Linearity investigation of ADC-TDC modules

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Abstract

Results of new USB-electronics calibration data processing are presented in this note. Analyzed data have been collected in July 2009. Studies of this calibration data allow us to estimate electronics linearity.

1 Introduction

During DIRAC setup upgrading some modifications of readout system was performed. New electronics was implemented for the following detectors: X-plane of scintillation fiber detector, ionisation hodoscope, horizontal hodoscopes and vertical hodoscopes, aerogel Cherenkov counters, heavy gas Cherenkov counters, nitrogen Cherenkov counters. Calibration data have been collected to examine electronics linearity. The following method has been used for this: input signals with different amplitudes were generated and measured output signal values were filed.

2 Data processing

2.1 Experimental data processing and calibration data analysis

The first part of data processing was experimental data studying. For this, run number 8898 taken in July 2009 have been selected. At first, hits associated with track have been selected. For different detectors various event pairs have been chosen: $\pi^+\pi^-$ pairs for scintillation fiber detector (ScFi), ionisation hodoscope (IH), vertical hodoscopes (VH), horizontal hodoscopes (HH), heavy gas Cherenkov counters (CHF), aerogel Cherenkov counters (CHA) and e^+e^- pairs for nitrogen Cherenkov counters (CHN). Finally 726 histograms containing event distributions have been plotted: 480 for ScFi X-plane, 64 for IH, 80 for VH, 64 for HH, 22 for CHN, 10 for CHF, 6 for CHA. There is an example of amplitude distribution for the column 50 of ScFi X-plane in Figure 1.

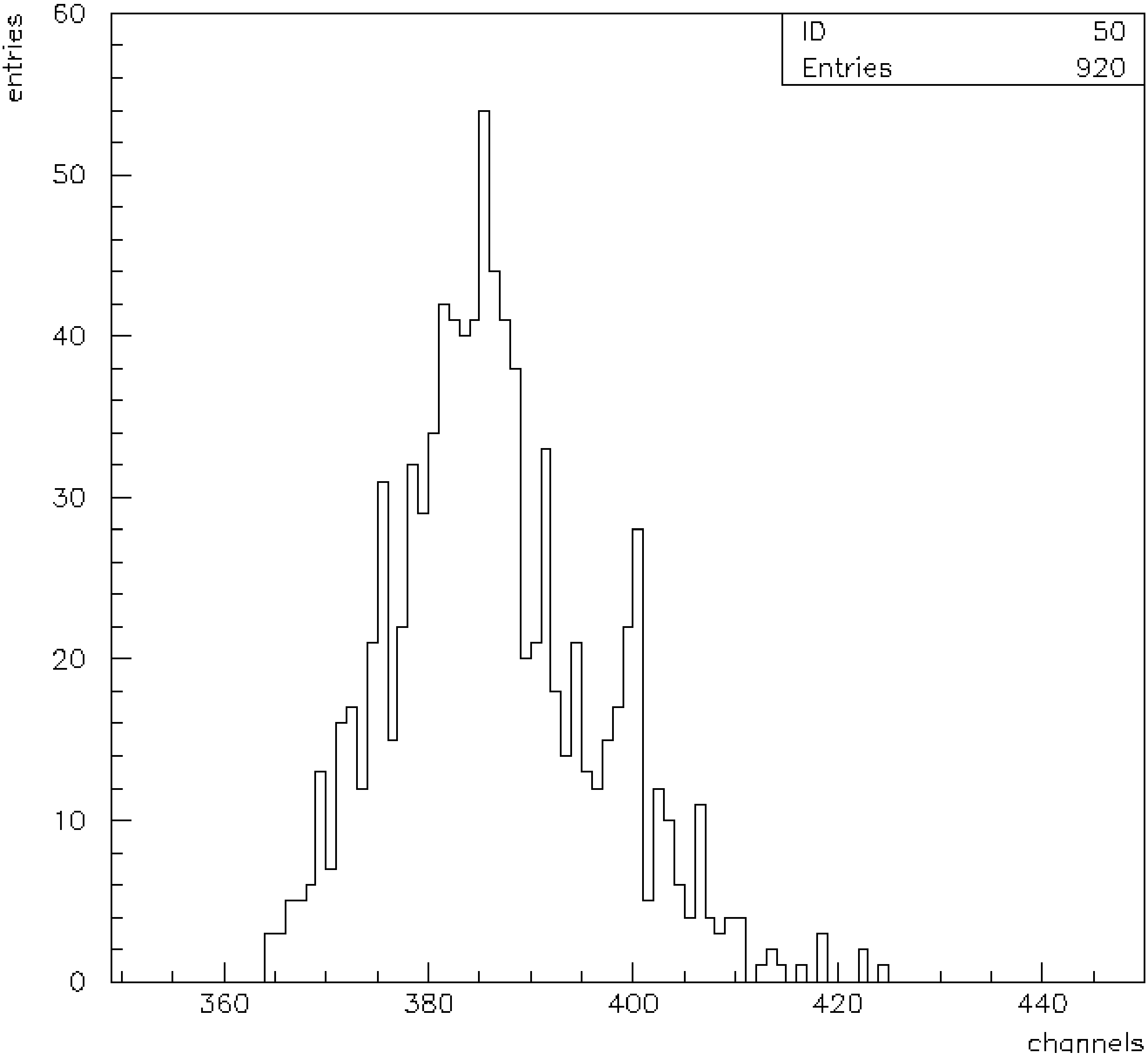


Figure 1. Events distribution in column 50 of ScFi X–plane

The second part of data handling was calibration data processing. Calibration files contain data structured in increasing order of electronics channels indices (the order of electronics modules.). The best part of work was determination of consistency between channels indices and detectors parts (slabs, photomultipliers, etc.). The next step was to convert structured data to the format analyzable through PAW. In consequence of these procedures we got an offing to plot calibration data and events distributions together. (Figure 2). The main purpose of these data presentation was to verify if real signal appears within electronics working range. An analysis of these histograms has showed that not all signals meet this requirement. But separate detectors consideration allows to get new requirements.

2.2 Analysis of calibration data for the scintillation fiber detector

ScFi is used for reliable particle detection. Additional requirement is a possibility to resolve charges from one or two particles crossed one column together with X-planes of IH. There is an example of satisfactory calibration in Figure 2. A major part of signal appears in linear range. ADC-TDC detects signals which have maximal amplitude above certain threshold. But measured quantity is a charge which depends both on an amplitude and a shape of the signal. Experimental signals have effectively narrower width and minimal charge of experimental about 2 times less then minimal calibration one. In November of 2009 there were an attempt to obtain a calibration with low threshold. Unfortunately the behavior was unstable: see a lot of wrong points in Figure 3.

For the resolution of a charge from one or two particles an interval (390:400) is a boundary between single and double amplitudes. It may be seen that this interval is also located within linear region. An example of controversial calibration is presented in Figure 4. Although a major part of the signal appears in a range of nonzero calibration values, calibration curve is not linear in this region.

The analysis results has showed that signals in ScFi generally appear at the beginning of calibration. It was concluded through visual evaluation that a half of ScFi calibration data has wavy structure in region under consideration. Results of calibrations with linear fit and polynomial interpolation have been compared to check an influence of non-linearity on amplitude resolution (see next section).

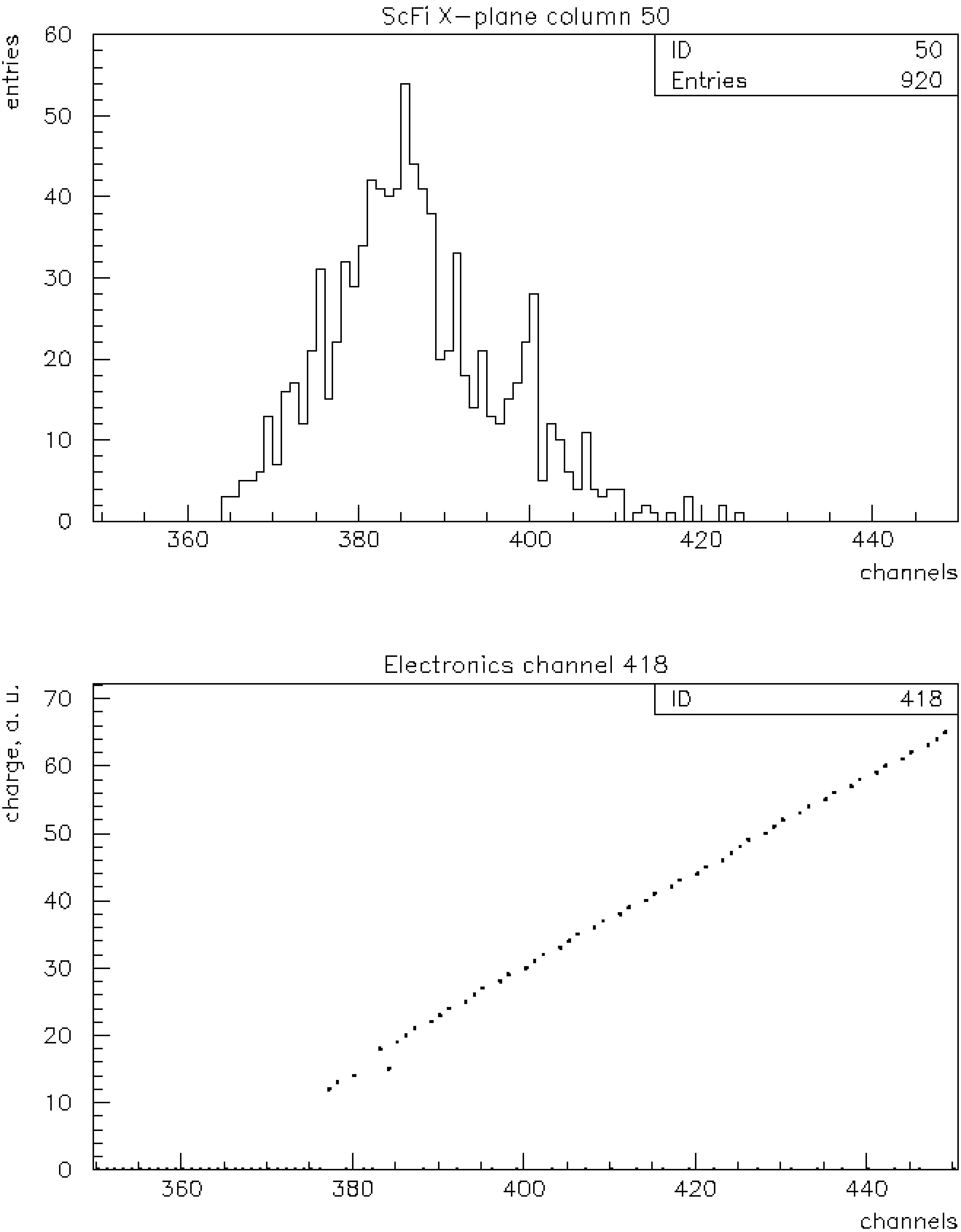
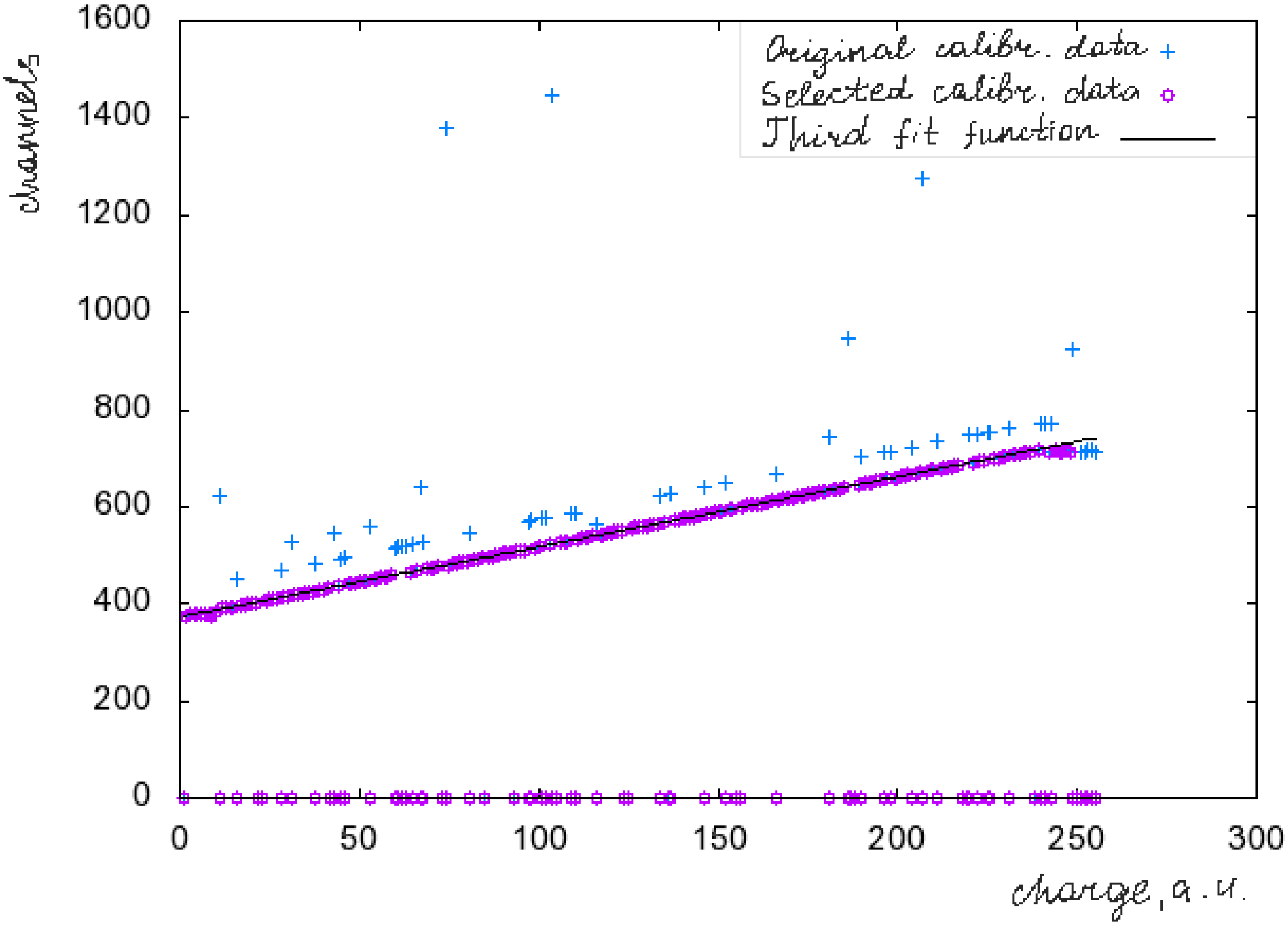


Figure 2. Comparison of signal position with calibration data

Figure 3. 2009-11-17 calibration data, histogram 507 (IH X2-plane slab 11)



