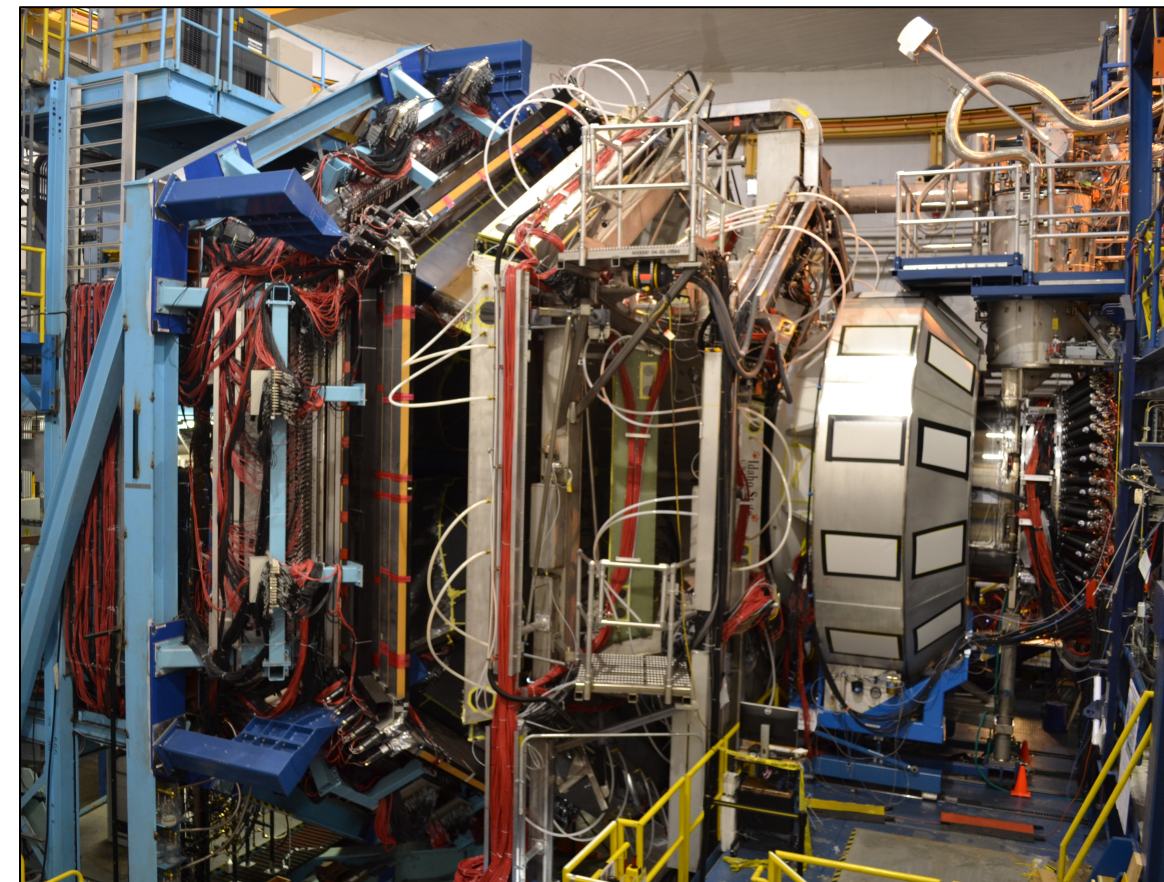
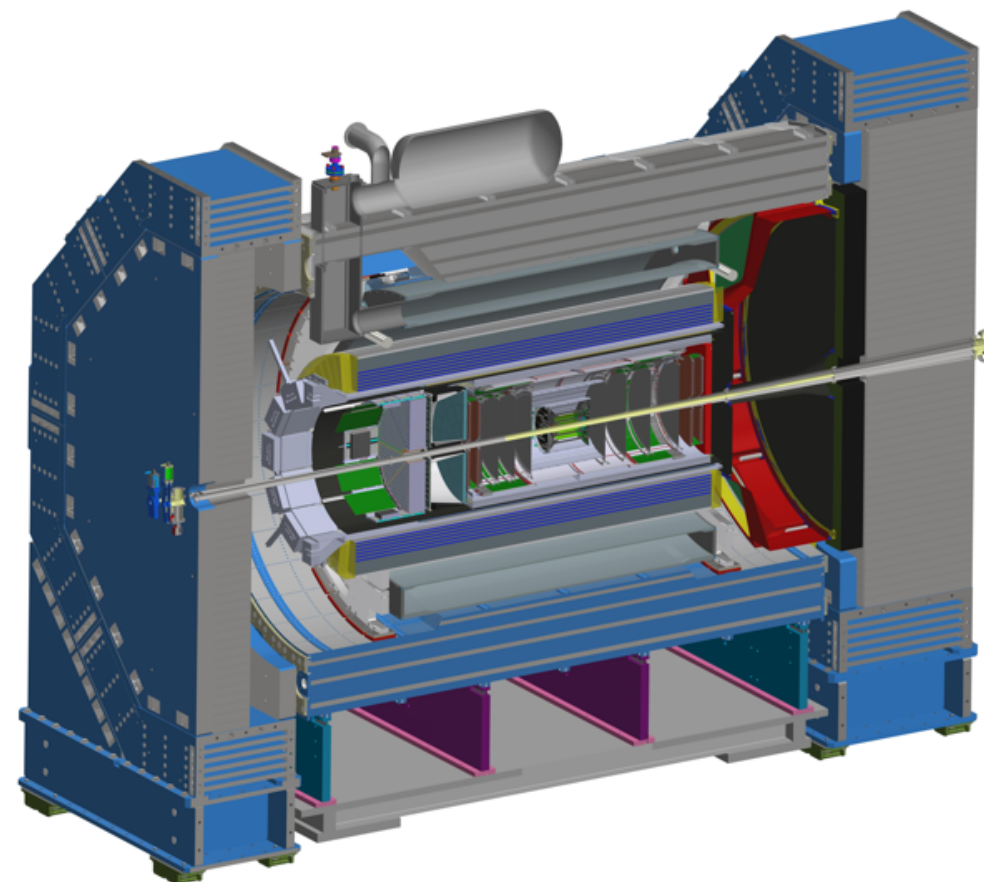
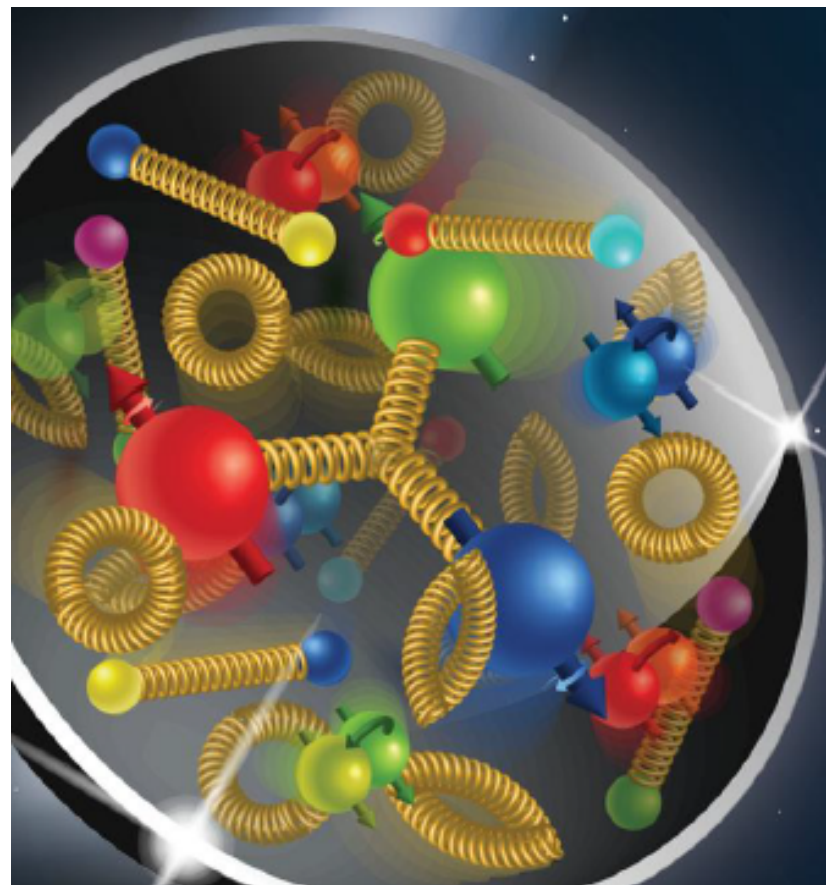


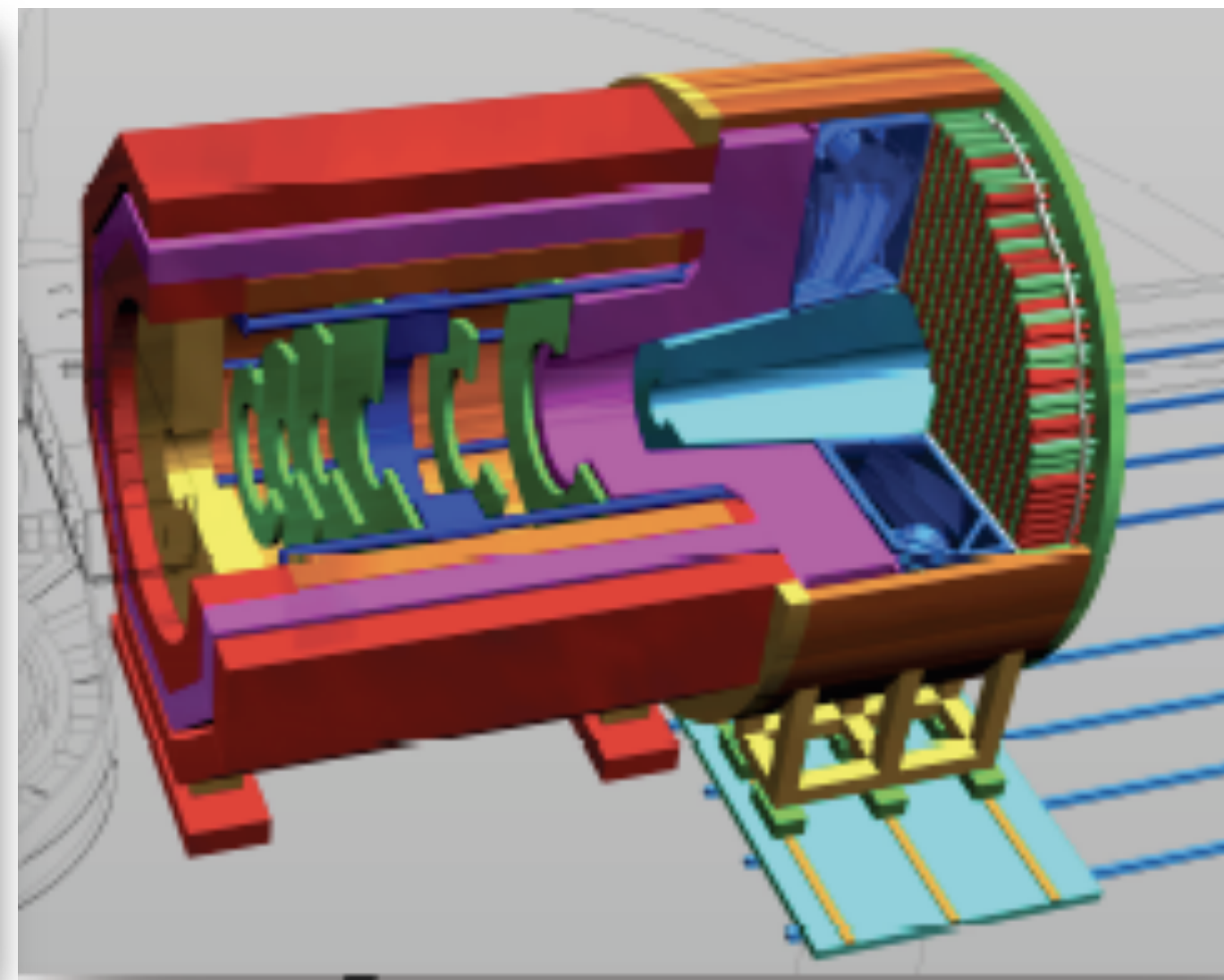


NUSDAF 2025
Catania, 22-24 Oct, 2025

**SYnergic Strategy for fuTure
ElectRronics and Streaming rEadout
solutions**

SYSTERSE: an overview

M.Battaglieri (INFN-GE), M.Bondì (INFN-CT)



Jefferson Lab

clas

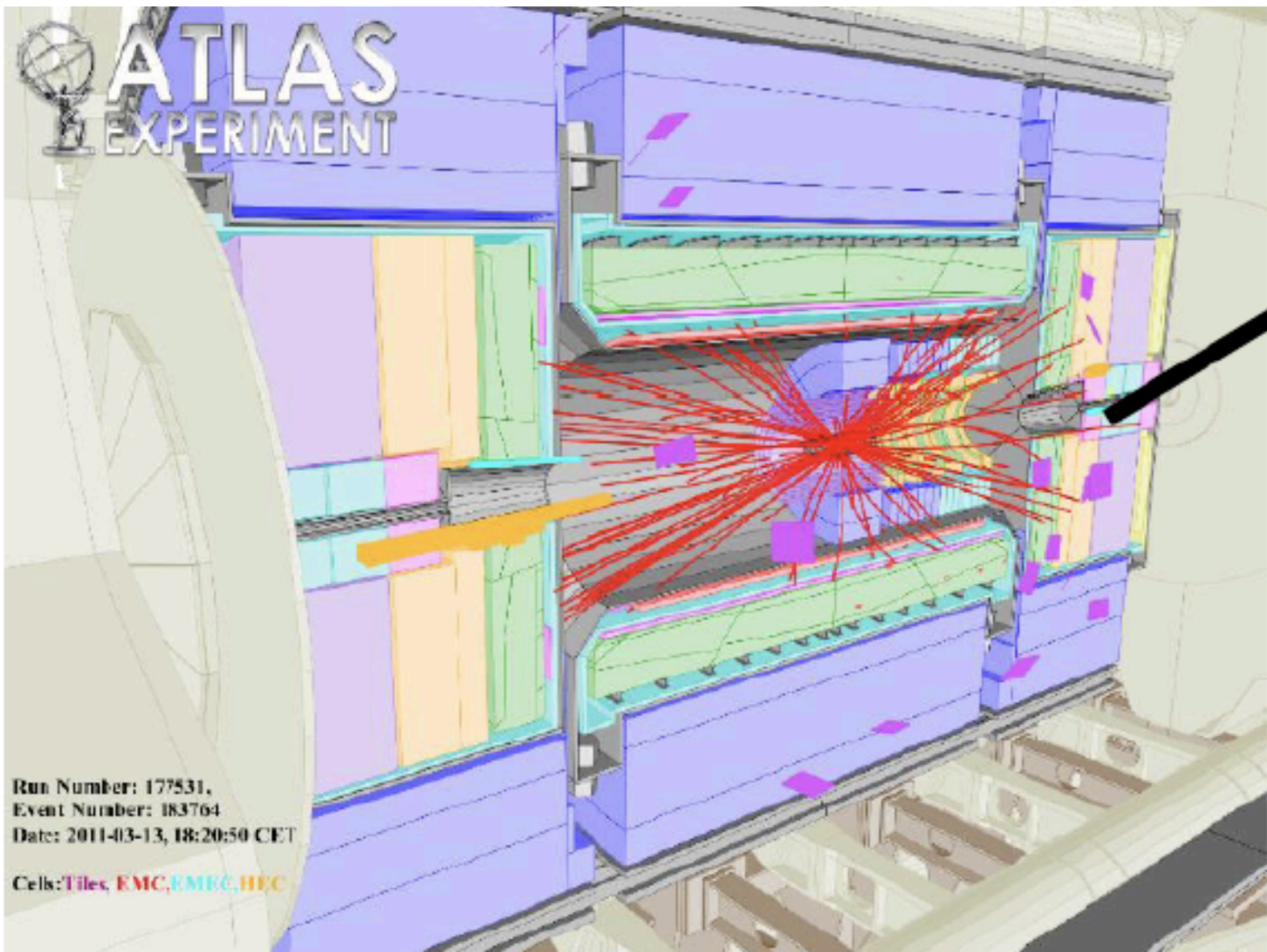
e⁻Lab12

Brookhaven
National Laboratory

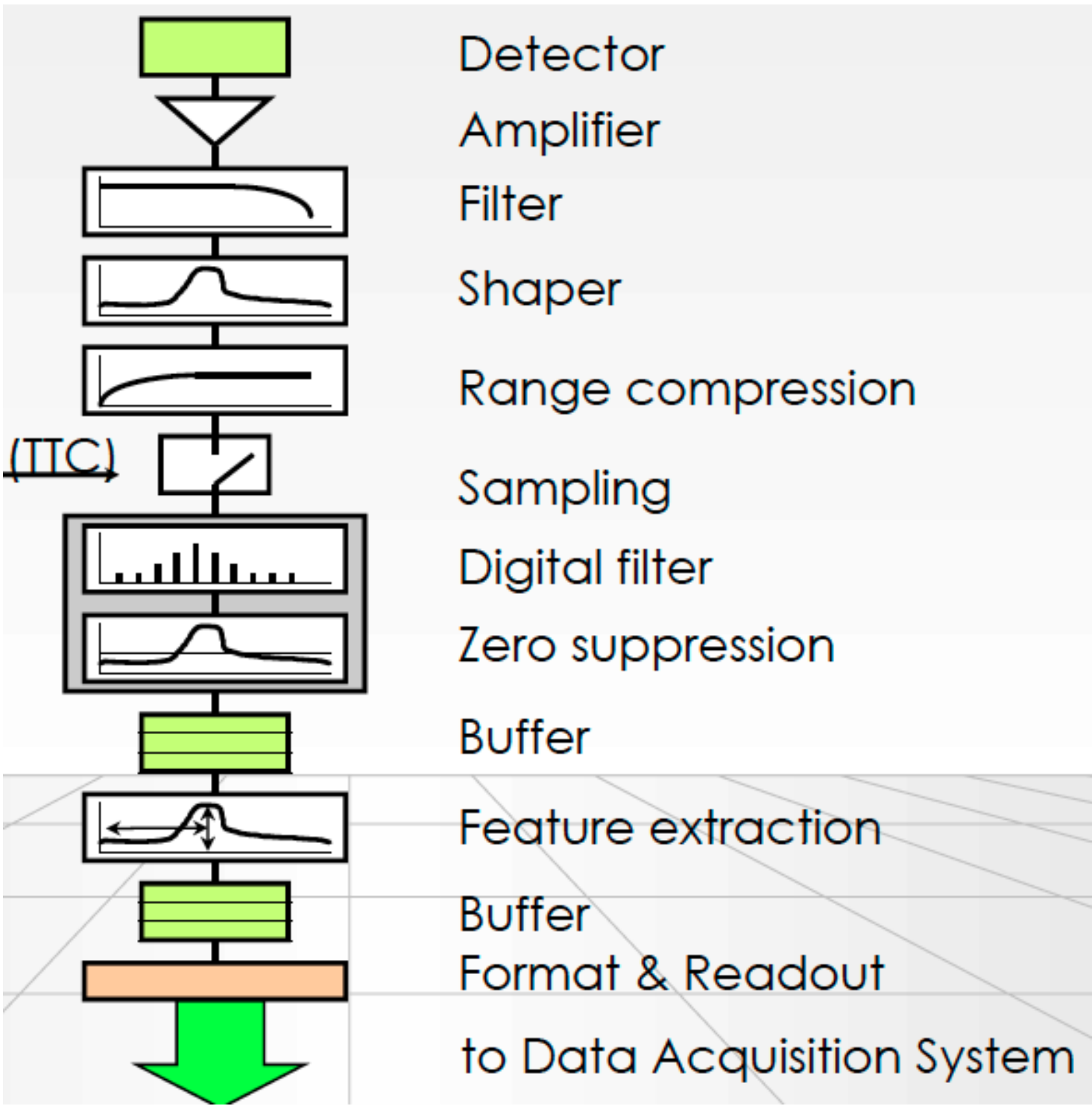
ePIC

INFN

From signals to physics



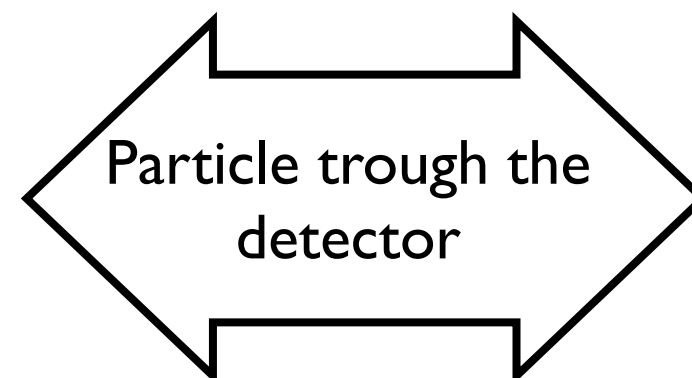
DAQ chain



Signals in HEP and NP physics: analog vs. digital

Particle

- Position: x, y, z
- Momentum: p_x, p_y, p_z
- Energy: $E^2 = (M^2 + p_x^2 + p_y^2 + p_z^2)$
- Electric charge



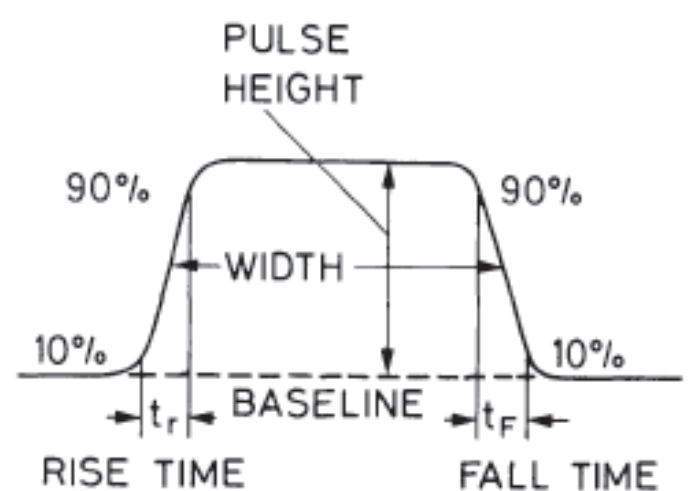
Detector

- Position
- Time
- Energy

HEP/NP detector

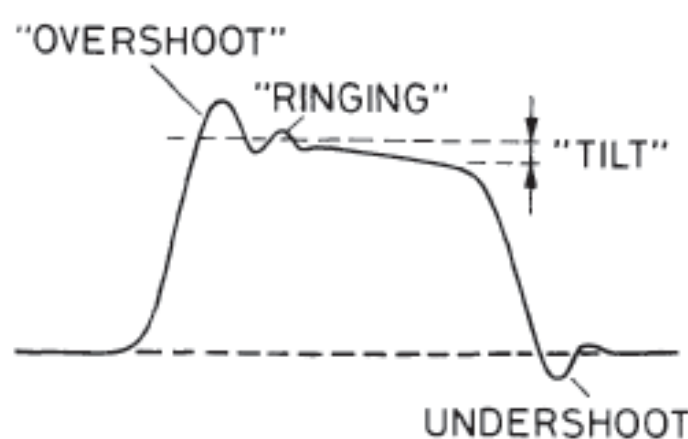
- ★ Interaction TIME
- ★ Interaction POSITION
- ★ Deposited ENERGY

Analog

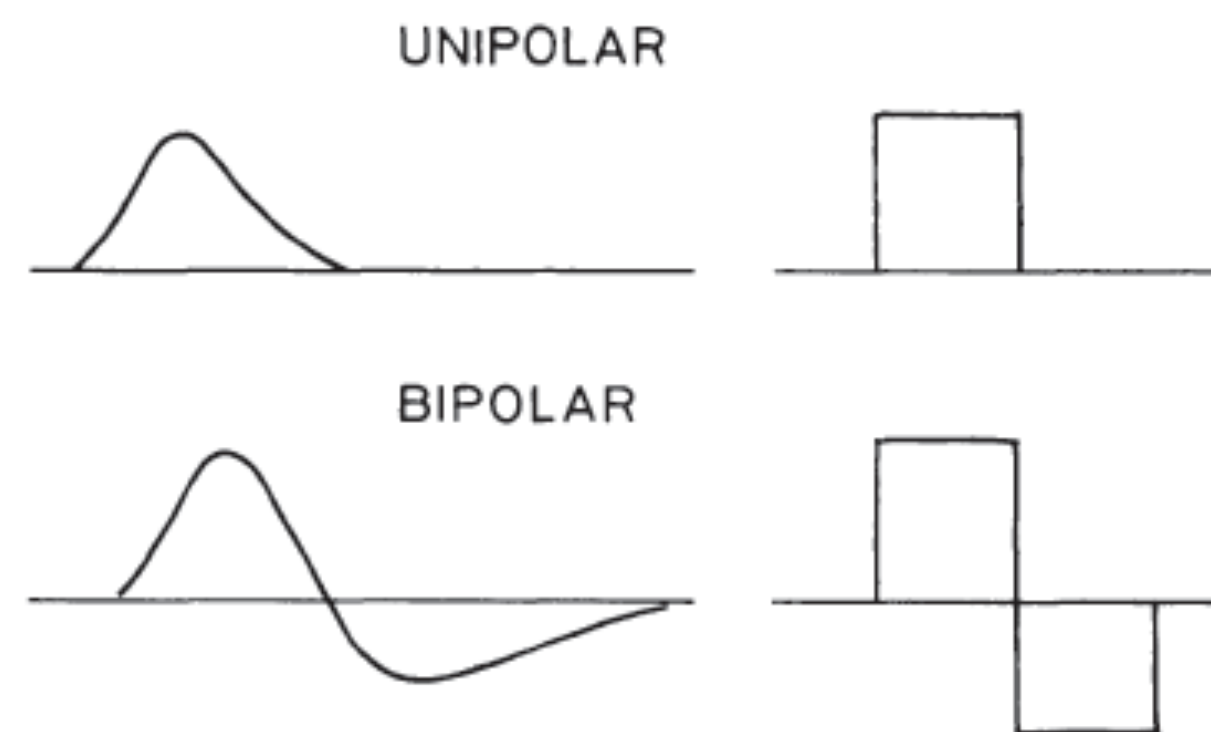


★ The Front End Electronics (FEE) produces analog signals. The information is coded into the signal shape

- PROS
 - coded info: height, length, shape ...
- CONS
 - distortions imply a loss



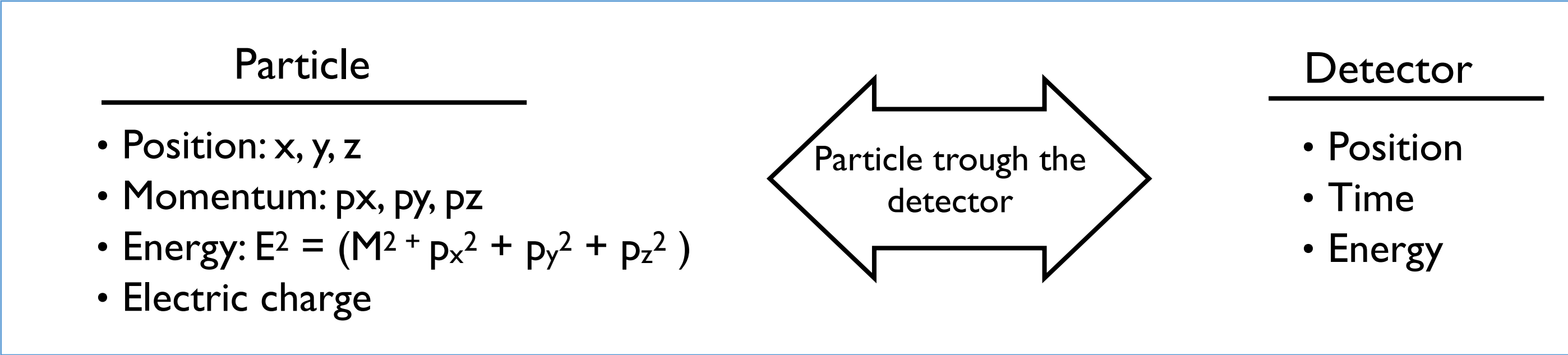
Digital



★ Coding the info in a conventional 'pulse' provides a simpler and effective manipulation of signals

