A compact neutron spectrometer for neutrons produced by cosmic rays

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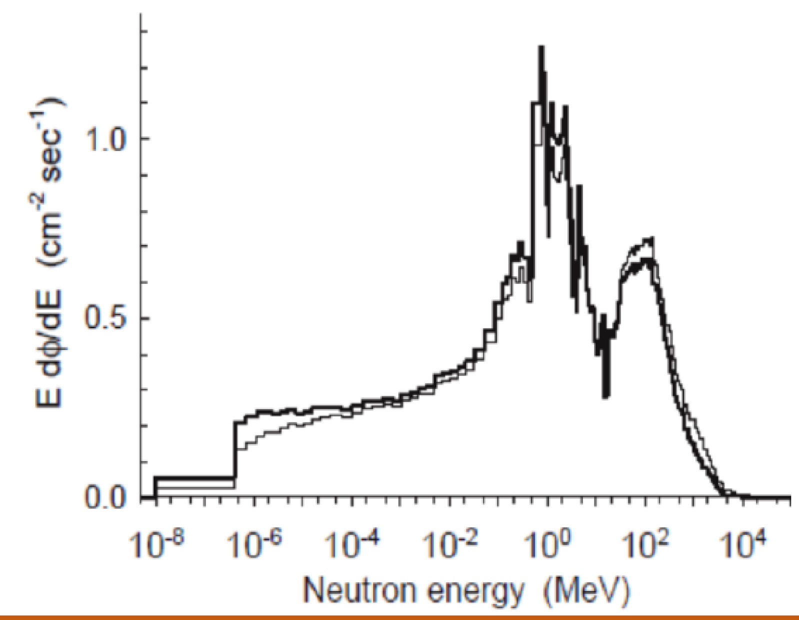
Cosmic rays and neutrons

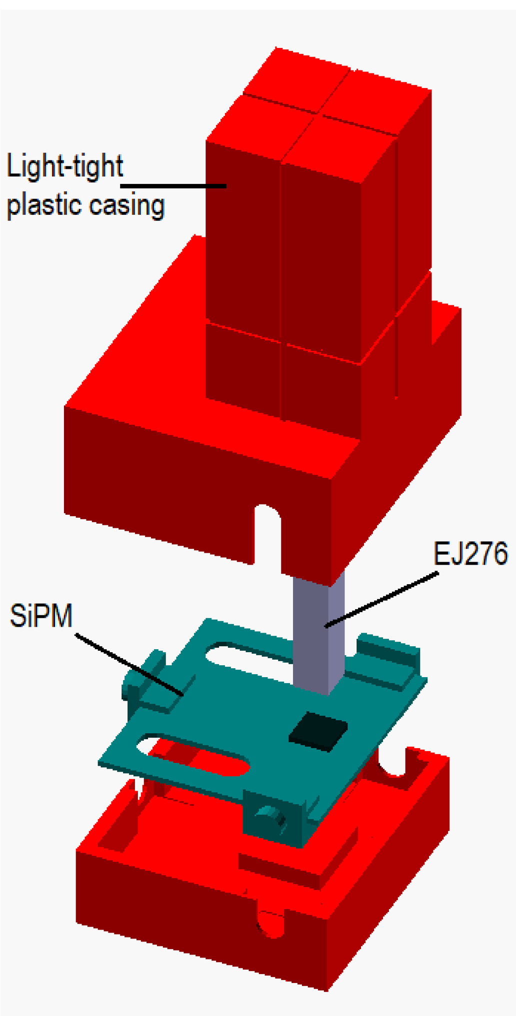
Cosmic rays are predominantly made up of high energy protons which interact with our atmosphere creating large amounts of secondary particles through spallation [1]. At aviation altitudes (10 -15 km) the radiation field is comprised of approximately 40% high energy neutrons with energies between 1 and 100 MeV [2].

During space weather events the amount of ionising radiation at these altitudes increases which poses a biological risk to air crew and damages sensitive aircraft electronics [3].



