provides lower collision rates than the proton-proton option.

For 10 T dipoles giving 16.6 TeV total collision energy the estimated luminosity using CERN's improved antiproton source is $2.7 \times 10^{30}\ cm^{-2}\ s^{-1}$. The introduction of electrostatic beam separators to eliminate unwanted proton-antiproton collisions (as is now done in the SPS) would boost the luminosity to 13.5×10^{30} but bites into the cost savings of the single aperture approach.

Pending further studies, the proton-antiproton option is disfavoured. Proton-antiproton collisions (useful for comparison with proton-proton) could be achieved in one of the apertures of the proton-proton configuration.

Electron-proton collisions

With protons in the upper ring and electrons in the lower, electron-proton collisions are a natural bonus. The radiofrequency power which will be installed to boost the energy of the LEP beams could either be used to maintain the electron beam at its highest energy, or to boost the electron current at lower energy to increase the luminosity.

The total collision energy would thus be between 1.4 and 1.8 TeV (compared with 314 GeV in the HERA Collider now being built at the German DESY Laboratory in Hamburg), and the luminosity between 10^{31} and 10^{32}.

Experiments

Initially, the four LEP experiments would continue to look at electron-positron collisions but would have to get out of the way of the proton beams, when these are in use. For protons, new experiments could be mounted in other areas of the tunnel (the LEP tunnel has eight large vertical shafts). In time, some or all of the LEP experiments could be transformed.

However the production of suitable superconducting magnets for the collider would require a vigorous development programme.

The future seen from Erice

A few specialists have been finding time to think beyond the LEP electron-positron Collider now being built at CERN and the SSC Superconducting Super Collider proposed for the US to the physics needs and accelerator possibilities of the future. Despite the modest effort, a lot of progress has been made in sorting the wheat from the chaff amongst proposed accelerator schemes and in defining crucial features of future machines.

Some of this thinking came together at a seminar on 'New Techniques for Future Accelerators' held in Erice, Sicily, from 12-17 May. It concentrated on linear electron-positron colliders with beam energies of at least 1 TeV and luminosities of at least 10^{33} per cm^2 per second. Earlier approaches concentrated on reaching accelerating gradients as high as possible (with reduced machine length and cost in mind). This, though still obviously very desirable, now carries less emphasis and other features are more prominent.

Two of these features were confronted by Bob Palmer in one of his usual stimulating talks. They concerned the input to the linacs, where reaching the desired luminosities will need very low emittance beams, and the output from the linacs, where luminosity again dictates concentration of the particle bunches in miniscule cross-sections when they collide.

Emittance should ideally be as low as 10^{-8} but, if this could be slackened off to 10^{-7}, it is not so frighteningly far from what should be achieved soon in the damping rings for the big linear collider nearing completion at Stanford. It could however require bunches spending a long time in damping rings which, to have a reasonable repetition rate, could involve tens or hundreds of such rings. Ugo Amaldi called attention to this problem because these rings could be as complicated and costly as the linacs themselves.

Palmer proposed, instead of the comparatively slow damping of conventional rings, to incorporate the idea of Klaus Stefan and use high field wigglers as the bending magnet structure to speed up the damping. Such a lattice could damage other beam properties too much but it is an approach to the important task of achieving low emittances in short times.

At the other end of the machine, the necessary colliding bunch cross-sections are likely to be of the order of a tenth of a micron; there the problem of the 'final focus' speaks for itself. Palmer discussed an idea which is misleadingly called 'super-disruption' since it uses the 'disruptive' focusing effect of the fields in a bunch acting on the particles in another bunch passing through. The idea is that each bunch intended for high luminosity collision is immediately preceded by a larger diameter bunch which serves as a focusing lens as the collision bunch passes through. An enhancement of about thirty could be feasible by this trick.

Having raised the problems of the beginning and the end, there comes the middle — the linacs themselves. The aim is to find the most cost-effective way of converting power drawn from the mains into power in the colliding beams. The presently considered possibilities were neatly reviewed by Kjell Johnsen who has become involved in this work as Chairman of the CERN Linear Collider (CLIC) Panel set up to advise the CERN Long Range Planning Committee led by Carlo Rubbia.

