BL4S 2018 Setup

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Our tools: detectors

- It sounds as a paradox, but we can detect particles only if they interact with matter then losing energy
- When a charged particle crosses the matter a lot of interactions occur, leaving a trail of electrons and ions besides photon coming from the de-excitation of the atoms or molecules
- The silicon detectors and the gaseous detectors collect the free electrons
- The scintillators reflect the photons towards a photocathode which emits an electron.
- We always deal with electronic signals, due to the INDUCTION of the electrons on the anodic plane

Our tools: scintillators

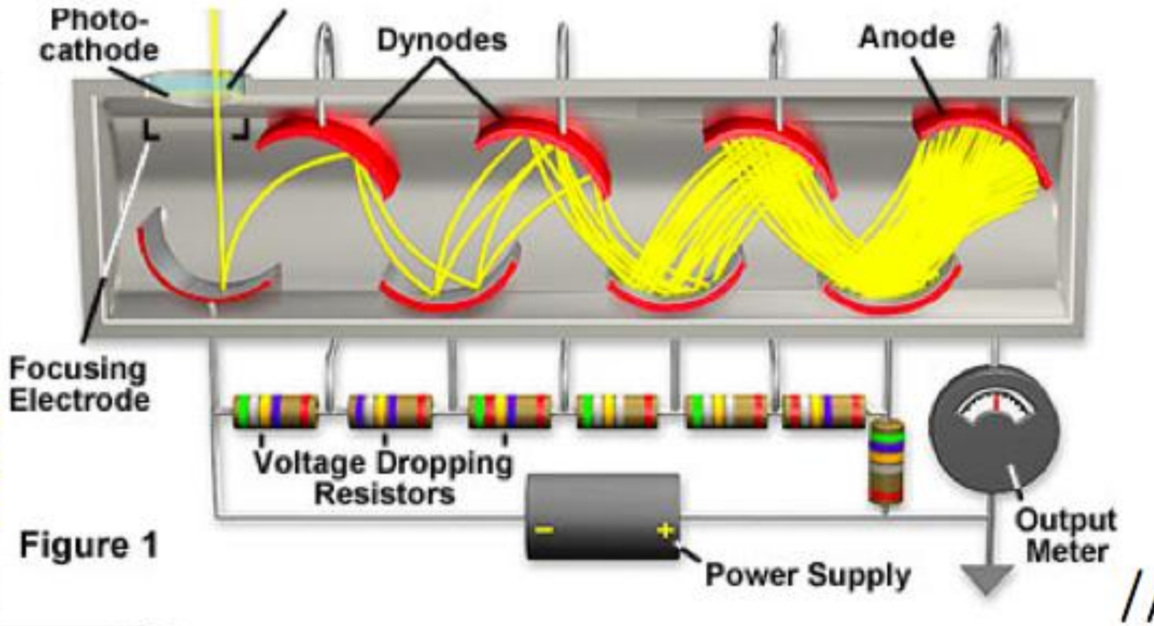
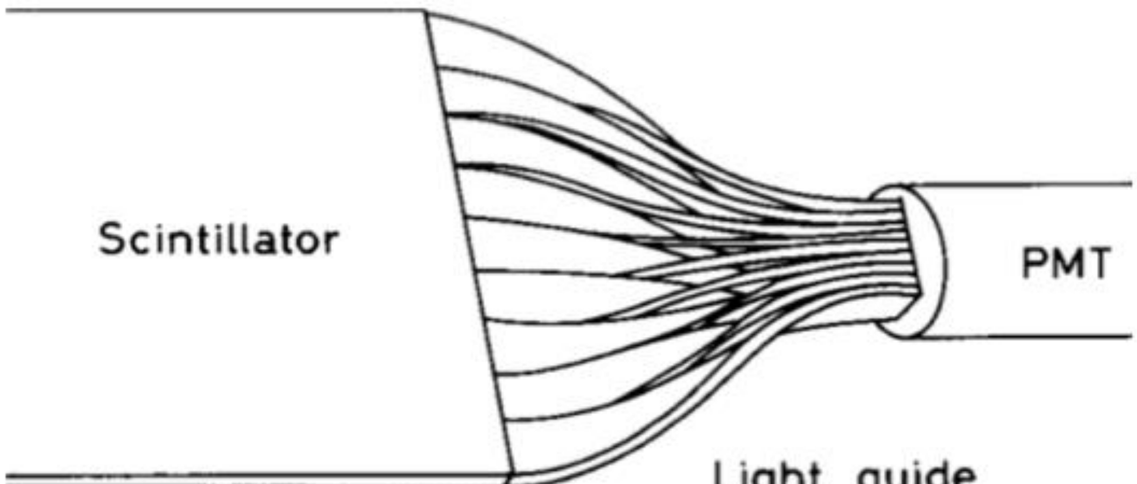


Figure 1



Our tools: scintillators

PRO: they're quite fast, we can then have time information about the particles motion. On the other side we can use them as counter: hits collected = particles passing through (or better, almost equal…)

CON: we cannot use them to have the position of the incoming particle, unless we do something fancy… but not in our cases!

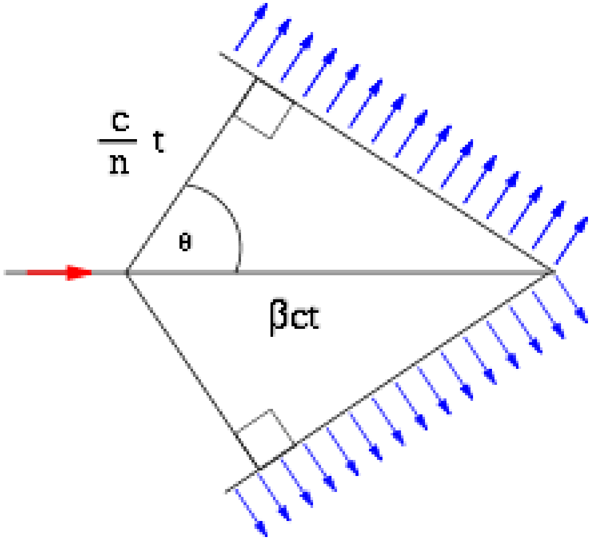
Our tools: gaseous detectors

The story started in 1908, with Rutherford, Geiger and Madsen…
The working principle is the same:

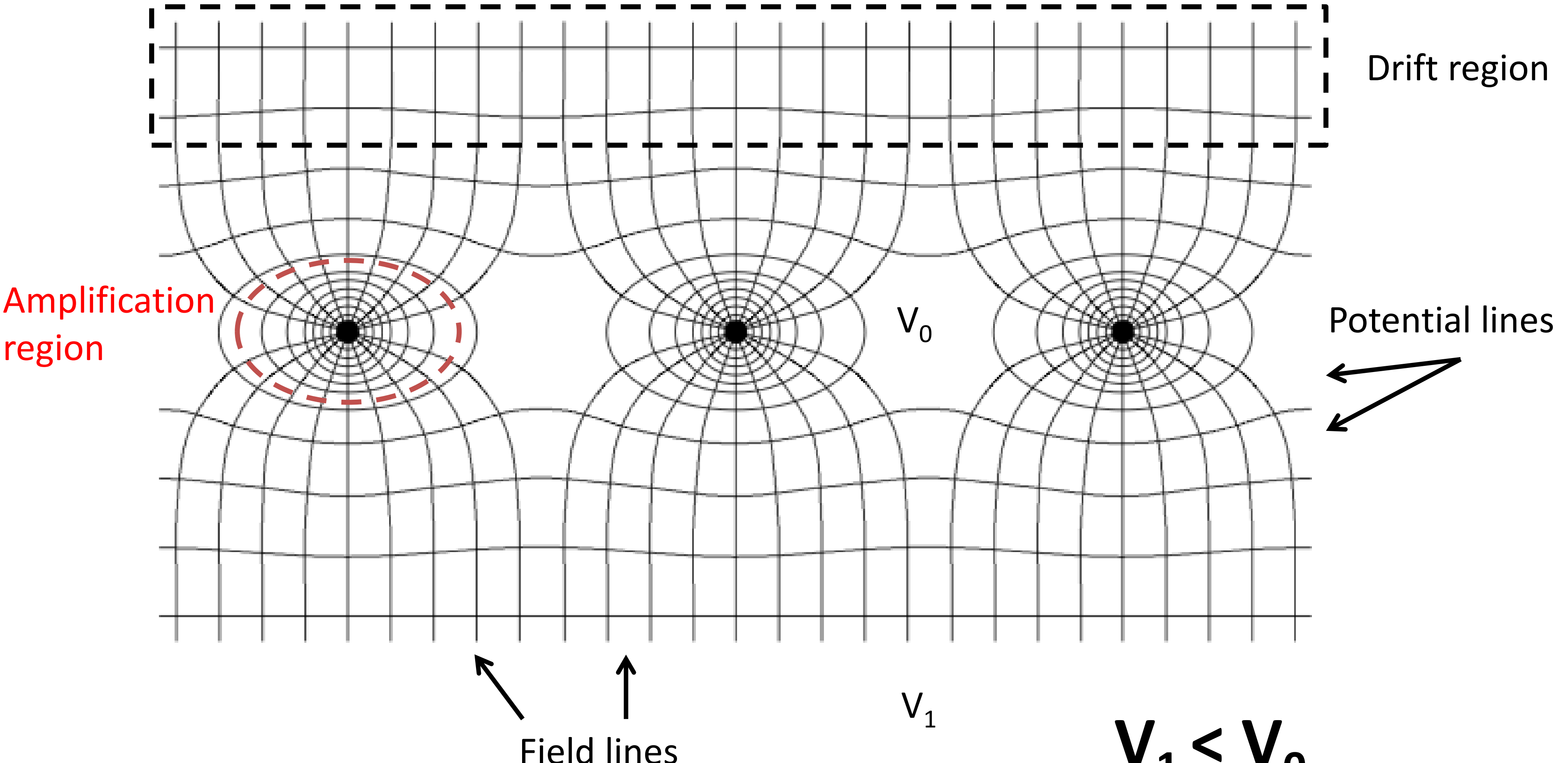
1) the particle creates **ion-electron pairs**
2) an electric field makes the ions **drift** towards a cathode (lower potential) and the electrons towards an anode (higher potential)
3) the electrons undergo a **high electric field**: they are accelerated, making further interactions with the atoms/molecules freeing other electrons: this is **the electronic avalanche**
4) part of all the electrons created in the avalanche drift towards the anode **inducing a signal**
5) we collect this signal

Čerenkov detector

The speed of light is unreachable by anyone or anything… **if the light travels vacuum!**
If not, something very very interesting happens: the light is slowed down by a factor ***n*** that is the refraction index of the material
The interactions between the crossing particle and the matter travel then at a speed c/n!
Now it is possible than a particle is **faster than the light** in that mean!
What if we have a set of particles at a given energy and different masses?
Is it possible than to use a Čerenkov to label an event?
As the particle passes, the molecules gets excited and they emit electromagnetic radiation especially in the UV, but also in the blue.



