BL4S 2023
Introduction To Data Acquisition (Part I)

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September 14th 2023

What This Talk Is About

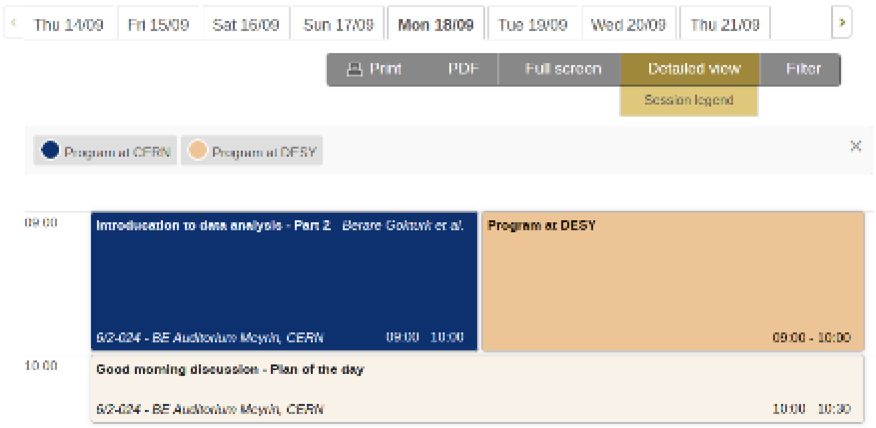
- The Why, What, Where and a little bit of the How
  - The big picture: triggering it out
  - It’s also about the location, location, location
  - How does this apply to our situation?

- But now really about the How: Our setup
  - Our detectors
  - The trigger logic
  - The digitizers and A/D converters
  - Everything else: Voltage supplies, gas, …

- How do we organize ourselves?
  - The logbook, good run list, mattermost,
  - Where to find the data

- But what do we do next?
  - Calibration?
  - Alignment ?
  - Data analysis?

  => To be continued on Monday



The Why, What And A Little Bit About The How

„The purpose of computing is insight, not numbers“

(Richard Hamming, „Numerical Methods For Scientists And Engineers“, 1962)

So: what is the purpose of data acquisition?

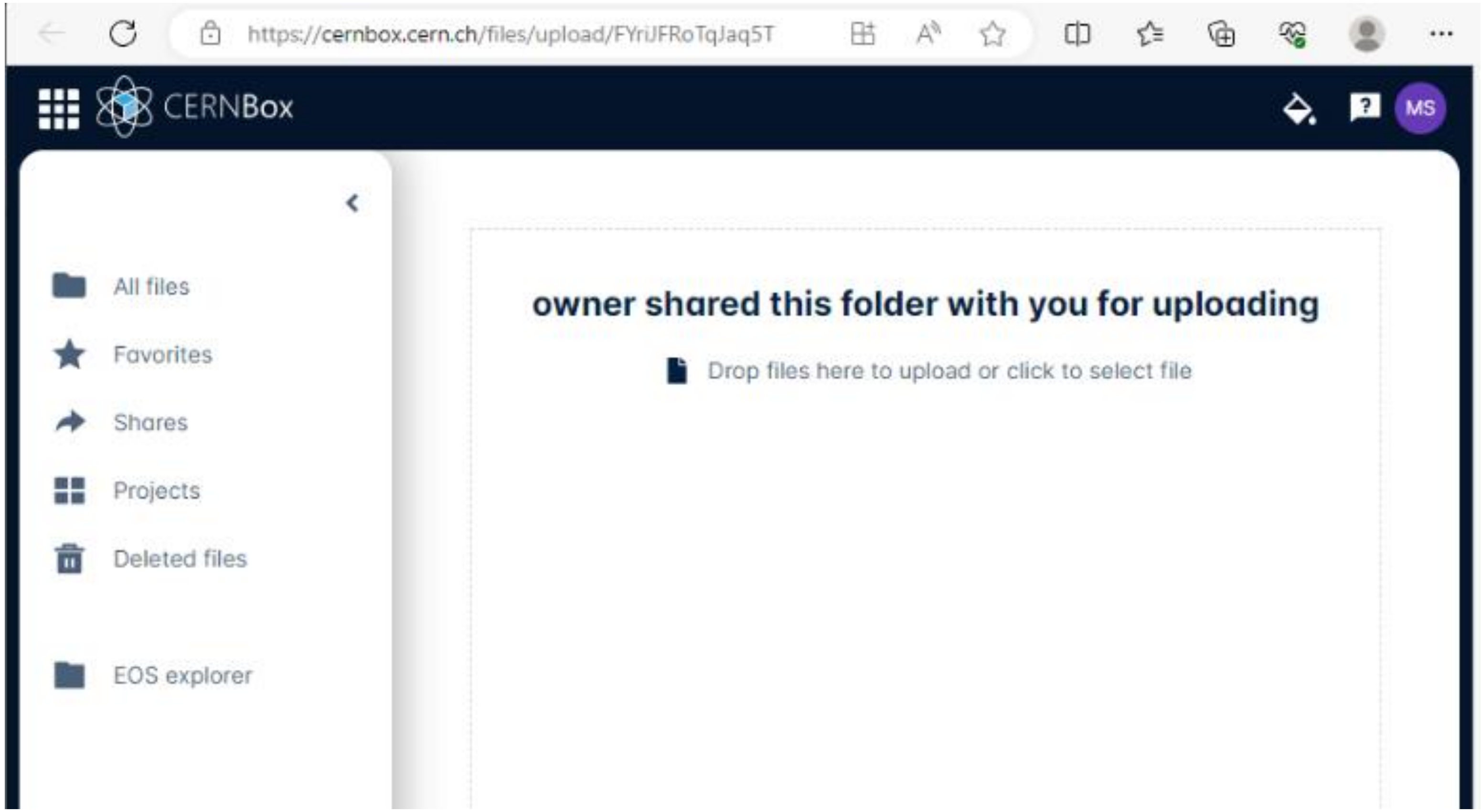
(Hint: it‘s not numbers either)

Triggering It Out: What did we do yesterday?

Remember This?

Triggering It Out: What did we do yesterday?

This is what I saw today at 08:19 CEST when I clicked on the link



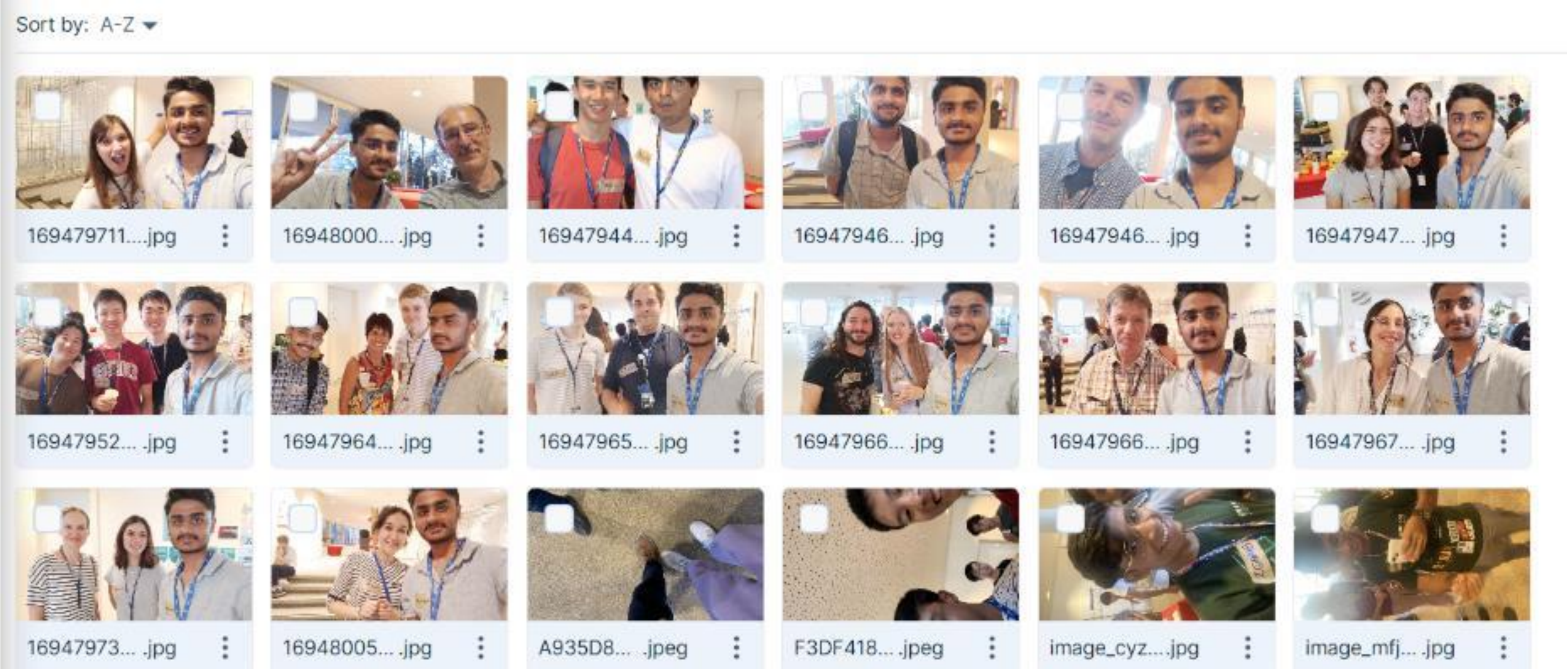
Non-Sarcastic Side Note:
This is perfect!!!!

This picture is a reminder about a point we ddin‘t even intended to make in the first place, but we will make now:

Just because you acquire data, it does not guarantee that you then actually *have* data!

Triggering It Out: What did we do yesterday?

No worries, everything is fine, it was just the wrong way to access the data that you uploaded)

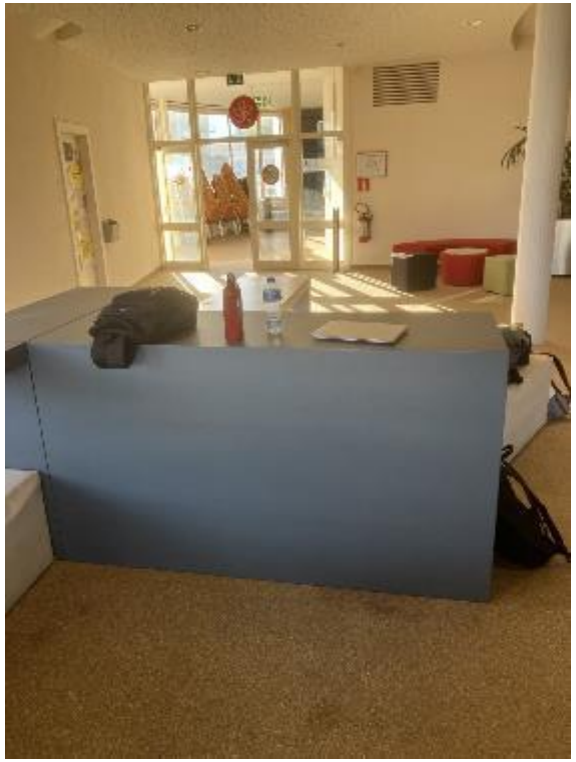


Triggering It Out: What did we do yesterday?

No worries, everything is fine, it was just the wrong way to access the data that you uploaded)

Triggering It Out: What did we do yesterday?

These are all great pictures, thank you for an amazing evening!
I also made some pictures, could you please help me to figure out if these pictures would qualify?

