NA62 data acquisition upgrade

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on behalf of the NA62 collaboration

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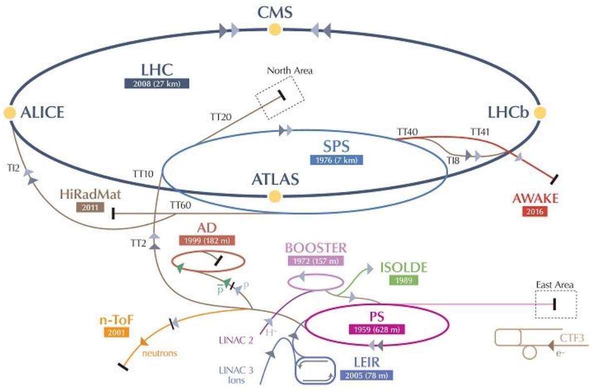
The NA62 experiment at CERN

NA62 is located at the CERN Super Proton Synchrotron

Aims at measuring the extremely rare kaon decay:
$K^+ \to \pi^+ \nu\nu$ $BR(K^+ \to \pi^+ \nu\nu) = (8.4 \pm 1.0) \times 10^{-11}$

10^{13} kaon decays need to be collected to measure it with a 10% precision



Data-taking	% of nominal intensity(*)	Decays recorded
2016	40%	5×10^{11}
2017-2018	60%	8×10^{12}
2021	100%	

100% of nominal intensity: kaon rate = 45 MHz

The NA62 trigger system

To reduce the data rate at a manageable level, NA62 uses two levels of triggers:

The **Level-0 (L0):** a hardware trigger implemented in an FPGA board called **L0TP** (Level-0 Trigger Processor).

Simple detectors associations.

Maximum trigger rate output: 1 MHz

The **Level-1 (L1):** a software trigger running on the DAQ-farm.

Complex algorithms.

Events rate reduction: 1 MHz → 100 kHz

Current NA62 data acquisition system

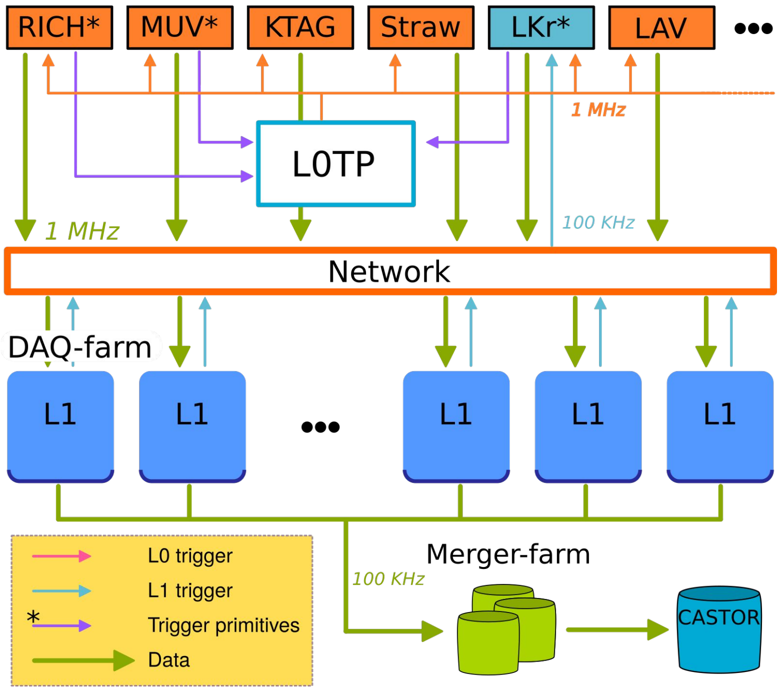
A subset of detectors produce the **trigger primitives**, the input of **L0TP**.

The readout generates the trigger primitives. The computation algorithm must not exceed 100 μs.

