Streaming Readout for CLAS12

Supported by Italian Ministry of Foreign Affairs (MAECI) as Projects of great Relevance within Italy/US Scientific and Technological Cooperation under grant n. MAE0065689 - PGR00799

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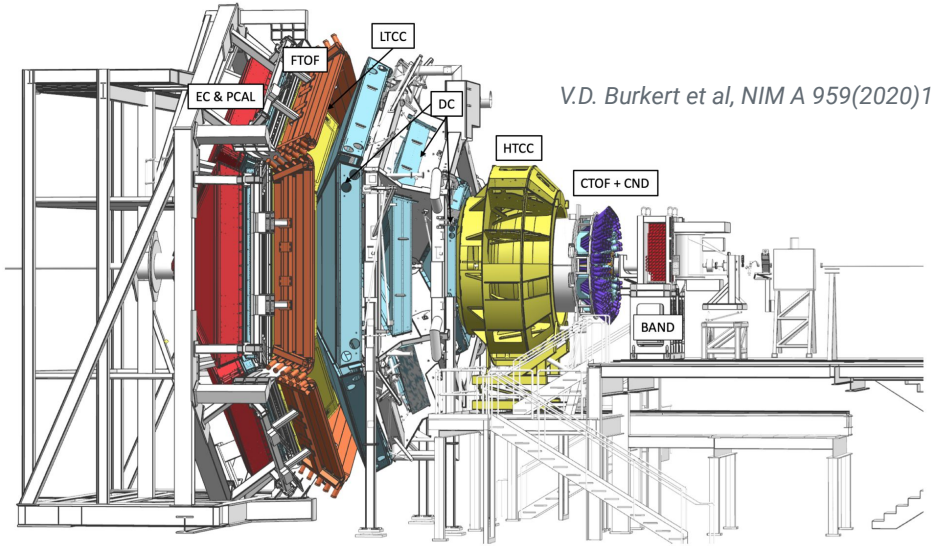
Jefferson Lab

Workshop VIII on Streaming Readout

CLAS12 @ JLAB

- Installed at Jefferson Lab's experimental HALL-B
- Expansive program of physics topics:
  - The multidimensional structure of the nucleon – from form factors and PDFs to GPDs and TMDs
  - Quark confinement and the role of the glue in meson and baryon spectroscopy
  - The strong interaction in nuclei – evolution of quark hadronization, nuclear transparency of hadrons, short range correlation


Jefferson Lab's accelerator site



V.D. Burkert et al, NIM A 959(2020)163419

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SRO for CLAS12

➢ **Streaming RO is necessary for a long-term HI-LUMI upgrade of CLAS12**

- Phase 1 : increasing luminosity of 2x in 2-3 year. Phase 2: increasing luminosity of 100x 5-7 year (wrt 10^{35} $cm^{-2}s^{-1}$)
- An update of the R1 CLAS12 DC with more dense detector (e.g. GEM) is expected in Phase I.
- With the current triggered technology the maximum possible event acquisition rate for CLAS12 is ~100 kHz (R~30 kHz now) upgrading several systems.

➢ **A prototype trigger-less DAQ was successfully tested in beam conditions**

- It brought together existing components
  - FEE: FADC250 + VTP + CODA
  - TRIDAS
  - JANA2
- Used to read out CLAS12-FT
  - FT - ECAL
  - FT - Hodoscope

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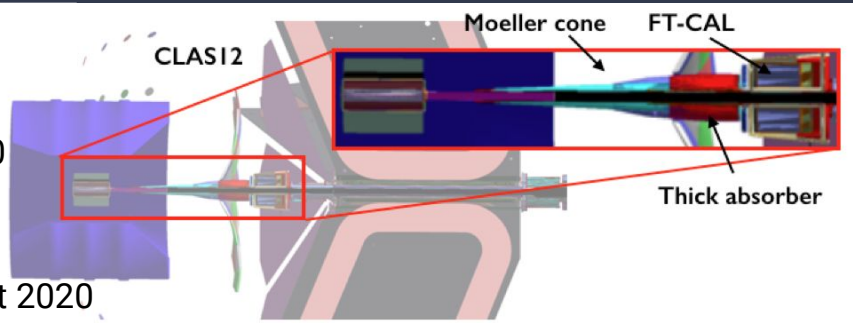
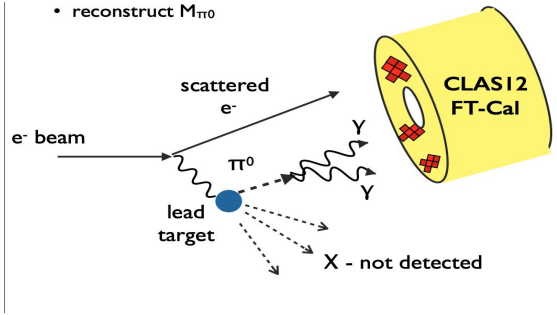
Streaming RO – CLAS12 FT tests:

- **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





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

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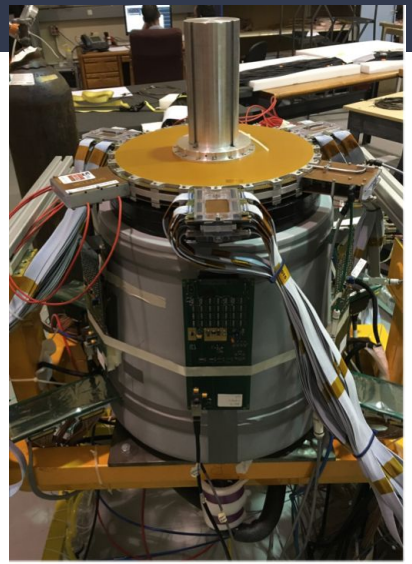
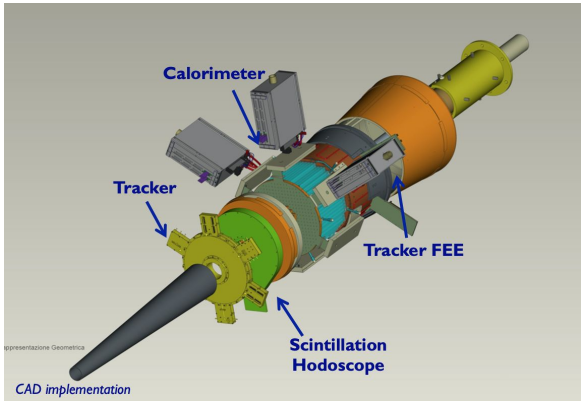
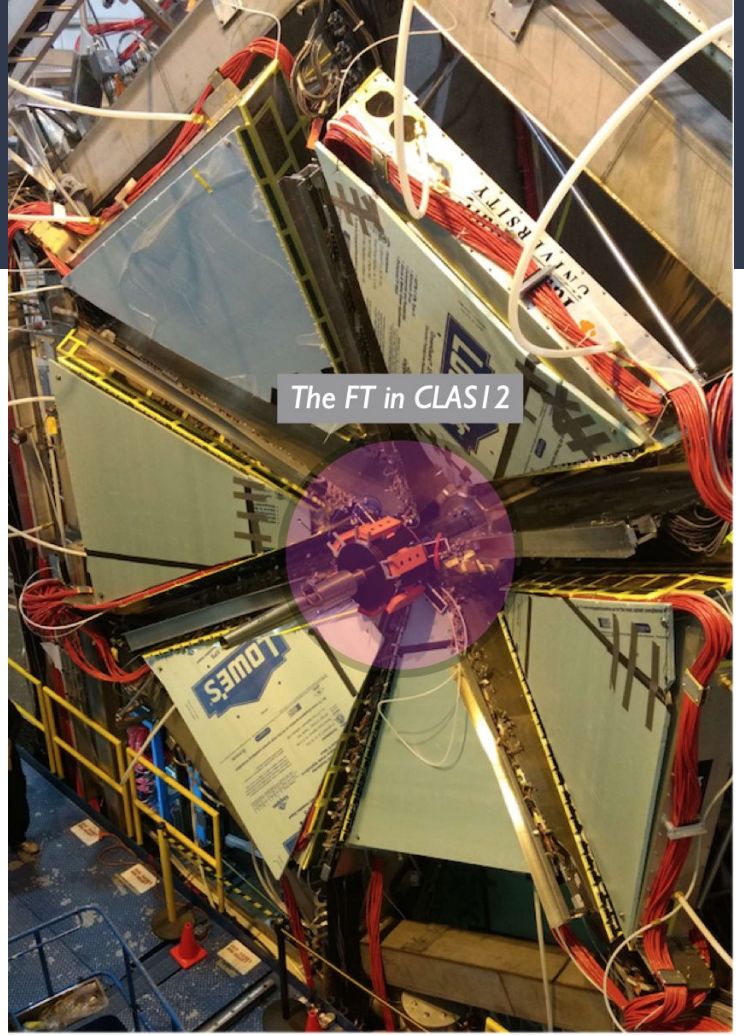
CLAS12 - Forward Tagger



