Streaming Readout, the JLab perspective

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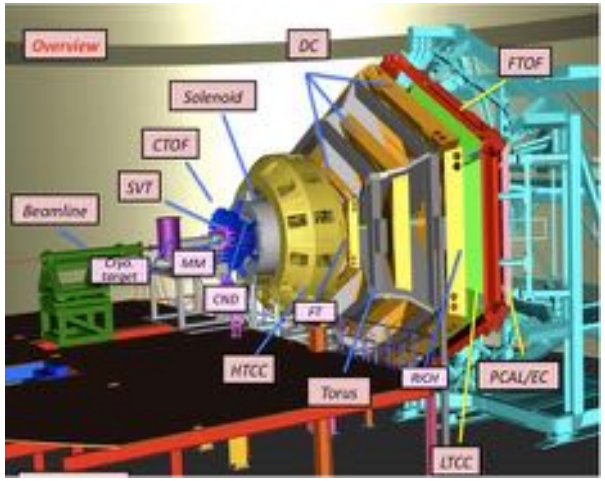
Introduction

- After the 12 GeV accelerator upgrade all four halls took production data in Spring of this year.
- The two large detectors, CLAS12 in hall-B and GlueX in hall-D are using very similar DAQ and trigger systems.

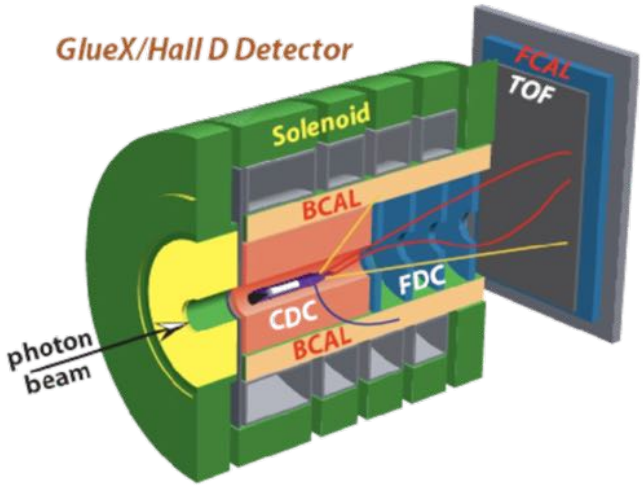
- We expect both DAQ system to evolve over the coming years.
- Other detectors are proposed for installation in hall-A over the next five years.

- This presentation will show :
  - The current state of the art at JLab.
  - Projects that we have planned for existing hardware.
  - Projects related to the proposed experiments.
  - Direction of future research and development.

Clas12/Hall B Detector



GlueX/Hall D Detector



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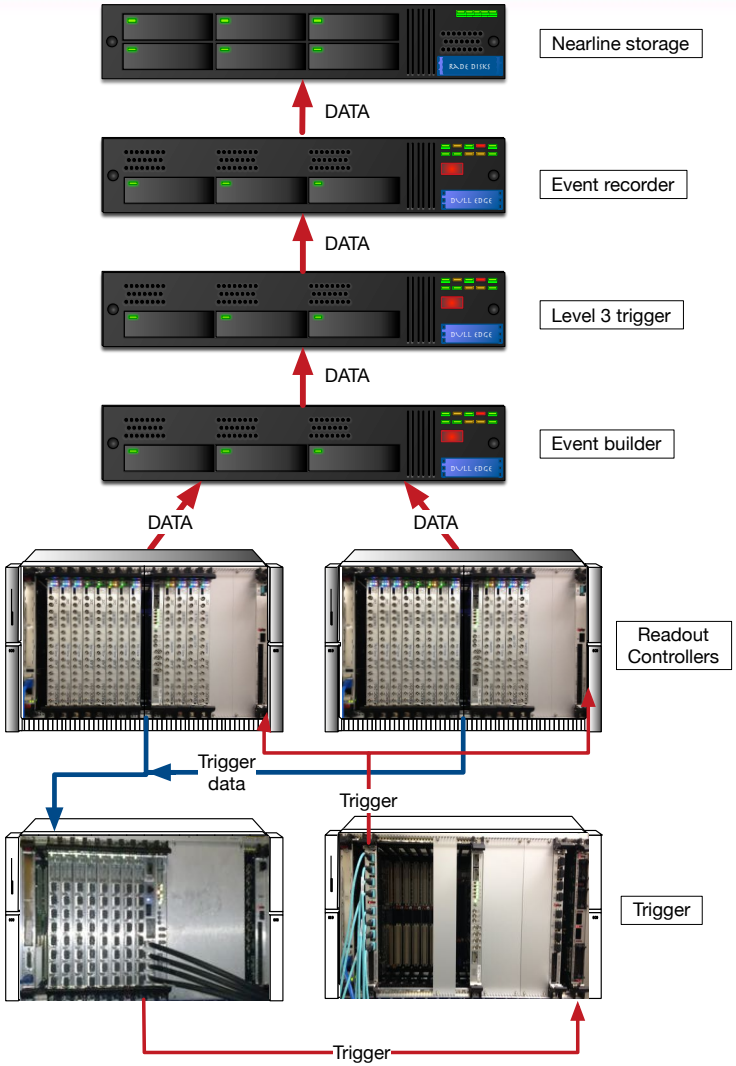
Data Acquisition at Jefferson Lab

