Access to neutron facilities

Title of proposed experiment

Investigation of the plasma delay time effect in PIPS detectors for the development of the VERDI fission spectrometer

Spokesperson

(name, affiliation, phone, email)

Ali Al-Adili, Uppsala University, +46735759309, ali.al-adili@physics.uu.se

Preferred facility

LOHENGRIN SPECTROMETER (ILL)

Contact person at ARIEL facility

ULLI KOESTER

Type of experiment

(incl. beam characteristics and experimental set-up of interest)

Characterization of Si detectors for fission experiments

Requested beam time

(beam time hours)

22 June 2021 - 2 July 2021

Preferred measurement period

22 June 2021 - 2 July 2021 (the beam is already accepted and scheduled by the ILL)

Synergy with SANDA

(if applicable, Work package, task number)

WP 2 (tasks 2.1.1 & 2.5)

Each experiment should support early stage researchers and lead to a publication in a peer-reviewed scientific journal and/or a conference presentation. In addition, validated data sets will be transferred to the NEA data bank /EXFOR. The PAC will assess the status of publications and will also monitor the transfer of nuclear data to the NEA data bank.

EURATOM support has to be acknowledged in all publications using: “This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 847594 (ARIEL).

Participants list and access period requested. Please put on top the names of the early stage researchers that you would like to be supported. Only users from other European countries than the ARIEL host institute can be supported. Typically, support for travel (400 EUR on average per user) and a per diem (150 EUR) during a maximum of 7 experimental days can be granted for up to four users.
For the 'research status' please indicate: UND= Undergraduate, GRA=Graduate (student with a first University degree enrolled in Master or PhD studies), PDOC= Post-doctoral researcher less than 6 years after PhD, TEC= Technician, EXP=Experienced researcher (professional researcher).

Researcher	Institution	Research Status	Total number of days	Total number of visits	First-time user Y or N
Ali Al-adili	Uppsala University	EXP	7	1	Y
Ana Maria Gomez Londoño	Uppsala University	GRA	7	1	Y
Samuel Bennet	Manchester Univ.	GRA	7	1	N
Stephan Pomp	Uppsala University	EXP	7	1	Y
Alf Göök	KTH	EXP	FUNDED BY ILL		
Andreas Solders	Uppsala University	EXP	FUNDED BY ILL		
Adhitya Sekhar	Manchester Univ.	GRA			
Stephan Oberstedt	JRC Geel	EXP			
Diego Tarrío	Uppsala University	EXP			
Nikolay Sosnin	Univ. of Edinburgh	PDOC			
Tobias Wright	Manchester Univ.	PDOC			
Kim, Yung Hee	ILL	EXP			
Ulli Koester	ILL	EXP			
Andreas Oberstedt	ELI NP	EXP			
Marzio Vidali	JRC Geel	TECH			
Gavin Smith	Manchester Univ.	EXP			

Date

2021-5-4

Signature of Spokesperson

Signed applications must be sent to the ARIEL management board at the following address:
proposals@ariel-h2020.eu

Disclaimer: by submitting this proposal the group leader accepts that the text of his proposal will be put on the non-public PAC section of the ARIEL website. This password-protected section of the website will be accessible by the PAC members and all group leaders that have submitted a proposal.

Contact: Ralf Nolte Tel .: ++49-531-592-6420, Fax: ++49-531-592-6405, E-mail: ralf.nolte@ptb.

Background

(Motivation, Relevance to ARIEL objectives

Uppsala University and the Joint Research Centre in Belgium, develop the fission spectrometer VERDI (VElocity foR Direct particle Identification) [1]. VERDI is able to measure the velocities and energies of both fission fragments, which allows a precise mass determination following the 2E-2v technique. The setup will provide important data on the fission process, correlating fission fragment and prompt neutron data. The setup contains up to 32 Passivated Implanted Planar Silicon (PIPS) detectors in each arm (each with an area of 450 mm^2) to measure the fragment energies. The setup also has two MCP detectors to provide the start signals following the ejected electrons from the sample. The TOF is measured between the MCP start signals and the stop signals from the silicon detectors. VERDI has successfully been employed in fission yield measurements [2,3].

The main challenge in VERDI currently is the precise determination of the Plasma Delay Time (PDT) in the silicon detectors [3]. The stop signal from the Si detector is delayed due to the produced plasma which hinders the movement of electrons. The typical PDT values experienced in Si detectors for FF are between 2 and 5 ns, which causes rather significant systematic errors in the fragment mass determination. If not accounted for, the mass distribution is smeared with about 2u (FWHM), and is shifted to wrong mean masses (between 1 and 2 u). The overall goal of the VERDI project is to achieve a total mass resolution of 1-2u (the main smearing being from the unavoidable prompt fission neutron emission). Hence, solving the PDT problem is an imperative for the success of the VERDI project.

