A new fast neutron facility for materials analysis at UCT

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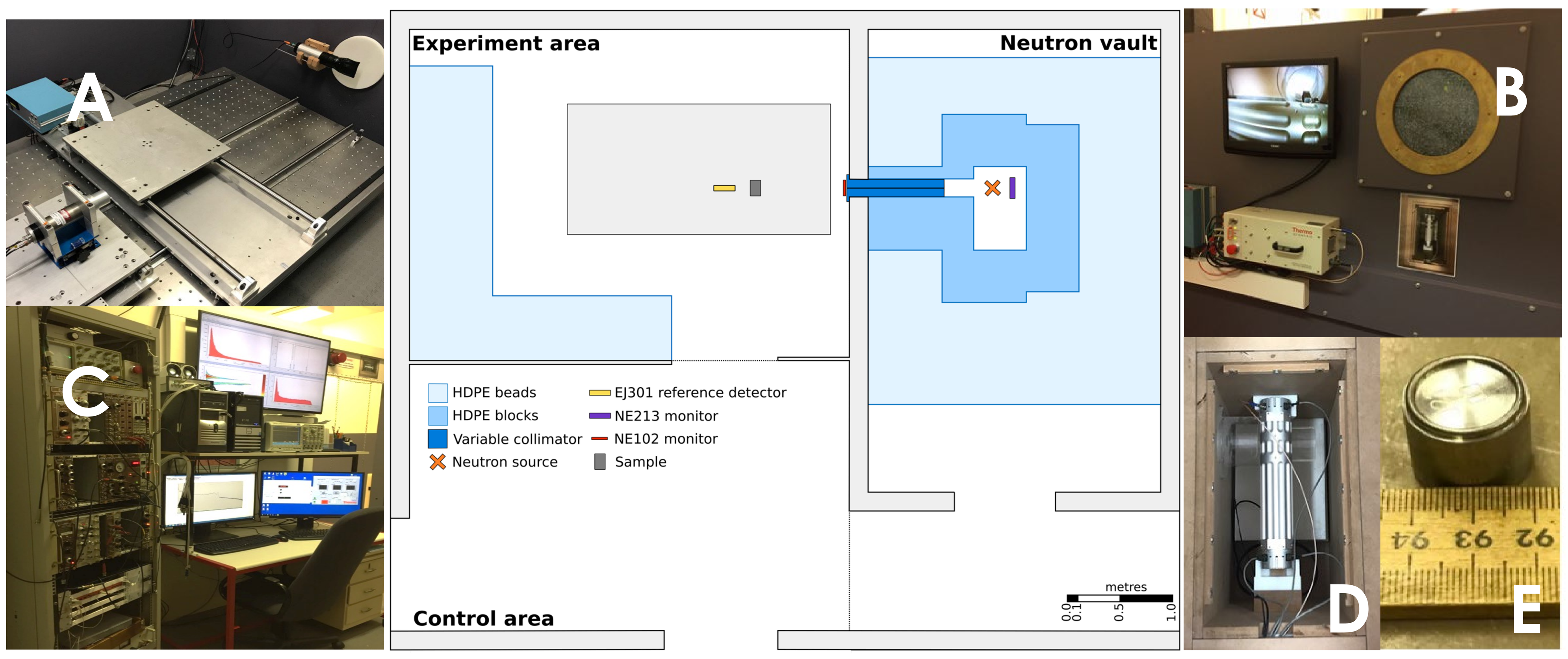
Neutron-based analytical techniques such as fast neutron analysis (FNA) and thermal neutron analysis (TNA) are among the most powerful techniques for elemental analysis in small and bulk samples [1,2]. The techniques are rapid, non-destructive and are capable of simultaneous multi-elemental analysis in samples with complex matrices [2]. In 2017, the Metrological and Applied Sciences University Research Unit (MeASURe) within the UCT Department of Physics commissioned the n-lab, a fast neutron laboratory centred around a Thermo MP-320 deuterium-tritium sealed tube neutron generator (STNG) and a 220 GBq americium-beryllium (Am-Be) radioisotopic source [3]. We aim to develop standardized neutron analysis techniques through experiments and Monte Carlo simulations. For such a study to be feasible, the neutron energy spectrum of any source must be well characterized. In this regard, the neutron yield of the STNG was measured to be $(1.22 \pm 0.10) \times 10^8$ neutrons s^{-1}. Additionally, proof-of-principle material analysis measurements were performed, the results allowed for a positive identification of carbon via $^{12}C(n,n')^{12}C^*$ inelastic scattering in graphite.

