Filtering and Tracking Efficiency

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In this note the filtering and tracking efficiencies are determined. The filtering efficiency is defined as the percentage of events passing the event cleaning filters. The tracking efficiency is defined as the percentage of filtered events that are successfully tracked. One may also wish to compute a track-to-trigger ratio which may be obtained by multiplying the filtering efficiency by the tracking efficiency.

As may be seen from column A in table 1, a filtering efficiency as high as 97% may be obtained. About 1% of the triggers have no DC hits, while a similar percentage have less than 6 DC planes firing. Another 1.6% of the events are rejected due to the presence of more than 4 hits in at least one plane.

Since most events in this file are 120 MeV/c pions at normal incidence, most events will fire only one cell in each plane. Multiple scattering, cross talk and noise hits will result in multiple plane hits as will tracks with non-zero θ angles. A crude way to eliminate events with noise and cross talk hits (for purposes of testing) is to reject events with high plane multiplicity. The extreme case of rejecting all events with more than a single hit is considered in column B of table 1. In this case 71.5% of the events pass the filter while 27% of the events are rejected due to this requirement. Column C requires less than 3 hits per plane, while column D is the same as column B (but different tracking conditions are imposed later as will be discussed below). Figures 1, 3, 5, and 7 show histograms of the failure codes for all 4 cases.

Failure Code	Test	Percentage			
		A	B	C	D
0	pass	96.7	71.5	89.7	71.5
2	no hits in the DC	0.9	0.9	0.9	0.9
11	$>$ N hits/ DC plane	1.6	27	8.6	27
12	$<$ 6 DC planes fired	0.8	0.8	0.8	0.8

Table 1: Percentage of events passing the cleaning filters. Case A: N=4; case B: N=1; case C: N=2; case D: N=1.

All events passing the cleaning filters are sent to the tracking. Of these events 60% are successfully tracked in case A, as may be seen from table 2. About 4% of the events result in less than 3 U or 3 V planes firing, such events are likely to be cases where a track fired only the first few planes before exiting the active area of the chamber, or cases where only noise hits were present in the chamber. Although this percentage might appear to be inconsistent with failure code 12 in table 1, a direct comparison is not possible since some hits with a TDC width smaller than 100 ns have been excluded prior to tracking. In addition the tracking requires at least 3 U and 3 V planes to fire whereas the filter cut requires a minimum of any 6 planes to fire. Only 0.4% of the events fail the Kalman filter, while 36% of the events result in a $\chi^2 > 20$. Figure 2 shows the χ^2 and residuals distributions for case A.

In case B where events with more than 1 hit/plane were rejected, an extra 10% of the events are successfully tracked as a result of a higher ratio of events passing the χ^2 cut. As discussed above, this is to be expected since higher plane multiplicity events are likely to contain noise and cross talk hits that escaped the TDC width cuts. Figure 4 shows the χ^2 and residuals distributions for case B.

Case C rejects events with plane multiplicity higher than 2. However, in this analysis an attempt was made to exclude the outliers, defined as hits with residuals $> 5\sigma(r)$ where r is the distance from the wire. In this case 62% of the events are successfully tracked, while 33% fail the χ^2 cut. This is not particularly surprising, since resolution variations exist between the various planes, while the same resolution function is currently used for all chambers in this analysis. In addition, time zero calibrations have not been optimized. As the various calibrations (including resolution) are further tuned, determination of the outliers will be more efficient. Figure 6 shows the χ^2 and residuals distributions for case C.

Case D requires a single hit per plane, but differs from case B by attempting to exclude outliers as in case C. The percentage of successful tracks is very similar to case B. Figure 8 shows the χ^2 and residuals distributions for case D.

Failure Code	Test	Percentage			
		A	B	C	D
0	pass	59.6	69.2	61.9	68.5
1	< 3 U or < 3 V	4.4	4.4	5.0	5.1
4	failed Kalman	0.4	0.0	0.1	0.0
8	$\chi^2 > 20$	35.6	26.4	33.0	26.4

Table 2: Percentage of events successfully tracked. Case A: N=4, noise not excluded; case B: N=1, noise not excluded; case C: N=2, noise excluded; case D: N=1, noise excluded.

Since cases where there are less than 3 U or 3 V hits do not go through the tracking code, the inclusion of these in calculating the "tracking efficiency" is inconsistent with the definition above. Table 3 shows the same percentages corrected for the number of events where there are insufficient planes firing.

Failure Code	Test	Corrected Percentage			
		A	B	C	D
0	pass	69.2	72.4	65.1	72.2
1	< 3 U or < 3 V	0.0	0.0	0.0	0.0
4	failed Kalman	0.4	0.0	0.15	0.0
8	$\chi^2 > 20$	37.3	27.6	35.0	27.8

Table 3: Same as table 2, but percentages are corrected for the number of events with insufficient chamber hits.