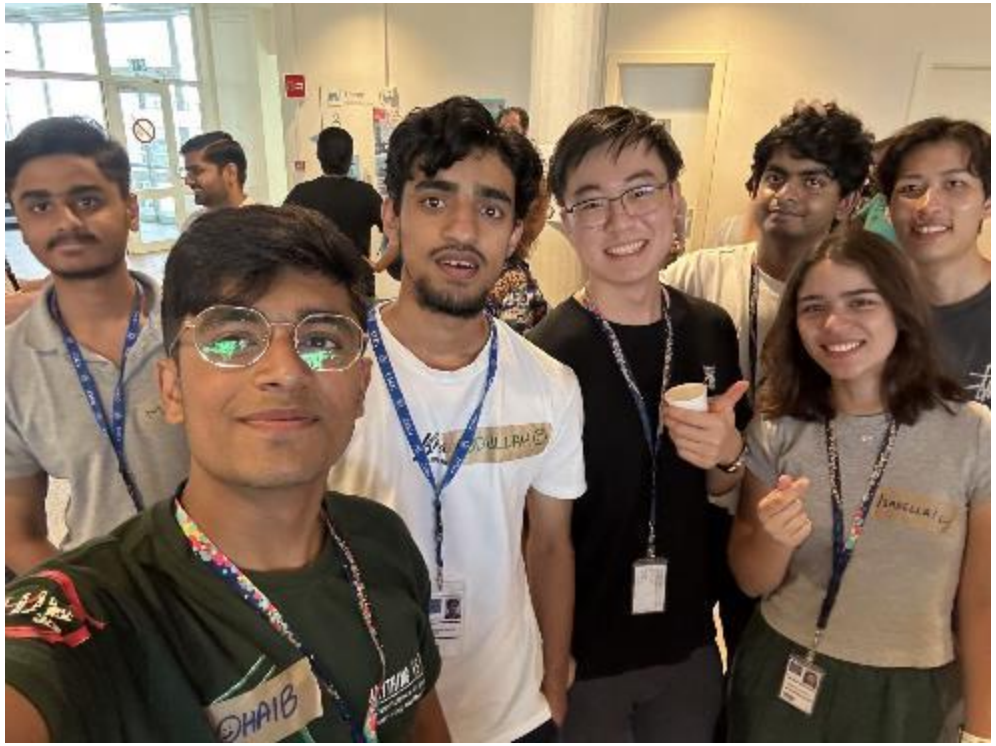


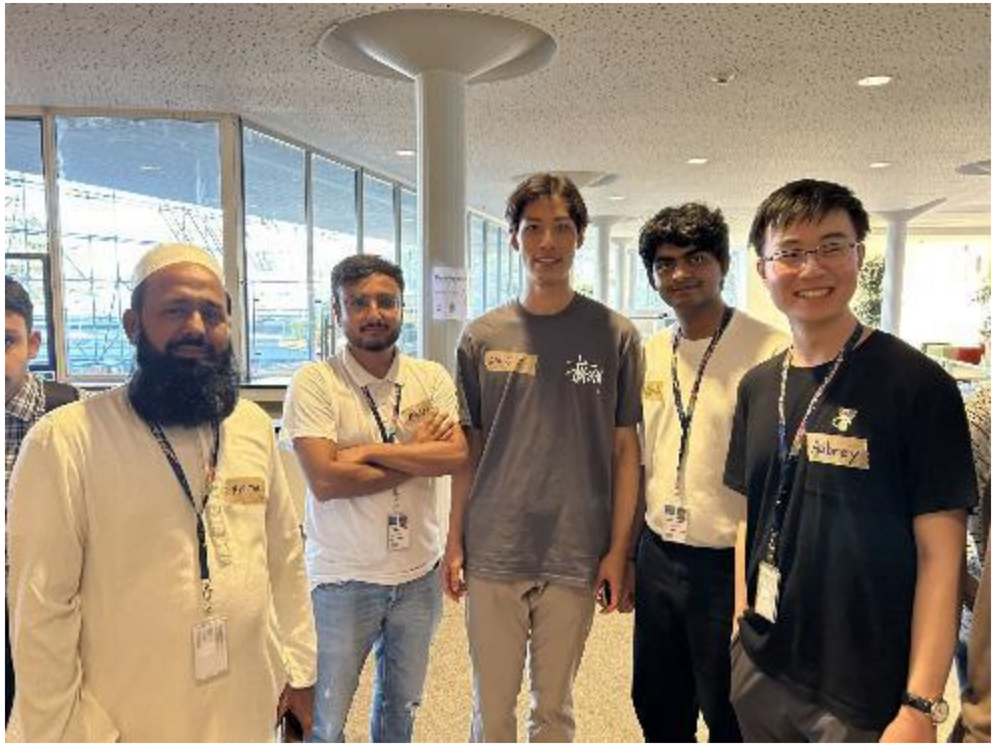
Triggering It Out: What did we do yesterday?

Some Questions & Remarks

- Did you talk while you were taking the picture
- How did you know what to photograph
- When did you stop taking pictures?
- The instructions say that the person taking the picture has to talk to somebody from another team, but how can we be sure that this is the case – we have no audio?

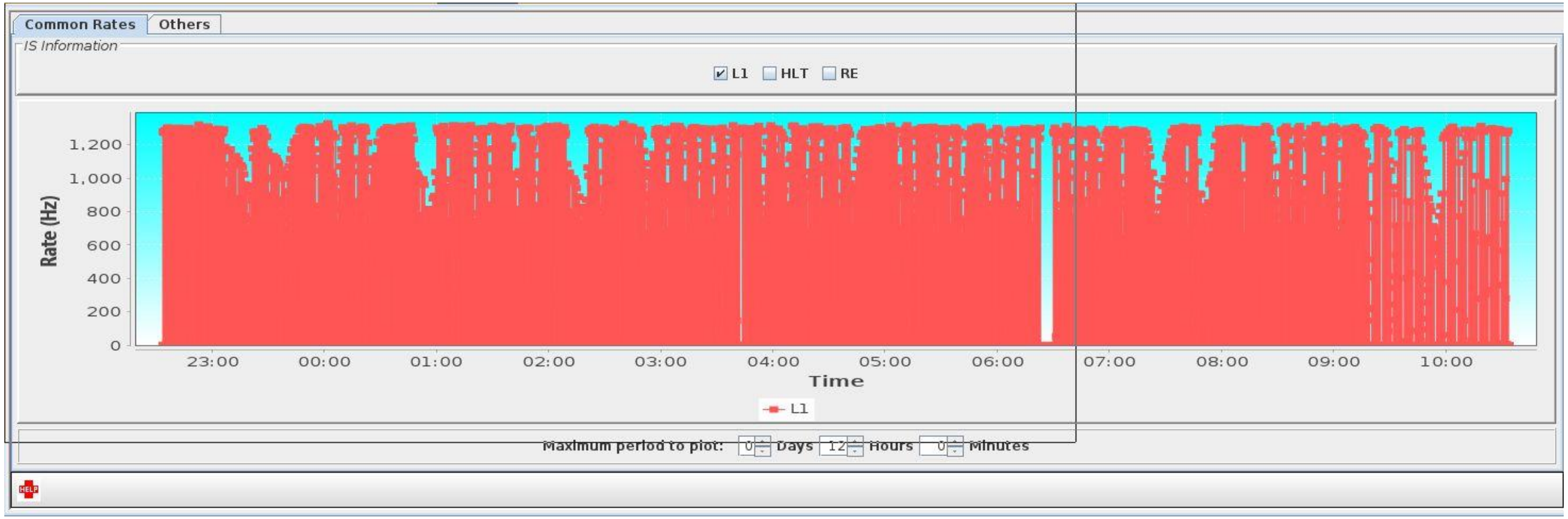
Thank you for participating in our Experiment!





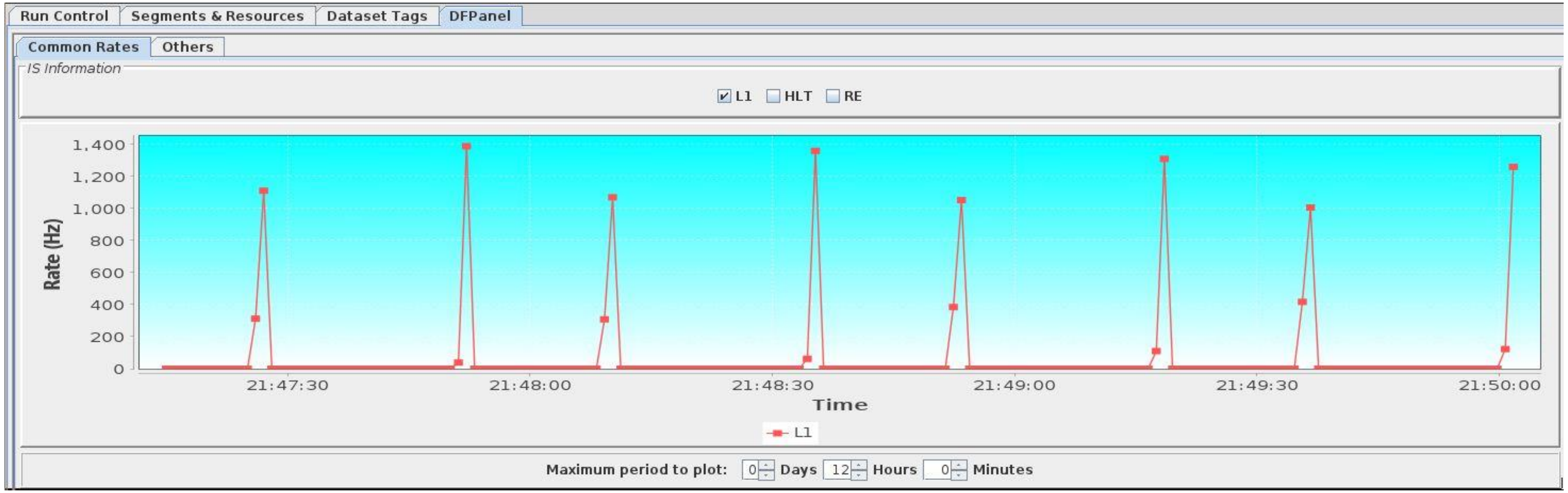
It’s also about the location, location, location: What happens at a beamline like T10?

- As it turns out: A lot!



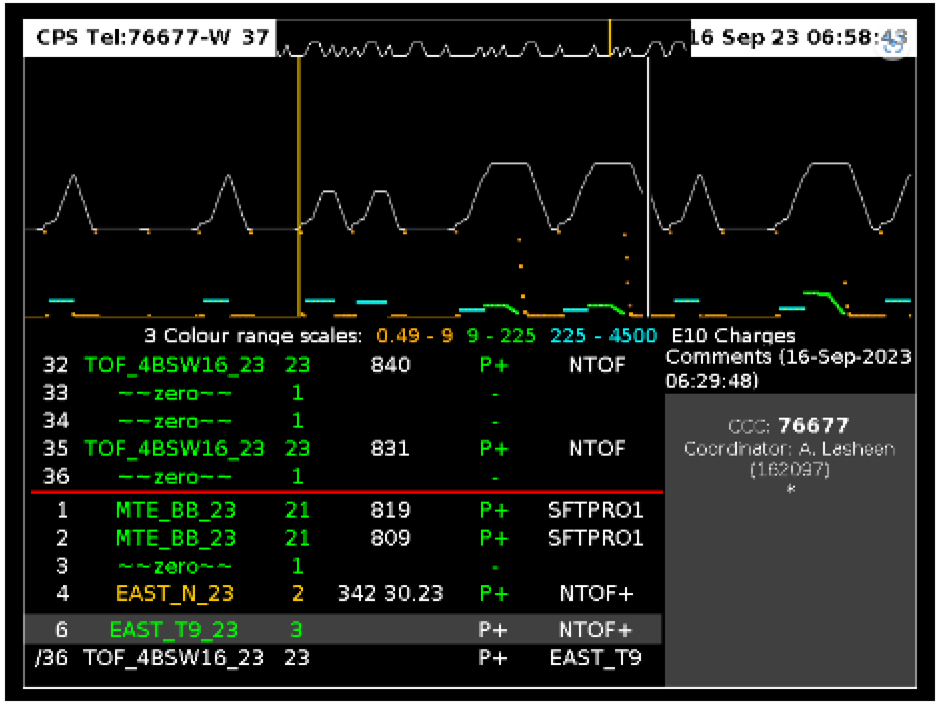
- Every red line corresponds to a „spill“ of particles received and data being recorded
- There is a structure in there – let‘s zoom in a bit!

It’s also about the location, location, location: What happens at a beamline like T10?



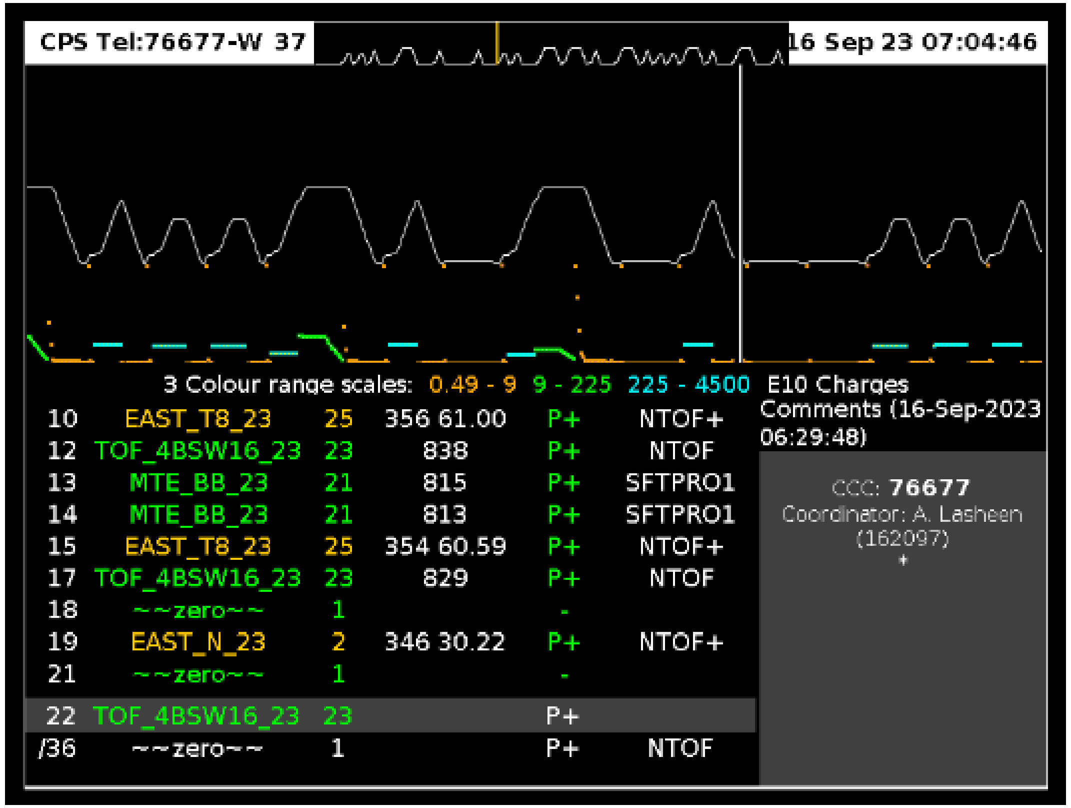
- The spills occur at fairly regular intervals (approx ~ 30 sec)
- According to the built-in detectors at T10, we receive ~ 5300 events per spill
- According to our DAQ system, we record ~ 1200 events per spill
- We will look into why the two numbers do not agree a little bit later => Stay tuned!

It’s also about the location, location, location: What happens at a beamline like T10?



