Scuola Nazionale Biennale
"Rivelatori ed Elettronica
per Fisica delle Alte Energie, Astrofisica,
Applicazioni Spaziali e Fisica Medica"

VI Edizione

INFN Laboratori Nazionali di Legnaro

23-27 Marzo 2015

Descrizione delle lezioni

Lunedì 23 marzo 2015 (pomeriggio)
Radiazione e rivelatori a semiconduttore: introduzione
Chairman: Dario Bisello
(Dipartimento di Fisica e Astronomia, Università di Padova e INFN Sezione di Padova)

14.00-15.40 **Introduzione al danno da radiazione: concetti base e quantità fisiche**
*(*Introduction to radiation damage: basic concepts and Physics)
Jeffery Wyss*, DIMSAT, Università di Cassino e INFN Sezione di Padova*

L'interazione fra radiazione e materia è alla base sia del funzionamento di rivelatori e di sistemi microelettronici per applicazioni scientifiche e tecnologiche sia, in alcuni casi, del loro malfunzionamento. L'importanza del concetto di radiazione e di danno da radiazione investe molti campi. É di notevole interesse per tutte le attività agli acceleratori di particelle e sui satelliti, dalle scienze di base (Fisica delle Alte Energie, Astrofisica, Scienze dei Materiali), alle attività commerciali nello spazio, per l'avionica, la medicina nucleare (diagnostica e terapia), e le applicazioni industriali. Garantire il corretto funzionamento dei rivelatori e dell'elettronica è importante soprattutto quando questi sistemi devono lavorare in ambienti ostili per la presenza di radiazione. Non è perciò sorprendente che lo studio del danno da radiazione costituisca un campo molto attivo nella ricerca applicata. In questa lezione illustrerò i concetti essenziali, le definizioni e le grandezze in gioco (dose, Linear Energy Transfer, Non-Ionizing Energy Loss, Single Event Effect, cross-section). L'approccio sarà elementare e di ampio respiro. Lo scopo è fornire ai novizi gli strumenti di base per la comprensione di articoli più tecnici.

16.10-17.50 **Dalla giunzione pn al rivelatore a semiconduttore**
(From pn junction to semiconductor detectors)
Gabriele Simi*, Dipartimento di Fisica e Astronomia, Università di Padova e INFN Sezione di Padova*

I will start from the basic properties of the pn junction relevant for the detection of ionizing radiation (band gap, carrier density, depletion etc.). I will then analyze the interaction of ionizing radiation with matter and the mechanism of signal formation in semiconductor devices. The relevant sources of noise will also be covered, including the important effects of radiation damage (defect formation, surface charge etc.) for the detector design. I will then discuss the application of the basic technology to segmented particle detectors, in particular strip and pixel detectors. I will also briefly discuss the application to the detection of light (avalanche photodiodes and silicon photomultiplers) presenting the basic principles of operation of these devices. I will then describe the application to complex detectors, in particular tracking detectors, starting from the basic design parameters (position and momentum resolution), the pattern recognition, and the requirements for high radiation and high occupancy operating conditions with examples from real experiments.

Martedì 24 Marzo 2015 (mattina)
Rivelatori a semiconduttore: effetti delle radiazioni e stato dell'arte
Chairman: Riccardo Rando
(*Dipartimento di Fisica e Astronomia, Università di Padova e INFN Sezione di Padova*)

9.00-10.40 **Danno da radiazione macroscopico in rivelatori a semiconduttore**
(Macroscopic radiation damage in semiconductor detectors)
Carlo Civinini, *INFN Sezione di Firenze*

Beyond particle fluences of 10^{14}-10^{15} cm^{-2} the macroscopic performances of a semiconductor detector (i.e. signal to noise ratio, position resolution, high rate capability) start to decrease. The subject of the first part of the lecture is to explain the mechanism of the radiation damage summarizing the principle of operation of a solid state detectors: signal formation and electronic noise. The key points, where the sensor macroscopic performance reduction turns up, will be described. The present research and development activities on silicon detectors are trying to push the sensor surviving limits to employ this kind of charged particle detecting systems in highly problematic environment, such as the next generation LHC experiments, where fluence of the order of 10^{16} cm^{-2} will be reached. The second part of the lecture will describe some of these solutions, which aim at mitigating the radiation effects on the detectors keeping them alive for the entire experiment lifetime.

