Streaming data acquisition system for CLAS12 Forward Tagger

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Mariangela Bondì
INFN - Sezione di Genova

Farnesina
Ministero degli Affari Esteri
e della Cooperazione Internazionale

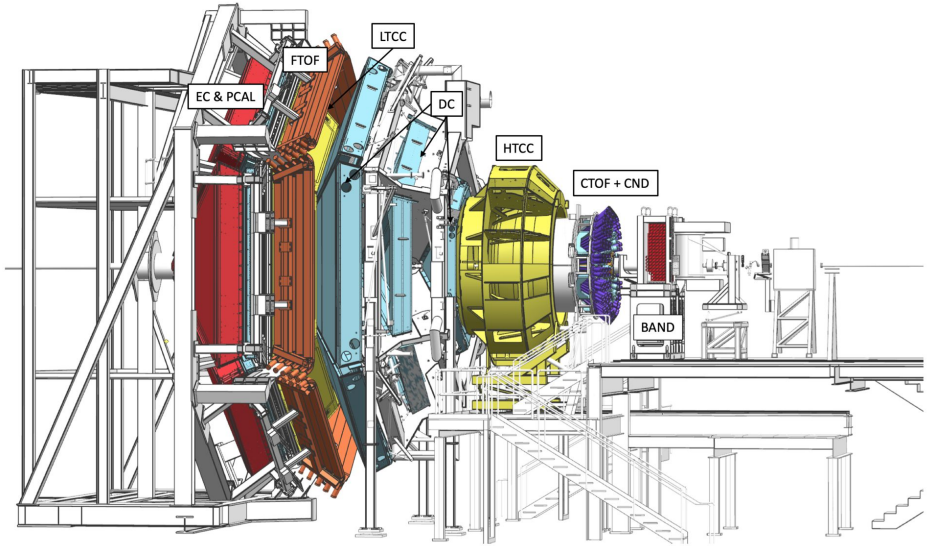
INFN
Istituto Nazionale di Fisica Nucleare

Jefferson Lab

CPAD Instrumentation Frontier Workshop 2021

CLAS12 @ JLAB

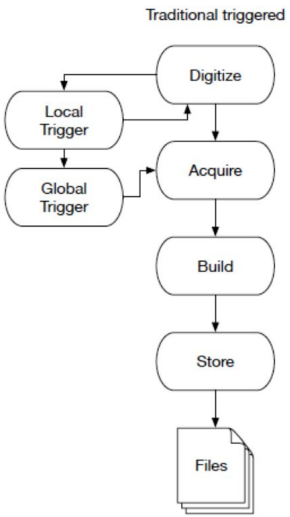
- Installed at Jefferson Lab's experimental HALL-B
- Expansive program of physics topics:
  - investigation of the structure of the proton and neutron both in their ground state, as well as their many excited states
  - searches for exotic meson and baryon configuration
  - …
  - ….



