



Application of digital sampling techniques to a “single chip telescope” for isotopic particle identification

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Some applications of digital sampling techniques are presented which can simplify experiments involving sub-nanosecond timing determinations and energy measurements with nuclear detectors used for Pulse Shape Analysis and Time of Flight measurements in heavy ion experiments. The basic principles of the method are discussed as well as the main parameters that influence the accuracy of the measurements. The method allows to obtain both high resolution time and amplitude information with an electronic chain simply consisting of a charge preamplifier and a fast high resolution ADC (in the present application: 100 MSample/s, 12 bit) coupled to an efficient on-line software: for example the timing resolution can be as good as 100 ps FWHM. Examples of this technique applied to various detectors in heavy-ion experiments involving particle identification via Pulse Shape Analysis (PSA) are presented. Particular attention is devoted to the analysis of the performance of a “Single Chip Telescope” detector coupled to such a sampling system.

1. INTRODUCTION

In this paper the use of fast digitizing systems for identification of charged particles using various detectors is discussed. Modern electronic sampling techniques (for example pipelining) have made it possible to design commercial high resolution ($\gtrsim 10$ bit) fast sampling analog to digital converters (ADC) which permit to retain the high precision of the standard analog methods (for instance for the energy measurement), while the detailed information achievable with signal sampling can be used in newly designed pulse shape discrimination applications: an example of these applications has been reported in [1–3].

The paper is organized as follows: in the next section a brief description of the sampling system used in our experimental tests is given. In section 3 the algorithms used for high resolution energy measurements are presented, and experimental results obtained with standard Si-CsI ΔE -E telescopes and CsI scintillators are discussed. In section 4 some experimental results regarding high resolution timing measurements with digital sampling systems will be shown, and results of digital PSA in a reverse mount Silicon detector will be presented. Section 5 will present the results obtained using a “Single Chip Telescope” detector coupled to such a sampling system.

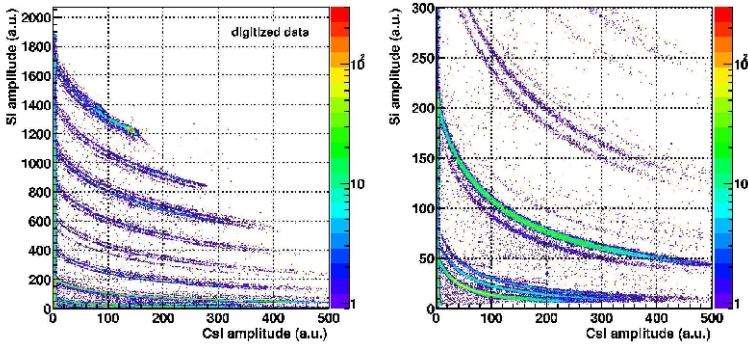


Figure 1. ΔE - E correlations obtained with a standard Si-CsI telescope and digital sampling techniques (see text). Both energy ranges have been obtained using only one converter for the Silicon detector.

2. THE DIGITIZER

In this work the digitizer already described in ref.[1] has been used: the system is provided with 4 independent input channels, each sampled by a fast Analog to Digital Converter (ADC, AD9432 from Analog Devices) with a resolution of 12 bit and 100 MSample/s. Specific measurements have determined the effective number of bits as $ENOB = 10.8$. The analog input stage of each channel is a 3-poles active Bessel filter, that operates as antialiasing filter while minimizing signal distortion. The sampled data is stored on a temporary memory (FIFO) and then transferred to the acquisition system through the VME bus for off-line analysis. As discussed in [1] and in the following, all the proposed algorithms are simple and fast enough to be used for on-line analysis with Digital Signal Processors (DSPs). A new modular system has been developed: it is provided with 8 channels per module, each of them using a Digital Signal Processor (DSP ADSP2189N) for on-line analysis of digitized data. This system will allow to apply the digital methods discussed in this paper and in [1,2] to large number of detectors: ~ 200 channels are in preparation for the 2004 Nuclex campaign at the Laboratori Nazionali di Legnaro of INFN (Padova, Italy).

