

CESAR

A further series of experiments have been carried out at the CERN Electron Storage and Accumulation Ring, CESAR. As described in the July issue (p. 135), this small electron storage ring is providing some important information for the large intersecting storage ring project (ISR), and is also making possible some interesting research in basic accelerator physics.

The vacuum pressure in the ring has been maintained at 4×10^{-10} torr for five months (an achievement in itself, since CESAR is the largest vacuum enclosure in the world operating at such a low pressure) and, because of this, the latest investigations have been with electron beams with much longer 'lifetimes' than previously. The predominant factor determining how long electron beams can be stored is the scattering of the electrons by the gas molecules remaining in the vacuum chamber. With a pressure of 4×10^{-10} torr, beams have been achieved with half-lives (the time taken for the beam to fall in intensity to half its value at injection) of 3 to 10 seconds (depending on where the beam is orbiting in the vacuum chamber and on the setting of the magnets).

This ability to observe beams over longer lifetimes has had several effects. It has made possible experiments with the radio-frequency system which can be reliably interpreted. It has given a first look at the possible existence of instabilities which could cause the beam to be lost, but which develop slowly. And finally it has increased confidence in the theoretically predicted lifetimes for the proton beams in the ISR. To simulate the ISR conditions exactly, it would be necessary to watch beams in CESAR for 100 seconds. This would involve achieving a vacuum about ten times better than at present and the indications are that this could not be done without extensive rebuilding of the vacuum system.

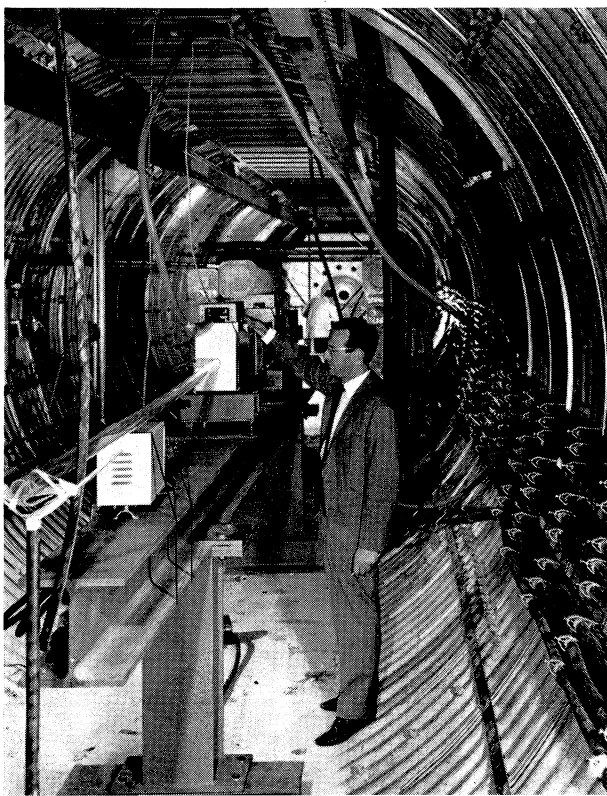
The efficiency with which the injected pulses of electrons can be stacked into a beam has been examined. Theoretically, this should depend on the number of pulses one stacks and on the speed with which one

This installation originates from a proposal by some of the first spark chamber team to test more precisely a law of 'muon conservation'. It is believed that the ν_μ always transforms to a μ^- , and a $\bar{\nu}_\mu$ to a μ^+ . Is this law exact? The spark chamber array will study muons whose sign will be determined when they pass through the high magnetic field in the HLBC, and it will be able to detect a violation of this law as small as one μ^+ per thousand muons produced by ν_μ .