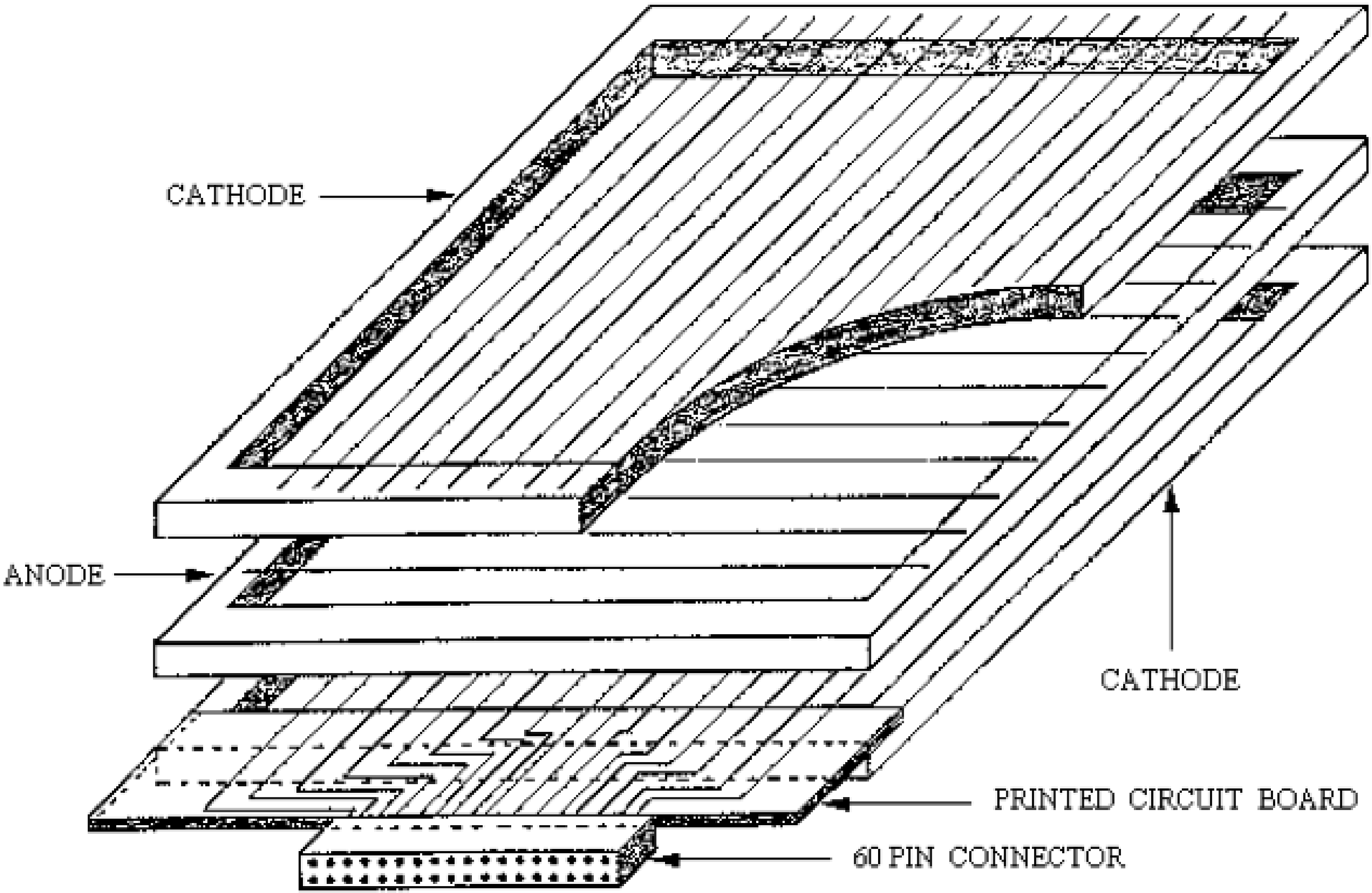
The Wire Chambers



$$V_1 < V_0$$

J. Spangaard, Delay Wire Chambers a users guide, CERN SL-Note-98-023

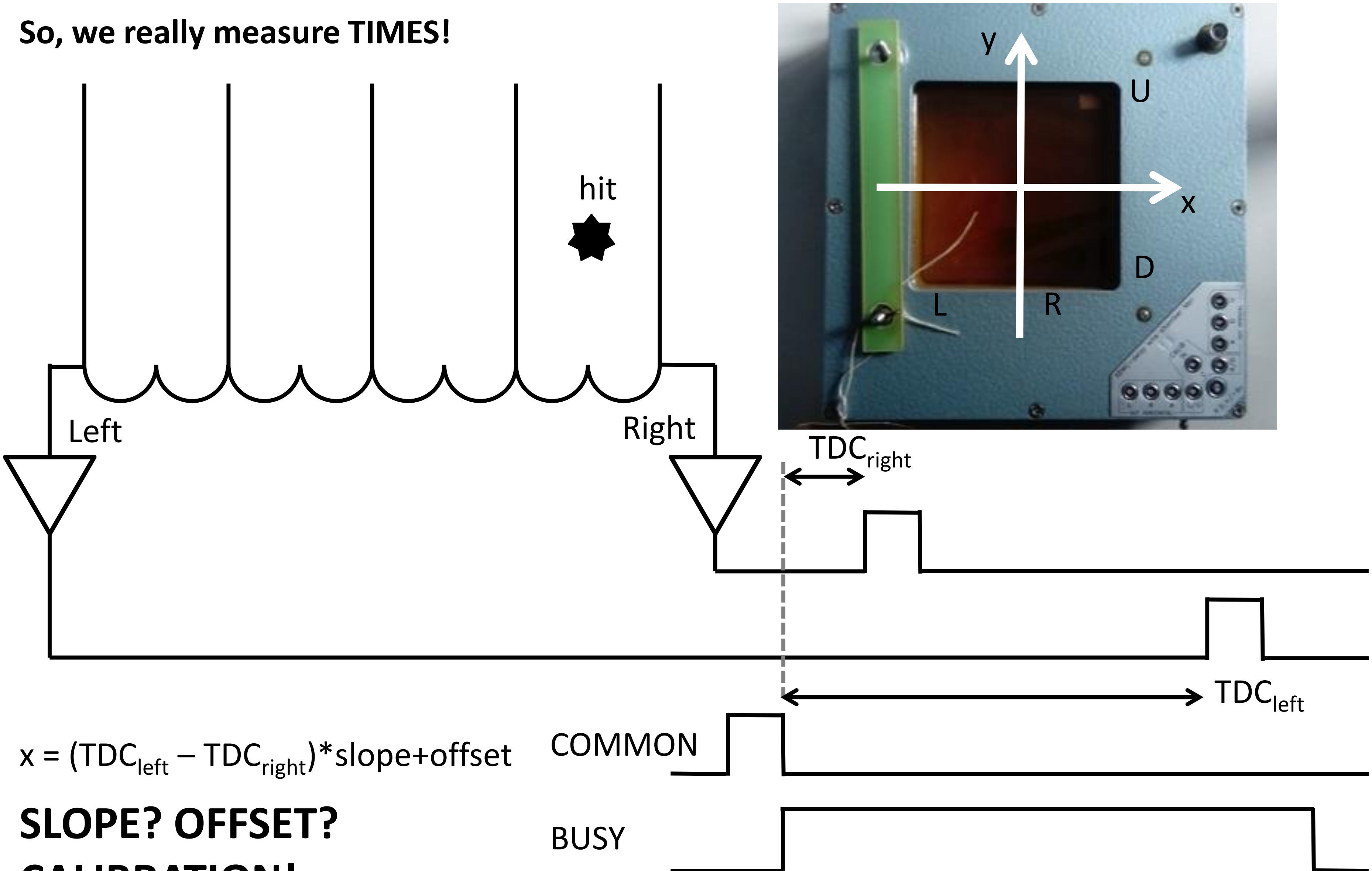
The Delay Wire Chambers



J. Spangaard, Delay Wire Chambers a users guide, CERN SL-Note-98-023

The Delay Wire Chambers

So, we really measure TIMES!



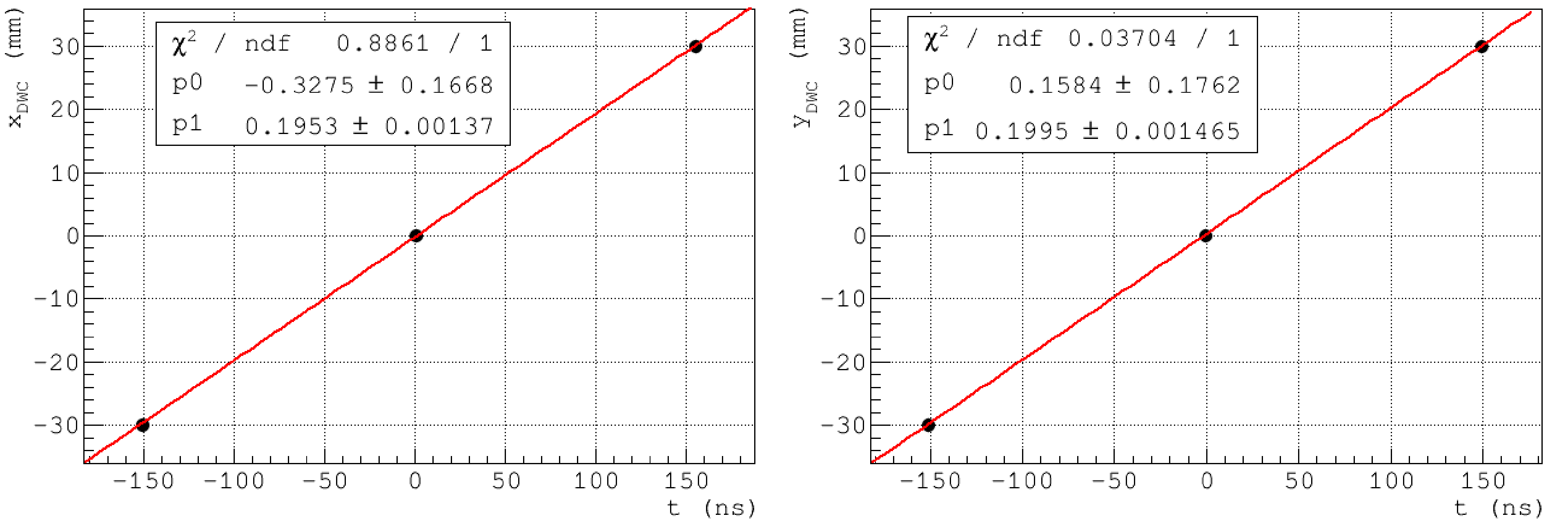
$x = (TDC_{left} - TDC_{right})*slope+offset$

SLOPE? OFFSET?

CALIBRATION!

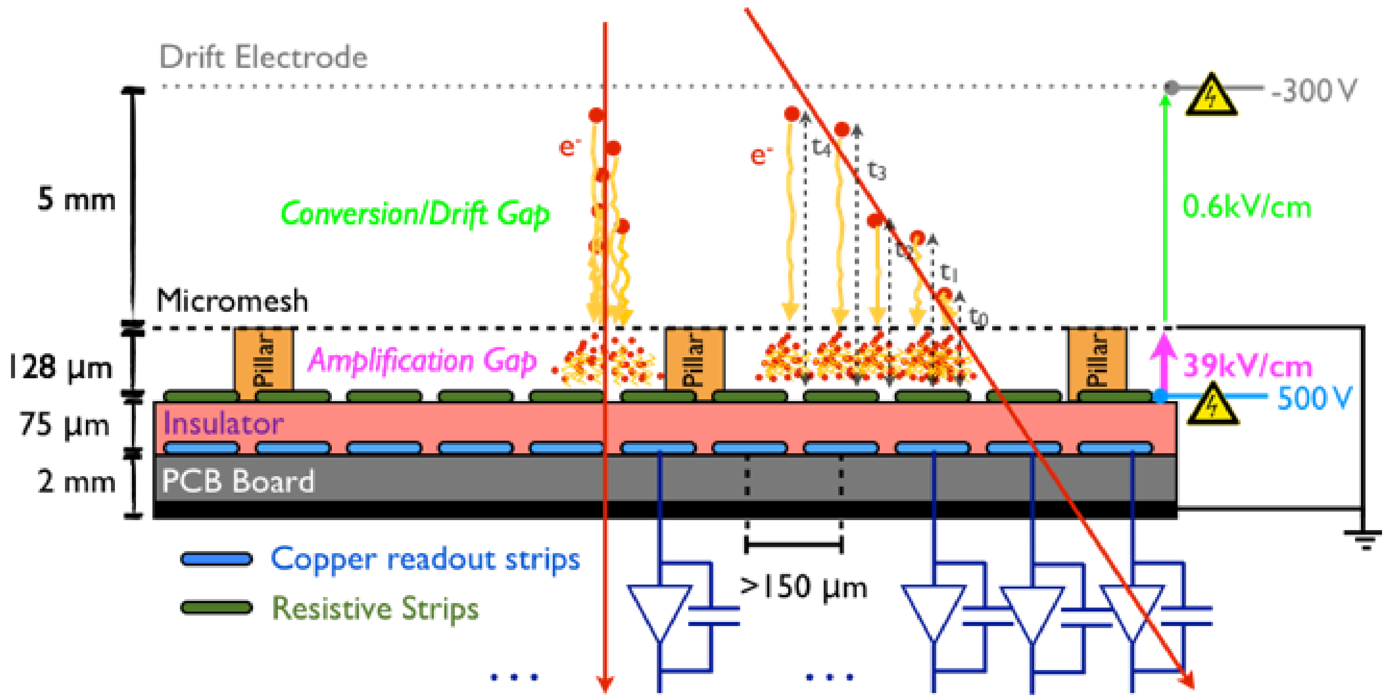
The Delay Wire Chambers

Calibration procedure: we know the position of the hit, we need to measure times to find slope and offset

