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LIST OF ACRONYMS AND ABBREVIATIONS

LEPS	Low-Energy Photon Spectrometer
GANIL	Grand Accélérateur National d'Ions Lourds
GTS	Global Trigger and Synchronization
SHN	SuperHeavy Nuclei

EXECUTIVE SUMMARY

As stated in the previous report, full isotopic identification of exotic species is often hampered by missing information on the atomic charge of the nuclei of interest. One possible solution is measurement of characteristic X-ray radiation. Two specific regions, where this information is essential, are isotopes in the N=Z region in the vicinity of ^{100}Sn [1] and SHN [2]. Therefore, the objective of this contribution to WP6 is the development of X-ray detection for Z-identification of nuclei produced in heavy ion reactions. The application of the developed technique is foreseen to be used in the framework of the study of exotic nuclei at the experimental facilities of GANIL/SPIRAL2.

Deep inelastic reactions in heavy ions collisions are possible alternative route to synthesize very nuclei heavy nuclei and possibly superheavy elements [3,4]. An experiment approved at GANIL will study the reaction ^{238}U+^{238}U with the aim to produce n-rich actinides in the uranium region close to N=152. It will possibly provide indications whether and how multi-nucleon transfer can be used to approach the region of the spherical shell-stabilized superheavy elements [5]. In order to prepare the experiment, we tested a setup using LEPS [6] and digital electronics in conditions close to the experimental ones. The objective was to qualify the setup at highest possible count rates.

INTRODUCTION

Study of super-heavy elements is challenged by experimental limitations related to their production and identification. Fusion evaporation experiments leading to the production of these elements are facing vanishingly small reaction cross sections as the charge number of the nucleus increases. Furthermore, there is no projectile-target combination to reach the so-called island of stability, where superheavy nuclei are expected to have an increased stability. The employment a new reaction mechanism for this purpose, like deep inelastic reactions could be possibly be a valid alternative. An important difficulty with heavy and superheavy nuclei resides in the identification of the reaction products. Synthesis experiments can rely on an identification method based on α-decay chains, i.e. recoil-decay correlations, only if for at least one member of the chain the α-decay properties are known. For heaviest neutron rich system this prerequisite is not given. Also, charge identification methods based on ΔE-E cannot provide sufficient resolution for heavy nuclei due to the difficulties to determine E with sufficiently high resolution, due to technical issues like the pulse-height defect in semiconductor detectors. As an alternative, an identification method based on the detection of characteristic X-rays can be envisaged. This method is very sensitive to the X-ray and γ background observed experimentally. Therefore, detector and acquisition system have to be optimized to conserve high resolution, and to reduce pile-up and dead-time issues due to expected high background counting rates. As a preparation of an accepted experiment investigating heavy reaction products in the reaction ^{238}U+^{238}U, we tested a setup composed of one LEPS and a silicon detector, both red out by a DAQ system based on a numexo2 digital electronics module. The setup will be described in the next session. Coincidence measurements of the α decay of ^{241}Am and the emission of a 59.5 keV γ ray are presented in section *Measurements* below.

EXPERIMENTAL SETUP

The germanium detector was mounted on a mobile arm allowing to adjust the detector position. The LEPS was separated from the vacuum by a 1.5 mm thick aluminum window. Inside the vacuum chamber a silicon detector was located, facing a mixed nuclide α source including ^{241}Am (3 isotopes). The source and the silicon detector were oriented in a way to avoid shadowing the germanium detector. The preamplifier output signals of the silicon and germanium detector were digitized by the numexo2 system. Timestamp generation was done by the GTS system. The timestamp was used to determine coincidences between the two detectors with a resolution of about 10 ns.

