1st EIC Yellow Report Workshop at Temple University

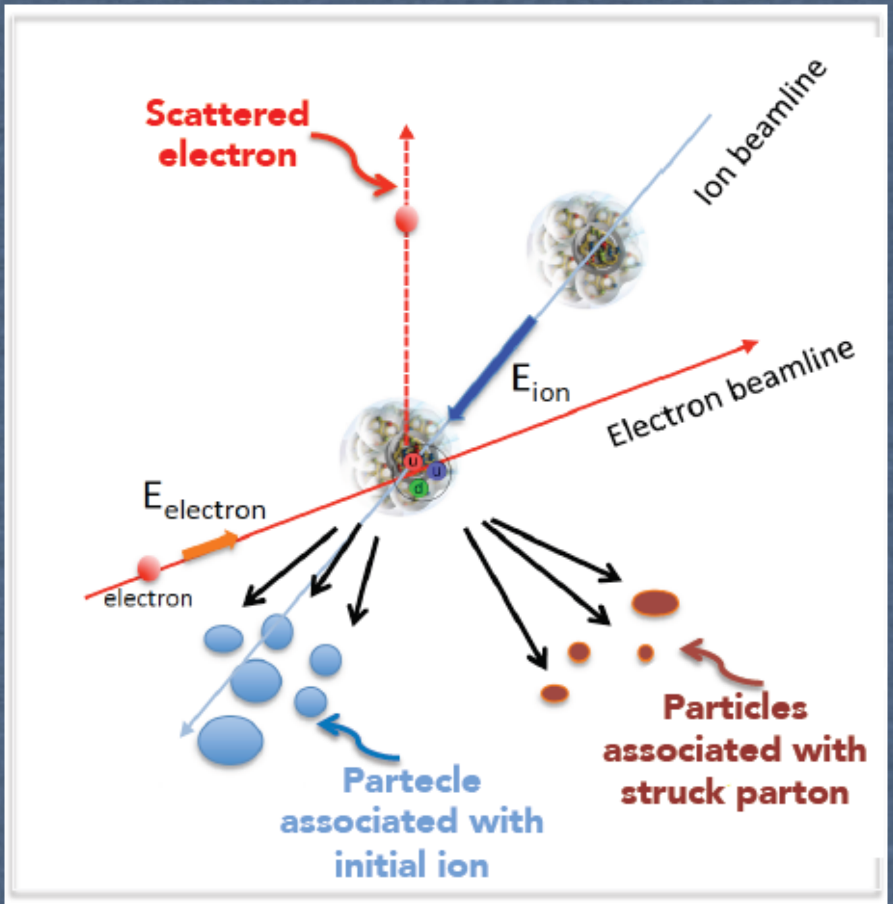
19-21 March 2020
Online

EIC YR Meeting
March 20 2020

Overview of eRD23 activities

M.Battaglieri
JLab/INFN
(on behalf of EIC eRD23 Streaming ReadOut Consortium)

EIC detectors

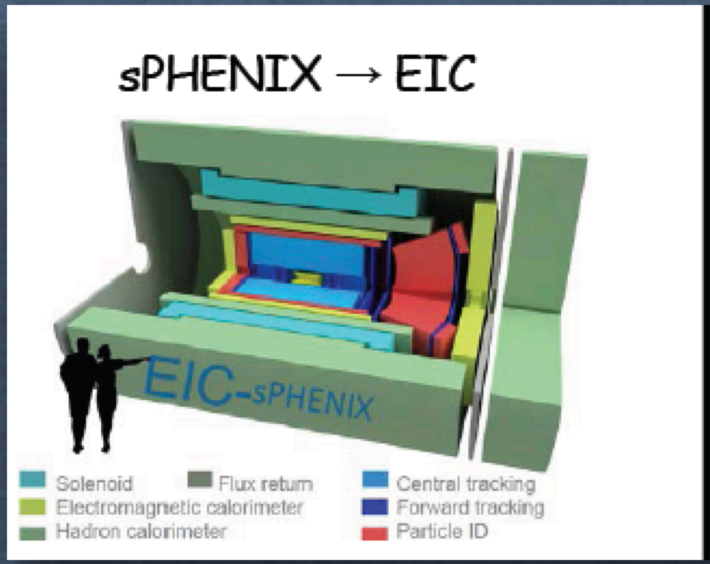


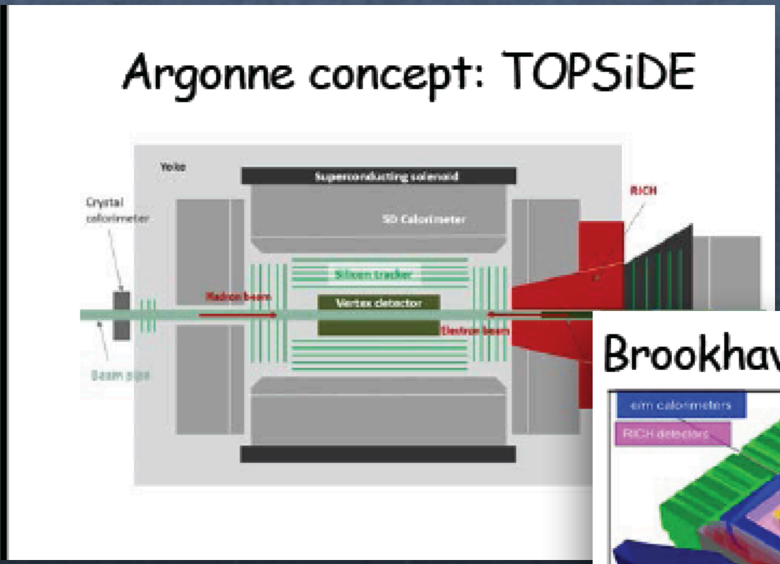
✳ Resolve partons in nucleons
- high beam energies and luminosities
- Q2 up to ~1000 GeV^2

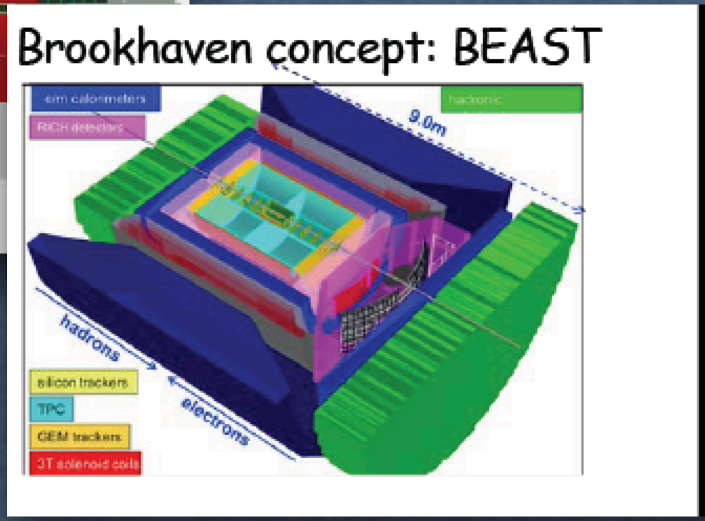
✳ Resolve (k_t, b_t) of the order a few hundred MeV in the proton
- High Granularity, wide dynamic range

