Neutron source at Rutherford

Beams of neutrons are playing an increasingly important role in the investigation of the structure of matter but, in the constant search for new and better experimental facilities, the limitations of fission reactors as neutron sources are becoming more and more evident. Scientists are likely to turn to accelerator based systems for improved neutron sources and proton synchrotrons could soon be in use as the 'next generation' of neutron sources.

Low energy neutron beams are widely used by physicists, chemists, materials scientists, biologists, etc., to investigate the structure and properties of a wide range of materials including alloys, defect solids, liquid crystals, ferroelectrics, amorphous polymers, organic molecules and membranes and macromolecules such as proteins and viruses. As is the case with high energy physics, few Universities have their own experimental facilities for neutron beam research.

In the UK, the Science Research Council (SRC) supports the work of university scientists by providing access to the necessary neutron beams and by supplying instrumentation support for experiments. At present the beams are provided mainly by fission reactors at a number of research centres — notably the UK Atomic Energy Research Establishment (AERE) at Harwell and the Institut Laue-Langevin (ILL) at Grenoble — and there is also modest but significant use of the AERE 30 MeV electron linac as a pulsed neutron source.

The importance of neutron beam experiments lies in matching the beam energies and other parameters to the binding energies and dimensions characteristic of the condensed matter being studied. These binding energies are typically in the thermal (up to say 100 millielectronvolts — meV) or epithermal (hundreds of meV) regions and, as a result, the maximum neutron energy available is of no consequence — a marked contrast to the high energy physicists' obsession with maximum energy.

Of major importance, however, is the intensity of the neutron beam. Neutron scattering is a notoriously low intensity activity and beam currents at the experiment are usually whole orders of magnitude down on the maximum flux close to the beam source. This decrease comes mainly from beam collimation and from the requirement to make the 'white' beam from the source, with its wide spread of neutron wavelengths, into a monochromatic beam. To put this inevitable beam attenuation into perspective, a hypothetical beam in which each neutron carried unit electric charge would, even at the highest flux fission reactors such as that at ILL, achieve a current at the experiment of only about 10^{-4} μA.

Recently the SRC, through its Neutron Beam Research Committee, has been considering new neutron sources to extend the application of neutron scattering beyond what is possible with present facilities. It is already apparent that the further development of reactor systems would be prohibitively expensive while the use of pulsed neutron sources based on particle accelerators looks a more economic alternative.

The Committee is now closely examining the scientific potential of a high intensity pulsed source of neutrons obtained by proton spallation of heavy targets. At the same time, the Rutherford Laboratory is studying the possibility of modifying the Nimrod complex into a high repetition rate, high intensity machine suitable for providing intense bursts of neutrons.

In the spallation mechanism, neutrons are produced by bombarding a target of a heavy element such as lead or uranium with protons of about 1 GeV energy. Spallation is a prolific neutron production mechanism and, more important, develops heat at the rate of about 50 MeV per neutron compared with 200 MeV per neutron in fission reactors. (Heat production is a limiting factor in reactor based systems.)

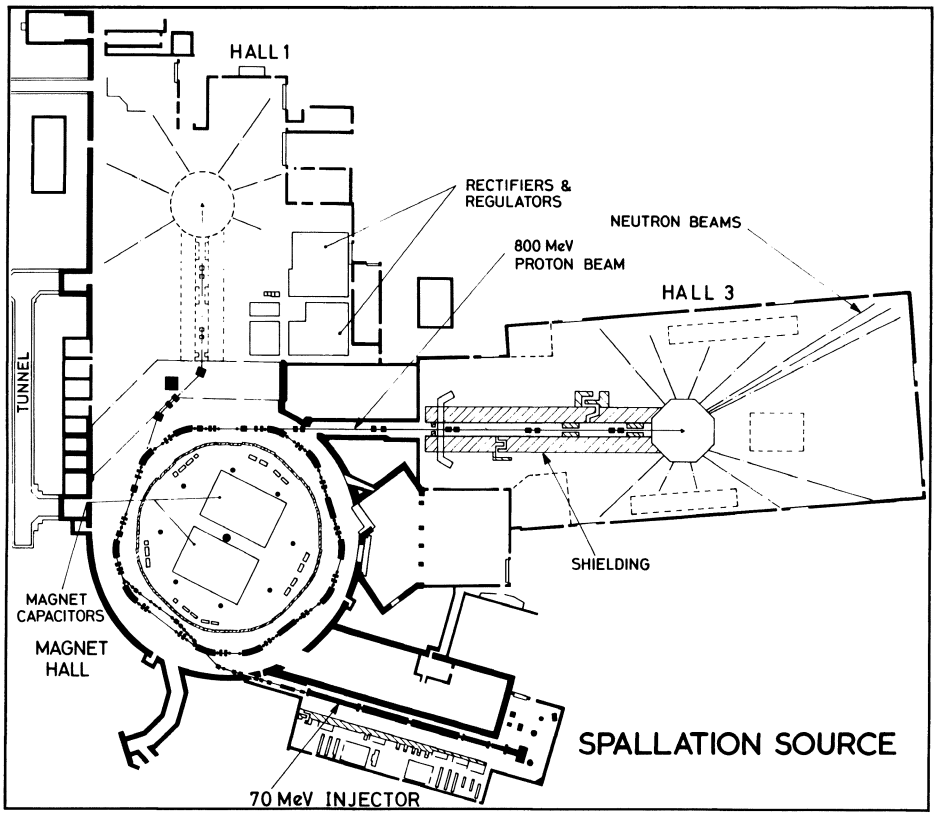
The advantages to be gained from accelerator based neutron sources are becoming widely recognised. In the USA, Argonne has a detailed project, under Jack Carpenter, for an Intense Pulsed Neutron Source (IPNS) ultimately using a dedicated 800 MeV proton machine (see COURIER, June 1975) and there are also moves afoot to install a condensed-matter research facility on the 500 MeV Booster at KEK in Japan (COURIER, October 1975). At the Los Alamos 800 MeV proton linear accelerator, LAMPF, there is a proposal to use the Weapons Neutron Research Facility, which is now nearing completion, also for general neutron research. At Oak Ridge they are thinking of converting their existing electron linear accelerator to produce neutron beams.