We need to investigate how this delay depends on the ion species and the ion kinetic energy. By measuring the "true" velocity and compare with the measured time from the Si detector, we aspire to get a better understanding of the systematic delay of the Si detectors. Currently we are testing our detectors at the Tandem facility of Uppsala University, with a dedicated TOF section for velocity measurement. However, the range of masses and energies are not characteristics for fission fragments in VERDI. Moreover, the Tandem facility is not suitable for multiple changes of energy to cover the energy distribution.

This project is relevant to the educational goal of ARIEL. It is a major part of the Ph.D. thesis of Ana Maria Gomez Londoño. The data will be paramount for her project and will help to develop the 2E-2v spectrometer, in order to prepare for her future high-precision fission experiments. The project will also benefit our collaborators, the Manchester group, since their Ph.D. student, Sam Bennet, will be engaged in this experiment.

Goals of the proposal

- *To characterise 4-8 detectors of VERDI to understand the Plasma Delay Time behaviour as a function of ion species and energy.*
- *Develop systematics for PDT corrections for our type of Si detectors, which will be paramount for the future of the VERDI spectrometer.*
- *Train our Ph.D. Student in fission experiments and prepare for her work on the VERDI spectrometer.*
- *Report the results in a peer-reviewed publication*

Description of work

(Description of work max. 3 pages)

The Lohengrin spectrometer at ILL is the ideal place for these systematic studies, since it provides the ions of interest for VERDI, namely fission fragments with

masses from about 80 to 160 and their typical energies obtained in the fission process. The LOHENGRIN spectrometer provides a velocity selection and a mass over ionic charge (A/q) selection. Combined this corresponds also to a kinetic energy per ionic charge (E/q) selection which is very well suited for our needs. We will map the characteristic masses and energies of fission fragments and compare their measured velocities. In order to do so we will need a dedicated TOF setup in the focal plane of LOHENGRIN and before the Si detector (see Fig. 1). An absolute time reference has to be provided from an MCP. For this purpose, we propose a novel collaboration with the STEFF group to use their TOF arm which had been adapted previously to the LOHENGRIN spectrometer.

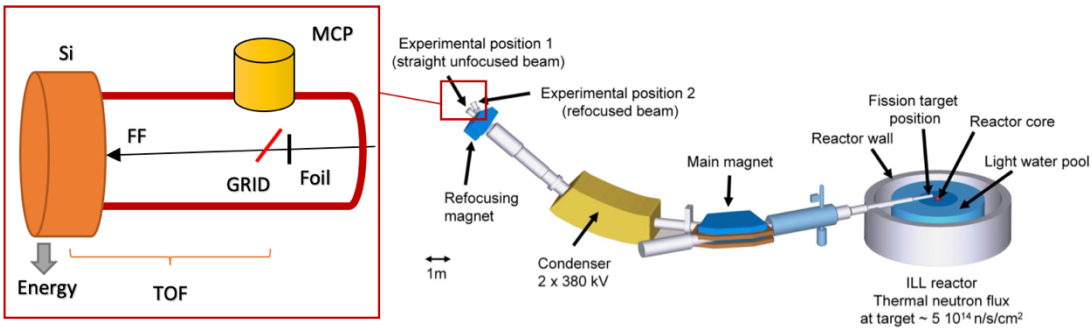

Figure 1: The Lohengrin spectrometers will be used to produce ion species of selected masses and energies. The ion velocities and energies will be measured.

VERDI has a combined intrinsic timing resolution of about 200 ps [1]. The timing resolution in the STEFF MCP is about 700 ps, measured for alpha particles. The resolution might improve for FF due to a larger number of sputtered electrons from the foil. In addition, if the degradation is caused by a limited grid/mirror field configuration, a collimation might improve the situation. The resolution will not be an issue for this measurement, if high statistics can be achieved allowing for an accurate determination of the average MCP time (using the peak centroid).

It is important to cover the entire range of typical fragment masses and kinetic energies. The energies deposited in the Si detector will be useful to select fragments based on their E/q and thus A/q. By selecting the E/q and A/q from the magnet, and selecting the fragments from the registered Si energies, we will obtain the velocity for each fission fragment event. This will then be compared with the measured TOF between the MCP and the Si. The correlation between the two will be studied as function of mass and energy to reveal the PDT behaviour of the Si. A typical ion spectrum is shown in figure 2 where the ions are well separated and are identified based on their characteristic masses/energies. The data are taken with an ionization chamber, but is very similar to the expected data taken with a PIPS detector. The energy resolution of our detectors is in the order of $\Delta E/E \sim 0.5$ %, so the separation of peaks will be straight-forward.

