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Electrostatic Field Simulations & Dynamic Monte Carlo Simulations of a Nanodosimetric Detector

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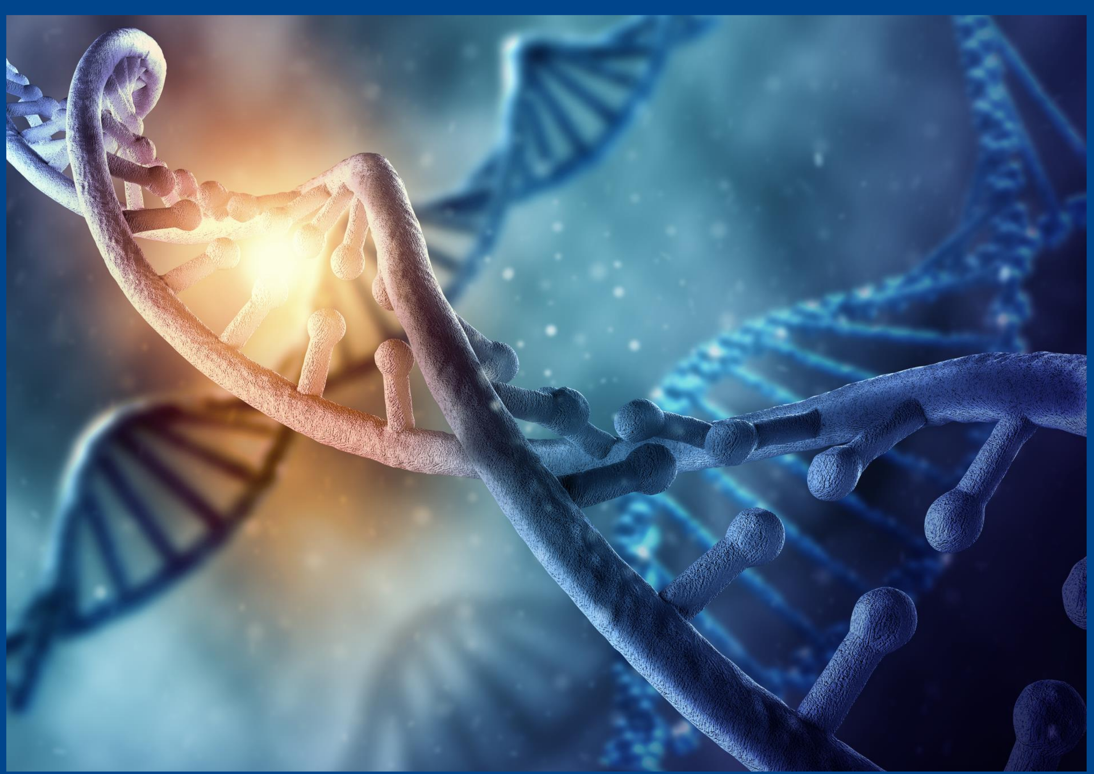
NANODOSIMETRY

Ionizing radiation can cause complex damage in the DNA, resulting in biological damage.

But how can we characterize damage occurring on a nanometer scale?



