BL4S 2023 Introduction To Data Acquisition (Part I)

<u>Martin Schwinzerl</u>, Berare Gokturk :: CERN 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)



Remember This?

" **"Trigger it out"**Let's experience how trigger systems work!

- 1) If you talk with a person who does not belong to your team, take a photo
- 2) Upload the photos here:
 - https://cernbox.cern.ch/s/FYriJFRoTqJaq5T





⇒ We will discuss your observations in tomorrow's session on data acquisition!



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

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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!



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

Sort by: A-Z -





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





M. Schwinzerl, B. Goktürk | BL4S Introduction To DAQ Part I | 2023

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?





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!







• 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!





- 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!





- 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
 - => <u>https://op-webtools.web.cern.ch/vistar/vistars.php?usr=CPS</u>



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- 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?



- 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!



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About the How: Our Setup(s)

Setup 2: Carbinarcateiroins, e Alaidona, c Belang Cetapos in at least 2 different Hatbach Array configurations





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

Let's assume a simple system: two scintillators on top of each other, detecting cosmic muons → t Leading Trailing Edge Edge Trigger ⇒ t Trigger Match Window 2nd Hit, CH0 TDC 1st Hit, CH1 1st Hit, CH1 Offset Width



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



You Will Always Find a Table With These Mappings In The Log Book (cf. a bit later)! There is a relationship between the detectors and signals in our setup and the input channels of each of the devices in this unit:





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



- 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?

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- 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!
 - => <u>https://cern.ch/bl4s2023-mattermost</u>





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 <u>Markdown</u>
- 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

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How do we organize ourselves: List Of Runs

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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?



Sarah Zoechling | BL4S Welcome session 2023