A Novel Approach to Partial Defect Testing of Spent Nuclear Fuel for Safeguards Applications

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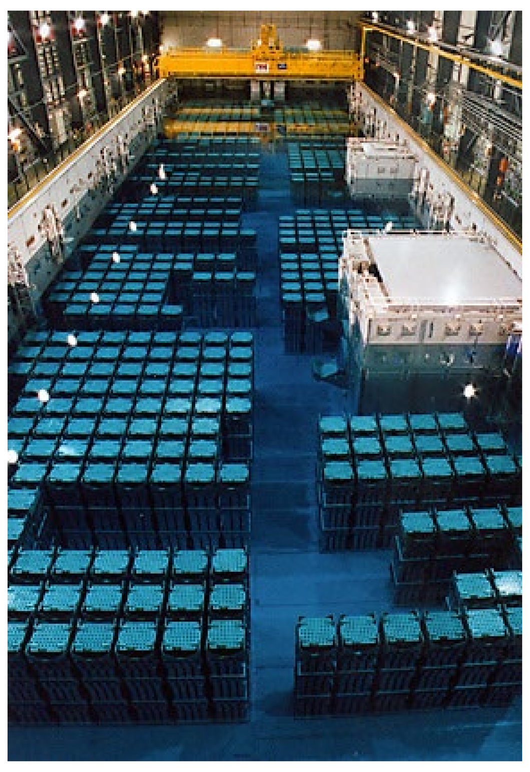
Introduction

Highly radioactive spent nuclear fuel (SNF) that is discharged from a nuclear power plant, is stored in a water pool before it is sent to the final repository.

In this period of time it is important to carry out regular inspections and assure that no radioactive material is missing from the water pool.



AREVA spent nuclear fuel storage facility in La Hague.[1]

