Summary of BigBite Background Tests after the SRC experiment

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1 Motivation

The Transversity experiment E03-004 is going to use BigBite for electron detection with maximum magnetic field. We would like to proposal some tests on BigBite so that we can have a better estimation of the singles rate on the wire chambers. Though we will have a HRS and calorimeter in the trigger during the experiment, the extremely high single plane rate will affect track reconstruction. The proposed singles rate tests on BigBite will also benefit other experiments such as sea asymmetry (PR04-114) and Gen (E02-013).

2 Configuration

- **Trigger Setup**
  - Only plug in a few paddles in forming T6. We will use the following PMTS in forming T6 (for central bending and straight traveling particles): aux PMT #27-29, aux PMT #53-55; dE PMT #11-12R, dE PMT #22R; and E PMT #10-12L, E PMT #21-22L. (Referring to halog 143902–Olivier/Xiaodong) But based on the self-timing peak in the TDC spectrum, it seems that **aux PMT #28-30**, **aux PMT #52-54**; **dE PMT #23R**; and E PMT #10-12L, E PMT #21-22L were connected into the trigger.
  - Use left HRS π^+ event as the T3 trigger to look at the performance BigBite PMTs within the timing window. The left HRS was at $\theta_L = 16.3^\circ$ and $P_L = -2.0$GeV/c.
- **Discriminator Threshold** The discriminator threshold for protons was lowered for electrons: from Setting I to Setting VII in Table 1.

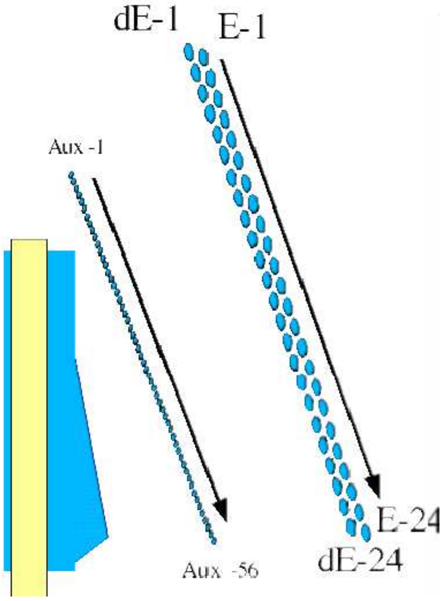

Figure 1: The detector map of the BigBite for SRC experiment.

Table 1: The dependence of T6 rate on the BigBite discriminator threshold. T6 here is from all paddles. (Referring to halog 143900–Doug/Xiaodong/Olivier)

Setting#	Aux Plane (mV)	dE Plane (mV)	E Plane (mV)	T6 (Hz)
I	-80	-120	-60	1
II	-40	-60	-30	4
III	-20	-30	-15	19
IV	-20	-30	-30	6
V	-20	-30	-10	32
VI	-20	-30	-20	14
VII	-20	-40	-20	8

3 Data Taken

We were scheduled to have three and half hours in total for the test (Apr 13 7pm- 10:30pm). The test went smoothly and the data are summarized in Table 2. The raw data files were copied to the directory: /w/work1707/e00007/jiang/raw/. The data files were replayed by using analyzer with modified SRC physics C script and the output root files were placed at the directory:/work/halla/e94104/disk3/bbtest/.

Table 2: BigBite settings for the test plan as well as those in Transversity (E03-004) and PR04-114 experiment. The Left HRS at $\theta_L = 16.3°$ and $P_L = -2.0$GeV/c was used to provide a trigger. The Right HRS at $\theta_R = 45.7°$ and $P_R = +1.41$GeV/c was not used. BigBite magnet field was 0.986 T with current readback of 550.4A. Based on the information from Dave Meekins, the thickness for different target is: 0.289 g/cm^2 for 4 cm LH2, 0.668 g/cm^2 for 4 cm LD2, 0.54 g/cm^2 for Dummy and 0.123 g/cm^2 for slanted Carbon. The distance of BigBite to the target is 1 meter.

Kin	E_e (GeV)	I_e (μA)	Target	θ_B (deg.)	run	T/N (min/k)	T3/T6 (kHz)	$R_{a57}/R_{dE12l}/R_{E12l}$ (kHz)
Cos.	-	-	-	99	3441	7/1	7.3/0.1Hz	0.3/0.2/0.2
Kin1	$I_B = -550$ A, a few paddle used for T6							
	4.6	2	4 cm Dummy	99	3435	6/105	1.1/1.6	184/400/68
	4.6	2	4 cm LD2	99	3436	8/238	2.4/1.9	191/465/62
	4.6	1	4 cm LD2	99	3437	9/177	1.2/0.5	102/252/32
	4.6	0.5	4 cm LD2	99	3438	9/133	0.6/0.1	50/125/16
	4.6	2	4 cm LH2	99	3439	7/157	1.1/1.1	157/437/41
	4.6	0.5	15 cm LD2	99	3440	6/150	2.2/1.3	170/358/54
	4.6	2	Empty	99	3442	2/0.4	7.2/0.5Hz	1.0/1.5/2.2
Kin2	$I_B = 0$ A,a few paddles used for T6							
	4.6	1	4 cm LD2	99	3443	5/235	1.0/2.0	194/237/57

4 Discussion on the ADC/TDC Spectrum.

- Noisy PMTs ⟶ Changes to Trigger Setup
  - **PMT#dE23R**: The PMT#dE23R rate is comparable with PMT#dE12R based on both scaler readings and TDC for T3 events. But PMT#dE23R has a TDC signal for about 95% of the T6 events and its entries with TDC>0 are about ten times those of the PMT#dE12R for T6 events, though both PMT#dE23R and PMT#dE12R together with PMT#dE11R should be connected into T6 trigger. One possible explanation is: PMT#dE23R is the only channel that is effectively connected into T6 trigger. If not, the T6 rate should be higher even just due to random coincidence.
  - **PMT#E22L**: The PMT#E22L has much more T6 entries than other four PMTS connected into the trigger, while comparable T3 entries. One possible explanation is: PMT#dE23R is the only channel that is effectively connected into T6 trigger. So PMT#E22L, as the only paddle both overlapped with PMT#dE23R and connected into the T6 trigger, has the highest T6 rate in the E plane.
- More TDC entries than ADC ⟶ Discussion on Pedestal Suppression
  - **ADC#aux28**: It does not show clear correlation with ADC#aux28. The spectrum with TDC>0 (9376 for run 3438) has a very high peak at ADC=0. There are very few events with ADC>0 (441 for run 3438) compared to neighboring paddles and TDC . The detector map seems to be correct since the neighboring channel 27 and 29 show strong correlation between ADC and TDC. The PMT itself seems to work since the PMT rate from scaler is comparable with neighboring channels. The TDC #aux28 seems to be fine since the PMT rate from TDC is consistent with that from the scaler. It is likely that there is something wrong with ADC#aux28 itself. Low counts of ADC#28 comopared to neighboring paddles can also be seen in an early SRC run 2144. There may be some problem with the cable or the ADC module, but one possiblility is that the pedestal suppresion is wrong. The threshold to generate TDC may be below the pedestal cut (CH96) on ADC, which happens when there is some significant shift in ADC.
  - **ADC#aux54**: The entries with ADC>0 is 1582 while the entries with TDC>0 is 8487 for run 3438. The problem may be similar as ADC#aux28 with the possibility that threshold to generate TDC is below the pedestal cut (CH64) on ADC.
  - **ADC#E11L**: The entries with ADC>0 is 1753 while the entries with TDC>0 is 2380 for run 3438. The problem may be similar as ADC#aux28 with the possibility that threshold to generate TDC is below the pedestal cut (CH240) on ADC.
  - **ADC#E21L**: The entries with ADC>0 is 830 while the entries with TDC>0 is 2607 for run 3438. The problem may be similar as ADC#aux28 with the possibility that threshold to generate TDC is below the pedestal cut (CH48) on ADC.

