DAQ/Trigger performance and plans for the Fall Run

1. DAQ/Trigger systems overview
2. Operational requirements and achieved performance
3. Remaining issues and path forward
4. Hardware and spares status

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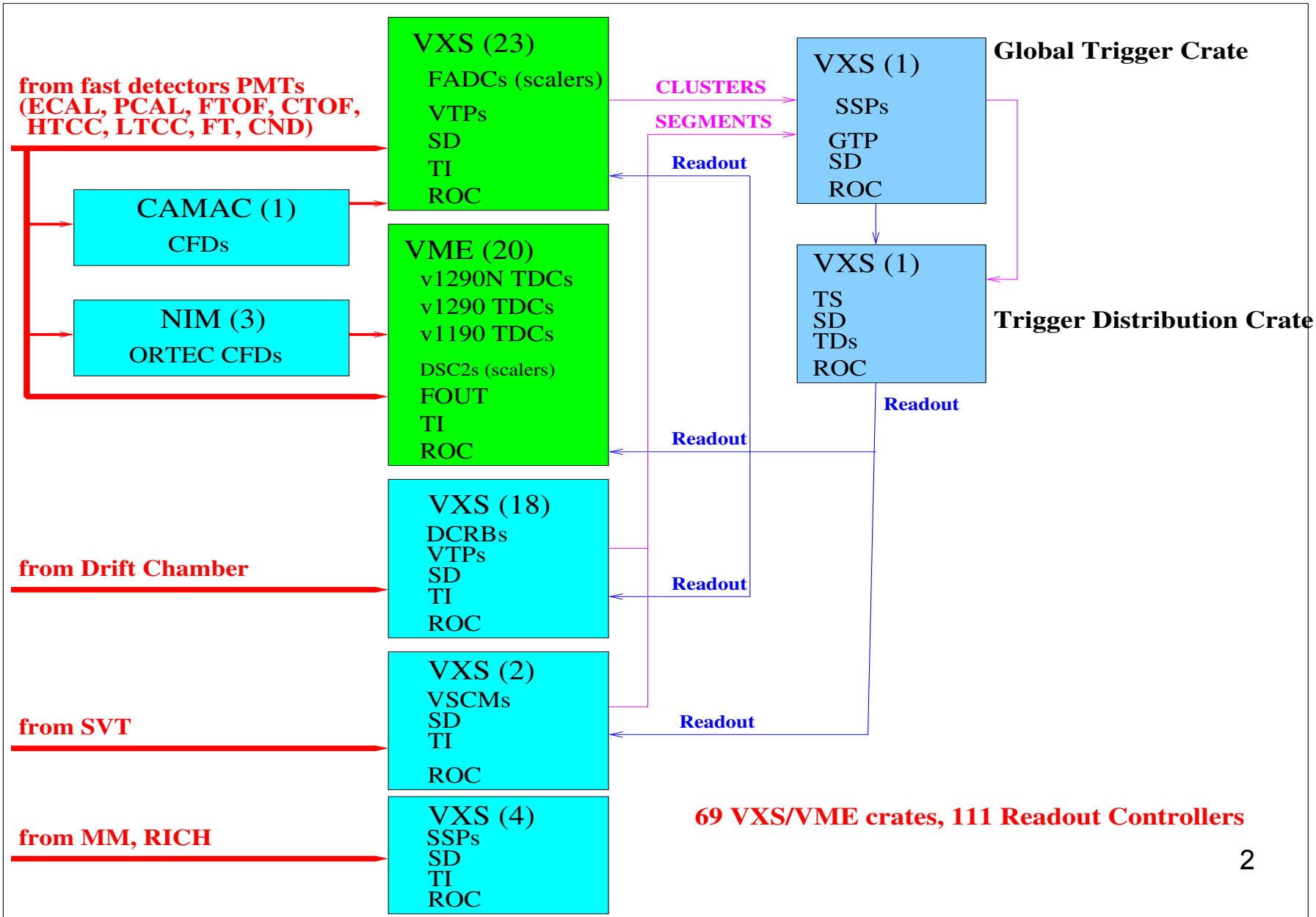
1. DAQ/Trigger Hardware



1. Readout channels count

Detectors with dual outputs (FADCs and Discriminators/TDCs):

ECAL: 1296
PCAL: 1152
FTOF: 1080
CTOF: 96
CND: 144
HTCC: 48
LTCC: 144
=== 3,960 x 2 = 7,920

Detectors with single output:

Drift chamber:	24,192
SVT:	21,504
MM:	24,576
RICH:	25,024
FT:	564

=== 95,860

====== Total in CLAS12: 103,780

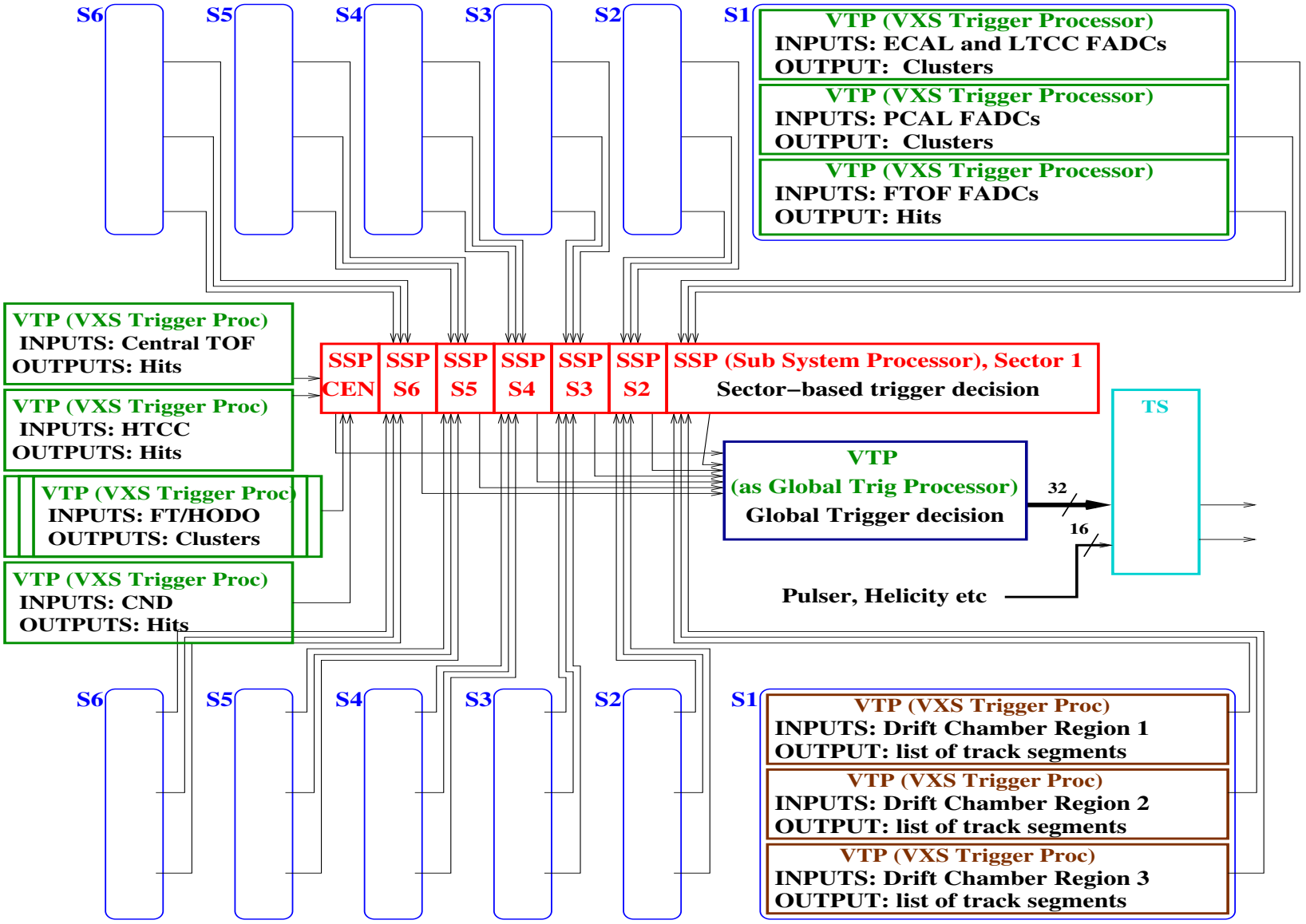
Most of channels have built-in scalers, they are reported to EPICS. Few channels are recorded into data stream (such as helicity-marked Faraday Cup)

