OPAC

Optimization of Particle Accelerators

A Marie Curie Research and Training Network

2nd Edition

CONTENTS

INTRODUCTION

ACCELERATING SCIENCE AND TECHNOLOGY

There are more than thirty thousand particle accelerators in the world, ranging from the linear accelerators used for cancer therapy in modern hospitals to the giant 'atom-smashers' at international particle physics laboratories used to unlock the secrets of creation.

The development and optimization of accelerators requires the collaboration of engineers and scientists from a broad range of disciplines from theoretical physics and mathematical modelling through to material science, electronics and mechanical engineering.

The oPAC consortium has carried out collaborative research to optimize the performance of present and future accelerators and light sources. The network brought together leading research centres, universities, and industry partners to pave the way for next generation research facilities and train the next generation of scientists and engineers.

oPAC RESEARCH

Beam Physics

A detailed understanding of the motion of charged particle beams in complex electromagnetic field distributions, the impact of beam-beam effects on experiment performance, as well as of collective effects and their potential to drive machine instabilities, and of beam halo formation and propagation processes is very important to optimize the performance of essentially any accelerator. The oPAC Fellows have worked on the development of beam handling techniques and carried out detailed studies into the beam dynamics of some of the most advanced particle beams in the world. This drives R&D also in other fields, as these developments are closely linked to new diagnostics tools, accelerator control systems and beyond state-of-the-art simulation tools.

Beam Diagnostics

Diagnostics systems are essential constituents of any accelerator; they reveal the properties of a beam and how it behaves in a machine. Without an appropriate set of diagnostic elements, it would simply be impossible to operate any accelerator let alone optimize its performance. Research of the network included, for example, investigations into novel monitors for beam halo monitoring, advanced instrumentation for light sources such as ALBA and Soleil, intensity monitors for nano-Ampere antimatter beams, diamond-based beam loss monitors that can operate in cryogenic environments, and diagnostics for the world's most powerful proton beam at the European Spallation Source.

Simulation Tools

Numerical simulations are important for the design and continuous optimization of particle accelerators. Research in oPAC has targeted the development of new computational methods that help improve performance and accuracy of such design work, as well as GPU-based simulation codes that give access to increased simulation speeds and larger problem sizes in terms of the number of unknowns.

Accelerator Control and Data Acquisition Systems

Large scale research infrastructures have significantly more stringent performance requirements than can be achieved using off-the-shelf industrial automation and control systems. Within oPAC, novel accelerator control systems have been pioneered and developed into industrial scale tools and platforms. This is benefiting many large-scale research infrastructures across Europe.

Courtesy of GSI

UNIVERSITY OF LIVERPOOL

Founded in 1881, and a member of the Russell Group of major research-intensive universities in the UK, the University of Liverpool has built up an international reputation of pioneering education and research. Currently around 20,000 students are enrolled into more than 400 programmes spanning 54 subject areas at its three faculties, including Health and Life Science; Humanities and Social Science; and Science and Engineering.

A rich variety of research is performed at Liverpool, including Particle Physics, Nuclear Physics, Condensed Matter Physics, Surface Science and Astrophysics.

Moreover, The University has the lead role in the Cockcroft Institute, an international centre 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. Home to the QUASAR Group, carrying out investigations into beam dynamics, accelerator design, laser applications, and innovative beam diagnostics solutions, the Cockcroft Institute is also the perfect environment for the coordination of the oPAC project.

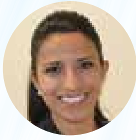
THE PROJECT: DEVELOPMENT OF DESIGNS FOR POSSIBLE LHC UPGRADE OPTIONS

Supervisor: Dr. David Newton†

The project has contributed to the development of the LHeC, a possible upgrade option to expand its research program by colliding an electron beam with the existing proton beam. The LHeC will run synchronously with the LHC and will substantially extend and complete the investigation of the physics of the TeV energy scale. The focus of this work has been on integrating an electron beam with the High-Luminosity LHC lattice at one of the interaction regions (IR) without perturbing the colliding proton beams at the other IRs.

An important part of this development involves reducing the beta function of the proton beam in the interaction region (β^*) to maximize the luminosity. This was achieved with the extension of the Achromatic Telescopic Squeezing Scheme (ATS) already studied for the High-Luminosity LHC. In this work, the flexibility of the IR design was explored in terms of increasing the distance to the inner triplet to reduce the chromaticity, and reducing the β^* to increase the luminosity. Furthermore, a chromatic correction was proposed and its limits explored. Single particle tracking was also performed to complement the analysis and validate the extension of the ATS, studies in dynamic aperture and Frequency Map Analysis provided further information about the stability of the beam and the effects of nonlinearities.

THE RESEARCHER: EMILIA CRUZ ALANIZ



Emilia Cruz Alaniz is originally from Guadalajara, Mexico, and studied physics in the Science Faculty of the Universidad Nacional Autónoma de México (UNAM).

As an undergraduate, she participated in an exchange program and studied one semester in the University of California, Berkeley. She also worked with the experimental nuclear and high-energy physics group in the Instituto de Física at UNAM and was involved in the CREAM project (Cosmic Ray Energetics and Mass). As part of this project Emilia spent a summer in the LPSC laboratory in Grenoble, France. Her work in this project consisted of analyzing the resolution of one of the detectors called the Cherenkov Camera. Emilia undertook a Master's in Physical Science with specialization in High Energy Physics. During this time she worked in the ALICE experiment at the LHC visiting CERN twice to develop her thesis. She worked on this project analyzing the resonances phi and rho by their decays in kaons and pions respectively in proton-proton collisions at 7 TeV and obtained her Master's degree in January 2012.

In November 2012, Emilia joined the oPAC project and is now enrolled as a PhD student at the University of Liverpool, UK.

THE PROJECT:
BEAM MONITOR FOR HALO PROPAGATION MECHANISMS

Supervisor: Prof. Carsten P. Welsch

The detection and possible control of the beam halo is of utmost importance for high energy accelerators, where unwanted particle losses lead to an activation or even damage of the surrounding vacuum chamber. But also in low energy machines, one is interested in minimizing the number of particles in the tail region of the beam distribution.

Since most part of a beam is concentrated in its core, observation techniques with a high dynamic range are required to ensure that halo particles can be monitored with sufficient accuracy. The goal of this project was to develop a micro mirror-based halo monitor with a dynamic range of better than 10^5. Such a monitor is based on High-Definition Digital-Micro-Mirror-Device (HD-DMD) technology, in which each of the 1,000 x 1,000 microscopic mirrors is programmable and controlled by a LabView program. A Matlab based code employing a unique optical adaptive masking algorithm has been developed that allows detecting only the particles of interest for study. The monitor is based on the latest technology of high definition mirror matrix devices, providing very high frame rates and superior spatial resolution.

THE RESEARCHER:
BLAINE LOMBERG

Blaine Lomberg studied nuclear physics at the University of the Western Cape in South Africa. In 2010, he joined the Accelerator Group at iThemba Labs where he worked on ion source physics undertaking a Master's degree. His thesis title was 'Studies of an emittance measurement device for beam quality optimization of ion sources'.

During the summer of 2010, he was a student at CERN working on the Linac3's ion source and developed a LabView application to investigate the charge state distribution of a lead ion beam.

Blaine joined the oPAC Project Network in September 2012 as a Marie Curie fellow. During his fellowship, Blaine has gained experience across all three sectors of work, i.e. academia, industry and national laboratories. He has participated in an industry work secondment with Thermo Fisher Scientific; he has been invited to talk at workshops, and he has presented results at various conferences. In addition to this, Blaine has been active in student intern trainings, disseminating science and his research to the public and local communities.

THE PROJECT:
DEVELOPMENT OF A SIMULATION SUITE BASED ON THE MULTILEVEL FAST MULTIPOLE METHOD

Supervisor: Prof. Carsten P. Welsch

The project aimed to optimize the performance of accelerators by applying the latest computational and numerical techniques in electromagnetic codes for the simulations of superconducting RF cavities. The Finite Difference Time Domain Method and the Method of Moments, typically used for the discretization of complex electromagnetic structures in the 3D space, lead to dense matrix equations constituting millions of unknowns. These matrix equations are solved iteratively and result in the need for large memories and processor speeds that often exceed the performance of even the best computers.

A Multilevel Fast Multipole Algorithm (MLFMA) code has been developed to analyze the scattering of plane waves by Perfect Electric Conductors (PEC) and dielectrics. It has proved to be more efficient if employed on parallel, distributed-memory computer systems as it significantly reduces the computational complexity. The accuracy of Integral Equation Formulation has been verified by various convergence tests and by comparisons with the analytical solutions for various shapes and sizes.

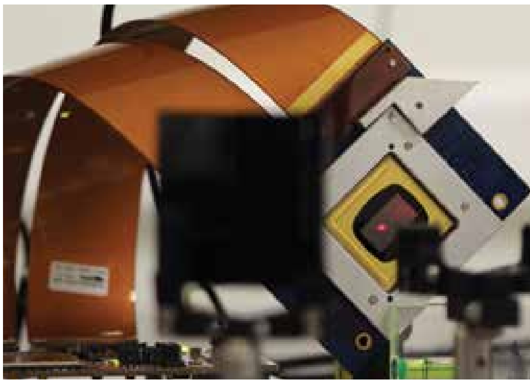
Simulations of low energy ion beam position monitors are being carried out with the help of MLFMA, including the calculation of electromagnetic fields and the measurement of impedance along with the signal response of the pickups.

THE RESEARCHER:
SEHAR NAVEED

Sehar Naveed was born in June 1985 in Depalpur, Pakistan. In December 2011, Sehar completed her Master's degree in 'Mathematics and Computational Sciences' at the University of Manchester, UK. She wrote her dissertation underlying the field of computational fluid dynamics. In addition, Sehar has worked as a lecturer in Mathematics after completing her postgraduation at the Government Degree College for Women, Depalpur, Pakistan.

In October 2012, Sehar Naveed joined the oPAC network at Cockcroft Institute, UK. She has worked there on the development of latest numerical and computational techniques for the optimization of accelerator applications. Sehar is in charge of the development of simulation suite based on the Multi-Level Fast Multipole Method and in the analysis of its comparison with other commercial codes.

Sehar Naveed is also registered at the University of Liverpool, UK as a PhD student of physics. Her research interests include Numerical Optimization, Computational Finite Element Methods and Computational Electromagnetism.



Halo monitor setup at the Cockcroft Institute.

University of Liverpool.

QUASAR GROUP
The Cockcroft Institute of Accelerator Science and Technology

ALBA LIGHT SOURCE

ALBA is a 3 GeV 3rd generation synchrotron light source located near Barcelona, Spain. The laboratory lines of research range from materials science, macro molecular crystallography, condensed matter and magnetic properties to chemistry and biology. Since May 2012, ALBA has been welcoming scientific users from all over the world.

The ALBA team currently consists of about 160 dedicated engineers, scientists, support staff and technicians. The early operation phase of the facility was particularly well suited for training early stage researchers in all aspects of the machine as continuous machine optimization became very important.

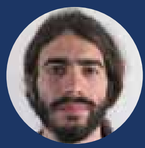
THE PROJECT:
ADVANCED BEAM PHYSICS PROBLEMS AT LIGHT SOURCES

Supervisor: Dr. G. Benedetti and Dr. Z. Marti

The goal of this project was to improve the knowledge and understanding of the nonlinear beam dynamics of the ALBA storage ring through simulations, beam measurements and lattice optimization.