5 Random Coincidence

The T6 trigger is formed in two steps and the random coincidence can be be caculated as

$$n_{acc} = (t_E + t_{dE}) * (t_{E\&dE} + t_{aux}) * n_{aux} * n_E * n_{dE} \ . \tag{1}$$

By using $t_E + t_{dE} = 100$ ns, $t_{E\&dE} + t_{aux} = 100$ ns and assuming the rate for each plane is the sum of those of connected PMTs, the random coincidence was shown in Table 3. The rate for each PMT was read from the scaler in the data file and averaged over time. If the PMT rates are correlated, the coincidence will be expected to be higher. For example, if the PMTs in the E plane are 100% correlated with those in the dE plane, then

$$n_{acc2} = (t_{E\&dE} + t_{aux}) * n_{aux} * n_E \ . \tag{2}$$

The n_{acc2} is larger than n_{acc} for $n_{dE} < 10$ MHz.

Table 3: The Random Coincidence. The T6^a corresponds to the case with a cut on the dE#23R TDC. It seems the majority of T6 event has a positive dE#23R TDC.The n^a_{acc} only include the rate of #23R paddle in the dE plane.

run	n_{acc} (kHz)	T6 (kHz)	T6^a (kHz)	n^a_{acc} (kHz)	T6^a-n^a_{acc} (kHz)
3435	1.478	1.635			
3436	2.776	1.940	1.868	0.982	0.886
3437	0.410	0.467	0.459	0.146	0.313
3438	0.045	0.108	0.107	0.016	0.091
3439	1.270	1.076	1.043	0.447	0.596
3440	1.204	1.253			
3441	0.000	0.000			
3442	0.000	0.001			
3443	1.040	1.963	1.927	0.382	1.545

6 Comparison of PMT rates from scalers and those from TDCs

There are two ways to get the average PMT rates for a run: from scalers and from TDCs. One should get consistent results with these methods. The comparison for run 3436-3439 were listed in Table 4 (from Yao Huan).

- PMT rates from the scalers: The BigBite scaler information are written into the data file every 6 seconds after the run starts and when the run stops. All the scaler counters are cleared to be zero at the start of run. The average PMT rates is obtained by dividing the total counting of the scaler at the end of run by the time of the run.

- PMT rates from the TDCs: The physical coincidence between the T3 events and BigBite PMT is negligible, which also reflects in the randomly distributed TDC spectrum of each PMT. Each channel corresponds to 35 ps. The TDC range of ∼180 to 4096 channel corresponds to the timing window of τ=137ns. Therefore one can get PMT rates by

$$n_{TDC} = \tau * n_{T3} * n_{PMT} \tag{3}$$
$$n_{PMT} = n_{TDC}/(\tau * n_{T3}) = N_{TDC}/(\tau * N_{T3}) \ . \tag{4}$$

7 Discussion on the threshold of PMTs

The correspondence of the ADC channels and energy loss was determined by analyzing a *ep* elastic run and pedestal runs. The *ep* elastic peak position was fitted using a function combining Gauss peak and exponential background. The mean value of the ADCs of the pedestal run was taken to be pedestals. The pedestal peak is more like a random distribution than a Gaussian peak. The threshold channel of PMT was found by adjusting the ADC cut so that the T3 events above that are equal to those with cut TDC>0. Assuming linear relation between the ADC channels and energy loss, the TDC threshold in energy loss was estimated as

$$Eloss_{\mathrm{th}} = Eloss_{ep}\frac{Peak_{ep} - Ped}{ADC_{th} - Ped} \tag{5}$$

One can also estimate the corresponding energy loss for any peak in the ADC spectrum. For example, there is a small peak around 400 Ch in the ADC#E10L-12L for T6 events (see Fig. 8). The energy loss is 4.9 MeV (359 Ch), 4.5 MeV (390 Ch) and 4.9 MeV(474 Ch) respectively, while the minimum ionization is 6 MeV.

8 The Difference between Magnet On and Off

The difference between the settings of run 3437 and run 3443 was the BigBite magnetic field. The beam currents were both 1μA and the targets were both 4 cm LD2. The field was 0.986 T with negative polarity with current 550A for run 3437. The field was off for run 3443. The PMT rates were compared in Table 6. With magnet on, the aux PMT rates were reduced by a factor of 2-4; the dE PMT rates were similar except for upper paddles which were higher; the E PMT rates were generally lower, around a factor of 2 for the central paddles.

Run	N_{T3}		Aux PMT #						dE PMT #			E PMT #				
			28	29	30	52	53	54	11R	12R	23R	10L	11L	12L	21L	22L
3436	100646	N_{TDC}	2562	1407	1484	2344	1946	2749	4607	6396	6014	774	786	926	781	790
		$scaler \rightarrow$	181	102	105	170	141	184	324	444	420	49	52	60	52	50
		$TDC \rightarrow$	186	102	108	170	141	199	334	464	436	56	57	67	57	57
3437	113665	N_{TDC}	1520	807	854	1414	1106	1542	2721	3875	3745	470	484	554	460	454
		$scaler \rightarrow$	95	53	55	89	74	96	173	242	229	25	27	31	27	26
		$TDC \rightarrow$	98	52	55	91	71	99	175	249	240	30	31	36	30	29
3438	91311	N_{TDC}	621	319	323	598	451	644	1114	1521	1516	171	182	243	189	215
		$scaler \rightarrow$	45	25	26	43	35	46	83	117	112	12	13	15	13	12
		$TDC \rightarrow$	50	26	26	48	36	51	89	122	121	14	14	19	15	17
3439	81803	N_{TDC}	1684	885	912	1553	1260	1781	3474	4742	4521	377	413	470	443	452
		$scaler \rightarrow$	142	79	81	133	110	144	300	411	386	30	33	38	34	32
		$TDC \rightarrow$	150	79	81	138	112	159	310	423	403	34	37	42	40	40

Table 4: Comparison of the PMT rates (kHz) from scalers and those from TDCs.

Table 5: The estimation of PMT threshold. The PMT pedestal positions were read from pedestal run 2202 and 3289 and the peak for *ep* elastic events were determined from run 2551 ($E_e = 1.204, P_e = 1.137$)with proton momentum 361 MeV. The corresponding energy loss in 3cm E, 2mm aux and 3mm dE plane is 31.2, 2.08 and 3.12 MeV respectively. The rate corresponds to the PMT scaler rate of bigbite test run 3436: 2 μ A beam on 4 cm LD2 target.

PMT	Pedestal	Suppression	*ep* Peak	TDC threshold		Rate	SRC threshold		Rate
	Run 3289(2202)	(Ch)	(Ch)	(Ch)	(MeV)	(kHz)	(Ch)	(MeV)	(kHz)
E10L	123±16(128)	127	1621	184	1.3	49	383	5.4	126
E11L	173±16(182)	239	1672	<239	<1.4	52	408	4.9	158
E12L	234±16(231)	191	1755	293	1.2	60	473	4.9	161
aux29	79±0.8(85)	95	1231	119	0.07	102	362	0.5	245
aux30	91±2(98)	111	1262	137	0.08	105	339	0.4	219
dE10R	197±16(199)	207	757	280	0.5	274	529	1.8	245
dE11R	288±16(291)	303	990	382	0.4	324	655	1.6	359

Table 6: The PMT rate snapshots for different magnet settings at beam current of 1.067 μA for run 3437 and 1.023 μA for run 3443. The numbers with * missed the snapshots and were extracted from the scaler data.

