WP5, Potential of radioluminescent optical fibers for 14 MeV neutron beam monitoring

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RADNEXT 3rd Annual Meeting – 10-11 June 2024

https://indico.cern.ch/e/radnext-2024

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008126

Outline

- Summary of UJM’s campaigns
- Radiation-Induced Luminescence
- RIL measuring setup
- The Frascati Neutron Generator
- Neutron monitors of the facility
- Raw and integrated RIL kinetics
- Calibration: integrated RIL vs fluence
- Validation of the obtained calibration
- Conclusions

Third year achievements and ongoing activities

Terminated campaigns UJM:

- July 2023: TRIUMF NIF and PIF facilities (Canada)
- October 2023: Frascati Neutron Generator 14 MeV neutrons (Italy)
- December 2023: CLPU PW Vega 3 Laser-driven accelerators (Spain)

Proposed campaigns:

- CHARM (mixed field)
- CNA (Low-energy protons)
- FNG2 (14 MeV neutrons)

Radiation-Induced Luminescence (RIL)

RIL is a light signal generated from the de-excitation of pre-existing or radiation-induced defects inside the optical fiber.

It can be optimized adding dopants in the silica glass matrix, in this case Cerium.

The resulting emission is centered around 500 nm.

And it can be further enhanced via pre-irradiation:

- Sensitivity gets higher with received dose (bright burn effect)
- After-glow (lingering luminescence after the irradiation ends) gets weaker

