

LHC goes global

As CERN's major project for the future, the LHC sets a new scale in world-wide scientific collaboration. As well as researchers and engineers from CERN's 19 European Member States, preparations for the LHC now include scientists from several continents. Some 50 per cent of the researchers involved in one way or another with preparations for the LHC experimental programme now come from countries which are not CERN Member States.

Underlining this enlarged international involvement is the recent decision by the Japanese Ministry of Education, Science and Culture ('Monbusho') to accord CERN a generous contribution of five billion yen (about 65 million Swiss francs) to help finance the construction of the LHC. This money will be held in a special fund earmarked for construction of specific LHC components and related activities.

To take account of the new situation, CERN is proposing to set up a totally new 'Associate State' status. This is foreseen as a flexible bilateral framework which will be set up on a case-by-case basis to adapt to different circumstances. This proposal was introduced to CERN Council in June, and will be further discussed later this year. These developments reflect CERN's new role as a focus of world science, constituting a first step towards a wider level of international collaboration.

At the June Council session, as a first step, Japan was unanimously elected as a CERN Observer State, giving them the right to attend Council meetings. Introducing the topic at the Council session, Director General Chris Llewellyn Smith sketched the history of Japanese involvement in CERN research. This began in 1957



At the June meeting of CERN's governing body, Council, Kaoru Yosano (left), Japan's Minister of Education, Science and Culture, and CERN Director General Chris Llewellyn Smith paint one eye of a 'daruma' talisman, marking commencement of Japanese collaboration in CERN's LHC proton-proton collider project. In Japan, daruma dolls are traditionally kept in a shrine awaiting the successful fulfilment of an ambition, when the remaining eye is painted.

and has gone on to include an important experiment at the LEAR low energy antiproton ring using laser spectroscopy of antiprotonic helium atoms, the new Chorus neutrino experiment using an emulsion target, and a major contribution to the Opal experiment at the LEP electron-positron collider.

In welcoming the development, many Council delegates looked forward to a fruitful new collaboration. They also pointed to the achievements of Japan's KEK Laboratory and its collaborative schemes, now a focal point of the world particle physics scene.

A surprise item was the speech, in Japanese, by A. Herdina of the Austrian delegation. Strictly speaking Mr. Herdina was breaking the rules, as only English, French and German are catered for at CERN Council meetings, but in this instance everybody was happy that the Austrian delegate made his point.

Speaking at the Council meeting (in

English) in his new capacity as Observer State spokesman, Kaoru Yosano, Japan's Minister of Education, Science and Culture, recalled his country's international tradition of cooperation in particle physics. Under a long-standing US/Japan agreement, Japanese teams are prominent in the CDF collaboration at the Fermilab Tevatron in the US, where the sixth ('top') quark was discovered earlier this year.

At the 'memorable Council meeting', Minister Yosano pointed out that his country's wish to contribute to the LHC project at an early stage. He said that large scientific projects like the LHC 'captivated the imagination of citizens' and looked forward to the opening of new scientific frontiers.

Discussions with other major Non-Member States, involved in the LHC programme, including the US, Canada (see page 15), Russia, Israel and India, are underway and in some cases negotiations are at an advanced stage.

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Proposed layout of the LHC ring, serving four experiments.