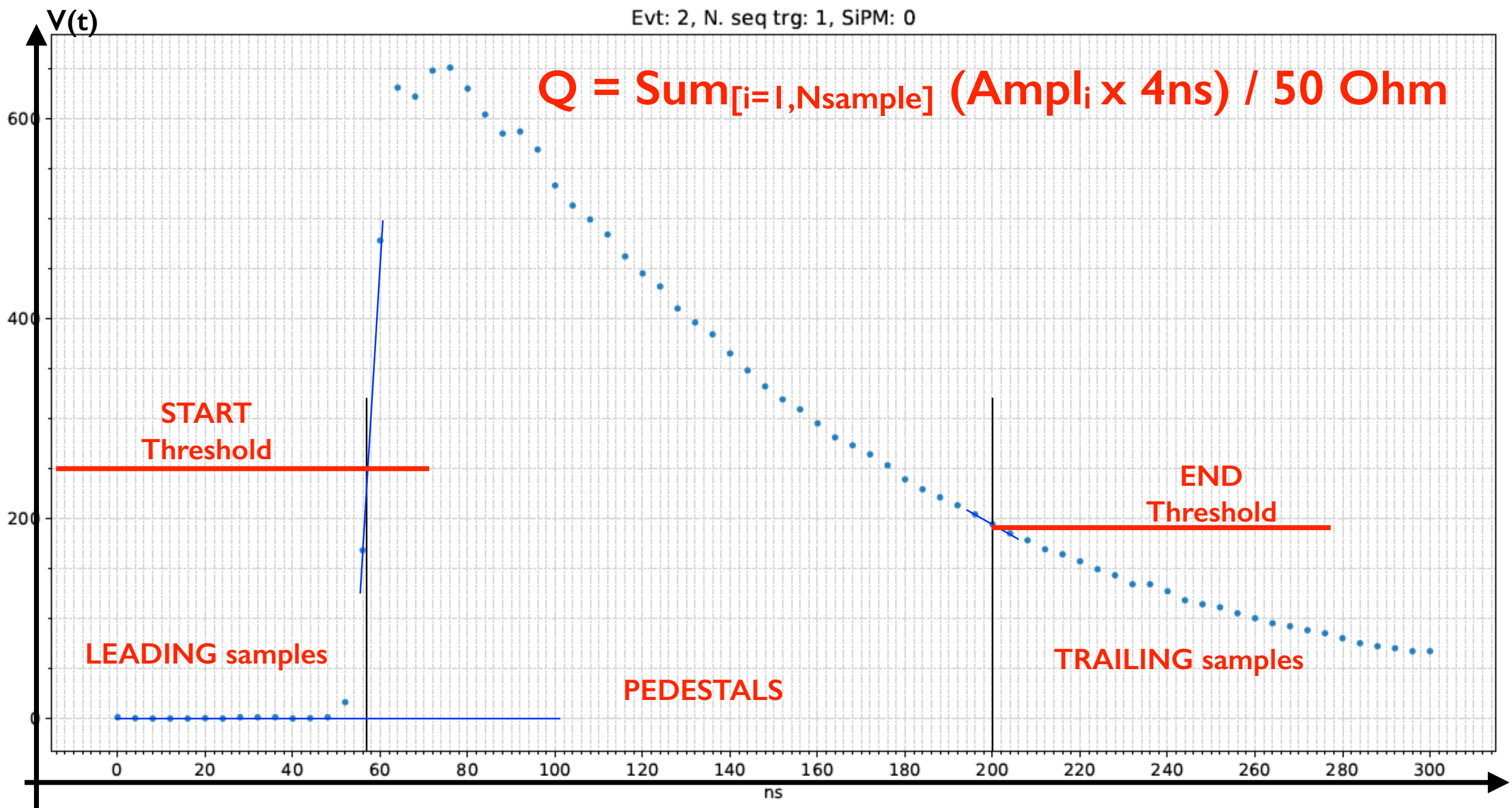
- PROS
 - distortion is not an issue
- CONS
 - coding requires a more complex elaboration and (often) a loss of information

Signals in HEP and NP physics: analog vs. digital

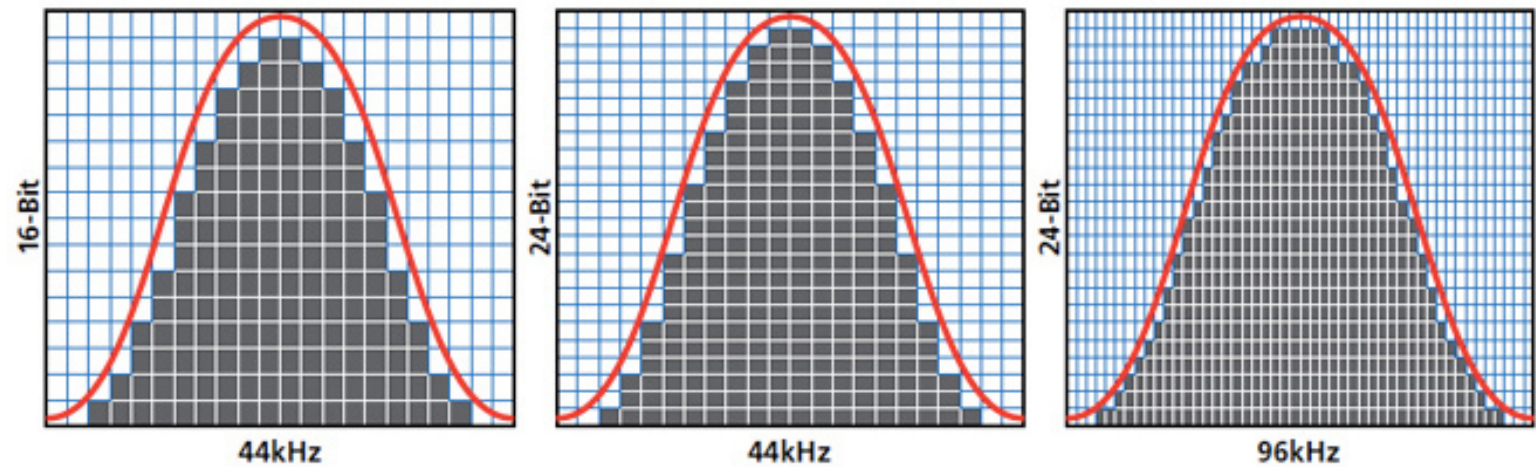


HEP/NP detector

- ★ Interaction TIME
- ★ Interaction POSITION
- ★ Deposited ENERGY



- ★ Full waveform contains information about the shape of the signal
- ★ Modern digitizers sample the waveform at a high rate and high definition (bits)

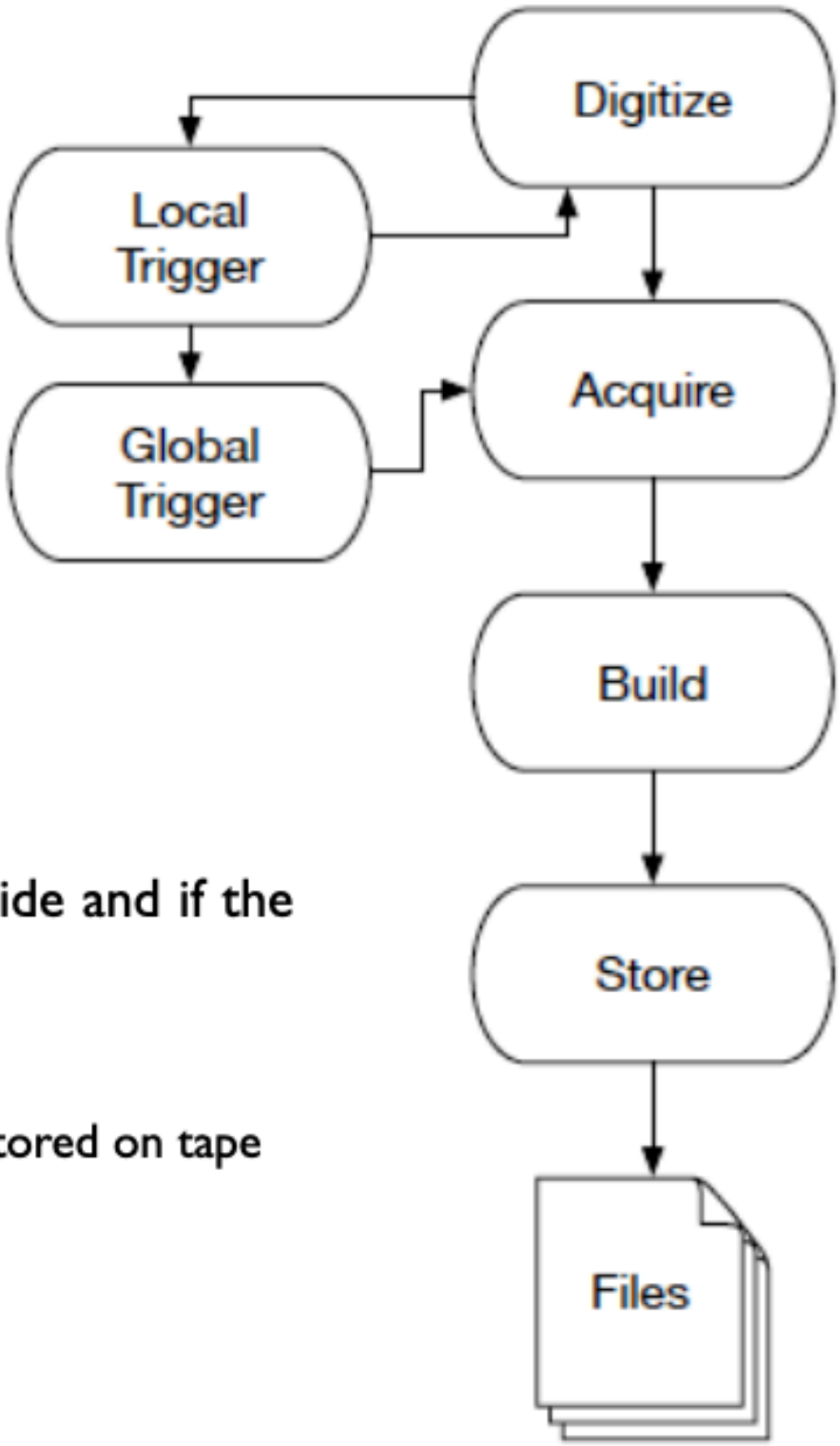


- ★ Interaction ENERGY $\Leftrightarrow Q$
- ★ Interaction TIME $\Leftrightarrow$ Threshold

Digitizers provide 'numbers' at the front end
SRO DAQ leverages modern FEE & data manipulation

Traditional (triggered) DAQ

Traditional triggered



* (few) trigger Channels participating send (partial) information to trigger logic

- * 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

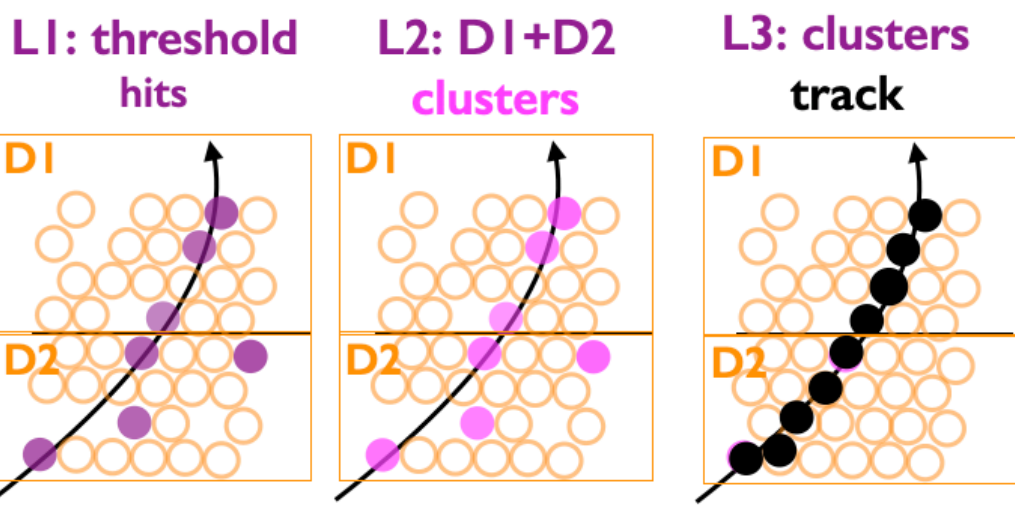
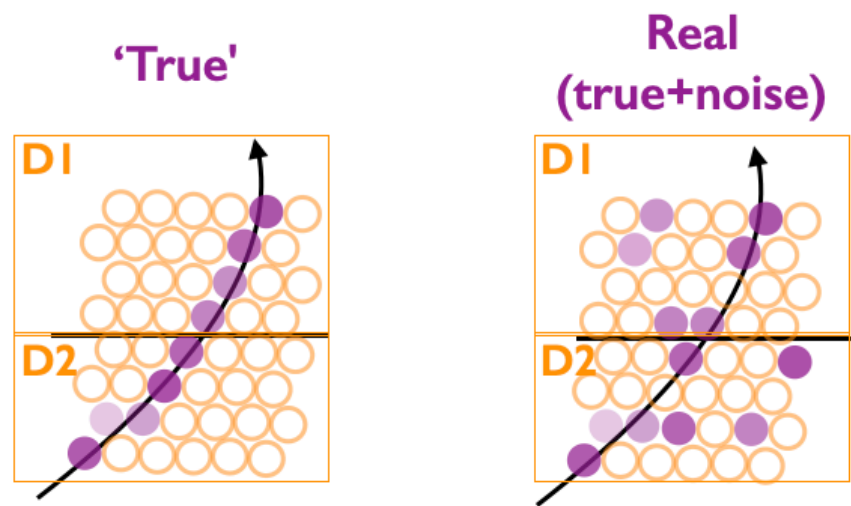
* All channels continuously measured, hits stored in short term memory

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

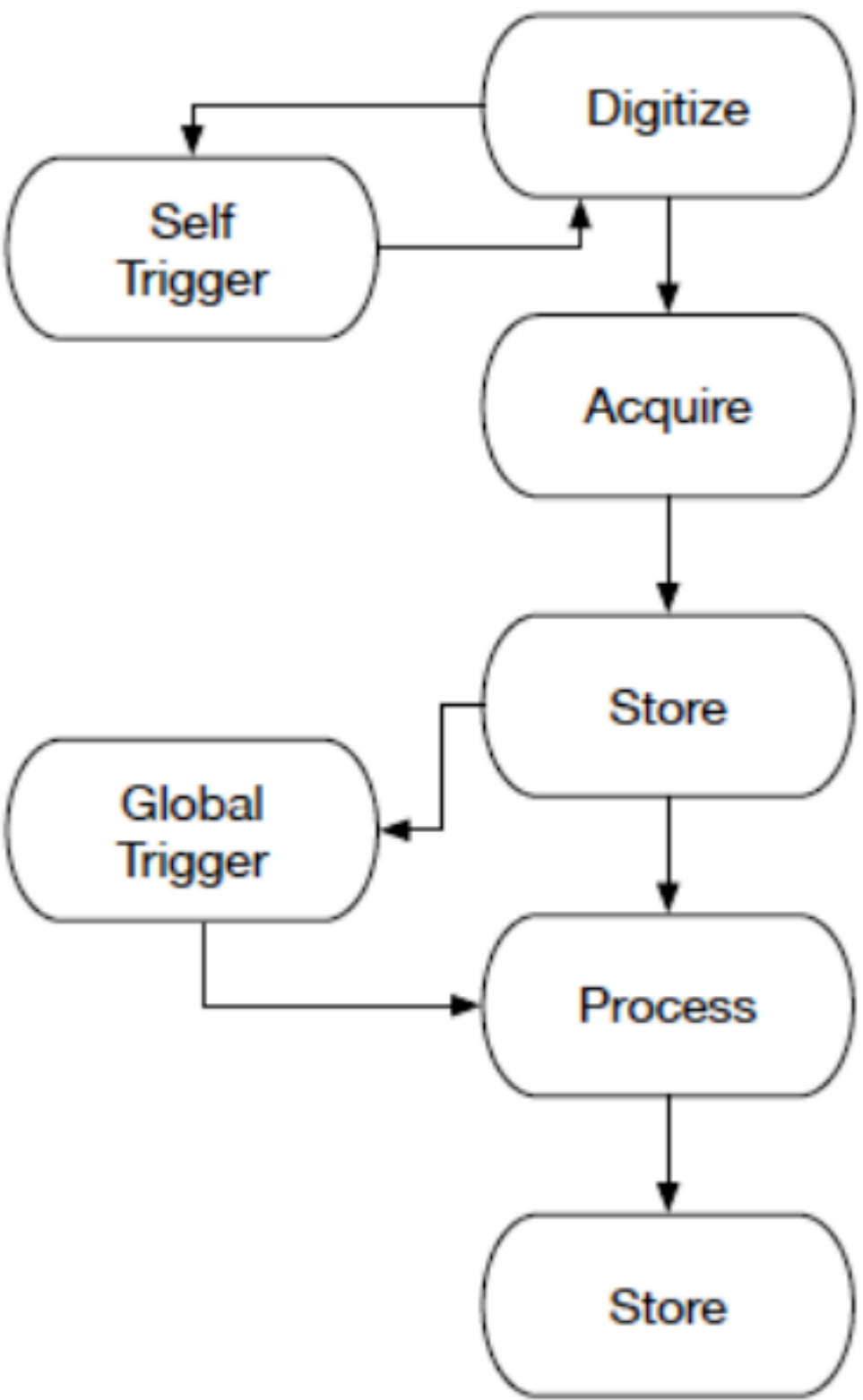
Trigger logic

- ★ decides if/when to collect detector information
- ★ Select 'events' over 'background'
- ★ Save data on disk for further processing
- ★ Different levels
 - L1: threshold on FEE
 - L2: combine information from different sub-detector components
 - L3: requires info processing



Streaming read out (SRO)

Streaming



* 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

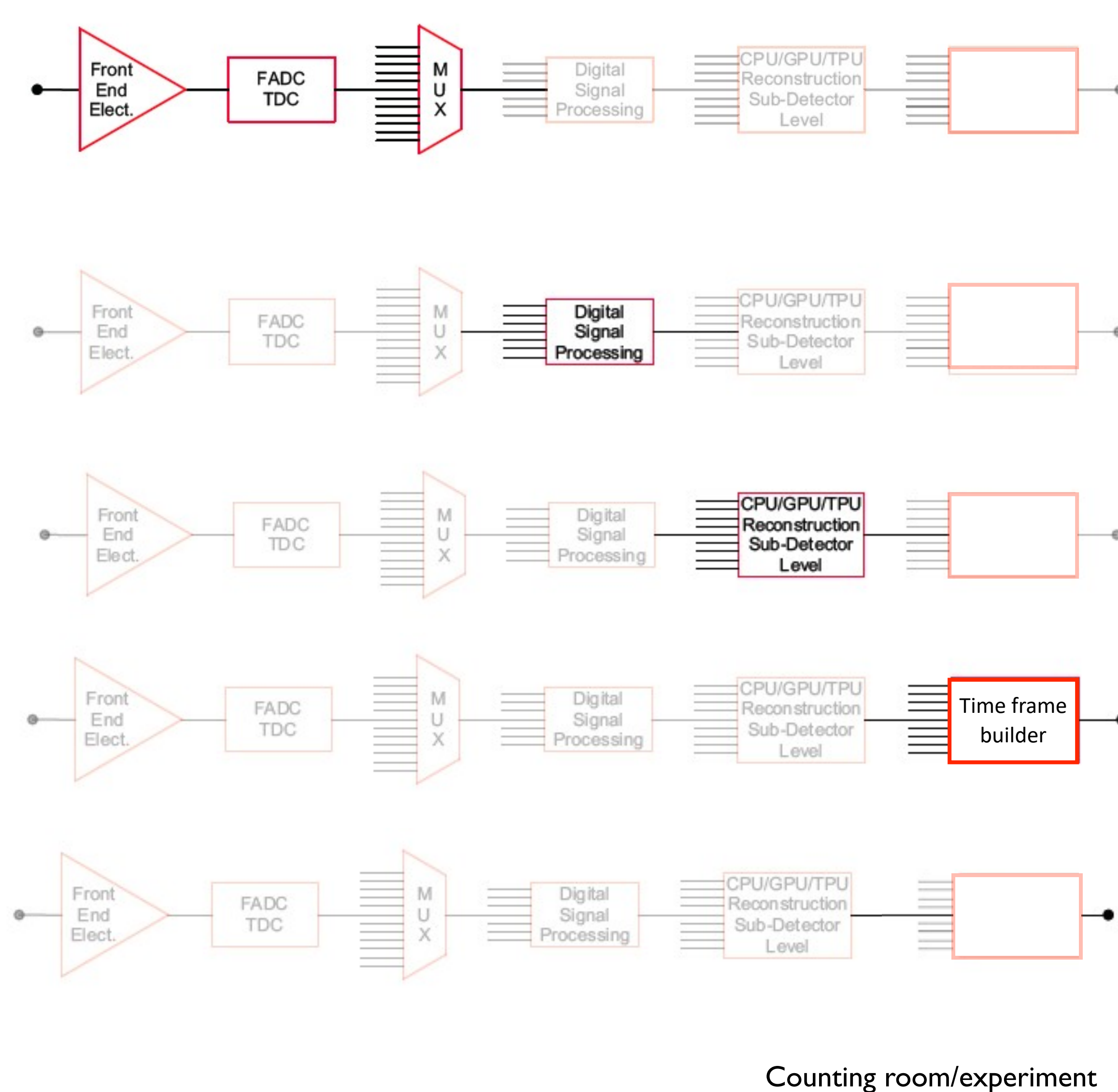
Why SRO is so important?

- * **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

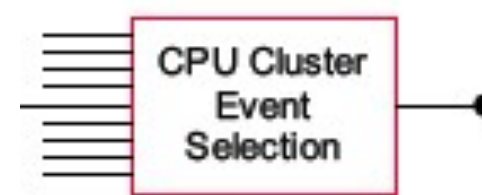
Many NP and HEP experiments adopt a SRO DAQ

- CERN: LHCb, ALICE, AMBER
- FAIR: CBM
- DESY: TPEX
- FRIBS: GRETA
- BNL: sPHENIX
- JLAB: SOLID, BDX, CLAS12, ...

Streaming RO



- FEE optimised for SRO
 - ASICS (cheap) or fADC (multiplexing) at ($O(\$10/\text{ch})$)
 - TDC if necessary to replace fADC
 - Zero-suppression mode
 - Fast readout (optical link)
- Signal pre-processing with fast hw (dedicated FPGA)
 - de-multiplexing fADC info
 - Charge, time, amplitude
 - Data compression
 - Data monitoring
 - Add other information (e.g. ch_ID eTimeStamp)
- CPU/GPU/TPU sub-detector analysis (single stream)
 - Local clusters, track segments, PID, ...
 - Time-frame building
 - If necessary only store high-level data dumping raw
- TF-Router Time frame construction
 - Use time stamps to reorganise data from all streams in time frames



- Full reconstruction CPU analysis (for each time frame)

Subtle
border
between
hard-wired
and
software
data
processing

Real Time data analysis

- In the SRO scheme, data analysis is performed online [this does not prevent to save unbiased frames for further analysis!]
- A sw trigger is released based on real-time data analysis
- SRO and real-time data processing shall use AI:
 - to adapt data analysis to the changed conditions of the run (e.g. thresholds)
 - to identify data features in real-time (e.g. clusters)
 - to extract calibration constants from a data sub-set
 - to define algorithms to run (fast!) in real time on heterogeneous systems (e.g. CPU+GPU+FPGA)

Partial Real-Time data reconstruction: clustering

- Look at all detector information (hit: x , y , t , E) to learn correlations: clusters of objects share common features
- Define a metric in a space and identify cluster features
- Tests on minimum bias trigger data before real-time
- Hyperparameters optimization based on data

Data reduction

- reduce data volume to a manageable level with minimum bias

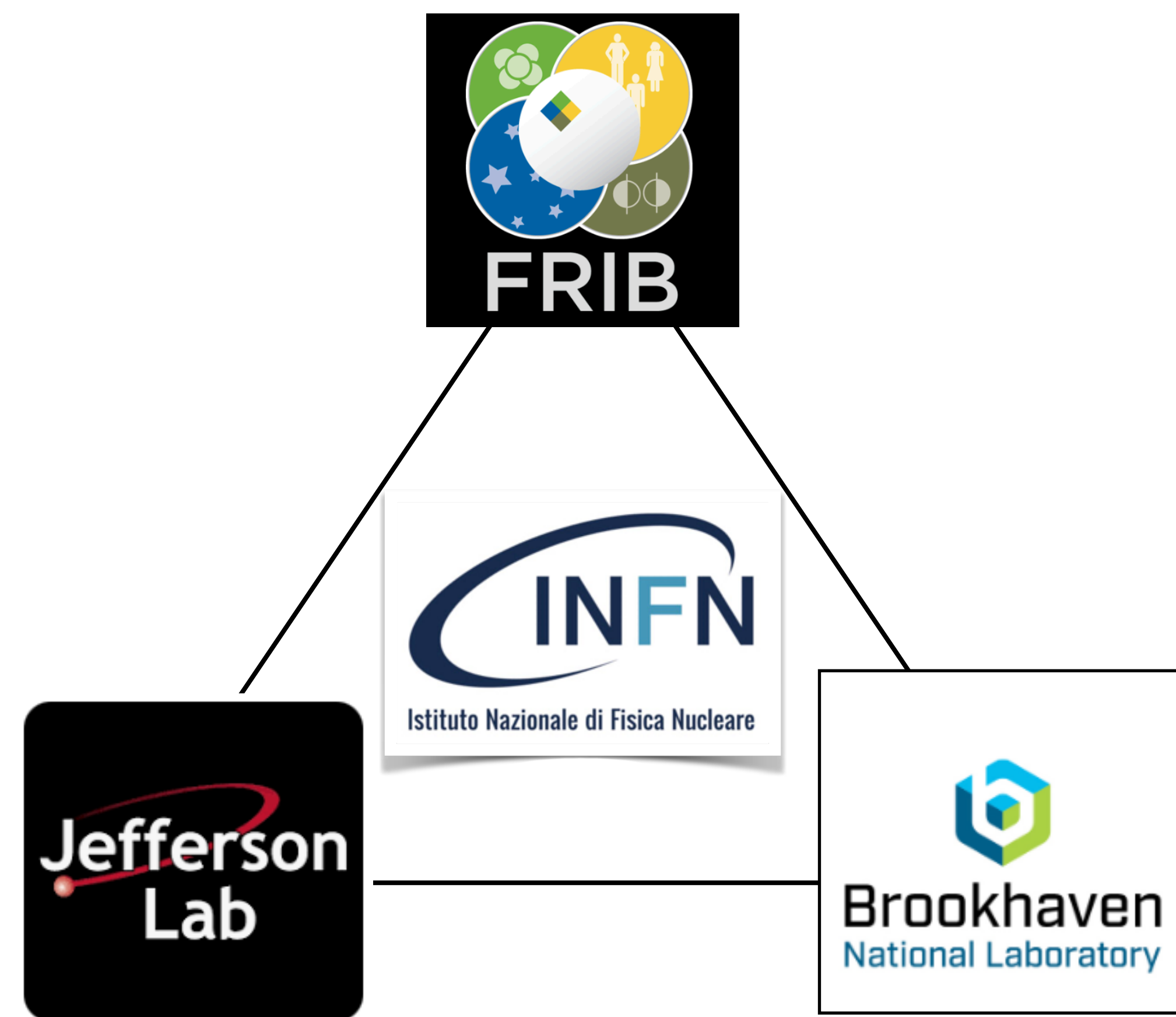
Fast inference

- Fast algorithms to extract data features to be used in data selections (and reduction)
- Mimicking a smart 'trigger'
- provide partial reconstructed quantity quickly

Calibration

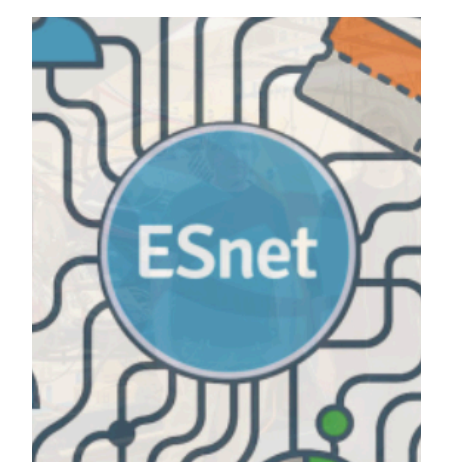
- Use smart algorithms to extract data features and correct detector parameters varying over time
- toward a self-calibrating detector

SYSTERSE



Common development of:

- Front end electronics (FEE)
 - ASICs for gaseous detector RO (APV25, VMM3, SALSA)
 - Data Concentrators (FELIX)
- Streaming readout framework
 - Prototyping
 - Off/on-beam tests
- Distributed Real-Time data analysis
 - ESNET
 - HPC nodes (CNAF, CINECA, HPDF)
- Collaborations
 - CERN
 - Japan: SPADI Alliance (JPARC, RIKEN, RIBF)
 - Germany: PRISMA clusters (GSI/FAIR, Mainz, Bonn)
- Training and education
 - Fast electronics, DAQ systems
 - AI on FPGAs, distributed HPC



SYSTEMERSE

Giordano's talk

Common development of:

- Front end electronics (FEE)
 - ASICs for gaseous detector RO (APV25, VMM3, SALSA)
 - Data Concentrators (FELIX)
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- **This talk**
 - Fast electronics, DAQ systems
 - AI on FPGAs, distributed HPC