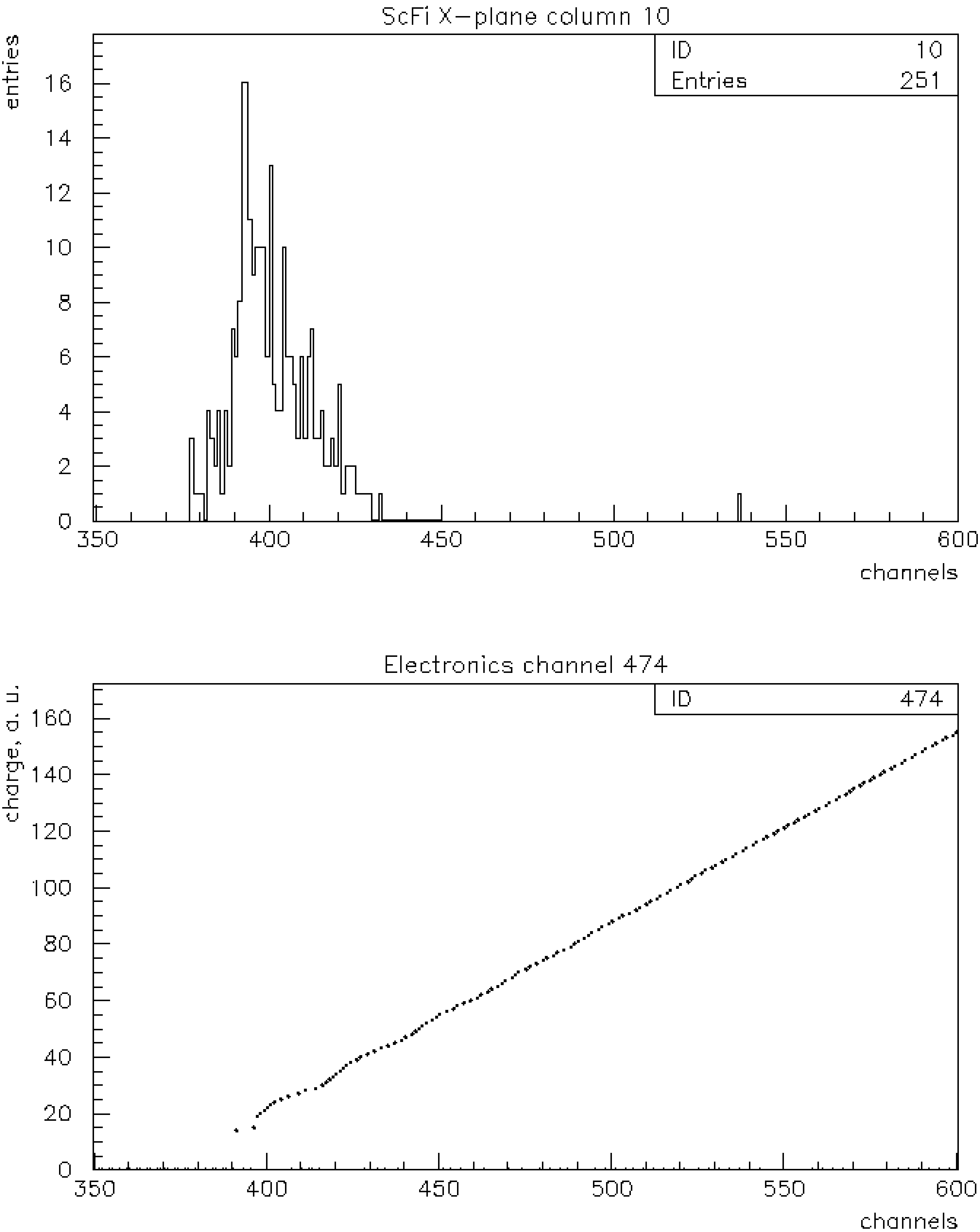


Figure 4. Comparison of signal position with calibration data

2.3 Other detectors with USB electronics

Main requirement for IH is distinguishing of the charge from one or two particles. The analysis of data has showed that in all instances the signal appears within calibration data range (Figure 5). Only three calibration histograms have insignificant wavy structure (Figure 6).

VH and HH should detect particles and in addition to this should have necessary amplitude resolution. Typical histograms for VH and HH are shown in Figure 7 and Figure 8 respectively. As in case of IH almost all calibrations for these detectors are linear.

All Cherenkov counters should also detect particles. In case of CHA and CHF an amplitude measurements are preferred. For these detectors the signal sometimes appears in a region lying before calibration beginning (Figure 9-11). The behavior of calibration curves allows to hope that dependence is linear below the threshold for calibrations.

