# Intermediate report on the HIGHSPID project

## I Project goals

The goal of the HIGHSPID (**HI**gh **G**ranularity **H**odoScope for **P**article **Id**entification) project is to build and test a prototype electronic chain to read out the information from a Si strip detector in order to measure the energy and identify in mass and charge light charged particles (from protons to Li) through pulse shape analysis. The first step is to measure precisely the shapes of the signals of the different types of particles through experiments at the tandem accelerator of IPN Orsay. The electronics to then be defined should be compact with low power consumption and multiplexed in order to be adapted for multidetectors with a large number of channels (more than 10000). This system will be employed for particle multidetectors based on Si-strip technology and in particular the GASPARD detector to be deployed at the next generation ISOL radioactive beam facilities such as HIE-ISOLDE, SPES and SPIRAL2. The electronics developed will also equip Si detectors devoted to the measurement of atomic clusters such as those accelerated at the Orsay tandem. The project associates physicists from the NESTER and NIM groups of IPN and the SPhN service of Saclay. The instrumentation and electronics departments of IPN Orsay, IRFU and LAL bring their demonstrated competences to the project.

## II Description of the work achieved

In order to solve the issue of particle identification, the pulse shape analysis technique for light particles has been investigated. It relies on the digitalization of the charge and/or current signal with a frequency that should be adapted to the rise time of the registered signal. The case of light particles should be the most difficult case as the rise time of the signal is very short and a high sampling rate may be essential to obtain a good discrimination. Several test experiments have been performed at the Orsay Tandem. In the GASPARD project highly segmented Silicon detectors will be used so that the PSD on DSSSD had to be investigated. In this aim, a 500um thick DSSSD made of nTD wafer in order to guarantee a good uniformity in resistivity The strip pitch of this detector is 485um for a surface of 62mm x 62mm. The detectors' N-side was facing the beam in order to increase the PSD possibilities. Four strips on each side of the detector were read by PACI preamplifiers designed and built at IPN Orsay. These preamplifiers give current and charge signal output that were read by the MATACQ digitizers at 1 GHz sampling rate with a time window of 2,048 us. A $^{7}$Li beam at 35 MeV was impinging on a $^{12}$C target and produced mostly Z=1 and Z=2 particles. The identification spectra obtained using only the maximum of the current signal and the maximum of the charge are shown on Fig. 1 for the N-side and the P-side with a bias of 300V corresponding to the depletion voltage of the detector. No filtering or interpolation has been applied to the data. Only the interstrip events have been removed from the analysis. The Z=1 particles can be well discriminated (seeTab. 3) down to 2.5 MeV on the P-side (the threshold is higher on the N-side as it is the low-field side).The isotopic separation Z=1, Z=2 and Z=3 is also very satisfactorily achieved.

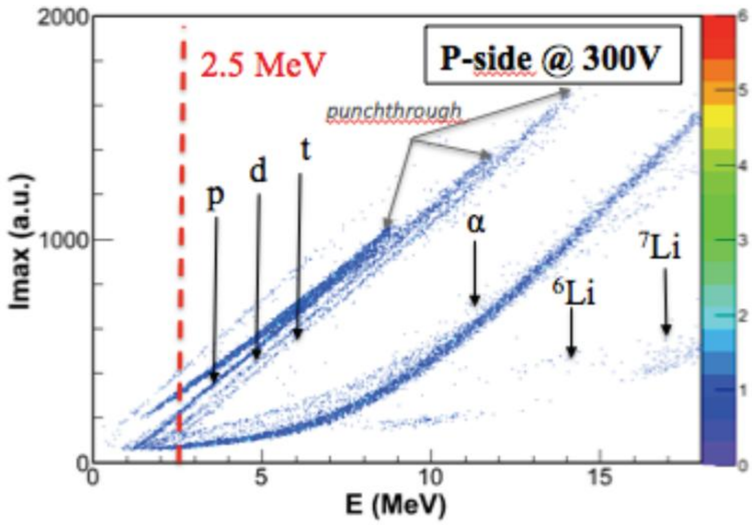


Fig 1:

This first test showed that very simple observable such as the maximum of the current signal can provide enough information to identify the light particles. It opens the doorway for analog electronics that would deliver, through fast peak finders, the maximum of the current and charge signals. Development of such a prototype will be one of the upcoming tasks of the project.

