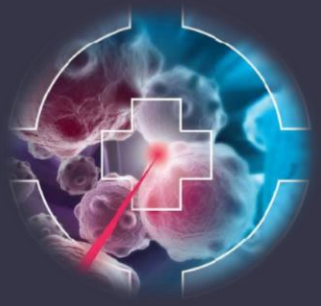


OMA Express
February 2020
Issue 12

Highlights

- Developing FLUKA for radio-biological studies and particle therapy range verification
- Star Wars meets OMA
- CNAO awarded grant to build new ion source

OMA is coming to its end,…but this is only the beginning!

On 31st January 2020 the OMA project came to its official end. It has been a fantastic journey and I am grateful that I was part of it. It has been an absolute pleasure and privilege to work with our Fellows and project partners.

I would like to thank all of our project partners for the time they spent on the individual projects, and our many international events, in particular our fantastic Steering Committee. A special thank you goes to my **project TEAM** for their support and help in delivering this exciting project.

This project is - and will always be - all about the **OMA Fellows**! They have been a fantastic group and achieved absolutely remarkable research results and have grown considerably as researchers and individuals during their time in the network. I am sure we will be meeting each other and working together for many years to come - independent of where their career will take them to next.

In our last Steering Committee meeting in Amsterdam, we decided that we would maintain many of our core activities for (at least) the next two years, including regular updates of our project website (so please continue to provide us with news!) and our quarterly *OMA Express* newsletter, distribution of our OMA brochure at conferences and other large scale events, organization of Topical Workshops at the interface between clinical and accelerator research, promoting and supporting new grant ideas between OMA partner organizations, and overall maintaining and growing the OMA brand identity.

To me, the OMA project has enabled amazing results and there is clearly room for many more trained experts in this interdisciplinary area. **Watch this space!**

With my very best wishes,

Prof Dr Carsten P Welsch
OMA Coordinator

Research News

Development of FLUKA for radiobiological studies and particle therapy range verification

OMA Fellow based at CERN Giulia Aricò has recently published two articles in Physics in Medicine and Biology, summarising her research on the modelling of radiobiological effects in hadron therapy, and FLUKA production cross sections of PET isotopes for particle therapy range verification.

Compared with conventional radiotherapy, charged particles offer a better dose localization. Moreover, heavy ions have a higher biological effectiveness, which makes them particularly advantageous for treating radio-resistant tumours.

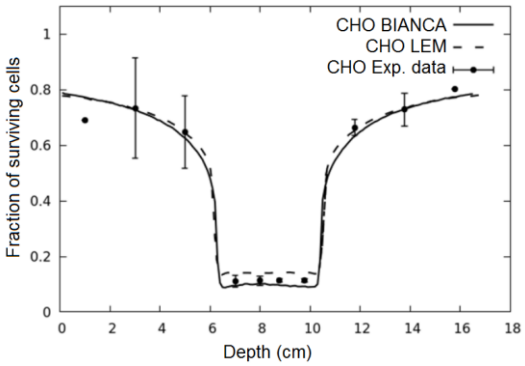
The biological effectiveness of a given ion is usually expressed in terms of the Relative Biological Effectiveness (RBE), defined as the ratio between the photon and the ion dose needed to obtain the same biological effect (*in vitro* cell survival). RBE in heavy ions is a complex quantity that depends on physical and biological parameters. Due to these dependencies, the RBE of heavy ions requires the development of appropriate models.

In one of the articles published in Physics in Medicine and Biology, a biophysical model developed in Pavia, called BIANCA, was extended up to oxygen ions and systematically tested against experimental data for V79 cells (a cell line from Chinese hamster lungs) irradiated by different types of ions. This allowed the authors to build a radiobiological database describing the survival of V79 cells, considered as a reference cell line. Using this database as a reference, a method was developed to perform full predictions of RBE for any cell line of interest.

BIANCA was then combined with the radiation transport code FLUKA in order to predict cell survival in typical patient treatment scenarios.

The model predictions were found to be in good agreement with Chinese hamster ovary cells survival data obtained at the Heidelberg ion-therapy centre, as well as predictions performed by the Local Effect Model.

