Streaming DAQ experience for small setups and plans for CLAS12

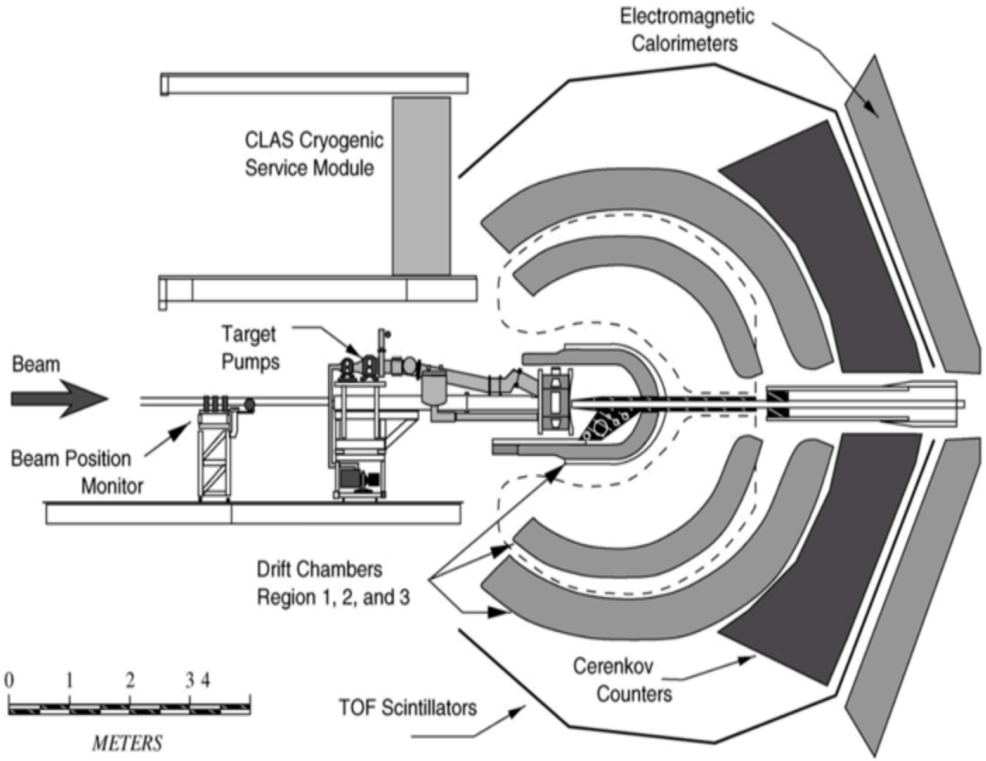
Sergey Boyarinov (JLAB)

Workshop XI on Streaming Readout

December 2, 2023

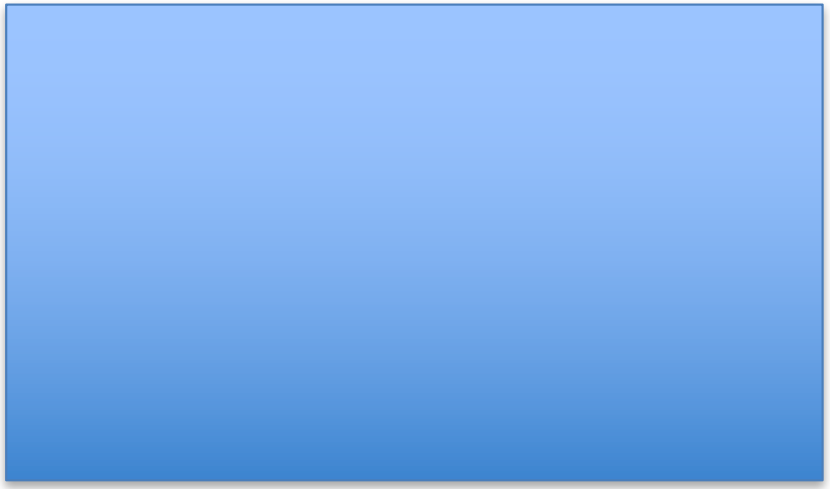
1. CLAS12 DAQ evolution from triggered to streaming
2. Small setups experience
3. CLAS12 plan for upgrade to streaming operation

CLAS (1997-2012)



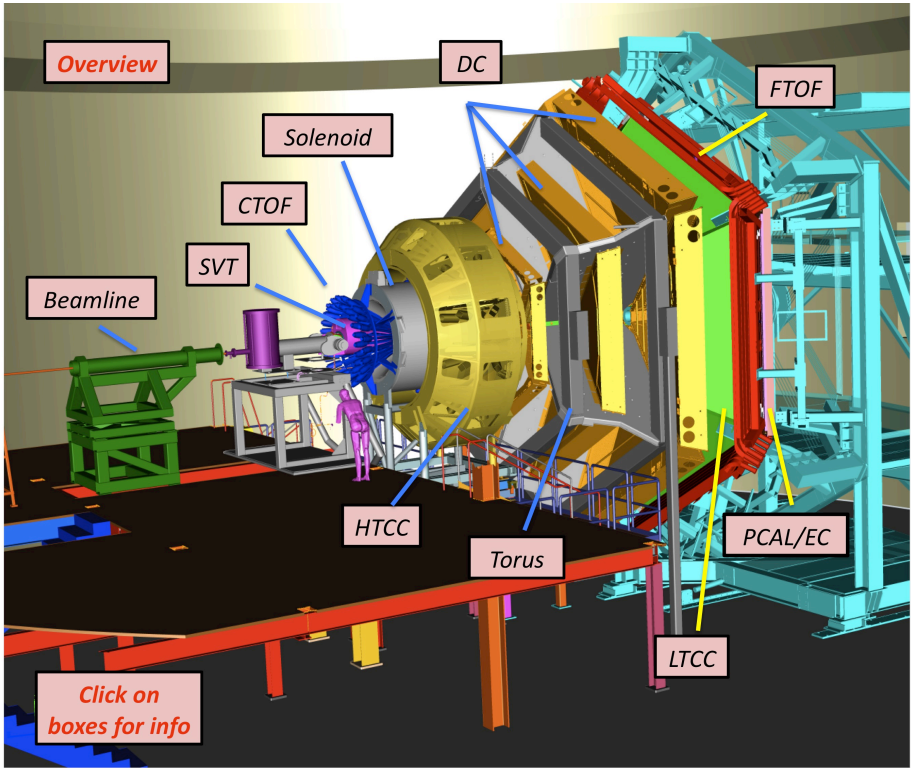
Trigger system design was limited by:

- Available technology
- Low latency (~100ns) defined by FASTBUS ADCs



Level1 trigger: calorimeter/TOF/Cherenkov/StartCounter/Tagger (timing coincidence of the discriminators output signals from 'fast' detectors)
Level2 trigger: drift chamber (no tracking, just multiplicity)
Hardware: since 1997 - JLAB-made electronics
since 2008 - CAEN v1495's (**Cyclone I –** our first experience with FPGAs)

CLAS12 (2017-present)



Trigger system improved because:

- Advanced FPGA technology
- Higher latency (up to 8 us) defined by FADCs

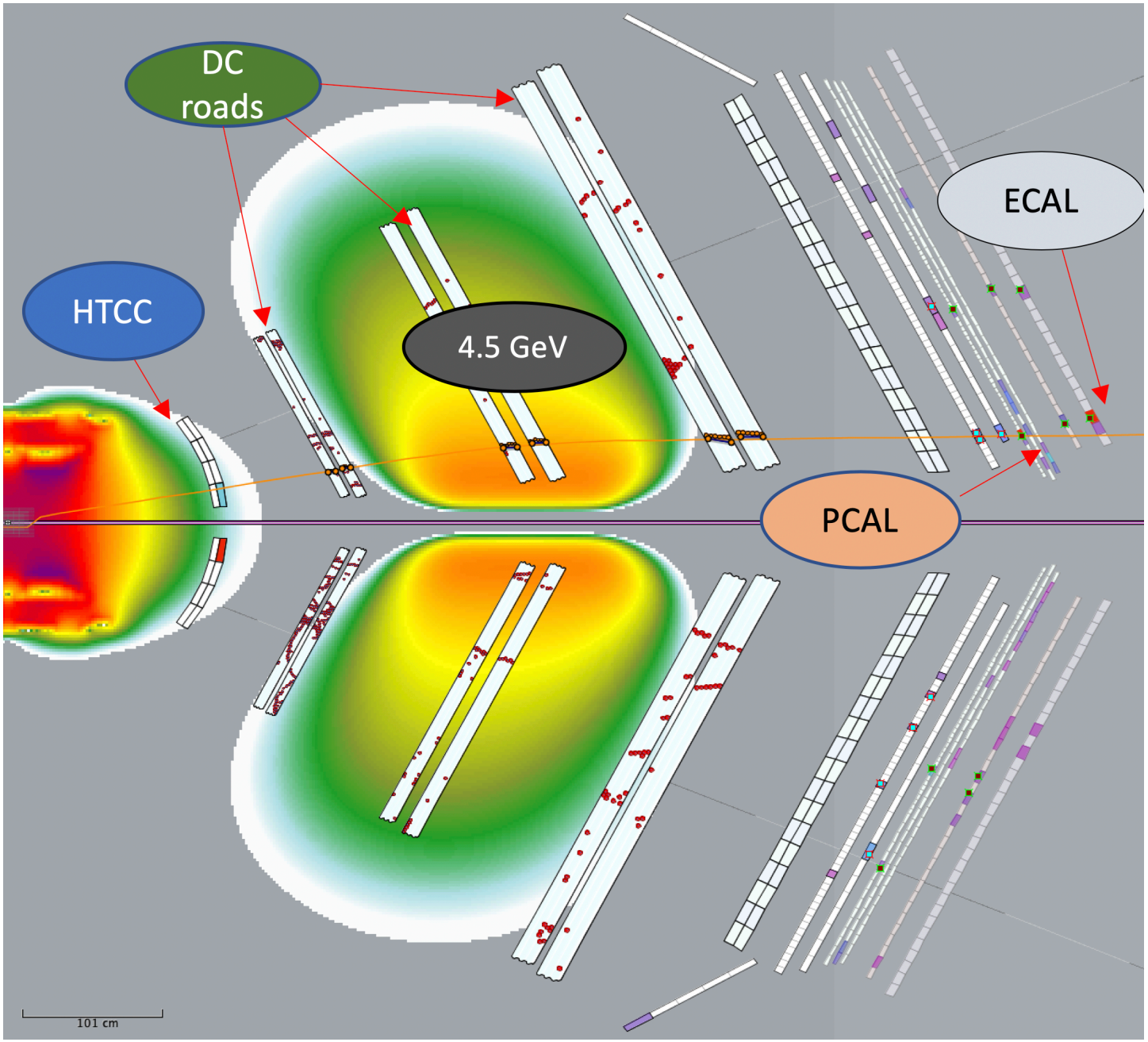
Level1 trigger: clusters in 3 calorimeters and hodoscope (FADC pulse integrals),
hits in 2 TOFs and 2 Cherenkovs (FADC pulse integrals),
tracks in Drift Chamber (discriminators/TDCs)

Hardware: JLAB-made VTP (VXS Trigger Processor) boards (Virtex7 FPGA)

