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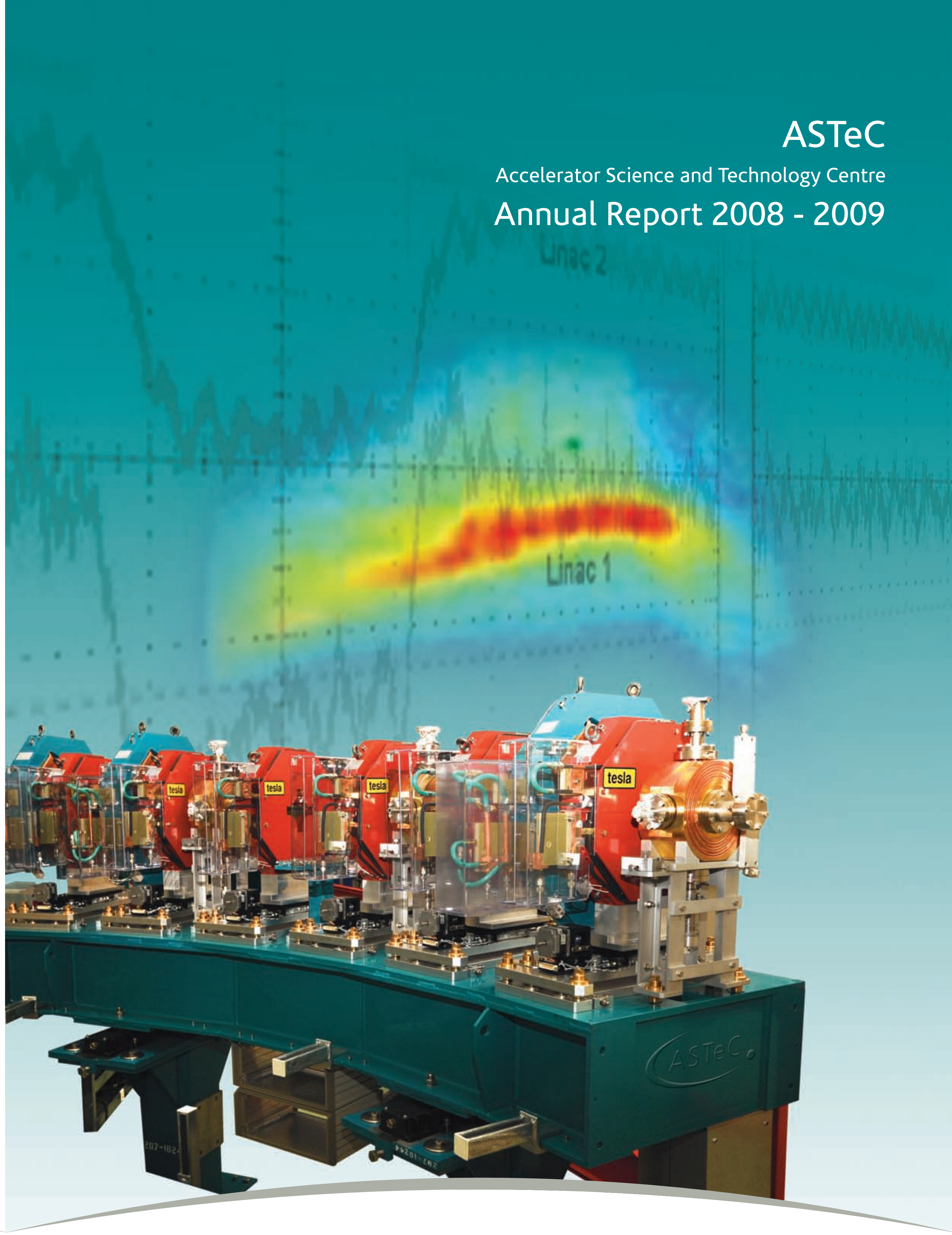
Science & Technology Facilities Council

ASTeC

Accelerator Science and Technology Centre

Annual Report 2008 - 2009



Science & Technology Facilities Council

ASTeC

Accelerator Science and Technology Centre

Annual Report
2008 – 2009

This report covers the work accomplished by the Accelerator Science & Technology Centre (ASTeC) for the financial year 2008 – 2009.

Editors: Deepa Angal-Kalinin & Sue Waller.
Designed & produced by: Media Services, Daresbury Laboratory.

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Foreward

ASTeC was created in 2001 as a Centre of Excellence in accelerator science and technology. Its first challenge was to deliver the final detailed technical design of the third generation light source DIAMOND, published in 2002 (the 'Green Book') and then handed over to the newly formed DLS joint venture company for its construction phase. Delivery of such major Design Studies continues to be the single most important element in ASTeC's portfolio of projects and skills as we are the principal UK resource for major accelerator based solutions. Our expertise in beam physics and core technology topics is of course supplemented by our partnerships with other STFC departments, including the generic engineering contributions that they bring to our joint enterprises. Our external collaborations have also continued to grow, both with major overseas centres and with the UK academic sector (Cockcroft and Adams institutes and other HEIs); ASTeC full membership of the Cockcroft Institute has been a particular success story delivering added strength to UK R&D programmes.

The ASTeC programme priorities have to reflect those of STFC and the various communities that it serves. Reading this Annual Report reminds us just how broad a set of programmes is being pursued. Often this requires staff to contribute to more than one project (indeed that is our norm) and this encourages skills sharing and development, but at some cost to personal focus. I congratulate those concerned on their success in handling this difficult mode of working. This year ALICE and EMMA have made great demands on our resources but we have been rewarded with outstanding progress on both topics. Meanwhile our particle physics project design programmes, on both linear collider and neutrino factory, have maintained a high profile and international leadership for ASTeC, STFC and the UK. In addition we have maintained smaller but important underpinning R&D programmes of a more generic nature on a variety of topics in magnetics, RF systems and vacuum science, progressing our knowledge and skills base.

None of our achievements would have been possible without the contributions of all of our highly motivated staff, but on this occasion I would like to refer more directly to the ASTeC leadership team that has supported me so directly in the formative years of ASTeC and its more recent consolidation. Jim Clarke, Joe Herbert, Peter McIntosh, Chris Prior and Susan Smith lead their five Groups with great skill and energy, whilst Mary Highmore and Sue Waller provide outstanding financial and administrative support to us all. I have been fortunate to be able to lead this management team since 2003 and ASTeC is in very good hands as it looks to a successful horizon maintaining its undoubted quality and impact in the future.

Senior Members of the ASTeC Management Team

Mike Poole - Director

Contents

ALICE -

ALICE (Accelerators and Lasers In Combined Experiments), an energy recovery linac based light source at Daresbury Laboratory, has achieved two major milestones in 2008-09: a full energy recovery was demonstrated in December 2008 and powerful coherently enhanced THz radiation was generated in February 2009.

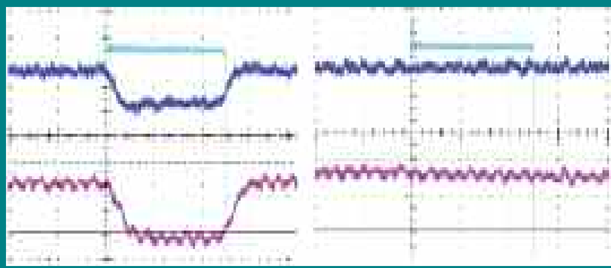
SRF Commissioning

ALICE incorporates two superconducting radio frequency (SRF) cryomodules each with two identical 9-cell cavities. The first cryomodule, the booster, accelerates the 350 keV electron beam from the photo injector to 8 MeV and the second cryomodule, the main linac, accelerates the beam up to 35 MeV. The SRF cavities operate at 1.3 GHz and are powered by 5 Inductive Output Tubes (IOTs). The overall system then incorporates a challenging low level RF system to maintain the amplitude and phase stability of the cavities during operation.

The original acceptance tests of the booster and linac cavities were performed in a vertical test stand at DESY in 2005 where all the cavities had reached the specified accelerating gradient of 15 MV/m. However, subsequent conditioning of the cavities at Daresbury Laboratory in 2007 following installation on ALICE showed excessive field emission and a consequent reduction in performance. An extensive improvement programme was undertaken over the last couple of years to overcome these limitations. The cavities were successfully operated from the end of November 2008 to the beginning of February 2009. Maximum accelerating gradients achieved for the linac cavities were 12.6 MV/m and 13.4 MV/m. During this period problems were experienced with beam loading in the booster cavities, which were initially resolved by reducing the external Q's. Definitive steps to resolve the beam loading problem in the booster are planned in the near future.

Energy Recovery

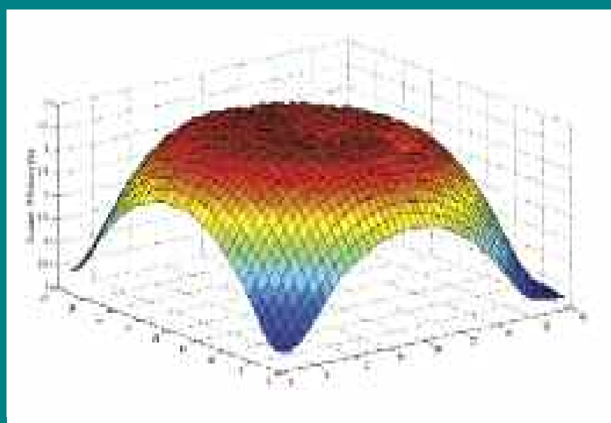
An energy recovery regime is established when the electron bunches accelerated in the main superconducting linac return back to the entrance of the linac but in a decelerating as opposed to the accelerating phase. The electrons give up their kinetic energy to the RF field thus ensuring that the power demand from the RF sources feeding the linac is close to zero. Full energy recovery has been demonstrated on ALICE in December 2008 at 21MeV beam energy with several bunch charges up to 20 pC. This is illustrated by the RF power demand signals from the two superconducting cavities of the main linac.



Main linac RF power demand signals: without (left) and with (right) energy recovery.

Note that the signals on the right are completely flat indicating that no RF power is required to maintain the electron beam acceleration, indicating full 100% recovery.

There has been a significant progress this year in increasing the quantum efficiency (QE) of the ALICE photocathode and its lifetime. After elimination of a minute vacuum leak detected in the gun vacuum vessel followed by a full cathode activation, the QE ~ 4% can now be routinely achieved and the 'dark' 1/e cathode lifetime (without beam generation) exceeds 800 hours. This will ensure ALICE operation at nominal bunch charges of 80pC for prolonged periods of time, expected to be 2-4 weeks, between cathode re-caesiations.