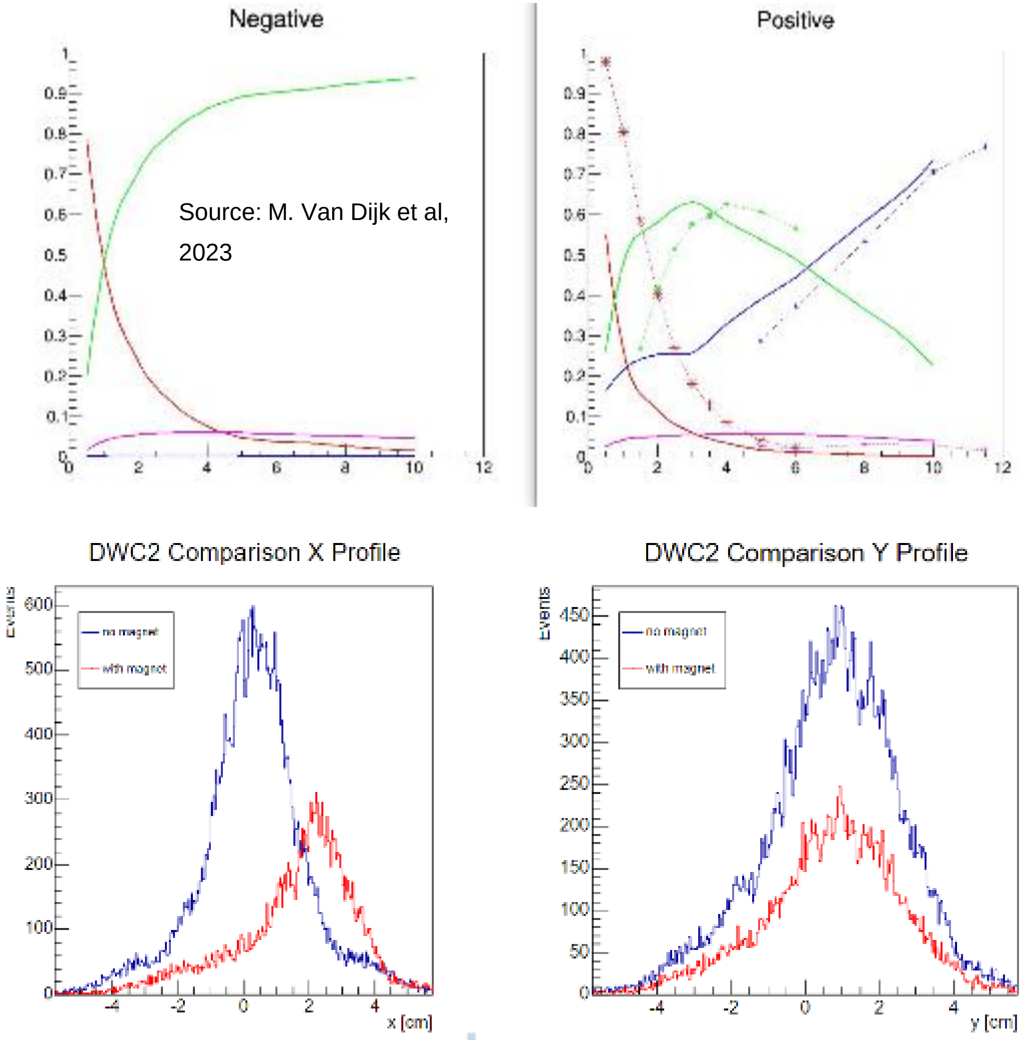
- The regular structure of the spills occurs because multiple users and facilities share the particles accelerated by the PS accelerator
- You can have a real-time view onto this cycle and see when it is your turn to get a spill
  => https://op-webtools.web.cern.ch/vistar/vistars.php?usr=CPS

It’s also about the location, location, location: What happens at a beamline like T10?



- Example: 2023/09/16 06:58:43
- The cycle contains 36 „slots“
- Each „slot“ is about 1.2 seconds long
- => The cycle repeats every ~ 43 seconds
- You can find the slots for T10 under the name „EAST_N23“
- At this time, T10 received two slots per cycle (#4, #19)
- The length of the cycle and our position(s) in the cycle can and will change over time

How does this apply to our situation?

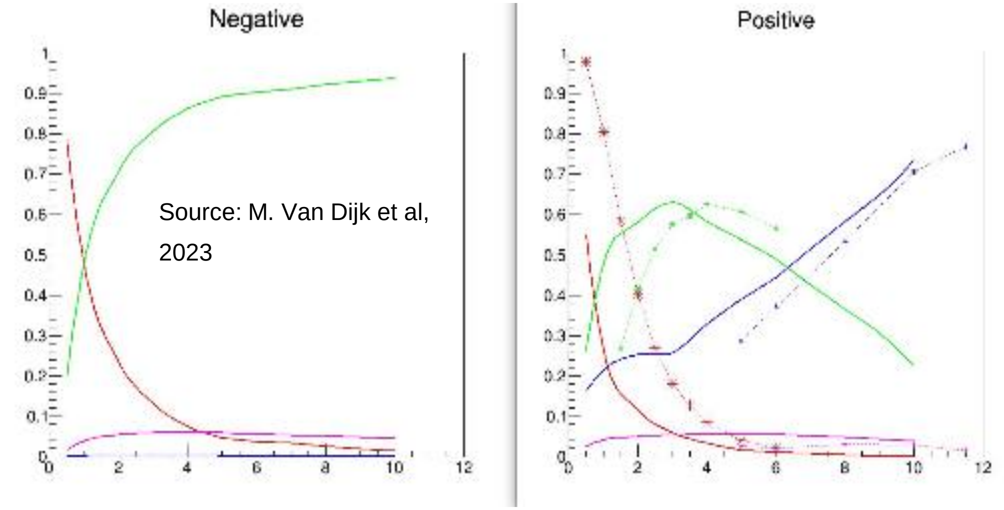


Source: M. Van Dijk et al, 2023

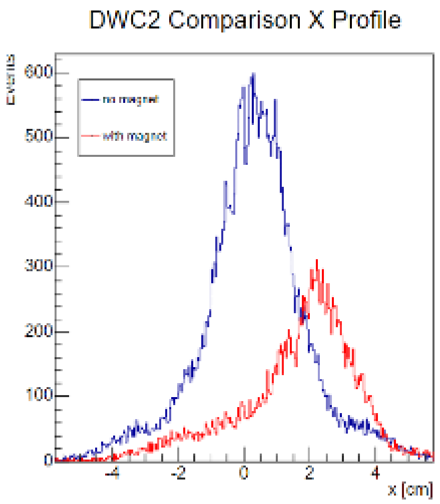
- We are not interested in approximate timing information (as in „when did we get any particles“)
- We are interested in the precise, per-particle information, including
  - their position along their way at certain points
  - their timing (which in turn gives us an idea about their energy and their momentum)
  - their type (positron, proton, pion, ...)

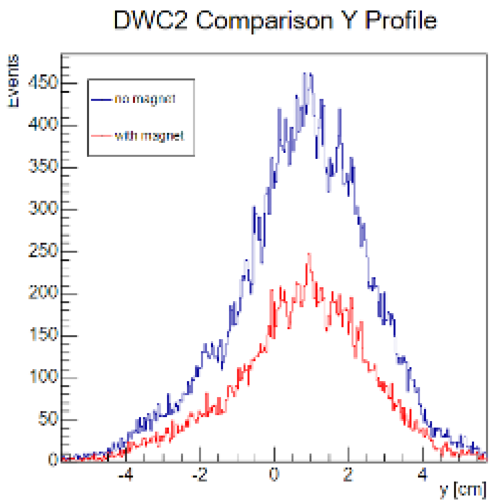
- It seems we need a DAQ system!

How does this apply to our situation?



Source: M. Van Dijk et al, 2023





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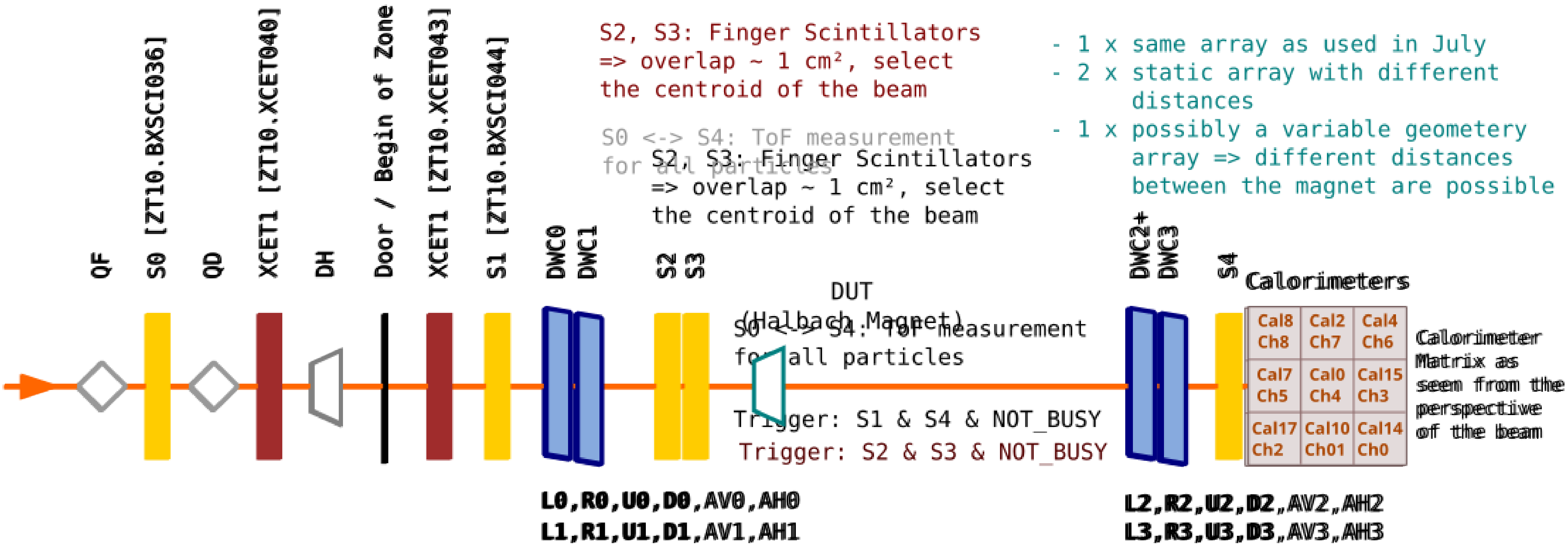
About the How: Our Setup(s)

Setup 1: Calibrate, Align, Beam Composition
Setup 2: Characterise Halbach Magnets

We have at least 2 different Halbach Array configurations (potentially >= 3)

- 1 x same array as used in July
- 2 x static array with different distances
- 1 x possibly a variable geometery array => different distances between the magnet are possible

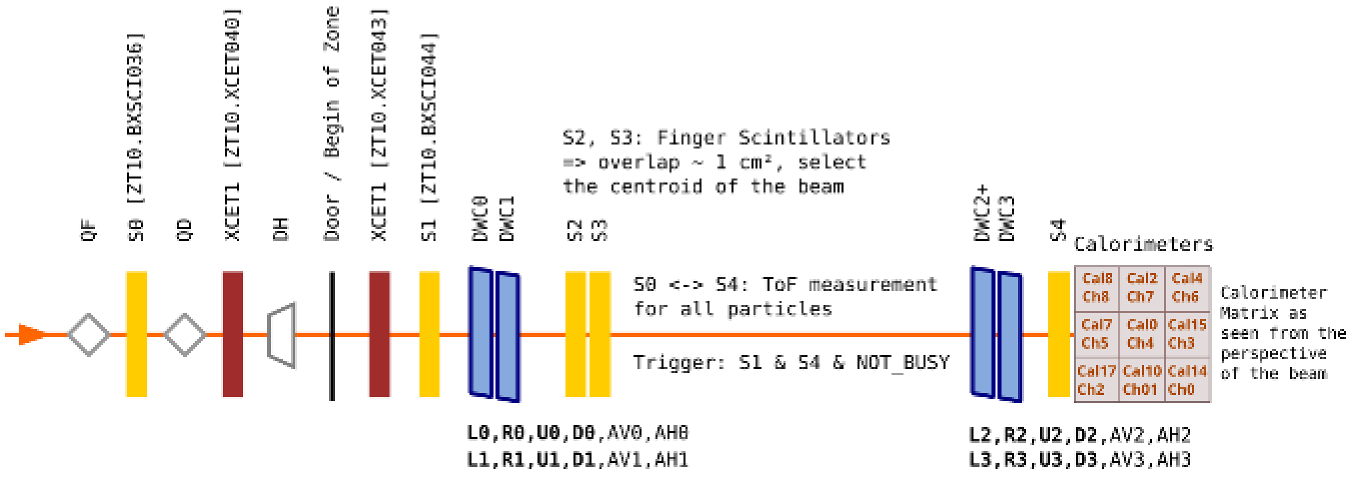


About the How: Our Setup(s)

Our setup has 4 main components:

1) The detectors
2) The trigger logic unit (TLU)
3) The data acquisition and digitizing unit
4) Everything else which does not have
   a neat catagory name, but is still very important
   (Power supplies, tables and platforms,
   calibration signal generators, gas delivery system,
   hall probes for magnet measurments,
   alignment instruments, ...)

