The UK Accelerator Science Centre

This document briefly makes the case for establishing an Accelerator Science Centre in the UK and proposes that the ideal location for this would be the Daresbury Laboratory in Cheshire.

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Introduction

Since their development for the investigation of the interactions of fundamental particles, accelerators have become important tools in many areas of medicine, industry and science. To pick just three examples, the radiation emitted by electrons when they are accelerated around an electron synchrotron can be used for:

1. The early diagnosis of heart disease.

2. The structural analysis of biological molecules.

3. The study of magnetic materials.

Setting up an Accelerator Science Centre would allow the UK to develop more efficiently the technologies necessary to exploit the scientific and industrial potential of accelerators, bringing a range of medical, industrial and scientific benefits for the country. Many of our accelerator experts are currently based at the Daresbury Laboratory. This, coupled with the recent changes in the plans for the Laboratory and the availability of the Synchrotron Radiation Source (SRS) at Daresbury, which could be adapted for medical use, lead us to suggest that the future of science in the UK would best be served by establishing the Centre at Daresbury. In the following, several areas in which important developments could be made are briefly discussed. More detailed information is provided in the accompanying documentation.

Medical Applications

Breast cancer diagnosis

Breast cancer is a major cause of early mortality in women and the success of treatments is largely dependent on how early the developing cancer can be detected. Recent work on improving mammographic imaging has shown that X-rays from the Daresbury Synchrotron Radiation Source (SRS) can be used to detect the presence of malignant disease at the molecular level, long before clinical symptoms are manifest. If the SRS could be used in a screening programme, such techniques would obviously have a dramatic effect on the health of the population in the region.

Early diagnosis of heart disease

Improved imaging techniques

Identifying potentially fatal blockages in the small arteries of the heart is difficult. Not only do the surrounding bones and tissue cloud X-ray images, but the heart moves vigorously, further blurring the pictures crucial for diagnosis. An ingenious way of circumventing these problems is to use synchrotron radiation with some additional optics to produce two intense beams of X-rays which are scanned across the heart. The high intensity means that the picture can be taken very quickly; the movement is “frozen”. Choosing the frequency of the beams to be above and below the K absorption edge of a contrast medium also allows the blurring due to the surrounding tissue to be removed from the image. This works as follows:

The contrast medium is injected into the blood.

Two pictures are taken simultaneously using the two frequencies of X-ray light.

The two pictures are subtracted.

Both pictures are approximately equally affected by the bones and tissue, but the higher frequency picture shows more strongly the effects of the absorption by the contrast medium in the blood than does that at lower frequency. Subtracting the two leaves just the effects of the contrast medium in the blood, allowing identification of blockages in arteries with diameters as small as ½ mm.

The UK silicon detector centre

Implicit in the above is the requirement that the “pictures” produced using synchrotron radiation can be reliably recorded, while the subtraction procedure requires that these images be in digital form. The UK’s Silicon Detector Centre, under construction at Liverpool University using Wellcome Trust funding, is a centre of expertise on the development of imaging devices for such purposes.

The SRS as a diagnostic tool

The above suggest that a possibility that deserves serious consideration is that the Daresbury Synchrotron Radiation Source be used increasingly for diagnostic purposes as its rôle as a research tool is taken over by DIAMOND. The benefits to the NHS and to the individuals involved of early diagnosis of breast cancer and heart problems are obvious, as is the desirability of re-using an existing synchrotron rather than building a completely new device.

Cancer treatment using protons

The advantages of proton irradiation

Perhaps the major problem that arises in the treatment of cancer using radiation is that of ensuring that the tumour is irradiated while surrounding healthy tissues are not. This is particularly so where the boundaries of the tumour are well defined and lie close to other critical organs, as in the case of many brain tumours, or prostate cancers, for example. In such situations irradiation with protons offers clear clinical advantages over the more common therapies using X-rays or electrons. The reasons for this are fundamental; the distance protons of a given energy travel in tissue is very well defined, whereas the distance electrons travel is subject to large variations and X-rays generally penetrate the entire body. This means that proton irradiation may be made to conform much more closely to the shape of the tumour under treatment than is possible if either X-rays or electrons are used. This principle is proven daily in the treatment of tumours of the eye in the UK’s only medical proton radiation facility at Clatterbridge, near the Daresbury Laboratory. Damage to the optic nerve can often be avoided using protons, where other treatments would result in blindness and possibly complete loss of the eye.

Plans for the future

Unfortunately, the scope of the treatments that can be offered at Clatterbridge is limited. The current facility produces a proton beam with an energy of 60 MeV, corresponding to a range of 31 mm in tissue; enough to treat tumours of the eye, but not those of the brain. The staff of the Douglas Cyclotron at Clatterbridge, working with accelerator physicists at Daresbury, have developed a scheme whereby the energy of the proton beam at Clatterbridge could be increased to 200 MeV, allowing treatment of tumours located anywhere in the body. An estimated additional 1000 patients per year would benefit from such a facility in the UK. Currently, these patients receive only conventional therapy or are flown to the USA or Europe for treatment.