Occasionally, it is necessary to verify that the operation and synchronisation of the HLBC is perfect during the $2\mu\text{s}$ when the neutrino beam is incident on the chamber, so that the one interaction which occurs every few hundred expansions is correctly registered. Such a verification is impractical with the neutrino beam itself, but it is simple to open a small hole in the shielding by letting mercury out of an iron pipe. Muons, produced at the same time as the neutrinos, will then be able to pierce the shielding and be observed in the HLBC. Incidentally, these test pictures, which will be obtained from a momentum analysed muon beam will not be wasted afterwards; they will be used by a different group of experimenters for a feasibility study of a proposal for a future study of inelastic muon interactions in the HLBC.

From this brief description, in which some other studies which are simultaneous with the neutrino experiment, such as the 'Adler test' and 'shielding studies', have not even been mentioned, it is clear that it would be more correct to describe all the different activities in operation simultaneously as a programme rather than a single experiment. It may be interesting to review later, what has been the outcome of the effort and machine time invested in this programme and to assess what contributions have been made to increase our understanding of the nature of neutrino interactions.

Inside the neutrino tunnel, looking down from the proton synchrotron. The first units, which will guide the extracted proton beam onto the target in the magnetic horn, are being mounted in position. The horn itself will be located where the steel ingots for shielding can be seen further down the tunnel. Further down still, is the end of the reflector R2 whose power cables run along the right-hand side of the tunnel.



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accelerated the successively injected pulses to the stacking orbit. Both these theoretical predictions have been checked and, in particular, a detailed curve showing how the stacking efficiency varies with the number of injected pulses for a given setting of the r.f. has been obtained in very good agreement with the theory.

Another investigation using the r.f. system, fed known amounts of 'noise' (random fluctuations) into the r.f. signal which is seen by the beam. In a conventional accelerator, where the acceleration process is over in a second, tiny fluctuations in the r.f. fields are of little importance. But with the ISR, beams will be subjected to r.f. fields for many minutes. Will imperfections in the r.f. then be serious? Again the results from CESAR are in agreement with theory, and say nothing which will give the ISR builders sleepless nights. They also indicate the degree of imperfection which can be tolerated while still achieving high stacking efficiency.

Most of the work on CESAR is now being concentrated on beam instabilities. Three types have been observed and are being investigated. The first, which may drastically limit the life of the beam, is due to magnet imperfections (octupole and decupole components in the magnetic field). The second is thought to be an instability caused by electrostatic interaction between the electrons, resulting in 'bunching' of the beam

(a rearrangement of the beam into a number of short sausages). The third results in coherent oscillations transverse to the direction of motion of the electrons and is probably due to an electromagnetic field in the vacuum chamber, produced by the beam itself and following it like a wake. The last two instabilities occur above a certain intensity and impose an upper limit to the current. This will be relevant to all high intensity machines.

Storage Ring Symposium

An international symposium on electron and positron storage rings was held at Saclay, France from 26-30 September. The symposium was devoted mainly to short research contributions, status reports on machine design, theory, and physics with storage rings. Several representatives from CERN covered the progress on the ISR project. (The contribution on work with the storage ring model CESAR is described above).

The Table on page 219, lists the storage rings in operation, under construction or proposed throughout the world. Here, we will consider only two new ideas which were discussed.

The first has been developed at the Cambridge Electron Accelerator.

Scientists there hoped to construct storage rings for their electron synchrotron but the proposal was not supported since electron rings at Stanford can potentially achieve much higher intensities. Attention then moved to the possibility of using the existing machine to accelerate a positron beam in the opposite direction to the usual electron beam, thus dispensing with the expensive storage ring. A positron injector has been requested for the Laboratory in the 1967 budget.

A pulse of positrons would be injected into the synchrotron ring and accelerated to an energy of a few GeV. At this energy, the synchrotron radiation from the beam damps the random motions of the positrons. The small beam would then be decelerated to injection energy and another pulse of positrons fed in, this pumping procedure continuing until 100 mA of positrons were stored. An electron beam of equivalent intensity would then be injected and the two beams simultaneously accelerated, in opposite directions.

