VII International Course

Detectors and Electronics for High Energy Physics, Astrophysics, Space Applications and Medical Physics

INFN National Laboratories of Legnaro

3-7 April 2017

Abstracts of the lectures

April 3, Monday (afternoon)

14.00-14.10 **Welcome address**

Diego Bettoni *(Director of the INFN National Laboratories of Legnaro)*

Francesca Soramel *(Director of the Physics and Astronomy Department, University of Padova)*

Introduction to radiation and semiconductor detectors
Chairman: Riccardo Rando *(University and INFN Padova)*

14.10-15.50 **Introduction to radiation damage: basic physics and concepts**

Serena Mattiazzo *(DEI, University of Padova)*

The interaction mechanisms between particles and matter are both at the basis of the working principles of detectors and microelectronics systems developed for scientific and industrial applications and, in some cases, of their malfunctions. The study of radiation (natural and artificial) effects on semiconductor devices and microelectronic systems is an important and lively field of scientific and technological research. Tolerance to radiation is an important issue for all those applications where electronic devices and sensors have to survive in very harsh environments (space research, telecommunications, avionics, high energy physics, nuclear plants, medical applications, etc. etc.). In this lesson the basic concepts and the definitions of the physical quantities involved (dose, linear energy transfer, non-ionizing energy loss, single event effects, cross-section) will be introduced.

16.20-18.00 **Principles of semiconductor detectors**

Gian-Franco Dalla Betta *(University of Trento and INFN TIFPA)*

The aim of this lecture is to provide the attendees with the basic knowledge about semiconductor radiation detectors with emphasis on silicon, which are widely used in many application fields. Starting from a review of semiconductor physics concepts, the talk will cover the operation principle of semiconductor detectors, their main figures of merit, design, simulations and technological issues. Then, an overview of different types of semiconductor detectors will be given from simple pad (diode) detectors, to segmented detectors (strips and pixels), to more advanced detector concepts (i.e., drift detectors, CCDs, DEPFET, 3D and active edge detectors), also highlighting some hot topics such as avalanche based detectors (LGAD, SiPM) and CMOS monolithic active pixel sensors (MAPS).

April 4, Tuesday (morning)
Semiconductor detectors: radiation effects and state of the art)
Chairman: Gabriele Simi *(University and INFN Padova)*

9.00-10.40 **Macroscopic effects of energetic radiation on semiconductor detectors**

Gianluigi Casse *(Fondazione Bruno Kessler, Trento)*

The non-ionising energy lost by energetic radiation to the structure of semiconductor sensors damages the crystal and consequently modifies the electrical characteristics of the devices. All the parameters that are relevant to the performance of the sensors are changed: the leakage current, the full depletion voltage, the signal response to ionising particles, the inter-electrode resistance and capacitance in segmented detectors. These changes are degrading the performance of the sensors and lead to their failure after significant fluences of impinging particles. The design of the sensors can be engineered to increase the failure fluence. This lecture will go through the working principles of the semiconductor sensors and the parameterisation of their degradation, finally the design solutions and operation methods that can mitigate these effects and extend the lifetime of the detectors operating in very harsh radiation environments (i.e., the future upgrade of the Large Hadron Collider at CERN) will be discussed.

11.10-12.50 **Microscopic radiation damage in semiconductor detectors**

Mara Bruzzi *(University and INFN 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 semiconductor detectors 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 the device performance, with special reference to detectors developed for high energy physics experiments.

14.00-14.50 **The experience of silicon detectors at CDF**

Franco Bedeschi *(INFN Pisa)*

CDF was the first experiment to install a silicon vertex detector at an hadron collider. It was a very challenging development at the limit of the technology available at the time. It was made possible thanks to the vision and dedication of a handful of physicists and it laid the way for the much larger and sophisticated implementations on present and future experiments. All this aspects will be presented and discussed in the lecture.

14.50-15.40 **The ATLAS Inner Tracker upgrade for the HL-LHC**

Daniela Bortoletto *(University of Oxford, UK)*

CERN has planned an upgrade for the Large Hadron Collider (LHC), called the High Luminosity LHC (HL-LHC), which will increase the luminosity of the machine by a factor of 5, up to $5 \cdot 10^{34}$ $cm^{-2} \cdot s^{-1}$, leading to a data sample larger than 3000/fb by the end of the program. The upgrade, which will take place in the middle of the next decade, will significantly extend the physics reach of the LHC but will also lead to larger particle rates and radiation doses. The ATLAS detector will be extensively changed to meet these challenges. The entire tracking system of the ATLAS experiment will be replaced for the HL-LHC by an all-silicon detector called the ITk (Inner Tracker) which will include strip and pixels. An overview of the ITk and the ongoing R&D activities are presented.

