Signal decompression and look-up table calculation for the FD read-out channel

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Abstract

The implementation of the FD read-out channel using the bilinear compressor [2]-[3]-[5] requires algorithms for the calculation and the inversion of the compression function.
These methods have been developed in the context of the FERMI project [4] and applied in the analysis of test beam data of a prototype calorimeter for ATLAS [1].
The methods have been developed in a very general framework and are readily applicable to the FD read-out channel. In order to illustrate the ideas beyond the algorithm, data from the FD read-out channel simulation are processed to extract the decompression look-up table (inverse of the compression function), that is compared to the true table.
The study is performed for bilinear compression functions with sharp and smoothed break point and for data with and without noise. In all cases the look-up table is obtained with very high precision.

1 Introduction

The look-up reconstruction algorithm has the goal to calculate the inversion of the compression function starting from a suitable set of data.
The first crucial step consists in obtaining the shapes of the signal before the ADC sampling for a few input amplitude lavels spanning the full ADC ranges. The only requirements are that one of the shapes be undistorted by the compressor and that the amplitude levels are known.
The shapes can be reconstructed either by the ADC samples, as necessary in realistic experimental conditions or taken with a digital oscilloscope for tests in the laboratory. Using the known input levels, the shapes can be rescaled and compared.
The basic assumption is that, before compression, the pulses have the same shape modulus the amplitude, hence the look-up tables is the set of coefficients minimizing the difference between the pulses after rescaling.
In the following the algorithm is explained with more detail and examples of

pulse reconstruction and look-up table calculation for simulated data generated by the simulation program are shown.

2 Shape reconstruction

During the data taking, the data will be available as realization of the pulse shapes sampled at the ADC period (100ns). The number of samples read out is assumed to contain the pulses.
The realization of the pulse will depend on its phase with the ADC clock. For the application of shape reconstruction, it is required that the phase distribution of the pulses spans the whole range of the ADC period. The situation most common and easiest to deal with is a uniform phase distribution.
If the pulses are generated with a test pulse generator, this requirement is equivalent to the request that the phase of the test pulese is uncorrelated with the ADC clock. In the simulation, this condition is satisfied selecting the phase randomly. Effects of finite statistic are discussed in [4], where this algorithm is presented in greater detail.
The algorithm requires that the phase of each realization be calculated (or be known from other sources). Assuming that this information is available, all the realizations with the same phase (within a given interval) can be averaged sample by sample. The same procedure can be repeated for all phase values and the whole signal can be reconstructed assembling the various averaged frames shifted by the corresponding phases.
As to estimation of the phase, the procedure is explained in [4] and requires the calculating of a (in general non linear) phase estimator monotonically dependent on the phase. The measured distribution of this estimator and the known phase distribution allows to measure the relation between estimator and phase, and therefore assign a phase to each realization.
A few applications of this algorithm are presented in Fig1 and Fig.2 for simulated shapes similar to those to be measured in the experiment. Shapes at 6 different levels have been reconstructed with a bilinear compressor with and without a smooth break point and with and without noise. Noise has been simulated with a root mean square of about 2 ADC counts. The reconstucted shapes are compared with the simulated (real) shapesshowing execellent agreement.

3 Look-up table calculation

Using the shapes reconstructed from the sampled data, or alternatively those directly taken with a digital oscilloscope in the laboratory, the look-up table can be calculated.
The only assumption on the compressor is that it is linear for small signals

