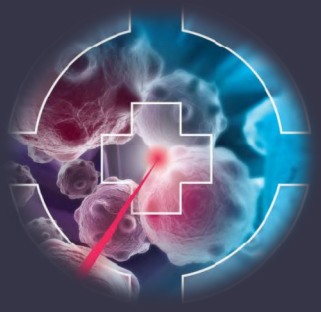


OMA Express
October 2023
Issue 20

Highlights

- Using beam quality Q to model relative biological effectiveness
- A feasibility study for prostate treatments in the upright position
- Beam dosimetry measurements made with gas jet monitor

"Collaborate or Crumble"

This statement was made by Professor Rocky Tuan, Vice-chancellor and president of the Chinese University of Hong Kong during the 2022 Times Higher Education World Academic Summit in New York. Whilst "publish or perish" has been an aphorism describing the pressure to publish academic work to succeed in an academic career for a long time, "collaborate or crumble" has become the modern-day equivalent for academics and entire institutions. OMA has embraced this principle from the start, and we have successfully built bridges with other networks (AVA) and national training initiatives, such as the data science centre LIV.DAT. This has led to joint events, career opportunities for our Fellows, as well as coordinated dissemination which was much more impactful than any of the projects alone could have achieved. I am delighted to report that the EC/REA has recognized this as excellent practice and has invited me to speak about our approach to exploiting synergies at a coordinator briefing meeting in Brussels in November. I believe this is an excellent example of the lasting legacy of our project.

I was absolutely delighted about the announcement that the UK will now become an Associated Country in Horizon Europe from 1 January 2024. Over the past few years, I have regularly highlighted the negative impact the uncertainty around the UK's position has had on science and innovation in online and print media, national and international TV and radio stations. Horizon is stronger with the UK - and UK science is stronger in Horizon; a classic win-win situation. It is now up to the community to fully embrace the opportunities this brings and revamp long-standing collaborations.

Many of our past OMA Fellows have continued their research into medical accelerators after graduating from our network. This OMA Express showcases some of the exciting research results they have published recently. I hope you enjoy reading about their studies as much as I did!

Prof Carsten P Welsch
OMA Coordinator

Research News

Using beam quality Q to model relative biological effectiveness

Beam quality Q, defined as the ratio between the ion charge squared and the ion energy, is an alternative to the conventionally used linear energy transfer (LET) to model the relative biological effectiveness (RBE) of ions.

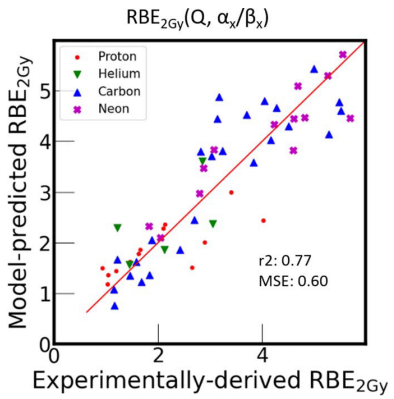
The Q concept is ion-independent, i.e. different ions with similar Q have similar RBE values. Therefore, it could help to transfer clinical RBE knowledge from better-studied ion types, like Carbon, to other ions. However, the validity of the Q concept has so far only been demonstrated for low LET values.

Former OMA Fellow Liheng Tian and Armin Lühr from TU Dortmund University have explored the Q concept in a broad LET range, including the so-called overkilling region.

The researchers used the particle irradiation data ensemble (PIDE) as experimental in vitro dataset. Data-driven models, i.e. neural network (NN) models with low complexity, were built to predict RBE values for H, He, C and Ne ions at different in vitro endpoints taking different combinations of clinically available candidate inputs: LET, Q and linear-quadratic photon parameter αx/βx.

Tian and his colleague compared the models in terms of prediction power and ion dependence. The optimal model was compared to published model data using the local effect model (LEM IV).
They found that the NN models performed best for the prediction of RBE at reference photon doses between 2 and 4 Gy, or RBE near 10% cell survival, using only αx/βx and Q instead of LET as input. The Q model was not significantly ion dependent (p>0.5) and its prediction power was comparable to that of LEM IV.