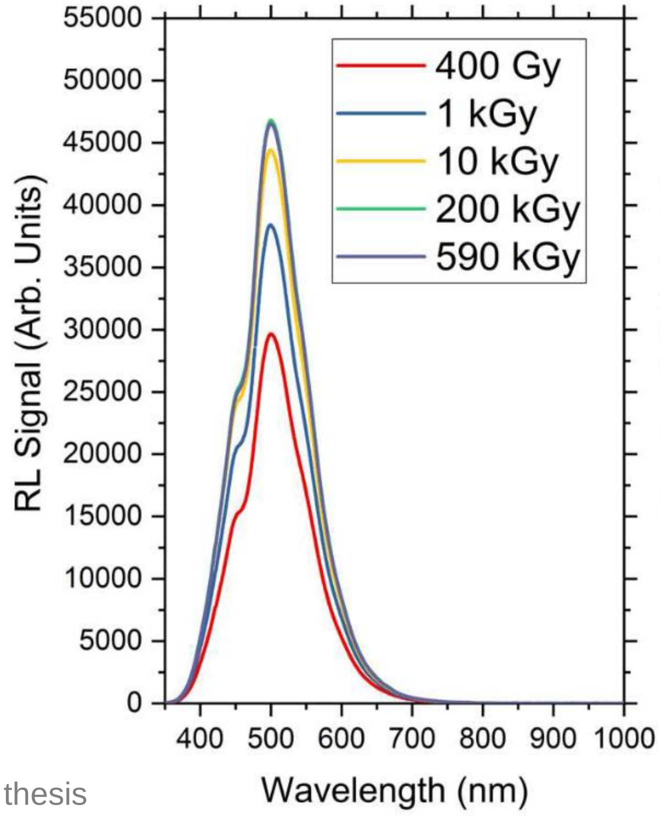


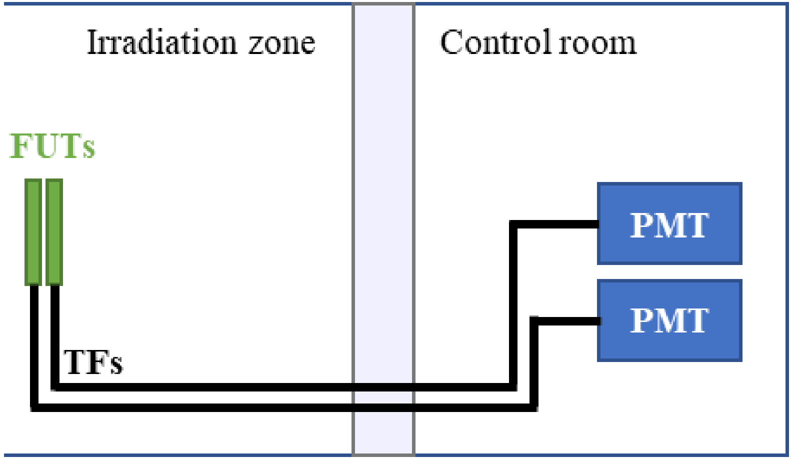
Figure adapted from Nordine Kerboub's PhD thesis

RIL measuring setup

The 102 µm core and 2 cm long radioluminescent optical fiber (FUT) is connected to a radiation hard transport fiber (TF), in this case a pure-silica fiber of 25 meters.

This transport fiber is connected on the other end to a photomultiplier tube (PMT) optimized for the central wavelength of the Ce RIL.

We employ two of these setups in parallel, to compare the response of two fiber samples, one pristine and one that was pre-irradiated at 250 kGy(SiO_2) under X-rays.



The Frascati Neutron Generator

14 MeV neutrons based on the Deuterium – Tritium fusion reaction.

Deuterons are accelerated and shot towards a tritiated target.

The neutrons are generated isotropically with a yield up to 10^{11} n/s.

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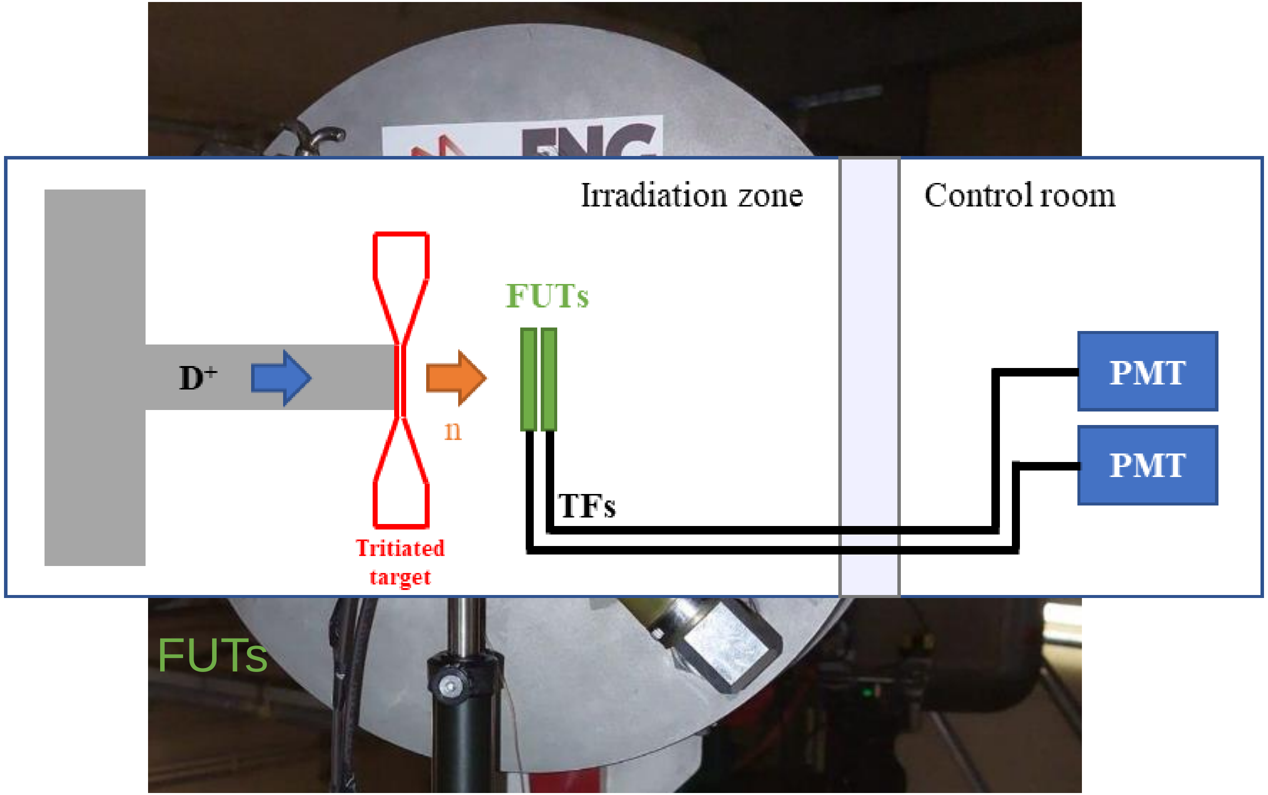