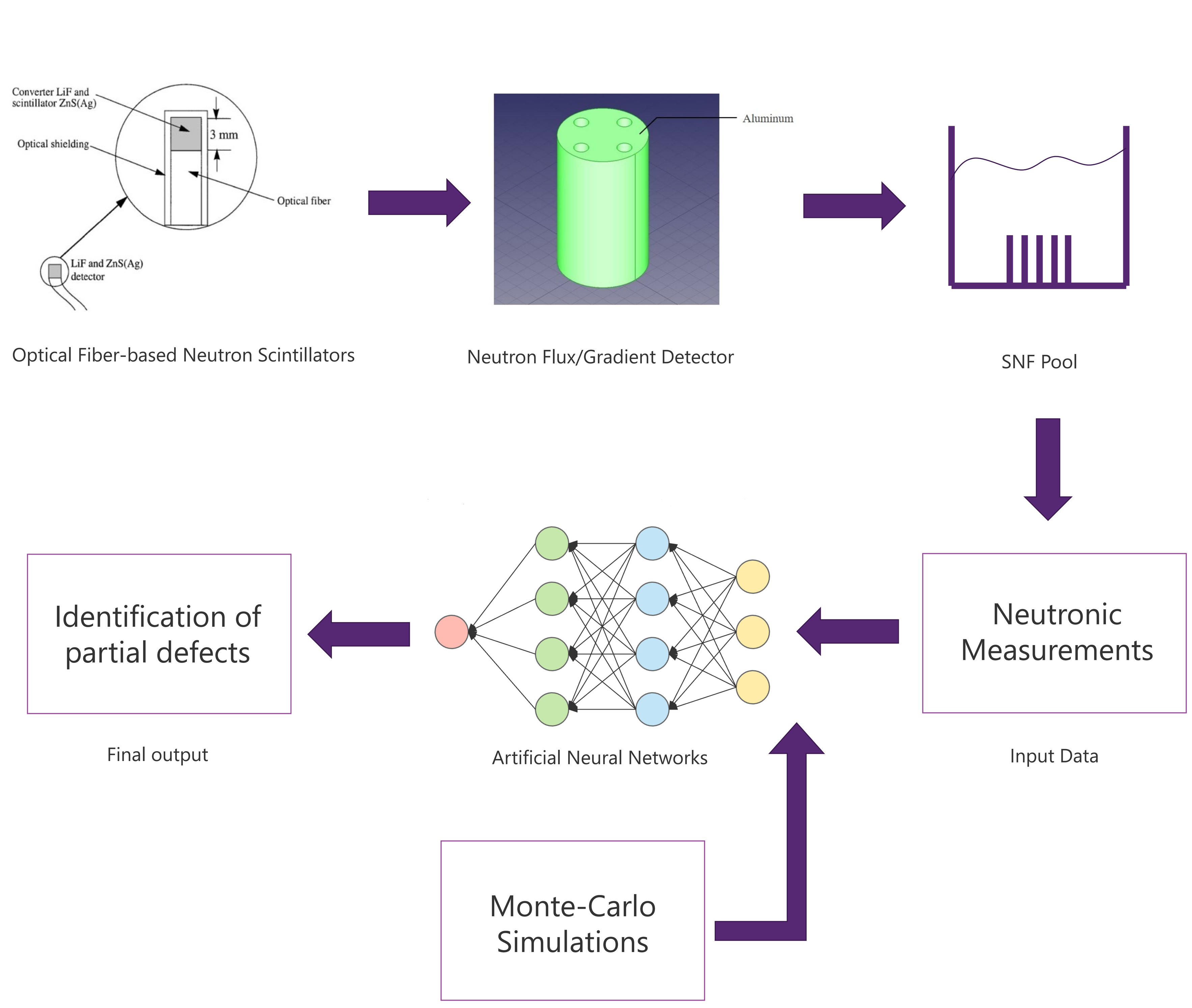
Objectives

The current PhD research concerns the development of a method to detect missing pins in a spent nuclear fuel assembly in the fuel pool, which is both accurate and non-intrusive, as well as it does not require the movement of fuel.

Significance

- Safeguards implementation
- SNF represent the majority of nuclear materials under safeguards
- Current methods are limited

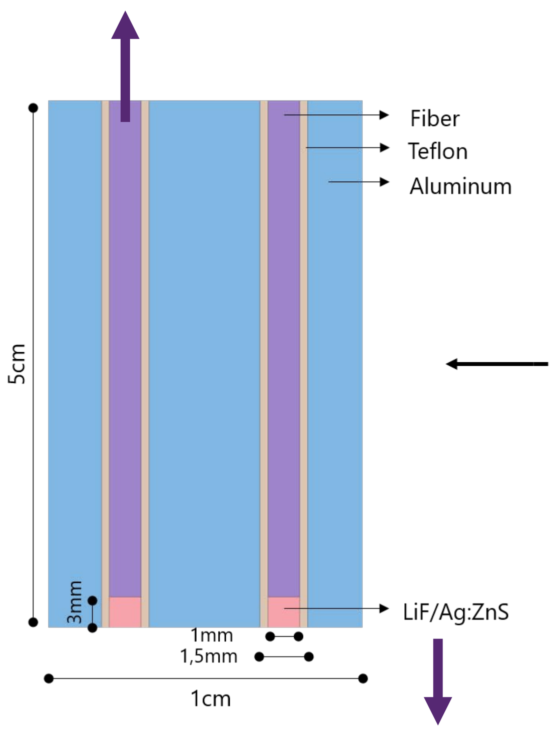
Methods

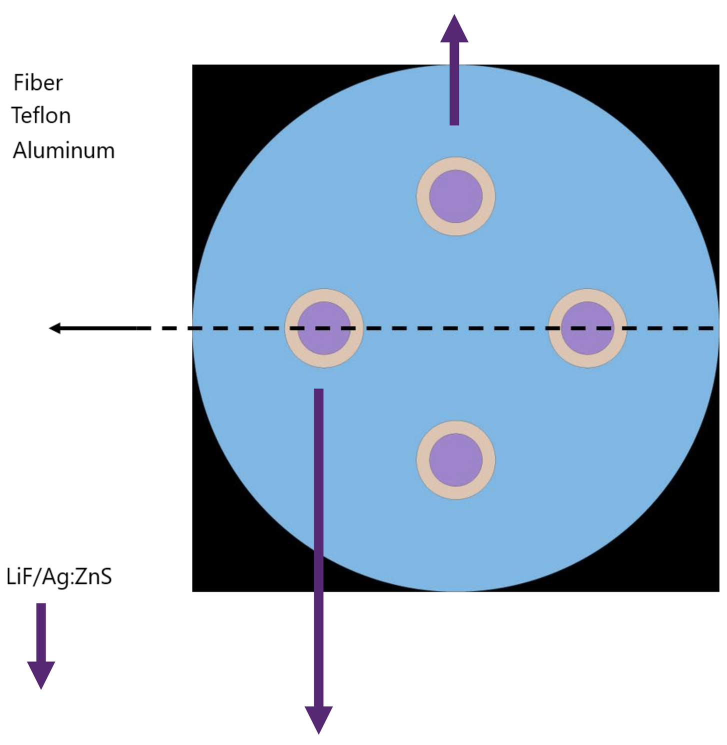


Results

A **gradient detector**, capable of measuring the X and Y components of the flux gradient, is proposed as follows:

- The fibers are inserted into the guide holes of the detector.
- Four axial holes in an aluminum cylinder serve as holders of four fiber-mounted scintillation detector.

