The ITk Pixel OptoSystem for the Phase-II Upgrade of the ATLAS detector

30th June 2022, SPS Annual Meeting

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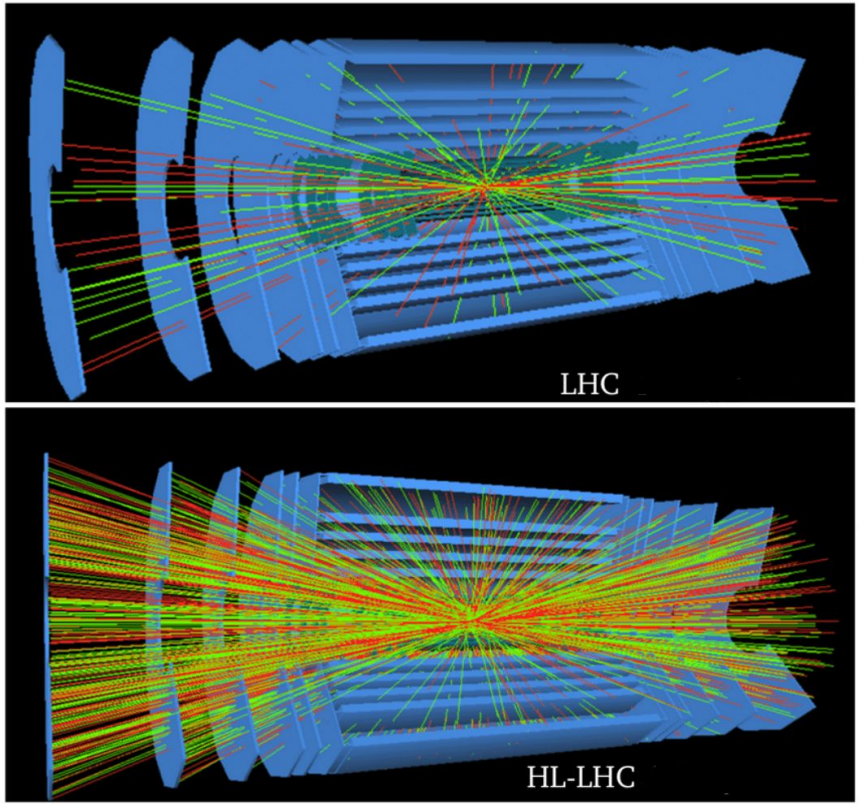
Motivations for ITk

The High-Lumi LHC will deliver on average *200 collision per bunch crossing* @ 40MHz. In order to maintain an effective particle reconstruction, an upgrade of the *ATLAS Inner Detector* is necessary.

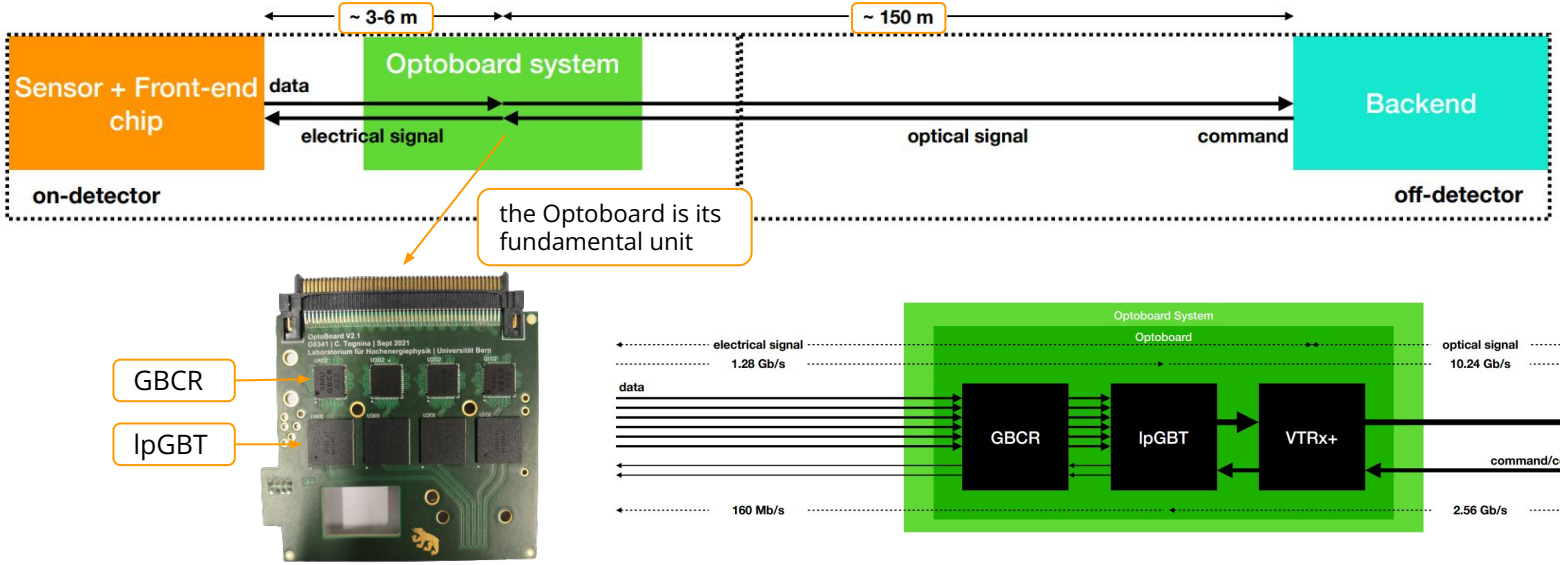
Characteristics required for Inner Tracker (ITk):

- highly segmented detector (from 92M pixel channels and 6M strip channels to 5G and 50M)
- radiation-hard components
- coverage up to $|\eta|=4$
- fast read-out electronics



