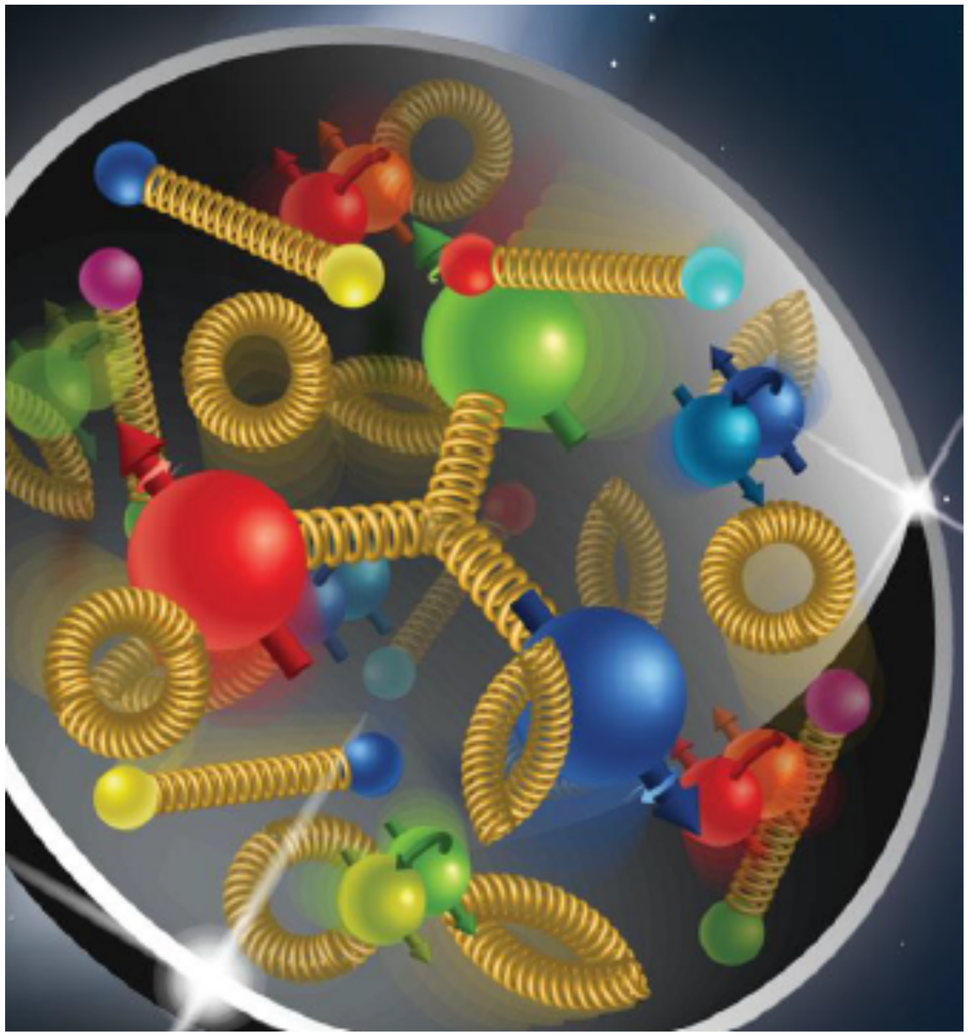
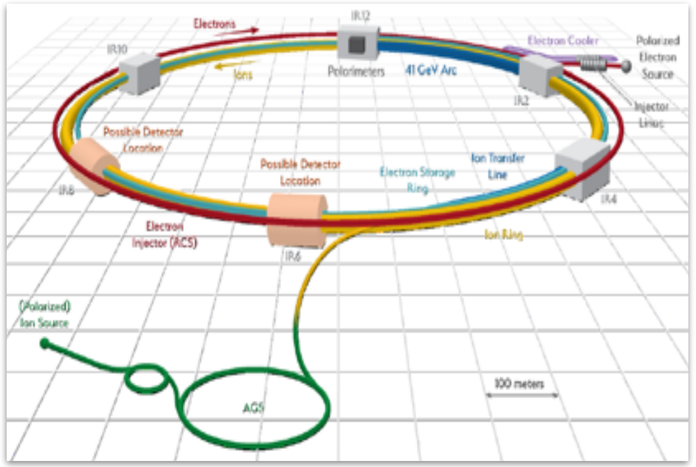
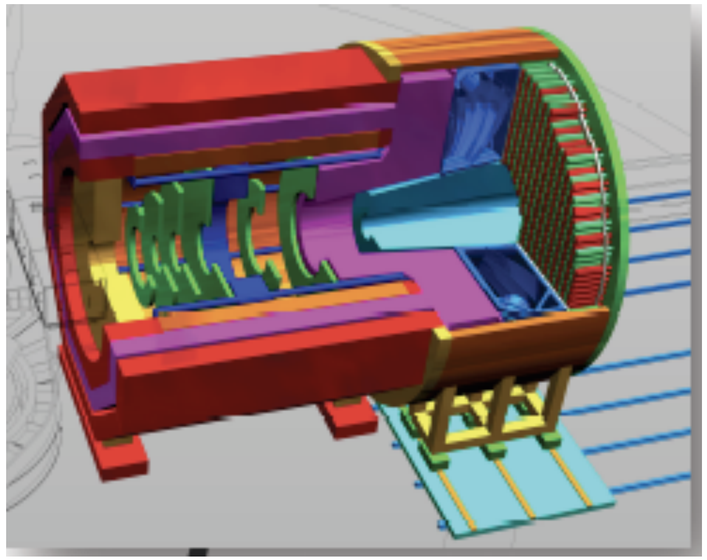






