Cosmic ray measurements – using those detectors in huge physical experiments as LHC or NICA

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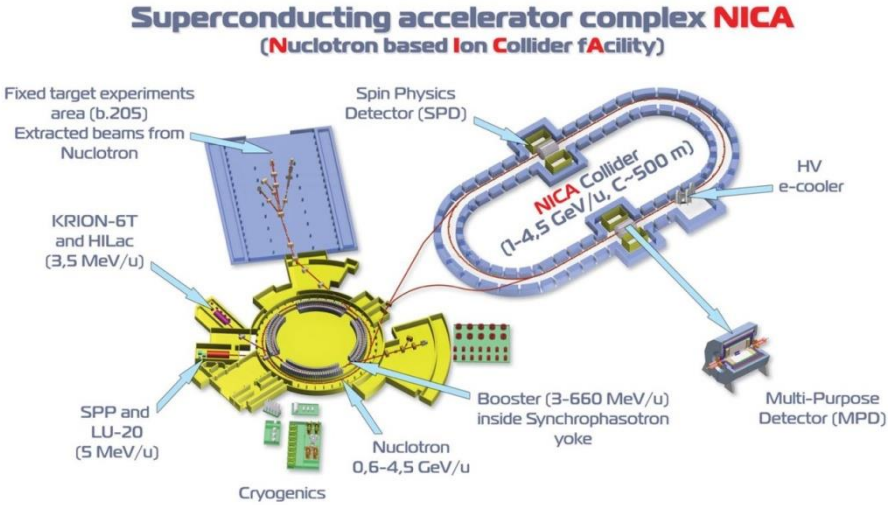
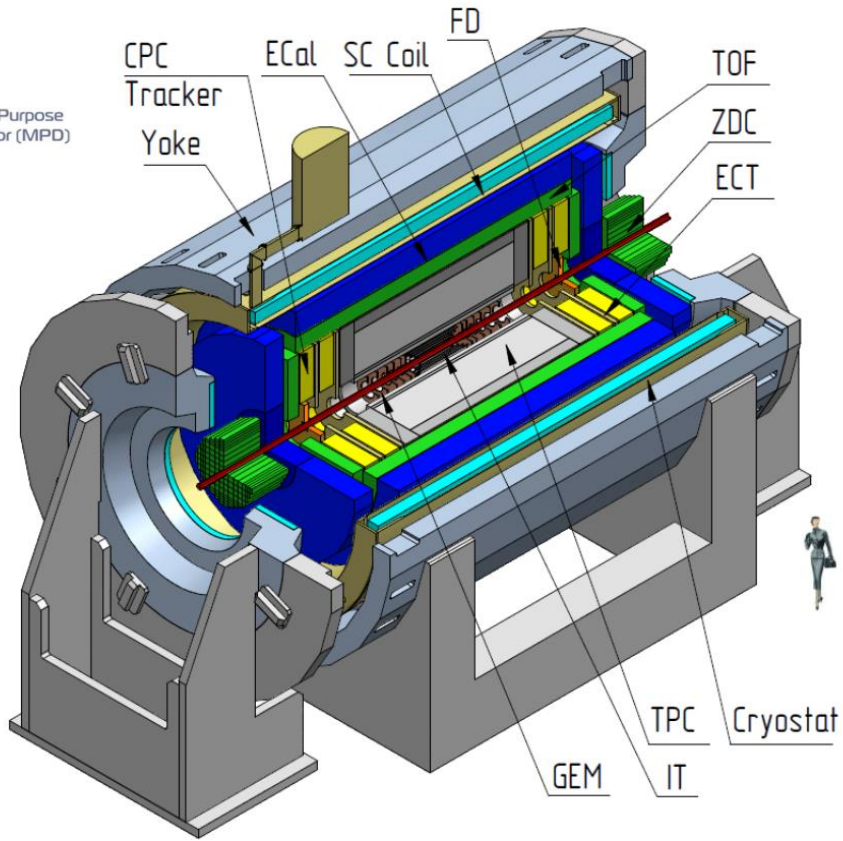
Outline

- NICA Project
- Cosmic rays
- Cosmic Watch Project
- Measurements, results and analysis

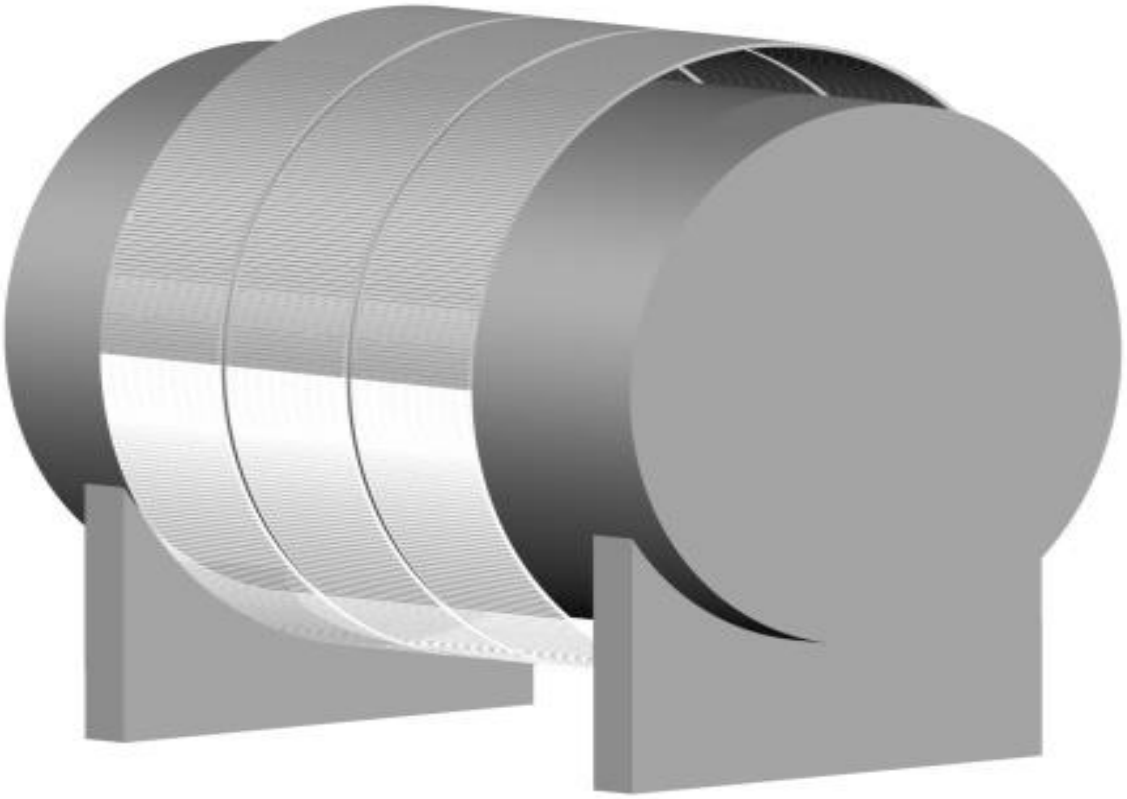
NICA MULTI PURPOSE DETECTOR (MPD)

NICA MPD scheme [1]



