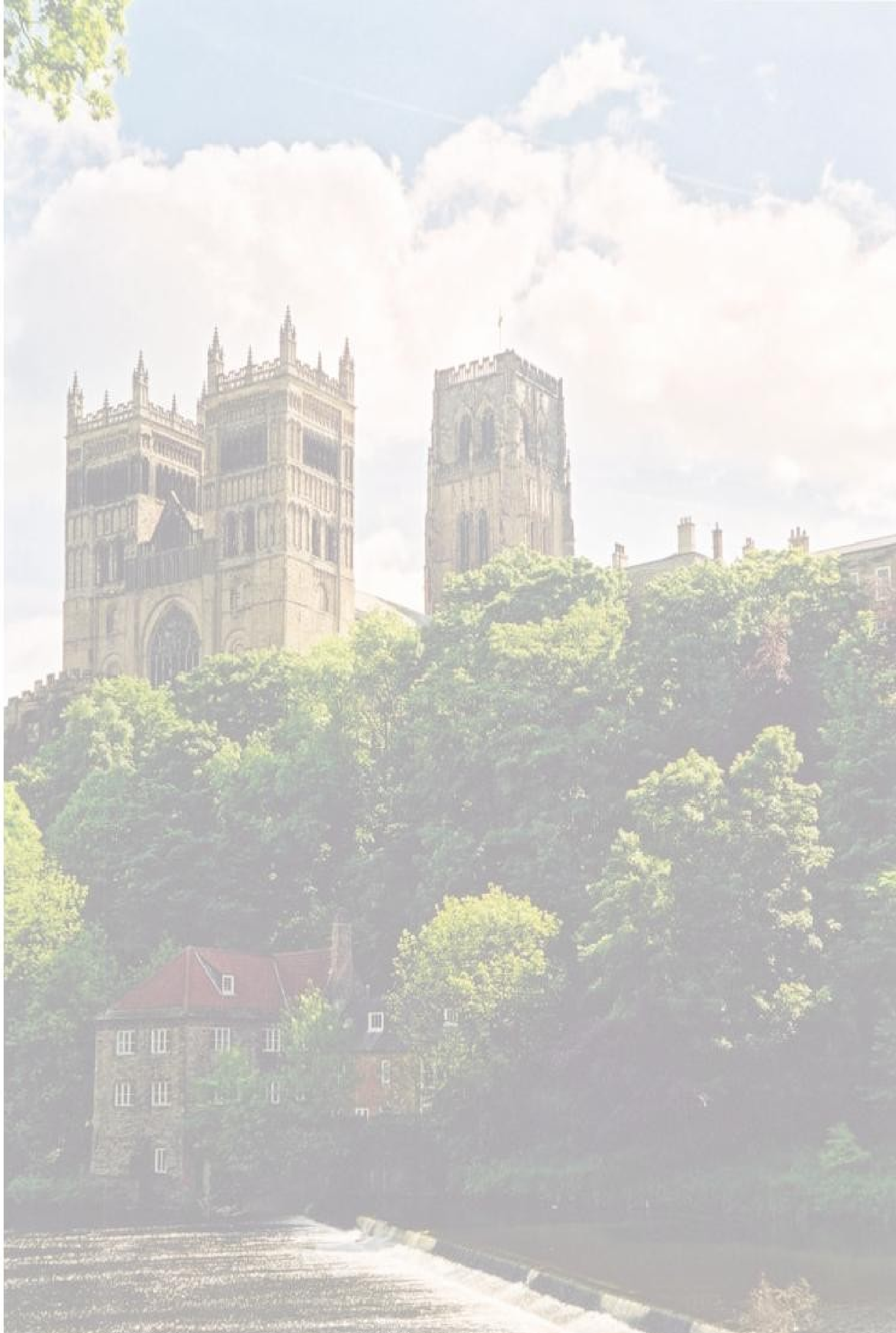

Document produced by IPPP, 2008

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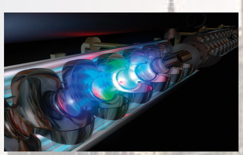
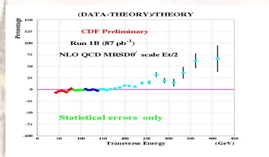
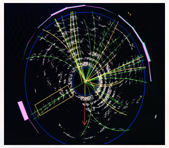
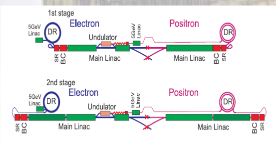
PARTICLE PHYSICS PHENOMENOLOGY

