Characterization of new generation silicon carbide for neutron diagnostic in harsh environments *

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The development of novel next-generation plasma diagnostics based on neutron flux monitoring is essential for nuclear fusion technologies. Because of the intense radiation present in fusion reactors, it is necessary to use neutron detectors that are highly radiation resistant and have a long operational lifespan. Silicon carbide (SiC) detectors are potential candidates that might be able to function in reactors like ITER. A new generation of SiC detectors with strong radiation resistance, quick reaction times, stability, and good energy resolution has been created at INFN-LNS in recent years [1]. These kinds of devices hold great promise not just for plasma diagnostics in fusion reactors but also for high intensity beam nuclear physics and laser beam facilities.

We will provide a more thorough description of these devices, concentrating on their ability to withstand neutron irradiation at energies ranging from thermal to tens of MeV. Specifically, we report on the irradiation campaign at the n_TOF facility, wherein an integrated neutron fluence of 10^{14} neutrons per cm^2 with a peak in the MeV was applied to SiC detectors. Furthermore, an initial study on the pulse shape approach to detect light ions with silicon carbide has been carried out, and preliminary results will also be shown.

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Study of neutron efficiency and cross-talk effects through Monte Carlo simulations for a new neutron detector NArCoS

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The simultaneous detection of neutrons and charged particles is an important goal for the present and future facilities delivering radioactive ion beams (RIBs), especially in the case of neutron-rich ones, to understand structure and dynamics of reactions between systems with high isospin asymmetry. The NArCoS project (Neutron Array for Correlation Studies) is aimed at studying and developing a new modular and versatile array devoted to detecting, at the same time, neutrons and charged particles both with high energy and angular resolution. Final detector prototype will be an array of 64 elementary cells of EJ-276G plastic scintillators, with a dimension of 3x3x3 cm^3, individually read by a SiPM matrix.

One of the main points of the project is to evaluate cross-talk phenomena in different conditions. In this contribution will be discussed the results about cross-talk probability and neutron detection efficiency, obtained using two different Monte Carlo simulation codes, GEANT4 and MCNPX. All these studies will allow to evaluate the better setup for NArCoS array in order to maximize neutrons detection efficiency and to minimize the cross-talk probability.

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nTD annular silicon detector: Charged-particle detection at n_TOF/CERN

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The study of neutron-induced reactions where one of the reaction products is a light-charged particle is at the forefront of neutron physics research. Besides the fundamental physics motivation, these reaction studies are important for fusion technology developments as well as for medical applications. In this framework, during the last years, an extensive research program has been initiated within the n_TOF collaboration aiming at the development of high-efficiency, position-sensitive charged-particle detection systems with particle identification abilities even at low particle energies [1].

Within the present work, the abilities and the performance of an nTD annular and double-sided silicon strip under specific conditions are discussed. In particular, as a validation step, was tested for the first time at the n_TOF facility at CERN. Combining the facility's unique characteristics with the detector's state-of-the-art technology, we aim not only to enhance existing scarce/discrepant datasets but also to investigate new aspects of fundamental and applied physics.

The detector is comprised of a silicon CD-shaped wafer segmented on both sides into strips/sectors, offering position-sensitive measurements. In particular, its sensitivity to the azimuthal φ angles allows the reconstruction of the energy-dependent particles' emission angles. The Data Acquisition system, consisting of a 14-bit Flash ADC, records the complete waveform directly from the preamplifiers, which is then processed using an in-house digital Pulse Shape Analysis (PSA) software developed at INFN-LNS in Catania [2]. This software utilizes Machine Learning (ML) algorithms to identify each product's atomic and mass numbers [3]. The Particle Identification (PID) method is strongly tied to the signal patterns formed due to the different energy loss profiles along the detector's depth. A neutron-transmuted (nTD) wafer has been chosen to enhance the PID performance. nTD silicons ensure a more uniform electric field all over the wafer volume, corresponding to a uniform response of the detector for the same particle. Thus, with only one silicon wafer coupled with digital PSA, we can reduce the PID energy thresholds compared to the up-to-now experimental techniques like the DE/E down to a few MeVs.

Following the abovementioned purposes, a natural carbon sample was chosen to study the (n, p) and (n, a) reaction channels in both n_TOF's experimental areas [4]. Data for both physics cases can be used both to benchmark the technique as well as to extend significantly the current experimental information. In this work, the experimental conditions at n_TOF/CERN will be presented along with the first results of this *"proof-of-principle"* experimental campaign, focusing on the detector's characterization and the PSA software and particle identification abilities.

