UNIVERSITA’ DEGLI STUDI DI TORINO

Scuola di Scienze della Natura

Corso di Laurea in Fisica

Repliche sperimentali di fenomeni luminosi visti da JEM-EUSO al TurLab mediante circuiti elettronici realizzati utilizzando la piattaforma Arduino

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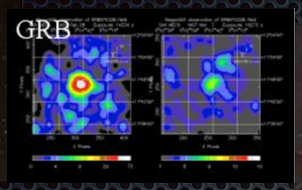
Tutor aziendale: Dott. Marco Aglietta

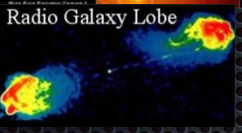
Candidato: Pier Silvio Tibaldi

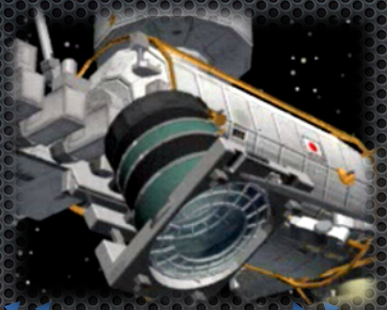
Anno Accademico 2013-2014

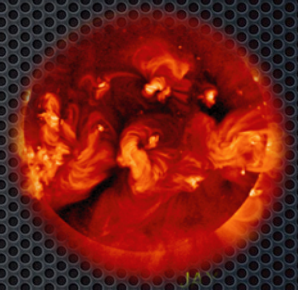
JEM-EUSO

an Astronomical Earth Observatory from Space









EECR s

Dust and Meteors

Ultraviolet photons

Charged Particles