In conclusion, Liheng Tian and his collaborator demonstrated the validity of the Q concept in a clinically relevant LET range including overkilling. They proposed a data-driven Q model and observed that it has an RBE prediction power comparable to a mechanistic model regardless of particle type. The Q concept provides the possibility of reducing RBE uncertainty in treatment planning for protons and ions in the future by transferring clinical RBE knowledge between ions.



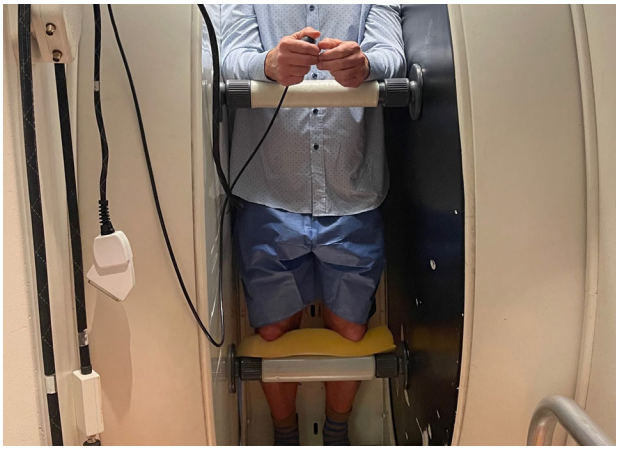
Comparison between the predicted RBE_{2Gy} (Q, α_x/β_x) and experimentally derived RBE_{2Gy} values for the test dataset. The ion type is color coded. The reference red line demonstrates y=x, i.e. the ideal case that the prediction equals the corresponding experiment. © The authors.

The work was published in Physics in Medicine & Biology.

Full article:

Liheng Tian and Armin Lühr, "**Data-driven ion-independent relative biological effectiveness modelling using the beam quality Q**", Physics in Medicine & Biology 68, 105009 (2023). https://doi.org/10.1088/1361-6560/acc9f9

A feasibility study for prostate treatments in the upright position



A volunteer in the MRI scanner demonstrating the upright position. Trans-polar VersaRests™ were positioned to support the knees and arms. © 2023 The Authors. Journal of Applied Clinical Medical Physics published by Wiley Periodicals, LLC on behalf of The American Association of Physicists in Medicine.

Treating and imaging patients in the upright orientation is gaining acceptance in radiation oncology and radiology and has distinct advantages over the recumbent position.

Former OMA Fellow Michelle Lis and colleagues from Leo Cancer Care, the University of Arkansas and Fornar Corporation have conducted an IRB approved study to investigate the positions and orientations of the male pelvic organs between the supine and upright positions.
The study comprised of scanning 15 male volunteers (aged 55–75 years) on a 0.6 T Fonar MRI scanner in the supine and upright positions with a full bladder and in the upright position with an empty bladder. The pelvic study revealed that (i) in the upright position the position and shape of the prostate are not impacted significantly by bladder fill; (ii) the distance between the sacrum and the anterior bladder wall is significantly smaller; (iii) the anterior-posterior length and the bladder width is significantly larger; (iv) the seminal vesicles are pushed down by the bladder; and (v) the top of the penile bulb is further away from the apex of the prostate.

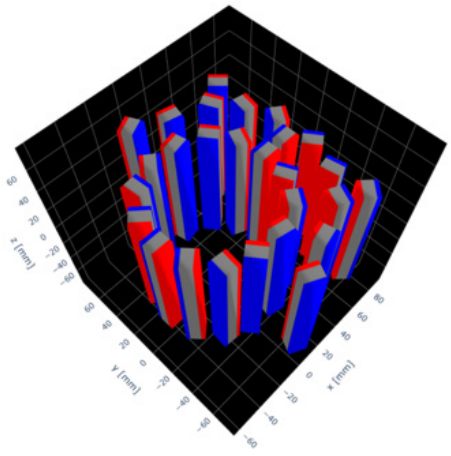
These observed differences could positively impact upright prostate treatments by reducing the risk of the small bowel approximating the treatment volume and reducing the average dose to the penile bulb. Moreover, prostate treatments can be done with a reduced focus on bladder fill. Radiation beams for treating intermediate risk prostrate can be made smaller or a larger portion of the seminal vesicles can be treated with the same beam size than typically used for supine treatments.