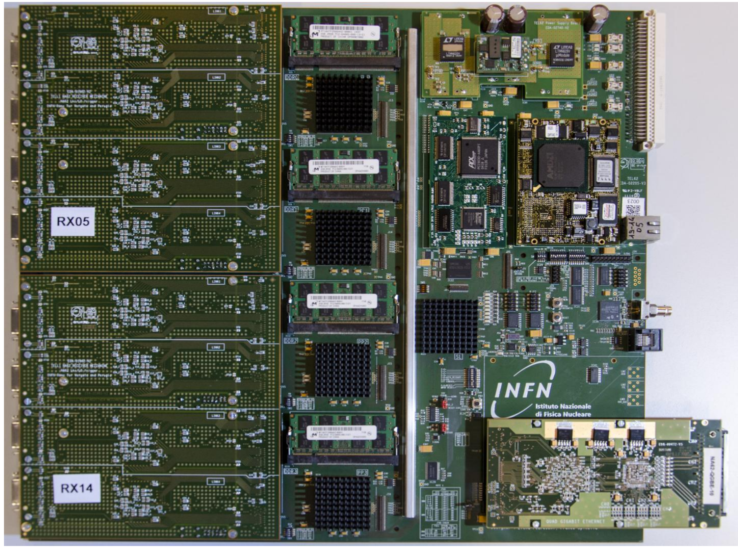
L0TP distributes the L0 triggers via TTC (Timing Trigger and Control system)

A partial event is built in the DAQ-farm.

The detectors that contribute the most in the event size are read out only after a positive L1 decision.



The TEL62 readout board

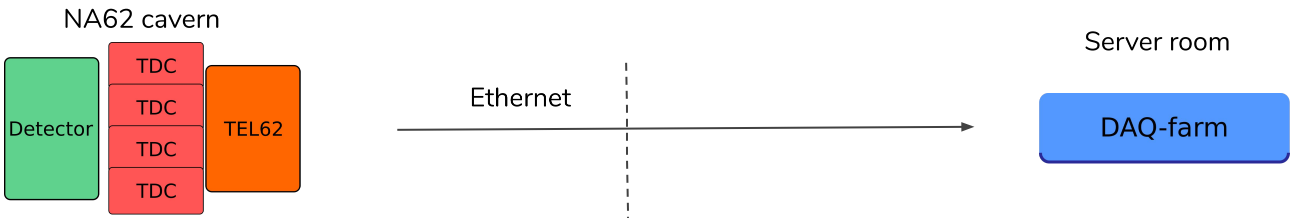


The TEL62 is an **integrated trigger and data acquisition board** used by the larger part of the detectors.

It can host up to four high-performance TDC boards

- Developed from the TELL1 board for the LHCb experiment (2006)
- Not designed to be radiation tolerant
- Has limitations at 100% of intensity especially for high rate detectors

The TEL62 readout concept



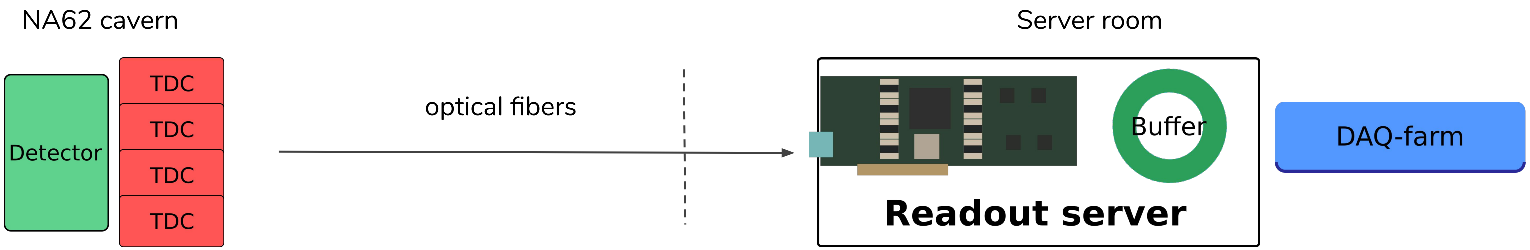
The TEL62 needs to perform lots of operations:

- Time To Digital conversion
- buffer the data (**limited**)
- produce the trigger primitives
- perform trigger matching
- pack the events in UDP data frames and send the to the DAQ-farm

Internal buffer limited to the readout memory.

