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LIST OF ACRONYMS AND ABBREVIATIONS

DSSD	Double-Sided Silicon-strip Detector
S^3	Super Separator Spectrometer
SIRIUS	Spectroscopy and Identification of Rare Isotopes Using S3

Optimisation of the Sirius silicon detector

Executive Summary

SIRIUS is a state-of-the-art detector system for nuclear decay spectroscopy that will be mounted at the focal plane of S^3 (Super Separator Spectrometer), which is part of the new SPIRAL2 facility at GANIL, Caen in France. Such a system requires high performance as it is dedicated to the study of very exotic nuclei. The detector and electronics chain have been mounted, characterised and evaluated. A special floating-point charge-sensitive amplifier has been developed. It has provided the required high dynamic range for super-heavy element research. A pulse-shape analysis of signals collected in the detection of alphas particles from radioactive sources has been performed and evaluated.

Introduction

During the last decades, continuous progress has been made towards the mass frontier of the nuclear chart. Today, all elements up to 118 protons have been synthesised, through fusion-evaporation reactions, with production cross-sections diving below the picobarn. Nevertheless, due to these low production levels, the superheavy elements are still barely known. The high-intensity stable beams of the superconducting linear accelerator of the SPIRAL2 facility at GANIL coupled with the Super Separator Spectrometer (S^3) and a high-performance focal-plane detector system will open new horizons for research in the domains of rare nuclei and low cross-section phenomena at the limit of nuclear stability. In order to study them, we need to perform the measurement of their decays (emission of proton, alpha, electron, and gamma). The objective of the SIRIUS (Spectroscopy and Identification of Rare Isotopes Using S3) project is to develop, commission and exploit a state-of-the-art focal-plane detector system for decay spectroscopy at S^3. In this activity, we focus on the use of silicon detectors to detect and measure the decay particles. This task aims at the test and development of the data-acquisition system of SIRIUS detector.

Section 1 SIRIUS

SIRIUS is a state-of-the-art detector system for nuclear decay spectroscopy that will be mounted at the focal plane of S^3 (Super Separator Spectrometer), which is part of the new SPIRAL2 facility at GANIL, Caen in France. Such a system requires high performance as it is dedicated to the study of very exotic nuclei. It is composed of a succession of detectors (Trackers, Si DSSD and Tunnel plus an array of five clover Ge detectors). This setup is mounted in a compact geometry using new advanced technologies. A sketch of the SIRIUS detector is shown here below (Fig. 1) together with the electronics cards and the turbo-pump systems.