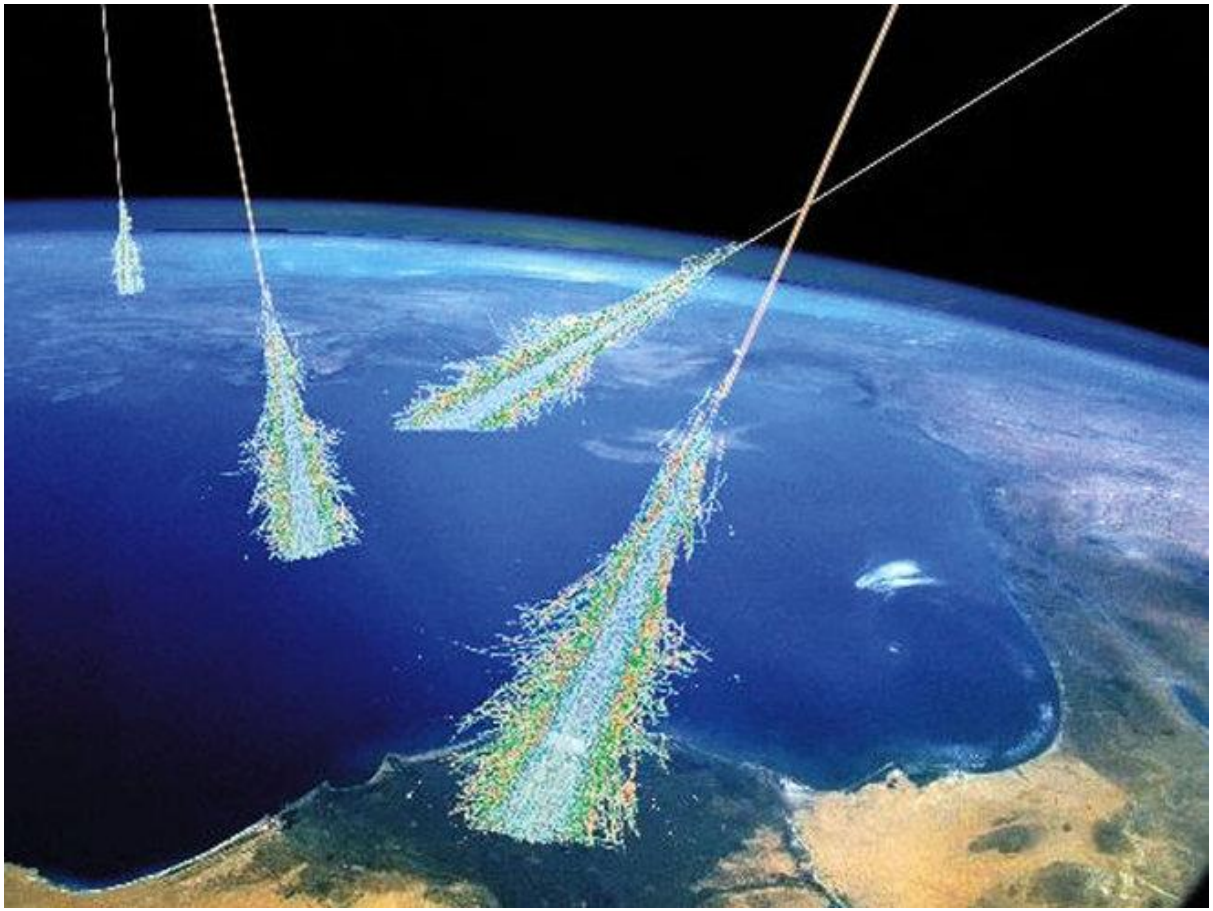


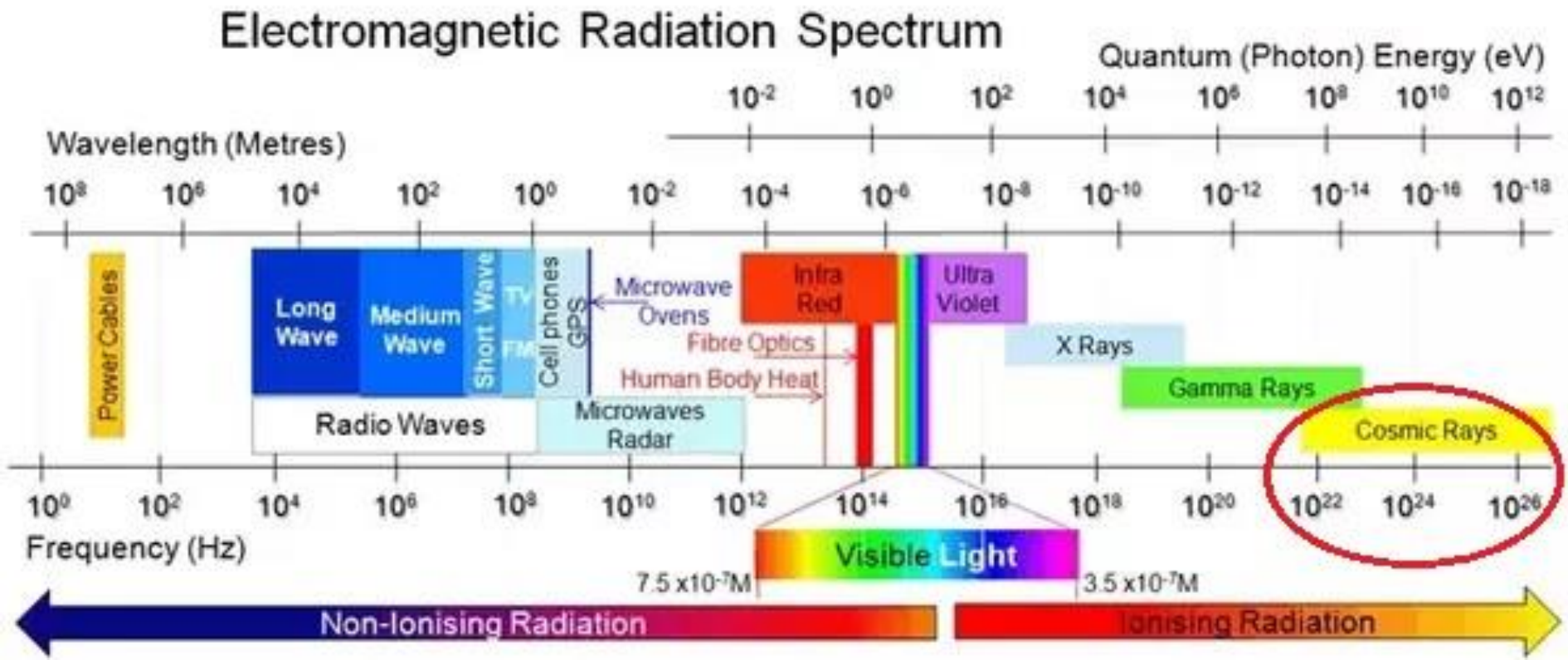
Cosmic rays detector [2]



MCORD – MPD Cosmic Ray Detector
MCORD suround MPD detector

COSMIC RAYS




Electromagnetic Radiation Spectrum
Quantum (Photon) Energy (eV)
10-2 10⁰ 10² 10⁴ 10⁶ 10⁸ 10¹⁰ 10¹²
Wavelength (Metres)
10⁸ 10⁶ 10⁴ 10² 10⁰ 10-2 10-4 10-6 10-8 10-10 10-12 10-14 10-16 10-18
Power Cables
Long Wave
Medium Wave
Short Wave
TV
FM
Cell phones
GPS
Microwave Ovens
Infra Red
Ultra Violet
Fibre Optics
X Rays
Human Body Heat
Gamma Rays
Radio Waves
Microwaves
Radar
Cosmic Rays
10⁰ 10² 10⁴ 10⁶ 10⁸ 10¹⁰ 10¹² 10¹⁴ 10¹⁶ 10¹⁸ 10²⁰ 10²² 10²⁴ 10²⁶
Frequency (Hz)
Visible Light
7.5 x10-7M
3.5 x10-7M
Non-Ionising Radiation
Ionising Radiation

