Vancouver Accelerator Conference

Michael Craddock, Chairman of the Conference, and Accelerator Research Division Head at the TRIUMF Laboratory gives the opening address at the 1985 Particle Accelerator Conference in Vancouver. He and his colleagues are to be congratulated on the very smooth organization of such a large gathering.

Anyone who contends that particle physics is conducted in an ivory tower, not contributing to other fields of science or to humanity at large, should have attended the 1985 Particle Accelerator Conference in Vancouver. Over a thousand participants contributed 781 papers and only a fraction were actually related to accelerators for high energy physics. The majority of present developments are in the service of other fields of science, for alternative power sources, for medicine, for industrial applications, etc.

Nevertheless, it is the spur of high energy physics that has driven accelerator technology along. As Burt Richter pointed out, in some fifty years since the first Cockcroft-Walton accelerators were built, accelerator physicists have increased peak machine energies by a factor of a million and have reduced the cost per GeV by a factor of over ten thousand. Conference Chairman Mike Craddock rejoiced in his opening address that the contributions of the accelerator community had been so significantly recognized at the end of the last year with the award of the Nobel Prize to accelerator physicist Simon van der Meer, jointly with Carlo Rubbia, for his part in the success of the CERN proton-antiproton Collider.

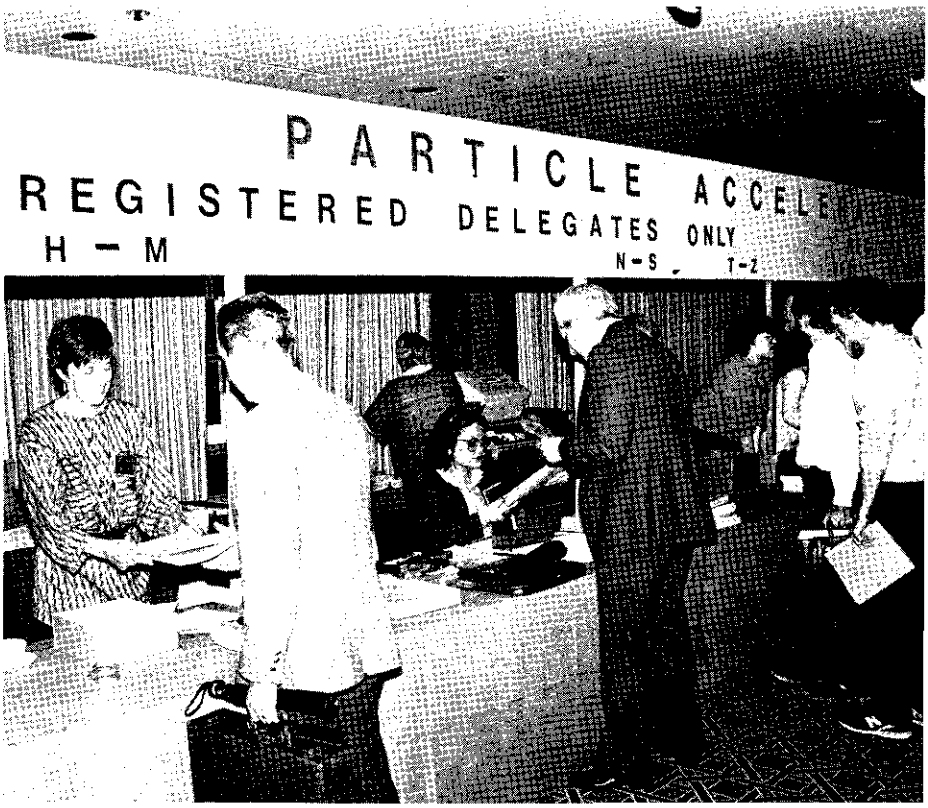
The big machines

Maury Tigner, Head of the Central Design Group based at Berkeley, gave an overview of progress towards the US 20 TeV Superconducting Super Collider, SSC. Their next major decision is the selection of the type of magnet, which of course carries a host of other parameters in its wake – particularly the machine diameter.

