# Experimental report

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**Proposal:** 3-01-656 **Council:** 4/2017

**Title:** Test of the response of diamond detectors to fission fragments of 235U

**Research area:** Methods and instrumentation

**This proposal is a new proposal**


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**Samples:**

| Instrument | Requested days | Allocated days | From | To |
|---|---|---|---|---|
| PN1 | 8 | 8 | 08/03/2018 | 22/03/2018 |


**Abstract:**

We propose to test the performance of various types of diamond detectors for the detection of fission fragments. Such detectors are very promising as focal plane detectors for LOHENGRIN and as fission trigger for FIPPS. The energy resolution and pulse height defect of single crystal, heteroepitaxial and polycrystalline diamond detectors will be characterized with energy- and mass-separated fission fragments and alpha and triton beams.

# Experimental Report

## Summary

In the framework of a collaborative work (IFJ PAN-Krakow, INFN-Milano, LPSC-Grenoble and ILL), single-, poly-crystalline and heteroepitaxial diamond detectors and their front-end electronics were studied at LOHENGRIN.

We characterized the spectroscopic and temporal signal responses of several diamond detector prototypes exposed to fission fragments (FF) and light ions (alpha). Their energy resolution and pulse height defect were characterized with energy and mass-separated fission fragments and alpha beams. We conclude that diamond detectors are very promising as focal plane detectors for LOHENGRIN and as fission trigger for FIPPS.

## Experimental set-up

Single crystal detectors were provided by IFJ PAN Krakow and LPSC, and polycrystalline and heteroepitaxial diamond-on-iridium (DOI) detectors were provided by LPSC. DOI are promising since they are potentially close to the performances of single-crystals in terms of spectroscopic response and they can be produced with larger areas in the perspective of future large coverage detector development for nuclear physics. Detailed diamond and preamplifier specifications are summarized in the table below. Commercial and custom made preamplifier were used.

| Diamond Manufacturer | Size (Area x Thickness) | Type | Institute | Preamplifier | Preamplifier Functionality |
|---|---|---|---|---|---|
| Element 6 | 2 mm diam., 0.05 mm thickness | Single Crystal | IFJ PAN | INFN | Charge |
| Element 6 | 2 x 2 x 0.3 $mm^2$ | Single Crystal | IFJ PAN | INFN | Charge |
| Element 6 | 4.5 x 4.5 x 0.517 $mm^3$ | Single Crystal | LPSC | LPSC | Charge |
| | | | | CIVIDEC | Current |
| Element 6 | 10 x 10 x 0.5 $mm^3$ | Poly Crystal | LPSC | LPSC | Current |
| | | | | CIVIDEC | Current |
| | | | | DBA | Current |
| Element 6 | 20 x 20 x 0.5 $mm^3$ | Poly Crystal | LPSC | LPSC | Current |
| | | | | CIVIDEC | Current |
| | | | | DBA | Current |
| AUDIATEC | 5 x 5 x 0.3 $mm^3$ | DOI | LPSC | LPSC | Charge |
| | | | | CIVIDEC | current |

## Results

The fission fragment separator LOHENGRIN is very well suited for rapid detector characterizations with mass- and energy-separated heavy ion beams. Fission fragments with masses ranging from A~80 to 150 and kinetic energies of about 50 to 110 MeV were available from the $^{235}U$ target.