PMT	Manget On (3437)	Magnet Off (3443)	PMT	Manget On (3437)	Magnet Off (3443)	PMT	Manget On (3437)	Magnet Off (3443))
Aux1	17.15	50.9*	dE1L	138.8	77.7*	E1L	27.36	20.7*
Aux2	18.22	62.1*	dE1R	66.90	39.4*	E1R	42.84	32.8*
Aux11	32.18	140.8	dE5L	230.2	153.6	E5L	21.57	30.50
Aux12	34.41	146.5	dE5R	176.4	121.0	E5R	14.86	22.60
Aux21	75.81	207.4	dE9L	210.8	176.3	E9L	19.16	34.65
Aux22	114.3	244.2	dE9R	173.4	145.7	E9R	23.54	36.28
Aux31	52.53	189.5	dE14L	237.6	227.3	E14L	24.01	48.65
Aux32	109.2	241.2	dE46R	138.3	141.2	E14R	16.66	40.25
Aux41	98.61	220.9	dE18L	230.3	228.6	E18L	22.93	46.05
Aux42	53.29	171.7	dE18R	224.5	226.4	E18R	31.30	55.35
Aux51	54.79	153.0	dE22L	242.0	245.6	E22L	26.99	46.22
Aux52	93.20	188.9	dE22R	187.9	189.9	E22R	30.39	50.25
Aux55	101.7	194.2	dE24L	191.7	196.9	E24L	46.33	60.30
Aux56	85.30	165.7	dE24R	209.5	214.8	E24R	86.58	100.9

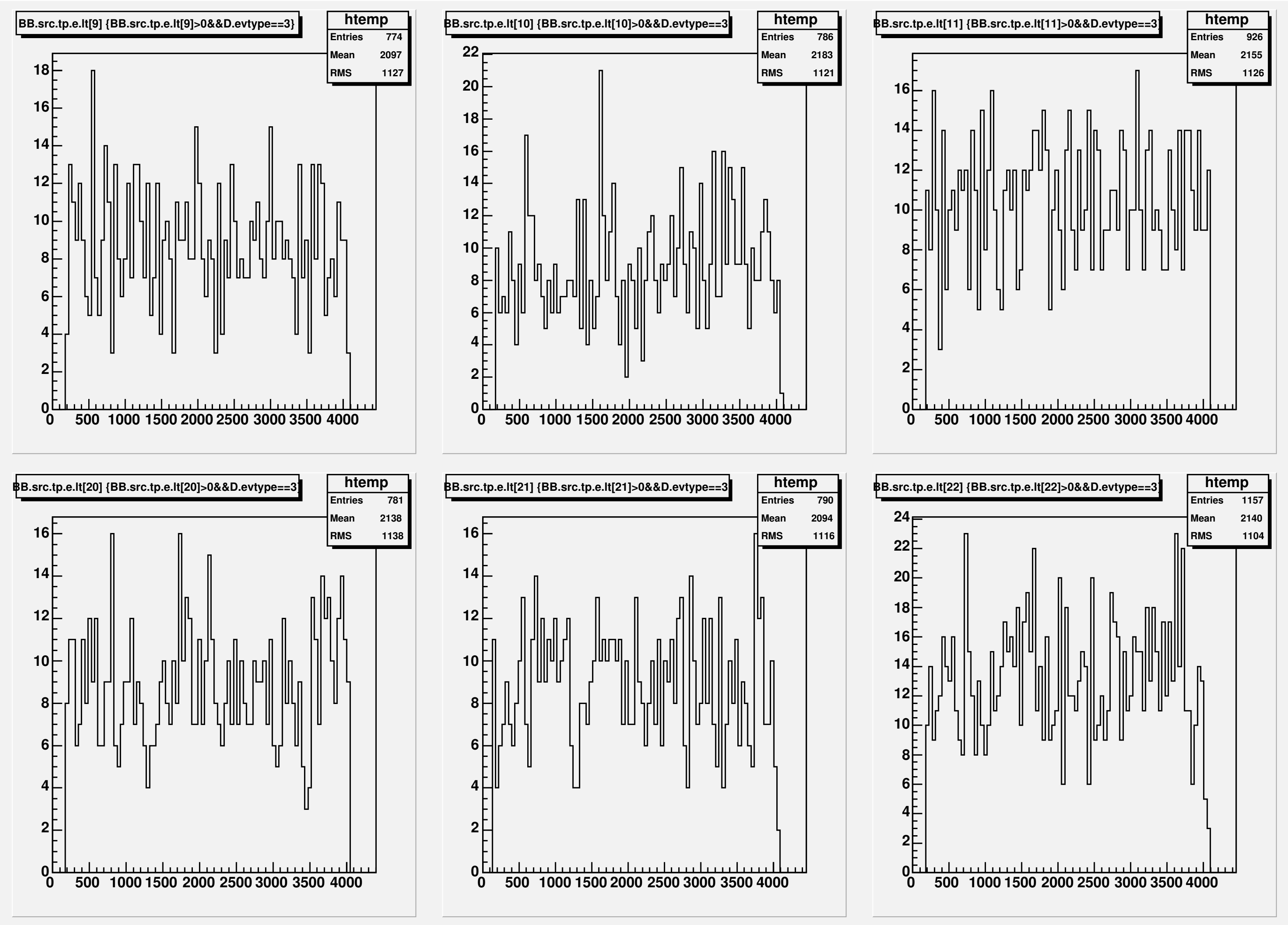

Figure 2: TDC spectrum of PMT#10-12L and PMT#21-23L in the E plane for T3 events .