In addition we have trigger system containing 42 VTP boards.
Only 3 of them being read out right now, but we are planing
to read all of them which may increase our data rate. It should
not be significant addition.

1. CLAS12 DAQ Status

- Detectors supported: ECAL, PCAL, FTOF, LTCC, DC, HTCC, CTOF, CND, SVT, MM, FT/HODO, RICH
- Online computer cluster: 30+ computers, 4 DAQ servers (2 in use and 2 hot swap)
- Networking: 1 router, 20+ switches, 40GBit to CC
- DAQ is operational, performance exceeded requirements, reliability is acceptable and will be improved

1. CLAS12 Trigger System Logic



1. CLAS12 Trigger status

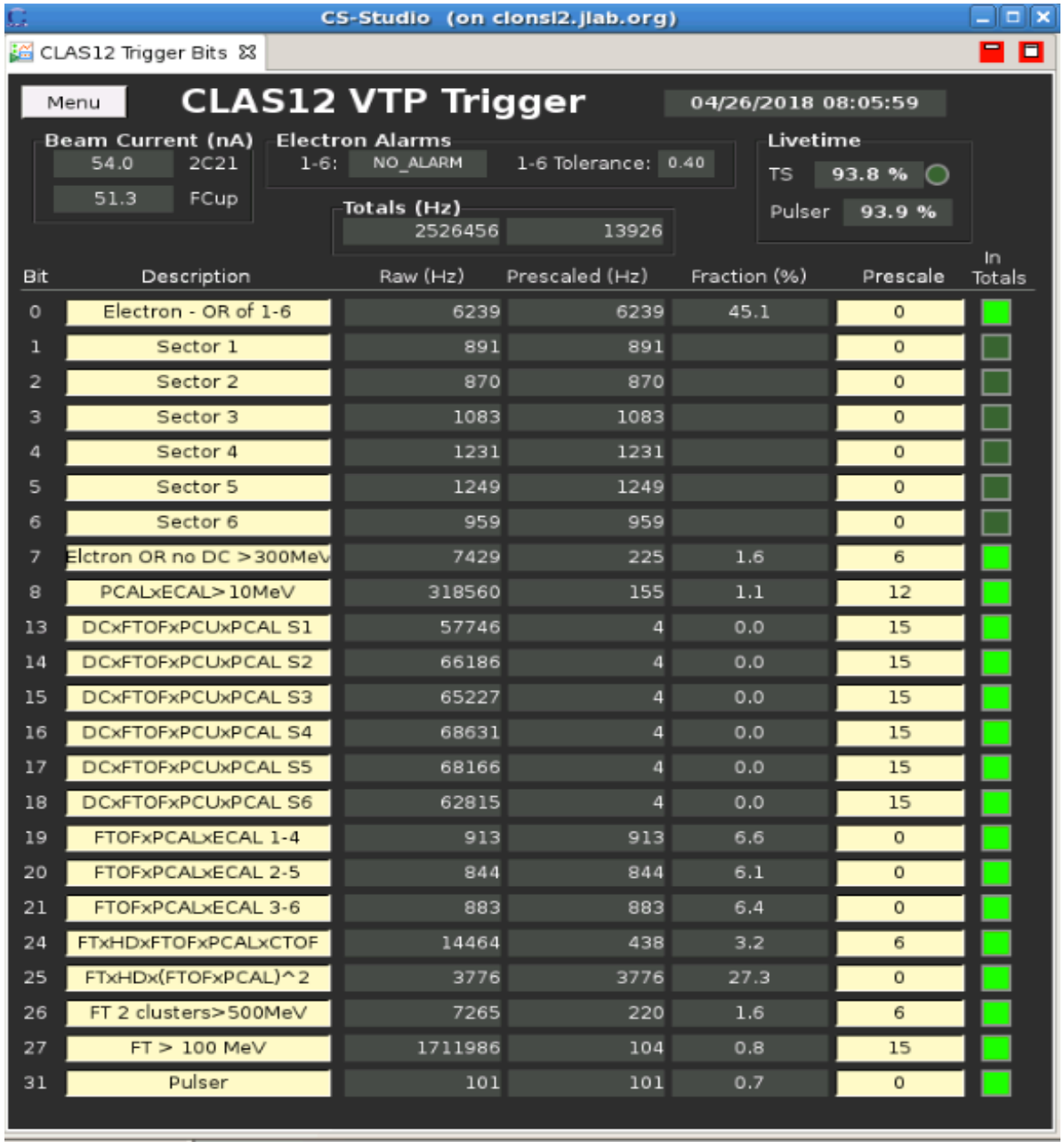
- Stage 1: ECAL, PCAL, HTCC, FTOF, CTOF, FT/HODO - operational
- Stage 1: CND – operational, calibration in progress
- Stage 1: DC segment finder and superlayer multiplicity − operational
- Stage 2: FTOF-PCAL(U) geometry match - operational
- Stage 2, stage 3: timing match/multiplicity/logic – operational
- Validation procedures well established and producing feedback allowing to implement new components and fix problems; validation was completed during engineering run so we entered production with ready-to-go trigger system
- The number of different trigger configurations were prepared and used during er-a/b and rg-a runs, parameter setting procedures were developed (delay scans, config files)

