Northern Ireland Assembly

Research and Information Service Briefing Paper

Paper 06/13 | 29 November 2012 | NIAR 881-2012

Eóin Murphy

CERN -The Potential Benefits of Links with Northern Ireland

1 Introduction

The following paper discusses CERN (Conseil Européen pour la Recherche Nucléaire - the European Organisation for Nuclear Research) and possible opportunities for Northern Ireland.

2 Key Points

- CERN was established in 1954. It is located on the Swiss/French Border and is the world's largest centre for the study of particle physics;
- CERN's main area of research is particle physics - the study of the fundamental constituents of matter and the forces acting between them;
- CERN is a collaborative project, with twenty nations contributing to the running of the organisation;
- CERN has 2,424 staff in total, and in addition to this scientists from 608 institutes and universities around the world use CERN's facilities. This amounts to 113 different nations and around half of the world's particle physicists using CERN (approximately 10,000 visiting scientists);

- Work at CERN is broken into two categories – Large Hadron Collider work (LHC) and non-LHC experiments;
- The development of experiments at CERN and their results has created a number of spin off technologies;
- These spin off technologies include the World Wide Web, Hadrontherapy (whereby cancer is treated via a proton beam) and advanced materials research;
- CERN encourages collaboration with companies and research institutions via its Knowledge Transfer Office;
- CERN provides a number of education programmes, including high school teacher programmes, a school of high energy physics and accelerator school;
- These programmes are open to schools, teachers and higher education students;
- There are a number of potential benefits of links being developed between NI and CERN, including:
  - Enhancing the knowledge economy through skills development;
  - Research and development; and
  - Encouraging links between research bodies in NI and CERN.

3 CERN

CERN is located on the Swiss/French Border and is the world's largest centre for the study of particle physics. Established in 1954, the organisation was initially created to examine the workings of the atom, at the time the smallest known particle (hence the use of 'nuclear' in the name).

Over time the mission of CERN has evolved with discoveries in physics with its main area of research focusing on particle physics - *the study of the fundamental constituents of matter and the forces acting between them*.[1]

CERN is a collaborative project, with twenty nations contributing to the running of the organisation. These Member States sit on a Council that directs the work of CERN. The UK is a Member State of CERN. The UK representatives are:

- Professor John Womersley: A graduate of Cambridge and Oxford (D. Phil. Experimental Particle Physics), he has played a leading role in particle physics both in Europe and the United States
- Dr Graeme Reid: Head of Research Funding in the Department of Business Innovation and Skills. Dr Reid has a BSc in Physics and a PhD in Mechanical Engineering. He is a Chartered Engineer, a Fellow of the Institute of Physics and a Fellow of the Institution of Engineering and Technology.

As stated by CERN:

[1] CERN, CERN in a nutshell http://public.web.cern.ch/public/en/About/About-en.html

> *Each of which* [Member States] *has two official delegates to the CERN Council. One represents his or her government's administration; the other represents national scientific interests. Each Member State has a single vote and most decisions require a simple majority, although in practice the Council aims for a consensus as close as possible to unanimity.*[2]

In addition to the 20 Member States who contribute to the running of CERN, a number of other nations are involved. These nations, and some organisations, are listed as 'Observers'. Observer status allows non-Member States to attend Council meetings and to receive Council documents, without taking part in the decision-making procedures of the Organisation.[3]

CERN has 2,424 staff in total,[4] and in addition to this scientists from 608 institutes and universities around the world use CERN's facilities. This amounts to 113 different nations and around half of the world's particle physicists using CERN (approximately 10,000 visiting scientists).

CERN has four main missions:[5]

- Push forward the frontiers of knowledge;
- Develop new technologies for accelerators and detectors;
- Train scientists and engineers of tomorrow; and
- Unite people from different countries and cultures.

3.1 Research at CERN

CERN is a massive research laboratory, with a number of experiments running at any one time. Work is broken into two categories – Large Hadron Collider work (LHC) and non-LHC experiments. There are currently six LHC projects ongoing and eleven non-LHC projects. Please see Annex 1 for further information on these experiments.

