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Serafima Nechaeva
(University and INFN Bologna)
nechaeva@bo.infn.it
on behalf of ATLAS-ITk collaboration

The ATLAS ITk Pixel Detector. The biggest challenges from design to construction.

Introduction

In the HL-LHC era, the radiation is expected to reach unprecedented values, with non-ionizing fluence of 1e16 n_{eq}/cm^2 and ionizing dose of 5 MGy. To cope with the resulting increase in occupancy, bandwidth, and radiation damage, the current ATLAS Inner Detector will be replaced by an all-silicon system – ATLAS **I**nner **T**racker (**ITk**).

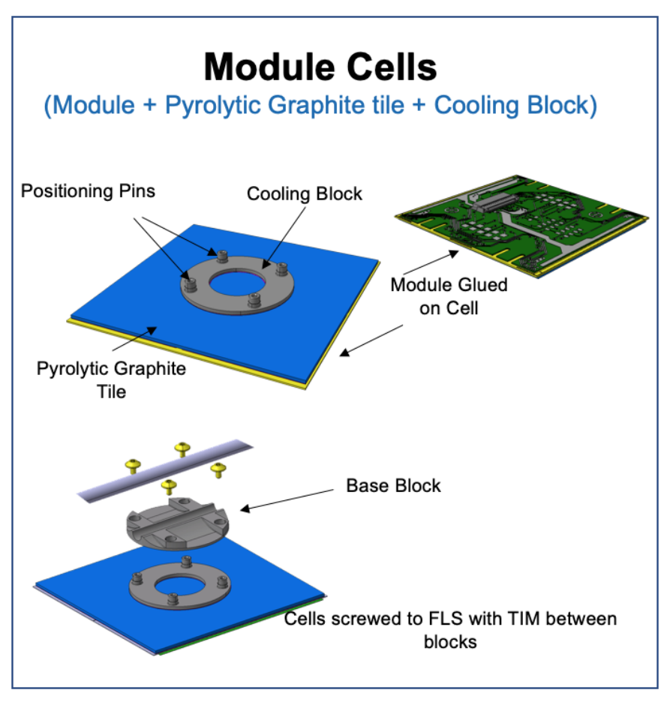
The Pixel part of new detector will consist of five-barrel layers and a number of rings, resulting in about 13 m^2 of instrumented area.

ITk Pixel Modules

Modules made of **Sensor + ASIC + Flex circuit**

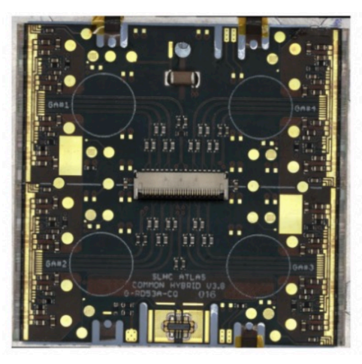
Module configurations:

- **Quad module**: 1 large single planar sensor bump bonded to four front-ends.
- **Triplet module**: 3 single-chip and 3D sensor modules connected to one flex for the innermost layer only

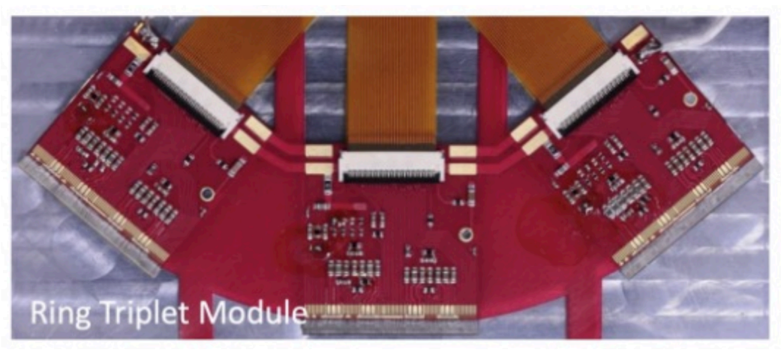


Layer	Module type	Sensor type	Sensor thickness (μm)	Pixel size (μm²)
L0 barrel	Triplet	3D n-in-p	270	25x100
L0 ring	Triplet	3D n-in-p	250	50x50
L1	Quad	Planar n-in-p	100	50x50
L2-L4	Quad	Planar n-in-p	150	50x50

