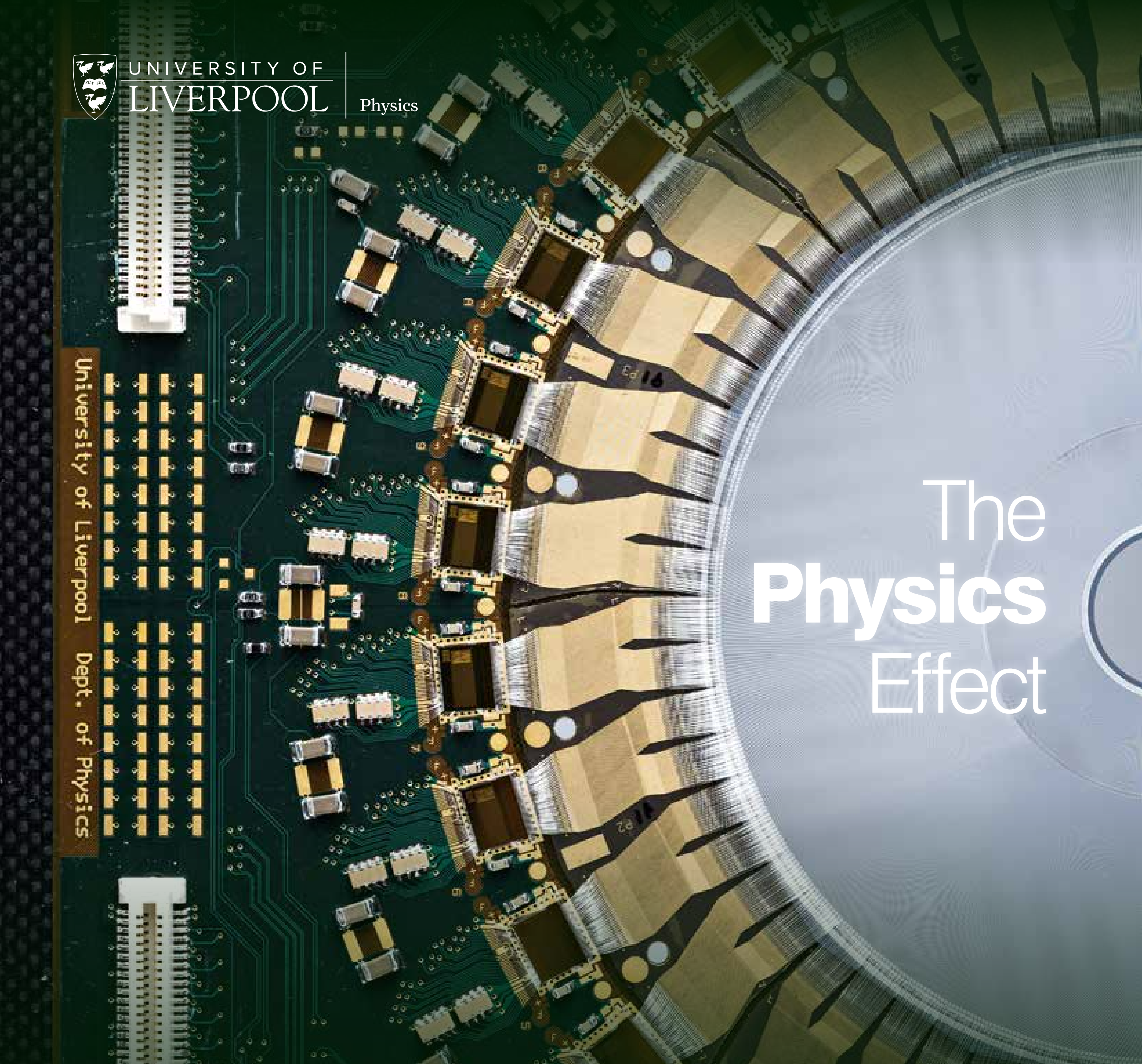
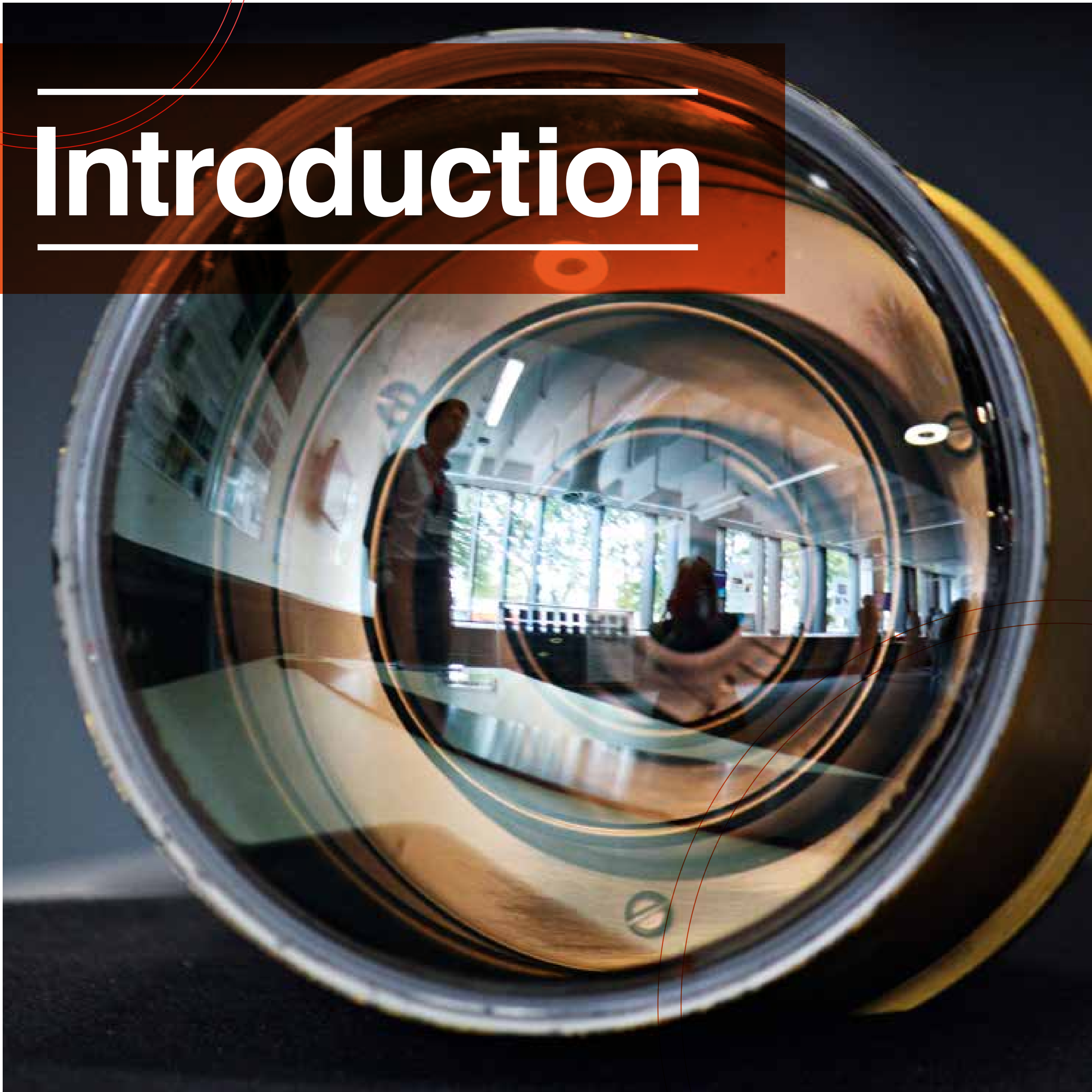
UNIVERSITY OF LIVERPOOL | Physics



