Muon detection

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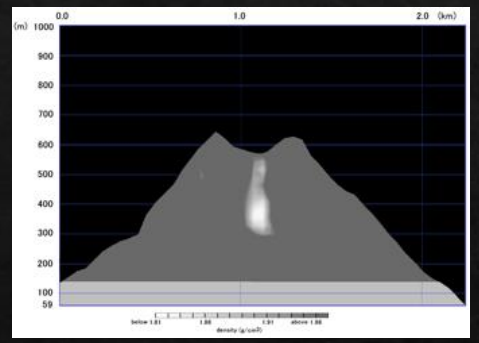
Muons

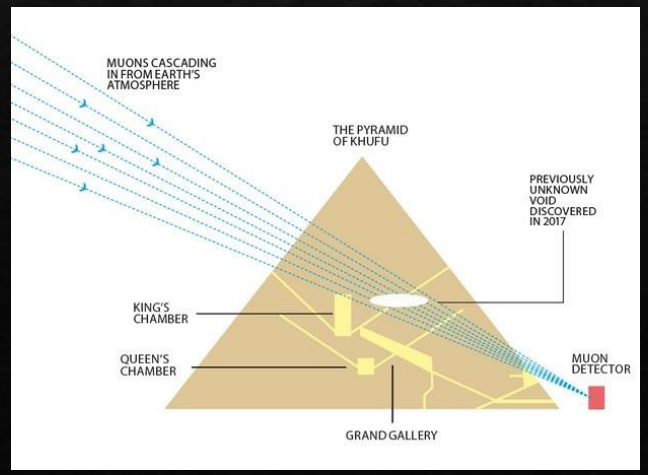
What are they? Why would we try to detect them?

A more massive version of the electron with a lifetime of 2,2μs

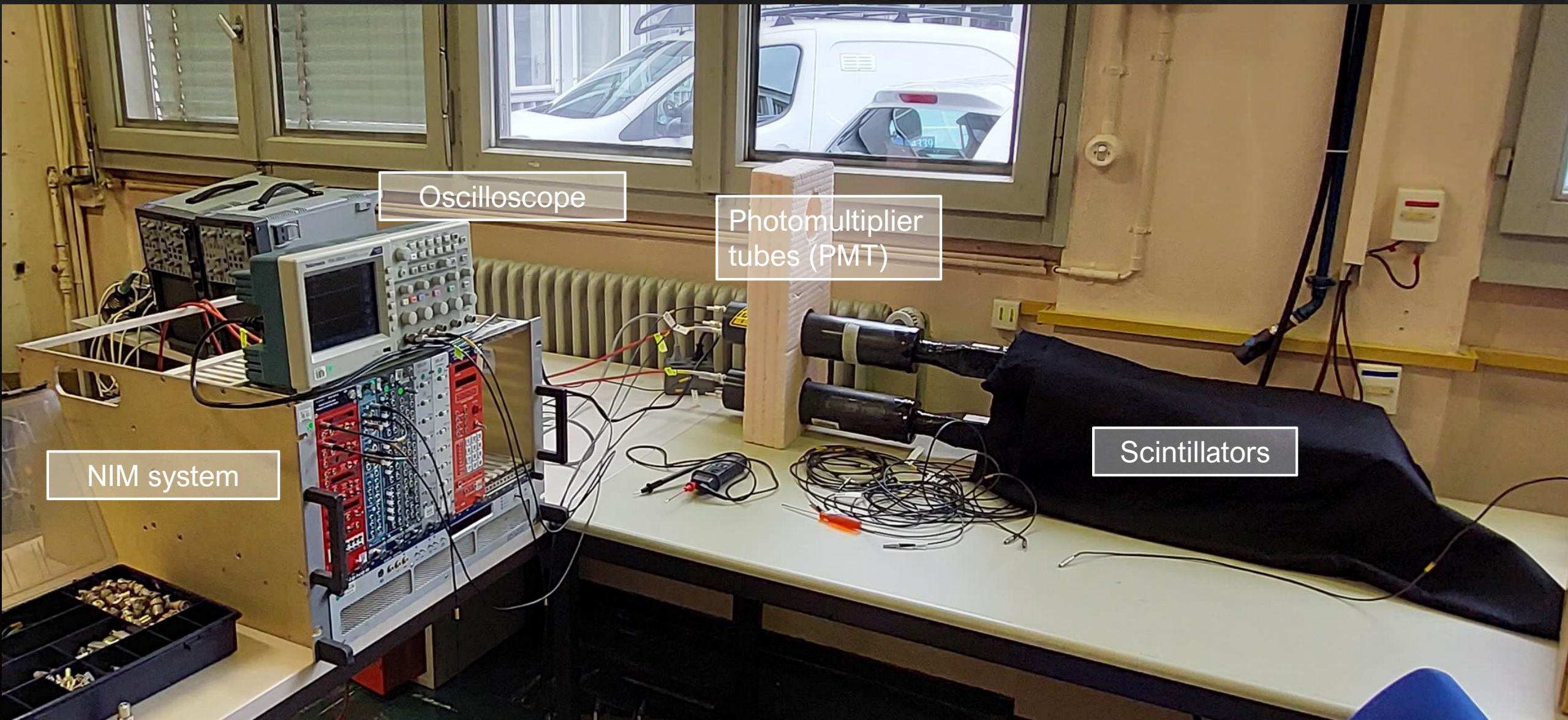
Cosmic radiation hitting Earth's atmosphere
Particle accelerators

