Trigger Upgrades and Performances

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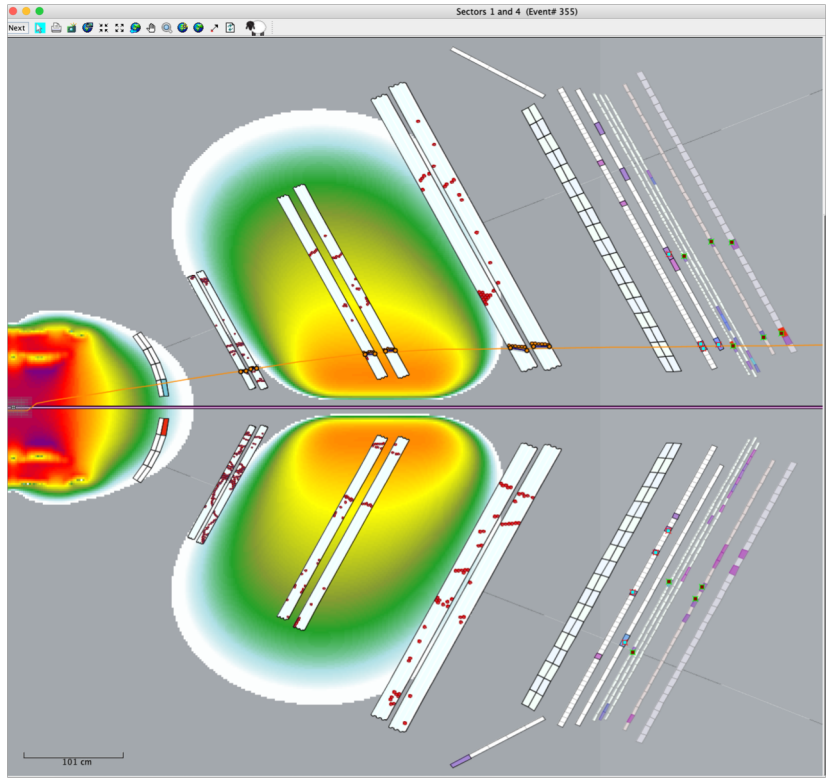
Trigger Physics Requirements

- **Run Group A (11 GeV, hydrogen target, 13 proposals) 2018, spring-fall**
  - Electron trigger
    - inbending/outbending configurations
  - MesonX, “photoproduction” trigger
    - Electron detected in the Forward Tagger (calorimeter AND hodoscope in coincidence)
    - Two charge particles in different sectors of the CLAS12 spectrometer
  - “Muon” trigger (opposite sectors trigger)
    - $J/\psi \rightarrow \mu^+\mu^-$
    - 2 MIP particles in *opposite sectors*
- **Run Group K (6.5-7.5 GeV, hydrogen target,3 proposals) 2018, autumn**
  - Electron (outbending)
  - FT trigger, electron in FT and additional particle in the forward and/or central detectors
- **Run Group B (11GeV, deuterium target, 9 proposals) 2019, running now**
  - Electron trigger
  - “Muon” trigger
  - Nobody wrote a proposal for the photoproduction out of neutron -> **No FT trigger** ☹

Electron Trigger

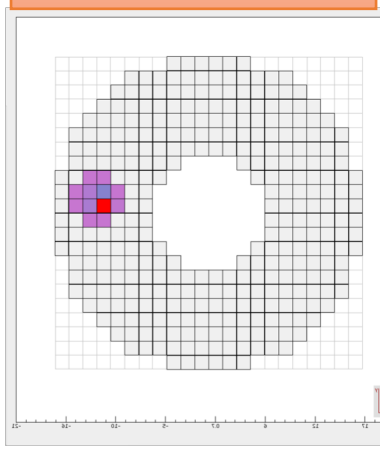
- **Trigger detectors**
  - High Threshold Cherenkov Counter (HTCC)
  - Preshower calorimeter (PCAL)
  - EC calorimeter (ECAL)
  - DC roads
- **Trigger parameters**
  - HTCC – minimum number of photoelectrons >2
  - PCAL – minimum cluster energy > 60 MeV
  - PCAL+ECAL – sum of the energy deposition > 300 MeV
  - DC segments and roads matching PCAU



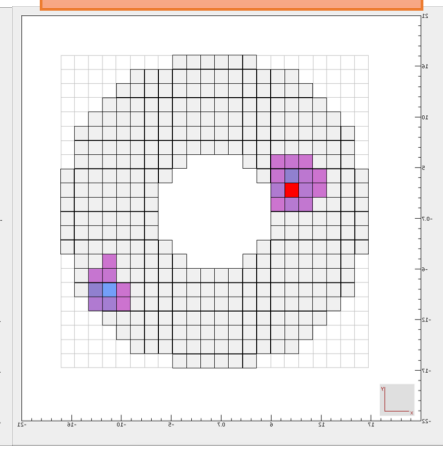
Forward Tagger Triggers

- **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] GeV
  - Hits in two layers of FTHodo matching the FTCal cluster position
  - 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)