Table 3 shows some interesting quantities related to the tracking for all 4 cases. One can clearly see the improvement in the χ^2 mean and in the σ of the residuals distribution as more stringent conditions are imposed to exclude outliers. The CPU time per event is also listed in table 4 for three of the four cases. When hits with "high" plane multiplicities are not filtered out, it takes extra tracking iterations to find and exclude the outliers resulting a in 20%-30% increase in cpu time.

	A	B	C	D
χ^2_{mean}	3.9	3.6	2.0	1.75
Resid RMS (μm)	193	190	160	158
σ (μm)	67	64	50	45
CPU/event (ms)	18		21	15

Table 4: Tracking quantities and CPU time.

This note is provided as a summary of where things stand at the moment. The tracking efficiency in particular depends strongly on calibrations, such as in the discussion above regarding the the rejection of outliers, as well as in the determination of the χ^2 cut. Similarly, the ability of the code to recognize outliers requires good calibrations as well as code fine-tuning. Perhaps one of the interesting things apparent in this note is the robustness of the Kalman filter with failures in the range of 0%-0.4%.

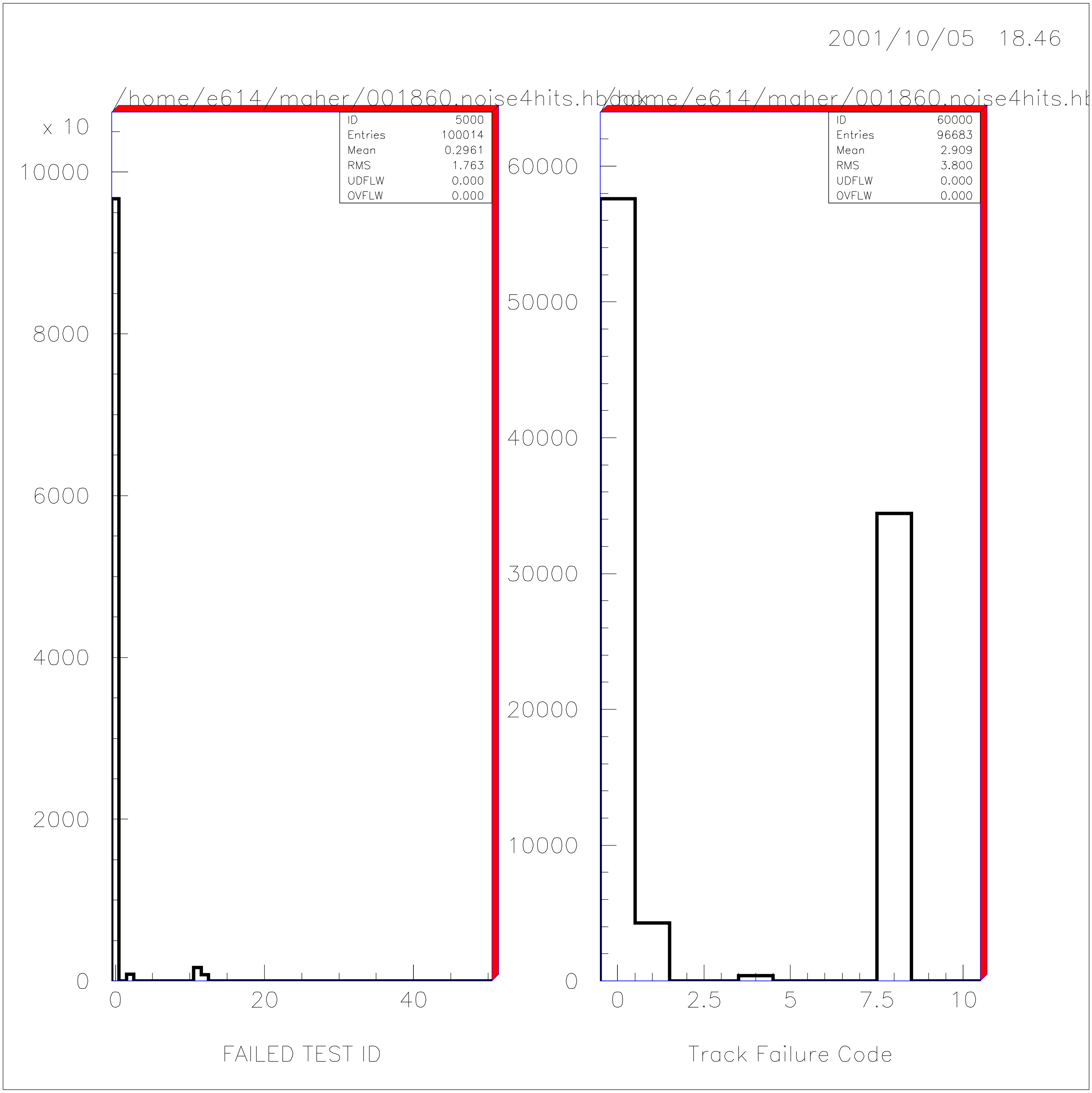

Figure 1: Event filtering failure code (left) and tracking failure code (right) for case A (see text).

