Calculation of signals in the FMD simulation and reconstruction

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Introduction

This is meant as a reminder of what kind of manipulations we do in the simulation and reconstruction of FMD data. Please refer to Table 1 for conventions and constants used in this document.

Simulations

In the hits (`AliFMDHit`) are generated per strip for each particle that impinges on a strip. Stored in the hit are the energy loss $\delta_{i,mc}$ of the particle impinging as well as the path length $l_{i,mc}$ of the particle track through the strip.

When generating simulated detector signal (`AliFMDSDigit` or `AliFMDDigit`) the energy loss in all hits in a single strip is summed to a total energy loss in the strip.

$$\Delta_{i,mc} = \sum_j \delta_{ij,mc} \quad [\text{MeV}] \tag{1}$$

The detector signal (ADC counts) is then calculated using the fixed gain of the VA1 pre-amplifiers (q_{mip}), the average energy deposition of a MIP $\bar{\Delta}_{mip}$, and the pulser calibrated gain of the strip g_i. These numbers combine to a conversion factor $f_{i,mc}$ given by

$$f_{i,mc} = \frac{q_{mip} g_i}{\bar{\Delta}_{mip}} \quad [\text{NMeV}^{-1}] \tag{2}$$

This factor and the constant value C_i is then used to calculate the number of ADC counts

$$c_i = \Delta_{i,mc} f_{i,mc} + C_i \quad [\text{N}] \tag{3}$$

In case of multiple samples (r) of the same strip, each sample j is given by

$$c_{ij,mc} = f_{i,mc}\left(\Delta_{i,mc} + (\Delta_{i-1,mc} - \Delta_i)e^{-b\frac{j}{r}}\right) + C_i \quad [\text{N}] \tag{4}$$

where j runs from 1 to r (the number of samples), and b is a constant that depends on the shaping time of the VA1 pre-amplifier (see also Figure 1).

Since the ADC has a limited range of 10bits ($= 10^2 - 1 = 1024 - 1$) all signals are truncated at 1023.

For summable digits (`AliFMDSDigit`) $C_i = 0$, but for fully simulated digits c'_i (`AliFMDDigit`) it is given by the pedestal p_i and noise n_i of the strip

$$C_i = \text{gaus}(p_i, n_i) \quad [\text{N}] \tag{5}$$

that is, a Gaussian distributed number with $\mu = p_i$ (pedestal) and $\sigma = n_i$ (noise).

Symbol	Unit	Value	Description
δ_{ij}	MeV		Energy loss by particle j in strip i
Δ_i	MeV		Summed energy loss in strip i
mc			Monte-Carlo mark
q_{mip}	Q	29.67	Number of e^- charges for a MIP
$\bar{\Delta}_{mip}$	MeV	0.124	Average energy deposition by a MIP
c_i	N	$[0, 10^2 - 1]$	ADC counts in strip i
g_i	N/Q	2.2	Pulser calibrated gain for strip i
p_i	N	100	Pedestal value in strip i
n_i	N	$2 - 4$	Noise value of strip i
f_{ol}		4	On–line noise suppression factor
f_{reco}		4	Reconstruction noise suppression factor
b		6	Shaping time parameter
ρ	g cm^{-3}	2.33	Density of silicon
T	cm	0.032	Thickness of sensors

Here,

$$\begin{aligned}\bar{\Delta}_{mip} &= 1.664\,\mathrm{MeVcm^2g^{-1}}\rho\,T \\ &= 1.664\,\mathrm{MeVcm^2g^{-1}}2.33\,\mathrm{g\,cm^{-3}}0.032\,\mathrm{cm} \\ &= 0.124\,\mathrm{MeV}\end{aligned}$$

where $\rho = 2.33\,\mathrm{g\,cm^{-3}}$ is the density of silicon, and $T = 320\,\mu\mathrm{m}$ the thickness of the silicon sensor. The factor q_{mip} is given by the electronics of the front–end cards of the FMD and was measured in the laboratory in August 2008. It is a digital–to–analogue setting corresponding to 1 MIP in the pulser injection circuit on the front–end electronics.

Table 1: Conventions used in this document, and constant values.

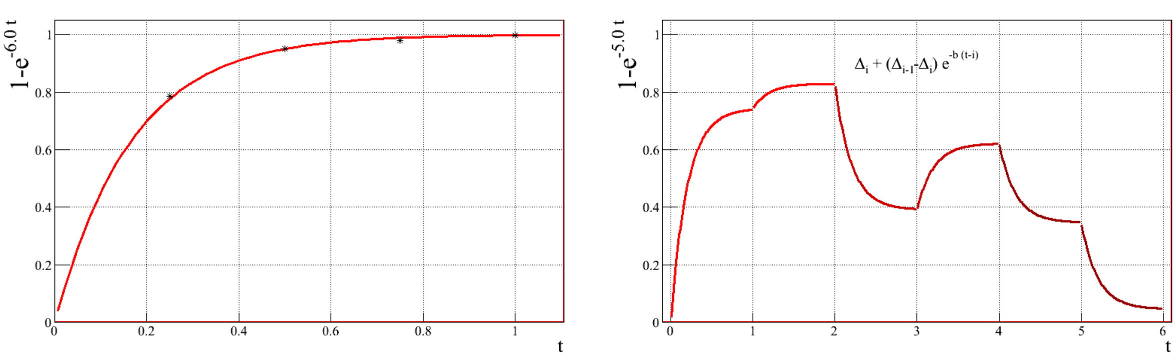

Figure 1: Left: Shaping function of VA1, right: the resulting train of signals from (4). Note, that the signal value used is just before the turn to the next value.

