MEASURING THE COSMIC RAY SPECTRUM USING NEUTRON MONITORS. P. A. Evenson, Department of Physics & Astronomy and Bartol Research Institute, University of Delaware, 217 Sharp Laboratory, Newark, DE 19716. (evenson@udel.edu)

**Introduction:** Variations in the spectrum of Cosmic Ray (CR) particles above 100 MeV are nearly all due to the so called "Solar Modulation" of the constant flux of Galactic Cosmic Rays (GCR) that surrounds the heliosphere in the local interstellar medium. The essential interaction is with magnetic structures embedded in the expanding solar wind. Quasi periodic variations result from the 11 year activity (sunspot) cycle, the 22 year magnetic reversal cycle, and the 27 day cycle of encounters with the heliospheric current sheet. Aperiodic variations result from local disturbances in the solar wind, often the result of Coronal Mass Ejections (CME) The most common manifestation is a sudden reduction in intensity, generically termed a "Forbush Decrease". Both variations in the spectral shape and the energy dependent anisotropy of the GCR are diagnostic of these magnetic structures. Since CR of relevant energies are rare, large detectors are required to get statistical precision on appropriate timescales.

Historically, only ground based detectors have been large enough. Recently PAMELA and AMS have been able to make such measurements directly from space. Presumably at some point in the not too distant future, ground based observations will again be the only option. It is important to use this period of simultaneous observation to understand ground based measurement better and to develop new techniques for the future and to secure the continued operation of the detectors.

**Neutron Monitors:** Since their invention by John Simpson in the 1950's [1] the worldwide array of neutron monitors has been the predominant tool in the study of cosmic ray spectral variations. Physical characteristics of the detector and its environment determine the energy response while the anisotropy is measured with similar detectors located at different parts of the globe. Very few results come from an individual monitor – the network is essential. For decades the international community of monitor operators has been a model of unselfish scientific collaboration.

Neutron monitors function by detecting particles, primarily but not exclusively neutrons, in the cascades produced by the interaction of the CR near the top of the atmosphere [2]. An individual monitor has roughly the same collecting power as AMS but the response is integral, not differential.

**Energy Spectrum:** Various techniques are used to derive cosmic ray spectrum variations using neutron monitors. The oldest and most commonly applied technique relies on the geomagnetic cutoff. At any location on earth the magnetic field prevents cosmic rays below a specific cutoff rigidity from reaching the atmosphere. Cutoffs range from near zero to 18 GV. The difference in counting rates between two monitors is proportional to the integral of the cosmic ray spectrum between the two rigidities. Fixed monitors are typically used, but they generally do not have identical inherent response and nearly always have secular variations in the cutoff as the magnetic field changes. Latitude surveys carry a monitor through different cutoffs on a ship to provide a constant environment and give more precise results for subtleties in the spectrum but they are difficult to arrange.

Other methods use the memory of the energy of the primary particle retained in the structure of the cascade, even down to sea level. Monitors located close together but at different altitudes have counting rate differences related to the spectrum. Differences in the internal structure of monitors, typically the ratio of lead to polyethylene, at the same location are similarly used.

A different class of techniques examines interactions in the monitor. Low energy environmental neutrons are excluded by a polyethylene enclosure. Incident neutrons over approximately 100 MeV penetrate this shield and interact with lead to generate 1-2 MeV neutrons which are captured in the detector. The number of these neutrons and the time structure of their detection are very sensitive to the energy of the incoming neutron. Neutrons also diffuse and are detected by adjacent detectors. Collection times range from microseconds to ten milliseconds, so identifying and characterizing these interactions requires development of specialized electronics.

**Conclusions:** Ensuring continuity in tracking variations in the cosmic ray spectrum requires maintaining the neutron monitor network, improving it with hardware employing the latest techniques and adding stations in geographically strategic locations.

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**References:** [1] Simpson, J. A., W. Fonger, , & S. B. Treiman, 1953, Cosmic Radiation Intensity-Time Variations and Their Origin, PhRv, 90, 934. [2] Hatton C, & H. Carmichael 1964. Experimental Investigation of the NM-64 Neutron Monitor. Can J Phys 42: 2443–2472.