CLAS12 DAQ & Trigger Status and Timeline

Sergey Boyarinov

Oct 3, 2017

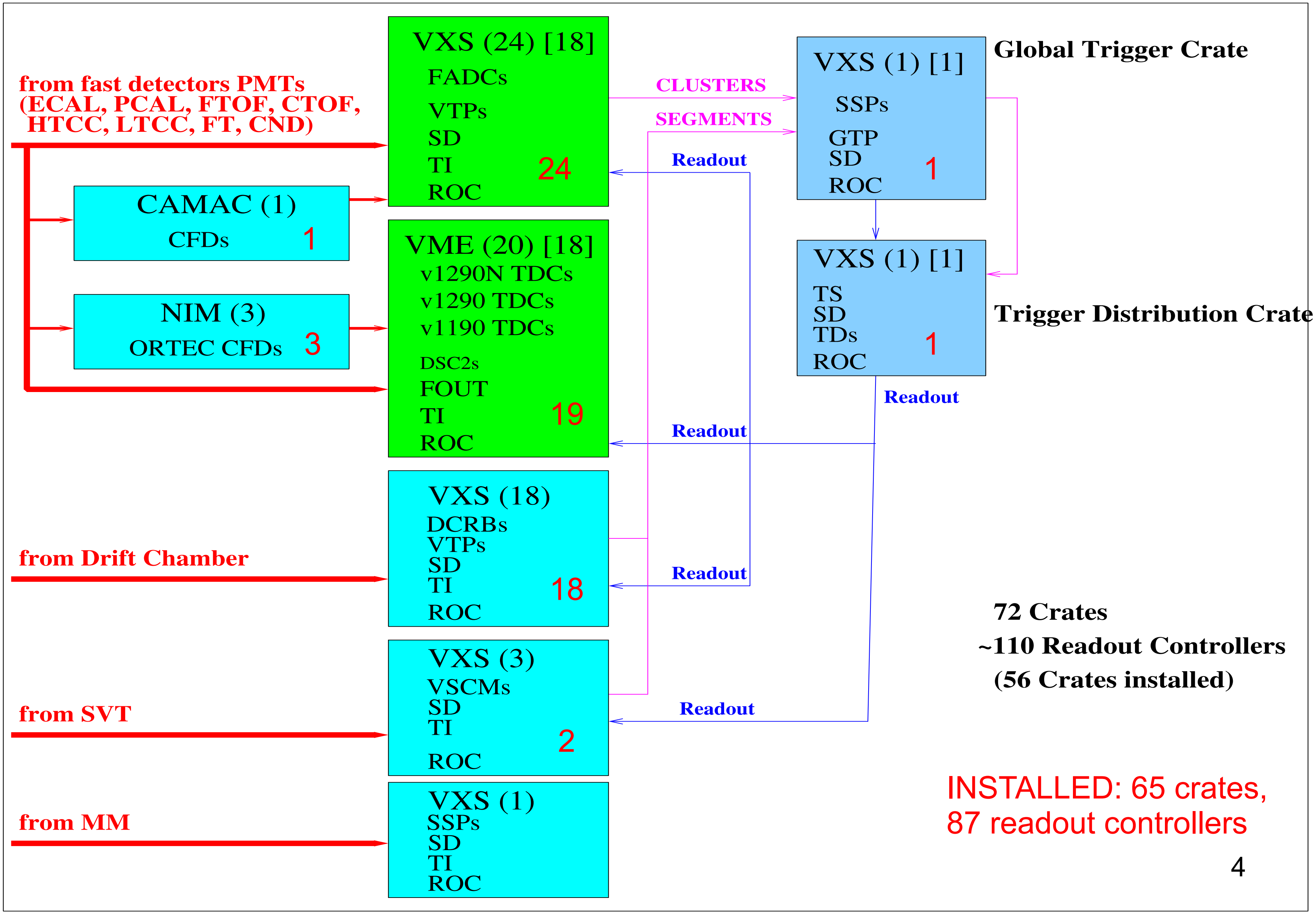
Notation

- ECAL – old EC (electromagnetic calorimeter)
- PCAL – preshower calorimeter
- DC – drift chamber
- HTCC – high threshold cherenkov counter
- FT – forward tagger
- TOF – time-of-flight counters
- MM – micromega tracker
- SVT – silicon vertex tracker
- VTP – VXS trigger processor (used on trigger stage 1 and stage 3)
- SSP – subsystem processor (used on trigger stage 2)
- FADC – flash analog-to-digital converter
- FPGA – field-programmable gate array
- VHDL – VHSIC Hardware Description Language (used to program FPGA)
- Xilinx – FPGA manufacturer
- Vivado_HLS – Xilinx High Level Synthesis (translates C++ to VHDL)
- Vivado – Xilinx Design Suite (translates VHDL to binary image)
- GEMC – CLAS12 GEANT4-based Simulation Package
- CLARA – CLAS12 Reconstruction and Analysis Framework
- DAQ – Data Acquisition System