ePIC General Meeting

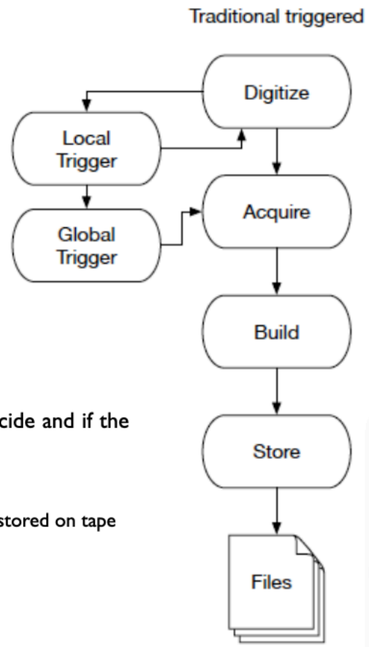
Thursday 5 Oct 2023, 19:30 → 21:30 US/Eastern

Report from ePIC Streaming Computing Model WG Meetings

M.Battaglieri (INFN), M.Diefenthaler (JLab), J.Huang (BNL), J.Landgraf (BNL), T.Wenaus (BNL)

Streaming RO

Traditional (triggered) DAQ

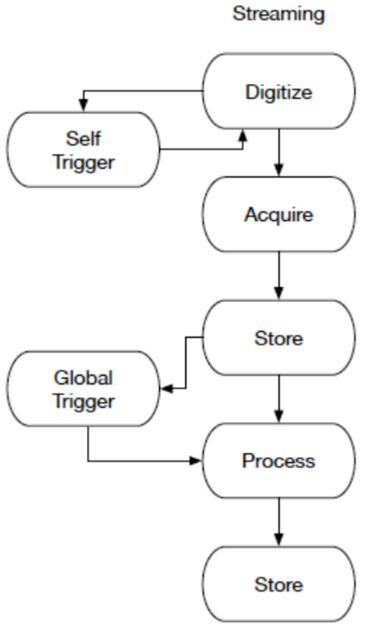


- (few) trigger Channels participating send (partial) information to trigger logic
- All channels continuously measured, hits stored in short term memory
- Trigger logic takes time to decide and if the trigger condition is satisfied:
  - a new 'event' is defined
  - trigger signal back to the FEE
  - data read from memory and stored on tape

Traditional triggered DAQ

- **Pros**
  - we know it works reliably!
- **Drawbacks:**
  - only few information forms the trigger
  - Trigger logic (FPGA) difficult to implement and debug
  - not easy to change and adapt to different conditions

Streaming read out (SRO)



- A HIT MANAGER receives hits from FEE, order them and ship to the software defined trigger
- All channels continuously measured and hits streamed to a HIT manager (minimal local processing) with a time-stamp
- 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

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
  - greater susceptibility to noise and background.