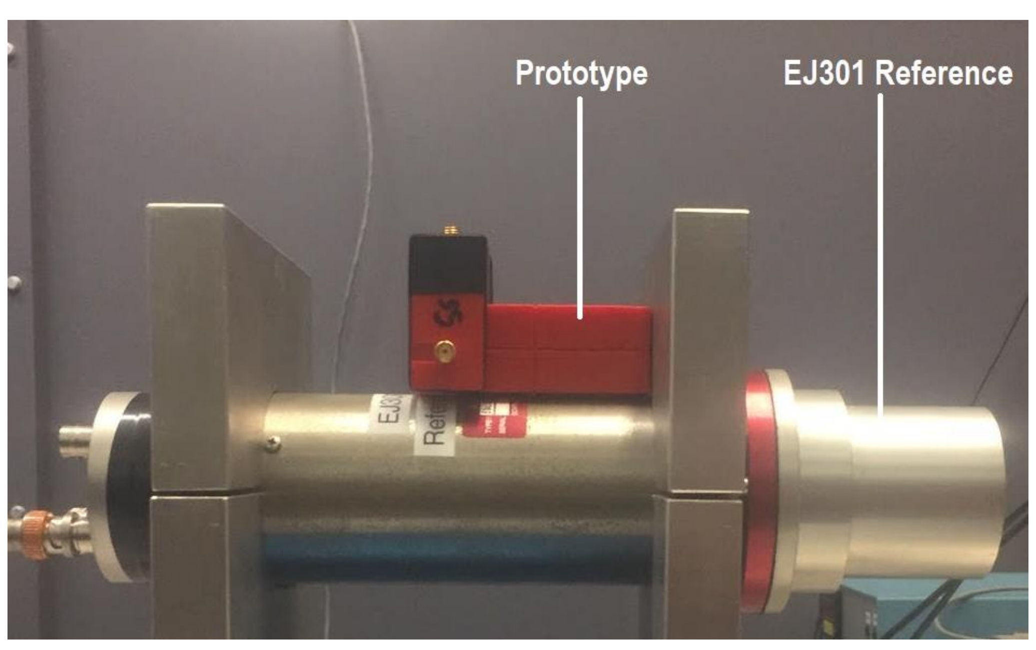
Neutron energy spectrum at 20km at 54°N,119°W [3]

Prototype and reference detectors



The prototype of the compact neutron spectrometer consists of a 6x6x50 mm^3 EJ-276 plastic scintillator coupled to a silicon photomultiplier (SiPM) in a light tight casing operated at +28.5 V using an external power supply.

