BASROC CONFORM

The nonscaling Fixed Field Alternating Gradient Accelerator

The Consortium

STFC Daresbury Laboratory
STFC Rutherford Appleton Laboratory
The Cockcroft Institute
The John Adams Institute
The University of Glasgow
The University of Huddersfield
The University of Manchester
The University of Oxford
The University of Surrey

The People

Accelerator Scientists
Accelerator Engineers
Particle Physicists
Ion Beam Physicists
Neutron Physicists
Oncologists
Clinicians

Particle Accelerators

In a Linear Accelerator a particle is given energy repeatedly by RF cavities. To reach high energes requires long and expensive accelerator systems

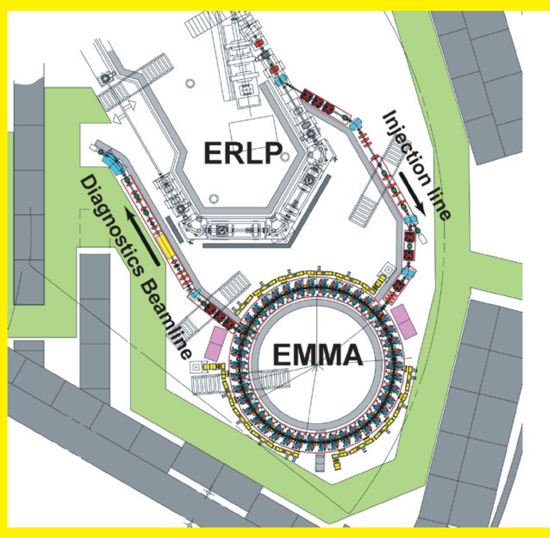
In a cyclotron a particle is constrained by a magnetic field to follow a spiral orbit,so the same cavity delivers repeated energy increases. The orbit frequency is constant - the increased speed exactly compensates for the increased path. But this only works at low (non-relativistic) energies.

In a synchrotron the increase in particle energy is matched by an increase in the magnetic field,so the orbit path is constant. But cycling the magnets is slow,so only a few bunches can be accelerated at once, and the currents are low.

In an FFAG the magnetic fields are fixed in time but vary in space, increasing with orbit radius. This makes the orbit change smaller than that in a cyclotron, and high currents can be produced at high energies. But the magnet shapes are complicated and the range of acceleration is limited. FFAGs have been constructed in the past, and are now under development in Japan.

These FFAGs are termed *scaling*: the beam optics does not change as the energy increases. It is this requirement that complicates the magnet shapes and limits the particle energy range. This scaling property ensures that the beams do not pass through resonances which, in a concentional accelerator, lead to instabilities. But we now believe that it is possible to accelerate the particles so rapidly that these resonances can be survived. Such *non-scaling* FFAGs can have simpler magnets and a larger range of acceleration, making them simpler and smaller and cheaper.

So to prove the calculations are correct, we had to build a prototype -



EMMA

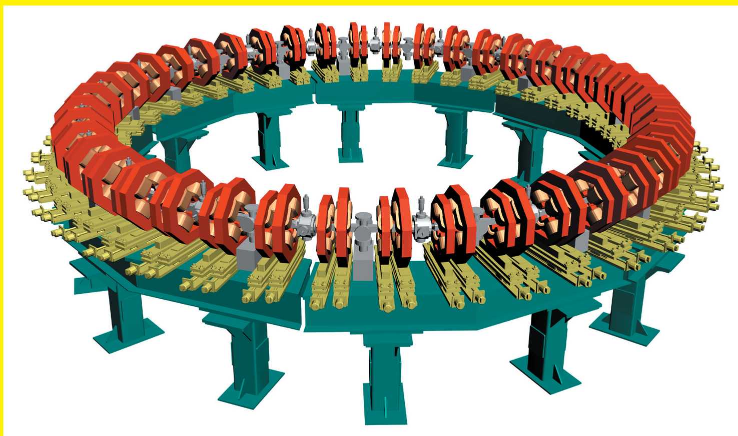
EMMA - the Electron Machine with Many Applications - the world's first non-scaling FFAG, is now nearing completion at the Daresbury Laboratory.