For that reason the L0 trigger must arrive within **1 ms**.

The new readout concept



On-detector:

- Time To Digital conversion
- send out the data via optical fibers

Off-detector:

- receive the data via optical fibers
- buffer the data (**all the data can be cached**)
- produce the trigger primitives
- perform trigger matching
- pack the events in UDP data frames and send them to the DAQ-farm

minimise the electronic exposed to radiation

Sitting on a readout server located in a protected environment

The Front-End Link eXchange board FELIX

The FELIX hardware platform has been developed for the final implementation in the ATLAS Run 3 upgrade.

FELIX is designed to:

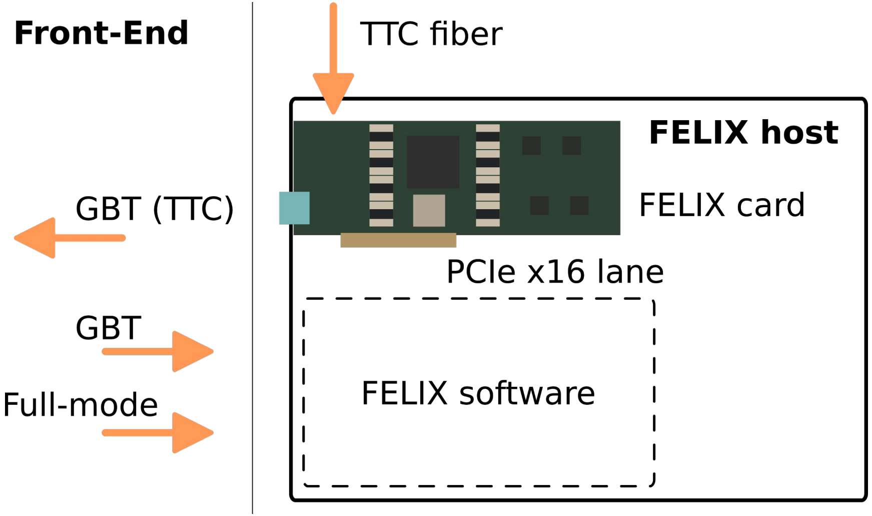
- act as a data router, receiving data from detector front-end electronics and sending on a commodity network through the readout server.
- be detector agnostic.

The FELIX system

The FELIX system consists of: the PCI express board, the firmware and the software that run on a Linux server.

Connectivity 2x MTP24/48 optical links.
Optional TTC mezzanine board.

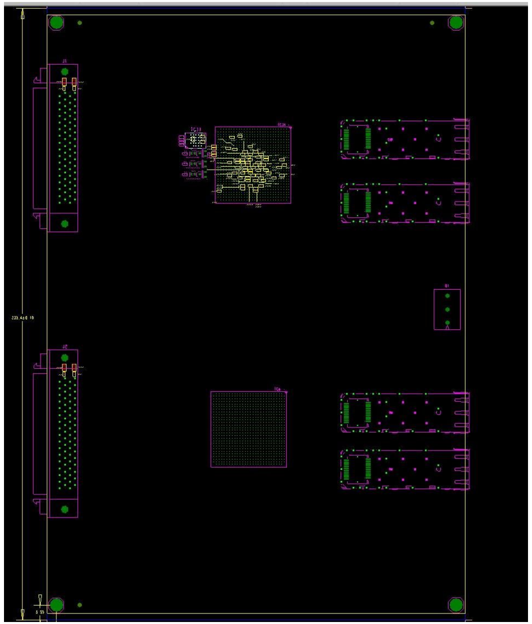
- FELIX -> Front-End: GBT (GigaBit Transceiver)
    - TTC clock distribution
    - Synchronous command distribution
    - runtime parameter loading
- Front-End -> FELIX
    - GBT
    - lightweight FULL mode designed for maximum throughput



On-detector: Custom TDC board

The design includes:

- 64 channels with 780 ps bin or 32 channels with 390 ps bin
- 2x CYCLONE10 FPGA
- 2x SFP links per FPGA:
  - 2x FULL mode: data to FELIX and slow control responses
  - 1x GBT for TTC and slow control request



Timeline and goals

NA62 will restart the data-taking in 2021 after the LS2.

