The Cosmic Box contest

a (not so) short **introduction**

to the **portable particle detector**

you're going to **set up**

for **your** original experiment!

Why a EEE - CB ?

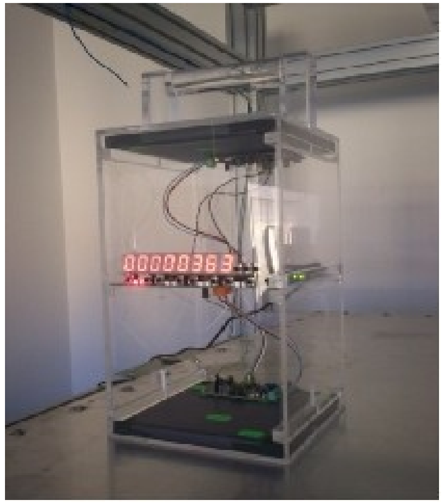
In the early EEE times

the CB

was thought for

- measuring the **efficiency** of the **Alice ToF MRPCs** and later **EEE MRPCs**

- allowing several **didactical measurements** about Cosmic Ray



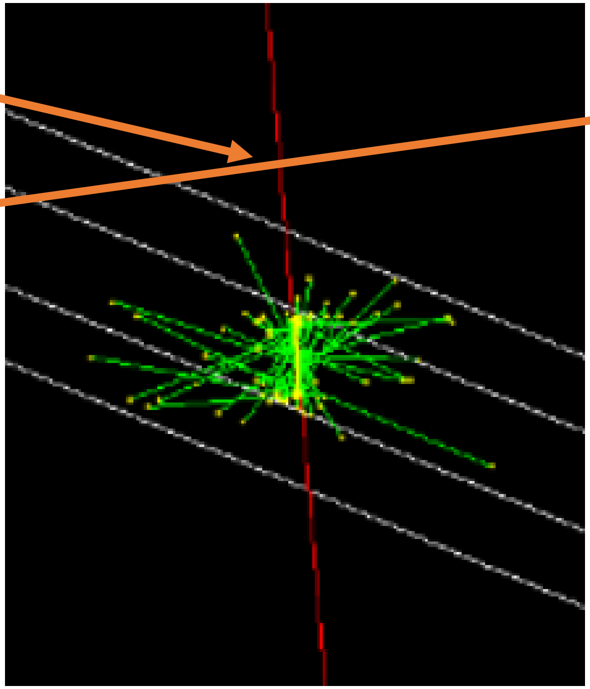
How does a scintillator work ?

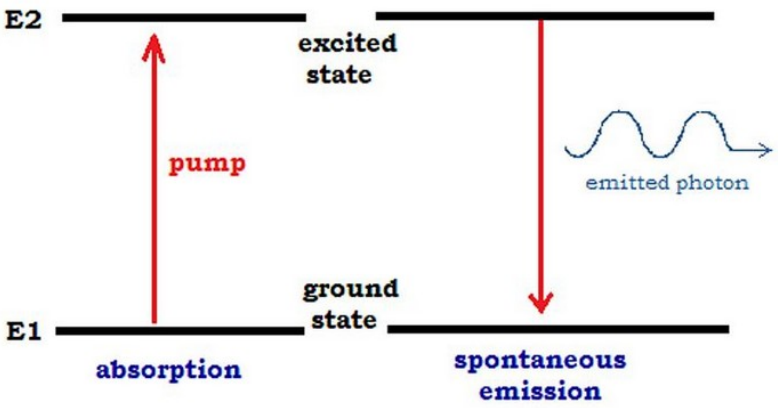
A scintillator emits photons

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

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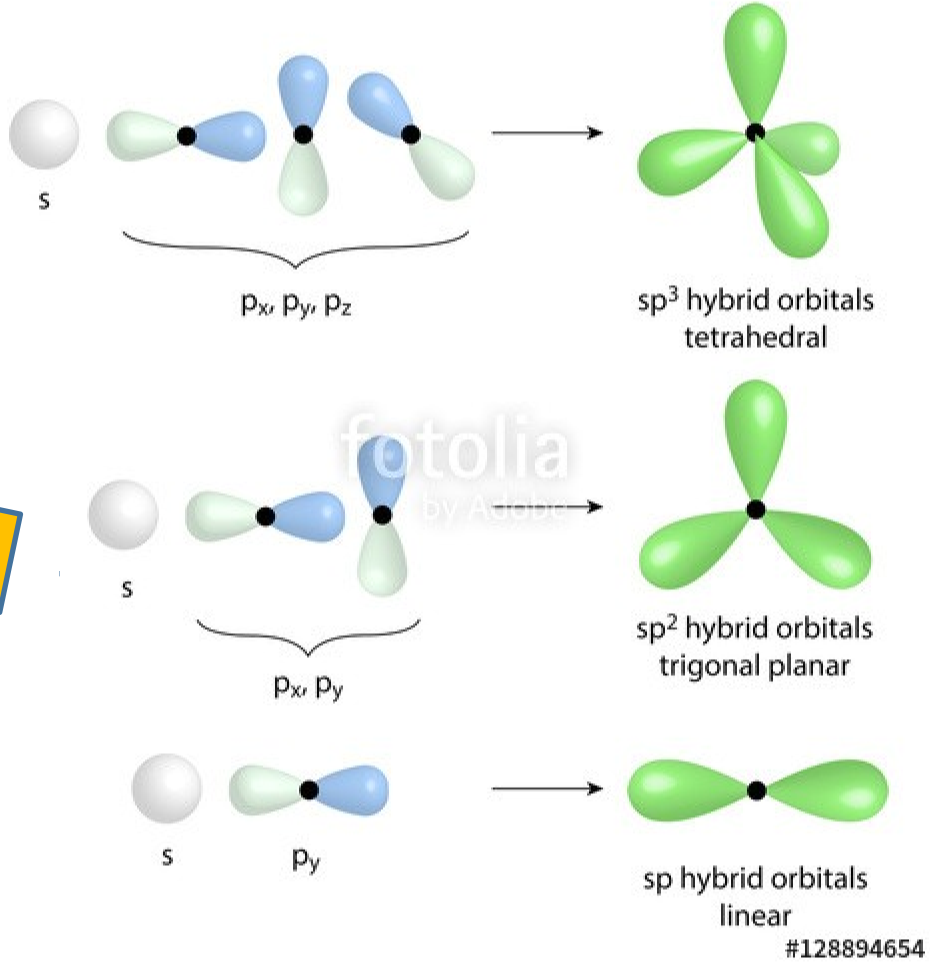


How does the light is collected ?

The surface of the scintillator is usually

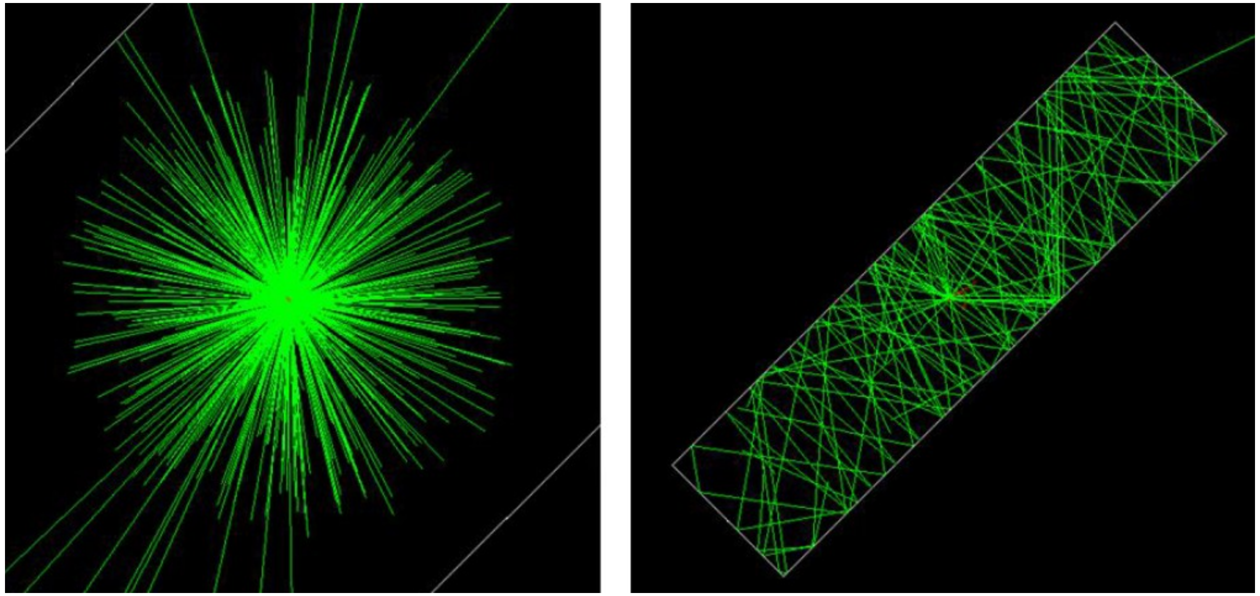
- painted

with reflective coating

- wrapped

with a reflective film

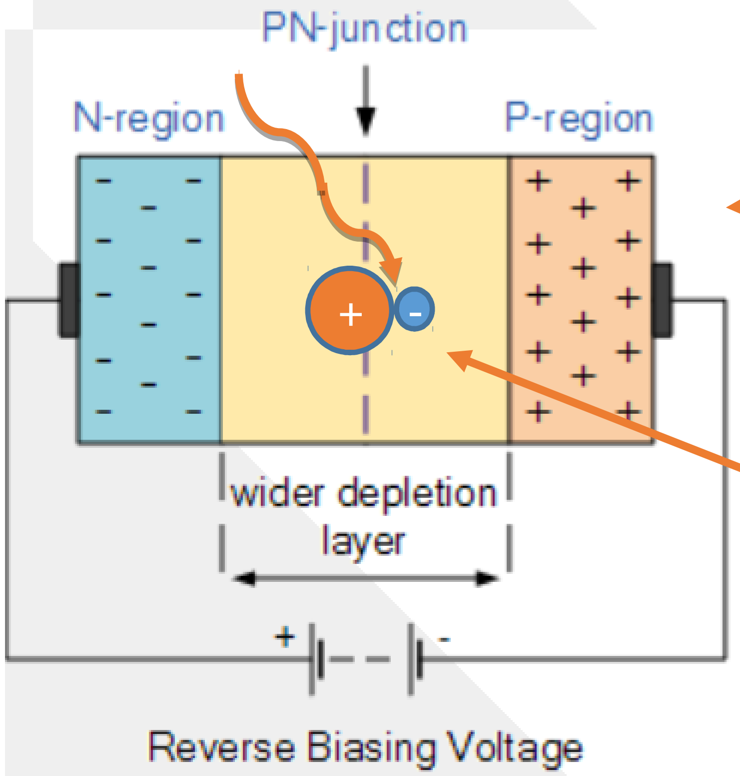
Thus **10-50%** of the emitted **light is "confined"** into the scintillator volume



