Around the Laboratories

SUPERCOLLIDER
The vultures of summer

As the CERN Courier goes to press, the economic vultures are once more circling around the young Superconducting Supercollider lamb. On June 24, the US House of Representatives approved an amendment to stop the 87-kilometre SSC proton collider, now being constructed underground in Ellis County, Texas. With the Senate vote the next step, SSC proponents and opponents are getting their legislative acts together.

Last year, the summer Senate decision reversed an earlier anti-SSC House vote. However unlike last year, when the House vote was buried deep inside a major annual package of energy-related items, this year's motion was SSC-specific. The anti-SSC House vote was also larger: 280-150 as against 232-181 in 1992. Allegations of frivolous SSC expenditure forced US Energy Secretary Hazel O'Leary to don appropriate sackcloth and ashes, and Texas state funding - for long a major SSC pillar - has been deferred while Washington makes up its mind.

With the US preoccupied by its huge budget deficit, many sacrificial lambs are on the market. The SSC is not the only one. But whatever the outcome of this summer's US legislative wrangles, these painful rites will have left their mark. If the SSC is cancelled or delayed, enquiring young minds, eager to grapple with front-line research problems, will turn away from timescales measured in decades rather than years. The sudden evaporation of such a vast project will impoverish the world scene.

The doyen of fundamental physics, Victor Weisskopf, points to a recent shift in science emphasis. Once the fundamental research spotlight was firmly focused on 'cosmic' science - basic physics and astronomy. In the light of new awareness of environmental problems, the emphasis has switched to what he calls 'terrestrial science'. Here immediate applicability and rapid pay-off is the warcry.

This myopic trend is a pity. It is fundamental science which is at the roots of everything else, Weisskopf points out. 'Cut these roots and the whole tree will wither.' (We will return to this Weisskopf message in the next issue.)

In cancelling the SSC, the US may reduce its financial debt, but it will emerge a poorer nation culturally and intellectually.

The Editor

CERN
TeV Electron-Positron Linear Collider Studies

The world's highest energy electron-positron collider - CERN's LEP, with a circumference of 27 kilometres - will also be the last such machine to be built as a storage ring.

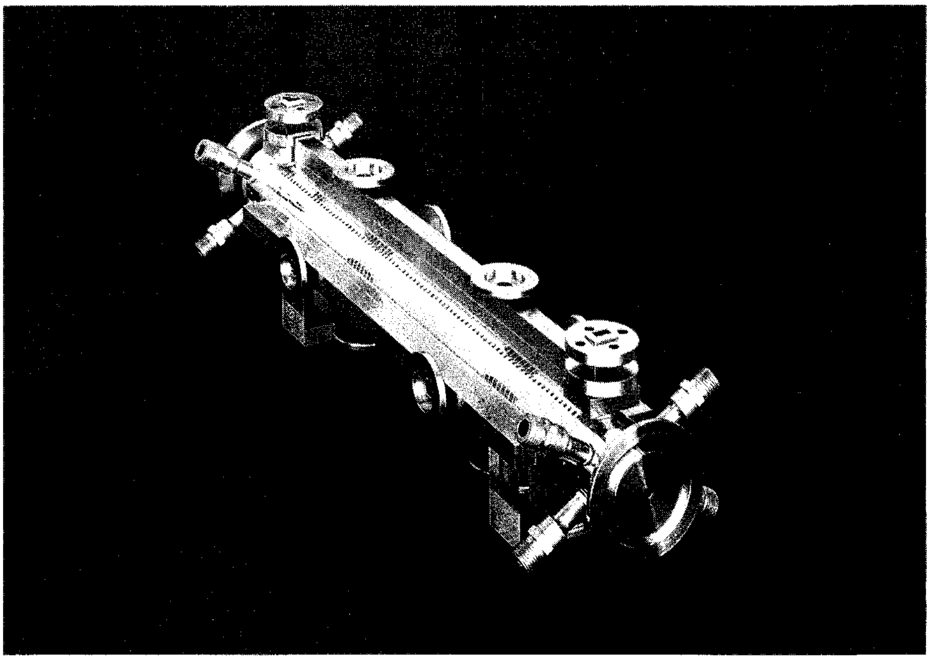
With interest growing in electron-positron physics at energies beyond those attainable at LEP, the next generation of electron-positron colliders must be linear if prohibitive synchrotron radiation power losses are to be avoided.