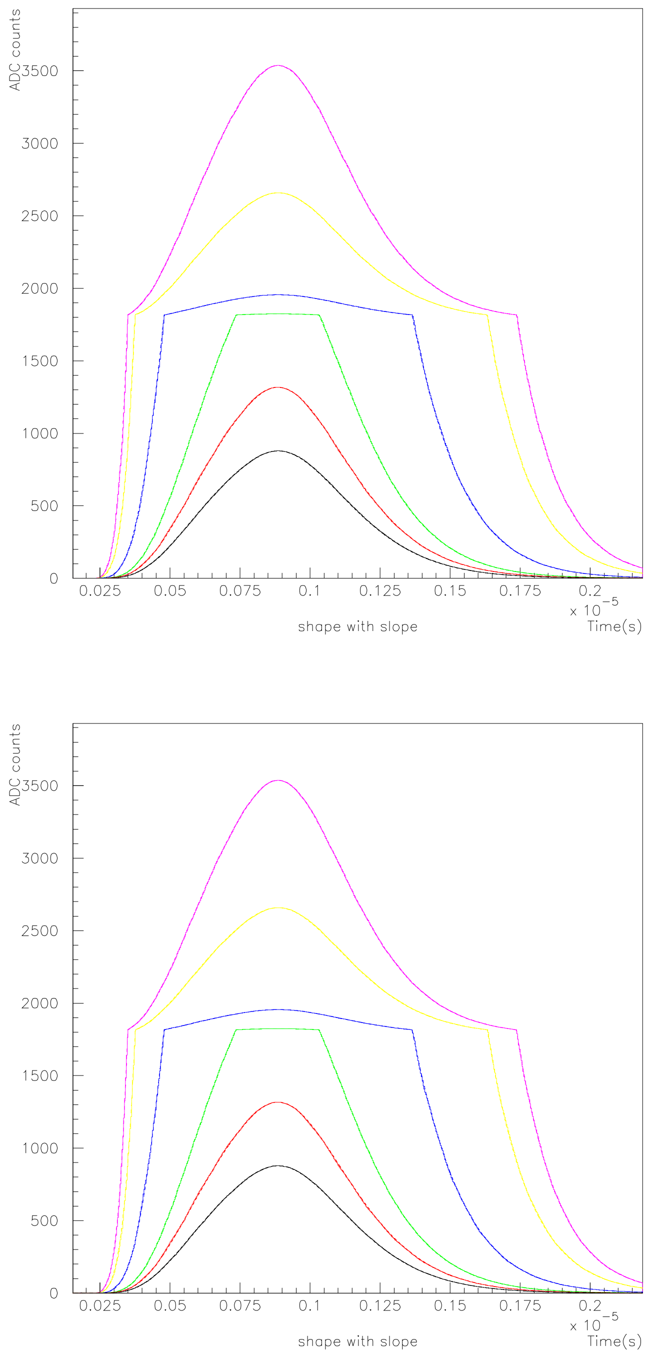
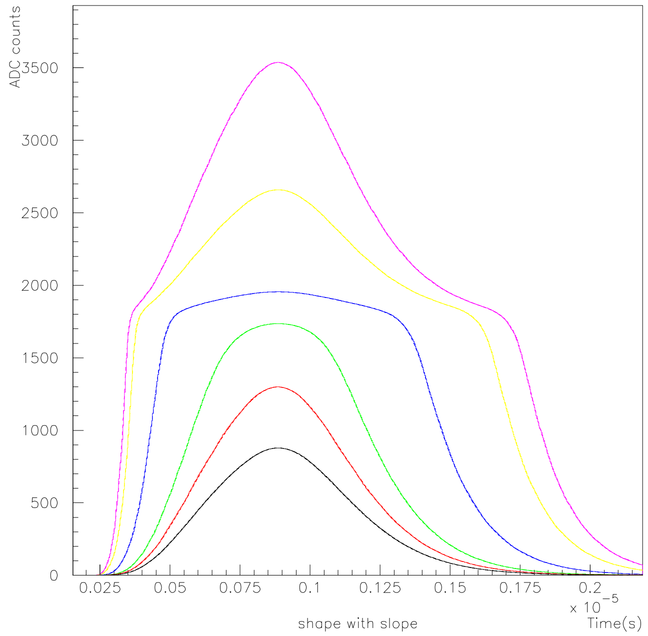


Figure 1: Reconstructed shapes for simulated data for 6 amplitudes (solid) and simulated shapes(dashed). Sharp break point, with and without noise.



