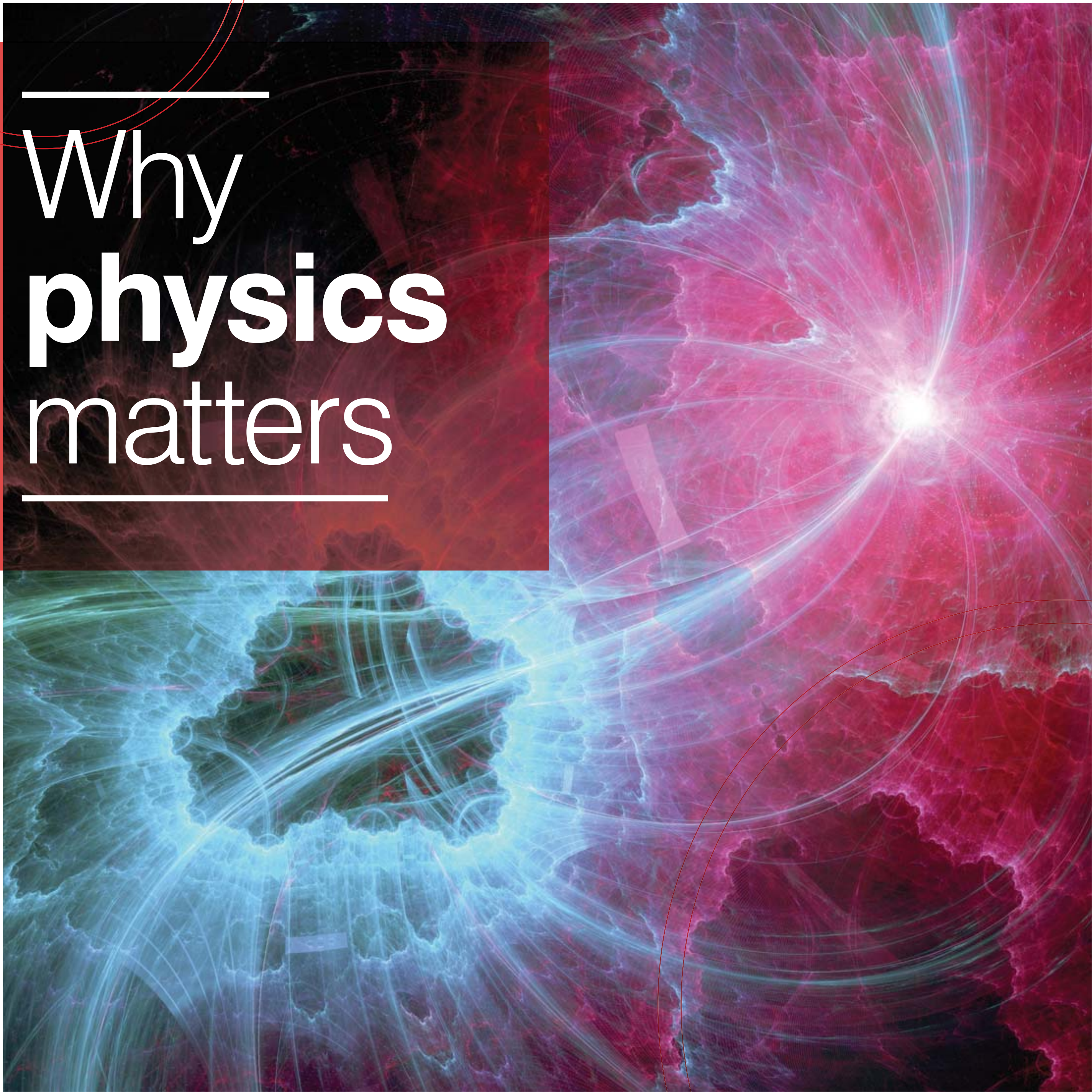
UNIVERSITY OF LIVERPOOL | PHYSICS

LIFE CHANGING
World Shaping

Powering innovation through great science

Why **physics** matters



Physics is a major driver of innovation and economic growth in the UK as well as world-wide in sectors ranging from energy, security, advanced manufacturing, data extraction and analysis to healthcare and diagnostics, finance and communication.