- Custom and commercial electronics in VME format.
- We use ANSI/VITA 41 – VXS, a variant of VME.
  - Switched serial backplane.
- Crate Trigger Processor (CTP) in VXS switch slot generates crate level trigger decision.
  - Blocks of data queued in “pipeline” while trigger is made.
  - Trigger passed to global trigger via fiber.
- Global Trigger Processor (GTP) makes global trigger.
- Trigger Supervisor (TS) queues triggers, assigns event types, and distributes trigger back to crates.
- Readout the data over VME bus by Read Out Controller (ROC) on embedded CPU.
- Blocks of events sent over network to software Event Builder on Linux server.
- Buffer manager allows L3 software trigger and data quality monitoring.
- Event Recorder writes event blocks to disk.



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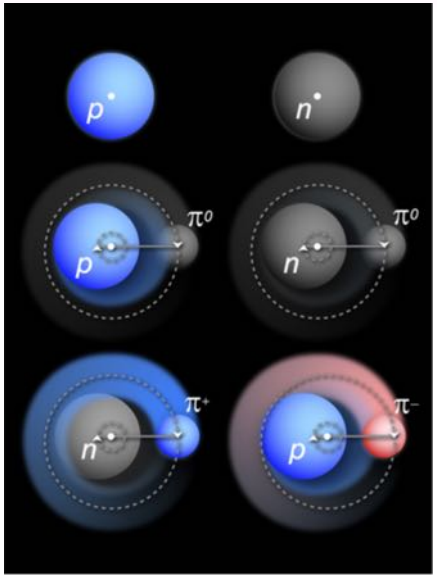
Why do anything different?

- Pros:
  - Data stream is a stream of events containing data from detectors.
  - Use of CTP and GTP allows complex triggers in firmware.
  - Trigger filters “unwanted data”.
  - Software event builder is scalable – buy faster machines – parallel topologies.
  - Data transport over network hardware – easy upgrade path.
  - Well understood way of doing things.
- Cons
  - Trigger pipeline and event building require strict online synchronization.
    - Have to delay prompt data until slowest data appears.
    - All parts of DAQ have to work. One failure stops the pipeline.
  - Relies on good understanding of trigger.
  - Doesn’t work well when events overlap in time.
  - **Obvious bottlenecks!**
  - Difficult to partition large detectors into independent systems – debugging, commissioning or some types of experiment.
  - Systems using “high end” crate based readout such as VXS are very expensive.
    - Buy-in problem for university collaborators

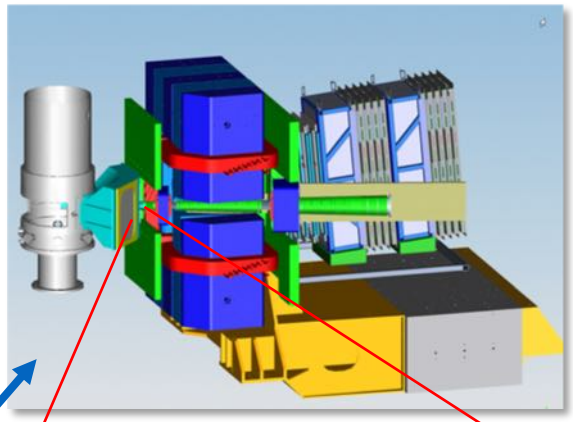
Future needs

- New experiments are being proposed
  - Detectors that do not play well together due to timing.
    - Traditional trigger and event builder strategies are not ideal.
  - Detectors with peculiar topologies.
    - Detectors split or segmented in a way that makes forming a trigger hard.
  - High event and/or data rates.
    - Particles from more than one event in a detector at the same time – need to disentangle.
- The data acquisition requirements of these experiments does not fit well with current techniques.