The intensities would still be low for colliding beam work and the second aspect of the proposal involves the construction of a 'bypass' — a loop alongside the synchrotron ring into which the full energy beams could be deflected. In the bypass, very high vacuum could be maintained (to increase the probability of looking at electron-positron collisions and not collisions with gas molecules) and also, by a special arrangement of magnets, the beams could be focused to very small cross-sections in the intersecting region. This would overcome the intensity limitation of the larger cross-section beams in the synchrotron.



Starting on the ISR tunnel. This photograph was taken on 2 November when work began at the position of the intersecting rings on the French half of the CERN site. The earth excavated in carving out this tunnel, 15 m wide about 7 m high and with an average diameter of 300 m, will be transported to a dump on the opposite side of the Geneva - St-Genis road using a tunnel cut under the road. The earth required later as shielding around the storage rings will be stocked on the site.

The idea will probably be incorporated in the Stanford proposal and the possible advantages of using a similar system for the ISR at CERN have been considered. It appears, however, that only small gains would be possible and at considerable increase in the cost and size of the project.

The second new development, from Novosibirsk, concerns the use of 'electron cooling' to increase the density of proton or antiproton beams in storage rings. The size of a beam is determined by the spread in energy of the particles it contains and by the spread in the radial and vertical oscillations of the particles. Any technique which reduces these 'spreads' can result in a more dense beam.

The 'electron cooling' idea is to use a parallel beam of electrons, with uniform velocity equal to that of the ideal average proton, to take the 'heat' out of the proton (or antiproton) beam, where 'heat' is considered as the random motion about the average proton energy. The carefully prepared electron beam would be fed into the proton beam, for example, along the length of a straight section in the storage ring. The 'hot' protons would tend to give up some of their energy to the electrons each time they passed through the electron beam. Over a very large number of turns, the random motion of the protons would be slowly reduced.

The use of electron cooling is a vital part of the 'VEPPONE' project (see Table). It is now being studied at ISR, to see if it could be employed in any future move to proton-antiproton physics.

This line of buckets hanging over part of the circumference of the proton synchrotron ring is not an indication of inadequate protection against the rain. It is, in fact, those most unorthodox experimenters from the Lawrence Radiation Laboratory, Berkeley, the Rutherford Laboratory, U.K., and CERN, who are carrying out a very detailed study of shielding properties. Not content with digging little holes in the earth mound over the PS tunnel (see CERN COURIER vol. 6 no. 9 (September) p. 176), they have also distributed their detecting samples in this curve of buckets to examine the radiation fluxes inside the tunnel. A second arc of detectors (covering the quadrant centred on the target in straight section 32) is visible above the magnet on the extreme right.

Machine	Laboratory	Colliding beams	Beam energy	Comment
ADA	Orsay/Frascati	electron-positron	200 MeV	Design study machines
VEP 1	Novosibirsk	electron-electron	150 MeV	
—	MURA	electron-positron	200 MeV	
PRI-STAN	Princeton/Stanford	electron-electron	550 MeV	First generation
VEP 2	Novosibirsk	electron-positron	700 MeV	
ACO	Orsay	electron-electron	500 MeV	
—	Kharkhov	electron-electron	100 MeV	
ADONE	Frascati	electron-positron	1.5 GeV	Under construction
'VEPPONE'	Novosibirsk	proton-antiproton	25 GeV	
		electron-positron	5 GeV	
ISR	CERN	proton-proton	28 GeV	
CEAB	Cambridge	electron-positron	3 + GeV	
—	Stanford	electron-positron	3 + GeV	Proposals
—	DESY	electron-positron	3 + GeV	