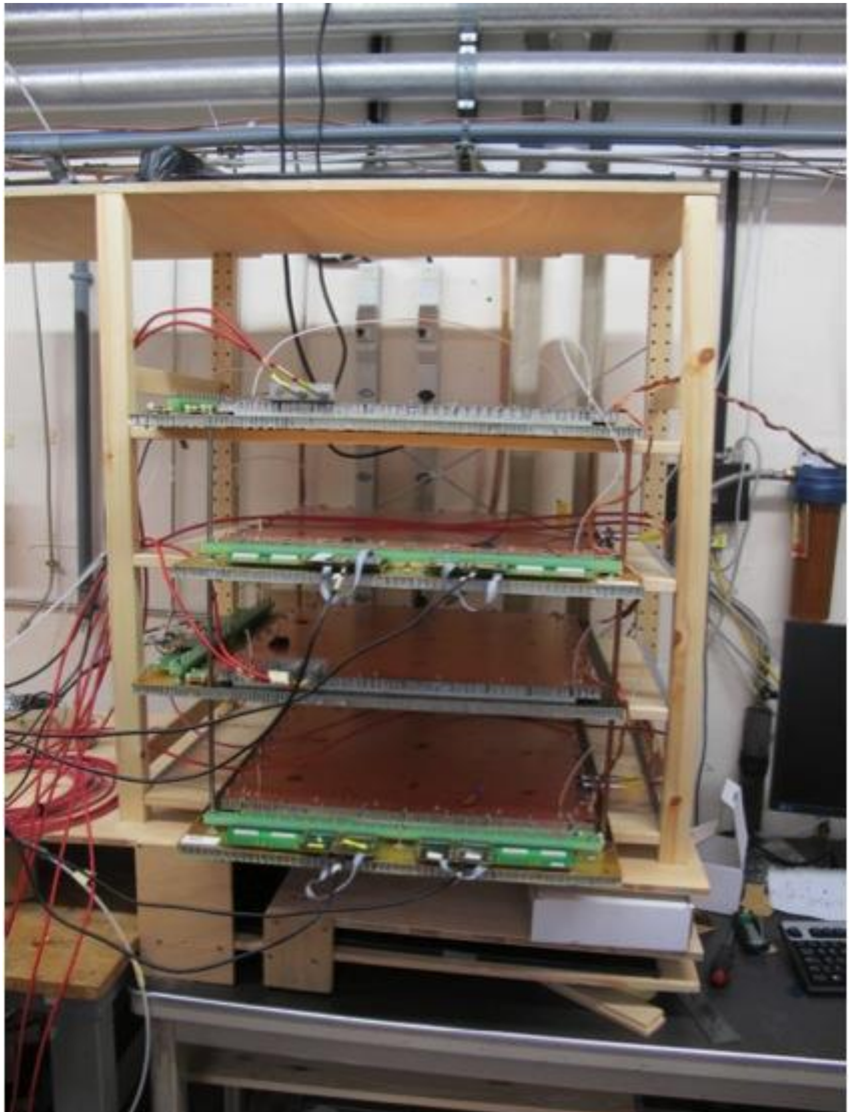


MicroMegas

- MicroMegas belong to the class of Micro-Pattern Gaseous Detectors, as well as GEM, THGEM, CAT, MSGC, WELL, micro-Resistive WELL, etc.
- W.r.t. wire chambers they can work is harsher environment
- They're faster than wire chambers
- They're more delicate than wire chambers…



MicroMegas



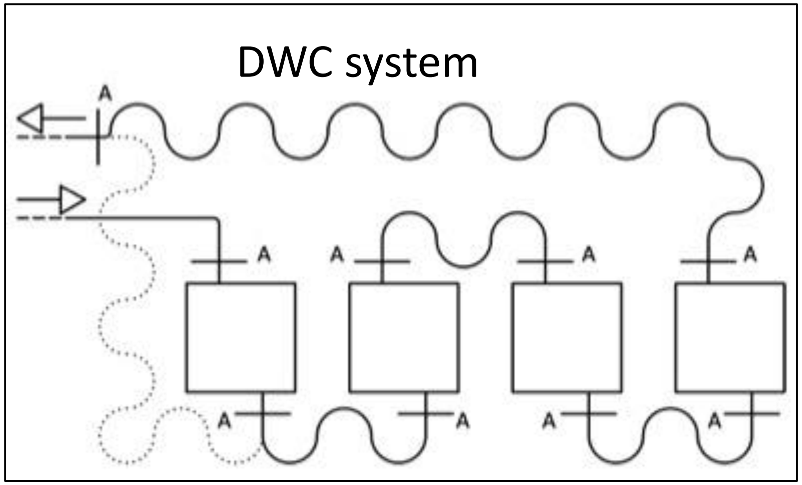
MicroMegas cosmic-ray muons stand in RD51 laboratory.

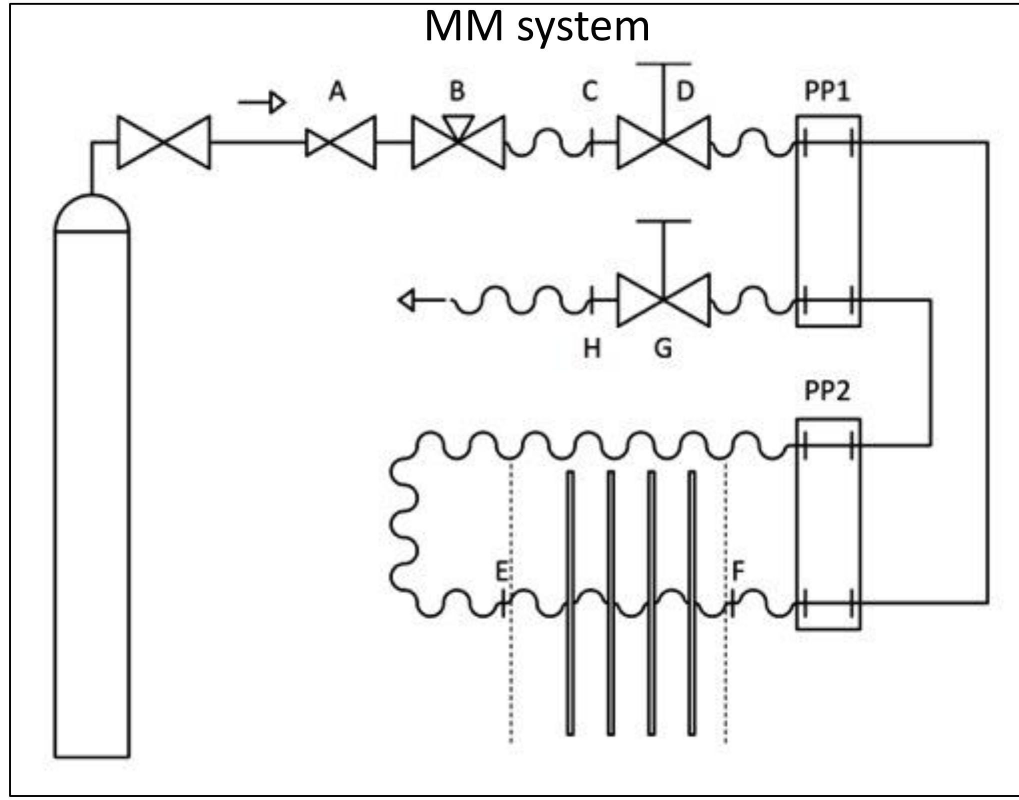
Our MicroMegas provide only the x or the y coordinate of a point in the space. Their position along the beam is the z of each point.
If we want to reconstruct the full point, we need to couple two of them, with different readout orientation

HOW TO FEED A MM?

- Gas (Ar:CO_2 93:7)
- HV (+520 V, -300 V)
- LV, provided by a system which in the meantime also reads and processes the signals

GAS



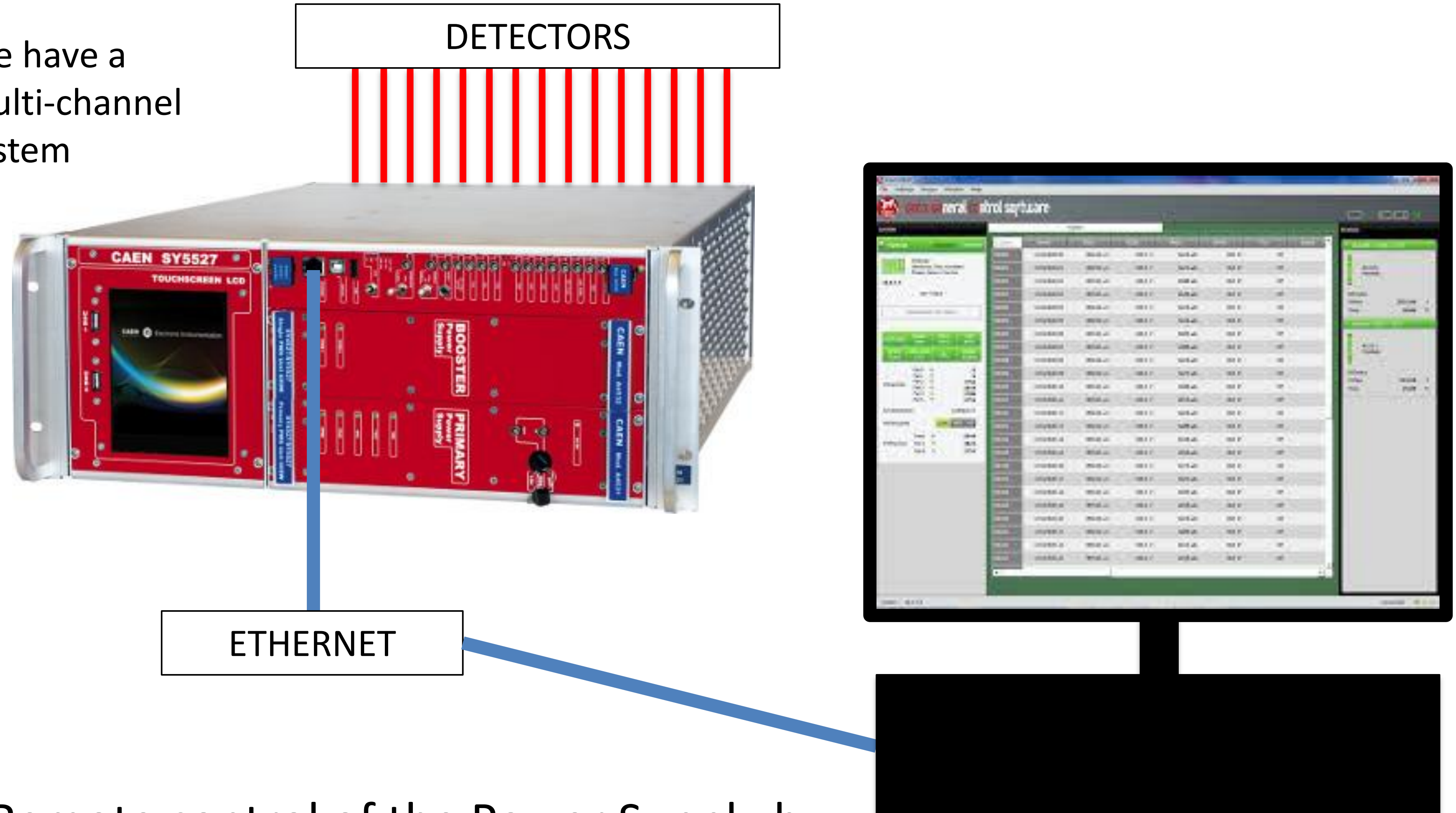


Čerenkov panel

No, seriously, **you don't really have to know too much about it**. We're not using flammable gases. The important thing is that from time to time you **check the gas flow** (B) and the **pressure in the bottle** (A). **We'll show you where to look!**

HV

We have a multi-channel system



Remote control of the Power Supply by the GECO program. Explanation during the shifts.

LV

DWC

ETHERNET

PC

MicroMegas

PC DAQ

More detail during the shifts

Glossary

- Detector: device telling us if the particle passed and some of its property
- Scintillator: it emits light when a particle passes
- Light guide: it drives the light produced by a scintillator towards the PMT
- PMT: it converts the light from a scintillator into an electric signal
- Gaseous detector: do you really need this definition?
- Wire Chamber: a gaseous detector with a lot of equidistant wires
- Cathode: electrode (wire or plane or whatever you can imagine) that in a detector is set to the lowest potential
- Anode: electrode (wire or plane or whatever you can imagine) that in a detector is set to the highest potential
- Electronic avalanche: multiplication in the gas of the electrons created by the passage of a particle through the detector
- Delay Wire Chamber: did I really fail so badly?
- MicroMegas: ~~ask Jorgen, please. Let me point out that I worked for years with planar GEM, cylindrical GEM and now with micro-Resistive WELL.~~ nice devices providing the position of an impinging particle

