the end of 1983. On 22 June last year, the new 72 MeV injector delivered an 0.5 microamp beam, and on 23 August it yielded 23 microamps which were taken to 590 MeV in the ring cyclotron. On 19 November a 590 MeV production run furnished 180 microamps of beam (from 3 mA d.c.), but an unfortunate vacuum leak prevented an attack on SIN's 190 microamp beam record. On 13 December, 500 microamps (from 4 mA d.c.) was obtained at the 72 MeV beam stop, with an extraction efficiency of 99.5 per cent.

After the successful commissioning of Injector II, a great deal of preparation for normal production running has to be done. In order to handle the increased output of Injector II, the main ring r.f. system is being upgraded for beams of the order of a milliamp. The future production schedule will be so organized that 25 per cent of beam time will be used for beam development and modifications. The most important question is the space charge limits of the beam, particularly in view of the planned neutron spallation source. At present, the current is limited by the Cockcroft-Walton preaccelerator, but its beam will be boosted by a factor of three or more during the course of the year.

ACCELERATORS
Nonlinear dynamics in Sardinia

At the recent joint US/CERN School on Particle Accelerators' Topical Course on Nonlinear Dynamics, held in Santa Margherita di Pula, near the southern tip of Sardinia. Left to right; Mel Month, head of the US School on High Energy Particle Accelerator; the Hon. M. Melis, President of Sardinia; Kjell Johnsen, Head of the CERN Accelerator School; G. Piredda, Mayor of Pula; John Jowett of CERN and syllabus organizer; and Prof. R. Habel of Frascati, representing the Italian Physical Society.

In the last few years, two schools devoted to accelerator physics have been set up, one on either side of the Atlantic. The US School on High Energy Particle Accelerators has organized Summer Schools on the physics of particle accelerators, hosted by the major American Laboratories, each year since 1981. The CERN Accelerator School started in 1983 with a special course on Antiprotons for Colliding Beam Facilities at CERN, followed at Orsay in 1984 with its first course of a regular series on General Accelerator Physics. In addition, it has helped organize special workshops. The response to these courses has demonstrated the great need for training in accelerator physics, a subject which appears on the curriculum of only a very few universities. Meeting this need requires an accelerator school at least on each side of the Atlantic.

However there is also a need to cover certain specialized topics with more general participation. For this purpose the two Schools have combined to create the Joint US/CERN School on Particle Accelerators, which will organize Topical Courses once a year, probably in the winter, in parallel with the separate summer schools. Nonlinear dynamics provided a promising start to this series.

The Italian Physical Society helped organize and support the school, which took place in Santa Margherita di Pula, near the southern tip of Sardinia, from 31 January to 5 February. The Sardinian Government and the local tourist authorities gave generous hospitality and entertainment which provided welcome relief from the long intense hours of the lecture sessions!

As Emilio Picasso (CERN) pointed out in the opening lecture, nonlinear effects are becoming ever more important in determining the ultimate performance and utility of particle accelerators and storage rings. On the other hand, recent explosive progress in the physics and mathematics of nonlinear systems means that there is a great store of exciting and potentially very useful material gradually being assimilated into accelerator physics. Thus about half the lectures covered ideas and techniques from outside accelerator physics.

Accelerator problems have provided a considerable impetus for the modern developments in dynamics. Lecturer Jürgen Moser (Zurich) had guided R. Hagedorn and A. Schoch in their early study of nonlinear resonances in the projected CERN PS back in the 1950s.

Resonances were a key theme, returned to again and again by many of the lecturers. They emerged in the introductory lectures on modern Hamiltonian dynamics given by Ian Percival (Queen Mary College, London). Ron Ruth (SLAC) then described the accelerator physicist's ap-

Jürgen Moser (Zürich) lecturing during the Joint US/CERN Accelerator School Topical Course on Nonlinear Dynamics.

proach which was applied to colliding beams by Alex Chao (SSC). Anton Piwinski (DESY) gave an account of the different sorts of synchro-betatron resonances which can cause problems for large storage rings.

Analytical perturbation techniques used in many nonlinear problems of applied mathematics and engineering were given a thorough exposition by Ali Nayfeh (Virginia Polytechnic). In a complementary set of lectures, Jim Crutchfield (Berkeley) described modern techniques for understanding dynamical systems through numerical experiment on computers and illustrated them in several striking films. He convincingly swept away the old belief that computer experiment does not allow one to go straight to the essence of the problem!

Computers have become indispensable tools in accelerator physics too. In particular, the nonlinear motion of particles in the magnet lattice of a storage ring is a formidable problem in the long-time behaviour of dynamical systems, crucially important in determining the magnet aperture (and thereby the cost) of the large hadron colliders planned for the future of high energy physics. The only tests for stability available in the design of a storage ring are programs which track the orbits of single particles. The tracking algorithms used in such programs were described by Chris Iselin (CERN) while Albin Wrulich (DESY) described their use including the DESY approach of using dedicated processors to speed up execution. The analytical tools available for arranging sextupole magnets to improve stability in storage rings were described by Gilbert Guignard (CERN) while Karl Brown (SLAC) discussed the art of designing single-pass nonlinear optics as in the Stanford Linear Collider.

