15th Workshop on Radiation Monitoring for the International Space Station

Villa Mondragone

University of Rome Tor Vergata, Rome

7th - 9th September 2010

Chairman: Günther Reitz, DLR

LOC: Livio Narici, URTV

Marco Casolino, INFN

Cristian De Santis, INFN

Luca Di Fino, URTV

Marianna Larosa, URTV

Veronica Zaconte, URTV

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15th Workshop on Radiation Monitoring for the International Space Station

Program

Tuesday, Sept. 7th

08:00 – 09:00	Registration
09:00 – 10:20	Scientific Session
10:20 – 11:20	*Coffee Break*
11:20 – 12:40	Scientific Session
12:40 – 14:00	*Lunch Break*
14:00 – 15:20	Scientific Session
15:20 – 16:20	*Coffee Break*
16:20 – 17:40	Scientific Session

Wednesday, Sept. 8th

09:00 – 10:20	Scientific Session
10:20 – 11:20	*Coffee Break*
11:20 – 12:40	Scientific Session
12:40 – 14:00	*Lunch Break*
14:00 – 15:20	Scientific Session
15:20 – 16:20	*Coffee Break*
16:20 – 17:40	Scientific Session
	Workshop Dinner

Thursday, Sept. 9th

09:00 – 10:20	Scientific Session
10:20 – 11:20	*Coffee Break*
11:20 – 12:40	Scientific Session
12:40 – 14:00	*Lunch Break*
14:00 – 15:20	Scientific Session
15:20 – 16:20	*Coffee Break*
16:20 – 17:40	General Discussion and Conclusions

15th Workshop on Radiation Monitoring for the International Space Station

Scientific Program

Tuesday, Sept. 7th

Welcome
Livio Narici

Introduction
Günther Reitz

Introductory talks

ESA's research on ISS
Christer Fuglesang

Space Radiation Cancer Risk Projections and Uncertainties - 2010
Francis Cucinotta

Session: Models

The dynamics of electrons under the radiation belts in the minimum of solar activity cycle
Vasily Petrov

Empirical model of the pitch-angle distribution of trapped protons at the inner boundary of the Earth's radiation belt
Natalia Nikolaeva

A Predictive Code for ISS Radiation Mission Planning
Samy El-Jaby

Space Radiation Shielding for Human Missions: Concepts and Materials
Emanuele Tracino

Can the Terrestrial Magnetosphere Mitigate Radiation Hazard on Moon Missions?
Rositza Koleva

Physics models for the simulation of biological effects of radiation and shielding with the Geant4 toolkit: the ESA AO6041 project
Sebastien Incerti

Session: Calibration/New developments

Space Radiation Dosimetry with the The Radiation Assessment Detector (RAD) on the Mars Science Laboratory (MSL)
Don Hassler

Summary of HIMAC Measurements with the TimePix version of the Medipix2-Based Detectors and Preparation for the First Flight of Medipix
Lawrence Pinsky

The sensitivity of a new type p-MOSFET dosemeter to high energy protons
Marianthi Fragopoulou

Portable High-Energy Neutron Spectrometer for Active Diagnostics of Radiation Environment aboard the ISS
Andrey Smirnov

Intercomparison measurements with Liulin and TEPC Hawk in HIMAC beams
Ondrej Ploc

The preliminary results of the Proton-ICCHIBAN-2 experiments for luminescence detectors
Yukio Uchihori

Charged particle LET threshold determinations for the HPA neutron PADC dosemeter
Luke Hager

Measurements of short range tracks produced by target fragmentation reaction in CR-39 PNTDs by high energy proton beam exposure
Satoshi Kodaira

Wednesday, Sept. 8th

Session: Calibration / New developments

Dose rate measurements of charged and neutral particles in the stratosphere
Esther M. Dönsdorf

Status of the Intravehicular - Tissue Equivalent Proportional Counter (IV-TEPC) development for ISS
Edward Semones

A Sort-of Tissue Equivalent Proportional Counter for Space Radiation Dosimetry Application
Eric Benton

Proposal for Intelligent Crew Personal Dosimeter
Tsvetan Dachev

Session: Measurements

Nine Years of the Radiation Monitoring System Operating in Service Module of ISS
Victor Benghin

Dose Measurements Onboard the ISS with the Pille TLD System
Peter Szanto

Recent results of TLD and OSL measurements on board of the ISS
Filip Vanhavere

Radiation Monitoring Using Area PADLES on board the ISS Japanese Experiment Module, Kibo
Aiko Nagamatsu

The DOSIS – Experiment onboard the Columbus Laboratory of the International Space Station – First mission results for the passive detectors of the DOSIS-1 experiment phase
Thomas Berger

Dose mapping by SSNTD inside the Columbus module of the ISS – DOSIS project
Joe Palfalvi

TL Dosimetry in Columbus during DOSIS-2
Christina Hofstätter

ISS Measurements at Solar Minimum (2008-2010)
Radiation Measured with Experiments DOSIS on the International Space Station (ISS)
Radiation Measured in LEO for Space Mission STS-125 with Low Inclination
Neal Zapp

The DOSIS – Experiment onboard the Columbus Laboratory of the International Space Station – First Mission Results From the Active DOSTEL Instruments
Soenke Burmeister

ISS radiation environment anisotropies measured by ALTEA
Luca Di Fino

ALTEA real-time monitoring of radiation environment inside the ISS-USLab and off-line data management
Luca Di Fino

An Intercomparison Study of PADC Track Etch Detector Evaluation with a Semi-Automated and a Manual System between AERI, Budapest and DLR, Cologne
Christine Körner

A proposal on CR-39 PNTDs analysis for space radiation Dosimetry
Satoshi Kodaira

Thursday, Sept. 9th

Session: Radiation Measurements

Measurements of cosmic rays inside the ISS and in low Earth orbit with Altcriss and Pamela experiments
Marco Casolino

Space experiment BTN-Neutron onboard of Russian segment ISS
Vladislav Tretychov

Measurements of neutron environment inside and outside of ISS
Vladimir Lyagushin

Estimation of the International Space Station attitude effect on dose rate inside the Service Module when crossing the South-Atlantic Anomaly
Sergey Drobyshev

Comparison of methods for estimation of dose equivalent by means of Liulin semiconductor spectrometer placed on-board ISS
Jan Kubancak

Session: Phantom Experiments

HAMLET – Human Model MATROSHKA for Radiation Exposure Determination of Astronauts – Current status and results
Guenther Reitz

HAMLET -Ground Based Verification of the MATROSHKA Facility: Results from the experiments at HI-MAC and GSI
***Pawel Bilsk*i**

Quasi-stable radiation belt in the slot region observed by MATROSHKA
Johannes Labrenz

PHITS simulations of MATROSHKA-1 experiment at ISS
Monika Puchalska

MATSIM - The Development and Validation of a Numerical Voxel Model based on the MATROSHKA Phantom
Sofia Rollet

MATROSHKA-R experiments: Results obtained with passive detectors in 2005-2009
Iva Ambrozova

Calculation of Bubble Detector Response Using Data from the Matroshka-R Study
Brent Lewis

Overview on the Radiation Quantities Observed by Liulin-5 Instrument in the Spherical Tissue-Equivalent Phantom on ISS
Jordanka Semkova

The dynamics of electrons under the radiation belts in the minimum of solar activity cycle

V.L. Petrov, M.I. Panasyuk

Skobeltsyn Institute of Nuclear Physics of Moscow State University

Prolonged solar activity minimum has led to a weakening of the geomagnetic activity and the depletion of the radiation belts at low altitudes up to 2010. But this anomaly had almost no effect on the level of precipitated electrons flux under the radiation belts, which remains roughly the same level except for periods of extreme geomagnetic conditions. The sources of electrons in the magnetosphere were reduced during the long minimum. This had led to a global reduction of trapped particles. However, such dynamics are not fully applicable to particles in the vicinity of the loss cone - out the South Atlantic Anomaly. Devastation radiation belt allowed brighter display modulation of energetic electrons flux near the equator and low latitudes, associated with their resonant interaction with low-frequency waves. In this work we present the long-term variations of electrons at $L < 2$ during the last solar activity minimum.

Empirical model of the pitch-angle distribution of trapped protons at the inner boundary of the Earth's radiation belt

N.I. Nikolaeva, N.V. Kuznetsov

Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University

The generalization of experimental data on the flux of trapped protons, which were measured by different instruments on three low-orbit satellites (NOAA-17, University-Tatiana and CORONAS-F) in April 2005. Based on these data, a new quantitative model of trapped protons, which allows to predict the fluxes of protons with energies from 30 keV to 140 MeV in a quiet geomagnetic conditions in the period close to the minimum of solar activity on the drift shells L = 1.14-1.4. The proposed model establishes the directed differential protons flux depending on the pitch angle at the geomagnetic equator. This model takes into consideration the anisotropy of the trapped particles on the lower boundary of Earth's radiation belt.