Though there are variants – such as two-in-one (both beam apertures in a single yoke) or one-in-one designs – there are essentially two basic magnet types now under consideration. The superferric, low field type aims for simplicity and attendant low cost. Work on their design (reported by Russ Huson) is at the Texas Accelerator Centre where most impressive progress has been made for such a newly created team. They have built and tested a series of 1 m and 7 m magnets, concentrating mostly on a two-in-one design, and are now assembling a 28 m prototype (their aim is magnet units 140 m long, including dipoles 105 m long, of which there would be 1330 around the ring). Magnet performance has been good with no training, no quenching problems, good cooling and with straightforward manufacturing processes.

Paul Reardon reported on the alternative high field type for which the initially separate proposals of Fermilab and of Brookhaven/Berkeley have now been amalgamated in what is called 'Design D'. They have built 4.5 m prototypes, 4 cm aperture, plus other prototypes for specific purposes, and have been encouraged by the recent improvements in superconductor cable quality (mentioned also in the recent story on HERA at DESY, see June issue, page 179) giving 25 kA/mm^2 rather than the 18 kA/mm^2 of the cable used for the Fermilab Tevatron, which makes higher fields accessible. Six 17 m magnets are now under construction; they are one-in-one, 4 cm bore, cold iron.

The 1985 Particle Accelerator Conference gets underway. The Conference, the eleventh in the series (based in the USA prior to this excursion over the northern border), was held from 13 to 16 May, attracting over a thousand participants.



A look at operational considerations (Peter Liman) does not give a clear message on low field versus high field magnets for the SSC. The low field, larger ring would be some 5 to 10 per cent more expensive to operate. The high field is more susceptible to trouble from collective effects and from synchrotron radiation (new to proton machines) in cryogenic conditions. Some experiments are planned on the Brookhaven 'Light Source' to give better estimates of the potential radiation problems. To retain its key attraction, however, the low field type will have to retain comparative simplicity of construction. As designs advance, it is not obvious that this will definitely be the case.

Site selection for the SSC is the most 'political' of the project decisions, apart of course from the overall project authorization. Jim Sanford described the present thinking on site layout. A 'composite' site has been invented in order to spell out the needs and get a feeling for costs. The Department of Energy has set up a selection procedure (involving outside experts) and the hope is that the decision would be taken at the end of 1986. If everything goes according to schedule, and authorization for the project is forthcoming, construction could begin in 1988.

Of the big machines already under construction, we have reported recently on LEP (May issue, page 132), covered at the Conference by Herwig Schopper, and HERA (June issue, page 179), covered by Bjorn Wiik. The Stanford Linear Collider, to achieve 50 GeV electron-positron collisions and to prepare the way for very high energy lepton colliders, was covered by S. Eckland. All the tunnelling for the two arcs, which will lead beams from the upgraded SLAC linac into collision, is complete and some 900 bending magnets for the arcs are available. The aim is to start commissioning of the arcs in the autumn of 1986. On the linac itself, the electron gun is giving over 5×10^{10} per bunch, the tiny damping ring has stored 4×10^{10} electrons, new focusing and guidance systems are being installed and the klystron and SLED upgrade of the linac is meeting specification.

The TRISTAN 30 GeV electron-positron collider project at the Japanese KEK Laboratory was mentioned in an overview of accelerator projects in Japan by Y. Hiras. The 2.5 GeV injector is operating and the accumulation ring is now being commissioned.

News from the big machines presently in operation concerned the CERN proton-antiproton Collider (Bas de Raad and Robin Lauckner) and the Fermilab Tevatron (G Dugan). The Collider performance climbed to an integrated luminosity of almost 400 nb^{-1} in 1984 (see page 229) and the current programme of improvements – particularly the construction of ACOL to give an order of magnitude improvement in the number of antiprotons stored per day (10^{12} rather than 10^{11}) and a change to six bunch operation – should take the luminosity to about 4.4×10^{30} per cm^2 per s with coasting beams at 315 GeV. The recent pulsed operation of the Collider sacrificed luminosity to take a look at higher collision energies (up to 450 GeV) and, in a very successful machine run, provided 95 hours of physics.

Commissioning of the antiproton source at the Tevatron started on 10 May. The antiproton yield with the lithium lens in operation has been measured as 3×10^{-5} per proton. Previously the debuncher ring was checked out with 8 GeV protons and beam was stored for the first time in April; now it is the turn of the accumulator ring where the stochastic cooling systems are installed. The superconducting ring has been tested as a storage ring with protons and has held beam for four hours. The hope is that antiprotons will be transferred to the Tevatron in July and that the first proton-antiproton collisions will be observed in August. Operation is likely to be at energies up to 800 GeV per beam, pushing to 1000 GeV later.