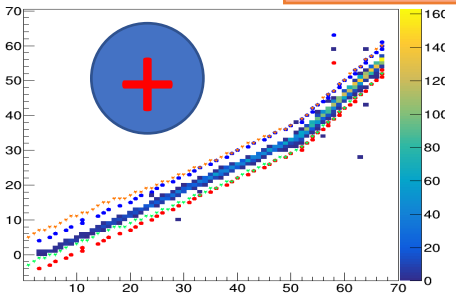
One cluster trigger



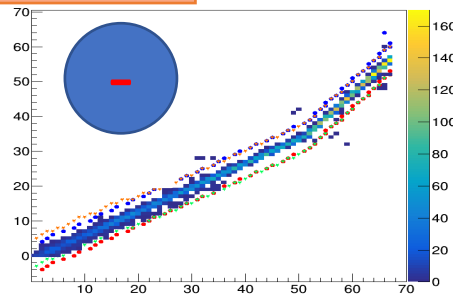
Two clusters trigger



FTOF PCALU match

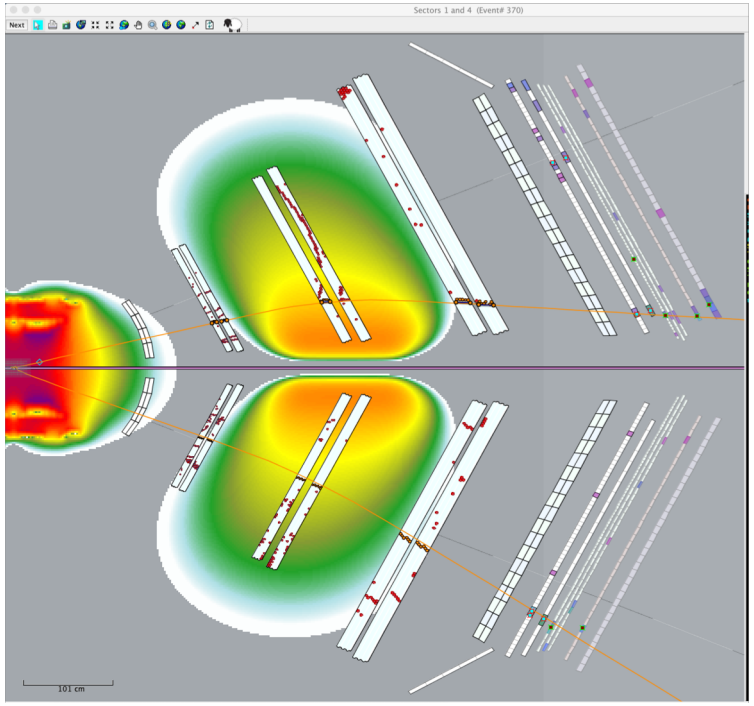


Positive particles



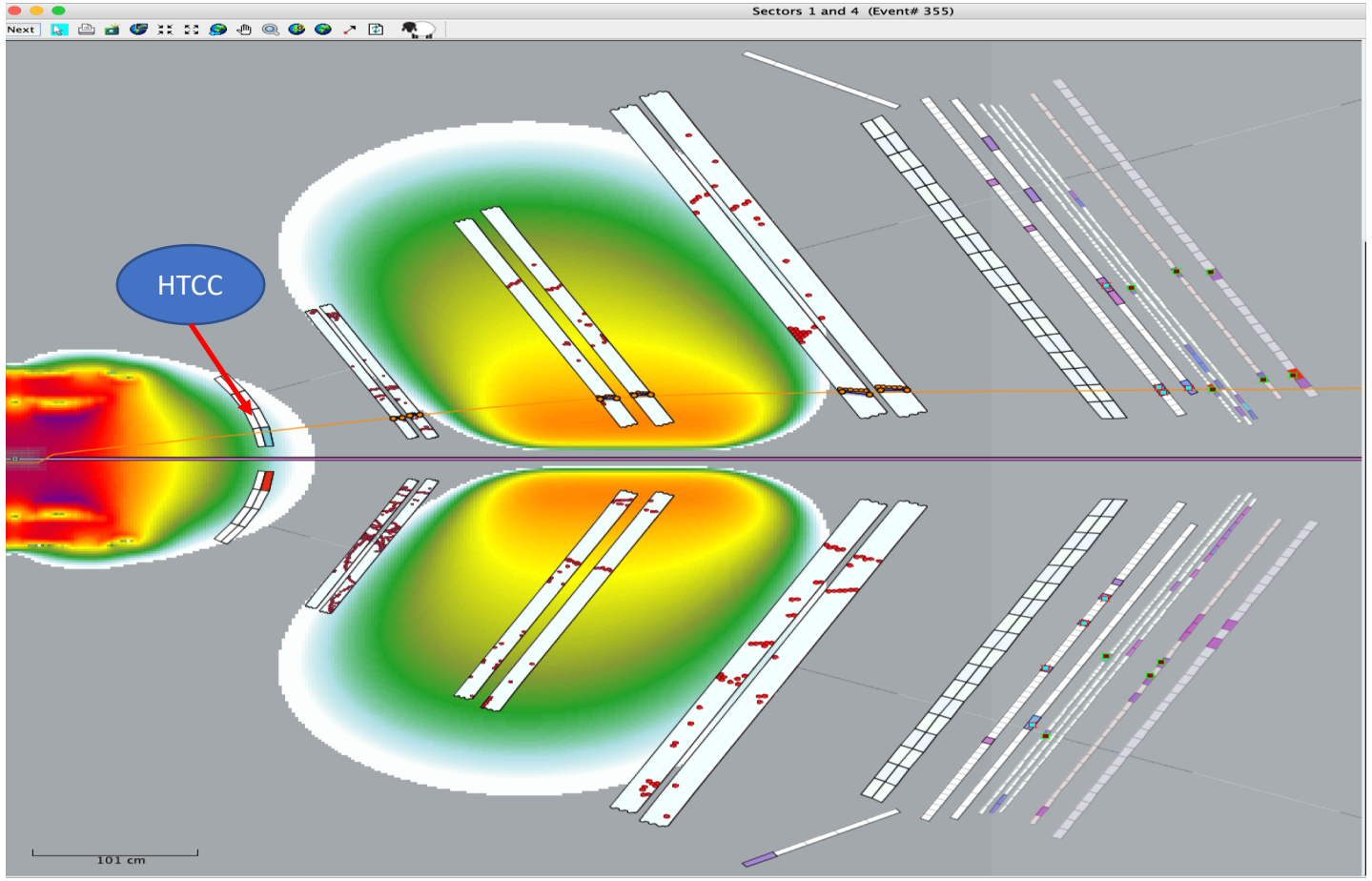
Negative particles

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



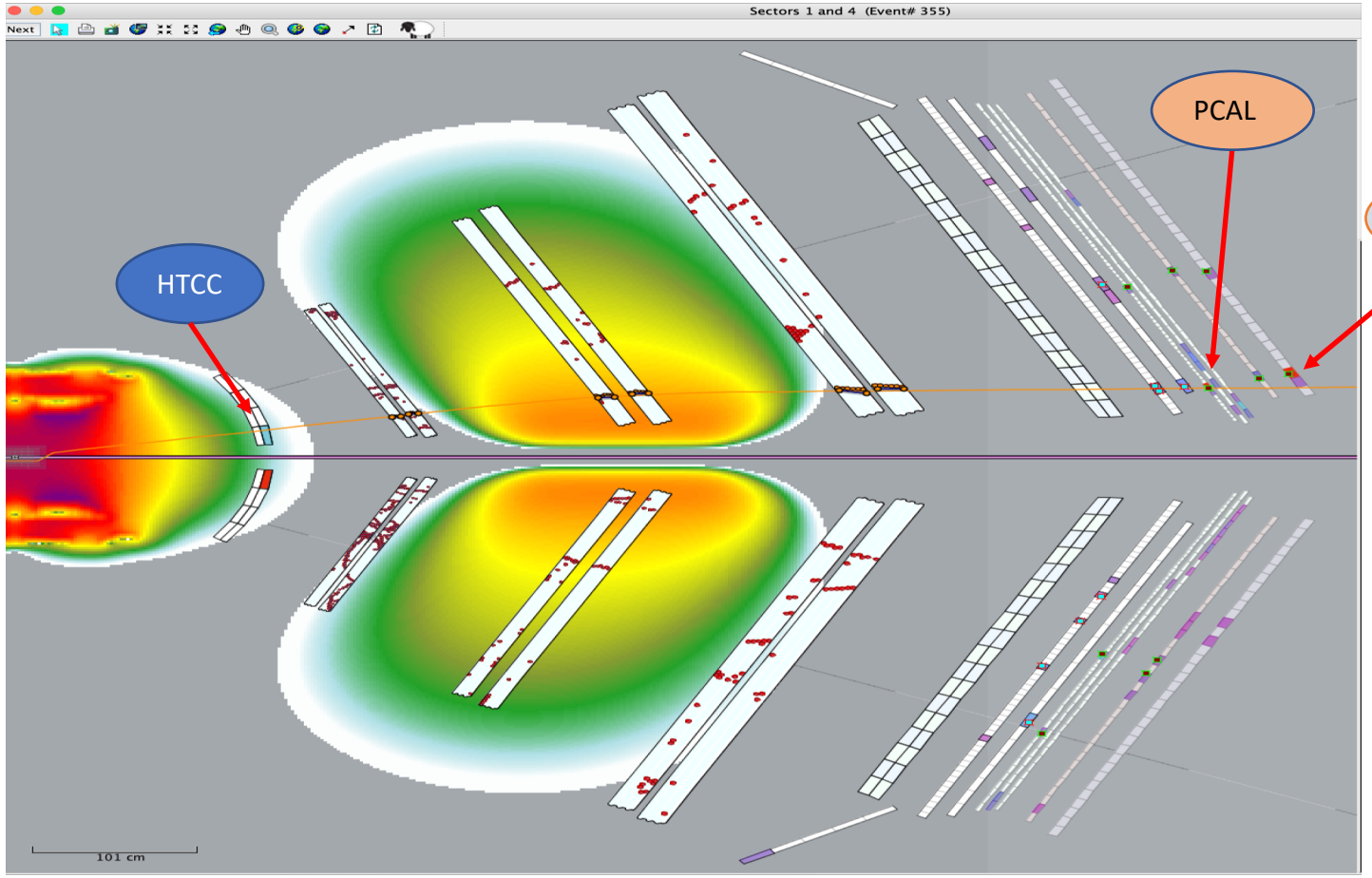
- **Trigger detectors**
  - Preshower calorimeter (PCAL)
  - Forward Time of Flight (FTOF)
  - EC calorimeter (ECAL)
  - DC roads
  - FTOF-PCALU match
- **Trigger parameters**
  - PCAL cluster energy [>10] MeV
  - ECAL cluster energy [40-120] MeV
  - Hits in FTOF matching PCAL U-strips
  - DC roads for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

