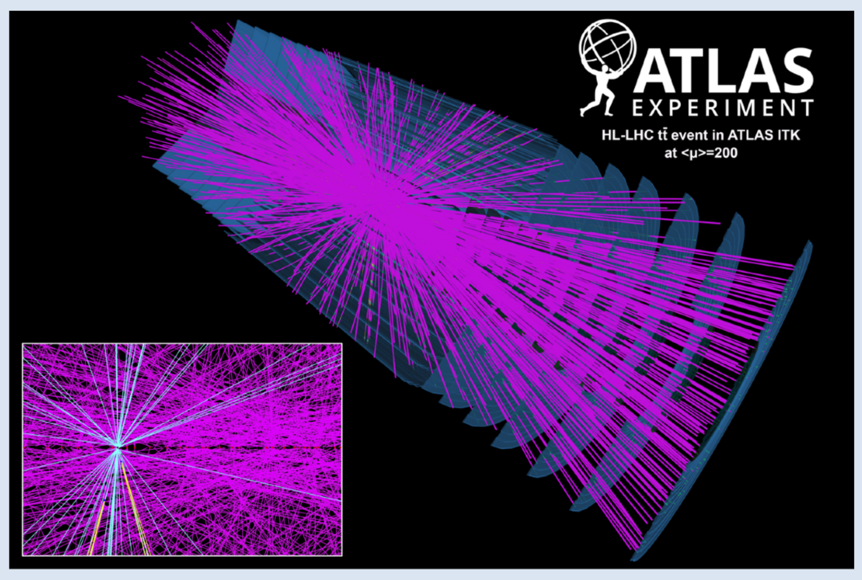
The Opto-electrical conversion system for the data transmission chain of the ATLAS ITk Pixel detector upgrade for the HL-LHC

High particle density and data rate in the HL-LHC call for the new ITk detector in ATLAS

The High-Luminosity LHC will deliver an average of 200 collisions per bunch-crossing.
In ATLAS, this large flux of particles will be detected by the new Inner Tracker (ITk) detector.



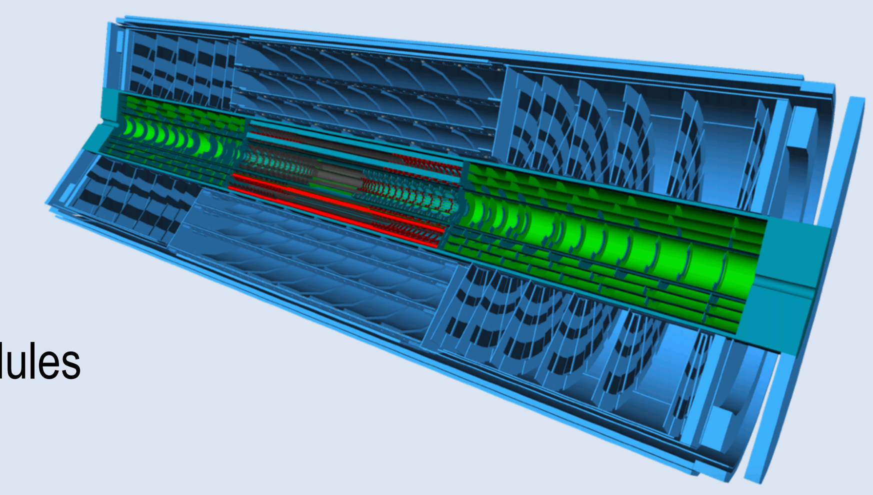
Simulated event display of a HL-LHC tt event in ATLAS ITk.

The ITk will feature highly segmented, radiation-hard modules and fast read-out electronics.

The ITk Pixel detector comprises about 10000 modules, each sending data at a rate up to 5.12 Gb/s.

Its layout consists of:

- an Inner System, with flat and ring modules
- an Outer Barrel, with flat and inclined modules
- an Outer Endcap, with ring modules



CAD of the ITk detector. The innermost layers are the Pixel section.

See F. Munoz Sanchez's talk, https://indico.cern.ch/event/981823/contributions/4293588/

The data transmission chain of the ITk Pixel

The ITk Pixel data transmission (DT) chain transports the detector signals from the modules to the readout cards in the electronics room (and trigger and command in the opposite direction).

The Opto-electrical conversion system (**Optosystem**) is the key stage that allows for electrical signal recovery, serialisation and conversion to optical.

Specifications:

- Multiple 6x 1.28 Gb/s data signals from detector (uplink) to 1x 10.24 Gb/s optical signals
- 1x 2.56 Gb/s trigger and commands (downlink) to 8x 160 Mb/s electrical lines
- Radiation-hard components (expected NIEL: 7x10^{14} n_{eq}/cm^2, TID: 50 kGy)
- Independent powering of elements reading separate serial powering (SP) chains
- Very limited space at R~1450 mm, z ~ 3500 mm
- Compliant with cooling and grounding and shielding specifications

The Optoboard

The Optoboard.

