The Case for Irish Membership of the European Laboratory for Particle Physics – CERN

Prepared by the Institute of Physics in Ireland

June 2014

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Image credit CERN

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Summary

CERN is the pre-eminent scientific laboratory in the world. Membership would underline Ireland's commitment to science and deliver significant benefits to the nation in terms of science, education, training, jobs, and technology. Membership of CERN would:

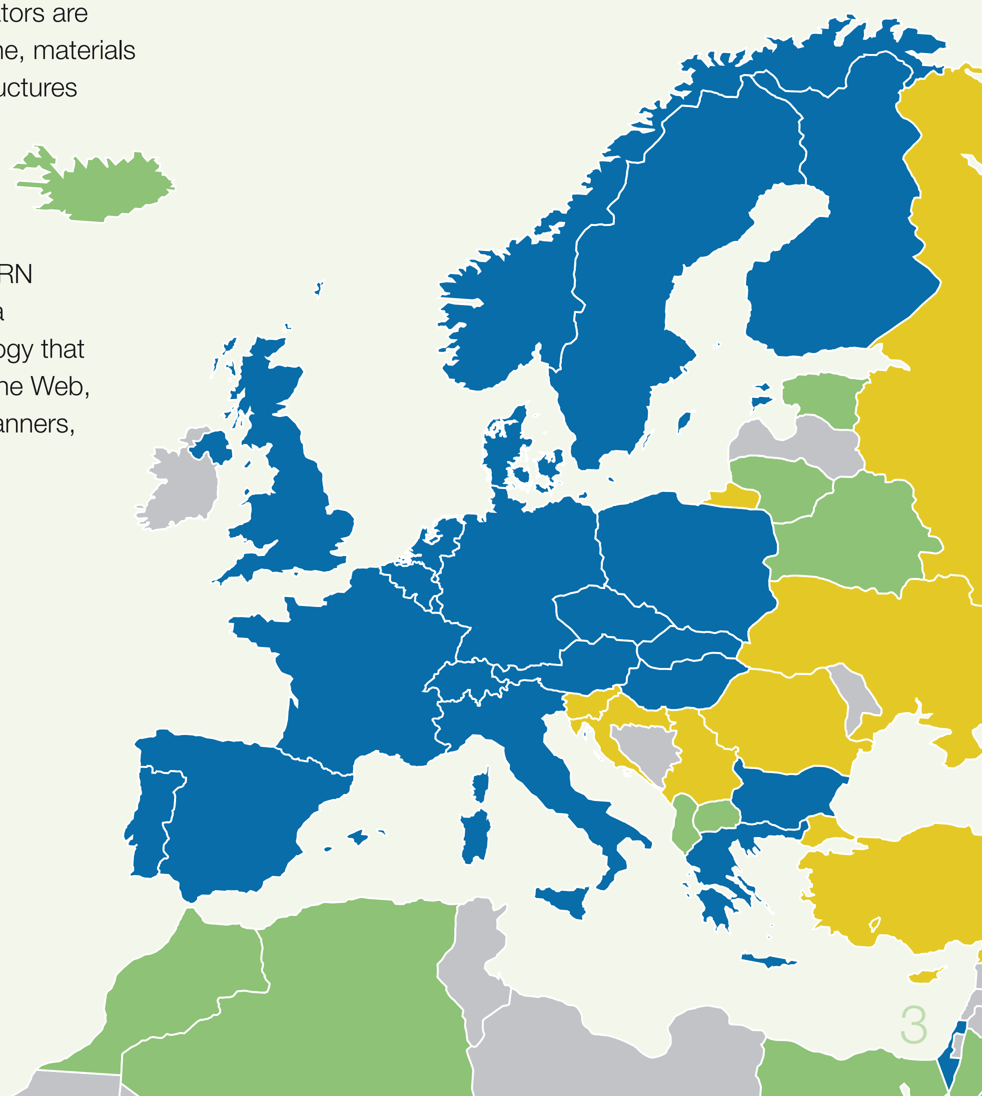
- Demonstrate Ireland's commitment to world-class science at the highest level and give a significant boost to the Irish research base.
- Align Irish science strategy closer to that of our European partners and create stronger links with worldwide science and scientists.
- Provide a direct return on investment through CERN contracts awarded to Irish companies in the high-value technology sectors.
- Expose Irish companies, scientists and engineers to new knowledge.
- In the **health** sector, allow involvement in emerging technologies for medical imaging and for hadron therapy.
- Involve the **micro-electronics**, semiconductor and sensor industry in Ireland with advanced use-cases at CERN.
- Be an opportunity for Irish computing and software manufacturers to provide and develop solutions for **Big Data** problems.
- Open exciting training opportunities for Irish students, teachers, scientists and engineers at every stage from apprenticeships to undergraduate and graduate studies and thoughout their professional careers.
- Increase the reputation of Ireland as a high-tech scientifically engaged nation.

Overview

CERN is the premier scientific laboratory in the world. Its primary mission is to understand the fundamental nature of the universe, basic research in which 14 Nobel prizes have been awarded in the last 50 years. In 2012, CERN announced the discovery of the Higgs boson, the proponents of which received the 2013 Nobel prize for physics.

The technology developed through this research has given us accelerators and new detectors, as well as making major contributions to micro-electronics and computing. Accelerators are important for radiotherapy in medicine, materials engineering, and imaging atomic structures in biology and chemistry. Detectors have applications in security, non-destructive testing, and medical imaging. Micro-electronics and computing developments at CERN push the boundaries of ultrafast data acquisition and processing. Technology that we take for granted today, such as the Web, touch-screens, and medical PET scanners, all have their genesis in fundamental research at CERN.

CERN has an extensive programme of education and training for students, teachers, engineers, scientists and the general public. It is a flagship for science (e.g. featuring in cover stories in Time magazine, Newsweek, and the Economist), an attractor for students, an engine for R&D, and an example of international collaboration at its finest. With an annual budget of about €850 million, it provides a multi-billion euro research infrastructure, unique in the world, for the benefit of the participating nations.



- CERN Member States
- Associate Members, Observers, or candidates for full or associate membership
- Countries with co-operation agreements with CERN

Science

Experiments at CERN seek to answer deep questions about the world we live in. What are the building blocks of matter? What symmetries and basic laws does nature follow? How does anti-matter behave and why is there so little of it in the universe? What is dark matter, the dominant matter constituent in the universe?

Using a methodology first developed by Ernest Walton, Ireland's only Nobel prize-winner in physics, CERN accelerates matter to almost the speed of light and smashes it together, recreating energy densities of the early universe. Detectors surround the collision region and take three-dimensional 'photographs' that are analysed using sophisticated computer algorithms.

Ireland has a community of about 50 theoretical and experimental particle physicists based at institutions including DIAS, DCU, NUI Galway, NUI Maynooth, TCD, UCC, UCD. Additional Irish scientists have contributed to data management and the computing infrastructure (the Grid). With membership, these numbers would substantially increase, allowing access for many physicists, computer scientists, engineers, biologists and medical specialists.