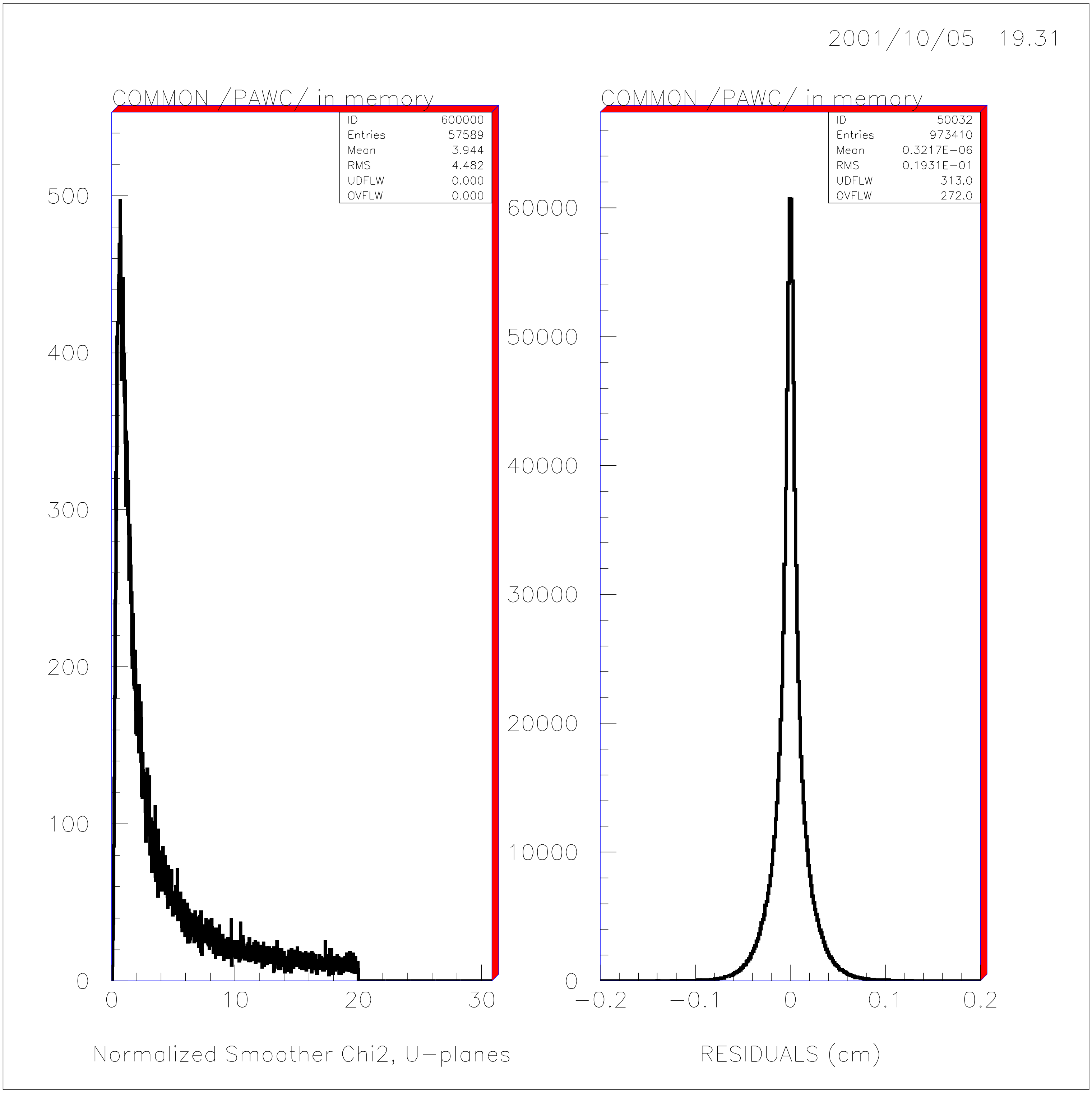

Figure 2: Kalman smoother χ^2 (left) and tracking residuals (right) for case A (see text).

