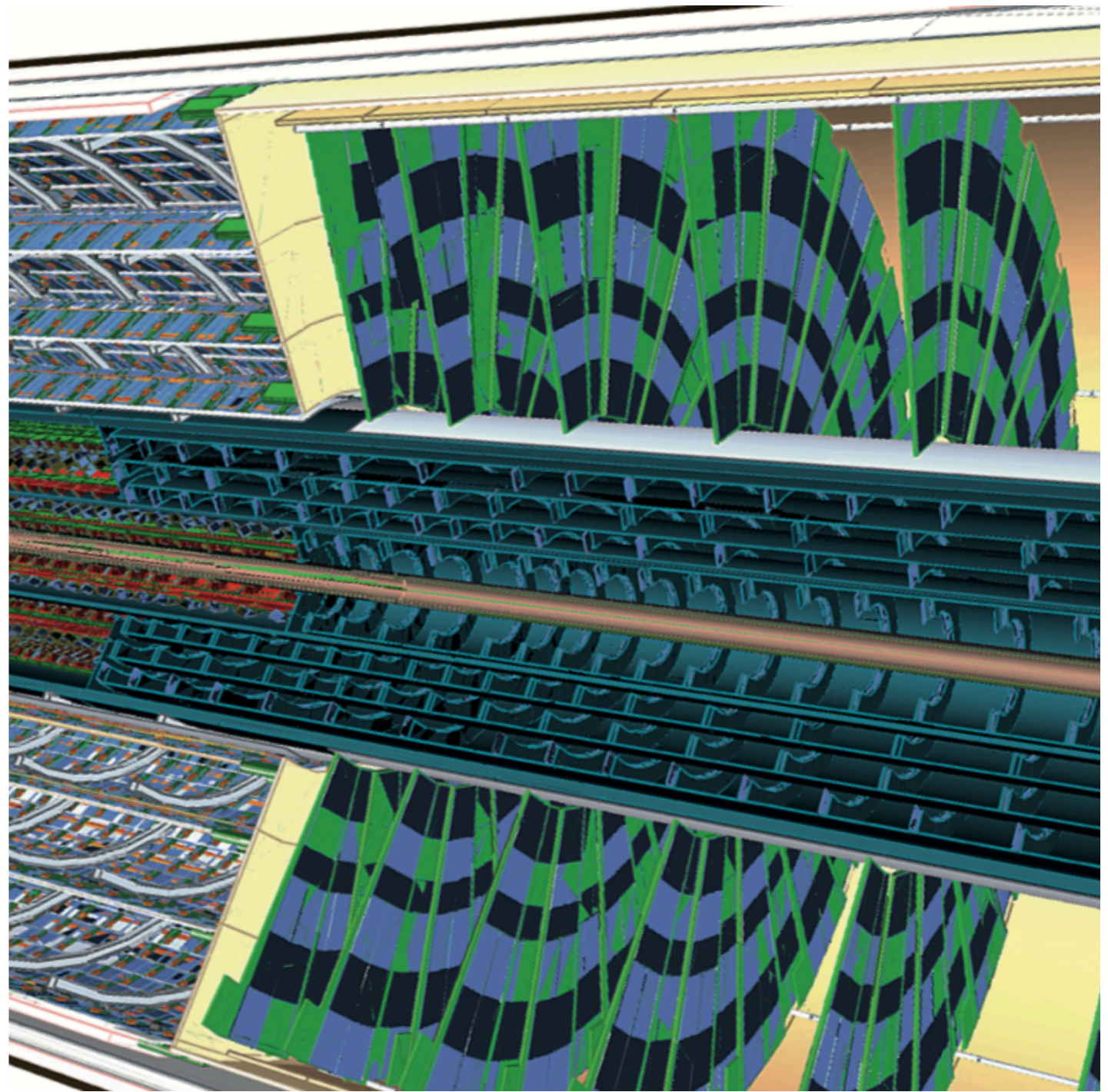
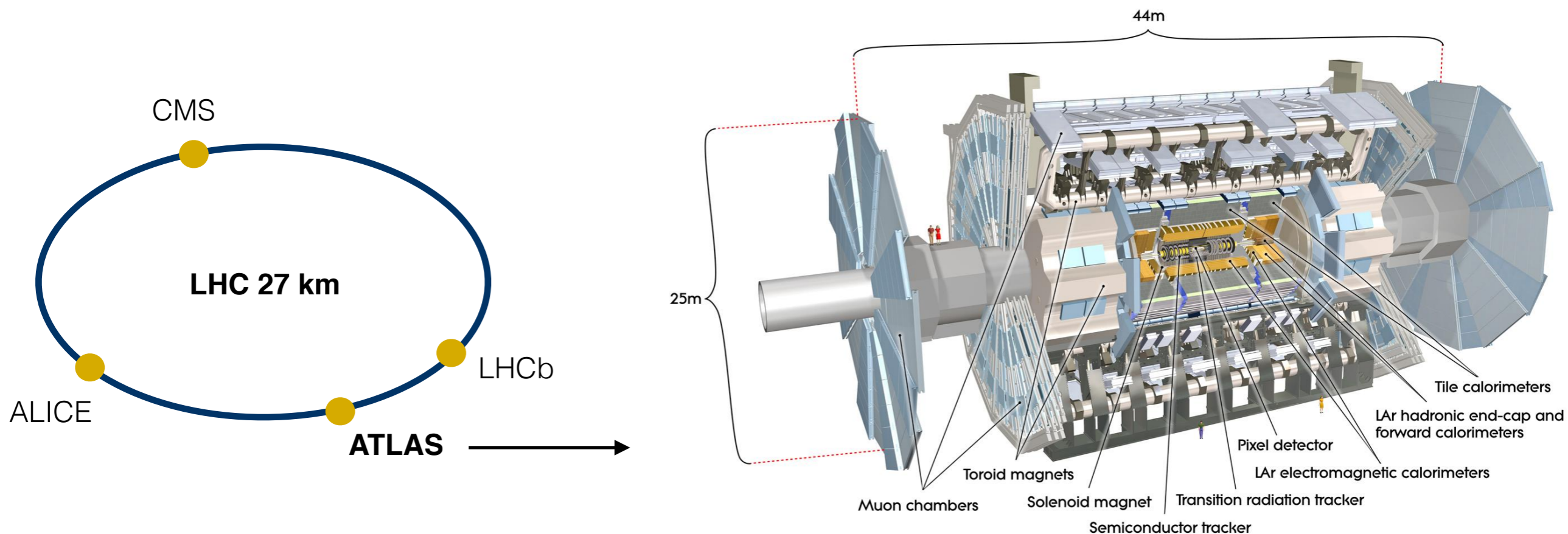


