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MERGING THE LAR SHAPER WITH THE FERMI COMPRESSOR : PRESENT STATUS.

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Abstract

The present state of the art about the interfacing of the FERMI module with the front-end electronics of the LAr e.m. calorimetry is discussed in this note.

1. Introduction

The interfacing of the FERMI module with the front-end electronics of the detector is done by adequately merging the shaper with the compressor actually sitting in the analog chip of FERMI.

In the present design (the FERMI module demonstrator), the compressor is integrated in the FERMI module [1]. It is envisaged to have the compressor integrated in the shaper of the detector [2]. A first attempt in this direction is being made by the L.A.L. electronic group and the L.P.N.H.E. PARIS 6-7 ATLAS group. In this note we are emphasizing the present status of this work by reviewing what are the main questions being or to be solved. In section 2 are presented the main steps of the processing by the front-end electronics of the e.m. liquid Argon signals. It follows in section 3 by the explanation of the signal processing as achieved by the FERMI compressor. The remaining problems to properly merge these two devices in order to achieve the processing of signals over the full LHC dynamic range (16 bits) are discussed in these two sections. Finally in section 4 are explained the foreseen solutions presently under study.

2. Liquid Argon signal processing in the front-end electronics.

The liquid Argon calorimeter provides, as information, a current which corresponds to the electrons drifting from one electrode to the other. This signal has a triangular shape with a width that varies with the gap between the electrodes. In the case of the central e.m. barrel of ATLAS, it is around 400 ns (fig 1). The initial current is typically 2.5 mA per TeV with the geometry described in ref [3]. This current is amplified by a current preamplifier to drive the signal outside the cryostat through 50Ω cables. The signal shape is conserved, although slightly integrated (slowed down), due to the non infinite preamp bandwidth.

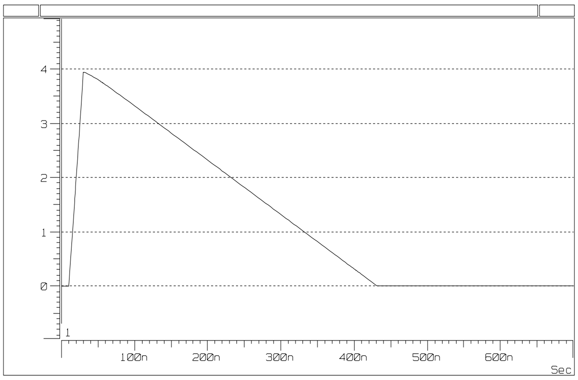

fig 1: Shape of the current signal delivered by the LAR e.m. central barrel of ATLAS.

By applying a derivation, this triangular shape is clipped. This is done in order to reduce as much as possible the effect of pile-up events. It leads to a decrease of the signal to electronic noise ratio, as a large fraction of the total charge is lost. The full analog processing applied to the signal in the shaper [5], includes the following sequence : an integration, a derivation, another integration. After such a processing, the signal exhibits a pseudo-gaussian shape.

The large energy deposited in some calorimeter cells (up to Et = 1.5 TeV) and the low noise achieved by the preamplifiers (=30 MeV) lead to a very large dynamic range (= 16 bits). This would require an even larger dynamic range (≈ 18 bits) at the shaper input and in the rest of the readout in order not to degrade the noise as all the contributions add quadratically. Either it should be designed with similar low noise as the preamps (but the problem would be transferred to the subsequent stages) or the signal should be substantially amplified which is barely possible, as the maximum input signal is already around a few volts. A classical solution is then to split the output into two ranges : one for the small signals requiring a low noise to preserve a .good energy resolution, and one for the high signals, with typically unity gain, where the noise is less crucial. Thus, the two outputs, typically in a ratio of 16, put the preamp noise in the mV region and the maximum signal around a few volts.