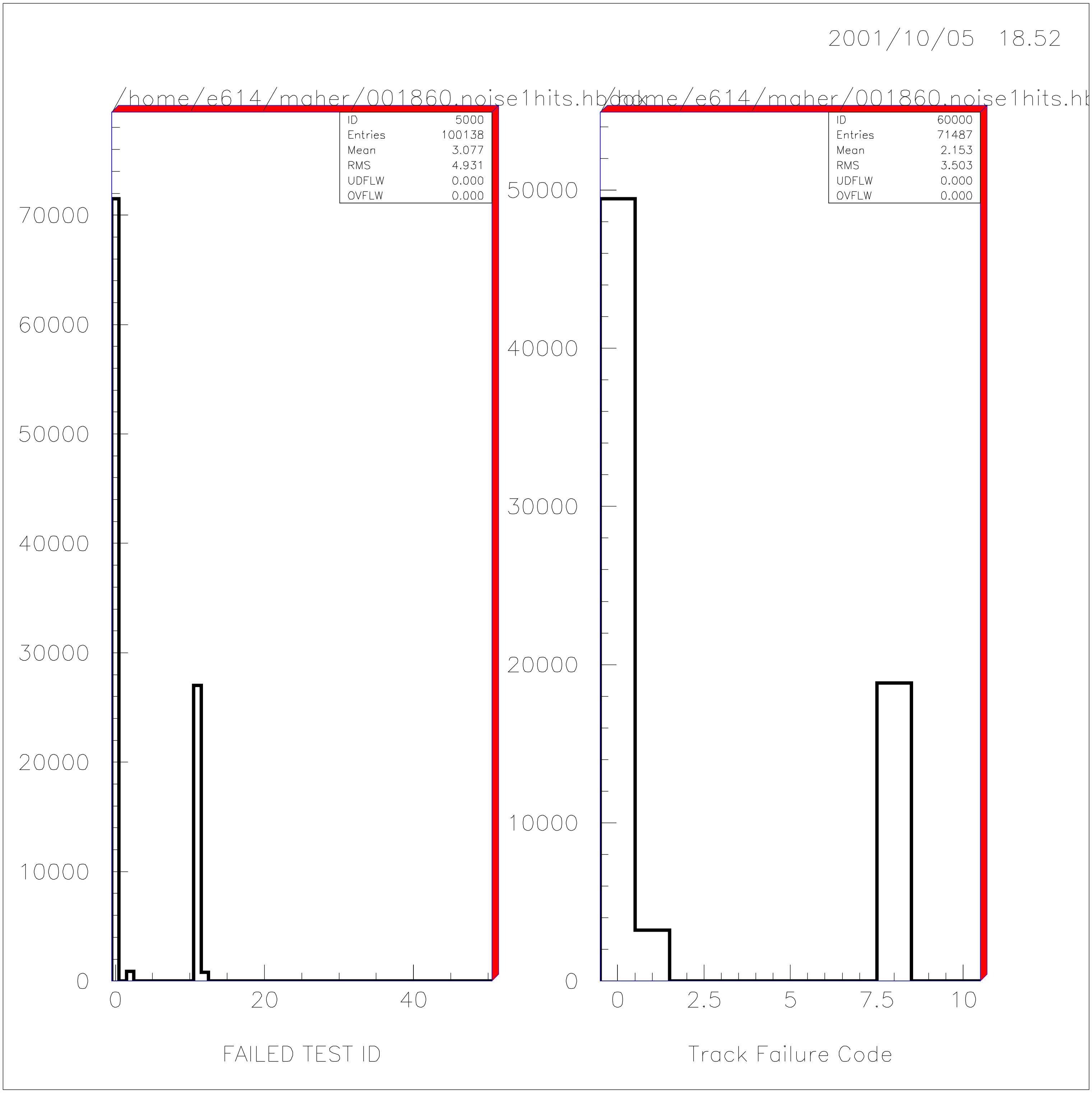

Figure 3: Event filtering failure code (left) and tracking failure code (right) for case B (see text).