16.10-17.00 **The CMS pixel detector and its upgrade**

Danek Kotlinski *(Paul Scherrer Institute, Zurich, Switzerland)*

The CMS pixel detector, build in the period 1998-2008, was installed in 2008 and was taking data until the end of 2016. It was built by three barrel layers (BPIX) and two forward disks in each endcap (FPIX). During the 2008-2016 data taking period, its performing characteristics have greatly contributed to the very successful physics analysis done by the CMS collaboration. In this lecture I will discuss the main design features of this detector and the most important performance parameters, i.e. position resolution and hit efficiency. I will also include some descriptions of the operational challenges faced during the data taking and the monitoring and calibration tasks, which are necessary in order to guarantee the high quality of the data.

The detector was designed for the nominal instantaneous LHC luminosity of 10^{34} $cm^{-2}\cdot s^{-1}$. Under the conditions expected in the coming years, which will see an increase by a factor of 2 of the instantaneous luminosity, the CMS pixel detector will see a dynamic inefficiency caused by data losses due to buffer overflows. For this reason the CMS Collaboration has built a replacement pixel detector, which has been installed during the winter shutdown 2016-2017. The upgraded CMS pixel detector will operate at full efficiency at the instantaneous luminosity of $2\cdot 10^{34}$ $cm^{-2}\cdot s^{-1}$ with increased detector acceptance and additional redundancy for the tracking and, at the same time, reducing the material budget. This contribution will review the design and the technological choices of the detector, finally its status and performance will be discussed.

17.00-17.50 **The upgrade of the ALICE Inner Tracking System**

Piero Giubilato *(University and INFN Padova)*

The ALICE experiment is preparing a major upgrade of the various detectors and subsystems for the long shutdown of the CERN LHC, planned for the year 2020. Highlight of the upgrade is the complete replacement of the Inner Tracking System (ITS): the new apparatus will be a 7-layers cylindrical tracker fully instrumented by Monolithic Active Pixels Sensors (MAPS) of large area (4.5 cm^2) and extremely low power consumption (about 25 mW/cm^2). The ITS upgrade specifications, design, and technical solutions will be briefly illustrated, with special focus on the sensors and the readout system.

April 5, Wednesday (morning)
Electronics: radiation effects and state of the art
Chairman: Matteo Pegoraro *(INFN Padova)*

9.00-10.40 **Ionizing radiation effects on electronic circuits: from micro(electronics) to nano, from mega(rad) to giga**

Lodovico Ratti *(University and INFN 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 particles or highly energetic photons, with a subsequent alteration of their electrical properties. The lecture will be concerned with ionizing radiation effects on electronic devices and circuits, especially in particle physics applications. The fundamental mechanisms underlying 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. Emphasis will be placed on how radiation tolerance is affected by the evolution of microelectronic technologies and by the growing hostility of the radiation environment.

11.10-12.50 **Front-end electronics for silicon trackers**

Valerio Re *(University of Bergamo and INFN Pavia)*

This lecture will discuss the general concepts and the technologies that are used for the design of the front-end electronics for silicon microstrip and pixel detectors in modern high energy physics experiments. Finely segmented detectors have to be read out by mixed-signal front-end integrated circuits fabricated in aggressively scaled technologies. These systems have to comply with severe requirements in terms of low noise, high speed, low power and high radiation tolerance.

This lecture will present the main problems that have to be tackled in the development of a microelectronic front-end integrated circuit, from the design of analog blocks to the digital architecture for the chip readout. The discussion will be focused on the recent developments of pixel readout chips in a 65 nm CMOS process for the upgrade of trackers at the High Luminosity Large Hadron Collider (HL-LHC) in the next decade.