The beam position monitor turn-by-turn technique was implemented for the first time in the ALBA synchrotron light source, providing a new tool to characterize the optics of the machine. By analyzing the spectra of turn-by-turn oscillations excited by a fast kicker magnet, it was possible to observe the resonant driving terms produced by the linear and nonlinear optics of the storage ring. Subsequently, the machine model has been adapted to reproduce the observed resonant driving terms and provide a map of the optics errors in the storage ring. Furthermore, the turn-by-turn technique has been applied to the measurements of the machine transverse impedance. In particular, it was found that the electromagnetic interaction of the stored electrons with the vacuum vessel results in a defocusing effect similar to the one produced by a common defocusing quadrupole. Thus a precise determination of the machine optics has been exploited to evaluate the contribution of the different accelerator sections to the impedance budget.

THE RESEARCHER:
MICHELE CARLA



Michele Carla is from Firenze, Italy where he studied physics at the Universitá degli Studi di Firenze. As an undergraduate in physics, he worked on the MU-RAY experiment. The MU-RAY project was aimed at the construction of muon telescopes and the development of new analysis tools for muon radiography. His work in this project consisted in building and characterizing the resolution of a prototype of scintillator hodoscope. Michele obtained his bachelor's degree in June of 2009.

Following this, Michele continued studying for a master's in physical sciences with specialization in high energy physics. He worked on his thesis in the SwissFEL facility at the Paul Scherrer Institute, Switzerland, where he did a systematic study of the Echo Enabled Harmonic Generation seeding scheme for the Athos beamline of SwissFEL.

In 2013 Michele joined the oPAC network at the synchrotron ALBA in Barcelona, Spain, where he continued his research on storage ring beam dynamics.

Courtesy of ALBA.

THE PROJECT:
OPTIMIZATION OF BEAM INSTRUMENTATION FOR LIGHT SOURCES

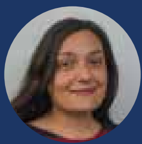
Supervisor: Dr. Ubaldo Iriso

ALBA is a low emittance 3 GeV third generation Synchrotron Light Source located in Cerdanyola del Vallès (Barcelona, Spain). As for all accelerator machines beam diagnostics is an essential task. The project was devoted to the development of non-invasive, on-line beam diagnostics using synchrotron radiation. The main focus was the development and characterization of detectors for different tasks such as photon counting or imaging for several photon energies.

Time Correlated Single Photon Counting (TCSPC) has been implemented and integrated into the ALBA control system. The performance of different electro-optical detectors was tested in order to obtain the best dynamic range not only for top-up operation but also for bunch purity and instability measurement.

The standard method to measure transverse beam size using an x-ray pinhole only provides a beam size measurement corresponding to the whole bunch train. An interferometry technique has been developed to measure the bunch by bunch beam size. Due to the sensitivity of this technique, a complete upgrade of the ALBA diagnostic beamline for visible radiation, Xanadu, was performed. The different cameras used for the imaging and the optical components of the beamline had to be carefully tested and characterized in order to obtain the bunch by bunch beam size, suitable to study beam instabilities. This part of the project was done in partnership with the CLIC collaboration.

THE RESEARCHER:
LAURA TORINO



Laura Torino was born in Naples, Italy, in 1988 and studied physics at the University of Pisa. In the summer of 2010 she joined the LIGO collaboration (Laser Interferometer Gravitational wave Observatory), to work on the characterization of auxiliary instrumental and environmental channels used in the latest LIGO science run.

In 2011 Laura obtained her bachelor's degree defending a thesis about the measurement of the anomalous magnetic moment of the muon. She then studied for a master's in physics of fundamental interactions. Also during 2011 she was a summer student at DESY, Zeuthen where she worked on image processing of raw experimental data to measure size and emittance of an electron beam. She finalized her master at the University of Pisa with a thesis about the measurement of the filling pattern of the ALBA storage ring.

During the oPAC project Laura also obtained another master about generation and application of synchrotron radiation at Universidad Autónoma de Barcelona.

Since November 2013 Laura is a PhD candidate at the University of Pisa, her thesis is about accelerator beam diagnostics using synchrotron radiation.

RF guides at ALBA.

Superconducting Wiggler at ALBA.

CERN - EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

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

In recent years the volume of training given has been in the order of 11,000 person-days per year. Large portions of this training are geared towards early stage researchers. CERN has the capacity and the necessary expertise to achieve the proposed tasks. It has great experience in tutoring and mentoring ESRs as well as in the transmission of complementary skills.

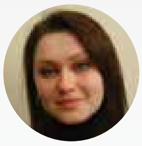
THE PROJECT:
OPTICS AND LATTICE DESIGN STUDIES FOR THE INTERACTION REGION DESIGN OF THE LHC EXPERIMENTAL INSERTIONS

Supervisor: Dr. Elias Metral and Dr. Nicolas Mounet

Transverse collective instabilities of high-intensity and high-brightness beams are one of the most important limitations to achieve higher luminosities in the LHC. Currently applied techniques for beam stabilization are likely to be insufficient for the future high-luminosity LHC upgrade, hence risking beam loss and potentially machine damage.

To study single-bunch instabilities, one can choose the tracking code HEADTAIL and/or the numerical code NHTVS (Nested Head Tail Vlasov Solver), using the LHC impedance model. During this three-year project, an analysis of the single-bunch instabilities observed in 2012 and a comparison between the HEADTAIL and NHTVS codes have been carried out. The codes have also been used to make predictions about the future operation of the LHC.

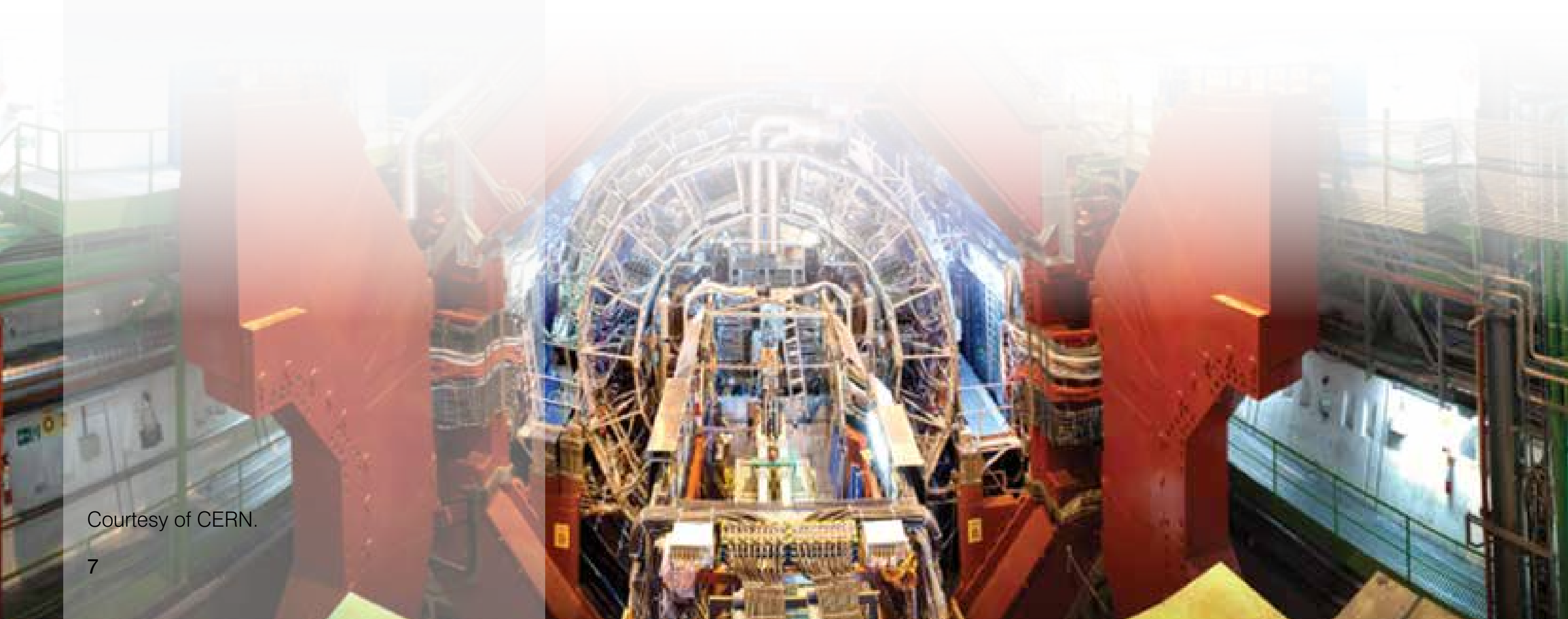
THE RESEARCHER:
DARIA ASTAPOVYCH



Daria Astapovych was born in Sumy, Ukraine in May 1990 and gained her diploma in physics at the Sumy State Pedagogical University. She obtained a bachelor's degree in physics during which she undertook pedagogical practice in schools as a teacher of physics and mathematics within the course 'General Physics / Electromagnetism'.

In May 2012 Daria obtained a master's degree in physics. She decided to focus on a computer simulation for beam dynamics, specifically in the electron cooling process using BETACOOL and worked at the Institute of Applied Physics of the National Academy of Science of Ukraine.

Daria joined the oPAC project as Marie Curie Fellow in 2013. Her research was focused on studying the single-bunch instabilities observed in the LHC, the verification of the accuracy of the impedance model, using HEADTAIL and NHTVS.



Courtesy of CERN.

THE PROJECT:
MEASUREMENT AND CORRECTION OF LINEAR AND NON-LINEAR OPTICS IN THE CERN PS BOOSTER

Supervisor: Dr. Christian Carli

Transverse direct space charge effects are the main beam brightness and intensity limitation for typical low-energy synchrotrons such as the PS Booster. The beam as a whole experiences a tune spread, making it impossible to locate the working point such that all low-order resonances are avoided. The maximum achievable beam brightness and intensity is compromised by resonance excitation from direct space charge forces and from machine imperfections.

The primary emphasis of the project was to define requirements and develop procedures for a system for measuring and correcting nonlinear resonance driving terms in the PS Booster, as well as coordinating the development of the necessary hardware and software. Precise measurements of linear optics in the PS Booster were also obtained. After the correction of optics perturbations, one expects that the PS Booster will be able to accelerate beams of higher brightness and intensity.

THE RESEARCHER:
MEGHAN MCATEER

Meghan McAteer grew up in Austin, Texas and earned bachelor's degrees in studio art and in physics and a PhD in physics from the University of Texas at Austin. As a PhD candidate, she was admitted to the Joint University-Fermilab Doctoral Program in Accelerator Physics and Technology and began research for her dissertation at Fermi National Accelerator Laboratory.

As part of an effort to increase total proton throughput of the Booster accelerator to meet the demands of FNAL's planned high-intensity experimental program, her research resulted in measurements of the linear optics in the FNAL Booster that were far more precise than had been achieved previously, as well as the first implementation of ramped linear optics corrections in that machine.

Meghan joined the oPAC project as a Marie Curie Fellow in 2012 and spent three years working in the Accelerator and Beam Physics group at CERN. She has attended five sessions of the US Particle Accelerator School and two sessions of the CERN Accelerator School as a student, and has also acted as an assistant instructor in the introductory-level accelerator physics course at the US Particle Accelerator School. Her teaching experience also includes assisting with both classroom and laboratory components and helping to develop curriculum for undergraduate physics courses at the University of Texas at Austin.

Photograph of tune kicker.

Meghan is currently a scientific employee in the Institute for Accelerator Physics at Helmholtz Zentrum Berlin, working on the design and commissioning of the proof-of-principle high-current energy recovery linac bERLinPro.