Very high energy linear colliders present many technical challenges but mastery of SLC at Stanford, the world's first electron-positron linear collider, is encouraging. The physics issues of a linear collider have been examined by the international community in ICFA workshops in Saariselka, Finland (September 1991) and most recently in Hawaii (April 1993). The emerging consensus is for a collider with an initial collision energy around 500 GeV, and which can be upgraded to over 1 TeV. A range of very different collider designs are being studied at Laboratories in Europe, the US, Japan and Russia.

Following the report of the 1987 CERN Long Range Planning Committee chaired by Carlo Rubbia, studies for a 2 TeV linear collider have progressed at CERN alongside work towards the Laboratory's initial objective - the LHC high energy proton-proton collider in the LEP tunnel.

The CERN Linear Collider (CLIC) study group, led by Wolfgang Schnell, has concentrated on a 30 GHz collider with a superconducting

Protoype accelerating section for the main linac of the CLIC scheme being studied at CERN.



drive linac power source. The high frequency allows the high accelerating gradient of 80 MV/m, resulting in a collider 2x4 km long for 500 GeV collision energy and 2x16 km long for 2 TeV. The drive linac power source eliminates the need for large numbers of klystrons, so most of the accelerator tunnel will be empty of active radiofrequency elements.

The design is technologically very ambitious, but with its fundamental simplicity has enormous potential for cost savings, as well as being particularly suited for TeV range energies. The dominant difficulty in a 30 GHz accelerator is however the degradation of the beams due to wakefields. Wakefields deflect the beams when there are misalignment of accelerator components, making the beams blow up. For this reason the CLIC study emphasizes beam dynamics, alignment and the development of very precise accelerator components. In fact CLIC accelerating sections need to be made to dimensional tolerances of a few microns.

A technique of manufacturing accelerating sections from brazed diamond machined discs has been developed at CERN and is now well established. The discs are diamond-tool machined in industry to tolerances of 1 to 2 microns by firms specializing in aspherical optical components. Two full-length, fully-engineered 86-cell prototype accelerating sections have been made, and 10 MW of 30 GHz power has been generated in the CLIC test facility (CTF) using one of the prototypes. The power corresponds to a gradient of 40 MV/m in the section, already half the nominal CLIC gradient.

In parallel, an 11.4 GHz accelerating section has been made using CLIC technology as part of a collaboration with KEK, Japan. This section has achieved 135 MV/m peak and 85 MV/m average accelerating gradients - values limited only by available power (January, page 32).

Accelerating sections must be installed and aligned to microns over tens of metres in the accelerator tunnel. To do this an active alignment system, measuring and compensating for tiny movements in real time, has been developed using accelerating sections and beam position monitors on silicon carbide girders connected through a system of link rods. The ends of the girders are moved by commercial 0.1 micron-resolution stepping motors, with alignment reference from a photodiode/lens/photodetector system. An alignment test facility in a disused beam transfer tunnel has demonstrated the micron capability of the alignment system, and a new 10 m long alignment test facility is under construction to demonstrate larger scale system behaviour.

Beam position in CLIC will be measured with sub-micron resolution and a few micron precision in resonant monitors fabricated using the same diamond machining technology as the accelerating sections.
A prototype beam position monitor (BPM) has been manufactured and tested in the lab using a small antenna scanned by micromovers. Sub-0.1-micron movements of an antenna have been resolved with this first prototype and measurements made to 3-micron precision.

Maximum physics with the accelerated beams from the two linacs means focusing the beams down to 8 by 90 nanometre spots where they collide head-on at the interaction point. A chromaticity-corrected final focus system also minimizing energy spread from synchrotron radiation in the focusing elements has been developed.

