DAQ and Trigger for HPS run

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HPS DAQ & Trigger Requirements

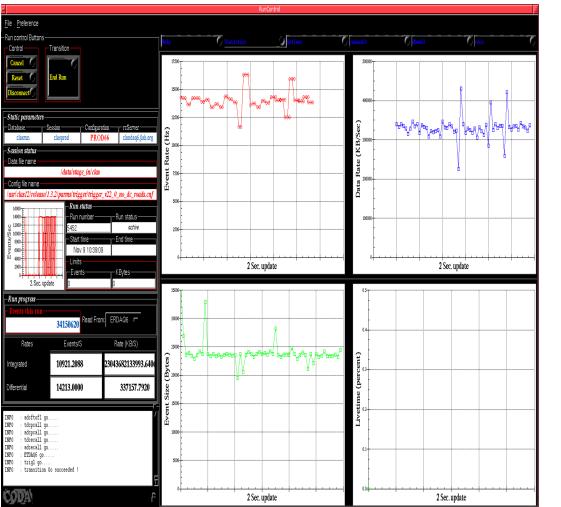
20kHz event rate 100MB/s data rate >95% livetime

> 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



CS-Studio									
🞽 CL	_AS12 Trigger Bits 🕱 🔛	AS12 Trigger Alarr	ns			- 0			
Menu CLAS12 VTP Trigger 11/09/2018 11:29:28									
Beam Current (nA) Electron Alarms									
	40.2 2C21 1-6	NO_ALARM	1-6 Tolerance: (0.40 TS	95.4 % 🔵				
	39.3 FCup	Totals (Hz) 1917652	15592	Pulser	93.9 %				
Bit	Description	Raw (Hz)	Prescaled (Hz)	Fraction (%)	Prescale	In Totals			
0	Electron - OR of 1-6	7593	7593.1	48.70					
1	Sector 1	1148	1148.4		0				
2	Sector 2	1202	1202.3		0				
з	Sector 3	1330	1330.1		0				
4	Sector 4	1336	1336.1						
5	Sector 5	1348	1348.1						
6	Sector 6	1266	1266.2						
7	Elctron OR no DC >300Me∨	8102	245.5	1.57					
8	PCALxECAL>10Me∨	244643	119.4	0.77	12				
13	DCxFTOFxPCUxPCAL S1	57001	3.5	0.02					
14	DCxFTOFxPCUxPCAL S2	55134	3.4	0.02					
15	DCxFTOFxPCUxPCAL S3	57096	3.5	0.02					
16	DCxFT0FxPCUxPCAL S4	56517	3.4	0.02					
17	DCxFTOFxPCUxPCAL S5	56810	3.5	0.02					
18	DCxFTOFxPCUxPCAL S6	56540	3.5	0.02					
19	FTOFxPCALxECAL 1-4	818	817.8	5.25					
20	FTOFxPCALxECAL 2-5	714	714.0	4.58					
21	FTOFxPCALxECAL 3-6		739.9	4.75					
24	FTxHDxFT0FxPCALxCT0F	10855	329.0	2.11					
25	FTxHDx(FTOFxPCAL)^2	4337	4336.8	27.81					
26	FT 2 clusters	4911	148.8	0.95					
27	FT > 100 Me∨	1175206	71.7	0.46					
31	Pulser		99.9	0.64					

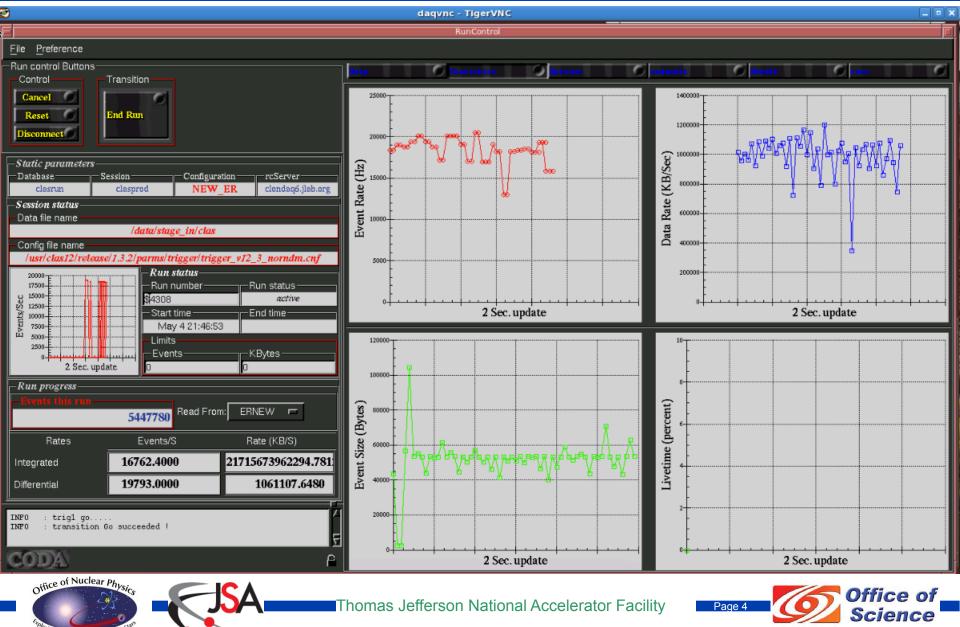
* Note, red warning status indiciators above are to aid diagnostics and log information when there is a persistent DAQ/Trigger alarm. If there are no active DAQ/Trigger alarms, these red indicators can be disregarded.