The Detectors



As outlined in the overview sketch, we have a number of different detector systems

a) Scintillators (3 movable detectors from BL4S, two installed at fixed positions provided by BI)

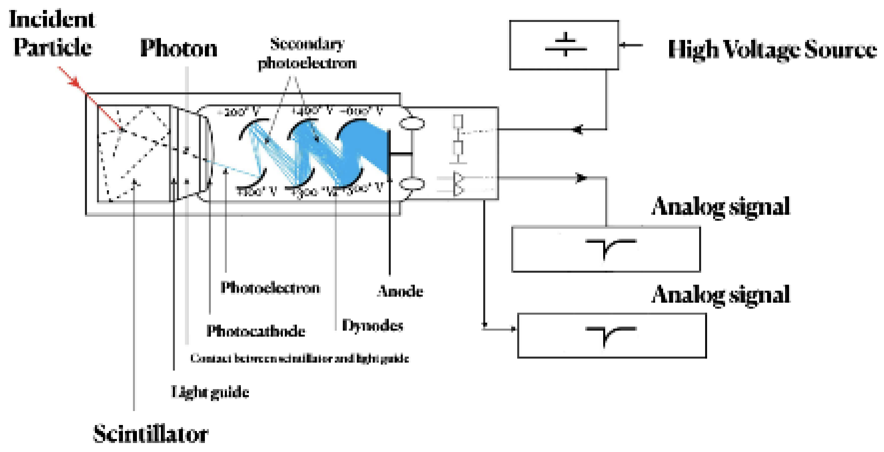
b) Delay Wire Chambers (DWC) in pairs of two, two upstream and two downstream from test subject

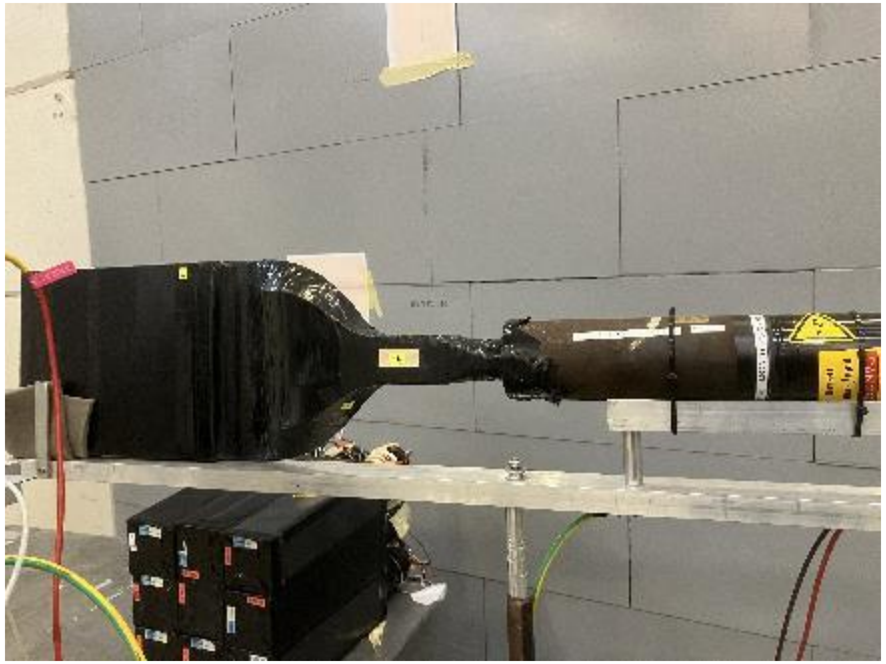
c) A 3 x 3 matrix of Calorimeters

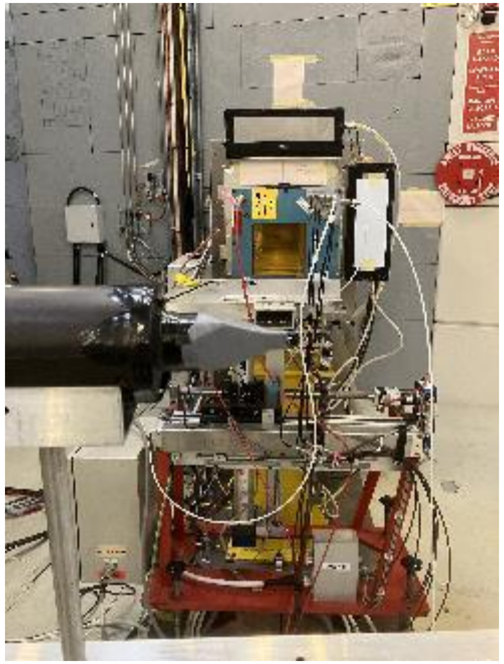
d) Cherenkov Detector(s) (fixed installation, provided by BI)

The Detectors complement each other and should help us to get data across a wide range of beam energy

Scintillator Detectors, Scintillating Paddles

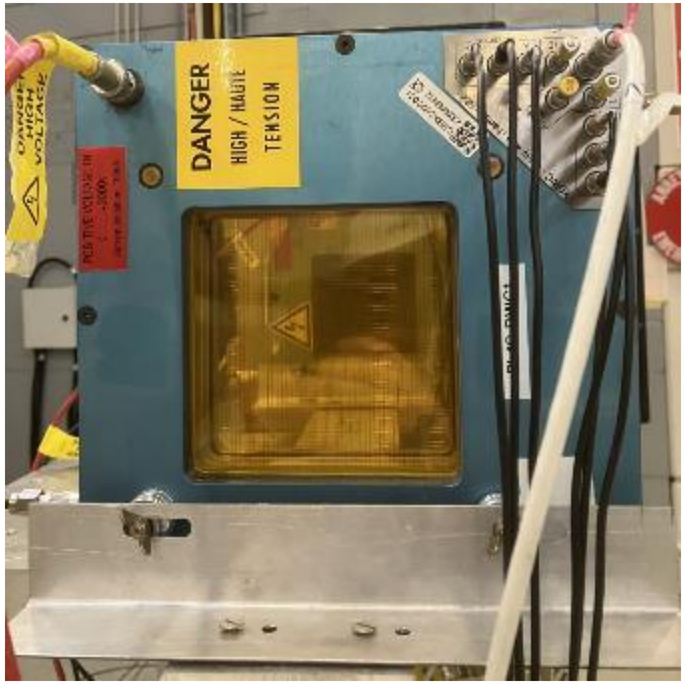


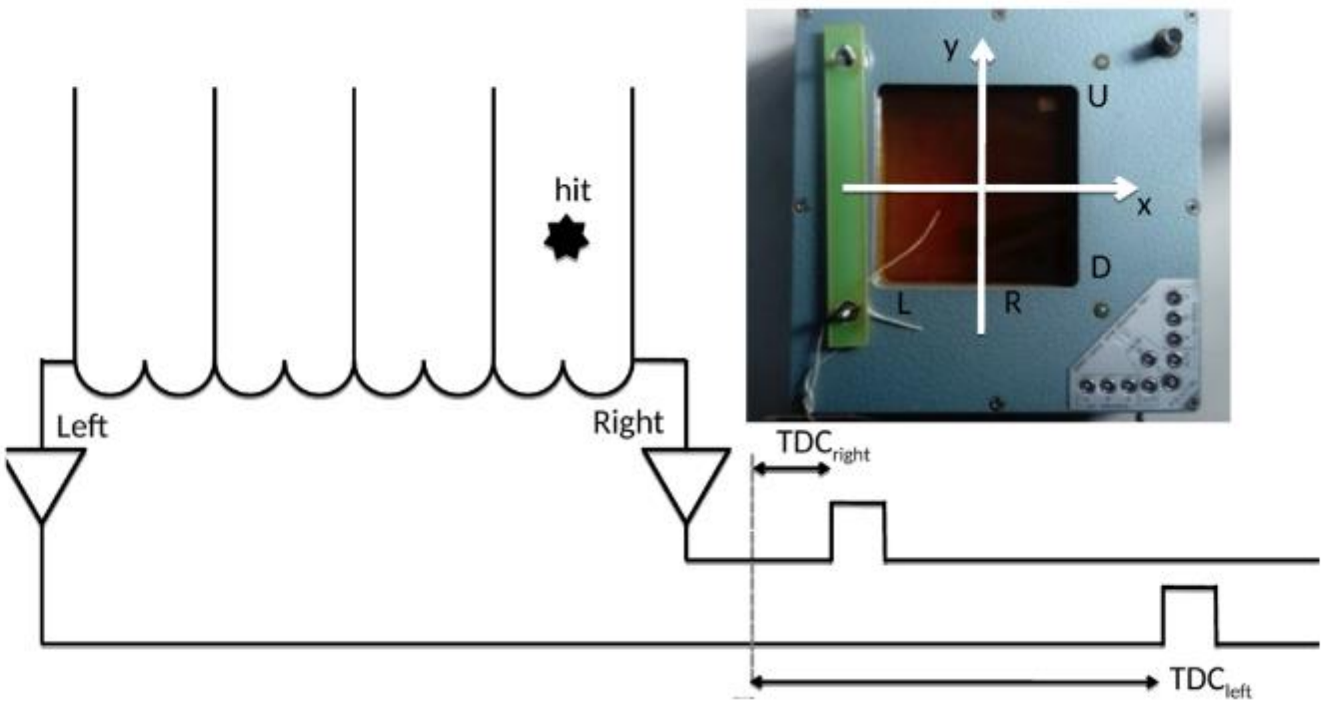




- Actually 3 components:
  - Scintillating material (here: sheet of plastic which emits a light if a charged particle crosses)
  - Light guide: collects the emitted photons and transfers them to the
  - Photo – Multiplier – Tube (PMT): enhances the signal by using the photo-electric effect to generate an avalance of electrons in multiple stages

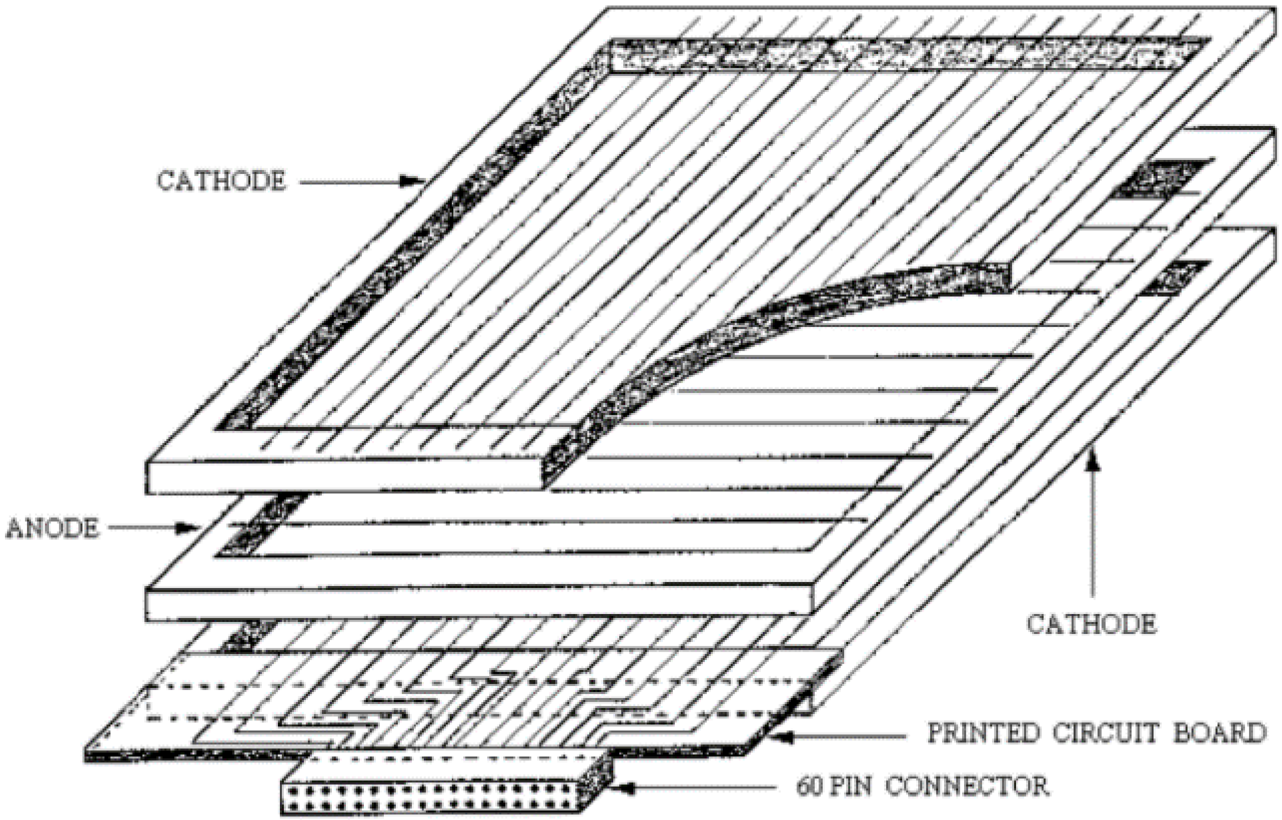
The Delay Wire Chambers (DWC)





- Two Planes: Horizontal (Left / Right: L/R) and Vertical (Up / Down: U/D) => At a minimum 4 signals
- Idea: Highly energized particles ionize gas molecules in a chamber
- Apply electric field of via high voltage (~2.5 – 3.0 kV) => Electron and Ion move according to their polarity
- Charged particles moving = electrical current => can be picked up by wires

The Delay Wire Chambers (DWC)



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

- By reading out both ends of a wire (L/R , U/D), we can more accurately determine the particle‘s location
- Normally for N wires:
  4 x N readout channels (that‘s a lot!)
- The „Delay“ part comes into the picture because if we can read all 60 wires sequentially over time, we only have to readout 4 signals
- But we have to reconstruct the spatial information from timing information!

Threshold Cherenkov Detectors (XCET)

- Principle:

$$\theta_c \sim \frac{1}{\beta \cdot n(p)}$$

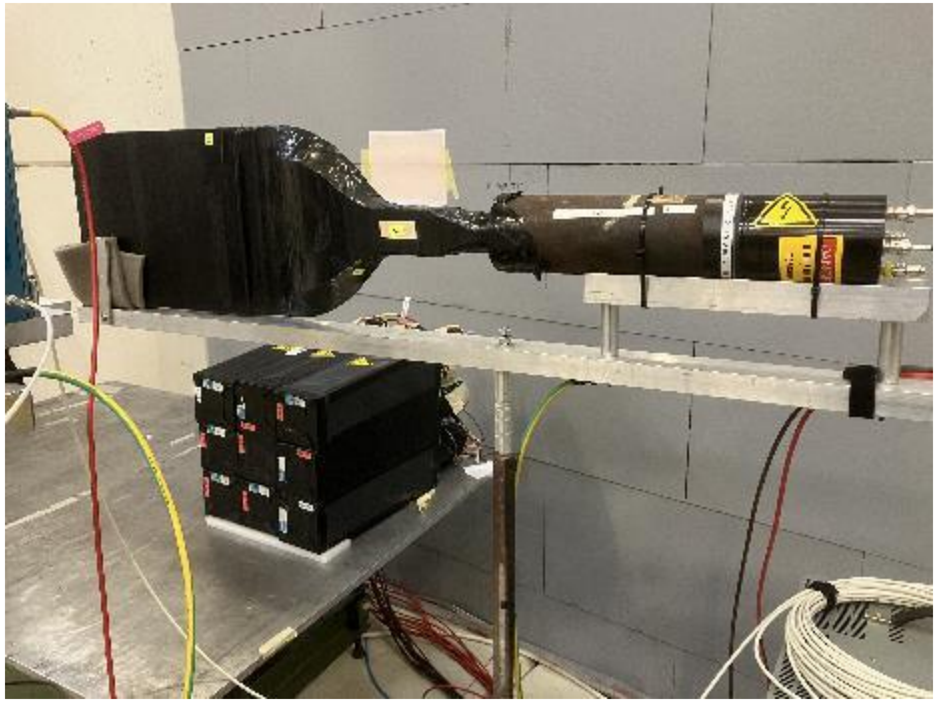
- $\beta = \frac{v}{c}, n \dots refractive\ index,$

  $p \dots pressure$

- If θ_c is above a threshold, then particles emit light as they pass through the gas enclosed in the detector

- One High – Pressure Threshold Cherenkov Detector (up to approx 15 Bar)
- One Low – Pressure Threshold Cherenkov Detector (up to approx 4.3 Bar)
- => Lecture on Tuesday for more details!