11.10-12.50 **Danno da radiazione microscopico in rivelatori a semiconduttore**
(Microscopic radiation damage in semiconductor detectors)
Mara Bruzzi, *Dipartimento di Energetica, Università di Firenze e INFN Sezione di Firenze*

Semiconductor-based devices are widely used in a variety of fields of application characterized by an hostile radiation environment. For this reason, radiation-damage research on them has received extensive attention in past years, in order to assess the radiation-induced performance degradation in operational conditions. This lecture presents an overview on microscopic disorder and its influence on device performance, with special reference to detectors developed for High Energy Physics experiments.

Martedì 24 Marzo 2015 (pomeriggio)
Rivelatori a semiconduttore: effetti delle radiazioni e stato dell'arte
Chairman: Flavio Dal Corso
(INFN Sezione di Padova)

14.00-14.50 **Rivelatori a pixel monolitici per Fisica delle Alte Energia**
(Monolithic pixel detectors for High Energy Physics)
Walter Snoeys, *CERN, Svizzera*

Monolithic pixel detectors integrating sensor matrix and readout in one piece of silicon are now making their way in particle physics. They offer significant advantages compared to hybrid solutions: detector assembly is facilitated and production cost reduced, charge collection electrodes can be realized with very small capacitance values (~ a few fF!) yielding extremely favorable power-signal-to-noise performance.

Monolithic detectors have been successfully implemented, but it has been difficult to fabricate them in a high-volume standard CMOS process and combine a very low capacitance electrode with full depletion of the sensitive layer, required for extreme radiation tolerance. Monolithic detectors are now installed for the STAR experiment and adopted for the ALICE ITS upgrade where radiation tolerance requirements are less stringent. With more and more CMOS technologies becoming available on substrates compatible with particle detection, it is likely that one or more of the many ongoing developments will provide a solution to address even the most challenging applications, either in the form of a monolithic detector or an advanced form of a hybrid detector.

This presentation will concentrate on monolithic detectors, with the design of device and readout, and will also present the development for the ALICE ITS upgrade as an example of such detectors.

14.50-15.40 **Rivelatori a pixel con tecnologia CMOS ad alta tensione**
(High Voltage CMOS pixel detectors)
Giovanni Darbo, *INFN Sezione di Genova*

Silicon pixel detectors are around since more that 30 years. The "classic" pixel detectors use a high resistivity silicon sensor bump-bonded to a read-out chip. More recently fully monolithic pixel detector found their way in collider experiments like STAR and the upgrade of ALICE at the HL-LHC. Monolitic pixel detectors, as today, have found applications for experiment with moderate radiation dose and relatively simple read-out architectures. On the other side hybrid pixel detectors have been developed for extremely high doses and event rates, but use low scale (not for commercial applications) industrial processes for sensors and bump-bonding.

In the last few years, a new approach is attracting interest for large area applications of pixel detectors: High Voltage CMOS (HV-CMOS) pixel detectors. These detectors use a CMOS technology designed for high voltage applications. Such technology allows a design where few tens or even hundred volt is applied to the substrate of the chip. The amplifiers in each pixel collect the charge in the depleted region of the substrate for a depth of few tens of microns. Collection by drift instead of diffusion makes these devices faster and more radiation hard (significant charge is also collected in presence of trapping due to radiation damage). One of the drawback of the HV-CMOS technologies is the minimum feature size that limits the complexity of the architecture needed for high rate applications as in the ATLAS and CMS upgrades. A possible solution is the use of a hybrid approach with only amplifier or amplifier/discriminator in the HV-CMOS sensor chip coupled to a high density read-out chip. Such coupling can be done through a dielectric glue layer as in the Capacitive Coupled Pixel Detectors (CCPD).

The lecture will illustrate this type of detectors, with possible applications to the upgrades of ATLAS and CMS.

16.10-17.00 **Lfoundry: Industria italiana di semiconduttori: settori di interesse, tecnologie, operatività e attività di punta**
(LFoundry - an Italian based, open silicon foundry in the center of Italy - Company description, technologies, capabilities and main activities)
Giovanni Margutti, *Lfoundry, Avezzano*

Lfoundry is a silicon foundry located in the centre on Italy (Abruzzo). The first half of the course will give an overview of the productive site and its role in the development and fabrication of silicon sensors and other More than Moore related technologies. After a brief introduction covering the definition and the main activities held in a silicon foundry, a specific description of the Avezzano plant will be given, including a brief overview of the site (location, dimensions, history, products). Some more details concerning further R&D activities will be also given. The second part of the lecture will consist of an introduction to the silicon sensors (history, main characteristic and features) with particular emphasis to the CMOS Active Pixel Sensors.

