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ANALYSIS OF THE CYCLOTRON FACILITY CALIBRATION AND AIRCRAFT RESULTS OBTAINED BY LIULIN-3M INSTRUMENT

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ABSTRACT

The LIULIN-3M instrument is a further development of the LIULIN dosimeter-radiometer, which has been used on the MIR space station in the 1988-1994 time period. The LIULIN-3M is designed for continuous monitoring of the radiation environment during the BION-12 satellite flight in 1999. A semiconductor detector with 1 mm thickness and 1 cm^2 area is used in the instrument. Pulse high analysis technique is used for measurement of the energy losses in the detector. The final data sets from the instrument are the flux and the dose rate for the exposition time and 256 channels of LET spectra if a normal coincidence of the particles to the detector is considered. The LIULIN-3M instrument was calibrated by proton fluxes with different energies at the Indiana University Cyclotron Facility in June 1997 and was used for space radiation measurements during commercial aircraft flights. Obtained calibration and flight results are analyzed in the paper.

INTRODUCTION

The LIULIN-3M instrument is a further development of the LIULIN dosimeter-radiometer (Dachev *et al.)*, which has been used on the MIR space station in the 1988-1994-time period. First the instrument was designed as a handy spectrometer-dosimeter for continuous monitoring of the radiation environment during the BION-11/12 missions. Later on it was recognized that the instrument could be redeveloped into a practical and low cost detector for use in characterizing the radiation environments encountered by airplanes and balloons. Further redevelopment of the LIULIN-3M instrument is named LIULIN-4 and will be used at the Russian segment of the International Space Station.

INSTRUMENT DESCRIPTION

The Liulin-3M instrument is a miniature, portable dosimeter - a radiometer which contains: one semiconductor detector, which is situated before a 5 mm tungsten shield; one charge-sensitive preamplifier; an 8-bits ADC; 2 microcontrolers (PIC16C74); a flash memory (1 Mbytes) and Lithium batteries. Pulse high analysis technique is used for measurement of the deposited energies (doses) in the detector. The unit is managed by 2 microcontrolers through specially developed firmware. Block schema of the Liulin-3M dosimeter-radiometer is presented in Figure 1.

Function of LIULIN-3M instrument. The basic detector of the instrument is a Russian produced Silicon-Lithium Drifted diode, 1 mm thick, with a sensitive area of 1 cm^2, and a weight of 0.233 g. Charge pulses generated in the detector from the energy deposited by incident particles are passed to the charge sensitive preamplifier, then to the discriminator and first microcontroler, which serves as a peak hold detector.