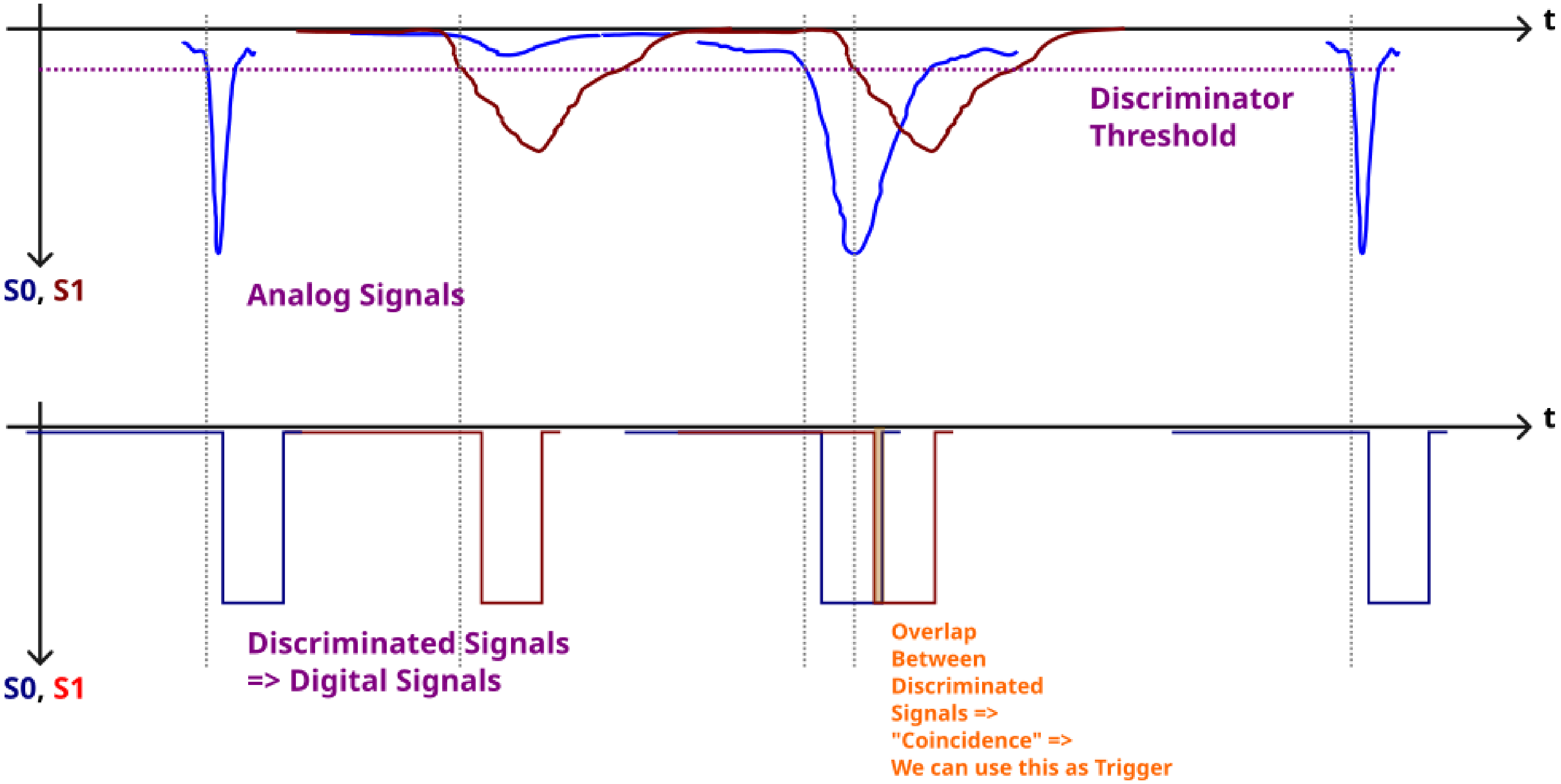
Calorimeter Matrix



- 9 Calorimeters with one PMT each
- Optimized for electrons but give also signal for muons and hadrons
- Very reliable detection of electrons / positrons above ~ 1.2 – 1.5 GeV, everything else is a bit tricky

Trigger Logic

Let‘s assume a simple system: two scintillators on top of each other, detecting cosmic muons



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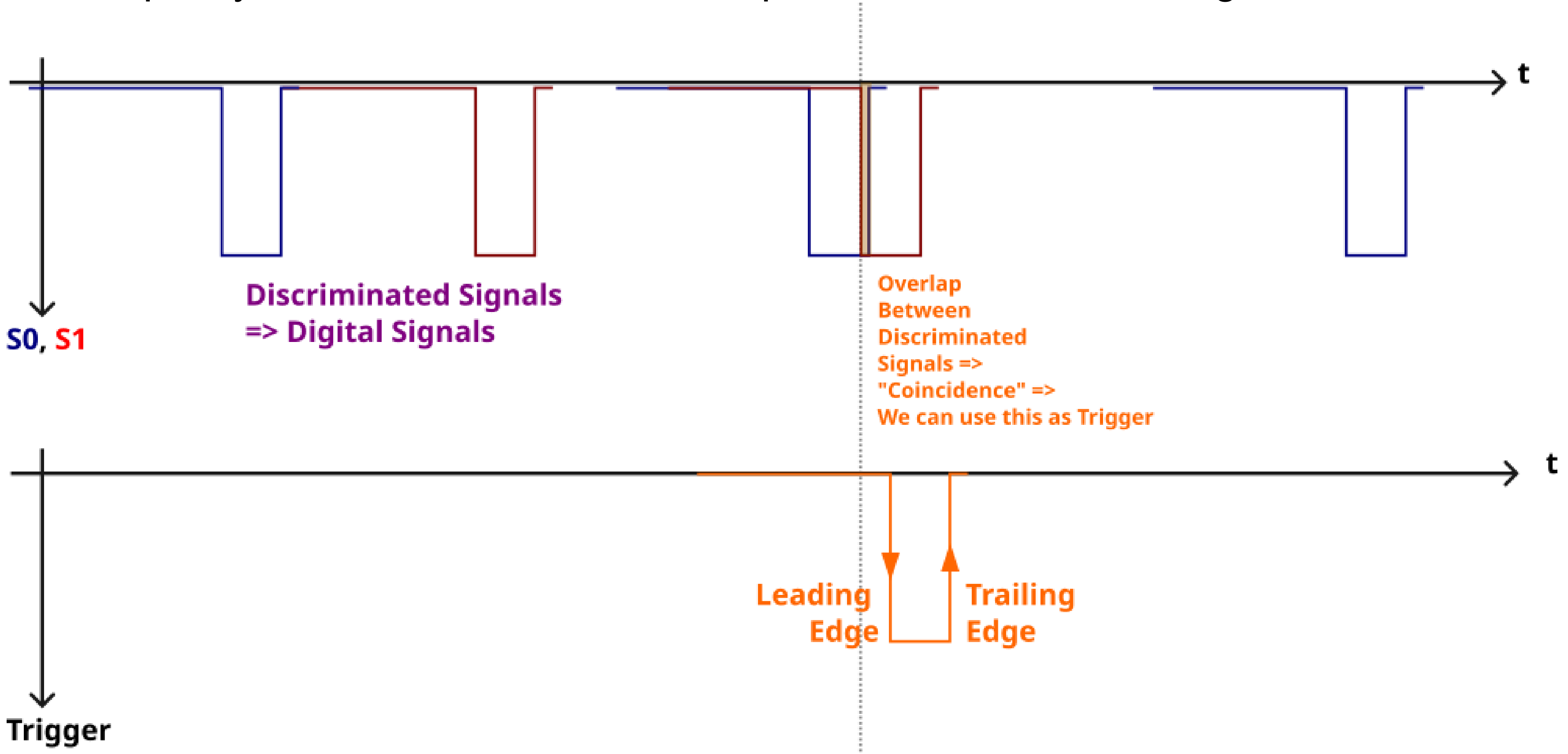