A walk round the LHC

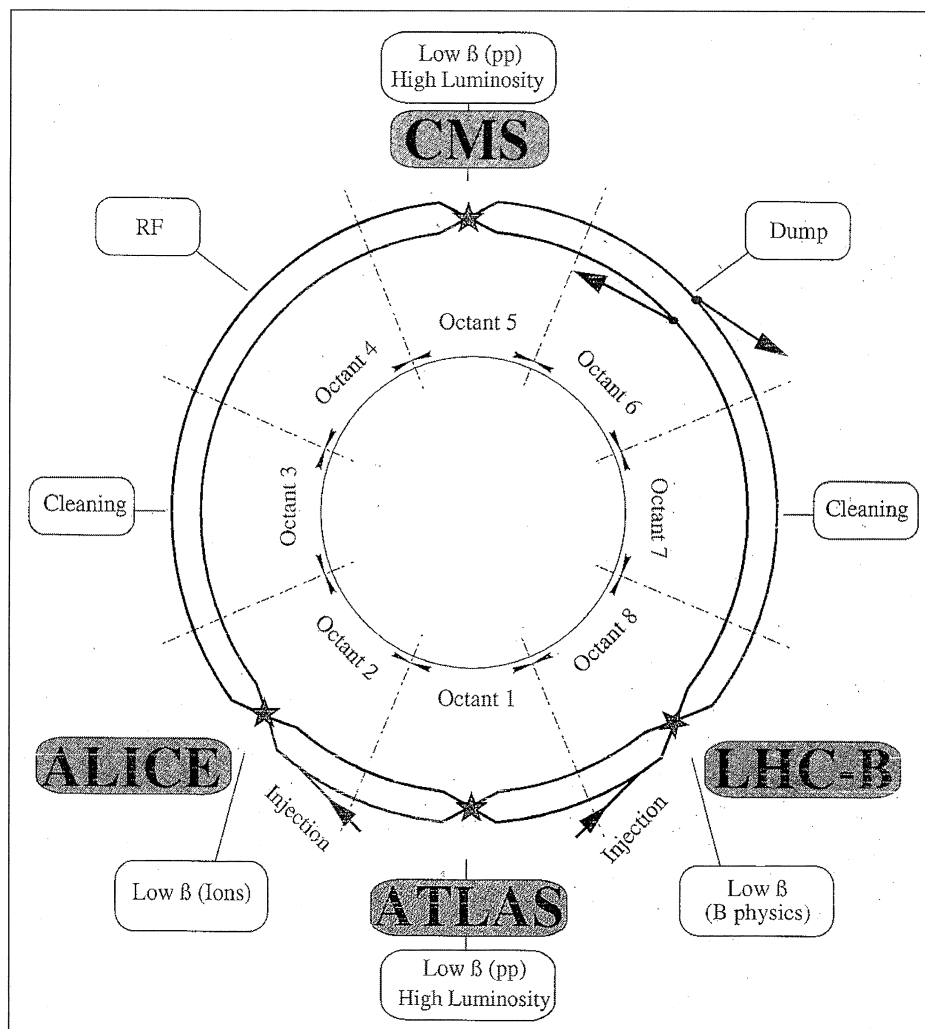
To expedite the commencement of excavation and construction work for the LHC, the general layout of the tunnel has been essentially finalized. The LHC and the LEP electron-positron collider share CERN's 27-kilometre tunnel with its eight symmetrically-placed access shafts, where the even-numbered regions 2, 4, 6 and 8 are currently occupied by LEP's L3, Aleph, Opal and Delphi experiments respectively.

The LHC layout foresees four beam crossing points, each one tailored for a planned experiment, with services such as power supplies and cryogenics in the even-numbered points, where maximum use can be made of existing LEP facilities.

At Point 1, nearest the main CERN site, the LHC beams will cross in a low beta (compressed beam) insertion and provide high luminosity collisions for the ATLAS detector (June, page 9).

Proceeding clockwise round the machine, at Point 2 the beams will cross in a similar insertion which will be mainly used to provide the highest possible luminosity ion-ion collisions for the ALICE detector. The straight section at Point 2 will also contain the injection elements for the clockwise LHC proton ring - a horizontally deflecting current septum and a horizontal fast kicker magnet. This is somewhat different to the system initially envisaged but requires a more straightforward modification of the tunnel.

The injection lines for both LHC rings will use normal conducting magnets rather than the previously proposed superconducting ones. These injection lines will only be