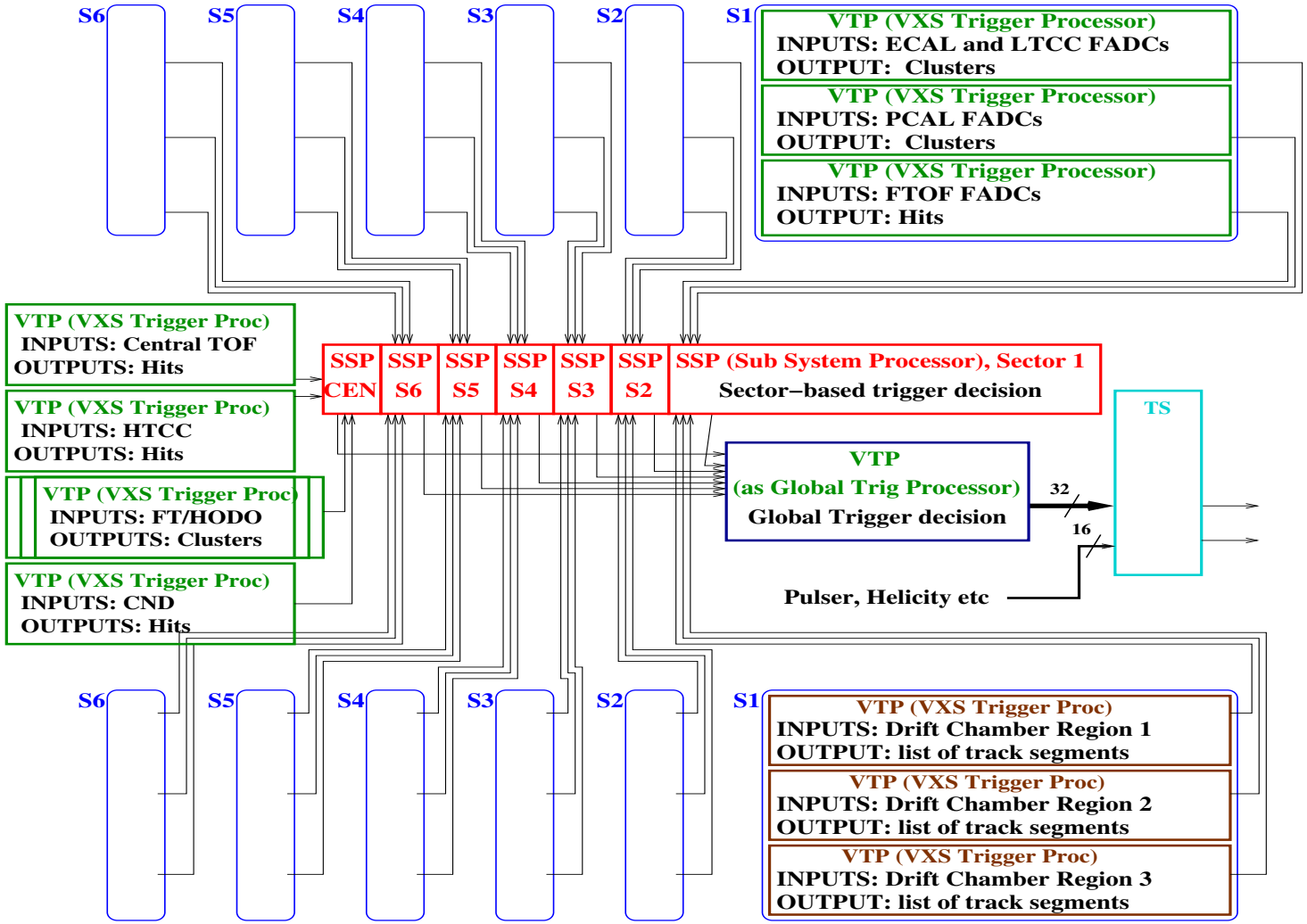
Trigger algorithms: uses energy, position and timing of the clusters in calorimeters,
uses energy, position and timing of the TOFs and Cherenkov hits,
performs drift chamber track finding (dictionary-based),
uses timing and position match between clusters, hits and track

Many algorithms were borrowed from offline software, redesigned and implemented using HLS/VHDL tools

CLAS12 Electron Trigger Event Example
(efficiency ~99%, purity 50-70%)