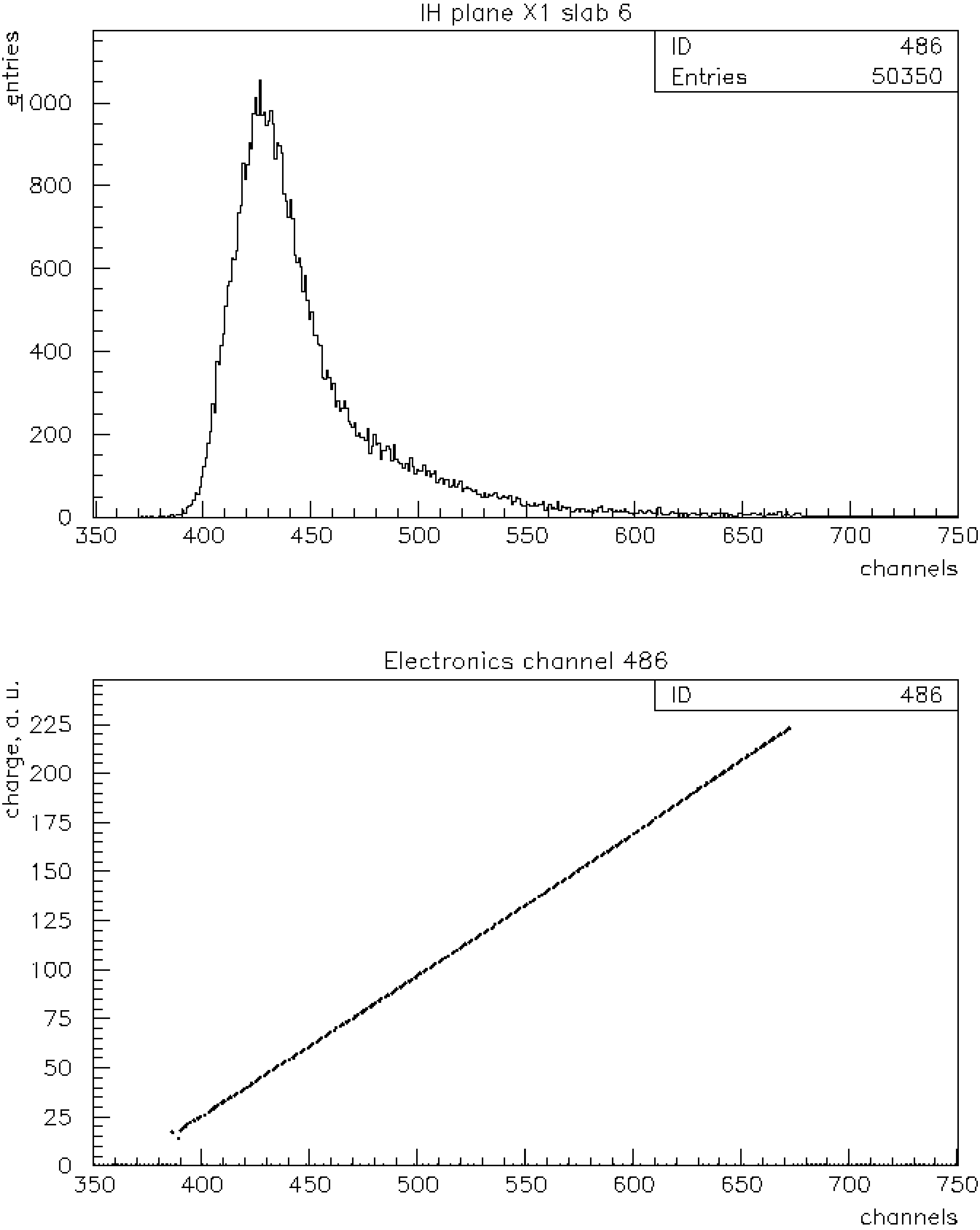


Figure 5. Comparison of signal position with calibration data

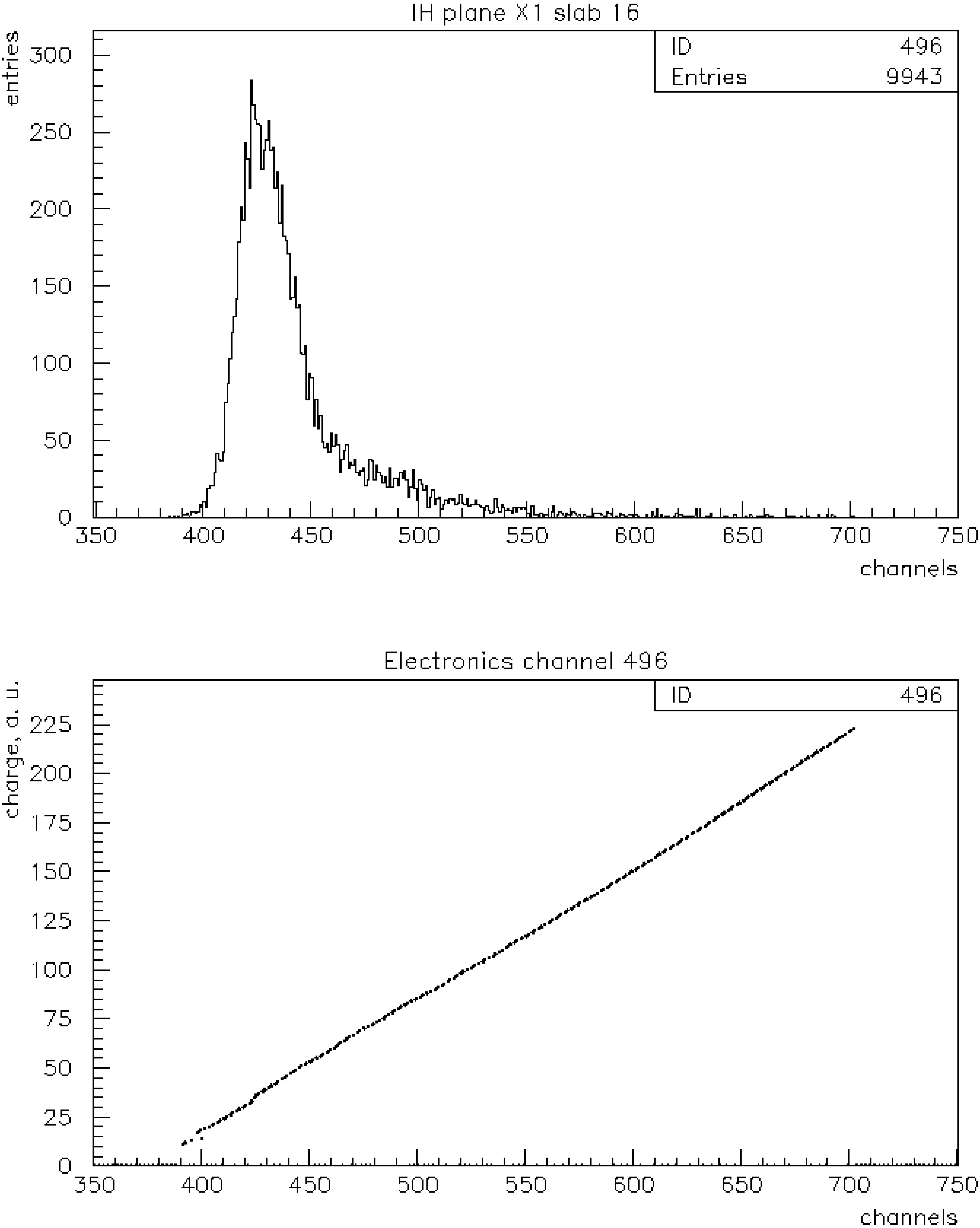


Figure 6. Comparison of signal position with calibration data

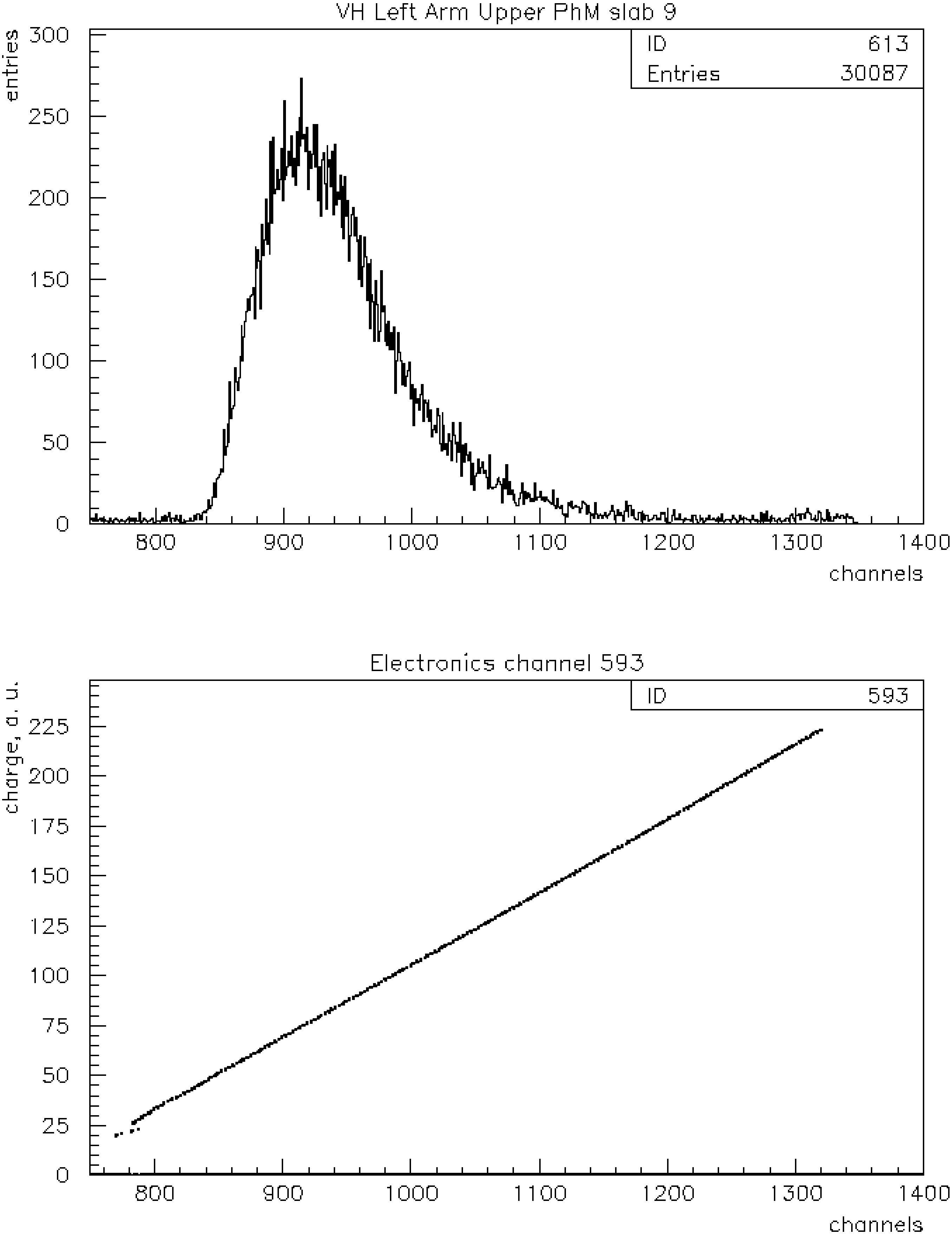
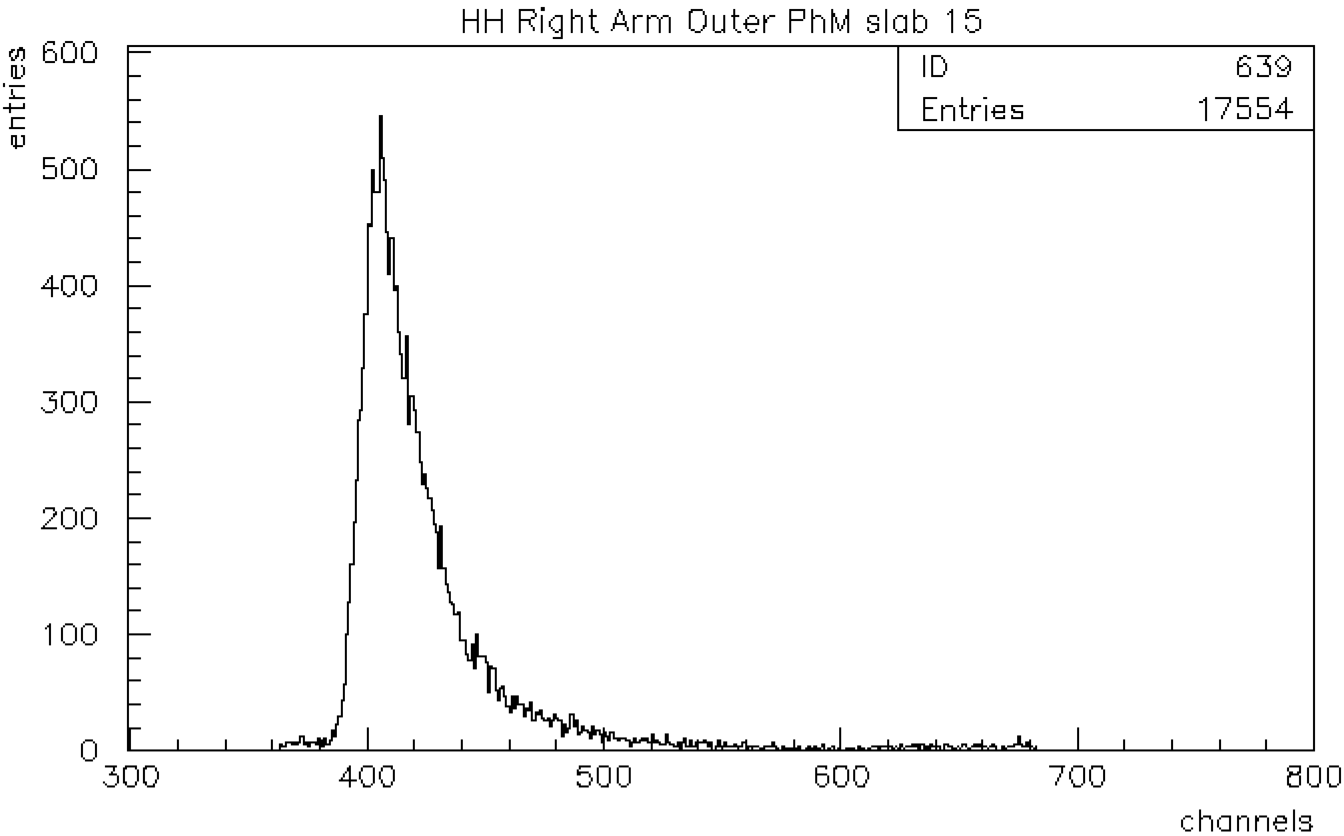


Figure 7. Comparison of signal position with calibration data



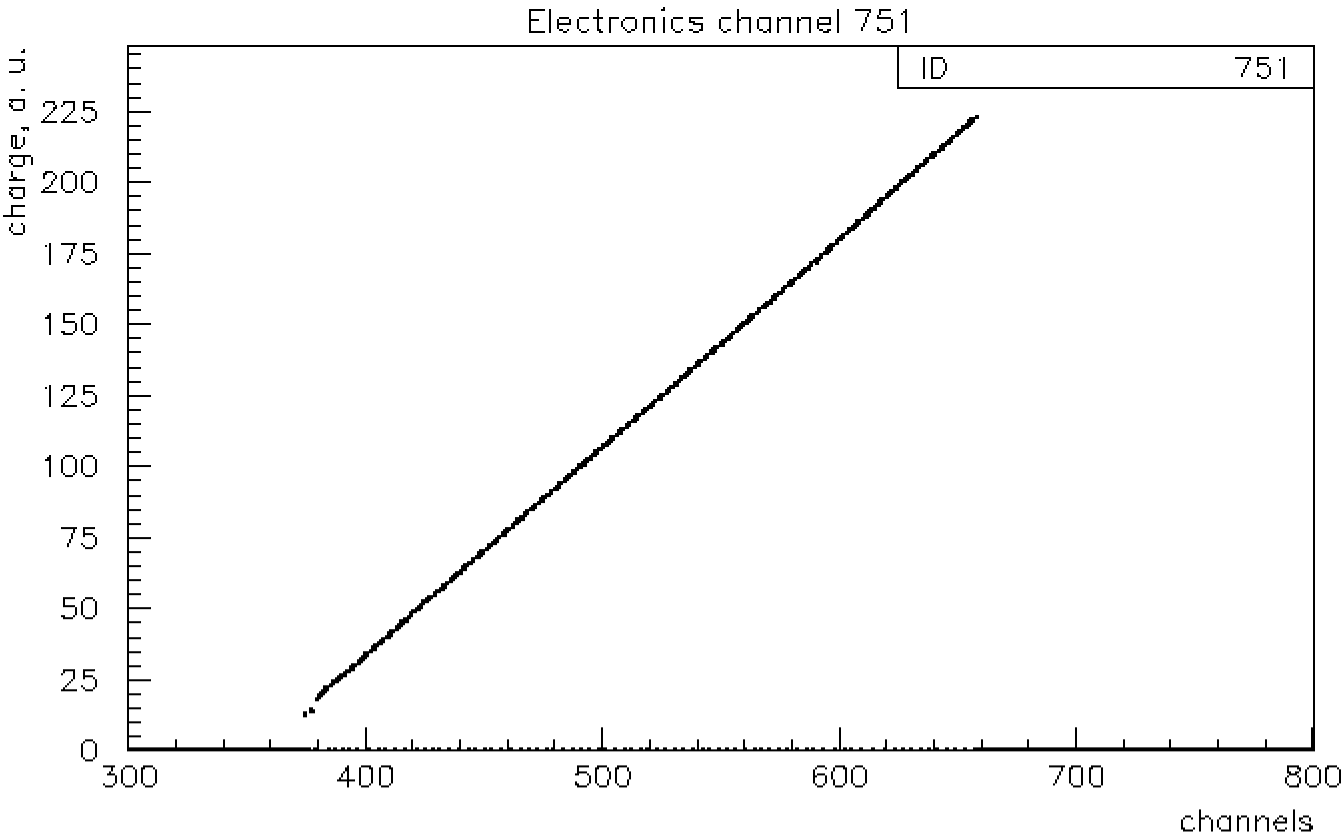


Figure 8. Comparison of signal position with calibration data

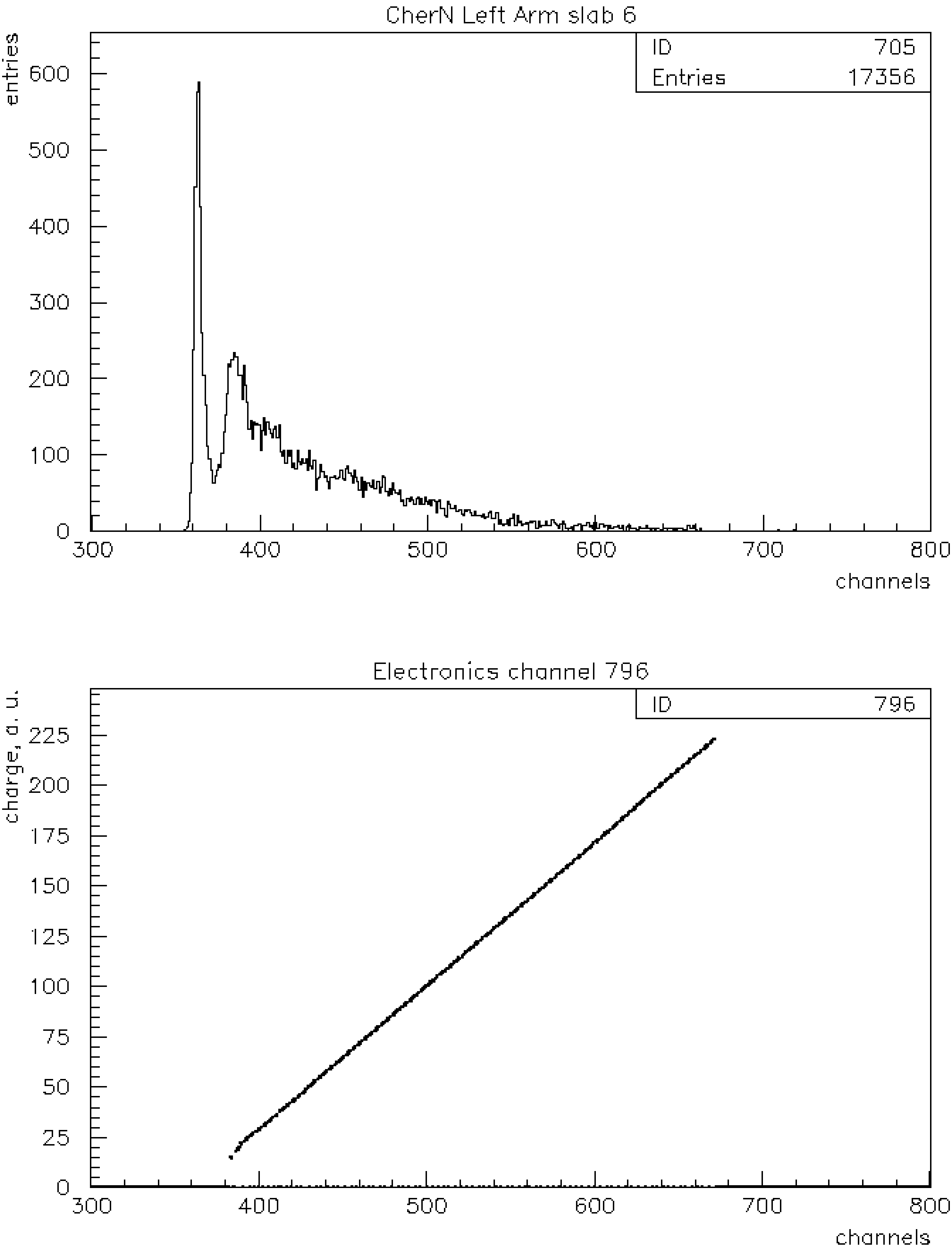
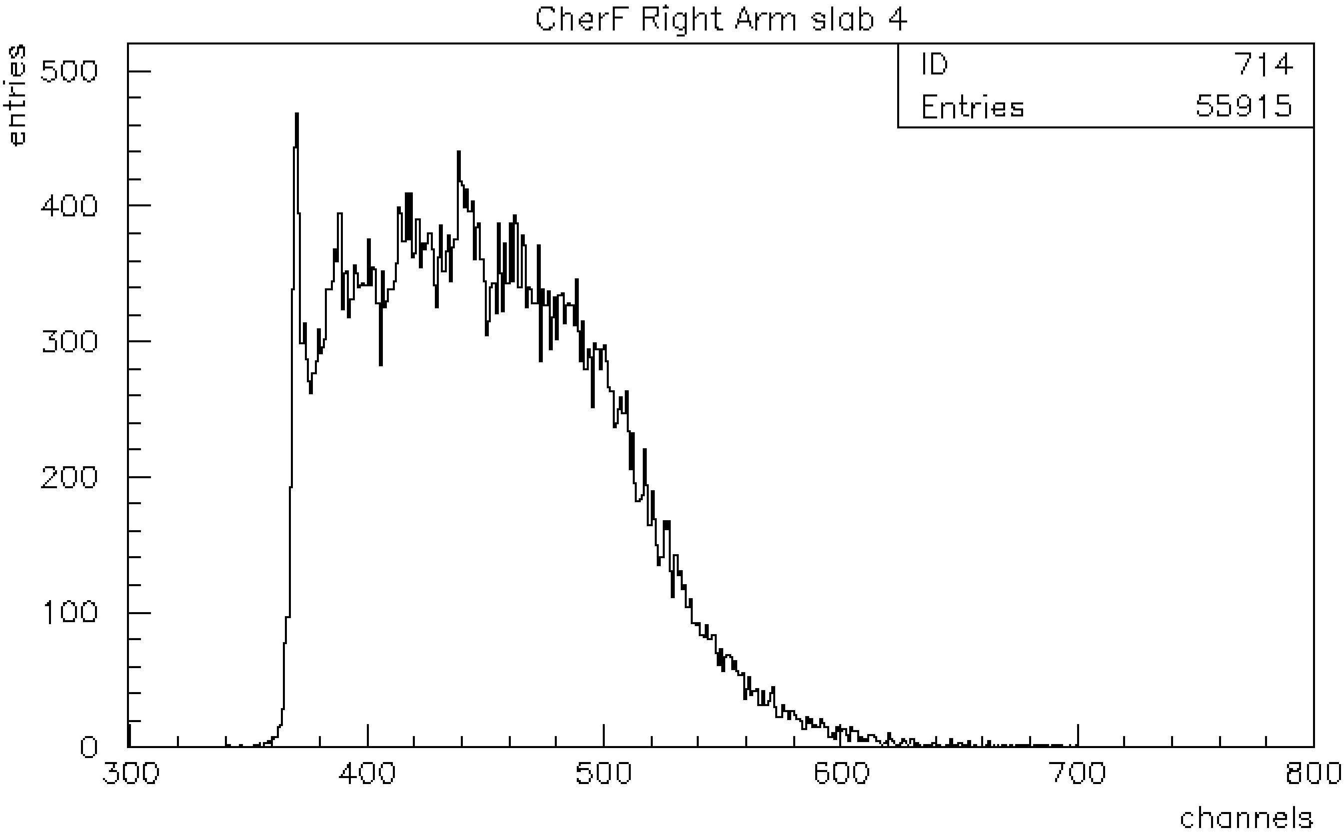


