BL4S 2020
Detectors & Setup

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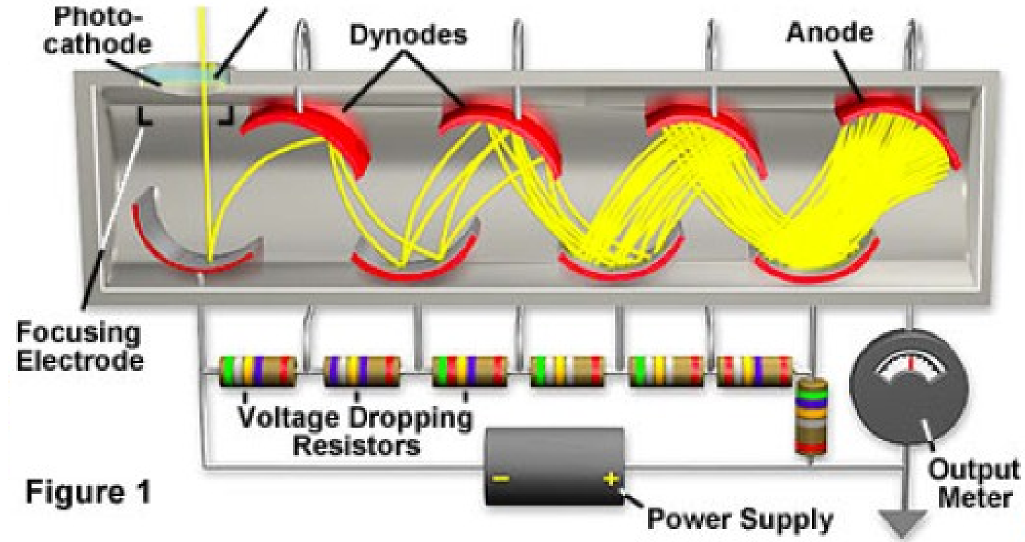
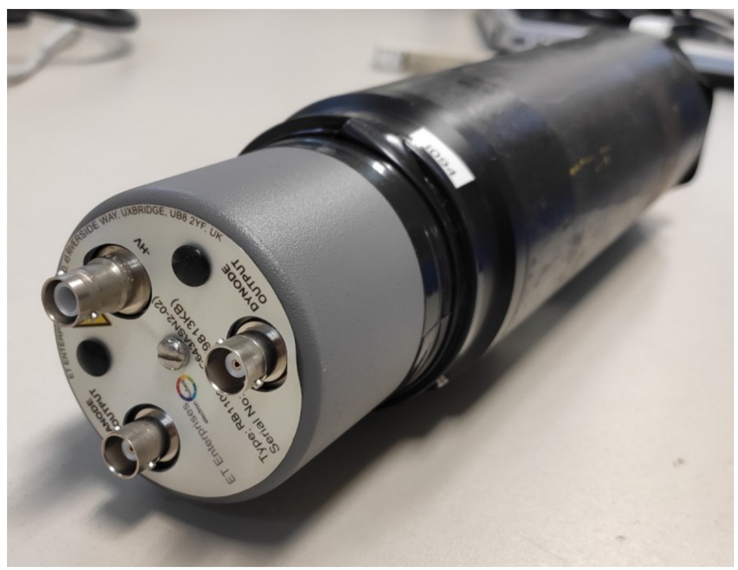
Our tools: Detectors

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

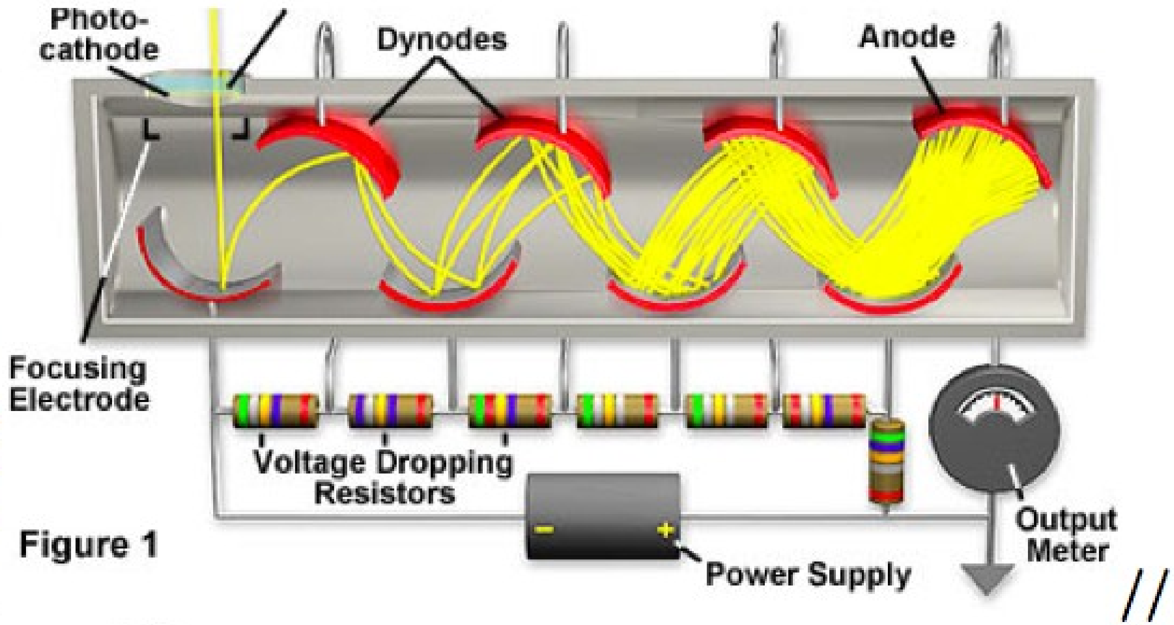
PhotoMultiplier Tube (PMT)

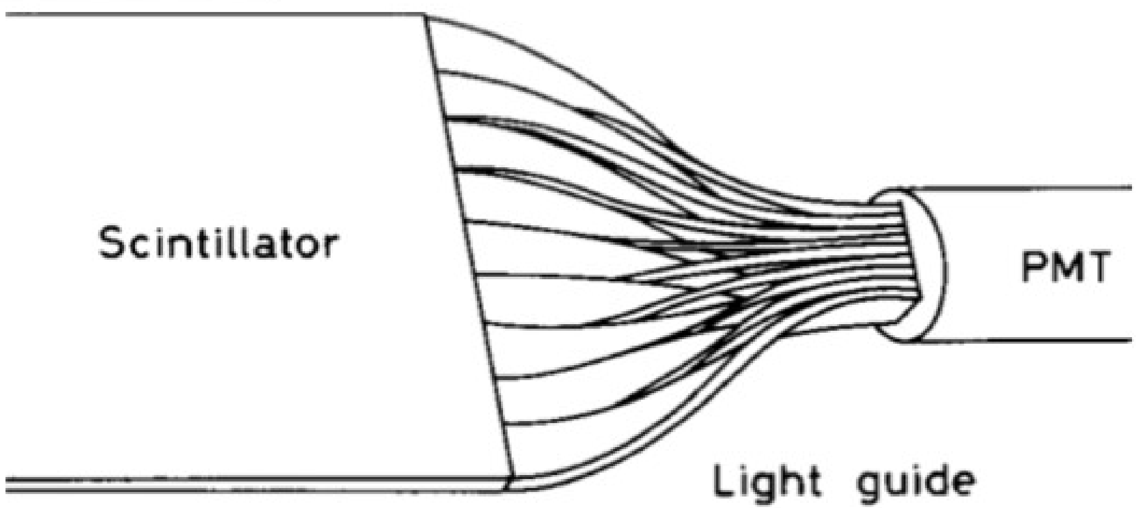
- **Input**: Photon(s)
- Photons are converted to electrons
- Electron multiplication
- **Output**: Electrical signal proportional to number of photons



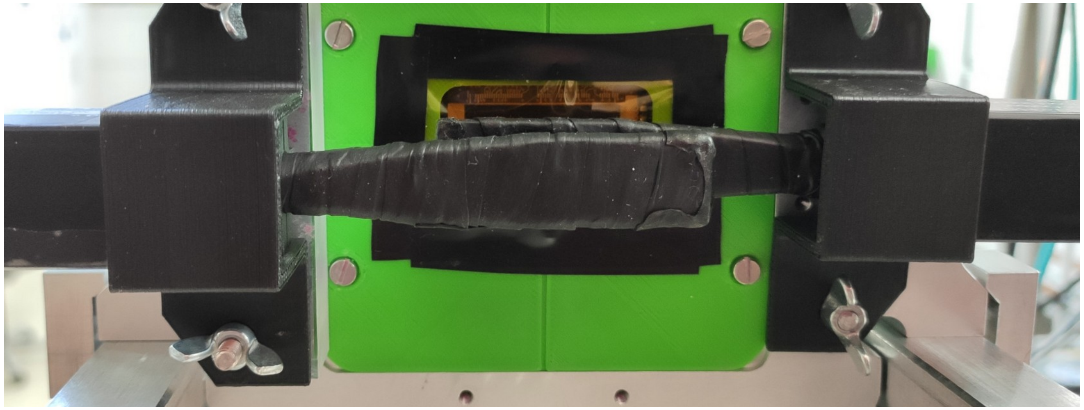


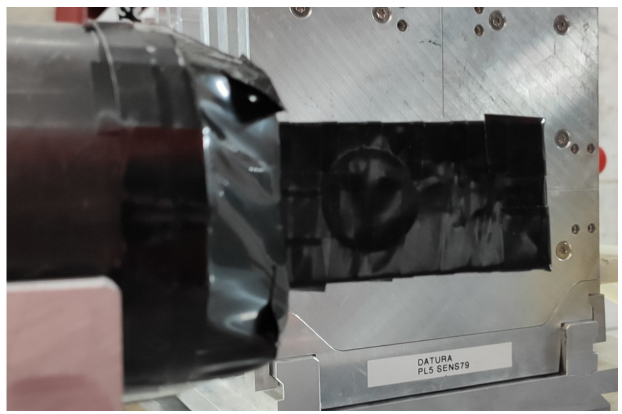
Scintillators

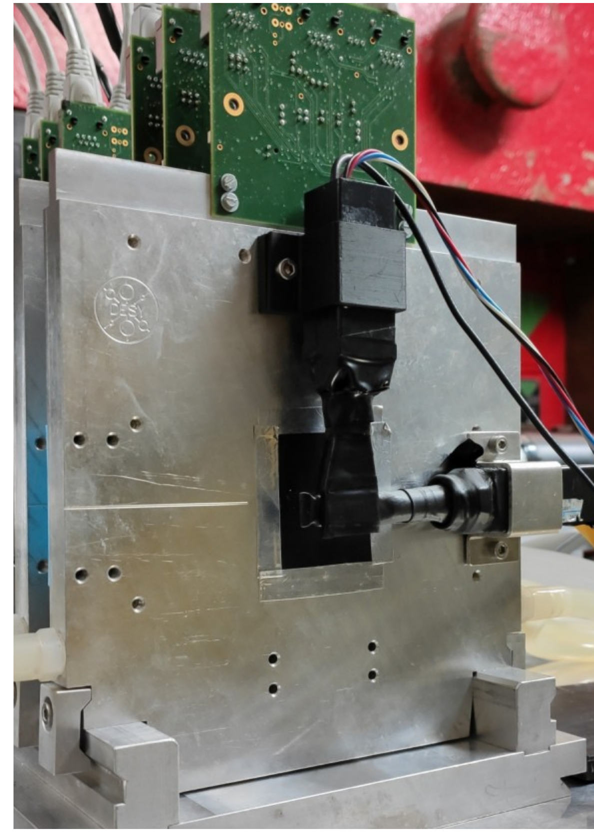




Scintillators







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: they don't tell us the position of the incoming particle, unless we do something fancy... Maybe a scintillating fiber..?