Recent reports* reveal that businesses for which the use of physics is critical to their existence contributed to 8.5% (i.e. £77 billion p.a.) of the UK's economic output in 2012. These same companies employ more than one million people – 4% of the total British workforce, a number comparable to both the financial and construction industries. When considering the supply chain connected to these businesses, the total contribution to the economy was raised to £222.7 billion and sustained up to 3.9 million jobs.

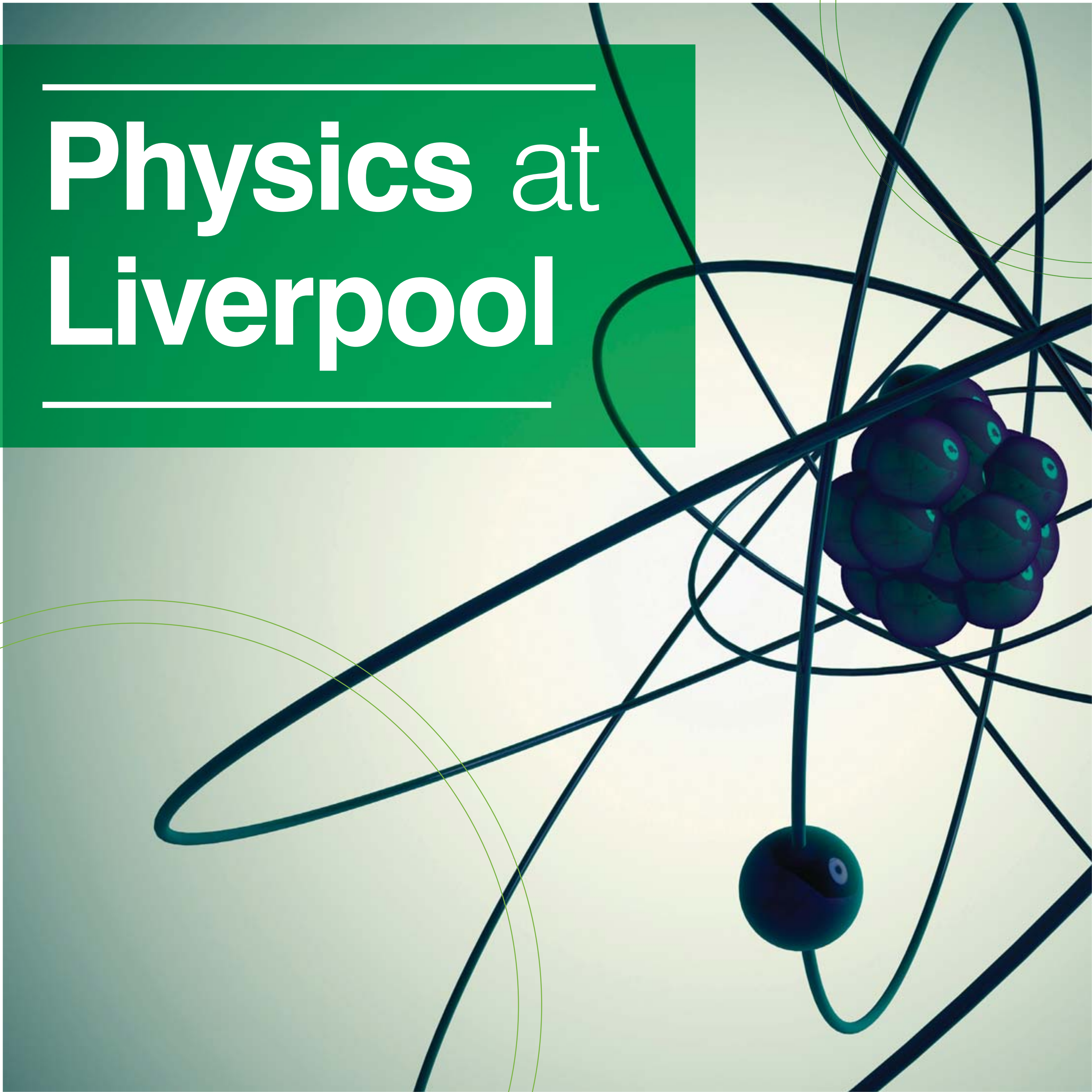
In Europe, physics-based industries employed 15.4 million people in 2010 (13% of total employment) and generated €3.8 trillion, representing over 15% of total turnover within Europe's business economy.