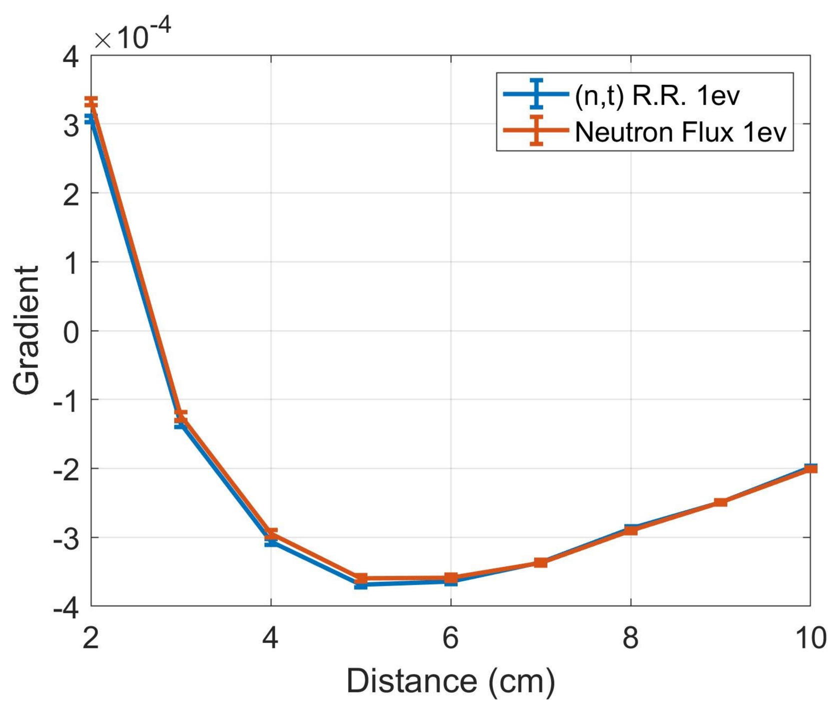




- The tip is covered in the neutron sensitive converter and scintillation material.
- The two detector pairs at diagonally opposite positions, can be used to measure the two horizontal components of the flux gradient.

The performance of the detector to determine the magnitude and the direction of the neutron flux gradient was investigated via **Monte Carlo** calculations. one goal was to investigate how the presence of the detector affects the accuracy of the estimation of the gradient.

It was noticed that the space dependence of the gradient, determined from the reaction rates in the detector, follows very closely the one of the gradient of the unperturbed flux over the whole spatial measurement range, indicating that the **distortion effect** of the proposed detector design is negligible.

