

HYBUC being prepared for its initial tests with nitrogen. The tests went well and conversion to hydrogen is under way. The superconducting magnet constructed in the USA is expected to arrive at CERN shortly.

as far as possible a 'finger' which is evacuated, extends into the expansion region almost as far as the useful volume.

The optical system consists of one viewing lens (objective) on the axis of the chamber and four others positioned around it. All five views are brought onto a single film. The film transport system is an extended version of that developed for the CERN 2 m chamber.

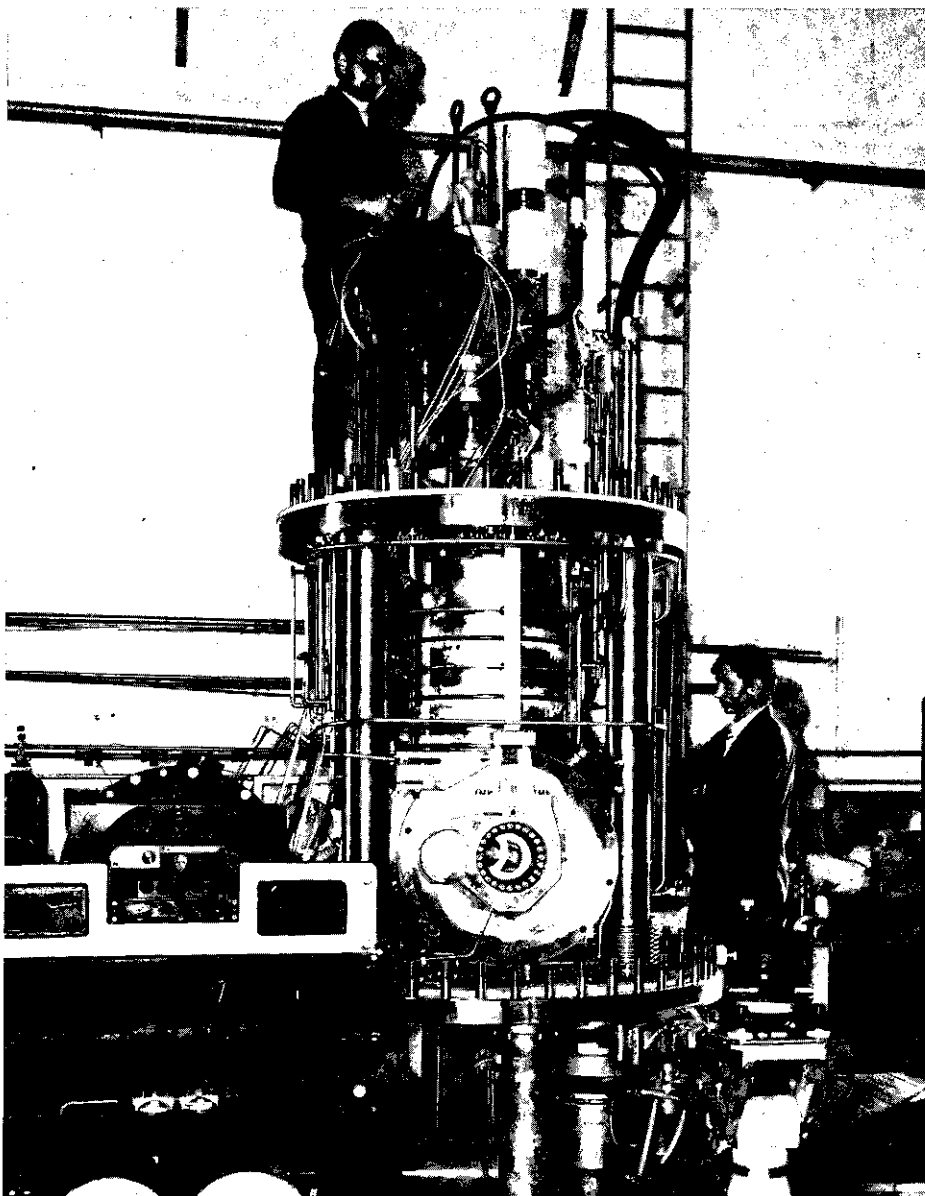
Perhaps the most interesting technical feature of the chamber is the superconducting magnet which is designed to give a field of at least 110 kG at the centre of the chamber. This probably ranks among the highest fields (not pulsed) over such a volume ever attempted. The magnet consists of a three part system of coils. A set of outer coils (28 cm inner diameter, 47 cm outer diameter, 48.2 cm long) is constructed of niobium-titanium superconductor designed to produce a field of 70 kG at its centre. Within the bore of these coils is another coil (with dimensions 17.8 cm inner diameter, 26.4 cm outer diameter, 27 cm long) constructed of niobium-tin superconductor. Niobium-tin will retain its superconducting property within the field produced by the outer coil and should itself add up to 50 kG to the field.

