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On-line trigger study for CLAS12

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Abstract

This document describes the study of CLAS trigger system efficiency based on experimental data for high energy electron beam run on CLAS detector. There are about 90% of events without electron candidate passing level 1 trigger for this energy. The main goal is to study a possibility to reduce the number of events without electron candidate on the trigger level and do not loose events with electron at the same time. New components were included into the trigger: the hit information of outer detectors (EC,CC and SC) and the hit information for tracking detectors (DC region 1,2 and 3). New fast electron reconstruction procedure on the trigger level using this new hit information is proposed. The rejection for all events on the level of 50% is achieved. The electron candidates have passed this procedure on the level of 99.5%. Achieved results will be used in CLAS12 trigger system design.

1 Introduction

The main goal of the electron trigger is to take events with electron with maximum efficiency and reduce the number of events without electron as much as possible at the same time. The possibility of the additional trigger conditions to achieve this goal was studied.

The hit multiplicity is increased with the beam energy. And the number of events without electron is also increased when the some thresholds on the electro-magnetic calorimeter and Cerenkov counter are used as a trigger. One way to reduce the number of "false" events is to apply the higher threshold on the Cerenkov counter. This way one can expect to decrease the efficiency of the detector due to loose events with electrons which have a small signal in the Cerenkov counter. We propose the another way to reduce the number of events without electrons. The idea is to use hit (cluster) information from different parts of the CLAS detector to reject the events without electron candidate. It will be shown that it is possible to achieve at least 50 % of rejection.

We think that additional hit-cluster matching at the level of trigger can be useful for new CLAS 12 detector. It will make the trigger more flexible and help to keep the high efficiency for all electrons including electrons which produce a small signal in the Cerenkov counter.

At the end of this paper we study how the Cerenkov counter threshold at the level of 2 photo-electrons can reduce the number of events without electron candidate. It is very effective trigger tool, but some amount of electrons with signal in Cerenkov counter less than 2 photo-electron will be lost in this case.

2 Data sample and procedure

The electron beam run *e1_6a* was used for the study. The measurements were performed with the CEBAF Large Acceptance Spectrometer (CLAS) [1] in Hall B at the Thomas Jefferson National Accelerator Facility. The beam energy was 5.76959 GeV. The beam current was about 10 nA. The Torus current was 3375.77 A and the mini-torus 6000 A. The liquid hydrogen target was used for this run. One raw file with name clas_030735.A00 was used for our studies. Due to high energy of the beam the hit multiplicity was very high. There were a lot of triggers without electron candidate. To obtain electron candidate events we were using standard version of CLAS software (*RECSIS* [2]), extracting final state information from EVNT bank.

The RECSIS reconstruction provided three types of event with respect to EVNT bank in this e1_6a run:

- No EVNT bank at all (about 20% of all statistics)
- id(1) is equal 0 (about 70% of all statistics)
- id(1) is equal 11 ($ID = 11$), which was our reference as electron candidate (about 10% of all statistics)

We have used the standard for this run init.tcl file which is shown in the appendix **A**.

We considered $ID = 11$ events as "good" events which have to pass our trigger selection criteria. All events with $ID \neq 11$ or without EVNT bank were considered as "bad" events so our procedure was set to cut them off.

The main goal of our study is to reduce the number of events without electron candidate and keep as much as possible the number of events with electron candidate. The acceptable level of electron candidate event reduction was set to less than one present.

We found that for this run very often first reconstructed particle in EVNT bank is not in sector where level1 hardware trigger bit was set. Because of nature of CLAS level1 hardware trigger in case if two particles in different sectors passed trigger criteria, most likely only one of them will be latched and reported as trigger bit. The distribution of the number of level1-triggers are shown in Fig. 1. One can see that there were about 95%

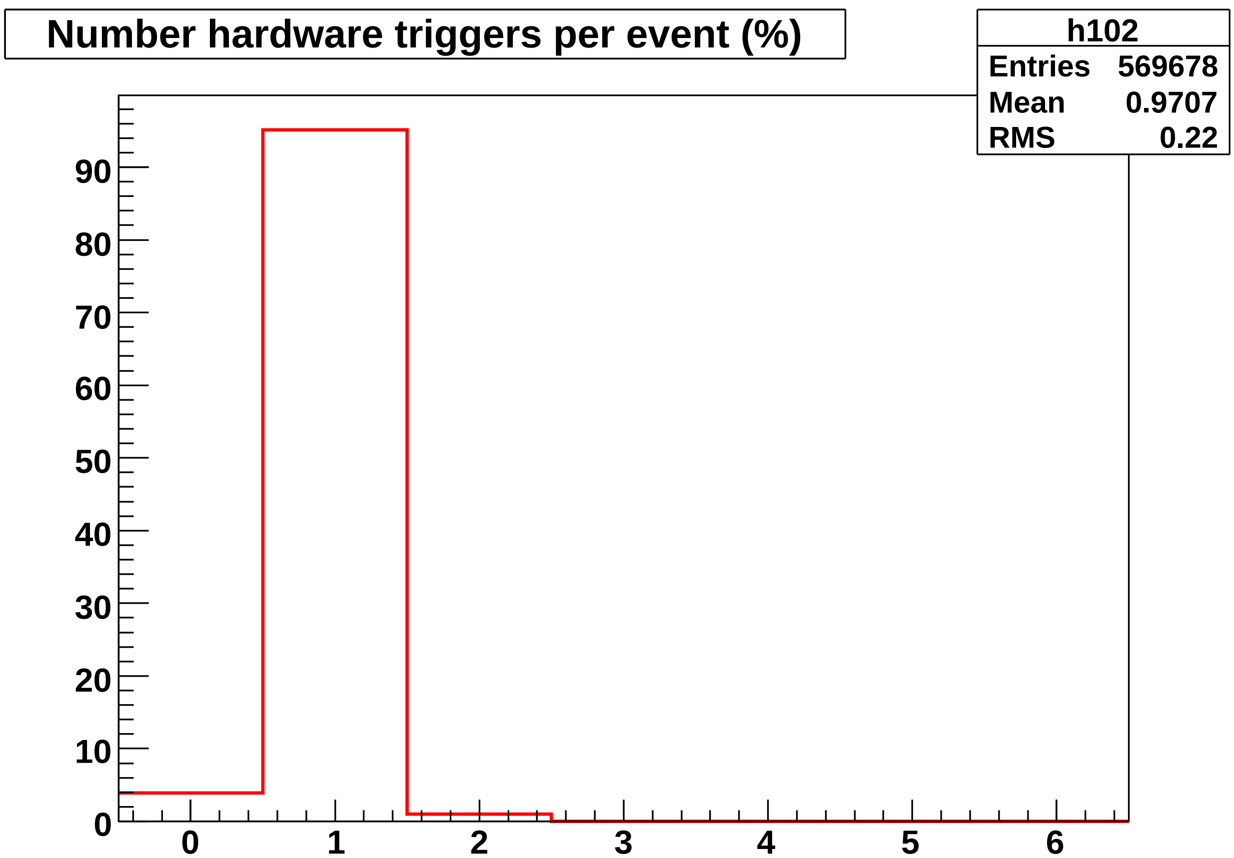

Figure 1: The number of hardware triggers (level1-triggers) per event.

events with one trigger bit and about 4% of events without triggers and only about 1% events with two trigger bits. In reality the number of two-sector events are much higher, as we see from off-line analysis. To correct this problem we introduced the software trigger latch. Our software trigger latch was constructed as on-line level1 trigger latch plus bit in the sector where first particle in EVNT bank was found, if EVNT bank existed for that event. The number of software trigger bits per event is shown in Fig. 2. It clearly seen