THE PROJECT:
PERLE - POWERFUL ENERGY RECOVERY LINAC EXPERIMENTS

Supervisor: Dr. Frank Zimmermann

The Large Hadron Electron Collider (LHeC) is an accelerator study for a possible upgrade of the existing LHC storage ring – the highest energy proton accelerator currently operating at CERN in Geneva. By adding to the proton accelerator ring a new electron accelerator, the LHeC would enable the investigation of electron-proton and electron-ion collisions at unprecedented high energies and rates, much higher than had been possible at the electron-proton collider HERA at DESY in Hamburg, which terminated its operation in 2007.

In preparation for a future LHeC, an ERL facility has been proposed as a test bed for SRF development, cryogenics, and advanced beam instrumentation, as well as for studies of ERL-specific beam dynamics. The project has been recently named 'PERLE – Powerful Energy Recovery Linac Experiments'. It would comprise two linacs, each ultimately consisting of eight superconducting five-cell cavities at ~802 MHz, and three return arcs on either side; a final electron energy of about 900 MeV will be reached. The average beam current should be above 10 mA to explore the parameter range of the future LHeC.

This fellowship has made a strong contribution to the preliminary Conceptual Design Report, proposed to the International Advisory Committee in June 2015.

THE RESEARCHER:
ALESSANDRA VALLONI

Alessandra Valloni, originally from Italy, received her master degree in electronic engineering from Sapienza - University of Rome.

Following graduation, she joined the INFN National Laboratory of Frascati and later the Particle Beam Physics Laboratory (PBPL) at University of California, Los Angeles (UCLA), where she obtained a PhD in Applied Electromagnetism for her research in novel methods of particle acceleration.

Since 2012 Alessandra has been based at CERN as an oPAC fellow, contributing to the design of an ERL (Energy Recovery Linac) test facility. In the last three years Dr. Valloni has acquired ample expertise in optics design and beam dynamics calculations, developing and validating a complete set of beam optics for the ERL accelerator complex, as well as establishing the system specifications and baseline beam parameters. Moreover, she has acquired a solid experience from experimental work in the accelerator control rooms at SLAC/FACET and KEK/cERL.

The oPAC program has given Alessandra the possibility to collaborate with the Jefferson Lab, Berkeley National Laboratory, KEK, and the Polish Light Source, as well as to present her results on the LHeC ERL test facility in invited talks at several international conferences.

PERLE Powerful energy recovery linac experiments

THE PROJECT:
STUDIES INTO A SQUID-BASED BEAM CURRENT MONITOR

Supervisor: Dr. Jocelyn Tan

The low energy antiproton beam obtained in the Antiproton Decelerator and future ELENA storage rings at CERN requires an increased sensitivity and resolution in beam intensity measurements. The limiting factor for the intensity measurement accuracy is the noise – either in the processing electronics, or acquired by the coupling of the measurement device to the vacuum chamber. Various laboratories have shown the potential of Superconducting Quantum Interference Devices (SQUIDS) to overcome some of these limits. These devices can provide a measurement dynamic range exceeding 80 dB and have enough resolution to measure beams down to the nano-Ampere level.

This project has resulted in the design, installation and test of a SQUID cryogenic current monitor for the Antiproton Decelerator ring to measure the accumulated number of antiprotons. The successful installation and first beam measurements of this new monitor represent a significant breakthrough when compared on the currently available intensity measurements based on a Schottky-noise monitor.

THE RESEARCHER:
MIGUEL FERNANDES

Miguel Fernandes was born in Porto, Portugal and has lived in the region of Lisbon since he was a child. There, he obtained the diploma in electrical engineering and computer science from Instituto Superior Técnico at the Universidade Técnica de Lisboa, specializing in control and electronic systems. After obtaining his degree, Miguel joined the telecommunication industry reference company Nokia Siemens Networks, where he stayed for three years.

Miguel then went on to continue his studies at Instituto Superior Técnico and enrolled in a Physics Master's degree. After completion he worked as a research fellow at the Laboratorio de Instrumentacao e Física Experimental de Partículas, in Lisbon, for the CMS project, one of the most important LHC experiments at CERN.

He joined oPAC as a fellow in January 2013 to work in the Beam Instrumentation group at CERN. During his fellowship he worked on the design, installation and test of a cryogenic current monitor for the Antiproton Decelerator ring.

Courtesy of CERN.

BLM detector tests at CERN.

THE PROJECT:
BEAM LOSS MONITORS FOR USE IN CRYOGENIC ENVIRONMENTS

Supervisor: Dr. Bernd Dehning

The goal of this project was to investigate the use of Beam Loss Monitors (BLM) in the cryogenic environment of the superconducting magnets at LHC, with the purpose of optimizing the detectors for magnet protection and beam adjustments at the high luminosity insertions.

It is expected that the luminosity of the LHC will be limited by the maximum possible beam loss at the superconducting magnets in the future. To allow optimal detection of the energy deposition in the magnet coils by the beam particles, the detectors need to be placed close to the particle loss locations. This implies installing the particle detectors in the cold mass of the magnets. Dose measuring devices operating at 2 Kelvin have been studied and developed for the first time within this project, in partnership with CIVIDEC.

The detectors tested with cryogenic irradiation were silicon and single crystalline chemical vapor deposition diamond (scCVD) detectors, as well as a liquid helium chamber. In the theoretical part of the project the irradiation impact on silicon and scCVD diamond detectors was simulated. To allow a deep understanding of cryogenic BLM materials the laser transient current measurement technique at cryogenic temperatures on silicon and scCVD diamond detectors was applied. The ultimate goal of the project is the preparation of cryogenic BLM prototypes to be placed inside the cold mass of a LHC superconducting magnet in 2018.

THE RESEARCHER:
MARCIN BARTOSIK

Marcin Bartosik grew up in Krakow, Poland and attended the Jagiellonian University in Krakow from 2005, where he studied general physics for three years. Thereafter, he chose to focus on experimental physics and undertook a master's degree, focusing on the research and development of an optoelectronic device for fiber Bragg grating spectroscopy.

After obtaining his master's degree he joined an international team developing the first Polish synchrotron light source facility, Solaris. Since then, he has gained unique experience in synchrotron light source construction and design, and developed his knowledge in radiation protection.

In October 2012 Marcin joined the oPAC project at CERN, where he continues his research on cryogenic beam loss monitors.

Courtesy of CERN.

CIVIDEC INSTRUMENTATION GMBH

CIVIDEC Instrumentation GmbH is developing the latest generation of beam instrumentation devices, which are based on CVD diamond particle detectors. The company is specialised in the design and construction of diamond beam monitors for a wide variety of applications, such as for example charged particles (electrons, protons and ions), photons (X-ray and gamma rays) and neutrons (thermal neutrons, as well as fast neutrons).

CIVIDEC is working in an international network of specialists, comprising six nations and seven research institutes, which are related to particle detection and beam instrumentation. Main partners are CERN, the Slovak Technical University, the Jožef Stefan Institute in Slovenia and Ohio State University in the USA.

THE PROJECT:
DEVELOPMENT OF A VERSATILE BEAM LOSS MONITOR

Supervisor: Prof. Erich Griesmayer

The aim of this project was to investigate the performance of a CVD diamond detector in neutral particle detection. Such properties of diamond as high radiation hardness, low leakage current, low capacitance, high thermal conductivity, and high mobility of charge carriers make it a robust and effective detector material. A number of crucial advantages over common semiconductor materials used in particle detectors presuppose a variety of applications of diamond in particle physics and related fields.

This research project involved the design of dedicated software for the PC-based readout system with dead time free data processing; the development of optimal solutions for neutron and X-ray detection with CVD diamond; the measurement and data analysis methods for real-time background rejection in neutron flux monitoring with diamond detectors; neutron cross-section measurements and spectroscopy using a diamond detector; Monte-Carlo simulations of various detector geometries; and beam tests of the detector, readout electronics, and software.

Several experiments were performed at the Atominstitut of the Vienna University of Technology (Austria) and the IRMM facility (Belgium). The results of the experiments proved that a CVD diamond detector can be effectively used as a neutron monitor for nuclear reactor instrumentation, as well as for neutron cross-section measurements. A range of software applications developed for CIVIDEC ROSY readout system allows diamond detectors to be used for beam loss monitoring, X-ray beam position measurements, neutron flux monitoring and spectroscopy.

THE RESEARCHER:
PAVEL KAVRIGIN

Pavel Kavrigin received his master's degree at the Saint Petersburg State University of Russia (SPbSU) in 2011. His graduate research at the Department of Computational Physics was related to numerical simulations in particle and nuclear physics with applications in hadron therapy. The title of his master's thesis was 'Simulation of processes of interaction of charged particles with matter in hadron therapy tasks'. Part of the research was also dedicated to the study of Cerenkov and Askaryan effects via simulation of charge distribution in liquid and gas media. Another aspect of the research was high performance computing. Pavel also participated in SPRINT Lab (SPbSU-Intel) and conducted a series of lectures on high performance computing solutions of Intel Corporation.

Pavel has been employed as a scientific researcher at CIVIDEC Instrumentation GmbH (Vienna, Austria) in the framework of the oPAC project since May 2012. Results of the various experiments performed within the scope of his project, as well as the corresponding theoretical investigations, will be included in his PhD thesis at Vienna University of Technology.

Photograph of a diamond detector.

COSYLAB

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 was 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, soon became 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. They cover hardware and software products and accompanying services such as customization and integration of already existing solutions, custom development, consulting and tutoring.

The team combines research level know-how with a professional business approach on a daily basis. Their experience has accumulated with years of work on successful projects in collaboration with international partners, including the development of control systems for Swiss Light Source (PSI), Australian Synchrotron, Diamond Light Source, ANKA (KIT), ESO and many others.

THE PROJECT:

ADAPTATION OF EXISTING OPEN-SOURCE CONTROL SYSTEMS FROM COMPACT ACCELERATORS TO LARGE SCALE FACILITIES

Supervisor: Klemen Žagar

In an experimental physics facility containing numerous instruments, it is advantageous to reduce the amount of effort and repetitive work needed for changing the control system (CS) configuration: adding new devices, moving instruments from beamline to beamline, etc.

In this project, a CS configuration tool, which provides an easy-to-use interface for quick configuration of the entire facility, has been developed. It uses Microsoft Excel as the front-end application and allows the user to quickly generate and deploy Input/Output Controller (IOC) configurations (EPICS start-up scripts, alarms, and archive configurations) onto IOCs; start, stop and restart IOCs, alarm servers, archive engines, and more.

The Device Control Database (DCDB) tool uses a relational database, which stores information about all the elements of the accelerator. The communication between the client, database and IOCs is realized by a REST server written in Python. The key feature of the DCDB tool is that the user does not need to recompile the source code. It is achieved by using a dynamic library loader, which automatically loads and links device support libraries. The DCDB tool is compliant with CODAC (used at ESS, ITER, and ELI-NP), but can also be used in any other EPICS environment.

THE RESEARCHER:

PAVEL MASLOV

Pavel was born and raised in St. Petersburg, Russia. In 2004 he was enrolled into the faculty of Robotics and Technical Cybernetics. Pavel went to the military department of the Polytechnic University as Reserve Officer of the Anti-aircraft Rocket Forces in 2010. During his 6th year at the Polytechnic he also he worked as a volunteer in AIESEC, a global youth non-profit organization that develops leadership capabilities. Pavel earned his bachelor's and master's degrees in automation and control with honors. His master's thesis was entitled 'Precise control of the Stewart platform (hexapod robot)'.

In December 2010 Pavel was employed as engineer and programmer by the D. V. Efremov Scientific Research Institute of Electrophysical Apparatus, were he got involved in the ITER project, implementing a distributed control system (based upon EPICS) in ITER's Fast Discharge, and a data acquisition system for the high-current test stand at the Pulsed Power Lab.