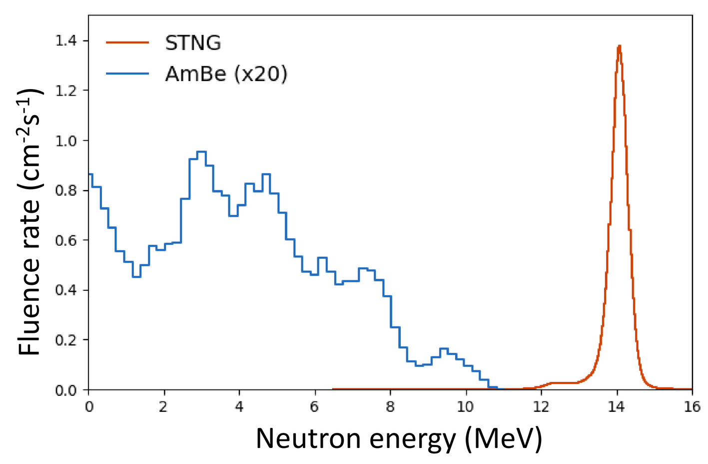
Overview of the n lab

The facility consists of a vault (**B**) where neutron sources are stored, the experimental area (**A**) where measurements are taken, and the control room (**C**) where the STNG (**D**), detectors, data acquisition and scanning tables are controlled.



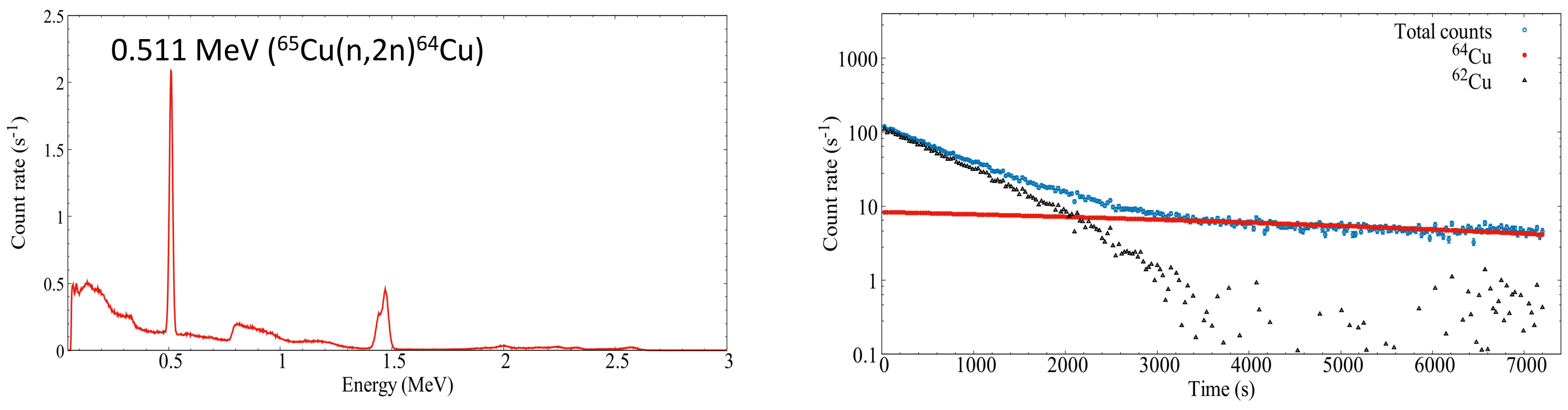
The n lab has two sources:

	STNG	AmBe
Type	Accelerator	Radioisotopic
Reaction	t(d, n)α	$^9Be(\alpha, n)^{12}C^*$
Energy	14 MeV	< 11 MeV
Yield	10^8 s^{-1}	10^7 s^{-1}



STNG yield measurements

- Copper foil irradiated with 14 MeV neutrons for 2 hours at a distance of 12 ± 1 cm to produce ^{62}Cu and ^{64}Cu.
- Time dependent gamma ray spectra measured with 2" x 2" $LaBr_3$:Ce detector.