17.00-17.50 **Rivelatori CMOS a Pixel Attivi a LFoundry: flusso di produzione, fattori di qualità, e criticità da affrontare dalla progettazione alla realizzazione del dispositivo**
(CMOS Active Pixel Sensors at LFoundry: production flow, quality factors and criticality to be faced from the device concept to the production phase)
Giovanni Margutti, *Lfoundry, Avezzano*

The lecture will give an highlight of the main phases of the production flow of a CMOS Active Pixel Sensors. The main modules and building blocks of silicon sensors and the link to their properties will be shown and discussed. In the second half of the discussion, the main quality factors (QE, dark I, sensitivity, SNR, etc. etc) will be briefly reviewed, mainly aimed to emphasize the criticalities to be faced and the precautions needed to ensure good sensors performances, from the design to the production phase.

Mercoledì 25 Marzo 2015 (mattina)
Elettronica per Fisica delle Alte Energie e Spazio
Chairman: Pierluigi Zotto
(*Dipartimento di Fisica e Astronomia, Università di Padova e INFN Sezione di Padova*)

9.00-10.40 **Elettronica di front-end per tracciatori in silicio**
(Font-end electronics for silicon trackers)
Valerio Re, *Dipartimento di Ingegneria e Scienze Applicate, Università di Bergamo e INFN Sezione di Pavia*

In questa lezione verranno discussi i principi generali e le tecnologie di realizzazione dell'elettronica di lettura per i tracciatori in silicio a pixel e a microstrip che vengono utilizzati nei moderni esperimenti di Fisica delle Alte Energie.

L'elevatissima granularità di questi rivelatori richiede di utilizzare circuiti di front-end a segnali misti fabbricati in tecnologie ad altissima densità di integrazione. Saranno analizzati i criteri di progetto che portano tali circuiti a soddisfare severi requisiti fra cui basso rumore, elevata velocità, bassa dissipazione di potenza ed elevata resistenza alle radiazioni. Verranno inoltre esaminati i problemi fondamentali che devono essere affrontati nella realizzazione di un circuito microelettronico integrato di front-end, dal progetto dei blocchi analogici alla definizione dell'architettura digitale di lettura del chip. Infine la lezione esaminerà alcune delle soluzioni che sono state adottate in chip di lettura utilizzati nelle applicazioni sperimentali. In particolare, verranno discusse le soluzioni tecnologiche e progettuali basate sul processo CMOS 65 nm, attualmente perseguite nello sviluppo dei circuiti microelettronici per la lettura dei rivelatori a pixel per gli upgrade dei tracciatori negli esperimenti a LHC previsti per la prossima decade.

11.10-12.50 **Danno da radiazione ionizzante e Effetti da Evento Singolo in dispositivi e circuiti elettronici**
(Ionizing radiation and Single Event Effects in electronic devices and circuits)
Lodovico Ratti, *Dipartimento di Ingegneria Industriale e dell'Informazione Università di Pavia e INFN Sezione di Pavia*

Electronic circuits and systems are employed in a number of different fields where some degree of radiation tolerance is required: these fields include, to mention but a few, space and avionic applications, high energy physics experiments, nuclear and thermonuclear power plants, medical diagnostic imaging and therapy. When operated in these environments, electronic systems may be directly struck by photons, electrons, nucleons or heavier particles, with a subsequent alteration of their electrical properties. The lecture will be concerned with ionizing radiation and single event effects on electronic devices and circuits. After a short introduction about the most important applications and environments requiring radiation hard electronics, the fundamental mechanisms underling performance degradation in electronic components will be described and discussed, paying particular attention to monolithic CMOS processes. Examples of radiation effects will be discussed through the analysis of experimental measurement results. Some emphasis will be placed on how radiation tolerance is affected by the evolution of microelectronic technologies and some examples of radiation hardness techniques in microelectronic design will be proposed.