# ATLAS Strip Detector Upgrade for the Inner Tracker: Tackling Big Data Readout Systems

WNPPC 2019  
Dominique Trischuk  
February 16, 2019

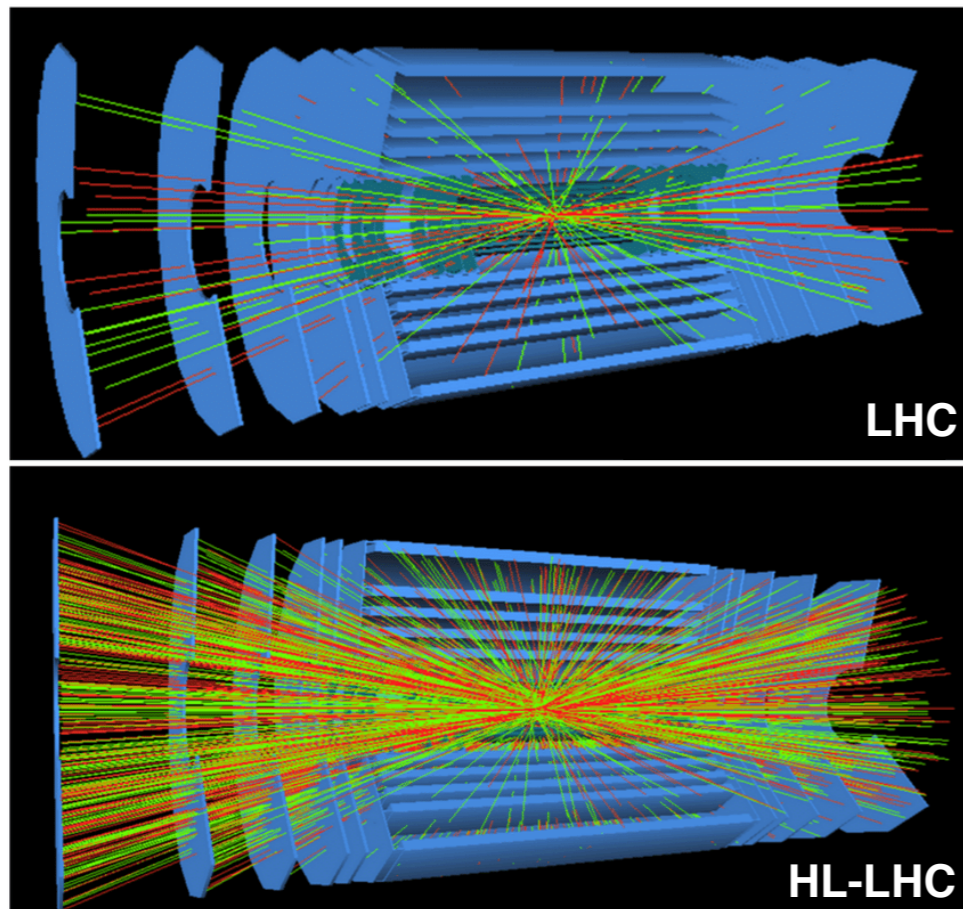
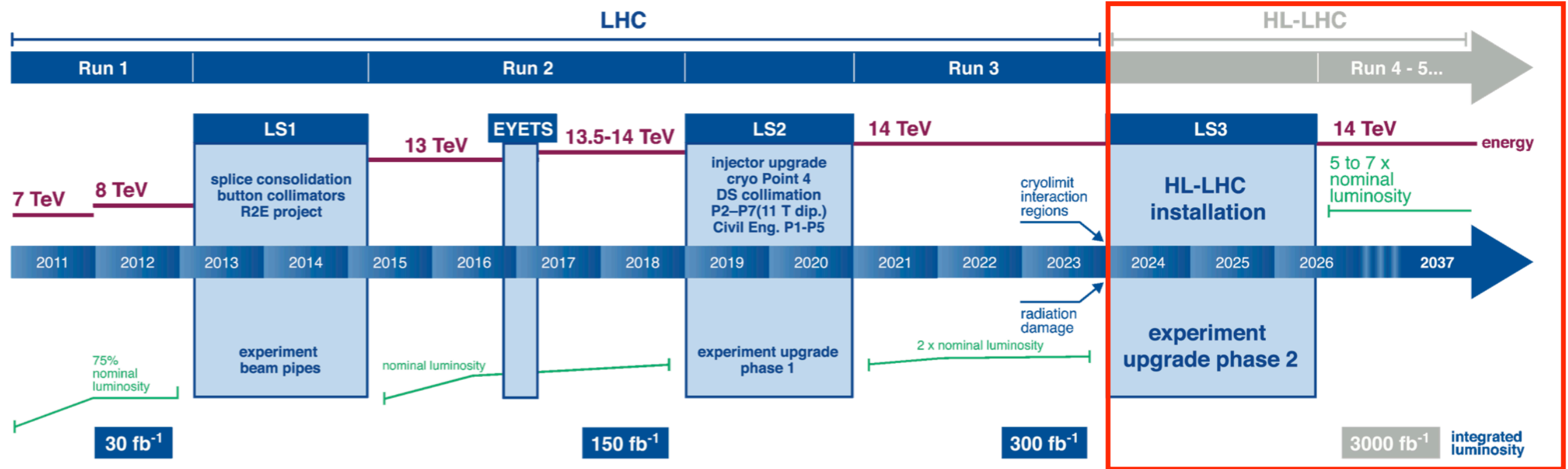


