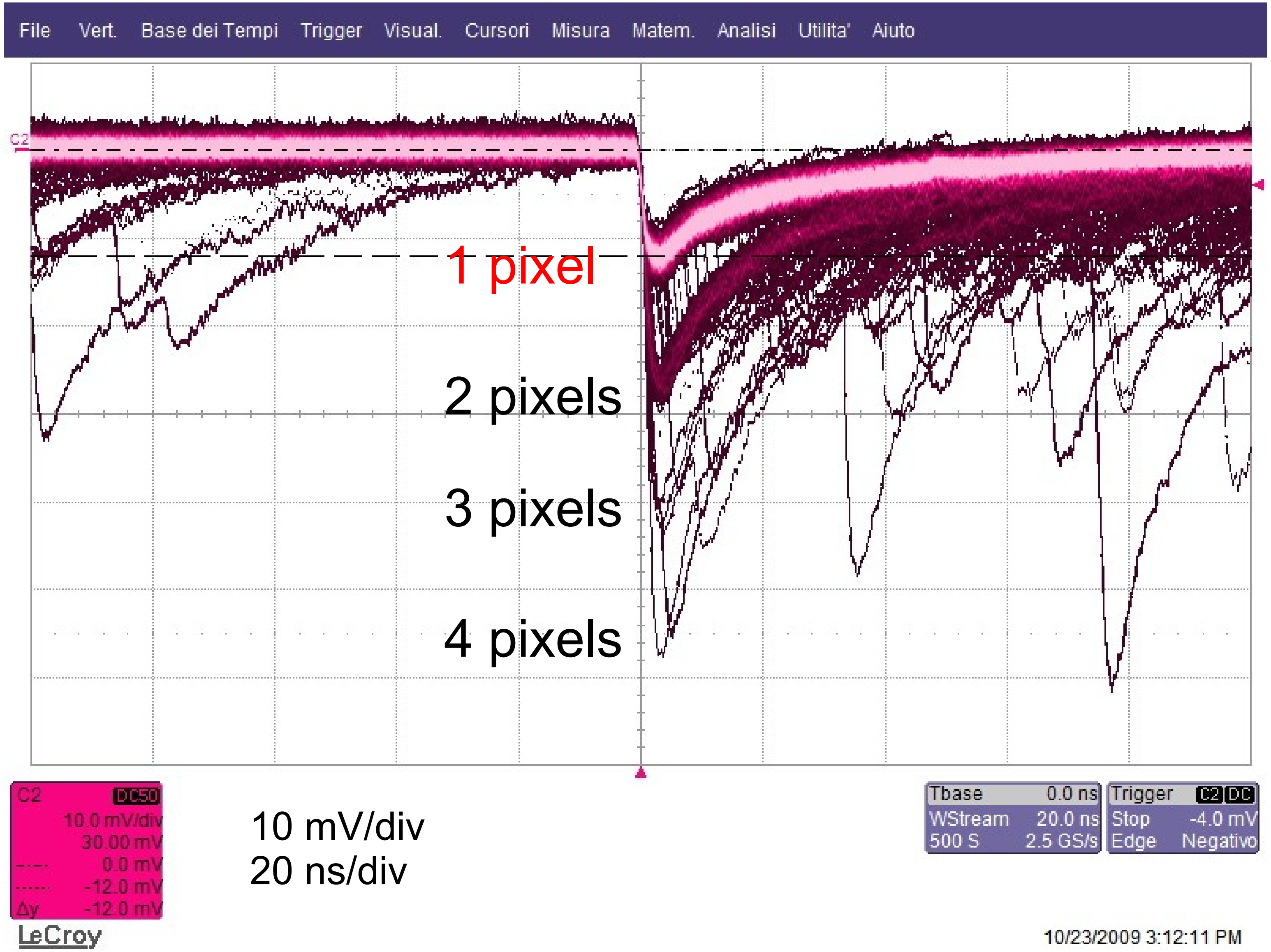
Test bench in Bologna



Trigger on cosmic muons:

~ 16 events / min
(on ~5x5 cm2)

SiPM dark pulses



1 pixel

2 pixels

3 pixels

4 pixels

C2 DC50
10.0 mV/div
30.00 mV
0.0 mV
-12.0 mV
Δy -12.0 mV

Tbase 0.0 ns
WStream 20.0 ns
500 S 2.5 GS/s

Trigger C2 DC
Stop -4.0 mV
Edge Negativo

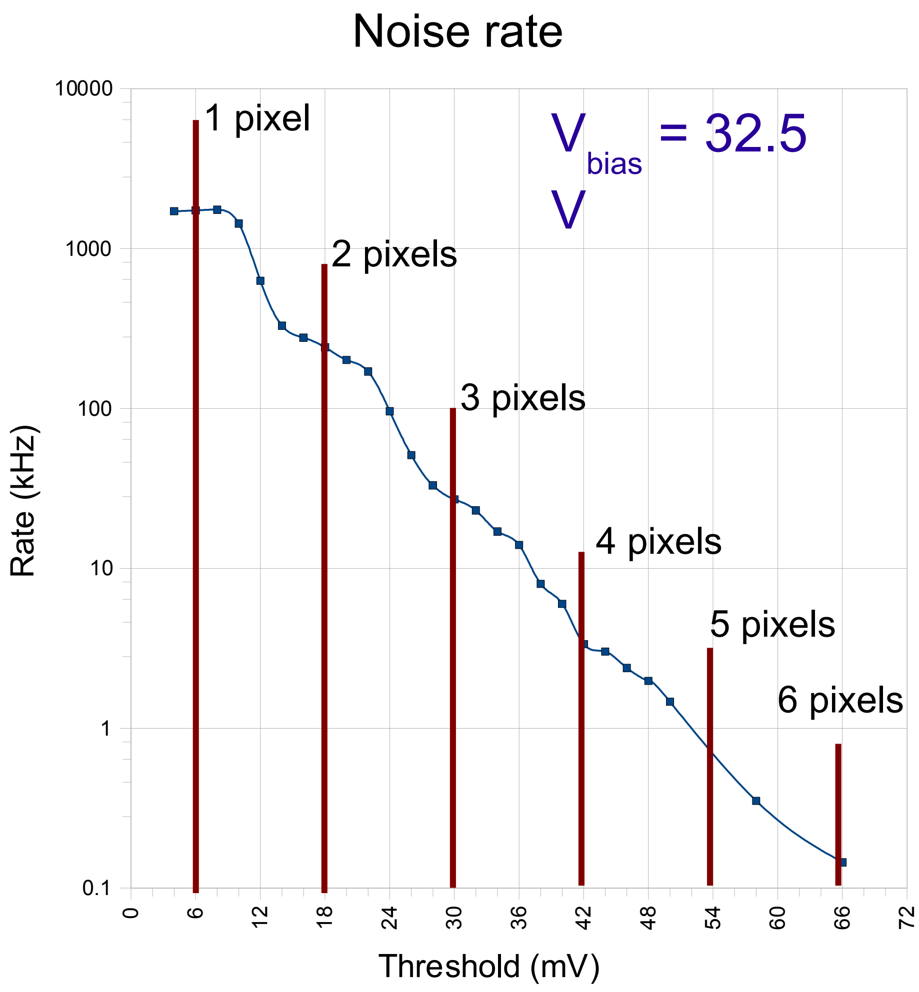
10/23/2009 3:12:11 PM

10 mV/div
20 ns/div

1 pixel pulse,
after preamp (x10),
on 50 Ω:

height: ~ 10 mV
length: ~ 100 ns

Dark noise rate

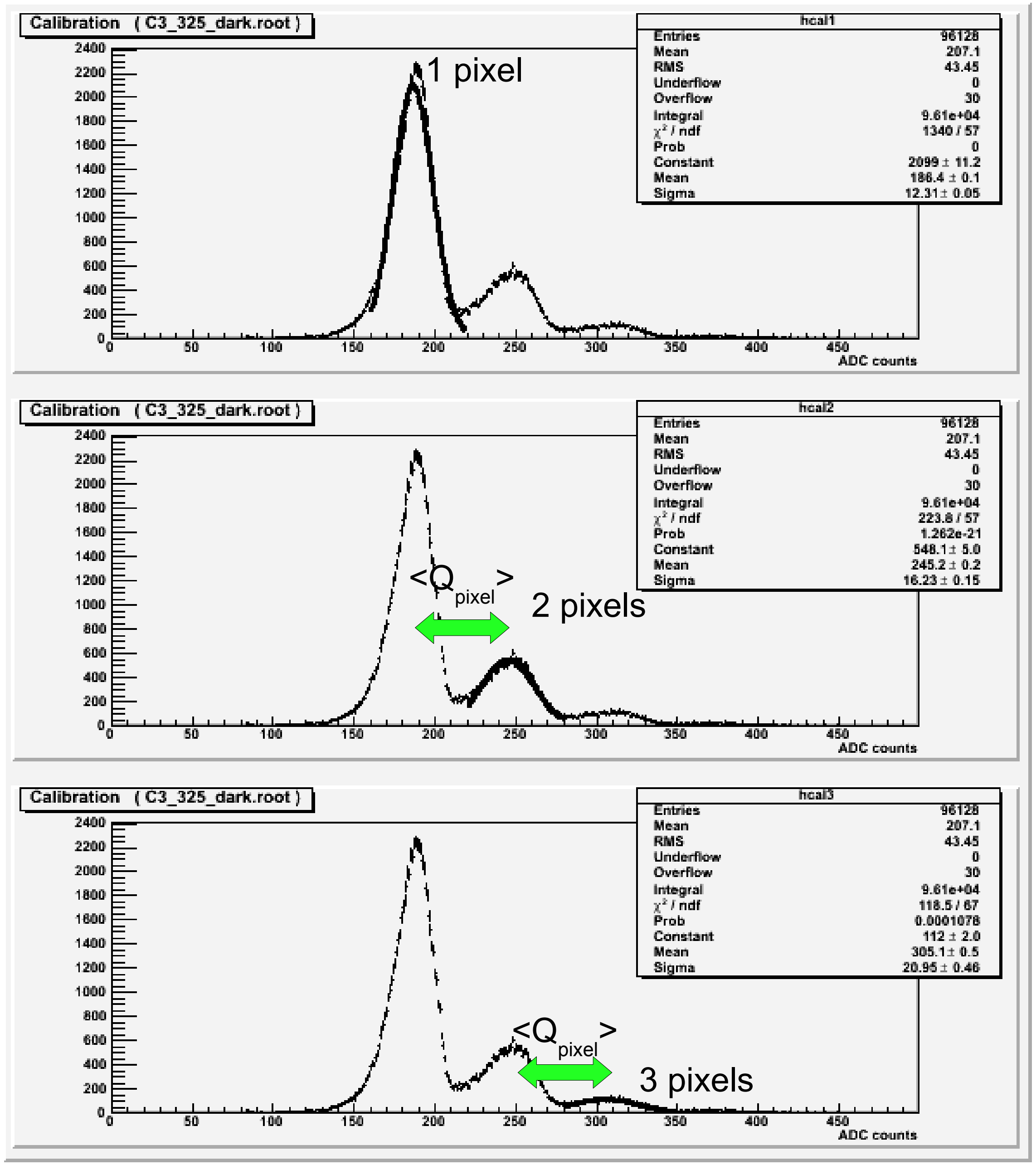


It decreases exponentially with signal height threshold

At low thresholds, plateaux corresponding to given numbers of fired pixels are visible (useful for calibration)