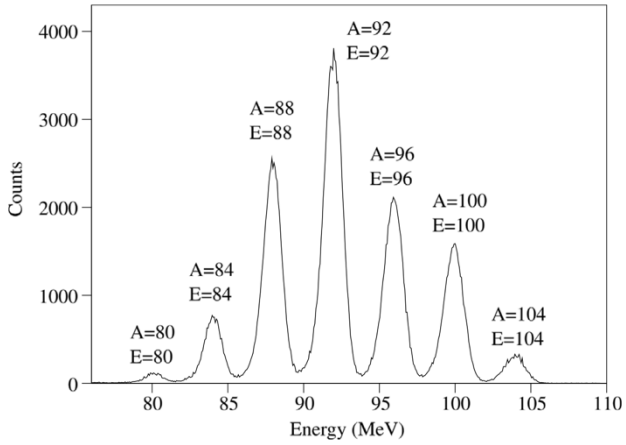

Figure 2: Typical ion spectrum taken at Lohengrin [4].

A ^{235}U target will be used for this experiment. Half of the target will be covered by a ≈1 μm thick Ni foil to slow down the fission fragments to much lower kinetic energies before selection with the LOHENGRIN spectrometer. This gives a wider coverage in term of incident energy and resulting plasma effect. Thus, an empiric parameterization of the PDT as function of mass, nuclear charge and kinetic energy can be developed that allows reliable inter- and extrapolation to masses and energies which are less produced in ^{235}U(n,f) reactions. Alphas from ternary fission will provide a cross-check for minimum PDT. We will also test the PDT trends in different types of Si detectors used in VERDI (timing optimized and neutron transmutation doped detectors).

A target holder for the Si detectors is being designed at Uppsala and will host 4 PIPS detectors (see Fig. 3). The beam profile allows measuring two aligned detectors at a time. A manipulator arm will be mounted to vary the TOF distance. The arm will also be rotatable to make it possible to change between detector pairs without breaking the vacuum. In total we will have 8 detectors ready to be characterised. The beam profile is about 7*0.5 cm^2 in the focal plane, and therefore with a use of a rectangular collimator, two detectors can be irradiated simultaneously. The chamber will have a separate pump system to allow for changing detectors without breaking vacuum at the MCP side, which could eventually be very time-consuming.

We plan to use a fully digital data acquisition system, where we will record all signal traces and analyse the data offline. Four channels with 1 GHz sampling frequency will be utilized to record the signals from the 2 detectors in use and the MCP signal. The idea is to measure the time of flight using the time pick-off signals and the energies from the Si detectors. Moreover, an independent method to extract the plasma delay time has been mentioned in literature. It relies on a Silicon pulse shape analysis and the rise-time variations which depend on the PDT. By recording the entire signal pulses, we are able to study this possibility.

References

[1] M.O. Frégeau et al., Nucl. Instr. and Meth. A817, 35 (2016)
[2] K. Jansson, PhD thesis, Uppsala University (2017).
[3] A. Al-Adili et al., EPJ Web of Conference 169, 00002 (2018).
[4] N. Sosnin et al., NIM A960, 163596 (2020).