Electron Trigger



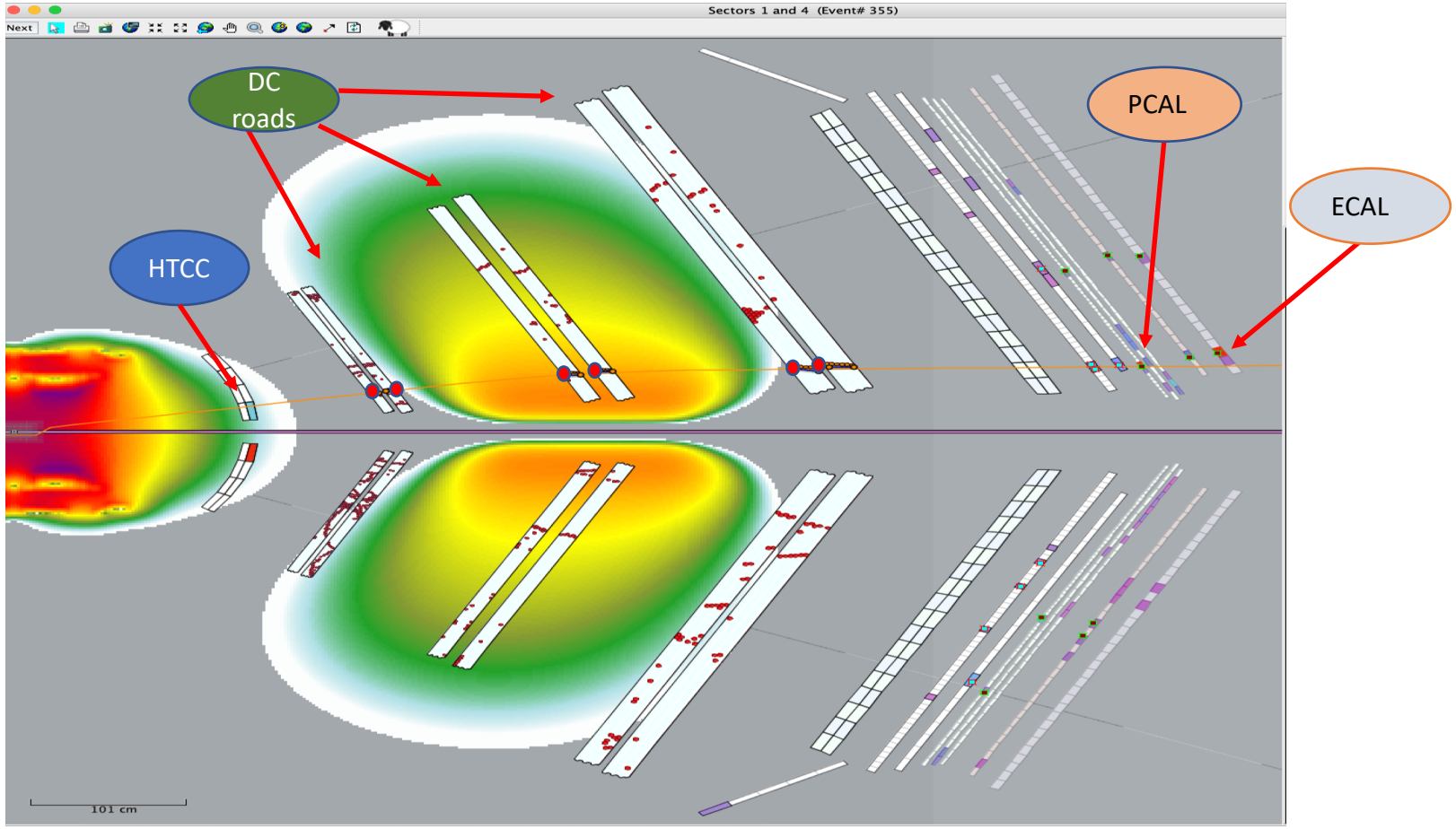
- HTCC > 2 phe

Electron Trigger



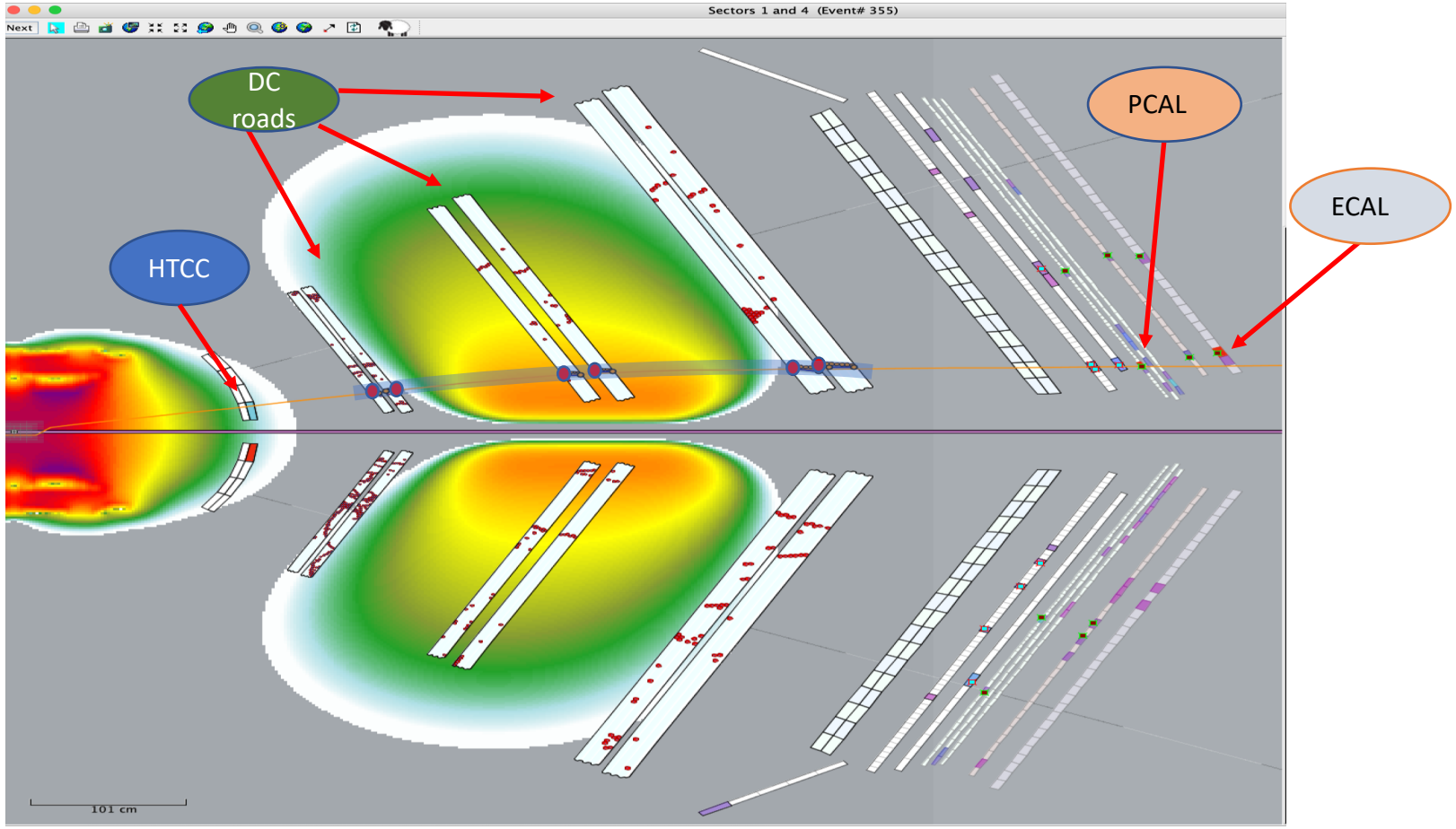
- HTCC > 2 phe
- PCAL+ECAL > 300 MeV

Electron Trigger



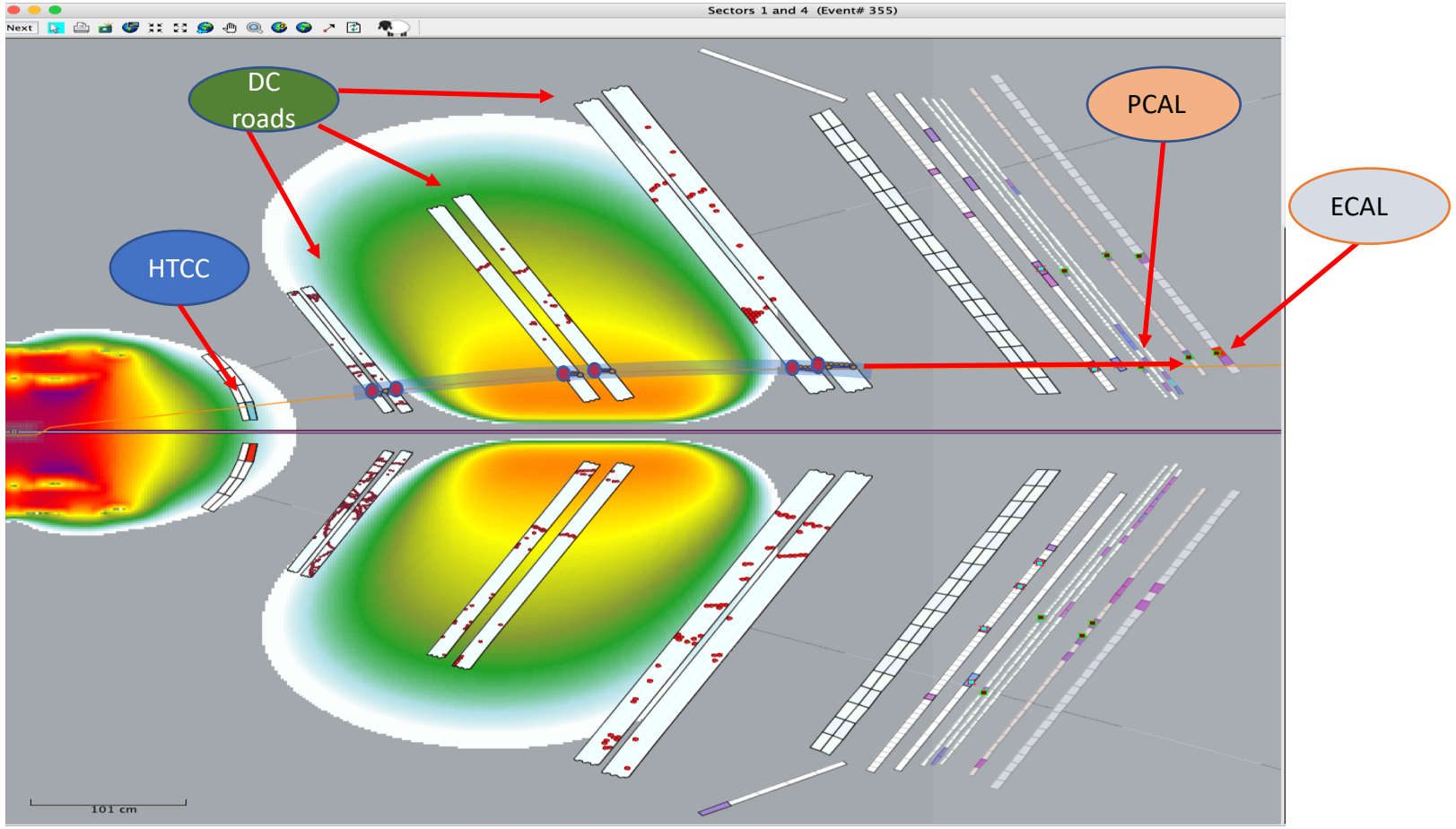
- HTCC > 2 phe
- PCAL+ECAL > 300 MeV
- DC segments: 5 out 6