14 MeV neutrons based on the Deuterium – Tritium fusion reaction.

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The neutrons are generated isotropically with a yield up to 10^{11} n/s.

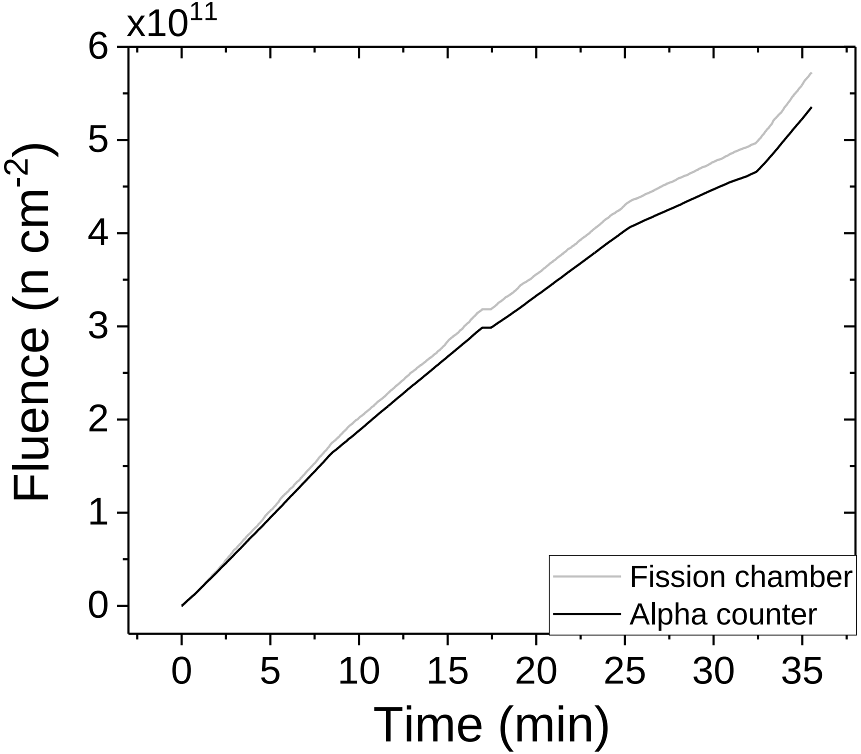
Neutron monitors of the facility

At FNG, the neutron yield is monitored in real time by their instruments:

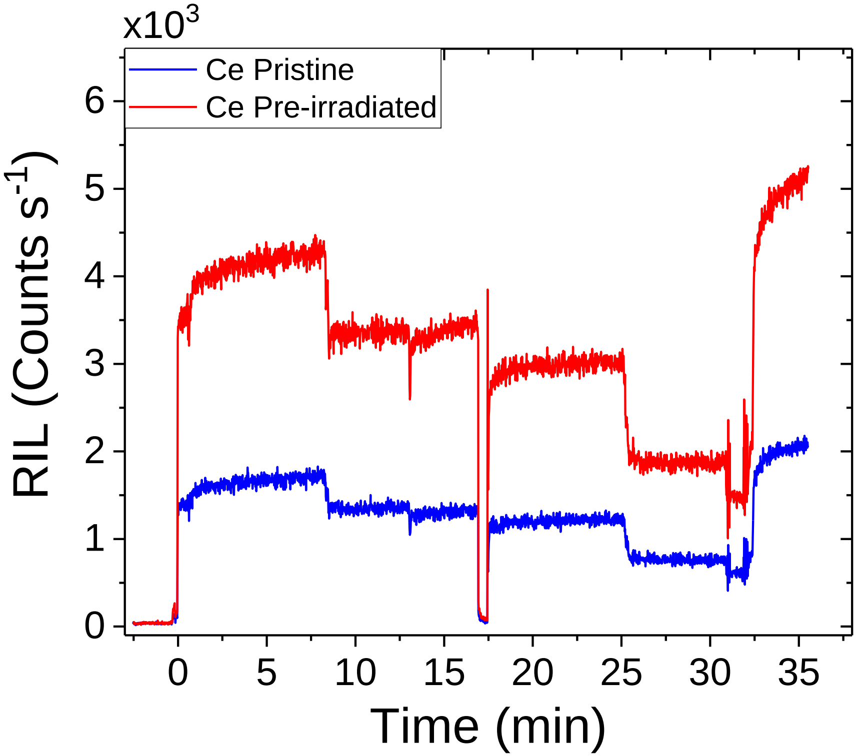
- An alpha counter
- A fission chamber

The area in front of the tritiated target has been mapped via MCNP simulations.

A conversion factor from the total neutron yield to the fluence in the position of the fiber is provided.



Raw RIL kinetics

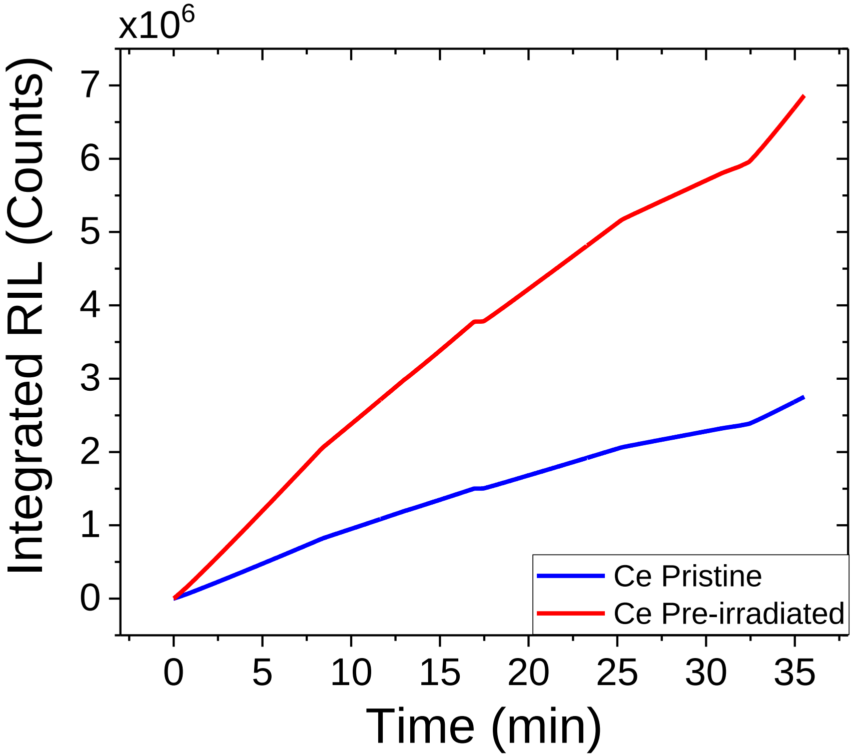


The signal before t = 0 is subtracted, as it is noise.

The sensitivity of the pre-irradiated sample is higher, as expected.

