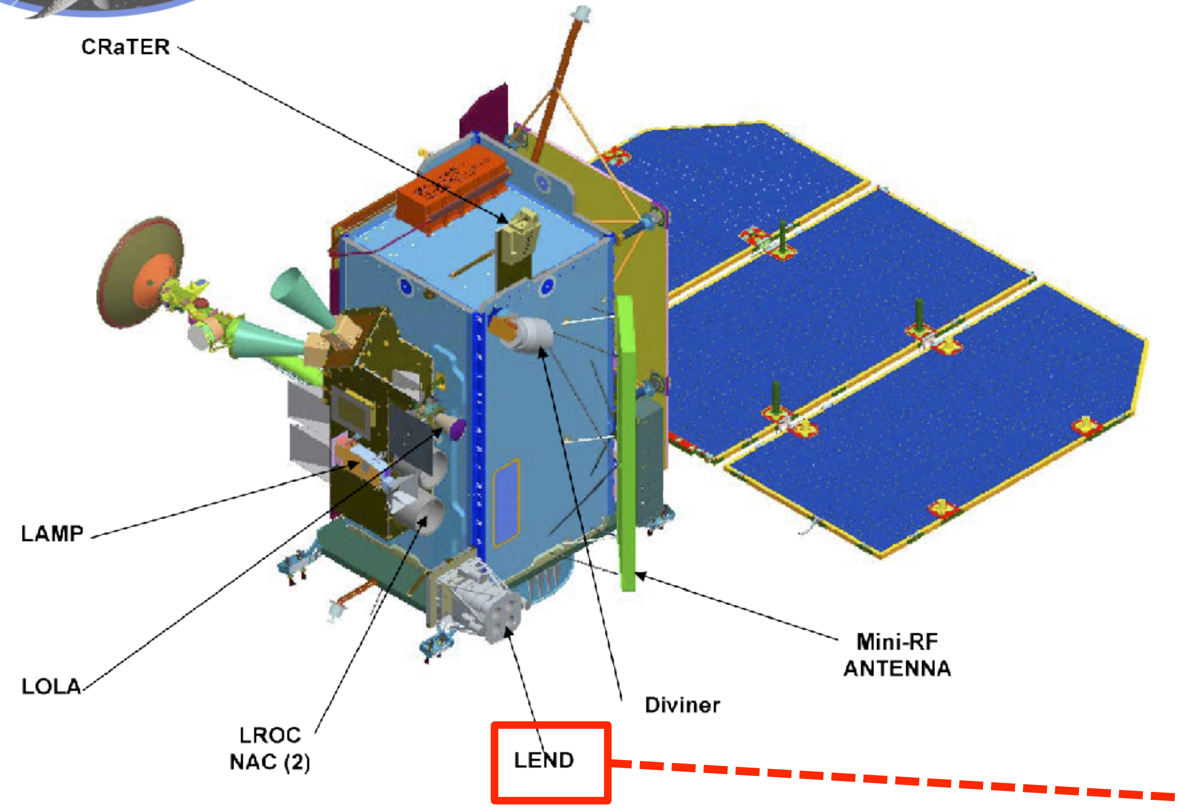
NEUTRON RADIATION ENVIRONMENT AROUND THE MOON FROM LUNAR EXPLORATION NEUTRON DETECTOR ONBOARD LRO

M.L Litvak[1] , I.G. Mitrofanov[1] , A.B. Sanin[1], V.I. Tretyakov[1], A.S. Kozyrev[1], A.V. Malakhov[1], M.I. Mokrousov[1], A.A Vostrukhin[1], D. V. Golovin[1], A.B. Varenikov[1], V. N. Shvecov[2], W.V. Boynton.[3], K Harshman[3], R.Z. Sagdeev[4], G. Milikh[4], G. Chin[5], J. Trombka[5], T. Mcclanahan[5], R. Starr[6], L. Evans[7], V. Shevchenko[8],

