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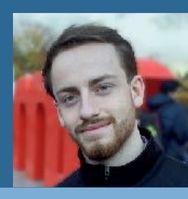
FELIX Goes to the DUNEs

FELIX-based readout of the Single-Phase ProtoDUNE detector



Andrea Borga[1], Eric Church[2], Frank Filthaut[1,3], Enrico Gamberini[4], Paul de Jong[1,5], Giovanna Lehmann Miotto[4], Frans Schreuder[1], Jörn Schumacher[4], Roland Sipos[4], Milo Vermeulen[1], Kevin Wierman[2], Lynn Wood[2]

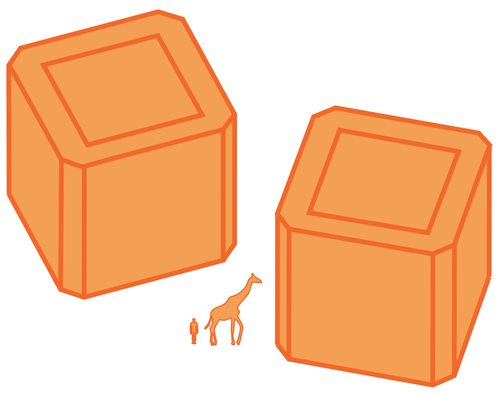
1. Nikhef 2. Pacific Northwest National Laboratory 3. Radboud University 4. CERN 5. University of Amsterdam

Contact: milov@nikhef.nl

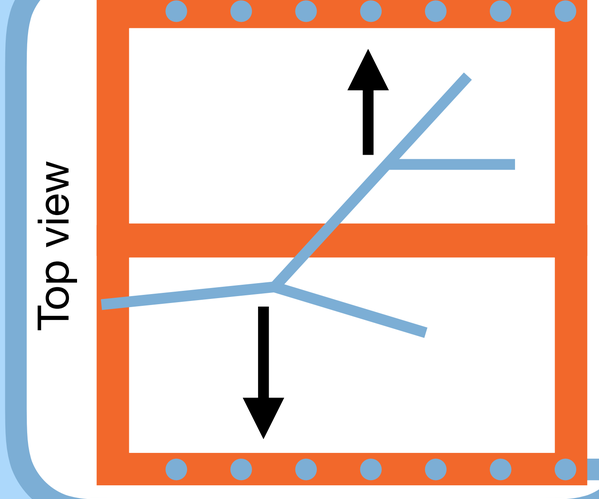
The ProtoDUNE detectors at CERN are prototypes for the far detector of DUNE, an upcoming neutrino experiment in the USA. They are meant to validate the technology behind large liquid argon time projection chambers at full scale and will receive SPS beam particles from August until November 2018. The FELIX (Front-End LInk eXchange) data acquisition system is envisioned to read out one sixth of the single-phase ProtoDUNE detector (ProtoDUNE-SP). It is based on the concept that a thin interface between the detector front-end and commodity servers provides superior system flexibility and longevity.

ProtoDUNE

The ProtoDUNEs feature approximately cubic liquid argon cryostats that encapsulate their respective time projection chambers. Charged particles travelling through the detector medium leave an ionisation track in their wake.



The scale of the ProtoDUNEs



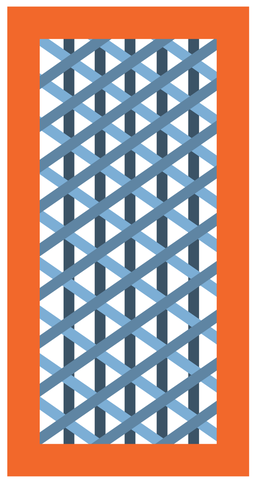
A strong electric field pulls the ionisation tracks into anode wires on either side of the detector. Recording the time and location of collected charge allows for the reconstruction of the original event.[1]

The anode wire planes are modular: ProtoDUNE-SP has three on either side, but the first DUNE far detector module is envisioned to use 150 in total.[2]

Cold electronics in the detector digitise signals recorded by wires at 2 MHz. Warm interface boards (WIBs) then group the resulting channels into frames, each of which consists of a single time slice of 256 channels.