A number of the sectors that will power the UK's economy in the future are built on the innovative application of physics and the skills of physics-trained people.

From understanding the fundamental laws of nature to the more applied endeavours, physics has led human progress through the centuries with huge economic and social benefits, and will undoubtedly keep doing so in the future.

**Sources: The Importance of Physics to Economic Growth (2013), Institute for Physics; The importance of physics to the economies of Europe (2013), the Centre for Economics and Business Research for the European Physical Society; Office of National Statistics (ONS) Annual Business Survey and Business Register Employment Survey.*

Physics at Liverpool



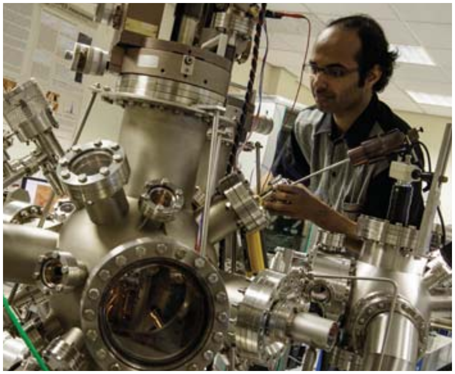
The University of Liverpool is one of the UK's leading centres for physics research, well-connected with the international community and with a history of discovery that goes back over 120 years. Our researchers in the Department of Physics have an excellent international reputation and extensive technical know-how and academic competencies.

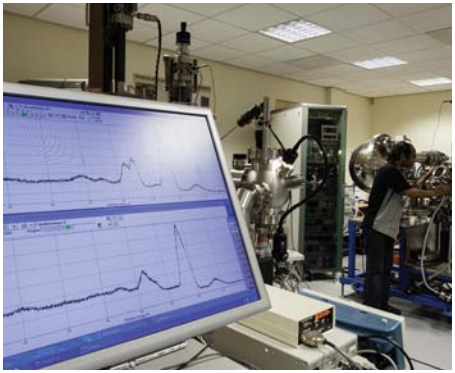
Four major research groups (Nuclear Physics, High Energy Physics, Accelerator Science and Condensed Matter Physics) form the core of the Department. In particular, the Science and Technology Facilities Council (STFC) is a major sponsor of the activities of the first three groups.

The Nuclear Physics (NP) group are world experts in high resolution gamma-ray spectrometry and gamma-ray imaging. This has come from their experimental research programme into the structure of nuclei, especially the spectroscopic studies of deformed nuclei, heavy nuclei and nuclei far from stability. The group works at a large number of leading international facilities including GSI (FAIR), in Germany and RIKEN in Japan.

The High Energy Physics (HEP) group is a lead participant in the ATLAS and LHCb experiments at CERN. The groups are part of the collaborations responsible for the Higgs discovery and the study of matter/antimatter asymmetry in the Universe. Furthermore, HEP researchers study the magnetic moment of muons at the Fermi Lab in US, neutrinos at the T2K and SNO+ experiments in Japan and US and lead the design of the Small Size Telescopes for the Cherenkov Telescope Array (CTA) project.

The Cockcroft Institute at Sci-Tech Daresbury host the Accelerator Sciences (AS) group. Through the Cockcroft Institute, Liverpool is making key contributions to the design and optimisation of new accelerator technologies. AS is contributing to the LHC and its future upgrades, to the next-generation antimatter research facilities FLAIR and ELENA and is carrying out cutting-edge research into beam diagnostics and laser applications. The Institute also has the lead role in the international research networks DITANET, oPAC and LA^{3}NET.





Key expertise and projects

The University's Department of Physics is developing a coherent strategy to maximise the impact of its core research programme within the following four economic sectors:

Healthcare

Security

Energy

Environment

Examples of current projects include:

Developing 3D imaging capable gamma-ray sensitive radiation detectors for the nuclear industry and the security sector.

Our work focuses on the development of transportable imaging capable systems for the detection of radioactive material that is illegally transported through international borders, or that represents a risk to civilians. We have developed detector systems with multi-modality image fusion capability which can be autonomously deployed to aid (for example) the decommissioning of nuclear sites while minimising risk levels for human operators.