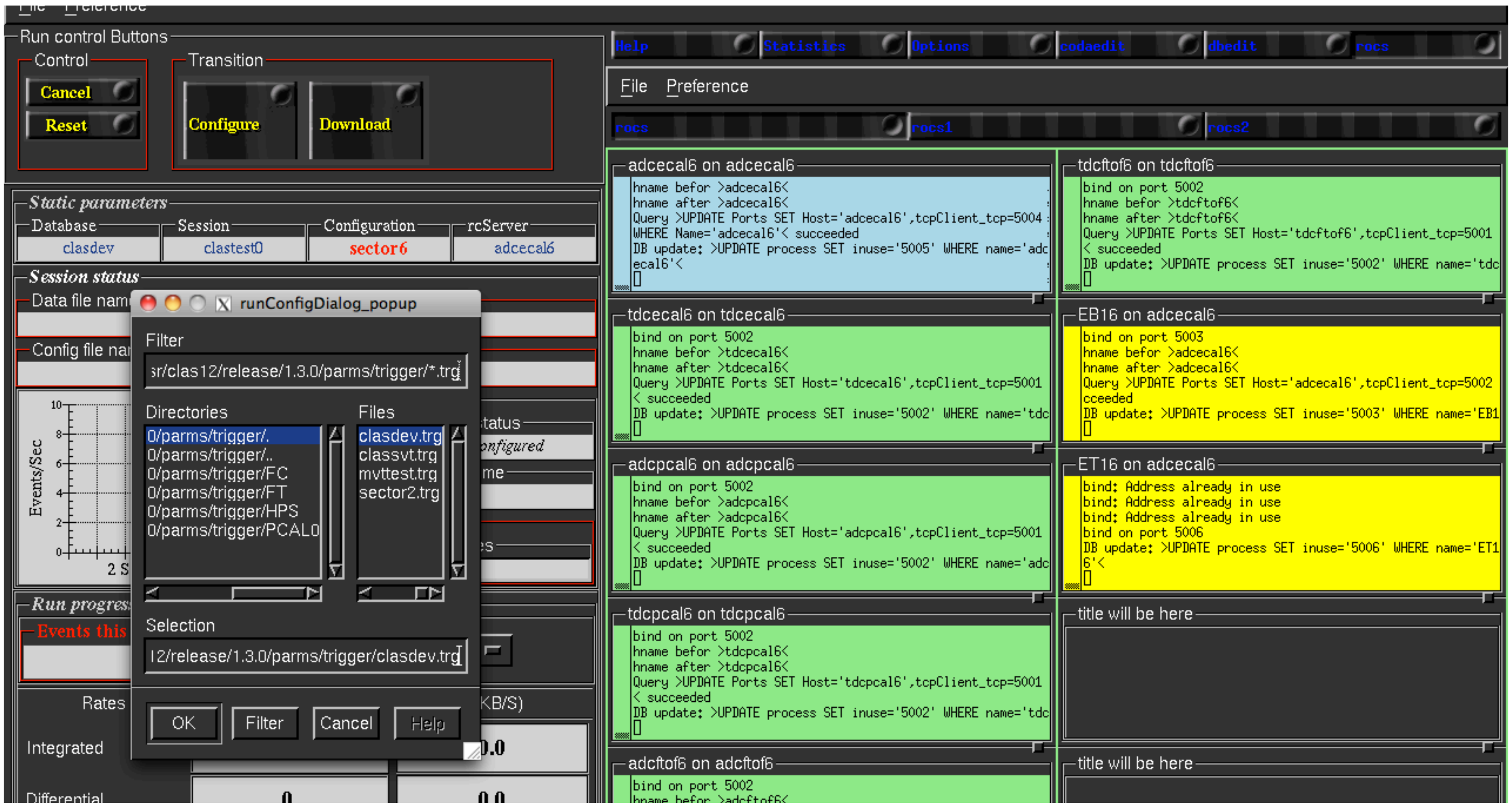
CLAS12 DAQ Status

- Online computer cluster is 100% complete and operational
- Networking is 100% complete and operational
- DAQ software is operational, reliability is acceptable
- Performance observed (KPP): 5kHz, 200MByte/sec, 93% livetime (livetime is defined by hold-off timer = 15microsec)
- Performance expected: 10kHz, 400MBytes/sec, >90% livetime
- Performance limitation expected: 50kHz, 800MBytes/sec, >90% livetime (based on HallD DAQ performance)
- Electronics installed (and was used for KPP): ECAL, PCAL, FTOF, LTCC, DC, HTCC, CTOF, SVT
- TO DO: Electronics installed recently or will be installed soon: FT, FTMM, CND, MM, scalers, helicity
- TO DO: CAEN v1290/v1190 boards (re)calibration
- TO DO: Full DAQ performance test