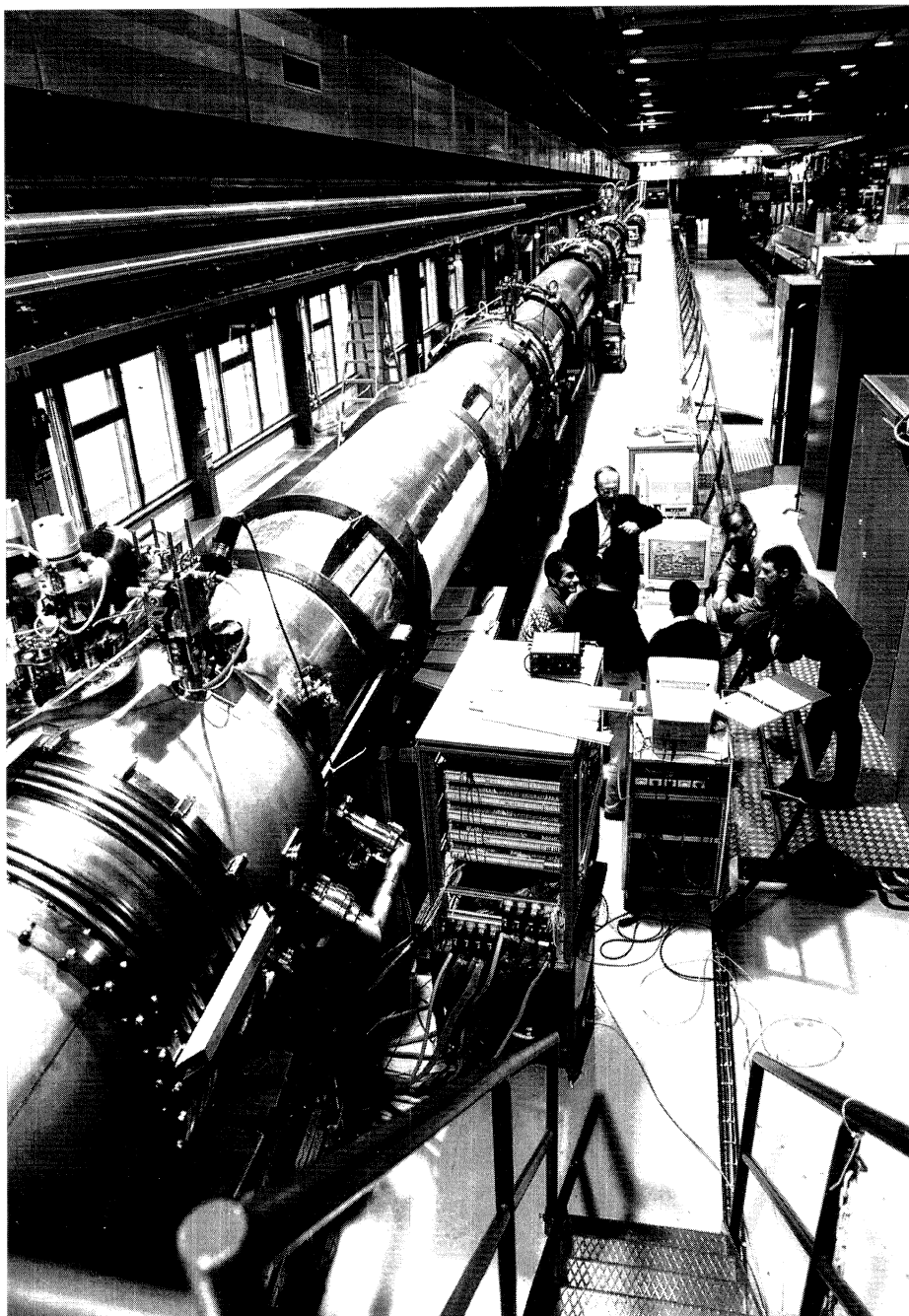
required for a few hours per day and an expensive cryogenic system is unrealistic.

At Point 3, the LHC beams will not cross, but will pass through a special insertion with normal conducting dipoles forming a double "dog-leg" on each beam. This will trap any secondary particles from a set of collimators designed to remove peripheral protons which might otherwise go on to strike the vacuum chamber and risk quenching neighbouring superconducting magnets.

Another non-crossing point is Point 4, where the beams will be pushed

further apart (to almost 50 cm) to allow room for superconducting radiofrequency cavities on each beam. This recent innovation, which is still under study, aims to reduce the effects of beam loading, particularly difficult to handle during injection, and significantly reduces the overall radiofrequency power requirements. Separate accelerating cavities for the two beams will also increase flexibility, allowing acceleration and collision of different particles in each beam - for example protons against ions.

After careful study, it has been



The LHC string test continues to give encouraging results. As well as the superconducting magnets, interest focuses on such questions as quench protection system and propagation.

decided that at Point 5 the beams will cross in an identical layout to that of Point 1 to provide high luminosity collisions for the CMS detector (June, page 5).

At Point 6, the beams will not cross but will pass through a special insertion with fast extraction elements to dump both beams if required into blocks which absorb the 2 x 334 MJ of stored energy.

At Point 7, another non-crossing point, room temperature magnets will be equipped with collimators to remove particles which would escape the acceleration cycle.