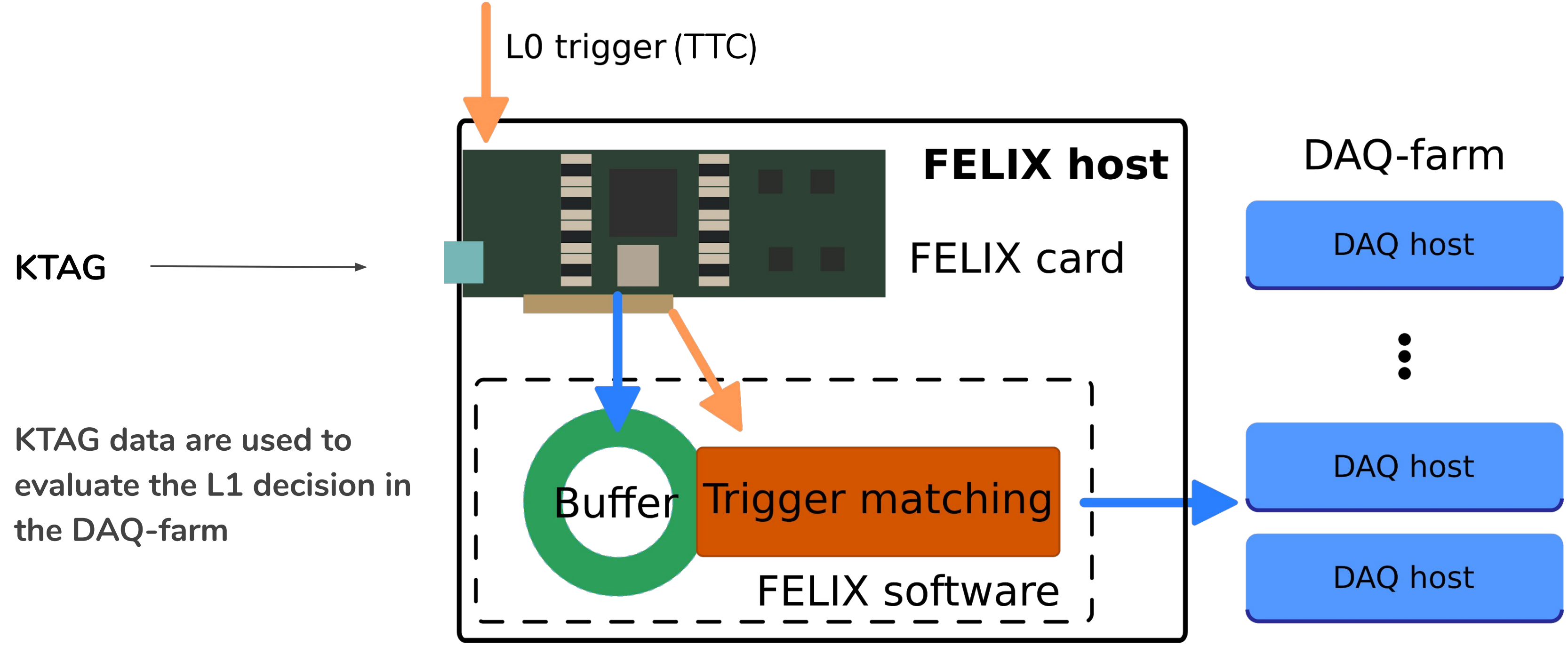
Goals:

- Equip **KTAG** and **CHANTI**, two high rate detectors, with new TDC and FELIX full readout.
- Demonstrate the capability to read data at 100% intensity
- Add NA62-specific trigger matching capabilities (**L0** or **L1**) in the FELIX host.

The TDC inputs plug is the same, will be possible to switch back to the old readout.

Will provide extra TEL62 **spares** for other detectors.