The study has been published in the Journal of Applied Clinical Medical Physics.

Full article:

Andries (Niek) Schreuder, Wen-Chien His, John Greenhalgh, Michael Kissick, Michelle Lis, Tracy S. A. Underwood, Harry Freeman, Michael Bauer, Stephen Towe, Rockwell Mackie, "**Anatomical changes in the male pelvis between the supine and upright positions—A feasibility study for prostate treatments in the upright position**", Journal of Applied Clinical Medical Physics, e14099 (2023). https://doi.org/10.1002/acm2.14099

TURBO: A novel beam delivery system for charged particle therapy



Preliminary magnet design for the scaled-down TURBO demonstrator. Credit: J. Yap

Charged particle therapy is a well-established modality of cancer treatment and is increasing in worldwide presence due to improved accelerator technology and modern techniques.

The beam delivery system determines the overall timing and beam shaping capabilities, but is restricted by the energy variation speed, which is determined by the energy layer switching time (ELST).

Beamlines at treatment facilities have a ±1% momentum acceptance range, requiring all the magnetic fields to adjust to deliver different energy beams at multiple depths in the tumour volume.

Minimising the ELST can enable the delivery of faster, more effective and advanced treatments but requires an improved BDS. A possibility for this could be achieved with a design using Fixed Field Alternating Gradient (FFA) optics, enabling a large energy acceptance to rapidly transport beams of varying energies.

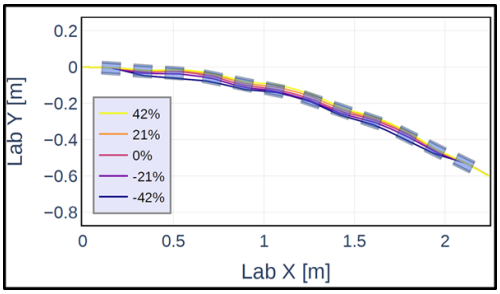
Former OMA Fellow Jacinta Yap, together with colleagues from the University of Melbourne and the University of Manchester have developed a novel beam delivery system to explore the potential of rapid depth scanning in charged particle therapy.

The system TURBO (Technology for Ultra Rapid Beam Operation) is a scaled-down proof-of-concept demonstrator adapted for low energy protons. TURBO comprises several interchangeable modules adapted for the University of Melbourne low energy ion ‘Pelletron’ accelerator.
Alongside development of the scaled-down TURBO beamline, work is underway towards a full clinical energy design for transportation of heavier ions.

The modularity of TURBO allows the flexibility to explore and iterate between different concepts: further experimental, simulation and design work will progress the development of a laboratory implemented demonstrator, to improve beam delivery for existing and future clinical charged particle therapy facilities.

Jacinta Yap and her colleagues have carried out simulation studies as well as characterisation measurements to determine realistic parameters for beam transport and particle tracking modelling.

The results, and considerations for implementing TURBO in a clinical setting, were presented at IPAC 2022 and 2023.



Beamline design with different orbit trajectories over the full momenta range. Credit: J. Yap

Further information:

S. L. Yap, S. L. Sheehy, A. F. Steinberg, H. X. Q. Norman and R. B. Appleby, **"TURBO: A novel beam delivery system enabling rapid depth scanning for charged particle therapy"**, Journal of Physics: Conference Series 2420, 012094 (2023). https://doi.org/10.1088/1742-6596/2420/1/012094

S. L. Yap, S. L. Sheehy, A. F. Steinberg, H. X.Q. Norman, R. B. Appleby, S. J. Clarke, **"Progress toward TURBO: A novel beam delivery system for charged particle therapy"**, 14th International Particle Accelerator Conference, Venezia, JACoW Publishing. https://doi.org/10.18429/JACoW-IPAC-23-THPM091