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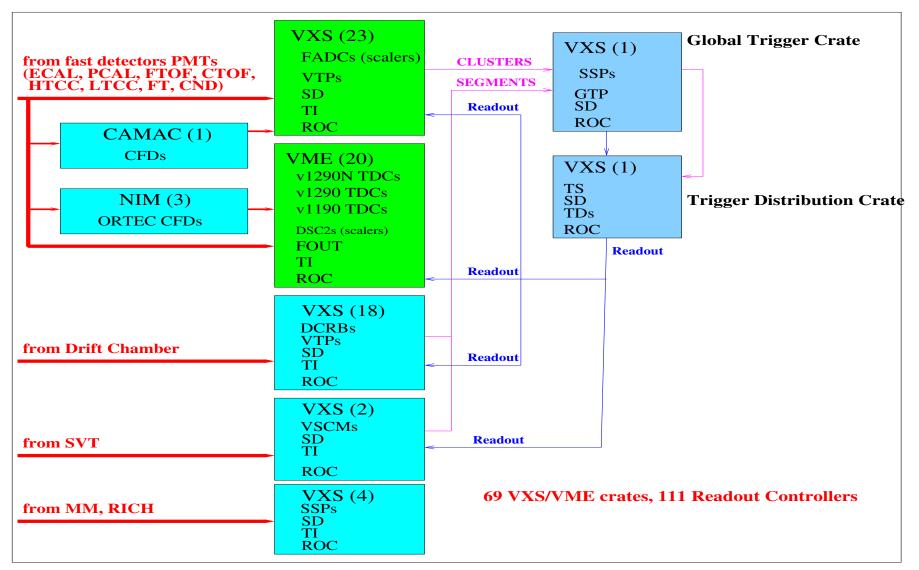
CLAS12 50nA beam DAQ test (some prescales removed) – 20kHz, 1000MB/s, 88% livetime



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CLAS12 DAQ & Trigger Diagram

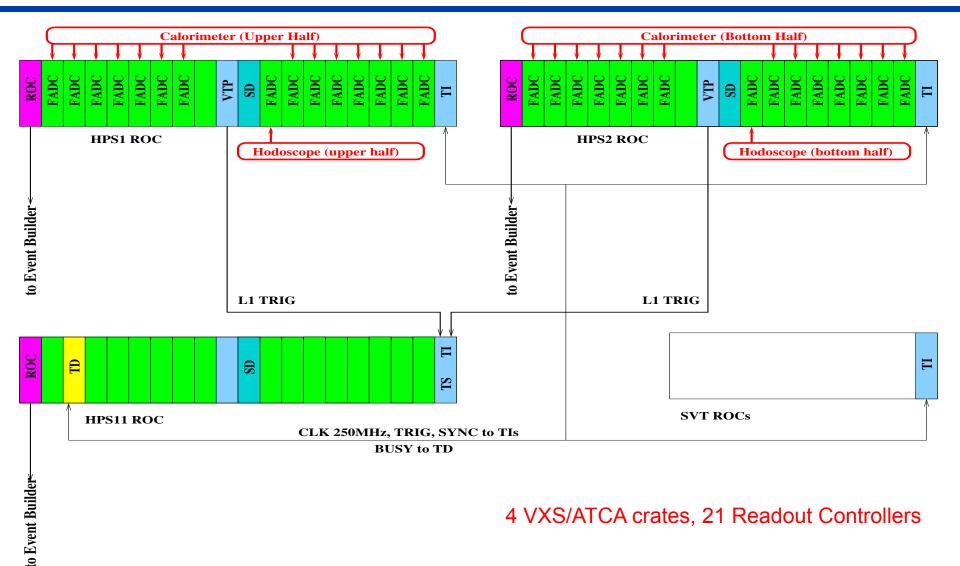


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HPS DAQ & Trigger Diagram



4 VXS/ATCA crates, 21 Readout Controllers

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HPS DAQ Status

All front-end electronics available, mostly installed:

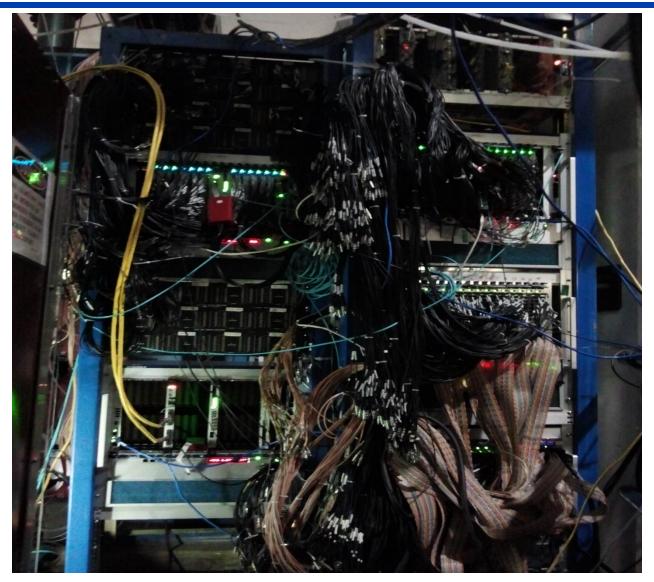
- Calorimeter Readout: 442 channels of 12bit 250MHz Flash ADCs
- Hodoscope Readout: 32 channels of 12bit 250MHz Flash ADCs
- VTP/TS/TD trigger and signal distribution boards
- 4 crates (1 VME64X, 2 VXS, 1 ATCA)

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

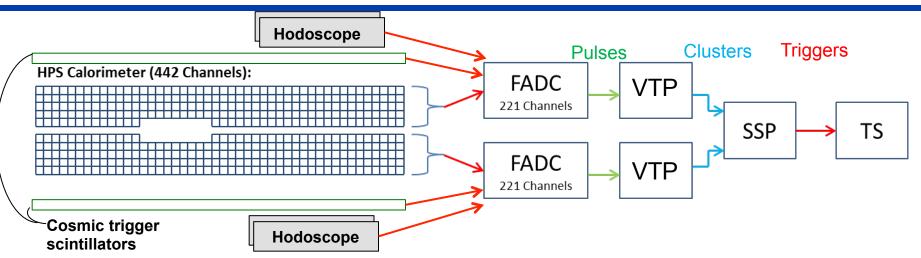








ECAL Trigger Overview



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 GTP
- Performs cuts on individual clusters: energy (positin 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, but hodoscope tagging logic is needed
- Hardware: installed, 1 spare unit
- Plans: expected firmware updates/testing: ~2 weeks

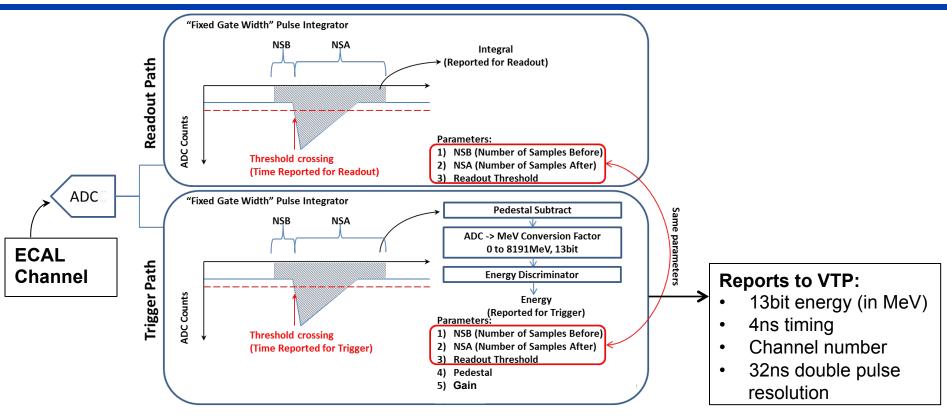
SSP Status

- Firmware: cluster triggers complete and tested, but hodoscope trigger option is needed
- Hardware: all installed, spares available
- **Plans:** expected firmware updates/testing: <1 week