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

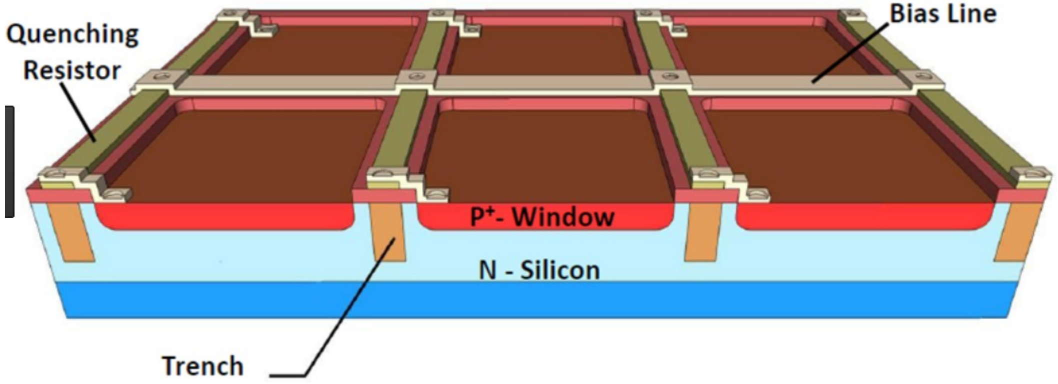
in the depletion region

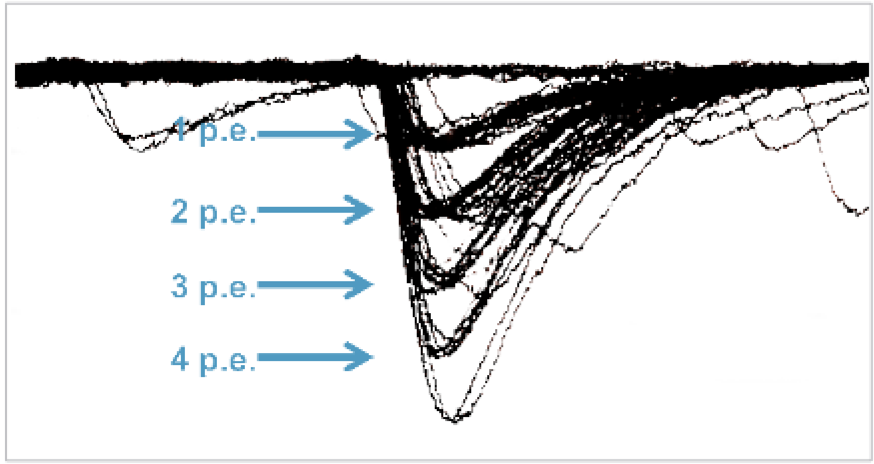
the strong electric field

brings to

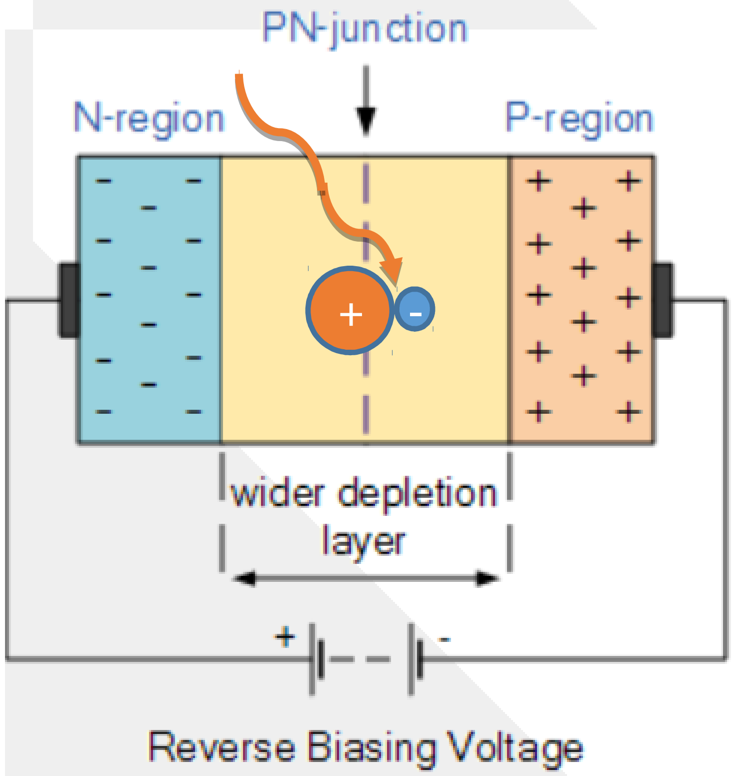
a **short and amplified**

electric pulse

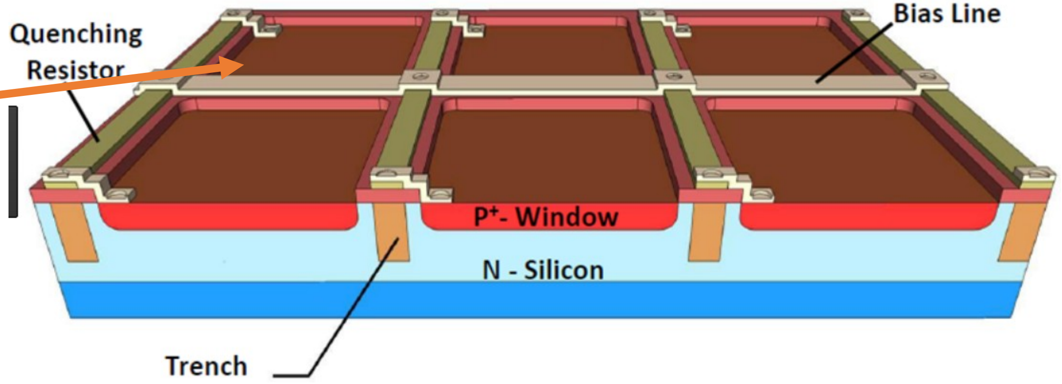




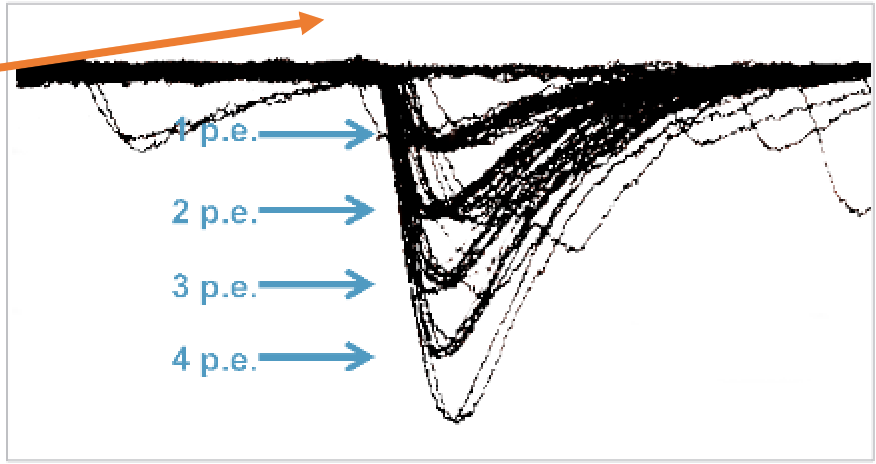
The Silicon Photomultiplier: a light amplifier



The SiPM is segmented into **little pads 10-30 µm**



the gain is **10^5-10^6**!



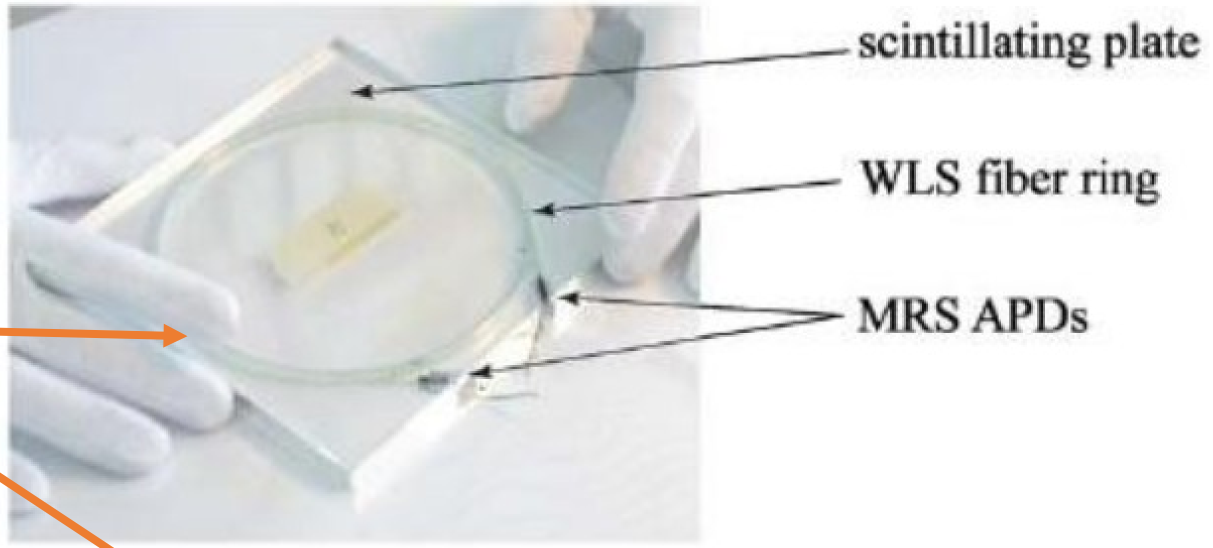
It is able to detect even a **single photon**! (sunlight is 10^{20}-10^{21} photon/s)

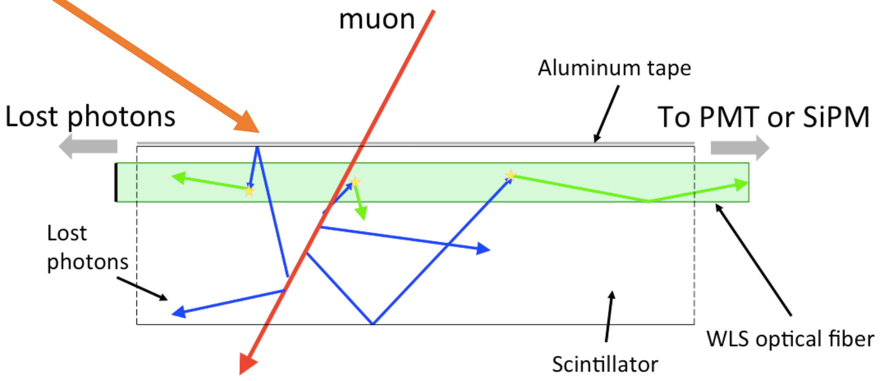
Coupling the SiPM to the scintillator

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

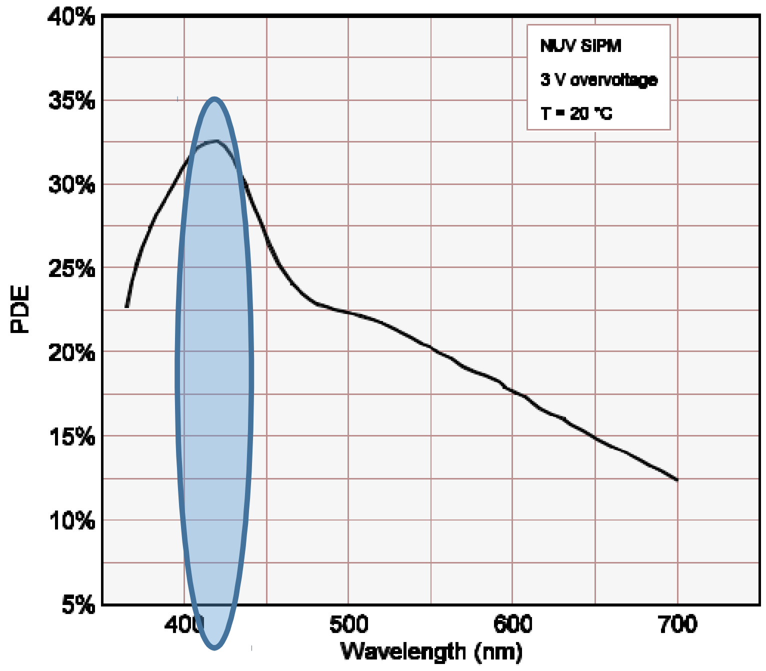
1. with wavelenght shifter:

"shift" the light emitted by the scintillator to the best frequency for SiPM

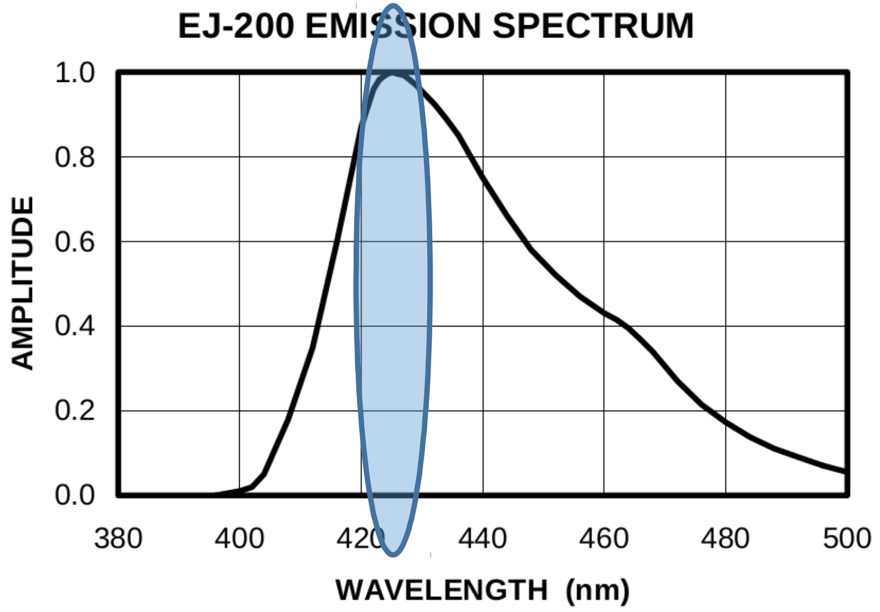
2. last CB versions:

both **scintillator** and **SiPM** are tuned on **Near UV light**

SiPM

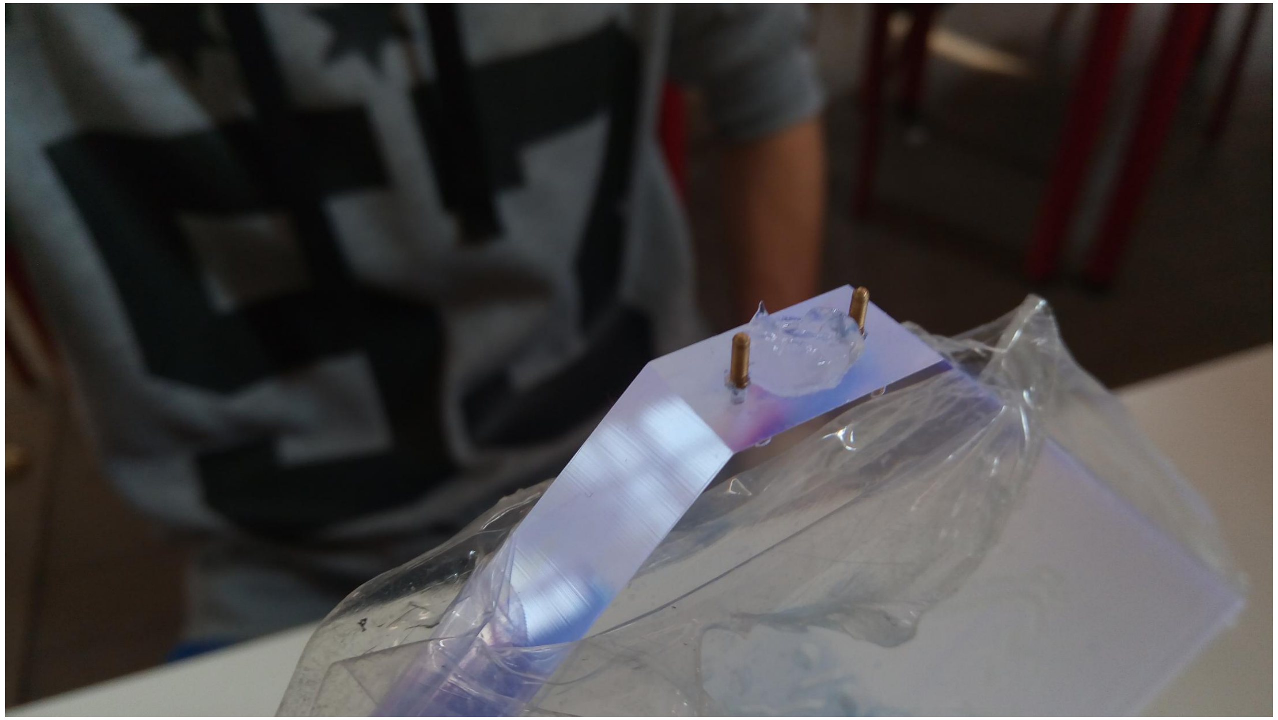


Scintillator



The CB construction

The **optical grease**



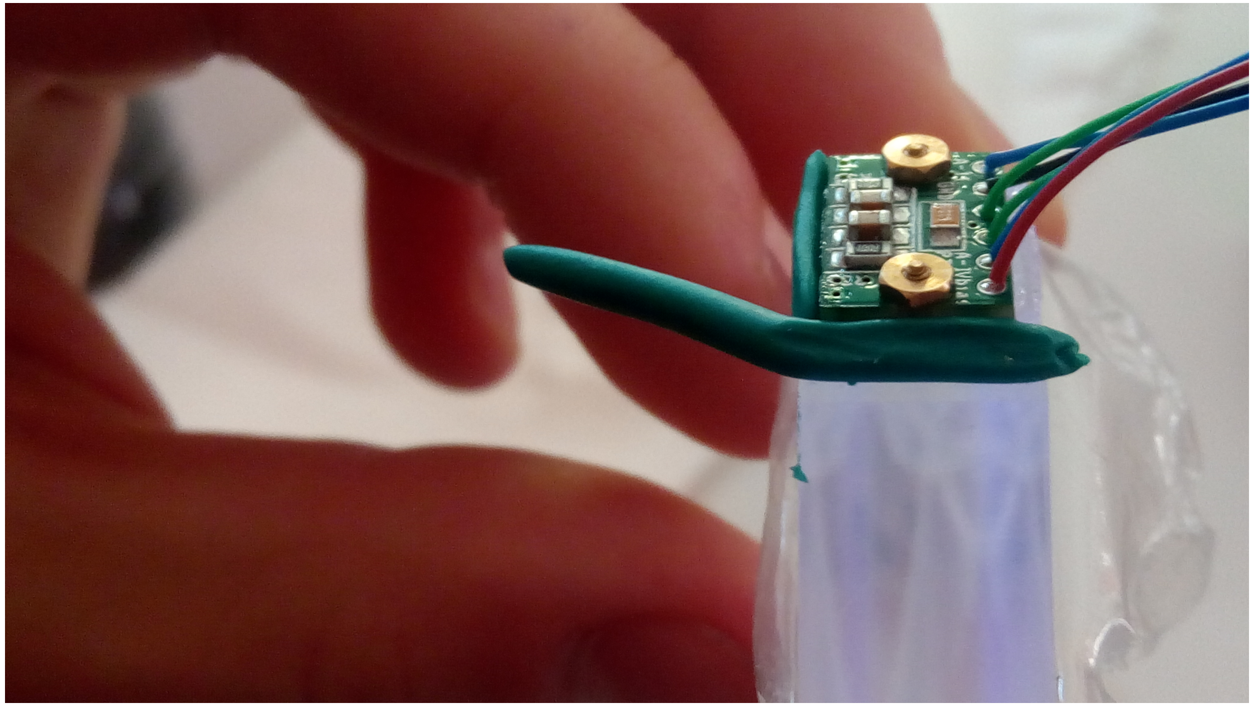
... for the **light coupling**
between scintillator and SiPM

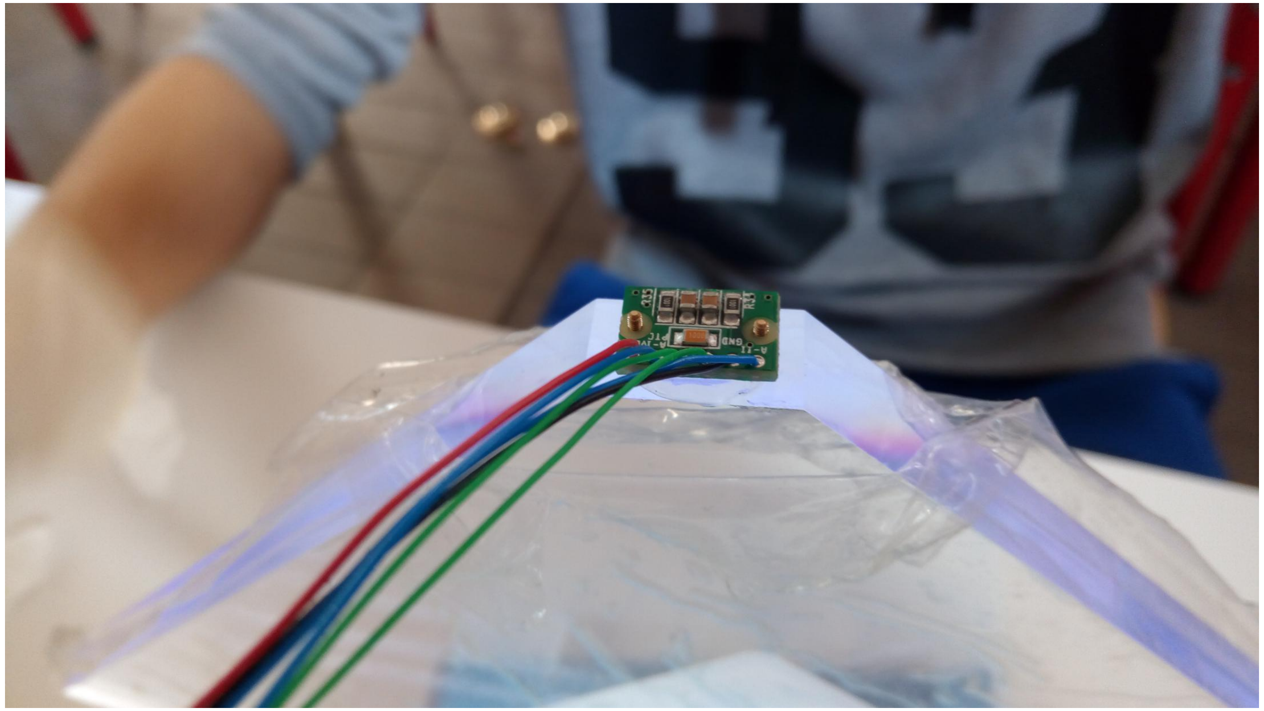
The CB construction

The **SiPM on the scintillator:**

2 SiPMs per scintillator tile are installed

for reducing the **noise** (see later)