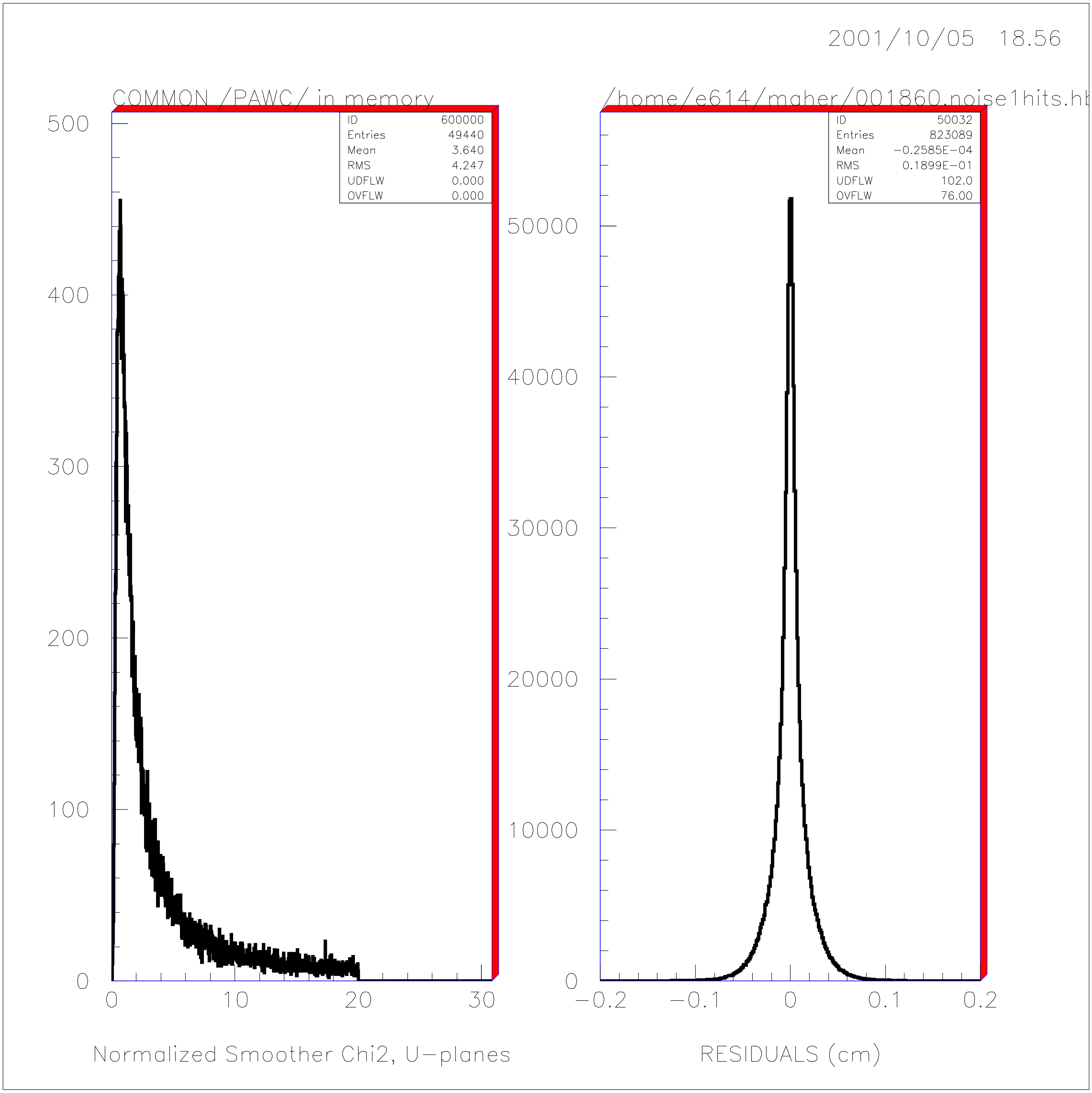

Figure 4: Kalman smoother χ^2 (left) and tracking residuals (right) for case B (see text).