The Large Hadron Collider

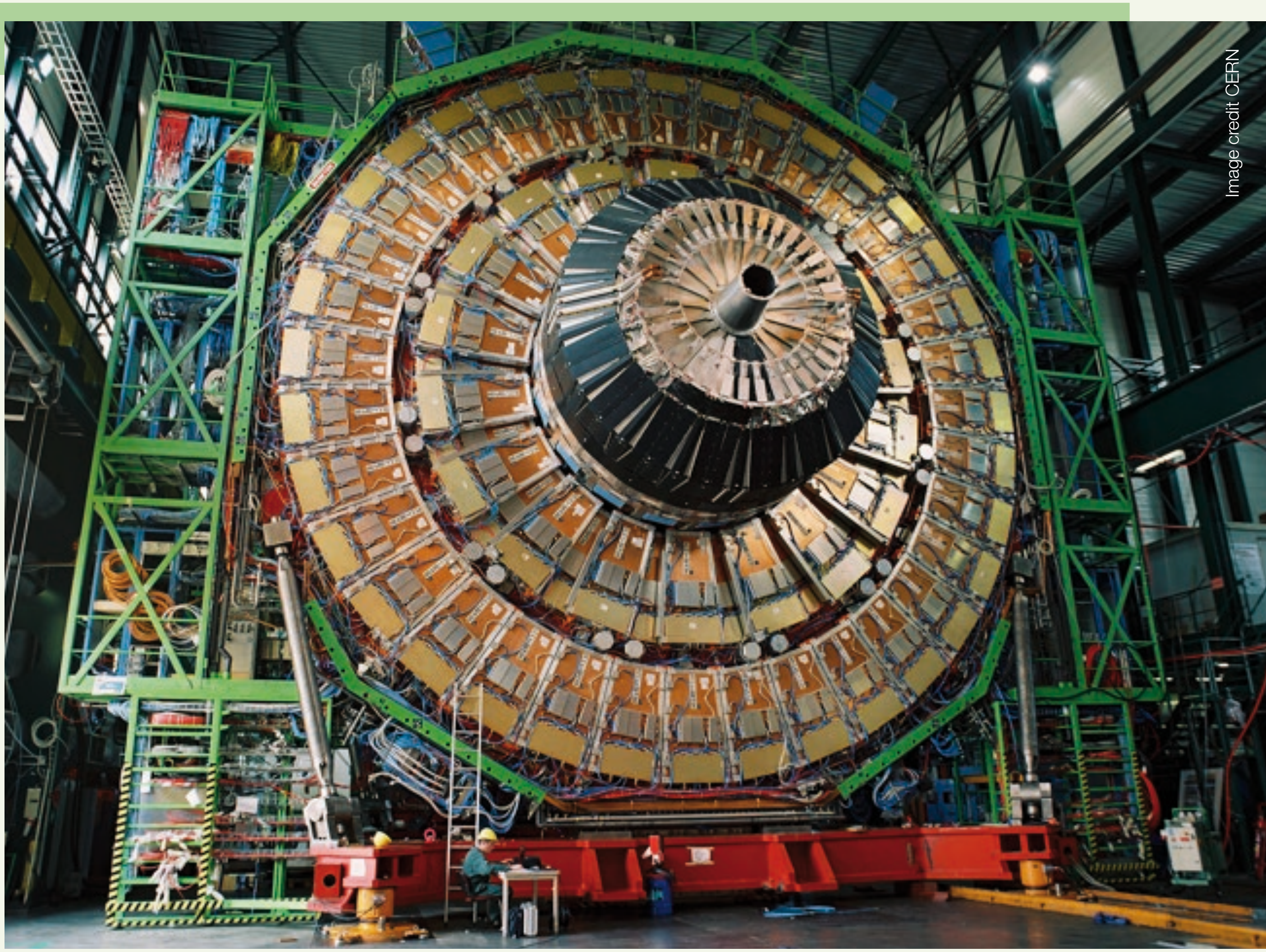
CERN constructed and operates the largest and most powerful particle accelerator in the world, the Large Hadron Collider (LHC), which is 27km in circumference. Surrounding the collision points, four detectors, each as large as a cathedral but capable of resolving particle positions to one tenth the width of a human hair, are operated by international collaborations consisting of thousands of students, scientists and engineers. Like gigantic microscopes, these detectors record precisely the particle collisions for subsequent physics analysis.

Within the first few years of data taking, the LHC experiments have revealed a cornerstone in our understanding of the world, by discovering a new fundamental particle with unique properties, the so-called Higgs boson. This discovery in 2012 was followed by the award of the 2013 Nobel prize in physics to scientists who had hypothesised the particle, 50 years previously. Scientists from University College Dublin, working on the CMS and LHCb experiments, played key roles by developing the real-time filtering algorithms that found the Higgs boson and writing the first papers on its properties.

The Antiproton Decelerator

CERN's Antiproton Decelerator (AD) is an 'antimatter factory' – the only source of low energy antiprotons in the world. It serves atomic physics experiments that measure the properties of antimatter to high precision to answer the outstanding question in modern physics of why matter won out over antimatter after the Big Bang.

Several experiments use the AD to make and trap the simplest pure antimatter atom: antihydrogen, consisting of a negative antiproton and a positive antielectron. Investigations of the mass, charge and atomic spectrum are searching for tiny differences with matter that would mean a rethinking of the foundations of physics. The intriguing possibility of antimatter falling 'up' due to gravity is also being explored. Several Irish physicists working for non-Irish universities are involved with AD projects.



Part of the CMS detector on the LHC accelerator at CERN.

ISOLDE

The ISOLDE Facility is a world-leading laboratory for the production and study of radioactive nuclei. It uses radioisotopes as probes to produce better semiconductor materials by studying doping, diffusion, and radiation damage, and to investigate materials for use in spintronics. It is also used to investigate biological systems (e.g. heavy-metal toxicity, water transport in plants) and it produces radioisotopes for medical diagnostics and therapy at University Hospital Geneva. Scientists from Dublin City University use ISOLDE to investigate defects in semiconductors and to characterise novel materials.

Technology

Answering fundamental scientific questions requires advanced technologies. CERN works closely with industry to develop solutions that often define the cutting edge of what is feasible and anticipate technology that will be commonplace in the future.

Linear accelerator at St. Luke's hospital in Dublin.

This presents an opportunity for companies both in acquiring new knowledge and getting ahead in the development cycle. Historical examples are provided by individuals and companies that developed the protocols and browsers for the World-Wide-Web and the electronics for the first touch-screen devices. More recently, companies that developed the high-powered magnets for the LHC, which when first proposed were beyond the technology of the time, are now market leaders in providing magnets for NMR spectrometers and MRI machines in hospitals. Currently, there are four areas where CERN pushes technology boundaries: accelerators, sensors, micro-electronics and computing. Each of these is of significant economic importance to Ireland.

Accelerator Technology

Only 1% of high-energy accelerators worldwide are in research institutes. About half are used in medicine, either in radiation therapy or in preparing radioisotopes for imaging. The remainder are found in industry, with diverse uses from ion implantation in semiconductor manufacture to food preservation. Research at CERN continually improves accelerator technology. Advances in electronics, magnet, and vacuum systems lead to smaller, cheaper and better accelerators. There are 29 linear accelerators in Ireland, all in hospitals treating cancer, and one circular accelerator at the Blackrock Clinic, Dublin that provides radioisotopes to all hospitals in Ireland for PET scans.

Irish ambassador, Patricia O'Brien, is shown a sensor for the LHC, part of which was developed at the Tyndall Institute in Cork.

An emerging technology for medicine is hadron therapy, in which protons and atomic nuclei are fired into the body to remove tumours. Unlike x-rays used in conventional treatment, hadron therapy has little effect on the healthy tissue surrounding the tumour. It is the preferred method for treating certain cancers in children. CERN is a leading partner in the development of hadron therapy for Europe.

Sensor Technology

The detectors and detection techniques developed at CERN have wide applications in medicine, industry and security. Particle physics technology is at the forefront of detecting radiation and charged particles with diverse detectors: scintillating fibre, single photon pixel, gas avalanche, multi-wire proportional, silicon microstrip, monolithic active pixel, CCDs, avalanche photo-diode, etc.

In medicine, detectors are used for dosimetry (monitoring patient and health worker exposure to radiation) and imaging (PET scans, large area cardiac imaging, X-rays). As detector technology becomes more sensitive, improved temporal and spatial resolution will be achieved. This results in a more precise image, better and more frequent patient monitoring, and a lower exposure to radiation. The Medipix project at CERN, initiated by Irish physicist Prof. Val O'Shea working at the University of Glasgow, allows single photon detection with a spatial resolution of 50μm, as well as having the ability to determine the energy (colour) of the photon.

Technology continued

Case Study:

Prof. Val O'Shea graduated from UCC with a BE in 1983. He received a Ph.D. from the University of Glasgow where he was responsible for the design and construction of detector systems for particle physics experiments at ZEUS (Hamburg), ALEPH and ATLAS (CERN). He initiated the Medipix collaboration to spinoff this detector technology for medical applications and industrial imaging. He leads the Glasgow detector development effort into novel detection techniques using semiconductor sensors, such as 3D detectors and active pixel sensors. He is a lead partner in six EC awards totalling over €14 million. His current research uses particle physics detector technologies to develop novel approaches for radio-pharmaceutical production and advanced techniques for neutron screening for security applications.

"The education I received in Ireland was first class and prepared me well to take advantage of the cutting-edge technologies and world class facilities available at CERN to inspire the development of new generations of sensors for a wide range of applications."

Prof. Val O'Shea, who attended CBC Cork, holding a copy of the school magazine, photographed in front of part of the ATLAS detector on the LHC.

Such novel techniques give rise to industrial applications that were previously not possible due to limitations in available technology. Examples abound in food scanning, fault detection, non-destructive testing, beam diagnostics, synchrotron imaging, measuring turbulence in long distance pipelines, etc. Security applications range from X-ray imaging of cargo, through passenger screening at airports, to the detection of explosives and fissile material.

