Dosimetry And LET Spectrometry In He 150mev/N MONO And C 290mev/N SOBP HIMAC Ion Beams – First Results Obtained By Different Detectors

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A new run of experiments at HIMAC has been realized in the beginning of 2009; He 150MeV/amu MONO and C 290MeV/amu SOBP ion beams were used. The experiment was performed in the frame of NPI project 20P241 agreed by HIMAC PAC with the goal to built a LET spectra database for HIMAC-BIO ion beams.

We exposed:

- The sets of track etched detectors (TED), together with two types of thermoluminescent detectors (TLD), in several depths in the beams
- MDU-Liulin spectrometer of the energy deposited in Si and HAWK-type tissue equivalent proportional counter in selected depths;

The contribution will present and discuss first results obtained, mainly:

- Direct readings of TLDs along the depth, including the estimation of their relative responses (RR);
- Spectra of LET as measured with TED, again along the depth, up to the region behind the Bragg peak; with the attention to the difference of primary and secondary particle track distributions;
- Spectra of the energy deposition in Liulin in the area corresponding to LET below about 10 keV/µm for He beam, in full other LET area and both beams as well;

The first attempt to compare TED based LET spectra with information deduced from MDU energy deposition spectrometer.

Preliminary Results Of SI3 And ICCH-CR-39 Experiments Obtained By PADC Track Etch Detectors.

B. Dudás, J.K. Pálfalvi, J. Szabó

The Radiation and Environmental Physics Department of the Atomic Energy Research Institute (Hungarian Academy of Sciences) participated in the Space-Intercomparison-3 and Icchiban CR-39 experiments with 13 PADC (polyallyl-diglycol-carbonate) nuclear track detector stacks. 7 stacks were placed in Box of ICCH-CR-39 and 6 in Box of SI3.

After their arrival, the detectors were etched in 6 n NaOH at 70 ˚C for 6 hours. This is the first etching step applied in our standard method used for the evaluation of space detectors, which results in an 8 µm thick surface removal. Semi-automatic measurements were carried out by the VIRGINIA image analyzer system on each side of each detector sheet. Beside these investigations, manual HZE track analysis was also performed. From the track parameter measurements the LET spectra were deduced. Based on these spectra the absorbed dose, the dose equivalent and the mean quality factor were calculated.

The configuration of the stacks, the preliminary results as LET spectra and dose values obtained based on these measurements will be presented.

DOSIS (HIMAC Intercomparison) And NSRL Solar Particle Event (Low LET Efficiency TL - Efficiency)

Thomas Berger for the DOSIS and the NSRL team
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The first part of the talk will focus on the DOSIS experiment and the associated ground based intercalibrations. The DOSIS experiment (Dose Distribution Inside the ISS) was launched with STS-127 to the ISS in July 2009. It consist of a combination of passive detector packages (PDP) distributed at 11 locations inside the European Columbus Laboratory and two active radiation detectors (DOSTEL´s) with a DDPU (DOSTEL Data and Power Unit) mounted at a fixed location beneath the European Physiology Module (EPM) inside Columbus. The PDP of DOSIS are built up as a combination of thermoluminescence and nuclear track etch detectors provided by various space agencies, universities and research organizations for absorbed dose, LET spectra and dose equivalent determination. For a pre- space exposure intercalibration the TLD/OSL detectors were exposed at HIMAC, NIRS, Japan to Helium (2.2 keV/µm) and Iron (201 keV/µm) ions for TL-OSL-efficiency intercomparison. The first preliminary results of this intercomparison will be presented.

The second part of the talk will give first results from the exposure of a phantom torso at the NSRL facility in Brookhaven in June 2009 to the simulated Solar Particle Event (SPE) of 1972. Beside the integral SPE spectra passive thermoluminescence detectors were also exposed to monoenergetic protons with energies of 50, 250 and 450 MeV in an LET range from 1.2 to 0.3 keV/µm. First preliminary results for the TL- efficiency in this low LET region – which is of special importance for space radiation dosimetry – will be presented and discussed.

Structuring of Database for ICCHIBAN Experiments and Brief Reports of the Ongoing Experiments

H. Kitamura, Y. Uchihori, N. Yasuda, S. Kodaira, I. Jadrnickova, E. Benton, M. Hajek, T. Berger on behalf of ICCHIBAN Working Group and Participants

Since the 1st ICCHIBAN experiment was performed in 2002, we exposed the radiation monitors developed by the ICCHIBAN participants to various types of radiations. Total number of the past exposures is over 2000. The ICCHIBAN Working Group is summarizing many exposure data as a database which can be accessible on the ICCHIBAN web site: http://www.nirs.go.jp/ENG/rd/1ban/ . It will be able to compare measured dose in different conditions, for example, exposed beams and dosimeter types. We present the status of development of the database and discuss about what information we should summarize. Additionally, we briefly report the ongoing CR-39 ICCHIBAN experiments to resolve the discrepancies in dose and dose equivalent measurements made using CR-39 PNTD in space.

Radiation Measurements for DOBIES (Dosimetry of Biological Experiments in Space)

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The objective of DOBIES is to investigate the response of biological samples to space environment. Radiation measurement is an important part of the project. It is known that the biological impact of radiation is dominated by high LET radiation. CR-39 detectors were used for DOBIES to measure radiation LET spectra (differential and integral particle fluence, absorbed dose and dose equivalent) for high LET radiation.

DOBIES experiments were conducted from 12 – 24 October 2008 with an exposure time of ~11.7 days in the Russian Zvezda service module on the ISS (International Space Station). After exposure the detectors were recovered and chemically etched by the JSC-SRAG (Space Radiation Analysis Group). Data scan and analysis were conducted in DIAS (Dublin Institute for Advanced Studies) and JSC-SRAG. The results measured with the DIAS-SRAG CR-39 PNTDs and presented here, indicate good agreement with those measured by the NASA-JSC TEPC (Tissue Equivalent Proportional Counter) and passive dosimeters for the same period and similar shielding.

