DAQ and Trigger for HPS run

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HPS DAQ & Trigger Requirements

20kHz event rate

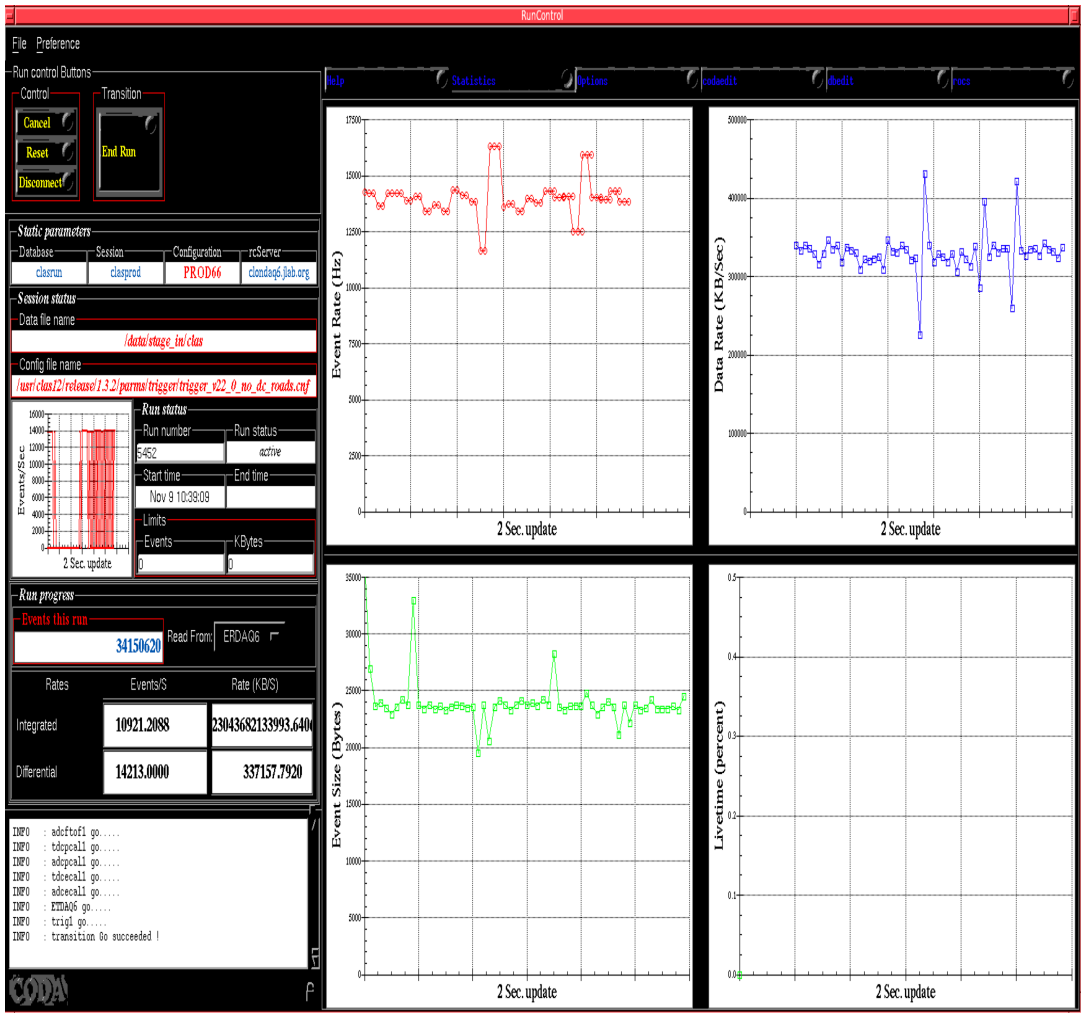
100MB/s data rate

>95% livetime

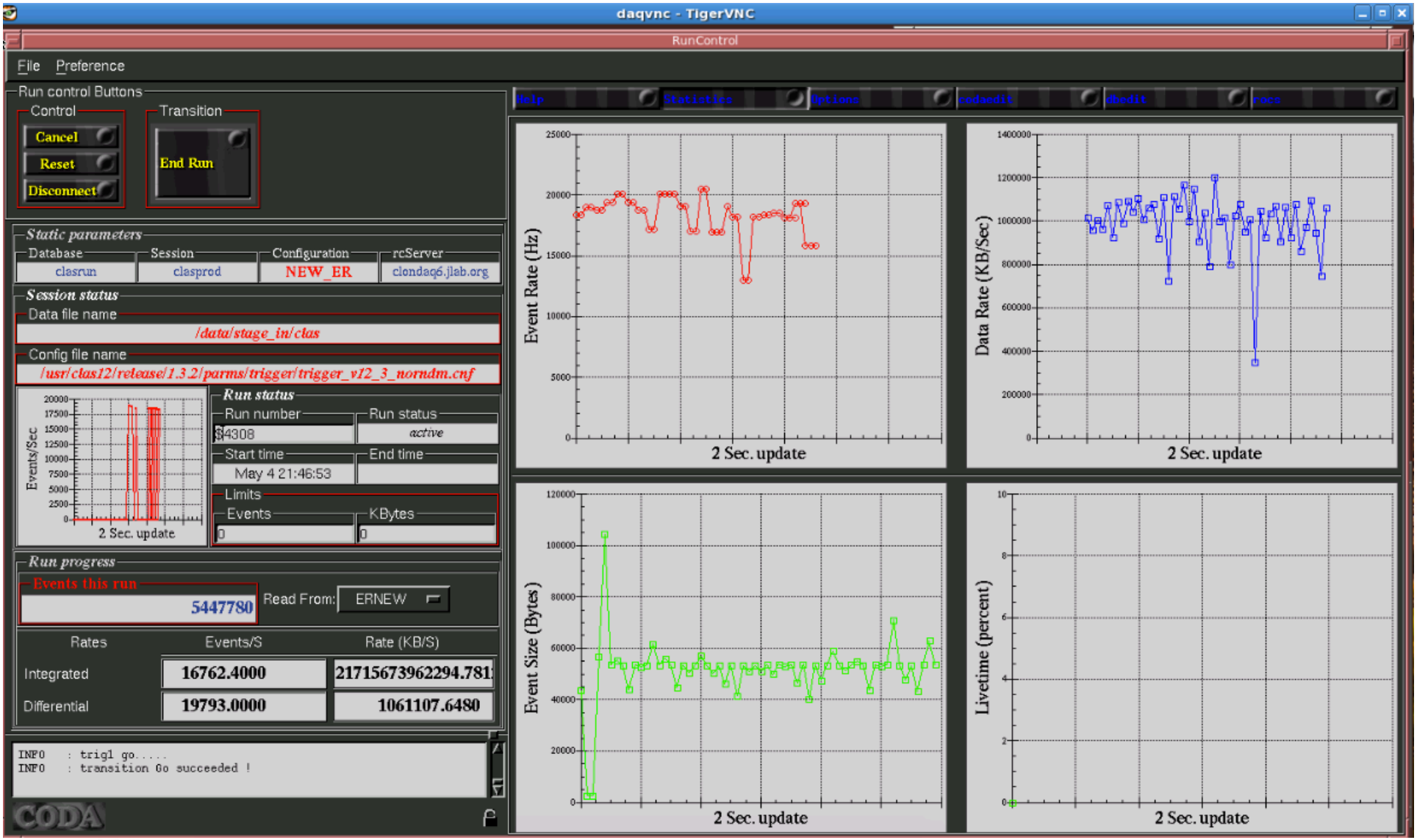