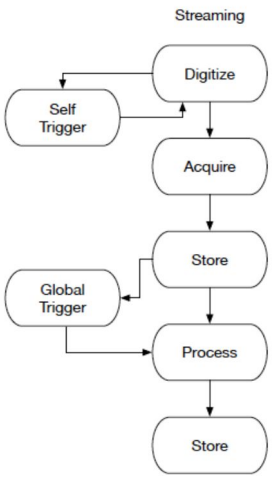
Streaming RO

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



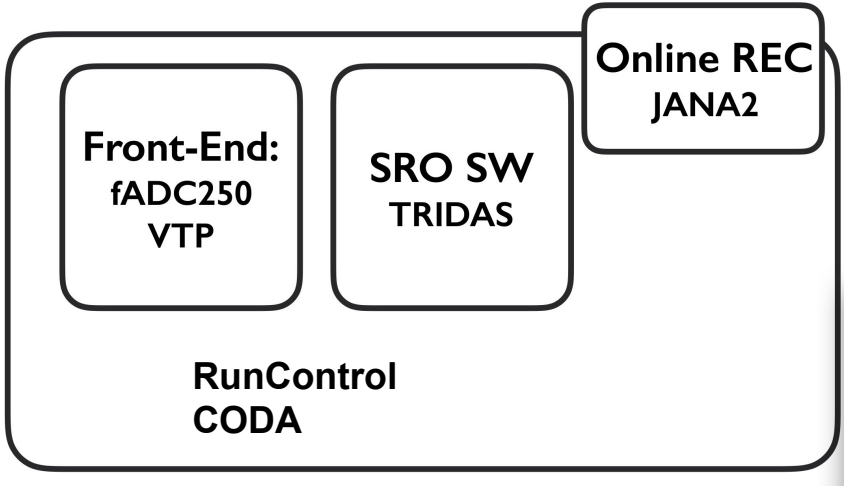
Streaming readout



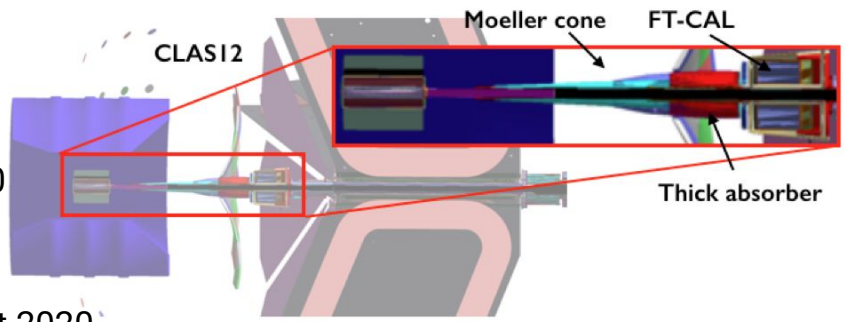
- All channels continuously measured and hits streamed to a HIT manager (minimal local processing) with a time-stamp
- A HIT MANAGER receives hits from FEE, order them and ship to the software defined trigger
- Software defined trigger re-aligns in time the whole detector hits applying a selection algorithm 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

M.Battaglieri - JLAB

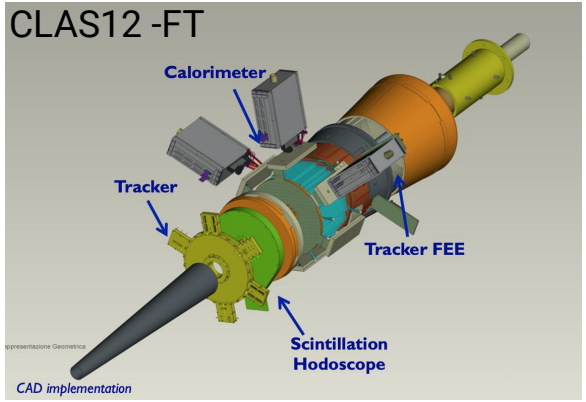
Streaming RO-CLAS12 FT tests: triggerless daq chain



Streaming RO - CLAS12 FT tests:



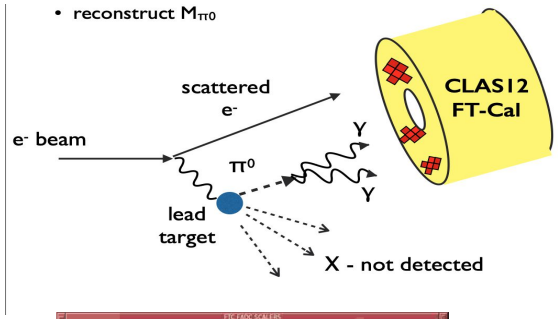
- **On-beam tests:**
  - Run 1:
    - 10.4 GeV electron beam on thin Pb target in Jan/Feb 2020
    - no Moeller cone, thin target, FT-CAL
  - Run 2:
    - 10.4 GeV electron beam on H2 and D2 targets in Aug/Sept 2020
    - Moeller cone, longer target, FT-CAL + FT-HODO
- **Hall-B CLAS12 Forward Tagger: 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**