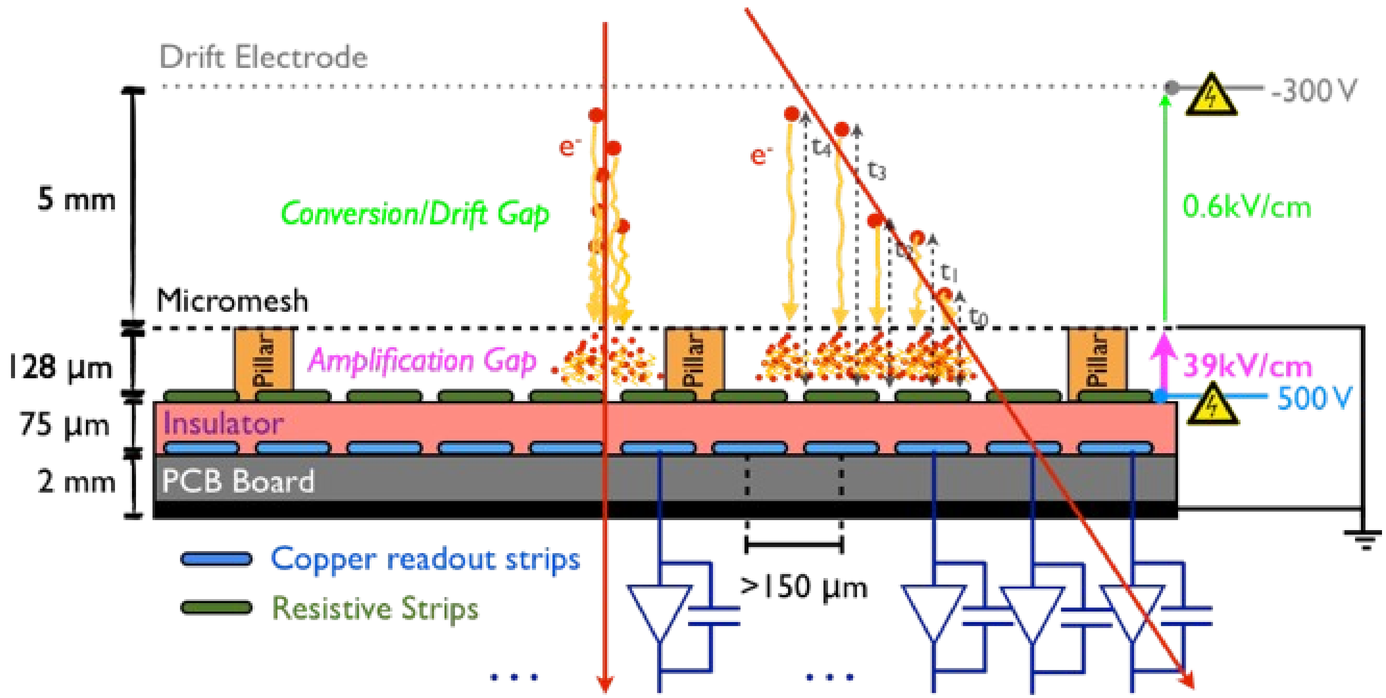
Gaseous detectors

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

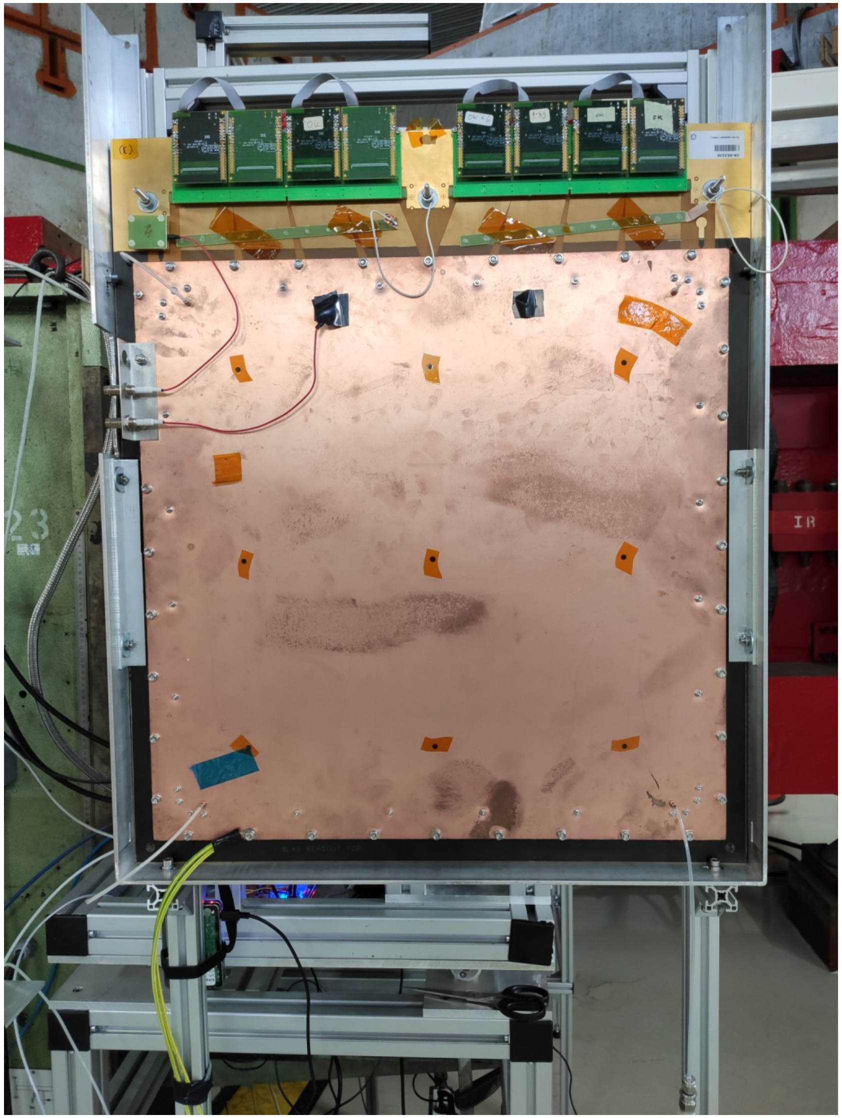
1)Initial particle creates **ion-electron pairs**
2)In an electric field: ions **drift** towards a cathode (lower potential), electrons towards an anode (higher potential)
→ Moving charges = Current = Signal
3)Electrons reach a **high electric field**:
→ They are accelerated
→ Interactions with the atoms/molecules freeing other electrons
→ **Electronic avalanche**
→ Increased current
4)Collection of the signal

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

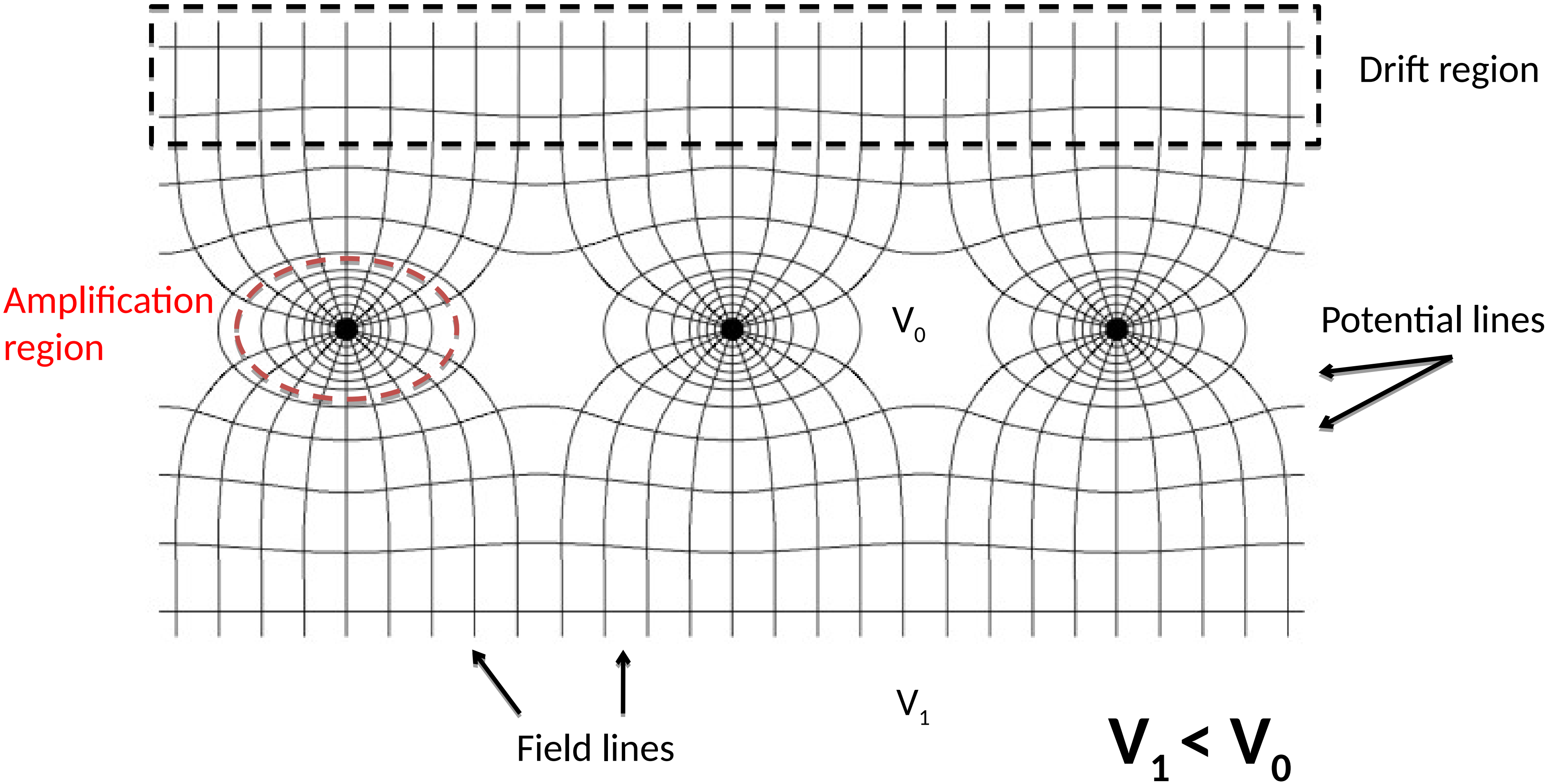


Our MicroMegas provide only the x or the y coordinate of a point in the space. Their position along the beam is the z of each point.
If we want to reconstruct the full point, we need to couple two of them, with different readout orientation

HOW TO FEED A MM?

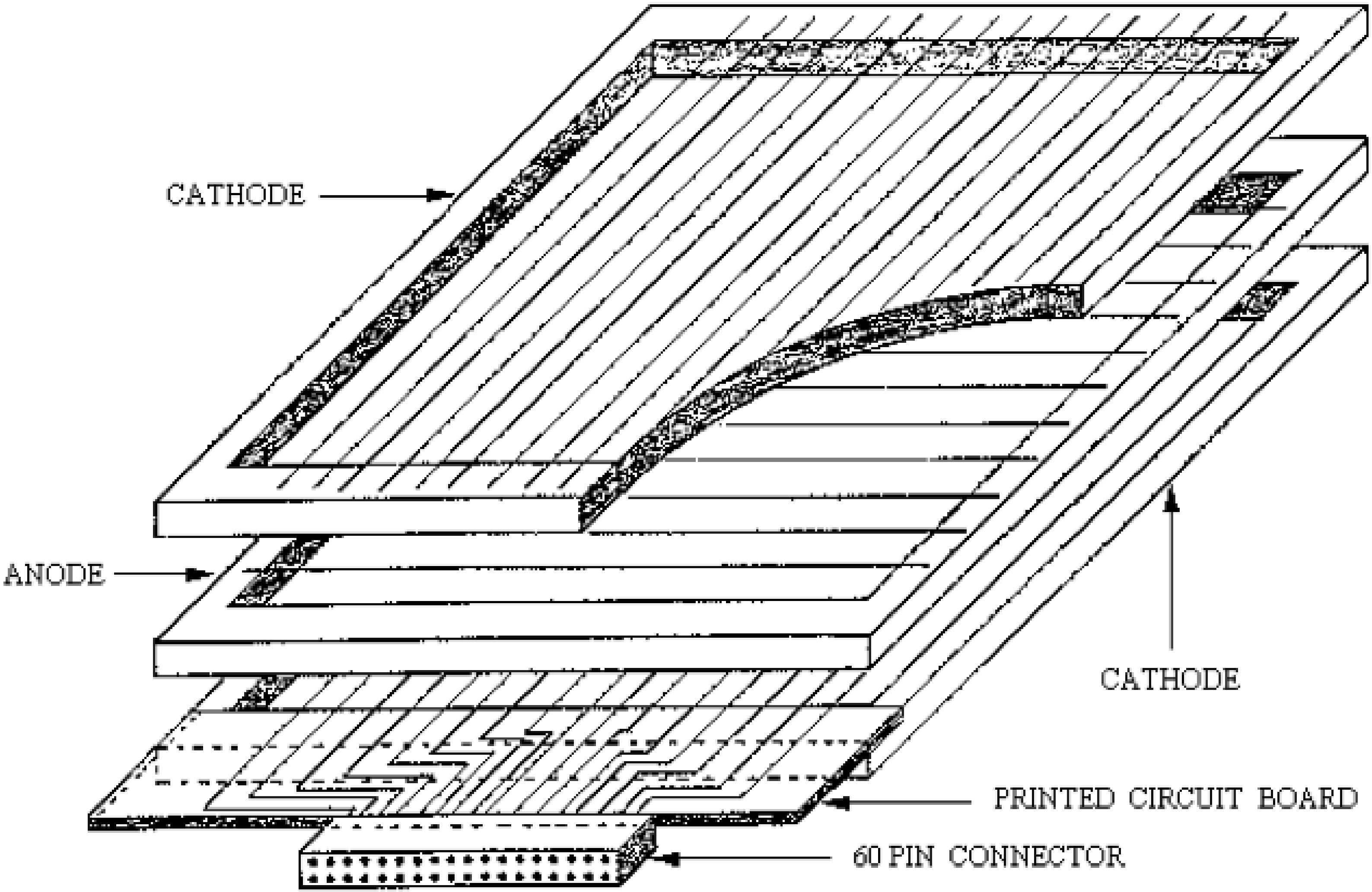
- Gas (Ar:CO_2 93:7)
- HV (+520 V, -300 V)
- LV, provided by a system which in the meantime also reads and processes the signals