A Predictive Code for ISS Radiation Mission Planning

Samy El-Jaby *(Royal Military College of Canada)*, Brent Lewis (*Royal Military College of Canada*), Leena Tomi (*Canadian Space Agency*)

Aboard the International Space Station (ISS), a US tissue equivalent proportional counter (TEPC) has been monitoring the mixed-radiation field stemming from cosmic radiation sources in order to provide an assessment of the ambient dose equivalent rate H*(10). These data are collected on a by-minute basis and are well correlated with ISS position (latitude, longitude, and altitude). Using world grids of effective cut-off rigidity, a semi-empirical predictive model has been developed to correlate the ambient dose equivalent rate with effective cut-off rigidity. This semi-empirical model is based on TEPC data collected from July 7-13, 2001 and December 10-16, 2008 and spans the solar maximum to solar minimum conditions, respectively, of Solar Cycle 23. The cut-off rigidities are estimated using the International Geomagnetic Reference Field world grids for years 2000 (IGRF-2000) and 2005 (IGRF-2005) as well as a 2001 grid predicted by the RCINTUT3 code of Smart an! d Shea. An estimation of solar modulation is made using four different parameters including sunspot numbers, the F10.7cm solar radio flux, the F81c (81 day centered average) solar radio flux and the heliocentric potential derived from the Apatity neutron monitor count. An estimation of the geographical boundary of the South Atlantic Anomaly is made using a proton flux map valid from 2001 to 2006. The predicted total ambient dose is compared against tabulated TEPC ambient dose equivalent data during three time periods including April 1-21, 2010, October 1-17, 2009, and June 4-20 2005. The predicted ambient dose equivalent is consistently within 20% of the measured value.

Space Radiation Shielding for Human Missions: Concepts and Materials

E. Tracino, C. Lobascio, R. Destefanis, M. Belluco, M. Briccarello, V. Guarnieri, M. Silvestri

Thales Alenia Space Italia

Passive Shielding is, up today, the only available, used and effective countermeasure against the radiation environment experienced by astronauts on the International Space Station (ISS). The aluminium primary structure and the micrometeoroids and Orbital Debris (MMOD) Protection System of a space module composing the ISS are the first barriers against the effects of the cosmic radiation. Kevlar® and Nextel® are in particular two materials of great interest for spacecraft shielding because they are hydrogen rich, flexible and used in MMOD protection systems: their use is envisaged also for futures inflatable habitats. As part of a research study aimed to understand the shielding behavior of the materials commonly present in these two main structures, we have tested on-ground and in-orbit Kevlar®, Nextel® and different multilayer comparing their response to real and simulated heavy-ion cosmic radiation with polyethylene and aluminum. The shielding performances obtained from flight and from ground laboratory experiments were compared and found to be in substantial agreement with the results of a series of Monte Carlo simulations based on GEANT4 toolkit. The simulation of novel multilayer to understand they shielding effectiveness has been performed in order to optimize the radiation protection and found new passive protection concepts and materials to employ in the future design of space habitats.

Can the Terrestrial Magnetosphere Mitigate Radiation Hazard on Moon Missions?

B. Tomov, R. Koleva, T. Dachev, Yu. Matviichuk, Pl. Dimitrov

Space and Solar-Terrestrial Research Institute

Bulgarian Academy of Sciences

One potential method of radiation mitigation on extra-terrestrial missions is in the form of magnetic fields. For Moon missions the Earth magnetosphere is a source of magnetic field, as the Moon spends about 25% of its orbit inside it. Recent modeling [Winglee, R. M., and E. M. Harnett, GRL 2007], suggested that the terrestrial magnetotail magnetic field can provide a significant level of shielding, the latter depending on IMF orientation and position on lunar surface. Using RADOM data from Chandrayaan-1 satellite we try to prove this hypothesis. The first results show that during solar cycle minimum the magnetotail does not mitigate doses on Moon orbiter. More detailed analysis is needed to check magnetospheric effect on doses for different locations on Moon.

Physics models for the simulation of biological effects of radiation and shielding with the Geant4 toolkit: the ESA AO6041 project

S. Incerti, B. Lund-Jensen, A. Le Postollec et al. on behalf of the the ESA AO6041 team

The European Space Agency is supporting the extension of the Geant4 general purpose Monte Carlo simulation toolkit for the modeling of biological effects of radiation at the DNA and cellular scales for space applications, in the framework of the ESA AO6041 project. In this talk, we will describe the context of this research project and overview on-going developments. These developments include new Geant4 Physics and Chemistry processes and models as well as the simulation of the radiation environment aboard the International Space Station, following the outcome of the ESA DESIRE project. The preparation of an irradiation campaign of biochip samples aboard the ISS for the search of traces of life in the Solar System (exobiology) will also be presented.

Space Radiation Dosimetry with the The Radiation Assessment Detector (RAD) on the Mars Science Laboratory (MSL)

D. M. Hassler (1), C. Zeitlin (1), R. F. Wimmer-Schweingruber (2), E. Böhm (2), S. Böttcher (2), S. Burmeister (2), F. Cucinotta (3), O. Kortmann (2), C. Martin (2), A. Posner (5), S. Rafkin (1), E. Weigle (1), and G. Reitz (4)

(1) Southwest Research Institute, USA,(2) Christian Albrechts University, Kiel, Germany,

(3) NASA/JSC, USA, (4) DLR, Cologne, Germany, (5) NASA HQ

The Radiation Assessment Detector (RAD) is a compact, lightweight energetic particle analyzer that will fly on the NASA 2011 Mars Science Laboratory (MSL) Mission. RAD will detect and analyze energetic particle species (p, n, He, $2<Z<26$) relevant for dosimetry on the Martian surface. The Galactic Cosmic Rays and Solar Energetic Particles produce both primary and secondary radiation, with secondaries being created in both the atmosphere and the Martian regolith. Fully characterizing and understanding the surface radiation environment is fundamental to quantitatively assessing the habitability of Mars, and is an essential precursor measurement for future manned Mars missions. An extensive database to be used for calibration has been obtained for a wide range of energetic charged particle beams at the NASA Space Radiation Laboratory (NSRL) and the Heavy Ion Medical Accelerator in Chiba (HIMAC). Neutron calibration data at 5, 15, and 19 MeV were obtained at the Physikalisch-Technische Bundesanstalt. This talk will discuss the highlights of the RAD calibration campaigns and talk about what we have learned from these campaigns with respect to operating RAD on the Martian surface. We will also discuss other mission applications for RAD where dosimetry in mixed fields of energetic charged and neutral particles is needed.

Summary of HIMAC Measurements with the TimePix version of the Medipix2-Based Detectors and Preparation for the First Flight of Medipix

L. Pinsky, N. Stoffle, J. Jakubek, S. Posposil, C. Leroy, A. Gutierrez, H. Kitamura, O. Ploc, N. Yasuda, Y. Uchihori

University of Houston

We have taken data with 18 different beam/energy combinations with the TimePix version of the Medipix2 technology at HIMAC and are analyzing them to determine the energy and charge resolution capability of the detector using various tract-structure techniques. The LET of traversing particles can be measured directly, but in order to provide a distinction between the potential for a depth-dose prediction and a simple dose equivalent measurement in the detector itself, some information regarding the energy and charge of the particles producing each track is required. A direct online conversation to water (and tissue)-equivalent dose has been deployed in the prototype and software is being developed to generate dose-equivalent outputs directly from the raw detector output as well. A satellite with 4 TimePix devices will be launched in a 600 Km 98 degree orbit in early 2012 as part of a UK outreach program. A status report on the present capabilities of this next-! generation dosimeter and area radiation monitor will be presented.

The ground-based development of the TimePix version of the Medipix2 technology has continued at HIMAC with progress towards determining the ultimate charge and energy resolution of a single stand-alone device. Software has been developed to produce dose and dose equivalent outputs directly from the detector interface, and studies have been undertaken in electron beams. 4 TimePix devices will be launched as part of a UK satellite payload in a 96 degree inclination polar (Sun Synchronous) orbit at ~650 km altitude in early 2012. Preparations for that mission are ongoing.