Cosmic Rays – content [3]

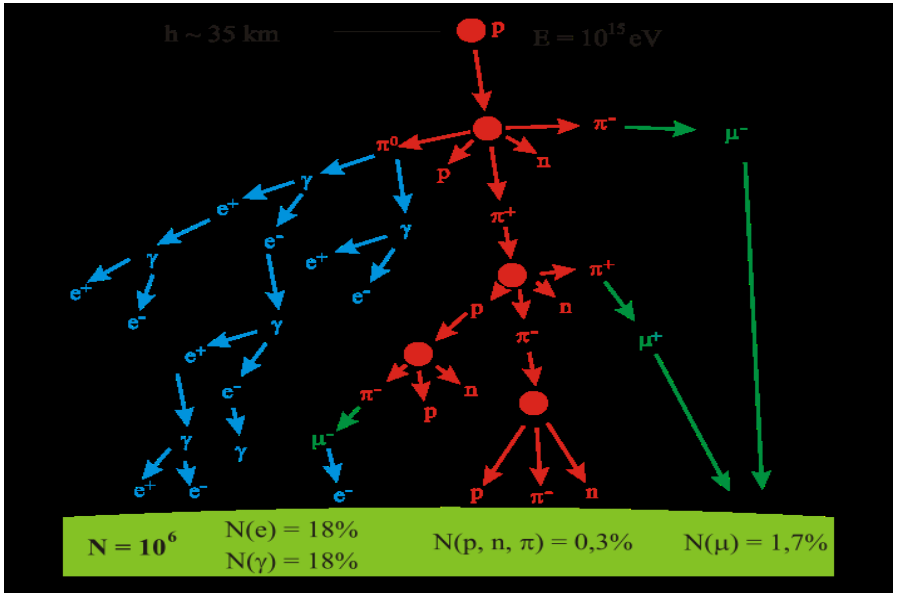
Primary particles:

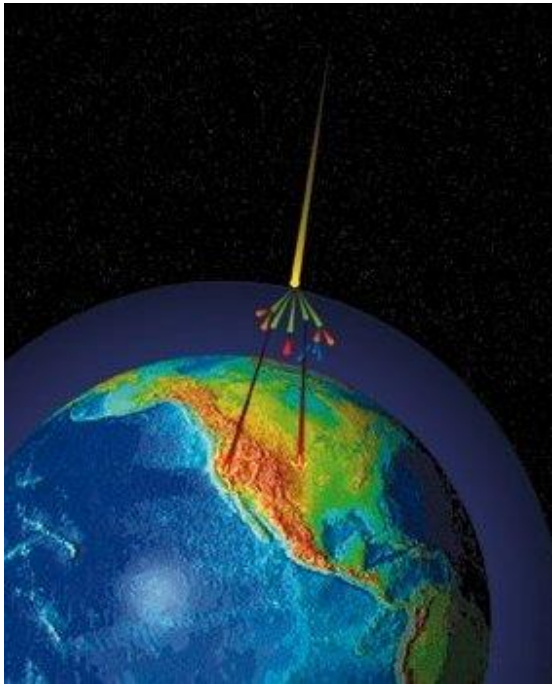
- Protons (90%)
- Alpha particles (9%)
- Heavy nuclei (1%)

Secondary particles:

- Pions
- Kaons
- Muons
- Protons
- Electrons and γ quanta

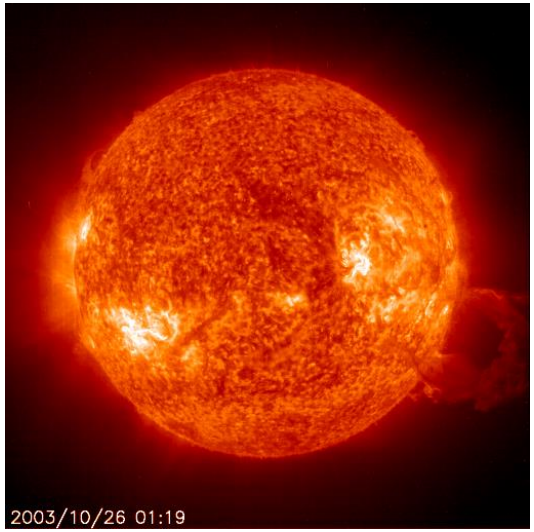
Cosmic Shower

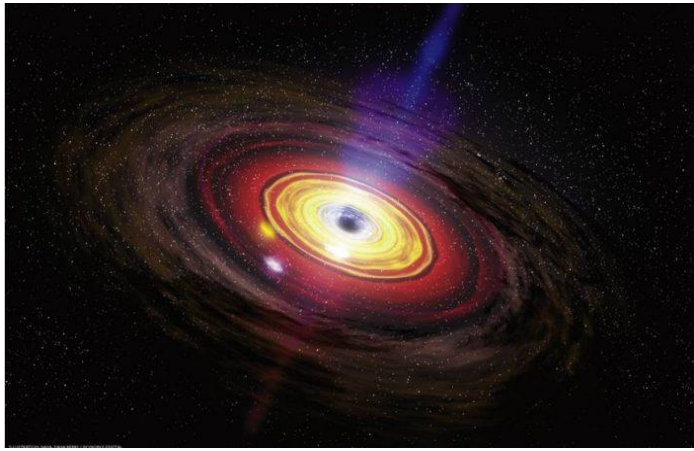


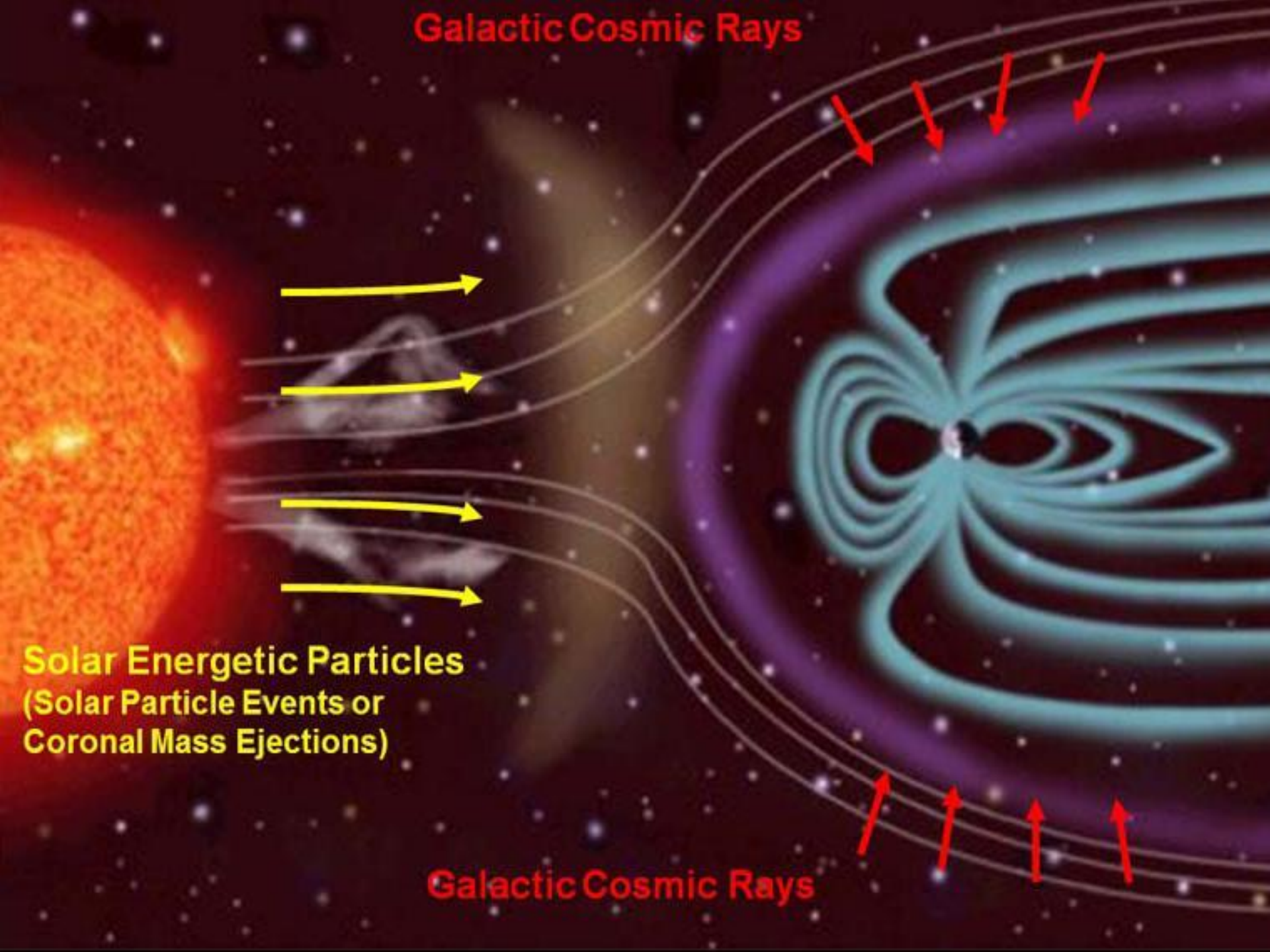


Cosmic Rays – sources [4]

- Solar activity
- Supernova explosion
- Pulsars
- Active galactic nuclei



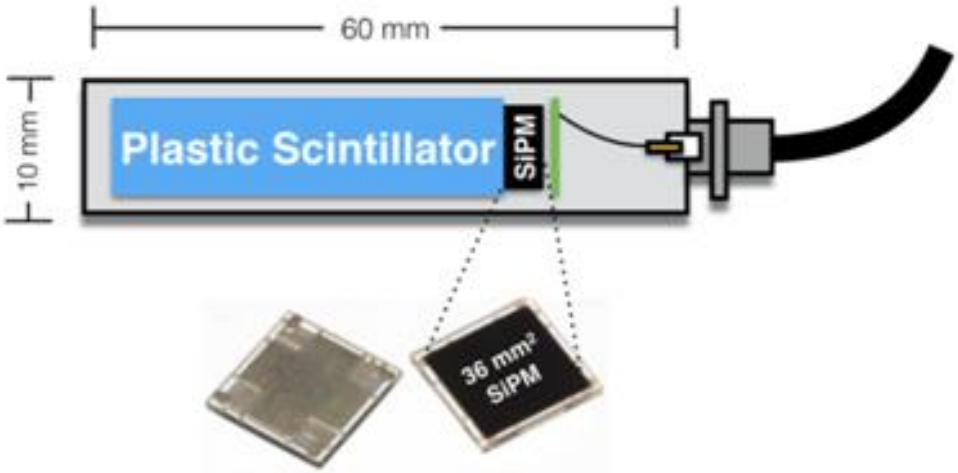



Galactic Cosmic Rays
Solar Energetic Particles
(Solar Particle Events or
Coronal Mass Ejections)
Galactic Cosmic Rays

COSMIC WATCH PROJECT

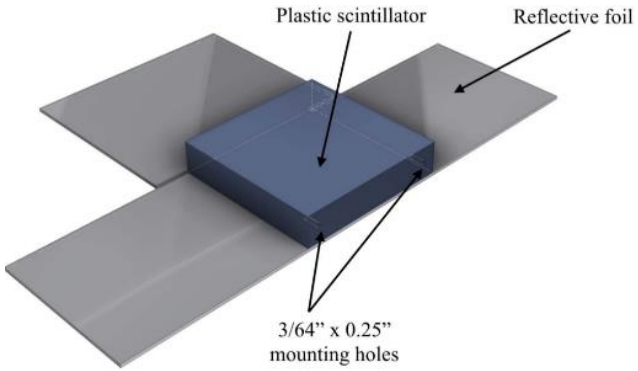
Cosmic Watch [5]

- Scintillation detector
- Designed for detecting and counting muons

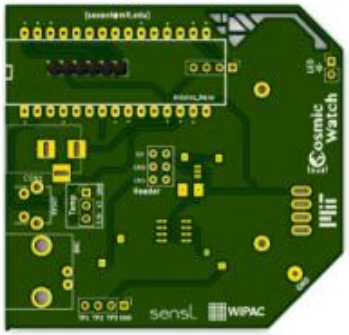


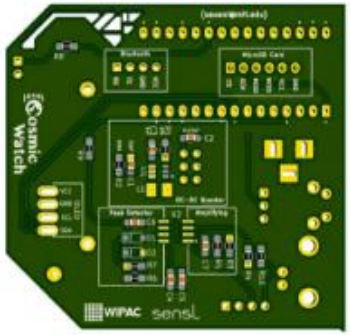
Detector components

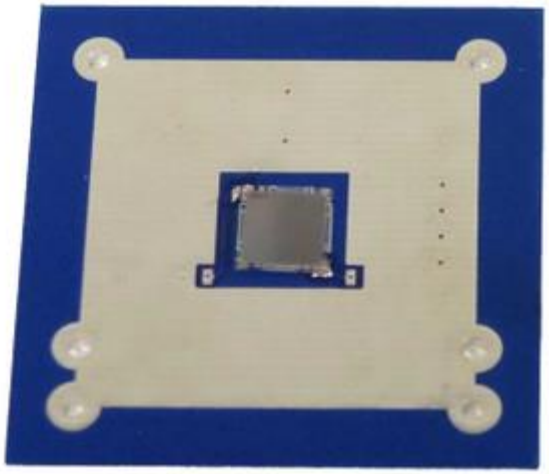
5 cm×5 cm×1 cm slab of plastic scintillator as a detection medium