3. ENERGY MEASUREMENTS

The use of a high resolution (12 bit) fast sampling analog to digital converter makes it possible to perform high resolution energy measurements with an intrinsic resolution that compares well with standard analog equipment. For example, it is possible to apply a Digital Filter (see for example [4,5]) to the collected samples in order to extract the relevant amplitude information and to achieve an optimal signal to noise ratio.

In order to check these assumptions we have performed an experimental test at the Laboratori Nazionali di Legnaro of INFN (Padova, Italy) using the $^{16}\text{O}+^{116}\text{Sn}$ reaction at a beam energy of 250 MeV. A first test has been performed on a common detector

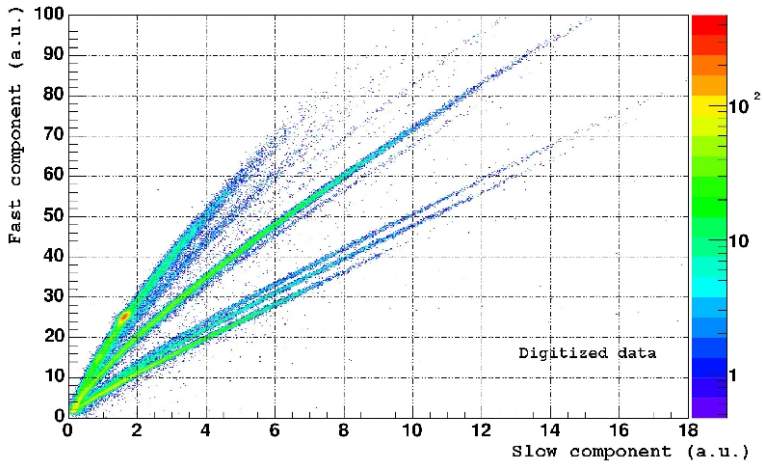


Figure 2. Pulse shape in a CsI scintillator with photodiode readout obtained using a single sampling system. Data have been processed using two different digital shaping time constants.

configuration: a standard Si-CsI ΔE - E telescope of the Garfield apparatus [6]. The Silicon detector was $300\ \mu\text{m}$ thick, and the CsI scintillator fluorescence was measured using a light guide and a photodiode. The outputs of the two charge preamplifiers connected to the detectors were directly fed into two channels of the digitizer system. A digital semigaussian-like shaping has been performed on both signals, and the results are shown in Fig. 1. The system achieves full isotopic resolution up to the used projectile in the whole dynamic range.

Signals coming from the CsI scintillator have been also processed with a different algorithm in order to study the pulse shape capabilities of the system with CsI scintillator: each signal has been digitally shaped with a semigaussian-like filter ($\tau_{fast} \simeq 700\ \text{ns}$, $\tau_{slow} \simeq 2\ \mu\text{s}$). The results presented in Fig. 2 show the achieved isotopic discrimination for $Z \lesssim 3$.

These test are a clear indication of how a high resolution sampling system can be effectively used as a replacement of the standard analog techniques for energy measurements and PSA. The digital resolution and identification performances compare well with the ones of analog systems, whereas cost and system complexity can be significantly reduced.

4. TIMING MEASUREMENTS

A very common PSA technique for particle identification is the study of signal risetime (or similar quantities) as a function of particle energy and type. Thus, an investigation of the timing properties of sampling systems is required to understand whether these methods can be used for this kind of applications.

In [2] a full discussion of this topic is reported as well as a characterization of the

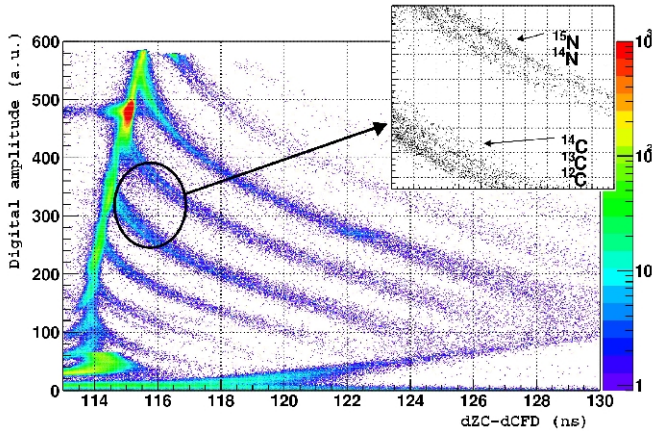


Figure 3. Identification plot for a reverse mount Silicon detector obtained using digital sampling techniques. Details of the isotope separation of Carbon and Nitrogen are shown in the inset.