14.00-14.50 **Attività di ricerca sugli Effetti da Evento Singolo al CIAE**
(Single-Event Effect activities at CIAE)
Guo Gang, *China Institute for Atomic Energy, Cina*

When an energetic charged particle in natural space environment passes through a sensitive region of microelectronic device, Single-event effect (SEE) occurs. SEE has been serious concerns for the reliability of devices used in satellite and spacecraft. The problems become more severe as the feature size of devices decreases continuously. It is necessary that the ground simulation test based on accelerator be carried out to evaluate the performance. Only the devices which ability of SEE hardening performance meets the requirement can be used in a specific space application. Beijing HI-13 tandem accelerator at China Institute of Atomic Energy has been widely used for this simulation. Irradiation techniques of broad-beam and micro-beam as well as the future plans about SEE will be briefly introduced in this talk.

14.50-15.40 **Programmi e ricerche sull'elettronica per lo Spazio in Brasile**
(Research activities on electronics for Space in Brasil)
Silvio Manea, *National Institute For Space Research (INPE), Brasile*

The Brazilian Space Program seeks to develop skills in the space-electronics area, where efforts are focused on getting electronic components radiation tolerant and specific functions that can be used on Brazil’s satellites. The National Institute for Space Research (INPE) established two programs intended to apply Brazil's technological knowledge of designing electronic components tolerant to radiation and the use of COTS components in satellite programs developed by INPE.

INPE has been the main space science inductor in Brazil, designing and building satellites to monitor our territory and to understand the global changes. Brazilian society has entrusted to INPE the mission of researching and manufacturing products that ensure access to space and contributing to global environmental knowledge.

16.10-17.00 **Componenti EEE: test di resistenza alle radiazioni e attivita' di R&D nell'Agenzia Spaziale Europea**
(European Space Agency EEE Component: Radiation Hardness Assurance and related R&D activities)
Cesar Boatella Polo, *European Space Agency, Noordwijk, Olanda*

The space environment is inhospitable to humans and the spacecraft utilised by us to access space its systems, subsystems and EEE component. An important element of the space environment is the abundance of high energy particles, constituting the natural space radiation environment. The space radiation environment detrimentally affects EEE components flown on ESA space missions. The impact on electronic components vary from slow degradation of electrical parameters, due to cumulative effects, or sudden unwanted events due to transient effects. The interplay between energetic particles impinging components in space, the particular radiation effect(s) induced and the subsequent electronic component response is complex.

To ensure that the EEE components selected and flown on ESA missions are suitable for their application when operated in their intended radiation environment, ESA initiates and runs a number of Radiation Hardness Assurance (RHA) related R&D activities. ESA RHA related R&D activities span topics from radiation characterisation of novel technologies (e.g. GaN, SiC, Deep-submicron, novel detector technologies etc.), R&D programmes in support of standardisation activities to radiation evaluation/qualification of EEE components. In this presentation, future ESA space missions are discussed in conjunction with technology needs, and associated R&D activities initiated and results obtained.

17.00-17.50 **La visione dell'industria sull'elettronica per applicazioni in ambiente spaziale: strategia di protezione alle radiazioni**
(Industrial vision on electronics for space environment applications: strategy to protect against radiation)
Mariolina Sarno / Roberta Mancini, *Thales Alenia Space, Italia*

Observation, Exploration, Navigation and Geosynchronous Communication satellite shall be designed to perform its function throughout the whole lifetime in the specified radiation environment.

The major factors that will affect the design of the space electronic systems are:

1) Total dose damage of electronics and solar arrays due to electrons and protons.

2) Single event phenomena (upsets, latchups, burnouts, transient, Hard Error, Functional Interrupt, ..) of electronics due to the cosmic ray, solar flare environments and trapped protons.

3) Displacement damage induced by protons.

All satellite systems require careful consideration of the effects of radiation.

Survival and successful operation of space systems in the space radiation environment can be ensured starting from the part selection and characterization, evaluation of radiation effects and identification of means to mitigate the system degradation due to space radiation.

Thursday 26th March 2015

RADFAC 2015 thematic day

A) DETECTORS

A1: 9.10-9.30) Modelling of diamond devices with TCAD tools

Arianna Morozzi, *INFN and University of Perugia (Italy)*

We propose suitable models and methodologies for device-level simulation of diamond devices within a commercial TCAD tool (Synopsys Sentaurus). The device-level simulation of such material is not straightforward within the state-of-the-art TCAD tools, consequently a new custom-defined "diamond" has been added to the TCAD library. The goal is reproducing the main physical and electrical characteristics of both single- and poly crystalline CVD diamond. A model based on the introduction of deep-level defects acting as recombination centers and trap states has been implemented. The modelling strategy has been validated by comparison with experimental results.

