2-AUG-82 DUMAND IR: 13-82

SUBJECT: DeSteigeur Cruise Data Analysis

FROM: P. Gorham

Although the muon string itself was lost, a considerable amount of data was taken during the DeSteigeur cruise of Feb.-Mar. '82. A total of 37 separate runs were made, and approximately 15,000 separate 4- and 5-fold coincidence events were recorded on disc, mostly at about 1500 m depth. In principle, times of arrival and pulse height for all light pulses forming the coincidences is available, but in practice this must first be corrected for displacement errors between the phototubes for the timing data, and calibrations for the slope of the response curve (number of ADC channels per photoelectron) of the individual tubes. Once these corrections and their corresponding errors are determined, a chi-square fit may be attempted to select out events with a high probability of being throughgoing muons. This report will indicate results to date of applying these procedures, and give some recommendations of how to avoid the problems that were encountered in the process.

Calibrations and Corrections

a) Timing

Due to the cruise deadline, inadequate data for timing corrections was taken before the cruise for one to feel confident in determining the necessary corrections, but it was assumed that this would be remedied with the nanosecond light pulser by doing on-line corrections. The data that was taken prior to the cruise consists of that taken by Y. Kawashima and D. O'Connor on 22 Feb. using the light pulser with 5-fold coincidence, and that determined similarly by O'Connor and Gorham on 28 Feb., the night before going to sea. The corrections as determined by comparing TDC histograms for both these dates are not consistent with one another; it is assumed that this is due to changes in the characteristics of the new phototubes as they became "burned in". Such changes were well noted in a number of cases (see Muon String Logbooks) as new 13 inch tubes were seen to apparently die and then later revive, or undergo significant gain changes in short time periods.The corrections as determined on 28 Feb. were considered more accurate because they were taken in close proximity to the cruise itself. The stability of the phototubes, at least of those which had been most recently incorporated into the string, was still very questionable considering the response problems of PMT no. 2, which required much higher voltage on the cruise than in the lab.

However, in examining the data of the cruise itself for tagged pulser events which could be used for corrections, it became apparent that the pulser timing histograms were clearly not looking like they were expected to look, and could not be immediately interpreted in any way consistent with what was known about the electronics configuration. Thus the pulser data was left alone for the time being and the initial corrections were used (along with voltage dependences as determined by relative shifts in LED events) in the chi-square with the aim of possibly selecting a few believable events whose probability exceeded some level as determined by applying the fitting program to a large sample of randomly-generated data.

b)Pulse height

Determining plausible pulse height calibrations for each of the phototubes was seen at first to be of less importance than determining the time corrections. However, the initial fits done only with timing data provided at most only one constraint on the chi-square and were thus not strong enough to reject randomized data, although a possibly significant tail on the probability distribution was seen above about 70 percent chi-square probability.

The problem of pulse height calibration was complicated primarily by the fact that only one of the phototubes (no.1) had been plateaued prior to the cruise, and it was only operated at the plateau voltage for seven out of thirty-seven of the runs. The reasons for these mistakes make them understandable; first, the quality of the PMTs was poor in most cases and no plateaus could be found for any other tubes except the 8 inch versions; second, there was a lack of communication about the objective of changing the voltage of tube 1 during the runs; i.e., the intent was to try to reproduce the known plateau to convince ourselves that we were seeing signal, but instead a new (and incorrect) plateau voltage was "found".

In any case, the attempt at determining the pulse height calibrations centered around a bootstrap process; look at histograms of pulse height where no. 1 was at plateau voltage, and see if these runs could be used to extrapolate to the response curves of the other tubes.

Further Problems

At this point in the analysis a variety of histograms and scatter plots were made; a number of these are shown (figures 1-7) The plots which first showed significant irregularity were the "counts per TDC channel" histograms (fig.s 1,2) for run 4, which was a short run (330 sec.) supposedly dominated by random coincidences, due to the high singles rates. This means that the plot should be essentially "flat" in time; the noise should be an effective random-number generator.

However, a definite time structure can be seen in the plot, and it is not limited to this run alone, but shows up in all the runs, and in all the tubes with almost identical form (fig.s 3-7). Two prominent peaks in the TDC values are seen, and appear in identical channels for all tubes. In particular, the peak at ch. 270 consists of as much as

25 percent of all of the events for each tube. In addition, some of the tubes show even further structure with intermediate peaks occuring, and most show a kind of "hole" at about ch. 100.

