Cross Calibration of GCR Spectrum, Orbital and In-Situ Planetary Neutron Detections by Monte Carlo Simulations – Revisiting Apollo 17 LPNE Measurement. Joseph Murray¹, Jao Jang Su¹, Roald Sagdeev¹, Gordon Chin², T. McClanahan³, T. Livengood⁴, R.D. Starr⁵, L.G. Evans⁶, (1)University of Maryland College Park, Physics, College Park, MD, (2)NASA Goddard Space Flight Center, Greenbelt, MD, United States, (3) CRESST/UMD/GSFC, Greenbelt, MD, United States, (4) Catholic Univ. of America, Washington DC, (5) Computer Sciences Corporation, Lanham MD

Introduction: Determining the quantity and vertical distribution of volatile species on and below the surface of planetary bodies is vital to understand the primordial chemical inventory and subsequent evolution of planets. The spectra of neutrons produced by interactions between galactic cosmic ray (GCR) particles and planetary surface materials yield information about regolith composition. Neutron detection has been widely used for this purpose in the past several decades. The history of nuclear physics experimental techniques as applied to lunar exploration goes back to the Apollo epoch (Apollo 17 - LPNE experiment, 1972) by Woolum et al.[1]. Orbital Lunar and Martian neutron detections such as Odyssey and LRO missions from the past 2 decades provide important time evolution information of GCR spectra correlated to solar activities.

Monte Carlo (MC) simulations have been used to investigate neutron production and leakage from the lunar surface to assess the compositions of lunar soil [2-4]. The in situ measurement of lunar neutron production made from the Apollo 17 mission was reconstructed by McKinney et al. [5] using MCNPX[6]. Spallation neutron production is strongly correlated to the GCR energetic particle spectrum. Using the differential neutron spectrum given by McKinney to calculate LRO LEND counting rates one will get a factor of 2 higher than the counting rates detected by LRO LEND instrument[7]. The most likely cause of the discrepancy comes from the GCR spectrum used in the calculations. Ota et al.[8] benchmarked PHITS[9] Monte Carlo simulations and McKinney MCNPX results with LPNE measurement. Ota’s results showed a good agreement with LPNE neutron density profile by counting neutrons of energy only below 500eV. It is important to cross calibrate GCR spectra for a precise calculation of neutron production in the lunar surface. We revisit Apollo 17 epoch using Geant4 Monte Carlo simulation code[10], GCR spectra from CREME model and the same analytical function  

\[ P(E, \phi) = \frac{A(E,E+2E_0)(E+m\phi)}{(E+2E_0+m\phi)} \]

in McKinney and Ota’s works for proton and alpha particles. We evaluate neutron production, transport, leakage neutron spectra and angular distributions to cross calibrate GCR spectrum, spallation neutron production and transport with LNPE type measurements and orbital detections.