The effect of the bias of the detector has also been investigated. Without filtering the best compromise is obtained with the depletion bias of the detector where the PSD is of good quality without affecting the energy resolution. However, we have shown that when using a bipolar filter, PSD can also be obtained at nominal bias (over-depletion).

A follow-up experiment was performed with the same detector and electronics except the digitizers that were changed for the state of the art WaveCatcher digitizers which were built at LAL and funded by the HIGHSPID grant. They offer more channels (64) at 1GHz sampling with an acquisition rate 10 times larger than the previously used MATACQ. The detector was mounted in between a thin (40um thick) epitaxial Silicon detector and a pad detector of 500um thickness. The reaction measured was meant to focus on the discrimination between $^{3}$He and $^{4}$He particles. A beam of deuterons at 24 MeV was impinging on a mylar target and the (d,3He) reaction was measured. The preliminary analysis shows that the discrimination between 3He and 4He can be achieved nicely.

The PSD technique shows large improvement as compared to the ToF technique. The tritons and $^{3}$He very well separated down to energies below 2.5 MeV (time-of-flight can still be used to recover the part below 2MeV). The $^{3}$He/$^{4}$He separation is also obtained. The analysis is still ongoing

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In conclusion the best observable for PSA technique has been investigated and shows that the best results can only be obtained from observables based on the current signal. Therefore both charge and current signals are needed in the electronics of GASPARD. We have now submitted a 9 channel ASIC version of the PACI preamplifier funded by the HIGHSPID grant and the tests are ongoing. On the other hand, the minimum sampling rate needed for digital electronics has also been investigated by reducing the number of samples starting from 1GHz down to 100MHz. The results are shown in Fig. 4. Below 200MHz the quality of the discrimination is dramatically reduced. The best sampling rate for GASPARD electronics would be close to 500MHz. Designing such fast sampling electronics for a large number of channels will be an exciting challenge.

## III Publication and presentation:

**Characterization of light particle discrimination performances by pulse shape analysis techniques with high granularity Silicon detector.**
M. Assié, B. Le Crom, B. Genolini, M. Chabot, D. Mengoni, J.A. Duenas, S. Ancelin, D. Beaumel, Y. Blumenfeld, N. de Sereville, J.-J. Dormard, T. Faul, J. Guillot, A. Jallat, V. Le Ven, I. Martel, E. Rauly, D. Suzuki, and A.-S. Torrento
To be published in EPJA.

**The GASPARD project: a 4pi array for direct reactions measurements**
M. Assié. EURISOL topical meeting: Innovative instrumentation for EURISOL. York, UK, 15-17 July 2014. Proceedings page 101.

## IV Relevance of the project within P2IO and specific added value for P2IO

The study of nuclei far from stability is one of the major subjects of current nuclear physics. Our collaboration (IPN/IRFU-SPhN) has been at the forefront of the study of reactions induced by radioactive beams through the exploitation of the MUST and MUST2 Si-strip detector arrays and their associated electronics which were designed and built by our collaboration. The arrival of next generation radioactive beam facilities (HIE-ISOLDE a CERN, SPES in Italy and SPIRAL2 at GANIL) is an opportunity for the P2IO laboratories to consolidate their world leading position in the field. For this a new and improved array (GASPARD) must be designed within an international collaboration using the expertise in detector technology and electronics present in the P2IO laboratories. The HIGHSPID project has provided funding for the R&D work to determine the relevant parameters for the Pulse Shape Analysis technique and to start prototyping the electronics for the array. It has strengthened the collaboration between the electronics groups of IPN Orsay and IRFU.

## V Expenditures

2013
Purchase of Si-Strip detector for PSA tests (IPNO): 15 k€
Test experiment at ALTO-Tandem facility: Connectors, PCB cards, mechanics (IPNO): 10k€
Construction of Wave Catcher digitizer (LAL): 12k€
Encapsulation of components for Wave Catcher (IRFU) 5k€
**Total spending 2013: 42 k€**

2014
Submission of iPACI preamplifier ASICS (IPNO): 6k€
Test card for iPACI (IPNO): 4k€
**Total Spending 2014: 10 k€**