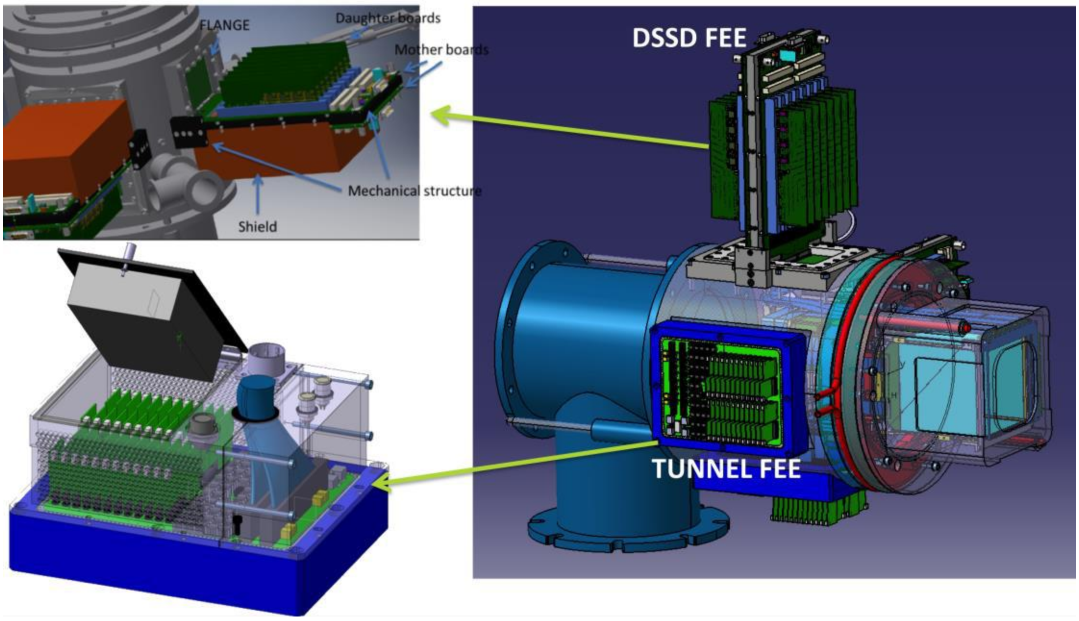

Figure 1 Layout of SIRIUS.

SECTION 2 CHARACTERISATION OF THE ELECTRONIC CHAIN

The complete detection and electronic chain for the DSSD has been built and integrated at IRFU, and is now currently under test for full characterisation and performance evaluation, using only two strips.

The new front-end electronics developed at IRFU allows energy measurements in the range from 50 keV to over 500 MeV with high precision (2 x 10^{-3}) for low energies and 1 % for the heavy ions. A major challenge has been the development of new electronics with a very large dynamic range maintaining an adequate resolution for the measured particles (with energies from a few hundred keV up to 500 MeV). The dual-channel Floating-Point Charge-Sensitive Amplifier (FPCSA) has been designed and built for the DSSD detector to meet these combined requirements. It implements an automatic gain-switching feature based on its voltage output. Gain switching from high to low occurs when the output voltage rises above a configured threshold. The FPCSA returns to high gain after 2.5 microseconds insuring system readiness for secondary detections in the same Si strip. A sketch of the electronic chain is shown in Fig. 2.

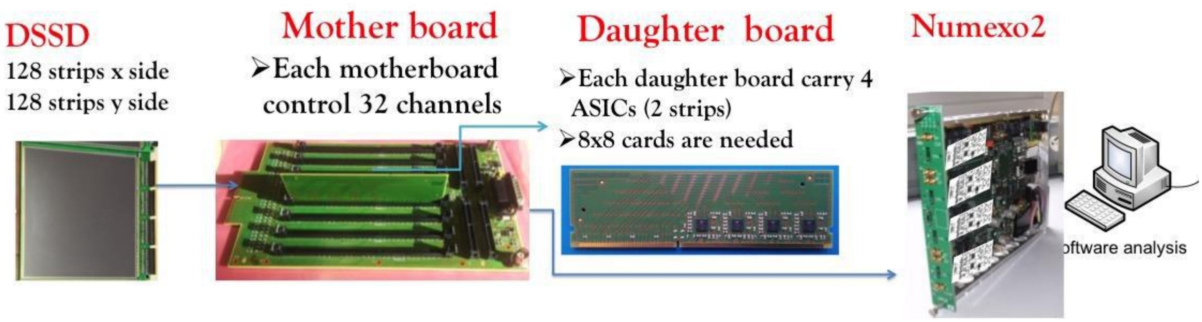

Figure 2 The full electronics chain is shown, where all the components from the motherboard to the daughter board hosting the Asics are shown.

SECTION 3 IMPLEMENTATION OF PULSE-SHAPE ANALYSIS

The 16 Numexo2 boards carry 16 ADC channels to digitise the input signals over 14 bits at 200 MHz. Each Numexo2 provides access to two Xilinx FPGAs (Virtex5 and Virtex6). A dedicated self-triggering and data concentration firmware is now under implementation in the Virtex6 to manage the incoming data flow.

Specific interfaces for slow control and data transfer has been developed during this task. Finally, the DAQ software implements online data-processing algorithms to extract physically meaningful information from the acquired data pulses accounting for the specific shaping induced by the FPCSA.