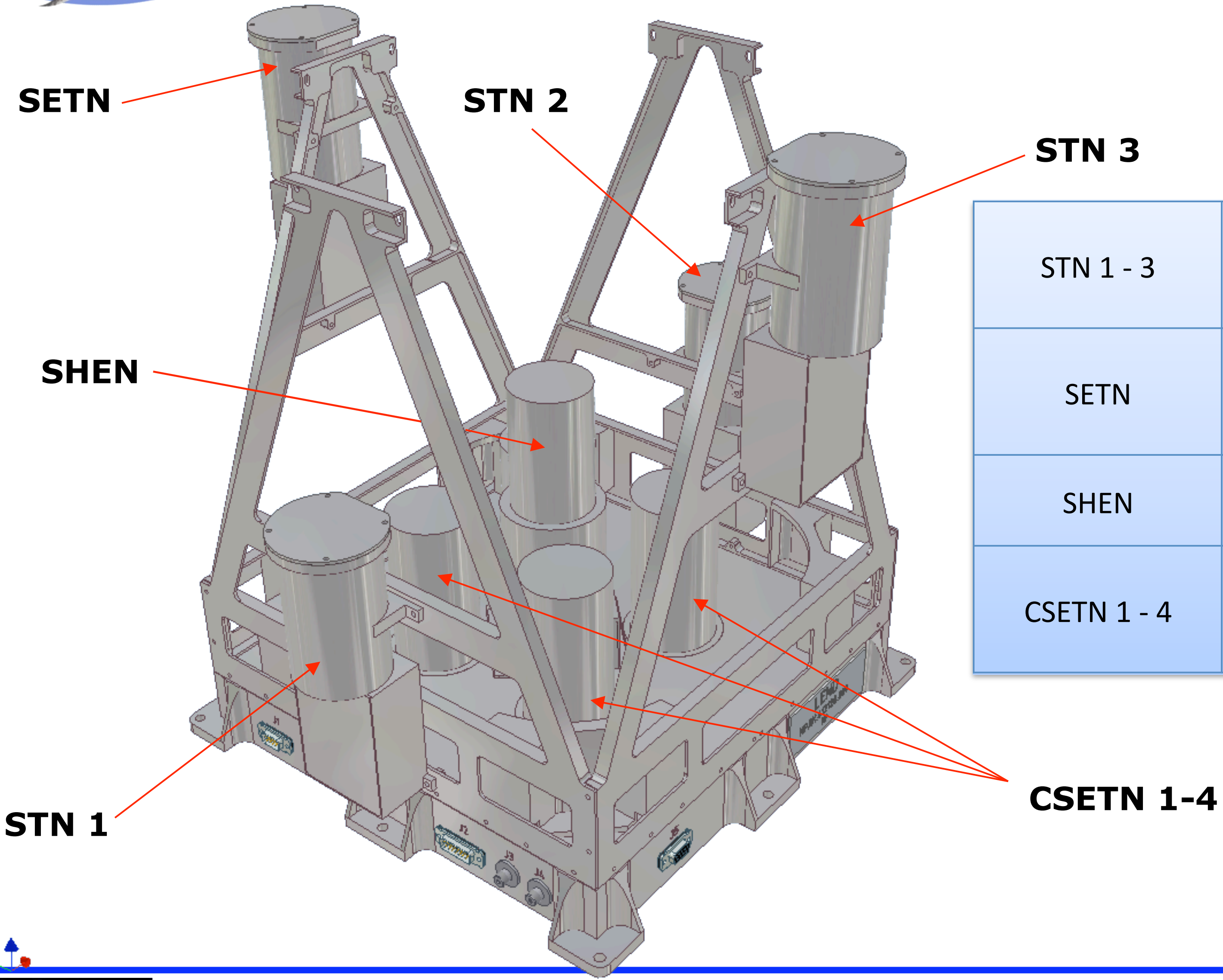
[1]Space Research Institute, RAS, Moscow, 117997, Russia, litvak@mx.iki.rssi.ru , [2]Joint Institute for Nuclear Research, Dubna, Russia, [3]University of Arizona, Tucson, AZ, USA, [4]University of Maryland, College Park, MD, USA, [5]Goddard Space Flight Center, Greenbelt, MD, USA., [6]Catholic University, Washington, DC, USA, [7]Computer Sciences Corporation, Glenn Dale, MD, USA. [8]Sternberg Astronomical Institute of Moscow State University, Moscow, Russia.

Annual Meeting of the Lunar Exploration Analysis Group
November, 16-19, 2009, Houston, Texas