The sensitivity of a new type p-MOSFET dosemeter to high energy protons

S. Stoulos, M. Fragopoulou, M. Zamani, E. Benton, Y. Uchihori, S. Siskos, T. Laopoulos, V. Konstantakos, G. Sarrabayrouse

School of Physics, Nuclear and Elementary particle section, Aristotle University of Thessaloniki

p-MOSFET based dosemeters have many advantages that make them attractive in space radiation dose measurements. The new type p-MOSFETs, with thick gate insulator, were manufactured at LAAS-CNRS Laboratory, Toulouse, France. In order to measure their sensitivity to high energy protons they have been irradiated at HIMAC accelerator through ICCHIBAN collaboration. The results show a sensitivity of 0.06-0.1 mV/mGy which is higher than 0.03 mV/Gy presented in literature for other types of MOSFETs. Their sensitivity can be improved up to 2 mV/mGy by using a stack of two identical MOSFETs of the same type.

Portable High-Energy Neutron Spectrometer for Active Diagnostics of Radiation Environment aboard the ISS

Kolychev S.A.[1], Kovalev N.V.[1], Kudryashev N.A.[1], Ryzhov I.V.[1], Saulskiy A.V.[1], Smirnov A.N.1, Tutin G.A.[1],Shurshakov V.A.[2], and Nikolaev I.V.[3]

[1] V.G. Khlopin Radium Institute, State Atomic Energy Corporation “Rosatom”,[2] State Research Center of the Russian Federation, Institute of Biomedical Problems, Russian Academy of Sciences, [3] S.P. Korolev Rocket and Space Corporation “Energia”

A detailed study of neutron fields aboard manned spacecrafts is of crucial importance for mapping out an effective risk reduction strategy. Neutron field inside a spacecraft is largely formed by secondary neutrons produced by high-energy charged particles of galactic and solar origin and the trapped radiation in their collisions with spacecraft structures. The neutron spectrum extends from thermal to GeV energies, but the most radiation effects on crewmembers are produced by neutrons in the energy range from 0.2 eV to 200 MeV. Neutron measurements in space remain a difficult problem especially at high energies. We report here on activity of KRI, IBMP and RSC “Energia” aimed at development of a portable high-energy neutron spectrometer (PHENS) for real-time measurements aboard the International Space Station.

In PHENS, a stack of thick silicon detectors is used as neutron-detecting element. The detector measures energy deposition spectrum of heavy recoils and light charged particles due to nuclear interactions (elastic and inelastic) between energetic neutrons and silicon nuclei. To separate neutrons from primary and secondary charged particles the silicon detector assembly is surrounded with anti-coincidence shield fabricated from CsI(Tl) crystals with PIN-diode readouts. The energy deposition spectrum measured by the silicon detectors is converted to the incident neutron energy spectrum using an unfolding procedure, for which the detector response function has to be known for a wide set of neutron energies.

The PHENS design is presented as well as preliminary results on response function measurement at 14 MeV. The outlook for the calibration measurements (up to 200 MeV) at the “white” neutron source GNEIS (Petersburg Nuclear Physics Institute, Gatchina) is also discussed.

Intercomparison measurements with Liulin and TEPC Hawk in HIMAC beams

Ondrej Ploc[1,2], Yukio Uchihori[1], Hisashi Kitamura[1], Satoshi Kodaira[1], Nakahiro Yasuda[1], Iva Ambrožová[2], Zlata Mrázová[2], František Spurný[2]

1 National Institute of Radiological Sciences, Chiba, Japan

2 Nuclear Physics Institute, Prague, Czech Republic

Liulin and TEPCs are often used for measurements onboard spacecrafts. We did several measurements with TEPC Hawk and several Liulins in HIMAC in order to compare measured values, namely LET spectra, fluence, absorbed dose and dose equivalent. We observed a difference in distributions of events number in ADC channels measured with two identical Liulins irradiated by heavy ions under identical conditions. In order to measure dose quantities correctly, a recalibration of Liulins was needed. We did it using PHITS. Further, we studied the effect of thicknesses in front of active volume of different models of Liulin and Hawk. We calibrate Liulin to measure LET spectra in a broad parallel beam impinging detector under specified angle to get values comparable with Hawk's lineal energy spectra. Taken into account the different thicknesses in front of active volumes, a good agreement between measurements with Liulin and Hawk in HIMAC can be stated.

The preliminary results of the Proton-ICCHIBAN-2 experiments for luminescence detectors

Yukio Uchihori[1], Nakahiro Yasuda[1], Eric Benton[2], Hisashi Kitamura[1], Satoshi Kodaira[1], Ondrej Ploc[1,5], Thomas Berger[3], Michael Hajek[4], Iva Jadrnickova[5] and ICCHIBAN Participants

(1) National Institute of Radiological Sciences, Chiba, Japan; (2) Oklahoma State University, Still-water, USA (3) German Aerospace Center, Institute of Aerospace Medicine, Cologne, Germany; (4) Institute of Atomic and Subatomic Physics, Technical University Vienna, Austria,(5) Nuclear Physics Institute, Prague, Czech Republic

For intercomparison of luminescence detectors (TLD, OSL, Luxel, RPL and so on), Proton-ICCHIBAN-2 experiments were performed on Jan. and Feb. in this year using lower LET proton beams. There are participation of 14 institutes and universities from 11 countries. Here, we will present results of characterization of the proton radiation field in NIRS cyclotron facility and preliminary results obtained from analysis of luminescence detectors by participants. Then, we would like to discuss comparison results from these data. In addition, coming experiments in the cyclotron facility in NIRS will be informed.

[1] E.R. Benton, E.V. Benton, A.L. Frank, Radiat. Meas., 35 (2002) 457-471.

[2] C.E. Johnson, E.R. Benton, N. Yasuda, E.V. Benton, Radiat. Meas., 44 (2009) 742-745.

Charged particle LET threshold determinations for the HPA neutron PADC dosemeter

L G Hager, R J Tanner, J S Eakins

Health Protection Agency, CRCE, UK

Charged particle LET threshold determinations for the HPA neutron PADC dosemeter L G Hager, R J Tanner, J S Eakins Health Protection Agency, CRCE, Chilton, Oxon, OX11 0RQ, UK. Abstract 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 rarely 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 either as direct collaboration with NIRS or as part of the EC-funde! d HAMLET project.

Measurements of short range tracks produced by target fragmentation reaction in CR-39 PNTDs by high energy proton beam exposure

S. Kodaira, N. Yasuda, Y. Uchihori, H. Kitamura, M. Kurano, H. Kawashima

National Institute of Radiological Sciences, Japan

High energy proton, main component of cosmic rays, dominates the radiation risk for astronauts in space. Although the linear energy transfer (LET) of proton is relatively lower than heavy ions, its flux is extremely high in cosmic rays. According to the results of space radiation dosimetry using CR-39 plastic nuclear track detectors (PNTD), it has been discussed that the secondary particles with high LET and short range produced by proton-induced target fragmentation reactions will give measurable additional dose contributions [1]. For the evaluation of such dose contribution, the 160 MeV proton beam exposures to CR-39 (BARYOTRAK) PNTDs were carried out in HIMAC. In principle, high energy proton with the LET of 0.5 keV/µm cannot make any tracks in CR-39 PNTDs because the LET detection threshold of CR-39 (BARYOTRAK) PNTDs is about 36 keV/µm. Therefore, we can detect only short range tracks of secondary particles produced by proton induced target fragmentation reaction in CR-39 PNTDs. The atomic force microscope (AFM) is useful tool to measure such short range tracks [2]. Exposed CR-39 PNTDs were etched ~2 µm from original surface. Produced short range tracks were measured using AFM. In this workshop, the preliminary results of short range track measurement will be presented.

Dose rate measurements of charged and neutral particles in the stratosphere

Esther M. Dönsdorf[1], Sönke Burmeister[1], Stephan Böttcher[1], Björn Schuster[1], Eric Benton[2], Bernd Heber[1],Thomas Berger[3]

[1]Institute for Experimental and Applied Physics, University of Kiel, Germany, [2]Department of Physics, Oklahoma State University, USA, [3] German Aerospace Center, Institute of Aerospace Medicine,Radiation Biology, Cologne, Germany

The interaction of the primary galactic cosmic rays with constituents of the atmosphere leads to a complex secondary radiation field at high altitudes. Of special interest for aviation and thereby also for radiation protection is the height up to 30 km where the radiation field consists of charged and neutral particles. For the determination of the dose rates up to this altitude in the Earth's atmosphere a stratospheric balloon flight will be performed in central Oklahoma which has a cutoff rigidity of about 4 GV. Onboard there will be two different active radiation detector systems to measure the dose of charged and neutral particles in the stratosphere. The first one is a silicon telescope similar to the DOSTEL. This instrument is used to measure the charged component of the radiation field. The second instrument is a so called phoswich detector. It is composed of two dissimilar scintillators optically coupled to each other and to a common photomultiplier tube. ! A combination of the fast plastic scintillator BC412 and the slow inorganic scintillator CsI(Na) is used. The objective of the phoswich detector is to distinguish between gammas and neutrons but it is also possible to measure charged particles with this setup. The aim of the balloon flight is to determine the dose measured with these two different instruments and in particular to differentiate between the dose induced by charged particles and by the different neutral components of the secondary radiation field at high altitudes. A description of the detection concept and the assembly of the instruments as well as first calibration results will be presented.