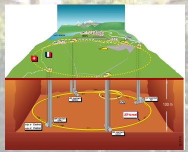




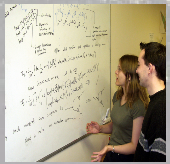


Experiment

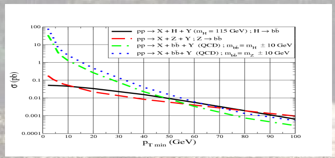




Particle physics phenomenology is the bridge between theory and experiment in the study of the building blocks of matter in the Universe - the fundamental particles - and how they interact through the fundamental forces



Theory



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The Institute for Particle Physics Phenomenology, Durham University

In 2000, it was recognised that there was a pressing need to strengthen and coordinate particle physics phenomenology research in the UK. PPARC decided to fund a dedicated Phenomenology Institute, large enough to serve fully the needs of the experimental community and staffed by world-class researchers. The aim was that such an Institute would unleash the great research potential of the UK high-energy physics programme in the next decade, and would reinforce PPARC's commitment to world-class particle physics research. After an open competition, it was decided to host the Institute in Durham.

With the founding of the IPPP, a joint venture of the University of Durham and PPARC, particle physics phenomenology in the UK has been substantially revived.[1]

The Institute was created as a partnership between Durham University and the Research Council. The University committed four new permanent staff positions (£3.2M). The Research Council provided a ten year grant (£8.3M) with funding for postdoctoral and support staff, together with a budget for workshops and visitors. Together, the University, the DTI and the Ogden Trust provided £6.6M for a new specially designed building large enough to house the Institute.

Since its creation, the IPPP has;

- produced 620 scientific papers with more than 13500 citations that were published in refereed journals (more than 380 papers) or appeared as conference proceedings
- organised or co-organised over 100 meetings or workshops, more than half of which have been in Durham, with a total of over 7500 participants
- produced 25 PhD's in particle physics phenomenology
- Taken a leading role in exploiting the physics of existing experimental facilities and in assessing the potential of proposed future experiments

The Institute for Particle Physics Phenomenology (IPPP) was set up in Durham in 2000 and has established itself quickly as a true centre of excellence on the international scale with an outstanding scientific performance in the field of particle physics theory.[2]

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1. Second International Review of UK Research in Physics and Astronomy, 2005
2. Report from Restricted European Committee for Future Accelerators (RECFA) which visited the UK in May 2007, sent to Secretary of State for Innovation, Universities and Skills, John Denham MP

Durham University

POLARISED POSITRONS AT THE ILC

The International Linear Collider will collide electrons and positrons at high energy. One of the major technological challenges will be to produce positrons at the required rate of 100,000,000,000,000 per second.

Science & Technology Facilities Council

EUROTeV

ASTeC Accelerator Science and Technology Centre

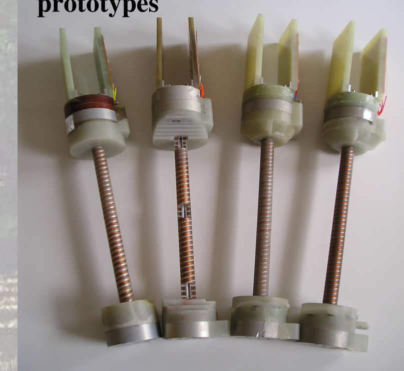
DESY

heLiCal

UNIVERSITY OF LIVERPOOL

A number of solutions were proposed, including a European suggestion to use an undulator-based design for the positron source. This design also has the extra characteristic of being able to produce polarised positrons. A Durham-led collaboration showed that using a polarised beam would significantly increase the scientific reach of the ILC, which led to the undulator-based design becoming the international favourite.