A.. Acker et al, NIM A 959(2020)163475





- **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

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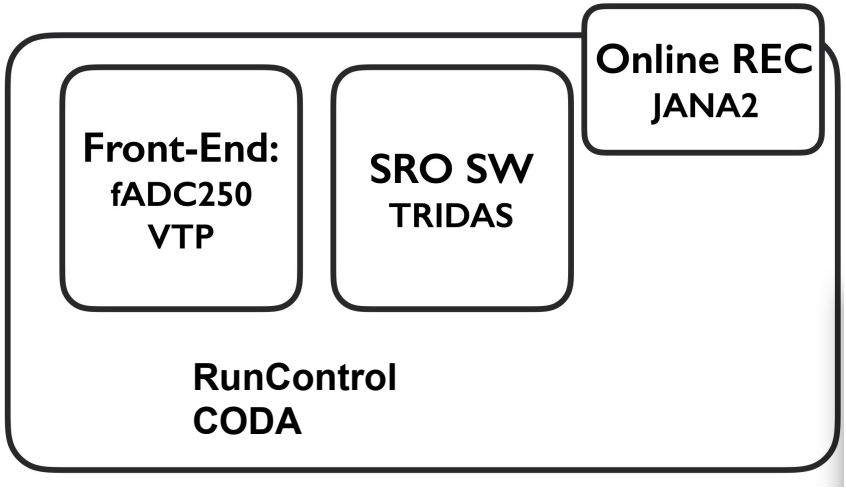
Streaming RO-CLAS12 FT tests: triggerless daq chain



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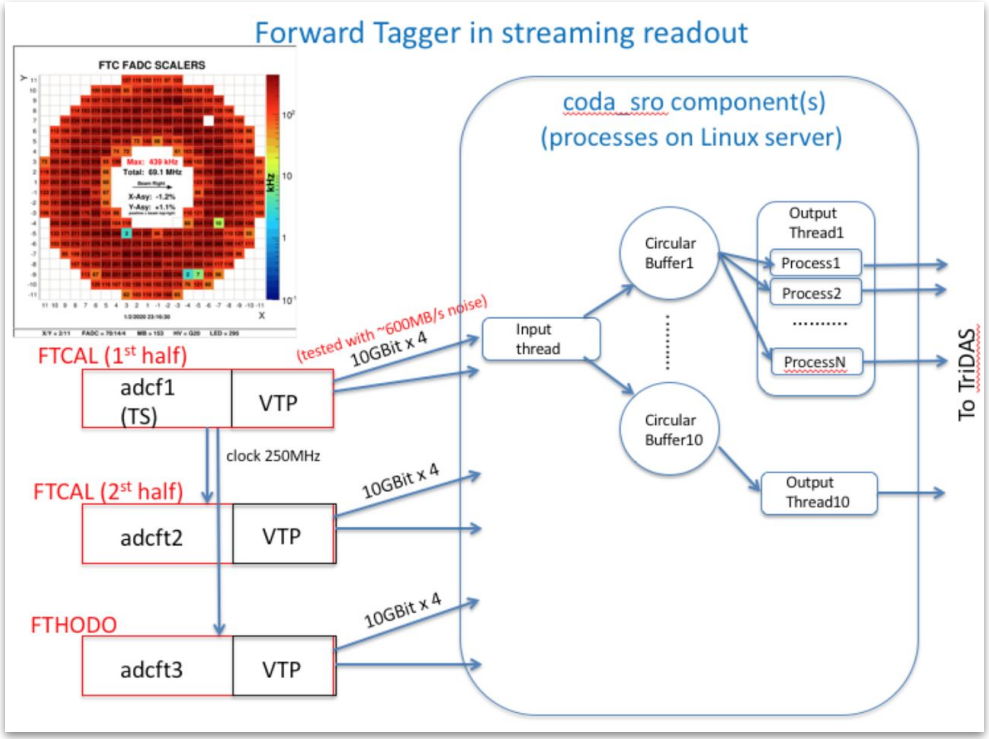
Streaming RO – CLAS12 FT tests: FEE + CODA