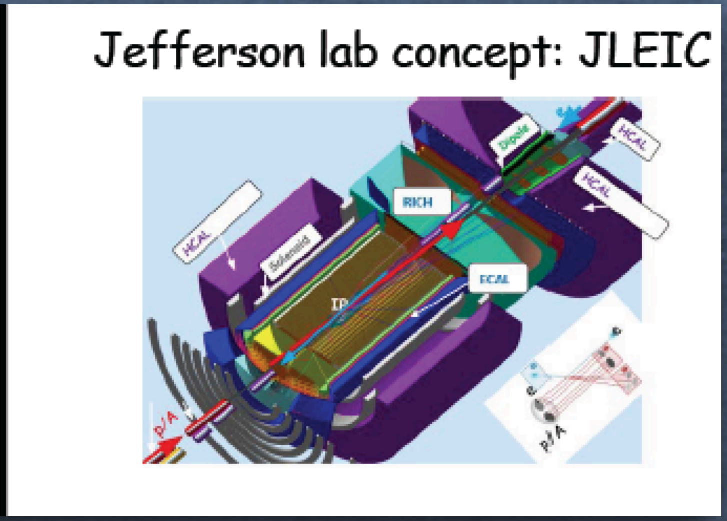
✳ Detect all types of remnants to seek for correlations:
- scattered electron
- particles associated with initial ion
- particles associated with struck parton

- Large acceptance
- Frwrd/Bckw angles
- Precise vertexing
- HRes Tracking
- Excellent PID









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

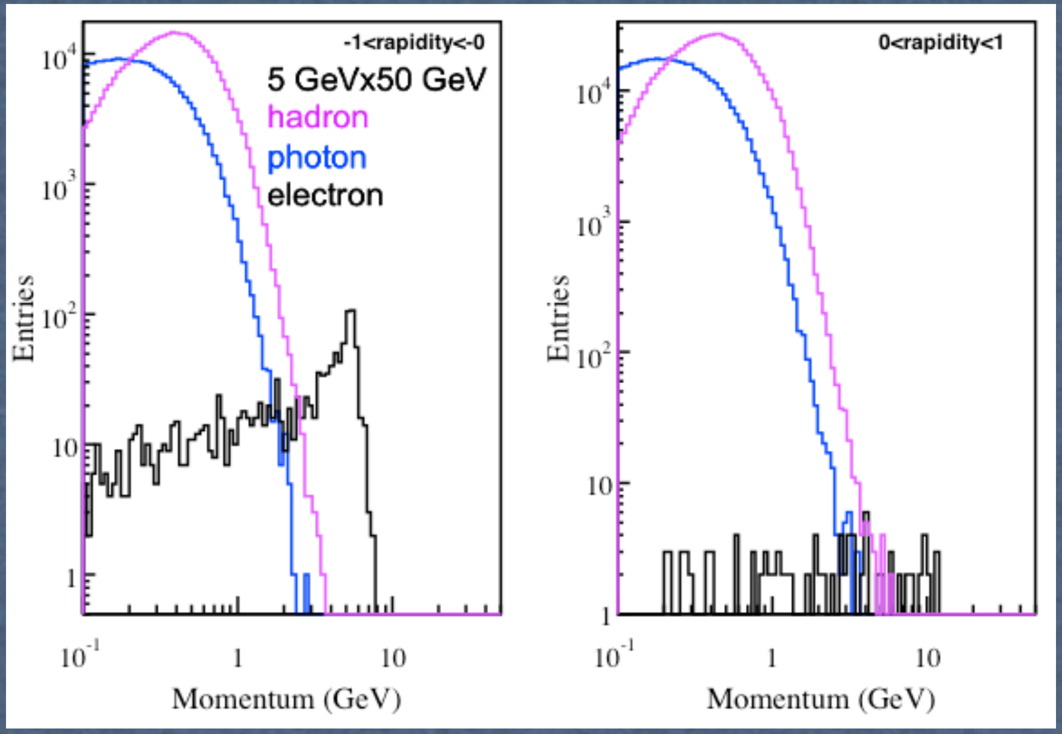
- All channels continuously measured and hits streamed to a HIT manager (minimal local processing) with a time-stamp
- A HIT MANAGER receives hits from FEE, order them and stream according to the software data selection
- Another high-level sw re-aligns in time the whole detector hits applying a selection algorithm to the time-slice
  - does not require definition of a 'event' at trigger level
  - 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
  - Full data stream to disk and 'trigger' off-line

Streaming readout for EIC physics

A triggerless DAQ provides advantages for all EIC reaction channels

Inclusive channel

- Excellent e/h and e/γ discrimination
- At large η (large Q^2), low-momentum electrons are overwhelmed by hadrons background