Although a small machine, accelerating electrons from 10 to 18 MeV, it is a very highly instrumented system that will enable the proprties of nsFFAG acceleration to be thoroughly and systematically studied and validated. Its 42 sectors use 84 quadrupole magnets, with fields defined to a very precise tolerance, and acceleration is provided through 19 RFcavities, which have to be carefully kept in step with each other and with the beam.

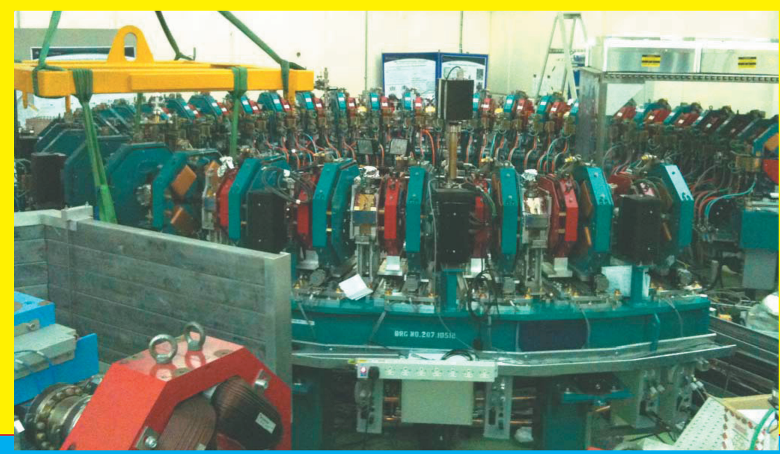
The beam is obtained from the ALICE accelerator which already exists ajd operates at Daresbury. The injection and extraction of the bem into and out of the EMMA ring use kicker and septum magnets requiring very high specification - fringe fields must be minimal

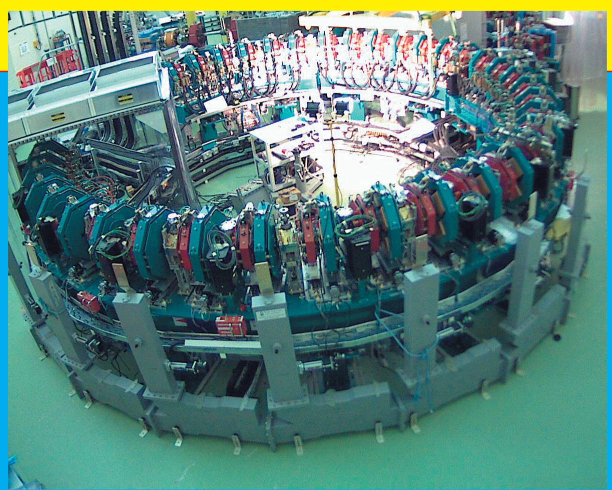
The design team is international, including members from the USA and continental Europe as well as the members of CONFORM, and EU funding has been obtained for part of the project.

The Design



The Reality





Training

As well as the studentships that are part of the bid, we have others working on the project with funding from other sources.

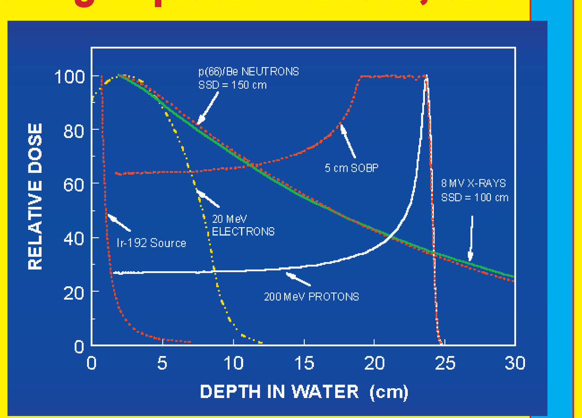
EMMA is already providing a training facility for these students and others, who are getting hands-on experience with a real accelerator. When it

