OMMA

OPTIMIZATION OF MEDICAL ACCELERATORS

A Marie Skłodowska-Curie European Training Network

CONTENTS

03 – INTRODUCTION

04 – UNIVERSITY OF LIVERPOOL

06 – ASI - AMSTERDAM SCIENTIFIC INSTRUMENTS

07 – CERN – EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

08 – CNAO - CENTRO NAZIONALE DI ADROTERAPIA ONCOLOGICA

10 – CSIC / IFIC - INSTITUTO DE FISICA CORPUSCULAR

11 – GSI HELMHOLTZ CENTRE FOR HEAVY ION RESEARCH

12 – IBA – ION BEAM APPLICATIONS

13 – LMU – LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

14 – MEDAUSTRON

15 – PSI – PAUL SCHERRER INSTITUT

16 – UNIVERSITY COLLEGE LONDON

17 – UNIVERSITY OF MANCHESTER

18 – UNIVERSIDAD DE SEVILLA / CENTRO NACIONAL DE ACELERADORES

19 – ViALUX

20 – TRAINING PROGRAM

22 – DISSEMINATION AND COMMUNICATION

23 – MANAGEMENT

24 – ASSOCIATED AND ADJUNCT PARTNERS

Image © Kästenbauer/Ettl

INTRODUCTION

Optimization of Medical Accelerators

The Optimization of Medical Accelerators (OMA) is the aim of this European training network. The project joins universities, research centers and ion beam treatment facilities together with leading industry partners, to address the challenges in cancer treatment facility design and optimization, numerical simulations for the development of advanced treatment schemes, beam imaging and treatment monitoring.

In the treatment of cancer, radiotherapy plays an essential role. Radiotherapy with hadrons (protons and light ions) offers several advantages over photons for specific cancer types. In particular, they penetrate the patient with minimal diffusion, they deposit maximum energy at the end of their range, and they can be shaped as narrow focused and scanned pencil beams of variable penetration depth. Continuing research into the optimization of medical accelerators is required to assure the best possible cancer treatment for patients.

The OMA network is built around 15 early stage researchers working on dedicated projects to maximize the benefits of the use of particle beams for cancer treatment. The network consists of an international consortium of almost 40 partner organisations working in this field. It provides a cross-sector interdisciplinary environment for beyond state-of-the-art research, researcher training, and new collaborations.

The network's main scientific and technological objectives are split into three closely interlinked work packages.

OMA Research

Beam Imaging and Diagnostics

Compared to conventional radiotherapy, proton therapy is still a developing technology. While the accelerator systems required to provide 200-400 MeV proton beams are a mature technology, numerous challenges, both clinical and technical, must be overcome before proton therapy has as sound clinical footing as e.g. X-ray radiotherapy. Amongst these challenges, effective imaging is of critical importance. All six projects in this area target the development of beyond state-of-the-art diagnostics that will provide more detailed and complete information about the beam.

Treatment Optimization

By combining advanced computer simulations for dose delivery planning with novel treatment schemes and innovative patient scanning systems, OMA strives to further improve one of the most technologically advanced cancer treatment modalities. Five projects are carried out in this area.

Facility Design and Optimization

Crucial for optimum use of particle beam based cancer therapy are facilities providing beams over a wide range of energies adjustable to patient needs. This research area will optimize existing and planned facilities. It will incorporate the results from other OMA work packages into advanced designs and also develop new underpinning technologies that will help overcome existing limitations. Four projects within OMA are dedicated to this topic.

UNIVERSITY OF LIVERPOOL

UNIVERSITY OF LIVERPOOL

A member of the Russell Group of major research-intensive universities in the UK, the University of Liverpool has an outstanding international reputation for innovative research. Currently around 20,000 students are enrolled into more than 400 programs spanning 54 subject areas at its 3 faculties, including Health and Life Sciences; Humanities and Social Sciences; and Science and Engineering.

A rich variety of research is performed at Liverpool, including Particle Physics, Nuclear Physics and Condensed Matter Physics. Moreover, the University is a key partner in the Cockcroft Institute, an international center of excellence for accelerator science and technology. Embracing academia, government and industry, it is unique in providing the intellectual focus, educational infrastructure and the essential facilities in innovating tools for scientific discoveries and wealth generation.

The Liverpool Accelerator Physics Group develops, optimizes and exploits national and international scientific accelerator facilities and generates ideas towards future accelerators and beam diagnostic techniques that allow novel experimental studies and applications. Our research strategy is developed in conjunction with the Cockcroft Institute and STFC in alignment with national priorities. It is focused on three thematic areas: frontier accelerators, novel accelerators, and accelerator applications. We have been the driving force behind large scale European networks in accelerator science and technology for many years. Through the DITANET (beam diagnostics), oPAC (Optimization of Particle Accelerators) and LA³NET (Laser Applications at Accelerators) we have successfully trained more than 60 Fellows across Europe and will use the experienced gained for the implementation of OMA.

We have pioneered jet-based beam profile monitors, advanced optical diagnostics for accelerators to measure the beam profile, intensity, halo, position and emittance in least-destructive ways, as well as high resolution beam loss monitors for energy frontier accelerators and light sources using optical fibres. Moreover, we have closely collaborated with the Clatterbridge Cancer Centre for many years with the aim of developing novel online beam monitors.

Project:

Halo-dose correlation in a medical accelerator

Supervisor:

Prof Carsten P Welsch

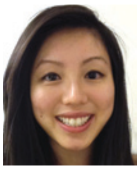
Online beam monitoring in medical accelerators is an essential part of the patient's safety and also assuring the high quality and efficacy of cancer treatment. Charged particle beams interact with patient's tissue depositing their kinetic energy in many elastic and inelastic collisions, demonstrating the highest energy transfer at the end of their path.
Hence the beam energy and energy spread; position and lateral profile of the beam, as well as the beam current have to be precisely determined and recorded.
In clinical practice ionisation chambers provide users with information on the dose rate. These are, however, interceptive devices, degrading both the beam profile and its energy spread. A new non – interceptive method of online beam monitoring would be highly desirable and shall be developed in the frame of this project.

The LHCb VELO detector is a position sensitive silicon detector, which has been used for tracking vertices originating from collisions at the LHCb experiment at CERN. Its advantageous semi-circular design enables approaching the core of the beam, without interfering with it. Thus, it allows precise measurements of the beam 'halo' around it. This halo is associated with nuclear and secondary products produced from the beam and in a clinical setting, can result in additional and unwanted dose also being delivered. This excess halo dose and the extent of its radiobiological effects is an approximated quantity and as such, the characterisation and understanding of these phenomena is an important consideration in treatment plans, verification and quality assurance.

In the frame of this project the stand alone operation of the VELO detector as an online monitor through obtaining treatment beam 'halo' maps at the Clatterbridge Cancer Centre (CCC) shall be investigated. This also includes experimental beam times, as well as Monte Carlo and beam transport studies in collaboration with CERN, INFN and LMU to fully characterize and understand beam behavior for precise numerical studies into halo propagation. This will also facilitate related studies into low dose effects, cell damage, radiobiological simulations and models.

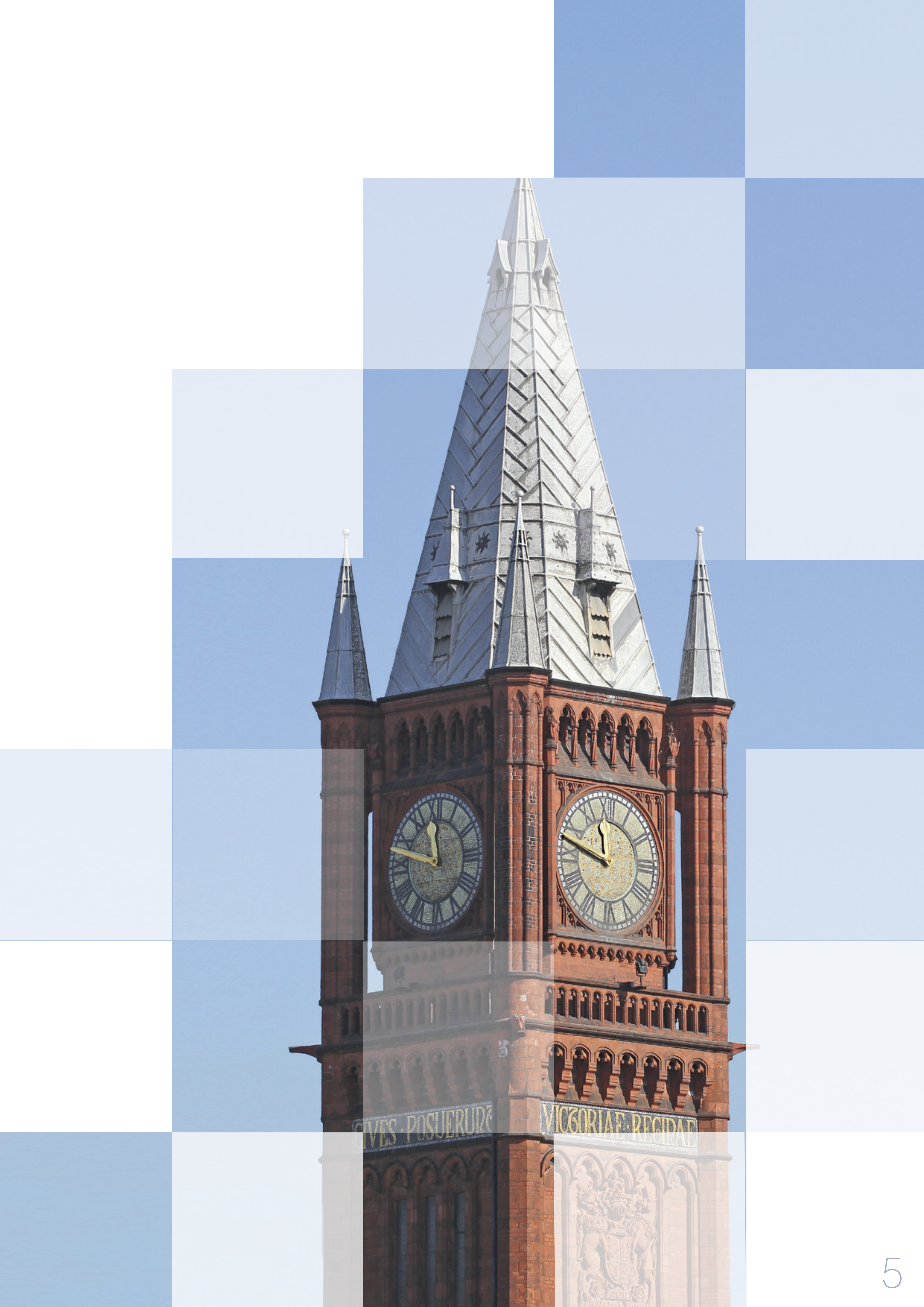
Researcher:

Jacinta Yap



Jacinta graduated with a Bachelor of Science majoring in Mechanical Engineering from the University of Western Australia in 2014. Thereafter, she pursued a Masters in Medical Radiation Physics with the Centre for Medical Radiation Physics (CMRP) at the University of Wollongong. Her thesis was a study of the Relative Biological Effectiveness (RBE) in proton beam therapy by application of a novel silicon microdosimeter. RBE was derived given a microdosimetric approach where experimental data was evaluated alongside Monte Carlo simulations generated using Geant4. Throughout her study she engaged in short summer internships in the Medical Physics Research Department, Sir Charles Gairdner Hospital in Perth, Australia and at the National Cancer Centre, Singapore General Hospital in Singapore.