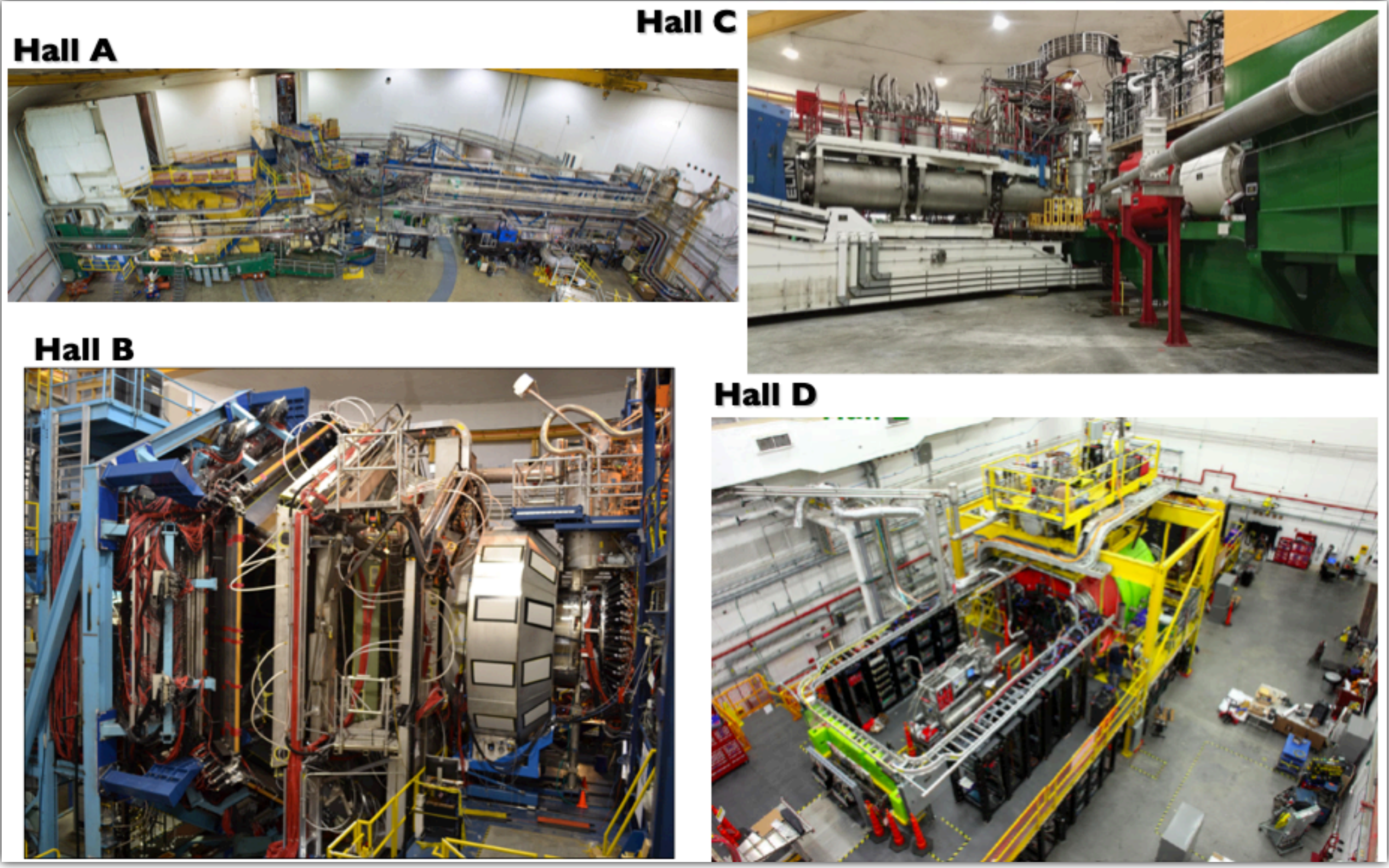
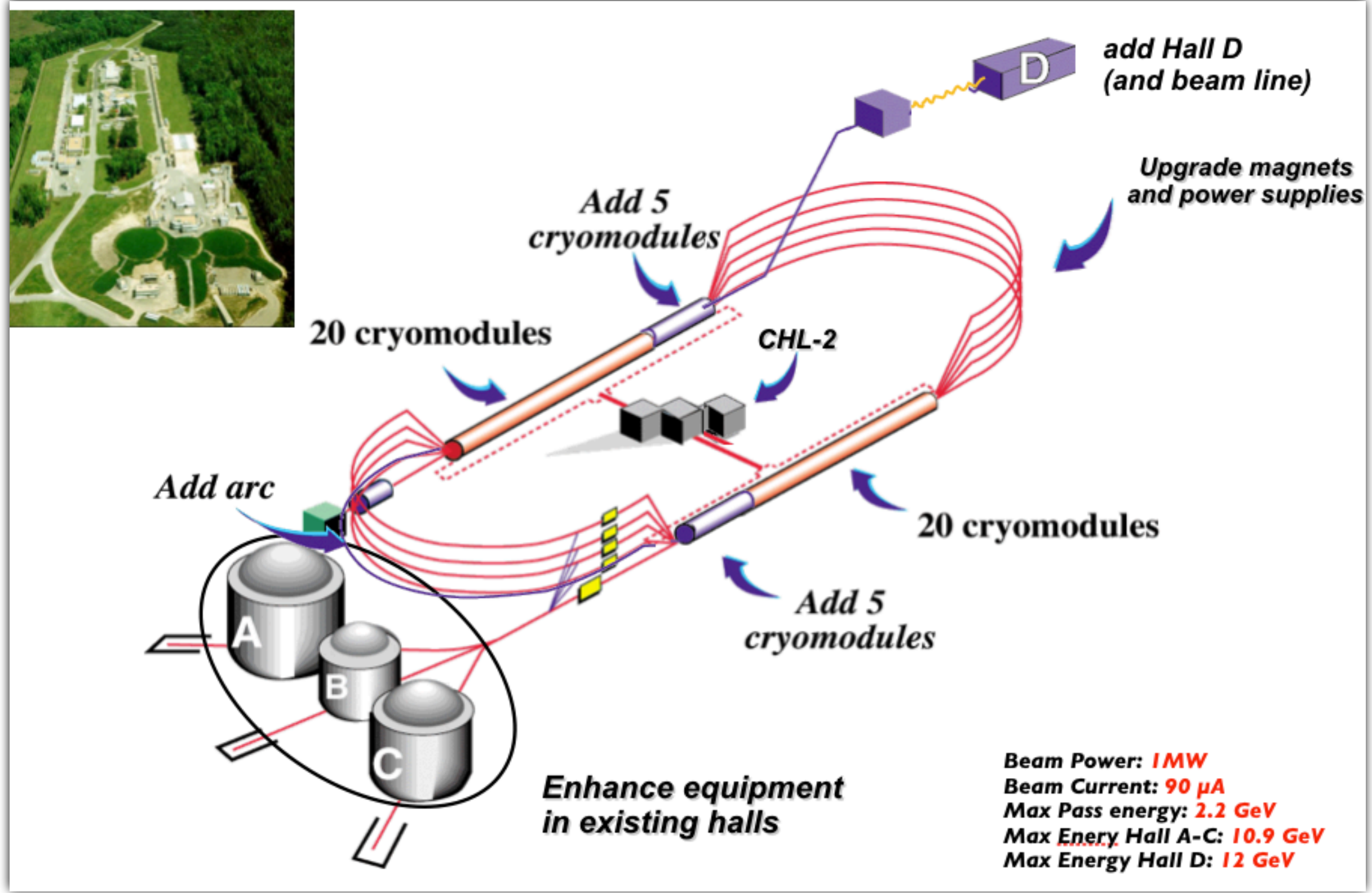




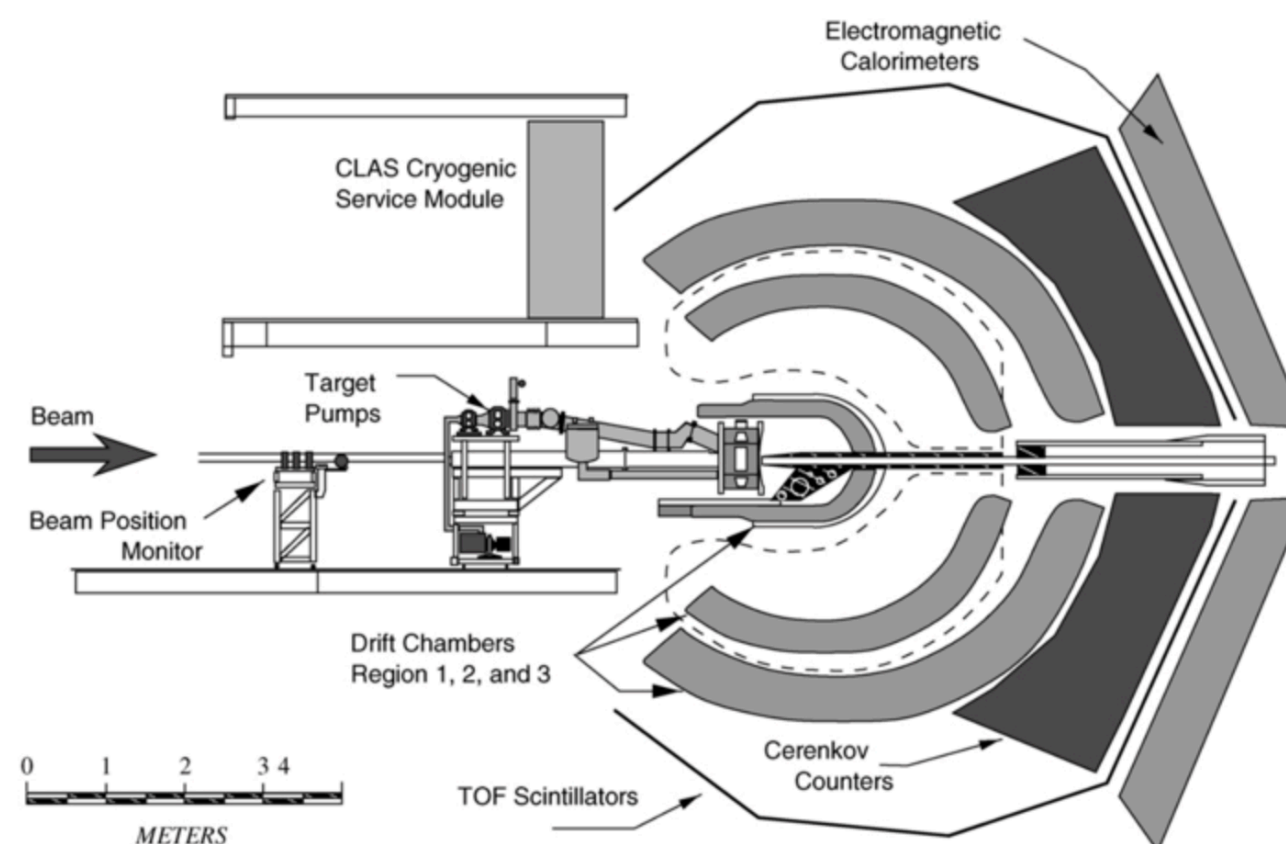
Jefferson Lab's accelerator site

- *Primary Beam: Electrons
- * Beam Energy: 12 GeV
 - $10 > \lambda > 0.1$ fm
 - nucleon $\rightarrow$ quark transition
 - baryon and meson excited states
- *100% Duty Factor (cw) Beam
 - coincidence experiments
 - Four simultaneous beams
 - Independent E and I

- * Polarization
 - spin degrees of freedom
 - weak neutral currents
- Luminosity $> 10^7 - 10^8 \times$ SLAC
at the time of the original DIS experiments!



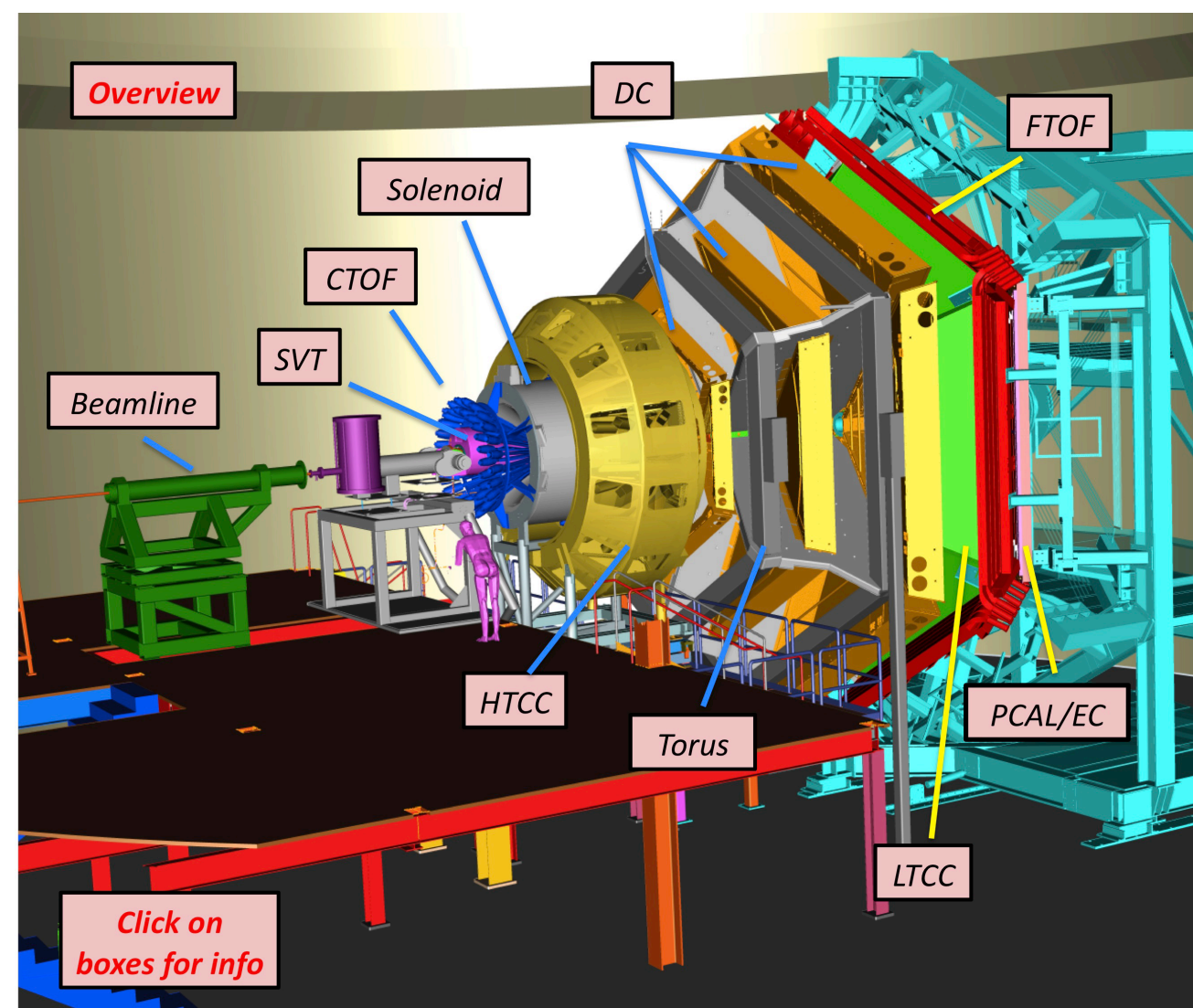
DAQ in Hall-B: CLAS and CLAS12



CLAS (1997-2012)

TRIGGERED system limited by:

- Available technology
- Low latency ($\sim 100\text{ns}$) defined by FASTBUS ADCs
- Level-1 trigger: calorimeter/TOF/Cherenkov/StartCounter/Tagger (time coincidence of 'fast' detectors discriminators)
- Level-2 trigger: drift chamber (no tracking, just multiplicity)
- Hardware: - since 1997: JLAB-made; - since 2008: CAEN v1495's (Cyclone I - first experience with FPGAs)



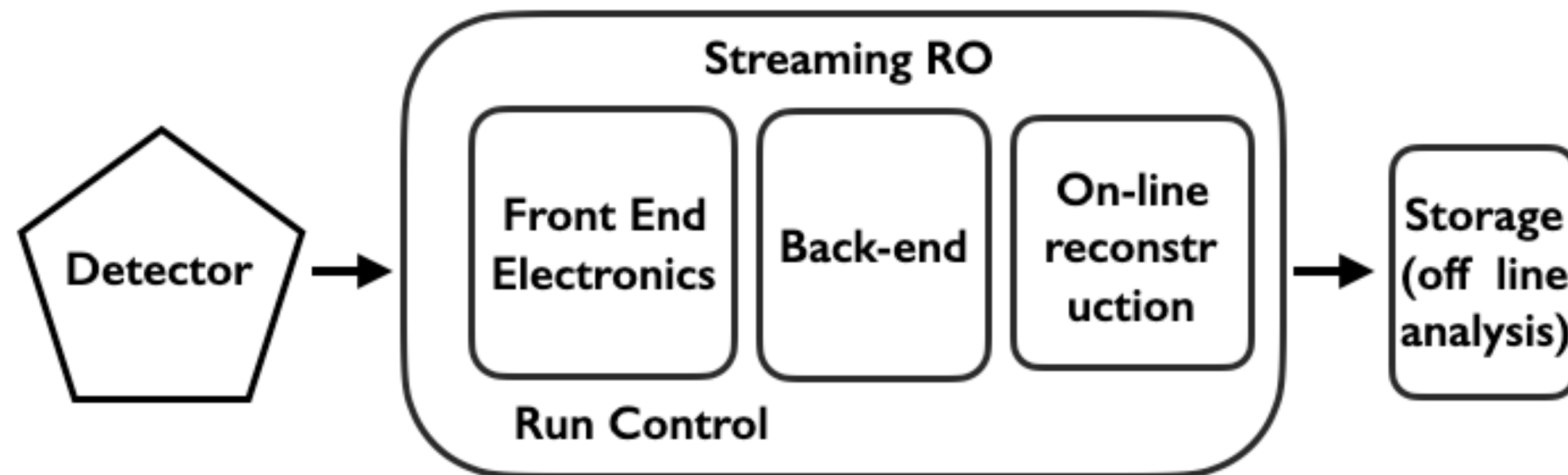
CLAS12 (2017 - present)

TRIGGERED system improved by:

- Advanced FPGA technology
- high latency ($\sim 8\text{ us}$) defined by fADCs
- Level I trigger: clusters in 3 calorimeters and hodoscope (FADC pulse integrals) + hits in 2 TOFs and 2 Cherenkovs (FADC pulse integrals) + tracks in Drift Chamber (discriminators/TDCs)
- Hardware: JLAB-made VTP (VXS Trigger Processor) boards (Virtex7 FPGA)
- Trigger algorithms: energy, position, and timing of the clusters in calorimeters; energy, position, and timing of TOFs and Cherenkov hits + drift chamber track finding (dictionary-based) + timing and position matching between clusters, hits and track

Credit: Sergey Boiarinov

Streaming RO at Jlab: the proof of principle



SRO concept validation

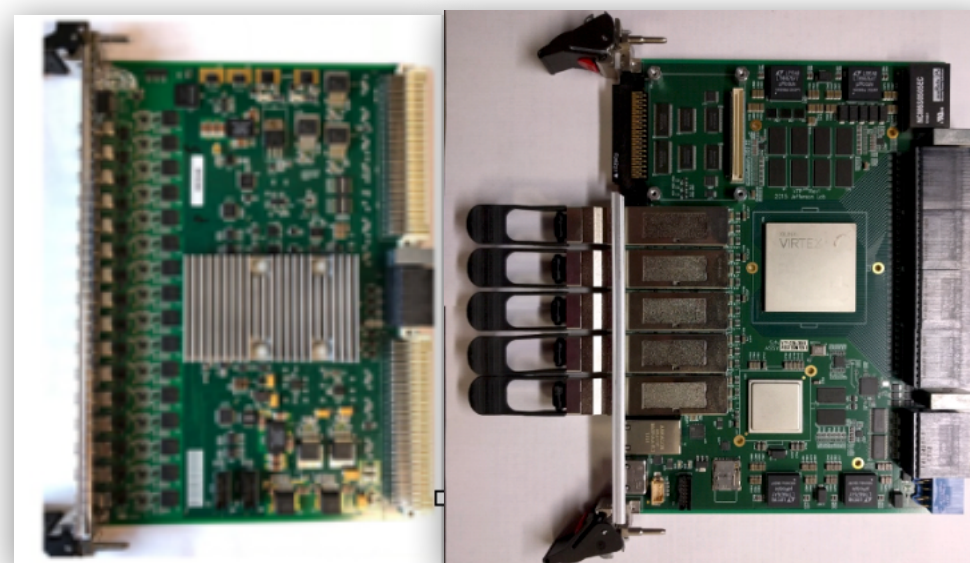
- 1) Assemble SRO components
- 2) Test SRO DAQ in lab
- 3) Test SRO DAQ on-beam

FrontEnd

D.Abbott, F.Ameli, C.Cuevas, P. Musico, B.Raydo

* JLab fADC250 + VTP board

- JLab 250 MHz flash ADC digitizer currently used in many experiments
- Overcome VXS limitations (<24 Gb/s) using JLab VTP board (<40 Gb/s)
- Not optimised but reuse of existing boards: ready-to-go solution while waiting for fADC250.v2



Jana2 + reconstruction

N.Brei, D.Lawrence,
M.Bondi', A.Celentano, C.Fanelli, S.Vallarino

* JANA2 + TriDAS

- Integration between On-line and off-line
- Real-time tagging/filtering data
- Offline algorithm development immediately available for use in Software Trigger
- Level 1 "minimum-bias": at least one crystal with $E > 2$ GeV
- Level 2 plugins (*tagging* and *filtering*)
 - "standard" FT-CAL clustering ($N_{\text{cluster}} \geq 1, 2, 3$)
 - cosmic tracking
 - AI clustering algorithm: at least two cluster in the FT-CAL

BackEnd

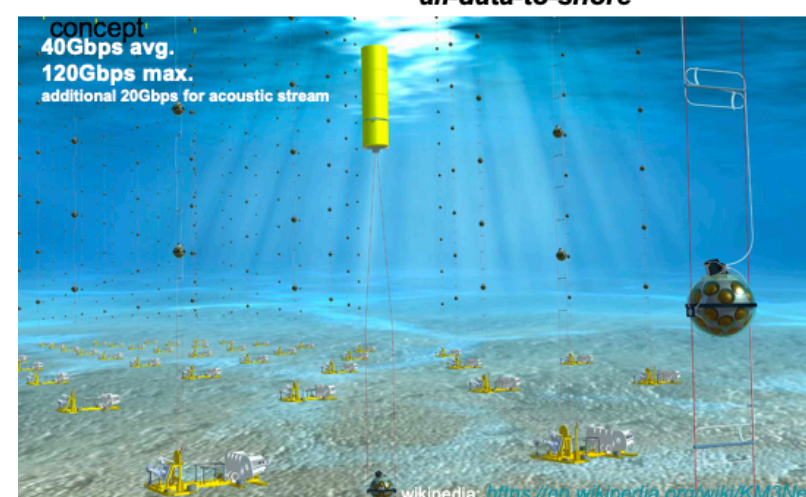
L.Cappelli, T.Chiarusi, F.Giacomini, C.Pellegrino

* TRiggerless Data Acquisition System (TriDAS)

- Developed for KM_3NET
- Installed on Hall-B DAQ cluster
- Multi CPUs, rate up to 20-30 MHz

TriDAS (Trigger and Data Acquisition System)
<https://inspirehep.net/files/26390da0ea937dddc80fbabde70c07ab>

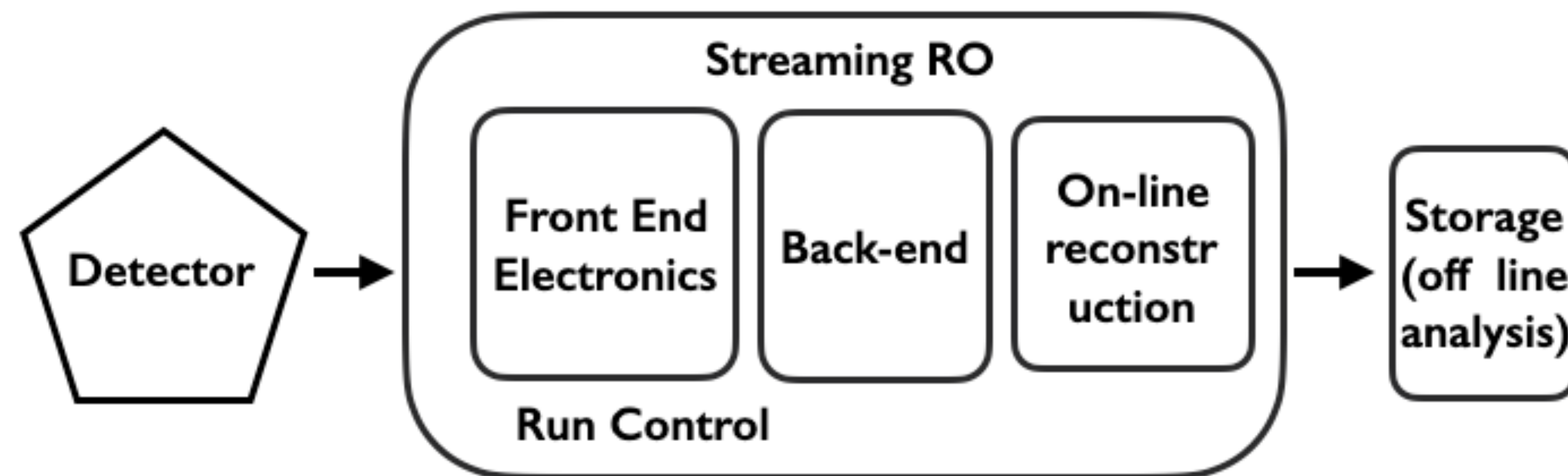
KM3NeT = Cubic Kilometre Neutrino Telescope
"all-data-to-shore"



Cebaf Online Data Acquisition (CODA)

D.Abbott, S.Boyarinov, B.Raydo, G.Heyes

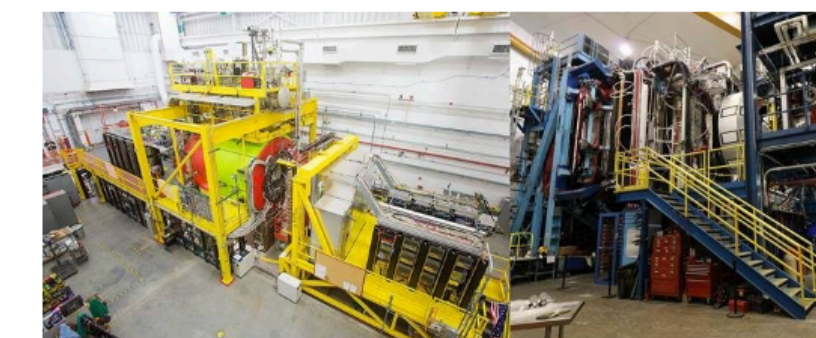
- Originally designed for trigger-based readout systems
- Controllers (ROCs) and VXS Trigger Boards (VTPs)
- The Trigger Supervisor (TS) synchronizes components using clock, sync, trigger and busy signals.-time tagging/filtering data
- CODA adapted to the SRO
 - Replaced EB to use timestamp)
 - ROC communication via VTP (not VXS bus)



SRO concept validation

- 1) Assemble SRO components
- 2) Test SRO DAQ in lab
- 3) Test SRO DAQ on-beam

Nuclear Physics » A Trial Run for Smart Streaming Readouts



Scientists tested streaming readout systems during nuclear physics experiments that collected data in Jefferson Lab's Experimental Halls B and D. Images courtesy of Jefferson Lab

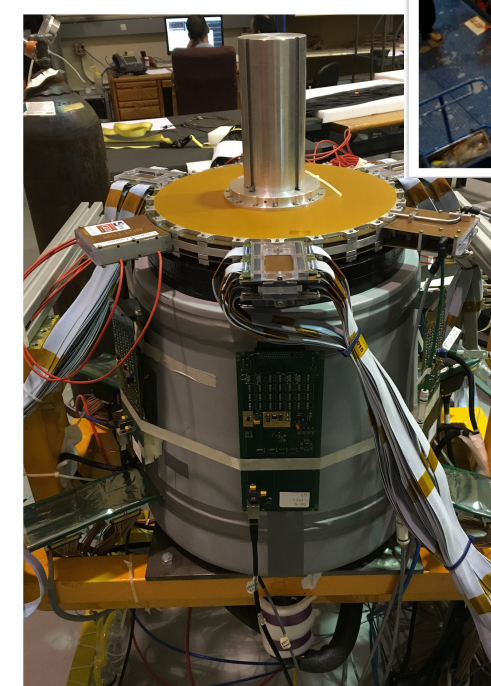
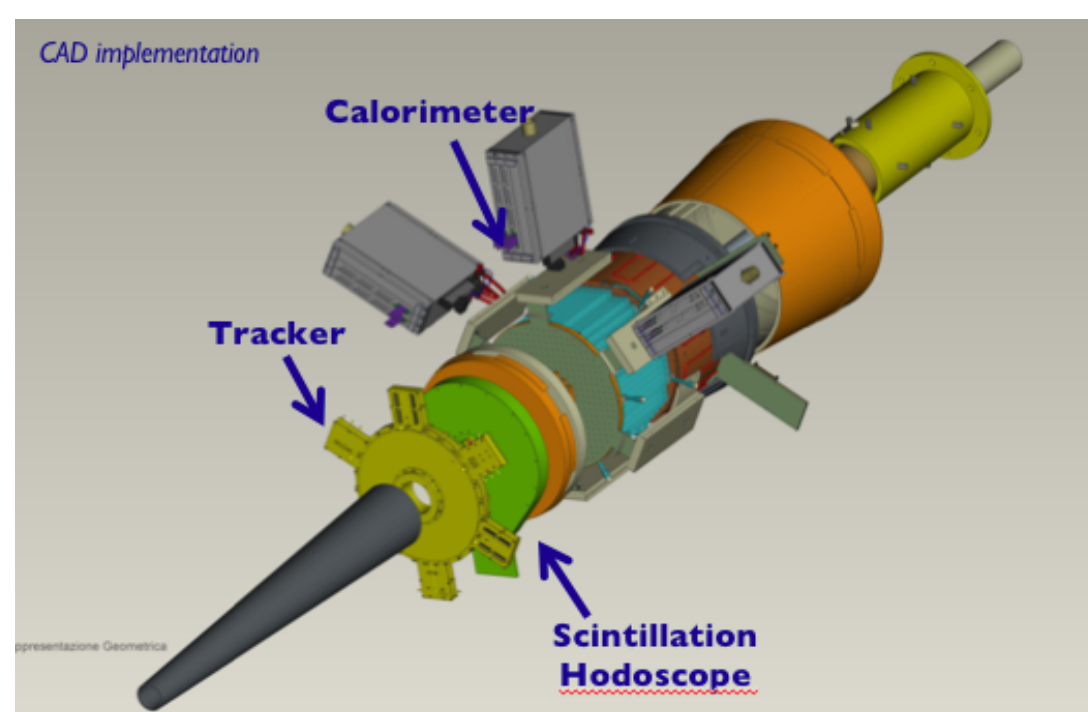
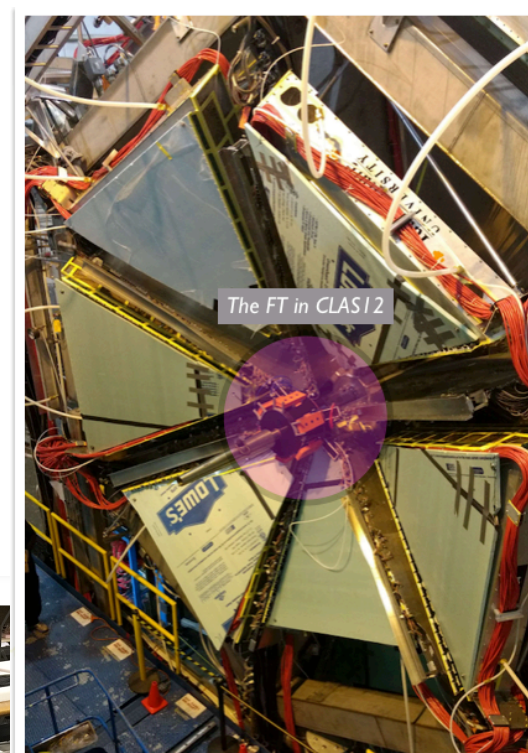
The Science

Nuclear physics experiments are data intensive. Particle accelerators probe collisions of subatomic particles such as protons, neutrons, and quarks to reveal details of the bits that make up matter. Instruments that measure the particles in these experiments generate torrents of raw data. To get a better handle on the data, nuclear physicists are turning to artificial intelligence and machine learning methods. Recent tests of two streaming readout systems that use such methods found that the systems were able to perform real-time processing of raw experimental data. The tests also demonstrated that each system performed well in comparison with traditional systems.