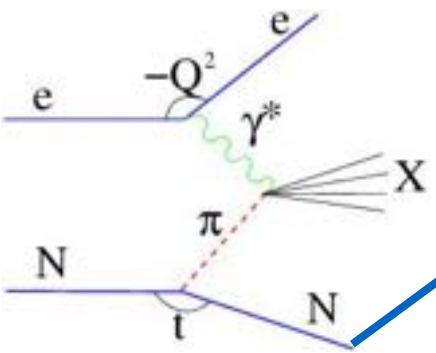
Tagged Deep Inelastic Scattering (TDIS)

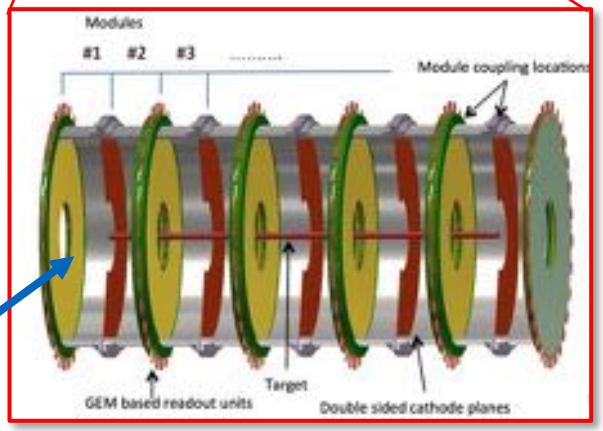


TDIS Scientific Goal: Access Elusive Partonic Structure of Mesons by Using Mesons in Nucleons as "Target"



- Scattered electrons detected in planned Hall-A Super Bigbite Spectrometer.
- "Spectator" protons detected by radial Time Projection Chamber (rTPC) with 25,000 pads.
  - Hit rate per pad ~800 kHz.
  - Up to 4 Gbyte/s total.





- How to read this out and match up the electrons with the protons?
- Event building online at these rates is a bottleneck.

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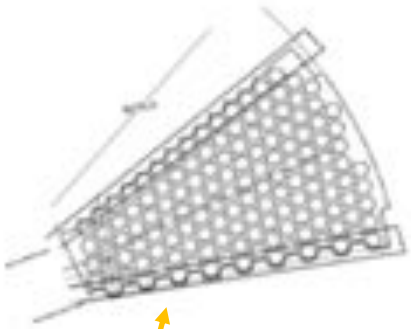
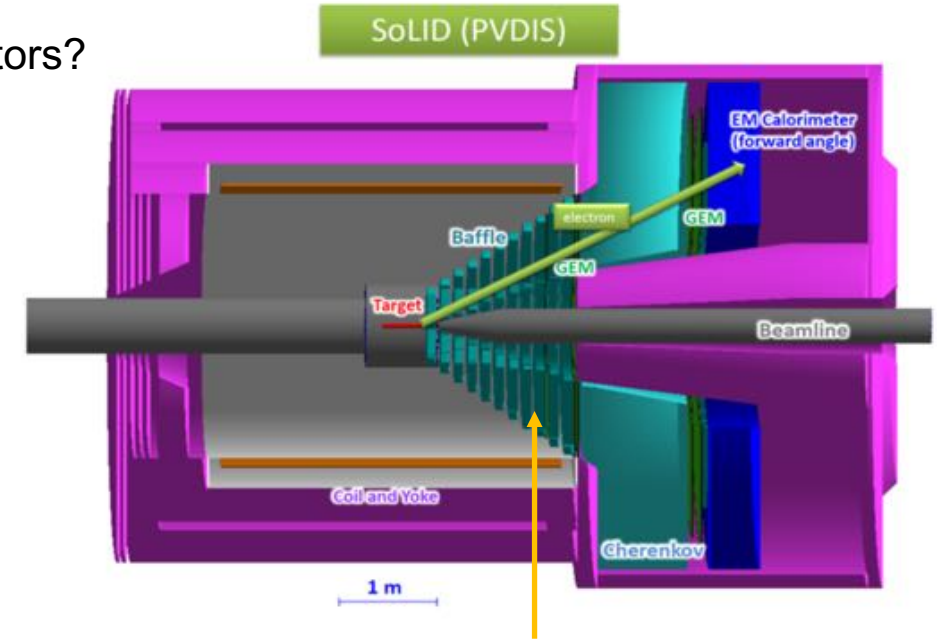
SoLID

- SoLID is another experiment proposed for installation hall-A at JLab.
- In the PVDIS configuration electrons are scattered of a fixed target at high luminosity.
- Spiral baffles cut background.
- The detector is split into radially 30 sectors, the single track event topology allows 30 DAQ systems to be run in parallel at rates of up to 1 Gbyte/s each 30 Gbyte/s total
- Challenges :
  - How to handle 30 Gbyte/s affordably?
  - Hits at sector edges span two sectors?
  - How to integrate GEM with other detectors?



GEM detectors are segmented into 30 sectors.



Baffles constrain momentum

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Streaming readout as a solution.