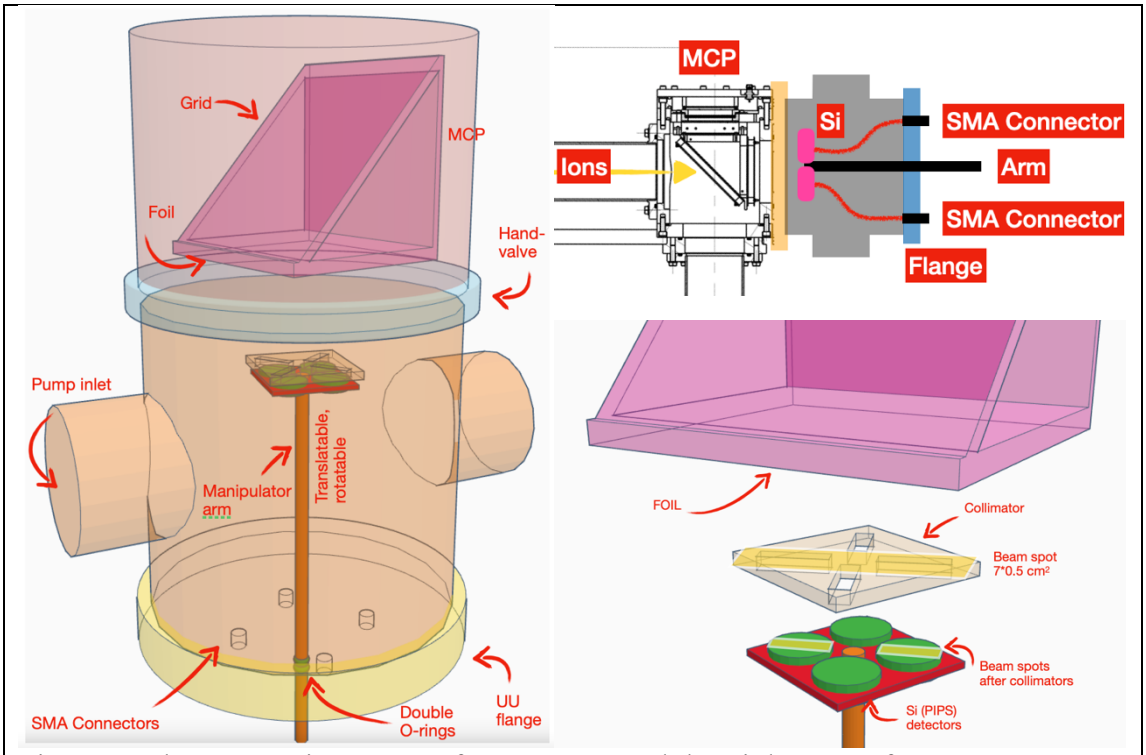

Figure 3: The setup using a MCP from STEFF and the Si detectors from VERDI. In total 4 detectors can be mounted on the designated movable arm, where two can be measured simultaneously, using the collimator.

Time schedule and beam time estimate

(Justification for requested beam time, setup and preparation)
This application has already been submitted to the ILL PAC and was accepted. The time proposed here is the actual scheduled time for the measurement campaign (22 June to 2 July 2021).

Requested time at ILL (which has been granted by the PAC):

- 3 days for mantling the setup, pumping (the MCP require very good vacuum) and testing of the equipment.
- 6 days in total for the experiment at Lohengrin. The cases we would like to measure are: **A=85** (60, 70, 80, 90, 100, 110 MeV), **A95** (60, 70, 80, 90, 100, 110 MeV), **A=105** (60, 70, 80, 90, 100, 110 MeV), **A=130** (40, 50, 60, 70, 80), **A=140** (30, 40, 50, 60, 70), **A=150** (30, 40, 50). Some lower energies will be reached by use of degrader, which helps mapping of other velocities.
- 1 day for dismantling the setup.

Justification for expenses

Support request:
*Number of days to be supported (typical 4*7 days) :*

- *7 for the Ali Al-Adili.*
- *7 for the Ph.D. student Ana Maria Gomez Londoño*
- *7 for Stephan Pomp*
- *7 for Ph.D. student Samuel Bennet*

Travel cost (4 400 EUR on average): 4*400 euro*

Support from other resources:

- The beam-time has already been approved by the ILL PAC. ILL will support two other scientists from the collaboration: Dr. Alf Göök from KTH and Dr. Andreas Solders from Uppsala University.

Education and training benefits

(Indicate education and training benefits for the early stage researcher, or knowledge transfer between the participants, e.g. relevance for thesis work; including a work schedule or list of training activities for technical staff in the description of the project.. Bulleted list

- Ana Maria Gomez Londoño is our PhD student and this is one of the most important experiments in her thesis. She will spend about a year analysing this data to further develop the VERDI spectrometer.
- In addition, this will be her first experiment under the guidance of the main supervisor Ali Al-Adili and the co-supervisors Stephan Pomp and Andreas Solders.
- Two Ph.D. students (Samuel Bennet and Adhitya Sekhar) from the STEFF group, will participate in the experiment and be responsible for the MCP. This will be a good opportunity for Sam and Adhitya to increase their experience with fission experiments.
- This proposal is a unique opportunity for comprehensive knowledge transfer between two major European 2E-2v projects, which will benefit both projects.

Deliverables and Publication plan

(Indicate the expected specific final results of the project that would be of interest to the scope of ARIEL and/or SANDA. Publication plan .)

The main results of this experiment are:

- Solving the Plasma Delay Time issue at VERDI which will pave the way for new fission studies with the spectrometer, in the near future.
- A peer-review article from this instrumental study.
- An oral presentation at a scientific conference is planned for the Ph.D. student Ana Maria Gomez Londoño.
- A Licentiate thesis (half-PhD thesis in Sweden) is planned for our PhD student. The data from this experiment will be the back-bone of her thesis.