THE HIGH-SPEED OPTO-ELECTRICAL CONVERSION SYSTEM FOR THE READOUT OF THE ATLAS ITK PIXEL UPGRADE

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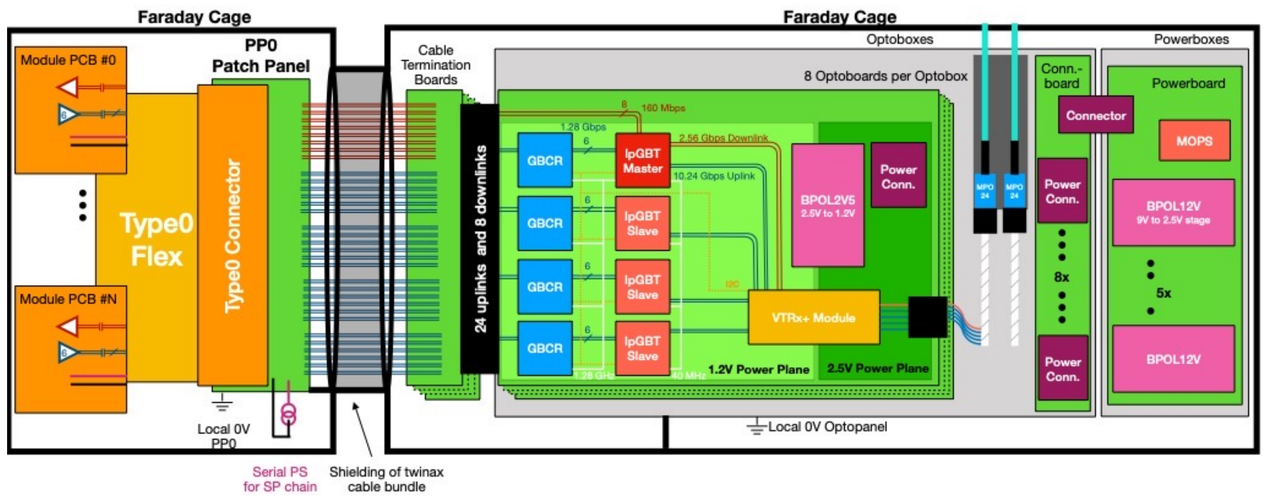
THE ATLAS ITK PIXEL DETECTOR AND READOUT SYSTEM

In 2029, **the high-luminosity LHC** (HL-LHC) will start to operate with an increased average of **200 interactions per bunch crossing at 40 MHz**. This new state of operation imposes higher constraints on the ATLAS detector. As a result, **the Inner Detector (ID) will be replaced by the Inner Tracker (ITk)**, which is designed to meet the new requirements such as:

- **An increased granularity** with $5 \cdot 10^9$ electrical channels for the ITk , 50x more compared to the current ID.
- A read-out speed of 1MHz corresponding to **50 Tbps.**
- **Radiation resistant** up to a foreseen maximum integrated dose of ~10 Mgy.

The Optosystem is the central component of the ITk pixel detector read-out system:

- **~1600 Optoboards** located inside the ATLAS detector.
- Opto-electrical conversion and transmission to around **190 FELIX cards.**
- More than **4000 optical fibres** for communication.

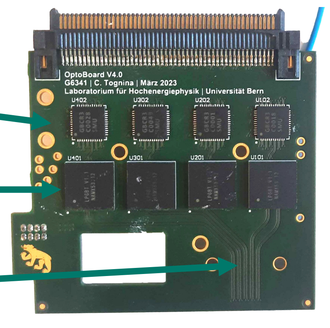


Overview of the data Transmission chain of the ITK pixel read-out.

THE ITK PIXEL OPTOSYSTEM ELECTRICAL COMPONENTS

Optoboards with

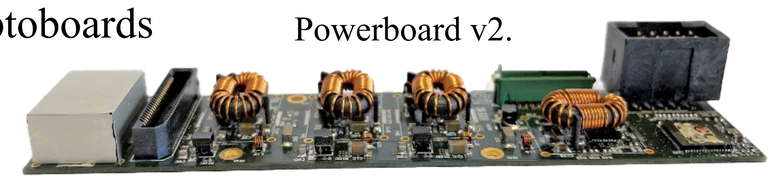
- **GBCR** chips (equalization)
- **lpGBT** chip (serialization)
- **VTRx+** chip (opto-electrical conversion)



Optoboard V4.

Powerboards to power up to 8 Optoboards and monitor the Optosystem.

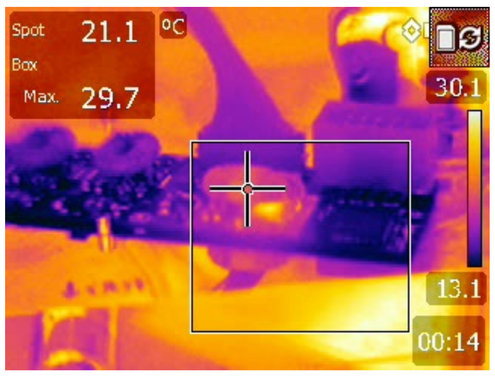
Powerboard v2.