# LHC and the ATLAS Experiment



- Large Hadron Collider (LHC) provides **proton-proton collisions**
- **ATLAS** = general purpose particle detector
  - ▶ Inner detector
  - ▶ Calorimeter (electromagnetic & hadronic)
  - ▶ Muon spectrometer
- Study **fundamental nature of matter**:
  - ▶ Origin of mass
  - ▶ Nature of dark matter
  - ▶ New forces and particles

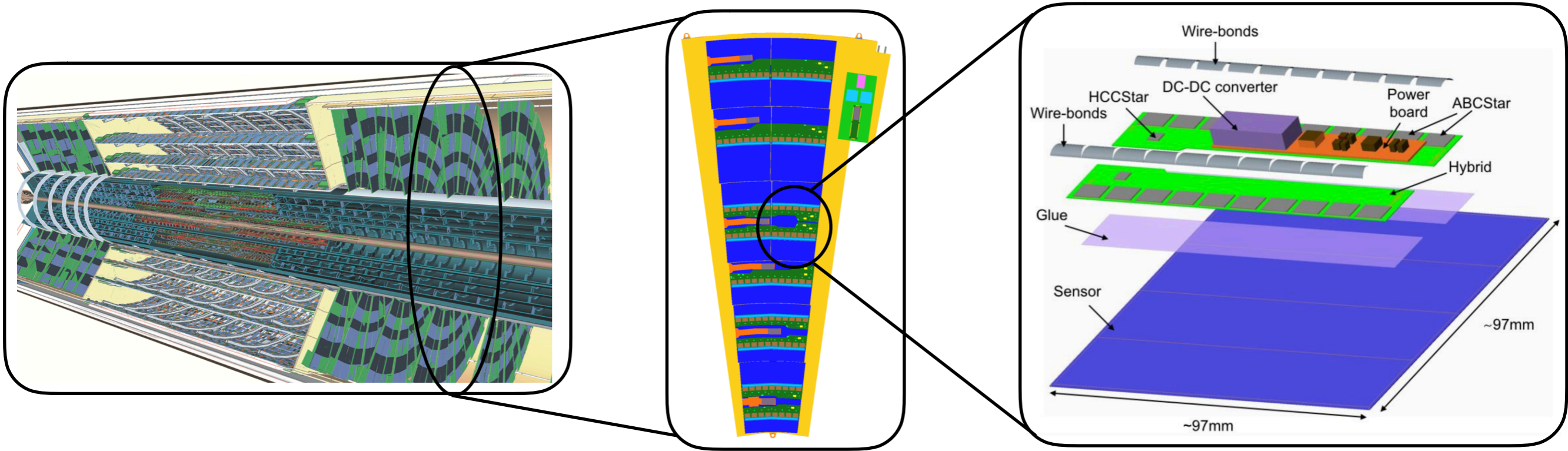
# HL-LHC and ATLAS Phase-II



- High Luminosity (HL) and ATLAS Phase-II Upgrade
  - ▶ Increase LHC **luminosity**
  - ▶ Increase **pile-up**: 200 interactions/ bunch crossing
  - ▶ More radiation damage
  - ▶ Produce **10 times** the amount of data
- Replace current ATLAS inner detector with Inner Tracker (**ITk**)

# ITk Strips Design

 Canadian contribution!



- ITk = silicon pixel + **strip** detectors
- Barrel and end-cap disks

- Strip end-caps segmented into 32 **petals**

- Strip modules
  - ▶ **silicon sensor**
- Electronics
  - ▶ **front-end chips**
  - ▶ power board
  - ▶ electrical sensor-chip connections via **wire bonds**

# Large Increase in Size and Complexity



Smartphone video

$\sim 10^8$  channels/s

vs

## Current Strip Tracker:

$$6 \times 10^6 \text{ Readout channels} \times 10^4 \frac{1}{\text{s}} = \sim 10^{10} \text{ channels/s}$$

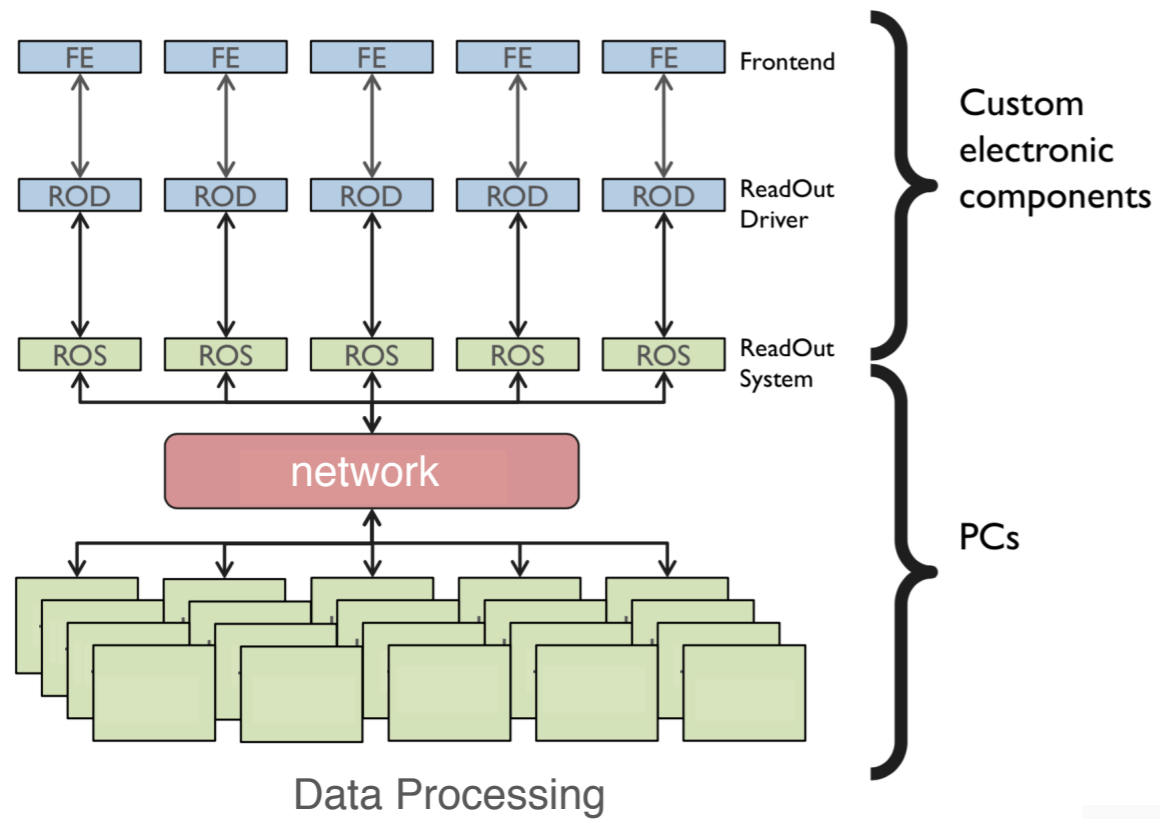
## New ITk Strip Detector:

$$6 \times 10^7 \text{ Readout channels} \times 10^6 \frac{1}{\text{s}} = \sim 10^{13} \text{ channels/s}$$