Why SRO is so 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, …

EIC (from the YR effort to ePIC) chose a SRO DAQ

ePIC Streaming Computing Model Working Group

Presented by Markus at RRB Meeting on Apr 3 2023

Compute-Detector Integration to Maximize 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 data for physics analyses.
- **Solution** Compute-detector integration using:
  - AI/ML for autonomous alignment and calibration as well as reconstruction in near real time,
  - Streaming readout for continuous data flow and heterogeneous computing for acceleration.

Data Flow: 100 Tbps → 10 Tbps → 0.1 Tbps

Streaming RO for ePIC

SRO calls for a new computing model …

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)**

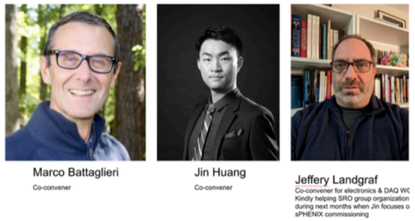
Development WGs (CI):
- **Physics and Detector Simulation**
- **Reconstruction**
- Analysis Tools

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-convener

Jin Huang
Co-convener

Jeffery Landgraf
Co-convener for electronics & DAQ WG
Kindly helping SRO group organization during next months when Jin focuses o ePHENIX commissioning

… we are working on it!

ePIC Streaming Computing Model Working Group

WG activity recap

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

So far:

- 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
- Data format, data cooking, …

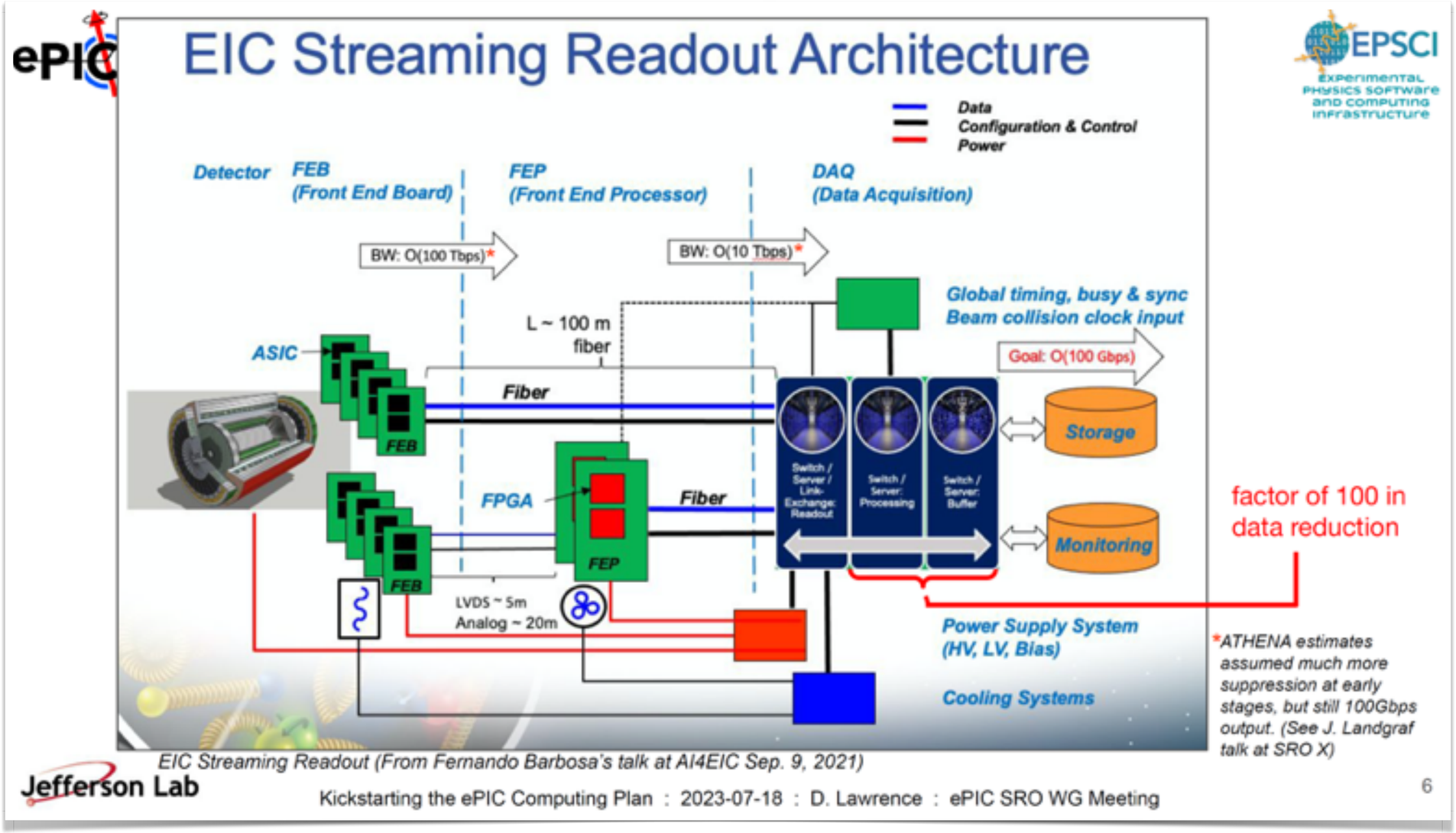
Other items to discuss:

- (Autonomous) calibrations;
- (raw) data filtering and storage;

Current activity:

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

ePIC Streaming Computing Model Working Group



EIC Streaming Readout (From Fernando Barbosa's talk at AI4EIC Sep. 9, 2021)

Jefferson Lab

Kickstarting the ePIC Computing Plan : 2023-07-18 : D. Lawrence : ePIC SRO WG Meeting

6

Streaming RO for ePICS

- Full consensus for SRO within the EIC community (Yellow Paper, DAQ models in ECCE, ATHENA, …)
- Rates at ePICS are not comparable to LHC HI-LUMI but advantages of SRO remain:
  - multiple channels to trigger on
  - Holy Grail: to manage (storage) an unbiased (un-triggered) data set for further analysis
  - on/off-line event selection with full detector information

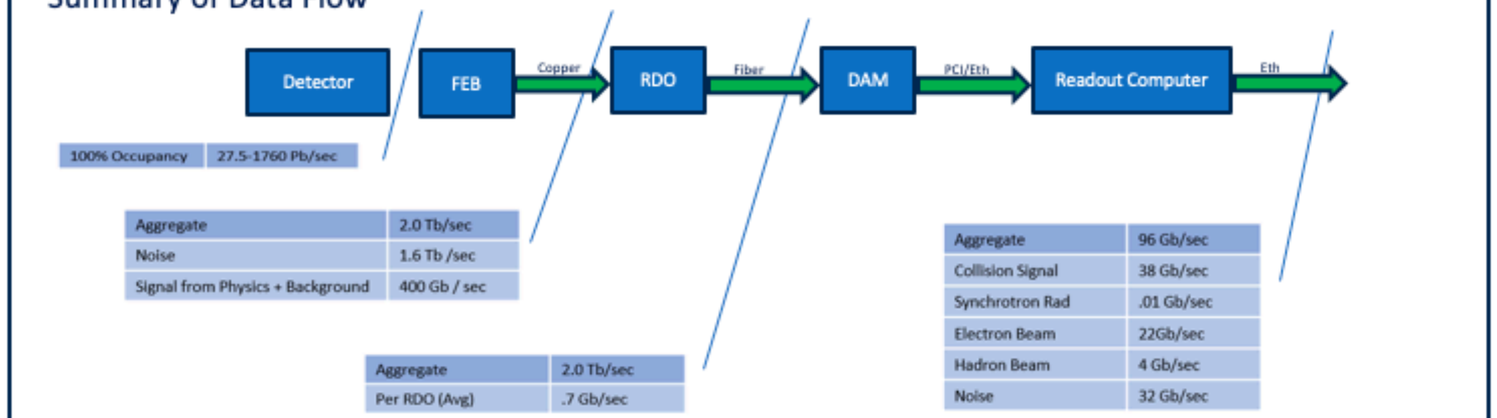
ePIC Streaming Computing Model Working Group