Civil and research nuclear facilities use anti-neutrino detectors, designed and assembled in our labs, to assess nuclear reactor core activities in real-time.

This innovative technology will provide regulators with an important tool to make sure no radioactive material of military grade is removed from the core reactor as this would trigger an immediate alarm from our system. Our research will therefore contribute to the international agreements limiting nuclear arms proliferation. An improved detector that would work not only as an on/off trigger, but also as an operation and control tool for nuclear reactors is also being developed. The application of this technology in more extreme, far-field detection scenarios is currently being investigated too, attracting interest from the defence sector.

A cold-atom interferometry system that is helping our researchers in the search of dark energy has a disruptive application in the field of gravimetric measurements for the detection of radioactive materials such as uranium or plutonium.

Scanning containers at ports, train convoys or airports to detect radioactive materials is a complex operation that needs to be executed in a timely fashion. Measuring gravity fields, rather than radiations, provides security personnel with a disruptive tool as gravity fields cannot be shielded whereas radiations can be in some cases. In addition to this, we are working on utilising a specific subset of the cold atom interferometer, the gyroscope, as an inertial position sensor. This could be an alternative, to current GPS localisation systems that are often affected by electromagnetic disturbances, in some case of malicious nature.

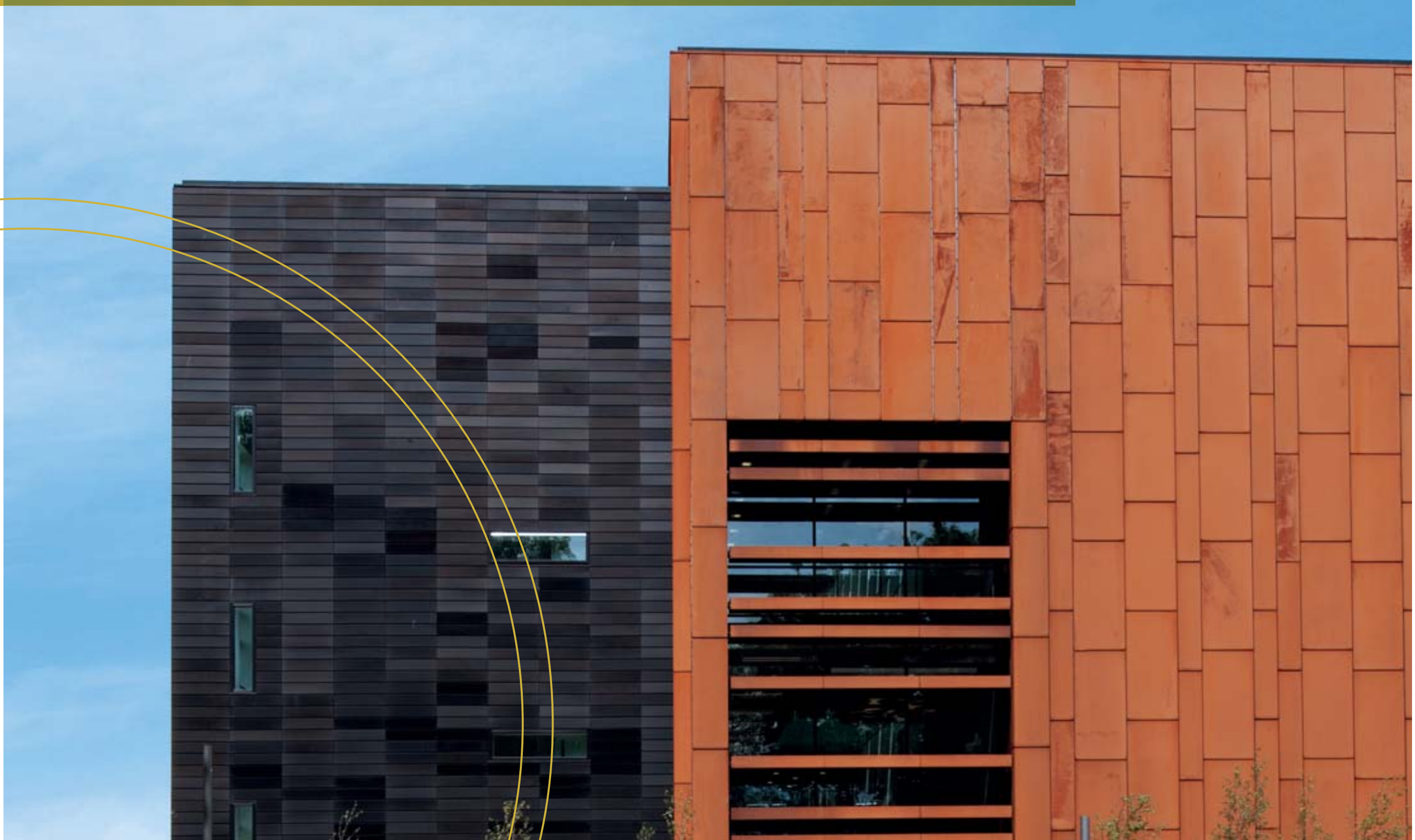
Design and fabrication of radiation-hard silicon detectors for medical imaging applications (including 3D imaging).