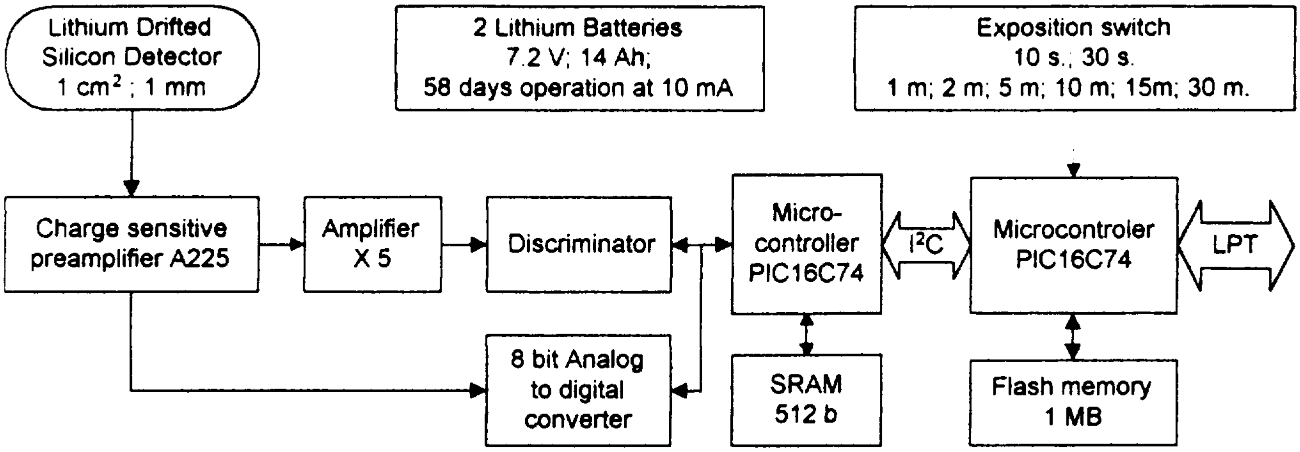


Figure 1 Block schema of LIULIN-3M instrument

Finally they are converted from analog to digital signals by the 8-bit ADC and sorted into 256 channels, according to their voltage amplitudes.

After finishing the first measurement cycle the accumulated spectra are stored in the flash memory. Each next measurement results are stored in a different place of the memory, which later is used for recalculating of the time of the measurement. The capacity of the memory is 1 MB or about 2000 spectra.

The following method for calculations of the dose is used: The dose D [Gy] by definition is one Joule deposited in 1kg or:

$$D = K.\mathrm{Sum}(EL_I * i)_{30\ sec}/MD,$$

where MD is the mass of the detector in [kg] and EL_i is the energy loss in Joules in channel i. Energy loss in channel i is proportional to the number of events A_i in it multiplied by i. K is a coefficient.

Operational modes. The instrument operates in 2 modes - Working mode and Mode of Transferring the data from the flash memory to PC. In the Working mode the instrument is operating under the software in the microcontrolers. The operational time of the instrument depends on the lifetime of the batteries and on the rate at which the memory fills up. In a case of continuous operation the lifetime is about 1000 hours with the standard 8 Ah Lithium batteries. The working mode is switched OFF automatically when either the memory is totally filled up or the supply voltage is falling below 7.2 V. In the mode of Transferring data the instrument is switched on automatically when it is connected to the LPT port of a standard PC. During this mode the correlation of the data with real time and the calculation of the physical values is performed.

CALIBRATIONS OF THE INSTRUMENT

Calibrations by the natural background radiation. The instrument sensitivity allows measurements of the natural background radiation on the surface of the earth, which for the most of places varies in the interval 0.15 - 0.25 μGy/hour. For example see the doses measured at the ground and presented on Figure 5.

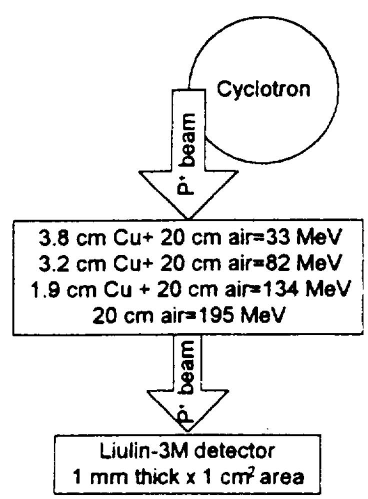


Figure 2 Sketch of the LIULIN-3M calibrations at the Indiana University cyclotron facility

Calibrations on the Indiana University Cyclotron Facility. The LIULIN-3M was calibrated by proton fluxes with different energies at the Indiana University Cyclotron Facility in June 1997. On Figure 2 the experiment design is presented. It is seen that the desired energies of the protons are reached from the basic energy of 200 MeV by shielding of the proton beam with Cuprous targets with 3.8, 3.2 and 1.9 cm thickness. The highest energy of 195 MeV is obtained only by 20 cm of air shielding.

The lower panel of Figure 3 is presenting four of the LET spectra obtained during the calibrations by proton fluxes normal to the front side of the detector. The energy of protons was 33, 82, 134 and 195 MeV respectively. On the X axes of the panel is plotted the deposited energy in MeV which in case of the1 mm detector is equal to keV/μ. It is seen that all spectra have one maximum which lies close to the table predicted energy loss presented with a vertical dashed line. Their values are 0.87, 1.1, 1.55, and 3.2 MeV/mm or keV/μ for protons with energies 195, 134, 82 and 33 MeV respectively. The upper panel of Figure 4 presents similar results for the case when the proton flux was normal to the back side of the detector. Only two real "LET" spectra of 195 and 134 MeV protons are existing on the panel. The other two lower energy spectra of protons have been shielded by the instrument electronics and the 5 mm tungsten shield behind the detector. The existing two spectra are shifted toward the higher energy deposition because of the decrease of the primary energy of the protons in the shielding.