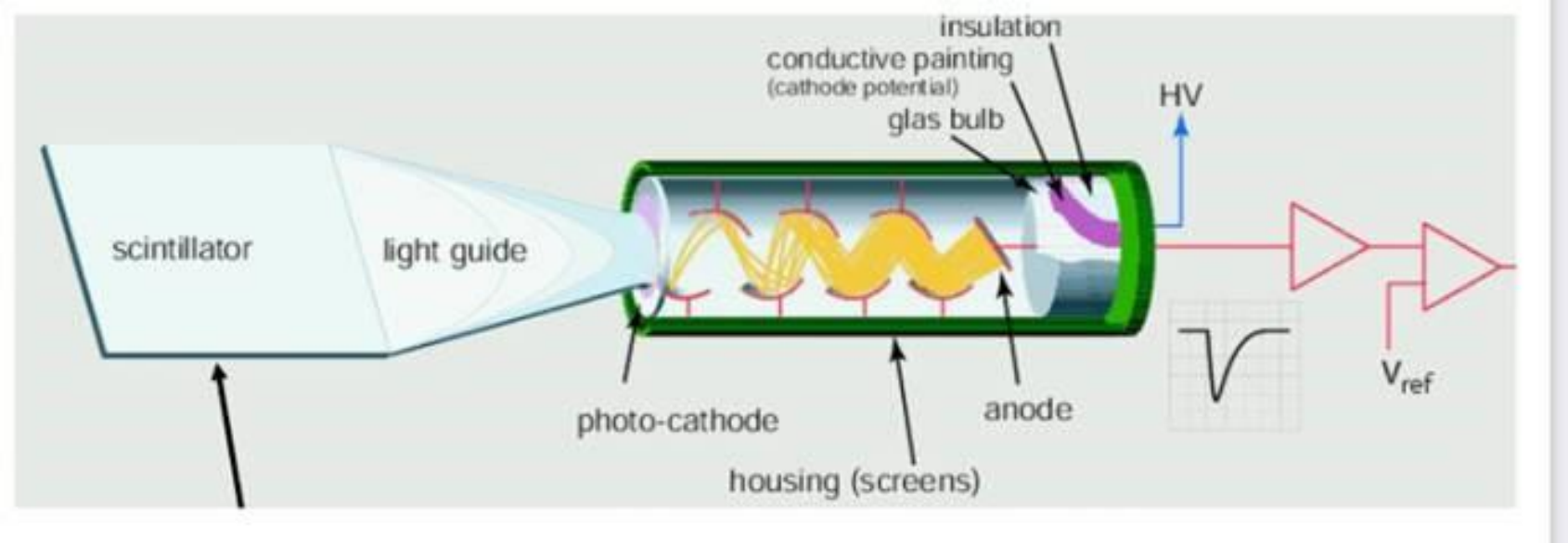
Curiosity
Applications





The set-up


Oscilloscope
Photomultiplier tubes (PMT)
NIM system
Scintillators


insulation
conductive painting
(cathode potential)
glas bulb
HV
scintillator
light guide
photo-cathode
anode
housing (screens)
V_{ref}

Noise

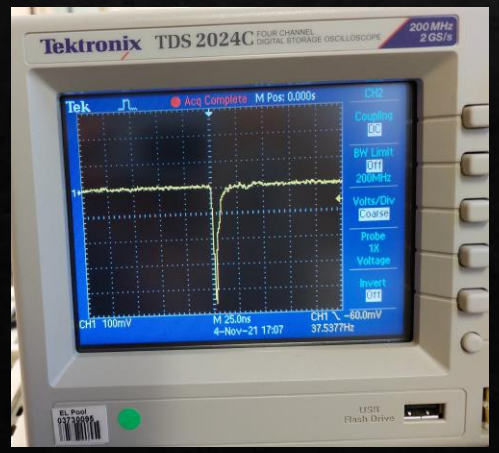
What is it? How to get rid of it?