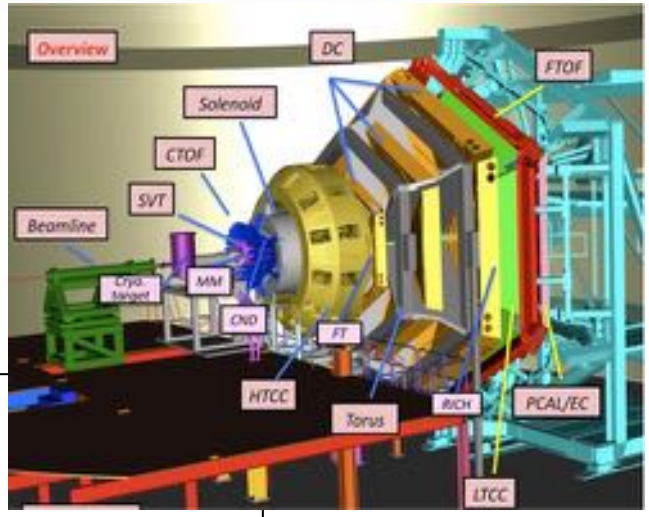
- High data rate detectors are handled as parallel streams.
  - No one stream handles all data from the whole detector.
- Data synchronization happens offline.
  - Removes high rate event building issue.
  - Detector edge effects dealt with offline.
  - Prompt data does not have to wait for slower detectors.
- Little or no online trigger.
  - Potentially useful physics is not discarded.
  - Groups of simultaneous experiments.
  - Complex trigger electronics eliminated – simpler system
  - Zero and noise suppression is still a requirement.

Projects

- We are starting to work on several pilot projects to gain experience with streaming mode readout and to put it in use in some experiments.

CLAS12 - RICH

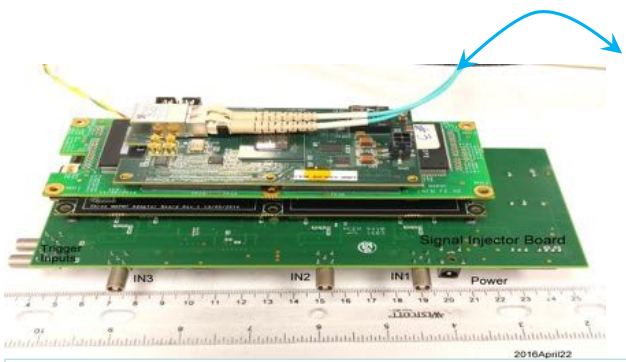
- CLAS12 is a general purpose detector with a lot of subdetectors.
- RICH detector is read out via fiber to Sub-System Processor (SSP) boards in VXS crates.
- Same setup is used by GlueX DIRC.



- **RICH (CLAS12) and DIRC (GlueX) examples**
  - **ALL FPGA boards have been tested(Completed in May 2016)**
  - **Production ASIC board(s) [2-MAROC and 3-MAROC] completed**
  - **Detector final assembly is ongoing**

391 -- H12700 Hamamatsu
64-anode PMT
Total anodes: 25,024

32 LC Fiber Links



On Board 192 channel FPGA Readout Board
MAROC3 ASIC mates to maPMT
Artix 7 FPGA drives LC fiber optic transceiver

VXS Sub-System Processor
32 - 2.5Gbps links to RICH
FPGA Readout Boards

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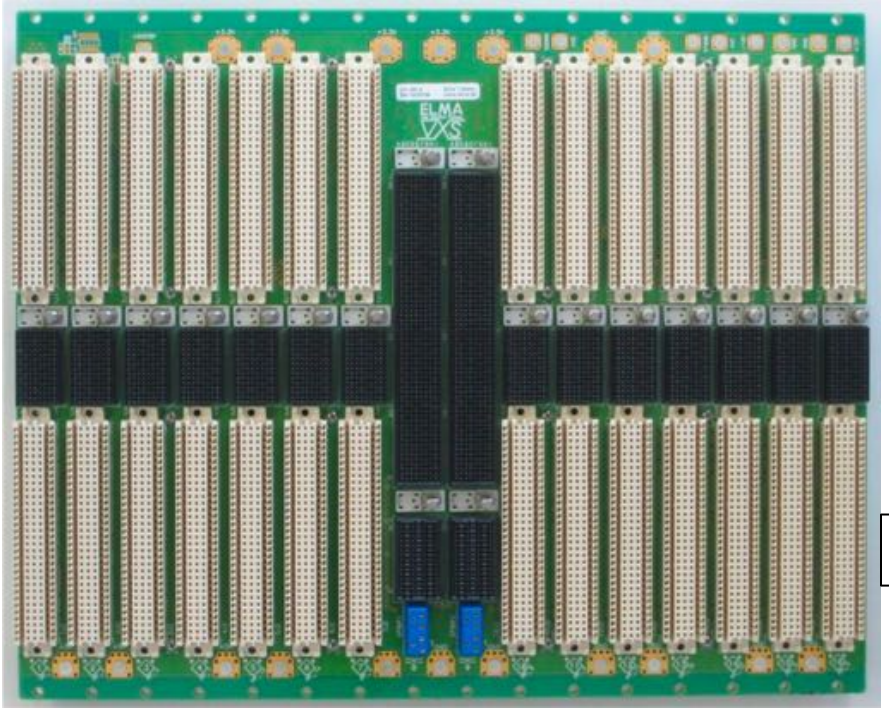
SSP Closeup

- Front panel has 32 x 2.5 Gb/s fiber links.
- VXS connector links to serial lines on backplane (~20 Gb/s).
- VME interface (~1.6 Gb/s).
- Rely on low occupancy, buffering and data processing to match rates.

