Validating current-mode operation of the Nested Neutron Spectrometer under high neutron fluence-rates in radiation therapy using a novel passive system with gold foils

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Disclosure

I have no financial disclosures or conflict of interest

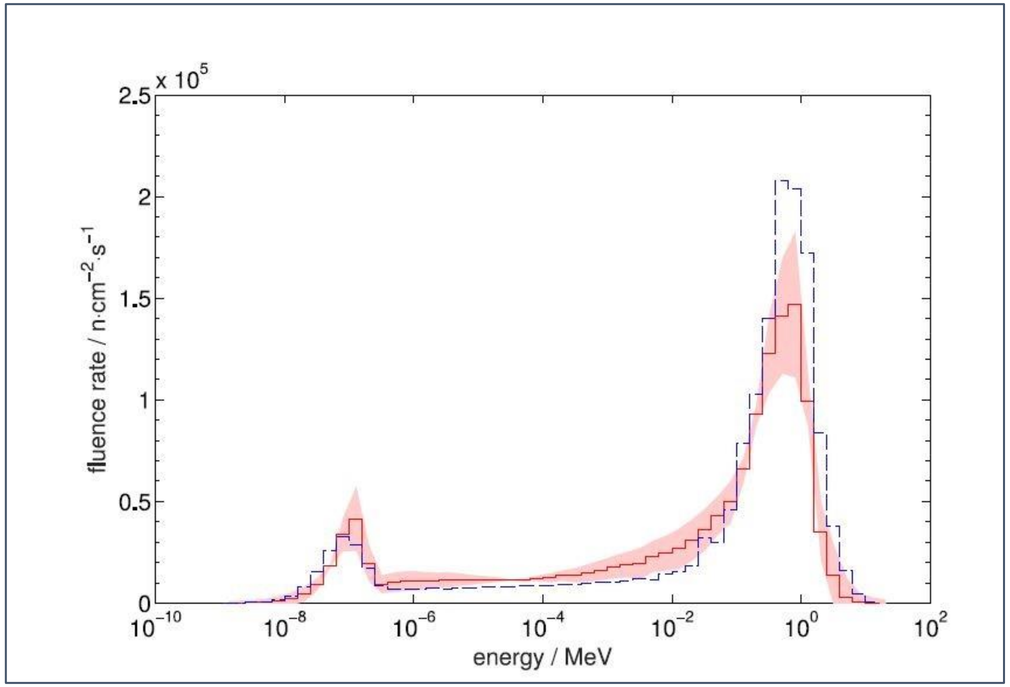
Nested Neutron Spectrometer (NNS)

- He-3 detector + 7 HDPE moderator shells
- He-3 detector is mostly sensitive to thermal neutrons and moderators are used to sample more neutron energies.

Figure from Dubeau et al., 2013, poster presentation CRPA conference, Sherbrooke, Quebec

Neutrons in radiotherapy

- Secondary neutrons are produced during high energy photon, electron and proton treatments.
- Neutron fluence-rate is ~10^5 neutrons/sec in high-energy photon therapy.
- He-3 detector will have pulse pile-up and long dead time above 10^4 counts/second.
- We operate NNS in current-mode for our measurements.