This work showed that BIANCA can be used for cell survival and RBE predictions in any cell line of interest. Furthermore, BIANCA was able to predict cell survivals in relevant treatment scenarios, which represent a starting basis for future clinical applications.



Two port irradiation with carbon ions

The second article reports the measurement of cross sections for the production of the PET isotopes ^{10}C, ^{11}C and ^{15}O from carbon and oxygen targets induced by protons (40–220 MeV) and carbon ions (65–430 MeV/u). The data were obtained via activation measurements of irradiated graphite and beryllium oxide targets using a set of three scintillators coupled by a coincidence logic.

The measured cross sections are relevant for the PET particle range verification method where accurate predictions of the ?¬+ emitter distribution produced by therapeutic beams in the patient tissue are required. The presented dataset is useful to improve and validate the FLUKA nuclear reaction parametrization, as well as as reference for other Monte Carlo codes.

Network News

Much to learn, you still have

These are the famous words of Jedi master Yoda to Count Dooku when he faces his old Padawan in Attack of the Clones. Based on these words, Liverpool University held a special event about the Physics of Star Wars to explore what is science and what is fiction in the famous movies. Hundreds of local high school students, university students and staff came on campus on 20 November 2019 and learned how world of Star Wars is connected with proton beam therapy and accelerator-based science in general.

Physics of Star Wars took place in the award-winning Central Teaching Laboratory, which was turned into a teaching space from a galaxy far, far away. The event started with an engaging lecture by OMA Coordinator Professor Carsten Welsch who immersed the participants into the Star Wars universe. He said: "I selected iconic scenes from the movies that everybody will immediately recognise, and used real-world physics to explain what is possible and what is fiction. However, this short scene from 'Star Wars' was just the introduction, the appetizer, to make the participants curious and discuss science. I then linked what I had just shown in the film to our current research."

After the lecture, everyone was able to explore the science of Star Wars themselves through a range of hands-on experiments that were prepared by staff and students of Liverpool University, including OMA Fellow Jacinta Yap.

In the very first Star Wars movie, Luke Skywalker uses proton torpedoes to destroy the Death Star – the giant space station that destroys planets. More than 40 years on, science fact has caught up with science fiction. Within our OMA project, accelerator and clinical experts have been exploring ways to better control proton beams to improve cancer treatment. These beams can be used to destroy a tumour hidden deep inside the body. Amongst others, OMA research targets

The Force was strong at the Physics of Star Wars day in Liverpool.

the use of a monitor originally developed for the Large Hadron Collider (LHC) at CERN to characterize the treatment beam without touching it.

Professor Welsch says: “For the students to experience for themselves the problems of controlling a beam you can’t see to hit an invisible target, OMA Fellows have created a Star Wars themed proton mini golf challenge. They experience first-hand that targeting becomes much easier if an advanced detector helps them guide the “beam”, i.e. the mini golf ball.”

Many other exciting developments, including novel plasma accelerating techniques, antimatter research, and upgrades to the world’s largest particle accelerator were discussed at this unique event which was deemed a roaring success. The day was an excellent example of how Star Wars fiction can inspire and train the next generation of researchers.
Yoda also said to Count Dooku “This is just the beginning!” and this is no doubt true in the case of science as well: Many more researchers will be needed in the future and Physics of Star Wars helped fascinate many more.

This is not an official Disney/Lucasfilm event, but planned, organised and run by Liverpool staff and students. The kind permission of Lucasfilm to use film excerpts as part of the seminar is acknowledged.

OMA Fellow Jacinta Yap explaining the proton mini golf challenge to a student.

Final meeting of the OMA Steering Committee in Amsterdam

OMA Steering Committee members (L-R) Carsten Welsch, Christian Graeff, Michelle Lis, Ricardo Torres, Miguel A Cortés-Giraldo, and Julien Smeets.

After four exciting years at the forefront of medical accelerator research and training, the OMA journey is coming to an end. Last week, the Steering Committee of OMA met for one last time at the facilities of NIKHEF, in Amsterdam, to review the outcomes of the project, plan future activities and write the final summary report for the European Commission.