Micro-electronics

Sensors at the LHC stream data at about 10 Terabytes(TB)/second and require massive real-time processing. This is beyond the scope of off-the-shelf components. Dedicated micro-electronics have been developed for rapid, highly parallel processing, which send data through optical links to computer clusters.

Multi-channel application specific integrated circuits (ASICs) developed at CERN in the late 1980s are now used in flat-panel X-ray devices to image patients in medical, or cargo in security, applications. Semiconductor chips (developed in CMOS technology) for the LHC are widely used in X-ray diffraction and non-destructive testing. In biochemistry, micro-electronics from the LHC are used for time-of-flight spectroscopy to analyse peptides and other large biological molecules.

Computing

Particle physics has always been a major consumer of computing resources and the challenges it has to overcome stimulate development. The most visible impact is the World-Wide-Web developed at CERN in 1989, born from the needs of particle physicists, the presence of smart educated people, and the 'can-do' problem-solving mentality at the lab. Quite apart from the social revolution or the wealth that the Web has created, its original goal, the ability to share and retrieve information quickly, was valued in 2011 to be $780 billion.[1]

The LHC provides a different challenge: big data. 100 Petabytes are stored at CERN, about 1/10,000th of all the data stored in the world, and physicists analyse 1% of this every day, using 'farms' of computers, distributed throughout the world. Grid computing is the name given to the infrastructure that facilitates this. 17 university and research institutes throughout Ireland contributed to the development of the Grid through the Grid Ireland project and had links to the European DataGrid, CrossGrid and EGEE projects.

The LHC is the principal test-bed for Grid technology, which is the fore-runner of Cloud Computing. John Womersley, head of the Science & Technology Facilities Council (STFC) in the UK, estimated that the stimulus provided by particle physics had a financial impact of $40 billion.[2]

Economics

Investment in science is a critical factor in bringing about a transformation in the Irish economy. Physics underpins all sciences; physics based industry employs over 86,000 people and has a value to the Irish economy of €12.7 billion annually[3].

As noted in the NSF comparative study of international R&D[4], high-income countries, which tend to emphasise production of high-technology goods and services, devote larger shares of their GDP to R&D. Ireland's R&D expenditure as a percentage of GDP is shown in Fig. 1 compared to other countries. From a low of 0.7% in 1981, Ireland has increased its relative spend in support of a 'knowledge-based' economy. In 2012 a historical high of 1.7% of GDP was achieved, although this is still below the EU average. The highest spend on R&D in 2012 was in Israel and South Korea where over 4% of GDP was committed.

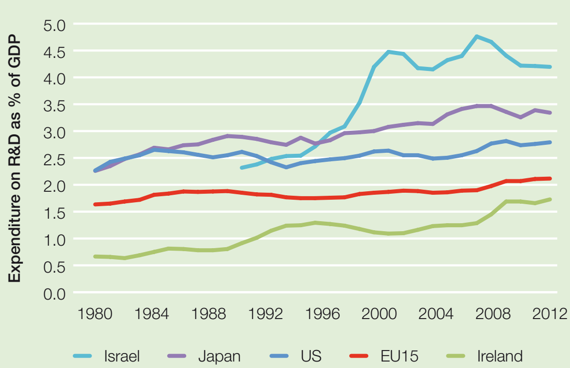


Fig 1: Gross domestic expenditure on R&D as a percentage of GDP per year for various countries.

The scientific impact of a nation is a measure of its global scientific importance and is a factor in company relocation, in investment, and in attracting students and expertise from abroad. One attempt at quantifying this in 2004, by a former scientific advisor to the UK government, plotted the citation intensity against the wealth intensity of a country[5] (defined as GDP per person). The results (see Fig. 2) show a correlation in scientific impact with increased wealth. Ireland, at that point, was notably below the curve. Over the last 8 years however, a combination of increased investment and a reduction in Ireland's wealth intensity now sees Ireland performing similarly to other EU nations. Of the countries above the curve, Switzerland, Scandinavia, and Israel have significantly elevated levels of scientific funding.

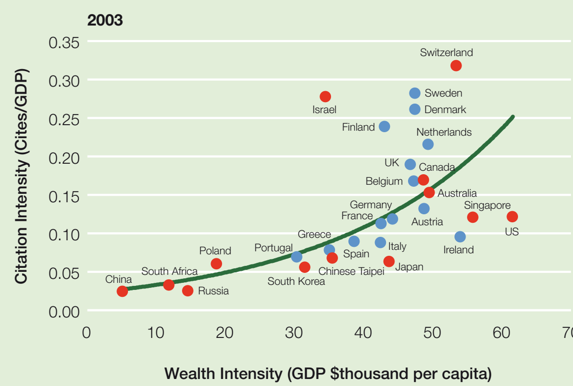


Fig 2: Citation Intensity as a function of Wealth Intensity for various countries.

Data from: SCImago Journal & Country Rank
http://www.scimagojr.com
OECD http://www.oecd.org/statistics

It is not surprising that spending more of a nation's GDP on science gives a higher scientific profile. The justification for maintaining a high level of science funding lies in the evidence shown in Fig. 3 which shows the converse to be true: the better the scientific health of a nation, the better its economy.

Fig. 3 shows the percentage increase in GDP in 2012 as a function of the money spent on research four years earlier, for EU countries, Israel and the US[6]. A correlation is observed between research spending and the increase in a country's wealth, showing that the countries that are best weathering the economic downtown are those that previously invested strongest in research. The data also suggests that spending more on research than your competitors gives a country an economic advantage.

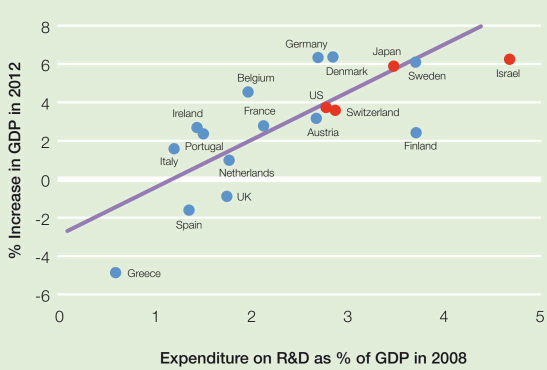


Fig 3: Percentage increase in GDP in 2012 as a function of R&D expenditure in 2008 for various countries.

Much of the high-tech industry in Ireland is not home-grown in contrast to countries like US, South Korea and Japan. This is a challenge for the future, if and when foreign companies relocate. Consequently, Ireland is committed to improving STEM education and developing indigenous industry. The 'knowledge' in the 'knowledge economy' is key. Joining CERN would create new knowledge for Ireland and act as a stimulant to the economy.

The importance of basic research

Basic research stems from curiosity and is designed to increase knowledge with the understanding that this will one day benefit humans. Applied research focuses on solving particular shorter term questions, often with a direct industrial or financial incentive. Both are needed in a healthy scientific ecosystem. The advantage of applied research is in better products leading to more manufacturing and a skilled work force in the area of the application. It produces incremental improvements using existing knowledge. Basic research on the other hand, results in disruptive technology that can completely change the status-quo and render existing technology redundant. A country must be ready to react to major and unexpected break-throughs. History shows most game-changing technologies arise out of curiosity: electricity, radio waves, the laser, the transistor, the computer, nuclear power, X-rays, PET scanners, etc. In contrast, applied research has given us mobile phones, compact disk players, the internet, and the World-Wide-Web, building upon the technology that basic science provided.

A much cited study by Mansfield[8] claimed to show that public investment in basic science generated a return of 28% from a sample of 75 major American firms in seven manufacturing industries. The dependence of applied research on fundamental research that precedes it is well illustrated by a NSF study[9] that found that 73% of the papers cited in industrial patents were published "public science", and overwhelmingly basic research papers.

CERN is a facilitator between pure and applied research. The fundamental understanding of the universe is probably the purest science one can think

Economics continued

> *Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. Today, it is truer than ever that basic research is the pacemaker of technological progress. A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill… Economic growth and the development of new products in industry are dependent upon rich resources of basic knowledge… Knowledge of the methods and techniques of basic research is essential to the training and full development of skilled research.*
>
> **Vannevar Bush**, US scientific policy advisor.[7]

of but the technology needed for this investigation creates innovation – better superconductivity, better magnets, faster electronic circuits, bigger computing, new sensors. Having Irish students, engineers, scientists and companies embedded in this process enables them to be the first in the world to hear about advances, to be the first experts on new technologies, and to be the first people to innovate, patent, and spin this off into their own companies and products. Kernels of experts interacting and 'brain-storming' bring about advances. This is how centres of excellence grew up in Silicon Valley and around MIT. CERN is such a centre on our doorstep, which including visitors, provides a community of about 15,000 scientific and engineering problem-solving interdisciplinary experts. Tapping into such a resource is a priority for most nations who prioritise science and technology and is an opportunity for Ireland to exploit.