Quantum efficiency spatial map of the ALICE photocathode after activation. The horizontal & longitudinal axes represent the cathode surface in arbitrary units and the verticle axis shows the QE in %.

Demonstration of Energy Recovery and Coherent THz Radiation

Achieving energy recovery was the main goal during the initial ALICE commissioning and thus only preliminary beam characterisation and measurements were carried out during this period. Because no attempt was made to minimise the emittance, the values measured were comparatively high. A systematic optimisation of the injector settings and change of the cathode are planned for the near future machine development and a significant improvement in overall beam quality including the transverse emittance is expected. This will be also complemented by installation of a new improved 500kV high-voltage gun ceramic which is currently being developed and manufactured in collaboration with Jefferson Laboratory and Cornell University.

Software Development

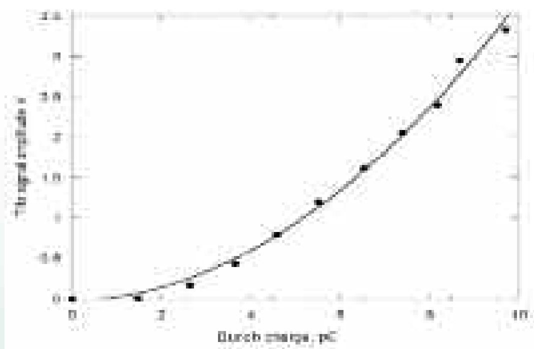
Commissioning of the ALICE accelerator demanded software applications to be developed, with a need to develop some small applications rapidly and flexibly. The interface to the ALICE control system is flexible and allows development of software using many different codes, allowing software development to be tailored to each task. The ALICE eLog is the primary method of recording work done during commissioning shifts. The log resides on a web server, and can be accessed instantly from anywhere, allowing stakeholders to monitor progress in real time.

A quick and accurate method of recording the machine settings in the log was developed. An extensive machine model has been developed using Mathematica. This can be run from the control room and linked to the control system to compare the real and modelled beam parameters. Optimisation routines have also been built into the code so that beam transport through the machine can be understood and improved.

THz Generation Studies

Coherent enhancement in the synchrotron radiation from short electron bunches produces high power THz radiation at high repetition rates. This radiation provides a useful diagnostics tool for the accelerator, but will also allow new photon science developments. The final dipole in the bunch compression chicane of ALICE is the source of THz radiation. The THz beamline was optimised by extensive modelling with the wavefront propagation code SRW. The beam can be directed into a nitrogen purged diagnostics enclosure which includes a custom high-aperture step-scan Martin-Puplett interferometer, or further transported on to a suite of THz exploitation laboratories including a tissue culture facility.

During the initial stage of experiments, a linear dependence of THz detector signal on the bunch train length was observed at constant bunch charge, and a clear quadratic dependence on bunch charge was observed at constant train length, as shown by the fitted line in figure below. This is indicative of coherent emission. With greatly increased photocathode quantum efficiency and lifetime and alleviation of the beam loading effects, the next stage of the THz studies is expected to be conducted at nominal bunch charges of 80 pC and long 100 μs train lengths which will significantly increase the level of THz intensity.



Dependence of the THz signal amplitude on the electron bunch charge.

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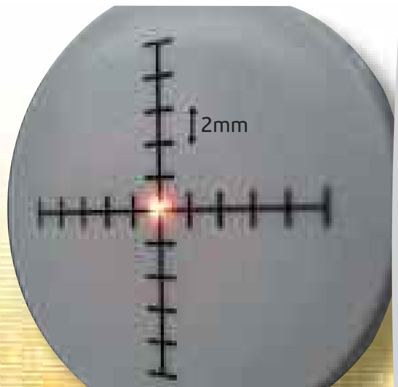
ALICE FEL Preparation

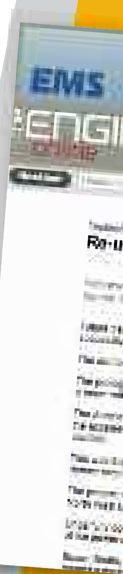
One of the next light sources to be installed on the ALICE accelerator is an Infra-Red Free-Electron Laser (IRFEL). The preparations are well under way to change the undulator gap to cover a wider wavelength regime and to study FEL alignment strategies.

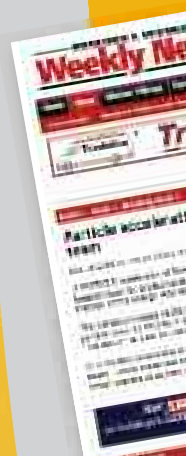
The IRFEL on ALICE has two principal components: an undulator, which is an array of alternating polarity permanent magnets, and an optical resonator comprising two curved mirrors surrounding the undulator. As an electron bunch passes through the undulator it will emit IR radiation which is captured within the optical resonator and amplified further by the interaction with the next electron bunch. This process continues and the radiation power is amplified exponentially until the point of saturation where the maximal power is extracted from the electron bunches. A small fraction of the radiation power, about 10%, is extracted through a small hole in one of the mirrors, and transported to a diagnostics room for measurement and eventual application in novel scientific experiments. The peak output power of the FEL pulses will be nearly 10 MW, with a pulse length of less than one picosecond.

The undulator that has been loaned by Jefferson Laboratory was previously used as a fixed-gap device on their IR-DEMO FEL facility. As part of the ALICE FEL preparation the device has been modified so that the undulator gap can be smoothly and continuously altered, giving a corresponding smooth scan of the output wavelength without changing the electron beam energy. This feature will facilitate certain scientific experiments, for example slow wavelength sweeps to pick out resonant responses in biological samples. A challenge of converting the fixed gap device to a variable gap device needs understanding of how to keep the the undulator arrays exactly parallel as the gap is changed in the presence of the strong magnetic forces between the arrays. ASTeC physicists calculated that the arrays must remain parallel to within 50 μm for the FEL performance to be optimal, and that the minimum step size for the gap control must be just 1 μm to give sufficient precision for the wavelength control. Close collaboration with the mechanical engineers helped to ensure that the engineering design could satisfy these tight tolerances.

Further work this year has been to devise a strategy for the alignment of the FEL. There are three axes which must be co-aligned to high precision for the FEL to lase: the magnetic axis of the undulator, the optical axis of the resonator, and the propagation axis of the electron beam. Calculations have shown that these axes must be aligned typically to within 200 μm. Small metal wedges with 1 mm holes in them will be inserted within the undulator to facilitate the alignment. First the holes in the wedges will be aligned with the magnetic axis via a survey. The axis of the optical resonator will then be aligned with the holes by injecting a HeNe laser into the resonator and adjusting the angles of the resonator mirrors until the HeNe beam is reflected off the mirrors and back through the holes. Finally the electron beam will be steered through the holes in the wedges. By this procedure, all three axes should be co-aligned. One aspect of the work this year has been to design and test the optical system to inject, steer and focus the HeNe beam within the resonator: this is necessary because the resonator mirrors can only be aligned using the HeNe beam once the HeNe beam itself is aligned with the holes in the wedges. The system was set-up and tested in the Laser Laboratory within the Cockcroft Institute building, using dummy targets instead of the real holed wedges, remotely steering the beam with picomotor drives, and viewing the image of the alignment beam with the same type of CCD camera that will be used in ALICE. Some images of the tests are shown. The work confirmed that the system should work well.







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ALICE
in the media spotlight

EMMA – The World's First Non-scaling FFAG

EMMA, the Electron Model with Many Applications, is the World's first prototype of a non-scaling Fixed Field Alternating Gradient (ns-FFAG) accelerator. The non-scaling properties of resonance crossing, small apertures, parabolic time of flight and serpentine acceleration are novel, unproven accelerator physics and require "proof of principle". EMMA has developed from a simple "demonstration" objective to a sophisticated instrument for accelerator physics investigation with operational demands far in excess of the original muon application, resulting in technological challenges in magnet design, RF optimisation, injection, extraction, and beam diagnostics. ASTeC staff have made significant contributions to the international collaborative effort during the year to study the accelerator science and deliver hardware solutions to the many new technological challenges.

EMMA will be used to make detailed studies and verification of the predictions and theories which underpin the non-scaling FFAG concept, such as rapid acceleration with large tune variation and serpentine acceleration. It will also be important to carefully map both the transverse and longitudinal acceptance. To do so EMMA must accommodate several machine configurations obtained by varying both RF and magnet parameters. These studies will require a scan of the full aperture at injection and extraction, at all energies; ability to run at fixed energy; independently variable dipole and quadrupole fields; variable RF frequency, amplitude and phase in all cavities; mapping of longitudinal and transverse acceptance with beam and a machine heavily instrumented with diagnostics. Accelerator components procured this year are being assembled offline, the first completed modules for the injection line from ALICE to EMMA have been installed and the EMMA accelerator ring and technical systems will be installed in the summer of 2009. Detailed plans for commissioning EMMA have started by the ASTeC accelerator physics group and commissioning will begin in the autumn of 2009.

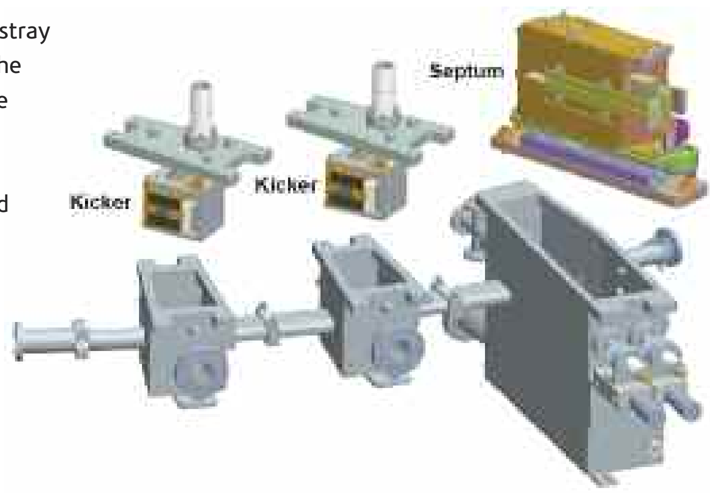
EMMA Girder Assembly, seven such girders will complete the full ring.

CAD model of ALICE and EMMA complex.

Magnets

Thirty four quadrupole magnets of each family have so far been delivered to Daresbury after extensive magnet field measurements and quadrupole centre fiducialisation. All 84 ring quadrupole magnets tested thermally and mechanically at the factory have been assembled. Field clamp-plates at either end of each doublet have been implemented to prevent the end field penetrating into the straight section components which would affect the requirement for near identical magnet fields in every cell.