DAQ/Trigger Hardware Layout



Runcontrol: setting DAQ/Trigger parameters



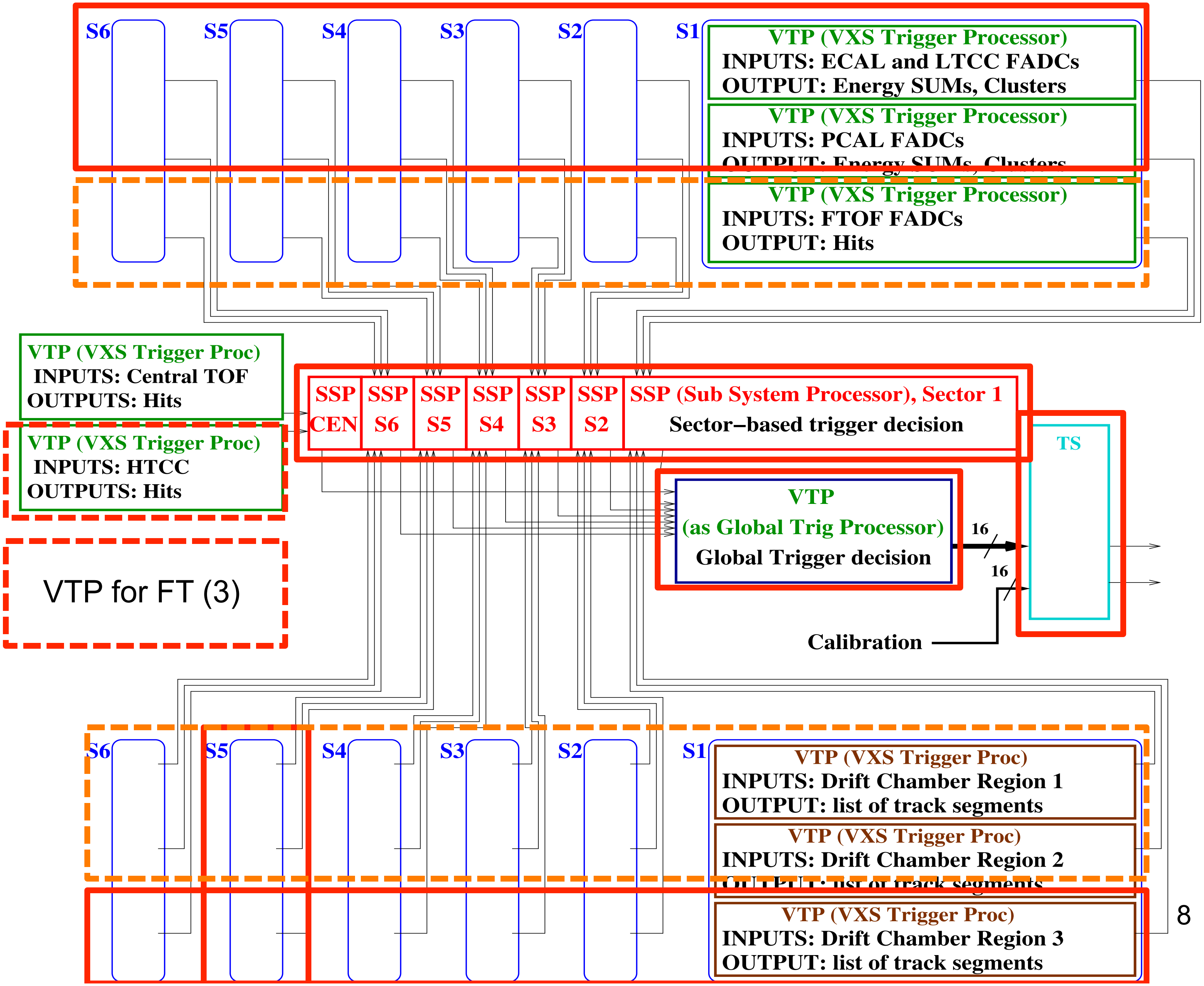
CLAS12 DAQ Commissioning

- Cosmic test (no central detectors): set electron trigger without HTCC (ECAL +PCAL and ECAL+PCAL+DC), check data integrity, check noise for DC and other detectors, check monitoring tools
- Cosmic test (central detectors only): set CTOF self-trigger and/or SVT self trigger, check data integrity and monitoring tools
- Random pulser test: set low channel thresholds, measure event rate, data rate and livetime; check monitoring tools performance
- Beam performance test: running from electron trigger – measure event rate, data rates and livetime with different beam conditions and DAQ/Trigger settings
- Timeline: cosmic and pulser tests – one month (November); beam test - one shift; we assume that most of problems will be discovered and fixed during cosmic and pulser tests