- DIRC readout – data comes in on fiber and is read out over VME.
- Per-crate data density is limited by VME backplane bandwidth.

Sub System Processor (SSP)



VXS Backplane

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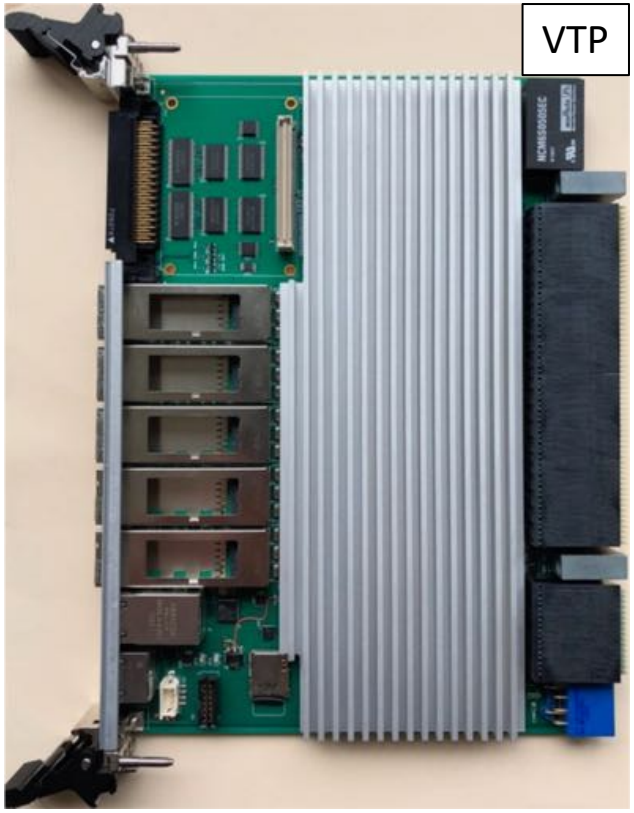
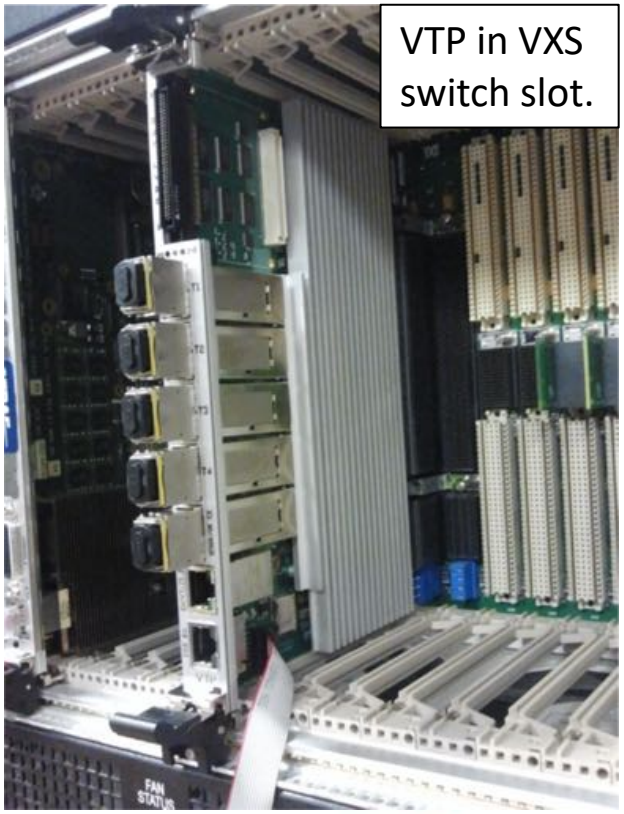
CLAS12 – RICH and GlueX DIRC

- A new generation of CTP, the VTP, can read out a crate over VXS ~10x faster than VME.
- Project : Read out RICH using VTP.
  - Data from front end over fiber to SSP –> 32 x 2.5 Gb/s = possible 80 Gb/s per SSP
  - SSP to VTP over VXS backplane –> 20 Gb/s –> need to reduce by factor of 4 in SSP.
  - VTP output over fiber on front panel – bottom of the five fibers is 40 Gb/s -> reduce by 5 in VTP.