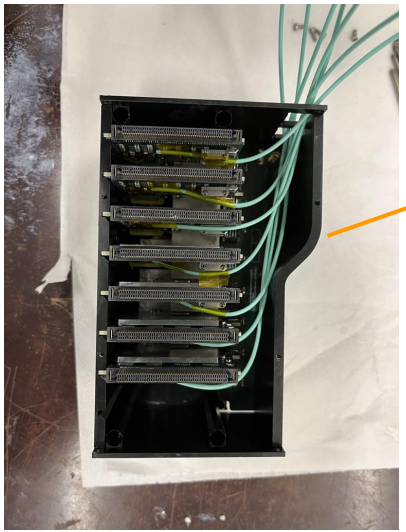
ITk Pixel Data Transmission Chain

- The ITk Pixel must be read out at 1MHz
- One of the pivotal components of the ITk is the OptoSystem
  - It handles the aggregation of signals from the sensors and the conversion from electrical to optical (and vice versa)

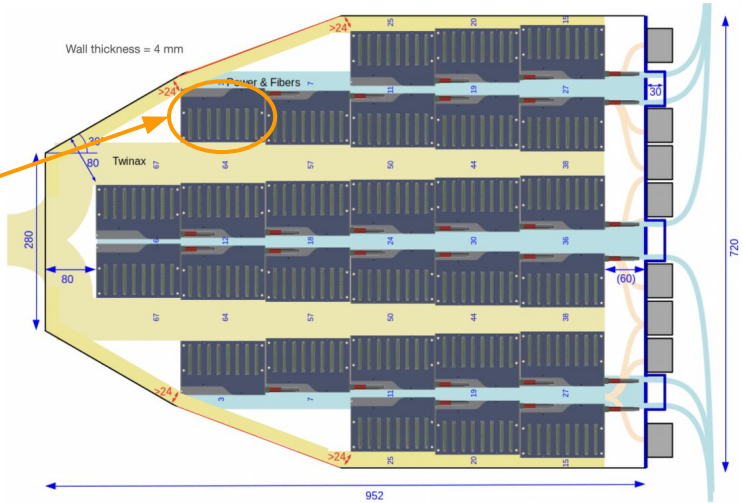


ITk Pixel Data Transmission Chain

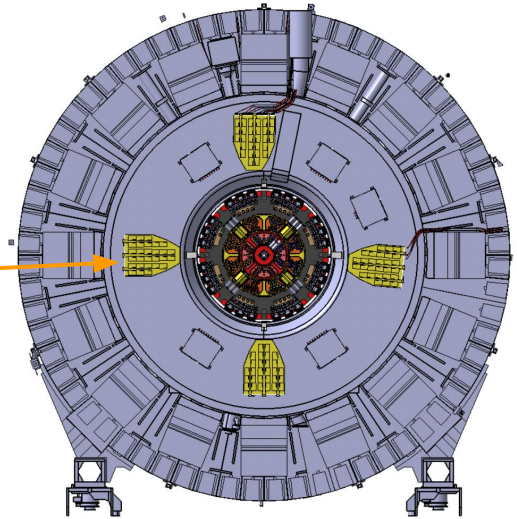
- 1564 Optoboards organized in Optoboxes located in 8 Optopanels: 4124 active fibers



First populated Optobox



28 Optoboxes are housed in each Optopanel

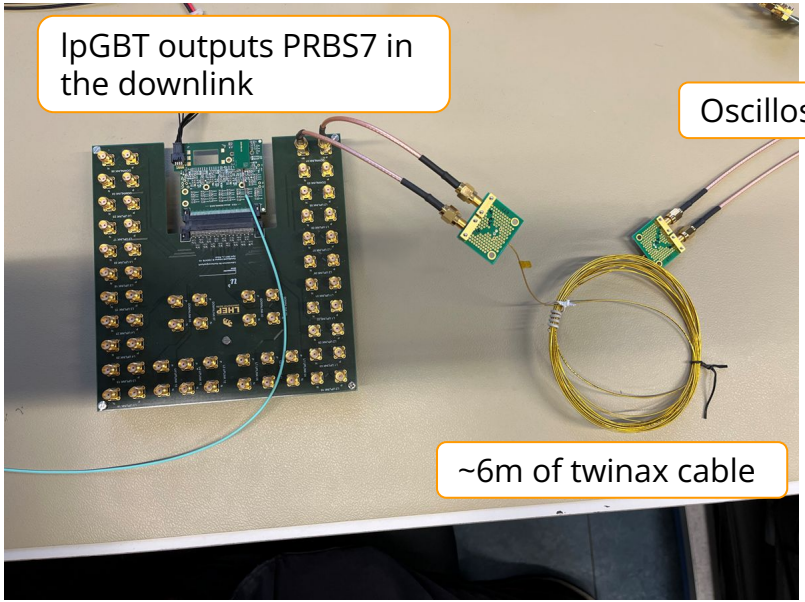


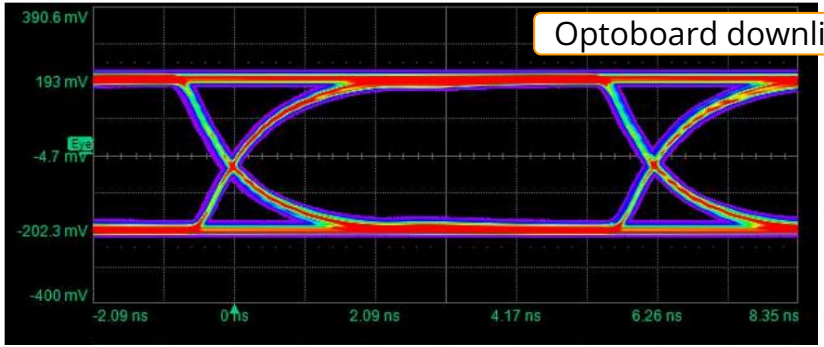
4 Optopanels on the ITk endplate on each side of ATLAS