HPS experiment will be using CLAS12 DAQ & Trigger Facility at JLAB; achieved CLAS12 performance:

- 20kHz event rate
- 600MB/s data rate
- >95% livetime

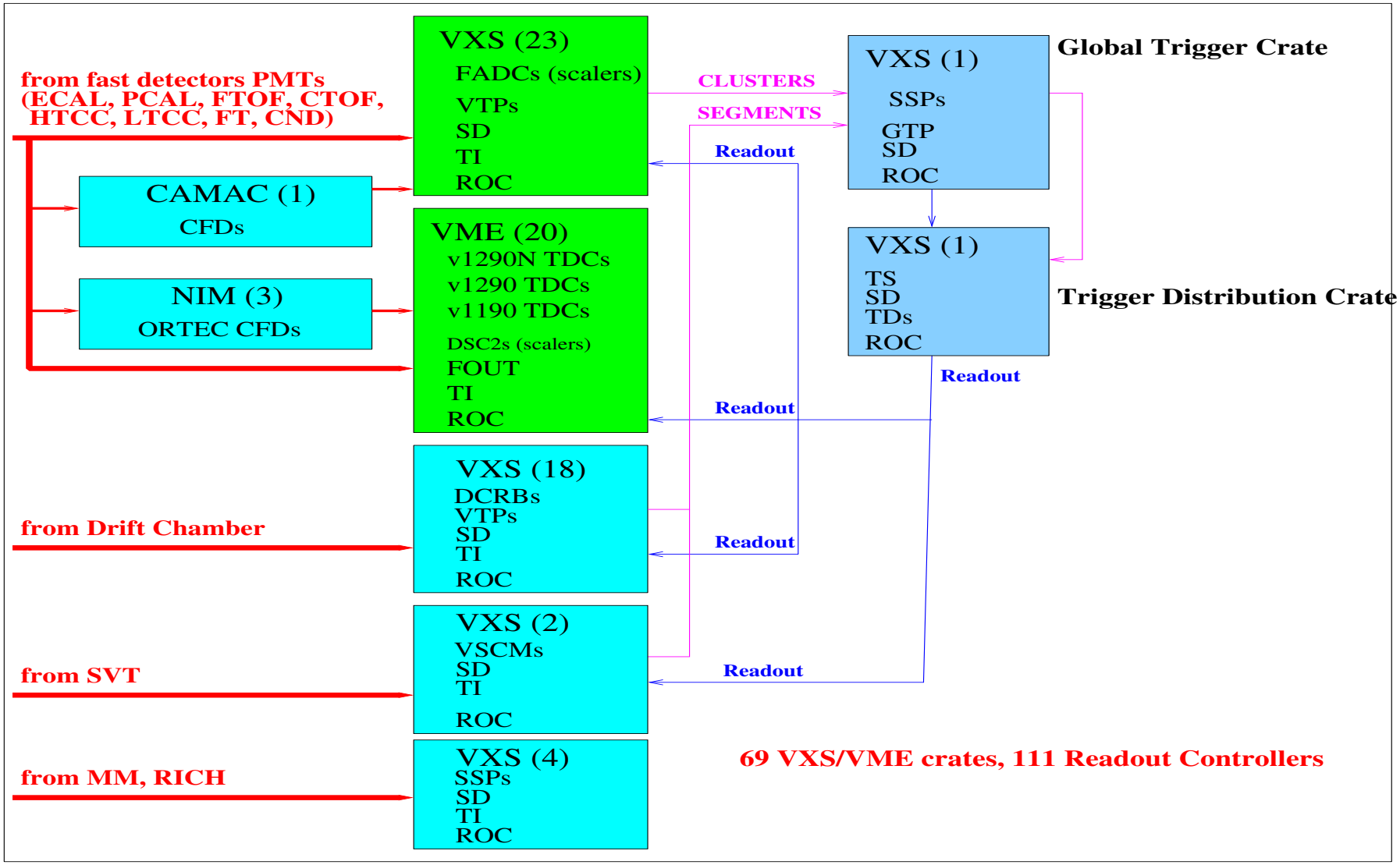
Typical CLAS12 DAQ performance: 40nA beam – 14kHz, 330MB/s, 95% livetime