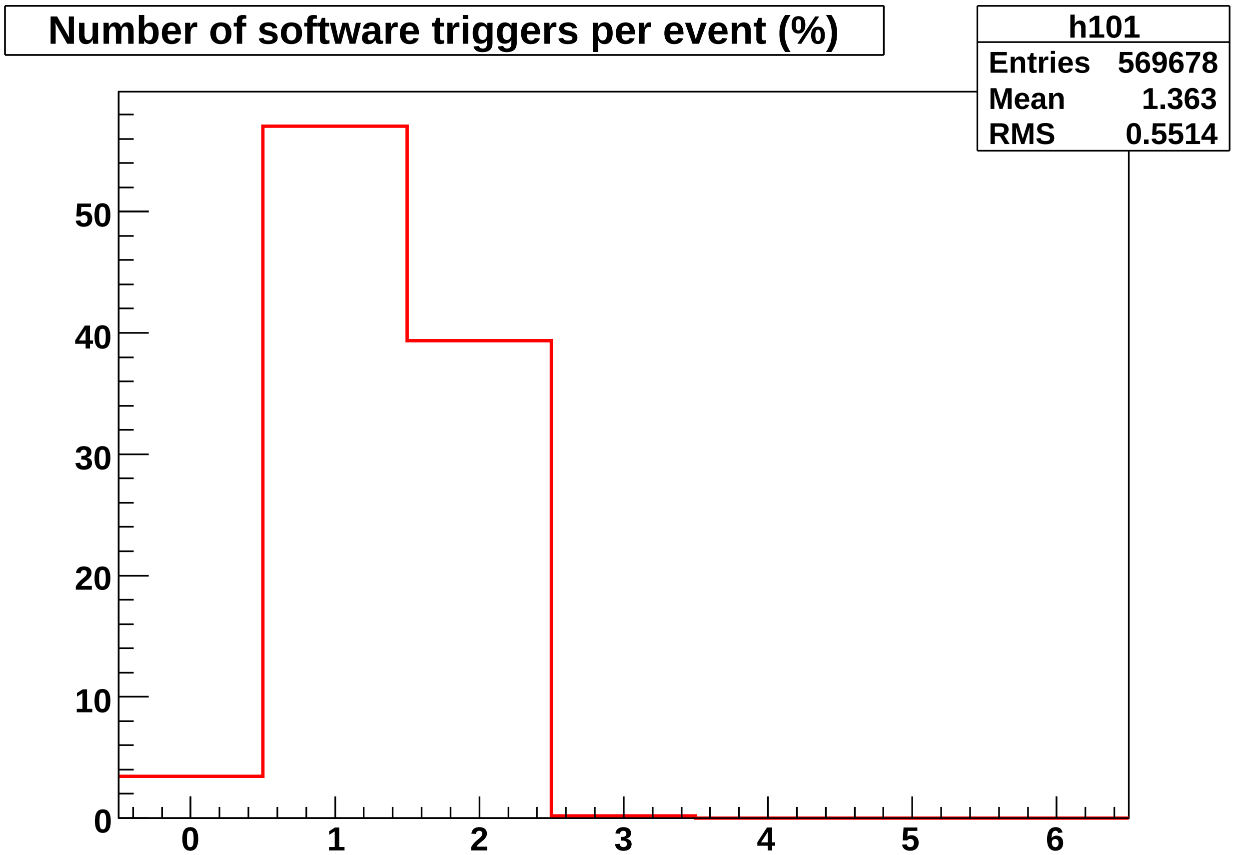

Figure 2: The number of our software triggers per event.

that there are about 60% of events with single-sector trigger and about 40% of events with two-sector triggers. There are still about 4% miss-bit events and is less than 1% events with 3 software triggers. Missing trigger bits can be related to other trigger bits (higher than 6).

3 Analysis and results

There are two groups of detectors which we are using to reject false trigger events. First are the "outer" detectors which are EC, CC and CC [3], [4], [5]. And the second are "tracking" detectors which is three regions of CLAS DC [6].

3.1 Outer detectors

The so-called fast electron identification is based on eid0 code [7]. It uses outer detectors only. Since Drift Chamber information is not in use the decision can be made quite fast.

The idea is the geometrical matching between outer detectors. The dependency of SC paddle number versus CC cluster number for electron candidate events is shown on Fig. 3. We have fitted the enhancement on this figure by second order polynomial function. The same procedure was performed for U-paddle number versus CC cluster number (see Fig. 4) and for the dependency of SC paddle number versus U-paddle number of EC (see Fig. 5).

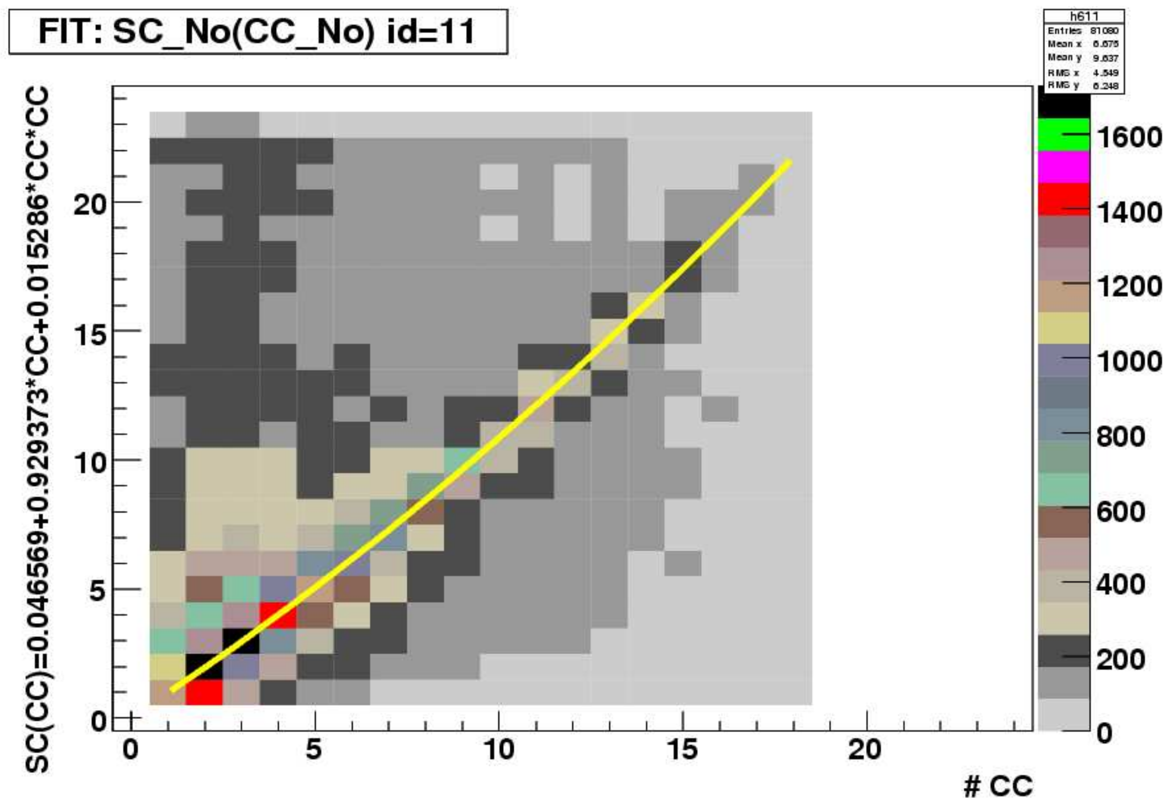

Figure 3: The result of fit for SC vs CC.

Using these fit functions we can construct three independent differences:

- a1-distribution of $|CC - SC|$ (see Fig. 6)
- a2-distribution of $|CC - EC|$ (see Fig. 7)
- a3-distribution of $|SC - EC|$ (see Fig. 8)

Now we can do the cut on the difference between the fit function and measured hit in outer detectors. We decided to do cut using mean value and the standard deviation (RMS) for these differences. The event was considered as accepted if at least one of a1, a2 and a3 values deviates from the mean value by less then one or two standard deviations.