Quality Test of the Data Transmission: downlink

Downlink: transmission line from the servers to the detector module

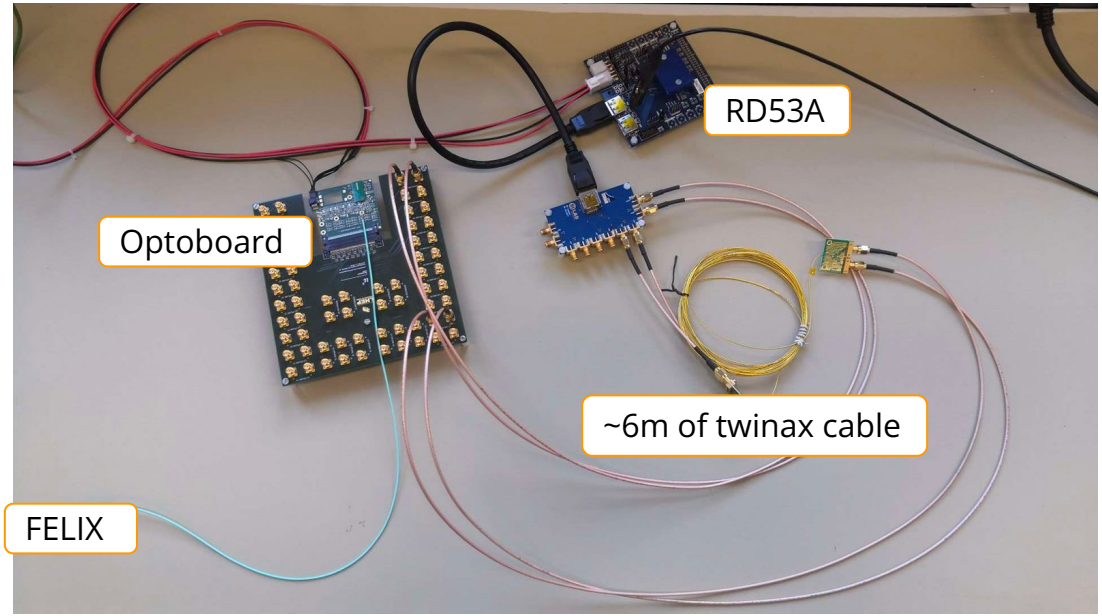
Eye diagram: a digital signal stream is sampled and the chunks are superposed and displayed



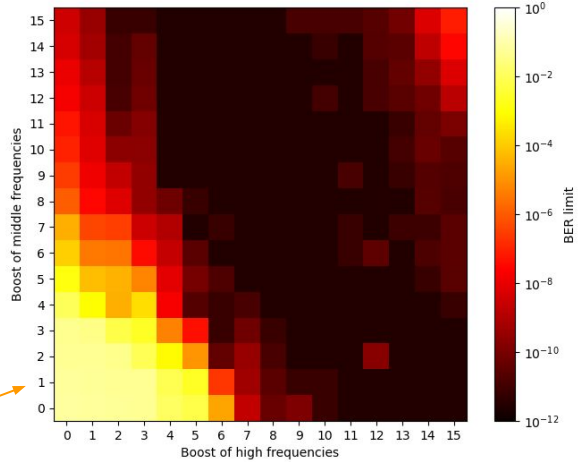


Quality Test of the Data Transmission: uplink

Uplink: transmission line from the detector module to the servers



- the pixel module (RD53A) outputs a PRBS7 pattern;
- a pattern checker on the lpGBT analyses the signal;
- BER tests are performed changing the parameters of the equalizer of the GBCR.



The ITk demonstrator

To finalize the design of the High-Lumi Upgrade, it's crucial to build a **demonstrator**:

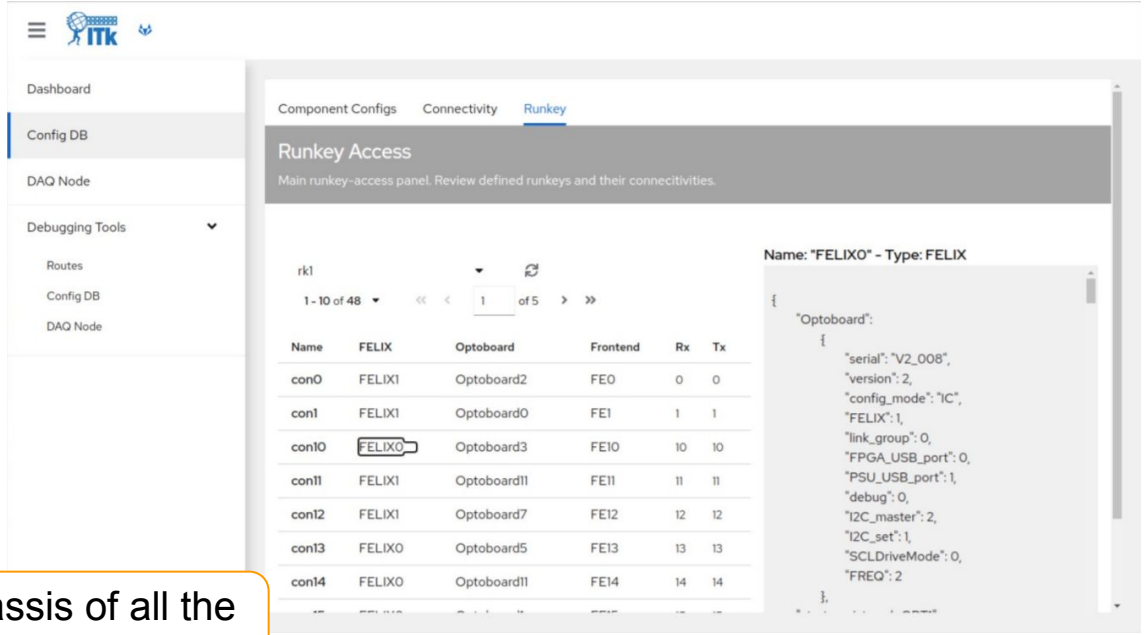
- data transmission with the final components;
- mechanics, cooling, grounding, shielding & powering;
- detector control system.