In order to minimize noise contribution from further stages inside the shaper, the signal is amplified before the differentiation. This also has the advantage to conserve a zero signal area, for AC coupling to avoid baseline shifts and low frequency noise. One problem appears when the saturation takes place in the electronic chain. It leads to a saturation of the triangular (i.e. non shaped) signal (see Fig. 2). According to the processing sequence applied to the signals, these triangular saturated signals are then submitted to a derivation (see Fig. 3)

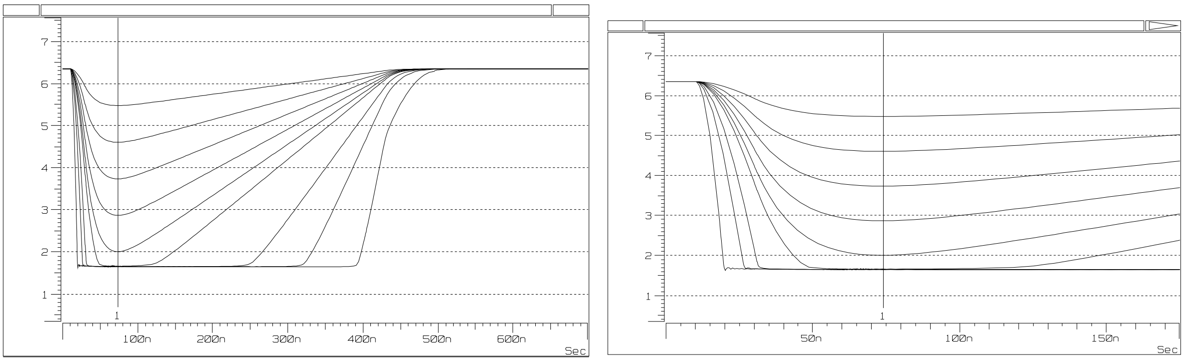

*fig 2 : shape of the signal **inside t**he shaper, **before the derivation,** for different input signal values*

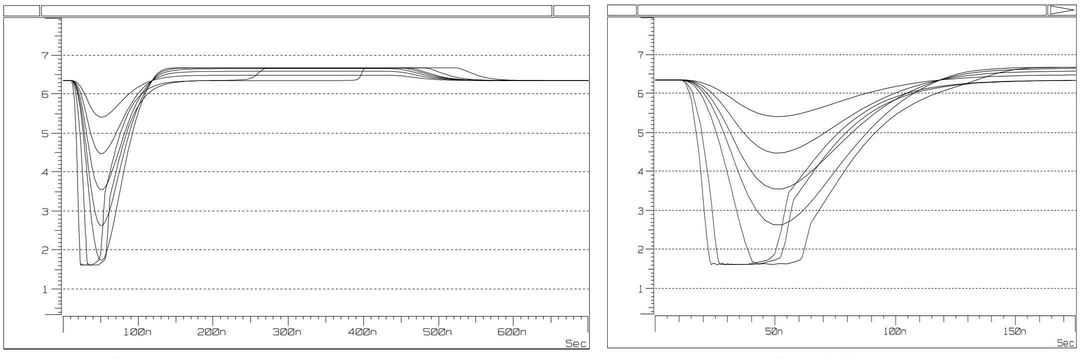

*fig 3 : shape of the signal **outside** the shaper, **after the derivation,** for different input signal values*

In fig 3, we observe that the deformations of the saturated signals are of several kinds. First there is a shift in time of the peak of the impulse, together with a saturation at this maximum peak. Secondly, the tail of the signal, that in normal case is a long flat undershoot, becomes in a first part a plateau at zero followed by a shorter undershoot. Moreover the zero crossing time, from the peak to the tail, that in normal case is fixed, becomes variable.

It is interesting to note that these deformations of saturated signals are also noticed by people studying the possibility to compress the signal immediately after preamplification [4]. It applies in the case of liquid Krypton where the dynamic range becomes at least 17 bits. The same effects, related to the saturation, occur but at a very early stage in the front-end electronic chain.

3. The signal processing in the FERMI compressor :

The input of the FERMI compressor is differential and the compressor is designed to cope with 16 bit dynamic range signals. As discussed in section 2, the present LAR shaper has two single-ended 15 bits outputs. For the same reasons than the shaper, the compressor cannot have a single input to ensure negligible noise contribution, as the dynamic range at the input would be order of 18 bits. Therefore the compressor is split into two parts for merging these two stages. One part receives and treats the low gain signals (i.e. the ones as given by the high energy particles). The second part is linked to the high gain shaper and thus corresponds to the low energy particles. The corresponding gains in the compressor are accordingly modified in order to fit with the required resolutions.