A major and unique CLIC feature is the drive beam power source which replaces the klystrons of more conventional designs. The drive beam travels parallel to the main beam about 1 metre away and

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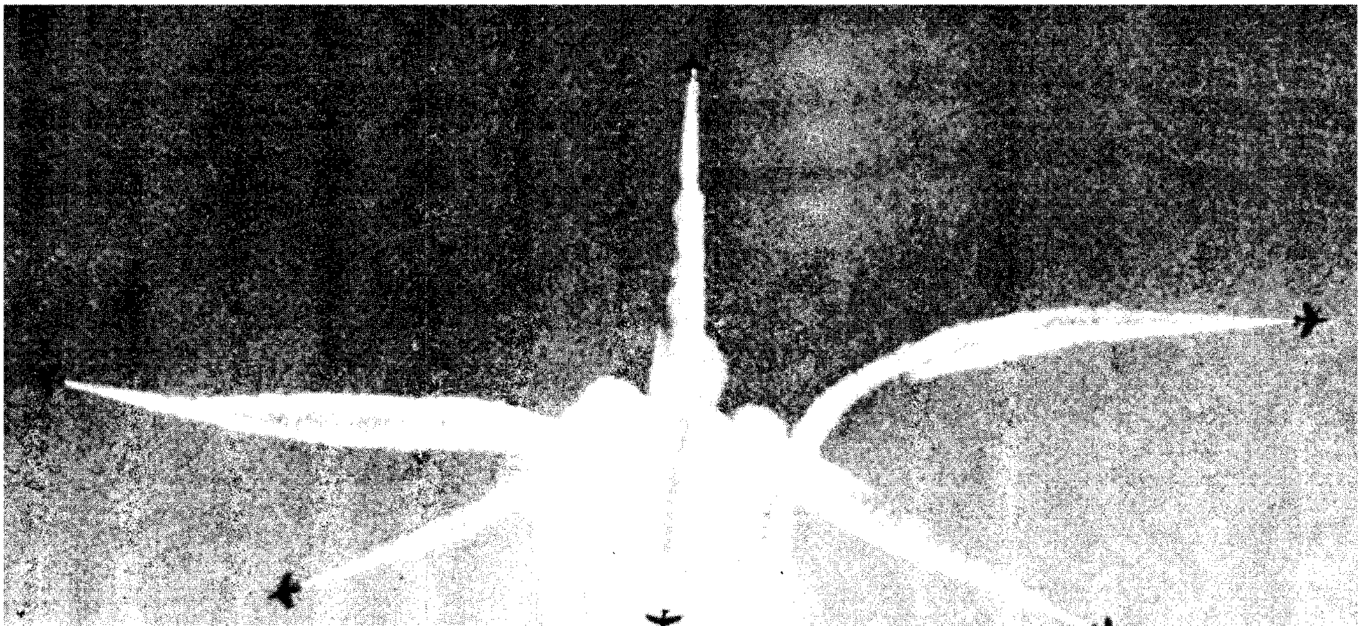

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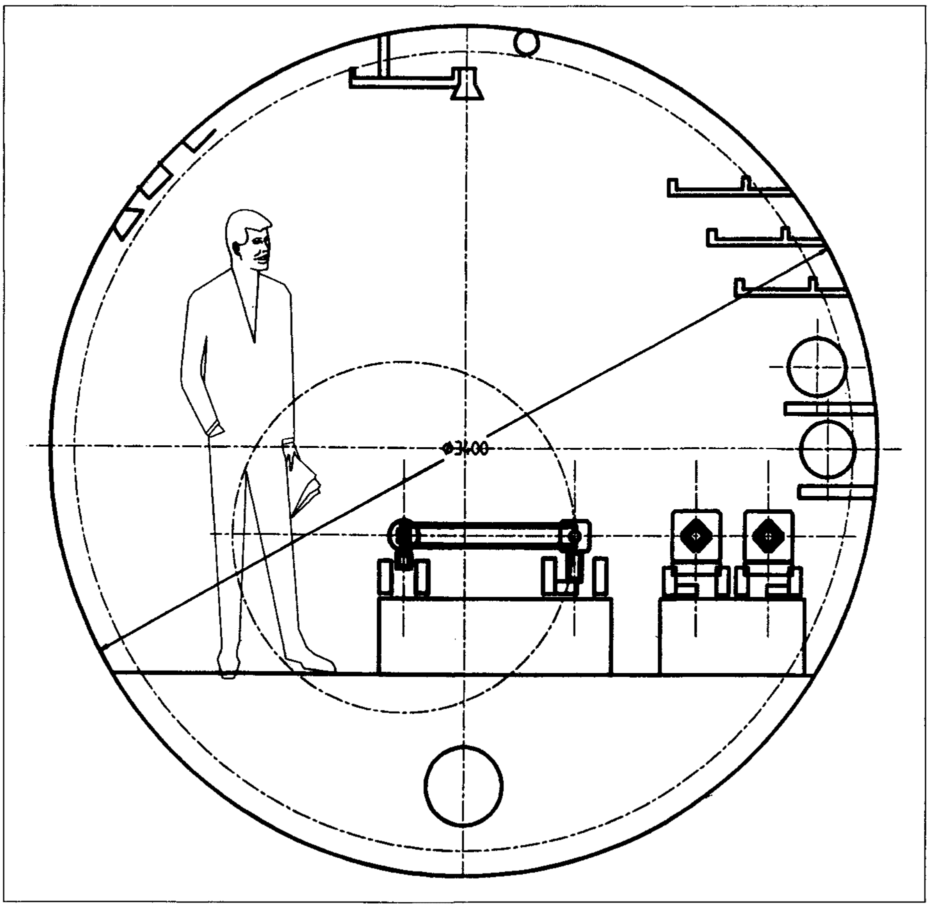