4 short undulator prototypes



Working with the polarised beam requires many additional theoretical and technical advances, and the UK is currently world-leading in this field. Now that the UK is no longer in the collaboration, there is a danger that the idea of using polarised beams will be dropped, which would reduce the amount of science the ILC is able to do.

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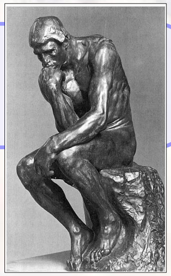
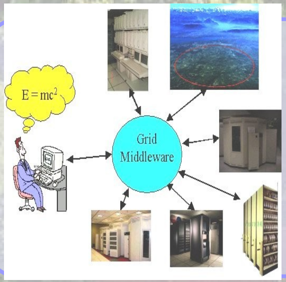
SPIN-OFFS FROM HEP



There is an intrinsic value inherent in basic science; most people are happy to know that the Earth orbits the sun rather than vice versa, but the practical and economic benefits are compelling as well.

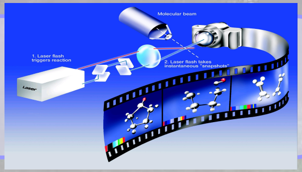
A previous spin-off:
The WEB itself was invented for particle physics by Tim Berners-Lee working at CERN. Today the WEB is an indispensable part of daily life.

Less than 15 years after the WEB was invented
* There are more than 2.5 billion web pages
* 14 million people in the UK shopped online in 2001
* World-wide $127 billion was spent online in 2000



Spin-off from the LHC:
Particle Physicists and CERN are now working on a new development called the GRID. The WEB allowed people to share information over the internet, the GRID allows sharing of computer resources and will cause a revolution in many fields as far apart as game consoles and artificial intelligence as well as cutting-edge science.

Spin-off from the ILC:
The Light of a New Millenium: A revolutionary new light source for applied sciences: new insights into the facets of nature and life.



Aside from fundamental knowledge and spin-offs, investment in basic science provides technologically and mathematically literate people able to drive innovation in diverse fields such as IT, finance and industrial research and development.

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It is also recognised that, over the past 6 years, the IPPP has contributed to the enormous growth in UK phenomenology, both as a centre for research and through the organisation of meetings and workshops.[1]

[the IPPP] is very important, since it is essential that UK experimentalists and theorists be ready to exploit discoveries made at the LHC in the near future.[2]

Some facts about the IPPP.
The Institute attracts leading experts from all over the world. 10 of 17 academic staff, 11 of 14 research staff and 12 of 28 postgraduate students are from outside the UK.
The Institute performs far above the average at attracting, and keeping, women in science. 5 of 17 academic staff, 2 of 14 research staff and 8 of 28 postgraduate students are female.

The Institute is committed to outreach and maintains a very strong outreach programme - more than 11000 school children from Key Stage 2 upwards have had direct contact with IPPP personnel, either through school visits, or visits to the IPPP itself, the annual Masterclass, the National Academy for Gifted and Talented Youth Summer Schools, the Junior Café Scientifique Scheme or the Ogden Teaching Fellowship Scheme. A fourth public art exhibition, 'CERN @ the Ogden', showcases a range of two- and three-dimensional artworks in a variety of media themed on a visit of local artists, school children and IPPP members to CERN in September 2007.

The next decade promises to be pivotal in our understanding of the microscopic world. The Large Hadron Collider, which is about to commence operations at CERN, will recreate the conditions of the early universe less than a billionth of a second after the Big Bang. The IPPP is very much at the vanguard of particle physics phenomenology, and we will be addressing fundamental questions about the fabric of the universe. New discoveries are inevitable and eagerly anticipated!

It is imperative that the IPPP continues to play a leading role in the UK and, on the behalf of the UK, on the worldwide stage, and the continuation of the IPPP beyond its initial ten-year period (2000-2010) must be a central component in the strategy.[1]

The IPPP proposal for STFC funding through until 2018 is being reviewed in 2008.