A further niobium-titanium coil at the expansion end of the chamber completes the magnet system. It will produce a field in the opposite direction to the other coils so as to bring the field where the beam enters to a low level.

The magnet has been manufactured in the USA and is the joint property of the Max Planck Institute and Vanderbilt University. When the experiment at CERN is concluded it is expected to return to the USA to be used in an experiment at Brookhaven. This would also be concerned with the sigma magnetic moment and would involve operation of wire chambers inside the magnetic field.

During the design and construction of the bubble chamber, the HYBUC team benefited from the close collaboration of members of the Track Chambers Division at CERN and in particular of the group constructing the large European bubble chamber (BEBC).

Assembly of the chamber, without the magnet, began at CERN at the beginning



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of September and tests with liquid nitrogen have been completed satisfactorily so that tests with liquid hydrogen can now proceed. The magnet, which is now complete, has been undergoing acceptance tests in the USA and is expected to arrive at CERN shortly. If all goes well the chamber will be moved into the North Hall early next year, where further tests will be carried out on a beam before it takes up its final position for the experiment.

Adiabatic trapping

Experiments are being carried out at the proton synchrotron on a new method of 'trapping', for further acceleration, the particles which are injected into the machine. To see the advantages of this method requires a brief discussion of the phenomenon of trapping itself.

The linac sends into the PS what can be considered for the purpose of this discussion as a continuous ribbon of protons, the width of which is mainly governed by the energy spread of the particles around the linac energy of 50 MeV (those with the

highest energy occupy larger radius orbits and vice versa).

The accelerating voltage applied in the synchrotron ring is sinusoidal and the r.f. accelerating system can only trap and accelerate those particles arriving at the r.f. cavities during certain intervals of time when the voltage in the cavities is right. The beam is thus cut into pieces where trapping takes place. The trapping zones can be represented on a graph of energy plotted against phase and, because of their shape, they are nicknamed 'fish'. When the PS first came into operation, the r.f. system was such that only about 50 % of the injected particles could be trapped in the fish and this theoretical figure was not reached in practice.

In 1960, it was found that higher trapping rates could be achieved by a preliminary concentration of the particles into regions of the beam by initially tuning the r.f. to a slightly different frequency from the one corresponding to the passage of the protons through the cavities. By coinciding these regions where protons are concentrated with the fish gives a theoretical