The results of reduction are presented on Tab. 1 and Tab. 2. Table 1 shows the result when deviation in at least one of parameters a1,a2,a3 is less than two standard deviations

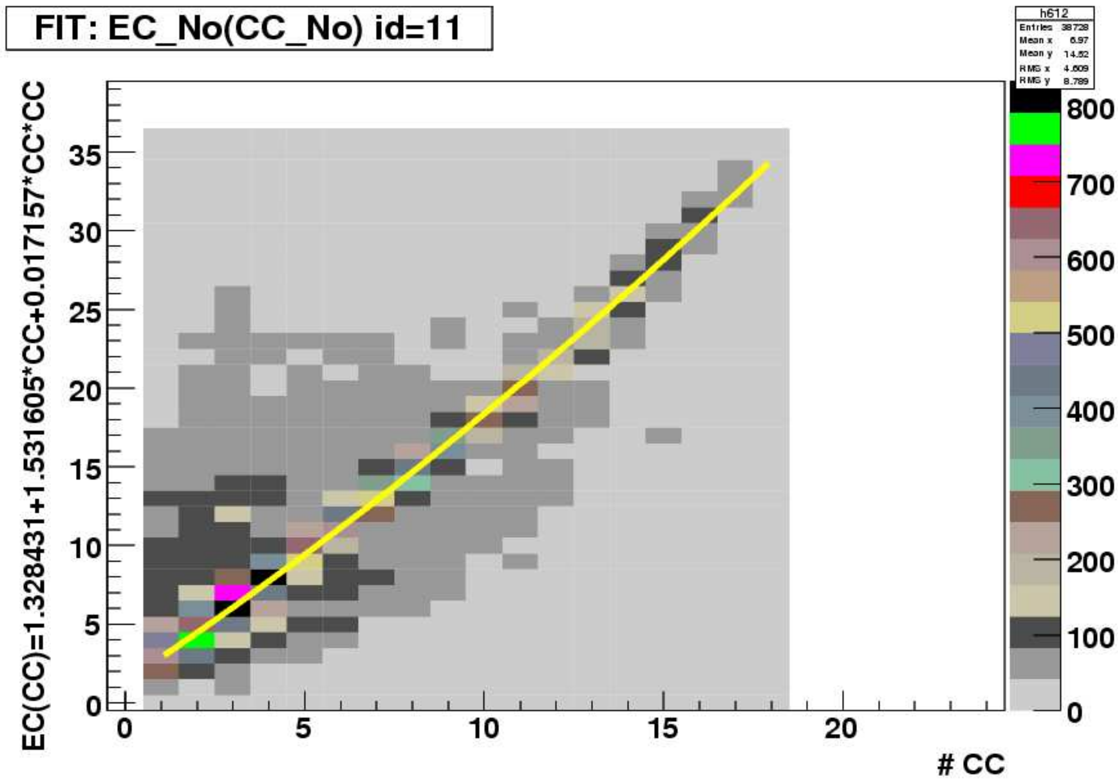

Figure 4: The result of fit for EC vs CC.

Table 1: The efficiency of fast reconstruction. Outer condition(ID0-0):$|Fit1(CC)-SC| < Mean + 2 \cdot RMS$ or $|Fit2(CC) - EC| < Mean + 2 \cdot RMS$ or $|Fit3(EC) - SC| < Mean + 2 \cdot RMS$. Tracking condition(TRK0): one track with charge -1 without any matching. Both outer and tracking (ID0-0+TRK0)

	ID0-0	TRK0	ID0-0+TRK0
Total	95.64%	77.19%	64.57%
Id=0 or 11	99.37%	90.86%	74.37%
Id=11	99.97%	99.91%	99.87%

(column "ID0-0"), Table 2 when it is less than one standard deviation (column "ID0-1"). It seems that this procedure did not cut false trigger events on significant level, but almost all "good" events passed. We lose events with electron candidate (row "Id=11") on the maximum level of about 0.2%. If we apply more strict condition, say all three cuts together, we will lose about 10% of events with id=11. So we definitely should study tracking detector hit information.

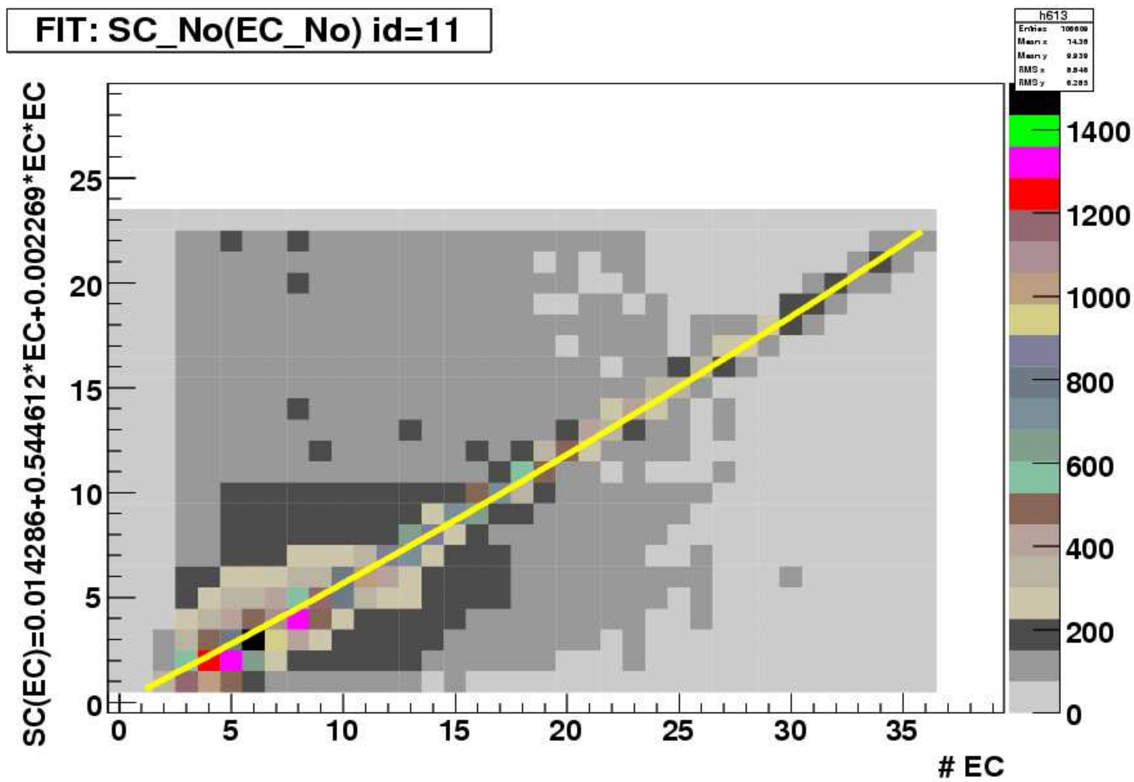

Figure 5: The result of fit for SC vs EC.

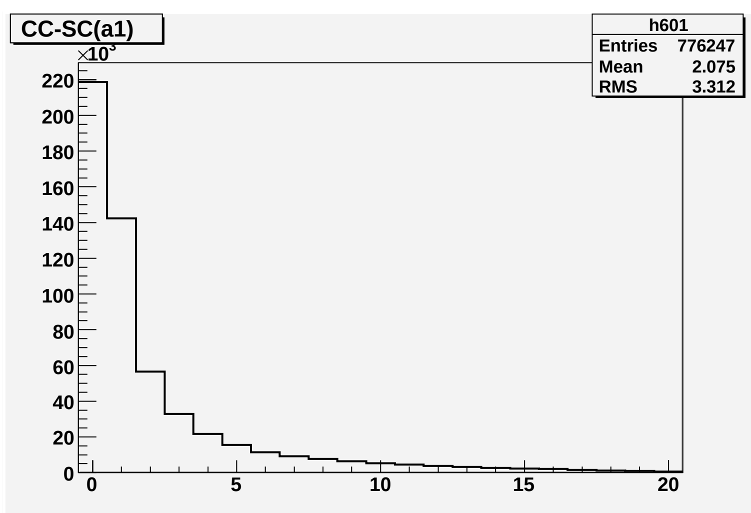

Figure 6: Distribution of $|CC - SC|$.

