

ITk Pixel Optosystem

6th September 2023

Daniele Dal Santo

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**UNIVERSITÄT
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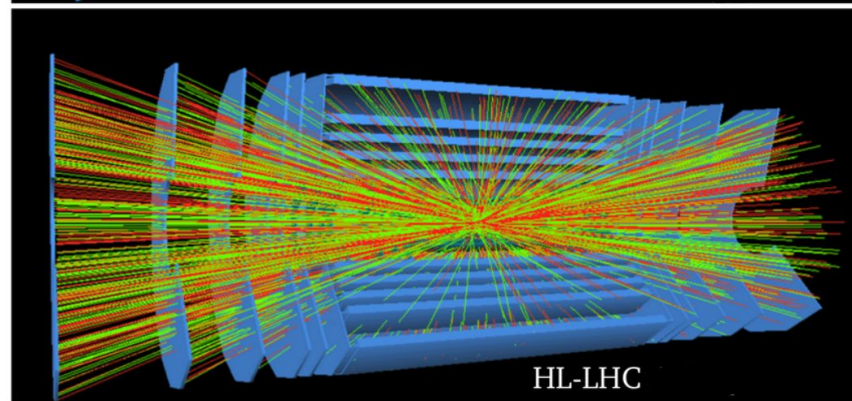
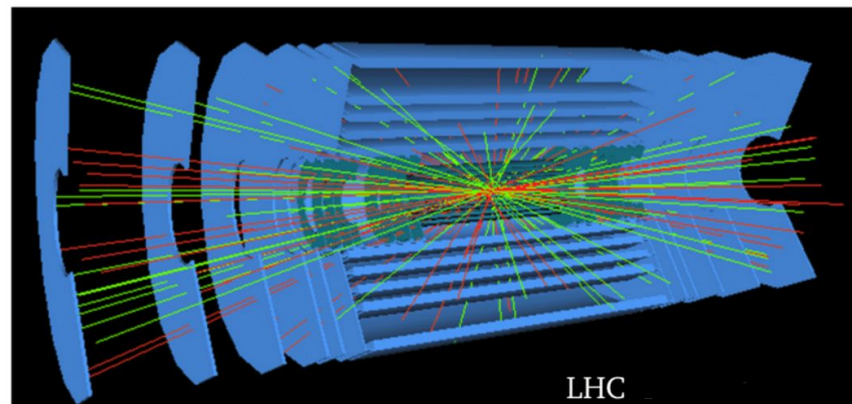


Motivations for ITk

The High-Lumi LHC will deliver *200 collisions per bunch crossing* @ 40MHz. Upgrading the *ATLAS Inner Detector* is necessary to maintain an effective track reconstruction.

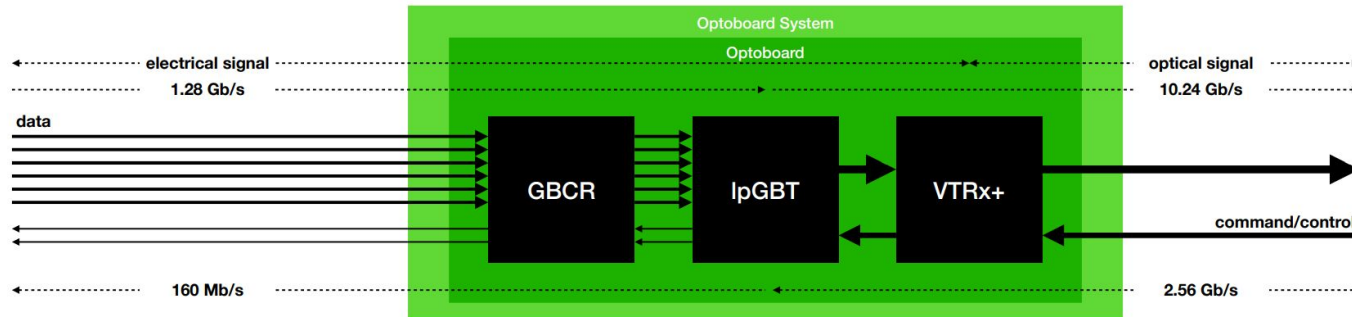
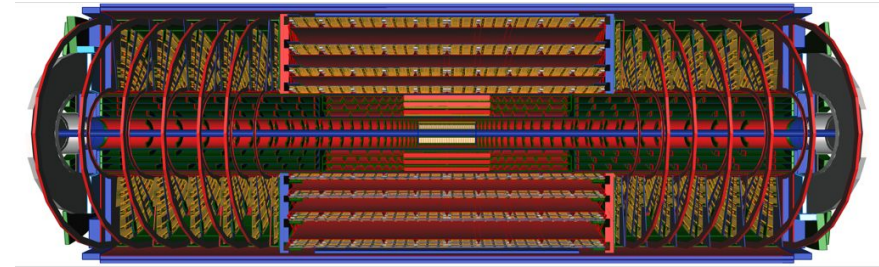
Characteristics required for Inner Tracker (ITk):