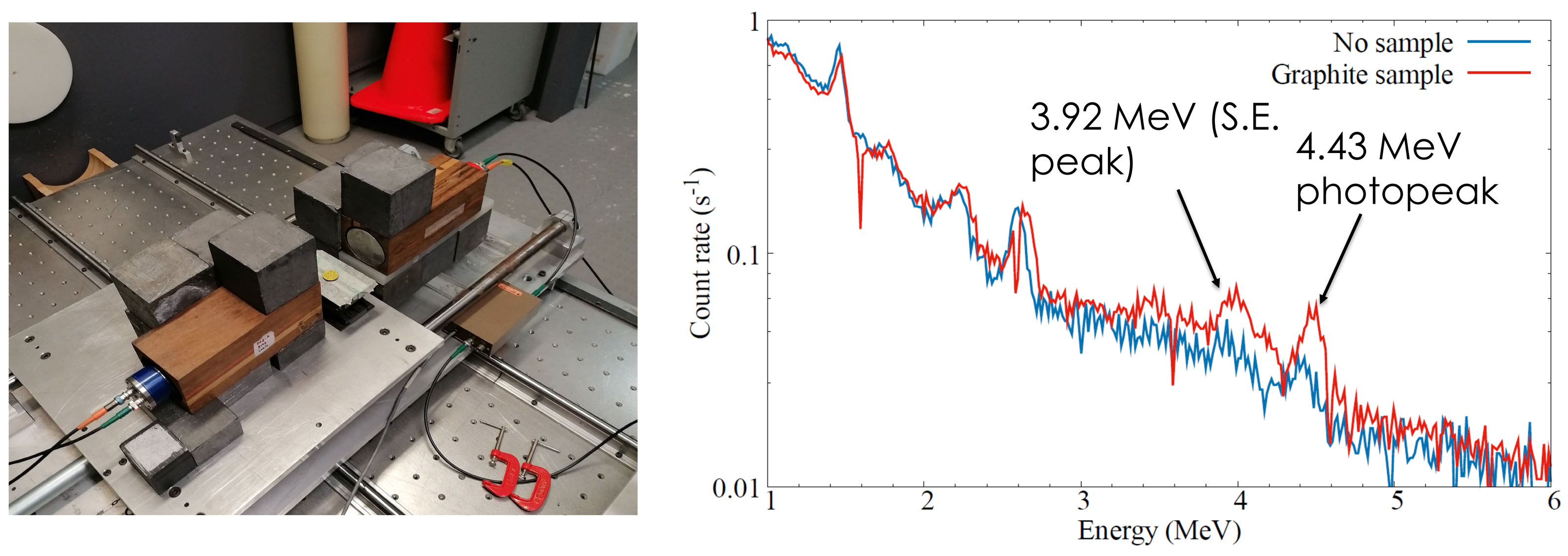


Spectrum of natural copper (left) and the 0.511 MeV decay curves (right).

$$Y = 4\pi r^2 \frac{N_p M \lambda}{N_A m \sigma \theta I_\gamma \varepsilon \Omega} \frac{1}{(1-e^{-\lambda t_i}) e^{-\lambda t_d} (1-e^{-\lambda t_c})}$$

Measured neutron yield, Y = $(1.22 \pm 0.10) \times 10^8$ s^{-1}.