The designs of the pulsed injection and extraction magnets are the most challenging. The septa bend the beam by 65° for injection and 70° for extraction respectively, with large vertical acceptance whilst minimizing the stray end fields that could impact on the circulating beam. Both septa are designed to have motorized actuators so as to be able to implement translations and rotations. The 0.1 mm laminations for the septum magnet are manufactured and the assembly and magnetic measurements of the devices will take place in-house during summer 2009 when the power supplies are delivered. The kickers need rise/fall time less than the revolution period of 55 ns and a compact design as they must fit in the available space of 20 cm. A prototype kicker has been constructed and tested at high voltage before delivery to a fast power supply company, APP who will optimise the power supply for the fast rise or fall times (35 ns), rapid change in current (50 kA/μs) and stringent constraints on pre- and post- pulses.



In-house design of injection septum and kickers exploded from the vacuum chamber. Extraction is a mirror configuration.

EMMA –
The World's First Non-scaling FFAG

RF System

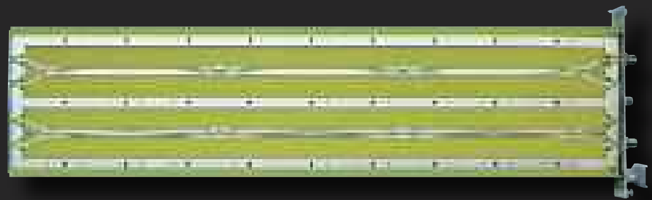
The RF cavities each need to provide a voltage of up to 180 kV to accelerate the beam by 10 MeV. Sixteen of the 19 cavities have been delivered by Niowave Inc. Testing of each cavity on delivery at low power gave a range of Q factors from 19000-22500 exceeding the specified value of 18500. The high power conditioning up to 10.8 kW on four cavities suggest that cleaning and handling of the cavities has been a great success. The power source implemented is a CPI IOT. An evaluation of the IOT under pulsed conditions has proven that it can meet the EMMA power requirements over the required 5.5 MHz frequency range. Production of the RF waveguide system which uses 17 hybrid and phase shifter waveguide modules to split the RF power in a cascade type system is manufactured and ready for testing. To evaluate amplitude and phase stability issues for the EMMA RF system, low level RF control system tests have been conducted, using 2 cavities, a Q-Par Angus hybrid module and an IOT. Results show a phase stability of 0.009° and an amplitude stability of 0.006%, well within the performance specification.

Two cavities prepared for high power testing

Diagnostics

The most challenging diagnostic system is the BPM system that is unique in its combination of measurement rate, dynamic range, accuracy and resolution.

A novel pick up signal converter has been developed by the ASTeC RF/Diagnostic Group that produces a signal which can be accurately processed, detected and precisely measured in 1/4 of a bunch turn (~14 ns). This converter is based on cascaded irregular strip line couplers and produces a burst of integer number of waves that has no lasting tails. This feature allows first, to avoid the turn-to-turn cross talk and second, to multiplex the signals from a pair of one-plane pickup electrodes in a single channel for each turn, which significantly reduces the cost of the system. The EMMA BPM system comprises 90 VME cards that amplify, detect, measure and memorise the signals coming from the converters placed on the accelerator. These cards have been designed as some universal beam diagnostic stations. Each card has a base board which comprises a power supply, a pair of fast precise ADCs with an individual memory, and a VME interface that connects the card to the machine high-level control system. The beam signal processing and timing circuits are made as replaceable 'mezzanine' boards that are individual for each beam diagnostic task. The BPM system design was completed in early 2009. BPM electronics fabrication planned to be done by several UK and European companies has been started.



EMMA BPM converter (coupler is open)

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Resonances in an FFAG

The recent development of Fixed Field Alternating Gradient (FFAG) accelerators raises the question as to whether a resonance is still harmful when the acceleration is very fast. Studies undertaken by ASTeC could help to understand this phenomenon.

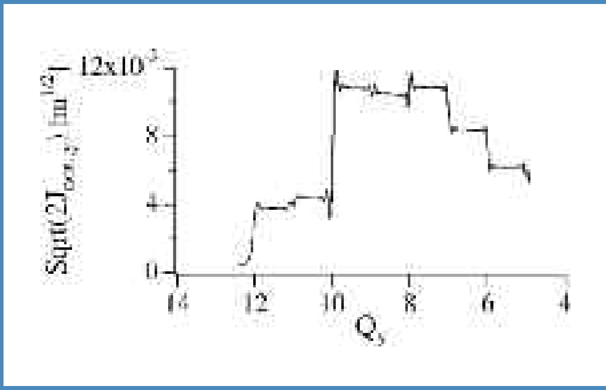
Resonance is a common undesirable phenomenon in a particle accelerator, especially in a ring accelerator where a beam goes around for many turns. When tiny deviations from the ideal accelerator design exist, such as errors in magnetic strength or slight inaccuracies in positioning accelerator components, their effects can be accumulated gradually and either the beam centroid will be deflected or the beam size will blow up until particles hit the vacuum chamber wall. Careful choice of operating conditions can minimise these effects, but the basic recipe is to keep away from major resonances in frequency space.

The recent development of Fixed Field Alternating Gradient (FFAG) accelerators raises the question as to whether a resonance is still harmful when the acceleration is very fast. Unlike conventional synchrotrons, an FFAG has the potential to increase the acceleration rate to the limit where the available rf voltage is the only constraint. As a result, the beam oscillation frequency - the betatron tune - may change considerably turn by turn with large energy gain. Because resonance is due to gradual accumulation of unavoidable imperfections in an accelerator, a rapid change in beam frequency may wipe out the coherence necessary to build up a resonance.

As an extreme example, the FFAG accelerator planned for muon acceleration in a Neutrino Factory will take a 12.5 GeV muon beam and accelerate it to 25 GeV. The betatron tune changes from around 33 to 15 during acceleration. The beam crosses strong integer resonances, which are excited when the betatron tune is an integer number, up to18 times but in only 10 turns. Study shows that there is no beam deflection or beam blow up due to the resonances. The orbits wobble, but the effect is the result of deflections by error fields that affect the beam in a random fashion.

When an FFAG accelerator is used for other applications such as proton therapy or driving a sub-critical reactor (ADSR), the acceleration rate has to be 10 to 100 times slower than for muon acceleration to bring the cost of the accelerators down to a reasonable level.

Nevertheless, this is still much faster acceleration compared to synchrotrons. Previously no clear answer existed as to whether the resonances would appear at such a high acceleration rate. The new study shows that resonance-like behaviour starts appearing at about 100 turns and manifests within 1000 turns. It turns out that the betatron tune has to be constant and major resonance crossing needs to be avoided over the whole momentum range even though an FFAG can accelerate a beam much faster than a synchrotron.



Normalized amplitude of a single particle (Jy) when alignment errors are included, taking the EMMA FFAG lattice as an example. Acceleration is completed in 1000 turns. Note that the betatron tune decreases as the beam is accelerated. Jumps where the betatron tune (Qy) hits an integer clearly show the beam deflection due to the resonances.

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New Light Source

The New Light Source (NLS) project was launched in April 2008 at the Royal Society London by the UK's Science and Technology Facilities Council (STFC), to consider the scientific case and to develop a conceptual design for a possible next generation light source based on a combination of advanced conventional laser and free-electron laser sources. STFC is collaborating with the Diamond Light Source on the source design for this facility.

The UK's New Light Source facility is intended to have unique and world leading capabilities, especially in regard to short pulse duration, high repetition rate and high intensity, with an optimised time structure and broad photon range providing the means to directly measure ultra-fast structural dynamics and thereby opening exciting new opportunities in material science, chemical science, nano-science, life sciences and high energy density science.

During May-June 2008 a series of workshops was held along with extensive consultation by working groups in: Life Sciences, Chemical Sciences, Condensed Matter Science, High Energy Density Science and Ultra-Fast Electron Dynamics. This led to the publication of the NLS Science Case in September 2008 which was subsequently approved by the Physical and Life Sciences Committee and Science Board of STFC. The NLS Project team was then given the 'green light' to proceed to phase 2 of the project. Phase 2 will cover production of a conceptual design study in which the detailed aims and technical features of the facility will be fully developed.

ASTeC staff are collaborating with the Photon Science Department and Diamond Light Source to develop the facility design. The ongoing R&D within ASTeC on superconducting RF (SRF), free-electron lasers (FELs), photoinjector developments and diagnostics on the ALICE project at Daresbury are of particular relevance for this future facility.

In order to reliably produce the extremely bright, stable and coherent pulses demanded by the scientific community, it is essential to perform detailed start-to-end beam dynamics simulations of the NLS accelerators, beam transport lines and radiation source systems. To this aim two options have received study for the main linear accelerator: a baseline single pass machine; and a two-pass recirculating machine. ASTeC staff are contributing to both designs as well as common, post-acceleration transport.

The NLS FELs will require a large number of high quality undulator modules capable of generating variably polarized light in order to achieve the specifications demanded by the Science Case. ASTeC staff are optimising the design of the undulators which in practice means achieving the highest possible magnetic fields at the shortest periods. The field level in an undulator is always limited by the gap required by the electrons between the arrays. For the NLS this gap is determined by the interaction of the electron bunch with the metallic vacuum chamber through wakefield effects. ASTeC staff have studied how these wakefields change with the vessel cross-section in order to minimise their effect and so maximise the field levels. This is a vital part of the NLS optimisation since it determines the operating energy of the facility which is a major cost driver for the project.

The SRF linac solution for NLS must be based on technology availability, demonstrated performance, reliability and anticipated capital and operational expenditure. The ASTeC team must therefore identify fundamental SRF system design choices for RF frequency, cryogenic temperature and operating gradient, whilst also proposing appropriate hardware solutions for each technology sub-system, to not only meet NLS operating specifications, but also to ensure a robustness commensurate with modern user requirements for such a 4^{th} generation light source.

To ensure that the potential for very high repetition rates afforded by the chosen SRF linac solution can be realised in future phases of the NLS project, the ASTeC staff have also been developing advanced injector designs capable of delivering repetition rates several orders of magnitude greater than the 1 kHz NLS baseline design.

For further details, see the project website:
http://www.newlightsource.org/

NLS FELs

ASTeC physicists have played leading roles in the development of the Free-Electron Laser designs for the Next Light Source. Their work has also defined key NLS parameters, such as the electron beam energy: studies showed that a beam energy of 2.25 GeV is required for the FELs to access the photon energy ranges specified by the Science Case.