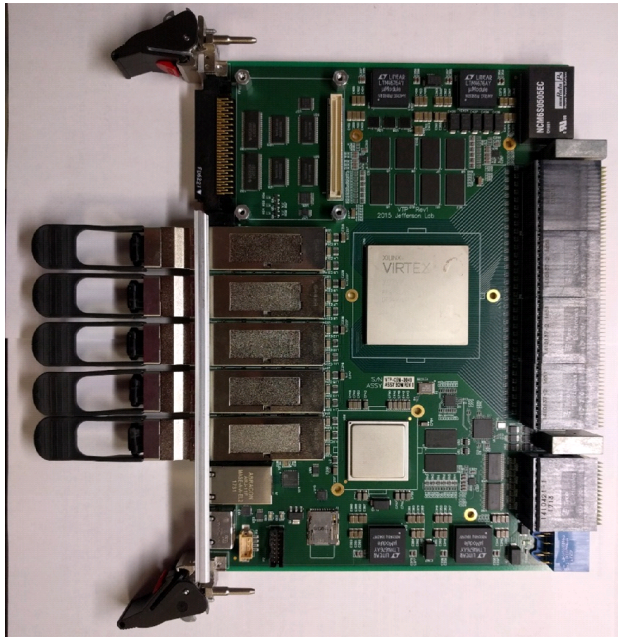
CLAS12 Trigger System Diagram

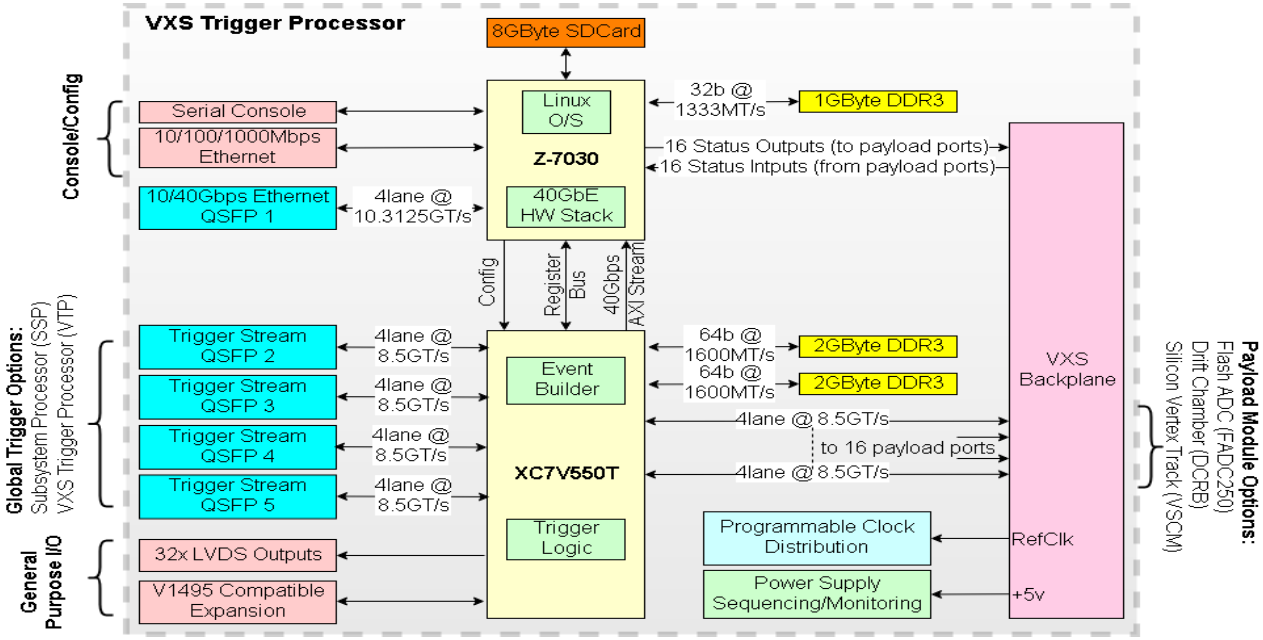


Trigger system core element: VTP boards (42 installed in CLAS12)

VTP design makes it possible to replace triggered daq system by streaming one

Using VTP board for streaming readout





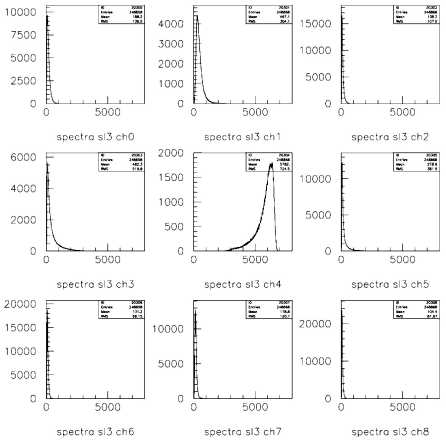
- In existing trigger-based mode, VTP makes trigger decisions and sends trigger information to the following trigger system stages. In addition, it is able to act as readout board
- In streaming mode, there is no trigger information, and VTP sends stream of data to DAQ, bandwidth up to 4 x 10Gbit/s
- VTPs allows smooth CLAS12 transition from triggered to streaming DAQ. Along with new non-VME/VXS readout electronics designed and built at present time, all VME/VXS electronics (50+ crates) can be reused

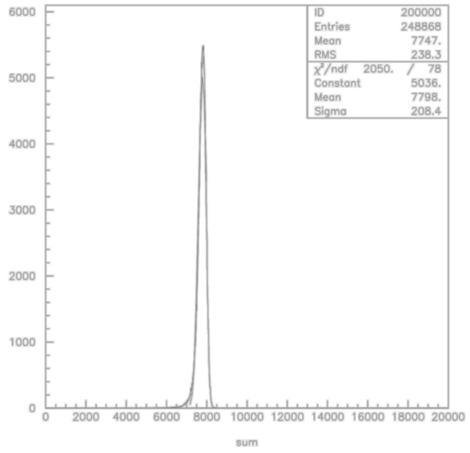
CLAS12 and Streaming DAQ Activity

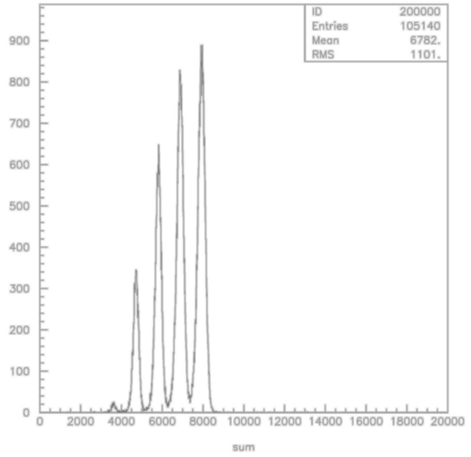
- CLAS12 is actively involved into streaming development since at least 2019, when we started to develop and test streaming firmware for VTPs, and simple C backend was created to test VTP-to-server communication in streaming mode
- Several iterations of the VTP firmware were made in 2020-2021. TriDAS and ERSAP back-ends development and testing with VTPs. First beam test runs.
- December 2021 - first beam run with reliably running streaming DAQ, including backend and event reconstruction – successful Proof of Concept.
- Several beam tests in 2022 and 2023, with different back-ends.
- November 2023 – 9 CLAS12 VXS crates were connected to JLAB computer center through new Arista network switch, allowing to create and test realistic streaming daq.
- Next step will be to use streaming DAQ to perform following physics tasks: (1) ECAL/PCAL calorimeters cosmic calibration with MIPs, (2) ECAL/PCAL calorimeters beam electron clusters finding with energy correction and multi-clustering; (3) after DCRB drift-chamber readout will be added to streaming – full electron ID in CLAS12
- Various performance tests will be conducted as well using artificially increased data rate