Jacinta was awarded her MSc with Distinction in July 2016 and following this, joined the OMA project where she is working in parallel towards a PhD with the University of Liverpool.


IVES · POSUERUNT
VICTORIAE REGINAE

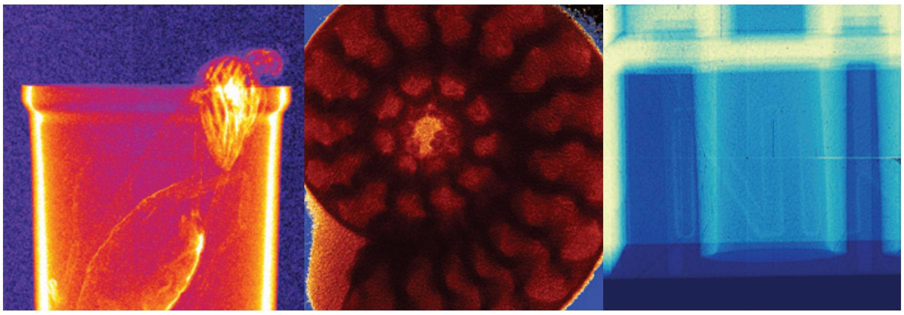
ASI – AMSTERDAM SCIENTIFIC INSTRUMENTS

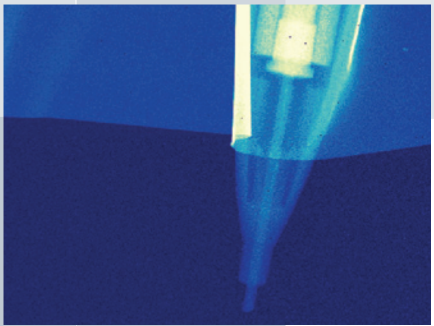
Amsterdam Scientific Instruments (ASI) is a high-tech SME. The company was incorporated in 2011 and is co-located at the Amsterdam Science Park with FOM-Nikhef, its founding institute. Since its start, ASI has already gained early attention and traction with a product portfolio of next generation imaging detectors.

ASI is a global player in the scientific and industrial market for detector technology. It offers imaging solutions for various types of radiation. The team consists of members who have worked at several research institutes focused on various types of radiation sources and are experts on detector development and radiation imaging in their research application. This makes ASI products a reliable and out of the box solution in many fields of research.

The infrastructure of ASI consists of two fully equipped and operational laboratories that allow development and testing of its detection cameras for multiple applications like X-rays, mass spectrometry and electron microscopy. ASI's facilities also allow proof of principle experiments and end-to-end testing of new prototypes.

ASI's collaboration with Nikhef and AMOLF also allows access to other facilities present at the Amsterdam Science Park. Via Nikhef, ASI has access to clean rooms, cooling systems, laboratories, bonding machines and a test setup for the strip sensors. In addition, via its technology partners ASI has access to various testing facilities around the world.





Images taken with the Medipix3RX chip. Courtesy of ASI.

Project:

A versatile high-speed radiation detection platform

Supervisor:

Dr Dmitry Byelov

ASI has unique expertise in the applications and improvements of the Medipix and Timepix detector technology developed by CERN.

Within this project the Fellow will explore ASI's hybrid pixelated detector technology, specifically Medipix3RX systems. He will first be trained in ASI's detector technology and laboratory capabilities. This will include training in X-ray imaging, mass spectroscopy and electron microscopy for detector characterization. Via existing collaborations, the Fellow will have access to other research facilities at the Amsterdam Science Park and receive hands-on training to develop an optimum solution for particle detection in medical applications.

Researcher:

Navrit Bal

In July 2016, Navrit Bal received a MPhys degree from the University of Kent with a study abroad year at the University of California, Berkeley.

At Kent, his undergraduate Master's thesis was based on a series of computational material simulations entitled: Simulating the density of states, band structure, Fermi surface of cobalt and copper at 0-200 GPa. His final year modules included rocketry and human spaceflight, particle and quantum physics, magnetism and superconductivity and finally topics in functional materials. He also co-founded the Physics Society (PhySoc) and was treasurer for 2 years.

At Berkeley, mostly Physics and Nuclear Engineering classes were taken which led into a summer job within the RadWatch group at Lawrence Berkeley National Laboratory (LBNL). This is where he was the primary developer for the DoseNet project, a network of custom-made dosimeter devices, primarily remotely installed in schools in the San Francisco Bay Area and now at a number of sites around the world.

In September 2016 Navrit joined the OMA project at ASI to work on Medipix3 detectors.

CERN – EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Image © CERN

CERN is the world's largest particle physics laboratory which acts as a focal point for European physics and technology collaborations.

CERN hosts each year a community of over 6,000 visitors from more than 300 external institutes around Europe, and from many non-CERN-Member States. CERN has world-class accelerator facilities, including the Isolde/PS/SPS/LHC complexes, a Technology Transfer Unit which enhances technology transfer and promotes communication and public education through press, publications, web pages, exhibitions and visits to the laboratory. CERN has a very strong track record as a European training center.

In recent years the volume of training given has been in the order of 11,000 person-days per year. Large fractions of these trainings are geared towards early stage researchers. CERN has great experience in tutoring and mentoring of ESRs as well as in the transmission of complementary skills.

Project:

Improvements on FLUKA for medical applications

Supervisor:

Dr Alfredo Ferrari

For efficient treatment planning and decision for optimum dose delivery schemes, Monte Carlo simulations are a key tool. The FLUKA code is de-facto standard in Europe for generation of physical input for carbon ion treatment planning systems, being used for this purpose by Siemens and RaySearch. The code is also used at two clinical facilities, CNAO and HIT, as a quality assurance, verification and research tool. The models embedded in the code for atomic and nuclear interactions have already demonstrated their accuracy for clinical applications.

This project targets further improvements in the modeling of the emission of secondary radiation. These improvements will allow to predict the influence of the primary particle fragmentation on the dose delivered in radiotherapy treatments with higher precision. Moreover, the secondary radiation (including prompt gammas, positrons and other charged particles) can be used for therapy monitoring.

Fragmentation of helium, lithium and carbon ion beams are analysed in different materials, and the results from the FLUKA simulations are validated against experimental data.

In collaboration with CNAO, STFC and PSI, a framework for the combined computation and visualization of (biological) dose and secondary radiation emission will be developed. This shall then be applied for the verification of dose distributions and associated imaging with LMU and INFN. Comparison of expected prompt photons and PET signals between very light ions and ^{12}C will be performed in realistic treatment scenarios.

Finally, the developed framework could allow to implement different radiobiological models for different regions of interest, e.g. healthy tissue vs tumor tissue, in the voxel description of the patient. More efficient radiotherapy treatments and reduced side effects could be achieved.

Researcher:

Giulia Aricò

Giulia Aricò carried out her Master's degree in Medical and Biological Physics at the University of Trento (Italy) from 2010 to 2012. She developed her Master thesis at the Paul Scherrer Institute (Switzerland), in the field of proton therapy.

In the years 2013-2016 she performed doctoral research at the Heidelberg University Hospital, in collaboration with DKFZ (Germany). She investigated the fragmentation of carbon and helium ion beams in different materials of interest for medical purposes. Fixed target experiments were performed at the HIT facility, and the Timepix detectors, developed at CERN, were used for particle identification and tracking. She also performed measurements at the HIMAC facility (Japan) to investigate the response of the Timepix detectors to heavy ions, like neon and argon.

In 2016 Giulia joined the OMA project at CERN to work on the improvement of the FLUKA code for medical applications. Afterwards Giulia obtained her PhD degree from Heidelberg University.

Her expertise includes proton and ion therapy, Monte Carlo simulations, solid state detectors and particle beam accelerators.

CNAO – CENTRO NAZIONALE DI ADROTERAPIA ONCOLOGICA

Centro Nazionale di Adroterapia Oncologica (CNAO) is the first medical accelerator facility for deep hadrontherapy with carbon ions and protons in Italy, whose mission is to provide hadron-therapy treatments and to perform research in related fields. CNAO is also a Center of Research and Development, whose activities range from clinical and radiobiological research to translational research with the objective of providing continual improvements in the capacity to cure.

The main accelerator of CNAO is a synchrotron. Outside the main ring there are four extraction lines leading the extracted beam into three treatment rooms. An experimental room already exists, and a dedicated beam line is planned to be realized. This experimental beam will be available for different types of experiments and for several external research groups.

The diagnostic imaging and nuclear medicine service is composed of a 3T MRI, one CT and one CT-PET. Although CNAO is a young facility, it has grouped many scientists with strong backgrounds in their field in order to achieve excellence in all fields related to hadrontherapy.

The radiobiology laboratory in CNAO was set up in 2011 to give the opportunity to perform wide radiobiological studies with proton and carbon ion beams to the internal radiobiology group and to external researchers. Although new and still under development, it is equipped for the large scale experiments typically needed for cell survival tests and radiobiological research.

The realization of CNAO is based on a strong collaborative network, the CNAO Collaboration, that links CNAO with the most important institutions in Italy and abroad. This network has guaranteed contributions of outstanding experts to the programs of the CNAO Foundation. In addition, it has been fundamental for formation of the people of CNAO, who over the years, have acquired expertise unique in Italy and also in the world.

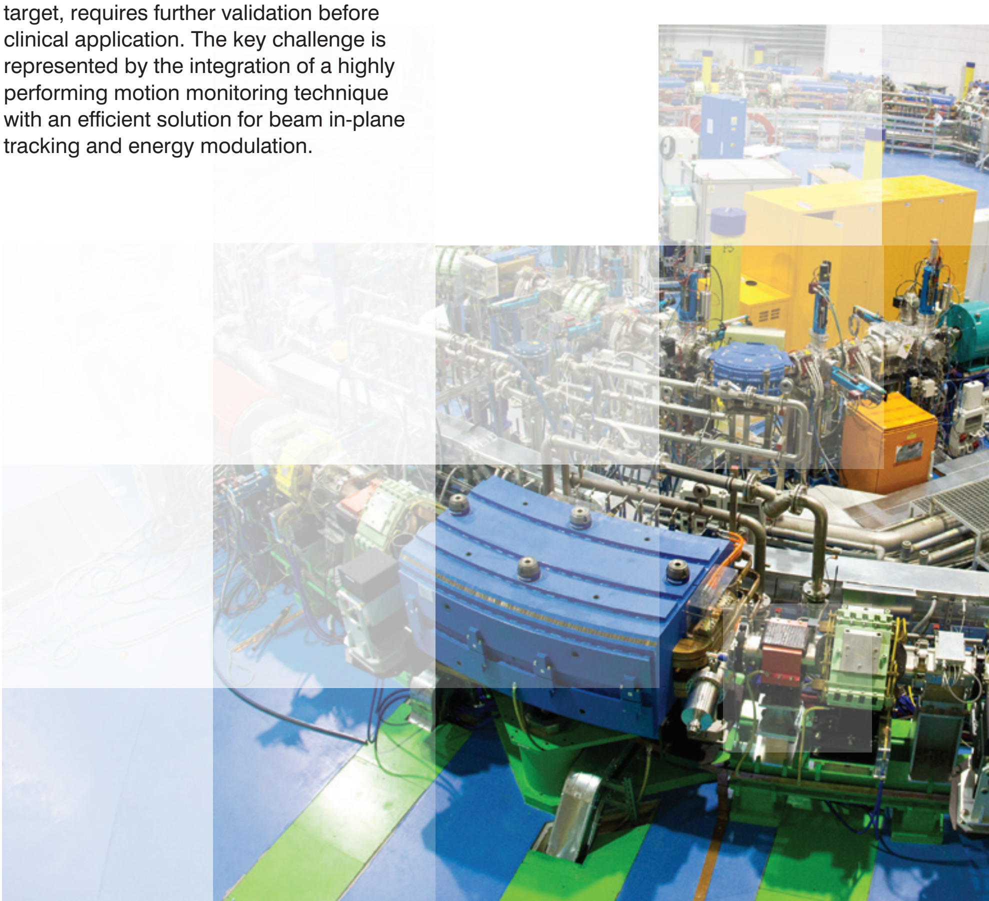
Images courtesy of CNAO
Centro Nazionale di Adroterapia Oncologica