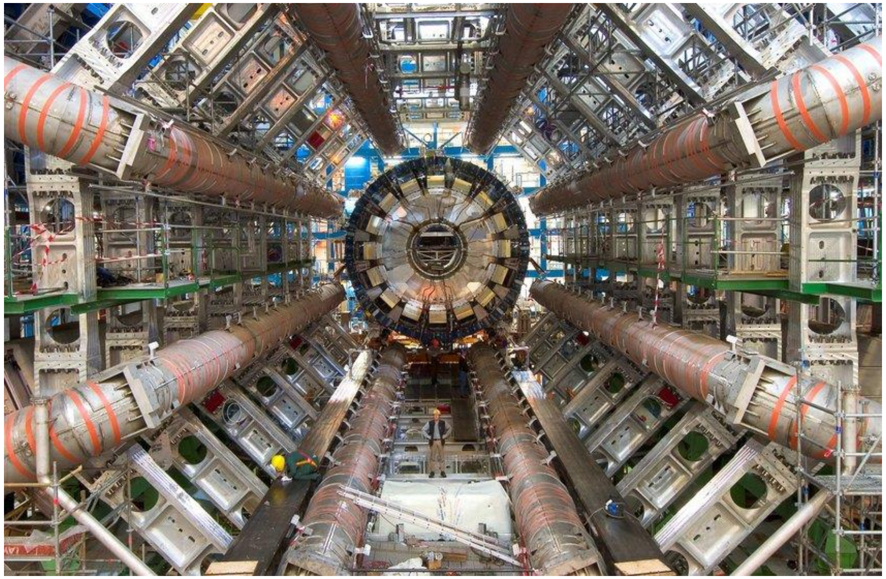
Glossary

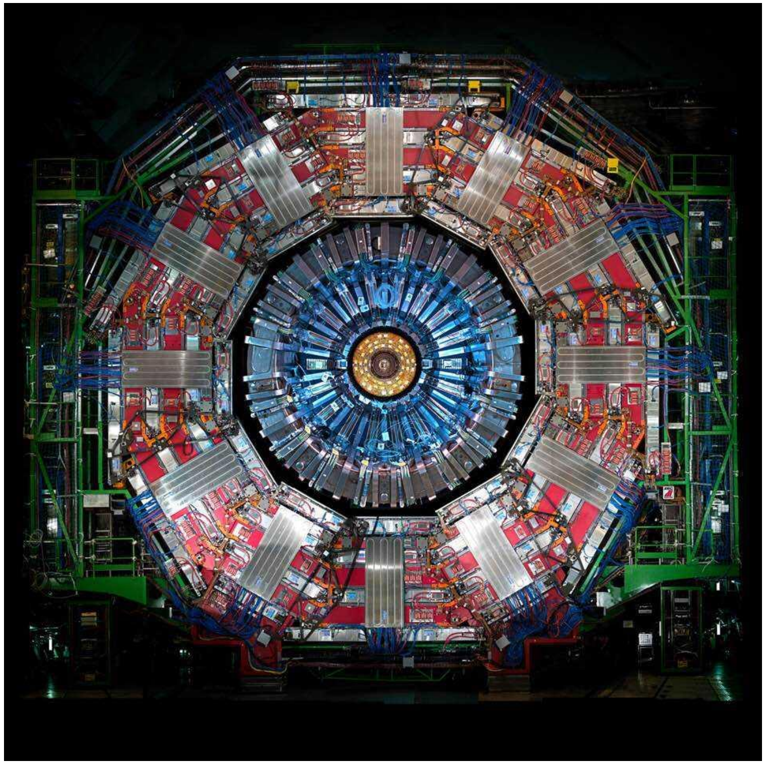
- Flowmeter, better called Rotameter: device telling us how much gas we are injecting in our detector
- Manometer: instrument to measure the gas pressure of a system
- Mainframe: a big heavy box used to supply the high voltage to several lines
- Low Voltage Power Supply: a small heavy box used to supply the low voltage to several lines
- Crate: a medium heavy box used to host always too many modules to post-process the signals from the detector
- Rack: a strange structure, but nevertheless quite useful. Indeed it is very light, when empty. Usually hosting crates, many crates, too many crates…
- Front-end electronics: boards that read directly the signals from the detector and process them
- Support scientists: people who’ll try to let you enjoy your experience at CERN. We’ll do our best, but of course Cristóvão can do much better than me.

Trigger

- In order to acquire data, a decision has to be made on when to acquire the data. This is the job of the Trigger

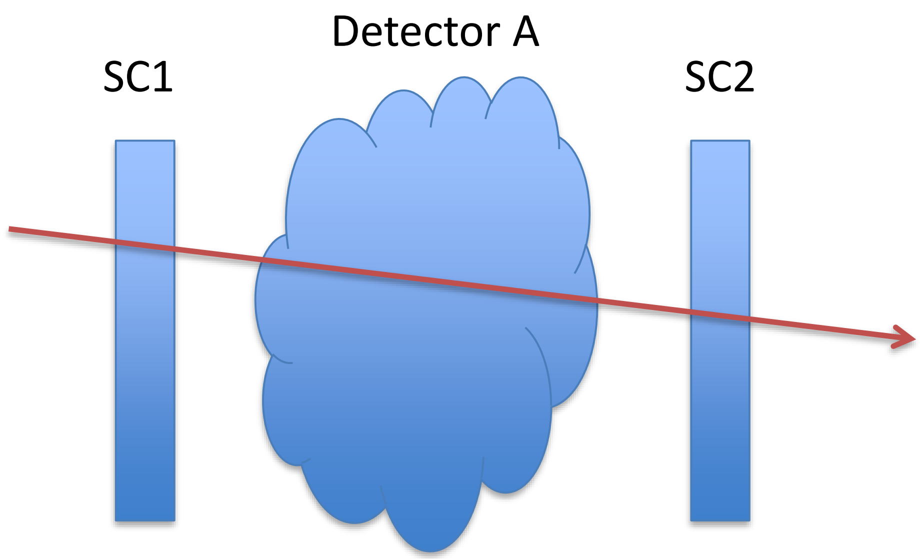
- In big experiments, the trigger has the additional job of managing the amount of data to be stored





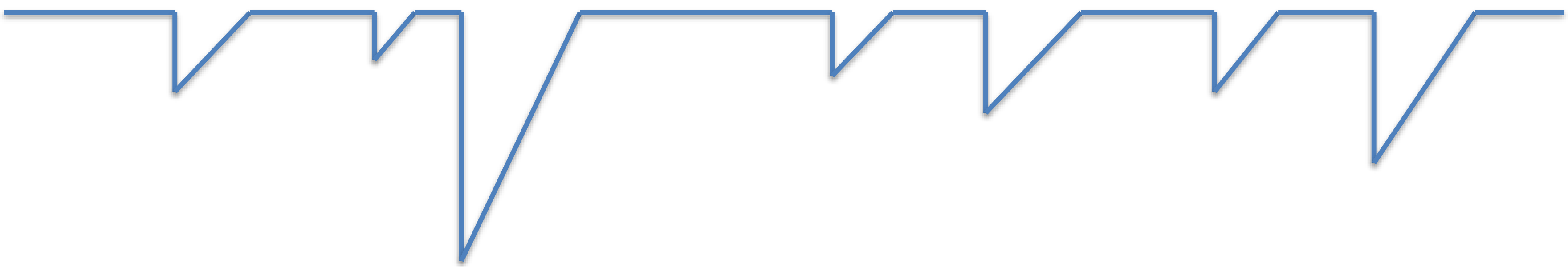
Building a simple trigger

- We want to measure the response of detector A to a particle:
  - Place one scintillator in front and one behind
  - A particle going through a scintillator will produce a signal
  - The presence of a signal simultaneously in both scintillators, means that a particle travelled between them, and consequently through detector A
  - Thus, we can use the coincidence of the signals from both scintillators as a trigger to only read the response of detector A when a particle goes through it

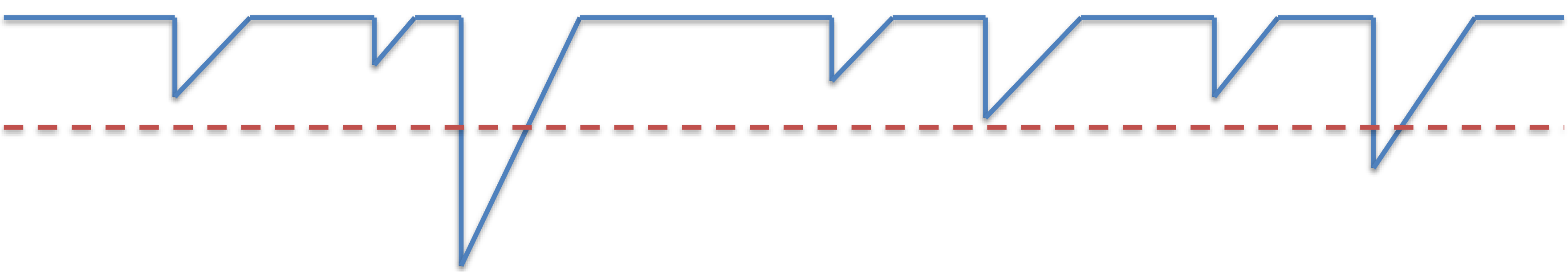


Triggering on Detectors

- Real detectors suffer several effects not present from theoretical expectations, most notably this reflects in noise in the output of the detector
- The noise is often indistinguishable from a real signal

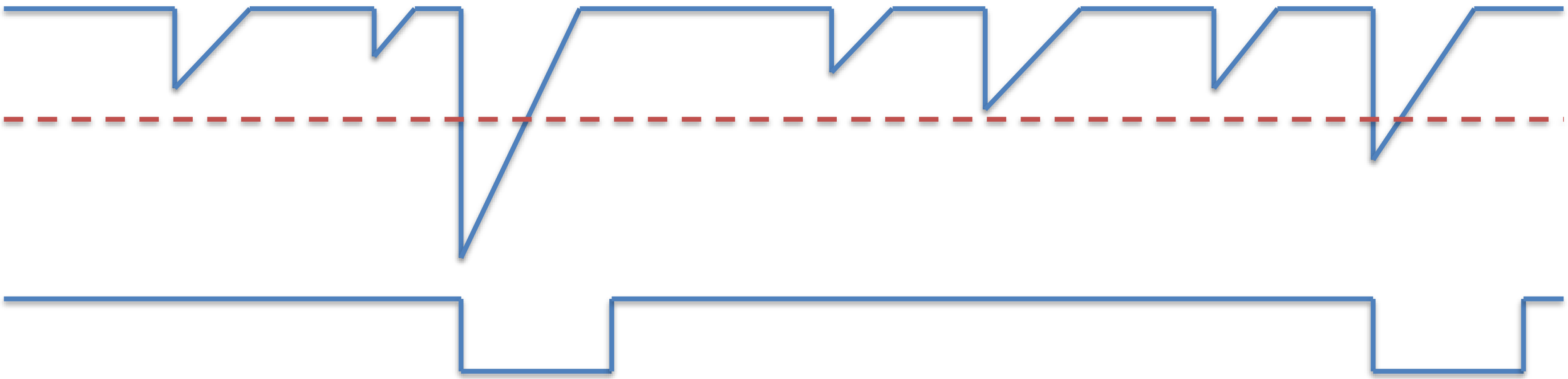


- The noise is typically small and sometimes produces large pulses, while real signals are almost always large

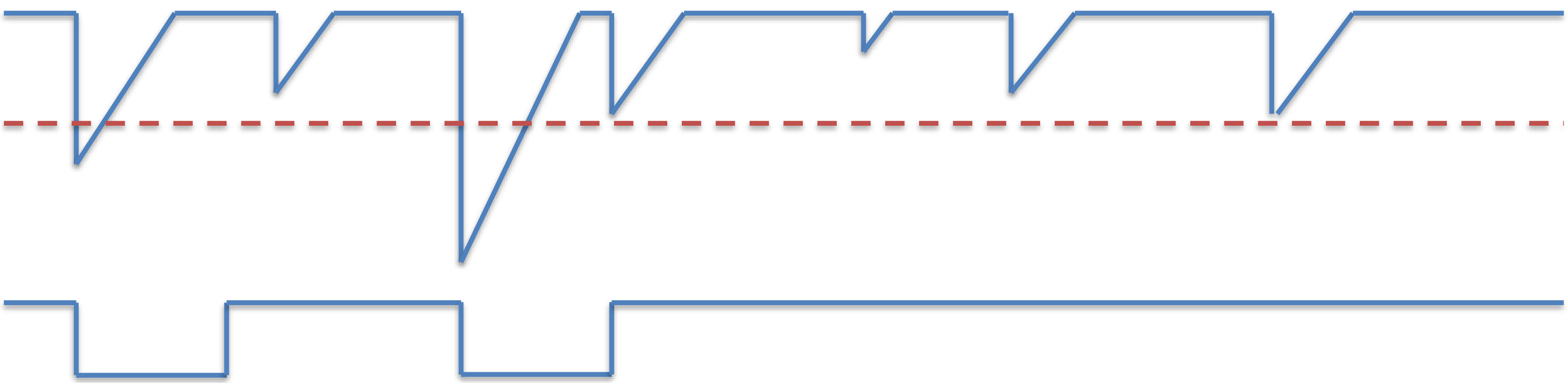


Triggering on Detectors

- A logic (true, false) signal is created from the comparison and if a signal is considered to be present, the state is kept for some time