FADC – Pulse Processing



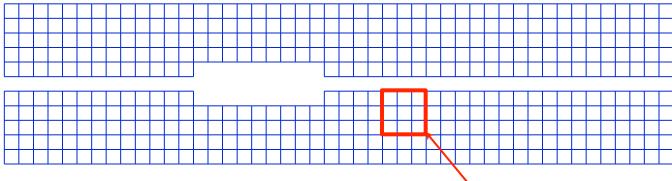
- Trigger pedestal is the same parameter that would be calculated for the readout data.
- Trigger gain parameter sets energy units in MeV so VTP and SSP trigger parameters work in these units as well.

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Both pedestal and gain require calibration to determine parameters.



VTP – Cluster Processing



Example 3x3 window view on ECAL

- 1. Search for ECAL hits ≥thr 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 (defined by step 3)
 - 4ns resolution timestamp
 - Hodoscope tag (hodoscope hit matches space & time coincidence)

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SSP Event Information

Structure Element	Size (bytes)	Element Information	SSP will create event data containing all found clusters.		
Block Header	4	Block Number: 11bits VME Slot: 5bits EventsPerBlock: 11bits	Programmable time window:		
Event Header	r 4 Event number: 27bits		 "trigger look-back" 		
Trigger Timestamp	8	Timestamp: 48bits (~13 day rollover)	 "window width" 		
ECal Cluster	Cluster Center X: 6bits Cluster Center Y: 4bits Cluster Center Y: 4bits Cluster Energy: 13bits Cluster Nhits: 4bits Cluster Time: 10bits Hodoscope Tag: 2bits		Clusters are tagged with trigger decision results (pass/fail): HPS physics cuts 		
Trigger	4	Trigger time: 10bits Trigger tags: 6bits Trigger type: 4bits	CosmicRandom		
ECal Cluster	8		• etc		
			Trigger tags are used for		
Event Header 4			efficiency measurements.		
Trigger Timestamp 8			Tags and clusters can be used to		
ECal Cluster	8		understand reason for inefficiency.		
Block Trailer	4	Block Word Count: 22bits VME Slot: 5bits			







TS Trigger Inputs

Up to 32 inputs are available:

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

Prescalers (inside TS) for each trigger input:

• programmable from 2 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 (NHits >= NHits_{min}) and (NHodoLayersHit >= NHodoLayersHit_{min})

"Pairs" Cluster Trigger equation:

$$\begin{split} (|\mathsf{T}_{\mathsf{Top}} - \mathsf{T}_{\mathsf{Bot}}| &<= \Delta t_{\mathsf{max}}) \text{ and} \\ (|\mathsf{E}_{\mathsf{Top}} - \mathsf{E}_{\mathsf{Bot}}| &<= \Delta \mathsf{E}_{\mathsf{max}}) \text{ and} \\ (\mathsf{E}_{\mathsf{Top}} + \mathsf{E}_{\mathsf{Bot}} &<= \mathsf{E}_{\mathsf{max}}) \text{ and} \\ (\mathsf{E}_{\mathsf{min}} &<= \mathsf{E}_{\mathsf{Bot}} &<= \mathsf{E}_{\mathsf{max}}) \text{ and} (\mathsf{E}_{\mathsf{min}} &<= \mathsf{E}_{\mathsf{Top}} &<= \mathsf{E}_{\mathsf{max}}) \text{ and} \\ (\mathsf{Nhits} &<= \mathsf{HitThreshold}) \text{ and} \\ (\mathsf{NHodoLayersHit} >= \mathsf{NHodoLayersHit}_{\mathsf{min}}) \text{ and} \\ (\mathsf{Min}(\mathsf{E}_{\mathsf{Top}}, \mathsf{E}_{\mathsf{Bot}}) + \mathsf{R} \times \mathsf{F} &<= \mathsf{Threshold}_{\mathsf{Slope}}) \text{ and} \\ (|\mathsf{tan}^{-1}(\mathsf{X}_{\mathsf{top}}/\mathsf{Y}_{\mathsf{top}}) - \mathsf{tan}^{-1}(\mathsf{X}_{\mathsf{bot}}/\mathsf{Y}_{\mathsf{bot}})| &<= \mathsf{Coplanarity}_{\mathsf{Angle}}) \end{split}$$