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

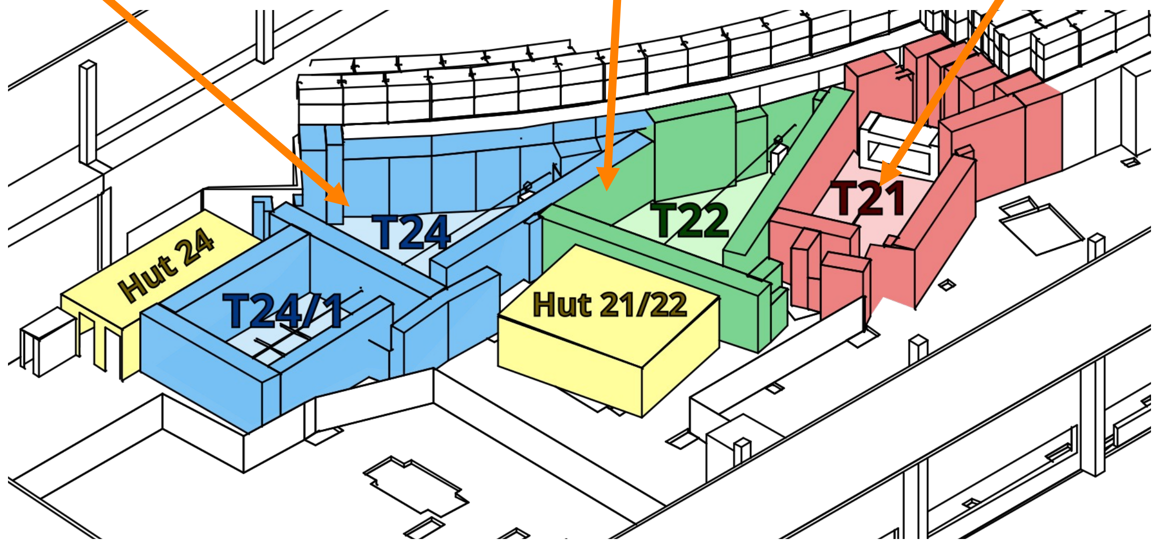
GAS

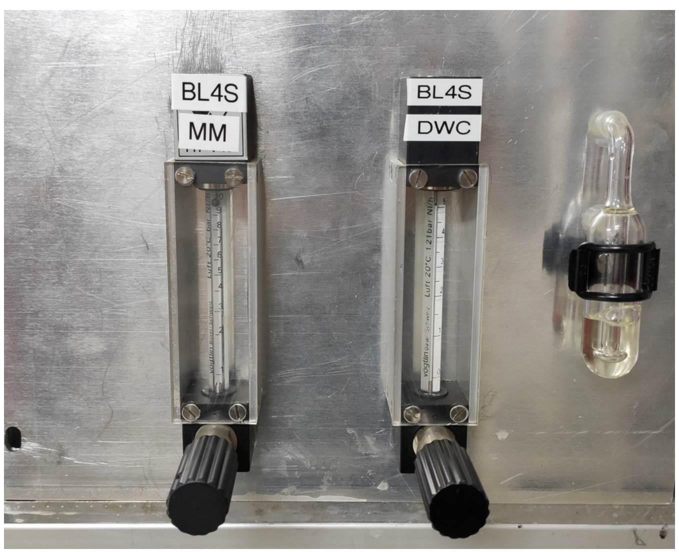
Gas cabinet
DWC

Gas cabinet
Micromegas

Your
Experiment

Gas cabinets
@TBs 22/24

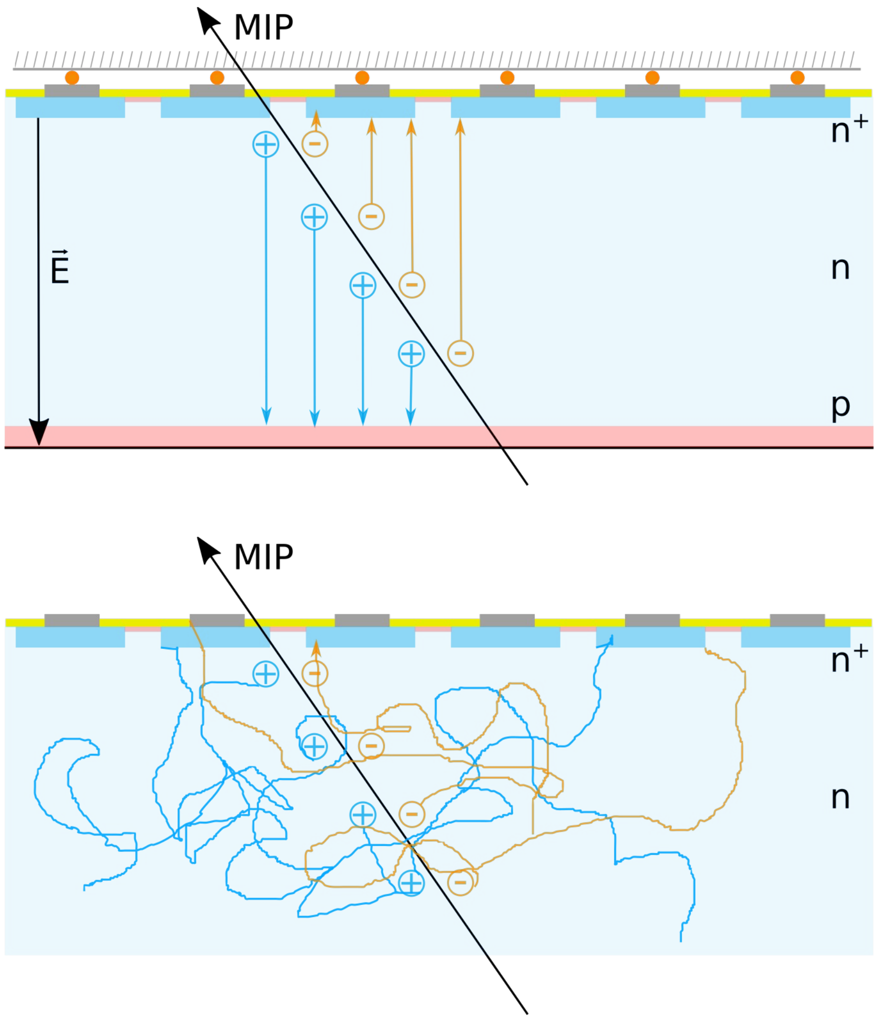




Flow meters
@TB 21

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

Silicon Detectors



Most Silicon Detectors are similar to gaseous detectors …

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

We also use CMOS sensors

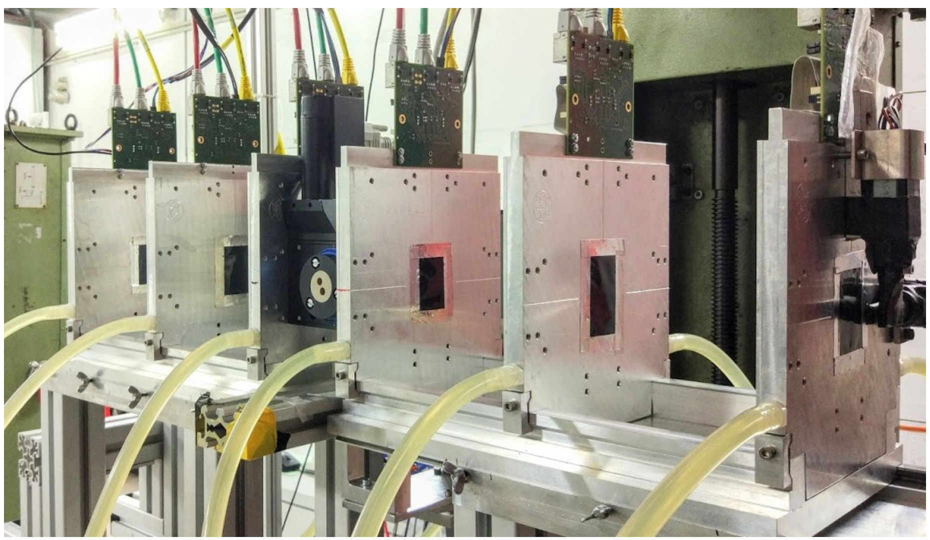
- Low electric field
  - Signal is induced by random walk of the electrons/holes

Beam Telescopes

Several layers of silicon detectors in an easy-to-handle frame

Measure the particle track

Good resolution (here 3-5 μm)

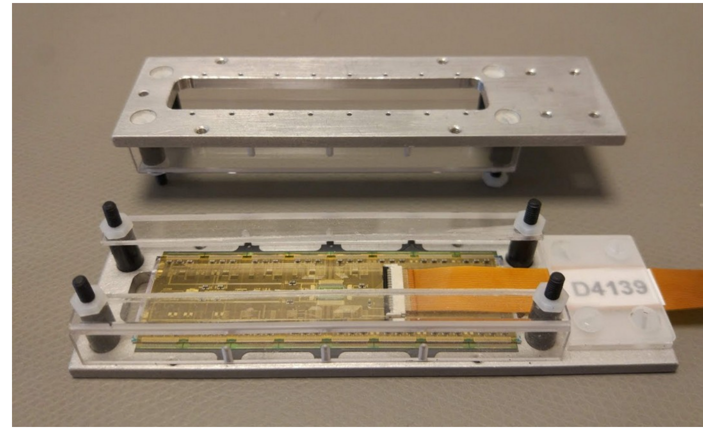


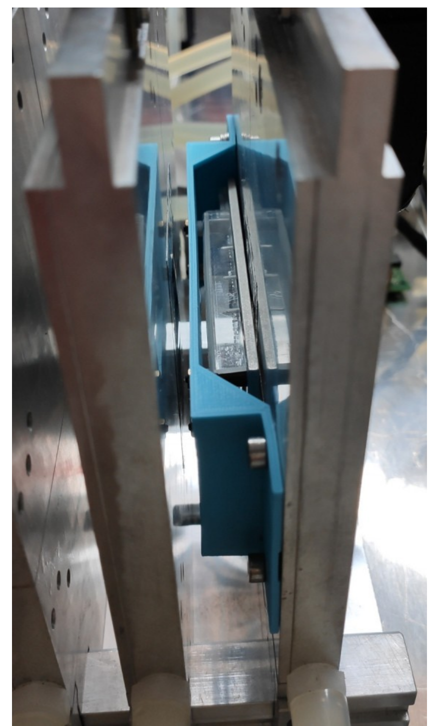
EUDET (Mimosa) Telescope

Alpide Telescope

CMS Pixel Detector Module

- Silicon pixel detector
- Less precise (spatial) than the beam telescopes
- Faster than the EUDET telescope
- Combine information of telescope and CMS module for more complete information on the particle (track)
- Side fact:
  Module originally produced for the use in the LHC-experiment CMS





High Voltage (> 60 V)

We have three multi-channel systems

Update images?