- highly segmented all-silicon detector (from 92M pixel channels and 6M strip channels to 5G and 50M)
- increased coverage (up to $|\eta|=4$)
- increased radiation-hardness
- faster read-out electronics

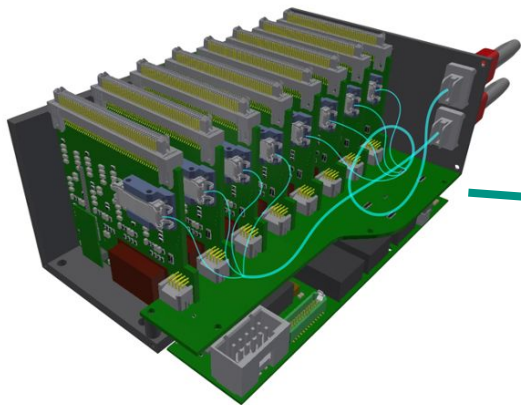


ITk Pixel Data Transmission Chain

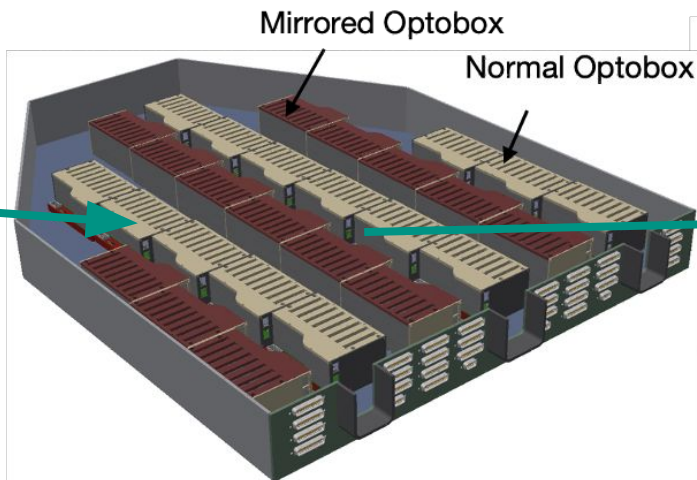
- The ITk Pixel must be read out at 1 MHz (50 Tbps)
- One of the pivotal components of the ITk is the Optosystem, whose fundamental unit is the Optoboard
- This handles the conversion of electrical signals to optical (and viceversa) and their aggregation



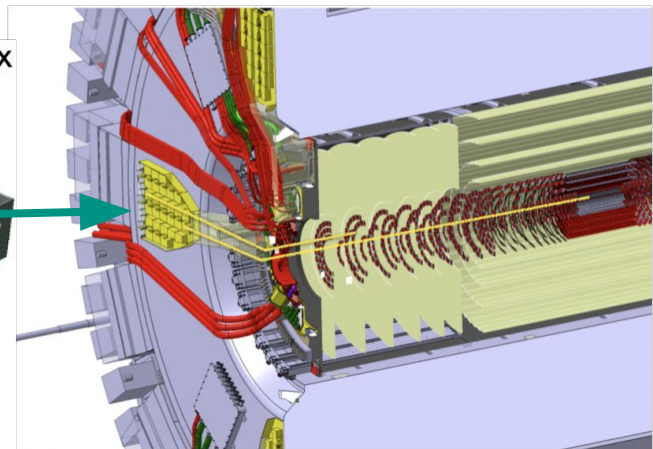
ITk Pixel Optosystem Overview



- Each of the Optoboxes contains up to 8 Optoboards.