Radiation Measurements With Passive Detectors During Recent Shuttle Flights

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Ensuring the ALARA principle is applied to radiation monitoring for astronauts in the Low Earth Orbit work environment is of significant importance. The National Council on Radiation Protection and Measurements recommends a combination of different passive detectors to be used as personal dosimeters since there are no available active personal dosimeters yet. The combination of the results measured with the passive detectors covers the entire Linear Energy Transfer (LET) spectrum of the complex space radiation field while thermoluminescence (TL) and optical stimulated luminescence (OSL) detectors measure the region of low LET (< 10 keV/μm water) and plastic nuclear track detectors (CR-39) measure particles with high LET (≥ 10 keV/μm water).

This method has been implemented in radiation measurements at the Johnson Space Center for crew personal dosimeters and for area monitoring on the Space Shuttle and the International Space Station for several years.

The results of the thermoluminescence measurements for the Shuttle flight STS-119 as well as the results of CR-39 measurements for the Shuttle flight STS-126 will be presented.

Summary of 2008-2009 SRAG's Radiation Measurements in Low-Earth Orbit Using Passive Radiation Detectors

GAZA, R., ZHOU, D., ROED, Y., SEMONES, E., ZAPP, N.

For any space exploration endeavour (i.e., trips to low-Earth orbit, Moon or Mars) measuring the crew exposure to space radiation is of great importance for crew protection, developing risk reduction strategies and future crew flight planning. Passive radiation detectors are currently used operationally by the Space Radiation Analysis Group at NASA/JSC for crew and environmental monitoring of the space radiation in low-Earth orbit (LEO). The passive radiation detector package consists of optically stimulated luminescence (OSL) detectors (i.e., Al_2O_3:C), thermoluminescence (TL) detectors (i.e., LiF:Mg,Ti and CaF_2:Tm) and plastic nuclear track detectors (i.e., CR-39) and they are distributed at 25 different shielding configurations inside the International Space Station (ISS) and 6 location inside the Space Shuttle. In addition, each crew members will carry a crew passive dosimeter for the whole duration of the flight, for each mission.

In this talk, a summary of the SRAG's 2008-2009 ISS and Shuttle radiation results for environmental monitoring in LEO will be presented, with emphasis on the most recent measurements: ISS expedition 16-17/1J-A, STS-119 and STS-125. The ISS expedition 16-17/1J/A analysis will bring new results for the two recently installed ISS modules: Node 2 and ESA's Columbus module. STS-125 it is also an interesting shuttle mission since it was a repair mission for the Hubble telescope and therefore, flew at higher altitude (~570 km) and lower inclination (28.5 degree) than regular shuttle flights (i.e., 51.6º inclination and ~340 km altitude). The results will be presented in terms of low-LET dose, measured by the luminescence detectors, and high-LET dose, measured by the CR-39 detectors. The OSL/TL/CR-39 combination method, operationally implemented at SRAG as a consequence of the NCRP 142 (2002) recommendations, will be used to calculate dose equivalent and quality factors for selected ISS and Shuttle shielding configurations.

In addition, a summary of our most recent OSL/TL/CR-39 fading studies will be presented.

First Area Monitoring Using Area PADELS Onboard The KIBO

A. Nagamatsu, K. Murakami, K. Kitajo, H. Kumagai and H. Tawara

The radiation environment of the ISS varies complicatedly depending on the stage of the solar activity cycle, the occurrence of large solar flares, and shielding conditions (i.e., walls of the ISS and its contents, such as payload racks). The radiation doses inside the ISS are thus greatly influenced by the radiation environment.

Area PADLES is the program to perform area radiation monitoring in the Japanese Experiment Module “Kibo”. In this program, JAXA performs continuous area radiation monitoring throughout the ISS operation by installing area dosimeters at fixed locations inside the Kibo. The area dosimeters will be replaced every 6 months or every increment. The dosimetry method, package configuration and analysis method of the area dosimeters are based on the PADLES dosimetry system that we have reported previous in this conference.

The first Area PADLES started on 1 June 2008 during Increment 17 just after Japanese Pressurized Module attachment to the ISS. Area PADLES packages were launched by space shuttle (STS-124/1J) and installed at twelve fixed locations inside the Kibo (the four corners of both endcones and the center stand off) from the latter half of Increment 17 to the end of Increment 18. These area dosimeters were recovered by Space Shuttle Mission STS-127/15A and exchanged with new packages in March 2009.

In this time, we will report the first dosimetric results of area monitoring onboard the KIBO.

Time Variation Of Dose Quantities Obtained By Passive Dosimeters Onboard International Space Station

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The passive dosimeters consisting of CR-39 plastic nuclear track detectors and TLDs were exposed to cosmic radiation in Biotrack space experiment in Piers-1 module of International Space Station for some different terms between Jan. 2007 and Oct. 2008 (~2yrs). We discussed on the time variation of dose quantities using passive dosimeters for separated 4 terms (I~IV) by merging different experiment terms through 2 yrs. The time variation of dose quantities from I to IV terms was verified and found that the increasing rate of absorbed dose from IV to I is ~160% (D_{IV}/D_I ratio). This increase tendency should be corresponding to the decrease of solar activity toward solar minimum.

Radiation Measured in Low Earth Orbit (LEO) during STS-126 Space Mission

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The radiation risk experienced by astronauts can be estimated using LET spectrum measured for astronauts and the radiation risk cross section determined by radiobiology and dominated by high LET. Therefore the measurements of LET spectrum for high LET particles are important and the task can be fulfilled with CR-39 PNTDs (Plastic Nuclear Track Detectors) sensitive to high LET particles.

At present, in addition to CR-39 detectors, TLDs (Thermoluminescence Dosimeters) and OSLDs (Optically Stimulated Luminescence Dosimeters) sensitive to low LET are also widely used for radiation measurement. Radiation quantities (absorbed dose, dose equivalent and quality factor) for all LET can be obtained by combining radiation results measured with TLDs/OSLDs and CR-39 PNTDs.

LET spectra (differential and integral fluence, dose and dose equivalent) and radiation quantities for STS-126 space mission were measured with CR-39 PNTDs for astronauts - CPDs (Crew Passive Dosimeters) and for different monitored locations inside the spacecraft - PRDs (Passive Radiation Dosimeters).

This presentation introduces the LET spectrum method using CR-39 detectors and the method to combine results from TLDs/OSLDs and CR-39 PNTDs, presents some results measured with CR-39 detectors and TLDs/OSLDs and the combined results for PRDs of STS-126 space mission.