Status of the Intravehicular - Tissue Equivalent Proportional Counter (IV-TEPC) development for ISS

Edward Semones on behalf of the Advanced Radiation Instrumentation Project at NASA Johnson Space Center

NASA Johnson Space Center, USA

The next generation of tissue equivalent proportional counters for use on the ISS is currently being developed at NASA Johnson Space Center. The IV-TEPC will be a single, portable unit comprised of two tissue equivalent proportional counters, a control and data processor, readout and display electronics, electronic non-volatile memory, 1553 data bus hardware, and power supply. The IV-TEPC has successfully completed the critical design review and the project is proceeding toward flight hardware fabrication. The IV-TEPC is currently scheduled to fly on ISS late in 2011. Details of the IV-TEPC design and radiation performance testing results will be discussed.

A Sort-of Tissue Equivalent Proportional Counter for Space Radiation Dosimetry Application

Eric Benton, Tyler Collums, and Art Lucas E. V. Benton

Oklahoma State University

A Sort-of Tissue Equivalent Proportional Counter for Space Radiation Dosimetry Applications Eric Benton, Tyler Collums, and Art Lucas E. V. Benton Radiation Physics Laboratory Oklahoma State University, Stillwater, OK USA We are developing and characterizing the response of a modular, low-cost Sort-of Tissue Equivalent Proportional Counter (STEPC) for use in space radiation and atmospheric radiation dosimetry applications. The detector consists of a 2" diameter spherical ionization cavity and a preamplifier circuit mounted inside a pressurized, resealable canister. We refer to the detector as a STEPC because the five version currently being tested differ from one another in the composition of the material out of which ionization cavity is constructed. Versions made of A150 tissue equivalent plastic, acrylic, Nylon, polystyrene, and polyethylene are being characterized using energetic heavy ion beams at HIMAC and energetic proton beams at the ProCure proton cancer treatment center in Oklahoma City in order to investigate the effect of ionization cavity wall composition on detector response. The effects of fill gas pressure and composition, detector bias, and amplifier gas gain on detec! tor response are also being investigated. A version that incorporates a spectrometer, power supply, and data logger is currently being designed for use on high altitude balloon flights and we plan to conduct an initial flight in early 2011.

Proposal for Intelligent Crew Personal Dosimeter

Ts. Dachev[1], B. Tomov[1], Pl. Dimitrov[1], Yu. Matviichuk[1], Y. Uchihori[2], O. Ploc[2]

[1]*Space and Solar-Terrestrial Research Institute, Sofia, Bulgaria,*

[2]*National Institute of Radiological Sciences, Chiba, Japan*

The 15 years development, calibrations and use of the Liulin type personal dosimeters confirm their reliability to measure the absorbed doses and fluxes in aircraft and spacecraft. Since 2002 many attempts were made to predict and evaluate the equivalent doses from the spectra obtained by them. Now we are confident that apparent dose equivalent interpretation procedure in aircraft is well developed and can be used in wide range of case. From other hand the necessity of ISS crew for active dosimeter is still not solved problem. The 4 years efforts of the ESA study group, leaded by Dr. Guenther Reitz for development of new "European Crew Personal Active Dosemeter" (EuCPAD) for astronauts give the result that this dosimeter has to be a mixture of modules for measurement of charged particles and neutrons with mechanical dimensions maximum 105x67x20 mm, volume below 150 ml and mass below 250 g. This dosimeter is under development The purpose of this talk is: 1) To present the developed Liulin personal devices and to compare their dimensions with the proposed EuCPAD 2) To review the existing Liulin dose interpretation and radiation sources separation procedures 3) To be proposed a new "Intelligent Crew Personal Dosimeter" on the base of the existing Liulin type devices, which can be used by astronauts in internal and external vehicle activities. The possible improvements are seen in both hardware and software directions. After analysis of the available new les consumption electronic elements a decision for building of 2 detectors telescope can be reached. The new software will be able on the base of the analysis of the deposited energy spectrum to distinguish the different kind of radiation sources in space as GCR, Inner radiation belt protons and outer radiation belt electrons and to calculate, store and present on display the absorbed and equivalent doses.

Nine Years of the Radiation Monitoring System Operating in Service Module of ISS

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The report presents the data on the radiation monitoring system (RMS) operating and results of dose rate measurements during the period from August 2001 to August 2009 both for normal radiation environment and during solar particle events (SPE). Comparison of the data obtained with the RMS silicon detectors with the R-16 ionizing chamber data showed that for equal shielding conditions the measured values coincide within the accuracy of 20%. Comparison of the absorbed dose rate measured by the detectors located in various points of the Service Module (SM) showed that difference of doses measured in low and high shielded areas of the SM at undisturbed radiation conditions is notably stable and does not exceed a factor of 2. At the same time during the disturbances caused by SPE it can reach the factor of 30. This fact confirms the efficiency of a crew passage in the high-shielded area for decreasing SCR dose. Variations of GCR and ERB contribution to daily dose are considered. It is shown that the main part of the daily dose variations due to ERB contribution is caused by ISS altitude variations.

Dose Measurements Onboard the ISS with the Pille TLD System

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Peter Szanto[1]

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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 obtained by the Pille system will be presented. The results will be compared with previous measurement results.

Recent results of TLD and OSL measurements on board of the ISS

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The DOBIES (Dosimetry of biological experiments in space) project focuses on the use of a standard dosimetric method (as a combination of different passive techniques) to measure the absorbed doses and equivalent doses in biological samples during space experiments. In order to achieve this, following passive detectors are used: • thermoluminescent detectors (TLD) : LiF:Mg,Ti and LiF:Mg,Cu,P • optically stimulated luminescence detectors (OSLD) : Al2O3:C (Luxel) The SCK•CEN group will report on 2 biological experiments that have participated to shuttle flights at the ISS: BASE B/C and YING B. In both experiments passive TL and OSL detectors were incorporated. Next to these experiments, the SCK•CEN group also participated to the EXPOSE-E experiment. During this experiment dosemeters were exposed outside the ISS on the Eutef platform from 2007 to 2009. The first dosimetric results of this exposure will be presented. The DOSIS1 experiment aimes at mapping the doses in the Columbus module. In a collaboration with different institutes, dosemeters were exposed during 136 days at the ISS. The methodology and results from our dosimetric measurements will be presented as well. The properties of the passive detectors must be tested in radiation fields that are representative for the characteristics of space radiation. In the course of several years we have participated in international irradiation experiments, to characterize the high LET behavior of our detectors. These experiments have lead to an efficiency curve, that can be used to correct the space dosimetry results. The results on the characterization of our passive detectors at high energy fields are presented.

Radiation Monitoring Using Area PADLES on board the ISS Japanese Experiment Module, Kibo

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The radiation environments in the International Space Station are influenced by an 11-year cycle of solar activity, shielding conditions, occurrences of large solar flares, and so on. We, JAXA, have conducted continuous and fixed-point area radiation monitoring inside the Japanese Experiment Module, Kibo. The program is called 'Area PADLES.' At present, seventeen Area PADLES dosimeters, which consist of CR-39 PNTDs and TLD-MSOs (Mg2SiO4:Tb), are installed in Kibo's pressurized module and logistics module. These Area PADLES dosimeters are exchanged at every expedition. First area monitoring started at the same time as the installation of Kibo's pressurized module during space shuttle mission STS-124/1J on June 1, 2008; second during STS-119/15A on Mar. 16, 2009; third during STS-119/17A on Aug. 29, 2009; and fourth during STS-131/19A on April 5, 2010. Various life science experiments under the different space environments (space radiation and microgravity) are also being conducted aboard Kibo. We provide Bio PADLES dosimeters for these life science experiments to measure radiation doses. We also report the results of the space radiation dosimetry, which has been obtained by the Bio PADLES dosimeters to date, in addition to past results of area radiation monitoring on Kibo.