By Jeff Landgraf, presented on Aug 22 WG meeting [link], Updated Sept 19

Summary of Channel Counts

Detector Group	Channels					RDO	Fiber	DAM	Data Volume (RDO) (Gb/s)	Data Volume (To Tape) (Gb/s)
	MAPS	AC-LGAD	SiPM/PMT	MPGD	HRPPD					
Tracking (MAPS)	36B					400	800	17	26	26
Tracking (MPGD)				202k		118	236	5	1	1
Calorimeters	500M		104k			451	1132	19	502	28
Far Forward	300M	2.6M	170k			178	492	8	15	8
Far Backward	82M		2k			50	100	4	150	1
PID (TOF)		7.8M				500	1500	17	31	1
PID Cherenkov			320k		140k	1283	2566	30	1275	32
TOTAL	36.9B	10.4M	596k	202k	140k	2980	6826	100	2,000	96

Summary of Data Flow



ePICS rates (first evaluation)

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

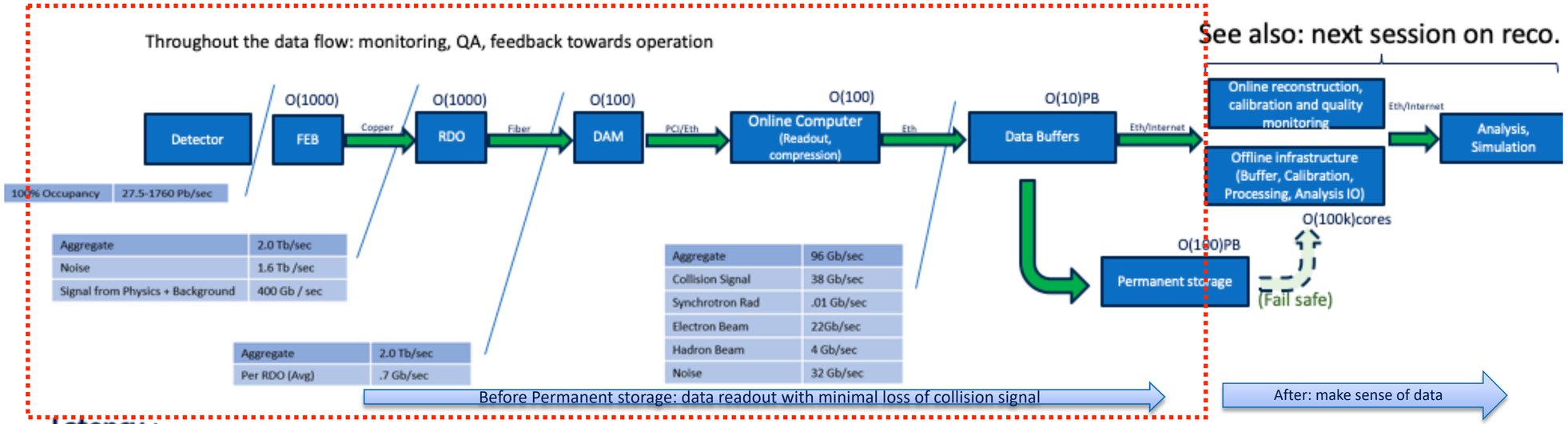
ePIC Streaming Computing Model Working Group

ePIC Software & Computing Meeting

20–22 Sep 2023
UIC Student Center East Tower
US/Central timezone

Presented by Jin at UIC Meeting on Sept 21 2023

ePIC streaming computing: follow the data & zoom out



Latency :

0ns | O(100)ns | O(1)us | O(10)us | O(1)min | O(1)min-O(1) day | O(1)day-O(1)week

Possible facilities:

On detector | On detector/rack | DAQ room | Host labs/Echelon 1 facility | Remote resources

Reference:
- ePIC DAQ wiki: https://wiki.bnl.gov/EPIC/index.php?title=DAQ
- ECCE computing plan, *Nucl.Instrum.Meth.A* 1047 (2023) 167859

Interfaces

- Each step in the workflow has a different latency
- Identify interfaces for a 'service-oriented' approach

Within the 'control room' (part of the project)
- Each stage in data flow will require IO specs (based on CPU, GPU, FPGA reduction)
- 'control room' boundary based on permanent data storage

Outside the control room (driven by the collaboration)
- Networking?
- CPU/GPU farm?
- Local/remote resources?
- on/off-line analysis?