3.2 Tracking detectors

The fast track finder which extracts tracks from the special dictionary was used to extract information from tracking detectors. It is based on fast online reconstruction code. Fol-

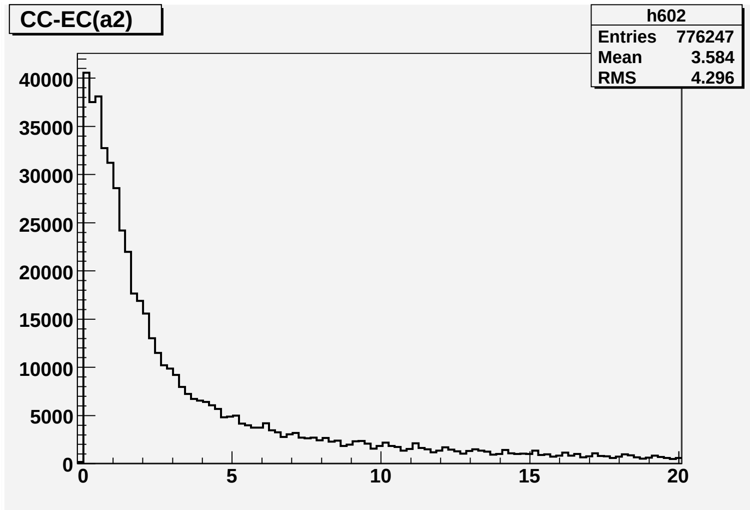

Figure 7: Distribution of $|CC - EC|$.

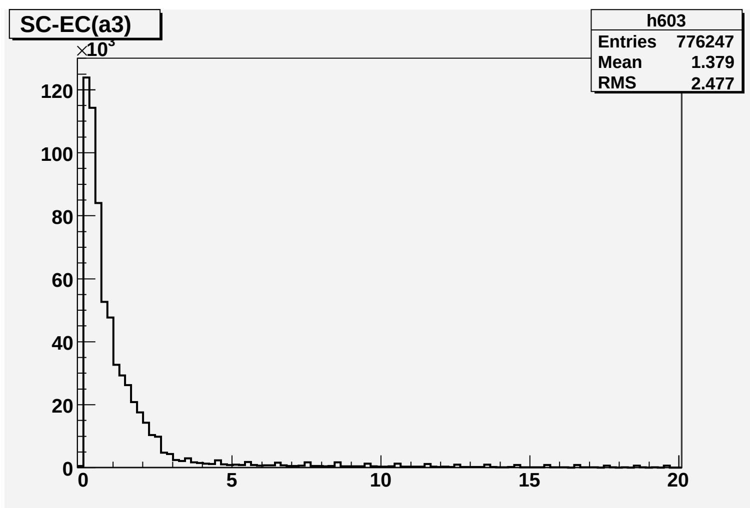

Figure 8: Distribution of $|SC - EC|$.

Table 2: The efficiency of fast reconstruction. Outer condition(ID0-1):$|Fit1(CC) - SC| < Mean + 1 \cdot RMS$ or $|Fit2(CC) - EC| < Mean + 1 \cdot RMS$ or $|Fit3(EC) - SC| < Mean + 1 \cdot RMS$. Tracking condition(TRK1): one track with charge -1 with at least matching to one of SC or EC paddle. Both outer and tracking (ID0-1+TRK1)

	ID0-1	TRK1	Id0-1+TRK1
Total	94.59%	55.30%	49.53%
Id=0 or 11	98.64%	65.89%	58.42%
Id=11	99.87%	99.66%	99.49%

lowing requirements were changed to make sure we are not loosing any reasonable electron track candidates:

1. minimum 3 hits were allowed in superlayers-based segment, except region one stereo where 2 hits were allowed
2. 5 out of 6 superlayers were considered as a track
3. "loose" dictionary was used: road finding procedure did not require exact match with the road dictionary, roads with 2 cell difference in region one and region two were considered acceptable.

It should be mentioned that every road in a dictionary contains prediction for the SC and the EC detector components it suppose to hit. That information was used in our studies to match tracking and outer detectors. It is important to say here that we use hit-cluster information from outer detector to make matching of track with SC and EC paddles.

3.3 Results

The results of reduction are presented on Tab. 1 for at least one track with charge -1 in triggered sector (column "TRK0") and on Tab. 2 for at least one track with charge -1 in triggered sector and match with SC or EC u-paddle which were found in outer detector (column "TRK1"). One can see that fast track reduction procedure is more effective than outer detector reduction. We achieved about 50% total event reduction with only a 0.5% of electron candidate events lost.

Still we lost some small value (less than 1%) of events from electron candidates. There are several reasons why we lost these events. CED plots for typical events with electron candidates which we lost can be found in the Appendix **B**:

- The uncompleted road dictionary to some class of tracks (see Fig. 13)
- The exceeding of the limit of the track candidate number (see Fig. 14)
- No matching between outer detectors (see Fig. 15)
- No SC hits and CC hits are not in right position (see Fig. 16)
- No matching between track and outer detectors (see Fig. 17). And this event looks suspicious.

4 Cerenkov counter amplitude

We did additional study of the influence of the Cerenkov counter amplitude signal on the electron candidate events rejection. The energy deposited in EC divided on the particle momentum which is defined by DC track reconstruction in *RECSIS* is shown in Fig. 9. The events with id(1) equal 0 or 11 are shown by white histogram. The electron candidate events are shown by filled histogram in this figure. It is evident that electron candidate events consist not only from electrons. They have some addition (possible pions) on the left and may be under the peak at 0.3 value in Fig. 9. The number of photoelectrons in Cerenkov counter versus the energy deposited in EC per the particle momentum for electron candidate events which was passed our "ID0-1 + TRK1" criteria is shown in top panel of Fig. 10. One can see two regions one this plot. First region corresponds to real electrons and is located around and above $E_{EC}/P_{DC} \sim 0.3$. Those events have a broad distribution of the number of photo-electrons in CC. Second region corresponds mainly to pions. They have almost fixed number of photo-electrons in CC with mean value around 1.

We introduced the cut on Cerenkov cluster total ADC value (CC_{ADC}). CC_{ADC} is calculated for whole cluster which was found in the sector where corresponding software latch bit was set. If there were two or more clusters in CC we applied the cut on both (all) clusters. If one of CC_{ADC} is greater than 400 (in our case it is about two photoelectrons) such event was accepted. The number of photoelectrons in Cerenkov versus the energy deposited in EC per the particle momentum with cut on $CC_{ADC} > 400[ADCchannels]$ is shown in bottom panel of Fig. 10. One can see that such cut rejects most of non-electron events. The value $CC_{ADC} = 400[ADCchannels]$ is approximately corresponds to two photo-electrons in Cerenkov counter. There are about 2% of events under two

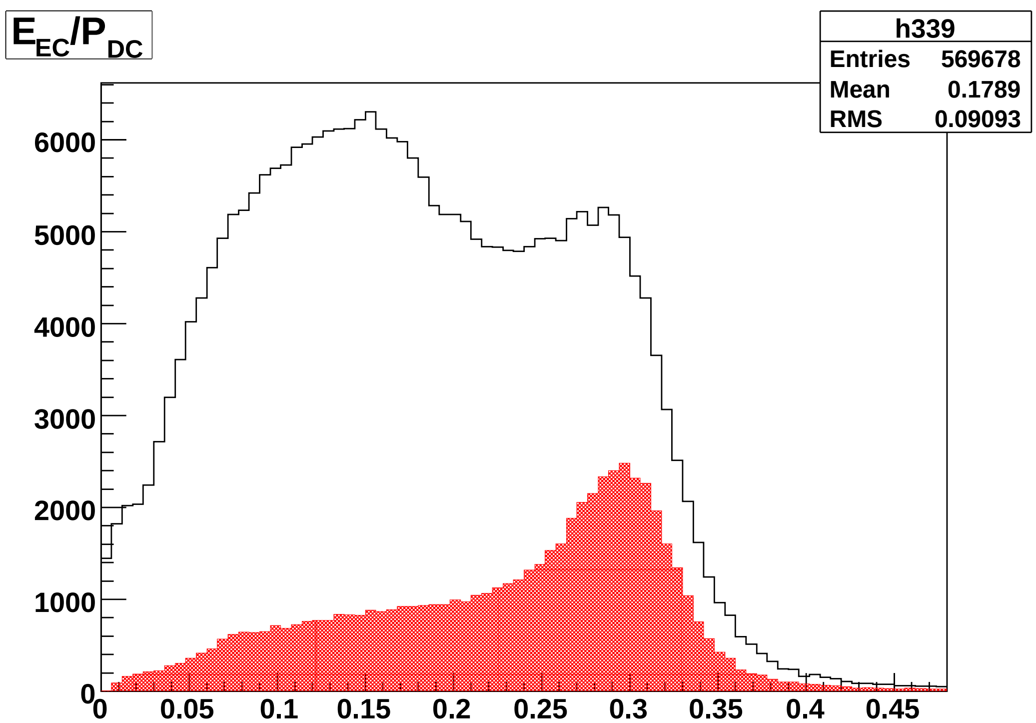

Figure 9: The energy deposited in EC divided on the particle momentum which is defined by DC track reconstruction in $RECSIS$. The events with id(1) equal 0 or 11 are shown by white histogram. The electron candidate events are shown by filled histogram.

photo-electron level due to the fact that the number of CC clusters per event is about 1.2. We applied the same cut $CC_{ADC} > 400[ADCchannels]$ to all events. The number of photoelectrons in Cerenkov counter versus the energy deposited in EC divided by the particle momentum without this cut is shown in the top panel of Fig. 11 and with this cut is shown in bottom panel of Fig. 11.