To compare this response with the fluence monitors we need to integrate the RIL over time.

Integrated RIL kinetics



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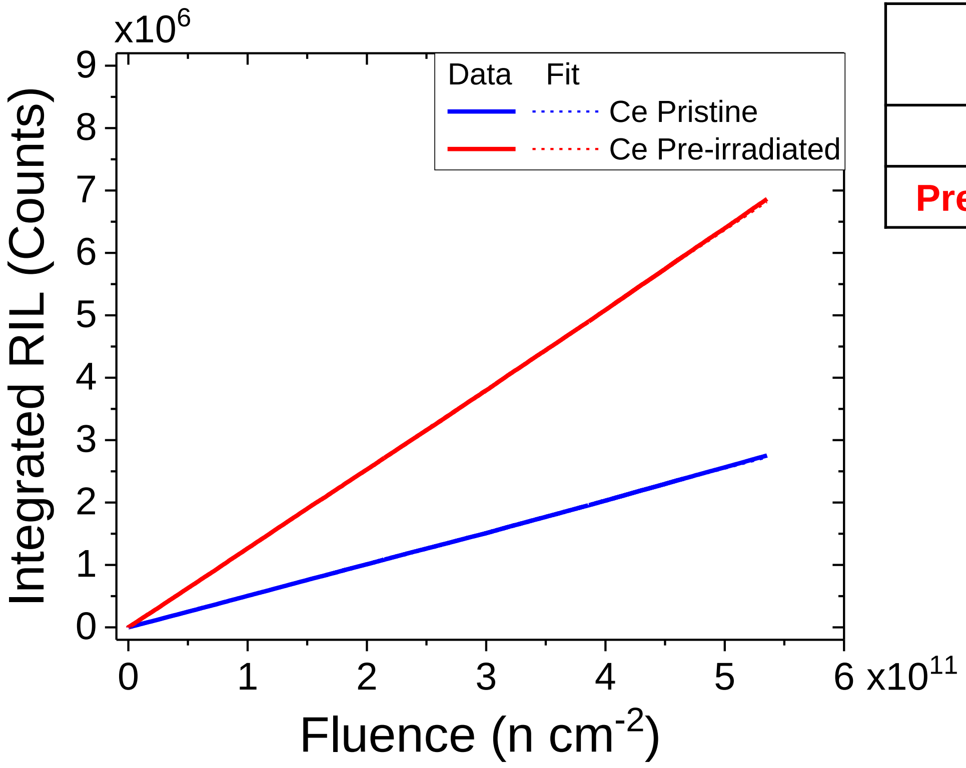
Integrated RIL vs Fluence Calibration



	Adj. R^2	Sensitivity ($Counts\ n^{-1}\ cm^2$)
Pristine	0.99996	$5.0873\times10^{-6} \pm 7\times10^{-10}$
Pre-irradiated	0.99998	$1.273\times10^{-5} \pm 1.13\times10^{-9}$

We can then have a better linear fit.

The linearity of the pre-irradiated is higher than the pristine one.

The sensitivity is 2.5x times higher on the pre-irradiated.

