The Cosmic Box

a (not so) short introduction
to the portable particle detector
you're going to share
your time
in Erice!

Why a EEE - CB ?

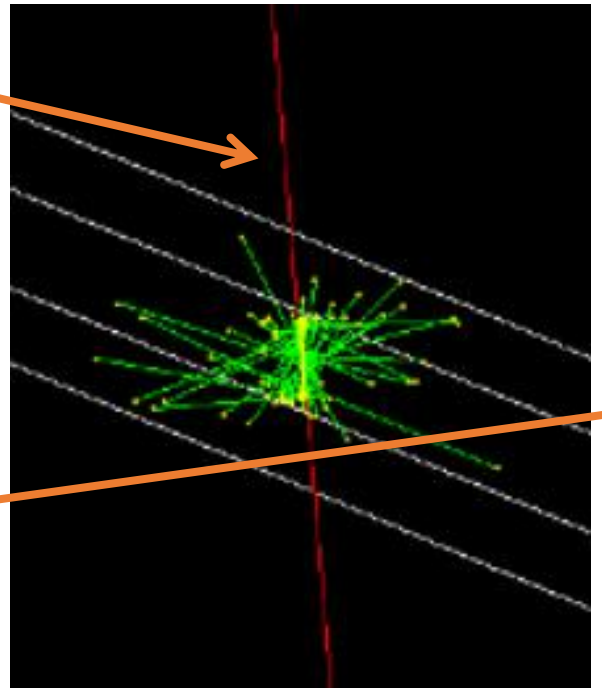
In the early EEE times
the CB
was thought for

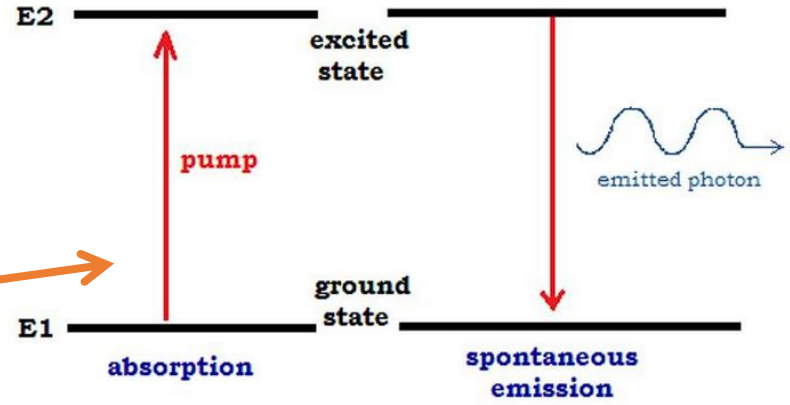
- measuring the **efficiency** of the **Alice ToF MRPCs** and later **EEE MRPCs**
- allowing several **didactical measurements** about Cosmic Ray

How does a scintillator work ?

A scintillator emits photons
when an ionizing particle
deposits energy
while passing through the material

Scintillation processes
are based on the
excitation-dexcitation
of electrons on hybrid orbitals,
typical in organic molecules

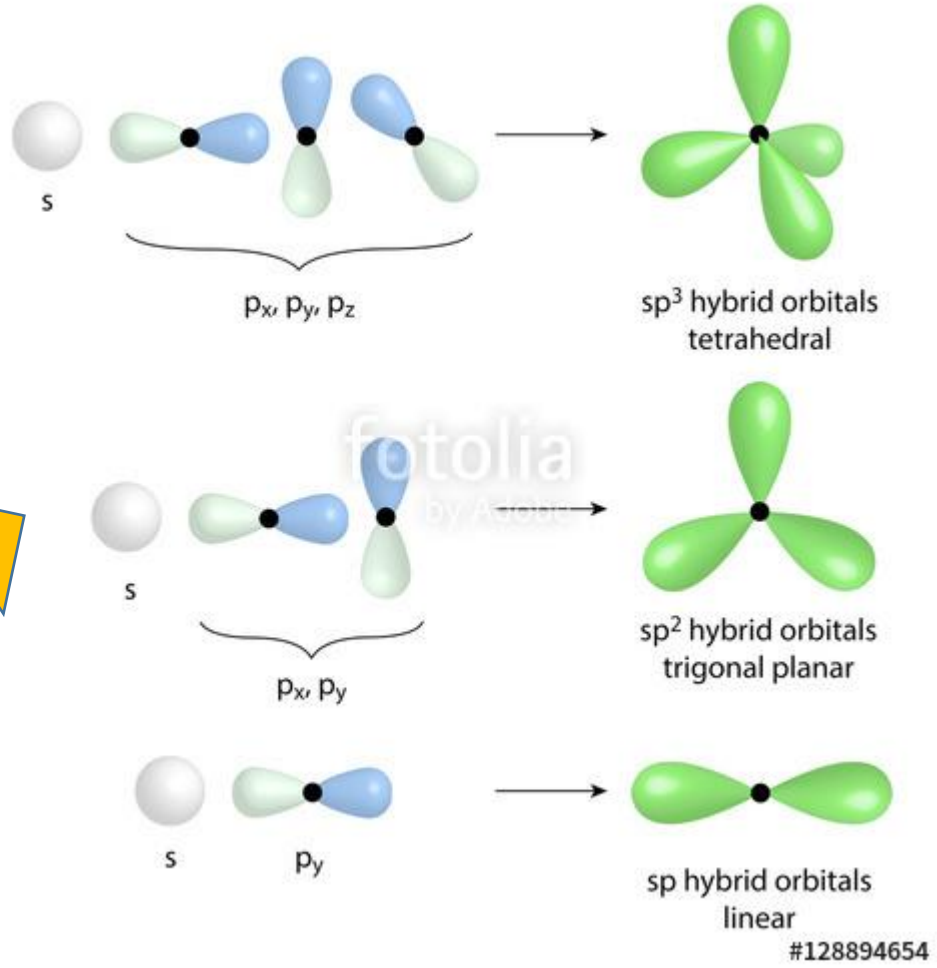




How does a scintillator work ?

A scintillator emits photons
when an ionizing particle
deposits energy
while passing through the material

Scintillation processes
are based on the
excitation-dexcitation
of electrons on hybrid orbitals,
typical in organic molecules



How does the light is collected ?

The surface of the scintillator is usually

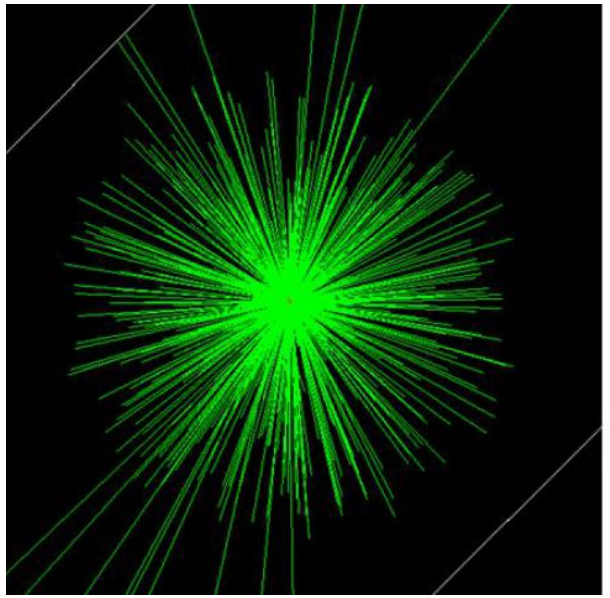
- painted

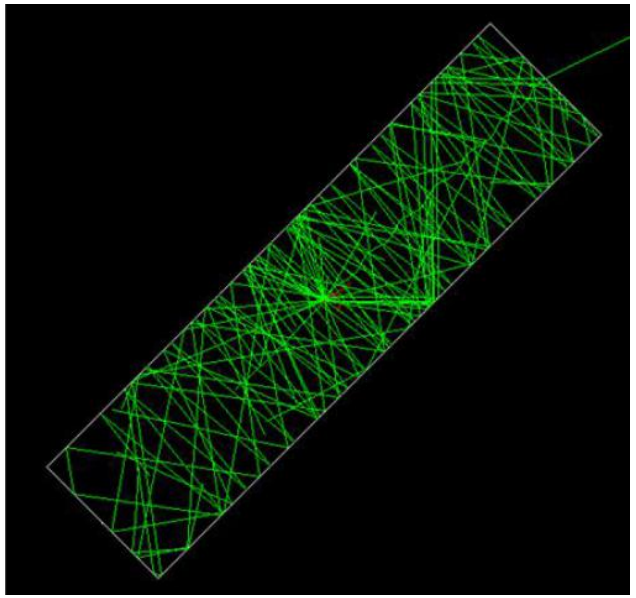
with reflective coating

- wrapped

with a reflective film

Thus 10-50% of the emitted light is "confined" into the scintillator volume

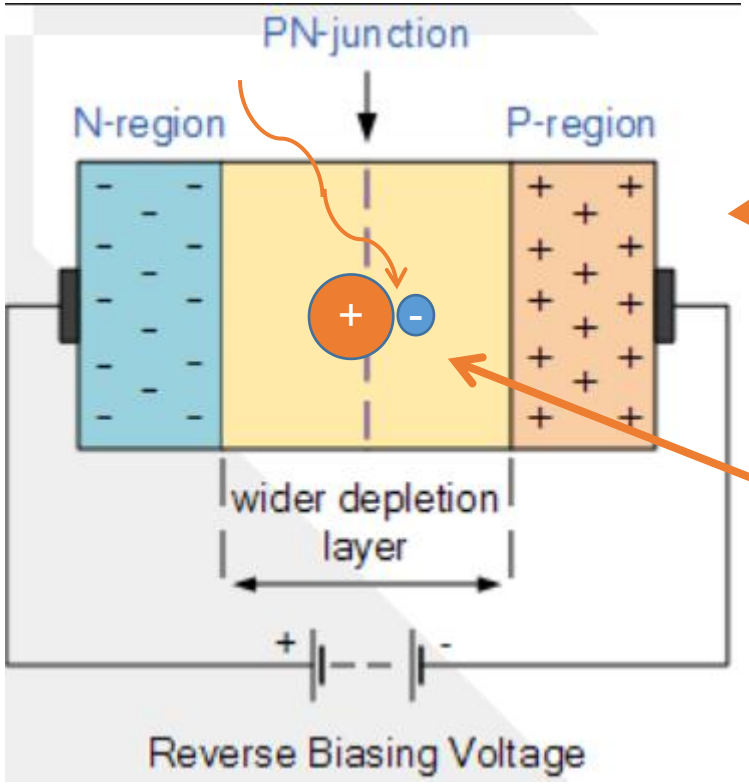




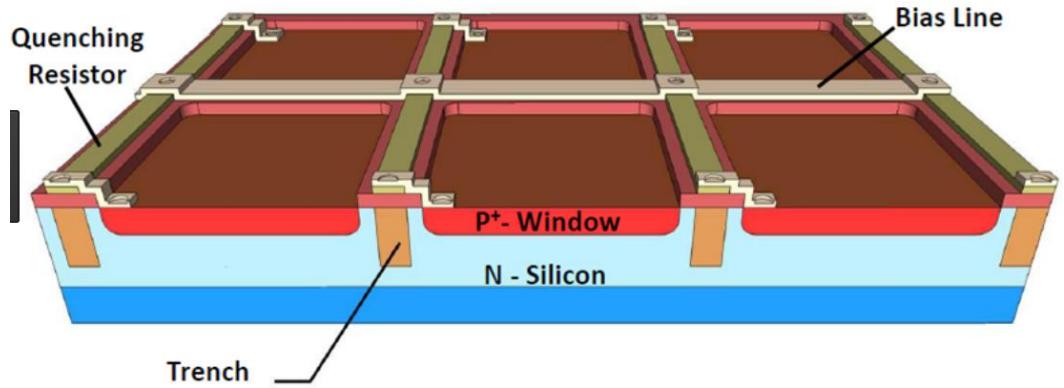
In average 10^4 to 10^5 photons are released per cm of scintillator, depending on