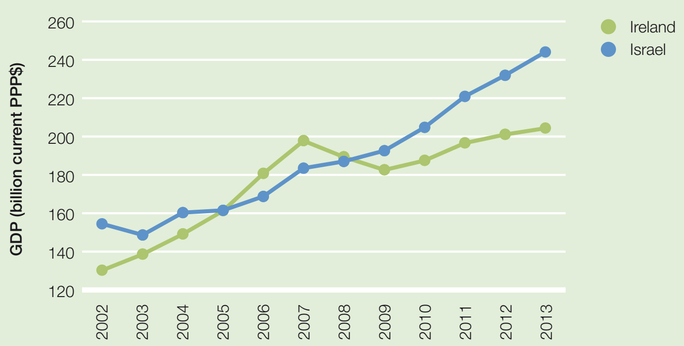
CERN patents technology mainly to record its priority, and licenses it inexpensively to companies it has worked with. CERN developed and gave for free the technology for PET scans in medicine, touch-screen devices, and the World-Wide-Web.

It is noteworthy that the success of the Web was due to its rapid adoption, particularly in universities in the US, which in turn was a result of the fact that it was free, and that these principles of open access for all are enshrined in the non-proprietary standards defined by the World-Wide-Web consortium. A recent study for STFC claims a ten-fold return on the investment at the Tevatron Collider in the US, and includes the effect on the economy of training Ph.D. students as well as advances in magnet and computing technology.[10] Three similar studies[11] have been performed at CERN. These concentrate on the payback for companies with CERN contracts and are discussed later in this document.

> *Knowledge transfers (at CERN) are high and this contributes to the value of our human capital which is identified by a large growth literature as crucial to economic growth and wealth creation.*
>
> **Peter Dunne** Ph.D., Economist, Central Bank of Ireland.

Case Study: Israel

There are similarities between the economies of Ireland and Israel. Both are small countries with populations of 4.5 and 8 million, respectively. Both populations have increased by about 20% over the last ten years. Both have well educated work forces and a strong diaspora. Both are high-tech economies and depend on knowledge as the engine for growth. Their GDPs are similar. Ireland's rate of increase in the early 2000s exceeded Israel's and Ireland's GDP was higher in 2006-8.[6]



GDP per year for Ireland and Israel.

However Israel's rate of increase is now stronger and their GDP today is 25% above that of Ireland. There are many factors for this performance. Most notable is the strong emphasis given to education and research. For the last ten years, Israel has spent over 4% of its GDP on research, the largest of any country[13].

> *(Israel joining CERN) reflects decades in which many Israeli scientists, technicians and Israeli industry have contributed significantly to the European scientific effort at CERN.*
>
> **Eliezer Rabinovici**, Chair of the Israeli Academy of Science's National Committee.

Israel has seen CERN as strategically important to its economy for exposure of its companies to European markets, for technology transfer, and for education. Since 1991 it has had 'Observer' status at CERN and through a series of negotiated agreements it made bids for CERN contracts. Payments to CERN in this period were mainly 'in-kind'; the Israeli government paid Israeli firms to produce products. This is an important model for Ireland to consider as it ensures that all the money 'given' to CERN is spent in Ireland supporting R&D and jobs. The Israeli return on contracts at CERN between 2000 and 2011 varied between 90 and 130%.[14] In October 2011, Israel became a candidate for membership and requested a 'fast-track' to full membership that occurred on 6th January 2014.

Education

Prof. Brian Cox meets students at UCD after a public talk about particle physics.

Particle physics, along with astrophysics, is a proven student attractor to science, as both deal with the 'big questions' about our place in the universe. Surveys[15] of 673 physics undergraduates in eight universities in the UK showed 95% were attracted to study science because of particle physics. Ireland for CERN, a campaign group of third level students performed a similar survey of 379 Irish secondary school students.[16] Of those interested in physics and intending to study science at third level, over 83% cited particle physics as an influence. Particle physics is popular in the Leaving Certificate physics examination. In the 2013 exam, 98% of students chose to answer a question about particle accelerators rather than about a moving coil galvanometer.

The increased uptake of science in university is encouraging and reflects on a national policy to promote STEM subjects. First preferences CAOs for science at UCD were up 20% in 2014. However, the increase into physics is even greater at 30%.[17] This sea-change in young people's attitudes, due in no small part to ambassadors for the subject like particle physicist Prof. Brian Cox, is a result of capturing young people's imagination. Credit is due to the messengers for breaking down barriers, but the real star is the science itself. In the survey of school students, more than half said they were inspired by the discovery of the Higgs boson.

Participants at the 2012 CERN Summer School photographed in front of the Globe at CERN.

The particle physics community in Ireland, though small, has played an important role in making science accessible to young people. Among the events targeted at young people are yearly master-classes, held at NUI Maynooth, TCD and UCD where school students analyse LHC data and discuss their results with their peers in Europe and the US. Tours and lectures for schools were organised as part of the recent Mission Higgs exhibition in Dublin. School tours of CERN have been arranged and documentaries about CERN have aired on RTÉ TV specifically for a young audience (Scope). The Ireland for CERN survey found that 50% of the participants had attended some particle physics event in Ireland.

Irish scientific policy recognises the importance of particle physics in promoting STEM via its presence on the Leaving Certificate syllabus and its invitation to the Director General of CERN to give a keynote address at the ESOF conference in Dublin. It can augment this by joining CERN and providing students with the opportunities to participate at CERN, allow engineers and teachers to receive training there and celebrate Irish people taking leadership positions at CERN. In the survey of Irish school children, half were unaware that Ireland was not a member of CERN and that they were at a competitive disadvantage, compared to their European colleagues, by dint of their passport. However, they were almost unanimous about one thing: 97% of those surveyed thought Ireland should join CERN.

Education continued

Education opportunities at CERN

Summer student programme: 250 students from around the world are embedded in one of the scientific collaborations, so they experience research first-hand. Some publish papers on their results. Irish students are not entitled to participate. However, since 2003, through the representation of Irish academics, one Irish student each year has been able to attend. Student living costs are met by Irish universities or from charitable donations that allow students from all over the world, particularly developing nations, to participate.

Teacher programmes: These enable teachers to keep up with changes in the field, to compare experiences with their peers in other countries and adopt international best practice. Unlike most of the secondary school curriculum in Ireland, particle physics knowledge changes frequently due to discoveries. Text-books are often behind the curve so training is important. Some of these courses are run in conjunction with national departments of education. It also runs a High School Physics Teacher Programme that has occasionally been attended by Irish teachers, courtesy of the Galway Science and Technology Forum who are supported by local scientific companies.

The CERN visit service provides guides to any schools or groups. Several Irish schools have availed of this including Holy Child Killiney, Ursuline Sligo, St. Angela's Cork, Arklow Community, Drogheda Grammar, Coláiste Rís, St. Mary's Rathmines, St. Mary's Mallow, as well as student societies at UCC, UCD, St. Patrick's College of Education, TCD, UL, NUI Maynooth.

The CERN website provides appropriately targeted information with links to videos, lectures and seminars. In the survey of Irish secondary school children, almost 40% said they had visited this site in order to understand more about particle physics.

> *When I was young, doing physics meant I was a 'nerd' – today it appears to be 'cool'.*
>
> Cambridge particle physicist, **Prof. Ben Allanach**, at a recent public talk at TCD.

> *Participating in the CERN studentship in 2004 gave me my first taste of what it meant to be a scientist, what it was like to work as part of an international research team, and gave me invaluable experience as an undergraduate student in attending lectures from Nobel laureates and world-renowned researchers. It was my first time working abroad on my own and as the only native English speaker of the COMPASS research team, honing my communication skills was incredibly important. Working for those summer months in CERN has given me a wealth of experience to draw from and has allowed me to maintain friendships and working relationships with research scientists from all over the globe.*
>
> Television & radio presenter, mathematics & physics teacher, and former Rose of Tralee **Aoibhinn Ní Shuilleabháin** attended the CERN Summer School in 2004. She is currently completing a Ph.D. with the School of Education at TCD.

