Streaming readout IV

22-24 May 2019
Camogli
Europe/Rome timezone

EIC Streaming Read-Out IV
May 23-24 2019

EIC overview

M.Battaglieri
INFN -GE
Italy

The Electron Ion Collider project

REACHING FOR THE HORIZON

The Site of the Wright Brothers' First Airplane Flight

The 2015
LONG RANGE PLAN
for NUCLEAR SCIENCE

- **The 2015 Long Range Plan for Nuclear Science**

Nuclear Science Advisory Committee (NSAC) and American Physics Society – Division of Nuclear Physics (APS-DNP) partnered to tap the full intellectual capital of the U.S. nuclear science community in identifying exciting, compelling, science opportunities

Recommendations:
- …
- Gluons…generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain…. These can only be answered with a powerful new electron ion collider (EIC). **We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.**
- …

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

CONSENSUS STUDY REPORT

AN ASSESSMENT OF
U.S.-BASED ELECTRON-ION
COLLIDER SCIENCE

- **In July 2018 the National Academy of Science endorsed unanimously EIC Science**

NAS Committee Statement of Task
from DOE/NSF to NAS (End of 2016)

The committee will assess the scientific justification for a U.S. domestic electron ion collider facility, taking into account current international plans and existing domestic facility infrastructure. In preparing its report, the committee will address the role that such a facility could play in the future of nuclear physics, considering the field broadly, but placing emphasis on its potential scientific impact on quantum chromodynamics.
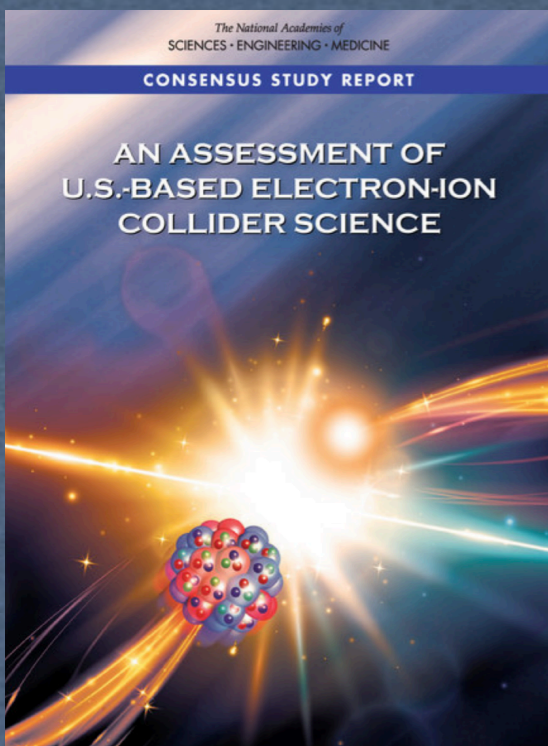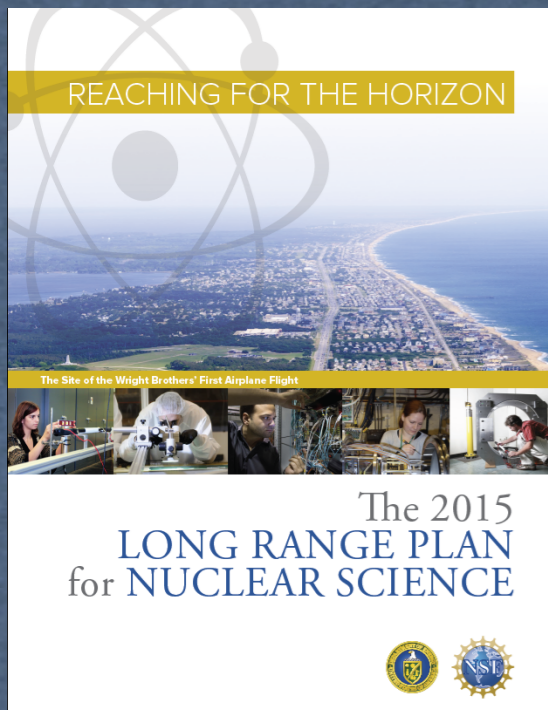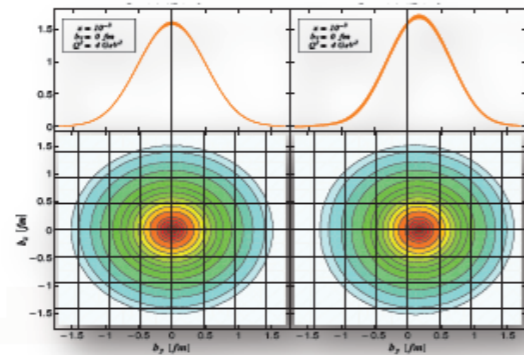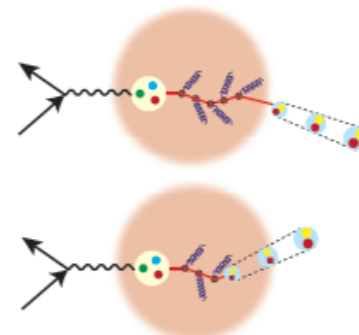
The EIC physics

