HPS – TDAQ Review
Trigger Implementation

Benjamin Raydo
Electronics Group (Physics Division)

HPS TDAQ Trigger Talk Overview

1. Trigger Requirements
2. ECAL Trigger
3. Modules
4. Latency
5. Verification
6. Status
7. Summary

1.0: Trigger Requirements

Summary of the HPS trigger requirements:

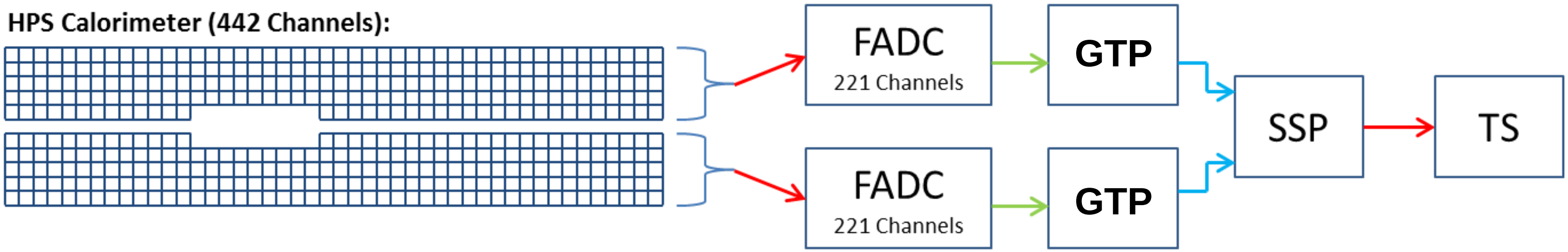
Limits set by SVT DAQ

- Reduce DAQ event rate below 43kHz
- Fixed latency trigger decision 3µs

General requirements

- Cluster finding on ECAL
- High level trigger cuts on clusters

2.0: ECAL Trigger Overview



FADC (Flash Analog-to-Digital Converter)

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

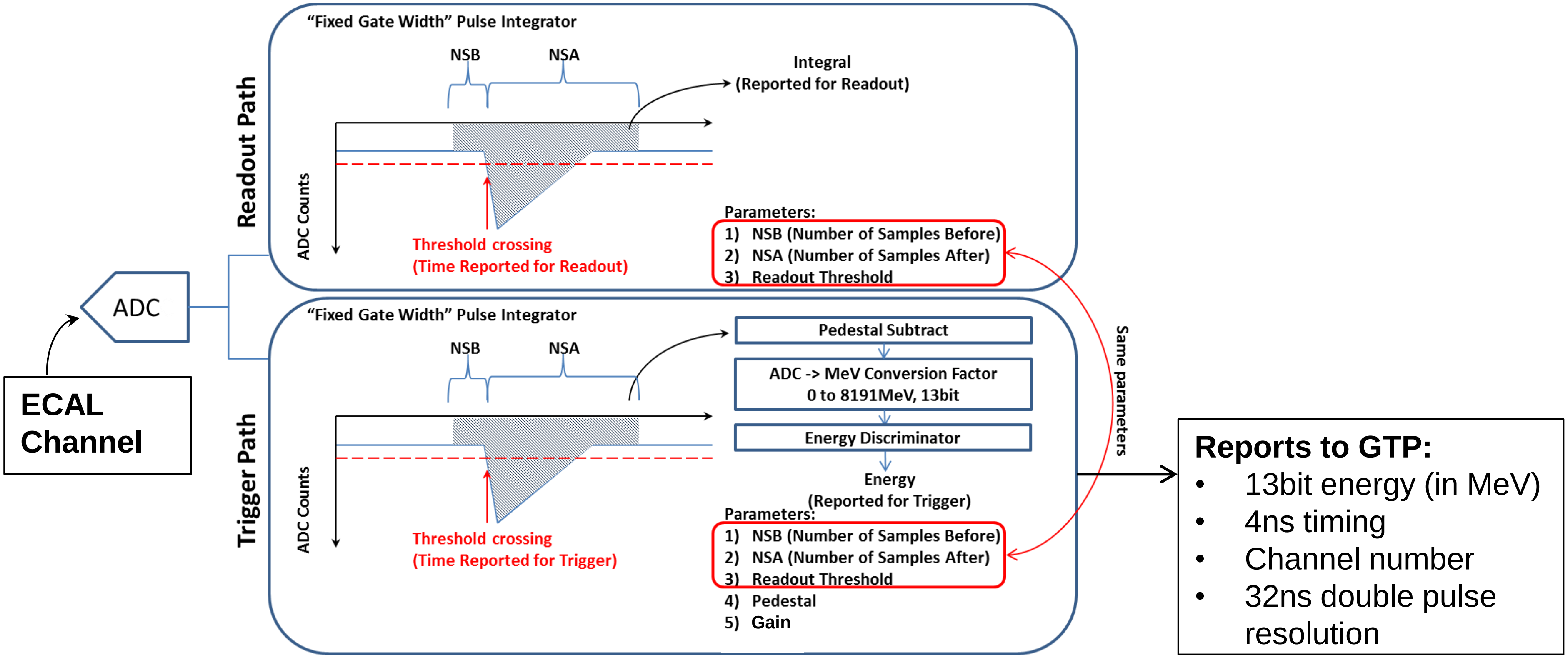
GTP (Global Trigger Processor)