Project:
Tumor tracking in particle therapy

Supervisor:
Prof Guido Baroni

The potential of treating mobile tumors by means of active particle beam scanning depends on the capability of overcoming a set of technological and methodological issues related to the geometric uncertainties and related dosimetric effects caused by motion. Since organ motion not only affects the target position, but also the position and the density of the surrounding anatomical structures, the radiological path length (i.e. the cumulated density) of tissues traversed by the particle beam may change as a function of time, both intra-fractionally and inter-fractionally. In addition, the dynamic motion of the beam overlaps with target motion creating an interplay pattern, which ultimately leads to dose inhomogeneities, thus potentially degrading target volume dose coverage.
Breath-hold irradiation and beam gating (with rescanning) represents motion suppression/compensation strategies already available (though in limited cases) in clinical practice. Conversely, beam tracking, which entails the real-time modulation of the beam direction and energy, in order to accurately conform the dose on an intra-fractionally moving target, requires further validation before clinical application. The key challenge is represented by the integration of a highly performing motion monitoring technique with an efficient solution for beam in-plane tracking and energy modulation. CNAO has a dedicated optical motion detection device.

Following preliminary studies at GSI and CNAO based on internal-external correlation models for tumor localization and dedicated interfacing between motion monitoring and beam delivery systems, additional activities are required to fill the gap between phantom studies and clinical application of tumor tracking in particle therapy.



The Optical Tracking System (OTS) is already available for patient set-up verification and applied for external-internal correlation modelling.

The goal of this project is to conduct activities for further validation of the tumor tracking system before clinical use to fill the gap between phantom studies and clinical application. Those activities include system performance evaluation and dosimetric experiments on more realistic respiratory motion phantom, strategy for motion compensation in depth (energy modulation) and a strategy for adaptive particle therapy quality assurance. Activities envisage the refinement of the interfacing between the OTS and the CNAO Dose Delivery System (DDS) developed by CNAO and the National Institute of Nuclear Physics (INFN).

Researcher:

Hanen Ziri

Hanen Ziri obtained her Bachelor's degree in biomedical engineering in 2011 and her first Master's degree in biomedical engineering (specializing in medical imaging) in 2013, both from the Higher Institute of Medical Technologies of Tunis. During her studies she worked on medical image and signal processing using MATLAB. Hanen obtained her second Master's degree in medical physics in 2016 from the University of Grenoble-Alpes. Her studies in France involved work in an interdisciplinary laboratory of physics in Grenoble to develop a software in MATLAB to interface a novel CMOS camera, designed for functional imaging at high resolution, with electrophysiology instrumentation. Her Master research was conducted in the department of radiation physics at the university of Texas MD Anderson cancer center. It was related to particle therapy and scintillator detectors use for proton beam quality assurance.

In October 2016 Hanen joined the OMA project as a Fellow at CNAO in Pavia.

Project:

Light ion therapy software for data exchange

Supervisor:

Prof Luigi Casalegno

This project is focused on creating a common software bus that shall enable any present and future package to easily interconnect in a complex and widely distributed hadron therapy facility environment.

An integral part of the project is the specification of protocols to be used in the facility's control system. These protocols should allow for data exchange, assurance of security and privacy, and discovery of devices. The design and development of libraries to support these protocols and enable to automatically connect and operate devices is also expected. As a result, an environment for supervision and monitoring of event creation and distribution will be developed. To achieve this goal, the Fellow shall research and be trained in existing software solutions for event creation, event decoding and event relaying in slow workflow environment and FPGA based solutions for the same tasks in fast workflow environments.

Novel control systems for a medical accelerator facility demand the increase of the monitoring via specification of tools that help with visualization and construction of workflows. To overcome this challenge, one part of the Fellow's research includes the design and development of a graphical environment that enables the description of workflows composed of several medical accelerator activities. The graphical environment shall be backed by an xml based language, described by the Fellow, allowing for the description of the workflow states and events for each connected device.

Finally, one of the major concerns in the medical environment is the assurance that programs and components are functioning as per specification. In order to address this concern, the specification of programs that validate the set of tools that altogether constitute the Fast Workflow Manager is foreseen. These specification programs shall, furthermore, be able to evaluate tools in several different environment configurations, because the means of accessing data and devices in the accelerator complex is manifold.

Researcher:

Carlos Afonso

Carlos Afonso graduated from University of Minho with a Bachelor's in Informatics Engineering in 2014. In the same year he started his Master's in Informatics Engineering at University of Minho, specializing in Applications Engineering, Distributed Systems, and Cryptography. During his Master's, he did an internship with the Iberian-International Nanotechnology Laboratory, working with data analysis of electron microscopy data. Carlos graduated with a Master's degree in 2016. His Master's project was the creation of an elasticity controller for applications orchestrated with Cloudify.

In October 2016 Carlos joined the OMA network to work at CNAO.

CSIC / IFIC – INSTITUTO DE FISICA CORPUSCULAR

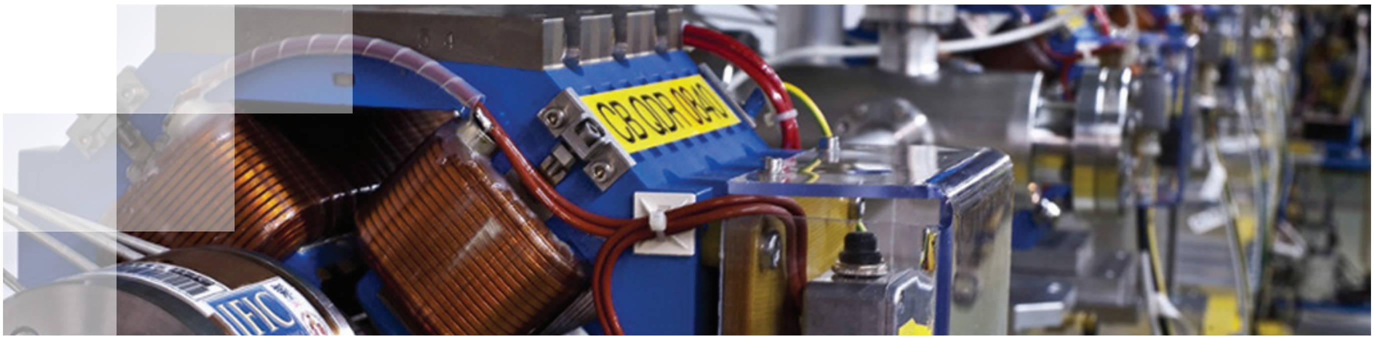


Image courtesy of IFIC

The CSIC (Agencia Estatal Consejo Superior de Investigaciones Cientificas) is a Spanish laboratory having a long-standing reputation in theoretical and experimental physics. It has expertise in the design and construction of detectors and beam instrumentation for nuclear, medical and particle physics. CSIC is the largest public multidisciplinary research organization in Spain. It has 116 institutes or centers distributed throughout Spain. There is also a delegation in Brussels.

IFIC (Instituto de Física Corpuscular) is a nuclear and particle physics institute, where ongoing research activities include experimental and theoretical work with application in near-term and far-future projects. The institute has been participating in leading particle physics experiments since 1950 when it was founded.

Project:

Application of high gradient RF technology for hadron therapy accelerators

Supervisor:

Prof Juan Fuster Verdu

A new High-Gradient (HG) RF lab is being constructed at IFIC since 2016, under a FEDER-funded collaboration agreement between the University of Valencia and the Spanish General Administration (MINECO) for the building integration and the equipment of scientific instrumentation. The main objective of the laboratory is the study of vacuum breakdown phenomenology of 3GHz HG accelerating structures, in particular for medical applications. The current activities of the IFIC HG-RF laboratory are developed in collaboration with CERN RF CLIC group within the framework of the knowledge transfer group project 'High-power testing of a medical high-gradient accelerating structure for proton therapy', for the design and testing of novel HG structures for compact and efficient proton beam facilities for cancer therapy.

In this context the main goal of this research project is contribution to testing and conditioning process, including breakdown studies of two novel high-power prototype 3 GHz accelerating structures commonly used in proton linacs. These accelerating structures are being built at CERN to prove the principle of HG acceleration of low energy protons required for hadron therapy. The Fellow will initially participate in the running of the CERN X-band testing facilities (Xboxes) including modulator, klystron and network conditioning and will collaborate in the operation of the test stand during structure measurements. On the basis of this experience she will then refine the optimization strategy of such a structure for hadron therapy. The experience acquired in the running of the Xboxes will serve to contribute to the finalization of the implementation of the HG-RF lab constructed in IFIC. The test of the two proton linac structures in the HG-RF test stand at IFIC-IFIMED labs of the University of Valencia will complement this work. It will include simulation of the most realistic conditions and running operation conditions for this kind of accelerating structures. Furthermore the Fellow will also participate in studies of other accelerating structures being tested in the HG-RF IFIC lab, such as the electron linac structures for VHEE radiotherapy applications.

Researcher:

Anna Vnuchenko

Anna Vnuchenko obtained her Master's degree in Physics from the University of Paris-Saclay, France in 2016. She completed a multidisciplinary program with a specialization in large facilities. Anna also holds a degree from the department of physics and mathematics of the National Teachers' Training University in Ukraine. She has work experience from the department of nuclear and physical research in IAP-NASU, where she took an active part in design, installation and commissioning of an automated goniometer on nuclear recoil end-station of the accelerator-based facility, to study the radiation damage produced due to ion implantation. Apart from accelerator physics other areas of research included fundamental investigations of interaction processes of MeV ions with matter by means of HRBS and HERDA techniques.

Anna joined the OMA network to work on the application of high gradient RF technology for hadron therapy accelerators, a project hosted by CSIC/IFIC.

GSI HELMHOLTZ CENTRE FOR HEAVY ION RESEARCH

GSI operates a world-wide unique accelerator facility for heavy ions comprising a linac, a synchrotron and a storage ring. The facility allows the production and acceleration of ions ranging from protons up to uranium. The high energy heavy ion beams are used to produce and separate rare isotope beams produced by projectile fragmentation. Based on the experience with the existing accelerators GSI has designed the accelerators of the new international Facility for Antiproton and Ion Research (FAIR) which is amongst Europe's largest accelerator projects presently pursued.