Electron Trigger



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

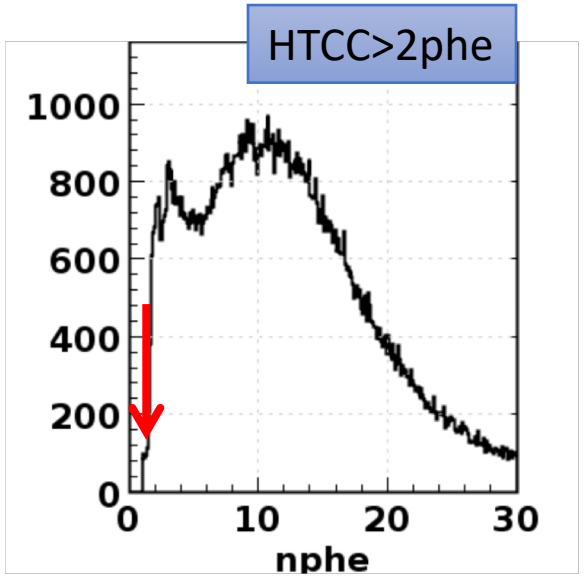
Electron Trigger



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

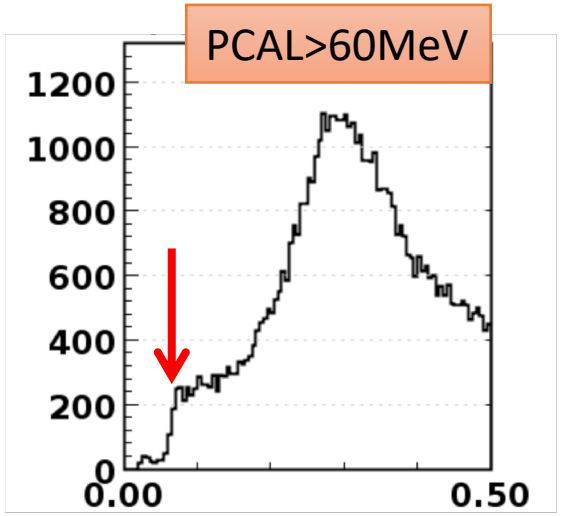
Electron Trigger Parameters

HTCC>2phe

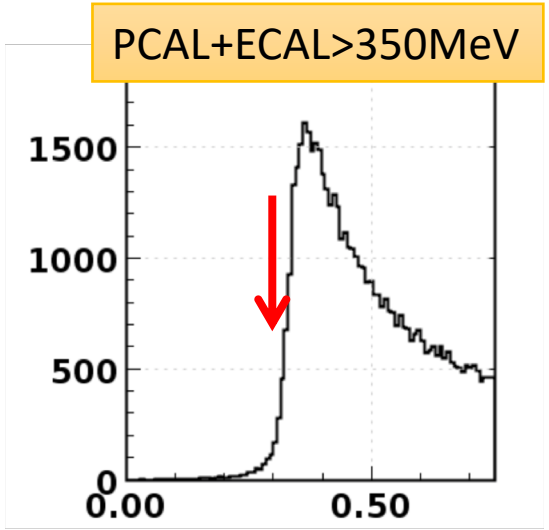


Threshold Cherenkov Counter
Reject pions with p<4.9 GeV

PCAL>60MeV



PCAL+ECAL>350MeV



Select electrons with high energy deposition in the PCAL and ECAL calorimeters

Electron Trigger

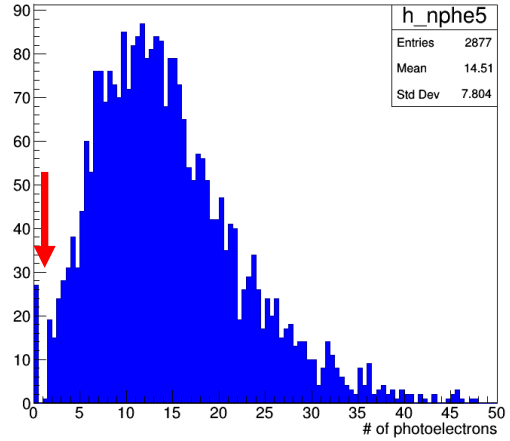
- Main trigger parameter

$$E_{SUM} = E_{PCAL} + E_{ECAL}$$

- For a moment this parameter is in the range **150-350 MeV** depending on the experiments request
- HTCC threshold = 2 phe.

$\varepsilon_{HTCC>2phe}$>99%

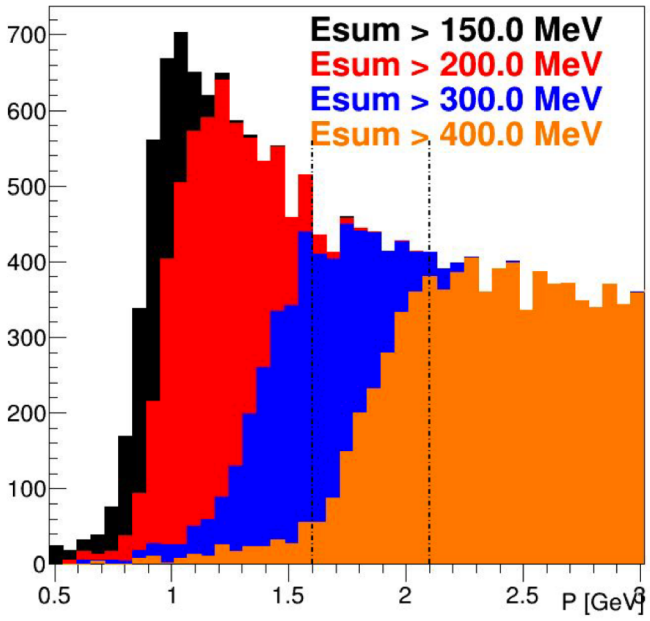
This is integrated over all HTCC counters efficiency

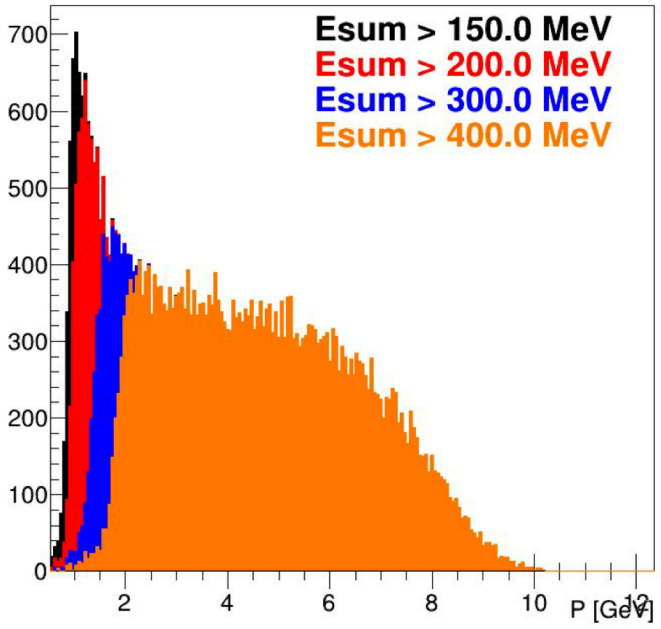


HTCC number of phe

Electron Momentum and PCAL+ECAL cuts

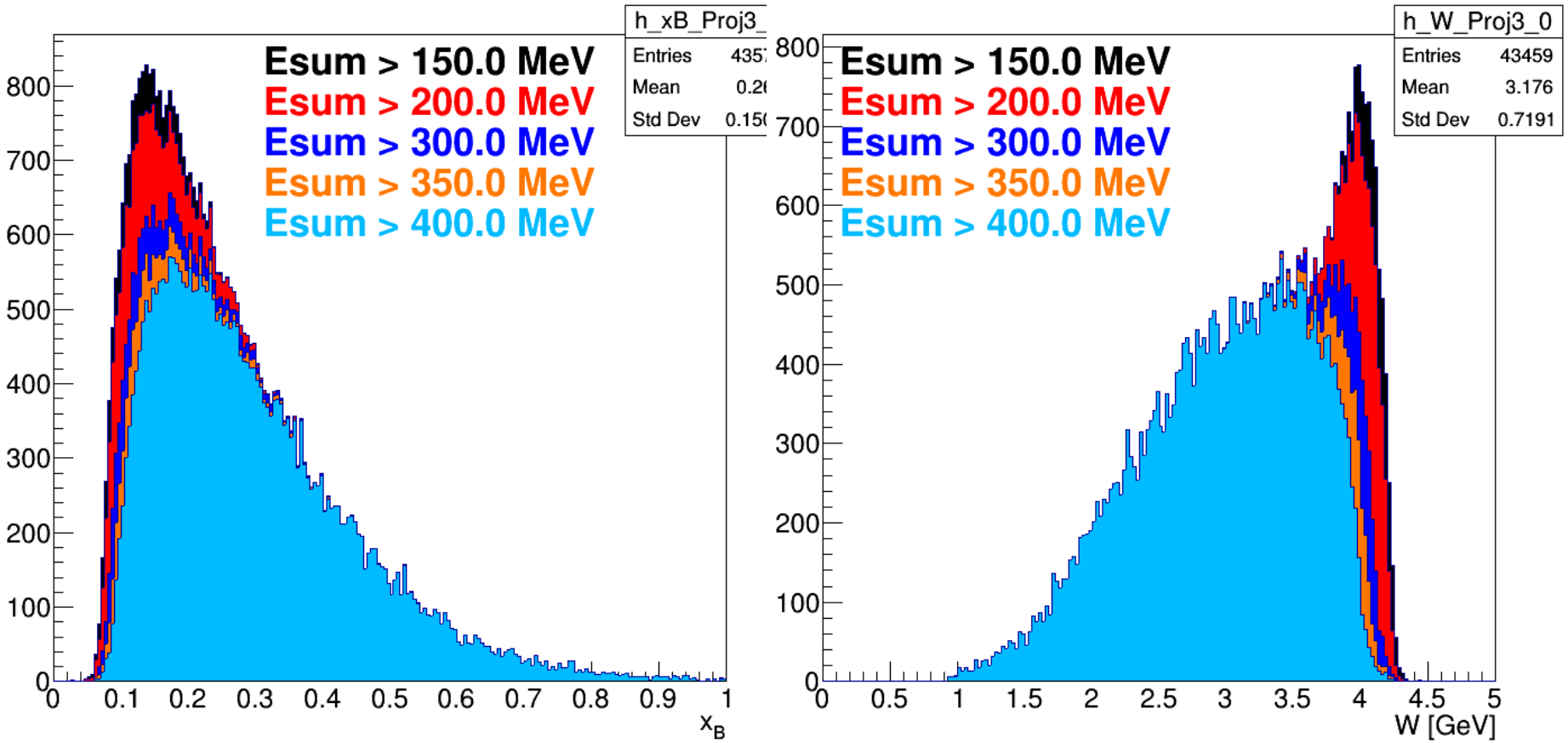
- Control the trigger rate: the higher the threshold the lower the rate
- Affect the detected electron momentum and reaction kinematic





PCAL+ECAL=300 MeV corresponds P_e~1.6 GeV when trigger is 100% effective.

PCAL+ECAL affects x_B and W distributions



PCAL+ECAL sum is important trigger parameter. It affects the kinematics, mostly W.