Radiation Measured During ISS-Expedition 16-17 With Different Dosimeters

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Determination of Radiation risk from radiation exposure is one of the most important purposes of radiation research. The risk can be estimated based on the LET spectra measured for astronauts and the radiation risk cross section determined by radiobiology.

At present stage, the best available personal dosimeters for high LET radiation measurement are CR-39 PNTDs (Plastic Nuclear Track Detectors) and the best personal dosimeters for low LET radiation measurement are TLDs (Thermoluminescence Dosimeters) and/or OSLDs (Optically Stimulated Luminescence Dosimeters). The chemical component of CR-39 material is $C_{12}H_{18}O_7$, very similar to human tissue, therefore CR-39 detectors are suitable to be personal dosimeters. CR-39 PNTDs can measure primary high LET particles directly or through secondary high LET particles produced in the interactions between the primary particles and the nuclei of the CR-39 material. CR-39 detectors and TLDs/OSLDs for space radiation measurements were carried by astronauts and located in the selected monitoring areas inside the spacecraft or attached to the active dosimeter TEPC (Tissue Equivalent Proportional Counter).

LET spectra (differential and integral fluence, absorbed dose and dose equivalent) with high LET were measured with CR-39 PNTDs and TEPC and radiation dose was measured with TLDs/OSLDs for the ISS-Expedition 16-17/1J-A space mission (3 Mar. – 30 Nov. 2008, 265 d, inclination 51.6^{o}, average altitude 353 km). The radiation quantities for all LET were calculated by combining results measured with TLDs/OSLDs (low LET) and CR-39 PNTDs (high LET). The comparisons between results obtained by passive dosimeters and TEPC are good.

This presentation introduces the LET spectrum method using CR-39 detectors, the combination method for radiation results from TLDs/OSLDs and CR-39 PNTDs, presents experimental results measured with TLDs/OSLDs and CR-39 PNTDs and TEPC for different monitored areas: TESS (Temporary Sleep Station), SM-P (Service-Module-Panel) 442 and 327 and TEPC (for seven different locations on ISS).

Canadian High-Energy Neutron Spectrometry System

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The Canadian high-energy neutron spectrometry system (CHENSS) has been constructed in order to accurately characterize the fluence and energy distribution of high-energy neutrons encountered on space missions in low-Earth orbit. The CHENSS is a proton-recoil spectrometer based on a cylindrical gelled scintillator, with pulse-shape discrimination properties comparable to those of a liquid scintillator, completely surrounded by thin plastic panels which can be used to veto coincident events due to charged particles. The CHENSS has been irradiated in a monoenergetic neutron beam, with energies up to 19 MeV at the Physikalisch-Technische Bundesanstalt. Higher-energy tests were conducted at the iThemba Laboratory Facility in p(^{7}Li,n)^{7}Be and p(^{7}Li,n)^{7}Be* quasi-monoenergetic neutron reference beams at 100 and 200 MeV as well as additional experiments for calibration at 66 and 80 MeV for different instrument orientations Neutron measurements were also recently performed with CHENSS at aircraft altitudes.

Determination Of The Charged Particle Response Of The HPA Neutron PADC Dosemeter In The ISS, Using Calibrations And Calculations

L G Hager, R J Tanner, J S Eakins

The Health Protection Agency (HPA) has supplied dosemeters for measurements of neutron doses inside the International Space Station for the MATROSHKA phantom exposures and for ESA astronauts, as one element of the European Crew Personal Dosemeter (EuCPD). The HPA PADC neutron dosemeter, however, is normally only issued for routine personal dosimetry in the terrestrial environment, where it is generally exposed to neutrons with energies lower than 10 MeV and never receives exposure to incident charged particles that are able to penetrate the holder and reach the neutron-sensitive PADC element. However, neutron detection works via etching of the tracks of the secondary charged particles produced by neutron interactions within the holder and PADC, so the dosemeter is intrinsically sensitive to charged particles other than electrons and muons.

The dosemeter has also been calibrated using reference neutron fields so that its response in terrestrial workplaces is well understood. These calibrations have been extended to higher energies so that it can also be used for the determination of dose equivalent in the cosmic radiation fields encountered at commercial aircraft altitudes. As a result, although the neutron response of the dosemeter is quite well characterized up to 200 MeV, its response to many charged particle types is not well known. The use of the device in space dosimetry therefore poses significant challenges. Specifically, when it is used in low-Earth orbits, it will record an over-response to neutrons if the component from the direct ions is not accounted for. The methods being used to account for some of the direct ion component will be discussed, and results will be presented of calibration irradiations performed at the HIMAC facility as part of the EC-funded HAMLET project.

Dose Measurements Onboard the ISS with the Pille TLD System

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The Pille system was developed by the KFKI Atomic Energy Research Institute as the first and to date the only TLD system containing an on-board reader designed specifically for use by cosmonauts and astronauts while traveling in space. Since the first time it was launched in 1980, the Pille system worked onboard each space station. It has been continuously used on board the International Space Station since October 2003 under the supervision of the Institute for Biomedical Problems (IBMP) as the service dosimeter system of the Russian Zvezda module. In the past six years the dosimeter system was utilized for routine dose measurements inside the ISS, and as personal dosimeter system during EVAs. With the system consisting of a lightweight reader device and a number of TL dosimeters, more than 20 000 read-outs were carried out until now. The Pille system provides monthly dose data from locations of the space station including Matroshka while two dosimeters are dedicated to EVA measurements, and one is read out in every 90 minutes automatically to provide high time resolution data.

The measurement data (including several EVA measurements) from the latest expeditions (Expedition 17 and 18, April 2007 – April 2008) obtained by the Pille system will be presented. The results will be compared with previous measurement results.