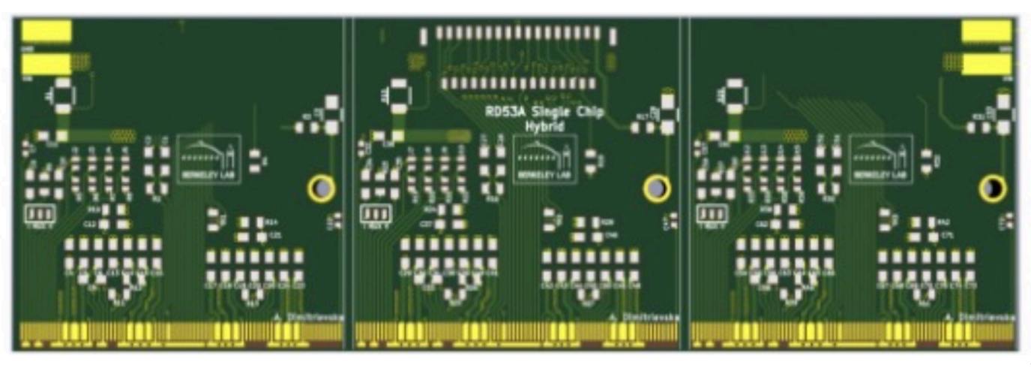
Module construction



Quad module



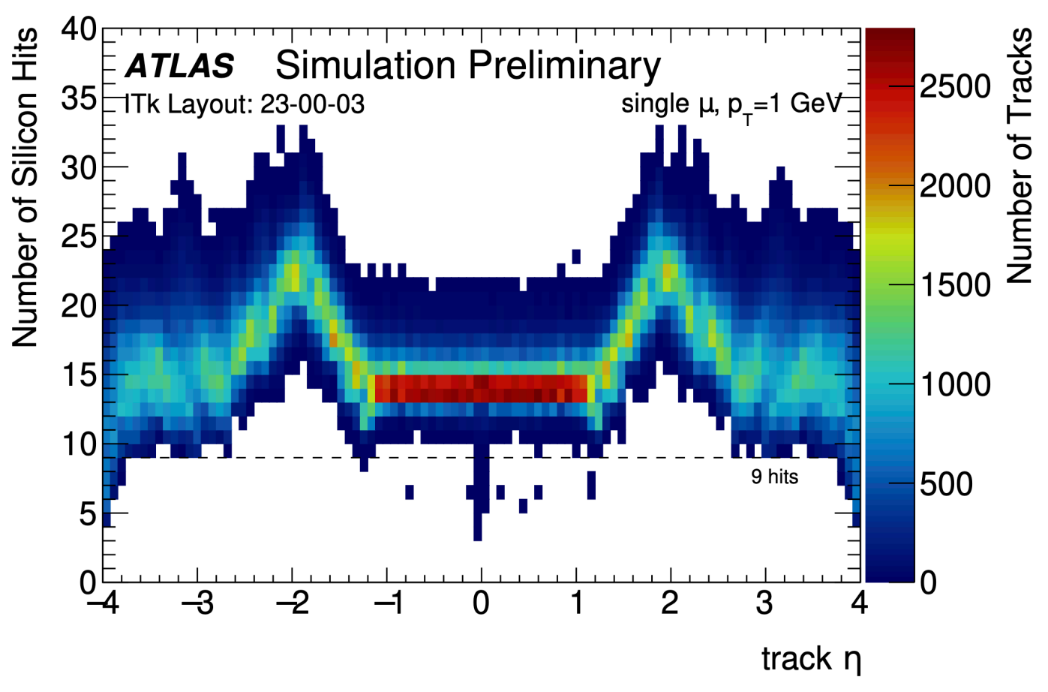
Ring triplet module



Stave linear triplet flex

HL-LHC

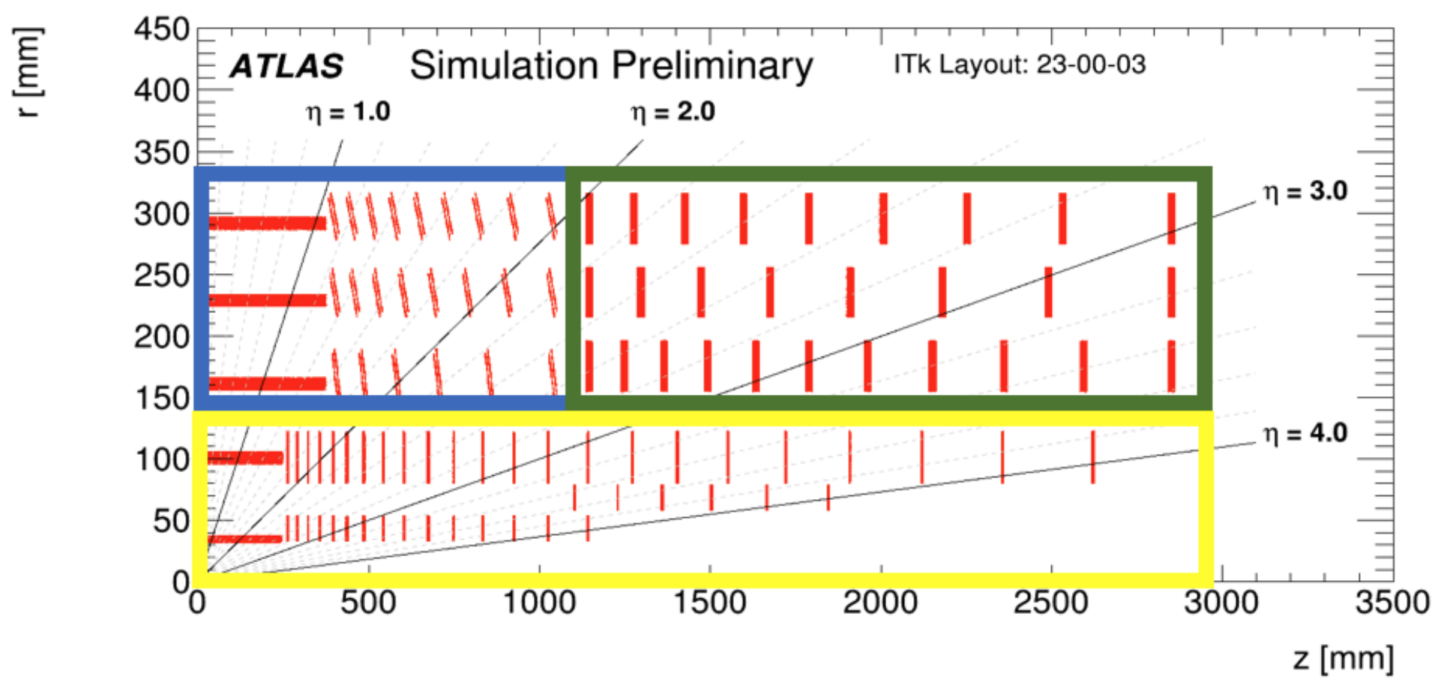