Trigger Logic

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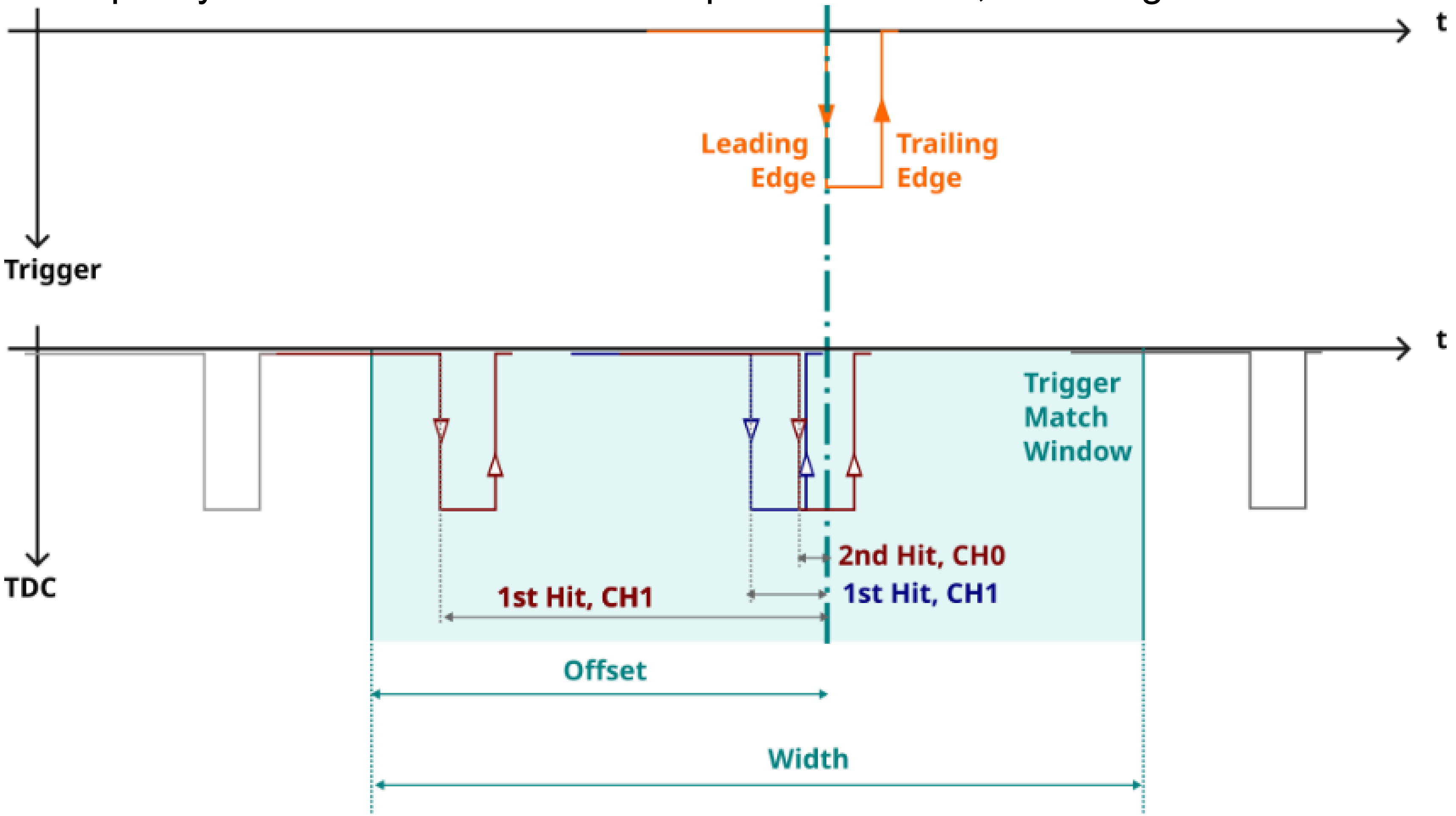
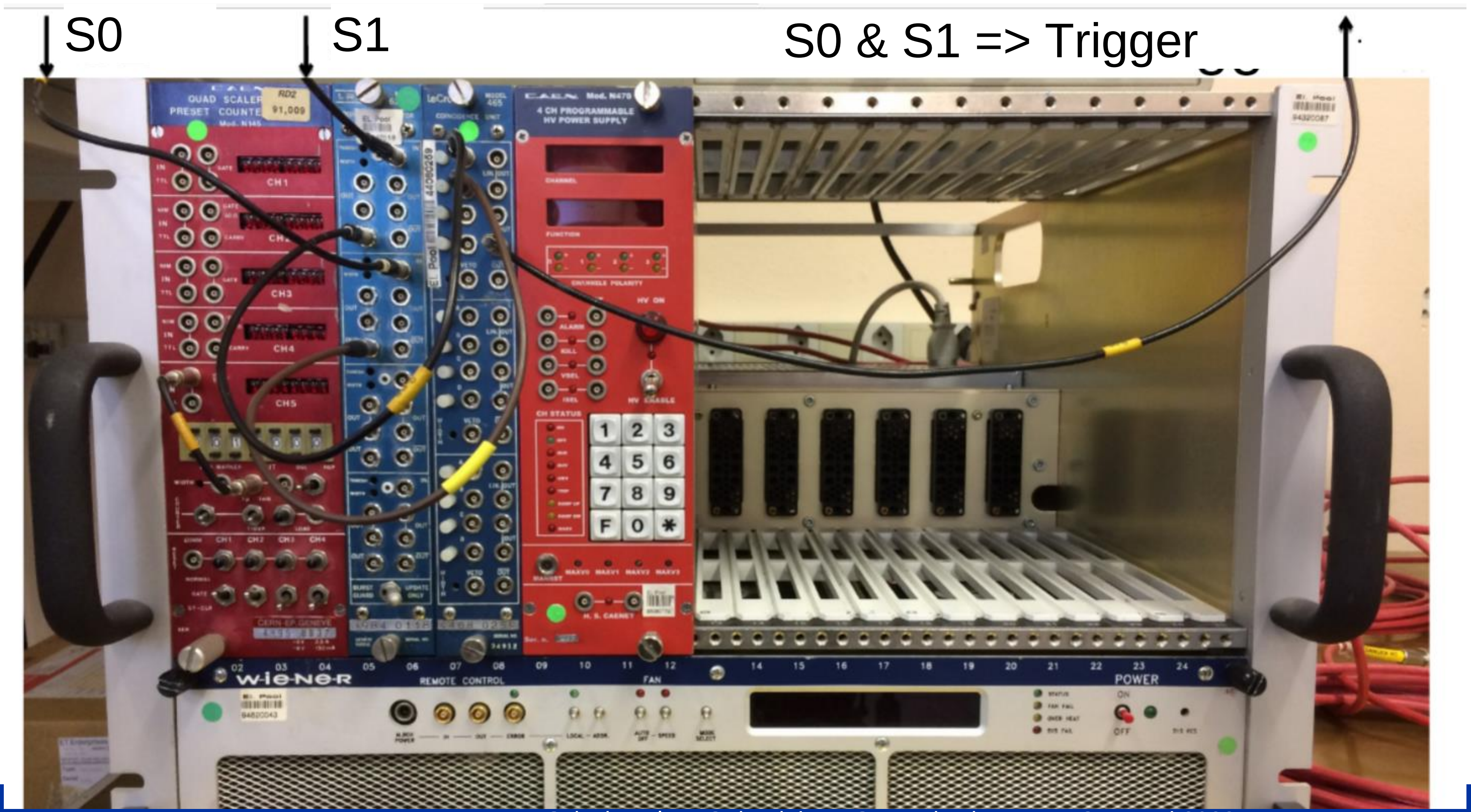
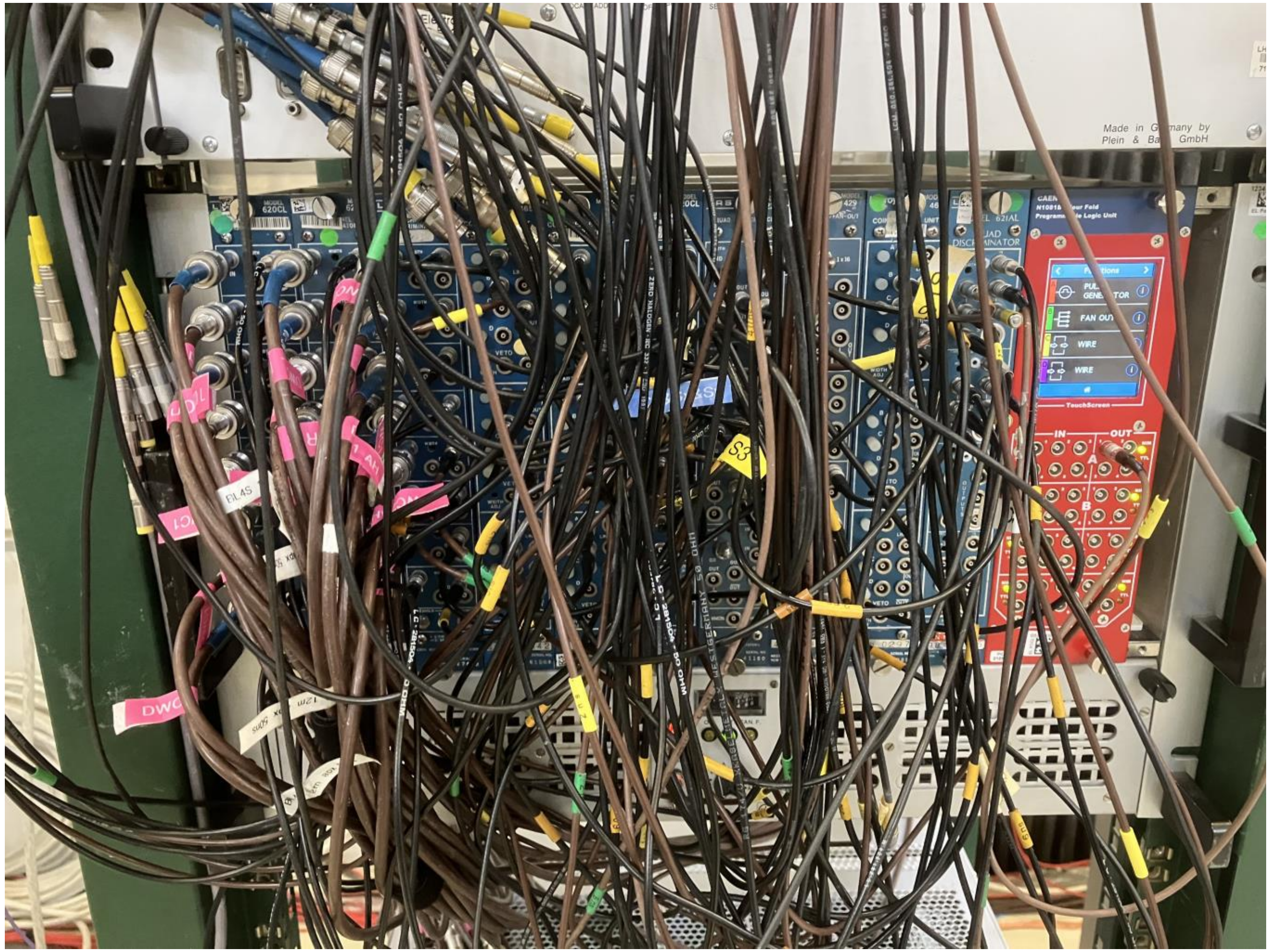


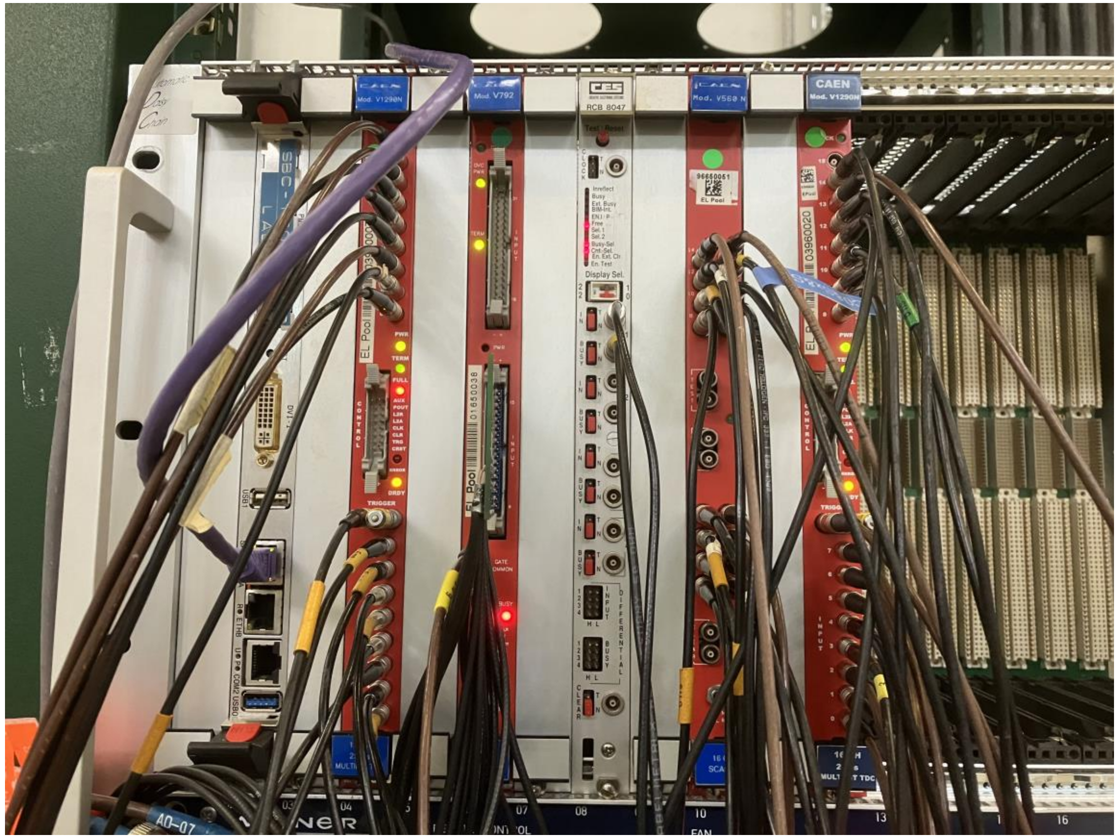
Implementing such a trigger logic unit



Or a *slightly* more complicated system ….



Data Acquisition and Digitizer Unit



- From Left To Right

  1) Single Board Computer

  2) TDC0 => Digitizer for the DWC main signals

     (Time To Digital Converter)

  3) QDC => Digitizer for the Calorimeter

     (Charge to Digital Converter)

  4) CORBO Card (more on this in a minute)

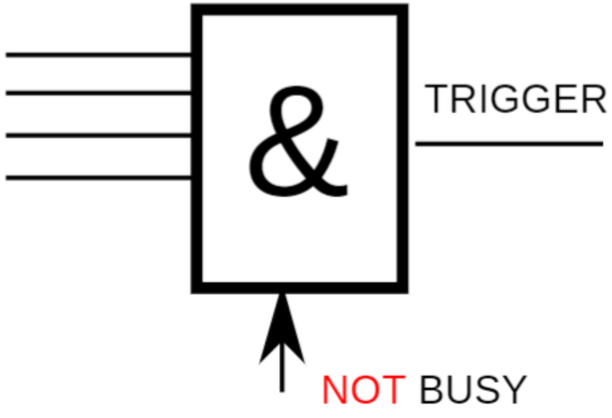
  5) Scaler => Counter, not triggered (!!)

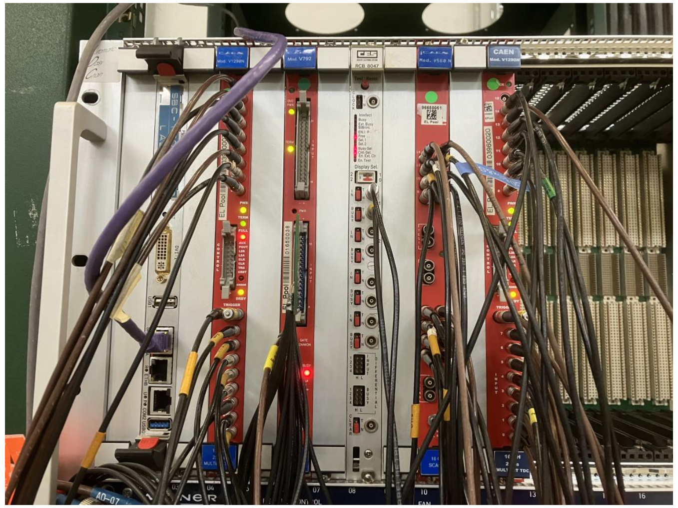
  6) TDC1 => Digitizer for the Scintillator,

     Cherenkov, and DWC Anode signals

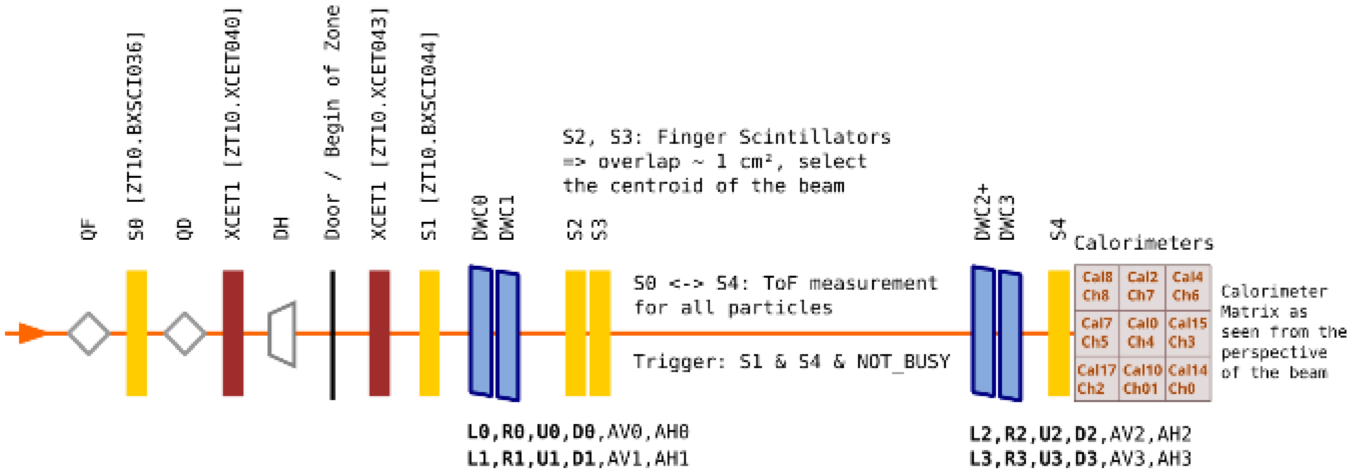
Trigger Busy Logic & Data Acquisition

- We have to ensure that our active measurements are not interrupted by incoming events that arrive a bit later => Block trigger until we are no longer **busy**
- Issuing and clearing the BUSY signal is handled via the CORBO card.
- **We can not record every particle that arrives and that would trigger our detector (at least not in T10)**
- That‘s why having a scaler is so important, it gives us a less detailed picture about some quantities for(almost) all particles while we take more detailed data (i.e., TDC, QDC) for as many particles as we can