- Collects pulse data from all FADC channels in crate
- Searches for clusters on half (top or bottom) of the ECAL
- Sends cluster energy, time, position, hit count to SSP for trigger processing

SSP (Sub-System Processor)

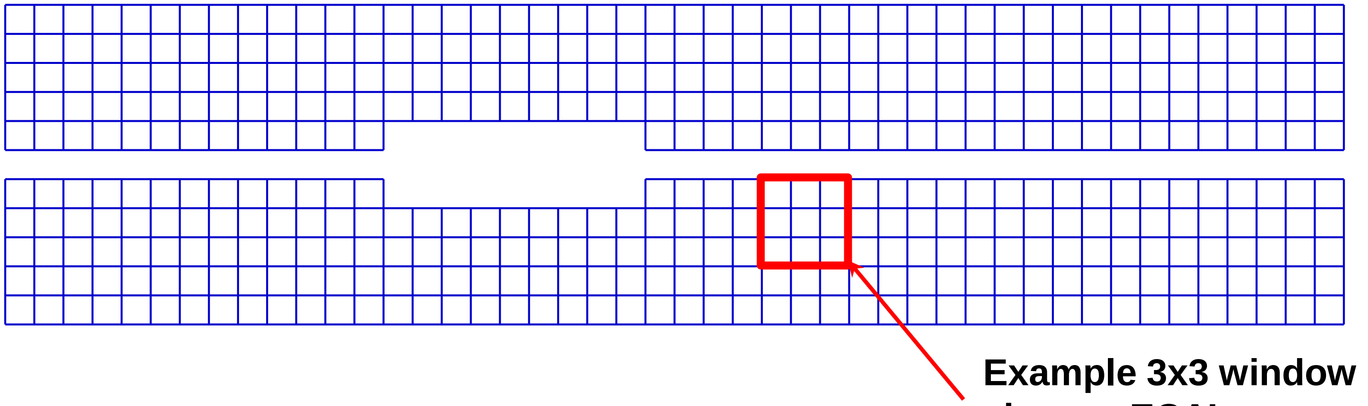
- Collects clusters from top & bottom halves of ECAL from GTP
- Performs cuts on individual clusters: energy, hit count
- Performs cuts on paired clusters: energy sum/difference, coplanar, distance-energy
- Delivers trigger signals to TS (Trigger Supervisor) for readout

3.0: 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 GTP and SSP trigger parameters work in these units as well.
- Both pedestal and gain require calibration to determine parameters.