April 5, Wednesday (afternoon)
Electronics: radiation effects and state of the art
Chairman: Serena Mattiazzo *(DEI, University of Padova)*

14.00-14.50 **High voltage/high resistivity CMOS pixel detectors**

Attilio Andreazza *(University and INFN Milano)*

High Voltage CMOS (HV-CMOS) pixel detectors are developed in technologies for "high" voltage applications and by using "high" resistivity substrates, which provide a depleted sensitive region. Collection by drift in the depleted region, instead of diffusion, makes these devices faster than standard CMOS detectors, and more radiation hard, since charge trapping is reduced. Therefore they are an interesting option for experimental conditions where time resolutions of few ns are required and particle fluences of 10^{15} particles/cm^2 are expected.

A brief introduction on the basic principle of the detector and available technologies will be provided. Different design choices, both on the sensitive components, with small and large fill factors, and on the system architecture, with hybrid solutions (using either capacitive or resistive coupling to a front-end readout chip) and full monolithic approaches, will be discussed, together with an overview of recent results on performance and radiation hardness of prototypes. Finally, current lines of development and potential applications of HV-CMOS detectors will be presented.

14.50-15.40 **The DEPFET pixel detector of the Belle II experiment**

Hans-Günther Moser *(Max Planck Institute, Munich, Germany)*

The Belle II experiment at KEK (Tsukuba, Japan) will explore heavy flavour physics (B, charm and tau) with unprecedented precision. In the innermost region a vertex detector is needed to reconstruct precisely the decay vertices of the B-mesons. The detector has to cope with high occupancy and harsh radiation conditions and needs to be very thin to reduce multiple scattering. Belle II opted for a DEPFET pixel detector. DEPFET pixels offer intrinsic amplification, high signal-to-noise ratio, fast readout, and can thinned to 75 µm. In this lecture I will explain the working principle of the DEPFET and how it is produced, especially for large and rigid but very thin monolithic detector modules. The layout and system design of the detector for Belle II will be explained. Furthermore, results from beam and system tests are summarized and the expected performance is discussed.

16.10-17.00 **Innovative front-end electronics in 65 nm CMOS for new generation pixel detectors for HL-LHC experiments: results from the CERN RD53 Collaboration and from the CHIPIX65 INFN project**

Lino De Maria *(INFN Torino)*

The High Luminosity Large Hadron Collider (HL-LHC) will constitute a new frontier for the particle physics after the year 2024. A major experimental challenge resides in the inner tracking detectors measuring the particle position. A new generation of pixel front-end chips must be developed both for the ATLAS and for the CMS detector upgrades, guaranteeing high performance even in the inner layers characterized by an extreme high particle flux, pixel-hit rates up to 3-4 GHz/cm^2, an extremely harsh radiation environment up to the total dose of 1 Grad and small signals of 5000-10000 electrons from the silicon sensors.

The CERN RD53 collaboration and the INFN CHIPIX65 project were constituted with the purpose to develop a pixel readout prototype for the HL-LHC pixel detector upgrades and formed the largest HEP community working on a microelectronic project. The 65 nm CMOS technology was chosen, as a promising innovative and novel technology for HEP experiments, in order to reach high pixel granularity, long trigger latency, high speed and low noise front-end electronics in a highly complex digital ASIC.

This lecture will describe the challenges and the solutions adopted, including radiation hardness; main building blocks; very front-end electronics; complex digital architecture with shared local resources organized in pixel regions. Main results obtained from the first full pixel matrices with 64×64 pixels will be described together with the design of a full size ASIC of 2 cm^2 area.

17.00-17.50 **ScalTech28 project: 28 nm CMOS technology for low-power and rad-hard analog circuits**

Andrea Baschirotto *(University and INFN Milano Bicocca)*

The ScalTech28 purpose is to investigate the performance of the 28 nm CMOS bulk technology in terms of signal processing quality, power consumption and radiation hardness for applications in instrumentation electronics for particle physics experiments. The study is carried out at device level by electrical characterization of single devices (n- and p- MOSFETs) before and after irradiation for TID up to 1 Grad, as foreseen in future HEP experiments. In addition, the design and the implementation of analog circuits are developed, evaluating also their performance before and after irradiation. The cases of analog filters and of the pixel read-out are used as benchmarks. Experimental results will be given to demonstrate the potentiality of such technology node for future HEP experiments.