Small setups where VTP-based streaming DAQ was used

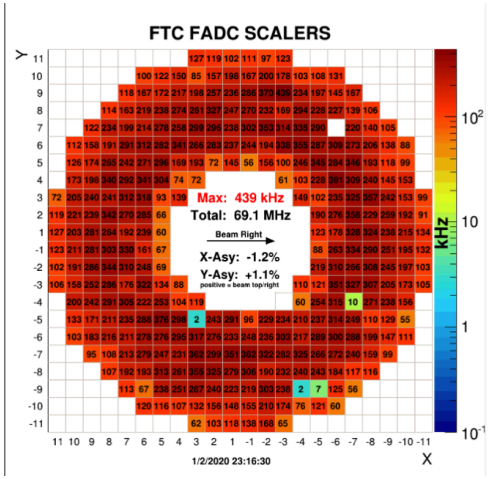
- 3x3 lead tungstate crystal calorimeter prototype beam test (1 VXS crate with 1 FADC, 1x10Gbit uplinks) – first reliably running streaming DAQ, December 2021







- 5x5 SciGlass calorimeter prototype beam test (1 VXS crate with 2 FADCs, 1x10Gbit uplinks)
- CLAS12 Forward Tagger beam test (3 VXS crates with 36 FADCs, 6x10GBit uplinks)



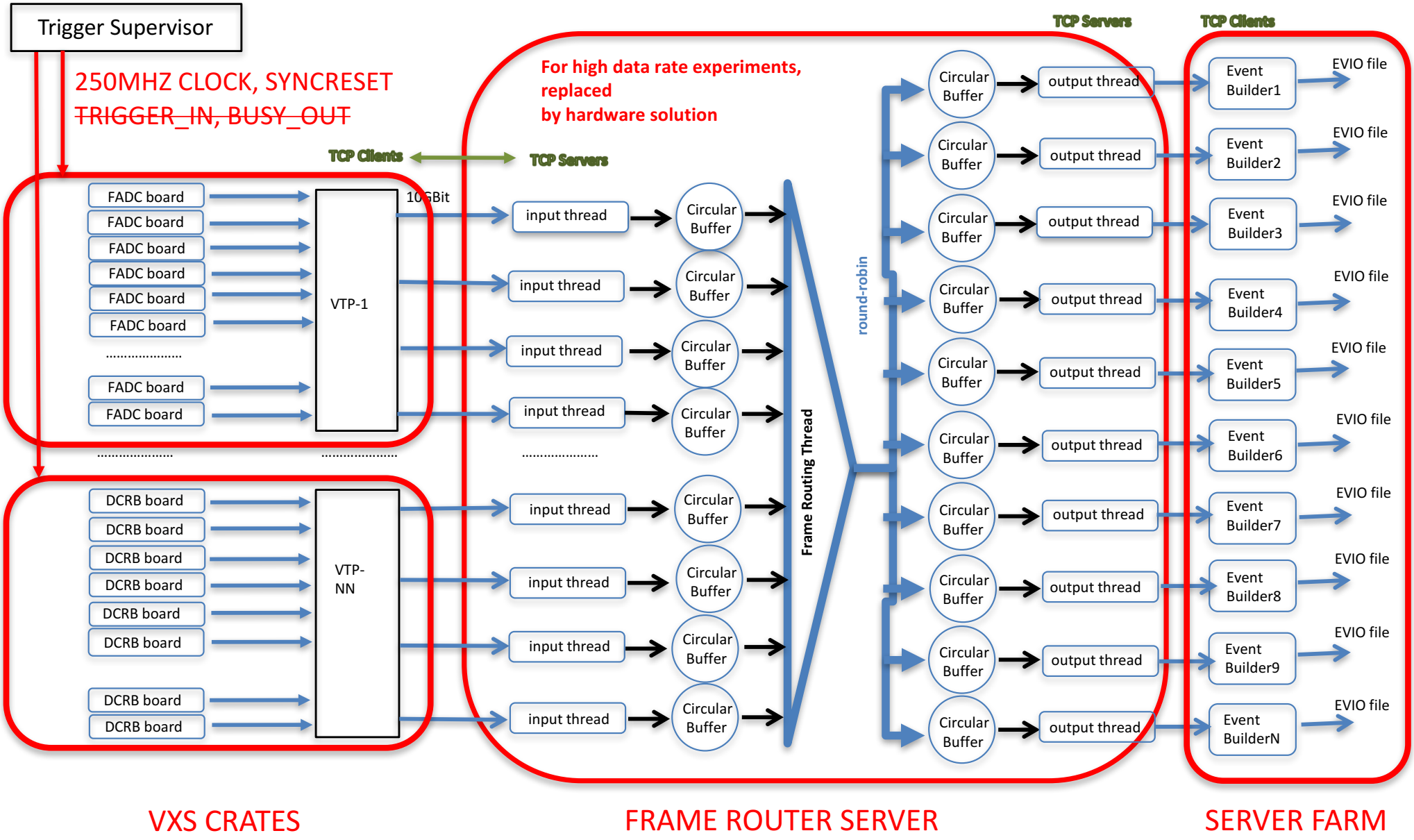
- Noise-base performance tests (low threshold on FADCs)

