

January 2024 ePIC Collaboration Meeting

9–13 Jan 2024



WG Overview ePIC Streaming Computing Model

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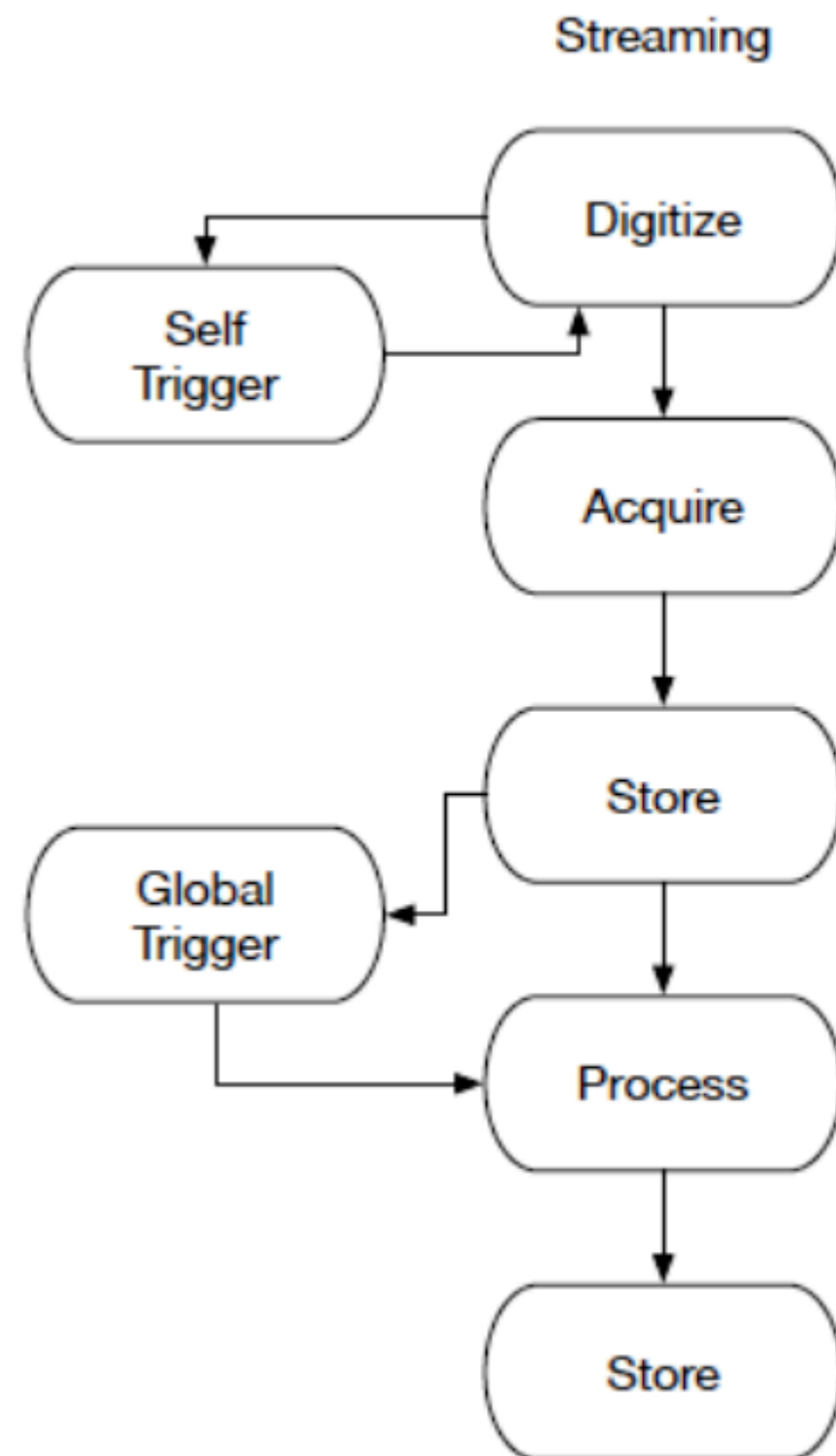


Streaming read out (SRO)

* A HIT MANAGER receives hits from FEE, order them and ship to the software defined trigger

* Software defined trigger re-aligns in time the whole detector hits applying a selection algorithm to the time-slice

- the concept of 'event' is lost
- time-stamp is provided by a synchronous common clock distributed to each FEE



* All channels continuously measured and hits streamed to a HIT manager (minimal local processing) with a time-stamp

SRO DAQ

- ▶ **Pros**
 - All channels can be part of the trigger
 - Sophisticated tagging/filtering algorithms
 - high-level programming languages
 - scalability
- ▶ **Drawbacks:**
 - we do not have the same experience as for TRIGGERED DAQ

Why SRO is important?