An important feature of the NLS FELs is that the output must be in very short pulses, of the order of 20 fs, and also with a temporal coherence close to the transform limit. These requirements can only be met by ‘seeding’ the FELs with a coherent external seed source. Coherent seed sources are not available at the higher photon energies required of the NLS FELs: in this case harmonic conversion must be done within the free electron laser. The approach taken by other FEL projects, such as the BESSY-FEL proposal and the FERMI@elettra project, is to use a high power laser as a seed source and then perform multiple stages of harmonic conversion in a harmonic cascade. Such a system is called a High-Gain Harmonic Generation (HGHG) Cascade FEL.

The alternative approach adopted by the NLS project takes advantage of recent advances in the field of High Harmonic Generation (HHG) in gases, and uses an HHG source to provide a coherent seed field. This helps immediately to reduce the complexity of the FEL design because the HHG seed source can access far shorter wavelengths than a conventional laser so that the number of harmonic conversions performed within the FEL is much smaller. Furthermore, the way in which the harmonic stages are cascaded is far simpler: in the HGHG scheme the high power radiation field generated by the first stage is used for the seed of the second stage, and so on. In the HHG-seeded design developed by ASTeC physicists it is the harmonic modulation in the electron beam density generated in one stage that is used to transfer the coherence of the seed to the next stage: the radiation field is not required. The implications of this are that the number of undulator modules and other physical components is much reduced. This is shown in figure below which gives a side-by-side comparison of a generic HGHG Cascade FEL design appropriate for NLS, and the adopted HHG Cascade FEL design.

Work is now ongoing to develop the full three dimensional simulations of the FEL designs, ready for the publication of the NLS Conceptual Design Report in Autumn 2009.

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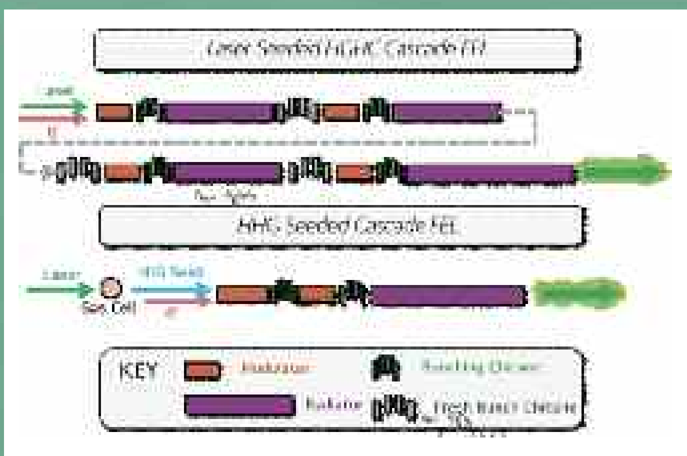

A side-by-side comparison of a generic HGHG Cascade FEL design appropriate for NLS, and the adopted HHG Cascade FEL design.

The ILC positron source is a major subsystem of the ILC and it is being designed by a large number of groups from around the world. ASTeC provides the leadership, coordination, and planning of this group of international experts and represents them at the numerous ILC project meetings. As well as this leadership role ASTeC has specific responsibility for the associated undulator system and the overall source integration and engineering.

ILC Positron Source

The proposed International Linear Collider (ILC) project requires such an intense source of gamma photons to generate the required number of positrons that the only really feasible way to create so many photons is with a 200m long short period superconducting undulator. ASTeC has been leading a project to prove the feasibility of such an undulator system for a number of years. Of course, the undulator will not be built in one piece but will actually be built up of about fifty undulator modules, each 4 m long. The world's first prototype 4 m long module has now been built in collaboration with Technology Department at Rutherford Appleton Laboratory and this has undergone testing and commissioning during the year. The design magnetic field of 0.86T has been successfully exceeded by about 30% during the tests which gives the project a very useful safety margin. The next step is to complete the commissioning of the cryo-cooler based cryogenic system and to then deliberately introduce sources of heat in the electron beam vacuum chamber to test how much energy can be tolerated before the magnet quenches. In addition, an EU sponsored project to look at more advanced superconducting materials in this application is about to start.

The skills and expertise that have been generated within STFC during this project are now being applied to other superconducting undulator designs that are more appropriate to conventional light sources, such as DIAMOND, or to Free Electron Lasers, such as NLS. Undulators based on superconducting technology will extend the photon range of existing light sources or enable new projects to be built with lower electron energy and so reduce the capital cost considerably.

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Linear Collider

The low emittance tuning studies and vacuum design for the ILC damping rings were part of ASTeC contributions to the European FP6 programme (EUROTeV). The test facilities at CESR-TA, Cornell & the AFT2 facility at KEK provide unique possibilities to test the low emittance tuning simulations for the damping rings and final focus system tuning for the beam delivery system.

ILC Damping Rings & ATF2

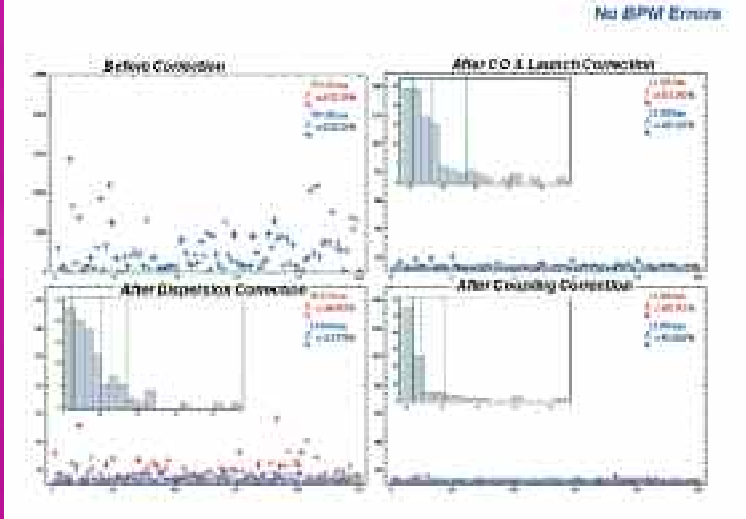
Extensive simulations were carried out during the last 4 year programme updating various low emittance tuning models for the damping rings. There was an opportunity to test these simulations at the CESR Test Accelerator at Cornell University, USA. As part of the Cockcroft team, ASTeC staff participated in commissioning shifts of the test accelerator and tested different methods for emittance reduction. Like the LC collider damping rings, the CESR-TA facility operates in a wiggler dominated regime. This makes it ideal for experimentally investigating the effects these magnets will have on the tuning of the accelerator using standard procedures, as well as providing an opportunity to investigate more wiggler specific tuning methodologies, such as dispersion waves and bumps. Understanding of these methods will be crucial for the future linear collider. The team was successful in measuring a vertical emittance of less than 40 pm, which is highly encouraging for this newly commissioned test facility.

ASTeC staff have continued to develop the detailed vacuum design for the ILC damping rings with mechanical designers in collaboration with University of Liverpool.

Accelerator Test Facility (ATF2)

The commissioning of the Accelerator Test Facility (ATF2) began in December 2008 at KEK in Japan. As part of an international collaboration, ASTeC has taken responsibility for developing software for orbit and dispersion correction. Both these tasks are vital to ensure the ATF2 goal of a vertical beam spot size of ~35 nm in the year 2010. As part of this work ASTeC staff members visited KEK to help with the ongoing commissioning of this exciting and important test facility for the beam delivery system of the future linear collider.

Dispersion and orbit correction in ATF2



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Vertical Tests of the ILC Crab Cavity

The ILC beam delivery system design requires crab cavities near the interaction region in order to compensate for the crossing angle between the incoming electron and positron beams. The phase control system of these cavities is critical to reach the luminosity goal. Two single cell cavities were tested at Daresbury Laboratory in a vertical cryostat to test the performance of the phase control system.

The crossing angle configuration of the ILC interaction region needs crab cavities to compensate for the loss of luminosity. A crab cavity solution of 3.9 GHz deflecting mode cavities has been developed for the ILC by ASTeC and Lancaster University as a part of the international collaboration. The phase control system of the crab cavities on either side of the interaction point needs to be better than 0.13° to achieve the optimal collision luminosity. In order to test the control system design, two single cell 3.9 GHz superconducting cavities were built and installed in a vertical cryostat. The coupling factors of the input and output couplers were tuned to be those required for the ILC cavities; which allowed the test to be representative of the performance expected on the real ILC beam delivery system.

View of the vertical cryostat during a test.

Superconducting Cavity Preparation

The superconducting cavities were prepared in an ISO 4 (class 10) cleanroom environment at Daresbury Laboratory. The cavities were cleaned with a high pressure ultra-pure water system in order to remove particulates from the surface. The input and output couplers were adjusted to reach coupling factors of 5.10^6 and 5.10^7 respectively on both the cavities. The couplers were then mounted on the cavity insert structure that supports them in the vertical cryostat.

Vertical Tests

The sealed cryo-vessel with the cavities inside was cooled down to 4.2K. A number of vertical tests were carried out, which demonstrated that the control system successfully keeps the cavity phases within the specified ILC limits. This two cavity synchronisation test performed at Daresbury Laboratory is the first superconducting cavity verification of this type in the world and highlights the collaborative effectiveness of ASTeC with its university partners from the Cockcroft Institute.

