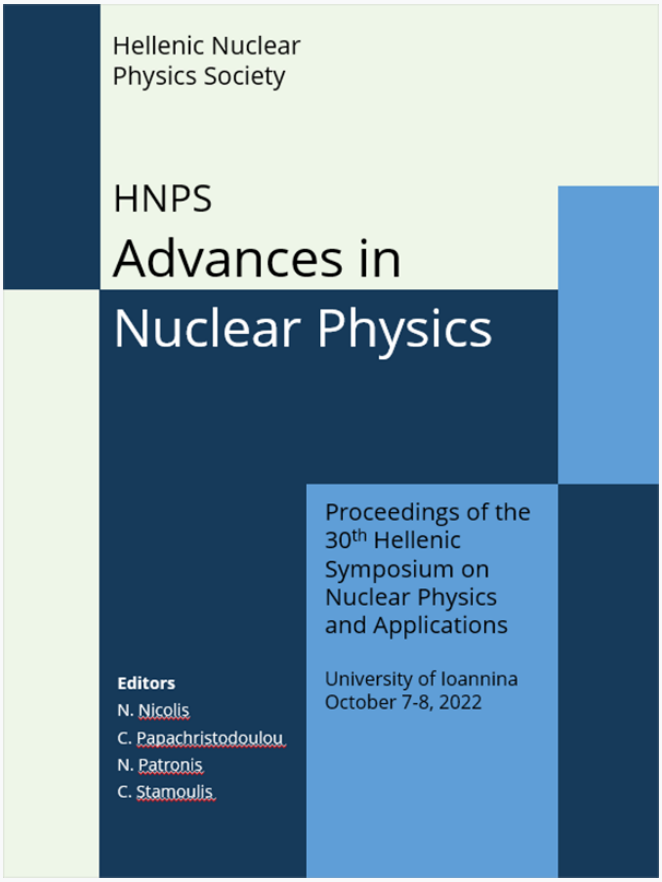
HNPS Advances in Nuclear Physics

Vol 29 (2023)

HNPS2022



Charged particles' detection at n_TOF/CERN: The new annular Double-Sided Silicon Strip Detector

Styliani Goula

doi: 10.12681/hnpsanp.5216

Charged particles' detection at n_TOF/CERN: The new annular Double-Sided Silicon Strip Detector

S. Goula[1,*], S. Amaducci[2,3], N. Patronis[1,2] , L. Cosentino[3], F. Murtas[2,4,†], M. Mastromarco, G. Vecchio[3], P. Finocchiaro[3], C. Massimi[6], A. Mazzone[5], N. Colonna[5], A. Mengoni[2], S. Pomp[7], D. Tarrio[7]

[1] *Department of Physics, University of Ioannina, 45110 Ioannina, Greece*
[2] *European Organization for Nuclear Research (CERN), 1211 Geneva, Switzerland*
[3] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italy*
[4] *Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali Frascati, Frascati, Italy*
[5] *Istituto Nazionale di Fisica Nucleare, Sezione di Bari, 70126 Bari, Italy*
[6] *Agenzia Nazionale per le Nuove Tecnologie (ENEA), 40129 Bologna, Italy*
[7] *Universitas Regia Upsaliensis, 75105 Uppsala, Sweden*

Abstract Studies of (n, cp) reactions are important for a variety of fields, such as Nuclear Astrophysics, Nuclear Medicine and Nuclear Energy Applications. Accordingly, towards the development of innovative detection systems that could address these needs, within this contribution, the proposed validation of a new annular neutron-Transmutation Doped (nTD) double-sided silicon strip detector (DSSSD) will be overviewed. The most important characteristics will be given along with the expected performance and abilities within the n_TOF facility at CERN. Furthermore, the adopted particle identification technique based on pulse shape discrimination will be outlined. Finally, some preliminary experimental results will be discussed.