1. Trigger Monitoring (ActiveMQ to EPICS)

Electroproduction (bits 0-6)

Muon (bits 19-21)

MesonX (bit 25)



Bit	Description	Raw (Hz)	Prescaled (Hz)	Fraction (%)	Prescale	In Totals
0	Electron - OR of 1-6	6239	6239	45.1	0	
1	Sector 1	891	891		0	
2	Sector 2	870	870		0	
3	Sector 3	1083	1083		0	
4	Sector 4	1231	1231		0	
5	Sector 5	1249	1249		0	
6	Sector 6	959	959		0	
7	Elctron OR no DC >300MeV	7429	225	1.6	6	
8	PCALxECAL>10MeV	318560	155	1.1	12	
13	DCxFTOFxPCUxPCAL S1	57746	4	0.0	15	
14	DCxFTOFxPCUxPCAL S2	66186	4	0.0	15	
15	DCxFTOFxPCUxPCAL S3	65227	4	0.0	15	
16	DCxFTOFxPCUxPCAL S4	68631	4	0.0	15	
17	DCxFTOFxPCUxPCAL S5	68166	4	0.0	15	
18	DCxFTOFxPCUxPCAL S6	62815	4	0.0	15	
19	FTOFxPCALxECAL 1-4	913	913	6.6	0	
20	FTOFxPCALxECAL 2-5	844	844	6.1	0	
21	FTOFxPCALxECAL 3-6	883	883	6.4	0	
24	FTxHDxFTOFxPCALxCTOF	14464	438	3.2	6	
25	FTxHDx(FTOFxPCAL)^2	3776	3776	27.3	0	
26	FT 2 clusters>500MeV	7265	220	1.6	6	
27	FT > 100 MeV	1711986	104	0.8	15	
31	Pulser	101	101	0.7	0	

1. Online System Status

- Available computing hardware is almost sufficient, need bigger data server
- Available software: process monitoring and control, CLAS event display, data collection from different sources (DAQ, EPICS, scalers etc) and data recording into data stream, online data monitoring
- EPICS in numbers: 100 IOCs, 4.6K HV channels, 150 LV channels, 70K scaler channels
- Runtime database (RCDB) is running
- ActiveMQ messaging system is running
- 'Online farm' issue to be resolved, need farm in CC (one rack, 10 machines scale), one machine was installed and tested during spring run

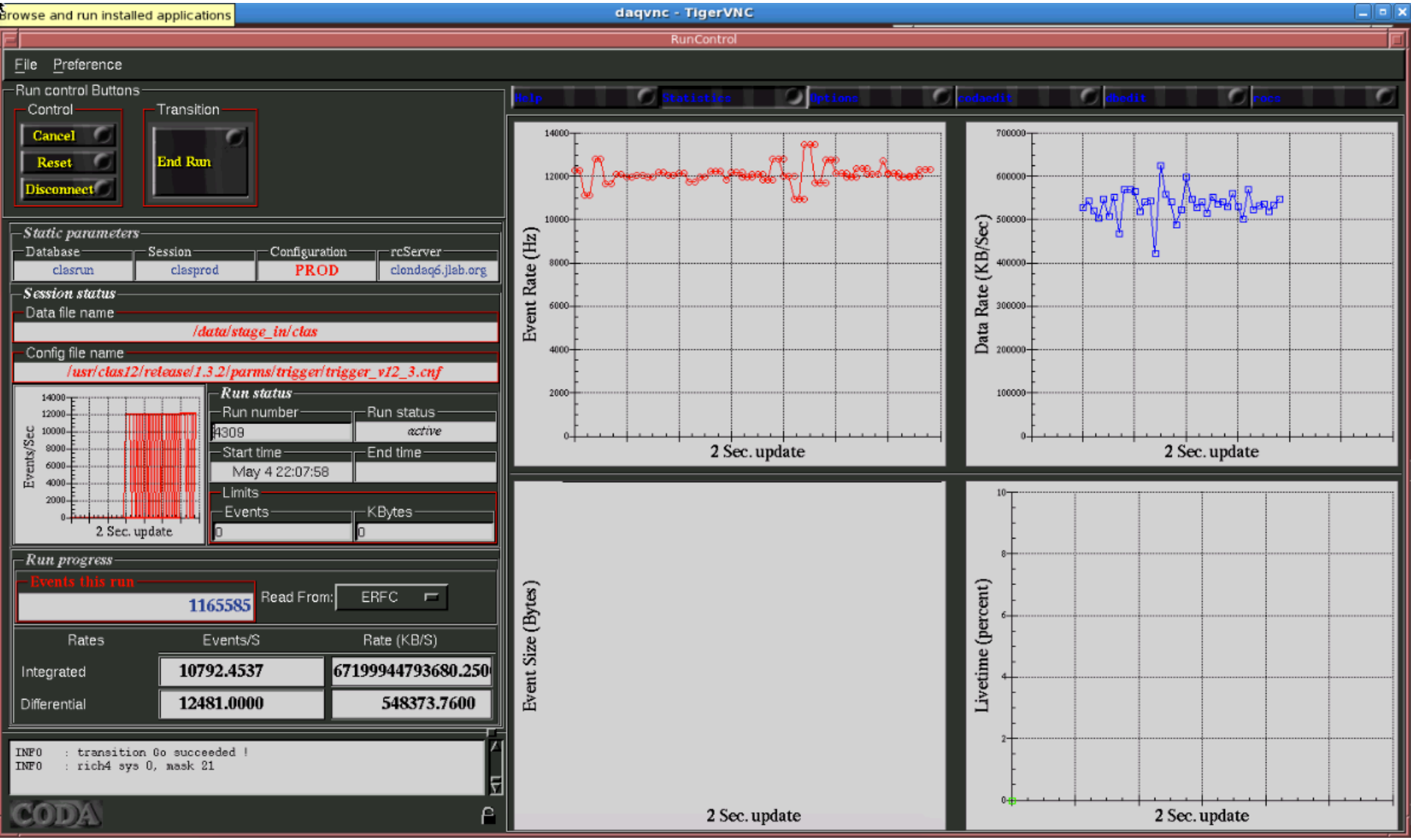
1. DAQ/Trigger/Online Summary

- DAQ/Trigger/Online systems are operational
- Systems are well supported by Hall B team (Sergey Boyarinov and Nathan Baltzell as first line of support, Valery Kubarovsky and Andrea Celentano from run group on trigger settings, and at least one person from every detector group for configuration and data monitoring including outside groups
- DAQ and Trigger systems are well supported by JLAB CODA and Fast Electronics Groups, in particular Ben Raydo and Bryan Moffit for trigger system and front-end libraries
- GIT is used as code management for all related software