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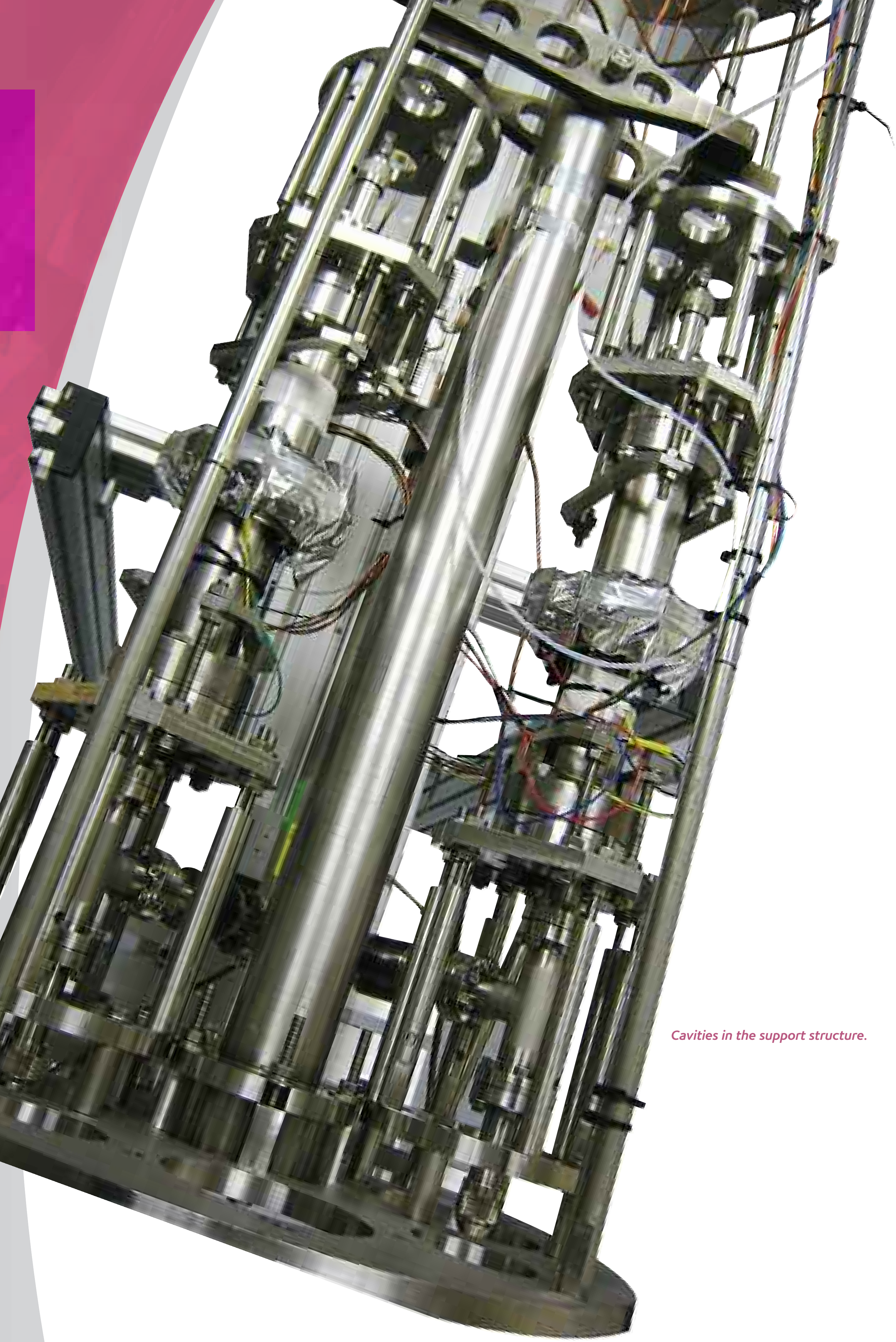


Cavities in the support structure.

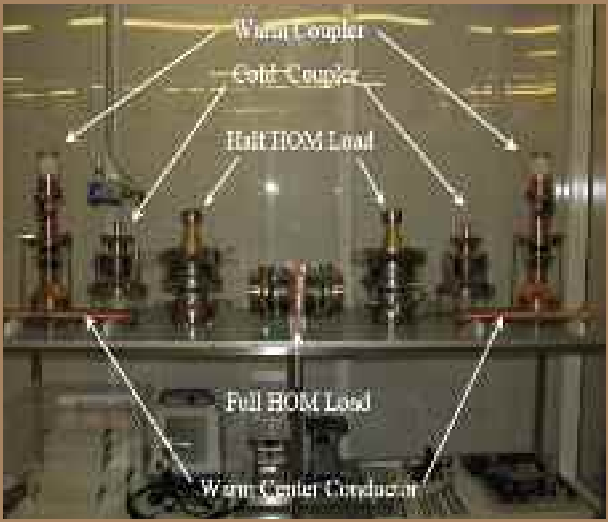
Daresbury International
Cryomodule Collaboration

The international collaborative development of an optimised cavity/cryomodule solution for high beam current applications such as ERL facilities has now progressed to final assembly and testing of the cavity string components and their subsequent cryomodule integration.

The collaborative programme to develop an optimised cavity/cryomodule solution for the demands of energy recovery linacs is being co-ordinated by ASTeC. The participating international partners (Cornell and Stanford Universities, Lawrence Berkeley Laboratory, FZD Rossendorf, DESY and Daresbury Laboratory) have identified appropriate sub-system solutions to achieve the fundamental requirements for this new cryomodule design, which will be installed on the ALICE accelerator and validated with beam in 2010.

Two niobium (Nb) cavities have been provided by DESY. These cavities were originally fabricated and tested together in TTF-I as a superstructure. LBNL, Daresbury and Cornell have developed a new design for the cavity end cells and associated beam-pipes, in order to propagate higher order mode power to ferrite-lined beam-pipe loads, and subsequently the cavities were sent to Cornell for modification. The two half-end cells of the 7-cell cavities have been successfully removed and new end cells and beam-pipe have been fabricated. It is planned to use Buffered Chemical Polishing (BCP) final treatment since the operating gradient is of the order of 20 MV/m. All flange designs were changed to knife-edge conflat interconnections, with brazing to Nb beam tubes similar to that used for the Cornell Injector cryomodule. The Titanium-Helium vessel and gas return pipe designs were modified to conform to the FZD Rossendorf cryomodule configuration.

Cavity Components at Cornell



Coupler and HOM absorber components at Daresbury

A blade tuner used for the TTF superstructure test was changed to a modified Saclay II tuner design so that it would fit inside the chosen cryomodule envelope. Input couplers and HOM loads were chosen to be identical to the proven devices used in the Cornell Injector module. The design of the cavity string is carefully laid out to fit inside the cryomodule. By utilisation of a cantilevered rail system, the sealed cavity string assembly can be rolled into the outer cryomodule vessel. Once positioned, the cavity string is then locked in place by a single titanium locking fixture, which then provides a longitudinal constraint on the mechanical component contraction when the cryomodule is cooled to cryogenic temperatures. In this way, the contraction occurs from both ends of the cryomodule towards this central, locked position. This ensures that the input couplers do not get exposed to excessive lateral stresses during cool-down. It is anticipated that both RF conditioned couplers and cavities will be available at Daresbury by June 2009. Final installation of the new cryomodule on ALICE is scheduled for May 2010, which will be followed by a thorough beam validation period.

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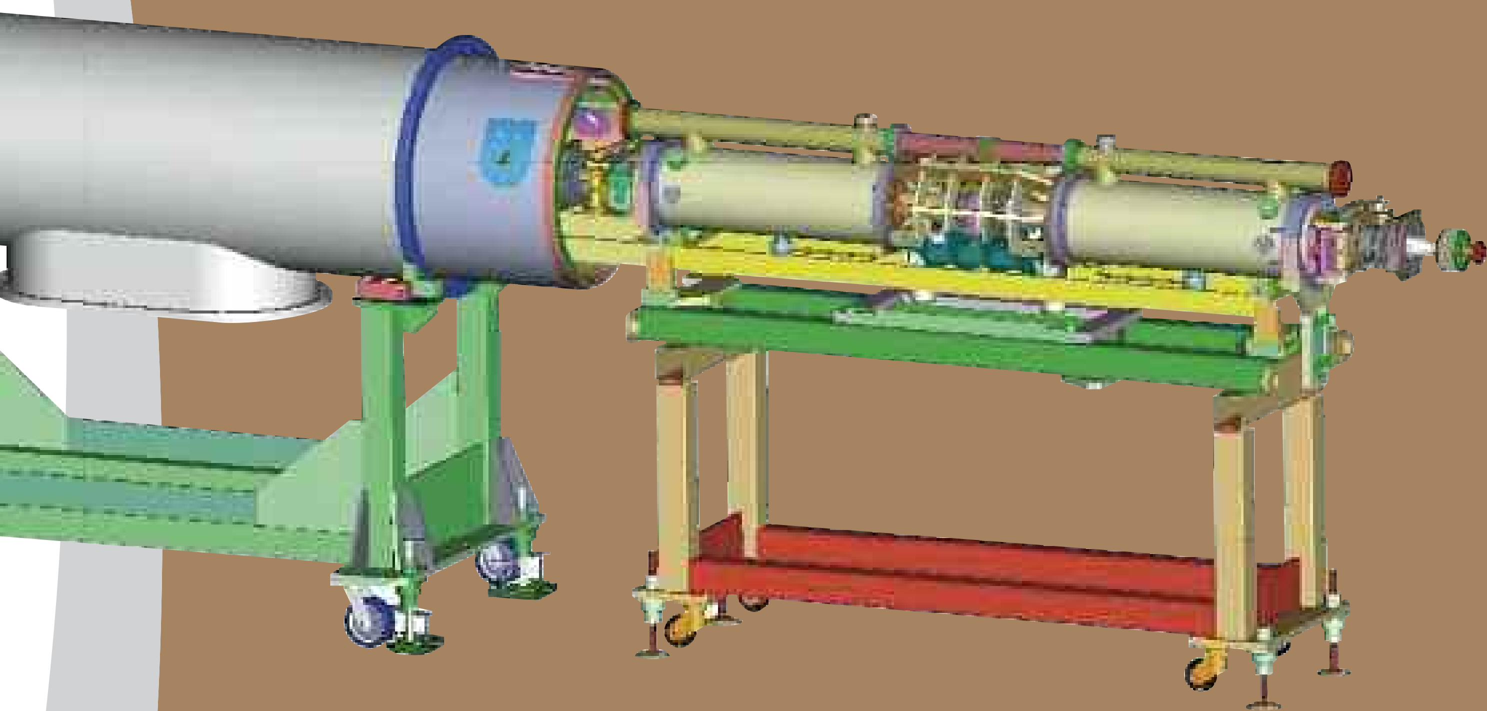
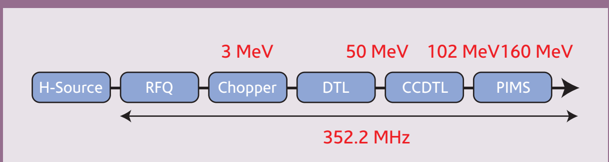


Cavity string integration into cryomodule

Extending the expertise gained on the collimation on the Linear Collider, ASTeC staff have taken up a new task to design the collimation system for the Linac4 machine which is a part of the new injector upgrade for the LHC at CERN.

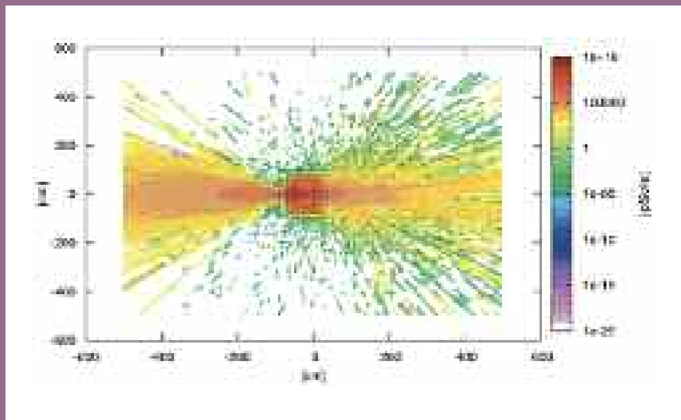
LINAC4 Collimation

Linac4 is a 160 MeV H$^-$ linac which will replace the existing Linac2, a 50 MeV proton linac, at CERN as a first step of the LHC injector upgrade. Collimation will help to reduce the activation of the machine at low duty cycles and it will certainly become mandatory at the high duty cycle (50 Hz) as injector for a future high-power superconducting linac (SPL). Different design options of collimator plus shielding are being studied in terms of collimation performance and activation/residual dose rate in surrounding areas.