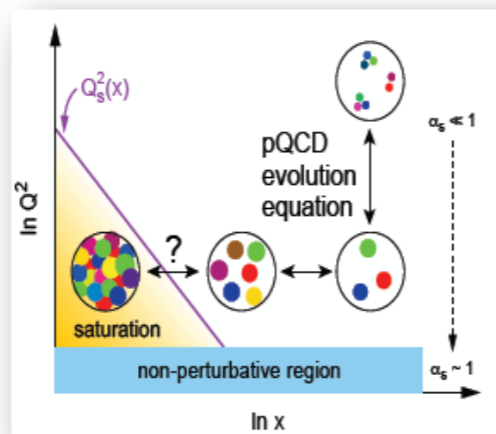Accardi et al., Eur. Phys. J. A (2016) 52: 268   arXiv: 1212.1701.v3

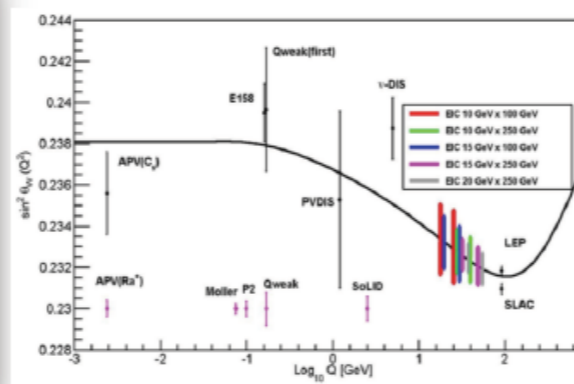**3D Imaging of Nucleon Structure**
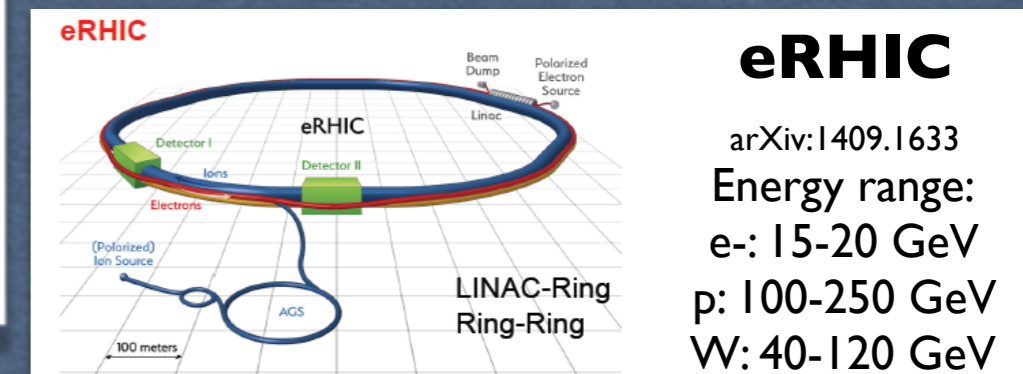
Hadronization in cold QCD matter