- Megapixel camera video rates are orders of magnitude lower than ATLAS strip trackers

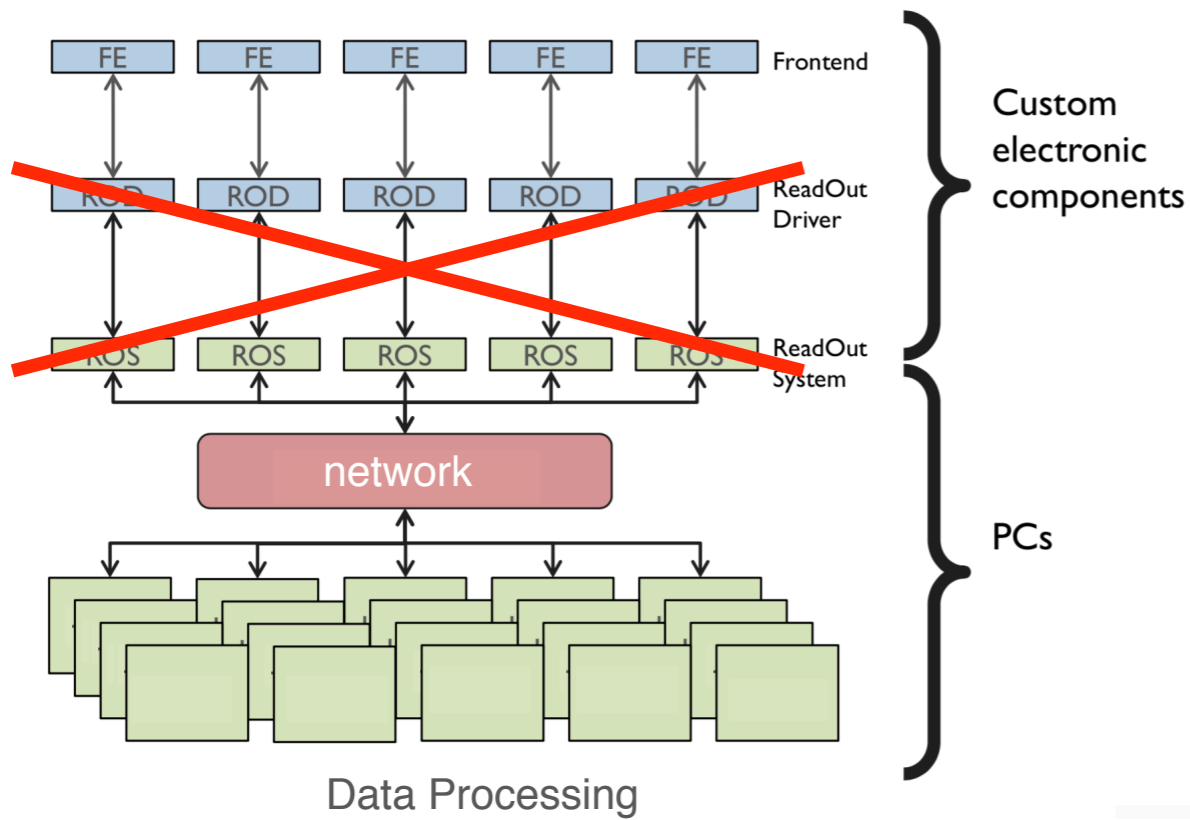
- ITk has a factor of 10 more channels to operate 100 times more often than current detector
- Added complexity requires a re-design of the ATLAS data acquisition (DAQ)

