Three prototype cells for a model 1.5 GeV superconducting synchrotron being assembled at Dubna prior to successful tests. The 2.5 T magnets have been specially designed with a view to eventually building a synchrotron, called the Nuclotron.

Besides the magnet design, the application of superconductivity in an accelerator leads to some problems of integration of the magnets with the r.f., vacuum, injection and extraction systems, etc. A model 1.5 GeV superconducting synchrotron is being designed at the Laboratory of High Energies to solve these problems and gain experience. The accelerator will contain more than 100 superconducting dipole and quadrupole magnets, in 24 regular FODO cells each 1.5 m long, and two matched 9 m straight sections.

The first step was the construction of three prototype cells which have been cooled and tested. Experience with the magnet system has answered many important questions not only concerning the design of the model synchrotron, but also the eventual construction of accelerators of the Nuclotron type for the acceleration of heavy ions.

DARESBURY Nuclear Structure Facility in action

As mentioned briefly in the previous issue (page 98), first major experiments have been carried out at the Nuclear Structure Facility (NSF) at Daresbury. Nuclear physicists working in the UK thus have a major new research tool.

The tandem accelerator at the heart of the facility has achieved stable operation with 18 MV on its terminal. The machine feeds a range of new experimental apparatus and a broad programme of studies is planned, including several important investigations of rapidly rotating nuclei.

The NSF is an advanced version of the tandem electrostatic accelerator which for the past two decades has been used with great effect in many nuclear physics laboratories throughout the world. These machines are capable of accelerating a wide range of nuclear species and are noted for their excellent energy resolution and easy energy variability.

Construction began in 1974. The tandem is contained in a steel pressure vessel, 40 m long and 8 m wide, inside a 70 m high vertical tower. Initial operation will be with some 20 MV on the terminal, although electrostatic tests have shown that the ultimate design voltage of 30 MV can be reached.

The most critical component limiting this voltage is the evacuated tube through which the accelerated ions pass. So far, the tandem with the Mk I accelerator tube installed has been operated at 19.5 MV for short periods, and since last December has run reliably at 18 MV for experimental work. Over the coming months, the accelerator will slowly be taken to higher voltages as operating experience is gained and according to the needs of the experimental programme.

In parallel with the construction of the accelerator, there were preparations for the experimental programme in close collaboration with prospective users. Seven beam stations were approved for the first phase of operation. Three of them will be devoted to in-beam gamma ray spectroscopy and related studies. A precision 1 m diameter scattering chamber and a multi-element, high resolution magnetic spectrometer occupy two other beamlines which will support a wide variety of charged particle scattering and reaction studies. An isotope separator and a recoil separator have been specifically designed for the study of unstable nuclei.

The recoil separator is a combination of two crossed-field analysers cooled by liquid helium in hollow superconducting cable. This brings the Dubna magnets still closer to conventional types. The first pulsed superconducting magnet with forced two-phase helium circulation was successfully tested in 1980 and had excellent characteristics. The predicted field value was achieved without training and the same field was reached when the frequency of triangular cycles was as high as 1 Hz.
A prominent local landmark — the 70 m high tower housing the Nuclear Structure Facility at Daresbury. The experimental programme at the NSF is now under way.

and a magnetic spectrometer. It is capable of detecting short-lived products of nuclear fusion reactions recoiling near zero degrees. Recent work in Germany has reawakened speculation that superheavy nuclei can be formed in fusion reactions. If this is so, the recoil separator coupled to the NSF tandem will be an ideal combination for studying them.

The isotope separator is basically of conventional design and can be operated in both on-line and off-line modes. More unconventional are the associated laser equipment and dilution refrigerator. Shapes and sizes of nuclei can be deduced from studies of laser-induced resonance fluorescence. Measurement of the gamma decay of nuclei oriented at the low temperatures (about 6 mK) of the refrigerator yields basic information about nuclear excited states. The ability to apply these techniques to beams of ions from the isotope separator will provide unique facilities for studying short-lived nuclei far from the line of beta stability.

So far experimental work has concentrated on investigating the behaviour of nuclei subjected to a high degree of rotational stress. This has demanded the full capability and versatility of the NSF tandem. Accelerated beams of isotopically enriched titanium, sulphur and calcium ions have been used to produce nuclei spinning at record speeds, and the cascades of de-excitation gamma rays were detected and recorded using a unique array of gamma detectors called TESSA. Evidence has already been obtained which seems to confirm theoretical predictions that
dramatic changes occur in the structure of a spinning nucleus at certain critical values of rotational frequency. In a normal nucleus, neutrons and protons move cooperatively in pairs, rather like electrons in a superconducting metal. However, as the nucleus rotates, the Coriolis force causes the pairs to break apart at given frequencies and tries to align the individual nuclear spins with the rotation axis. At very high spins, extensive realignment of the nucleons is expected. These effects are analogous to the quenching of superconductivity by an applied magnetic field. Scientists are encouraged by these early results and look forward to a period of rapid advance in understanding high spin phenomena in nuclei.

These first experiments are only part of the planned programme for research using the NSF and scientists from many UK universities will extend their studies into many different areas of nuclear physics in the near future as the other major pieces of equipment are commissioned and brought on-line.

**Universal hadron behaviour**

Current dogma says that hadrons (particles which interact through the strong nuclear force) are composite, with an internal quark structure. Naturally, recent experiments have tended to look more at the hard collisions when individual quarks crash into each other, rather than the soft collisions due to collective quark interactions.

However the soft collective interactions still have a clear physics interest. Axiomatics says that the laws of these soft collisions should follow certain fundamental theorems expressed as ‘dispersion relations’ (mathematical convolutions incorporating the natural assumptions of analyticity, unitarity and crossing symmetry). Each time higher ener-

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A compilation of world data on the elastic scattering of protons on protons compared with protons on antiprotons (top), negative and positive kaons on protons (centre) and positive and negative pions on protons (below). The $b$ parameter gives the exponential decrease with momentum transfer of the elastic scattering spectrum. These results suggest that at high energies $b$ varies with momentum in the same way for all hadrons.