Neutron fluence spectra in high-energy photon radiotherapy

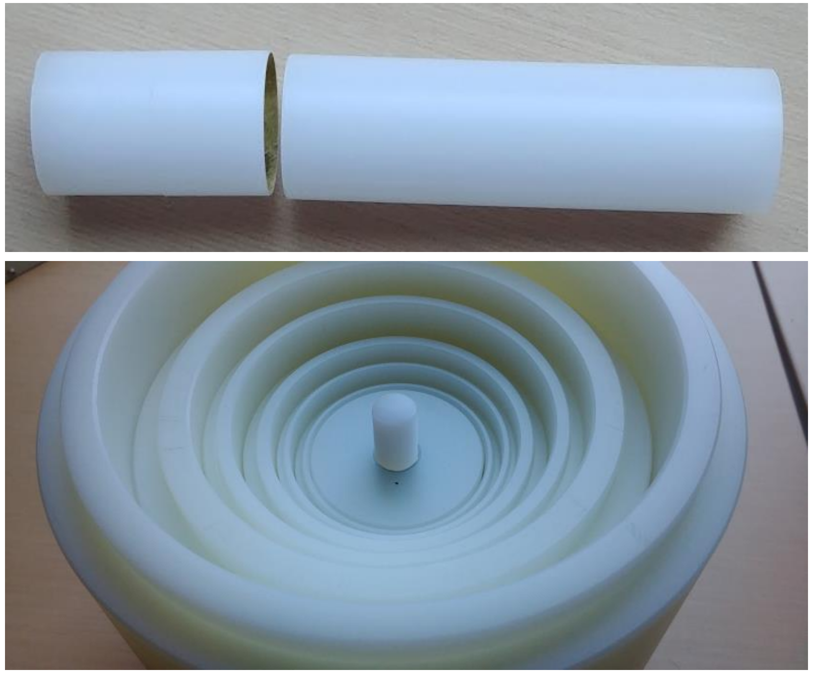
NNS calibration

- NNS is calibrated using an Am-Be source at Ionizing Radiation Standards Laboratory of the National Research Council of Canada.
- Am-Be source has a low fluence-rate.
- NNS is also used to measure the neutron current from the Am-Be source in current-mode.
- Vendor provide us with a conversion factor that is the ratio of neutron count-rate and current.
- There is no way to directly validate the calibration factor in high fluence-rate.

We developed a passive NNS with gold-foils

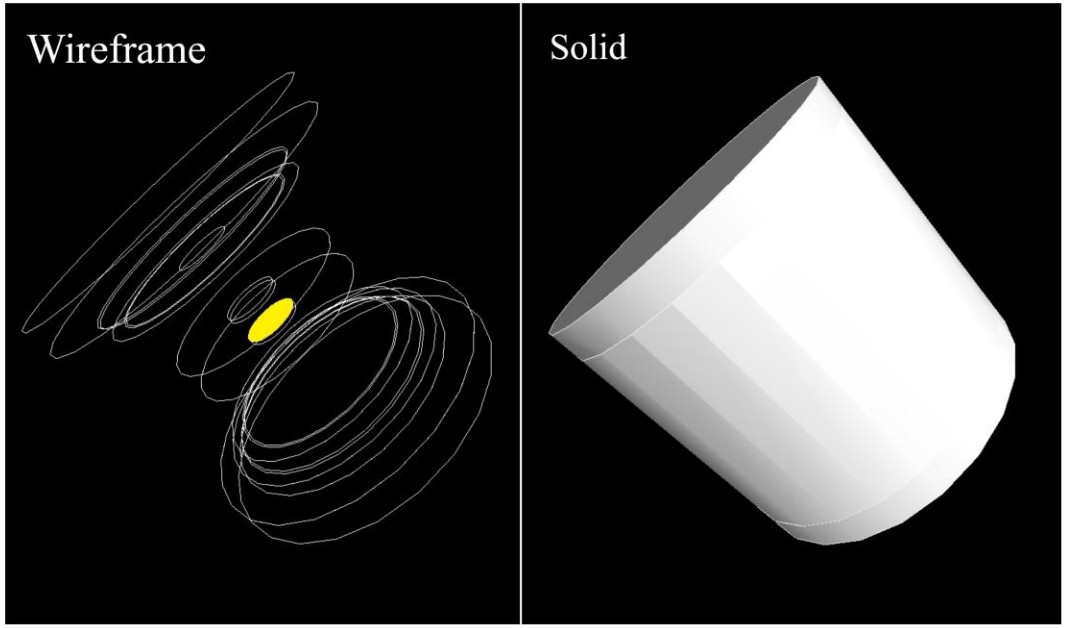
- He-3 detector was replaced with passive gold-foils.
- Gold foils get activated on interaction with neutrons and they are not affected by the neutron fluence-rate.
- By measuring the radioactivity of the foil after neutron exposure, we can determine the number of neutron interacted.