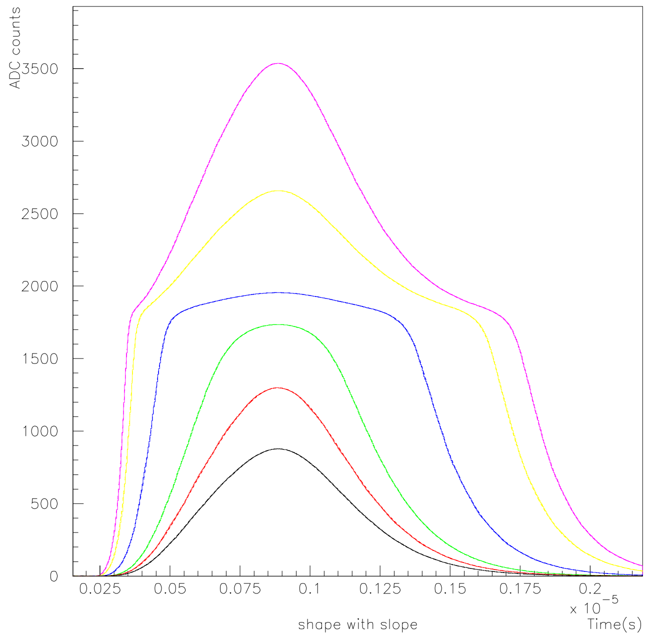


Figure 2: Reconstructed shapes for simulated data for 6 amplitudes (solid) and simulated shapes (dashed). Smooth break, with and without noise.

and that at least one of the shapes, used as reference, resides entirely in the linear region. Furthermore we require that the shapes span the full ADC range and that their (relative) amplitudes are known.
The basic idea of the algorithm is that the shapes before the compression are identical modulo the scaling factors of their input amplitudes. Therefore the look-up table is given by the set of coefficients making the shapes the most similar to the reference shape. The details are given in [1], where the algorithm was applied for the first time.
In Fig.3-Fig.4-Fig.5-Fig.6, the look-up tables reconstructed using the shapes shown in Fig.1-Fig.2 are compared with the true compression functions from the simulation. It is evident that the agreement is excellent both for sharp and smoothed break point and with or without noise.

4 Conclusion

A procedure for look-up table reconstruction developed for application for calorimetry at LHC has been applied to data from a detailed simulation of the AUGER FD read-out channel. Different combination of noise and break point transition have been considered and the reconstructed look-up table compares very precisely with the true look-up table used in the simulation. This algorithm is therefore apt to be used for decompressing the signal of the compressor once calibration data of adequate quality are taken.

References

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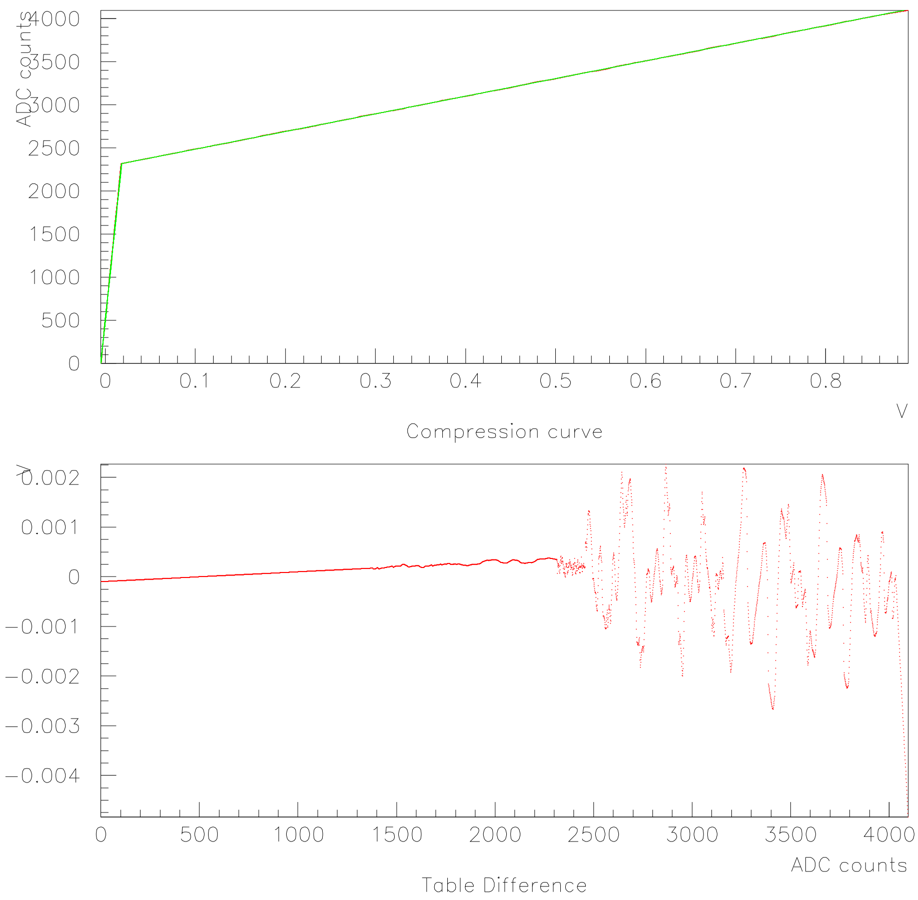

Figure 3: Reconstructed (red) and true (green) look-up tables and their differences for simulated data. Sharp break point without noise.