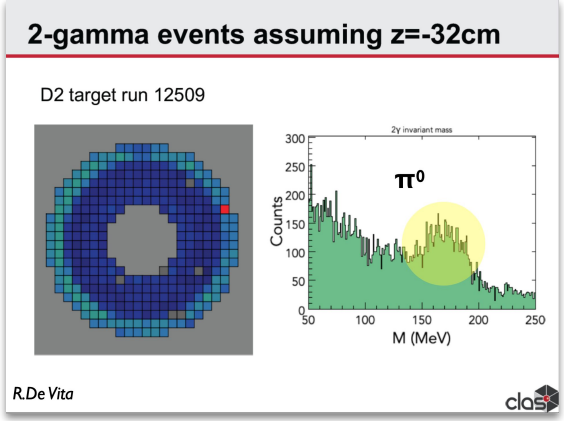


Streaming RO - CLAS12 FT tests:

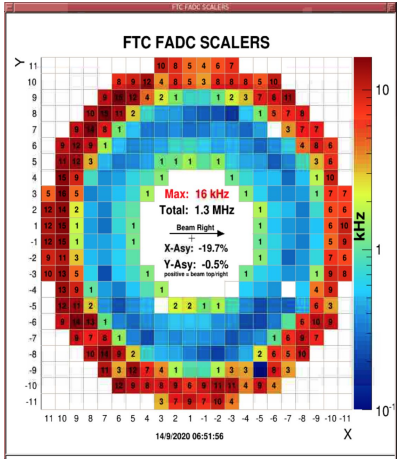
Goal:

- Study RO performance: memory + cpu use, trigger efficiency, …
- Identify the reaction :
  e- H/D2/Al/Pb -> (X) e- π0 -> (X) e- γγ
- SRO system vs trigger DAQ



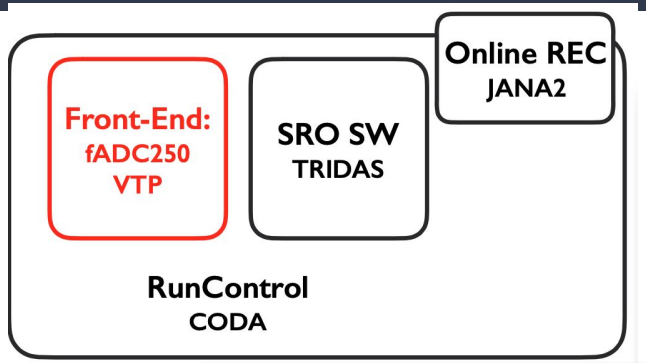


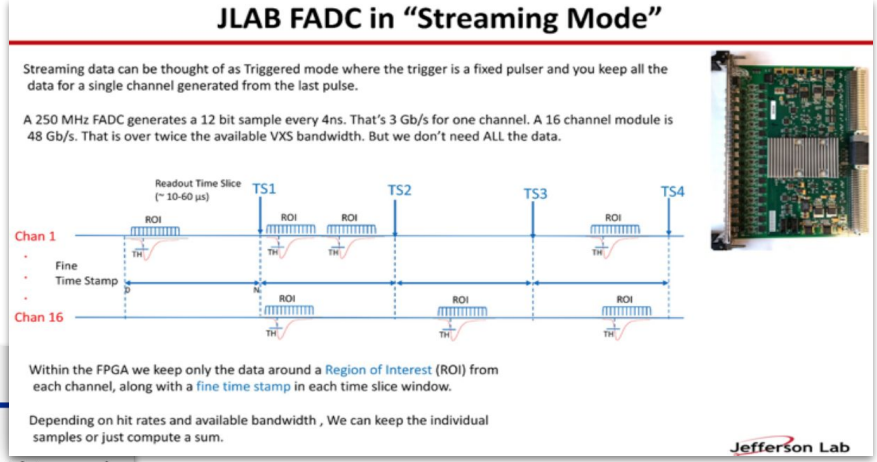
As a reference, data taken both in “triggered” and SRO mode