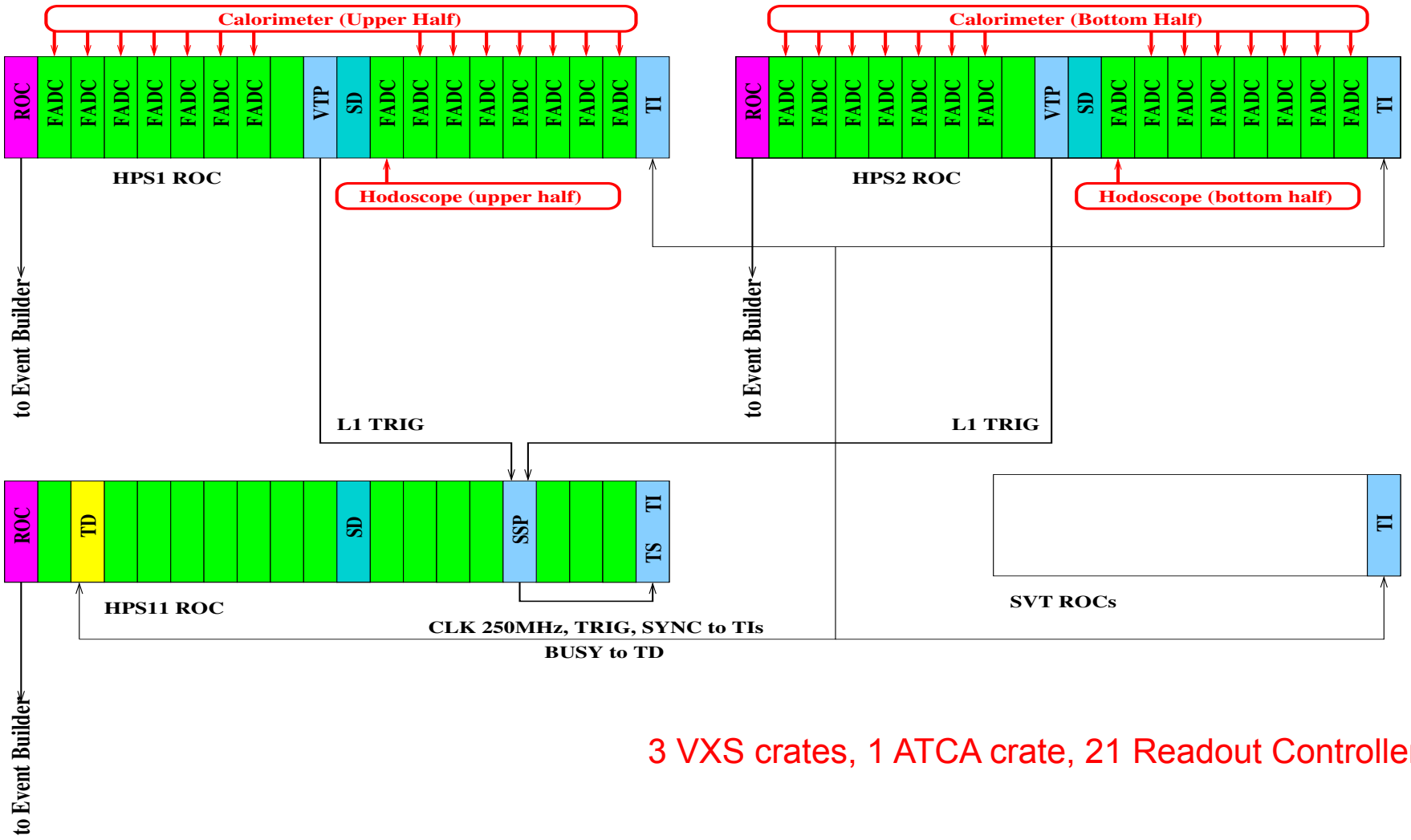
CLAS12 50nA beam DAQ test (some prescales removed) – 20kHz, 1000MB/s, 88% livetime