Most events below $CC_{ADC} = 400[ADCchannels]$ are not electrons. This cut reduces whole statistics by factor 4.4. The mean value of the photo-electrons in CLAS Cerenkov counter in the effective region, defined by fiducial cut, is about eight [8]. So far, the cut on the level of two photo-electrons can't reduce the number of real electrons significantly. It means that implementing such cut to the level 1 trigger would be very useful for high energy runs.

5 Summary

We have studied CLAS electron run at 5.7 GeV energy. There are about 90% of events without electron candidate passing level 1 trigger for this energy.

The feasibility of reduction of the events without electron candidate on the level 1 of trigger is shown.

We proposed the new and fast trigger procedure which uses hit information from outer detectors (EC,CC and SC) and hit information from tracking detectors (DC region 1, 2 and 3).

The rejection factor for all events on the level of 50% is achieved. The electron candidates have passed this procedure on the level 99.5%.

Additional study was performed for the rejection based on Cerenkov detector different thresholds. It was shown that higher threshold on the CLAS Cerenkov counter may be very useful for high energy runs. However high CC threshold was not used by CLAS because of possibility of electron losses.

Developed approach may be helpful for CLAS12 detector at 12 GeV where we expect very high multiplicity. More other detectors will be involved (two Cerenkov counters, two calorimeters and two TOFs). So outer detector-based trigger will be even more effective then it is for CLAS detector.

6 Acknowledgments

We would like to express our special thanks to all CLAS collaborators who made comments and suggestions for this study.

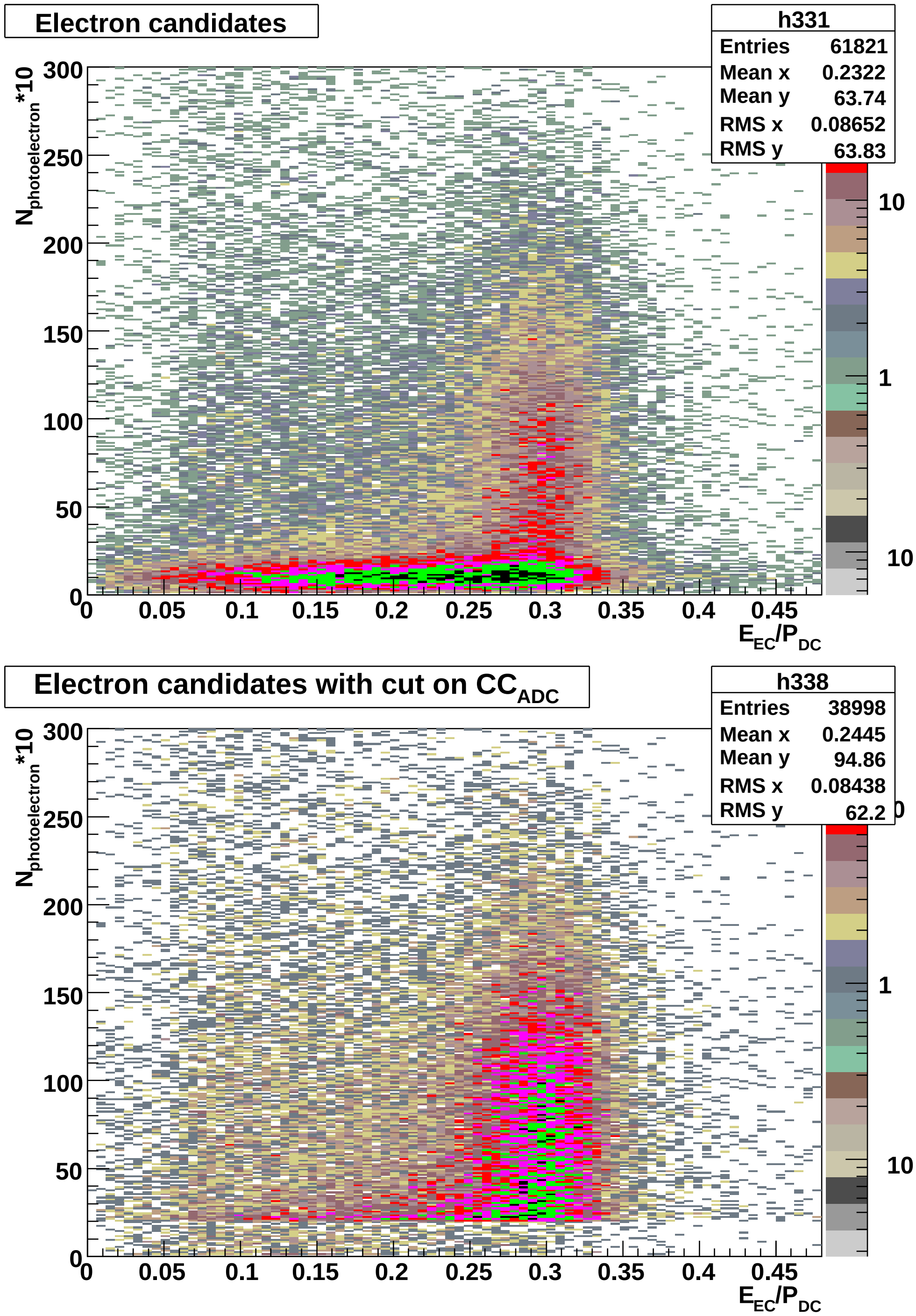

Figure 10: The number of photo-electrons in Cerenkov versus the energy deposited in EC per the particle momentum. Top panel: The events with id(1)=11 are presented. Bottom panel:The events with id(1)=11 and with cut on $CC_{ADC} > 400[ADCchannels]$ are presented