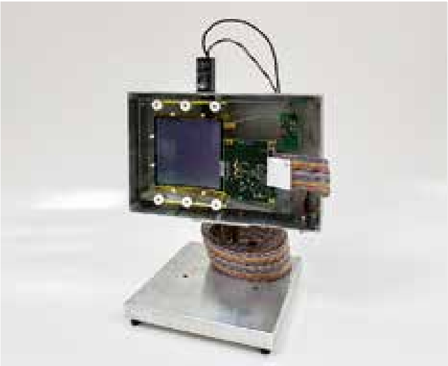
The **Physics** Effect

LIFE CHANGING
World Shaping

Introduction



Welcome to the first edition of *The Physics Effect* – a yearly report which showcases a collection of case studies and applicative projects that the Department of Physics at the University of Liverpool has been working on.



It is an exciting time for Physics with the discovery of the Higgs in 2012, work on antimatter, the discovery of gravitational waves this year, the increasing attention to neutrino physics and quantum physics, dark matter and dark energy, and the important work done in the Energy sector, with a new class of material for solar cells.

At the University of Liverpool, our physicists are working on projects that are directly addressing these fundamental challenges and we hope this report will give you an insight into the life-changing work we specialise in.

So, how can Physics help you and your business? Behind almost everything that pushes the world economy and society today there are examples of seminal work done by a Physicist. Our impact on society and economy is not a new thing; from Archimedes, to Faraday and Brunel, to the recent discoverers of 2D materials, Physics has always shaped our society, continues to power it, and will remain central to unlocking the secrets to solving many of mankind's largest problems such as health, energy and security.

We believe that understanding the world means changing and improving it and our work is pivotal in making it happen, so why don't you join us?

Marco Palumbo
Commercial Manager, Department of Physics

Projects

Compton Cameras

Four Physicists from the University: Professor Paul Nolan, Dr Andy Boston, Dr Helen Boston and Dr Laura Harkness-Brenna, as well as their PhD students and postdoctoral researchers, represent perhaps the best of what the UK can offer in terms of understanding radiation instrumentation and Gamma Ray Detectors.

The group has specialised knowledge on the Compton Camera technique and have applied this to the healthcare, security and energy sectors. Working in partnership with the Science & Technology Facilities Council (STFC), Daresbury; design company 257; CANBERRA and the Kromek group on the projects GRi and GRi+ (Gamma Rays Imager) is helping to bring years of hard work closer to the market and at a faster pace.

GRi

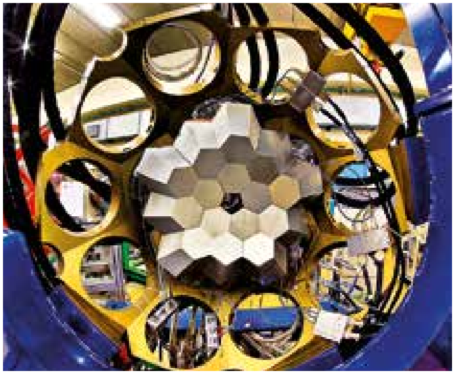
The first example of GRi will be a light (total weight less than 5kg) portable gamma ray detector integrated with a traditional camera and/or a stereoscopic and thermal camera. This will be used by police forces and rescue teams around the world to detect radioactive sources at a crime scene. Once launched on the market, we believe this device will change police operations worldwide.

GRi+

GRi+ is a larger detector mounted on a gantry or an autonomous system to help in the decommissioning of nuclear power stations at the end of their working life.