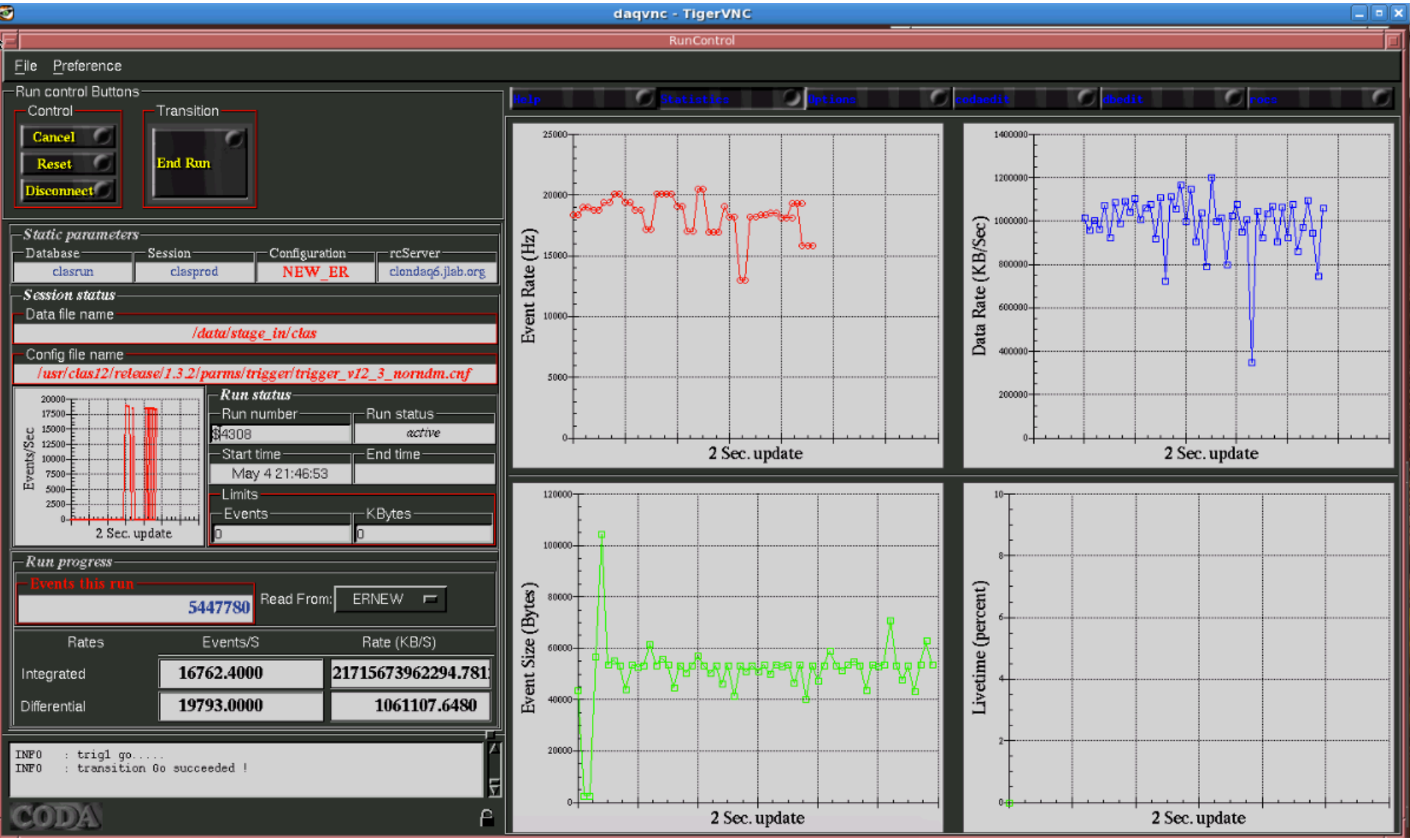
2. Requirements and achieved performance

- Original DAQ requirements: 10kHz event rate, 100MB/sec data rate, 90% livetime
- Rates estimates after KPP run (February 2017): 10kHz event rate, 200MB/sec data rate with FADCs in mode 7, 800MB/sec with FADCs in mode 1
- Production rates at 50nA beam (spring 2018): 12kHz event rate, 600MByte/sec data rate, 94% livetime
- Rates with new multi-stream Event Recorder: 20kHz and 900MByte/sec with 88% livetime on beam test
- Move to tape: up to 1500MByte/sec
- DAQ works as expected, performance exceeded requirements, reliability is reasonable and will be improved