It is the heart of the Optosystem.

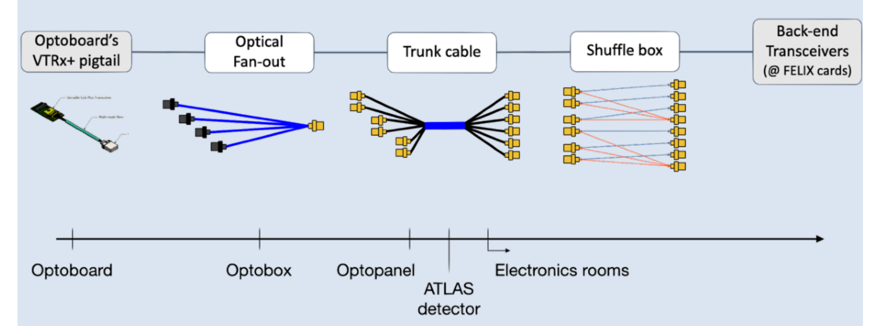
It hosts radiation-hard, custom-made chips:

- four GBCRs (Gigabit Cable Receivers) recover the signals coming from the detector (uplinks) after ~6 m of electrical cables (twinax) and ~1 m on-detector services
- four lpGBTs (low-power GigaBit Transceivers) serialise 6 uplinks at 1.28 Gb/s into a single 10.24 Gb/s line
- the VTRx+ module converts the electrical signal into optical

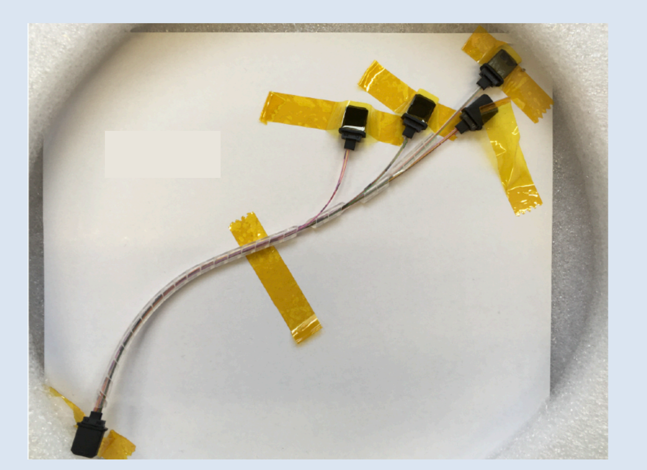
The twinax cables are soldered on the Termination board connected to the Optoboard.

The optical fibre system

Transmits the optical signals from the VTRx+ module to the FELIX readout cards.



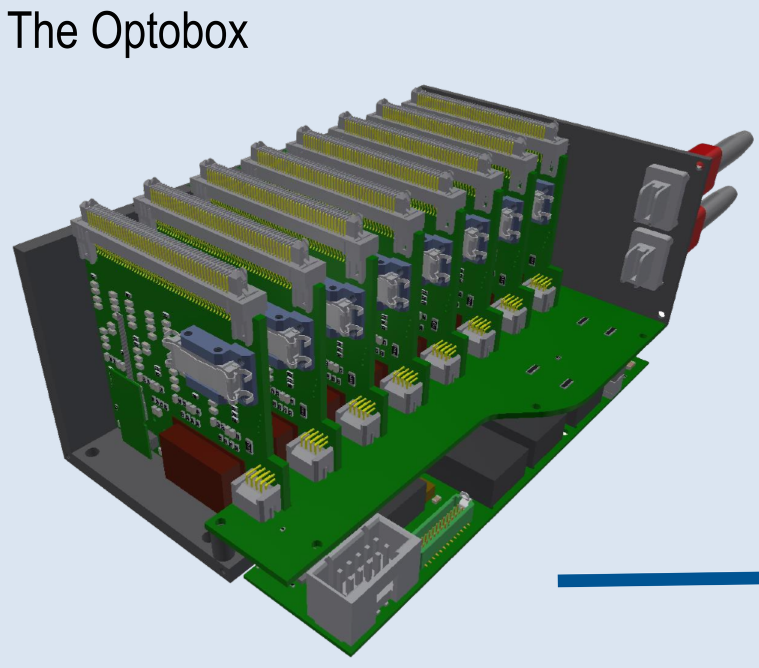
- Several flavours of optical fan-outs and shuffle boxes optimise the number of active fibres bringing signal between the detector and the readout cards (FELIX)