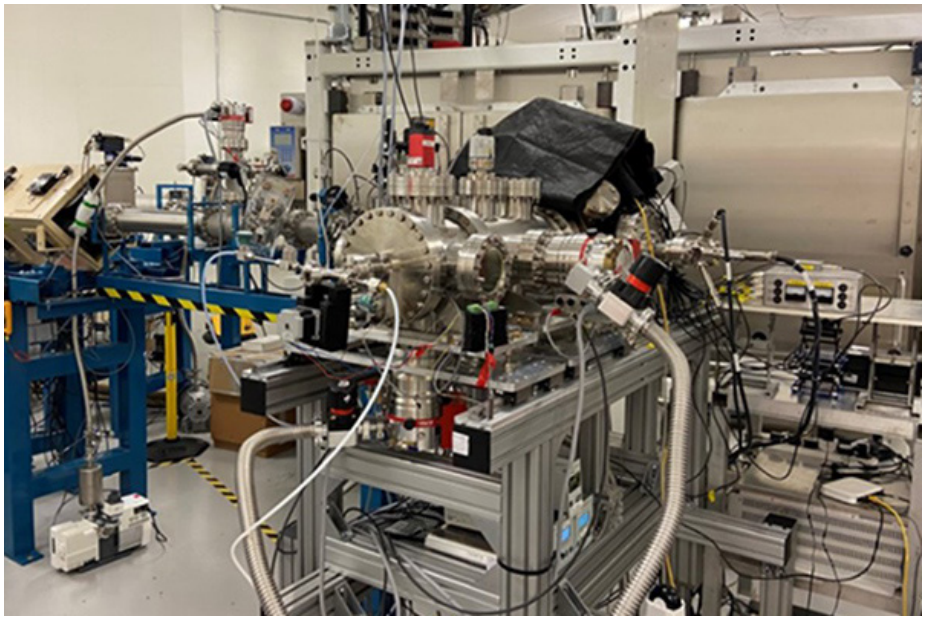
Beam dosimetry measurements made with gas jet monitor

A team from the University of Liverpool's QUASAR Group has been investigating the possibility of conducting non-invasive beam dosimetry measurements at Dalton Cumbrian Facility (DCF), Whitehaven (UK). Non-invasive in-vivo dosimetry is a key goal for medical facilities, as highlighted in the widely recognized "Towards safer radiotherapy" report which was published in 2008. Despite significant efforts internationally to create non-invasive dosimetry, it is not yet sufficiently developed to be available for routine operation.

The QUASAR Group, based at the Cockcroft Institute, has led the design of a novel monitor capable of imaging the proton beam in the High Luminosity Large Hadron Collider (LHC) and the beam in the Hollow Electron Lens simultaneously. This monitor shows excellent prospects for imaging proton and ion beams at clinically relevant energies and intensities as well. The study builds up directly on previous research where Silicon strip detectors were used for online dosimetry.

As a part of STFC-funded CLASP project, the design of the gas jet monitor has been adapted and will be optimised for use at medical accelerators. With the additional funding secured from the Faculty Impact Fund project, targeted measurements were made at the Dalton Cumbrian Facility's tandem accelerator with beam parameters close to a clinical facility. The results are currently being analyzed and will be submitted to a journal for publication in the near future.

As well as the CLASP project, the study is also going to benefit the recently funded £2M conceptual design study into a Laser-hybrid Accelerator for Radiobiological Applications (LhARA). These measurements will inform the design of future facilities such as LhARA which targets short pulse, high repetition rate beam delivery for which online beam monitoring remains an unsolved challenge.

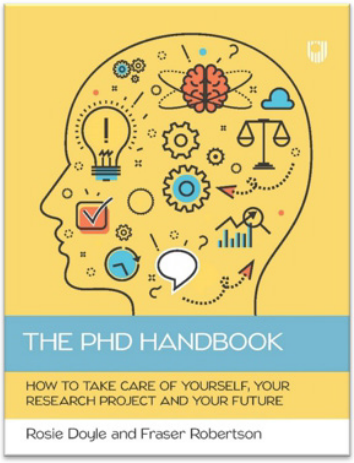


Gas Jet Monitor coupled with DCF accelerator beam line.