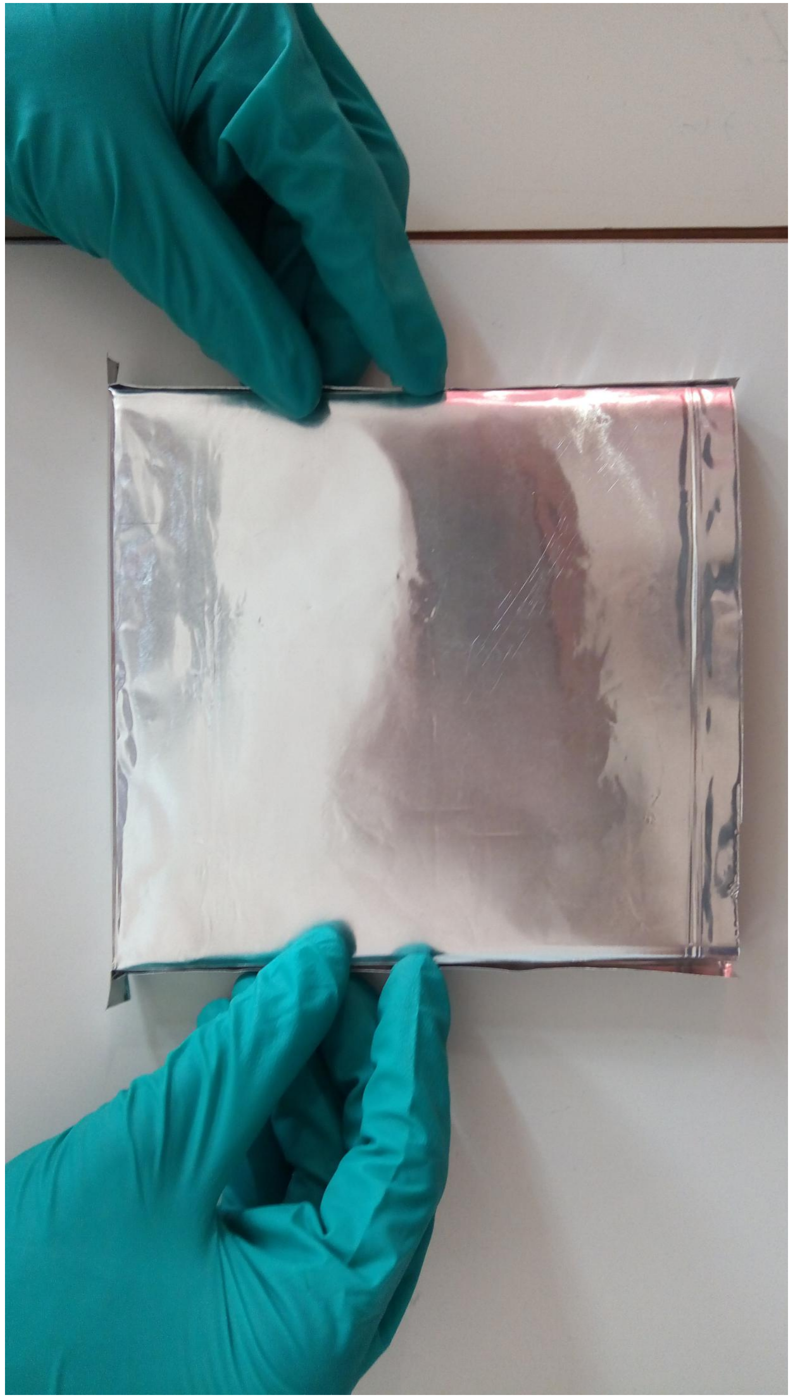


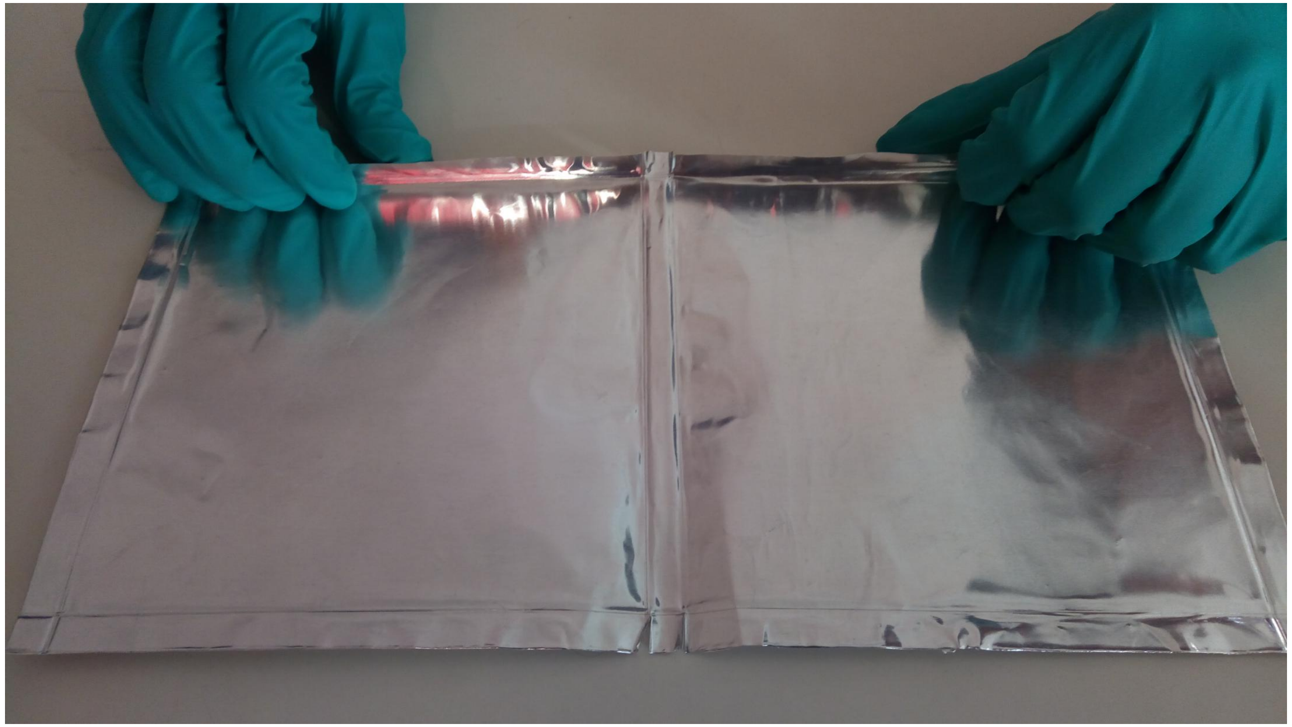


modeling clay for

keeping out the light

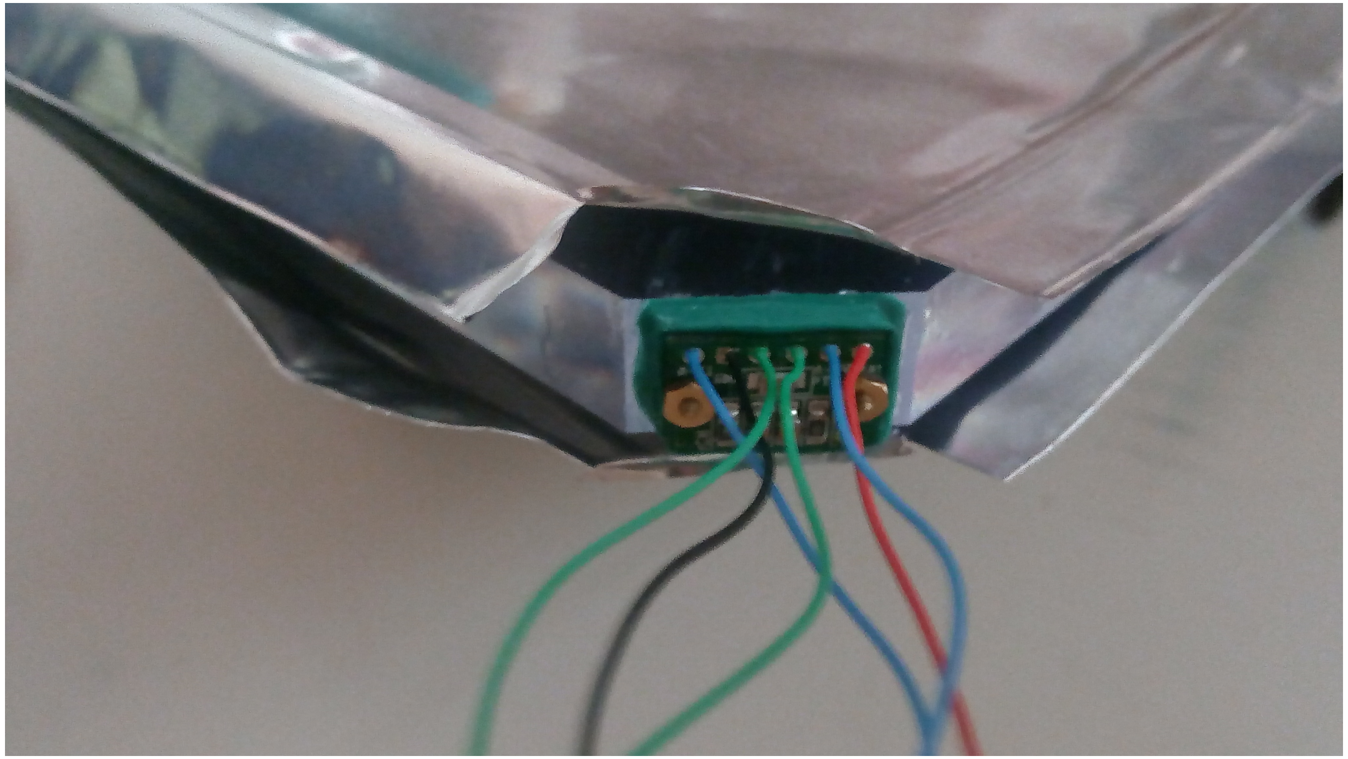
The CB construction





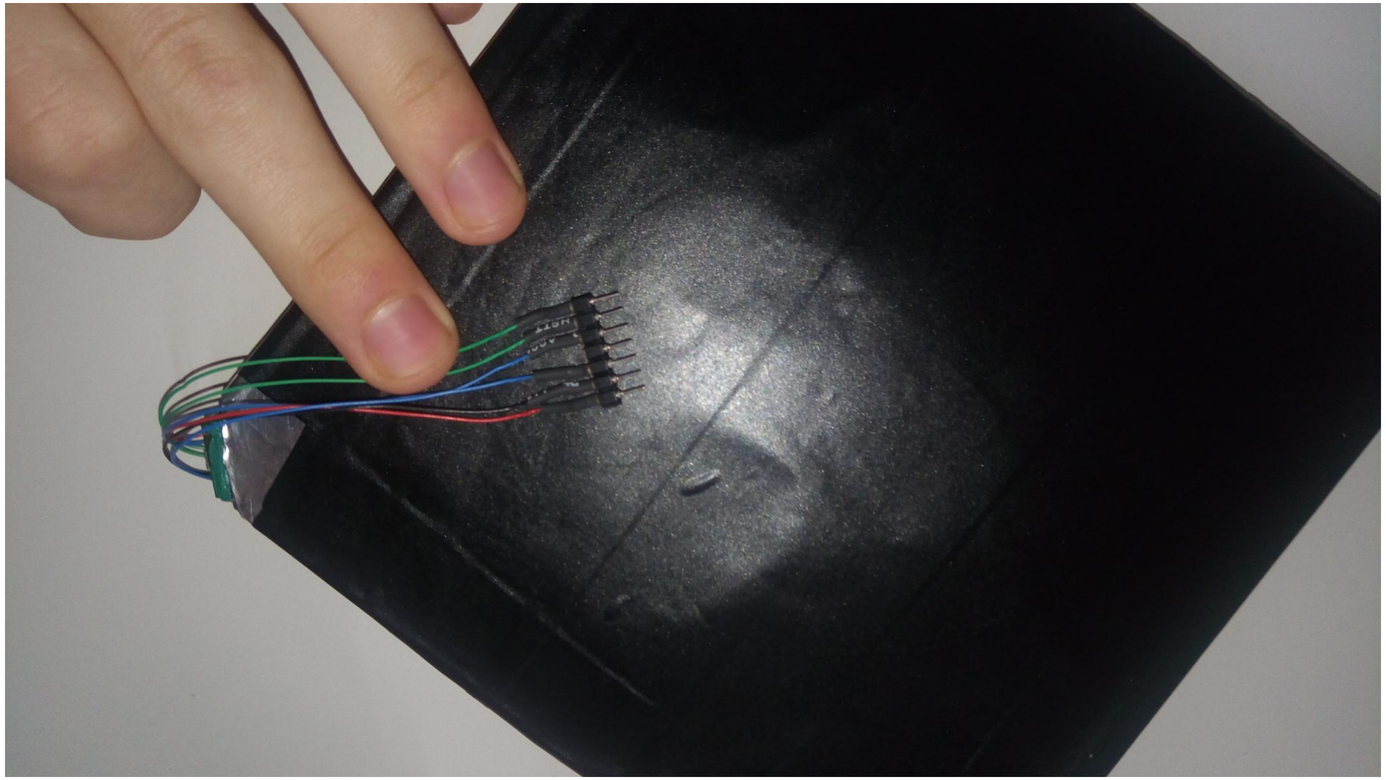
The **mylar reflective coating**

The CB construction

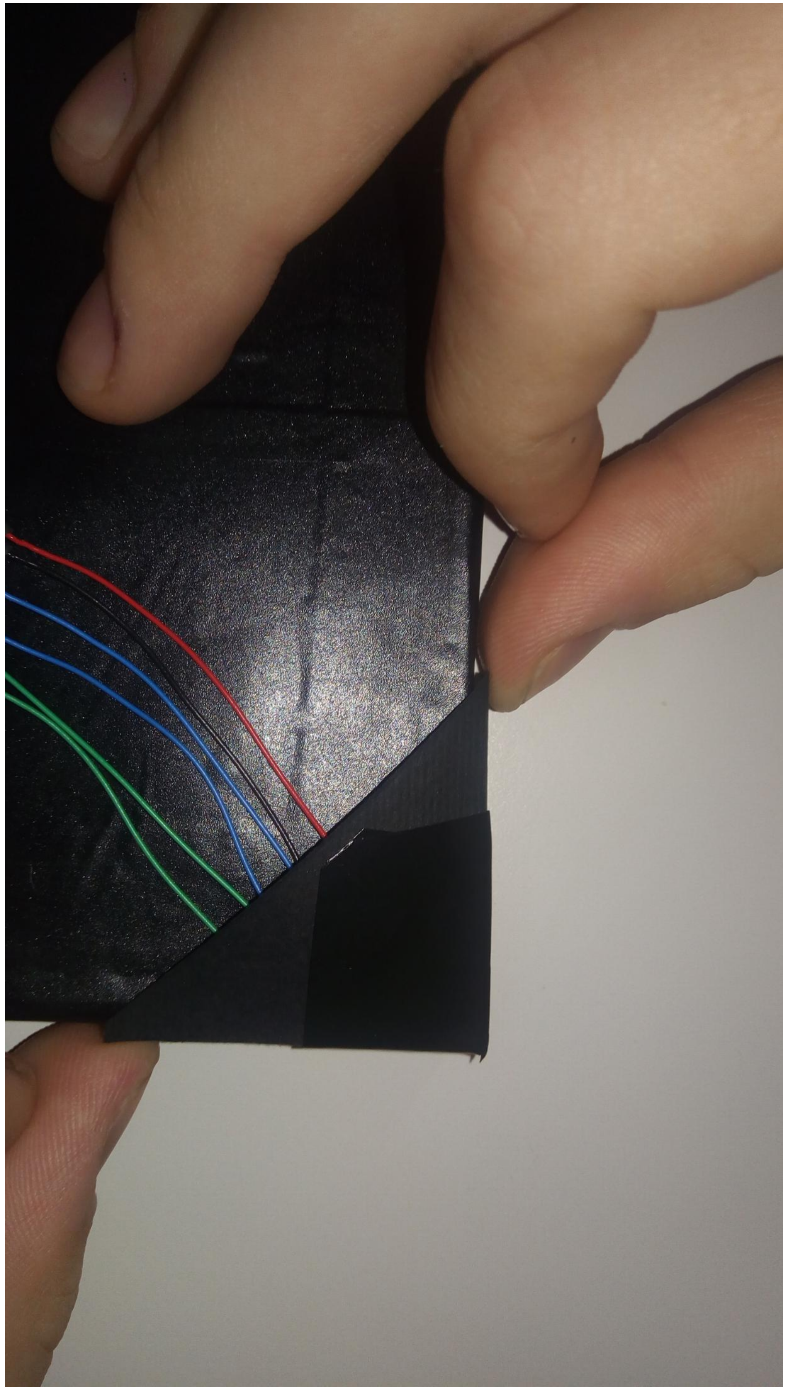


Closing the scintillator

The CB construction



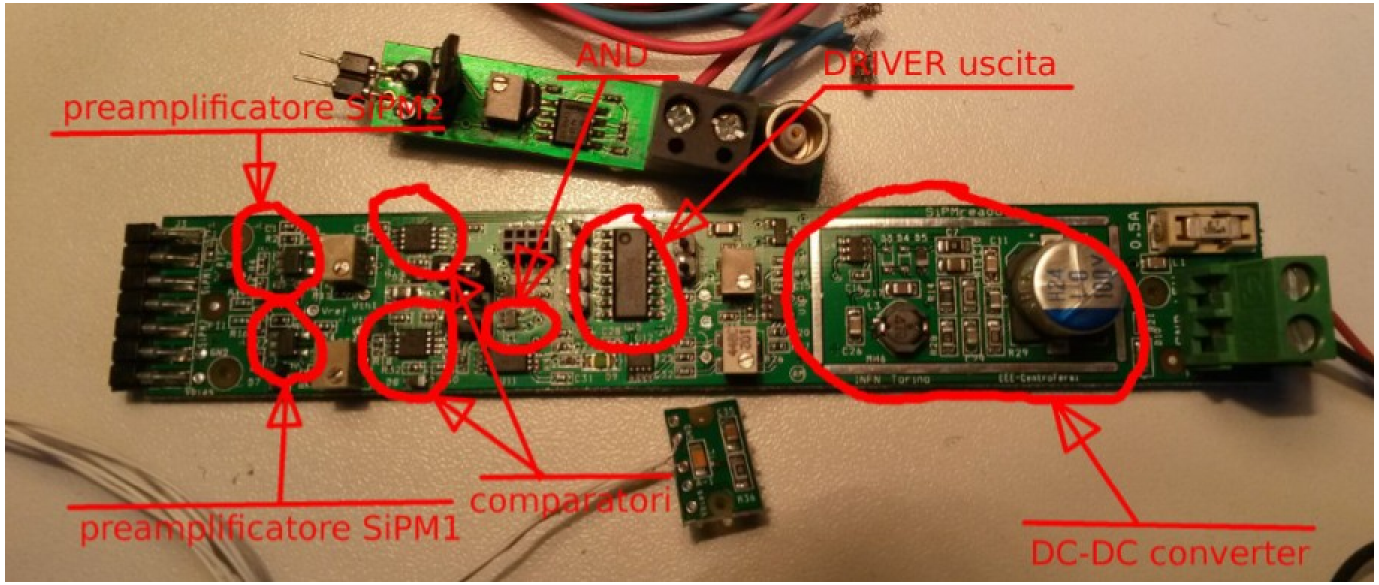
Closing the SiPM

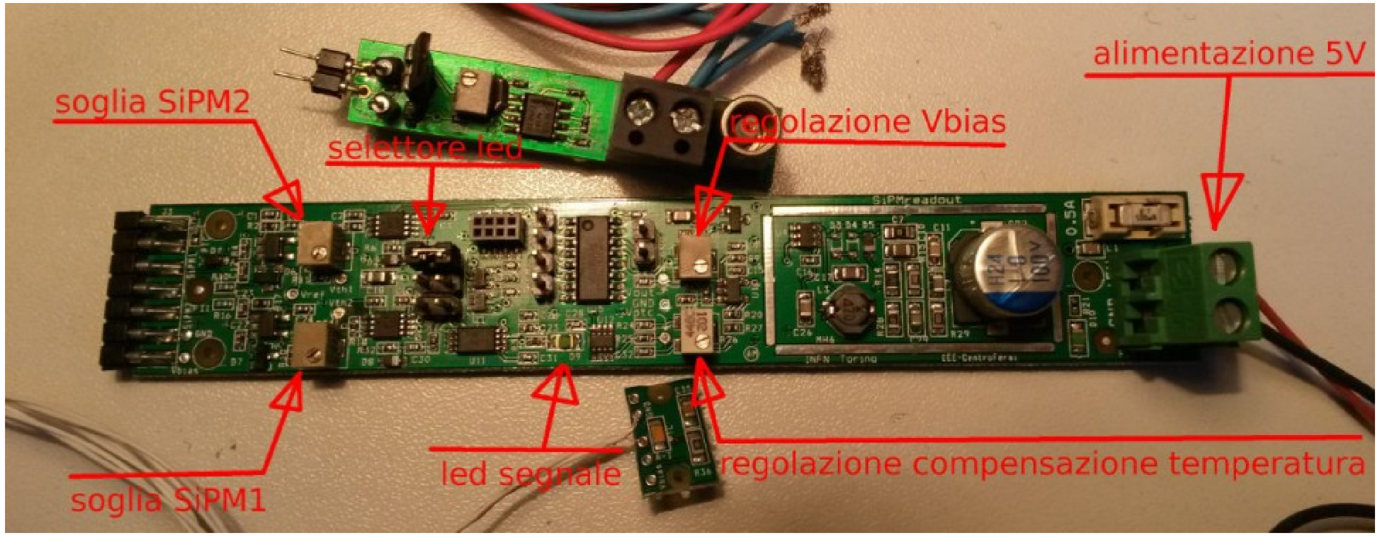


The CB construction

A scintillator
ready for calibration
!

The Front End electronics

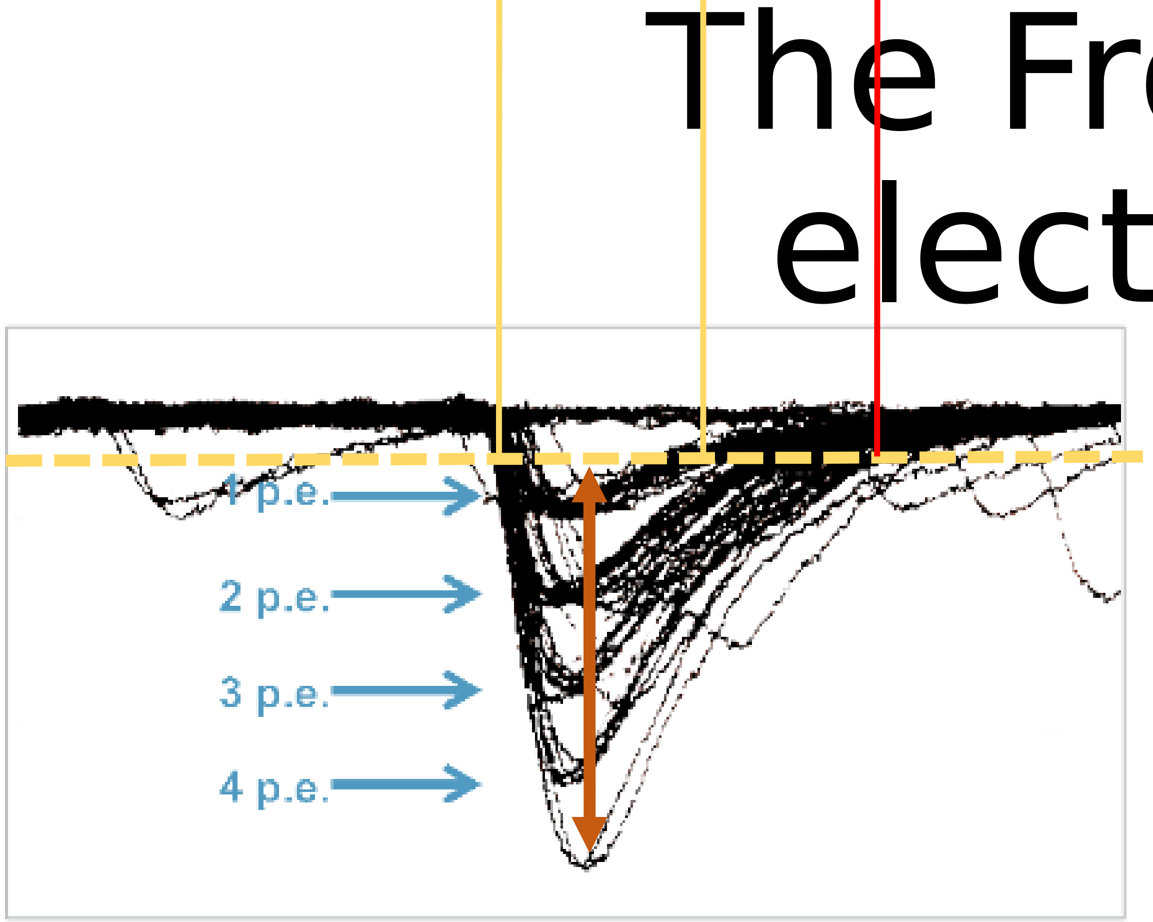




The 2 SiPM signals are **amplified** and **compared** with a reference **threshold**.