Prompt gamma neutron analysis



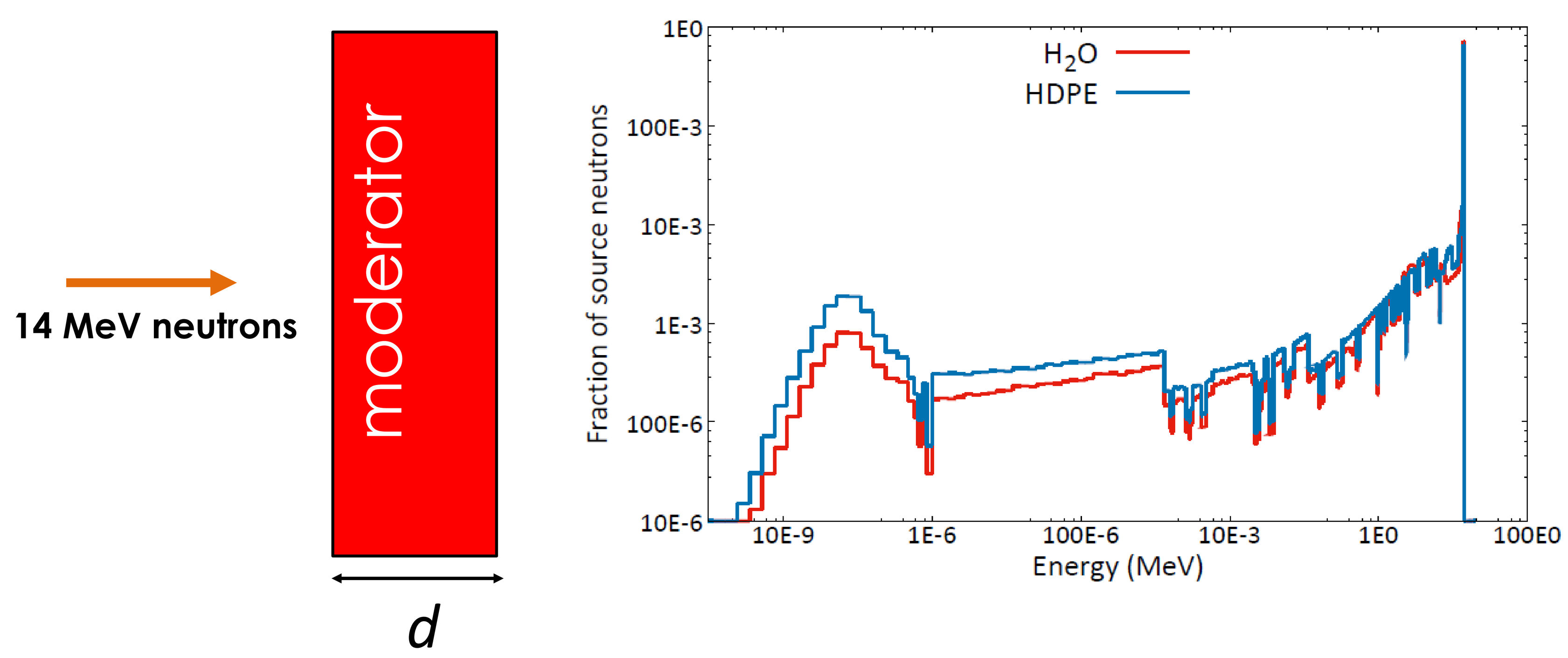
Experimental set up (left) and measured spectra (right).

- 5.9 x 5.9 x 13.8 cm^3 graphite block irradiated with pencil beam of 14 MeV neutrons for 1 hour.
- Prompt gamma rays from ^{12}C (4.43 MeV) were detected using two calibrated 3" x 3" NaI detectors.
- Rates of 0.8 counts s^{-1} were achieved in the region of interest.

Future plans at the n lab: PFNA and production of thermal neutrons

- Pulsed fast-thermal neutron analysis possible by operating the STNG in microsecond pulsing mode.
- Thermal neutron analysis is also possible at the n-lab via thermalization of fast neutrons.

Ultimate aim: to develop the n lab for bulk materials analyses using multi-modal, standardized neutron analysis techniques.



A simple target-beam FLUKA model (left) and the resulting spectra (right) after moderation of 14 MeV neutrons by a 2 cm thick H_2O and HDPE target.

References

[1] J. Csikai, Proc. SPIE 2339, 318-334 (1995)

[2] Z. Alfassi, Activation Analysis Vol.1, CRC Press (1990).

[3] T. Hutton & A. Buffler, Proceedings of SAIP2017, SA Institute of Physics (2018).