- * **High luminosity experiments**
 - Write out the full DAQ bandwidth
 - Reduce stored data size in a smart way (reducing time for off-line processing)
- * **Shifting data tagging/filtering from the front-end (hw) to the back-end (sw)**
 - Optimize real-time rare/exclusive channel selection
 - Use of high-level programming languages
 - Use of existing/ad-hoc CPU/GPU farms
 - Use of available AI/ML tools
 - (future) use of quantum-computing
- * **Scaling**
 - Easier to add new detectors in the DAQ pipeline
 - Easier to scale
 - Easier to upgrade

Many NP and HEP experiments adopt a SRO DAQ

- CERN: LHCb, ALICE, AMBER
- FAIR: CBM
- DESY: TPEX

- FRIBS: GRETA
- BNL: sPHENIX
- JLAB: SOLID, BDX, CLAS12, ...

Compute-Detector Integration to Maximize Science

Broad ePIC Science Program:

- Plethora of observables, with less distinct topologies where every event is significant.
- High-precision measurements: Reducing systematic uncertainties of paramount importance.

Streaming Readout Capability Due to Moderate Signal Rate:

- **Capture every collision signal**, including background.
- Event selection using all available detector data for **holistic reconstruction**:
 - **Eliminate trigger bias** and provide accurate estimation of uncertainties during event selection.
- Streaming background estimates ideal to **reduce background** and related systematic uncertainties.

	EIC	RHIC	LHC → HL-LHC
Collision species	$\vec{e} + \vec{p}, \vec{e} + A$	$\vec{p} + \vec{p}/A, A + A$	$p + p/A, A + A$
Top x-N C.M. energy	140 GeV	510 GeV	13 TeV
Peak x-N luminosity	$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$	$10^{32} \text{ cm}^{-2} \text{ s}^{-1}$	$10^{34} \rightarrow 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
x-N cross section	50 μb	40 mb	80 mb
Top collision rate	500 kHz	10 MHz	1-6 GHz
$dN_{\text{ch}}/d\eta$	0.1-Few	~3	~6
Charged particle rate	4M N_{ch}/s	60M N_{ch}/s	30G+ N_{ch}/s

Streaming Readout XI, December 2, 2023.

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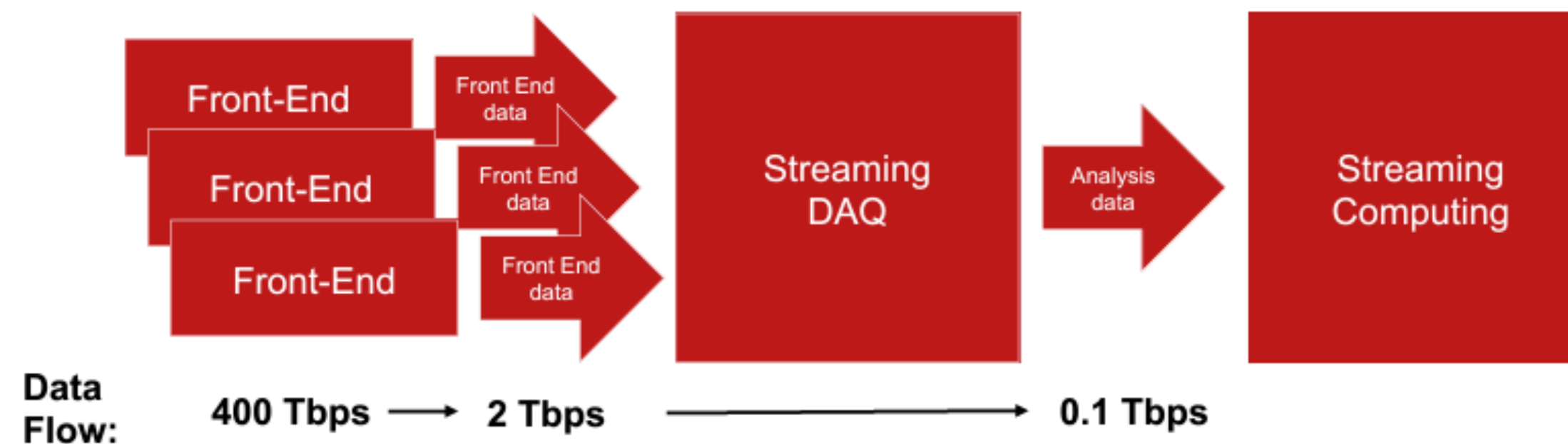
Why SRO is important for ePIC?