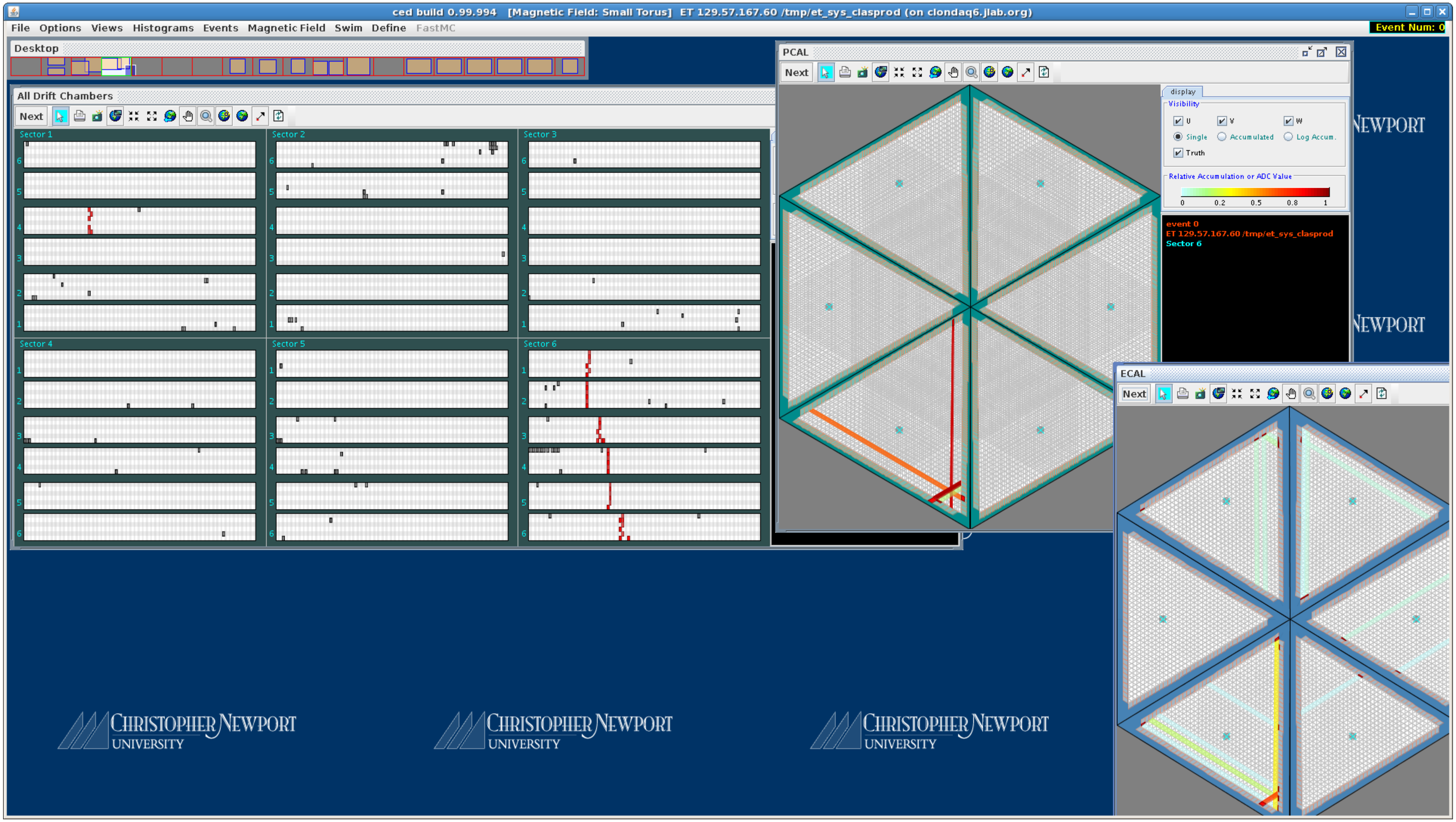
CLAS12 Trigger Status

- All available trigger electronics installed. It includes 25 VTP boards (stage 1 and 3 of trigger system) in ECAL, PCAL, HTCC, FT, R3 for all sectors and R1/R2 for sector 5 in Drift Chamber and main trigger crates, 9 SSP boards in stage 2
- 20 move VTP boards arrived and getting ready for installation in remaining DC crates and FTOF crates, should be ready soon
- All C++ trigger implementation completed for ECAL, PCAL, DC and HTCC, TOF C++ implementation and FT C++ simulation to be done
- Trigger hardware implementation completed for ECAL, PCAL and DC, HTCC and FT is in progress, TOF will follow
- 'pixel' trigger is implemented in ECAL and PCAL for cosmic calibration purposes
- Validation procedures under development

CLAS12 Trigger System Layout



PCAL+DC trigger event example



CLAS12 Trigger Components Summary

stage	name	Clock (ns)	algorithm	input	Output to trigger	Output to datastream	Control registers
1	ECAL	32	Cluster finding with energy correction	FADC	4 clusters	List of clusters	Thresholds, windows
1	PCAL	32	Cluster finding with energy correction	FADC	4 clusters	List of clusters	Thresholds, windows
1	DC	32	Segment finding	DCRB	Segment mask	Segment mask	Thresholds, windows
1	HTCC	4	Cluster finding	FADC	Cluster mask	Cluster mask	Thresholds, windows
1	FT	4	Cluster finding	FADC	Cluster mask	Cluster mask	Thresholds, windows
2	sector	4	Stage1 components coincidence, DC road finding	stage1	Component mask	Component mask	Coincidence logic, windows
3	global	4	Stage2 components coincidence	stage2	16-bit trigger	Component mask	Coincidence logic, windows

NOTE: FTOF, CTOF and CND can be added to trigger stage 1

CLAS12 Trigger requirements

#	Notation	Reaction	Final State	Trigger	
1	R1			Generator	DAQ
2	R2	Random Tr.		Faraday cup	Background
3	E1	ep->e'X	e'(CLAS)	Ectot*(DCtrack)	ECAL only, prescaled
4	E2	ep->e'X	e'(CLAS)	PCAL*Ectot*(DCtrack)	PCAL*ECAL, prescaled
5	**E3**	**ep->e'X**	**e'(CLAS)**	**HTCC*E2**	**Inclusive electron trigger**
6	FT	ep->e'X	e'(FT)	$FT_{cluster}$(Emin,Emax)	FT only, prescaled
7	FT_{HODO}	ep->e'X	e'(FT)	FT*HODO1*HODO2	Electron in FT, prescaled
8	FT_{π}	ep->e'X	e'(FT)+pi0	FT_{HODO}*2clusters	Electron in FT+2γ, prescaled
9	H1	ep->e'h+X	1 hadron	FTOF1a*FTOF2*PCAL(DC_{track})	One hadron, prescaled
10	H2	ep->e'2h+X	2 hadrons	FTOF1a*FTOF2*PCAL(DC_{track})	Two hadrons, prescaled
11	H3	ep->e'3h+X	3 hadrons	FTOF1a*FTOF2*PCAL(DC_{track})	Three hadrons, prescaled
12	**mu2**	**ep->e'p+$\mu^+ \mu^-$**	**p+$\mu^+ \mu^-$**	**FTOF1a*FTOF2*[PCAL+EC_{tot}]*(DC_{track})**	**$\mu^+ \mu^-$ +hadron**
13	FT1	ep->e'+h	e'(FT)+h+X	FT_{hodo}*H1	FT+ 1 hadron, prescaled
14	FT2	ep->e'+2h	e'(FT)+2h+X	FT_{hodo}*H2	FT+ 2 hadrons, prescaled
15	**FT3**	**ep->e'+3h**	**e'(FT)+3h+X**	**FT_{hodo}*H3**	**FT+3 hadrons**

Trigger Configuration file

```
VTP_CRATE adcecal1vtp # trigger stage 1
VTP_ECINNER_HIT_EMIN     100 # strip energy threshold for 1-dim peak search
VTP_ECINNER_HIT_DT       8 # +-8clk = +-32ns: strip coincidence window to form 1-dim peaks,
                           # and peak-coincidence window to form 2-dim clusters
VTP_ECINNER_HIT_DALITZ   568    584   # x8: 71<dalitz<73
…………………………..


SSP_CRATE trig2 # trigger stage 2
SSP_SLOT all
SSP_GT_STRG_ECALIN_CLUSTER_EMIN_EN    0  1 # enable ECAL_INNER clusters in trigger
SSP_GT_STRG_ECALIN_CLUSTER_EMIN      0  2000 # ECAL_INNER cluster threshold
SSP_GT_STRG_ECALIN_CLUSTER_WIDTH     0  100 # coincidence window to coincide with PCAL etc
……………………………..


VTP_CRATE trig2vtp  # trigger stage 3
#       slot:              10 13  09 14  08 15  07 16  06 17  05 18  04 19  03 20
#     payload:             01  02  03  04  05  06  07  08  09 10 11 12 13 14 15 16
VTP_PAYLOAD_EN   0    0    0    0    1    0    1    0    1   0   1   0   1   0   1   0
# 6780 corresponds to 7900 FADC latency
VTP_GT_LATENCY 6780
# sector bits: trig number, ssp trig mask, ssp sector mask, multiplicity,
# coincidence=number_of_extended_clock_cycles
VTP_GT_TRGBIT 8 1 1 1 1
……………………………….
```