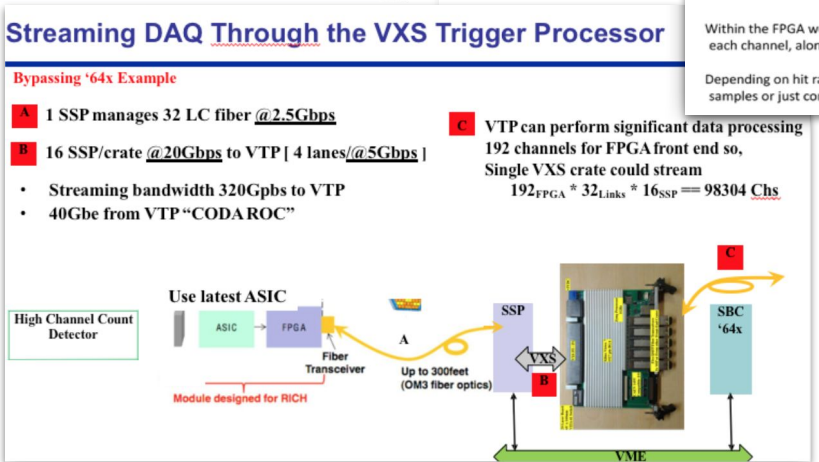


On-line scalers during run2

Streaming RO - CLAS12 FT tests: FrontEnd

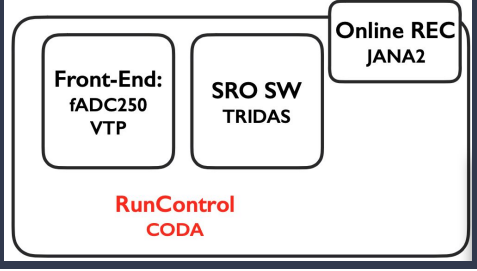






D. Abbott, F. Ameli, C. Cuevas, P. Musico, B. Raydo

Streaming RO - CLAS12 FT tests: CODA



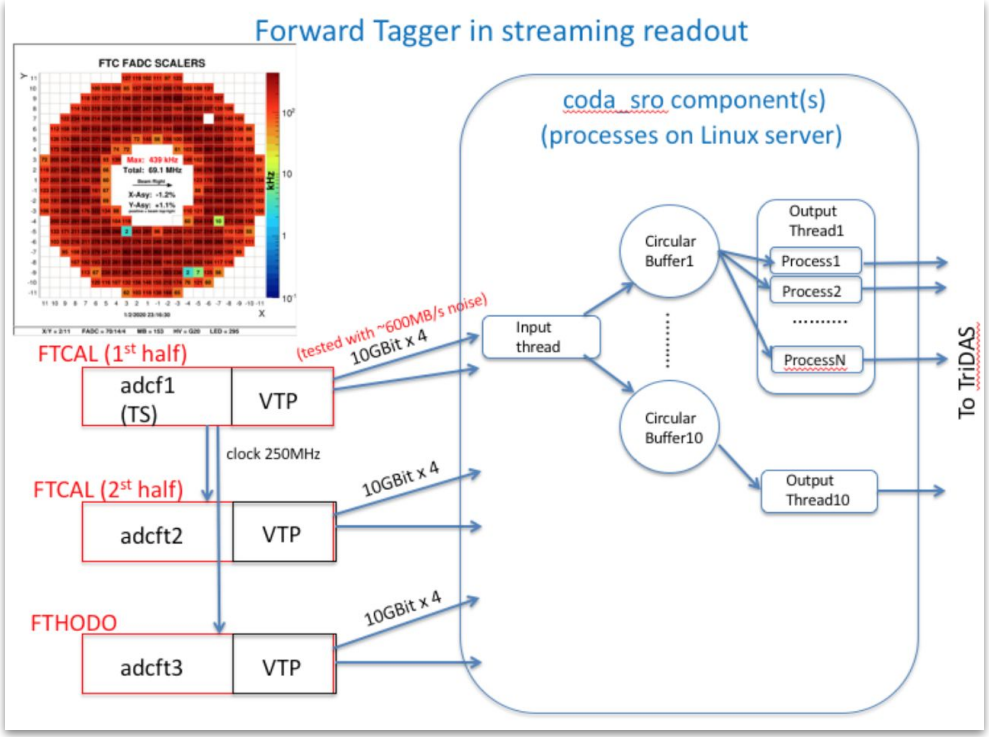
S. Boyarinov, B. Raydo, G. Heyes

Cebaf Online Acquisition (CODA):

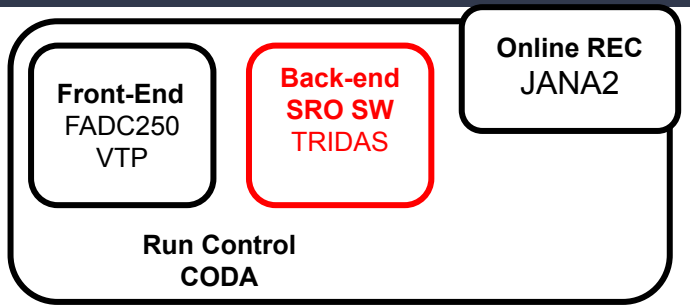
- Designed for trigger readout system
- The Event Builder (EB) collects data from 100+ Readout Controllers and VTP
- The trigger Supervisor (TS) synchronizes components using clock, sync, trigger, busy signal

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)