At present there is no satisfactory explanation for these problems in the data, and it is difficult to continue analysis until one is obtained, since the problem seems to pervade all the data. The possibilties fall into two categories: either we are seeing some type of strange signal, or we are seeing some artifact of our electronics. Since the string was functioning the night before the cruise and since the system produced normal TDC and ADC histograms at that time, it is tempting to believe that the data represents actual signal in some convoluted way. In this respect the anomalous data is intriguing, but it is difficult to imagine any physical process in the ocean which could yield the structure that is seen, so we expect that the electronics is at fault.

One possible explanation which at first seemed to show promise relates to the nanosecond light pulser. It was noted that the structure of the data closely resembled that of tagged pulser events alone, which were previously noted to have appeared inconsistent with expectations. If the electronics problem were related specifically to the pulser, then it is possible to interpret the appearance of a similar structure in the data as being evidence that the pulser was firing repeatedly (a rate of about 10 hertz would be sufficient) without its software command. Thus the pulser event structure would effectively mask the real data in the histograms.

The problems with this explanation are numerous, however. If the pulser was firing, why were the events not being tagged, when in fact other pulser events (even in cases where no software command had been issued) were tagged? This question is a difficult one to sidestep, since the software tag came from an independent induction coil which in principle sensed the actual high-voltage pulse which initiated the events. Also, what could cause such structure in the timing data of these events? A careful analysis of the hardware timing sequence shows that, although there is an indication that the timing data from tube 5 may have been cut off due to an inadequate delay, there is no obvious way to derive the complex structure that is seen. In addition, there is no a priori reason to assume that the structure is pulser-related, since it could equally well come from some other cause and be superposed on both pulser and non-pulser data alike.

At this point, the possibility of a software error should be mentioned, since it cannot be ruled out. Although, as in the case of the hardware, the IS-11/TERAK data handling was operating correctly before the cruise, there were some minor problems (downloading; communication losses;etc.) which could have been an indication of system bugs. However, very little thought has gone into explanations along these lines; the best response here is probably to try to reproduce the system with the SPS and look for possible problems.

Although promising at first, the final Muon String data requires some very clever interpretation if we are going to make any sense of it, at least as far as the coincidence events go. The singles rates are perhaps still believable, since they were recorded independent of the master trigger/coincidence part of the logic. But identification and reconstruction of muon tracks is presently unfeasible without some model to understand the anomalous data by.

This is not intended as a total abandonment of the problem, however. Given that we had assumed we understood our system when we went to sea, to discover something so foreign to our expectations in the data means that our understanding was much more limited than we believed. For this reason, an explanation is still very desirable, although it may be unverifiable in practice. In particular, if the anomaly is signal-related, however unlikely this may be, then the data may have much greater importance than it appears to. Thus part of the purpose of this report was to present the problem in such a way that it might stimulate some further thought among those involved with the Muon String (or anyone else) toward some kind of explanation. Anything half-plausible (short of submarines and flying saucers) will be entertained.

```
            HTDC1  DISTRIBUTION - RUN     4     20-JUL-82     21:48:00
DA9                                 EVENTS                               COUNT
       0.000      0.200      0.400      0.600      0.800      1.000      1.200
         !          !          !          !          !          !          !
         +----------+----------+----------+----------+----------+----------+!
0.010  -!XXXX                                                             !    78
0.135  -!XXXXXX                                                           !   117
0.259  -!XXXXXXXXX                                                        !   175
0.384  -!XXXX                                                             !    79
0.509  -!XXXXXXXXX!XXXXXXX                                                !   336
0.634  -!XXXXXXXXX!XXXXX                                                  !   291
0.759  -!XXXXXXXX                                                         !   148
0.883  -!XXXXXXX                                                          !   128
1.008  -!XXXX                                                             !    70
1.133  -!XXXX                                                             !    75
1.258  -!XXXXXXXXX                                                        !   167
1.382  -!XXXXXX                                                           !   107
1.507  -!XXXXXX                                                           !   117
1.632  -!XXXXXXX                                                          !   140
1.757  -!XXXXXXX                                                          !   128
1.881  -!XXXXXXX                                                          !   129
2.006  -!XXXXXXXX                                                         !   144
2.131  -!XXXXXXX                                                          !   134
2.256  -!XXXXXXXXX!XXXX                                                   !   274
2.380  -!XXXXXXXX                                                         !   144
2.505  -!XXXXXX                                                           !   117
2.630  -!XXXXXXXXX!XXXXXXXXX!XXXXXXXXX!XXXXXXXXX!XXXXXXX                  !   938
2.755  -!XXXXXXXXX!XXXXX                                                  !   293
2.879  -!X                                                                !    17
3.004  -!X                                                                !     9
3.129  -!X                                                                !     7
3.253  -!X                                                                !     2
3.378  -!X                                                                !     5
3.503  -!X                                                                !     7
3.628  -!X                                                                !    10
3.752  -!X                                                                !     6
3.877  -!X                                                                !     4
4.002  -!X                                                                !     6
4.127  -!X                                                                !     2
4.252  -!X                                                                !     3
4.376  -!X                                                                !     6
4.501  -!X                                                                !     4
4.626  -!X                                                                !     4
4.751  -!X                                                                !     6
4.875  -!                                                                 !     0
         +----------+----------+----------+----------+----------+----------+!
         !          !          !          !          !          !          !
       0.000      0.200      0.400      0.600      0.800      1.000      1.200
DA9                                 EVENTS                               COUNT
      X SCALE FACTOR - 1.0E+02               Y SCALE FACTOR - 1.0E+03
MEAN     176.
SIGMA    94.5
SUM      4.427E+03
LOSUM    1.125E+03
HISUM    1.704E+03
```