# ATLAS DAQ in the HL-LHC Era

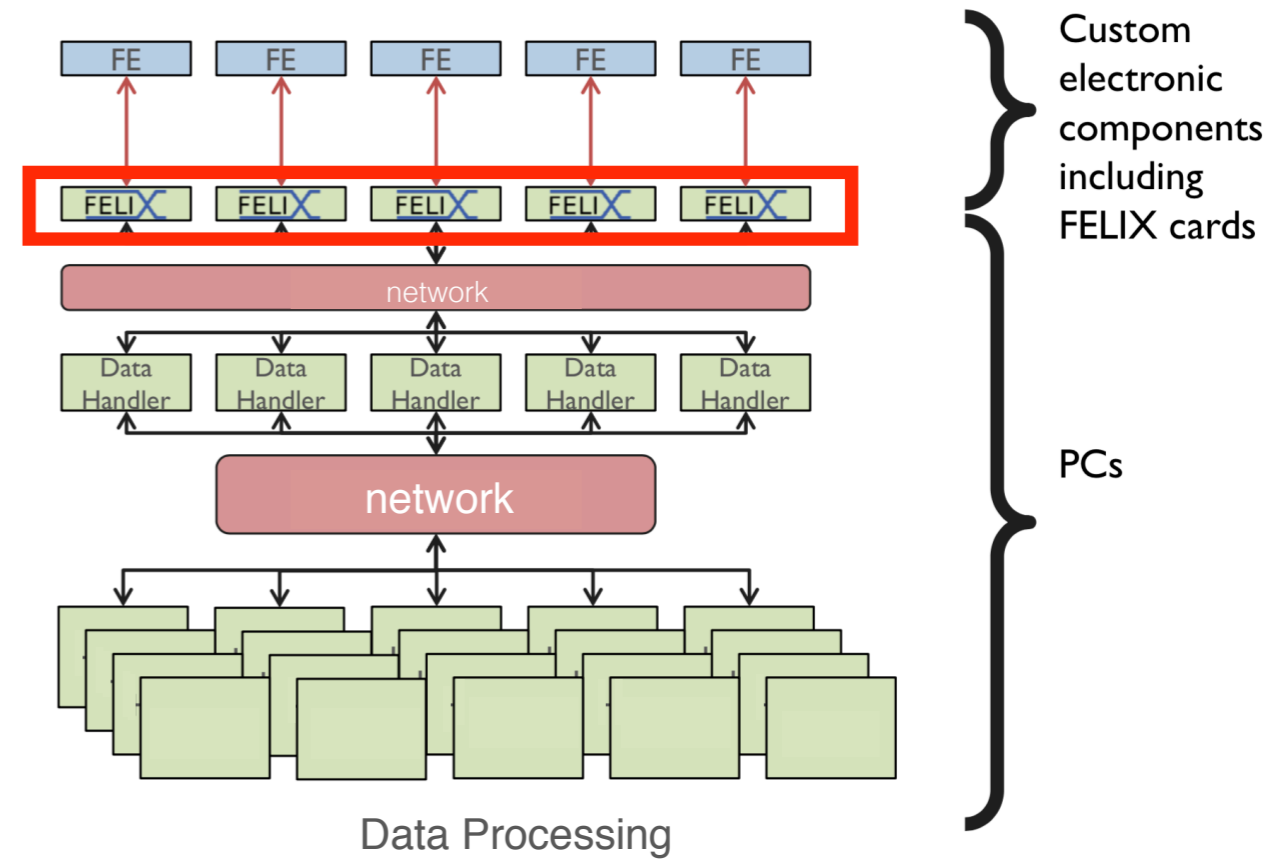
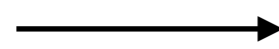