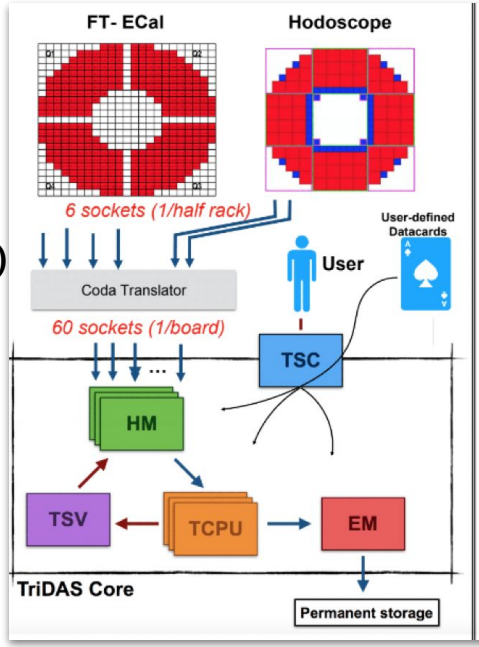
Streaming RO - CLAS12 FT tests: TRIDAS

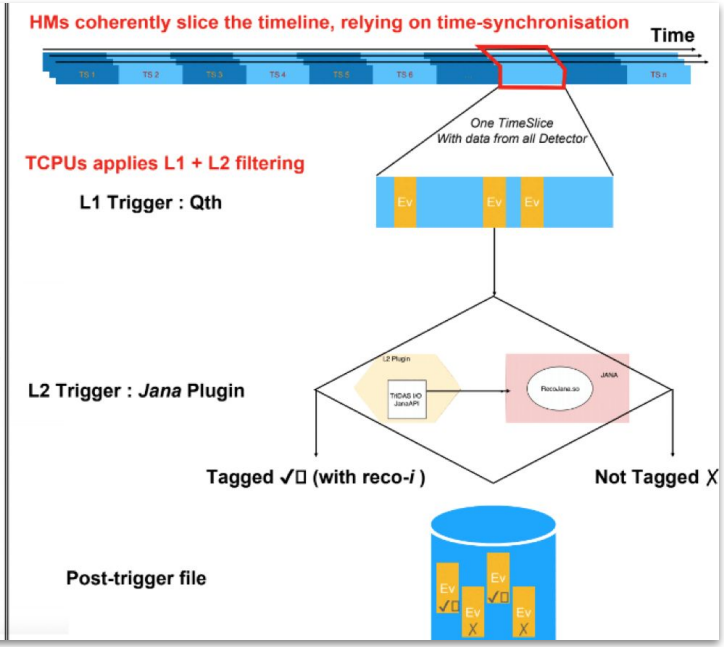


T. Chiarusi, C. Pellegrino

Trigger and Data acquisition system (TRIDAS)

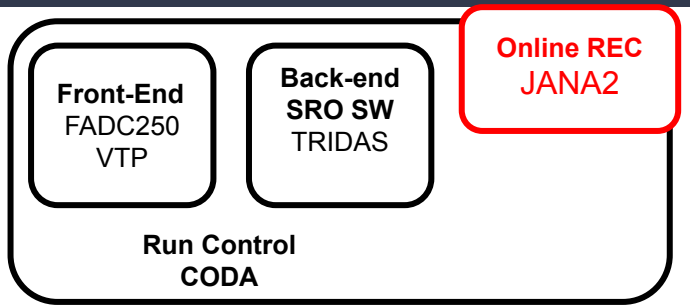
- originally develop for KM3-NET
- FT rate : 20-30 MHz
- Input data rate : ~50MB/s
- Output data rate: ~4MB/s
- Test performed with different parameters (FE-thresholds, HM, L1 thresholds,..)