* Broad ePIC Science program

- Unbiased data set for unplanned physics
- Selective (sw) triggers to focus on for planned physics

Compute-Detector Integration to Accelerate Science

- **Problem** Data for physics analyses and the resulting publications available after O(1year) due to complexity of NP experiments (and their organization).
 - Alignment and calibration of detector as well as reconstruction and validation of events time-consuming.
- **Goal** Rapid turnaround of 2-3 weeks for data for physics analyses.
- **Solution** Compute-detector integration using:
 - AI for autonomous alignment and calibration as well as reconstruction and validation for rapid processing,
 - Streaming readout for continuous data flow of the full detector information,
 - Heterogeneous computing for acceleration.



Streaming Readout XI, December 2, 2023.

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* Expedite ePIC Science outcome

- Computing/detector integration for a rapid turnaround

Presented by Markus at APS/SRO-XI in Kona (HI) in December

ePIC Streaming Computing Model Working Group

ePIC Streaming Computing Model Working Group

Kick-off meeting - July 11, 2023

Software and Computing Coordinator (Markus)
+ Deputy Coordinator **Operations (Wouter)**
+ Deputy Coordinator **Development (Sylvester)**
+ Deputy Coordinator **Infrastructure (Torre)**
Guiding Principles: DE&I, Software Principles, Sustainability

Operation WGs:

- Production (CD)
- User Learning
- Validation (CD)

Development WGs (CI):

- Physics and Detector Simulation
- Reconstruction
- Analysis Tools

Infrastructure WGs:

- Streaming Computing Model
- Multi-Architecture Computing
- Distributed Computing

Cross-cutting WG:

- Data and Analysis Preservation

- Structure of Software and Computing in ePICS
- Presented by Markus on May 2nd 2023 kickoff-meeting

- ePIC SRO Computing Model WG belongs to 'infrastructure'
- Co-conveners: M.Battaglieri (INFN), J.Huang (BNL) + J.Landgraf (BNL)



Marco Battaglieri
Co-convenor

Jin Huang
Co-convenor

Jeffery Landgraf
Co-convenor for electronics & DAQ WG
Formerly leading ePIC group operations during recent months when Jin focuses on ePIC/DAQ commissioning.

WG activity

- WG activity started in July 2023, regular Zoom (bi-and) weekly meetings (Tue 9:00 AM ET) + dedicated 1-2 days workshops
- Each meeting focused on a specific topic
- Invited talks of world-experts
- ... a lot of discussion