properties of digital sampling systems that allows to perform high resolution timing measurements (for example 100 ps FWHM timing resolution with a 100 MSample/s, 12 bit digitizer). Sampling system are usually controlled by a sampling clock (for example a quartz oscillator) that is characterized by a very good stability over time and temperature (in our case errors are in the 1-10 ps range). Thus, as long as the signal risetime is not too fast with respect to sampling period (see Fig.4 of [2]), the achievable timing resolution is determined by the Effective Number of Bits (ENOB) of the converter and the overall electronic noise. It is possible to interpolate between the acquired samples (cubic interpolation is far superior than linear one, see [2]), and then reach a digital timing resolution much better than the sampling period of the system [2].

As an example of this application, we have performed a Digital Pulse Shape Analysis on a reverse mount Silicon detector (for details see [2]). The results are reported in Fig. 3. The Amplitude vs. Digital Zero Crossing time correlation allows the identification of particles stopped in Silicon with full charge resolution (partially for mass): the subnanosecond resolution attainable with this digital sampling system is evident.

5. THE SINGLE CHIP TELESCOPE

In the previous sections the main characteristics of high resolution energy and timing measurements using digital sampling techniques have been discussed and their performances tested using common detector configurations. It has to be noted that the flexibility of digital sampling techniques allows also for a simple and compact implementation of new types of detectors. For example, we have tested the performance of a Single Chip Telescope (SCT) [7] coupled to such a digital sampling system. With respect to the standard analog implementation described in [7], the digital one provides an impor-

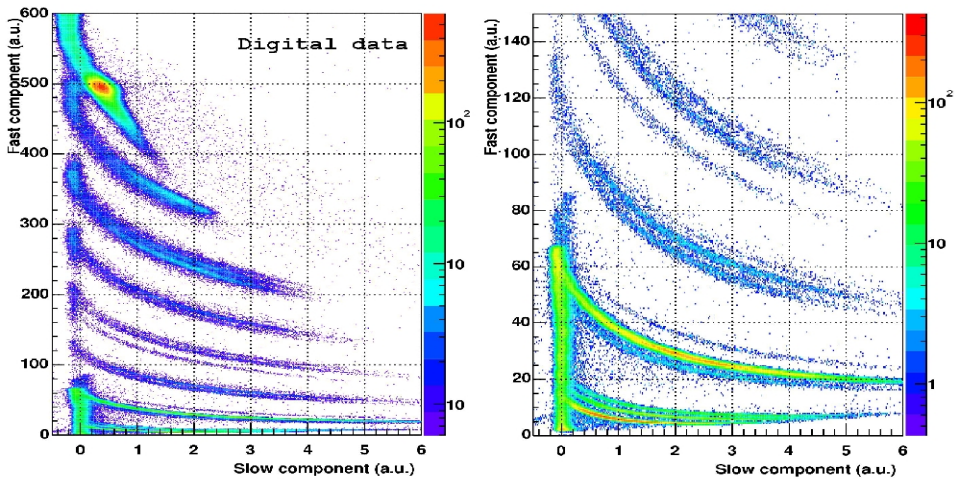


Figure 4. ΔE - E -like correlation obtained using a Single Chip Telescope coupled to one digital sampling channel. Both energy ranges (left and right panels) have been obtained using only one converter.

tant reduction of the required electronics, making the SCT an attractive device for high granularity experiments.

For particles stopped in the Silicon detector the same analysis described in the previous section can be applied, and identification of particle achieved using Pulse Shape Analysis of Silicon signals. Particles punching through the Silicon detector can be identified using a standard Fast vs Slow identification method (the same method used in [7] with analog electronics). The results obtained using digital shaping are presented in Fig. 4. The achieved identification results of this very first digitized SCT prototype are indeed encouraging and further work to improve the isotopic resolution of the system is in progress.

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