CLAS12 DAQ & Trigger Diagram



HPS DAQ & Trigger Diagram



3 VXS crates, 1 ATCA crate, 21 Readout Controllers

HPS DAQ Status

All front-end electronics installed:

- Calorimeter Readout: 442 channels of 12bit 250MHz Flash ADCs

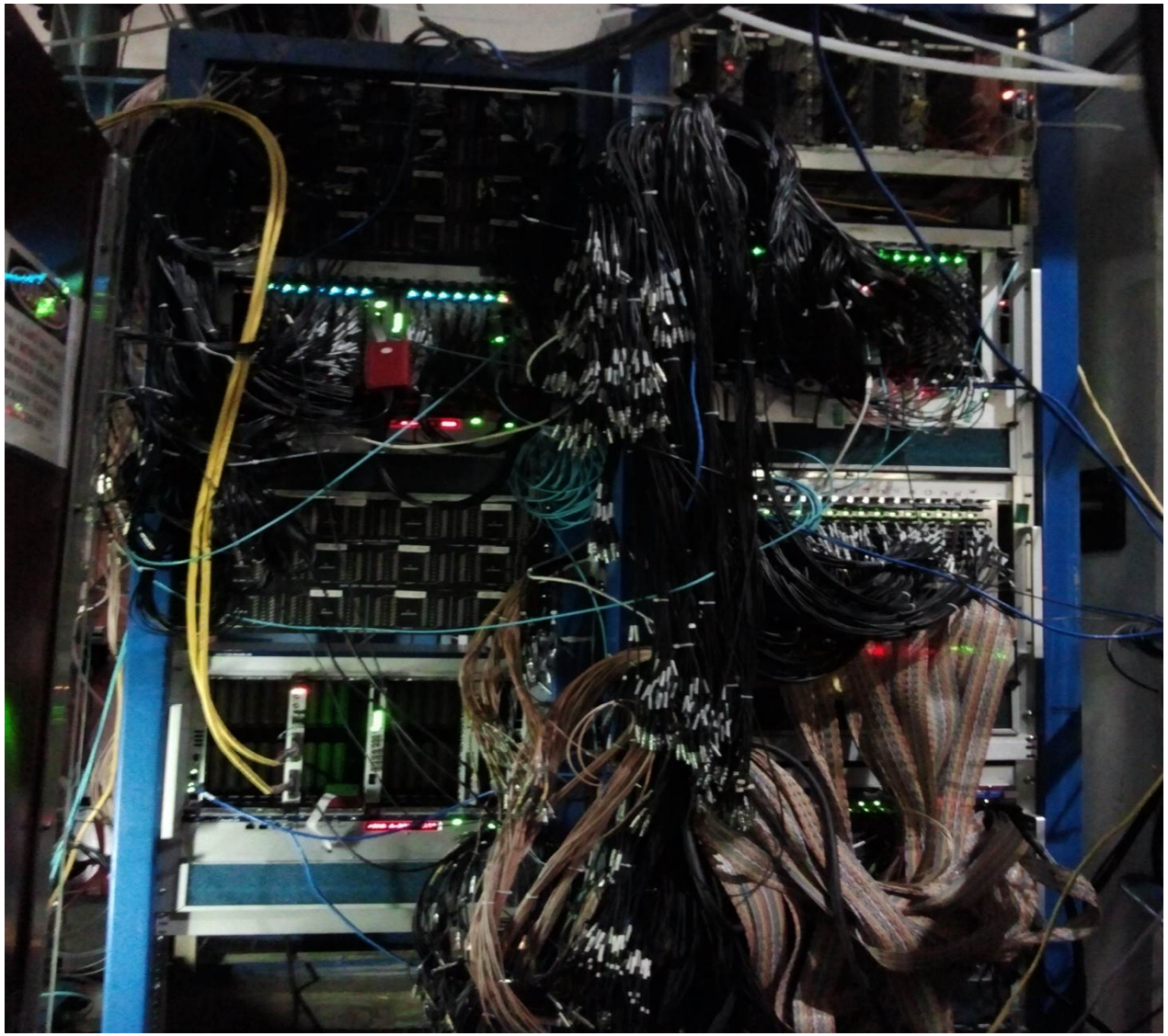
- Hodoscope Readout: 32 channels of 12bit 250MHz Flash ADCs (in hodoscope test setup)