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

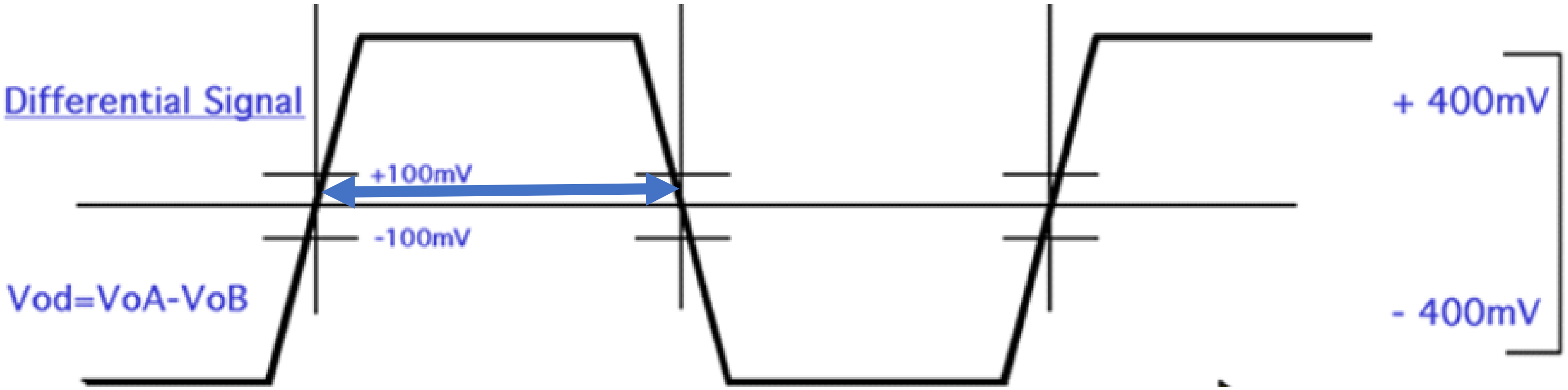
The Front-End electronics



The **higher the analog** signal

the **wider the digital** signal

threshold



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

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

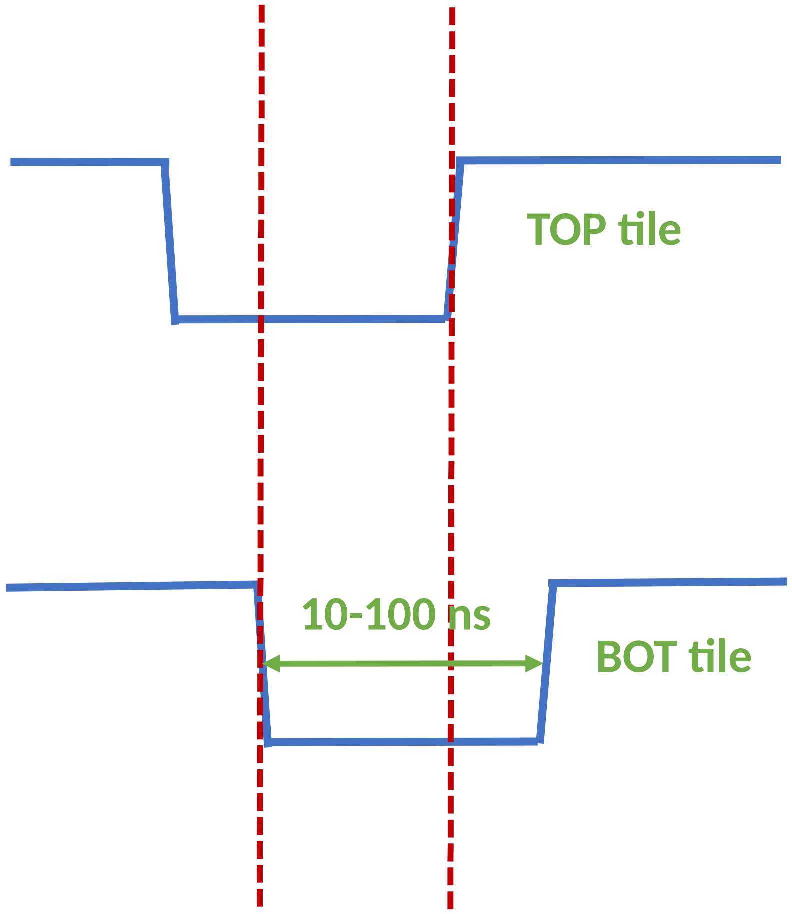
spurious signals in scintillator TOP in $\Delta T = v1 \bullet \Delta T$
spurious signals in scintillator BOT in $\Delta T = v2 \bullet \Delta T$

where v1 and v2 are spurious signal rate per scintillator

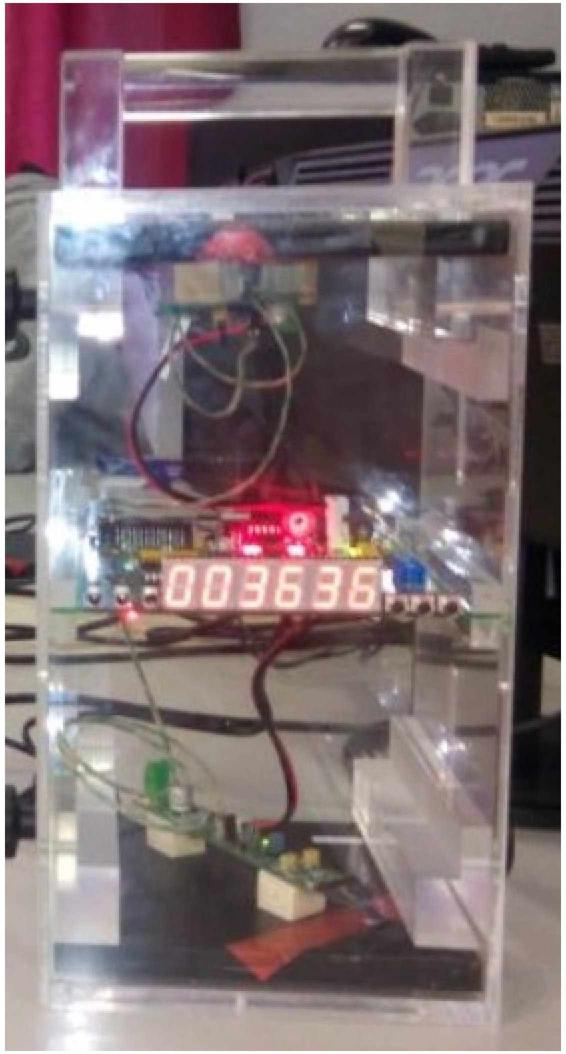
Rate of spurious coincidences:

$v(\text{false coincidences}) = 2 \bullet v1 \bullet v2 \bullet \Delta T^2 \sim 2 \bullet (10\ \text{Hz})^2 \bullet 10^{-7}\ \text{s} =$
$\sim 2 \cdot 10^{-5}\ \text{Hz}$

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



The CB - how to operate



Powering the CB:

there are **2 power connectors**:

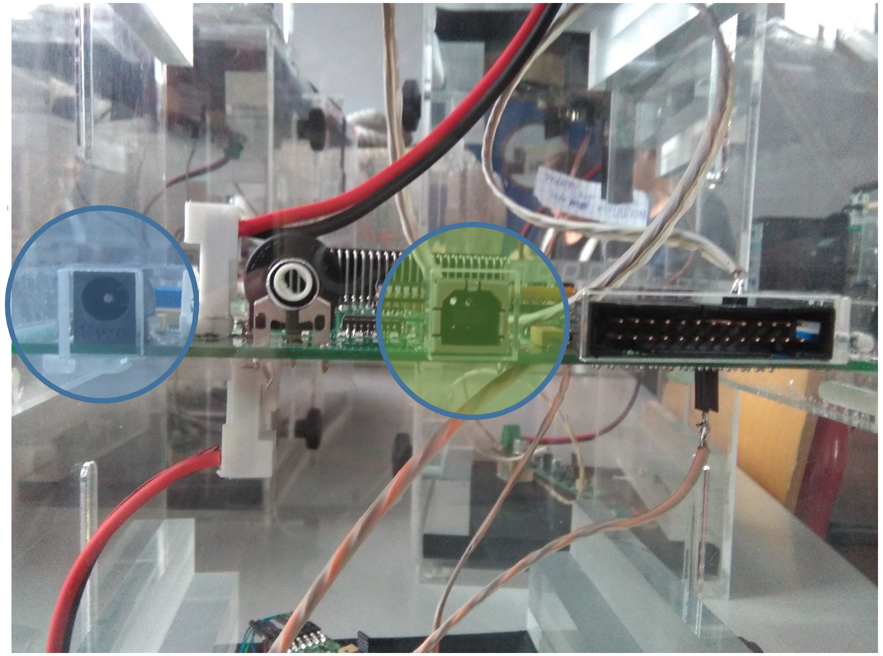
1. jack 5.5 mm

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)



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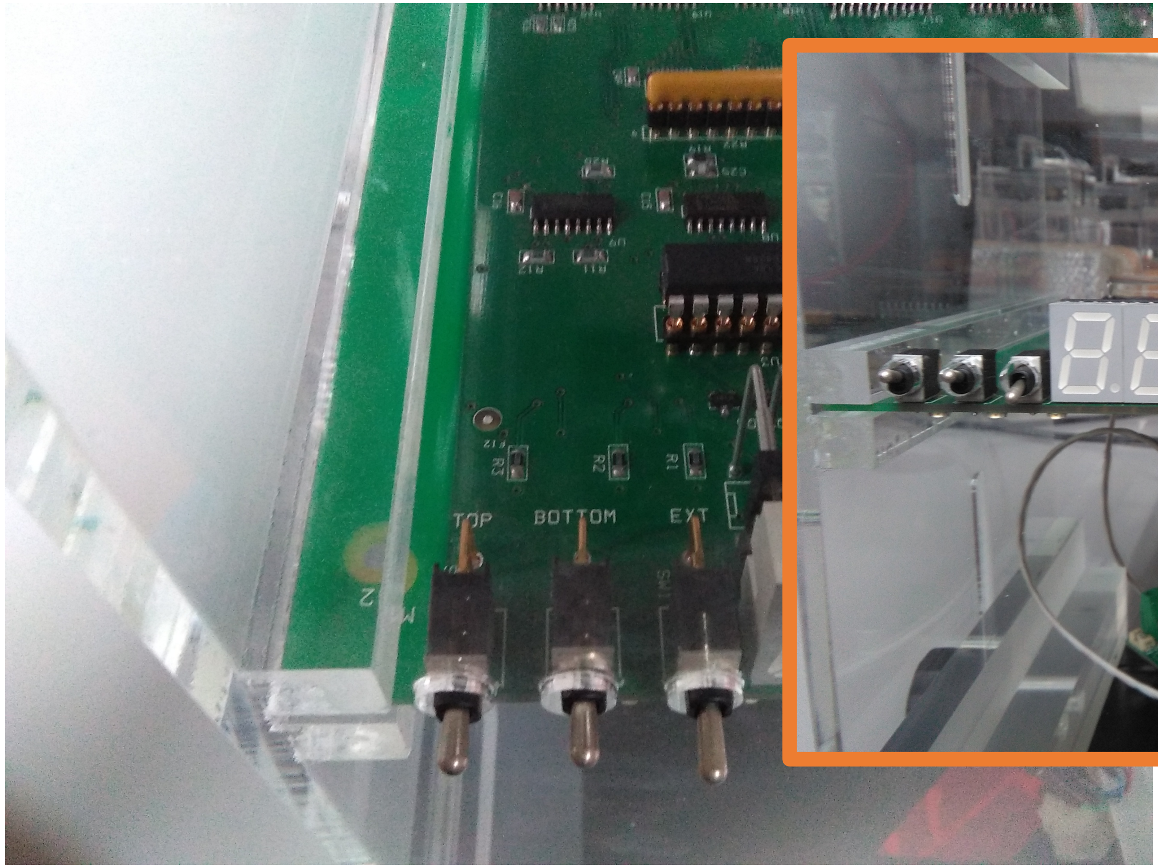
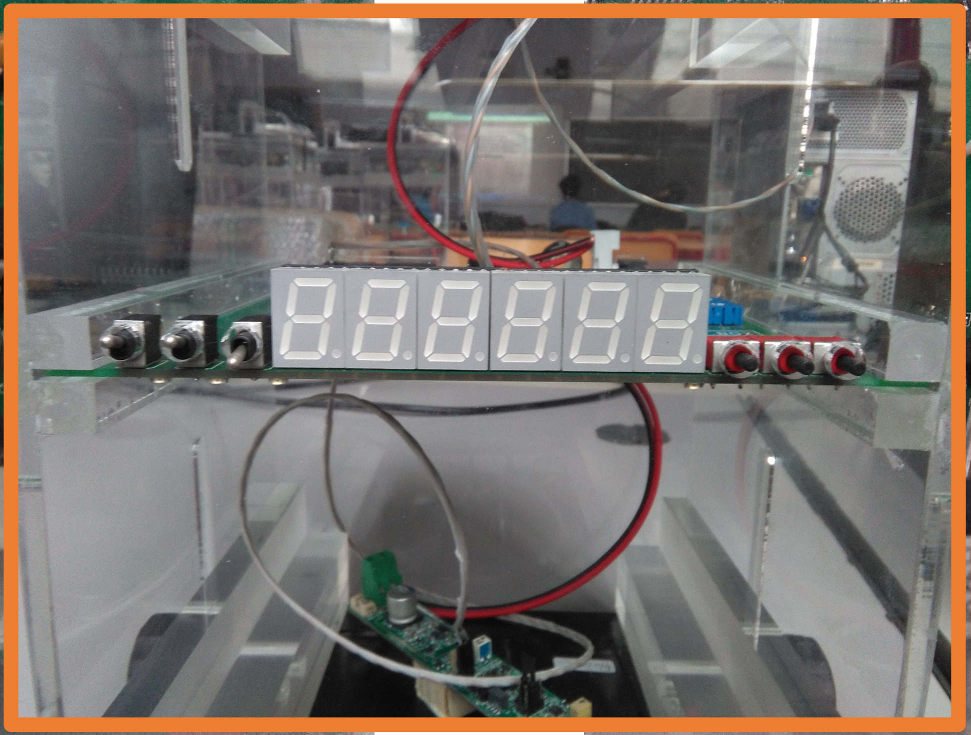
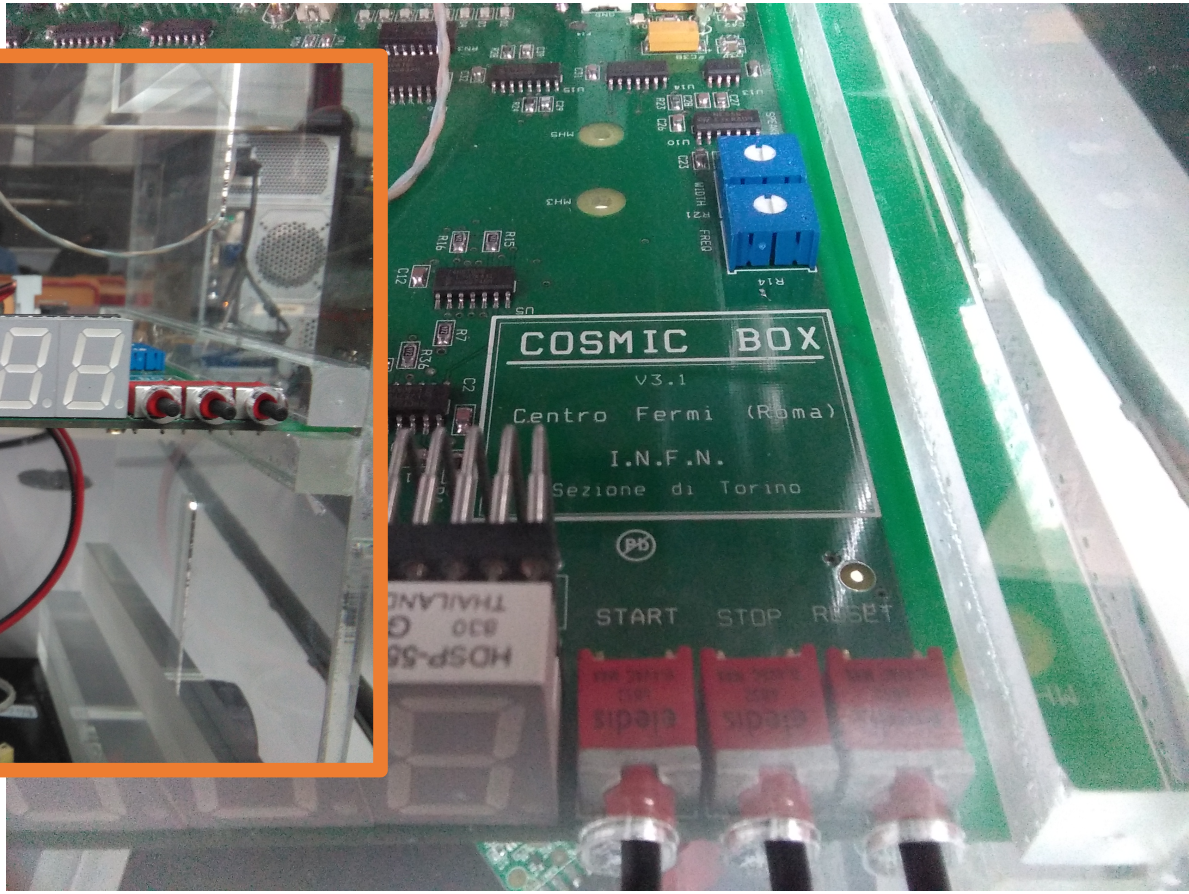


Front buttons and display





Selectors for COINCIDENCE logic (UP means ON)