A **user-friendly GUI** is under development to simplify the operation of the demonstrator:

- access the configuration database & configure each part of the demonstrator;
- interface with the DAQ;
- visualize the results.

The ITk demonstrator software project

- architecture: set of microservices accessible from a browser GUI
- this GUI will also be used during the operation of ATLAS during High-Lumi



Chassis of all the microservices

The Optoboard GUI

Optoboard Browser GUI

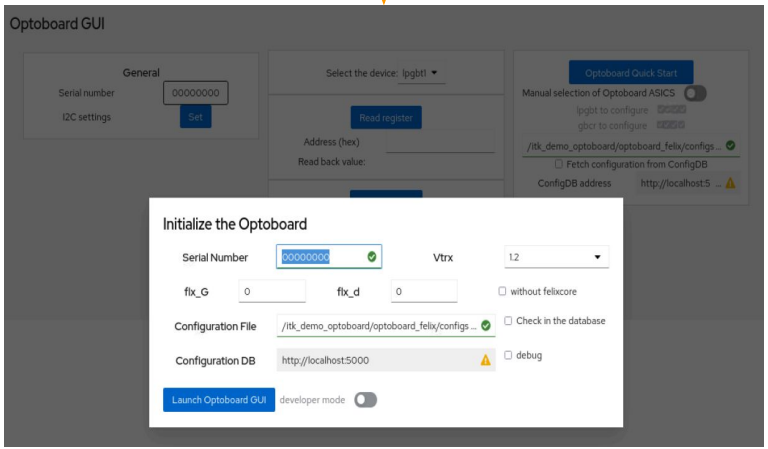
HTTP requests

Flask framework:

1- render the GUI
2- route the requests from the client (GUI) to the backend

Task queue and message broker

Backend to interface FELIX with Python API



Work to make the GUI accessible via web is in progress

Outlook

Future activities:

- **support activities** for the tests on the demonstrator and finalization of the **development of the Optoboard GUI;**
- **loopback BERT on the downlink** of the Optoboard;
- **test of the data transmission** with the final design components;
- **thermal** test of the **Optopanels;**
- **radiation hardness** test of the Optoboard.

More info about **irradiation tests** will be given in the next talk by Dr. A. O'Neill.

Thanks for the attention
Questions ?

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ATLAS EXPERIMENT

Backup


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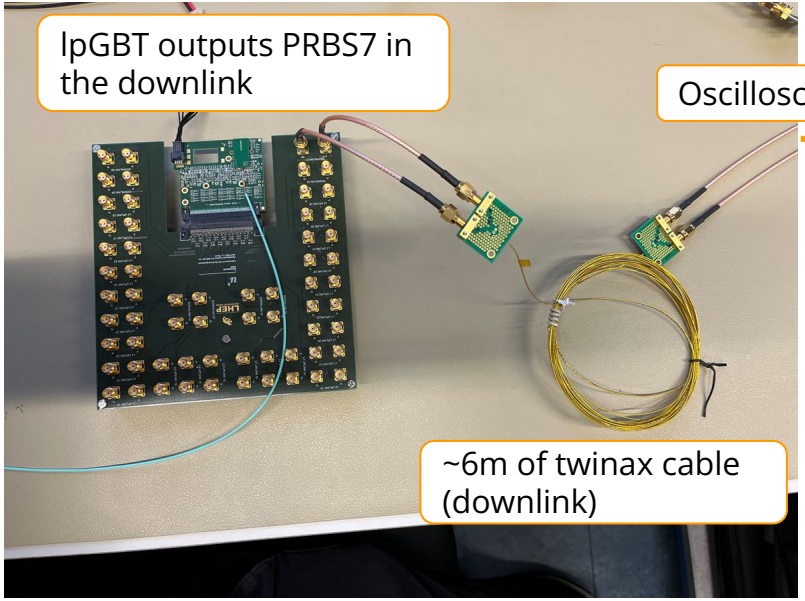
Additional activities

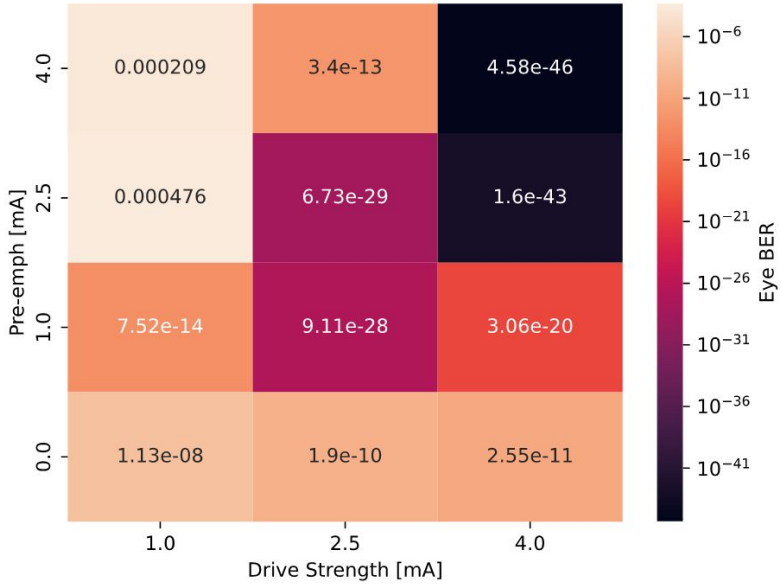
Other activities:

- **quality control of the bPOL2V5 and bPOL12V** for the powering of the Optobox
- test of the **e-fusing** procedure of the lpGBT
- test of the **uplink of the ITkPixV1** with the Optoboard
- definition of a procedure to **test the Optoboards**
- **production of the Optoboxes and Optopanel**