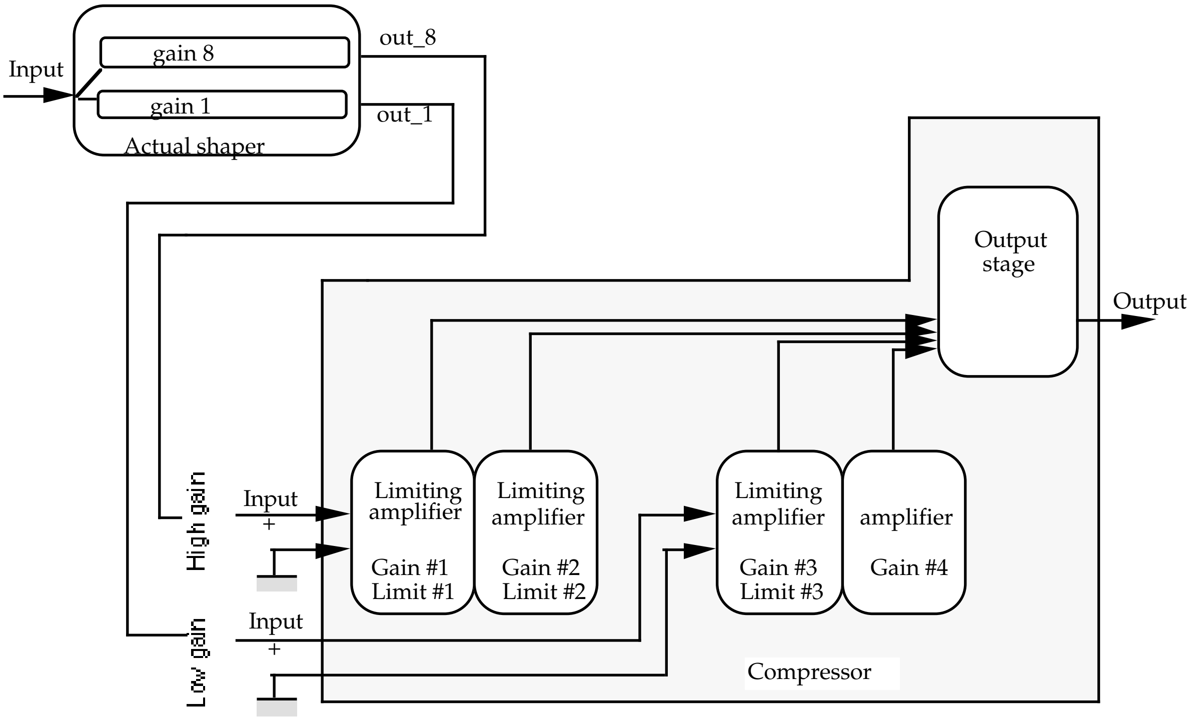

Fig 4: synoptic view of the analog chip in FERMI

The circuit of the compressor has been modified and studied running a full SPICE simulation both of the LAR shapers and the FERMI compressor. The actual results are given in Fig. 5.