Figure 9. Comparison of signal position with calibration data



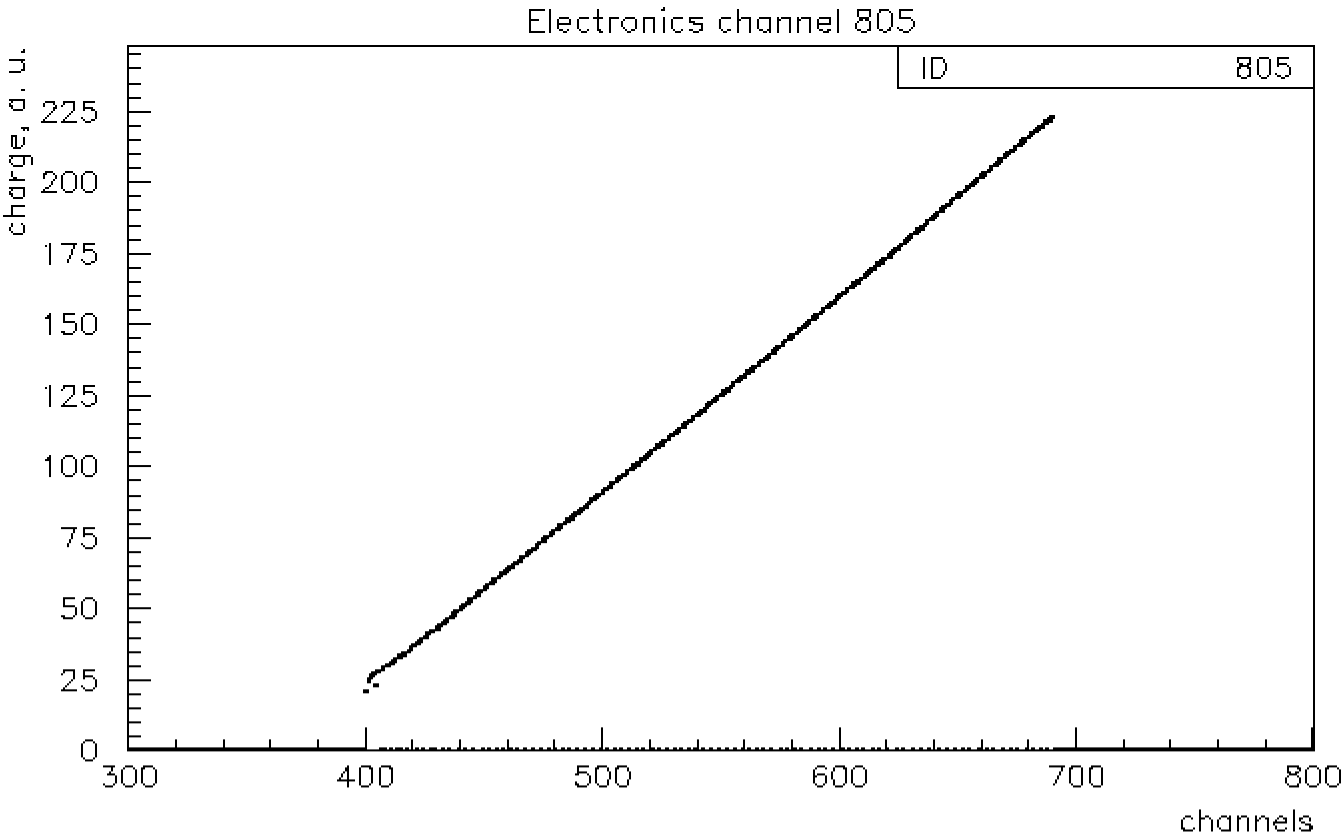


Figure 10. Comparison of signal position with calibration data

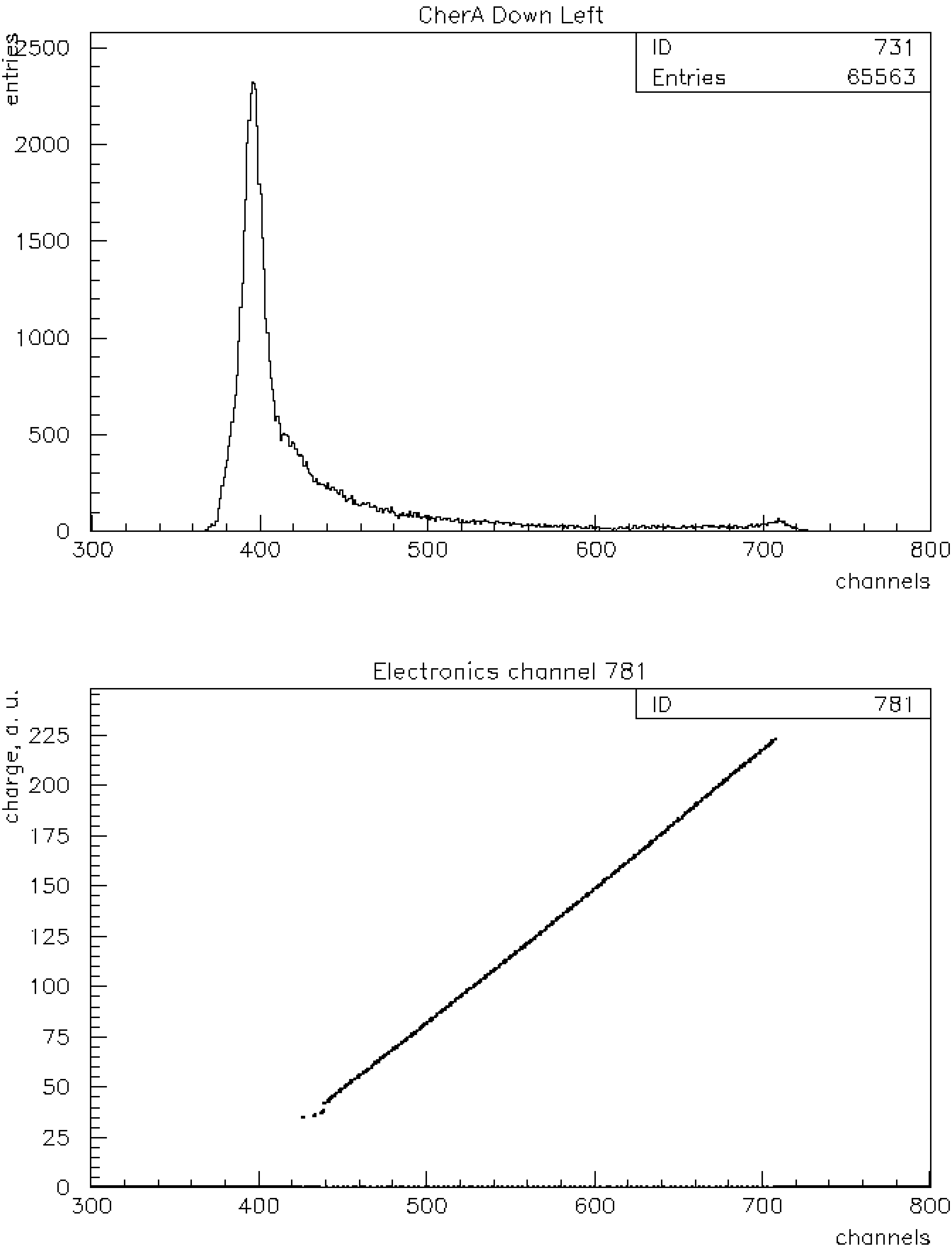


Figure 11. Comparison of signal position with calibration data

3 Calibration data processing

The last part of data handling was calibration data processing using two different fits. The first one is linear fit in a specified interval. The second fit is polynomial interpolation. The difference between charges obtained with two different fitting procedures have been plotted to provide correct comparison of these procedures. As an example the difference between charges obtained using linear fit and charges obtained using polinomial interpolation for ScFi X-plane column 175 is presented on lower plot in the Figure 12. Upper plot is a charge distribution in ADC-TDC channels.

Unlike linear fit polinomial interpolation cannot be calculated in a region where calibration data is missing. This results in an absence of polinomial interpolation data in such regions. At the beginning of lower histogram in the Figure 12 one can see a linear dependence being a result of linear interpolation with opposite sign. Then in channels region (350:390) differences data appears in non-linear form with the maximum -4 a.u. In this channel linear fit with opposite sign takes on the value of -12 a.u. Polinomial fit gives a result 8 a.u. over here. Therefore one may state that linear fit gives an overevaluated result, which means that hits will not be lost in this region.

An example of histogram with controversial differences data is presented in Figure 13. Software criterion on the signal in ScFi is 0.2 from the charge corresponding to a maximum of distribution. In the channel 382 linear fit value is 24 a.u. Polinomial interpolation gives a value 27 a.u. Thus threshold value is 5.4 a.u. In the channel 352 corresponding fits values are 4 a.u. and 14 a.u. Therefore linear fit gives a result below the threshold whereas polinomial interpolation result is above the threshold. This may produce loss of hits in this channels region.

For IH an accurate difference distibution for the slab 13 of X1-plane is presented in Figure 14. One can see close agreement of linear fit and polinomial interpolation results. One of few histograms with essential difference between these fits for slab 11 of IH Y1-plane is presented in Figure 15.

Histograms examples for the other detectors except CHA are presented in Figures 16-23 (in the same order: the first figure for each detector shows polinomial and linear results appearing to be near, the second shows divergent polinomial and fit results). For aerogel Cherenkov counters all histograms are similar (Figure 24).

For ScFi, VH, HH, CHN wavy structure of some differences distributionsis a consequence of the same structure of calibration data.

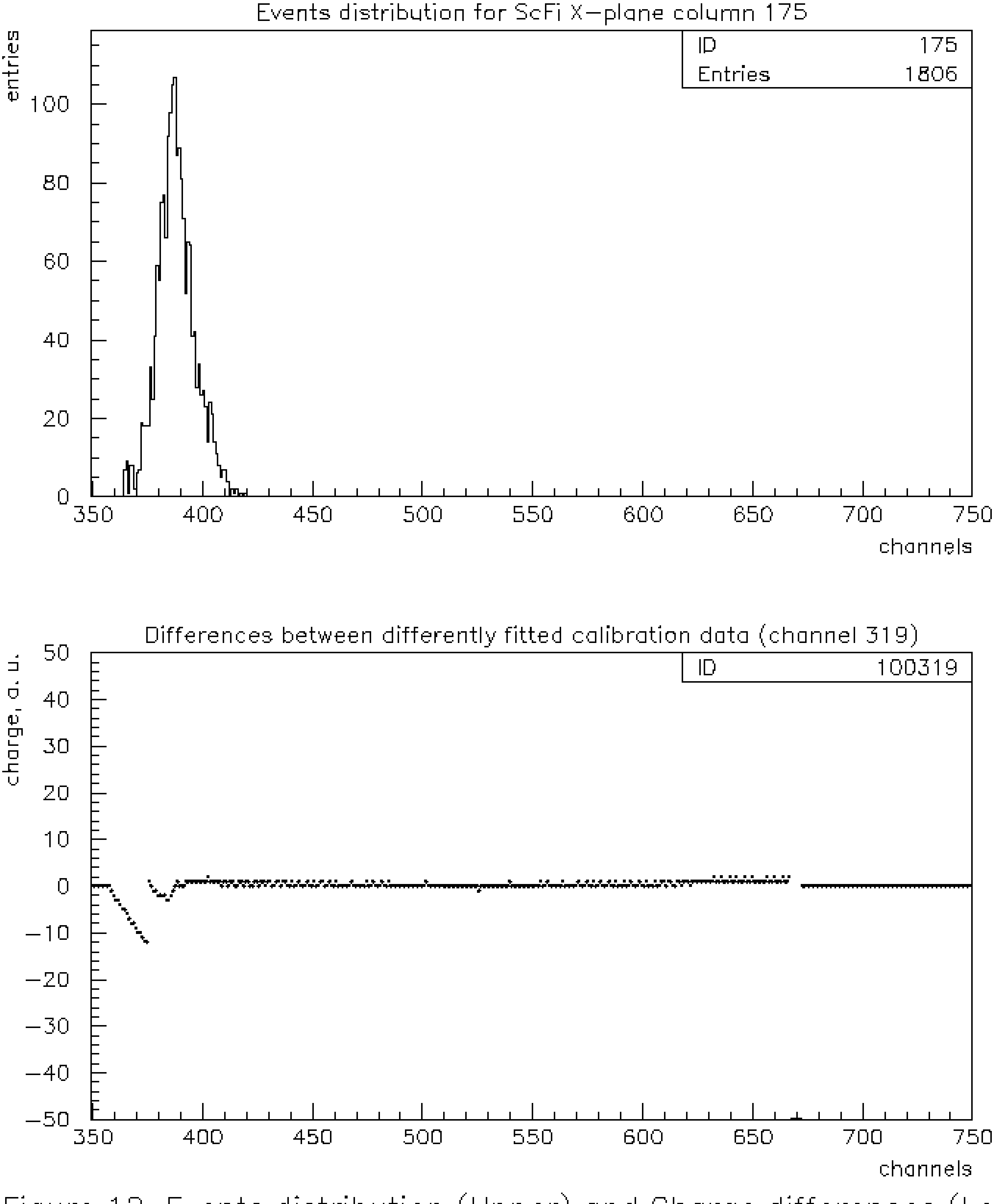


Figure 12. Events distribution (Upper) and Charge differences (Lower)