Pavel received a Marie Curie fellowship within the oPAC project at Cosylab in Ljubljana, Slovenia, in May 2013. His main focus was the study and optimization of control systems for large physics machines, including particle accelerators, fusion reactors and radio telescopes. Among other things, Pavel is developing a control system configuration tool for EPICS – based physics facilities.

Courtesy of COSYLAB.

COMPUTER SIMULATION TECHNOLOGY (CST)

CST develops and markets high performance software for the simulation of electromagnetic fields in all frequency bands. CSTs success is based on the implementation of unique, leading edge technology in a user-friendly interface. Its products allow the computer based characterization, design and optimization of electromagnetic devices before actual lab measurements.

The extensive range of tools integrated in CST STUDIO SUITE® enables numerous applications to be analysed without leaving the user-friendly CST design environment and can offer additional security. Its customers operate in industries as diverse as telecommunications, defence, automotive, electronics, and medical equipment, and include market leaders such as IBM®, Intel®, Mitsubishi, Samsung, and Siemens.

CST markets its products worldwide through a network of distribution and support centres which also provide comprehensive customer support and training.

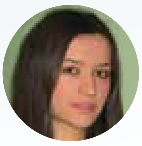
THE PROJECT:
DEVELOPMENT OF A GPU-BASED PIC SOLVER

Supervisor: Dr. Frank Hamme

The focus of this project was the development a Multi-GPU based Particle-in-Cell (PIC) solver so that simulations can be executed much faster in comparison with a CPU or single-GPU solution. Such implementation is needed since the optimization and design of accelerator components generally requires PIC simulations with huge amounts of particles. These simulations can be quite time consuming, sometimes taking up to several weeks. The particular challenge was to develop interpolation and load balancing schemes which take full benefit from modern GPU architectures.

Besides a standard domain decomposition scheme, alternative load balancing schemes were investigated. The conclusion was that the standard scheme is suitable for most of the applications, and in the context of this project it is the optimal choice as a general scheme. Load balancing is simply in contradiction with the objective of increasing the amount of particles. The computation of 3D field distributions is of high relevance for almost all accelerator components. The more realistic an initial (numerical) design is the faster is the progress towards an operating facility.

THE RESEARCHER:
MARTINA SOFRANAC



Martina Sofranac was born in Titograd, SFR Yugoslavia, in 1984. She obtained her bachelor's degree at the Faculty of Electrical Engineering, University of Montenegro, graduating in 2007 as the student with the best average grade in her year. Thereafter, she was an intern at the Research Center Dinamia which is part of ISCTE University in Lisbon.

From 2008 – 2010 she held an Erasmus Mundus Category A scholarship from the European Commission. As part of her master's studies she studied at three universities: University of L'Aquila in Italy, University of Nice-Sophia Antipolis in France, and Gdansk University of Technology in Poland. The scope of her master's thesis was solving numerically the coupled nonlinear Schrödinger equations with periodic boundary conditions to simulate soliton collisions in Kerr media. She defended her thesis in July 2010, at the Faculty of Applied Mathematics and Engineering Physics, Gdansk University of Technology.

During 2009 Martina took up an internship at Orange R&D Lab for Antennas in La Turbie (France) to work on inverse computational electromagnetics problems.

After graduating Martina worked for two years as implementer and developer in a software company in Montenegro. Martina joined the oPAC project in 2013 as a Marie Curie Fellow at CST – Computer Simulation Technologies AG in Darmstadt (Germany), where she carried out research on the development of a GPU based Particle-in-Cell Solver and its parallelization.

EUROPEAN SPALLATION SOURCE

EUROPEAN SPALLATION SOURCE AB

The European Spallation Source, to be built in Lund, Sweden, will be the world's most powerful neutron source, once completed. Based on a 5 MW superconducting proton linac, it will also be at the forefront of high-intensity accelerators. The project is currently in a pre-construction R&D phase, where the accelerator R&D is carried out by a collaboration of mainly European institutes, including a number of oPAC partners. In addition, the local organisation in Lund is rapidly growing.

ESS will become a multi-scientific facility for advanced research and industry development. More than 300 researchers from 11 countries have taken part in the planning, which has lasted about 15 years. ESS will open up entirely new opportunities for researchers within a large number of fields of research: chemistry, nano and energy technology, environmental engineering, foodstuff, bioscience, pharmaceuticals, IT, materials and engineering science and archaeology.

THE PROJECT: STUDIES INTO BEAM LOSS PATTERNS AT ESS

Supervisor: Dr. Andreas Jansson

The understanding of beam losses is essential for high energy, high intensity accelerators. The project focused on studies into beam loss patterns at the European Spallation Source with the aim to optimize the distribution (location and type) for beam loss monitors and improve the interpretation of the BLM data. The project's main goal was to develop a full ESS accelerator's model in the Monte-Carlo simulation code (MARS) and use it to study the optimal location of loss monitors and develop algorithms to analyze the measured spatial loss profile. The model started as a rough estimation of the foreseen machine and became more detailed as more information about the accelerator's components became available. The optimization suite created for the analysis of the beam loss simulation data resulted in proposals for the beam loss monitors mounting locations and the interpretation of their readings.

THE RESEARCHER: MICHAŁ JAROSZ

Michał Jarosz, was born in 1987 in Warsaw, Poland. He studied electronics and informatics in medicine at the Warsaw University of Technology where he obtained his bachelor's and master's degree. During his undergraduate studies, he joined the Polish-Swedish cooperation program for the future European Spallation Source (ESS) and he got involved in the Linac4 project at CERN, creating a bead-pull RF measurement system which was the topic of his bachelor's thesis in 2010. Michał spent two summers at ESS helping in the design of the proton accelerator's tunnel layout, and in March 2012 he successfully defended a master's thesis based on this research. In addition, he worked at the National Centre for Nuclear Studies in -Swierk, Poland, where he took part in smaller accelerator projects for medicine and industry.

In August 2012 Michał joined the oPAC network at ESS. There, he became a specialist in Monte Carlo simulations, investigating beam loss patterns of the ESS accelerator. He then started to work on the layout design for the Beam Loss Monitoring System. The results of this project are included in Michał's PhD thesis.

THE PROJECT: METHODS FOR MEASURING THE BEAM PROFILE IN HIGH INTENSITY BEAMS

Supervisor: Dr. Andreas Jansson

This project focused on the development of non-invasive methods for measuring the transverse beam profile of the European Spallation Source (ESS) high intensity proton beam. Two different devices were studied: a beam induced florescence monitor (BIF) and an ionization profile monitor (IPM). For the BIF, experiments at the COSY facility were performed in order to determine the fluorescence yield of the ESS residual gas present is the beam pipe. For the IPM, experiments were carried out at the DESIREE facility in order to compare the efficiency of different scintillator screens used to collect the secondary ions. The effects of space charge on the beam profile were also investigated.

THE RESEARCHER: CHARLOTTE ROOSE

Charlotte Roose was born in Brussels, Belgium, in 1987. In 2008, she started engineering studies at the Institut Superieur Industriel de Bruxelles (ISIB), Belgium. In 2011, she obtained her bachelor's degree in technological engineering. During her 3rd year, she joined the Cyclotron Research Centre (CRC) at the Université Catholique de Louvain-la-Neuve (UCL) as an intern. There, she worked with the accelerator department on the implementation of a quality control on the heavy ion line and with the radioprotection department on the analysis of activated concrete samples.

In 2013, Charlotte graduated with a Master´s in Physics and Nuclear Engineering at ISIB. For her master's thesis, she undertook an internship at the École Polytechnique de Montréal, Canada. The subject was the verifying the cross sections libraries used for the calculation of a cell of a supercritical water reactor fuelled with thorium.

Charlotte joined the oPAC network in 2013 to work at the European Spallation Source, specializing in beam profile monitors. In 2014 she enrolled as a PhD student at the University of Bologna.

GSI HELMHOLTZ CENTRE FOR HEAVY ION RESEARCH

GSI is operating 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.

The research covers a broad range of fields extending from nuclear and atomic physics to plasma physics and also involves 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 also 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 is built in industry and delivered to hospitals for patient treatment.

THE PROJECT:

DESIGN AND DEVELOPMENT OF RESONANT STRUCTURES AS SCHOTTKY NOISE DETECTORS FOR VARIOUS FREQUENCIES

Supervisor: Dr. Markus Steck

The aim of this project was to design and develop resonant structures as Schottky noise detectors for different applications in mass and lifetime spectrometry in the Collector Ring (CR) at FAIR.

Schottky noise detection is a powerful tool in storage rings to determine beam properties and to continuously optimize the beam quality. This Schottky resonator is intended to distinguish the revolution orbits of the stored ions when the CR is operated in the isochronous ion-optical mode. The measured position information can help correct for the anisochronism effect in the Isochronous Mass Spectrometry (IMS), and hence improve the accuracy and precision of the evaluated nuclear masses.

A novel design, which offsets the cavity away from the central orbit and utilizes the resonant monopole mode, was investigated during this project. Two cavities of rectangular and elliptic shape were optimized by analytic and numerical means. Based on the design concept, two scaled prototypes on an automatic benchtop were also tested. The results were then compared with simulations, and found to be in good agreement.

THE RESEARCHER:

XIANGCHENG CHEN

Xiangcheng Chen was born in Chaohu, China in 1989. His four-year bachelor study in the University of Science and Technology of China (USTC) nurtured his academic interests on particle and nuclear physics. Xiangcheng specialized in high-energy physics, successfully defending his bachelor's thesis in 2010.

Thereafter, he was enrolled in the University of Chinese Academy of Sciences (UCAS) as a master student, while he was working on the nuclear mass and lifetime spectroscopy at the Institute of Modern Physics (IMP) in Lanzhou. Being the center for heavy ion research in China, IMP provided him a perfect environment to develop his interests on mass and lifetime measurements of exotic nuclides in storage rings.

Xiangcheng joined oPAC in January 2013. As an oPAC fellow at GSI, he worked on the design and development of a position-resolving cavity as a Schottky noise detector for the Collector Ring (CR) at FAIR. He defended his doctoral thesis at Heidelberg University in November 2015.

Courtesy of GSI.

Instrumentation Technologies

INSTRUMENTATION TECHNOLOGIES

Instrumentation Technologies was founded in 1998, combining eight years of accelerator experience with a new industrial approach. Two thirds of the thirty five employees are working in R&D. The first contracts for the equipment of whole BPM systems at the Synchrotrons SOLEIL and DIAMOND were signed in 2003. Instrumentation Technologies is a provider of the Libera family of instruments.

These state-of-the-art instrumentation systems are used for diagnostics and beam stabilization at 49 accelerator facilities around the world. Different Libera products are designed to work together, getting synergetic effects and enabling turnkey solutions for beam stabilization. Instrumentation Technologies specializes in instrumentation for beam stabilization in the accelerator field, including analogue and digital engineering, high and low level software, extensive FPGA programming, user-specific applications and solutions.

THE PROJECT:

DESIGN AND DEVELOPMENT OF COMMON APPLICATIONS FOR PARTICLE ACCELERATORS

Supervisor: Dr. Dejan Tinta

As the technology of particle accelerators advances, the instrumentation used to monitor and control the particle beam characteristics is required to provide higher performance, increased reliability, and custom data-intensive applications. With a modular approach and taking advance of the reconfigurability offered by silicon technology, Instrumentation Technologies has developed different instrument platforms which are the base from which the Libera instruments are developed.

The aim of this project was to develop generic functionalities and applications for particle accelerator instrumentation. It involved every phase of the instrument lifetime: from the software development to the functional and performance tests, from the definition of new functionalities to the technical assistance. On-site support and trainings were also provided in different accelerator facilities in Europe, United States and China.

