Development of advanced radiation monitors for pulsed neutron fields

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ABSTRACT

In spite of the fact that the problem of detecting radiation in pulsed neutron fields is known since the 40s, there is still a shortage of active instruments capable to efficiently work in these conditions. A new technique that overcomes the limitations of conventional detectors has been approached and a prototype conceived to work both for machine and personnel protection has been developed.

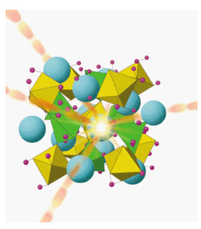
INTRODUCTION

The problem of radiation detection in **pulsed neutron fields** is attracting widespread interest because of the increasing number of applications in which these radiation fields are encountered.

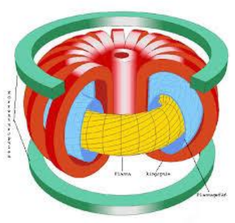
ACCELERATORS

CANCER THERAPY

SPALLATION SOURCES

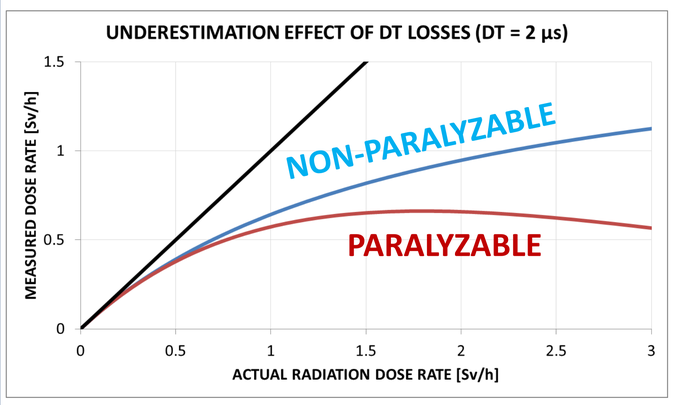


FUSION FACILITIES



PROBLEM

Radiation detectors are employed for **machine & personnel protection**. They usually suffer from **saturation issues** in pulsed fields (high interaction rate): the measured level of radiation is lower than the actual one. This is mainly due to **dead time losses**.



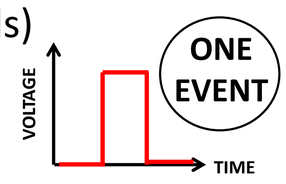
EFFECT OF DEAD TIME LOSSES ON PARALYZABLE / NON PARALYZABLE SYSTEMS

DEAD TIME = minimum time that must separate two events in order to be recorded as separated

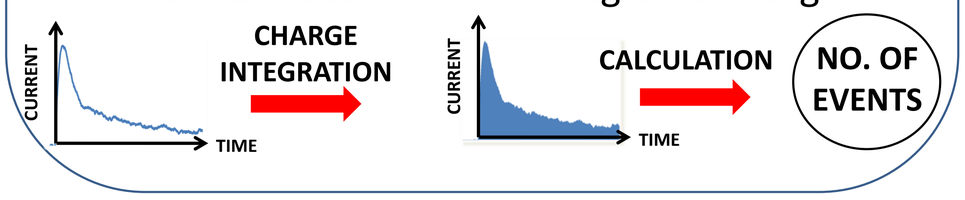
SOLUTION

SOLUTION: implementing a new acquisition mode not characterised by a dead time.

- **STANDARD (PULSE) MODE**: Each neutron interaction is recorded and analysed as a single pulse (10^6 interactions = 10^6 signals)



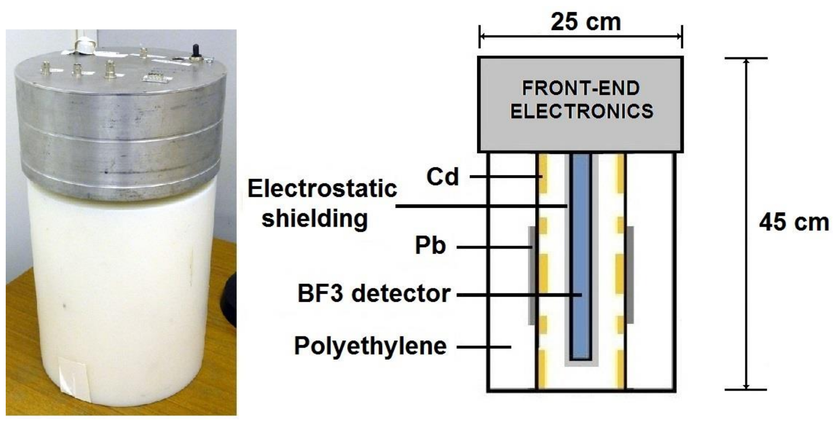
- **NEW MODE**: All the interactions are recorded as a single signal and the total number of events is derived from the integrated charge.