LRO Instruments



LEND Instrument Overview

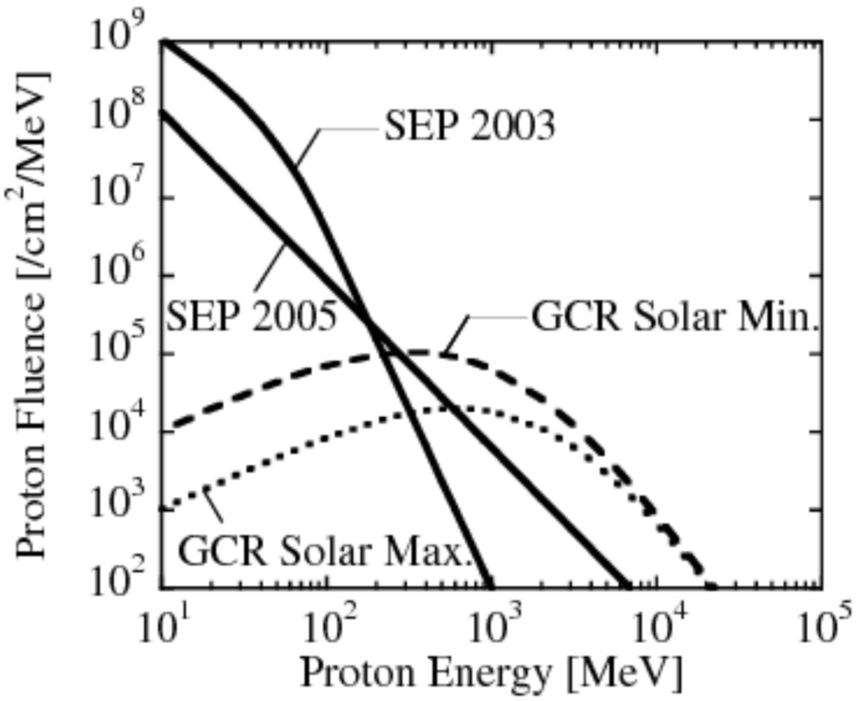


STN 1 - 3	Omnidirectional detectors for thermal neutrons
SETN	Omnidirectional detector for epithermal neutrons
SHEN	Collimated detector for high energy neutrons
CSETN 1 - 4	Collimated detectors for epithermal neutrons

LEND Instrument Overview

LRO Mission Requirement	Instrument Requirement	LEND: Required Data Products
The LRO shall obtain high spatial resolution hydrogen mapping of the Moon's surface to a 20% accuracy and 5 km resolution at the poles.	LEND IMR 1: *Hydrogen mapping*	***Surface Composition Data Product (I):*** The content of Hydrogen in subsurface at polar regions with spatial resolution from 5 km (Half-Width at Half-Maximum) and with variation sensitivity from 100 parts per million (ppm)
The LRO shall identify putative deposits of appreciable surface or near surface water ice in the Moon's polar cold traps at 100m scale spatial resolution	LEND IMR 2: *Testing for water ice*	***Surface Composition Data Product (II):*** The water ice column density on polar regions of the Moon with spatial resolution from 5-20km.
The LRO shall characterize the deep space radiation environment in lunar orbit, including neutron albedo.	LEND IMR 3: *Radiation environment*	***Radiation Data Product (III):*** Global distribution of neutrons at Moon's orbit with spatial resolution of 50 km at different energy ranges from thermal energy up to >15 MeV separately for periods of quiet Sun and for periods of Solar Particle Events.

Estimation of Moon Radiation Dose



Estimation of Moon radiation doze shall be considered for two major cases: Quiet Sun and Solar Particle events

Quiet Sun:

$$H_{total}\ [Zv/Day] = H_{GCR}+H_{neutron}+H_{gamma}$$

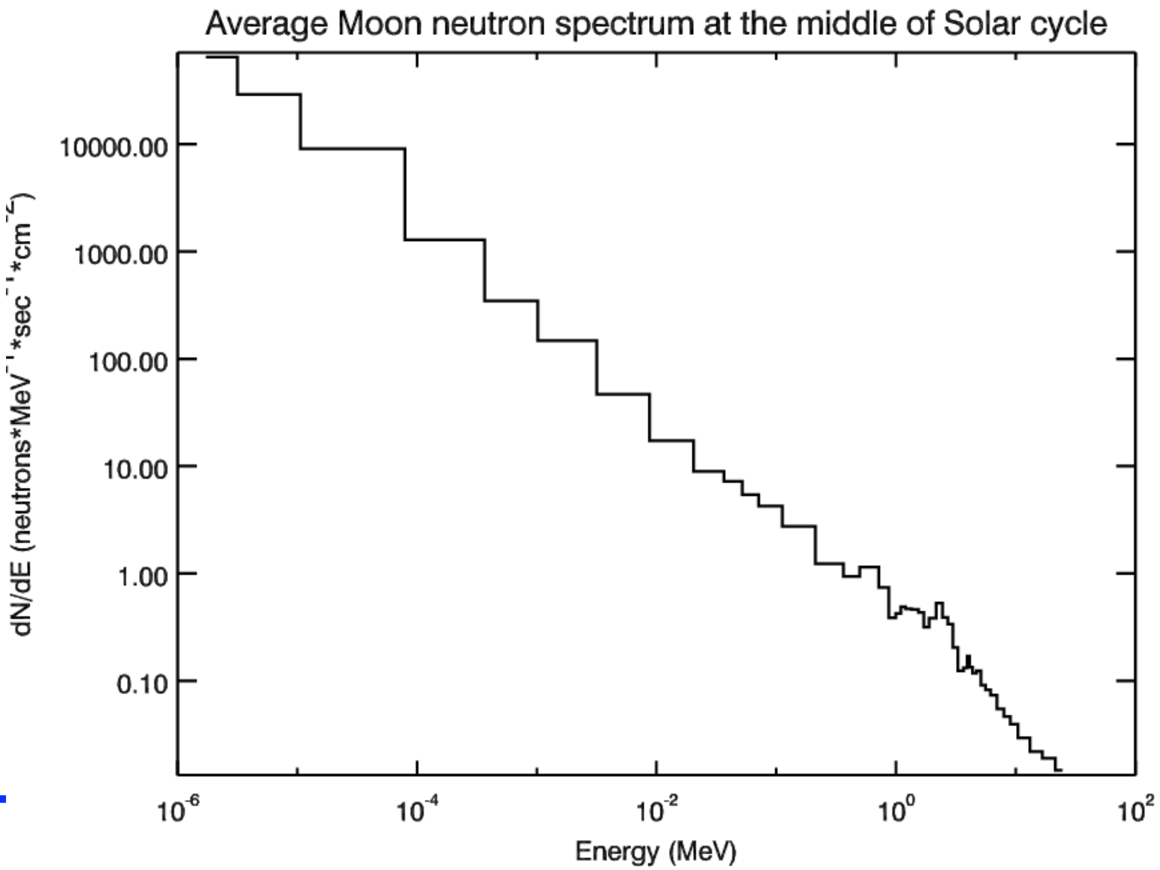
Where neutron and gamma are secondary radiation produced by Galactic cosmic Rays in Lunar subsurface. Major contribution is provided by protons and ions of GCR (~90%), minor contribution is provided by neutrons (~10%), gamma radiation contribute less than 0.5% of total dose

Solar Particle Event:

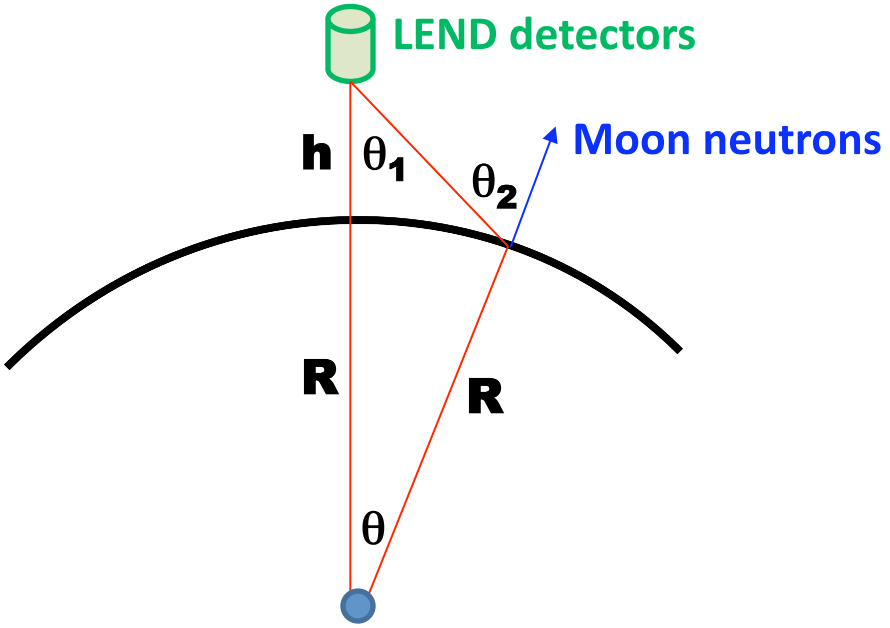
In worst case for strong Solar Particle Event the total dose per day may be 1000 times more than dose contributed by GCR.