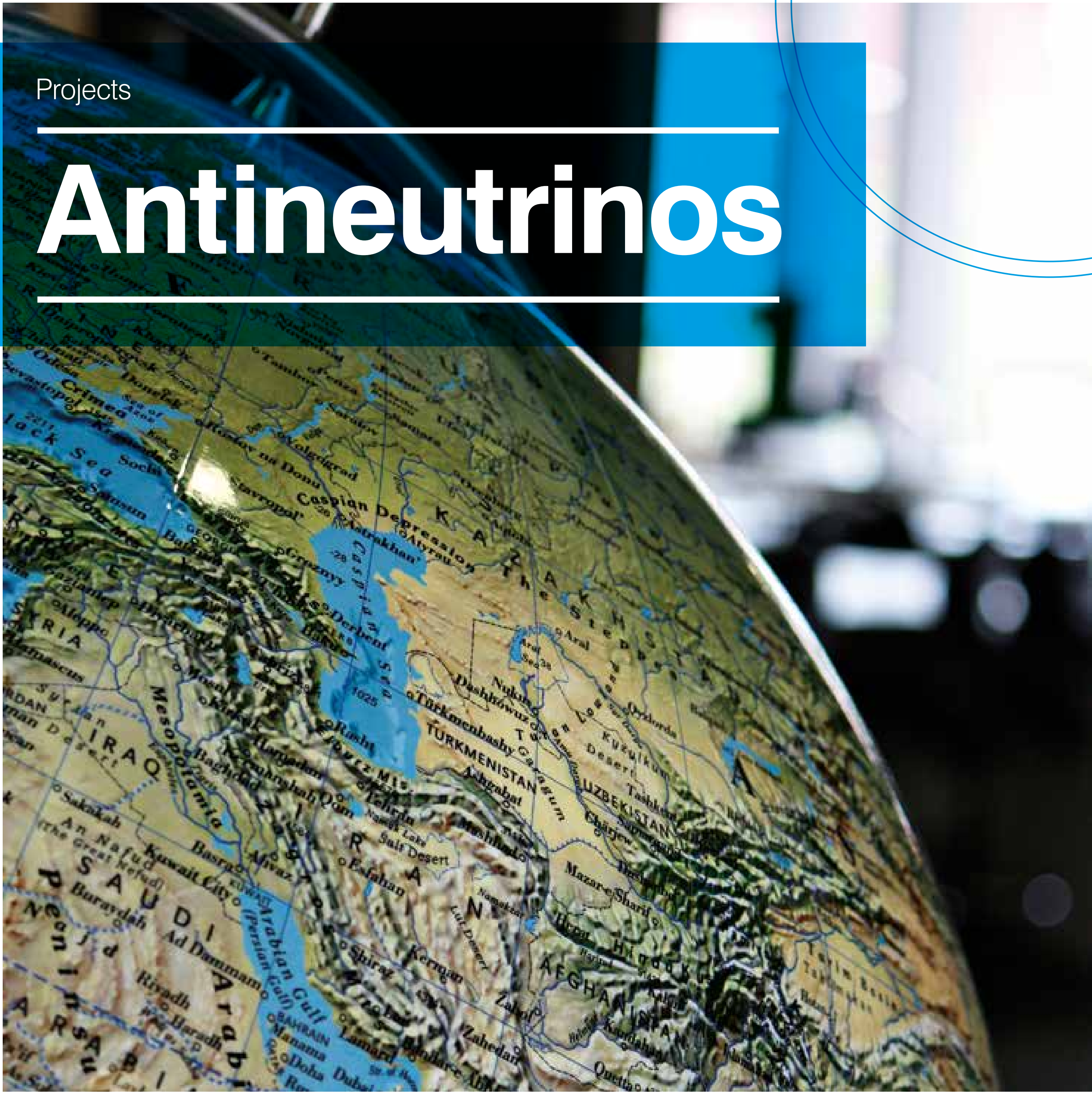
As more nuclear power stations are constructed, the importance of nuclear energy continues to grow globally, raising concerns in the industry around safe disposal of radioactive material, precise categorisation, and the prevention of unnecessary risk to individuals.

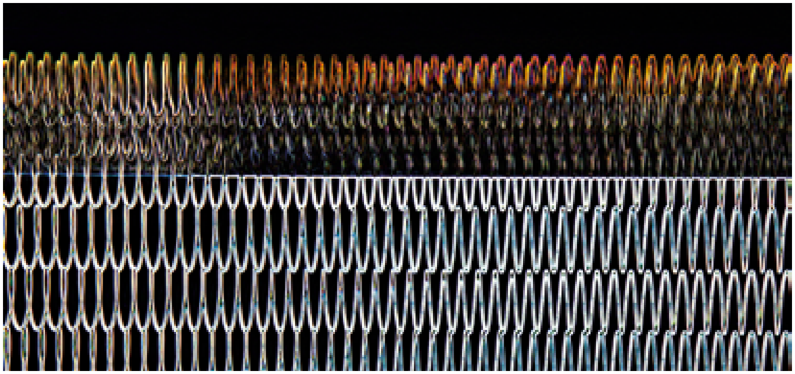
GRi+ has been designed to answer those concerns and we are working hard with our partners CANBERRA and the National Nuclear Laboratory to provide the industry with the right tool for the job.



Projects

Antineutrinos





The VIDARR antineutrino detector is a flagship project for the Department of Physics and is currently being worked on by Dr Jon Coleman and his team. This project is a key example of how technology, which was first developed exclusively for scientific purposes (for example the T2K project in Japan), can be applied in industry.

In 2012, Dr Coleman (pictured above, front right) was thinking about how he could identify if a nuclear reactor was operating correctly and that crucially it had not been tampered with during operation.

It turned out that the detection of neutrinos (emitted from the reactor) was probably the best answer to this question and luckily, he had the plans for such a detector on his desk.

Thanks to the STFC and Innovate UK support, and in collaboration with John Caunt Scientific (JCS) Ltd, the first prototype of the detector has just undergone a year-long field test at Wylfa power station, Anglesey, where it was purposely installed outside the station precinct.

