2019 HPS Trigger

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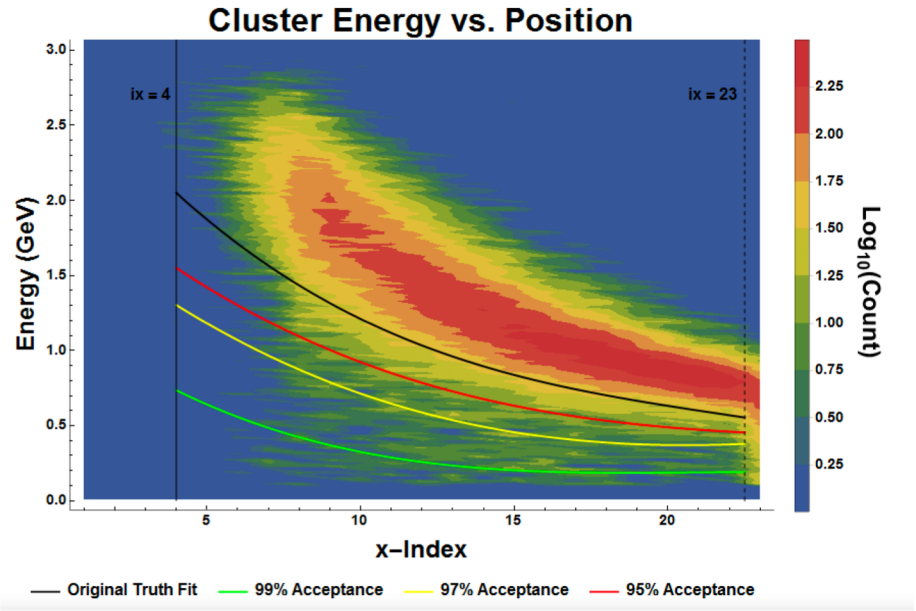
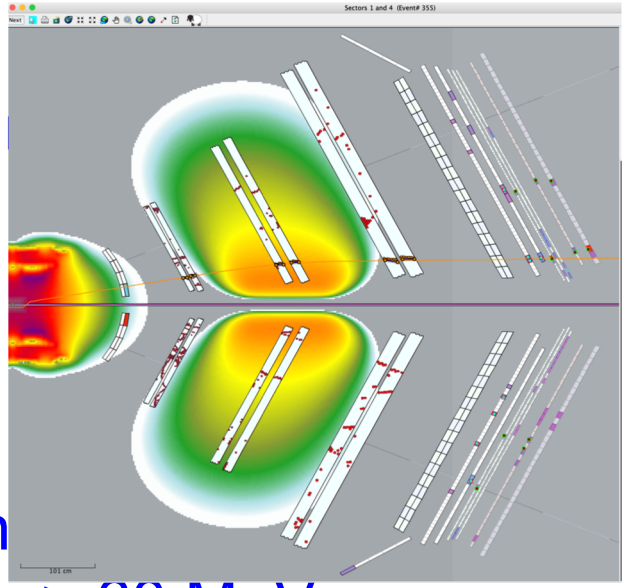


HPS Trigger Detectors

- Silicon vertex Detector (SVT) does not participate in the trigger
- The Calorimeter, 442 lead tungstate ($PbWO_4$) crystals
  - Split into two identical halves (top and bottom)
  - The main trigger primitives is a cluster (Energy, Coordinate) in a 3x3 crystal window
  - Position dependent energy cut (PDEC) was implemented for the positron trigger
- The Hodoscope
  - Split into two identical halves (top and bottom)
  - Located at the positron side only
  - Has two layers, layer1 and layer 2, with 5 tiles in each layer
  - The main trigger primitive is the hit (only coordinate)
  - Correlation matrix was used for the coincidence between layer1 and layer 2 hodoscope planes
- Correlation matrix between hodoscope hits and calorimeter clusters was implemented for the positron trigger

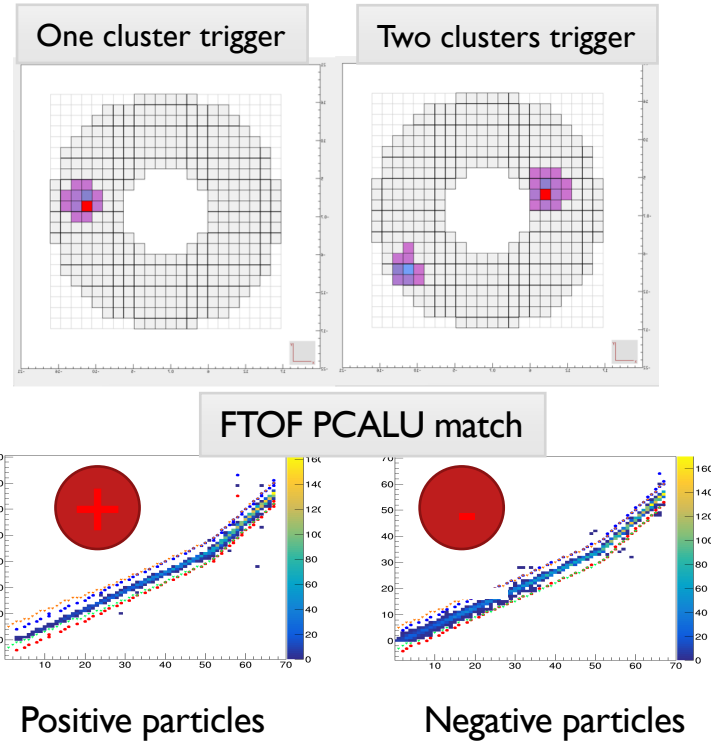
Electron Trigger

- **Trigger detectors**
  - High Threshold Cherenkov Cou
  - Preshower calorimeter (PCAL)
  - EC calorimeter (ECAL)
  - DC roads
- **Trigger parameters**
  - HTCC – minimum number of ph
  - PCAL – minimum cluster energy > 60 MeV
  - PCAL+ECAL – sum of the energy deposition > 300 MeV
  - DC segments and roads matching PCAU



Forward Tagger Triggers

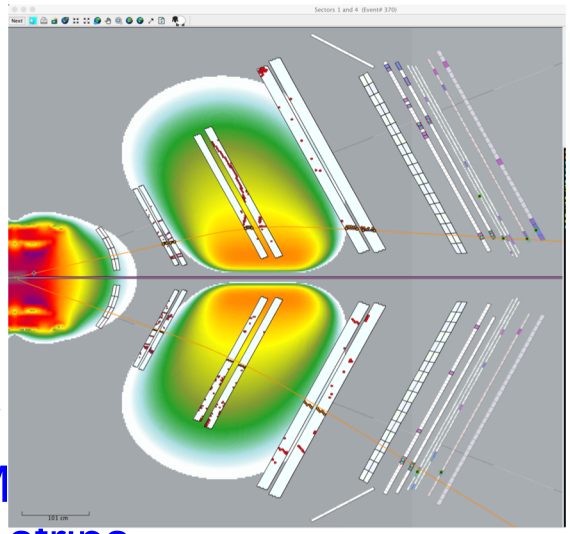
- **Trigger detectors**
  - Forward tagger calorimeter (FTCal)
  - Forward tagger hodoscope (FTHodo)
  - Forward time of flight (FTOF)
  - Preshower calorimeter (PCAL)
  - EC calorimeter (ECAL)
  - DC track segments and roads
  - Central time of flight (CTOF)
  - Central neutron detector (CND) matching CTOF
- **Trigger parameters**
  - Cluster energy in forward calorimeter [0.2-4.0] Ge
  - Hits in two layers of FTHodo matching the FTCal
  - PCAL cluster energy > 10 MeV
  - Hits in FTOF matching PCAL U-strips
  - DC roads
  - Hits in CTOF detector and/or CND detector
- **Trigger configurations**
  - FTCal x FTHodo coincidence with FTOF x PCALxUstrips in **two CLAS sectors**
  - FTCal xFThodo coincidence with FTOFxPCALxUstrips and CTOF (prescaled)