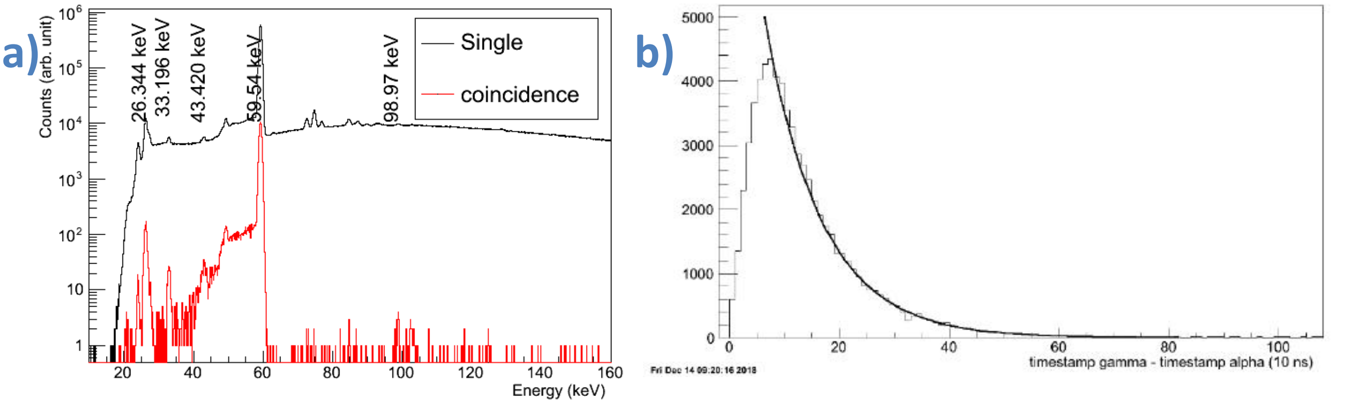

Figure 1 – a) LEPS single and coincidence spectrum - source combination: ^{241}Am + ^{60}Co – b) Decay curve: 1st 5/2- state of ^{237}Np populated by ^{241}Am α decay (note the x-axis unit: 10 ns).

Measurements

Measurements were carried out with a mixed nuclide α source containing ^{239}Pu, ^{241}Am (α-decay daughter ^{237}Np) and ^{244}Cm. Among those nuclides only the ^{241}Am provides in its α decay γ rays of significant intensity bellow 200 keV. The inclusive and α gated γ ray spectra are shown on

a) b)

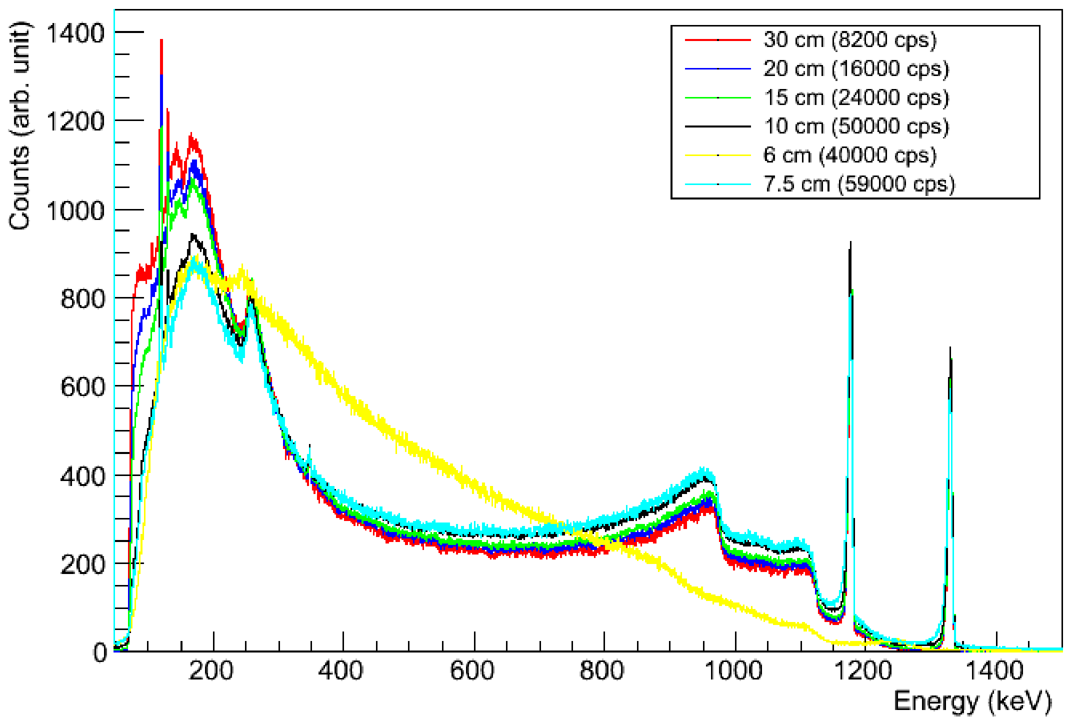

Figure 1 a). It can be observed that the coincidence algorithm can efficiently use the timestamps generated by the GTS to build coincidence with the alpha particles and hence suppressing the background coming from the environment. The good timing properties can also be seen in figure 1 b), showing the decay curve obtained when gating on the 59.5 keV γ ray produced in coincidence with the α decay of ^{241}Am. The measured half-live is 70 ns while the reference value is 67.2.