**Gluon Saturation**

EW Physics

The primary aim of an EIC is to understand how up and down quarks, sea quarks, and gluons create the building blocks of the nuclei of atoms, neutrons, and protons, and furthermore how neutrons and protons in nuclei are held together by the color force.
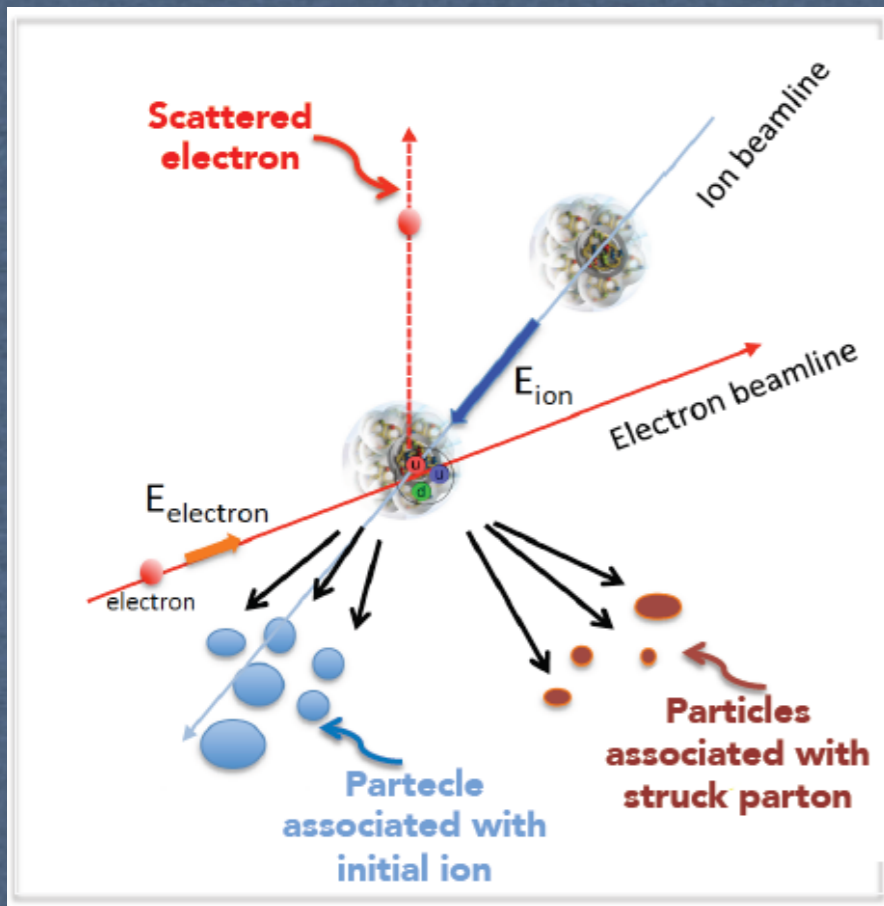
eRHIC

arXiv:1409.1633
Energy range:
e-: 15-20 GeV
p: 100-250 GeV
W: 40-120 GeV

JLEIC

arXiv:1504.07961
Energy range:
e-: 3-10 GeV
p : 20-100 GeV
W: 20-100 GeV

- Luminosity 100-1000 times that of HERA
- Polarized protons and light nuclear beams
- Nuclear beams of all A (p→U)
- Center mass variability with minimal loss of luminosity

EIC detectors
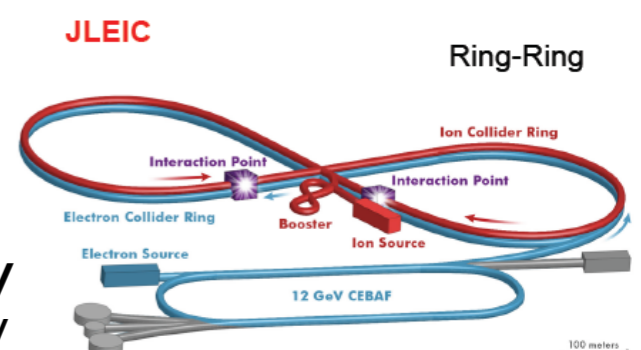
✳ Resolve partons in nucleons
- ➩ high beam energies and luminosities
- ➩ Q2 up to ~1000 GeV^2

✳ Resolve (k_t, b_t) of the order a few hundred MeV in the proton
- ➩ High Granularity, wide dynamic range

✳ Detect all types of remnants to seek for correlations:
- ➩ scattered electron
- ➩ particles associated with initial ion
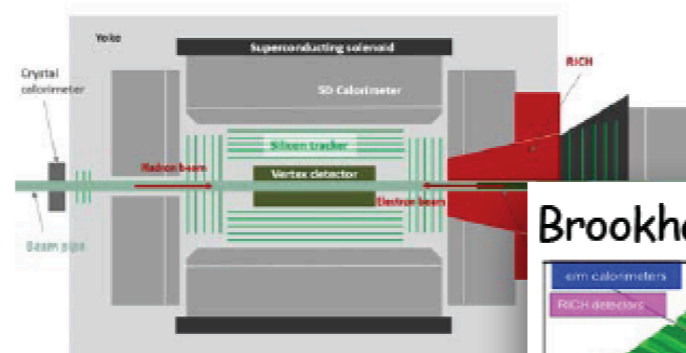- ➩ particles associated with struck parton