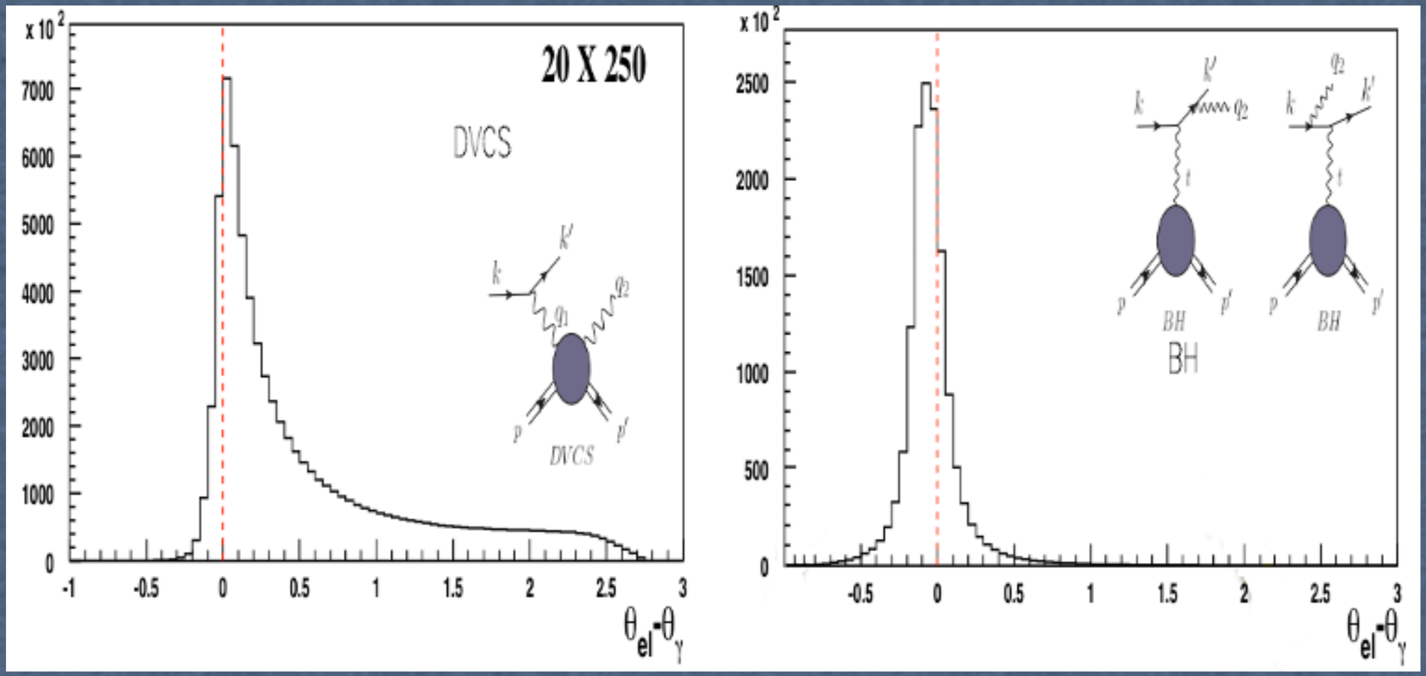


Triggerless DAQ system allows a sophisticated electron selection, making use of advanced algorithms applied to the full information from detectors

Exclusive channels

Several data selection conditions tailored to physics Eg. DVCS

- DVCS benefits by the measurement of the hard photon together with the scattered electron
- The dominant BH background can be rejected by reconstructing θ_e and θ_γ and cutting on $(\theta_e-\theta_\gamma)$



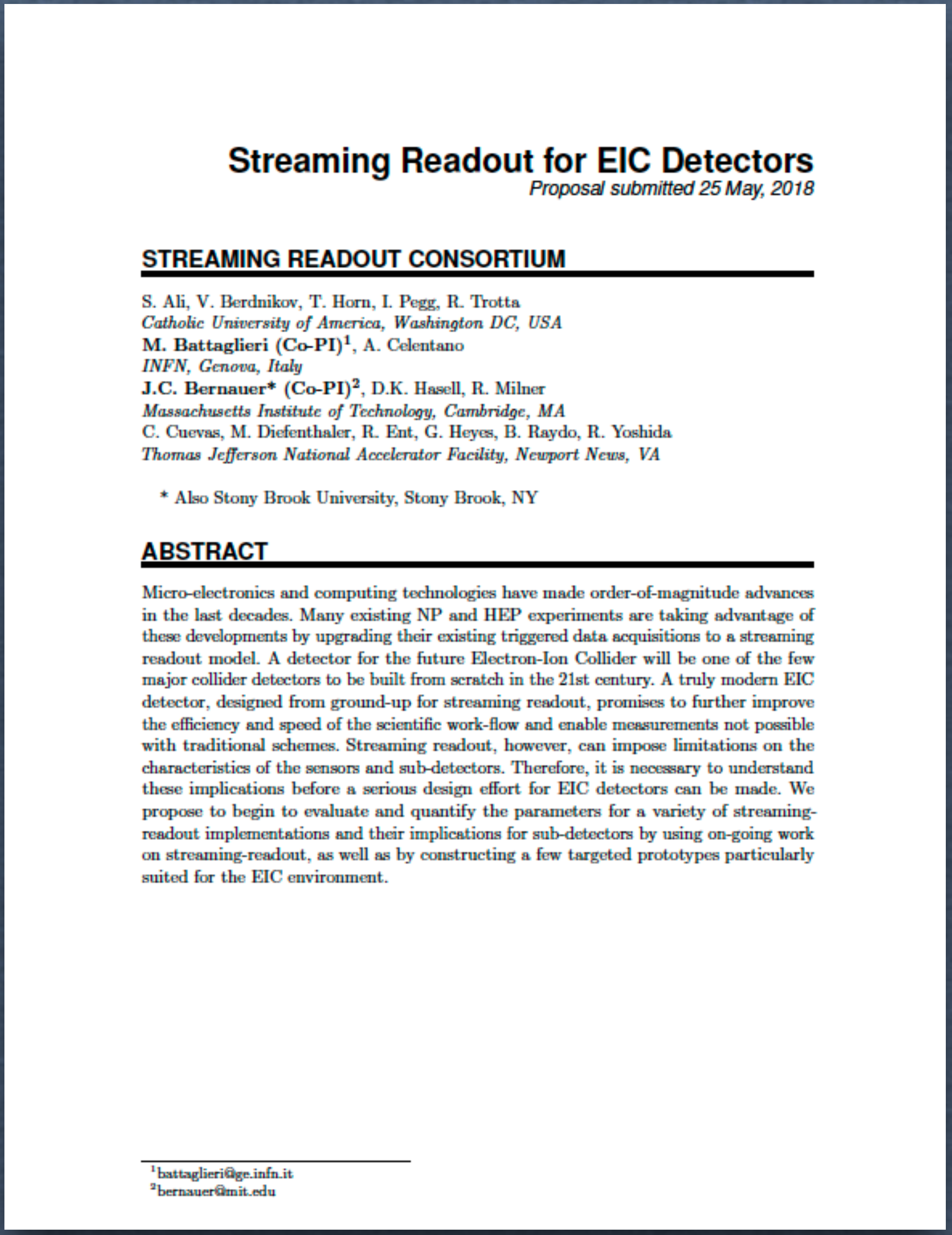
Large flexibility to add new data selections for different physics cases!

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



Streaming Readout for EIC Detectors

Proposal submitted 25 May, 2018

STREAMING READOUT CONSORTIUM

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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.

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Jefferson Lab: M.Battaglieri, C. Cuevas, M.Diefenthaler, R. Ent, Y.Furletova, G. Heyes, B. Raydo

BNL: M.Purschke, J.Huang

Externals: M. Locatelli(CAEN), E. Mikkola (Alphacore), ...