A2: 9.30-9.50) Results on FBK 3D pixel detectors for CM

Fabio Ravera, *INFN and University of Tourin (Italy)*

Results of laboratory and test beam measurements will be presented for FBK 3D silicon pixel detectors for CMS. In particular, 1E sensors (single readout electrode for each pixel), coming from the same wafers of the ATLAS-IBL production, read out by the new PSI46 digital chip developed for the Phase I upgrade of the CMS silicon pixel detector, have been tested on a 120 GeV proton beam at Fermilab, before and after being irradiated with 23 MeV protons at KIT, within the AIDA project, to fluences of 1-3-6-10x10^{15} n_{eq}/cm^2.

A3: 9.50-10.10) Radiation hardness study on double sided 3D sensors after proton and neutron irradiation up to HL-LHC Fluencies

D.M.S. Sultan, *INFN and University of Trento (Italy)*

Double-Sided-3D-pixels with passing-through columns, produced by FBK for the ATLAS-IBL, had a relatively low breakdown voltage (~50V before irradiation, up to ~180V after irradiation). A modified technology adopted later by FBK, where the junction columns have been slightly shortened and the ohmic columns remain passing through, has shown a great improvement in breakdown voltages up to more than 100 V before irradiation and almost 300 V after irradiation. This report addresses the electrical characterization of both types of sensors, irradiated with protons and neutrons up to the fluencies as the foreseen HL-LHC compliance.

B) TEST/QUALIFICATION OF ELECTRONICS FOR SPACE AND S-LHC

B1: 10.10-10.30) A Radiation qualification procedure for nanosatellites and high energy applications at the CHARM facility at CERN

Raffaello Secondo, *University of Montpellier (France) and CERN (Switzerland)*

Nanosatellites have become more and more attractive for space research and commercial applications. The investigation of mission constraints includes a full radiation qualification procedure very often highly expensive and time consuming. An alternative qualification methodology for space and high radiation environment applications is currently being studied at the new CERN High energy AcceleRator Mixed field facility (CHARM). A CubeSat mission based on the CERN Radiation Monitoring (RadMon) technology has been proposed to benchmark radiation fields measured at different orbits with experimental data collected in a space-like environment. The mission parameters are described together with the preliminary test results.

B2: 10.30-10.50) A method for measuring the effect of total ionising dose on temperature coefficients of semiconductor devices

Jiri Hofman, *Cobham RAD Solutions (United Kingdom)*

This work presents a new test method that allows in-situ measurements of radiation-induced changes in temperature coefficients to be made. The preliminary results of a pilot experiment on commercial PMOS transistors and voltage references will be presented and discussed.

B3: 11.20-11.40) Study of a thermal annealing approach for very high total dose environments

Stephanie Dhombres, *University of Montpellier and Systheia (France)*

Total dose effects remains one challenging issue for electronics for space or civilian nuclear applications. Embedded electronics components such as CMOS APS image sensor are sensitive to dose effect and it can result in a loss of functionality of the entire system.

For very high dose environments, solutions must be found to ensure system reliability and extend component lifetime. In this lecture, an analysis of isothermal annealing is done to recover electrical characteristics after total ionizing dose degradation. The analysis is based on experimental results on Power MOSFET and CMOS image sensor. Electric field impact during annealing is also investigated.

B4: 11.40-12.00) Evaluation of neutron-SEB thresholds of COTS power MOSFETs with TCAD simulations

Carlo Giordano, *University of Cassino (Italy)*

As well as heavy ions in space, terrestrial neutrons can induce Single Event Burnouts (SEB) on power MOSFETs, even at the sea level. The probability of SEB can be significantly reduced, de-rating the device’s maximum drain-source voltage down to a threshold value (SEB threshold voltage). In this work, we estimate the SEB threshold voltage of a commercially available power MOSFET by mean of TCAD simulations and we compare the simulation results with the experimental data obtained from irradiation tests performed with a moderated Am-Be neutron source.

B5: 12.00-12.20) Radiation-induced Single Event Transients Modeling on Ultra-Nanometric Technologies

Boyang Du, *Politecnico di Torino (Italy)*

The increasing technology node scaling makes VLSI devices extremely vulnerable to Single Event Effects (SEEs) induced by highly charged particles such as heavy ions, increasing the sensitivity to Single Event Transients (SETs). In this presentation, we describe a new methodology combining an analytical and a pattern-oriented simulative model for analyzing the sensitivity of to SET of ultra-nanometric technologies. The presentation includes simulative experimental results applied on the NanGate 15-nm technology library implementing a set of realistic benchmark circuits related to the ITC-benchmarks. Besides, experimental results are compared with radiation test experiment performed on a different technology.