Raw data

The raw data, whether from simulation or the experiment, is stored in the ALTRO/RCU data format. The ALTRO has 10 bit (maximum count value of $10^2 - 1\,\mathrm{N} = 1023\,\mathrm{N}$) ADC with up to 1024 consecutive samples of the input signal. The 128 input strip signals of VA1 chips, are multiplexed into a single ALTRO channel in such a way that each strip signal is sampled 1, 2, or 4 times[1].

The signal is then pedestal subtracted

$$d_i = c_i - p_i + f_{ol} n_i \quad [\mathrm{N}] \tag{6}$$

where p_i and n_i are the pedestal and noise value, evaluated on–line in special calibration runs, and f_{ol} is a integer factor selected when configuring the detector[2]

After pedestal subtraction, which ensures that strips not hit by a particle has a 0 signals, an zero–suppression filter is applied by the ALTRO. This filter throws away all 0s from the data and replaces them with markers that allows one to reconstruct the position of the remaining signals in the sample sequence.

The signals from each ALTRO input channel is then packed into blocks and shipped to the RCU and eventually the data acquisition system.

In simulations a similar filter is applied to the data to simulate the ALTRO channels. The total signal from the a strip (3) is then given by

$$c_i = \Delta_{i,mc} f_{i,mc} + \mathrm{gaus}(p_i, n_i) - p_i - f_{ol} n_i \quad [\mathrm{N}] \tag{7}$$

and similar for c_{ij} (4).

Reconstruction

When reconstructing of either simulated data or data from the experiment, the first thing is to read in the raw data stored in the ALTRO/RCU data format[3]. This is done by the `AliFMDRawReader` class.

Depending on whether or not the data was zero–suppressed, the `AliFMDRawReader` code will do a pedestal subtraction, or add in the noise previously subtracted in the ALTRO (or simulation there of)

$$s'_i = c_i + C_i = c_i + \begin{cases} -p_i & \text{not zero–suppressed} \\ +f_{ol} n_i & \text{zero-suppressed} \end{cases} \quad [\mathrm{N}] \tag{8}$$

where f_{ol} is the noise factor applied by the ALTRO[4], and p_i and n_i are the pedestal and noise value of the strip in question.

In the reconstruction it is possible (via a `AliFMDRecoParam` object) to specify a stronger noise suppression factor f_{reco}. If the signal s'_i is smaller than the noise n_i times the greater of the two noise suppression factors, it is explicitly set to 0

$$s_i = \begin{cases} s'_i & s'_i > n_i \max f_{ol}, f_{reco} \\ 0 & \text{otherwise} \end{cases} \quad [\mathrm{N}] \tag{9}$$

We now have a signal s_i which is akin to $f_{i,mc}\Delta_{i,mc}$ of (7). We therefor calculate the energy loss in the i^{th} strip using the factor

$$f_{i,reco} = \frac{\bar{\Delta}_{mip}}{q_{mip} g_i} = f_{i,mc}^{-1} \quad [\mathrm{N}^{-1}\mathrm{MeV}] \tag{10}$$

which is the inverse of (2), and the energy loss is then

$$\Delta_{i,reco} = s_i f_{i,reco} \quad [\mathrm{MeV}] \tag{11}$$

[1] Currently, the default is to sample 2 times.

[2] Typically $f_{ol} = 4$.

[3] There is an option to reconstruct from the simulated `AliFMDDigit` objects directly, in which case this step is skipped entirely.

[4] This factor is stored in the event header and read by the `AliFMDRawReader` — thus ensuring consistency.

From energy loss to ADC counts and back

If we take (3) and (11) and assume

- that s_i is not suppressed by (9)
- (8) removes the fluctuations put in (5)

and put them together we get

$$\begin{aligned}\Delta_{i,reco} &= s_i f_{i,reco} \\ &= (c_i + C_i)\frac{\bar{\Delta}_{mip}}{q_{mip} g_i} \\ &= \Delta_{i,mc} f_{i,mc} f_{i,mc}^{-1} \\ &= \Delta_{i,mc} \end{aligned} \tag{12}$$

Some calculations

Assuming a typical energy loss of $2.9\,\mathrm{MeV\,cm^{-1}}$ and applying (3) and (2), we get a signal value over pedestal of

$$\begin{aligned} c_i &= 2.9\,\mathrm{MeV\,cm}^{-1}\,T\,f_{i,mc} \\ &= 0.0928\,\mathrm{MeV}\frac{29.67\,\mathrm{Q}\ 2.2\,\mathrm{N\,Q}^{-1}}{0.124\,\mathrm{MeV}} \\ &= 0.0928\,\mathrm{MeV}\ 526.40\,\mathrm{NMeV^{-1}} \\ &= 48.85\,\mathrm{N} \end{aligned} \tag{13}$$