Proposed Athena DAQ

DAQ WG Conveners:

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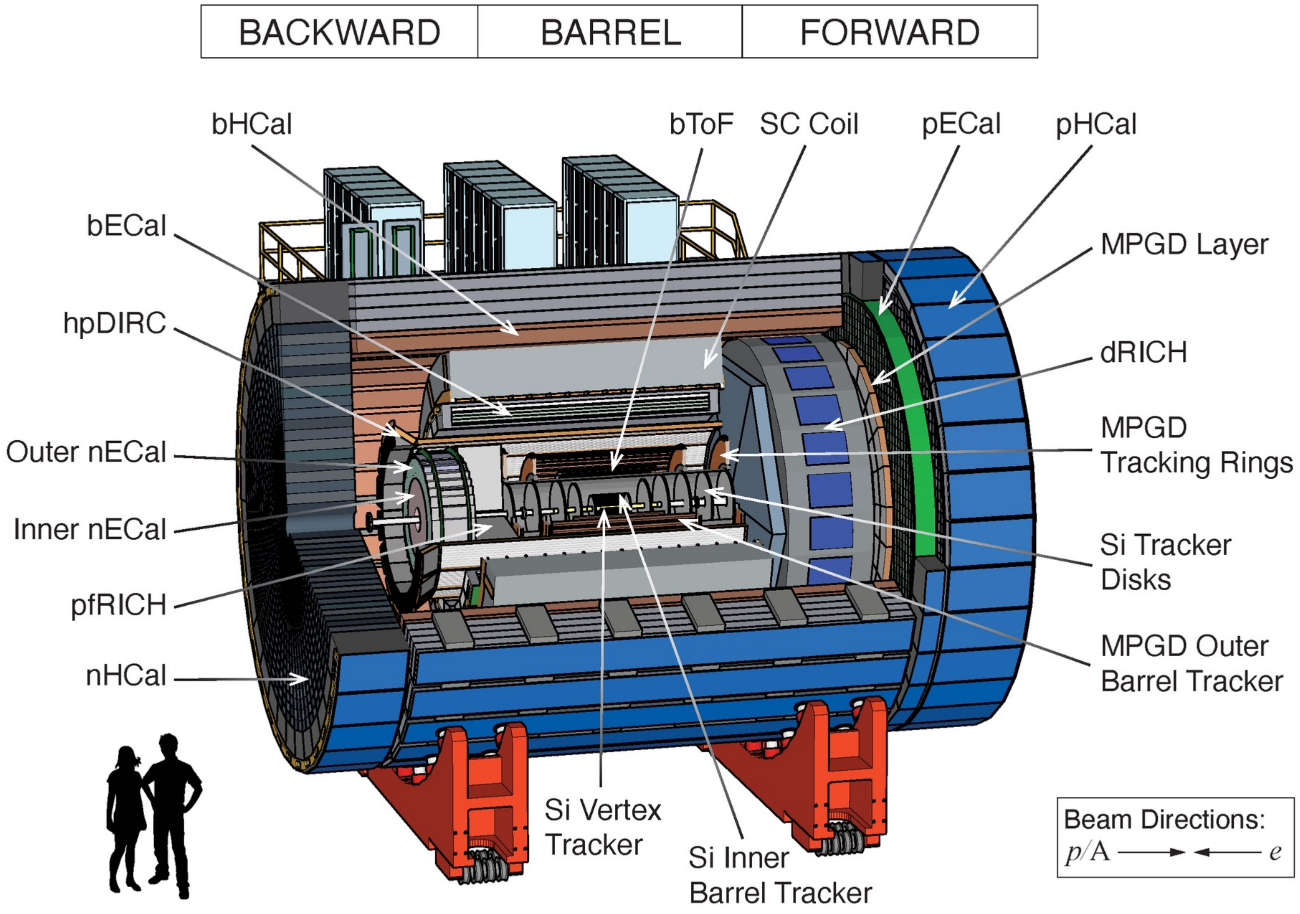
Streaming Workshop X