Streaming Back-End

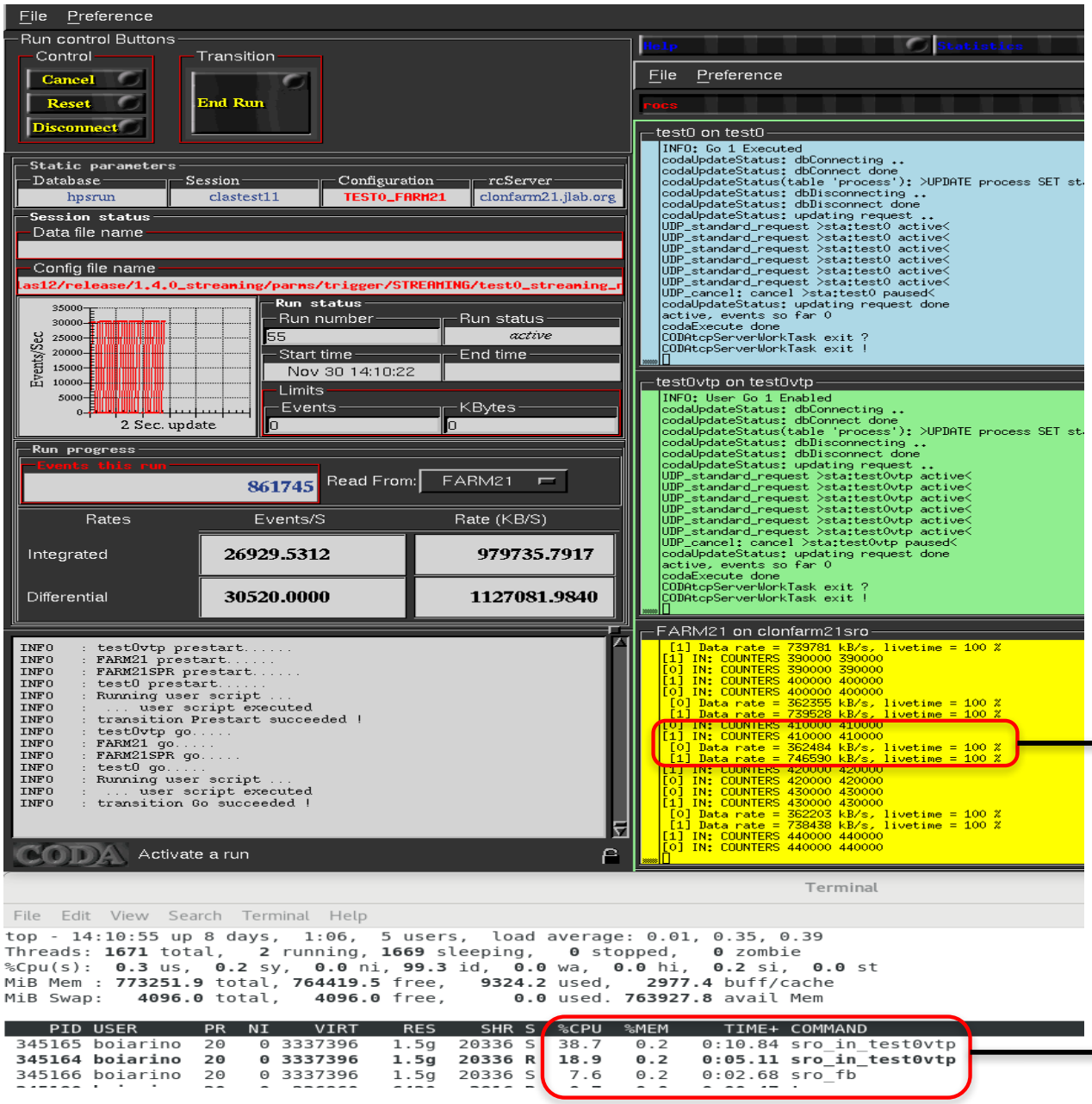
While Streaming Front-End Electronics stays the same for different setups (FADCs+VTPs for now), back-end solutions were actively developed by different groups

- CLAS12 developed simple back-end – mostly for hardware/firmware testing and performance measurements purposes (few thousands of lines of C code)
- TriDAS+JANA - Mariangela Bondi talk
- ERSAP - Vardan Gyurjyan talk
- Hardware (FPGA-based NICs) solutions

Streaming DAQ diagram (with C version of the Frame Router)