15 ns

53 ns

PMT # 1
4-fold coincidence
RUN 4 only
no pulser or LED events

Fig. 1

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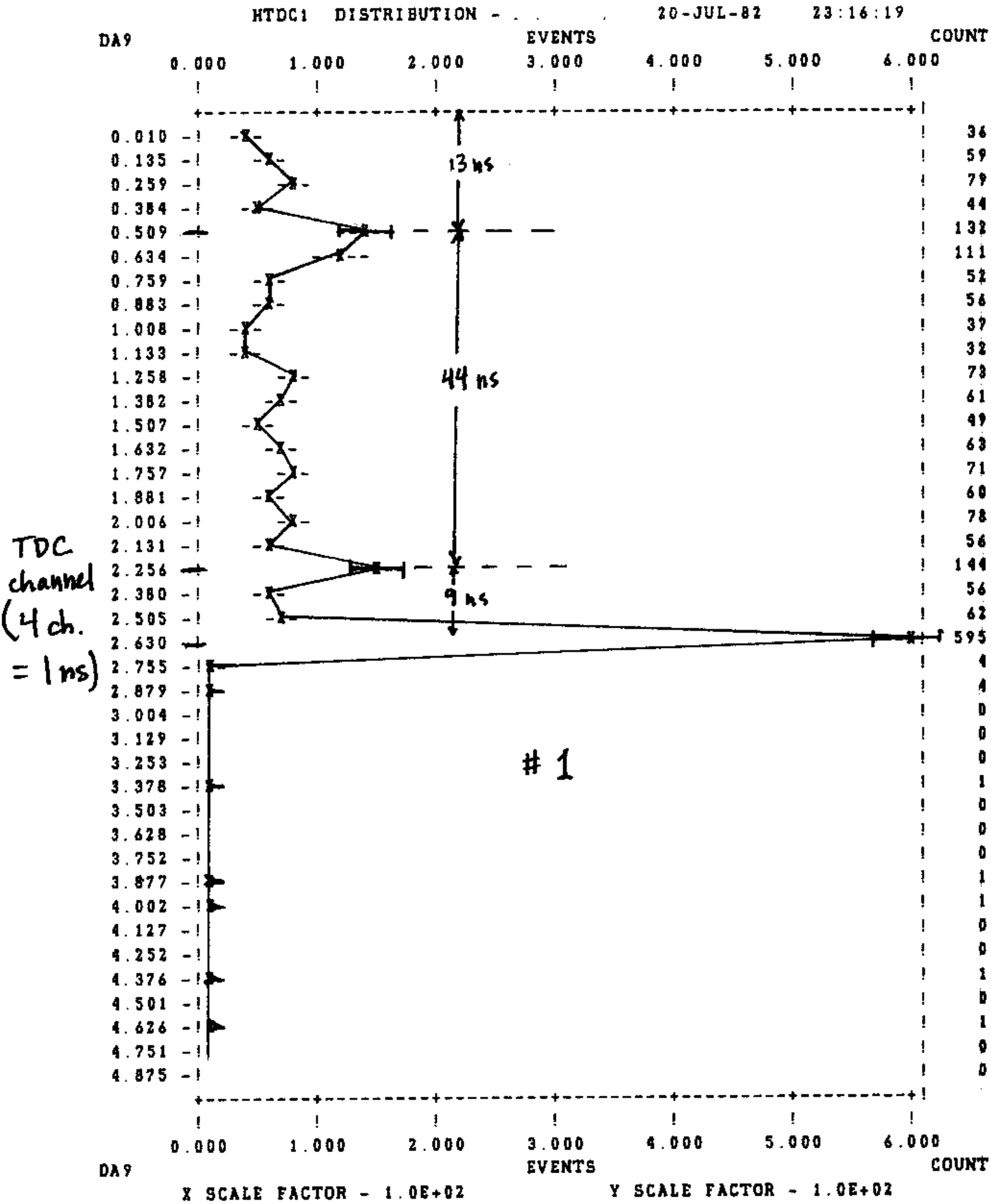
              HTDC3  DISTRIBUTION - RUN    4    20-JUL-82    21:48:25
DA11                                  EVENTS                              COUNT
        0.000     0.200     0.400     0.600     0.800     1.000     1.200
          !         !         !         !         !         !         !
          +---------+---------+---------+---------+---------+---------+!
 0.010 -!XXXXX                                                         !   84
 0.135 -!XXXXXXXXX!X                                                   !  213
 0.259 -!XXXXXXXXX                                                     !  164
 0.384 -!XXXXXXX                                                       !  121