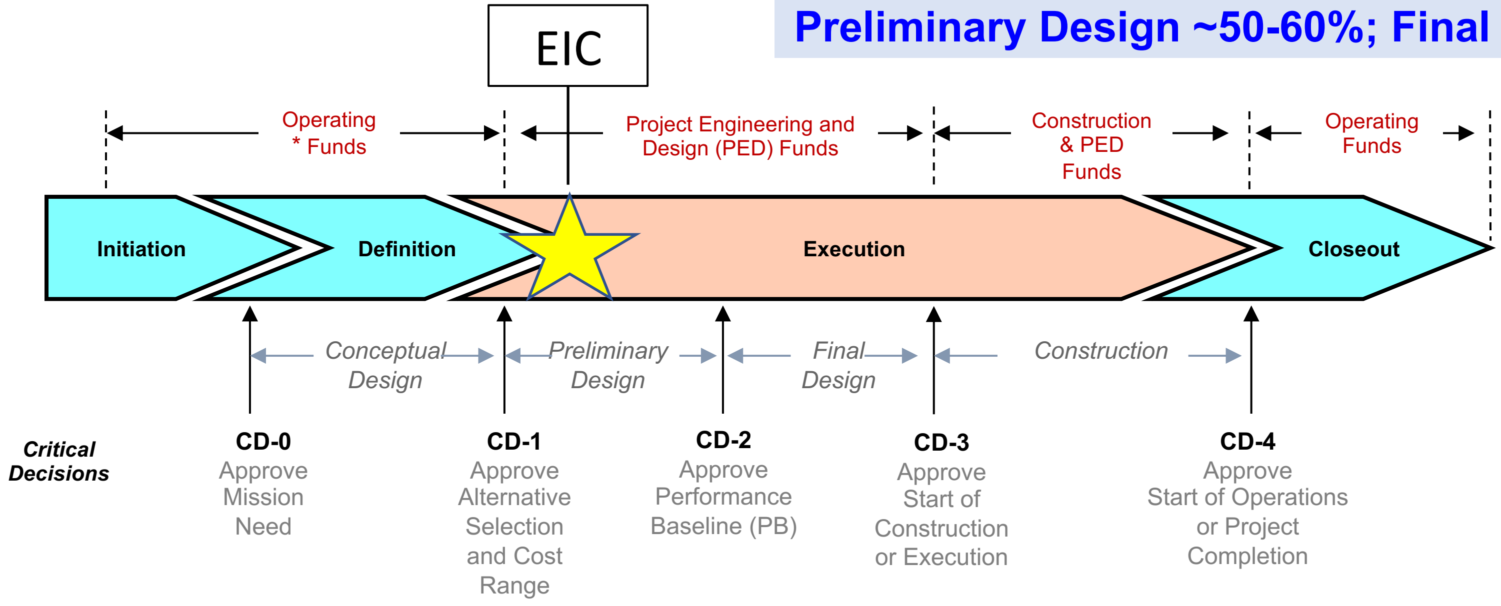
5/17/2022



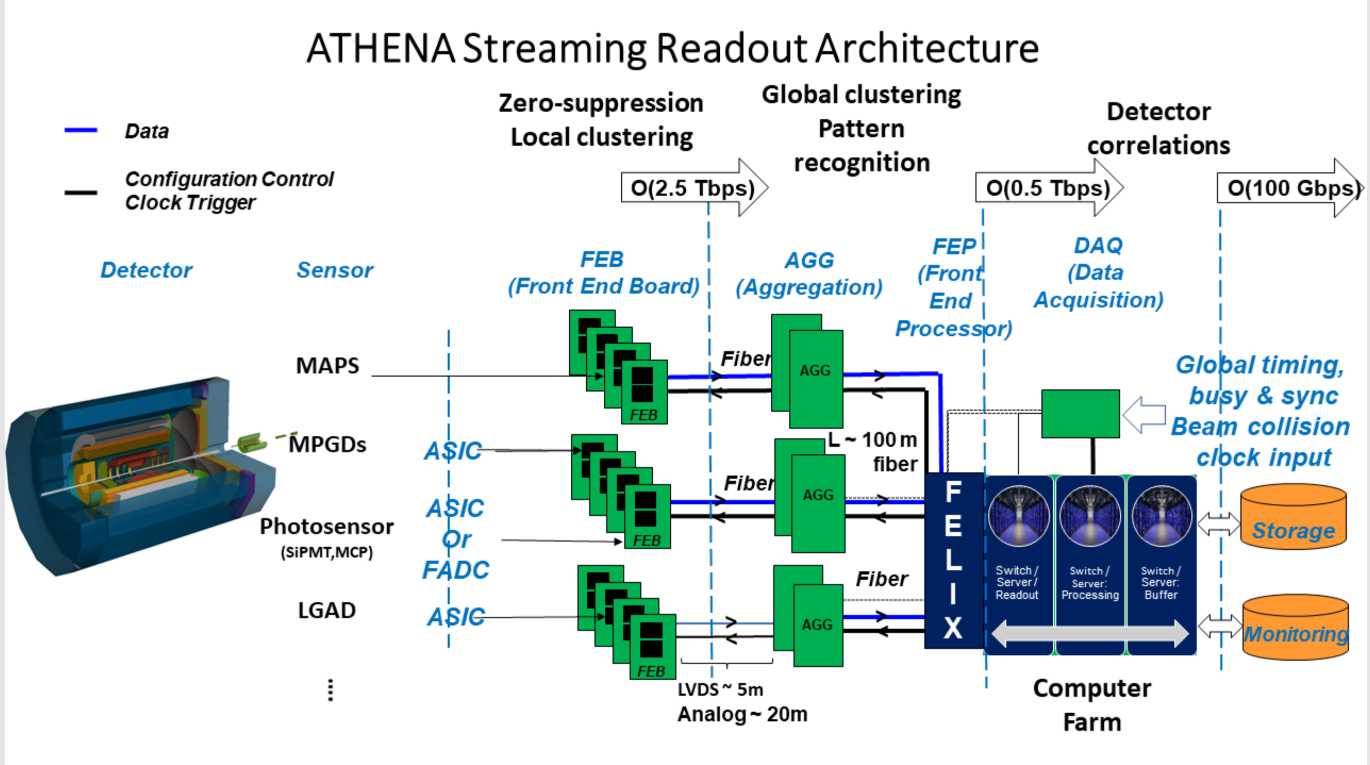
Introduction

- The project is beginning preliminary design
  - ➢ We need to start making and documenting technical decisions
- The DAQ WG is in the process of merging ECCE and Athena using ECCE as the reference
- The most useful topics to discuss the challenges we expected and our planned solutions to these challenges with the expectation that the discussion carries over to the project detector
  - ➢ Brief outline of the Athena DAQ proposal
  - ➢ Use selected DPAP and DAC questions, as well as a few of my own, as a repository of the challenges to be discussed.