A large number of experiments have been carried out at CERN since it was founded in 1954. These have included:

- The true story of antimatter: the first antihydrogen;
- Enigma of the muon: the g-2 experiments;
- Tracking down the weak force: Gargamelle and neutral currents;
- Protons head on: the Intersecting Storage Rings;
- The Z factory: the Large Electron-Positron collider;
- Testing the Standard Model: the LEP experiments;
- A tiny preference for matter: NA31 and NA48 experiments;

[2] CERN, CERN's structure, http://public.web.cern.ch/public/en/About/Structure-en.html
[3] CERN, About CERN, http://public.web.cern.ch/public/en/About/Global-en.html
[4] CERN, Press Office, Factsheet 2012 http://press.web.cern.ch/facts-and-figures/factsheet-2012
[5] Stephen Myers Presentation for the NI Assembly/Committee for Employment and Learning

- The primordial soup: high-energy lead ion collisions; and
- A Nobel discovery: hunting the heavy weights with UA1 and UA2.

One of the most notable pieces of research carried out at CERN since the completion of the Large Hadron Collider is the confirmation of the existence of the Higgs Boson Particle.

3.2 Spin – off Technologies

All of these experiments have added to the body of knowledge in particle physics and have led to awards (there have been five Noble Prizes in Physics awarded to researchers working at CERN). In addition, the development of the experiments and their results has created a number of spin off technologies. These include:

- Bike frames: Carbon fibres and composite materials;
- Pace makers: Li batteries and new materials for energy;
- Artificial hips: Bio-compatible materials; and
- Glasses: Optical materials and UV Filters.

Please note, this is just a small list of some of the spin off technologies developed as a result of the work at CERN.

In addition to areas such as materials research, CERN has also developed technology which has helped in the medical field, including Hadrontherapy whereby cancer is treated via a proton beam – the use of such technology to control tumours (brain, head and neck, spine and pelvis sarcoma) is 95% effective. In addition, the use of a proton beam rather than radiotherapy results in significantly less damage to surrounding tissue, reducing the traumatic effects on a patient.

Alongside the medical technology, other innovations have been developed as a result of advancements made at CERN, such as the World Wide Web, superconductive cables for the transfer of electrical power and Particle Accelerators used for a variety of purposes (such as food sterilization, mining and even the production of diapers).

CERN encourages collaboration with companies and research institutions via its Knowledge Transfer Office. It provides four types of technology transfer opportunities:[6]

- **R&D Collaborations:** CERN has a well-established tradition of collaboration with companies and research institutes, with the objective to generate technological results having a potential for commercial exploitation. In this framework, the research goals are agreed and achieved through a collaborative contribution of technologies and/or resources. Collaborative R&D projects can be developed in CERN's areas of technical expertise, such as superconductivity to ultra-high vacuum, from detectors to ICT;

[6] CERN, Knowledge Transfer, http://knowledgetransfer.web.cern.ch/technology-transfer/external-partners/opportunities

- **Service and Consultancy:** CERN's expertise and cutting edge infrastructures represent a unique opportunity for companies and academics in need of a specific high-tech service. CERN experts in the many areas of technical excellence are available to provide professional advice or specific studies to a business;
- **Spin-off companies:** CERN encourages the creation of new companies based on CERN technologies in the Member States. The creation of spin-off companies is also fostered through incubation centres – for example, in April 2012 CERN and STFC (Science and Technology Facilities Council in the UK) announced the launch of a new Business Incubation Centre at the STFC's Daresbury Science and Innovation Campus; and
- **Licencing:** CERN grants licences to commercial and academic partners for the exploitation of its technologies. A selection of these technologies is available through CERN Easy Access IP, a royalty free licence.