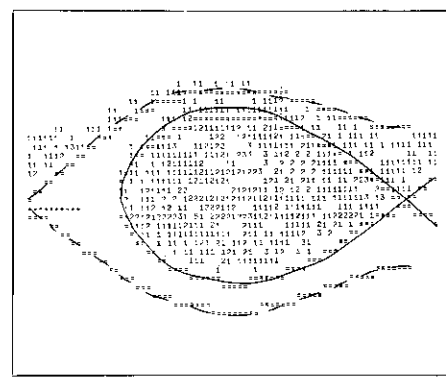
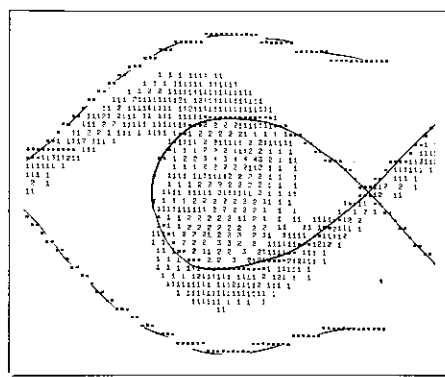
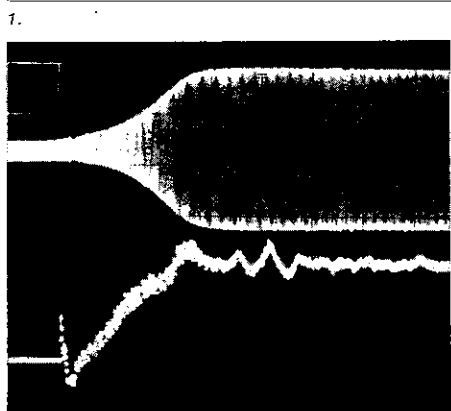
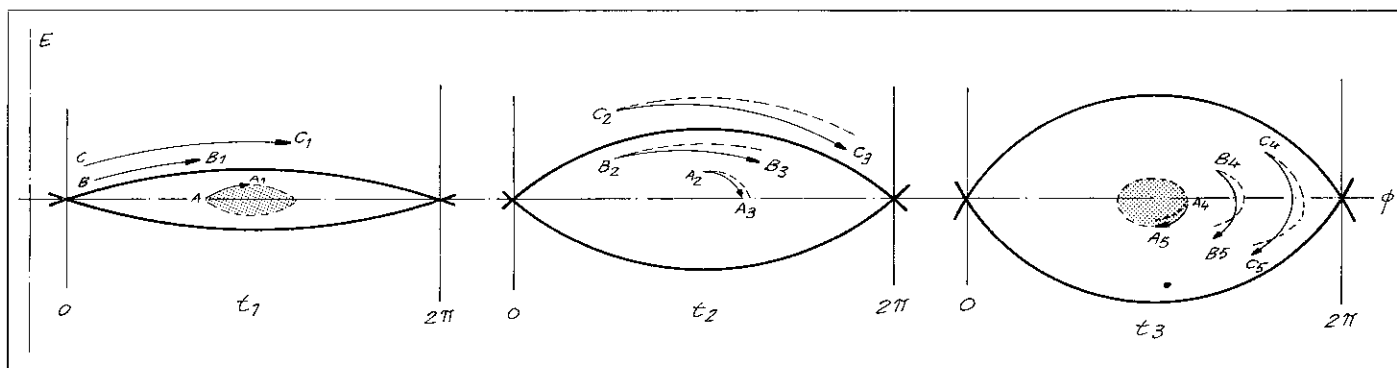
1. Three diagrams illustrating three stages of adiabatic trapping. The r.f. voltage increases progressively, while the stable phase is maintained at zero. Particle trajectories deviate towards the centre, both outside and inside the 'fish'. The particles inside (A) describe ellipses of ever-diminishing width and increasing height, whose surface-area decreases progressively until it reaches a minimum. The particles outside (B and C) also show this centripetal tendency, which brings them so near to the boundary of the fish that a tiny increase in its surface-area captures them. It is the small increases in the voltage applied to particles as they pass

successive accelerating cavities which cause the trapping.

2. At the top of the photo, is the r.f. voltage as it grows during adiabatic trapping. At the bottom, is the contour of a proton bunch recorded at the same time; the size of the bunch is very stable.

3. and 4. Computer print out simulating two types of trapping. 3. represents the situation at the end of a 'gross trapping'. The proportion of particles in the fish is smaller than that left outside which will be lost. There is also significant dilution. 4. represents the situation at the

end of adiabatic trapping (not perfect because of the limitations in applying this method at the PS); the proportion of particles captured is much higher, and dilution is low.



trapping efficiency close to 70% (in practice about 50% is achieved). The method, known as 'high trapping' is now in routine use at the PS.