“Muon” Trigger, J/ψ $\mu^+\mu^-$ decay

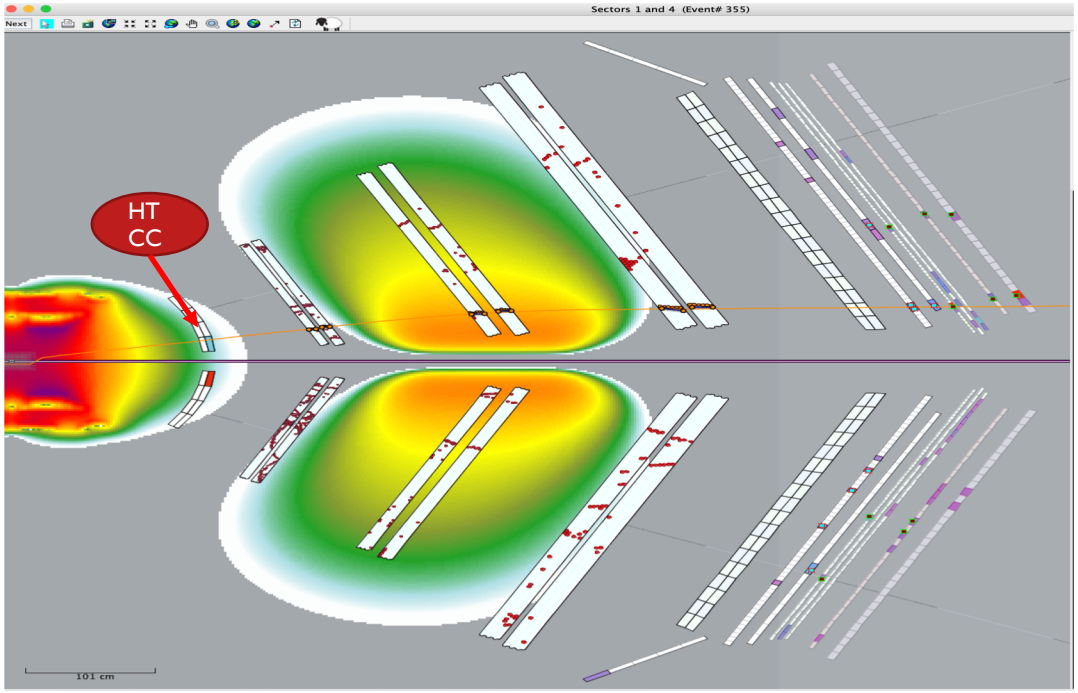
→

- **Trigger detectors**
  - Preshower calorimeter (PCAL)
  - Forward Time of Flight (FTOF)
  - EC calorimeter (ECAL)
  - DC roads
  - FTOF-PCALU match
- **Trigger parameters**
  - PCAL cluster energy [>10] MeV
  - ECAL cluster energy [40-120] M
  - Hits in FTOF matching PCAL U-strips
  - DC roads for positive and negative particles in opposite sectors



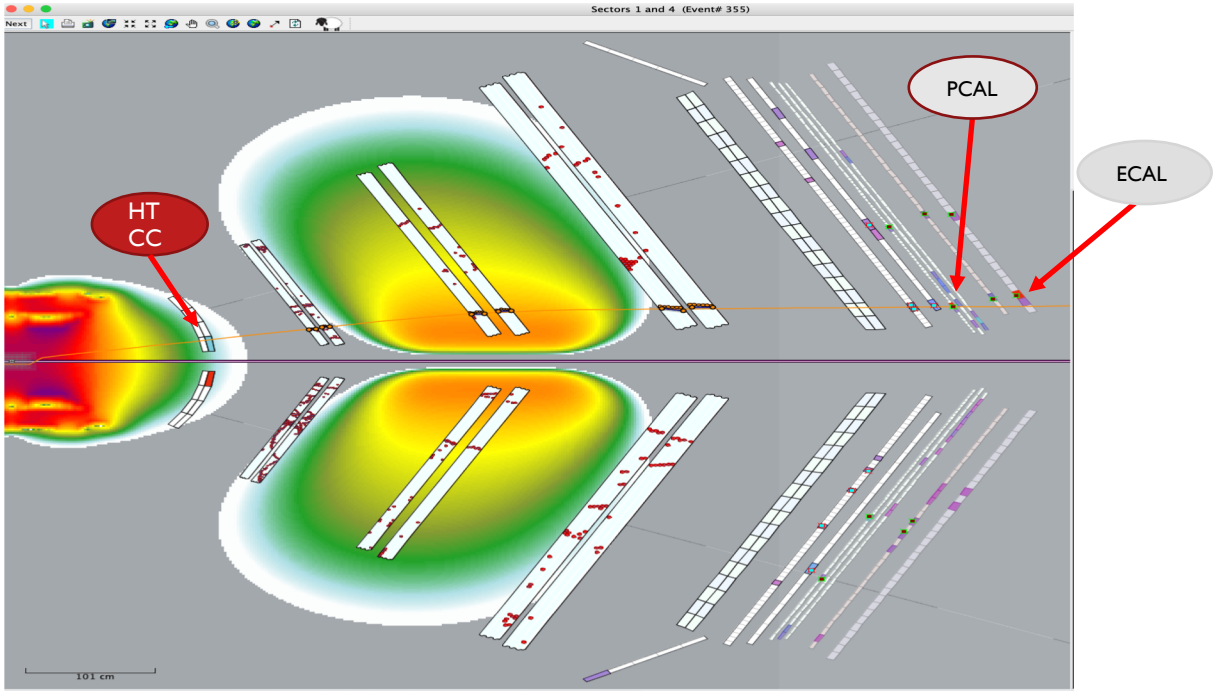
- **Trigger configuration**
  - PCAL x ECAL x FTOF x PCAU strips in opposite sectors