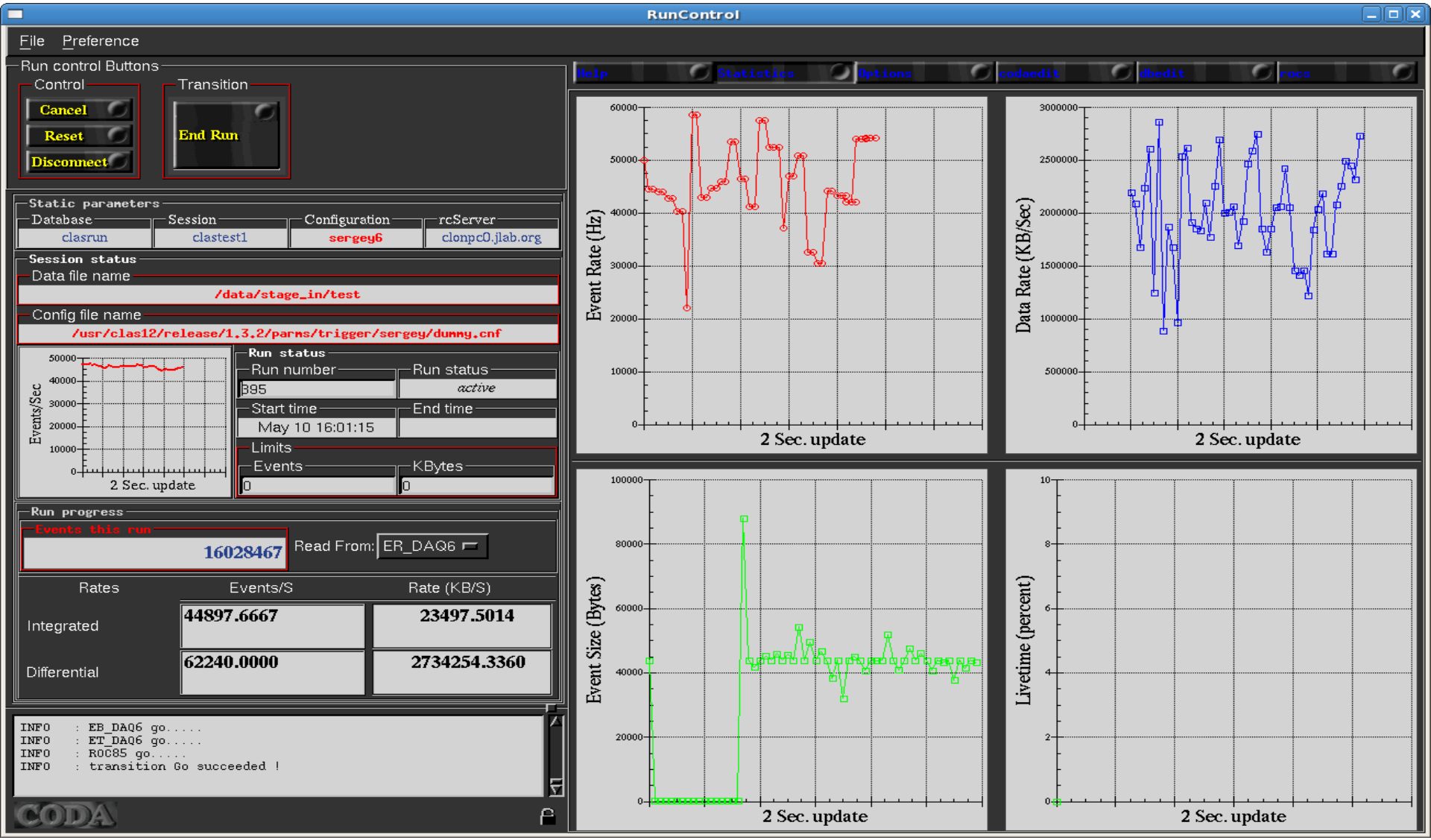
2. 50nA beam rates (production data taking) – 94% livetime



2. 50nA beam rates, multi-stream Event Recorder on clondaq6 (some prescales removed) – 88% livetime



2. Backend test (ET+ER only, no front-end, no EB), multi-stream Event Recorder on clondaq6

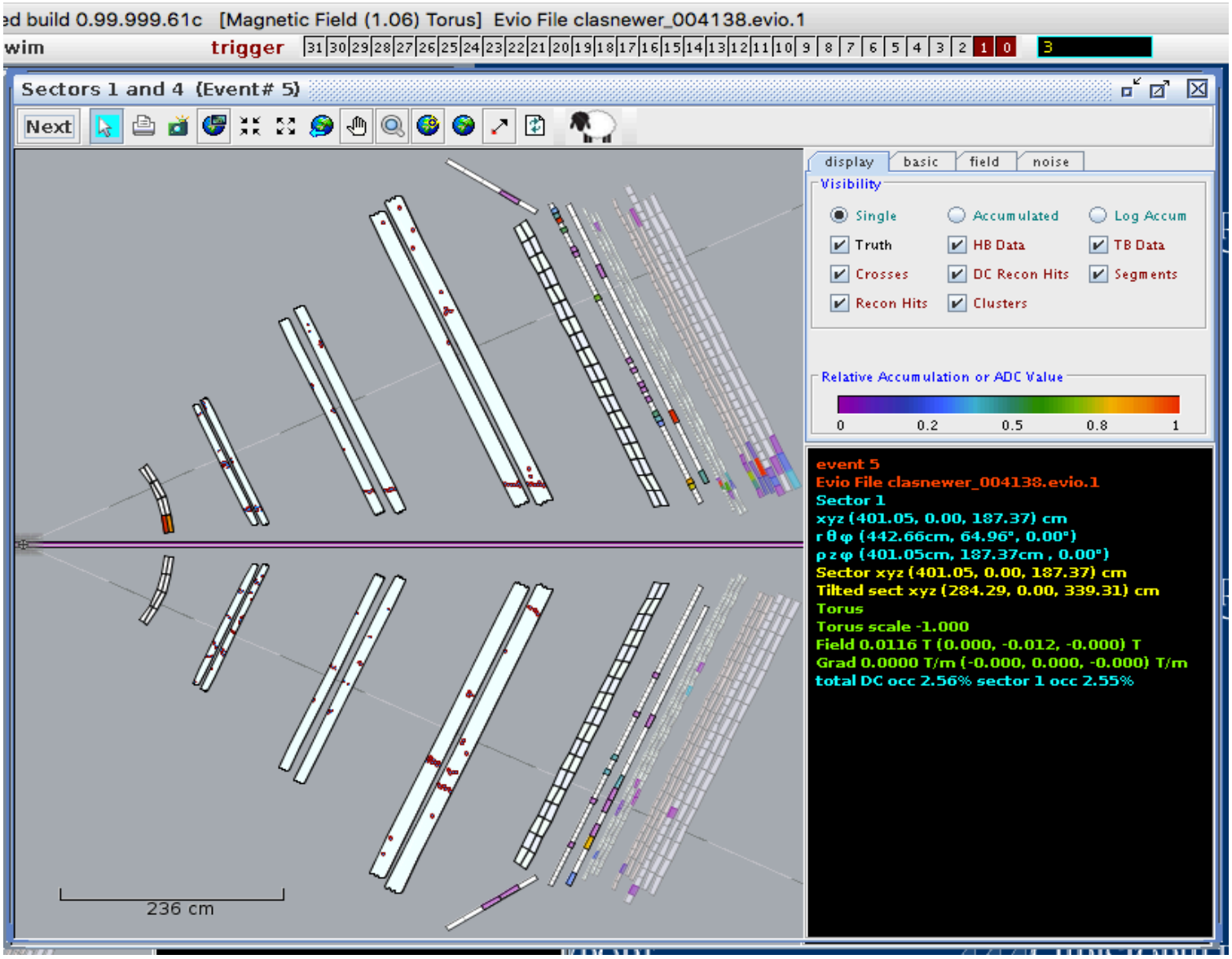


3. Remaining issues and path forward

- Drift Chamber-based trigger improvement
- Geometry match between different detectors participating in trigger
- Forward Calorimeters trigger improvement
- FADC data reduction
- MM data reduction
- Fix remaining DAQ and Trigger Issues, mostly related to reliability
- CAEN TDC calibration
- Trigger logic improvements
- Online Farm construction