A strong link with the Simulation and Reconstruction WGs is needed!

ePIC Streaming Computing Model Working Group

Streaming Computing Model

Echelon 0	ePIC experiment
Echelon 1	Host labs
Echelon 2	Global processing and data facilities
Echelon 3	Home Institute Computing

Use Case	Echelon			
	0	1	2	3
Streaming DAQ	✔			
Streaming Computing				
Monitoring I + II	✔	✔	✔ *	✔ *
Data Reduction	✔	✔		
Alignment / Calibration		✔	✔	
Prompt Reconstruction		✔	✔	
Modeling		✔	✔	
Experimental Control	✔	✔		
Reprocessing		✔	✔	
Raw Data Storage		✔		
Computing				
Storage		✔	✔	
Simulation		✔	✔	
Physics Analysis		✔	✔	✔

*	Offline only

Streaming Computing

- **Monitoring I**:
  - Data quality monitoring of the streaming data.
  - Alert about changes.
  - Identify data taking periods that require new alignment or calibration.
  - Online monitoring of the experiment.
- **Data Reduction I**:
  - Data reduction of streaming data, e.g., noise reduction
- **Alignment and Calibration**:
  - Autonomous alignment of the integrated detector.
  - Autonomous calibration of the detector subsystem.
- **Reconstruction**:
  - Processing from the detector readout to the reconstructed physics events.
- **Monitoring II**:
  - Data quality monitoring of the reconstructed physics events.
  - Alert about changes.
  - Identify data taking periods that require new alignment or calibration.
  - Online monitoring of the experiment.
- **Data Reduction II**:
  - Filtering out reconstructed physics events according to data quality criteria.
- **Modeling**:
  - Modeling of the experiment and its conditions, e.g., background modeling or digital twin.
- **Experimental Control**:
  - Offline monitoring of the experiment.
  - Optimization of the experiment and its running conditions

Computing

- **Re-processing / Re-reconstruction**
- **Storage**:
  - Storage of the streaming data (raw data), reconstructed data, and simulations.
  - Distribution of the storage among data centers.
- **Simulation**:
  - Physics and detector simulations.
  - Reconstruction of the simulated events.
- **Physics Analysis**:
  - Analysis of the reconstructed physics events and interpretation.

Use case to Echelon mapping

- Work in progress
- Definition of different tiers
- Splitting between computing and data storage
- Enhance and go beyond the original ‘butterfly model’
- Special attention to international partners’ contributions
- Towards a definition and design of computing/networking infrastructures

ePIC Streaming Computing Model Working Group

WG current activity

Preparation of Oct 19-20 Computing review

Charge
- Long-term plan for ePIC software and computing
- Integration of international partners in the project
- Integration into HEP/NP community development
- Resources
- ePIC SRO integration into the computing model

Preparation of the paper *The ePIC Streaming Computing Model*
- Architecture
- Streaming
- Use cases
- Resources

Keep discussing to cover missing items

Summary

- SRO is expected to shorten the time between data taking and physics output
- ePIC DAQ will be streaming
- SRO provides new opportunities but poses challenges
- To take full advantage of the SRO, the workflow needs to include both hardware and software
- The time distance from ePIC ops requires a careful scheme that could be updated to include tech progress (on DAQ side) and a better definition of sub-detectors requirements and performance
- The SCM WG is working to define a suitable computing model for SRO
- Possible solutions need to satisfy the specific requirements of ePIC collaboration
- Strong link with DAQ, SW, and Physic WGs to design a sound framework (+ algorithms)
- Interaction with ePICS sub-detector groups will be the next step for an optimized design
- The WG is currently auditing experiments that have adopted different computing models
- The WG is working to define as soon and as precise as possible the necessary resources for an optimal implementation
- Meetings, discussions, and written reports will help define a clear path and incorporate (internal and external) suggestions and feedback
- This is only the first step because on-field validation needs to be pursued in parallel
- It is a long way to go but we are progressing!