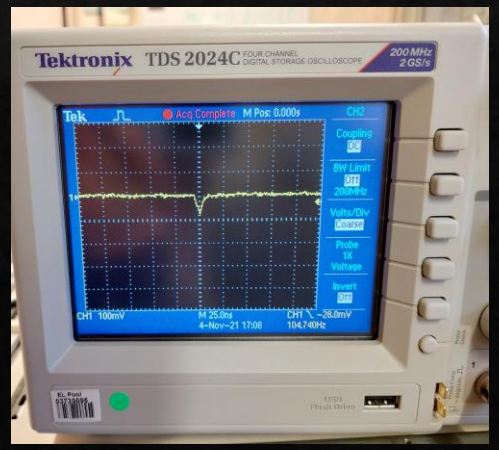
= signals that aren't caused by a muon going through the detector

Causes?
- thermal emission
- light leak

Discriminator unit
=> trigger limit: 50mV

Coincidence unit
= emits signal when receiving simultaneous signal from both detectors
BUT random coincidences still exist!



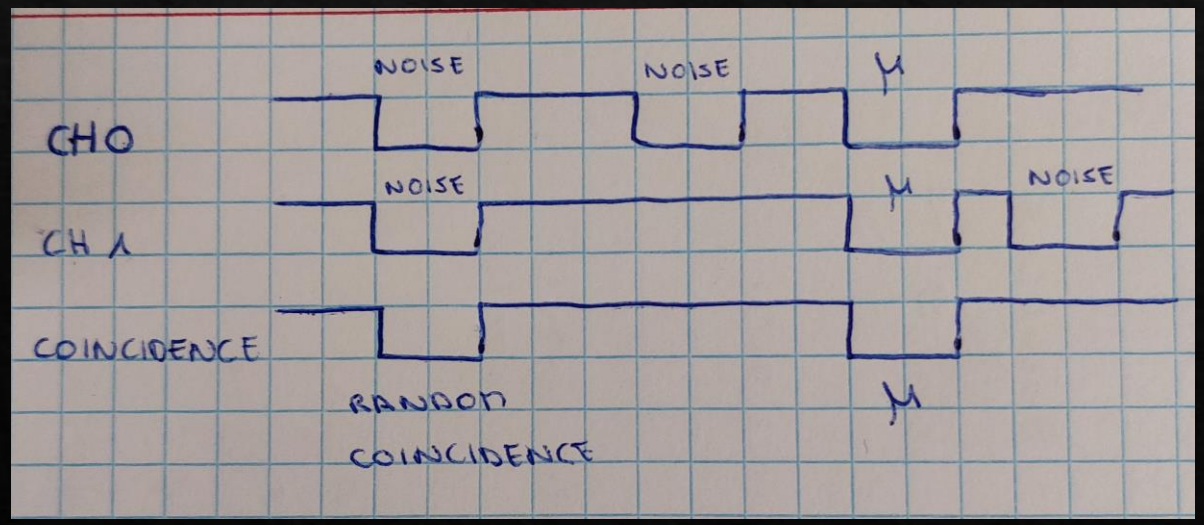


Analog signals from PMT

Random coincidences

What are they? How to rule them out?

= two simultaneous noise signals that are interpreted as a muon by the coincidence unit



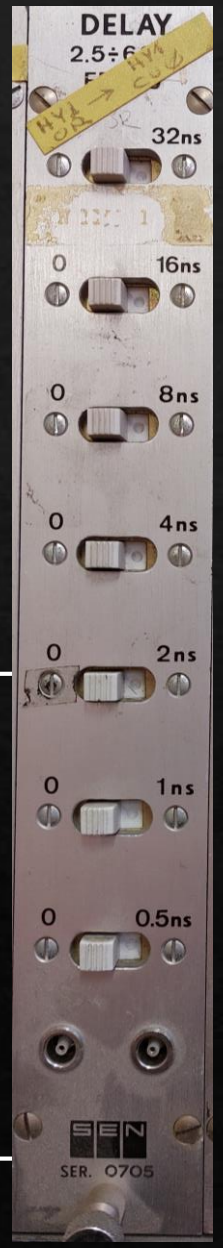
Theoretical

$$f(RC) = \frac{N_0 * N_1 * (W_0 + W_1)\, ns}{1\,000\,000\,000\, ns}$$

=> 1 RC/45 minutes

Experimental

1. Put the detectors away from each other
   => results: 4, 5 or 27 per hour
2. Delay unit
   => results: 0, 4 or 9 per 15 minutes