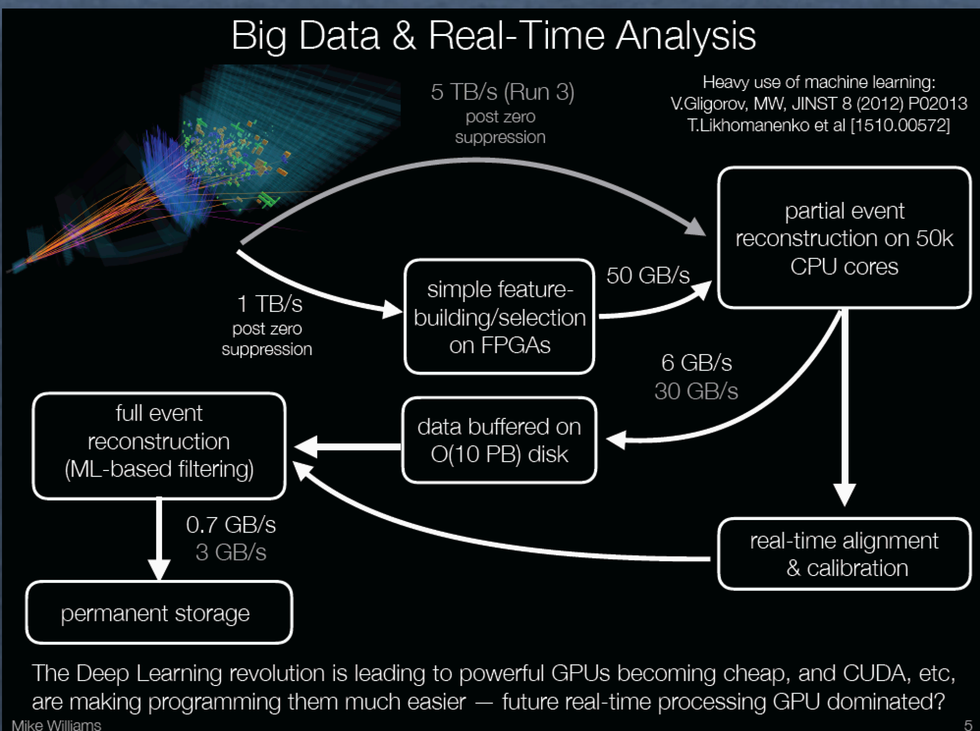
EIC detector R&D community

- Working with other consortia to find the best read out solution
- Some detectors will need specialized electronics to meet performance and cost requirements
  Example: GEM-TRD: Works beautifully with streaming-capable fADC125. Does not work with APV DREAM, VMM. Might work with modified SAMPA.
- Test of custom/commercial product and/or development of new electronic custom boards
- Dedicated ASICs: considering long development time, need to be designed in advance
- Loose boundary between online/offline software

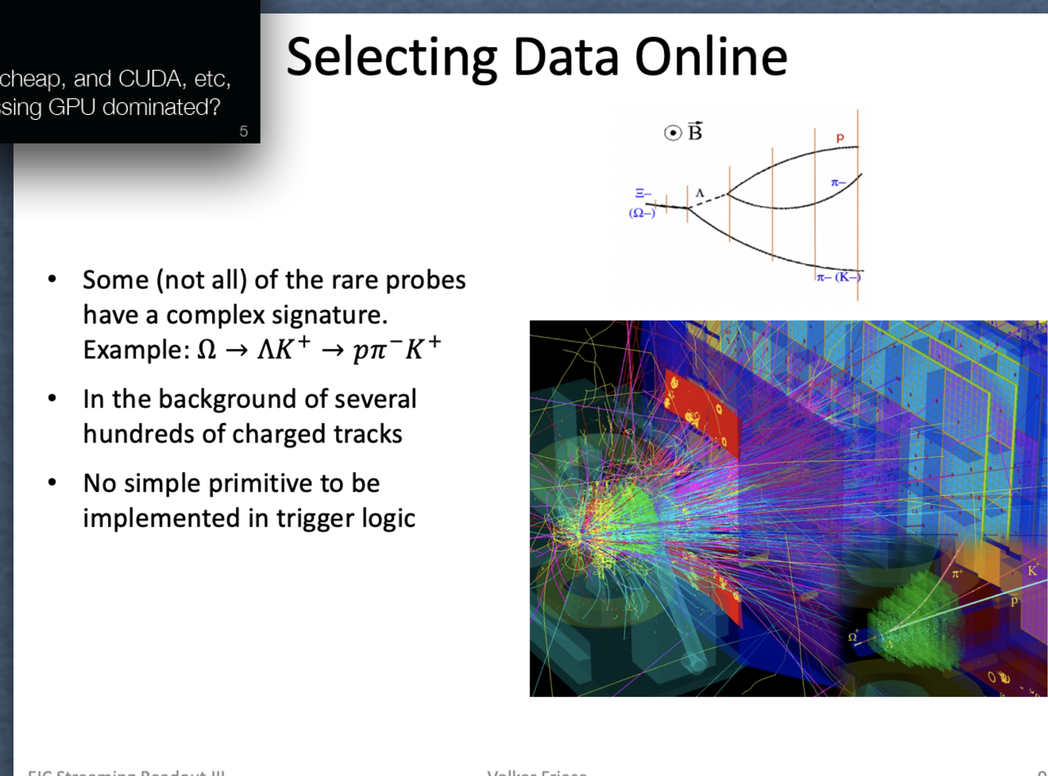
Where/how to test a triggerless solution for EIC?

- All labs are planning test setups + experiments in the near future which will make use of streaming readout. All of these activities should have been carried to fruition before 2023.
  - **JLab: CLAS12**
    - Aims to convert to fully streaming in the time scale of few years making full use of SRO capabilities
  - **BNL: sPHENIX**
    - Hybrid system, similar conditions as EIC (Integration time x collisions >1, data rates), uses RHIC RF clock source, which will likely basis of EICRF source
- These experiments will demonstrate the benefits of SRO and the readiness at EIC scale

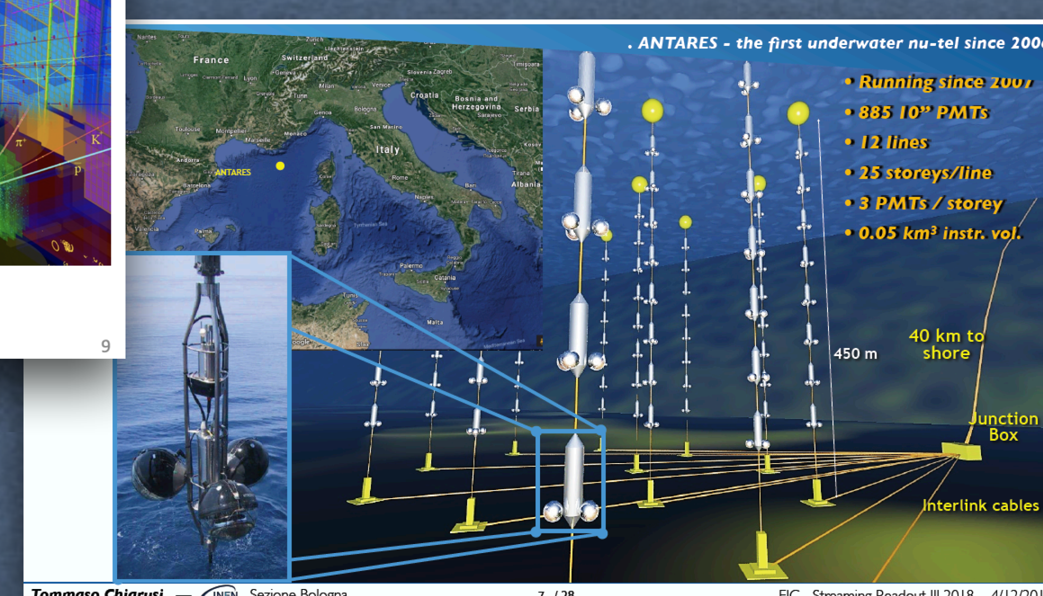
✳ Learn from the ongoing S-RO activity in current and future experiments