CPU usage on clonfarm21: FADC noise test, 2 streams



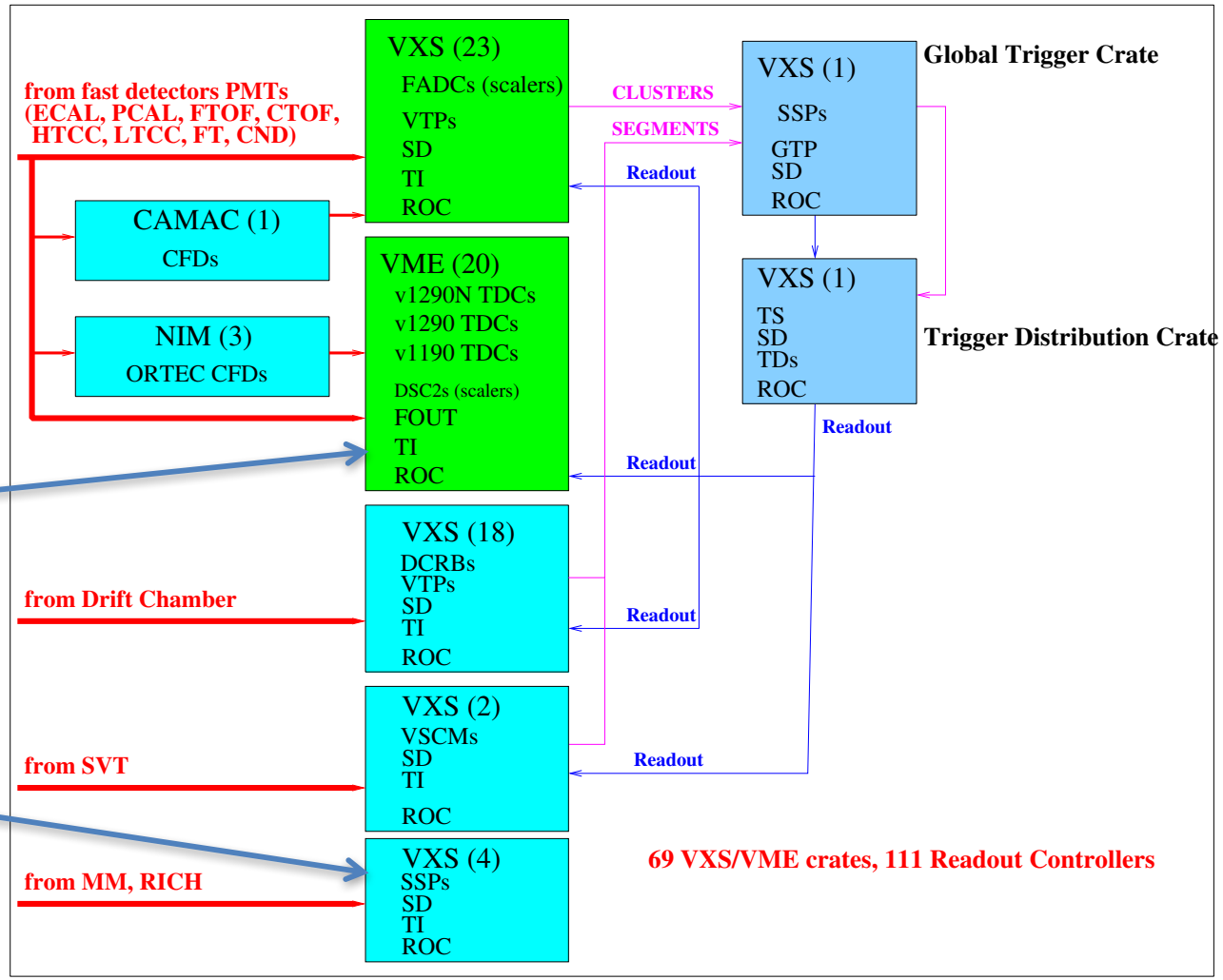
Component	Data Rate (Mbyte/s)	CPU usage (per core)
InputThread	360	19%
InputThread	740	38%
FrameRouter	1100	8%

CLAS12 front-end upgrade to streaming mode

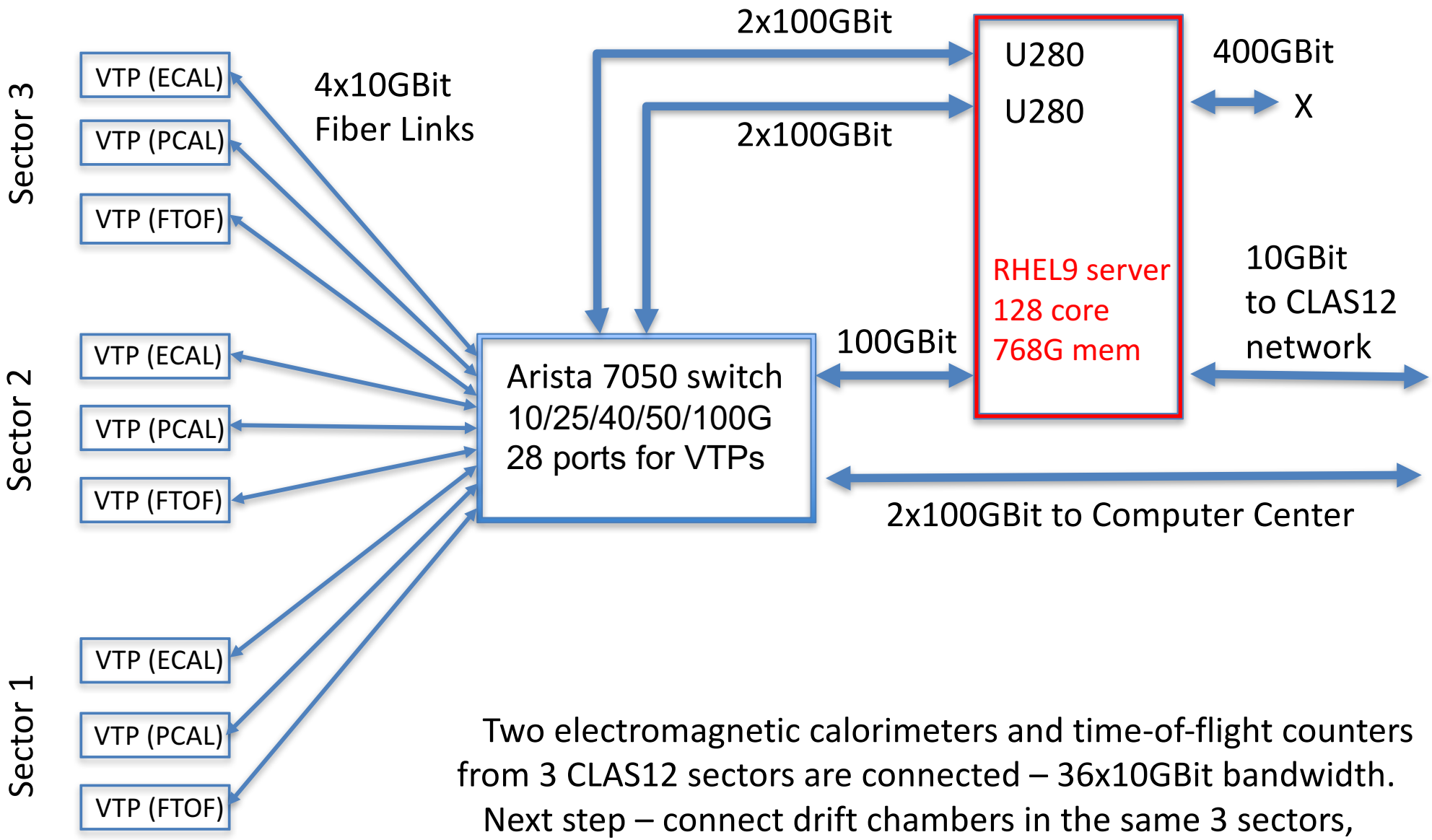
Replace CAEN TDCs V1190/v1290 with JLAB vfTDCs