Partner News

The PhD Handbook

The PhD is usually the first and most challenging stage of a researcher's career. A new book by Rosie Doyle and Fraser Robertson, from Fistral, addresses these challenges offering practical guidelines for students on how to take care of themselves, their research and their future, during this difficult phase.



An associate partner of OMA, Fistral has been delivering training events for OMA and other Initial Training Networks led by the University of Liverpool, but also to research groups and industrial companies like the European Space Agency.

This book builds on the type of events delivered face-to-face for OMA and other successful training courses run by the authors around the world for thousands of PhD students. Drawing on personal experiences of completing their own doctoral degrees, the book offers tried and tested approaches to help students at all stages meet the demands of a PhD.

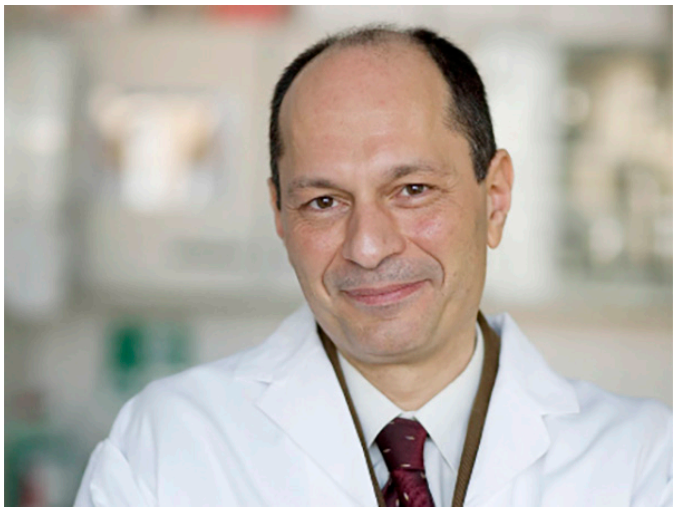
Full of practical and highly applicable tools, techniques, activities and templates, *The PhD Handbook* looks beyond research challenges to provide an accessibly written step-by-step guide to the wider project management and personal effectiveness skills needed throughout the journey toward a successful and timely qualification. Each chapter focuses on the most common issues PhD students encounter, including how to create a useful plan when you don't know what you're doing, how to get going again if you get stuck, and how to use your PhD as the launchpad for your future career.

As well as helping the students to make the most of the doctoral experience, the book also provides a toolbox of transferable skills that they will find useful in setting themselves up for a successful career beyond their degree.

OMA Coordinator Prof Carsten P Welsch said: "The PhD Handbook is an essential read to make this journey easier and more structured."

The book will be out on 20th October. The QR code below links directly to the book in the Open University Press (OUP) bookstore and offers a 20% discount on any OUP purchase from the date of publication. Any pre-orders can be done via Amazon. For bulk pre-orders please contact either Fistral or the publisher directly for discounts.

Prof Marco Durante obtains the 2023 Henry S Kaplan award



Prof Marco Durante (wikipedia CC BY-SA 4.0)

Professor Marco Durante has been recognised with the 2023 Henry S Kaplan Award by the International Association for Radiation Research (IARR).

The Henry S. Kaplan Distinguished Scientist Award was established in 1985 by the IARR and it is presented every four years to a scientist who exhibits outstanding contributions to radiation research in the fields of biology, chemistry, medicine or physics. The award was presented at the International Congress of Radiation Research in Montreal, Canada in August 2023

Professor Durante is the Director of the Biophysics Department at GSI Helmholtz Center for Heavy Ion Research which has had a leading role in OMA through Professor Christian Graeff as a member of the network's Steering Committee. He is internationally renowned for his studies in charged particle therapy, cosmic radiation, radiation cytogenetics, and radiation biophysics. Currently, Durante's research efforts are directed toward the optimization of charged particle therapy, mainly focusing on reducing the costs and increasing the benefits of this treatment.

Congratulations!

This article is based on:

https://radconnections.org/2023/08/28/marco-durante-2023-kaplan-award-winner/

Upside down – The Science of Stranger Things

Prof Carsten Welsch talking to the audience at Lymm Festival.