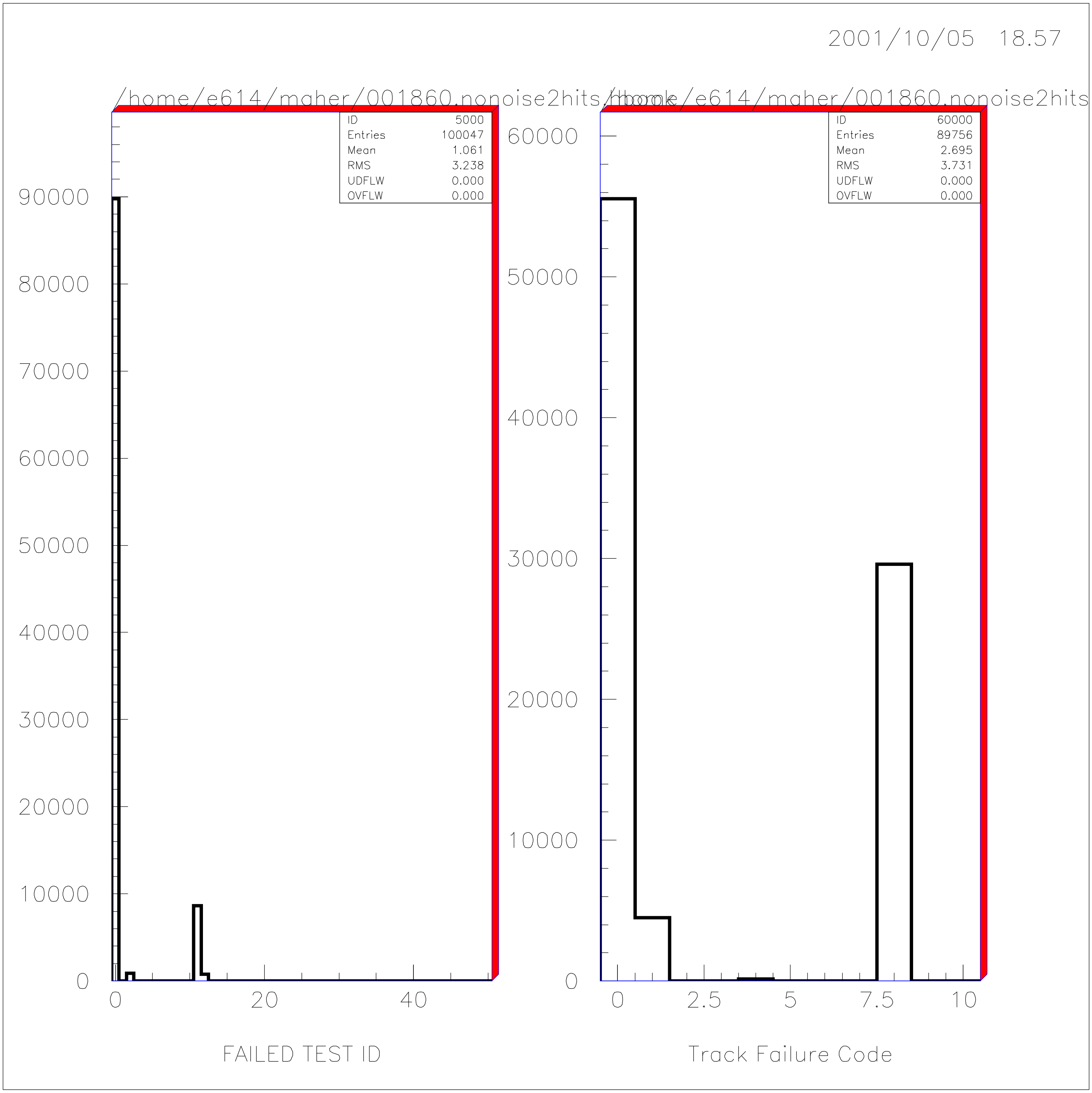

Figure 5: Event filtering failure code (left) and tracking failure code (right) for case C (see text).