Training

The bar to careers in high-technology is high as it requires firstly, a good grounding in STEM and secondly, specialist training. In a country dependent on high-tech industries, access to high-level training, and exposure to new ideas, is imperative. CERN has schemes in which universities and businesses can participate. The most valuable training occurs on the job with experts supervising, and is best obtained through apprenticeships and collaborating on projects of mutual interest.

CERN allows universities participating in its projects to send student engineers and scientists to the laboratory to be trained. The students work as part of an international team of experts and are trained in the classic elements: preparing apparatus, data-taking, data analysis, hypothesis testing, critical thinking, project management, statistical techniques, communication, report writing, presentations. What distinguishes the experience at CERN from that obtained in a university or national centre, is the level of expertise available, the scale of the projects, the interdisciplinary nature of the work and exposure to tools and techniques at the technological frontier. Also, as scientific work becomes increasingly collaborative and international, there is no experience quite like learning how to work and communicate effectively in a thoroughly international atmosphere. Eight scientists, who have received Irish Ph.D.s since 2004, spent between one and two years working at CERN during their studies. The calibre of this training and their abilities ensured that each now has a scientific research position. One of them (holding a non-Irish passport) now works for CERN.

Case Study:

In June 2012, Susan Reilly applied for the position of Scientific Information Officer at CERN, to manage the SCOAP3 open access consortium. She could not be interviewed because she is an Irish citizen and Ireland is not a member of CERN.

"With a background in international membership organisation and library related projects the position was a natural progression for me. Salvatore Mele, head of Open Access at CERN, personally contacted me to express his regrets that I could not be interviewed for the position as I was uniquely qualified and deserving of consideration by the interview panel. I missed out on the opportunity to work on a project that went on to be the first of its kind in the world and that set an example for others to follow. This is what CERN does and, by not being a member, Ireland is denying its graduates the opportunity to develop their international leadership skills through working on prestigious and innovative global projects."

Through its Graduate Engineering Training scheme, CERN offers training and work experience in engineering fields. Fellowships are offered to talented engineers from member states at both graduate

Case Study:

James Casey, a student at TCD, had a strong interest in the early Internet and was introduced to the World Wide Web in 1993. As he was born in Northern Ireland, he was able to go to CERN as a summer student in 1994, where he sat in an office two doors down from Tim Berners-Lee. Today he works on cloud computing infrastructure with Seattle-based start-up CHEF.

"It was an incredible time of learning. I and some of the most innovative people in computing were brainstorming ideas. It was a culture of idea sharing, a culture of discussion, of creation and innovation. There was a feeling that through collaboration there was nothing we couldn't do. What was brainstormed over coffee five years later were ideas on which multi-million dollar Internet companies were built."

and postgraduate level. There are also partnership arrangements with institutes in member states that allow universities to send engineers for one-year placements at CERN. Similarly, fellows employed by CERN can spend some of their contract at member-state institutes.

CERN has recently introduced a pilot programme for technicians giving them the opportunity to work in a diversity of fields including electronics, computing, safety, vacuum, cooling and ventilation, electricity, radioprotection, survey engineering, and building works.

Formal training courses are provided by CERN through a series of technical and academic training lectures. All lectures are archived and available through the CERN website, which has become a comprehensive repository of high-level training resources for physics and engineering. CERN also organises summer schools each year in locations throughout the world, in the fields of particle physics, accelerator engineering, and computer science.

> *"The skills learned in particle physics train people especially well to be problem solvers. In a world that's constantly changing, being able to solve tough quantitative problems and never assuming anything is impossible really sets particle physicists apart."*
>
> **Michelangelo D'Agostino**, former particle physicist and digital analyst for the Obama presidential campaign, who now works at the credit-card-payment-processing company Braintree.

Contracts

CERN has an annual budget of over €850 million (in 2012) and spends in the region of €217 million annually on contracts for supplies.[14] While some of this budget is spent on the development of new technologies and new facilities, CERN's requirements are not all high tech. For example, CERN is a large site with over 15,000 people working there and so it has civil engineering requirements to maintain and develop infrastructure. It also has vast amounts of data to manage and needs computing equipment and support to achieve this.

Some of the membership fee is returned to each country as CERN contracts are awarded preferentially to companies residing in member states. CERN aims to have a ratio of 0.91 between the percentage of expenditure in an individual member state and that member state's percentage contribution to the CERN budget. For countries falling below the target, a form of weighting is used to enhance bids from such countries. It is significant also, that a member country's size is not necessarily the most important factor in obtaining business contracts. For example, Hungary, with a ratio of 1.31, recently won a significant contact to supply computing and data hosting services.

Contracts for Ireland

A small number of Irish companies already supply CERN since non-member states can receive contracts where member states lack specific expertise. Membership would strengthen these relationships, which are vulnerable to any competition, besides allowing many more Irish companies to receive contracts. It would also prevent situations that arose in the past where multinational companies, with headquarters in Ireland, were unable to bid for large contracts. This is of particular importance when Ireland markets itself as a gateway economy between Europe and the USA.

With membership, Irish companies and multinationals resident in Ireland could bid on an equal footing with other countries for all CERN contracts. Many contracts are in areas that map onto well-established high-tech industry in Ireland, in particular, computing, software engineering, electronics and devices. Some of the world's most important ICT companies have a significant presence in Ireland, including Google, IBM, Intel, HP and Microsoft, while the country has developed considerable expertise in electronics, vacuum technology, detectors and imaging. In these areas there are businesses ranging from SMEs such as ProVac in Wexford, SensL Technologies and Firecomms in Cork, through to multinationals such as Analog Devices. Many such companies are well placed to bid for contracts at CERN or to develop additional expertise to allow them to do so. Additionally, Ireland has the capacity within university research labs to develop spin-off businesses in niche areas.

Northern Ireland has benefited considerably from the UK's membership of CERN with 17 companies, including Mivan Ltd, FG Wilson and Micro-Flextronics, winning significant supply contracts. Most recently, Elite Electronics in Fermanagh won a contract to provide power supply components for use with the magnets at the core of the accelerator. This particular contract arose from Invest NI bringing the CERN procurement team to Enniskillen to visit the company.

Enterprise Ireland is skilled in identifying opportunities and matching companies to contracts as proven from Ireland's exceptional success in obtaining contracts with the European Space Agency. With an annual membership fee of €10 million, over 80 Irish firms have won ESA contracts worth an estimated €80 million since 2000.[18] Annually Irish companies successfully tender for around 20-30 contracts each year with around four new companies getting involved each year. There is every reason to believe that, with membership, contracts from CERN will follow a similar pattern. CERN has a dedicated Procurement and Industrial Services group that works with national agencies to alert suitable companies to upcoming contracts.

Given the government's aim to dramatically increase the level of high-tech business and research in Ireland, CERN membership provides a particularly strong stimulus both to the many existing companies in Ireland and in encouraging new spin-off businesses. It is also open to member states to direct public monies to companies to help develop new products specifically for the CERN market, thereby giving a cohesiveness to government policy on R&D and enabling high-tech companies to compete effectively.

Membership sends out a clear signal to international scientists and investors that we are open to opportunities and are willing to be part of the largest, high-tech, scientific, worldwide collaboration of scientists and engineers. This must have a significant impact on Ireland's reputation as a beacon for scientific investment.

Irish companies and organisations with contracts at CERN

Agtel

Authentik

Social Talent

SensL Technologies Ltd.

Flag Telecom Ireland

Testwall Test and Measurement Ltd.

Beta Layout Ltd.

Symantec Ltd.

Maxim Integrated Products

Microsoft Ireland Operations Ltd.

Gateway 2000

Sonru Limited

Tyndall National Institute

Hyperion Ltd.

Nations Language Training Centre Ltd.

VMware International Ltd.

GE Sensing

Talconic International Ltd.

Nesgen Digital Europe Ltd.

Synopsys International Ltd.

Red Hat Ltd.

Knowledge Transfer

Although companies benefit financially from contracts, most point to knowledge transfer and the acceleration of their R&D cycle, as even more important advantages of their collaboration with CERN. Many of the solutions required by CERN are at the edge of what is technologically achievable or require working with and developing prototypes that will later become established products.

A number of studies have been undertaken in an attempt to quantify the knowledge transfer outcomes. M. Bianchi-Streit et al.[19] made no attempt to calculate the effects of new technology or training, but concentrated on quantifying CERN's economic spin-off to 166 companies that had contracts with CERN from 1973-1982, in terms of both increased sales and cost savings. From initial orders of CHF 748 million, the companies benefited to the tune of CHF 3107 million. Of the increased sales, only 24% were related to particle physics; the remainder were in fields such as solar energy, the electrical industry, railways, computers and telecommunications. A similar multiplier has been found in studies of ESA, although here 80% of the increased sales remain inside the space industry.