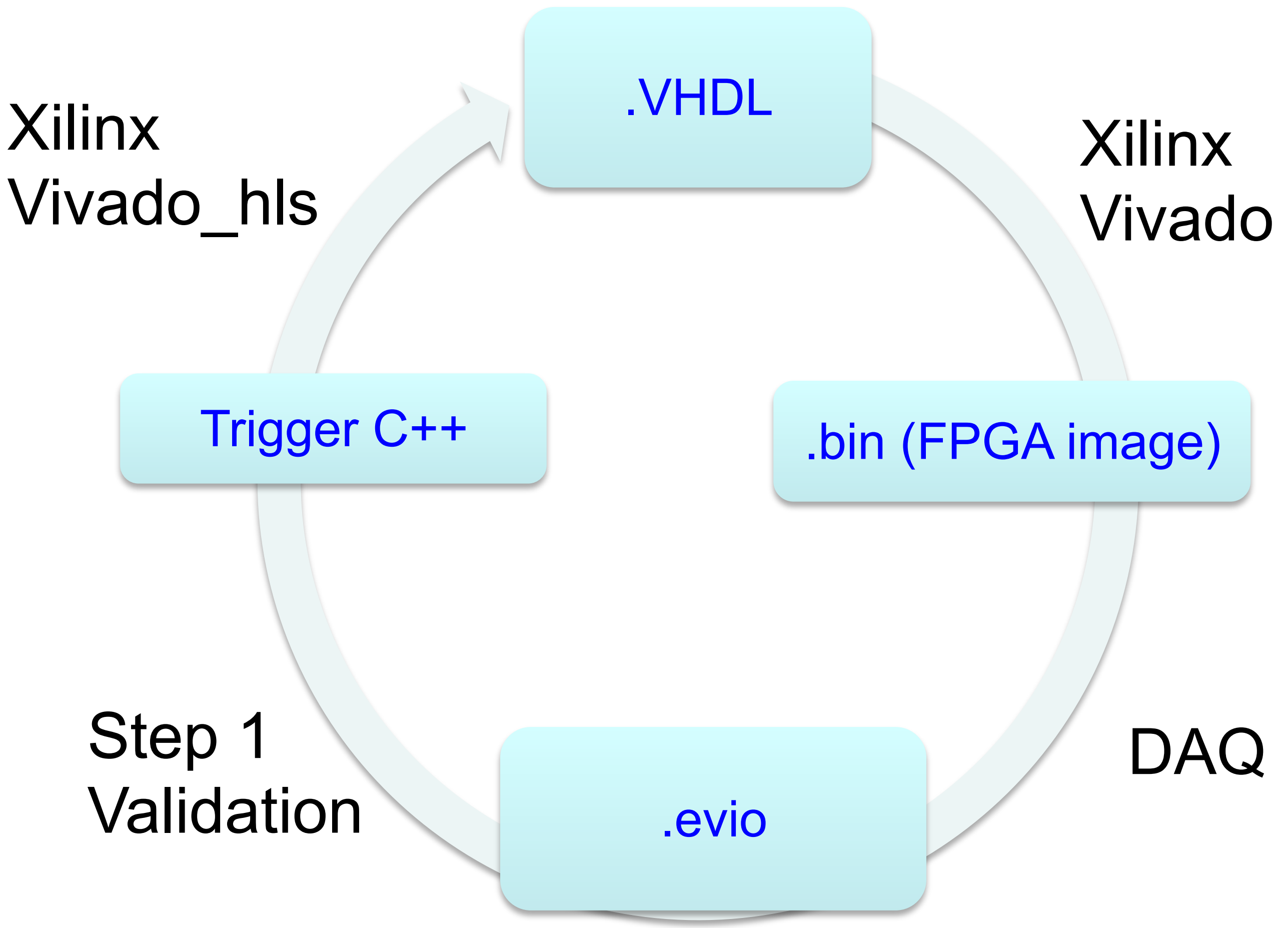
There is a plan to provide GUI to handle configuration files

CLAS12 Trigger Validation

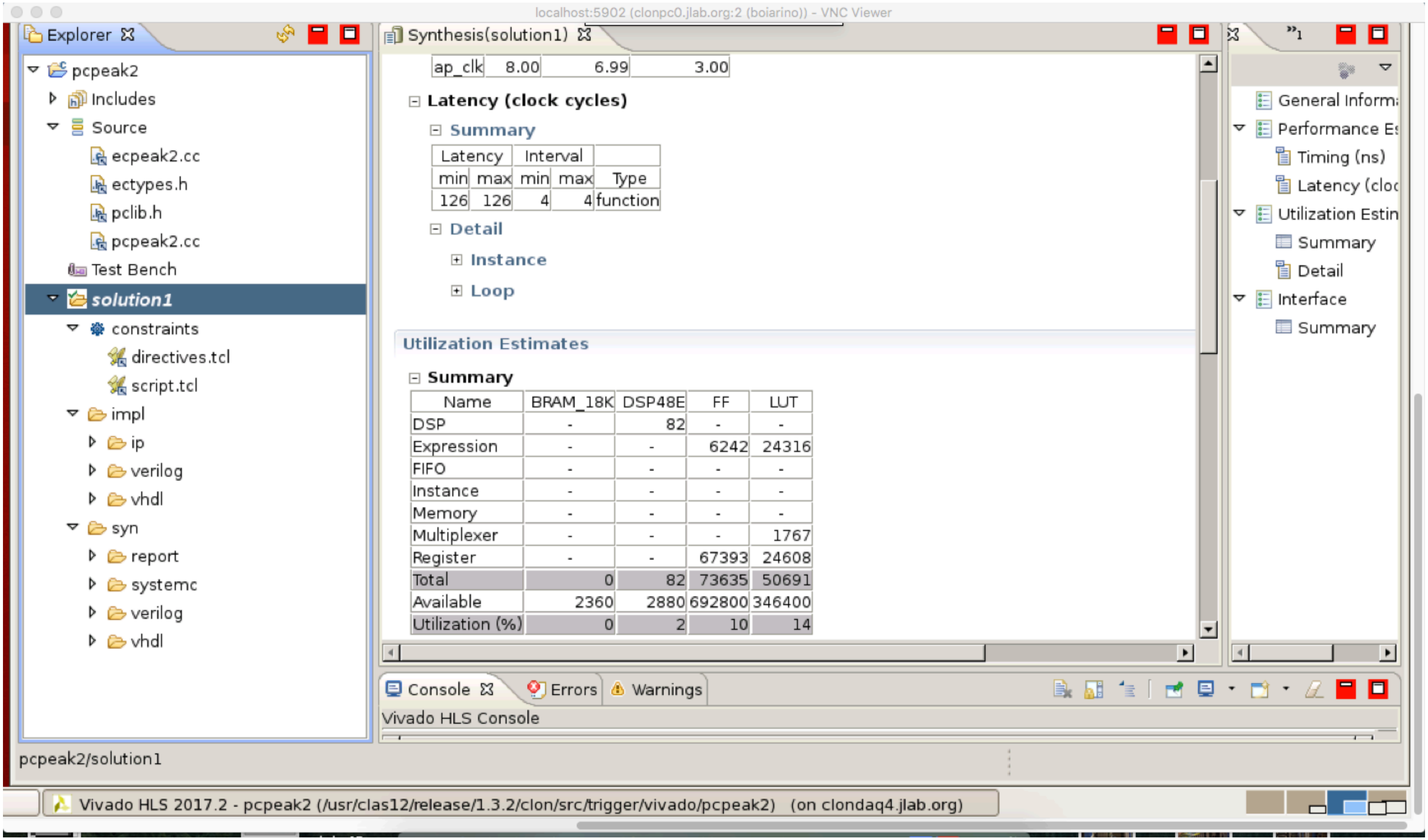
- All stage 1 trigger algorithms ether implemented in C++ (ECAL, PCAL, HTCC) or have C++ simulation of the hardware implementation (FT – to do)
- Higher stages will be simulated – under discussion, likely the same way as stage 1
- Validation process has 2 steps:

1. Comparison between C++ implementation and hardware response
2. Comparison between C++ implementation and GEANT and reconstruction results

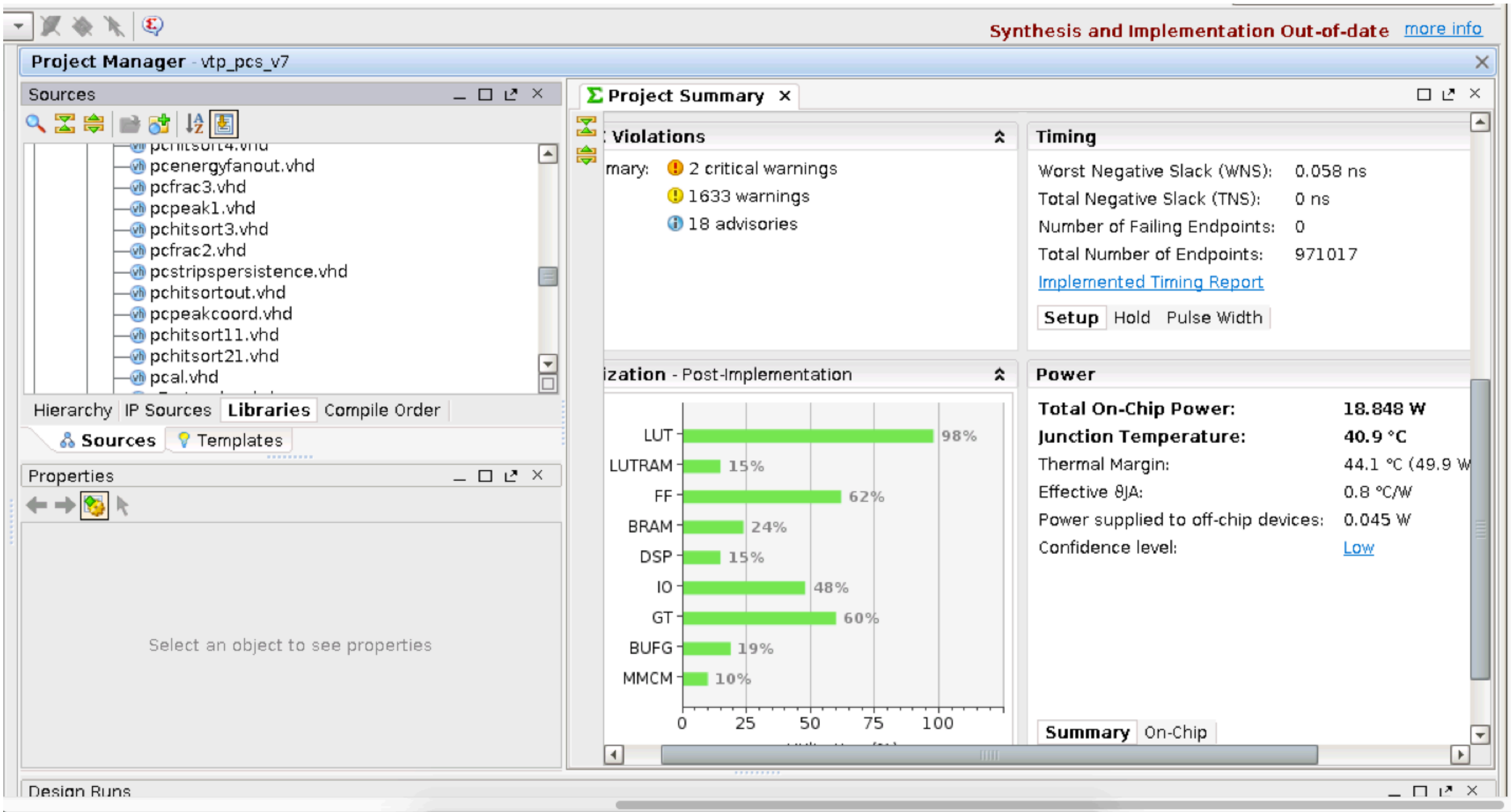
FPGA Image Building Chain and Validation Step 1: Comparison between C++ implementation and hardware response (cosmic and beam)



Xilinx Vivado_HLS (C++ to VHDL)