Liverpool's physicists have made crucial contributions to the ATLAS and the LHCb experiments at CERN. State-of-the-art particle detectors developed by the University are able to reach radiation tolerance levels beyond $2 \times 10^{16}\, n_{eq}\, cm^{-2}$ thanks to a novel P-type substrate technology. This has allowed Micron Semiconductor Ltd (MSL) to attain an excellent commercial position with their pixel and strip detectors. These devices represent 30% of MSL's business and the technology edge over competitors allows MSL to bid successfully in major contracts, both in the UK and worldwide (cit. Colin Wilburn, MSL's MD).
While our researchers are currently focusing on pushing these limits even further, we are also working on applying the first generation of radiation-hard silicon detectors in the healthcare sector. For example, we work with the Clatterbridge Cancer Centre NHS Foundation Trust on the precise monitoring of the profile and halo of the irradiation beam used in the treatment of eye cancer. Our detectors have also been used for the measurement through a liquid phantom – an increasing necessity in medical research – of the energy profile of the irradiation beam. We also collaborate with academic groups across the UK in the development of hadron therapy instrumentation. Finally, we have a dedicated program on neutron detectors, based on advanced configurations of our radiation-hard silicon detectors, for the detection of secondary, and potentially harmful, irradiation during cancer treatment.

Novel cancer detection equipment (PET/SPECT) based on germanium, CZT or CdTe sensors, including expertise in imaging analysis and data-handling algorithms.

Techniques such as detector segmentation and pulse shape analysis have been developed and have enabled our scientists to track gamma rays in the Advanced Gamma Tracking Array (AGATA). We are now working on novel Compton Camera configurations that can be used in Single Photon Emission Computed Tomography (SPECT). Such a system will be 10-100 times more efficient than current SPECT instruments, allowing quicker image acquisition with increased levels of detail. Lowering the radiation dose opens up new possibilities, such as breast-cancer screening in patients with dense tissues where x-ray screening often fails to spot tumours. The SPECT machinery we are developing is based on semiconductor technology that can be exposed to strong magnetic fields, such as those found in MRI scanners, without detriment to the measurement itself. Therefore, a combined MRI/SPECT system could enable clinicians to assess the anatomy of the body via MRI and the biological function via SPECT.

Key centres and facilities



We have access to a range of state-of-the-art facilities across campus, and are involved in a number of internationally recognised Centres and Institutes, including:

Liverpool Semiconductor Detector Centre (LSDC) and the Radiation Detector Laboratory

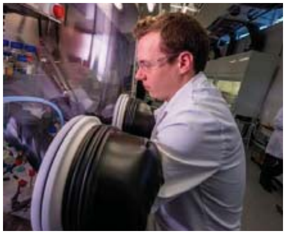
The LSDC is a large clean room complex where semiconductor sensors are assembled into complex instruments. The facility enables the construction and testing of detector systems for use in experiments at accelerator facilities across the world. Detectors have recently been made for the ATLAS and LHCb experiments at CERN and the ALPHA antihydrogen experiment. The Radiation Detector Laboratory houses the Liverpool detector characterisation and scanning system. This unique facility allows the automatic characterisation of large volume semiconductor and scintillation detector systems.