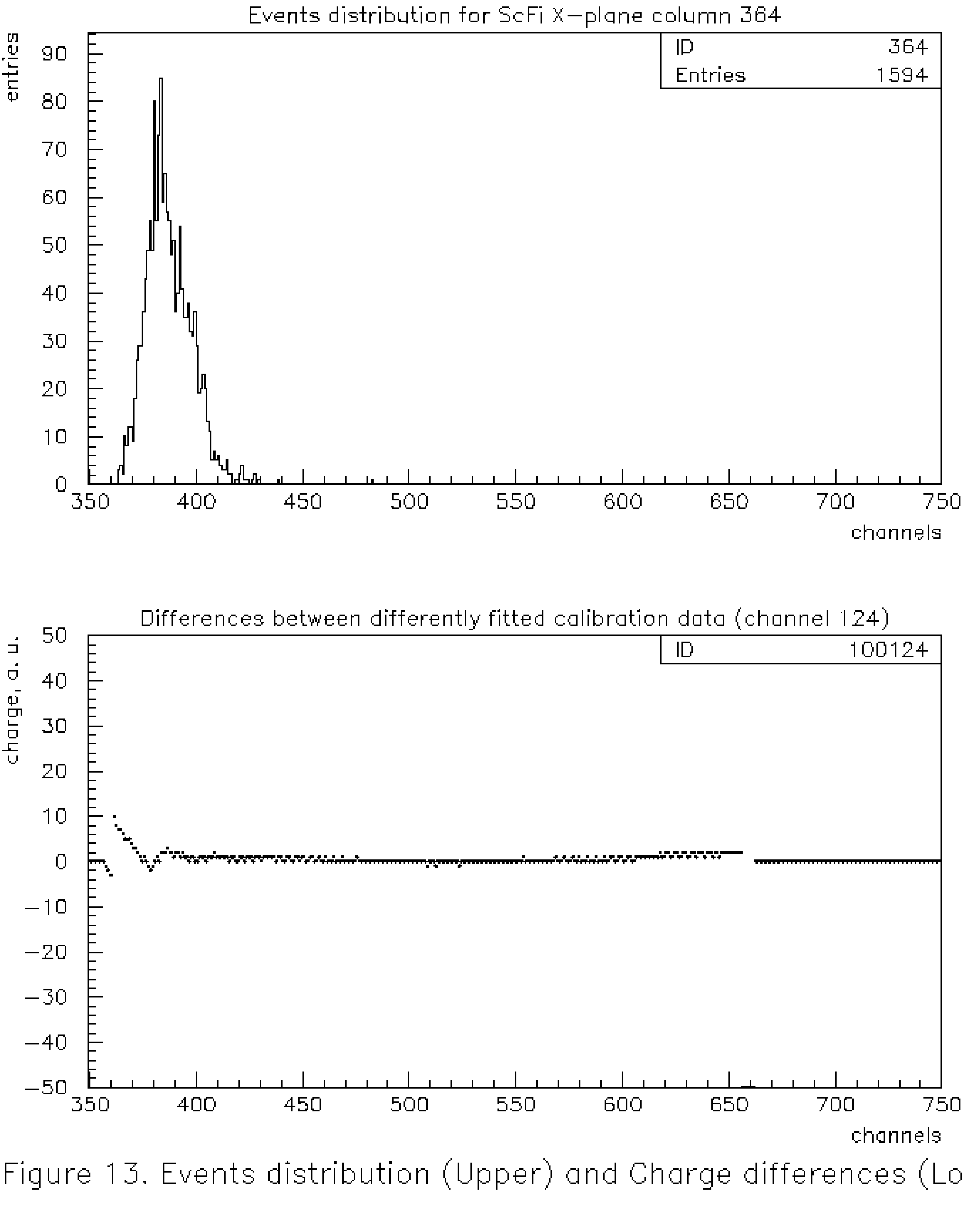


Figure 13. Events distribution (Upper) and Charge differences (Lower)

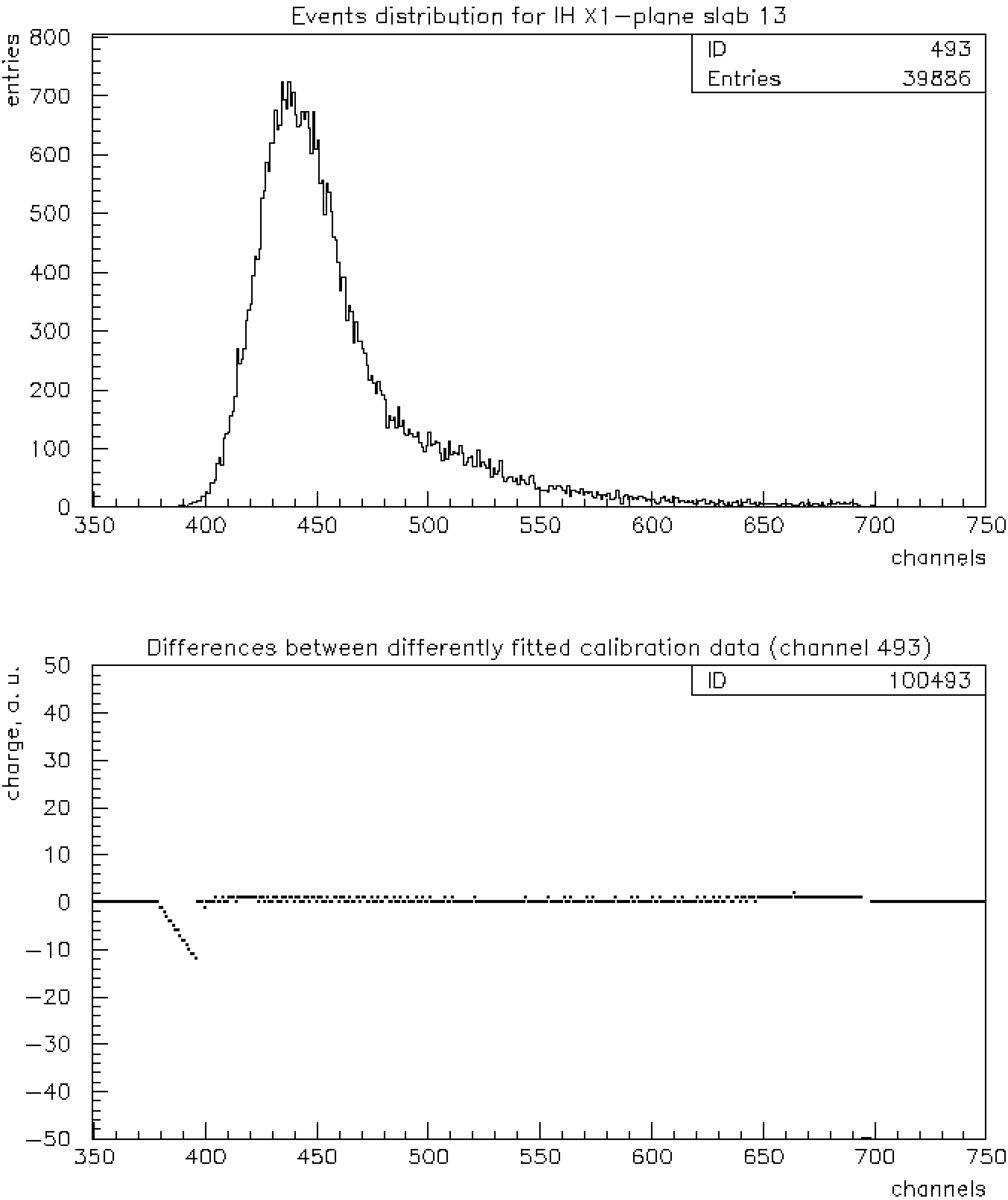


Figure 14. Events distribution (Upper) and Charge differences (Lower)

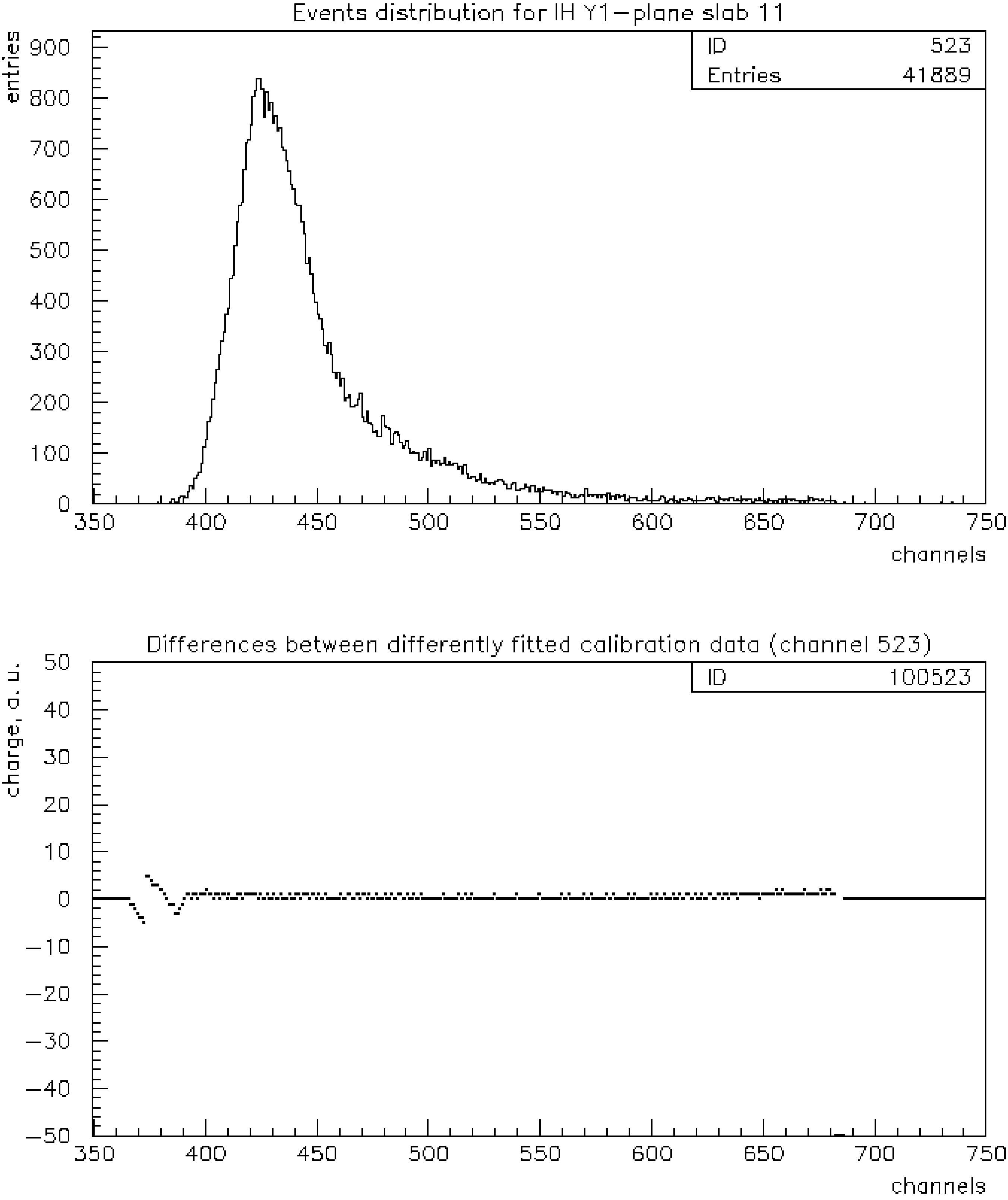


Figure 15. Events distribution (Upper) and Charge differences (Lower)

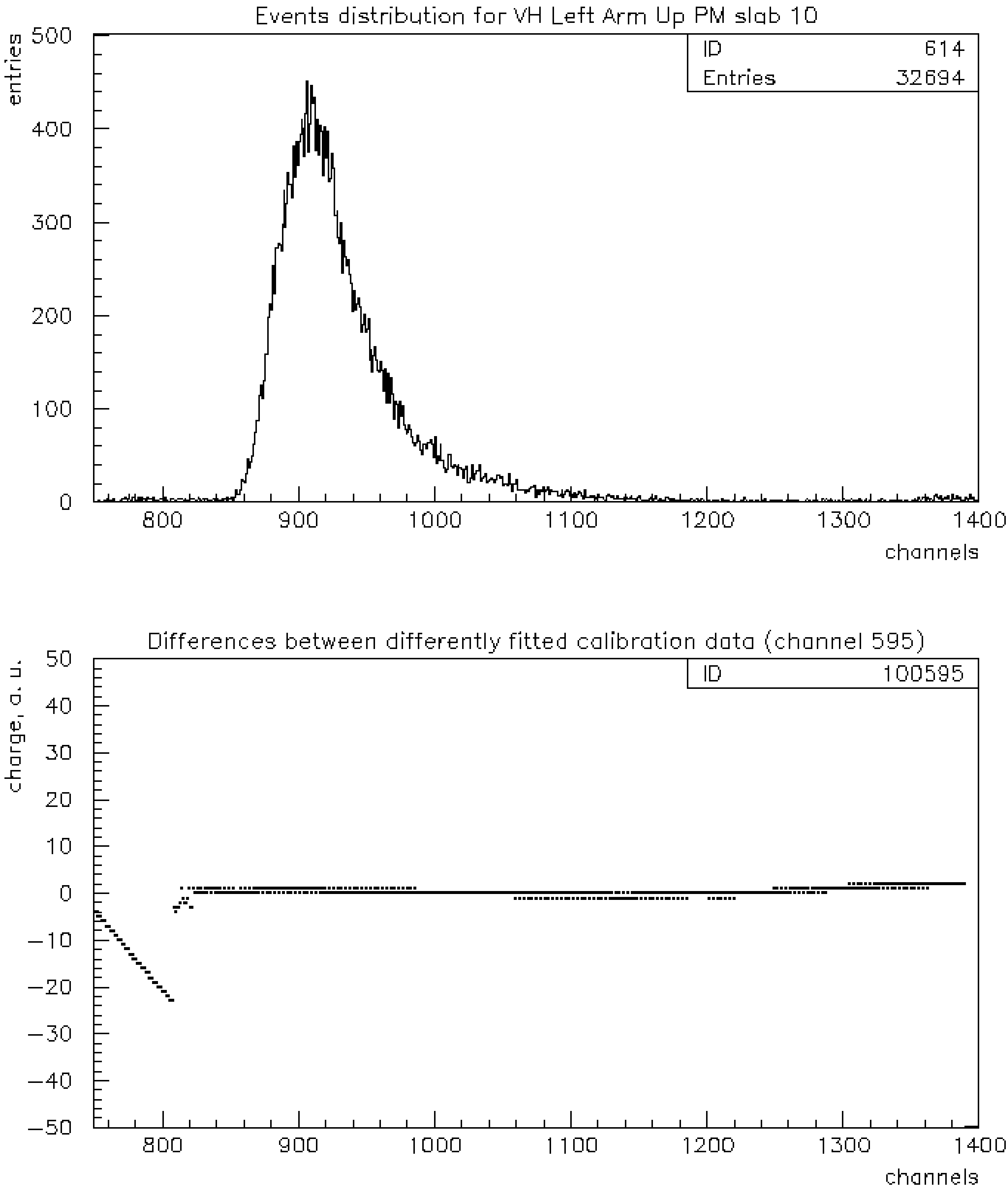


Figure 16. Events distribution (Upper) and Charge differences (Lower)