- CPU/VTP/TS/TD trigger and signal distribution boards

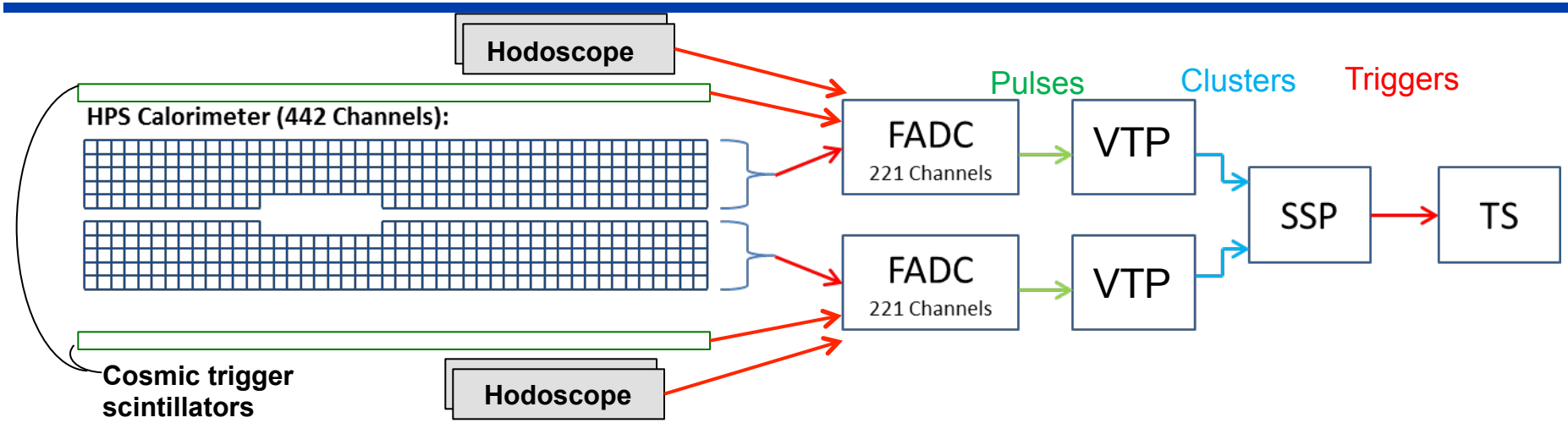
- 3 VXS crates

Back-end computing and software is ready as part of CLAS12 facility: network, computing, DAQ software, data monitoring, messaging system, realtime database etc

DAQ & Trigger System View



ECAL Trigger Overview



FADC (Flash Analog-to-Digital Converter)

- 250Msps, 12bit pulse digitizer for: Readout & Trigger (energy, timing)

VTP (VXS Trigger Processor)

- Collects pulse data from all FADC channels in crate
- Searches for clusters on half (top or bottom) of the ECAL
- Positron side clusters are tagged with hodoscope (using a hodoscope -> cluster map)
- Sends cluster energy, time, position, hit count, hodoscope tag to SSP for trigger processing

SSP (Sub-System Processor)

- Collects clusters from top & bottom halves of ECAL from VTP
- Performs cuts on individual clusters: energy (position dependent), hit count, hodoscope tag
- Performs cuts on paired clusters: energy sum/difference, coplanar, distance-energy
- Delivers trigger signals to TS (Trigger Supervisor) for readout

Trigger Module Status

FADC Status

- **Firmware:** complete and tested
- **Hardware:** all installed, spares available

