COMPACT, LOW-VOLTAGE NEUTRON DETECTOR FOR VOLATILE DISCOVERY C. B. Shahi,[1] M. A. Coplan,[1] J. J. Su,[2] L. F. Lutz[1], C. W. Clark[3] [1]University of Maryland, College Park, MD 20742, [2]Systems Engineering Group, 9861 Broken Land Pkwy, Columbia, MD 20742 [3]National Institute of Standards and Technology, 100 Bureau Drive Stop 8420, Gaithersburg, MD 20899-8420 charles.clark@nist.gov

Introduction: Absorption of thermal neutrons by ^{3}He or ^{10}B results in reaction products (*t,p* and ^{7}Li, α, respectively) with excess energy of the order of 1 MeV. When these energetic reaction products traverse noble gases at atmospheric pressure (~ 10^5 Pa), they generate noble-gas excimer dimers that emit far-ultraviolet (FUV) radiation of wavelength $\lambda = 120 – 170$ nm. The ground states of those excimers are unbound, so the noble gases are transparent to this radiation. We have found that up to a third of the nuclear reaction energy is channeled into those FUV scintillations, which can result in tens of thousands of FUV photons generated per neutron absorbed. [1-3]

We have developed basic neutron detector cells that exploit the FUV scintillations. Micron-thick films of ^{10}B are deposited by electron-beam evaporation on aluminum substrates. These films are incorporated in a physics package of about 10 cm^3 volume filled with Xe gas around atmospheric pressure. The far-ultraviolet light is detected by silicon photomultipliers (SiPM).

The small footprint of these basic cells enables us to pack them in clusters that draw all their power and voltage from a USB bus. A given basic cell can be configured with attachments, such as high-density polyethylene (HDPE) and cadmium sheets. These respectively moderate the energies of high energy neutrons and absorb thermal neutrons. Use of diverse attachments gives us information about the phase-space distribution (energy and directionality) of neutron fields. We have also made “sterile” cells in which ^{11}B is substituted for ^{10}B, but the cells are mechanically and chemically identical. Since the ^{11}B isotope does not react with neutrons, a sterile cell can be used to discriminate effects of gamma radiation.

The sensitivity of any neutron detector is limited by the quantity of neutron-absorbing material in it. In a ^{3}He proportional counter, all helium atoms are potential reactants and they are uniformly distributed as a gas within a tube. The probability that a thermal neutron entering the tube will be absorbed, and trigger a discharge signal, is close to 1. Our ^{10}B film targets have a much higher density of neutron absorbers, packed in a condensed phase; the probability that an incident neutron is absorbed by one film and triggers a scintillation burst is around 10%. By increasing the number of compact physics packages in a neutron detector, we can approach the performance of ^{3}He, and we can extract information on the neutron distribution in phase space using with compact high-density polyethylene (HDPE) diffusers and cadmium filters.

Our goal is to bring to TRL 4 a compact, portable, low-power, low-voltage neutron detector. With appropriate engineering, this might be configured for service on a rover or fixed array on the Moon, to infer the presence of hydrogenic volatiles. This work is supported by the NASA PICASSO program.

References: [1] Hughes P. P. et al. (2010) Ap. Phys. Lett. 97, 234105. [2] McComb J. C. et al. (2014) *J. Appl. Phys.* 32*,* 144504. [3] Graybill J. R. et al. (2020) *Appl. Opt.* 59*,* 1217.

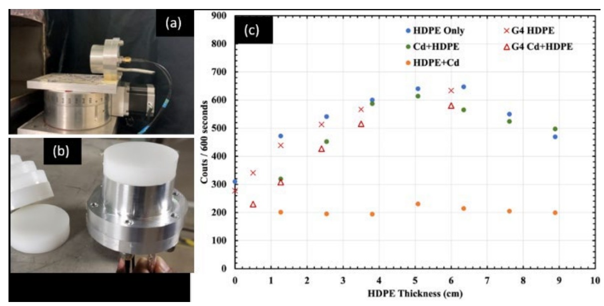

Fig. 1. (a) Prototype detection cell faces the National Institute of Standards and Technology Californium Neutron Irradiation Facility neutron beam that comes from the output port on the left. (b) The cell affixed with ½’’ thick HDPE attachment. (c) Neutron counts vs. HDPE attachment thickness for HDPE only (blue); HDPE + cadmium sheet on outer surface (green); HDPE + cadmium sheet on outer surface (orange). Circles: experiment; crosses and triangles: Geant4 simulations. Note that for bare HDPE, the signal increases at first with thickness due to thermalization of the high-energy Cf neutrons; the ^{10}B neutron absorption probability is proportional to $1/\sqrt{E}$, where E is the neutron energy.