B6: 12.20-12.40) Radiation vulnerability in 65 nm CMOS I/O transistors after exposure to Grad dose

Lili Ding, *INFN and University of Padova (Italy)*

This talk focus on the total ionizing dose effects of 2.5 V I/O transistors and 1.2 V core transistors from a 65 nm commercial bulk CMOS technology, which is a strong candidate for LHC upgrade. In particular, enhanced radiation vulnerability in I/O transistors comparing to core transistors is explored.

B7: 12.40-13.00) Noise performance of 65 nm CMOS Transistors Exposed to Ionizing Radiation

Elisa Riceputi, *University of Bergamo (Italy)*

The goal of this work is to provide an extensive analysis of total dose effects in devices belonging to a commercial 65 nm CMOS process, in the context of designing rad-hard analog integrated circuits for front-end applications in future colliders. The target total ionizing dose of 1 Grad will be reached in several steps. Static, signal and noise parameters were monitored before and after each irradiation step. The effects on key parameters such as threshold voltage shift and 1/f noise are studied and compared with previous CMOS generations devices behavior under irradiation.

C) IRRADIATION FACILITIES

C1-C5: 14.00-15.40) Invited talks on irradiation facilities in Italy

D) ELECTRONICS FOR HIGH ENERGY PHYSICS APPLICATIONS

D1: 16.10-16.30 Use of FPGAs in radiation areas in HEP experiments and colliders
Tullio Grassi, *FNAL (USA)*

In HEP detectors and accelerators, commercial-grade FPGAs have become extremely useful to build digital hardware tailored to specific requirements, including non-standard data processing and interfaces. Being commercial circuits, they are not (necessarily) tolerant to ionizing radiations. This point will be the focus of the talk.

D2: 16.30-16.50) A new analog front-end for the HL_LHC upgrade of the CMS pixel detector
Ennio Monteil, *INFN and University of Tourin (Italy)*

A next generation pixel readout chip is needed for the CMS pixel detector upgrades for HL_LHC. The main requirements are: smaller pixel size (50x50 or 25x100 um^2); very high hit rates (2 GHz/cm^2), unprecedented particle fluence (1 Grad in 10 years); higher output bandwidth; low power consumption; large areas IC. The CMOS 65 nm technology has been chosen to design the new readout chip. In particular the design of an analog front-end will be presented. The work is done in the framework of the RD53 collaboration and the CHIPIX65 project.

D3: 16.50-17.10) Radiation hardness techniques for the digital parts of the chip pALPID
Serena Panati, *INFN and University of Tourin (Italy)*

In view of the upgrade project of the Inner Tracking System (ITS) of the ALICE experiment at CERN LHC, pixel monolithic detectors 50um thick have been studied to reduce the material budget. The prototypes pALPIDE (prototype ALICE PIxel DEtector) are developed in a Tower Jazz CMOS 180nm process and some implementations of rad-hard systems have been provided. More specifically, this work deals with the techniques used for the digital parts in the block transmission of high-speed data (DTU Data Transmission Unit).

E) LASER & OPTICAL FIBERS

E1: 17.10-17.30) Radiation effects on semiconductor laser diodes

Giulia Marcello, *University of Cagliari (Italy)*

The effect of radiation damage on solid state photonic devices is studied by irradiating some laser diodes for telecommunication. In particular, a GaAs-based VCSEL emitting at 850 nm and an InP/InGaAsP edge emitter at 1310 nm have been exposed to 3 MeV protons.
The electro-optical characteristics have been measured just before and after the irradiation, and then monitored along some days. A surprising opposite evolution of the post-irradiation characteristics in the two types of laser is reported and interpreted.

E2: 17.30-17.50) Common problems in Time Domain Reflectometry attacked with the Ramer-Douglas-Peucker algorithm: from radiation effects on optical fibres to coaxial level monitoring

Francesco Cordella, *ENEA Casaccia (Italy)*

Long term exposure to ionising radiation induces transmission losses in optical fibres. When Time Domain Reflectometry (TDR) techniques are used to study these effects, some common problems may emerge. We propose here an application of the Ramer-Douglas-Peucker (RDP) algorithm for the analysis of the experimental results of a simple coaxial level monitoring sensor. The sensor is used as a level control device. An advanced automatic level detection system, using some undocumented built-in functions of MATLAB, allows an easy signal conditioning and data recording.