3.3 Training Programmes

CERN provides a number of education programmes, including:

- **The High School Teacher Programme** is a comprehensive international course held in English, aimed at teachers who would like to spend the first three weeks of July at CERN. The Programme is designed to keep teachers up-to-date with the latest developments in particle physics and related areas, and experience a dynamic, international research environment.[7] The next session will take place from 30 June to 20 July 2013. The school is fully funded by CERN for successful applicants from CERN member states.
- **The National Teacher Programmes** are held in the mother tongue language of the participants from CERN member states. The Programme is designed to keep teachers up-to-date with the latest developments in particle physics and related areas, and experience a dynamic, international research environment. CERN provides all scientific, administrative and technical support for the programme, such as scientific content and provision of national language facilitators, lecturers and guides. Travel and subsistence funds, covering accommodation and meals, are expected to be provided by national authorities or by other sources, e.g. educational foundations.
- **European School of High Energy Physics (HEP):** targeted particularly at students in experimental HEP who are in the final years of work towards their PhDs. The programme takes place over three weeks and involves around 32 lectures with discussion sessions most afternoons.
- **CERN Accelerator School**:[8] holds training courses for accelerator physicists and engineers twice a year. The courses take place in conference centres in different member states of CERN and consist of a programme of lectures and tutorials

[7] CERN, Education – Teacher Programmes https://education.web.cern.ch/education/Chapter1/Intro.html
[8] CERN, CERN Accelerator School http://cas.web.cern.ch/cas/

spread over a period of one or two weeks. Participants are welcome from member states of CERN and other countries world-wide.

- **CERN School of Computing:** [9] Since the early seventies CERN has organized the CERN Schools of Computing (CSC), usually held in August/September. They last two weeks and are open to postgraduate students and research workers with a few years of experience in elementary particle physics, in computing or in related fields. Attendance ranges usually from 60 to 80 students, typically of 15 to 30 different nationalities.
- **CERN Academic and Technical Training Programmes:** open to members of CERN personnel (staff members and fellows; associates, students, users, project associates; apprentices; employees of CERN contractors, with some restrictions).

The existence of these programmes may be an area of exploitation for Northern Ireland's schools, regional colleges and universities.

4 Potential Benefits to Northern Ireland

There are a number of potential benefits of links being developed between NI and CERN. The following section discusses the potential benefits of enhanced links with CERN and includes potential learning outcomes for any future committee visit.

- **Enhancing the Knowledge Economy through Skills Development**

A key part of the NI Economic Strategy is the development of the Knowledge Economy. As stated in a DEL report in 2007:[10]

> *Regional economic growth strategies increasingly stress the importance of building a knowledge-economy, with universities as knowledge-generators and industry as a key exploiter of this knowledge.*

This need for skills development is reflected throughout the strategy, with objectives on STEM (Science, Technology, Engineering and Mathematics) teaching and learning; stimulating innovation and R&D; and ensuring the workforce has the appropriate skills to meet the needs of companies.[11]

For students, CERN has the goal of raising their interest in modern science in order to motivate them to carry on with science at school and at University.[12]

CERN, through its education programmes, provides opportunities for school pupils, HEI students and teachers to enhance their knowledge of physics and engineering. The

[9] CERN, School of Computing, A Summer University https://csc.web.cern.ch/CSC/2012/Leaflets_Documents/CSC_Leaflet_Jan-12_FF-v1-full.pdf

[10] Department for Employment and Learning, An Examination of Higher Education Research and Development and Knowledge Transfer in Northern Ireland http://www.delni.gov.uk/07-01-08_herdkt-executive_summary.pdf

[11] Northern Ireland Executive, Northern Ireland Economic Strategy,

[12] CERN Education Programmes, Landau, R http://lhc.fuw.edu.pl/symp08LHC/Landua.pdf

site welcomes visitors (including school groups) and actively encourages young people to become involved in the sciences (albeit with a focus on particle physics).

This openness to knowledge transfer may be of benefit to NI's identified need to enhance its labour forces skills base, especially in the STEM areas. Whilst it may only provide benefit to a relatively small portion of the workforce, advances in these areas in terms of research may have long term benefits to the NI economy.

- **Research and Development**

The Northern Ireland Economic Strategy highlights the need for rebalancing the NI economy. As part of this there are a number of targets, including;

- Increase in Business Expenditure on Research & Development (BERD) as a percentage of Gross Value Added (GVA); and
- Increase the proportion of innovation active firms.