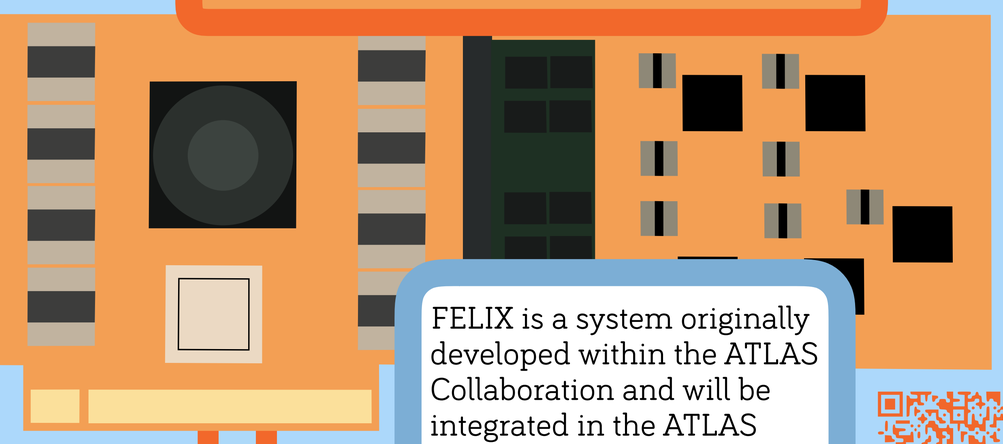
FELIX will read out one of ProtoDUNE-SP's APAs. Since an APA holds 2560 wires in total, 10 frames are sent out to FELIX per time slice, each over a separate link. The total data transfer, including 8b/10b overhead, amounts to 96 Gb/s.[1]

Anode Plane Assembly (APA)



Each APA consists of three wire planes: two induction planes and a collection plane. Due to the angle between the wires of different planes, the location of any collected charge can be reduced to a point.

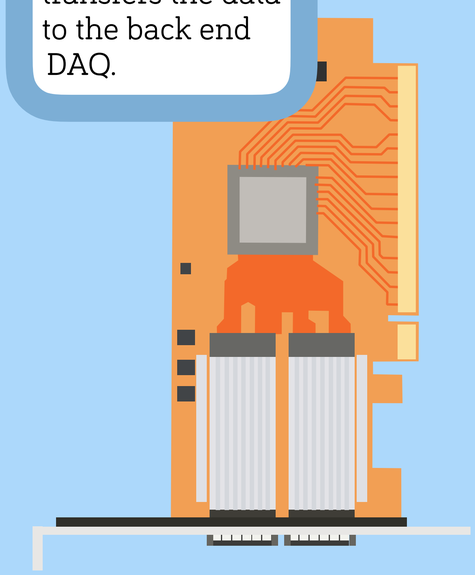
FLX-711 FPGA Board



The FLX-711 board features a 16-lane Gen3 PCIe slot capable of outputting data at 128 Gb/s. The system performs continuous 75 Gb/s DMA transfer to its host PC's memory.[3]

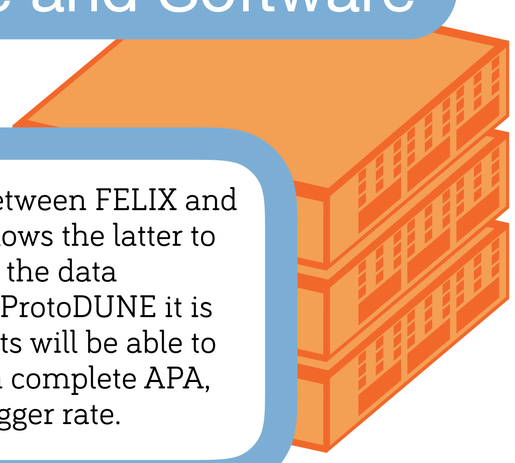
Using a PCIe card as a front-end interface allows for the use of off-the-shelf and upgradeable hardware. FELIX software in the host PC controls the complete FELIX system, including data transfer to the network.

A 2x100 Gb/s network card transfers the data to the back end DAQ.



FELIX is a system originally developed within the ATLAS Collaboration and will be integrated in the ATLAS detector during its Phase-I upgrades in 2019.[3]

Hardware and Software



The network layer between FELIX and the back end DAQ allows the latter to be sized according to the data processing needs. In ProtoDUNE it is expected that 1-2 hosts will be able to deal with data from a complete APA, depending on the trigger rate.

Data are received through the NetIO[4] messaging service. Based on a requested trigger timestamp, a range of data is selected to be passed on to the event builders.

In order to minimise long-term storage requirements, data are losslessly compressed online. The compression is carried out via Intel® QuickAssist Technology (QAT)[5], thereby minimising the necessary computing resources.

FELIX back end software elements

NetIO[4] messaging layer

WIB link separation

Trigger-matching in a circular buffer

QAT[5] data compression

Conclusion

FELIX is a cutting-edge solution for long-lasting systems that require capable and flexible data acquisition. Its generally applicable hardware ensures the longevity of the system and allows for the use of more complex software. The challenges faced within the ProtoDUNE-SP project have been as good as overcome: on a single link, the nominal design requirements have been exceeded. The system is now moving towards data taking stability in expectation of the SPS beam at the end of August.

Acknowledgements

We would like to thank the ATLAS collaboration for having shared the FELIX hardware, firmware and software developments with us.

References

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DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

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