USB

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

Low Voltage

Mimosa Detectors

Alpide Beam Telescope

More detail during the shifts

Glossary

- Detector: Device telling us if the 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 (often 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
- CMS Pixel Detector: Silicon detector that is faster than the beam telescope

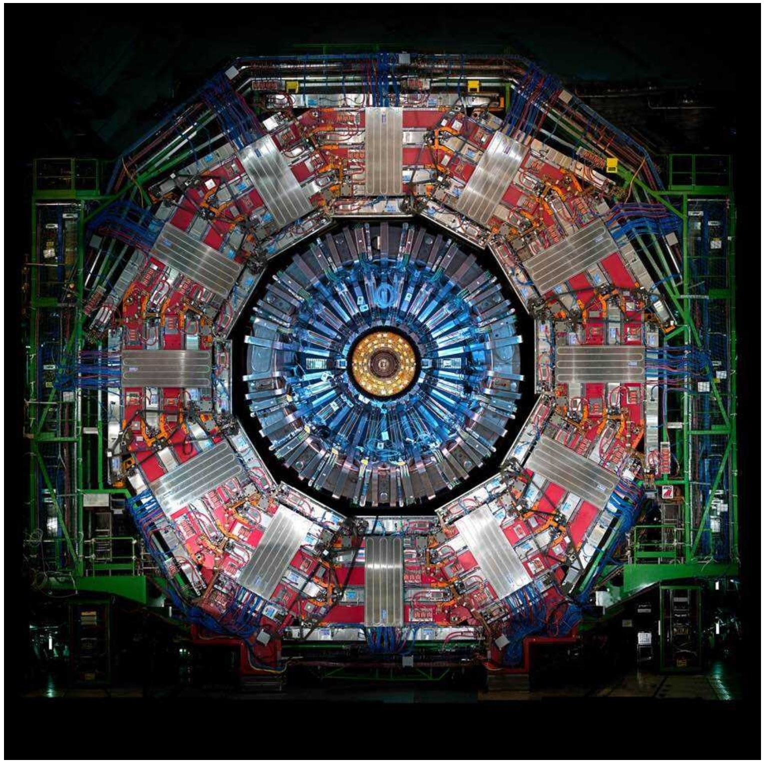
Glossary

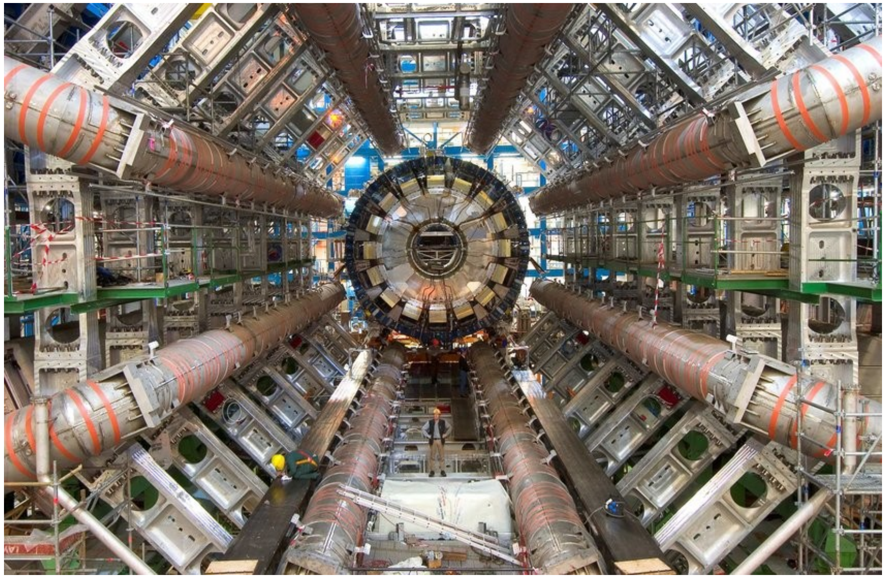
- Flowmeter, better called Rotameter: Device telling us how much gas we are injecting in our detector
- Manometer: Instrument to measure the gas pressure of a system
- Low Voltage Power Supply: Small heavy box used to supply the low voltage to several devices
- Crate: Medium heavy box used to host always 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 or too many crates
- Front-end electronics: Boards that directly read 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

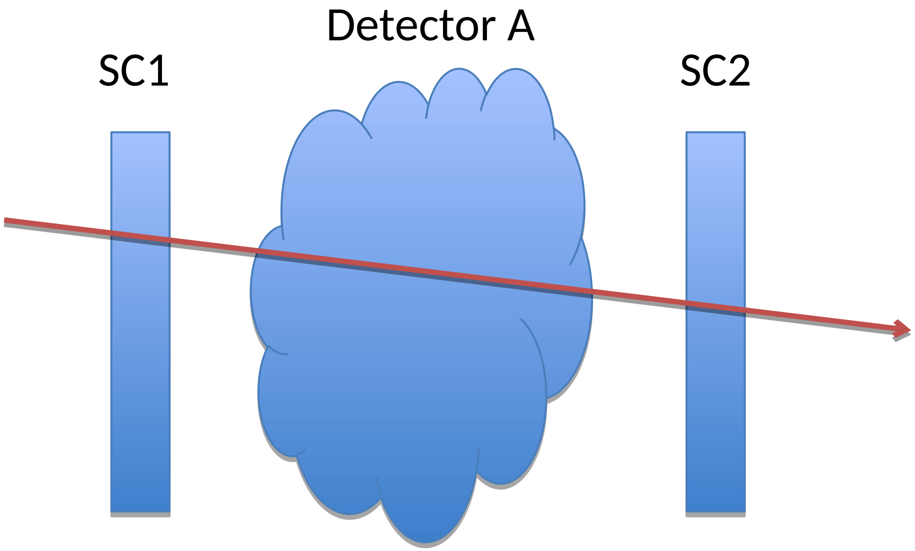
- In big experiments, the trigger has the additional job of managing the amount of data to be stored





Building a simple trigger

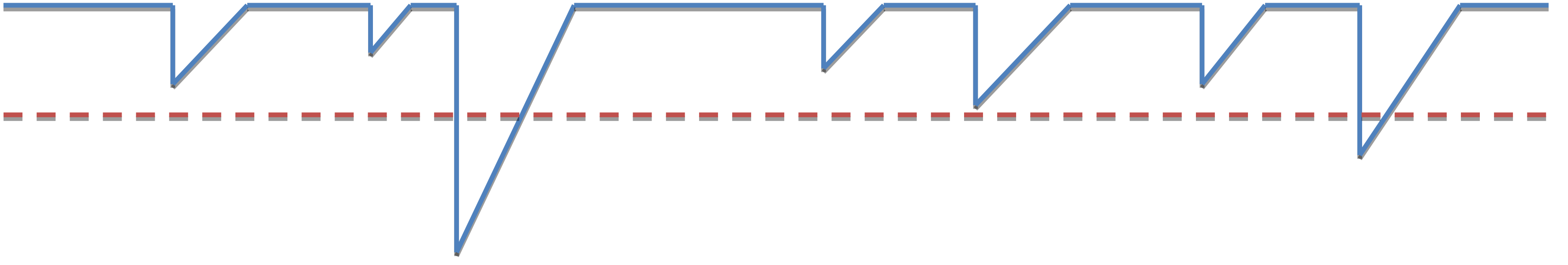
- We want to measure the response of detector A to a particle:
  - Place one scintillator in front and one behind
  - A particle going through a scintillator will produce a signal
  - The presence of a signal simultaneously in both scintillators, means that a particle travelled between them, and consequently 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

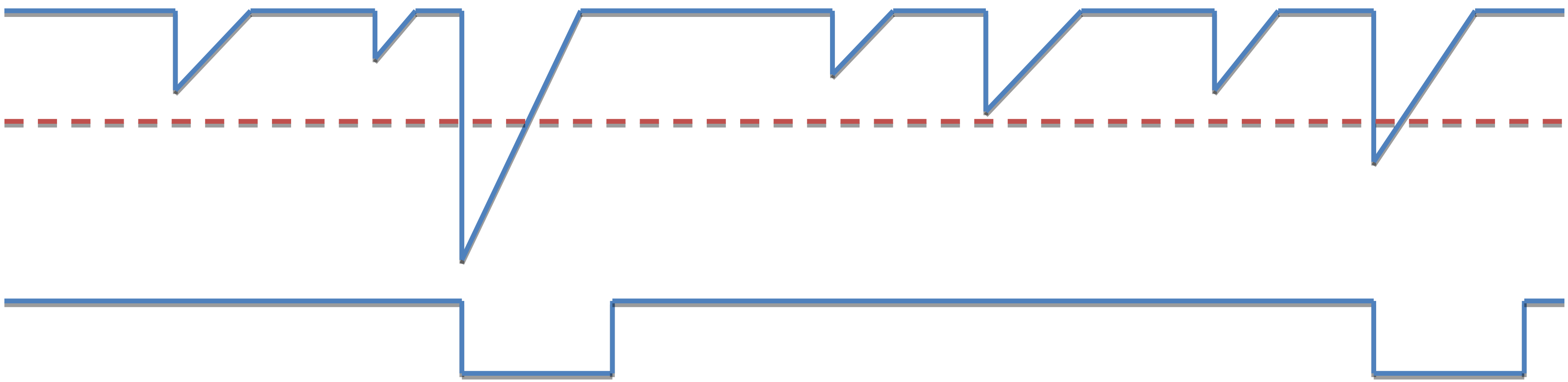
- Real detectors suffer several effects not present from theoretical expectations, most notably this reflects in noise in the output of the detector
- The noise is often indistinguishable from a real signal