UV, X, γ, ν
p, n, e

$X, \gamma, \upsilon, p, e$

Air shower

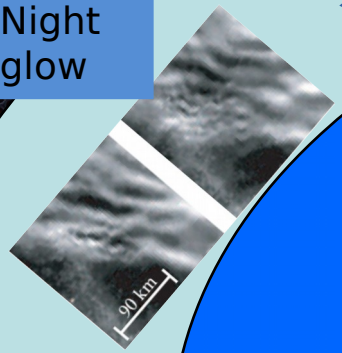
Air shower

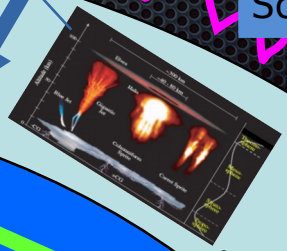
Atmospher

Solar wind

The Earth

Night glow





Plasma Discahrge

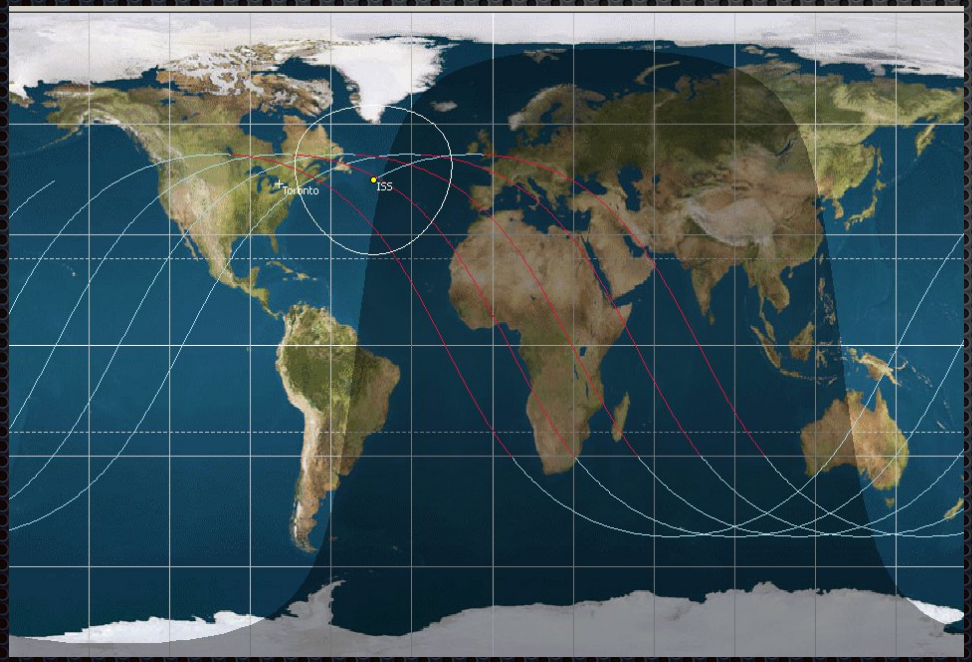
EHE Neutrinos

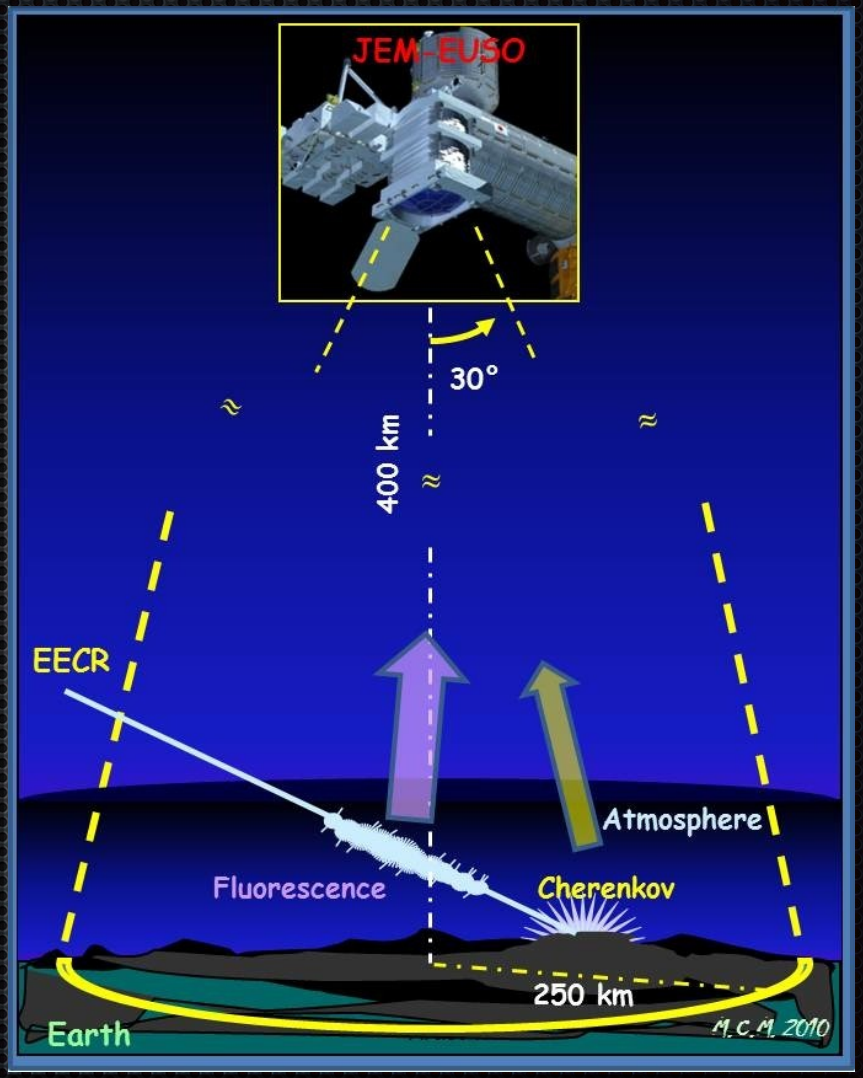
JEM-EUSO

FoV $1.4 \times 10^5 \text{ km}^2$

time resolution (GTU) $2.5\ \mu s$

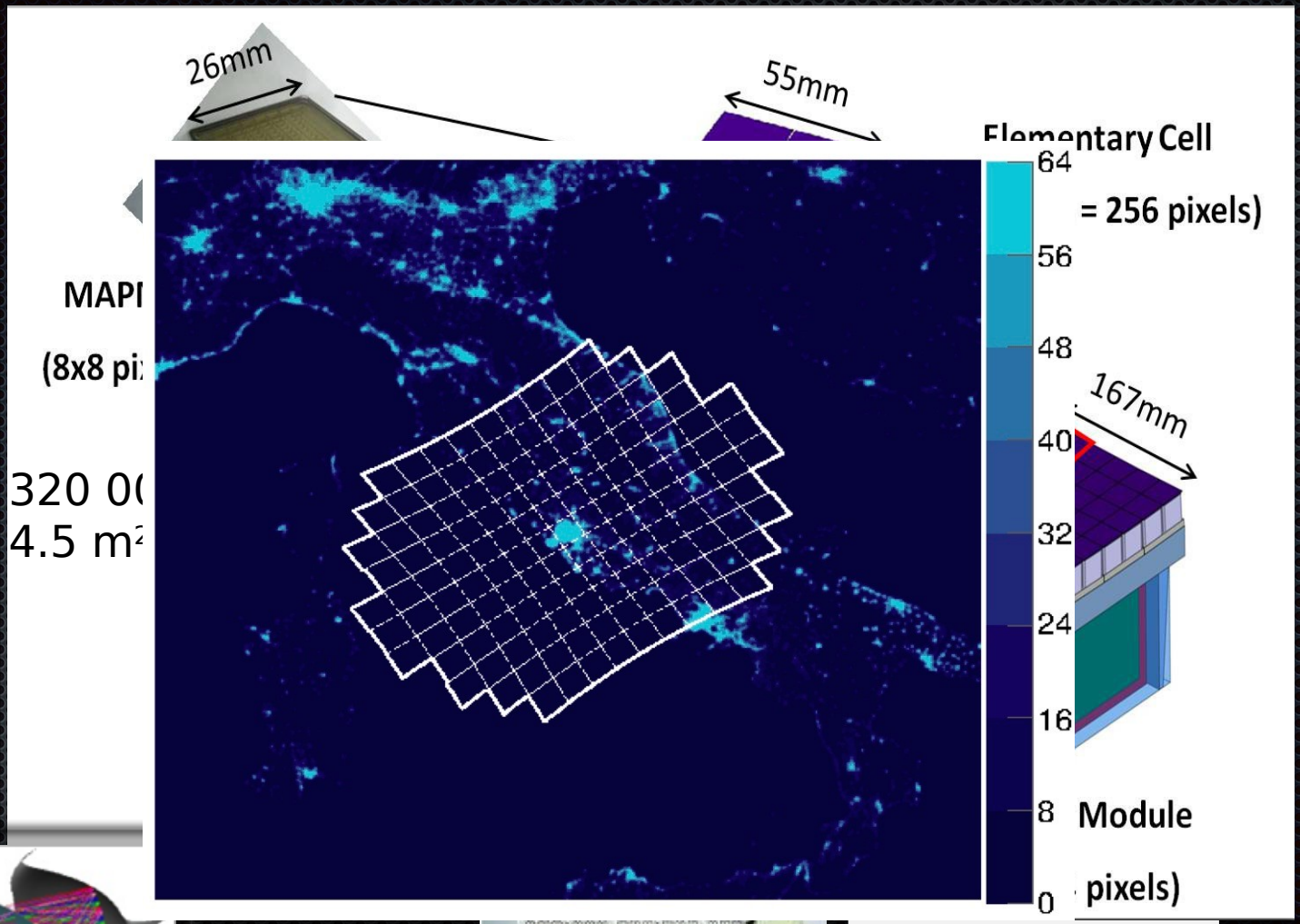
spatial resolution 500 m

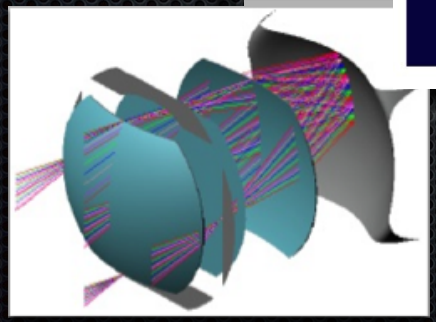




orbit = 90 min

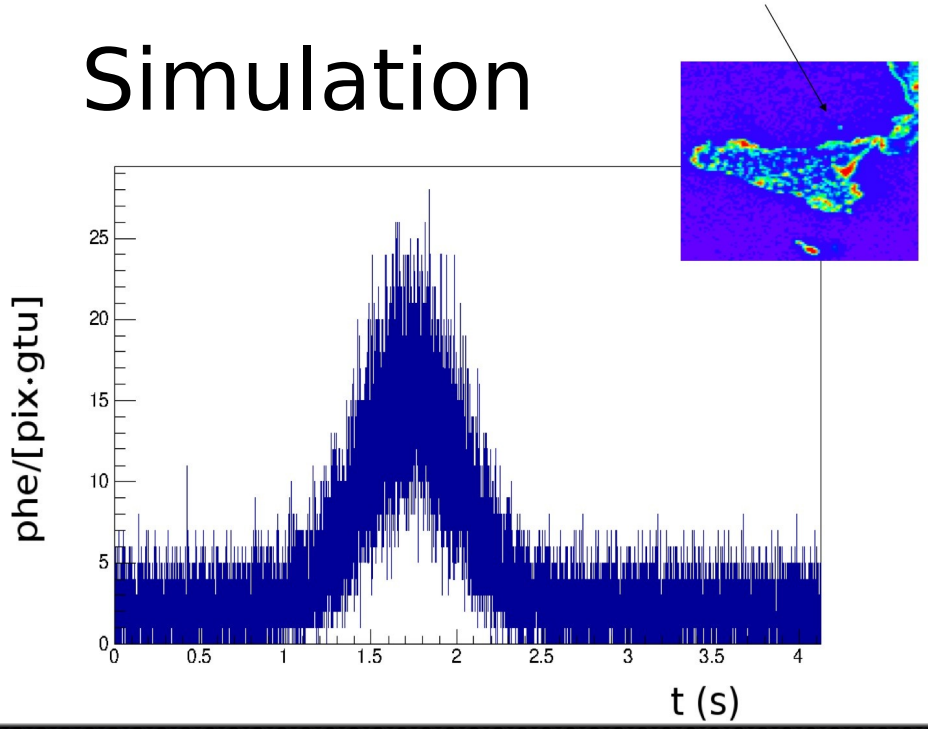
telescope





each PDM works independentl y

Simulation



simulating the Earth

Aeolian Islands

500 ph/(m²·ns·sr)