Trigger Slow Control

I= 55 nA

Menu

CLAS12 VTP Trigger 11/03/2018 03:56:02

Beam Current (nA): 55.0 2C21; 52.5 FCup

Electron Alarms: 1-6: NO_ALARM; 1-6 Tolerance: 0.40

Livetime: TS 95.4 %; Pulser 96.0 %

Totals (Hz): 2575393 15333

Bit	Description	Raw (Hz)	Prescaled (Hz)	Fraction (%)	Prescale	In Totals
0	Electron - OR of 1-6	4178	4177.6	26.82	0	
1	Sector 1	723	722.9		0	
2	Sector 2	585	585.1		0	
3	Sector 3	624	624.0		0	
4	Sector 4	759	758.8		0	
5	Sector 5	737	736.9		0	
6	Sector 6	761	760.8		0	
7	Elctron OR no DC >300MeV	6156	186.5	1.20	6	
8	PCALxECAL>10MeV	336639	164.3	1.05	12	
13	DCxFTOFxPCUxPCAL S1	74637	4.6	0.03	15	
14	DCxFTOFxPCUxPCAL S2	72307	4.4	0.03	15	
15	DCxFTOFxPCUxPCAL S3	76519	4.7	0.03	15	
16	DCxFTOFxPCUxPCAL S4	76734	4.7	0.03	15	
17	DCxFTOFxPCUxPCAL S5	76394	4.7	0.03	15	
18	DCxFTOFxPCUxPCAL S6	73737	4.5	0.03	15	
19	FTOFxPCALxECAL 1-4	1225	1225.1	7.86	0	
20	FTOFxPCALxECAL 2-5	1054	1054.4	6.77	0	
21	FTOFxPCALxECAL 3-6	1154	1154.2	7.41	0	
24	FTxHDxFTOFxPCALxCTOF	15909	482.1	3.09	6	
25	FTxHDx(FTOFxPCAL)^2	6441	6441.1	41.35	0	

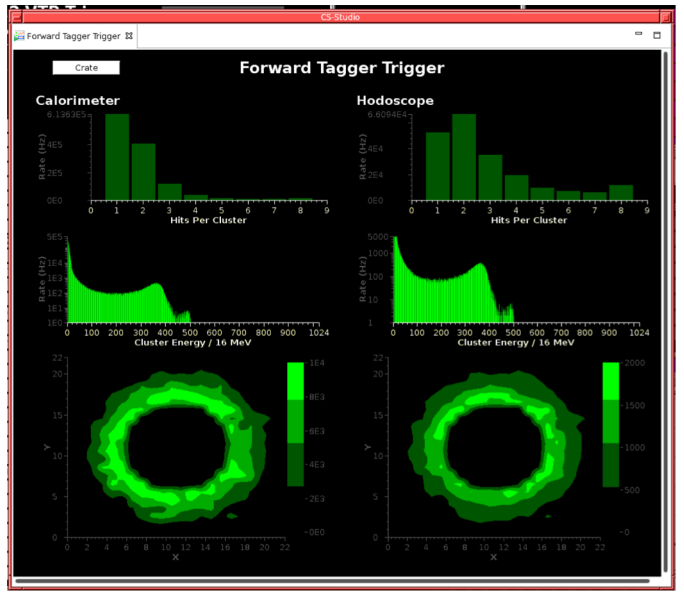
Electron trigger 4.2 kHz

Muon trigger 3.4 kHz

FT trigger 6.4 kHz

LT=95.4 %

Forward tagger trigger control



DAQ accept 15 kHz events @ 95% live time

RG-A: Hydrogen target

Trigger	Rate @ 55 nA Inbending	%
Electron	4.2 kHz	30%
Photoproduction	6.4 kHz	46%
“Muon”	3.4 kHz	24%
Total	14 kHz	100%

I= 55 nA
LT=95%

Trigger	Rate @ 40 nA Outbending	%
Electron	7.9 kHz	54%
Photoproduction	4.5 kHz	30%
“Muon”	2.4 kHz	16%
Total	15 kHz	100%

I=40nA
LT=95%

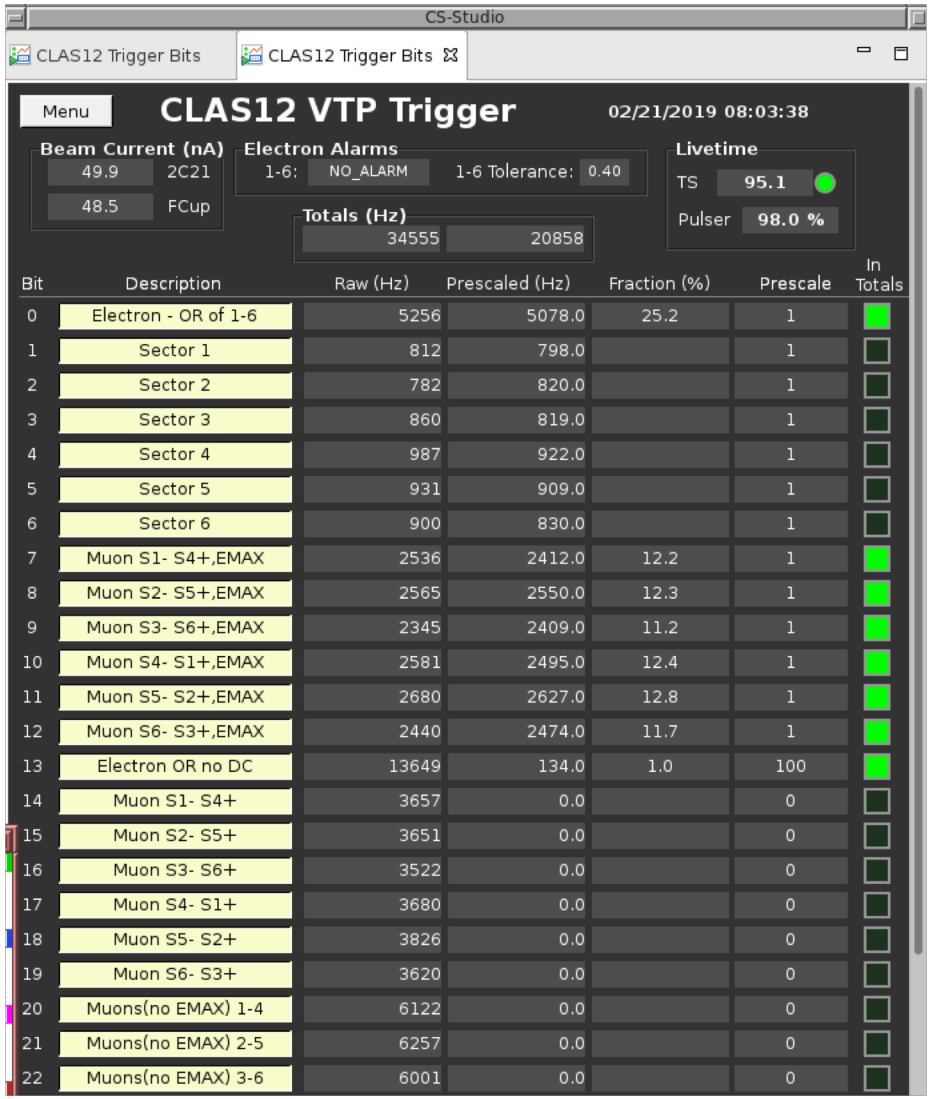
RG-B: Deuterium target

Trigger	Rate	Tr. Conditions
Electron	5.3 kHz	DC negative roads PCU space correlation
Muons	10 kHz	+/- Roads FTOF-PCALU space correlation

