tra from the moderators are expected to be rich in "epithermal" neutrons (more energetic than thermal ones). In the radiation-effects facility, time-average fast neutron ($E > 0.1$ MeV) fluxes of 1.5×10^{13} and 3×10^{14} neutrons/cm^2-sec would be generated in the two stages. The accompanying flux of gamma rays would be very small, an advantage for many kinds of measurements.

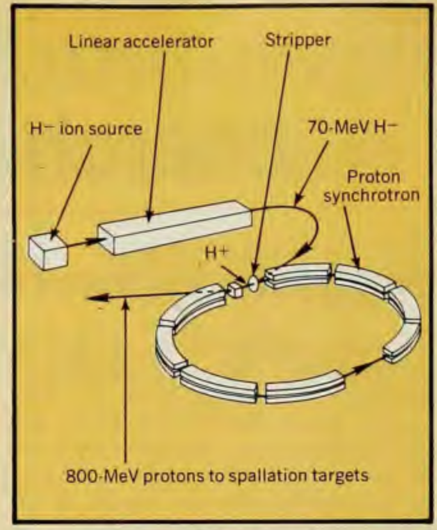
The Argonne lab has submitted a major construction proposal for the source, according to John Carpenter, project manager, for consideration by ERDA's Materials Research branch. The agency is examining the possibility of funding the proposal for fiscal year 1978.

Research in preparation for the first phase of the intense pulsed facility has gone on at the laboratory for two years by means of a prototype device based on the 200-MeV Booster I. Experimenters conducted neutron-diffraction and inelastic-scattering studies, reports David Price, director of Argonne's Solid State Science Division.

Oak Ridge considers. A group at the Oak Ridge laboratory has met to analyze the feasibility of modifying the Oak Ridge Electron Linear Accelerator to provide thermal neutrons for solid-state physics experiments. The facility was built originally for neutron cross-section studies of nuclei. Robert Peelle, co-director of the accelerator, urges that the changes necessary to make the device also a source for slow neutrons would be minor and—at $9 million, including $2 million for experimental facilities—comparatively inexpensive. However, no formal proposal has been made, though the idea has been extensively studied.

The Oak Ridge facility has a high pulse rate, 1000 pulses per second. If a narrow pulse width of less than 1 microsecond were assumed, and if the entire accelerator capability were utilized, a fast-neutron production rate of 10^{16} neutrons/sec could result, spread among the 1000 pulses. This is about five to ten times weaker than is provided for in Argonne's proposal for research with epithermal neutrons. Peelle suggests that the chief advantage of the contemplated modification is that, for a low capital investment, a facility three orders of magnitude higher in pulsed fast neutron production than any device currently devoted to scattering research would be obtained.

And Los Alamos. The Los Alamos workers have recognized the potential for employing its nearly completed Weapons Neutron Research Facility as an instrument with which to conduct solid-state physics. The $5.5-million device, scheduled for initial operation in late 1976, is to be a pulsed source that will utilize 800-MeV protons from the Clinton P. Anderson Meson Physics



Proposed Argonne intense neutron source is to use H$^-$-ion stripping to obtain protons.

Facility (commonly called "LAMPF") to produce neutrons by spallation for time-of-flight spectroscopy. As presently planned, the proton beam intensity at the target will be up to 10^{12} protons/pulse at a repetition rate of 120 Hz, which provides a time-average current of 1.2×10^{14} protons/second. This figure is comparable with the proton output of Booster II in the Argonne proposal, and the protons would be at a higher energy. For an equivalent target–moderator configuration, the Los Alamos facility would provide an approximate 60% increase over Argonne's thermal-neutron flux.

The lab has placed a $10 million proposal before ERDA's Division of Military Applications for FY 1977 funding of a proton storage ring to enhance the facility's pulsed-neutron capability. The ring would be for weapons research, according to Physics Division leader Henry Motz and facility program manager Roger Perkins.

Overseas, the Soviet Union has progressed in the last 15 years through a succession of pulsed fast reactors, called "IBR's," at Dubna. The IBR-II, a 2-MW device that could generate a very high fast-neutron production rate, is expected to begin operation within a year. Pulsed facilities with a fast-neutron production rate of 10^{13} neutrons/sec exist at Tohoku in Japan and at Harwell in the United Kingdom. Scattering researchers anticipate a tenfold increase in this rate at Harwell upon completion of a new linear accelerator. –FCB

Promising new results from Alcator

New results from the MIT tokamak caused quite a stir when they were reported at the APS plasma-physics division meeting in St. Petersburg, Florida in mid-November. The experiment, known as "Alcator," achieved a value for the Lawson number, $N\tau$ (where N is the peak particle density and τ is confinement time) greater than 10^{13} sec/cm^3. This value for $N\tau$ is five times greater than has been achieved in any other confinement experiment. It is generally believed that an $N\tau$ of about 10^{14} sec/cm^3 and an ion temperature of about 6 keV must be achieved to reach breakeven conditions for a fusion plasma.