OMA has been a highly successful training initiative, bringing together 38 institutions from all over Europe with the common purpose of providing the best training experience to a cohort of early stage researchers in the fields of beam imaging and diagnostics, treatment optimization, and facility design. Through a series of cutting-edge research projects, the network has trained 15 highly qualified fellows, equipping them with a broad set of skills.

The OMA network has produced more than 40 publications in journal and conference proceedings in four years. It has organised 11 training events, in the form of schools and topical workshops, one international conference, one outreach symposium, and a large number of outreach activities that have brought the social benefits of particle accelerator research closer to the public.

The steering committee highlighted, among other benefits, the opportunities for collaborative research offered by the extensive programme of secondments built in the OMA project, and it decided to capitalise on its legacy by continuing the communication and network activities of OMA beyond the official end of the project.

Stay tuned!

Upcoming Events

Healthcare Instrumentation Workshop

24th March 2020, University of Liverpool, UK

Open to industry, researchers, and potential partners, this workshop will explore some of the key challenges faced in the healthcare instrumentation sector.

The workshop also offers the opportunity to:

• Meet potential collaborators, based in the Department of Physics at the University of Liverpool, to solve business challenges through collaborative research and development.

• Access specific research knowledge and support to enable delegate to prepare joint research proposals and develop new products.

• Hear about funding opportunities available from a range of funders, including STFC, EPSRC, the Industrial Strategy Challenge Fund, EU and CRUK.

To register please visit: https://www.eventbrite.co.uk/e/healthcare-instrumentation-workshop-registration-83588199555

Attendance is free of charge, and the registration deadline is 28th February 2020.

Email questions to: c.astreos@liverpool.ac.uk

LINAC2020 will take place in Liverpool

30th August – 4th September 2020, ACC Liverpool, UK

In 2020, the linear accelerator conference (LINAC) will come to England, the birthplace of accelerator science, and take place at the Arena and Convention Centre in beautiful Liverpool, UK on 30 August - 4 September 2020.

LINAC is the main bi-yearly gathering for the worldwide community of linear accelerator experts. The conference will provide a unique opportunity to hear about the latest advances in research and developments on hadron and lepton linacs and their applications.

Following a long and successful tradition, LINAC2020 will feature invited and contributed talks, as well as poster sessions and an industry exhibition. The scientific programme will be complemented by social events that promote informal knowledge exchange. There are a number of sponsorship opportunities for all those who would like to support the event and gain visibility.

LINAC encourages in particular students to participate and a number of scholarships will be offered. Registration will open later this summer and we encourage you to register early to secure a place.

More information is available via the conference website.

Fellows Activities

Fostering collaboration within OMA

Sudharsan Srinivasan, OMA Fellow based at the Paul Scherrer Institute (PSI), has completed a secondment at Centro Nacional de Aceleradores (CNA), as part of his OMA training. CNA is recognized as a national singular infrastructure for particle accelerator based interdisciplinary research. Amongst others it features a 3 MV tandem van de Graaff accelerator, a 18 MeV proton cyclotron, a 1 MV tandem Cockcroft-Walton for accelerator mass spectrometry, a compact accelerator for ^{14}C dating, and a PET/CT scanner for humans and large animals. This gave Sudharsan excellent opportunities to understand the experimental capabilities and an insight into current R&D.

According to Sudharsan, the secondment led to many fruitful conversations, networking possibilities, and memorable lunch breaks. Thanks to Anna Baratto Roldán, the OMA Fellow based at CNA, Sudharsan had the opportunity to tour the entire facility and get detailed insight into current experiments.

He also presented the work he carries out at PSI in a seminar talk. His presentation on the design and commissioning of a cavity beam position monitor led to discussions about the use of cavity resonators for beamline monitoring at CNA and the limitations they currently face. The problems discussed included the customization of the cavity design, the opportunity to it use for low energy beams, and the measurement of the bandwidth.

This secondment is and example of the opportunities that OMA offers to its Fellows to open new international collaborations within the network.

Sudharsan Srinivasan at CNA

Spotlight on Samuele Cotta

What did attract you to the OMA network? Has it fulfilled your expectations?