CERN (European Organization for Nuclear Research)

We use the world's largest and most complex scientific instruments to study the fundamental laws of physics and understand the real nature of the universe. A number of our researchers are leading figures at the Large Hadron Collider and contribute greatly to the scientific achievement of CERN. We are leading the ATLAS upgrade project and are working on the next generation of detectors for ATLAS and other experiments.

The Cockcroft Institute

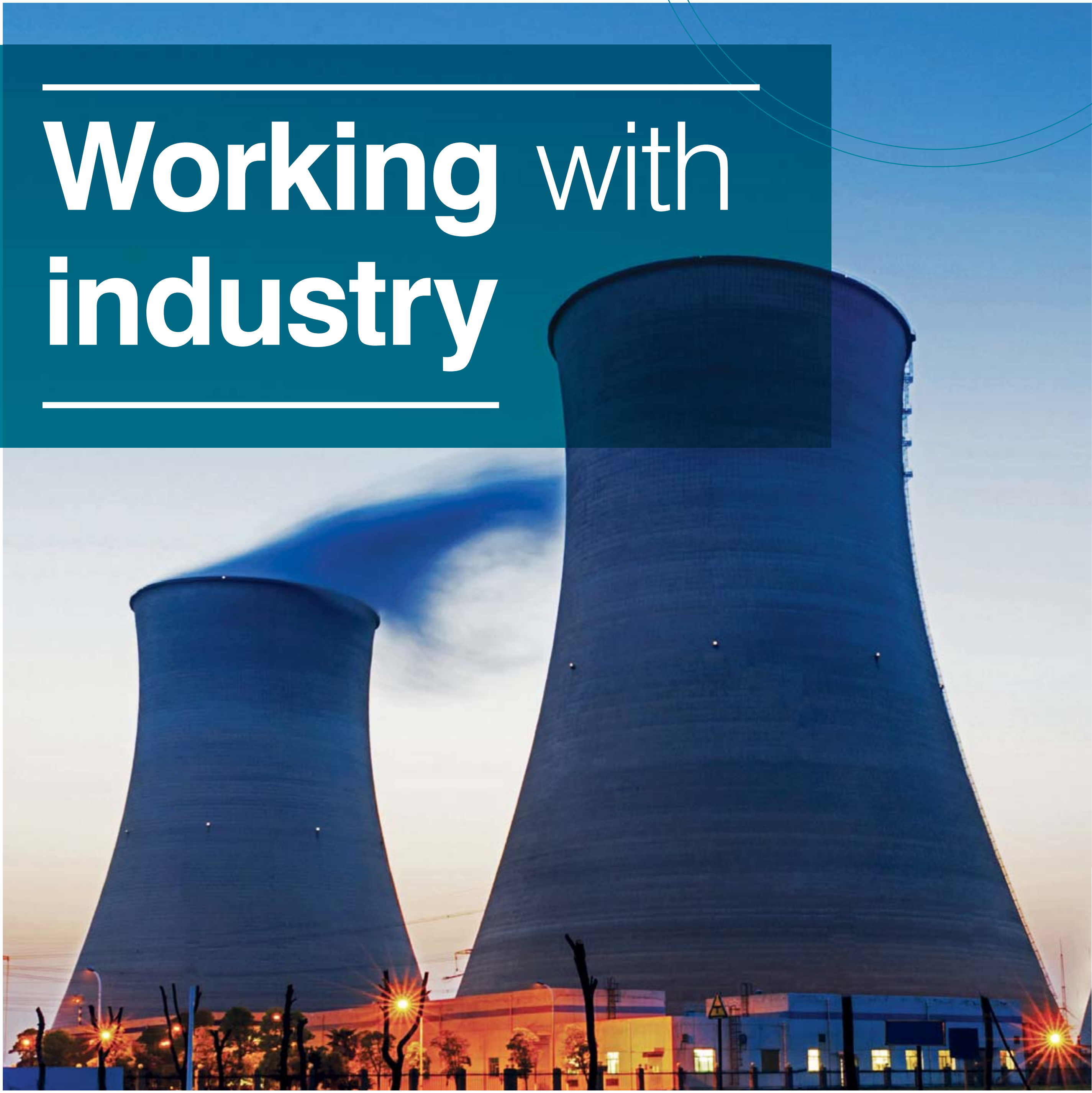
A collaboration between academia, national laboratories, industry and local economy, bringing together the best accelerator scientists, engineers, educators and industrialists. Together we conceive, design, construct and use innovative instruments of discovery at all scales and lead the UK's participation in flagship international experiments.