The prototype has delivered crucial data and given a clearer understanding of requirements, which has allowed the team to work on upgrading a more robust, self-standing and tamper-proof system for safeguarding and operational purposes.

Jon's work is attracting the interest of a range of stakeholders and a strong consensus is now building in the UK and worldwide that this is the right solution for a problem that has vast political and societal implications.

Projects

GAMBE

In 2013, Dr Sergey Burdin and Professor Gianluigi Casse started working on their new project, Gamma-blind neutron-efficient detector (GAMBE). Their main concern was assuring a high rejection rate between gammas and neutrons during radiation measurements, which is an important issue in several fields – from scientific imaging, to the energy sector, to personal security.

Building on a foundation of hundreds of years' worth of knowledge in silicon detectors and sensor systems, Sergey (pictured right, front left) and his team have been able to prove that GAMBE's rejection rate is at least 100 times higher than any current commercial device.

This means we now have the most accurate and discriminating measurement device for neutron concentration in the world and it's only the size of a small packet of mints.

Due to its small size, Sergey envisages integrating GAMBE with a smartphone for personal protection purposes or for diffuse monitoring, ie mapping a very large area, thanks to a distributed and mobile network of small sensors.

They have also started discussing the use of a tiled system for neutron imaging, which is a powerful crystallography technique that is used by pharmaceutical and chemical companies.

The application where GAMBE could really take off is in the oil and gas exploration sector. Neutron interrogation of hydrocarbon reserves is not a new thing. But what is new is that exploration companies are now looking closely at the exploitation of deep seeded reserves or at extending the lifetime of the current sites by drilling beyond exhausted reserves or at dramatic cost reductions, for example having exploration wireline that can operate for an extended period of time without the need to be replaced. Even with the oil price at historically low levels, there is space for innovation in this sector and the team's new development to extend Gambe capability in extreme environments could just be the solution.

Projects

Fast Read-out Silicon Detectors

Dr Joost Vossebeld is one of our best scientists in the particle physics field. Together with colleague Dr Andrew Metha, Joost was involved in the discovery of the Higgs boson at the Large Hadron Collider (LHC) in 2012 by analysing more possible decay channels of the Higgs than any other group.

Joost (pictured above, right) and Professor Gianluigi Casse were approached at the end of 2014 by Q-Technology (a spin-off company of the University of Liverpool) to work together on an applicative project because of their strong expertise in fast read-out sensors.

Having worked for many years on spectrometry, Q-Technology thought there would be a substantial gain for this industry by accessing the class of sensors Joost and Gianluigi's team were internationally known for. Thanks to an STFC Global Challenges grant, Joost and Gianluigi put together a small team of engineers, and started working on a first prototype which will be ready for full testing this summer.

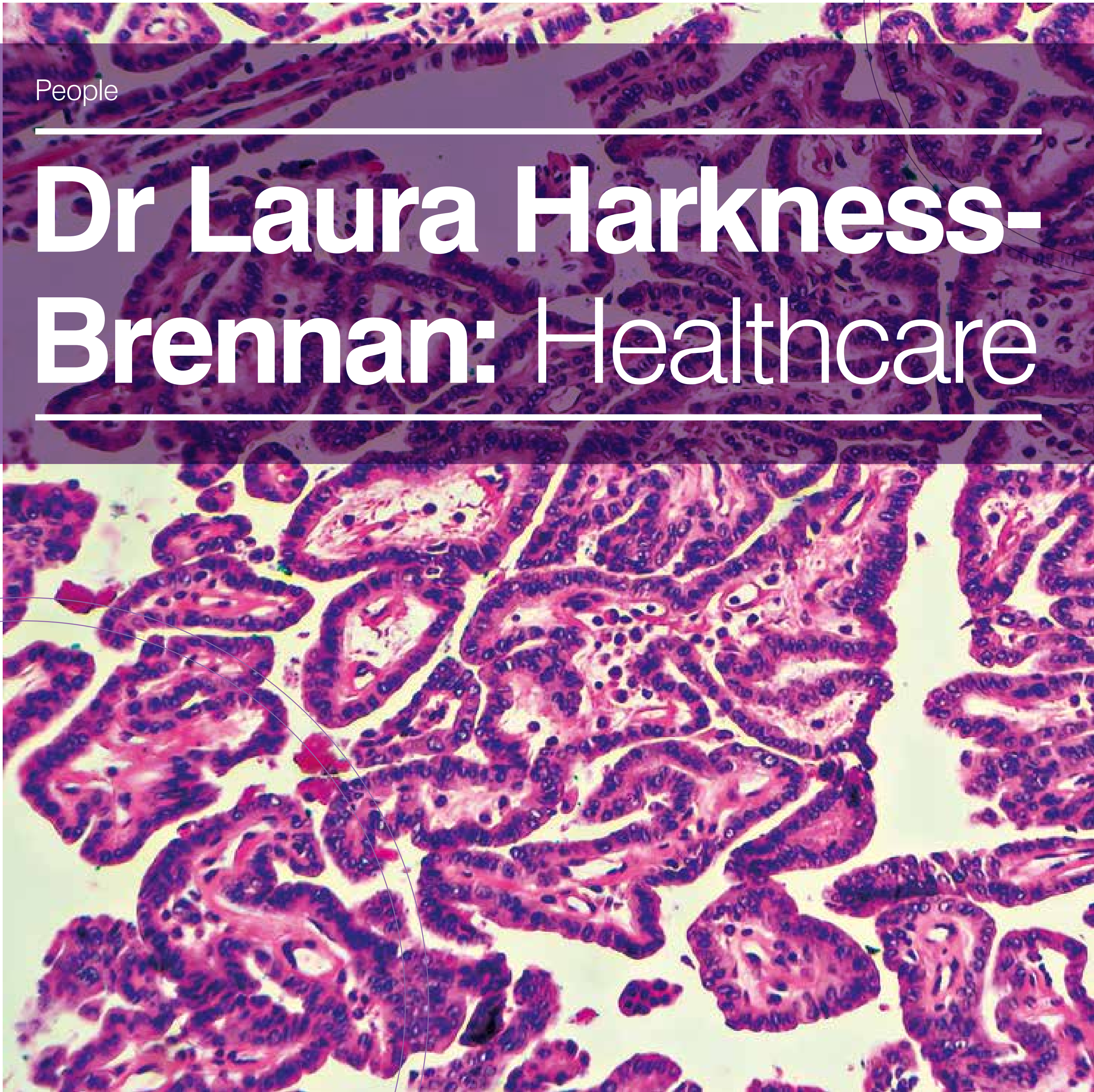
Joost and colleagues have created new intellectual property and have demonstrated that sensitivity levels down to a part-per-trillion can be achieved in a mass spectrometer not bigger than a small suitcase and at a fraction of the costs of traditional scientific instrumentation of comparable sensitivity.