Deconvolution of Lunar neutron leakage spectrum

We used numerical simulation (MCNPX) to derive the shape of lunar leakage neutron spectrum $dN_{model}/[dEdtdS]$ and angular distribution of neutrons produced in the subsurface. It has been calculated for average Moon composition and average Galactic Cosmic Rays spectrum (middle of Solar cycle). We used it as $A*dN_{model}/[dEdtdS]$, where A is unknown amplitude which is varied as a free parameter and may be defined from comparison between model counting rates and measured counting rates



Deconvolution of Lunar neutron leakage spectrum

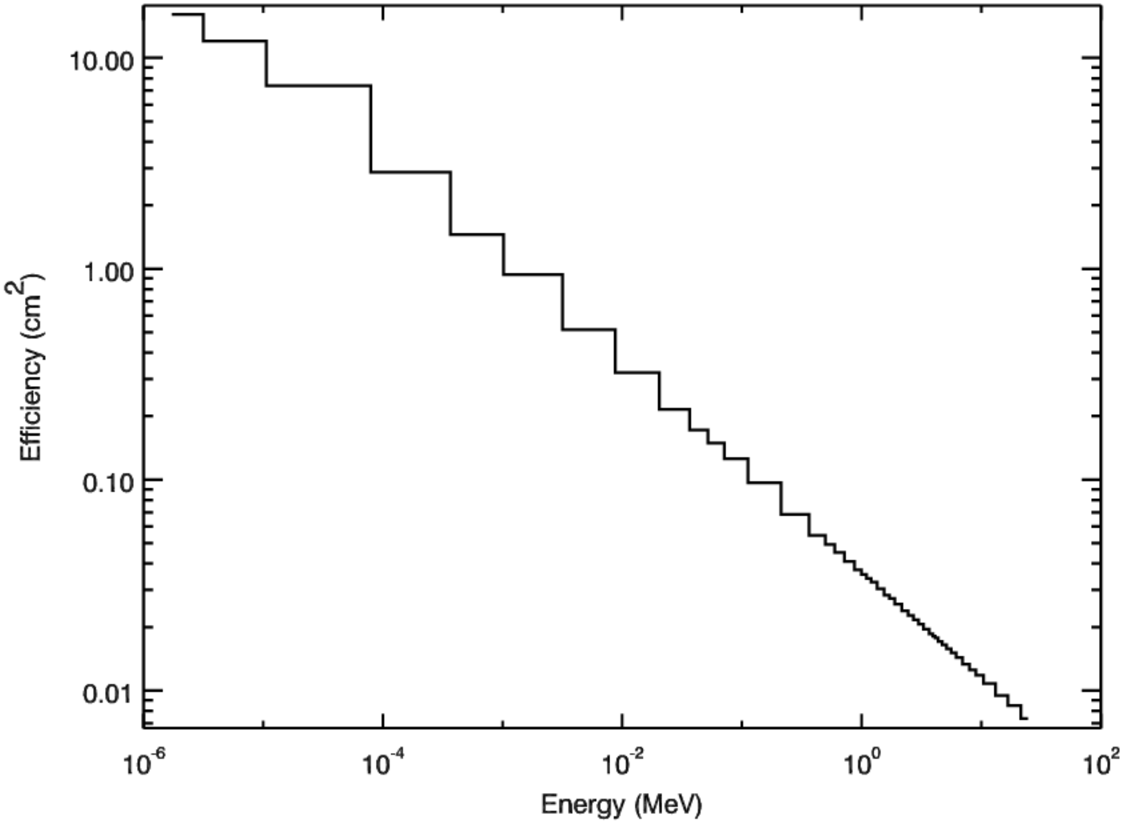


$$\frac{dC}{dt} = \int_{0.4eV}^{20MeV}\int_{0}^{S_{moon}} \frac{dN}{d\Omega_2\, dE\, dS\, dt}(E,\theta_2)\, d\Omega_2\, dE\, dS$$

Where dC/dt – counting rate (counts per second) detected by LEND neutron sensors

Deconvolution of Lunar neutron leakage spectrum

We started preliminary data deconvolution of lunar neutron leakage spectrum from estimation of counting rate in LEND omnidirectional epithermal detector SETN. Its efficiency (S_{eff}) function recovered from physical calibrations and presented below:



Estimation of Moon Radiation Dose

In our study we concentrated on the neutron dose $H_{neutron}$ for period of quiet Sun at the stage of solar minimum (beginning of LRO observations). In this case neutron doze is maximal. Neutron dose may be estimated as a convolution of Neutron leakage spectrum and conversion coefficients from fluence to effective radiation dose:

$$H_{neutrons}[Zv/Day] = \int \frac{dN}{dEdSdt} \times C_n(E)dE$$

Estimations based on deconvolved neutron leakage spectra measured by LEND showed that $H_{neutrons}$ is equal

0.12 mZv per day

Conversion coefficient from neutron fluence to effective radiation dose