Active NNS with He-3

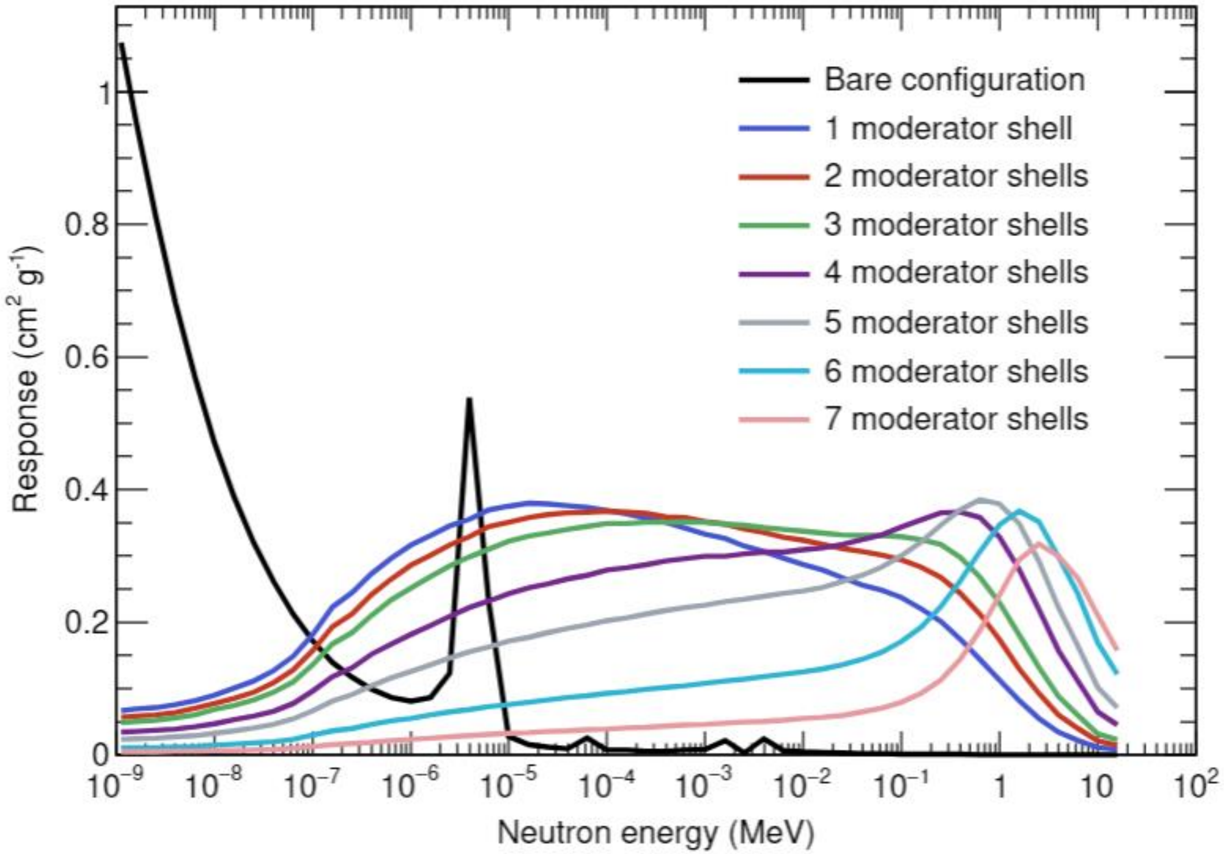


Passive NNS with gold-foil

Performed Monte Carlo simulations to generate response functions

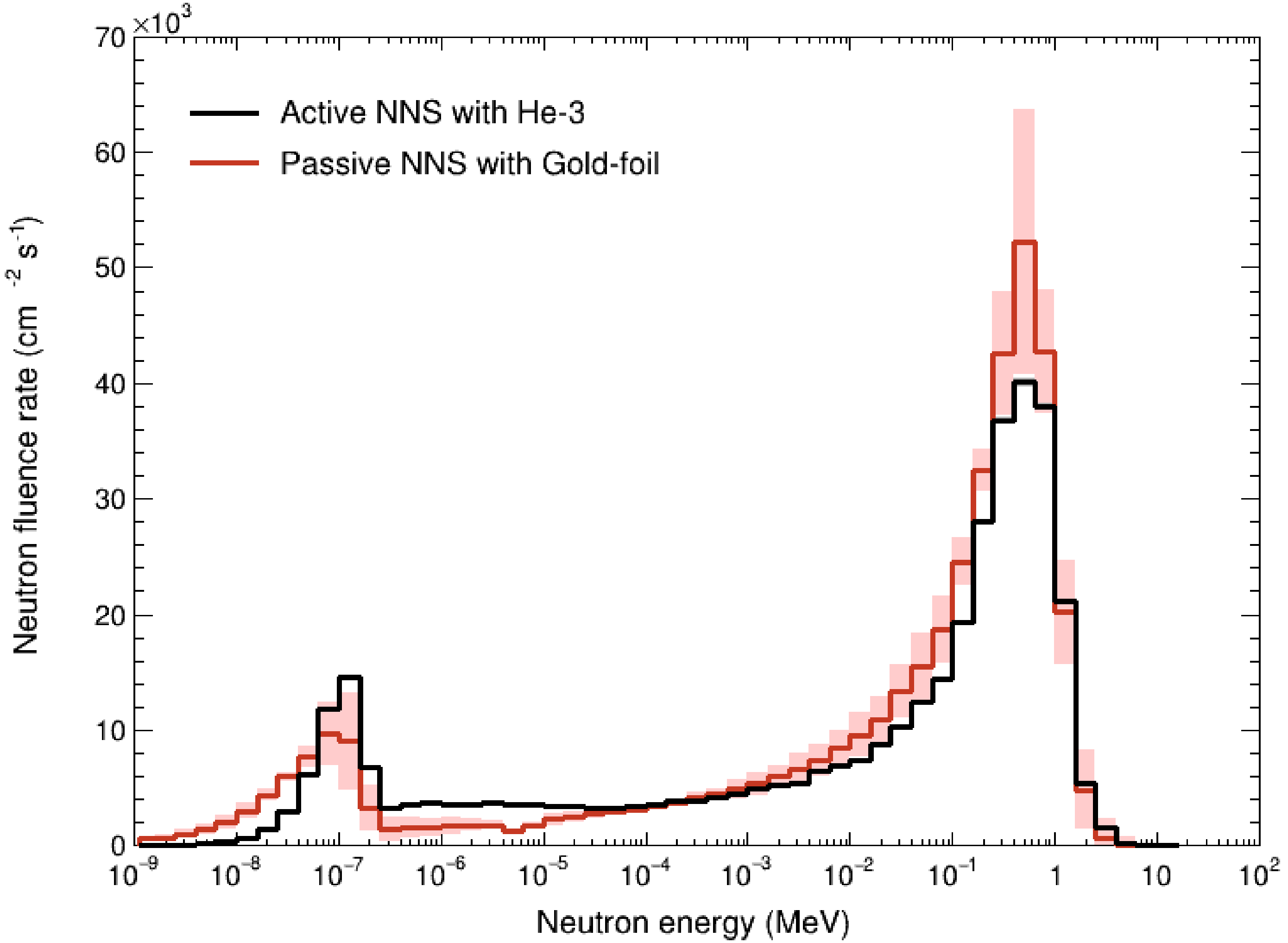


Monte Carlo model of the passive NNS in Geant4



Response functions of the passive NNS with gold foils determined from the MC simulation

Simultaneously determined the neutron fluence spectrum using both active and passive NNS



- Both spectra agreed reasonably well within uncertainties

- This validated the accuracy of the current-mode measurements with the active NNS in high fluence-rate conditions

Conclusions

- We use the current mode of the NNS to make neutron spectral measurements in high-fluence rates.

- A conversion factor, determined in low fluence-rate conditions, is used to obtain count-rate from current.

- The accuracy of the conversion factor is questionable under high fluence-rates and it is not possible to directly validate the accuracy due to pulse pile-up.

- We developed a passive NNS with gold foils that works well irrespective of the fluence-rate.

- We compared the passive NNS spectra with the active NNS one in high fluece-rate and indirectly validated the accuracy of current mode measurement.

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