Electron Trigger



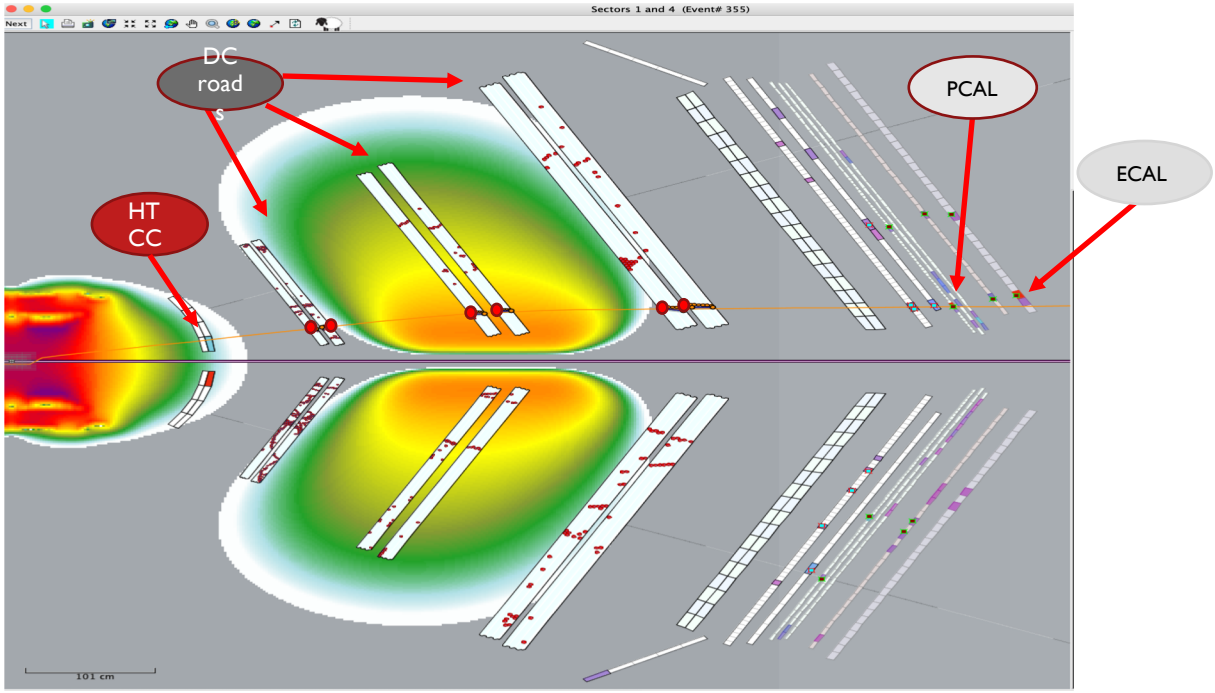
- HTCC > 2 phe

Electron Trigger



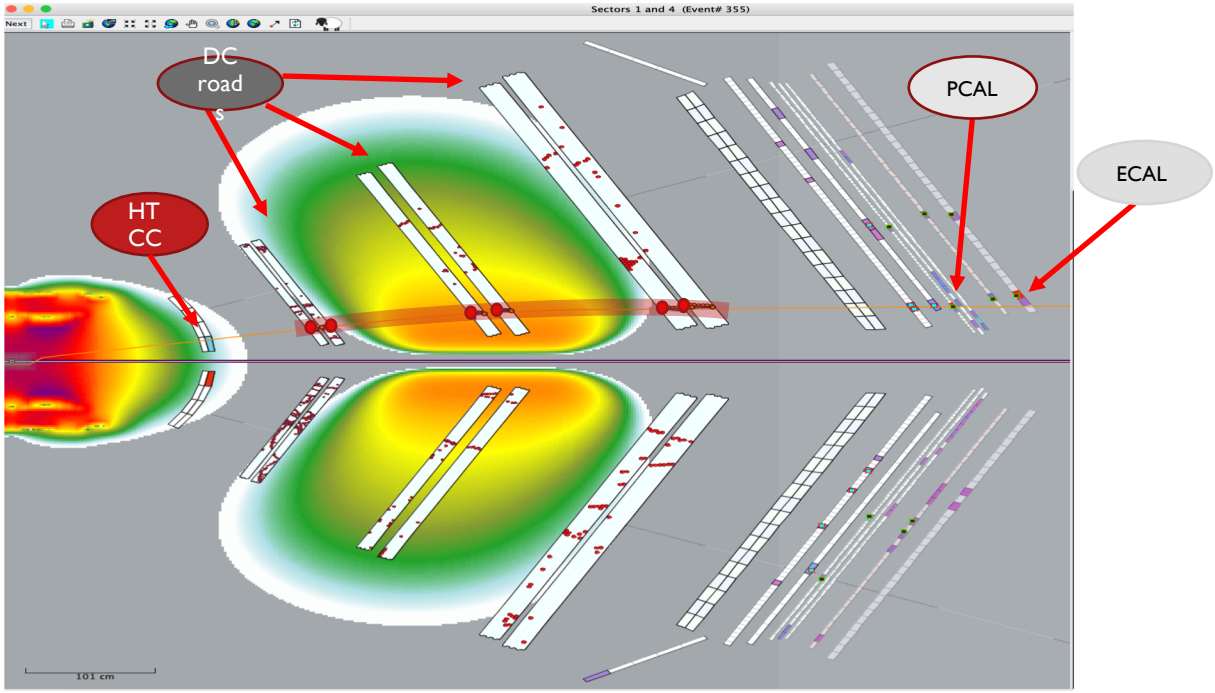
- HTCC > 2 phe
- PCAL+ECAL > 300 MeV

Electron Trigger



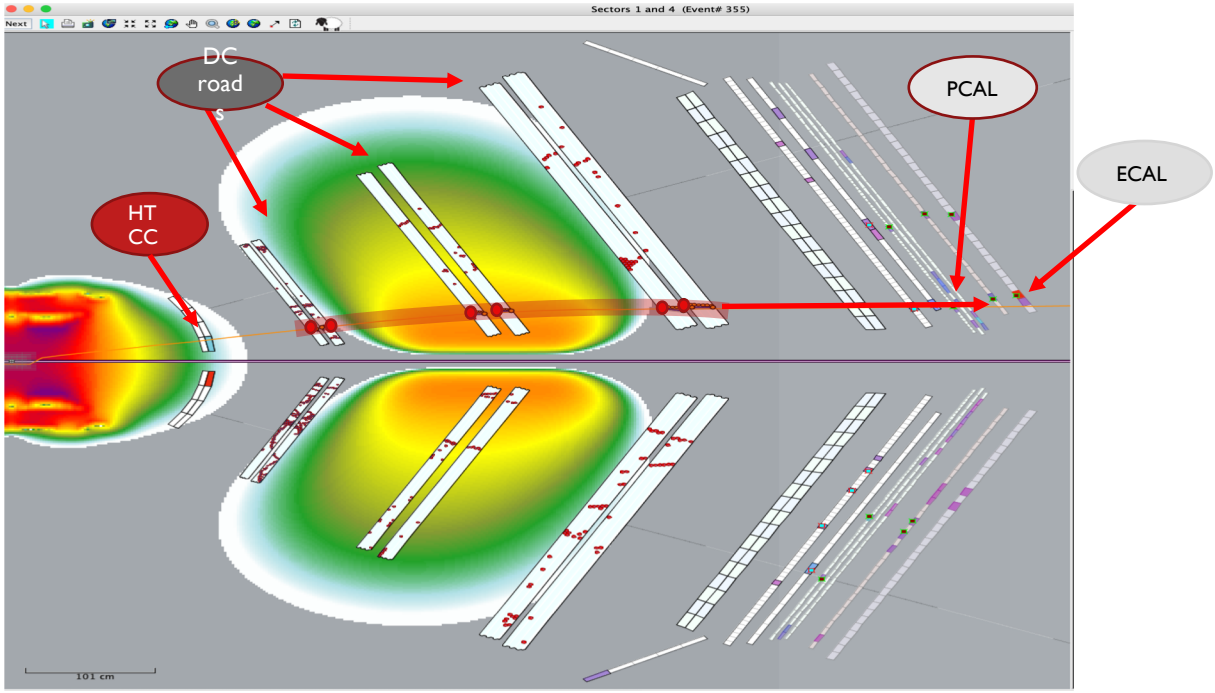
- HTCC > 2 phe
- PCAL+ECAL > 300 MeV
- DC segments: 5 out 6

Electron Trigger



- HTCC > 2 phe
- PCAL+ECAL > 300 MeV
- DC segments: 5 out 6
- DC roads

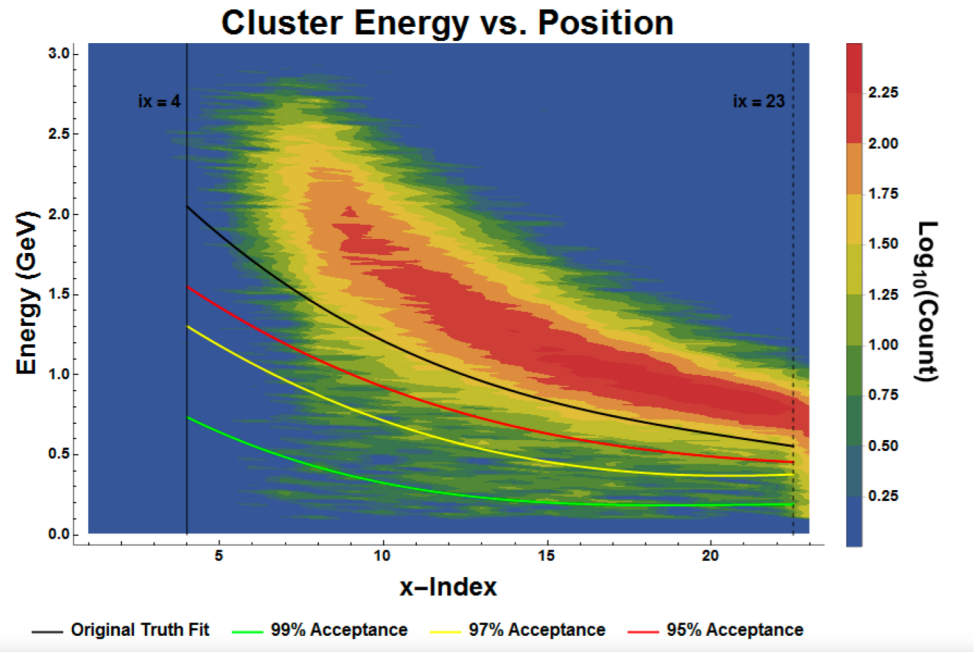
Electron Trigger



- HTCC > 2 phe
- PCAL+ECAL > 300 MeV
- DC segments: 5 out 6
- DC roads
- PCALU and track match

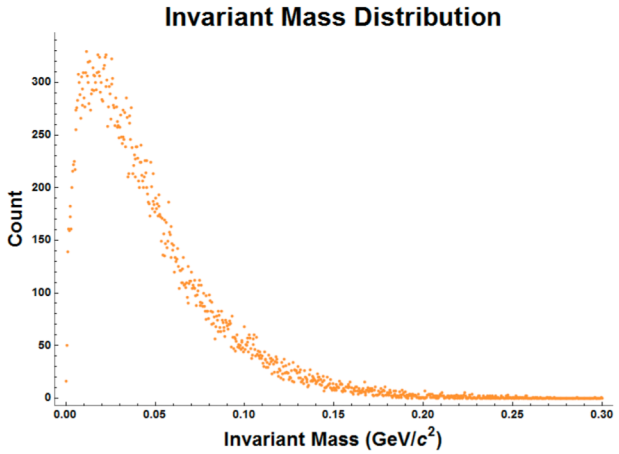
Position Dependent Energy Cut (PDEC)

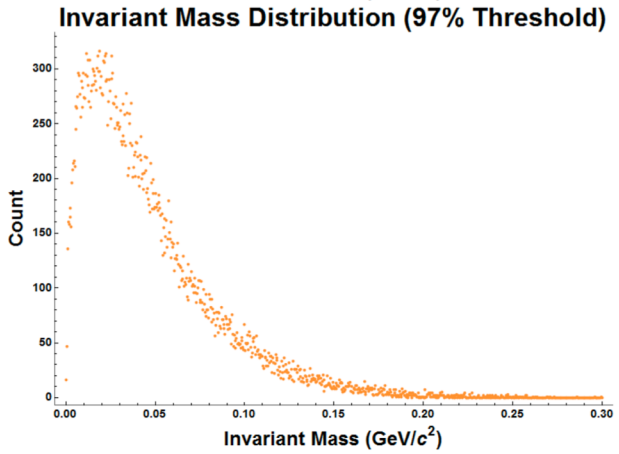
- 4 different versions to choose from
  - 99% acceptance
  - 97% acceptance
  - 95% acceptance
  - 93% acceptance
- Trident events were used for the tuning PDEC

