The Radiological Research Accelerator Facility www.raraf.org

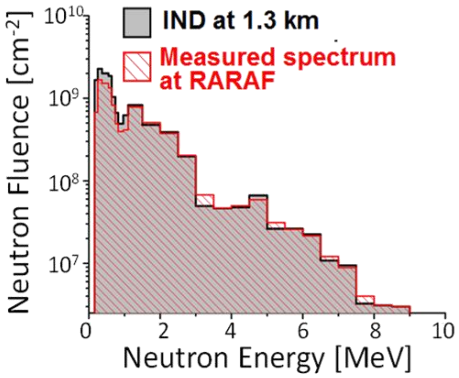
The Radiological Research Accelerator Facility (RARAF) provides the radiation research community advanced irradiation techniques using charged particle and neutron beams. During the more than 50 years that RARAF has been in operation, experiments have been performed for over 50 different research groups from more than 40 institutions including universities, national laboratories, cancer centers, and private corporations. These experiments, performed with radiations such as protons, alpha particles, and neutrons, have resulted in more than 200 publications in refereed journals, proceedings, and books. Research has been conducted in the fields of radiation biology, radiological physics, radiation chemistry, health physics, and medicine.

Iirradiations are supported by NIST-traceable doismetry where appropriate.

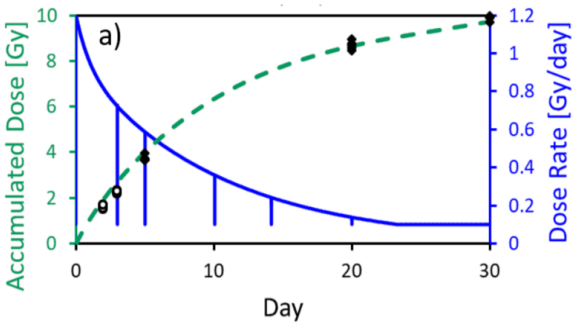
Marino, S. A. (2017). "50 Years of the Radiological Research Accelerator Facility (RARAF)." Radiation Research **187**(4): 413-423.

Neutrons:

The **C**olumbia **I**ND **N**eutron **F**acility (CINF), is a novel accelerator-based neutron source with an energy spectrum modeled on the Hiroshima atomic bomb spectrum at 1.5 km from the epicenter. Beams are generated by impinging a mixed proton/deuteron beam on a beryllium target generating a broad spectrum neutron beam peaked around 1 MeV. Mice and tissue samples can be irradiated at a dose rate of up to 3 Gy/h. The neutron energy spectrum obtained is also a good model for space radiation such as lunar albedo neutrons.



Xu, Y., et al. (2015). "Accelerator-Based Biological Irradiation Facility Simulating Neutron Exposure from an Improvised Nuclear Device." Radiation Research **184**(4): 404-410.



Dose rate profile mimicking ^{137}Cs ingestion in mice. Symbols are measured per-mouse doses

Low dose rates:

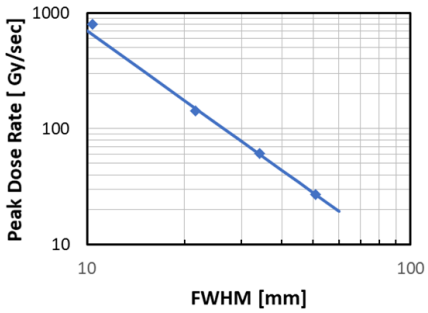
The ***VA**riable **D**ose-rate **E**xternal ^{137}Cs irradiato**R** (**VADER**)* allows modeling of low dose rate ^{137}Cs exposures in mice and other samples using repurposed ^{137}Cs brachytherapy seeds to generate low dose rates (0.1 to 1 Gy/day), mimicking fallout and ingestion exposures. Within the VADER, up to 15 mice can be housed in an IACUC approved “mouse hotel” for a few weeks. A custom incubator is available for performing ex-vivo blood (or other tissue) irradiations.

Garty, G., et al. (2020). "VADER: a variable dose-rate external ^{137}Cs irradiator for internal emitter and low dose rate studies." Scientific Reports **10**(1): 19899.

High dose rates

To mimic prompt exposures from an Improvised Nuclear Device (IND), we have adapted a retired clinical accelerator to deliver high dose rates:

Operating in 9 MeV electron mode, samples can be irradiated inside the Clinac head at **average** dose rates of up to 600 Gy/sec (3 Gy per 0.5 µsec pulse, 180 pulses per sec). In this mode multiple pulses are required for most irradiations. By modulating pulse repetition rate, dose rates of 1 Gy/sec to <1 Gy/min can be achieved at the isocenter, allowing comparison of FLASH and conventional irradiations with the same beam.



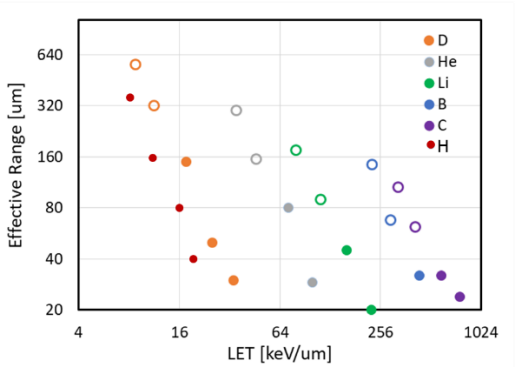
Dose rate vs spot size

Operating in 6 MV photon mode, with the conversion target removed, samples can be irradiated at **instantaneous** dose rates of up to 300 MGy/sec (0.2-150 Gy per 0.5 µsec pulse, 360 pulses per sec) and most irradiations can be performed with a single very high dose rate pulse.

A 4 kGy/sec proton beam (4.5 MeV – 10 keV/µm) is also available for irradiation of thin samples.

Ion beams

Our Singletron accelerator provides ion beams with a range sufficient to irradiate cellular monolayers, targeting cellular or sub-cellular objects or very thin tissues. Hydrogen and helium beams with LET ranges of 10-200 keV/µm are offered in micron to cm sizes and carbon boron and lithium beams (LET range of 200-1000 keV/µm) are coming online. The recent installation of a linac booster allows irradiation of thicker samples beams enabling irradiation of thin tissue samples in addition to cell cultures.



Ion beams available at RARAF

Lab facilities

On-site fully equipped biology labs and a mouse housing facility are available to support experiments.

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