⇓

1.4 phe/pix/GTU

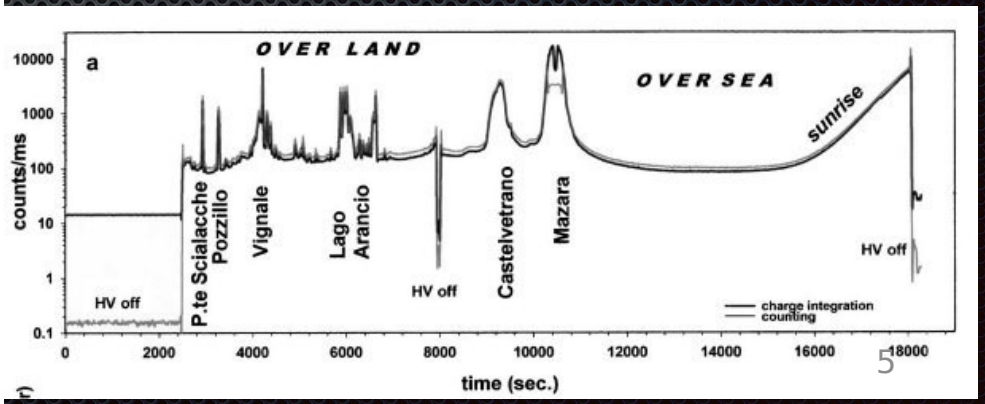
sky

JEM-EUSO

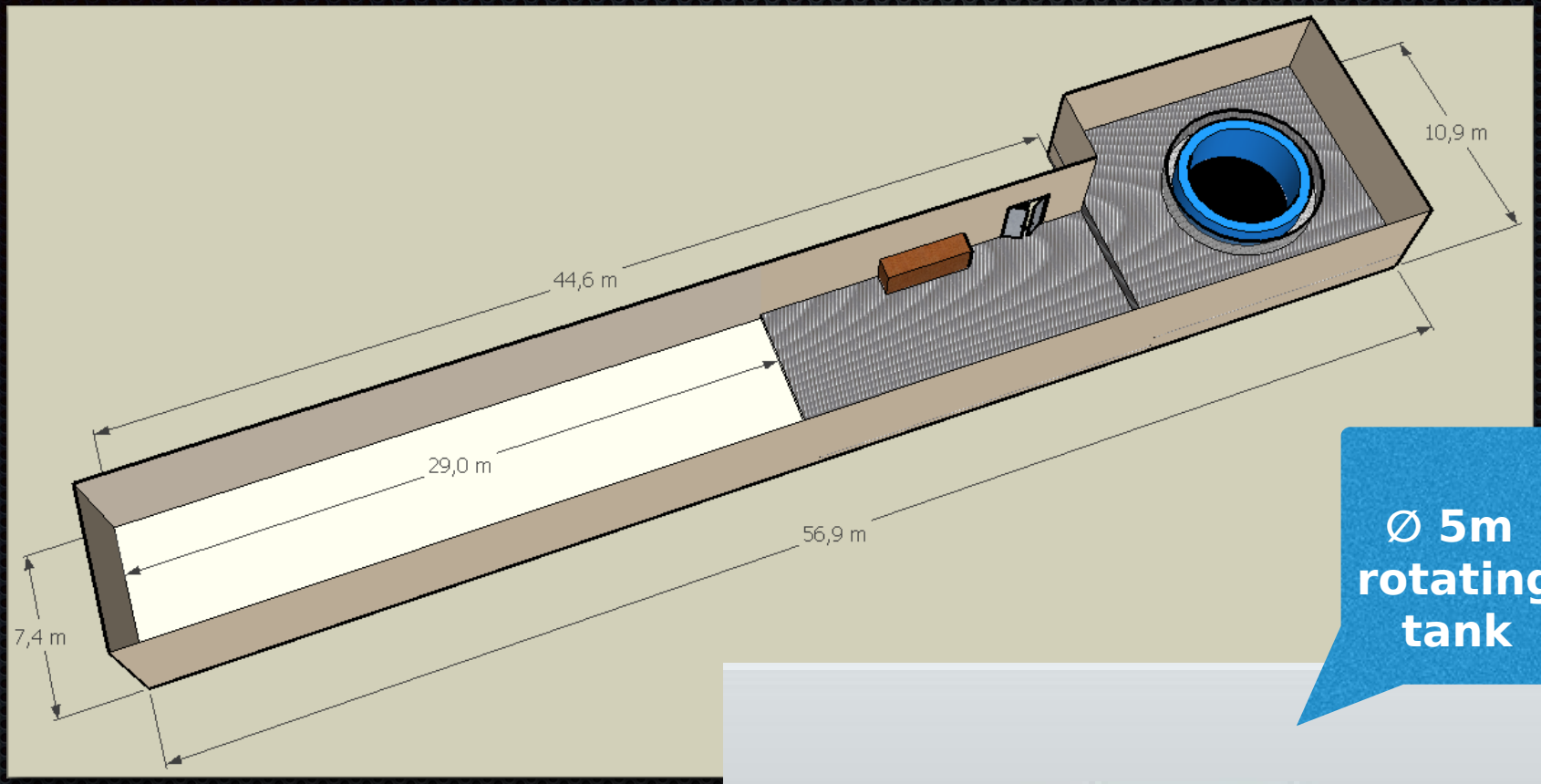
reasonable scaling compared to BABY balloon data

O. Catalano et al. NIM A 480 (2002) 547

Experimental data



EUSO @ TurLab



Ø 5m rotating tank

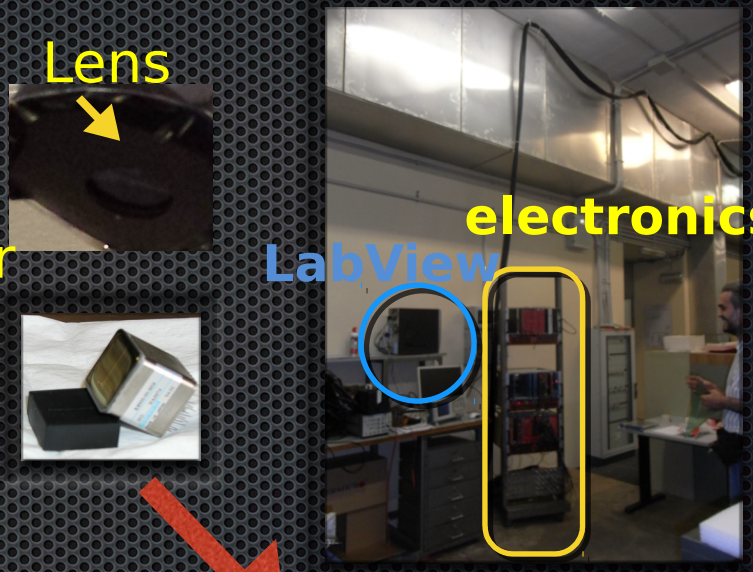
TurLab

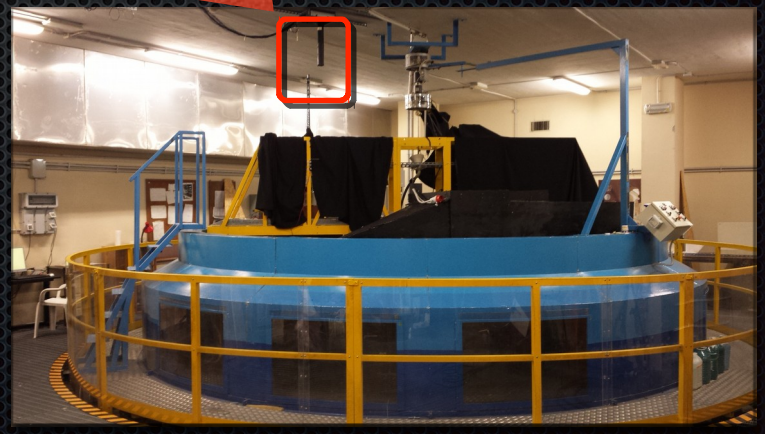
Rotational speed
max:1 rot. in 12 s
min: 1 rot. in 20 min