A 2003 survey[20] by CERN of 629 companies from 22 countries that received CHF 1197 million in contracts from 1997 to 2001 reported that 38% developed new products as a direct result of being a supplier, 13% started new R&D teams, 14% started a new business unit, 17% opened a new market, 42% increased their international exposure, 44% indicated technological learning, and 36% indicated market learning.

A report this year by Erkko Autio to the UK Department for Business, Innovation and Skills, on the effects of Big Science to the economy used CERN as a case study.[11] It was noted that the learning and innovation benefits were driven by the performance requirements and were greatest when the quality of the relationship between the supplier and CERN was strongest. Several reasons for industry collaboration with CERN are detailed and include technological motivations (the stretch provided by the frontier-pushing performance requirements, the ability to tap into expertise, and development support) as well as strategic motivations (access to new markets, support for internationalisation, and the status of being recognised as a supplier to CERN).[11]

The environment at CERN is also important in terms of driving innovation. Hameri and Nordberg[21], commenting on the birth of the Web, pointed to the low threshold to initiate new projects and a

> *“Every €1 paid to industrial firms (through CERN contracts) generates €3 of additional business.”*
>
> J.M. Le Goff, ‘The impact of CERN on high-tech industry developement’ Workshop: Research infrastructures for industrial innovation, European Commission, Brussels. See also [19].

Examples of benefits accruing to companies by working with CERN

- The magnets that steer the protons around the LHC are the largest and most powerful in the world and were the result of 15 years of R&D with industry that led to major advances in superconductivity and magnet design. These companies use the technology developed at CERN when making superconducting magnets for magnetic resonance imaging (MRI) machines. Babcock Noell uses its improved welding capabilities in work with other partners. One Italian company learned new ways of working with stainless steel by manufacturing the collars that enclose the magnets and is now putting those capabilities to work for the car companies Citroën and Peugeot.
- India's CAT laboratory produced two patent applications for ingenious construction methods: one is a diaphragm centring system that could be used for holding wheels on axles; the other is for an automatic coil-winding machine.
- After collaboration with CERN, the French company Fogale now sells a hydrostatic levelling system that allows micron precision of height variations across hundreds of metres, which have applications from civil engineering to tsunami observations.
- SRB Energy was set up in 2005 to manufacture solar panels using a new procedure developed by Cristoforo Benvenuti working with vacuum technology at the LHC. In 2012, Geneva airport installed 300 solar panels, creating one of the largest energy systems in Switzerland.
- Micron Semiconductors employs 30 people in custom designed semiconductor sensors and has a turnover in excess of £3 million. Working with physicists has established their sensors as the most radiation-tolerant in the world and represents more than 30% of their business.
- Force 10 Networks was a network switch company with which Irish scientists collaborated in 2004 to simulate the data-patterns of computer farms attached to the LHC experiments. Changes were made to improve switch performance and Force 10 subsequently won a several million euro contract with CERN. It became the industry leader for very high throughput switching. It is used by technology giant Google, and was bought by Dell in 2011 in a deal thought to be worth $700 million.
- Fibernet Ltd (Israel) employed 150 people in 2005 and manufactures and distributes fibre optic and electronic products. It was named as outstanding supplier to CERN for 2005 with a contract estimated to be worth $6 million, for the real-time transmission of experimental data to CERN's control room. The development of special optical connectors has had a major impact on its business. It now employs over 300 people.

light management of people: ideas succeed or not depending on individual enthusiasm and evolutionary contingencies. The Web project at CERN was never formally approved, but it was supported in terms of infrastructure. Above all, it required a vision, expertise and profound understanding among the original innovators.

Health

Health for an aging population is of critical importance in Europe with 40% of people likely to develop cancer. Improvements in diagnostics and treatment are vital. Imaging a tumour inside a patient is very similar to imaging a Higgs boson inside the LHC. In both cases radiation and charged particles are detected by sensors, data is transmitted to computers, a visual representation is produced, and a quantification provided for expert interpretation.

Medical Sensors

The Medipix collaboration at CERN uses pixel detectors and special micro-electronics developed for the LHC to produce devices that will allow more precise medical imaging with lower radiation doses. Evaluation of these in collaboration with St. Luke's hospital, part of the Dublin radiation oncology network, has commenced. This is an opportunity for spinoff and has obvious commercial implications, but its success depends on working with experts at CERN.

Another breakthrough that Irish particle physicists are familiar with, is ultra fast detection of radiation. New micro-electronics have been developed that boast a time resolution of 4 picoseconds. This has been described as the 'Holy-Grail' for PET scanning as it will allow clinicians to perform real-time imaging of tumours rather than needing to wait several hours.

Accelerators for biomedicine

Research is on-going into producing better accelerators for medicine. CERN is working with Spanish research centre, CIEMAT, to develop an ultra-compact cyclotron for single-dose production in collaboration with an industrial consortium.

Recently, CERN announced the creation of a new accelerator facility called BioLEIR that will provide particle beams of different types at various energies for biomedical research and heavy-ion radiobiology. Oncologists in Ireland, working with physicists and cell biologists at UCD, DIT, Belfast and DCU are keen to apply for time on this facility.

Hadron Therapy

Hadron therapy is a new and promising technique for treating cancer and is the optimum treatment for a range of paediatric tumours and an increasing range of adult cancers. About 65 children per year in Ireland require proton therapy and many are sent to the US for treatment. Studies estimate that 8-12% of all radiotherapy patients would benefit sufficiently from hadron therapy to justify the cost of treatment.

However, the current high price of facilities (about $100 million) limit their number; currently about thirty proton centres are either in operation or in construction worldwide. The UK intends to build two new facilities in the coming years and a treatment centre on the island of Ireland would be highly desirable. Talks are on-going between the HSE's National Cancer Control Programme and the NHS on co-ordinating both research and future treatment.

Case Study:

Belfast born Steve Myers OBE is instantly recognised as the engineer who delivered the LHC. After graduating from Queen's University, Belfast with a Ph.D. in electrical and electronic engineering, he briefly considered at job at a Dublin university, before taking a staff job at CERN in 1972, by virtue of his UK citizenship. He quickly became one of the most sought-after accelerator scientists in the world, rising to head up the Large Electron Positron collider. He wrote the original proposal to build the LHC and later took charge of this project. He became head of the Accelerator and Beams department at CERN in 2000 and in 2009 became Director of Accelerators and Technology, the second highest position at CERN.

A longer-term goal of CERN is the development of cheaper hadron therapy centres, costing about one tenth the current price, for deployment throughout Europe. CERN leads the ENLIGHT network of clinicians, physicists, biologists and engineers whose goals are to improve and make hadron therapy more accessible. It currently attracts over €24 million of EU funding.

The ultimate aim is for CERN to establish itself as an important facilitator of medical physics in Europe. Heading up the office for medical applications is Belfast born Steve Myers, the former head of the Accelerators and Technology division at CERN.

He regularly visits Ireland to give lectures at schools, university and professional organisations, and to meet with health professionals in the North and South. Irish expertise is feeding back into the CERN programme: Prof. Brendan McClean, Director of Medical Physics, St. Luke's Radiation Oncology Network and Prof Kevin Prise, a radiobiologist from Belfast were invited from Ireland to join a small group providing clinical input into the design of new particle accelerators for clinical use at the CERN meeting in Divonne this year.

Big Data

Government policy sees Ireland becoming a leading country in Europe in Big Data. A recent Forfás report[22] entitled Assessing the Demand for Big Data and Analytics Skills, 2013-2020, looks at how to build up the big data and analytics talent pool in line with enterprise demand.

A working definition of big data is provided in terms of the '3Vs': volume (petabytes (PB) or above); variety (diverse sources); and velocity (real-time collection and analysis). All three exist at the technological limit at CERN: colliding protons at the LHC produce about 1PB of data every second and provide a grand challenge in data analytics, requiring compression, suppression, computer decision making, parallelism, real-time analysis, storage, and multidimensional analysis techniques. One concern in the Forfás report is access to real-life test-bed applications both for training purposes and to develop methodologies. CERN provides the perfect environment and is the reason that companies like Force 10 test their switches using LHC data, Yandex, the Russian search engine, use LHC data to refine machine learning techniques, and Blue Yonder, a German company, use predictive analysis, developed using LHC data, to help their clients make the most of big data.