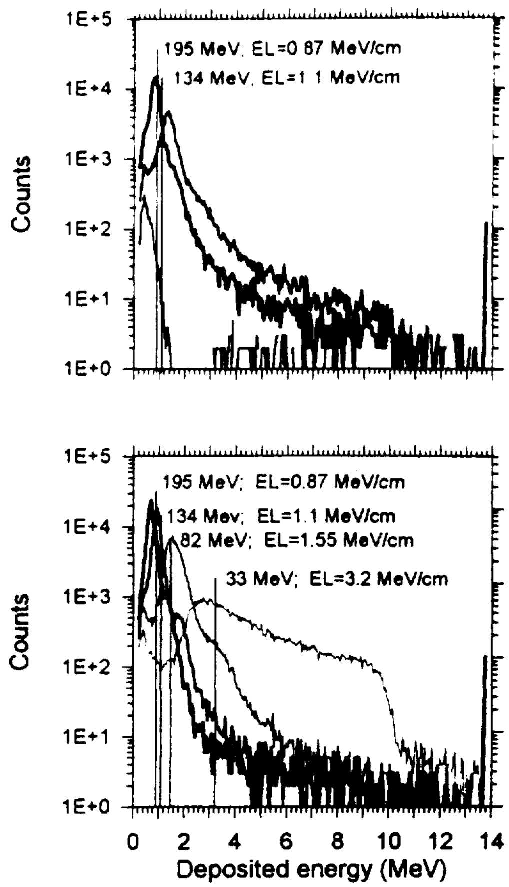
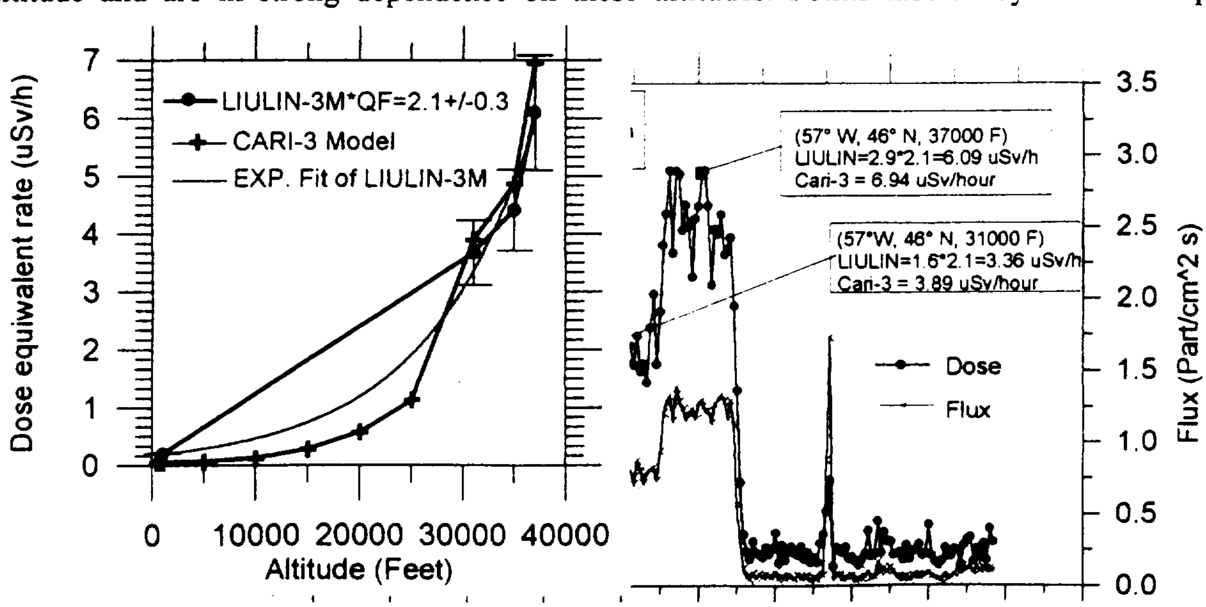


Figure 3 "LET" spectra obtained at the Indiana University cyclotron facility with LIULIN-3M instrument.