Image © A.Zschau, GSI

The research covers a broad range of fields extending from nuclear and atomic physics to plasma physics and is also engaged in materials research, biophysics and cancer treatment with heavy ion beams. GSI is most famous for the research of heavy elements culminating in the discovery of six new chemical elements. GSI has developed a new type of cancer treatment using carbon beams. This advanced technique is the basis for a new generation of dedicated medical accelerators which are built in industry and delivered to hospitals for patient treatment.

Project:

R&D into software solutions for a next generation dose delivery system

Supervisor:

Dr Christian Graeff

Though scanned ion beams permit highly conformal treatment, and have been shown to be successful in treatment of several tumor sites, transferring this success to the mobile tumors of the thorax and abdomen has been challenging. Interference of target and beam motion as well as the changing beam range to the moving target pose challenges to exact dose delivery. Advanced stage lung cancer but also hepatic or pancreatic cancer patients could benefit tremendously from particle therapy.

Within this project, a next generation dose delivery system will be developed, specifically aiming at the treatment of moving tumors but also non-cancer targets of the upper body. Besides faster beam delivery, it will integrate both motion detection and mitigation methods in its core functionality.

The Fellow will design and implement an advanced motion mitigation strategy, where the dose delivery is synchronized to the target motion to achieve a safe and conformal treatment. In this fashion, prior knowledge of the patient anatomy and tumor motion can be incorporated in treatment plan optimization to generate a whole library of plans for possible different motion states, achieving optimal tissue sparing and conformal dose coverage.

Experimental validation with sophisticated moving phantoms will show the efficacy of the strategy and conclude the project.

Researcher:

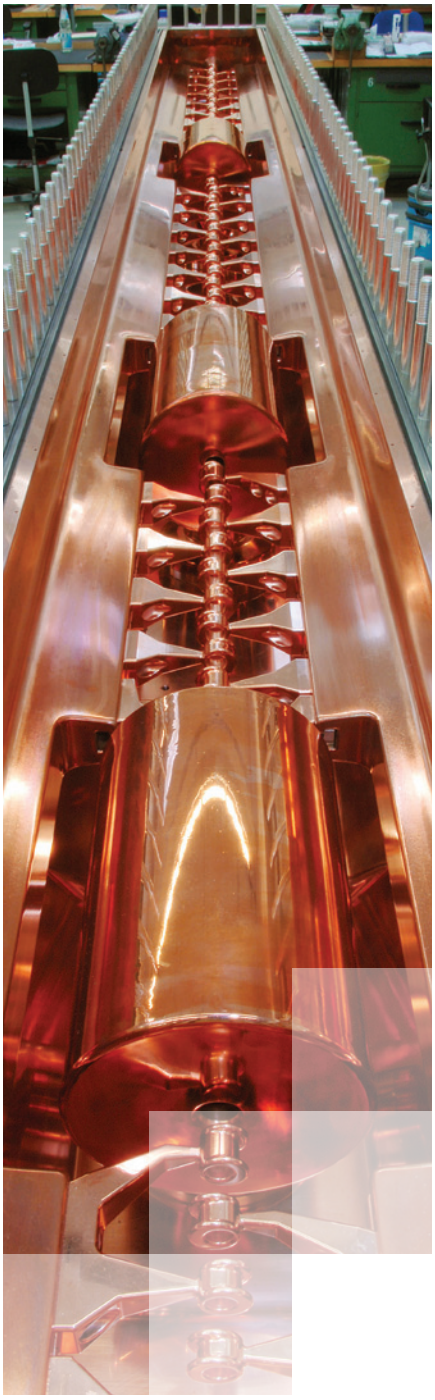
Michelle Lis

Michelle studied physics and molecular biology at Loyola University Chicago. She obtained her Bachelor's degree in 2014. During her studies, she performed research on quantifying image distortions and treatments planning errors in MRI scans due to patient motion, at Loyola University Medical Center in Maywood, Illinois.

She continued her education at Louisiana State University, a CAMPEP accredited university, where she was accepted into the Medical Physics program in 2015. Her research focused on developing a physics-based model for low doses due to patient scatter and the risk on developing secondary cancers.

In January 2017, Michelle joined the OMA project at GSI to work on developing a 4D-optimized dose delivery system for scanned carbon ion beams. This research will allow her complete her PhD at LSU.

Image © G.Otto, GSI



IBA – ION BEAM APPLICATIONS

IBA is the world leader in advanced cancer radiation therapy and diagnostic technologies. The company's special expertise lies in the development of innovative proton therapy technologies, supplying the oncological world with equipment of unequalled precision and benefiting from unrivaled experience in building more than 40 proton therapy centers worldwide.

Beside this, IBA develops and commercializes a full range of high-end monitoring equipment and software enabling hospitals to perform the necessary checks and calibration procedures of radiation therapy and radiology. Precision and control are essential in the delivery of radiation as treatment success and patient safety depend on it.

IBA has installed more than 400 accelerators worldwide. Most of these are used to produce radioisotopes in oncology (for cancer detection), and in neurology and cardiology. In addition to its medical activity, IBA leverages its scientific expertise in radiation to develop sterilization and ionization solutions for various industrial uses.

Project:

Imaging solutions for a novel prompt gamma camera

Supervisor:

Dr Julien Smeets

Ion therapy offers extremely high precision in beam delivery and hence demands very high accuracy to ensure that the maximum penetration depth coincides with the tumor. On-line beam range verification is therefore highly desirable and would reduce the safety margins, currently applied in clinical practice. Prompt gamma rays are emitted along the particle track due to nuclear collisions between ions and patient tissue. Hence, they are an ideal probe to determine the particle range due to their correlation to the dose, the low attenuation inside the patient and their instantaneous emission.

The 'slit camera' of IBA measures the spatial prompt gamma emission separately for each pencil beam and allows therefore a range retrieval on a spot level. Two prototypes of the camera are used by the clinical partners in the US and Europe. First patient measurements have been performed in 2015 and 2016 by the partner institutions. In this project, the Fellow will develop software tools to perform and test the various new treatment workflows made possible by the 'slit camera'.

The Fellow also supports clinical partners in their efforts to increase the number of different treatment cases, which can be monitored by the camera. One possibility would be the development of a faster and more robust implementation of the camera into the clinical workflow by means of positioning and position reproducibility.

Researcher:

Johannes Petzoldt

Johannes Petzoldt studied Physics at the Technische Universität Dresden, Germany. He obtained his Diploma in March 2013, with a project on neutron and proton activation of natural neodymium for the SNO+ experiment.

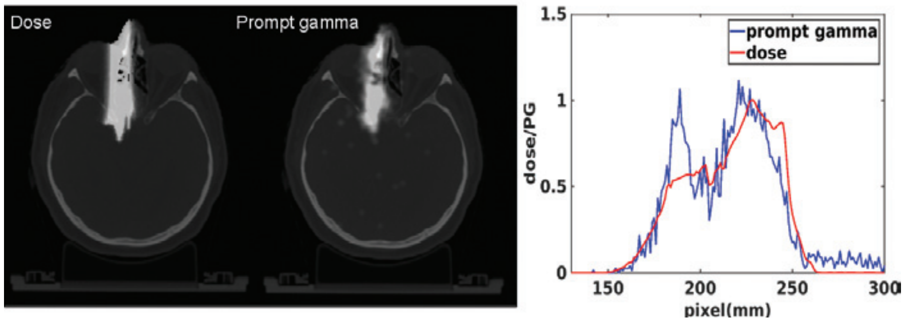
Until September 2016, he worked as an assistant researcher on the topic "range verification for proton therapy" at OncoRay in Dresden, Germany. Johannes investigated scintillation materials, as well as beam characteristics at the proton therapy facility with respect to the novel Prompt Gamma Timing (PGT) method. Furthermore, he tested and characterized a PGT prototype system for the application in clinical practice.

Johannes joined the OMA project to work at Ion Beam Applications (IBA) in Louvain-La-Neuve, Belgium. There, he will continue his research on range verification based on prompt gamma rays.

Image courtesy of IBA

LMU – LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Image courtesy of LMU



Ludwig-Maximilians-Universität München - the University in the heart of Munich. LMU is recognized as one of Europe's premier academic and research institutions. Since its founding in 1472, LMU has attracted inspired scholars and talented students from all over the world, keeping the University at the nexus of ideas that challenge and change our complex world.

The recently established Chair of Experimental Physics - Medical Physics in the Faculty for Physics of LMU aims to promote research and teaching in the field of medical physics, with special focus on advances in pre-clinical and clinical radiotherapy. The R&D activities include new detector developments for dosimetry and in-vivo imaging, as well as analytical and stochastic (Monte Carlo) computational methods for application to a wide range of beam modalities, from established conventional sources of photons and hadrons up to laser-based systems. The department offers a stimulating scientific environment, with multidisciplinary and international team and excellent research infrastructure.

Project:

Advanced Monte Carlo and imaging methods

Supervisor:

Prof Katia Parodi

Compared to traditional Treatment Planning System (TPS) for Proton Radiotherapy, Monte Carlo (MC) techniques show great potential for improving the accuracy of dose calculation.

On the other hand, in-vivo dose monitoring or proton range monitoring is needed to ensure the safety of treatment delivery considering the uncertainty of proton range. Detecting the Prompt Gamma (PG) emission following inelastic nuclear reaction of incident protons and their secondaries with tissues is currently one of the most promising solutions. However, due to the inhomogeneous density of tissue, the PG profile is not always corresponding to the dose profile, which would lead to mis-evaluation for proton range.

The focus of this project is to investigate dose and PG profiles, and quantify the PG-dose correlation for each pencil beam. In this way, pencil beams with poor PG-dose correlation could be excluded in treatment planning ensuring the precision of dose delivery.

First, proton treatment planning will be performed based on a research TPS environment based on the CERR framework coupled to the Geant4 Monte Carlo calculation engine, which is able to simulate both dose delivery and PG profiles on the same patient anatomy (from the planning CT or updated patient information). Then, the dose and PG profile will be investigated with different methods. Pencil beams with a large difference between the fall off position of dose and PG profile suggest poor dose-PG correlation and thus will receive a lower weight in a new optimization. This method will be optimized, tested for different anatomical locations and finally introduced in a research TPS environment.

Researcher:

Liheng Tian

Liheng Tian received his Bachelor's degree in Particle Physics and Nuclear Physics at the University of Science and Technology of China in 2013. During his Bachelor's studies, he investigated the enhancement of radiation effects by nanogold for carbon radiation therapy at Institute of Modern Physics, Chinese Academy of Sciences.

In 2013, he started his Master's study at the University of Chinese Academy of Sciences in Beijing. From 2014 to 2016 his research focused on the use of radioactive ^{9}C beam in radiotherapy. In his work, a Monte Carlo - based Local Effect Model (LEM) re-implementation was built for the evaluation of Relative Biological Effect (RBE) for radiation. Then, combining the LEM re-implementation and Geant4 MC simulation software, the RBE enhancement for ^{9}C beam was simulated and investigated. The work about ^{9}C was published in Medical Physics.