- particle energy
- particle type
- scintillating material

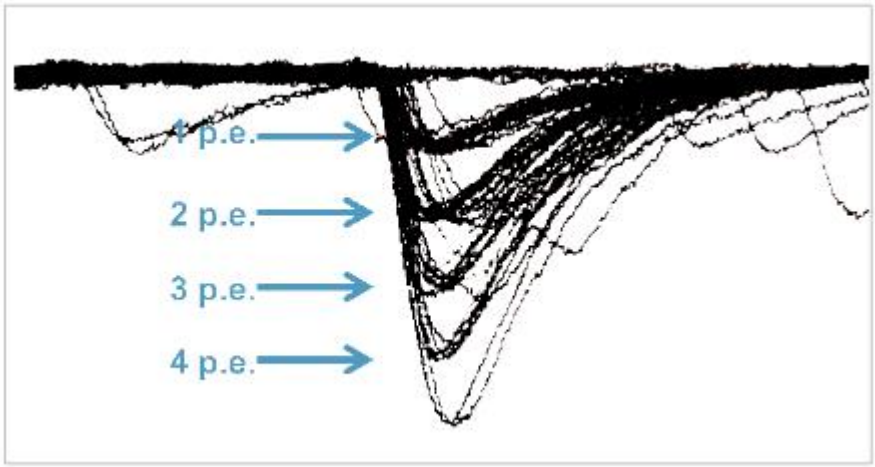
The Silicon Photomultiplier: a light amplifier



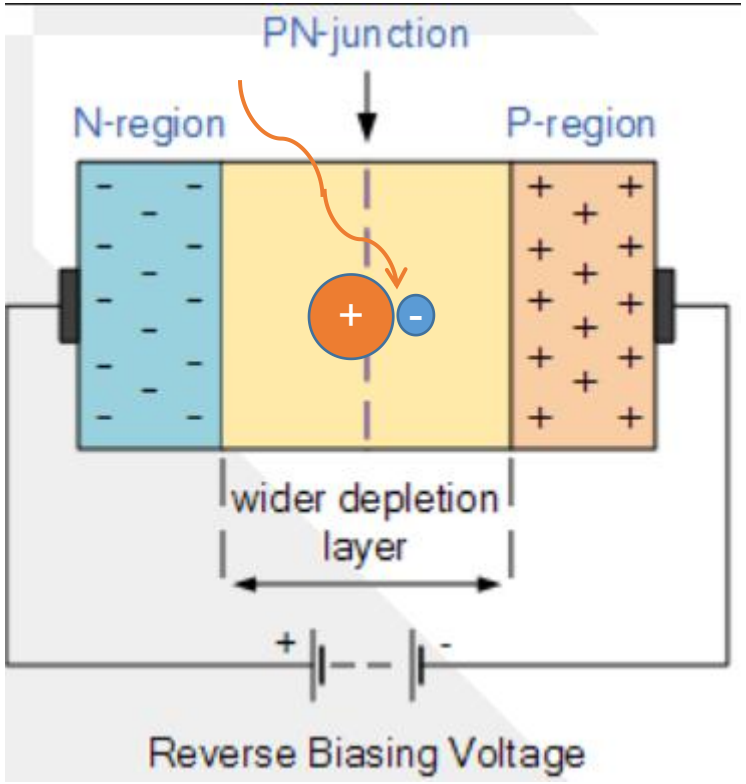
The SiPM is simply a
p-n semiconductor junction
reversed biased



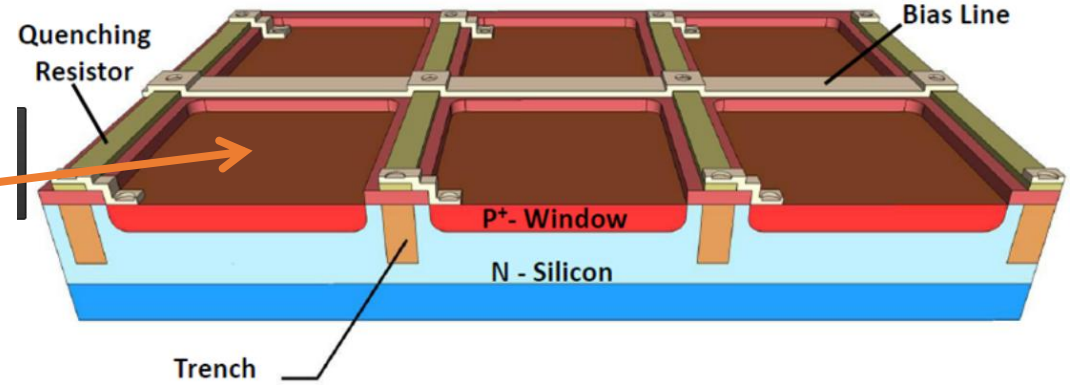
A **photon** creates
charge-hole pairs
in the depletion region
the strong electric field
brings to
a **short and amplified**
electric pulse



The Silicon Photomultiplier: a light amplifier

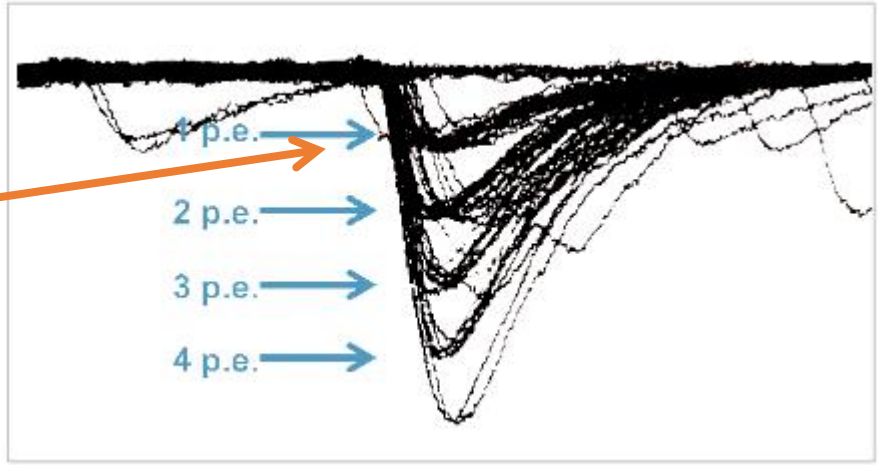


The SiPM is segmented into little pads 10-30 μm



the gain is 10^5-10^6!

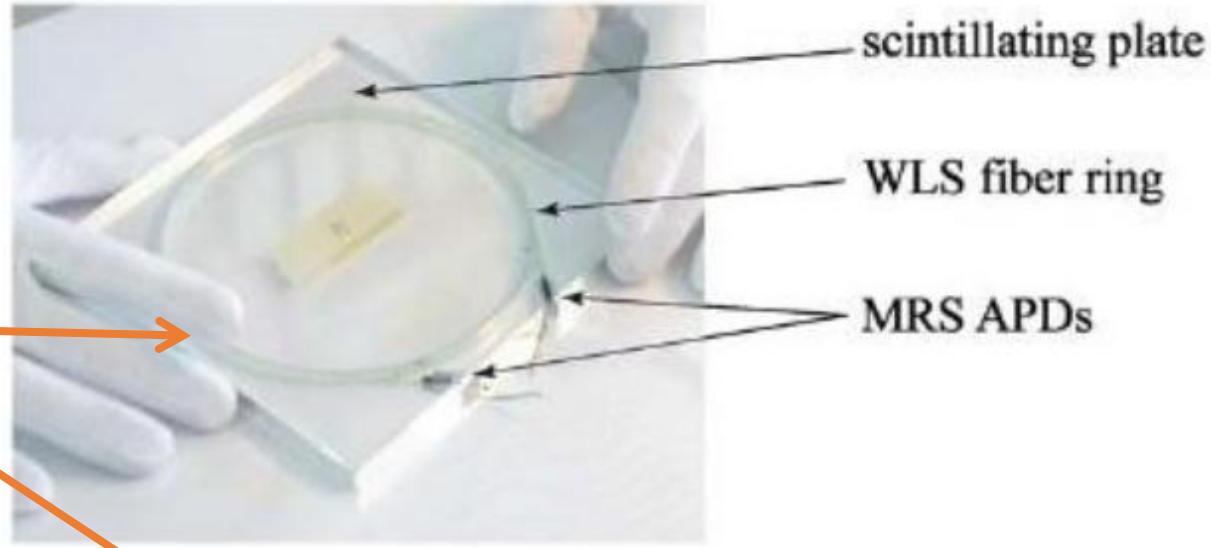
It is able to detect even a single photon! (sunlight is 10^{20}-10^{21} photon/s)



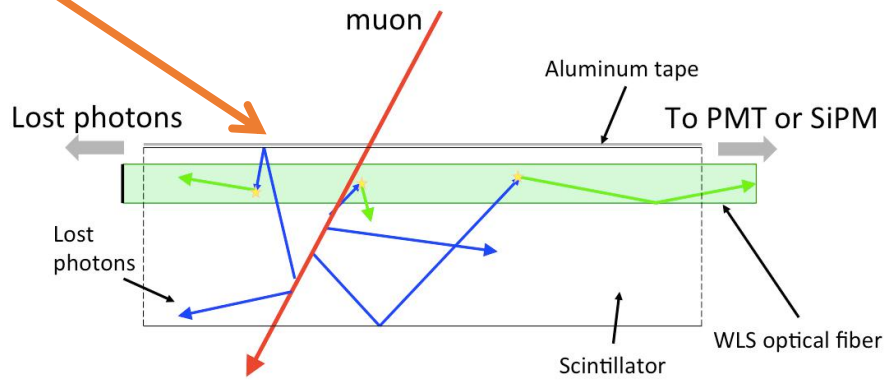
Coupling the SiPM to the scintillator

Different coupling methods

1. with wavelenght shifter:
"shift" the light emitted by the scintillator to the best frequency for SiPM