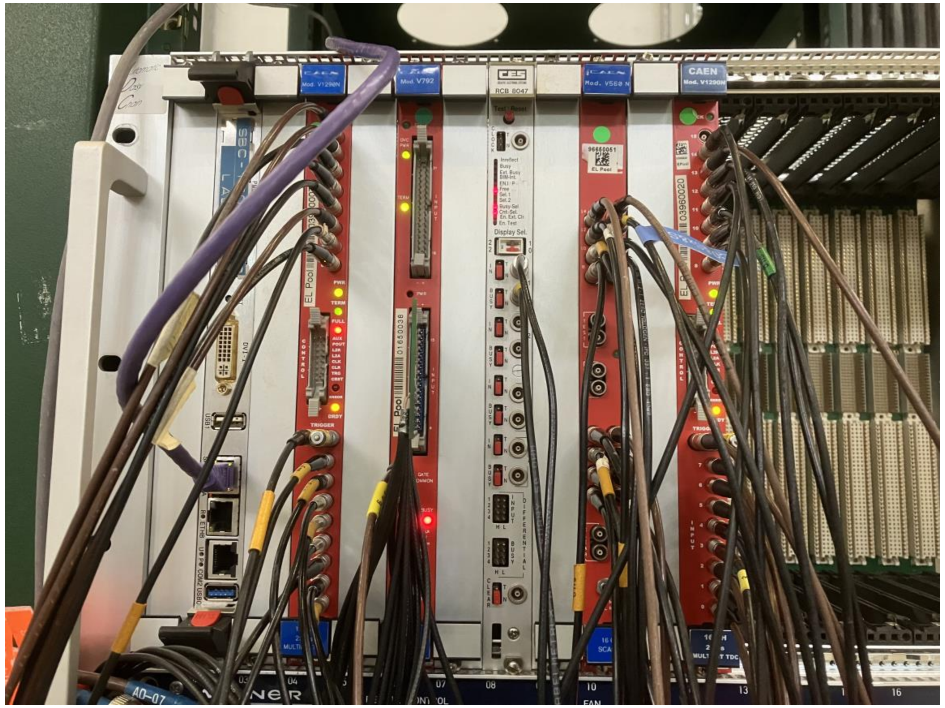




Data Acquisition and Digitizer Unit

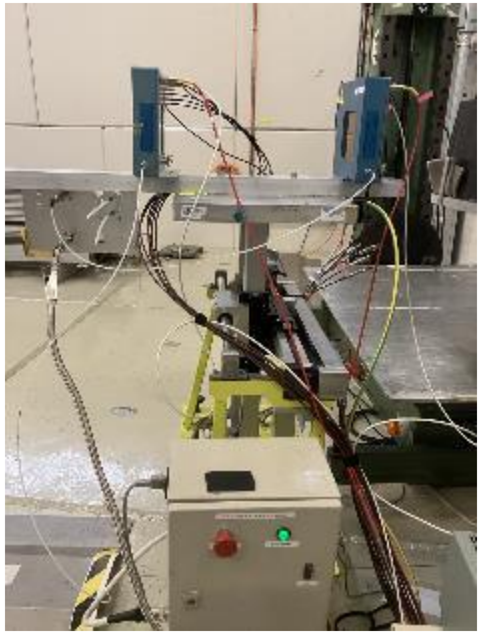


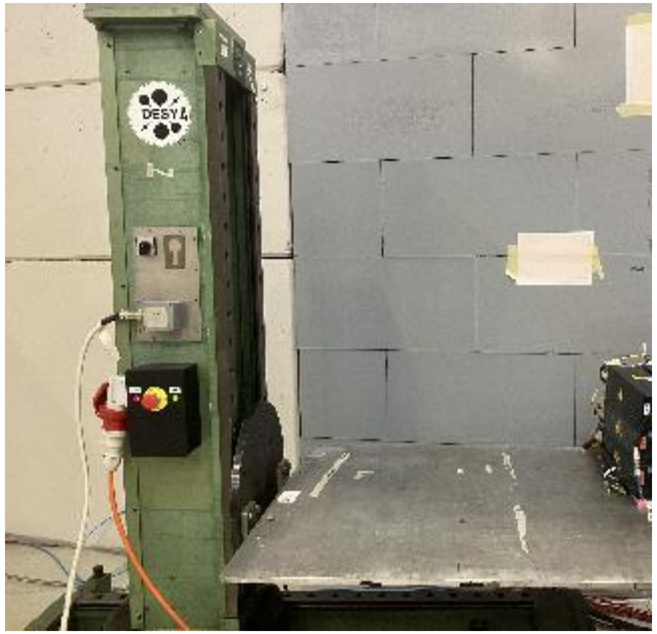
- There is a relationship between the detectors and signals in our setup and the input channels of each of the devices in this unit:



You Will Always Find a Table With These Mappings In The Log Book (cf. a bit later)!

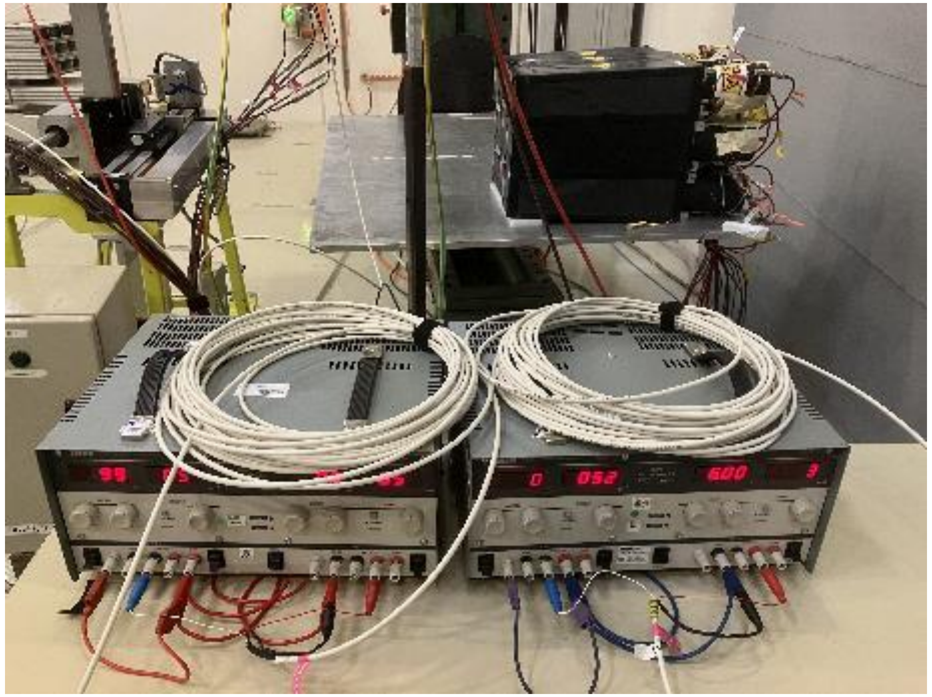
Platforms And Tables





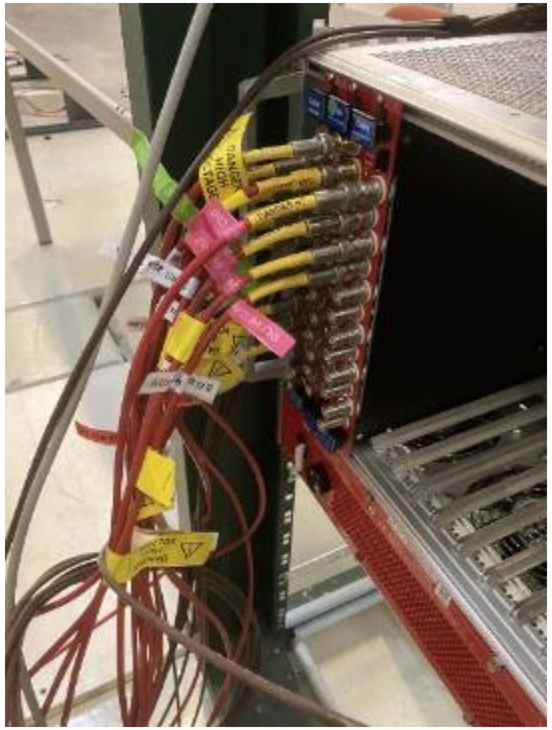
- We have two remote controllable tables for the two pairs of DWCs (XSCA Table)
- We have one so called “DESY” table carrying the calorimeter array
- All three platforms can move in two dimensions and will be used for alignment and to expose different detectors to the centroid of the beam
  And to carry the calorimeters because they are really reall heavy !

Low Voltage Supplies



- Required for the DWCs
- Four units, symmetrically +/- 6V with approx. 50 – 60 mA
- Have to be carefully monitored to detect issues with the DWC before they take damage

High Voltage Supplies



SY4527 SN0429

Custom	Name	I0Set	V0Set	IMon	VMon
02.000	CAL16	700.00 uA	1200.00 V	0.000 nA	1200.03 V
02.001	CAL10	700.00 uA	1200.00 V	356.718 nA	1200.10 V
02.002	CAL17	700.00 uA	1225.00 V	356.304 nA	1224.91 V
02.003	CAL15	700.00 uA	1100.00 V	326.878 nA	1100.01 V
02.004	CAL0	700.00 uA	1050.00 V	313.718 nA	1050.20 V
02.005	CAL7	700.00 uA	1100.00 V	327.084 nA	1100.07 V
02.006	CAL2	700.00 uA	1100.00 V	327.212 nA	1100.17 V
02.007	CAL4	700.00 uA	1100.00 V	323.796 nA	1100.13 V
02.008	CAL1	700.00 uA	1150.00 V	347.992 nA	1150.12 V
03.000	S2	2000.0 uA	2150.0 V	1433.5 nA	2152.0 V
03.001	S3	2000.0 uA	2100.0 V	1347.0 nA	2101.5 V
03.002	S4	2000.0 uA	1900.0 V	1213.0 nA	1901.5 V
03.003	S5	2000.0 uA	2200.0 V	1573.0 nA	2201.5 V
04.000	DWC0	100.00 uA	2800.00 V	7.952 nA	2799.67 V
04.001	DWC1	100.00 uA	2800.00 V	39.502 nA	2799.61 V
04.002	DWC2	100.00 uA	2800.00 V	19.632 nA	2799.78 V
04.003	DWC3	100.00 uA	2800.00 V	23.692 nA	2799.67 V

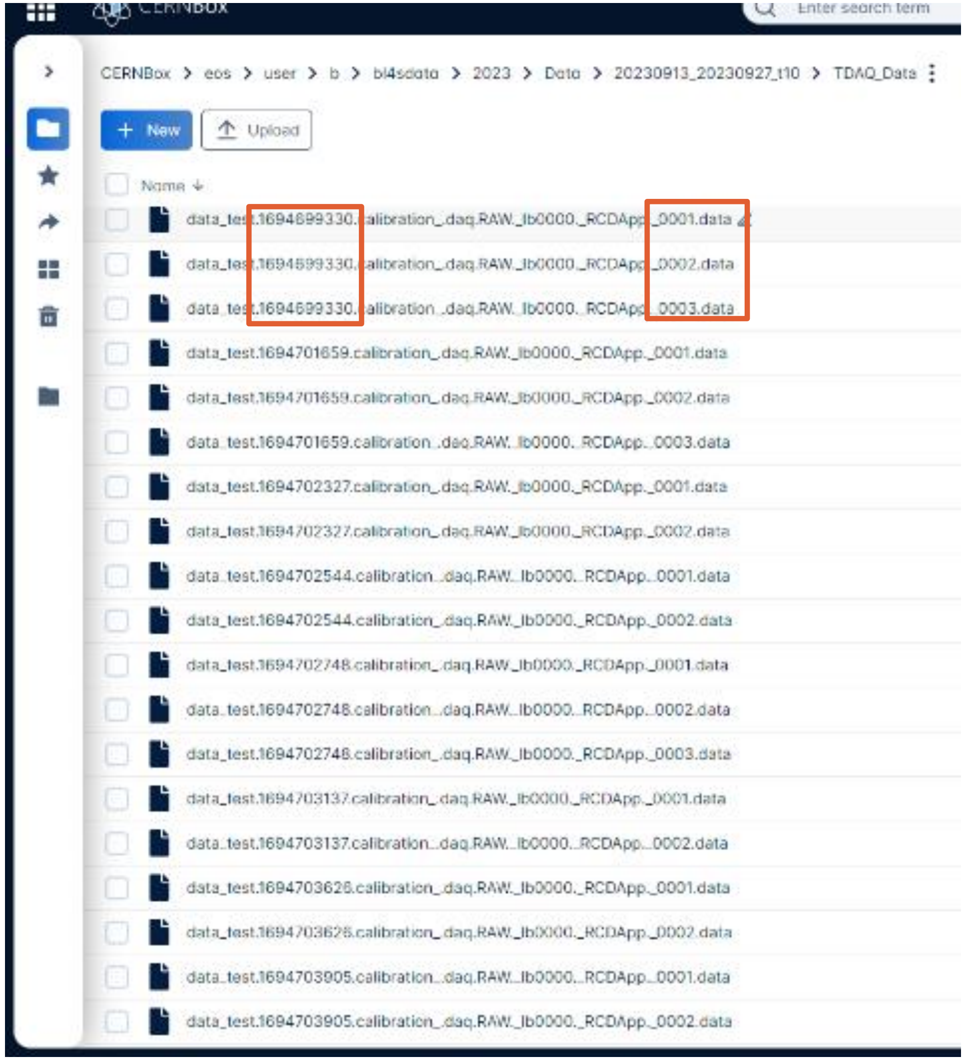
- Different voltages have to be provided to different detectors and devices
- => We have quite a lot of them and need (literally) a bunch of cables to distribute the power
- The voltages and currents can be remotely monitored and controlled from the counting room

How do we organize ourselves ?

This is not a rhethorical question.

How do we organize ourselves during the next days???

How do we organize ourselves: Where is the data?