Block diagram of Linac4.

The layout of Linac4 is sketched in figure above. First possible location for collimation without space constraints is after the PI-Mode accelerating Structure (PIMS). The collimator apertures have been investigated using 1/r beam halo distribution to absorb different power levels. A suitable material as well as the required shielding is being worked out in detail. Several options exist such as: graphite for the collimator; low Z material to avoid neutron generation, and borated paraffin, or concrete, together with lead to shield from the generated dose rate are the most probable options, though investigation is still continuing.



Residual equivalent dose rate, in pSv/s, after 1 month of operation and 1 day of cooling time for a graphite collimator with a concrete covered with lead shielding absorbing 50W of beam power at high duty cycle (50Hz) located 3.5 m after the PI-Mode structure.

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The Compact Linear Collider (CLIC) is a proposal to build a multi-TeV electron-positron collider led by CERN. The project is in the design study phase, and has already spawned several test facilities (CTF1-3) to demonstrate some of the technology. ASTeC is collaborating with CERN to develop a design for the drive beam deceleration line quadrupoles.

CLIC Quadrupoles

The CLIC design involves a unique 'drive beam acceleration' scheme, where a high-current, low-energy **drive beam** is decelerated in **power extraction structures** and used to accelerate a low-current, high-energy **main beam**. The project is in the design phase with an active test facility programme at CERN to demonstrate the feasibility of this concept. ASTeC is collaborating with CERN to develop a design for the drive beam deceleration line quadrupoles. This line is made up of 48 sectors, each 877 m long, and requires more than 40,000 quadrupole magnets in total to keep the beam focused along its length. Innovative, assembly line style manufacturing techniques will need to be developed to build this number of magnets in an acceptable timescale. Magnet design options are being examined at the moment. Although the magnets are not demanding in terms of strength, they need to be reasonably tolerant to mechanical errors to reduce the demands on the manufacture process.

Powering and cooling such huge numbers of magnets in a confined tunnel also needs consideration, and hybrid (electromagnet + permanent magnet) designs are being examined.

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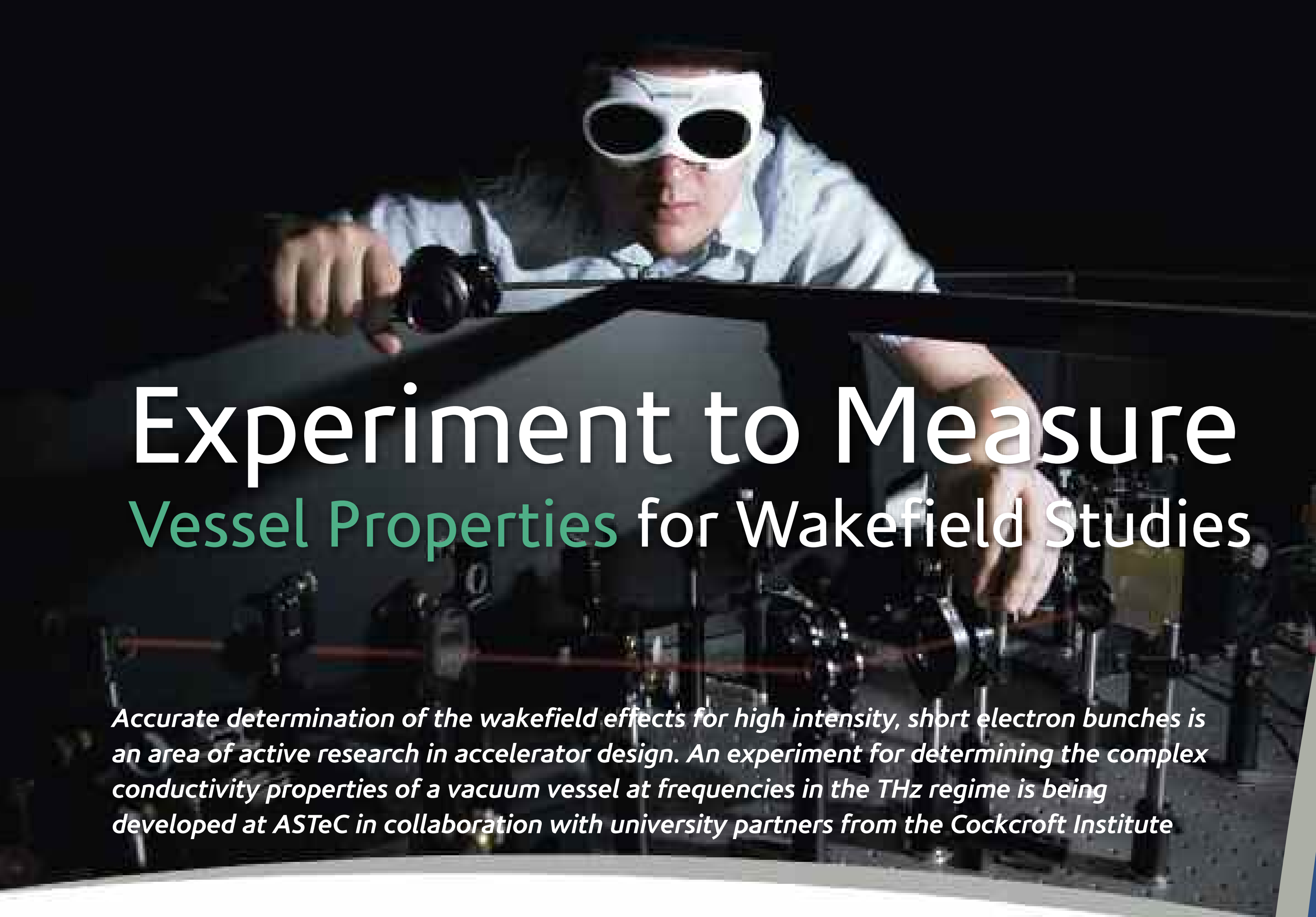

Experiment to Measure Vessel Properties for Wakefield Studies

Accurate determination of the wakefield effects for high intensity, short electron bunches is an area of active research in accelerator design. An experiment for determining the complex conductivity properties of a vacuum vessel at frequencies in the THz regime is being developed at ASTeC in collaboration with university partners from the Cockcroft Institute

The wakefield effects can have a significant impact on the accelerator design. The size of the wakefield depends upon the vessel material, dimensions and operating temperature and its effect can be to heat the vessel and to reflect back on the electron beam, possibly disrupting the beam properties. Typically the wakefield effects scale as an inverse power of the vessel radius and so using larger apertures can minimise the effects. However, in certain magnet designs, such as undulators, a narrow-gap vessel is desired to increase the on-axis magnetic field strength.

To accurately calculate the wakefield, the complex conductivity of the vacuum vessel is required. This conductivity depends on factors such as the frequency of the applied field, the temperature of the vessel and the level of impurities in the vessel material and so is generally difficult to characterise for real vessels. Another complication is that the short bunches that are used in next generation light sources generate electromagnetic waves in the Terahertz regime. These frequencies are between the well understood regimes of radio frequency waves and visible light waves, and are an area of active research in many different areas of physics.

An experiment for determining the complex conductivity properties of a vacuum vessel at frequencies in the THz regime is being developed at ASTeC in collaboration with the university partners from the Cockcroft Institute. The experiment relies on the sub-picosecond time-resolved measurement of pulsed THz radiation transmitted through a vessel, which acts as a waveguide. The waveguide can be modelled assuming the THz acts as an RF wave or as an optical wave, each theory giving different results. The experiment might show that neither theory is valid and thus requires a new theory. The proposed experiment will be able to measure the conductivity for different vessel materials, geometry and temperatures. This will be useful in calculating the effects of non-evaporable getter coatings, a thin film used for vacuum pumping narrow gap vessels. Also taking measurements at cryogenic temperatures will enable a better characterisation of the wakefield effects of superconducting undulators.

In a waveguide the electromagnetic field propagates as a series of orthogonal modes, for the dimensions used in accelerator vessels there can be many hundreds of modes propagating. This complicates the mathematical analysis of the experiment and so it is planned to fabricate some vessels that will only allow a single mode to propagate. For THz waves this means that the waveguide must be ~40 microns in size and collaboration is being set-up with the micro-engineering group at RAL to build waveguides at these dimensions.

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Superconducting Planar Undulators

After spending many years developing a superconducting helical undulator for the International Linear Collider positron source ASTeC and its collaborators from RAL have started to use the skills acquired from that successful project to develop a superconducting planar undulator that would be suitable for synchrotron light sources.

Superconducting planar undulators are a new technology just starting to be developed. These undulators have the potential advantage of providing a greater magnetic field compared to standard permanent magnet undulators already used in light sources and have a number of challenging technical features.

The amount of heating of the cold, 4 K vessel due to wakefields induced by the beam is of serious concern and so ASTeC is involved in a number of experiments to help measure this. The ColdDiag experiment aims to manufacture a test cryogenic vessel and, with appropriate diagnostics, measure the heating from an electron beam. It is planned to install the experiment on the Diamond synchrotron. Knowing the conductivity at these frequencies and at low temperatures is essential to accurately model resistive wakefield effects.

For third generation light sources an extremely precise periodic field is required so that higher harmonics of the fundamental radiation wavelength emitted by the undulator can be accessed. Traditional undulators are made of permanent magnet blocks and these can be shimmed and sorted to give a high field quality. A superconducting planar undulator consists of coils of superconductor wrapped around iron poles and due to the cryogenic system required the field cannot be corrected after manufacture. A typical superconducting undulator would consist of approximately 260 poles each about 3 mm length. Complex magnet modelling of the entire undulator including random displacement of the poles compared to the electron beam has been performed. The results show that if the poles are all aligned to less than 100 microns then the magnetic field will be of a high enough quality for a synchrotron such as Diamond. Although this is technically challenging to build it should be possible and the next stage of the project is to build a short prototype and demonstrate the field quality and strength.

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Vacuum Science
Facility Developments

The Vacuum science laboratory of ASTeC continued to develop the essential vacuum facilities to support various R&D activities. These facilities include ion pump testing, material characterisation for vacuum applications, bakeout coating, cleaning and surface analysis facilities and a photocathode preparation facility.