Preliminary Design ~50-60%; Final Design $\geq$ 85%

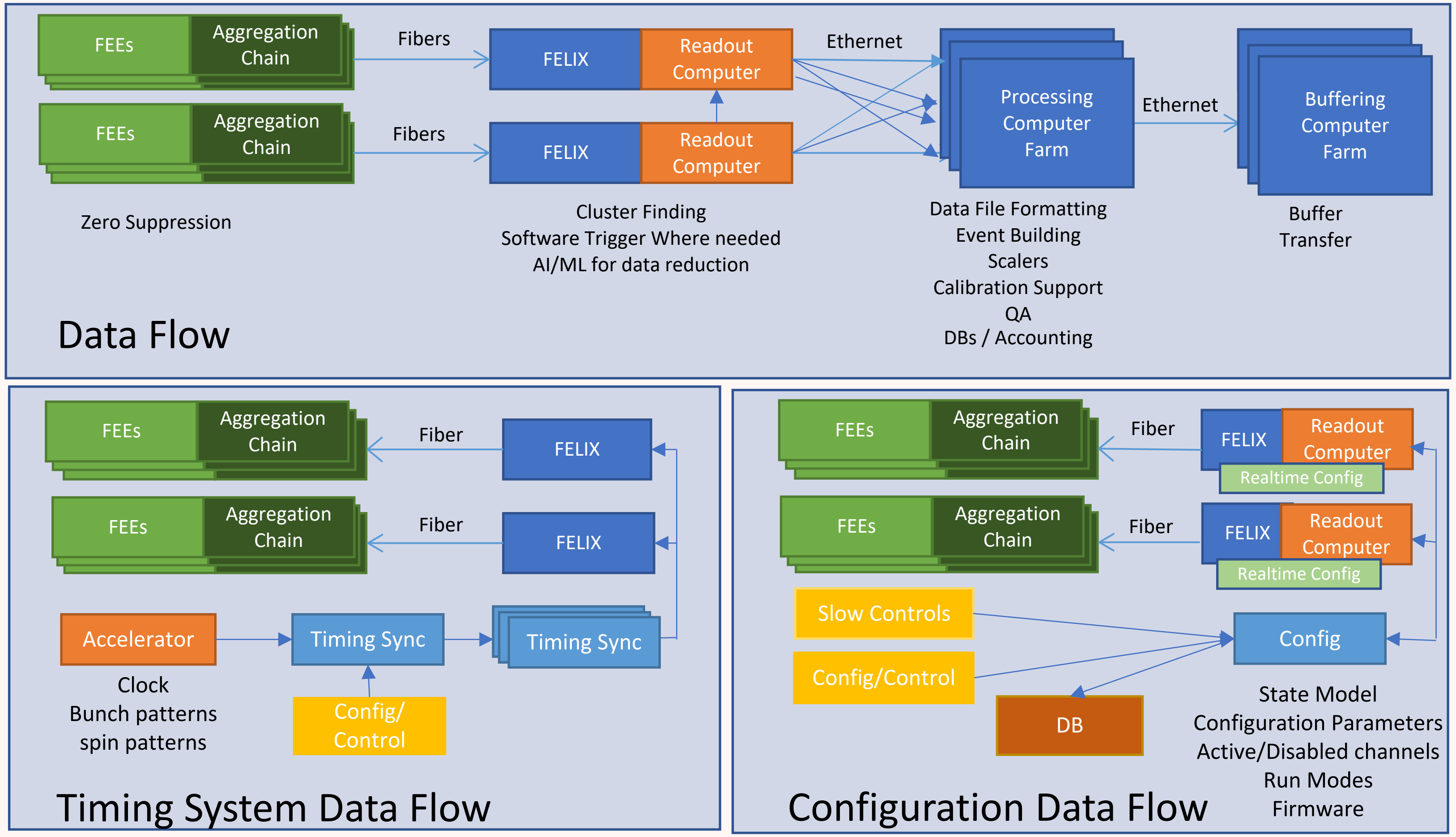


Proposed Athena DAQ



Detector	Number of Channels	Detector Readout Technologies
DIRC	100k	MCP-PMT
DRICH	300k	SiPM *
ERICH	225k	SiPM *
EcalBarrelScFi	4000	SiPM using FPGA based readout boards derived from the STAR DET-ADC board
EcalEndcapN	3080	SiPM
EcalEndcapP	26600	SiPM
EcalImgBarrel	619M	MAPS*
HcalEndcapN	10000	SiPM
HcalEndcapP	2375	SiPM
HcalBarrel	26600	SiPM
Inner Vertex Tracker	60B	MAPS*
MPGDTrackerBarrel	66k	Micromegas
urWELLTrackerEndcap	50k	uRWELL
GEMTrackerEndcap	28k	GEM
B0Silicon [[2]] [3]	400M	MAPS*
B0preshower	260k	AC-LGAD readout with ALTIROC ASIC
RP	550k	AC-LGAD readout with ALTIROC ASIC
OffM	320k	AC-LGAD readout with ALTIROC ASIC
ffiZDCSi	213k	Silicon strip detectors - DC-LGADs
ffiSDCSciFi	576	PMTs
ZDCSiPb	500k	If silicon used, less if silicon fibers used.
ZDCScint	36-72	PMTs; depends on whether two sections are read-out indepdenently.
TOF	332k	AC-LGAD
Luminosity monitoring and Low Q tagging	4000	6 PMT based calorimeters *

Summary of the Athena Streaming Readout Concept:



Characteristics of Athena Streaming Model

- Very large number of channels
- Very low occupancy
- Connection limited rather than throughput limited, so extra throughput capacity is present for most detectors
- No trigger, but FEEs perform aggressive zero suppression
- Collision Hit + Background Hit data volumes low enough to be read out to tape as clusters

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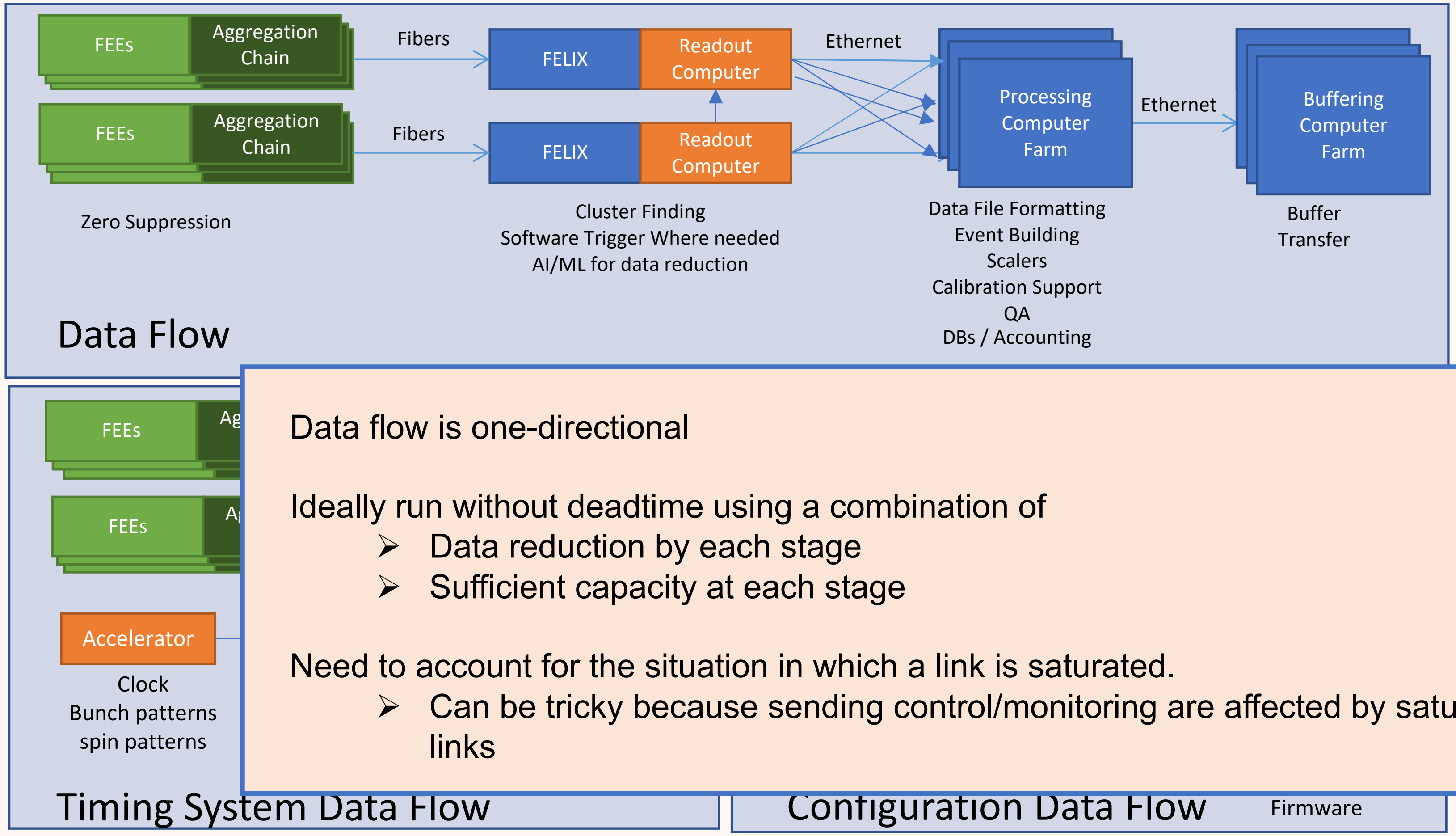

Data flow is one-directional

Ideally run without deadtime using a combination of

- ➢ Data reduction by each stage
- ➢ Sufficient capacity at each stage

Need to account for the situation in which a link is saturated.