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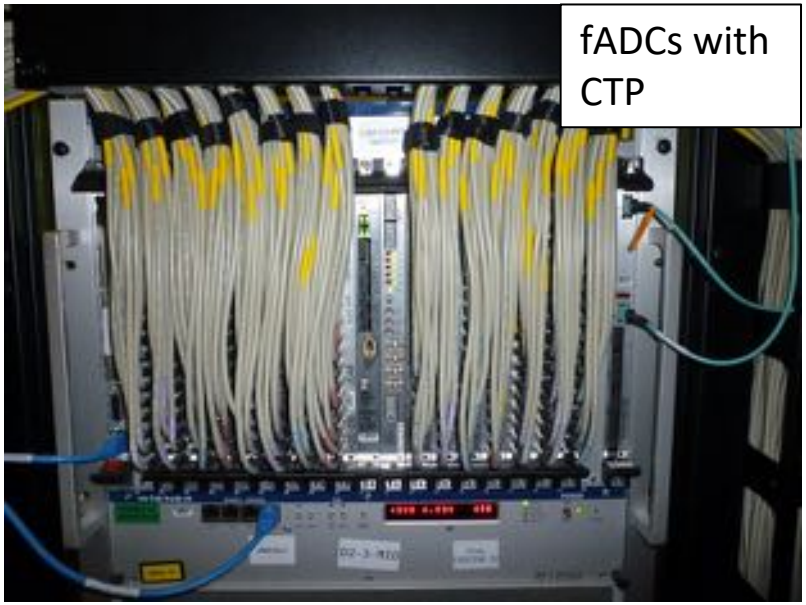
fADC readout

- CLAS12 and GlueX are instrumented with 250 MHz fADCs in VXS.
  - Read over VME.
  - CTP only used for trigger.

- Project : Swap the CTP for a VTP.
  - Read fADC to VTP over VXS serial.
  - Send data from VTP over front panel fiber.



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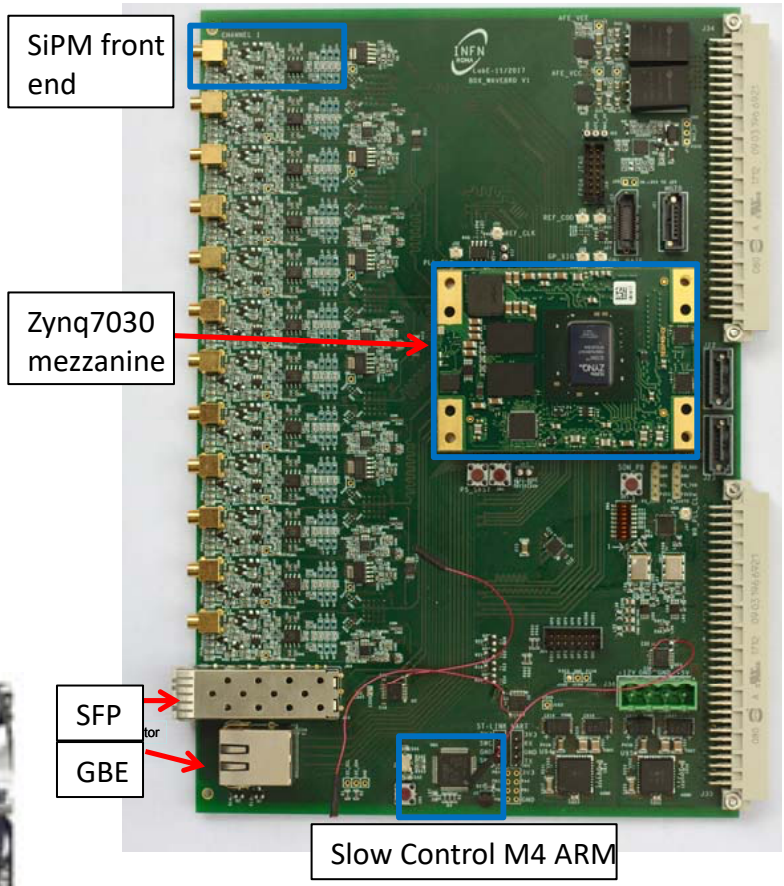
INFN – low cost ADC board

- 12-channel board
- Configurable:
  - 12-bit 65 MHz to
  - 14-bit 250 MHz.
- Application - BDX at JLab.

- Project: Reprogram Zynq7030 to match protocol expected by SSP front panel fiber inputs.