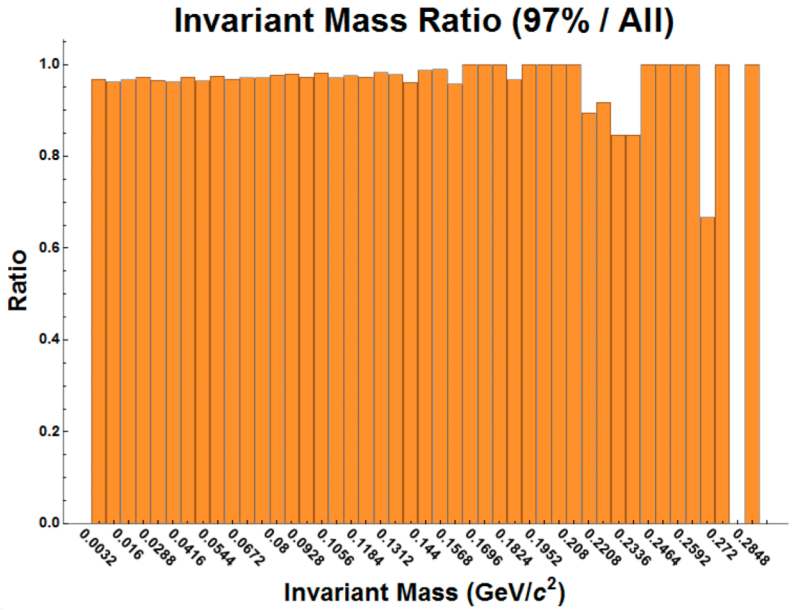


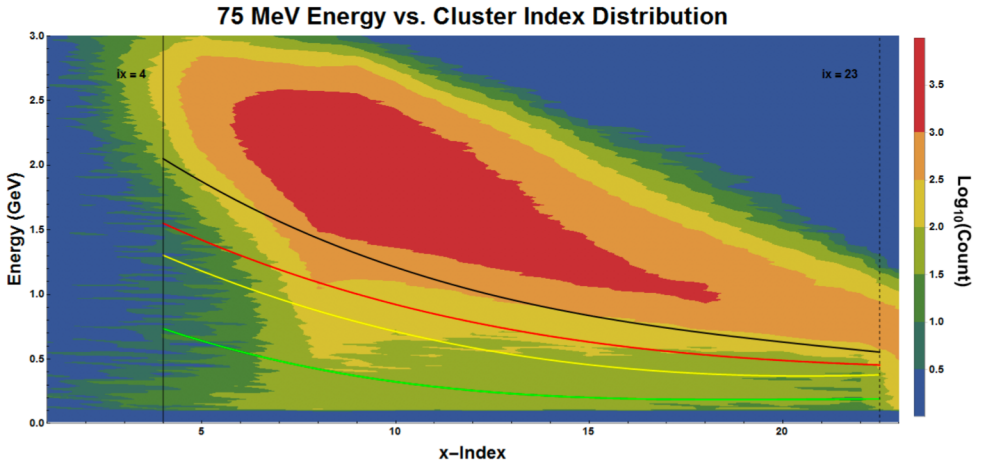
Position Dependent Energy Cut (PDEC)

Invariant Mass









2019 HPS Triggers

- Positron trigger
  - 4 tops
  - 4 bottoms
- Pairs (top-bottom)
  - old 2016 trigger
  - Moller
  - 2 gamma
  - Muon trigger
- 2 gammas (anywhere in the calorimeter)
- 3 gammas (anywhere in the calorimeter
- FEE
  - Top
  - Bottom
- Special triggers
  - Pulser
  - Hodoscope
  - Cosmic
  - LED

Positron Triggers

Top

- **#00 Singles-0 Top** Low energy cluster (150-8191) MeV Calorimeter iX index=(-23,+23). Full detector
- **#01 Singles-1 Top** Positron. Energy cluster (200-3000) MeV (+4,+23)
- **#02 Singles-2 Top** Positron. Energy cluster (200-3000) MeV (+4,+23)

  Position Dependent Energy Cut (PDEC)
- **#03 Singles-3 Top** Positron. Energy cluster (200-3000) MeV (+4,+23) (PDEC) and Hodoscope

Bottom

- **#04 Singles-0 Bot** Low energy cluster (150-8191) MeV Calorimeter iX index=(-23,+23). Full detector
- **#05 Singles-1 Bot** Positron. Energy cluster (200-3000) MeV (+4,+23)
- **#06 Singles-2 Bot** Positron. Energy cluster (200-3000) MeV (+4,+23) Position Dependent Energy Cut (PDEC)
- **#07 Singles-3 Bot** Positron. Energy cluster (200-3000) MeV (+4,+23) (PDEC) and Hodoscope

Positron trigger

September, 2019 I=120 nA

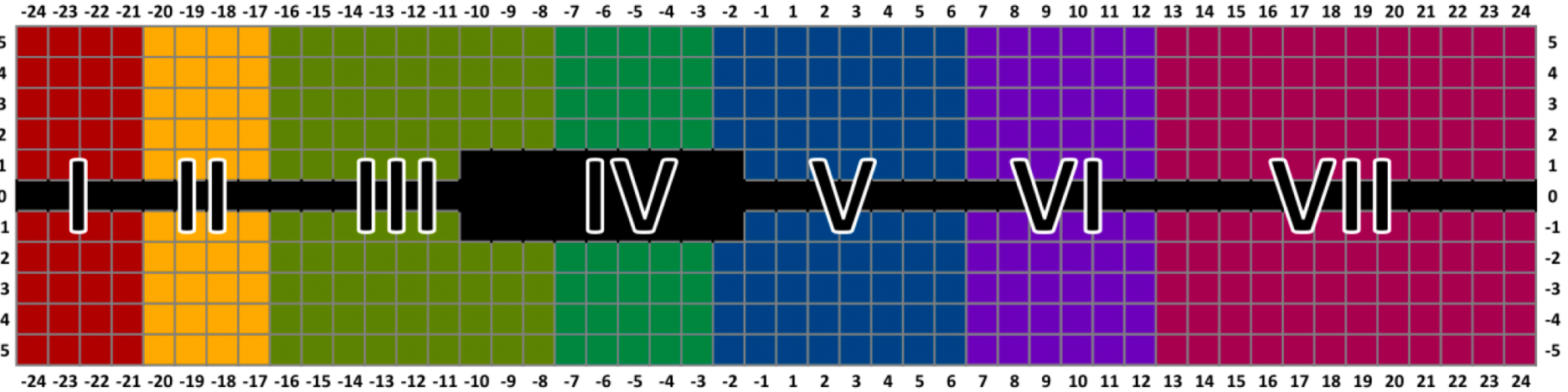
			E_{min}	E_{max}	PDEC	Hodo	Rate	Pre scale
#00	Single-0	Top	150	8191			1.9M	20000
#01	Single-1	Top	200	3000			32K	0
#02	Single-2	Top	400	3000	93%		7.7K	2
#03	Single-3	Top	200	3000	99%	Geom	10K	1
#04	Single-0	Bot	150	8191			2.0M	20000
#05	Single-1	Bot	200	3000			31K	0
#06	Single-2	Bot	400	3000	93%		8.3K	2
#07	Single-3	Bot	200	3000	99%	Geom	10K	1

- Trigger version hps_v12_1.trg
- Current 120 nA
- Total trigger rate 25kHz,
- Lifetime 95%

Pair Triggers, FEE and others

			E_{min}	E_{max}	Rate	Pre scale
#08	Pair-0	Old e^+e^-	300	3000	15K	100
#09	Pair-1	Moller	300	3000	120K	1000
#10	Pair-2	2 gammas Top-Bot	300	3500	80K	500
#11	Pair-3	Muons	80	300	730	1
#16	2 gammas	Top or Bot	150	8191	170K	20000
#17	3 gammas	Top+Bot	200	3000	8.7K	0
#18	FEE	Top	2600	5200	170	1
#19	FEE	Bot	2600	5200	161	1

FEE prescales



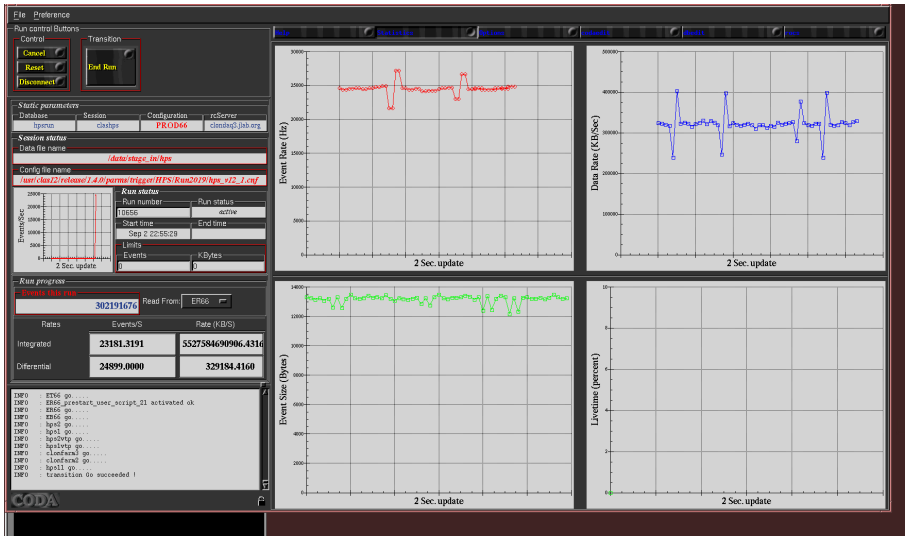

```
#                        prescale region
#                        |    region xmin
#                        |    |      region xmax
#                        |    |      |      prescale
#                        |    |      |      |
VTP_HPS_FEE_PRESCALE   0    -22   -20     0
VTP_HPS_FEE_PRESCALE   1    -19   -16     8
VTP_HPS_FEE_PRESCALE   2    -15    -7     128
VTP_HPS_FEE_PRESCALE   3     -6    -2     1024
VTP_HPS_FEE_PRESCALE   4     -1     6     512
VTP_HPS_FEE_PRESCALE   5      7    12     12
VTP_HPS_FEE_PRESCALE   6     13    23     0
```