*Current ATLAS DAQ*

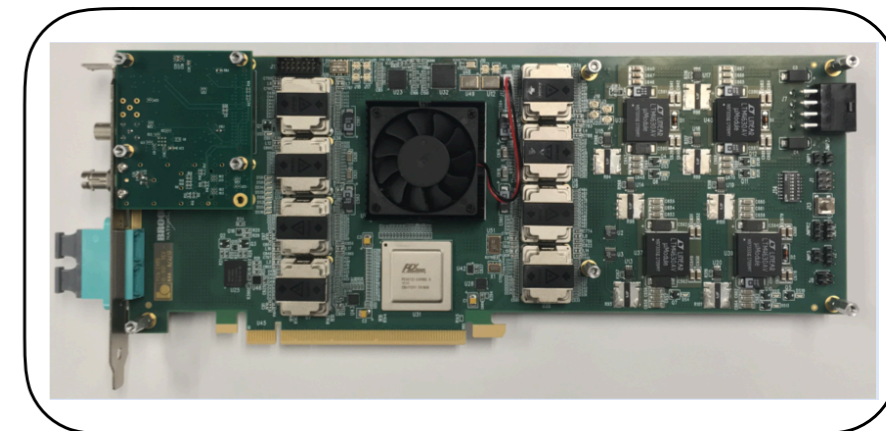
# ATLAS DAQ in the HL-LHC Era



*Current ATLAS DAQ*

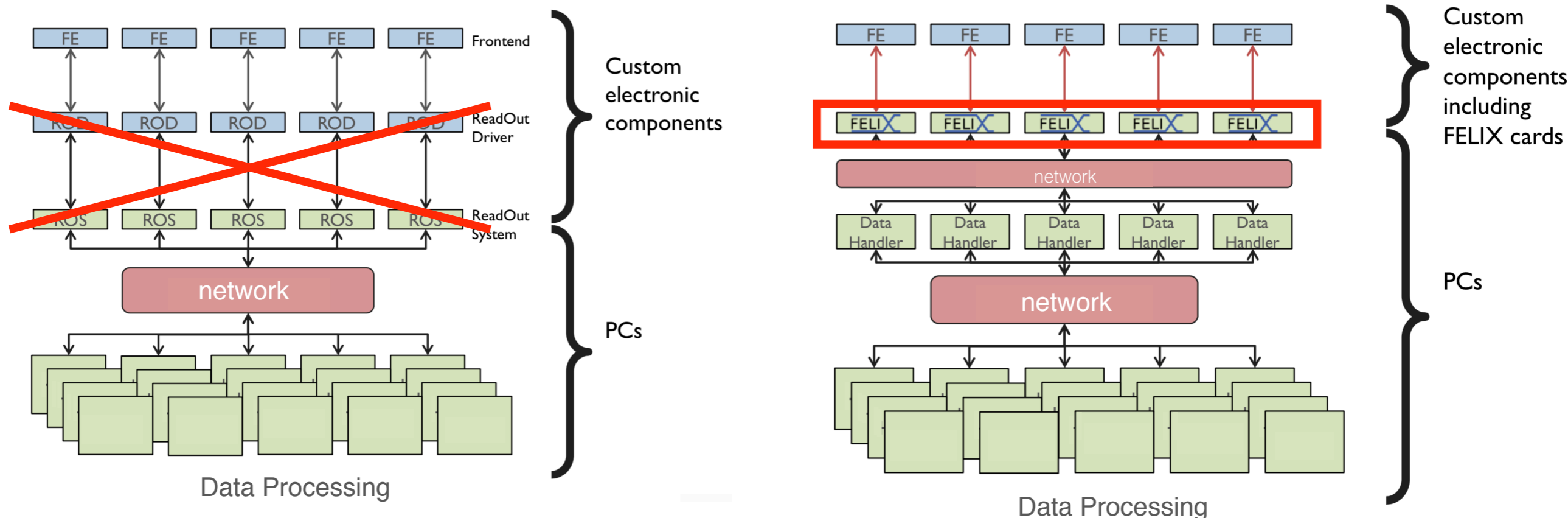


*HL-LHC Era DAQ (2025)*



**Front-End Link Exchange**

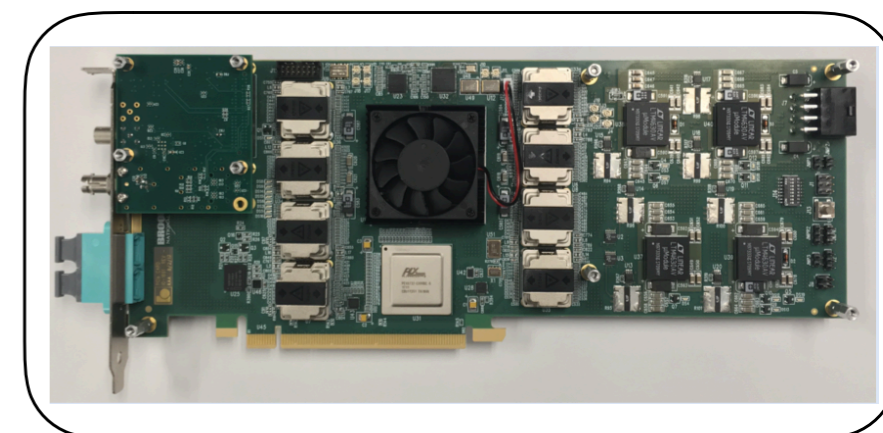
# ATLAS DAQ in the HL-LHC Era



*Current ATLAS DAQ*

*HL-LHC Era DAQ (2025)*

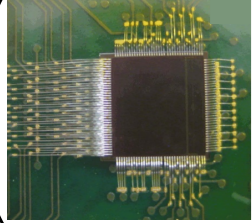
- Remove some of the dependency on custom electronics (i.e. ROD/ROS)
- Replace with commercially available components (**FELIX**)
  - ▶ scalable architecture
  - ▶ detector independent
- How do we **test** a large scale readout?



*Front-End Link Exchange*

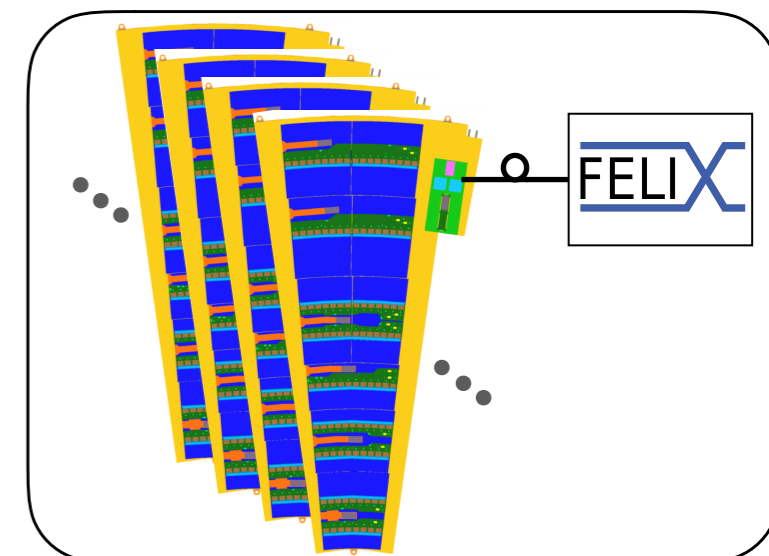
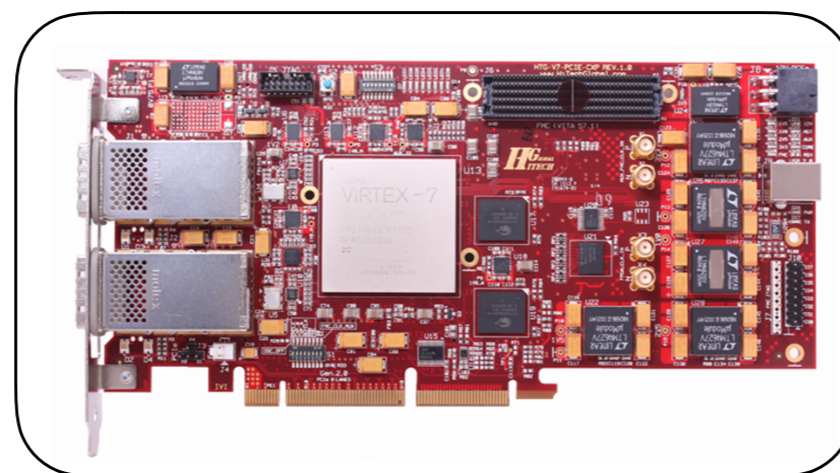
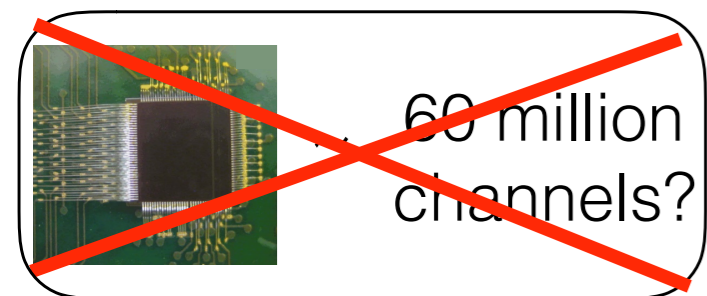


# Testing the ITk-Strip Readout



~ 60 million  
channels?