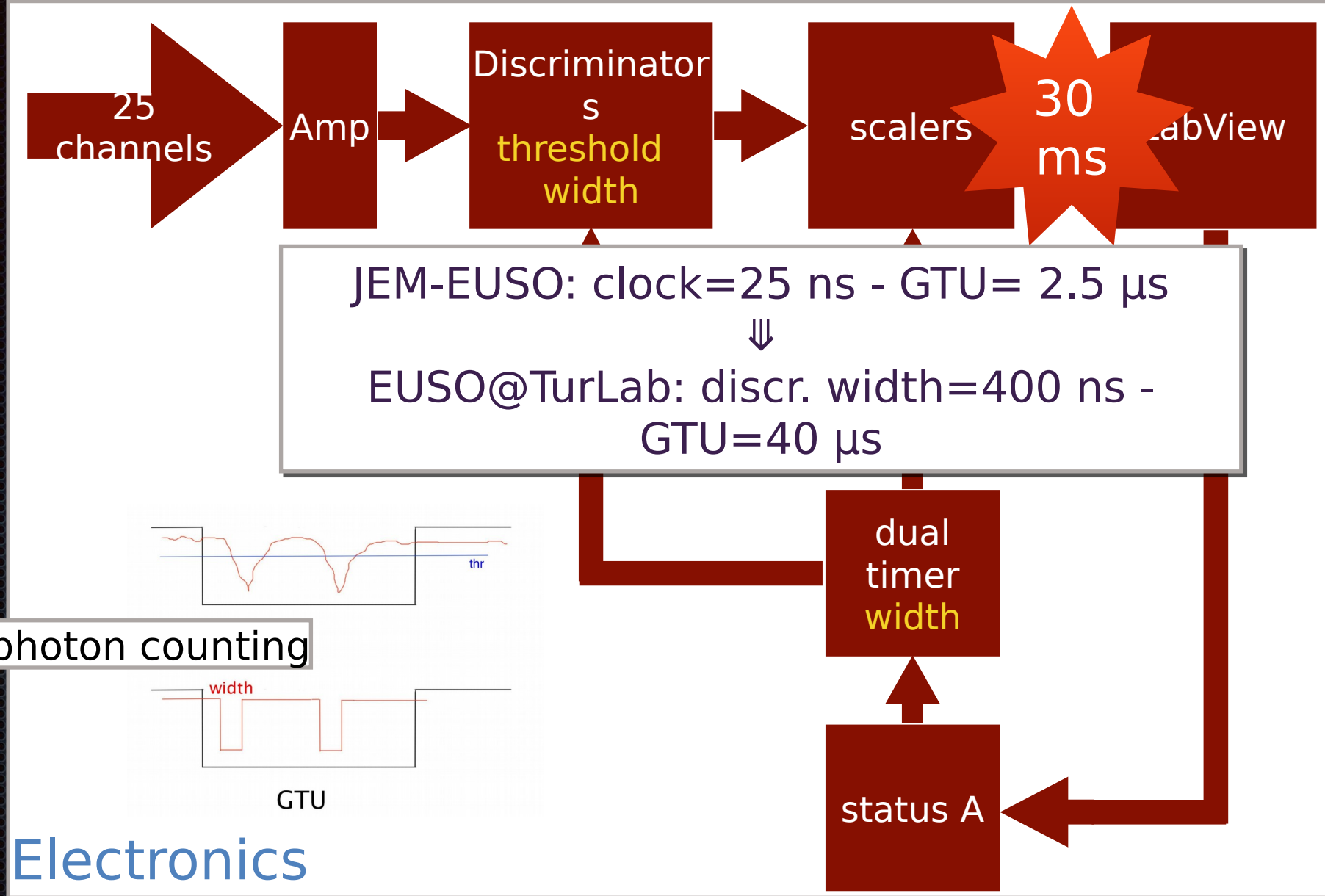
range: 1-100

Current set-up

- focusing lens
- 5x5 pixel MAPMT
- electronics
- the tank







Electronics

resolution

time
1 GTU = 40 µs sampled every 30 ms

space
1 pixel watches a
FoV of 5x5 mm2

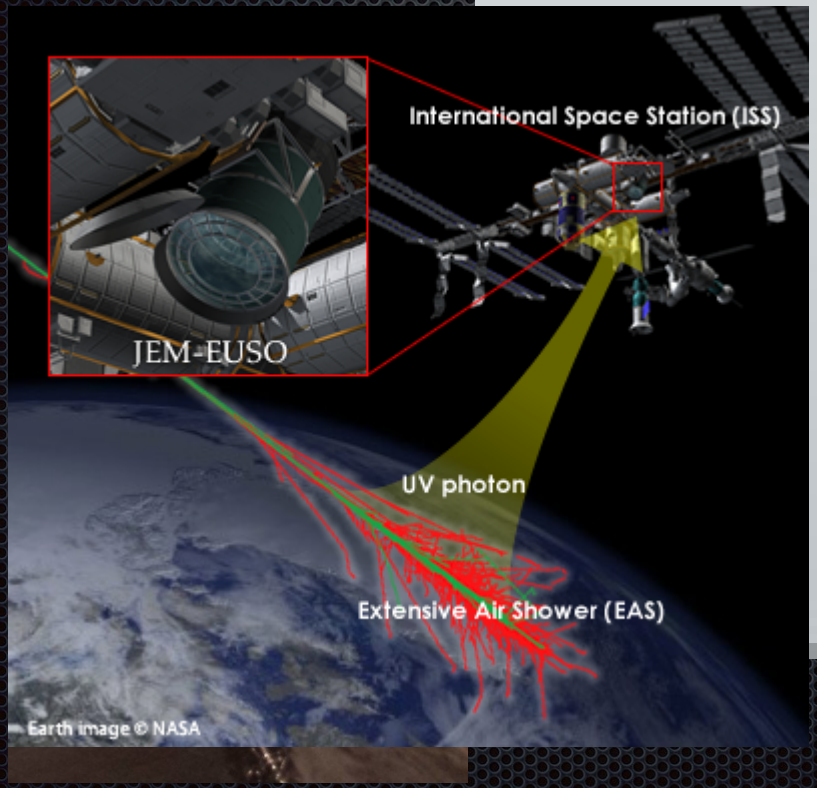
1 rot/3 min
R = 2 m

ISS: $8 * 10^3$ m/s — TurLab: 10^{-1} m/s

speed ratio $\frac{TurLab}{ISS} \approx 10^{-5}$

FoV ratio: $\frac{5*10^{-3}m}{5*10^{2}m} = 10^{-5}$

cosmic rays
using rotation of the tank



simulating events

OUR ELECTRONICS

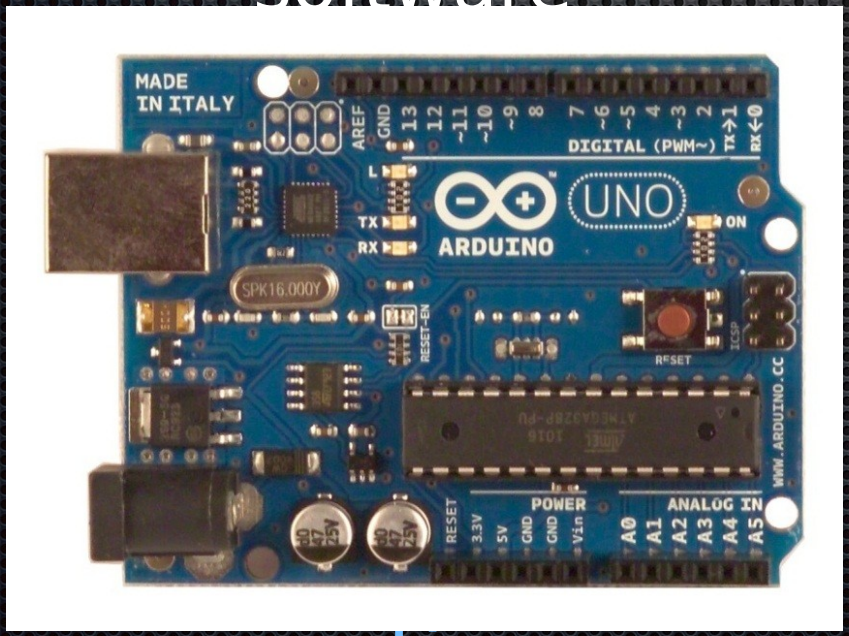
- GTU = 40μs
- Dead time = 30ms

JEM-EUSO ELECTRONICS

- GTU = 2.5μS
- No dead time inside a bunch of 128GTU

Arduino

An electronics prototyping platform based on open-source hardware and software



connection

Led_Jem_Euso | Arduino 1:1.0.5+dfsg2-1

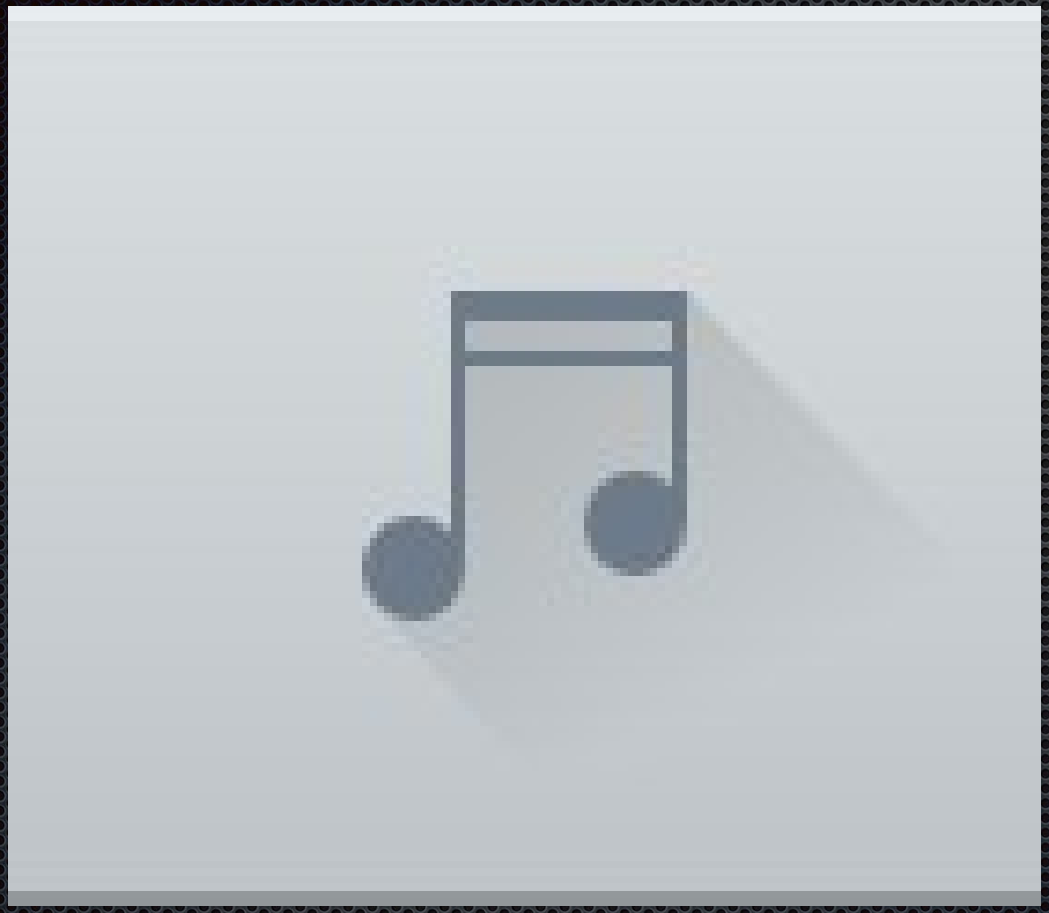
File Edit Sketch Tools Help

Led_Jem_Euso §

```
#define durata 100000 //microsecondi -- impreciso se troppo
#define sovrap 0 //microsecondi
#define intervallo 1000 //millisecondi
#define numLed 10
//

unsigned long timer;
int i=0;
int j=0;
boolean flag=true;

void setup() {
  for (int pin=2; pin<=13; pin++){
   pinMode(pin, OUTPUT);
  }
}

// the loop routine runs over and over again forever:
void loop() {
  if (flag){
    delay(intervallo);
   timer=micros();
  flag=false;
  }

    if(((unsigned long)micros()-timer) >= i*(durata-sovrap)
    digitalWrite(i+2, HIGH);
    i++;
    }

    //i-1 perchè intanto ha già acceso il successivo
    if(((unsigned long)micros()-timer) > ((j+1)*durata-j*sov
```