An example of pulse-shape analysis algorithm, developed during this task, to extract the energy is shown in the figure below, using the well-known trapezoidal filter method. The tests have been performed using an external triple alpha source of ^{239}Pu, ^{241}Am, ^{244}Cm and an electron source of ^{133}Ba. The resulting tests with the relative signals and the resulting alpha and electrum spectra are shown in Figure 3 and Figure 4. Tests have been performed at IRFU/Dedip in the vacuum chamber at different temperatures (-20, 0, +20 °C) and optimising the bias voltage to apply to the DSSSD.

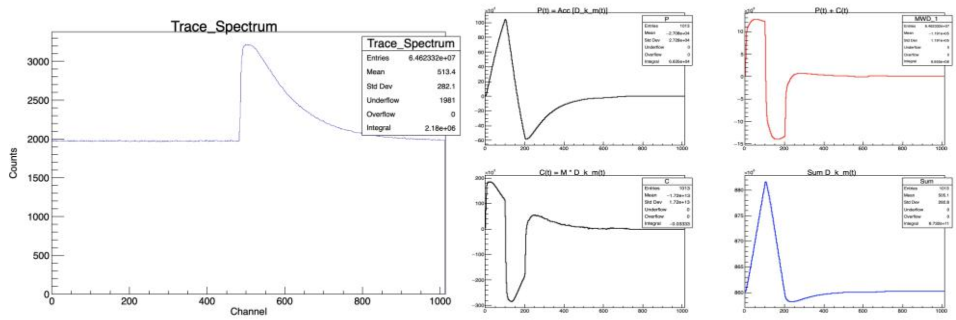

Figure 3 (Left side) An example of alpha trace signal. (Right side) A trapezoidal filter applied to the signal to extract the energy and time of the alpha particle.

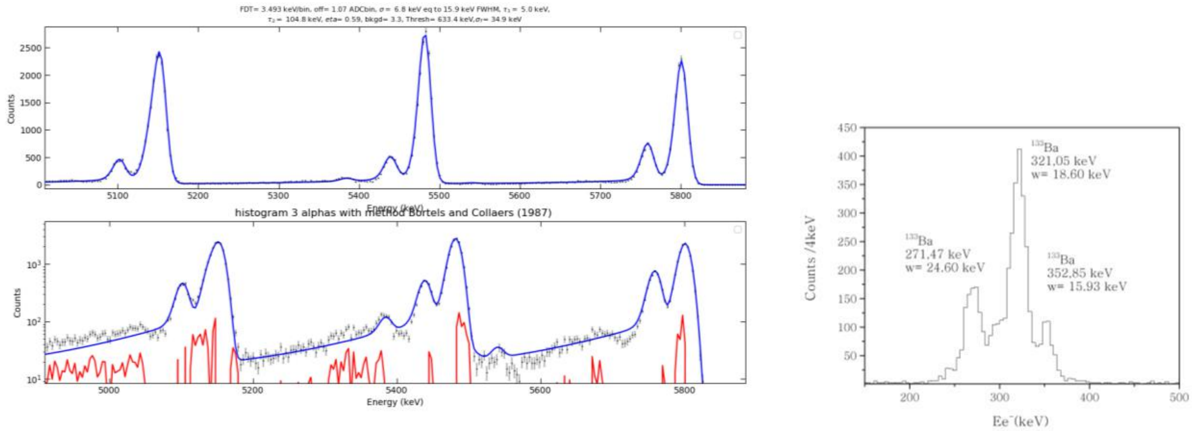

Figure 4 Left) Resulting alpha spectrum fitted via Bortoles and Collaers method. Right) Resulting electron spectrum.

SECTION 4 NEXT STEPS FOR THE SIRIUS PROJECT

SIRIUS will be shipped to GANIL in the next few months. It will then be tested with an external source in the LISE2000 experimental area. In-beam test at the LISE 2000 line will be performed in 2021/2022, according to beam time allocation by the laboratory.