Docking of Space Shuttle with ISS Drops down the Measured SAA Doses

Dachev Ts., J. Semkova, B. Tomov1, Pl. Dimitrov, Yu. Matviichuk, R. Koleva, St. Maltchev, G. Reitz, G. Horneck, G. De Angelis, D.-P. Häder, V. Petrov, V. Shurshakov, V. Benghin, I. Chernykh, S. Drobyshev, N. Bankov

Long-term analysis of the data from 2 Bulgarian instruments on the International Space Station (ISS) shows that the docking of the Space Shuttle drops down the measured dose rates in the region of the South Atlantic Anomaly (SAA) by factor of 2-3. Measurements either with the R3DE detector, which is outside ISS at the EuTEF facility on Columbus module behind a shielding of less than 0.45 g/cm^2, and by the 3 detectors of the Liulin-5 particle telescope, which are inside the Russian PEARS module in the spherical tissue equivalent phantom behind much heavier shielding demonstrate that effect. Simultaneously the estimated averaged incident energies of the incoming protons rise up from about 30 to 45 MeV. The effect is explained by the additional shielding against the SAA 30 to 150 MeV protons, provided by the 78 tons Shuttle to the instruments inside and outside of the ISS. The Galactic Cosmic Rays dose rates are practically not affected.

Long-Term Variation Of The Trapped Proton Flux.

Kuznetsov N.V., Nikolaeva N.I., Panasyuk M.I.

Low-altitude fluxes are known to be dependent on solar activity levels due to the resulting heating and cooling of the upper atmosphere. However, variation of the trapped proton fluxes with the solar activity still cannot be accurately predicted. The AP8 model widely used for the practical purposes exists only in two variants for solar maximum and solar minimum. Nowadays there are an attempts to create new models (empirical, semi –empirical and theoretical) that are dependent on a solar activity. But despite on a significant progress in this work investigation of trapped proton fluxes measured on board modern satellites is still actual for the improvement of the existing models.

In this work we analyze the equatorial proton flux with energy over the 70 MeV on L-shells less then 1.2 measured on board NPOES-15 satellite during the 23d solar cycle. These data were compared with the experimental data obtained in 21st and 22d solar cycles.

Recent DOSTEL Measurements Inside and Outside COLUMBUS (DOSIS / EuTEF)

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The DOSIS experiment (Dose Distribution Inside the ISS) was launched on July 16th with STS-127 to the ISS. The experiment package has been transferred from the Space Shuttle into COLUMBUS on July 18th. It consists of a combination of passive detector packages (PDP) distributed at 11 locations inside the European Columbus Laboratory and two active radiation detectors (DOSTEL´s) with a DDPU (DOSTEL Data and Power Unit) mounted at a fixed location beneath the European Physiology Module (EPM) inside COLUMBUS. After the successful installation the active part has been activated. Each of the DOSTEL units consists of two 6.93 cm² PIPS silicon detectors forming a telescope with an opening angle of 120°. The two DOSTELs are mounted perpendicular to each other to investigate anisotropies of the radiation field inside the COLUMBUS module especially during the passes through the South Atlantic Anomaly (SAA) and during Solar Particle Events (SEPs).

The data from the DOSTEL units are transferred to ground via the EPM rack which will be activated every four weeks for this action. The first data downlink was performed on July 31st. First Data such as count rate profiles, dose rates and LET spectra will be presented in comparison to the data obtained by the EuTEF-DOSTEL within the same time frame. EuTEF-DOSTEL is mounted on the European Technology Exposure Facility (EuTEF) outside the European COLUMBUS module.

ALTEA: Latest Results And Comparisons With Other Instruments

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The ALTEA space detector has been in use between August 2006 and July 2007 almost continuously. It can discriminate fluxes of ions with charge $5 \leq Z \leq 26$ and energy above 100 MeV/n, it is also capable to determine the trajectory of the cosmic rays providing a complete coverage of the solid angle.

ALTEA has been also activated again in June this year, as an operational device, following a recent ASI – NASA Memorandum of Agreement.

We present here some of the latest analysis for the 2006-2007 period, including data from the angular distribution of the total particle flux divided into different geomagnetic zones (poles, equator and SAA), and first results from the latest measurements of this June-July period.

We also attempt a comparison with other devices active on the ISS in the same periods.

Bubble Detector Measurements On The International Space Station As Part Of The Matroshka-R Experiment

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As part of the Matroshka-R experiments, a spherical phantom and space bubble detectors were used on board the International Space Station to characterize the neutron radiation field. Several experimental sessions with space bubble detectors were carried out during expeditions ISS-13, 14, 15, 16, 17 and 18. The bubble detectors were positioned at various places throughout the Space Station, in order to determine dose variations with location. Detectors were also placed on the surface of the phantom and inside the phantom, in order to establish the relationship between the neutron dose measured externally to the body and the dose received internally. The experimental data will be presented.

Dose Characteristics On And Inside The Spherical Phantom MATROSHKA-R

I Jadrníčková, K. Brabcová, F. Spurný, V. Shurshakov, I. Kartsev, R. Tolochek

This contribution deals with the measurement of dosimetric characteristics and spectra of linear energy transfer (LET) onboard the International Space Station (ISS) during MATROSHKA-R experiments. The detectors (plastic nuclear track detectors and thermoluminescence detectors (TLD)) were placed at various locations on the surface of the spherical phantom; some TLD were also inserted inside this phantom. The phantom was located in Piers-1 module of ISS; the exposure period was from May to December 2008 (206 days in total).

Absorbed dose, dose equivalent, and spectra of LET are presented. The dose characteristics vary with the position of the detectors on or inside the phantom; the absorbed dose can differ almost twice depending on the position. The contribution of particles with different LET to the absorbed dose and dose equivalent is also analyzed. The obtained results are compared with the results from previous experiments with the same spherical phantom; the variation of the dosimetric quantities during various missions is discussed.

Comparison Of Space Radiation Doses Inside The Matroshka-Torso Phantom Installed Outside The ISS With Doses In A Human Body In Orlan-M Spacesuit

V.A.Shurshakov,_V.M. Petrov., Yu.A. Akatov, D.A. Kartashov, A.V.Kolomensky

The radiation field during EVA is that of the free space environment modified only by the space suit. In Matroshka space experiment a human phantom upper torso placed into a special container is used to estimate the space radiation doses in critical organs of a human body during EVA. However, the space suit shielding properties are different from that of the Matroshka container. The purpose of our study is to compare the doses inside the Matroshka-Torso phantom with the doses in a human body in ORLAN-M space suit during EVA.