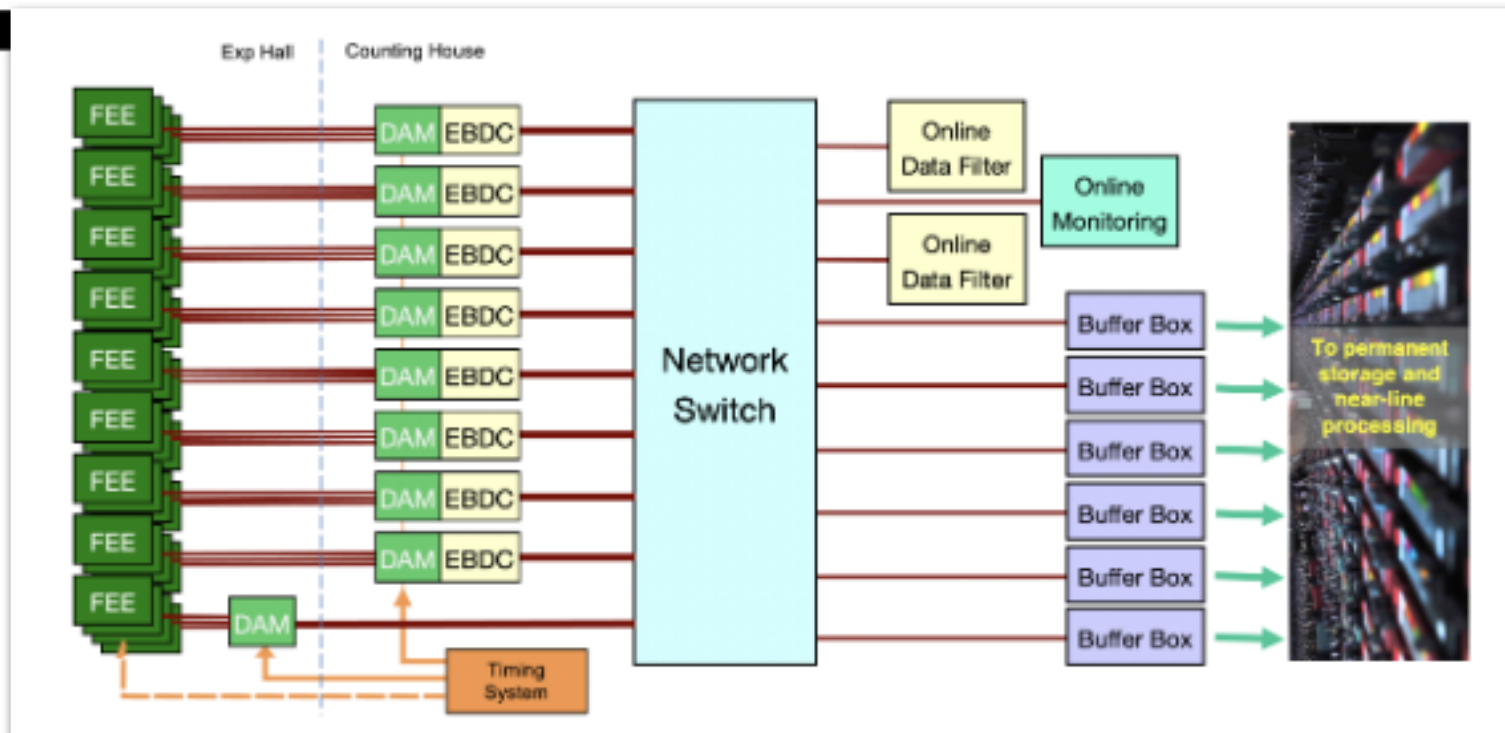
Items discussed

- Streaming RO computing model
- ePIC Data Rates
- The interface between DAQ and computing
- ePIC butterfly computing model (Echelon 0-3)
- Algorithmic workflow data analysis requirements
- (Autonomous) Calibrations
- (raw) data filtering
- Data format, data cooking, ...

Achievements

- ePIC computing review (Oct 19-20 23)
- *The ePIC Streaming Computing Model* paper

ePIC Streaming Computing Model Working Group



Streaming RO for ePICS

- Full consensus for SRO within the EIC community (Yellow Paper, ECCE, ATHENA, ...)
- ePICS rates are not comparable to LHC HI-LUMI but the advantages of SRO remain
- Holy Grail: to manage (storage) an unbiased (un-triggered) data set for further analysis

ePICS rates

- Established a strong link with DAQ WG
- Define an envelope for the workflow (<100/400Gb/s)
- First estimate of ePICS data rate/volume to be updated based on new information
- Provide feedback to sub-systems groups to reduce the data stream to a compatible level

Interfaces

Within the 'control room' - Project driven (boundary based on permanent data storage)