JLab SRO validation

* CLAS12 Forward Tagger

- Complete system that include calorimetry, PiD, Tracking in a simpler (than CLAS12) set up
- FT-ECAL: 332 PbWO crystals, APD readout
- FT-HODO: 224 plastic scintillator tiles, SiPM readout
- FT-TRK: ~3000 channels, MicroMegas
- fADC250 digitizers + DREAMs for MM

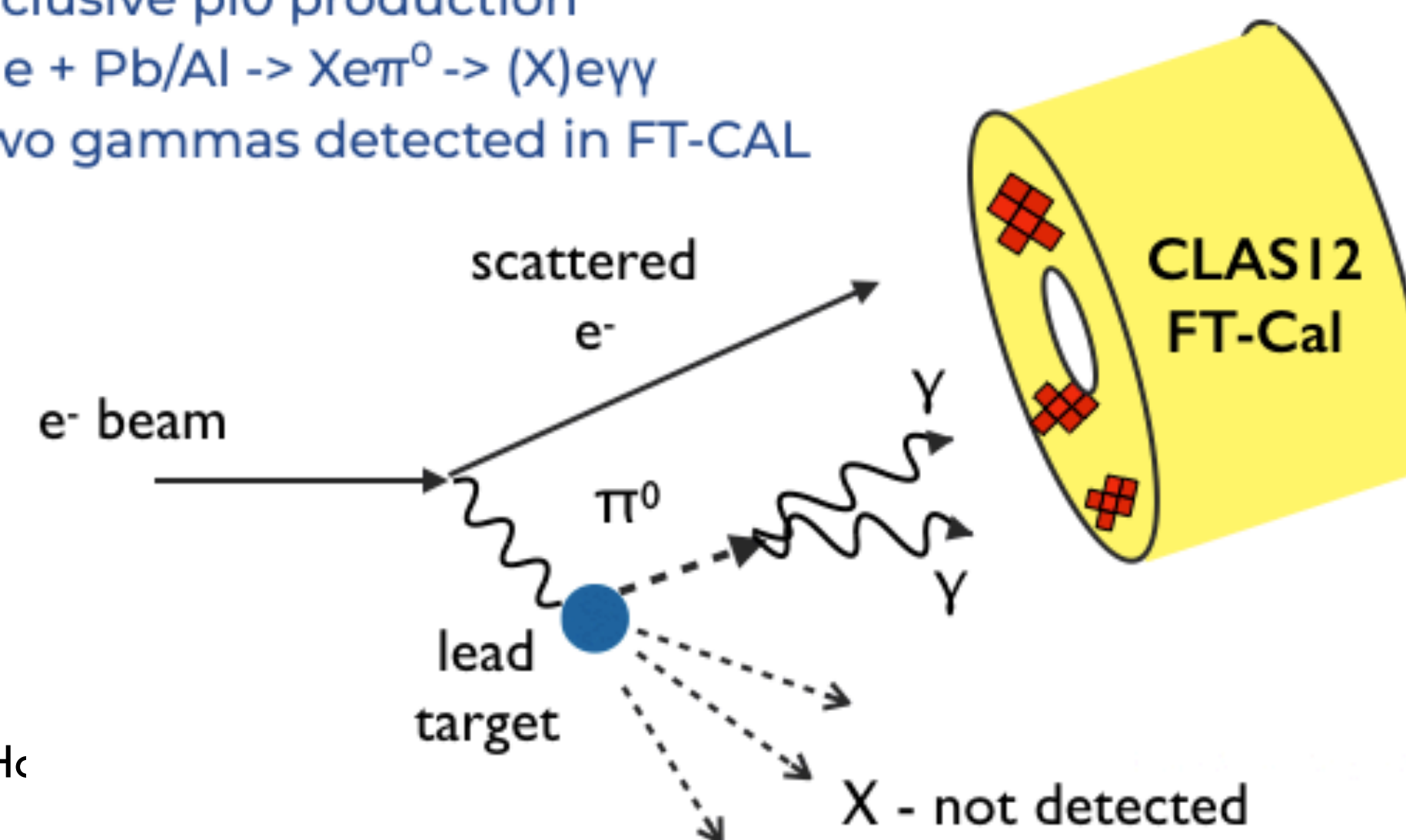


* CLAS12 Forward Tagger

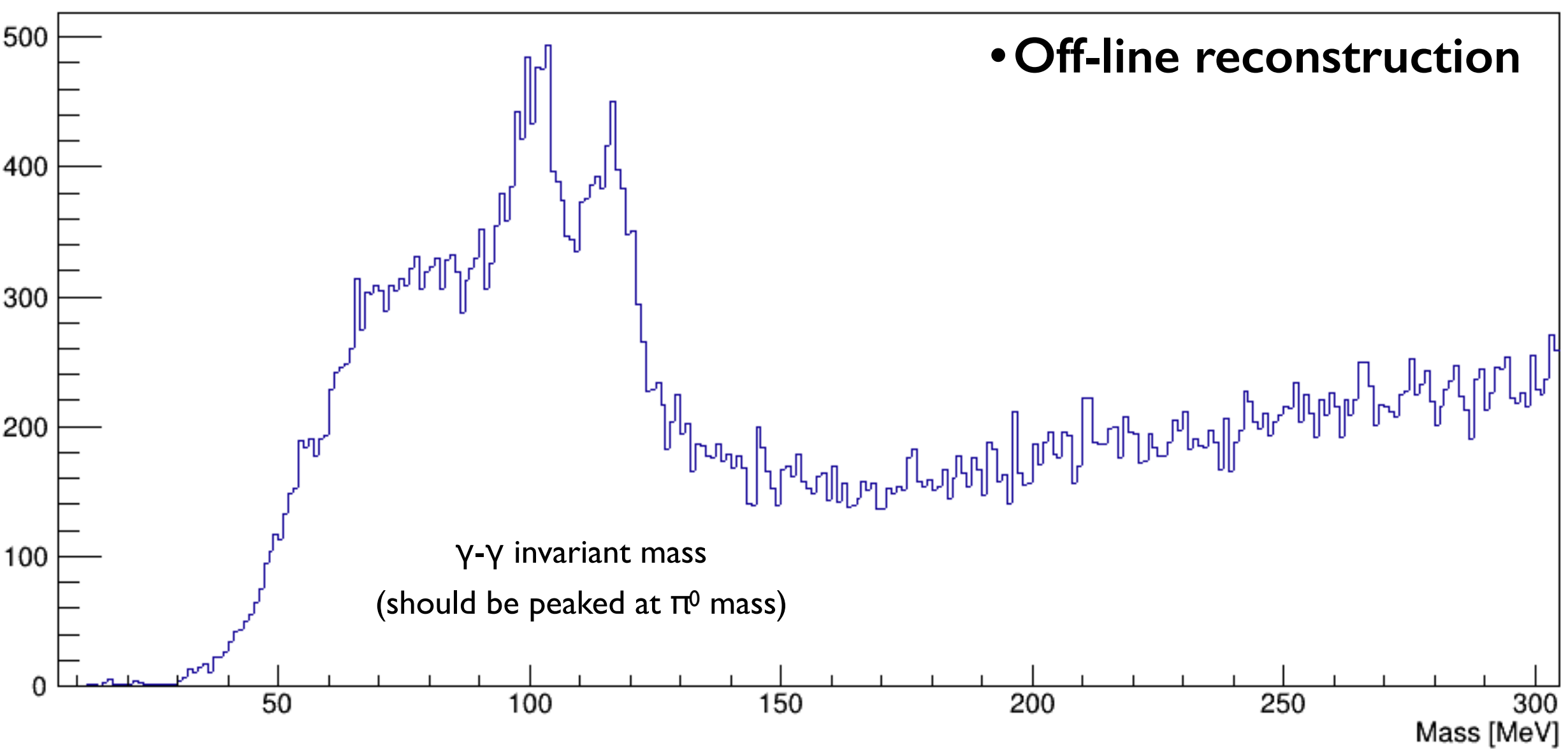
- Inclusive pi0 electroproduction
- Two gammas detected into FT-CAL
- EM clusters identification, anti coincidence with FT-Hc
- Self-calibration reaction (pi0 mass)

• On-beam tests:

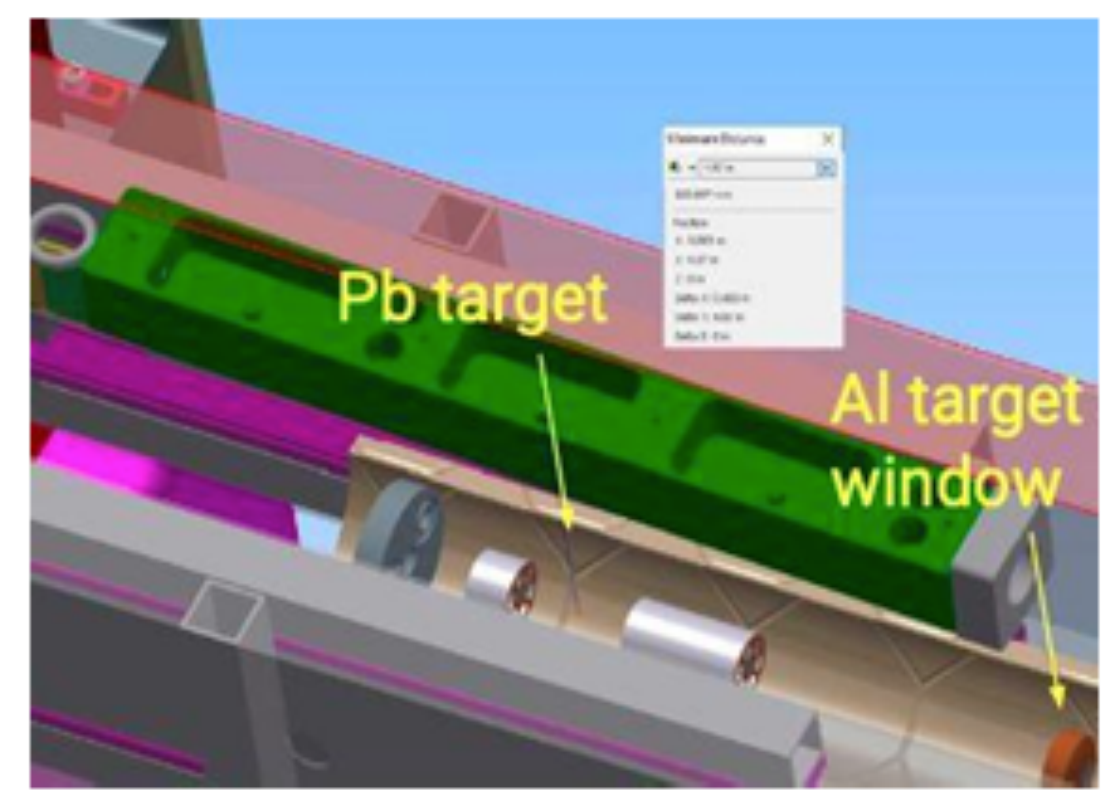
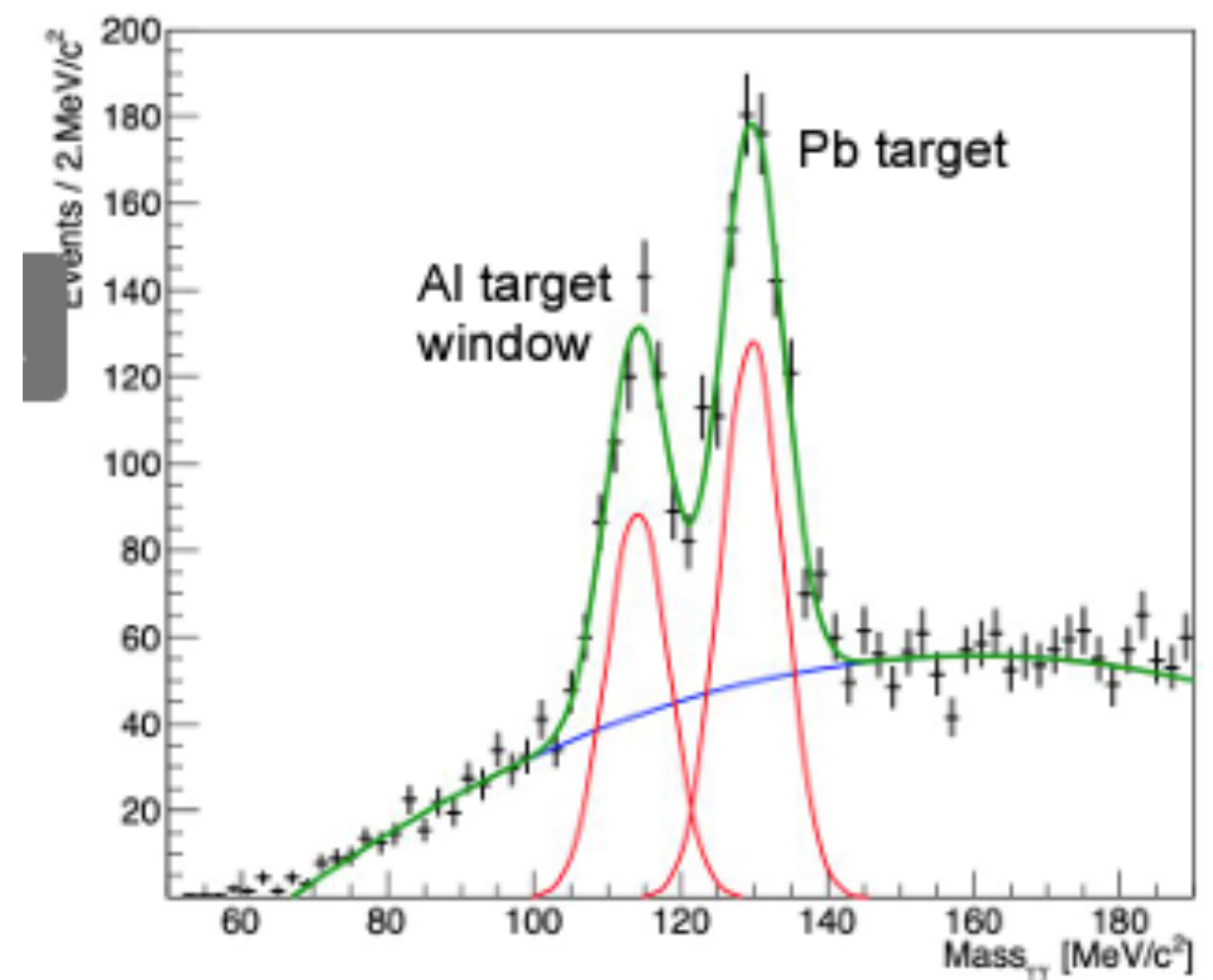
- 10.4 GeV e- beam on thin Pb/Al target
- Inclusive pi0 production
 - $e + \text{Pb/Al} \rightarrow X e \pi^0 \rightarrow (X) e \gamma \gamma$
- Two gammas detected in FT-CAL



Streaming RO at Jlab: pioneering tests

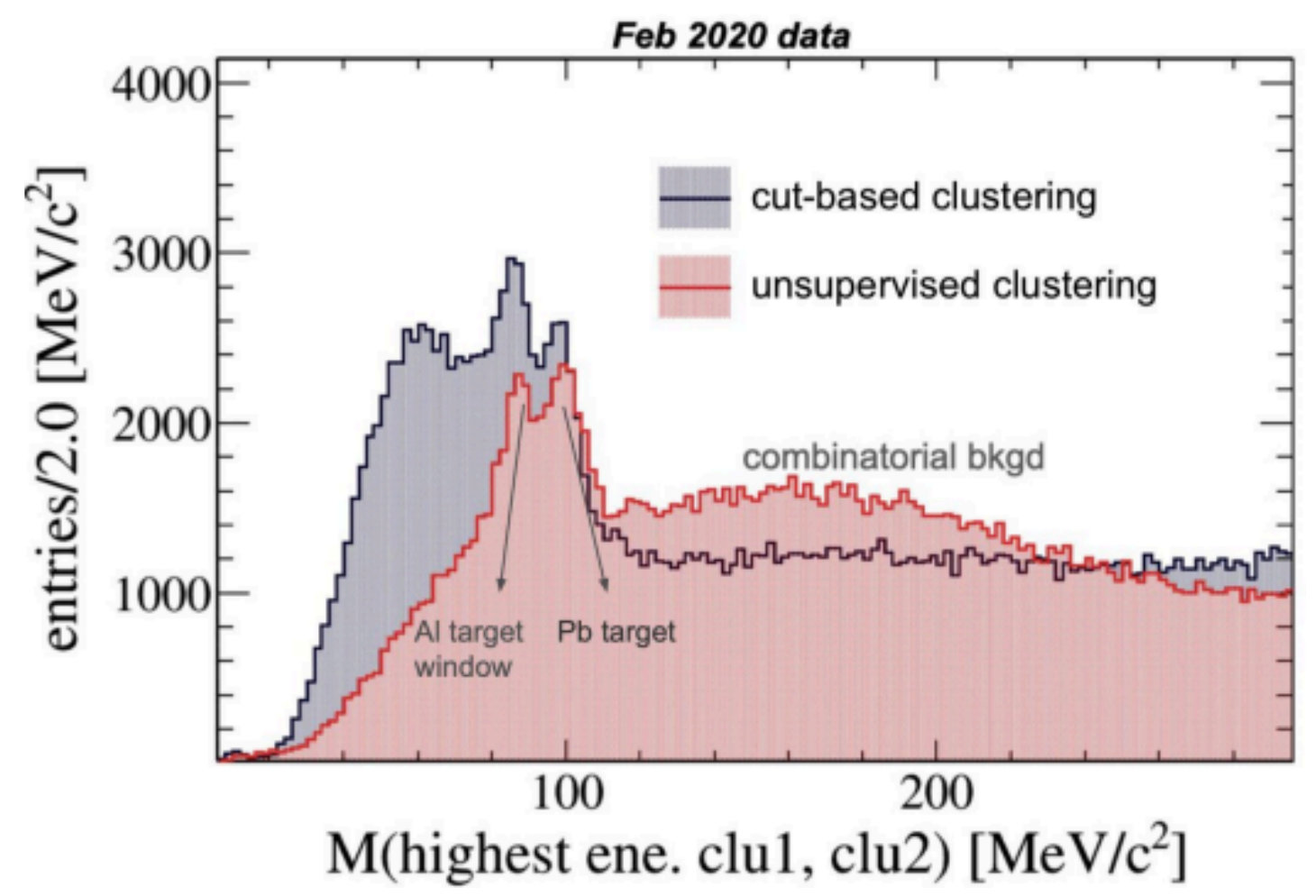


• Two π^0 peaks corresponding to two vertices (and a wrong assumption on the vertex position)



AI to analyze data in real time, and extract features (e.g. number of peaks and position)

- AI clustering inspired by *Hierarchical Density-Based Spatial Clustering of Applications with Noise* (HDBSCAN)
 - It is not cut-based
 - it is able to cope with a large number of hits
- Compared $\gamma\gamma$ -invariant mass spectrum obtained utilizing both the standard and the HDBSCAN clustering algorithm
 - AI significantly improves signal-to-background ratio in the π^0 region
 - A longer runtime of ~30% relative to the standard clustering algorithm
- AI clustering approach promising alternative to traditional cut-based approaches

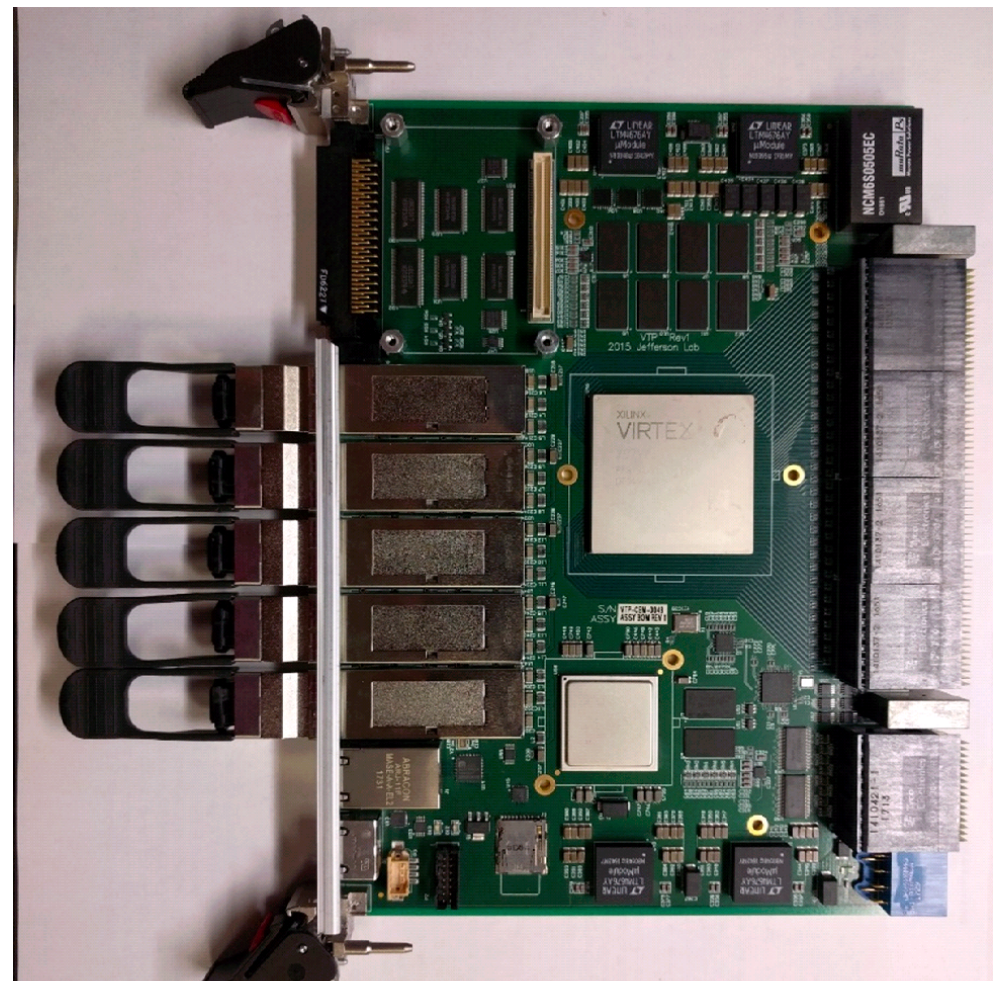


Streaming RO in Hall-B

CLAS12 (Future)

Streaming ReadOut

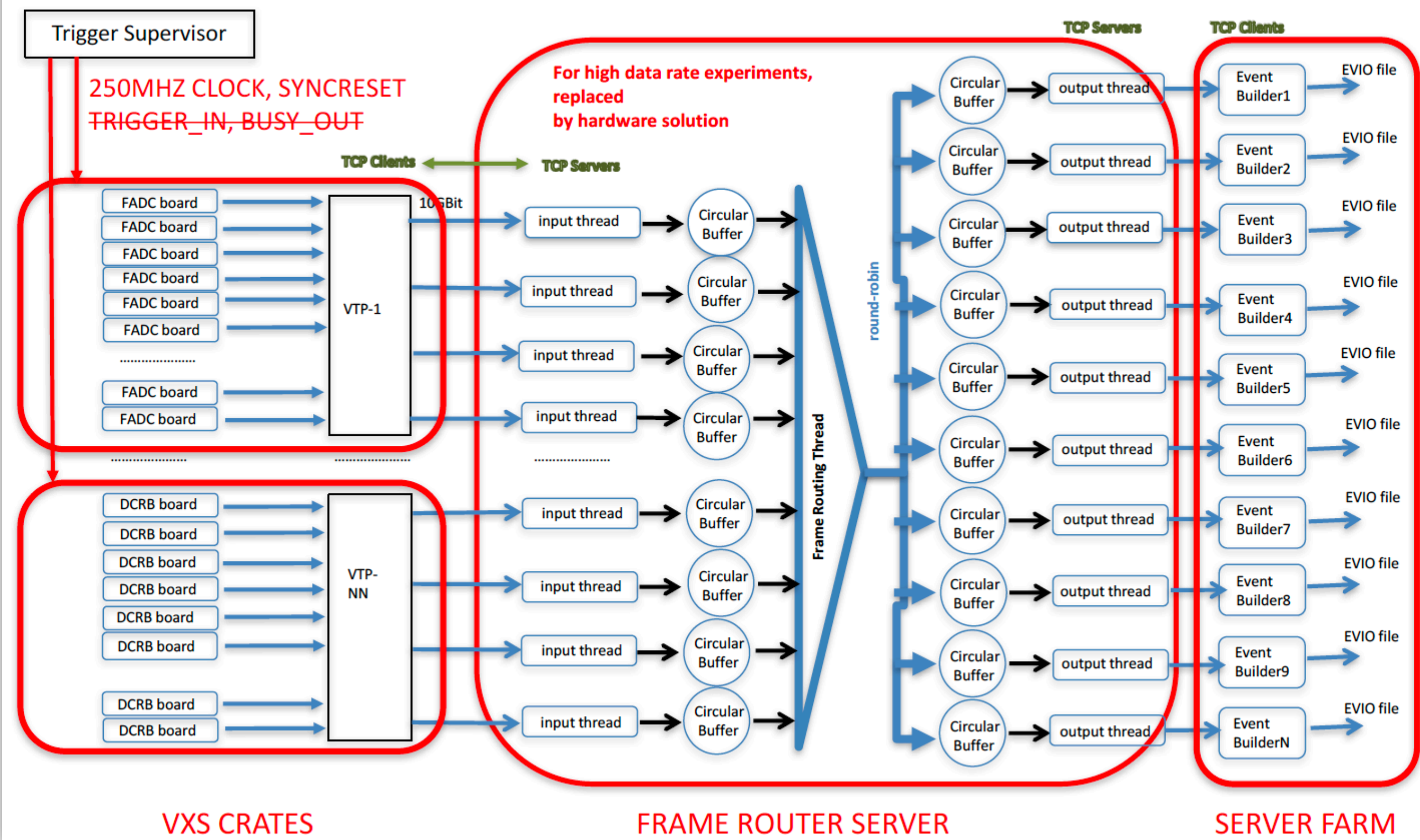
- Alternative use of the VXS Trigger Processor (VTP) board
- Up to 4 x 10 Gbit/s
- More than 50 crates (VME/VXS) can be reused