- ➢ Can be tricky because sending control/monitoring are affected by saturated links

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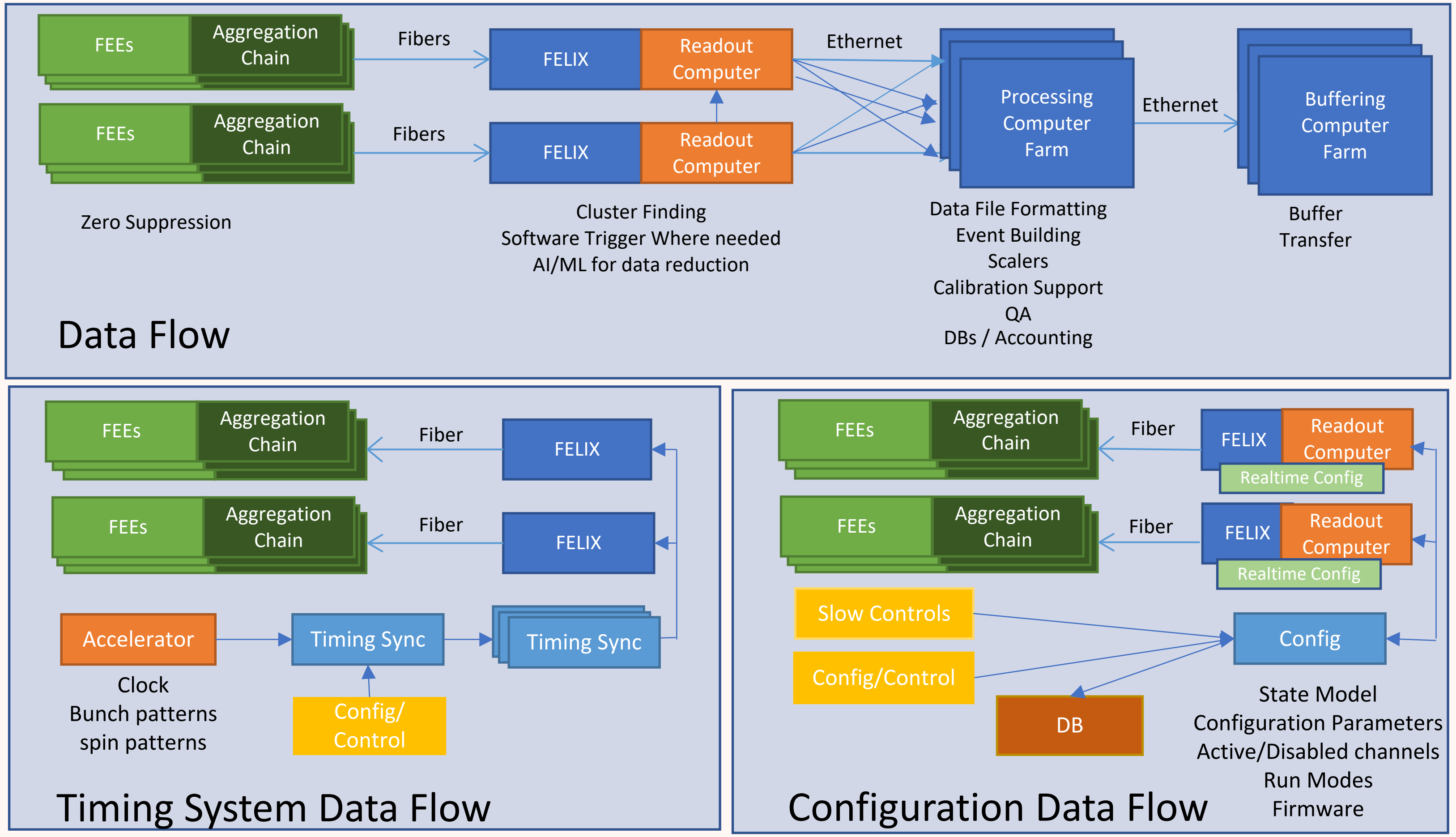

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Summary of the Athena Streaming Readout Concept:

The timing system is two systems!

Electronics interface between fiber and FEE chain

- In Athena assumed to be in detector responsibility, but as a yet under-developed puzzle piece. We discussed:
- GBT chipset
  - Configuration
  - Timing
  - CERN ASIC interfaces
  - Fiber transducers / data transfer
  - Rad Hard -- but cost / 40Mhz
- (or) FPGA based (discussed JLAB system)
- (or) Hybrid

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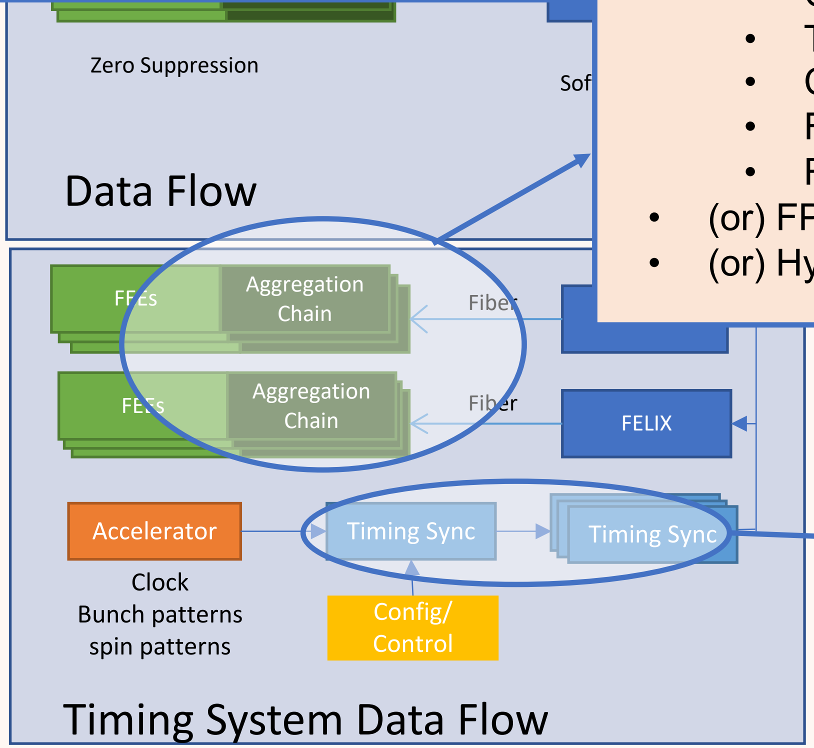

The interface boards between Accelerator, Run Control, and FELIX

- Self contained, but
- Rich functionality (Identify bunches, defining time frames, setup special run modes, actual triggering as fallback or debugging, allow shift control)
- Defines functional operation of whole DAQ