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

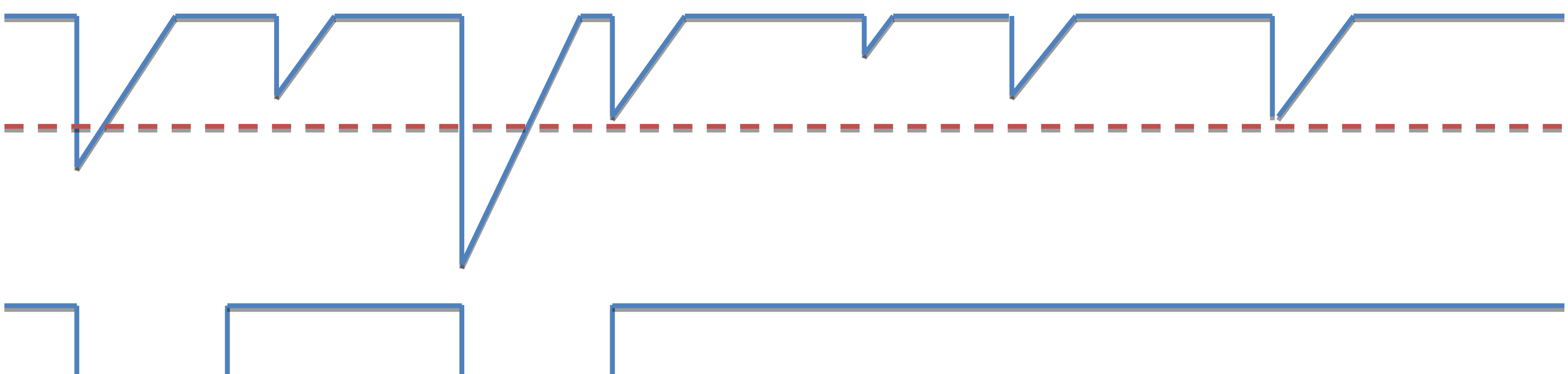


Triggering on Detectors

- 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

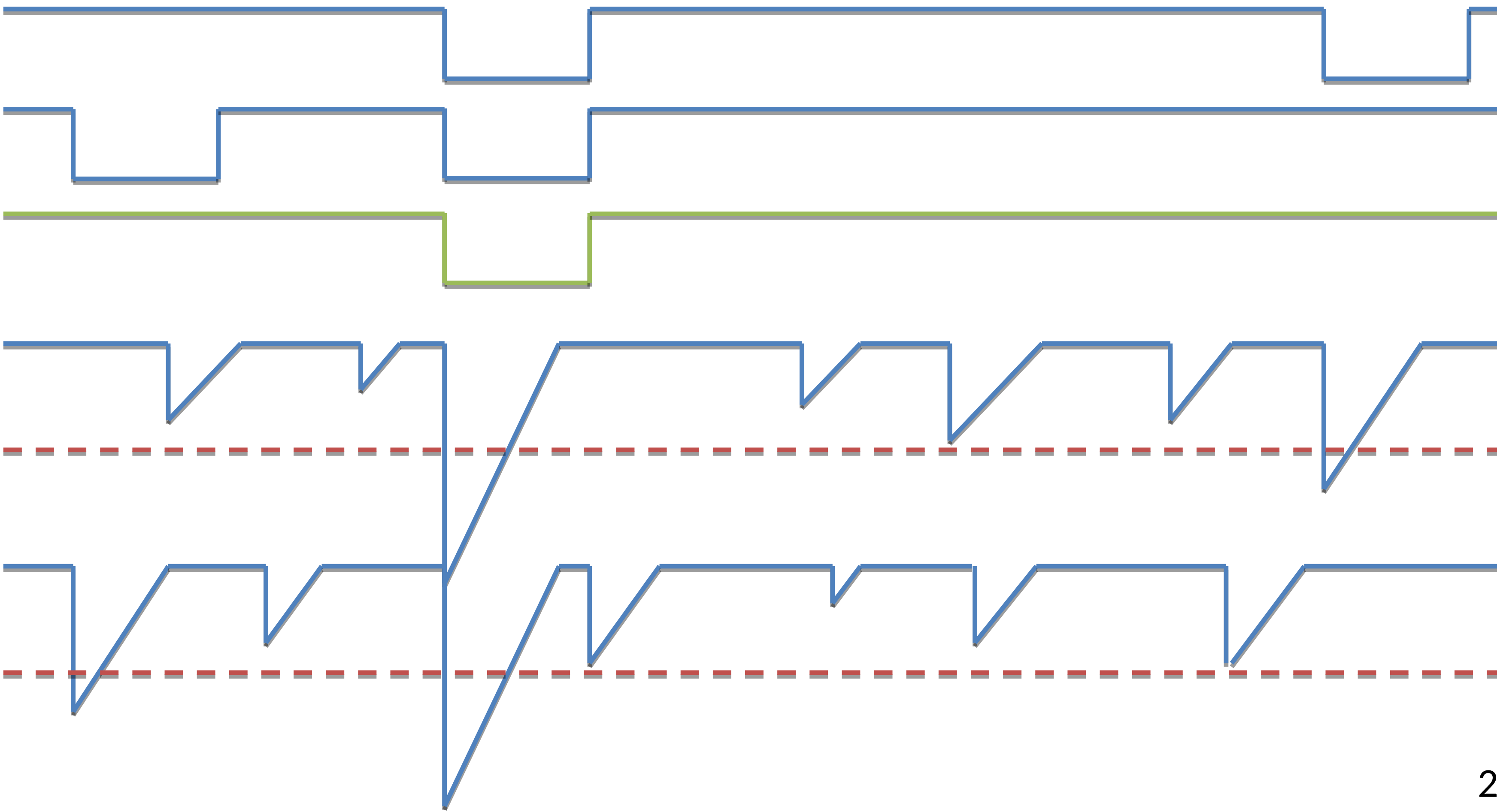


- Some of the noise still survives in the logic signal, consider the other scintillator:



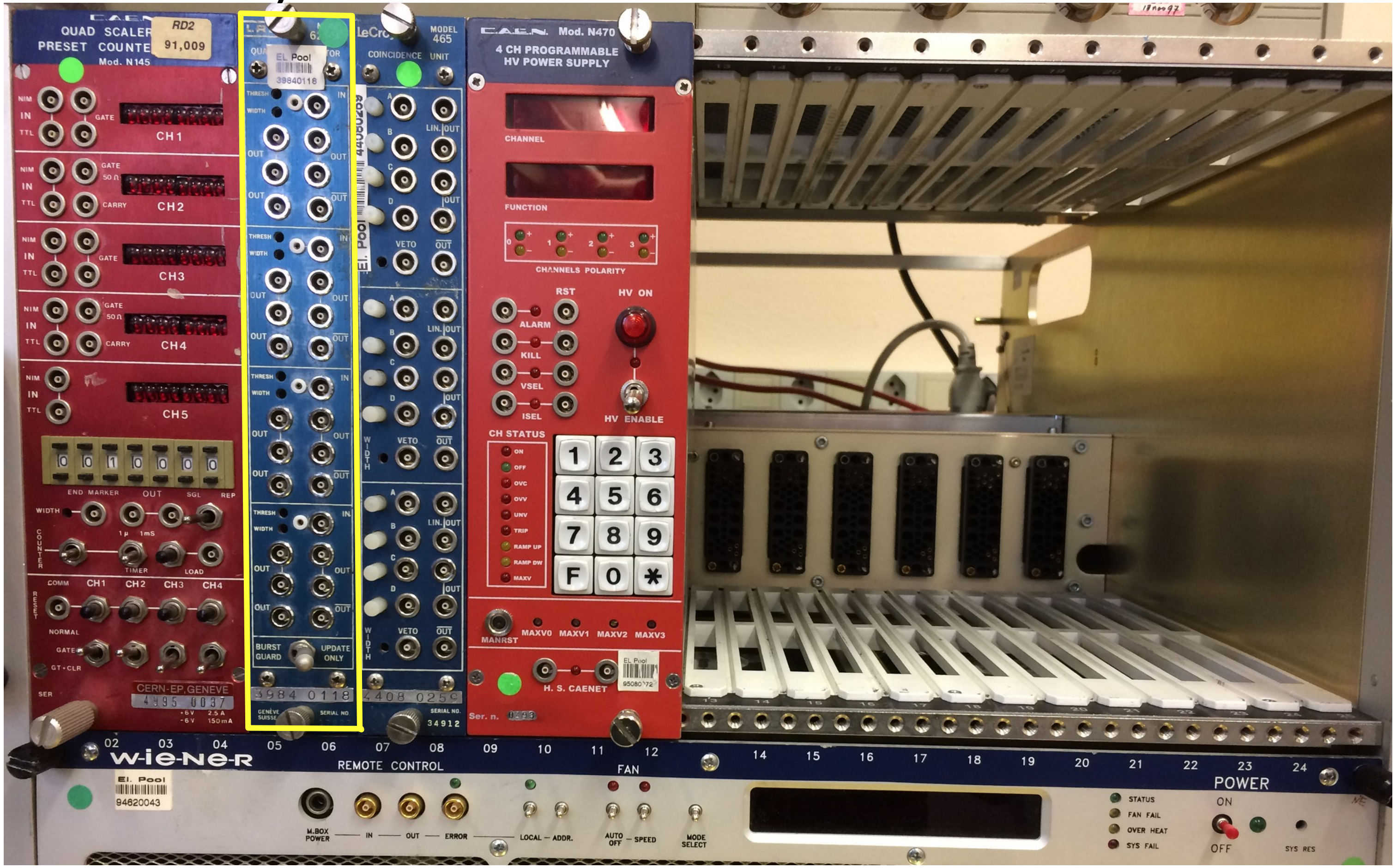
Triggering on Detectors

- 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



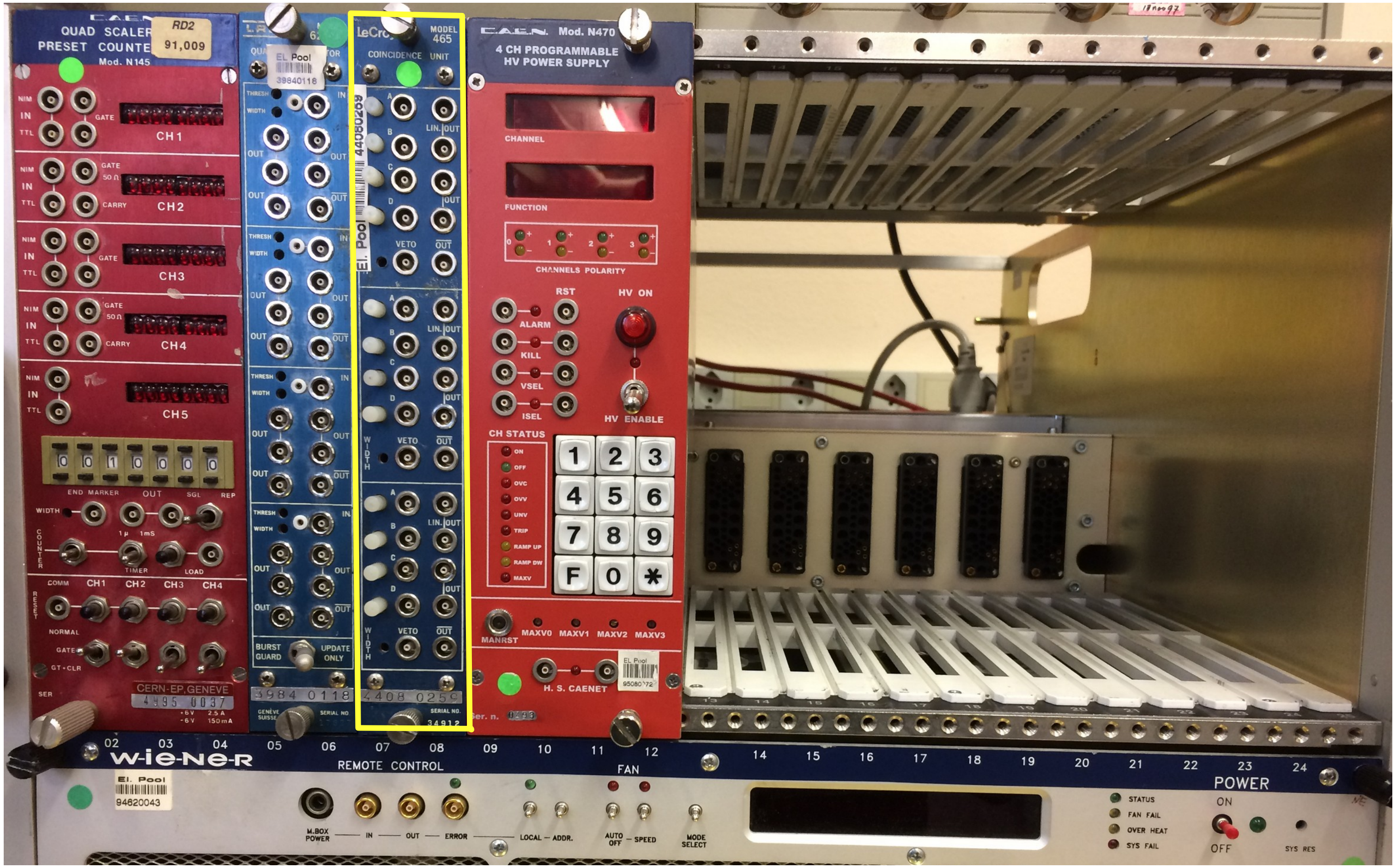
Trigger Logic

- 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 can be performed by a Discriminator Unit



