BL4S 2019
Detectors & Setup

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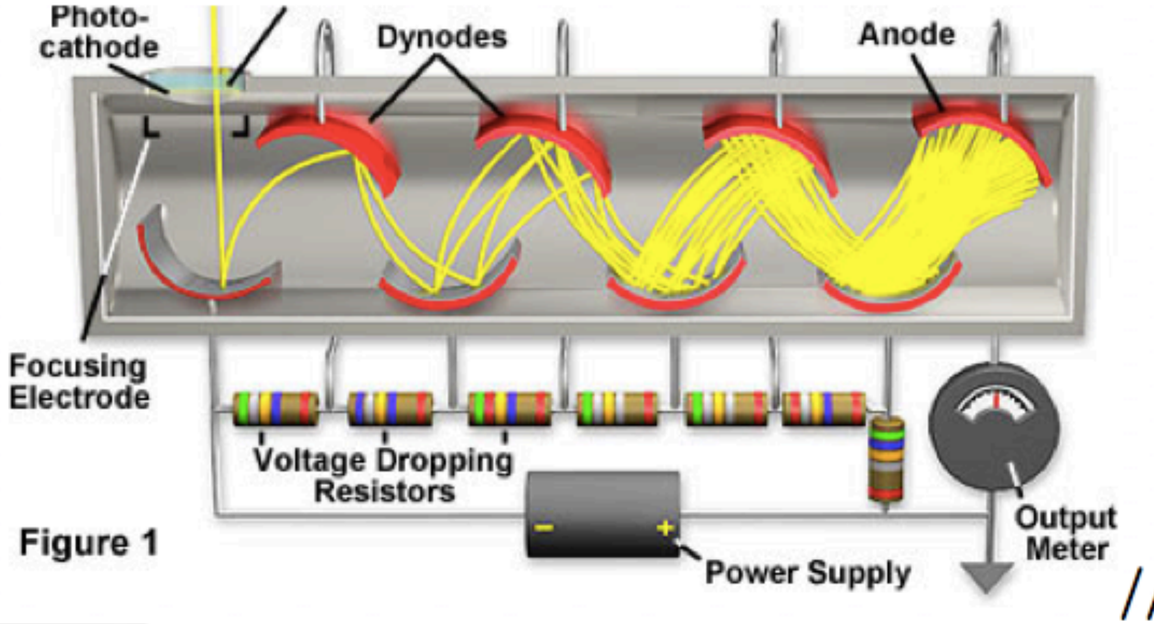
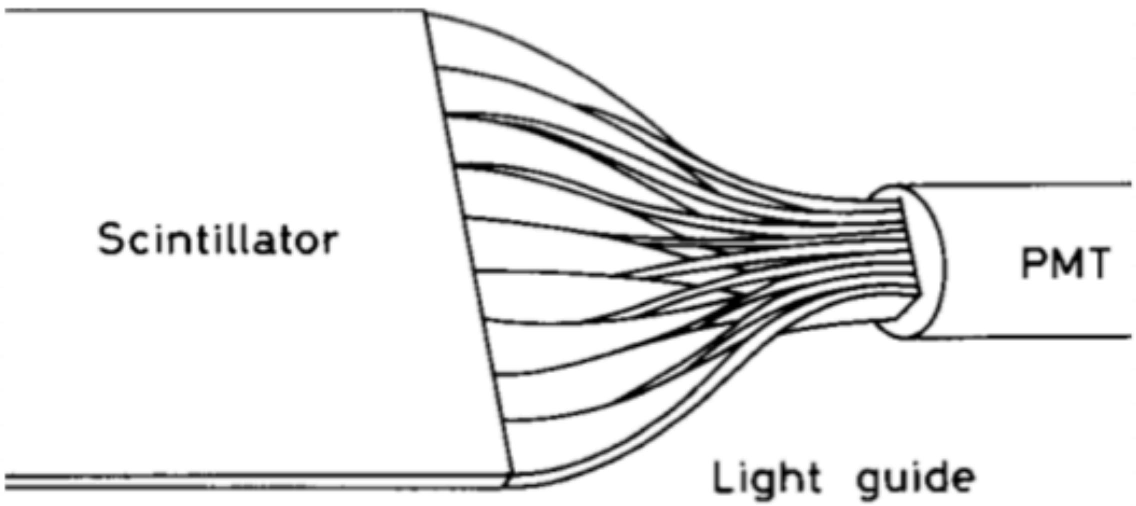
Our tools: Detectors

- It sounds as a paradox, but we can detect particles only if they interact with matter, consequently they also lose energy
- When a charged particle crosses matter a lot of interactions occur, leaving a trail of electrons and ions as well as photons 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

Scintillators





Scintillators

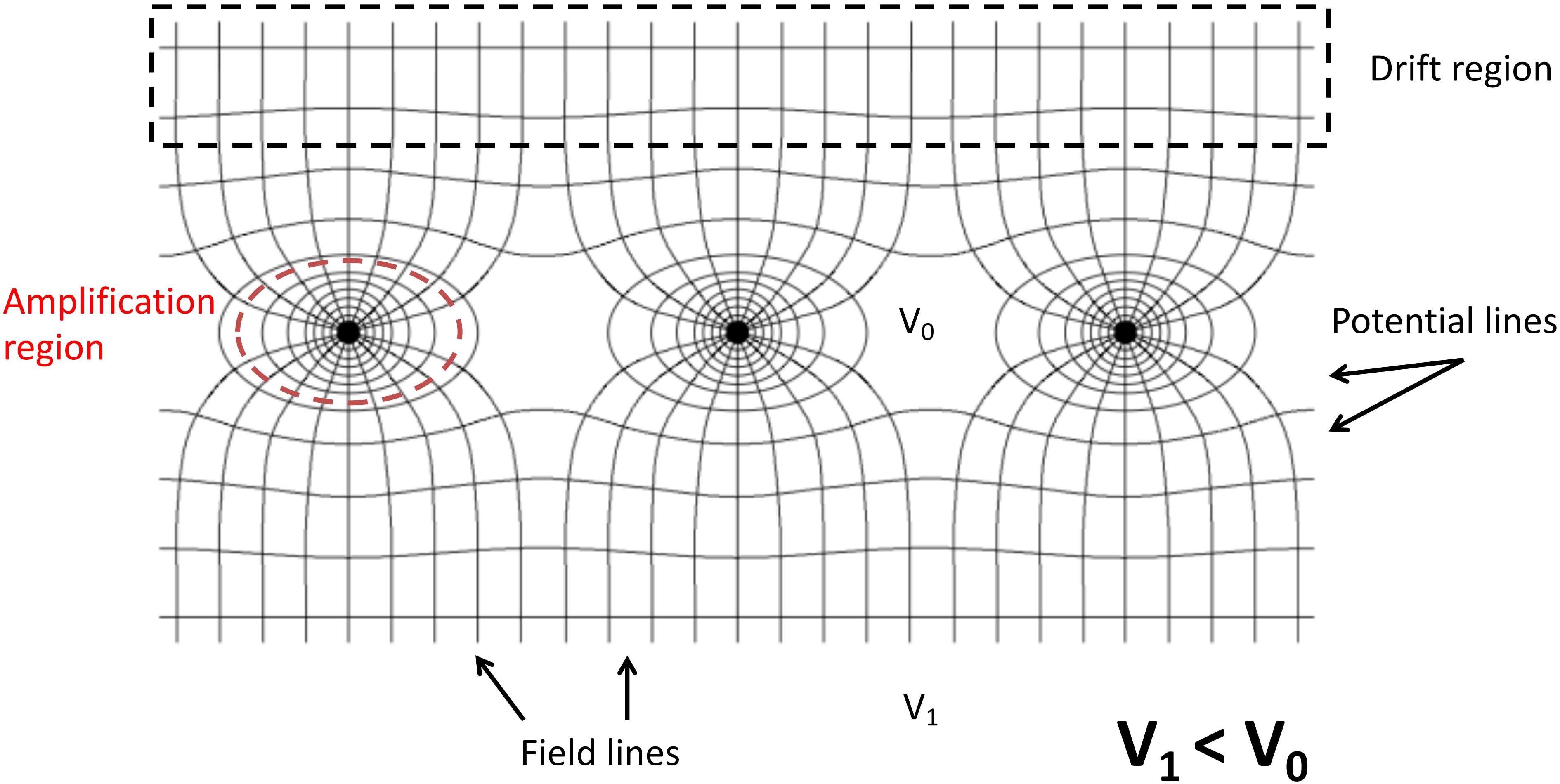
PRO: they're quite fast, we can then have time information about the particles motion. On the other side we can use them as counter: hits collected = particles passing through (or better, almost equal…)
CON: we cannot use them to have the position of the incoming particle, unless we do something fancy… but not in our cases!

Gaseous detectors

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

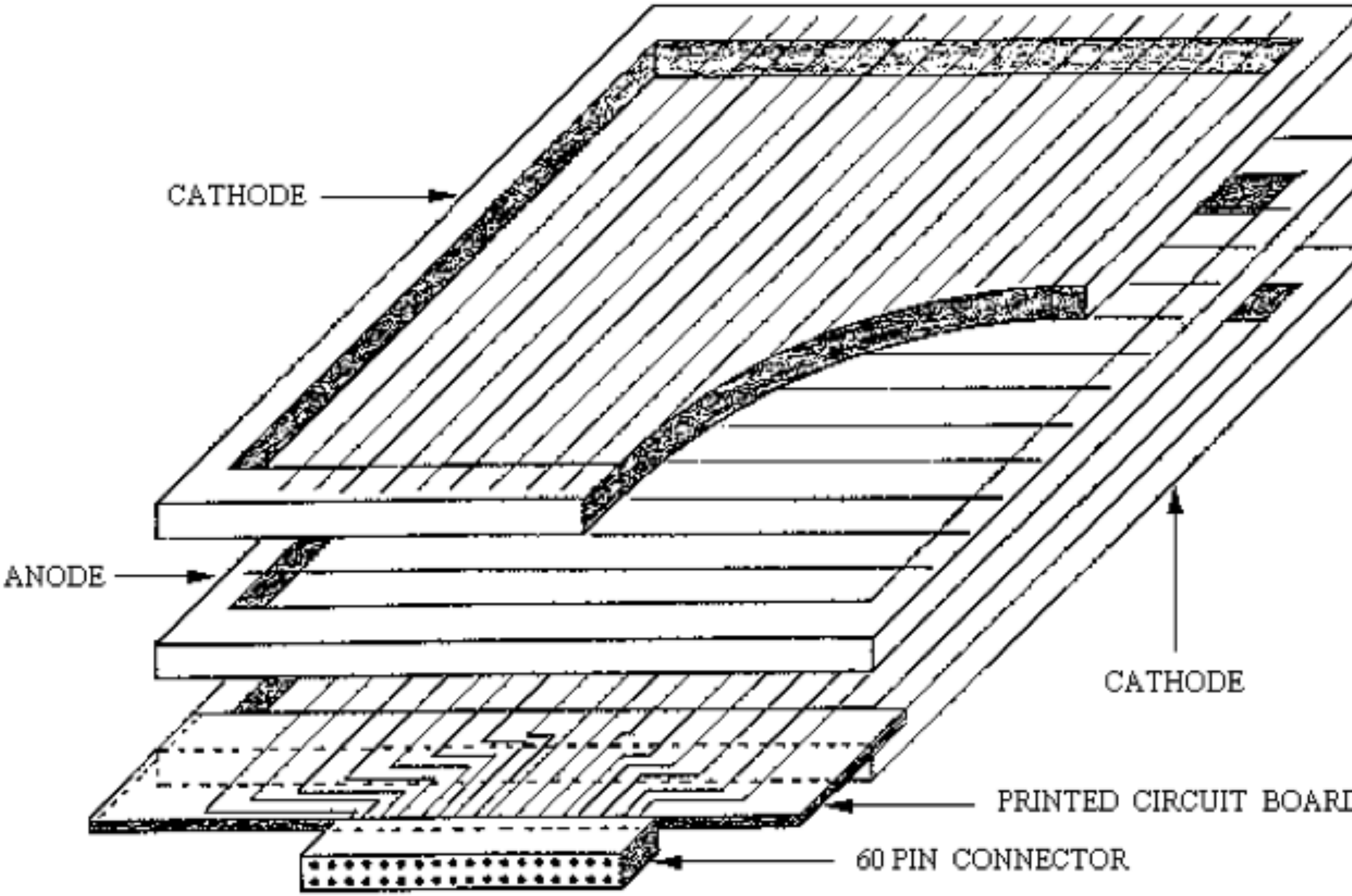
1) the particle creates **ion-electron pairs**
2) an electric field makes the ions **drift** towards a cathode (lower potential) and the electrons towards an anode (higher potential)
3) the electrons undergo a **high electric field**: they are accelerated, making further interactions with the atoms/molecules 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