In collaboration with companies that operate in the security sector, Joost and his team are currently working on a larger project that deals with the implementation of a discreet, always-on detection system, which allows the screening of people and goods with minimal or no interruption to their flow. There is plenty of interest in this field as well as in the arena of industrial process and environmental control in high-risk working environments.

Joost in now pitching this product to potential investors and partners and we are confident you will find this new system on shelves in the near future.

People

Dr Laura Harkness-Brennan: Healthcare



One of our newest lecturers, Dr Laura Harkness-Brennan, is a veteran of the Department of Physics. She started here as a student and worked her way through the ranks at speed. After working in industry for a short spell, she decided to return to academia and now leads one of the most dynamic and exciting groups in the University.

Laura (pictured above, front left) works across two major lines of applicative research, which includes with the defence/security sector on the safe handling and disposal of radioactive materials, and with a network of clinicians and companies developing new diagnostic and treatment technologies for cancer.

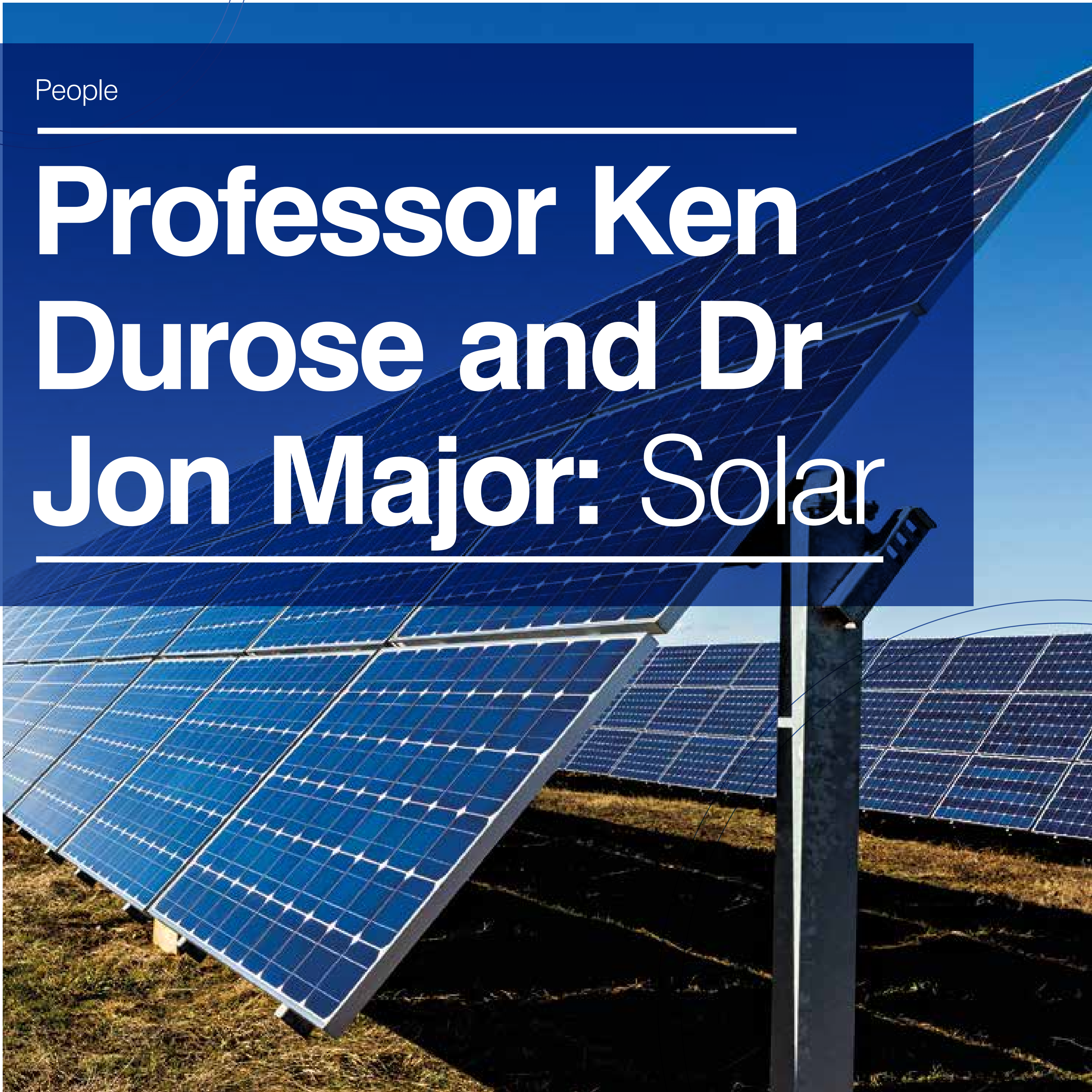
In collaboration with the Royal Marsden University Hospital, the Royal Liverpool University hospital and the Kromek group, Laura and her team are currently developing a gamma-ray imaging system that aims to deliver dosimetry during molecular radiotherapy. In this type of radiotherapy treatment, unsealed radioactive substances are administered to a patient to target specific diseases, such as thyroid cancer. Although the treatments can be highly effective, planning can be difficult due to the varying biokinetics of patients.