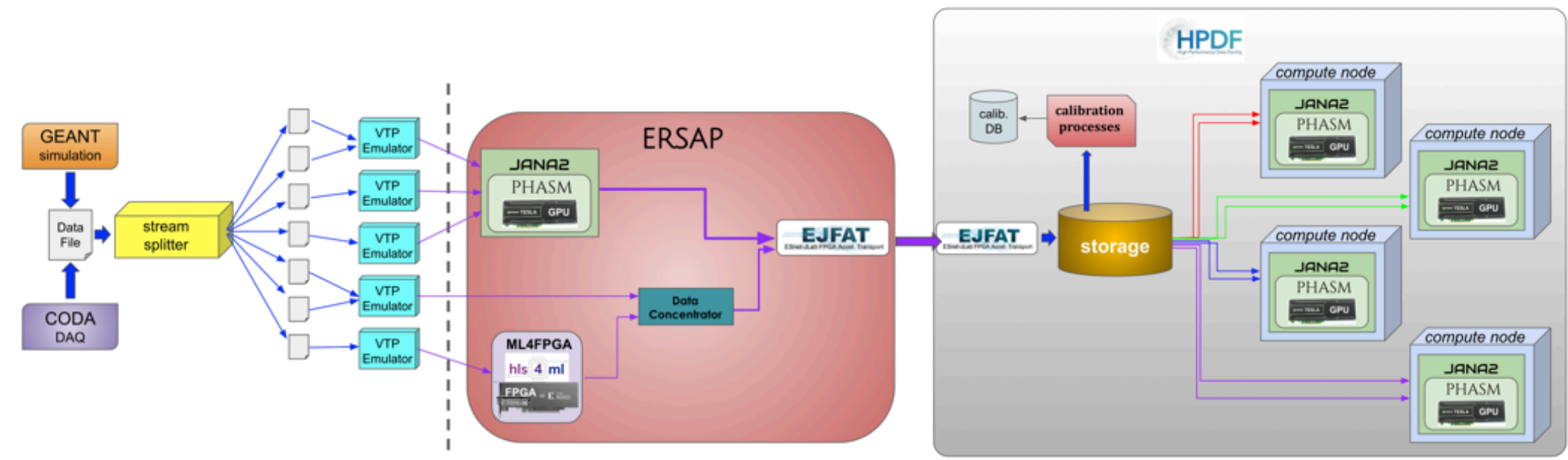
Status of SRO in Hall-B

- VTP firmware updates
- Beam tests with local resources (Hall-B counting house)
- Tests with remote resources (Computer Center) using Arista smart switch
- Planned test to stream ~half CLAS12 data to CC
- Final goal (~5y): x2-3 CLAS12 Luminosity (~50GB/s)

Streaming DAQ diagram (with C version of the Frame Router)



Streaming RO at Jlab: the current effort



Highly configurable multi-stream source allows realistic streaming simulations

Onsite components will implement first stages of data filtering/reduction

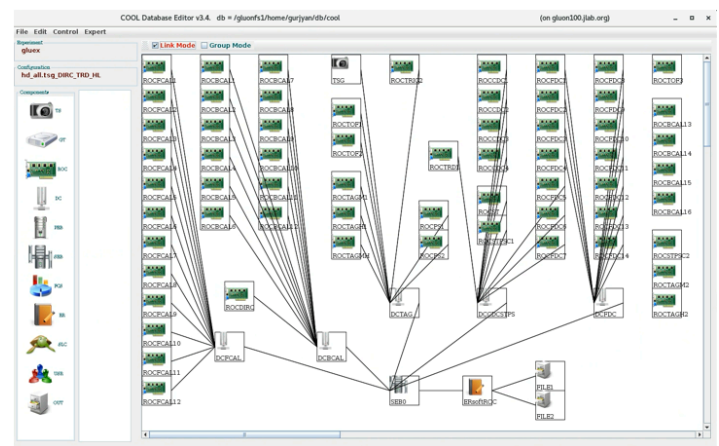
Offsite processing must incorporate built-in calibration latencies and storage. This will also help inform HPDF design

- Integration of different components in an optimised SRO framework

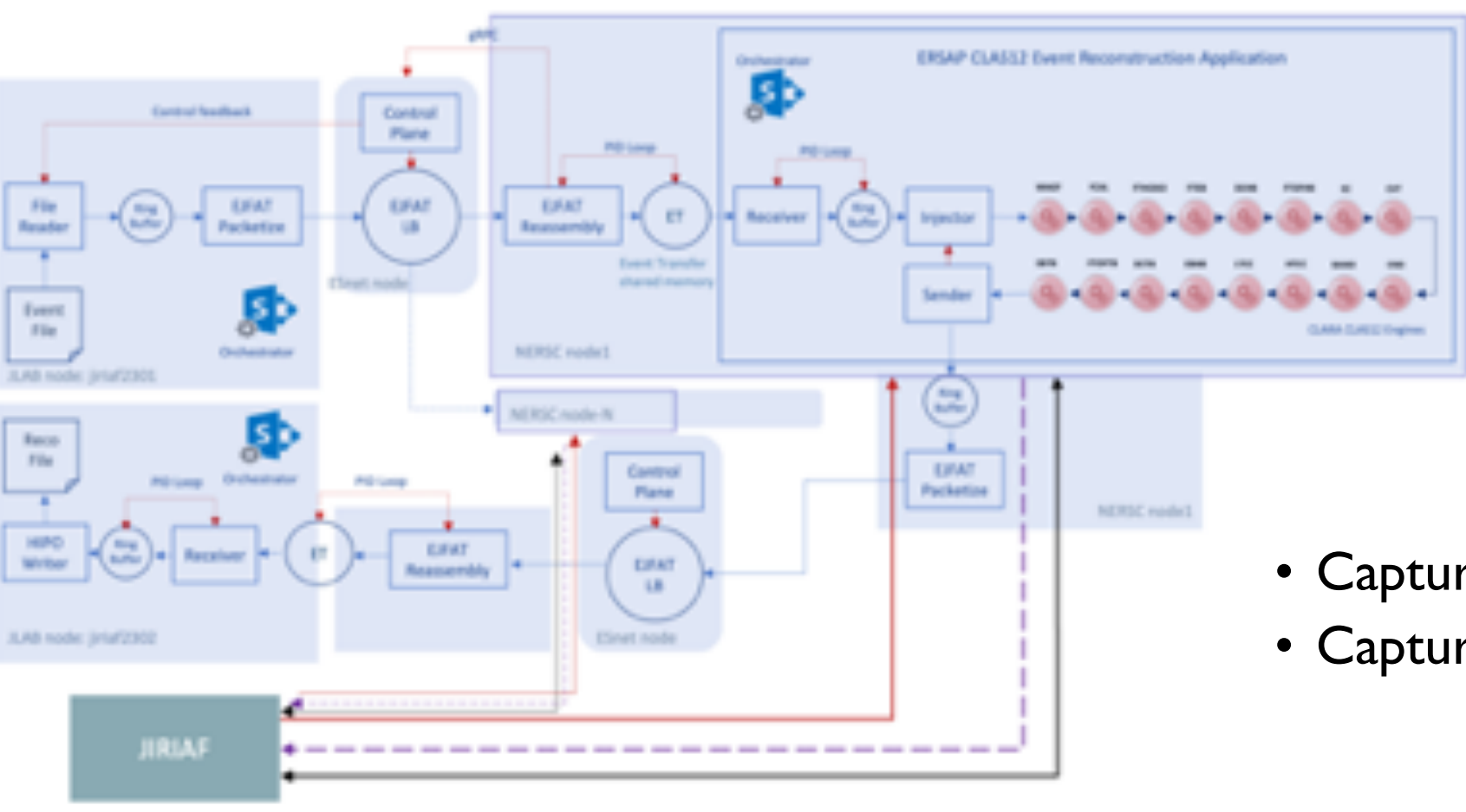
ERSAP

- Reactive, event-driven data-stream processing framework that implements micro-services architecture
- Provides basic stream handling services (stream aggregators, stream splitters, etc.)
- Adopts design choices and lessons learned from TRIDAS, JANA, CODA and CLARA

- Development of SRO DAQ pipeline tools

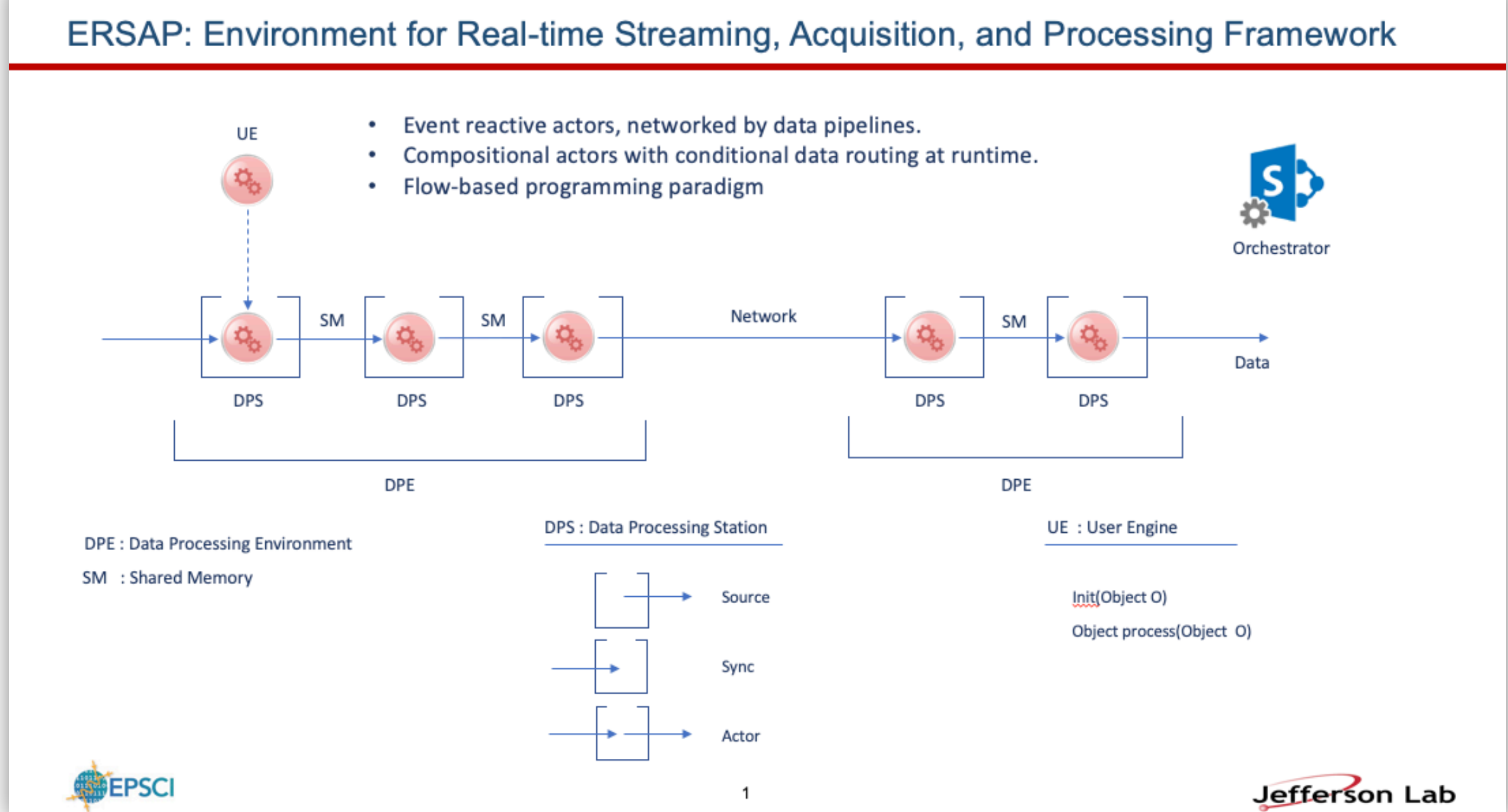


- Development of JLAB CLAS12 Remote data-stream processing over a distance



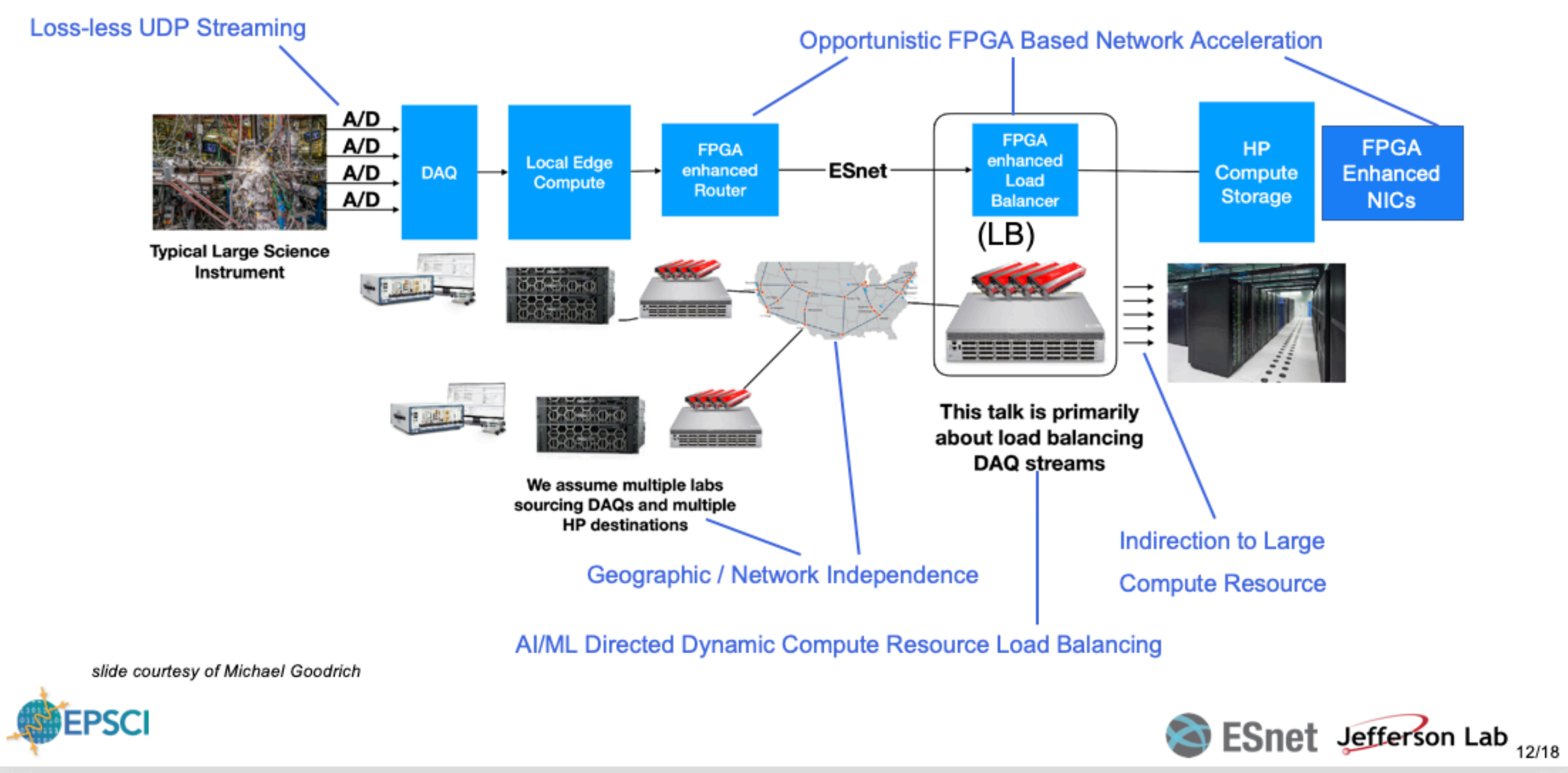
Inaugural demonstration of remote data-stream workflow deployment and processing over a distance

- Captured CLAS12 data, streamed across the Jlab campus using a 100Gbps high-speed NIC featuring hardware timestamps
- Captured data using synchronized streams from multiple network sources

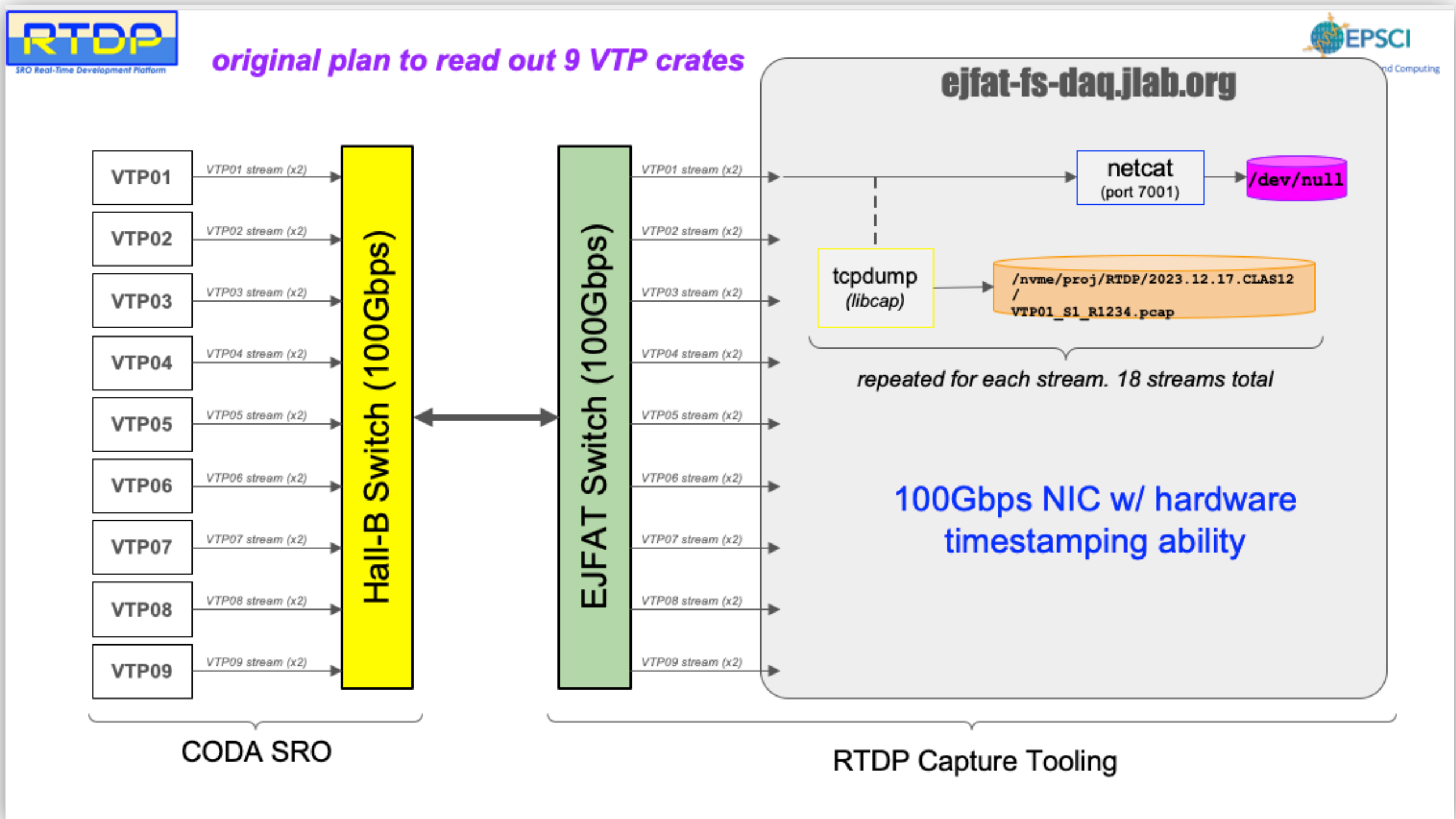


JLab SRO R&D: networking and data transfer

EJFAT = ESnet/JLab FPGA Accelerated Transport



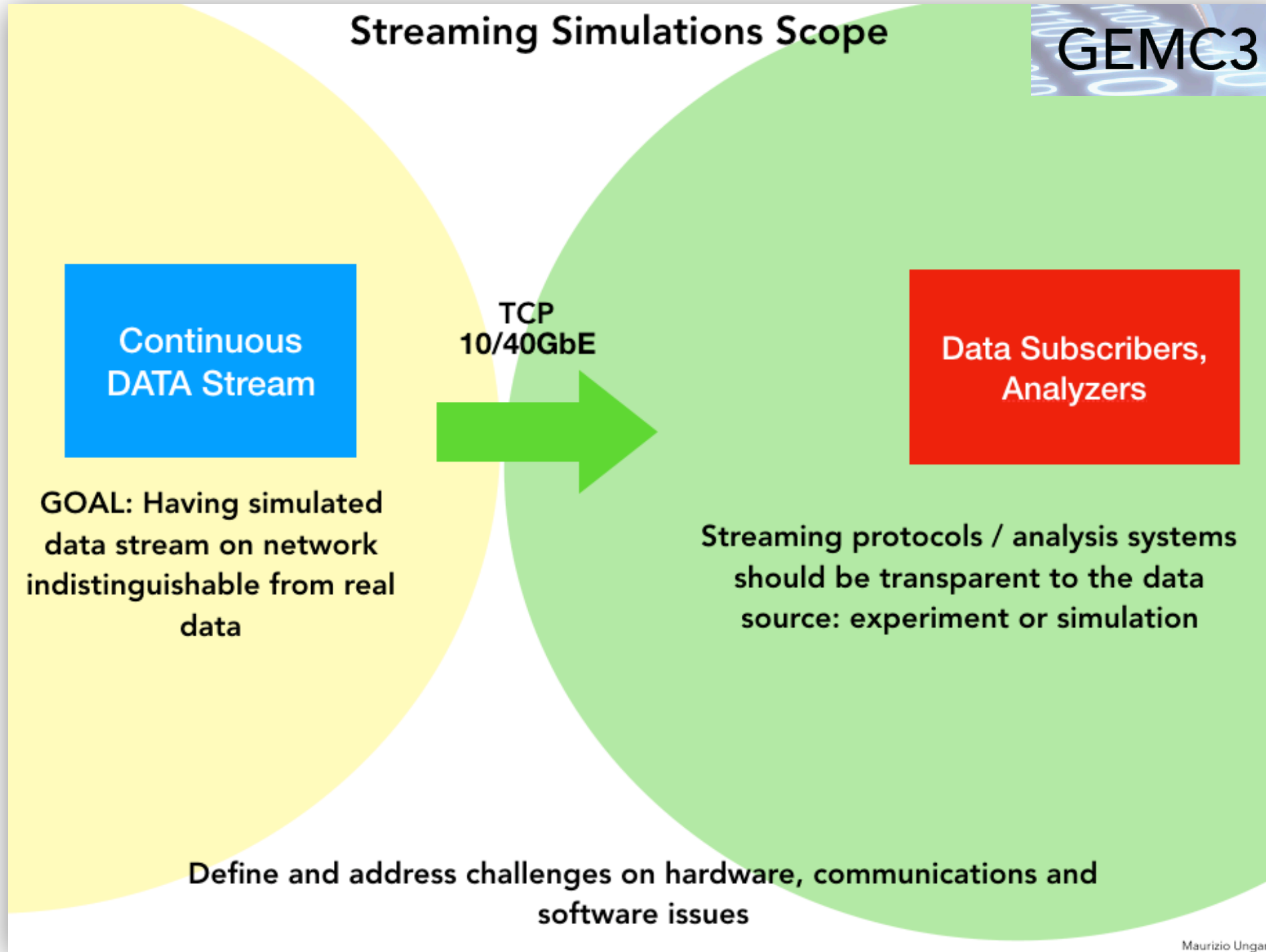
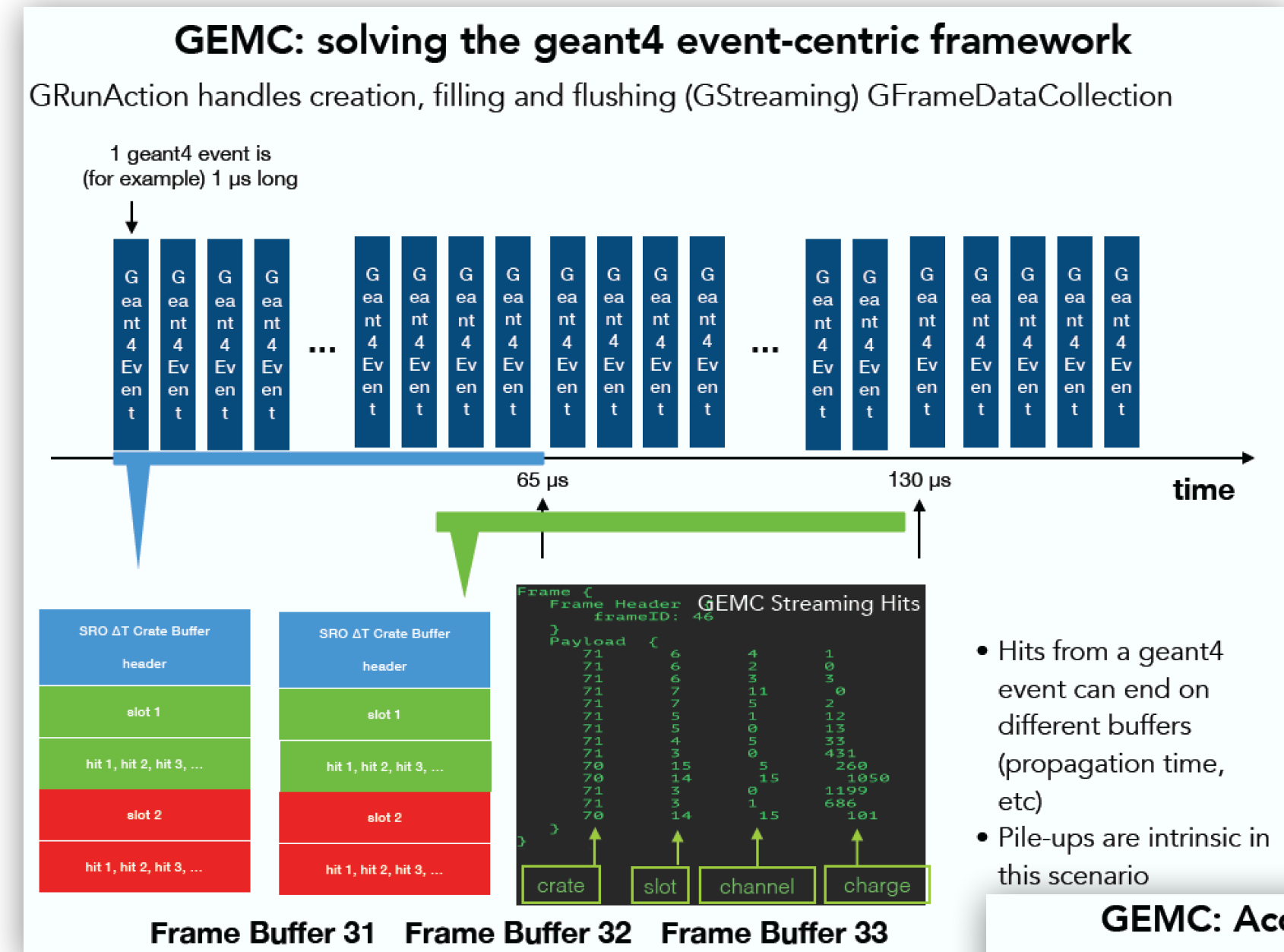
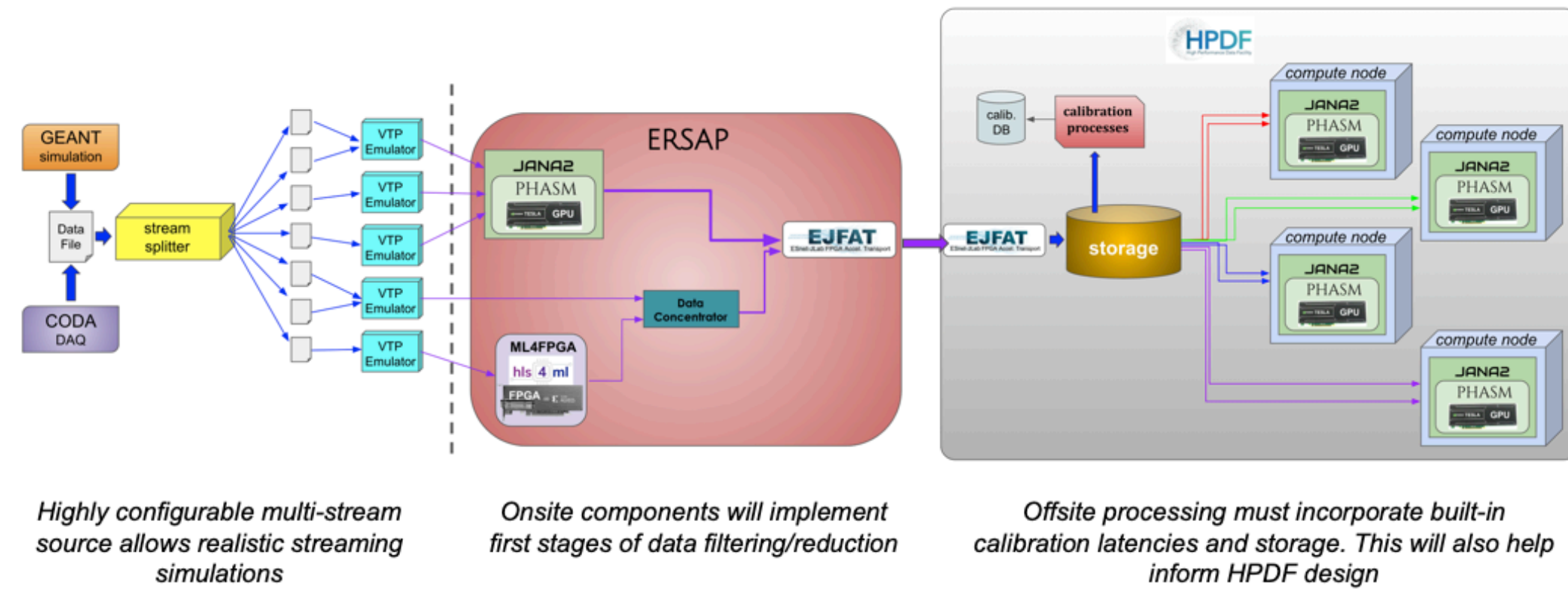
- Re-utilize the existing data transfer infrastructures developed at Jefferson Lab