- Large acceptance
- Fwd/Bak angles
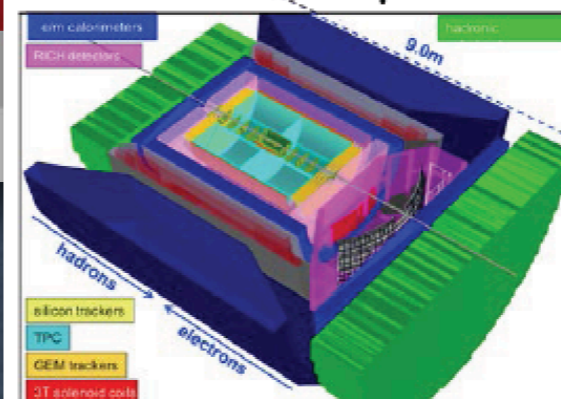- Precise vertexing
- HRes Tracking
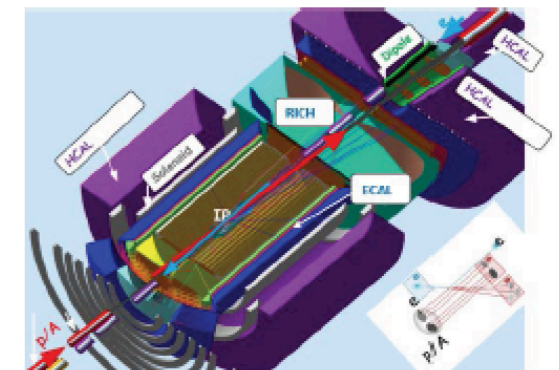- Excellent PID

sPHENIX → EIC
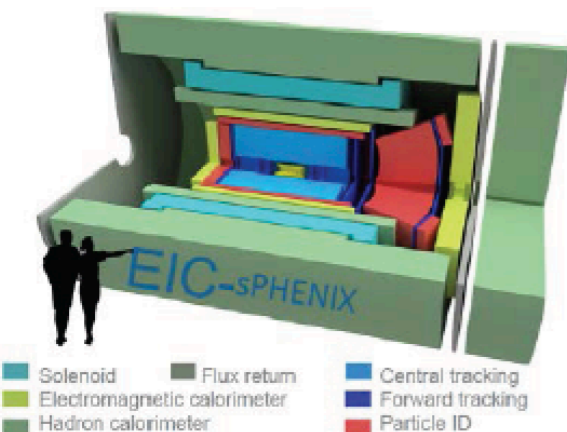
Argonne concept: TOPSiDE

Brookhaven concept: BEAST

Jefferson lab concept: JLEIC

EIC detectors readout system

Vertex detector → primary and secondary vrtx(s)
Silicon pixels, e.g. MAPS

Central tracker → Measure charged track momenta
Drift chamber, TPC + outer tracker or Silicon strips

Forward tracker → Measure charged track moment
GEMs, Micromegas, or Silicon strips, MAPS

Particle Identification → pion, kaon, proton separation
Time-of-Flight or RICH + dE/dx in tracker

Electromagnetic calorimeter → Photons (E, angle), identify electrons
Crystals (backward), Shashlik or Scintillator/Silicon-Tungsten

Hadron calorimeter → Measure charged hadrons , neutrons and KL0
Plastic scintillator or RPC + steel

Options for EIC readout

Traditional (triggered) DAQ

* All channels continuously measured and hits stored in short term memory by the FEE
* Channels participating to the trigger send (partial) information to the 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
* **Drawbacks:**
  * only few information form the trigger
  * Trigger logic (FPGA) difficult to implement and debug
 * not easy to change and adapt to different conditions

Streaming readout

* All channels continuously measured and hits streamed to a HIT manager (minimal local processing) with a time-stamp
* 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
* **Advantages:**
  * Trigger decision based on high level reconstructed information
  * easy to implement and debug sophisticated algorithms
  * high-level programming languages
  * scalability

EIC R&D

A Streaming Read-Out scheme for EIC requires:
- to identify and quantify relevant streaming-readout parameters
- to be implemented in realistic study cases
- to compare performances with traditional DAQ
- to evaluate the impact on EIC detector design
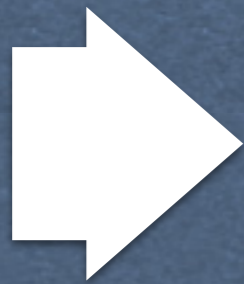
EIC R&D
Streaming Readout Consortium
eRD23

Catholic University of America: S. Ali, V. Berdnikov, T. Horn, M. Muhoza, I. Pegg, R. Trotta

INFN Genova: M. Battaglieri, A. Celentano

Stony Brook University / RBRC: J. C. Bernauer

Massachusetts Institute of Technology: D. K. Hasell, R. Milner

Jefferson Lab: C. Cuevas, M.Diefenthaler, R. Ent, G. Heyes, B. Raydo, R. Yoshida

Additionally many regulars like Martin Purschke (BNL), M. Locatelli (CAEN), J.Huang (BNL), E. Mikkola (Alphacore), ...