The system under development will be used to aid planning by determining the effectiveness of treatments and preparing personalised treatment plans for patients.

Beside the day to day academic job, Laura always finds time for outreach activities and she is known for travelling extensively around the country enthusing young students and the public on the fascinating topics she works on and the excitement of doing science in general.

People

Professor Ken Durose and Dr Jon Major: Solar



Dr Jon Major and Professor Ken Durose are specialists in solar energy materials and solar cells. Their work centres on improving the efficiency, cost-effectiveness and sustainability of solar electricity generation.

In 2015 they established a breakthrough in solar cell materials processing in which an expensive toxic chemical that had been in use for decades was replaced with an inexpensive one. Their work was published in *Nature* and they have recently won the prestigious Global Award for Energy from the Institution of Chemical Engineers (IChemE). This is the first time a team of physicists has won this award.

Both physicists are part of the University of Liverpool's Stephenson Institute for Renewable Energy – an energy materials research institute with an interdisciplinary team of physicists and chemists. They work on a diverse range of future high-tech energy issues, including batteries, heat storage, thermoelectrics, photocatalysis, creation of sustainable chemical feedstock from bio-mass and of course solar electricity. Ken is Director of the Institute and the Sustainable Energy Research Theme leader for the University of Liverpool.

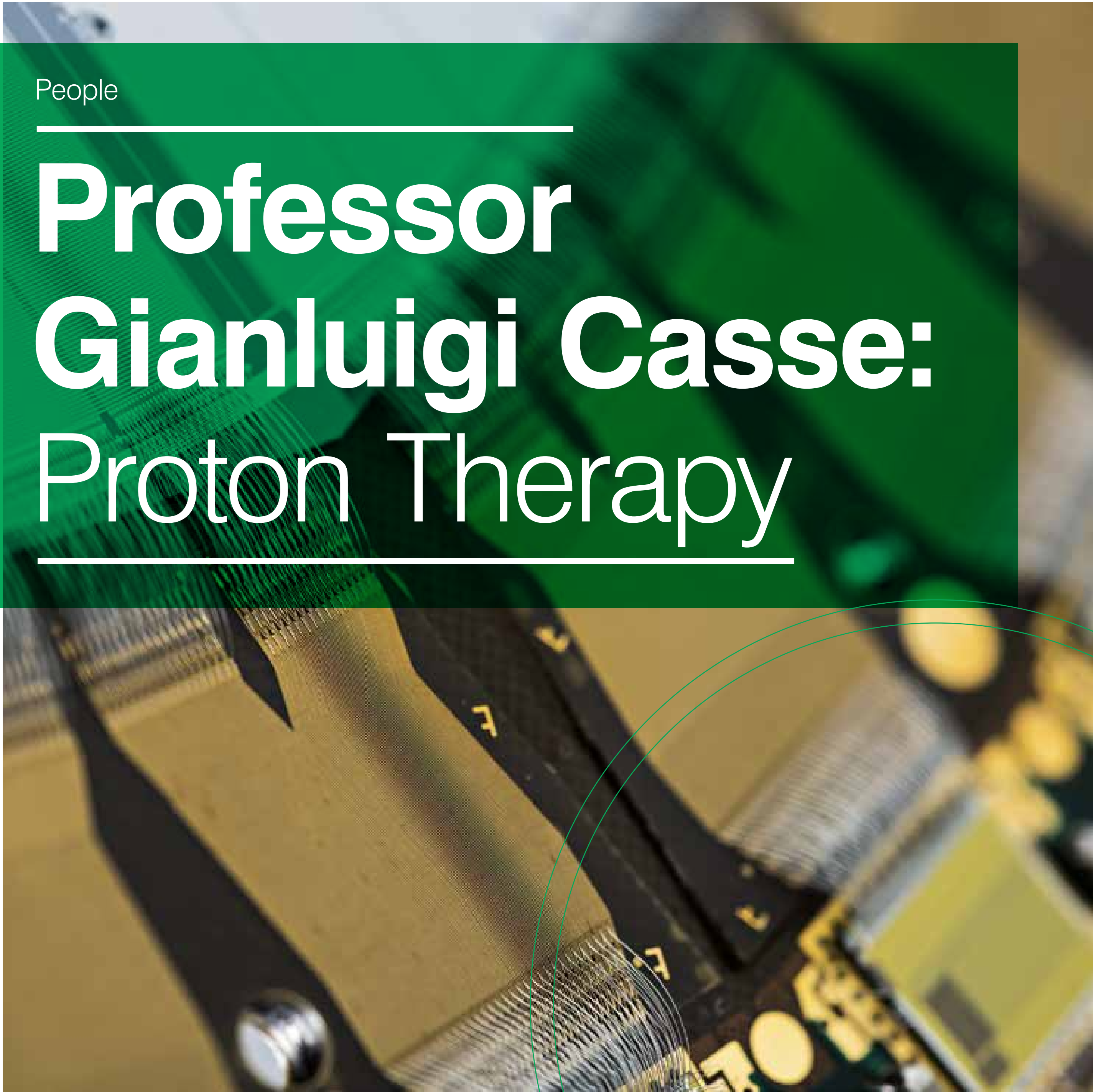
When asked what their biggest challenge is and what really would be a breakthrough in their field of solar electricity they said:

Jon (pictured top left) – "The target is always to make solar cost competitive with fossil fuels. This is a difficult challenge, but one which could revolutionise power generation for the whole planet."