The ideas for the Rutherford Laboratory machine indicate that the main accelerator modification could be made in three or four years for less than £7 million. This estimate assumes that the new source will be able to use much of the existing equipment at the 8 GeV Nimrod synchrotron together with the magnet power supply from NINA (the Daresbury Laboratory electron synchrotron which is soon to close down). Without this existing equipment and surrounding resources, the cost of the new source would be about £30 million.

The machine would also use the new 70 MeV Nimrod injector which is being commissioned. All four accelerating tanks for this linac have been installed and protons have been accelerated to 10 MeV through the first tank with currents of 75 mA. The second tank will shortly come into

Possible layout of an 800 MeV proton accelerator and experimental facilities within the Nimrod complex at the Rutherford Laboratory. The machine would be used to produce pulsed high fluxes of neutrons.

Parameters of the machine	
Proton energy	*800 MeV*
Protons/pulse	*2.5 × 10¹³*
Protons/s	*1.3 × 10¹⁵*
Injection energy	*70 MeV*
Frequency	*53 Hz*
Peak magnetic field	*0.7 T*
Vertical emittance	*500 mm mrad*
Horizontal emittance	*950 mm mrad*
Bending radius	*7 m*
Mean radius	*26 m*



operation and progress on this injector will be described in a future article.

The main parameters for the new synchrotron are given in the table. The machine requires long straight sections for extraction of the large emittance beam and this leads to a relatively large mean machine radius, although one which fits conveniently into the existing Nimrod magnet hall.

The peak r.f. accelerating voltage is 140 kV and there is a frequency swing from 0.7 MHz to 1.6 MHz requiring cavities tuned by biassed ferrite. A total of 12 m of r.f. cavity would be required, distributed in two of the five straight sections of the machine, while one of the remaining straight sections would contain the necessary equipment to extract the protons and guide them into the experimental area and the heavy metal target.

The existing Nimrod magnet hall also provides sufficient shielding for the new accelerator but care would have to be taken to control beam losses and minimise the level of induced radioactivity. This would be reflected in the design of components for the new system, but existing electrical, cooling and other mechanical services could be easily adapted for the new machine configuration.

In addition to the condensed matter research programme, other uses for the new source are possible. Copious production of 150 MeV/c pions is feasible and, as well as being used in nuclear structure work, such beams would be of assistance in medical studies on the effect of pions on tumours and in general pion therapy. This would extend the radiobiological work currently in progress at Rutherford.

Other possible uses for the new machine, which would give it a multidisciplinary research role, include isotope production (both for commercial purposes and for hot-atom chemistry) and radiation damage studies (for fission and fusion research). Muon precession in solids is increasingly being used in other Laboratories to study the internal fields in ferromagnetics, type II superconductors and spin glasses where dilute random alloys have their spin orientations frozen in the matrix. Other applications for muon precession are the study of defects in solids, biological work and critical fluctuations in antiferromagnetics. The study of X-rays from exotic atoms would also be a significant field.

The Rutherford Laboratory is no newcomer to neutron research. For several years a Neutron Beam Research Unit, under Leo Hobbis, has been supporting the research by University physicists using facilities in the UK and at ILL. The unit is involved with the development of new instruments and techniques, the study of new neutron sources and in neutron experiments. The proposal for a higher flux neutron source would be a major extension of this work and would provide the Rutherford Laboratory, as the national high energy physics programme is curtailed, with a significant central project.