Streaming Readout for EIC Detectors
Proposal submitted 25 May, 2018

STREAMING READOUT CONSORTIUM

S. Ali, V. Berdnikov, T. Horn, I. Pegg, R. Trotta
Catholic University of America, Washington DC, USA
M. Battaglieri (Co-PI)[1], A. Celentano
INFN, Genova, Italy
J.C. Bernauer* (Co-PI)[2], D.K. Hasell, R. Milner
Massachusetts Institute of Technology, Cambridge, MA
C. Cuevas, M. Diefenthaler, R. Ent, G. Heyes, B. Raydo, R. Yoshida
Thomas Jefferson National Accelerator Facility, Newport News, VA

* Also Stony Brook University, Stony Brook, NY

ABSTRACT

Micro-electronics and computing technologies have made order-of-magnitude advances in the last decades. Many existing NP and HEP experiments are taking advantage of these developments by upgrading their existing triggered data acquisitions to a streaming readout model. 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, designed from ground-up for streaming readout, promises to further improve the efficiency and speed of the scientific work-flow and enable measurements not possible with traditional schemes. Streaming readout, however, can impose limitations on the characteristics of the sensors and sub-detectors. Therefore, it is necessary to understand these implications before a serious design effort for EIC detectors can be made. We propose to begin to evaluate and quantify 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.

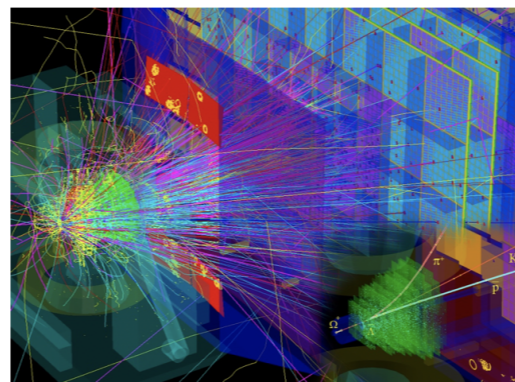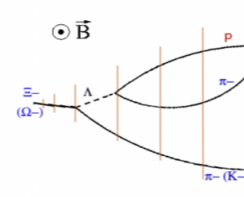[1] battaglieri@ge.infn.it
[2] bernauer@mit.edu