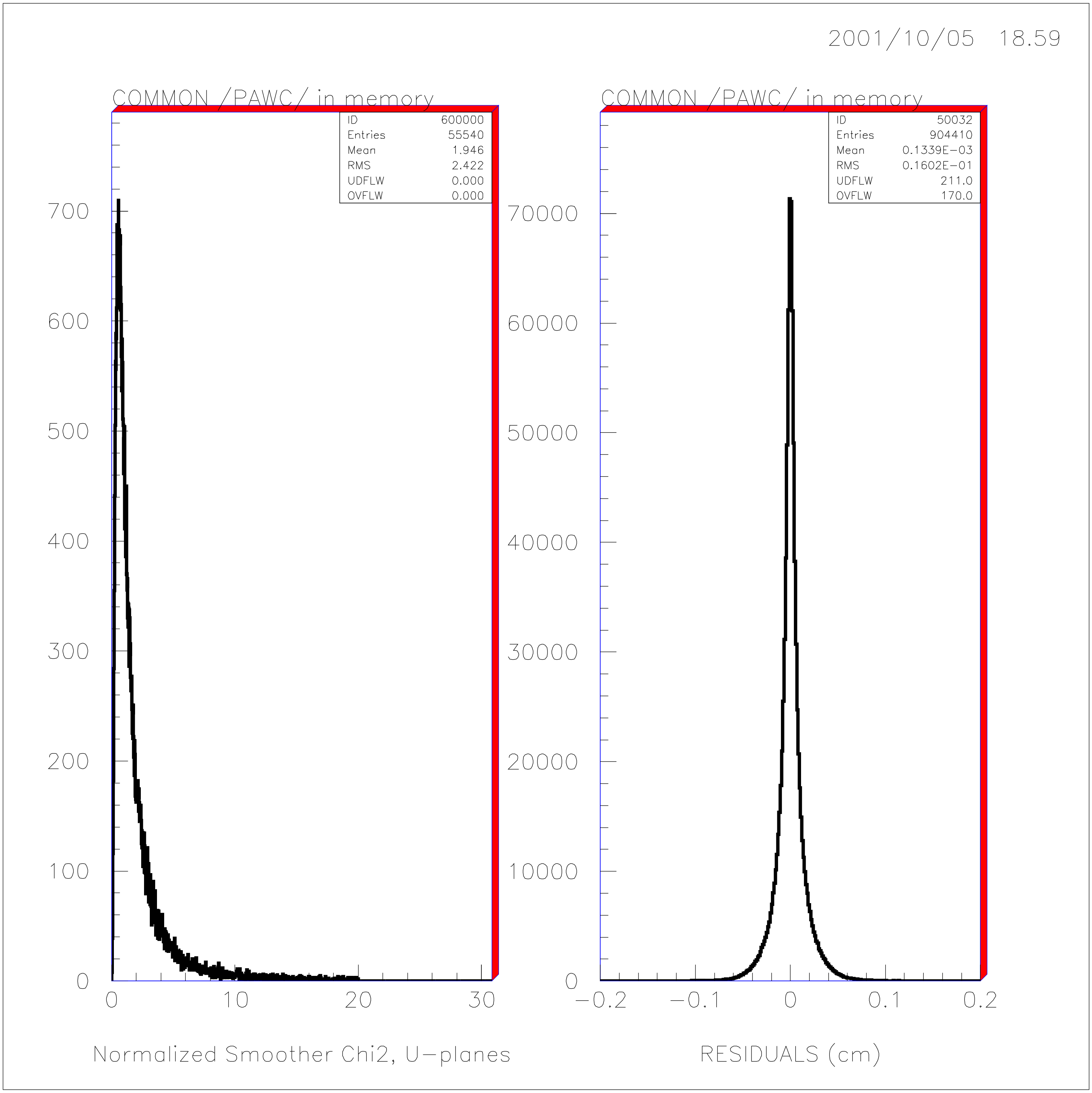

Figure 6: Kalman smoother χ^2 (left) and tracking residuals (right) for case C (see text).