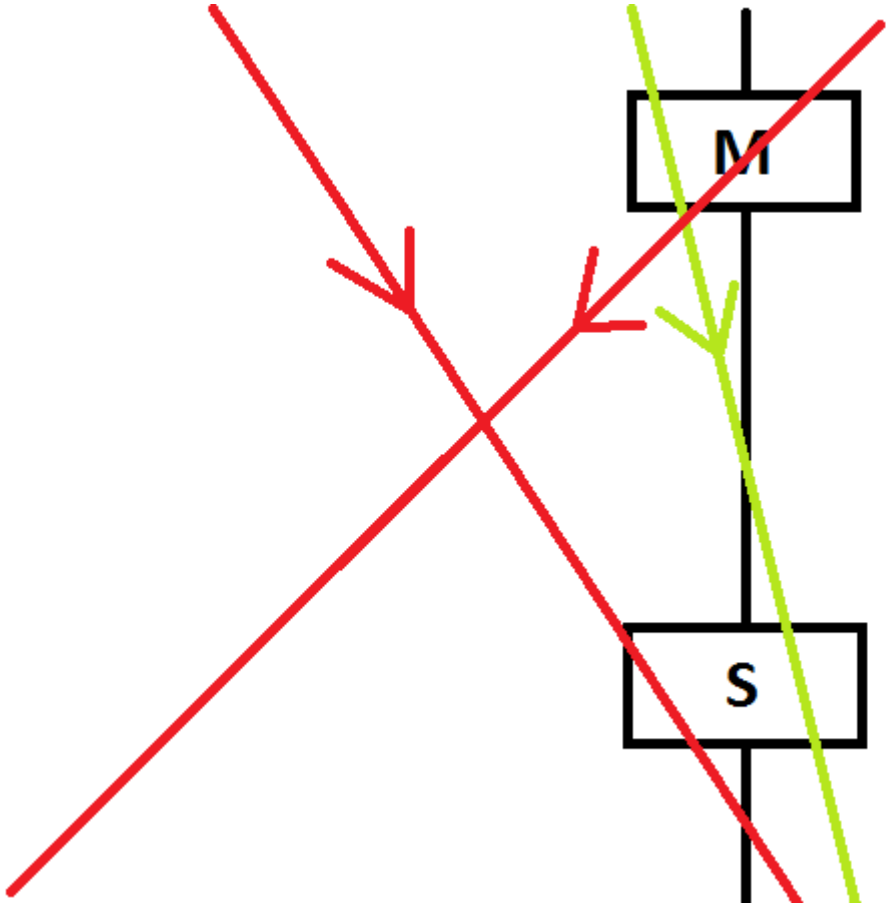
Custom designed PCB to shape the signal



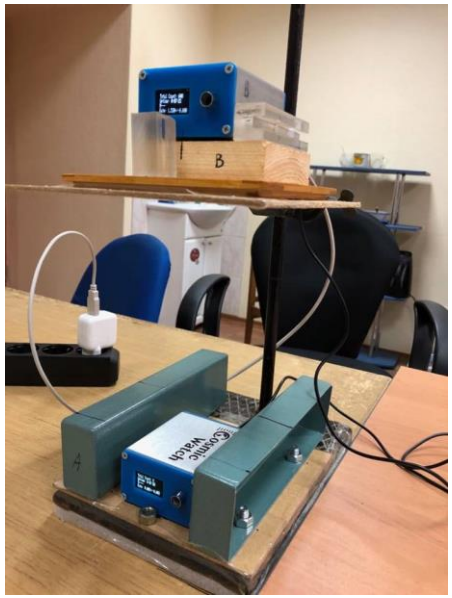


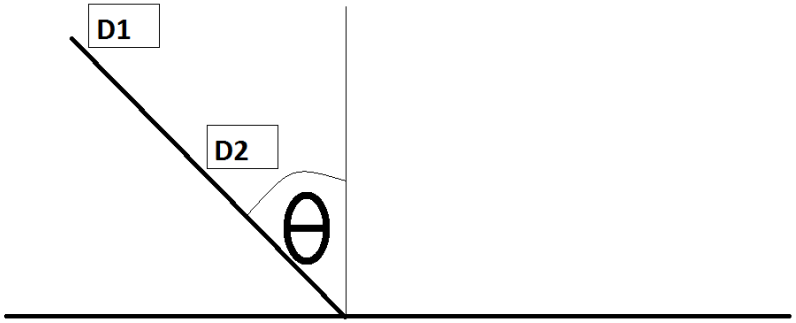


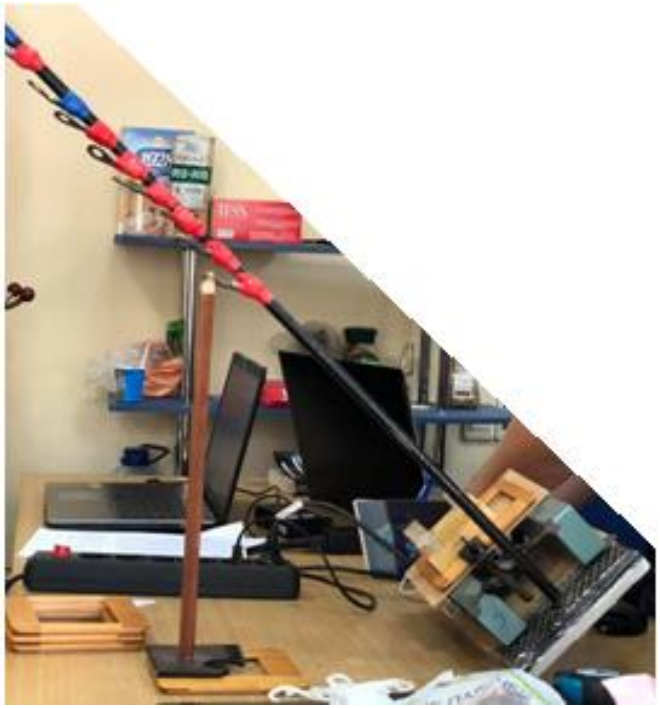
Master – Slave mode (Coincidence mode)



Measurements

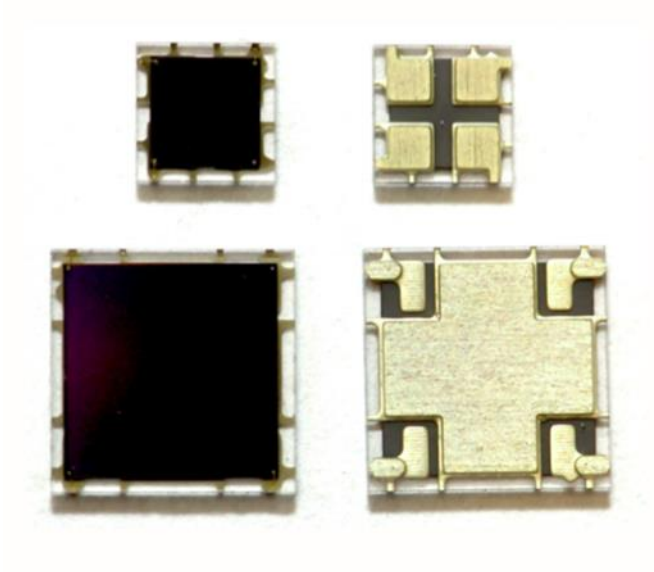


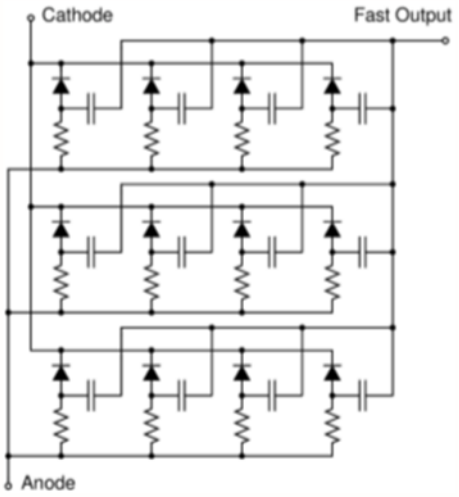




SiPM (Silicon Photomultiplier)

- Low-light signal
- Low voltage operation
- Insensitivity to magnetic fields
- Uniformity of response
- Small size (6mm x 6 mm)