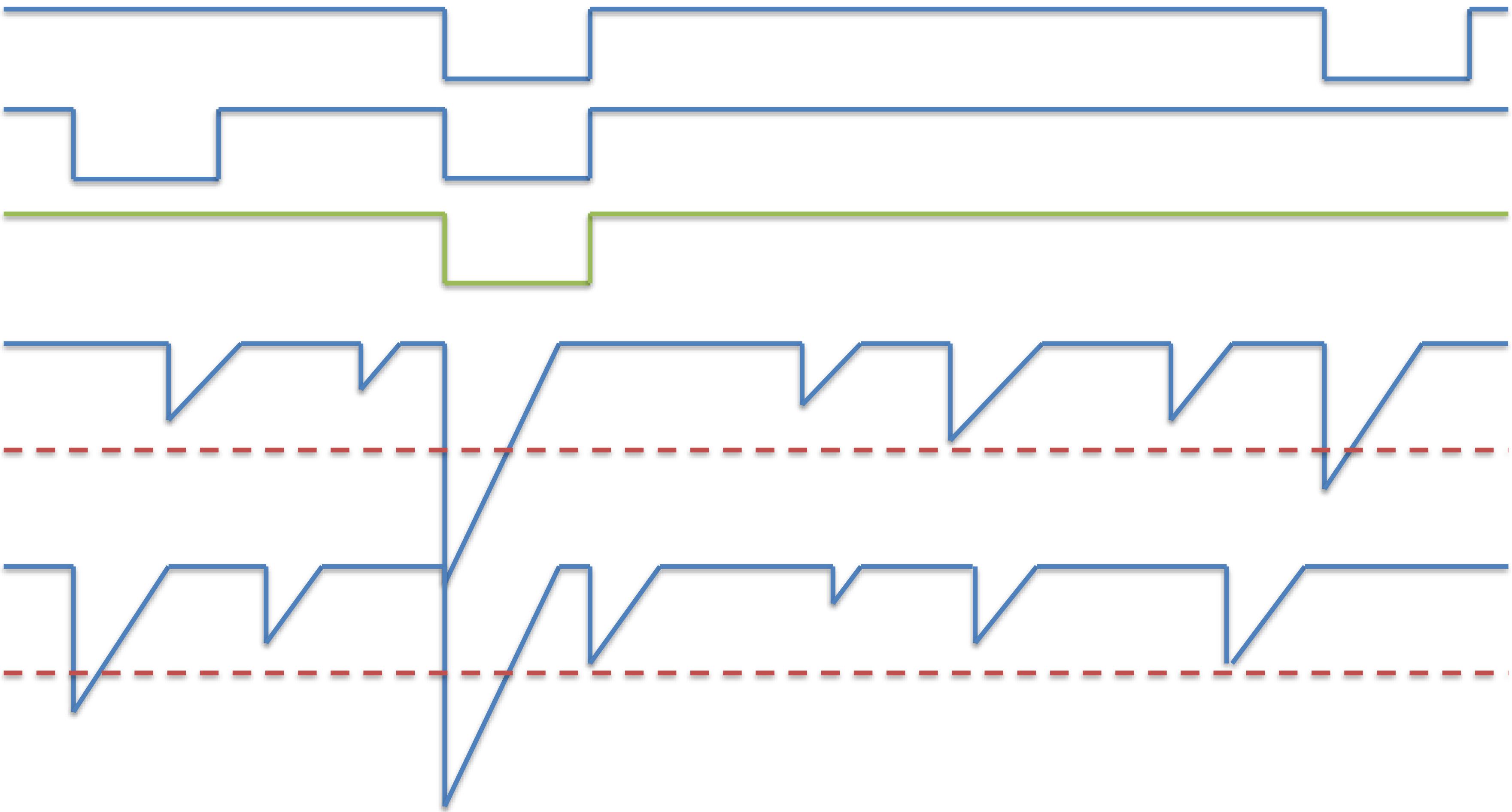


- Some of the noise still survives in the logic signal, consider the other scintillator:



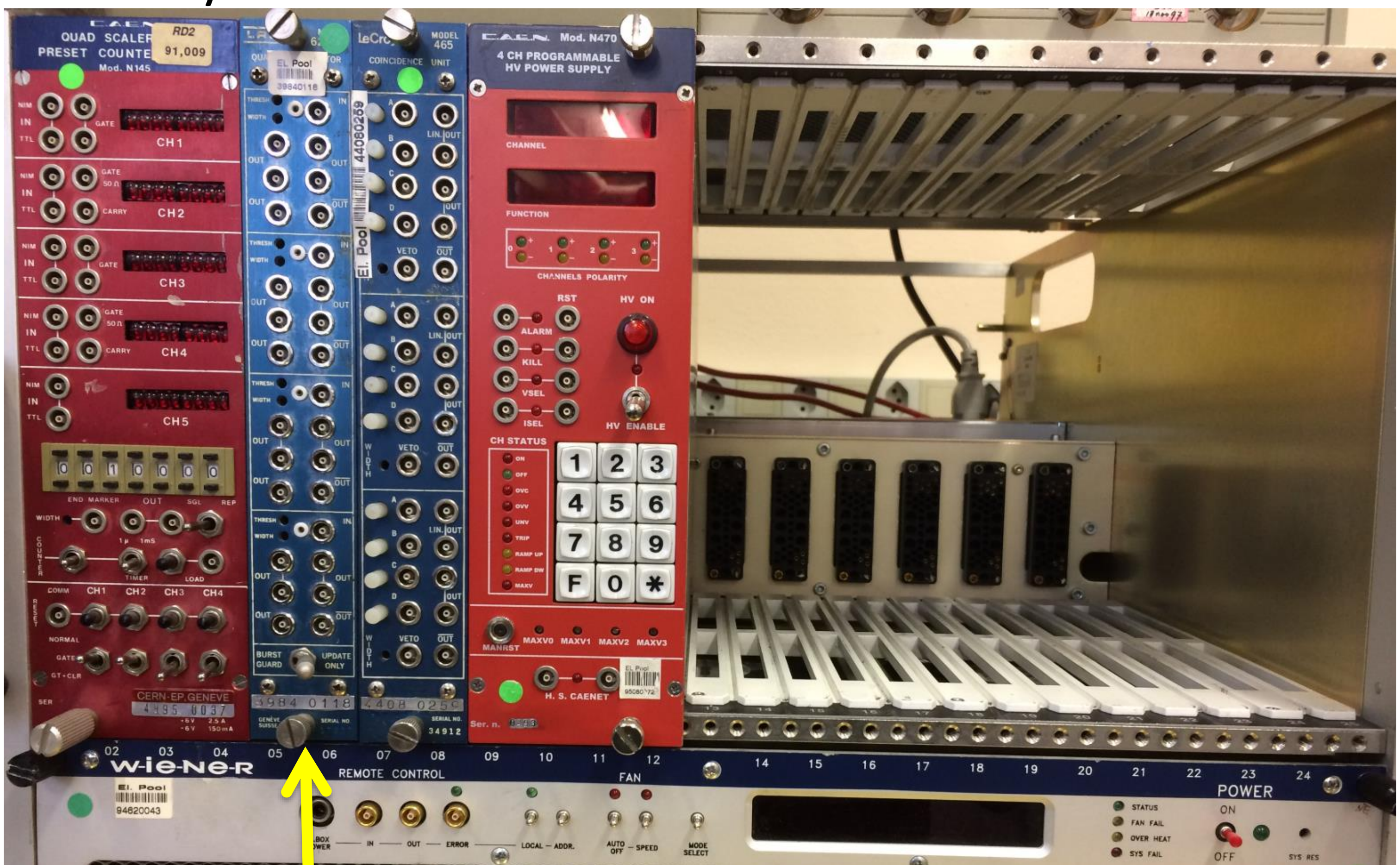
Triggering on Detectors

- The coincidence between the two logic signals significantly reduces the noise, since it is very unlikely for two detectors to simultaneously have a pulse from noise that exceeds the threshold value



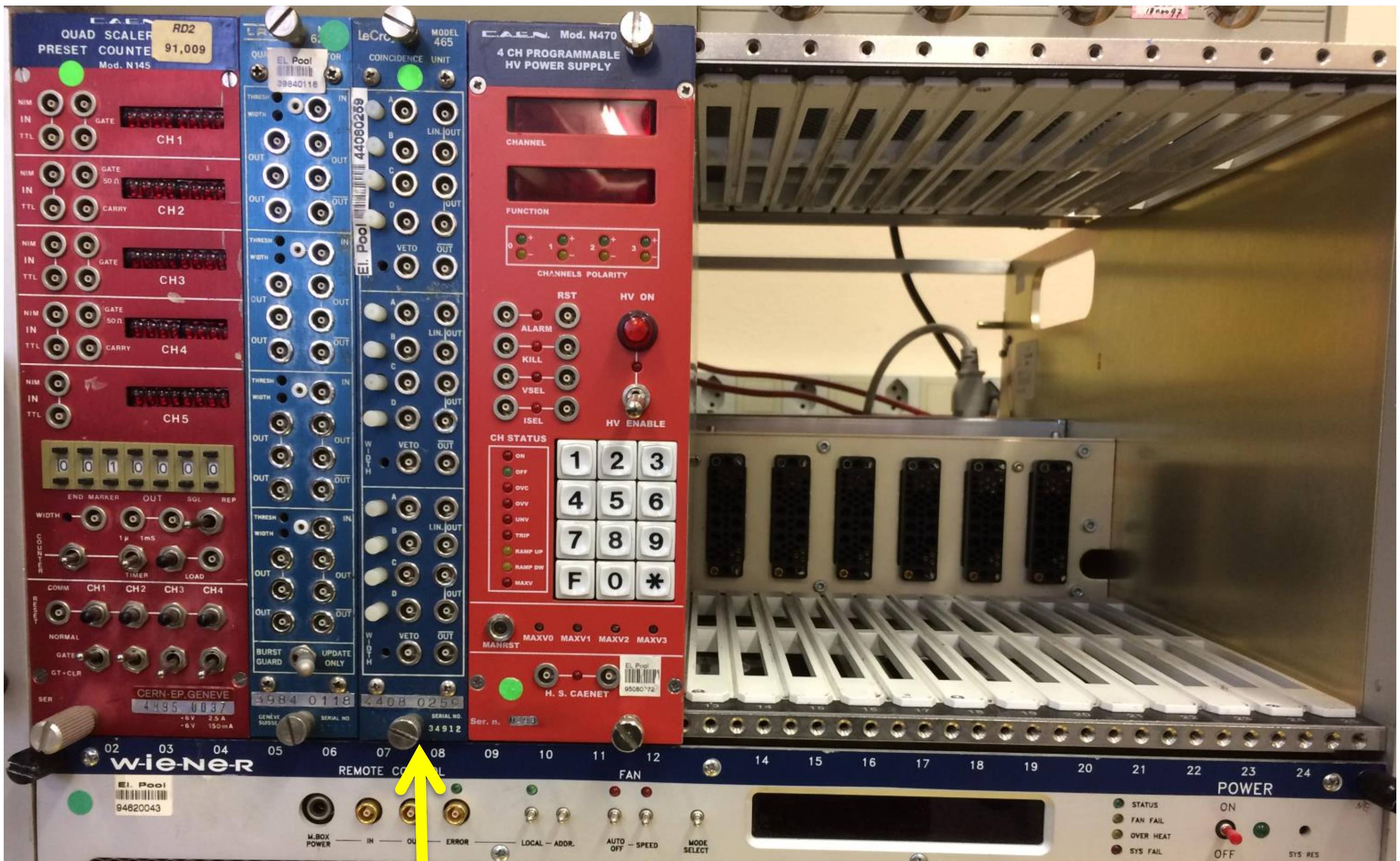
Triggering on Detectors

- The process of setting a threshold, checking if a pulse exceeds the threshold and defining a logical “true” state for a while if it does is performed by a Discriminator Unit