In addition the strategy states that:

> *significant government expenditure needs to be directed towards innovation and R&D, with much of this aimed at developing research capacity and the commercialisation of research.*[13]

CERN is one of the largest research labs in the world, with over 10,000 scientists accessing its facilities (either on site or remotely) each year. In addition, CERN is involved in a number of other research projects, including via Framework Programme 7.

CERN is a partner in over 70 FP7 projects, including 6 based in the UK.

Encouraging NI Universities, Companies, SMEs and Research Institutes to become involved in projects with CERN may have long term benefits to NI. Whilst CERN focuses very much on "basic" science i.e. *research made without any idea of application to industrial matters but solely with the view of extending our knowledge of the Laws of Nature*[14], the expansion of knowledge leads, inevitably, to advances in technology and innovation in existing methods.

Encouraging links between research bodies in NI and with CERN would enhance not only the region's Research and Development base in line with the Economic Strategy, but could potentially impact on the skills base and on the economy.

5 Possible Learning Outcomes

The work being carried out at CERN has an impact across the world, with its exploration of the fundamental building blocks of matter resulting in new technologies,

[13] Northern Ireland Executive, Northern Ireland Economic Strategy,
[14] CERN, The Use of Basic Science http://public.web.cern.ch/public/en/About/BasicScience2-en.html

methodologies and theories which can have a remarkable influence on a nation's economy.

If the Committee visits CERN, Members may wish to consider the following potential learning outcomes:

- What links can be developed between NI's private sector (especially in areas such as manufacturing, engineering, aeronautics and food production) and CERN. The Committee may wish to consider the development of links between the NI Assembly Business Trust and CERN.
- What links can be developed/further developed between NI's Universities and Regional Colleges and CERN, including in the areas of Physics, Engineering, Medicine and Technology;
- How best can NI link up with CERN to encourage skills development and transfer for NI students and employees; and
- What role can the Committee and the Assembly play in encouraging schools in NI visiting CERN or linking up with it in order to encourage young people to study STEM topics.

In addition, the Committee may wish to invite representatives from the University of Ulster and Queen's University Belfast to comment on what links they currently have with CERN and, following any Committee visit, how they intend to exploit any links made.

The Committee may also wish to provide any information or links developed with CERN to the Northern Ireland Assembly Business Trust in order to ensure the visit provides maximum added value.

Annex 1: Experiments operating at CERN

Large Hadron Collider

- **ALICE (A Large Ion Collider Experiment):** For the ALICE experiment, the LHC will collide lead ions to recreate the conditions just after the Big Bang under laboratory conditions. The data obtained will allow physicists to study a state of matter known as quark-gluon plasma, which is believed to have existed soon after the Big Bang.
- **ATLAS:** ATLAS is one of two general-purpose detectors at the LHC. It will investigate a wide range of physics, including the search for the Higgs boson, extra dimensions, and particles that could make up dark matter. ATLAS will record sets of measurements on the particles created in collisions - their paths, energies, and their identities.
- **CMS (Compact Muon Solenoid):** The CMS experiment uses a general-purpose detector to investigate a wide range of physics, including the search for the Higgs boson, extra dimensions, and particles that could make up dark matter. Although it has the same scientific goals as the ATLAS experiment, it uses different technical solutions and design of its detector magnet system to achieve these.
- **LHCb (Large Hadron Collider beauty):** The LHCb experiment will help us to understand why we live in a Universe that appears to be composed almost entirely of matter, but no antimatter. It specialises in investigating the slight differences between matter and antimatter by studying a type of particle called the 'beauty quark', or 'b quark'.
- **TOTEM (TOTal Elastic and diffractive cross section Measurement):** The TOTEM experiment studies forward particles to focus on physics that is not accessible to the general-purpose experiments. Among a range of studies, it will measure, in effect, the size of the proton and also monitor accurately the LHC's luminosity.
- **LHCf (Large Hadron Collider forward):** The LHCf experiment uses forward particles created inside the LHC as a source to simulate cosmic rays in laboratory conditions. Cosmic rays are naturally occurring charged particles from outer space that constantly bombard the Earth's atmosphere. They collide with nuclei in the upper atmosphere, leading to a cascade of particles that reaches ground level. Studying how collisions inside the LHC cause similar cascades of particles will help scientists to interpret and calibrate large-scale cosmic-ray experiments that can cover thousands of kilometres.

