Outer Barrel services chain characterization for the ATLAS ITk Pixel Detector

CHIPP/CHART Workshop on Sustainability in Particle Physics and CHIPP 2023 plenary
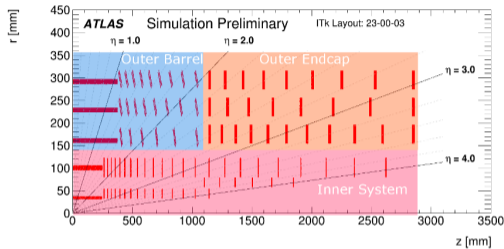
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HL-LHC & ATLAS ITk upgrade for High Luminosity

- ▶ HL-LHC
    - ▶ Circular p–p collider, 14 TeV, 40 MHz
    - ▶ ≈ 200 collisions per bunch-crossing

- ▶ ITk upgrade
    - ▶ Pixel and strips part
        - ▶ High granularity
        - ▶ Radiation hard modules
        - ▶ Fast readout electronics
    - ▶ The ITk Pixel system:
        - ▶ Inner System, with flat and ring modules
        - ▶ Outer Barrel, with flat and inclined modules
        - ▶ Outer Endcap, with ring modules
    - in total 5×10^9 channels
    - $\Rightarrow$ new readout system required

ATLAS ITk Outer Barrel

- 1.7 MGy at 4000 fb^{-1}
- 3 layers of flat staves and inclined rings
- 4772 quad modules, 6.94 m^2
- Output data (≈ 2 MB/event) with up to 4×1.28 Gb/s links
- data transmission relies on data merging:
  - 2-to-2 mode for layer 2
  - 4-to-1 mode for layers 3&4

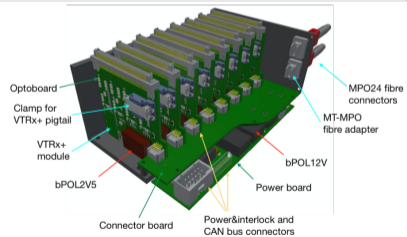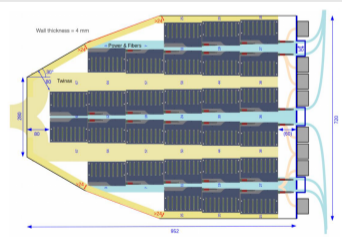OB Inclined Half Ring

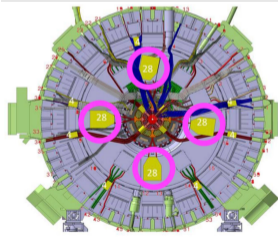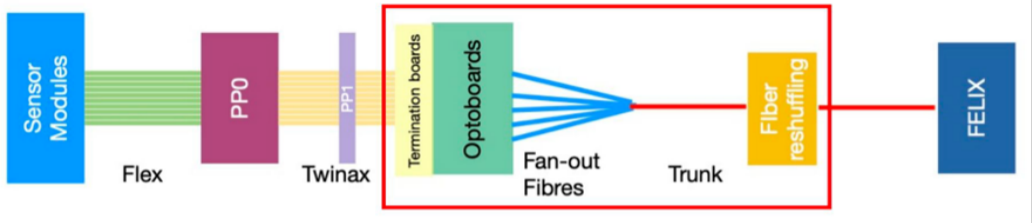OB Longeron

B. Vormwald and SR1 Team
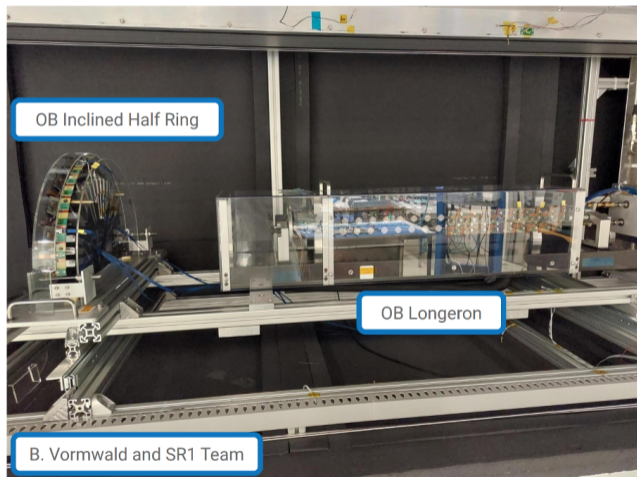
ITk Pixel data transmission chain I

- ► Transports detector signals from modules to readout cards in electronics room
- ► Routes trigger and command from readout system to detector
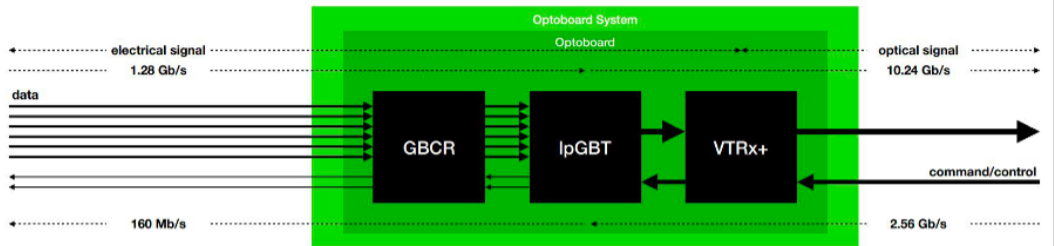- ► Opto-electrical conversion system is key component in readout path