Option 1: Direct observation

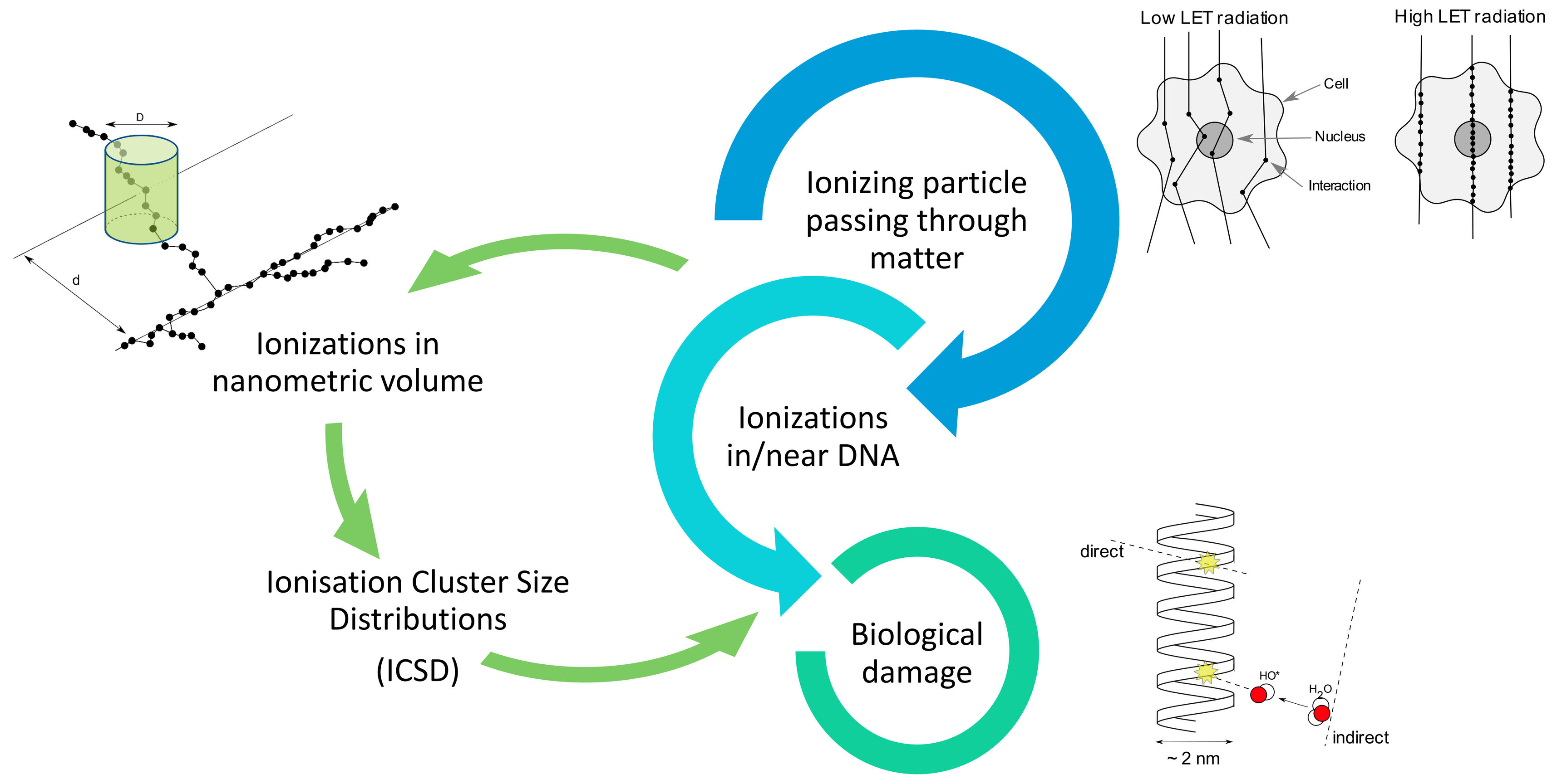
Not possible with current technology.

Option 2: Nanodosimetry

By using a density scaling procedure, we can measure the ionizations occurring within a nanometric volume by measuring the ionizations in a macroscopic volume of low pressure gas.