- Current = 50 nA
- Total rate = 15 kHz
- Life time = 95%

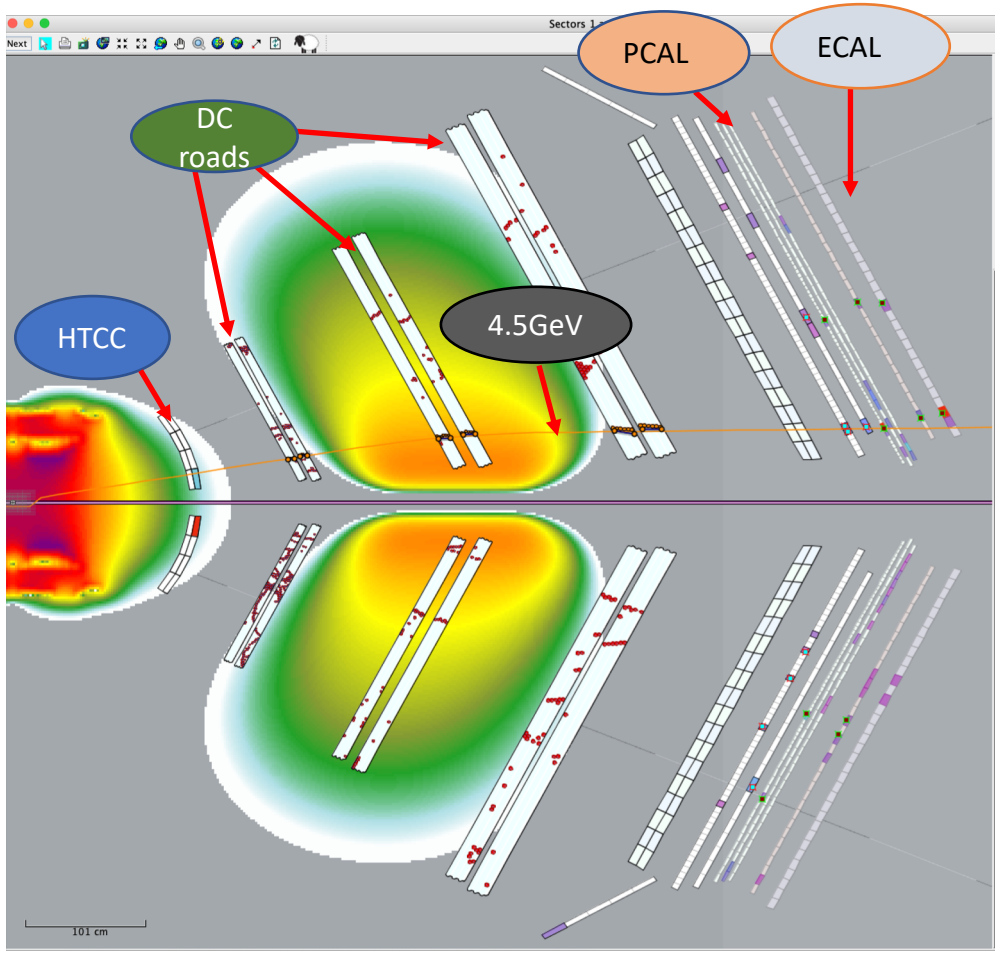
e^-

$\mu^{+/-}$



Bit	Description	Raw (Hz)	Prescaled (Hz)	Fraction (%)	Prescale	In Totals
0	Electron - OR of 1-6	5256	5078.0	25.2	1	
1	Sector 1	812	798.0		1	
2	Sector 2	782	820.0		1	
3	Sector 3	860	819.0		1	
4	Sector 4	987	922.0		1	
5	Sector 5	931	909.0		1	
6	Sector 6	900	830.0		1	
7	Muon S1- S4+,EMAX	2536	2412.0	12.2	1	
8	Muon S2- S5+,EMAX	2565	2550.0	12.3	1	
9	Muon S3- S6+,EMAX	2345	2409.0	11.2	1	
10	Muon S4- S1+,EMAX	2581	2495.0	12.4	1	
11	Muon S5- S2+,EMAX	2680	2627.0	12.8	1	
12	Muon S6- S3+,EMAX	2440	2474.0	11.7	1	
13	Electron OR no DC	13649	134.0	1.0	100	
14	Muon S1- S4+	3657	0.0		0	
15	Muon S2- S5+	3651	0.0		0	
16	Muon S3- S6+	3522	0.0		0	
17	Muon S4- S1+	3680	0.0		0	
18	Muon S5- S2+	3826	0.0		0	
19	Muon S6- S3+	3620	0.0		0	
20	Muons(no EMAX) 1-4	6122	0.0		0	
21	Muons(no EMAX) 2-5	6257	0.0		0	
22	Muons(no EMAX) 3-6	6001	0.0		0	

Electron Trigger RG-B

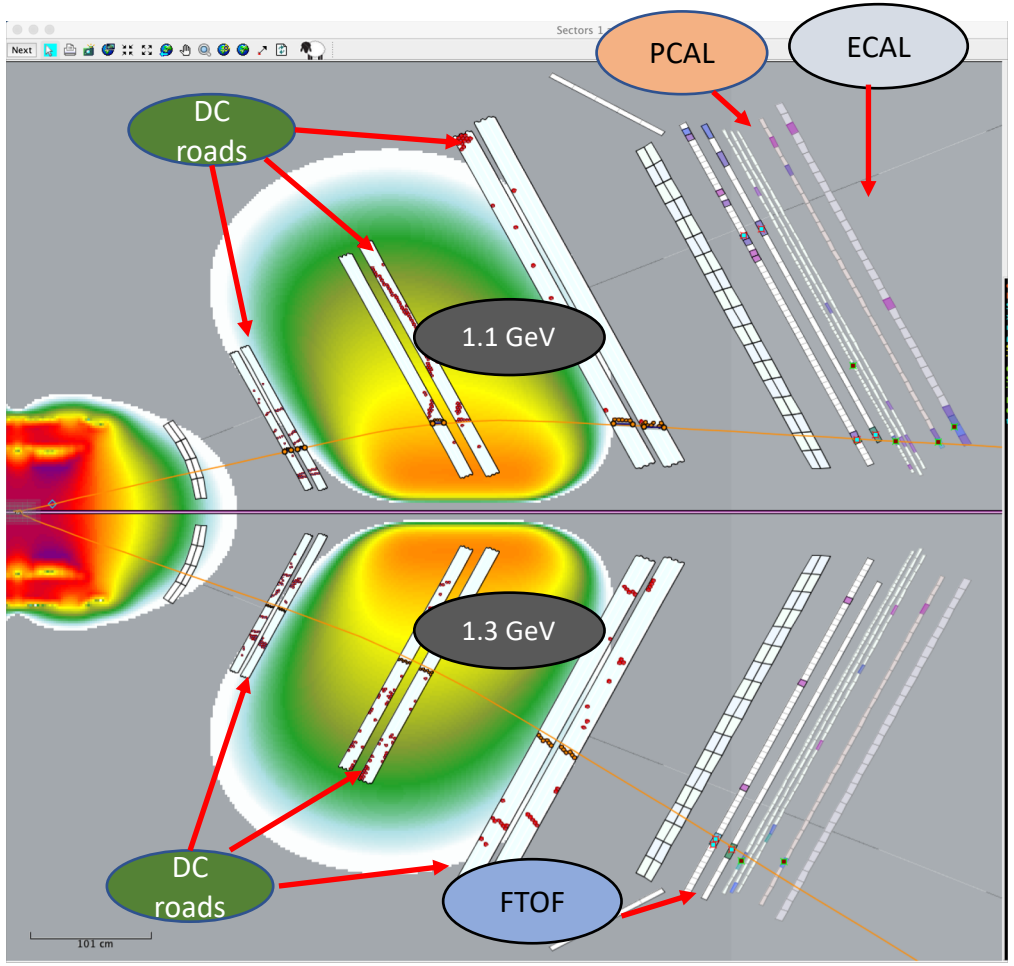


The trigger is 99% efficient for CLAS12 kinematics

Trigger conditions

Target	LD2
HTCC	> 2 phe
ECAL+PCAL	> 250-300 MeV
DC ROAD	Data based
Track-PCALU	Space correlation
Sign of the particle	Negative
Trigger purity	**54%** of events have PID=11 particle
Current	50 nA
Trigger Rate @50 nA	**5 kHz**

Muon trigger: RG-B



The trigger is 99% efficient for CLAS12 kinematics

Trigger conditions

Target	LD2
PCAL	> 10 MeV
ECAL	40<E<120 MeV
FTOF-PCALU	Space correlation
DC ROAD	GEMC based
Sign of the particle	Positive and Negative
Trigger purity	**28%** of events have 2 +/- TB tracks
Current	50 nA
Trigger Rate @50 nA	**10 kHz**

RG-K: Hydrogen target

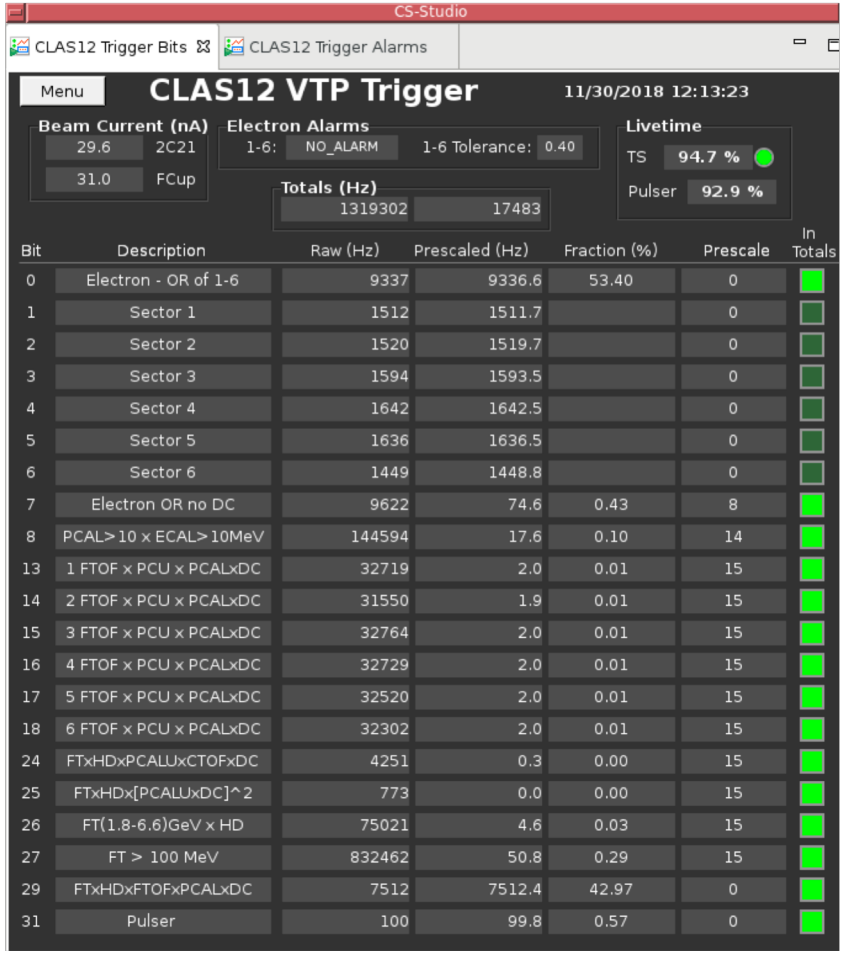
Only two triggers with zero prescale

- Electron trigger (outbending)

HTCC x (PCAL+ECAL) x DC segments (5/6)
DC on/DC off=0.97. So, DC-roads were not used.

- Forward tagger trigger (#29)

FT(1.8-6.6 GeV)x(FTOFxPCALU)xDC
We demand cluster in the FT with the energy between 1.8 and 6.6 GeV and at least one charge particle going in forward direction hitting PCAL and TOF.