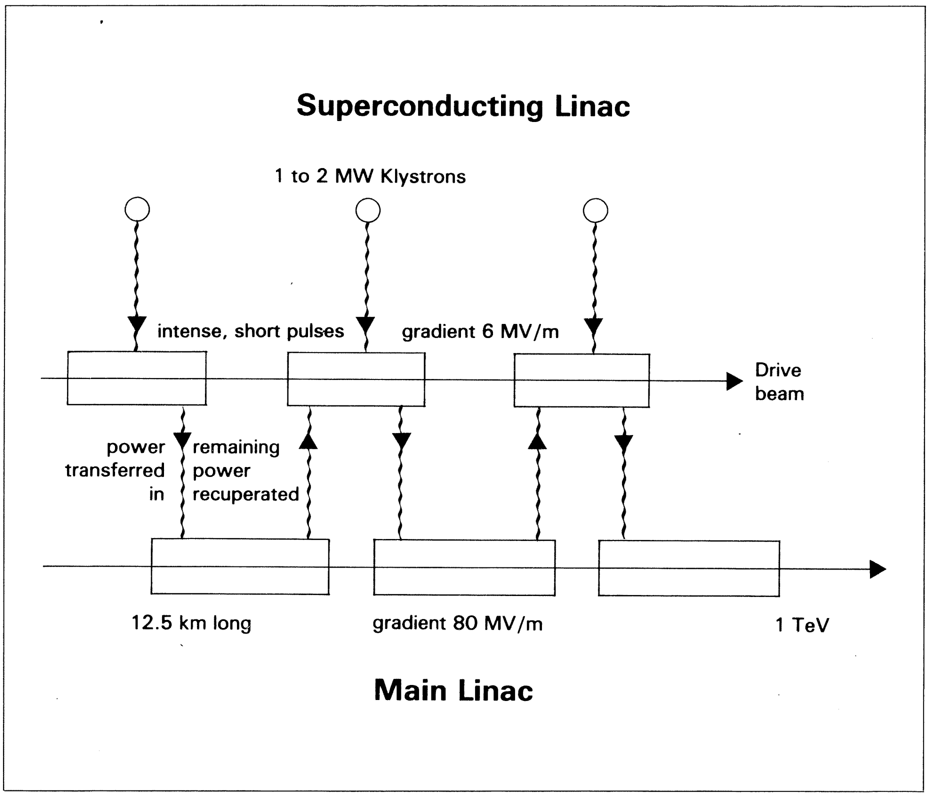
The GeV per metre accelerating gradients which can be generated in plasmas by beating two laser beams have made the beat-wave scheme the most alluring of all and it must obviously be thoroughly investigated. Recent work was described by Vittorio Vaccaro. Experiments at Los Angeles and Quebec confirm the basic principle and further tests are being prepared at Rutherford Appleton. However grown men, particularly those involved in controlled thermonuclear fusion, have been known to weep at the thought of taming a plasma and the payoff of the technique is likely to take a very long time.

Though not discussed at Erice, a much simpler idea for using the high gradients in plasmas was put forward by Chen, Huff and Dawson in 1984 which involves using the fields left in the wake of intense bunches fired through a plasma. Theoretical work is going on at Stanford (Ron Ruth, Chao, Phil Morton and Perry Wilson) and at CERN (Simon van der Meer), where Ted Wilson has proposed experimental tests using the new LEP electron linac.

Tom Weiland described progress at DESY in investigating the wakefield technique to achieve high gradients. A hollow beam, 10 cm diameter, travels down the rim of a cylindical structure to generate high gradients along the axis where the beam to be accelerated will pass. In April they achieved the necessary hollow beam accelerated to 7 MeV. They hope to be ready for experiments at the end of this year.

Some of the interest in this wakefield route to high gradients has waned since experiments at Stanford showed that over 150 MV per metre can be obtained in conventional structures provided

An idea for a future linear collider using a high current drive beam travelling down a superconducting linac alongside the main linac.