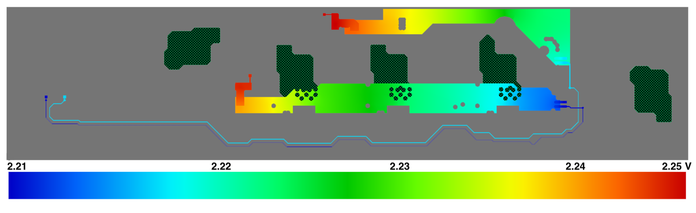


Composed of **1 MOPS chip** for temperature and voltage monitoring and **5 bPOL12V DC-DC buck converters** converting 9V from the ATLAS cavern to 2.5V.

I. POWERBOARD TESTS

- The bPOL12V output voltage range is defined and successfully tested over a range of loads. **Conversion efficiency is above 70%.**
- Other tests performed: **Voltage drop characterisation**; **Temperature management** with thermal paste.
- The component was also tested after being irradiated (see Part II).

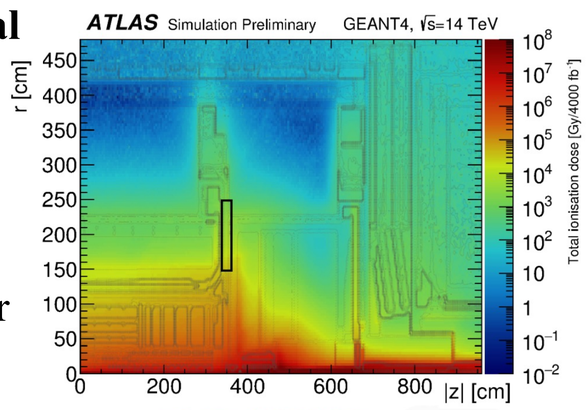




(top): Voltage drop simulation of the Powerboard.
(Left): Thermal camera image to monitor the heat of the bPOL12V.

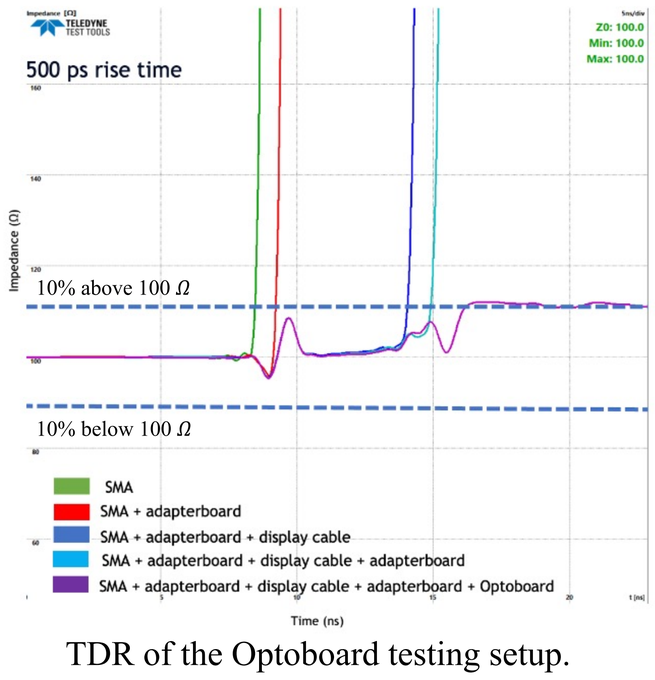
II. IRRADIATION STUDIES AT CYCLOTRON

- The Optosystem will receive **a total dose of 45.8 kGy** for the HL-LHC phase of the LHC.
- All components were irradiated at **the Bern Cyclotron facility** to a total dose of 150 kGy (safety factor of 3).
- All components were successfully tested after irradiation.



Simulation of the radiation dose in ATLAS and the position of the Optosystem. [1]

III. TIME DOMAIN REFLECTOMETRY (TDR)

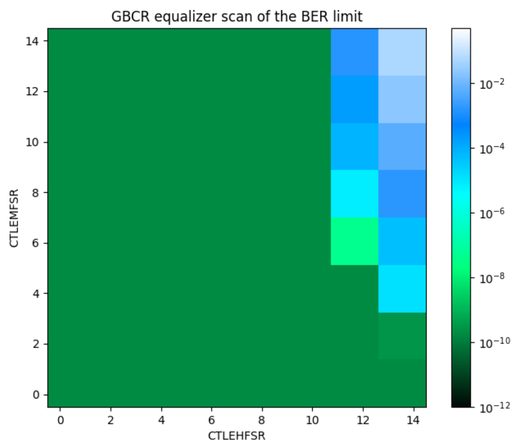


TDR of the Optoboard testing setup.

- Tool used for **impedance matching** of the electrical component.
- Differential impedance required to be at **100 Ω within 10%.**
- The Optoboard testing setup passed the requirement.

IV. OPTOBOARD TEST : BER LIMIT

- **The Bit Error Ratio** (BER) to 95 % confidence limit of the system must be below 10^{-12}.
- The BER limit didn't change during and after irradiation of the Optoboard.
- The equalization **parameters of the GBCR can be adapted** resulting in a different BER.



BER limit at different GBCR configuration.

OUTLOOK

- Towards production of the Optosystem. **More than 5000 components need to be tested and validated.**
- **Test setups finalized** in September for arrival of first batches of components.
- Finalization of **the software for system tests.**

References: [1] ATLAS Collaboration. Radiation simulation public results. https://twiki.cern.ch/twiki/bin/view/%20AtlasPublic/RadiationSimulationPublicResults#Phase_II_ITk_Inclined_Duals_Apri