3.1: GTP – Cluster Processing

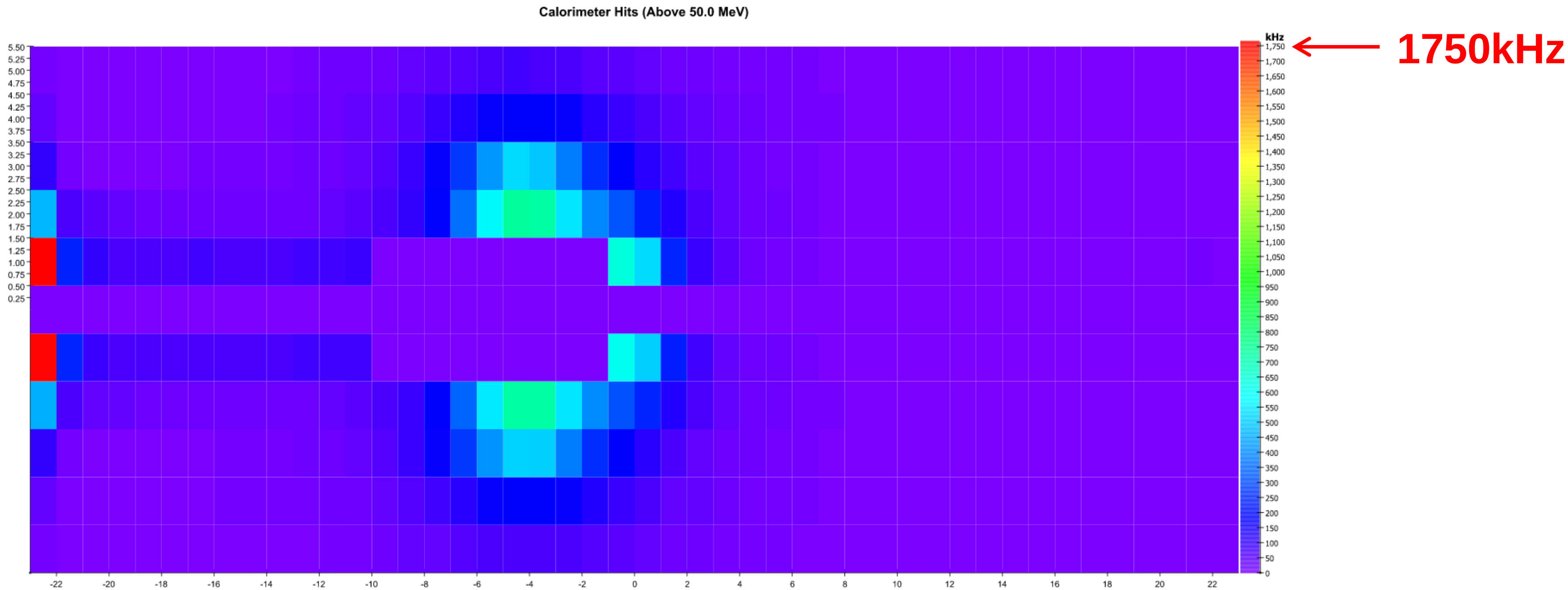


1. Search for ECAL hits ≥50MeV that is a local maxima
2. Sum 3x3 window of hits within 8ns of hit from step 1
3. Identify 3x3 window hit pattern ≥30MeV
4. Report cluster to SSP defined as:
   - cluster center (defined by step 1)
   - 3x3 window energy sum (defined by step 2)
   - 3x3 hit pattern (defined by step 3)
   - 4ns resolution timestamp

Note: thresholds and coincidence times are settable via registers

3.2: GTP – Cluster Processing Continued…

- All ECAL positions search for clusters in parallel at 4ns steps.
- Each GTP can report 500M clusters/sec to the SSP. The nominal cluster rate must be less to prevent trigger data loss due to buffer overrun.
- At worst case conditions, 6GeV @ 200nA, the total ECAL 50MeV hit rate for each half is less than 17MHz, so we have a ~30x margin and also include buffering so burst rates can be 55GHz with no data loss!