Opto V2.1 vs V3.0: downlink test



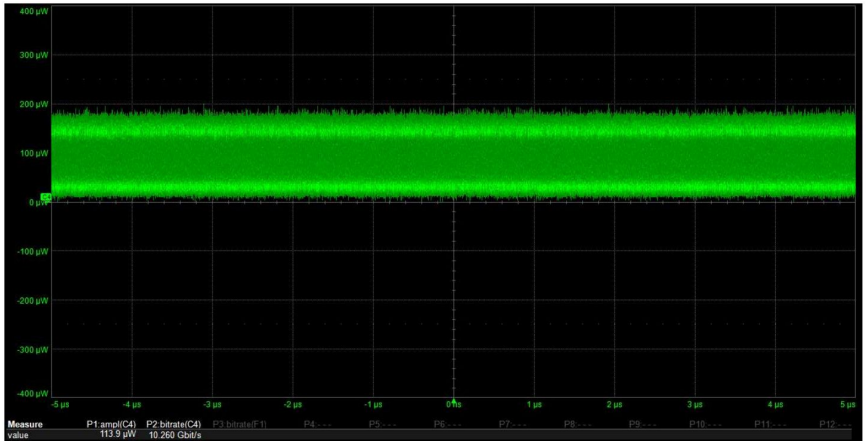
Optoboard V3.0: estimated downlink BER limit

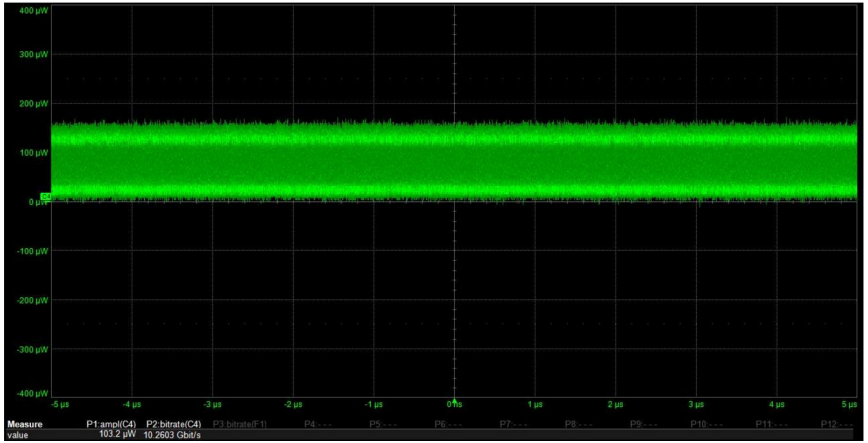


Quality Test of the Data Transmission: optical uplink

The amplitudes of the optical signal from the 4 lpGBTs on the Optoboard have been compared: a small variability among the ASICS was found but

- it doesn't significantly impact the quality of the Data Transmission
- the difference doesn't seem to be related to the master/slave distinction

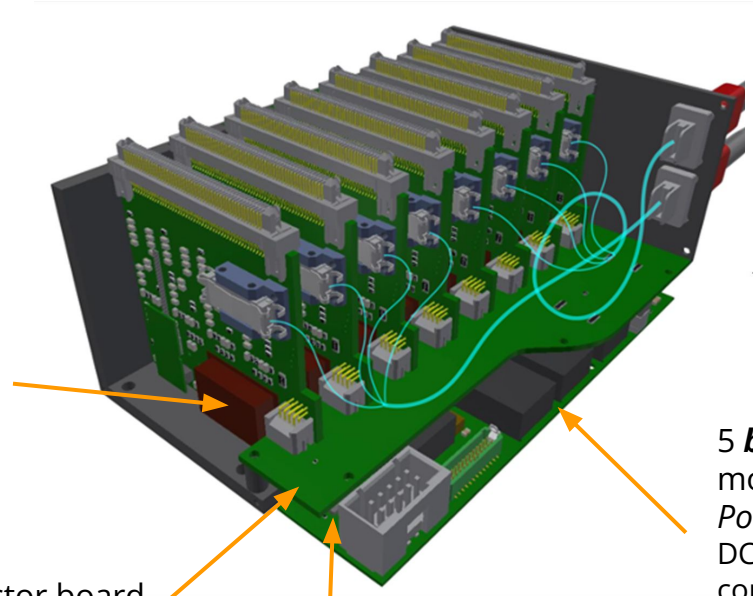


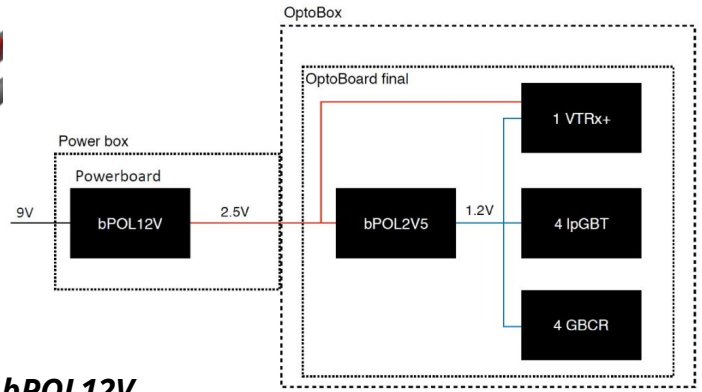


Powering and monitoring of the Optoboards

The ATLAS service caverns house power supplies which deliver *9V* to the Optosystem

bPOL2V5 mounted on each *Optoboard*: DC-DC step-down converters *from 2.5V to 1.2V*