- Average multiple pp collisions (pile-up) will increase to <μ> = 200
- The integrated luminosity on the whole HL-LHC operative period will be 4000 fb^{-1}



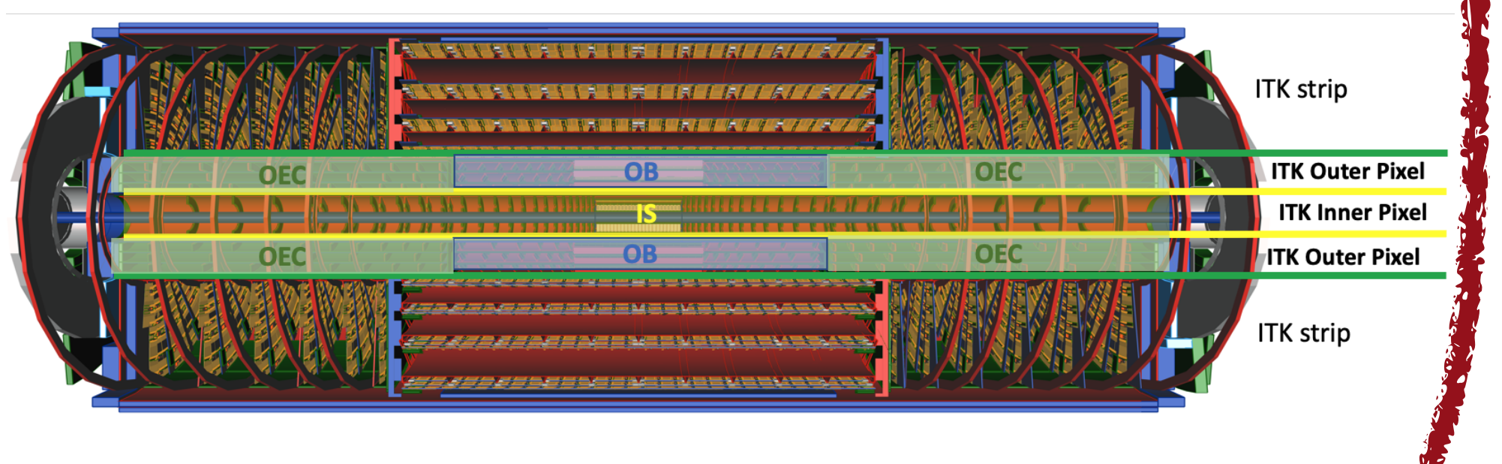
Number of strip + pixel measurements on a track as a function of η [1]

