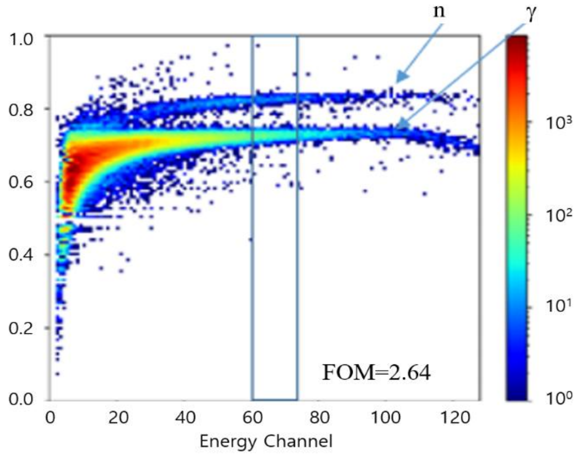
Development the Neutron Spectrometer on the Moon using Scintillators

Sunghwan Kim[1], Uk-Won Nam[2], Sukwon Youn[3], Hongjoo Kim[4], Hwanbae Park[4], Won-Kee Park[2], Jongdae Sohn[2], Chae Kyung Sim[2], Young-Jun Choi[2], Insoo Jun[5], Sung-Joon Ye[3]

[1]*Cheongju University, Cheongju, Korea*
[2]*Korea Astronomy and Space Science Institute, Deajeon, Korea*
[3]*Seoul National University, Seoul, Korea*
[4]*Kyungpook National University, Daegu, Korea*
[5]*California Institute of Technology, Pasadena, USA*
Corresponding Author Email: kimsh@cju.ac.kr

There are various types of radiation on the lunar surface, including protons and other charged particles originating from the Sun and the Galaxy, as well as albedo neutrons and gamma rays produced by the interaction of these particles with the lunar crust [1]. These cosmic rays provide valuable scientific insight into solar activity and the space environment, motivating extensive research efforts [2]. However, such radiation environments can cause radiation exposure to crew members and payloads during lunar exploration missions, potentially degrading mission safety and performance.



2D SPD plot of CLYC-6 for ^{252}Cf

In this study, scientific payloads were developed to measure the neutron energy spectrum on the lunar surface and to investigate evidence of water existence within the lunar crust. A fast neutron energy spectrometer was designed and fabricated using a stilbene scintillator, enabling the separation of gamma-ray and neutron energy spectra through the pulse shape discrimination (PSD) method. Since stilbene is an organic scintillator with tissue-equivalent properties, it can also be applied to the assessment of neutron dose to crew members during space missions. In addition, two ^{6}Li-enriched CLYC-6 scintillators with high sensitivity to thermal neutrons were employed as detectors for water exploration within the lunar crust [3]. The structures of the fast neutron energy spectrometer and the scintillation detectors for water exploration were optimized by simulating the lunar surface radiation environment using Monte Carlo methods. Furthermore, their applicability as lunar surface neutron spectrometers were evaluated through calibration experiments using high-energy and thermal neutrons.

1. M. Naito, H. Kusano, S. Kodaira, "Global dose distributions of neutrons and gamma-rays on the Moon", *Sci. Rep.*, **13**, 13275 (2023).
2. F. Rahmanifard, W.C. de Wet, N.A. Schwadron, M.J. Owens, A.P. Jordan, J.K. Wilson, C.J. Joyce, H.E. Spence, C.W. Smith, L.W. Townsend, "Galactic Cosmic Radiation in the Interplanetary Space Through a Modern Secular Minimum", *Space Weather*, **18(9)**, 1 (2020).
3. A. Giaz, L. Pellegri, F. Camera, et. al., "The CLYC-6 and CLYC-7 response to γ-rays, fast and thermal neutrons", *Nucl. Instr. Meth. in Phys. Res. Sec. A*, **810(21)**, 132 (2016).

Acknowledgments
This work was supported by the National Research Foundation of Korea (NRF) Grant funded by Korean Government under Grant NRF-2020M1A3B7040417, Grant NRF-2020M1A3B7108845 (MIST), and Grant NRF-2022R1A6A1A03063039 (MOE).