Professor Nigel Glover,
Director, Institute for Particle Physics Phenomenology,
Durham University
email E.W.N.Glover@durham.ac.uk
tel: 0191 3343692

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3. The Future UK Strategy for Phenomenology - A PPAP consultation paper (March 2007)
4. Second International Review of UK Research in Physics and Astronomy, 2005
5. The Future UK Strategy for Phenomenology - A PPAP consultation paper (March 2007)

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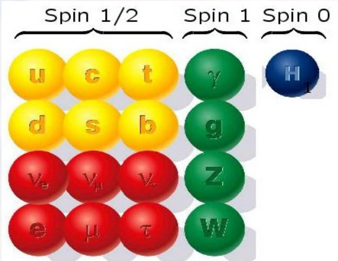
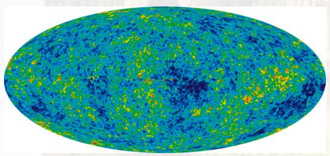
SUPERSYMETRY



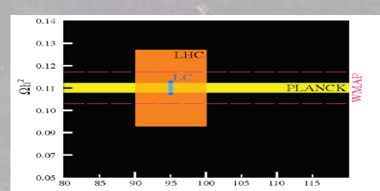
The Standard Model is an extremely precise model of the particles in our Universe and their interactions. There are two types of particle – fermions and bosons. All of the matter around us is made up of fermions, like electrons and quarks. The bosons are responsible for carrying the three forces of the Standard Model: electromagnetism, the strong force and the weak force.



Despite its many triumphs, there are some problems with the Standard Model. For example, by studying the cosmic microwave background, and the rotation curves of galaxies, astronomers have determined that there is far more mass in the Universe than can be accounted for by the normal 'shiny' matter that makes up stars and gas. Approximately a quarter of the Universe consists of dark matter, which isn't made up of any of the particles that are included in the Standard Model.

Supersymmetry is a way of directly relating fermions and bosons. The theory postulates that every particle in the standard model has a supersymmetric partner of the opposite type: for every Standard Model fermion, there is a corresponding supersymmetric boson, and for every boson there is a corresponding fermion.

The lightest supersymmetric particle provides an ideal candidate for dark matter. Precise measurements are needed to verify whether the properties of the lightest particle are consistent with cosmological data. The ILC will give us the chance to discover and study supersymmetry in depth, allowing the most precise measurements of supersymmetric particles.



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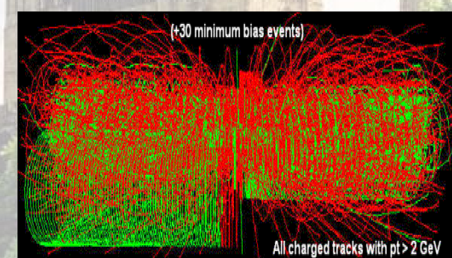
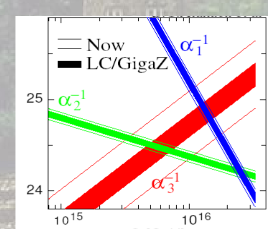
SYNERGY OF LHC AND ILC

At the Large Hadron Collider (LHC), protons will be fired around the CERN ring. Protons are composite particles – each proton is composed of three quarks. The LHC is a discovery machine, and will shed light on high energy physics.

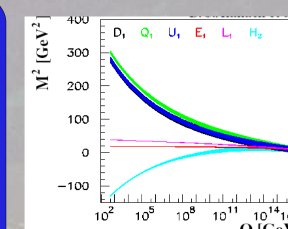
At the International Linear Collider (ILC), electrons and their anti-particles, positrons, will be fired towards each other and annihilate into pure energy. Since electrons are fundamental particles, these collisions will produce clean, clear signals.