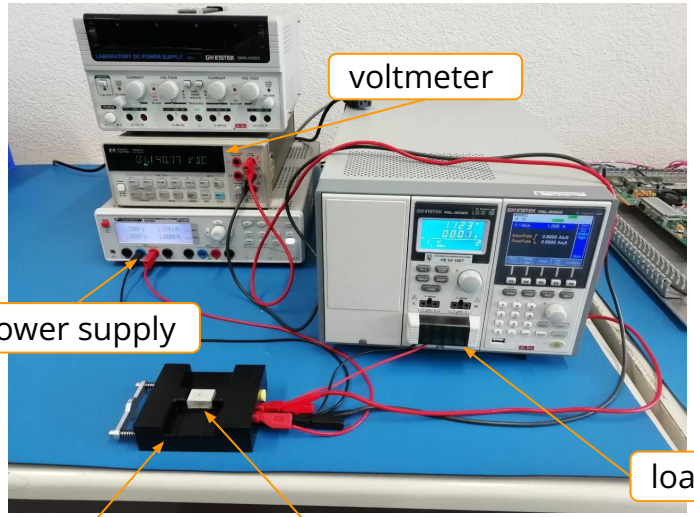


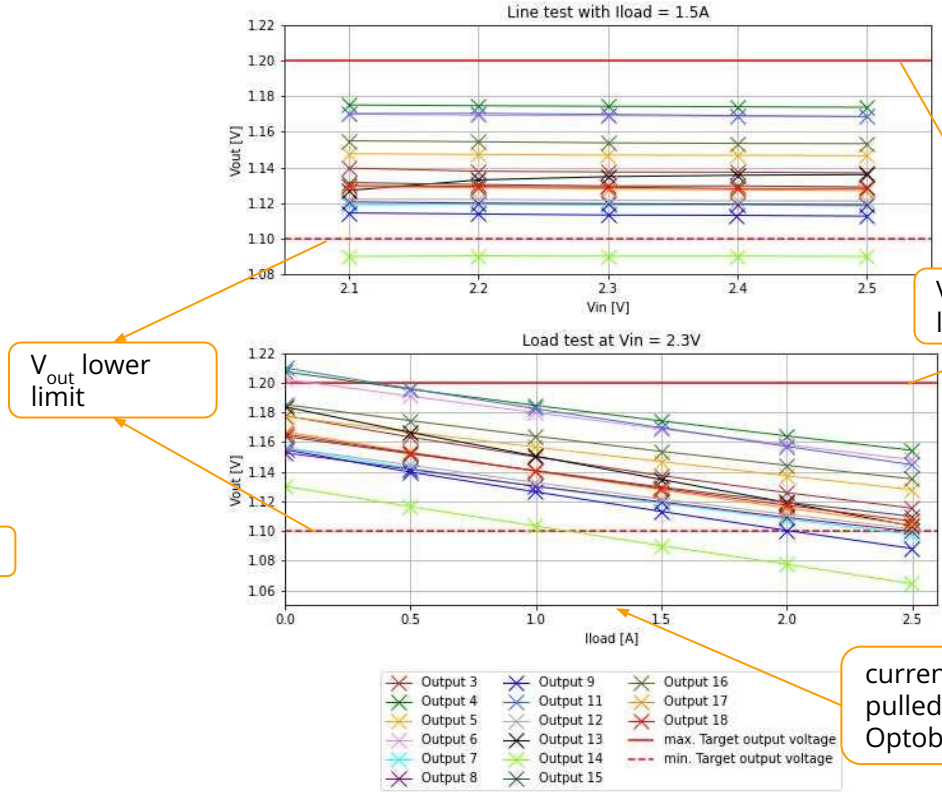


5 ***bPOL12V*** mounted on the *Powerboard*: DC-DC step-down converters *from 9V to 2.5V*

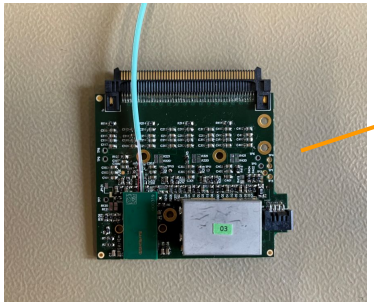
Voltage Tests of the bPOL2V5

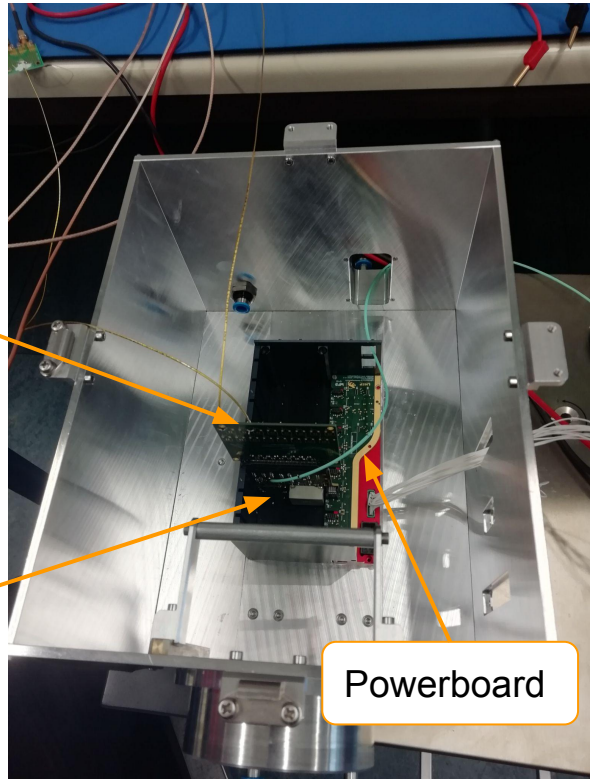
A new test board for the QC of the bPOL2V5 with the shield mounted has been produced





Optoboard test with powerboard and bPOL2V5





Tests:

- configuration of the optoboard powered by the bPOL2V5
- configuration of the optoboard powered by the bPOL12V and bPOL2V5
- digital scan of the RD53A