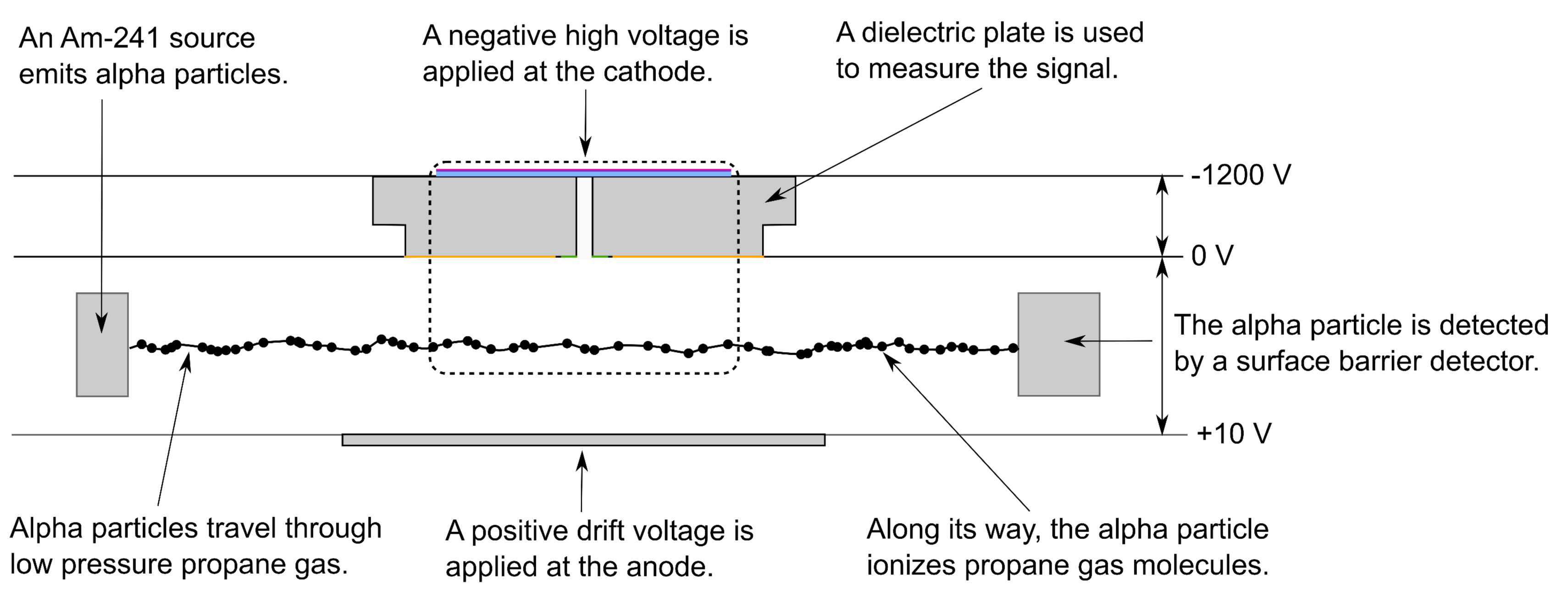
Nanodosimetry uses physical quantities based on ionization cluster size distributions to model the biological effectiveness of different radiation qualities. The FIRE (**F**requency of **I**on **Re**gistration) detector is a novel compact and portable nanodosimeter detector. It can detect ionizations operating on a similar principle to Gas Electron Multipliers and simulates nanometric sensitive volumes based on a density scaling principle.