The benefits to the UK of extending the range of treatments available at Clatterbridge are obvious, as is the desirability of exploiting to the full the existing facilities and the collaborative work that has been done at Daresbury and Clatterbridge. This has been recognised by our

European colleagues (see page 15 of Amaldi's paper "Cancer Therapy with Particle Accelerators"), as well as those at Daresbury and Clatterbridge. Note that about twenty cyclotrons of similar design to that at Clatterbridge exist in hospitals world-wide. The energy of all of these could be boosted to allow their use for deep-seated tumour treatment using similar apparatus; there is considerable potential for collaboration, reducing the costs of the development to the UK.

Science

High energy physics

The field responsible for the design and construction of the first accelerators continues to be the major force driving innovations in accelerator technology. Two projects in which UK scientists are leading world efforts illustrate this.

Linear colliders

While the energy lost as synchrotron radiation when electrons are accelerated around circular synchrotrons can be of great use, as discussed above, when the goal is to reach the highest possible electron energies, such radiation must be suppressed. The only way to do this is to avoid bending the electrons round in a circular path. This is one of the tactics being used by the world's high energy physicists, who want to investigate particle interactions in conditions as close as possible to those that prevailed in the Big Bang. This is to be achieved by using two opposing linear accelerators to bring electrons into head-on collision with positrons; a so-called linear collider. UK accelerator physicists from the Daresbury Laboratory have recently been asked to join the team designing the European linear collider, TESLA. UK physicists are also involved in the design of a collider in the USA. More information on the contribution that the UK can make to these projects is contained in the document "Electron-Positron Collider Research in the UK". Which of the proposed colliders is to be built, and where, will be decided in the next two to three years, following the completion of the design reports to be submitted to the German and American governments in about a years time.

Neutrino physics

One of the most exciting scientific developments in recent years has been the recognition that neutrinos, emitted in fusion reactions in the sun or created when cosmic rays bombard the atmosphere, can flip from one type to another. This overturns decades of scientific thought about the nature of these elusive particles. Neutrinos interact extremely rarely, so intense sources are needed if their behaviour is to be studied in detail. Physicists at the Rutherford Laboratory lead world efforts in the design of the high intensity proton target from which a muon beam can be extracted, which in turn produces neutrinos.

Unstable beam accelerators

The development of particle accelerators is poised to take off in a radically new direction. Limited up to now to the acceleration of stable (naturally occurring) species of atomic nucleii, nuclear physicists have recently realised that it is possible to study nuclear reactions using unstable, or *exotic* beams. This new capability has the potential to make a major impact on many different fields of study; in particular it would allow an improved understanding mechanisms leading to the production of the heavy elements we see around us in the universe. The document "SIRIUS Science" describes this and other examples in more detail. Daresbury has all the necessary expertise to construct such a facility, and scientists from the North West have played a leading rôle in developing the ideas and generating the momentum behind the SIRIUS project.

Industrial Applications and Partnerships

Isotope production

Nycomed Amersham is a large international company which markets healthcare products based on radioactive isotopes. These isotopes are usually made using a proton beam accelerated in a cyclotron. This process could be made more efficient, and hence cheaper, if more intense proton beams (several hundred mA) were available at energies of several ten or hundreds of MeV. This would require advances in ion source and accelerator technology.

Klystron development

One of the crucial components of many accelerators are the klystrons that transfer the power from the plug in the wall to the particles to be accelerated. The UK company Marconi Applied Technologies (formerly EEV) is one of the world's leading suppliers of klystrons. The potential for collaboration between the Daresbury klystron experts and Marconi on the development of more powerful klystrons is considerable.

Accelerators and the Universities

The above makes clear that there is a growing demand for scientists able to contribute to the design and operation of accelerators. The Universities in the UK are not producing people with the necessary expertise. Indeed, there is a world-wide shortage of accelerator physicists, as witnessed by the strong interest of the German synchrotron laboratory DESY and the American Stanford Linear Collider Centre in involving the Daresbury staff in their projects. Liverpool University have recently undertaken first steps to address this problem. In collaboration with Daresbury, applications for studentships to work on accelerator science are being prepared. In the long term, it is proposed that this be extended to provide an M.Sc. programme in accelerator physics. Clearly, the establishment of an Accelerator Science Centre at Daresbury would be a boost to this programme.

Conclusions

Accelerators are tools useful in a wide range of applications. The UK would benefit significantly from increased investment in the development and exploitation of accelerators for medicine, industry and science. The existence of a synchrotron at Daresbury which could be used for cancer diagnosis and the early recognition of heart disease, the proximity of the Daresbury Laboratory to Clatterbridge, the UK's only proton therapy unit, and to the Silicon Detector Centre, the pool of internationally recognised accelerator expertise at Daresbury and the large number of scientists at Northern Universities interested in exploiting the possibilities opened up by new detector technologies, look for example at the SIRIUS documentation author list, make Daresbury the ideal location for the establishment of an Accelerator Science Centre.