KTAG read with the Level-0 trigger

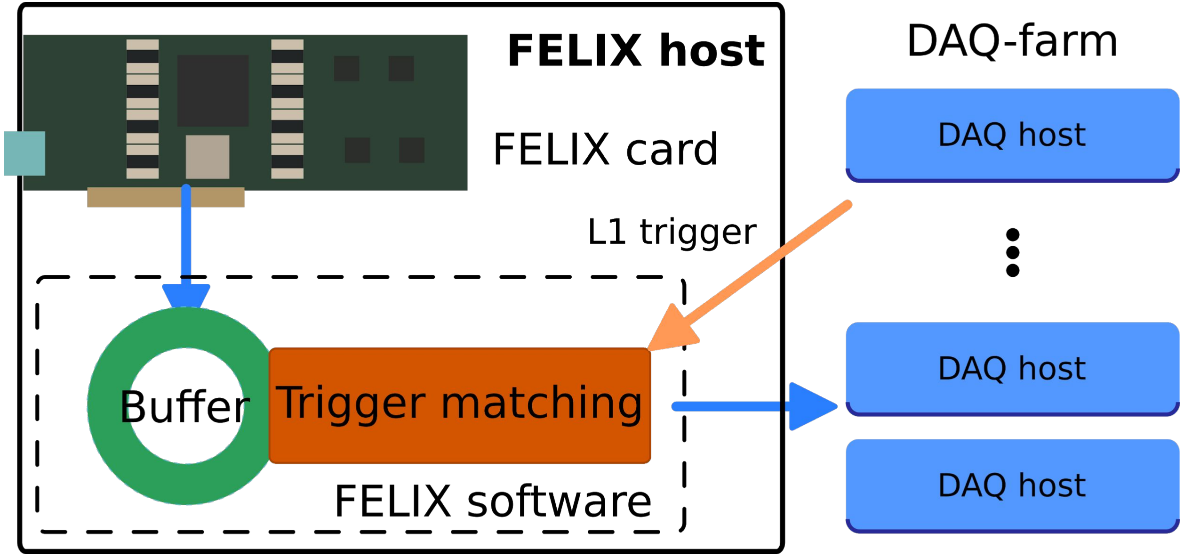


KTAG data are used to evaluate the L1 decision in the DAQ-farm

384 channels - 16x TDC boards 32 channels / 390 ps bin resolution - 3x FELIX servers

CHANTI read with the Level-1 trigger

CHANTI



CHANTI is not used in the trigger can be read at any level.

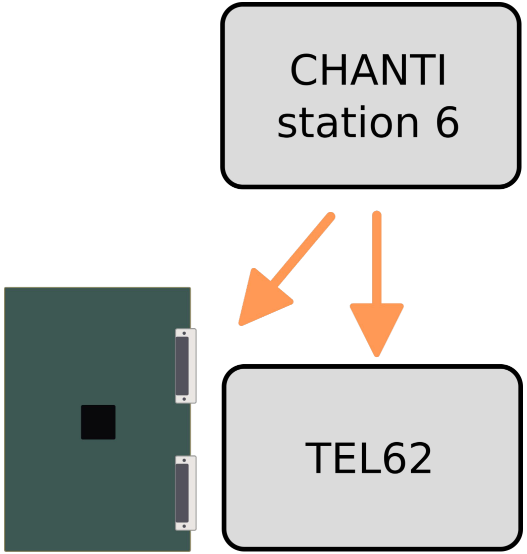
576 channels - 9x TDC boards 64 channels / 780 ps bin resolution - 2x FELIX servers

TDC prototype acquisition test during 2018 data-taking

Test done on 1 out of the 6 CHANTI stations with beam at 100% intensity.