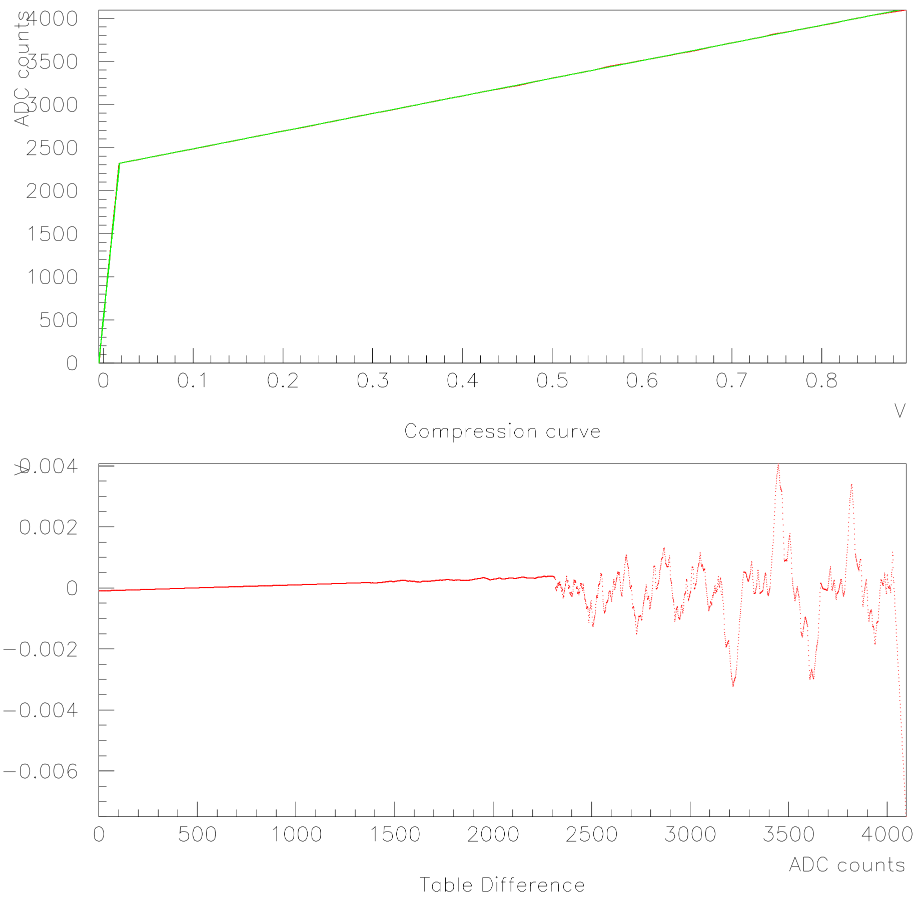

Figure 4: Reconstructed (red) and true (green) look-up tables and their differences for simulated data. Sharp break point with noise.