Ken (pictured top right) – "Our aim is to make scientific advances that will enable the solar photovoltaic (PV) market to break free from government subsidies. To do this we will have to undercut silicon and that's going to require some advanced materials and device ideas."

People

Professor Gianluigi Casse: Proton Therapy



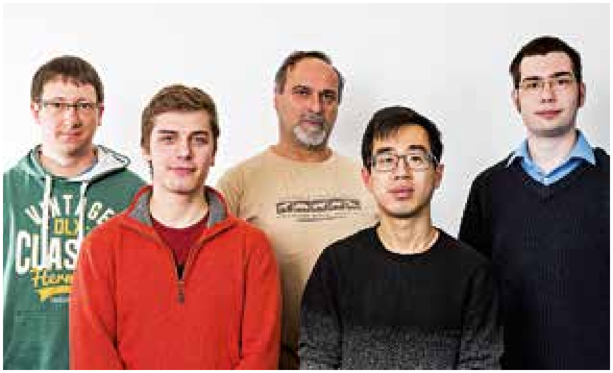
Professor Gianluigi Casse leads the research and development division in the Department of Physics. He is also co-spokesperson at CERN for the RD50 programme, as well as Director of Fondazione Bruno Kessler (FBK), a Microelectronics Centre in Trento, Italy.

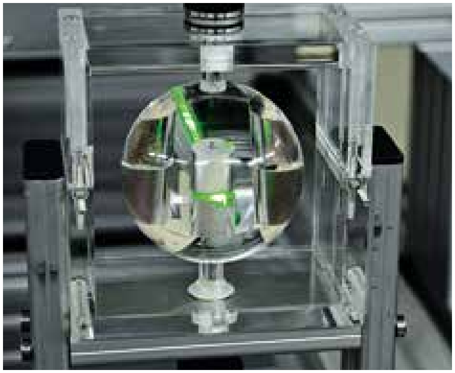
In the early 2000s Gianluigi (pictured below, centre) and the Particle Physics team (led by Professor Themis Bowcock) built the Vertex Locator (VELO), the world's most sophisticated radiation detector. To date, no other system has been developed that can withstand a similar level of radiation. This class of silicon sensor is known in the field as rad-hard detectors. You can actually see the VELO as part of the Collider exhibition. Produced by the Science Museum in London, the exhibition will tour across Europe, Asia, and Australia until April 2017.

For more information please visit: www.sciencemuseum.org.uk/visitmuseum/Planyourvisit/exhibitions/collider.

In parallel to research and development associated with fundamental Physics experiments, Gianluigi and his team are always looking for alternative uses for developed technologies, especially in the healthcare sector and in particular around proton therapy machines for the treatment of some forms of cancer.

With a string of patents and projects under his belt, Gianluigi is now being courted by a number of companies and investors, which is a triumph for the Department of Physics as we believe that if there is an opportunity to contribute to the provision of better care for patients, than it is our duty to do so.





People

Our technical team

Staff

The work of the Department of Physics would not be possible without the support and help of our technical teams.

We are proud to have some of the best people in the country who have knowledge and skills in a range of subjects including: advanced manufacturing, detector integration and packaging, and electronics and mechanical design.

The wealth of expertise that comes from these people, together with the know-how of our scientific team, is really what makes the University so special.

Equipment design

We have a long tradition of designing and manufacturing complex, state-of-the-art equipment for use in some of the largest, most exciting experiments in the world.

Whilst our scientific area of expertise has always been in radiation and particle detectors, years of experience in electronic, manufacturing and mechanical assembly allows us to work with global partners and clients interested in this high quality, high-end instrumentation.

Our prowess in equipment manufacturing helped find the Higgs and discover the nature of neutrinos. Imagine what it could do for you and your company.

Clean room

The Clean room area comprises 100m² of ISO Class 5 and 300m² of ISO Class 7 labs.

Over the last five years we have invested more than £5 million in equipment which includes: three large high-speed wire bonders, two probe-stations, several DAQ systems for module testing, one large environmental chamber, touch probe measuring machines, thermal cameras, assembly, probing and material testing capabilities. Every year we continue to upgrade and enhance our offering.

Workshops

The mechanical workshops cover an area of 350m² and our highly specialised technicians have access to a 5-axis milling machine, a large bed four-axis milling machine, two CNC lathes, one wire eroder, several manual lathes, a laser cutter and one coordinate measurement arm.

Our outreach work

You may think that CERN, the European laboratory for Particle Physics, is strictly for scientists, but there are many other professions interested in the work that happens there.