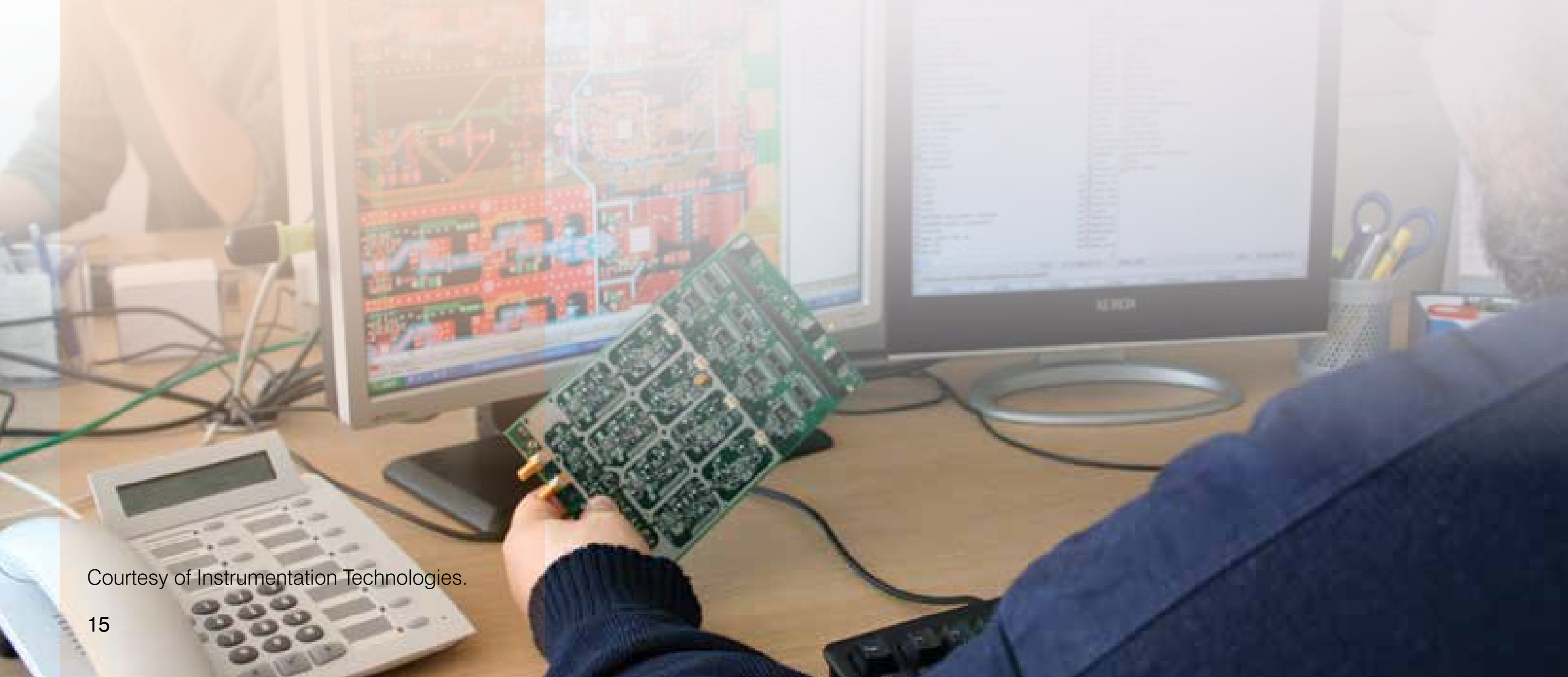
THE RESEARCHER:

MANUEL CARGNELUTTI

Manuel Cargnelutti was born in Tolmezzo, Italy in March 1987. He studied electronic engineering at the Universitá degli Studi di Udine. During his studies he undertook two internships with ST Microelectronics, focusing on SW development and multimedia signal processing algorithms applied to video transmission and streaming techniques.

After joining the oPAC project at Instrumentation Technologies in September 2012, he spent two years on SW development and testing procedures within the Libera Beam Position Monitor readout instruments. In the last year he joined the technical support group in the company and started to develop an interest in the high-level definition of new instruments and in the active communication with the users.

Manuel has contributed to several particle accelerator workshops and international conferences with papers and talks. This exposure helped him to establish the knowledge and the contact network necessary to identify and actively discuss new possible technological and business opportunities with the users.



Courtesy of Instrumentation Technologies.

ROYAL HOLLOWAY UNIVERSITY OF LONDON

Royal Holloway University of London is one of the major constituent colleges that form the University of London. The current enrolment is over 9,000 students, 2,000 of which are postgraduates, from over 100 countries, distributed between 22 departments divided into three faculties of Science, Arts and Humanities and Management and Economics. Royal Holloway University of London was a founding member of the John Adams Institute (JAI) together with Oxford University and the UK Science and Technology Facilities Council (STFC). Central to the mission of the JAI is the training of accelerator physicists at PhD level. This includes world-leading efforts in the developments of laser wire scanners for high energy particle accelerators as well as advanced simulation of accelerator beamlines, including secondary particle production and transport. The accelerator group has been involved in many research and training programmes on a national and international level.

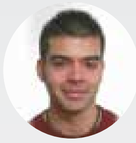
THE PROJECT:
OPTIMIZATION OF THE LAYOUT OF THE LHC COLLIMATION SYSTEM

Supervisor: Prof. Stewart Boogert

Machine related backgrounds arise mainly from the halo that accompanies the core beam or from accidental losses due to individual events. Particles at large displacements from the core can impact on beam-line apertures, including collimators, and then exit the beam-pipe downstream. The goal of this project was to optimize the layout of the LHC collimation system to minimize beam related backgrounds in the ATLAS detector, and to optimize the LHC injection region to minimize activation in that region.

The new collimation system was commissioned for the run at 6.5 TeV after the LHC restarted its operation in March 2015. Novel collimation techniques were also tested during two Machine Development weeks, and detailed measurements of the machine aperture and the collimation efficiency were carried out. Novel techniques based on theoretical models have been developed in order to perform simulations of the collimation efficiency for particles whose energy differs significantly from the nominal value. These simulations gave a theoretical model to compare with the measurements taken during LHC Run I and Run II.

THE RESEARCHER:
HECTOR GARCIA MORALES



Hector Garcia Morales was born in Barcelona, Spain, in 1987. He studied physics at the University of Barcelona and after completing his degree, he started his master studies in particle accelerators at the same university. His master thesis was carried out in collaboration with CERN and focused on the optics design of an emittance measurement station at the RTML line for CLIC. After presenting his master's thesis, he participated in the Joint Universities Accelerator School before getting a position at CERN as a PhD student.

In recent years Héctor has been focused on the study and optimization of the final focus system for future linear and circular colliders, especially on CLIC and ILC. During his PhD, he attended the Linear Collider School 2011 in Monterey, California.

In 2014 Héctor joined the oPAC network at Royal Holloway University of London, where he continued his work in the LHC collimation systems.

THE PROJECT:
LASER-WIRE BEAM PROFILE MONITOR FOR MEASURING THE TRANSVERSE BEAM PROFILE OF AN H- BEAM

Supervisor: Dr. Pavel Karataev

Laser-wire systems employ laser beams to scan accelerated particle beams to determine their transverse profile by measuring the yield of secondary particles produced in the laser-beam interaction. They are well suited to operation at high power or low emittance machines because they are almost non-invasive devices and they cannot be destroyed by the beam they are measuring.

The aim of this project was to develop a laser-wire beam profile monitor for measuring the transverse profile of an H- beam. In a first step, experiments were carried out at the KEK-ATF/ATF2 facility to learn the state-of-the-art system in laser-based diagnostics of the transverse electron beam size. Experiments on sub-micrometer optical transition radiation beam size diagnostics were carried out for comparison with the laser-wire, demonstrating the micrometer resolution of the system which will be required in future linear colliders such as ILC or CLIC. After that, the project was focused on the development of a laser-wire system to measure the transverse profile and emittance of an H- ion beam at the Linac4 accelerator in CERN, in collaboration with the Front End Test Stand at Rutherford Appleton Lab (RAL). The laser-wire system was successfully commissioned and tested at different stages of the Linac4. First tests were performed with the beam energy of 3 MeV and 12 MeV. In both cases the results showed very good agreement with the expected ones from simulations as well as with the results obtained by the conventional (invasive) slit and grid method.

THE RESEARCHER:
KONSTANTIN KRUCHININ

Konstantin Kruchinin was born in Aleksandrovsk-Sakhalinsky, Russia in June 1988 and studied nuclear and particle physics at Tomsk Polytechnic University (TPU). During his studies he undertook an internship at the Joint Institute for Nuclear Research in Dubna (Russia) where he participated in CERN's ALICE experiment analyzing detector effects by extracting information on gluon structure functions from the modelling of heavy quarkonium production in proton-proton collisions at the LHC. Konstantin developed an algorithm for calculating amendments for the data analysis using the software packages of the ALICE experiment.

Konstantin's interest was later focused on diffraction radiation and its possible applications for beam diagnostics in modern accelerators. He developed and analyzed a model for generation of diffraction radiation by a charged particle moving near a rectangular screen with finite size and permittivity. Konstantin presented the results of this research in his master's thesis, graduating at TPU in 2011. He was then appointed part-time engineer in the Applied Physics Department.

Konstantin joined the oPAC project at Royal Holloway University of London in 2012, completing his PhD in June 2015.

Courtesy of RHUL.

SYNCHROTRON SOLEIL

SOLEIL is a 3rd generation synchrotron radiation facility aiming at delivering photon beams on 29 beamlines to national and international users on a free-access basis. 24 beamlines are presently operational and open to external visiting scientists; this number will reach 29 by the end of 2017.

The exceptional characteristics of its synchrotron light allow a considerable advance in the quality of measurements when compared to those obtained via classic laboratory photonic techniques.

The SOLEIL staff is composed of about 350 permanent employees, either on secondment from research organizations or directly recruited by SOLEIL. 80% of the staff has scientific or technical vocations. SOLEIL has developed a strong policy in terms of training, hosting permanently about 20 PhD students, 30 post-docs and dozens of engineers under training alternating school and professional periods. About 50 SOLEIL personnel are regularly involved in training actions in regional universities and prestigious high schools. In the field directly linked to accelerator physics and technology, SOLEIL has already trained dozens of undergraduate, graduate and PhD students.

THE PROJECT:
IMPROVEMENT OF THE UNDERSTANDING OF NON-LINEAR BEAM DYNAMICS EFFECTS IN LIGHT SOURCES

Supervisor: Dr. Laurent Nadolski

The goal of this project was to optimize the linear and nonlinear beam dynamics of the SOLEIL storage ring to explore all possible optical settings available for the current accelerator lattice. The project has applied Multi-Objective Genetic Algorithms (MOGA) with other analysis techniques such as driving term analysis and frequency map analysis using information collected on turn-by-turn position monitors to maximize both the injection efficiency and the beam lifetime. In addition, the tracking codes ELEGANT and TRACY3 have been used to study the completeness of the optimized solutions.

A selected number of "optimized" lattices were tested in the control room of SOLEIL using beam-based experiments. A complementary study of the electron beam lifetime helped to improve the understanding of the real contribution of both the Touschek and the gas lifetimes in the SOLEIL storage ring after nine years of operation. These experimental measurements were compared with the simulations to examine the agreement and refine the theoretical models.