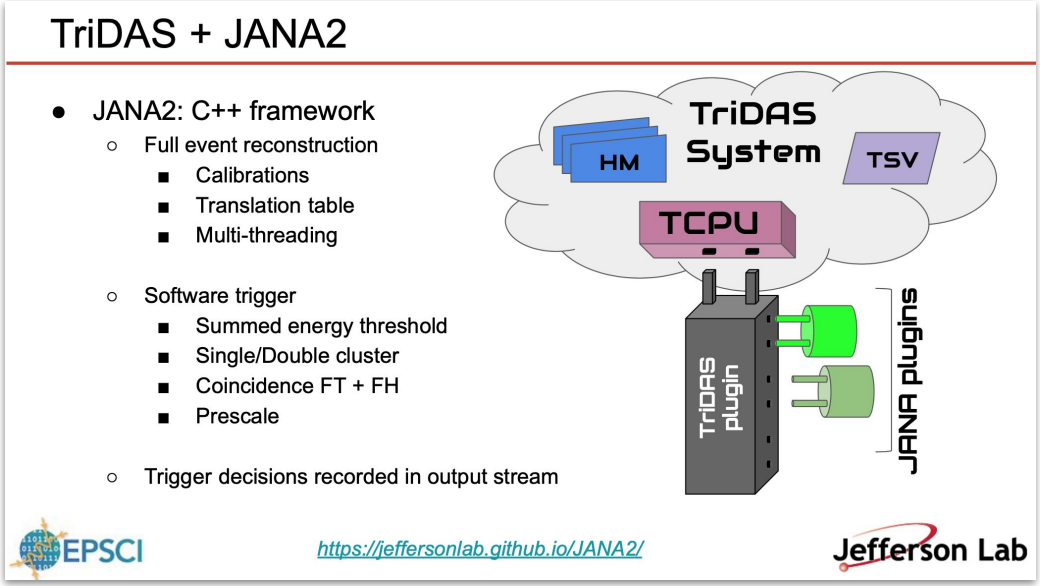


- L1 plugin:
  - at least one crystal with energy > 2 GeV

Streaming RO - CLAS12 FT tests: JANA2 + Rec



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



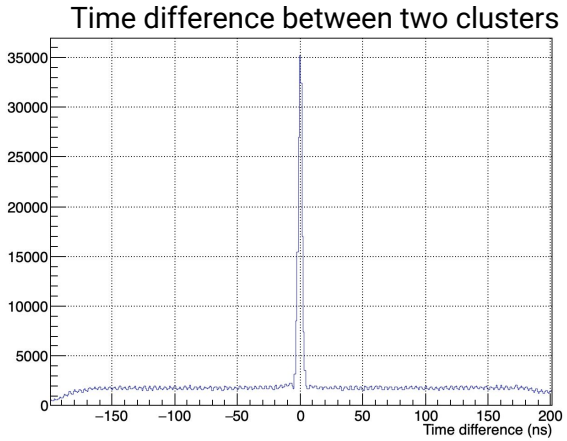
JANA2

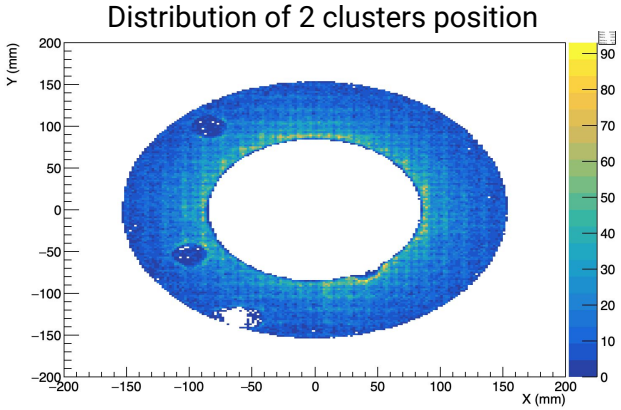
- L2 plugings (tagging and filtering)
  - "standard" FT-CAL clustering (Ncluster>=1,2,3)
  - cosmic tracking
  - AI clustering algorithm: at least two cluster in the FT-CAL
- Read TRIDAS file.pt for offline analysis
- Offline algorithm development immediately available for use in Software Trigger