April 6, Thursday (morning)

Radiation effects on components and materials for space and other applications
Chairman: Alessandro De Angelis *(INFN Padova)*

9.00-9.50 **The space environment, models and in-flight prediction tools**

Giovanni Santin *(ESA ESTEC, Netherlands)*

Space missions are exposed to a range of hostile environments, which can limit part, unit or system reliability, whose combined and often synergistic effects need to be addressed in hardness assurance processes. For the radiation issues, environment specification and shielding analyses are a pre-requisite for detailed calculations of degradation and single event effects in electronic components: in recent years significant efforts have been considered in R&D to understand the underlying physics phenomena, improving the prediction capability of our models and assessing their uncertainties.

In the lecture, an introduction to established new models for the (external) space radiation environment, experienced along traditional Earth orbit scenarios, shall be complemented with a discussion of challenges due to radiation exposure in ambitious deep space exploration programmes, including Jupiter missions or planetary habitats.

The lecture will also introduce the new tools, which are under development for accurate calculation of the local (internal) environment experienced on-board spacecraft by sensors, electronic components and astronauts, with the aim of implementing state of the art Monte Carlo simulations, via reliable and friendly interfaces, through the entire mission lifetime, from early feasibility studies to hardware manufacturing and in-flight operation.

9.50-10.40 **Electrostatic Discharges (ESD) in microelectronic devices**

Marco Barbato *(DEI, University of Padova)*

Electrostatic discharges (ESD) can cause a significant failure rate in the electronic components. The continuous miniaturization of microelectronics is leading to an improvement of electronic circuits especially for space application, where the area and power saving are the two main targets for electronics. The device shrinking and the gate oxide thinning contribute to increase ESD sensitivity. Therefore, understanding ESD events and ESD protections are two key factors to improve the device reliability, thus reducing the electronic circuit failures. This presentation introduces the ESD event theory and the laboratory systems considered to emulate and study ESD in microelectronics. The HBM (human body model), MM (machine model) and TLP (transmission line pulse) will be introduced and some real examples of ESD in microelectronic devices will be presented. In particular the application of TLP to MEMS (Micro Electro-Mechanical System) devices and HEMT (High Electron Mobility Transistor) switches will be shown. In order to reduce the failure of devices due to ESD events, the use of protection circuits is of crucial importance. Some theory elements regarding the ESD protection will be introduced and some basic snapback circuits will be described.

11.10-12.00 **Radiation testing of optical coatings**

Maria Guglielmina Pelizzo
(CNR, Institute for Photonics and Nanotechnology, Padova)

Optical coated elements are mainly optimized for their optical characteristics, such as transparency or reflectivity in a desired spectral region. However, for the space missions of the very next future it will be fundamental to ensure the sustainability of these components in the harsh conditions of the space environment, preventing the occurring of any degradation of their performance. Although there are some studies on the interaction of ions with coatings for space applications, these are not systematic but limited to specific values of energy for selected ion species, thus having more the characteristics of a validation for components already selected.

A more systematic approach is required. The damage effects on optical materials and coatings depend on the ions species, their energy, the flux and the total fluence. Once these parameters are defined, laboratory tests can be used to qualify the components by reproducing the operational conditions. In particular, particle accelerators are commonly used to irradiate such components, even though with limitations. Optical, morphological and structural properties, prior and after irradiation, have to be investigated by using different techniques. Such studies are fundamental to select the best candidate materials and to optimized the coatings design. The outcomes are also important to address the procedures for space qualification tests.

12.00-12.50 **Optoelectronics for space**

Carlo De Santi *(DEI, University of Padova)*

This lecture will briefly introduce two material systems considered for optoelectronics in space applications: Gallium Arsenide (GaAs) and Gallium Nitride (GaN).

A short tutorial on the structure and physical operating principles of the main optoelectronic devices (light emitting diodes and laser diodes) will follow, establishing a sound basis for the understanding of the last part.

Then, some case studies will be presented and discussed:

1) satellite-based earth monitoring techniques;

2) possible application fields for optoelectronics in space (both inside satellites and in free space);

3) the radiation hardness and reliability of the devices in the harsh space environment.