3.3: SSP – Trigger Processing

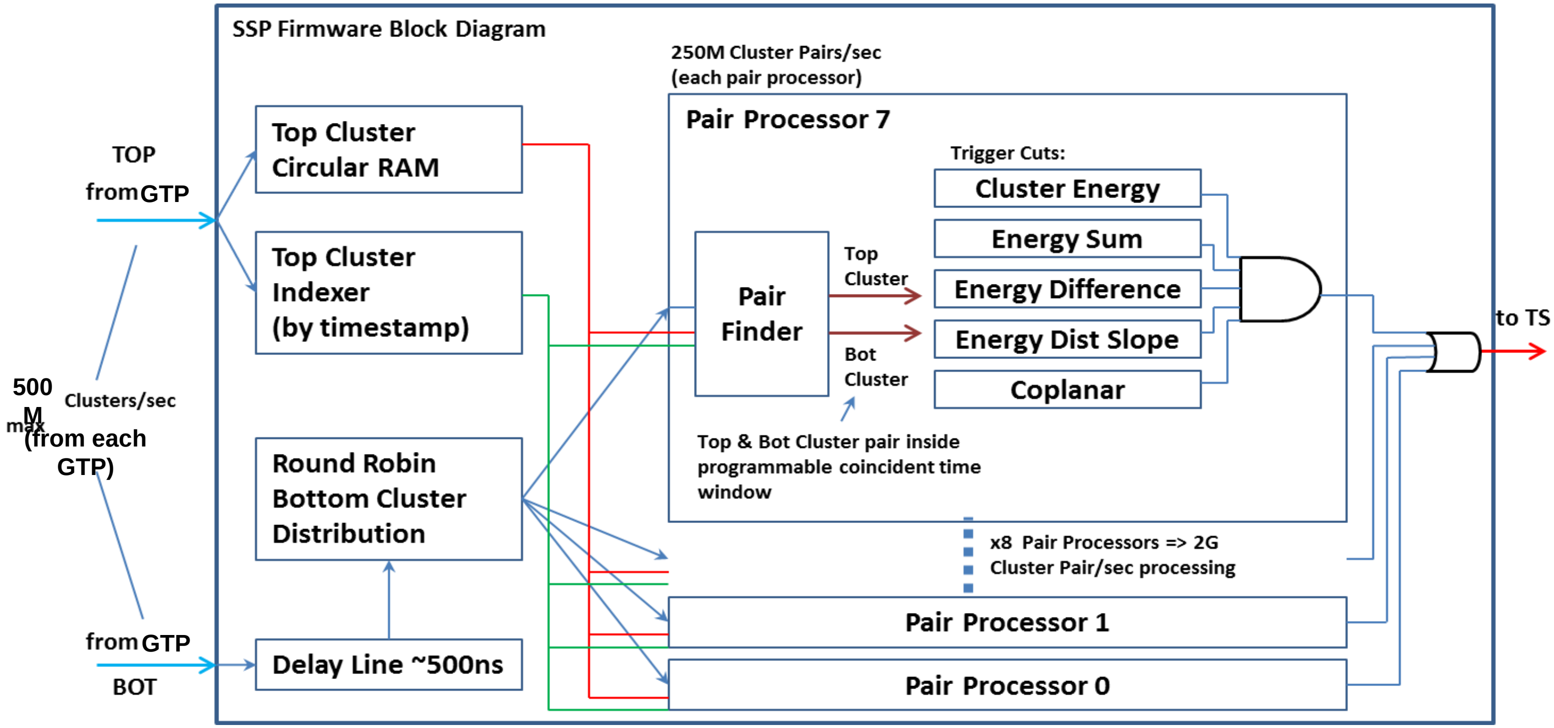
SSP receives clusters from ECAL top and bottom halves (from the GTP) and applied following cuts:

1. **Cluster singles Trigger**
   - Cluster Energy Discriminator: $E_{min} \leq E \leq E_{max}$
2. **Cluster pair trigger cuts:**

- Energy sum, $E_{min} \leq E_{top} + E_{bottom} \leq E_{max}$
- Pair time coincidence, $|t_{top} - t_{bottom}| \leq \Delta t_{max}$
- Energy difference, $|E_{top} - E_{bottom}| \leq \Delta E_{max}$
- Energy slope, $E_{cluster\_with\_min\_energy} + R_{cluster\_with\_min\_energy} \times F_{energy} \leq Threshold_{slope}$
- Co-planarity, $|tan^{-1}(\frac{X_{top}}{Y_{top}}) - tan^{-1}(\frac{X_{bottom}}{Y_{bottom}})| \leq Coplanarity_{angle}$
- Number of hits in 3x3 window, $\#hits_{3\times3} \geq HitThreshold$

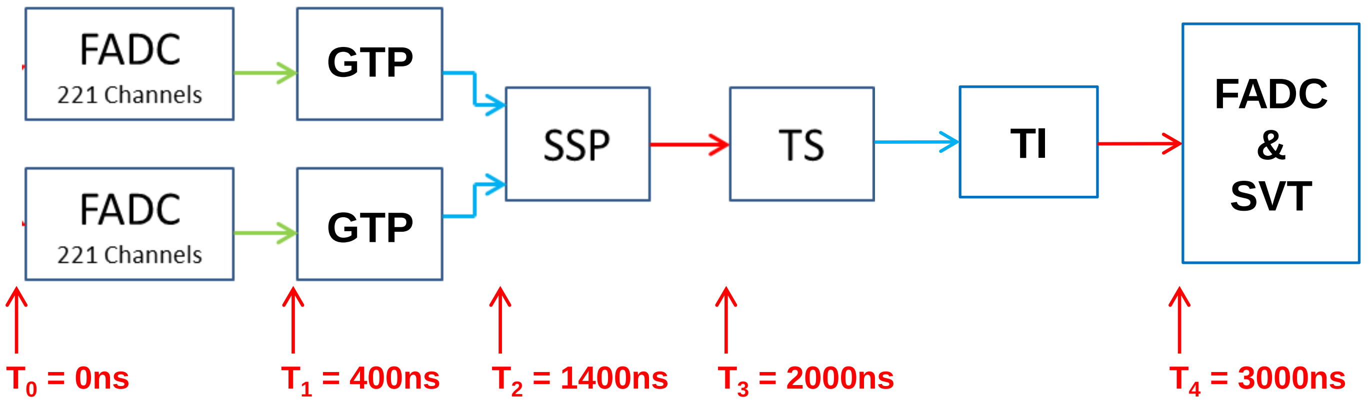
where E_{max}, Δt_{max}, ΔE_{max} , $Threshold_{slope}$, F_{energy}, $Coplanarity_{angle}$ and $HitThreshold$ are programmable parameters.

3.4: SSP – Trigger Processing Continued…



- SSP logic can process 2G cluster pairs/sec: i.e. SSP can sustain 500M cluster per sec each paired with 4 cluster on opposite calorimeter half
- Using the cluster timestamp, the trigger output is adjusted delayed to achieve a 3μs latency

4.0: Trigger Latency



FADC pulse processing latency:	400ns
GTP cluster processing latency:	200ns to 1000ns (variable – cluster load dependent)
SSP trigger cut processing latency:	600ns
TS, TI trigger distribution latency:	1000ns
Total Trigger latency:	**3μs**

Notes:

1) HPS test run latency was about 3μs. We have improved latency since now by using faster links (2.5Gbps -> 5Gbps trigger links) and fewer FPGAs.
2) Any slack in latency will be used to increase the GTP cluster buffer. Currently can queue up to 400 clusters in case clusters are ever found faster than they can be sent to SSP (500M cluster/sec limit)
3) SSP retimes the trigger output to ensure a fixed latency of 3μs (even when GTP latency is minimal)

5.0: Verification

FADC Playback Mode:

- FADC modules can be loaded with arbitrary waveforms, which are used to send through the trigger and readout system.
- Slow, but allows checking any pattern to verify trigger logic

Simulation:

- Full HPS ECAL system (28 FADC, 2 GTP, 1 SSP) is simulated and fed known good and bad Monte Carlo events which validates the trigger logic.

Online Monitoring:

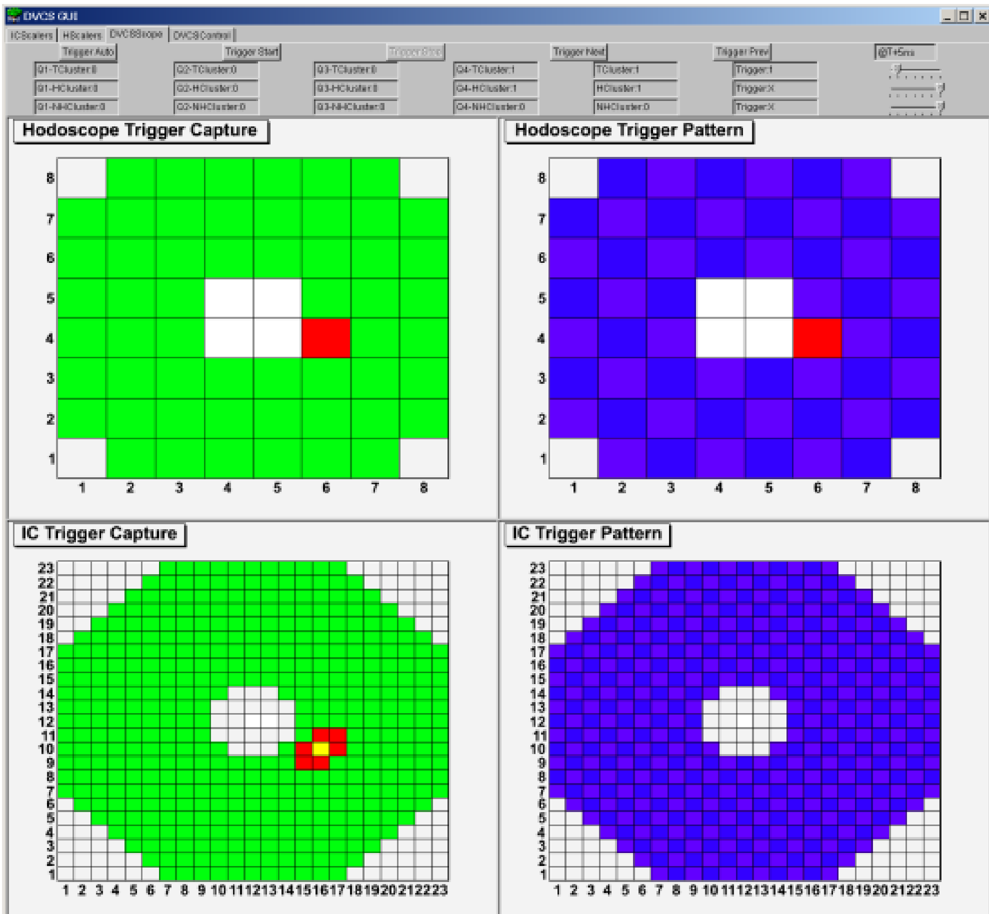
- Verification of the trigger is part of the online monitoring requirement.
- GTP and SSP will provide trigger results to event stream for offline/online consistency checking.