THE RESEARCHER:
XAVIER NUEL GAVALDA

Xavier Nuel Gavaldà was born in Reus, Spain, and he has a degree in physics from the University of Barcelona. In October 2011 he started his master's degree in synchrotron radiation and particle accelerators at the Autonomous University of Barcelona in collaboration with the ALBA-CELLS synchrotron light source. Xavier joined the ALBA Beam Dynamics division to work on his master's thesis dedicated to linear and nonlinear optics models of the ALBA gradient storage ring dipoles. He did a comparison between the different dipole models based both on the magnetic measurements and on the orbit response matrix.

Xavier joined the oPAC network at the SOLEIL synchrotron in December 2012. In 2013 he participated in the Join Universities Accelerator School (JUAS) in Archamps, France. Beside the different activities of the oPAC program, Xavier has been a member of several organizing committees as Journée Des Doctorants in the doctoral school MIPEGE (April 2014), TWIICE workshop in SOLEIL (January 2014) and CAoPAC workshop in GSI (March 2014).

Courtesy of SOLEIL.

UNIVERSITY OF SEVILLE / CENTRO NACIONAL DE ACELERADORES

The University of Seville (US), with more than 70,000 students and 6,700 staff, is the third largest university in Spain. More than 10,000 students are following postgraduate courses, enrolled into 86 master programmes and 152 doctoral programmes. The Centro Nacional de Aceleradores (CNA) is the national Centre of Excellence for particle accelerator research and development. A unique scientific and technological institute dedicated to interdisciplinary, fundamental and applied research with ion accelerators. CNA is a joint research centre belonging to the University of Seville, the Junta de Andalucia and the Spanish Research Council (CSIC).

US/CNA main facilities include a 3 MV Tandem accelerator, an 18 MeV Cyclotron for PET isotope production, a 1 MV Tandetron for AMS, a compact accelerator for ^{14}C dating, a ^{60}Co photon irradiator, and a human PET-CT scanner. CNA is a user-oriented facility, with more than 100 experimental applications per year, and 48 staff, from which 23 are doctors and 9 are PhD students.

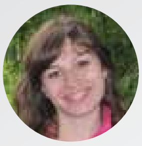
THE PROJECT:
DETECTION SYSTEM FOR VERIFICATION OF A 2D METHOD OF IMAGE RECONSTRUCTION FOR INTENSITY MODULATED RADIOTHERAPY TREATMENT

Supervisor: Dr. José Manuel Espino Navas and Dr. Marcos Alvarez

The characterization of a novel dual chip silicon detector was carried out within the nuclear physics group at the University of Seville / Centro Nacional de Aceleradores (CNA), and it was realized in collaboration with the University's Department of Atomic, Molecular and Nuclear Physics and the hospital "Vírgen Macarena" of Seville.

Such a detector was characterized as a dosimeter with the purpose of using it for checking the dose map delivered during a treatment plan. Another important part of the project was to install a radiobiology beamline at the 3 MV Tandem Accelerator of CNA. The beam profile was optimized in terms of homogeneity and uniformity, and the dosimetry of low energy proton beam inside and outside the Bragg peak region was investigated with radiochromic films and ionization chambers.

THE RESEARCHER:
MARIA CRISTINA BATTAGLIA



Maria Cristina Battaglia was born in Comiso, Italy, in August 1988. In 2007 she moved to Catania to pursue her professional goal of studying physics at the University of Catania. In 2010, she obtained her bachelor's degree in physics, and in November 2012 she defended her master thesis on the development of a novel imaging technique named "Orthogonal Ray Imaging", within a collaboration with the University of Coimbra, Portugal.

In March 2013, Maria Cristina became a Marie Curie Fellow within the oPAC project at CNA in Seville, Spain. She worked both in the characterization of a novel system for 2D dose map treatment verification and the installation of a beamline dedicated to dosimetry and radiobiology studies. During the fellowship work, she focused her interest on nuclear physics applied to medicine, with a special interest on dosimetry studies with different instruments and techniques.

SARA, AMS system at CNA.

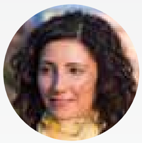
THE PROJECT:
OPTIMIZATION OF ^{10}Be DETECTION

Supervisor: Dr. Jose María López

In this project, the overall efficiency of the Accelerator Mass Spectrometry (AMS) machine hosted at CNA was improved. The efficiency is a critical parameter in AMS, as it has a strong influence on the sensitivity of the system and on the accuracy of the results. The improvement was accomplished by working on the modifications recently made on the existing facility, in such a way that the ion transmission along the accelerator and the resolution of the minority isotopes detector was optimized.

When the molecular beam generated by the source enters the accelerator, it undergoes a stripping process, passing through a gas-filled channel where molecules break up and interferences are eliminated. After changing the stripping gas from argon to helium, a detailed study was performed with many different isotopes in order to find the optimum work conditions (full molecular suppression, low background levels, best transmission). Besides, being the detection a critical parameter for lighter ions such as ^{10}Be, a new gas ionization chamber was installed. The chamber was characterized by a very low noise design, and it was optimized for AMS purposes through a batch of tests on the different physical and electronic aspects involved.

THE RESEARCHER:
GRAZIA SCOGNAMIGLIO



Grazia Scognamiglio was born in Pompeii (Italy) in 1987 and studied physics at the University 'Federico II' of Naples. As an undergraduate student, she worked within the ATLAS group of Naples, developing software for monitoring the muon detectors of the ATLAS experiment at LHC. This work became her bachelor's degree thesis in 2010. In the same year, Grazia started a master's course with specialization in electronics. She implemented and tested communication protocols between FPGAs optimized for spatial applications, adapting them to the requirements of the JEM-Euso project, and obtained her master's degree in 2012.

After her studies, Grazia improved her software and hardware programming skills in private and public companies, before joining the oPAC network at CNA in January 2014. Part of her training also took place in the Ion Beam Physics group at ETH-Zürich. Grazia enrolled in a PhD program at the University of Seville, and the work carried out within the oPAC project has become part of her thesis.

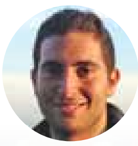
THE PROJECT:
ION IMPLANTATION AT PARTICLE ACCELERATORS FOR NANOPARTICLE PRODUCTION.

Supervisor: Dr. Javier García López and Dr. F. Javier Ferrer Fernández

The aim of the project was to study the ion implantation of noble metals (Au, Ag, Pt, Pd) in transparent metal oxides thin films (SiO_2, TiO_2) with an accelerator that can provide ions in the MeV energy range. The implantation process allows a precise control of dose and depth, a wide selection of masking materials, and an excellent lateral dose uniformity.

Several techniques of material analysis were employed in this project, namely Rutherford Backscattering Spectrometry (RBS), Elastic Recoil Detection Analysis (ERDA), and Nuclear Reaction Analysis (NRA). RBS is an ion scattering technique used for compositional thin film analysis, and it is unique in that it allows quantification without the use of reference standards. RBS was used before implantation to check the thickness of the sample and after implantation to determine the concentration and depth distribution of the implanted ions. In order to calculate the depth concentration, SRIM (Stopping and Range of Ions in Matter) simulations were performed and compared to the experimental results obtained by RBS analysis using a 2 MeV He beam.

THE RESEARCHER:
SALVATORE BRUSCHETTA



Salvatore Bruschetta was born in Palermo in 1990. He completed his bachelor degree in energy engineering at the University of Palermo, graduating in 2012. The title of his thesis was "Measurement of the Neutron Flux produced by a Cyclotron to create PET Radiopharmaceuticals". He continued his studies with a master degree in energy and nuclear engineering at the same university and, after participated in the SARA project in Prague in 2013, he wrote a thesis on "Non-destructive quantitative analysis of various materials and evaluation of acquired data with XRF".

Salvatore joined the oPAC network at CNA in 2014. Within this project he had the opportunity to work with the Institute of Materials Science of Seville, joining the research group of Nanotechnology of Surfaces and participating in a course on physical methods of analysis for thin layers and solid surfaces.

 Courtesy of US/CNA.

MANAGEMENT

PARTNERS

Twelve beneficiary partners have hosted between one and five fellows who each had their own specific research projects. The associate and adjunct partners played a distinct role within the network training with some providing secondment places in relevant scientific areas.

SUPERVISORY BOARD

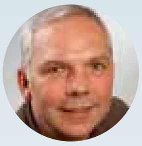
Every partner in the network was represented on the Supervisory Board. The board met annually and its role was to monitor the progress of the fellows and the quality of their training. Feedback from industry partners was essential in ensuring that the training offered remain relevant to the job market.

STEERING COMMITTEE

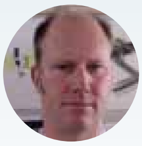
The Steering Committee has been responsible for the overall network strategy taking all decisions concerning the network. An elected Fellow representative joined the Steering Committee in its meetings and provided feedback and input from the trainees. Currently it consists of the following elected members:

Dr. Meghan McAteer is the researcher elected to represent the fellows at the Steering Committee. She joined the oPAC network in 2012 as a Marie Curie Fellow in the Accelerator and Beam Physics group at CERN. Meghan is currently a scientific employee in the Institute for Accelerator Physics at Helmholtz Zentrum Berlin.

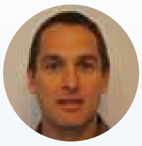
Prof. Joaquín Gómez Camacho studied physics at the University of Seville, graduating in 1982 and went to Daresbury Laboratory to work on nuclear reactions. He obtained his PhD in 1986. Afterwards, he went to the University of Surrey as a Postdoc to work on nuclear reactions with polarized nuclei. In 1987 he returned to the University of Seville, where he is a Full Professor and Director of CNA. His research interests include nuclear reactions with exotic beams, theory and experiment, and detector instrumentation.



Prof. Erich Griesmayer is founder and CEO of CIVIDEC Instrumentation, formed at the end of 2009. During more than 20 years of work at CERN he collected broad knowledge and experience in accelerator technology. He is also an Associate Professor at the Vienna University of Technology. His professional background is in electronic measurement technology with a focus on diamond detectors and fast electronics.



Dr. Andreas Jansson has an MSc from Linköping University and a PhD from Stockholm University. During his career, Andreas has been working on the development of various diagnostics devices, including ionisation profile monitors, microwave Schottky pick-ups and AC dipoles, mainly at the Fermilab Tevatron and the CERN LHC. Since 2010 Andreas has led the Beam Diagnostics Group at the European Spallation Source in Lund, Sweden.



Dr. Rhodri Jones is head of the Beam Instrumentation Group at CERN, responsible for the beam instrumentation and diagnostics on all CERN accelerators and transfer lines. He obtained his PhD on resonance ionisation laser spectroscopy in 1996 from the University of Wales, Swansea. His interests include high frequency RF diagnostics, laser and electro-optical diagnostics.

Dr. Pavel Karataev is a Senior Lecturer at RHUL and a member of the John Adams Institute for Accelerator Science. With work experience in Tomsk Polytechnic University, Tokyo Metropolitan University and KEK, his research interests span the development of advanced charged particle diagnostics techniques and investigations into charged particle generated radiation and its transportation, detection and application.

Dr. Nika Vodopivec studied at the University of Trieste, International University Institute for European studies where she finished her master's thesis on European Policy Making in 2002 and completed her doctoral thesis on Transborder Policies for Daily Life in 2009. Since 2009 she has been working for Instrumentation Technologies as Head of HR and General Affairs.

Prof. Carsten P. Welsch initiated the oPAC project and is the scientific coordinator on behalf of the University of Liverpool, based at the Cockcroft Institute, UK. He carried out his PhD studies at the University of Frankfurt and his work brought him to UC Berkley, RIKEN, MPI Heidelberg, CERN and GSI before joining Liverpool in 2008. His QUASAR Group focuses on R&D into frontier accelerators, novel accelerator techniques, accelerator applications, and beam instrumentation.