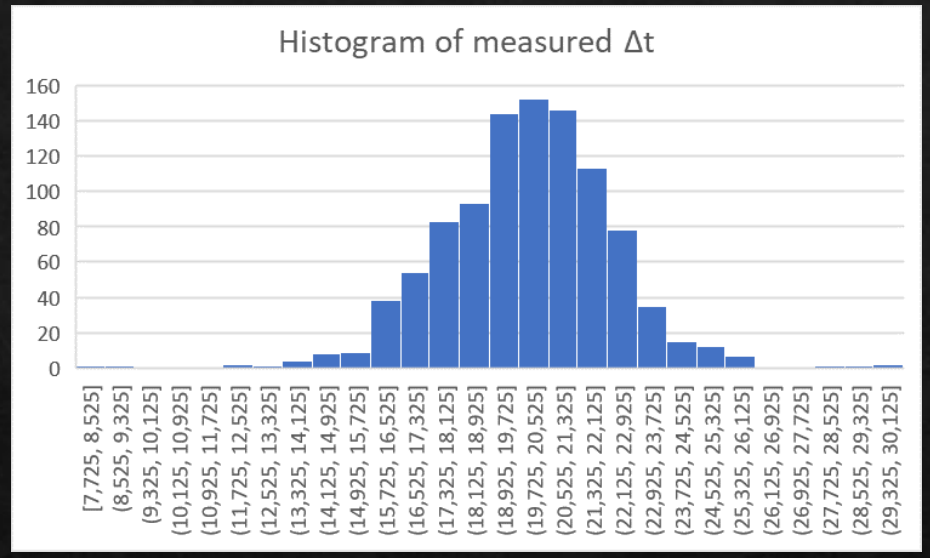


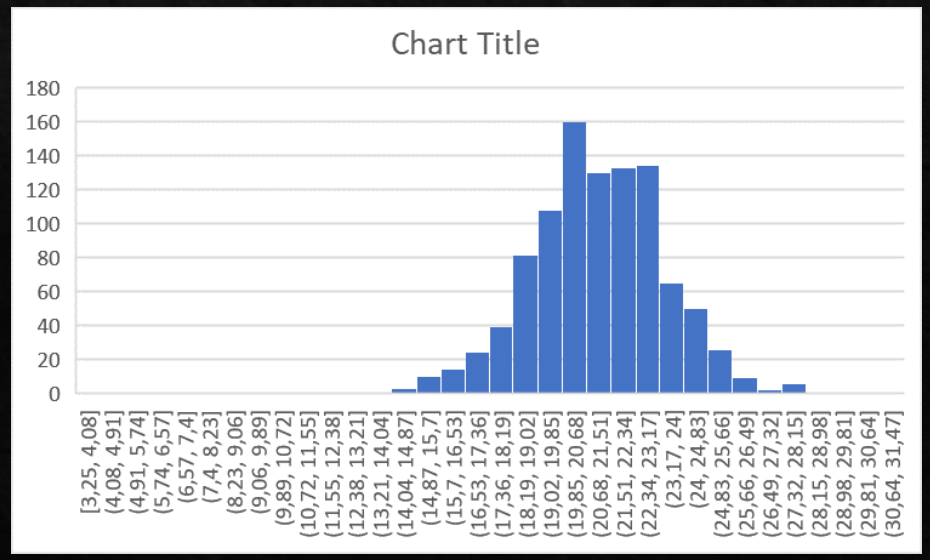
Data acquisition system (DAQ)

A small computer programme in plain C

Purpose?
Calculating the velocity of the muons and comparing the data from the different measurements
=> result: muons move at the speed of light