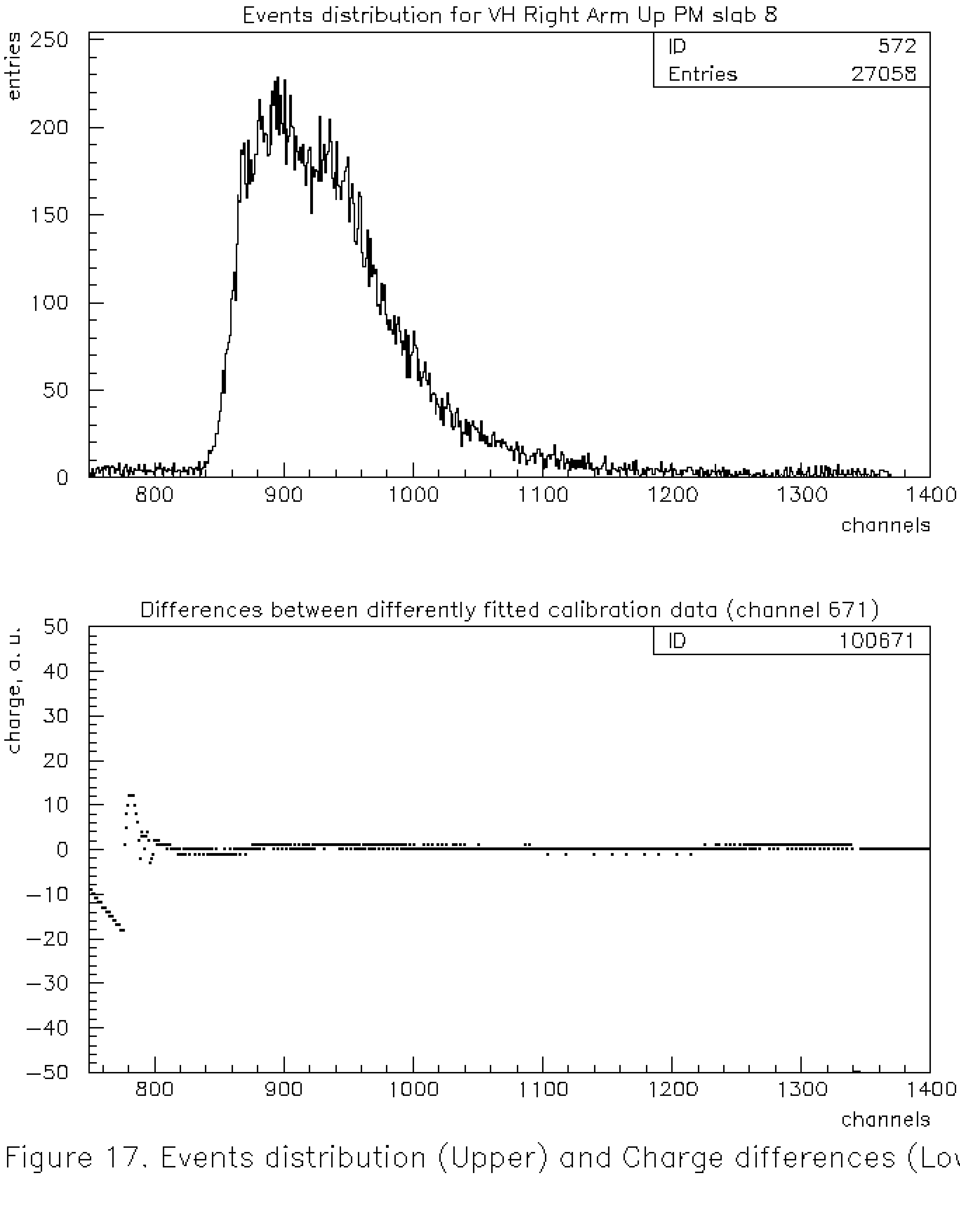
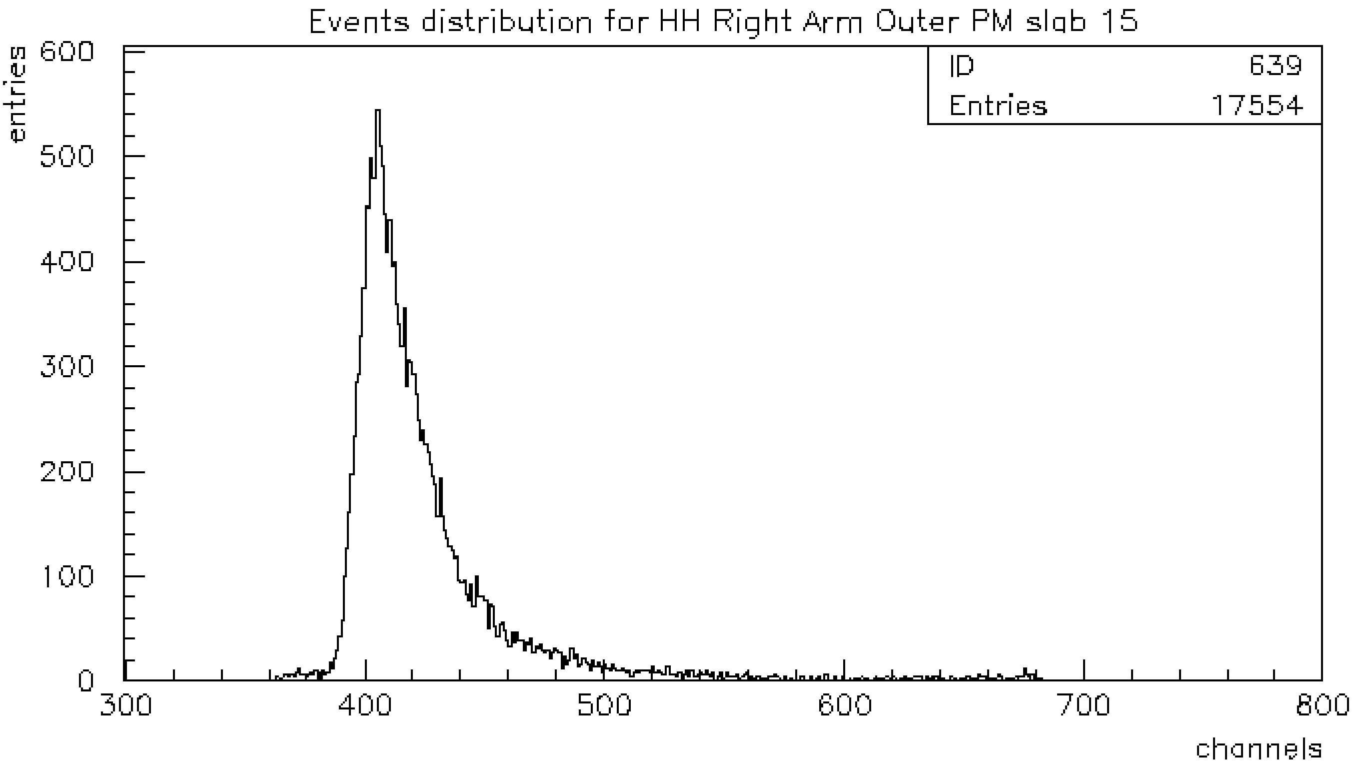


Figure 17. Events distribution (Upper) and Charge differences (Lower)



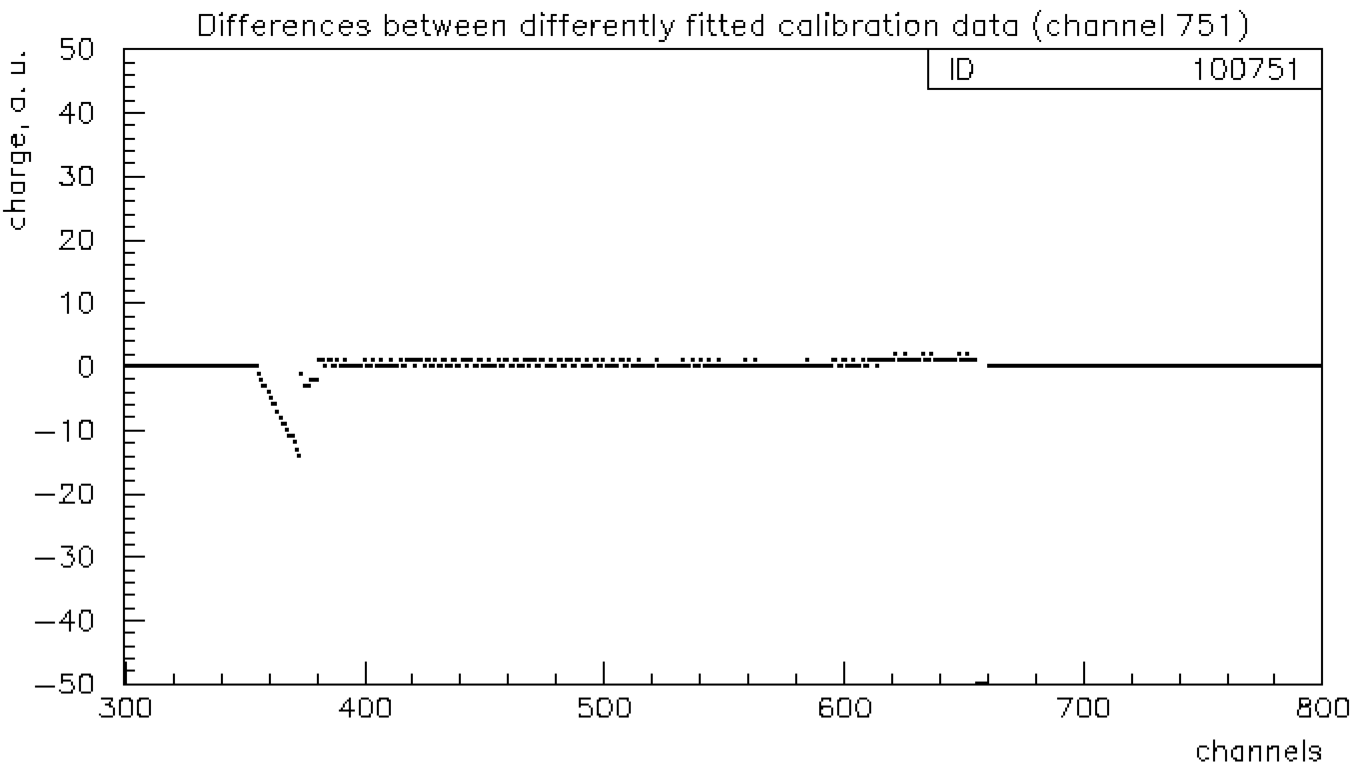


Figure 18. Events distribution (Upper) and Charge differences (Lower)

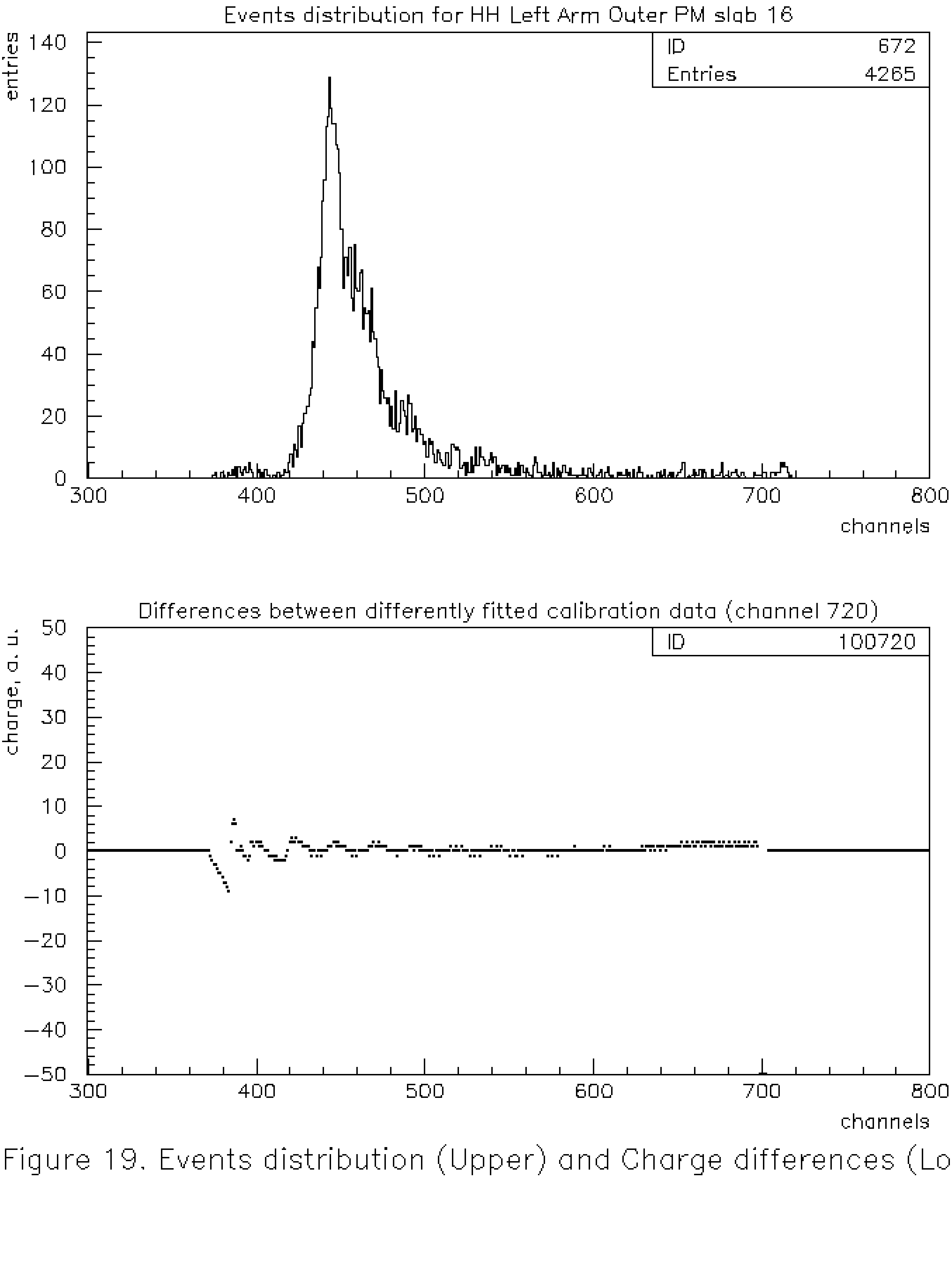
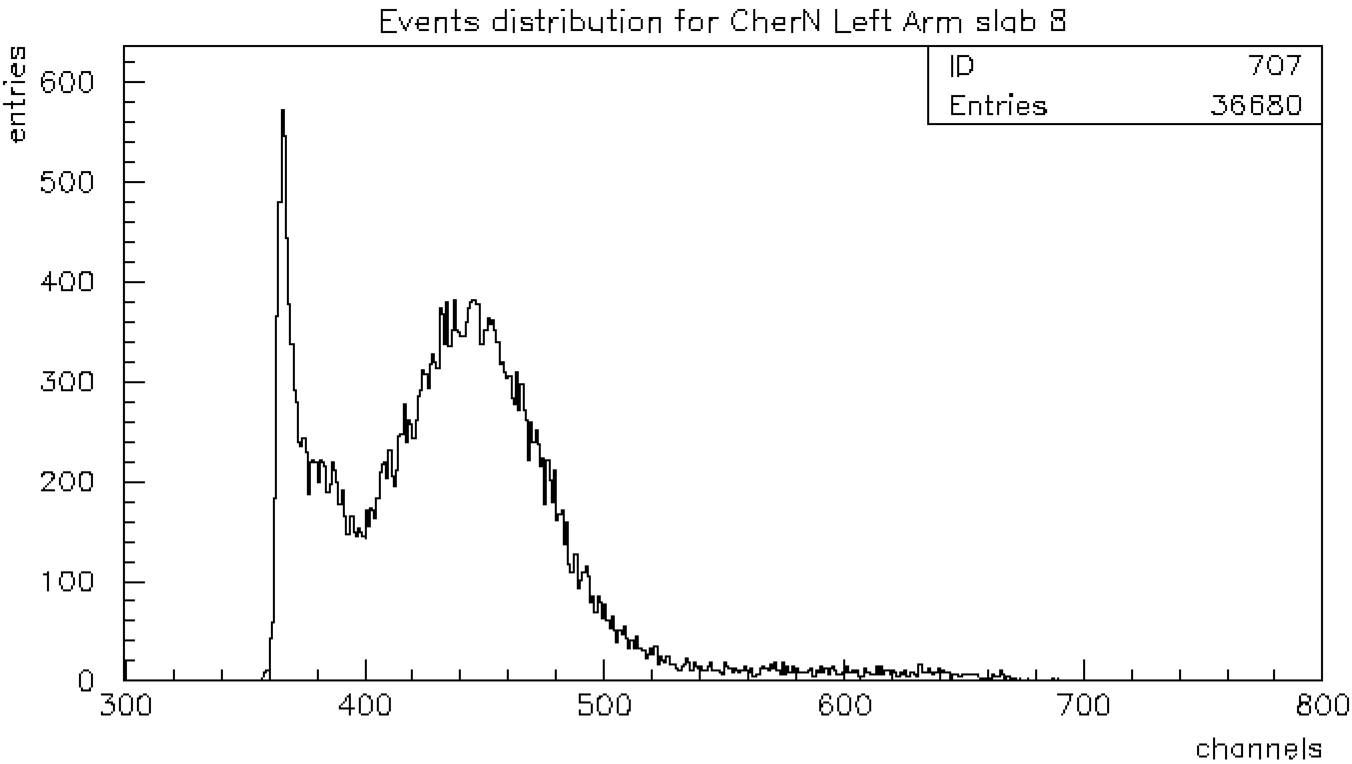