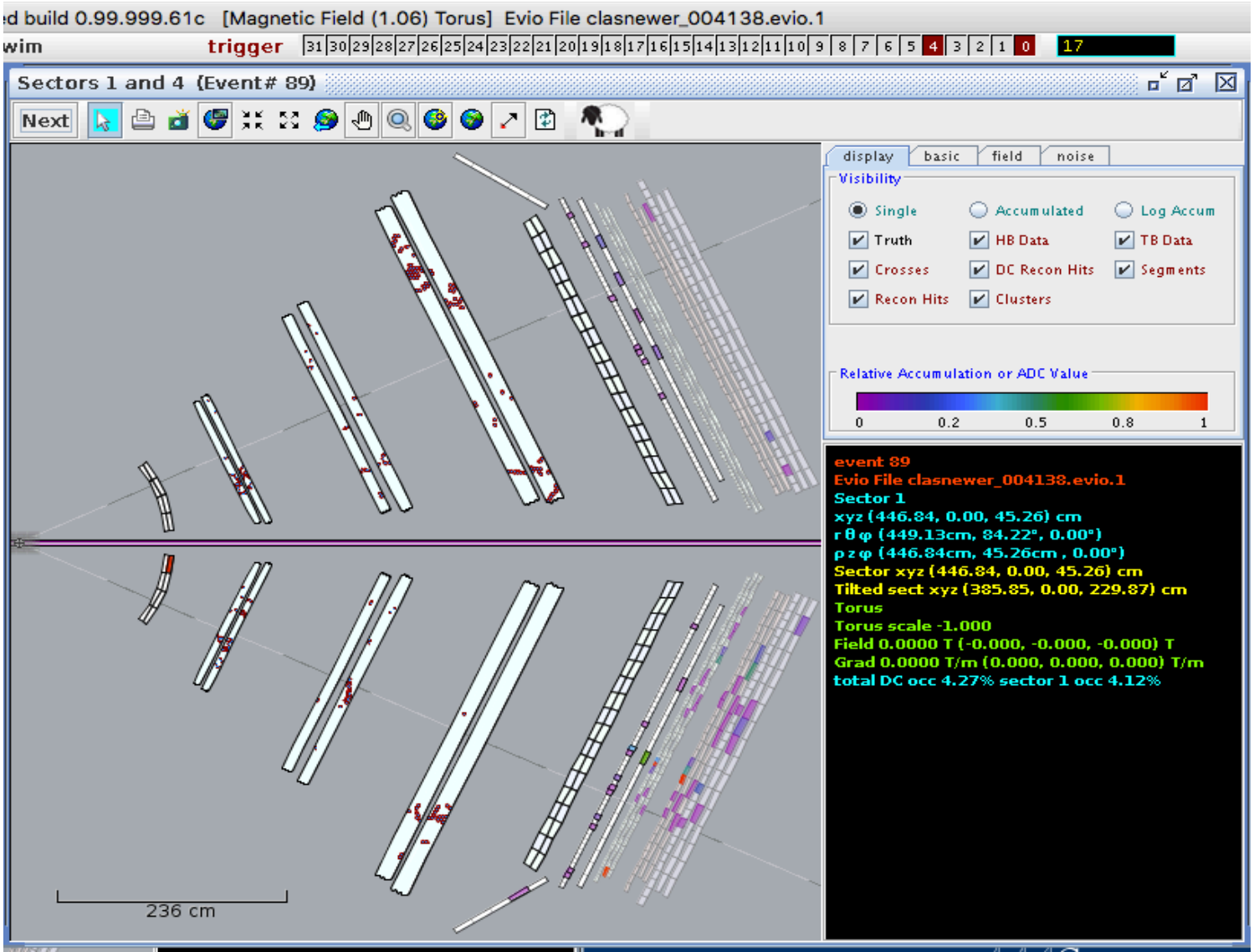
3. Drift Chamber-based trigger − ‘good’ event

- Current algorithm includes segment finder in every superlayer, we are triggering on segment multiplicity