Industry

If nsFFAG accelerators find the applications we expect, this presents great opportunities for K industry: magnet and RF systems, and beam instrumentation.. We are keeping in close touchwith existing and potential suppliers to assiste them in taking advantage off this

PAMELA

Proton therapy - the treatment of tumours using protons instead of X-rays - is very effective, as the energy is mostly deposited at the desired depth in the body, rather than all the way through. This means the tumour can be targeted, avoiding healthy tissue. It has been growing in practice abroad, and the NHS is now considering its use.



Despite its effectiveness, progress has been limited by the cost of the accelerator required, and the difficulty of fitting a large particle accelerator into a hospital site. An nsFFAG system would be smaller and cheaper, and could open the door for this technique.

The nsFFAG would also be able to vary the energy of the beam bunch by bunch, so that the tumour could be targeted in detail (1 mm^3 voxels) for more effective treatment and lower damage to surrounding organs. It would also be able to use Carbon (and other light element) nuclei in the treatment, as there are reasons to believe they may be even more effective than protons.

This was seen as the primary possible application for our new type of accelerator, so as part of the project we have proposed a medical machine based on the nsFFAG principle. The concept of PAMELA - the Proton Accelerator with MEdicaL Applications - was developed by accelerator scientists and clinicians working closely together. The design is now nearing completion and will soon be ready to take to the MRC and NHS to seek appproval for funding.

Beam studies

The ability to target the proton beam much more accurately and specifically, coupled with the choice of beam particle, opens the door to detailed and different treatments, beyond a simple dosage in Grays.

Surrey Ion Beam Centre

It is not clear whether the effecti of radiation is linear for low dosages, or whether cells can self-repair for minor energy deposits.

The relative power of Carbon (and other) nuclei compared to protons is still largely hypothetical: their are good reasons for believing that Carbonis better, but not definite clinical evidence yet.

Conventional studies involve the exposure of a population of test animals to various doses and measurung the proportions of successful and unsuccessful outcomes. This is slow and expensiuve and of low accuracy.

The new Ion Beam facility at the University of Surrey enables the targeting of specific cells with specific particles to be observed, and the outcomes followed. We have been using this to bombard specific cell lines (both benign and tumourous) with protons,and are obtaining teh answers that will enable the fully effective deployment of charged particle therapy, for this project and also for others.

Next step

As part of our dissemination and outreach program, we are hosting an Open Day for the project on June 24th in Church House, Westminster, London.
If you would like to attend, please take a leaflet or see http://www.conform.ac.uk/Openday

ADSR

The need to switch from fossil fuels to power sources that do not generate carbon dioxide is now recognised, but there is no agreement on a solution. If wind, wave and solar power prove insufficient for our energy needs, then nuclear power is the only option left.

However it facesa hard probelm of public acceptance, largely due to its safety record, the problem of long-lived radioactive waste, and the danger of proliferation.

The use of Thorium as fuel in accelerator-driven subcritical reactors (ADSRs) has long been proposed as an alternative to the U/Pu fuel cycle that overcomes these problems.
- when you switch off the accelerator you switch off the reactor, so there can be no Chernobyl-style accidents.
- the waste is relatively short lived, hundreds of years rather than tens of thousands.
- it is very difficult to convert to weapons use.

Such a system requires a high current(~10 mA) high energy (~1 GeV) proton beam: the nsFFAG can deliver this much more effectively than a cyclotron or synchrotron. It also requires exceptional reliability, and the simplicity of the nsFFAG makes this possible.

As part of the project we have been investigating this possibility, with such success that a new consortium, ThorEA, was founded to carry the idea forward. Membership has spread to many others outside the original projectc. We hold frequent workshops and meetings and are now the centre of activity for Thorium based nuclear power in the UK.

ThorEA
the thorium energy amplifier association