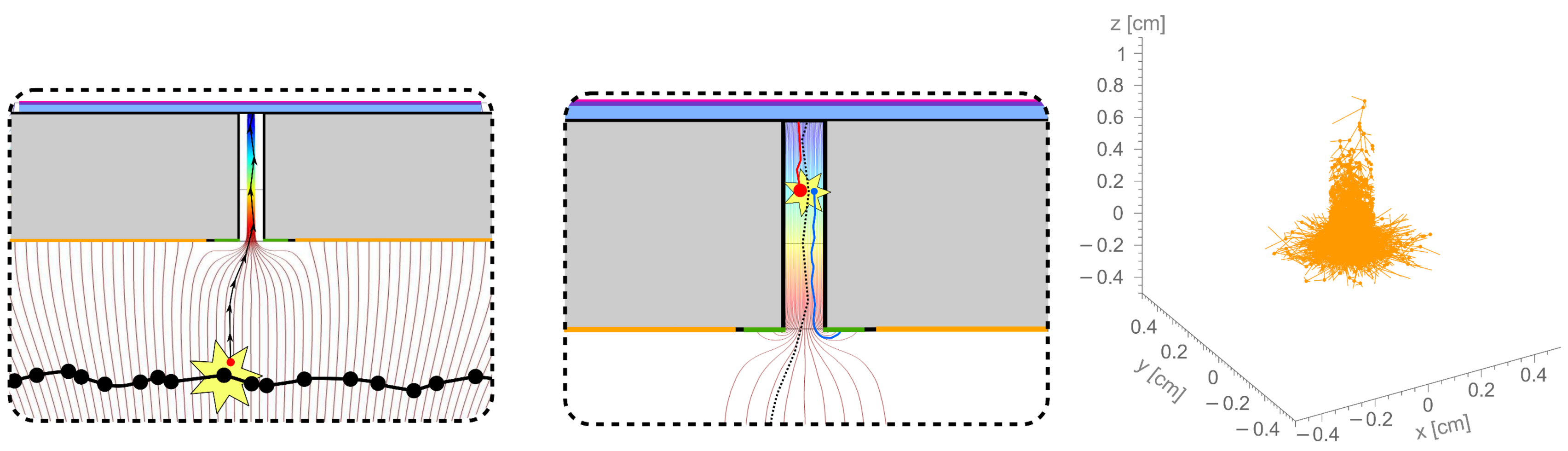
The dependency of electron avalanche formation on experimental parameters, such as pressure or electric field configuration, was studied and compared to experimental results.



MATERIAL & METHODS

Principle of Operation:





The electric field creates a funnel, causing the ions to drift towards the dielectric plate hole and being accelerated towards the cathode.

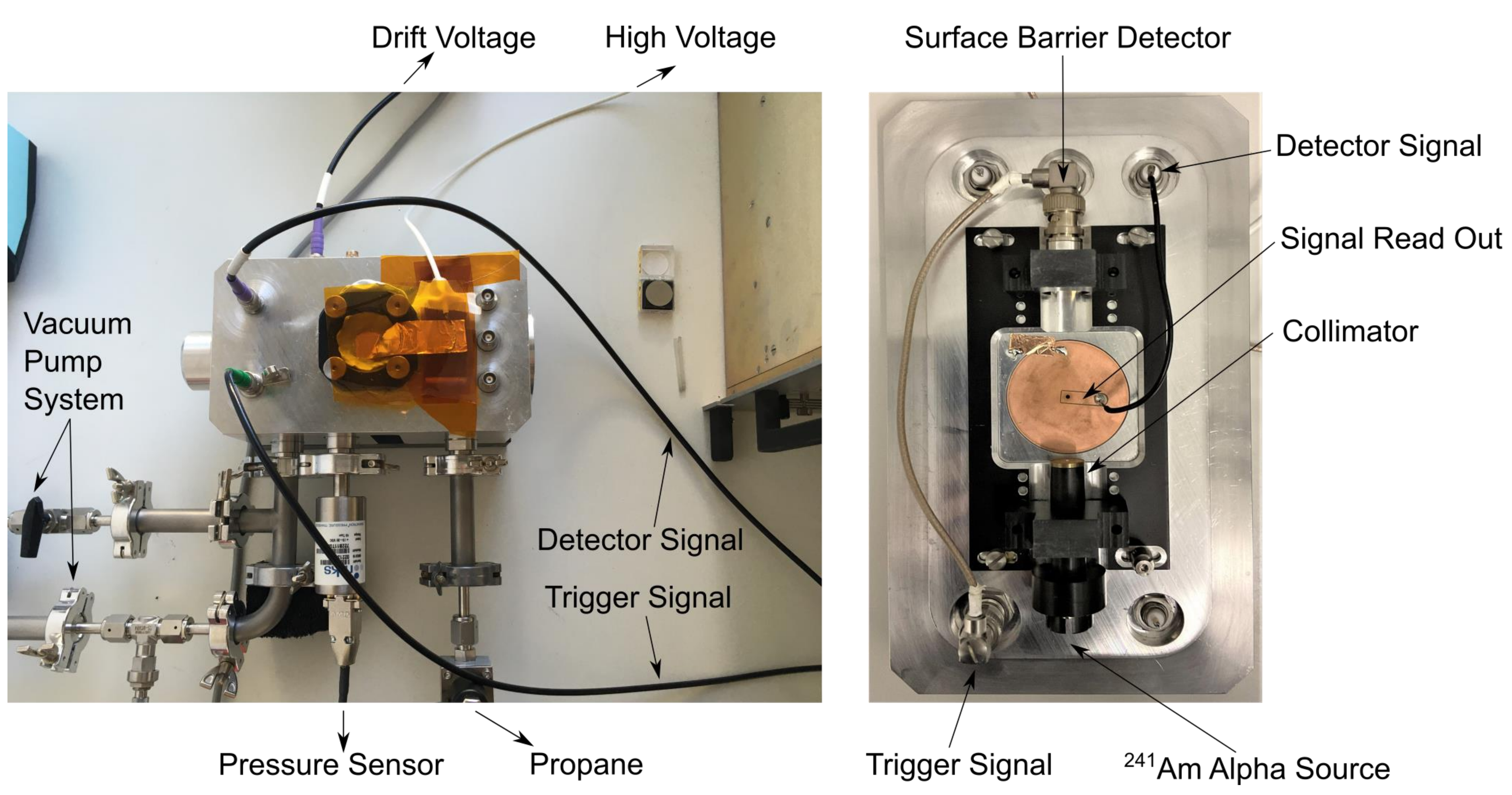
Through impact ionization the ion creates new electron ion pairs along its way.