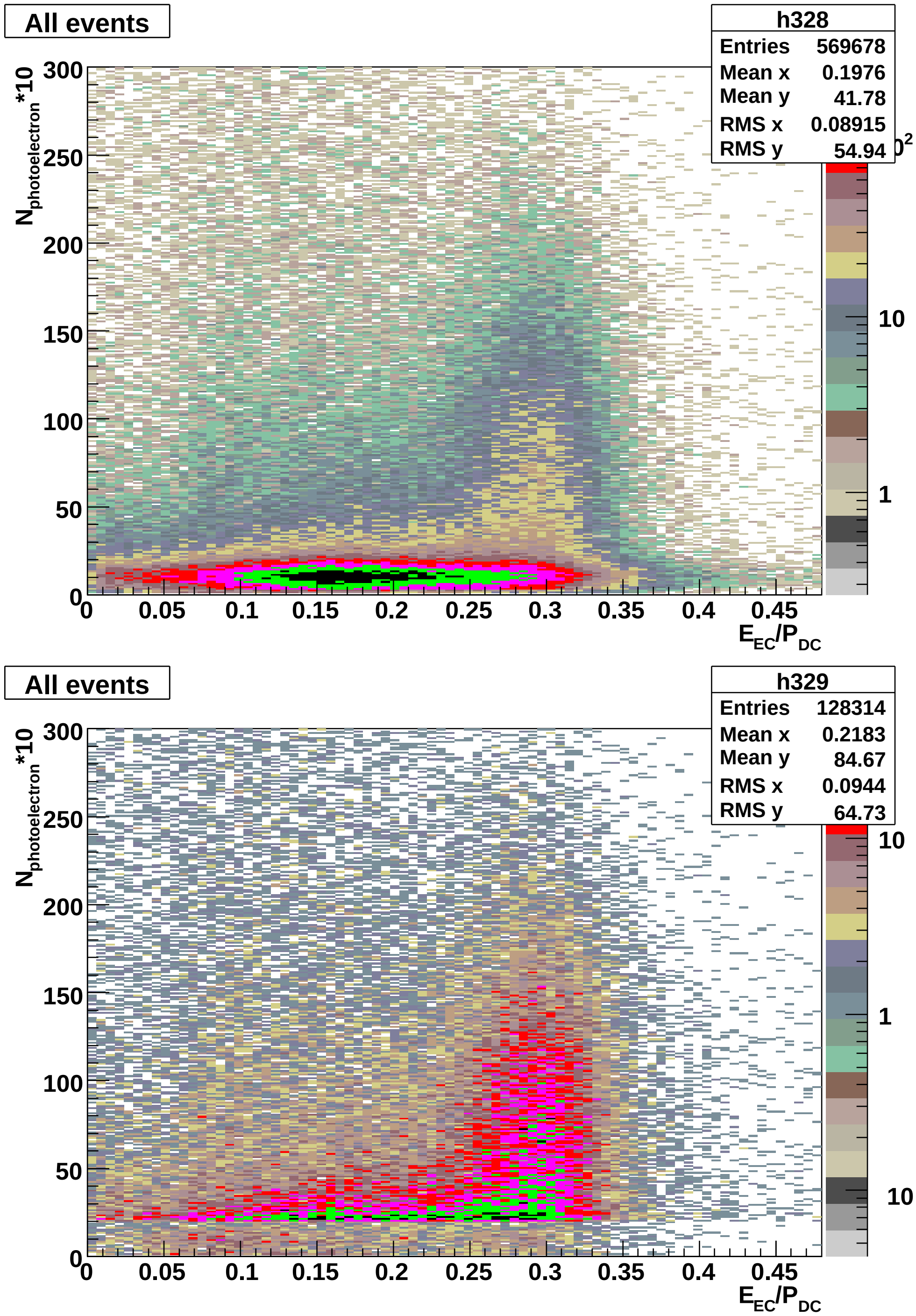

Figure 11: The number of photoelectrons in Cerenkov versus the energy deposited in EC per the particle momentum for all events. Top panel: without cut on CC_{ADC}. Bottom panel: with cut on $CC_{ADC} > 400[ADC channels]$.

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A Init.tcl file

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```
source /u/group/clas/builds/release-4-9/packages/tcl/recsis_proc.tcl;
# define packages
turnoff ALL;
global_section off;
turnon seb trk cc tof egn user pid;
set trigger_particle_s 2212;
#
inputfile InputFile
setc chist_filename histfile;
setc log_file_name logfile;
#
#level of analysis 0: raw  2: hbt 4: tbt
#set trk_level 4;
#set trk_maxiter 6;
#
#DSTS INCLUDE1 ----
setc outbanknames(1) "TRGSHEADEC  SC  DC0 CC  ECPIECHBPARTTBIDHEVTEVNTDCPBCCPBSC
PBECPBCALLTBERTGBITRKSTBTRSCR SCRCECPCCL01LCPBBMPRTDPL";
#                     123456789|123456789|123456789|123456789|123456789|12345678
9|123456789|123456789|123456789|123456789|123456789|12
#                              1         2         3         4         5
 6         7         8         9        10        11
#   28 banks
setc prlink_file_name "prlink_e16_tg4.bos" ; #for target at zero (-4cm)
setc bfield_file_name "bgrid_T67to33.fpk"
#km outputfile outfile PROC 2047;
#outputfile /work/clas/disk1/kmikhail/e1_6a/clas_030735_10000evntIfId11.B00; #
PROC 2047;
#
set lseb_nt_do  -1;
set lall_nt_do  -1;
set lscr_nt_do  -1;
#set lmctk_nt_do -1;
set lseb_hist   -1;
set lseb_h_do   -1;
set lmon_hist   -1;
set ltrk_h_do   -1;
set legn_h_do   -1;
set ltof_h_do   -1;
set lec1_h_do   -1;