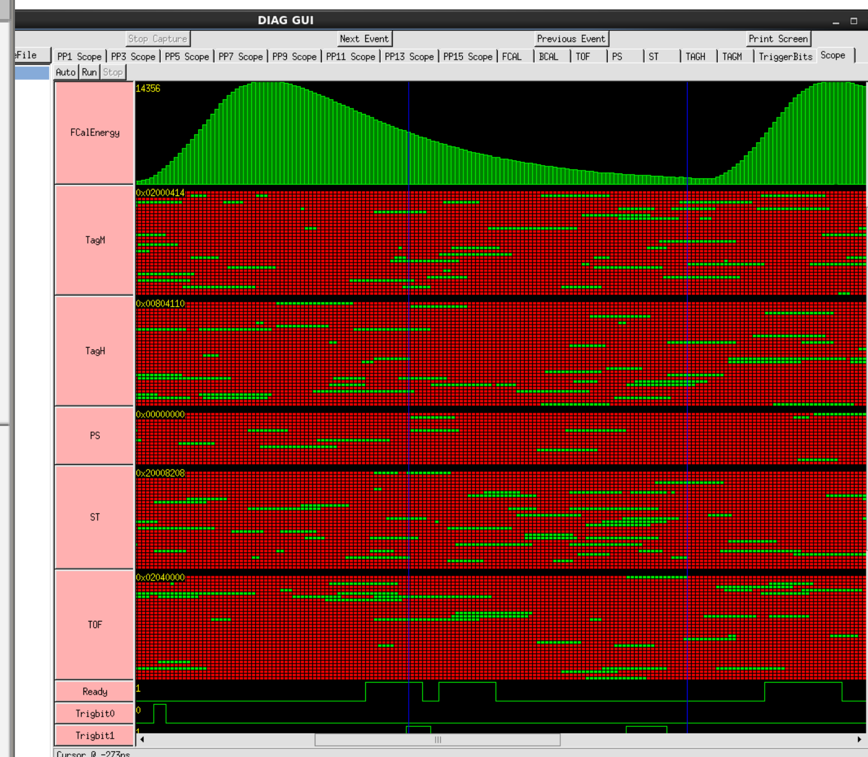
5.1: Scope - 1

- **Remote 'scope' runs on FPGAs of the various trigger and front end boards and gives visibility to internal signals (ADC waveforms, trigger decisions, etc)**
- **This feature has proved to be very valuable in the past for finding bad cables, detector channels, bad logic/configuration, etc…**
- **We are planning to implement this on each FADC channel, cluster finding level, and final trigger stage.**

5.2: Scope – 2

Example of 1D and 2D scopes:





6.0: Status

FADC	Test Run	Production Run	
Trigger Energy Resolution	~50MeV-100MeV	1MeV	DONE
Trigger Energy Dynamic Range	31:1	8191:1	DONE
Trigger Channel Gain Matching	Factor 2	+/-2%	DONE

GTP	Test Run	Production Run	
Energy Units	~50MeV-100MeV	1MeV	DONE
3x3 Cluster Hit Pattern	No	Yes	DONE

SSP	Test Run	Production Run
Energy Units	~50MeV-100MeV	1MeV
Hit Based Triggering	No	Yes

6.1: Status - continued

- **Firmware for the FADC and GTP are nearly completed.**
- **SSP firmware is mostly the same as from the HPS test run so isn't expected to take much effort to prepare**
- **Full trigger setup is expected to be ready for testing mid-March (2014)**
- **After hardware/logic is verified the focus will be on diagnostic/debug support tools**

Summary

- **HPS trigger system is very similar to the HPS test run implementation: so the changes are relatively small compared to the HPS test run development**
- **Much of the firmware is completed so we can begin validation of the trigger system in a few weeks**
- **Many diagnostic features will be available for this run to identify and help fix problems**