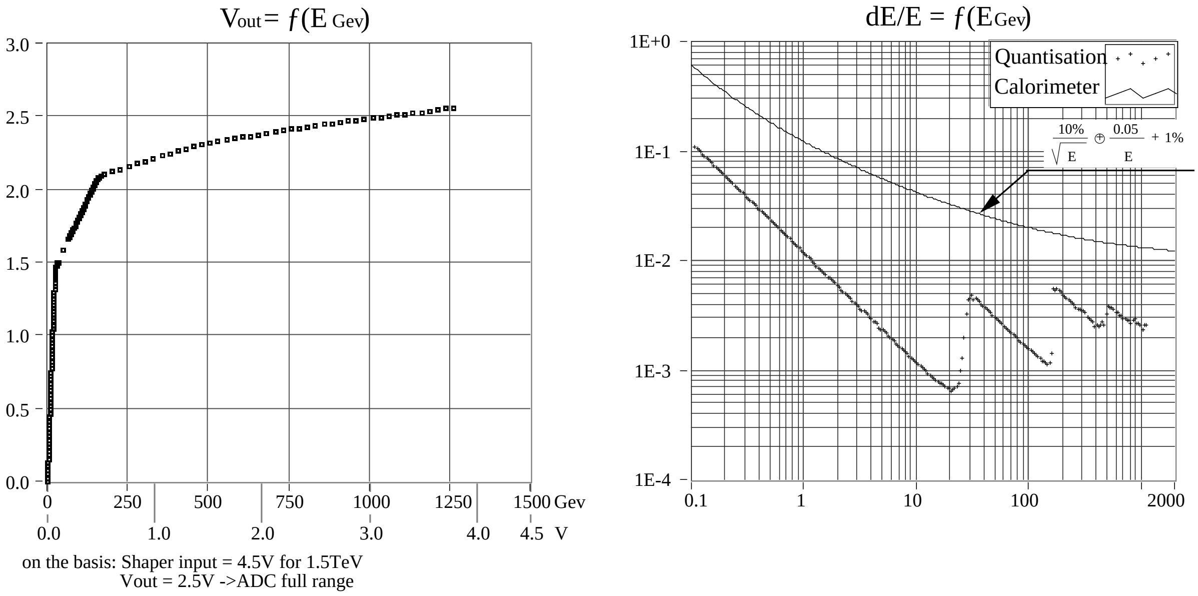

Fig. 5 : Resolution with the modified FERMI compressor

In this design, the high gain channel has an overall amplification factor that corresponds to the high gain of the shaper multiplied by either Gain #1 or Gain #2 of the compressor. The low gain is obtained by multiplying the low gain of the shaper (i.e. 1 in general) by Gain #3 or Gain #4. These gains have to be optimized :

1)- to minimize the contribution of the shaper plus the compressor to the overall electronic noise,

2)-to keep the quantisation noise of the shaper plus the compressor well below the resolution curve of the calorimeter.

The transfer curve of the compressor, shown in fig 5, reflects this preliminary attempt to merge the LAr shaper with an adapted compressor. In this first try, the gains have being modified in such a way as to reproduce the resolution curve obtained with a generic FERMI compressor. Obviously, these parameters can still be worked out to improve the performances of the device.

At this stage, it is important to note the following problem shown in Fig 6. The saturation effect, described in Section 1, that occurs for particles with an energy around 200 GeV (i.e. at around one tenth of the maximum scale in energy), and is a saturation appearing in the front-end electronics, has some consequences when processing the corresponding signals in the FERMI compressor. When passing the saturated signals in the compressor, their shape is further modified as shown in Fig. 6.

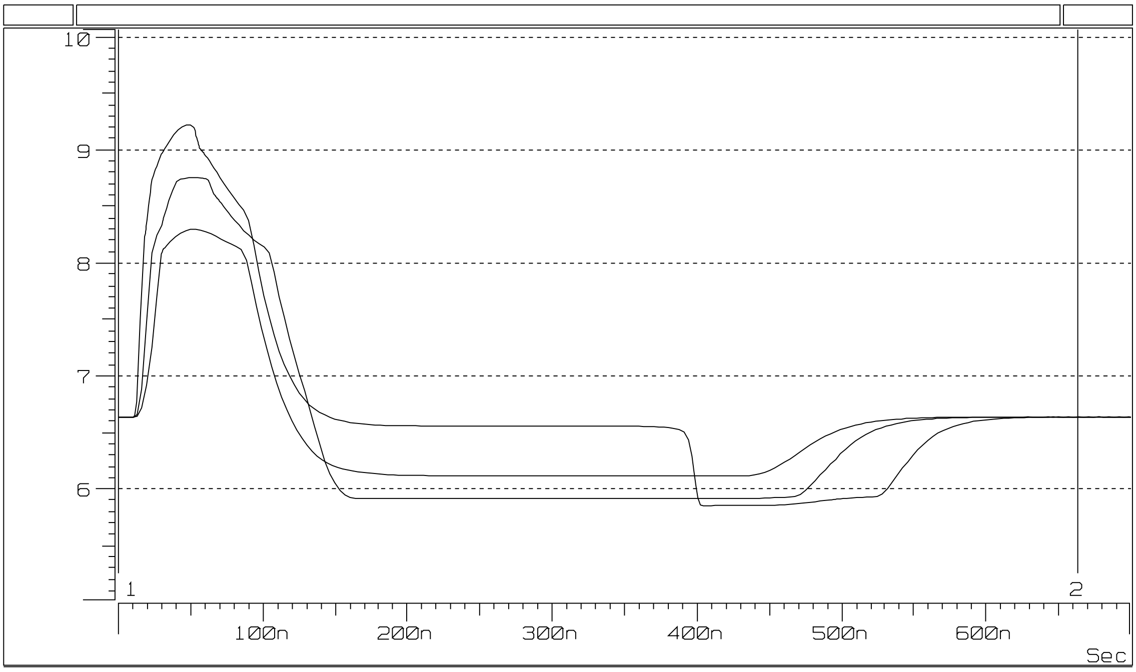

Fig. 6 : Output of the compressor connected to the LAr shaper for signals of different amplitudes.