2. last CB versions:
both scintillator and SiPM are tuned on blue light



Coupling the SiPM to the scintillator

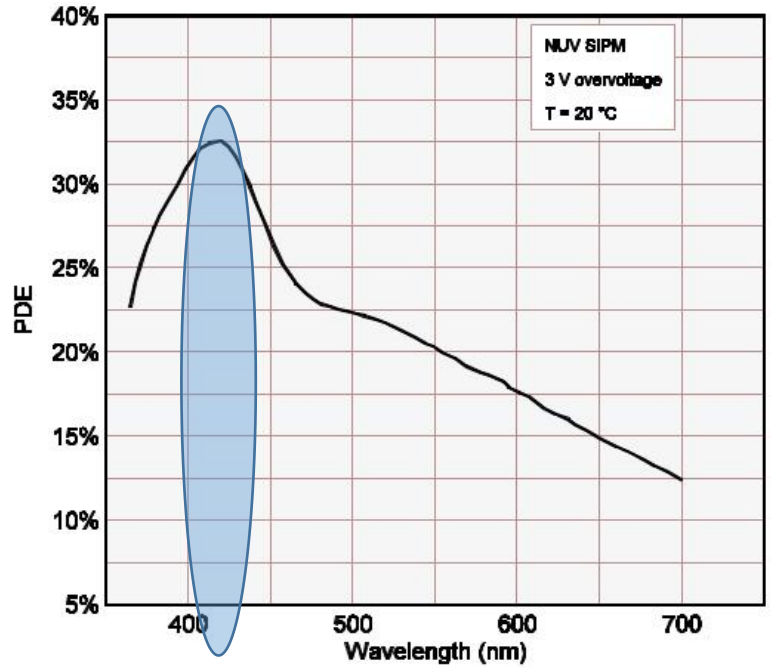
Different coupling methods

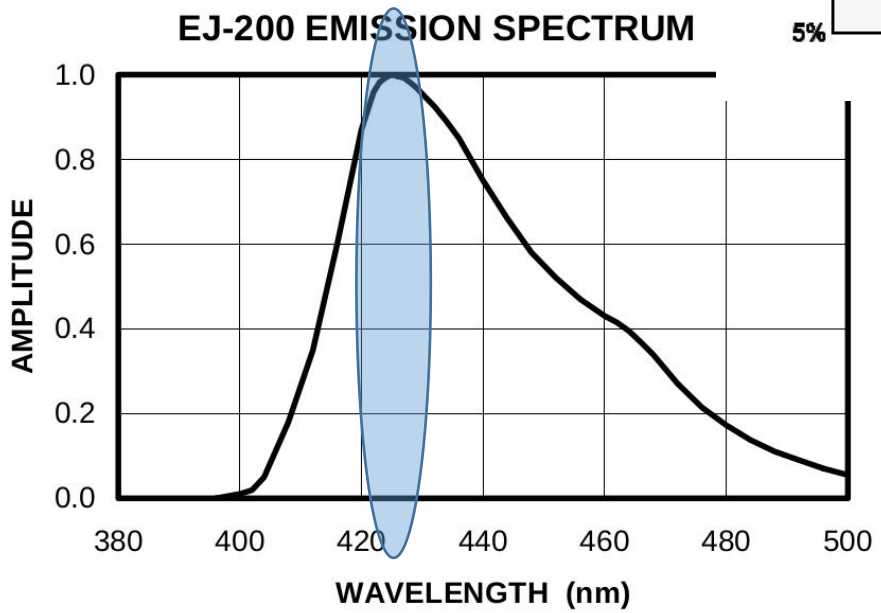
1. with wavelenght shifter:
"shift" the light emitted by the scintillator to the best frequency for SiPM