LHCb (CERN) is planning to use S-RO scheme for the HI-LUMI run to cope with the expected high rate

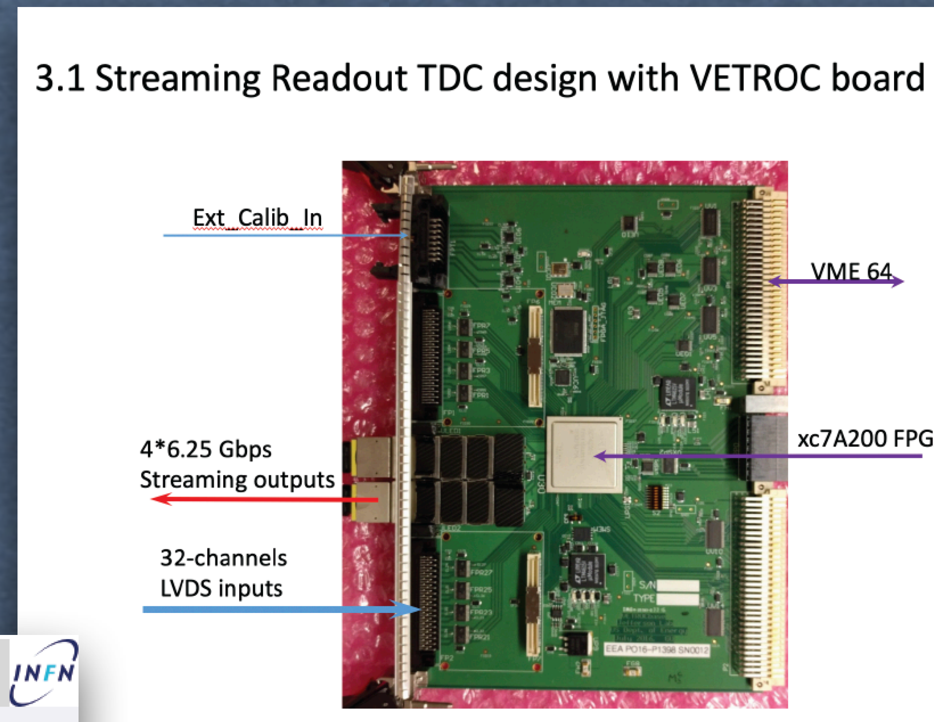


CBM (FAIR) developed a full S-RO DAQ aiming for stored data reduction an on-line event reconstruction



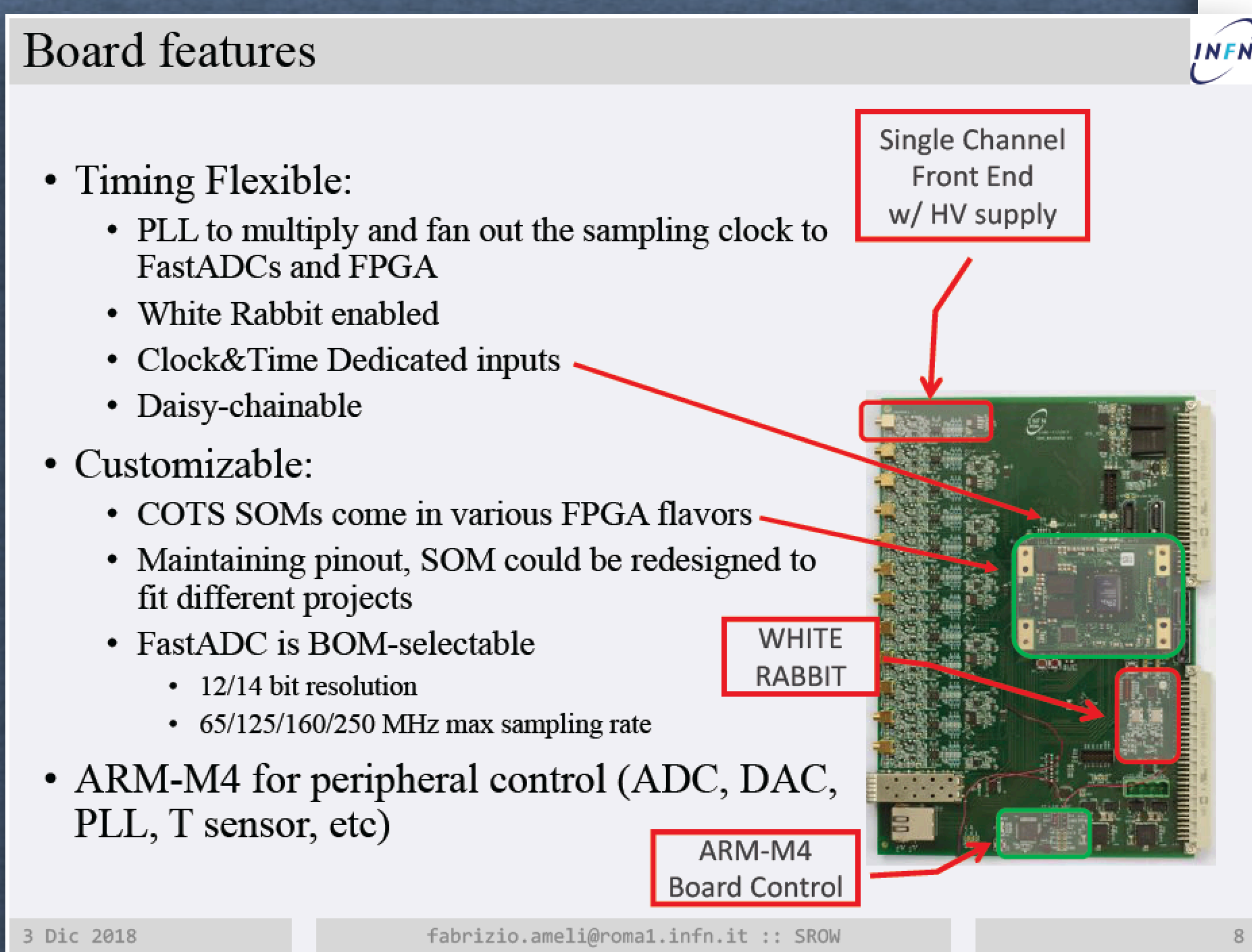
KM3NET (EU) developed a full S-RO infrastructure (TRIDAS) for a underwater neutrino telescope to readout 4k PMTs located 50Km off-shore