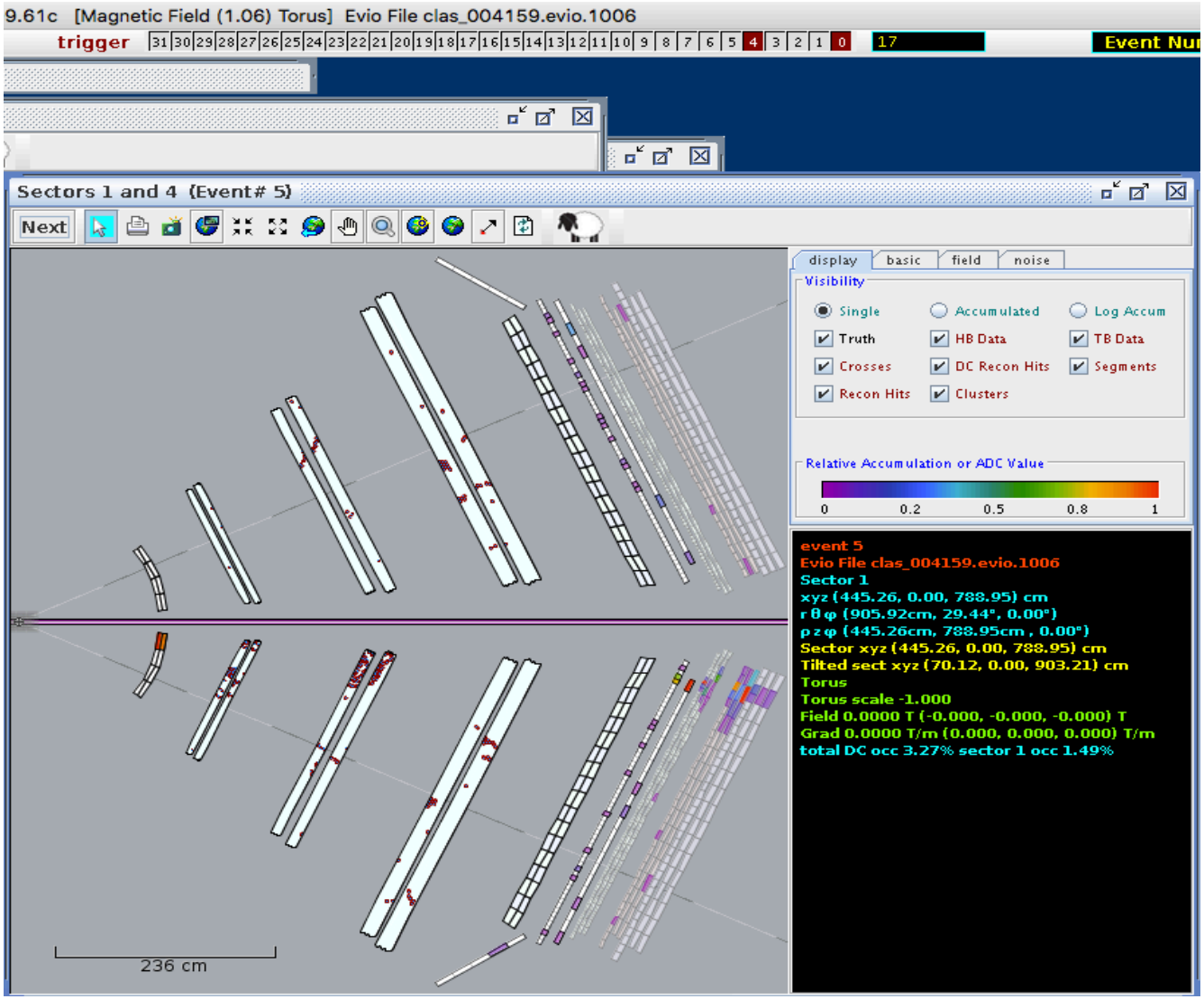
3. Drift Chamber-based: ‘bad’ event

- Plan is to add road finder so we can trigger on real tracks
- Expected improvement is about 30% decrease in event rate



3. Drift Chamber-based: ‘bad’ event

- Plan is to add road finder and geometry match
- Expected improvement is about 45% decrease in event rate

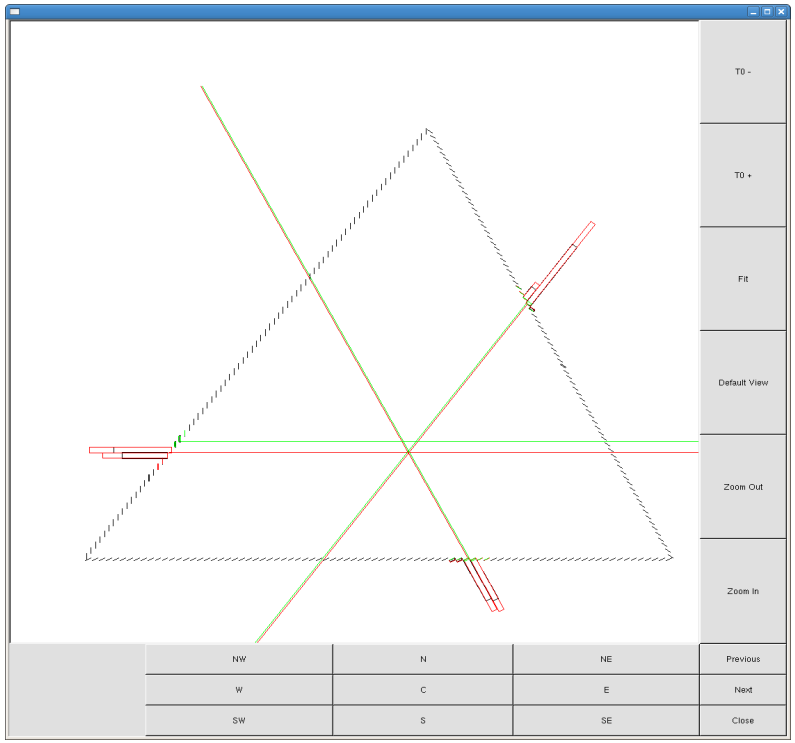


3. Geometry match between different detectors participating in trigger

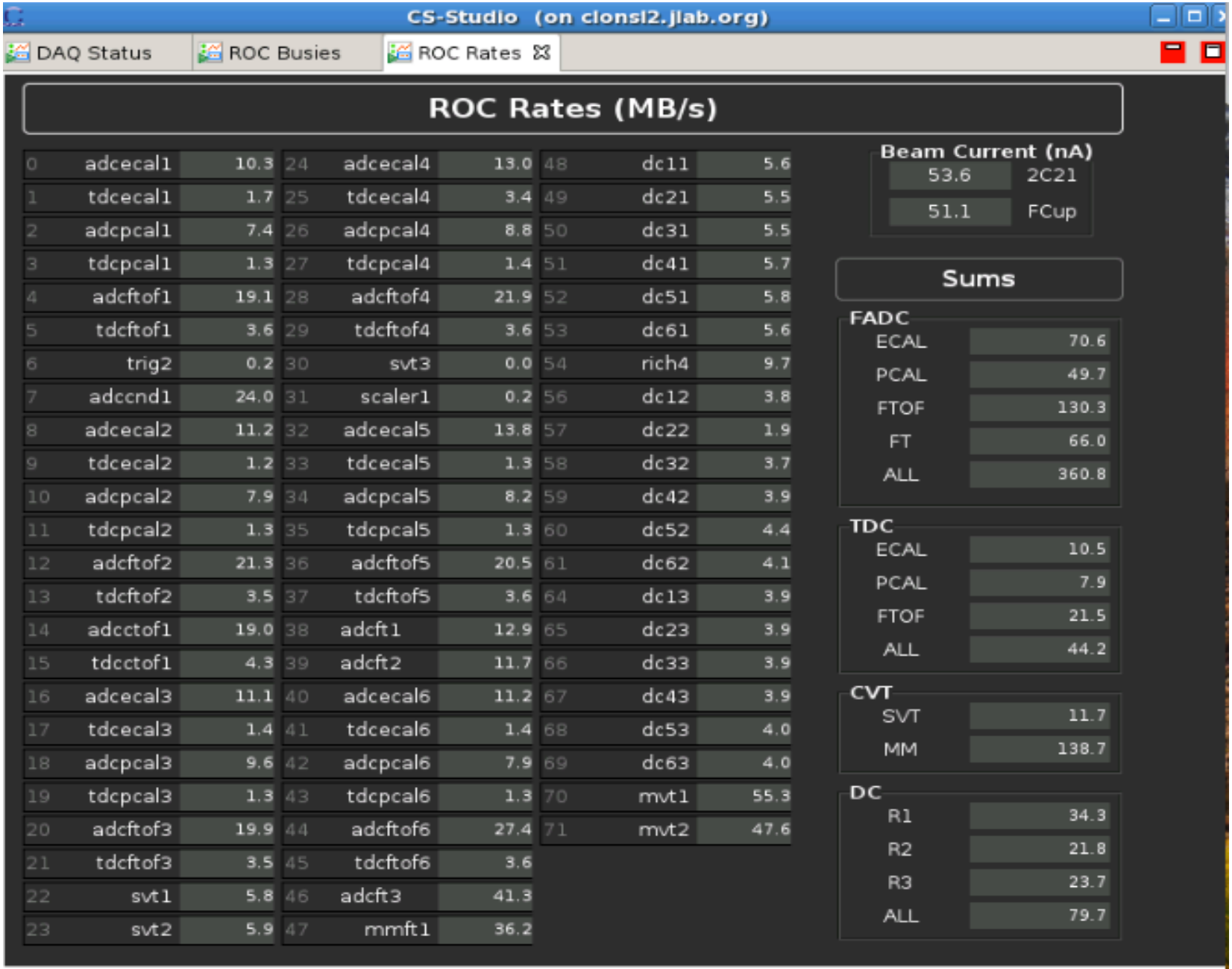
- Currently trigger has two geometry matches: Forward Tagger ECAL − Hodoscope, and Forward TOF − Preshower Calorimeter U plane
- With Drift Chamber road finder implemented, geometry match between Drift Chamber track and forward detectors (FTOF hits, PCAL clusters, ECAL clusters) can be included into trigger logic
- Possible trigger rate reduction from both road finder and geometry match can be estimated on the level of 45%
- Current status: first revision of firmware with road finder and dc-ftof match being implemented and should be ready for testing by July 15, preliminary road dictionary from Veronique has 100K roads and is not complete, fpga can fit about 200K roads, if not fitted we will make roads wider; complete road dictionary generation requires more work