The DOSIS – Experiment onboard the Columbus Laboratory of the International Space Station – First mission results for the passive detectors of the DOSIS-1 experiment phase

Thomas Berger[1], Christine Körner[1], Christine Hill[1], Sönke Burmeister[2], Michael Hajek[3], Pawel Bilski[4], Tomasz Horwacik[4], Filip Vanhavere[5], Iva Ambrozova[6], József K. Pálfalvi[7], Zoltan Kató[7], Denis O´Sullivan[8], Nakahiro Yasuda[9], Yukio Uchihori[9], Hisashi Kitamura[9], Satoshi Kodaira[9], Eduardo Yukihara[10], Eric Benton[10], Neal Zapp[11], Ramona Gaza[11,12], Dazhuang Zhou[11,12], Edward Semones[11], Yvonne Roed[11,12], Matthias Boehme[13], Lutz Haumann[13], Günther Reitz[1]

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The DOSIS (Dose Distribution inside the ISS) experiment, under the project and science lead by the DLR, aims at the spatial and temporal determination of the radiation field parameters inside the European Columbus laboratory onboard the International Space Station. This goal is achieved by applying a combination of passive (Thermo- and Optical luminescence – TLD and OSL - and Nuclear track etch), as well as, active (silicon telescope) radiation detectors. The passive radiation detectors – so called passive detector packages (PDP) were mounted at eleven positions within the Columbus laboratory – aiming at the spatial dose distribution measurement of the linear energy transfer spectra, absorbed dose, and the dose equivalent with an nominal exposure time of six months. Two active silicon telescopes – so called- Dosimetry Telescopes (DOSTEL 1 and DOSTEL 2) together with a Data and Power Unit (DDPU) were mounted within the DOSIS Main Box at a fixed location beneath the European Physiology Module (EPM) rack. The DOSTEL 1 and DOSTEL 2 detectors were positioned at a 90° angle to each other for the precise measurement of the temporal and spatial variation of the radiation field, especially during crossing the South Atlantic Anomaly (SAA). The DOSIS-1 hardware was launched with the Space Shuttle Endeavour to the International Space Station on 15 July, 2009 and installed by European Astronaut Frank de Winne on 18 July, 2009. The first PDP set was downloaded after an exposure time of 136 days in November, 2009 and a second PDP set was installed in November, 2009 and downloaded in May, 2010 after an exposure time of 191 days. The active, silicon detector system has been continuously working since July, 2009. The presentation will give an overview about the DOSIS experiment and then focus on the intercomparison of TLD/OSL and nuclear track etch detector results from the DOSIS-1 experiment phase (July – November, 2009). First results for the TLD/OSL data show a variation of the absorbed dose rate within Columbus ranging from 220 to 300 µGy/d (data: DLR) with dose equivalent values at the DOSIS-Main-Box position beneath EPM reaching up to 700 µSv/d (Preliminary data: DLR).

Dose mapping by SSNTD inside the Columbus module of the ISS – DOSIS project

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AERI, Budapest

In the frame of the ESA Combined Radiation Dosimetry Package the DOSIS project intends to investigate the dose distribution inside the Columbus module of the ISS.

The first exposure of the detectors was carried out between July and November, 2009, while the second phase lasted from November, 2009 till May, 2010. The Atomic Energy Research Institute participated with SSNTD packages to measure the flux and the dose of cosmic rays above 10 keV/μm.

The evaluation method and the comparative results obtained on some selected locations will be presented in the form of LET spectra and tables containing dose values.

TL Dosimetry in Columbus during DOSIS-2

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Realized within the ESA European Programme for Life and Physical Sciences (ELIPS) under the direction of DLR, the DOSIS experiment is a multi-lateral research effort to determine absorbed dose, particle flux density and energy spectra at eleven differently shielded locations throughout the European Columbus laboratory of the International Space Station (ISS). The second passive detector suite, comprising thermally and optically stimulated luminescence dosimeters along with nuclear track detectors, was launched on 16 November 2009 by Space Shuttle Atlantis (STS-129/ULF3) and exposed in Columbus for 191 days during Increment 22. After having been returned to ground by Atlantis (STS-132/ULF4) on 26 May 2010, the detectors were read out and evaluated by the participating laboratories. In this paper, we are reporting results from thermoluminescence dosimetry using CaF_2:Tm (TLD-300) and LiF:Mg,Ti phosphors, the latter being enriched in 6Li (TLD-600) and 7Li (TLD-700), respectively. Absorbed dose rates ranged between 200 and 270 µGy/d. The contribution of (slow) neutrons is indicated through the high-temperature ratio in TLD-600. The presented data are compared with results from the DOSIS-1 experimental phase.

ISS Measurements at Solar Minimum (2008-2010)

GAZA, R.[1, 2], ZHOU, D.[1, 2], ROED, Y. [1, 2], STEENBURGH, R. [1], LEE, K. [1], FLANDERS, J. [1,3], SE-MONES, E.[1], ZAPP, N.[1]

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A summary of SRAG's 2008-2010 ISS radiation dosimetry results for inside vehicle radiation monitoring in Low-Earth Orbit will be presented, namely ISS expedition 18/ULF2 (11/15/2008-07/31/09) and ISS expedition 20/2J/A (07/15/2009-02/22/2010). ULF2 radiation measurement locations included ESA Columbus and JAXA Kibo modules. Moreover, 2J/A RAM measurement locations included the new Node 2 crew quarters (NOD2S5_CQ and NOD2P5_CQ). Both expedi-tions were flown at 51.6° inclination and 350-360 km altitude. The passive radiation results will be presented in terms of measured dose obtained using the luminescence de-tectors (i.e., Al2O3:C, LiF:Mg,Ti and CaF2:Tm), high-LET dose measured by the CR-39 detectors, and dose equiva-lent and quality factors calculated using the OSL/TL/CR-39 combination method. Quality factors obtained by passive radiation detectors will be compared with TEPC quality factors, for 2008-2010 ISS and Shuttle flights. In addition, results from the DOSIS 1 Project, in collaboration with the German Space Agency (DLR) and funded by the European Space Agency (ESA), will be presented. SRAG's participation to the DOSIS 1 exposure on ISS (07/15/2009-11/27/2009) in-volved passive radiation measurements at 11 different shielding locations inside the ESA Colum-bus Module. DOSIS 1 exposure on ISS overlapped for its whole 135 days duration with SRAG's 2J/A RAM exposure, thus a comparison between measured dose results will be shown. SRAG's DOSIS 1 luminescence detec-tors measured dose values between 174-250 µGy/day (Luxel, LiF) and 181-272 µGy/day (CaF2) dependent on differ-ent shielding locations. For detector X, the calculated dose equivalent was ~580 µSv/day.

Radiation Measured with Experiments DOSIS on the International Space Station (ISS)

D. Zhou[1, 2], R. Gaza[1],[2], Y. Roed[1,2], E. Semones[1], K. Lee[1], N. Zapp[1], D. O'Sullivan[3], G. Reitz[4], T. Berger[4]

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The primary radiation particles in the low Earth orbit (LEO) are mainly composed of galactic cosmic rays (GCR), solar energetic particles (SEP), particles trapped in the south Atlantic anomaly (SAA) and the albedo protons and neutrons scattered from the Earth's upper atmosphere. In addition to the primary particles, a variety of secondary particles can be generated through the interactions between the primary particles and the nuclei of the space craft's skin, internal instruments and equipments as well as structures, thus a very complicated radiation field with a wide range of particles' charges and energies is generated. The radiation field strongly varies with the locations on the ISS and a detail radiation measurement should be conducted so as to make the radiation received by astronauts as low as reasonably achievable (ALARA). DOSIS experiments can measure the distribution of radiation as a function of the different location and direction on the ISS by using active and passive dosimeters. For the passive dosimeters of DOSIS, thermoluminescence dosimeters (TLDs) and optically stimulated luminescence dosimeters (OSLDs) sensitive to low LET and CR-39 plastic nuclear track dosimeters (PNTDs) sensitive to high LET are used. The radiation LET spectrum with high LET (≥ 5 keV/μm water) can be measured with CR-39 detectors and the radiation quantities for all LET can be obtained by combining results measured using TLDs/OSLDs and CR-39 PNTDs. DOSIS-I experiments were conducted on board Columbus – EPM (European Physiology Module) from July to November 2009, the exposure time was 135 days. JSC-SRAG (Space Radiation Analysis Group) and DIAS (Dublin Institute for Advanced Studies) took part in the DOSIS experiments. This paper presents the radiation LET spectra measured with SRAG-DIAS CR-39 detectors (x, y, z) and the radiation dose measured with SRAG TLDs/OSLDs as well as the radiation results (total LET) combined from results obtained with TL/OSL and CR-39 dosimeters.