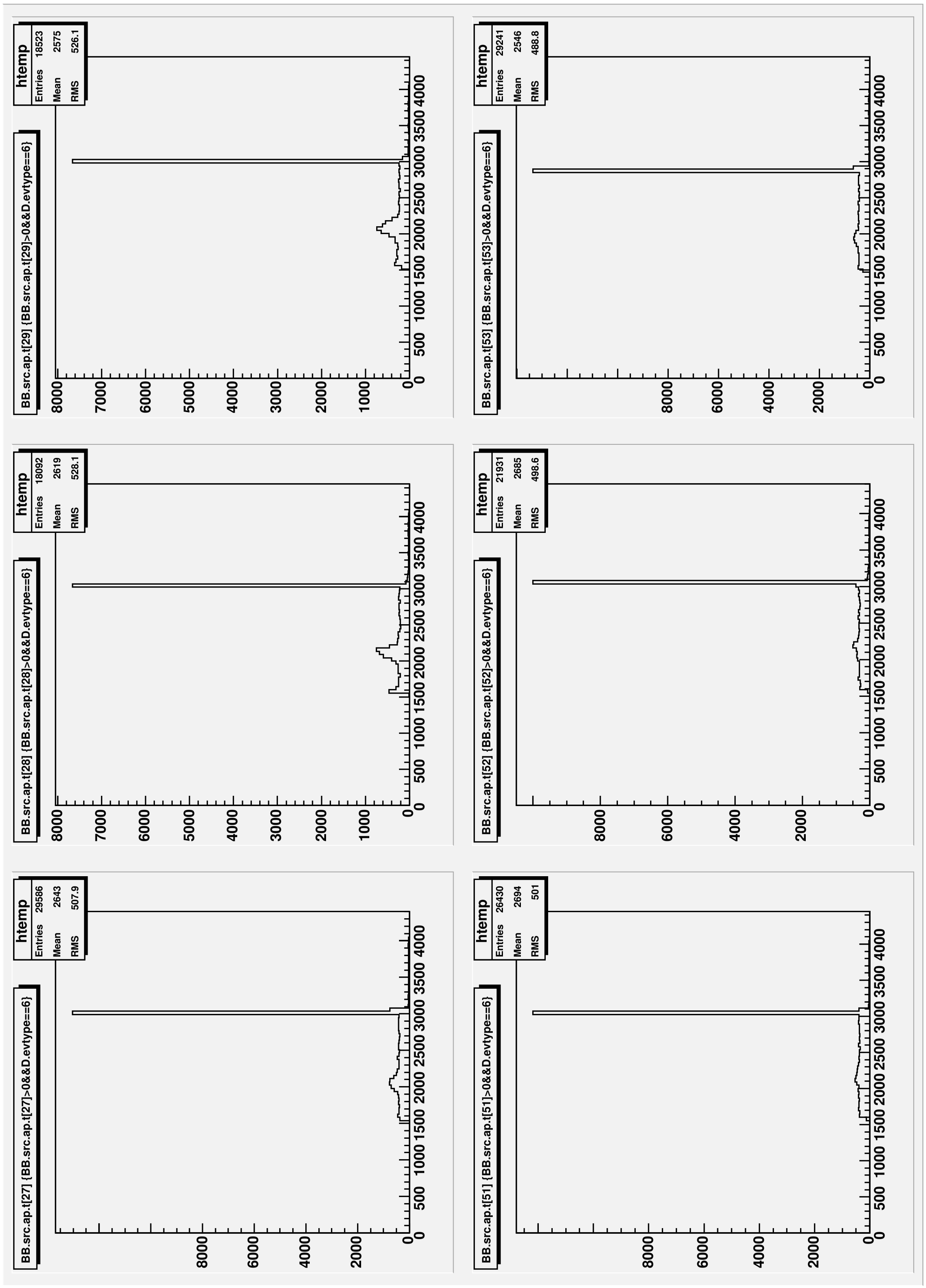

Figure 3: TDC spectrum of PMT#28-30 and PMT#52-54L in the aux plane for T6 events. The spike in each spectrum is the self-timing peak, which is formed when the pulse from that PMT in the aux plane arrives later than that from the trigger plane and determines the common START. The ~1500-channel (52.5ns) region before the spike are the T6 triggers when the pulse from aux plane arrives earlier than that from the trigger plane. The few events after the spike correspond to the case when another PMT in the aux plane generates the aux trigger and the TDC of this PMT comes a little later. (Based on the discussion with Olivier Gayou)

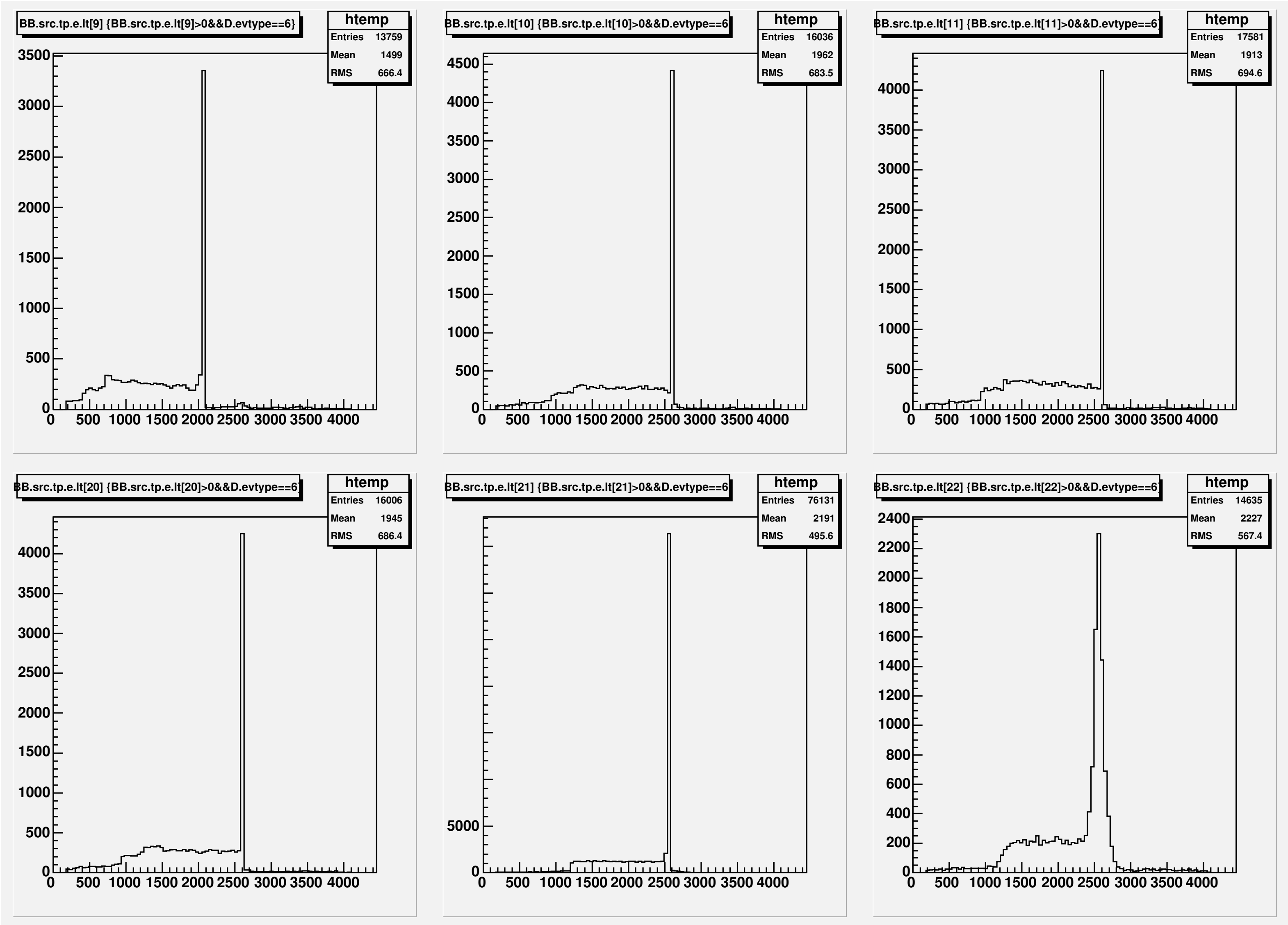

Figure 4: TDC spectrum of PMT#10-12L and PMT#21-23L in the E plane for T6 events .