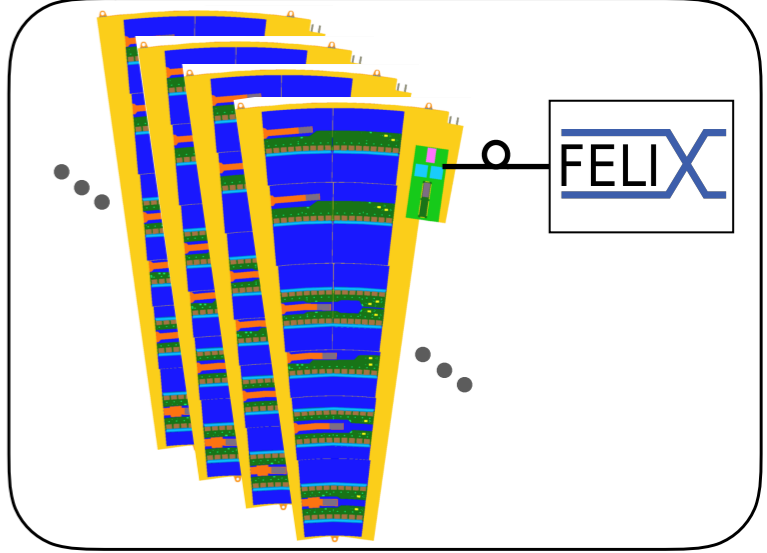
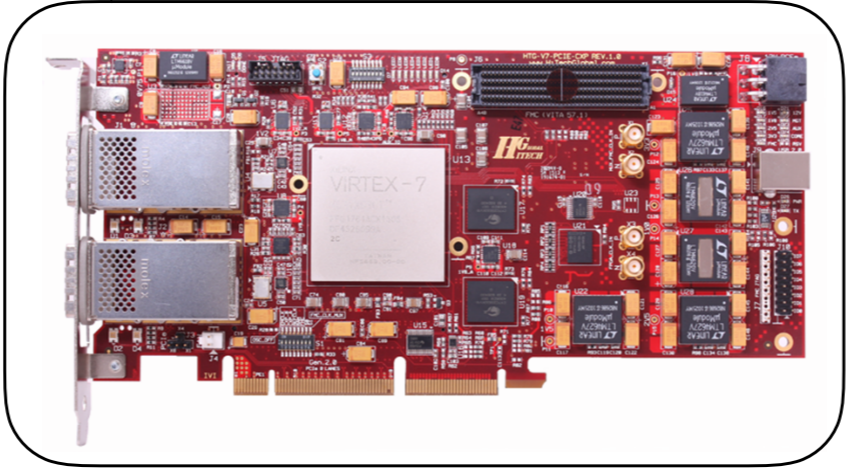
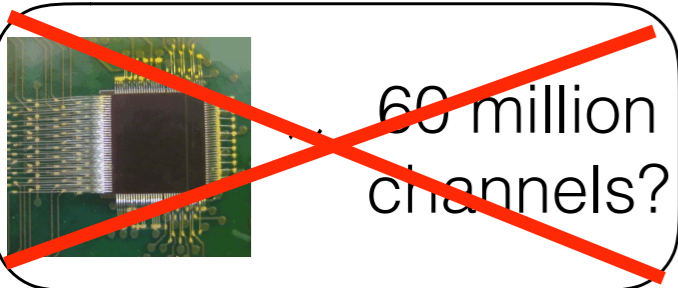
# Testing the ITk-Strip Readout



- **Emulate** many chips using a field programmable gate array (FPGA)

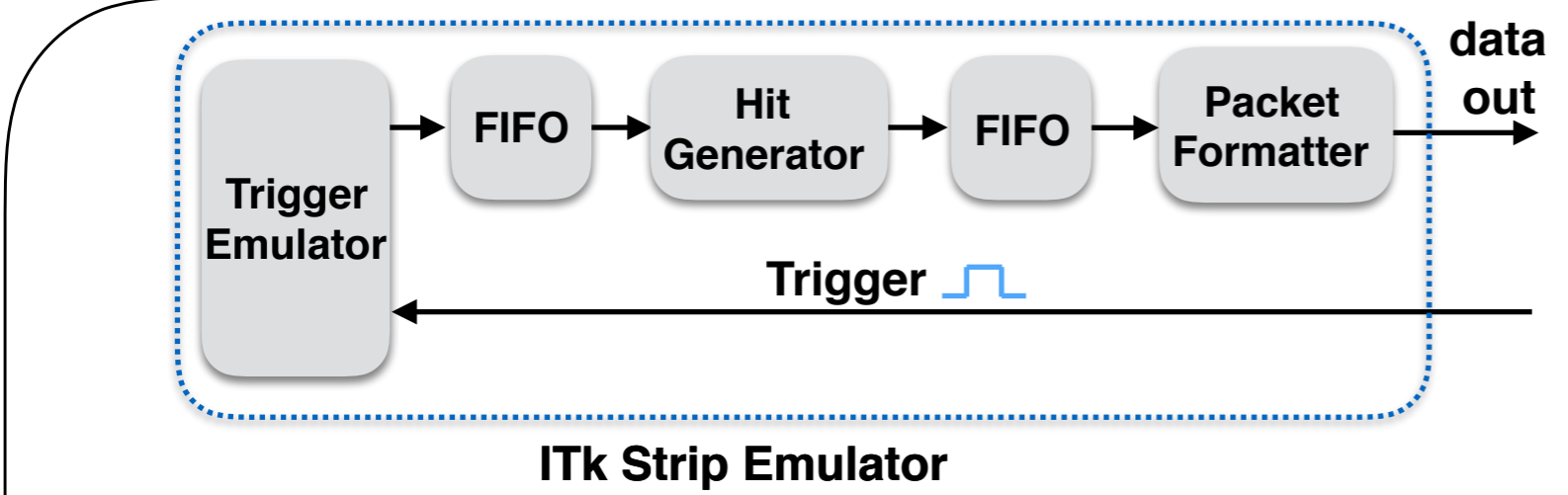
- Mimics the detector and the readout

# Testing the ITk-Strip Readout



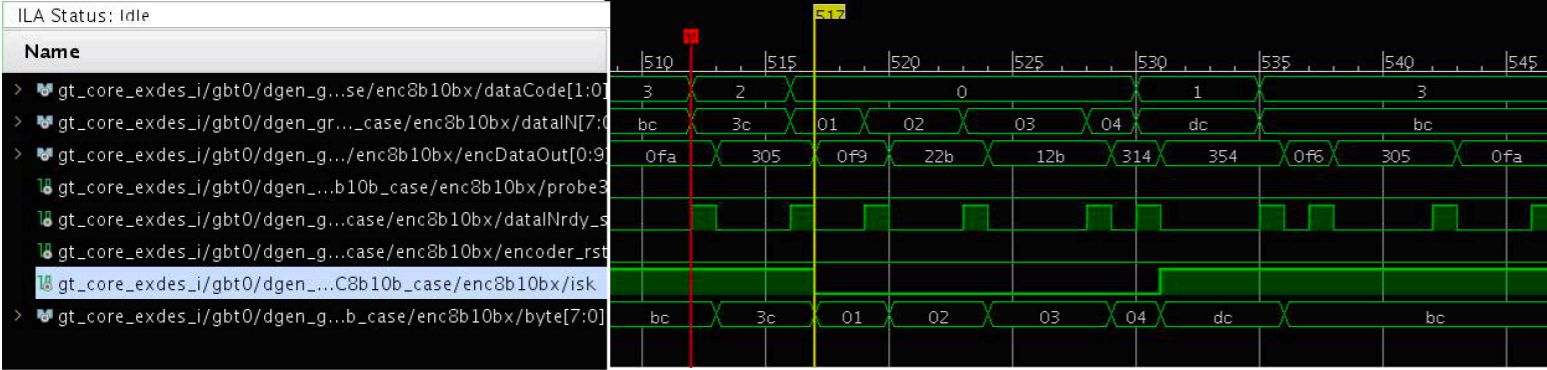
- **Emulate** many chips using a field programmable gate array (FPGA)