Figure 2 – Energy spectra of the LEPS observed at various distances of a high-intensity (24 MBq) ^{60}Co source.

The second test that we performed with the setup, was meant to evaluate to capability of the numexo2 system to handle high counting rates. To enable acceptance of high counting rates, the parameter of the trapezoidal filter was modified to achieve a trapezoid of less than 2 µs of total width. The count rate was modified by placing an intense ^{60}Co source (24 MBq) at a variable distance 90 degrees to the detector axis. For comparison, the activity of the 3-nuclide α source was 1535 Bq on 27/03/2014, which lead to a count rate on the Si detector in our arrangement of 20 Hz and 6 x 10^{-2} coincidences per second. This configuration was chosen to simulate by Compton scattering of the ^{60}Co γs a substantial background in the region of the ^{241}Am 59.5 keV γ line. A maximum count rate of 59000 counts per second was reached without significant reduction of the detector's energy resolution. For the measurement at the closest position, at 6 cm from the detector with the highest γ flux on the detector, the energy information is lost and the observed count rate value is reduced due to saturation and pile-up issues. The energy spectra at the various distances are shown in figure 2.

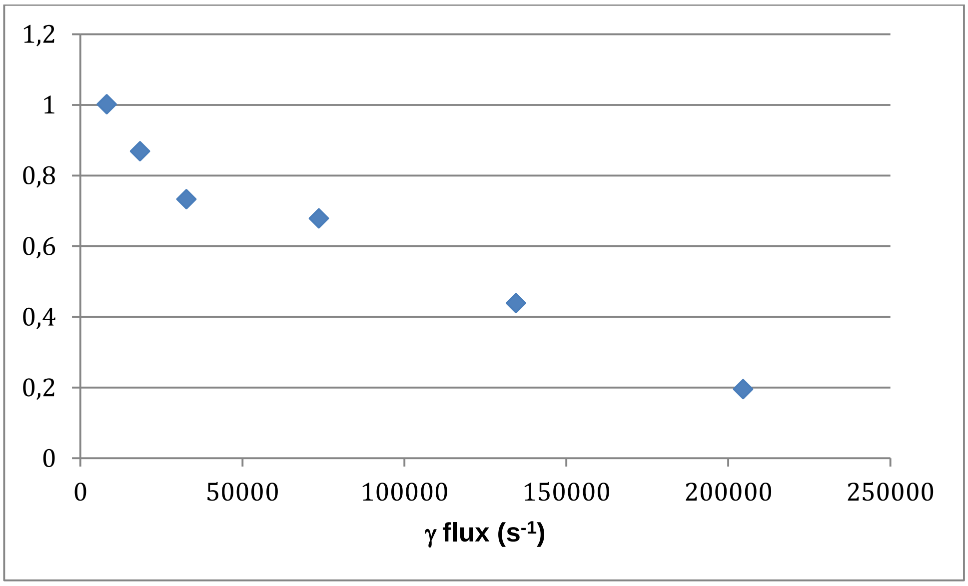

Figure 3 – Ratio of observed count rate to γ flux as a function of the γ flux.

Figure 3 shows the measured count rate over the estimated γ flux incident on the detector normalized to the measurement performed with the lowest γ flux, where little pile-up rejection was observed. It shows that a count rate of about 50000 counts per second was achieved while keeping a rejection rate below $\approx$ 30%.

Conclusion

A source test of a LEPS detector was performed with the new numexo2 digital electronics module, employing photon spectroscopy in the X-ray energy region and α-γ coincidence detection. A maximum count rate as high as 59000 counts per second was reached, without limited loss of resolution and counting efficiency.