17 Arduino Mega 2560 or Mega ADK on /dev/ttyACM0

driving 10 LEDs

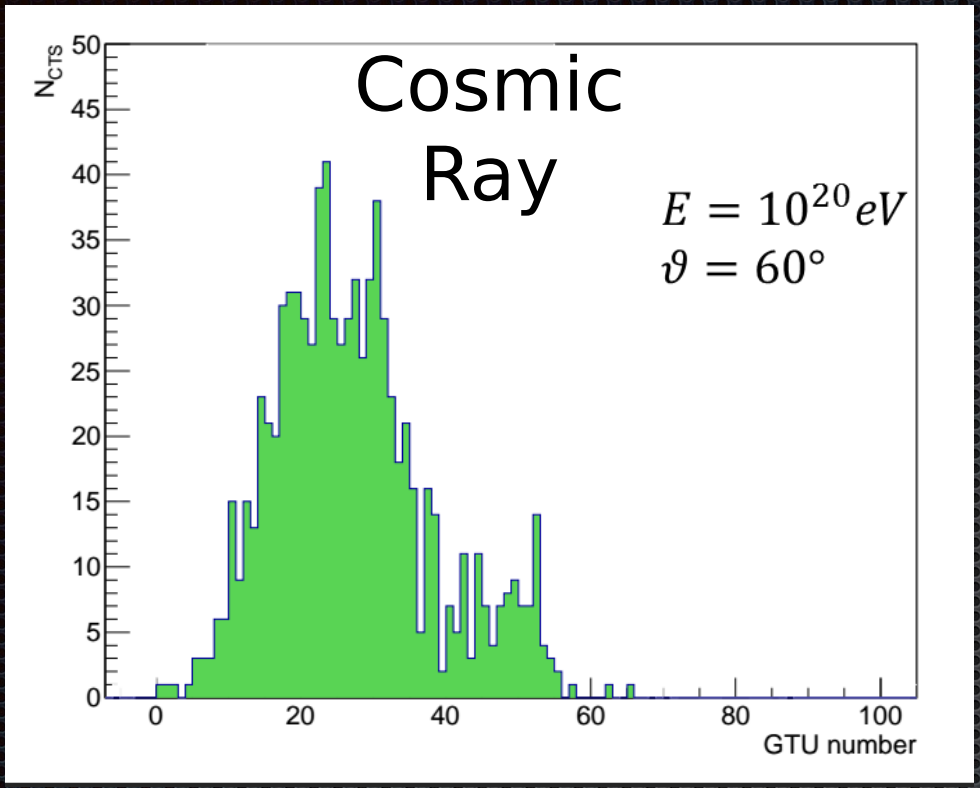


Min Time LED’s light: down to 2 µs

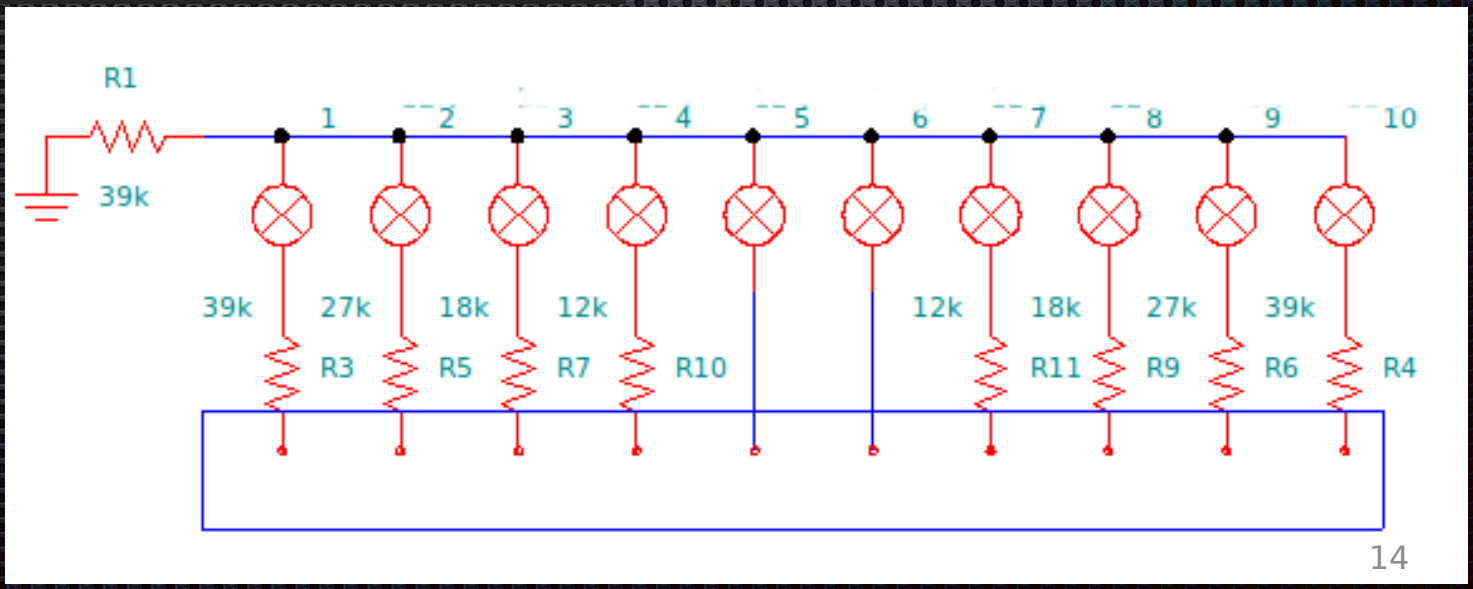
Portions of code written in Assembly

With JEM-EUSO instrumentatio

Cosmic rays: T LED from 2.5µs to 25µs



Light intensity of each LED is controlled to match the CR brightness profile



instrumentation cosmic rays

GTU number ≈ 20, Real time≈ 600ms