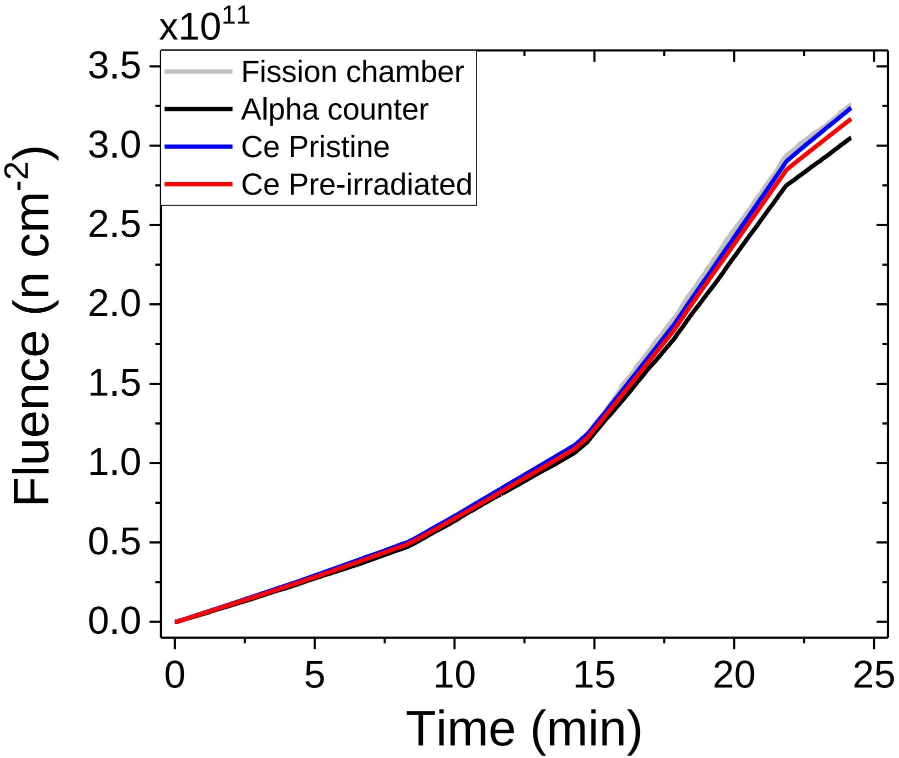
Validation results: comparison

On a new run, performed without changing the position of the samples, we validated the obtained calibration.

The integrated RIL and the sensitivity values were used to estimate the neutron fluence.

The maximum deviations from the alpha detector are:

- ~6% for the Pristine
- ~4% for the Pre-irradiated
- ~7% for the Fission chamber

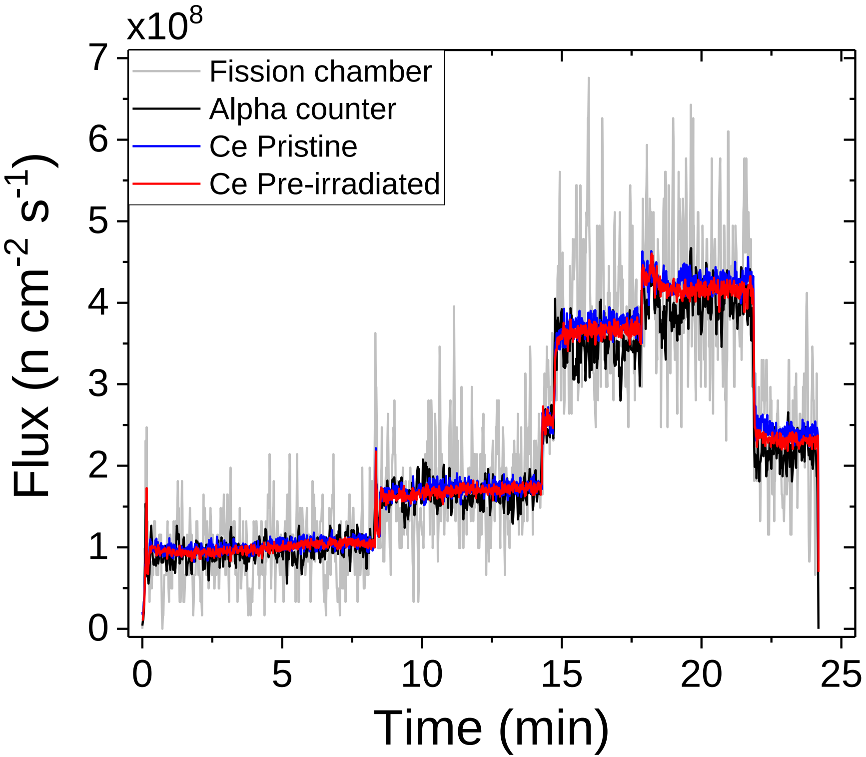


Validation results: comparison

Via a time derivative, we can estimate the flux kinetics with all detectors.