3. Forward Calorimeters trigger improvement

- Forward Calorimeters (PCAL and ECAL) trigger components reports coordinate and energy for up to 4 clusters
- Clusters energy is corrected for attenuation length using the same attenuation for all scintillating strips; timing resolution is 32ns
- Planned improvement includes usage of individual attenuation for every strip to do energy correction more precisely, and improved cluster timing reporting by using actual distance from cluster to PMT (expect 8ns resolution)
- Improved timing will allow to decrease coincidence windows, decreasing accidentals and readout window size, and decrease both event and data rates
- Current status: not started



3. Data Rates



65%

25%

3. FADC data reduction

- Running in raw mode, FADC data makes 2/3 of overall data traffic
- Plan is to use bit packing algorithm
- C implementation was tested on CLAS12 data, showing more then 2.5 times FADC data size reduction, and it takes up to 40us per event on CLAS12 VME controllers
- C code was passed to CODA and Fast Electronics Groups to be implemented into FADC hardware; when implemented, it will be possible to switch between normal and packed data output
- Current status: firmware development is in progress by Hai Dong, Ed Jastrzembski and Ben Raydo, have to be ready for testing by July 15

3. MM data reduction

- Micromega data is second largest contributor into event size after FADCs, it creates about 25% of overall data traffic
- Reason for high data rate is that there is no sparsification, and it seems impossible to implement it in current readout design
- Bit packing mechanism was suggested
- MM group is working to implement it
- Possible data rate reduction is 40-45%
- Current status: in progress, plan is to implement it not in firmware but in second readout list, some work is done already by Irakli, will continue to work on it and hope to finalize it during first week of August

3. Rates summary

- Event size will be decreased up to factor 1.5 using bit packing and readout windows optimization, to about 30KB from current 45KB
- Event rate for current running conditions (2/3 of maximum luminosity) will be decreased by trigger efficiency improvement by about 45%
- In the same time, event rate will go up by about 80% when running at nominal luminosity (75nA beam current, right now 50nA)
- As result, expected event rate for nominal luminosity is 15kHz, and data rate is 450MB/sec
- Taking into account contingency we have to assume data rate on the level up to 1GB/sec; Hall B DAQ/Trigger system is getting ready to accept it, and appropriate resources have to be allocated on CC side

3. Other Remaining Work

- Fix problems in DAQ front end responsible for occasional crashes and speedup run startup; right now time loss is up to 10% because of DAQ/Trigger reconfiguring, runs restarting and various crashes − some software issues fixed already, new firmwares and libraries from CODA group (William Gu) are installed, cosmic looks Ok, more testing will be performed
- Fix broken VTP boards and improve VTP readout protocol − in progress, some fixed, last 4 VTPs to be fixed in a week
- Add more monitoring and control components (readout from all VTP boards, more scalers and histograms over messaging, convenient delay scan procedures, built-in scopes etc) − not started
- Trigger logic improvements (more stage2 elements etc) − not started
- CAEN TDC calibration − not started
- Online Farm − preliminary approved by all sides, will be located in CC, plan being finalized

3. Online Farm Plan

- Purpose: perform real time events reconstruction to provide shift takers with data monitoring information
- Contains 40/10GB network switch and about 10 servers located in one rack in computer center room in CEBAF center building (est. $100K), can be build in stages
- Maintained by jlab farm personal
- Running the same operating system as jlab farm
- Receives data from counting room over 40GB ethernet link
- Process data running standard CLAS12 offline software
- Report results back to counting room using messaging software, to be presented in form of histograms, timeline plots etc
- Does NOT write reconstruction results to disk
- All computers in online farm have dual connection, 10G ethernet and infiniband, which make it possible to incorporate them into jlab farm between runs
- Next work day support: if down, we'll use counting room machine(s) as backup

4. Hardware status and spare parts

- All needed hardware is installed, but some items were borrowed, and spare pool was almost completely used
- Have to purchase hardware borrowed from other groups (2 VXS crates etc)
- Have to restore spare electronics pool (originally planed 5-10% spares, need at least 2-3%): VME/VXS crates, HV mainframes, VTPs, SSPs, TIs, TDs, FADCs, SDs, DCS2s, TDCs, CPUs, Scalers, HV/LV boards etc
- Have to buy bigger event recorder server (have 41TB storage, need at least 86TB to run 24 hours with 1GB/sec data rate)
- Have to buy several servers for EPICS and counting room desktops

4. Critical hardware needed

- 6 TD boards − PR approved, expecting delivery in August
- 6 old TD->TI conversion ($3k) − to be done after new TDs received
- Fix broken VTPs ($4k) − in final stage of processing
- More FADCs and SDs − handled by Fast Electronics Group (Chris Cuevas)

- 4 VXS crates ($60k) - PR submitted, waiting signatures
- 4 VME CPUs ($22k) - PR submitted, waiting signatures
- Event recorder server ($30k) - PR submitted and blocked, vendor change requested, will run tests using Hall D machine

Conclusion

- DAQ, computing and network works as expected exceeding original CLAS12 requirements; some reliability problems remains and will be addressed
- Trigger system works as expected; some parts to be finished; trigger structure will be constantly improving to meet experiment demands
- Online software is operational, available tools allows to run; online farm, if implemented, will significantly improve prompt data processing
- Fall Run preparation under way, most critical issues being addressed and should be resolved before August 22
- New hardware purchases still an issue, effecting spare pool and new CLAS12 additions