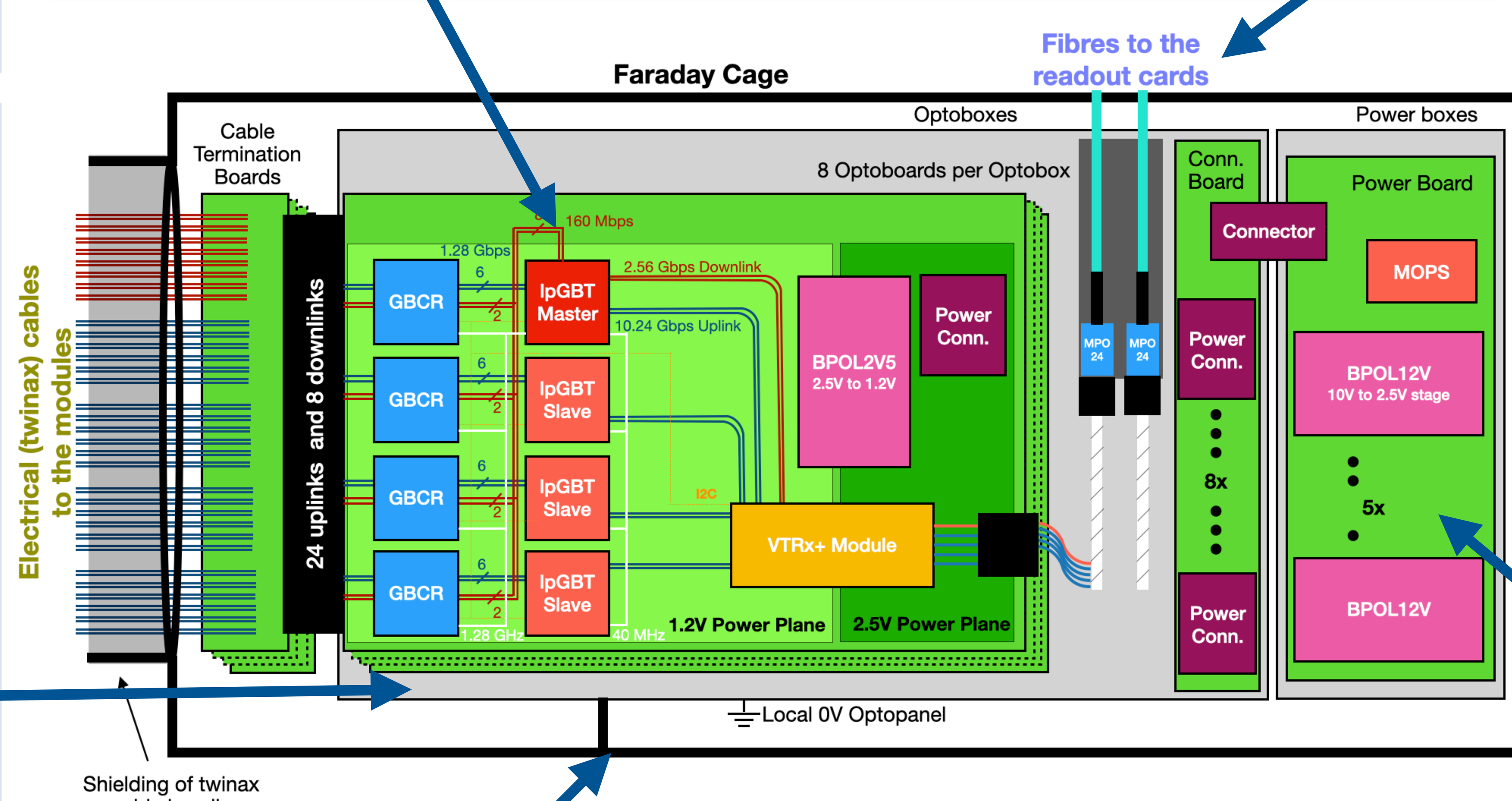
First prototype of the in-box optical fan-out.

The mechanics

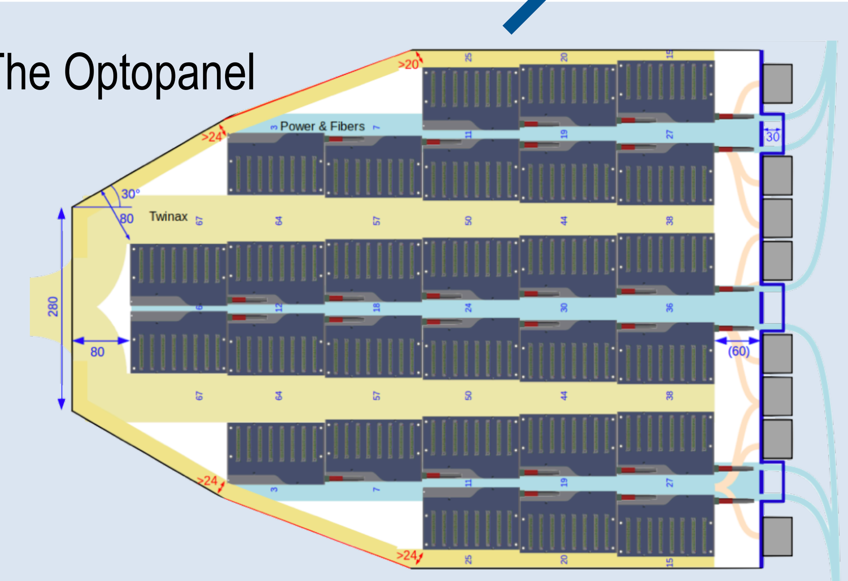
The Optobox



CAD of an open Optobox. Optical fibres are not shown. On the bottom right, the Powerboard.