A higher thresholds, no plateaux because of signal smearing effects

SiPM calibration

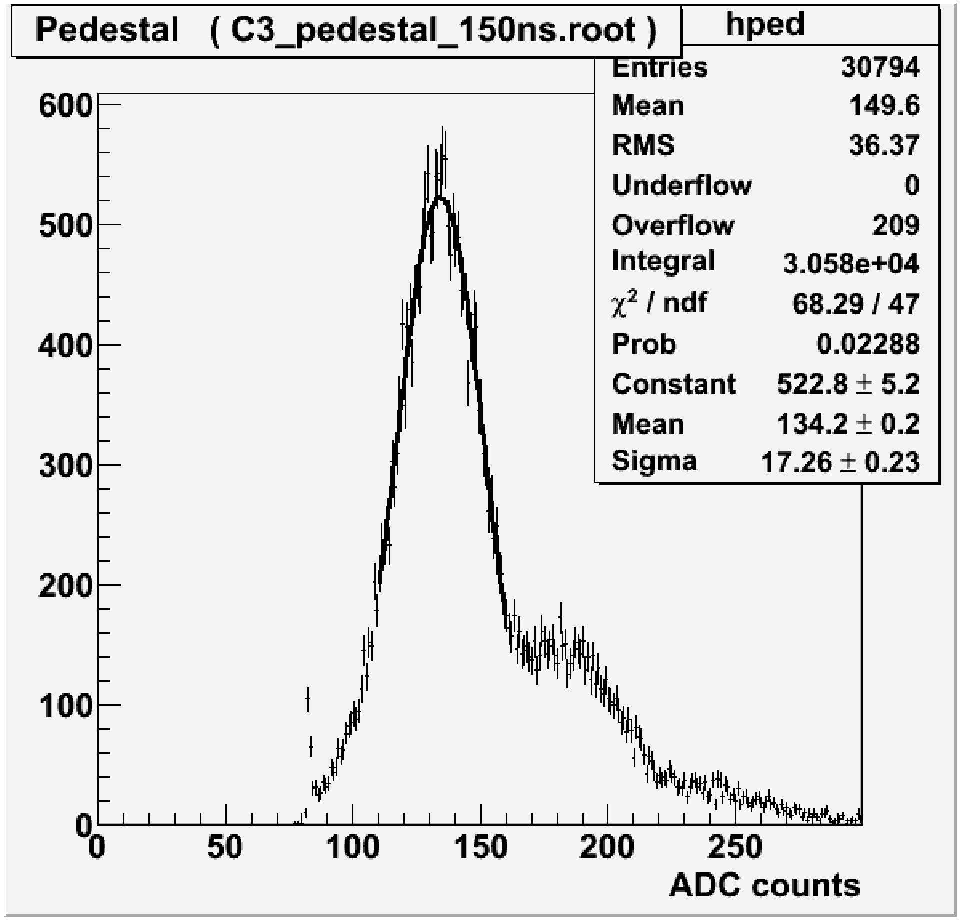


The spectrum of the charge of the noise signals (integrated with a QDC over 150 ns and triggered on noise) shows peaks corresponding to 1,2 or 3 fired pixels

The distance between peaks corresponds to the charge associated to one pixel:

$\langle Q_{pixel} \rangle$ = 59 ADC counts

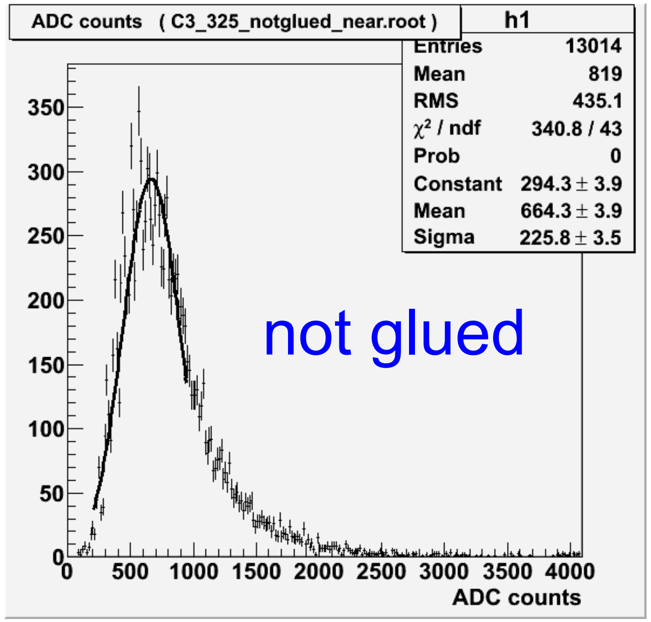
QDC pedestal

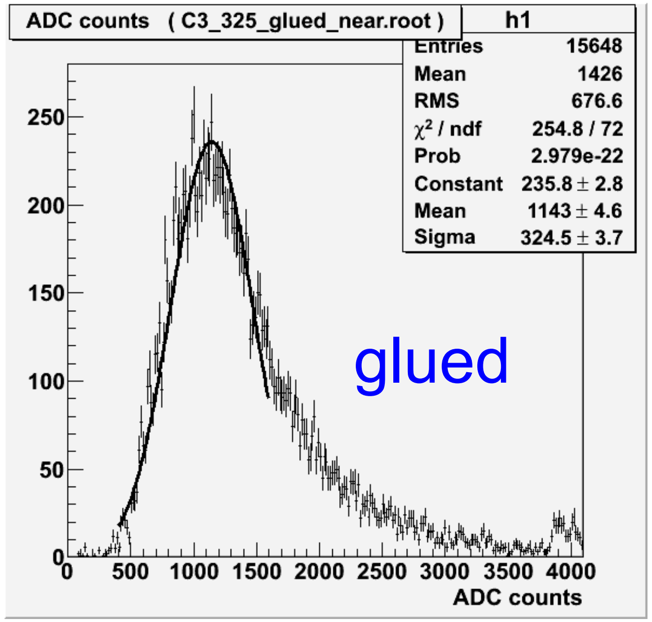


The pedestal is determined by the spectrum of the charge integrated over 150 ns, on random triggers:

Q_{ped} = 134 ADC counts

Detected photons with glued/not-glued fiber





- Trigger on muon, integrate charge in 150 ns
- Gaussian fit around the maximum of integrated charge distribution to obtain <Q> (discard Landau tail to be conservative)
- The most probable number of collected photons can be derived, using calibration data:

$$\langle N_{ph}\rangle = (\langle Q\rangle - Q_{ped}) / \langle Q_{pixel}\rangle$$

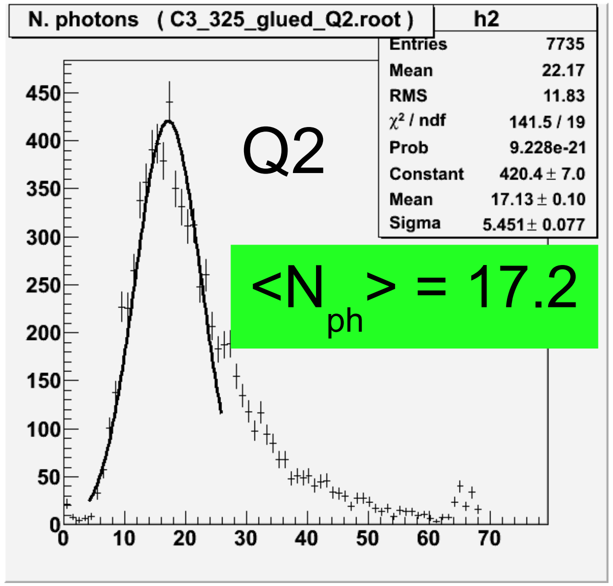
(..neglecting inter-pixel cross talk..)