At Point 8, the beams will cross in a similar insertion to that of Point 2, this time for a dedicated B-physics experiment. The upstream straight section of the anti-clockwise ring will

be used for injection.

Although as definitive as possible, this scenario retains some flexibility for the experimental programme at a relatively modest cost.

The LHC string test

The LHC string test assembled towards the end of last year (January, page 2) continues to give encouraging results. In the 1995 tests, nominal current was achieved (corresponding to a field of 8.36T) without a quench and when the current was further increased, the first quench occurred at 12,773 A, equivalent to a dipole field of 8.64T. Operation and tests have regularly used the region between nominal

and maximum current (9 T maximum field).

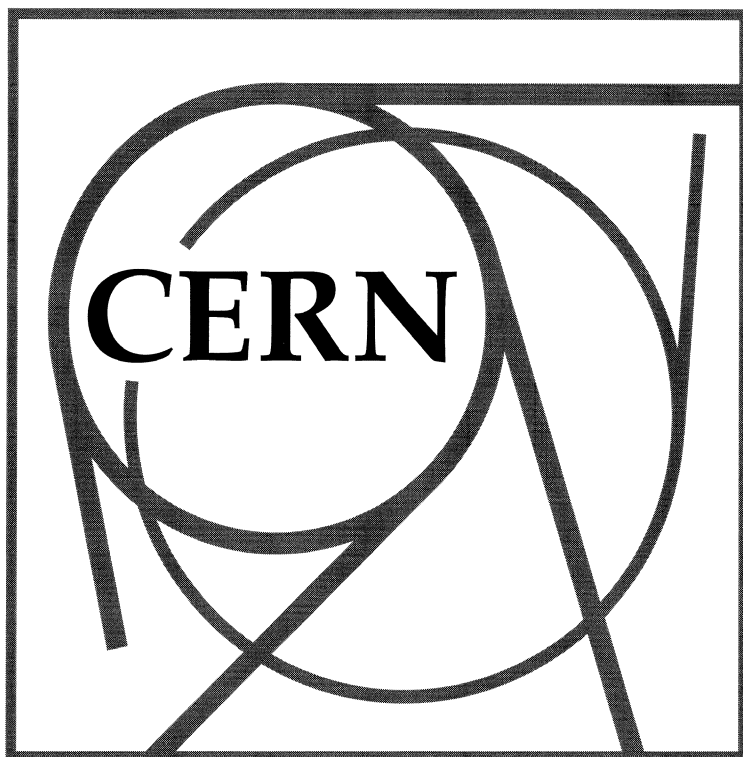
In this initial phase, the test string uses two 10m dipole prototypes and a 3 m quadrupole prototype, together with dummy corrector magnets, making a total length of 35 m. The 110m support beam could eventually accommodate a full cell. It is mounted on a 1.4% slope, the steepest gradient in the LHC ring, and, as in the LHC itself, the magnets are installed in a single continuous cryostat.

Initial results have been so encouraging that during a scheduled interruption to upgrade the cryogenic plant a third dipole magnet will be added to the string, making it look almost like a full 50 m half-cell. This latest dipole, from Ansaldo, has already been thoroughly bench-tested.

Later these test magnets will be replaced by 14.2 m prototypes, a second generation quadrupole prototype and a complete set of corrector magnets to provide a full half-cell LHC prototype, with attendant service systems very close to the final configuration.

Each half-cell of the LHC's normal lattice will consist of four superconducting magnets - three twin-aperture dipoles and one twin aperture quadrupole - installed in a short straight section together with other elements such as correction magnets and beam observation pickups. The total length of 53 m constitutes the basic unit for the cryogenic feed, powering etc.

Besides testing magnets, the string test assembly has now also become an excellent testbed for the highly specialized cryogenics, power, vacuum and control systems needed to operate the LHC at superfluid helium temperatures (1.8K), the first



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Around the Laboratories

Cryogenic modules containing superconducting radiofrequency cavities being prepared for installation in CERN's LEP collider, where they will provide additional accelerating power to take the electron and positron beams to higher energies.