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


3.1 Streaming Readout TDC design with VETROC board

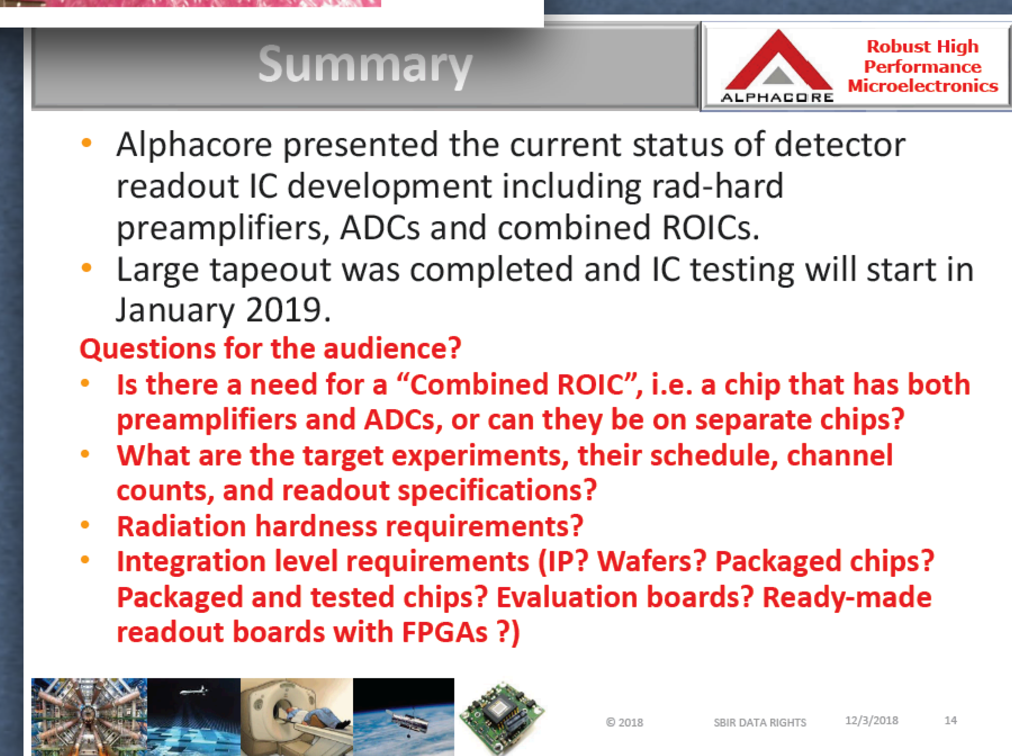
Implementing ALICE SAMPA GEM in streaming mode at JLab

BDX WaveBoard: 12ch 14 bits 250MHz digitizer


Board features

- Timing Flexible:
  - PLL to multiply and fan out the sampling clock to FastADCs and FPGA
  - White Rabbit enabled
  - Clock&Time Dedicated inputs
  - Daisy-chainable
- Customizable:
  - COTS SOMs come in various FPGA flavors
  - Maintaining pinout, SOM could be redesigned to fit different projects
  - FastADC is BOM-selectable
    - 12/14 bit resolution
    - 65/125/160/250 MHz max sampling rate
- ARM-M4 for peripheral control (ADC, DAC, PLL, T sensor, etc)

3 Dic 2018 fabrizio.ameli@roma1.infn.it :: SROW 8


Summary

Robust High Performance Microelectronics

- 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 ?)**

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Developing new fADC/ASIC in conjunction with private companies (ALPHACORE, CAEN)

✳ Validation of streaming RO scheme against triggered DAQ

Progress: SBU/RBRC and MIT

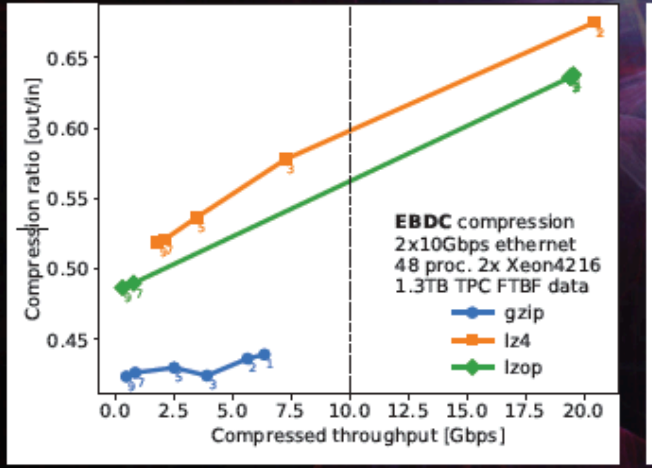
- SBU/RBRC: Organized the workshop :)
- MIT: Funding from DOE was received late, so could not work with Alphacore on ASIC design
- Test beam time at DESY, parallel read out of calorimeter via triggered and streaming electronics
- Calorimeter was constructed from tungstate crystals on loan from Tanja Horn (CUA)
- Analysis ongoing

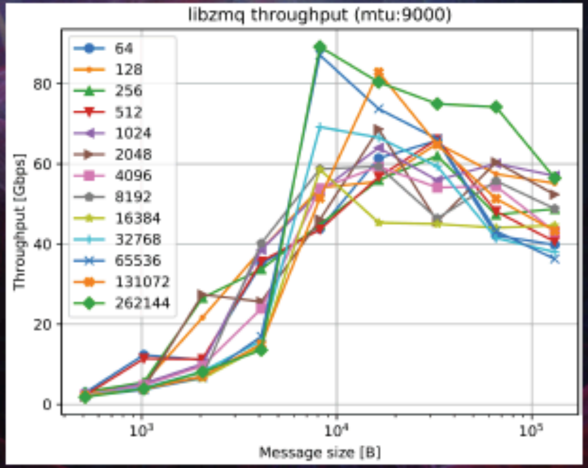
Testing the streaming RO concept using an EIC Cal PbWO prototype at DESY

sPHENIX proposal is testing Streaming RO architecture replacing the current triggered DAQ for the TPC and MVTX

Progress: BNL

- FVTX@PHENIX and eTOF@STAR already streaming in hybrid configuration
- ATLAS FELIX: 48x10GBps bi-directional interface card
- RCDAQ DAQ software
- SAMPA based streaming digitizer
- ZeroMQ-based streaming over 100 GbE + lossless data compression