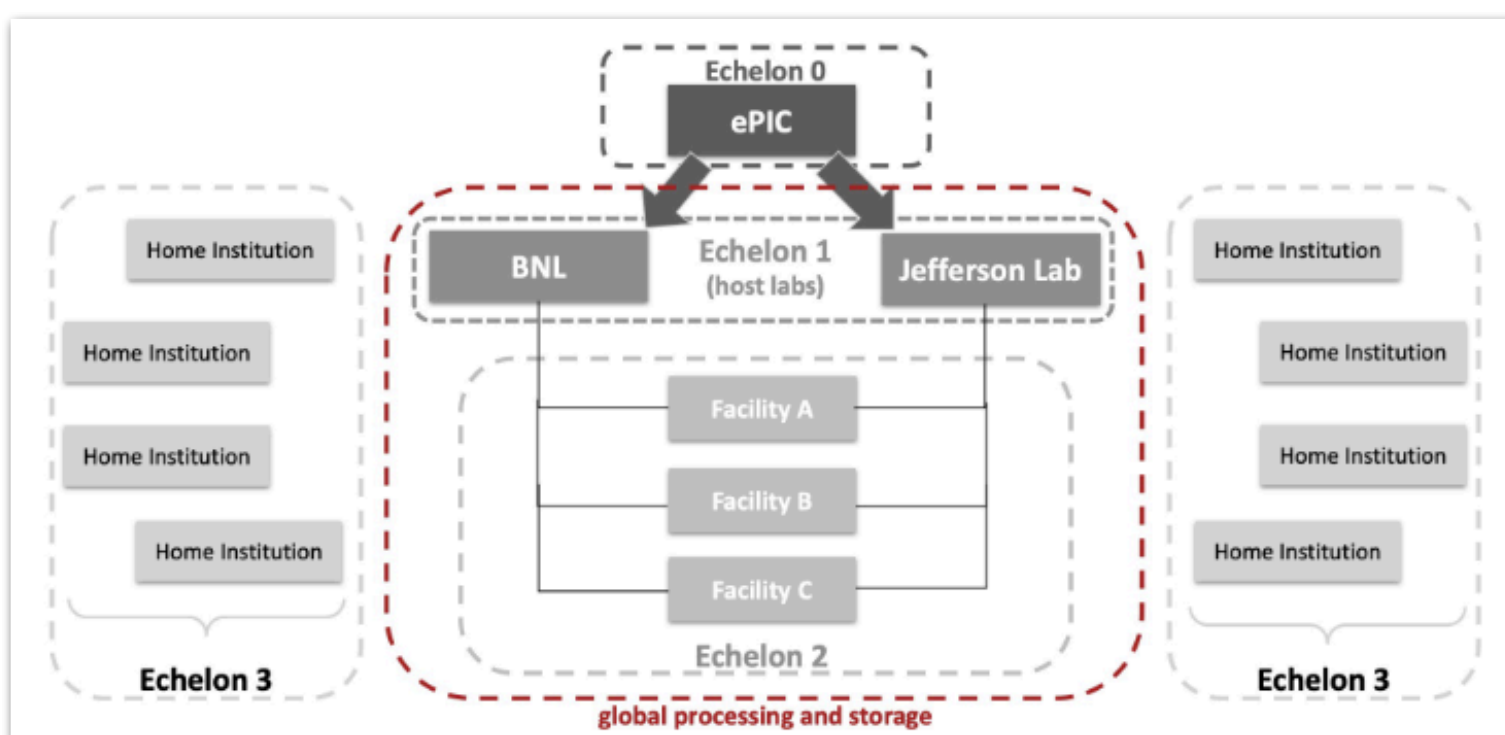
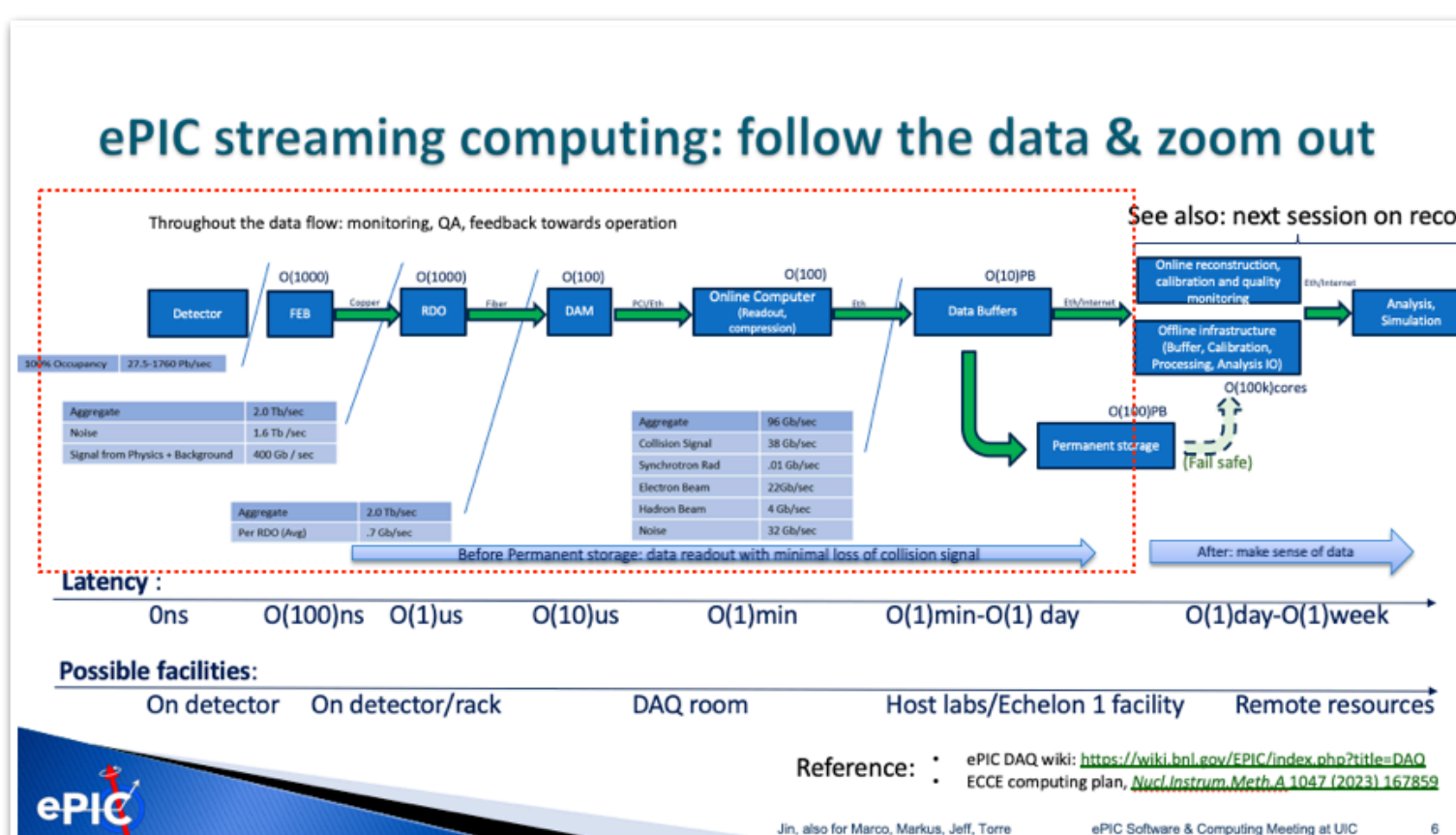
- Each stage in data flow will require IO specs (based on CPU, GPU, FPGA reduction)