Region	Prescale
I	I
II	9
II	129
IV	1025
V	513
VI	13
VII	I

Special Triggers

			Rate	Prescale
#12	LED	Calorimeter	15K	0
#13	Cosmic	Calorimeter	120K	0
#14	Hodoscope		6.3M	0
#15	Pulser		100	1
#16 Front Panel	Faraday Cup		4648	5

DAQ and Trigger Performance



- I=120 nA
- DAQ rate 25 kHz
- Data Rate 325 MB/s
- Event size 13 KB
- Lifetime 95%
- Trigger version hps_v12_1.trg

Run# 10656 Target: 20 um W HPS Triggers Latency 09/03/2019 02:32:50

Beam Currents (nA) 2C21: 127.97 FCup: 120.48 Livetime (%): 94.70

#	Description	Raw Rate (Hz)	Prescaled Rate (Hz)	%	Prescale
00	Single-0 Top	1950547.0	87.0	0.2	20000
01	Single-1 Top	32839.0	0.0	0.0	0
02	Single-2 Top (e+)	7867.0	7970.0	20.0	1
03	Single-3 Top (e+/Hodo)	10408.0	10536.0	26.4	1
04	Single-0 Bottom	2113550.0	94.0	0.2	20000
05	Single-1 Bottom	31733.0	0.0	0.0	0
06	Single-2 Bottom (e+)	8627.0	8577.0	21.5	1
07	Single-3 Bottom (e+/Hodo)	10922.0	10768.0	27.0	1
08	Pair-0 (Old e+e-)	15798.0	152.0	0.4	100
09	Pair-1 (Moller)	122979.0	110.0	0.3	1000
10	Pair-2 (2gamma)	83160.0	152.0	0.4	500
11	Pair-3 (mu+mu-)	766.0	722.0	1.8	1
12	LED	0.0	0.0	0.0	0
13	Cosmic	0.0	0.0	0.0	0
14	Hodoscope	6275500.0	0.0	0.0	0
15	Pulser	99.0	101.0	0.3	1
16	Multiplicity-0 (2gamma)	175732.0	88.0	0.2	2000
17	Multiplicity-1 (3gamma)	8820.0	111.0	0.3	80
18	FEE Top	206.0	190.0	0.5	1
19	FEE Bottom	195.0	194.0	0.5	1

Sum: 39852.00

Front Panel (Hz): Faraday Cup 4721.0 N/A 0.0

FADC Data Rate (MB/s): hps1 50.68 hps2 60.37

Trigger Validation

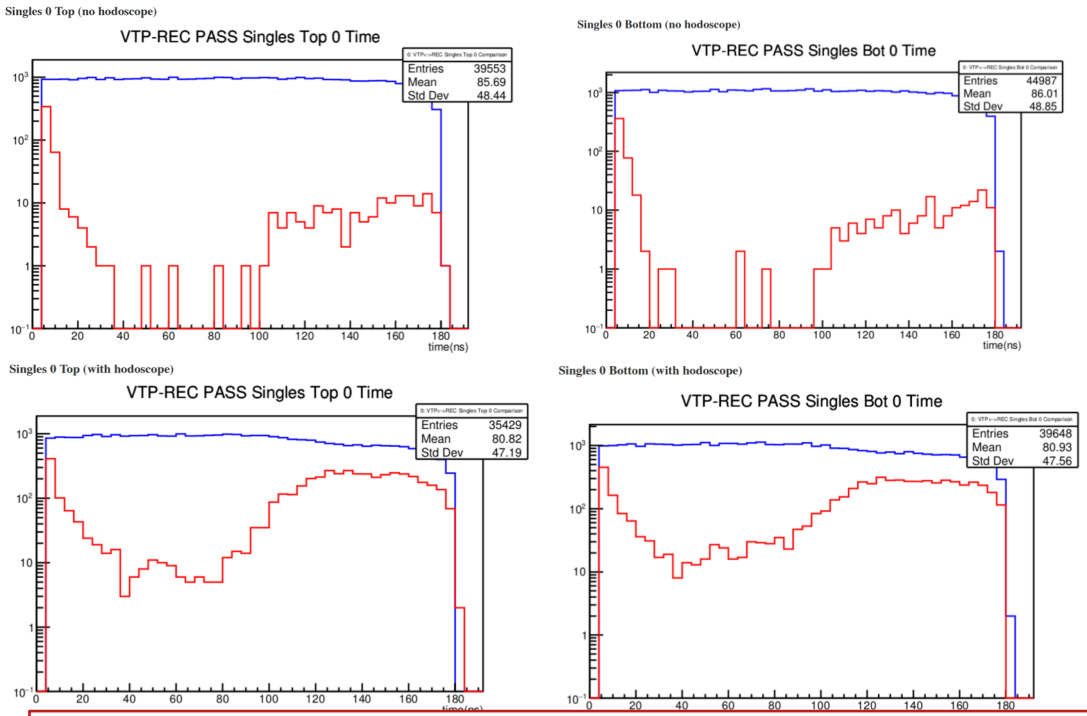
- Validation of the trigger firmware performance
- Absolute trigger efficiency estimation

Validation of the trigger firmware performance

- Random trigger data
- Full simulation of the trigger firmware based on the FADC data
- Selection of the events that satisfied the trigger conditions
- Test the hardware trigger bits.

Trigger inefficiency due to the high hodoscope hit rate

Plots for each trigger bit show the successful reconstructed trigger to VTP bank matches **(Blue)** and failures **(Red)** as a function of time in the FADC window. It was plotted as a function of FADC time so that window edge effects could be seen and ignored from the overall efficiencies. You can see that times near the beginning and end of the FADC window tend to cause problems because the ECAL pulses are clipped. Mismatches in the middle of the window can happen due to pile-up where the FADC hits can be ignored by the trigger or due to a bug.

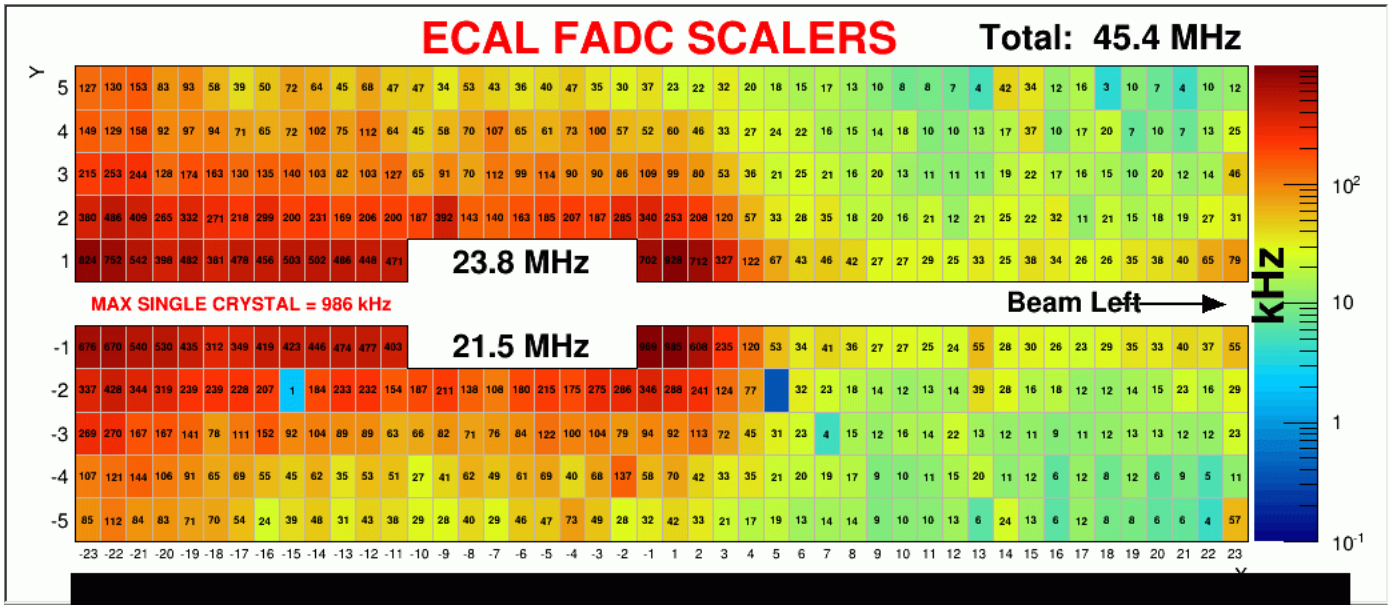


Effect of the high hit rates on the FADC on the trigger logic (pile up hits are missed by trigger when within 32ns of each other)
~1% loss effect (roughly consistent with the FADC hit rate seen from hodoscope).