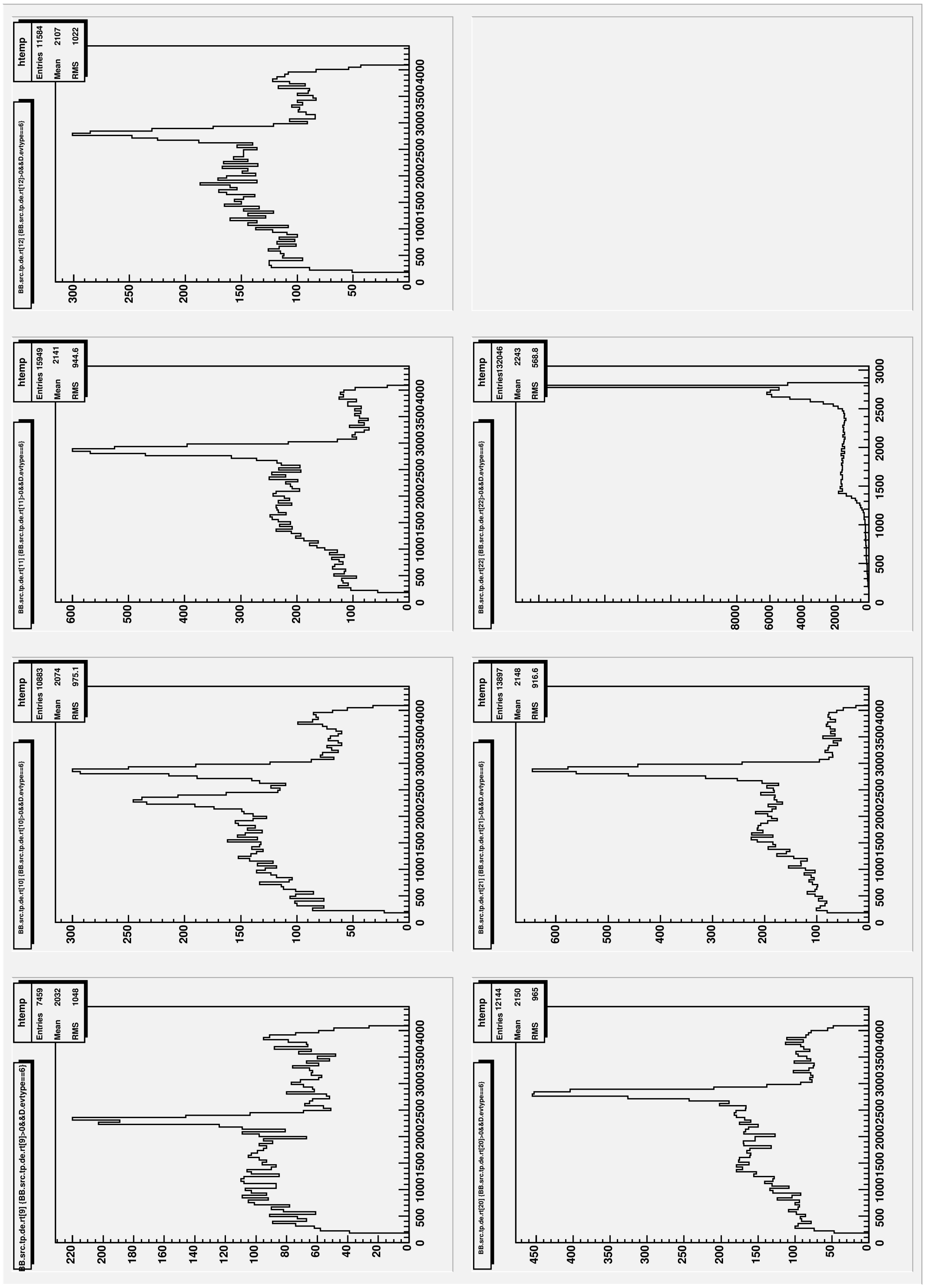

Figure 5: TDC spectrum of PMT#10-13R and PMT#21-23R in the dE plane for T6 events .

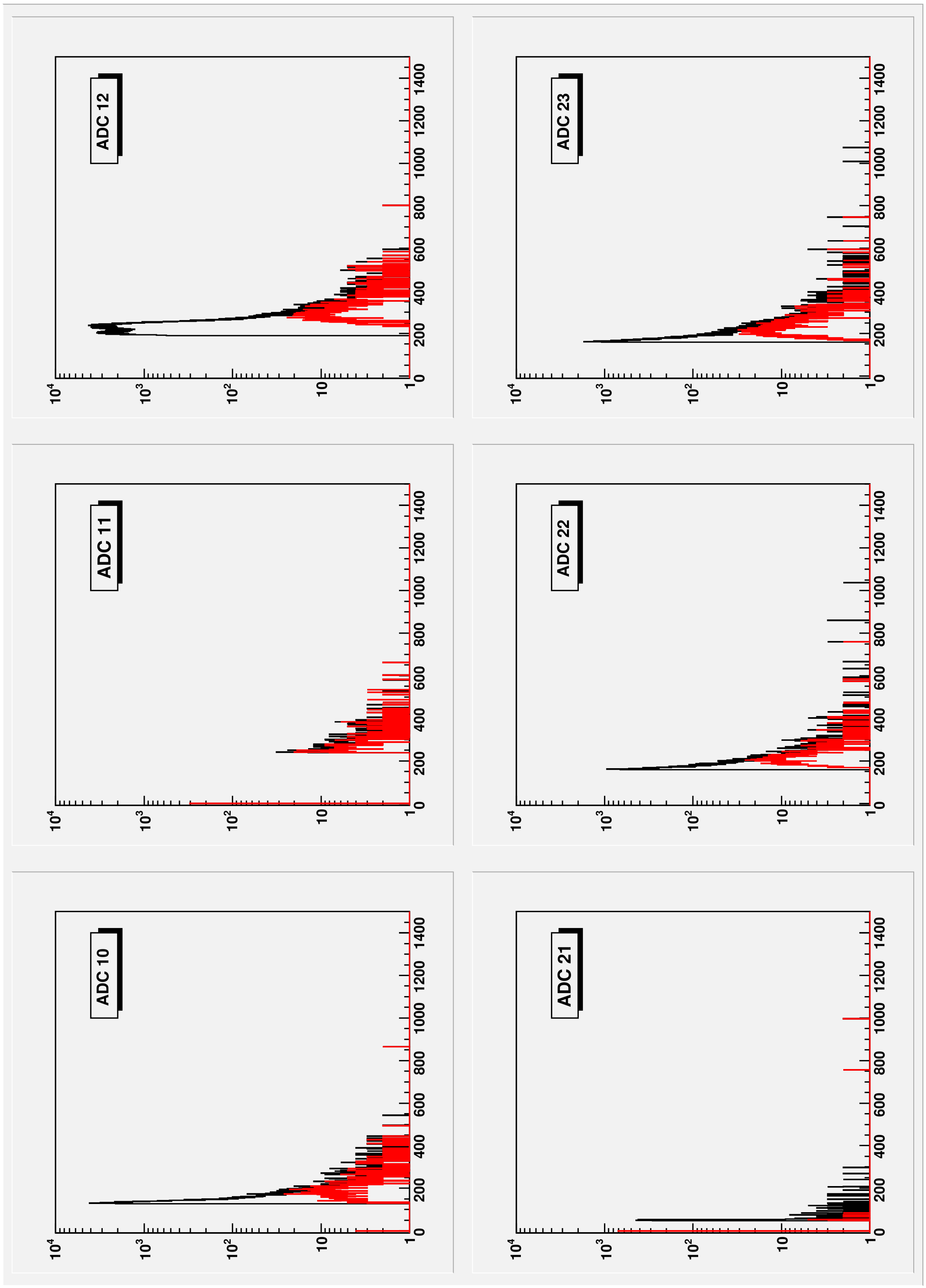

Figure 6: ADC spectrum of PMT#10-12L and PMT#21-23L in the E plane for T3 events. The black line is with cut ADC>0 while the red line with the cut TDC>0.