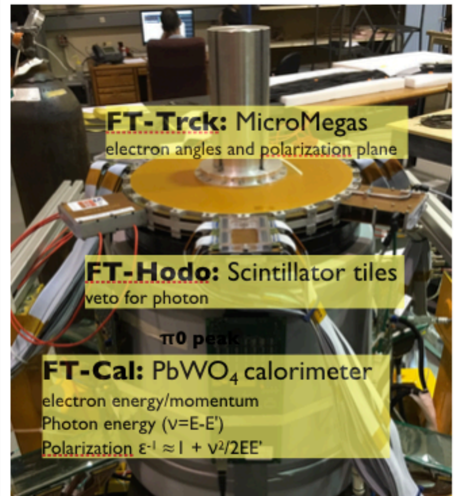


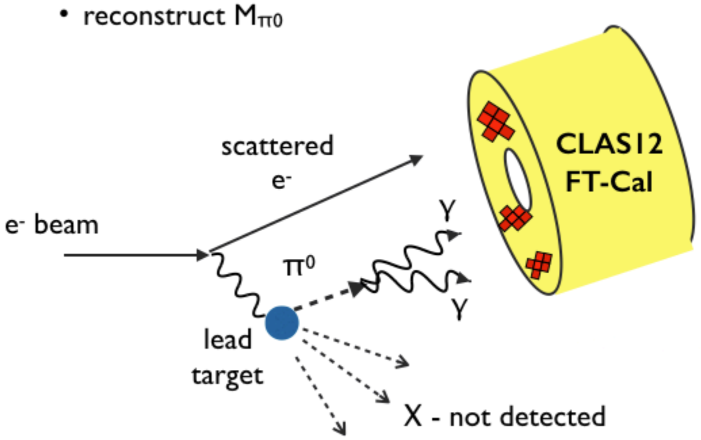


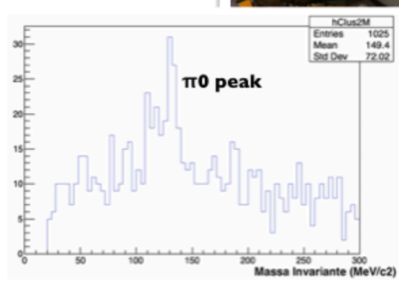
✴ Progress at Jefferson Lab

Streaming RO - CLAS12-FT tests

- SRO DAQ full chain test: FE + RunControl + Streaming ROsw + Rec
- On-beam test (10.4 GeV on lead target) in Jan/Feb 2020
- Hall-B CLAS12 Forward Tagger: Calorimeter + Hodoscope + Tracker
- This test:
  - FT-Cal only
  - 332 PbWO crystals (APD)
  - 10+12 fADC250 boards + 2 VTPs (in 2 crates/ROCs)
- Goal:
  - collect data with 1-2-3 clusters in FT-CAL
  - Identify the reaction e Pb → (X) e' π^0 →(X) e' γ γ
  - reconstruct $M_{\pi 0}$







double-clusters (π0) mass obtained from FT-Cal RG-A data fed to TRIDAS

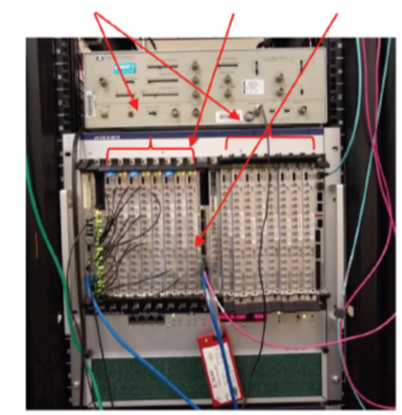
Streaming RO - CLAS12-FT tests

Front-End: fADC250 VTP | SRO SW TRIDAS | Online REC JANA2 | RunControl CODA

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

Streaming FADC250 Setup

16x FADC250 Modules -> VTP -> 2x 10Gbps Ethernet -> PC



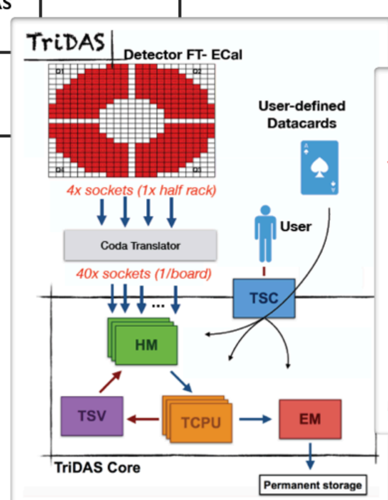
Pretty much the same configuration FADC250 present throughout much of Hall B already

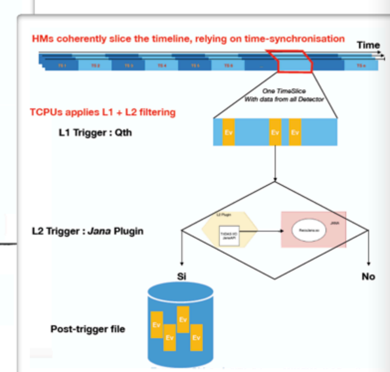
- Peak data rates ~150MBytes total (from both VTPs)
- Current VTP limit ~2GByte/sec
- Max: 10GBytes/sec
- VTP 10GbE ethernet links showed stability problems,
- TCP/IP stack found to be responsible
- Working on fixing it

Streaming RO - CLAS12-FT tests

Front-End: fADC250 VTP | SRO SW TRIDAS | Online REC JANA2 | RunControl CODA

TRIDAS
T.Chiarusi, C.Pellegrino



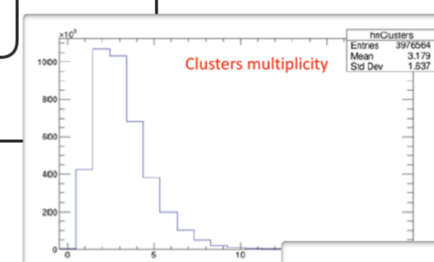


- TriDAS installed on Hall-B cluster
- Tested on multiple CPU: clonfarm1,2,3 and clondaq 4,5,7
- FT-Cal rate: 20-30 MHz
- Few hot-channels > 1 MHz

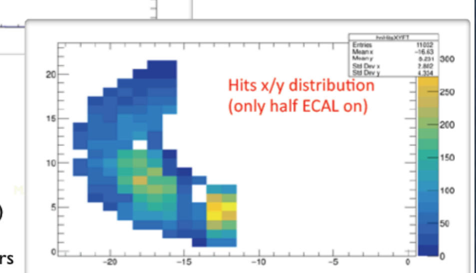
Streaming RO - CLAS12-FT tests

Front-End: fADC250 VTP | SRO SW TRIDAS | Online REC JANA2 | RunControl CODA

JANA2 + REC
N.Brei, D.Lawrence,
M.Bondi', A.Celentano, C.Fanelli, S.Vallarino



- FE setup:
  - FT-Cal only
  - TET (on fADC250)=15/50,
  - L1 threshold: 2000 (MeV)
  - L1 timme window: 400 ns
- Tridas+JANA2+monitoring
- JANA2:
  - single-thread
  - L2 plugins: scaler (write all L1 to disk) + JANA2 (tag L1 events)
  - Online clustering enabled
  - Different runs taken with >=1 cluster, >=2 clusters, >=3 clusters



✳ Network and software aspects

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

WS: Online/offline convergence

- Working together with eRD20 / EICUG Software WG
- Goal is to develop machine-detector interface (MDI) to machine-detector-analysis interface
- Integrate DAQ and analysis to have high level analysis available at data taking
  - For data verification
  - Data reduction / experiment optimization
- Discussed AI approaches