Wire Chambers



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

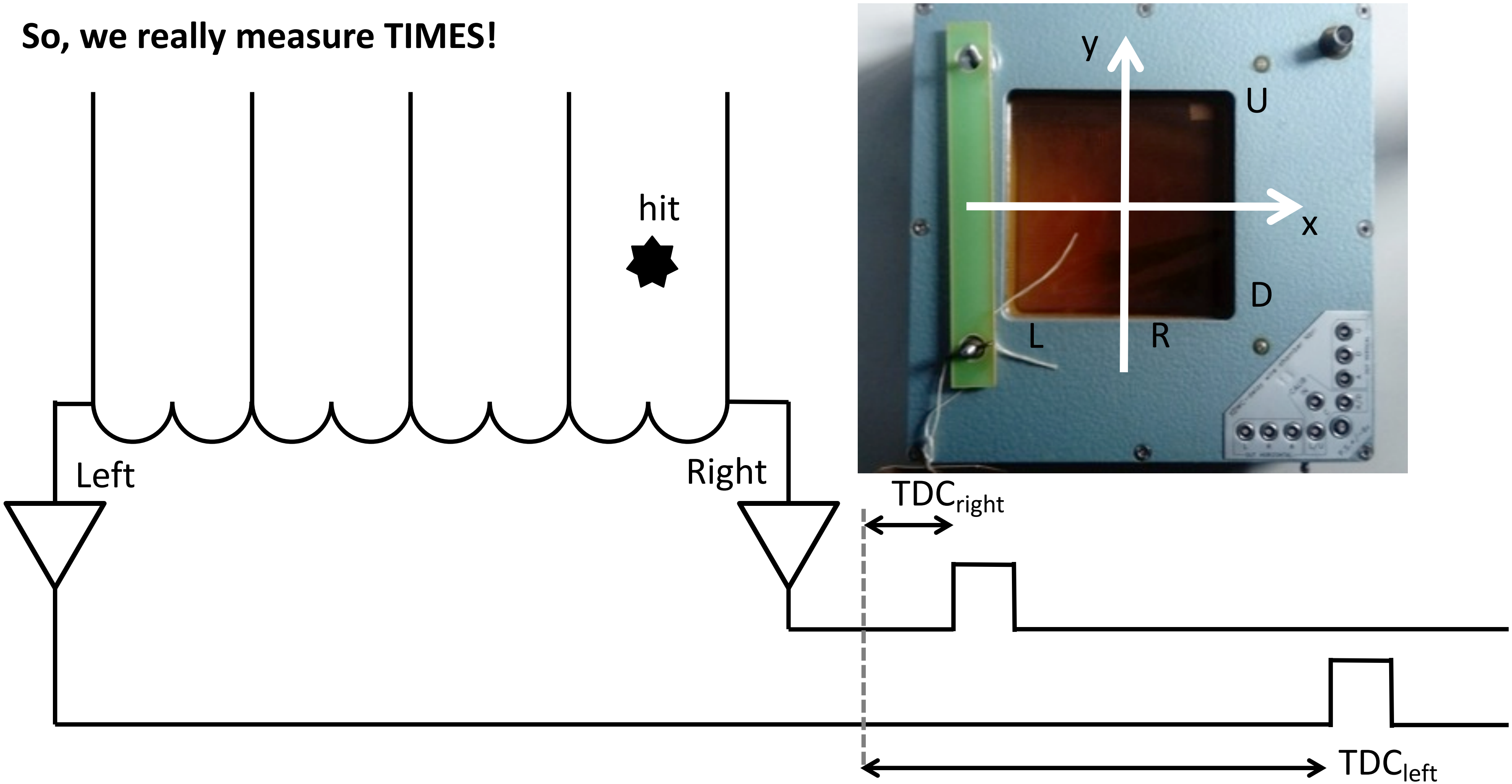
Delay Wire Chambers



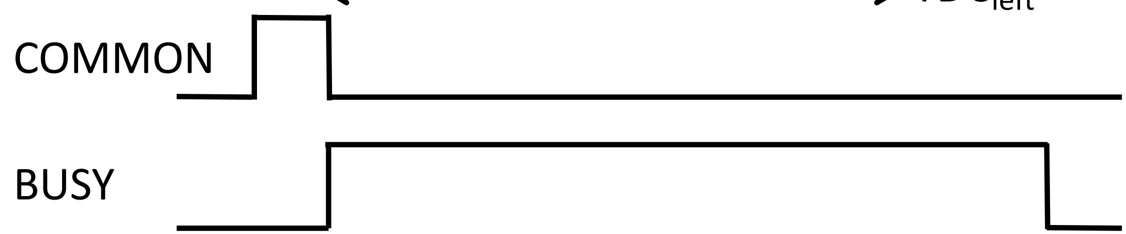
J. Spangaard, Delay Wire Chambers a users guide, CERN SL-Note-98-023

Delay Wire Chambers

So, we really measure TIMES!



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

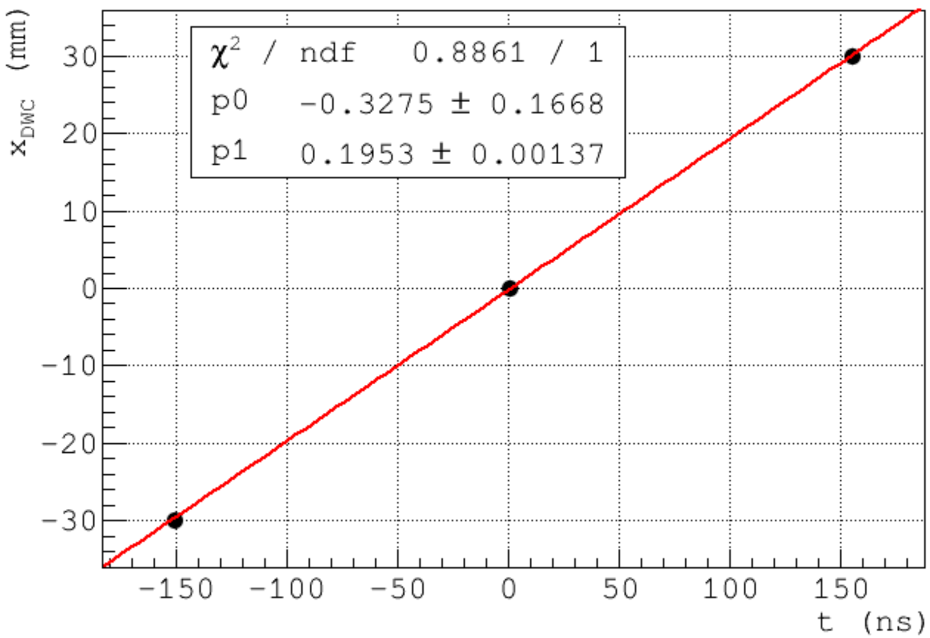


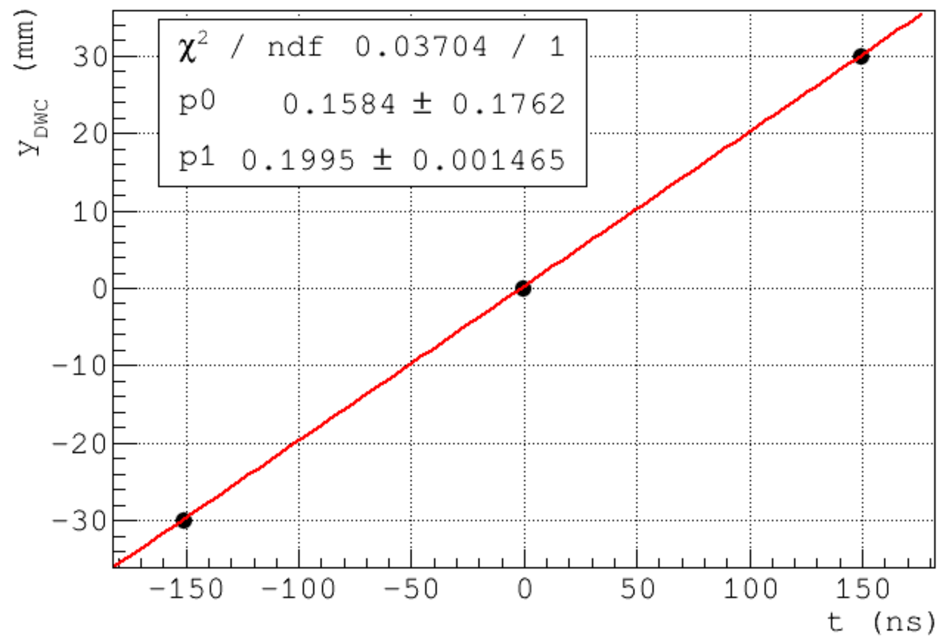
SLOPE? OFFSET?

CALIBRATION!

Delay Wire Chambers

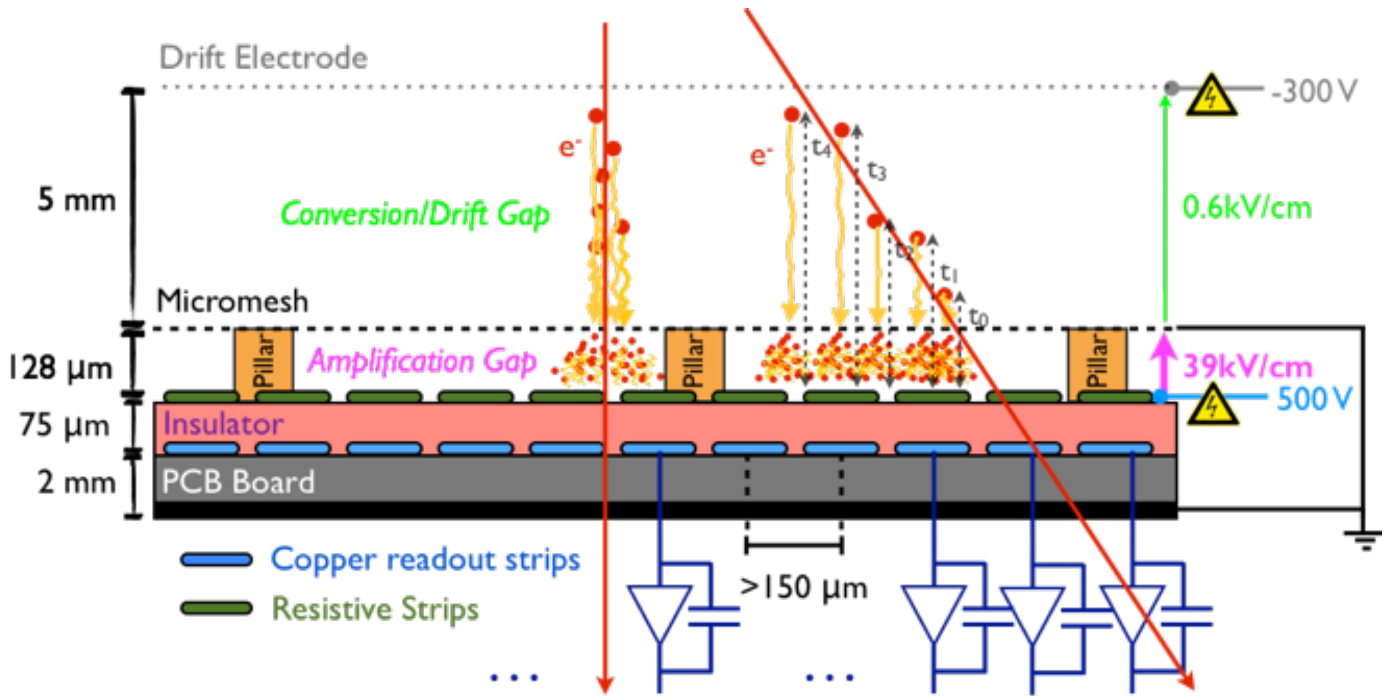
Calibration procedure: we know the position of the hit, we need to measure times to find slope and offset



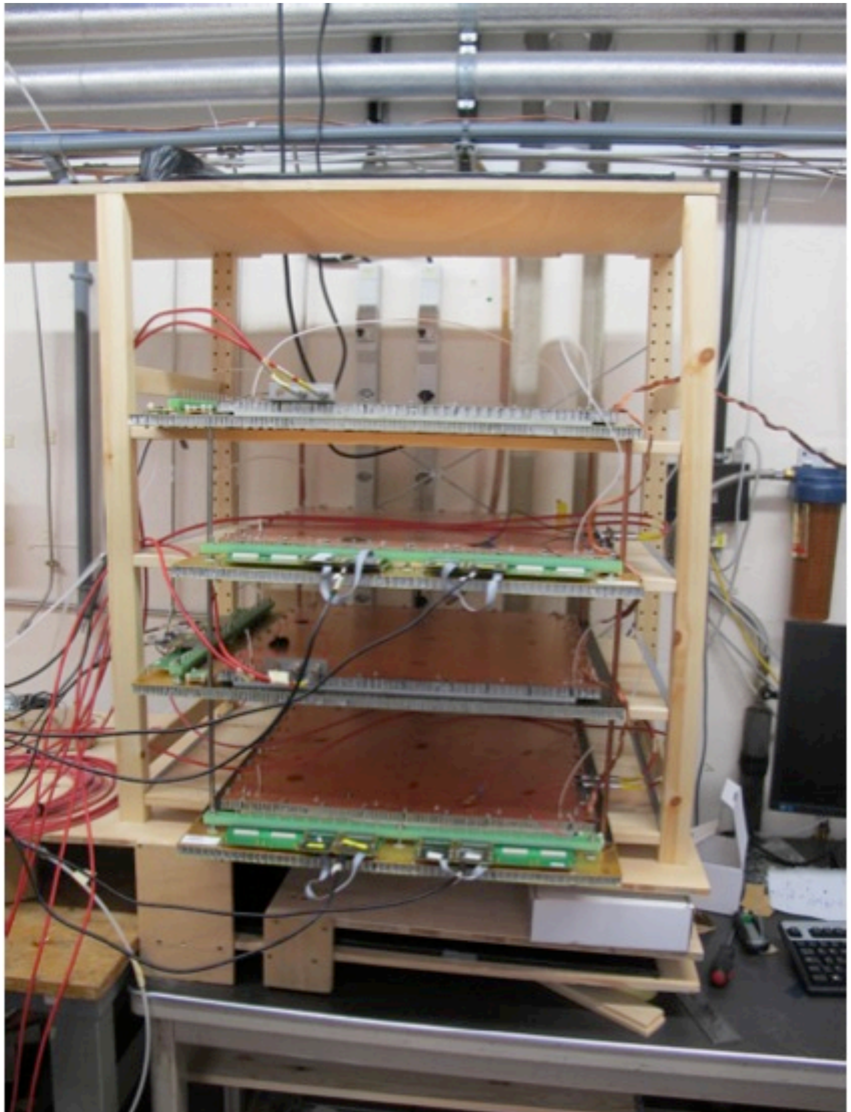


MicroMegas

- 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 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 orientations

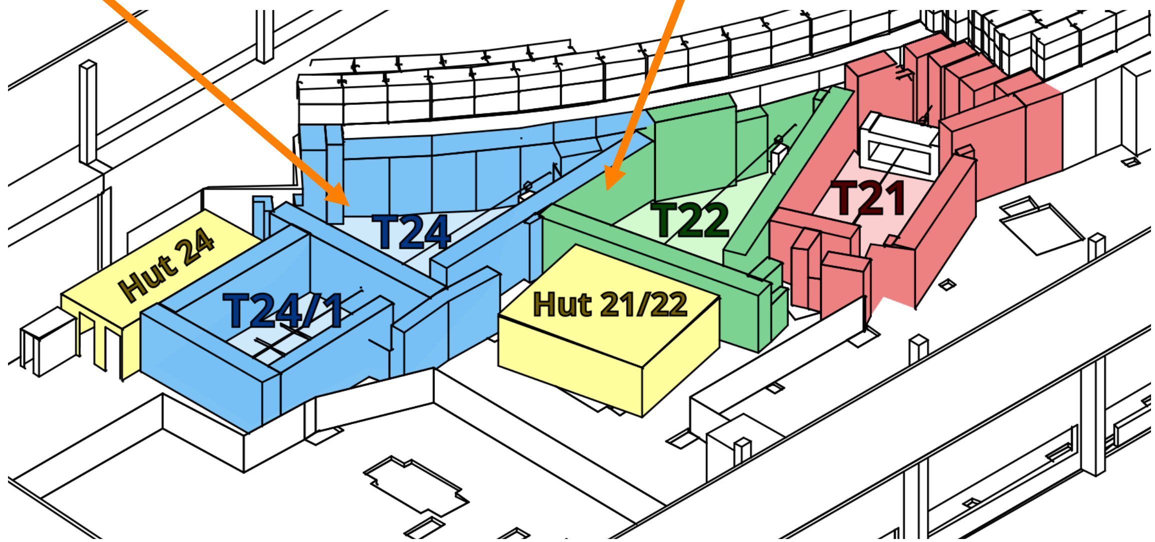
HOW TO FEED A MM?