The shielding probability functions for human critical organs in Matroshka-torso phantom inside the container are calculated based on geometry model and technical description of the Matroshka experimental facility. Similar shielding functions are calculated for the ORLAN-M space suit using its technical description and the results of the ORLAN-M space suit shielding on-ground study by gamma-transmission method.

Calculated ratios of dose equivalents in critical organs of the ORLAN-M space suit to that in Matroshka-Torso *H(ORLAN-M)/H(Matroshka-Torso)* vary from 0.1 to 1.8 as dependent on the selected critical organ and solar cycle phase. The best agreement is observed for the eye lens when protected from solar light with extra screen. In some practical cases considered in the study, Matroshka-Torso doses are well below or above the doses in real space suit. Thus, the results obtained should be taken into account when transferring the data of Matroshka-Torso experiment to the real EVA radiation conditions in ORLAN-M space suit.

MATROSHKA - Current Status And Effective Dose From MTR 1 And MTR 2A

Thomas Berger for the MATROSHKA team
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The first part of the talk will give a short overview of the current status of the ESA MATROSHKA experiment under the project lead of DLR. The MATROSHKA project onboard the International Space Station ISS finished its third exposure phase (MTR – 2B) using active and passive radiation detectors for the determination of the skin, organ and depth dose distribution with the download of the passive detectors in March 2009. A fourth exposure phase – MATROSHKA 2 KIBO – is currently in the preparation phase aiming to be launched with a Progress Cargo Ship at the end of 2009.

The second part of the talk will give the first preliminary results for the determination of the Effective Dose E for the MATROSHA 1 experiment (outside the ISS) and the MATROSHKA 2A experiment (inside the Russian Part of the ISS).

The baselines for the determination of the Effective Dose E for the MATROSHKA 1 and 2A exposures are :

(1) the depth dose distribution measured with thermoluminescence detectors in the 33 slices of the phantom

(2) the calculation of the organ doses using the so called NUNDO (Numerical RANDO) phantom based on the CT-scan of the MATROSHKA phantom.

(3) the data from the CR-39 detectors positioned inside the critical organs as well as on the skin surface of the MATROSHKA phantom.

The data for the Effective Dose E will further on be compared with results from previous phantom experiments performed on Space Shuttle and ISS missions.

The third part of the talk will give a short overview of the current activities performed in the frame of the FP7 HAMLET project for the dissemination and further exploitation of the MATROSHKA data.

Part of this work is funded by the European Commission in the frame of the FP7 HAMLET project (Project # 218817)

Preliminary Results from MATROSHKA-2B Thermoluminescence Dosimetry.
Part 1: Spatial Distribution of Absorbed Dose in the Phantom Slices

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The ESA MATROSHKA facility has been designed to simulate a human upper torso during intra- and extravehicular activity in space and measure the distribution of absorbed dose rate within the anthropomorphic phantom body. During the MATROSHKA-2B mission, the facility has been installed in the Russian Zvezda module of ISS from 18 October 2007 to 18 March 2009. Preliminary results from thermoluminescence dosimetry are presented, with special emphasis being laid on the doses absorbed in the head and a comparison to previous MATROSHKA missions.

This work has been supported in part by the EU 7th Framework Programme under contract no. 218817 (HAMLET) and the Austrian Space Applications Programme under funding no. ASAP-WV-215/05 (RADIS).

Preliminary Results from MATROSHKA-2B Thermoluminescence Dosimetry. Part 2: Absorbed Doses in the Organ and Poncho Packages

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During the ESA MATROSHKA-2B mission an anthropomorphic phantom simulating a human upper torso was exposed in the Russian Zvezda module of the ISS for a period of over a year (October 2007 – March 2009).

Except TLDs located in the tubes in all slices of the phantom, measurements were realized also with the passive detector packages (12 pcs). They were placed in positions of selected organs (kidney, lungs, eye, stomach, intestine, head), and also on the "poncho", which was covering the phantom. The packages contained detectors from different investigators. In the presentation the preliminary results of thermoluminescent detectors from all organ and poncho packages will be discussed.

This work has been supported in part by the EU 7th Framework Programme under contract no. 218817 (HAMLET)

MATROSHKA 2B: SRAG's Preliminary Results

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Space Radiation Analysis Group (SRAG) at NASA/JSC had a strong contribution over the years to national and international research collaborations in the field of space radiation dosimetry, using both passive and active radiation detectors. This presentation involves passive dosimetry results from two recent international collaborations for the MATROSHKA 2B and DOSIS 1 Projects, both in collaboration with the German Space Agency (DLR) and funded by the European Space Agency (ESA).

The main objective of the MATROSHKA 2B Project was to measure the depth dose (at different organs) and the skin dose inside the International Space Station (ISS) by using a simulated anthropomorphic phantom. SRAG contributed to this project with a suite of optically stimulated luminescence (OSL) detectors, thermoluminescence (TL) detectors and plastic nuclear track detectors (PNTD). SRAG's detectors were distributed inside and outside the phantom targeting different dose points of interest (i.e., top of the head, eye, lung, stomach, intestine, and skin). In this presentation, preliminary results from the OSL and TL dosimeters exposed during MATROSHKA 2B project will be discussed.