- The setup with the glued fiber is ~90% more efficient in collecting light:

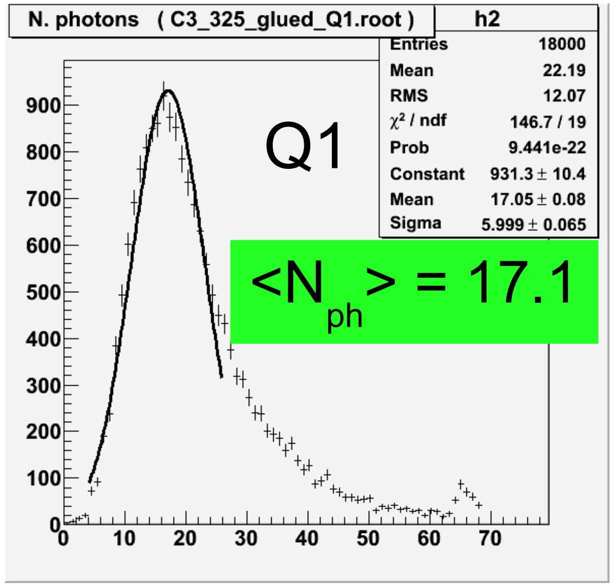
$$\langle N_{ph}\rangle(\text{not glued}) = 9.0$$

$$\langle N_{ph}\rangle(\text{glued}) = 17.1$$

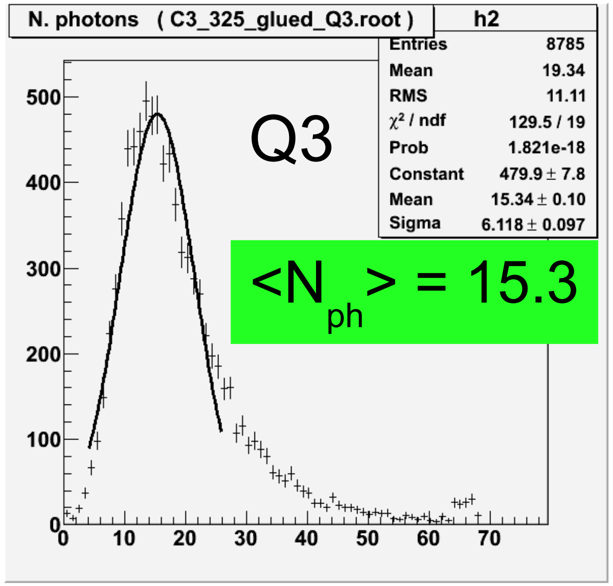
Light collection uniformity



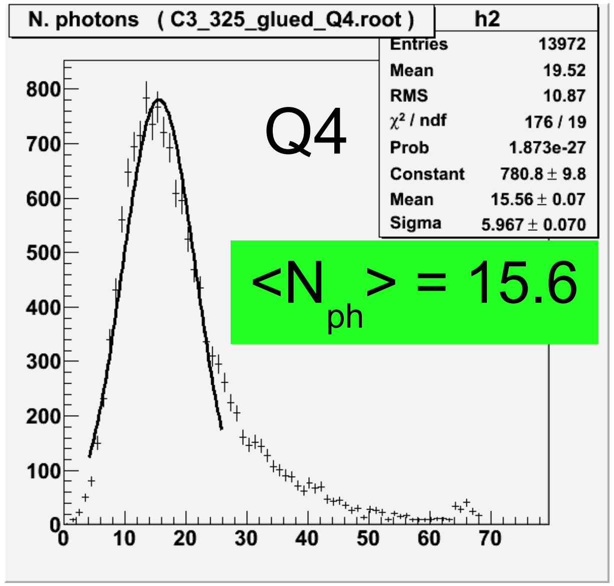
$\langle N_{ph} \rangle = 17.2$



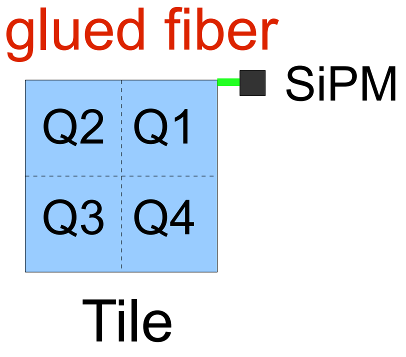
$\langle N_{ph} \rangle = 17.1$



$\langle N_{ph} \rangle = 15.3$



$\langle N_{ph} \rangle = 15.6$



- Rather uniform response along the fiber
- ~10% more photons detected when muon is in quadrants close to the fiber: due to photon attenuation in the scintillator.

Efficiency (threshold on signal charge)

Efficiency for MIP detection, can be evaluated from integrated charge spectra:

Q2	
Thr (#ph)	Eff.
≥ 4	99.5
≥ 5	99.5
≥ 6	99.3
≥ 7	98.9

Q1	
Thr (#ph)	Eff.
≥ 4	99.9
≥ 5	99.7
≥ 6	99.3
≥ 7	98.8

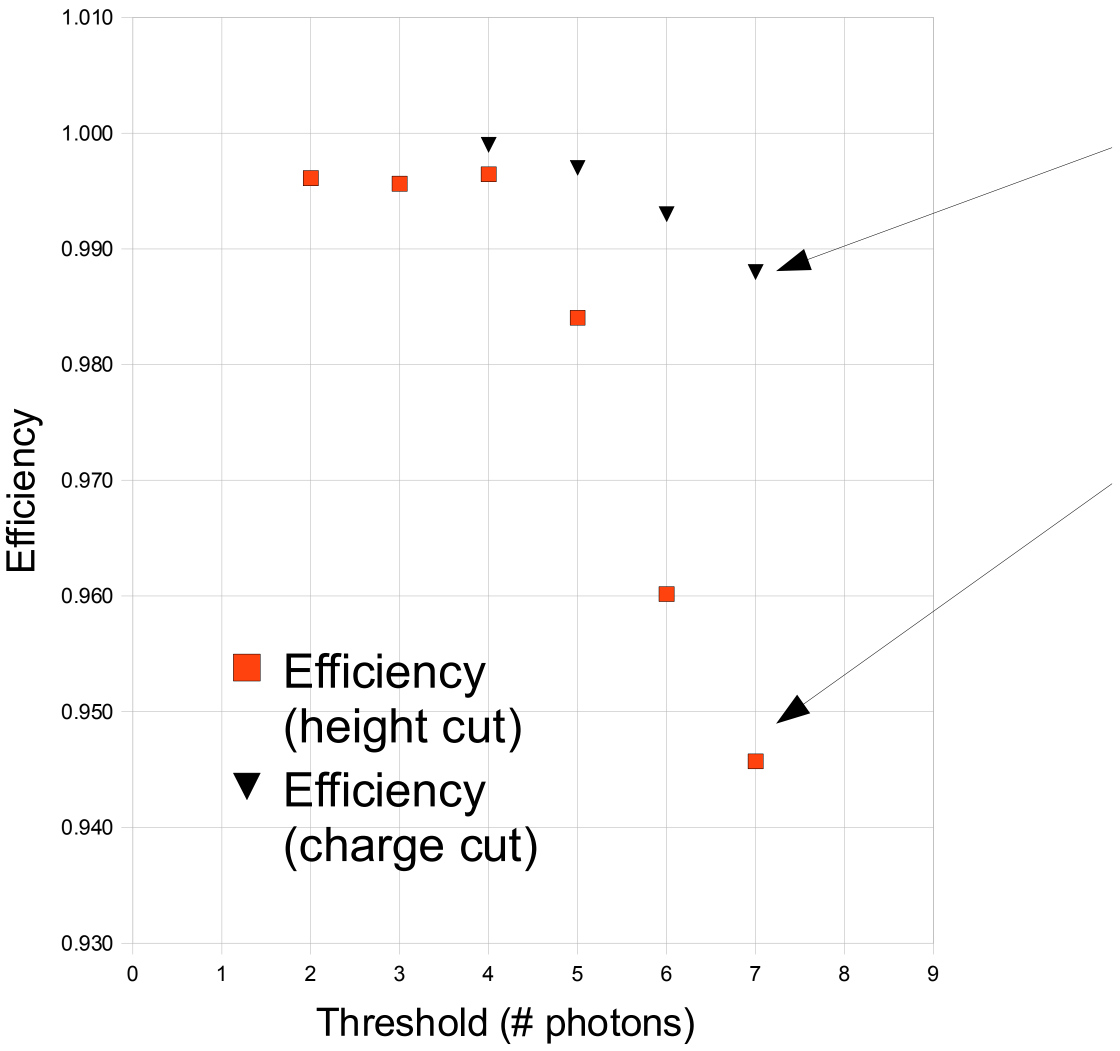
Q3	
Thr (# ph)	Eff.
≥ 4	99.5
≥ 5	99.1
≥ 6	98.4
≥ 7	97.2

Q4	
Thr (#ph)	Eff.
≥ 4	99.8
≥ 5	99.4
≥ 6	98.8
≥ 7	97.8

- for “low” thresholds the efficiency is not much affected by non uniformity in light collection:
- As an example, requiring
  ≥ 5 photons
  ε > 99%
- the Poisson probability that dark noise signals in a 150 ns time window cross the 5 photon threshold is ~ 10^{-5}
  … but it has to be measured !

Efficiency (threshold on signal height)

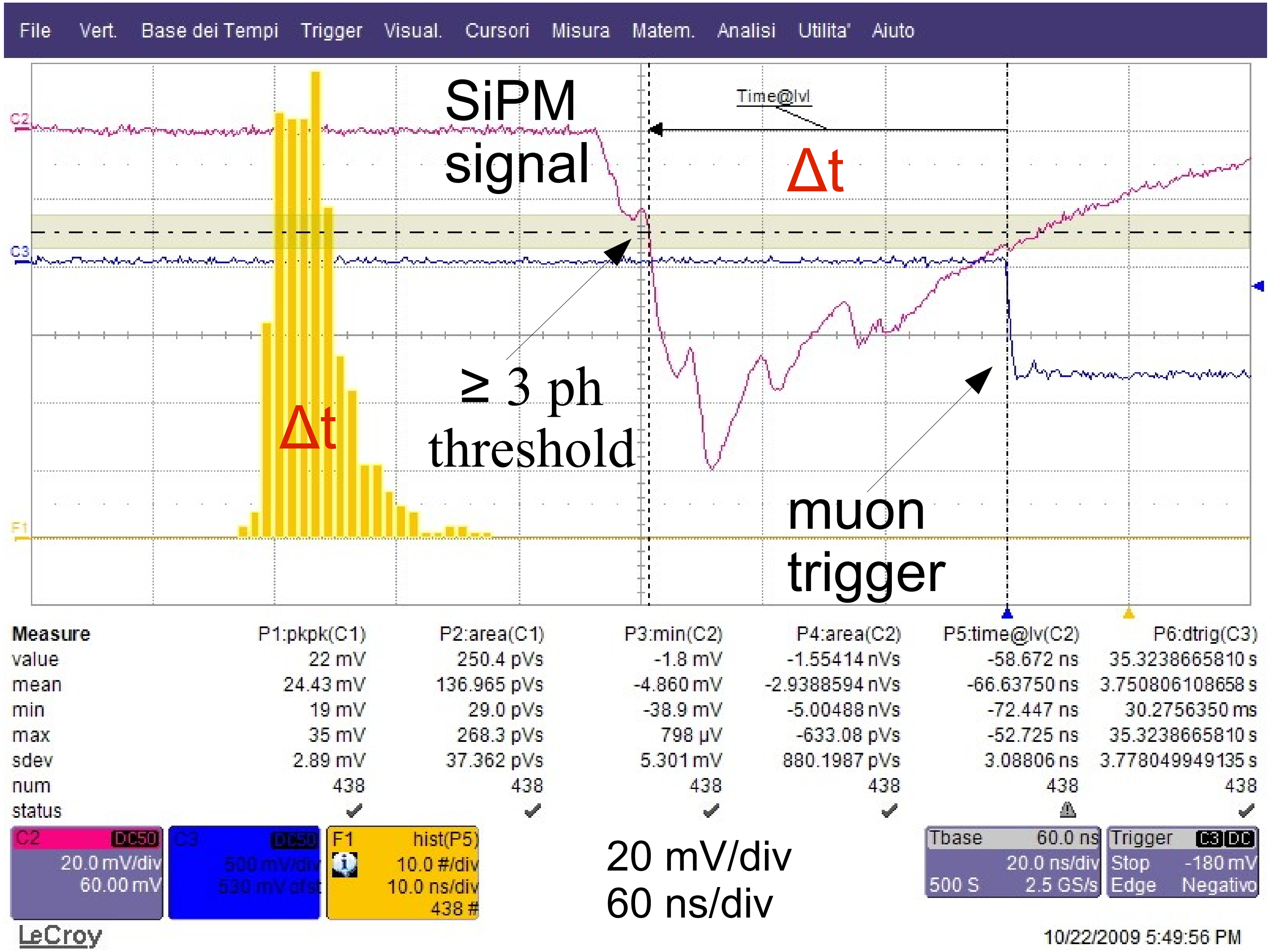
Compare MIP selection efficiency by cutting on signal height wrt signal charge:



- Cutting on charge integrated over 150 ns is more efficient.. ..but slower and more sensitive to noise
- Cutting on signal height is faster but less efficient
- Both would benefit of more efficient light collection

Time walk

Timing resolution is dominated by the the spread in arrival times of the collected photons: it can be improved with more efficient light collection



SiPM signal

Δt

≥ 3 ph threshold

muon trigger

Δt

Measure	P1:pkpk(C1)	P2:area(C1)	P3:min(C2)	P4:area(C2)	P5:time@lv(C2)	P6:dtrig(C3)
value	22 mV	250.4 pVs	-1.8 mV	-1.55414 nVs	-58.672 ns	35.3238665810 s
mean	24.43 mV	136.965 pVs	-4.860 mV	-2.9388594 nVs	-66.63750 ns	3.750806108658 s
min	19 mV	29.0 pVs	-38.9 mV	-5.00488 nVs	-72.447 ns	30.2756350 ms
max	35 mV	268.3 pVs	798 µV	-633.08 pVs	-52.725 ns	35.3238665810 s
sdev	2.89 mV	37.362 pVs	5.301 mV	880.1987 pVs	3.08806 ns	3.778049949135 s
num	438	438	438	438	438	438
status	✓	✓	✓	✓	⚠	✓

20 mV/div
60 ns/div

Threshold (# photons)	RMS of arrival time (ns)
≥ 2	2.7
≥ 3	3.0
≥ 4	3.4
≥ 5	3.6
≥ 6	3.7

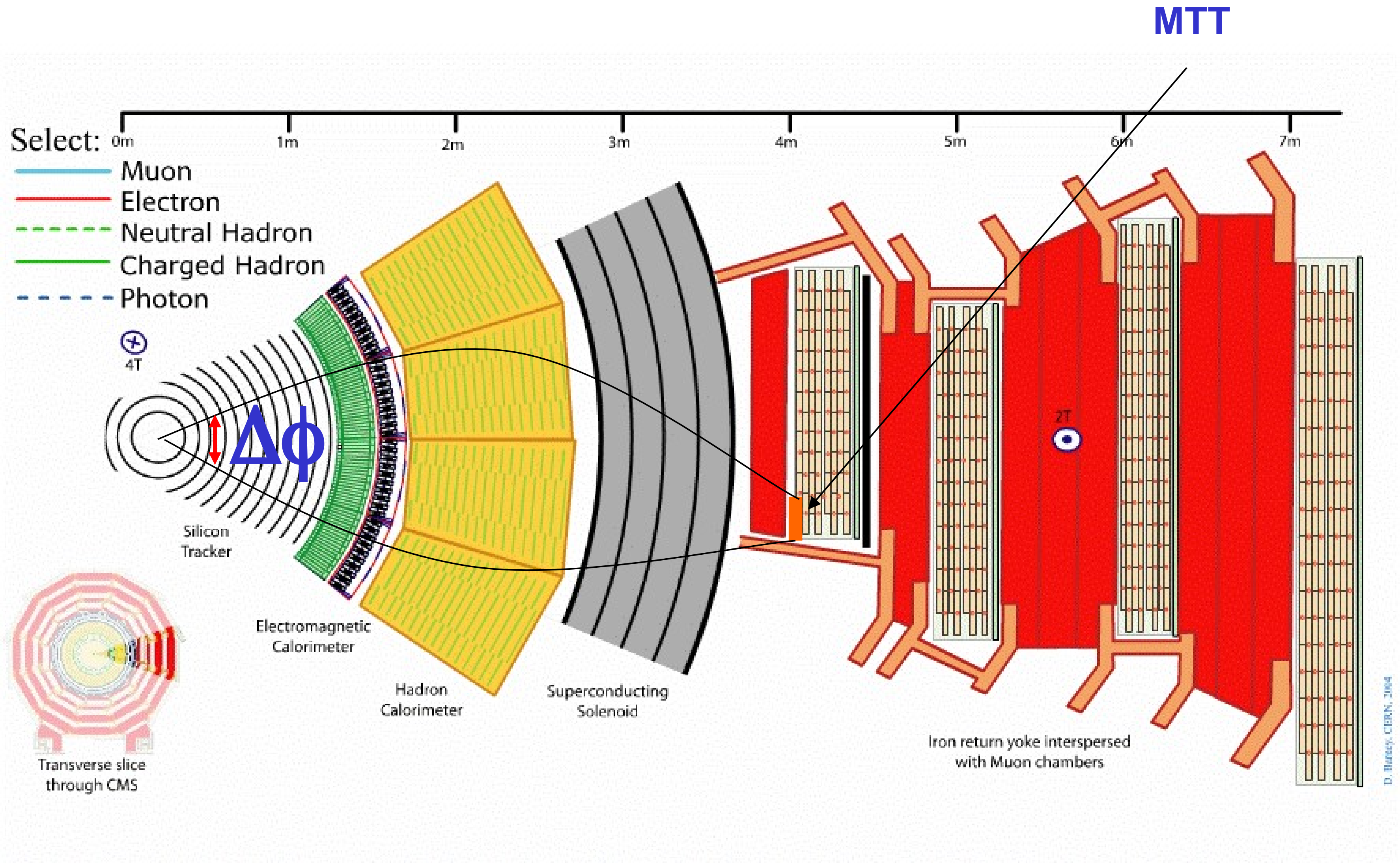
Summary

- First results are very promising:
  - very simple geometry, easy construction
  - good light collection with only one fiber..if glued
  - good efficiency..if charge is integrated
  - time resolution seems to be dominated by photon statistic
  - noise background still to be studied...