Bit	Description	Raw (Hz)	Prescaled (Hz)	Fraction (%)	Prescale	In Totals
0	Electron - OR of 1-6	9337	9336.6	53.40	0	
1	Sector 1	1512	1511.7		0	
2	Sector 2	1520	1519.7		0	
3	Sector 3	1594	1593.5		0	
4	Sector 4	1642	1642.5		0	
5	Sector 5	1636	1636.5		0	
6	Sector 6	1449	1448.8		0	
7	Electron OR no DC	9622	74.6	0.43	8	
8	PCAL>10 x ECAL>10MeV	144594	17.6	0.10	14	
13	1 FTOF x PCU x PCALxDC	32719	2.0	0.01	15	
14	2 FTOF x PCU x PCALxDC	31550	1.9	0.01	15	
15	3 FTOF x PCU x PCALxDC	32764	2.0	0.01	15	
16	4 FTOF x PCU x PCALxDC	32729	2.0	0.01	15	
17	5 FTOF x PCU x PCALxDC	32520	2.0	0.01	15	
18	6 FTOF x PCU x PCALxDC	32302	2.0	0.01	15	
24	FTxHDxPCALUxCTOFxDC	4251	0.3	0.00	15	
25	FTxHDx[PCALUxDC]^2	773	0.0	0.00	15	
26	FT(1.8-6.6)GeV x HD	75021	4.6	0.03	15	
27	FT > 100 MeV	832462	50.8	0.29	15	
29	FTxHDxFTOFxPCALxDC	7512	7512.4	42.97	0	
31	Pulser	100	99.8	0.57	0	

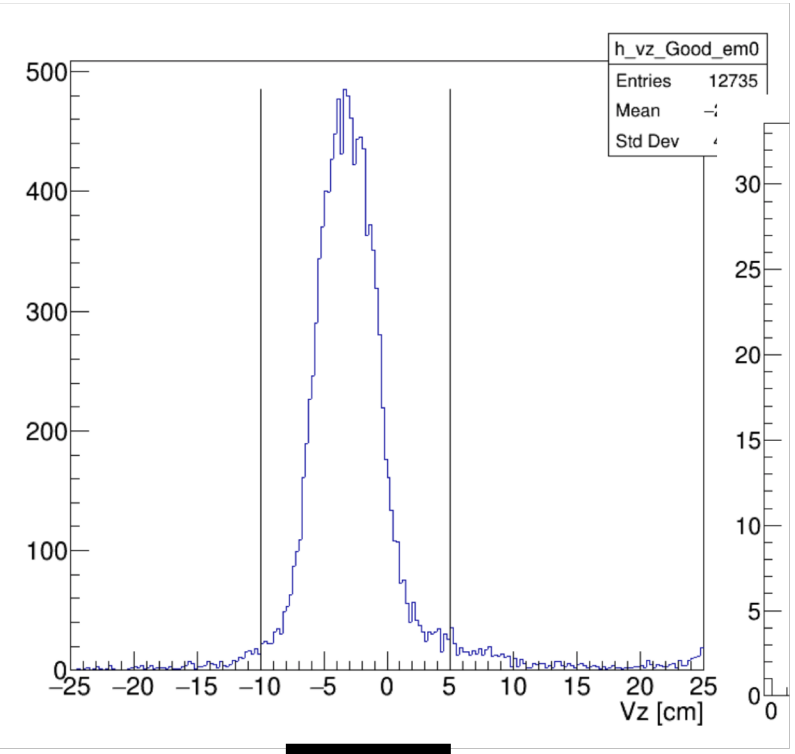
- Production current 30 nA
- Trigger rate total 17 kHz
  - Electron trigger 9.5 kHz
  - FTxHDx(one forward going particle) – 7.5 kHz
- Data rate 325 MB/s
- Live time 95%

Strategy of the Trigger Validation

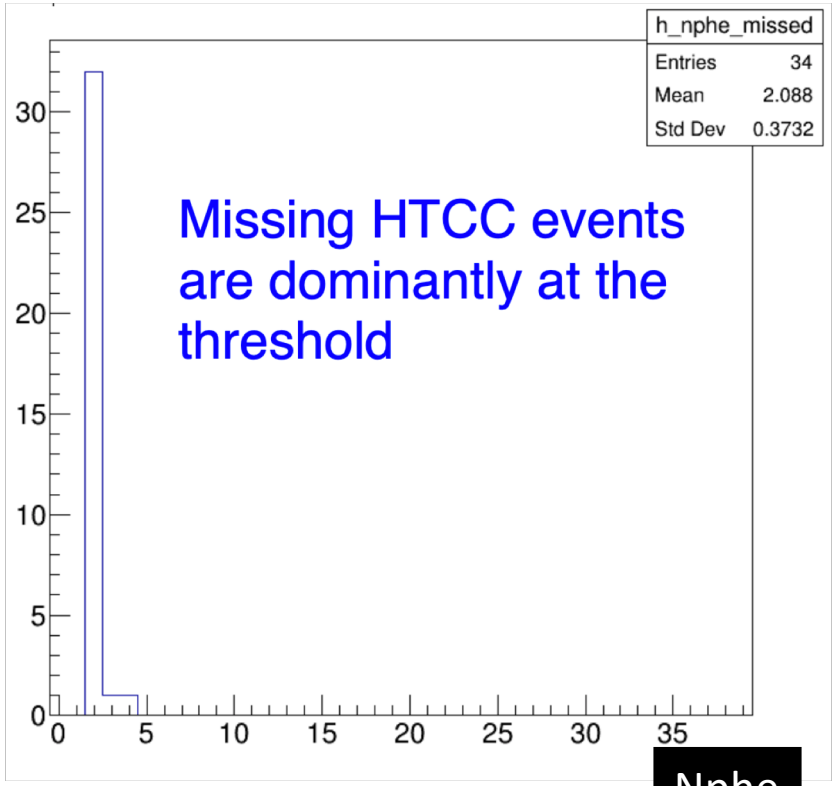
- Take random trigger run, usually with the same current as in production data taking. This is completely unbiased trigger.
- Cook data and *select the events of interest*
  - Electron, PID=11 with the fiducial volume cuts
  - Events with the tracks in the opposite sectors (for muons)
- Apply the trigger cuts to the selected events: HTCC, PCAL, ECAL, FTOF, for example: HTCC>2phe, PCAL+ECAL>300 MeV, MIP signal in calorimeters for muons…
- Check the trigger bit. If it is ON -> the trigger is effective
- Electron trigger, Forward tagger trigger and ”muon” trigger were validated in such a way.
- The trigger efficiency for these selected events and different reactions was found to be very close to 100%.

Electron Trigger Validation

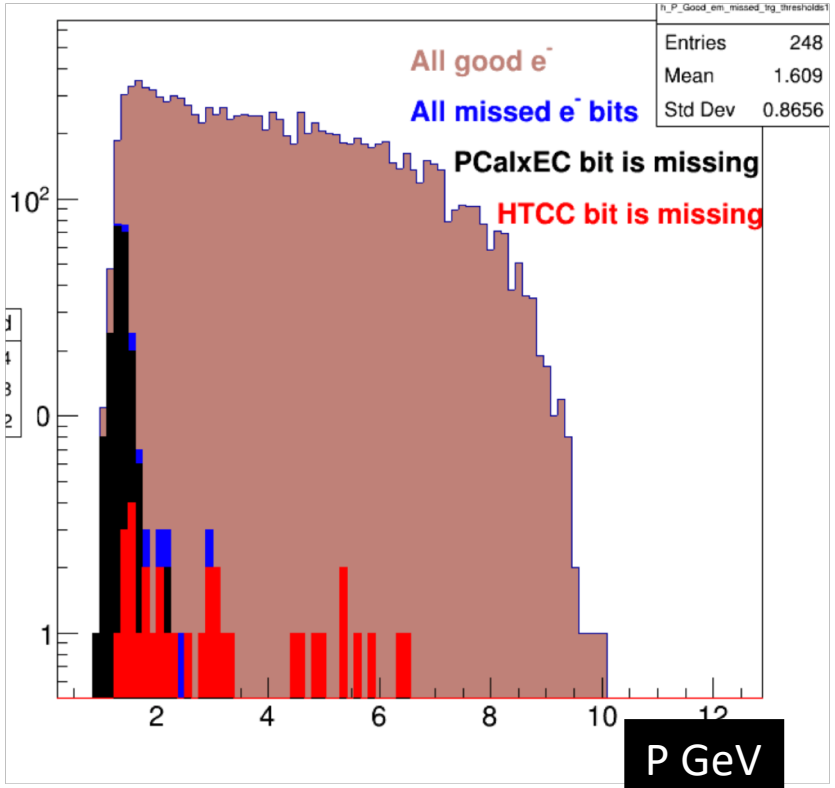
- Random trigger
- Select electron in the Forward direction
- HTCC and PCALxECAL are in the same sector
- Apply vertex cut, HTCC and PCALxECAL cuts