Radiation Measured in LEO for Space Mission STS-125 with Low Inclination

D. Zhou, R. Gaza, Y. Roed, E. Semones, K. Lee, S. Johnson, D. Fry,

Presenter : Neal Zapp

Radiation particles in LEO (Low Earth Orbit) are mainly composed of galactic cosmic rays (GCR), solar energetic particles (SEP) and the particles trapped in the south Atlantic anomaly (SAA). The intensity of the trapped particles varies strongly with the altitude and inclination, therefore radiation at low inclination is high comparing to that at high inclination. For the radiation measurements, JSC-SARG (Space Radiation Analysis Group) has been using both active dosimeter TEPC (Tissue Equivalent Proportional Counter) sensitive to all LET (Linear Energy Transfer) and passive dosimeters - TLDs (Thermoluminescence Dosimeters) and OSLDs (Optically Stimulated Luminescence Dosimeters) sensitive to low LET as well as CR-39 PNTDs (Plastic Nuclear Track Detectors/Dosimeters) sensitive to high LET. Radiation quantities (absorbed dose, dose equivalent and quality factor) for all LET can be obtained by combining data measured with TLDs/OSLDs and CR-39 PNTDs. TEPC, TLDs/OSLDs and CR-39 detectors were used for the STS-125 space mission (11-24 May 2009, 499.8 km, inclination 28.5o, 12.9 days, near solar minimum activity). LET spectra (differential and integral particle fluence, absorbed dose and dose equivalent) and radiation quantities were measured with TEPC and CR-39 PNTDs. Radiation quantities for all LET were also obtained by combining the results measured with TLDs/OSLDs and CR-39 PNTDs. Data were scanned and analyzed for two CR-39 detectors of the six PRDs (passive radiation dosimeters): PRD1 (above external airlock hatch, higher shielding and lowest radiation) and PRD2 (mid deck outer wall, starboard, lower shielding and highest radiation). This paper presents the LET spectra measured with TEPC and CR-39 detectors, radiation results measured with TEPC, TLDs/OSLDs and CR-39 detectors and the combined results for PRD1and PRD2.

The DOSIS – Experiment onboard the Columbus Laboratory of the International Space Station – First Mission Results From the Active DOSTEL Instruments

Soenke Burmeister, Johannes Labrenz, Rudolf Beaujean, Onno Kortmann, Thomas Berger , Matthias Boehme, Lutz Haumann and Guenther Reitz

CAU- *Kiel University*

Besides the effects of the microgravity environment, and the psychological and psychosocial problems encountered in confined spaces, radiation is the main health detriment for long duration human space missions. The radiation environment encountered in space differs in nature from that on earth, consisting mostly of high energetic ions from protons up to iron, resulting in radiation levels far exceeding the ones encountered on earth for occupational radiation workers. Accurate knowledge of the physical characteristics of the space radiation field in dependence on the solar activity, the orbital parameters and the different shielding configurations of the International Space Station ISS is therefore needed. For the investigation of the spatial and temporal distribution of the radiation field inside the European COLUMBUS module the DLR experiment DOSIS (Dose Distribution Inside the ISS) was launched on July 15th 2009 with STS-127 to the ISS. The experimental package was transferred from the Space Shuttle into COLUMBUS on July 18th. It consists in a first part of a combination of passive detector packages (PDP) distributed at 11 locations inside the European Columbus Laboratory. The second part are two active radiation detectors (DOSTELs) with a DDPU (DOSTEL Data and Power Unit) in a nomex pouch (DOSIS MAIN BOX) mounted at a fixed location beneath the European Physiology Module (EPM) inside COLUMBUS. After the successful installation the active part has been activated on the 18th July 2009. Each of the DOSTEL units consists of two 6.93 cm^2 PIPS silicon detectors forming a telescope with an opening angle of 120°. The two DOSTELs are mounted with their telescope axis 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 (SPEs). The data from the DOSTEL units are transferred to ground via the EPM rack which is activated approximately every four weeks for this action. The first data downlink was performed on July 31st 2009. First Results for the DOSTEL measurements such as count rate profiles, dose rates and LET spectra will be presented in comparison to the data obtained by other experiments. The contributions of the Kiel University were supported by DLR under grants 50WB0826 and 50WB1026.

ISS radiation environment anisotropies measured by ALTEA

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The detailed knowledge of the radiation environment inside the International Space Station is mandatory for an accurate radiation risk assessment. The uneven shielding of the Station induces a modulation of this environment which must be taken into account. We present here the first measurements of the Station radiation environment, discriminating particle trajectory and LET, made possible utilizing the 3D, LET-discriminated detection capability of the ALTEA-space detector. We bring evidences for anisotropy in the radiation flux of heavy ions between the main Station axis and normal directions. This anisotropy reduces integrating over all detected particles, showing that secondary particles produced in the most shielded direction approximately maintain flux isotropy.

ALTEA real-time monitoring of radiation environment inside the ISS-USLab and off-line data management.

L. Di Fino[1,2], M. Casolino[2], C. De Santis[1,2], M. Larosa[1,2], L. Narici[1,2], P. Picozza[1,2], V. Zaconte[1,2]

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ALTEA particle detector is composed by six silicon telescopes devoted at monitoring the International Space Station radiation environment. Real time telemetry is a distinctive feature of the particle detectors of ALTEA. The ALTEA experiment is onboard the ISS-USLab since August 2006 acquiring ~200MB/day for a total of about 300 million events. ALTEA allows real-time monitoring of the radiation environment inside ISS-USLab obtaining the particle flux, the LET rate, the dose rate, the equivalent dose rate, the LET spectrum and ion composition of fast particles. We will present the software structure, algorithm and implementation together with results from the latest data, including August 2010. The complete data set was also ingested in a database for the off-line analysis. The ALTEA database (ALTEADB), which relies on the well-known PostgreSQL engine, allows the users to perform complex queries to obtain particle fluxes, rates or LETs applying several selection criteria. A web interface named ALTEAWEB has been developed to provide an easy way access data. We present the ALTEADB and its web interface ALTEAWEB.

An Intercomparison Study of PADC Track Etch Detector Evaluation with a Semi-Automated and a Manual System between AERI, Budapest and DLR, Cologne

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The radiation environment encountered in space differs in nature from that on Earth, consisting mostly of high energetic ions from protons up to iron and heavier particles, resulting in radiation levels far exceeding the ones encountered on Earth by occupational radiation workers. The accurate knowledge of the physical characteristics of the space radiation field in dependence on the solar activity, the orbital parameters and the different shielding configurations of the International Space Station (ISS) is, therefore, needed to ensure reliable radiation protection for the crew. The combination of passive thermoluminescence detectors (TLD) and nuclear track etch detectors (PADC) for the determination of the LET spectra, absorbed dose and dose equivalent has been used onboard the ISS, both for area monitoring and as part of the personal dosemeters of the astronauts in the last years. Starting with the ICCHIBAN project a lot of effort has been put in the intercomparison of TLD and CR-39 data – especially aiming at a better understanding of the differences still seen in the results of space related measurements by different research groups. The aim of this work was the intercomparison of the evaluation of space exposed PNTD detectors by two different groups (DLR and AERI). The detectors were taken from two space experiments as "BLIND" samples. DLR provided detectors from the ALTEINO experiment while AERI provided detectors from the Space-ICCHIBAN experiment. A semi-automated track detection and measurement system, run by AERI and a manual track detection and measurement system, run by DLR were used for the evaluation of the detectors. Each institute provided to the other participant the calibration data, the removed bulk layer thickness and the bulk etch rate for its own detectors. The results of the standard evaluation method of both institutes showed very good agreement for the "short time etched" detectors (LET starting around 30 keV/µm). For the "long time etched" detectors the main differences are seen in the lower LET part of the spectra, especially in the range from 10 to 30 keV/µm, which is due to the difference in track detection (manual versus semi-automated system).

A proposal on CR-39 PNTDs analysis for space radiation Dosimetry

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The preliminary results of CR-39 PNTDs measured by some Institutes in the DOSIS-I experiment show some discrepancies on LET spectra and dose results [1]. For the understanding of those discrepancies, we tried to compare the dose results on the following view points: measurement position and area dependences and track selection criteria, by additional CR-39 measurements. In this workshop, the results of such trial measurement and a proposal on CR-39 PNTDs analysis will be presented.