Trigger Logic

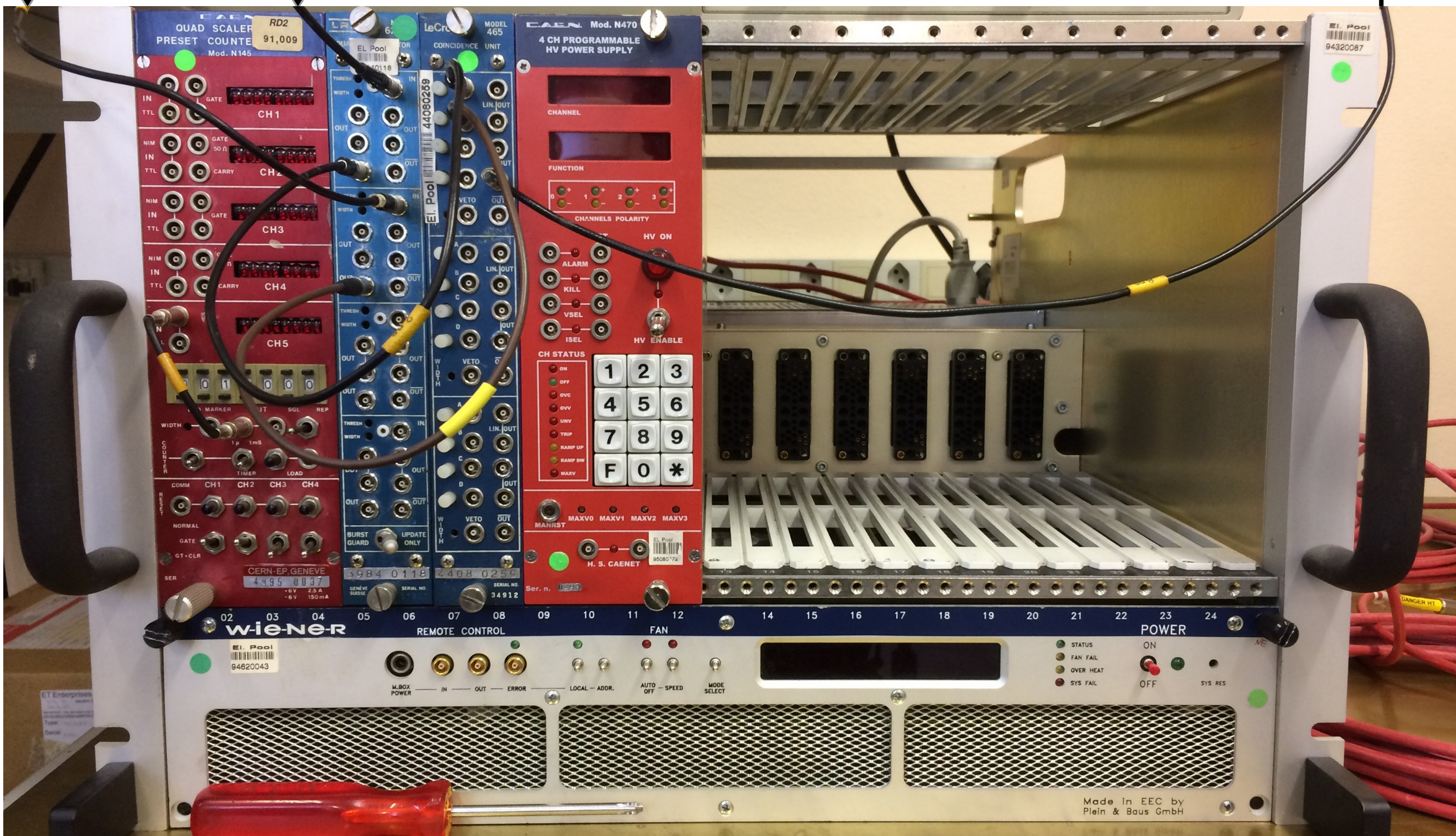
- Performing the coincidence between two logic signals can be performed by a Coincidence Unit



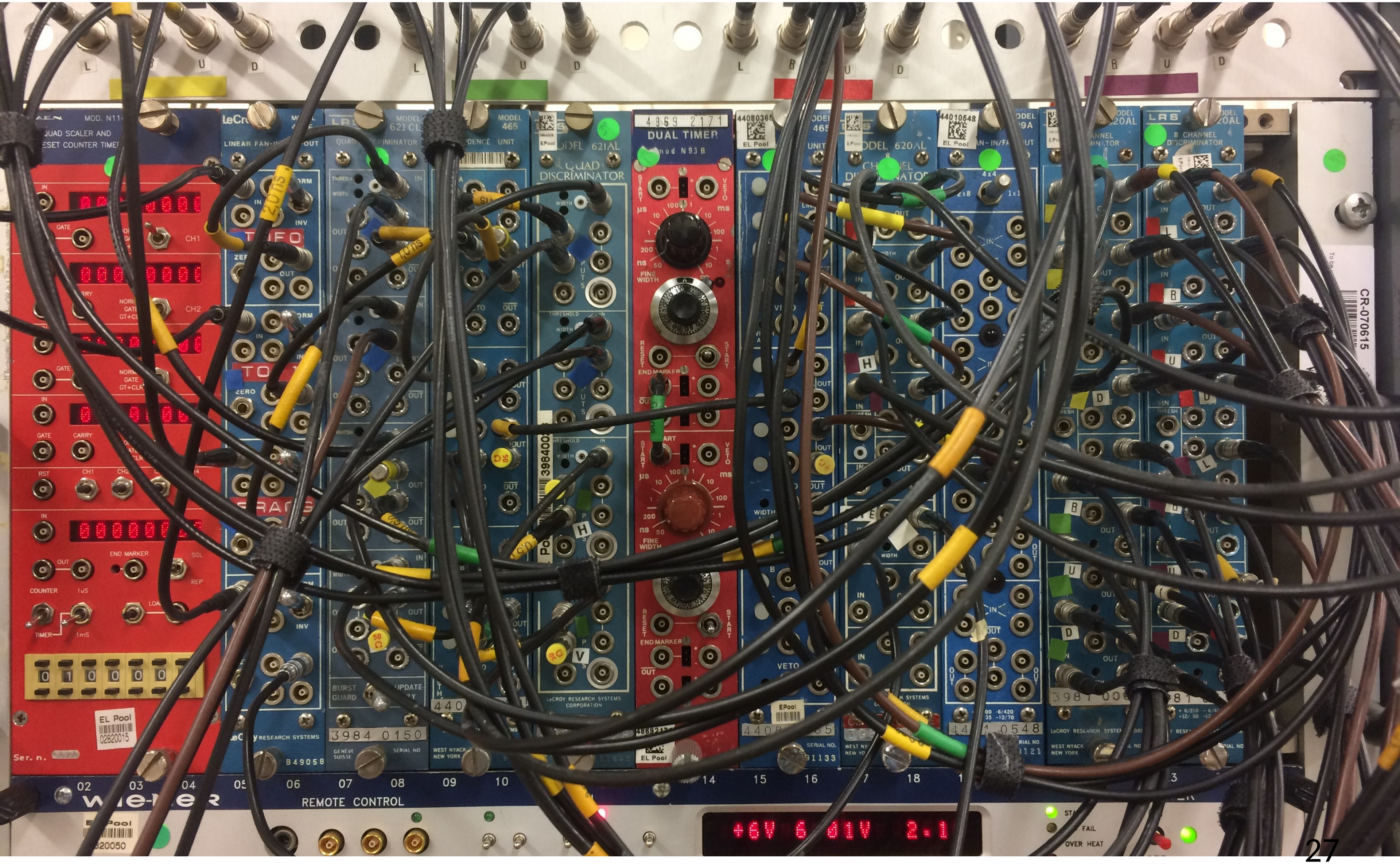
Trigger Logic

- The final trigger logic might look something like the below:

SC1 SC2 Trigger



A More Complex Example

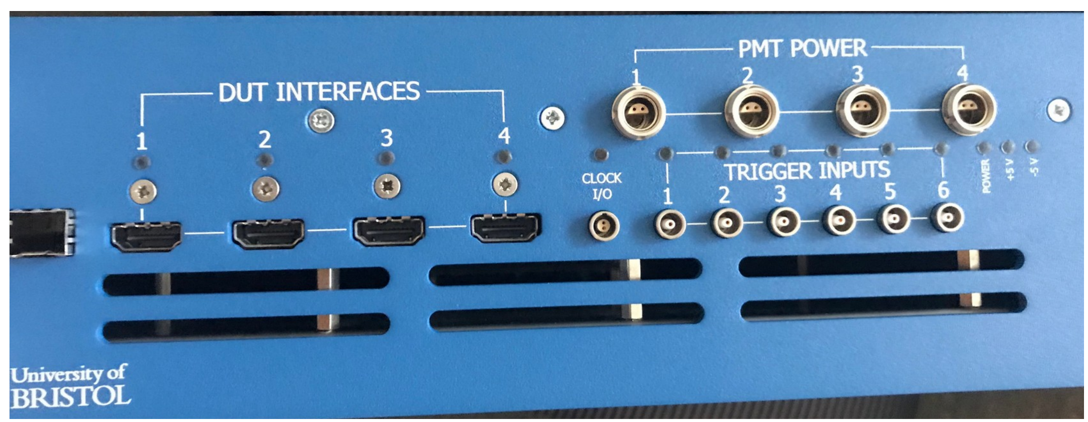


Trigger Logic Unit (TLU)

- Most of the trigger logic for our experiments is done in these configurable devices
- We still need NIM logic to distribute triggers to the detectors …

EUDET TLU (EUDAQ 1 / NFF)

AIDA TLU (EUDAQ 2 / ChDR-Cheese)