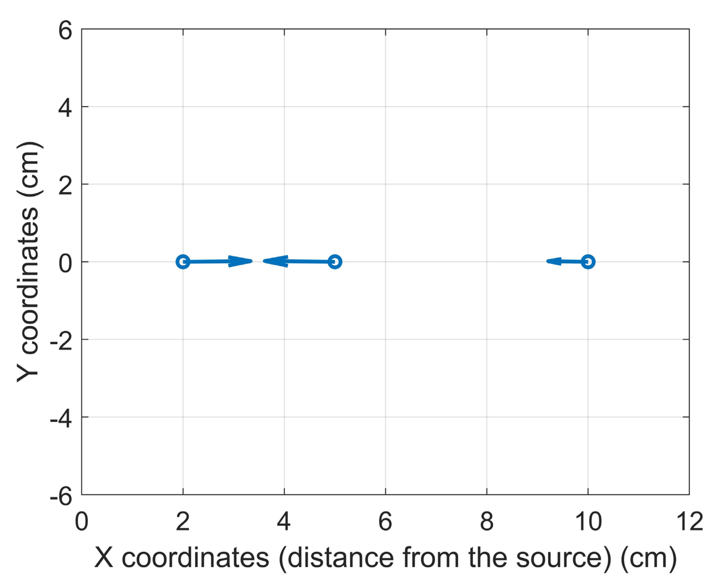


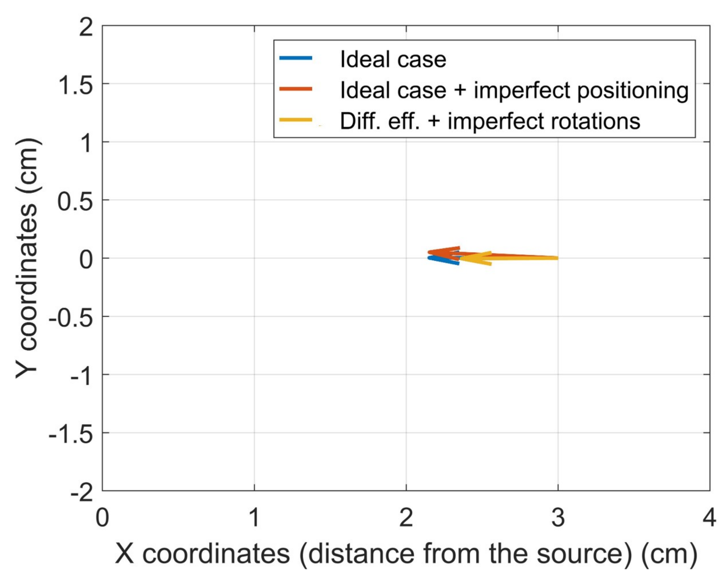
For practical purposes, instead of using the two cartesian components of the gradient, the space dependence of the magnitude and its **direction** are used in unfolding problems.

The ability of the detector to reconstruct both the magnitude and direction of the gradient vector was further investigated by assuming more **realistic conditions.**

The material composition of the four scintillators inside the detector (and hence their individual efficiencies) were changed to different values, a random error was introduced in the initial positioning of the detector in the measurement setup and a random error in the rotation angles was also introduced.

The effect of the different scintillator efficiencies can be compensated for by an in-situ **calibration procedure**. The randomness of the error in the rotation seems to have a cancellation effect. The results show that the detector is still capable of providing an accurate estimation of the gradient and its direction even under such conditions.



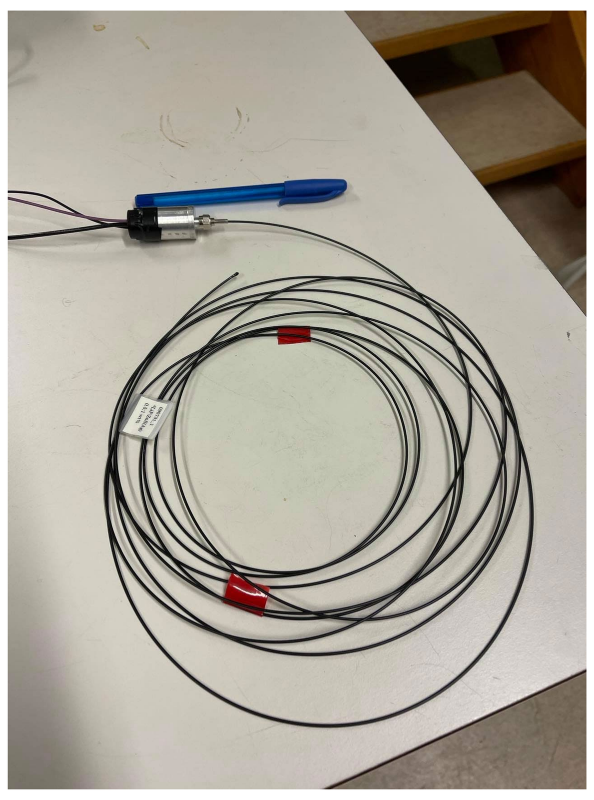


Conclusion

The design of a new neutron detector, capable of measuring the gradient of the neutron flux within a fuel assembly has been suggested and evaluated using Monte Carlo simulations.

Future work is planned to study the detector in a full fuel assembly and its performance to identify possible local inhomogeneities (e.g., a missing fuel pin in the assembly).

Manufacturing and testing of the proposed detector has already started, the performance of such fiber-based neutron scintillators was recently tested at the BR1 facility at SCK CEN.



Experimental setup at the BR1 facility.

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[1]https://www.nti.org/analysis/articles/2016-nuclear-security-summit-progress-report