The Forfás report identifies the lack of experienced manpower, particularly those with 'deep analytical talent', as the most acute constraint on industrial growth. The skillset required (advanced mathematical and statistical knowledge, visualisation, data-mining, communication, problem solving and team working) are those of particle physicists and computer scientists working at CERN. Over 90% of Ph.D.s trained at CERN, on leaving academia, end up in ICT, as financial data-analysts, or in high-tech careers.[23] Purely in terms of training, funding Ph.D.s or developing M.Sc. programmes with CERN, would be ideal ways to attract and train deep analytical talent for Ireland.

The Forfás report also comments on the necessity of improving Ireland's international competitiveness versus European counterparts. It should be noted that the competitors already have access to CERN and projects like **Openlab**, a public-private partnership between CERN and leading IT companies, is defining the standards for the future. A recent white paper[24] points out that technologies that today are at the bleeding edge of research will be commodity items tomorrow and that continuous collaboration between research infrastructures and IT companies is critical.

Big Data is in its infancy in Ireland while a wealth of knowledge on how to manipulate and extract information from large-scale data has been built up at CERN over more than 20 years. Membership of CERN would allow Ireland to train students, use test-beds, transfer knowledge, be exposed to the state-of-the-art, access a skilled pool of world-class experts, and be part of Openlab.

> *"There is strong evidence that big data can play a significant economic role to the benefit not only of private commerce but also of national economies and their citizens."*
>
> 2011 Report by **McKinsey Global Institute** entitled 'Big data: The next frontier for innovation, competition and productivity'.

Micro-electronics

Digital electronics depend on particle beams for ion implantation. Dublin City University is playing a leading role in ISOLDE at CERN, developing improvements for semiconductor devices and have worked on dye-sensitive solar cells with SolarPrint and metal oxide nanostructures with Glebe Scientific in Ireland.

The special read-out-architecture in deep sub-micron CMOS technology used by the Medipix collaboration, is making real-time, high-resolution colour X-ray imaging possible. Apart from medical applications, this allows detection of explosives and drugs in luggage, as well as discovering faults in mechanical structures.

Another emerging technology under research at CERN is 3D integrated circuits in which components are stacked vertically as well as horizontally. Apart from improving speed and packing densities, it allows edgeless sensors to be produced, which can pave an active area without the dead regions normally required for read-out electronics. Discussions on possible collaboration have taken place with the Tyndall Institute in Cork.

Microfabrication and the integration of readout and processing services into devices is another active area at CERN with major potential. One current project integrates cooling into semiconductor devices and has applications in improving processors where heat generation is often a limitation on performance.


Image credit CERN

Outreach

Members of the public attend the opening of the Mission Higgs exhibit in Dublin, 2013.

The discovery of the Higgs boson in 2012 was a worldwide sensation and a shy, retiring octogenarian became the poster-child for the excitement that fundamental science can generate. The Higgs boson was headline news across the globe. Practically everyone knows something about its fundamental role in our understanding of the universe, the story of the grand challenge to find the 'Holy Grail of Physics', and the scale of the international collaborations and underground experiments at CERN. The story showcases science at its best: curiosity; cooperation; exploration; discovery. It is a triumph for science and for humankind.

An important feature of this outreach is that it was not manufactured in the way that many media sensations are. The facts speak for themselves and they clearly touch on something in everyone's psyche. Probably the last time science 'outreached' with such impact was the moon landing.

The outreach of particle physics into entertainment is notable. There are over 50 popular science or fiction books for sale on Amazon that use CERN or particle physicists as their main characters. Most notable perhaps is Dan Brown's 'Angels and Demons' that became a Hollywood film. Science has become 'cool' – one of the most popular sitcoms on television is called 'The Big Bang Theory', and the lead character is a theoretical particle physicist.

The societal benefit of this outreach is that science is enjoying a renaissance in popularity leading to better informed citizens with greater expectations for how science can enrich and improve their lives. This in turn leads to a more scientifically literate workforce, a greater use of science and technology to solve problems and innovate, and an overall improvement in the quality of life for everyone.

Outreach in Ireland

The rise in popularity of particle physics in Ireland mirrors that in the rest of the world. Therefore, it is important to feed this enthusiasm by providing opportunities for young people who have been inspired by this positive message.

In 1980, few Irish people knew what CERN was; today, most do due in no small part to local activity of Irish scientists working at the LHC. Three times over the last 10 years, CERN has been front-page news in the Irish Times newspaper.

Peter Higgs speaking at NUI Maynooth in 2013.

Sean Kelly MEP, speaking at the launch of the Ireland for CERN campaign at the Science Gallery in Dublin.

CERN has featured regularly on news bulletins and documentaries on radio and television. Irish scientists have been on hand to provide expert commentary and context. Of particular note is a live transmission on RTÉ's Morning Ireland from the seminar at CERN where the Higgs boson discovery was being announced, thus giving Irish people a direct link to the biggest science story in 40 years.

Many public talks have been given throughout Ireland by local and international scientists. The DG of CERN gave the DIAS statutory lecture at the RDS in 2007 for which over one thousand people applied for tickets, and returned in 2012 to give a key-note address at ESOF. Peter Higgs visited in 2013 and spoke to capacity crowds at the RIA and Maynooth. There have also been panel discussions organised at the RIA to coincide with the physics behind the film 'Angels and Demons' and to discuss the significance of the Higgs boson.

Two large exhibitions from CERN have been brought to Ireland. Over 14,000 people visited the 'Accelerating Science' exhibition in Leisureland, Galway in 2012, made possible by significant funding from Boston Scientific. A further 6,000, including 20 school groups, attended the 'Mission Higgs' exhibit in Dublin in 2013.

Reflecting the enthusiasm in the public for particle physics and CERN, particularly among young people, an 'Ireland for CERN' campaign[16] was launched on January 30th 2014 at the Science Gallery, attended by Sean Kelly MEP. What is notable is that this campaign was initiated and is run by third-level students whose vision for the future Ireland they wish to live in is of a vibrant, scientifically aware and internationally engaged country.

Internationalisation

European Commissioner for Research, Innovation and Science, Máire Geoghegan-Quinn speaks with ERC and Marie-Curie fellows during her recent visit to CERN.

CERN was founded 60 years ago under the moniker 'Science for Peace' in order to rebuild European scientific research after World War II. In contrast to science during the war that was secretive and had been misappropriated for military means, all research at CERN is open, freely available, and governed by the common human search for ultimate truth. These lofty ideals make it the flagship project for international scientific collaboration. Indeed, where other international bodies might argue over subjective viewpoints, scientists tend to unite behind objective truths, making CERN a unique and uplifting organisation to visit or work in. Ireland has a long and proud history of involvement with international organisations in general and European organisations in particular, from which stems much of the economic growth of the country post-1971. It is therefore decidedly anomalous, that Ireland finds itself as the only sizeable European country that is neither a member nor has any formal agreement with CERN.

Countries having agreements with CERN

The 12 founding states of CERN in 1954 were Belgium, Denmark, France, the Federal Republic of Germany, Greece, Italy, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom and Yugoslavia. These were subsequently joined by Austria, Spain, Portugal, Finland, Poland, Czech Republic, Slovak Republic, Hungary, Bulgaria and Israel.

Romania is a Candidate for Accession and Serbia an Associate Member in pre-stage to Membership. Association agreements have also been signed with Cyprus, Turkey and Ukraine, and are awaiting ratification by the respective national parliaments.

Observer states and organisations include the European Commission, India, Japan, the Russian Federation, UNESCO and the USA. Slovenia has applied for full Membership, Croatia, Brazil, Pakistan and Russia have applied for Associate Membership.

Non-member states with co-operation agreements with CERN include Algeria, Argentina, Armenia, Australia, Azerbaijan, Belarus, Bolivia, Canada, Chile, China, Colombia, Ecuador, Egypt, Estonia, Former Yugoslav Republic of Macedonia, Georgia, Iceland, Iran, Jordan, Korea, Lithuania, Malta, Mexico, Montenegro, Morocco, New Zealand, Peru, Saudi Arabia, South Africa, United Arab Emirates and Vietnam.

CERN's links with the EU

CERN participated in 87 FP7 projects, of which it coordinated 36, and was in receipt of €110 million. Several CERN scientists have European Research Council advanced grants, and a large number of Marie-Curie fellows at universities throughout Europe do their research at CERN. It is extremely difficult for Irish scientists to participate in these awards due to Ireland's non-membership of CERN. Joining CERN would strengthen the ability of Irish scientists to receive European funding in particle physics and associated fields such as ICT, new materials, health and energy that are priority areas of Horizon 2020.