ITk Pixel readout system

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

Optosystem

- ▶ Electrical signal recovery, serialisation and conversion to optical signal
- ▶ Radiation-hard components (GBCR, lpGBT and VTRx+) (estimated absorbed dose for optoboards is 150 kGy)
- ▶ Compliant with cooling and grounding and shielding specifications

Validation of data transmission chain I

Past tests:

- ▶ Tests on the single components: VTRx+, lpGBT, GBCR
- ▶ Tests of the first prototypes of the optoboards
- ▶ Different data transmission chains: from FELIX card to readout chip with different cables and connectors
- ▶ Irradiation of components of the data transmission chain
- ▶ Test of operation of the optoboard during irradiation
- ▶ Experimental verification of the powering scheme concept
- ▶ Tests and simulation of the thermal management

Validation of data transmission chain II

Recent tests:

- ▶ BER tests on data transmission chain with final components
  - ▶ Using PRBS7 signal
    - ▶ Pattern checker on the lpGBT can execute a BERT
    - ▶ Result is sent via optical fiber to FELIX
  - ▶ Using 64b/66b ITkPix idle signal $\rightarrow$ test on realistic data stream
- ▶ Multiple BERTs are performed, changing the parameters of the equalizer of the GBCR

Outer Barrel IL3 PP0 + Samtec bundle - Setup
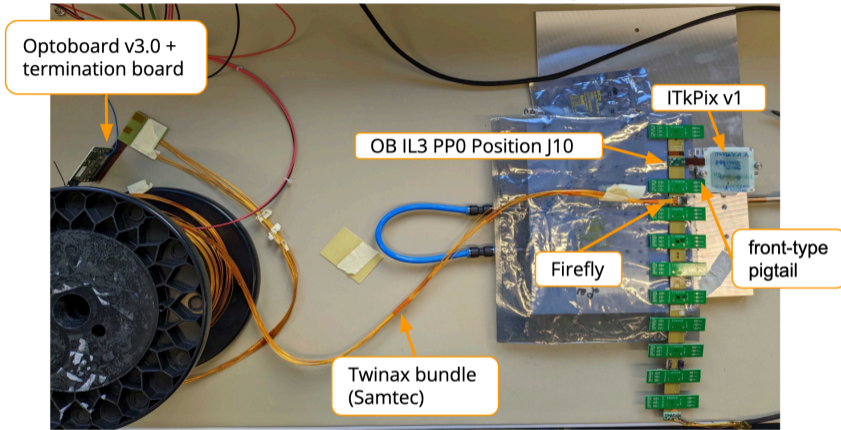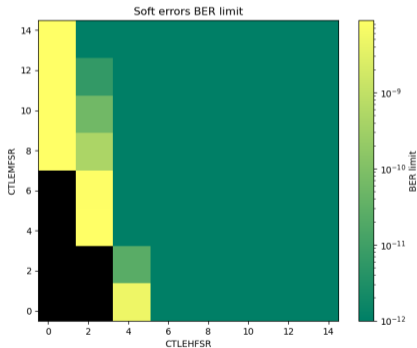

First complete functioning data transmission chain:

▶ Working communication with ITkPix v1.1 (almost final module type)
▶ Manually assembled 6 m long twinax bundle (10 cables) with ECUE and termination board
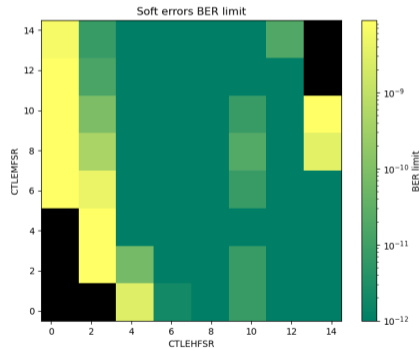
Outer Barrel IL3 PP0 + Molex/Samtec bundle - Results

BER tests with 95% CL BER limit $< 10^{-12}$ for several configurations, using 64b/66b ITkPix idle signal

Molex bundle

Samtec bundle

Data merging

- ▶ Space issues in the detector and data rates low enough: not every channel in the modules is individually read out
- ▶ Data merging mechanism in chip allows to get data from several FEs in one physical cable
  - ▶ ITkPix v1.1 has known issue: prevents data merging to work according to phase of the data of all FEs in the module
  - ▶ Workaround: Changing powering of individual FEs in order to change phase of the data
  - ▶ Fixed in final version of the chip
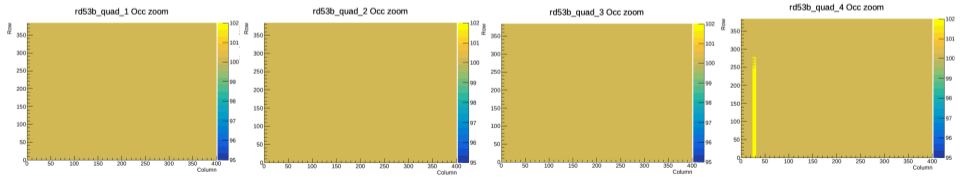
Summary and Outlook

- ► Almost final data transmission chain working within required BER limits
- ► Final version of the optoboard to arrive soon and be tested
- ► Final version of the readout chip fixing data merging problems

Moving towards system tests on a larger scale $\Rightarrow$ several institutes are testing modules with the full data transmission chain