Figure 19. Events distribution (Upper) and Charge differences (Lower)



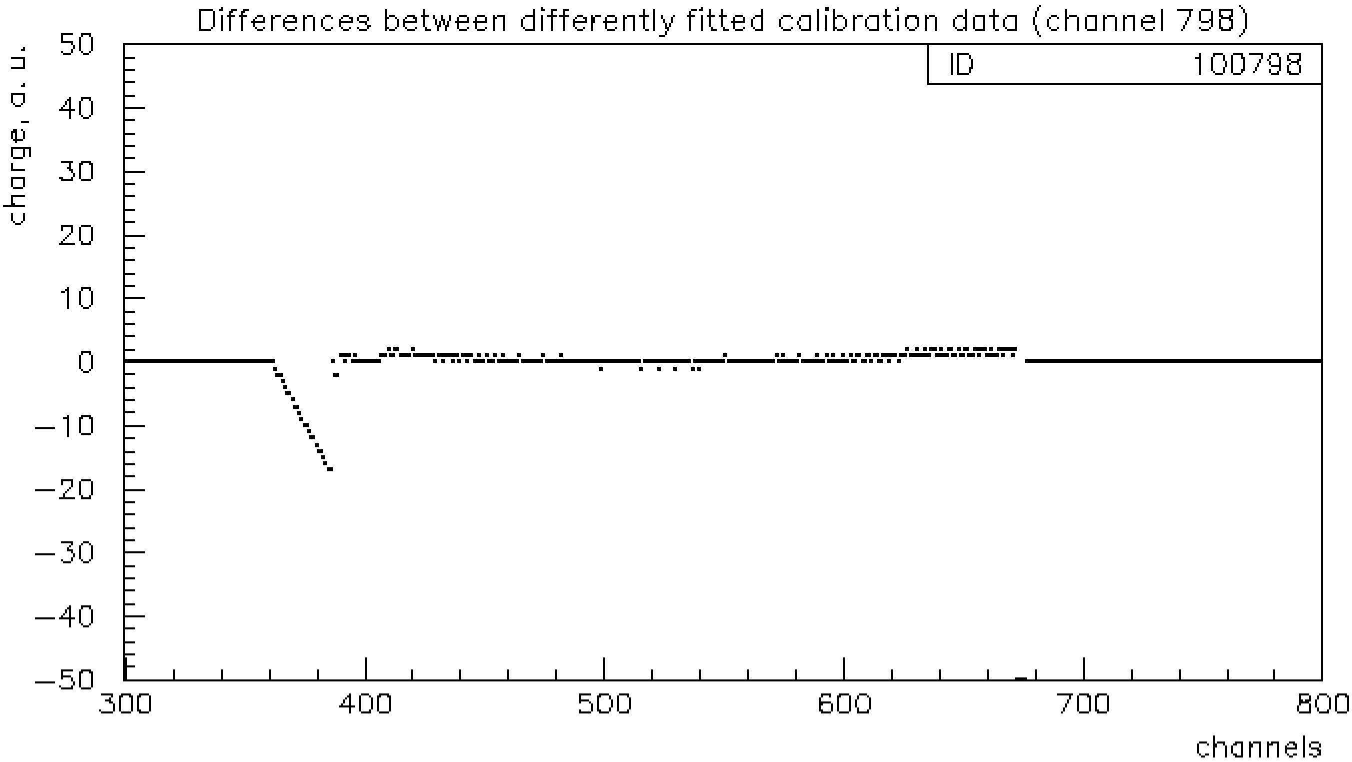
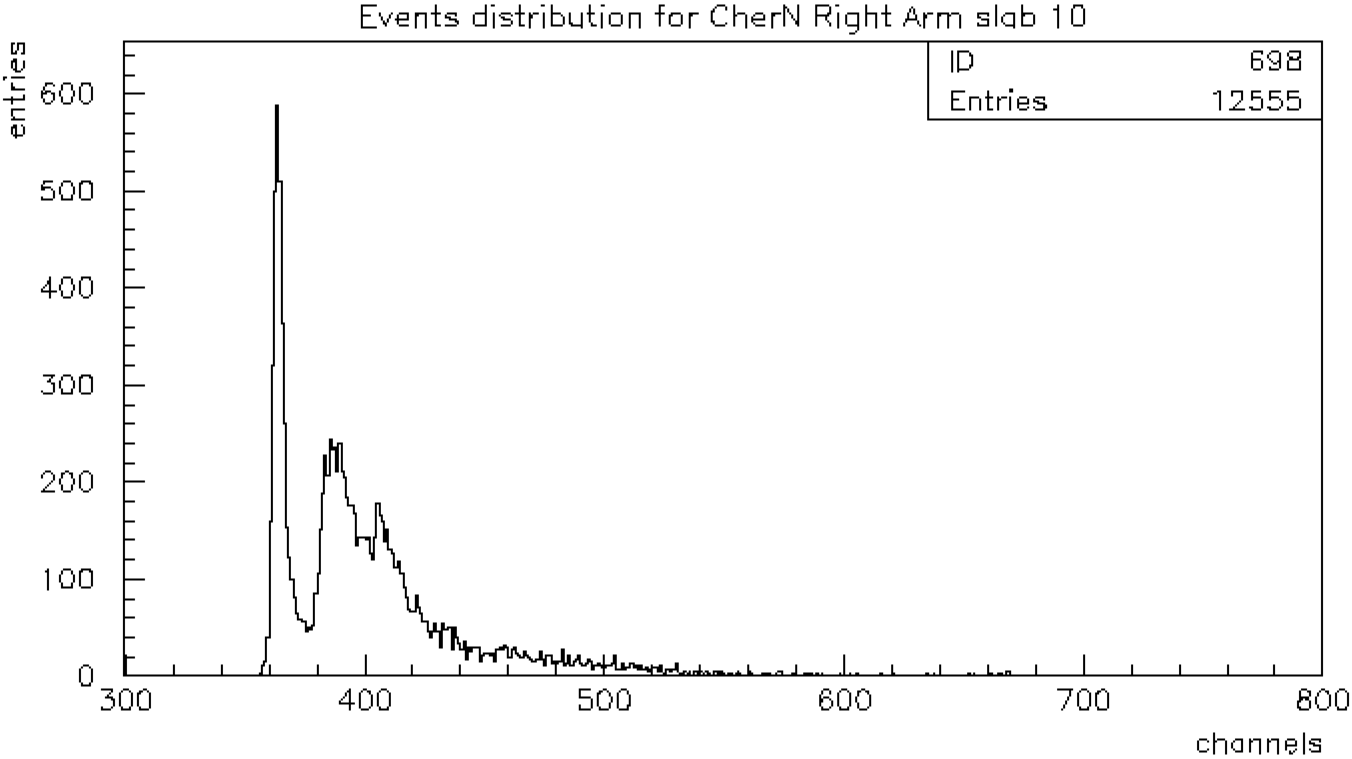


Figure 20. Events distribution (Upper) and Charge differences (Lower)



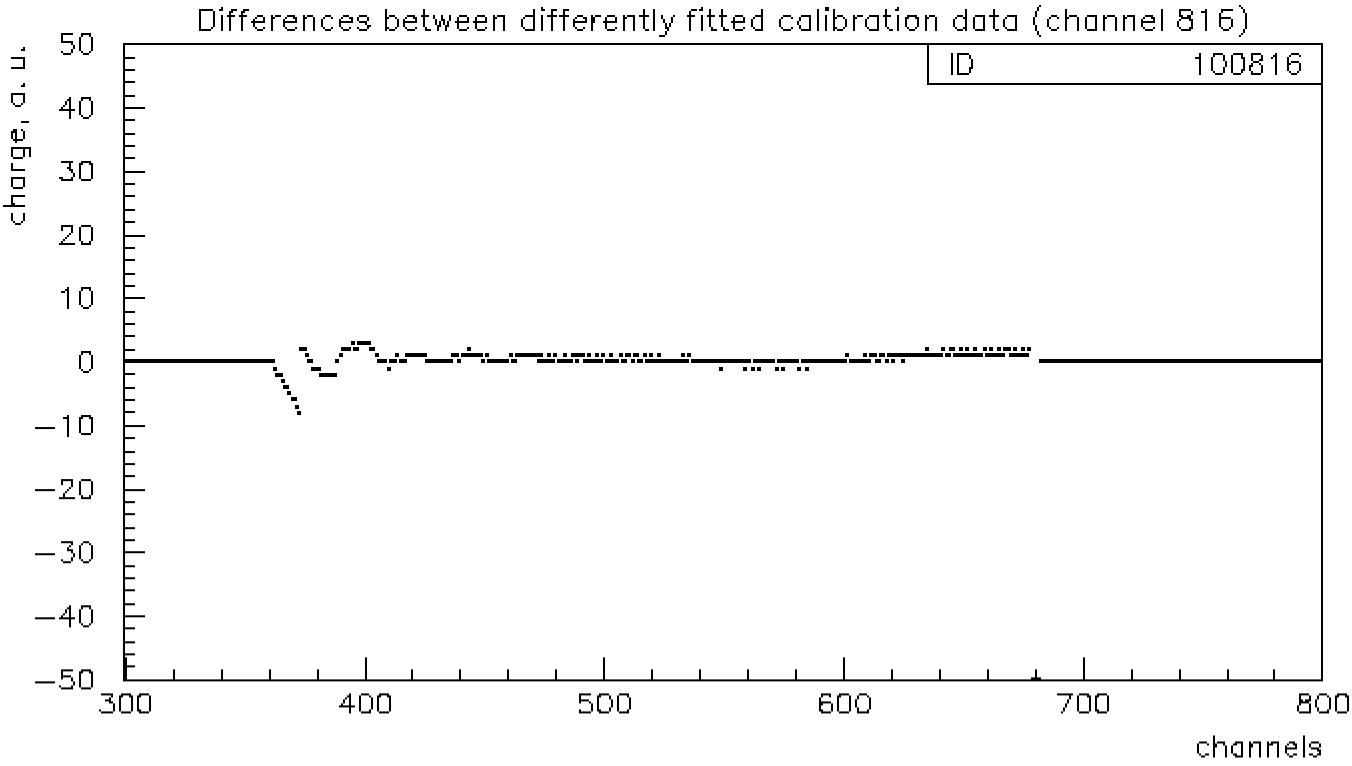
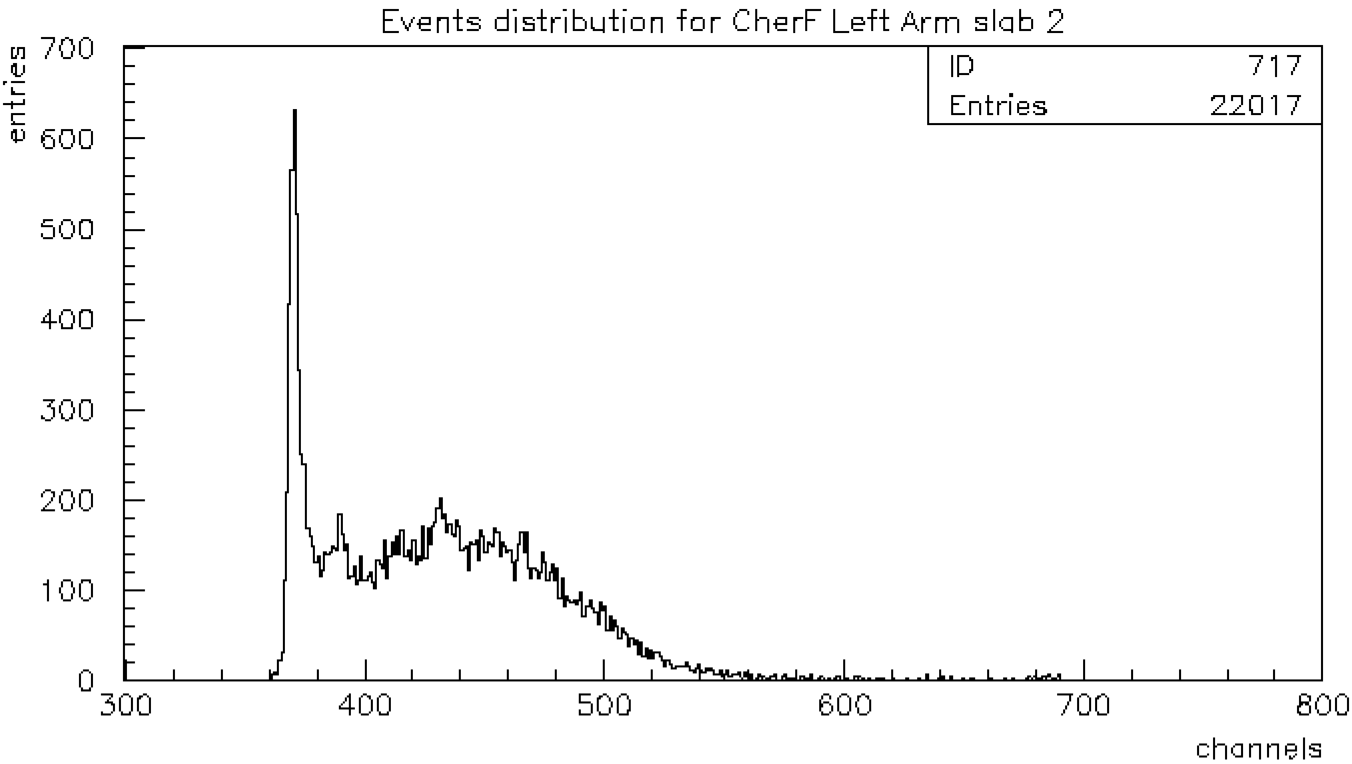


Figure 21. Events distribution (Upper) and Charge differences (Lower)