- Strong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

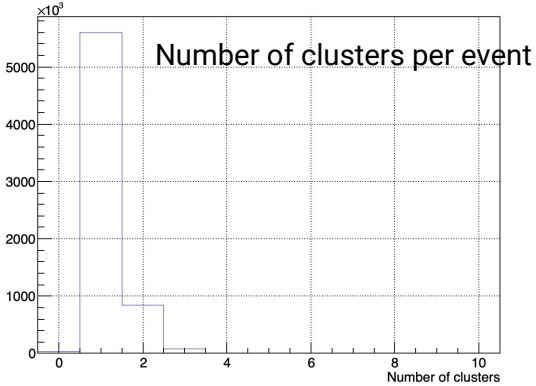
Streaming RO - CLAS12 FT tests: Run 1 Data analysis

M. Bondi', A. Celentano, S. Vallarino

- 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







- SRO data behaves as expected (Nclusters, XYclusters, ΔT,...)

Streaming RO - CLAS12 FT tests: Run 1 Data analysis

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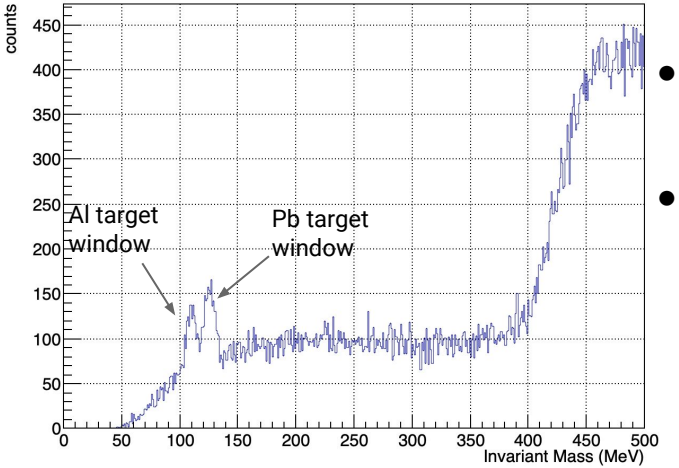
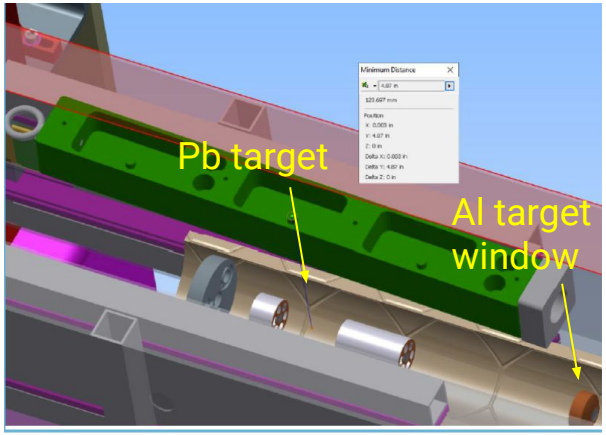