[1] T. Berger et al., "The DOSIS (Dose Distribution Inside the ISS) Experiment onboard the Co-lumbus la-boratory of the ISS – Overview and first mission results", the 38th COSPAR, Bremen, Germany, 2010.

Measurements of cosmic rays inside the ISS and in low Earth orbit with Altcriss and Pamela experiments

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We will present cosmic ray data measured in 2006-2009 with the Altcriss and Pamela experiment. Altcriss data refer to nuclei from B to Fe and have been taken in various locations, shielding configuration and orientations in the Russian section of the ISS. Pamela is a satellite borne detector orbiting the Earth in a 70 deg inclination, 350-600km elliptical orbit. Data of protons of galactic, trapped and solar nature will be presented and discussed as input of cr flux to ISS orbit.

Space experiment BTN-Neutron onboard of Russian segment ISS

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The science goals and description of equipments BTN-M1 for first stage of space experiment “BTN-Neutron” onboard the Russian segment of the International Space Station are presented. The experiment deals with registration of fast and epithermal neutrons, X-rays, and gamma rays in near-earth space. Results of experiment for first three years as well the future stages of experiment are presented.

Measurements of neutron environment inside and outside of ISS

V.Lyagushin[3]; A.Kozyrev[1]; M.Litvak[1]; A.Malakhov[1]; I.Mitrofanov[1]; M.Mokrousov[1]; A.Sanin[1]; V.Tretyakov[1]; A.Vostrukhin[1]; V.Arkhangelsky[2]; I. Chernykh[2]; V. Petrov[2]; V.Shurshakov[2]; H.Ing[4]; R. Machrafi[4]; L. Toomi[5]

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Results of neutron dose measurements inside and outside International Space Station are presented. Measurements outside module «Zvezda» were conducted with Board Neutron Telescope (BTN) from 2007 to 2010. The telescope consists of three 3He counters and organic scintillator crystal (stylbene). BTN performs to work within the range of 0.1eV – 10MeV. Measurements inside module «Zvezda» were conducted with so called Bubble Detectors in the same energy interval. Comparison of results is presented.

Estimation of the International Space Station attitude effect on dose rate inside the Service Module when crossing the South-Atlantic Anomaly

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During orbital manned space flights aboard the International Space Station (ISS) considerable part of radiation dose is absorbed by cosmonauts when crossing the South-Atlantic anomaly (SAA) zone that is characterized by the radiation field anisotropy. Due to the rather complicated ISS configuration and a large amount of equipment aboard the station angular distribution of shielding at some point aboard the station is not uniform, as a rule. It leads that radiation level inside the station can depend on its attitude at some conditions. The ISS attitude influence on the data obtained by the Radiation Monitoring System (RMS) installed inside the Service module (SM) of the station has been investigated. It was shown that dose rate value registered by the RMS detectors could vary more than two times when changing of the ISS attitude. The method of calculating the anisotropic radiation field in the SAA region has been developed on the basis of the Earth radiation belt proton spectral-angular distribution model recently created at the Research Institute of Nuclear Physics of the Moscow State University. Using the method in combination with the SM shielding model allowed us to describe qualitatively the ISS attitude effect when calculating the dose rate at inner points of the station. Obtained calculation results on the dose rate dynamics have been compared with the data of the RMS detectors for two typical ISS trajectories of crossing the SAA zone (ascending and descending) and two different types of the station attitude relative to its orbit line. For all considered conditions, the deviations of the calculated values from the measured data near the center of the SAA region don't exceed 50%, as a rule, that can be regarded as a satisfactory agreement.

Comparison of methods for estimation of dose equivalent by means of Liulin semiconductor spectrometer placed on-board ISS

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Our department has used Liulin for measurements of H*(10) ambient dose equivalent on-board aircrafts since 1999. Recently, the method of H*(10) estimation was improved; this method takes into account different contribution of low and high LET radiation in the equatorial and polar areas. On the base of our experience with dose measurements we tried to develop improved method for estimation of dose equivalent on-board space-crafts. In comparison with the original method, in the new method we calculate dose equivalent for Galactic Cosmic Rays (GCR) area from contribution of three types of particles: low LET particles, high-energetic charged particles and neutrons. Methods which we use for calculation of dose equivalents in South Atlantic Anomaly (SAA) and Outer Radiation Belt (ORB) areas remain unmodified. The new method was applied to data from Liulin placed outside the Columbus module of ISS behind the 0.4 g cm-2 shielding. Data were acquired during the first two quarts of 2009. Results obtained using new and original method were compared. It was found that the dose equivalents calculated using the new method are higher by up to 40 % in comparison with the original method. Comparison of Liulin measurements with thermoluminescent and track-etch detectors (TLDs and TEDs) measurements is not simple because we do not have data from respective period and same place. However results will be compared with other available data from ISS space missions.

HAMLET – Human Model MATROSHKA for Radiation Exposure Determination of Astronauts – Current status and results

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The exploration of space as seen in specific projects from the European Space Agency (ESA) acts as groundwork for human long duration space missions. One of the main constraints for long duration human missions is radiation. The radiation load on astronauts and cosmonauts in space (as for the ISS) is a factor of ~ 100 higher than the natural radiation on Earth and will further increase should humans travel to Mars. In preparation for long duration space missions it is important to evaluate the impact of space radiation in order to secure the safety of the astronauts and minimize their radiation risks. To determine the radiation risk on humans one has to measure the radiation doses to radiosensitive organs within the human body. One way to approach this is the utilization of a human phantom called MATROSHKA (MTR), under the scientific project lead by DLR. It is dedicated to determine the radiation load on astronauts when staying within or outside the International Space Station (ISS). This ESA facility was launched in January, 2004. Currently, the MTR is in its fourth experimental phase inside the Japanese Experimental Module (JEM). The MTR mimics a human head and torso, it is an anthropomorphic phantom containing over 6000 radiation detectors to determine the depth dose and organ dose distribution in the body. It is the largest international research initiative ever performed in the field of space dosimetry and combines the expertise of leading research institutions around the world, thereby generating a huge pool of data of potentially immense value for research. Aiming at optimal scientific exploitation, the FP7 project HAMLET intends to process and compile the data acquired individually by the participating laboratories of the MATROSHKA experiment. Based on experimental input from the MATROSHKA experiment phases, as well as, on radiation transport calculations, a three-dimensional model for the distribution of radiation dose in an astronaut's body will be built up. The scientific achievements contribute essentially to radiation risk estimations for future interplanetary space exploration by humans, putting them on a solid experimental and theoretical basis. Data received up to now from the MTR experimental phases (MTR-1, 2A and 2B) are already implemented in the data base together with relevant experimental and scientific background data.

HAMLET: Ground Based Verification of the MATROSHKA Facility: Results from the experiments at HIMAC and GSI

Pawel Bilski[1], Thomas Berger[2], Christine Körner[2], Daniel Matthiä[2], Michael Hajek[3], József K. Pálfalvi[4], Tomasz Horwacik[1], Luke Hager[5], Rick Tanner[5], Sönke Burmeister[6], Johannes Labrenz[6], Monika Puchalska[7], Lembit Sihver[7] and Günther Reitz[2]

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The FP7 HAMLET project is devoted at one part to the data compilation from the MATROSHKA experiment and includes as a second part a big ground based detector intercomparison study at various heavy ion research facilities. Due to the fact, that in the framework of the MATROSHKA experiment several investigator groups applied different passive and active radiation detector systems for the evaluation of skin and organ doses using an anthropomorphic head/torso phantom onboard the International Space Station an intercomparison of the detector properties is a prerequisite for a concise space data compilation.. The first aim of these studies is the intercomparison of the relative efficiency of thermoluminescence detectors (TLD) to a simulated heavy ion space radiation environment by the joint irradiations of TLDs from various groups. The second aim are irradiations of the ground based model (phantom head) of the MATROSHKA facility equipped with passive (TLDs and Nuclear Track Etch Detectors (NTD)) as well as active radiation detectors (Silicon Scintillator Devices (SSD)). This allows the direct intercomparison of the various detector systems measurements inside the phantom head and further comparison of experimental results with simulations by Monte Carlo codes as GEANT4 and PHITS. Most of the experiments were realized at the NIRS, Chiba, Japan, exploiting the HIMAC accelerator. Between May 2008 and May 2010, four irradiation campaigns were conducted, using helium, carbon, silicon and iron beams (in the energy range from 150 to 500 MeV/amu). Additionally, two irradiations were realized at the GSI, Darmstadt, Germany, using 1GeV/amu iron and nickel beams. The talk will give overview of the performed experiments and will present a summary of the available TLD and NTD results.