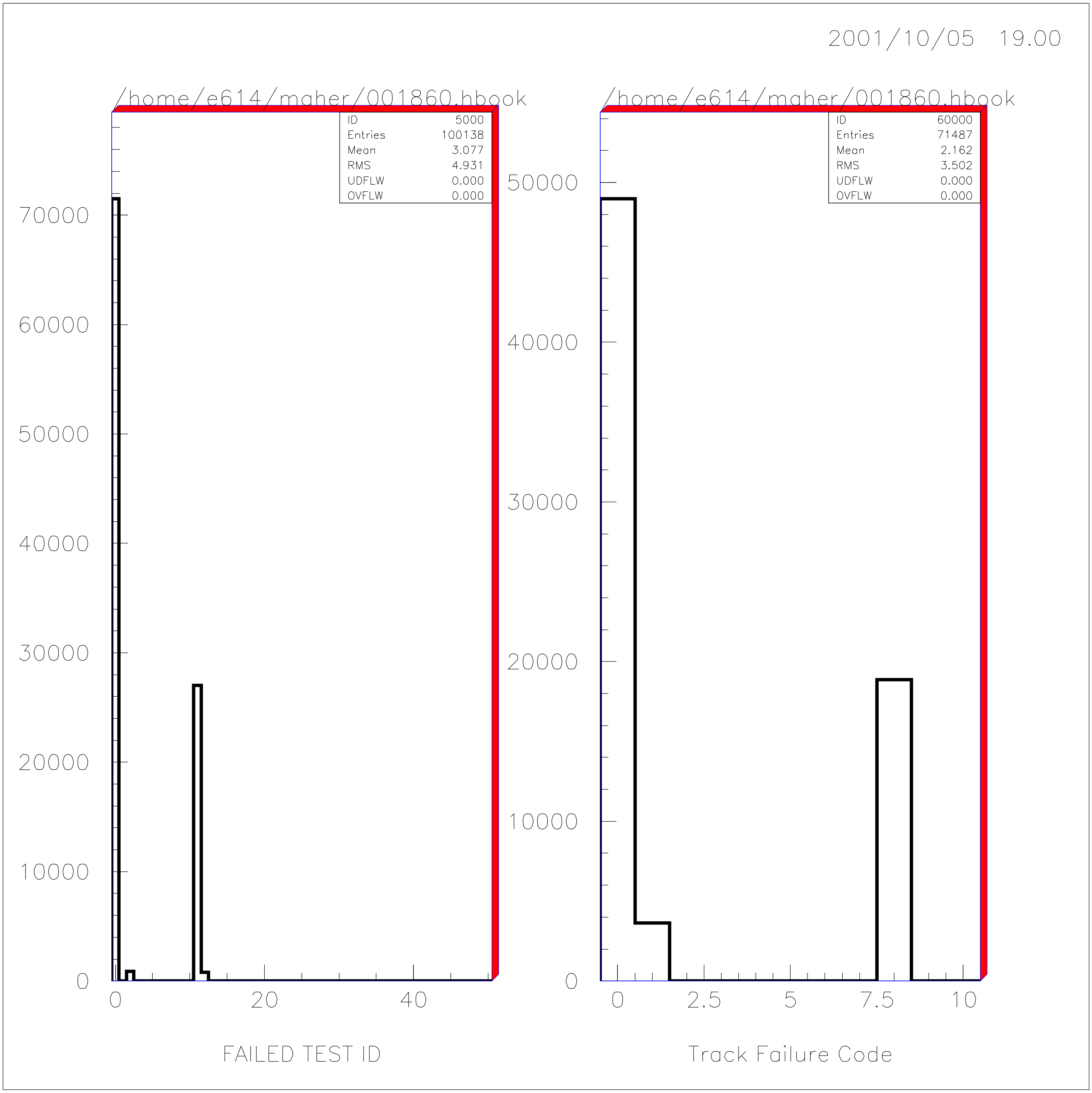

Figure 7: Event filtering failure code (left) and tracking failure code (right) for case D (see text).

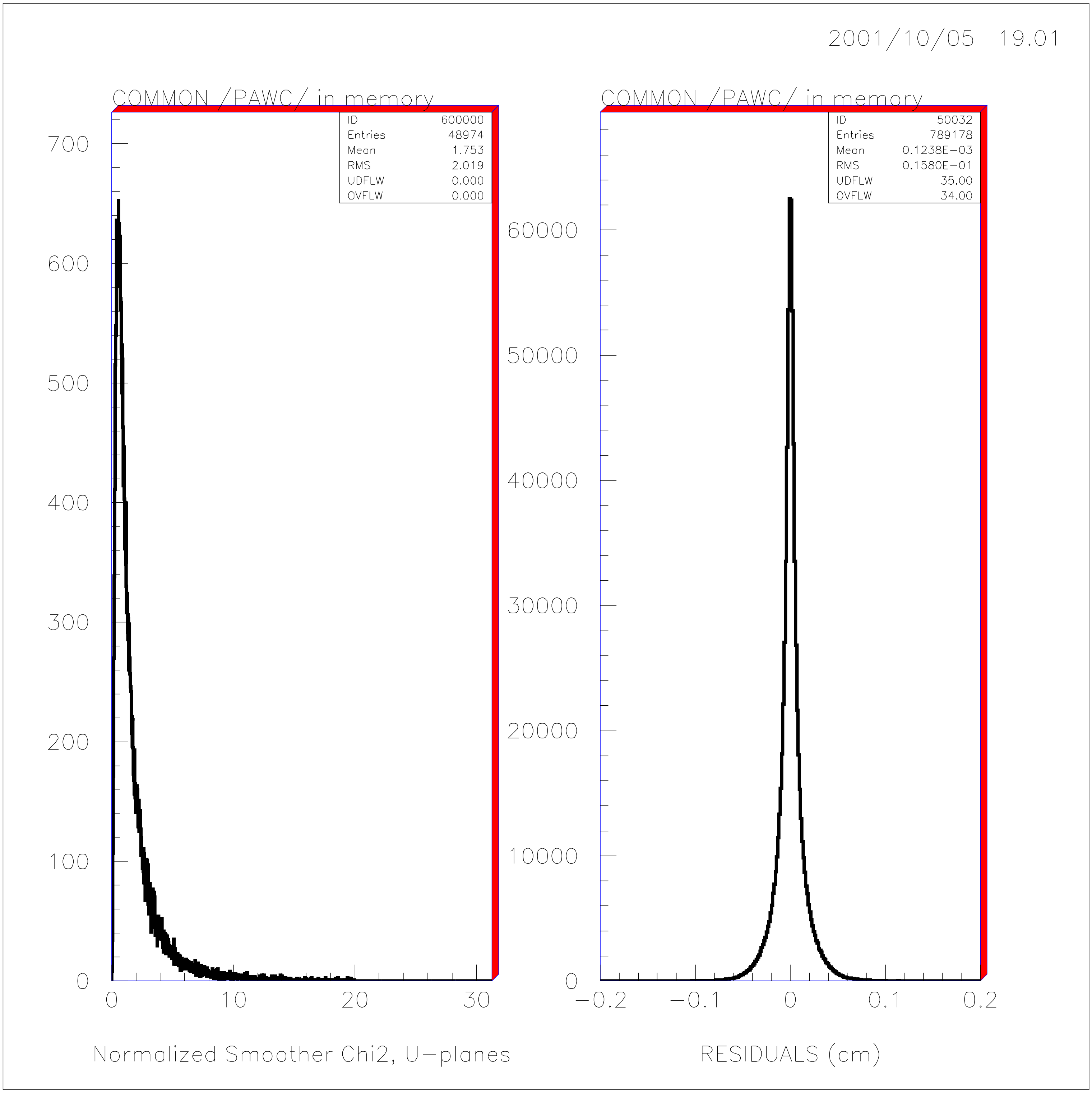

Figure 8: Kalman smoother χ^2 (left) and tracking residuals (right) for case D (see text).