Accelerator technologies for the future

While the above paragraphs communicate that the accelerator community has much to keep it busy in the cause of particle physics for some years to come, there is also the realization that with LEP and SSC we are bumping into physical and fiscal limits in the climb to the ever higher energies demanded by the particle physicists. Thus, despite the burden of present projects, some hardy souls have started the very long term search for new methods of acceleration which would bring down the size and cost of the next century's machines.

The technologies need to be radically different. Recent advances, like the hard won mastery of superconducting magnets and radiofrequency cavities, do not take us far enough beyond previous techniques. We have described some of the new ideas before (see, for example, December issue 1984, page 436), and several schemes remain in favour – particularly laser beat waves, wake field and two-beam schemes.

C. Joshi reviewed those involving access to the high accelerating field of laser beams (1 TV/m transverse). A number of exploratory experiments are underway or proposed at the UK Rutherford Laboratory, in Canada, and at UCLA and Los Alamos in the US. At UCLA a CO_2 laser experiment has achieved accelerating fields of up to 1 GV/m via beat waves in plasmas. Over the next few years it is hoped to demonstrate acceleration of electron beams with such beat waves. Joshi emphasized that this research with lasers will be fruitful in any case since the special characteristics of the laser fields will be applicable in other areas such as the focusing of beams, ion guns and power sources.

Tom Weiland described work on the wake field scheme at DESY. The immediate aim is to demonstrate that short pulses of high gradient fields (over 100 MeV/m) can be achieved in structures where the wake fields left by hollow beams in an outer channel are transformed through to a central beam aperture. A test unit to produce doughnut-shaped electron beams has had encouraging initial tests and it is hoped to have tried the wake field transformer principle by the end of the year.

Work based at Berkeley on the two-beam scheme was reported by Don Hopkins. They are benefitting from the availability of the free electron laser facility at Livermore where the first ever operation of a FEL as a high gain microwave amplifier was achieved at the end of last year. The idea is to use a low energy, high current (few MeV, 1 kA) beam through a wiggler to produce copious microwave radiation (35 GHz) via the FEL mechanism. This radiation then passes energy to a second beam by activating a high gradient structure. Such a structure has been made for the experiment (requiring Swiss watch dexterity in manufacture and assembly) and tests should be underway at Livermore soon. If all goes well, there are dreams of a 30 m prototype by the end of the decade.

Applications of accelerators in other areas of science

If the above paragraphs are already a cursory summary of the flood of information communicated at the Conference, we now move to topics where the volume of presented papers was even greater. We, therefore, take a selective look at accelerator developements in branches of science other than particle physics concentrating on synchrotron radiation sources, neutron sources, heavy ion accelerators and kaon facilities.

The explosion in the use of synchrotron radiation from electron-positron storage rings, plus wiggler and undulator additions to extend the range of the light beam characteristics, was evident in the talks of Mark Barton, Lee Teng and Michael Knotek. Barton listed 23 operating facilities (18 of them dedicated light sources) in Europe, Japan, USA and USSR. Teng added about 20 others now under construction or proposed and it was pleasing to note that some of these are in countries outside the above usual geographic locations – Brazil, China, India and Taiwan. To give an idea of just how heavy the demand is for the use of each of these light sources, the National Synchrotron Light Source at Brookhaven operates eighteen beamlines with seventeen more planned on the X-ray ring and thirteen beamlines with eleven planned on the ultra-violet ring.

The most advanced machines are 6 GeV, very high brightness proposals in the USA (designs from Argonne, Brookhaven and Stanford) to use full energy injection into the light source storage ring after a booster synchrotron, with many long straight sections for wigglers and undulators. Such a facility was recommended by the 'Seitz-Eastman Committee on Major Facilities for Materials Research', and preparatory Workshops have been held at Ames and the National Bureau of Standards. Almost equivalent thinking is behind the design proposed for a European Synchrotron Radiation Facility (reported in a poster session by S. Tazzari). The European design has electron energy of 5 GeV with thirty straight sections (we will have an article on the ESRF in the near future). Knotek commented that the availability of such machines will bring a revolution in X-ray science equivalent to that experienced when moving from the old X-ray sources to the first light beams from electron synchrotrons.