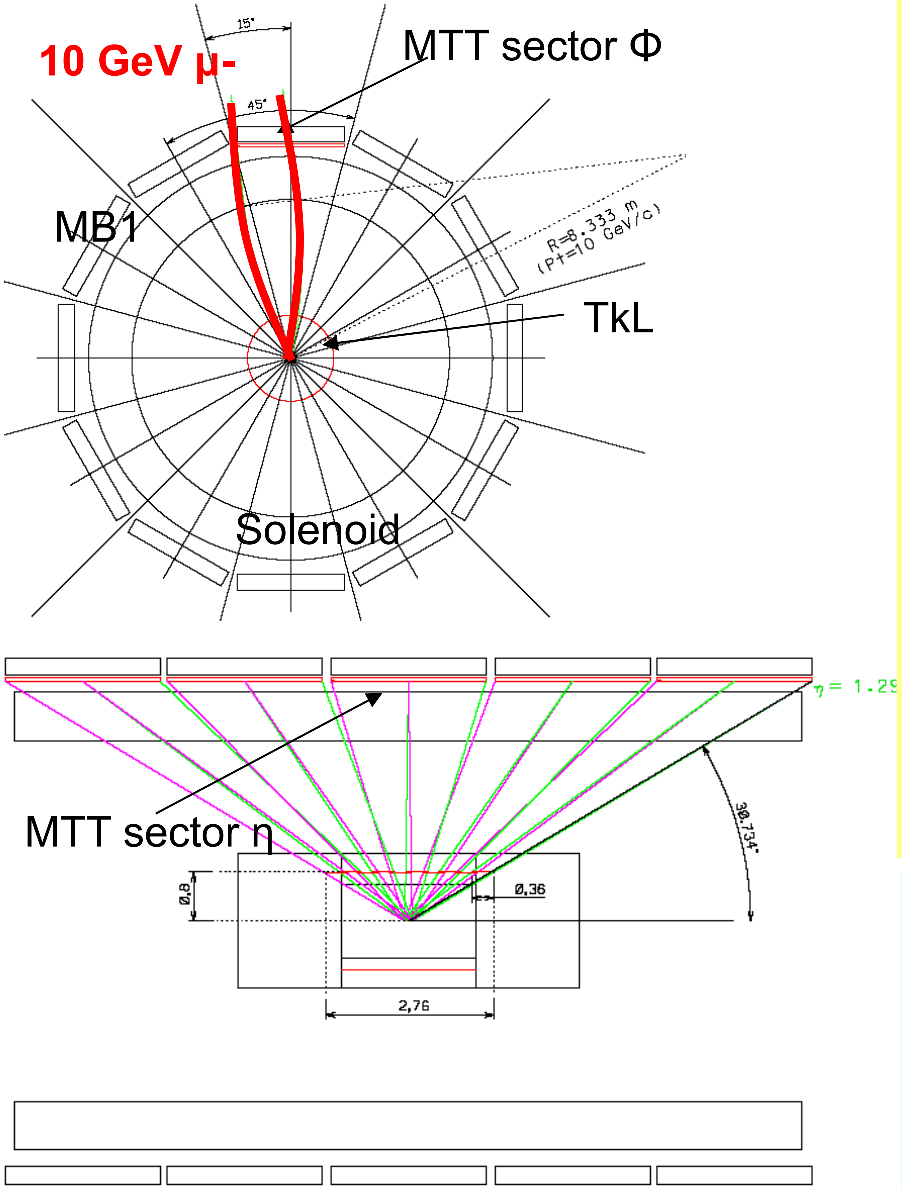
- Next tests:
  - improve photon statistic (more efficient SiPM, 2 WLS,..)
  - study noise (and noise reduction with 2 SiPM coincidence)
  - develop front-end electronics for readout and control of few ch.

Backup slides

Region of interest with MTT



Static mapping with MTT



- Define coarse muon tagging sectors outside Solenoid:
  - -all tagged muons above 10 GeV come from an associated Region of Interest (RoI) in Tracker

- Natural choice for sectors in an MTT layer near MB1 (and corresponding RoI in a Tracker Layer (TkL)):

  Φ MTT sector:15° -> half MB1=100 cm
  Φ TkL sector: 3 x 15°

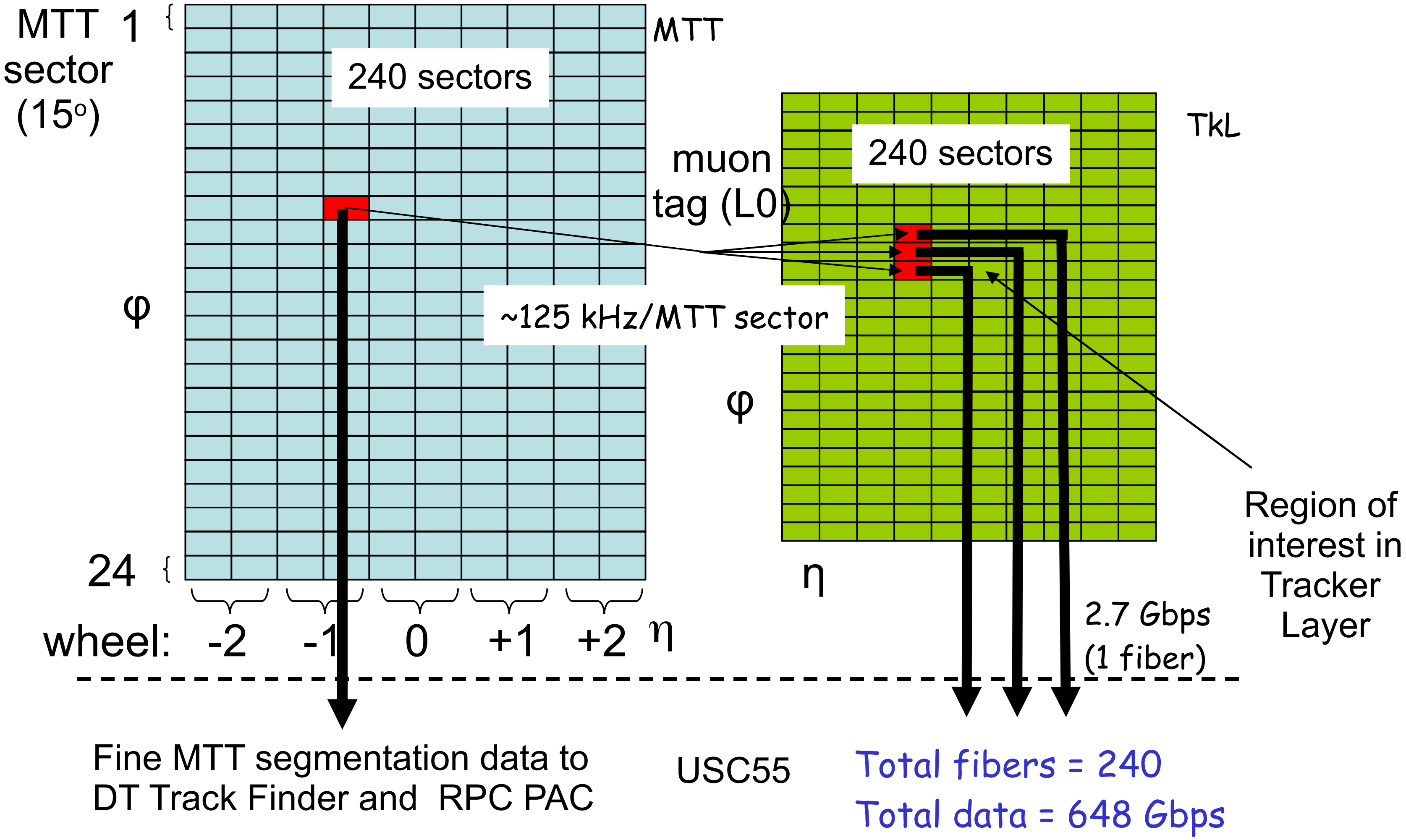
  η MTT sector: -> half MB1=125 cm
  η TkL sector: -> depends on radius