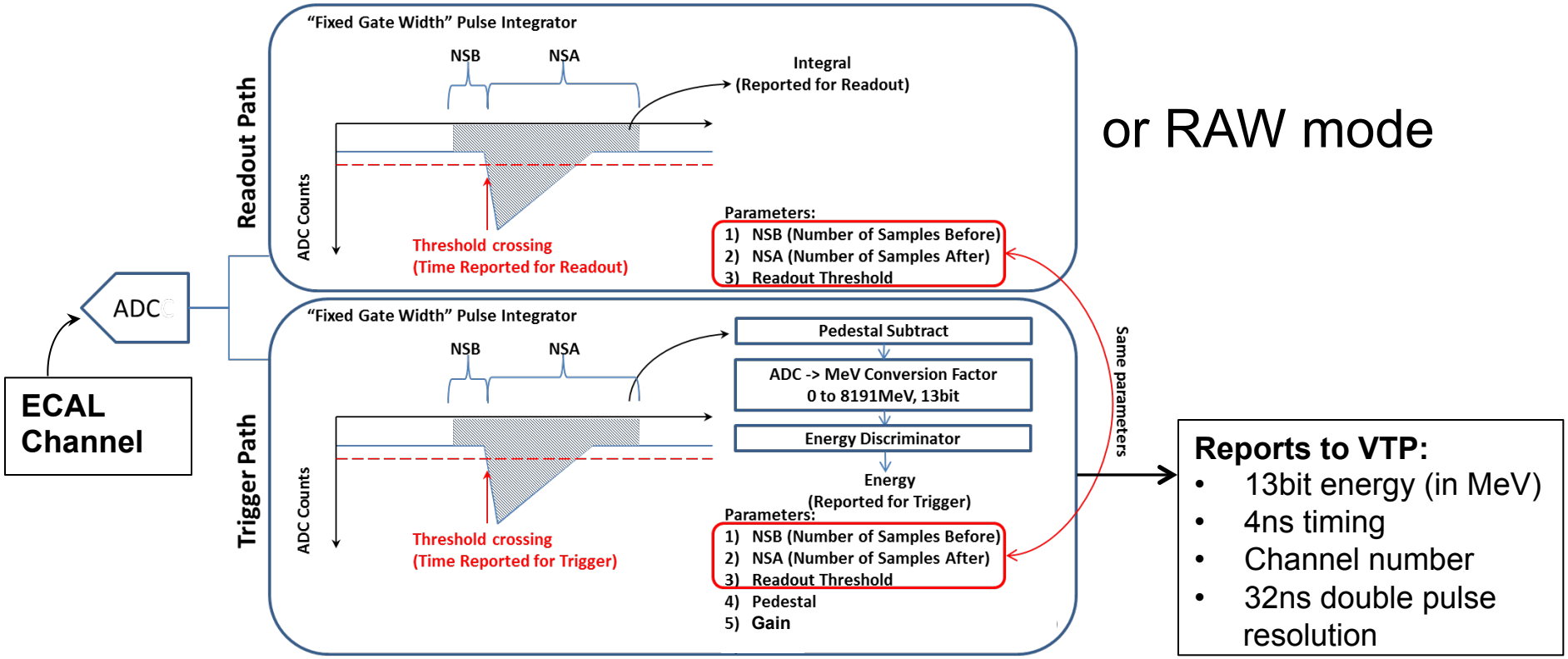
VTP Status

- **Firmware:** clustering complete and tested, hodoscope tagging logic is needed
- **Hardware:** installed, 1 spare unit
- **Plans:** expected firmware updates/testing: ~2 weeks needed

SSP Status

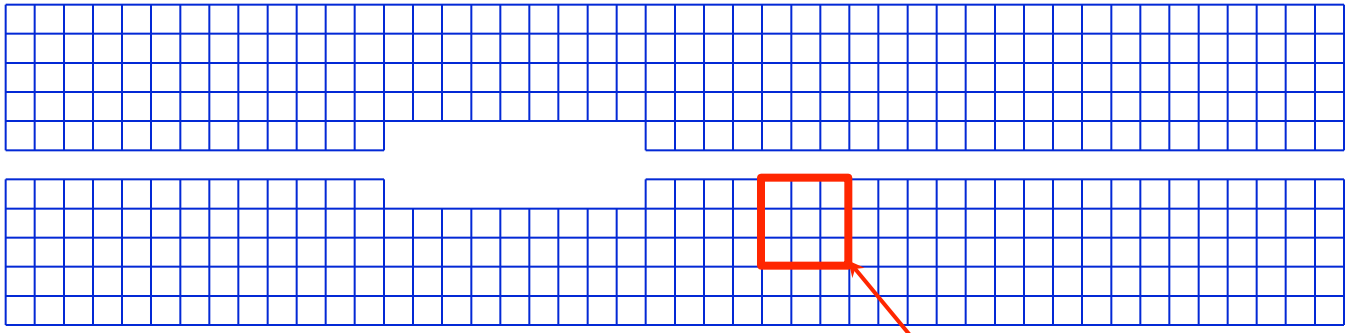
- **Firmware:** cluster triggers complete and tested, hodoscope trigger option is needed
- **Hardware:** all installed, spares available
- **Plans:** expected firmware updates/testing: ~2 weeks needed

FADC – Pulse Processing



- Trigger pedestal is the same parameter that would be calculated for the readout data.
- Trigger gain parameter sets energy units in MeV so VTP and SSP trigger parameters work in these units as well.
- Both pedestal and gain require calibration to determine parameters.

VTP – Cluster Processing



1. Search for ECAL hits ≥threshold that is a local maximum (in 3x3 window and in cluster coincidence time Δt)
2. Sum 3x3 window of hits within Δt of hit from step 1
3. Identify 3x3 window hit pattern
4. Report cluster to SSP defined as:
   - cluster center (defined by step 1)
   - 3x3 window energy sum (defined by step 2)
   - 3x3 hit pattern (count - defined by step 3)
   - 4ns resolution timestamp
   - Hodoscope tag (hodoscope hit matches space & time coincidence)

SSP Event Information (to datastream for efficiency measurement)

Structure Element	Size (bytes)	Element Information
Block Header	4	Block Number: 11bits VME Slot: 5bits EventsPerBlock: 11bits
Event Header	4	Event number: 27bits
Trigger Timestamp	8	Timestamp: 48bits (~13 day rollover)
ECal Cluster	8	Cluster Center X: 6bits Cluster Center Y: 4bits Cluster Energy: 13bits Cluster Nhits: 4bits Cluster Time: 10bits Hodoscope Tag: 2bits
Trigger (per trigger bit and per time stamp)	4	Trigger time: 10bits Trigger tags: 6bits Trigger type: 4bits
ECal Cluster	8	
…		
Event Header	4	
Trigger Timestamp	8	
ECal Cluster	8	
Block Trailer	4	Block Word Count: 22bits VME Slot: 5bits

SSP will create event data containing all found clusters.

Programmable time window:

- **"trigger look-back"**
- **"window width"**

Clusters are tagged with trigger decision results (pass/fail):

- **HPS physics cuts**
- **Cosmic**
- **Random**
- **etc…**

Trigger tags are used for efficiency measurements.

Tags and clusters can be used to understand reason for inefficiency.