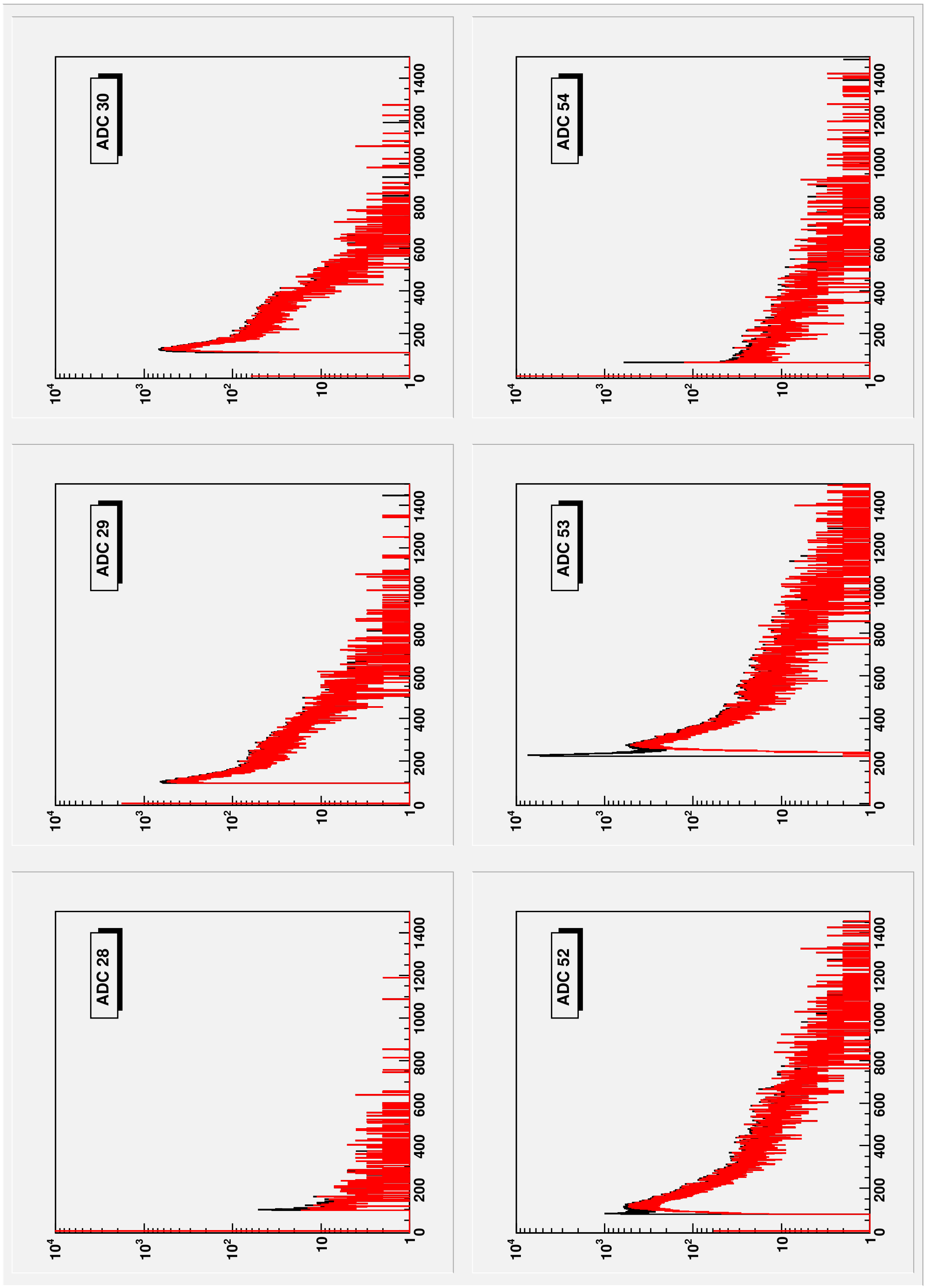

Figure 7: ADC spectrum of PMT#28-30 and PMT#52-54L in the aux plane for T6 events. The black line is with cut ADC>0 while the red line with the cut TDC>0.

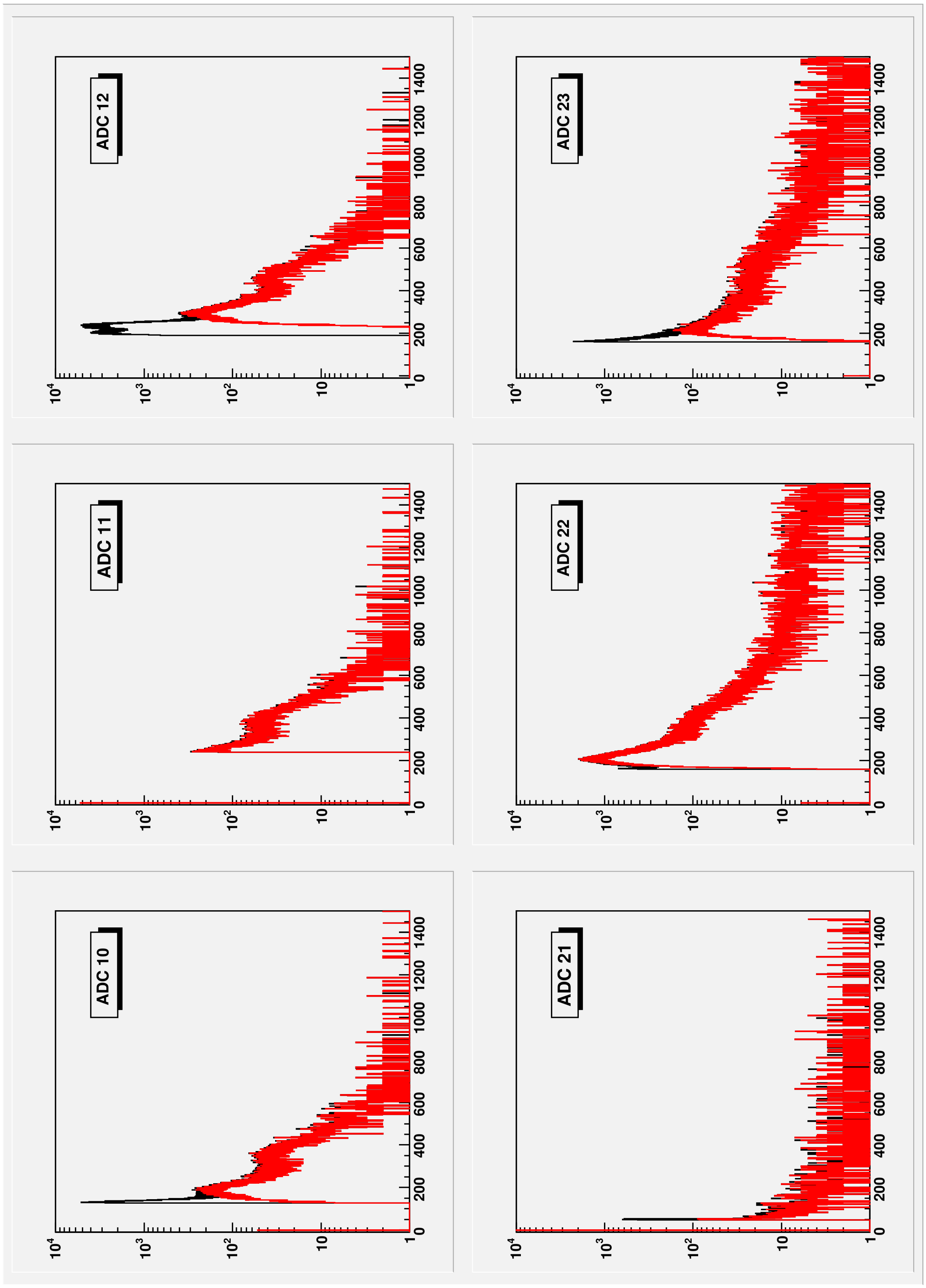

Figure 8: ADC spectrum of PMT#10-12L and PMT#21-23L in the E plane for T6 events . The black line is with cut ADC>0 while the red line with the cut TDC>0.