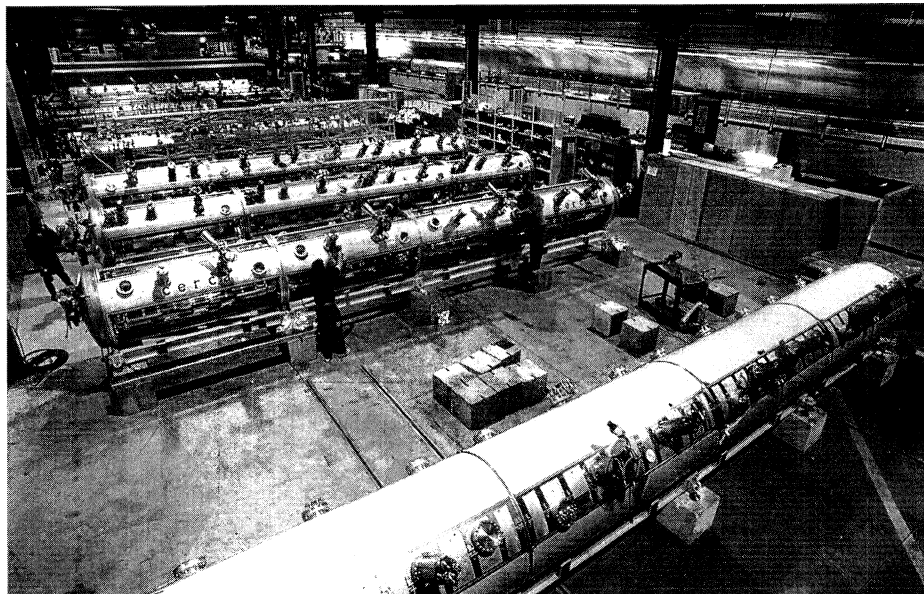
(Photo CERN AC 17.4.95)

time such cryogenic systems will have been used on such a large scale.

When this work is underway, the magnets of the string can take a back seat, and interest focuses instead on such questions as understanding the behaviour of the quench protection system and investigating quench propagation from one magnet to the next. Because of the complicated plumbing, replacing an LHC magnet is not easy. However quenches due to beam losses may be inevitable during commissioning. The onset of small voltage differences can be used to trigger the quench protection system. Its final form will depend on experience with the string tests.

At its first cooldown at CERN on June 7, a 1-metre LHC model dipole magnet using niobium-tin conductor and designed and built by the University of Twente in the Netherlands in co-operation with CERN, NIKHEF and HOLEC and supported by the Netherlands Technology Foundation STW achieved at its first quench a record central field of 11.1 T at 4.4 K.

Niobium-tin operating at 4.4K was initially investigated as a possible conductor for LHC magnets, but the practical problems of handling this very brittle material and its very high cost led to a decision in favour of niobium-titanium at 1.8K. Niobium-tin has to be wound and then processed to produce the superconducting alloy (the 'wind-and-react' technique). In addition, the electrical insulation would have to withstand this difficult heat treatment. However this achievement is interesting for possible high field magnets for special applications, such as low-beta quadrupoles to compress the beams at the interaction regions.



CERN A hinge between LEP and the LHC

Later this year, if all goes well, the beam energy of CERN's LEP electron-positron collider should be increased to around 70 GeV per beam (collision energy 140 GeV), giving a foretaste of things to come. Since 1989, the 27-kilometre ring has been operating around 45 GeV per beam to feed its four physics experiments with a steady diet of Z particles, the electrically neutral carriers of the weak nuclear force. This has given precision results on vital parameters of the Standard Model.

Meanwhile work has been steadily pushing ahead to upgrade LEP to LEP2, installing superconducting radiofrequency cavities (January 1994, page 6) and ancillary cryogenics equipment to boost the machine's energy and reach new areas of physics interest. The initial goal is to produce pairs of W particles, the electri-

cally charged counterparts of the Z.

As far as the machine is concerned, at these higher energies, the 'beam-beam' interaction between the contra-rotating electrons and positrons is reduced, so more particles can be pumped into the ring. To achieve this, LEP has switched to the new 'bunch train' scheme (see page 14) each train containing several 'carriages' (bunches) of particles.

To attain its physics objectives, LEP2's target is 500 inverse picobarns of integrated luminosity over the next few years. This is a challenge as LEP's integrated luminosity to date (since the machine was commissioned in 1989) is some 160 inverse picobarns, itself viewed as no mean achievement.

To reach higher energies, the accelerating power at LEP is being increased with installation of superconducting radiofrequency cavities. After initial trials with solid niobium, LEP2 relies on the more reliable performance provided by copper, with its better heat conduction properties, coated with a superconducting film of niobium. Even so heroic