Streaming Readout Real-Time Development and Testing Platform

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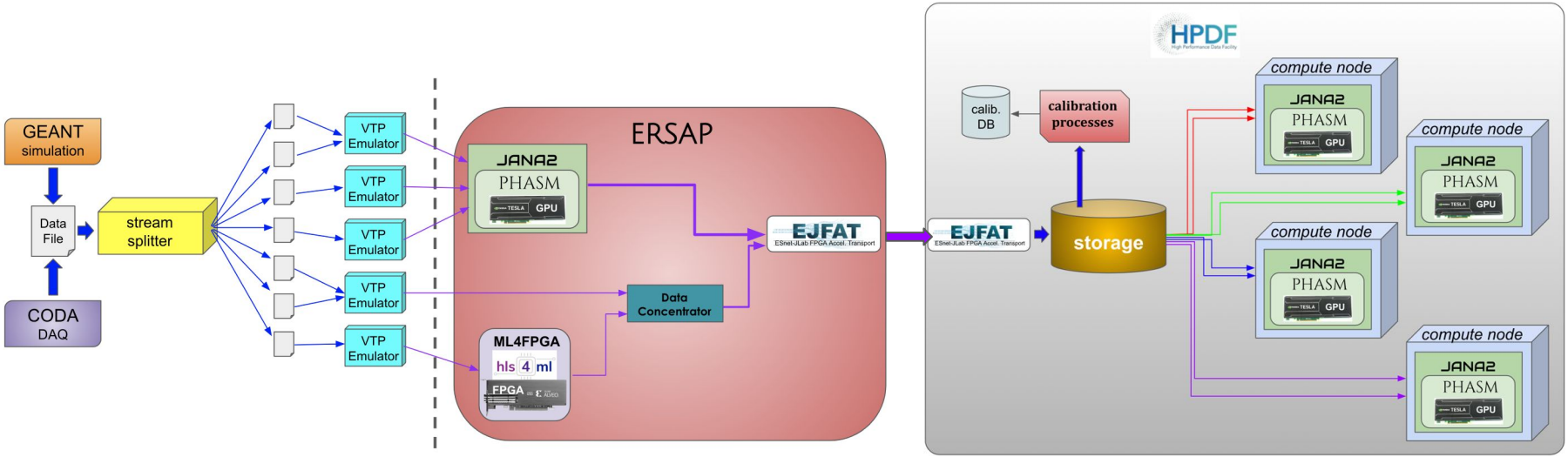
Simple Example of a Streaming Readout (SRO) System



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

Objectives

1. Develop software platform capable of configuring and launching various existing software and hardware **SRO** components as a **complete chain**. *This will start by surveying the field.* *(e.g. Amazon Kinesis, Apache SPARK, Apache Kafka)*

2. Develop **monitoring** system capable of monitoring performance of all components specifically for identifying **bandwidth** and **compute bottlenecks**. *Prometheus, Grafana, Hydra, …*

3. Develop proxy components that can effectively **simulate** performance of specific **hardware** or **software components** that do not currently exist. *Requires combination of innovation and integration (e.g. hls4ml)*

4. Develop **multi-stream software source** that can take existing experimental or simulated data and broadcast it into the system with time structure and stream count that mimics a running experiment. *Requires development.*

5. Configure a system comparable in size and bandwidth to a future JLab experiment (e.g. SoLID) which includes a **400Gbps** transfer requirement from the counting house to the Computer Center, at least one **FPGA** component and one **GPU** component for at-scale testing. *This places specific, quantifiable goals on the project that match experiments JLab can expect to design in the near future.*

6. Identify potential issues relevant to a future **HPDF** in receiving and processing SRO data, including from **remote**, non-JLab **experiments**. *The platform can be used to exercise a variety of configurations that will help HPDF systems design choices*

Applicable Area of Research

- **Nuclear Physics Research**: R&D leading to or supporting new scientific research directions and new generation of experiments which leverage existing TJNAF research areas or facilities, including investigations of scientific reach of electron scattering at **higher energies or beam intensities.** Proposals that would enable nuclear physics capability to be exploited in other areas, such as high-energy physics, will also be considered.

- **Data and Computational S&T**: Areas of interest include projects at the intersection between data science other laboratory core capabilities, such as detector simulation, science and/or technology demonstrators for HPDF and automated operations for data centers, EIC and CEBAF. In addition, proposals in mission expansion activities such as the application of Data Science to facilities outside of TJNAF and emerging priorities in applied computer science, cyber security, health, climate, and Data Science R&D will be encouraged.

- **Advanced Detector Technologies**: Areas of interest include development of advanced detector and related technologies that facilitate novel approaches in capability, size, performance or cost for the broad TJNAF science program - including science **at 22 GeV energies,** detectors that can accept high luminosity beams, and detector applications in medicine and industry.

- **Accelerator S&T:** Areas of interest include R&D toward a cost-effective energy upgrade to 22 GeV, and toward a positron beam at 12 GeV. Proposed work will be based on TJNAF's core strengths in accelerator science and technology.

Y1Q1

- **M01**: Create prototype ERSAP configurations for INDRA and CLAS12 test systems
- **M02**: Identify or capture SRO formatted data from CLAS12 and INDRA test systems with data tag/filtering capability (output data ready for further offline processing)
- **M03**: Evaluate existing solutions for configuring and launching remote distributed processes
- **M04**: Establish code repository(s), project site, and method of documentation

Y1Q2

- **M05**: Create stream splitter program for EVIO or HIPO data formatted files
- **M06**: Create stream splitter program for simulated data in PODIO for ePIC
- **M07**: Create VTP emulator using files produced by stream splitter
- **M08**: Create controller program to synchronize multiple VTP emulators

Y1Q3

- **M09**: Determine appropriate schema for all aspects of monitoring system.
- **M10**: Establish databases for monitoring system using existing JLab servers.
- **M11**: Integrate Hydra as monitoring component.