Liheng Tian joined the OMA network in 2016 at LMU Ludwig-Maximilians-Universität München in Germany.

MEDAUSTRON

Image © Kästenbauer/Ettl

MedAustron is one of the most advanced centers for ion beam therapy and research in Europe. The facility is designed to deliver proton and carbon beams to four different rooms; one reserved to non-clinical research and three dedicated to patient treatment, among which a combined horizontal-vertical beam line and a proton gantry.

Clinical operation with protons started in December 2016 and the commissioning of carbon beam has recently started. Full operation is envisaged for 2020, when more than one thousand patients per year are expected to benefit from the world-class treatment offered by MedAustron. In order to reach this ambitious patient throughput, intense upgrade work in various fields of the accelerator must be carried out.

Project:

Treatment facility optimization studies

Supervisor:

Dr Claus Schmitzer

The Fellow will study upgrade scenarios and elaborate a benefit analysis for the specific case of the MedAustron facility to reduce patient treatment time, thus allowing for a larger number of patients to be treated each year. The Fellow will participate in the commissioning of the not-yet-operational beam lines and contribute to the further development of the accelerator.

The possibilities to enhance the machine performance comprise:

a) Reduction of the cycle time of the synchrotron.

Presently, one of the most impacting factor is the reproduction of the magnet hysteresis in each cycle to assure reproducibility, which can be avoided through the development of a system for magnetic field regulation of the power converters for the synchrotron dipoles and quadrupoles (B-train and Q-train system). Other factors that are affecting the cycle time and need further optimization are: the time needed for acceleration (currently the maximum ramping rate achievable for the magnets cannot be reached due to the beam optics limitations leading to beam losses); extraction delay due to resonant extraction mechanism.

b) Active stabilization and control of the beam extracted from the synchrotron.

The intensity stabilization of the extracted beam on a sub-millisecond timescale would ease the irradiation process; furthermore the adaptation of the extracted particle rate to the amount of particles requested per raster point in the tumor region would significantly speed up the irradiation process.

c) Variable energy extraction.

Adapting the extraction energy of the synchrotron during one spill will allow the irradiation of multiple energy layers in the tumor with one synchrotron filling, while the synchrotron is always filled with the maximum number of ions provided by the injector.

Researcher:

Andrea De Franco

Andrea graduated from the University of Genova with a Master in Subatomic Physics in 2012. His thesis concerned the design and development of a novel neutron detector based on diamond with the main purpose of measuring neutron flux and spectrum in accelerator driven fast nuclear reactor prototypes. He spent one year in Japan in the framework of the Vulcanus project, at the beginning of which he studied Japanese for 4 months. Later he did an internship of 8 months in the nuclear power plant system engineering department of Hitachi, where he performed safety system analysis for possible facility upgrade. Starting 2013 Andrea performed doctoral research at the sub-department of astrophysics of the University of Oxford for the Cherenkov Telescope Array project. His focus was on the development of a camera for ground based multi-Teraelectronvolt gamma-ray astrophysics.

In November 2016 Andrea joined the OMA project as a Fellow at the EBG MedAustron.

PSI – PAUL SCHERRER INSTITUT

The Paul Scherrer Institut is the largest research centre for natural and engineering sciences in Switzerland with its research activities concentrated on three main subject areas: Matter and Material; Energy and the Environment; and Health. By conducting fundamental and applied research, the PSI works on long-term solutions for major challenges facing society, industry and science. To address some of these challenges, the PSI develops, constructs and operates complex large-scale research facilities, such as the SINQ neutron source, the Swiss Light Source (SLS) and the SμS muon source. An x-ray free electron laser, named SwissFEL, will go into operation in 2017.

The PSI operates a 590 MeV cyclotron, the world's most powerful proton accelerator, that delivers a 1.3 MW proton beam needed for the neutron and muon sources. The PSI also developed and is operating a superconducting cyclotron named COMET dedicated to the treatment of cancer patients. A third gantry is presently undergoing some final tests before machine operation with patients.

Project:

RF-based measurement of ultra-low charges

Supervisor:

Dr Pierre-André Duperrex

In addition to its research activities, the Paul Scherrer Institut operates Switzerland's sole facility for the treatment of specific malignant tumors using proton beams. Since 1984 more than 6400 patients with ocular melanomas have been treated at PSI. This places PSI among the centers with the largest experience with treatment of this rare disease worldwide. In 2005 the compact, superconducting medical therapy cyclotron COMET became operational. The protons accelerated up to 250 MeV are exclusively used for medical purposes. Two gantries are in operation and a third one is presently being built to offer wider treatment possibilities.

Improvements or development of new diagnostic systems play an important role to optimize medical treatment schemes. Currently, ionization chambers are the most commonly used detector type for beam intensity measurement. However, they use thin foils which are crossed by the beam and decrease the beam's quality by scattering. To mitigate this problem the Fellow shall develop a sensitive RF-based current monitor for fully non-interceptive beam current measurement and he shall study the possibilities to measure the beam position. This project will be performed in collaboration with studies done at the University of Liverpool.

These improvements will target the measurement of beam currents at a very low beam intensity. The design will be based on previous developments at PSI, but will also take into account developments at other OMA institutions. A prototype will then be used for scans at the PROSCAN facility and fully characterized during the second year of the project. In combination with beam dynamics studies this design will be further optimized and result in the design of a detailed pre-series prototype.

Researcher:

Sudharsan Srinivasan

Sudharsan graduated as a mechanical engineer from National Institute of Technology, Raipur, India in the year 2011. During his Bachelor's studies, he worked at Indira Gandhi Centre for Atomic Research (IGCAR), India under Indian National Academy of Engineering (INAE) summer fellowship on artificial neural network modelling of welding joints.

After obtaining his Bachelor's degree, Sudharsan worked at Coal India Limited as an assistant manager for two years. In 2013, he started his Master's studies in nuclear applications at the University of Applied Science Aachen, Germany. His Master thesis project was carried out at the Institute for Nuclear Physics, Forschungszentrum Jülich, Germany. His study focused on fundamentals of nuclear physics and detector technology with the emphasis on medical applications. The work was to design and construct an automated test bench to calibrate beam position monitors (BPMs) for the HESR in Darmstadt. In 2016, Sudharsan graduated with a Master's degree specialized in medical physics.

In January 2017 Sudharsan joined the OMA project at Paul Scherrer Institut.

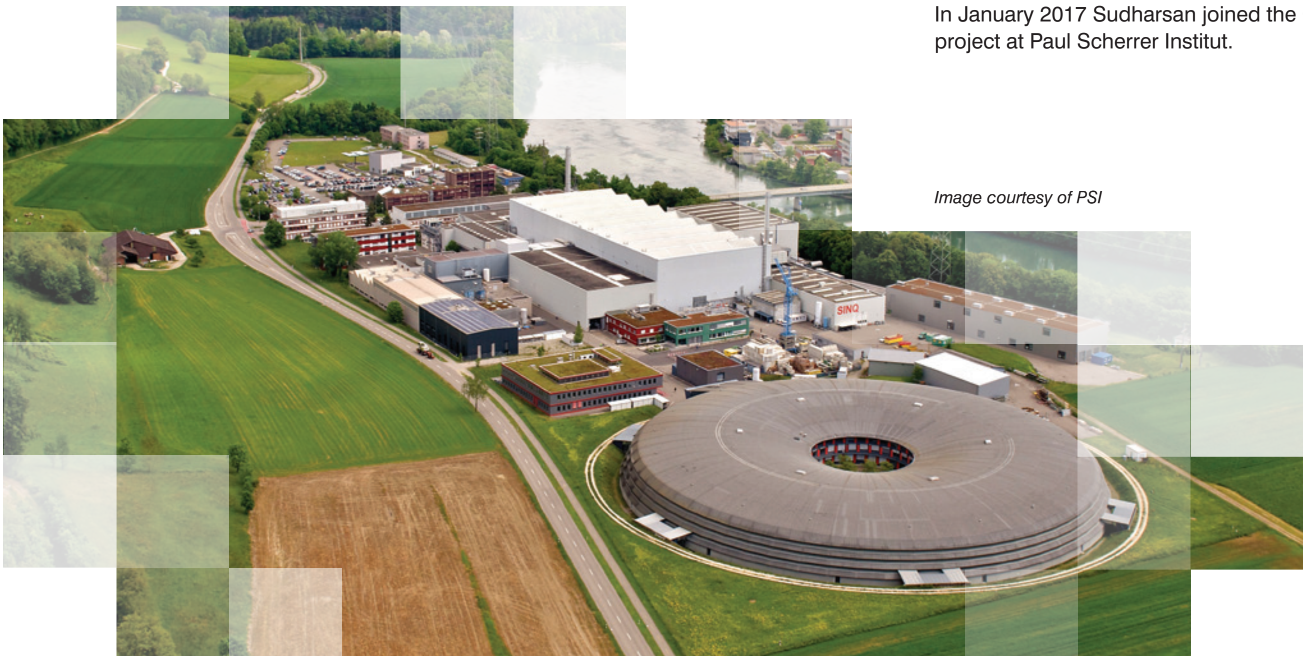


Image courtesy of PSI

UNIVERSITY COLLEGE LONDON

UCL is one of the UK's premier universities and is consistently ranked in the world's top 25. It is a world-class research and teaching institution whose staff and former students have included 21 Nobel Prize winners.

Founded in 1826, it was the only university in England at that time which admitted students regardless of race or religion and the first to admit women on equal terms with men. It has an annual turnover (2011/12) of £871M and receives over £300M in research funding, the third largest in the UK. It has 29,000 students and 4,000 staff which includes the largest number of Professors of any HEI in the UK and the largest number of female professors. UCL has 74 academic departments organised into 10 faculties and is associated with several major teaching hospitals: UCLH, Great Ormond Street Hospital for Children, the Royal Free Hospital and Moorfields Eye Hospital.

Project:

Calorimeter for proton therapy and radiography

Supervisor:

Dr Simon Jolly

Chief amongst the challenges inherent in providing effective treatment with proton therapy is effective imaging. Traditional treatment planning with photons requires multiple patient CT images to build up an effective diagnostic image for patient planning. However, the increased localization of proton dose delivery requires a corresponding increase in imaging resolution, exposing the limits of traditional CT imaging. In addition, X-ray CT images do not provide information on the proton-specific absorption characteristics of tissue surrounding the treatment volume.

An alternative is to use protons for imaging: an energy is chosen such that the protons do not stop within the body of the patient but pass through to be detected. Using the same proton beam for both imaging and treatment ensures the patient does not have to be moved between imaging and treatment: in addition, the anatomical information acquired from the imaging does not have to be adjusted from a different imaging modality. A conceptual proton Computed Tomography (pCT) system consists of a series of tracking layers upstream and downstream of the patient, with some method of measuring the final energy of the diagnostic protons at the 1% level.

This project seeks to adapt existing calorimetry technology for the precise measurement of proton energy in a clinical setting. This technology was developed by the UCL High Energy Physics group for the SuperNEMO experiment. Preliminary calculations and early experimental measurements indicate that such a SuperNEMO detector achieves an energy resolution in the region of 1% for clinical proton energies. Further measurements will be made to fully characterize the performance of the detector. This will form the basis of the calorimetry stage for a proton CT system.