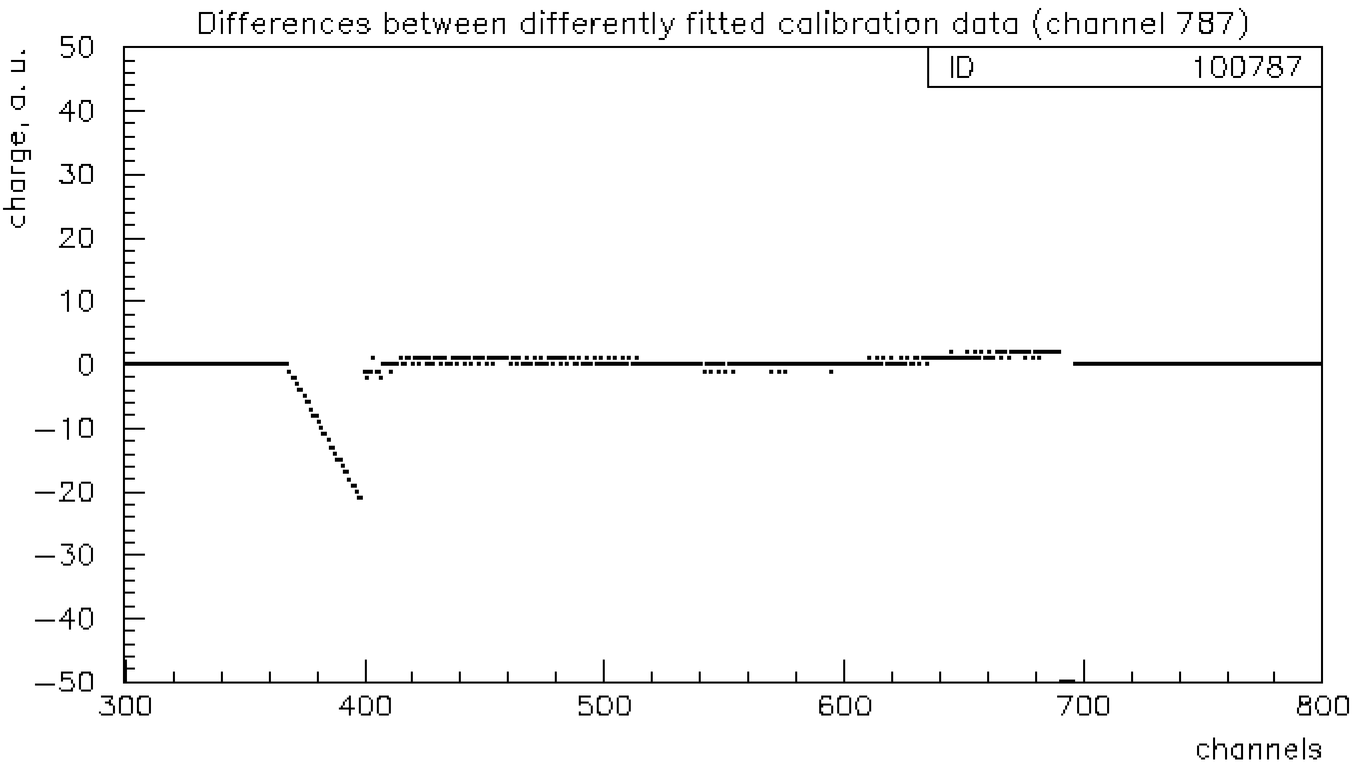


Figure 22. Events distribution (Upper) and Charge differences (Lower)

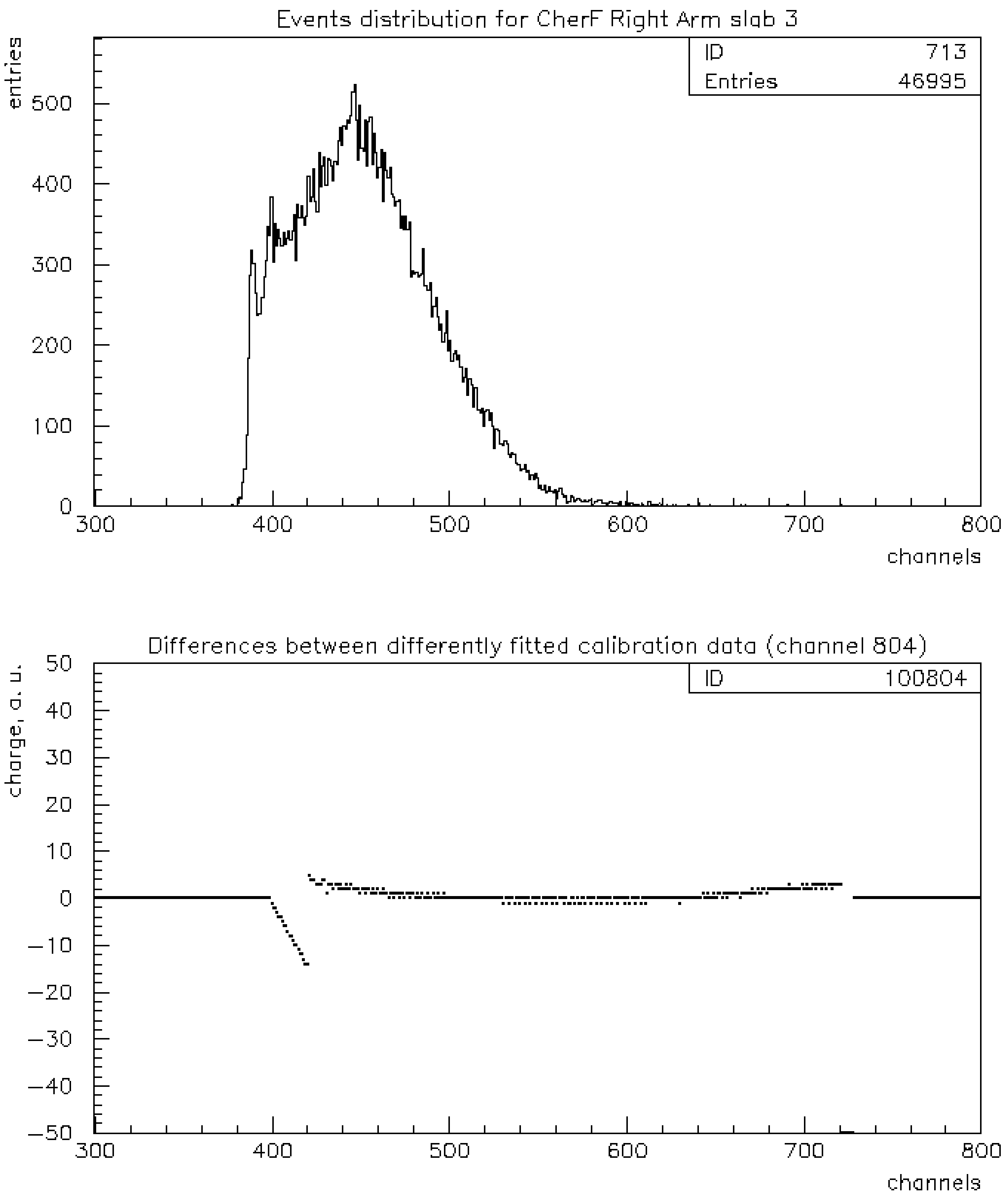
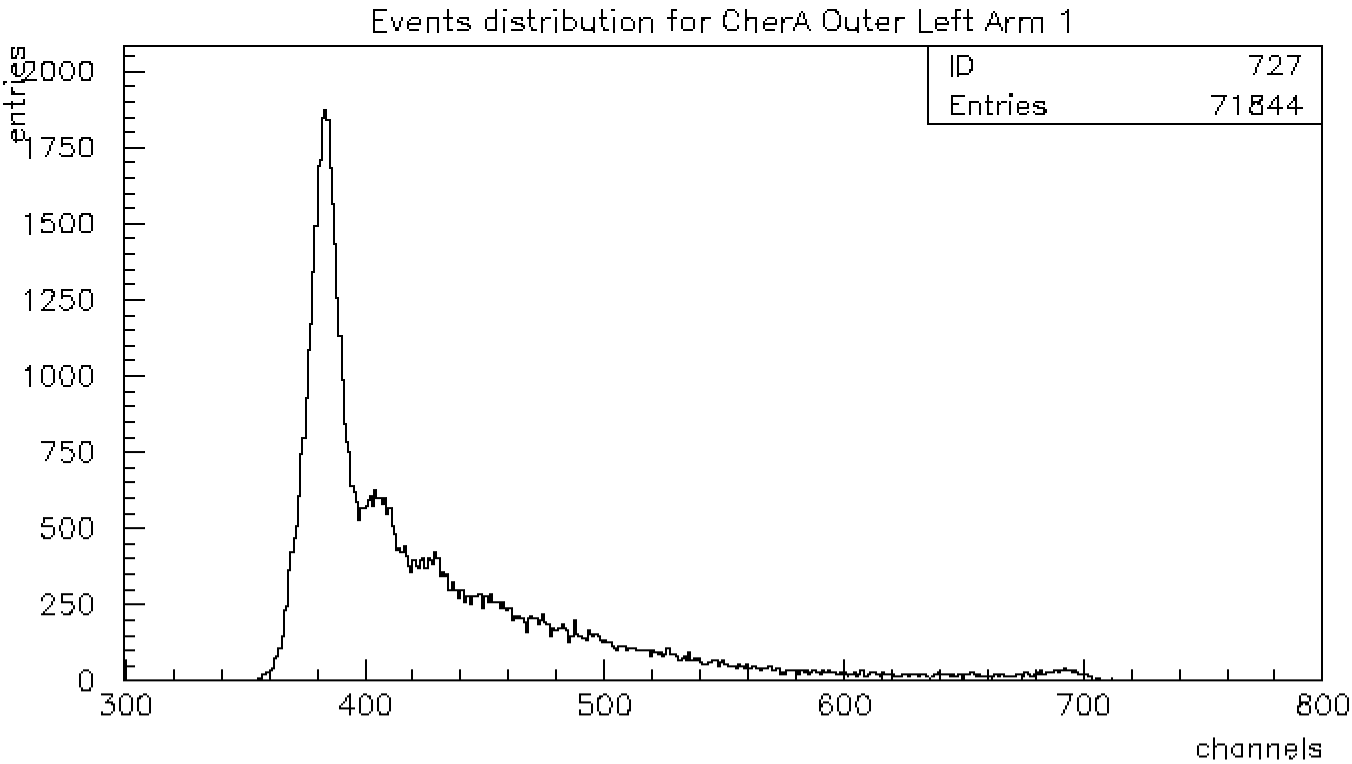


Figure 23. Events distribution (Upper) and Charge differences (Lower)



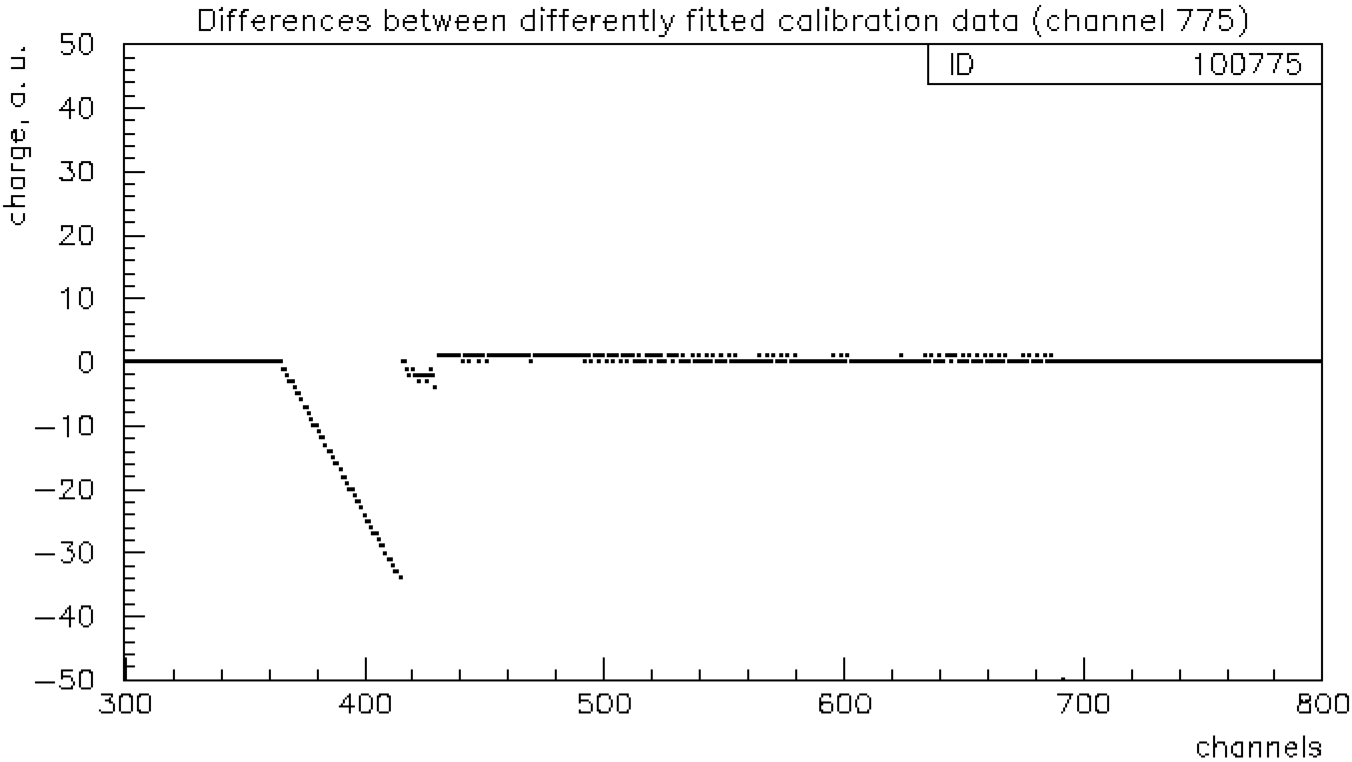


Figure 24. Events distribution (Upper) and Charge differences (Lower)

4 Conclusion

The analysis of different fitting procedures connected with the processing of calibration data has showed the following. For scintillation fiber detector 2% of histograms shows significant deviation of polinomial interpolation from linear fit. Nevertheless the criterion on a threshold shows that this deviation leads to loss of hits which is less than 10% . Therefore detector effectiveness reduction is not significant. For ionisation hodoscope the value of histograms with considerable deviation is 6%. It should be noted that in the case of ionisation hodoscope a divergence appears in a region where few events are observed, i.e. not major part of the signal. For vertical hodoscopes a signal appears in a region with close agreement of polinomial and linear fits. For horizontal hodoscopes differences distributions mostly have concave form. Wavy structure appears in 30% of these distributions (more for the left arm than for the right one). For Cherenkov nitrogen and heavy gas counters polinomial interpolation and linear fit take on close values. A signal in Cherenkov aerogel counters tends to appear before the beginning of calibration data.

For ionisation hodoscope it is of particular concern to have linear structure of calibration data in a region between single and double amplitudes. For scintillation fiber and Cherenkov counters this is an additional requirement. It has been shown that nonlinear structure has no influences on charge resolution for ionisation hodoscope and for most slabs of Cherenkov nitrogen and heavy gas counters.