The synergy between the LHC and the ILC during simultaneous running of the two machines has the potential to maximise the physics gain from both facilities. Due to its high collision energy and luminosity, the LHC has a large mass range for the discovery of new heavy particles, and the ILC's clean experimental environment and tunable collision energy allows it to perform detailed studies of directly accessible new particles. The ILC also has exquisite sensitivity to quantum effects of unknown physics - indeed, the fingerprints of very high scale new physics will often only show up in small effects whose measurement requires the greatest possible precision.



The International Linear Collider together with the Large Hadron Collider: Fundamental research towards the Theory of Everything



LHC / LC Study Group World-wide working group:
www.ippp.dur.ac.uk/~georg/lhclc

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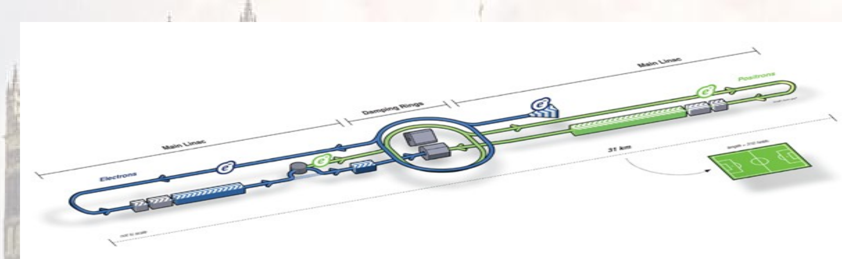
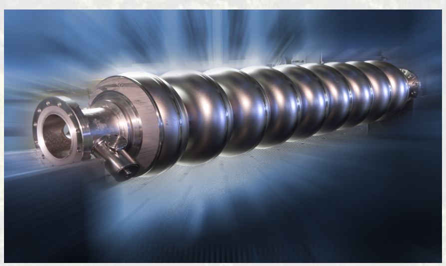
THE INTERNATIONAL LINEAR COLLIDER

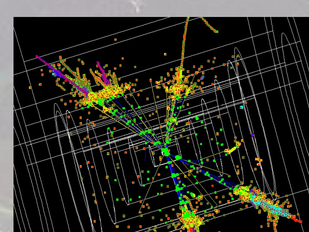


At 31km in length, the **ILC** will be the largest and also the most complex accelerator ever built. Besides the main linacs, damping rings with a circumference of 6 km for electrons and positrons are needed to produce the high quality beam required at interaction point. Physicists from all over the world participate in its design, but it is not yet known where the machine will be built.



The ILC proposes 250 GeV (upgrade: 500 GeV) beams at a luminosity of over 10^{34}. That is ten times more energetic and corresponds to a hundred times more interactions per second than the SLC at SLAC. The main linac consists chiefly of superconducting acceleration structures with an acceleration gradient of 31MeV per metre. The beam delivery system prepares the beam to be focused by a final quadrupole magnet to a vertical beam size of 5 nm. This ensures a high e^+e^- interaction rate since unlike circular colliders non-interacting electrons are lost. Every second 5 trains of 3000 bunches of electrons and positrons will be sent to interact in the middle of the detector.

The ILC includes study of Higgs, SUSY or any other new phenomena. Precision achieved at ILC will allow for model independent observation of Higgs and will study in detail the mass generation mechanism of the Standard Model. If SUSY exists in Nature, ILC can determine its symmetry breaking mechanism and precisely measure properties of accessible supersymmetric particles.



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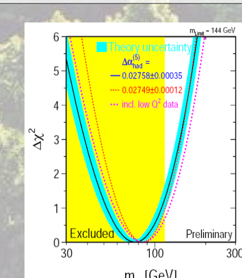
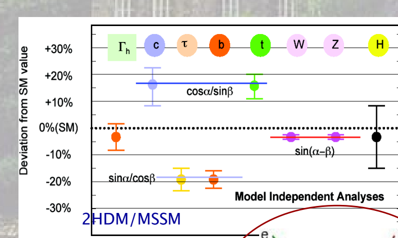
THE HIGGS BOSON

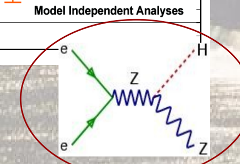
In 1964, Peter Higgs suggested the existence of a new field (now called the Higgs field) to explain why particles have mass. The Higgs mechanism explains mass by saying that the Universe is filled with the Higgs field. Interacting with the Higgs field gives the particles mass.