This figure shows that the non saturated signals are properly transferred by the modified compressor. But, when the incoming signals are distorted by the saturation that occurs in the front-end electronics, they are further modified by the compressor. This is due to the addition by the compressor of the regular signal from the low gain channel and the distorted saturated signal from the high gain channel.

4. Foreseen solutions for the saturation problem.

To cope with this effect we are studying various possible solutions. One possibility that seems to cure the saturation effect is to change the sequence in the front-end processing. Namely by doing first the derivation and then amplifying, the effect we have noted disappears (see Fig. 7). However the price to pay is a worsening of noise. Very preliminary simulations seems to indicate an increase of about 20% of the total noise at the output of the compressor (350 μV instead of 300 μV). However this scheme modifies the adaptation at the input of the shaper, that, indeed, is not anymore 50Ω adapted. A detailed simulation study is under way in order to evaluate whether or not an additional adaptation stage is required. If required, it would lead to an increase of the electronic noise, that has to be estimated.

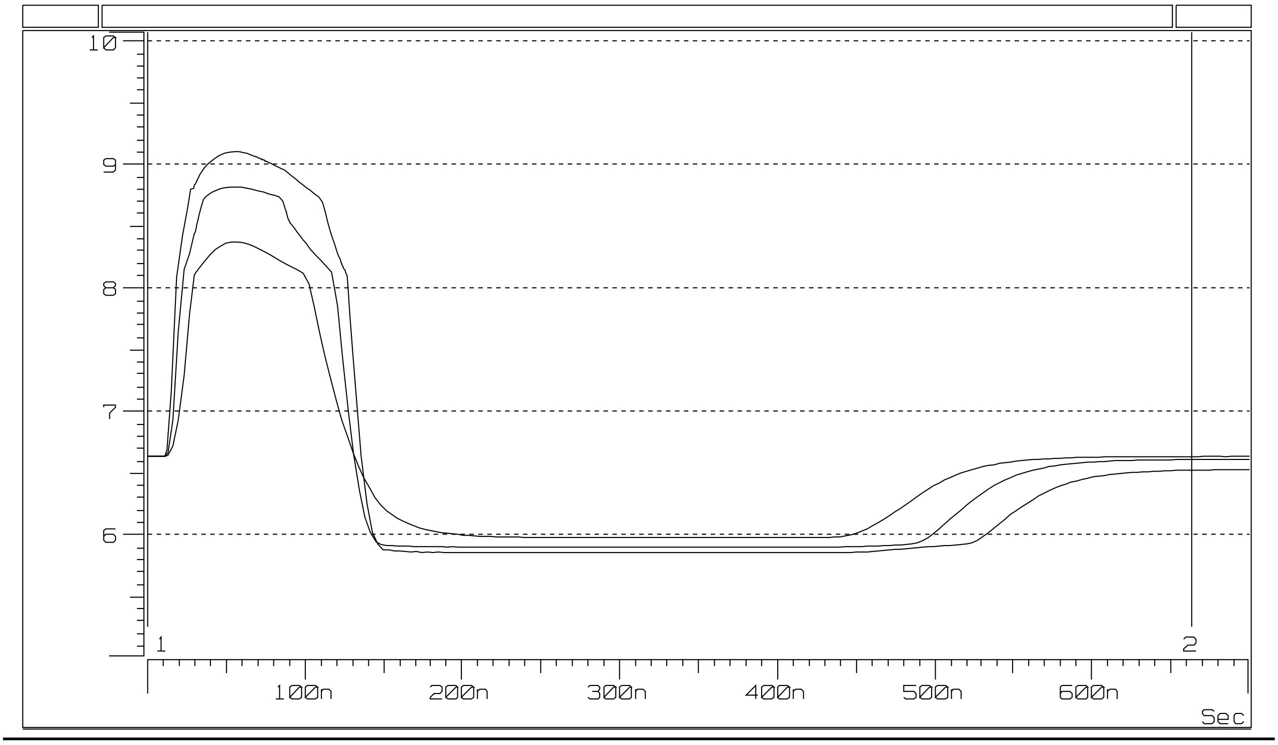

fig 7 : simulation of amplification after derivation.