The CLIC tunnel cross-section. Left to right, the drive linac, connecting waveguides, the main linac, and then two transfer lines for drive and main linac injection. Compact technology gives the tunnel an uncluttered look.

30 GHz power is transferred in specially developed structures. The performance of the transfer structure has been verified by computer calculations and tested with stretched wire measurements in a 9 GHz scale model. A 30 GHz prototype is under construction.

The drive beam has a lower energy, an average of a few GeV, but higher current than the main beam, in a train of bunches spaced by 1 cm. Several possibilities of producing this drive beam are being looked at - laser-illuminated photocathodes in radiofrequency guns, an induction linac and a free electron laser, and conventional radiofrequency bunching with magnetic bunch compression.

The first method is being tested in the CTF. A train of short (15 psec) electron bunches generated using a radiofrequency gun with a laser-driven photocathode are accelerated to 60 MeV in a spare LEP injector linac accelerating section.

With demonstration of CLIC technical feasibility well underway, attention shifts towards cost projection. This will be accomplished with the test facilities and through detailed cost estimates of individual components, although the cost of many elements of a linear collider, like the tunnel itself, can be estimated from past experience.

By Walter Wünsch

More polarization in LEP

Handling spin-oriented (polarized) beams at CERN's LEP electron-positron collider has become an important physics goal and reflects the excellent progress being made in mastering the world's largest accelerator and colliding beam machine.

The electrons coasting round the 27-kilometre ring behave like tiny magnets and tend to line up with the machine's magnetic field. Working in the other direction are whole series of depolarizing resonances, strongly enhanced by the high LEP energy, which push the electron spin out of line.

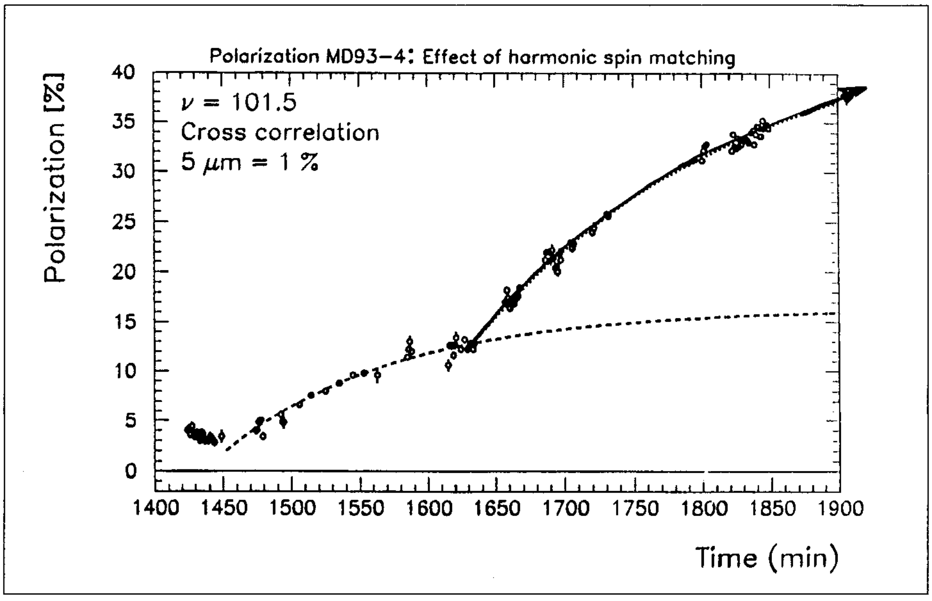
Initial studies in 1990 saw a LEP polarization level of around 10 per cent, a surprise to those pessimists who thought the effect would never be seen in LEP. In 1991, with polarization improved to 18 per cent, accurate energy calibration by resonant depolarization was on the cards.