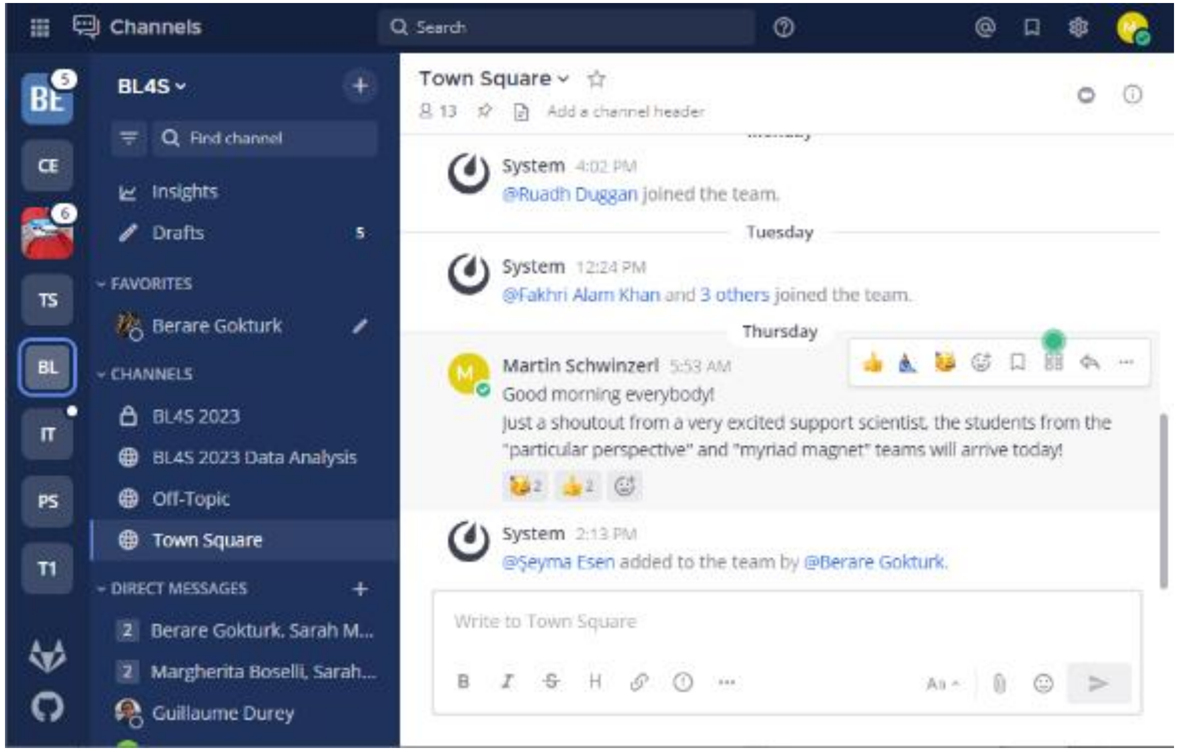


- Data is recorded locally, on our DAQ system
- The format (.data) is optimized for fast storage and efficient transfer, but not direct readable (let alone „human readable“)
- The filename contains a long number => This is the run-number
- We can cross reference runs using this number with other sources of (meta) information: the logbook, the run list, ...
- We can convert the data to ROOT & share it via cernbox
- => We would ask you to help with this task as part of your data analysis and control ream / beam line shifts!
- => We will send you the coordinates how to access to the data collection on CERNbox via email and via Mattermost.
- Speaking of Mattermost ....

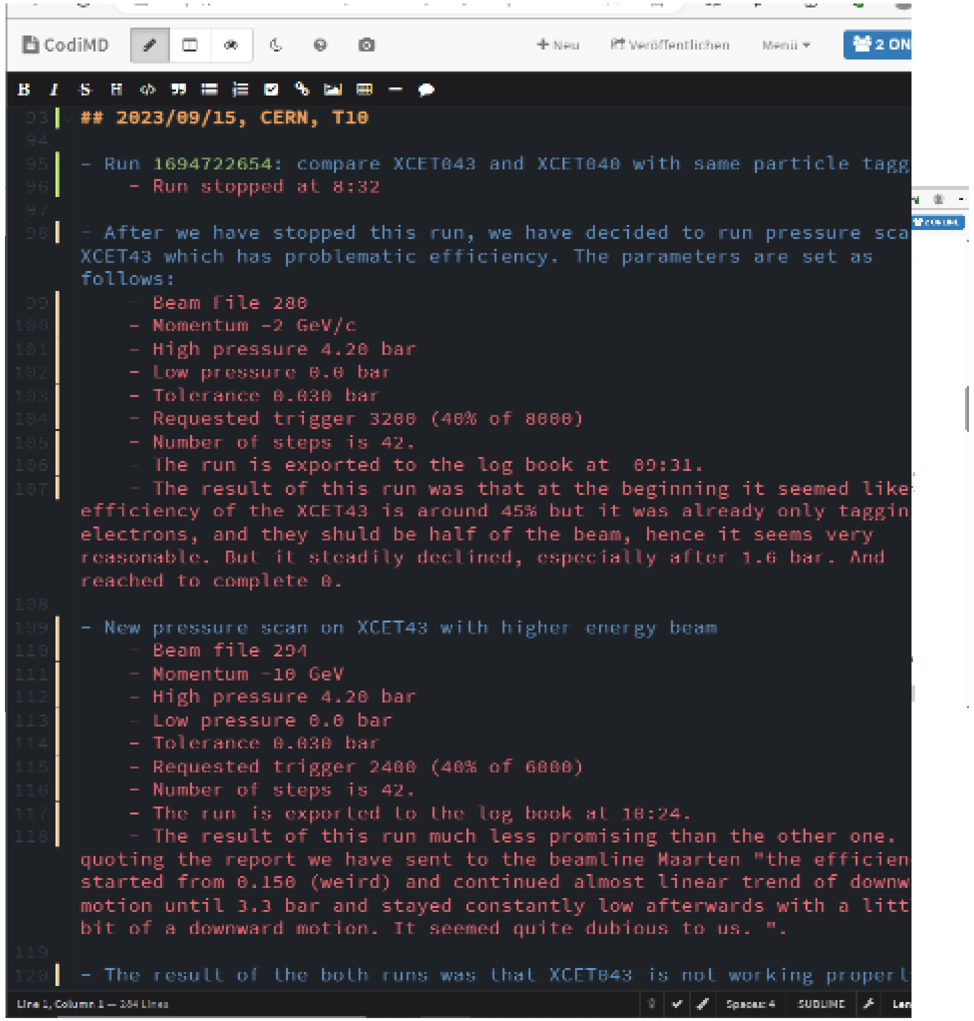
How do we organize ourselves: Mattermost

- We have a Mattermost channel for BL4S, please join!

  => https://cern.ch/bl4s2023-mattermost



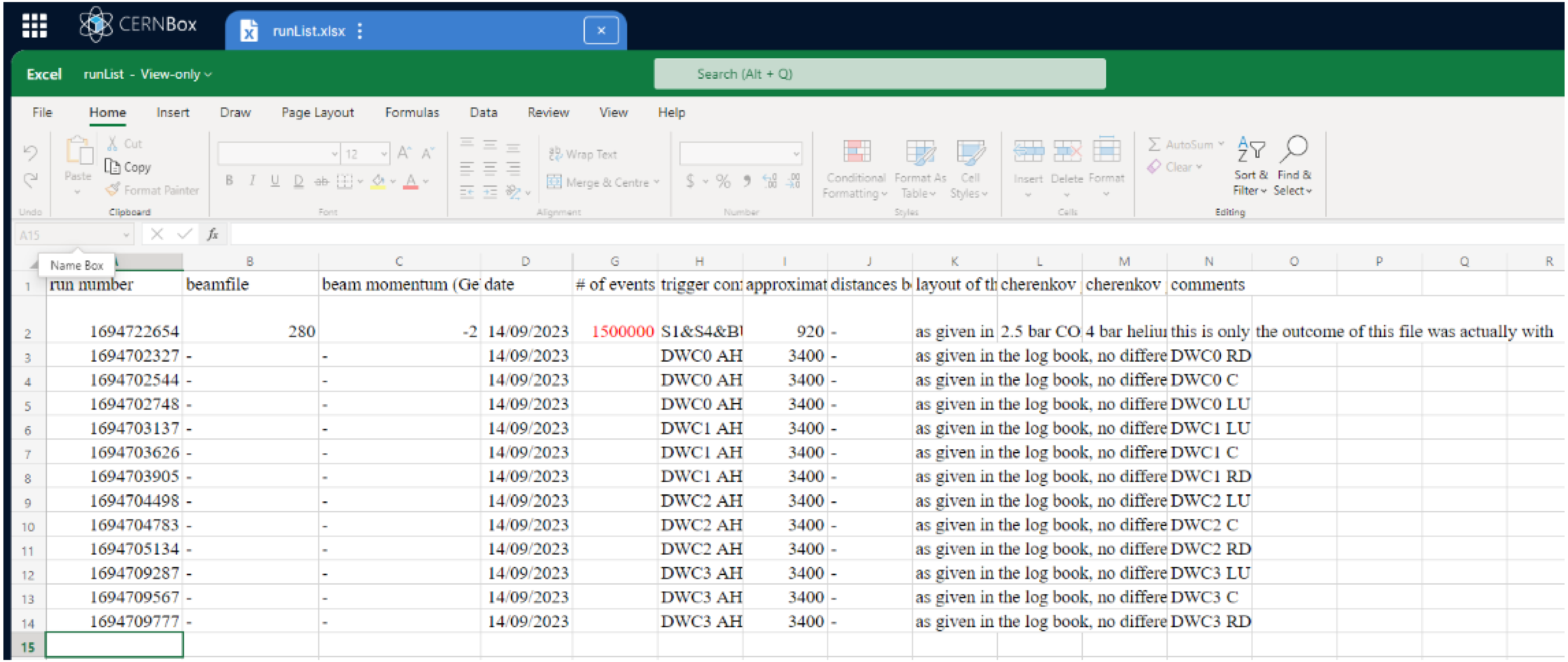
How do we organize ourselves: The Logbook



- You can find the logbook at https://cern.ch/bl4s2023-logbook2
- It is a „living document“, writtin in a language called Markdown
- Multiple persons can write and read the same document at the same time.
- We would ask you to help us document as many information as possible into this logbook
  - Information about each run (beam config, voltages, ...)
  - Meta data (alignment, distances, which setup, changes in equipment , ...)
  - Any special occurances (power outages, problems, bugs, ...)

- It will also be very helpful during data analysis!
- Don‘t worry, we will help you maintain and write the log book
- Remember: Runs are identified by their run number, the data files and the entries in the log book belonging to the same run will all carry the same number

How do we organize ourselves: List Of Runs



	A	B	C	D	G	H	I	J	K	L	M	N	O
1	run number	beamfile	beam momentum (Ge	date	# of events	trigger con	approximat	distances b	layout of th	cherenkov	cherenkov	comments	
2	1694722654	280	-2	14/09/2023	1500000	S1&S4&B	920	-	as given in	2.5 bar CO	4 bar heliu	this is only	the outcome of this file was actually with
3	1694702327	-	-	14/09/2023		DWC0 AH	3400	-	as given in the log book, no differe			DWC0 RD	
4	1694702544	-	-	14/09/2023		DWC0 AH	3400	-	as given in the log book, no differe			DWC0 C	
5	1694702748	-	-	14/09/2023		DWC0 AH	3400	-	as given in the log book, no differe			DWC0 LU	
6	1694703137	-	-	14/09/2023		DWC1 AH	3400	-	as given in the log book, no differe			DWC1 LU	
7	1694703626	-	-	14/09/2023		DWC1 AH	3400	-	as given in the log book, no differe			DWC1 C	
8	1694703905	-	-	14/09/2023		DWC1 AH	3400	-	as given in the log book, no differe			DWC1 RD	
9	1694704498	-	-	14/09/2023		DWC2 AH	3400	-	as given in the log book, no differe			DWC2 LU	
10	1694704783	-	-	14/09/2023		DWC2 AH	3400	-	as given in the log book, no differe			DWC2 C	
11	1694705134	-	-	14/09/2023		DWC2 AH	3400	-	as given in the log book, no differe			DWC2 RD	
12	1694709287	-	-	14/09/2023		DWC3 AH	3400	-	as given in the log book, no differe			DWC3 LU	
13	1694709567	-	-	14/09/2023		DWC3 AH	3400	-	as given in the log book, no differe			DWC3 C	
14	1694709777	-	-	14/09/2023		DWC3 AH	3400	-	as given in the log book, no differe			DWC3 RD	

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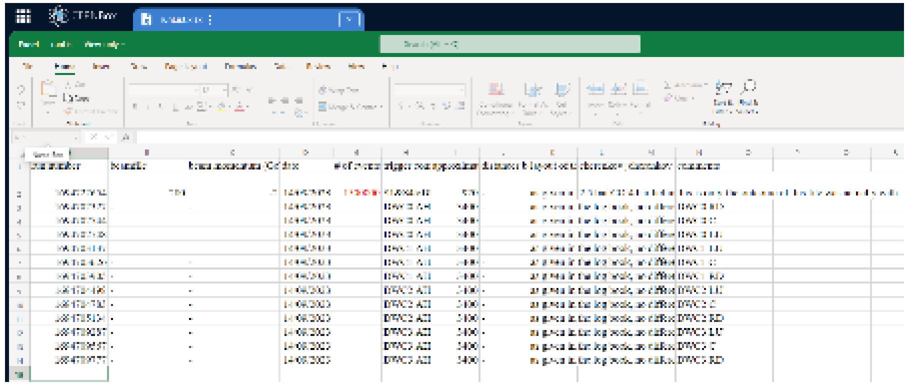

- The logbook is great to document things that are somewhat structured but allow also for some variations
- For example: some measurements and runs require different sensors and detectors to be online, sometimes you need additional information that is not required otherwise, etc.
- But: This flexibility can be confusing and make looking things up a bit tedious
- => We will try to compile a common set of data into spreadsheets where you can immediatley see which runs are interesting for certain applications
- => We will ask you to help here, again as part of your data analysis and beamline / counting room shifts

Thank you for your Attention!
Any Questions?