Cosmic trigger equation:

(|ScintillatorHitTime_{Top} – ScintillatorHitTime_{Bot}| <= Δt_{max})

[Position dependent Energy range] [Minimum number of hits in cluster] [Minimum number of hodoscope layers]

[Pair cluster time coincidence]
[Pair energy difference]
[Pair energy sum]
[Energy range]
[Minimum number of hits in cluster]
[Minimum number of hodoscope layers]
[Energy distance cut]
[Pair coplanarity cut]

[Scinillator time coincidence]

Note:

• Currently 2 independent "singles" and 2 independent "pairs" trigger are available for use. May need to be expanded to support additional singles trigger given the addition of the hodoscope.

Color legend:

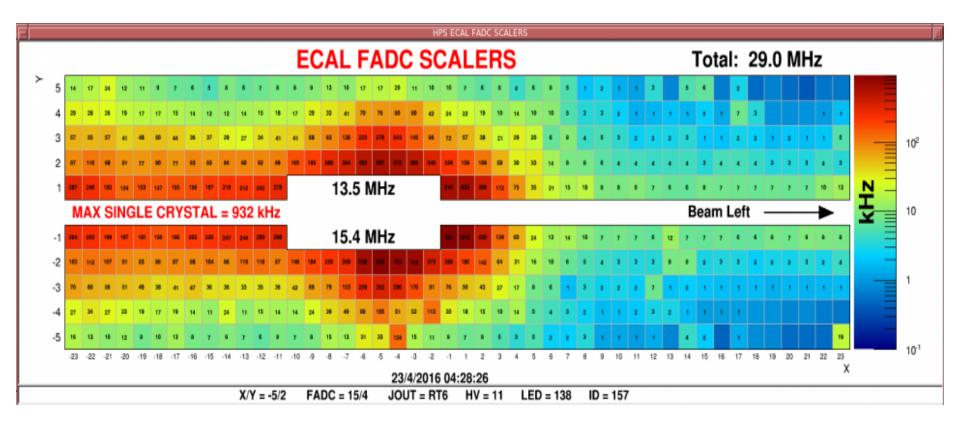
Trigger data from detector VME programmable parameter Hardcoded parameter/logic

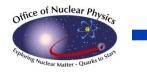




Monitoring examples

• ECAL FADC channel scalers





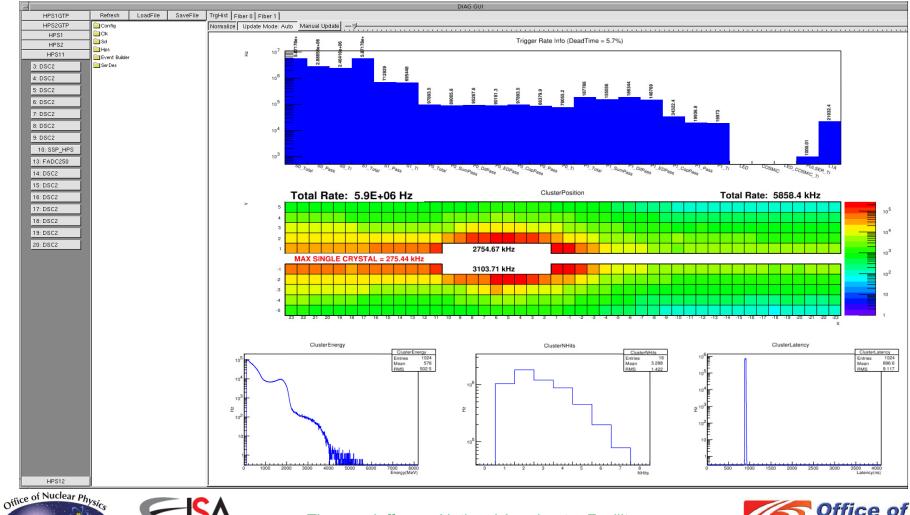


Monitoring examples

• Trigger bits and term cut rates

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• Trigger cluster positions, energy, number of hits



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Conclusion

All trigger & DAQ hardware is available

Trigger system successfully used during the 2015-2016 runs

Diagnostic trigger tagging data demonstrated >99% efficiency for cluster reconstruction and physics triggers

Firmware updates are small, but will take a few weeks to finish. Expected 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