In addition, an accurate calorimeter would also provide valuable quality assurance measurements of the treatment protons. In order to ensure that treatment is carried out safely, a range of quality assurance (QA) procedures are carried out each day before treatment starts. The majority of this time is spent verifying the Bragg Peak and depth dose curve of several proton beam energies. These energy QA measurements take significant time to set up and adjust for different energies.

The calorimeter system under development will also be used as the basis for a fast energy QA system. This would allow several energies to be measured across the full energy range available at the nozzle in only a few minutes, significantly reducing the time taken to carry out the daily QA.

The PVT scintillator also has the advantage of having very similar properties to water, providing an almost identical proton range as a function of energy and giving a similarly accurate measurement of Water Equivalent Path Length.

Researcher:

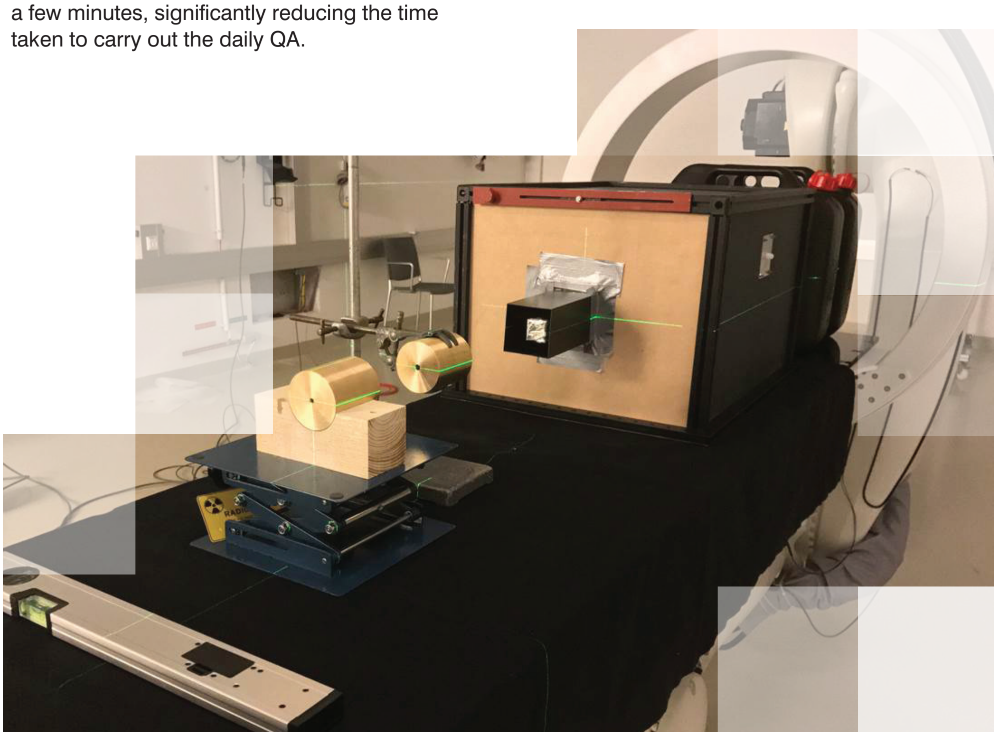
Laurent Kelleter

Laurent obtained a Bachelor's degree in physics in 2013 from RWTH Aachen University. He graduated with a work on the set-up of a SiPM-based scintillation detector prototype to measure atmospheric air showers.

After spending a year abroad at the university of Montpellier, France, he obtained a Master's degree in experimental particle physics in March 2016 from RWTH Aachen. For his Master's thesis he worked on future online beam monitoring in ion therapy via prompt gamma radiation. The project included a two-week experimental beam time at the Heidelberger Ionenstrahl-Therapiezentrum (HIT). After completing his studies, he drew up a publication on the team's results in collaboration with the project partners from Jagiellonian University in Krakow, Poland.

In October 2016, Laurent joined the OMA network at University College London.

Image courtesy of UCL/MedAustron



UNIVERSITY OF MANCHESTER

MANCHESTER 1824
The University of Manchester

The University of Manchester is one of the largest in the UK. It has an exceptional record of generating and sharing new ideas and innovations and is applying its expertise and knowledge to solving some of the major social, economic and environmental problems confronting mankind around the globe.

Manchester has the largest student community in the UK, with more than 28,000 undergraduates and 11,000 postgraduates. The University's four faculties include twenty academic schools and hundreds of specialist research groups undertaking pioneering multi-disciplinary teaching and research of worldwide significance in Engineering and Physical Sciences, Medical and Human Sciences, Life Sciences and Humanities.

In the physics of particle accelerators, the University has international expertise in the dynamics of charged particles, RF accelerating structures and novel machines. It plays a key role in the luminosity upgrade of the Large Hadron Collider and central roles in future collider projects such as the LHeC. Moreover, it is involved in a number of international projects utilising its expertise in beam dynamics.

Project:

Gantry design for linac-boosted protons

Supervisor:

Dr Hywel Owen

The program of work consists of examining the beam transport both through the booster linac and through candidate superconducting gantry designs. The overall objective of the project is to determine a detailed beam-optical design and outline magnet design for a combined superconducting gantry and booster linac system. Initial work has concentrated on the use of combined-function superconducting dipoles using a canted cosine-theta winding method as demonstrated separately at NIRS and LBNL. The Fellow will examine this option including an assessment of how scanning and focusing should be performed. In particular, it is likely that a downstream scanning option will be chosen but the relative merits of this compared to upstream scanning will be examined as part of the project. Alternative schemes such as the use of compact superconducting achromats will also be studied.

The Fellow works alongside existing postdoctoral and doctoral researchers who are developing the design and implementation of a high-gradient proton linac to be used within the overall design. It is hoped that a demonstration of a test structure will occur during the Fellowship, and the Fellow will also contribute to implementation and testing work as appropriate. The Fellow will spend some portion of their time at PSI and may assist them with the development of their facility as part of the overall training programme. In addition, there will be opportunities to contribute to the design and implementation of the research beam-line at the Christie Hospital, and to undertake other project work there that will contribute to the Fellow's training.

The Fellow is employed as part of the Accelerator Group in the School of Physics and Manchester University, but based at the Cockcroft Institute at the Daresbury Science and Innovation Campus. The Fellow has joined this group and will perform the essential work of designing how to integrate the high-gradient structures into a complete treatment and imaging system. The issues to investigate are: capture losses in the first structures and how to mitigate these; dose delivery rates to the patient and how to carry out efficient imaging; coupling of the booster linac output to a suitable gantry design; beam control and switching between treatment to imaging energies; beam-optical design; magnet design; particle tracking and scanning.

Researcher:

Ewa Oponowicz

Ewa studied biomedical engineering and physics at the Warsaw University of Technology, Poland. She obtained her Bachelor's degree in 2013 in cooperation with National Centre for Nuclear Research in Poland where she worked on the beam forming systems in medical electron accelerators.

She graduated in 2015 at the National School of Engineering in Nantes, France. Her Master's degree was carried-out at CERN, where she was a Technical Student in the Beam Instrumentation group. Her work focused on the software development for the beam position and intensity measurement systems in the Antiproton Decelerator.

In 2016 Ewa joined the OMA project at the University of Manchester.

UNIVERSIDAD DE SEVILLA / CENTRO NACIONAL DE ACELERADORES

CNA (Centro Nacional de Aceleradores) is a mixed centre of the University of Seville, Junta de Andalucía and the Spanish research council (CSIC). It is recognized as a national singular infrastructure (ICTS) for particle accelerator based interdisciplinary research and carries out fundamental and applied research. The center's main facilities are: a 3MV tandem van de Graaff; a 18 MeV proton (9 MeV deuteron) cyclotron; 1 MV tandem Cockcroft-Walton for accelerator mass spectrometry: a compact accelerator for ^{14}C dating (MICADAS); a ^{60}Co photon irradiator; and a PET/CT scanner for humans and large animals.

Beside these instruments, the center has sample preparation laboratories, as well as an installation for radiopharmaceutical production. A small positron emission tomograph (PET) for animal studies completes the cyclotron laboratory. The tandem has seven independent beam lines, equipped for Ion Beam Analysis techniques and nuclear physcis experiments. The cyclotron has ports for PET isotope production, and an external beam line.

CNA has been involved in European programs in both the 6th and the 7th framework program and has a strong track record of training researchers at both ESR and ER level. It is also supported by Spanish national and regional grants. CNA has also contracts and agreement with companies and institutions, which provide a large fraction of its budget. 61 people work at CNA, from which 28 have PhDs. 14 PhD theses have been defended at CNA between 2011 and 2016.

Project:

Radiobiological effectiveness of protons

Supervisors:

Prof José M Espino, Dr Miguel A Cortés-Giraldo

Cancer is one of the leading causes of mortality worldwide, killing more than one million people per year just in Europe. Accelerator based hadron therapy is nowadays one of the most promising techniques in the fight against cancer, and many dedicated accelerators are being installed in hospital-based clinical centres around the world. However, more research is required in order to understand deeply the interaction mechanisms and the biological effectiveness of hadrons (protons and heavy nuclei) on both cancerous and healthy cells.

The aim of the project is to study the behaviour of the Relative Biological Effectiveness – RBE of protons along the depth-dose profile of the proton beam as it is absorbed in tissues. To this end, the already existing 18 MeV external beam-line at the National Centre of Accelerators – CNA, will be adapted to perform irradiations of biological samples and study the response of radiochromic films.

Firstly, the Fellow will work at the 18 MeV proton cyclotron facility at the CNA to ensure an overall optimization of the beam diagnostics for the determination of all the essential beam parameters. This includes the measurement of energy, intensity profiles, fluences and homogeneities of the proton beam in correspondence to the target position, in order to define the best beam-line set up suitable for the irradiation of biological samples. Therefore, a framework for cells studies will be provided, as well as important information for a critical performance assessment of all diagnostics R&D in this WP.

Once the mentioned framework is ready, dedicated setups, allowing for the irradiation of cell cultures in controlled environment, will be mounted on the external 18 MeV proton beam-line. This part of the work will be carried out in collaboration with groups of biologists, which will lately analyze the cultures. At this stage, for example, it could be interesting to study the "low-dose hyper-radiosensitivity (LDHRS)" phenomenon with protons, to understand the dependence of LDHRS on the type of radiation and linear energy transfer (LET).

Finally, each step of the Fellow's work will involve Monte Carlo simulations, which will be performed to compare experimental measurements with simulated data. These calculations, mostly carried out with the Geant4 toolkit, will involve both macroscopic quantities (dose, fluence, LET etc.) and the characterization of the radiation quality through microdosimetry quantities (distributions of lineal energy, energy imparted etc) in order to obtain the magnitudes needed to apply theoretical RBE models.

Researcher:

Anna Baratto Roldán

Anna Baratto Roldán studied Physics at the University of Trieste in Italy. Following the completion of her Bachelor's degree in 2013, she enrolled in the MSc course of Nuclear and Subnuclear physics at the University of Trieste, choosing medical Medical Physics as her main subject. During her studies she developed a keen interest in the fields of charged particle therapy and radiobiology.