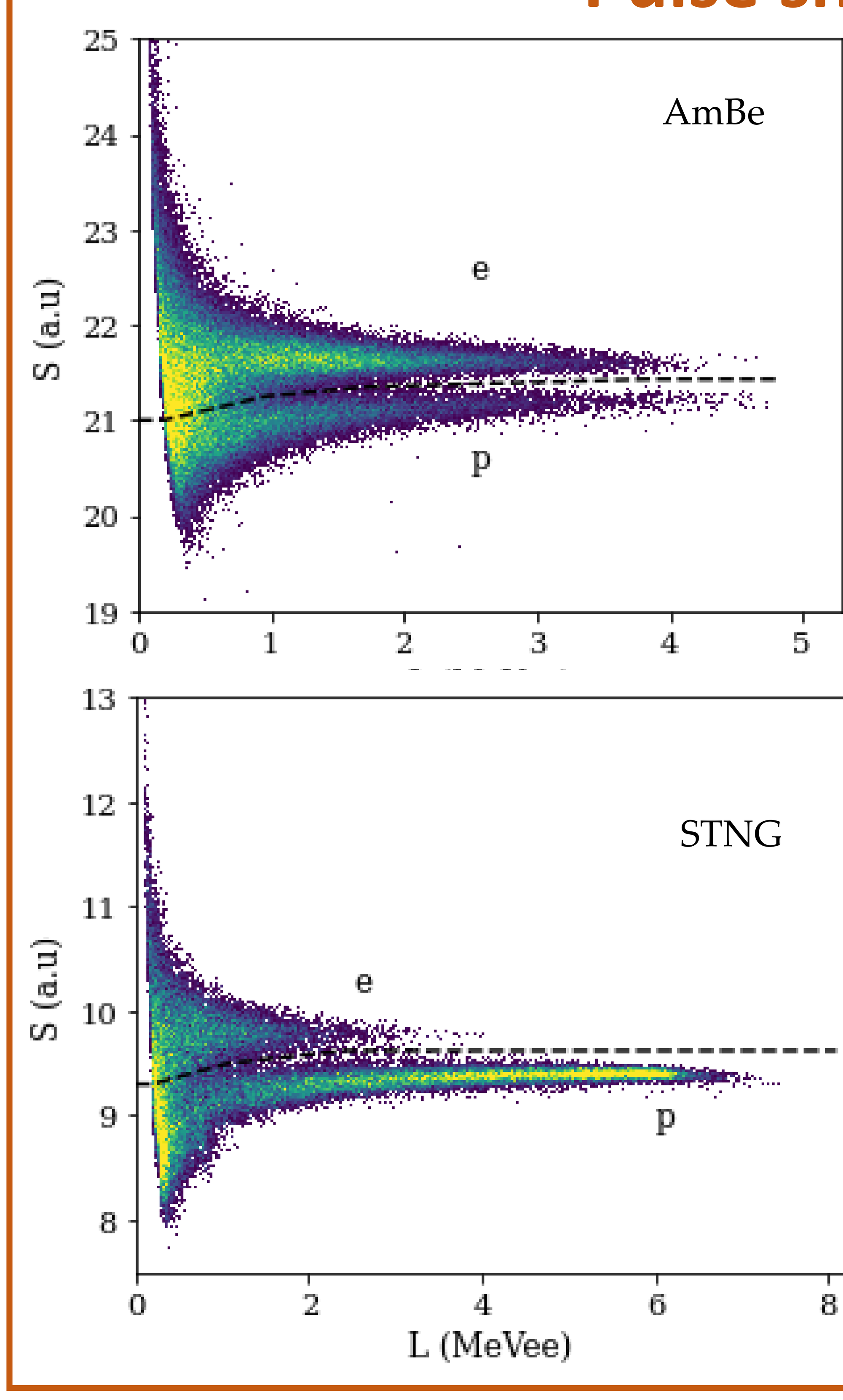
The reference detector is a 50 x 50 mm^2 cylindrical EJ-301 liquid scintillator coupled to a 12-stage photomultiplier tube operated at a bias of 1000 V.



A digital data acquisition system consisting of a CAEN DT5730 digitiser and QtDAQ [4], a custom open source software developed at UCT, was used with both detectors.

Measurements of a 2.2 GBq americium-beryllium (AmBe) source and 14.1 MeV neutrons from a sealed tube neutron generator (STNG) were made at the n-lab in the Department of Physics at UCT using the prototype and reference detectors.

Pulse shape discrimination



The neutron (p) and gamma ray (e) events were separated using the pulse shape parameter, *S*, which is defined as

$$S = k\frac{Q_s}{Q_L} + c$$

where k and c are arbitrary scaling factors and Q_s and Q_L are the integrals of the detector pulses over a short and long time period respectively.