However, a 'dilution' problem is encountered with both these methods. The area of the fish is not fully occupied by the particles and this room for manoeuvre inside the fish results in an increase in the longitudinal emittance of the beam.

A few years ago there arose the idea of 'adiabatic trapping' which could, theoretically, allow 100% of the particles to be trapped, while reducing the dilution to a minimum. The method involves starting with a reduced peak accelerating voltage and a voltage applied to the synchronous particle equal to zero. What is done is to increase these two voltages progressively (adiabatically) gradually blowing up the area of the fish until it is at least equal to that of the beam which we want to enter the fish. Particles would not normally cross the boundary of the fish but, with this method, all the particles initially outside can, surreptitiously, be manoeuvred in.

It offers so many advantages that it

was adopted in the design of the Booster. Then, in the course of tests on the PS to develop the technique, it seemed possible to adapt it to the PS itself, and a detailed study began. The work has led to a series of successful experiments which have been carried out for a month on the PS. From the beginning, they have given excellent results.

The method cannot be applied to the optimum in the PS because it is not possible either to have the r.f. voltages near to zero or to obtain a very slow increase in the magnet fields (which must keep in step with the accelerating particles). With a rate of increase of field set at 25% of its maximum value the theoretical trapping efficiency is limited to 90%. The practical rate is restricted to about 70%, which is however considerably better than with 'high trapping'. It is affected by two factors. The first is the transverse instabilities (betatronic resonances) which the particles undergo during the time for which the lower voltage is applied. This effect is quite normal but is not so pronounced with high capture when they are passed

through more quickly. Methods of correcting this are at present being studied, and consist essentially of harmonic corrections. The second factor is the energy spread of the linac beam.

When, the improvement programme at the PS is complete, the linac will provide 100 μs pulses (instead of the present 20 μs) and multi-turn injection will be used. This type of injection, which requires a slow increase in the field, is in tune with the conditions of adiabatic capture, which is not the case with single-turn injection used at present.

Adiabatic trapping should prove of particular benefit as regards the provision of bunches by the PS for the ISR. We mentioned above that the earlier trapping techniques could result in an increase in the longitudinal emittance. Adiabatic trapping, however, so fills the fish that this effect is not so pronounced. This reduction in dilution will be a great advantage from the point of view of ISR operation since the luminosity of the ISR varies with the square of the longitudinal emittance. It is here, even more than in the increased

Around the Laboratories

trapping efficiency, that the great attraction of this method lies.

Röntgen Prize

On 17 October the 1970 Röntgen Prize was awarded to G. Backenstoss (of CERN and Karlsruhe) for his work on 'exotic' atoms. The story of the latest discoveries in this field, where sigmic and antiprotonic atoms were identified, appeared in CERN COURIER two months ago (vol. 10, page 251). Observation of X-ray emission from exotic atoms is a source of a great deal of information on the nucleus.

The Röntgen Prize is awarded by the Science Faculty of Justus Liebig University in Giessen, Federal Republic of Germany, where Röntgen was Professor of Physics at the end of the last century when he discovered X-rays in 1895. It is given for distinguished work in experimental physics. It has not been awarded since 1967 and this year has therefore seen a triple award on the occasion of the opening of a 'Radiation Centre' at the University where research in physics and biophysics will be carried out using a 60 MeV electron linac. In addition to Backenstoss the Prize went to E. Stuhlinger of the Space Research Centre, Huntsville, Alabama, for his research in extra-terrestrial X-rays carried out using detectors in rockets and to T. Kirsten of the Max Planck Institute Heidelberg for his discovery of double beta decay.