In a small town where everyone knows everyone, right next to a mysterious laboratory, a peculiar event about supernatural powers, parallel dimensions and portals to another world, mesmerized the audience.

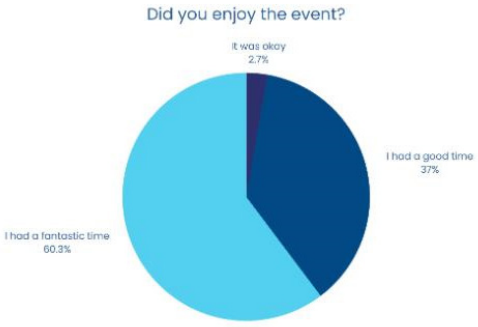
Prof Carsten P Welsch returned to Lymm Festival on 28 June 2023, a local summer festival, bringing families and friends together in a variety of organised events, to take an entertaining look into the science behind the sci-fi horror *Stranger Things*. The Netflix hit series is set in 1980s Indiana. A group of young friends witness supernatural forces and secret government exploits. As they search for answers, the children unravel a series of extraordinary mysteries, experience psychokinetic powers and venture into the *Upside Down*. The *Upside Down* is described in the show as an alternate dimension that mirrors our world, an extra dimension that can be accessed through a mystical portal. This all sounds more like fiction than fact, but is it?

Using actual scenes from the *Stranger Things* series, Prof Welsch examined some of the technologies and elements that feature in the films and showed how they relate to the world of physics and connect to the research programmes that physicists from the University of Liverpool and the Cockcroft Institute are involved in.

The talk attracted over 80 people of all ages from the local community, some even travelling from Liverpool, Prescot and Stockport. Prof Welsch explained how accelerator physics connects with the real world and the use of accelerator applications in daily life in an interesting and humorous way, which was accompanied by laughter and applause from the audience.

The Q & A session after the talk was very well received and triggered questions about the Big Bang, the existence of parallel universes, Liverpool's involvement in the discovery of the Higgs particle, quantum physics and much more.

The feedback from the event was remarkable with one attendee stating that "it changed [their] perspective of how physics can be taught" and another one saying that the best thing about this event was "hearing someone talk with such passion, explaining complex and difficult ideas!"



86% of the participants indicated after the event that they know about the use of accelerator applications in daily life, compared to 22% at the start of the evening. With 90% stating that they are now aware of Liverpool's connections to a global community, compared to 35% before.

The event was a great success, and everybody left with a big smile on their face. Prof Welsch and his helpers from the QUASAR Group thoroughly enjoyed the evening and the amazing audience. A big thank you to the organisers of Lymm Festival and the wonderful group of volunteers for making this event possible.

Stay curious!

Selected Publications

Liheng Tian and Armin Lühr, "Data-driven ion-independent relative biological effectiveness modelling using the beam quality Q", Physics in Medicine & Biology 68, 105009 (2023). https://doi.org/10.1088/1361-6560/acc9f9

Andries (Niek) Schreuder, Wen-Chien His, John Greenhalgh, Michael Kissick, Michelle Lis, Tracy S. A. Underwood, Harry Freeman, Michael Bauer, Stephen Towe, Rockwell Mackie, **"Anatomical changes in the male pelvis between the supine and upright positions—A feasibility study for prostate treatments in the upright position"**, Journal of Applied Clinical Medical Physics, e14099 (2023). https://doi.org/10.1002/acm2.14099

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Upcoming Events

8th – 13th Oct 2023	International Workshop on Beam Cooling and Related Topics (COOL23), Montreux, Switzerland
9th – 13th Oct 2023	68th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams (HB2023), CERN, Geneva, Switzerland
18th – 24th May 2024	15th International Particle Accelerator Conference (IPAC24), Nashville, USA
25th – 30th Aug 2024	32nd International Linear Accelerator Conference (LINAC'24), Chicago, USA
7th – 11th September 2025	14th International Beam Instrumentation Conference (IBIC25), Liverpool, UK

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