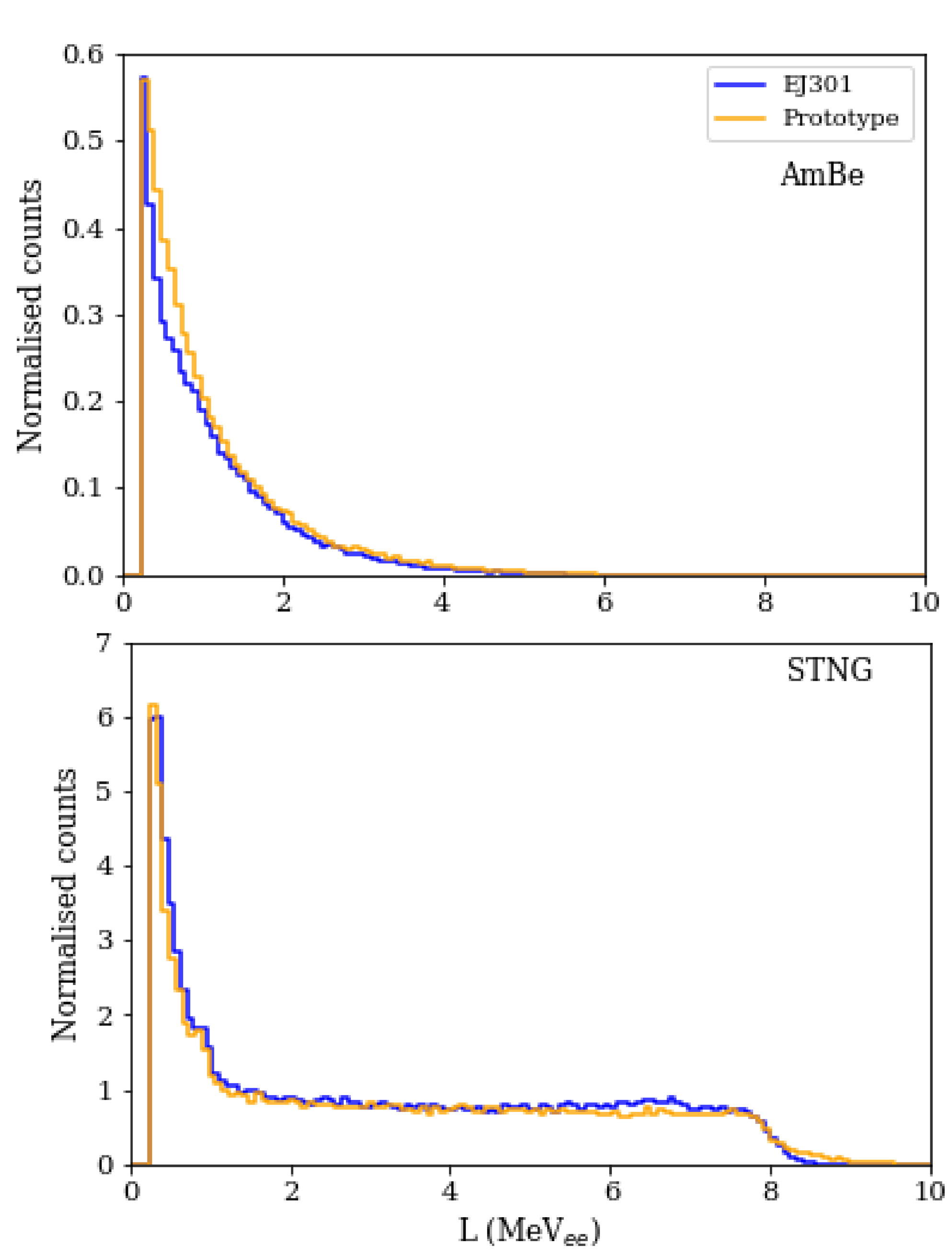
The quality of the separation of events can be quantified by the figure of merit (*FoM*).