The Alcator plasma is unusually free from impurities. Furthermore, as the density has been raised, the scaling for which τ is proportional to N has continued to hold.

Alcator is located at the MIT Francis Bitter National Magnet Laboratory, and its development has been led by Bruno Coppi, Bruce Montgomery, Ronald Parker and Robert Taylor. In addition to other experimenters at MIT, the group has included people from the laboratories at Jutphaas, Holland, Frascati, Italy, Fontenay-aux-Roses, France, and Kurchatov Institute, USSR.

Alcator, unlike most toroidal confinement devices, is capable of sustaining high plasma current densities without inducing macroscopic plasma instabilities, thanks to its reduced dimensions and higher magnetic field that distinguish it from other tokamaks. In addition this device has produced a much wider range of plasma densities. In earlier experiments (PHYSICS TODAY, June 1975, page 18) the device was operated at 65 kG. The new results have been obtained at 75 kG, and the machine is expected to be able to reach 100 kG.

In the new experiments, the MIT team found that they could achieve high plasma densities by keeping constant the ratio of the poloidal field to the toroidal field (the ratio is about $1/25$) as they raised each field value. And the temperature increased essentially proportionally to the poloidal field.

For a current of 100 kA at 75 kG, the temperature at the center of the plasma column was about 1 keV. Density was about 6.5×10^{14} particles/cm^3 and confinement times were greater than 20 millisec. Thus $N\tau$ was greater than 10^{13} sec/cm^3.

The observation of scaling behavior has pleased the MIT experimenters. They find that as N is increased, τ increases roughly proportionately, so that $N\tau$ increases roughly as N^2. This behavior persists over the whole range of densities studied, which can be varied by a factor of 200. Coppi told us that the MIT group has no sure explanation of why τ is roughly proportional to N, but they are considering several possibilities. All other tokamaks seem to observe that τ is proportional to N, but the range over which N can be varied is generally only factors of five.

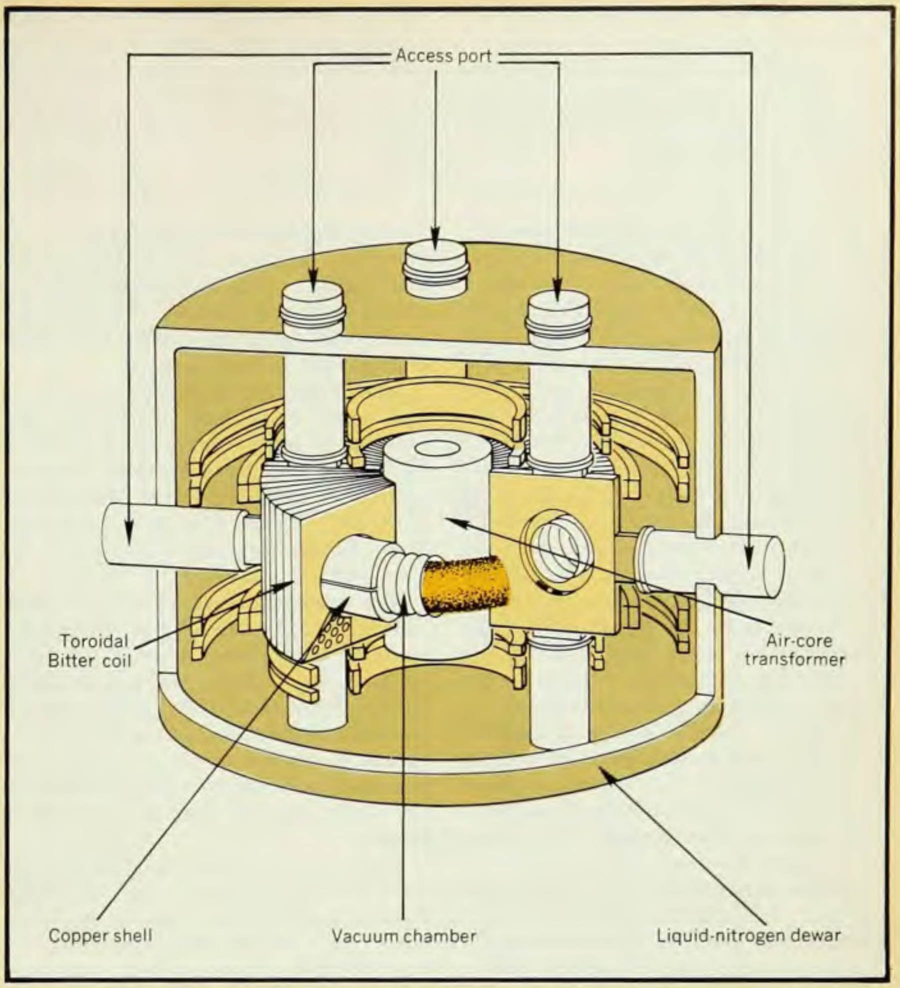
Because Alcator can be operated over such a large range of densities, Coppi told us, one can explore both the collisional (low ratio of mean free path to the device length) and collisionless (high ratio) regimes. Until now, tokamak experiments have all operated in the collisional regime (or between the two regimes), where trapped particles modes (driven by particles that are trapped in mirror-like regions and causing plasma to leak out of the machine) are not important. The Princeton Large Torus, about to go into operation, is also designed to reach the collisionless regime, to explore what happens when phenomena associated with trapped particles take over. The record parameters achieved in Alcator were all in the intermediate region between collisional and collisionless. When the plasma was studied in the collisionless regime, the confinement time deteriorated to the extent that the density was decreased; Coppi says that among the various possible explanations of this phenomenon it is not yet known what the correct one is.