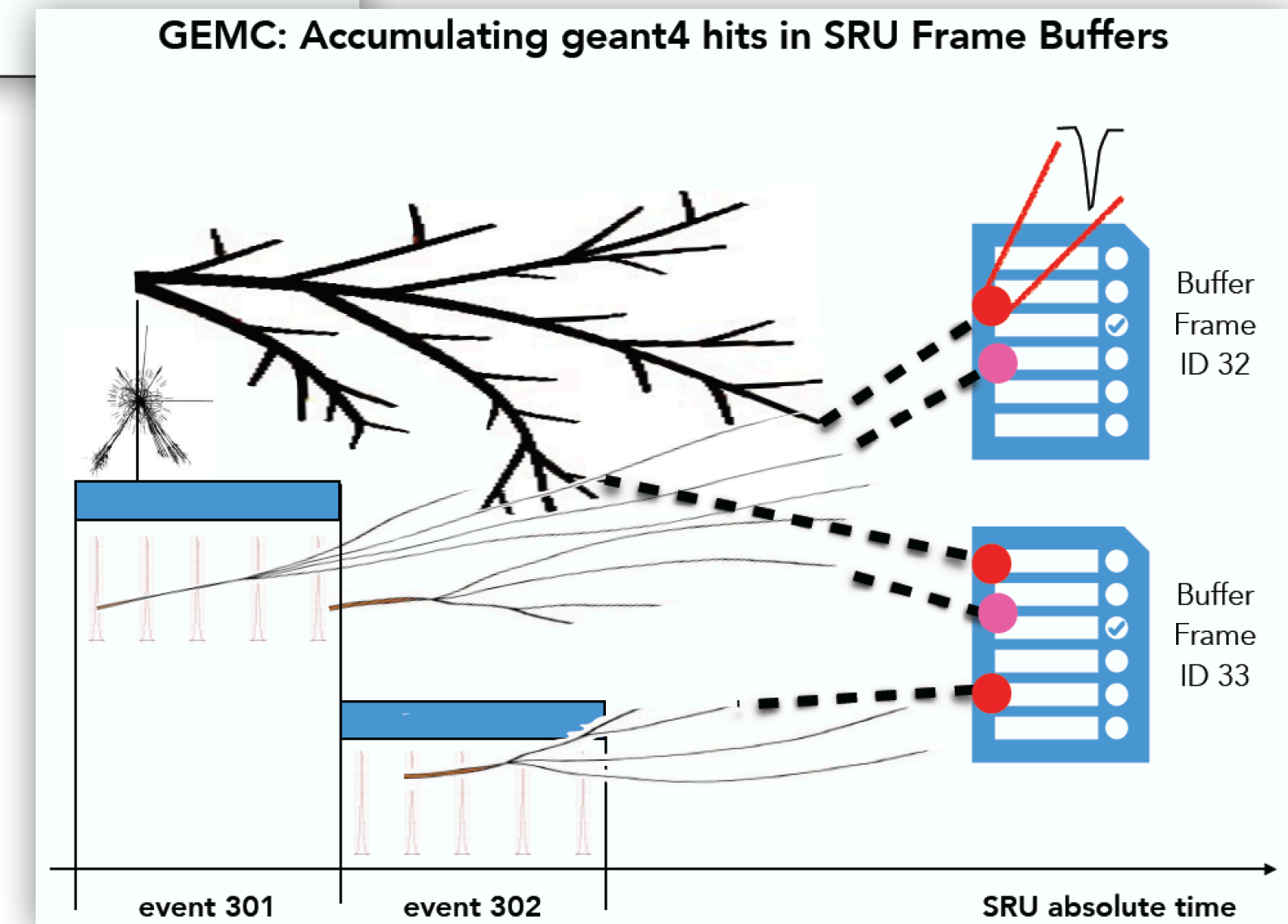
- Networking test for JLab SRO framework just started

JLab SRO R&D: GEANT simulations

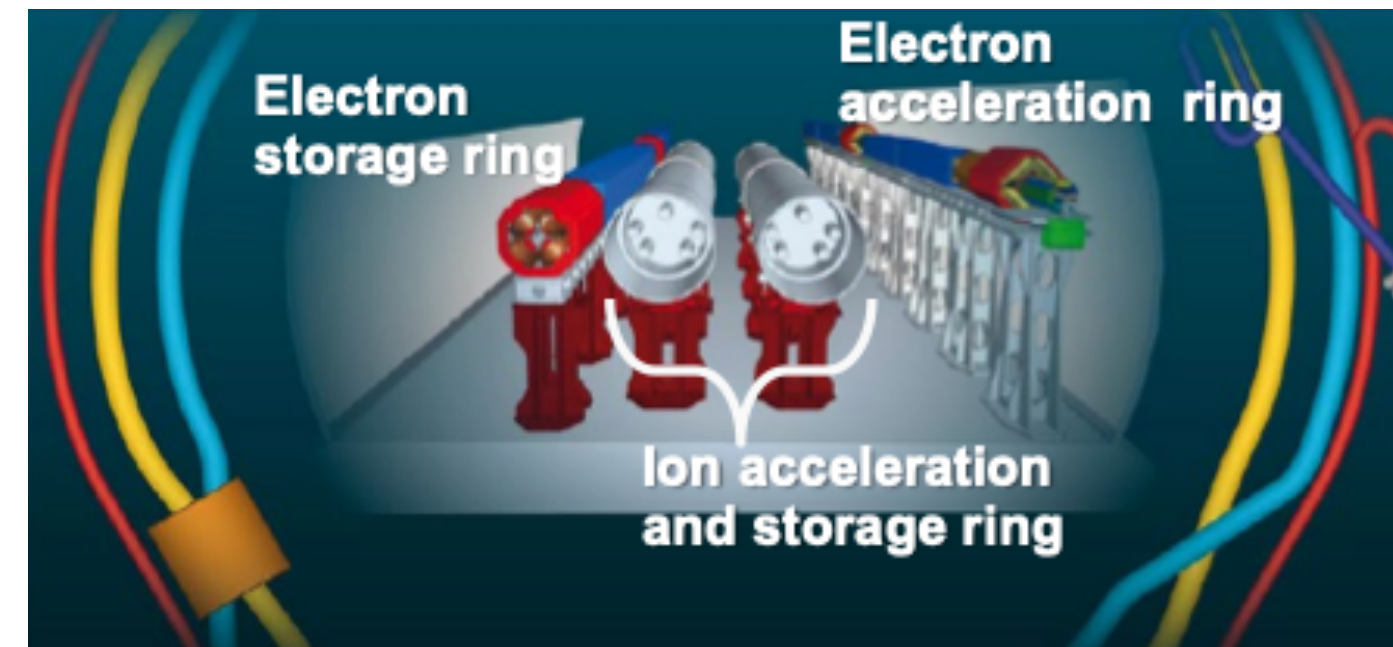
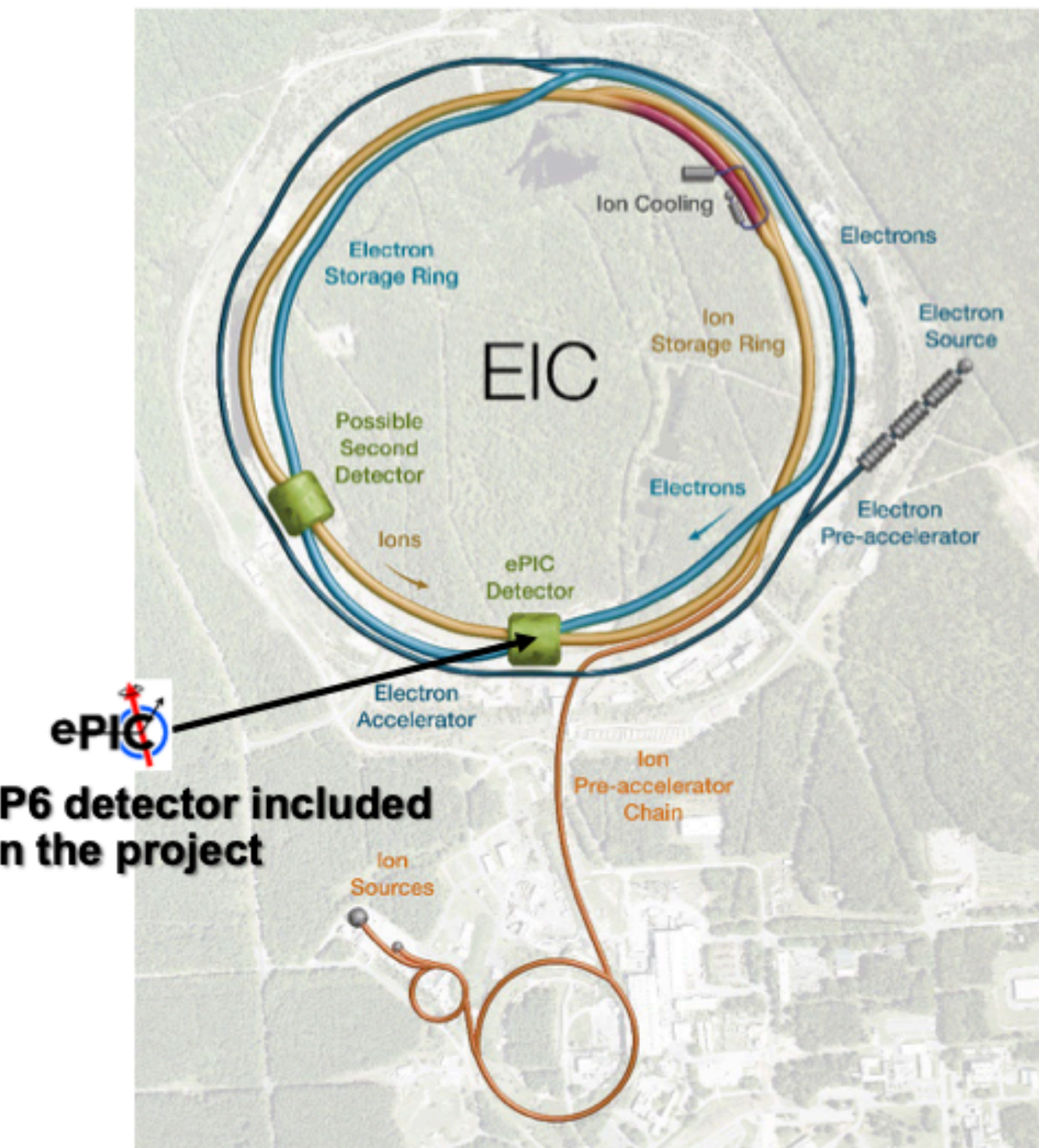
Credit: Maurizio Ungaro



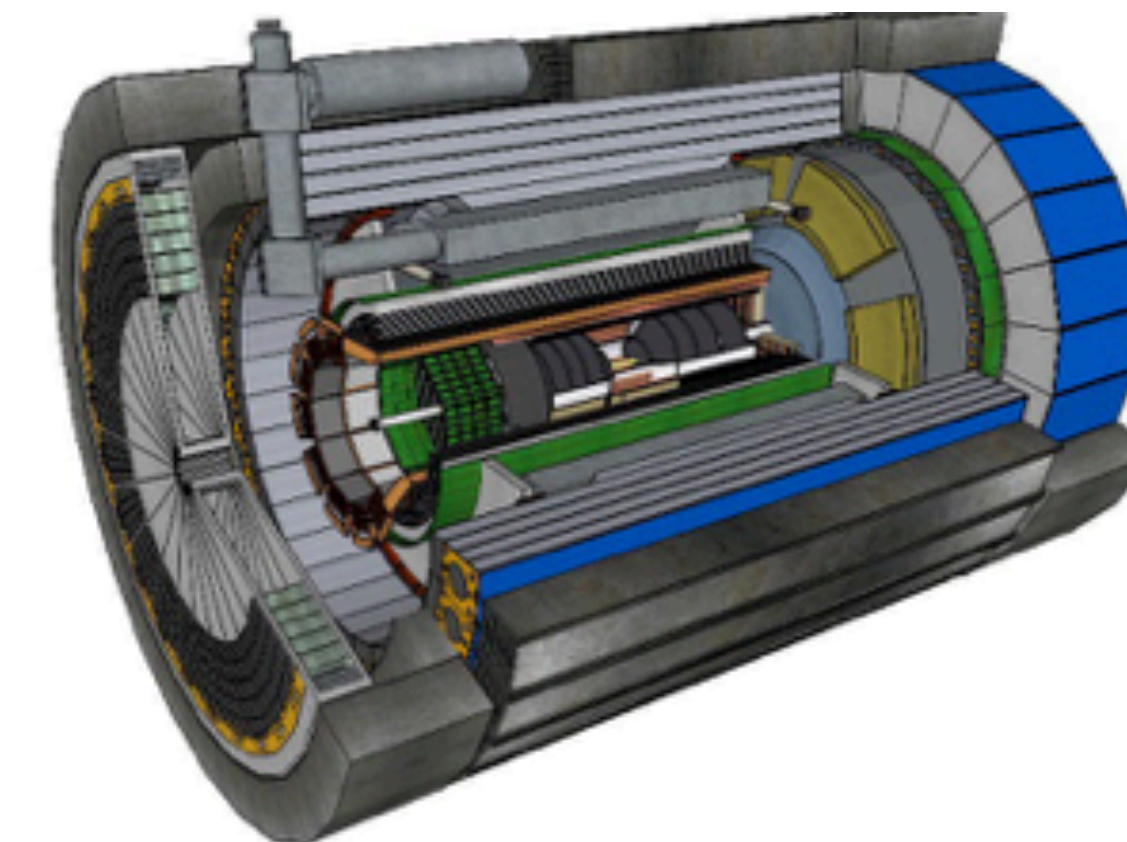
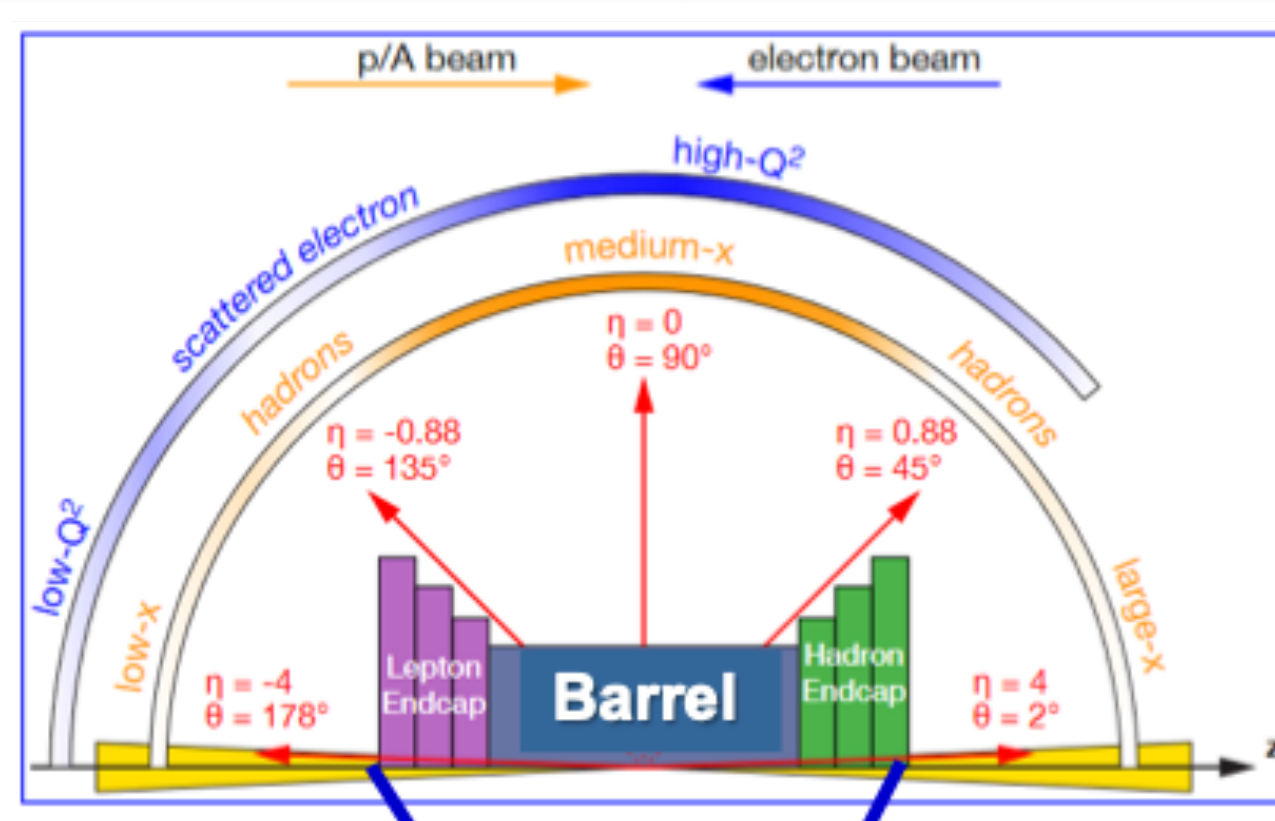
- Development of a MC GEANT-based toolkit to implement SRO in detector simulations
- Transform event-based to stream-based G4 logic
- Develop libraries share same on-line data format
- Emulate TCP output to feed to ERSAP
- Milestone Nov 2021, FT Calorimeter streaming



EIC @ Brookhaven National Lab (BNL)

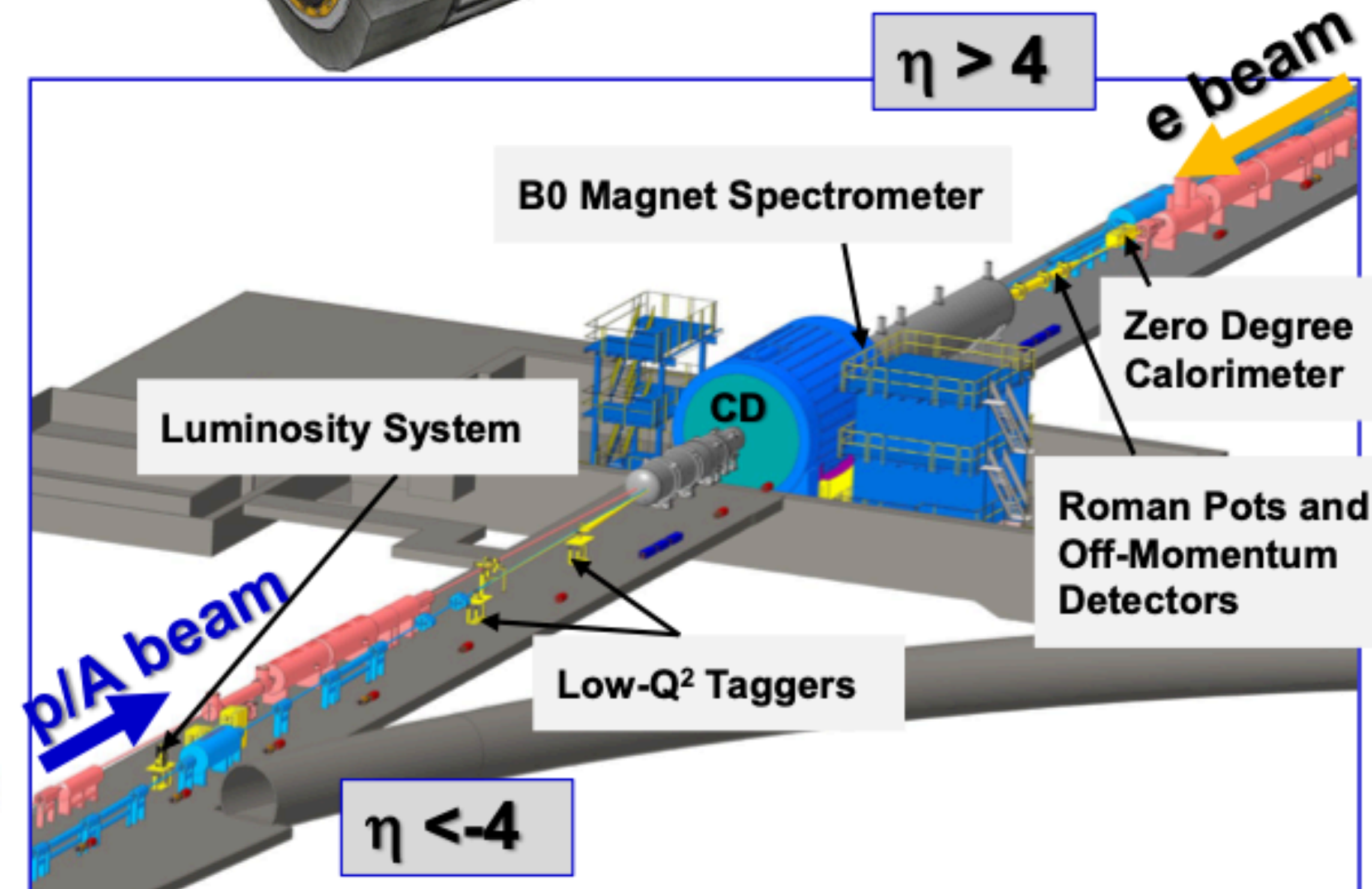


- spanning a wide kinematical range
 - ECM: 20 – 141 GeV
- High luminosity
 - up to $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
- highly polarized e (~ 70%) beams
- highly polarized light A (~70%) beams
- wide variety of ions: from H to U
- Number of interaction regions: **up to 2**

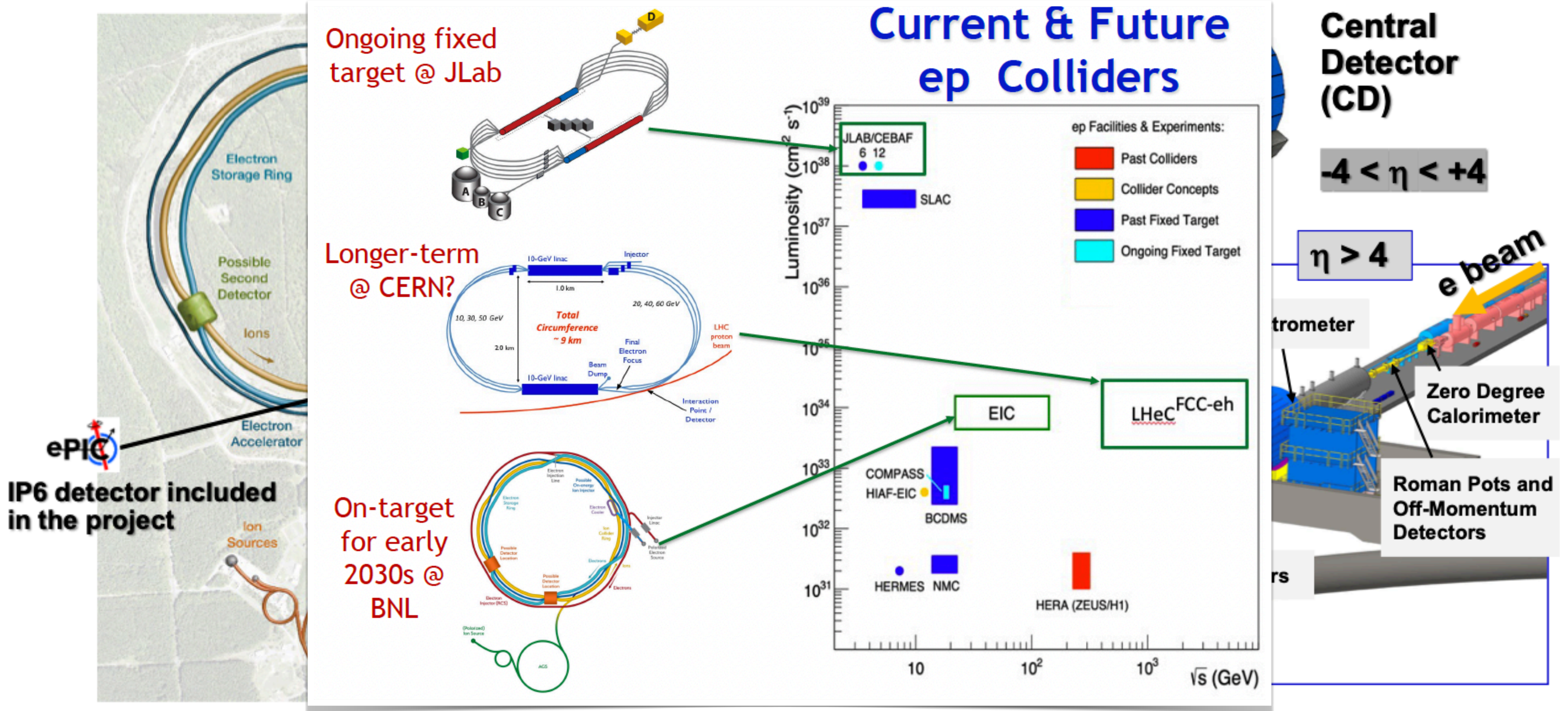


Central Detector (CD)

$$-4 < \eta < +4$$



EIC @ Brookhaven National Lab (BNL)



Compute-Detector Integration to Maximize and Accelerate Science

- **Maximize Science** 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.
- **Accelerate Science** Rapid turnaround of 2-3 weeks for data for physics analyses.
 - Timeline driven by alignment and calibration.
 - Preliminary information from DSCs indicates that 2-3 weeks are realistic.
- **Technologies** Compute-detector integration using:

Streaming readout for continuous data flow of the full detector information.

AI for autonomous alignment and calibration as well as autonomous validation for rapid processing.

Heterogeneous computing for acceleration (CPU, GPU).

ePIC Collaboration Meeting, January 20, 2025.

11

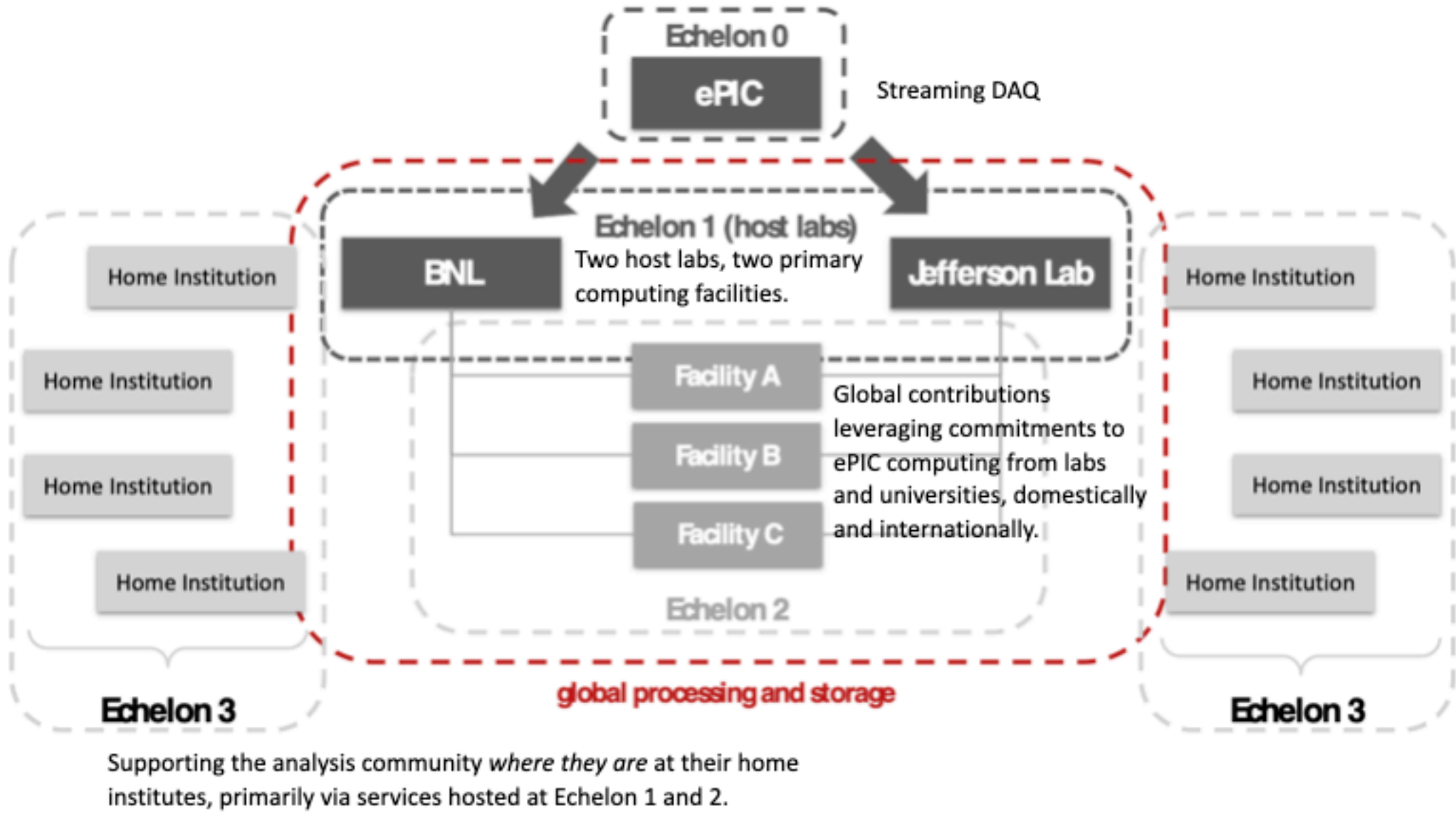


Use Case	Echelon 0	Echelon 1	Echelon 2	Echelon 3
Streaming Data Storage and Monitoring	✓	✓		
Alignment and Calibration		✓	✓	
Prompt Reconstruction		✓		
First Full Reconstruction		✓	✓	
Reprocessing		✓	✓	
Simulation		✓	✓	
Physics Analysis		✓	✓	✓
AI Modeling and Digital Twin		✓	✓	

Why SRO is important for ePIC?