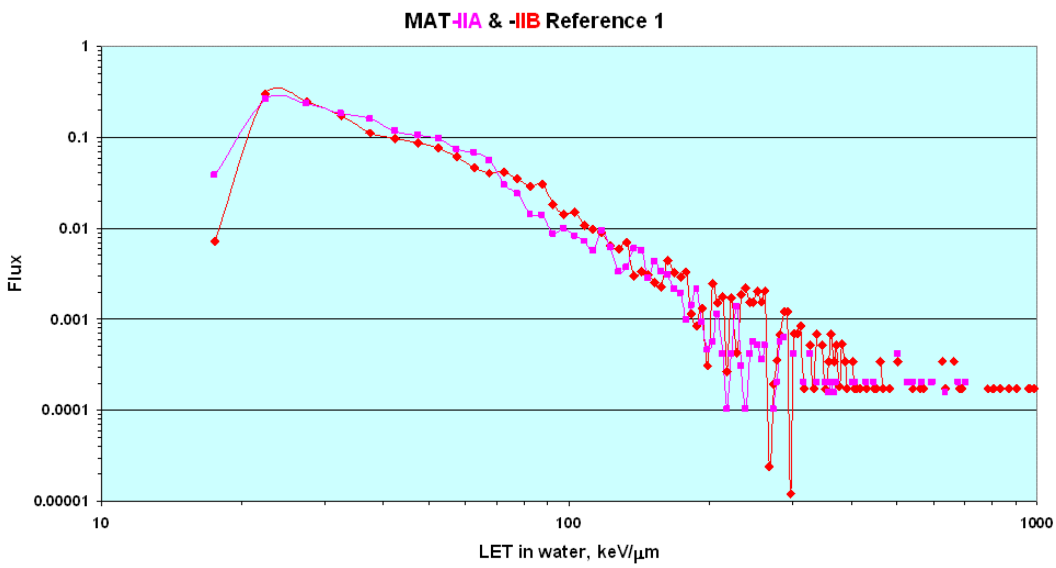
In addition, a summary of our most recent OSL/TL/CR-39 fading studies will be presented.

Preliminary Results Of MATROSHKA-IIB Experiments And Comparison To Previous Measurements On The ISS

J. K. Pálfalvi and B. Dudás
KFKI Atomic Energy Research Institute of the Hungarian Academy of Sciences

Two types of track etch detector stacks were constructed, one for the organ dose measurements in the lung and kidney of the phantom, the other one for the skin dose measurements attached to the poncho of the phantom. The detector assemblies allow to determine the combined LET spectra of primary GCR particles and of the secondary ones generated by trapped protons and GCR particles by nuclear reactions, including target and projectile fragmentation. The track detectors were evaluated by a semi automated image analyzer and from the track parameter measurements the absorbed dose, the dose equivalent and the mean quality factor were calculated.

The configuration of the stacks, the methods of the calibration and evaluation and the preliminary results obtained after short etch (8µm removal) will be presented and compared to previous measurements made on the ISS. The Figure below shows two LET spectra of selected detectors after short etching time exposed inside the Reference box No. 1 during the Matroshka –IIA and –IIB experiments.



The Flux –corrected for background and critical angle- is given in [cm^2 sr d keV/µm]$^{-1}$ unit.

MATROSHKA/DOSTEL Measurements

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MATROSHKA is an ESA experiment under the leadership of DLR, Cologne. The radiation exposure inside a human phantom is measured by active and passive radiation detectors.

The DOSimetry TELescope (DOSTEL) as one of the active instruments of MATROSHKA, which was built at CAU Kiel in a cooperation with DLR, is a particle telescope consisting of two Si-semiconductor detectors.

The energy depositions inside the detectors are measured. By using the average path length in the detectors, the Linear Energy Transfer – LET and so the dose equivalent can be estimated.

MATROSHKA is on board ISS since January 2004. During the first mission phase (MTR 1) the phantom was mounted outside the ISS from February 2004 to August 2005. From April 2008 till February 2009 the active experiments where operating in another mission phase (MTR 2B) inside the Zvezda Module of the ISS.

A comparison between the DOSTEL measurements inside and outside the Space Station including count rates and dose values will be presented.

Part of this work is funded by the European Commission in the frame of the FP7 HAMLET project (Project # 218817)

ODI - Open Data Interface for SAAPS, SEDAT, and SPENVIS

P. Wintoft [1], D. Heynderickx [2], L. Eliasson [1], and H. Evans [3]
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Several different systems for space weather analysis, monitoring, and prediction exist today. For their operation they rely on space weather data that comes from many different sources, both archived data and real time data. Three such systems are "Satellite Anomaly Analysis and Prediction System (SAAPS)", "Space Environment Data Analysis Tool (SEDAT)", and "Space Environment Information System (SPENVIS)". SAAPS, SEDAT, and SPENVIS have several common data sets but use different databases and different database engines. To simplify the operation of the three systems a common database, called "Open Data Interface (ODI)", is under development. ODI is implemented in MySQL as this provides a good platform with search capabilities and many database tools in different programming languages. In addition to the data the metadata must also be stored in the database. As many data sets are stored in "Common Data Format (CDF)" following the "International Solar Terrestrial Physics (ISTP)" and "Panel on Radiation Belt Environment Modelling (PRBEM)" guidelines ODI will also store the metadata that are associated with CDF, ISTP, and PRBEM
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MATSIM: Development of a Numerical Model for the MATROSHKA Phantom

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The Austrian Institute of Technology coordinates the project MATSIM (MATROSHKA Simulation) in collaboration with the Vienna University of Technology and the German Aerospace Center, to perform Monte Carlo high energy particle transport simulation of the MATROSHKA phantom used at the International Space Station (ISS). Funded by the Austrian Space Applications Programme, MATSIM is a co-investigation to the European Space Agency ELIPS project MATROSHKA, an international collaboration of more than 18 research institutes and space agencies from all over the world, under the science and project lead of the German Aerospace Center. The MATROSHKA facility is designed to determine the radiation exposure of an astronaut onboard ISS and especially during an extravehicular activity. MATSIM is a validation study of dose prediction calculations using the MATROSHKA phantom, managed in two phases A and B. In MATSIM-A a simulation model of the MATROSHKA phantom is developed with the use of the Monte Carlo transport code FLUKA. During MATSIM-B the numerical model will be validated by radiation reference measurements.