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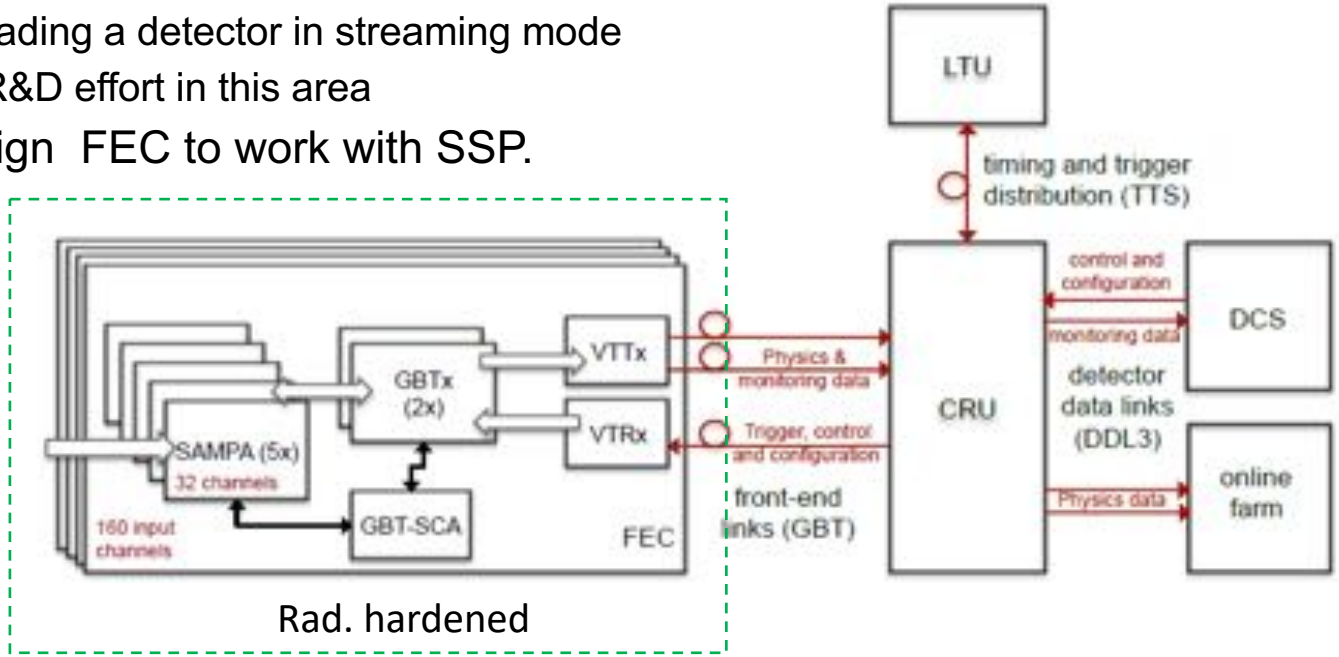
JLab TDIS TPC test stand using SAMPA

- **Fast Track test stand**– use as many components of the ALICE TPC readout/control chain as possible
- Target test stand operational July 1st 2018
  - Validate use of SAMPA for TDIS
  - Experience reading a detector in streaming mode
  - Guide future R&D effort in this area
- Project : Redesign FEC to work with SSP.



FEC – Front End Card
CRU – Common Readout Unit
DCS – Detector Control System
LTU – Local Trigger Unit

Goal – common system architecturefor TDIS and SoLID.

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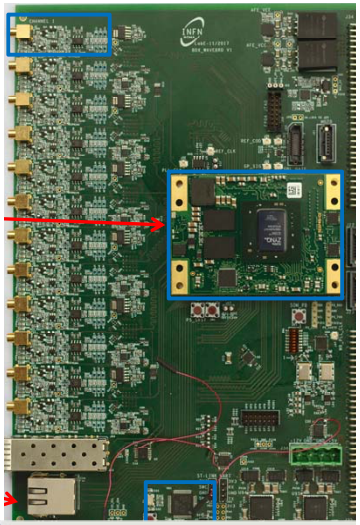
Where to go next - hardware

- Currently we have several hardware components that are suitable for use in a streaming system.
- In this mode we have a system where the VME bus is no longer used for data.
- Data output is to a fiber based network
- If we can also configure via the fiber network then..