Start/Stop/Reset the counter

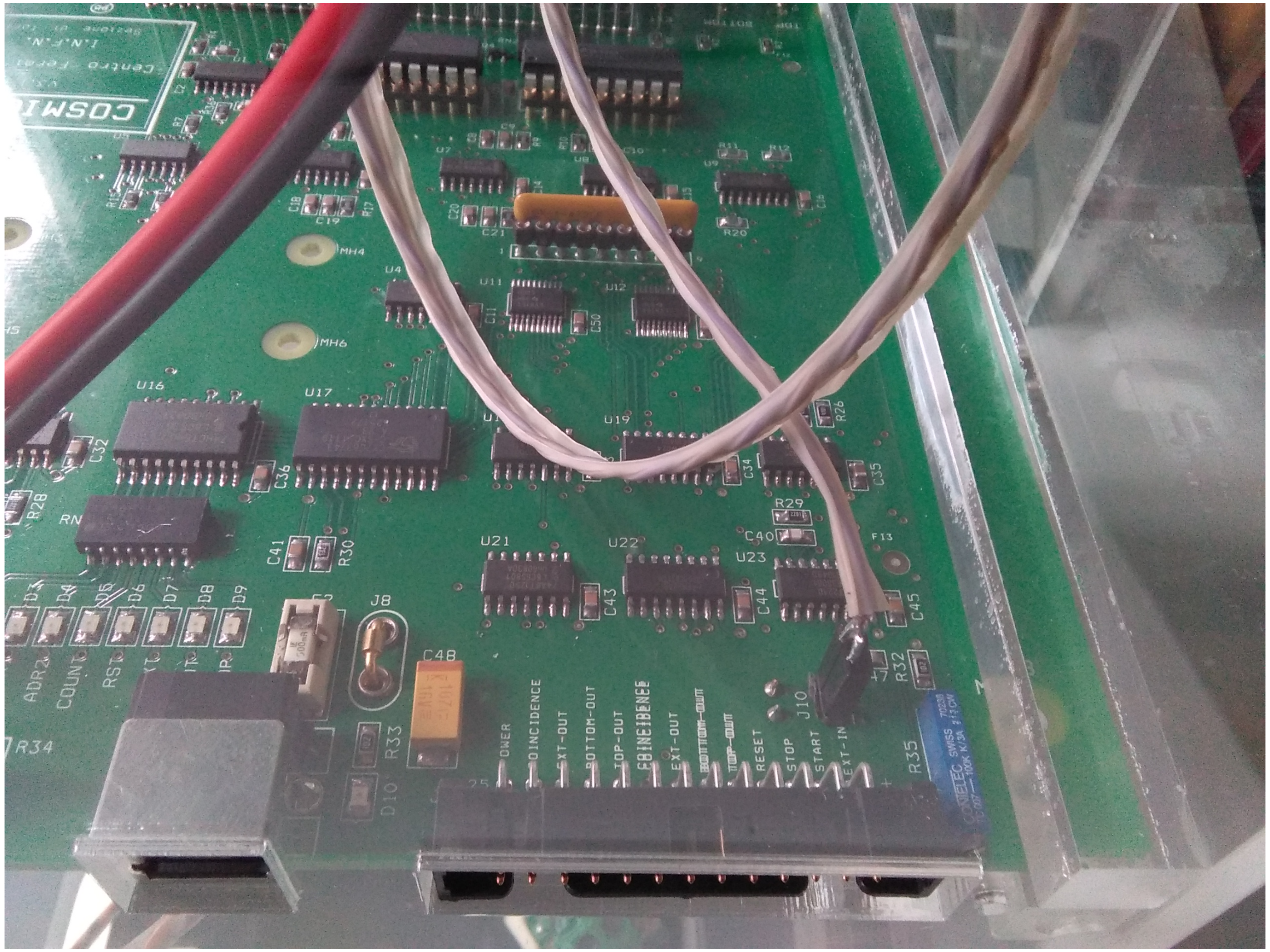
The CB - how to operate

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)

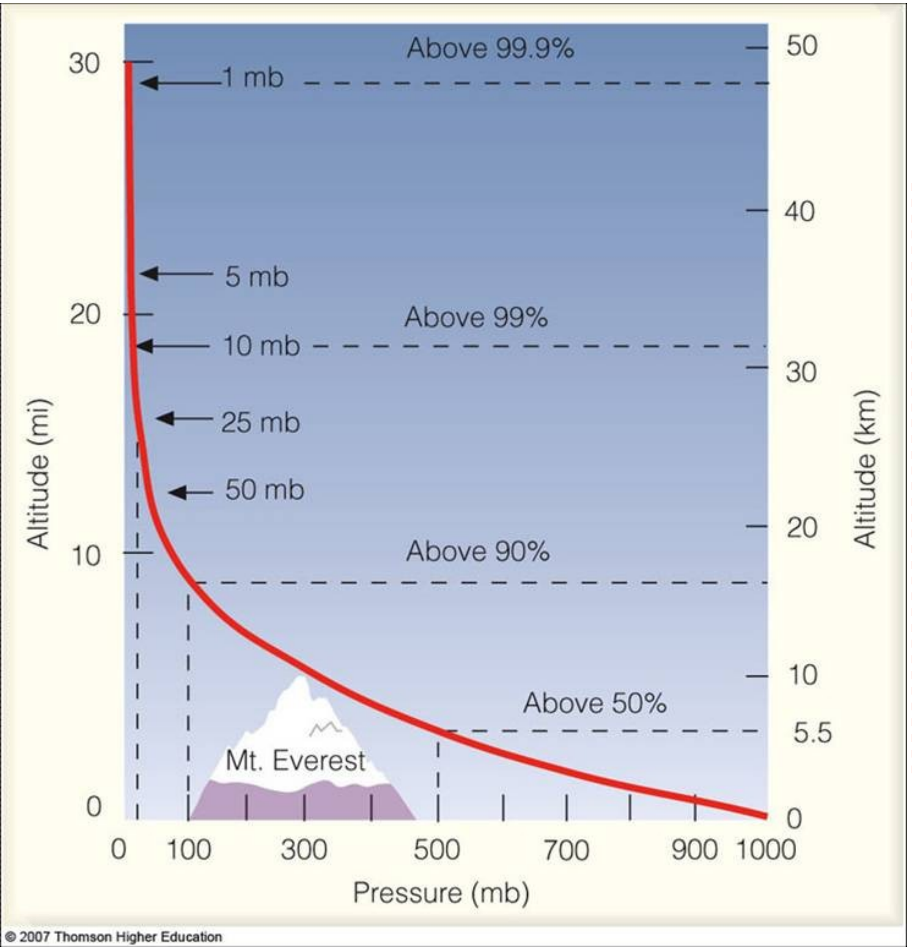
c. **pressure** (at least 3 measurements during the count)

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

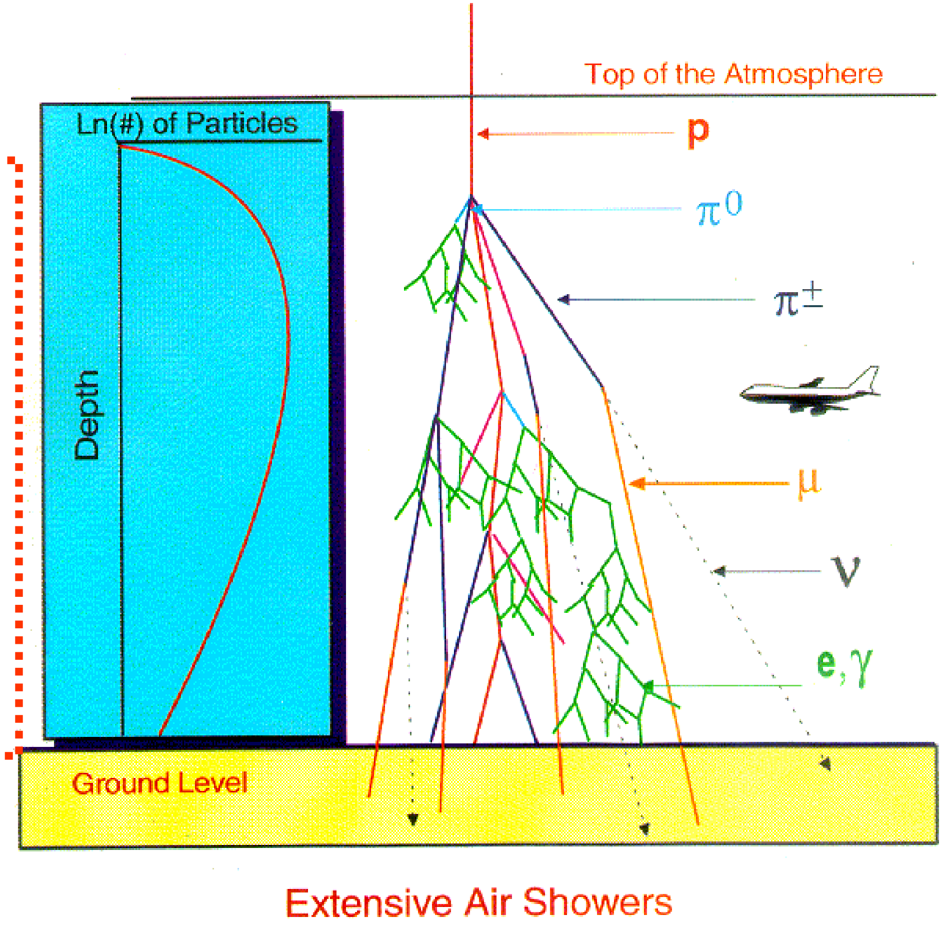
Always **take note of all the values**!

Absorption measurements

P



- In ATMOSPHERE
  - How to measure it?
  - Which law relates the muon flux and the pressure?



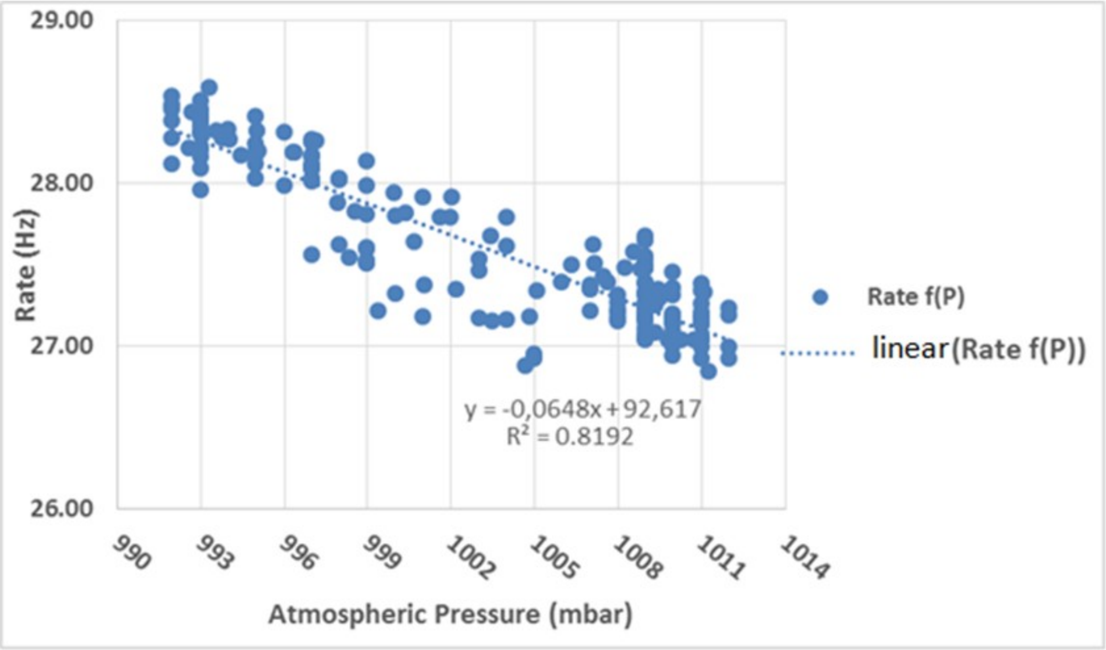
Absorption measurements

P

May we:

- Build our own
  - → cosmic rays altimeter?
    (for our excursions!)
  - → cosmic ray barometer?

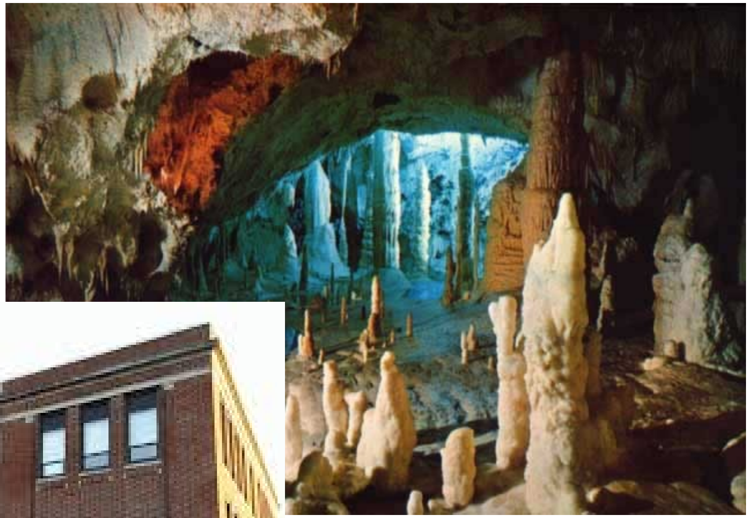
Does the Temperature play a role?
→ on SiPM
→ on muon flux at ground level?



American Journal of Educational Research. 2016, 4(16), 1164-1173 doi:10.12691/education-4-16-7

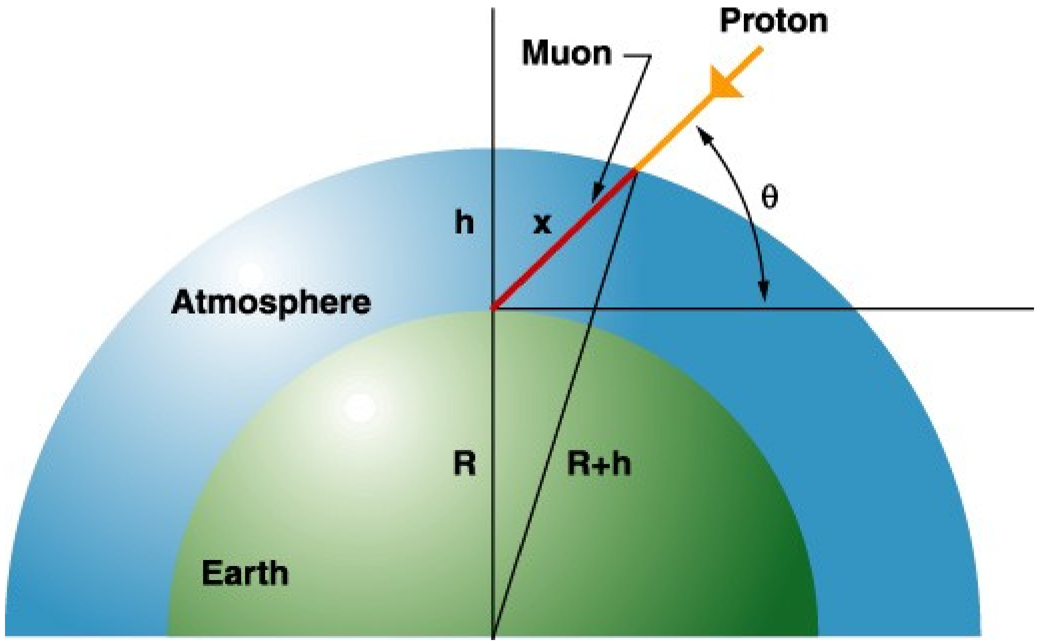
Absorption measurements

- Underground / inside buildings
  - Has the absorption phenomenon the same roots as for the atmosphere?
  - Can we get information
    → on the average density of material (by knowing the thickness)?
    → on the total thickness traversed (by knowing the material density?