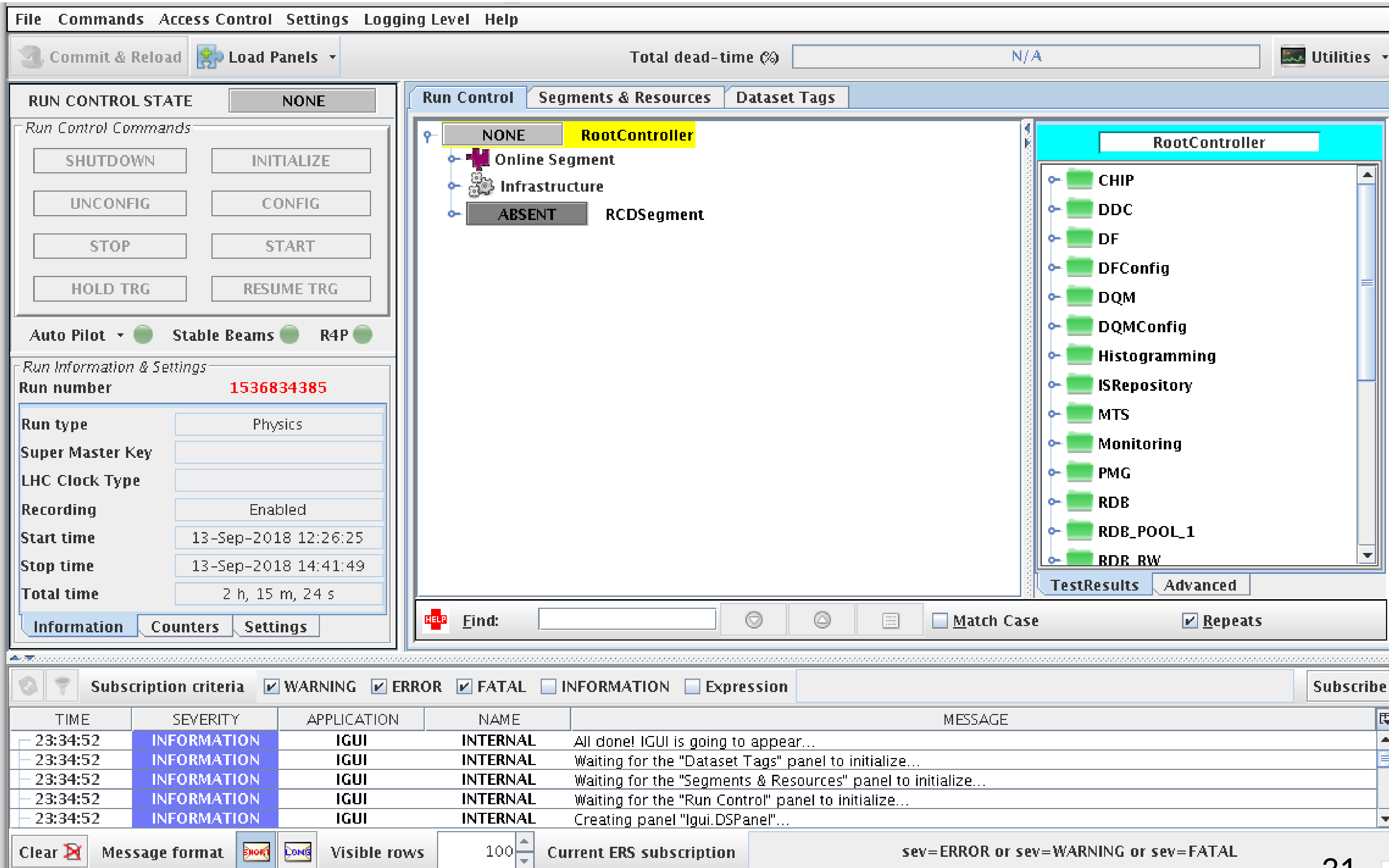


Data Acquisition

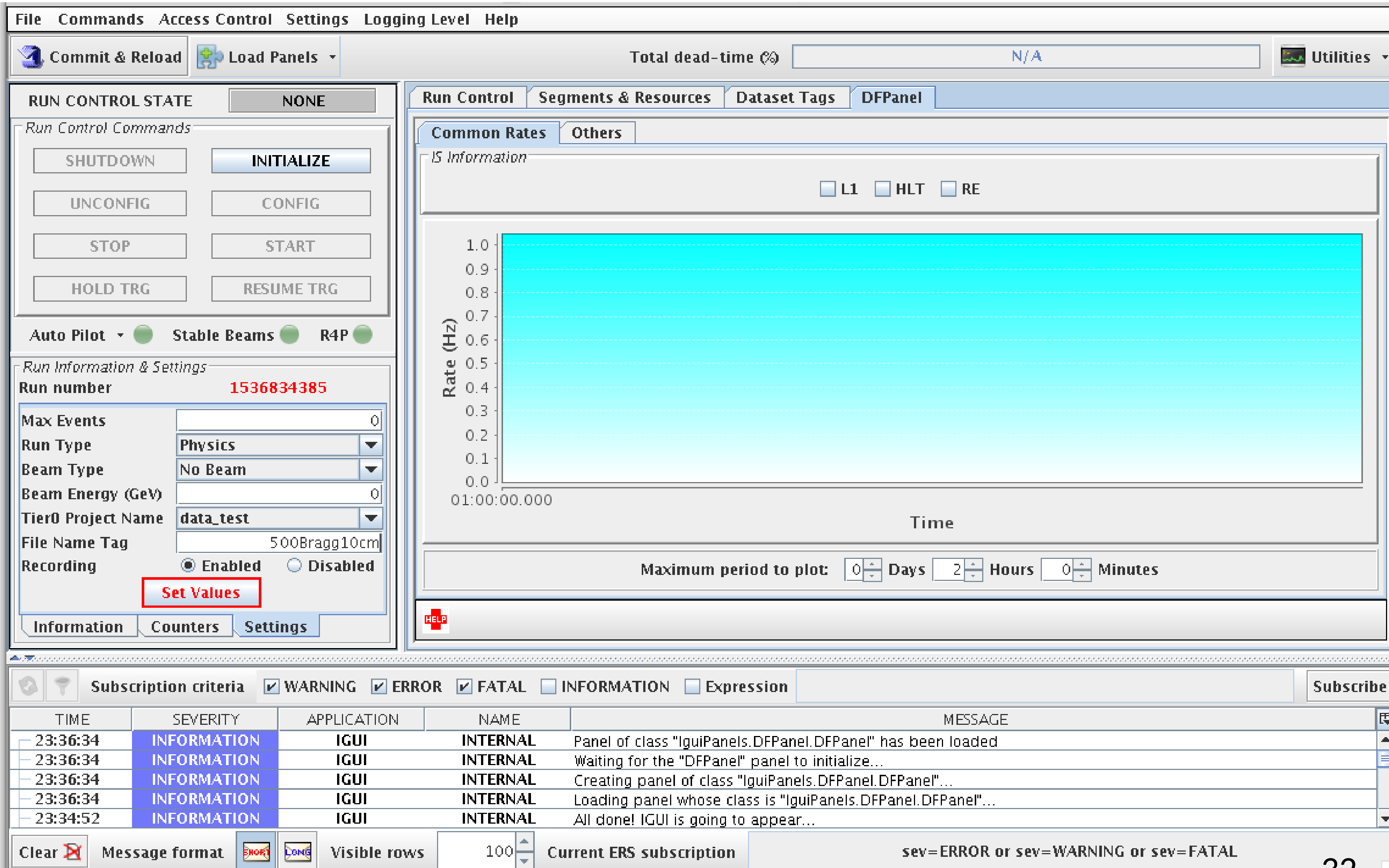
- Once the decision has been made to keep an event, the data has to be read and recorded. This is the job of the Data Acquisition system (DAQ)
- Main components:
  - Hardware – modules that read and digitize the electronic signals
    - SBC – Single board computer
    - CORBO – Trigger input
    - QDC – 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

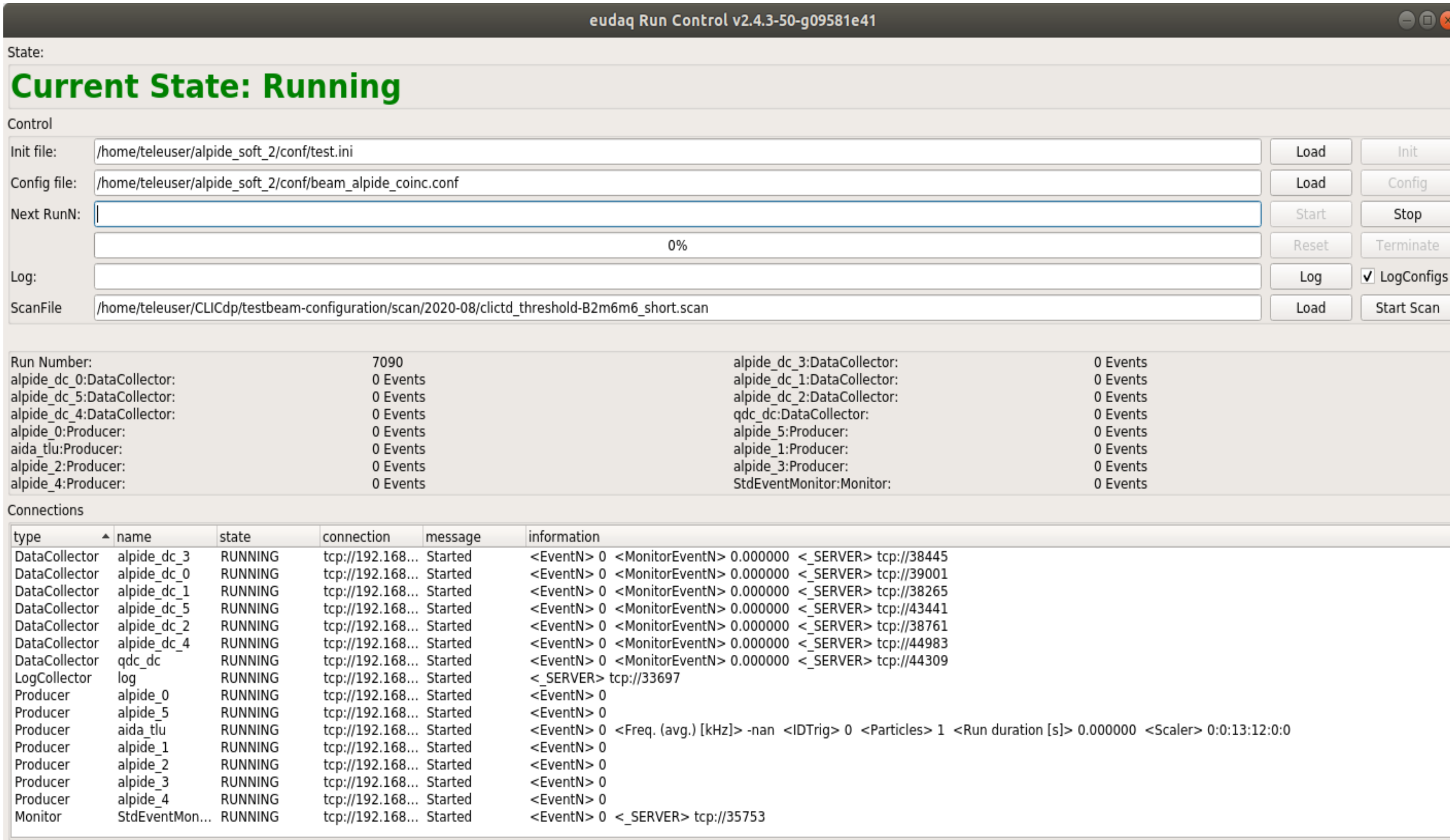
Data Acquisition Software TDAQ



Data Acquisition Software TDAQ



Data Acquisition Software EUDAQ



Electronic Logbook

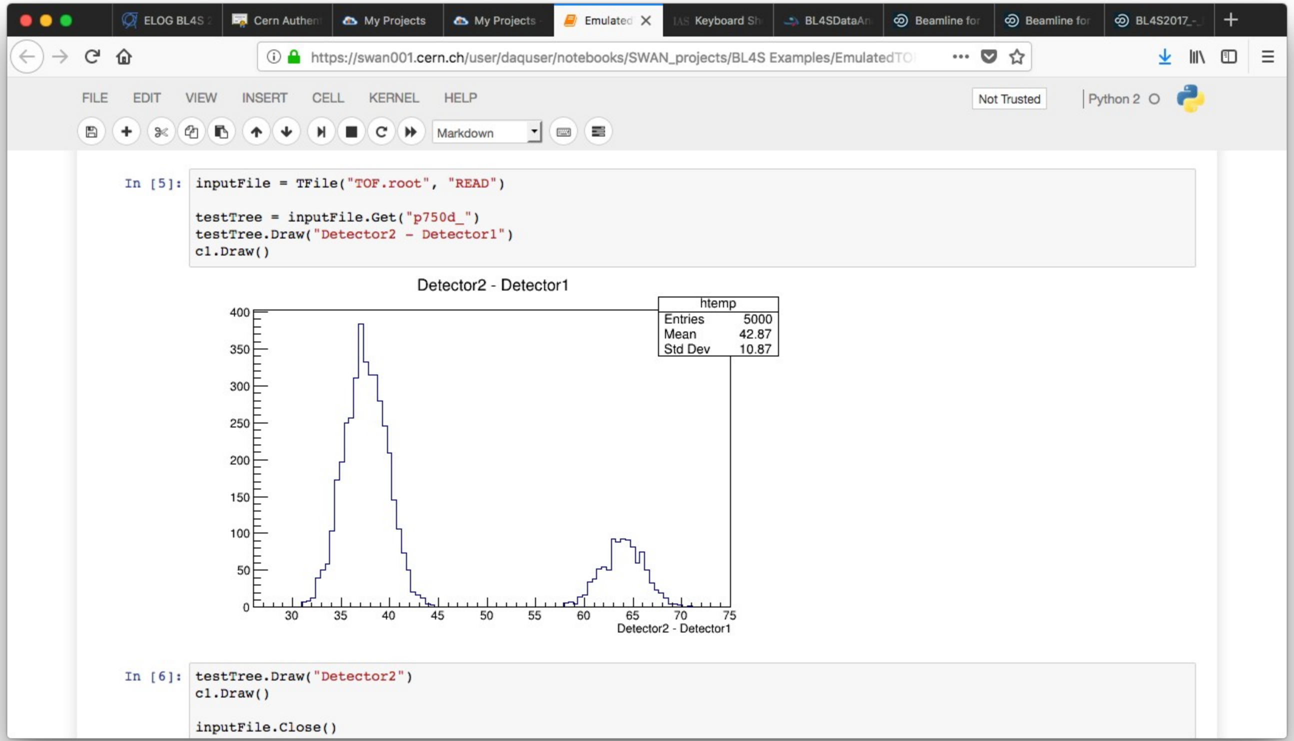
- Available at: https://bl4s-elog.desy.de - log in with school accounts
- Write down <u>everything</u> that happens:
  - When you start a run, write it down with the run number and the settings
  - If there is a problem during a run, write it down
  - If the conditions change (HV, gas pressure, etc), write it down
    - ! Also check them regularly …
  - If someone eats a cookie, 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
  - Things that are not written down have never happened

Shifts

- Each person will have several ~~one~~ task s
- Make sure all detectors and systems are working
- For the logbook:
  - Make sure to write down the beam momentum and positions of rotation/translation stages
  - Write down the magnet current too
  - Write down the pressure/gas flow of the gas systems every now and then (even if you are not directly using them)

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 share your experience and help each other out
  - Of course the analyses will diverge as soon as you dive into actual physics…