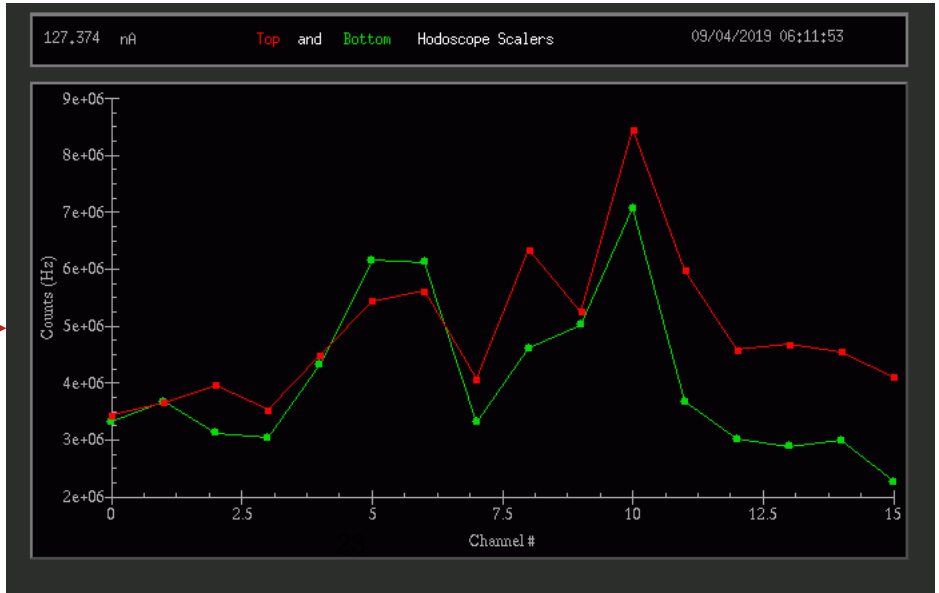
Ben

Change of persistency up to 64 ns (that was done after this study) eliminated any inefficiency due to the 32ns pileup feature.

Rates @120 nA

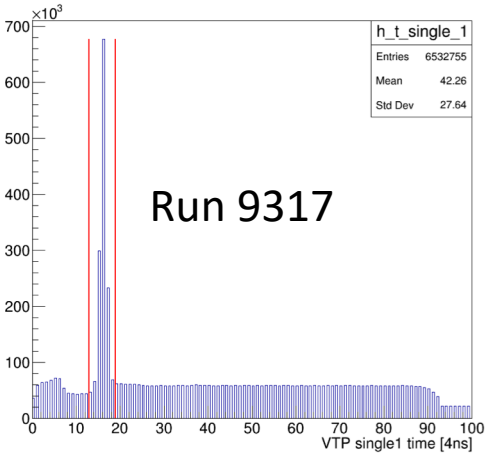


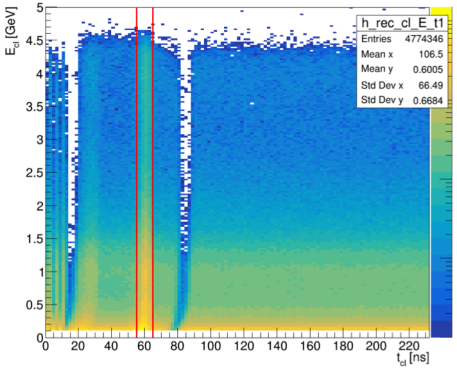
5 MHz



ECal Efficiency

- Trigger with Hodoscope only
- Check the efficiency of the ECal PDEC trigger



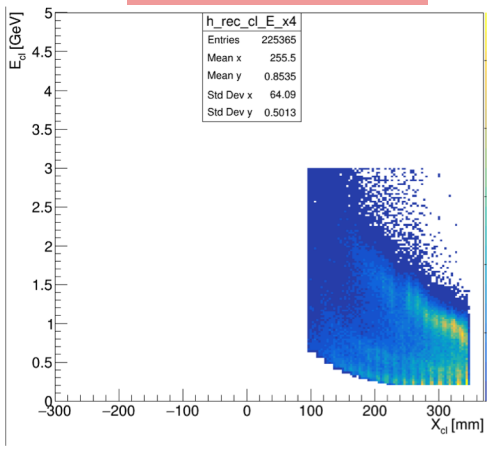


The offline ECal cluster should satisfy trigger conditions

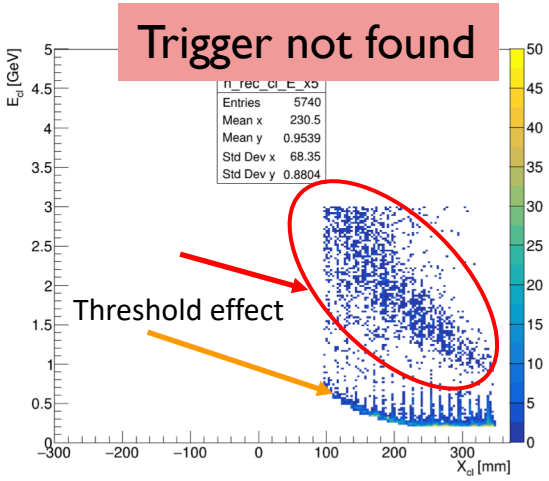
- X > 90
- E_cl < 3. GeV
- PDEC cut
- To be in time: t > 55 ns & t < 65 ns
- N_Hits > 1

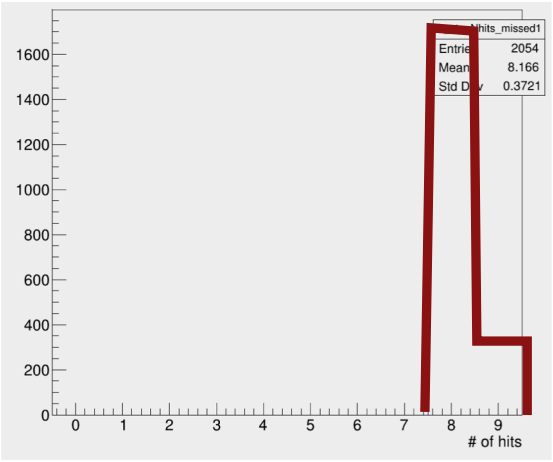
Events with E > 1 GeV
No cluster with 8 and 9 hits was accepted
Ben found a bug and quickly fixed!

Trigger found



Trigger not found





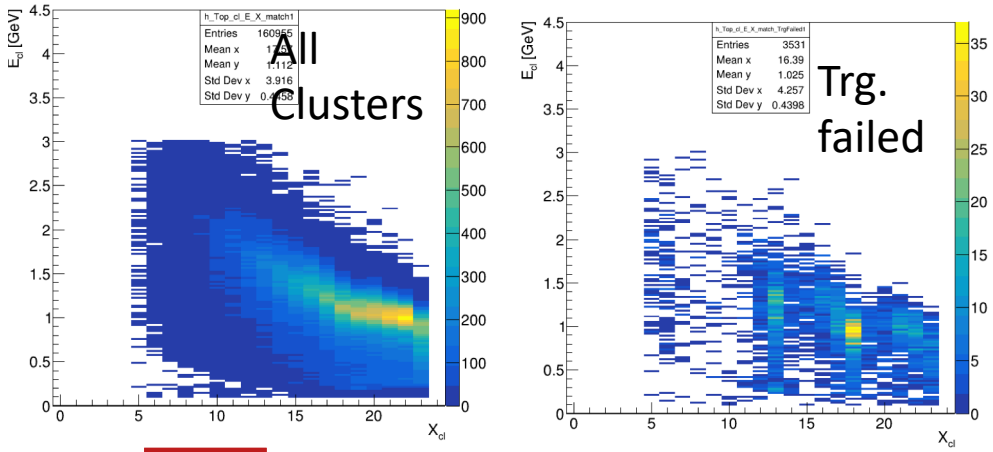
Rafo

Production Single-3 trigger efficiency

Data: single2 trigger (ECal only PDEC trigger)

Single3 trigger (The production trigger)

- Hit in L1 is above threshold
- Hit in L2 is above threshold
- L1xL2 geom and time matching
- L1xECal_X geom and time matching
- L2xECal_X geom and time matching
- ECal PDEC (validated earlier)