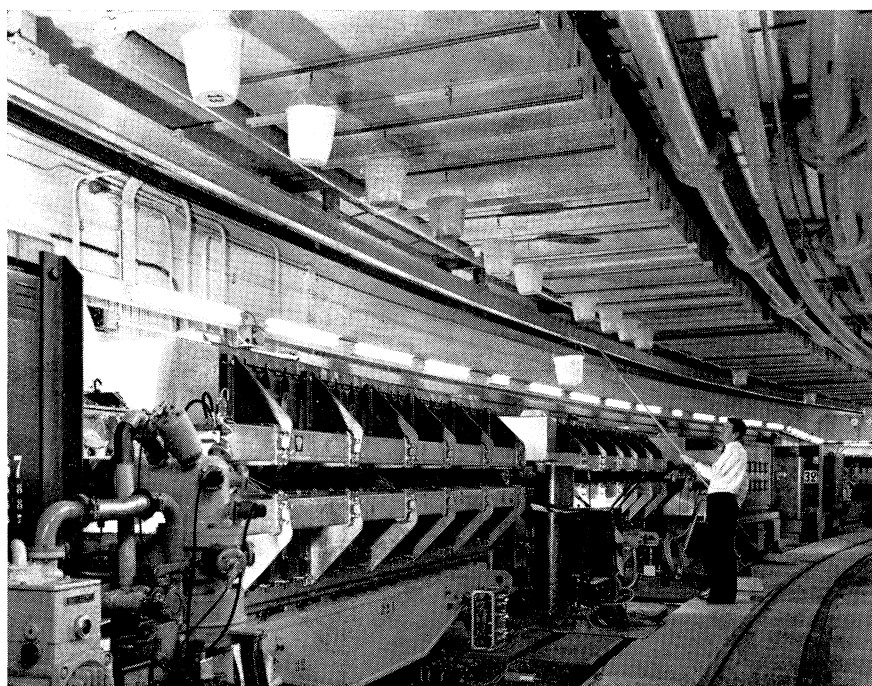
CERN Colloquia

The CERN Colloquia for 1966/67 began on 20 October and continue through to June 1967. A short exhortation on the subject of the colloquia from Dr. Hagedorn, Chairman of the Organizing Committee, appears on page 220.

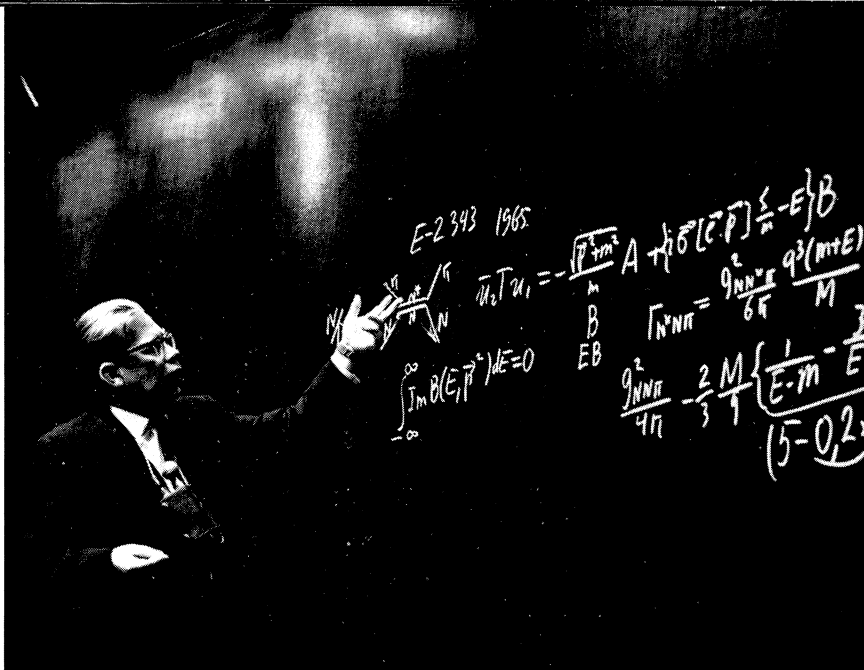
The Committee are trying to ensure as big an attendance as possible at the colloquia — first, to fulfil their basic aim of increasing awareness of work in other branches of science, and also to ensure that the efforts of the speakers in coming to CERN, often from very far away, will be

rewarded by the pleasure of speaking to a large audience. To help towards this end, each issue of CERN COURIER will carry some information on the colloquia scheduled for the coming month.