Open Systems Interconnection layers

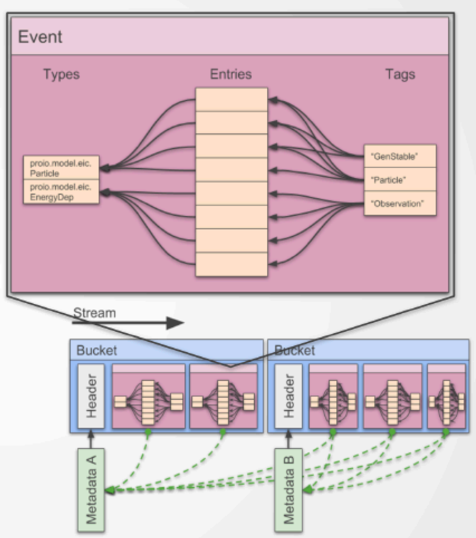
7 Layers of the OSI Model

Application	• End User layer • HTTP, FTP, IRC, SSH, DNS
Presentation	• Syntax layer • SSL, SSH, IMAP, FTP, MPEG, JPEG
Session	• Synch & send to port • API's, Sockets, WinSock
Transport	• End-to-end connections • TCP, UDP
Network	• Packets • IP, ICMP, IPSec, IGMP
Data Link	• Frames • Ethernet, PPP, Switch, Bridge
Physical	• Physical structure • Coax, Fiber, Wireless, Hubs, Repeaters

ProIO

- project for utilizing protobuf for HEP/NP in a language-neutral way
  - C++, Python, Go, and Java native libraries already implemented*
- supported by ANL LDRD and eRD20 (multi-lab EIC Software Consortium)
- based on pioneering work by Sergei Chekanov (ProMC) and Alexander Kiselev (EicMC)
- https://github.com/proio-org
- preprint available end of this week (contact me at dblyth@anl.gov for copy)

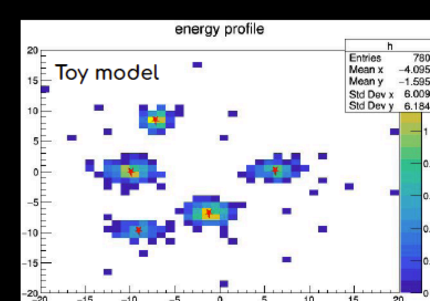
*Java implementation is currently incomplete, but read functionality is there

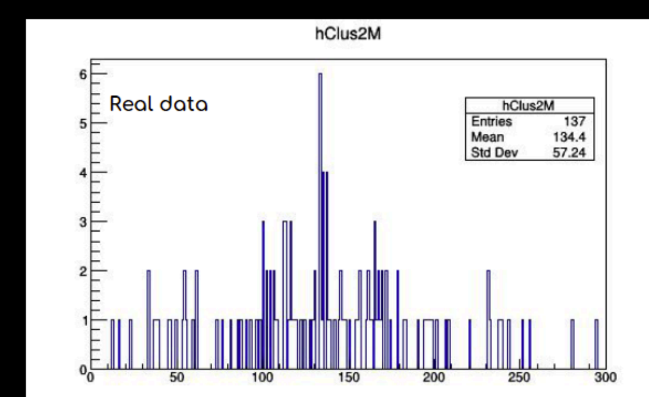


Exploring suitable I/O data format for data exchange in streaming-RO mode

Clustering

- Went through the academic exercise of implementing in the JANA-based reconstruction framework an (almost) unsupervised clustering algorithm
- The algorithm has been first tested on a toy model then used offline on real data (dataset provided by Gagik)



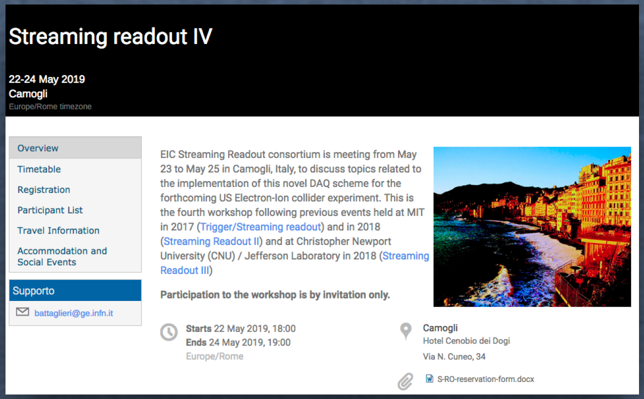


- Start seeing π^0 peak. Need more data.
- In the pipeline:
  - Reiterate with more stats (different datasets).
  - Compare to another clustering algorithm (underway)

- Hits are clustered based on x, y, t through a metric in that space
- Then the cluster observables are obtained weighting with the hit energy

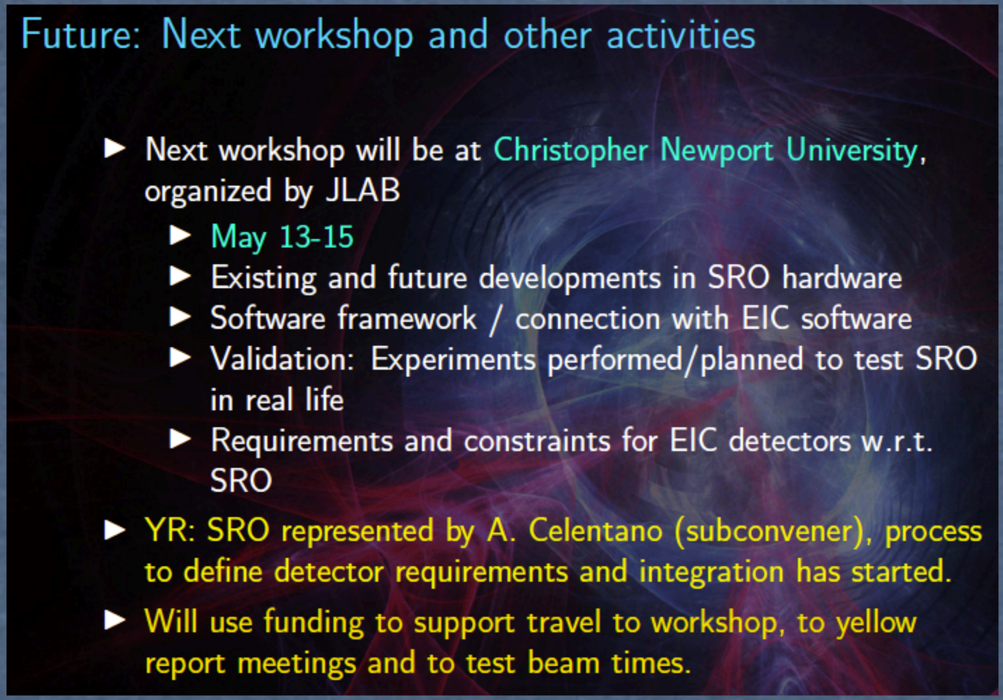
AI-supported algorithm for off-line and real time self-calibration

Conclusions and and plans



- ✳ 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
- ✳ A significant effort by the EIC scientific community is being put to
  - survey parallel streaming-RO projects
  - develop a suitable FE/RO electronics
  - validate the streaming RO scheme wrt triggered DAQ
  - define the software/networking framework

- ✳ Regular meetings are organised to discuss options and progress



We aim to include in CD1 detector design a (Streaming!) RO solution!