"After my master's degree I was looking for a challenging adventure, both for my work experience and for my personal life, so when I heard about the OMA network I had the feeling that it could be the right opportunity. During these years I had the chance to conduct a research project, working not only within ViALUX, but also collaborating with the other fellows and institutions within the OMA network. Beside this, I had a wonderful experience, living almost three years in a new country, learning a new language and discovering a different culture."

Why did you choose to go to ViALUX?

"I found the project at ViALUX really interesting because they offered me to explore a field which was almost new for both me and them: the radiation hardness of electronic devices. The perspective was to work together with colleagues with different backgrounds (e.g. informatics and electronic engineering), learning how to deal with a task from different perspectives and contributing with my point of view as a physicist. I also considered doing my project in a company as an additional value, because the approach to research is very different from the pure academic environment."

Can you explain in a few words what your project was about and what have you achieved?

"My project was focused on the optimization of optical 3D scanners to be integrated in the radiotherapy treatment rooms as devices for patient positioning and monitoring. I investigated in particular the radiation hardness of these devices, since they are exposed to the secondary radiation. Single electronic components as well as a whole 3D scanning device were tested during radiation tests both in irradiation facilities and in the real radiotherapy environment. The tests were successful and only few recoverable misbehaviours were detected when the devices were irradiated with irradiation conditions more severe than in the radiotherapy environment. In conclusion, the ViALUX 3D scanners turned out to be ready to be integrated and to work in the real radiotherapy facilities."

What has OMA provided you professionally?

"During my experience within OMA I had the chance to work in an international environment and to get in touch with many researchers from universities and big research centers. Attending the OMA schools and workshops I learnt a lot about the principle of particle therapy and its most recent developments and I improved my skills in scientific communication. Finally, I realized how important it is to not limit the research just to the host institution, but to establish links and collaborations outside too. Presenting and discussing the research results during schools and workshops was sometimes the best way to find new ideas for the project."

What will be your most cherished memory from OMA?

"I remember fondly my three-day trip to GSI to prepare with Harry and Michelle an experiment for the schools coming to the OMA Outreach Symposium. I always enjoy to share my passion for science with young students and it was great to spend a couple of days preparing an activity just for them. We put a lot of effort into this and it was amazing to see how what we planned via Skype became real. The whole OMA Outreach Symposium was a success thanks to the efforts of all the fellows from OMA, AVA and LIV.DAT networks and I hope that the young students who took part in it enjoyed it as much as us!"

And the one you'd rather forget?

"My "last" evening with the other OMA fellows, which was last June in Liverpool, at the end of a one-week workshop focused also on our expectations for our future careers.
That event was a great opportunity for thinking about what we really wanted from our future, but at the same time it was a perfect point to turn back and realize how much I and the other fellows did and learnt in these years and how much we grew together within the OMA network."