- 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

Gas cabinet
DWC

Gas cabinet
Micromegas

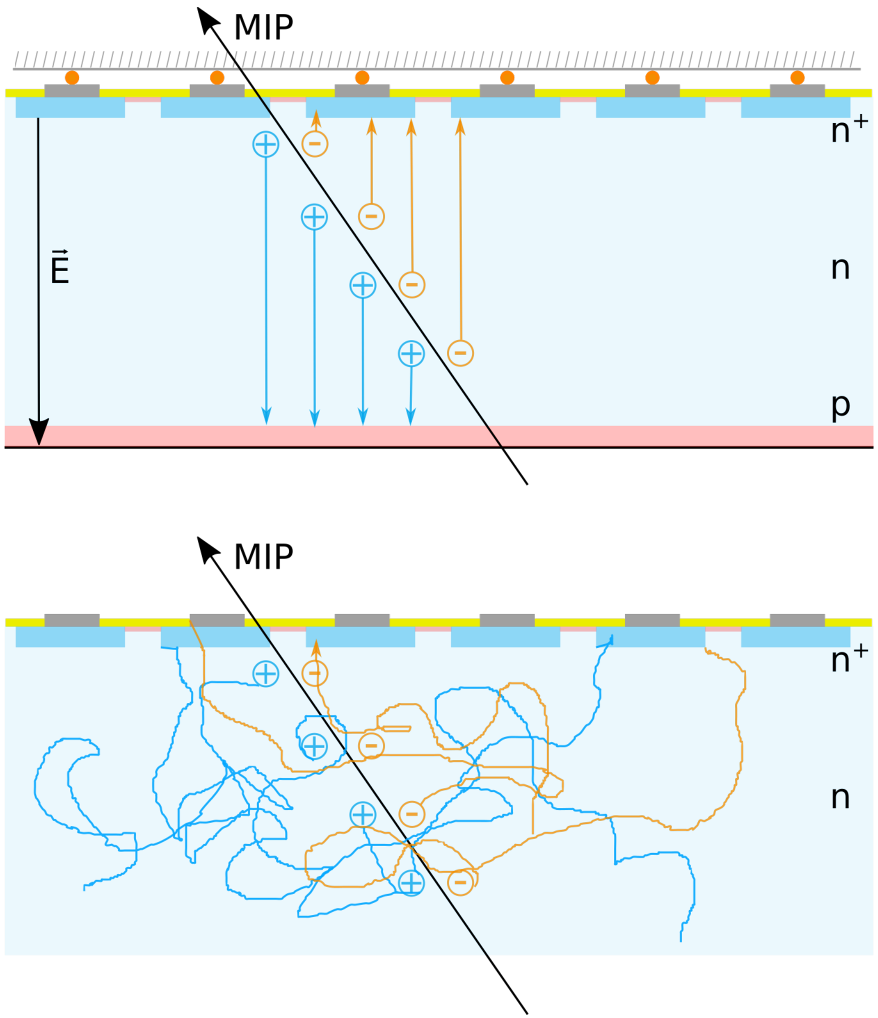


Gas cabinet
@TBs 22/24

Flow meters
@TB 21

You don‘t have to know the full system.
It is however important that you **check the gas flow** (A) and the **pressure in the bottle** (B). **We’ll show you where to look!**

Silicon Detectors



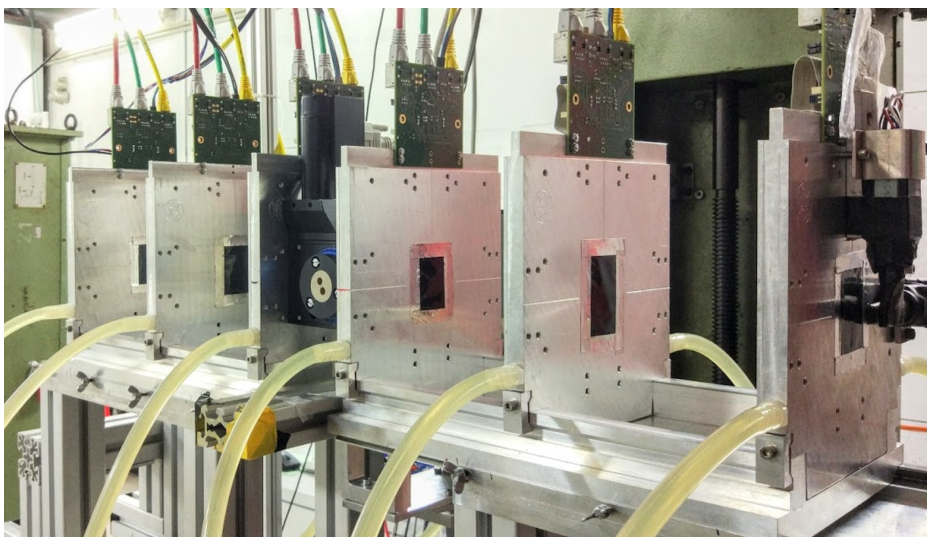
Silicon Detectors are similar to gaseous detectors …

- An electric field is created in manipulated silicon
- The traversing particle ionizes silicon atoms
- Movement of the electrons/holes induce a current → Signal
- Segmented readout electrode
  - → Position information

- We use CMOS sensors →
  - Low electric field
  - → Signal is induced by random walk of the electrons/holes

Beam Telescopes

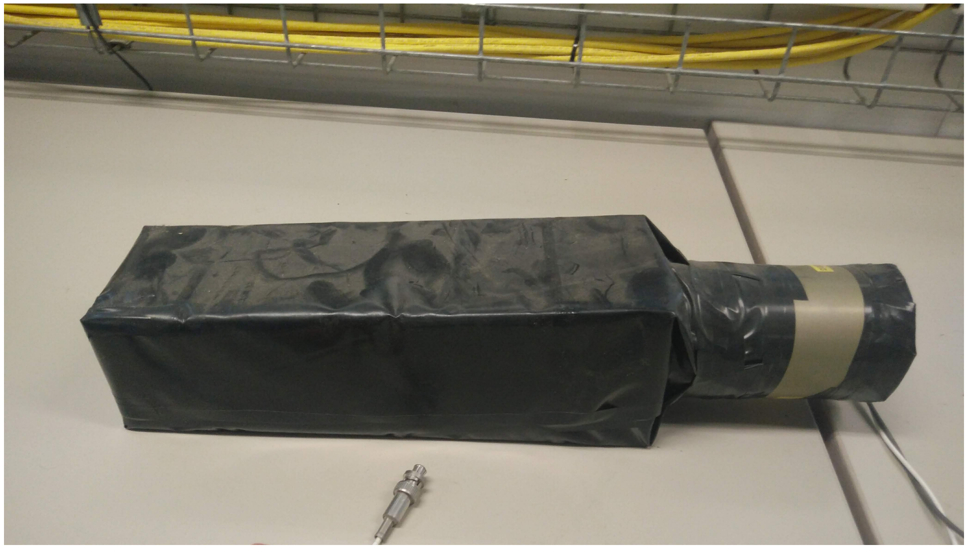
- Several layers of silicon detectors in an easy-to-handle frame
- Measure the particle track (or else..)
- Good resolution (here 3-5 µm)



EUDET (Mimosa) Telescope

Alpide Telescope

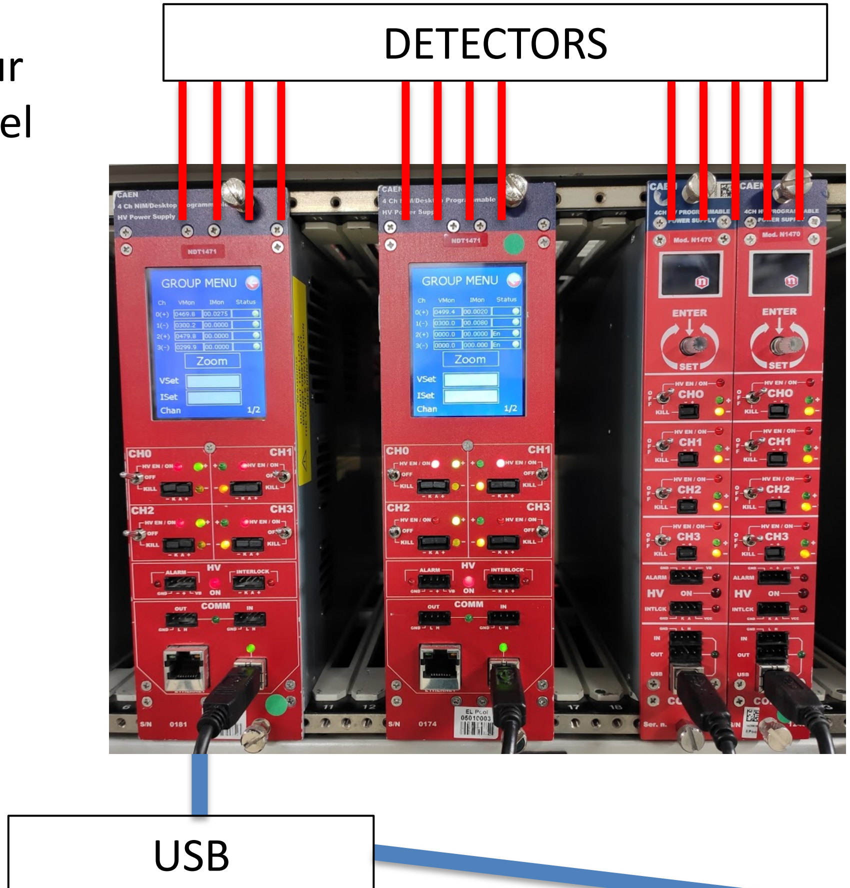
Lead Glass Calorimeter

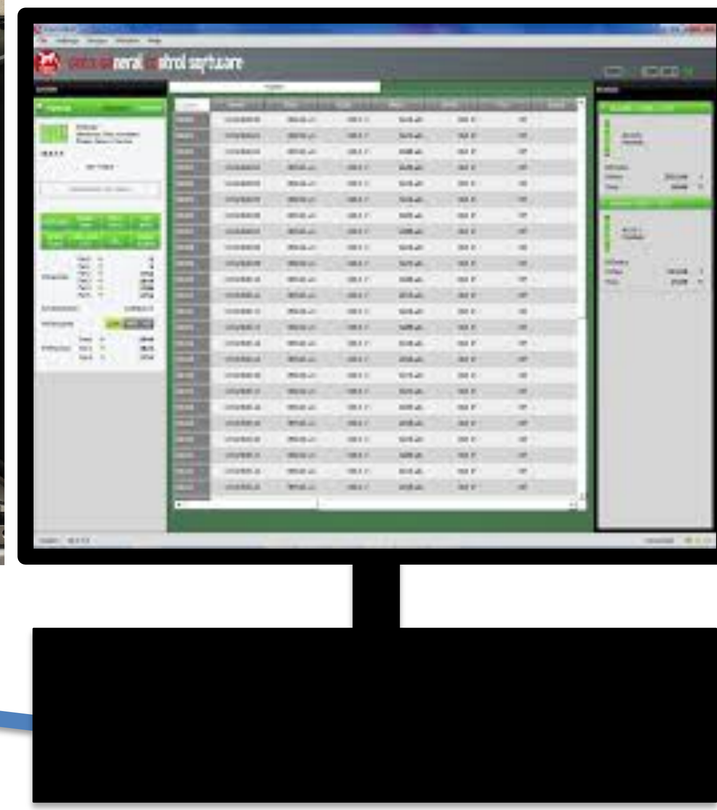


- Block of lead glass
- Generation of a particle shower
- Scintillating material
- Energy of the particle is (partially) converted to light
- Scintillating light is detected in the PMT

High Voltage (> 60 V)

We have four multi-channel systems





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

Low Voltage I

DWC

MicroMegas

More detail during the shifts

Low Voltage II

Mimosa Detectors

Alpide Beam Telescope

More detail during the shifts

Glossary

- Detector: Device telling us if a particle passed and some of its properties
- Scintillator: Emits light when a particle passes
- Light guide: Drives the light produced by a scintillator towards the PMT
- PMT: Converts the light from a scintillator into an electric signal
- Gaseous detector: Do you really need this definition?
- Wire Chamber: 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 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: Nice devices providing the position of an impinging particle
- Silicon Detector: Small detector measuring the position of a traversing particle
- Beam Telescope: Array of silicon detectors measuring a particle track
- Calorimeter: Device to (destructively) measure the energy of a particle.