Rafo

Event's Selection

Clusters
- In-time cluster
- $E_{cl} < 3$ GeV
- $X_{cl} > 105$

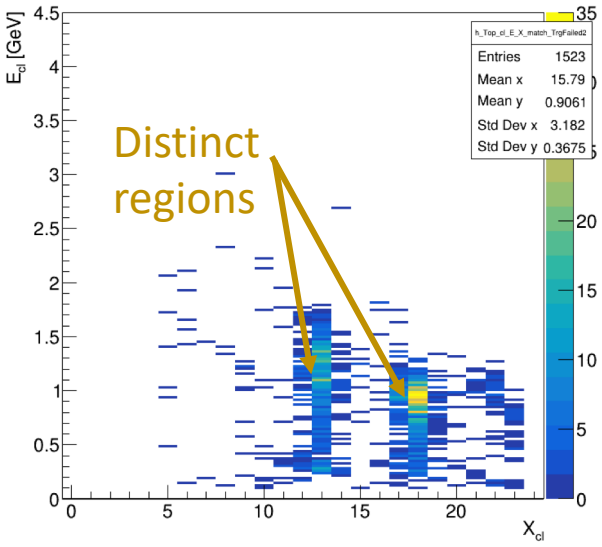
Tracks
- $P > 0.85$ GeV
- chi2/NDF < 5 (to avoid fake tracks)
- Positive charge
- Track-Cluster matched

About 2% failed
≈ half of failed events failed
"$X_{Hodo} \otimes X_{ECal}$"