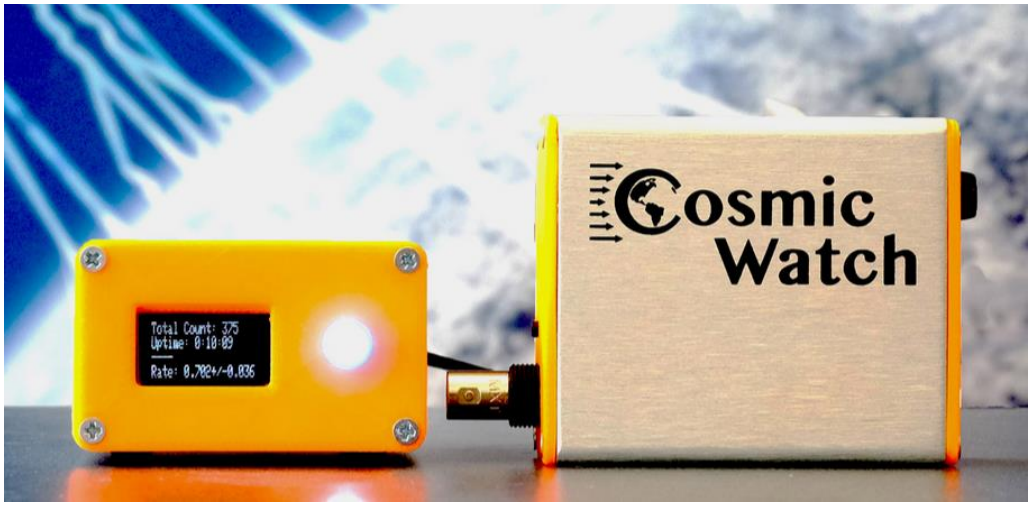
Detector components

- Open-source micro-controller

16 MHz Arduino Nano ATmega328
to perform the measurement

Features

- Threshold trigger
- Amplitude measurement
- SD cards / screen
- Total counts
- Counting rate
- Time
- Dead time



Arduino - programming

kod_detektor | Arduino 1.8.5

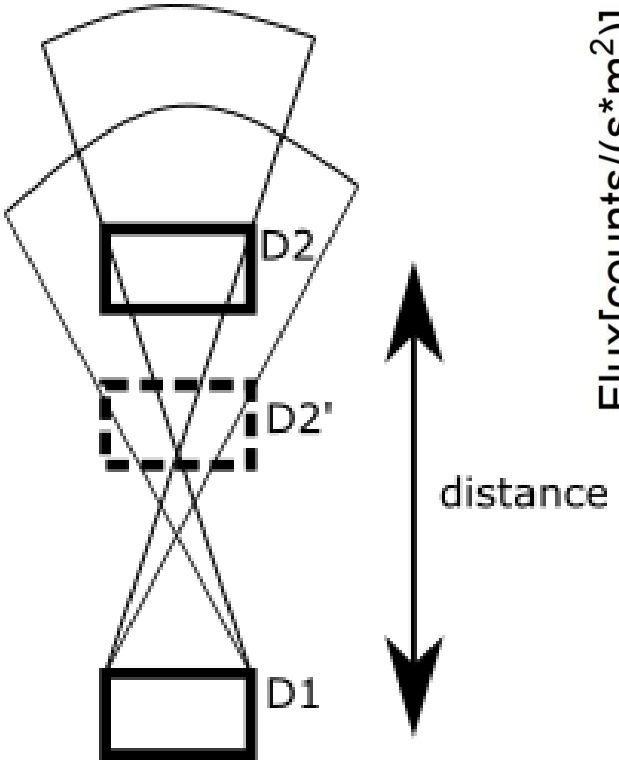
Plik Edytuj Szkic Narzędzia Pomoc

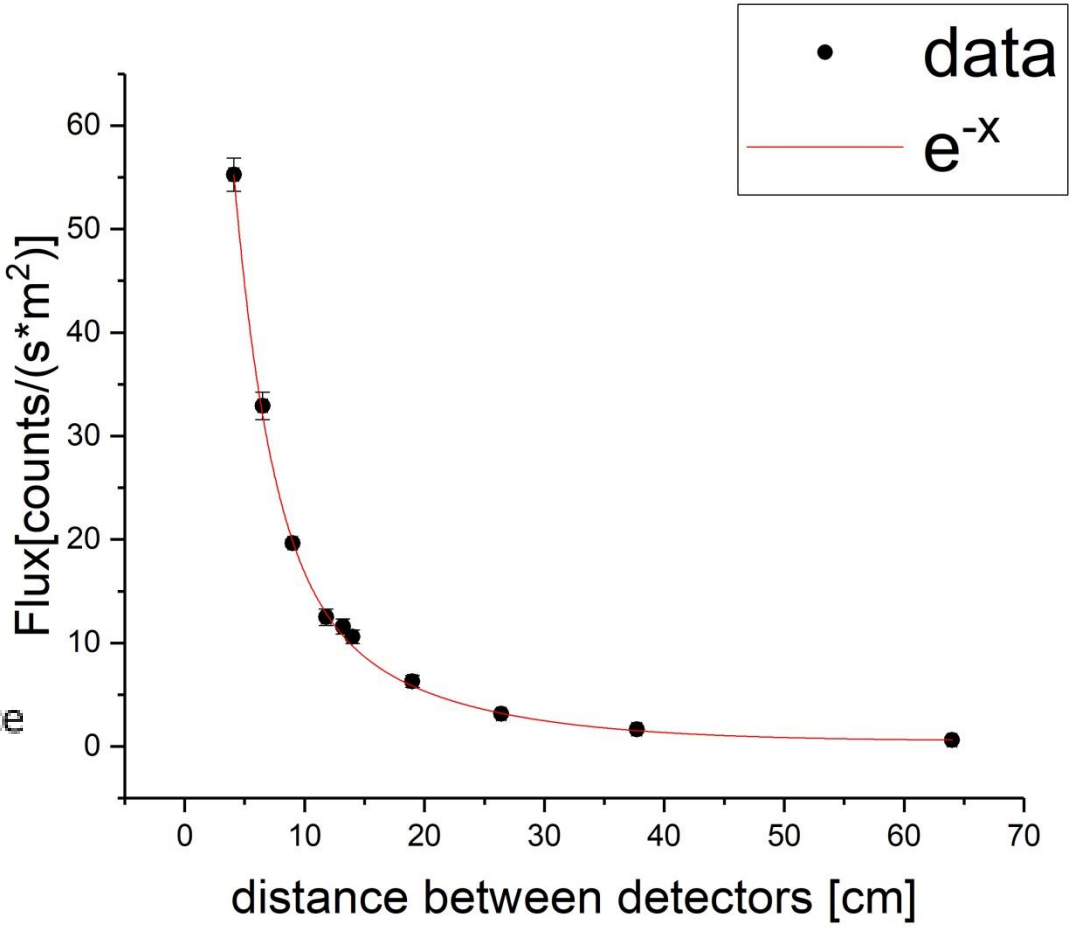
kod_detektor

```
#include <Adafruit_SSD1306.h>
#include <Adafruit_GFX.h>
#include <TimerOne.h>
#include <Wire.h>
#include <SPI.h>
#include <EEPROM.h>

const byte OLED = 1;                      // Turn on/off the OLED [1,0]

const int SIGNAL_THRESHOLD      = 50;    // Min threshold to trigger on. See calibration.pdf for conversion to mV.
const int RESET_THRESHOLD       = 15;

const int LED_BRIGHTNESS        = 250;    // Brightness of the LED [0,255]

const long double cal[] = {-9.085681659276021e-27, 4.6790804314609205e-23, -1.0317125207013292e-19,
  1.2741066484319192e-16, -9.684460759517656e-14, 4.6937937442284284e-11, -1.4553498837275352e-08,
   2.8216624998078298e-06, -0.000323032620672037, 0.019538631135788468, -0.3774384056850066, 12.324891083404246};

const int cal_max = 1023;

//INTERUPT SETUP
#define TIMER_INTERVAL 1000000          // Every 1,000,000 us the timer will update the OLED readout

//OLED SETUP
#define OLED_RESET 10
Adafruit_SSD1306 display(OLED_RESET);

//initialize variables
```