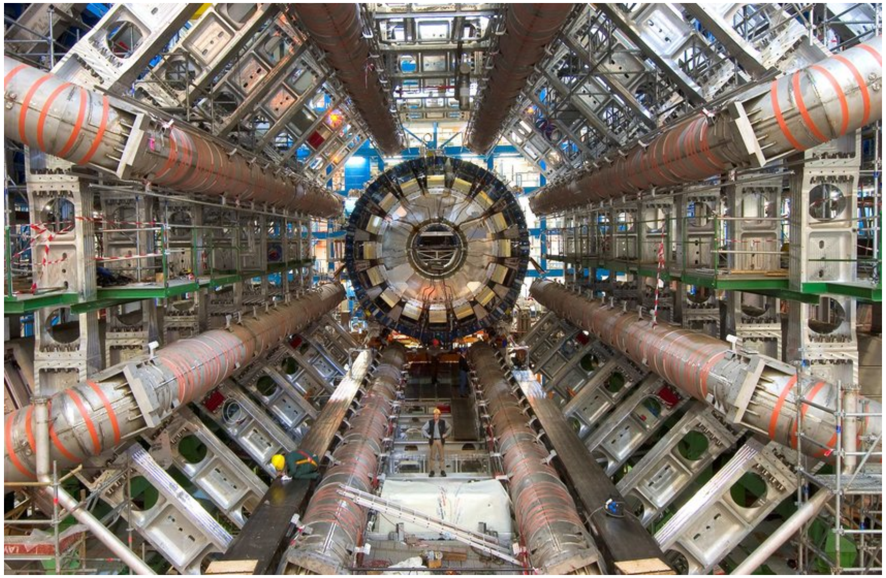
Glossary

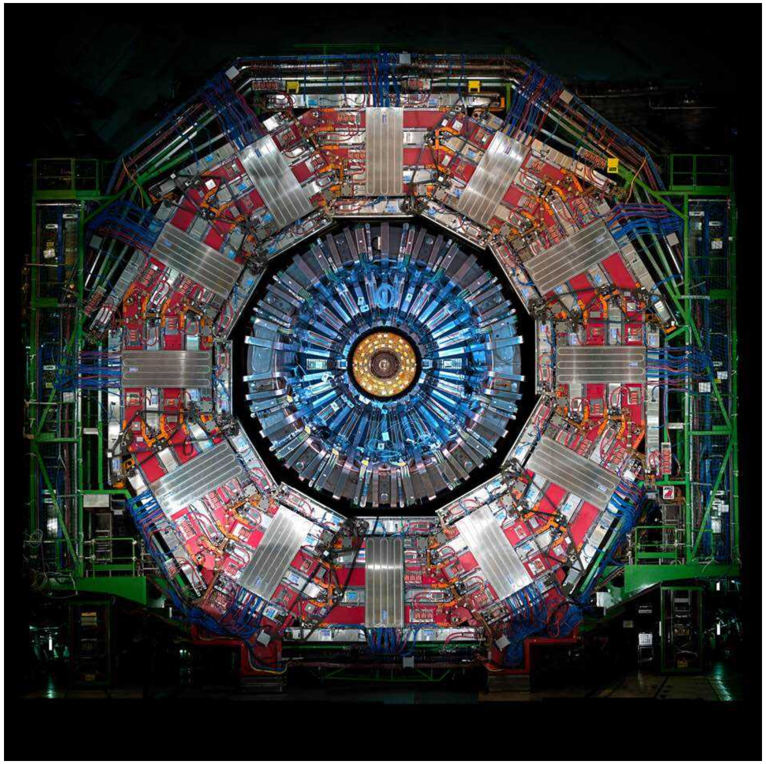
- Flowmeter, better called Rotameter: Device telling us how much gas we are injecting in our detector
- Manometer: Instrument to measure the gas pressure of a system
- Low Voltage Power Supply: Small heavy box used to supply the low voltage to several lines
- Crate: Medium heavy box used to host always too many modules to post-process the signals from the detector
- Rack: 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 the Test Beam and still get good data
- Cookies: Life support at the Test Beam, especially when handed to support scientists or to Marcel

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

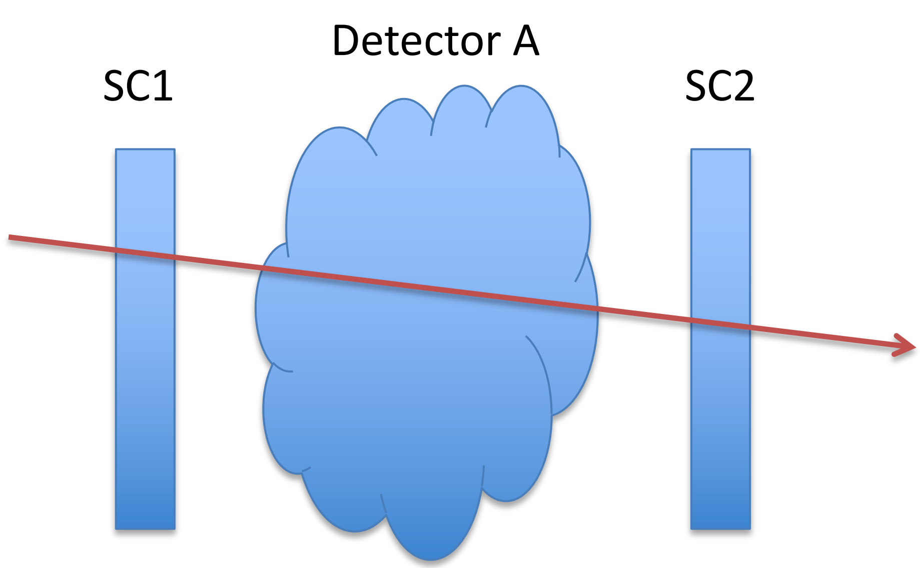
- In big experiments, the trigger has the additional job of managing the amount of data to be stored





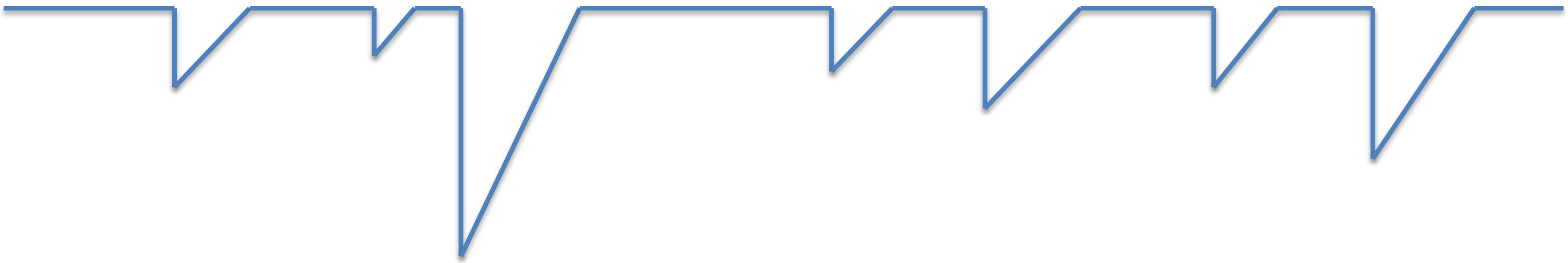
Building a simple trigger

- 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

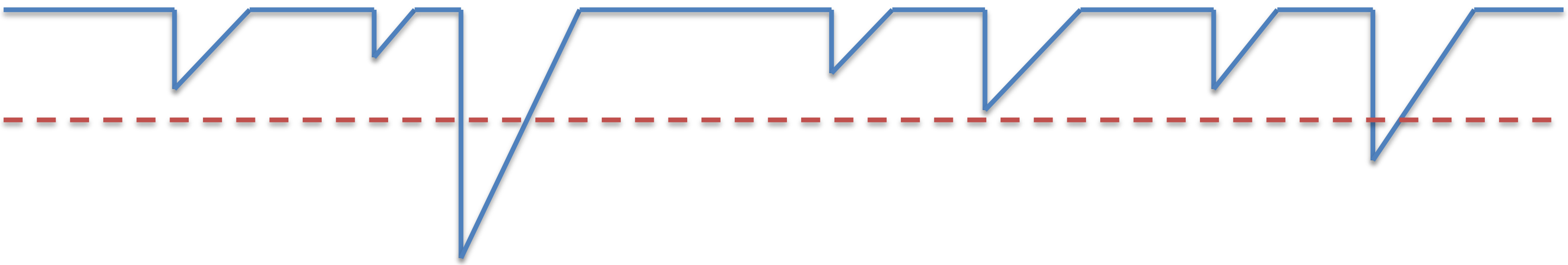


Triggering on Detectors

- 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

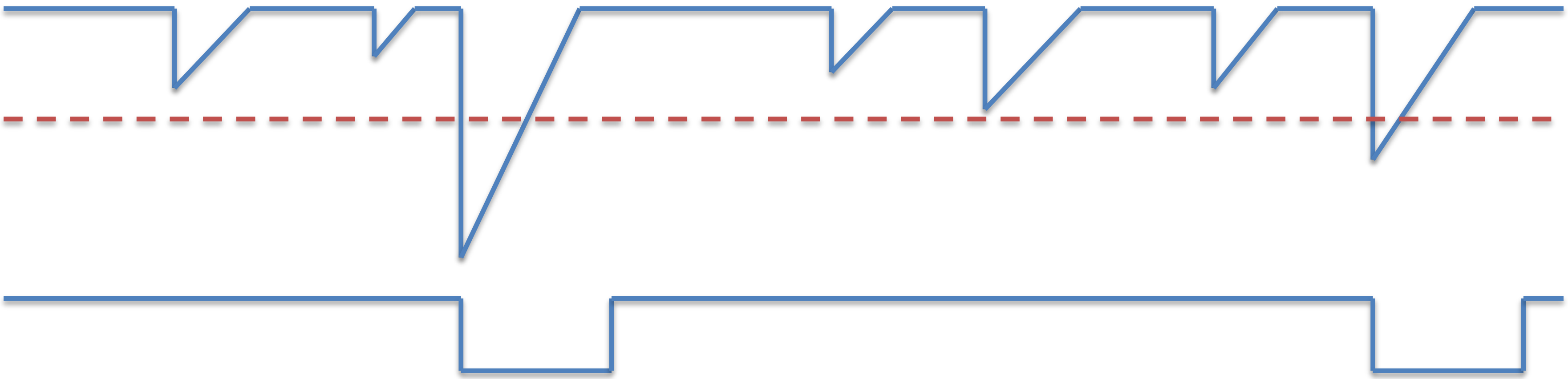


- The noise is typically small and sometimes produces large pulses, while real signals are almost always large