 0.509 -!XXXXXXXXX!XXXXXXXXX!XXXXXXXXX!XXXXXXXXX!X                     !  805
 0.634 -!XXXXXXXXX!XXXXX                                               !  291
 0.759 -!XXXX                                                          !   73
 0.883 -!XXXX                                                          !   69
 1.008 -!XX                                                            !   36
 1.133 -!XXXX                                                          !   72
 1.258 -!XXXXXXXXX                                                     !  177
 1.382 -!XXXXXXX                                                       !  125
 1.507 -!XXXXXX                                                        !  112
 1.632 -!XXXXX                                                         !   83
 1.757 -!XXXXXX                                                        !  119
 1.881 -!XXXXX                                                         !   97
 2.006 -!XXXXXX                                                        !  105
 2.131 -!XXXXX                                                         !   94
 2.256 -!XXXXXXXXX!X                                                   !  204
 2.380 -!XXXXXXXX                                                      !  156
 2.505 -!XXXXX                                                         !   89
 2.630 -!XXXXXXXXX!XXXXXXXXX!XXXXXXXXX!XX                              !  625
 2.755 -!XXXXXXXXX!XXXXXXXXX!X                                         !  418
 2.879 -!XXX                                                           !   48
 3.004 -!X                                                             !    8
 3.129 -!X                                                             !   13