In addition to the great impact on all areas of materials research at the present light sources, research workers in other disciplines, such as biology (where the speed at which information can be gathered allows complex structures, like proteins, viruses, and dynamic systems to be studied), medicine (just one potential application in preventive medicine is picked out below), industrial uses (crystal studies for the semiconductor industry, lithography, microscopy, etc.) are also benefitting from access to synchrotron radiation facilities.

The main social event took the participants out to TRIUMF on the campus of the University of British Columbia where they could tour the Laboratory and enjoy a salmon barbecue, Indian style. The weatherman decreed that this should be the one rainy day of an otherwise sunny week, which drove the barbecue indoors. Even with this complication, the excellent organization ensured a very pleasant evening.

David Gray reported on initial operation of the Spallation Neutron Source at the Rutherford Appleton Laboratory which is taking over from the neutron sources at Argonne, Los Alamos and KEK as the most prolific source of neutrons for research. Proton accelerators bombarding uranium targets surrounded by moderators are capable of neutron fluxes far higher than those of high flux beam reactors. The research programme at Rutherford started in June, continuing to the end of the year with proton beam energies up to 550 MeV rather than the design 800 MeV (while awaiting installation of the last two of the six r.f. accelerating cavities). There is no development on the authorization of the spallation neutron source, SNQ, proposed at Jülich in Germany.

The acceleration of heavy ions is back in the news and Nick Samios spelled out some of the reasons why. The most intriguing for particle physics is that colliding high energy heavy ions could allow access to short distances between components in the nucleons where the force acting between quarks is weak (the quark-quark binding force increases with distance). Thus heavy ion collisions could open up for study a new state of matter – the quark/gluon plasma. Energies of some 100 GeV per nucleon are probably neces-

Lee Teng, seen here touring the TRIUMF installations with his wife, gave a Conference report on the booming area of synchrotron radiation applications.

sary but the colliding ion beam luminosities need not be very high $\sim 10^{26}$ per cm^2 per s or less).

A. Ruggiero reviewed schemes to reach such machine performance. The Bevalac at Berkeley has been the front runner in heavy ion energies for many years reaching the range of 1 GeV per nucleon for fixed target physics. They have had the ambitious VENUS project on the table since 1979 (see December 1979 issue, page 406) to reach energies of 20 GeV per nucleon in colliding beams and, in the absence of authorization, have a more modest version (the 'Mini Collider') for colliding beams at 4 GeV per nucleon in rings with 4 T superconducting magnets. Oak Ridge have a proposal for a 10 GeV per nucleon collider using ions from their operating tandem into two synchrotron/storage rings with superferric magnets.

Brookhaven are working hard on a 100 GeV per nucleon collider known as the Relativistic Heavy Ion Collider, RHIC. Beams from the existing tandem will be transferred to the Alternating Gradient Synchrotron (the transfer line is being built and the AGS r.f. system is being modified to accept ions). Eventually a booster synchrotron would be added to allow injection of fully stripped ions. From the AGS, accelerated ions would be fed to storage rings installed in the completed tunnel which was for the CBA/ISABELLE project. (Since, for some purposes, heavy ions could extend down to protons, it has to be acknowledged that RHIC is a most imaginative way of building the CBA!) A proposal has been put forward and construction could take off in 1988 after further R and D. The size of the user community interested in such heavy ion experiments in the USA is estimated at up to 400 scientists.

In the meantime, there are some interesting intermediate developments in Europe. At CERN, oxygen 16 ions will be accelerated through the PS and SPS and the possibility of antiproton-ion collisions has not escaped attention. For a broader programme, D. Bohme reported that authorization has recently been given for the construction of a synchrotron, SIS, to be fed by the existing UNILAC linear ion accelerator at GSI Darmstadt (see June issue, page 181). UNILAC provides ions at some 20 MeV per nucleon; SIS will take energies to 1 GeV per nucleon for uranium ions. It will be linked to an Experimental Storage Ring, ESR, which is being designed. Construction time is some four to five years (dominated by the building construction).