Surface Analysis Facility

ASTeC has made significant improvements in the understanding of GaAs photocathode physics with the help of a Ph.D. student (Manchester University). The surface analysis system has been used to improve understanding of handling procedures, heat cycling and hydrogen cleaning processes. This work was well received at the PESP workshop (Sources of Polarized Electrons and High Brightness Electron Beams) at JLab in October 2008 and has been critical in further improvements to ALICE cathode handling and activation. A major redesign of the system has been undertaken to further improve the range of experimental capabilities. This programme of work strongly influences ALICE photoinjector activities and it is anticipated that it will heavily influence the photocathode choices for NLS. Activations of GaAs in the vacuum science laboratory are now a routine procedure with quantum efficiencies in excess of 4% regularly achieved on ALICE.

Photocathode Preparation Facility

The design and build of a photocathode preparation facility has been completed. This 3 stage loadlock vacuum system will eventually be incorporated into the ALICE photoinjector to allow rapid cathode transfer. The current photoinjector can hold only a single photocathode, thus when a change is required a complete vent of the vacuum system is required followed by a lengthy vacuum bake process to obtain the correct vacuum conditions required for operation. The new system can hold up to 6 activated cathodes at any time and thus when a new cathode is required in the ALICE photoinjector one can be transferred quickly without any vacuum intervention. This will be a major advantage to ALICE operations and will further improve cathode performance.

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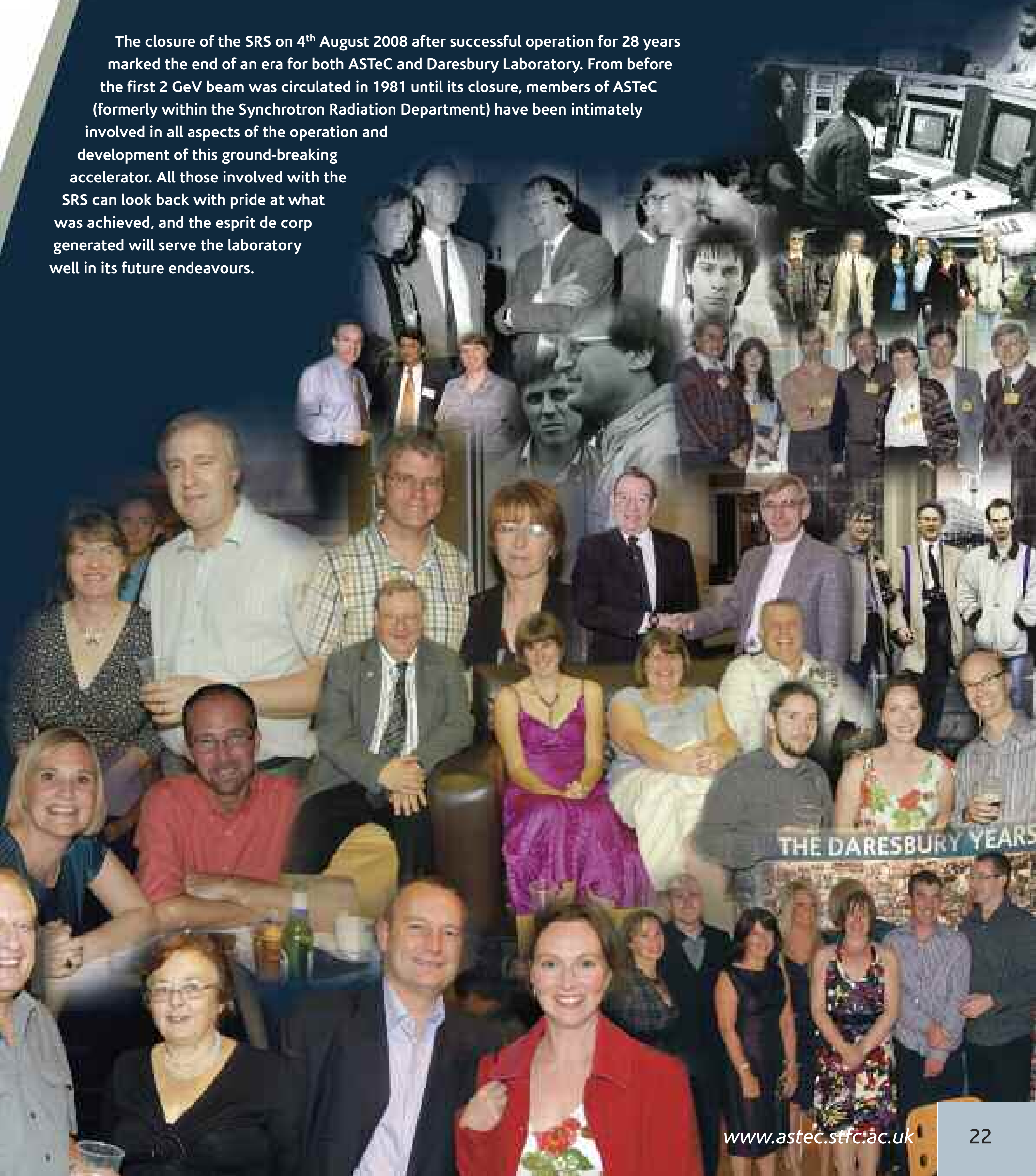
THE SRS –
AN END OF AN ERA

The closure of the SRS on 4th August 2008 after successful operation for 28 years marked the end of an era for both ASTeC and Daresbury Laboratory. From before the first 2 GeV beam was circulated in 1981 until its closure, members of ASTeC (formerly within the Synchrotron Radiation Department) have been intimately involved in all aspects of the operation and development of this ground-breaking accelerator. All those involved with the SRS can look back with pride at what was achieved, and the esprit de corp generated will serve the laboratory well in its future endeavours.



European Synchrotron Light Source Workshop

The sixteenth European Synchrotron Light Source workshop was held at Daresbury on the 27th and 28th November 2008. More than 30 accelerator scientists from across Europe met to discuss both 3rd and 4th-generation light sources and the technology and methods that underpin their operation. The focus of the meeting was the discussions surrounding developments and issues of third generation light sources. With many of the participating laboratories now also developing next generation sources the opportunity was taken by the community to discuss the issues and the developments of these sources. The discussion in the final session was focused on available techniques and technologies which could be used to stabilize and improve the output of light sources.

ALICE Stakeholders Meeting

The first ALICE Stakeholder's Meeting was held on the 24th February 2009. Scientists from STFC and collaborating universities met to discuss the wide range of research that could be undertaken on ALICE. One of the hot topics discussed was how the technology, instrumentation, accelerator and photon science on ALICE could contribute to future light sources. Planned highlights for the coming year include:-

- Utilisation of the unique in the world, tissue culture laboratory for THz research
- Commissioning of ALICE Free Electron Laser during 2009, the first such device to operate in the UK
- The injection of the first beam from ALICE into the demonstrator accelerator EMMA, the World's first NS-FFAG accelerator. This is a novel concept for fast acceleration and the accelerator will be commissioned towards the end of 2009
- Compton Back Scattering

etings and Visits

ALPHA-X

The ALPHA-X project was originally funded in 2002 through the RCUK Basic Technology Programme, with an objective to develop innovative laser-plasma acceleration solutions with particular application as drivers of radiation sources. Based at Strathclyde University it comprises a national consortium of HEIs plus the Rutherford Appleton (RAL) and Daresbury Laboratories. ASTeC has mainly contributed design expertise but also two undulator magnets for emission experiments (described in previous Annual Reports).

Following construction of the photo-gun driven apparatus and early electron beam trials a Workshop was held at Daresbury on the 13th and 14th November 2008 to review aspects of the beam physics and technology challenges, especially the short bunch diagnostics issues. A very successful meeting reviewed progress and addressed future planning. The Workshop also attracted some broader contributions on synergetic programmes.

MICE

Collaboration Meeting (CM21)

The 21st MICE (Muon Ionization Cooling Experiment) collaboration meeting was held at the Cockcroft Institute from 4-7 June 2008. The meeting was attended by MICE collaborators worldwide. The meeting was focussed on reviewing the status of the worldwide individual projects contributing to the MICE experiment; viz. the magnets, solenoids, hydrogen absorbers, cryogenic system, RF cavities and power system and the infrastructure project that will come together to provide the MICE physics experiment. The collaboration reviewed several areas of the project and planned the management of the commissioning periods.

ILC Positron Source Collaboration Meeting

The positron source for the International Linear Collider was the subject of a three day workshop hosted by ASTeC at Daresbury Laboratory in October 2008. The workshop was very lively as this is one of the most challenging areas for the whole of the ILC. The delegates also took part in a tour of the ILC target prototype experiment that is hosted by Daresbury Laboratory whilst they were here.

Joint Accelerator Workshop

Advanced accelerator activities are proceeding both at RAL and Daresbury Laboratory, not only involving ASTeC staff but also those of other departments. For many years a workshop has been held, alternating between the two host Laboratories, to share scientific and technical experiences and to ensure that the professional communities maintain good contacts. This year RAL hosted the event and almost 30 Daresbury based ASTeC staff travelled down to attend it. Reviews of ISIS progress, including upgrade options, and DIAMOND recent developments were followed by a series of talks on the accelerator test facilities: ALICE, EMMA, FETS and MICE. Updates followed on the collaborative Linear Collider and Neutrino Factory programmes, and also the NLS design studies. Finally a number of accelerator R&D talks included superconducting RF developments, NEG pumping research and laser wakefield progress. ASTeC staff were also able to tour some of the RAL based facilities. Such collaborative workshops are invaluable in sustaining productive relationships across the portfolio of diverse STFC accelerator based projects.

Institute Of Physics:
Particle Accelerators and Beams Group Launch

The Institute of Physics (IOP) is the premier professional body for the discipline in the UK but has never included a Subject Group dedicated to accelerator physics topics. This situation was redressed in 2008 by an initiative led by ASTeC staff to form such a Group and that resulted in a major workshop of interested UK scientists meeting at IOP headquarters in London in September, culminating in formal recognition of a new Group by IOP Council in November. This positive development will serve to enhance the status of the discipline, provide a national forum for strategic consultation and sustain and develop professional standards. ASTeC, with strong support from the Cockcroft and John Adams Institutes and other HEIs, is committed to the success of this professional development that will have a positive impact on STFC programmes.