Test of the uplink of the ITkPixV1

Problem: FELIX still doesn't support the configuration of the ITkPixV1

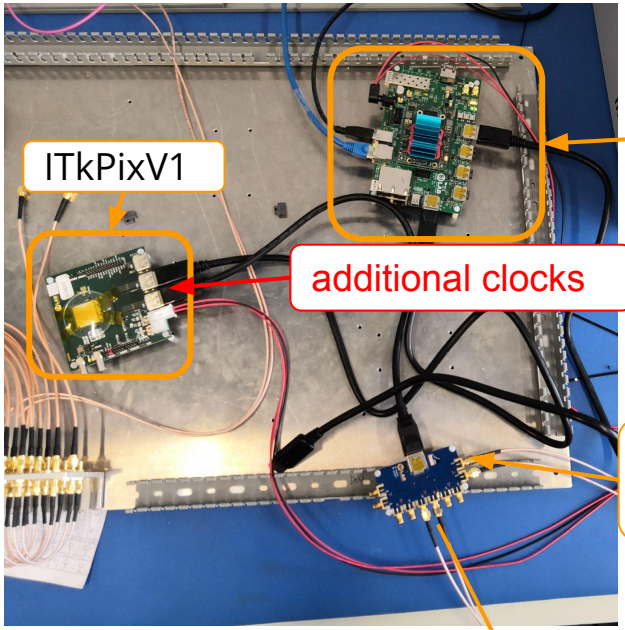
Connect the ITkPixV1 to the BDAQ53 and use it to program it in ***bypass mode*** (additional clocks required)

PRBS7 in the uplink

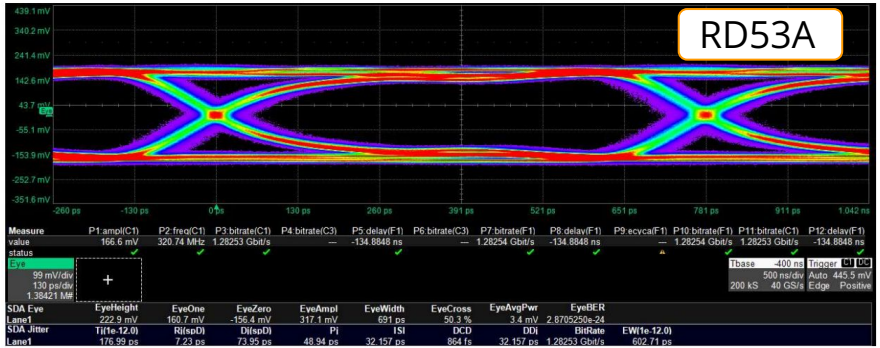
Disconnect the ITkPix from the BDAQ and connect it to the optoboard