2. last CB versions:
both scintillator and SiPM are tuned on Near UV light

SiPM

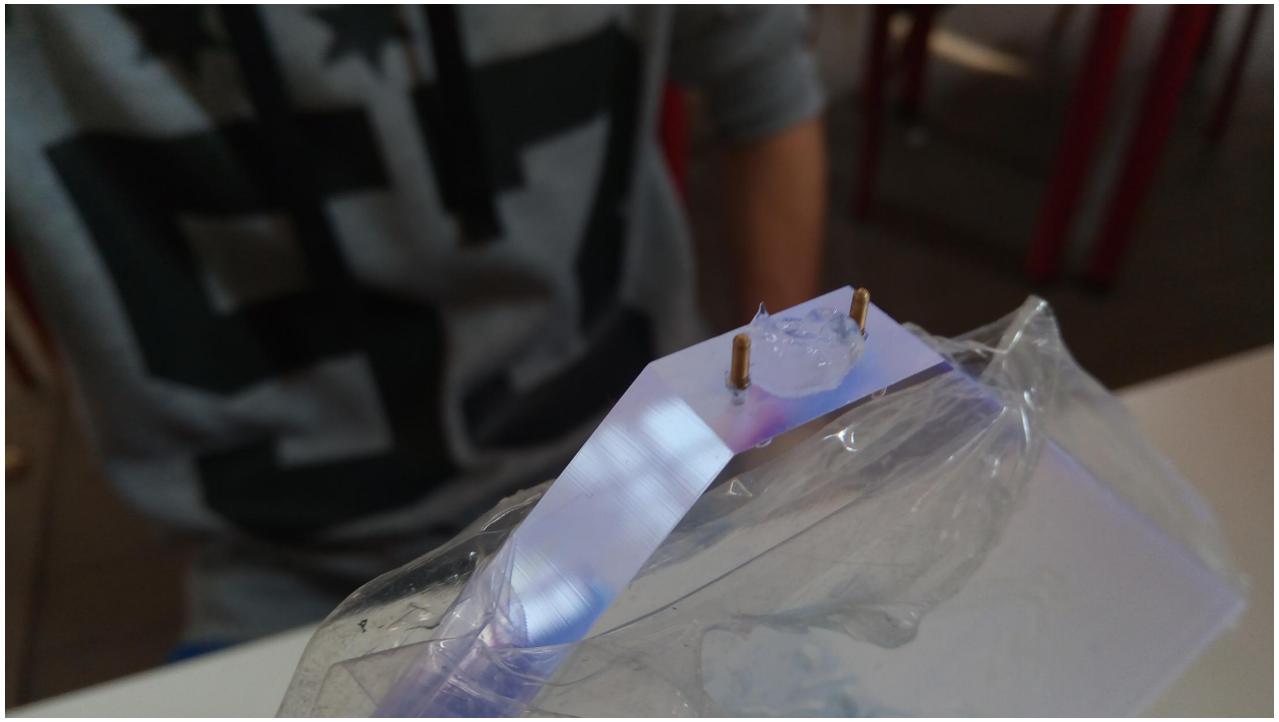
Scintillator





The CB construction

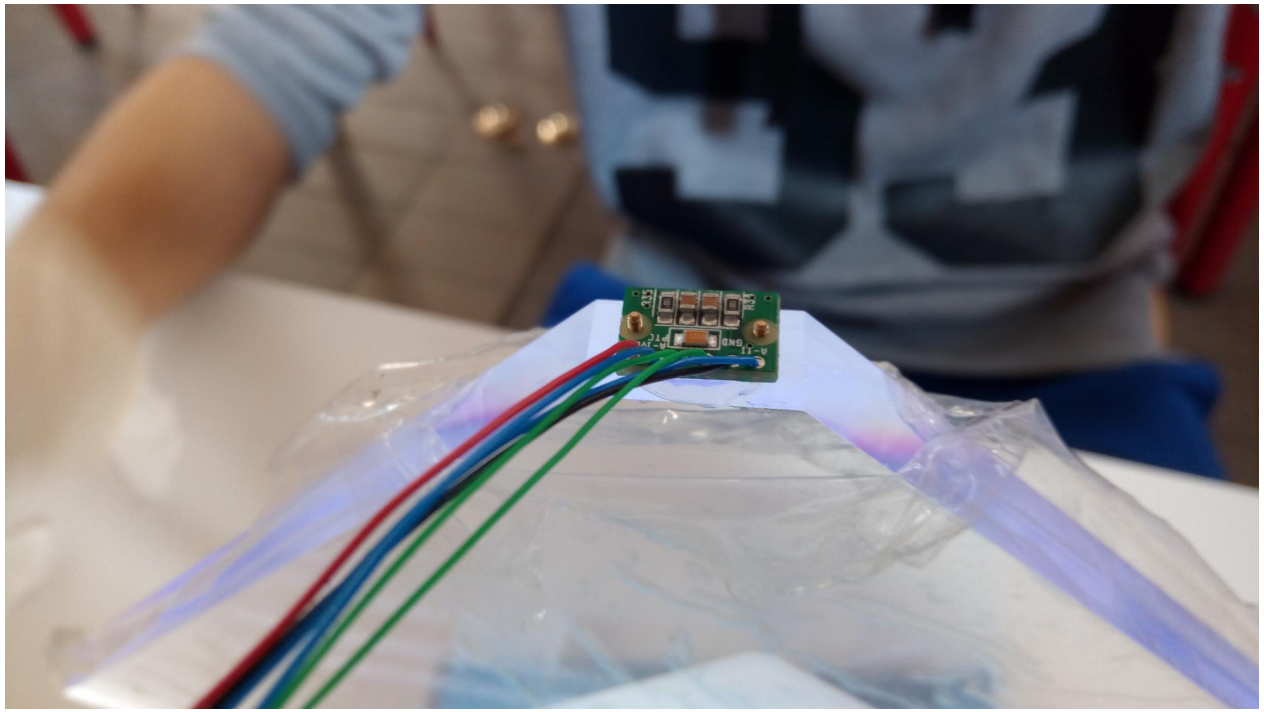
The optical grease

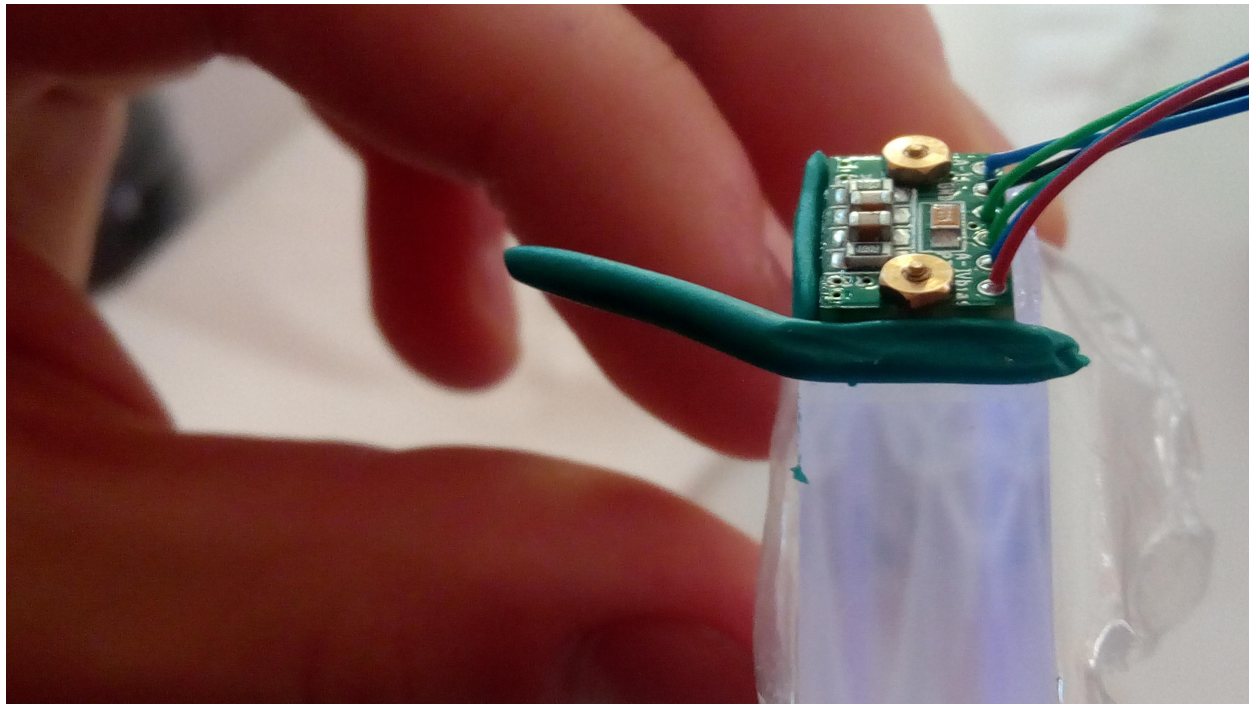


... for the light coupling between scintillator and SiPM

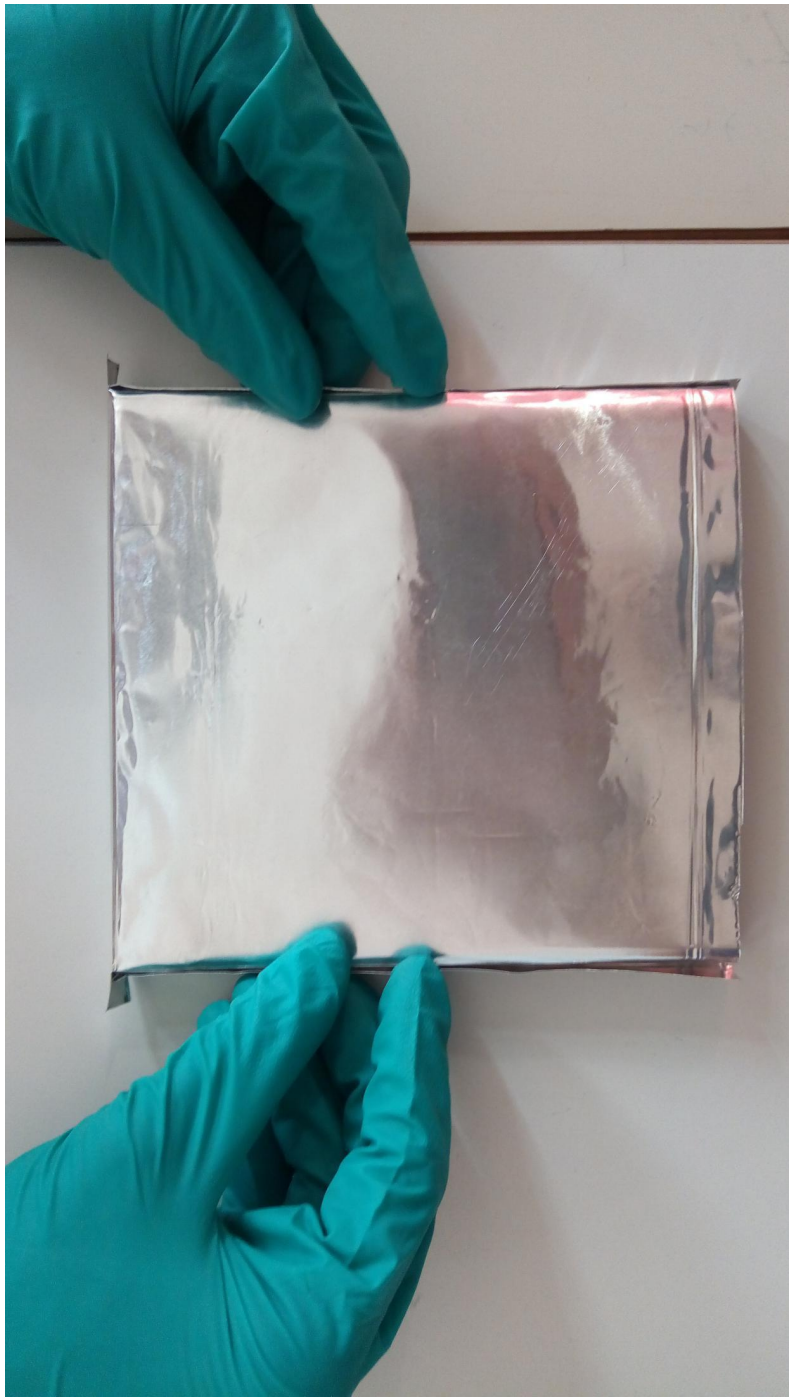
The CB construction

The SiPM on the scintillator:
2 SiPMs per scintillator tile are installed
for reducing the noise (see later)