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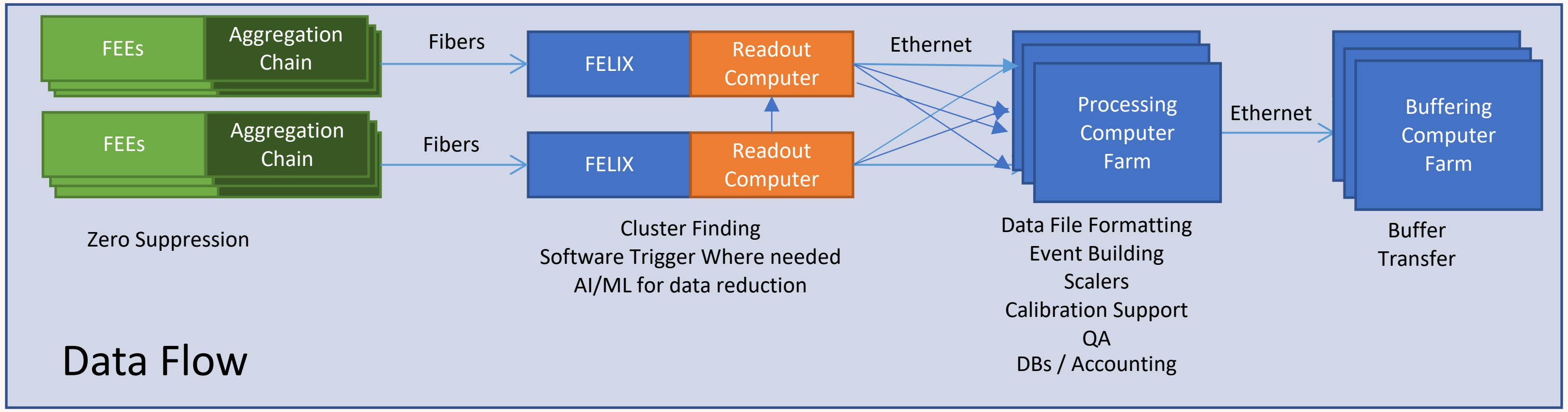

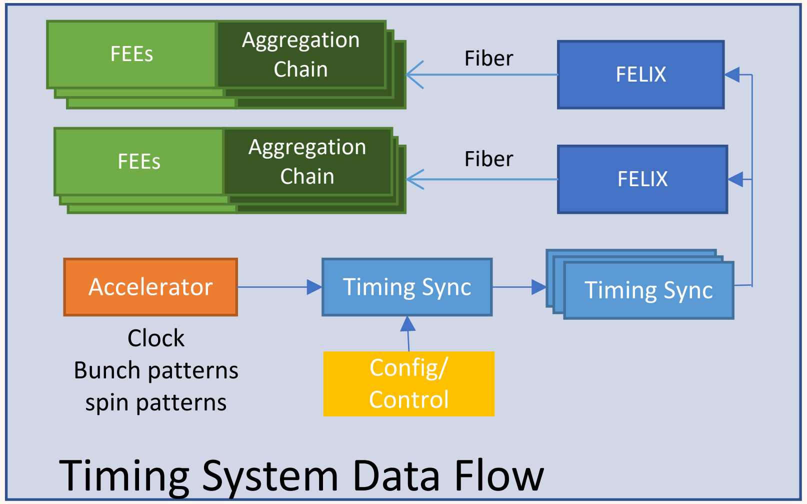

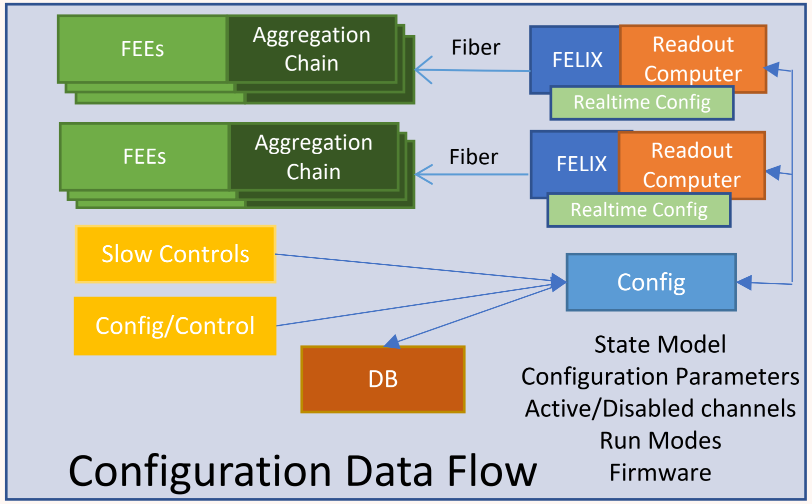

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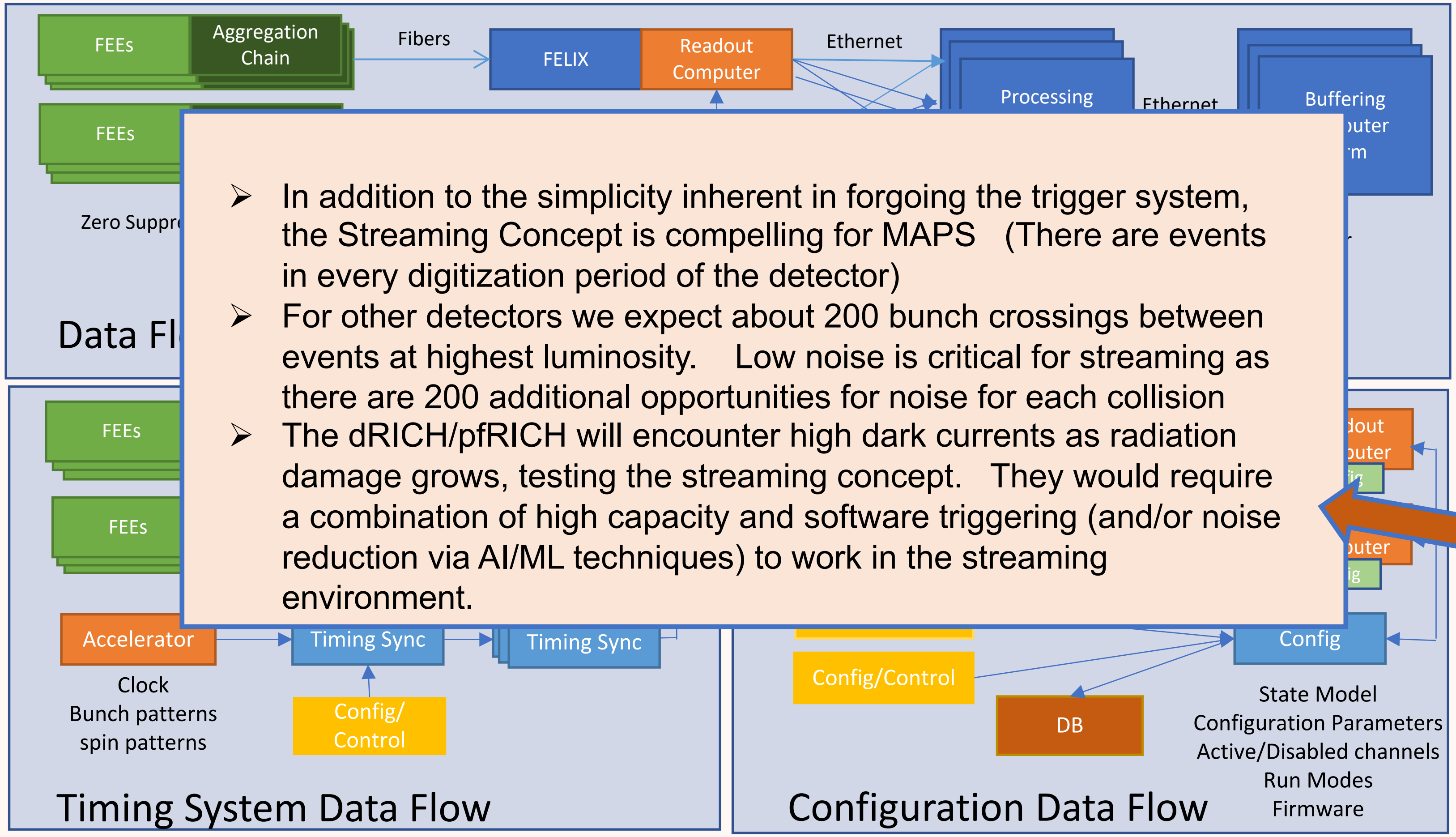