From *EIC Streaming Read-Out III* ws

✳ **Learn from the ongoing S-RO activity in current and future experiments**
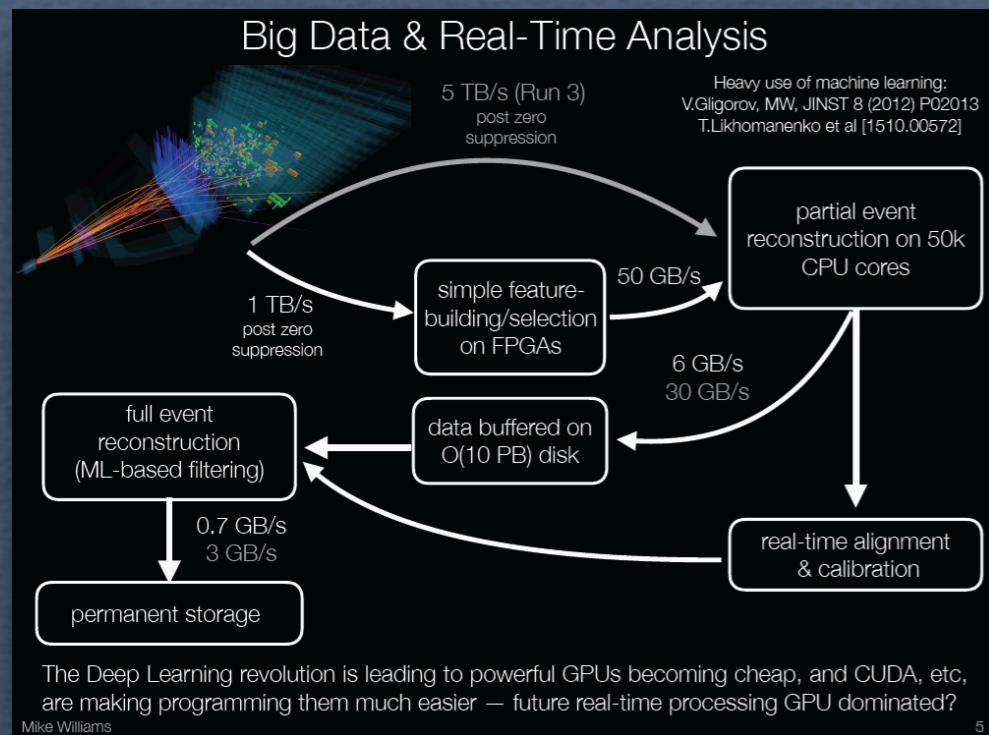
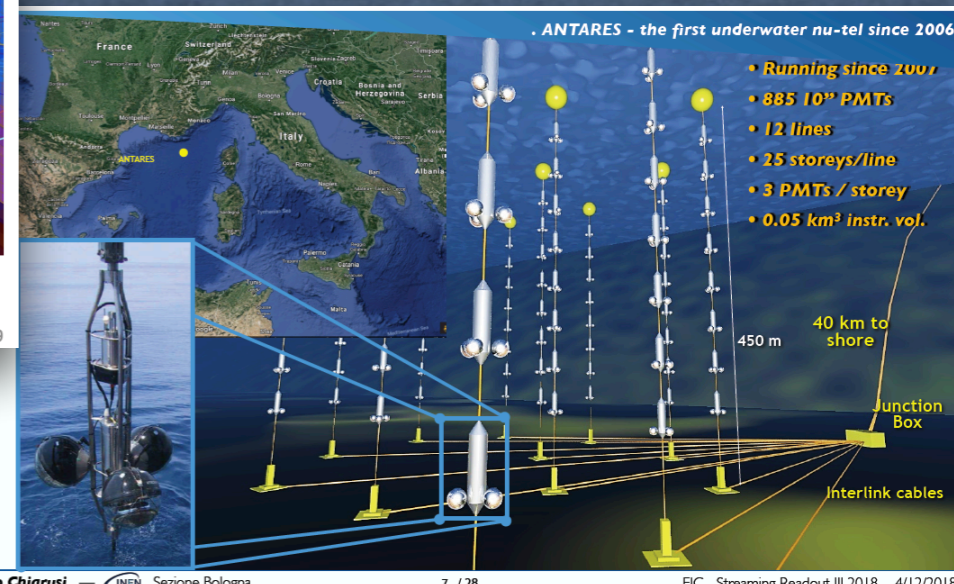LHCb (CERN) is planning to use S-RO scheme for the HI-LUMI run to cope with the expected high rate

CBM (FAIR) developed a full S-RO DAQ aiming for stored data reduction an on-line event reconstruction

KM3NET (EU) developed a full S-RO infrastructure (TRIDAS) for a underwater neutrino telescope to readout 4k PMTs located 50Km off-shore

From *EIC Streaming Read-Out III* ws

✳ **Develop new FE/RO electronics fully S-RO compatible**

BDX WaveBoard: 12ch 14 bits 250MHz digitizer

Implementing ALICE SAMPA GEM in streaming mode at JLab

3.1 Streaming Readout TDC design with VETROC board

- Alphacore presented the current status of detector readout IC development including rad-hard preamplifiers, ADCs and combined ROICs.
- Large tapeout was completed and IC testing will start in January 2019.

Questions for the audience?
- Is there a need for a "Combined ROIC", i.e. a chip that has both preamplifiers and ADCs, or can they be on separate chips?
- What are the target experiments, their schedule, channel counts, and readout specifications?
- Radiation hardness requirements?
- Integration level requirements (IP? Wafers? Packaged chips? Packaged and tested chips? Evaluation boards? Ready-made readout boards with FPGAs ?)
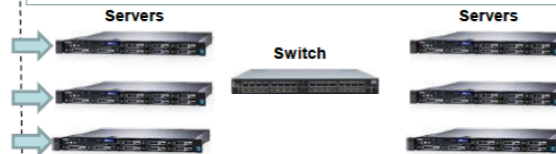
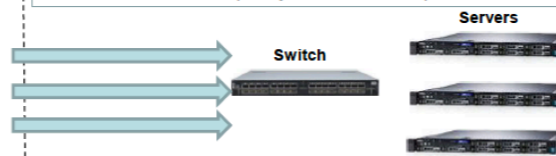Adding optical-link connection to JLab fADC250 via VTP board
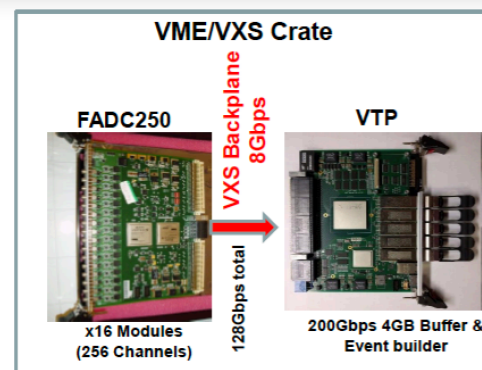
Developing new fADC/ASIC in conjunction with private companies (ALPHACORE, CAEN)

