CELLULAR ARRAY NEUTRON DETECTOR FOR LUNAR AND PLANETARY MISSIONS C. B. Shahi,[1,2] R. Haun,[1,2] M. A. Coplan,[2] J. J. Su,[3] L. Lutz,[2] L. Putnam,[2] J. K. Graybill,[1] A. K. Thompson[1] and C. W. Clark[1,2]. [1]National Institute of Standards and Technology, Gaithersburg, MD 20899, chandra.shahi@nist.gov [2]University of Maryland, College Park, MD 20742, [3]Systems Engineering Group, Inc., 9861 Broken Land Parkway, Suite 350, Columbia, MD 21046.

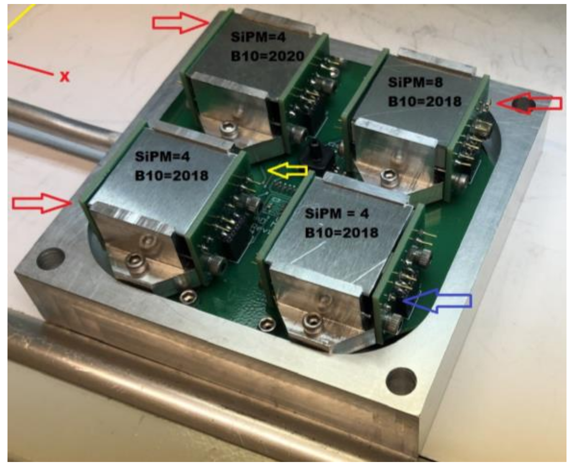
Introduction: The distribution and quantity of water has become a dominant theme in solar system exploration, because of its importance to create potentially habitable environments and its value for *in situ* resource utilization (ISRU). Remote-sensing neutron spectroscopy is especially well suited to the direct detection of hydrogen down to ~1 m in depth. [1] Measurements of lunar south pole epithermal neutron flux by orbiting detectors suggest ice deposits in permanently shadowed regions (PSRs). [2-4] Neutrons cannot distinguish water from hydroxl in such environments, but in late 2020 infrared spectroscopy [5] confirmed the presence of water in sunlit regions of the Moon between 55° and 75° S latitude, at concentrations of up to 400 ppm in lunar soil. There is new evidence for perhaps 40,000 km^2 of cold-trap regions at higher lunar latitudes. [6]

We propose a method for finding surface or subsurface hydrogen deposits on the Moon by local surveys conducted by astronaut, rover or autonomous array.

Approach: Ambient lunar neutrons are produced by galactic cosmic ray collisions with lunar soil within about 1 m of its surface. Such collisions initiate high-energy neutrons, some of which are thermalized by subsequent collisions with hydrogen in the lunar soil. The energy and momentum spectra of lunar neutrons thus contain signatures of the location and quantities of lunar hydrogen.

We are building a cellular array neutron detector to measure those spectra. It could serve as a local survey instrument for hydrogen within 1 m of the lunar surface. The cells of the array are light (0.2 kg), compact (50 cm^3, low-voltage, atmospheric-pressure gas scintillators activated by the $n(^{10}\mathrm{B},^{7}\mathrm{Li})\alpha$ nuclear reaction. That is the same reaction used in the only ground-truth measurement to date of neutron density at the Moon's surface: the Apollo 17 Lunar Neutron Probe Experiment (LNPE). [7]

The energy and momentum distributions of the neutrons are obtained by *detector diversity*. Each cell is configured with compact material attachments made of high-density polyethylene and cadmium, which enhance individual detector sensitivities in different regions of the neutron energy-momentum spectrum.



The figure shows an assembly of four basic cells in an open milled aluminum cartridge. The cartridge is sealed with a symmetric aluminum top, and the cavity is filled with xenon gas at a pressure of one atmosphere. The four silvery squares are the backsides of aluminum substrates, the front sides of which are plated with a 1-micron-thick film of 93% ^{10}B. They face an identical boron-plated surface below. Silicon photomultipliers (SiPMs) view the space between the two films. Neutrons absorbed by a film generated two reaction products which can induce far ultraviolet emissions in the gas; these can be detected by the SiPMs. In this configuration, 10% of incident neutrons are absorbed, with unit optical detection efficiency.

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References:

[1] T. H. Prettyman, et al., (2017), *Science 355*, 55. [2] M. L. Litvak, et al., (2012), *J. Geophys. Res. 117*, E00H22. [3] A.B., Sanin, et al., (2016), *Icarus 283*, 20 [4] Lawrence, D., (2016), *J. Geophys. Res. Planets 122*, 21. [5] C. I. Honniball, et al., (2020), *Nature Astron.* 10/26. [6] P. O. Hayne et al., (2020), *Nature Astron.* 10/26. [7] D. S. Woolum, et al., (1975), *Moon 12*, 231 [8] J. C. McComb, et al., (2014), *J. Appl. Phys. 115*, 14450