D. Abbott, F. Ameli, S. Boyarinov C. Cuevas,G. Heyes, P. Musico, B. Raydo



- Front-end electronics are based on available FE electronics JLAB-FADC250 and VTP modules.
- Streaming version of CODA (without back-end):
  - the front end readout software running inside the VME controllers and VTP boards was modified to stream data out freely.
  - new SRO component was developed to be the intermediate translator between front-end and back-end

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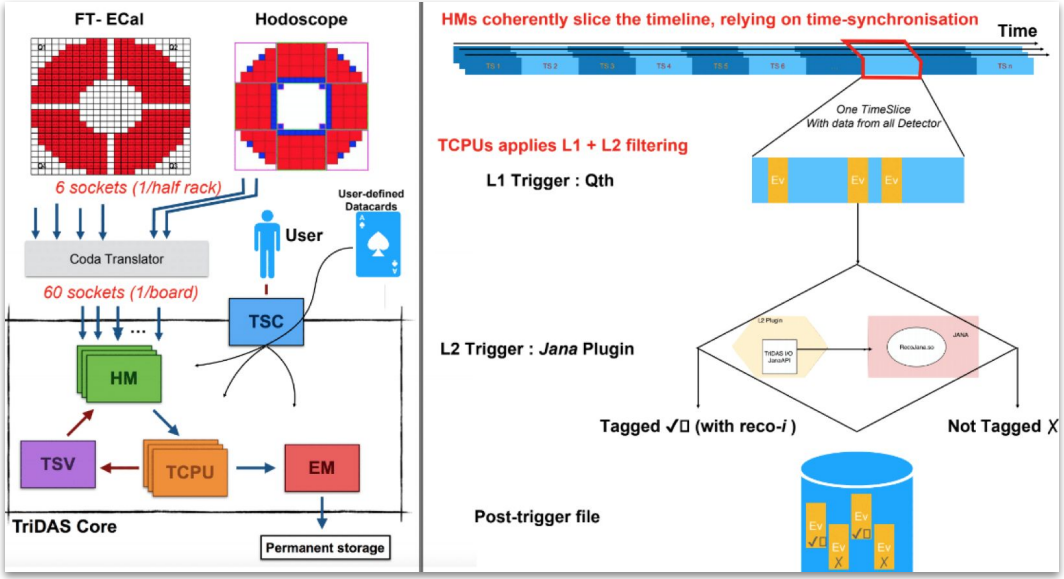
Streaming RO – CLAS12 FT tests: TRIDAS