April 6, Thursday (afternoon)

Radiation effects on components and materials for space and other applications
Chairman: Alessandro Paccagnella *(University and INFN Padova)*

14.00-14.50 **Radiation effects in multi-junction solar cells for space applications**

Erminio Greco *(CESI, Milano)*

III-V based solar cells are currently the dominant power generation technology in space thanks to their high efficiency and reliability. All the recent GEO and LEO satellites are powered by 30% AM0 efficiency InGaP/InGaAs/Ge triple junction solar cells. Today CESI has a full production line with proprietary technology that covers all the manufacturing steps of TJ solar cells. In order to assure the reliability during the whole space mission, these devices must be subjected to different qualification tests following the ESA ECSS E ST20-08 standard.

Among these tests, ground based irradiations by unidirectional and mono-energetic particle beam are very important for predicting the degradation of solar cell performance in the space environment, where the cells will be exposed to spectra of omnidirectional electrons and protons.

The principle of operation for a multi-junction solar cell and the most important aspects to be taken into account in order to maximise both the BOL (Beginning of Life) and the EOL (End of Life) performance of the final device will be discussed during this lecture. Experimental data, showing how InGaP/InGaAs/Ge solar cells degrade, as a function of the particle fluence of electrons and protons of various energies, will be presented. Moreover, it will be explained how these data are used to derive the RDC's (Relative Damage Coefficients) required to calculate the equivalent damage for omnidirectional incident space radiations.

14.50-15.40 **Space debris: a threat for space assets from LEO to GEO**

Alessandro Francesconi *(DEI and CISAS, University of Padova)*

All the spacecraft in Earth's orbit are exposed to the risk of hypervelocity impacts with micrometeoroids and orbital debris. Given the high number of objects currently in space and the predictable increase of the launch traffic, the debris threat is going to seriously grow till a point where the sustainability of LEO activities could be called into question in the next few years.

This lecture provides an overview of the space debris environment from LEO to GEO, including its principal sources, related risks and possible damage to orbital assets. Current methodologies for risk reduction are also discussed, and the need of further actions to preserve the space environment from an irreversible debris pollution is pointed out.

16.10-17.00 **Total dose issues in remote handling electronics for the ITER reactor maintenance**

Marco Van Uffelen *(Fusion for Energy, Barcelona, Spain)*

ITER is a first-of-kind Tokamak fusion nuclear plant. During the ITER lifetime, many components operating near the hot plasma will have to be replaced due to erosion and damage. Once the Deuterium-Tritium phase of the ITER operation will be reached, the resulting large neutron flux will lead to activation of many internal components and so to high radiation levels. This in turn will mean that their maintenance will be carried out by full Remote Handling (RH) procedures.

The novel and complex requirements for the RH tasks in such an hostile environment make the RH maintenance procedures also deeply linked to the whole ITER design, schedule and operation. Moreover, the space where the bulky equipment will operate is limited. Therefore, myriads of interconnected tools, manipulators and cranes will have to be routinely operated and inspected remotely with a millimetric accuracy.

Fusion for Energy (F4E) actively contributes to the design and procurement of these RH system, which will incorporate both front-end electronics and CMOS-based cameras. This lecture will firstly introduce the main RH systems and their challenges and, the second part, the current design and radiation test results obtained for the embarked electronics and cameras will be considered.

17.00-17.50 **The CHARM irradiation facility at CERN**

Salvatore Danzeca *(CERN, Geneva, Switzerland)*

The CERN High energy AcceleRator Mixed field (CHARM) facility has been recently built in order to qualify electronic components and large electronic systems for the challenging radiation environment of particle accelerators such as the one of the Large Hadron Collider (LHC). The multiple facility configurations allow to emulate radiation spectra very similar to the LHC tunnel and shielded areas but also the ground, atmospheric and space ones. The mixed radiation field is unique in term of multitude of particles and energy ranges. It is generated from the impact of a mono-energetic (24 GeV/c) proton beam extracted from the Proton Synchrotron (PS) on a cylindrical metal target (Al or Cu). The radiation spectra of CHARM are characterized by a complex calibration procedure providing, an accurate mapping of the irradiation area in term of total ionizing dose, high-energy hadron fluence (>20 MeV), thermal neutron fluence and 1 MeV neutron equivalent fluence. The lecture will focus on the complexities and singularities of this unique facility addressing how to operate, calibrate and use it.

9.00-9.50 **The production target of the ISOL-RIB facility at SPES**

Alberto Andrighetto *(INFN National Laboratories of Legnaro)*

The Target Ion Source unit is the core of an ISOL-RIB facility. Many international ISOL facilities have chosen a different layout for the target unit. All research groups are meanwhile together in order to implement a dedicated R&D for targets capable in dissipating high power and, at the same time, having a fast isotope release. This is mandatory in order to produce radioactive beams with short half-life. In particular, the research for new materials with advanced microstructural features is crucial in this field.