EU PROJECT T.E.A.M.

EU PROJECT T.E.A.M.
Training, Enterprise, Administration, Management

The University of Liverpool has established a dedicated EU Project T.E.A.M., based at the Cockcroft Institute. This T.E.A.M. assists in the day-to-day running of the oPAC project, under the guidance of the coordinator, and comprises the project manager Dr. Ricardo Torres, a financial administrator, Samina Faisal, project assistant, Blaise Guénard, and web developer Alexandra Welsch.

Fellows during tour of Daresbury Sci-Tech campus.

TRAINING PROGRAMME

TRAINING

In oPAC all Fellows have received extensive research-based training within a unique European partnership. Working within the network they have gained a broad insight into both the academic and industrial aspects associated with accelerator research with opportunities for specific training and secondments.

All project partners covered a very broad, yet closely interconnected, experimental program that combined many different scientific disciplines, such as mechanical and radio frequency engineering, physics, electronics, IT, material sciences and medical applications. The contribution of industry partners to the definition phase of all research projects and their continued active role ensured that the transfer of industry-relevant skills was an integral part of all individual projects.

The fundamental core of the training was a dedicated cutting-edge research project for each Fellow at their host institution. The network was then used to provide opportunities for secondments for all Fellows to spend time working at other institutions within the network for hands-on training in specific relevant techniques and for broader experience including different sectors. Most Fellows have been in post for 36 months and were registered into a PhD program. This local training was complemented by a series of network-wide events that included external participation.

INTERNATIONAL SCHOOLS

As an introduction to the field of accelerator science all recruited oPAC fellows took part in either the CERN Accelerator School in autumn 2012 or the Joint Universities Accelerator School (JUAS) in 2013 and 2014.

Several oPAC Schools have been held throughout the four years of the project. They brought together experts from across the world, in focused research areas, to discuss the present state-of-the-art and review challenges with the network's researchers. An international School on Accelerator Optimization was held at Royal Holloway University of London in July 2014 and covered beam physics, instrumentation R&D and charged particle beam simulations at an advanced level. It targeted PhD students, postdocs, and experienced researchers from inside and outside the network.

TOPICAL WORKSHOPS

A series of Topical Workshops have covered all important research areas within the network. The first of these on Challenges in Accelerator Optimization took place at CERN in June 2013 and attracted more than 100 delegates. In 2014 workshops took place at CIVIDEC (Vienna, Austria) on Beam Diagnostics, and at Instrumentation Technologies (Solkan, Slovenia) on Libera Technology. In March 2015, a workshop on Computer-Aided Optimization of Accelerators was organized by the Fellows of the network, providing them with the opportunity to take charge of a whole event from scratch. The workshop was held at the Institute for Heavy Ion Research – GSI (in Darmstadt, Germany). In June 2015 the University of Liverpool hosted a workshop on Technology Transfer. Participation to these workshops was open to scientists external to the network.

In addition, specialist hands-on workshops have been provided by Bergoz on Beam Instrumentation, and by CST on the Particle Studio software.

COMPLEMENTARY SKILLS TRAINING

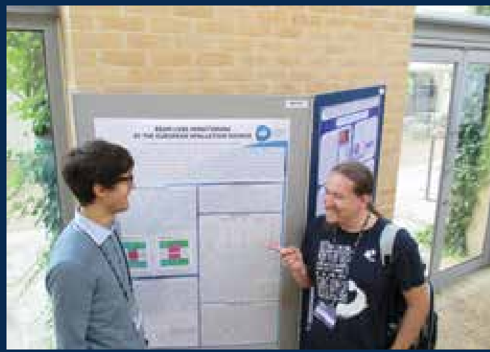
All Fellows have received training in aspects such as presentation skills, scientific writing, entrepreneurship and handling intellectual property through an established quality school implemented by the University of Liverpool. This Complementary Skills School has been recognized by the European Commission as 'best practice' for providing future generations of scientists and engineers with the skills to produce world-class research. This training has provided the Fellows with the non-technical skills that are invaluable for their future careers, whether that be in academia or industry.

The researchers worked in small teams during this training course to develop and plan an outreach event. This familiarized them with the challenges linked to team working, project management, event organization, publicity and delivery. This training was complemented by an Advanced Researchers Skills School, held at the University of Liverpool in June 2015. It covered CV writing, interview skills, scientific communication and advanced project management

CONFERENCE AND OUTREACH SYMPOSIUM

An International Conference on Accelerator Optimization was held in October 2015 at Centro Nacional de Aceleradores in Seville (Spain). All the researchers from the network had the opportunity to present the outcomes of their research. Therefore, the event helped to promote the scientific results and techniques developed during the project, and enabled the Fellows to engage with other university groups and private companies. The conference also paved the way for follow-up activities between the oPAC partners and participating scientists from outside the network.

A Symposium on Accelerators for Science and Society was organized in Liverpool on 26 June 2015 as a finale to the outreach activities undertaken during the course of the network. This symposium presented the main project findings in an accessible way for the general public, emphasizing the possible applications of the technologies concerned.



Manuel and Michal presenting at IBIC 2013.

Fellows' Daresbury visit.

Researcher Skills School in Liverpool.

SECONDMENTS, DISSEMINATION AND OUTREACH

SECONDMENTS

By the nature of the scientific collaborations within oPAC, all Fellows were immersed in a pool of networking opportunities and training. In addition to the numerous network-wide training events, oPAC provided a secondment scheme which allowed them to train with the other partners involved in the network. This has provided training in research areas that were not directly linked to their research projects, thereby broadening the expert knowledge of each Fellow substantially. These trans-national and cross-sectorial secondments have also triggered exchange across institutional and national boundaries, and have helped to develop and maintain working relationships within the wider research community.

DISSEMINATION AND OUTREACH ACTIVITIES

Research results from the project were disseminated via our events and international peer reviewed journals and can be accessed through our web site www.opac-project.eu. Our web site featured regularly details of all the research projects being undertaken by the Fellows, and it continues being updated today with the outcomes of their research, and news from the consortium partners. The oPAC Facebook page and quarterly newsletter still serves to keep interested parties updated on the outcomes of the project, and advertises forthcoming events and future opportunities.

Connections to accelerator scientists outside the network were enabled through adjunct partnership to oPAC in addition to providing scholarships for external participants wishing to contribute to our events. Membership grown from the start of the project, and several adjunct partners joined the consortium, furthering links and networking for the fellows.

The oPAC fellows were actively involved in outreach activities within their communities, participating in school visits, open days, and science festivals, in order to educate and create interest with the general public, schools and teachers. The fellows have also produced video webcasts about their individual research projects. The videos are available via the project web page and YouTube.

www.opac-project.eu

The main outreach event of oPAC took place on 26 June 2015 in Liverpool. The Symposium on Lasers and Accelerators for Science & Society gathered around 250 participants. World-renowned scientists presented highlights in accelerators and laser research and the enormous impact these tools have on science and society. They were joined by Fellows from the LA³NET and oPAC networks who presented the results of their research and shared their fascination for science. The event attracted considerable attention from the media, and the talks available online at: www.opac-project.eu/symposium.

PARTNERS

ASSOCIATED PARTNERS

There are 11 Associated Partners in the network. Although not financial beneficiaries, these contribute significantly to the training of the oPAC fellows. They are actively encouraged, through membership of the Supervisory Board, to improve training strategies and help ensure the highest possible standards of training are met, particularly with regard to industry-relevant skills.

Bergoz Instrumentation, France

Bergoz Instrumentation develops and manufactures transformers, transducers, monitoring devices and electronic instrumentation for current measurement and elementary particle beams diagnostics, non-destructively. Their instruments are found in applications as diverse as high energy particle accelerators - in research and medicine, synchrotron radiation light sources, ion implanters used for materials surface modification, conformance test benches - measure partial discharge and many more. Bergoz specialises in ultra-low-noise analogue electronics design in the DC – 3 GHz range. This is combined with knowledge of cobalt-based amorphous magnetic alloys annealing processes for response up to 2 GHz and very low Barkhausen noise. The company's workshop is well equipped with production machinery and test instruments.

Institute for Storage Ring Facilities, Denmark

The Institute for Storage Ring Facilities (ISA) is a Danish National Facility, where research is carried out in Physics, Chemistry, Materials Science and Biology using accelerators and storage rings. The institute has long standing experience in the design and operation of accelerators, in particular storage rings. It owns several facilities for the production and storage of ions, electrons and positrons. Recently, a low-emittance light source, ASTRID2, has been taken into operation, using top-up injection from the old ASTRID synchrotron/storage ring. Six synchrotron radiation (SR) beamlines at ASTRID2 cover a wide photon energy range from the visible to the soft X-Ray region supporting a diverse SR research programme. ELISA is an electrostatic storage ring with its own ion injector and is capable of storing a very wide range of ions.

Oxford Instruments, UK

Oxford Instruments plc is a leading provider of high technology tools and systems for industry and research. It uses innovation to turn smart science into world-class products that support research and industry to address the great challenges of the 21st Century. Oxford Instruments' core competencies lie in analyzing and manipulating matter at the atomic level and hence the company focuses on developing high-technology tools and systems that meet the stringent requirements demanded by its customers. The present products cover a very wide spectrum of applications, from cryogenic systems and coating thickness analysers to low temperature and high magnetic field applications.

Polish Light Source, Poland

Polish Light Source will be a state-of-the-art synchrotron light facility, once completed. It will provide its users with radiation from the far infrared to the X-ray region and hence allow a multitude of experiments for a very wide and interdisciplinary user community. At low energy operation, the production of intense coherent radiation at THz frequencies is envisaged. Successful design, construction, commissioning and operation of such a demanding facility are only possible in close collaboration with experienced international partners. The accelerator scientists and engineers of PLS are highly experienced in both cutting edge research and intense training of early stage researchers.

RHP-Technology GmbH & Co. KG, Austria

RHP Technology is a solution provider in powder technology and hot pressing. Rapid hot pressing is a pressure-assisted sintering technique, allowing the consolidation of high performance materials such as special alloys, ceramics as well as metal or ceramic matrix composites up to a temperature of 2,400°C. This is possible in overall cycle times of less than one hour and therefore very economic. The SME focuses on the development of metal matrix composite materials, i.e. high thermal conductivity materials with a low coefficient of thermal expansion, ceramic materials, as well as on the development of sputtering target materials with customised composition for thin film deposition.

Stockholm University, Sweden

Stockholm University is one of the largest universities in Sweden and one of the largest employers in the capital. People of many different nationalities, with contacts throughout the world, contribute to the creation of a highly international atmosphere at Stockholm University. Staff in the physics department has extensive experience in the design, operation and continuous optimisation of particle accelerators. For many years, ground-breaking studies were realised at the University's CRYRING facility and the accelerator experts have pioneered many developments related to beam handling and cooling techniques in medium and low energy storage rings.

Thermo Fisher, USA

Thermo Fisher Scientific CIDTEC Cameras & Imagers is the world leader in serving science. They serve over 350,000 customers within pharmaceutical and biotech companies, hospitals and clinical diagnostic labs, universities, research institutions and government agencies, as well as environmental and industrial process control settings.

Thermo Scientific offers a complete range of high-end analytical instruments as well as laboratory equipment, software, services, consumables and reagents to enable integrated laboratory workflow solutions. The CIDTEC Cameras & Imagers product line has successfully collaborated with Universities and large research centres in the past, and is a direct partner within oPAC.