L. Cappelli, 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



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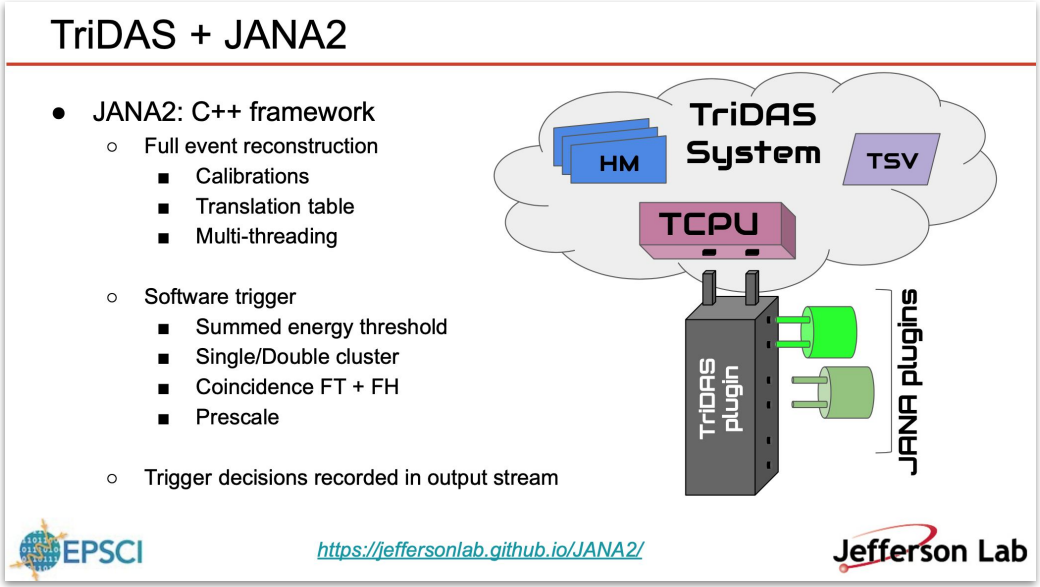
Streaming RO – CLAS12 FT tests: JANA2 + Rec

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

JANA2

- L2 plugins (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



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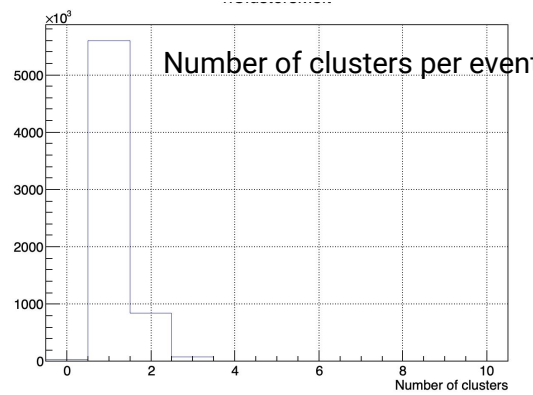
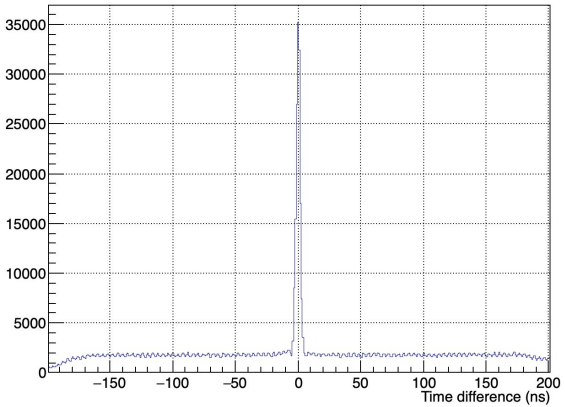
Streaming RO – CLAS12 FT tests: Run 1 Data analysis

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

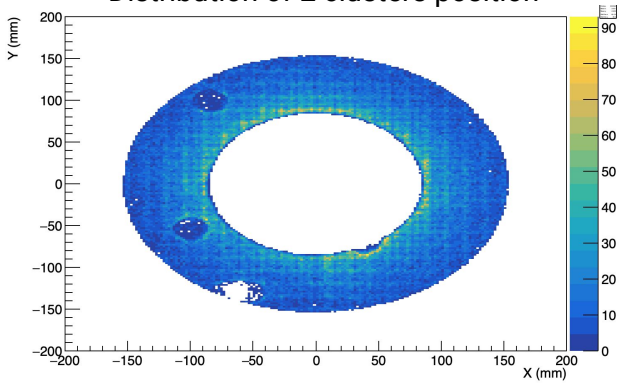
- Run 1: 10.4 GeV electron beam on thin Pb target in Jan/Feb 2020
- offline analysis focused on identification of π0->γγ events
- offline reconstruction performed by applying the same full suite of reconstruction algorithm used in the on-line reconstruction.
- Energy calibration and time-walk correction



