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EIC Detector R&D Progress Report

Project ID: eRD23
Project Name: Streaming readout for EIC detectors
Period Reported: from 8/28/18 to 12/31/2018
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Abstract

A detector for the future Electron-Ion Collider will be one of the few major collider detectors to be built from scratch in the 21st century. A truly modern EIC detector design must be complemented with an integrated, 21st-century readout design that amplifies the scientific opportunities of the machine, improves time-to-analysis and thus maximizes the scientific output. A fully streaming readout design delivers on these promises, however, can impose limitations on the characteristics of the sensors and sub-detectors. The streaming readout consortium will research the design space by evaluating and quantifying the parameters for a variety of streaming-readout implementations and their implications for sub-detectors by using on-going work on streaming-readout, as well as by constructing a few targeted prototypes particularly suited for the EIC environment.

Past

What was planned for this period?

What was achieved?
What was not achieved, why not, and what will be done to correct?

The eRD23 group was charged to further develop the proposal of a streaming read-out for the EIC detectors and compare it to the 'traditional' DAQ highlighting pros and cons.

A workshop has been organized (CNU-Newport News VA) in December 2018. Results obtained in world-wide facilities (FAIR, KM3NET, ..) have been presented, discussed and projected to the EIC kinematics and rates.
Different options for a streaming readout have been presented and a work plan to implement and compare them has been defined. Results will be presented in another workshop planned for the end of May in Italy (Camogli - Genova).

In preparation to address the charge of the review panel: "The proponents are asked to compare streaming solutions with a well-designed conventional triggered system and show where a conventional trigger fails but a streaming readout is plausible.", some test benches have being set up at Jlab (INDRA), INFN-Genova and BNL.

Some achievements presented in the workshop include:

- Streaming readout for CBM @FAIR
  The CBM project at FAIR will operate at a event rate of 10 MHz and raw rates of 1 TByte/s. Their streaming readout solution aims to reduce this rate to a manageable rate of few Gigabyte/s. Their current design is well advanced and includes the full stack from front end electronics to data processing CPU farm.
- Alphacore
  Alphacore presented on their line of radiation hard, low-power, high-density ADCs and shaper ASICs which are well suited for triggered and streaming readout solutions.
- Projects at Jefferson Lab's INDRA
  JLab's Facility for Innovation in Nuclear Data Readout and Analysis, INDRA, develops multiple readout electronics projects. They are assembling a streaming RO system by repurposing FADC250 boards currently used in Hall-D and Hall-B experiments, replacing the triggered readout via the VME bus with a streaming readout using optical fibers. The scheme is currently under test with few boards.
- The BDX experiment and progress towards an EIC Calorimeter
  At INFN-Genova a dedicated laboratory for streaming has been set up. The experimental setup is made by an array of plastic scintillator counters and PbWO4 crystals read by SiPM. This choice is motivated by the fact that these technologies will be largely used in the EIC detectors and thus provide a convenient test-bench. In particular, PbWO4 crystals and SiPMs represent the leading option for EIC endcap calorimeters, currently under study in eRD1 consortium. The application of the streaming RO to the main system responsible for the trigger in a traditional scheme represents the first step towards a full characterization of streaming RO performance for all EIC detectors. Crystals (16 PbWO4 crystals), and a set of plastic scintillators paddles instrumented with SiPM and associated readout electronics have already been procured.
- TRIDAS and KM3Net
  T. Chiarusi presented on the triggerless data acquisition system for the KM3Net experiment, an underwater neutrino experiment, highlighting the advantages of a

streaming readout for this experiment and describing the overall design. TRIDAS is the basis of the current BDX streaming readout tests.

- Streaming readout EIC detector based on sPHENIX

  J. Huang presented on an EIC detector design based on sPHENIX. The current sPHENIX design is hybrid: While the calorimeter uses a triggered design, the TPC and MVTX has a streaming read out, as a triggered system would not suit the rate environment. Results from prototype detectors and a possible readout design for an sPHENIX based EIC detector were presented.

- Protocols and software

  M. Diefenbacher presented on software aspects for a streaming readout solution, developing a data flow and processing model which is agnostic of implementation language. J. Bernauer evaluated available low-level link protocols. The conclusion is that TCP/IP is a cost effective and time-saving basis for both prototypes and final hardware. However, higher level parts of the readout framework should be agnostic to the underlying layers, assuming a FIFO-like interface, which is the common denominator for all commonly used technologies. D. Blyth presented ProIO, a possible data model framework.

Future

What is planned for the next funding cycle and beyond? How, if at all, is this planning different from the original plan?
What are critical issues?

- TPC in streaming-readout at JLab

  We have assembled a small scale streaming data acquisition system based on the SAMPA front end ASIC for the Tagged Deep Inelastic Scattering (TDIS) experiments in Hall A. These experiments employ a Gas Electron Multiplier (GEM)-based Time Projection Chamber (TPC). The SAMPA chip was designed for the high luminosity upgrade of the ALICE TPC and muon chamber detectors at CERN and supports continuous readout mode. The primary goal of the prototype system is to determine if the SAMPA chip is appropriate for use in the TDIS TPC and other future detector systems at Jefferson Lab. The prototype system is composed of actual components used in the ALICE TPC data acquisition upgrade so we benefit from the extensive development work done by ALICE and CERN. The system is by design scalable, and as such provides a functional prototype for high rate streaming readout at Jefferson Lab and the EIC. Over the next several months we plan to study the performance of the SAMPA ASIC and learn how to best utilize its sophisticated DSP capabilities. We will begin by stimulating the SAMPA inputs in a controlled fashion and then connect our 800 channel system to an existing GEM detector at JLab. The data from this detector should also be useful in guiding the development of data acquisition software at JLab that can handle streaming data. All major DAQ components of our system are in place and so the only additional funds required are to interface the system to the GEM detector and for the support systems necessary to operate the detector.