Triggering on Detectors

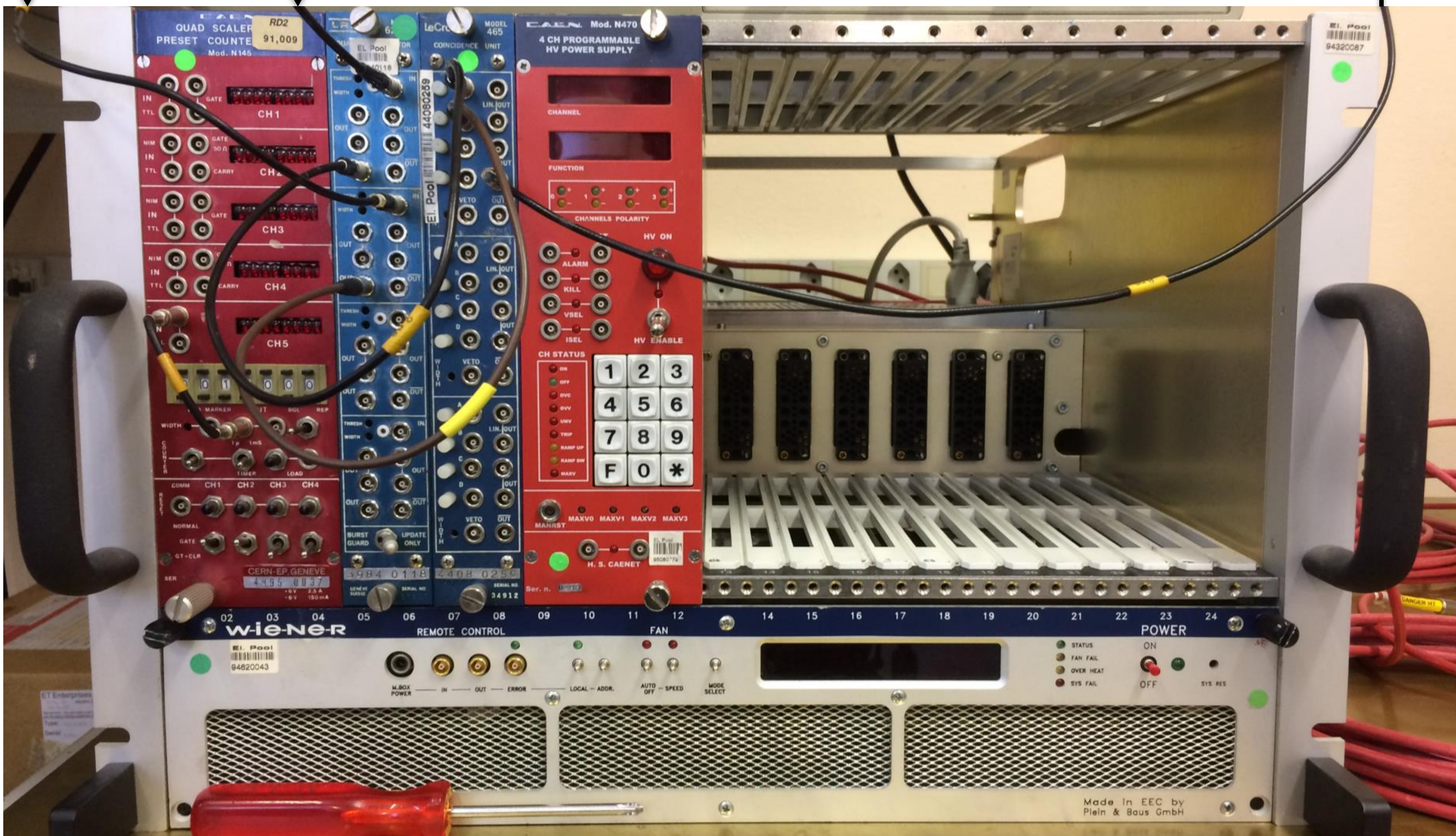
- Performing the coincidence between two logic signals is performed by a Coincidence Unit



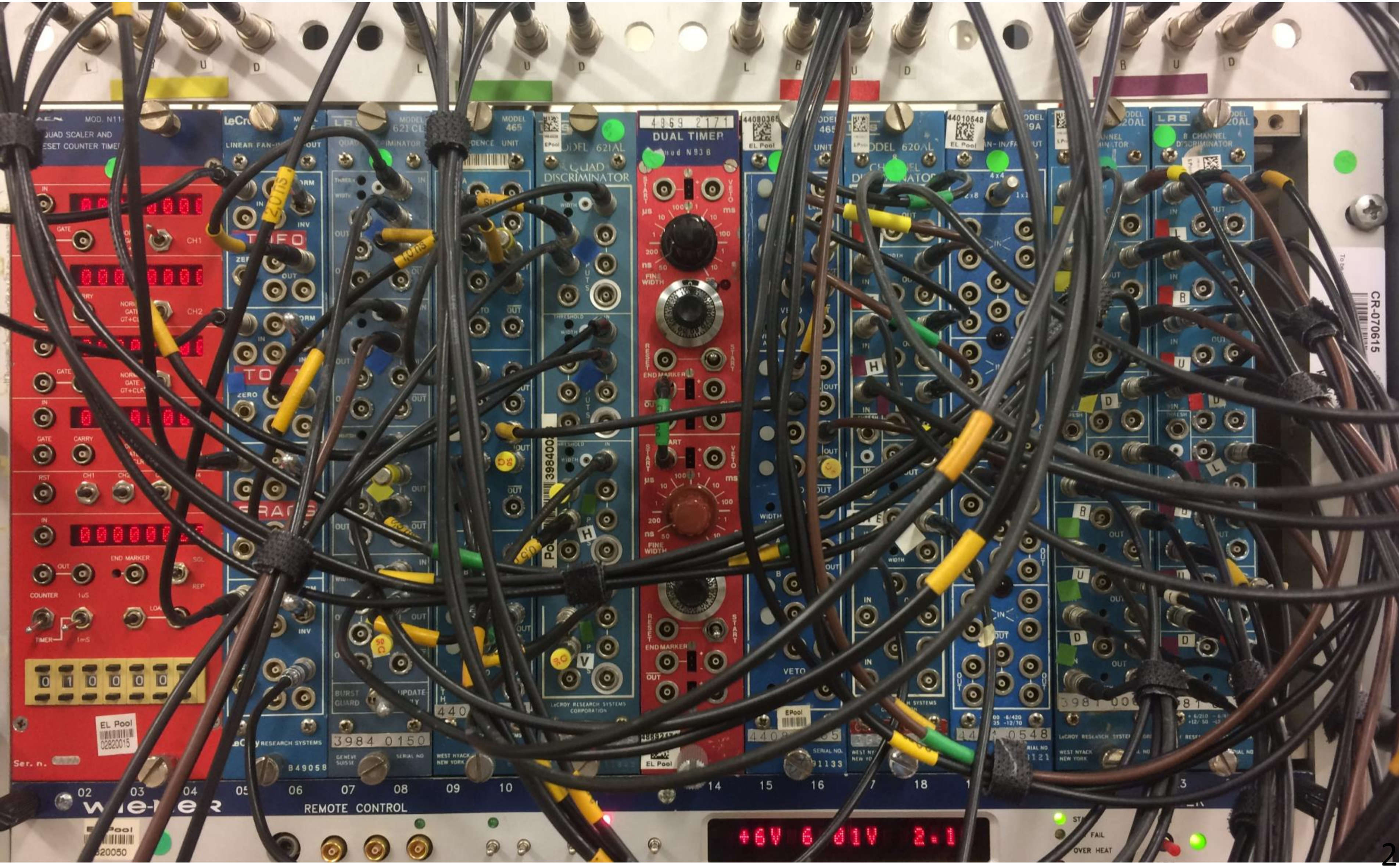
Triggering on Detectors

- The final trigger might look something like the below:

SC1 SC2 Trigger



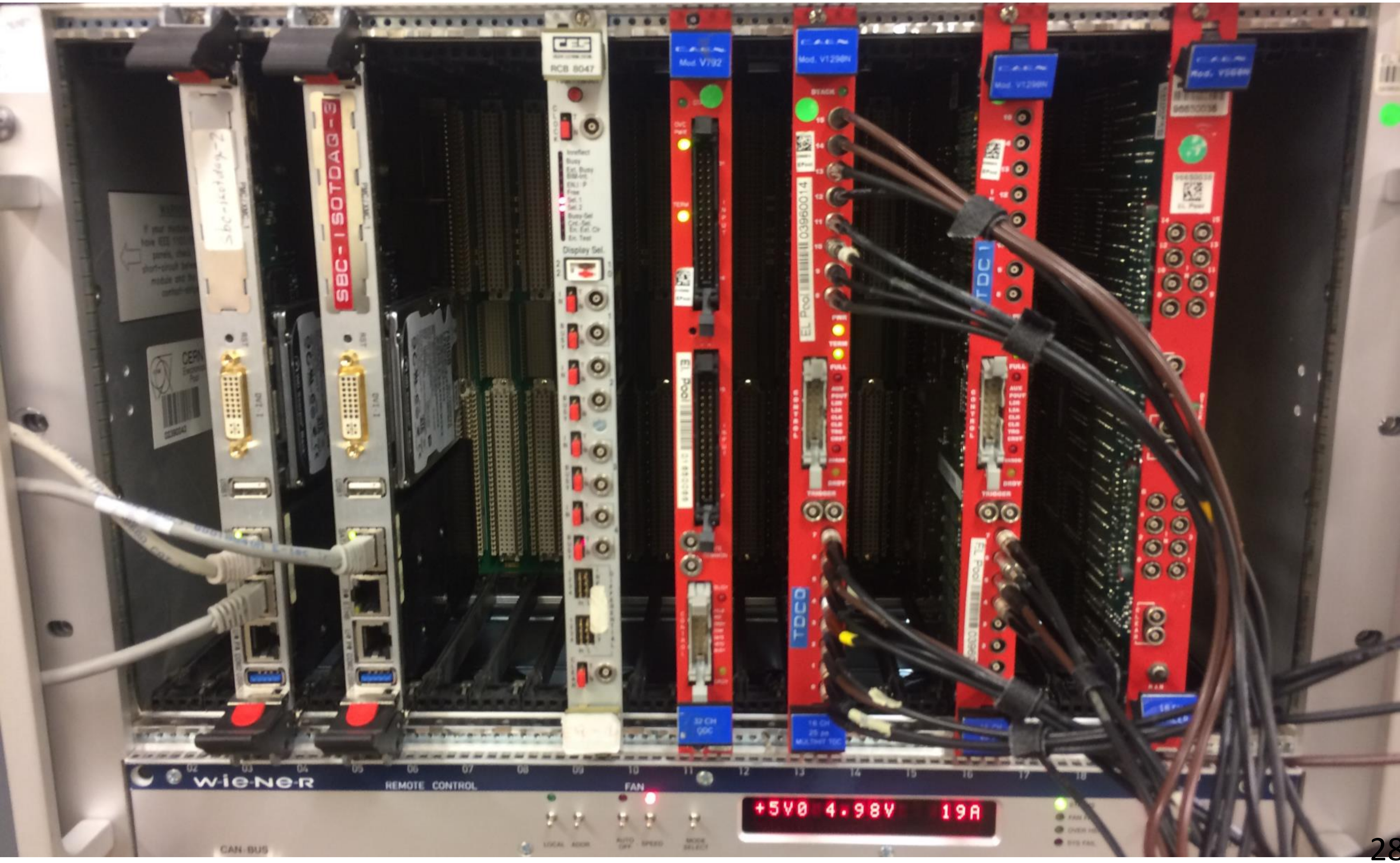
A More Complex Example



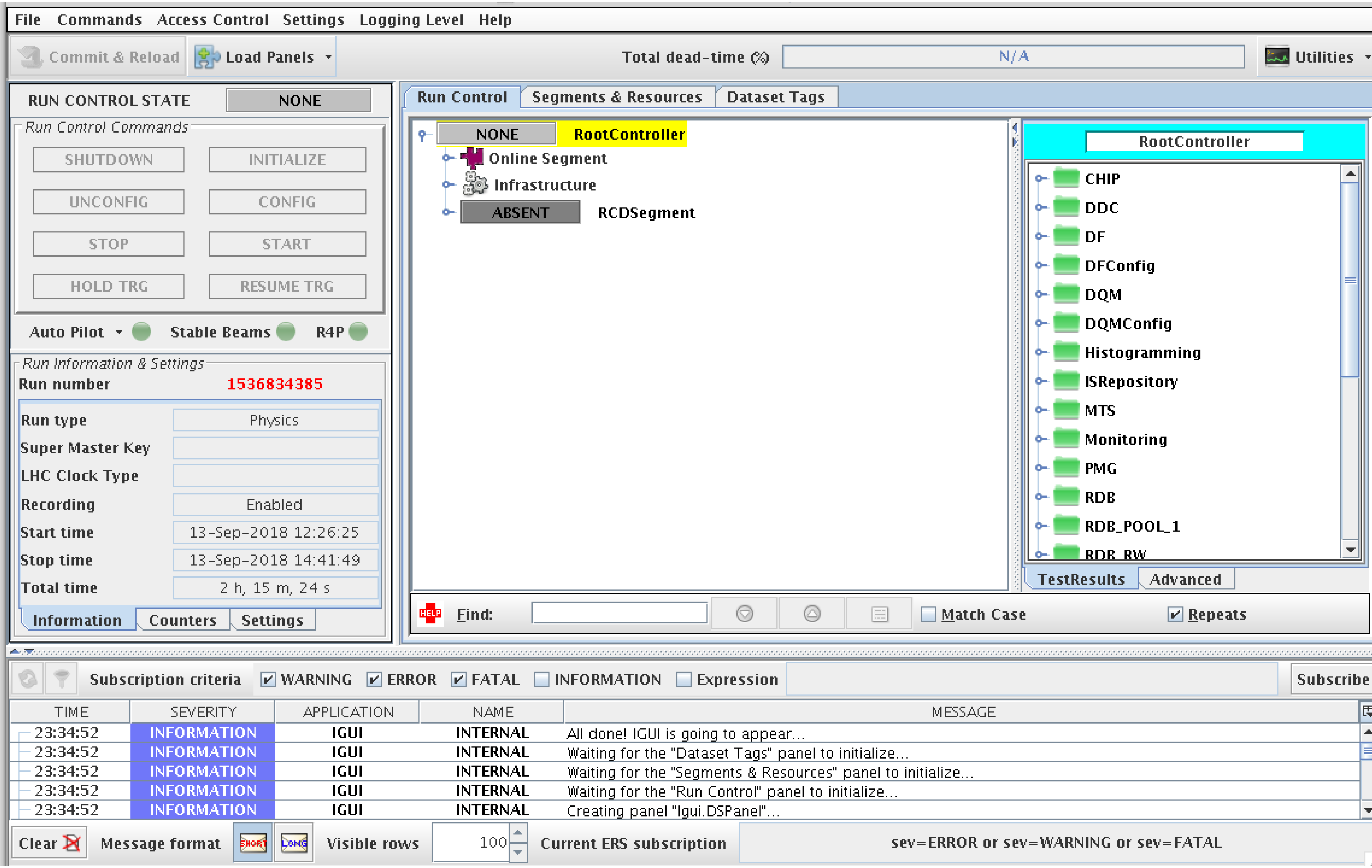
Data Acquisition

- Once the decision has been made to keep an event, the data has to be read and recorded. This is the job of the Data Acquisition system (DAQ)
- Main components:
  - Hardware – modules that read and digitize the electronic signals
    - SBC – Single board computer
    - CORBO – Trigger input
    - QDC – Charge to digital converter
    - TDC – Time to digital converter
    - Scaler – Counts events
  - Software – controls the system and records the digitized data into a RAW format file
    - TDAQ – Same DAQ control system as used in the Atlas experiment