Y1Q4

- **M12**: Integrate off-line data analysis framework into platform for CLAS12 data
- **M13**: Integrate off-line data analysis framework into platform for ePIC or GlueX simulated data
- **M14**: Integrate example JANA2 analysis into platform

Y2Q1

- **M15**: Create configurable CPU proxy component
- **M16**: Create configurable GPU proxy component (hardware and software)
- **M17**: Create configurable FPGA proxy component (hardware and software)
- **M18**: Create functioning hardware GPU component (e.g. CLAS12 L3)
- **M19**: Create functioning hardware FPGA component (e.g ML4FPGA)

Y2Q2

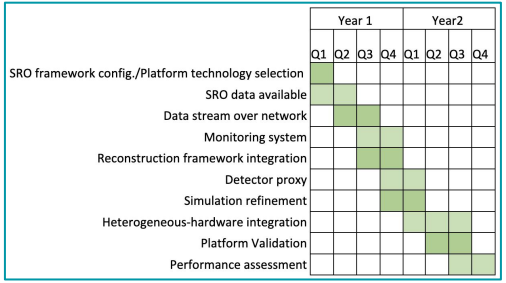
- **M20**: Impose artificial time structure on stream sources to mimic beam-like conditions
- **M21**: Configure simulation of full SRO system using existing JLab hardware resources

Y2Q3

- **M22**: Establish working test of system that transfers >=100Gbps from CH to compute center
- **M23**: Establish working test of system that includes GPU component for portion of stream
- **M24**: Establish working test of system that includes FPGA component for portion of stream
- **M25**: Test system with remote compute facility (e.g. BNL or NERSC) at limits of available resources

EPSCI
Experimental Physics Software and Computing Infrastructure

Milestones and Schedule



Y2Q4

- **M26**: Configure system that results in stream(s) being received by JLab from external source
- **M27**: Collaborate with HPDF group to evaluate processing SRO data at JLab for external experiments
- **M28**: Complete documentation for platform to be used by non-experts

Reviewer Questions

For simulating hardware, especially hardware which comes in the future, how can you ensure accuracy?

- *For hardware for which there is at least one item available at JLab, we will stress test it to derive the appropriate parameters. Similar tests using the same upstream and downstream components will be done for both the simulated and real hardware to ensure similar behavior.*
- *For hardware for which we have no hardware, specs will need to be used. This may be a common use case for the completed tool when used to develop future experiments.*

Why is this needing a separate funding stream?/ why aren't there already plans to do integration tests?

- *The current level of SCIOPS funding dedicated to DAQ and SRO cannot support this in a short time scale.*
- *LDRD funding is appropriate as this is a new type of tool that has not been used before and is of strategic advantage for the lab.*
- *Every new experiment configuration will require a new integration test(IT). This will provide that. A one-time IT is not sufficient for all future experiments.*

Please describe (in the presentation) details of the test setup(s) and testing procedures which will be used for validation of the streaming platform

- *A similar procedure will be followed as was used for the paper: "Streaming readout for next generation electron scattering experiments" https://link.springer.com/article/10.1140/epjp/s13360-022-03146-z*

  In short, comparison with triggered data under similar conditions.
- *Note that a key part of the platform is the monitoring system which will also provide an aspect of validation.*

Reviewer Questions

Will CLAS12 VTPs be connected to the U280 FPGAs (how many VTPs are you planning to use)? What CLAS-12 sub-detectors will be used?

- *The proposed High Bandwidth Test would use the U280 FPGA cards in the Computer Center with existing network connections. Dedicated connections between the VTPs and U280s is not required as both are already on the DAQ subnet.*
- *This test will use all VTPs from all CLAS-12 sub-detectors. (see additional info below.)*

Do you plan to use dedicated CLAS12 runs for testing ?

- *"The high speed testing will be coordinated to occur when the beam is down so that the full bandwidth will be available for the testing periods.". So ,yes, we will need dedicated use of the CLAS-12 detector for short periods of time, with very little requiring the beam to be on. The beam data could be taken during times when good experimental data is not possible (e.g. target filling/emptying)*

What is the plan to study performance of the system at high rate (include noise) ?

- *The plan is to use real data taken at high luminosity and feed it into the system. This will already include some amount of noise. This data could be fed at a higher rate than originally acquired.*
- *Custom data sets with increased noise can be generated from real data by mixing in and overlaying hits from random triggered events. The mixing of random triggered events allows simulation of a full stream that includes times between events. (see Y1Q2 milestones)*

Budget and Summary

- SRO experiments will have a **diversity** and **complexity** of components **beyond** that of **traditional** DAQ systems.
- A Real-Time Development and Testing Platform for Streaming Readout DAQ is a **tool** that will help **develop** the **technical aspects** of **future** JLab **experiments**
- This platform will **benefit** the **HPDF** in being flexible enough to provide streaming profiles for even non-NP experiments

Budget	**FY24**	FY25	Total
($K)	**$271K**	$274k	$545k

David Lawrence (PI)	SSCS	10%
Vardan Gyurjyan	SSIII	25%
Cissie Mei	SCSII	25%
TBD	Postdoc	100%