Stephenson Institute for Renewable Energy

Dedicated to exploring renewable, clean and sustainable energy technologies. Through its integrated approach, it can tap into a unique, interdisciplinary pool of research expertise, essential to developing truly innovative solutions that meet the world's future energy demands.

Working with industry



Exchanging knowledge and expertise are an integral part of the University and accelerate the utilisation of our research achievements, which are at the forefront of scientific development worldwide.

Partnerships

We work closely with industry, business and Government to develop applications, products, technologies, processes, techniques, policies and services. These partnerships are an important way of translating our ground-breaking research to real situations, while helping organisations to accelerate innovation and economic growth.

Collaborations include:

- Joint research grant proposals and projects
- Collaborative or contract research projects
- Knowledge Transfer Partnerships
- Consultancy (including testing services)
- Providing access to facilities and academic networks
- Postgraduate education and training at PhD and MSc level
- Continuous Professional Development

Postgraduate education and training

With our exciting international research programme and top rated teaching, we offer exciting opportunities for postgraduate study and research.

Postgraduate study

Our postgraduate taught programmes provide cutting-edge physics teaching and career enhancement in fields such as radiometrics, nuclear science & technology and medical physics.

We build considerable flexibility into our modular masters programmes, with many options available to meet your career and academic aspirations.

Postgraduate research

We are creating exciting postgraduate research opportunities across all areas of our research. These include fully funded studentships. If you are considering a PhD, we provide high quality lecture courses, excellent research training and many opportunities to pursue research at leading institutes and laboratories around the world.

Study

Research

Case
Studies

Industry partnership will improve radiation detectors

The University is working with CANBERRA, a global supplier of instrumentation for the nuclear industry, to make their products more sensitive and able to pick up lower levels of potentially harmful radiation.

In safety and security applications, radiation detection systems must be easy to use, reliable, and cost-efficient. A commonly used method of identifying and quantifying radioactive isotopes in safety, security and environmental applications is to measure the gamma-ray spectrum using a high-resolution germanium detector. This allows individual gamma-ray energies to be exactly determined and then the isotope uniquely identified and quantified.

Using a prototype manufactured by CANBERRA, our physicists will create new algorithms to reduce the time required to take these samples and increase sensitivity. The new models will also increase the accuracy of the radiation count.

Reducing the time it takes to count samples will also help security services who are checking for banned materials – for example at airports. In civil nuclear work, greater sensitivity will mean that safety checks at power stations can be even more rigorous than they already are.

This project is funded by the Science and Technology Facilities Council.

"Liverpool is recognised as a world leader in detector research with access to great facilities. Working together delivers enormous benefits to both organisations and the measurement community as a whole."

Dr James Cocks,
Vice-President for Research and Development at CANBERRA

Liverpool to develop sensors for Fukushima monitoring

Research at the University will develop ways to detect, measure and monitor nuclear radiation in the environment so that a radioactive substance beneath the ground can be located and monitored at higher resolution than previously possible. It will help the recovery and regeneration of the post-disaster Fukushima region and pave the way for improved monitoring and control of radioactivity at nuclear sites worldwide.

The team, made up of engineers, environmental scientists and physicists, aims to develop smaller and more accurate versions of detectors known as Compton-geometry sensors. The aim is to see how radioactivity moves with changes in water flow or sediment movement, and how the radiation in contaminated soil gets into the food chain through plants and animals.

The new imaging sensor has the potential to significantly increase speed and scope, allowing more detailed measurements and more flexible experiment designs. When fully developed, these will be the first cameras of this type which can be used in environments other than industrial and medical facilities.

The project is funded by the Natural Environment Research Council. Liverpool's Compton-geometry sensors programme has also been supported by the Science and Technology Facilities Council.

"The work on developing a Compton camera is very important to the Japanese efforts to monitor the impacts of the Fukushima-Daiichi nuclear disaster. Liverpool is a team we trust and we are pleased to work with."

Professor Yuichi Onda,
Faculty of Life and Environmental Sciences, University of Tsukuba, Japan

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