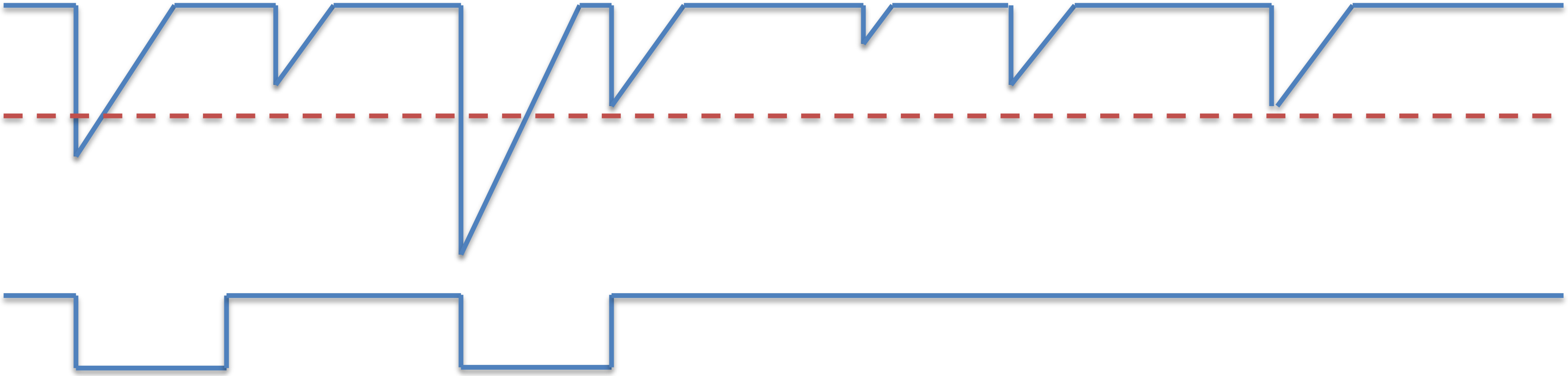


Triggering on Detectors

- 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

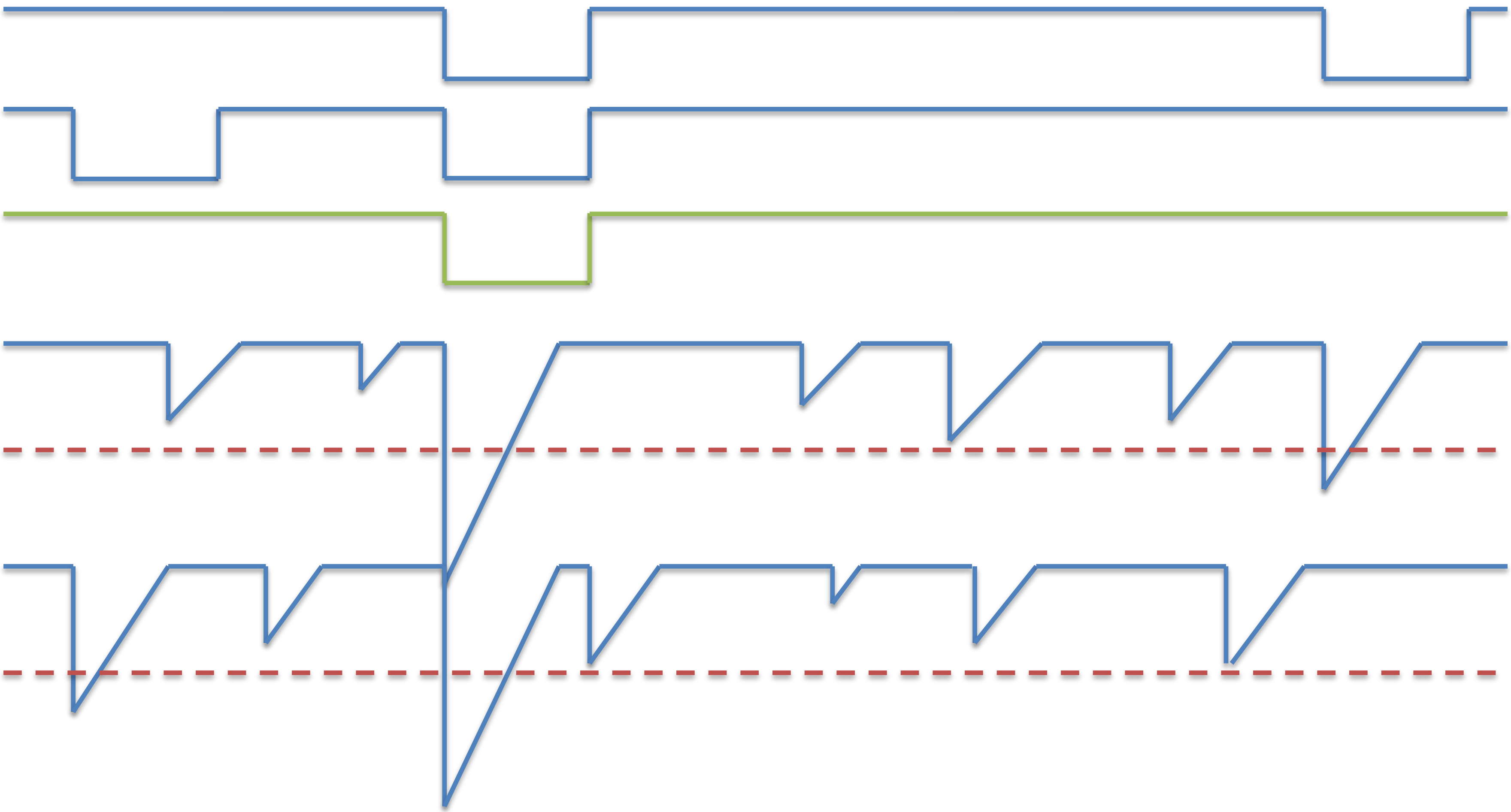


- Some of the noise still survives in the logic signal, consider the other scintillator:



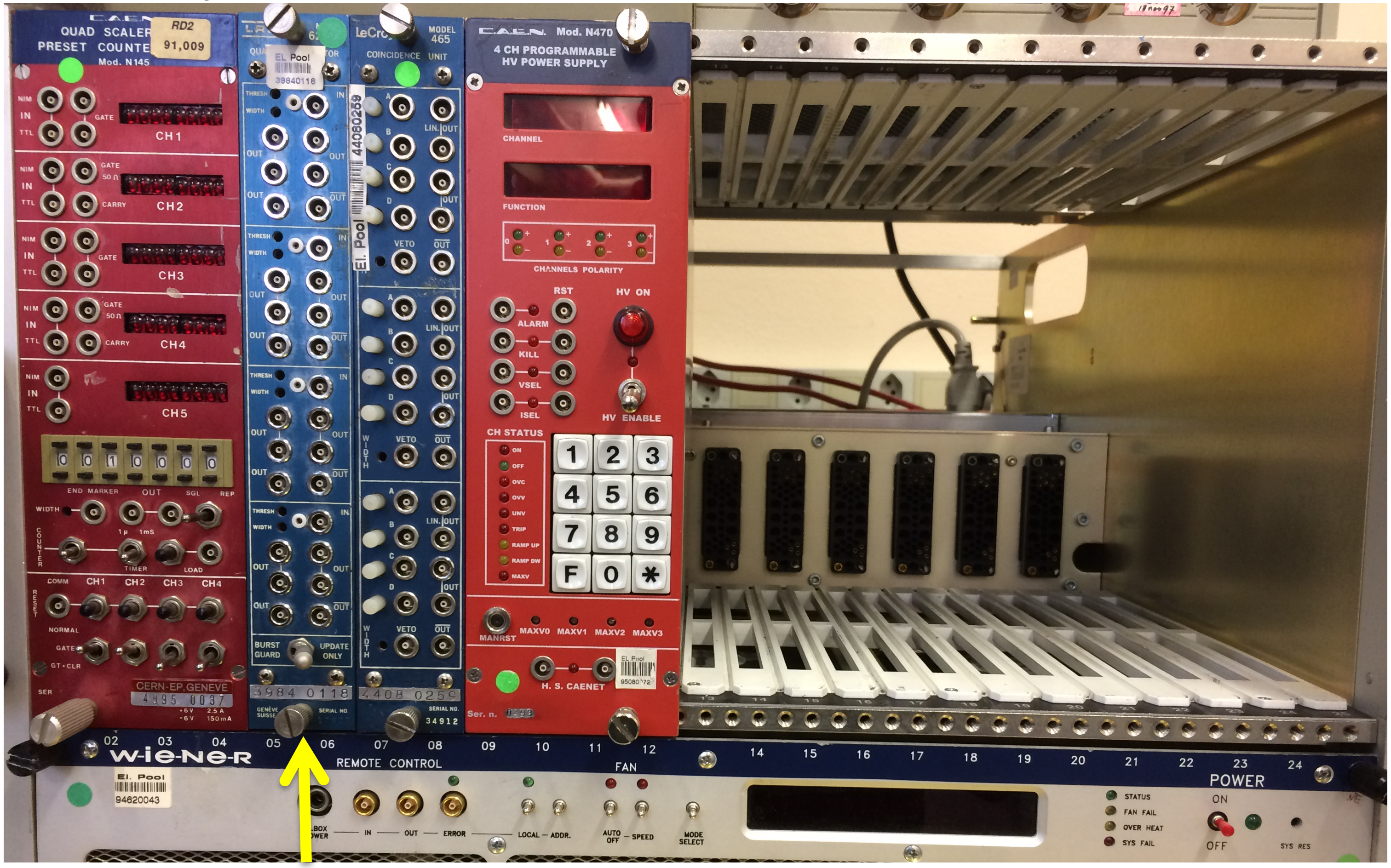
Triggering on Detectors

- 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



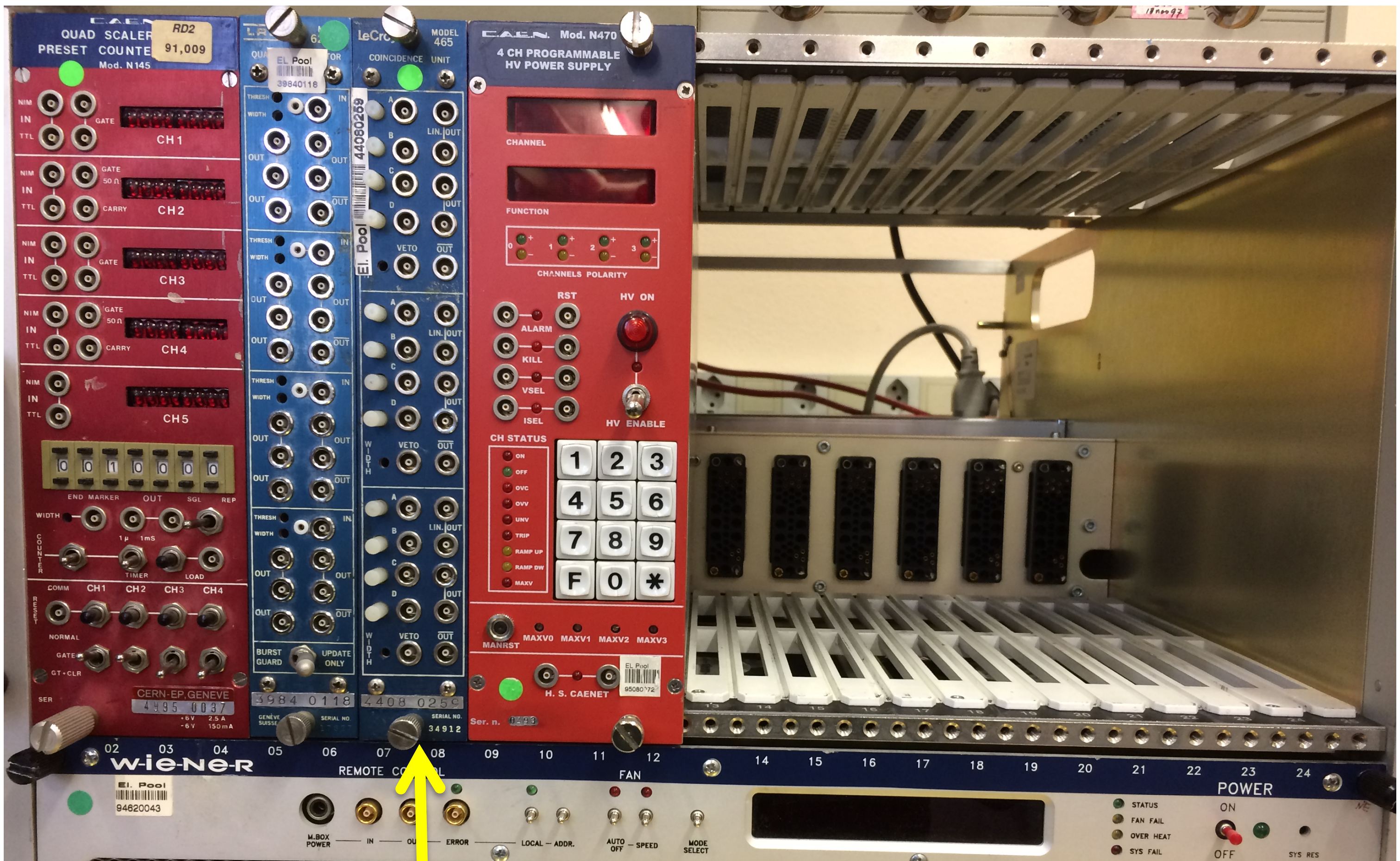
Triggering on Detectors

- 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



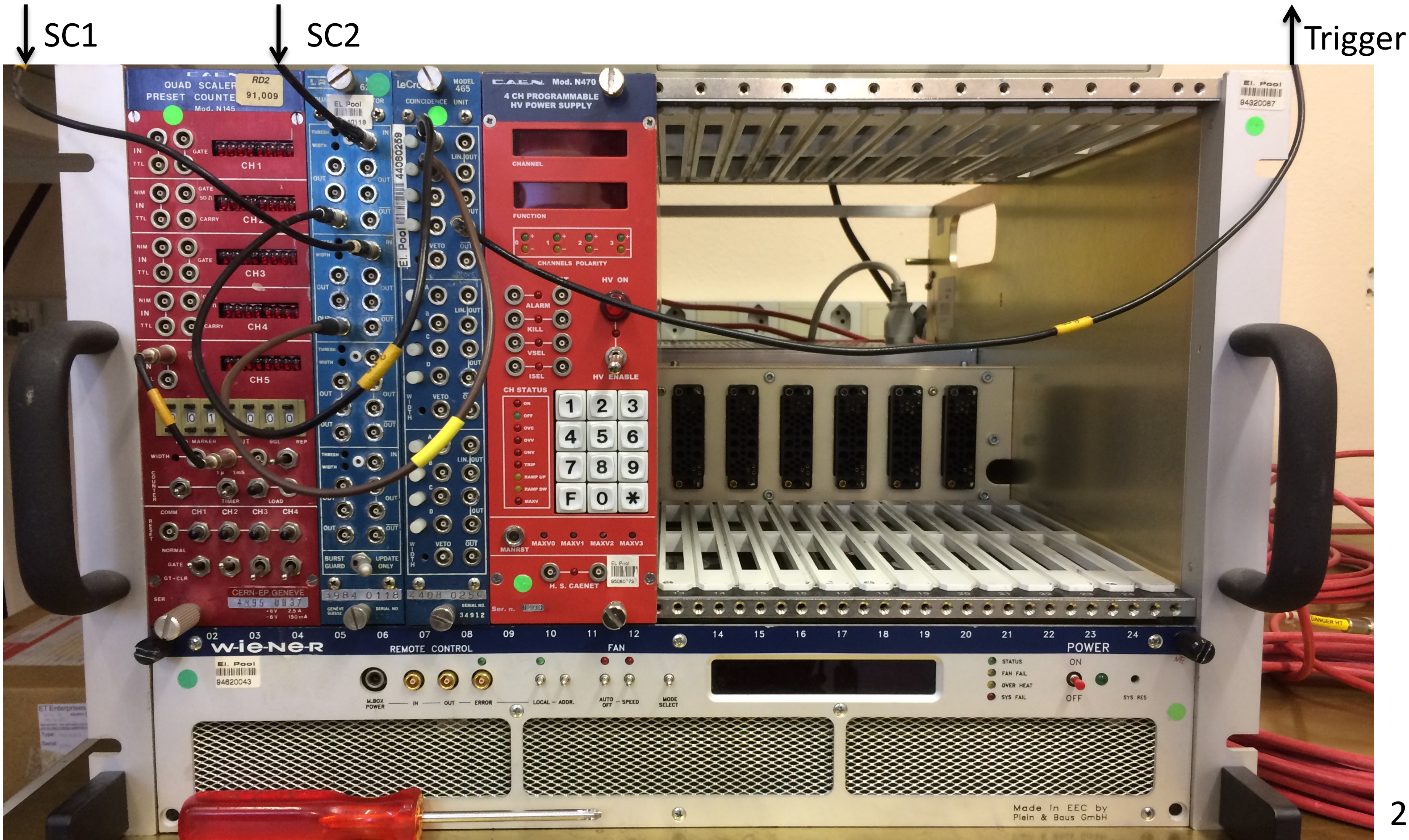
Triggering on Detectors

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

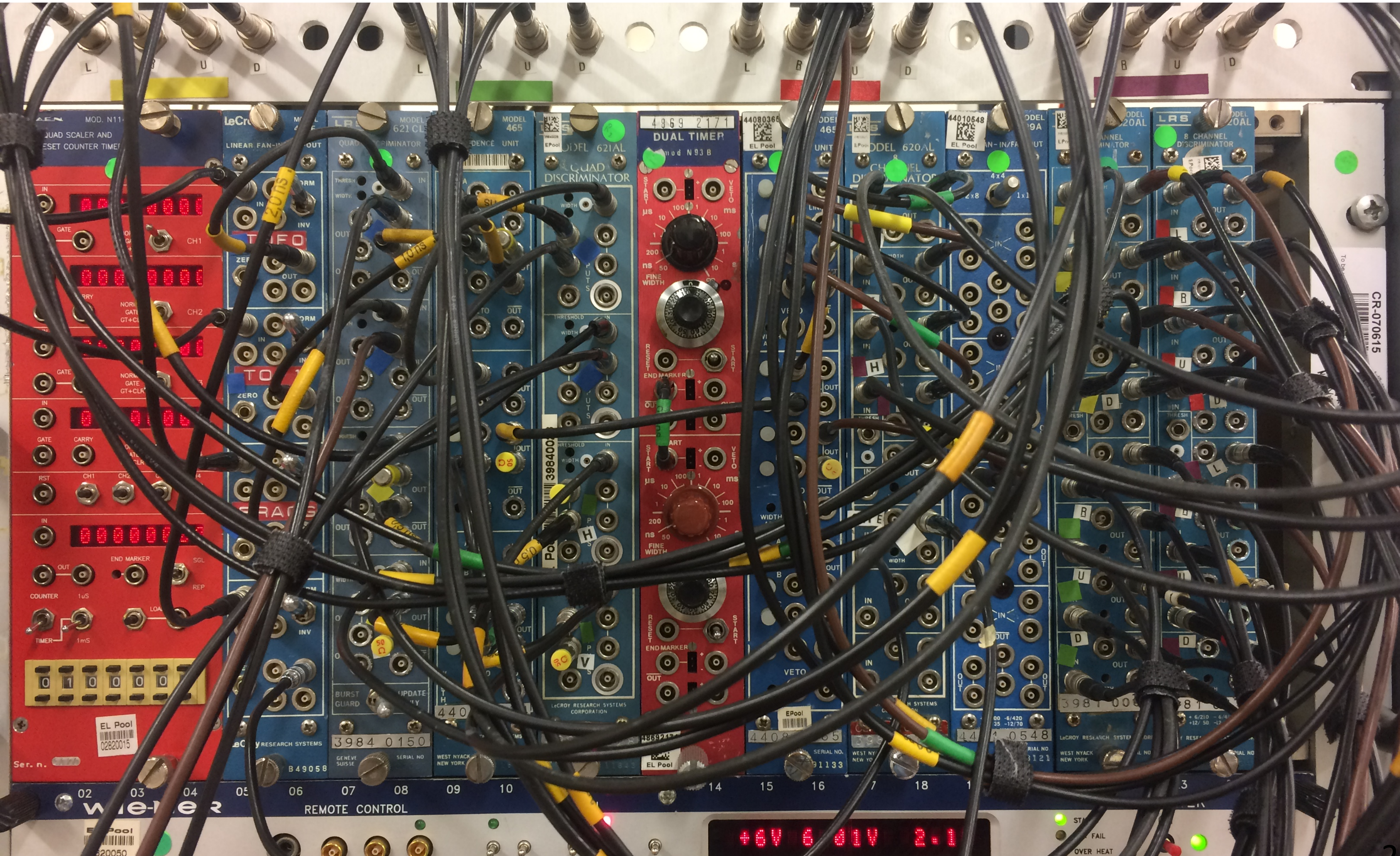


Triggering on Detectors

- The final trigger might look something like the below:



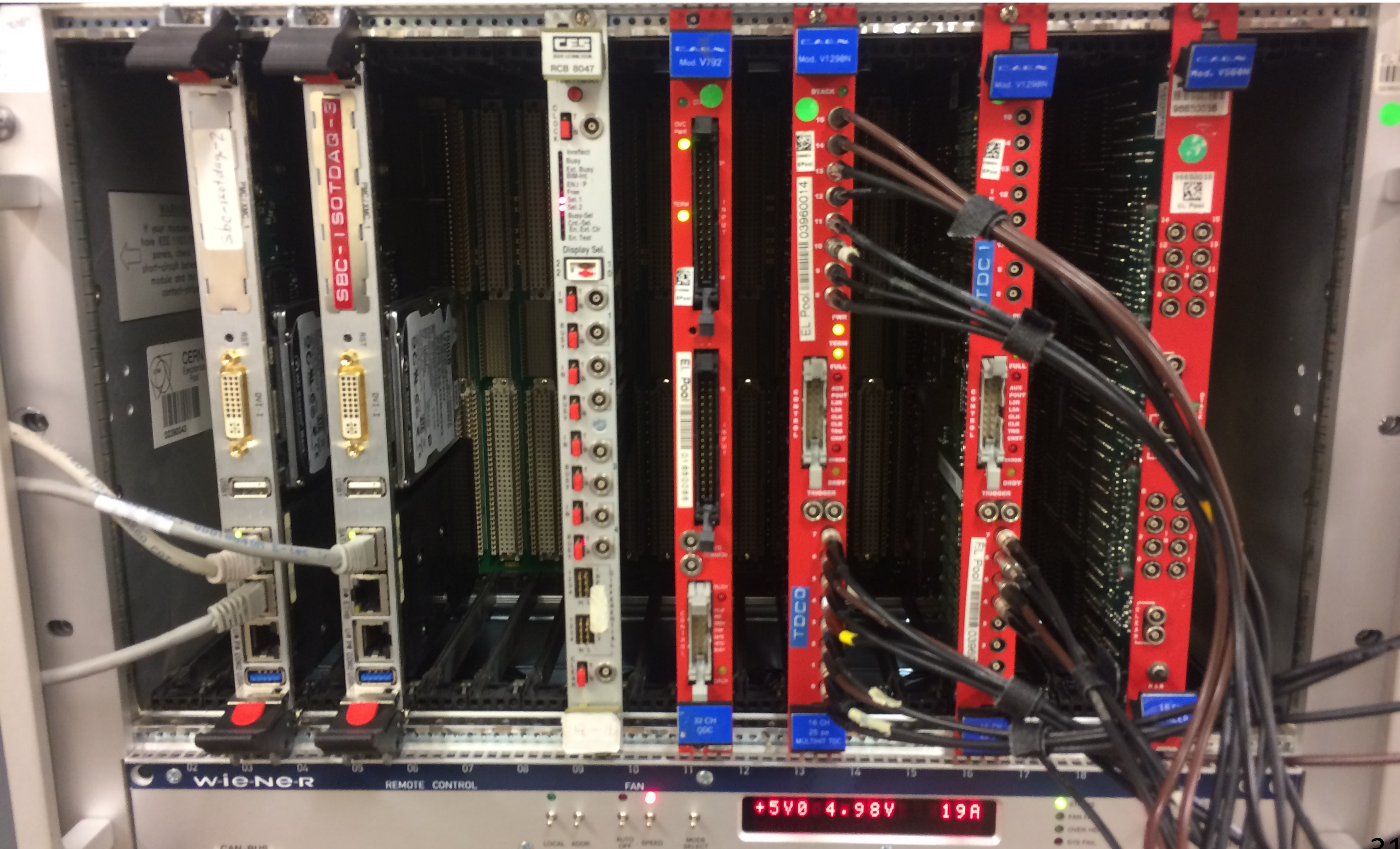
A More Complex Example



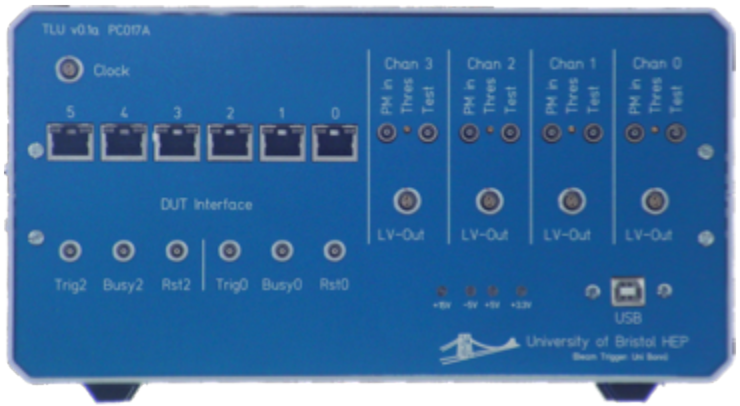
Data Acquisition

- 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
    - TLU – Trigger Logic Unit
  - 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
    - EUDAQ –DAQ software for the use in Test Beam experiments

Data Acquisition Hardware - VME

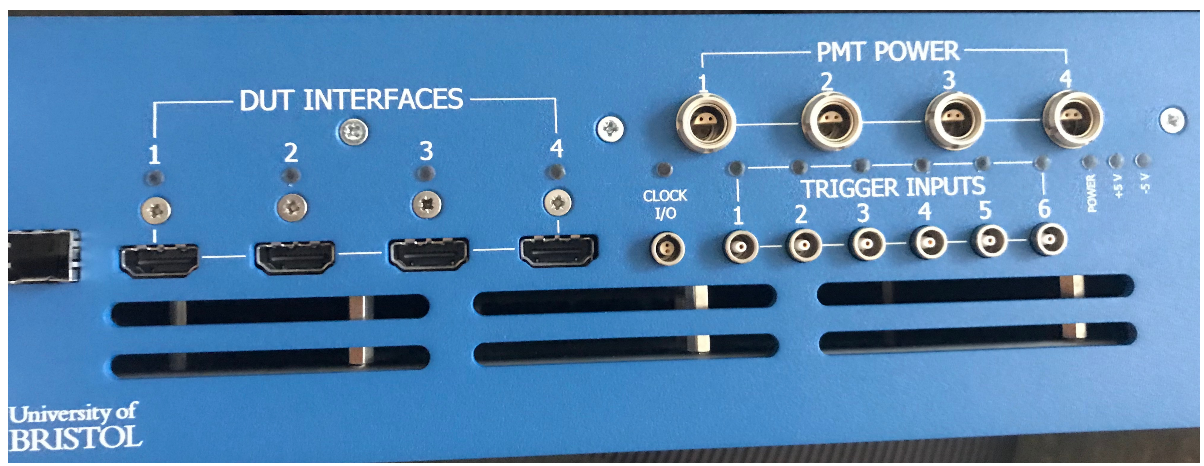


Data Acquisition Hardware - TLU

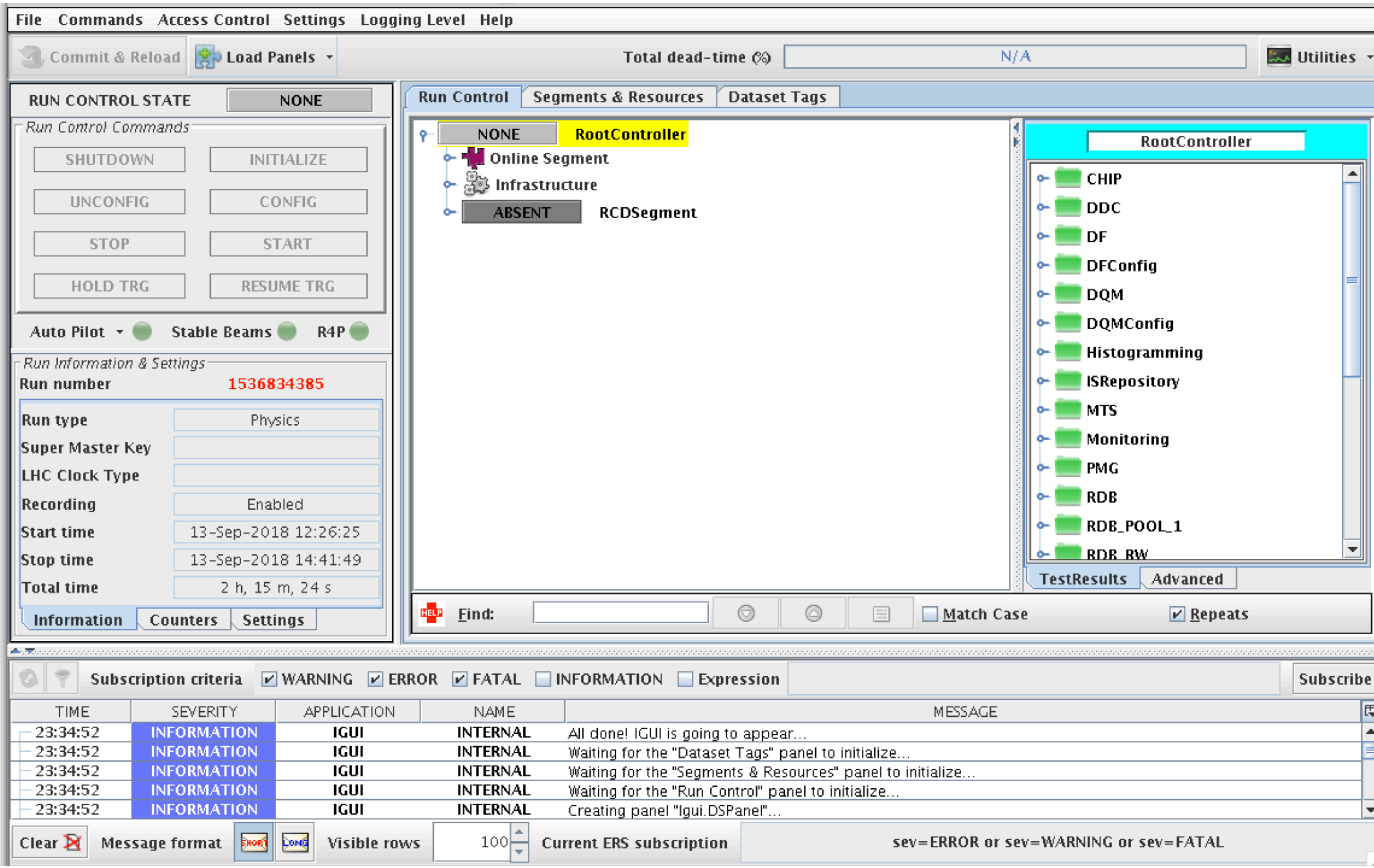


EUDET TLU (EUDAQ 1)