- * **Expedite ePIC Science outcome**
 - Computing/detector integration for a rapid turnaround
- * **SRO breaks barriers between DAQ and computing**
 - Data collected at Echelon0 and processed at BNL and JLab
 - Important role of Echelon2 and Echelon3

The ePIC Streaming Computing Model

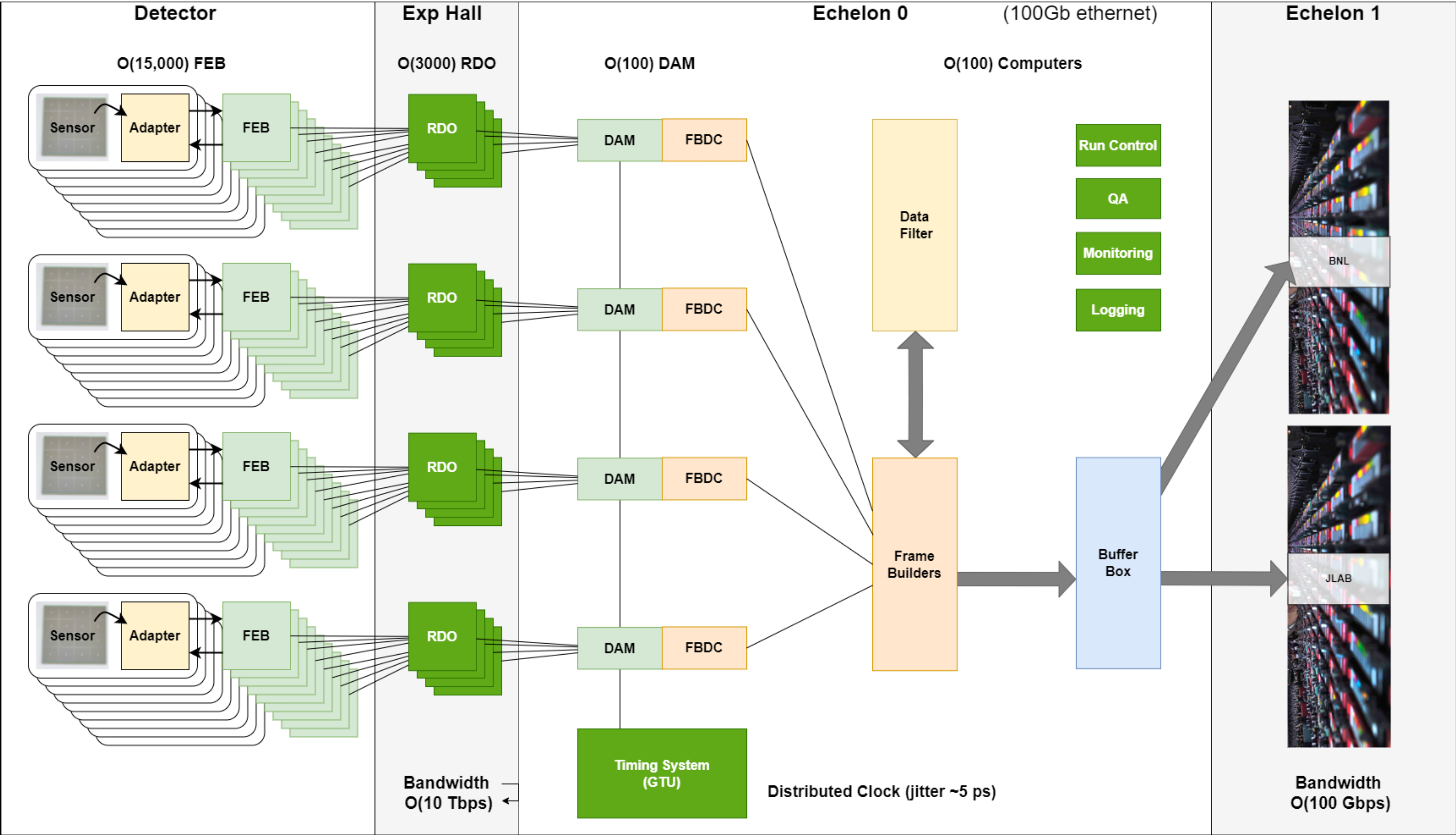


ePIC Collaboration Meeting, January 20, 2025.

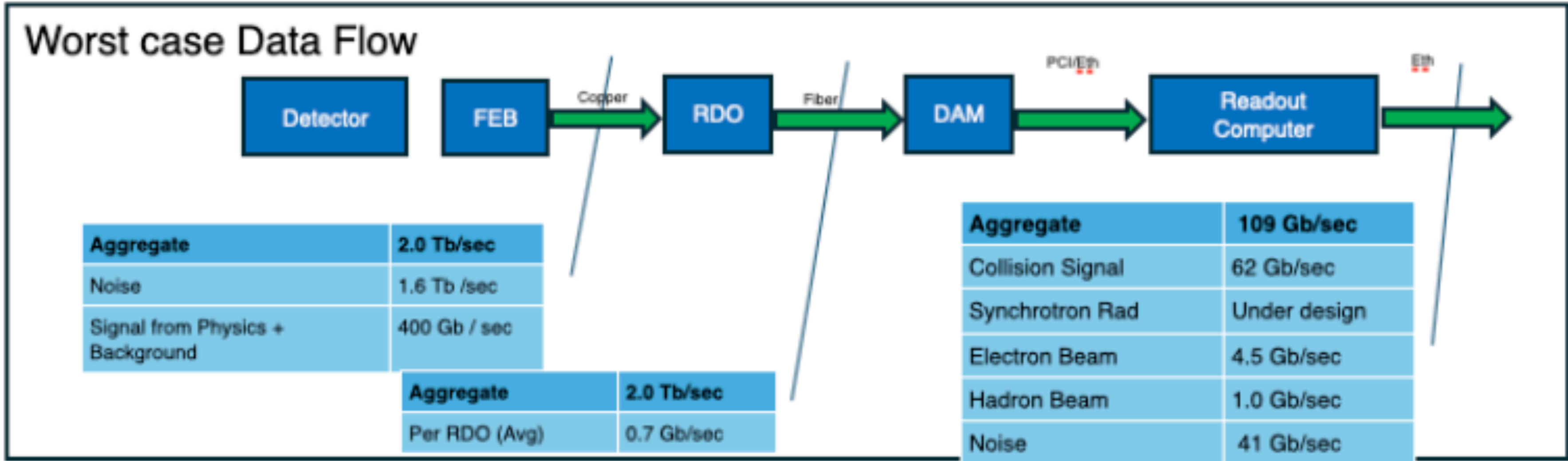
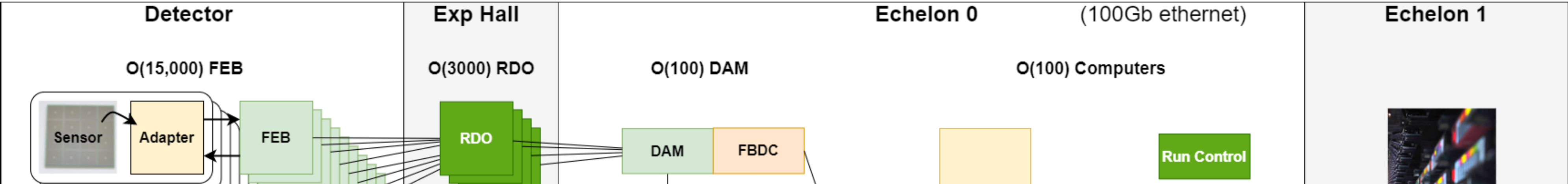
12



ePIC Streaming Computing



- Rates at ePICS not comparable to LHC HI-LUMI but the advantages of SRO remain:
- multiple channels to trigger on
- Holy Graal: to manage (storage) an unbiased (un-triggered) data set for further analysis
- on/off-line event selection with full detector information

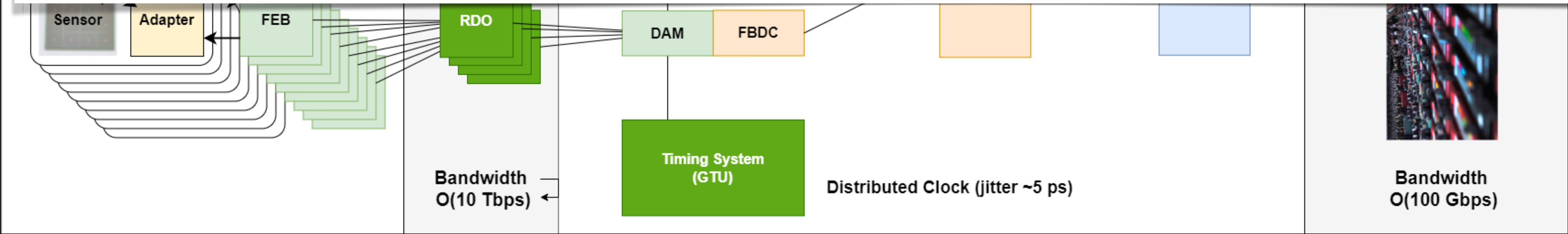


“Worse Case Data Flow”

- $\mathcal{L}_{max} \Rightarrow 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
- 10 x 275 GeV DIS
- DIS rate ~500kHz
- After $9 \times 10^9 \text{ (1-MeV } n_{eq} / \text{cm}^2)$ delivered fluence
 - 300kHz DCR in dRICH
 - 200x rate with no damage

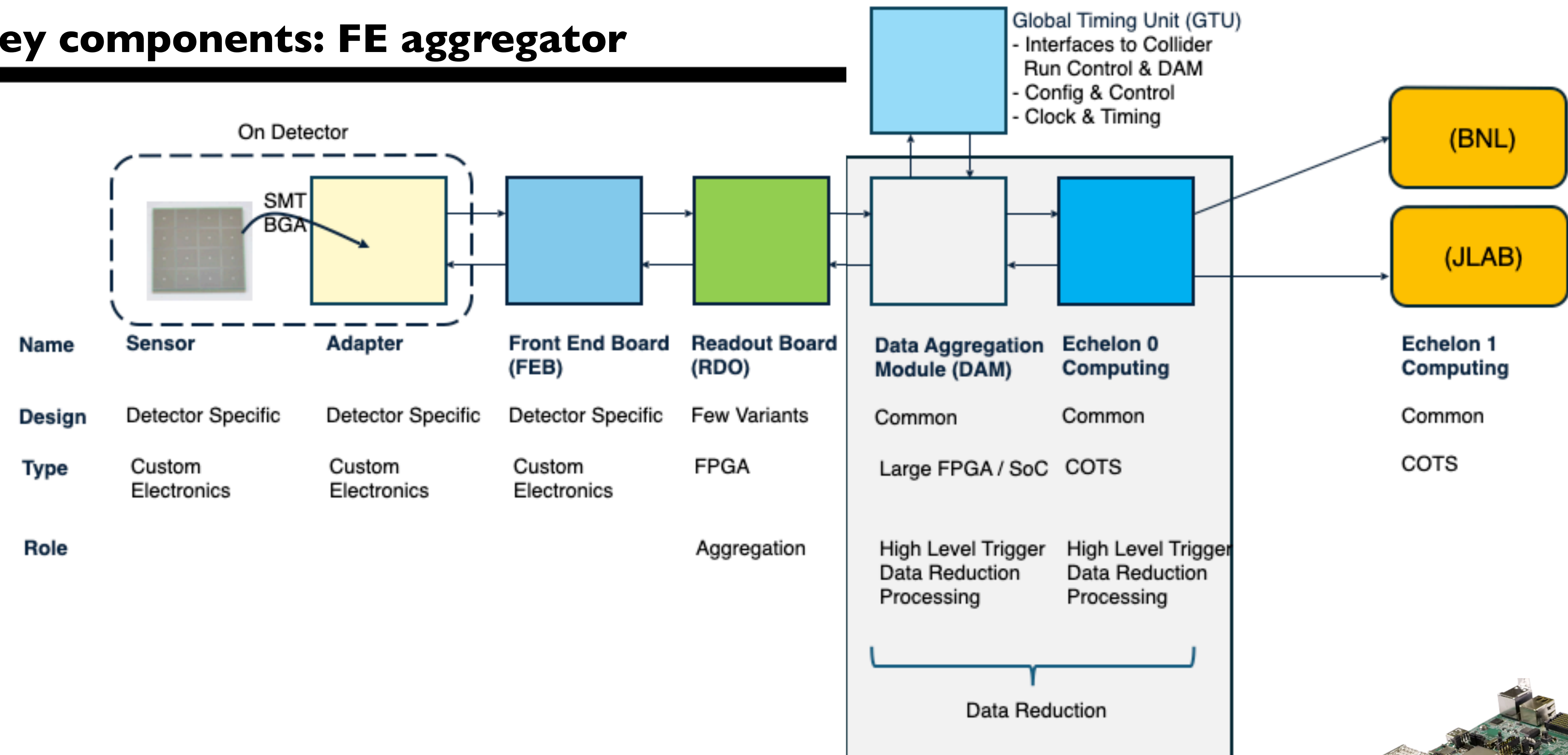
At Worse Case

- Need a factor of 20 reduction



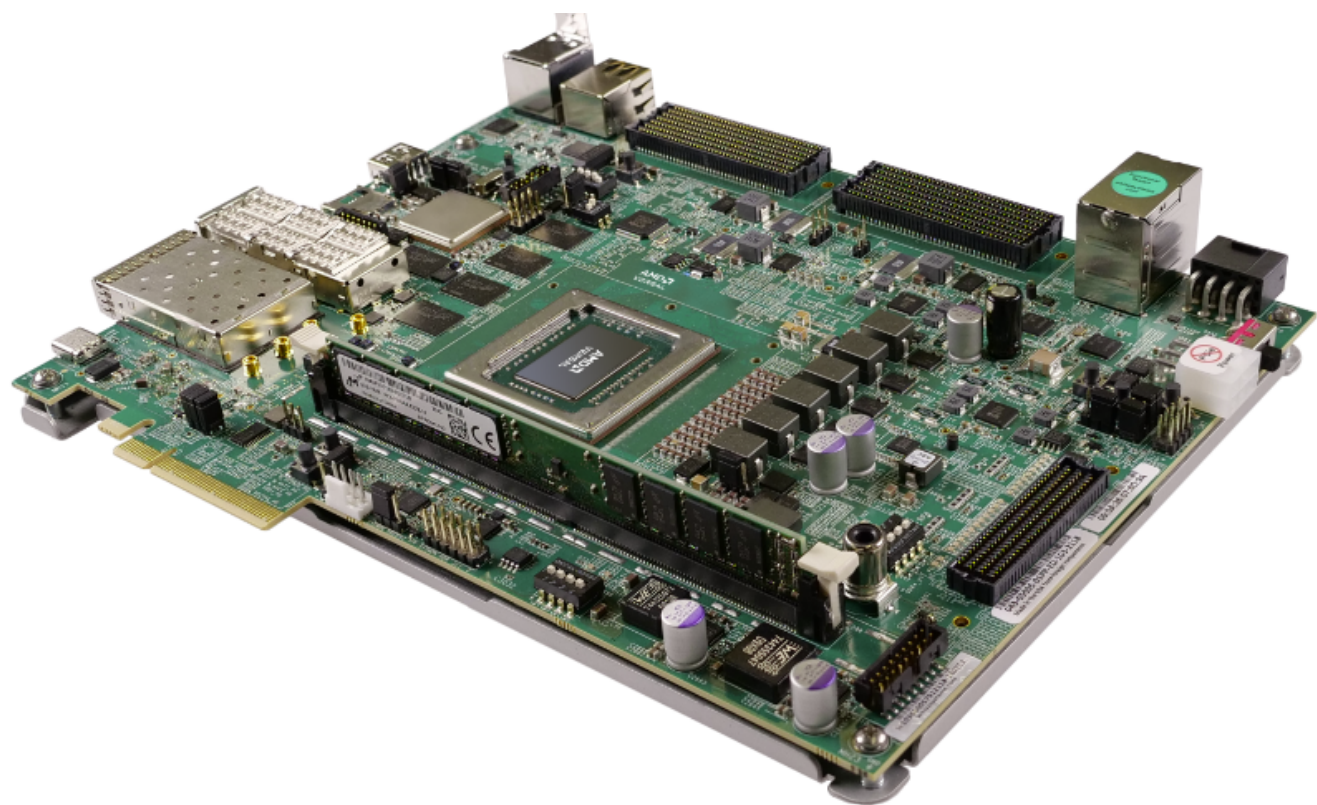
- on/off-line event selection with full detector information

Key components: FE aggregator



DAM Board – FLX-I55

- FELIX (Front-End Link Exchange) hardware for future ATLAS experiments at HL-LHC is being developed at BNL (Omega Group)
- First boards under evaluation at BNL by Omega group



Key components: data reduction

General Principles

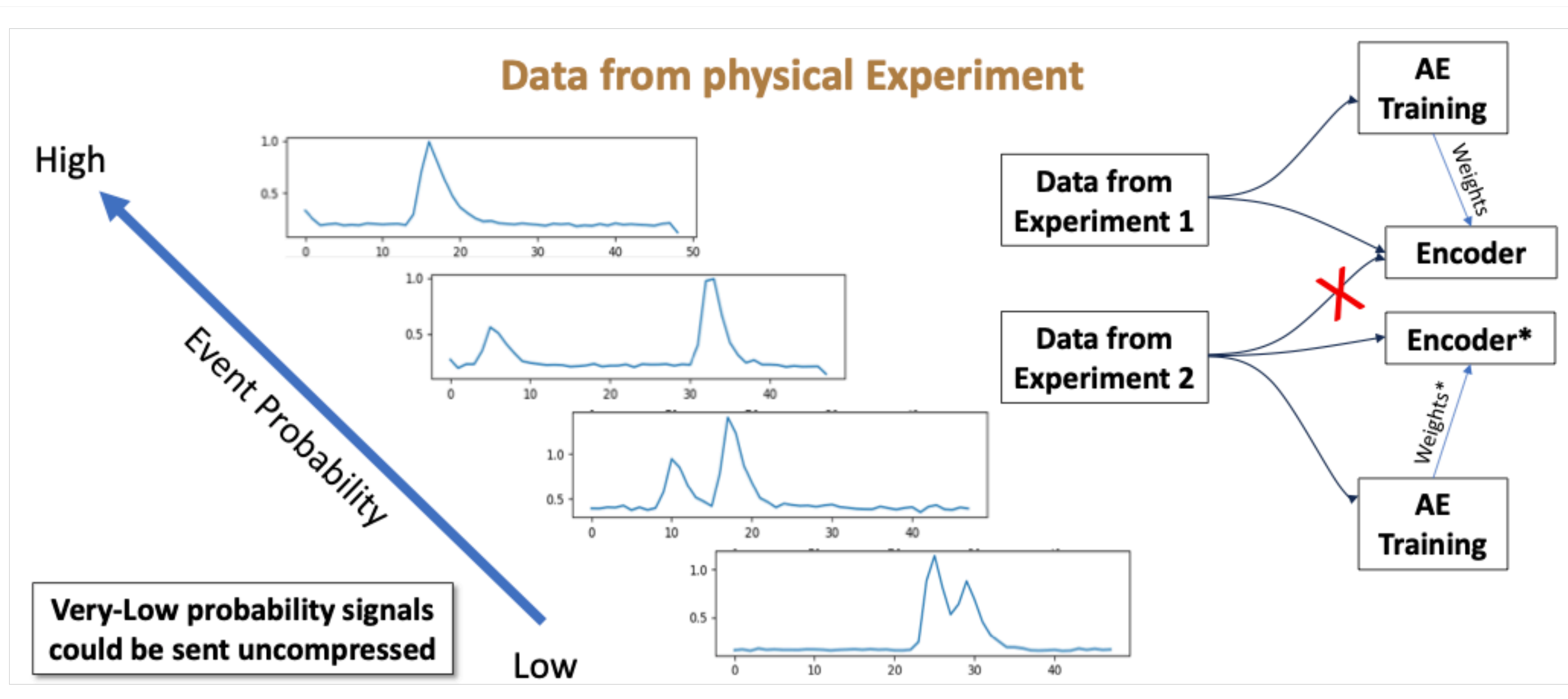
1. Don't remove any information unless required by throughput / storage requirements
2. If any information is removed, write out a fraction of data without removing the information (in conjunction with the reduced data)
3. Any filtering / data reduction code needs to be documented and available for access by the collaboration

Non-destructive reduction techniques:

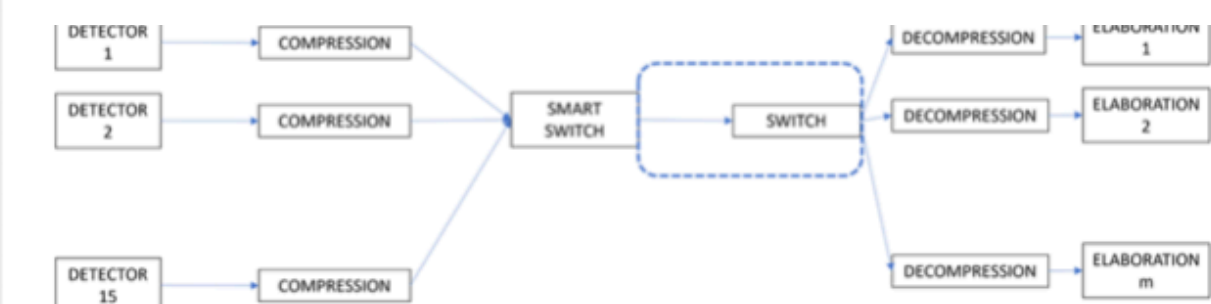
- Compression (Standard or ML techniques)
- Reduction of ASIC data inefficiencies
- Aggregation of headers

Techniques that drop information:

- (1-d) cluster finding for ADC data
- (2-d) cluster finding
- Feature finding
- High Level Noise Rejection
- Averages / Histograms
- Simple Analysis
- Arbitrary Deadtime

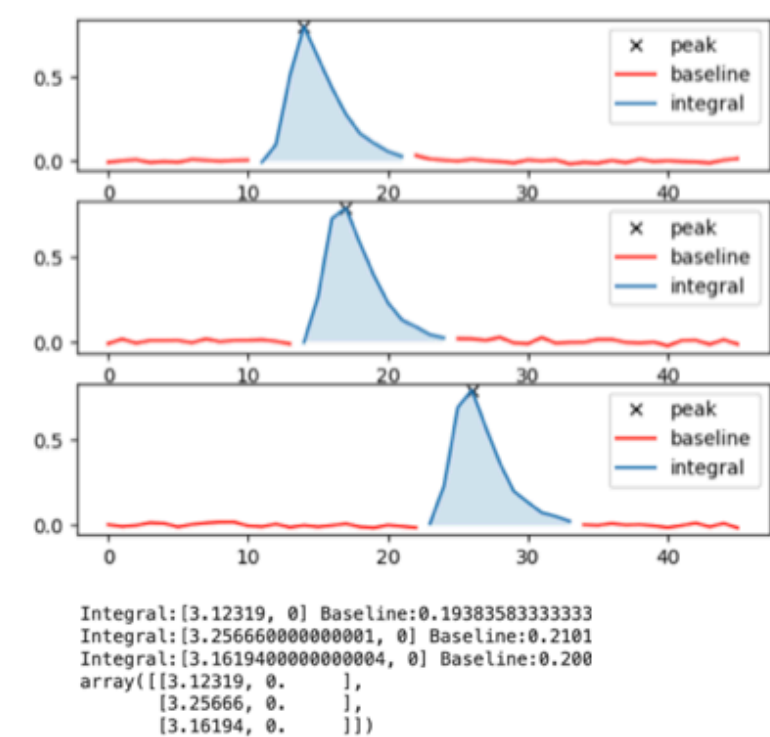
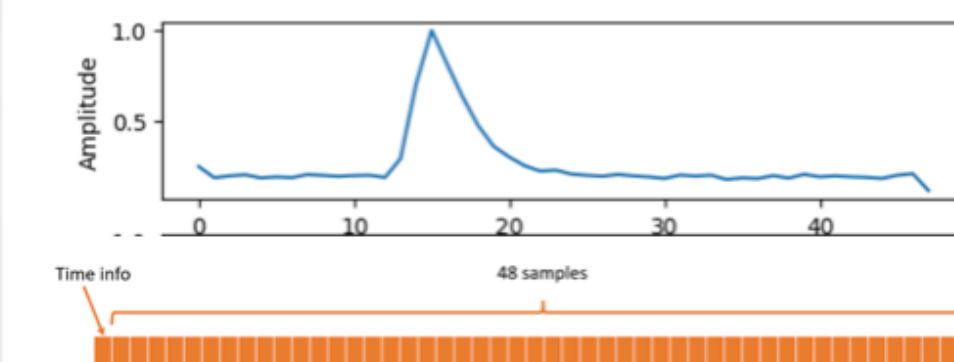


- Real-time data processing using an autoencoder to compress the digitised waveform



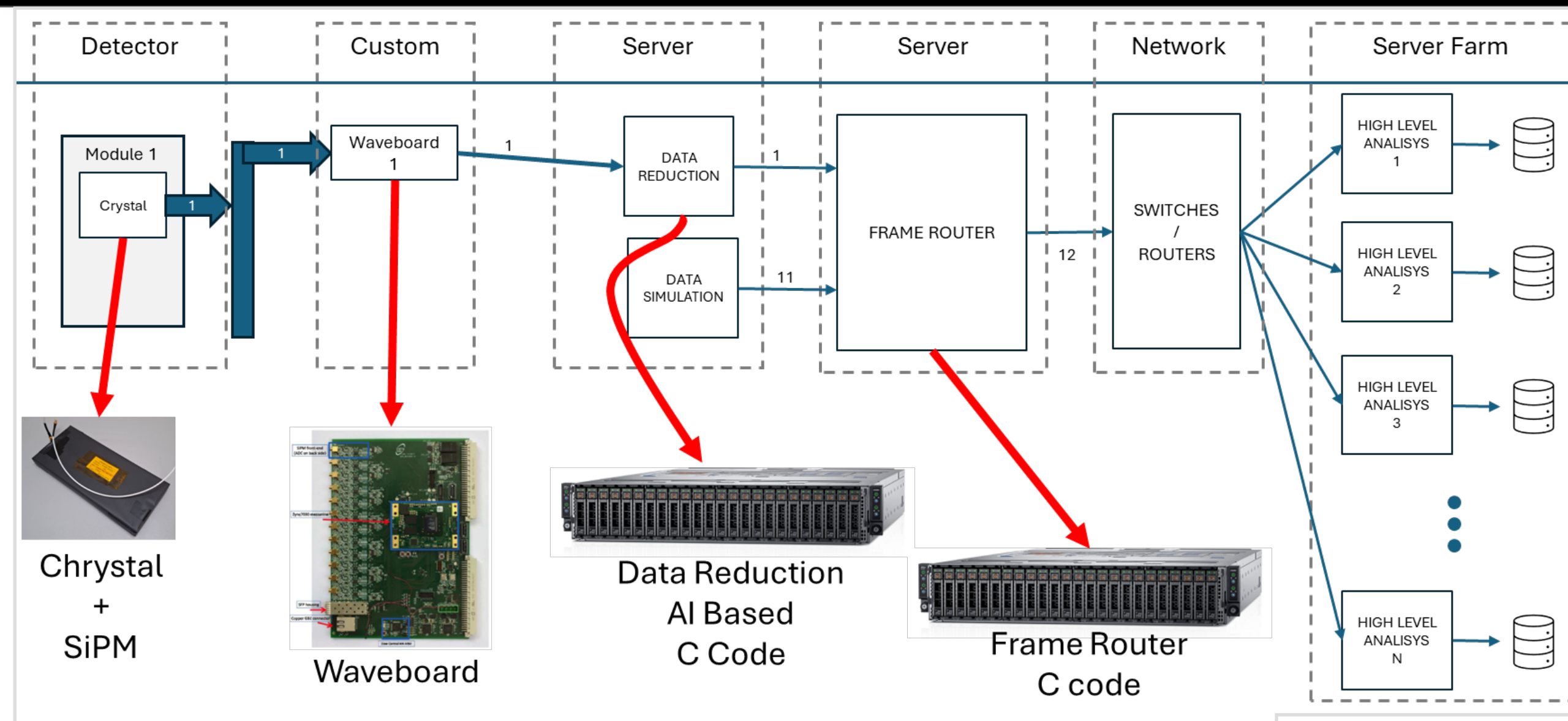
Goal: compress the waveform preserving the information (and eventually retrieve it)

Digitized waveform (48 samples)