DDL – Diamond Detectors Ltd., UK

DDL is a company manufacturing innovative diamond radiation detectors. It offers a range of fully packaged diamond radiation detectors and diamond plates, as well as custom design services. The initial products developed in association with different Universities cover applications in high energy physics research such as the Large Hadron Collider (LHC) project at CERN, the new Facility for Antiproton and Ion Research (FAIR) at GSI in Germany, as well as the Diamond Light Source (UK).

Diamond Detectors is used to work within large international collaborations and successfully developed detector prototypes into diagnostics standards.

TMD Technologies Limited, UK

TMD Technologies Limited is among the world's leading manufacturers of microwave tubes, high voltage power supplies, and transmitters for radar, EW, communications, EMC RF testing, and other laboratory applications. TMD can trace its roots back to the early 1940's, when the microwave tube research division of EMI Electronics was established to develop high power klystrons. TMD has continued to invest in research and development of new products and technologies, and together with significant investment from customers has resulted in a wide range of leading edge products.

Technical University of Darmstadt, Germany

The Technical University of Darmstadt has been an internationally-oriented university since its founding in 1877. Many pioneering achievements and internationally recognized scholars have contributed to significant progress in many different fields. The Institute for Nuclear Physics at TU Darmstadt operates the superconducting, recycling electron linear accelerator S-DALINAC. This accelerator has been the key research infrastructure at the institute since 1991 and is being continuously improved. In 1996, for example, the very first IR-FEL light in Germany was produced in this machine, which has enabled many ground-breaking experiments since. High system availability and a cutting edge accelerator R&D program covering all aspects of the accelerator are only two of the outstanding characteristics of this facility.

University of Maryland, USA

The Institute of Research in Electronics and Applied Physics at the University of Maryland has long standing experience in training graduate students at the University's Electron Ring and other accelerators in new diagnostic techniques. The accelerator physics group has pioneered the development of many new diagnostics for particle accelerators and FELs using a variety of different techniques, such as for example OTR, COTR, CTR, ODR, CDR, OSR and OER and is renowned around the world.

ADJUNCT PARTNERS

Adjunct Partners are those who have joined oPAC after its inception. These institutions are active in R&D fields closely related to the network and they share the network's training visions. They are an important part of oPAC's long-term strategy in establishing lasting bonds and partnership across institutes and disciplines in Europe.

CIEMAT, Spain

A Public Research Agency attached to the Spanish Ministry of Economy and Competitiveness, CIEMAT is mainly focused in the fields of energy, environment and technology related with them. It aims to link basic research with the industrial applications. With a team of around 1400 people, CIEMAT is diversified technologically and geographically. The main site is in Madrid. In addition CIEMAT manages other centres like the Almeria Solar Platform (PSA), an outstanding solar technology facility.

CMAM Centre for Micro Analysis of Materials, Spain

CMAM is a research laboratory belonging to the Universidad Autónoma de Madrid (UAM) whose main experimental facility is an electrostatic ion accelerator devoted to the analysis and modification of materials. Their accelerator, built by HVEE, is of the tandem type and the acceleration system is the co-axial Cockcroft-Walton type with a maximum terminal voltage of 5 MV. It is equipped with two sources: a plasma source and a sputtering source and provides a broad range of ions in the six experimental stations.

Forschungszentrum Jülich, Germany

Forschungszentrum Jülich is one of the largest interdisciplinary research institutions in Europe. It comprises nine research institutes working in the areas of energy, environmental science, and others. Within Forschungszentrum Jülich, the institute for nuclear physics (IKP) operates and designs particle accelerators. Its main activity is the operation of the 2.88 GeV Cooler Synchrotron COSY. IKP is also responsible for the design and construction of the High Energy Storage Ring (HESR) of FAIR. The accelerator is dedicated to studying future accelerator and detector techniques. Although mainly reserved for the FAIR and EDM project, this gives a unique possibility of having a large scale accelerator available for the evaluation of new accelerator based methods and devices.

INFN Laboratori Nazionali del Sud, Italy

Laboratori Nazionali del Sud (LNS) is one of four national laboratories of INFN. Founded in 1976, it currently employs about 150 people, and represents an advanced development centre for technology and instrumentation. The research activity is mainly devoted to the study of structure and properties of atomic nuclei, in collaboration with researchers coming from several countries. At LNS two particle accelerators are available: a 15MV Tandem Van De Graaff and a K800 Superconducting Cyclotron.

Institutul National pentru Fizica si Inginerie Nucleara Horia Hulubei, Romania

IFIN-HH is the central institute for nuclear and atomic physics in Romania. Its more than 400 scientists are collaborating with numerous institutes (e.g.: IUCN, CERN, IAEA, GSI...) and projects (PHARE, FAIR, SPIRAL2...) in almost all fields of fundamental and applied nuclear physics. The Department of Nuclear Physics IFIN-HH is a multidisciplinary research unit in the field of nuclear and atomic physics. The department's mission lies in the areas of basic and applied research, particularly in the fields which are relevant for sustainable development and the national endeavour for integration in the European Union.

SLAC National Accelerator Laboratory, USA

SLAC National Accelerator Laboratory attracts thousands of users, visiting scientists and students from all over the world each year. Its 2-mile-long linear accelerator has enabled Nobel prize-winning discoveries in particle physics and now powers a revolutionary X-ray free-electron laser, the Linac Coherent Light Source (LCLS). Launched in 2009, the LCLS pushes photon science to new frontiers with ultrabright, ultrashort X-ray pulses that allow atomic-scale snapshots of material dynamics in the femtosecond regime. SLAC's other facilities include the Stanford Synchrotron Radiation Lightsource, providing bright, broad-spectrum X-rays and the Facility for Advanced Accelerator Experimental Tests (FACET).

University of Dundee, UK

The University of Dundee is one of the UK's leading universities, internationally recognised for its expertise across a range of disciplines. The Carnegie Laboratory of Physics is part of the School of Engineering, Physics and Mathematics. It has a history of world leading research into photonics, materials, biophysics and communications. Its laboratories are equipped with state-of-the-art facilities for miniature laser development, bio-photonics, biomedical physics and optical manipulation, materials deposition and laser processing, nano-scale materials research, and organic materials.

University of Manchester, UK

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. 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.

University of Sussex, UK

Sussex is a leading research university with over 90 per cent of its being research activity rated as world leading, internationally excellent or internationally recognised. The Experimental Particle Physics (EPP) Research Group has leading roles in a number of experiments: ATLAS at CERN's Large Hadron Collider; NOvA and MINOS+ that use the NuMI neutrino beam at Fermilab, USA; CryoEDM that is searching for the Electric Dipole Moment (EDM) of the neutron at ILL, Grenoble; SNO+ and DEAP that are located at SNOLAB, Canada. They also host a Grid Computing site.

Uppsala University, Sweden

Uppsala University is the oldest university in the Nordic countries, with a living cultural environment and 40,000 students. World-class research and high quality education pursued here benefit society and business on a global level. The members of the Accelerator Physics Group participate in the realization of several large international projects ranging from the X-ray free electron laser X-FEL at DESY in Hamburg, seeding experiments at FLASH, various activities at CERN in Geneva such as the design and construction of the Two-beam Test-stand at CLIC test facility CTF3 and work at the European Spallation Source ESS in Lund, Sweden.

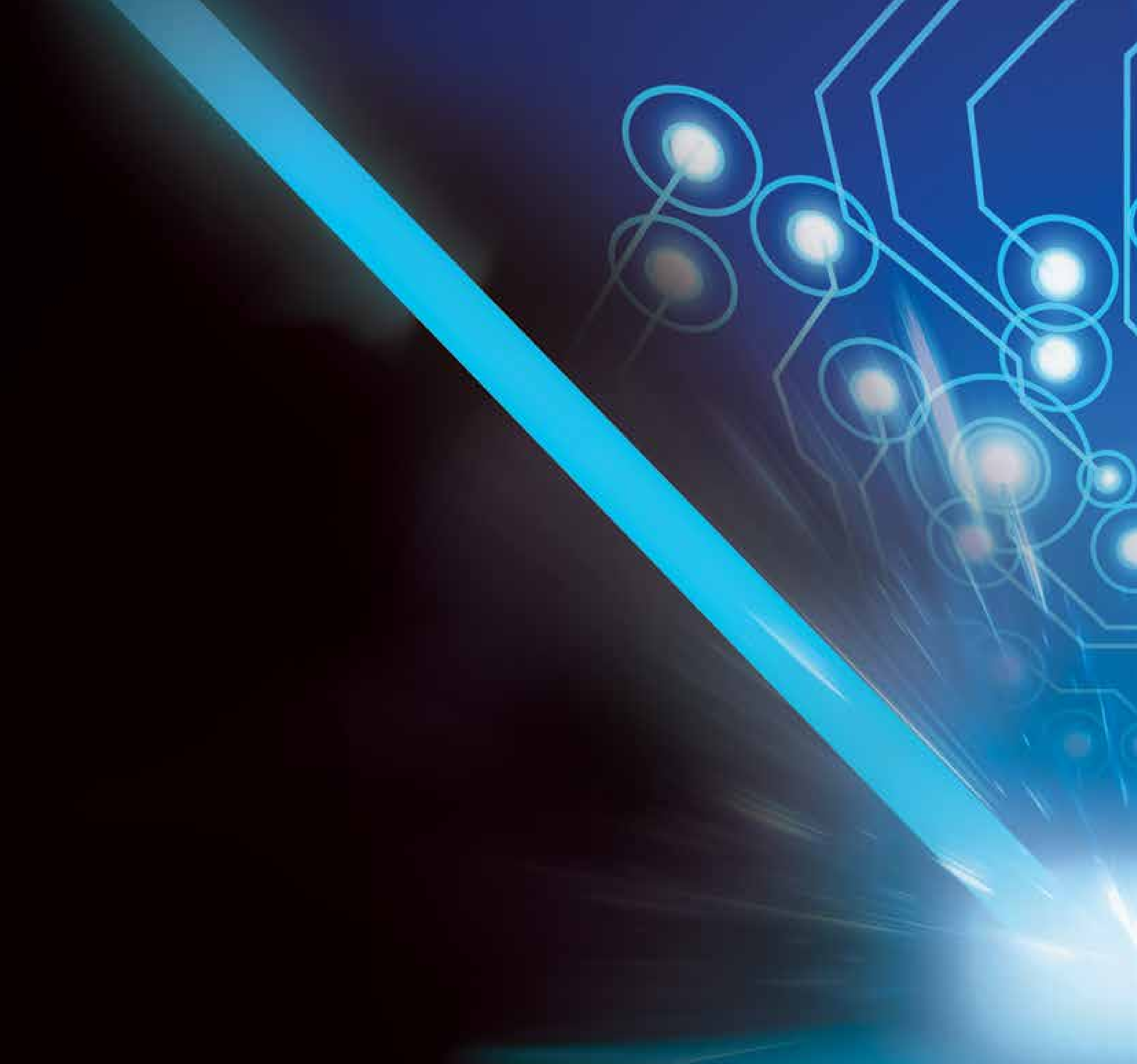
ViALUX, Germany

ViALUX GmbH was founded in 2000 and is a privately held company with a worldwide network of representatives. It is a highly innovative company with a continuing focus on latest technology developments. 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 of success.

The University of Bologna, Italy

The University of Bologna is the oldest continually operating degree-granting university in the world. Its history makes it a landmark reference in European culture. It is one of the most important institutions of higher education across Italy with more than 90,000 students and over 6,000 permanent staff. Internationalization is one of its key strategies, including the participation as leader or partner in many EU cooperation initiatives. The School of Engineering, with a Faculty of approximately 300 members, offers majors in all branches of engineering. Nuclear competencies have been present since the mid 1960's.

Courtesy of CERN.



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