ATLAS ITk Pixel

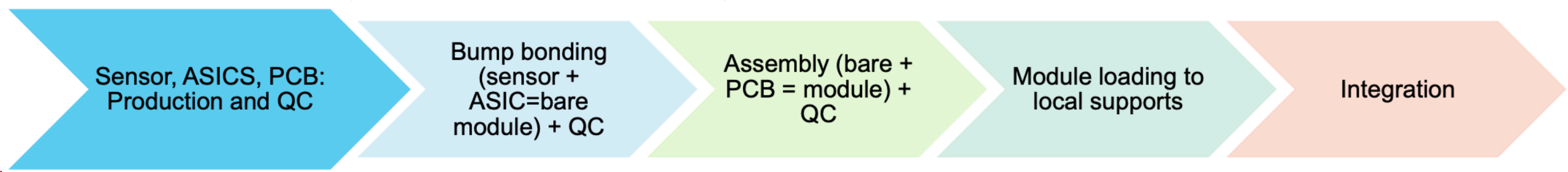
- Outer barrel (OB) **150 μm-thick planar sensors *(L2-L4)***
- Outer Endcap (OEC) **150 μm-thick planar sensors *(L2-L4)***
- Inner system (IS) **100 μm-thick planar** sensors (the outermost layer – ***L1***) and **3D sensors** (innermost layer - ***L0***).



A quadrant of the ITk pixel detector [2]