Keywords DSSSD, nTD, Pulse Shape Analysis, Particle discrimination capability, n_TOF

INTRODUCTION

Neutron-induced reactions are of great importance in a range of fundamental and applied physics fields, including Nuclear Astrophysics and Nuclear Technologies. At the time being, there is an increasing need for Research & Development (R&D) of cutting-edge detection systems to extend the nuclear community's current knowledge. One of the most interesting type of nuclear reactions that remain almost unexplored are neutron-induced reactions that lead to the production of charged particles. The precise knowledge of such reactions is vital for the design of nuclear factories/reactors, such as the ITER (International Thermonuclear Experimental Reactor) which is currently under construction in France [1].

Nowadays, information regarding experimental or evaluated nuclear data is easily and anytime accessible in online nuclear databases. Nevertheless, inconsistencies or even lack of experimental data points have been observed amongst libraries, involving elements such as Be, Fe, Mo, and W as depicted in Fig. 1. The key-point to diminish this scarcity/discrepancy of experimental data points is to develop and validate novel detection setups.

Driven by the reason discussed above, an accurate position-sensitive detection assembly system devoted to particle discrimination is under development at the *neutron Time-Of-Flight* facility (n_TOF) at CERN. The granularity of the annular detector offers the ability to deduce the angular distribution of the reaction products and, at the same time, the implementation of advanced pulse shape analysis techniques can be used for particle identification [2].

* Corresponding author: styliani.goula@cern.ch

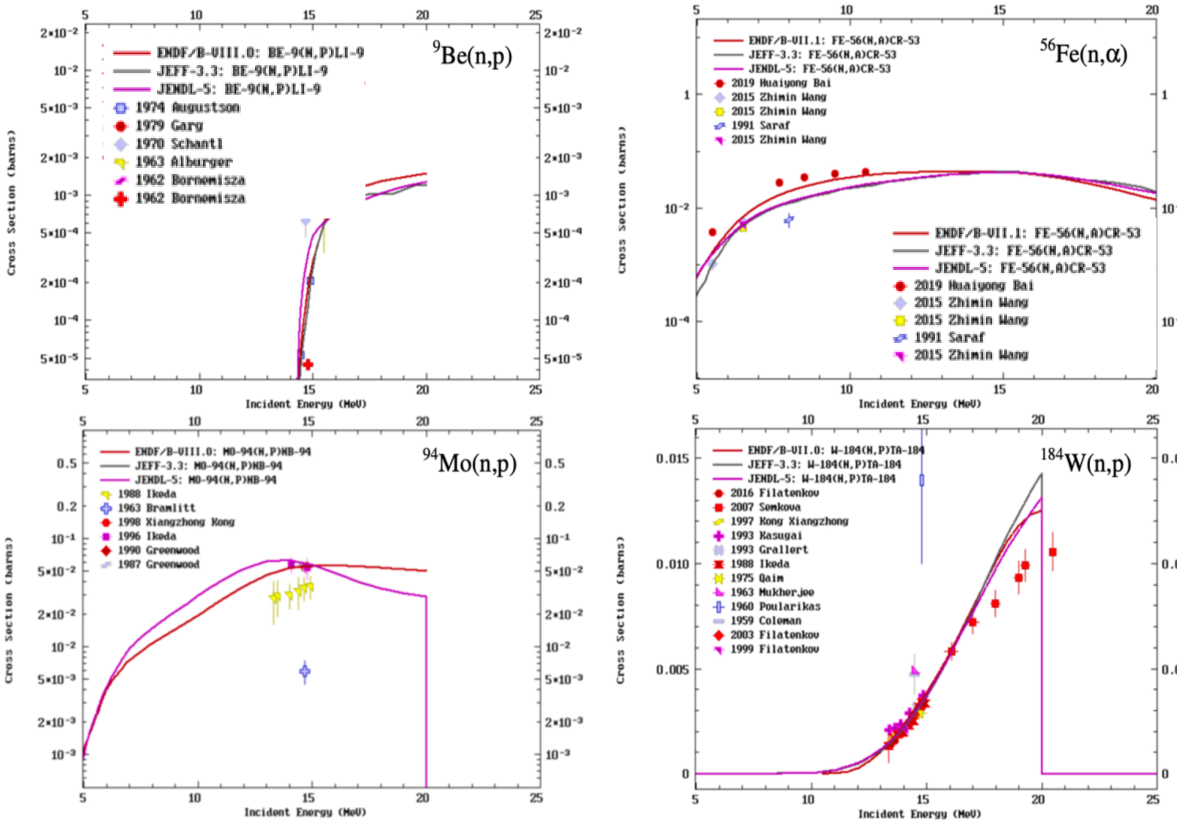
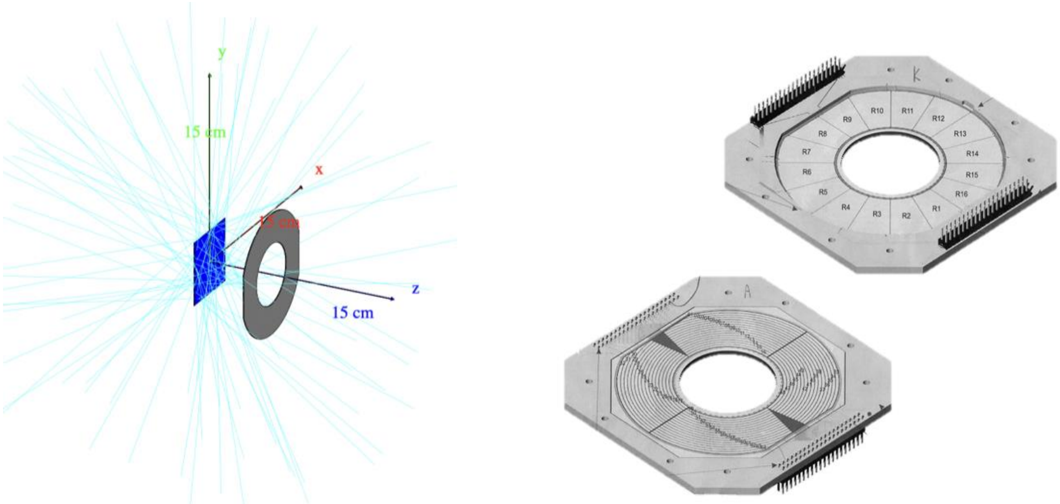