- Crateless-Streaming at JLab

  The existing FADC250 board is by default read out in a triggered mode, but the ADC also allows for a continuous operation. The project aims to develop a new firmware to enable streaming of the data via optical links without the use of the

crate backplane. As a second part of the project, the usability of a COTS programmable network switch as a core component of the data transport network will be studied.

- FEE and Circuit Designs for Streaming Readout at MIT

  MIT will work, together with the ASIC design company Alphacore, to develop prototype front-end electronics for a number of common detector types (*e.g*. PMTs, SiPMs, and GEMs). The goal will be to match the available Alphacore ASIC pre-amplifiers and ADC chips with the various detectors and FPGA based readout to provide a set of designs and prototypes that could be adopted by other groups in reading out their detectors with a view to implementing them into a streaming readout system. The project would also develop a library of algorithms that could be used on the FPGAs to extract high-level information from the raw data signals (*e.g.* integrated charge, time, time above threshold, amplitude, *etc.*). Unfortunately, to date, the MIT group has not received any indication from DOE regarding the funding for the current fiscal year; so we have been unable to proceed very quickly.

- Streaming readout for an EIC Calorimeter at INFN Genoa and CUA

  The first goal will be to validate this technology in a well-controlled setup, by comparing streaming RO performances to what obtained by a traditional triggered readout. A triggered DAQ setup based on the CAEN v1725 board has been borrowed from another experiment and is currently under test. We plan to characterize the streaming readout technology with the aforementioned setup available at INFN-Genova. The first step will be to identify and test an available board compatible with this technology. A possible option is to use the WaveBRD board currently being developed for the BDX experiment at Jefferson Laboratory. A simple experimental arrangement sandwiching the PbWO4 crystals matrix between plastic scintillator paddles will be used to detect cosmic rays and benchmark the triggered and triggerless DAQ in a controlled set up. CUA will provide samples of crystals and ceramic glasses currently being evaluated as possible option for EIC calorimetry (eRD1). Tests include measurements of coincidence rate, crystal energy resolution, and time resolution allowing a direct comparison of the two technologies. The main results and findings will be reported in a note and presented to the eRD23 group. The timescale of this activity is dictated by funds availability to procure the elements of the triggerless DAQ chain.

- Multilayered Architecture for Streaming Readout at Stony Brook

  The development of a OSI 7 layer protocol has been started. Possible serialization generators like ProtoBufs, Capt'n Proto etc. are currently being evaluated. We plan to develop prototypes for streaming readout and real-time data analysis systems and aim to develop for the prototype systems software based on existing protocols and open standards. This will allow us to identify the software R&D required for the upcoming streaming readout and real-time data analysis systems. In FY19, we will prepare a document describing our software concept and discussing the options for implementing the first software prototypes.

The next collaboration meeting will be in Camogli (Genova - Italy) in May. We plan for two full days of discussion to report on progress in EIC streaming RO tests as well as reports from other experiments that will make use of a streaming RO scheme. Experts from CERN, FAIR, Frascati and other EU Labs, beside US, are expected to attend. We are planning to use the awarded funds to offset some of the workshop costs and invite speakers outside of the collaboration.

We are aware that some detector groups are already looking into readout solutions which are incompatible with a streaming approach. We will intensify our outreach to the detector groups to prevent premature technology lock-in.

Manpower

Include a list of the existing manpower and what approximate fraction each has spent on the project. If students and/or postdocs were funded through the R&D, please state where they were located, what fraction of their time they spend on EIC R&D, and who supervised their work.

- TPC in streaming-readout and Crateless-Streaming at JLab
  The TPC in streaming-readout work is currently carried out by Ed Jastrzembski of the JLab DAQ group. C. Cuevas, G. Heyes and B. Raydo are working on the FADC250 based streaming readout.

- FEE and Circuit Designs for Streaming Readout at MIT
  The work is currently carried out by Douglas Hasell and Richard Milner with the intention of involving graduate students and post-docs once the funding issue is resolved.
- Streaming readout for an EIC Calorimeter at INFN Genoa and CUA
  At INFN-Genoa, the work is currently carried out by Dr. Battaglieri and Dr. Celentano, with support from the electronic department of INFN Genoa (Ing. Paolo Musico). At CUA, the work is currently carried out by Dr. Horn and Dr. Pegg and their teams including postdoctoral researcher Dr. Berdnikov and graduate and undergraduate students.
- Multilayered Architecture for Streaming Readout at Stony Brook
  The work is currently carried out by J. C. Bernauer, with frequent input from M. Diefenthaler, C. Cuevas and M. Purschke.

External Funding

Describe what external funding was obtained, if any. The report must clarify what has been accomplished with the EIC R&D funds and what came as a contribution from potential collaborators.

The Genova Group, in collaboration with MIT received a grant from the Italian Ministry of Foreign Affair for 'A triggerless DAQ for the Electron Ion Collider (EIC)' (PIs: M.Battaglieri and D.Hasell) to study and develop a triggerless DAQ system for the future EIC. Funds will be available for years 2019-21.

The MIT group has requested support at the level of 60 k$ from the DOE for its streaming readout efforts but, to date, has not received any indication of what funding will be available.

All projects are currently funded from external sources.

Publications

Please provide a list of publications coming out of the R&D effort.

We are preparing a summary paper of the last workshop at Christopher Newport University.