For the month of December, two seminars have been arranged. On 1 December, Professor O. Frisch from the Cavendish Laboratory, Cambridge, U.K. will give a talk with the title 'Take a photon...'. On 15 December, Professor J.D. Jackson from the University of Illinois, USA, will talk on 'Peripheral processes of intermediate energy'. These two colloquia will assume some knowledge of physics.



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Professor Bogolyubov, Director of Dubna, lecturing at CERN on 19 October on some problems in the theory of particle physics which are of particular interest to him.

Visitors

Mr. K. Bondevik, the Norwegian Minister of Church and Education, visited CERN on 5 November. He was accompanied by Mr. J. Bargem, Secretary of State, by Mr. Holtan-Hartvig and by the Norwegian ambassador, Mr. S. Chr. Sommerfelt, who is a delegate to the CERN Council. Mr. Bondevik met the Director General, Professor Gregory, and other members of the CERN staff including several Norwegian scientists. About thirty Norwegians are at present working at CERN.

Another welcome visitor was Professor N. N. Bogolyubov, the Director of the Joint Institute for Nuclear Research, Dubna, USSR. He spent

several days at CERN for discussions with senior staff and, on 19 October, included a seminar on the work of the Laboratory of Theoretical Physics at Dubna.

On 29 September, a group of 22 physicists attending the General Assembly of IUPAP (International Union for Pure and Applied Physics) at Basle visited CERN. They were accompanied by Prof P. Huber of the University of Basle. IUPAP sponsors the large international conferences in high energy physics, such as that held at Berkeley this year.

In addition to these distinguished visitors, the flow of people coming for a general visit on Saturdays

continues. More specialized visits during the week bring people from other Laboratories and Universities to acquaint themselves with CERN and to meet CERN staff. For example, on 7 and 8 October, 24 physicists, engineers, technicians and film-scanners from the High Energy Laboratory of the Belgian 'Institut inter-universitaire des Sciences nucléaires' came to CERN. This group is one of the many teams throughout Europe doing 'physics at a distance', using the photographs produced at the bubble chambers on the CERN 28 GeV accelerator. About 85% of the film from CERN is sent for analysis to other European Laboratories and it is estimated that some 700 physicists and students are supplied with their research material in this way.

Come to CERN Colloquia

Colloquia have been organized for many years at CERN, following more or less the same pattern as Colloquia which are a long-established feature of University life throughout the world. But there is a great difference between our environment and a University. At University, you have your friends and colleagues from other faculties right next door. Here at CERN, you may find people with interests in many other fields, but expert knowledge is concentrated in the fields of physics, mathematics and engineering and related subjects such as nuclear chemistry and health physics. Science, however, is a whole, and CERN scientists are definitely the poorer for this lack of loose contact with other branches of Science, which is so necessary to set our work in perspective. We must remain aware of the fact that our science is no better than any other and that it forms only part of the general aim of man to know where and what he is.

Much more than in any University, the CERN Colloquia serve to keep alive an awareness of what is happening elsewhere in Science. The Committee

organizing the lectures go to considerable trouble to induce outstanding scientists to speak at CERN. They are chosen not only for their distinction in their fields but also because they are known to be good speakers.

It proved difficult to have a selection of suitable speakers concentrating on one overall theme for each academic year (as was initially intended) and as a result the Colloquia cover a variety of topics. The variety is broad enough to provide everyone, including non-scientific staff with something of interest. Therefore, everyone is invited to attend these lectures — all CERN staff and people from outside CERN. The lectures are given in English and their titles are usually designed to indicate whether they are of a rather technical nature, understandable only to those with some basic knowledge of physics or mathematics.

If all this does not suffice to attract you to go to the Colloquia, then please think of another point: if **you** had been invited to a distant Laboratory (perhaps three days of travel there and back) and found yourself lecturing in a huge hall in front of twenty lonely people... not a pleasant thought? But that is what some colloquia speakers have suffered at CERN.

R. Hagedorn