- ➢ In addition to the simplicity inherent in forgoing the trigger system, the Streaming Concept is compelling for MAPS (There are events in every digitization period of the detector)
- ➢ For other detectors we expect about 200 bunch crossings between events at highest luminosity. Low noise is critical for streaming as there are 200 additional opportunities for noise for each collision
- ➢ The dRICH/pfRICH will encounter high dark currents as radiation damage grows, testing the streaming concept. They would require a combination of high capacity and software triggering (and/or noise reduction via AI/ML techniques) to work in the streaming environment.

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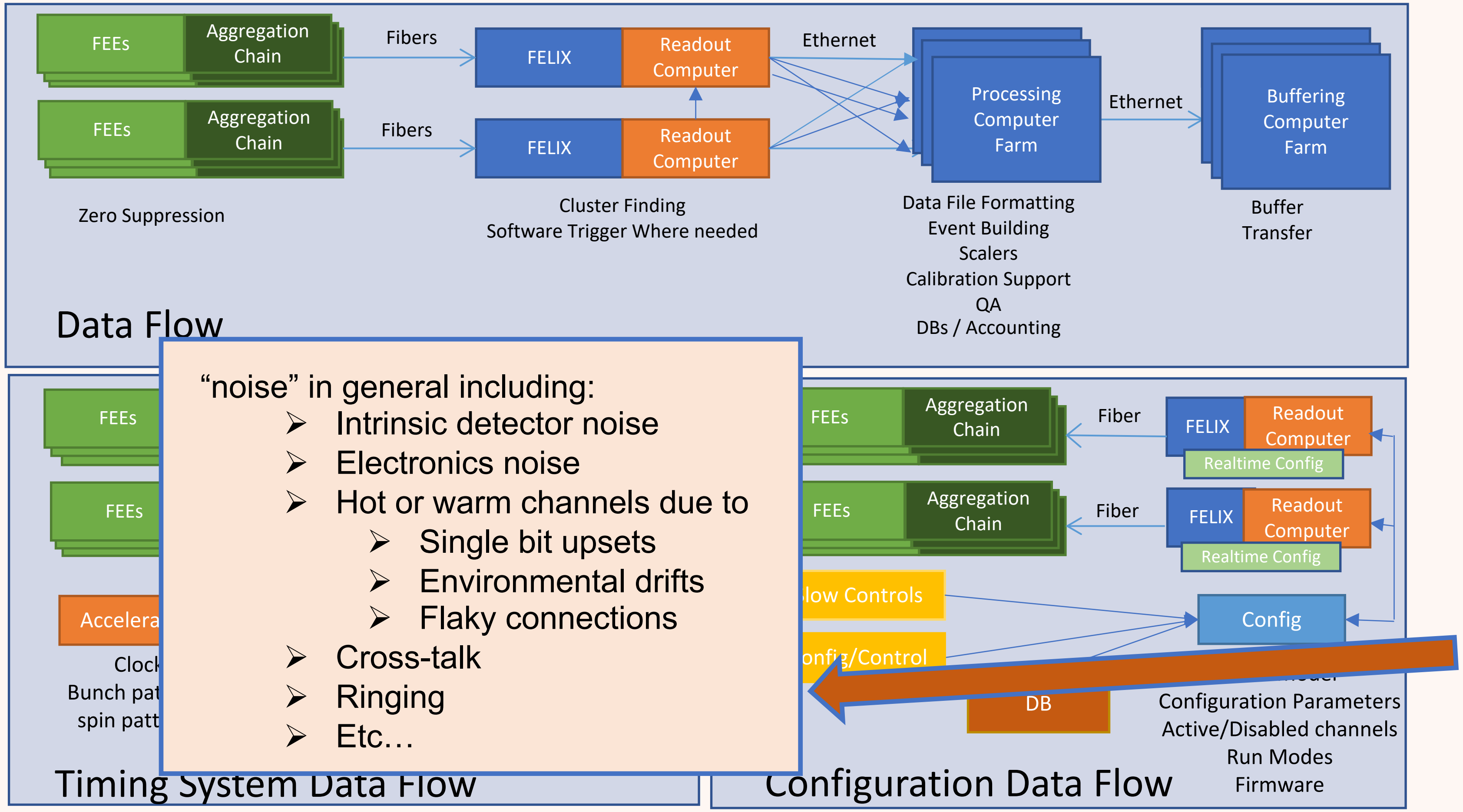

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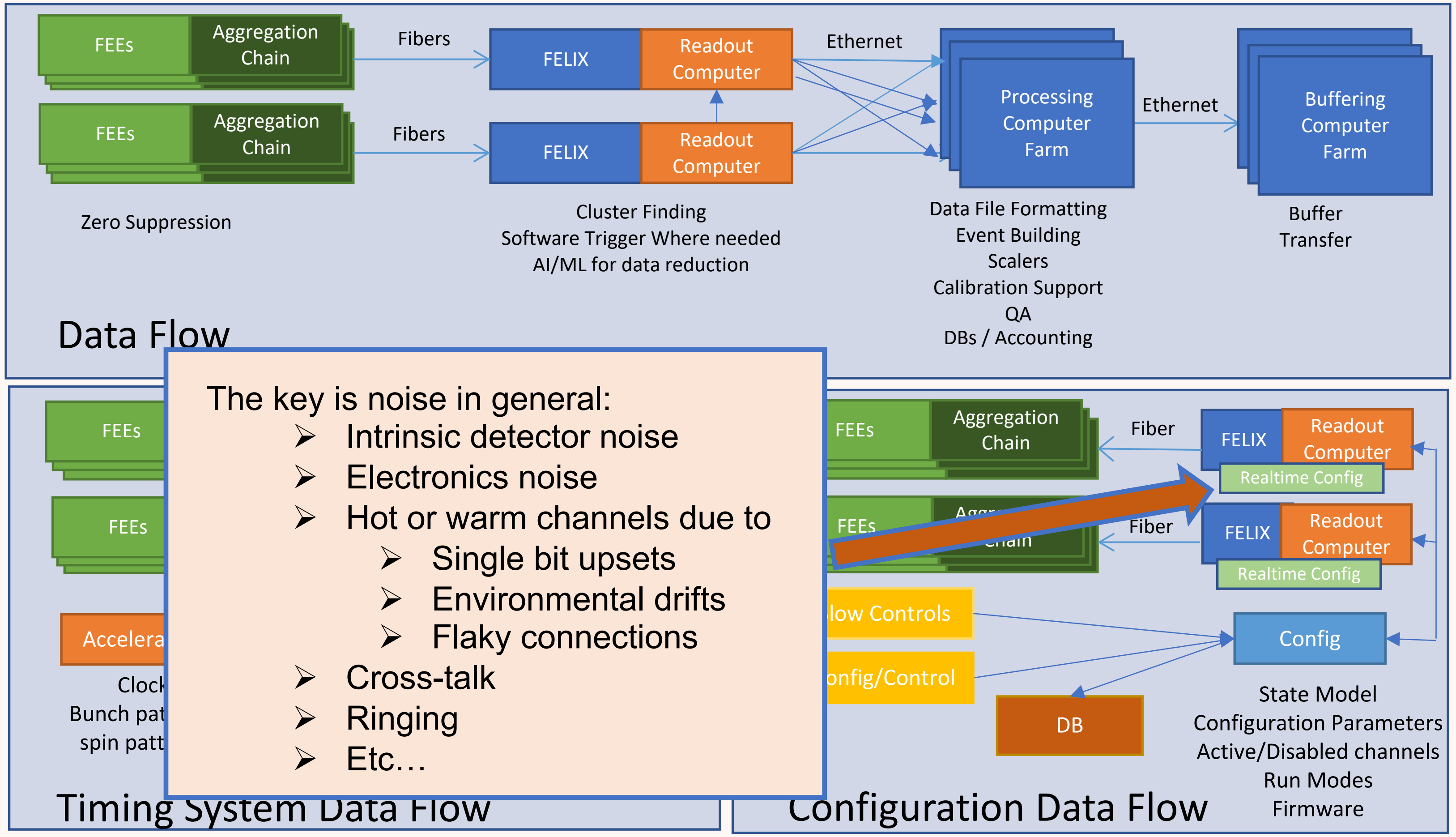