From *EIC Streaming Read-Out III* ws

✴ **Validation of streaming RO scheme against triggered DAQ**

"Physical validation" process:

Compare between "standard" (triggered) and "triggerless" DAQ system in a real measurement: perform the analysis of the **same observable** in the two cases and **compare results**

BDX-proto measurement @ JLab:

- Place a small scale prototype of one BDX module in a setup with similar overburden configuration as in the final setup
- Measure cosmogenic rate and evaluate foreseen backgrounds
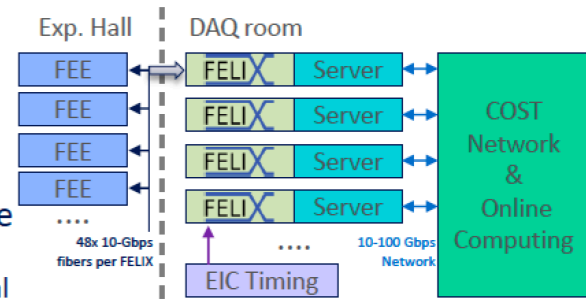
BDX DAQ system validation
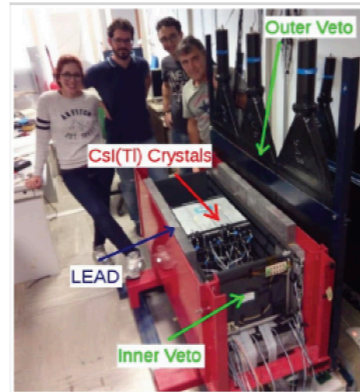
BDX-proto detector:

- 16x CsI(Tl) crystals, SiPM readout
- 2 plastic scintillator veto layers, SiPM readout
- Setup to be modified to be compatible (cabling, …) with wave-brd readout
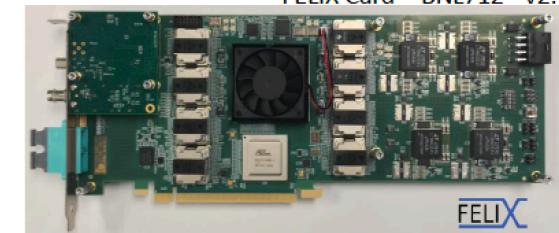
Tests foreseen in 2019

Testing the streaming RO concept in BDX-MINI experiment at JLab and BDX-PROTO set up. One-to-one comparisons to CAEN FPGA-triggered DAQ

sPHENIX proposal to test Streaming RO architecture replacing the current triggered DAQ for the TPC and MVTX