Venerdì 27 Marzo 2015 (mattina)
Applicazioni delle radiazioni e degli acceleratori in campo medico. Radiobiologia
Chairman: Dario Bisello
(*Dipartimento di Fisica e Astronomia, Università di Padova e INFN Sezione di Padova*)

9.00-9.50 **Particelle cariche: aspetti di rilievo nello Spazio e in terapia**
(Charge particles in therapy and Space)"
Marco Durante, *GSI, Germania*

Research in the field of biological effects of heavy charged particles is needed for both heavy-ion therapy (hadrontherapy) and protection from the exposure to galactic cosmic radiation in long-term manned space missions. Although the exposure conditions (e.g. high- vs. low-dose rate) are different in therapy and space, it is clear that a substantial overlap exists in several research topics, such as individual radiosensitivity, mixed radiation fields, and tissue degenerative effects. Late effects of heavy ions are arguably the main health risk for human space exploration, and with the increasing number of cancer patients treated by heavy-ion therapy, including young adults and children, this issue is now becoming the main source of uncertainty for the success of hadrontherapy as well. Reducing uncertainty in both cancer and non-cancer late risk estimates is therefore the first priority in heavy-ion radiobiology. In addition, researchers involved either in experimental studies on space radiation protection or heavy-ion therapy often use the same accelerator facilities.

9.50-10.40 **Rivelatori di frammentazioni di particelle: applicazioni nello Spazio e in terapia**
(Detectors for fragmentation in therapy and Space)
Vincenzo Patera, *Università di Roma "La Sapienza" e INFN Sezione di Roma 1*

The role of the nuclear fragmentation process in particle therapy and radioprotection in space will be discussed. The state of the art of the measurements in literature will be presented, as well as the features of some typical experiments of the past.

The design of possible future experimental setup for fragmentation measurements will be reviewed in terms of needed efficiencies and resolutions. The role of simulation software will also be discussed.

11.10-12.00 **Acceleratori di particelle in bio-medicina**
(Particle accelerators in bio-medicine)
Roberto Cherubini, *Laboratori Nazionali di Legnaro dell'INFN*

Driven by the particle and nuclear physicists' demand for ever increasing available energy to probe the matter structure and his proprieties, the development of charged particle accelerators offered since his beginning the unique chance to undertake a very wide spectrum of applied and interdisciplinary researches.

Beside the "proper" particle and nuclear physics investigations, the particle accelerators became sudden powerful tools in a variety of fields as material science and analysis, chemistry, biology, archaeology as well as in bio-medicine (radio-therapy, radio-diagnostics, nuclear medicine, ...) and industry.

In the lecture, after a general excursus on the main applications of the particle accelerators, especially in bio-medicine, particular emphasis will be paid to the accelerator-based radiation sources for radiation biology studies and charged particle radio-therapy (hadron-therapy) applications.

12.00-12.50 **Dalla microdosimetria alla nanodosimetria**
(From microdosimetry to nanodosimetry)
Valeria Conte*, Laboratori Nazionali di Legnaro dell'INFN*

Radiation-induced damage to living cells is governed, to the greater part, by the pattern of inelastic interactions of ionizing particles in sub-cellular targets (e.g. the DNA). In consequence, the radiation effectiveness should be defined more in terms of quantities, which are directly related to the particle-track structure than in terms of macroscopic quantities like absorbed dose and linear energy transfer (LET). At the same time, these quantities should be measurable by physical means. To tack this challenge, a track-structure based concept of radiation damage has been developed assuming that the initial damage to nanometre-sized volumes like the DNA is mainly due to the number of ionizing processes of single particles within a target volume or in its near neighbourhood. The radiation-induced damage probability is described, therefore, in terms of particle interaction probabilities in nanometric volumes (nanodosimetry) instead of micrometric volumes (microdosimetry). Three different types of nanodosimeters have been developed to date, which measure the frequency distribution of ionization cluster size, i.e. of the number of ionizations produced in a specified target volume by single ion tracks. To check the validity of the track-structure based concept of radiation quality, experimental radiobiological data are compared with nanodosimetric quantities derived from measured ionization-cluster size distributions.