The ions drift towards the cathode and the electrons towards the signal read out pad.

An electron avalanche is produced which is then measured at the signal read out pead.

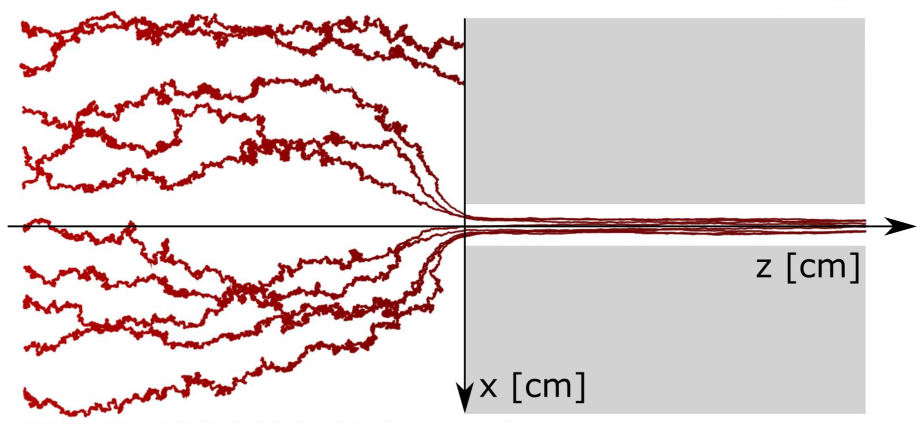
Simulations: The electrostatic field simulations were performed with COMSOL Multiphysics. The Dynamic Monte Carlo simulations of the electron avalanches were computed with Garfield++, an object-oriented toolkit for the detailed simulation of particle detectors based on ionization measurement in gases or semiconductors developed by CERN.