LUPIN

(Long Interval Ultra-wide dynamic Pile-up free Neutron rem counter)

LUPIN is a neutron detector (or **REM counter**) consisting of a proportional counter (**^{3}He or BF_3**) placed inside a moderator, designed so that the response reproduces the curve of conversion coefficients **neutron fluence → dose** from thermal energies up to few GeV.



PHOTOGRAPH AND SKETCH OF THE LUPIN MODERATOR

Innovative working principle:

1. Signal acquired via a **logarithmic amplifier**
2. Charge produced in the gas calculated by integrating the output current
3. Integrated charge divided by the average expected by 1 interaction = no. of interactions

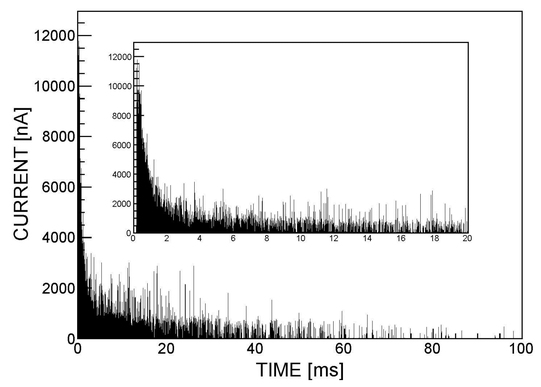
Therefore LUPIN can operate even in case of a huge interaction **pile up**.

RESULTS

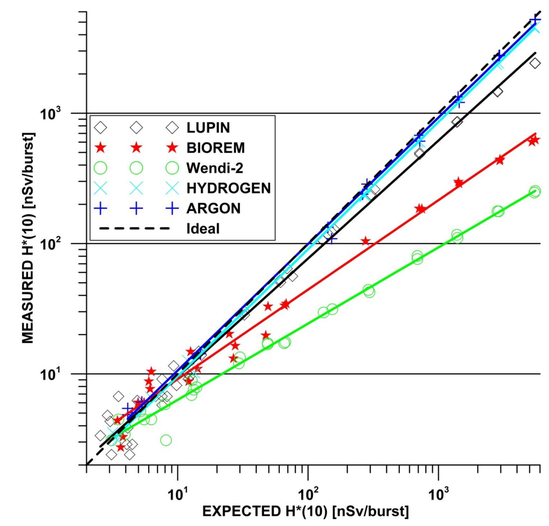
LUPIN was tested at the CERN **HiradMat facility** with other detectors employed in the CERN radiation monitoring system:

- **Argon & Hydrogen-filled ionisation chambers (IC)**, working in current mode (not affected by dead time)
- **BIOREM and Wendi-2**: conventional rem counters, similar to LUPIN, but working in pulse mode.

The detectors were installed in positions where the neutron stray field could be increased **from 5 nSv to 5 µSv per burst** by increasing the intensity of a proton beam impinging on the dump.



EXAMPLE OF SIGNAL ACQUIRED WITH LUPIN



DETECTOR RESPONSE (MEASURED vs EXPECTED DOSE)

- IC, as expected, show a linear response, but need to be **characterised** for a specific stray field
- LUPIN shows an **acceptable underestimation** (< 30%) **up to 1 µSv**
- Conventional rem counters are not reliable due to their **huge underestimation** for dose > 10 nSv

CONCLUSION

LUPIN is a prototype working with an innovative acquisition mode. It is not affected by dead time losses and it can properly operate in pulsed neutron fields. Its performance has been tested at the CERN HiRadMat facility: the response is linear up to 1 µSv per burst, whereas conventional rem counters show huge underestimations for much lower doses. Due to its unique properties, LUPIN can find application around medical or research accelerators as a radiation protection detector, as well as a beam loss monitor.