ITkPixV1 doesn't reset and recovers the correct clock

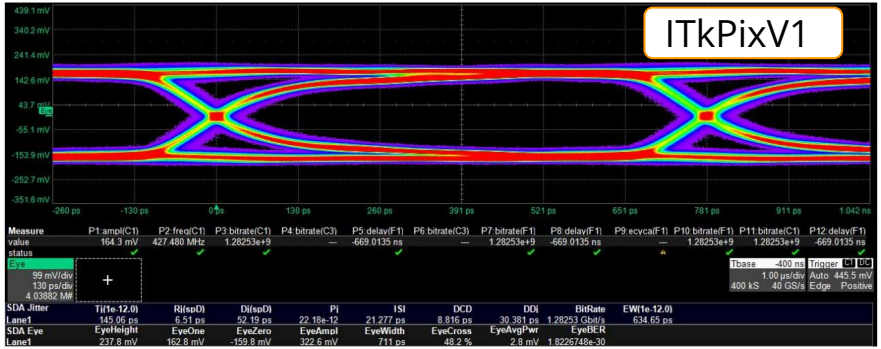
Eye diagram and BERT on the uplink



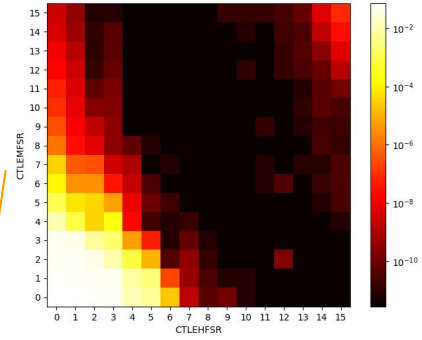
Test of the uplink of the ITkPixV1

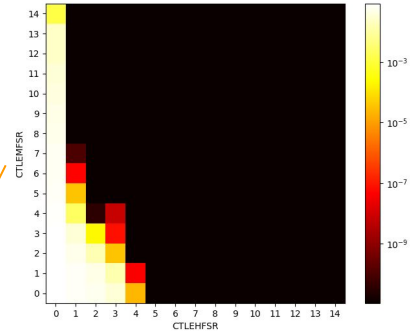


Total jitter: 177ps



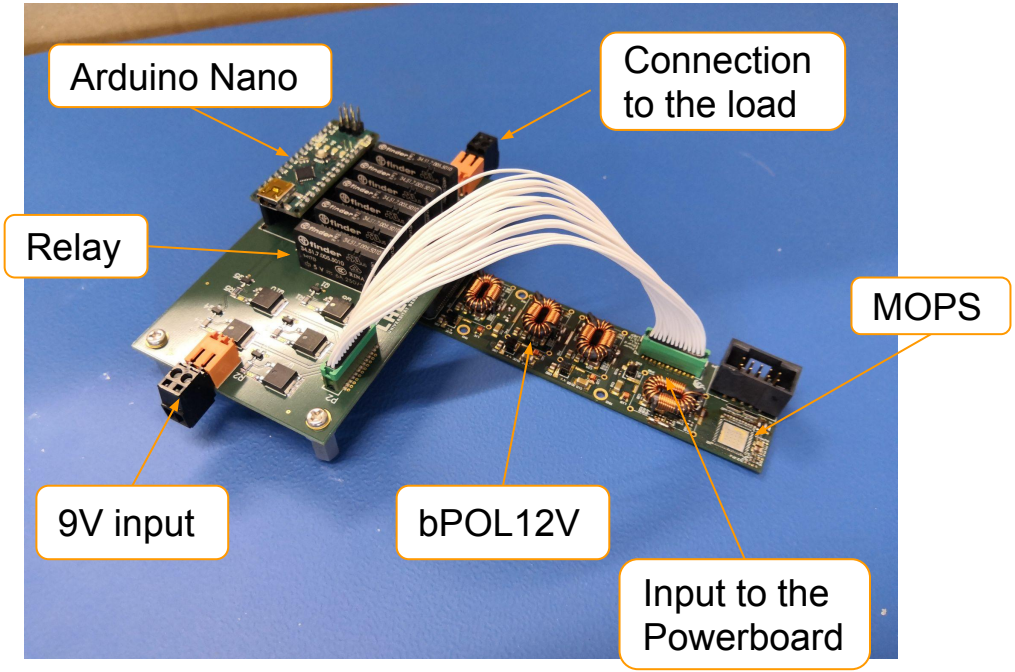
Total jitter: 145ps





BER limit varying the parameters of the equalizer of the GBCR

Load Line Test Board



New board for the test of the powerboard:

- allows to test each bPOL12V independently
- optical relays:
  - require a very small current → controllable by an Arduino nano

Beginning of testing is foreseen in the next weeks

Test of the e-fusing procedure

The E-Fuser, a device for direct communication via I^2C with the lpGBTs (Opto V2.1 and V3.0), was designed.

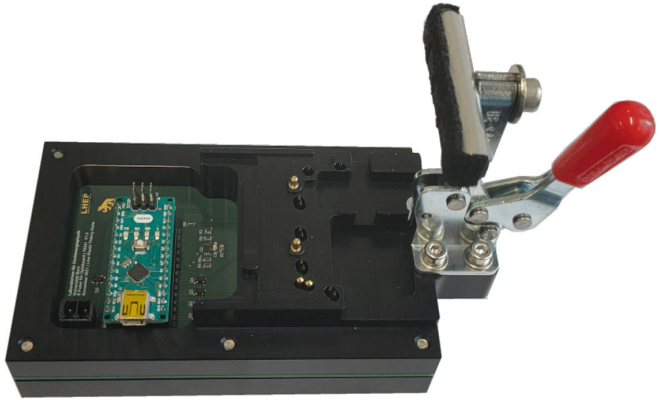
Applications:

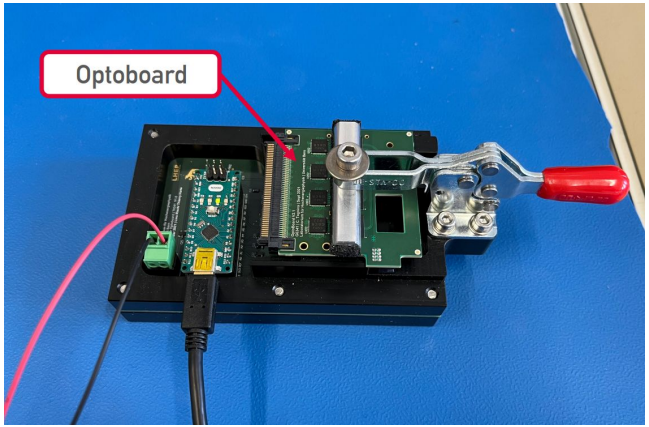
- *first test of the e-fusing of the lpGBT*

  What is the e-fusing?

  Each register of the lpGBT has an e-fuse that can be blown to change the default configuration of the chip; it is an irreversible procedure → substantial time saving during the operation of ATLAS

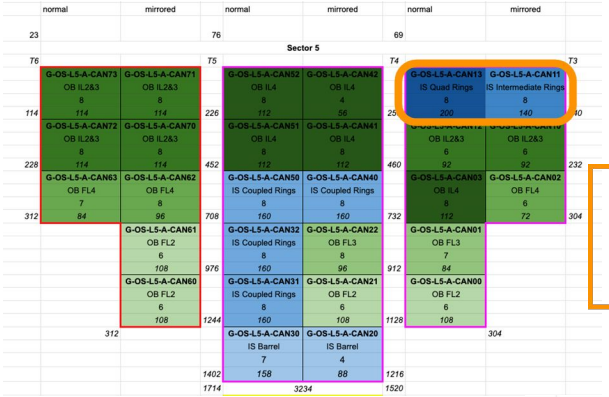
- *useful tool for debugging*: IC & I^2C communications can work simultaneously (I^2C doesn't need any initial configuration)





New Optopanel mapping

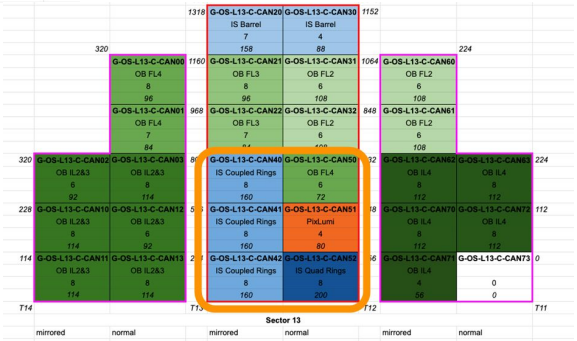
Motivation: reduce the number of bundle flavours by limiting to either normal or mirrored type



A-side quadrant 2/3

This new mapping allows to have:
All IS QR normal
All IS IR mirrored

C-side quadrant 6/7



All EC L2 (rings 1-5) mirrored
All EC L2 (rings 6-11) normal
All EC L3 mirrored
All EC L4 (rings 1-7) normal
EC L4 (rings 8-9) mirrored