set lfec_hist   -1;
set lfec_h_do   -1;
set lpart_nt_do -1;
#set lmysql      -1;
#set nmysql      -1;
# tbt stuff realistic curve for drift time to drift distance.
## tell FPACK not to stop if it thinks you are running out of time
fpack "timestop -9999999999"
# do not send events to event display
set lscat $false;
set ldisplay_all $false;
#set nevt_to_skip  500000; # how many events to SKIP set to .le. 0 to NOT SKIP
####set nevt_to_skip  1000;
# tell recsis to pause or go
setc rec_prompt "CLASCHEF_recsis> ";
go 100000000;
exit_pend;
```

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Figure 12: Init.tcl file

B Lost events

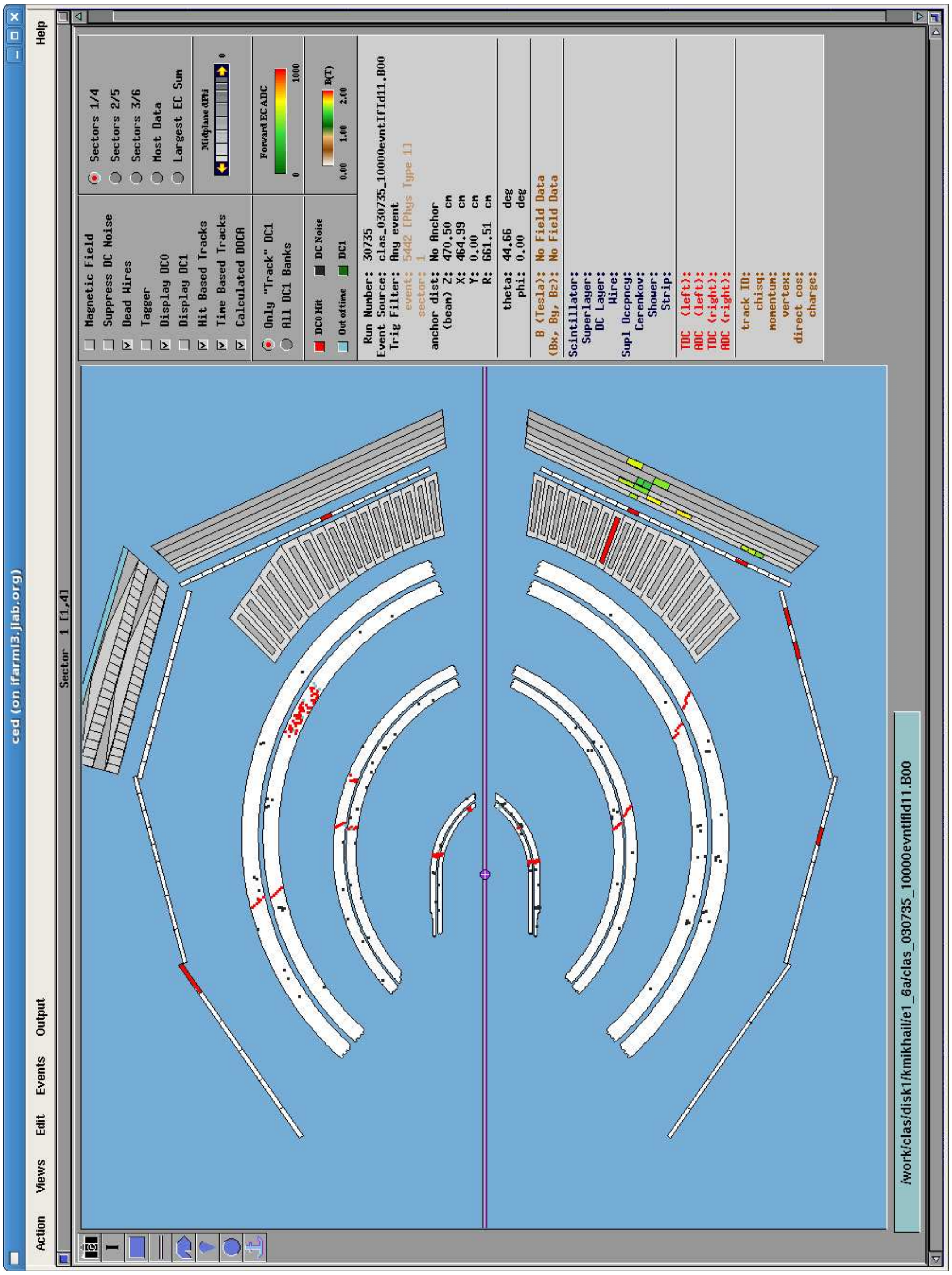

Figure 13: The inconsistence (poor) of the track dictionary to some class of track.

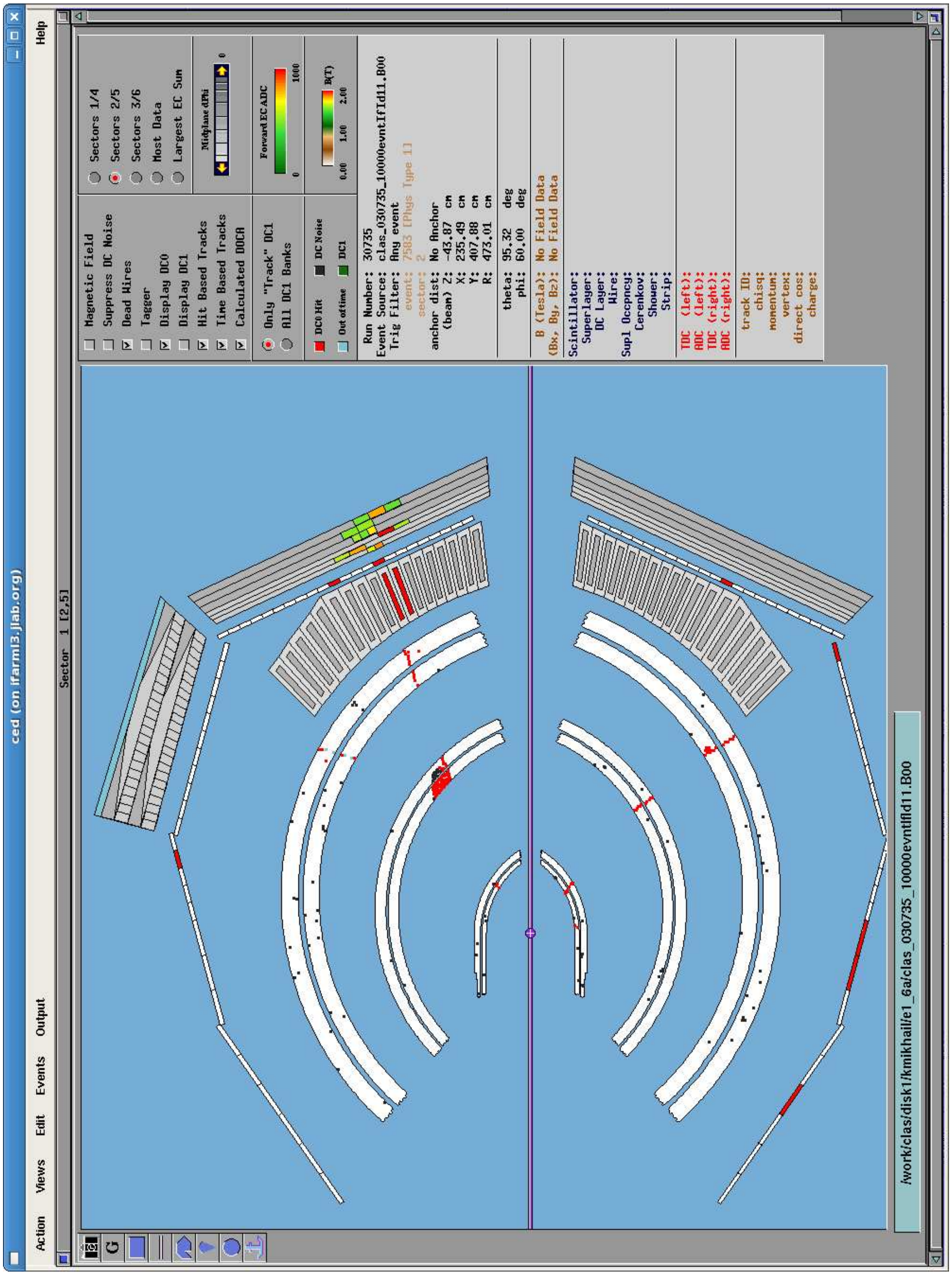

Figure 14: Exceeded the limit number of the tack candidate.

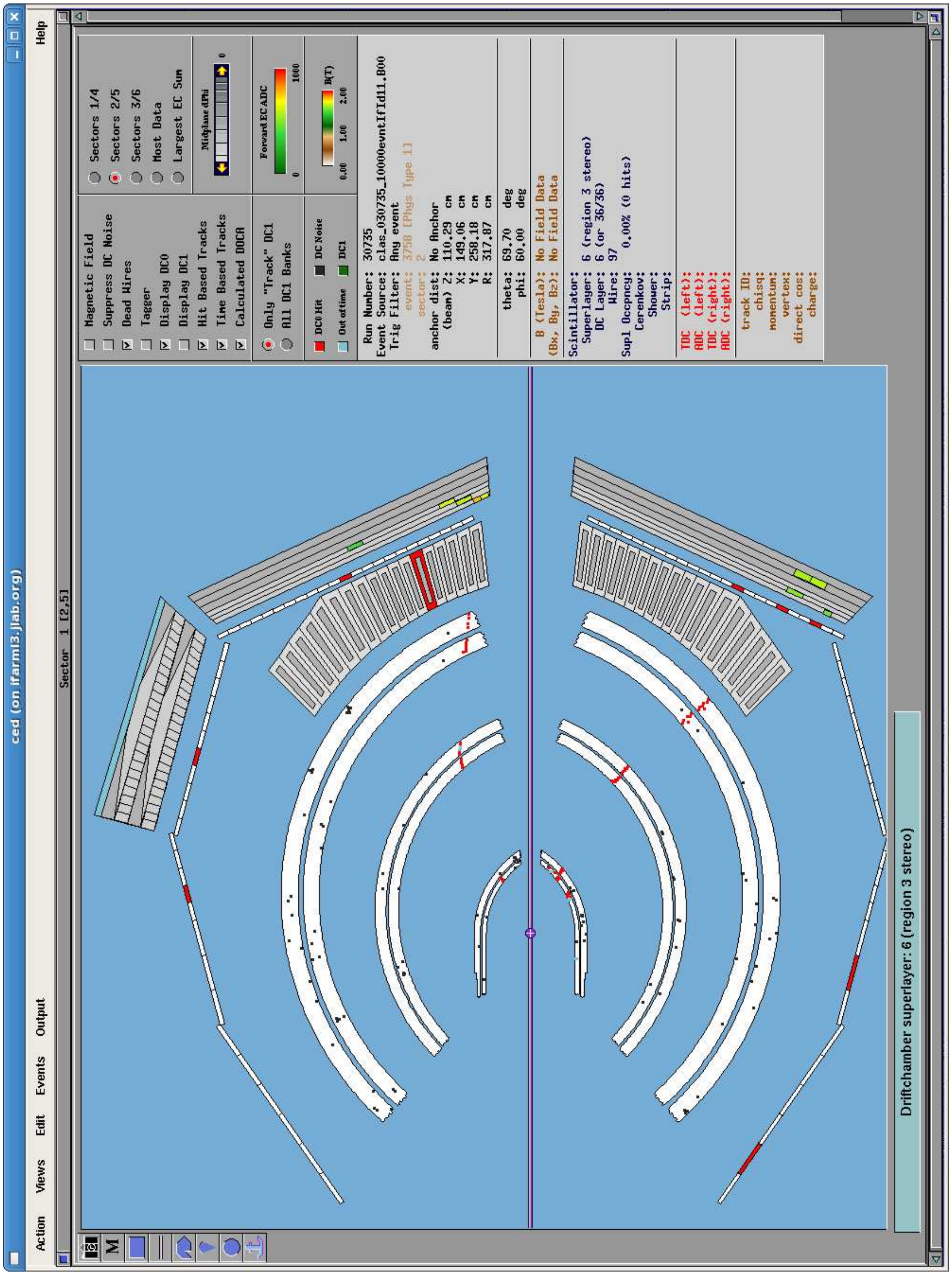

Figure 15: No matching between outer detectors.

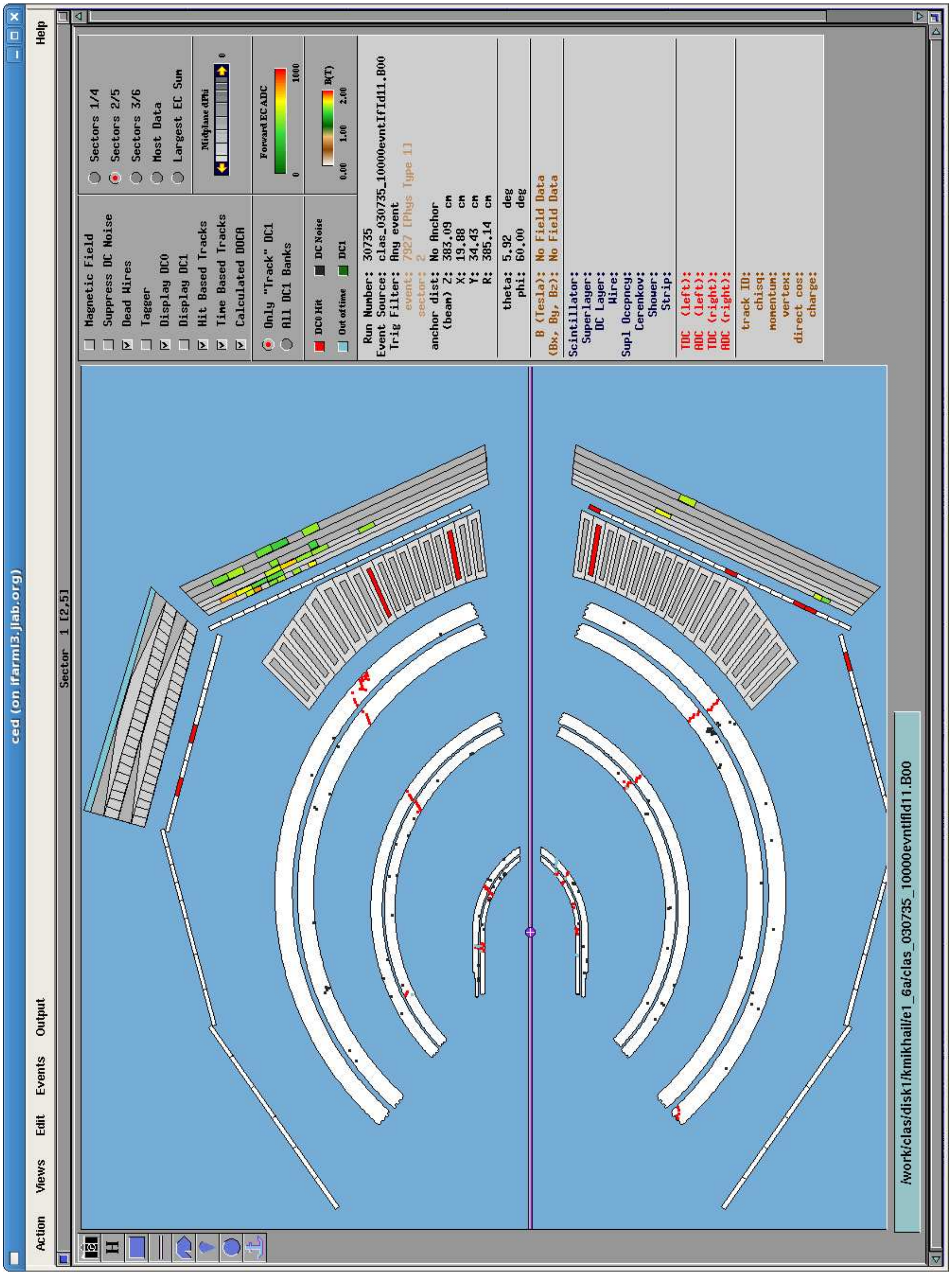

Figure 16: No SC hits and CC hits are not in right position.

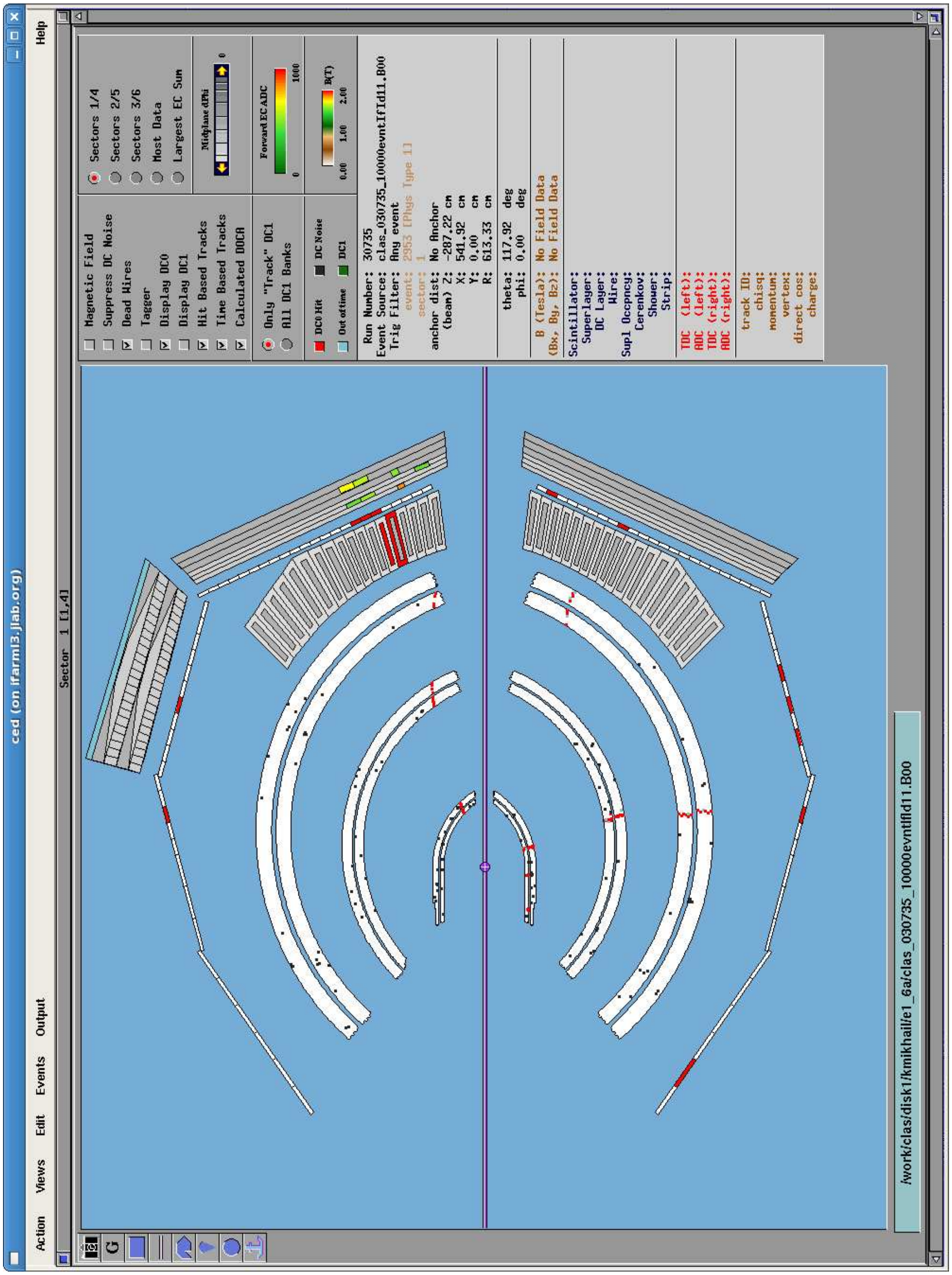

Figure 17: No matching between track and outer detectors.