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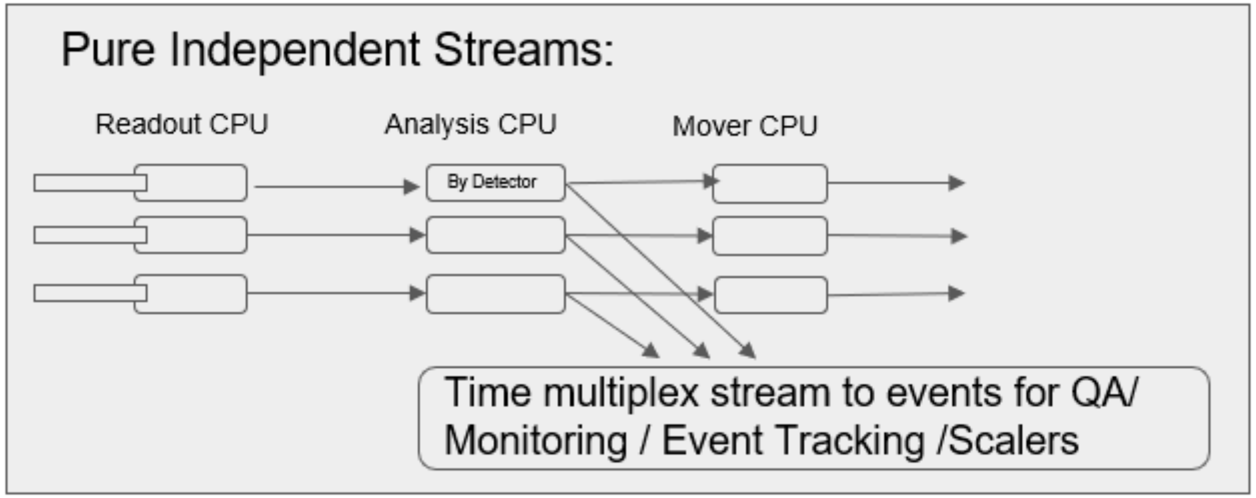
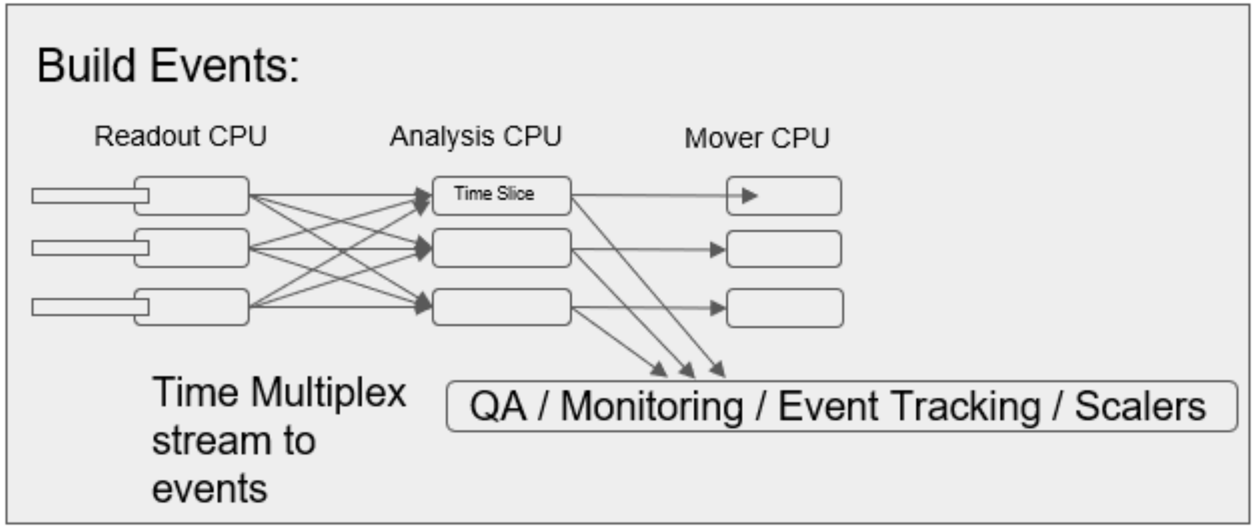
Streaming Model





Athena did not fully specify the streaming model. However, we did consider the following tasks to be part of the responsibilities of DAQ:

- Online QA
- Monitoring detector performance
- Monitoring beam for collider feedback
- Keeping track of events/event types to aid in tracking physics goals as well as goals for the collider and the operations group.
- Scalers

These seem to require identifying/building at least a fraction of events online.

E-1: Identify the main uncertainties/risks/challenges in implementing full streaming readout with the proposed sub-detector technologies and DAQ system concept. (Page 1)

ATHENA

- Challenge: A single channel firing at the bunch crossing rate would represent approximately 1/20th of the full data budget of the entire Athena DAQ. This fact, combined with the enormous number of channels represents the largest expected challenge to the streaming concept.

  Requirements:

  - We will need to evaluate each design decision of the FEE/Readout chain for each detector in the context of streaming data volume
  - We will need to control FEE level detector calibration, particularly as it relates to zero suppression with a preference towards automated methods for pedestal subtraction and common mode noise removal.
  - We will need to monitor for bad or noisy channels or modules at every level within the system, and we will need the dynamic ability to identify, reset, and disable them.