- 28 Optoboxes are housed in Optopanel.
- These create twinax and fibres+power+monitor cable channels.

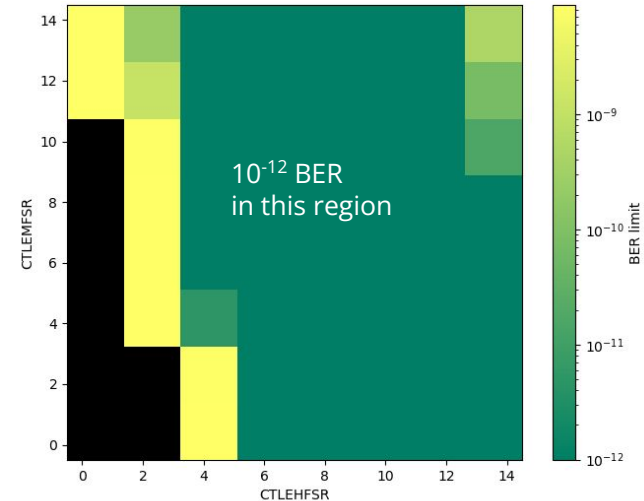
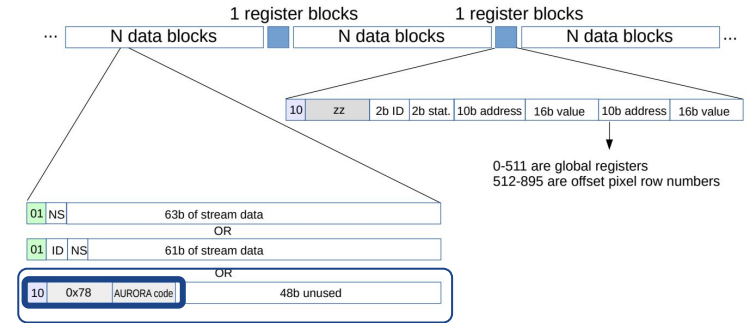
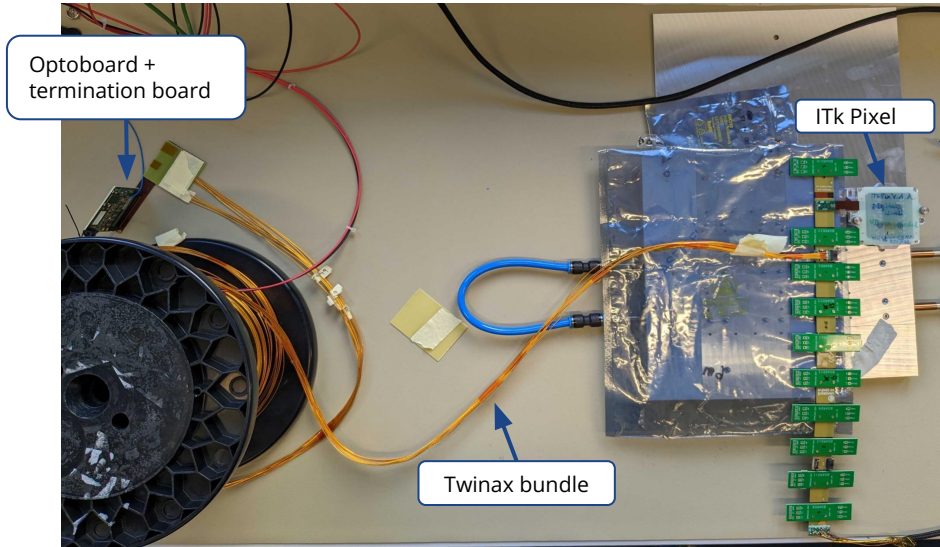


- There are four Optopanel on the endplate at each side of ITk, inside ATLAS.

