Streaming data acquisition system for CLAS12 Forward Tagger

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CLAS12 @ JLAB

- Installed at Jefferson Lab’s experimental HALL-B
- Expansive program of physics topics:
  - investigation of the structure of the proton and neutron both in their ground state, as well as their many excited states
  - searches for exotic meson and baryon configuration
  - ...
  - ....
Streaming RO

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
Streaming RO-CLAS12 FT tests: triggerless daq chain
Streaming RO – CLAS12 FT tests:

- **On-beam tests:**
  - Run 1:
    - 10.4 GeV electron beam on thin Pb target in Jan/Feb 2020
    - no Moeller cone, thin target, FT-CAL
  - Run 2:
    - 10.4 GeV electron beam on H2 and D2 targets in Aug/Sept 2020
    - Moeller cone, longer target, FT-CAL + FT-HODO

- **Hall-B CLAS12 Forward Tagger: Calorimeter + Hodoscope**
  - FT-CAL: 332 PbWO4 crystals (APD)
    - 10 +12 FADC250 boards + 2VTPs (in 2 crates/ROCs)
  - FT-HODO: 232 scintillator tiles (SiPM)
    - 15 FADC250 boards
  - FT-Tracker: MicroMegas

- **SRO DAQ full chain:** FE + RunControl + Streaming ROsw + Rec
Goal:
- Study RO performance: memory + cpu use, trigger efficiency, ...
- Identify the reaction: $e^- \text{H/D2/Al/Pb} \rightarrow (X) e^- \pi^0 \rightarrow (X) e^- \gamma \gamma$
- SRO system vs trigger DAQ

As a reference, data taken both in “triggered” and SRO mode
Streaming RO – CLAS12 FT tests: FrontEnd

D. Abbott, F. Ameli, C. Cuevas, P. Musico, B. Raydo
Streaming RO – CLAS12 FT tests: CODA

Cebaf Online Acquisition (CODA):
- Designed for trigger readout system
- The Event Builder (EB) collects data from 100+ Readout Controllers and VTP
- The trigger Supervisor (TS) synchronizes components using clock, sync, trigger, busy signal

CODA adapted to SRO mode
- EB replaced with new SRO component and back-end software capable of gluing ROC information based on timestamp instead of event number
- ROCs not send data on VME bus (only initial configuration)
- Readout performed by VTP boards over serial lines
- 20GBit/s per crate (up to 40 Gbit/s if needed)
Trigger and Data acquisition system (TRIDAS)

- originally develop for KM3-NET
- FT rate : 20-30 MHz
- Input data rate : ~50MB/s
- Output data rate: ~4MB/s
- Test performed with different parameters (FE-thresholds, HM, L1 thresholds,..)

- L1 plugin:
  - at least one crystal with energy > 2 GeV
JANA2

- L2 plugings (tagging and filtering)
  - "standard" FT-CAL clustering (Ncluster>=1,2,3)
  - cosmic tracking
  - AI clustering algorithm: at least two cluster in the FT-CAL
- Read TRIDAS file.pt for offline analysis
- Offline algorithm development immediately available for use in Software Trigger
- Strong integration between online and offline

TriDAS + JANA2

- JANA2: C++ framework
  - Full event reconstruction
    - Calibrations
    - Translation table
    - Multi-threading
  - Software trigger
    - Summed energy threshold
    - Single/Double cluster
    - Coincidence FT + FH
    - Prescale
  - Trigger decisions recorded in output stream

https://jeffersonlab.github.io/JANA2/
Streaming RO – CLAS12 FT tests: Run 1 Data analysis

- Run 1: 10.4 GeV electron beam on thin Pb target in Jan/Feb 2020
- offline analysis focused on identification of π0→γγ events
- offline reconstruction performed by applying the same full suite of reconstruction algorithm used in the on-line reconstruction.
- Energy calibration and time-walk correction

M. Bondi’, A. Celentano, S. Vallarino

- SRO data behaves as expected (Nclusters, XYclusters, ΔT,...)
Streaming RO – CLAS12 FT tests: Run 1 Data analysis

- Run 1: 10.4 GeV electron beam on thin Pb target in Jan/Feb 2020
- Offline analysis focused on identification of π0→γγ events
- Offline reconstruction performed by applying the same full suite of reconstruction algorithm used in the on-line reconstruction.
- Energy calibration and time-walk correction

- Peak at higher mass is associated to π0 production from Pb target
- Peak at lower mass is related to π0 production from Al target window
  - Lower invariant mass due to the assumption that the vertex is located at the Pb target position when calculating the invariant mass.

RUN 2 data analysis in progress

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Streaming RO – CLAS12 FT tests: Run 1 Data analysis (AI – supported)

- Run1: off-line only
- Run2: real-time

C. Fanelli

- Implementation of AI supported L2 reconstruction algorithms for SRO: offline and online tests accomplished
- Unsupervised (no cuts required) hierarchical clustering generally robust against variations in experimental conditions
- AI tolerates larger hits multiplicities
Summary

- Streaming Readout on-beam tests performed using the CLAS12-FT at JLAB
- The full chain (FT + SRO sw + ON-LINE REC) tested with exiting hw
- Data taken in full streaming mode, analysis in progress (traditional and AI-supported)
- Analysis was able to extract a clean physics signal in the form of a $\pi^0$ invariant mass peak
- The prototype system is being used as the basis for developing a larger system planned for the entire CLAS12 detector and its future physics program

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