Find out more about Samuele Cotta

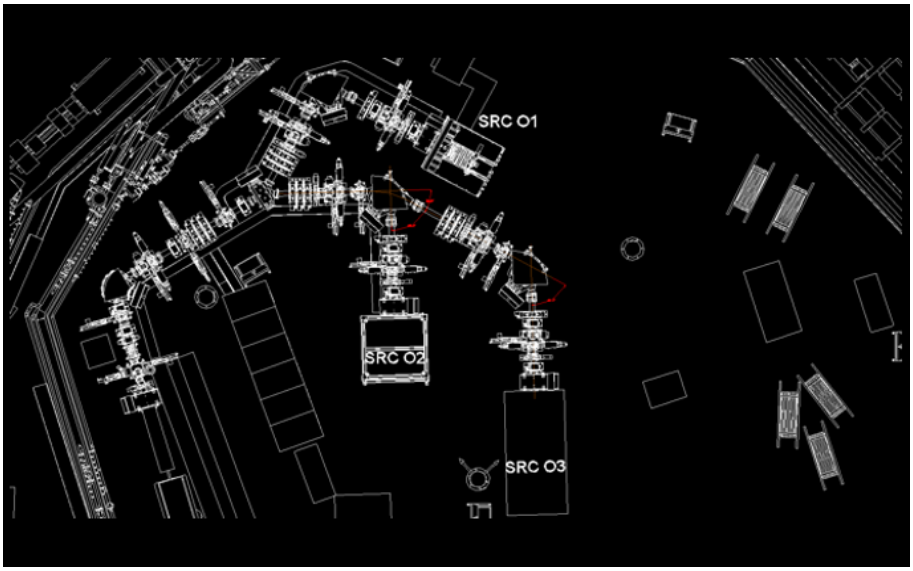
Partner News

CNAO awarded grant to build new ion source

An innovative irradiation facility with an ionic source for research and radiation hardness studies with industrial and clinical applications (INSpIRIT).

The Centro Nazionale di Adroterapia Oncologica (CNAO) in Pavia is one of the key partners in the OMA project and one of only six centres in the world capable of treating tumours with protons and carbon ions. CNAO stands out for its excellence in the panorama of national and international health facilities. CNAO is also a Centre of Research and Development, whose activities range from clinical and radiobiological research to translational research, with the objective of providing continual improvements in the treatment of inoperable or radio-resistant tumours.

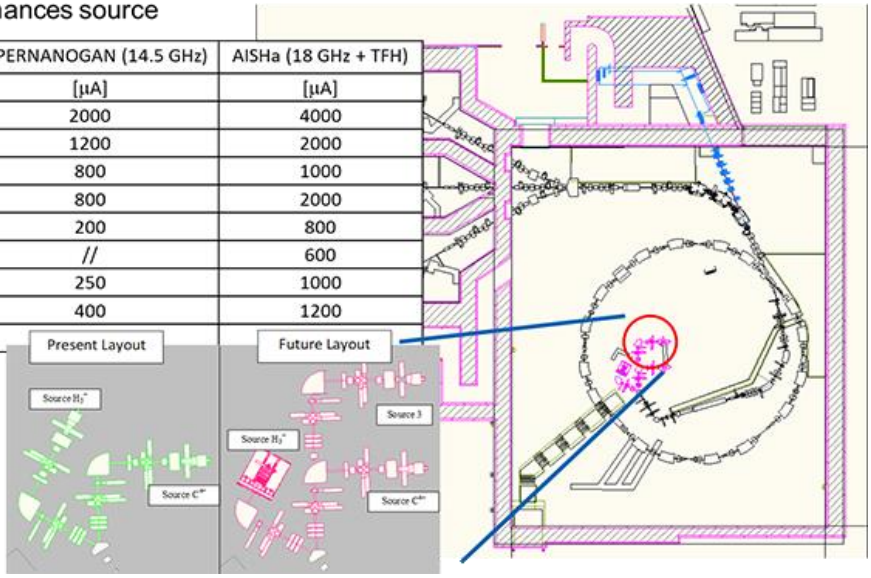
In the last decade, the scientific community has been showing a renewed interest in the possibility of extending the spectrum of ions in the hadron therapy domain; the recent technological advances are pushing research centres in the direction of implementing new ion species in the existing irradiation facilities. In this context, CNAO's Research Department has obtained a grant, funded by the regional government of Lombardy, for the construction of a new ion source. The project, called INSpIRIT, foresees the production of new ionic species, such as oxygen, helium and lithium, which will be accelerated by the synchrotron, transported to the experimental room, and made available for both scientific and industrial activities. In particular, the new ion source will be built in collaboration with the National Institute of Nuclear Physics (INFN) with an innovative technique based on a hybrid technology, exploiting super-conducting magnets.



Possible layout of the INSpIRIT ion source inside the CNAO synchrotron, Courtesy of S. Sironi

Higher performances source

Ion	SUPERNANOGAN (14.5 GHz)	AISHa (18 GHz + TFH)
	[μA]	[μA]
H^+	2000	4000
H^{2+}	1200	2000
H^{3+}	800	1000
$^3He^+$ - $^4He^+$	800	2000
$^{12}C^{4+}$	200	800
$^6Li^{2+}$	//	600
$^{18}O^{6+}$	250	1000
$^{16}O^{6+}$	400	1200
$^{21}Ne^{7+}$ - $^{20}Ne^{7+}$		



Main parameters of the new ion source (AISHA column), Courtesy of L. Celona

Once the INSpIRIT project is completed, the CNAO facility will include a beam line capable of providing the user with many ionic species to study radiobiological effects of different charged particles, thus extending the spectrum of possibilities for the clinic. For example, helium and lithium ions have been proposed as candidates for their better lateral dose distribution with respect to protons; at the same time, they have a lower biological efficacy (RBE) than that of carbon ions and consequently would be useful to adopt for clinical use. Oxygen is also considered a good candidate considering its energy deposition characteristics.