Data Transmission Quality

Test of the final data transmission chain:

- Opto-board optimization to ensure high signal quality from ITk Pixel via patch panel and 6m twinax bundle

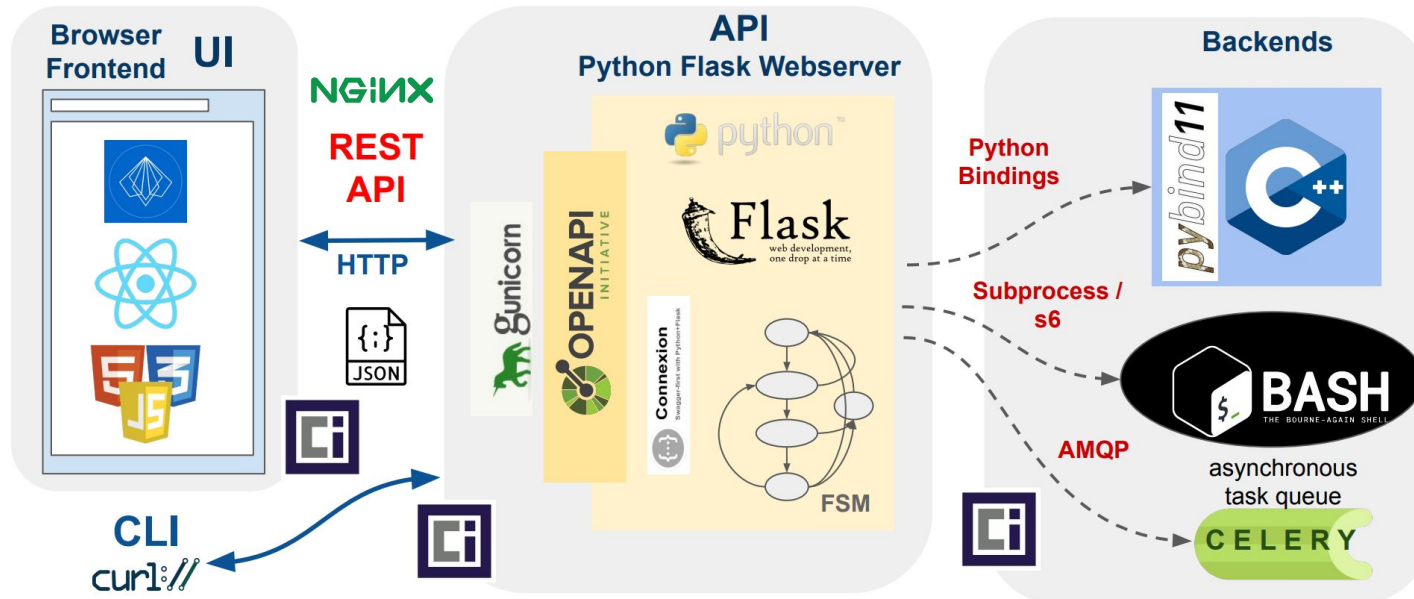


- development of a user-friendly GUI to interact with the Optoboards

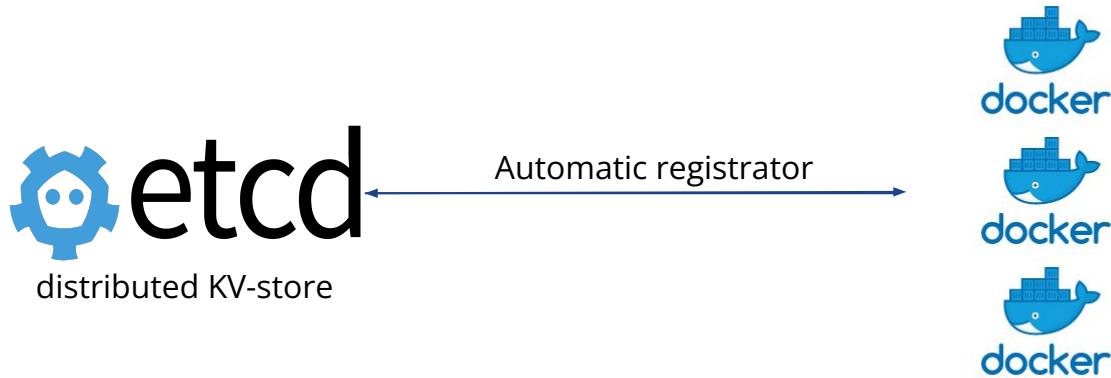
The screenshot displays the Optoboard GUI interface. At the top, there are buttons for "Configure all Optoboards" and "Add GUI Configuration", along with a dropdown menu for "SRI" and a "Health" indicator. The main area is divided into several panels, each representing an Optoboard (OBO, OB1, OB2, OB3, OB5, OB6). Each panel contains a "Select device: lpGBT" dropdown, a "Configure" button, and a "Manual selection" toggle. Below these are "Read register" and "Write register" buttons, each with a "Read back" or "Value to be written" dropdown. A "Perform BERT" button is also present, with "BER limit" and "Uplink" dropdowns. A "Read Status" button shows the "lpGBT status" with a progress indicator. A dropdown menu is open over the OBO panel, listing various configuration registers such as EPRXDLLCONFIG, EPRXDLLCONFIG EPRXDLLCURRENT, and EPRXDLLCONFIG EPRXDLLCONFIRMCOUNT.

