beam was obtained earlier than expected although there has never been a public announcement of the target date. For example, there do not appear to be any physicists at the site yet with the equipment needed to start experiments. Magnets for experimental beams have yet to be delivered, and the building that will house generators for them is not finished although the generators themselves are already on hand.

Detection equipment planned for the facility includes a 4.5 by 1 by 1.5-meter heavy-liquid bubble chamber, a 6-meter magnetic spectrometer and multiton spark chambers.

Superconducting Alpha-Uranium Shows Positive Isotope Effect

The superconducting transition temperature T_c of alpha-uranium is higher for U^{238} than for U^{235} according to a recent experiment at Los Alamos by Robert D. Fowler, James D. G. Lindsay, Ralph W. White (Los Alamos), H. Hunter Hill (Los Alamos and University of California, La Jolla) and Bernd T. Matthias (Bell Labs and University of California, La Jolla). It was reported in *Phys. Rev. Letters*, 16 Oct.

This is the first report of a positive isotope effect, in which $T_c \propto M_\alpha$ with $\alpha > 0$ (M is isotopic mass). For other substances, one sees either a negative isotope effect ($\alpha < 0$) or none at all.

The experimenters believe they have uncovered a new mechanism that leads to superconductivity. Some theorists feel, however, that the results are inconclusive.

In the experiment high-purity samples of alpha-uranium isotopes 235 and 238 were made bulk superconducting by applying hydrostatic pressure of 11 kilobars in a He^4 cryostat. The experimenters detected transitions with a resonant-ac-bridge method and measured temperatures with a germanium resistance thermometer calibrated against the vapor pressure of He^4. They found $T_c \propto M^{2.2}$.

Fowler and his collaborators, who did the experiment with the expectation that they would find a positive isotope effect in uranium, are of the opinion that this reversal in sign and magnitude is strong evidence that "here a mechanism other than the phonon-electron interaction leads to superconductivity." They suggest that the superconductivity they observe is due essentially to the f-electron interaction with the conduction electrons.

Theory. Superconductivity is usually explained as due to an interaction between conduction electrons and lattice vibrations of the metal. In BCS (John Bardeen, Leon Cooper and J. Robert Schrieffer) theory one usually assumes that an attractive interaction between electrons and phonons produces superconductivity. However, the theory is a general one and allows for other kinds of attractive interaction.

We asked Schrieffer to comment on the Los Alamos work. Schrieffer told PHYSICS TODAY, "The observation of a positive isotope effect in uranium does not necessarily rule out the conventional phonon mechanism of superconductivity in this system." He noted that in fact the electron-phonon interaction allows for a positive isotope effect.

The electron-pairing theory of superconductivity was originally worked out for a model in which electrons moving in broad energy bands, such as in mercury or tin, are coupled by phonon and Coulomb interactions. Using this model one correctly obtains $\alpha \approx -0.5$ for mercury and tin. With the same phonon and Coulomb mechanism, the theory was extended to include narrow-band and strong-coupling effects; one finds α can deviate significantly from -0.5 using the conventional mechanism.

A few years ago J. C. Swihart and James Garland showed that for systems in which superconductivity arises primarily from electrons moving in narrow bands, or in bands whose density of states varies rapidly near the Fermi surface, α can increase sharply from -0.5 and may well be positive. Its actual value depends on details of the band structure, phonon and Coulomb interactions, etc. Such deviations are known to occur for transition metals. Garland's original paper predicted that iridium would show a positive isotope effect; it assumed superconductivity arises only from an electron-phonon interaction.

When we asked Garland to comment on the observations of a large positive isotope effect in uranium, he pointed out that such an effect could not be explained without consideration of the f bands. A model calculation in which the bottom edge of the f band lies slightly more than a typical phonon energy above the Fermi level yields a large positive isotope effect. The phonon-induced interaction, he explained, reduces the total repulsive interaction between electrons at the Fermi level and f states above the Fermi level.

Garland noted that the observed T_c for uranium is too high to permit an explanation of the positive isotope effect similar to his original theory. Thus he agreed with the Fowler group that there is a new superconductivity mechanism.

Schrieffer feels that "although the recent isotope-effect measurements on uranium reopen the interesting possibility of superconductivity occurring in exceptional systems through a pairing interaction other than the phonon mechanism, the present experiments are inconclusive in establishing whether other mechanisms are in fact realized in nature." —GBL

Surveyor V Finds Basalt on the Moon

The wealth of information provided by Surveyor V's successful journey to the moon includes an analysis of the surface rocks but still brings us no nearer to a solution of the biggest lunar problem: How was the moon formed? Did it break off the earth during our planet's infancy; was it captured by the earth, or were the two bodies formed simultaneously?

On 8 Sept. Surveyor V appeared to be going the way of its predecessor, Surveyor IV, and heading for a crash landing on the moon. Trouble with a helium pressure-regulating valve had caused a loss of pressure for the rockets that were to control the soft landing. However a modified landing sequence was hastily improvised with the remaining helium, and on 10 Sept. the vehicle dropped at about 4 meters/sec onto the Sea of Tranquillity, bounced, slid about 1 meter and finally came to rest on a 20-deg slope inside an elliptical rimless crater.

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