- Mimics the detector and the readout



## ITk-Strip Emulator Development at UBC:

- Designed firmware to generate ITkStrip-like data packets
- Modified existing data generating infrastructure to successfully readout emulated ITk-Strip data with FELIX
- Developing control interfaces for generating different data patterns

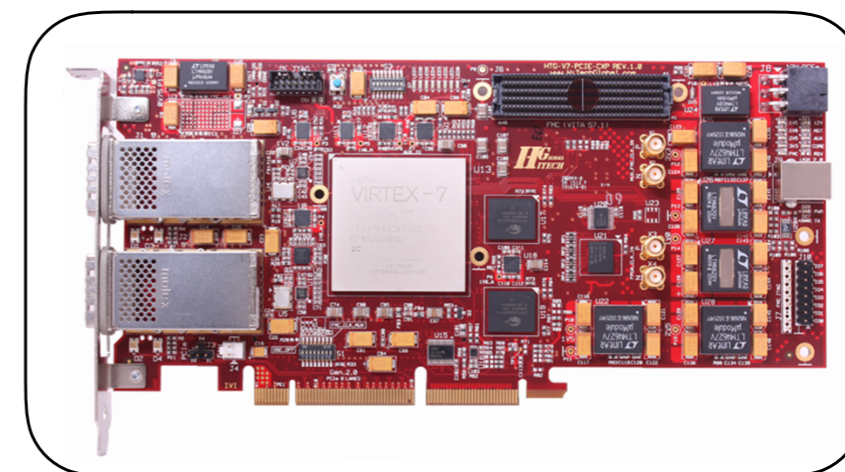


# What Do We Do With an Emulator?

Help to answer questions like:

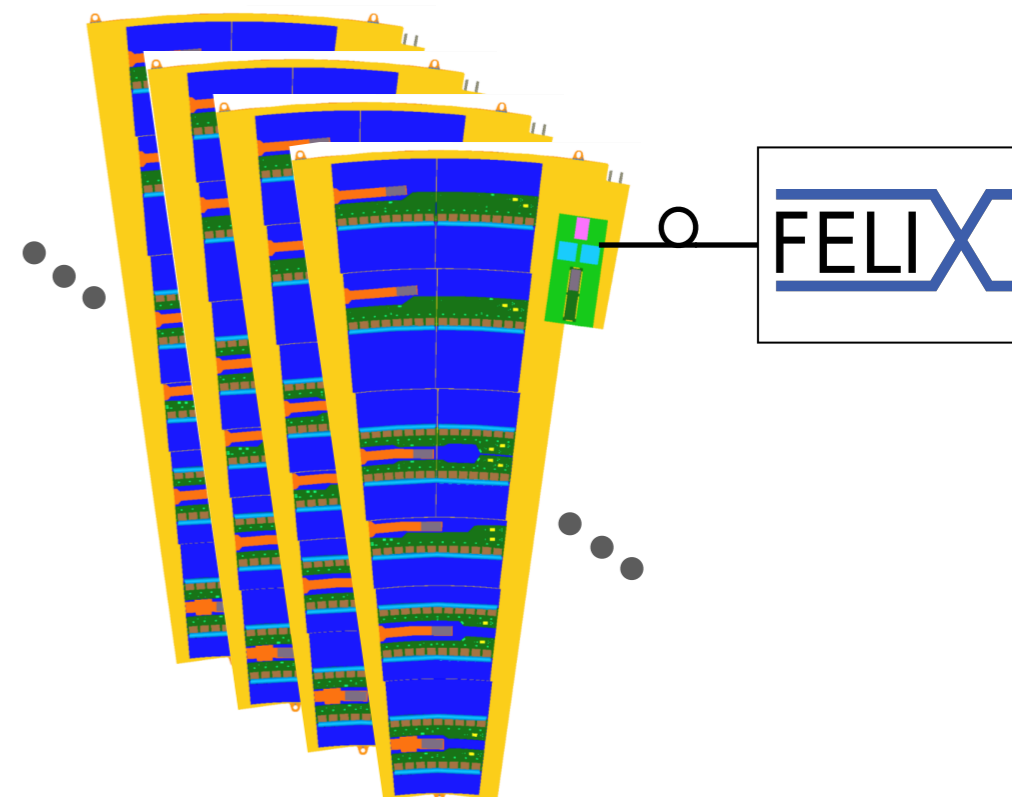
- How do we **integrate** the ITk-Strip front ends with the ATLAS DAQ
- Are **customizations** within FELIX required?
  - ▶ specific information front ends need from FELIX
  - ▶ live data checks in FELIX during readout
- Will it work and **meet the Phase-II readout requirements**?
  - ▶ i.e. Can we successfully operate  $10^{13}$  channels/s?

**Need to answer these questions well in advance of installation (2025)**



**ITk-Strip Emulator**

mimics the detector and the readout



- **ATLAS will be upgraded** starting in 2024 to install new detectors and readout systems that can withstand the high rate environment of the High-Luminosity LHC
- New inner tracker will consist of silicon pixel and **strip detectors**
- Increase in size and complexity of the new detector presents a unique challenge in the design and testing of the ITk readout system
- **ITk-Strip emulator** will allow us to answer fundamental questions about the integration of this new detector within the larger ATLAS data acquisition system