Optoboard GUI: under the hood - Part 1

- UI, API and backend in separate docker containers published in gitlab-registry
 - NGINX for static file serving and reverse proxy
 - openAPI standard for Flask endpoint definition
 - Celery + RabbitMQ to connect web app to backend



Optoboard GUI: under the hood - Part 2



- used for dynamic service discovery with automatic registration of labelled containers
- single source of truth for runtime configuration

ITk Production Database

- ITk is made of $O(500k)$ components
- ATLAS ITk Production Database guarantees:
 - component traceability
 - storage of test results
- easy access via [itkdb API](#)

20UPGOB4400072

Optoboard - Optoboard V4.0

Basic Info

ATLAS Serial Number: 20UPGOB4400072

Alternative Identifier: No alternative identifier

Component Type: Optoboard OPTOBOARD

Type: Optoboard V4.0

Current Stage: **DOWNLINK TEST** Show History

Current Location: University of Bern BERN

Shipment Destination: No current shipment destination

Home Institute: University of Bern BERN

Properties

LHEP serial number: 20UPGOB4400072

Number of IpGBTs mounted: 4

Optoboard Version Number: 5

Number of GBCR mounted: 4

GBCR Version Number: 1

Stage History

21/08/2023 19:57 Downlink test

Child Component List

Dummies

- GBCR 20UPGOG3000017 Disassemble History
- 11/08/2023 Laura Francesca Iacob
- GBCR 20UPGOG3000018 Disassemble History
- 11/08/2023 Laura Francesca Iacob
- GBCR 20UPGOG3000019 Disassemble History
- 11/08/2023 Laura Francesca Iacob
- GBCR 20UPGOG3000020 Disassemble History
- 11/08/2023 Laura Francesca Iacob
- VTRx+ 0 (VTRX+) is missing Assemble
- bPOL2V5 Carrier Board 0 is missing Assemble
- IpGBT 20UPGOL2000114 Disassemble History
- 13/08/2023 Laura Francesca Iacob
- IpGBT 20UPGOL2000115 Disassemble History
- 13/08/2023 Laura Francesca Iacob
- IpGBT 20UPGOL2000116 Disassemble History
- 13/08/2023 Laura Francesca Iacob
- IpGBT 20UPGOL2000117 Disassemble History
- 13/08/2023 Laura Francesca Iacob

- improved documentation
 - automated for code with [MkDocs](#)

Optoboard System Documentation

Optoboard

Table of contents

Basic Principle:

Data:

Command:

PCB & Schematics

The following versions exist:

- V0: only one IpGBTv0, no GBCRs.
- V1.1: four IpGBTv0 and four GBCRV2, no configuration possible through external I2C controller.
- V2.0: four IpGBTv0 and four GBCRV2, configuration possible through external I2C controller, more test points accessible.

```
method Lpgbt.read_adc
```

```
read_adc(adcchannel1)
```

Read the ADC channel of the IpGBT.

Time-out set to 5 s.