The design of a proper target is strictly related to the obtainment of porous refractory materials, which are capable to work under extreme conditions (temperatures up to 2000 °C in high vacuum) with a high release efficiency. For SPES, the second generation Italian ISOL–RIB Facility, the target will be of Uranium Carbide (UCx) in which, by fission induced by a 40 MeV proton beam (8 kW power), isotopes in the 60-160 amu mass region are produced.

All these technological developments are also crucial in the study for the third generation ISOL facility.

9.50-10.40 **MUNES: Multidisciplinary Neutron Source**

Enrico Fagotti *(INFN National Laboratories of Legnaro)*

Neutron applications, using compact accelerator driven neutron sources, are becoming more and more important since they can cover various research fields such as material science, engineering, nuclear physics, cancer therapy and so on.

The MUNES (MUltidisciplinary NEutron Source) project, aiming to the realization of an intense thermal-epithermal neutron source for these applications, has been launched in 2012. The source is based on a high intensity linear accelerator under construction at INFN-LNL. It was born as a CW source for medical applications but, due to its high average current, it can operate as a pulsed source chopping the main proton beam.

The accelerator was developed in collaboration with INFN-LNS and industries. The injector was developed at INFN-LNS and upgraded in INFN-LNL. It is a high current ECR off-resonance proton source able to accelerate a 50 mA proton beam up to 80 keV. The main accelerator is a RFQ structure able to accelerate and transport the beam up to 5 MeV. It was designed with a 30 mA CW nominal current but it can work at 50 mA without affecting the performance. The 5 MeV proton beam impinges on a thin Beryllium converter to produce a neutron flux up to 2×10^{14} neutrons/s. Details on the machine architecture and status will be presented in this lecture.

11.10-12.00 **The LARAMED project: a bridge between nuclear physics and medicine**

Adriano Duatti
(Department of Chemical and Pharmaceutical Sciences, University of Ferrara)

Outstanding progress in medicine has been always driven by the application of fundamental physical discoveries to the biological field. For example, the development of modern diagnostic imaging techniques was made possible by key progresses in detector technology and image reconstruction that allowed to obtain highly precise 3-dimensional maps of the anatomy of a living organism. In this context, the future paradigm is even more ambitious as it envisages the possibility to visualize, using a totally non-invasive procedure, the tremendously complex network of biochemical reactions occurring inside the chemical fabric of cells belonging to an intact living organism. This concept is conventionally called "molecular imaging". In order to achieve this fundamental objective, nuclear physics can play a key role because it can potentially supply a high number of radionuclides having nuclear characteristics suitable for monitoring single radiolabelled molecules using an external gamma-ray detector with high spatial resolution. This effort always requires to set up collaborations among a broad community of specialists ranging from nuclear physicists for radionuclide production and cross-section measurements, radiochemists for radionuclide purification, and biologists for evaluation of the in vivo behaviour of radiolabelled probes.

The purpose of the LARAMED project (acronym of LAboratory for the production of RAdionuclides for MEDicine) is to create at the INFN National Laboratories of Legnaro a research network aimed to the production of novel and unprecedented radionuclides for molecular imaging, in particular by exploiting the high technological potential of the recently installed high-energy (70 MeV) and high-proton-current (800 μA) cyclotron. Examples of research projects specifically tailored to investigate the production of a number of biologically active and highly interesting diagnostic and therapeutic radionuclides will be illustrated..

12.00-12.50 **Present and future radiation beams at TIFPA**

Chiara La Tessa *(University of Trento and INFN TIFPA)*

The experimental room at the Protontherapy Center in Trento became operational in 2016. This facility is run in collaboration with the APSS, TIFPA, IBA and the University of Trento, merging biology, physics, engineering and medical applications. The scientific program includes internal and external users, whose experiments are focused on both radiotherapy and space radioprotection. An overview of the facility, including the present status and the future updates will be presented in the lecture. Examples of the challenges from a technical and scientific point of view will be also discussed. Beam line developments necessary to produce a quasi-mono-energetic neutron beam will be discussed together with the impact on the research program.

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