- peak at higher mass is associated to π0 production from Pb target
- peak at lower mass is related to π0 production from Al target window
  - lower invariant mass due to the assumption that the vertex is located at the Pb target position when calculating the invariant mass.

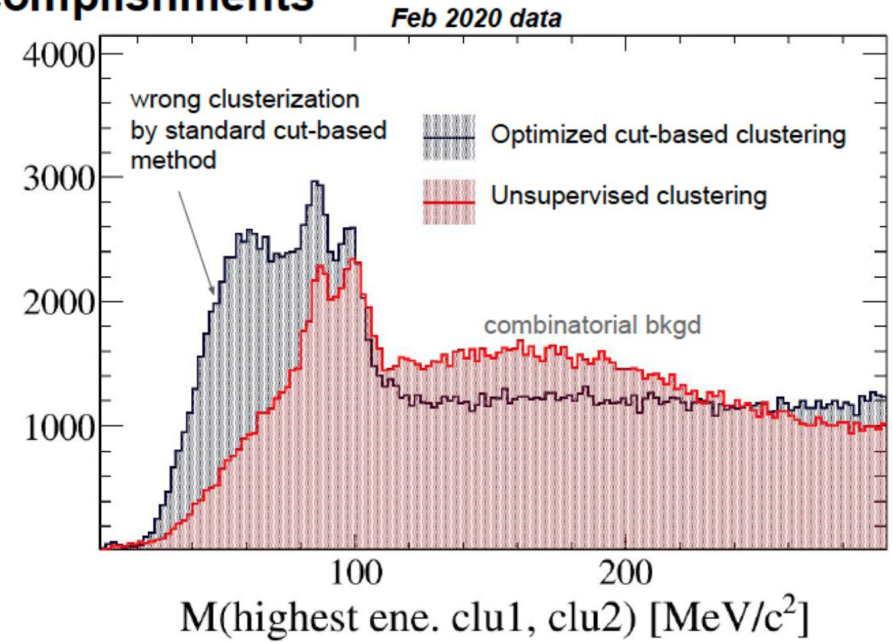


RUN 2 data analysis in progress

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

C. Fanelli

Accomplishments



- 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

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

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 (tradiational and AI-supported)
- Analysis was able to extract a clean physics signal in the form of a π° 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

Many thanks to the whole JLAB SRO team: F.Ameli (INFN), M. Battaglier (JLab/INFN), V.Berdnikov (CUA), S.Boyarinov (JLab) M.B. (INFN), N.Brei (JLab), A.Celentano (INFN), T.Chiarusi (INFN), C.Cuevas(JLab), R. De Vita (INFN), C.Fanelli (MIT), G.Heyes (JLab), T.Horn (CUA), V.Gyurjyan(JLab), D.Lawrence (JLab), L.Marsicano (INFN), P.Musico (INFN), C.Pellegrino (INFN), B.Raydo (JLab), M.Ungaro (JLab), S.Vallarino (INFN)

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