Measurements during airplane flight. The Liulin-3M instrument was used for measurement of the airplane dose rates and fluxes during a commercial flight from Sofia to New York on June 16, 1997. On Figure 4 are presented the dose rates and fluxes obtained during this flight. There are 4 "steps" on the curves which correspond to the dose rates at 4 different altitudes. The lower level is obtained at about 600 - 1500 feet altitude and the measured dose rates are close to the natural background radiation. The other 3 are obtained at 31000, 35000 and 37000 feet altitude and are in strong dependence on these altitudes. Points labeled by ■ are compared by the



predictions of the CARI-3 (O'Brien et al., 1996) model and relatively good ratios with the measured data are obtained. The two thin spikes at about 1 and 13 hours after "Switch on" are generated during the airport security X-rays check of the luggage in which the instrument was situated. On Figure 5 are presented 4 spectra obtained at different conditions during the flight between Sofia and Washington DC. Two of them show again the spectra obtained during the airport security X-rays check. Those spectra together with the spectrum obtained at the Sofia airport are the softest, as expected. The "hardest" spectrum is that obtained at 37000 feet altitude, where about 35% of the dose is generated by protons (O'Brien et al., 1995).

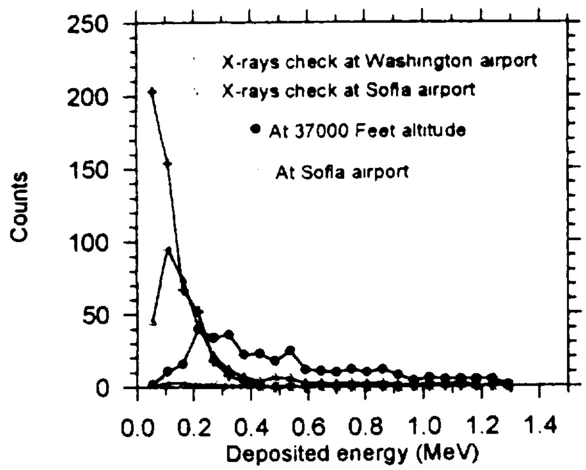


Figure 5 "LET" spectra obtained by LIULIN-3M instrument

On Figure 6 are presented together the measured by LIULIN-3M doses multiplied by a quality factor equal of 2.1±0.3 Spurny, (1996) (by dots) at 4 different altitudes and the predicted by CARI-3 model (by crosses). An exponential fit of the LIULIN-3M data is presented as well. The formula of it is:

Dose[uSv/h]=exp(9.296E-5)*Altitude[feet])*0.1809

More airplane results obtained at different routes are presented by Stassinopoulos et al. (1998).

ACKNOWLEDGEMENTS

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REFERENCES

O'Brien, K. et al., Atmospheric cosmic rays and solar energetic particles at aircraft altitudes, Review article presented at "Natural Radiation Environment VI - NRE VI, Montreal, June 1995.

O'Brien, K. et al., Cari-3 model was kindly provided by Dr. Karen O'Brien, Department of Physics and Astronomy, Northern Arizona University, Flagstaff, Arizona 86011, USA, 1996.

Dachev, Ts.P., Yu.N. Matviichuk, J.V. Semkova, R.T. Koleva, B. Boichev, P. Baynov, N.A. Kanchev, P. Lakov, Ya.J. Ivanov, B.T. Tomov, V.M. Petrov, V.I. Redko, V.I. Kojarinov, R. Tykva, Space radiation dosimetry with active detection for the scientific program of the second Bulgarian cosmonaut on board the MIR space station, Adv. Space Res., 9, 10, 247 (1989).

Spurny, F., How large is the exposure in Aircraft and Space Vehicles?, 9th Intern. Congress of IRPA, Vienna, 1996.

Stassinopoulos et al., The LIULIN-3M radiometer for measuring particle doses in space and on aircraft, to be submitted for publication to the IEEE Trans. Nucl. Sci., 1998