VZ cut

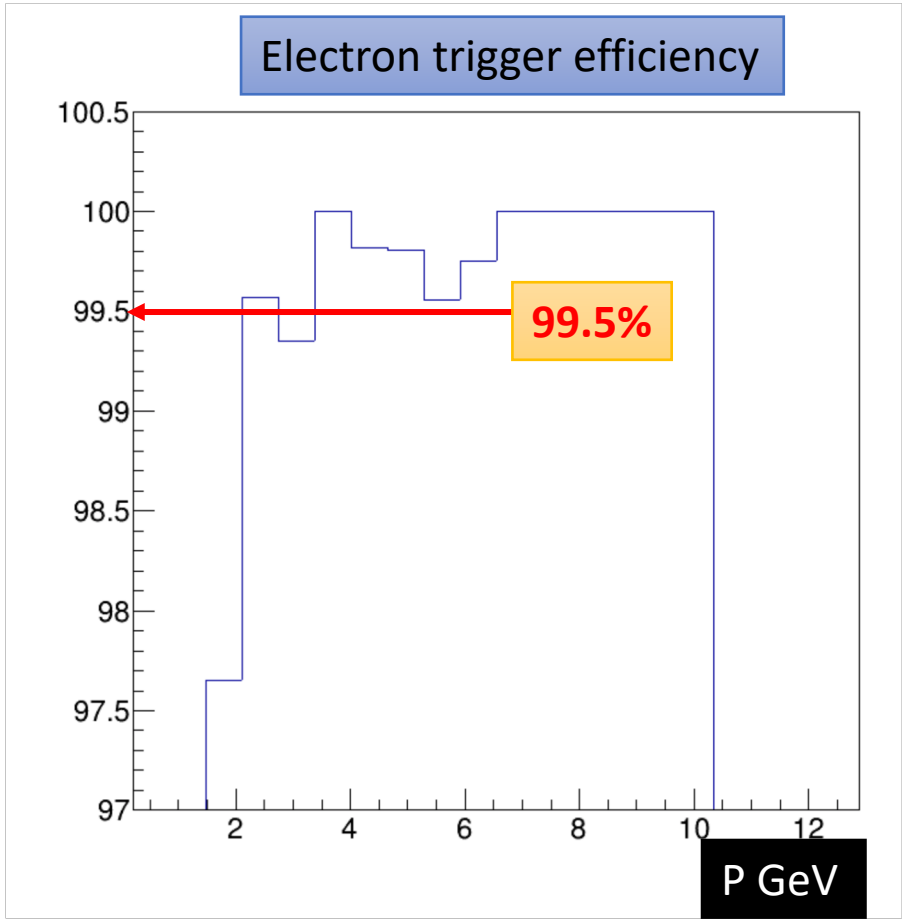


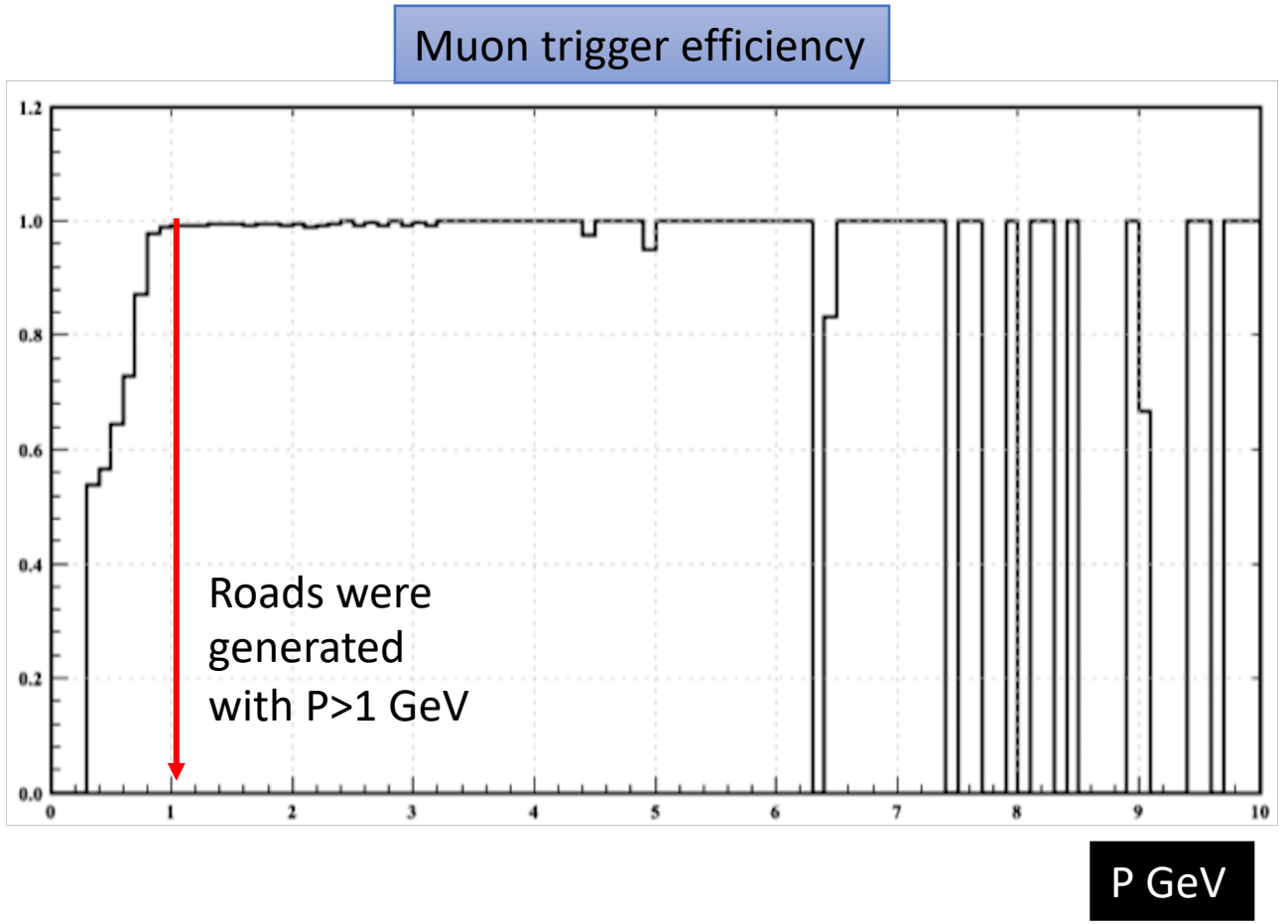
Nphe



P GeV

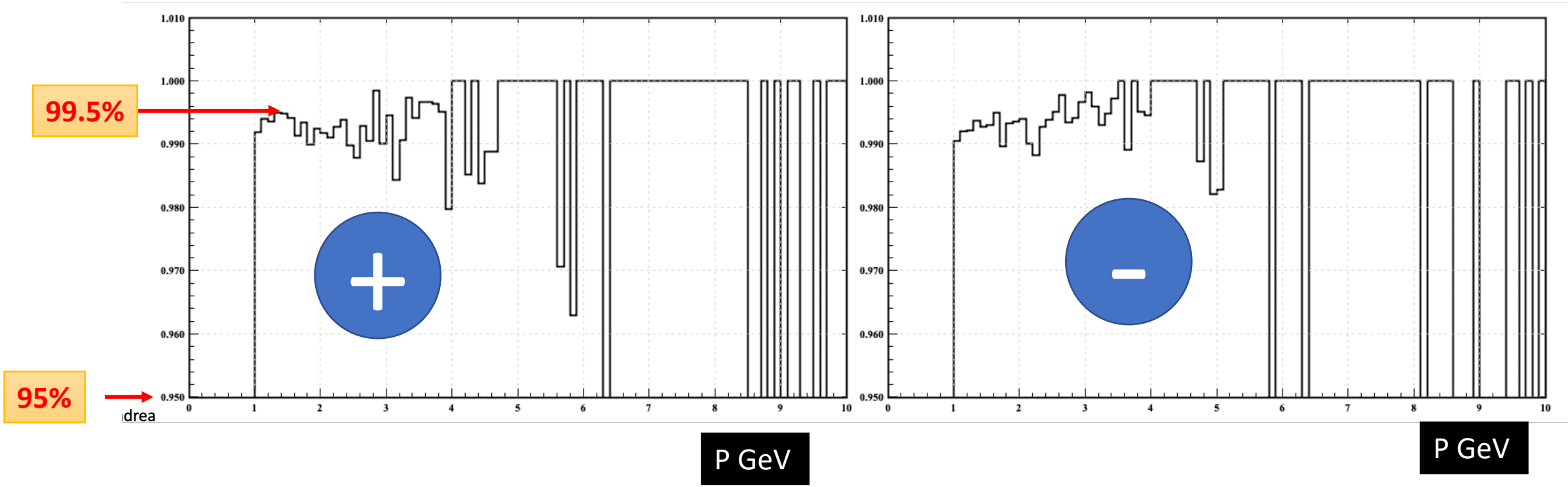
Trigger Efficiency





- The DC-roads and space matching between track and PCALU were found to be 100% efficient

Muon trigger efficiency for positive and negative particles



Muon trigger efficiency more than 99%. It includes DC positive and negative roads, matching of track with PCALU

Trigger Improvements

- Data based road maps with better resolution, 80K DC-roads in the dictionary
- Track – PCALU space matching. HTCC is the next in the line to be matched with track
- Positive and negative particles in opposite sectors in muon trigger

DC roads and matching with PCALU	**2.5** electron trigger reduction rate
Electron trigger purity (inbending)	**54%** of events have time based track and reconstructed as PID=11 particle (electron)
Electron trigger purity (outbending)	**72%** even without DC roads
Muon trigger purity (any particles)	**46%** of events have two time-based tracks in opposite sectors
Muon trigger purity (+/-)	**28%** of events have one positive and one negative track in opposite sectors
Trigger efficiency	**> 99%** for all types of trigger

Conclusion

- The CLAS12 trigger is fully operational
- The trigger requirements of all three groups were satisfied
- Completed first part of data taking for Run groups A and K
- Run group B is taking production data
- Three physical triggers were developed:
  - Electron trigger
  - Forward tagger trigger
  - Muon trigger
- DC road trigger together with geometrical match with PCALU give very good result
- All triggers were validated and demonstrated high (>99%) efficiency
- The electron trigger purity during the last run was 54% (inbending) and 72% (outbending)
- Muon trigger has 28% trigger purity for pair of positive and negative particles
- We looking forward to discuss the future experiments in HALL-B with spokespersons