The Röntgen Prize was awarded to J.B. Adams in 1960 for his leading role in the construction of the CERN proton synchrotron. This new award is a tribute to the whole team from CERN, Heidelberg and Karlsruhe who for about five years have been producing important results, first on mu-mesic and pi-mesic atoms working at the synchro-cyclotron and more recently on K-mesic, sigmic and antiprotonic atoms working at the proton synchrotron.

BERKELEY

'Proton decay' confirmed

...not, be it hastily said, the decay of the proton itself but the first clear observations of the radioactive decay of a nucleus by means of proton emission. The possibility of such a decay mechanism has been realized for a long time. It is possible to produce nuclei which are 'proton rich' such that the energy binding the proton in the nucleus falls to zero or to negative values. But to identify the process occurring is not easy. This has now been done at the Lawrence Radiation Laboratory, Berkeley, following previous work at Harwell in the UK. The achievement was reported in Physics Letters on 26 October.

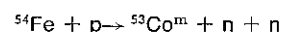
Four mechanisms of radioactive decay are well established - beta decay (emission of an electron or positron), alpha decay, gamma decay and spontaneous fission. 'Proton decay' is now added to the list. It has been looked for during the past few years particularly at Dubna where a team, led by V.A. Karnaikhov, has done much of the original thinking on this topic and reported some results, which were not conclusive, at the 'Conference on the Properties of Nuclei Far from the Region of Beta Stability' held at Leysin, Switzerland, from 31 August to 4 September 1970.

The results from the experiments at Harwell were also, by themselves, not conclusive. They were carried out by K.P. Jackson, C.U. Cardinal, H.C. Evans, N.A. Jelly and J. Cerny using the Variable Energy Cyclotron (built for Harwell by the Rutherford Laboratory) to accelerate oxygen ions which bombarded a calcium target. In the reaction, a cobalt isomer $^{53}\text{Co}^m$ can be produced, which is proton rich and is a comparatively long-lived excited state of cobalt-53. Though nuclei in the ground state which are proton unstable have not been found, the cobalt isomer is an unusual case where a high energy state is proton unstable. Its high spin value (19/2) prevents decay by electromagnetic radiation. In the Harwell experiments, protons which could have come from proton decay of the nucleus were observed but they could not be unambiguously distinguished, firstly because of the complexity of the oxygen-calcium nuclear interaction, and secondly because

it could not be proved that the emerging protons were not of the 'beta-delayed' type.

Beta-delayed proton emission has been known since the early 1960s from the work of Karnaikhov at Dubna and R.E. Bell at McGill, Canada. In this phenomenon the fundamental decay process is beta decay which is followed by the emission of a proton from the highly excited state of the daughter nucleus. It is not true radioactive decay by proton emission, though it also provides considerable information about nuclear properties. Studies on delayed proton emission are under way at CERN with ISOLDE (see CERN COURIER vol. 10, page 4) and the latest results were reported at Leysin.

Following the Harwell experiments, Cerny returned to Berkeley and, together with J.E. Esterl, R.A. Gough and R.G. Sextro, was able to carry out a 'cleaner' search using the 88 inch cyclotron to bombard iron-54 with protons again to produce nuclei of cobalt-53 m.



The cyclotron provided beam for 0.8 s and was then switched off while the iron target was observed for 0.6 s. Emerging protons were detected in a counter telescope and the absence of simultaneous beta particles confirmed that true proton decay of the cobalt isomer was being observed.

STANFORD (SLAC)

Half a SPEAR

As mentioned in the last issue of CERN COURIER, page 320, Stanford Linear Accelerator Centre are going ahead with the construction of an electron-positron storage ring which is a trimmed down version of their project SPEAR (Stanford Positron Electron Asymmetric Rings) described in vol. 9, page 271. SPEAR consisted of two asymmetric rings (slightly pear-shaped) overlapping to provide two beam interaction regions.

What is now being built is a single asymmetric ring in which both electrons and positrons will orbit in opposite directions. Two 'low beta' regions, where the beam will be specially concentrated, will be available for collision experiments. Initially, a single r.f. cavity will limit peak