Time difference between two clusters



Distribution of 2 clusters position



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

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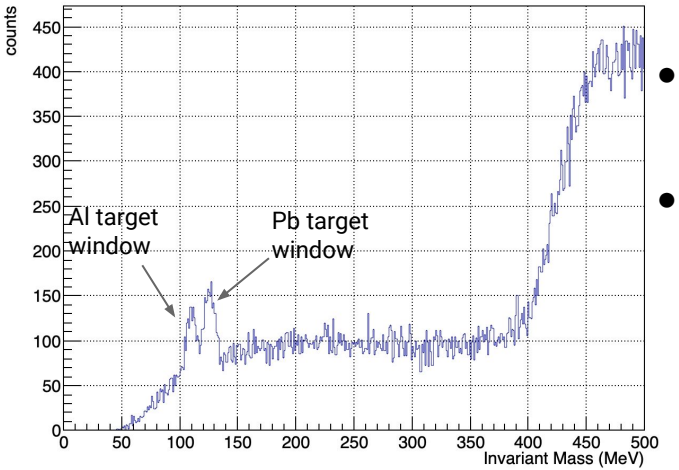
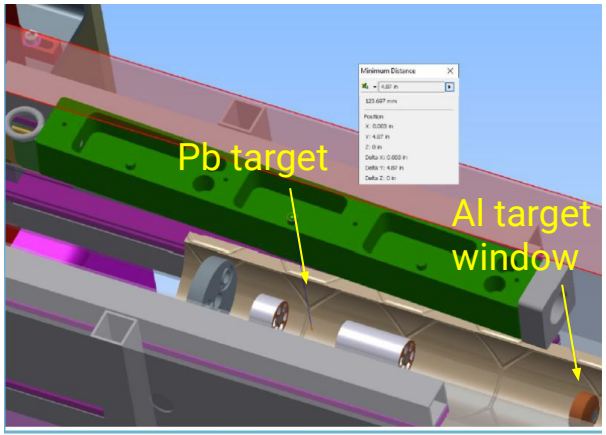


- peak at higher mass is associated to π0 production from Pb target
- peak at lower mass is related to π0 production from Al target window
  - lower invariant mass due to the assumption that the vertex is located at the Pb target position when calculating the invariant mass.



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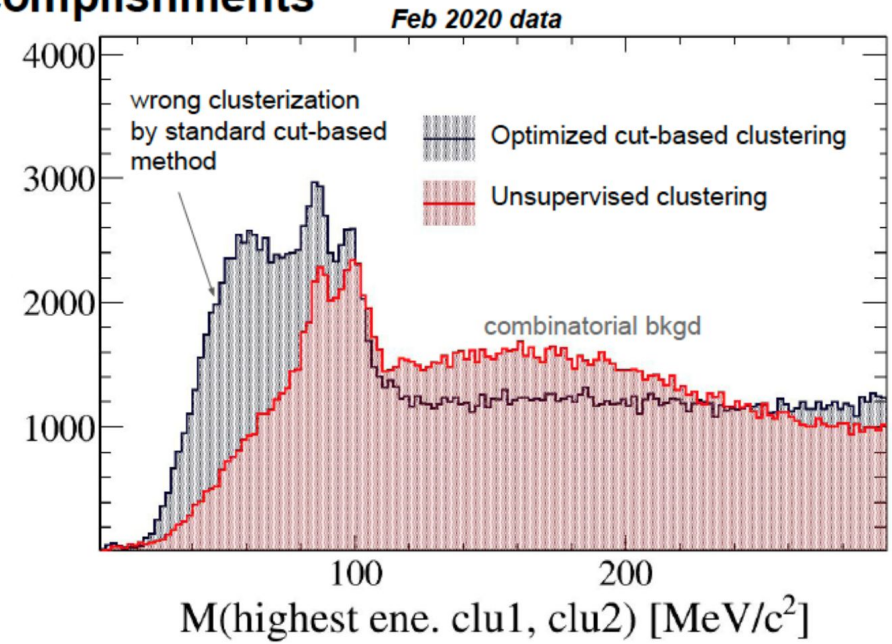
Streaming RO – CLAS12 FT tests:
Run 1 Data analysis (AI - supported)