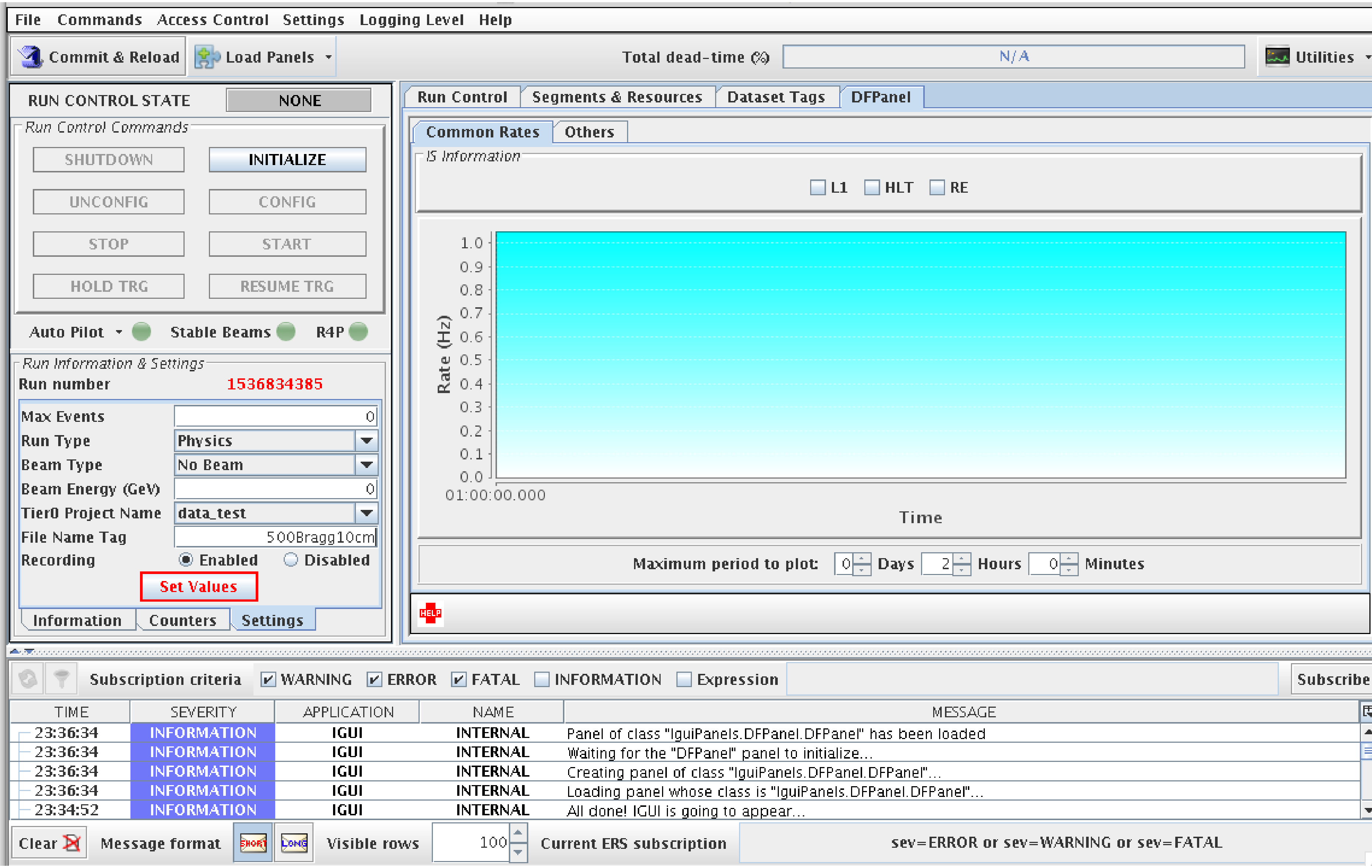
Data Acquisition Hardware



Data Acquisition Software



Data Acquisition Software



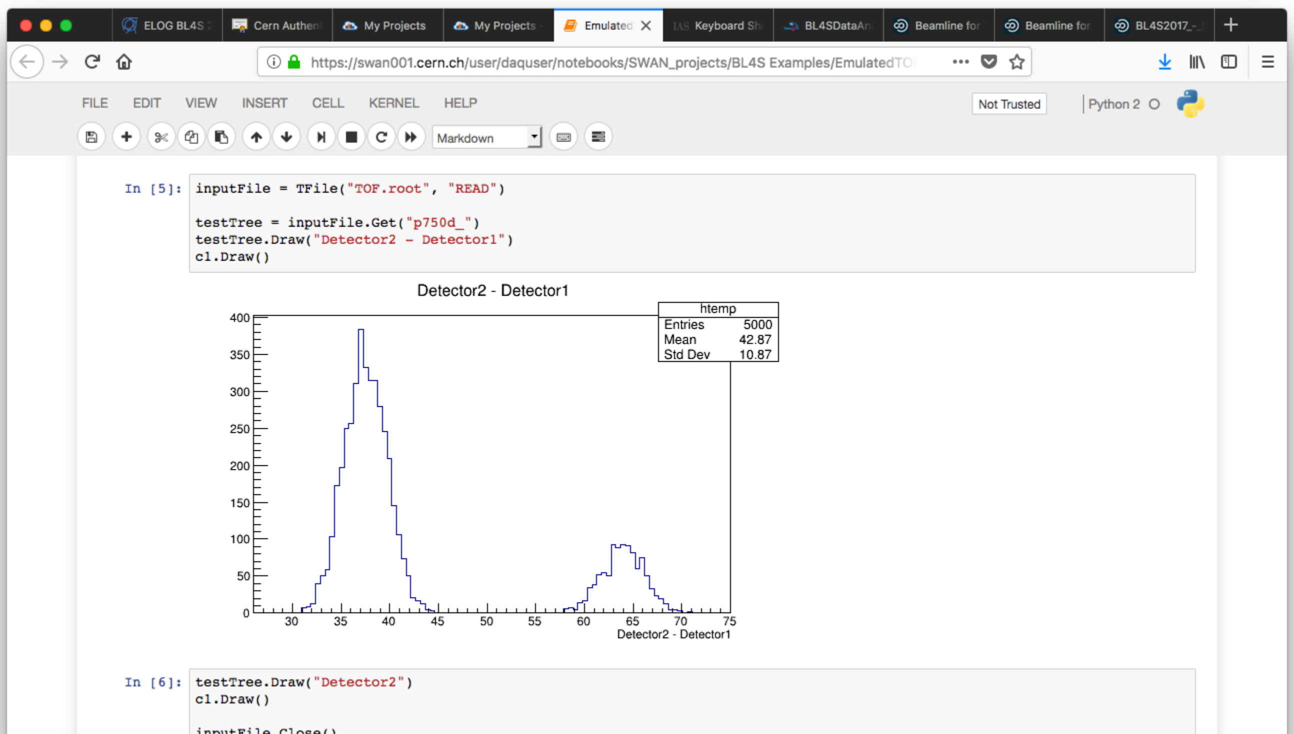
Electronic Logbook

Please send me your CERN username for access to elog: cbeiraod@cern.ch

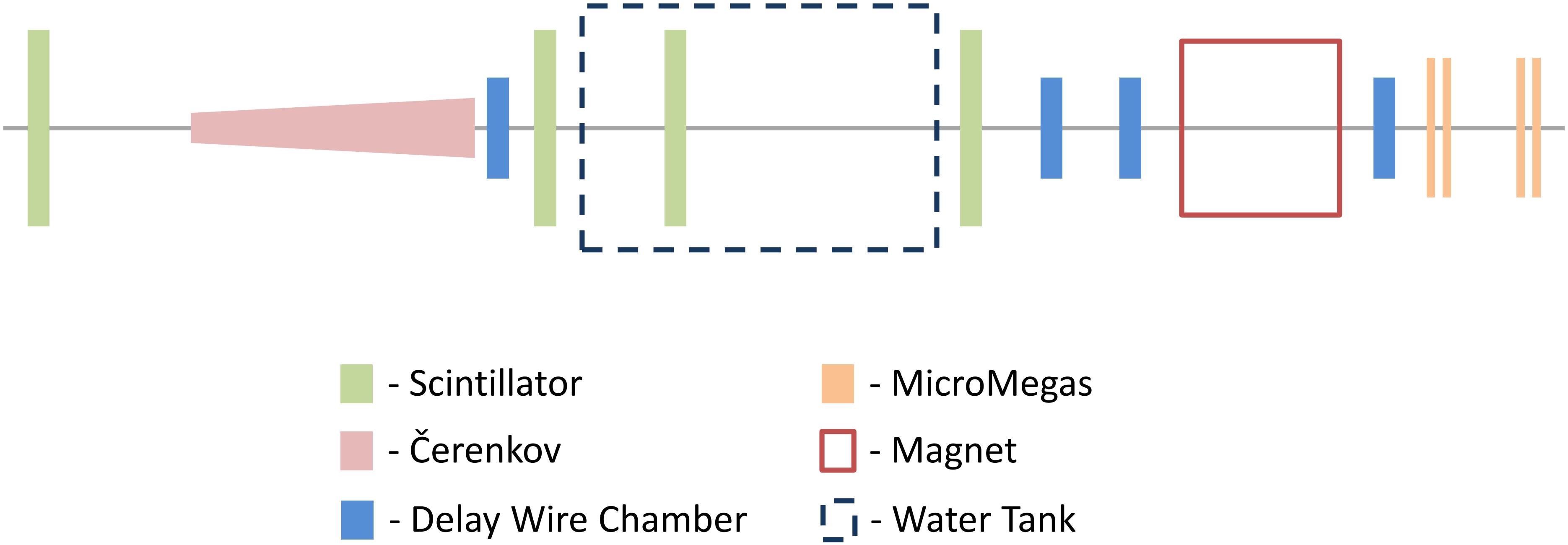
- Available at: https://pc-bl4s-07.cern.ch:8080
- Write down everything that happens:
  - When you start a run, write it down with the run number and what it is for
  - If there is a problem during a run, write it down
  - If the conditions change (HV, gas pressure, etc), write it down
  - You can and should use the elog for the analysis part as well: if you have a doubt; if you want to discuss some detail; even to share some plots

Analysis

- We encourage you to use Jupyter: it is available on SWAN (swan.cern.ch) and no setup is necessary
- First go to CERNbox (cernbox.cern.ch) and activate your account
- We ask that each team choose a language (C++ or Python) and that all notebooks be written in that language