Arrival direction (muon flux w.r.t. angle)

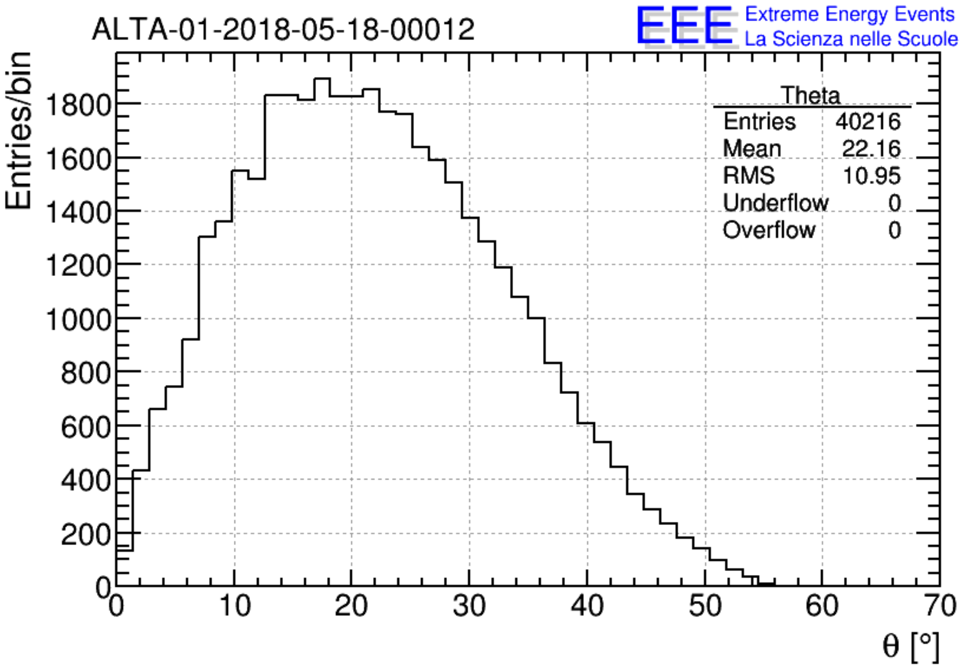
- What we should expect?
- How to measure it?

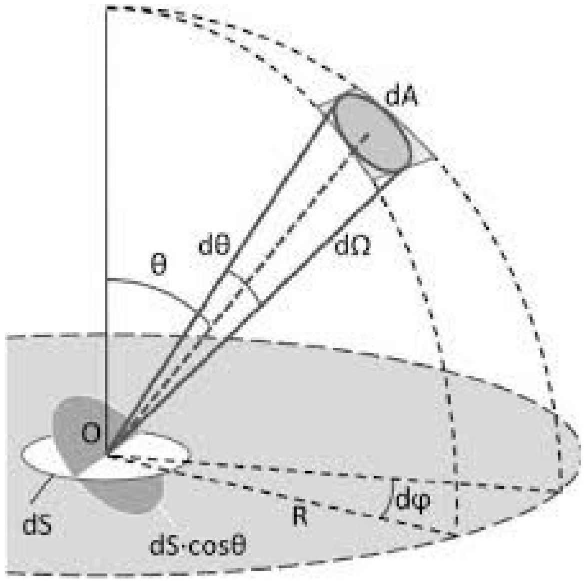


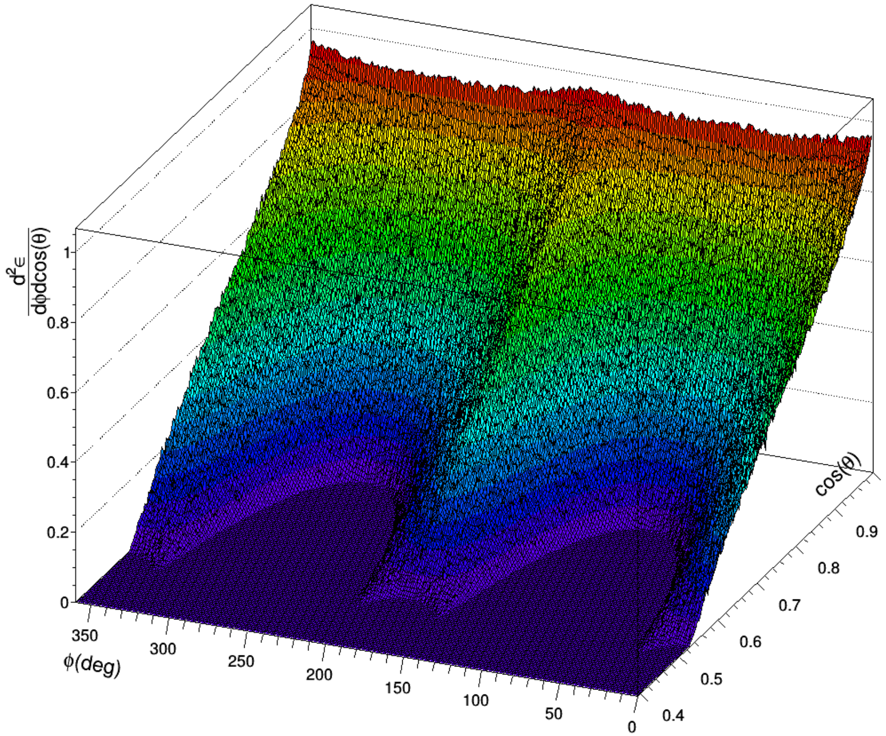
Arrival direction (muon flux w.r.t. angle)

P

- Acceptance?
- Solid angle?



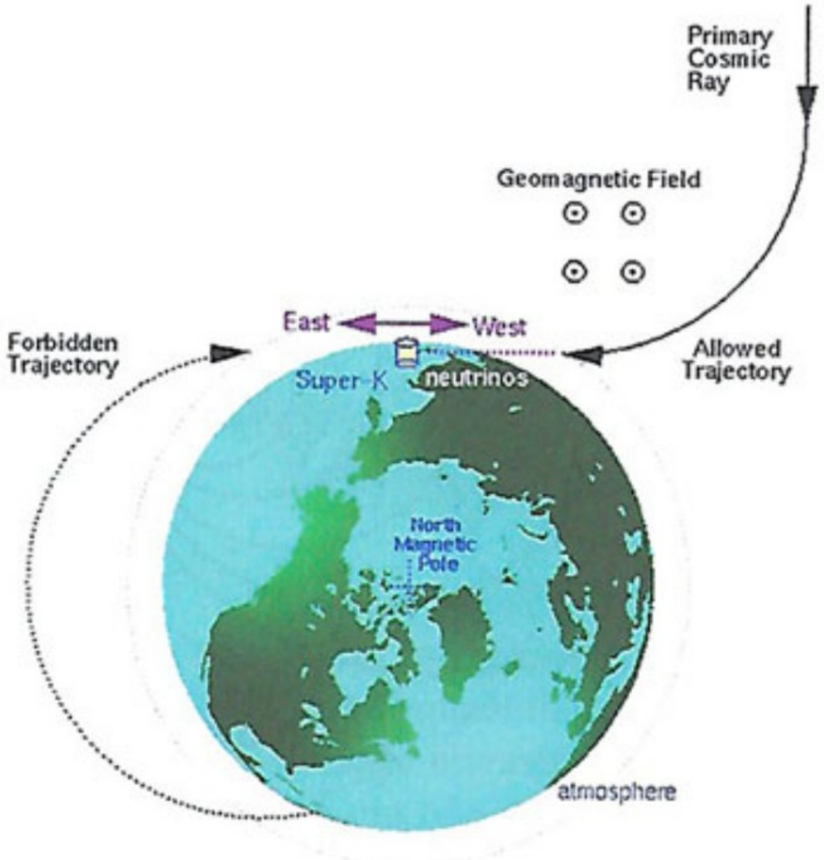




Arrival direction (muon flux w.r.t. angle)

P

- East-West effect
  - Is it possible to measure it with a CB?
  - Maybe making use of the orography?



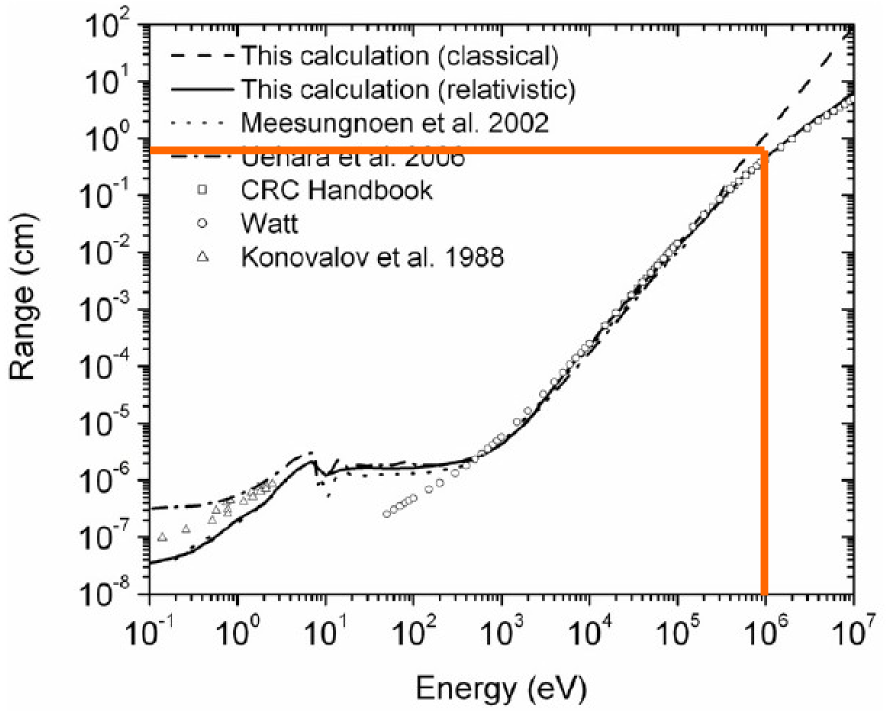
Natural radioactivity

P

- Most of the natural radioactivity (gamma, electrons) cannot traverse both scintillators
- Is it possible to measure somehow the natural radioactivity with a CB?
- Of course taking into account the uncertainties related to the rate of false signals for a single scintillator?

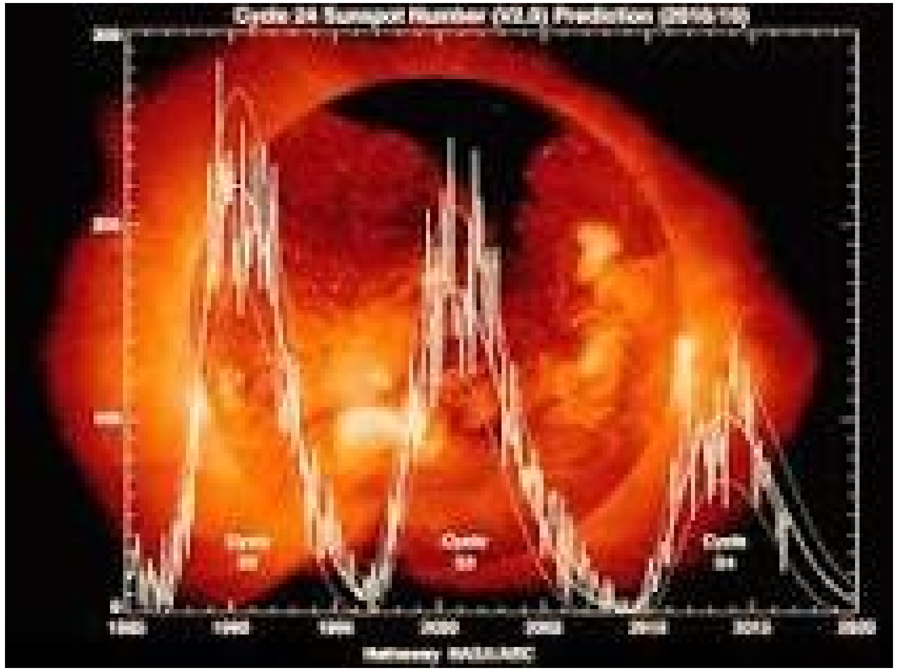
Electron range in water

IOP Institute of Physics   DEUTSCHE PHYSIKALISCHE GESELLSCHAFT



… and monitoring solar activity?

… and many other experiments!!



Welcome to Physics!

BACKUP slides

The Coincidence calibration

The 2 scintillators + the coincidence module

have been tested in **3 different configurations**

for the final approval