T Led = 60ms

Repetition cycle = 1Hz

instrumentation

T Led = 10µs

Repetition cycle = 1kHz

transient luminous event

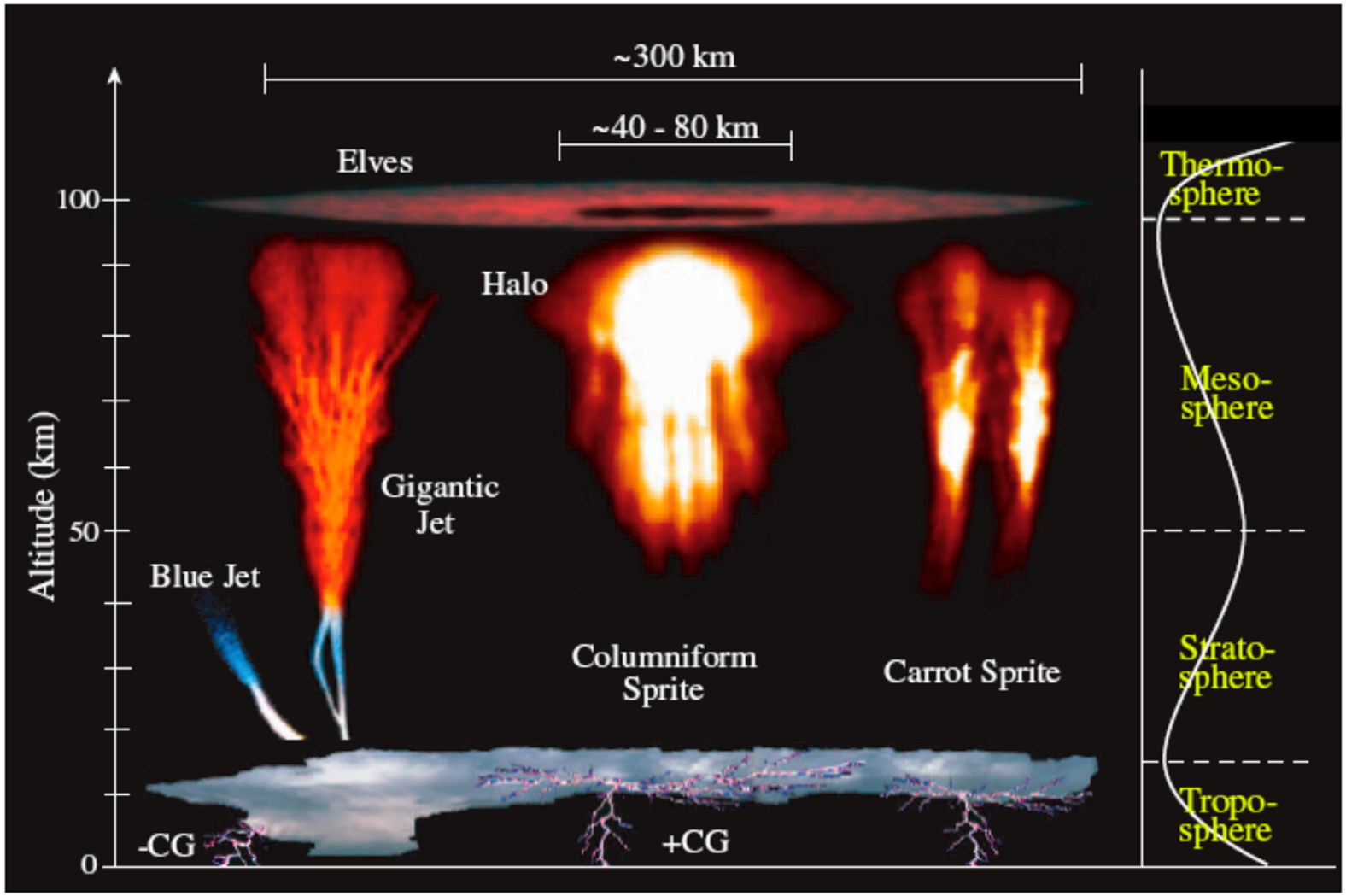


Figure 2.2.5-2. *Various transient luminous events associated with lightning.*

Helve:

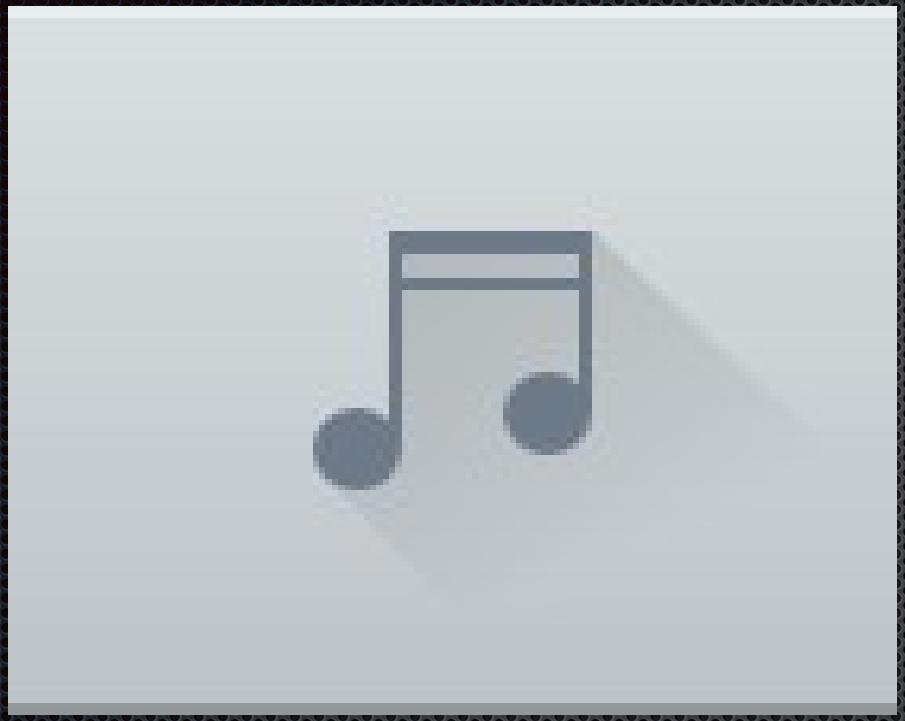
- r ≈ 200km
- duration ≈ 1ms

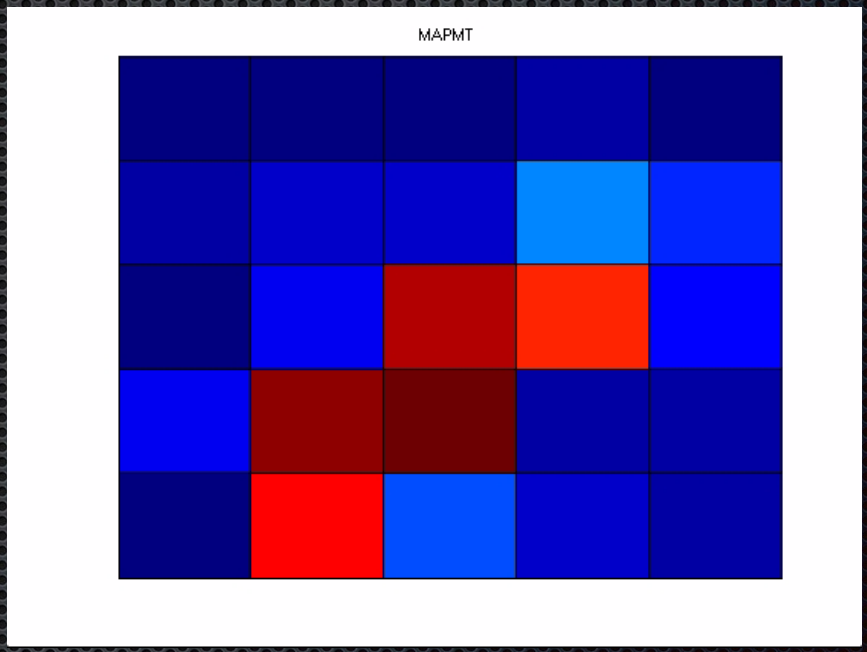
$$w \approx 2 * 10^8 \frac{m}{s} \longrightarrow \approx 0{,}7\,c$$