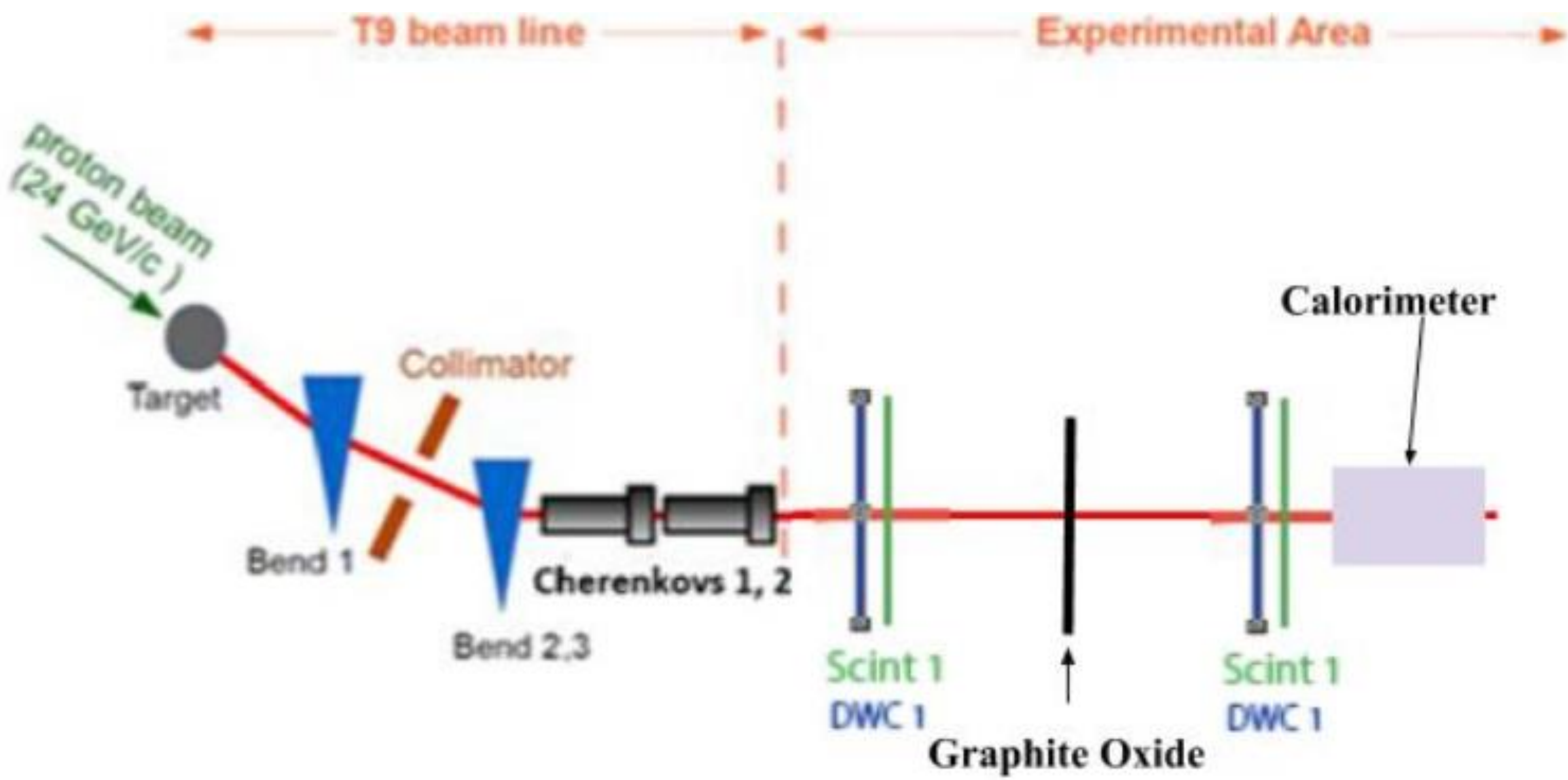
Experimental Setup



Measuring the Bragg Peak

BEAMCATS

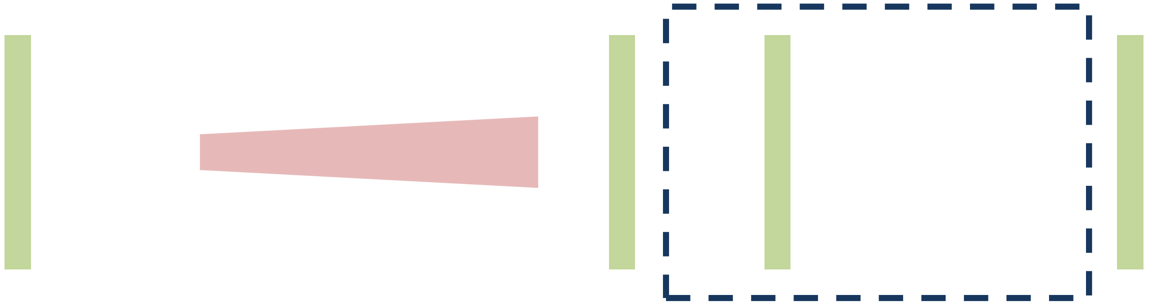
Proposed Setup



- Use the calorimeter to measure the particle energy remaining after a certain amount of material
- Use pions

Updated Setup

- The pions are quite difficult to use in the T9 beamline: identification and distance needed to see a Bragg peak → Use protons
- Change material to Water: readily available and easy to handle
- Directly measure the dE/dx over a centimeter length with a scintillator
- Added particle identification: TOF for protons and čerenkov for electrons



Shifts

- Each person will have one task
- Make sure all detectors and systems are working
- For the logbook:
  - Make sure to write the beam momentum and the "Scuba" scintillator distance
  - Write the pressure/gas flow of the čerenkov detector and of the other gas systems (even though you are not directly using them)
  - Write the magnet current too (same comment as above)

Analysis

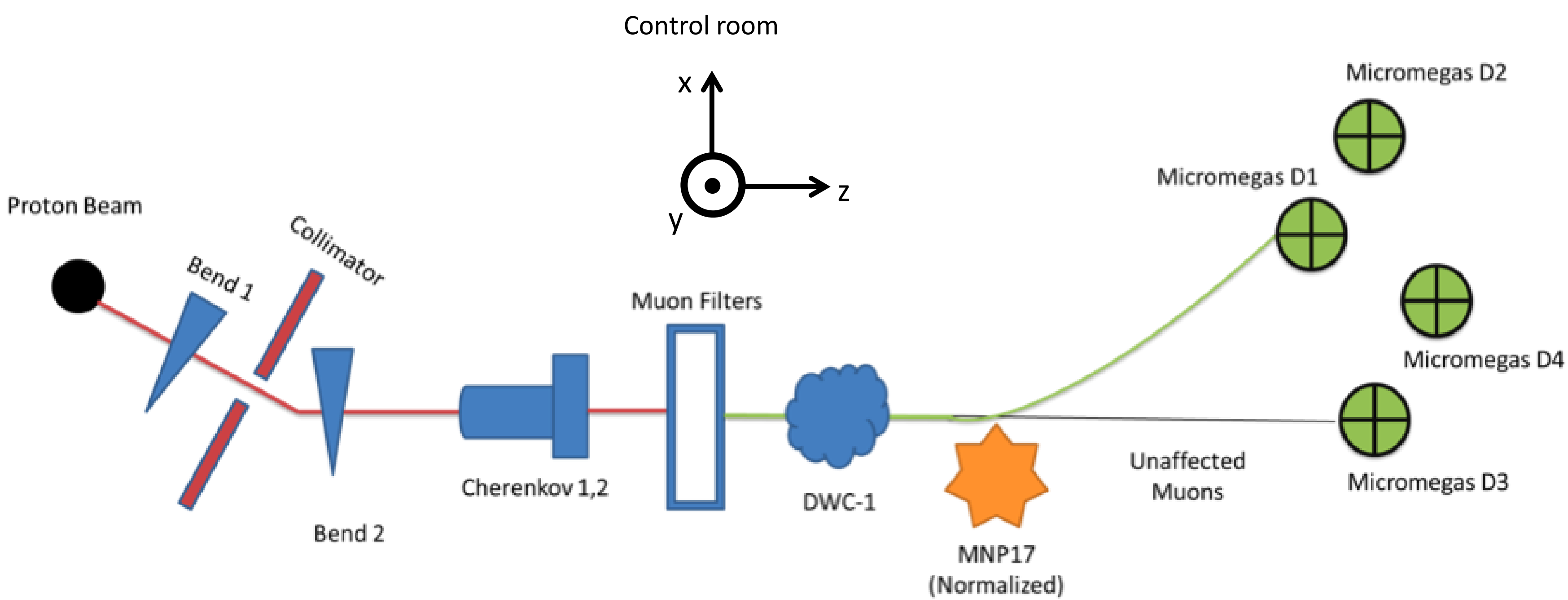
- Start with plotting the TOF spectra for one run. Identify the protons and other particles
- Remove the electrons from your data using the signals from the čerenkov detector. Does the TOF spectra look better? Use the veto scintillator to remove other particles that are not protons.
- Use the TOF data to select the protons; only for the protons plot the energy deposited in the Scuba scintillator
- Repeat the energy calculation for several distances of the Scuba scintillator. Plot the deposited energy as a function of the distance. Do you see a Bragg Peak? Is the position where you expect it to be? If not, why?
- Repeat the above for a different momentum and/or for other particles (electrons using čerenkov signal or electrons+muons+pions using the Veto scintillator signal)

Deflecting particles with the Lorentz force

CRYPTIC ONTICS

Proposal

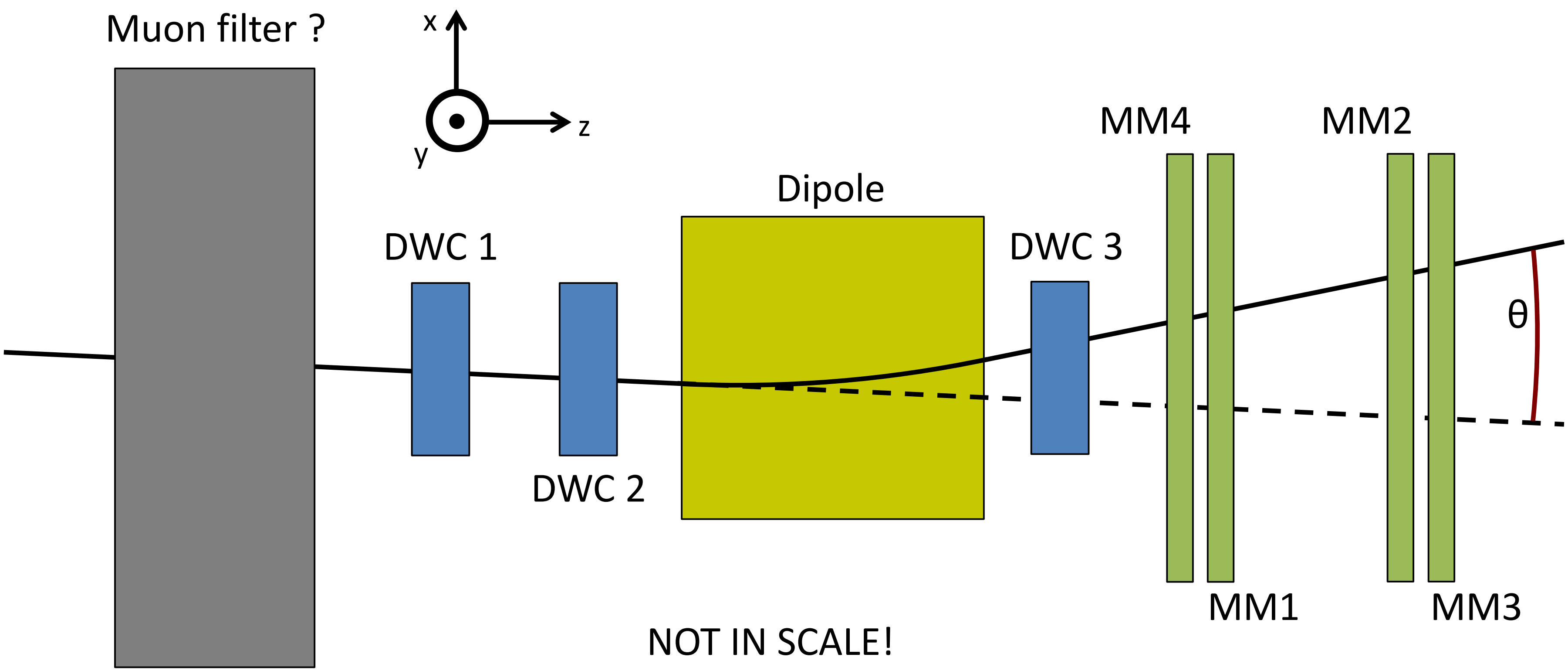
Measuring the muon rate at different deflection



WARNING:

- We need to reconstruct two track segments before and after the magnet: one detector is not enough due to the beam spread
- While the DWC provides two coordinate (x,y), the MicroMegas readout plane is segmented in one-dimensional strips

Final experimental setup



DWC 0 is already present in the area as beam monitor
MM1 and MM2 oriented with strips along y (x coordinate)
MM4 and MM3 oriented with strips along x (y coordinate)

2 detectors providing **two points in the space** after the filter and before the magnet.
5 detectors providing **three points in the space** after the magnet

Recipe

- Making sure that the WHOLE system works: detectors, FEE, DAQ, PCs, analysis codes, brains
- **EVERYONE WILL HAVE A GIVEN TASK. THE FIRST IS TO BE READY TO DO ALL THE TASKS!**
- Select the momentum. We'll see ALL the particles incoming
- Collect the data
- **WRITE ALL THE CONDITIONS in the lobgooks**: beam momentum, magnet current, gas flow
- Reconstruct the track segments with the help of the detectors
- Compute the deflection
- Plot the deflection as a function of the beam momentum or as a function of the magnetic field
- Verifying the Lorentz equation for the charge deflected in a magnetic field
- In a last moment let's place the muon filter and let's take muons

Thanks for the Attention

Make sure to enjoy your time here

Ask questions, we are here to help!