Outside the control room - Collaboration driven

- Networking? CPU/GPU farm? Local/remote resources? on/off-line analysis?

Streaming Data processing

- Time-critical, data-driven, autonomous, distributed
- Four tiers of the ePIC Streaming Computing Model
 - Echelon 0: ePIC experiment and SRO
 - Echelon 1: shared between BNL and JLab
 - Echelon 2: global contributions
 - Echelon 3: analysis community



ePIC Streaming Computing Model Working Group

The ePIC Streaming Computing Model

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Abstract

This document provides a current view of the ePIC Streaming Computing Model. With datataking a decade in the future, the majority of the content should be seen largely as a proposed plan. The primary drivers for the document at this time are to establish a common understanding within the ePIC Collaboration on the streaming computing model, to provide input to the October 2023 ePIC Software & Computing review, and to the December 2023 EIC Resource Review Board meeting. The material should be regarded as a snapshot of an evolving document.

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ePIC Software & Computing review (October 19-20, 2023)

Review charge

1. At this stage, approximately ten years before data collection, is there a comprehensive and cost-effective long-term plan for the software and the computing of the experiment?
2. Are the plans for integrating international partners' contributions adequate at this stage of the project?
3. Are the plans for software and computing integrated with the HEP/NP community developments, especially given data taking in ten years?
4. Are the resources for software and computing sufficient to deliver the detector conceptual and technical design reports?
5. Are the ECSJI plans to integrate into the software and computing plans of the experiment sufficient?

Summary and outlook

- ePIC DAQ will be streaming
- SRO is expected to facilitate (and extend!) the ePIC science and shorten the time between data taking and physics output
- SRO provides new opportunities but poses challenges (e.g. new detector-computing relationship)
- The SCM WG is working to define a suitable computing model (based on ePIC Coll requirements) for SRO
- Strong link with DAQ, SW, and Physic WGs to design a sound framework (+ trigger/analysis algorithms)
- Interaction with ePICS sub-detector groups will be the next step for an optimized SRO DAQ design
- On-field validation needs to be pursued in parallel
- It is a long way to go but we are progressing!

ePIC Milestones