The experimental room, as well as the laboratory and preparation facilities, can be used in parallel to the clinical activity without interference. Thanks to this project, CNAO will take a leading in scientific research and industrial innovation. The availability of an intermediate ion source and an adequate research area will represent a unique opportunity for experimental and industrial research in nuclear physics, hadronic and particle physics, atomic and antimatter physics, high density, physics of plasma, condensed matter physics, radiation hardness for microelectronics, aerospace and spectrometry, biology and biomedical sciences.

Last but not least, one of the objectives of the partnership is to create a living lab to engage young people and schools, involving them not only as “observing subjects”, but also as sources of creation, no longer just at the centre of innovation, but rather as real drivers of change.

Hitachi to provide CNAO with proton therapy system

The Japanese company Hitachi has entered into an agreement to provide Centro Nazionale di Adroterapia Oncologica (CNAO) with its proton therapy system.

In comprehensive public tender process, Hitachi has been selected to provide a proton therapy system with the latest technologies, including advanced scanning to irradiate tumours with complex shapes with high precision. This will be the 1st Hitachi Proton Therapy System to be installed in Italy and the 2nd in Europe.

Hitachi has been proactively promoting particle therapy systems, supplying world-class facilities with highly reliable machines, which have treated more than 60,000 patients worldwide.

Centro Nazionale di Adroterapia Oncologica (Pavia, Italy) @2020 Google

CNAO pioneers heart treatment with proton beams

Centro Nazionale di Adroterapia Oncologica (CNAO), a beneficiary member of the OMA network, has carried out a world-first operation to treat heart arrhythmia.

The intervention, on an Italian patient with ventricular arrhythmia, was conceived and performed in collaboration with the Fondazione IRCCS Policlinico San Matteo in Pavia.

The pioneering treatment used a beam of protons to target the part of the heart responsible for the irregular heartbeat, with a minimal impact of the delicate tissue surrounding it.

UHDpulse: A new European research project

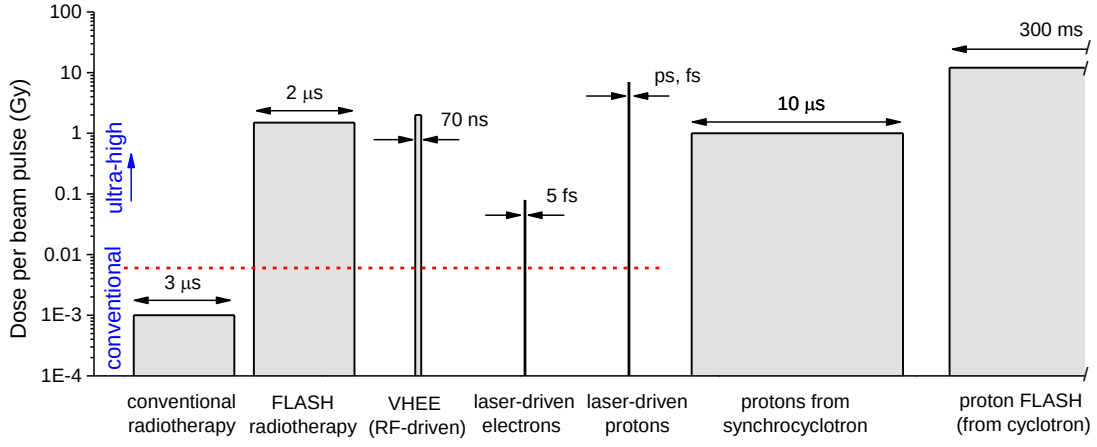
UHDpulse - Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates is a Joint Research Project with 3-year duration launched in September 2019. It brings together 16 institutes from 8 countries and consists of European metrology institutes, universities, research institutes, and university hospitals in the field of radiation dosimetry and dosimetry detector development.