Kaon factory proposals were reviewed by H.A. Thiessen. The aim is to build a high intensity proton machine in the 30 to 50 GeV range to produce (amongst other beam species) a flux of kaons some hundred times higher than those available from the CERN PS and Brookhaven AGS for research in nuclear and particle physics. The Los Alamos, TRIUMF, SIN, Brookhaven and KEK Laboratories have all looked at the possibilities; the first two have developed proposals. Project preparation is most advanced at Los Alamos where the LAMPF linear accelerator would be used as injector into a booster and fast cycling synchrotron. At TRIUMF the injector would be the existing cyclotron into booster, synchrotron and storage rings. TRIUMF have obvious interest in opening up a new programme;

the existing cyclotron has been in action for a decade (in fact there will be a celebration of 'Ten Years of Scientific Research at TRIUMF on 7, 8 July). Certainly, if they build kaon factories as well as they organize Conferences they would do an impressive job!

It was intriguing that heavy ion machines and kaon factories got so much attention at the Conference – they were second and third priorities, respectively, in the recommendations for the Nuclear Physics Advisory Commitee concerning the facilities most appropriate for nuclear physics reseach in the coming years. The first priority machine, a recirculating linac to give 4 GeV electron beams, did not figure at the Conference though preparatory work is underway at the Virginia site of the Southern Universities Research Association, SURA, under the project name of CEBAF (Continuous Electron Beam Accelerator Facility).

Some applications of accelerators

To conclude, we mention a few of the Conference topics where accelerators are used or planned, not for particle physics or other areas of scientific research, but directly in 'practical' applications.

Medical applications have been a major spin-off ever since the first X-ray machines. Now accelerators are in use for isotope production, in radiography, and in particle beam therapy. For therapy, various accelerated particles are used – heavy ions (in particular at Berkeley), protons (2600 people have been treated at the Harvard cyclotron), pions (the TRIUMF Laboratory itself has a pion radiotherapy facility) and neutrons (for example, at Fermilab – a total of over 4000 have been treated in the USA).

Because it is so elegant, we mention in addition one recent idea for a medical application which is under investigation – heart scans using synchrotron radiation (reported by H. Wiederman). What is needed is a small (1.2 to 1.5 GeV) high intensity (1 A) light source able to provide a high flux of photons of energy 33 keV. Iodine is introduced into the bloodstream and one scan of the heart (with some 10^8 photons per mm^2) is done with the photon energy just below the iodine K absorption edge and a second with the energy just above. The readings of these scans are subtracted, one from another, via computer. The only thing that changed in the two readings is the photon flux absorbed by the iodine in the bloodstream. Thus, the coronary arteries appear with remarkable clarity while the rest of the anatomy 'disappears'. Such scans could readily give advance warning of potential heart troubles and the economic values of such warnings (quite apart from the humane social value) would be great. The technique is very much faster and more pleasant for patients than the presently used techniques.

It is impossible to report on an Accelerator Conference which concentrated mostly on the work of the USA community without a few words about a proposed practical application going in the opposite direction to medical applications – the Strategic Defense Initiative, SDI, beloved of the media as 'Star Wars'. One of the mechanisms to be studied under SDI for 'zapping' alien objects is the particle beam weapon. There were a few papers at the Conference from laboratories clearly involved in such studies which mainly reported work aimed at improving the quality of low energy particle beams. There was certainly no open information which can yet move the particle beam weapon out of the category of science fiction.

The interest in particle beams to achieve commercially viable fusion reactors via the inertial confinement technique continues and there were review papers on light ion (M. Buttram) and heavy ion (Dennis Keefe) developments. The aim is to deposit several megajoules on the surface shell of a deuterium-tritium pellet in some 10 ns requiring accelerators delivering a few terawatts. (Buttram remarked that the calculations ranged 'from the optimistic to the conservative to the realistic'.) Sandia is concentrating on producing beams of 30 MV lithium ions. A 100 TW machine called PBFA-II is scheduled for operation early next year to study beam and target behaviour under single pulse conditions. They use a high power pulse compression scheme with laser triggered spark gaps.

For heavy ions, a bank of r.f. linacs cascading ions into an Alvarez linac, followed by transfer and storage rings, remains under study in Europe and Japan. The alternative scheme using induction linacs is pursued in the USA. An induction linac, MBE-4, to demonstrate current amplification with four caesium ion beams is under construction at Berkeley.

Also related to fusion reactor technology is the Fusion Material Irradiation Test (FMIT), a 35 MeV deuteron accelerator to provide intense fluxes of neutrons of fusion reaction energies. These neutron beams will be used to study the behaviour of materials subjected to the bombardment they will receive in fusion reactors. Several papers reported progress on the machine development (for example, the successful operation at Los Alamos of appropriate radiofrequency quadrupoles for the FMIT injector; it is amazing how the new technology of RFQs has swept the board in accelerator injection systems in the space of a couple of years).