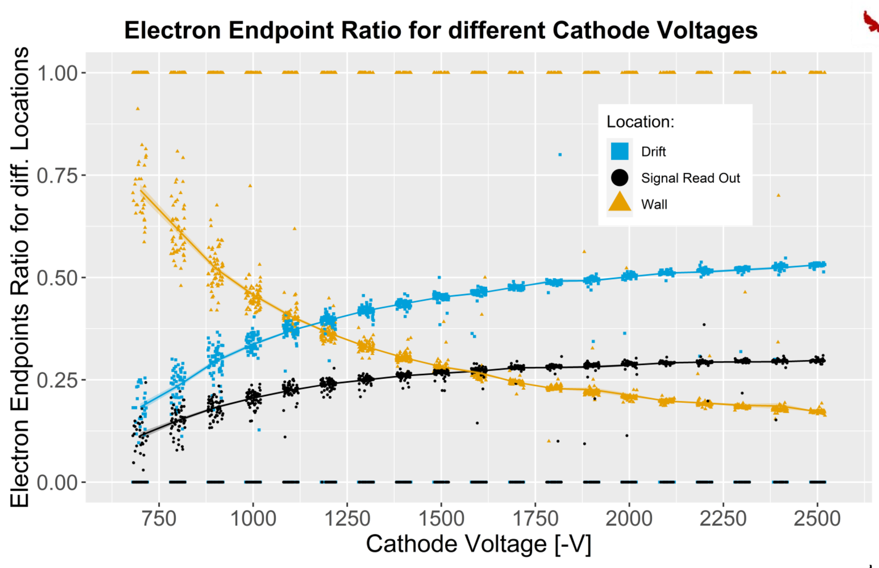
The Frequency of Ion Registration Detector:



RESULTS

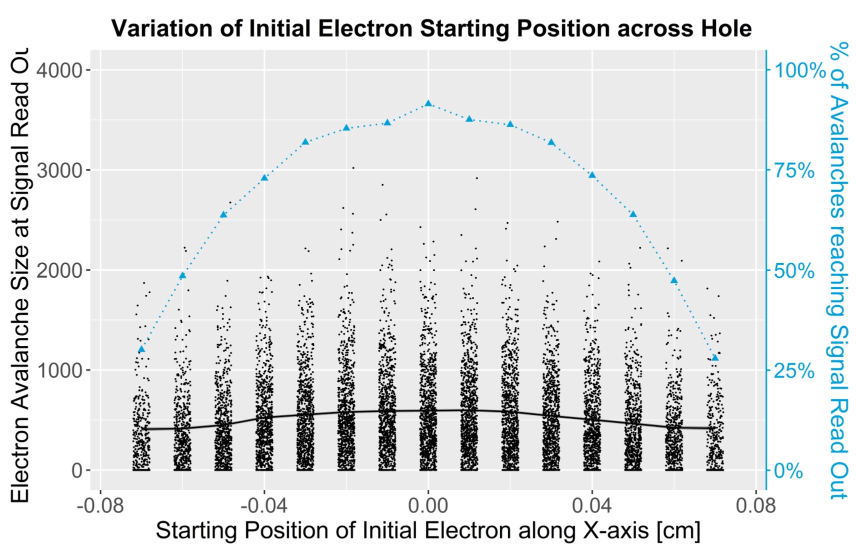
Visualization of simulated paths with Garfield++ of 10 ions drifting along the electric field lines towards the dielectric plate hole.





The electrons can end the simulation within the drift volume, on the walls of the dielectric plate hole or on the signal read out pad. By adjusting the cathode voltage, the relative ratios can be finetuned such that a larger fraction of electrons reach the signal read out.

The mean electron avalanche size is weakly influenced by the starting position of the initial electron. However, if the initial electron is produced near a wall, it is less likely that an avalanche reaching the signal read out is created.



SUMMARY / CONCLUSION

The results presented in this work offer insights into the inner workings of the FIRE detector, as well as clarify how different experimental parameters influence signal creation. The simulations can be used as a guide to future experimental setups, as they showed how each experimental parameter influences the electron avalanche formation within the detector.

REFERENCES

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This work was supported by the Swiss Federal Nuclear Safety Inspectorate (ENSI, contract CRT00512).