Figure 1. *Experimental data of 4 reactions taken from online databases i) ^{9}Be (n, p), ii) ^{56}Fe(n, a), iii) ^{94}Mo(n, p), iv) ^{184}W(n, p). In some cases, the presence of measured data is scarce, and in others, data have been acquired almost 20 years ago, with critical inconsistencies in comparison with theoretical calculations.*

EXPERIMENTAL DETAILS

In the direction to establish a high-efficiency charged-particle detection setup with the aforementioned characteristics during the 2023 n_TOF campaign, a “proof of principle” experiment is scheduled. Specifically, the ^{12}C(n, p)^{12}B reaction study will take place in both experimental areas available for *time-of-flight* measurements (EAR-1 & EAR-2). The scope of this first measurement is to study the detector’s response under operation in the n_TOF experimental areas. In particular, the implications of the gamma-flash will be evaluated along with the ability with respect to particle identification using advanced neural network pulse shape analysis algorithms.

The detector is depicted in Fig. 2(a). It is manufactured in an annular-CD shape using natural silicon, double-sided, and segmented into strips and sectors. The detector is 305 μm thick with an outer diameter of 96 mm and an aperture of 46 mm diameter in its center. The inner diameter of the CD-detector is larger than the neutron beam in both experimental areas (~ 30 mm diameter using capture collimators) avoiding any neutron-silicon interaction. The front-edge side is separated into 16 strips, while the rear-edge is divided into 16 sectors, providing that way the capability of obtaining more than 48 different channels. As a result, the determination of energy-dependent angular distributions is feasible for obtaining high resolution. In addition, the detector has undergone through a neutron Transmutation-Doped process (nTD) in an attempt to achieve particle discrimination ensuring a uniform electric field [3]. A sketch of the principle of operation is represented in Fig. 2: the sample is placed in the forward angles of the detector at the best-suited distance regarding the reaction under investigation.