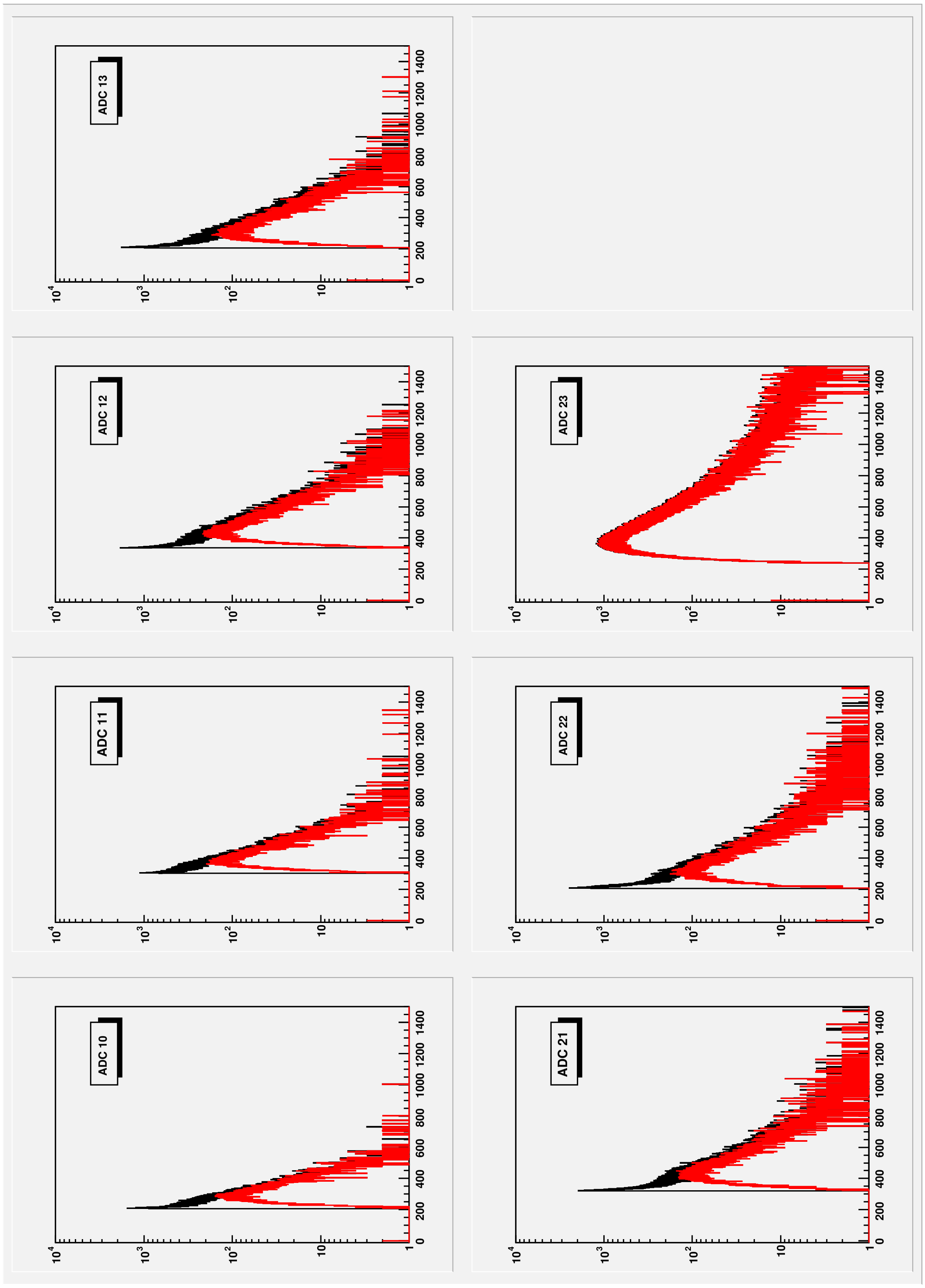

Figure 9: ADC spectrum of PMT#10-13R and PMT#21-23R in the dE plane for T6 events. The black line is with cut ADC>0 while the red line with the cut TDC>0.

9 Appendix A: TDC spectra for T3 and T6 events.

10 Appendix B: ADC spectra for T3 and T6 events.

11 Appendix C: ADC spectra for *ep* elastic events.

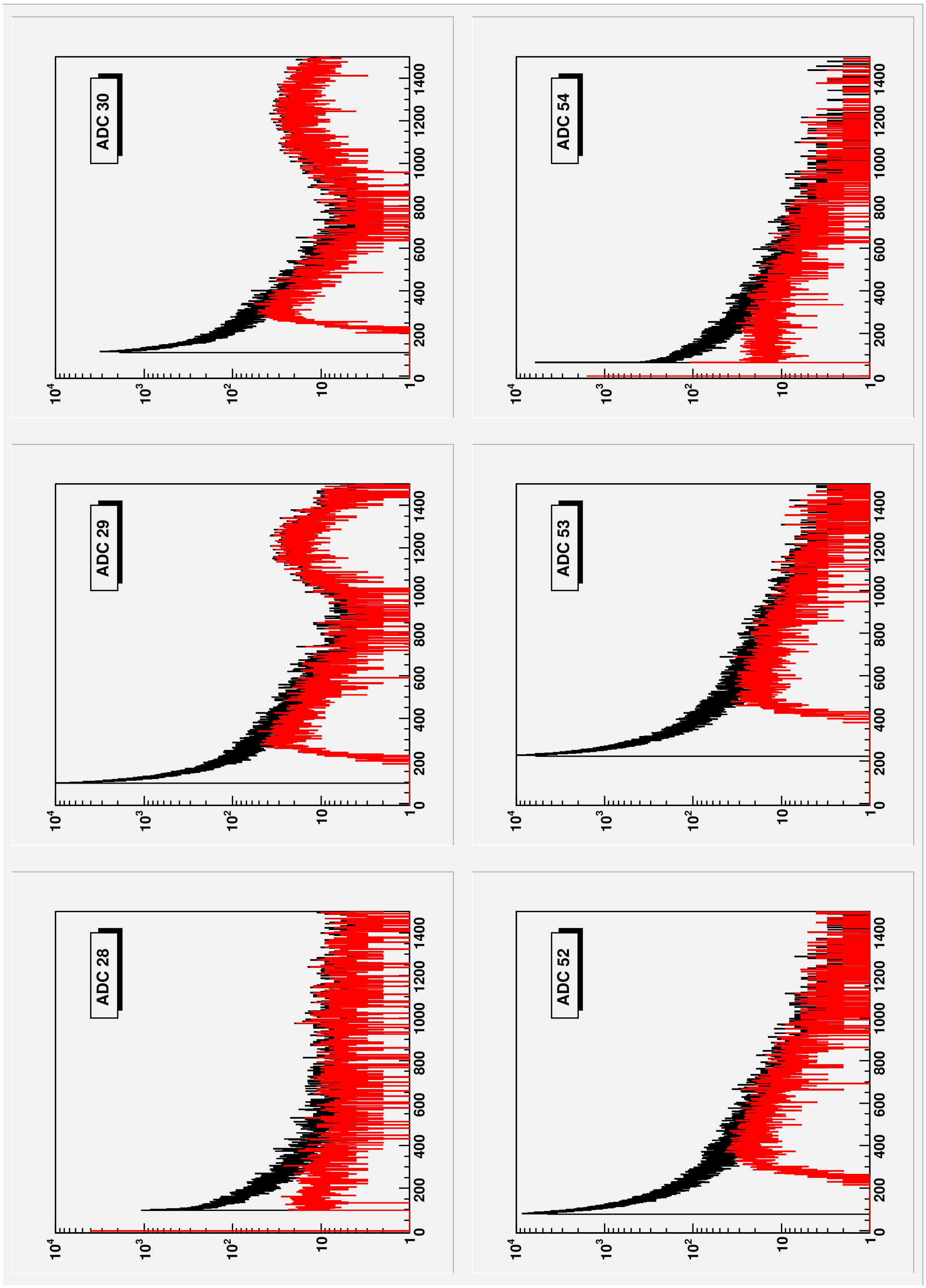

Figure 10: ADC spectrum of PMT#28-30 and PMT#52-54L in the aux plane for T3 events of an *ep* elastic run (2551). The black line is with cut ADC>0 while the red line with the cut TDC>0.