The Optopanel



Design of the Optopanel.

The Optopanel is the Faraday cage of the Optosystem

- There are four Optopanels per ATLAS side
- Each Optopanel contains 28 Optoboxes
- Optoboxes are arranged in rows, to form twinax-cable channels and optical-fibre channels
- Entrance for twinax cables, OptoPatchPanel for connectors and fibres
- Its floor is a cooling plate, for thermal management

The Optobox hosts:

- up to 8 Optoboards
- the optical fan-out fibres
- the Connector board

The Powerboard is hosted by the Powerbox.

The Optosystem consists of 222 Optoboxes

- Each Optobox contains Optoboards that read only a type of sub-detector

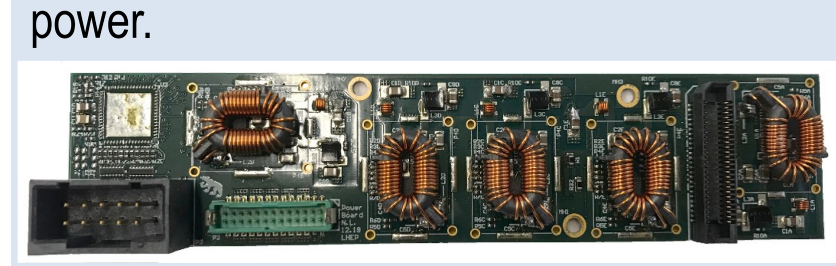
The powering scheme

Custom-made DCDC converters distribute the power to the Optosystem chips:

- bPOL12V converts 9 V into 2.5 V (5 chips on each Powerboard)
- bPOL2V5 converts 2.5 V into 1.2 V (1 chip on a separate carrier board, mounted on each Optoboard)

Only Optoboards reading the same SP chain are biased by the same bPOL12V.

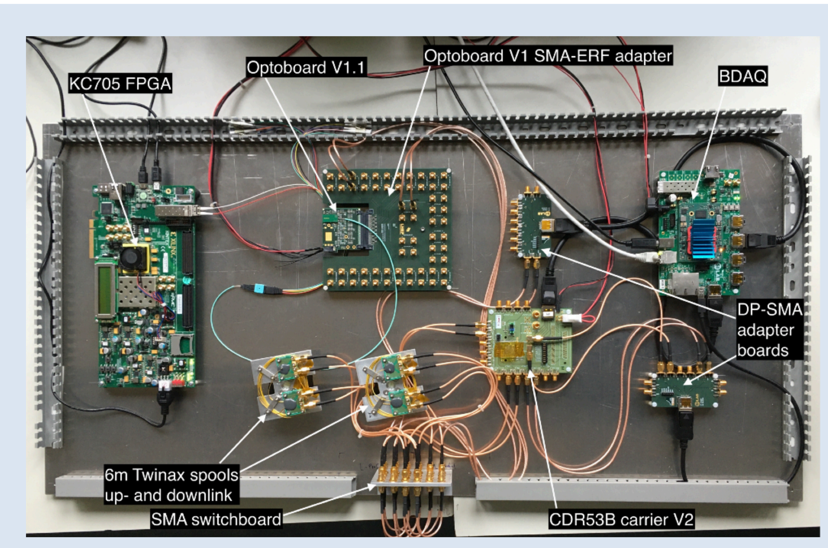
The Connector board distributes the 2.5 V power.



The Powerboard.

Validation of the Optosystem

- Tests on the single components: VTRx+, lpGBT, GBCR (e.g. Bit Error Rate (BER) and jitter tests, scan of the setting phase space to find optimal values)
- Tests of the first two prototypes of the Optoboards, as individual elements and in the data transmission setup
- BER and jitter tests, to validate the DT chain
- First test on complete DT chain, from FELIX card to readout chip
- Irradiation of components of the DT chain (see L. Halser's talk, https://indico.cern.ch/event/981823/contributions/4293580/)
- Experimental verification of the powering scheme concept
- Tests and simulation of the thermal management



The Bern data transmission setup.

Laura Franconi, University of Bern — laura.franconi@cern.ch

TIPP conference, May 2021