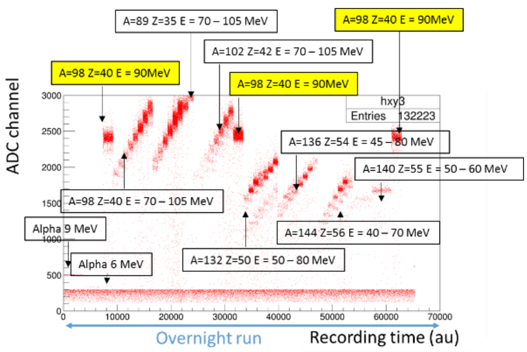


Figure 1 Overnight run

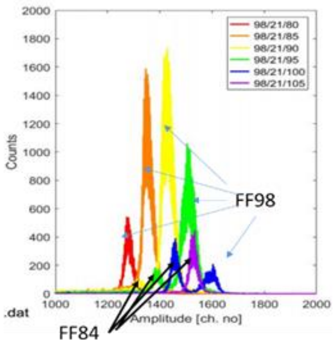


**Figure 2 Fission fragment separation during the night run A=98 Z=40 E=70-105 MeV**

In overnight runs as illustrated on Fig 1, fission fragments were produced in the energy range 70-105 MeV and 40-70 MeV. As with LOHENGRIN fission fragments are separated according to their A/q and E/q ratio (A is the ion mass, q its ionic charge and E its kinetic energy), for each LOHENGRIN setting, several fragments arrive to the detector. As illustrates on the Fig 2, for the run [A=98 Z≈39 E=70-105 MeV] both fragments FF98 and FF84 were isolated in the data using the very thin diamond: 50µm (2mm in diam.) from Krakow. Furthermore, the energy resolution was found to be at the level of 1% which has been also confirmed by the analysis of the LPSC data on their own diamond samples. The measured energy resolution for alpha particles with the 4.5 x 4.5 x 0.517 mm$^3$ single crystal from LPSC is shown in Fig 3.

The Pulse Height Defect (PHD) was observed and characterized. Its study is crucial for the spectroscopy of heavy ions. Three effects contribute to the PHD: energy loss in dead layers, nuclear stopping power and recombination losses reducing the charge collection efficiency. The first contribution was studied on the Krakow 2mm diameter single crystal diamond by changing the angle of incidence of the beam which enabled a controlled variation of the effective dead layer. In addition, a comparison was made concerning energy resolution between DOI and single-crystal diamond.

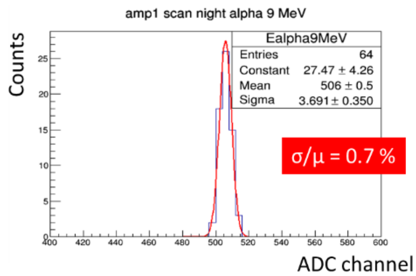


***Figure 3 Energy resolution measured on 9 MeV alpha particles with LPSC-sc.***

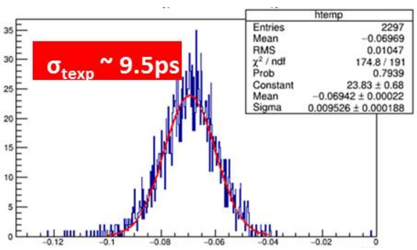


**Figure 4 Time resolution measured on a 10 x 10 x 0.5 mm$^3$ polycrystalline diamond (difference of the timing between both surface signals) measured with $^{98}Y$ at 90 MeV.**

Finally, an offline procedure was established to determine the time resolution of the detectors. The averaged readout signal waveforms were recorded independently on both faces of a detector. A numerical Constant Fraction Discrimination (CFD) was used by averaging the background, determining the maximum of the pulses, and interpolating the 50 % rise time value. A result is shown on Fig 4. Note that the 9.4 ps rms value has to be divided by 1.41 for a single signal since this is an auto-convolution. This is a very encouraging result for the use of such a diamond as a time trigger for future experiments

## Conclusion and perspectives

The potentiality of fission fragment detection for nuclear application was investigated. The detector response linearity with the FF energy was demonstrated. A time resolution better than 10 ps and an energy resolution better than 1 % rms for mass 98 at the energy of 90 MeV was reached. Consequently, we conclude that diamond detectors are promising for applications like time-of-flight measurements or as “start” detectors for fast timing studies or g-factor measurements, e.g. in coincidence with LaBr3:Ce gamma ray detectors. There are also potential applications at ILL. Indeed, diamond detectors could serve as focal plane detectors at LOHENGRIN or for recoil identification with the v-E method at FIPPS.