Anna carried out her Master's thesis within a cooperation program between the University of Trieste and the INFN Section of Milan, and obtained her Master's degree in March 2016. For her thesis project, she worked on the measurement and analysis of charged secondary particles emitted by oxygen beams impinging on a PMMA target. The project was part of a larger experiment, held at the Heidelberg Ion Beam Therapy centre, which aimed to develop new real-time monitoring techniques for Charged Particle Therapy.

In November 2016, Anna joined the OMA project at University of Seville and CNA.

ViALUX

ViALUX GmbH is a privately held company with a worldwide network of representatives. The ViALUX team has long-term experience in optics, image processing, and optoelectronics.

Knowledge and skills of a highly qualified team of engineers is the source of product innovations at the cutting edge of technology. A network of distributors covers the industrial areas in Asia, America, and Europe providing local service. Exporting more than 80% of its annual production ViALUX is proud to serve customers worldwide.

ViALUX develops, produces, and distributes electro-optical components and optical measurement systems for 3D-shape and deformation analysis. ViALUX products are successfully sold into different markets: automotive industry, steel industry, machine-vision industry, life science, medicine, and research & development. ViALUX is an authorized DLP® Design House of Texas Instruments supporting customers in various high-performance industrial applications of the DLP micro-mirror device. One of such DLP applications is 3D scanning where ViALUX itself has developed high competence for specific medical 3D applications.

ViALUX engineers work on sustained product development along customer needs. Combining advanced opto-electronics with outstanding metrology software forms the core competence and is the key to company's success.

Project:

Optimization of high-performance 3D/4D surface scanning technology for patient monitoring in radiotherapy environment

Supervisor:

Dr Roland Höfling

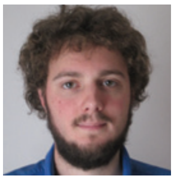
Patient movement monitoring takes advantage of high-precision, high-resolution 3D surface scanning technology. DLP micro- mirror technology was adopted to implement state-of-the-art solutions in terms of accuracy, speed, and data density. For ultra-high-speed 3D/4D scanning, it would be ideal to use the 10-20 kHz switching rate of DLP pattern generator combined with an equivalent area imaging device. New sensor concepts are under development to overcome the speed barrier of conventional machine vision cameras and a new level of electronics integration is promising to solve the task.

Within this project, the Fellow will conduct a systematic study of the performance of that new generation of 3D/4D sensors and will contribute to the optimization of the system used over an extended time with radiation exposure. In general, this project is focused on optimizing the long-term availability and reliability of new 3D/4D scanning sensors made by ViALUX.

The theoretical background of radiation interaction with electronic devices will be systematically summarized and experimental work will be performed, involving the partner network of the OMA project for gaining real-world data and application knowledge.

Researcher:

Samuele Cotta



Samuele received his Bachelor's degree in Physics in 2013 from the University of Insubria in Como (Italy), with a thesis about the characterization of a $PbWO_4$ calorimeter read out by SiPM.

In the same year he started his Master's studies at the University of Insubria, focusing on medical physics.

Samuele obtained his Master's degree in Physics in March 2016 with a thesis about the characterization of an active detector for neutron flux measurements. During his thesis work he assembled and tested a detector based on a CsI crystal, which was then used to measure the neutron contamination flux in a radiotherapy treatment room. The results were also obtained through Monte Carlo simulations with Geant4.

In January 2017 he joined the OMA project at ViALUX in Chemnitz.

3D/4D scanning sensor made by ViALUX. Image courtesy of Vialux.

TRAINING PROGRAM

The OMA Fellows receive an extensive research-based training within a unique international partnership. Working within the network they gain a broad insight into both academic and industrial aspects associated with medical accelerators, with opportunities for specific training and secondments. The OMA partners cover a very broad, yet closely interconnected, program that combines many different fields. These range from biomedicine, oncology, Monte Carlo studies, electronics and imaging systems to accelerator science and technology. The contribution of industry partners ensures that the transfer of industry-relevant skills is an integral part of all individual projects.

This creates a truly collaborative network within a strong interdisciplinary environment that provides an excellent basis for the training of researchers. The fundamental core of the training is a dedicated cutting-edge research project for each Fellow at their host institution. To complement this, the network provides opportunities for cross-sector secondments for all Fellows. The secondment scheme enables them to spend time working at other institutions within the network, receiving hands-on training in specific techniques and a broader experience in different sectors. Another important aspect of the training is a series of network-wide events comprising several schools, topical workshops and an international conference, open also to the wider scientific community.

INTERNATIONAL SCHOOLS

Three OMA Schools will be organized during the life time of the project. Each School will be one week long and participation will be open to researchers from outside the consortium.

1st OMA School – Medical Accelerators

The OMA School on Medical Accelerators will cover such topics as beam generation, transport and delivery to the patient, as well as treatment schemes, beam extraction and clinical assessment of effectiveness. Challenges related to beam diagnostics, imaging and patient issues will also be discussed. The School will be held at CNAO in Pavia, Italy, in June 2017.

2nd OMA School – Monte Carlo Simulations

The School will cover geometry definition, material assignment, analysis, dose calculations, different solvers and post processors, as well as data visualization tools. It is planned for November 2017.

3rd OMA School – Particle Therapy

This School will take place in spring 2019 and cover advanced and combined techniques. These will include real time beam monitoring, variable energy and intensity beam delivery for 3D tumor ‘painting’, online beam and patient imaging.

Information about all OMA Schools will be announced via the project website, social media and the network’s quarterly newsletter. A limited number of scholarships will be provided for external participants.

TOPICAL WORKSHOPS

The network will organize a series of Topical Workshops covering all important research areas of the OMA project. A typical workshop will last two days and will be open to external participants.

1st OMA Topical Workshop –

Facility Design Optimization for Treatment

2nd OMA Topical Workshop –

Diagnostics for Beam and Patient Monitoring

3rd OMA Topical Workshop –

Accelerator Design and Diagnostics

The OMA Fellows will also participate in the COSYLAB Academy. Further workshops may be organized by the network; details will be posted on the project website.

COMPLEMENTARY SKILLS TRAINING

The OMA Fellows receive training in complementary skills through an established quality School implemented by the University of Liverpool. This Complementary Skills School model has been recognised by the European Commission as ‘best practice’ for providing future generations of scientists and engineers with relevant skills. Through this training the Fellows develop the non-technical skills that are invaluable for their future careers, whether that be in academia or industry.

The OMA Complementary Skills School was held at the University of Liverpool in April 2017 and included training on presentation skills, science communication, project management, intellectual property rights and team working. Building on this school a Workshop on Technology Transfer and an Advanced Researcher Skills School will be organized by the University of Liverpool in 2019. These courses will familiarize the Fellows with such topics as research commercialization, entrepreneurship and patent regulations. The Fellows will also receive training in skills useful in the labor market, such as CV writing and job interviews, and will be made aware of different career pathways available to them.

FINAL CONFERENCE AND OUTREACH SYMPOSIUM

The OMA Final Conference will take place in autumn 2019 to summarize and promote the scientific results of the project and discuss further challenges. In the same year the project will also host an outreach Symposium as a culmination of the outreach activities undertaken during the course of the network. The Symposium will present the main research findings to the general public, emphasizing applications of the technologies concerned.

DISSEMINATION
& COMMUNICATION

The research results of the project are disseminated via scientific journals, international events, and via our website www.oma-project.eu. The website features details of all research projects undertaken by the Fellows and is regularly updated with consortium news. This is complemented by social media and a quarterly newsletter. Dialogue with scientists outside the network is enabled through a series of OMA events open to external participants.

The consortium as a whole and the Fellows individually are actively involved in communicating the project to general public. The Fellows regularly participate in school visits, open days and science festivals to share their passion for science. Each OMA School features a public lecture by a renowned scientist. The network will also organize a major outreach event towards the end of the project. The outreach Symposium will present research results and their importance for science and society to the general public.

www.oma-project.eu

Images courtesy of University of Liverpool

MANAGEMENT
STEERING COMMITTEE

The Steering Committee is responsible for the overall network strategy and takes all decisions concerning the network. It consists of the following elected members:

Prof Dr Joaquín Gómez Camacho, Director of Centro Nacional de Aceleradores in Seville, Spain, which provides infrastructure for particle accelerator - based fundamental and applied research. His research focus is on the scattering of exotic nuclei on heavy targets.

Dr Christian Graeff, leader of the Medical Physics group of the GSI Biophysics department in Darmstadt, Germany. His main research interests are the treatment of moving targets with scanned ion beams, including treatment planning strategies and their experimental validation.

Dr Monica Necchi, Research Grants Manager at Fondazione CNAO in Pavia, Italy. Her main research interests deal with application of physics into the biomedical field and interactions of radiation with matter.

Dr Julien Smeets, Research Project Manager at Ion Beam Applications SA in Louvain-La-Neuve, Belgium. His research focuses on prompt gamma imaging and its development for proton therapy.

Prof Dr Carsten P Welsch, Head of the Physics Department of the University of Liverpool and scientific coordinator of the OMA network. His research covers frontier accelerators, novel acceleration schemes, as well as accelerator applications.

A Fellow representative will join the Steering Committee in due time.

SUPERVISORY BOARD

Each beneficiary partner of the network is represented on the Supervisory Board. The board meets annually to monitor progress and ensure that the training is of the highest standard and remains relevant, also in relation to industry and the job market.

PROJECT T.E.A.M.

Day to day project management is carried out by the Project T.E.A.M. from the University of Liverpool based at the Cockcroft Institute in Daresbury, UK. The T.E.A.M. supports Prof. Carsten Welsch in coordinating large scale research projects and is responsible for project management, monitoring, communication, and organisation of events.

Prof Dr Joaquín Gómez Camacho

Dr Christian Graeff

Dr Monica Necchi

Dr Julien Smeets

Prof Dr Carsten P Welsch

ASSOCIATED AND ADJUNCT PARTNERS

Adaptix Ltd.

Adaptix is transforming planar X-ray – the diagnostic imaging modality most widely used in healthcare worldwide. We are adding low-dose 3D capability – digital tomosynthesis - to planar X-ray while making it more affordable and truly portable so radiology can more easily travel to the patient. This transformation will enhance patient's access to the world's most important imaging technologies and likely increases the diagnostic accuracy for many high incidence conditions such as cardiovascular and pulmonary diseases, lung cancer and osteoporosis.

Adaptix will replace tube-based Victorian-era technology with an innovative Flat Panel X-ray Source made in a semiconductor foundry that will reduce costs to manufacture, deploy and maintain.

Clatterbridge Cancer Centre

The Clatterbridge Cancer Centre is one of the largest networked cancer centres in the UK. From nine operating sites across Merseyside and Cheshire we treat over 9,000 new patients a year, offering pioneering chemotherapy, radiotherapy and proton therapy treatments. The National Eye Proton Therapy Centre, which has provided the UK's only proton therapy service since 1989, is the world's first hospital-based proton facility. We bring together high quality clinical services, research and academic excellence to drive forward the development of new leading edge drugs and therapies and provide the highest quality, specialist care for patients.

The Christie

CHRISTIE Hospital is the largest single-site cancer center in Europe, and treats around 40,000 patients per year (with over 130,000 radiotherapy treatments) with a dedicated oncology focus; since its foundation over 100 years ago The CHRISTIE and is associated research institutes have pioneered many new techniques in radiotherapy, including: leading early developments of dosimetry and fractionated treatment; first UK clinical use of multileaf collimation and intensity-modulated radiotherapy; first clinical use in the world of image-guided radiotherapy. The CHRISTIE presently has 16 networked linear accelerators and organizes chemotherapy delivery on 15 sites.