> *"Ireland has a reputation for punching above its weight in international organisations. However, to win a boxing match, you first have to be in the ring."*
>
> **Sean Kelly** MEP at the launch of the Ireland for CERN campaign at the Science Gallery, February 2014

> *"My insight into why, in the middle of the worst crisis I have witnessed, we still abide by our obligations to spend taxpayers money (at CERN) is that first of all it was a sign of trust in the might of Greek scientists to contribute to this fine European effort and it was a sign also of optimism that has led, in a way, to something of a scientific recovery that we are experiencing now. The second reason is that we felt strongly about the spill-over effects of technologies and all the goodies that are coming out of the big experiments and last but not least, the educational aspect of it, the human network that was created."*
>
> **Yannis Mallikourtis**, Permanent Mission of Greece in Geneva, speaking at the European Commission panel discussion on basic research, Brussels, 29 May 2013.[12]

Membership and Membership Fee

There are three categories of institutional participation in CERN: Full membership; Associate membership; and Observer status.

Full members participate in the governance of the organisation and have full voting rights. They contribute to the budget of the organisation in proportion to the Net National Income (NNI) of their countries. The contribution for year N is calculated from the average NNI of the years N–5, N–4, and N–3. For Ireland, this would amount to around MCHF 12 in 2014, corresponding to around €10 million.

Associate membership is available to other nations who are represented at open and restricted (but not closed) CERN Council meetings, and do not have voting rights. Associate members pay a reduced contribution (**from 10% of the full membership contribution**) and receive pro-rated benefits. In particular, the combined value of personnel cost and of any contracts received is capped at the membership fee. Brazil, Pakistan, Ukraine, Russia and Turkey have applied for Associate Membership. Association agreements have been signed with Ukraine and Turkey and are presently awaiting ratification by the national parliaments.

Associate membership is also a compulsory pre-stage to full Membership lasting between two and five years. In this scenario, the Membership contribution is gradually ramped up from a minimum of 25% to the full contribution. The first new Member State that joined CERN under this scheme was Israel in 2014. Cyprus, Romania, Serbia and Slovenia have also applied for full Membership, and are presently in different stages of the accession and association procedure.

The **Observer status** has been granted in the past to non-Member States who have made a significant contribution to the infrastructure or the experimental equipment at CERN, for example by providing magnets for the LHC. The present Observer States are India, Japan, Russia, Turkey and the United States, however this status will be gradually phased out in the framework of CERN's new Membership policy, expecting that these states will all move up to Associate or full Membership.

In contrast, the Observer status will be maintained for other international organisations which are important co-operation partners of CERN, presently the European Commission and UNESCO. For example, about 110 million euro of EC funding has been directly or indirectly committed at CERN under FP7 (2007-2013) through thematic areas such as Big Data, Health, and Marie Curie training schemes.

Minister for Research and Innovation, Sean Sherlock TD, in front of the CMS detector at CERN.

Minister Sean Sherlock is the first TD to visit CERN. In early 2014, he announced a review of Ireland's membership of international research organisations, in response to which this document has been prepared.

Conclusions

Image credit CERN

Membership of CERN sends out a clear signal to international scientists and investors that we intend to be part of the largest high-tech, scientific world-wide collaboration of scientists and engineers. It would demonstrate the country's commitment to science and consolidate the reputation of the country as a beacon for scientific investment.

Full membership of CERN is the preferred option as it allows the maximum benefits as outlined in this document. An alternative route is provided by associate membership where the membership fee is reduced although so too are the benefits. Nonetheless, this may be an attractive option as for €1 million per year, it would allow Ireland evaluate the return from the inside, and following a review, a more informed decision could be made on whether to increase contributions or not.

This document has presented a case for Irish membership of CERN. We believe Ireland is missing an opportunity to take its place among the scientific nations of the world. CERN is far more than a particle physics laboratory. It is a melting pot for ideas, technology, innovation and scientific collaboration. It operates at the boundaries of current knowledge developing new technology to understand the fundamental nature of our universe. Access to this environment is a priority for most countries, as we believe it should be for Ireland.

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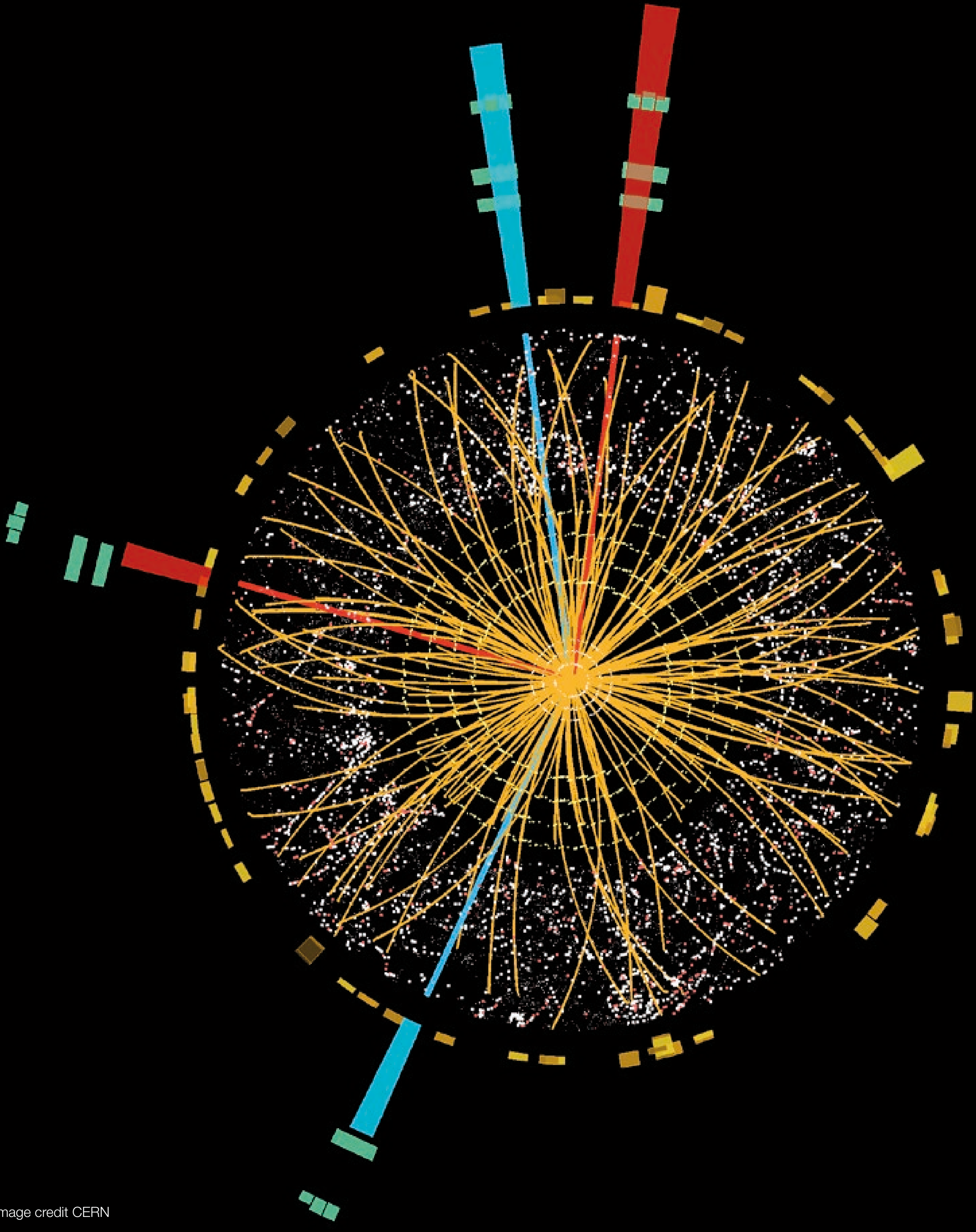

Image credit CERN

IOP Institute of Physics in Ireland

The Institute of Physics in Ireland (IOPI) is part of the Institute of Physics, which is a leading scientific society.

It is a charitable organisation with a worldwide membership of more than 50,000, working together to advance physics education, research and application.

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For more information contact

Institute of Physics in Ireland
c/o School of Physics
University College Dublin
Belfield, Dublin 4

Tel +353 86 2600903
email ireland@iop.org
www.iopireland.org