Xilinx Vivado (VHDL to FPGA image)



Validation Step 1: Comparison between C++ implementation and hardware response

/work/boiarino/data/vtp1_001212.evio.0 event 3:

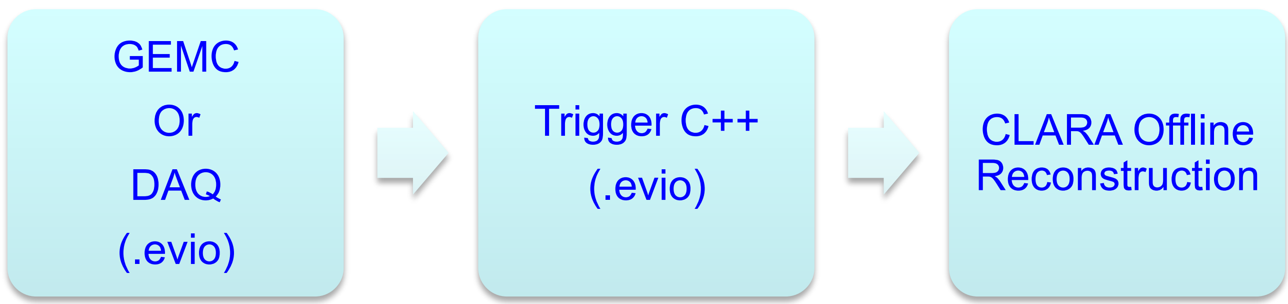
FPGA implementation data bank ==========================

TRIG PEAK [0][0]: coord=298 energy=1610 time=7
TRIG PEAK [1][0]: coord=174 energy=1012 time=7
TRIG PEAK [1][1]: coord=174 energy=294 time=8
TRIG PEAK [2][0]: coord=447 energy=1226 time=7
TRIG HIT [0]: coord=298 174 447 energy=4936 time=7

C++ implementation using FADC data =====================

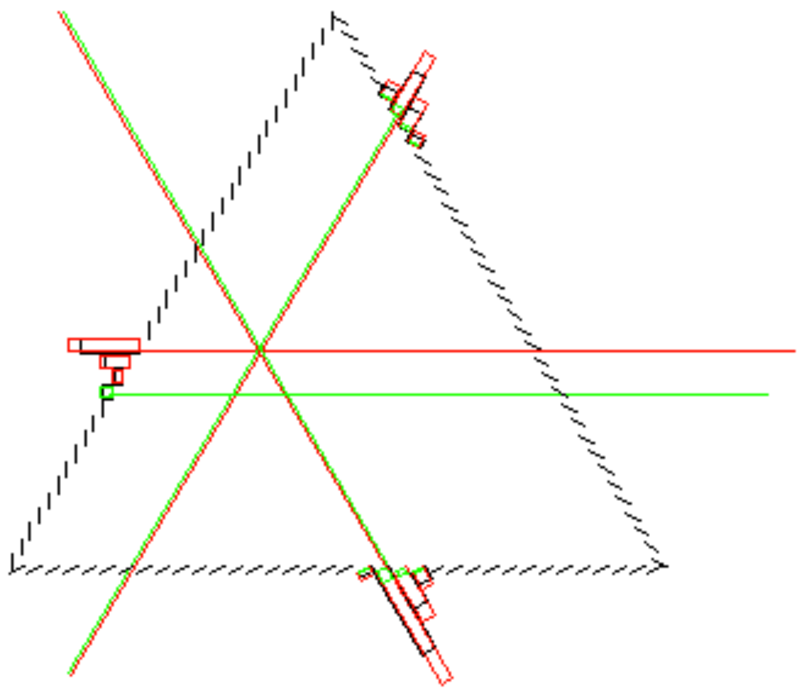
U: IT=7
peakU[0]: coord=298 energy=1610
V: IT=7
peakV[0]: coord=174 energy=1012
W: IT=7
peakW[0]: coord=447 energy=1226
SOFT HIT: coord=298 174 447 energy=4936