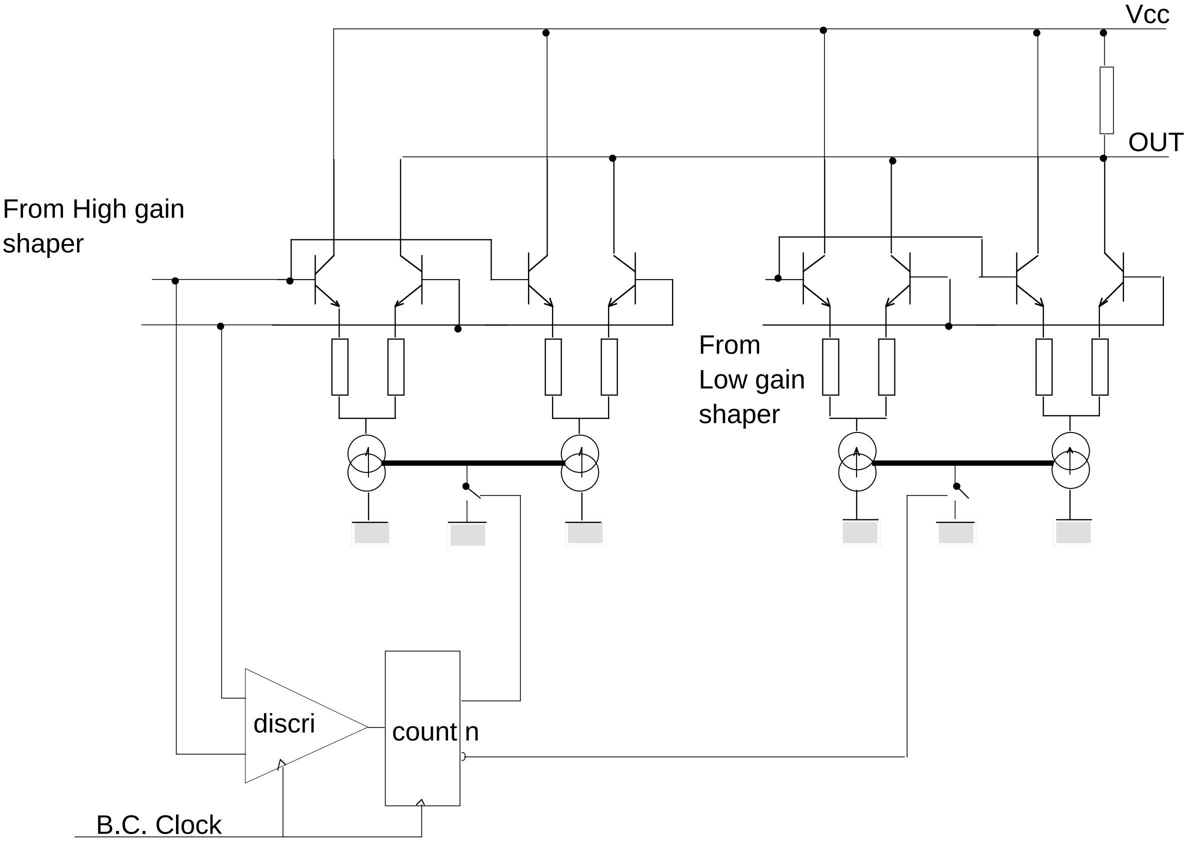

fig 8: sketch of a two channels compressor using commutation.

Another possibility under study is to reproduce, in the compressor, the two range channel (low gain resp. high gain), as in the LAR shaping sequence (see Fig. 8). This implies to split even more the compressor, i.e. to include two outputs and to send to the ADC, with the help of a fast comparator, the signal of the non-saturated channel. This means a dramatic change in the compressor. The analog design must be completely reviewed and the commutation problems must be properly solved. A possibility would be to discriminate, synchronously with the beam-crossing, on the high gain channel at a level before the saturation, and to choose during a time corresponding to the drift time in the detector, the gain which stays linear.

Besides these two hardware solutions, a work is undertaken that consists in processing the saturated signals in the level-1 and the level-2 filters as designed for the FERMI readout. The aim is to evaluate how well these rather rare signals can be recovered this way.

Acknowledgments

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[5] ATLAS Internal Note, LARG #10