Detector layout

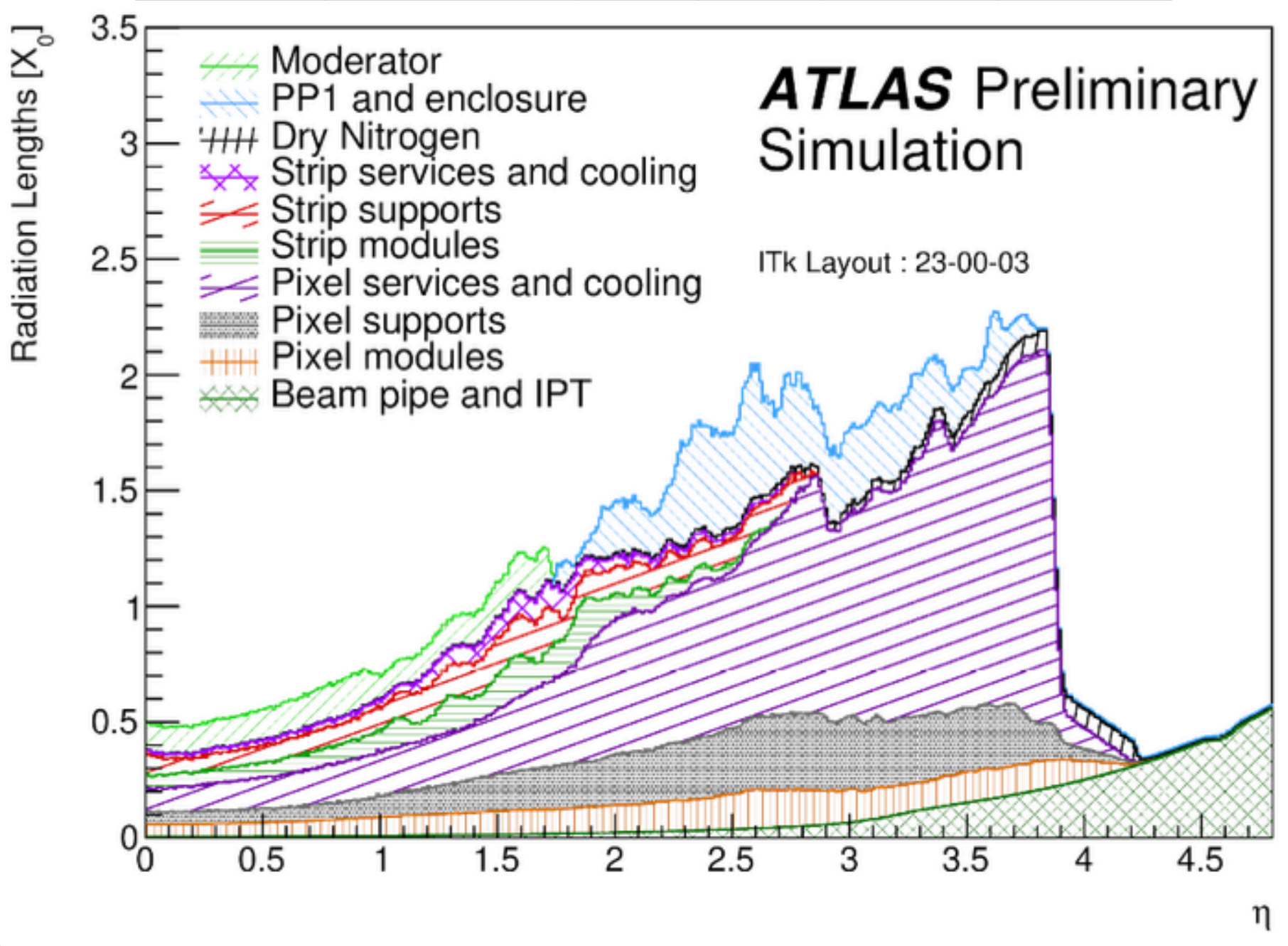


Sensor, ASICS, PCB: Production and QC
Bump bonding (sensor + ASIC=bare module) + QC
Assembly (bare + PCB = module) + QC
Module loading to local supports
Integration

The main features of the detector:

- Increased acceptance up to η ~ 4
- A number of points per track higher than 9
- High granularity
- Radiation hardness with minimized material budget.

Detector	Eta Coverage	Strip (m^2)	Pixel (m^2)	Pixel Ch.	Pixel Modules
ATLAS ID	$\|\eta\| < 2.5$	61	1.9	92×10^6	2.0K
ITk	$\|\eta\| < 4$	165	13	5.1×10^9	9.2K



Major challenges of the ITk project

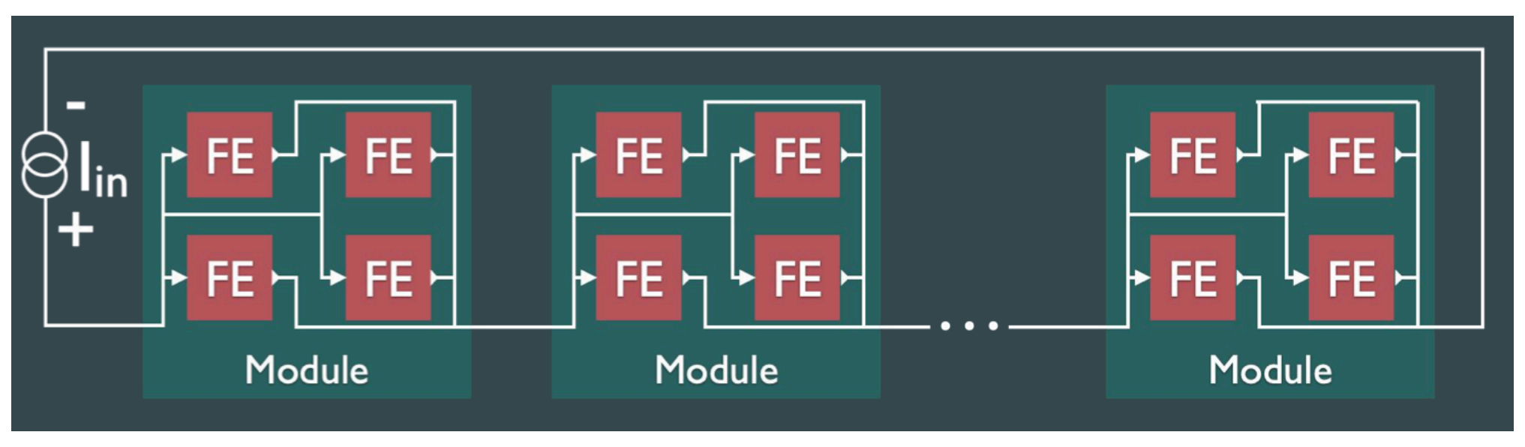
- **Robust and light global mechanics**
- **Customised Cooling CO_2 bi-phase cooling system** driven through titanium pipes will cool ATLAS-ITk **down to -35 °C**
- **Serial powering chain** allowing to reduce material budget of detector
- Every pixel module needs to be powered and monitored using a **Detector Control System (DCS)** providing Low Voltage (LV) to power up the ASIC and High voltage (HV) to bias the silicon sensors.
- **An extensive R&D program** for the pixel modules (to determine sensor technologies/thicknesses and parameters of readout chip)