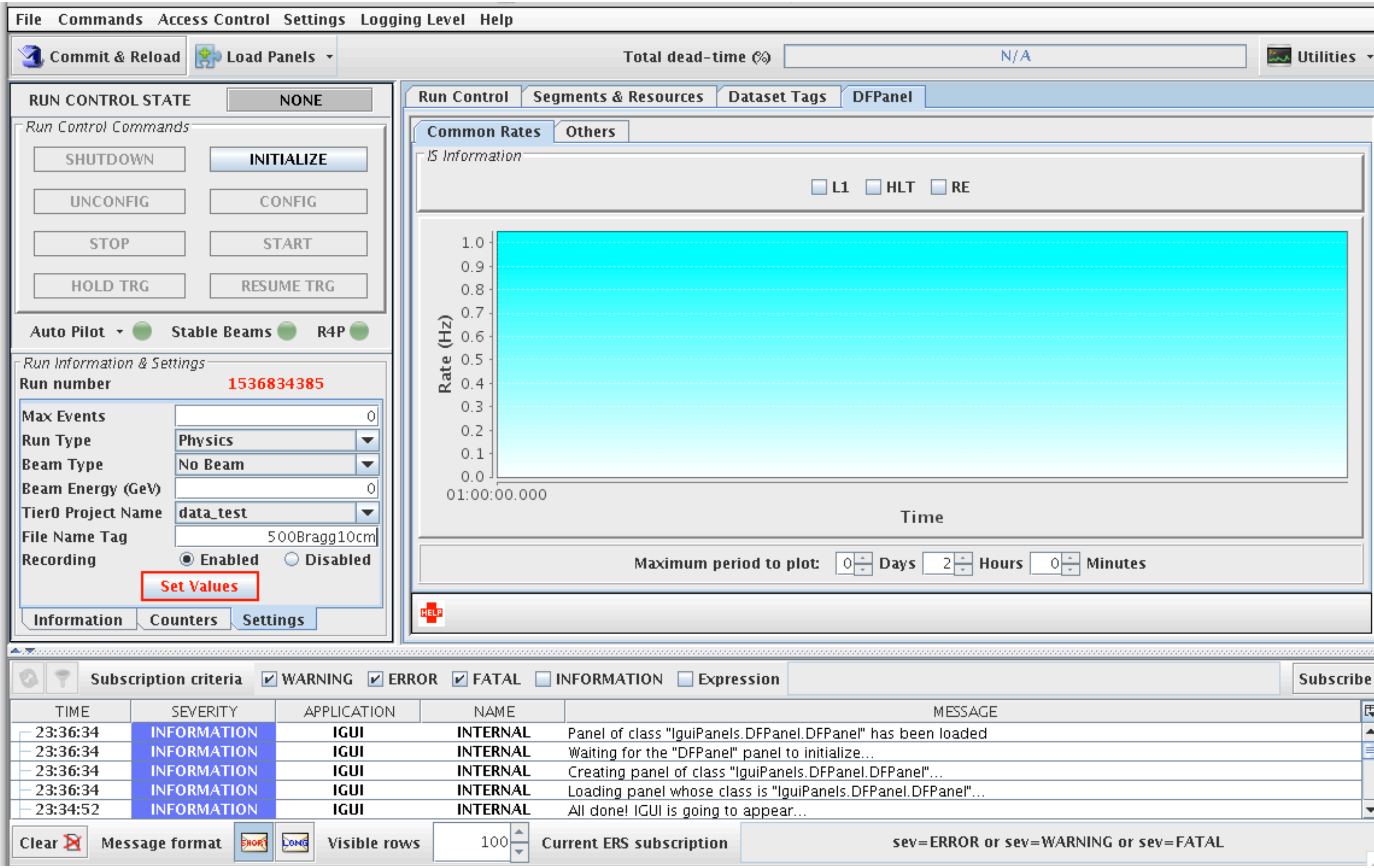
AIDA TLU (EUDAQ 2)



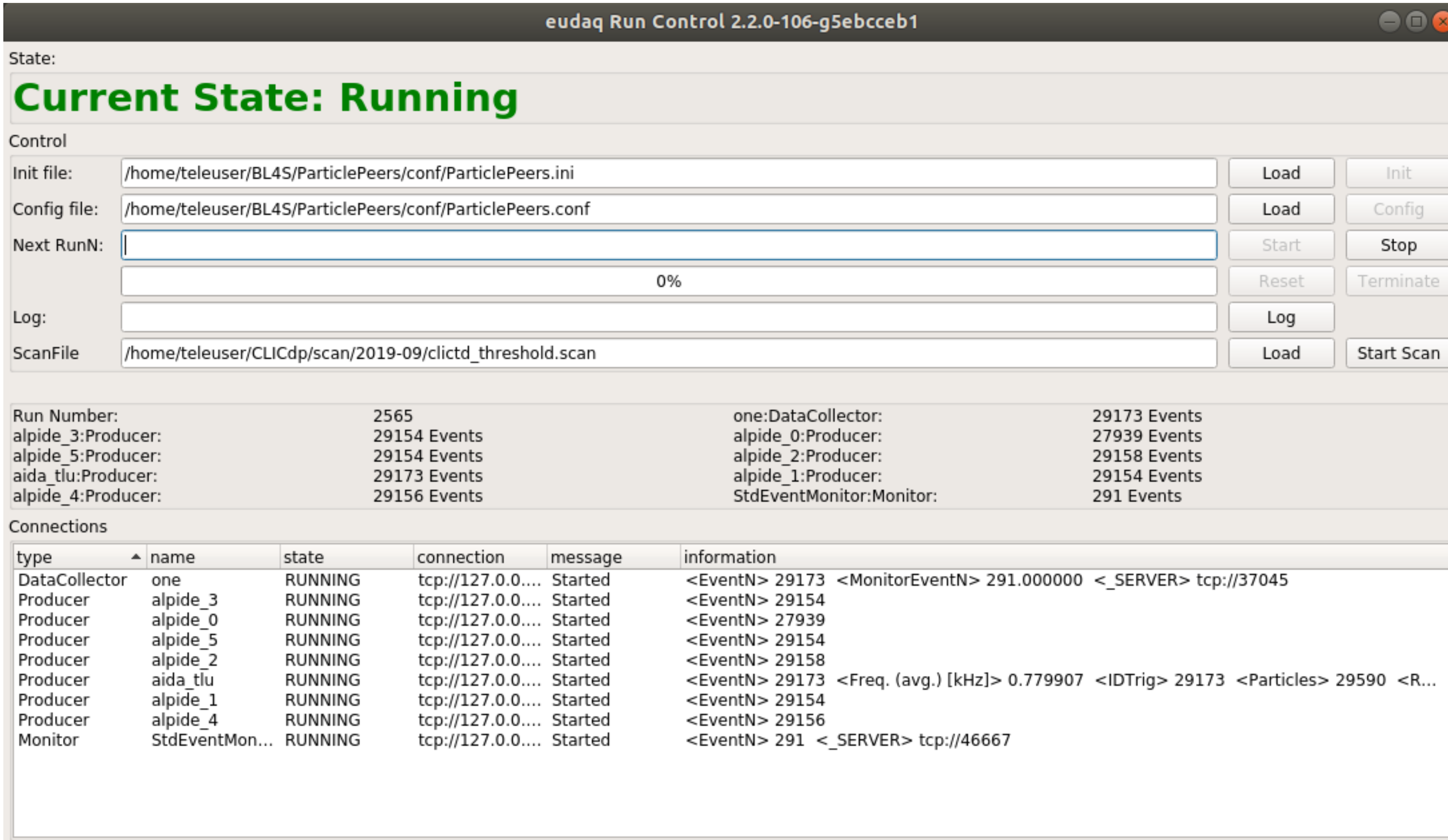
Data Acquisition Software TDAQ



Data Acquisition Software TDAQ



Data Acquisition Software EUDAQ



Electronic Logbook

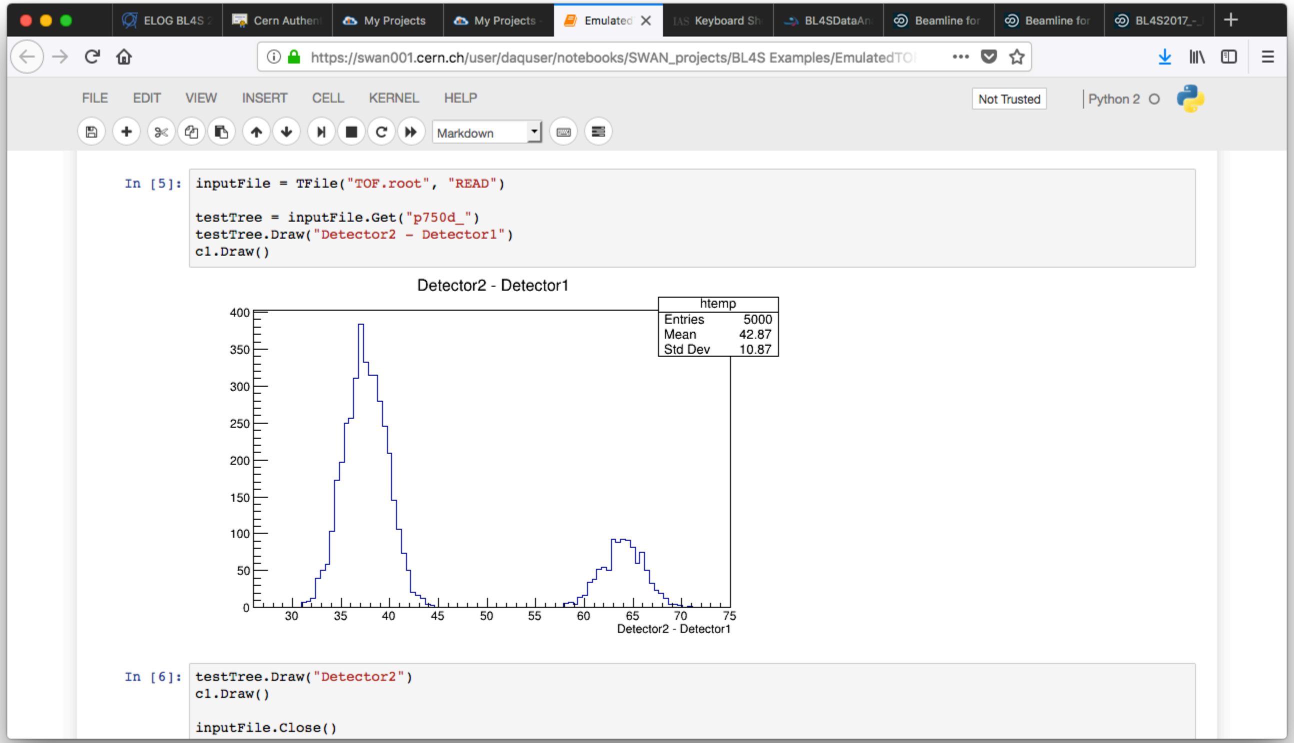
- Available at: https://tblogs.desy.de
- Write down <u>everything</u> that happens:
  - When you start a run, write it down with the run number and what it is for
  - If there is a problem during a run, write it down
  - If the conditions change (HV, gas pressure, etc), write it down
    - Also check them regularly …
  - 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
  - Things that are not written down have never happened

Shifts

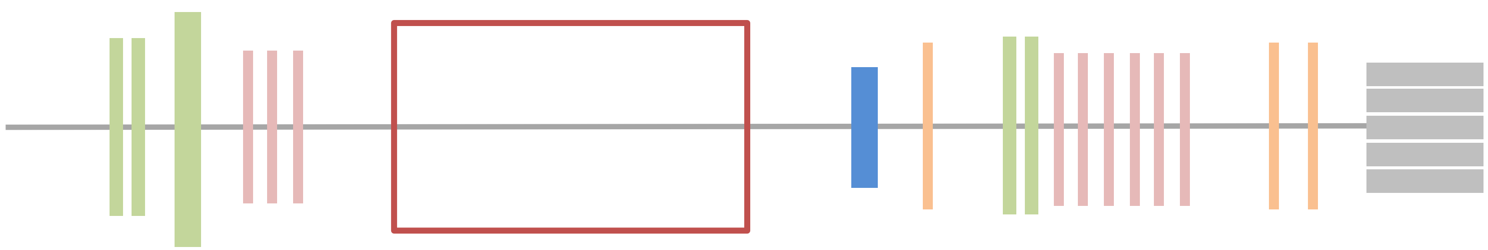
- Each person will have one task
- Make sure all detectors and systems are working
- For the logbook:
  - Make sure to write the beam momentum and the experimental setup conditions
  - Write the pressure/gas flow of the gaseous detectors (even though you may not be directly using them)
  - Write the magnet current too (same comment as above)