$$FoM = \frac{|\mu_e - \mu_p|}{FWHM_e + FWHM_p}$$

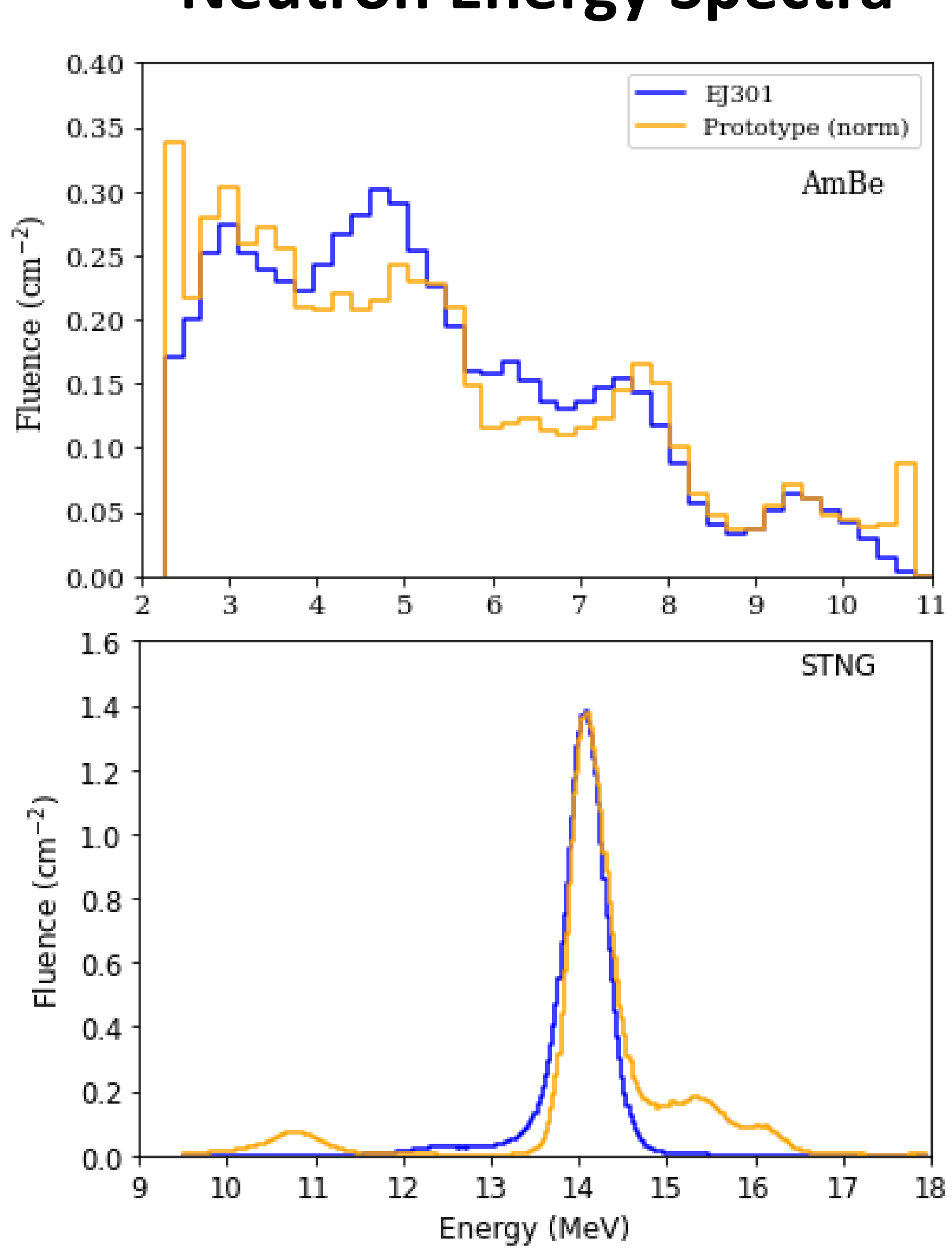
A *FoM*>1 implies adequate separation

Unfolding

Neutron LOS



Neutron Energy Spectra



The neutron energy spectra were produced by unfolding the measured neutron light output spectra (LOS) using the GRAVEL and MAXED algorithms [5].

The difference in energy spectra for the 14.1 MeV neutrons at high energy is due different light output characteristics prototype detector system

	EJ301	Prototype
FoM (1.9<L<5.0 MeV$_{ee}$)	2.5±0.2	1.2±0.4
Relative neutron efficiency (AmBe)	1	0.38±0.01
Relative neutron efficiency (STNG)	1	0.15±0.01

The results showed promise that this detector system could be capable of fast neutron spectroscopy and further development and characterisation of the prototype is being done.

[1] P. Grieder, Elsevier(2001) [2] Goldhagen et. al. (2001) [3] Tobiska et. al., Space Weather, vol.13, (2015) [4] A. Comrie, et al., Nucl. Instr. Meth. A, 772, 43–49 (2015) [5] M. Reginatto, et al., Nucl. Instr. Meth. A, 476, 242-246 (2002).

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