(a) *(b)*

Figure 2. *(a) Final configuration of the setup: Monte-Carlo Simulation using the GEANT4 toolkit [4], and (b) A scheme of the newly-manufactured annular double-sided silicon strip detector (DSSSD)*

The high-granularity silicon annular detector is the ideal novel apparatus for delivering the lack of experimental data at the n_TOF facility. At n_TOF, neutrons are produced through spallation when a 20 GeV/c proton bunch impinges on the n_TOF lead target, approaching the two time-of-flight experimental areas with high velocity. The EAR-1's well-suited characteristics, like its wide neutron spectrum, and the high instantaneous flux, make it appropriate for testing in the annular detector [5].

Keeping all that in mind, a preliminary test has been conducted in the very last hours of 2021’s experimental campaign (Fig. 3). The reaction measured was neutrons on a LiF target because it produces mainly alpha- and triton-particles. The emitted particles were detected from the annular DSSSD that was placed 2 cm away from the LiF target. The particles’ discrimination is achieved by exploiting the signal shape by applying the Pulse Shape Discrimination technique (PSD), through an in-house developed software based on the python programming language using Machine Learning (ML) at INFN-LNS, in Catania [6]. The particle identification code is still under development and is based on the fact that different particles with the same energy can be separated due to the different stopping powers inside the silicon detector [7]. Moreover, the discrimination technique is suitable for neutron Transmutation-Doped detectors, since the produced wafer’s electric field, is uniform.

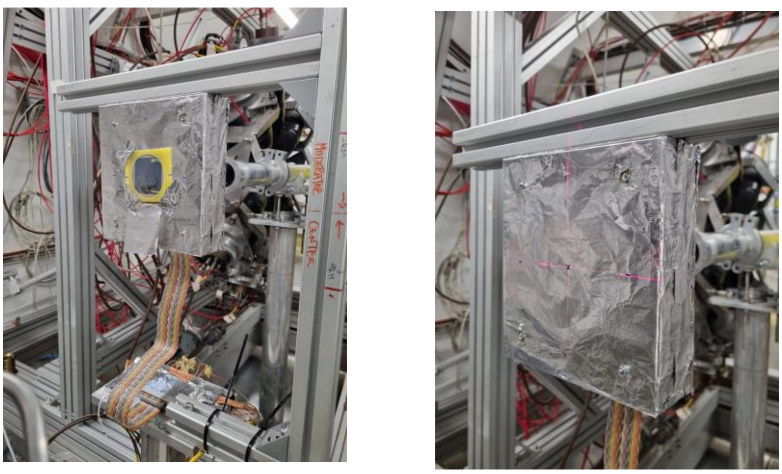


Figure 3. *First test conducted in the first experimental hall EAR-1 at n_TOF facility. The data taking was performed in the very last hours of the 2021 experimental campaign.*

CONCLUSIONS

In this work, the initial test has been conducted in the first experimental hall EAR-1 of the n_TOF facility at CERN utilizing the new annular DSSSD of 305 μm thickness. Preliminary results from this test revealed that particle identification capabilities using ML pulse-shape-analysis techniques are feasible. In the upcoming 2023 n_TOF experimental campaign, the main part of the "principle of operation" experiment will be realized. In this study, ^{12}C (n, p) ^{12}B reaction will be used to benchmark the technique [8, 9].

References

[1] R. Albanese et al., Fusion Eng. Des. 146, 197 (2019)
[2] M.R. Gilbert et al., J. Nucl. Mat. 442, S755 (2013)
[3] L. Cosentino, F. Murtas, CERN-INTC-2022-019 ; INTC-P-629 (2022)
[4] https://ntof-exp.web.cern.ch
[5] https://geant4.web.cern.ch
[6] M. Assié et al., Eur. Phys. J. A 51, 11 (2015)
[7] https://www.lns.infn.it/it/
[8] P. Žugec, CERN-INTC- 2017- 001 / INTC-P-488 (2017)
[9] M. Barbagallo et al., EPJ Web of Conferences 239, 01045 (2020)