Quasi-stable radiation belt in the slot region observed by MATROSHKA

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MATROSHKA (MTR) is an ESA experiment facility under the science and project lead of DLR, Cologne. The radiation exposure inside a human phantom is measured by active and passive detectors. The DOSimetry TELescope (DOSTEL), built at CAU, Kiel in cooperation with DLR, Cologne is a particle telescope consisting of two Si-semiconductor detectors. Count rates as well as energy deposit spectra are measured by this instrument. The MATROSHKA facility is on board The International Space Station (ISS) since January 2004. The active instruments were operating during the first mission phase (MTR-1) where the phantom was mounted outside the Zvzeda module (Service Module SM) of the ISS from February 2004 to August 2005. In 2008 the active instruments were operating again in another mission phase (MTR-2B). During MTR-2B the MATROSHKA facility was mounted inside the SM of the ISS. The DOSTEL measurements during these two experiment phases showed the expected enhanced dose rates d! uring transits through the inner radiation belt (SAA) over the South Atlantic and transits through the outer radiation belt at the highest magnetic latitudes. In September and October 2004 – during the MTR-1 phase - an additional radiation belt in the so called slot region appeared. In this work the measurements of this quasi stable slot region belt will be presented and compared to results of other experiments.

PHITS simulations of MATROSHKA-1 experiment at ISS

M. Puchalska, L. Sihver, T. Sato, T. Berger and G. Reitz

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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 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 was launched in January 2004 and has measured the absorbed doses from space radiation both inside and outside the ISS. Here the comparison of measured and calculated doses and organ doses in the MTR-1, located outside the ISS, will be presented.

MATSIM – The Development and Validation of a Numerical Voxel Model based on the MATROSHKA Phantom

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The AIT Austrian Institute of Technology coordinates the project MATSIM (MATROSHKA Simulation) in collaboration with the Vienna University of Technology and the German Aerospace Center (DLR). The project is funded by the Austrian Space Applications Programme (ASAP). The aim of the project is to develop a voxel-based model of the MATROSHKA anthropomorphic torso used at the International Space Station (ISS). The numerical model developed in the frame of MATSIM project is validated by reference measurements in neutron and photon fields on ground. Exposure of the MATROSHKA phantom to Co-60 photons was realized in the standard irradiation laboratory at Seibersdorf, while investigations with neutrons were performed at the thermal column of the Vienna TRIGA Mark-II reactor. The phantom was loaded with passive thermoluminescence dosimeters. The simulation of the experimental set-up was done using the Monte Carlo code FLUKA. An overview of the numerical model and a comparison between the simulated and measured values for the photon and neutron irradiations of the detector-equipped phantom torso will be presented.

MATROSHKA-R experiments: Results obtained with passive detectors in 2005-2009

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The contribution deals with the results obtained with passive detectors (thermoluminescence and plastic nuclear track detectors) within the scope of MATROSHKA-R experiments. The detectors were placed at various locations inside the Russian part of ISS, and also on the surface and inside the Russian spherical phantom. During 2005-2009, several exposures were performed; many data were accumulated in these experiments. Variation of dosimetric quantities (LET spectra, absorbed dose, and dose equivalent) with the position of the detectors inside the ISS as well as with the phase of solar cycle and orbit parameters of ISS will be discussed.

Calculation of Bubble Detector Response Using Data from the Matroshka-R Study

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The bubble detector is a passive dosimeter developed in Canada and has been used for neutron radiation monitoring in space since 1989. During 2006-2008, bubble detectors were used in the Matroshka-R study aboard the International Space Station (ISS) during four expeditions (ISS-13, -14, -15 and -16). Using the bubble-detector data, along with differential-flux data calculated using the CREME code, and bubble response data of neutrons, protons and heavy ions, calculations were performed to determine the contribution of charged particles to bubble formation in the detectors. The final results suggest that charged particles have a negligible (< 0.5%) contribution to the bubble count and that shielding parameters may be altered with only a small change in the results. Results from this analysis will be presented, as well as response data for neutrons, protons and heavy ions, based on a comprehensive review of all literature regarding studies using the bubble detector.

Overview on the Radiation Quantities Observed by Liulin-5 Instrument in the Spherical Tissue-Equivalent Phantom on ISS

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The objectives of Liulin-5 experiment are studying the dynamics of depth-dose distribution of the orbital radiation field in a human phantom and mapping the radiation environment in the phantom and its variations with time and orbital parameters (such as solar cycle, solar flare events and altitude). The particle telescope Liulin-5 measures the linear energy transfer spectrum, flux and absorbed dose rates for electrons, protons and the biologically relevant heavy ion components of the cosmic radiation, simultaneously at three depths of the phantom\'s radial channel. In this report we present some results for radiation quantities inside the phantom obtained from different components of the complex radiation field in ISS in the period July 2007-April 2010.

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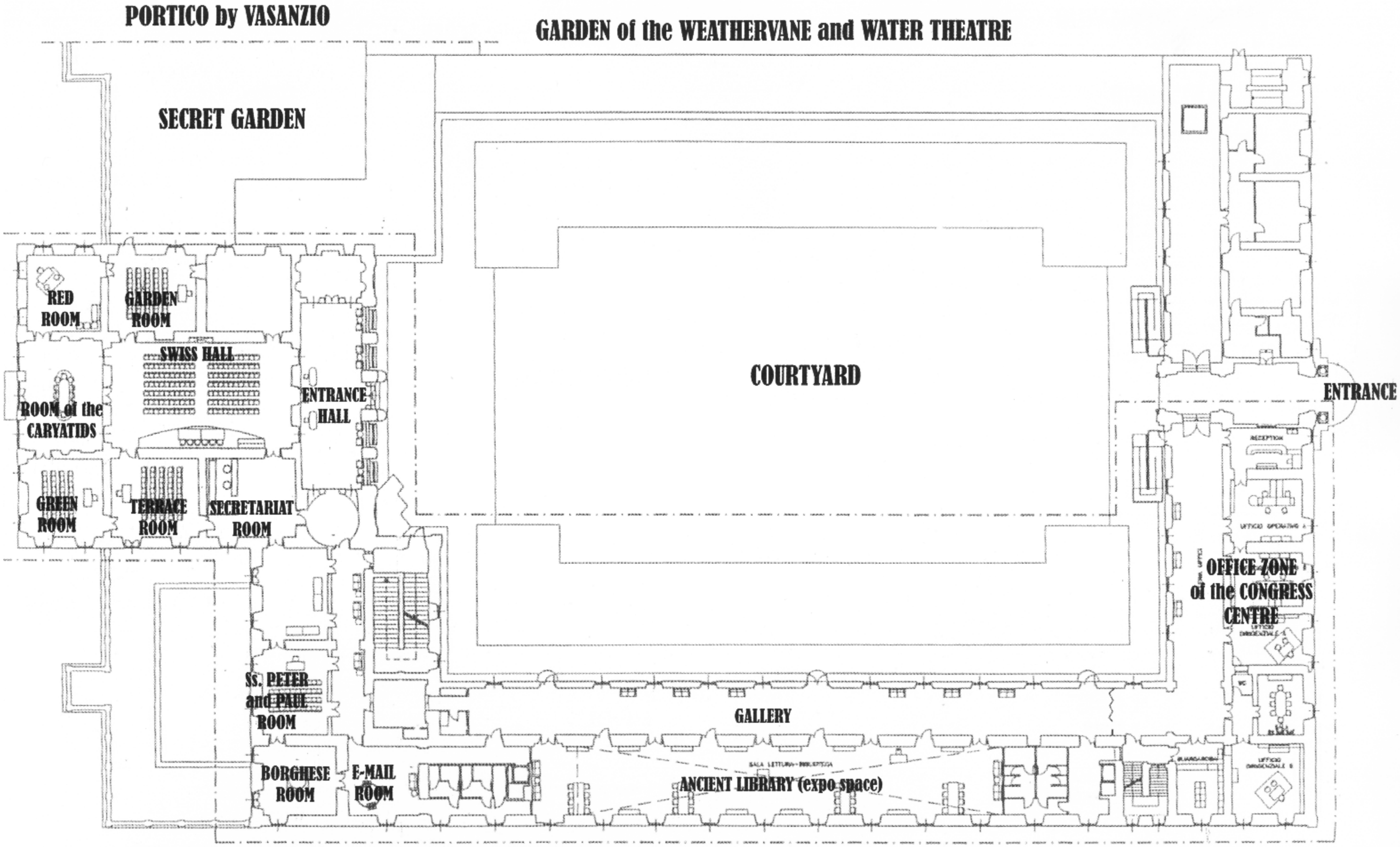

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