TS Trigger Inputs

Up to 32 inputs are available:

1. SSP – "singles #0" (top) EC cluster tagged by hodoscope (HPS Physics)
2. SSP – "singles #1" (bot) EC cluster tagged by hodoscope (HPS Physics)
3. SSP – "singles #2" (top) EC cluster tagged by hodoscope (Calibration)
4. SSP – "singles #3" (bot) EC cluster tagged by hodoscope (Calibration)
5. SSP – "singles #4" EC cluster (Calibration)
6. SSP – "singles #5" EC cluster (Calibration)
7. SSP – "pairs #0" EC cluster pair (Calibration)
8. SSP – "pairs #1" EC cluster pair (Calibration)
9. SSP – "triplet #0" EC cluster triplet (Calibration)
10. SSP – Ecal scintillator 'vertical' coincidence (Cosmic)
11. Pulser (Random)

Pairs of identical triggers have different thresholds or timing or geometry etc

Prescalers (inside TS) for each trigger input:

- programmable from 1 to 32,768 (in powers of 2)

HPS Trigger Bit Definitions

"Singles" Cluster Trigger equation:

$(E_{min}(X,Y) <= E <= E_{max}(X,Y))$ and	[Position dependent Energy range]
$(NHits >= NHits_{min})$ and	[Minimum number of hits in cluster]
$(NHodoLayersHit >= NHodoLayersHit_{min})$	[Minimum number of hodoscope layers]

"Pairs" Cluster Trigger equation:

$(\lvert T_{Top} - T_{Bot}\rvert <= \Delta t_{max})$ and	[Pair cluster time coincidence]
$(\lvert E_{Top} - E_{Bot}\rvert <= \Delta E_{max})$ and	[Pair energy difference]
$(E_{Top} + E_{Bot} <= E_{max})$ and	[Pair energy sum]
$(E_{min} <= E_{Bot} <= E_{max})$ and $(E_{min} <= E_{Top} <= E_{max})$ and	[Energy range]
$(Nhits <= HitThreshold)$ and	[Minimum number of hits in cluster]
$(NHodoLayersHit >= NHodoLayersHit_{min})$ and	[Minimum number of hodoscope layers]
$(\text{Min}(E_{Top}, E_{Bot}) + R \times F <= Threshold_{Slope})$ and	[Energy distance cut]
$(\lvert \tan^{-1}(X_{top}/Y_{top}) - \tan^{-1}(X_{bot}/Y_{bot})\rvert <= Coplanarity_{Angle})$	[Pair coplanarity cut]

Cosmic trigger equation:

$(\lvert ScintillatorHitTime_{Top} - ScintillatorHitTime_{Bot}\rvert <= \Delta t_{max})$	[Scinillator time coincidence]

Note:

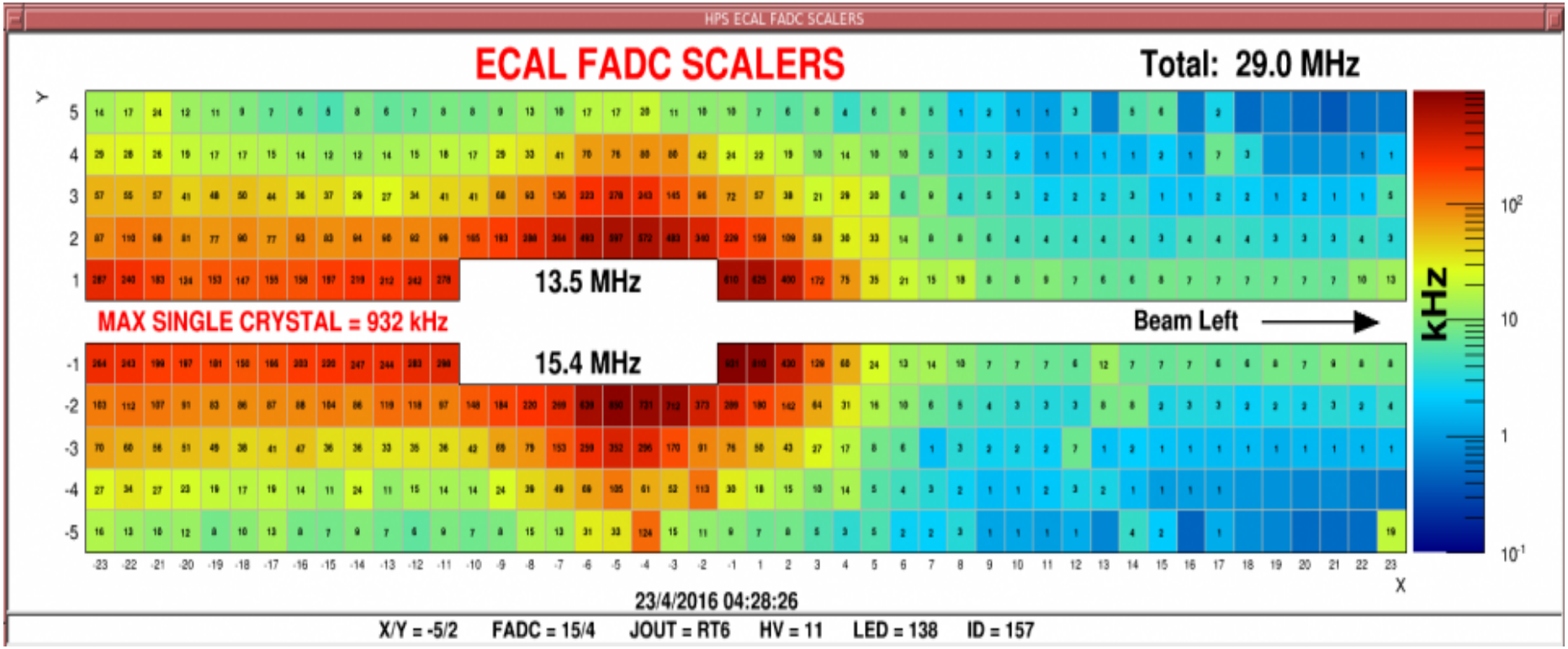
- Currently 2 independent "singles" and 2 independent "pairs" trigger are available for use. It will be more triggers to support additional singles given the addition of the hodoscope.