Another cause of enthusiasm is the exceptionally clean plasma obtained for peak particle densities larger than 10^{14} particles/cm^3. Its effective ion charge is about one. Some other tokamaks have had effective ion charge of one, but typically have had about four. In addition, the lack of impurities, Coppi feels, may prevent the onset of disruptive instabilities.

The ability to raise plasma densities in tokamaks is limited by the maximum plasma pressure (product of density and temperature) that can be supported by the poloidal magnetic field pressure, and depends also on the density of the available heating power and the size of the toroidal field. There is a strong incentive to raise the poloidal field so as to maintain the plasma density as the temperature is raised, but it is technically difficult to do so.

Alcator has achieved about an order of magnitude stronger ohmic heating than any previous tokamak because of its high magnetic field and small size. To reach temperatures of reactor interest, however, some form of non-ohmic heating will be needed, for example neutral-beam heating or microwaves.

One possible application of the Alcator concept is to use it as a compact materials-testing reactor, in which one burns deuterium and tritium in the device to study the behavior of materials being bombarded by 14-MeV neutrons, alpha particles and thermonuclear plasma in general.



MIT tokamak device, Alcator, has reached an $N\tau$ value greater than 10^{13} sec/cm^3, a record.

Reactor possibilities. However, the Alcator concept conceivably could also be used for a power-producing reactor. At present, ERDA's emphasis is on the Tokamak Fusion Test Reactor (PHYSICS TODAY, October 1974, page 77), a \$215-million facility to be completed at Princeton by 1981. This is a device with a major plasma radius of 250 cm and a minor radius of 85 cm. The present Alcator has a major radius of 54 cm and minor radius of 9.5 cm—considerably smaller.

We asked Robert Hirsch, head of ERDA's controlled thermonuclear research program, how the Alcator results are going to affect the tokamak program. The results are too new to be sure, he says, but they are definitely causing ERDA to look more intensely at this regime of tokamak operation. Before following this approach, we must improve our understanding of scaling and whether or not the economics of a very high-field reactor are favorable, he says. ERDA's technology studies have concentrated on systems that use lower magnetic fields. Alcator, on the other hand, uses higher magnetic fields in a smaller system. Whether or not this will be more economical is not yet known.

Right now ERDA is continuing to go ahead with the Princeton Large Torus approach, which is incorporated in the TFTR design—larger size and lower magnetic fields—because that approach appears to be reasonable for reactors. Hirsch cites a statement made by S. J. Buchsbaum (Bell Labs) and others, "If Nature is going to let one approach work, she will let all of them work."

—GBL

Dimuons

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thought that a search for such dimuons might yield a charged intermediate vector boson (W particle). In the early 1960's such a search was made at Brookhaven, for example, but the W was not found. With the higher energies available at Fermilab, it was of course natural to conduct the search again. And this time the experiment yielded dimuons—but apparently not a charged intermediate vector boson.

Although the Harvard–Penn–Wisconsin–Fermilab group only see two muons in the final state, they believe that a third lepton is produced because