This report of the Vancouver Particle Accelerator Conference will give some feeling for the range and the volume of modern accelerator physics and technology.

By Brian Southworth

Collision course

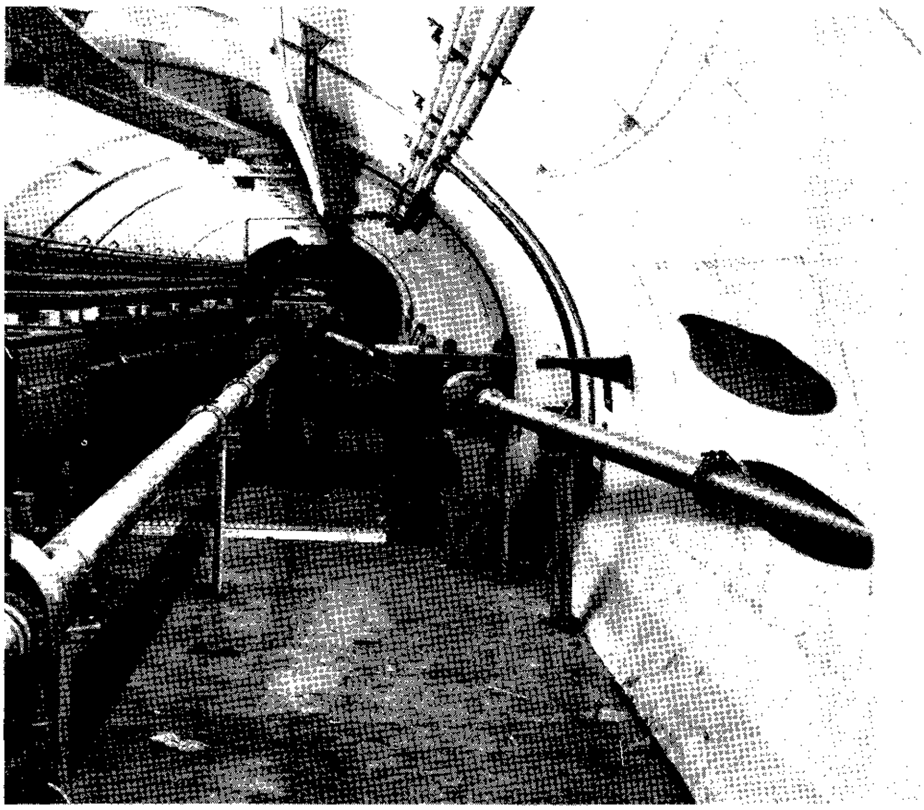
On 10 July 1981, Carlo Rubbia burst into the Lisbon Particle Physics Conference clutching the first recordings of high energy collisions of matter and antimatter in the CERN SPS ring. His announcement, the culmination of many years of intense and careful preparation, was greeted with spontaneous applause.

More than three years later, the SPS Collider's performance has improved more than a hundredfold, but the applause has died down. With the collection of antimatter mastered and almost routine, Lyndon Evans and Vincent Hatton review the achievements to date and the lessons learned.

The Collider's peak luminosity (a measure of the instantaneous proton-antiproton collison rate) has been pushed up by almost two orders of magnitude from 5×10^{27} per cm^2 per s in 1981 to 3.5×10^{29} cm^{-2} s^{-1} in 1984. More important, the daily average performance (integrated luminosity) has increased by more than an order of magnitude.

In view of the scarcity of antiprotons, the reliability of the whole chain of injectors is of crucial importance. The SPS itself is particularly vulnerable to faults, due mainly to its large size and heavy demands on primary services.

After the first proton-antiproton collisions were recorded in the summer of 1981, the first physics run took place at the end of that year, when 2×10^{32} per cm^2 (0.2 nb^{-1}) of integrated luminosity was produced. In the second run at the end of 1982 the peak luminosity was increased to 5×10^{28} cm^{-2}



Emerging from the tunnel wall on the right is the beamline which feeds 26 GeV antiprotons from the PS to the CERN SPS. On the left are proton lines emerging from the SPS main ring.

(Photo CERN 38.4.81)