Args:

- `adcchannel1` (int): ADC channel to measure, from 0 to 15

Returns:

- `adcval1` (int): ADC value of the channel

Raises:

- `ValueError` : wrong ADC channel input
- `TimeoutError` : ADC conversion takes to long

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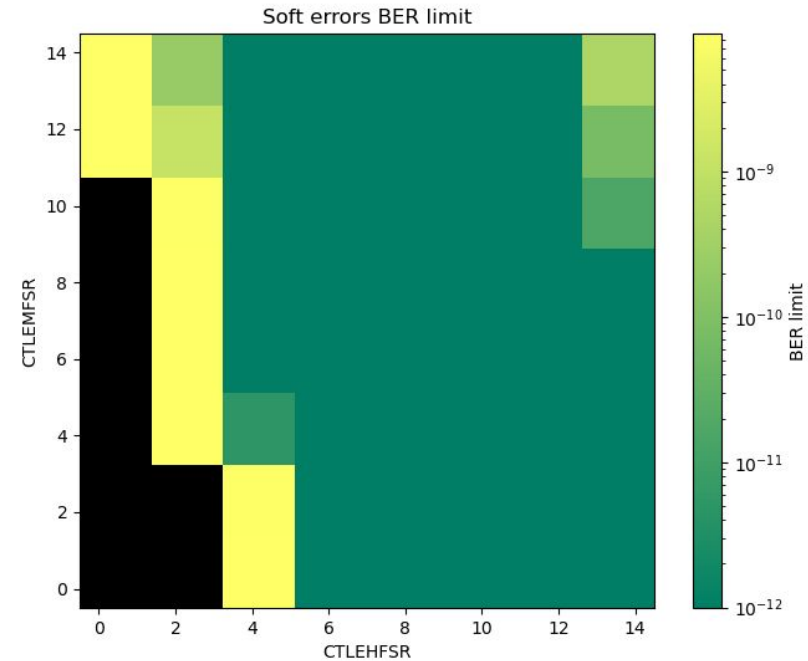
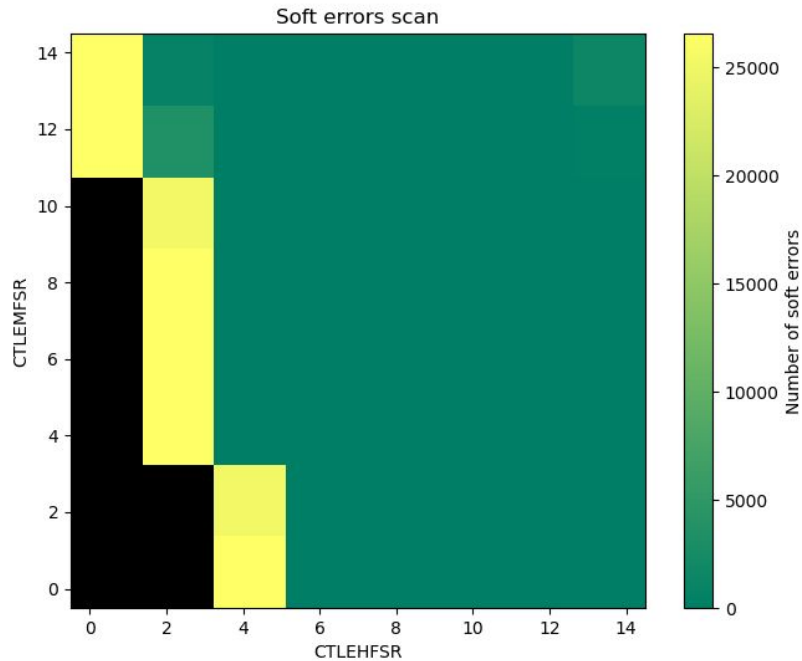
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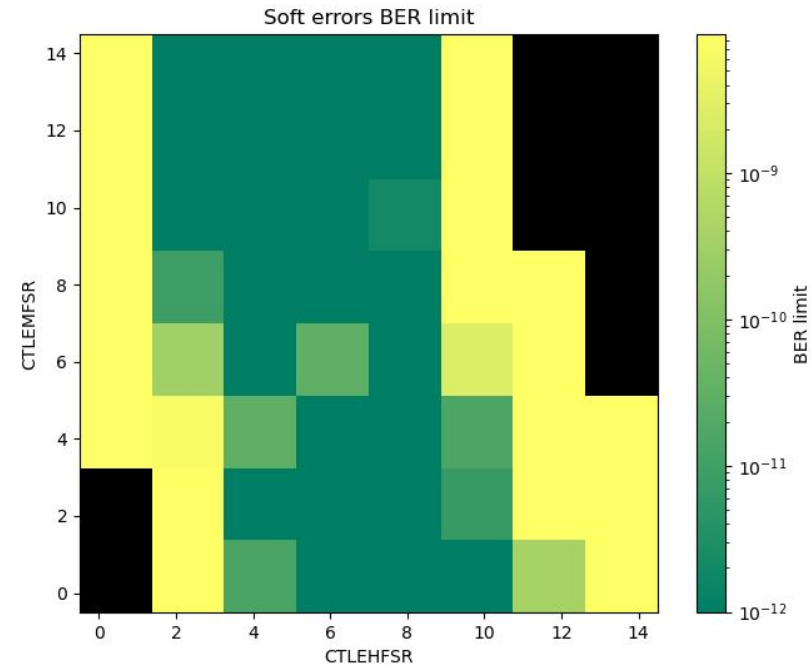
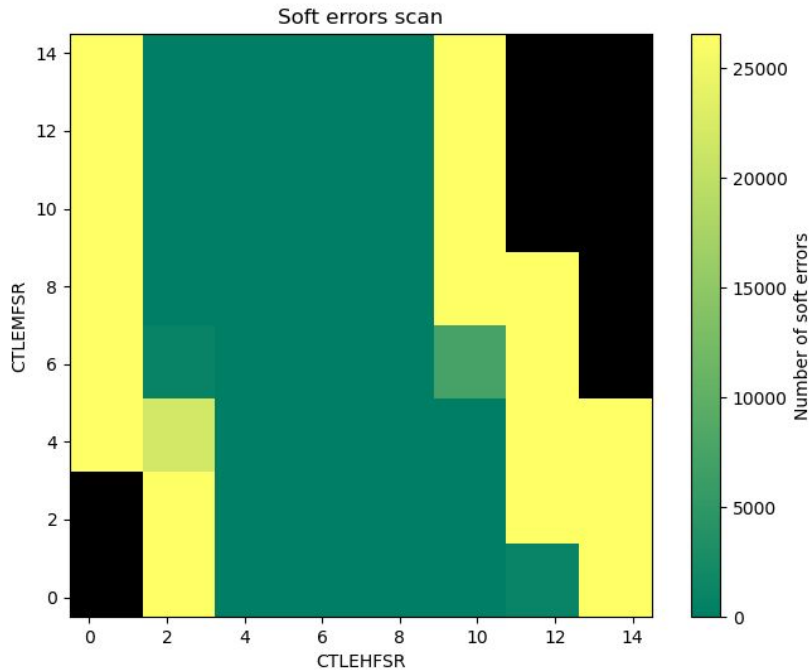
- info about the structure of the ITkPix output data: [Manual for the RD53B](#)
 - ITkPix encodes 64b in 66b adding 2b of preamble that can take values 01 (data) or 10 (idle or register block)
 - idle signal contains 2b of preamble + 0x78 + Aurora code -> 18b whose validity can be checked
 - to unscramble a xor operation is performed between 1) current bit 2) bit in position -38 3) bit in position -57 => errors propagate to the headers and around 62% of the bits are effectively checked
- scrambling is applied by both ITkPix and IpGBT
- unscrambling applied on scrambled data == identity transformation unless there are errors introduced by the data transmission between the two operations

Results Molex

- 3800s for each heatmap point
- 43/64=67% $\leq 10^{-12}$; 42/64 with no errors



- 3800s for each heatmap point
- 27/64=42% $\leq 10^{-12}$; 24/64 with no errors



Microservice structure

- UI, api, celery, rabbitmq on localhost
- UI static files served by Flask server
- openAPI standard for Flask endpoint definition, Flask binding to 127.0.0.1
- Celery + RabbitMQ to connect Flask with backend