See next slide for these failed events

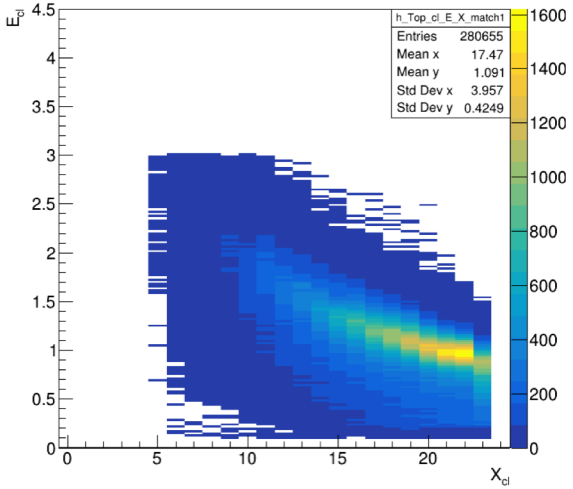
Production Single-3 trigger efficiency

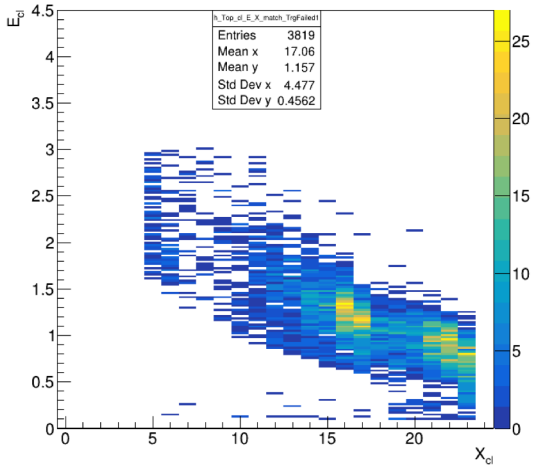
Events that failed "$X_{Hodo} \otimes$



This led to loosen a bit "$X_{Hodo} \otimes X_{ECal}$" matching cut

Trigger efficiency with new "$X_{Hodo} \otimes X_{ECal}$" table

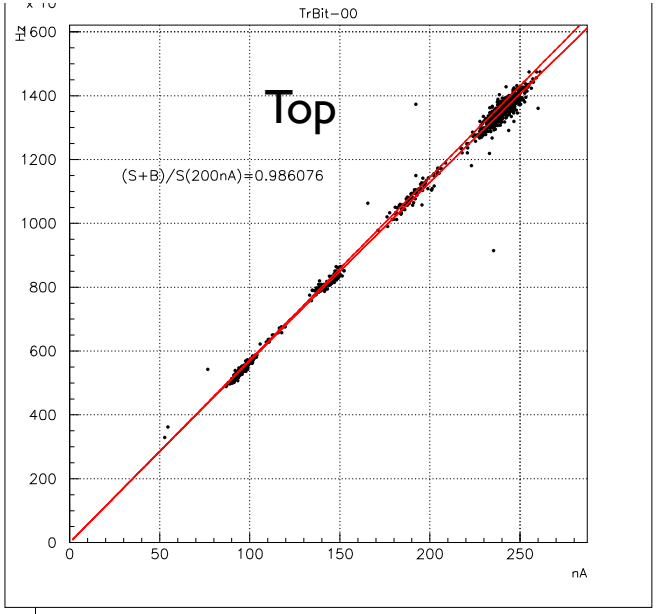


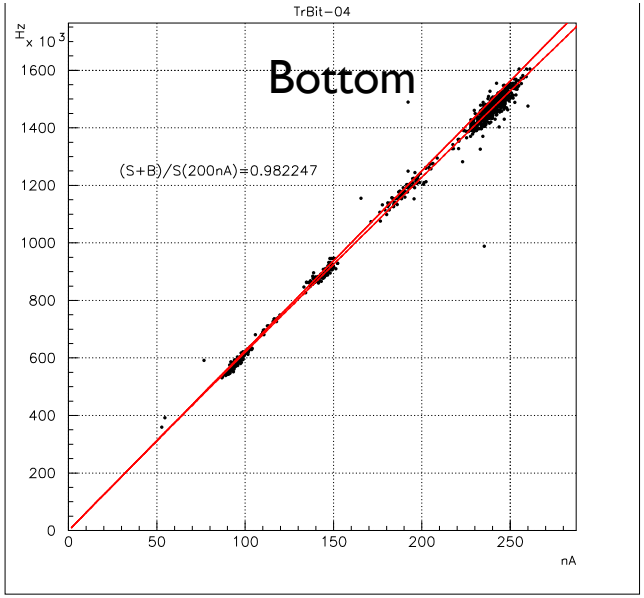


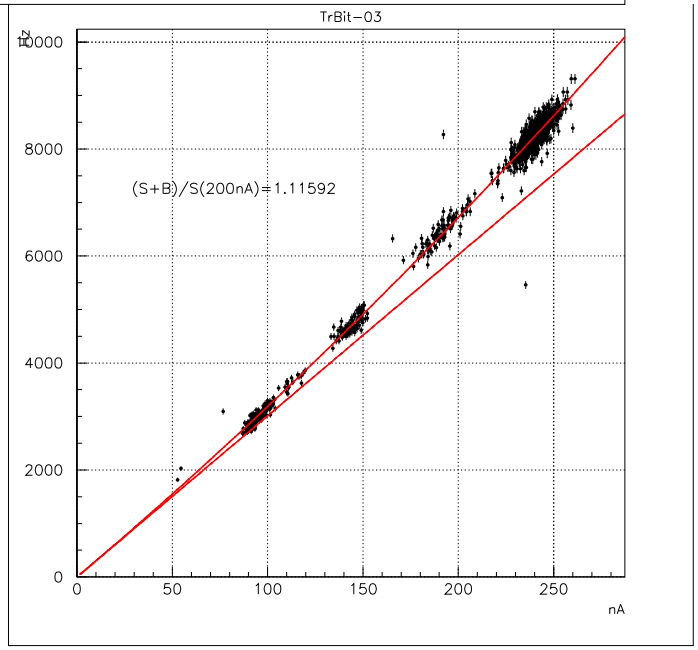
<u>Inefficiency is 1.3%</u>

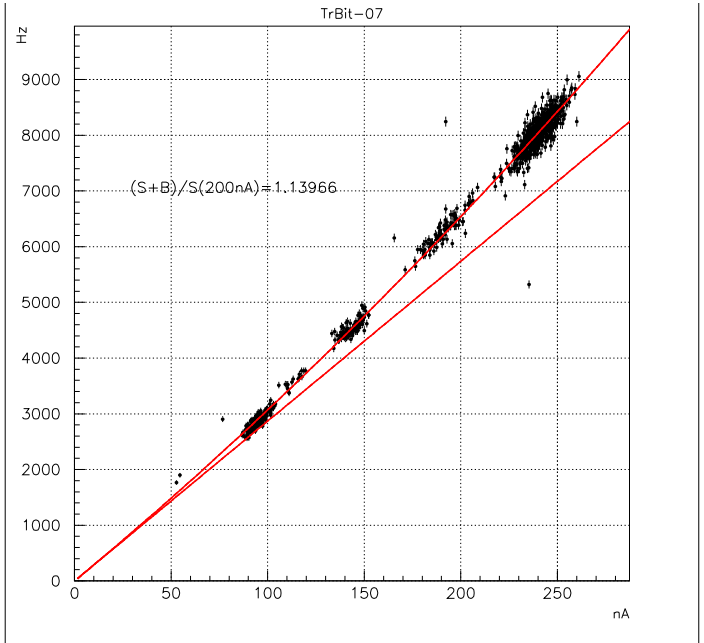
Rafo

Trigger rate vs beam current

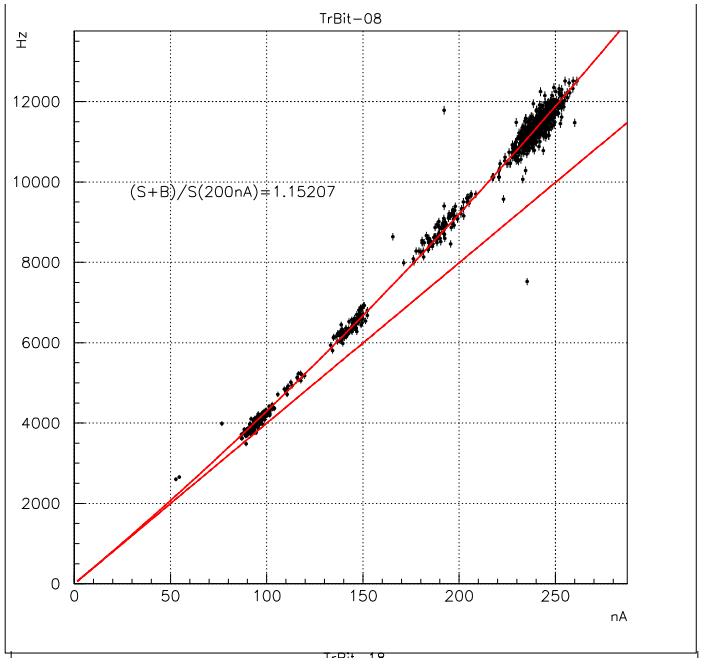


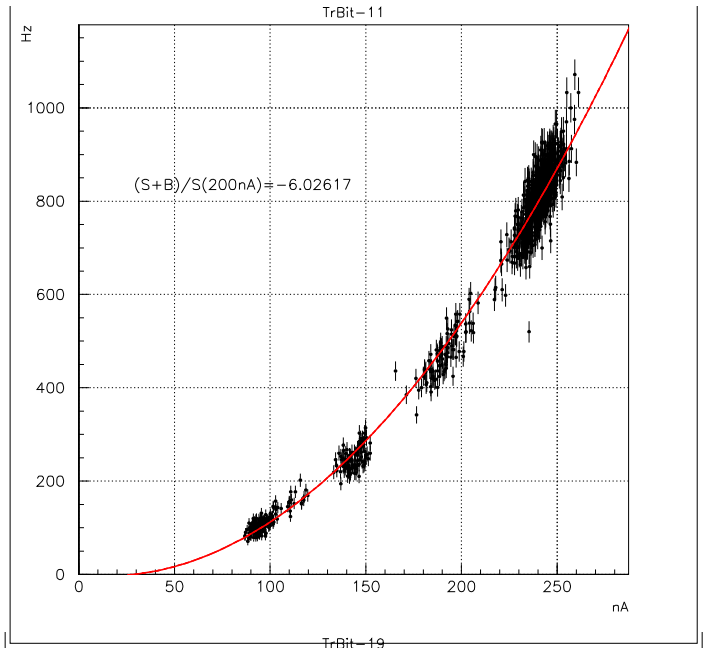


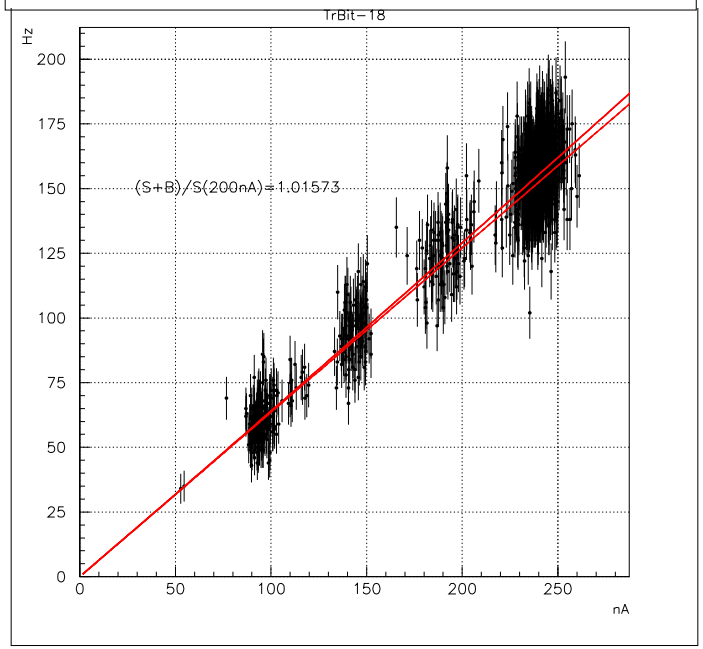


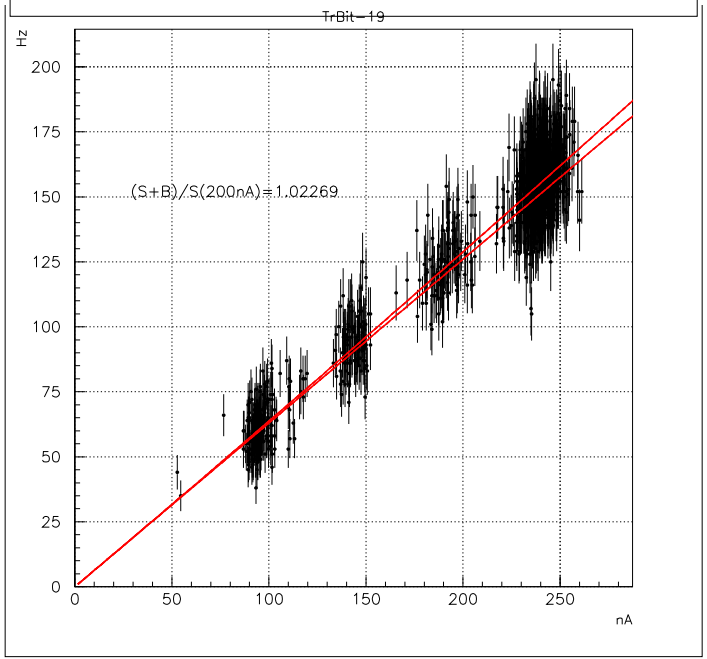


Pair, Muon and FEE









HPS Trigger Description

https://userweb.jlab.org/~vpk/HPS/Trigger/Run2019/HPS_trigger_versions.xlsx

8/25/19		Tr. Bit		Prescale	Emin	Emax	Nmin	CPDE	iX	Hodo	Coin.	SUM min	SUM max	DIFF max	Complan
un 10496	Single-0	T=0 B=4	Low E clust	20000	150	8191	1								
	Single-1	T=1 B=5	Positron	0	200	3000	2	No	5						
	Single-2	T=2 B=6	Positron	2	400	3000	2	93%	5						
og Entry	Single-3	T=3 B=7	Positron	1	200	3000	2	99%	5	Geom					
ps_v11_6.trg	Pair-0	8	A'	100	300	3000	2				12ns	1200	4000	2200	40
rigger	Pair-1	9	Moller	1000	300	3000	3				16ns	1000	3800	2200	
	Pair-2	10	pi0	500	300	3500	3				12ns	800	4000	4500	
	Pair-3	11	Muons	1	80	300	1			Yes	12 ns	160	600		40
	LED	12		0											
	Cosmic	13		0											
	Hodo	14		0											
	Pulser	15	100 Hz	1											
	Mult-0	16	2 clusters	2000	300	3500	3				16				
	Mult-1	17	3 clusters	80	300	3500	3				16				
	FEE	18 - 19		400	2600	5200	3								
	Faraday Cup		6800 Hz	6	1133 Hz	205nA									

9/2/19		Tr. Bit		Prescale	Emin	Emax	Nmin	CPDE	iX	Hodo	Coin.	SUM min	SUM max	DIFF max	Complan
un 10655	Single-0	T=0 B=4	Low E clust	20000	150	8191	1								
	Single-1	T=1 B=5	Positron	0	200	3000	2	No	5						
	Single-2	T=2 B=6	Positron	1	400	3000	2	93%	5						
og Entry	Single-3	T=3 B=7	Positron	1	200	3000	2	97%	5	Geom					
ps_v12_1.trg	Pair-0	8	A'	100	300	3000	2				12ns	1200	4000	2200	40
rigger	Pair-1	9	Moller	1000	300	3000	3				16ns	1000	3800	2200	
	Pair-2	10	pi0	500	300	3500	3				12ns	800	4000	4500	
	Pair-3	11	Muons	1	80	300	1			Yes	12 ns	160	600		40
	LED	12		0											
	Cosmic	13		0											
	Hodo	14		0											
	Pulser	15	100 Hz	1											
	Mult-0	16	2 clusters	2000	300	3500	3				16				
	Mult-1	17	3 clusters	80	300	3500	3				16				
	FEE	18 - 19		400	2600	5200	3								
	Faraday Cup		6800 Hz	6	1133 Hz	205nA									

Conclusion

- The positron trigger was designed, implemented and validated
- Muon trigger was implemented
- FEE trigger was improved
- Multiphoton triggers were added to the trigger list
- The trigger efficiency was at the level of 99% or better
- The production main trigger rate was at the level of 20 kHz
- The total rate was about 25 kHz with 95% life time

Let me wish you Merry Christmas and Happy New year!