The project aims to develop and improve dosimetry standards and dose measurement methods for the novel radiotherapy modalities FLASH radiotherapy and very high electron energy (VHEE) radiotherapy as well as for laser-driven medical accelerators. The existing primary standards and dosimetry tools used in conventional radiotherapy are not applicable due to the ultra-high dose rate (UHD) in short beam pulses at these novel radiotherapy techniques. However, accurate measurement of radiation doses is crucial for comparison of preclinical radiobiological studies against each other and for comparison with established treatment modalities. It is vital for delivering successful radiation therapy.

The project partners will respond the challenge in four work packages (WP). WP1 is focused on primary standards of absorbed dose to water including the establishment of reference radiation fields. WP2 deals with secondary standards and their traceability, relative dosimetry, and characterization on current radiation detectors. In WP3 and WP4 selected current and newly developed radiation detectors are tested, characterized and optimized for measurement of absorbed dose in and outside of UHD primary beams. Recommendations on the basis of the knowledge gained in the project will be summarized in a code of practice.

Interested institutes that want to contribute to the goals of the project may join the consortium as a collaborator. More information about the project can be found on the project home page:
http://uhdpulse-empir.eu/

This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.



Typical dose per beam pulse and pulse length in conventional and novel radiotherapy techniques.

Selected Publications

Experimental exploration of a mixed helium/carbon beam for online treatment monitoring in carbon ion beam therapy
L. Volz, L. Kelleter, S. Brons, L. Burigo, C. Graeff, N. I. Niebuhr, R. Radogna, S. Scheloske, C. Schoemers, S. Jolly and J. Seco
Physics in Medicine & Biology, in press (2020)

First benchmarking of the BIANCA model for cell survival predictions in a clinical hadron therapy scenario
M. Carante, G. Aricò, A. Ferrari, W. Kozlowska, A. Mairani and F. Ballarini
Physics in Medicine & Biology 64, 215008 (2019)

Measurement of PET isotope production cross sections for protons and carbon ions on carbon and oxygen targets for applications in particle therapy range verification
F. Horst, W. Adi, G. Aricò, K.-T. Brinkmann, M. Durante, C.-A. Reidel, M. Rovituso, U. Weber, H.-G. Zaunick, K. Zink and C. Schuy
Physics in Medicine & Biology 64, 205012 (2019)

Measurement of ^{4}He charge- and mass-changing cross sections on H, C, O and Si targets in the energy range 70–220 MeV/u for radiation transport calculations in ion-beam therapy
F. Horst , G. Aricò, K.-T. Brinkmann, S. Brons, A. Ferrari, T. Haberer, A. Mairani, K. Parodi, C.-A. Reidel, U. Weber, K. Zink, C. Schuy
Physical Review C 99, 014603 (2019)

Processing of prompt gamma-ray timing data for proton range measurements at a clinical beam delivery
Theresa Werner, Johannes Petzoldt et al.
Physics in Medicine & Biology 64(10), 105023 (2019)

Range verification in proton therapy: Can prompt-gamma imaging identify the source of deviation?
Chirasak Khamfongkhruea, Johannes Petzoldt et al.
Radiotherapy and Oncology 133 (Supplement 1), S296–S297 (2019)

Upcoming Events

24th March 2020	Healthcare Instrumentation Workshop, Liverpool, UK
22nd March – 4th April 2020	CERN Accelerator School "RF for Accelerators", Kaunas, Lithuania
23rd – 27th March 2020	AVA International School on Precision Studies, Prague, Czech Republic
9th- 14th May 2020	PTCOG59, Taipei, Taiwan
10th – 15th May 2020	IPAC20, Caen, France
30th Aug - 4th Sept 2020	LINAC2020, Liverpool, UK
13th – 17th Sept 2020	IBIC 2020, Sao Paulo, Brazil

NOTICE BOARD

DEADLINE FOR THE NEXT NEWSLETTER **26th April 2020**

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