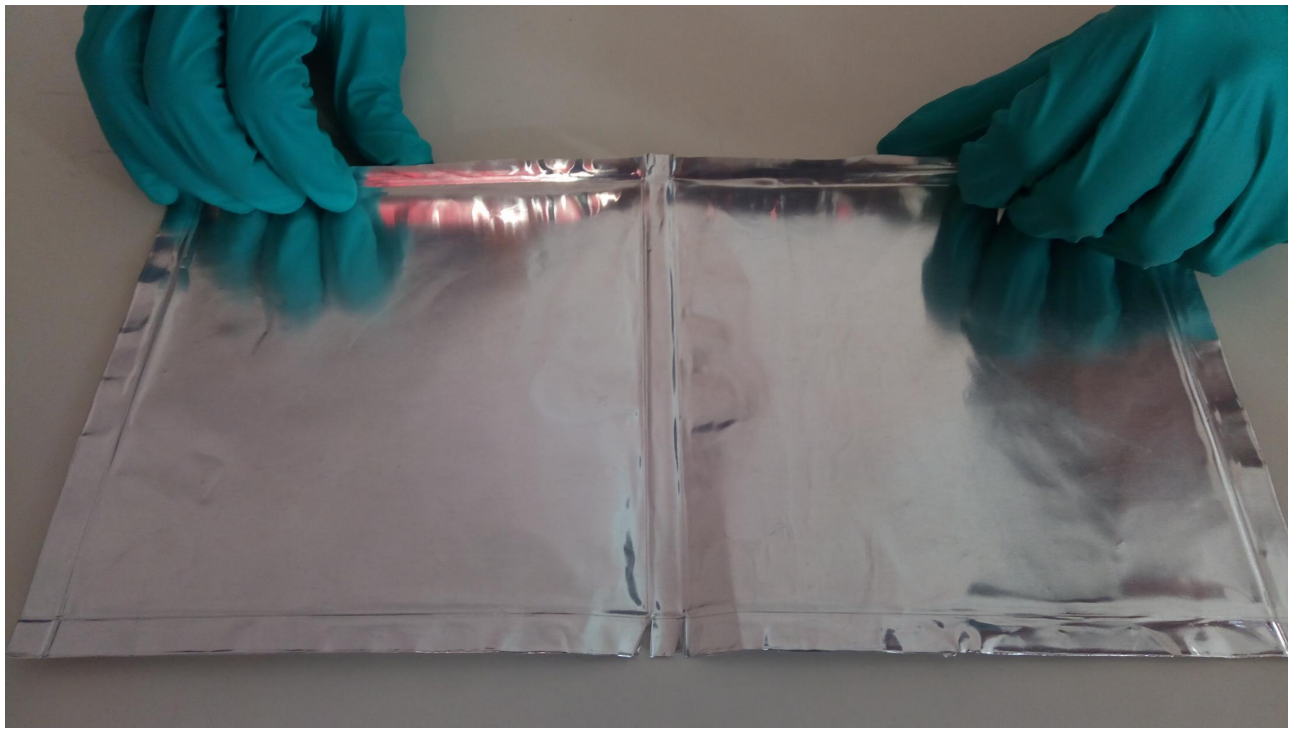




modeling clay for
keeping out the light

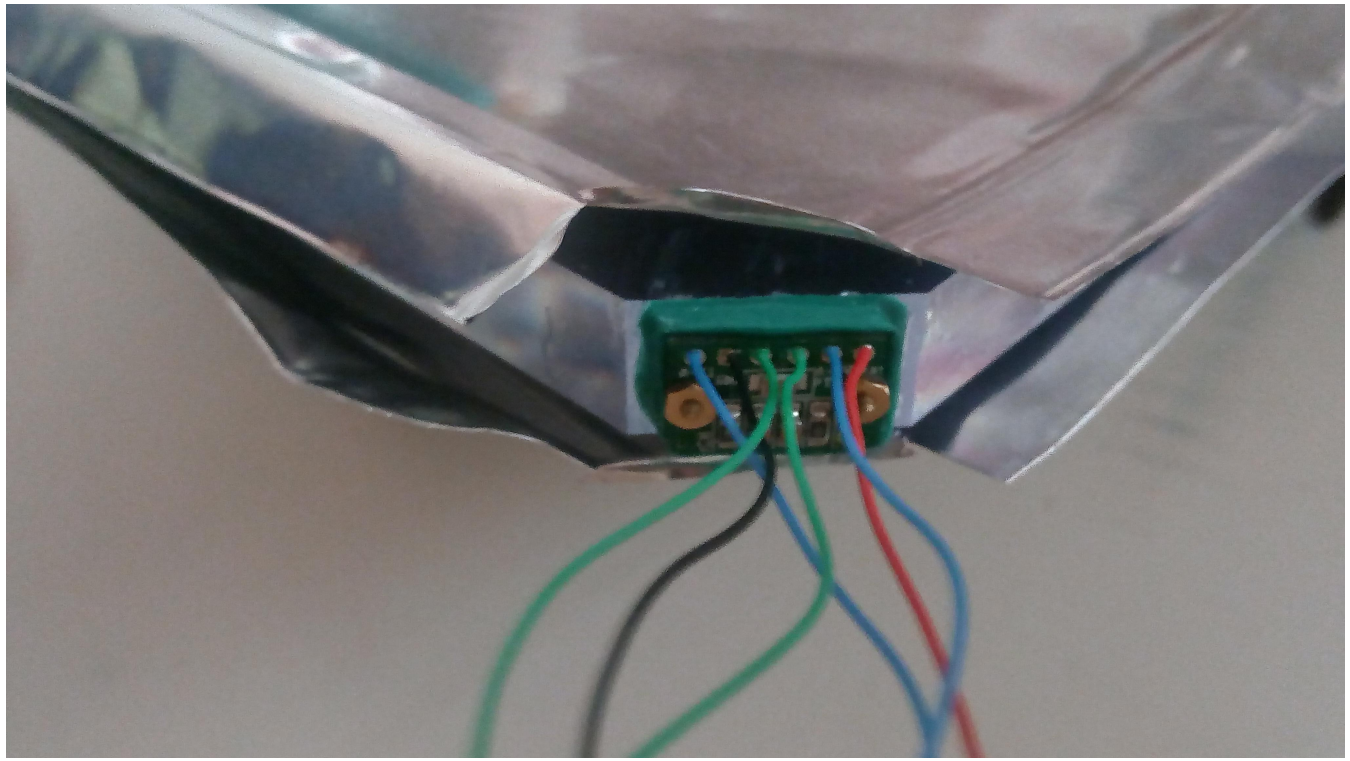


The CB construction



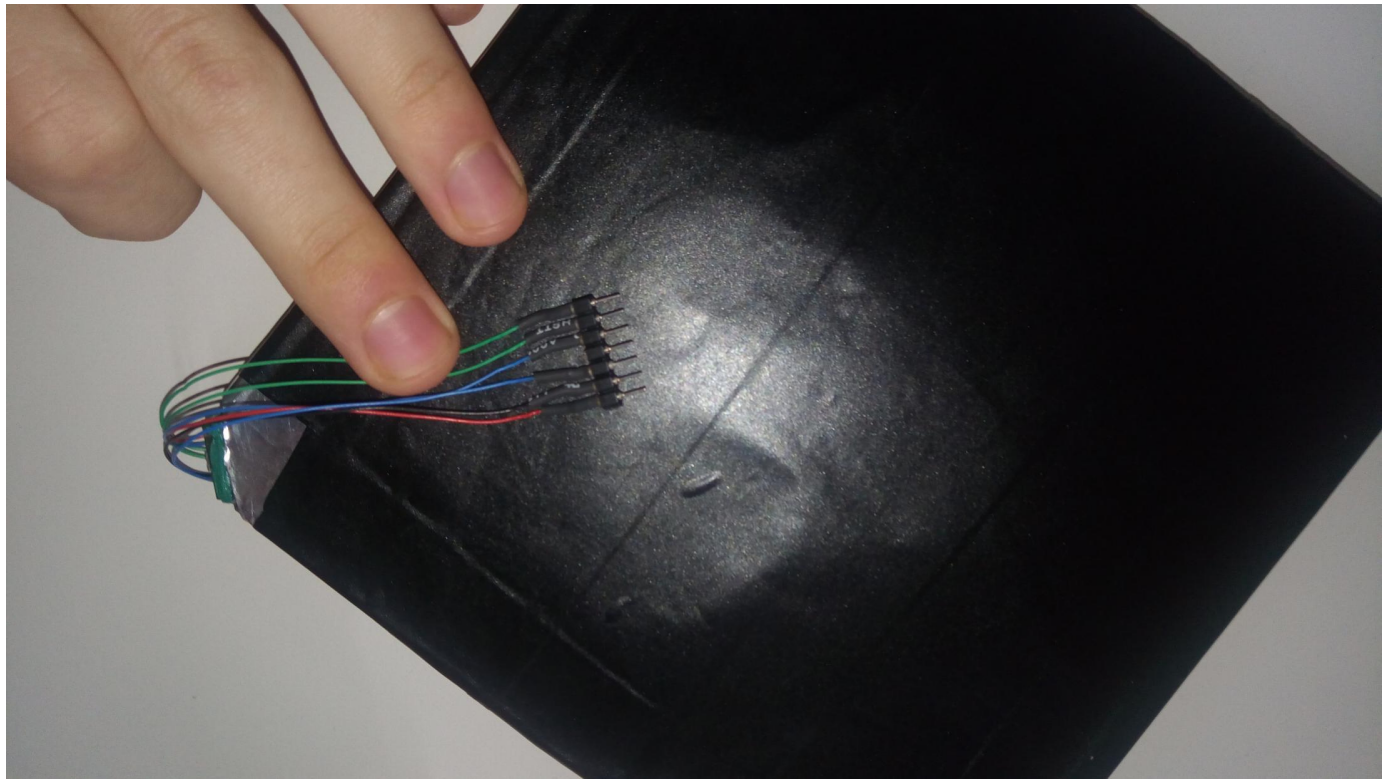
The mylar reflective coating

The CB construction

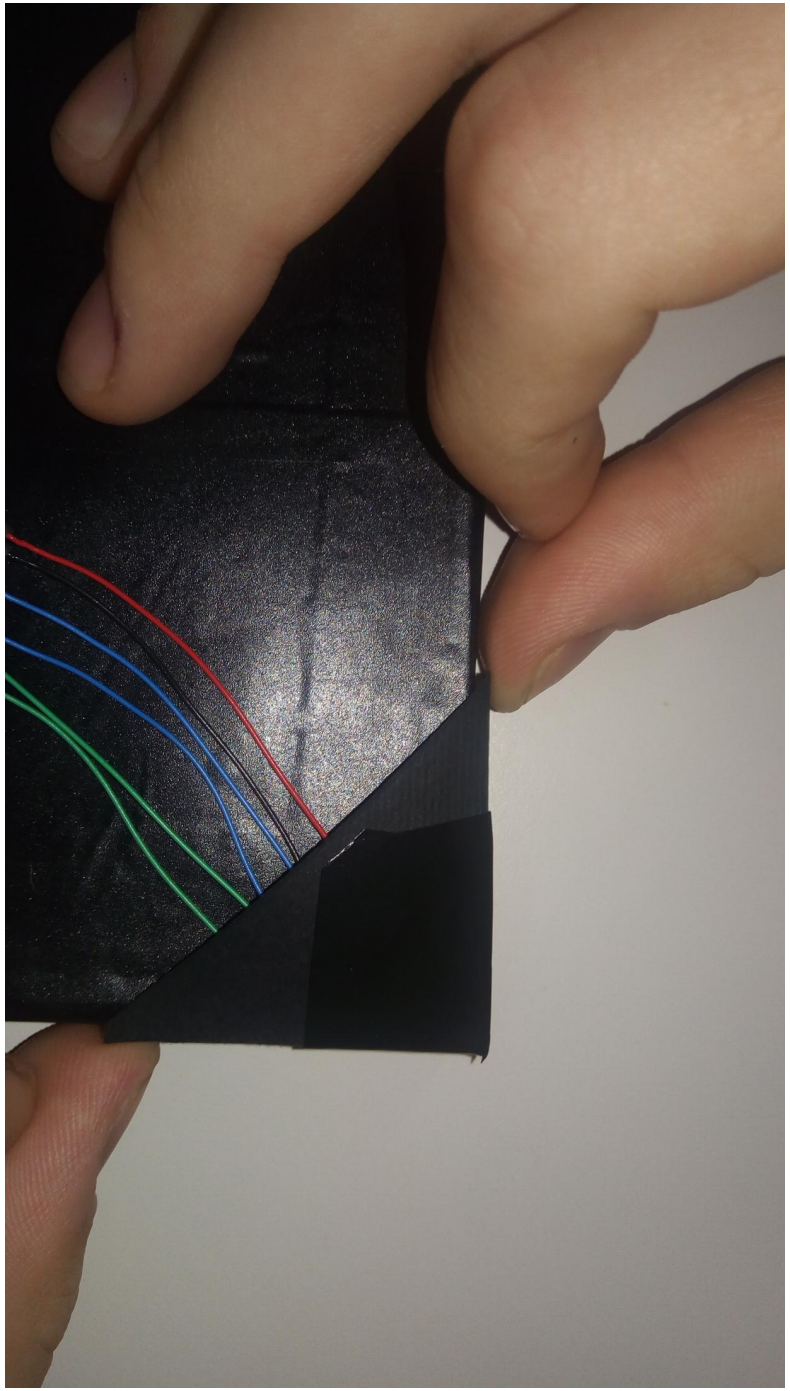


Closing the scintillator

The CB construction



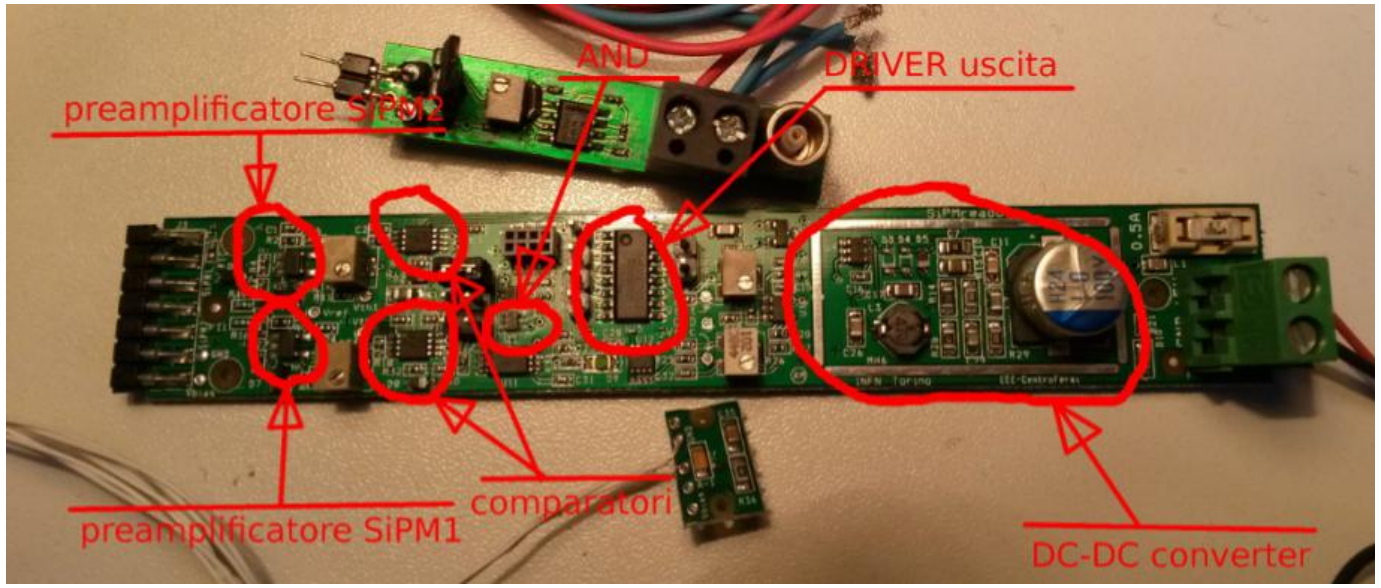
Closing the SiPM



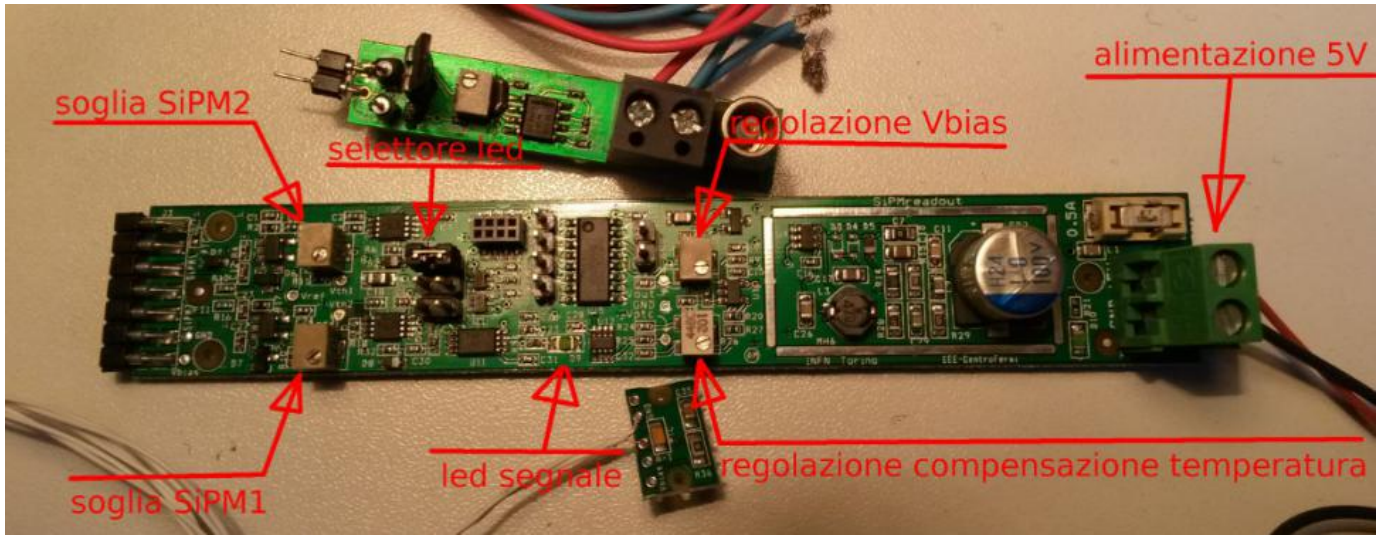
The CB construction

A scintillator
ready for calibration
!

The Front-End electronics

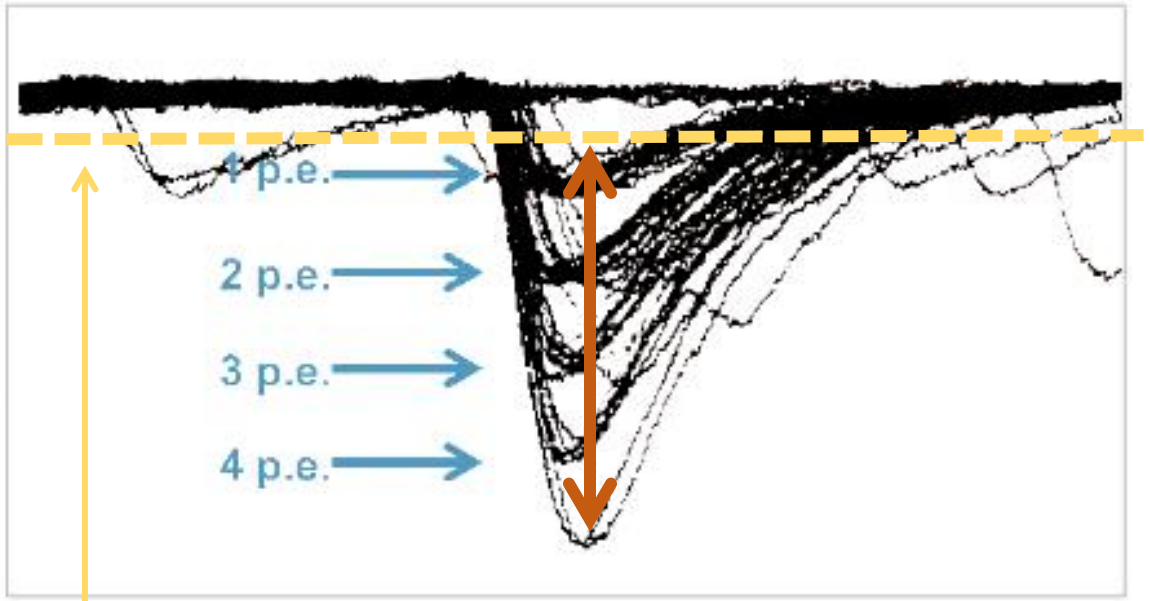


The 2 SiPM signals are **amplified** and **compared** with a reference **threshold**.