Replace micromega Dream-based readout with Sampa-based

Install missing VTPs, connect all VTPs to streaming network



CLAS12 network/computing- current status

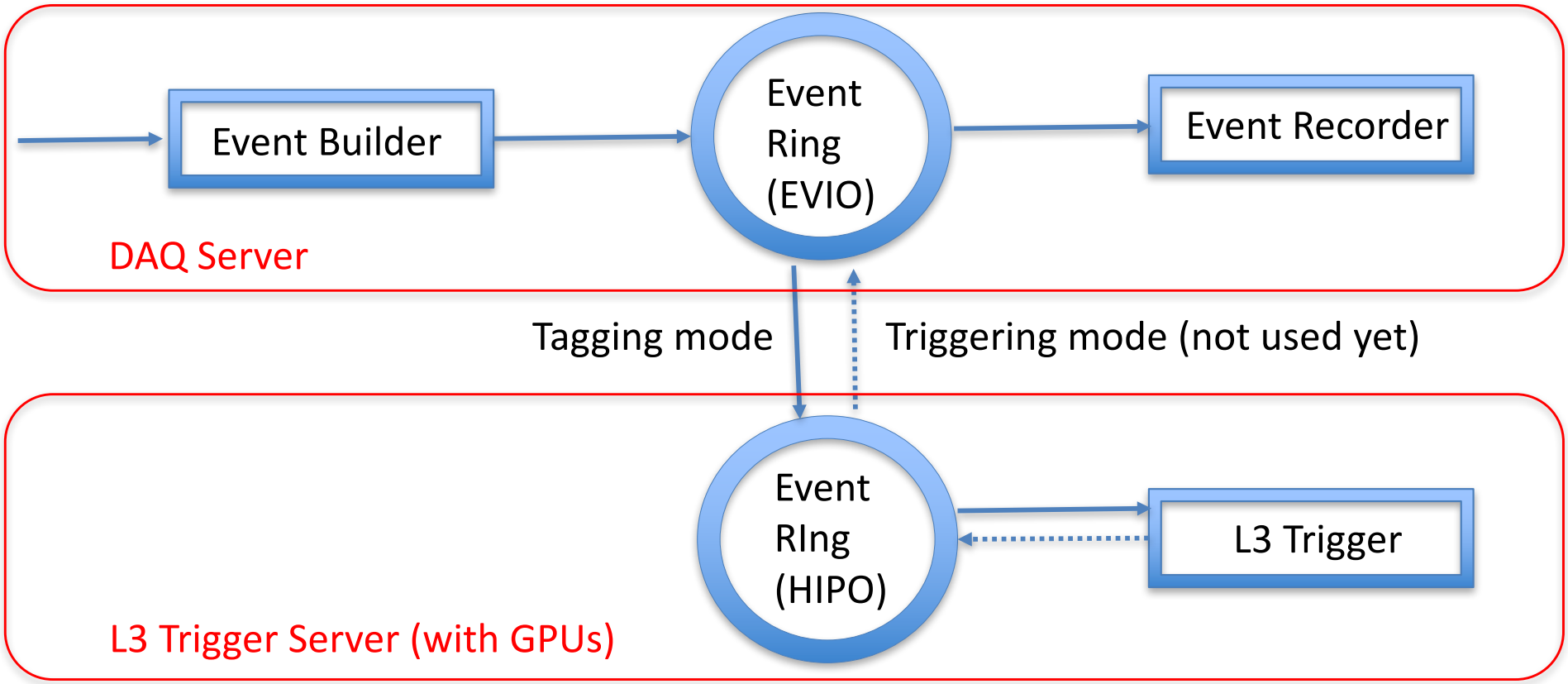


Two electromagnetic calorimeters and time-of-flight counters from 3 CLAS12 sectors are connected – 36x10GBit bandwidth.

Next step – connect drift chambers in the same 3 sectors, allowing electron ID algorithms to be tested in streaming mode, and increasing overall bandwidth to 72x10GBit

CLAS12 Level3 as testbed for streaming daq data processing

- Level3 (software) trigger was recently added to CLA12 DAQ, with main goal to improve the purity of the data collected. At present time, it is running in tagging mode, performing AI-based track finding in CLAS12 Drift Chambers. It the same time, it allows to develop solutions for future streaming DAQ data processing.



CLAS12 DAQ Status and Streaming Prospective

- CLAS12 will continue to run with triggered DAQ configuration for another 1.5-2 years, after that beam current in Hall B will be increased factor 2-3 (so-called high-luminosity running)
- DAQ preparation for high-luminosity running is underway. In addition to TDCs replacement and micromega readout upgrade, readout system for the new uRWELL detector have to be built. All efforts are focused on those tasks. In the same time, all new or upgraded components are designed to be compatible with streaming mode
- Realistically, CLAS12 may switch to streaming DAQ not earlier than 5 years from now – unless high-luminosity running will require it. Expected raw data rate from all CLAS12 detectors in streaming mode is very preliminary estimated on the level of 50GByte/sec

Conclusion

- CLAS12 operates using triggered DAQ with typical event rate up to 30kHz, and will continue to operate same way through high luminosity upgrade, reaching event rate close to 100kHz
- In the same time, CLAS12 readout system being upgraded and eventually will become fully compatible with streaming DAQ mode
- Data processing solutions for the future streaming operation being developed and tested as part of the level3 trigger
- We are working closely with jlab and outside groups assisting them with streaming DAQ back-end development, providing big scale testing facility