- Challenge: A shift in the bunch crossing identifier in any detector component could make it impossible to fully reconstruct events. The initial construction of data packets will occur in the FEEs of the various detectors so there will be multiple possibilities for errors. It will be necessary ensure that such errors don't happen and to monitor for such occurrence.

  Requirements:

  - Procedures for timing in detectors must be considered with every iteration of FEE/Readout chain design
  - Capability to set and monitoring timing must be incorporated with detector design and readout protocols. Pulsers or other hardware features that can explicitly determine timing of components must be evaluated.
  - The streaming readout paradigm offers automatic "pre & post bunch crossing readout". Effective monitoring of the pre-post information must be performed in the online QA to ensure that detectors and detector components are properly timed.

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  Every DAQ system…

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  More unique to Athena / EIC Detector because of high channel count, low occupancy, and streaming design

  Potentially large databases
  Supervisor hardware?
  Implications for analysis?

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  > These imply cross-detector correlation (ie event building) within the online QA

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E-1: Identify the main uncertainties/risks/challenges in implementing full streaming readout with the proposed sub-detector technologies and DAQ system concept. (Page 2)

ATHENA

- Challenge: Unexpected backgrounds could potentially overwhelm the links between the FEEs and the Readout computers

  Requirements:

  - Overcapacity between FEE and Readout Computers. The number of channels and scale of envisioned aggregation define the overcapacity, but it also serves as valuable insurance against unexpected background. If detectors can be successfully read into the COTS computing, then software triggers or other pattern recognition technologies can be adopted to reduce the bandwidth. The current expected throughput overhead for various detectors is described in the following table:
  - Retain possible hardware trigger via the timing system
    - Could aid in commissioning and debugging
    - Could prove necessary to solve issues with irreducible backgrounds
  - Maintain close contact with collider throughout design and operations.
    - Understand expected backgrounds
    - Maintain vacuum to keep beam gas low
    - Coat beamline with Au layer to reduce synchrotron radiation
    - Control beam characteristics
    - Control and monitor beam quality

Detector	Available Bandwidth Overhead
B0, RP, OffM, ZDC	x1000
Si Calorimeters	x200
Imaging Calorimeter	x20
MAPS Tracking	x200
MPGD Tracking	x400
dRICH/eRICH	Conservative Estimate of Maximum Radiation Damage
DIRC	x200
TOF	x120

E-3: At what point in the data acquisition does software (and firmware) become common for all readout chains? Which hardware and software control, configuration, and timing are common for all detectors?

- The interface to the fiber will be have three defined protocols that must be implemented in each detector’s custom electronics
  - The Data transfer protocol
  - The clock protocol for transferring the clock up to the FEE
  - The configuration protocol
- The strategy for both firmware and software will be to use general frameworks for the operation of the DAQ system with specific modules to implement the detailed requirements of each detector
  - For FEE this will mean
    - Definition of and adherence to general protocols on the fiber
    - Reuse same hardware, firmware for similar technologies where possible.
  - For FELIX and readout computers the framework is conceptual. The code will implement the exterior protocols to the fiber and to the DAQ computing and have a shared core for all detectors but will have modular detector specific processing.
  - Proven frameworks such as Guadi to be used for higher level DAQ, QA and analysis tasks
- Data formats will be chosen so that navigation within files to detector data is independent of detector. The contents of detector data banks will be specific to the needs of each detector and each detectors running mode. Data readers will use the most general interface possible depending upon detailed data contained in each bank

E-4: To what extent are offline algorithms foreseen to be used in the online system, and in which part(s) of the readout/DAQ system?

- The data volume from collisions and backgrounds is expected to be low enough to record all data after zero-suppression and cluster finding. We do not plan to do online reconstruction for use offline.
- We do expect that there will be significant overlap and re-use of code between the offline and online processing. For example:
  - Data file readers would be provided by, and maintained by DAQ
  - QA plots should have a significant overlap with similar requirements offline
  - There will be calibration tasks that need to be handled by DAQ that will demand significant overlap with offline. These overlaps would include method and documentation of the method, specific code, and database management.
  - We will use offline reconstruction code running online for DAQ tasks.
    - QA,
    - Support for calibrations,
    - Support for monitoring calibrations
    - Providing feedback to the collider.

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This answers the intent of the question

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This responds to the wording of the question

E-5: Within your proposed DAQ/computing model, at what point will online calibration be required? Describe a high-level strategy for online calibration, and significant technical considerations in achieving this?

ATHENA

We distinguish between online and offline calibrations

- Online calibrations are necessary to ensure that the data taken is of high quality
  - Global timing and detector timing
  - Gains, zero suppression thresholds, slewing corrections, time windows
  - Disable bad/noisy channels, disable bad/noisy modules
- Support for online calibrations
  - Integrate online calibrations with DAQ computing framework
  - Capability to retain fraction of data and selected periods of data online to run calibration jobs
  - Capability to run calibration code on local processing farm
  - Use dynamic methods where supported by the ASICs / FEEs
  - Implement dynamic monitoring, control, and record keeping of bad/noisy channels and modules as part of configuration interface
- Full reconstruction for analysis is not expected to be done online. The final calibration for the offline reconstruction will be done offline.
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Similar to the previous question, the first two bullets answer the wording of the question, which is a significant set of tasks.

However, the intent of the question, seems to probe the difficulties of doing final analysis calibrations within DAQ, and the answer is that we did not intend to.

ATHENA

E-6

Q: Describe how the development of the readout electronics for different subdetectors will be centrally coordinated.

ATHENA

- **2 main ingredients**
  - the **internal ATHENA** effort
  - the **project** effort, with 2 main branches
    - FEE ASIC development and coordination
    - DAQ development and coordination

- **Within ATHENA:**
  - Appoint a DAQ-Electronics Coordinator (DEC)
  - form a DAQ-Electronics Coordination Board (DECB) with representatives of the groups with major involvement in DAQ or FE electronics development and a representative of the ATHENA Technical Board

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Many overlapping groups:

- Project Electronics
- Project DAQ
- Detector DAQ & Electronics WG
- Each Detector
- eRD projects / ASIC developers

To make progress in overlapping areas:

- Iterative process involving
- Define smaller groups doing specification and design for each subproject
- Coordination of feedback from all the groups.

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Ex: Most conceptions of the organization of the detector data is into “time windows” or “time frames”

- What is the duration of a time frame?
- Is the duration the same for all detectors?
- Is the timing of the frames synchronized for all detectors?
- Are time frames defined arbitrarily by the timing system or are they defined algorithmically?
- Athena suggested a fallback trigger mechanism. How does this work with the time frame definition?
- What is the granularity of time for the FEEs (3 levels of time? Frame, BX within frame, high detector time?)

Many more questions… but these have implications far outside of the timing system itself. But until there is a proposed detailed design, one doesn’t know the implications.

Summary

- Presented the proposed Athena DAQ system
- Focused on
  - our perception of the challenges that EIC project DAQ is likely to face
  - Athena's ideas to address these challenges