After a lot of work in the 1992-3 winter shutdown, conditions in LEP this year are a 'dream'. Magnets have been realigned, the beam orbit monitoring (BOM) and the polarimeter upgraded, while the decision to go for a split 90/60 degree betatron phase advance in the arcs (after trying each phase advance separately) is paying off. The polarization level has increased to 35 per cent, with fitted asymptotic levels ranging from 40 to 50 per cent. Harmonic spin matching of a subset of the spin resonances allowed the asymptotic level to be pushed from a 'natural' 25 per cent to the high levels presently observed. It works by feeding in tiny perturbations to the closed orbit over some 7 per cent of the LEP circumference.

The successful compensation of the depolarizing effect of the experimental solenoids by a pattern of orbit bumps opens the possibility of energy calibration in physics conditions. LEP's beam energy can be fixed to a fraction of an MeV in 45 GeV, after correction for tiny effects due to earth tides and temperature. This is below the physics requirement of 1 to 2 MeV, leaving a safety margin.

These successful polarization and other machine studies have not detracted from the main physics business of LEP. Despite an abrupt 1993 commissioning with less chance to check everything out beforehand, the collision score and Z detection rate got off to a good start and continue to climb impressively, promising a bumper LEP harvest. On 1 August LEP's design luminosity of 1.3 x 10^{31} was exceeded in all four experiments simultaneously.

The payoff of artificially compensating for depolarizing resonances which would otherwise mar spin performance in CERN's LEP electron-positron storage ring.



CERN
Intensity records

On 28 July, CERN's veteran 28 GeV PS proton synchrotron (commissioned in 1959) attained a new record intensity with 2.703 x 10^{13} protons per pulse at 14 GeV. Its previous record, dating from 1959, was 2.57 x 10^{13}.

The record followed careful adjustments in the PS itself and in its Booster injector synchrotron. High intensity beams of about 2.5 x 10^{13} protons per pulse were sent to the SPS downstream as a rehearsal for next year's neutrino run. This allowed the SPS to obtain a new intensity record of 3.73 x 10^{13} protons per pulse at 450 GeV.

DESY
First physics from HERA

At the HERA collider at DESY, the dreams of electron-proton scattering experiments are becoming reality, with electron-proton collisions at an energy of about 300 GeV opening up new physics.

Information about the distribution of quarks, antiquarks and gluons inside the proton can now be obtained with a precision never attained before. But there are many other reactions which could provide surprises at these energies.

Collisions between HERA's 820 GeV protons and 26.7 GeV electrons started in June 1992. With a total of about 30 inverse nanobarns of integrated luminosity collected up to the winter shut-down (November 1992), the H1 and ZEUS experiments published results which gave a foretaste of things to come.

As most electron-proton interactions take place through the exchange of a photon, this was the first reaction to be studied. When the scattered electron emerges at a very small angle, the mass of the exchanged virtual photon is close to zero and the photon nearly real.

This opens up the study of photon-proton collisions at energies in the region of 200 GeV. The total cross-section for these reactions previously known up to 18 GeV collision energy was 118 microbarn, and was predicted to rise with energy.

From data taken in the first few weeks, the H1 and ZEUS collaborations determined this cross-section to be about 160 microbarn at a mean energy of 200 GeV. This is in excellent agreement with extrapolations