COSYLAB d.d.

Cosylab is developing next generation technologies for global niche markets and is a fast growing technological company, committed to creating innovative products and services intended for demanding markets and customers.

The company has started in a laboratory at the Jožef Stefan Institute , the largest Slovenian research institute and, due to first-hand experience of working in major accelerator facilities, has soon become the largest company specialized in developing control systems for particle accelerators. Amongst others, Cosylab is specialized in the field of control systems for particle accelerators and other large experimental physics facilities. We cover hardware and software products and accompanying services such as customization and integration of already existing solutions, custom development, consulting and tutoring.

C-RAD

C-RAD was founded in 2004 by researchers from Karolinska Institutet and the Royal Institute of Technology in Stockholm, clinics at Karolinska Hospital in Solna and people with extensive industrial experience in the field of radiation therapy.

C-RAD develops innovative solutions for use in advanced radiation therapy. The C-RAD group offers products and solutions for patient positioning, tumor localization and radiation treatment systems.

In 2015, C-RAD has acquired the Franco-Belgian Cyrpa group. Cyrpa develops innovative laser solutions for patient positioning and virtual simulation within radiation therapy.

Danfysik

Danfysik is one of the world's leading companies within the development and manufacturing of high quality equipment for particle accelerator laboratories, healthcare and industry, and employs some of the most skilled, experienced and dedicated engineers and technicians. Danfysik has customers and partners all over the world and our business is accelerating like our technology.

Major past projects include 3 complete injector synchrotrons for synchrotron light sources (ANKA, CLS, ASP), a complete synchrotron based particle therapy accelerator system, as well as state-of-the-art insertion devices for synchrotron light sources. Our products our renowned around the world and we are recognized for example through King Frederik IX's Award for Excellence in Export.

DTBS Healthcare department of CEA-LETI

A subsidiary of the Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA) France's nuclear and renewable energy commission, Leti was established in 1967 in Grenoble. Today, the CEA-Leti is granted over 286 patents a year and handles a portfolio of more than 2,200 patented inventions. It has extensive facilities for micro- and nanotechnology research, and laboratories and equipment that provide first-class nanoscale characterization, chemistry and biology, photonics, design and upstream research capabilities.

The Detector Laboratory Department of micro Technology for Biology and Health of CEA-LETI works on integration of technologies in systems using X-ray or gamma-ray for medical imaging, security, NDT and environment for industrials partners.

Fistral Training and Consultancy Ltd

Fistral Training and Consultancy Ltd has been providing highly successful practical training courses and consultancy to organisations globally since 1991. Fistral deliver training courses in areas such as Project Management, Risk Management, Team Working, Communication, Collaboration, Influencing, Personal Effectiveness and Leadership.

Fistral has wide-ranging experience in knowledge-intensive sectors in both academia and industry. We support research staff from first-entry to board-level in world-class organisations, institutions and research centers. Instructors are active practitioners in their field ensuring training is applicable and focused on techniques and skills used in real life. This experience underpins the training we deliver and ensures it remains current and relevant.

Holdsworth Associates

Holdsworth Associates is an award-winning public relations consultancy with a creative approach to communications. We support an exciting range of clients with innovative, cost-effective campaigns that achieve results.

In 2013 we were voted 'Best PR Agency' in the Business Weekly New Year Honours Award and received an 'Outstanding Small Consultancy' silver award from the Chartered Institute of Public Relations (CIPR) PRide Awards. We have specialist knowledge in science and technology and offer a wide range of public relations services including engagement with the media, content creation, preparing press releases, publication of technical articles, social media and online communications.

INFN

INFN is the Italian research public institution devoted to nuclear physics, particle and astro-particle physics and their applications. INFN runs 4 national laboratories. Three of them are running and developing accelerators. Amongst others, there are specific projects for hadron therapy. INFN also runs laboratories for the development of detection techniques. INFN has unique and certainly largely sufficient infrastructure, specialized equipment and experienced personnel for training young researchers. INFN activity is deeply connected to that of Italian Universities and other academic Institutions. This ensures that the young researchers have the possibility to gain diplomas or PhD theses and learn more about research methods before going out to industry, to other nuclear installations or to the health-related field.

Innovation Agency

The Innovation Agency is the Academic Health Science Network (AHSN) for the North West Coast, covering Cheshire, Lancashire, Merseyside and south Cumbria.

They are one of 15 AHSNs, funded by NHS England to improve health and generate economic growth by accelerating the spread and adoption of innovation.

They work through collaborations - with individuals and organisations in the NHS, other AHSNs, academia, local government, businesses, patients and voluntary sector organisations.

They are led by a partnership Board comprising senior leaders from these different sectors, to address the health needs of the region's population.

Instrumentation Technologies d.d.

Instrumentation Technologies is a provider of comprehensive solutions for the instrumentation of particle accelerators, which it markets under the established and protected trademark Libera and around which it has established a global community based on collaboration, bringing together some of the most prominent experts, engineers and scientists from many of the well-regarded international scientific and research institutes. Libera state-of-the-art instrumentation systems are used for diagnostics and beam stabilization at the accelerator facilities around the world. Many instruments have been developed in close collaboration with experts from research institutes. Different Libera products are designed to work together, getting synergetic effects and enabling turnkey solutions for beam stabilization.

ASSOCIATED AND ADJUNCT PARTNERS (Cont.)

Inventya Ltd

Inventya is a leading innovation management consultancy providing proof-of-market research, product-service commercialization and market-oriented due diligence services for R&D-led organisations. Our services validate the commercial potential of new ideas, increase market penetration, reduce risk and optimize investment. Specialists in business-to-business market intelligence and commercialization services, Inventya works across all scientific and technology domains, and across global markets. We work with R&D-led growth firms, investors, universities and public research laboratories.

OncoRay - National Center for Radiation Research in Oncology

The Dresden Center OncoRay pools the strengths of its three operating partners: the University Hospital Carl Gustav Carus Dresden; the Faculty of Medicine at the Technische Universität (TU) Dresden; and the Helmholtz-Zentrum Dresden-Rossendorf (HZDR). Together with the Heidelberg-based HIRO/German Cancer Research Center (DKFZ), OncoRay is the National Center for Radiation Research in Oncology (NCRO).

Across its locations the Center has an outstanding infrastructure and expertise in radiation research – also by international comparison. About 80 scientists from all over the world work on multidisciplinary programs at OncoRay, with research focusing on the fields of medicine, physics, biology and information sciences. The objective is to achieve a decisive improvement in the treatment of cancer using biologically individualized, technologically optimized radiotherapy.

PTB - Physikalisch-Technische Bundesanstalt

The Physikalisch-Technische Bundesanstalt (PTB) is the National Metrology Institute of Germany with scientific and technical service tasks. PTB measures with the highest accuracy and reliability – metrology as the core competence.

For service and research in the field of dosimetry for external beam radiotherapy PTB operates the Metrological Electron Accelerator Facility (MELAF) in Braunschweig, Germany. Three accelerators, two clinical accelerators and a 50 MeV research electron accelerator, offer excellent experimental possibilities for investigations with high-energy photon and electron radiation: from fundamental research to applications in hospitals. The PTB offers access to its metrologically well characterized radiation fields also for external researchers with other research projects beyond dosimetry.

Research Instruments GmbH

Research Instruments is focusing on rf cavities and systems, linear accelerators, particle sources, beam lines and diagnostics. They develop and provide special products for physics and energy research as well as for medical applications. Through their company history of Interatom, Siemens, ACCEL and now as part of Bruker Corporation they are continuously developing turn-key accelerator systems and key components for large scale accelerator facilities. Many of these projects were carried out in partnership with Universities and research centres from around the world.

STFC

STFC is the UK organization responsible for providing large scale accelerator facilities within the UK, and UK involvement in international accelerator programs.

The Accelerator Science and Technology Centre (ASTeC) is a distinct department with STFC which has the remit to undertake advanced research and development activities that will allow STFC to provide or contribute to current and future accelerator projects, both with the UK and internationally. ASTeC was responsible for accelerator design work on Diamond, 4GLS and the New Light Source Project, and has contributed to many international projects such as the International Linear Collider and CLIC. ASTeC is a core member of the Cockcroft Institute for accelerator research.

UK Intellectual Property Office

The Intellectual Property Office is the UK Government's official body responsible for Intellectual Property (IP) rights in the United Kingdom. These rights include patents, designs, trademarks and copyright. We are an Executive Agency of the Department for Business Innovation and Skills (BIS) with the aim of promoting innovation by providing a clear, accessible and widely understood IP system. Ultimately, this enables the economy and society to benefit from knowledge and ideas.

University of Lancaster

University of Lancaster is one of only a handful of universities with a collegiate system which has helped to forge a strong sense of identity and loyalty, and continues to be a distinctive feature of student life at Lancaster. Students from one hundred countries make up a thriving community based around our nine colleges, creating a culturally diverse campus in a location that boasts the combination of city, coast and countryside.

Lancaster's community extends far beyond the campus with research, teaching and student exchange partnerships with leading universities and institutions in 24 countries around the world. Lancaster's journey has been a remarkable one, and it is now amongst the top one per cent of universities in the world, with an ambitious strategic plan.

University of Pennsylvania School of Medicine

Penn Medicine is one of the world's leading academic medical centres, dedicated to the related missions of medical education, biomedical research, and excellence in patient care. Penn Medicine consists of the Raymond and Ruth Perelman School of Medicine at the University of Pennsylvania (founded in 1765 as the nation's first medical school) and the University of Pennsylvania Health System, which together form a $5.3 billion enterprise.

The Department of Radiation Oncology at Penn Medicine is one of the largest and most respected programs in the world. The comprehensive program provides patients access to nearly every option available to treat their cancer. The department has an outstanding research program that provides patients with access to clinical trials that expand their treatment options.

University of Salamanca

Founded in 1218, the University of Salamanca is a well-recognized Spanish academic institution. It offers a wide range of studies to about 35,000 students, 4000 of which are international students, and it contracts 2,500 researchers and lecturers. The graduate and post-graduate programmes cover the diverse fields of knowledge, including Physics and Medical Science. The University is partner in a variety of international research projects, including several ITN Actions, and has collaborations with many institutions in Europe and all over the world.

University of Santiago de Compostela

Located in a World Heritage city, the University of Santiago de Compostela (USC) traces its roots back to 1495. This institution maintains one of the most important academic traditions in Europe, being today a modern university committed with societal progress through the highest quality standards in academic and research activities. The university ranks 5th in Spain's best universities ranking. The USC offers 48 official degrees, 71 master's degrees and a significant number of doctoral programs covering almost any branch of knowledge. It is made of around 30000 students, 350 professors, 1900 lecturers. 300 research groups and 12 research institutes generate a highly recognized research activity.

Contact

Prof Dr Carsten P Welsch
OMA Coordinator

The Cockcroft Institute
University of Liverpool
WA4 4AD
Warrington
UK

carsten.welsch@cockcroft.ac.uk

www.oma-project.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 675265. The information herein reflects only the views of its authors and the Research Executive Agency is not responsible for any use that may be made of the information contained.