Monte Carlo Modelling of Microdosimetric Spectra of the Absorbed Dose and Dose Equivalent due to Exposure of Tissue and Silicon in the ISS Space Radiation Field

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The response of TEPC and silicon detectors was simulated with Monte Carlo methods free in air and on ISO water Phantom. Protons, neutrons, helium and iron ions with complex energy spectra, such as the one present outside ISS have been considered. The conversion of the absorbed dose in silicon detectors into absorbed dose and dose equivalent in tissue is discussed. In addition, the readings of a TEPC have been simulated and its results are compared to the detector results. A reasonable agreement between LIULIN and TEPC could be found. The effective dose equivalent values as presented by Sato are also shown for comparison

Simulations Of MATROSHKA Experiment At ISS Using PHITS

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Concerns about the biological effects of space radiation are increasing rapidly due to the perspective of long-duration manned missions, both in relation to the International Space Station (ISS) and to manned interplanetary missions to Moon and Mars in the future. As a preparation for these long duration space missions it is important to ensure an excellent capability to evaluate the impact of space radiation on human health in order to secure the safety of the astronauts/cosmonauts and minimize their risks. It is therefore necessary to measure the radiation load on the personnel both inside and outside the space vehicles and certify that organ and tissue equivalent doses can be simulated as accurate as possible. In this paper we will present an update of the ongoing simulations using the three-dimensional Monte Carlo Particle and Heavy Ion Transport code System (PHITS) of long term dose measurements performed with the ESA supported experiment MATROSHKA (MTR), which is an anthropomorphic phantom containing over 6000 radiation detectors, mimicking a human head and torso. The MTR experiment, led by the German Aerospace Center (DLR), was launched in January 2004 and has measured the absorbed dose from space radiation both inside and outside the ISS. In this paper preliminary comparisons of measurements outside the ISS will be presented. The results confirm previous calculations and measurements which indicate that PHITS is a suitable tool for estimations of dose received from cosmic radiation and when performing shielding design studies of spacecraft.

Correlating The ISS-6A Liulin / TEPC Measurements With Simulation Using HZETRN”

Francis. F. Badavi, John E. Nealy

Using the silicon and tissue based dose measurements from the ISS 6A-configuration (July 2001), the deterministic transport code HZETRN is used to correlate measurements of Liulin and TEPC instruments with the corresponding numerical simulation. For the definition of the LEO environment, the simulation uses the LaRC developed trapped protons code (a modified AP8/AE8 using F10.7, SSN, DRNM and SAA drift model and data) and JSC developed GCR model. Actual telemetry trajectory data as provided by Dachev and JSC-SRAG were synchronized and used throughout the simulation. The presentation will focus on the Liulin and TEPC measurements during ISS passage through the SAA region and will discuss how measurement were reduced for the purpose of correlating with simulation. Other areas of discussion will be comparing sample dose rate result from measurement and simulation per SAA pass and for the entire measured data set, silicon and tissue based LET comparison and the effect of incorporating directionality in the simulation.

Earth and Moon Radiation Environment Results Obtained by RADOM Instrument on Indian Chandrayyan-1 Satellite. Comparison with Model

Ts.P. Dachev, B.T. Tomov, Yu.N. Matviichuk, Pl.S. Dimitrov, G. De Angelis, F. Spurny, O. Ploc

This paper describes preliminary scientific results from the measurements of the Earth and Moon radiation environment by RADOM instrument since 22nd October 2008. The instrument is a miniature (98 grams, 100 mW) 256 channels spectrometer of the deposited energy (dose) in a single 2 cm^2 0.3 mm thick silicon detector.

The RADOM spectrometer main tasks are to measure the spectrum (split into 256 channels) of the deposited energy from primary and secondary particles onboard the Indian Chandrayaan-1 mission and to transmit these data to the Earth. The solid state detector of RADOM instrument is behind ~ 0.45 g.cm^{-2} shielding from front 2π angle, which allows direct hits on the detector by electrons with energies in the range 0.85-10 MeV. The protons range is 17.5-200 MeV. On other 2π angle where the satellite is the shielding is larger but not known exactly.

RADOM instrument was switched on about 2 hours after the launch of the Chandrayaan-1 satellite on 22nd October 2008. The doses observed inside of the outer (electron) radiation belt reach 4.10^4 μGy.h^{-1}, while the fluxes are $1.5.10^4$ cm^{-2}.s^{-1}. The doses inside the inner (proton) radiation belt reached about the 3 times higher values of $1.2.10^5$ μGy.h^{-1}. The doses out of radiation belts are dominated by the GCR particles. The GCR doses are very stable around 12 μGy.h^{-1}. The maximal observed GCR doses of 12.2 μGy.h^{-1} by RADOM instrument were when the Chandrayaan-1 satellite was away from both Earth and Moon during the lunar transfer orbits from 7th to 12th November 2008. When on 12th November 2008 the satellite entered a 100 km circular orbit around the Moon the GCR doses fall down because of the Moon surface shielding to about 8.8 μGy/h and stayed stable around this value. After the increasing of the orbit altitude of Chandrayaan-1 satellite on 15th of May 2009 up to 200 km the mean dose rate value increase to 10.5 μGy.h^{-1}.

Models for the Moon radiation environment already developed have been used to be compared with the data coming from the RADOM experiment. The models have been set to a 100 km altitude circular orbit, to the actual mission time frame (both punctual and averaged data), and to the actual environmental shielding inside the spacecraft. As a preliminary comparison, RADOM data at 100 km altitude around the Moon give a mean flux for GCR of 2.29 cm^{-2}.sec^{-1}. The rescaled for CHANDRAYAAN-1 orbital conditions and timeframe model, with a shielding pattern of 0.45 g.cm^{-2} on the 2π solid angle before the detector and more shielding on the other 2π solid angle at the back side of the detector give a value for GCR of 2.55 cm^{-2}.sec^{-1}, which is relatively very good result.

Update On NASA TEPC Measurements And Next Generation Hardware Developments

Eddie Semones on behalf of SRAG and NASA Advanced Radiation Instrumentation Project

During the past year, the NASA JSC Tissue Equivalent Proportional Counter made measurements throughout the ISS including Node 2, Service Module, US Lab, Columbus, and the JPM. Absorbed dose and dose equivalent due to galactic cosmic rays (GCR) and particles trapped in the SAA (South Atlantic Anomaly) will be presented.

In preparation of supporting long term presence of crews on ISS post shuttle retirement and future exploration class missions, NASA is initiating several dosimetry projects ranging from pre-staging backup hardware to development of new designs. Status of each of these projects will be presented.

High Sensitive MOSFET-Based Neutron Dosimeter For Space Applications

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Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET) dosimeters have numerous advantages such as: low cost, small size and weight, robustness, accuracy of measurement, real-time or delayed direct read-out, information retention with small fading, possibility of integration with other sensors and/or circuitry. In addition they can be used without power supply during irradiation i.e. as passive dosimeters. They are able to measure large dose ranges, which is very important for a dosimeter. These advantages demonstrate that MOSFET's can be successfully applied in space dosimetry. MOSFET dosimeters have been used in space dosimetry for proton and electron measurements. The neutron contribution to the total ambient dose equivalent during space mission is not negligible. Neutrons contribute up to 30% of the dose equivalent of the intravehicular crew exposure. Therefore the neutron ambient dose equivalent is an important component to be studied.