Much of the recent interest in nonlinear systems has come through the realization that even very simple deterministic classical systems are inherently unpredictable because of the chaotic behaviour which they (nearly always) exhibit. Insight into the origin of such motion was given in the lectures of Jürgen Moser while Robert Mackay (Warwick) described the breakdown of regular motion and the transport effects which arise in the chaotic phase space of a Hamiltonian system.

The limitation of storage ring performance by the collective electromagnetic interactions of colliding beams has long been associated with the transition to chaos in non-linear dynamical systems and there were several speakers on this 'beam-beam effect'. However, some warned against conclusions drawn using the approximation of two intense colliding beams by the perturbation of a 'weak' beam by an opposing fixed 'strong' beam.

Experimental observations were comprehensively surveyed by John Seeman (SLAC) while Jacques Gareyte (CERN) gave an account of the latest impressive results from the proton-antiproton collider at the CERN SPS. Some of the theoretical attempts to understand the beam-beam effect were described by Jonathan Schonfeld (Fermilab) and Jeffrey Tennyson (currently at Novosibirsk). Steve Myers (CERN) reviewed the success story of computer simulation of the beam-beam effect in electron-positron colliders, although simulation for hadron colliders remains an open problem due to the absence of radiation effects.

The difference between electron-positron and hadron colliders provided a nice illustration of the contrast between dissipative and conservative systems in general which was discussed by Robert Helleman (Enschede and La Jolla). John Jowett (CERN) discussed some of the ways in which dissipative nonlinearities could arise in large electron-positron rings. Some of these, like nonlinear quantum diffusion, were detrimental to performance but non-linear wiggler magnets can be used to mould bunches to improve beam stability. George Dome (CERN) described nonlinear longitudinal motion in hadron colliders and the dissipative effects caused by r.f. noise.

The final lecture was given by L. Jackson Laslett (Berkeley), one of the pioneers in the study of nonlinear effects in accelerators, who gave a fascinating insight into his personal approach using meticulous numerical and analytical study.

As Mel Month, Chairman of the US School on High Energy Particle Accelerators pointed out in his closing remarks, 'One of the most difficult aspects of this school was the necessity to affect what has been called the 'transatlantic barrier' for our field... to find support for a significant number of young accelerator physicists to cross the Atlantic is very, very difficult indeed.'

Including the lecturers, the course was attended by 44 North American accelerator physicists together with 73 participants from Europe and the rest of the world. It provided a welcome opportunity for both young and mature accelerator physicists to listen to each other and discuss some of the most pressing and exciting problems in their field.

The proceedings of the school should be published in a few months' time in the Springer-Verlag series 'Lecture Notes in Physics'.

From John Jowett

BETA DECAY Enigma resolved

With the underlying theory of the weak nuclear interaction in such good shape after the discovery of the W and Z particles which carry the force, it would be surprising if the agreement did not extend to the whole of weak interaction theory.

In some of the first physics results to emerge from the new Tevatron ring at Fermilab, an experiment by a Chicago / Elmhurst / Fermilab / Iowa / Iowa State / Leningrad / Yale collaboration (E 715) has tied up one of the last remaining loose ends in the otherwise immaculate theory of weak interactions.

The classic example of the weak interaction is the beta decay of the neutron into a proton and a neutrino. In the same way, the heavier baryons (hyperons) have similar (semi-leptonic) decays. Each hyperon corresponds to a different mixture of quarks and all these semi-leptonic (beta-like) decays are described by an elegant model proposed by Nicola Cabibbo in 1963.

Hyperons are hard to come by in sufficient quantities to test the Cabibbo predictions, but over the years, most of the experimental data has lined up with the model, in particular the studies by the Bristol / Geneva / Heidelberg / Orsay / Rutherford / Strasbourg group which exploited the special hyperon beam in the West Experimental area of the CERN SPS (see December 1983 issue, page 418). This experiment was in complete accord with the Cabibbo picture, with a slight reservation about the sign of the axial vector to vector form factor ratio (a measure of the relative left/right 'handedness' of these decays).

These CERN studies used unpolarized hyperons. Four low energy experiments on polarized (spin oriented) hyperons, the last reporting in 1981, had observed a positive electron asymmetry (more of the produced electrons emerging in the direction of the spin of the sigma rather than the opposite direction) based on a total of 353 events. The magnitude of the axial vector to vector form factor ratio inferred from these measurements was in good agreement with the results of the two highest statistics unpolarized experiments (Brookhaven and the CERN SPS study, together providing 8 000 events) provided the positive value for the form factor ratio was taken.

The problem was that the Cabibbo model definitely predicted that the ratio should be negative in the beta decay of negative sigmas. If these indications could be confirmed, either the Cabibbo model is wrong, or the weak interaction in the decays of negative sigmas is right-handed, in stark contrast to the left-handed behaviour seen everywhere else!

In an unpolarized experiment, all the observables except one depend only on the absolute value of the axial vector to vector form factor ratio. However the shape of the electron energy spectrum is slightly sensitive to the sign of this ratio. By studying this electron spectrum, the CERN SPS experiment concluded that the negative sign predicted by Cabibbo was favoured, in contradiction with the