The results for the facility counters have been smoothed via a 3s moving average.

Both fibers are clearly capable of following the variations in the neutronic flux.



Conclusion

The RIL has been proven to be linear with flux. With the pre-irradiation the sensitivity is higher, and the parasitic RIL phenomena are weakened.

Able to detect the neutron flux, and quantify the neutronic fluence.

Less variation than the facility counters.

Simple single-ended setup that can easily be setup remotely so that any delicate instrument is outside the irradiation zone.

Thanks for your attention!

Image Source: CERN

Extra

Radiation-Induced Luminescence (RIL)

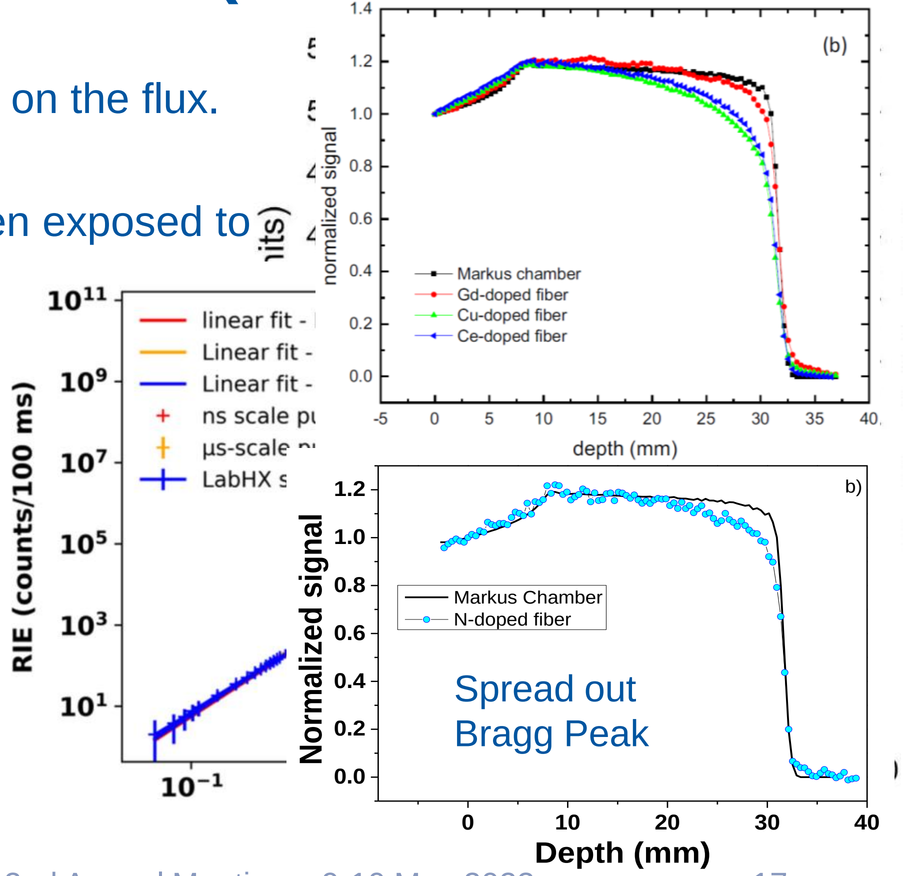
RIL is then a light signal which linearly depends on the flux.

It has been proved to maintain this linearity when exposed to different particles and energies.

Some results:

- 10-decades linearity under X-rays of different facilities.
  - J. Vidalot et al., Sensors, 2022.
- The capability of reproducing the shape (for protons.
  - S. Girard et al., IEEE TNS, 2019.
  - C. Hoehr et al., Sci. Rep., 2019

Figure adapted from Norc



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