Integral and peak position is a possible data reduction (lossy) algorithm

Key components: data reduction

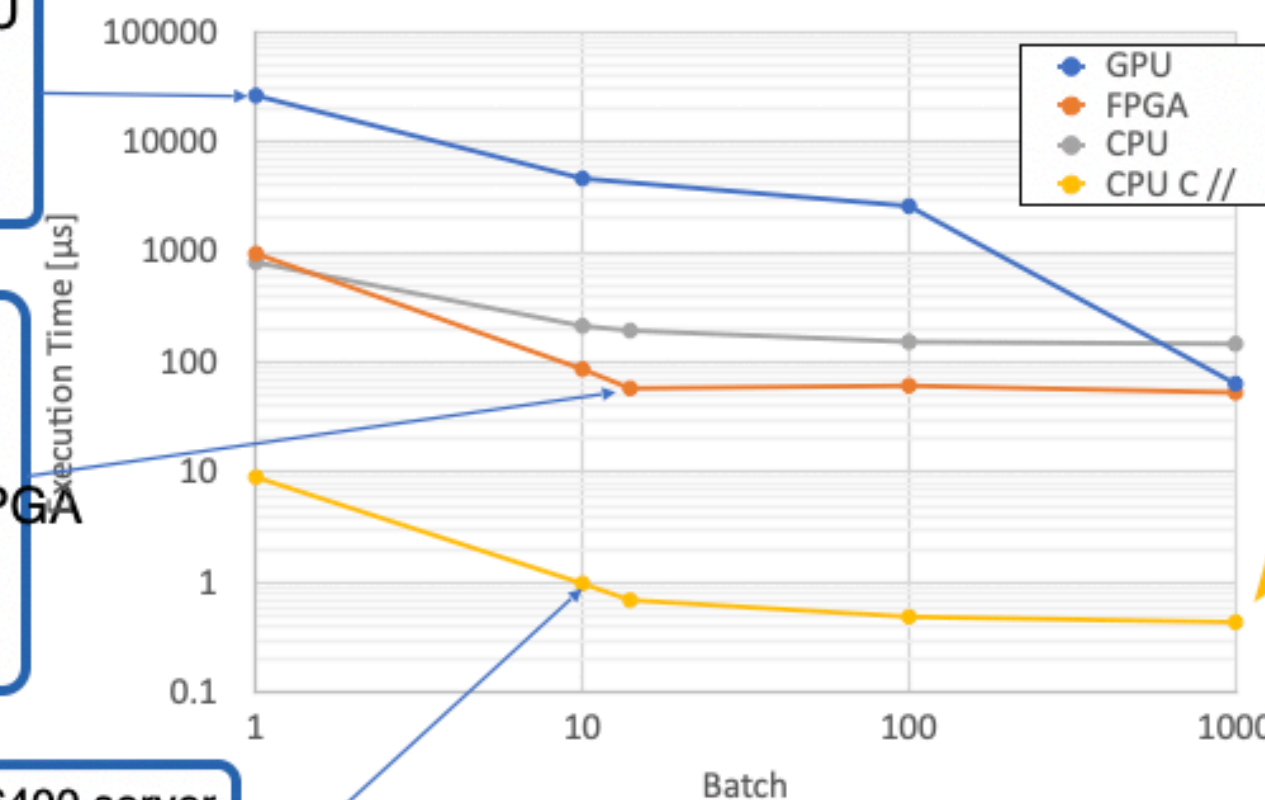


Test Setup at INFN-Genova

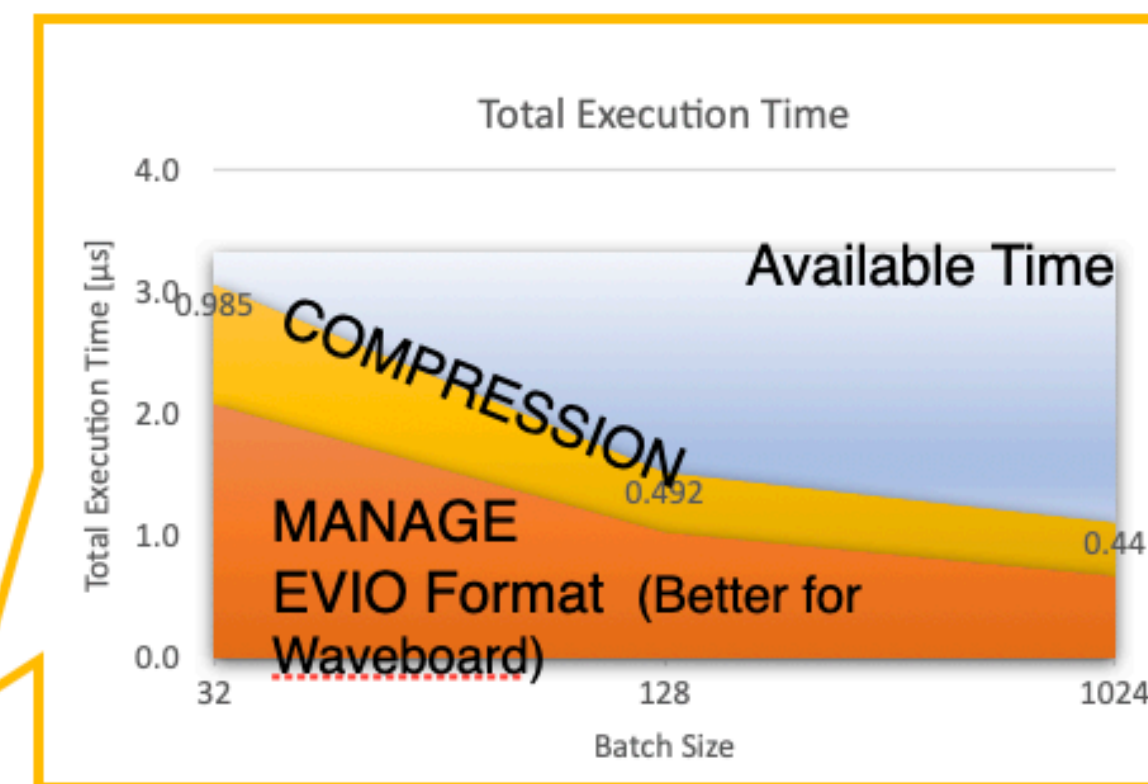
- Sample signals from JLAB-CLAS12 detector (similar to PbWO ECal crystal + PMT signals)
- fADC 250MHz, 16bits, discrete
- dedicated (heterogeneous) hardware for data reduction
 - GPU: Tesla V100
 - FPGA: Alveo V70
 - CPU: Dell C6400

Results

Best performance achieved with a CPU-based server



Test results for CLAS12 signals



Next Step

Hardware level
HLS4ML
Dedicated connectivity

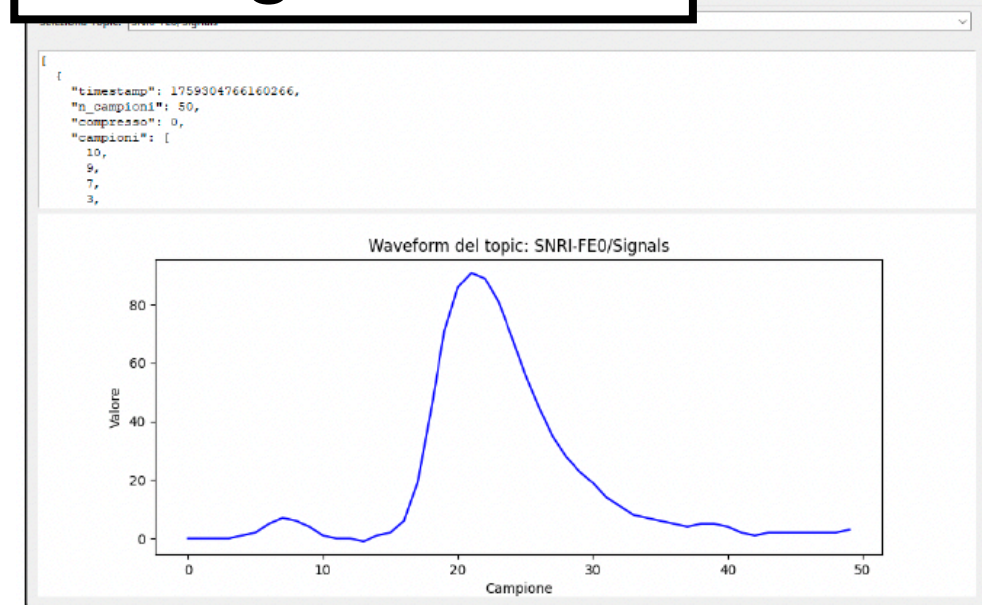


STREAM-AI Streaming Readout Educational Assistant for modern AI DAQ

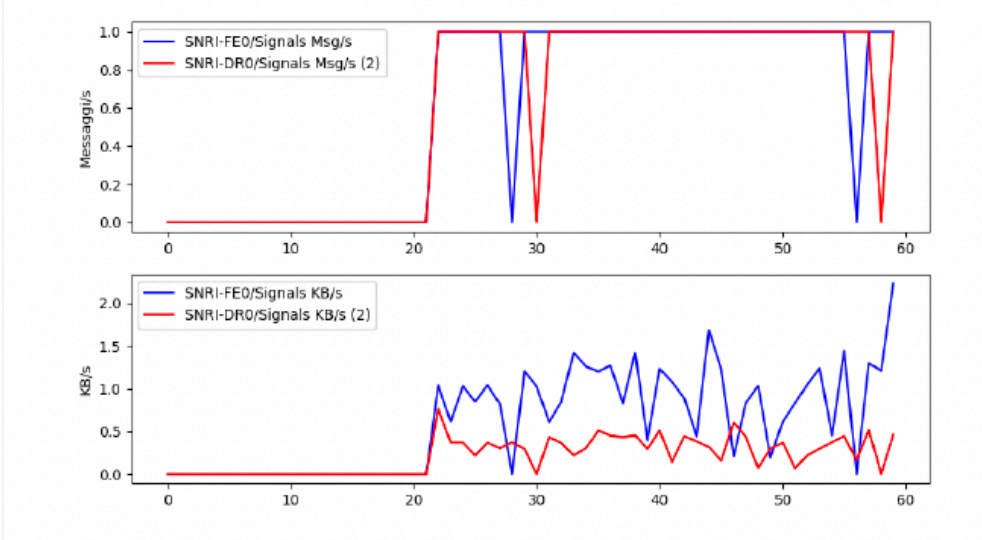
Two-channels SRO DAQ demonstrator

- Csl(Tl) crystals, 10 MHz 12 bit digitizer, Raspberry, AI-data reduction, Frame routing, high level data analysis
- Full SRO DAQ pipeline e functionality (at low rates)
- Signals and data flow visible at each step

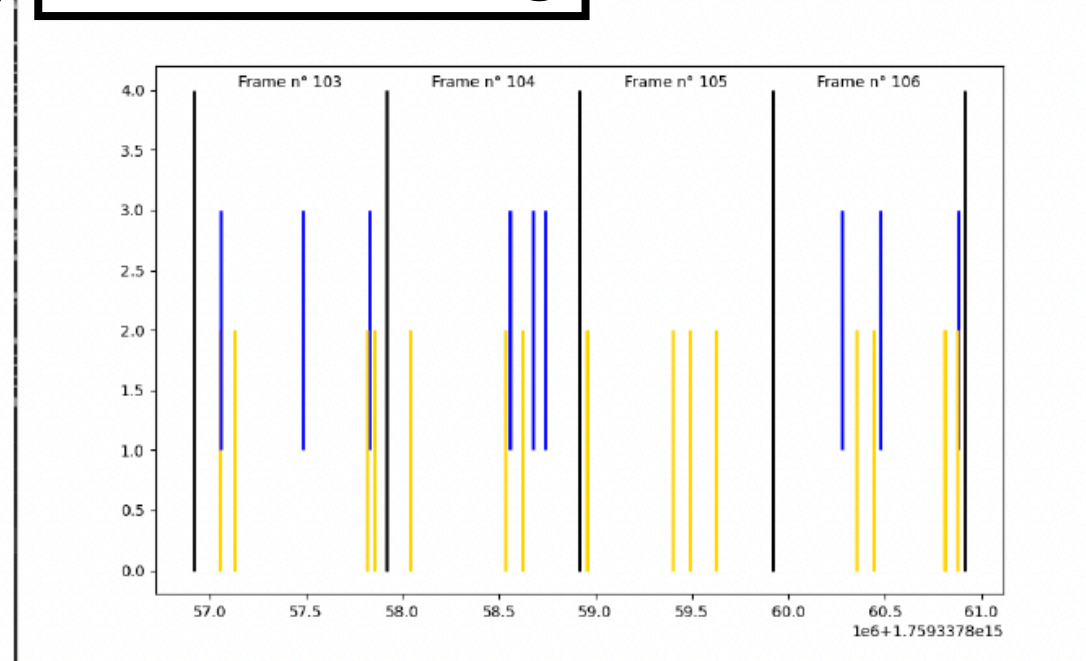
FEE: digitized data



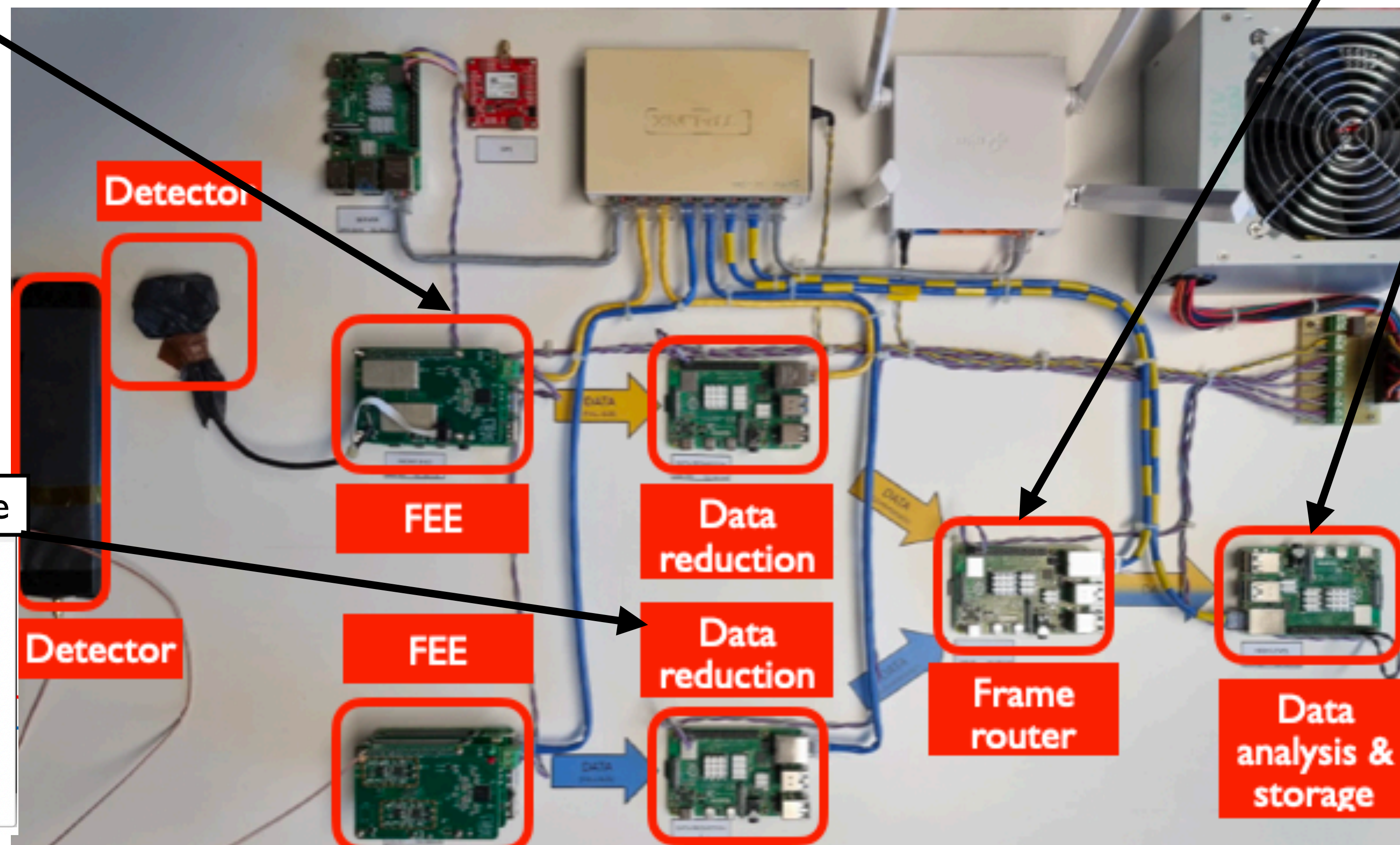
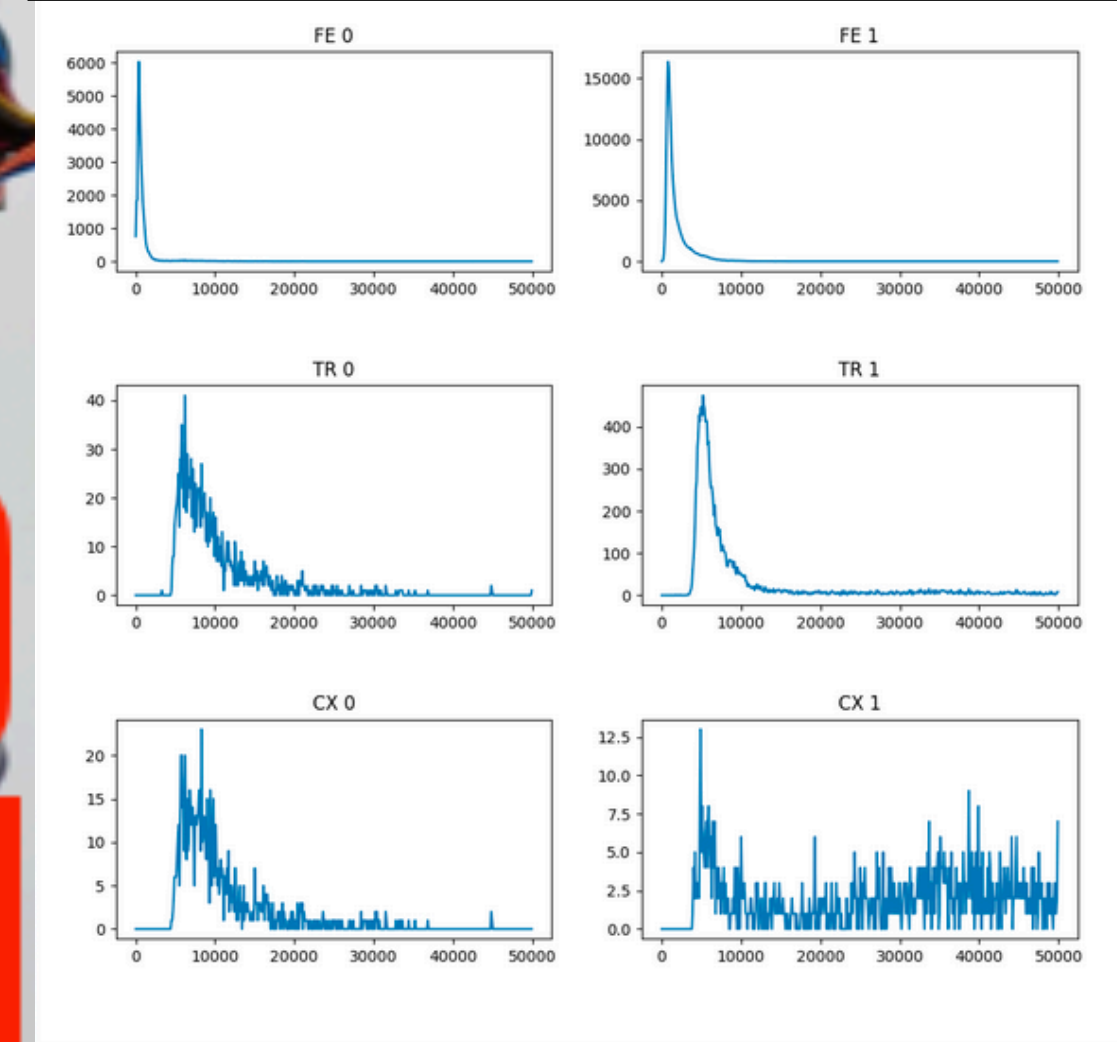
Data reduction performance



Frame building



Real-time data rate (L0, L1, Time-coincidence)

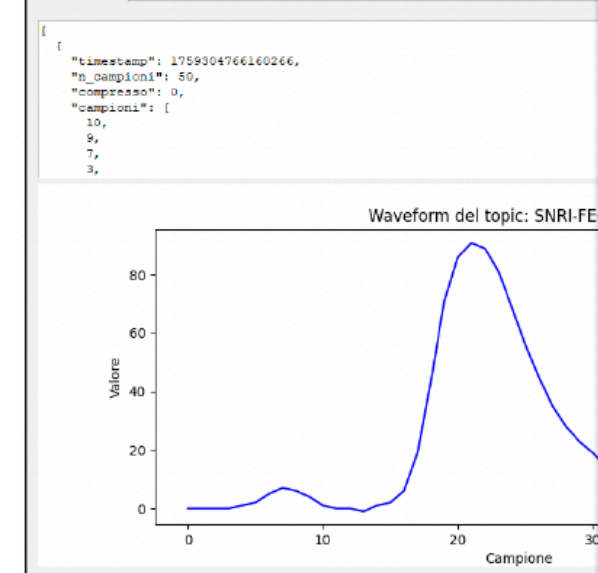


Credit: Stefano Grazzi, Fabio Rossi

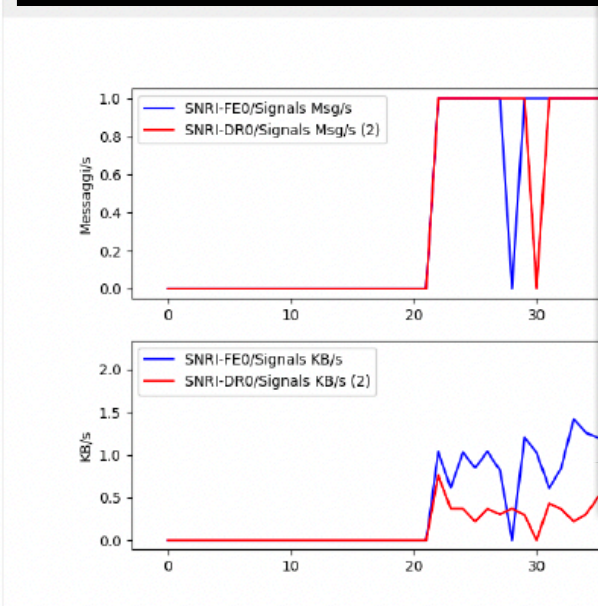
Two-channels SRO DAQ demonstrator

- Csl(Tl) crystals
- Full SRO DAQ
- Signals and data

FEE: digitized data



Data reduction p



SNRI 2025

24 Nov 2025, 08:30 → 28 Nov 2025, 18:30 Europe/Rome



Claudia Gemme (Istituto Nazionale di Fisica Nucleare) , Marco Ripani (Istituto Nazionale di Fisica Nucleare) ,
Monica Sisti (Istituto Nazionale di Fisica Nucleare)

Description The VIII National Seminar on Innovative detectors (SNRI-VIII) is an INFN Educational Program for researchers and technologists aiming at improving awareness and knowledge on the "state of the art" in novel detection techniques. The course will investigate current limits and future developments as well as various related aspects such as simulation, signal acquisition, tracking, particle identification, and much more. Although intended for INFN personnel, the course is also opened to a limited number of external participants, so-called "auditors". SNRI-VIII is organized by INFN Genova and will be hosted by the Physics Department.

While filling the registration form the applicants will be prompted to upload a **short CV**. Please have the file ready in advance. The applicants will receive notification about their acceptance by **October 17th**.

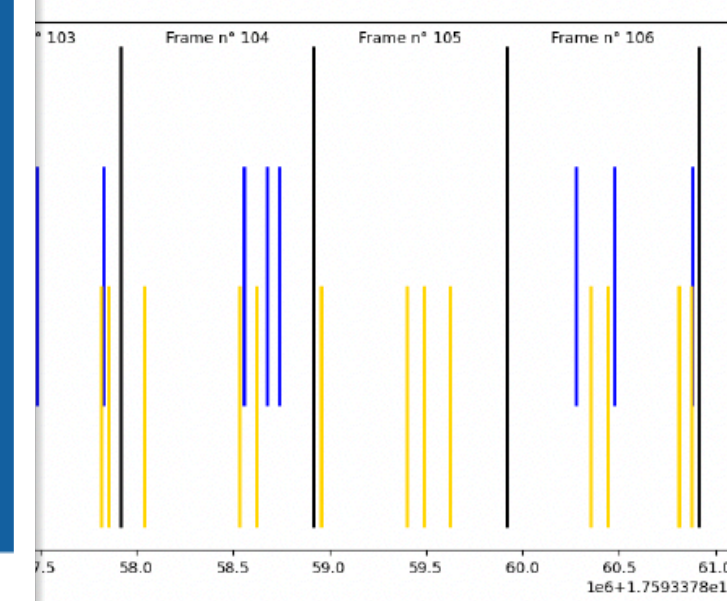
The Seminar is part of the INFN Educational Program for the INFN personnel; nevertheless a limited number of external auditors is welcome.



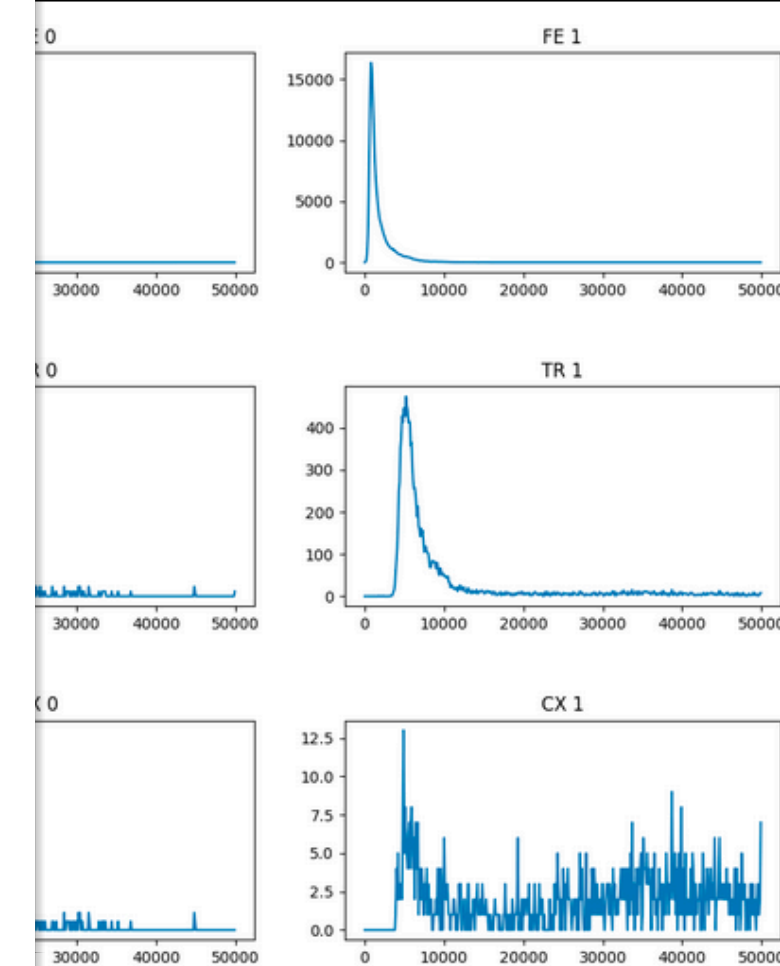
UniGe | DIFI

storage

Frame building



e data rate (L0, L1, incidence)



Credit: Fabio Rossi

Summary and Outlook

- Modern technologies (high rate digitisers, ASICs, FPGAs) are changing the DAQ paradigm
- Streaming RO is needed for high-luminosity experiments to explore increasingly rare reactions
- Streaming RO is ‘THE’ option for future electron beam experiments running at high luminosity (JLab, EIC, ...)
- Take advantage of the full detector’s information for optimal (smart) tagging/filtering
- Pioneering SRO chain (FE + SRO sw + ON-LINE REC) tested with existing hardware at Jefferson Lab
- Deployment of JLab SRO framework based on micro-services architecture (ERSAP)
- Development of ancillary components such as G4 MC (GEMC3), real-time calibrations, ...
- Developing solutions applicable to ePIC experiment at the future Electron Ion Collider
- SYSTERSE promotes synergies between low/medium energy NP/HEP experiments leveraging existing tools
- Built a working SRO prototype and a work team!

Many thanks to the whole SRO team:

D.Abbott (JLab), F.Ameli (INFN), MB (JLab/INFN), V.Berdnikov (CUA), S.Boyarinov (JLab) M.Bondí (INFN), N.Brei (JLab), L.Cappelli (INFN) A.Celentano (INFN), T.Chiarusi (INFN), C.Cuevas (JLab), R. De Vita (INFN), M.Diefenthaler (JLab), J. Landgraf (BNL), W. Gu (JLab), C.Fanelli (MIT), R. Fang (ODU), A. Farhat (ODU), S.Furletov (JLab), F.Giacomini (INFN), V.Gyurjyan (JLab), W.Gu (JLab), G.Heyes (JLab), T.Horn (CUA), J.Huang (BNL), E. Jastrzembski (JLab), D.Lawrence (JLab), L.Marsicano (INFN), X.Mei (JLab), P.Moran (MIT), P.Musico (INFN), C.Pellegrino (INFN), E. Pooser (JLab), B.Raydo (JLab), A.Roy (JLab), F.Rossi (INFN), H. Szumila-Vance (JLab), C.Trimmer (JLab), M.Ungaro (JLab), S.Vallarino (INFN), J-Y Tsai (JLab), Y. Xu (ODU).