Data transmission

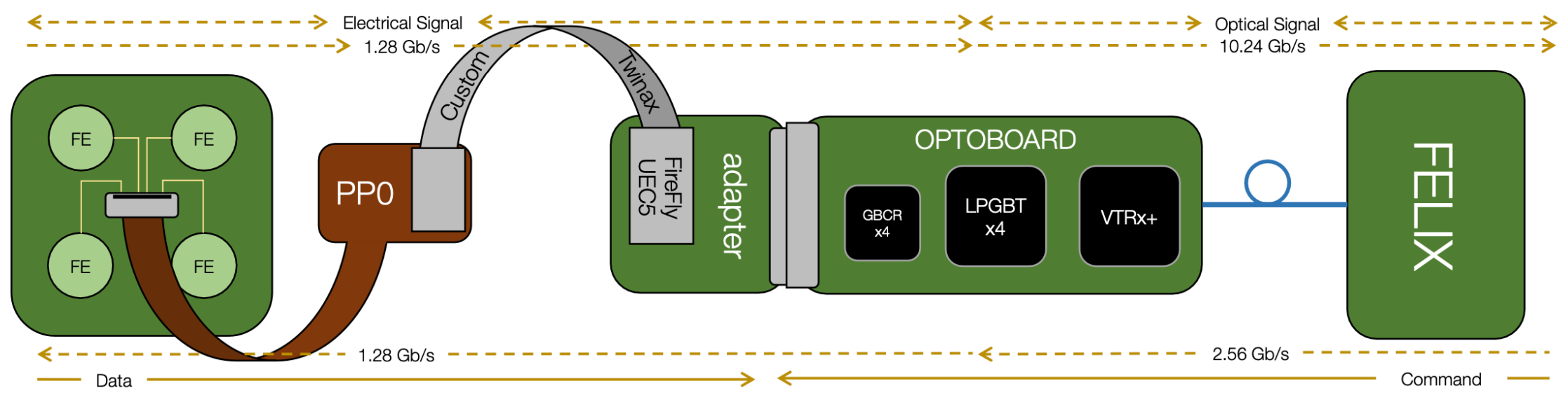
Serial powering:

- N modules connected in series
- Each module consists of m readout chips in parallel
- Total current defined by single module
- Reduces power losses on cables, material budget, requires less space

Data transmitted with custom **TwinAx** cables from patch pannel **PP0** to **optobox**) at 1.28 Gbps and with optical fibres at 10.24 Gbps



Module serial powering (groups of modules powered in parallel)



Data services scheme

Local supports

Different geometries optimized for the various layers and regions of the detector:

- Inner system: 2 layers of staves and double-sided rings in the endcaps
- Outer Barrel: 3 layers of longeron and inclined rings
- Outer Endcap: 3 layers of endcap rings composed by 2 half-rings (HR)

References

[1] ATL-PHYS-PUB-2021-024
[2] J. Francisca *et al* 2022 *J. Phys.: Conf. Ser.* **2374** 012061