Analysis

- We encourage you to use Jupyter notebooks
  - We'll show you how to login and how to use it tomorrow
- The teams will have some similar workflows, so you can work together
  - Of course the analyses will diverge as soon as you dive into actual physics…



Experimental Setup

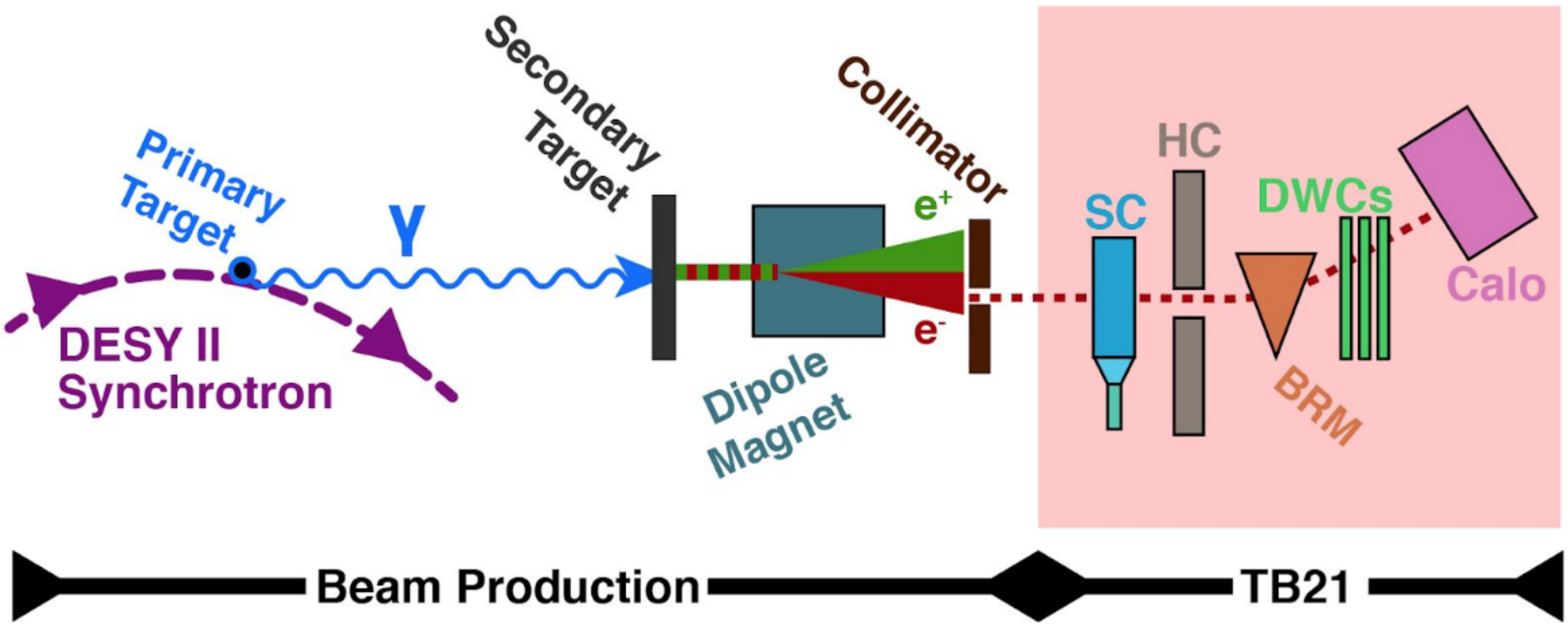


- Scintillator
- Beam Telescope
- Delay Wire Chamber
- MicroMegas
- Magnet
- Calorimeters

Probing Scintillators

DESY CHAIN

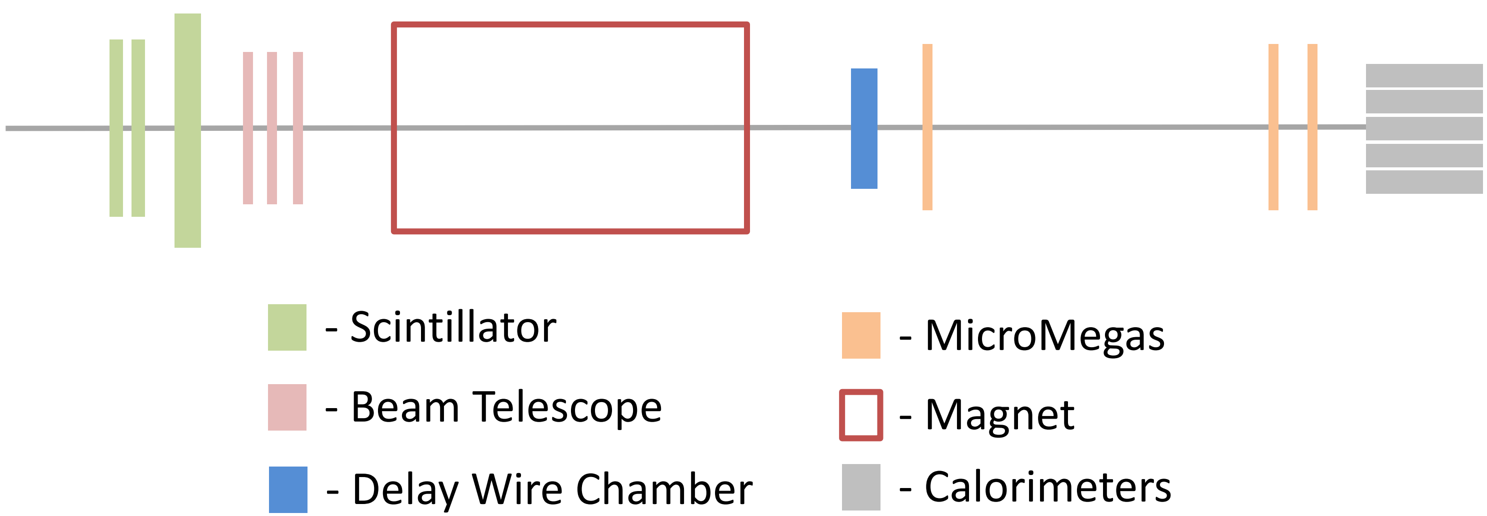
Proposed Setup



- Measure the signal in a scintillator (SC)
- Correlate it to the energy loss
  - Beam energy derived from the deflection in the magnetic field and the calorimeter measurement

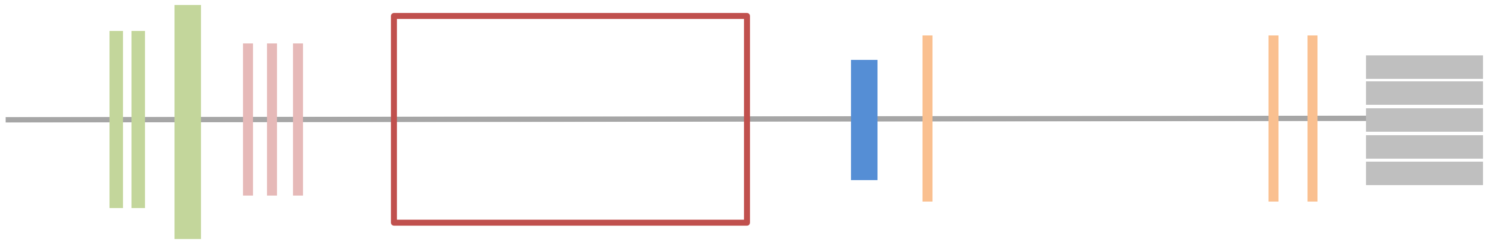
Updated Setup

- Small scintillators are used to trigger the data acquisition
- A beam telescope is used before deflecting the particles in the BRM to measure the initial angle
- Two of the DWCs have been exchanged by MicroMegas due to their larger area
  - No movement of the detectors needed
- The Halo counter is not required in this setup



Recipe

- Don’t be impatient: Take data without the scintillator under test first to characterize the particle beam and the detectors
  - Calibrations of several detectors are required
- Add the scintillator at a later time to see the difference in deflection
- We can provide you with tools to estimate the expected deflection of the particles by the BRM

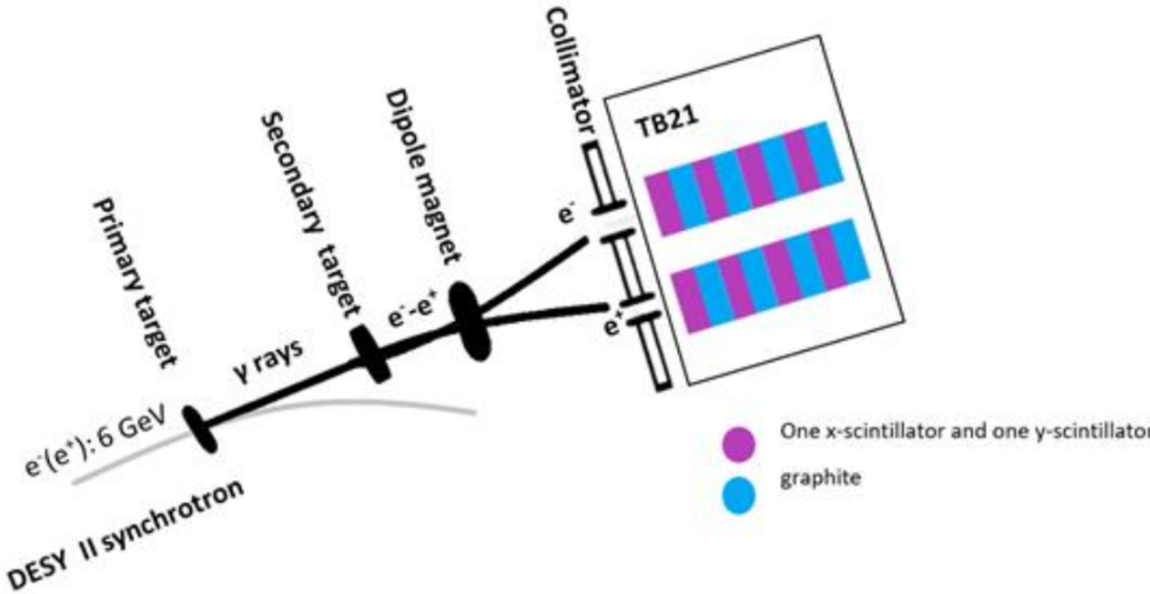


- The BRM creates fields of up to 1.5 T – this is a lot! Be careful what you place around the magnet – it might change its location …

Characterizing Particle Showers

PARTICLE PEERS

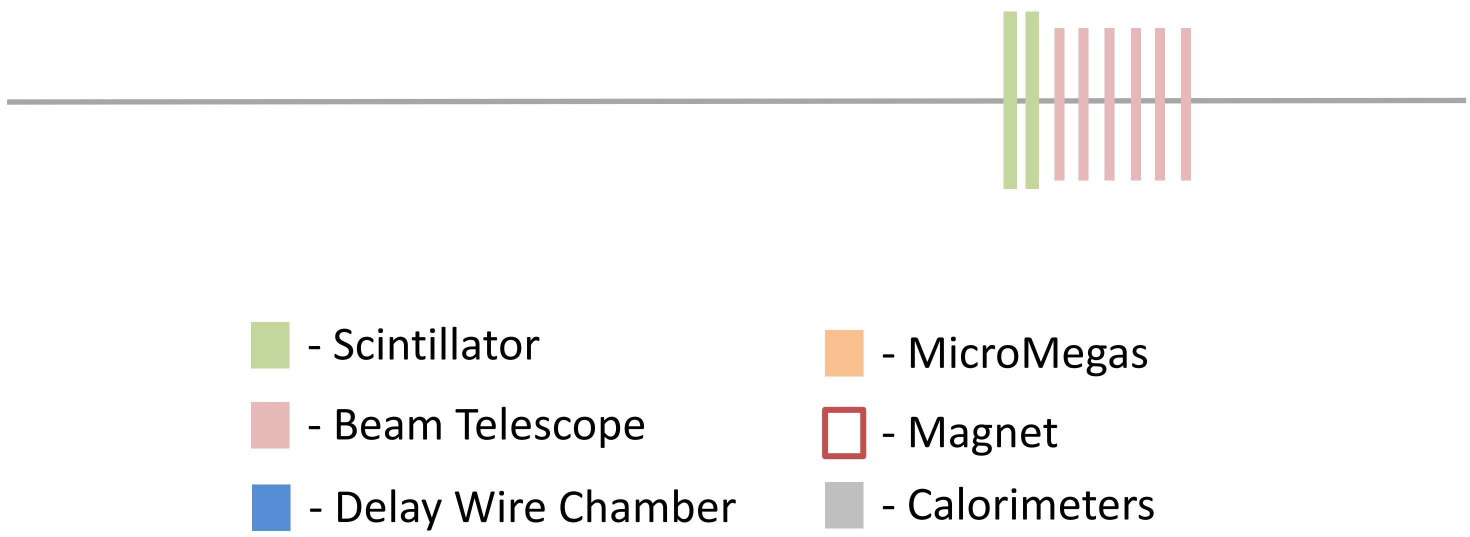
Proposed Setup



- Use position-resolving detectors interleaved with absorbers to characterize the shape of particle showers
- Usage of two similar devices for simultaneous use of electrons and positrons

Updated Setup

- Only one particle type at a time available
  - Use one device
- Use of silicon pixel detectors for position measurements
- Graphite is quite light – let's use something more heavy ☺



Recipe

- Make sure to align the detectors first to make the most of your data
  - A misaligned detector reduces the field of view for your shower
- Systematic scans of parameters
- An early analysis of the data can help to find the optimal settings for the next measurements
- Be careful when inserting/extracting the absorbers – the sensors are fragile!

- Can you think of other materials to test…?

Thanks for the Attention

Enjoy your time @DESY,
enjoy being scientists!

Ask questions, we are here to help!