FFAG'08

More than 40 people converged on Manchester in September 2008, attracted by the prospect of hearing about the EMMA FFAG. This was the first time the workshop had been held on UK shores, and the strong attendance including many young people was indicative of the enthusiasm triggered by the promise of this new type of machine. FFAG'08 featured the use of FFAGs for muon acceleration in a Neutrino Factory, low intensity proton and ion beams for cancer therapy, multi-megawatt proton drivers, neutron production, and ADS as drivers of sub-critical reactors. The international flavour of the workshop was demonstrated by presentations on projects such as RACCAM in France, PAMELA in the UK, ERIT and PRISM in Japan, and FFAG studies both for therapy and for eRHIC in the USA. Following the UK's initiative in funding the world's first non-scaling FFAG, a special session was devoted to EMMA, where details were provided on every aspect of the accelerator from theory to hardware, current status and future operation.

This was followed by a visit to the Daresbury Laboratory, where tours were provided of ALICE and visitors were able to see some of the novel EMMA magnets and RF systems.

The workshop dinner, on the final evening, was held in the Board Room at Old Trafford, preceded by a guided tour of the ground and the players' changing rooms. With a mix of slightly bemused overseas visitors who had probably never heard of Manchester United Football Club and local people whose footballing sympathies almost certainly lay elsewhere, the dinner was well attended and formed a suitable ending to an excellent workshop.

All the presentations given during FFAG'08 are available at:

http://www.cockcroft.ac.uk/events/FFAG08/programme.htm

Workshops, Mee

X-band RF Structures and Beam Dynamics Workshop

ASTeC and the Cockcroft Institute hosted the ICFA sponsored X-band RF Structures and Beam Dynamics Workshop from 1st -4th December 2008. The workshop was attended by over 80 worldwide experts within this field. The purpose of this workshop was to explore a range of RF and beam dynamics issues associated with X-band accelerators. In order to achieve high gradient accelerating voltages, room temperature X-band structures are a natural choice. Synergies between light source and collider activities were highlighted along with the potential use for this technology for medical and security applications.

Surface Conditioning for Ultra High Vacuum

A business brokering meeting entitled 'Surface Conditioning for Ultra High Vacuum' took place at the Daresbury Laboratory on 25th February 2009. The event was initiated and organised by ASTeC vacuum science group and Q3i (Q3 Innovations, LLC) with a support of KITE (Knowledge, Innovation, Technology Enterprise).

The aim of the event was to bring together STFC funded scientists involved in the development of surface conditioning, surface coatings and getter technologies with representatives of the UK industry. Discussions concentrated on industry requirements for vacuum technologies and further proposals for interdisciplinary and industrial partnerships focussed on preparation and conditioning of vacuum vessel surfaces including NEG coatings.

Speakers from ASTeC, Manchester Metropolitan University, CERN and RAL gave an extensive overview of different techniques for surface conditioning for ultra high vacuum, including a novel NEG coating technology. Technology transfer experts from CERN and STFC elaborated how the industrial partners can receive these technologies in a few available schemes. The event also included a tour of the ASTeC vacuum laboratory.
The event was very successful and the participants confirmed that it was a good idea to organise such an event on useful topics. The event underlined that ASTeC is a well recognised centre of expertise where industry can learn and participate in knowledge exchange.

Further information can be found at:
http://www.scitech.ac.uk/KE/Events/suface_conditioning.aspx

Important Visits

The year started and ended with two major political visitors to Daresbury Laboratory each of whom spent time with ASTeC staff whilst visiting ALICE, EMMA and the Cockcroft Institute. On 2nd April 2008 the Minister for Science and Innovation, Ian Pearson was thoroughly briefed and he was followed on 26th March 2009 by the Secretary of State for Innovation, Universities and Skills, John Denham, in a high profile visit in which recognition was given to the importance of accelerator based activities as a core STFC activity. Once again ALICE and EMMA, two of ASTeC's most high profile projects, proved a major attraction to government representatives, as they do to other stakeholders.

Particle Physics Master Class

The annual Particle Physics Master Class at Daresbury Laboratory attracted more than 100 students from 7 schools. This year saw a significant expansion of this event, with direct support of ASTeC and the university sector of the Cockcroft Institute and an enhanced range of activities intended to draw attention to the link between fundamental physics and the actual particle accelerators which drive this aspect of science.

Challenges for the visiting students this year included a tour of the ALICE energy recovery linac accelerator and a hands-on experiment to measure the particle beam energy, demonstration of RF accelerating technology, plus interactive computer simulations which gave students the opportunity to examine particle collisions in the ATLAS detector on the LHC at CERN, and practical hands-on sessions aimed at conveying an understanding of electromagnetic forces. There were also talks on particle physics and the history of particle accelerators at Daresbury, and the day was rounded off with a brief review of the important points, and a light-hearted quiz with a trophy for the best student from each school. Significant focus was also placed on the engineering challenges faced in delivering the accelerators and detectors needed for this work, emphasising the range of roles and skills which are needed by the STFC to deliver the cutting-edge science which is our hallmark, and making the link to the government's recently launched 'So What? So Everything' *[http://sciencesowhat.direct.gov.uk/] campaign.*

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The Cockcroft Institute

The Cockcroft Institute (CI) has been in existence now for five years of its first core funding cycle 2004-2012 which was agreed by the founding stakeholders, the Universities of Lancaster, Liverpool, and Manchester, the NWDA, ASTeC/CCLRC and PPARC. STFC which has taken over the funding agency role from its predecessors CCLRC and PPARC launched a major review of Cockcroft in 2008.

This review included a request for CI to produce a bid document which outlined the achievements of the Institute and its plans for the future, identifying the required resources to support a programme extending to 2017. Throughout the summer of 2008 Cockcroft staff, including ASTeC, undertook the major task of analysis and documentation of the important contribution that CI has made to accelerator research and development over its first four years of existence. This material was then combined with the plans and vision for how that contribution could be developed and expanded over the next decade to form the final bid document, which was submitted in October 2008.

As part of the STFC review process, CI also hosted a visit from an STFC international review panel in February 2009. This visit consisted of presentations from Cockcroft staff including key ASTeC contributors of the bid, combined with tours of technical facilities including the ALICE accelerator. This process of review has highlighted the impressive progress that has been made in the evolution of the Institute from its infancy to a world leading accelerator centre in only five years with very substantial ASTeC contributors. Although STFC has yet to make public the results of this review exercise, the centre has proved it is well positioned to make considerable impact in the future.

Tall Ships Event

In June 2008, David Dunning and Julian McKenzie from ASTeC took part in a one week voyage aboard the Tall Ship TS Royalist as part of the Science and Technology Facilities Council (STFC) graduate training scheme. The event delivered many tremendous experiences being away from normal working roles and was enjoyed by most.

As part of the STFC graduate scheme, the Tall Ships event has been run every other year with the aim of personal development, particularly developing understanding of personality types and team roles. It is mainly aimed at members of the graduate scheme but other STFC employees at a similar stage in their careers are also included. The event provides an opportunity to get to know people at a similar career stage in other areas of STFC and hence to see the organisation from different perspectives; a project set in advance of the voyage to come up with a 'Vision for STFC in 2015' helped to prompt these discussions.

The voyage began from Milford Haven in South Wales and set sail towards Ireland, the crew was split into watches of six, with the watches taking turns to sail the ship and assist with mess duty etc. Ireland was reached at nightfall and the night was spent aboard the ship in Waterford harbour. Next was a trip up the coast to Arklow where shore leave granted the crew the opportunity to explore Ireland - or search for a much-needed shower! When not busy on watch or mess duty, the graduates took part in various team activities such as an emergency rescue scenario, personality and team roles evaluations and discussions of the impending 'Vision for STFC' presentations. Plus relaxing and enjoying experiences such as dolphin watching!

A particular highlight of the trip was the final leg into Liverpool in the very early hours of the last day. The wind picked up and the ship swayed as the graduates tried to hold a straight course. Liverpool's Albert dock was the final destination and the Royalist was moored outside the TATE art gallery. A barbecue was served up and the highlights of the trip were recalled in an amusing quiz.

Three weeks later the graduates were reunited at RAL for a debriefing session and to present their 'visions'. A large audience including senior STFC management listened attentively as the four groups outlined their various strategies, and then had the opportunity for questions. The group bonded well despite – or in reaction to – the difficult living conditions and sometimes onerous duties. The experiences and friendships will be remembered, and will hopefully prove useful in the future.

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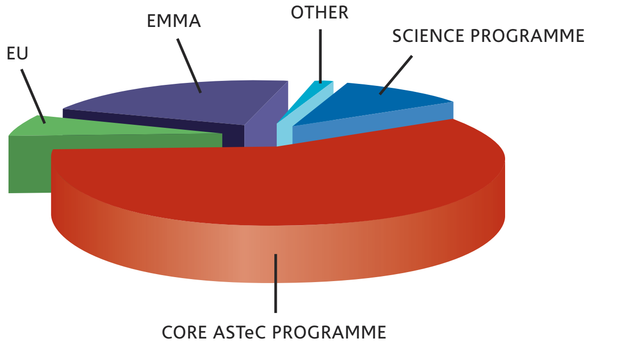
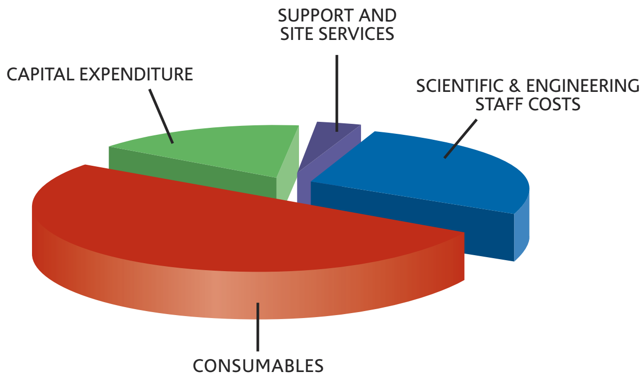
Financial Summary

INCOME SOURCES 08/09	£K
SCIENCE PROGRAMME	1159
CORE ASTeC PROGRAMME	5865
EU	620
EMMA	2394
OTHER	185
	10223



EXPENDITURE 08/09	£K
SCIENTIFIC & ENGINEERING STAFF COSTS	2831
CONSUMABLES	5220
CAPITAL EXPENDITURE	1784
SUPPORT AND SITE SERVICES	388
	10223



EXPENDITURE BY PROGRAMME 08/09	£K
LC-ABD PROGRAMME	820
UK-NF PROGRAMME	893
HIGH POWER PROTON ACCELERATORS	939
HIGH BRIGHTNESS ELECTRON ACCELERATORS	1667
UNDERPINNING RESEARCH	1597
NEW INITIATIVES	271
OTHER PROFESSIONAL ACTIVITIES	822
EU	437
EMMA	2613
OTHER REPAYMENT WORK	164
	10223