The p-MOSFETs studied in Physics Departement of the Thessaloniki University (Greece) were fabricated at LAAS-CNRS Toulouse, France. They consisted by thick SiO_2 (1.6μm) in small size and low weight and cost. The new p-MOSFETs, operate at negative threshold voltage, about -5 Volts, are developed following a process designed for improving both sensitivity to radiation dose and stability. A layer of ^{6}LiF converter with 3μm in thickness has been evaporated on the surface of the MOS gate in order to enhance neutron dose measurements. The sensitivity of the specific p-MOSFETs has been studied for neutron doses ranging from thermal up to fast neutrons. For thermal neutrons the sensitivity is found to be 11 mV/mSv (56.6 mV/mGy), much higher than the dosimeter response to intermediate-fast neutrons in which 0.045 mV/mSv (0.59 mV/mGy) has been measured. By a separate experiment the sensitivity of the new p-MOSFETs to γ-rays was estimated to be 0.5 mV/mGy.

Development of Tissue Equivalent Detectors for Space Crew Dosimetry and Characterization of the Space Radiation Environment

E. R. Benton, C. E. Johnson, J. DeWitt, A. Lau, E. G. Yukihara, A. S. Arena, Jr., and A. C. Lucas

This presentation details recent progress on the development of a progressively sophisticated and capable series of compact, self-contained tissue-equivalent ionization chambers and proportional counters for real-time space radiation dosimetry being carried by the Radiation Physics Laboratory at Oklahoma State University (OSU) as part of a three-year grant from the NASA Experimental Program to Stimulate Competitive Research (EPSCoR) program. Results from flights of the Balloon-Borne Ionization Chamber (BBIC) developed during this project will be reported. This 8 liter plastic ionization chamber is capable of measuring dose rates from 0.1 to 10 μGy/hr. BBIC serves as the centerpiece of a Near Space Standard Science Platform (NS^3P) for use by high school and college students conducting experiments with high altitude balloons in order to promote Science, Technology, Engineering, and Mathematics (STEM) education and interest in NASA's mission throughout the USA.

RAZREZ System For RADIOSCAF Experiment

Petrov V.L., Panasyuk M.I., Amelyushkin A.M., Drozdov A.Yu., Nechaev O.Yu.

The creation of RAZREZ system for RADIOSCAF mission is described in this paper. The system consists of several units with different detectors. These detectors will measure charged particles fluxes (protons with energies > 50 MeV and ~5 MeV electrons, and bremsstrahlung of 50 keV to 3 MeV; electrons of ~100 keV to 3 MeV energies), and neutrons of thermal energies, > 10…50 keV, and > 100 keV. The system also includes 5 dosimeters with different polyurethane shielding. All the units will be mounted in a fulfilled spacesuit and launched from ISS towards the Earth. The estimated lifetime of the satellite will make up to 6 months, altitudes on which it will work – from 350 to ~180 km. RAZREZ will have its separate telemetry and power supply systems. As a result of experiment we plan to obtain the data in a wide high-rise range and on removal from massive space objects. This experiment is very important for investigation of radiation at small altitudes.

RaDI-N Measurements of Neutron Radiation on the International Space Station

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The neutron radiation field inside the ISS is undergoing characterization in a series of experiments using bubble detectors. The RaDI-N measurements are being performed during the ISS-20 and ISS-21 expeditions, using space bubble-detector dosimeters and the newly-developed space bubble-detector spectrometer (BDS). The space BDS is a temperature-compensated neutron spectrometer consisting of a set of bubble detectors with six different energy thresholds. By performing a simultaneous measurement with all six detectors, and analyzing the bubble counts from each using an unfolding process, it is possible to determine the energy spectrum of neutrons. During the RaDI-N experiments, the neutron energy spectrum will be determined at various locations inside the ISS, allowing a comparison of the spectra behind various amounts of radiation shielding. The results will also be compared to earlier spectral measurements performed with bubble detectors on the Russian Bion satellites and the Mir space station. The RaDI-N experiments include measurements of the neutron dose using bubble-detector dosimeters. The dose results will be compared to those obtained from bubble-detector measurements performed during expeditions ISS-13, ISS-14, ISS-15, and ISS-16 as part of the Matroshka-R experiments, and with available data from tissue-equivalent proportional counters.

Study of Phoswich Detectors for Dosimetry Measurements

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A phoswich detector consists of two or more dissimiliar scintillators which are optically coupled to each other and to a common photomultiplier (PMT). When a combination of a fast and a slow scintillator is used and pulse shape analysis is applied the pulses from the two scinitillators can be separated. For the digital pulse shape analysis a FPGA and a fast ADC will be used. The main purpose of this study is to distinguish between gammas and neutrons but it is also possible to measure charged particles with this setup and thus such a detector is well suited for an application in dosimetry. In order to distinguish between gammas and neutrons a fast plastic scintillator for the detection of neutrons and a slow inorganic scintillator for the detection of gamma has been chosen. As a test setup the PMT R1924-01 from Hamamatsu with a wavelength of maximum response of 420 ± 50 nm is used and the pulses are acquired with a Tektronix oscilloscope. So far the scintillators CsI(Na) and BC400 have been investigated with gammas, alphas and cosmic muons.

A description of the concept of the phoswich detector including electronics as well as first preliminary results will be presented.

"Preparation of Proton Irradiation System for Intercomparison Experiments of Luminescence Detectors (Proton-ICCHIBAN-2)"

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In order to understand responses of luminescence detectors as Thermo-Luminescence, Optically Stimulated Luminescence dosimeters for space radiation, an irradiation system has been prepared in the cyclotron in NIRS. The dosimeters can be exposed to 30 to 70 MeV protons. These middle energy particles have lower LET and they are suitable for researches around LET~1 keV/um where the response of the detectors have not been well known. The irradiation system and its dosimetry methodology in the cyclotron facility will be reported.