Total:
2 x (12 MB sectors) x
2 x (5 wheels) = **240 coarse** MTT sectors

- 4 coarse MTT sectors for each MB sector
- also TkL is divided into 240 sectors

Tag connection from MTT to (one) TkL

A fast muon tag signal (0.5 μs) can be sent directly to Tracker sensors: reduced bandwidth of Tracker data to be sent to following trigger stages in USC



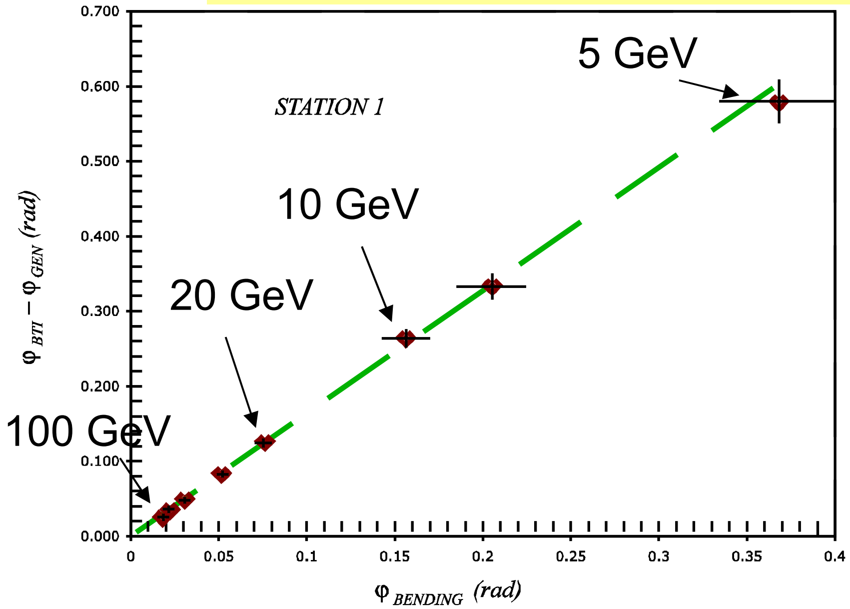
Total fibers = 240

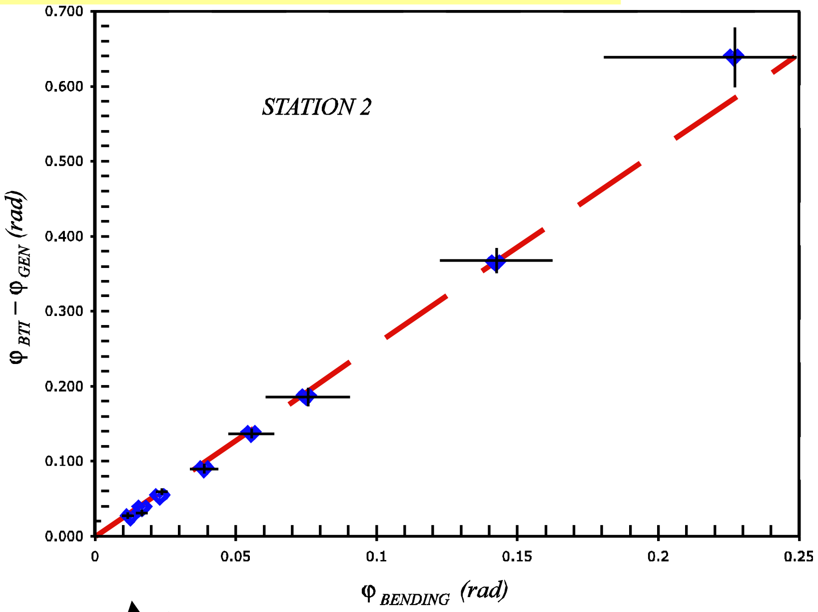
Total data = 648 Gbps

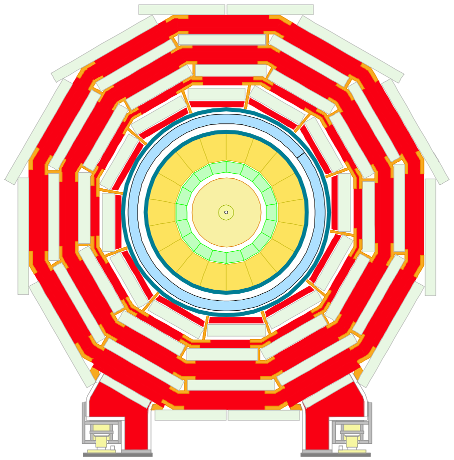
(rates calculated for L=10^{35}cm^{-2} s^{-1} and a TkL at 80 cm from vertex, as in CMS-IN 2007/058)

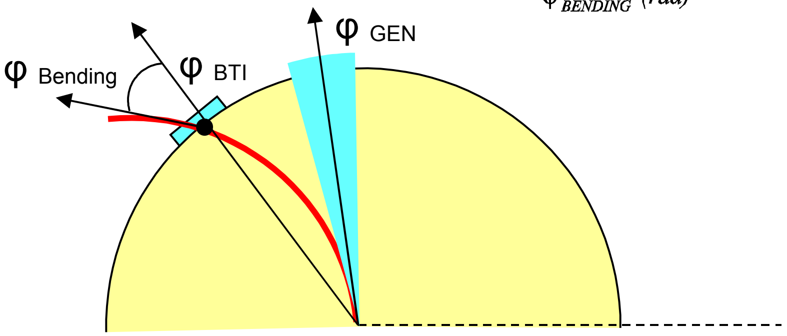
Connecting to tracker with Dynamic Mapping

Correlation between deviation and bending angle allows
the prediction of muon position at any depth inside CMS
(use also station 2 when bending is not measured by station1)









$$\varphi_{Predicted} = m\,\varphi_{Bending} + q - \varphi_{BTI} + \varphi_{sector}$$