Validation Step 2: Comparison between C++ implementation and GEANT/ CLARA



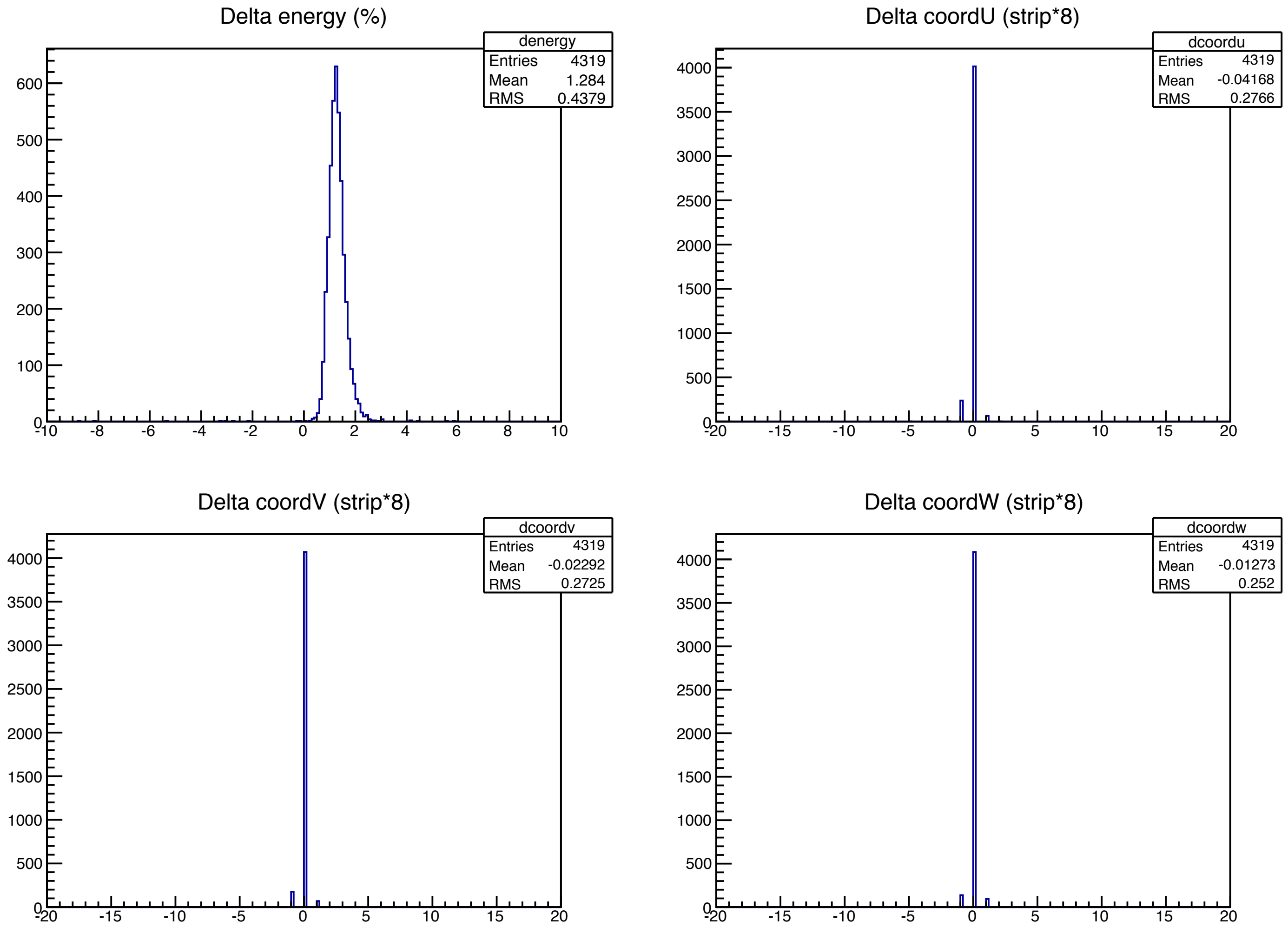
NOTE: that step allows Offline Reconstruction team to get ready for trigger results processing during beam time

C++ trigger on GEANT data – ECAL event example



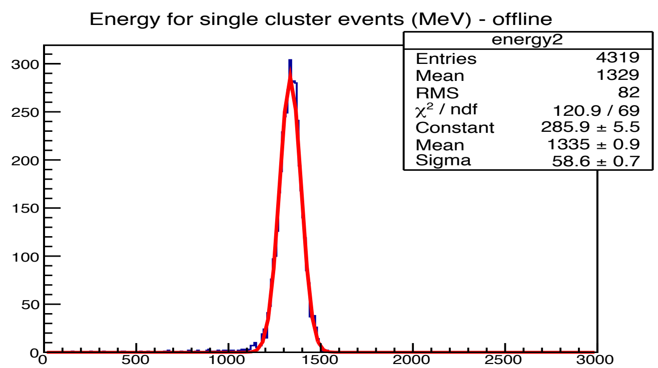
Validation Step 2: Comparison between C++ implementation and GEANT/ CLARA (cont.)

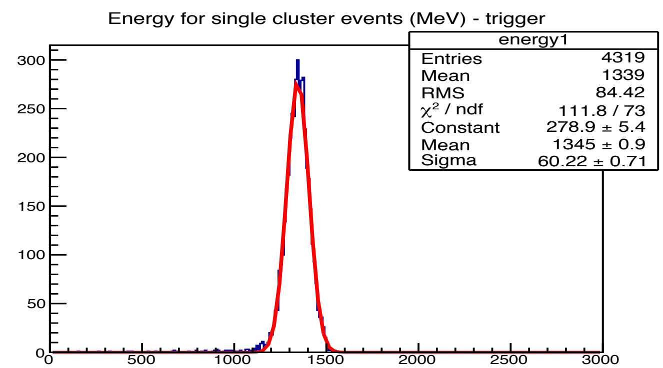
ECAL cluster finding: difference trigger-offline



Validation Step 2: Comparison between C++ implementation and GEANT/ CLARA (cont.)

ECAL cluster finding: 5GeV electron, no PCAL, energy deposition, offline and C++ Trigger





Sampling fraction 27%

CLAS12 Trigger Commissioning

- Validation step 1 (cosmic): running from electron trigger (ECAL+PCAL and ECAL+PCAL+DC) and comparing hardware trigger implementation results with C++ trigger implementation results
- Validation step 2 (GEANT with different event generators): processing GEANT evio file (currently contains ECAL and PCAL, will add HTCC, DC and FT) through C++ trigger implementation and producing evio file with trigger banks for following offline reconstruction analysis
- Validation step 1(beam): running from electron trigger (ECAL+PCAL, ECAL +PCAL+DC, ECAL+PCAL+HTCC) and comparing hardware trigger banks with C++ trigger implementation banks
- Beam data with random pulser – for trigger efficiency studies in offline reconstruction
- Beam data with electron trigger (ECAL+PCAL [+HTCC] [+DC]) with different trigger settings – for trigger efficiency studies in offline reconstruction
- Beam data with FT trigger - for trigger efficiency studies in offline reconstruction
- Timeline: cosmic and GEANT tests – underway until beam time; beam validation – 1 shift, after that data taking for detector and physics groups

Future trigger development plans

- Geometrical match between different detectors – stage 2
- Drift Chamber road finding, probably using drift time information – stage 2
- Trigger on tracks multiplicity – stage 3
- Timeline: during following year, may require new hardware, requests from physics groups will help

Conclusion

- CLAS12 DAQ, computing and network was tested during KPP run and worked as expected, reliability meets CLAS12 requirements, performance looks good but final tests have to be done with full CLAS12 configuration (waiting for remaining detectors electronics and complete trigger system)
- Trigger system (included ECAL and PCAL) worked as expected during KPP. Other trigger components (DC, HTCC and FT) were added after KPP and being tested with cosmic; remaining hardware has been received and being installed
- Timeline: few weeks before beam full system will be commissioned by taking cosmic data and running from random pulser; planning 2 shifts for beam commissioning