CHANTI station channels duplicated and sent to the TEL62

- The test validated the new TDC
- **Full raw output saved**



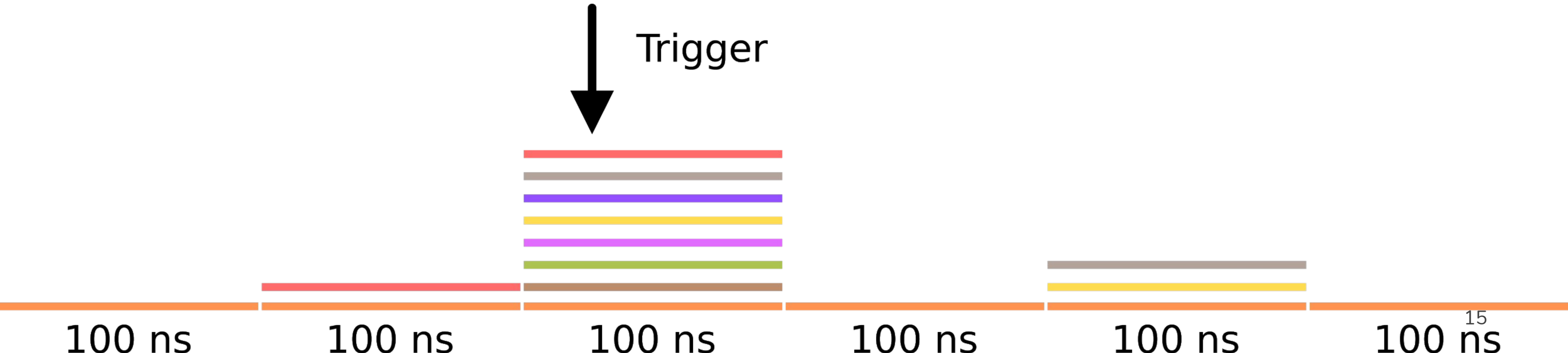
Trigger matching software

The trigger matching software uses:

- the raw data collected during TDC test (**words**)
- the L0 triggers

It is a C++ application that:

- loads the words into memory
- sorts the words in intervals of 100 ns (**sorting**)
- performs the **trigger matching** with the L0 triggers (75 ns window)



Trigger matching software

L0 triggers: $2x10^6$

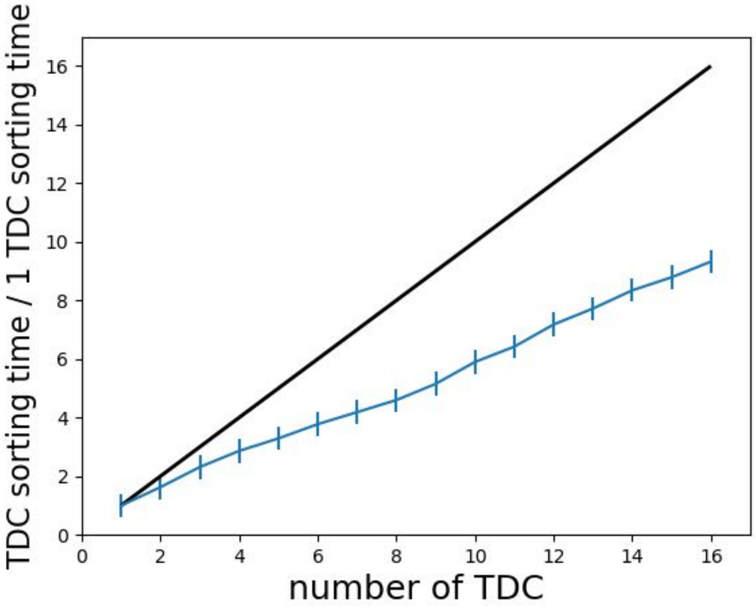
Average trigger rate: 520 KHz

4 seconds of data at 100% intensity.

1 out of 6 CHANTI stations

- Sorting: **~3.3 s**
- Trigger matching: **0.3 s**

Using 1 thread of an Intel Xeon Silver 4214 @2.2 GHz CPU



Conclusions

- I showed you the design of the NA62 data acquisition upgrade
- This is the first step towards a completely asynchronous readout system
- The first results with trigger matching software using data at full intensity show that is possible to cope with the event rate
- FELIX software can handle the L1 triggers from the DAQ-farm

What's next?

- TDC prototypes will arrive in November
- Start testing the communication between FELIX and the TDC board
- Prepare the FELIX software to handle L0 triggers