Results & Conclusion

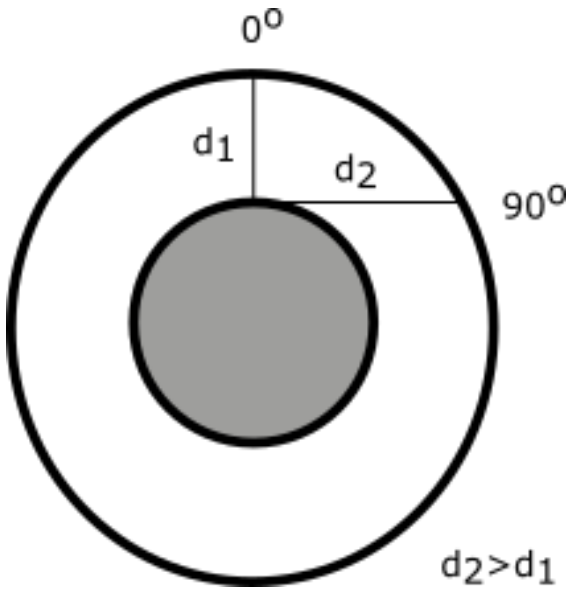
A.Distance dependence

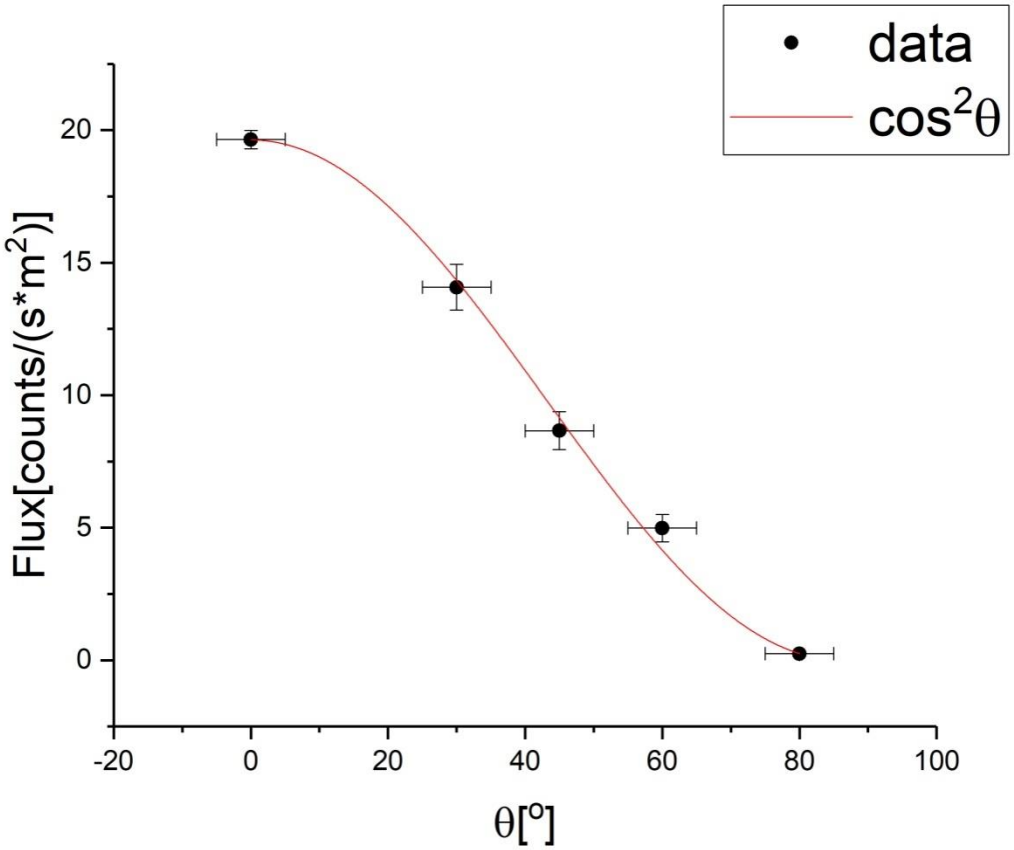




There is an exponential dependence as we change the distance between the detectors, as expected.

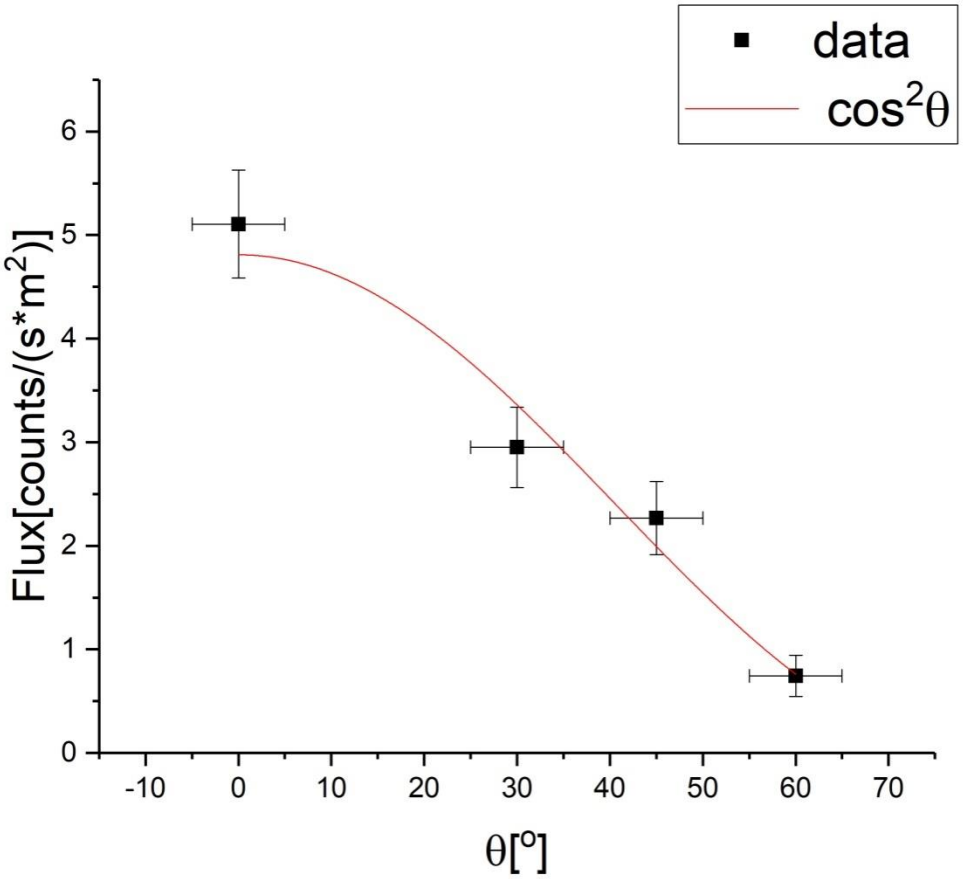
B. Angle dependence (indoors)