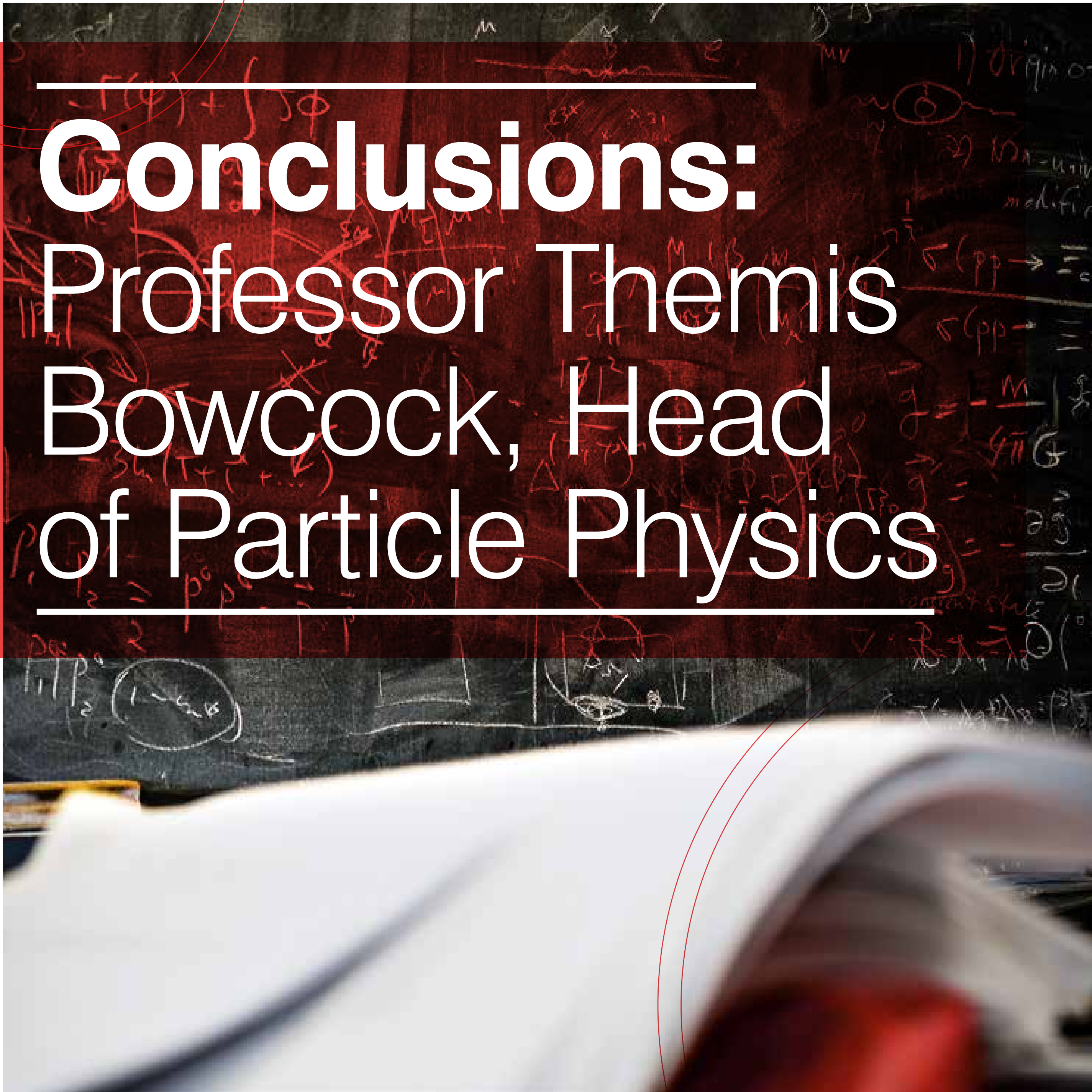
Professor Tara Shears (pictured top right) has been working with artists Evalina Domnitch and Dimitry Gelfand to understand the idea of quark gluon plasma, a perfect liquid which is formed when quarks and gluons start to condense into bigger particles like neutrons and protons.

After visiting CERN on an intense research trip, Evalina and Domnitch became interested in images that scientists were producing when trying to understand quark gluon plasma and its behaviour. With help from Tara, they want to understand these images and develop their own illustration for an exhibit at the Foundation for Art and Creative Technology (FACT), Liverpool in November 2016.

Tara believes that the intersection of science with the arts can be immensely valuable. "We (scientists) spend much of our time trying to understand and visualise what the equations that describe our universe mean, and even more of our time trying to explain our understanding to other people. Sometimes it can really help to have an alternative visualisation of a concept and this is where art comes into its own. When this works it is brilliant; an aspect of a difficult scientific concept is illustrated instantly in a way we would never think of doing. The result gives you that fleeting insight and first step to an understanding in an entirely new (and painless) way."

The collaboration between CERN, the Department of Physics and FACT is a fantastic opportunity for the University to develop something special that won't fail to impress the general public.

Conclusions: Professor Themis Bowcock, Head of Particle Physics



I hope you have enjoyed reading this short report on some of our applied projects in the department. I find it exhilarating to see the range and quality of work that is being done and I am very proud to have such energetic and exciting colleagues who are helping to define new standards of how we take ideas and turn them into highly marketable products.

The impact and effect of science in society is measured by the tangible devices or techniques that are developed. We live in a world where there are very real and immediate challenges that affect the fabric of our lives. This is why the University has invested in programmes like the Stephenson Institute for Renewable Energy and why Physics is working closely with the Department of Chemistry in the University's new Materials Innovation Factory.

Opportunity, either incremental or 'disruptive', comes through the research and insight of our staff. Our ability to attract and retain the very brightest from round the world is critical to providing the infrastructure to support our brilliant engineers and world class technical staff.

Inspiration of the next generation of young scientists, and continuous engagement with the public with the science we do, is part and parcel of attracting people to Liverpool. Our research profile is key in this motivation and is the fuel that powers our ability to deliver applications for society. Studying the Higgs particle, neutrino oscillations, anti-hydrogen or the physics of materials is what defines the environment where creative ideas are nurtured. Our biggest resource is our researchers and staff. Their unique skillsets are defined by their world-leading research. This is why you see such amazing ideas generated.

With the help of specialists such as Marco Palumbo, the University's Business Gateway department, our partners in industry and our Research Councils, we aim to continue to do the very best science we can, to innovate, and to deploy our ideas for the benefit of society and the market.

UNIVERSITY OF LIVERPOOL | Physics

Contact the Department of Physics for more information about accessing our expertise:

Dr Marco Palumbo
IPS Fellow and Commercial Manager
Department of Physics
Oliver Lodge Building
Liverpool L69 7ZE

T: +44 (0)151 794 3379
E: m.palumbo@liverpool.ac.uk

www.liverpool.ac.uk/physics