The Higgs boson would be experimental evidence of the Higgs mechanism. The Higgs field doesn't just interact with particles – it also interacts with itself. This self-interaction is the Higgs boson. The analogy most often used is to think of the Higgs field as a room full of physicists. Suddenly, Einstein walks into the room and everyone gathers around him. This makes it very difficult for Einstein to walk through the room – he (the particle) has acquired mass by interacting with the physicists (the Higgs field).

Although we haven't yet directly detected a Higgs boson, there is a vast amount of indirect evidence that its mass is within the kinematic range to be seen at the LHC and ILC. In order to understand the origin of mass we need to measure its mass and couplings with high precision. The ILC will be able to make these precision measurements and to establish uniquely the Higgs mechanism. It will even be possible to verify whether it behaves like a Standard Model Higgs boson or whether it points to new physics beyond the Standard Model, such as Supersymmetry.







At the ILC, we will be able to make a decay-mode-independent observation of the properties of the Higgs boson to incredible precision. For instance,

* Mass (to within 50MeV)
* Absolute couplings (to within 1-5 %)
* Total width
* Self coupling (to within ~20%)

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Experiment to recreate the Big Bang interpreted visually by professionals and A-level students

Artists inspired by visit to a science lab

by Gavin Engelbrecht

Times Arts

edited by Pru Farrier

ARTISTS gain inspiration from many sources – but particle physics are a less obvious starting point.

However, a visit to CERN, the European laboratory for particle physics in Switzerland, has led to a striking exhibition of two- and three-dimensional works in the Ogden Centre at Durham University.

The laboratory houses the powerful large hadron collider – a particle accelerator designed to recreate conditions immediately after the so-called Big Bang thought to have brought life into being.

The visit last September, funded by the Science and Technology Facilities Council and the Institute of Physics, was made by A-level art and science pupils of Heworth Grange Comprehensive School, Gateshead, along with members of East Durham Artists' Network, which is based at Peterlee.

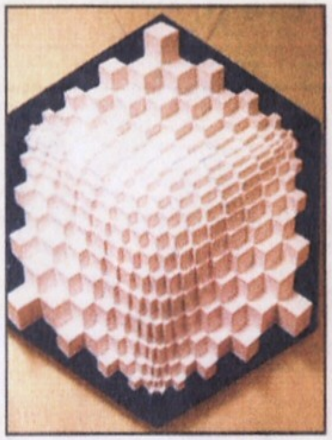
The group looked at work on mankind's biggest ever experiment, due to take place in September this year.

Dr Pete Edwards, science and society officer in the physics department at the university, said: "The Ogden Centre is an international centre of excellence and innovation, largely known for its pioneering work in computational cosmology and particle physics.

"This exhibition adds to our extensive programme of outreach activities with the local community and beyond."

The artists' network has staged exhibitions at the centre in the past, following visits by the members and their talks with the scientists.

One of the pieces in the latest exhibition is *Circular Cape* by textile designer, Angela Sandwith.



Dr Edwards said: "It represents the circumference of the accelerator and the colours depict the flags of all the nations contributing to the project.

"If you look inside, it is shiny, representing the search for the hidden secrets of nature."

Members of the university Institute for Particle Physics Phenomenology have also contributed work to the exhibition as part of a move to place science before the public.

Dr Edwards said: "I think, certainly, the artists have brought a new view of the world of physics. The way they have depicted things has given physicists a chance to reflect on things."

The exhibition is open from 10am-4pm, Monday to Friday, in the Ogden Centre, South Road, Durham, until Friday, March 28.

OUTREACH: *right*, Dr Pete Edwards, of Durham University; *above and left*, some of the images in the exhibition – Pictures: Gavin Engelbrecht/DT