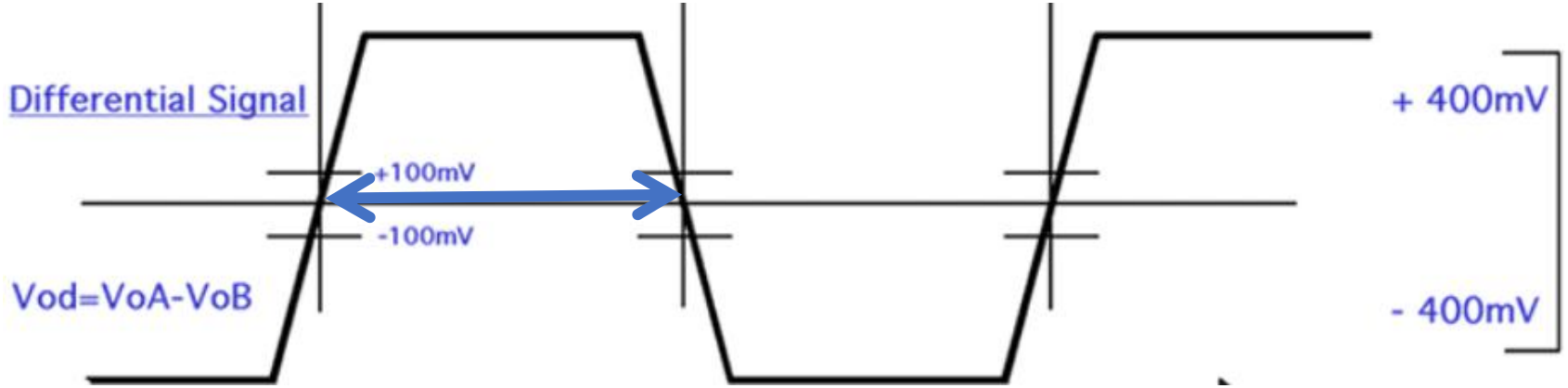
A **digital LVDS signal** is provided by the FE electronics **per each analog signal** from the SiPM (single SiPM or coincidence can be selected).

The Front-End electronics



The higher the analog signal

the wider the digital signal



The FE first calibration

The scintillator + FE
yields **false signals**
(not related with particles)
it's called **NOISE**.

The **threshold are adjusted** in order to have a **counting rate** per SiPM **higher than the expected** particle rate.

$\nu_{exp} \sim 170\ \mu/(s\ m^2) \cdot (0.15\ m)^2 \sim 3.8\ \mu/s$

The coincidence module: how to reduce false particle rate

$P(A \cap B) = P(A)P(B)$ uncorrelated

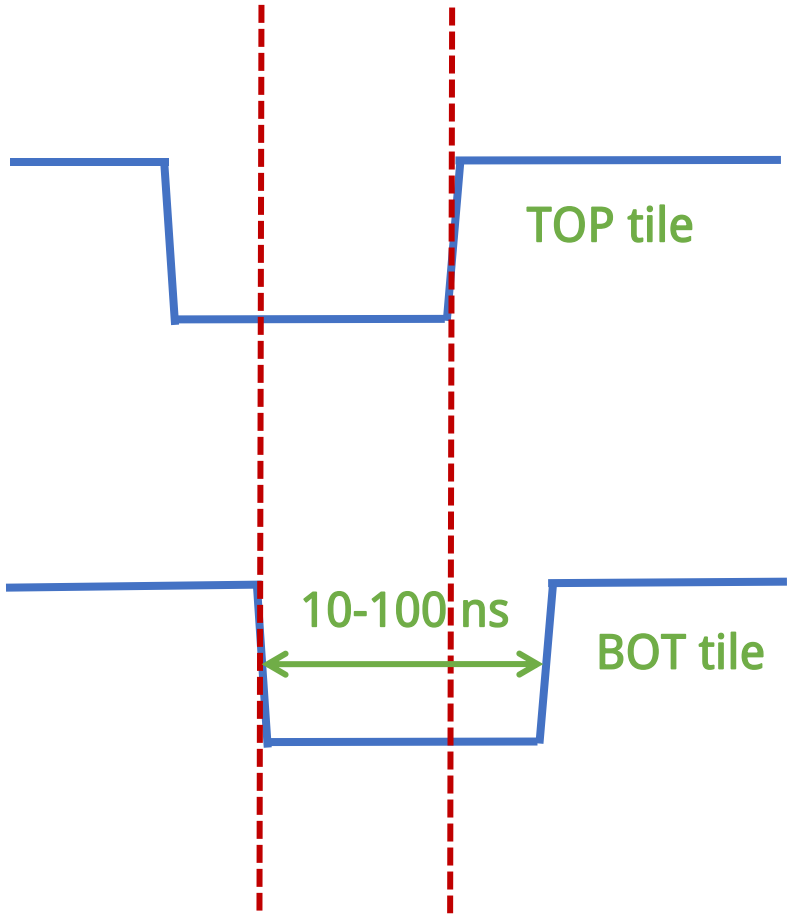
spurious signals in scintillator TOP in $\Delta T = \nu 1 \bullet \Delta T$
spurious signals in scintillator BOT in $\Delta T = \nu 2 \bullet \Delta T$

where $\nu 1$ and $\nu 2$ are spurious signal rate per scintillator

Rate of spurious coincidences:

$\nu(\text{false coincidences}) = 2 \bullet \nu 1 \bullet \nu 2 \bullet \Delta T^2 \sim 2 \bullet (10\ \text{Hz})^2 \bullet 10^{-7}\ \text{s} =$
$\sim 2 \cdot 10^{-5}\ \text{Hz}$

Exercise: since each scintillator tile is equipped with 2 SiPM, which is the real spurious rate for the CB detector?

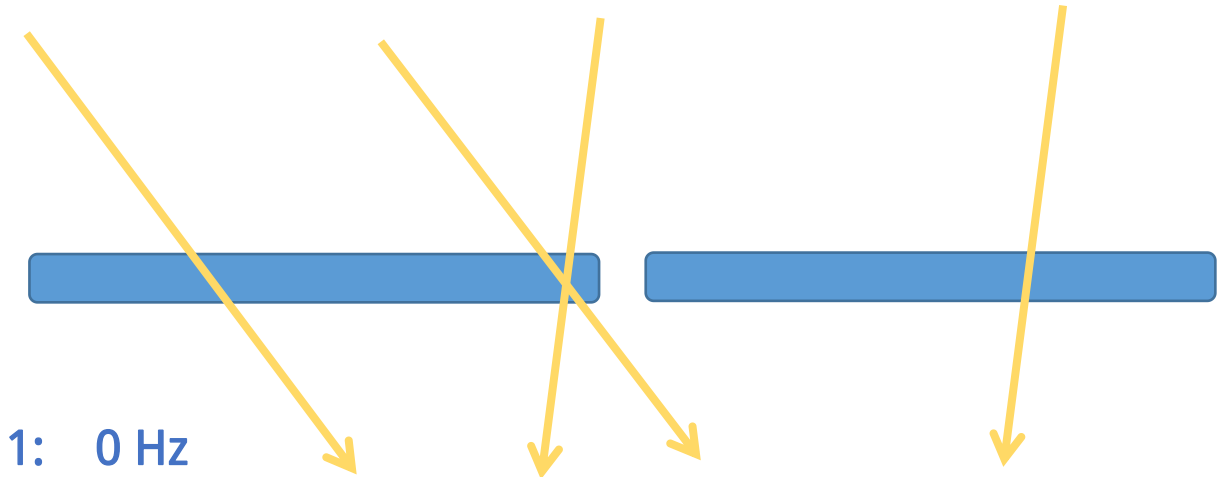


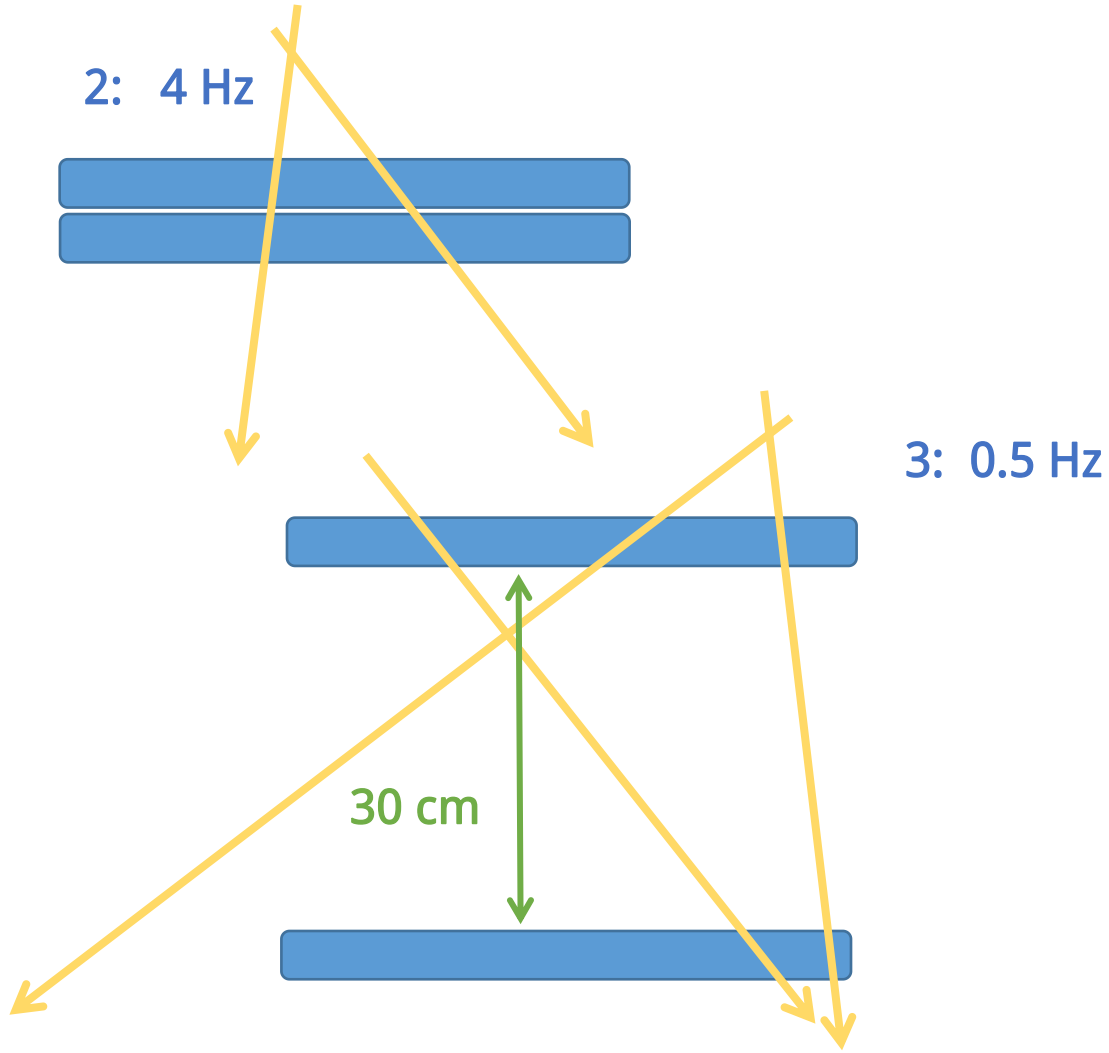
The Coincidence calibration

The 2 scintillators + the coincidence module

have been tested in 3 different configurations

for the final approval





The CB - how to operate

Powering the CB:

there are 2 power connectors:

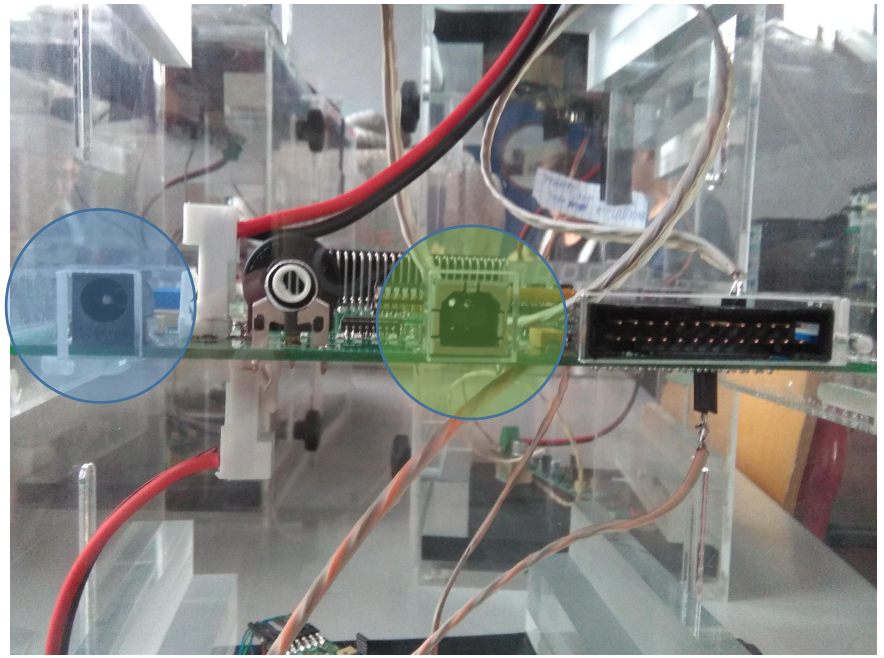
1. jack 5.5 mm

2. USB

both powered at 5 V

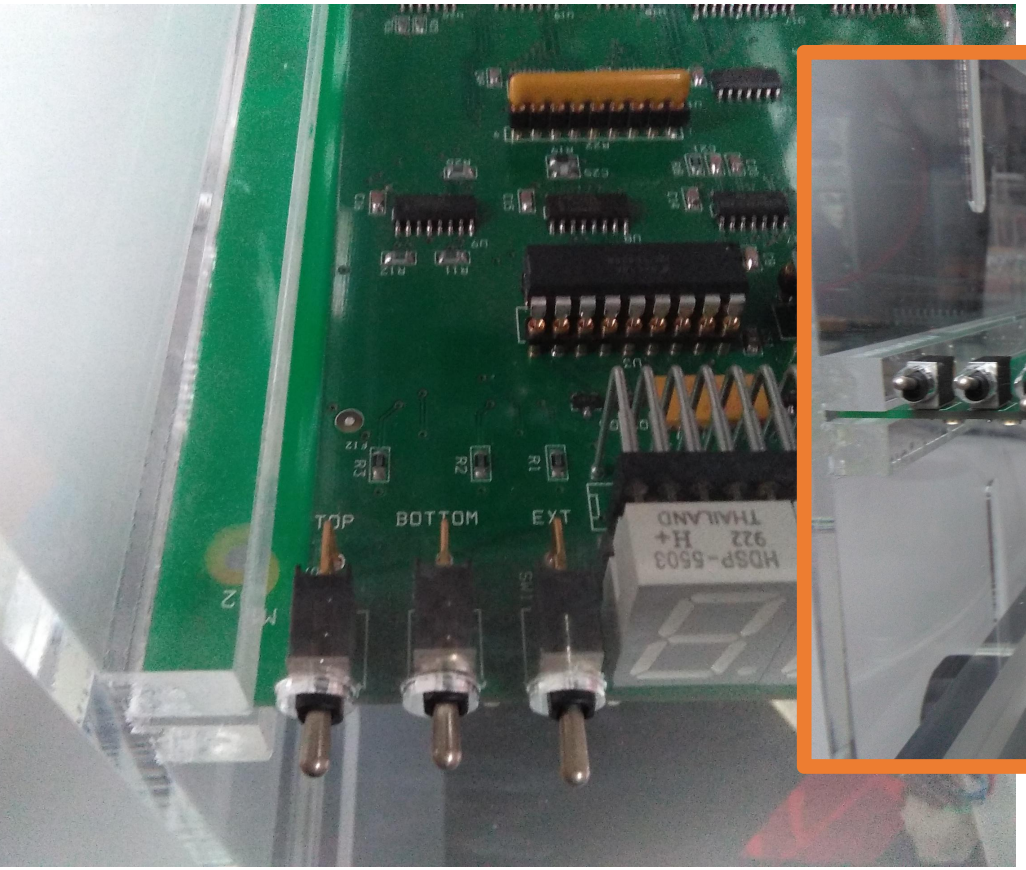
by a power bank

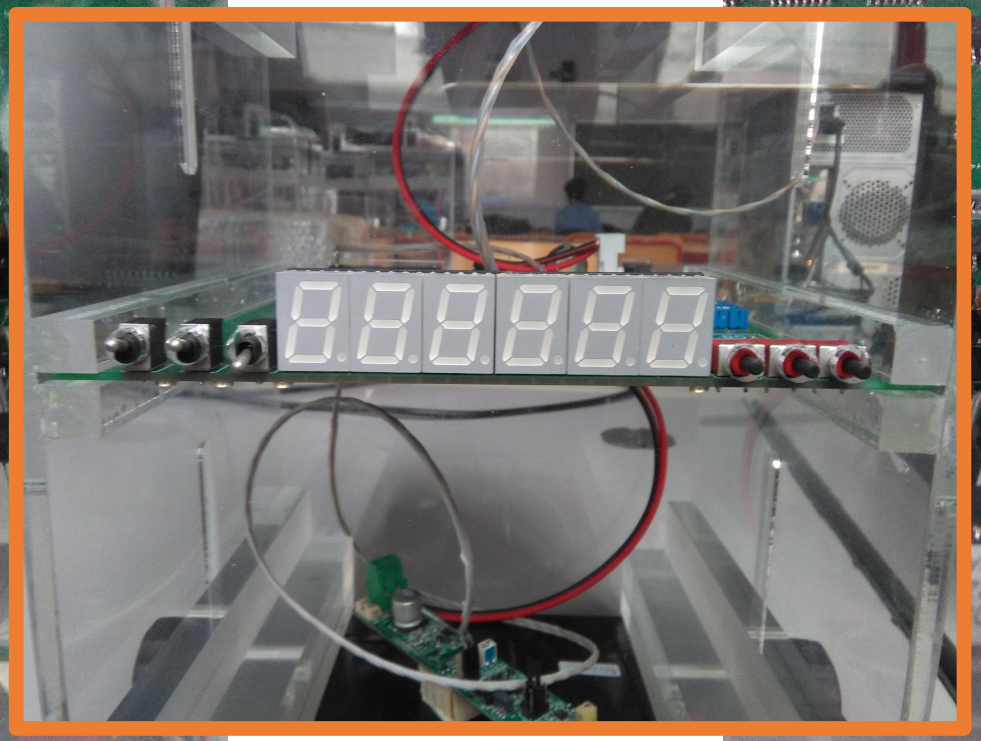
(but you can also use your laptop or the DCDC provided with the CB)

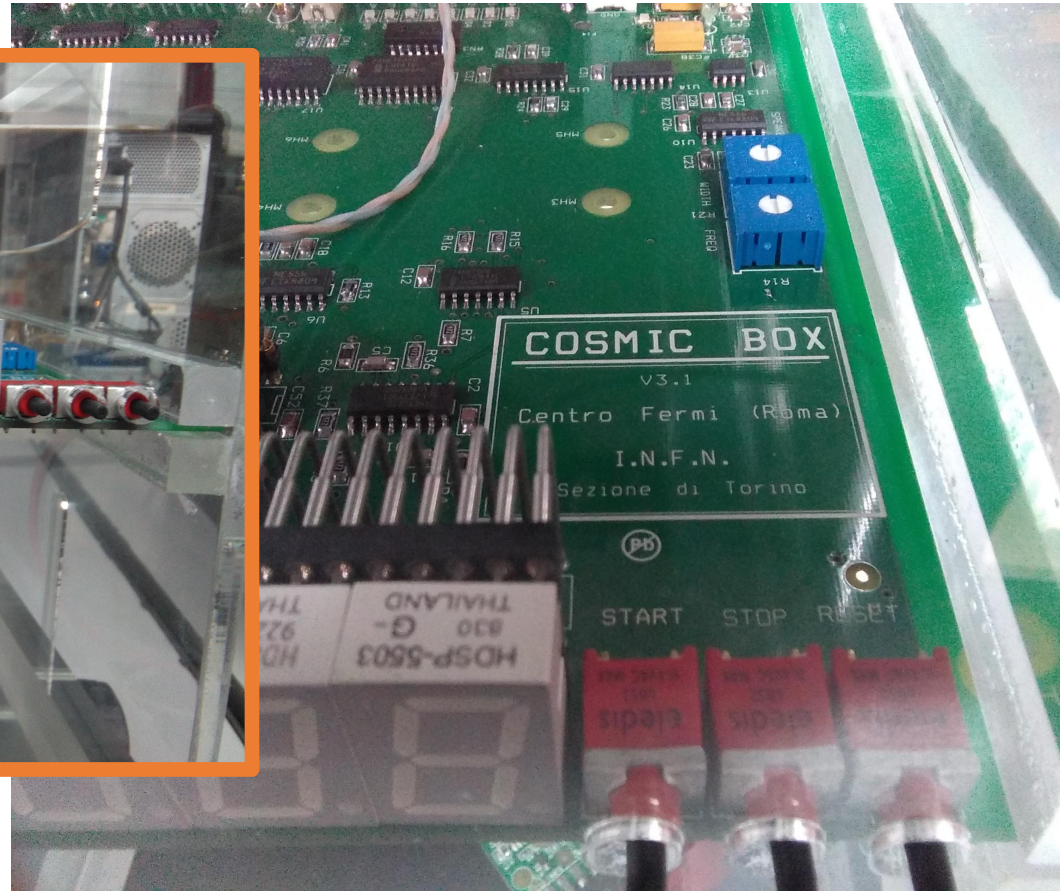


The CB - how to operate

Front buttons and display







Selectors for COINCIDENCE logic (UP means ON)

Start/Stop/Reset the counter

The CB - how to operate

Each CB has

a complete set of signals

available on the rear dual-in line connector:

TOP out signal

BOT out signal

EXT out signal

COINCIDENCE signal

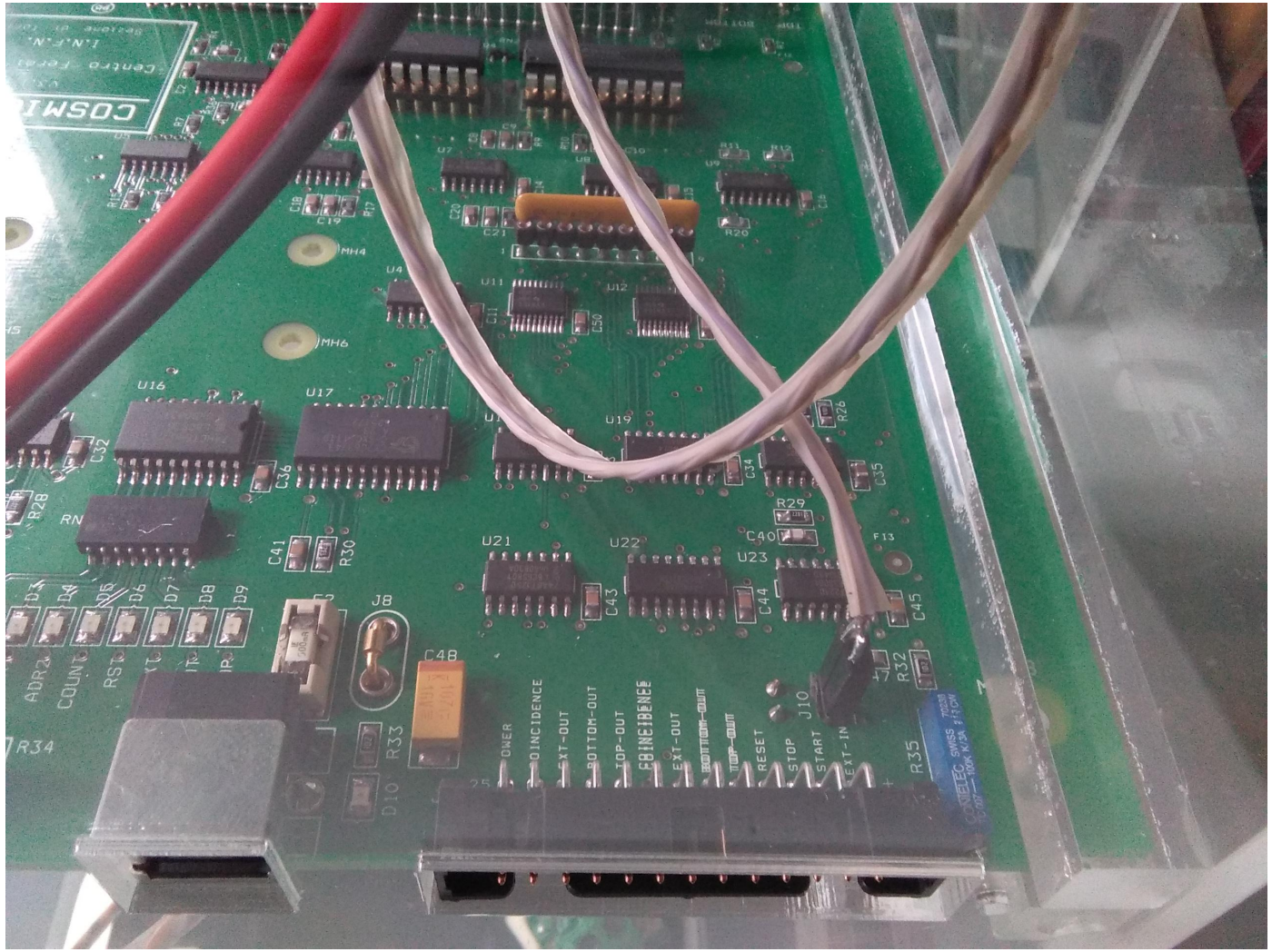
EXT in signal

START

STOP

RESET

thus can be operated by a dedicated PC



The CB - how to operate

The sunlight

The e.m. waves

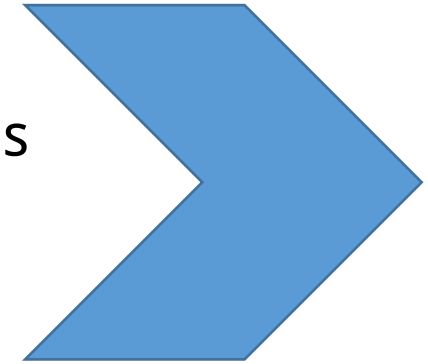
are NOISE sources

Before starting the measurement use the aluminum cover to protect the CB from external noise

The CB - how to operate

How to perform a measurement:

1. find a flat surface where laying your CB
2. check the acceptance of the CB is not shadowed by any building
3. power it
4. protect it with the cover
5. start the measurement



take note of:

a. counts

b. start and stop time (with 5 seconds max uncertainty)

c. pressure (at least 3 measurements during the count)

d. altitude (try several measurements with different mobiles using GPS)

Always take note of all the values!

Welcome to Physics!

A big THANK

to the students of the ITIS Amedeo Avogadro in Turin

to the EEE researchers

Carlo Avanzini
Federico Pilo
Fabrizio Coccetti
Stefano Grazzi

to the teachers and researchers of the EEE Torino group

Lorenzo Galante
Fabrizio Pusceddu
Tommaso Angileri
Maria Bonifati
Rita Guma
Antonietta Mastrocinque

Cosmic Box deliver to the groups

CB 1	Bari	Liceo Scientifico A. Scacchi
	Avellino	Liceo Scientifico P.S. Mancini
	Bra (CN)	Liceo Giolitti Gandino
CB 2	Bologna	Liceo Classico L. Galvani
	Caltanissetta	Liceo Scientifico Volta
	Rimini (Viserba di Rimini)	Liceo Statale "Alssandro Serpieri"
CB 3	Cariati (CS)	Liceo Scientifico Stefano Patrizi
	Treviso	Liceo Duca degli Abruzzi
	Roma	Liceo Scientifico Francesco D'Assisi
CB 4	Torino	Liceo Scientifico A. Volta
	Catania	ITI Marconi
	Vicenza	Liceo Scientifico Quadri

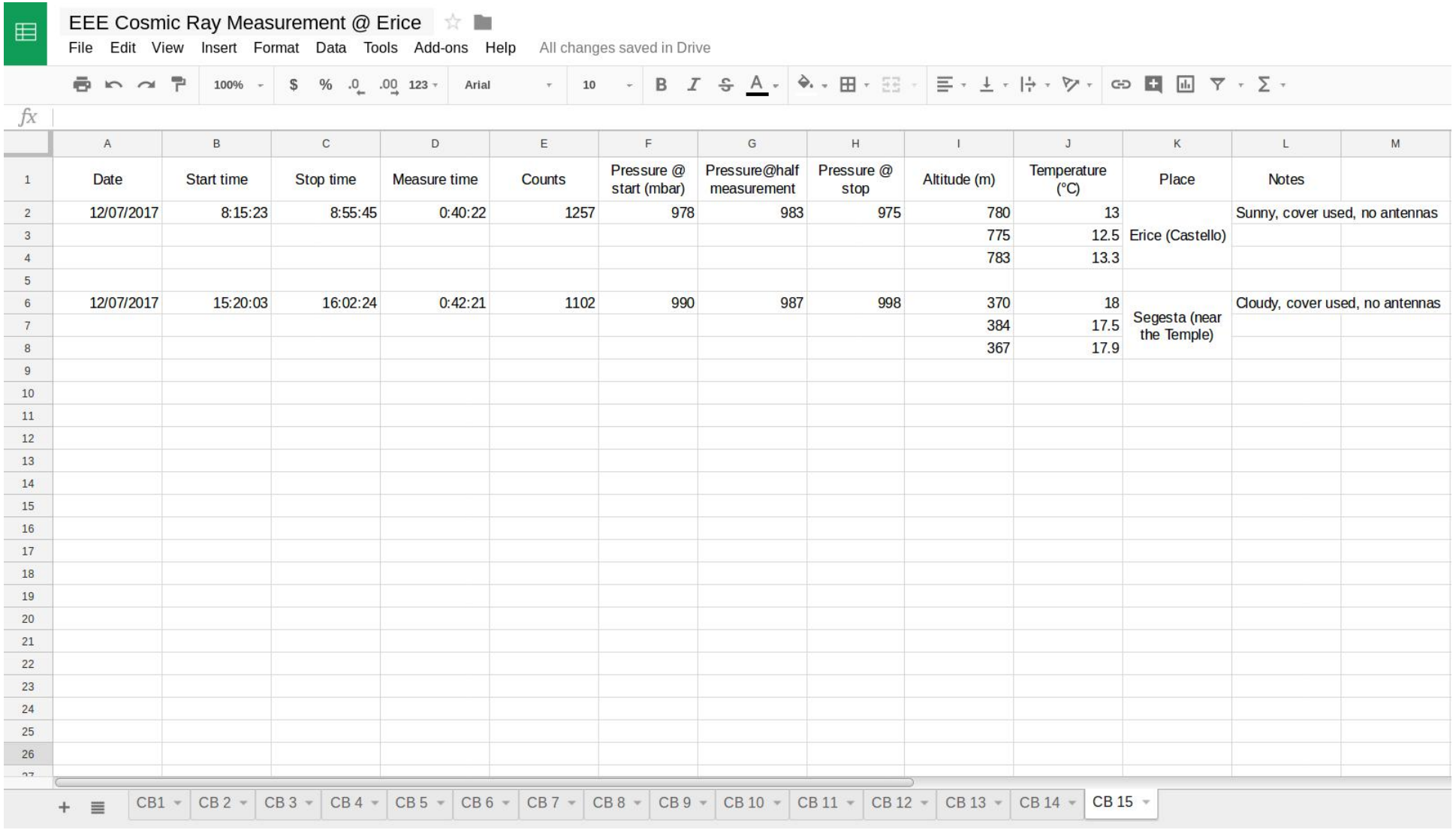
CB 5	Lecce	Liceo Classico Palmieri
	Colleferro (RM)	ITI Cannizzaro
	Recco/Rapallo	IIS Giovanni da Vigo Recco - Nicoloso da Recco
CB 6	Frascati (RM)	ITT Fermi
	Trento	Liceo Scientifico Leonardo da Vinci
	Trinitapoli (BAT)	IISS S. Staffa
CB 7	Salerno	Liceo Scientifico G. Da Procida
	Roma	Liceo Scientifico Righi
	Torino	IIS Einstein
CB 8	Siena	IIS Sarrocchi
	Torino	Liceo Scientifico Gobetti Segrè

Cosmic Box deliver to the groups

CB 9	Cagliari	Liceo Scientifico Michelangelo
	Maglie (LE)	Liceo Scientifico Leonardo da Vinci
	Codogno (LO)	Liceo G. Novello
CB 10	Cagliari	Liceo Scientifico A. Pacinotti
	Gardone V.T. (BS)	IIS Carlo Beretta
	Trento	Liceo Classico Prati
CB 11	Carcare (SV)	Liceo Giuseppe Calasanzio
	Catania	ITIS S.Cannizzaro
	Roma	Liceo Classico P. Albertelli
CB 12	Catanzaro	IIS E. Fermi
	Iseo (BS)	IIS Giacomo Antonietti
	Livorno	Liceo Scientifico Enriques

CB 13	Paternò (CT)	Liceo Scientifico E. Fermi
	Fermo	Liceo Scientifico Temistocle Onesti
	Torino	Liceo Scientifico G. Ferraris
CB 14	San Benedetto del Tronto (AP)	Liceo Scientifico Rosetti
	Piacenza	Liceo Scientifico Respighi
	Viareggio (LU)	Liceo Scientifico Barsanti e Matteucci
CB 15	Savona	Liceo Classico Chiabrera - Martini
	Viareggio (LU)	IIS Galilei - Artiglio
	Lampedusa e Linosa (AG)	Istituto Luigi Pirandello - Liceo scientifico Majorana

A GoogleSheet
for the data sharing, collection and analysis



EEE Cosmic Ray Measurement @ Erice

File Edit View Insert Format Data Tools Add-ons Help All changes saved in Drive

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Date	Start time	Stop time	Measure time	Counts	Pressure @ start (mbar)	Pressure@half measurement	Pressure @ stop	Altitude (m)	Temperature (°C)	Place	Notes	
2	12/07/2017	8:15:23	8:55:45	0:40:22	1257	978	983	975	780	13		Sunny, cover used, no antennas	
3									775	12.5	Erice (Castello)		
4									783	13.3			
5													
6	12/07/2017	15:20:03	16:02:24	0:42:21	1102	990	987	998	370	18		Cloudy, cover used, no antennas	
7									384	17.5	Segesta (near the Temple)		
8									367	17.9			

CB1 CB 2 CB 3 CB 4 CB 5 CB 6 CB 7 CB 8 CB 9 CB 10 CB 11 CB 12 CB 13 CB 14 CB 15