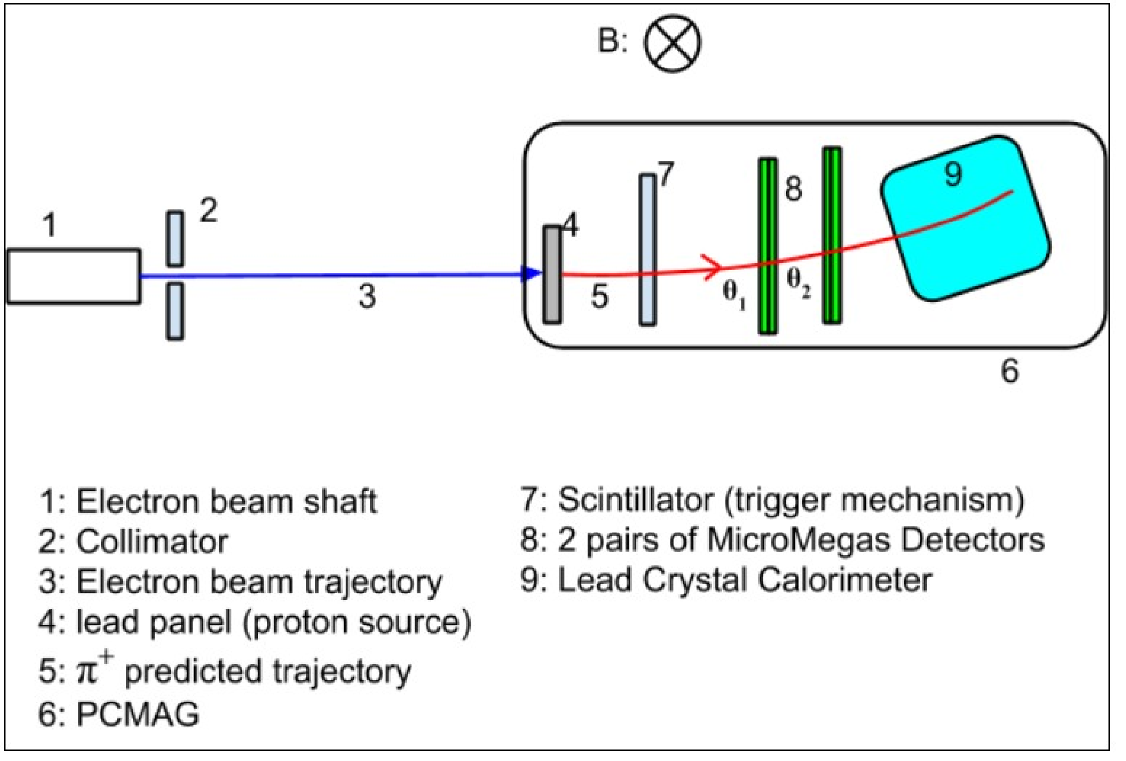
Experimental Setup

- Scintillator
- Beam Telescope
- Timing plane
- Target
- Radiator
- MicroMegas
- Magnet
- Calorimeters
- PMT

The Δ+ resonance

NATIONS’ FLYING FOXES

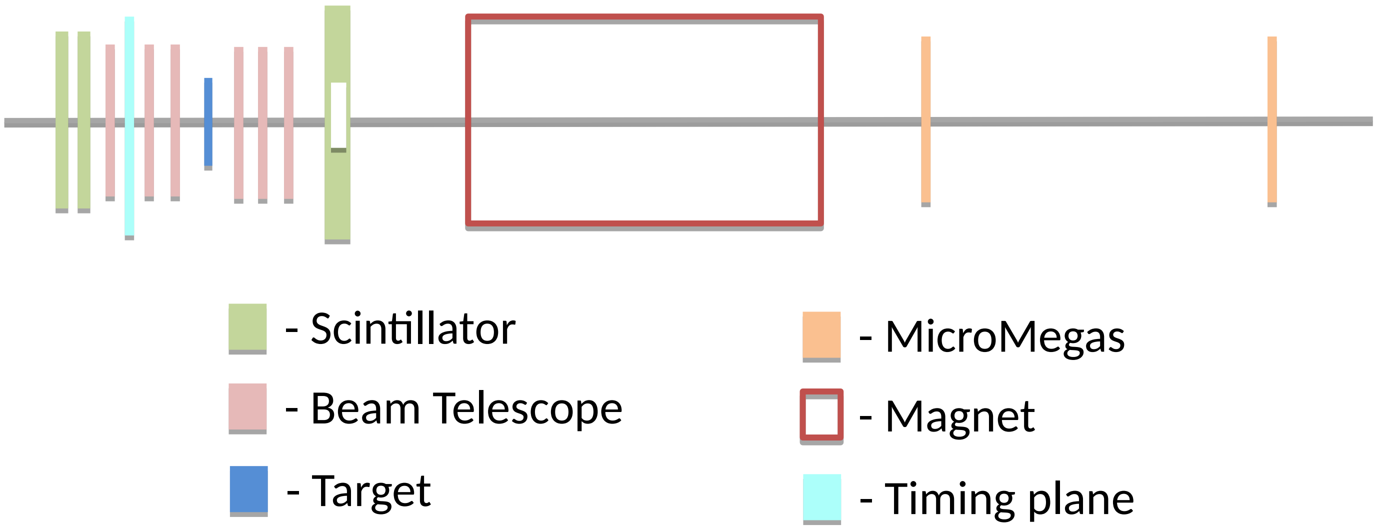
Proposed Setup



- Make an electron collide with a proton in target → Scattering event
- Scattering produces Δ^+, which decays mostly into a neutron and pion
- Pion's trajectory is bent by magnet
- Micromegas measure trajectory → momentum

Updated Setup

- Small scintillators are used to trigger the data acquisition
- A beam telescope is used before the target in order to measure the scattering angle
- Another triplet after the target measures the interaction angle
- The two Micromegas measure the deflection angle
- The Timing Plane is to help identify which particle triggered the experiment



Recipe

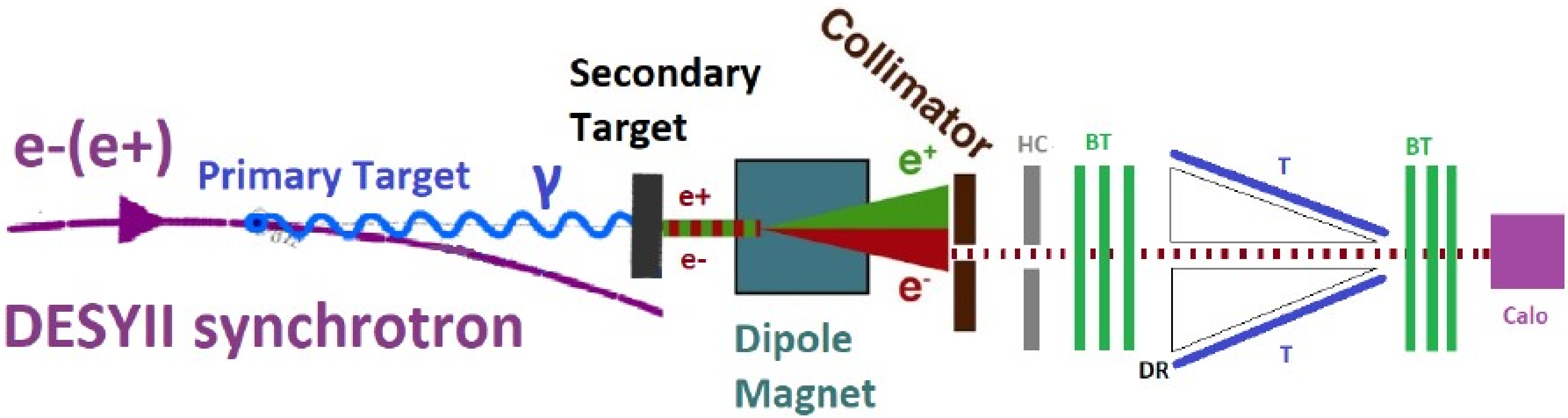
- Don’t be impatient: Take data without the target first, in order to characterize the particle beam and the detectors
  - All the tracking detectors need to be aligned in a first step
  - The position of the angular scintillator needs to be inferred and corrected if needed
  - The beam energy spread needs to be understood and improved if possible
- Add the target at a later time to see the difference in scattering

- 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 …

Cherenkov Diffraction Radiation

CHDR-CHEESE

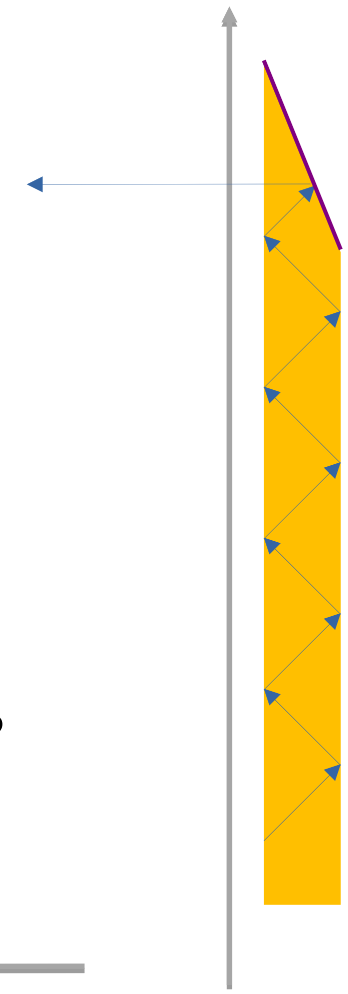
Proposed Setup

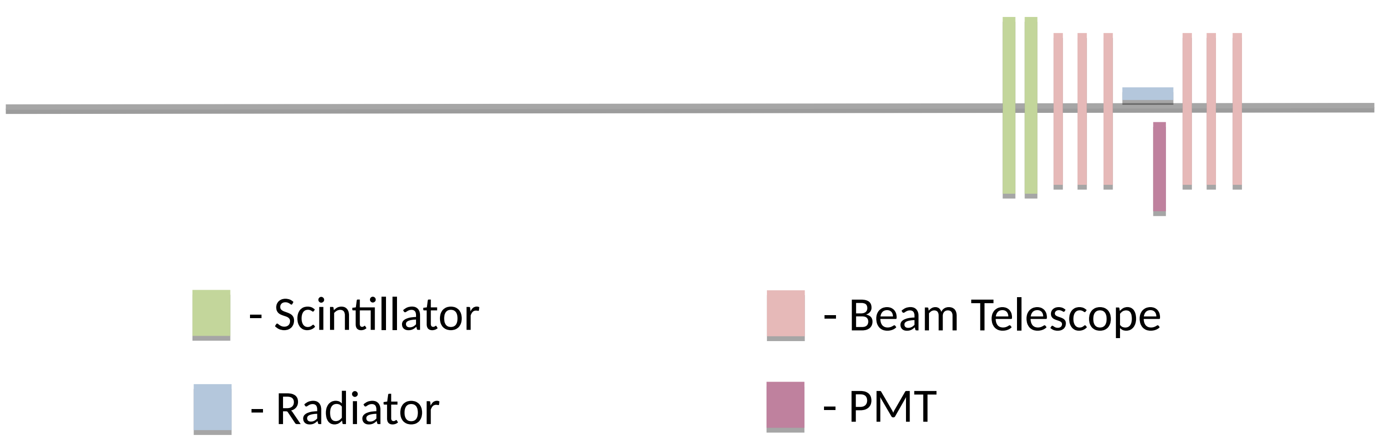


- Propagate particle beam near a radiator made from fused silica
- Detect Cherenkov Diffraction Radiation with photon sensitive detectors
- Particle tracking before and after the radiator
- Measurement of the energy via calorimeter

Updated Setup

- The Halo Counter is not required here
- Use PMT for photon detection
- Add trigger scintillators
- Improved radiator design for an increased photon yield
  - Larger active surface
  - Emitted photons concentrated on small surface
- Energy resolution of Calo not good enough – still use it?





Recipe

- Align the beam telescope first – mechanically and in software
  - A mechanically misaligned telescope reduces the field of view
- The radiator should be as parallel to the beam as possible
  - We can use the beam (telescope) for imaging, this will help you
- Check whether you can see direct Cherenkov radiation first
- Try different beam parameters (energy, particle type) as well as different radiators
- Does the photon polarization play a role?

Thanks for the Attention

Enjoy your time @CERN and @DESY,
enjoy being scientists!

Ask questions, we are here to help!