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A tracking fast neutron detector concept

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The detection of fast neutrons is determinant for a variety of different application, form nuclear physics experiments to radioprotection in space and in nuclear fusion and fission facilities. Despite their wide-ranging uses, fast neutron detectors still lack in providing fundamental information on the detected particle as, for example, the incoming neutron direction. Bearing this issue in mind, several experimental techniques have been proposed and carried out [1][2]. Most of these techniques exploit single and double neutron-to-proton elastic scattering - referred to as Recoil Proton Track Imaging

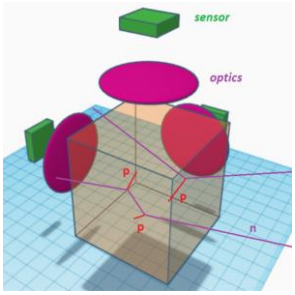

Figure 1- A sketch of the detector concept

(RPTI) - to determine the incoming neutron energy or/and direction, but none of them are currently operational. The detector we propose, RIPTIDE, fits into this scenario. RIPTIDE[3] aims to determine the initial direction and energy of fast neutrons by exploiting their interaction with the protons contained in the detector itself. It consists of a cubic plastic scintillator coupled with an optical system based on CMOS sensors. When a neutron passes through the scintillator, it has a probability to hit a proton that recoils and, being charged, induce photon emission along its path. The key idea of RIPTIDE is to *take pictures* of the recoil protons and use the information on the proton range, stereoscopically reconstructed, to determine the neutron energy and direction. To date, Monte Carlo simulations have been carried out in order to optimize the geometry, and a first prototype was built and is being studied. In this contribution, we report the analysis performed on the first prototype as well as further Monte Carlo simulations that were performed.

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Novel Diamond Detector Measurements at the n_TOF facility at CERN*

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Various fields of nuclear physics, such as fusion research as well as space or medical applications, require resilient detectors capable of long-term operational stability in high mixed particle radiation fields. Diamond is considered one of the most promising materials for constructing fast semiconductor detectors with high energy resolution, able to remain operational in harsh environmental conditions [1]. A novel diamond detector system was developed by the CIVIDEC Instrumentation [2] along with the necessary electronics. The key components of the detector are a single crystal diamond sensor with dimensions 4 mm x 4 mm x 50 μm thickness produced via the Chemical Vapour Deposition (CVD) technology and a ^{6}LiF foil with 1.9 um thickness acting as a converter to increase the efficiency for neutrons with energy below 1 MeV. This new detector was irradiated in a mixed field beam dominated by neutrons at the newly built NEAR station [3,4] of the neutron time of flight facility (n_TOF) at CERN [5].

The flight path of the NEAR station from the spallation target is 2.5 m, resulting in a high instantaneous neutron flux, thus it is considered one of the most challenging environments to perform active measurements. In this work the first attempt was made to measure the neutron fluence and the beam profile with the novel diamond detector system in this experimental area. The performance of the detector was tested at different areas of the n_TOF facility. The preliminary results of these tests will be presented and discussed.

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First gamma-ray imaging measurements with the SIGMA detector*

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The Segmented Inverted-coaxial Germanium (SIGMA) detector offers state of the art gamma-ray spectroscopy, tracking and imaging capabilities. Construction of gamma-ray tracks and imaging with the detector is facilitated by knowledge of the Compton scattering kinematics. The state of the art performance over other large volume germanium based gamma-ray tracking detectors is achieved through its excellent energy resolution, which is enabled by a small point-contact readout and the ability to precisely determine gamma-ray interaction position through novel detector design and digital signal processing techniques. The detector has been designed for use in decay spectroscopy experiments at radioactive ion beam facilities but has significant potential as a gamma-ray imaging device operating in environments that include nuclear decommissioning, nuclear waste assay and monitoring contaminated spaces. A prototype SIGMA detector was manufactured and experimentally characterized as reported in [1]. The main findings experimentally verified the excellent energy resolution and demonstrated that the charge signals read from the detector varied according to gamma-ray interaction position, such that a characteristic reference signal database could be established for the prototype. This is due to the weighting potential within the detector that is defined by the detector shape and electrode configuration. This characteristic charge signal response underpins the position resolution of the detector. Further work recently submitted for publication reports on the position resolution achieved with the detector when using pulse shape analysis algorithms in combination with the experimentally generated reference signal database. This talk will report on the current research, which is unpublished and demonstrates proof-of-concept gamma-ray imaging with the SIGMA detector using point-like and distributed gamma-ray imaging sources. An overview of its operational principles and its potential user applications will also be given.

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