 3.253 -!X                                                             !    5
 3.378 -!X                                                             !   10
 3.503 -!X                                                             !    2
 3.628 -!X                                                             !    8
 3.752 -!X                                                             !    6
 3.877 -!X                                                             !    4
 4.002 -!X                                                             !    4
 4.127 -!X                                                             !    6
 4.252 -!X                                                             !    4
 4.376 -!X                                                             !    6
 4.501 -!X                                                             !    6
 4.626 -!X                                                             !    8
 4.751 -!X                                                             !    5
 4.875 -!X                                                             !    5
          +---------+---------+---------+---------+---------+---------+!
          !         !         !         !         !         !         !
        0.000     0.200     0.400     0.600     0.800     1.000     1.200
DA11                                  EVENTS                              COUNT
          X SCALE FACTOR - 1.0E+02          Y SCALE FACTOR - 1.0E+03
MEAN      159.
SIGMA     102.
SUM     4.480E+03
LOSUM   1.071E+03
HISUM   1.705E+03
```

13 ns

53 ns

PMT #3
4-fold coincidence
RUN 4 only
no pulser or LED events

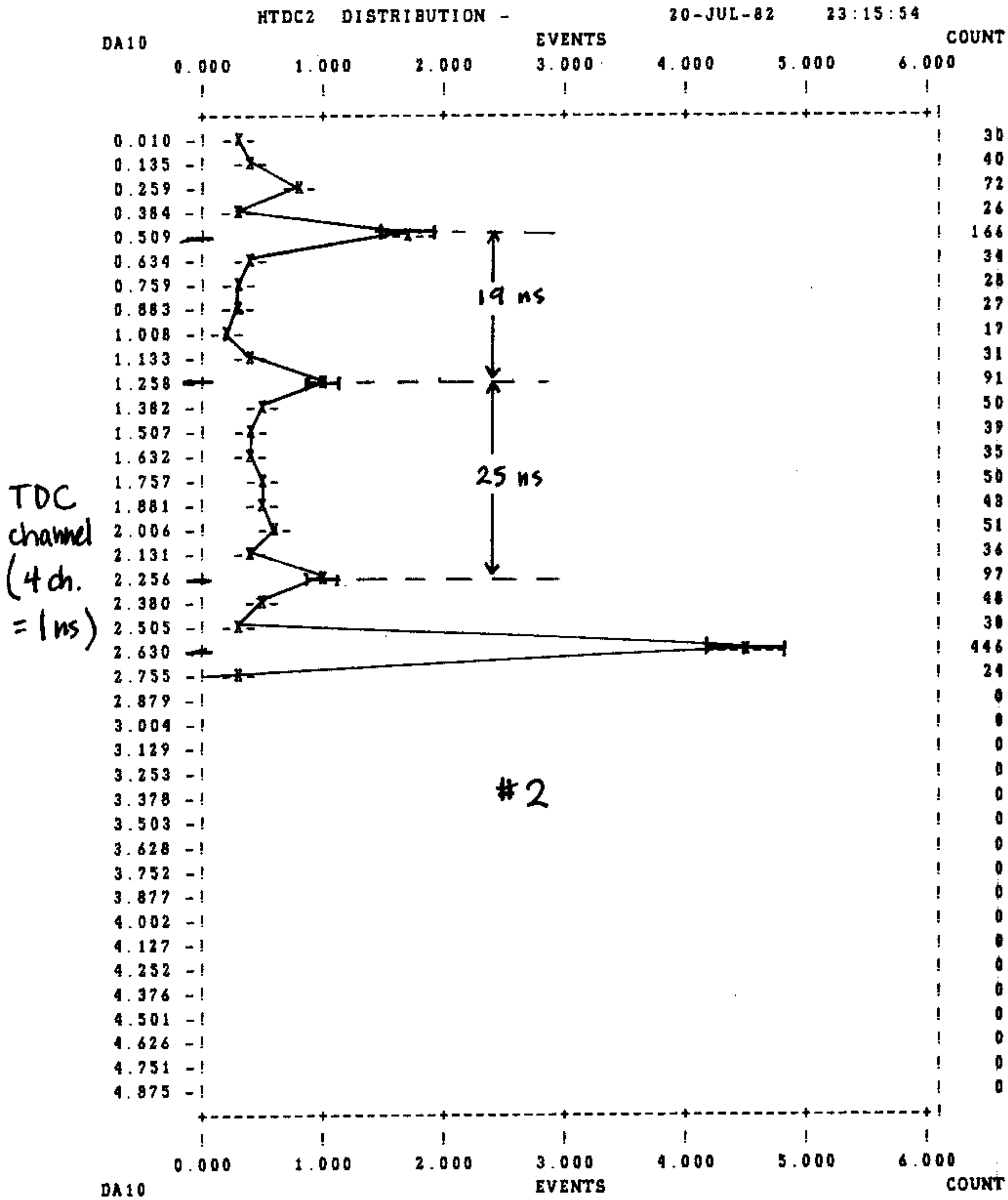
Fig. 2



MEAN 176.
SIGMA 89.5
SUM 2.019E+03