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

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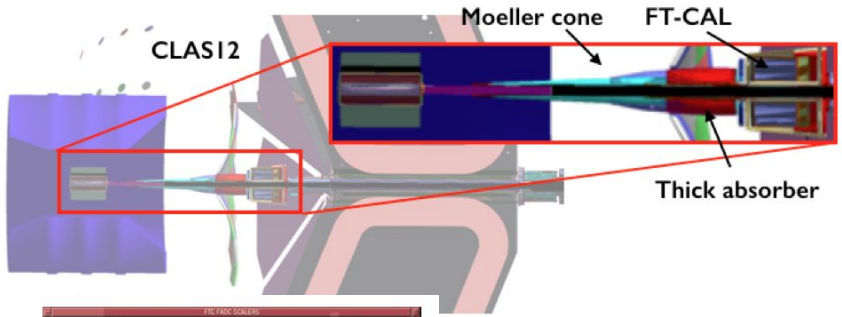
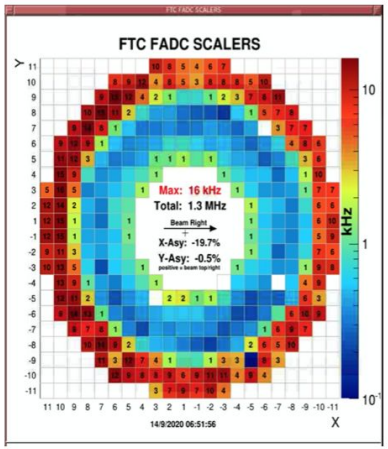
Streaming RO – CLAS12 FT tests: Run 2 Data analysis

- Run 2: 10.4 GeV electron beam on thick H2/D2 target and thin Al target (target window) in Sept 2020
- Read out in streaming mode: FT-CAL and FT-HODO
- TRIDAS profiling and performance studies (analysis is ongoing) as function:
  - FEE threshold
  - L1 threshold
  - L2 algorithms.
- Disadvantageous experimental conditions: thick absorber that shield the most of FT acceptance





on-line scalers

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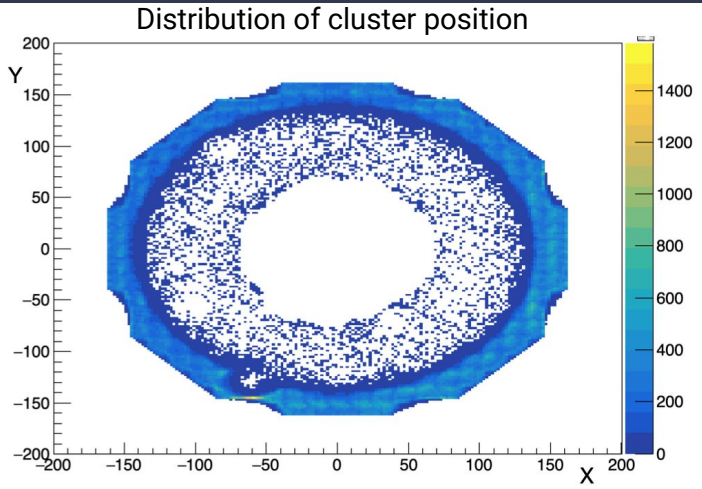
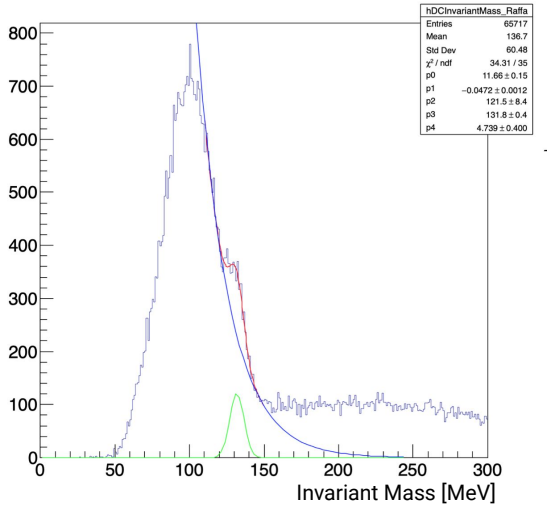
Streaming RO – CLAS12 FT tests: Run 2 Data analysis



Most of events are associated to clusters in the outermost crystals that are not shielded by thick absorber



A peak compatible with pi0s production is visible in γγ-invariant mass spectrum due to dominance of Al target window

- SRO data behaves as expected

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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), L. Cappelli (INFN), 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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