Non – LHC

- **ACE (Antiproton Cell Experiment):** ACE is a pioneering experiment that started in 2003. It aims to assess fully the effectiveness and suitability of antiprotons for cancer therapy. The experiment brings together a multidisciplinary team of experts in physics, biology and medicine from 10 institutes around the world who are the first to study the biological effects of antiprotons.
- **AEgIS (Antihydrogen Experiment: Gravity, Interferometry, Spectroscopy):** The primary scientific goal of the AEgIS experiment - a collaboration of physicists from all over Europe - is the direct measurement of the Earth's gravitational acceleration, g on antihydrogen.
- **ALPHA (Antihydrogen Laser PHysics Apparatus):** The ALPHA experiment is a successor of an earlier antimatter experiment, ATHENA. Set up in late 2005 with similar overall research goals as its predecessor, ALPHA will make, capture and study atoms of antihydrogen and compare these with hydrogen atoms. This time, the physicists are using equipment of a different design which has evolved from the previous experiment.
- **ASACUSA (Atomic Spectroscopy And Collisions Using Slow Antiprotons):** ASACUSA aims to learn more about fundamental differences in the behaviour of matter and antimatter. However, instead of directly comparing atoms with their corresponding antiatoms (for example, as in the ATRAP and ALPHA experiments), ASACUSA's physicists are creating hybrid atoms such as 'antiprotonic helium'.
- **ATRAP (Antihydrogen TRAP):** ATRAP is an experiment to compare hydrogen atoms with their antimatter equivalents – antihydrogen atoms.
- **CAST (CERN Solar Axion Telescope):** CAST is an experiment to search for hypothetical particles called 'axions'. These have been proposed by some theoretical physicists to explain why a subtle difference between matter and antimatter is found in processes involving the weak force, but not the strong force. If axions exist, they could be found in the centre of the Sun and they could also make up the invisible dark matter.
- **CLOUD (Cosmics Leaving OUtdoor Droplets):** CLOUD is an experiment that uses a cloud chamber to study the possible link between galactic cosmic rays and cloud formation. Based at the Proton Synchrotron at CERN, this is the first time a high-energy physics accelerator has been used to study atmospheric and climate science; the results could greatly modify our understanding of clouds and climate.
- **COMPASS (COmmon Muon and Proton Apparatus for Structure and Spectroscopy):** COMPASS is a multi-purpose experiment taking place at CERN's Super Proton Synchrotron accelerator. It is looking into the complex ways in which the elementary quarks and gluons work together to give particles we observe, from the humble proton to the huge variety of more complex particles.A major aim is to discover more about how the property called spin arises in protons and neutrons, in particular how much is contributed by the gluons that bind the quarks together via

the strong force. To do this the experiment fires ‘heavy electrons’ (particles called muons) at a ‘polarized’ target.

- **DIRAC (DImeson Relativistic Atomic Complex):** DIRAC is an experiment to help physicists gain a deeper insight into the fundamental force called the strong force. This plays a crucial role in particle physics, as it binds together particles called quarks, which in turn make up many other particles, including the protons and neutrons that form the nuclei of ordinary atoms.
- **NA61/SHINE:** Hadrons are particles that take part in the strong interactions – the force that binds quarks together and keeps atomic nuclei from falling apart. NA61/SHINE (the SPS Heavy Ion and Neutrino Experiment) studies the properties of the production of hadrons in collisions of beam particles (pions, and protons, beryllium, argon and xenon) with a variety of fixed nuclear targets. NA61 reuses most of the detectors of its predecessor NA49 with important upgrades.
- **NA62 - Measuring rare kaon decays:** The main aim of the NA62 experiment is to study rare kaon decays. Understanding these decays will help physicists to check some of the predictions that the Standard Model makes about short-distance interactions. Specifically, NA62 will measure precisely the rate at which the charged kaon decays into a charged pion and a neutrino-antineutrino pair.