- We no longer need a bus at all…

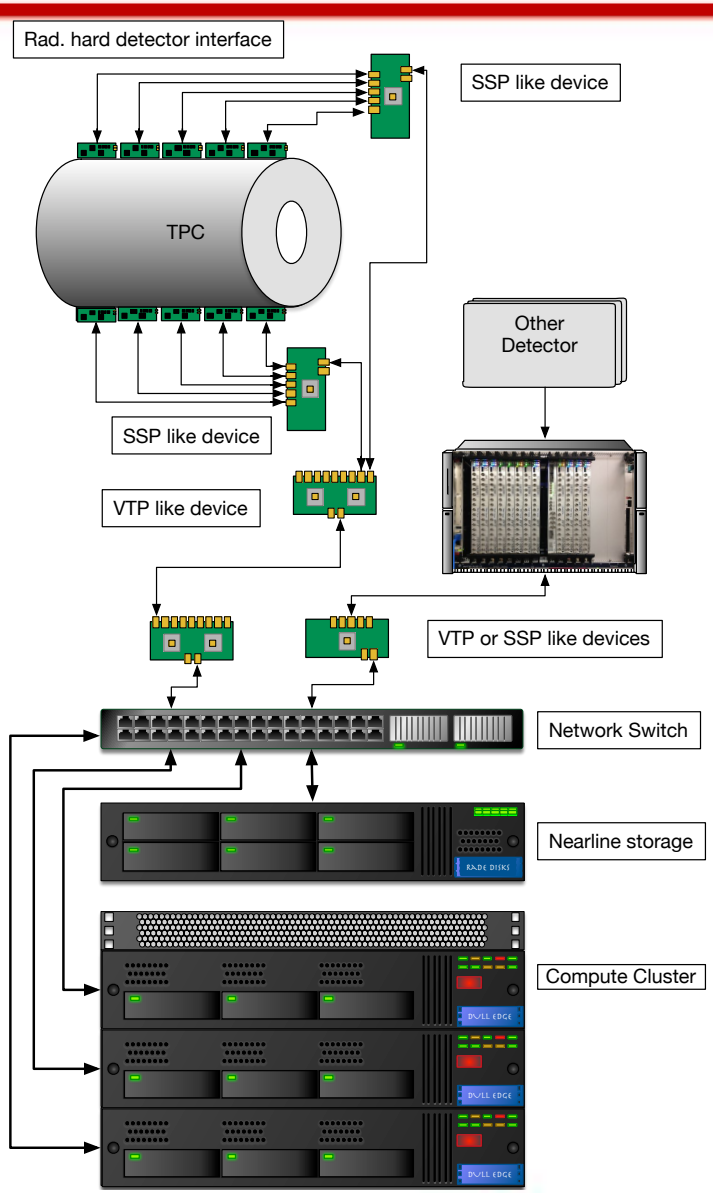


All streaming DAQ

- The projects in the previous few slides are hardware solutions that can operate in either traditional or streaming mode.

- We intend to use these projects to gain insight that will be used to:
  - Refine the hardware, firmware and software.
  - Aid detector design.
  - Suggest future directions.

- In an “all streaming DAQ” detectors have detector specific interfaces which stream data on a fiber with a **well defined protocol**.
- Devices similar to the VTP and SSP take the data streams and :
  - Merge streams to reduce number of fibers.
  - Provide buffering to take advantage of occupancy.
  - Reformat or compress to reduce rate.
  - Zero and noise suppress.
  - Provide online monitoring and calibration.
  - Not necessary in all situations.
- If all devices use **the same protocol** on the fiber then we have a plug and play kit of parts each of which is relatively inexpensive.



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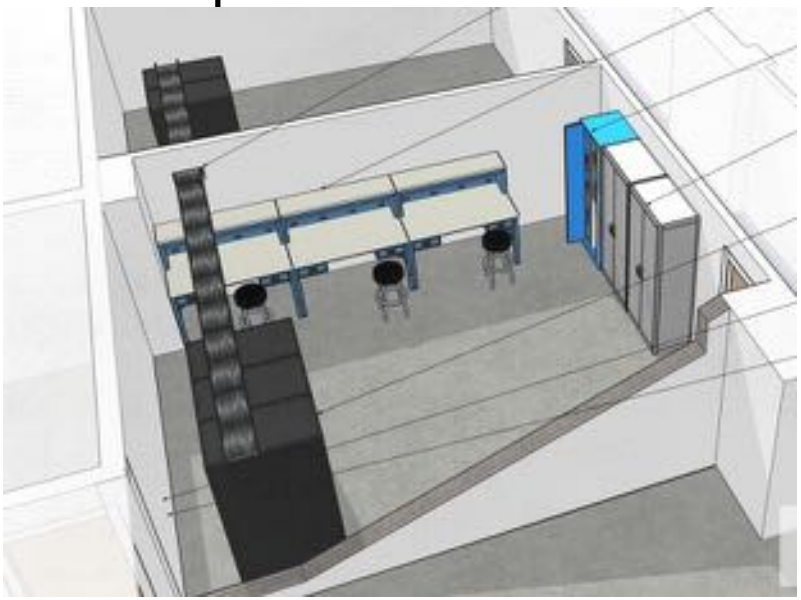
Facility for Innovation in Nuclear Data Readout and Analysis (INDRA)

- Having a bunch of interesting projects is all well and good but progress would be speeded by having a dedicated facility for R&D.
  - Semi-permanent test stands without having to borrow hardware.
  - Proximity to existing data acquisition lab.
  - Proximity to JLab datacenter.
- Have acquired space and modifications for power etc. are underway.
- Procurement of hardware will start soon.



Summary

- Jefferson lab has electronics that were designed for use in traditional triggered readout.
- With firmware modification these boards could be used in a streaming mode.
- Several projects will enhance the triggered mode readout to the point where it can be flipped into streaming mode.
- Operating in this mode we can find out what the critical parameters are for the design of the next generation of electronics.
- We have several customers lined up to use this.
- The goal is to increase flexibility and reduce cost – in particular for university collaborators.
- Our experience should be very useful to the EIC detector readout community.