Erice's Centre for Scientific Culture

Erice is a small pre-medieval city huddled on a hill with splendid views over the countryside and the sea near Trapani in Sicily. Its age and evident history give a deep sense of participating in continuing human culture; its isolation turns off the everyday world making it an ideal environment for thinking.

It is here that Antonino Zichichi set up the Centre for Scientific Culture named after the Italian theoretical physicist Ettore Majorana. Two monasteries (San Domenico and San Rocco) and a former palace of the Viceroys of Sicily (which became a Convent named San Francesco) have been restored and provide the lecture halls, the accommodation and the offices for the Centre.

By now over seventy Schools, covering almost all branches of science, hold regular Conferences at the Centre and many of them have high international reputation in their respective fields. For example the International School of Subnuclear Physics draws the leaders of our own research every year and there are Schools on Nuclear Physics, Experimental High Energy Physics, Cosmic Ray Astrophysics, Accelerator Physics, and Instrumentation.

Zichichi is particularly proud to have initiated a series of Seminars on Nuclear War where scientific implications are debated with participants from all the major powers. From these Seminars in 1982 emerged the 'Erice Statement' on Science, Technology and Peace which has since been signed by over ten thousand scientists worldwide.

It is a brilliant achievement to have created and sustained such a wide ranging and evidently successful forum for science. These days, it seems to be particularly in Italy that people have the vision, the courage and the political will to give practical expression to belief in the cultural value of science.

the power pulse is not long. This led to the proposal from Bill Willis to switch short pulses of power, for example using photocathodes, rather than using conventional r.f. power. Bob Palmer has recently extended this in a 'micro-lasertron' and tests are planned at Brookhaven to see just what it is possible to get out of photocathodes where currents like1 kA per cm^2 might be called for.

Another way of getting power in an appropriate form into a high gradient structure is a two-beam scheme promoted by Andy Sessler. It involves a high current, low energy beam (topped up in energy en route by induction accelerator modules) travelling alongside the main linac and generating microwave power to feed the linac by passing through free electron laser sections. Don Hopkins reported the Berkeley/Livermore work which has given encouraging results on the ELF free electron laser and has produced very elegant high precision engineering in the production of pencil-thin accelerator structures.

A major problem with this scheme could be retaining the correct timing between the drive beam and the main linac beam. This is circumvented in a new scheme developed by Wolfgang Schnell in the context of the CLIC thinking. This received a lot of interest at Erice because the concepts are not so remote from presently mastered technology.

It is another two beam system with a high current drive beam travelling through a superconducting linac (which keeps average power down) alongside the main linac. A parameter list has a drive linac of 15 GeV powered at 350 GHz using high efficiency (70 per cent) klystrons of 1 MW giving accelerating gradients of 6 MV/m along an active length of 2.5 km. These figures are all achievable today and ought to be considerably exceeded by the time such linacs are built, with the exception that the superconducting linac would be required to handle very intense bunches (around 4×10^{11}).

The drive linac would be coupled to the main linac by using very short drive bunches which would interact directly with travelling wave transfer structures at the main linac frequency. (There are similar ideas developed by Ugo Amaldi and Claudio Pellegrini using free electron laser sections to create coherent radiation at the main linac frequency.)

In principle high values of transfer efficiency can be obtained, and the ratio of the accelerating gradients is proportional to the ratio of the linac frequencies. Thus setting the main linac at 30 GHz would correspond to an accelerating gradient of 80 MV/m even with the low estimate of 6 MV/m in the superconducting linac. For 1 TeV main linac energy the active length would be 12.5 km.

The outstanding advantages of the scheme are the fact that it is possible to recuperate into the superconducting linac the energy remaining in the main linac structure after the main linac bunches have passed, and the fact that the drive beam is highly relativistic so that the timing relative to the main beam would remain in phase all along the machine. The main problem is the need to have very intense (some 4×10^{11} electrons) drive bunches which are very short (a millimetre or less).

Nevertherless this looks the sort of system that could be put on the table for construction in some ten years or so if a Laboratory has sufficient courage to launch a serious research and development programme. This was an encouraging thought to carry away from Erice.

By Brian Southworth