LOSUM 524.
HISUM 724.

RUNS 16-32 combined
No pulser or LED events
(4-folds)

Fig. 3

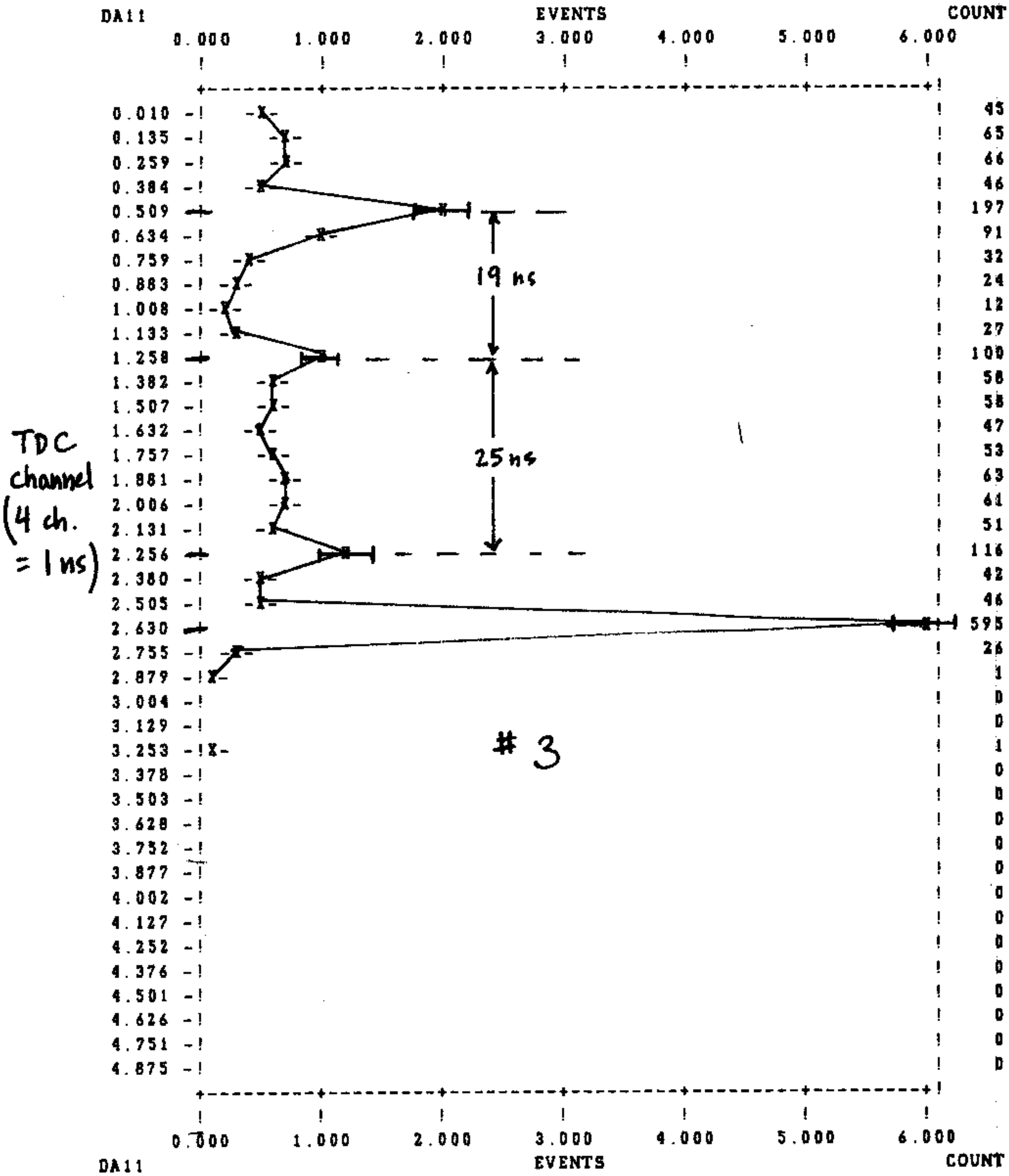


MEAN 174.
SIGMA 90.4
SUM 1.511E+03
LOSUM 378.
HISUM 1.378E+03

Runs 16-32 combined
no pulser or LED events
(4-folds)

Fig. 4

HTDC3 DISTRIBUTION - . . . 20-JUL-82 23:15:29

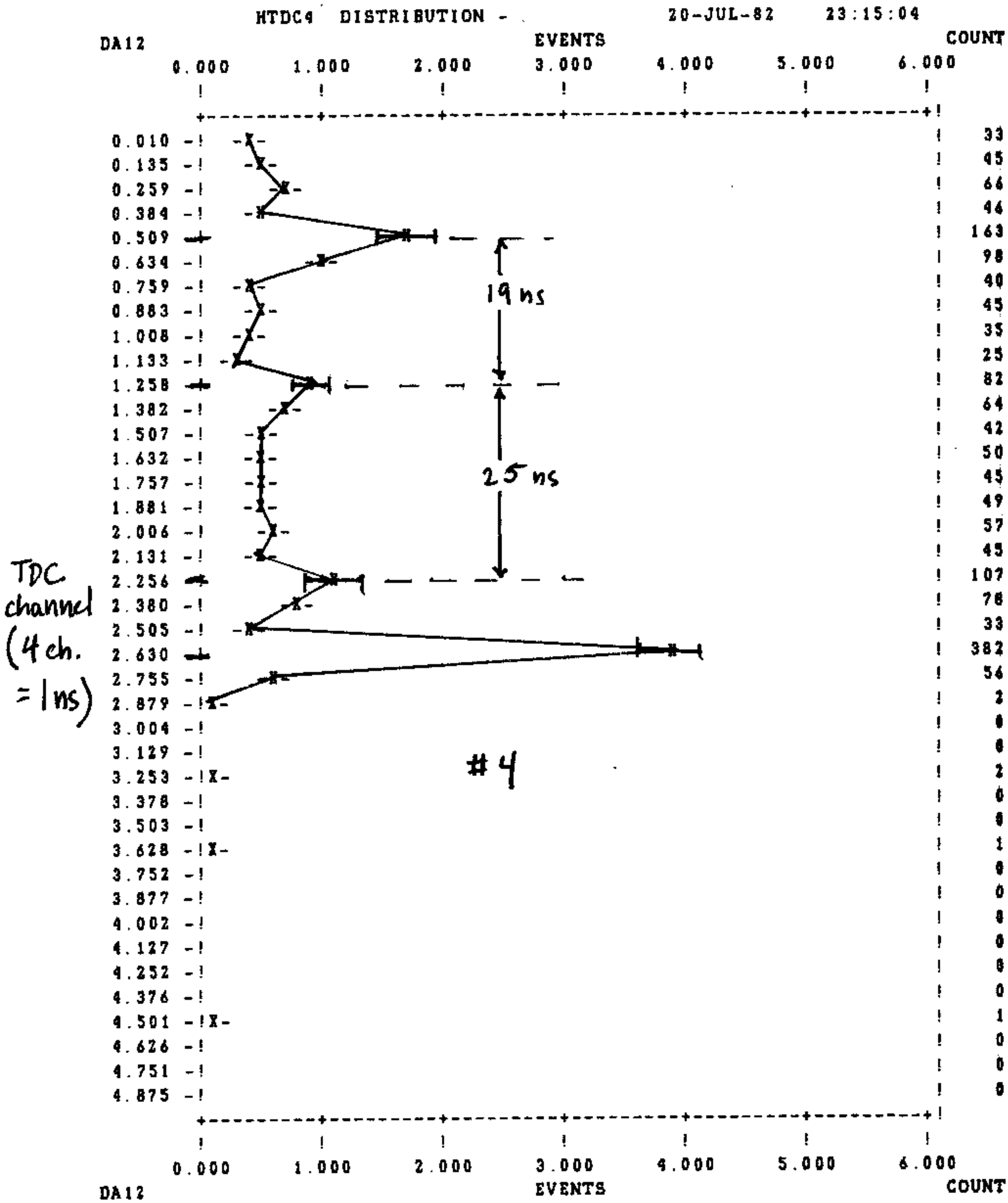


X SCALE FACTOR - 1.0E+02 Y SCALE FACTOR - 1.0E+02

MEAN 174.
SIGMA 91.8
SUM 1.923E+03
LOSUM 518.
HISUM 826.

Runs 16-32 combined
no pulser or LED events
(4-folds)

Fig. 5

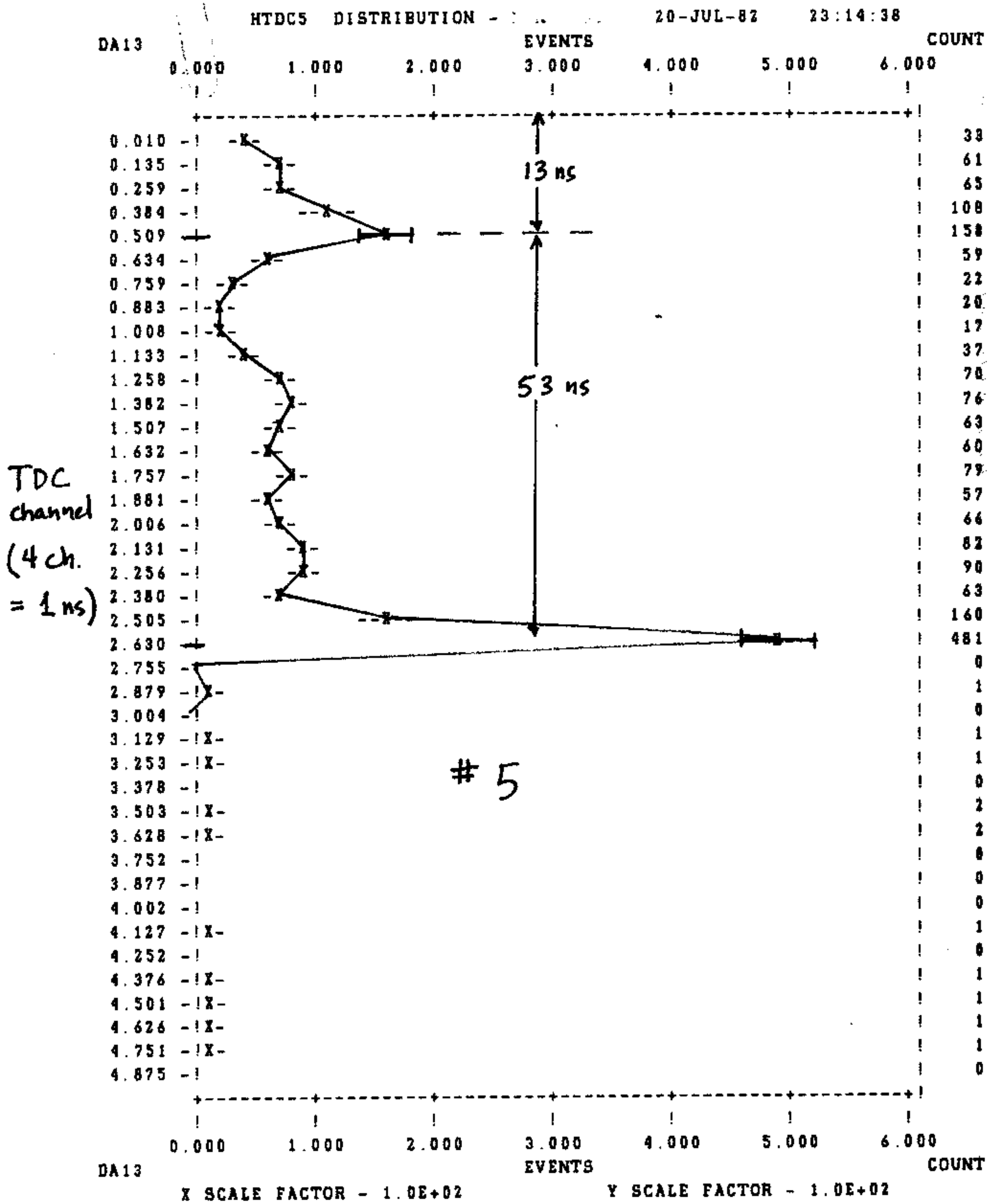


X SCALE FACTOR - 1.0E+02 Y SCALE FACTOR - 1.0E+02

MEAN 167.
SIGMA 90.4
SUM 1.692E+03
LOSUM 317.
HISUM 1.258E+03

Runs 16-32 combined
no pulser or LED events
(4-folds)

Fig. 6



MEAN 175.
SIGMA 90.6
SUM 1.939E+03
LOSUM 495.
HISUM 833.

Runs 16-32 combined
no pulser or LED events
(4-folds)

Fig. 7