A streaming DAQ architecture

- ▶ Using PCIe FPGA card bridging stream-readout FEE on detector and commodity online computing
  - ○ Similar approach taken at ATLAS, LHCb, ALICE phase-1+ upgrades and sPHENIX
- ▶ Implementation: BNL-712-series FPGA-PCIe card
  - ○ 2x 0.5-Tbps optical link to FEE: 48x bi-directional 10-Gbps optical links via MniPODs and 48-core MTP fiber
  - ○ 100 Gbps to host server: PCIe Gen3 x16
  - ○ Large FPGA: Xilinx Kintex-7 Ultra-scale (XCKU115), 1.4 M LC
  - ○ Bridge μs-level FEE buffer length with seconds level DAQ time scale
  - ○ Interface to multiple timing protocols (SPF+, White Rabbit, TTC)
  - ○ Developed at BNL for ATLAS Phase-1 FELIX upgrade, down selection to use for streaming FEE readout in sPHENIX, proto-DUNE, CBM
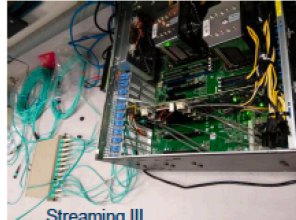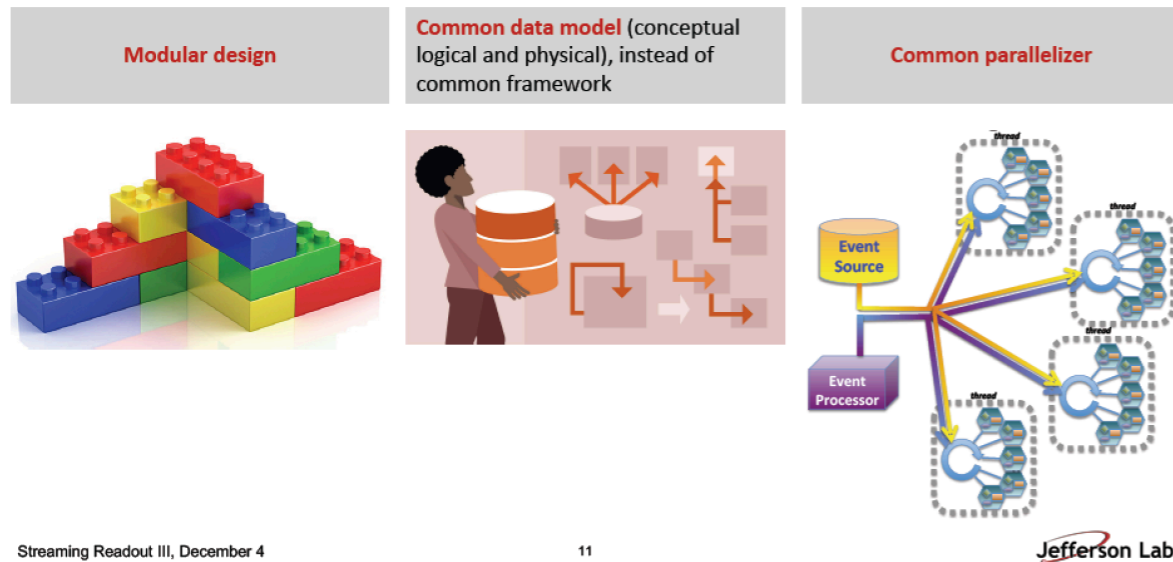 - ○ Continued development to upgrade to 25-Gbps optical links, Vertex7 FPGA and PCIe-Gen4

Jin Huang <jihuang@bnl.gov>

From *EIC Streaming Read-Out III* ws

✴ **Network and software aspects**

Building up the software framework able to do a semi on-line reconstructions that include calibration, tracking, ….

Exploring suitable I/O data format for data exchange in streaming-RO mode

EIC Streaming RO IV ws

Streaming Readout III

from Monday, 3 December 2018 at **09:00** to Tuesday, 4 December 2018 at **18:00** (US/Eastern)
at **Christopher Newport University (Freeman Center - Room 201)**

✳ **The Electron Ion Collider project is recognised as a top priority for future Nuclear Physics programs in US**

✳ **The machine and detector design will be soon finalised**

✳ **The rich physics case of EIC requires flexible detectors able to measure and identify particles in wide kinematic range**

✳ **A streaming Read-Out scheme for EIC will be able to provide the necessary flexibility**

✳ **Goals of the workshop:**

- **streaming RO validation**
  (A.Celentano, D.Hasell)

- **progress in FE/RO electronics**
  (C.Cuevas)

- **define the software/networking framework**
  (J. Bernauer, M.Diefenthaler)

- **Streaming RO options for EIC(s)**
  (M.Battaglieri, R.Corliss)

✳ **eRD23 WorkingGroup: define and prepare plans and strategies for the upcoming EIC R&D call**

Streaming readout IV

22-24 May 2019
Camogli
Europe/Rome timezone

Overview
Timetable
Registration
Participant List
Travel Information
Accommodation and Social Events

Supporto
✉ battaglieri@ge.infn.it

EIC Streaming Readout consortium is meeting from May 23 to May 25 in Camogli, Italy, to discuss topics related to the implementation of this novel DAQ scheme for the forthcoming US Electron-Ion collider experiment. This is the fourth workshop following previous events held at MIT in 2017 (Trigger/Streaming readout) and in 2018 (Streaming Readout II) and at Christopher Newport University (CNU) / Jefferson Laboratory in 2018 (Streaming Readout III)

Participation to the workshop is by invitation only.

🕐 **Starts** 22 May 2019, 18:00
Ends 24 May 2019, 19:00
Europe/Rome

📍 Camogli
Hotel Cenobio dei Dogi
Via N. Cuneo, 34

📎 S-RO-reservation-form.docx