Wavelength shifting fiber

```
#define durata 80 //millisecondi
#define sovrap 0 //millisecondi
#define intervallo 500 //millisecondi
#define numLed 5
//
unsigned long timer;
int i=0; int ii=7; int j=0; int jj=7; boolean flag=true;

void setup() {
  for (int pin=2; pin<=13; pin++){
   pinMode(pin, OUTPUT);
  }
}
void loop() {

  if (flag){
        delay(intervallo);
        timer=millis();
        flag=false;
  }
    if(((unsigned long)millis()-timer) >= i*(durata-sovrap) && i<numLed){
        digitalWrite(i+2, HIGH);
        digitalWrite(ii,HIGH);
        ii++;
        i++;
    }
    if(((unsigned long)millis()-timer) > ((j+1)*durata-j*sovrap) && j<numLe
        italWrite(j+2,LOW);
        italWrite(jj, LOW);
        ++;
        ;


        =numLed){
              i=0;
              ii=7;
              j=0;
              jj=7;
              flag=true;
              }
```

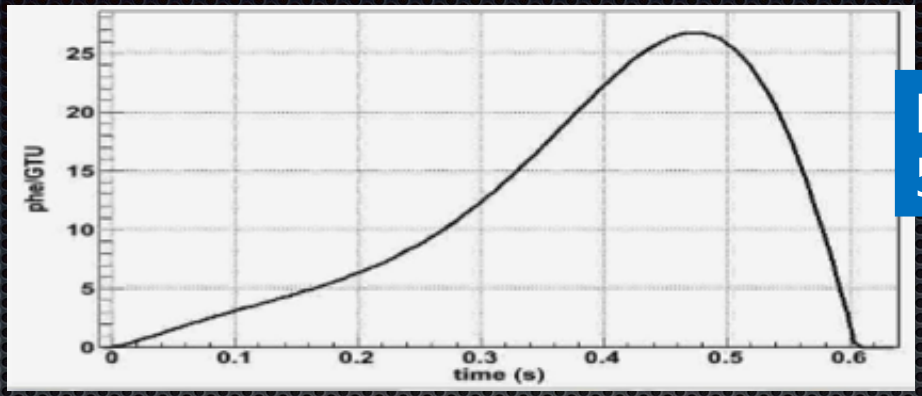
ith our electronics: T
Ds ≈ 80ms
ectronics: T LEDs




MAPMT

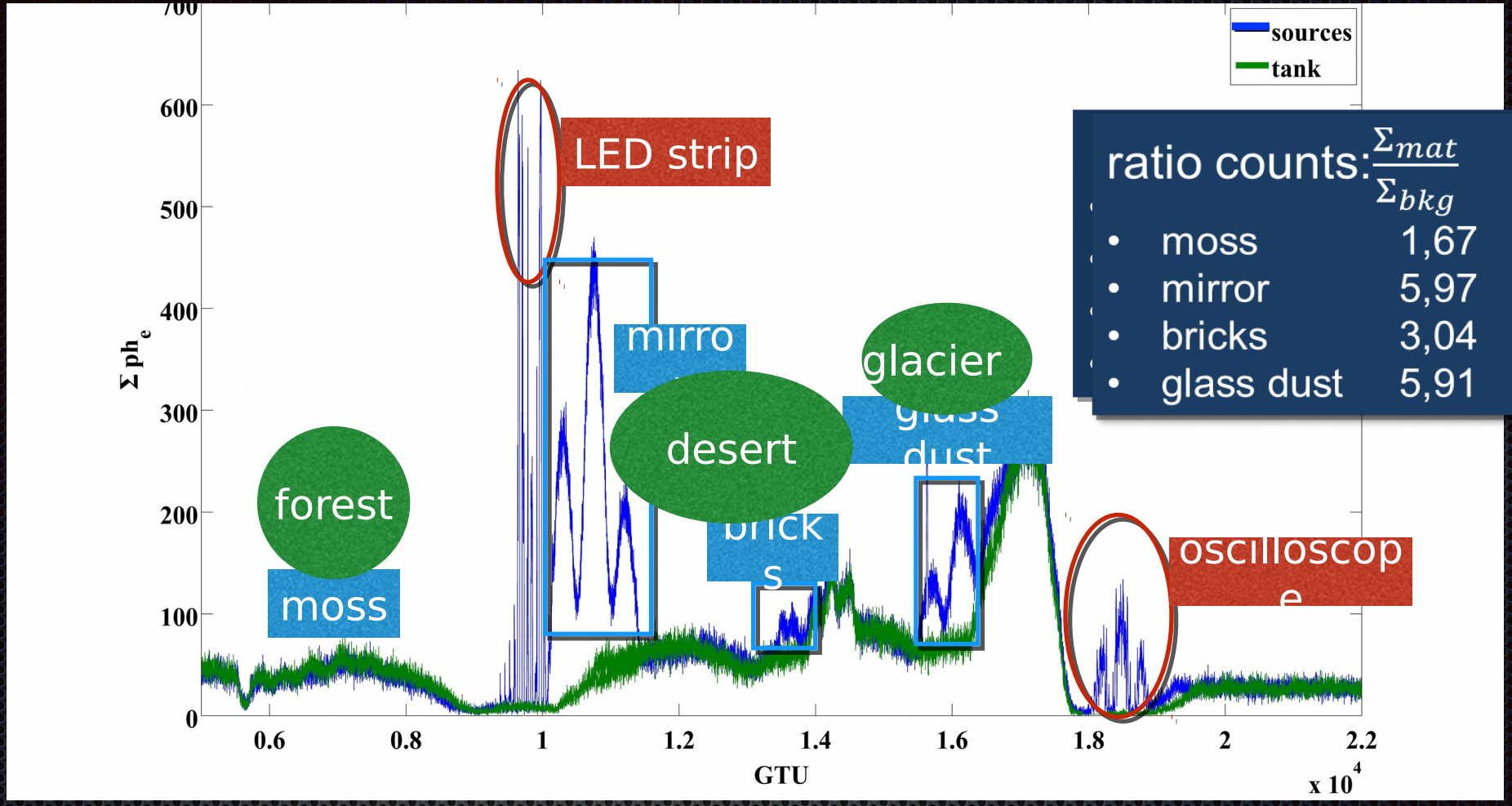
r

intensity of each LED has been tuned



M ≈ 5

different backgrounds



different light sources

- **light emitting sources**
- materials reflecting background ligh

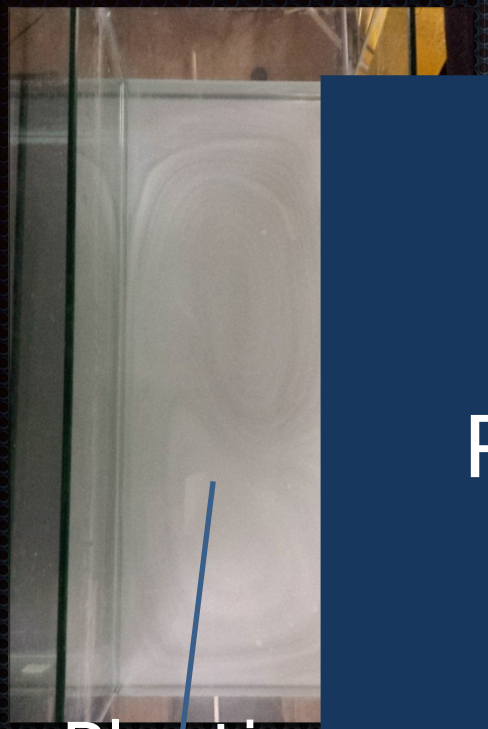
mean albedo: $\frac{I_r}{I_i}$

UVB ($\lambda \geq 320$nm)