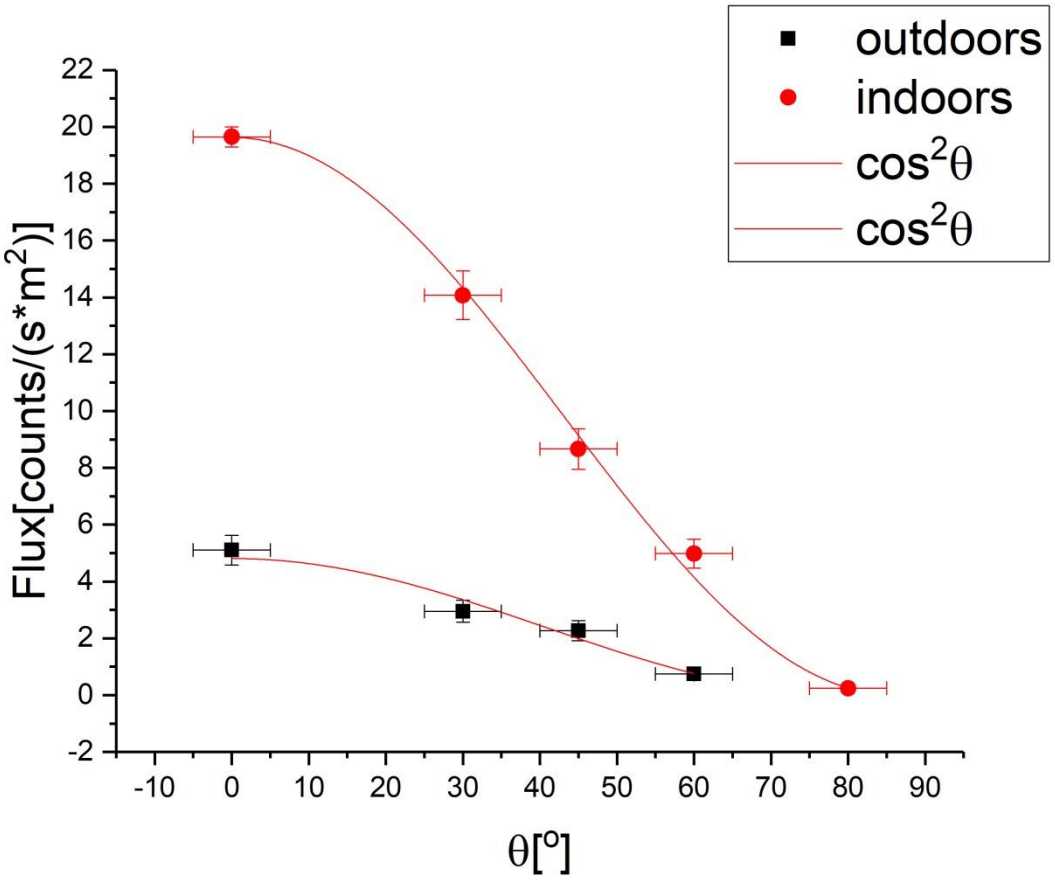
We expect data points to align with cosine squared curve, as indicated in [6]. We can see that the experimental data correspond with theoretical prediction.

B. Angle dependence (outdoors)



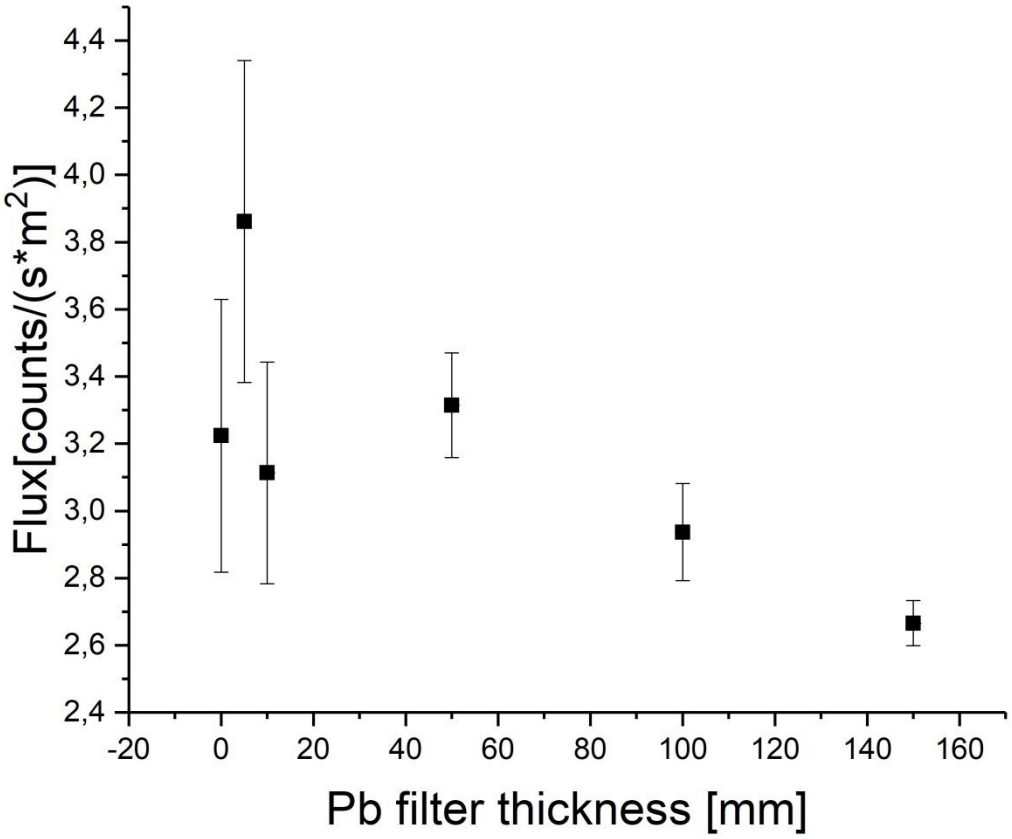
Similar to the previous result, but slightly worse fit parameters

C.Angle dependence – indoors vs. outdoors



There are more particles observed indoors – not as expected. Possible reason: the building itself generates additional particle cascades.

D. Pb filter thickness dependence



We expect to get rid of low energy components (about 30% of particles) and to obtain an exponential dependence, but the result is ambiguous

Conclusion

- Cosmic rays detectors are necessary for the MPD to eliminate the background from cosmic radiation
- The result of the Pb filter measurement is ambiguous and remains an open question for future measurements
- Most of the results matched the predictions
- The results of our work can be used as a set of initial conditions for future theoretical calculations

THANK YOU FOR YOUR ATTENTION

Reference

[1] Golovatyuk V., Kekelidze V., Kolesnikov V., Rogachevsky O., Sorin A. The Multi-Purpose Detector (MPD) of the collider experiment, Eur. Phys. J. A (2016) 52: 212

[2] Bielewicz M. and all *MCORD – MPD Cosmic Ray Detector for NICA,* Proc. SPIE, 2018

[3] Strugalski Z. *Promieniowanie kosmiczne* Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 1993

[4] Moczulska M. *Promieniowanie kosmiczne* Uczelniana Oferta Dydaktyczna PW, 2009

[5] http://cosmicwatch.lns.mit.edu/about

[6] M. Tanabashi *et al.* (Particle Data Group), Phys. Rev. D **98**, 030001 (2018), p.6