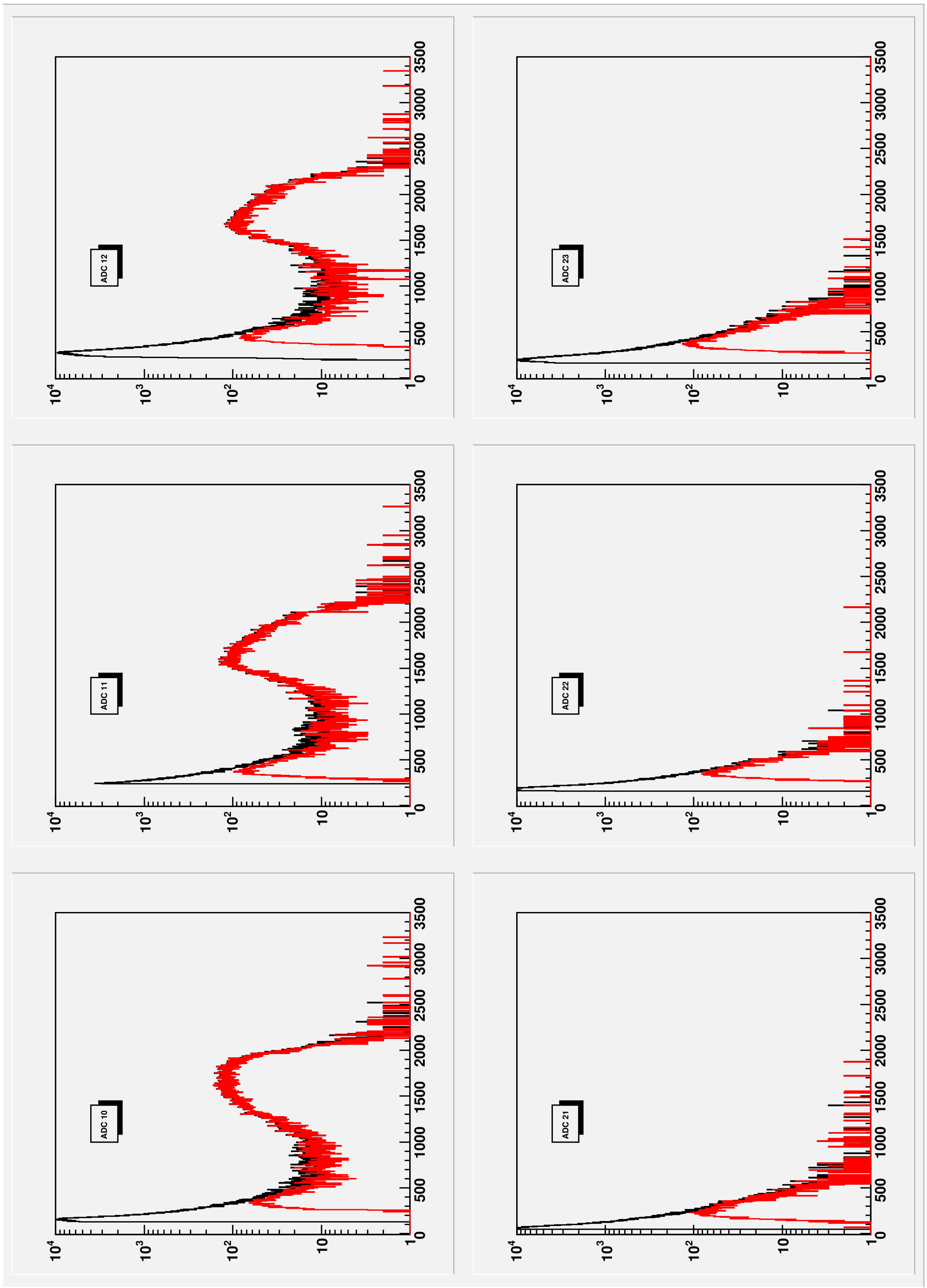

Figure 11: TDC spectrum of PMT#10-12L and PMT#21-23L in the E plane for the T3 events of an *ep* elastic run (2551). The black line is with cut ADC>0 while the red line with the cut TDC>0.

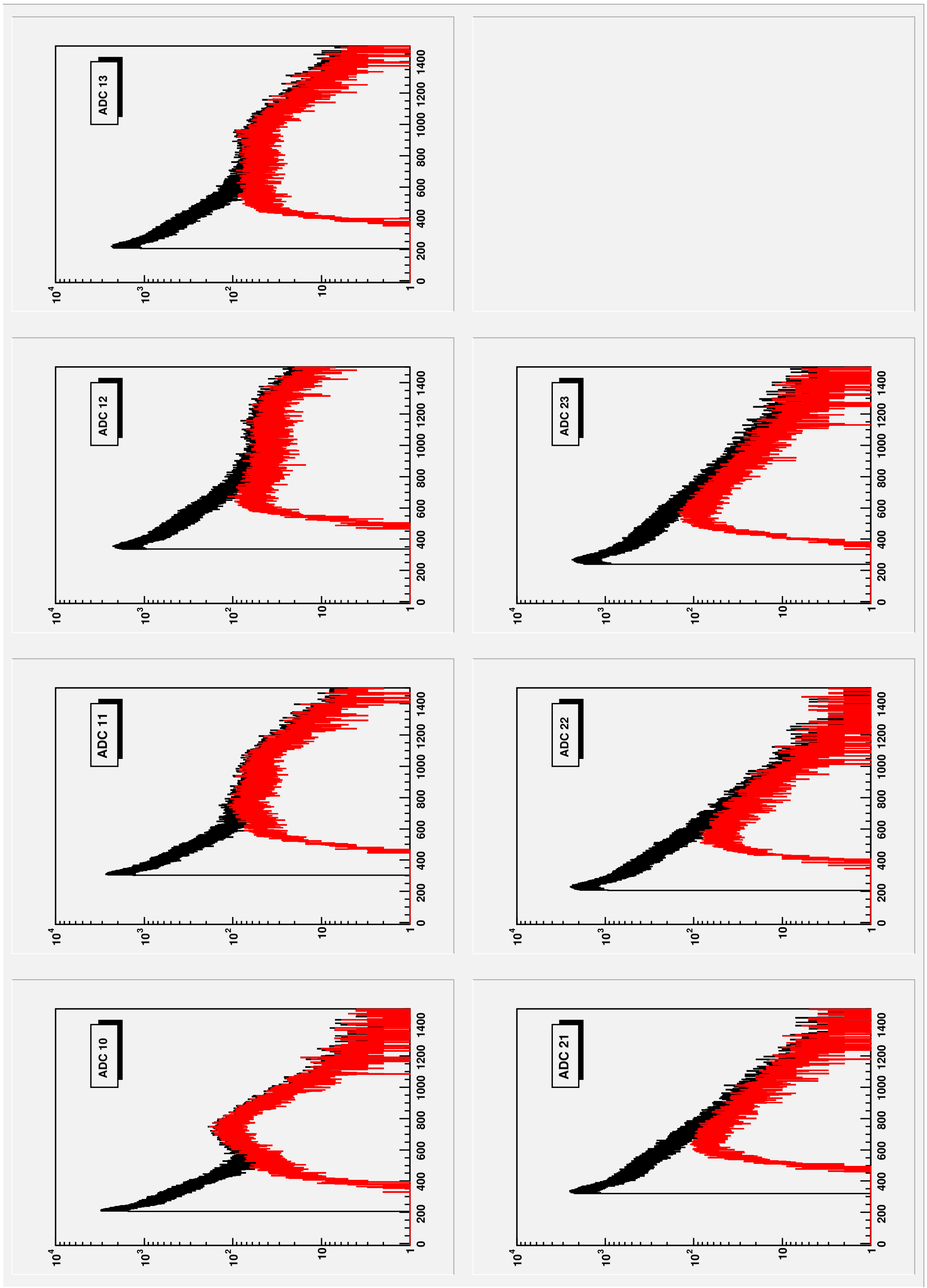

Figure 12: ADC spectrum of PMT#10-13R and PMT#21-23R in the dE plane for the T3 events of an *ep* elastic run (2551). The black line is with cut ADC>0 while the red line with the cut TDC>0.