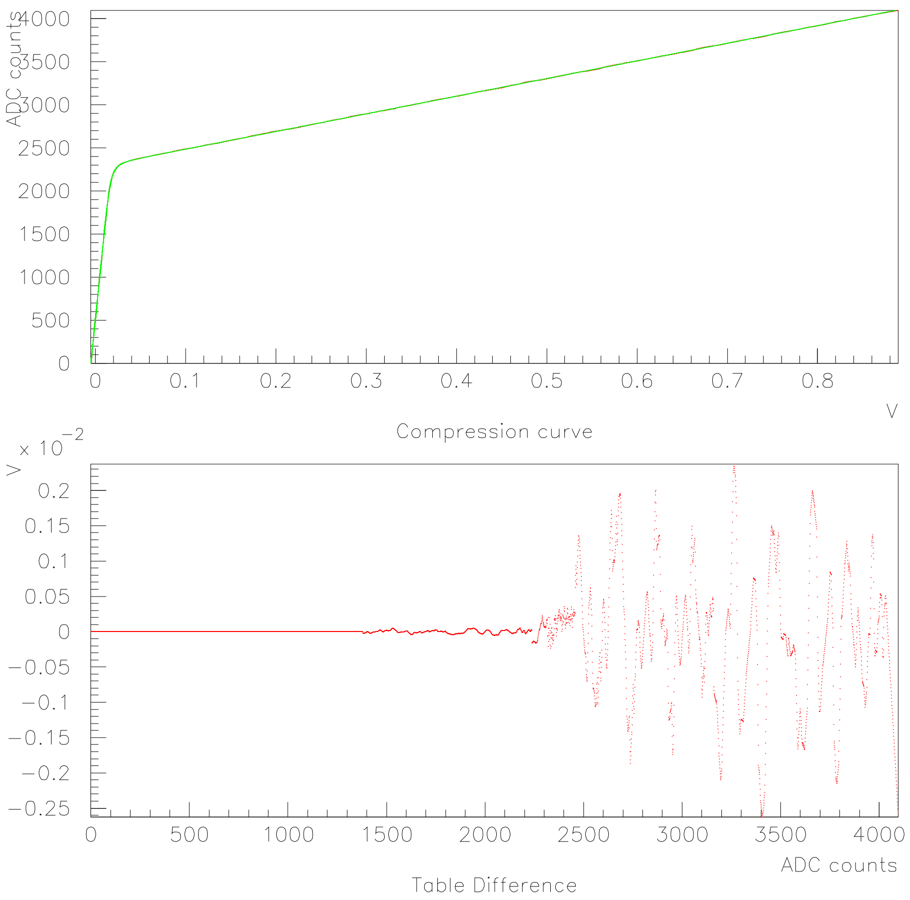

Figure 5: Reconstructed (red) and true (green) look-up tables and their differences for simulated data. Smooth break point without noise.

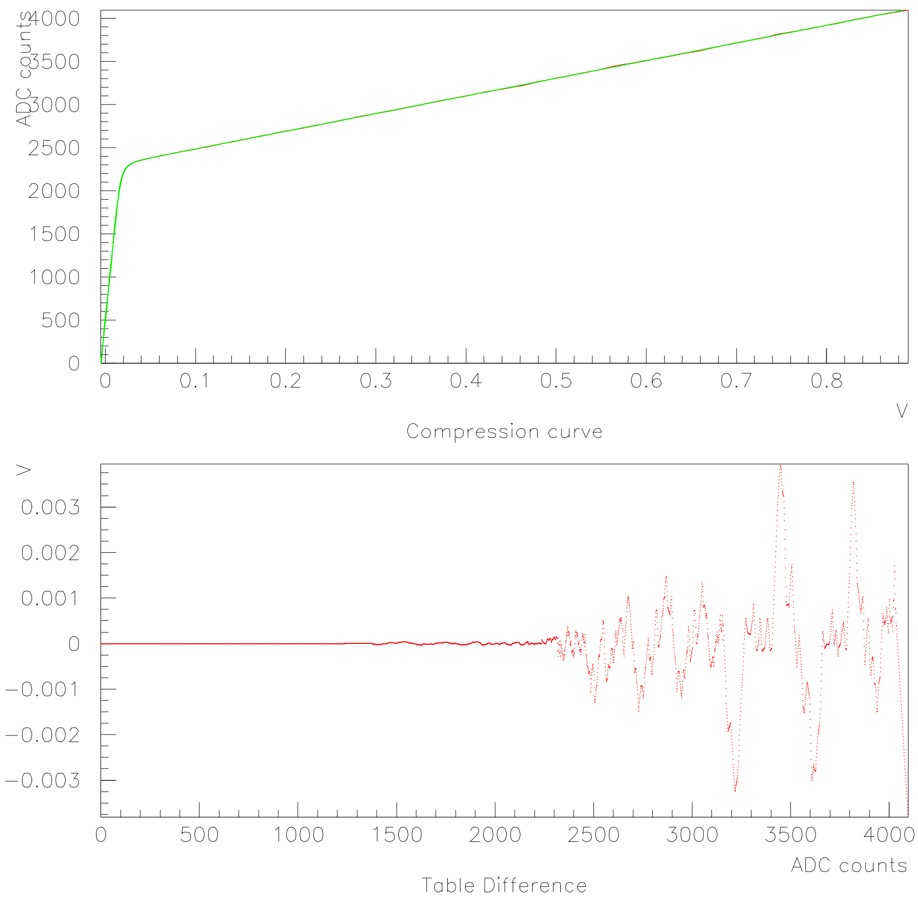

Figure 6: Reconstructed (red) and true (green) look-up tables and their differences for simulated data. Smooth break point with noise.