- forest 0,05
- desert 0,09
- fresh snow 0,85

Stefanie Falk, Photon Transmission and Cherenkov Peak, Atmospheric Monitoring and Simulation Meeting – Karlsruhe 2013

clouds

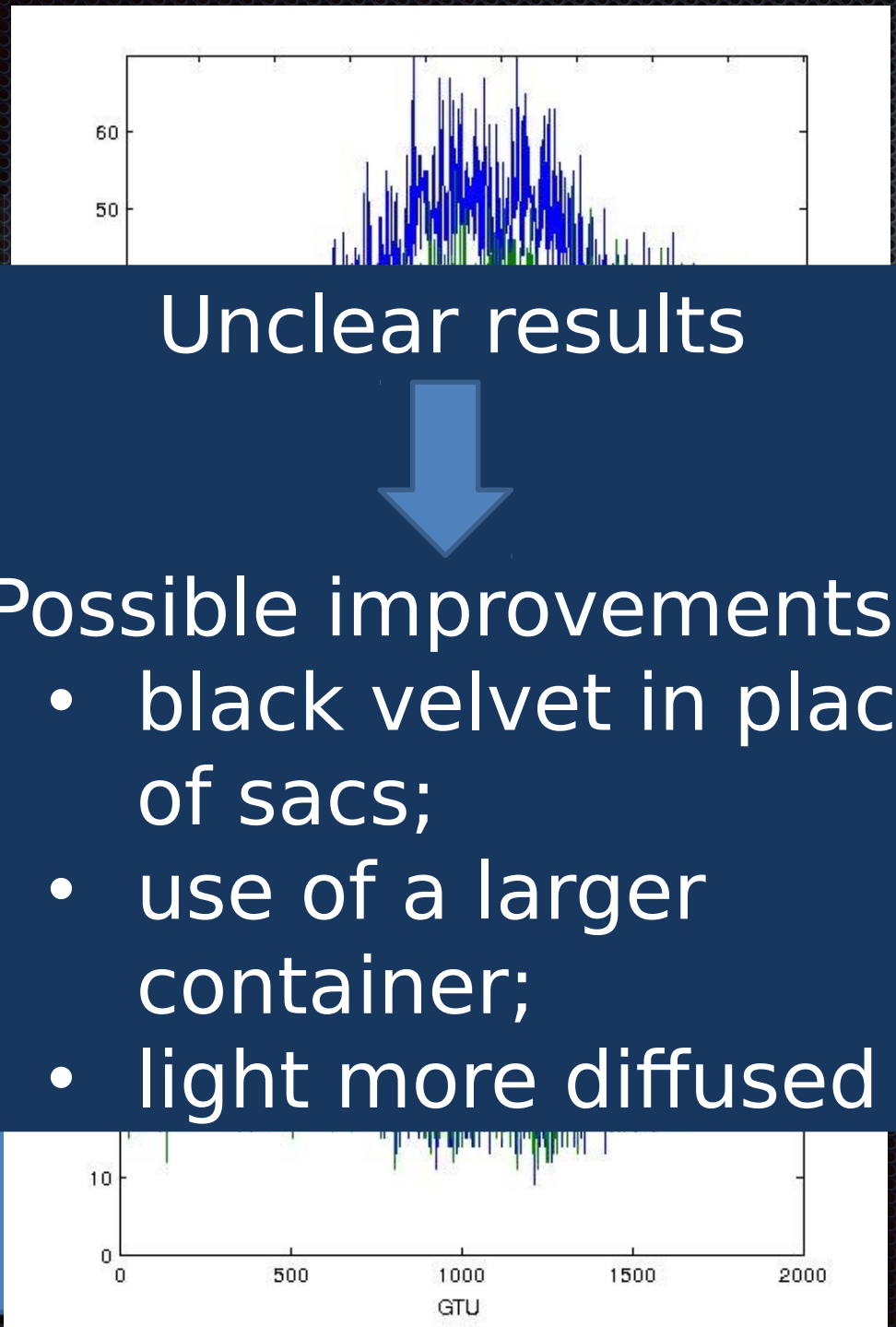


Plastic particle

Dark

container

(obtained with black



Unclear results

Possible improvements:

- black velvet in place of sacs;
- use of a larger container;
- light more diffused

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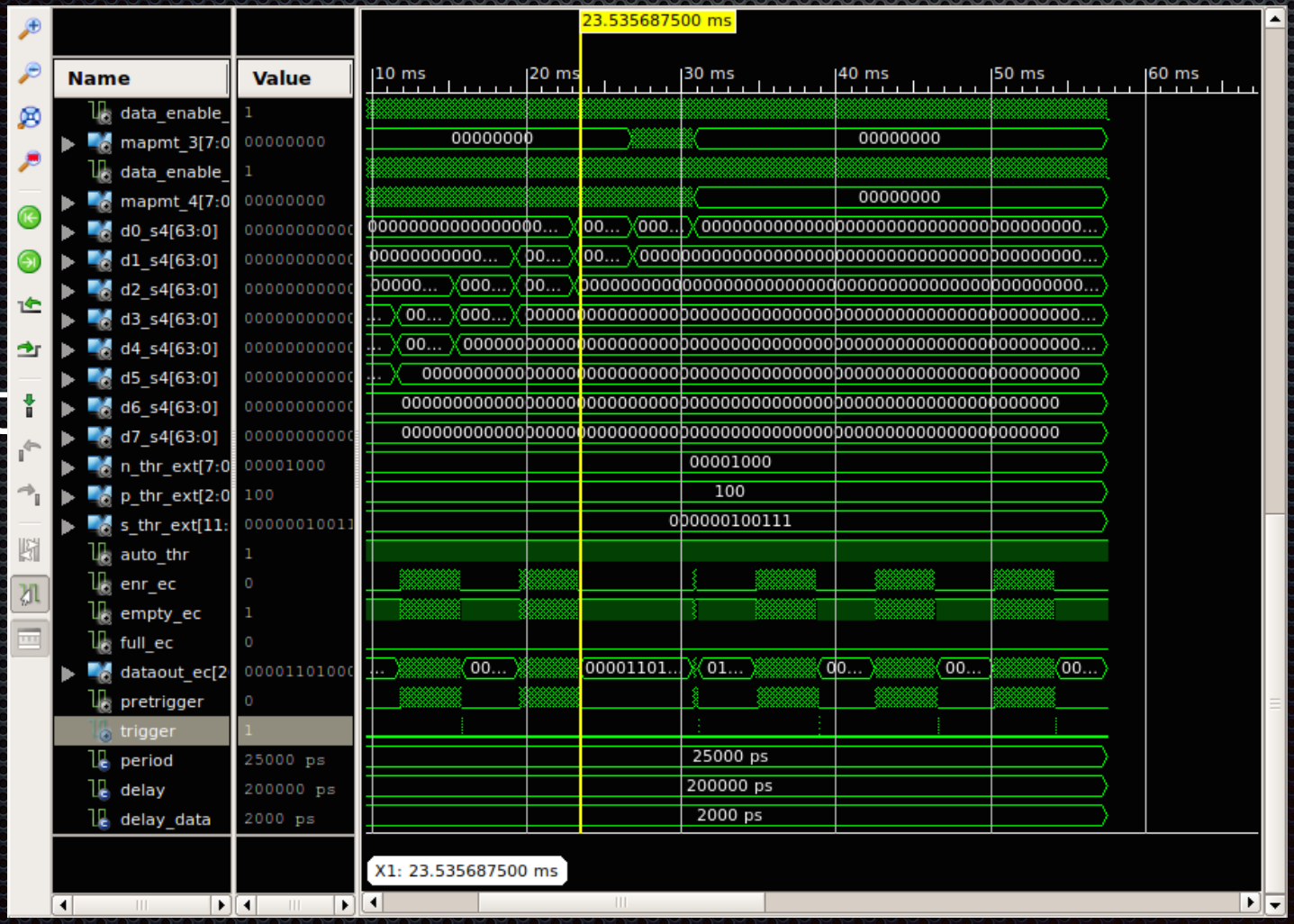
testing the trigger VHDL



what has been done

- reproduction of cosmic rays with Arduino
- replica of upper-atmospheric lightning
- replica of background conditions
- data analysis with MatLab

Ringraziamenti:

Ringrazio il prof. Mario Bertaina e il dott. Marco Aglietta per la loro professionalità e grande disponibilità.

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