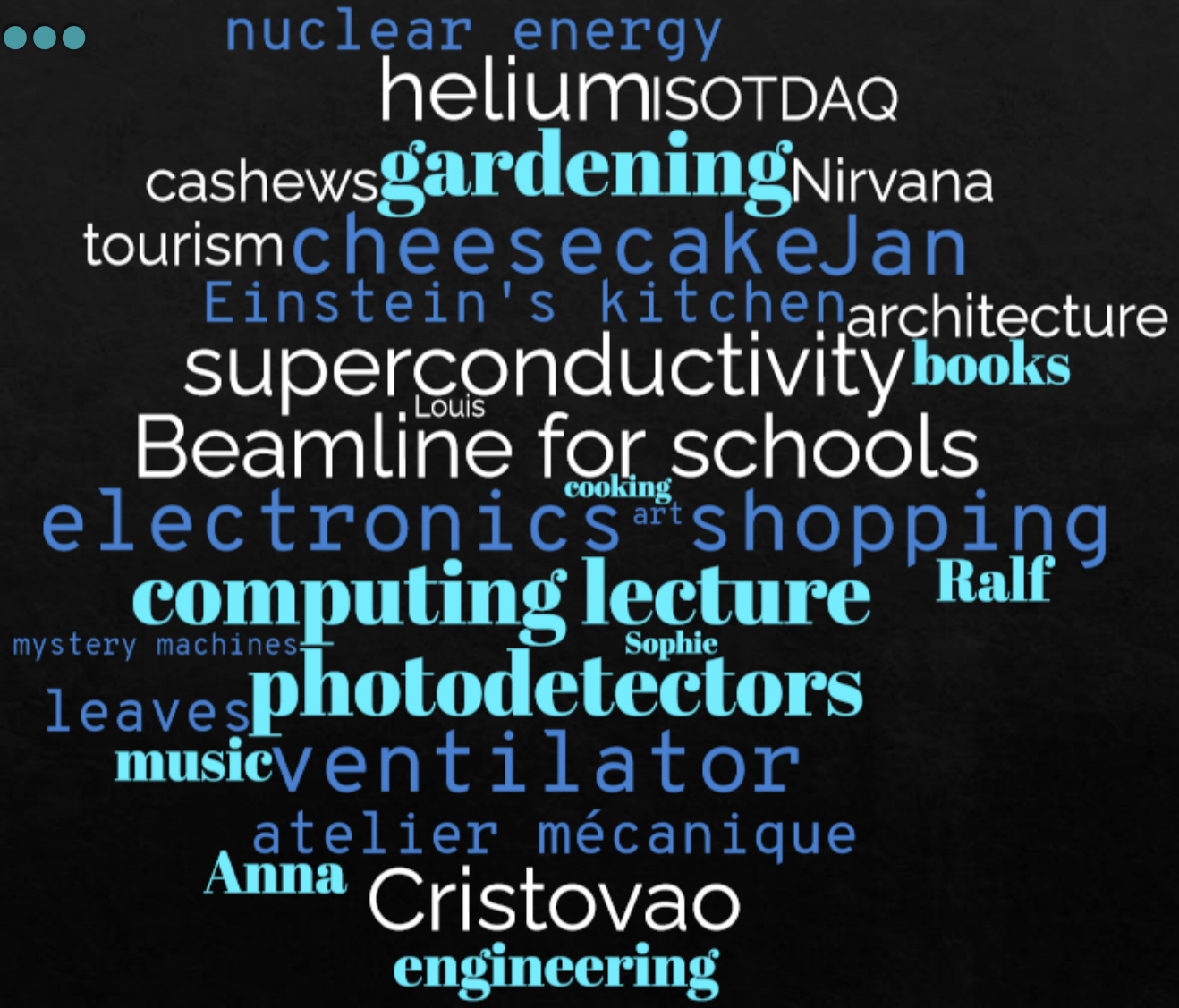
How?
1) Two detectors at a certain distance on top of each other
2) Time to Digital Converter (TDC) records the time between signals from each detector when muon passes through
3) This data is put into a file via the DAQ
4) We put this data in an Excel histogram => Gaussian distribution






```
FILE *out_file;
u_short value0;
int loop, event_number;
u_int wtype, vme32;

printf("This is a very simple piece of code to acquire timestamps
from the TDC\n");

out_file = fopen("time_stamps", "w+");
if (out_file == 0)
{
 printf("Can't open output file\n");
 exit(0);
}
fprintf(out_file, "event_number; channel; time in ps\n");

printf("Enter the number of events to record\n");
event_number = getdecd(100);

for (loop = 0; loop < event_number; loop++)
{
 printf(" processing event %d\n", loop);
 //Wait for data
 while(1)
 {
  value0 = v1290->status_register;
  if (value0 & 0x001)
   break;
```

And so much more...



What did we learn about CERN?

There is your job, but there is also a lot of space for your own project ideas, your own interests, creativity and self-development.

Thank you!

- Thank you François, Jean-Pierre, Cédric, Margherita, Feza … for making this internship possible
- Thank you Cédric and Marijke for accompanying us
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- Thank you weather for being quite nice ☺
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- Thank you to all the others that made this happen from behind the scenes!