Color legend:

- Trigger data from detector VME programmable parameter Hardcoded parameter/logic

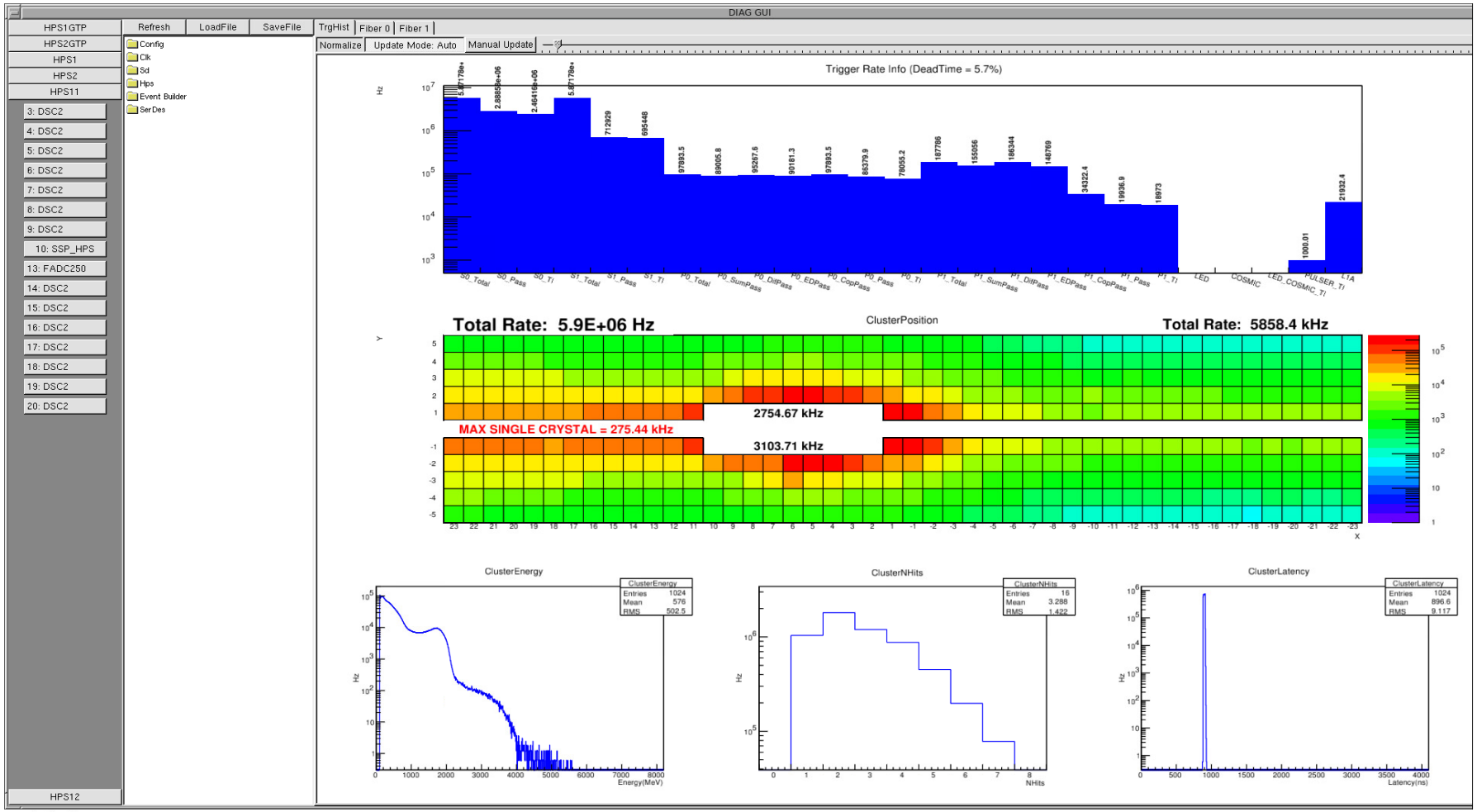
Monitoring examples

- **ECAL FADC channel scalers**
- **Similar monitoring will be provided for hodoscope**



Monitoring examples

- **Trigger bits and term cut rates**
- **Trigger cluster positions, energy, number of hits**



Conclusion

All trigger & DAQ hardware is installed

Trigger system successfully used during the 2015-2016 runs; diagnostic trigger tagging data demonstrated >99% efficiency for cluster reconstruction and physics triggers

For upcoming run, firmware updates are relatively small and will take a few weeks to finish; plan to do this during March/April 2019

Integration with SVT DAQ was complete for 2015-2016 run, need to be updated to be consistent with recent changes on both subsystems, mostly on SVT side

HPS DAQ & Trigger System will be completely ready by May 1, 2019