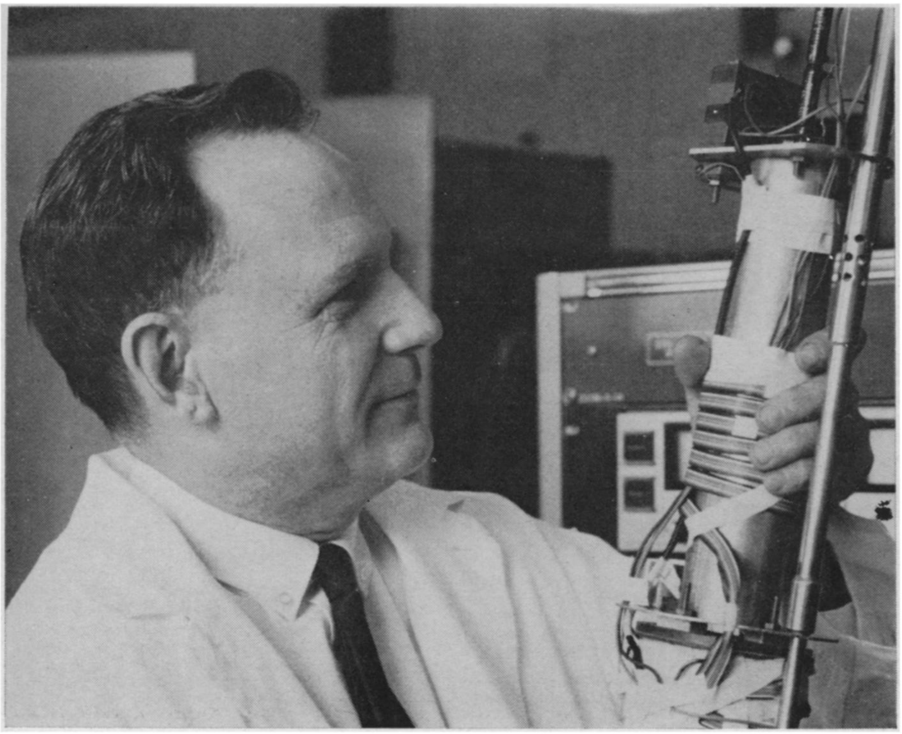
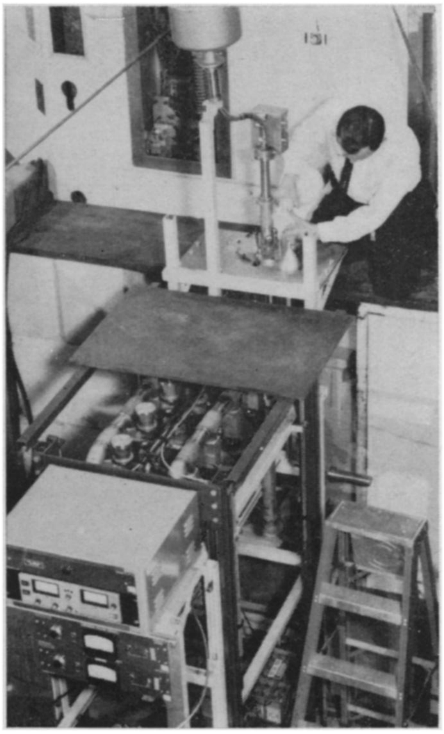


All photos: Argonne

Dr. S. Bradley Burson examines the magnet of his electron spectrometer.



Dr. Burson prepares for experiment.

PHYSICS

Nudging the nucleus

Sensitive new equipment may gain important information from radiated electrons

by Dietrick E. Thomsen

Physicists have been learning about the structure of atomic nuclei since the turn of the century. But in spite of libraries of data, so complex are these structures that knowledge is still very incomplete and the picture of what goes on inside a nucleus is still very sketchy.

A nucleus may consist of more than 200 individual protons and neutrons. Each particle is affected by forces generated by all the others and each can be in any of several states of energy or of other relevant qualities.

There are two main forces at work: The strong or nuclear force by which neutrons and protons all attract one another, and the electrical force by which protons repel each other. The balance between them determines whether a nucleus is stable or not.

While high-energy accelerators have allowed physicists to leap-frog the nuclear problem and study the individual particles that make up the nucleus, as well as many that seem to have nothing to do with it, what is known of nuclear structure has been summed up in more or less empirical models which do not always agree with each other.

Some see the nucleus as a structure of concentric shells, something like an onion, each shell containing a certain number of neutrons and protons. This is a somewhat more complicated analogue to the shells of electrons in an atom.

Others use the analogy of a liquid drop, comparing the neutrons and protons to the atoms of a liquid, and talking of such things as nuclear surface tension.

Yet others speak of the nucleus as a kind of energy well in which the neutrons and protons are held captive and into which particles from outside may fall, sometimes with enough force to bounce others out.

All these pictures can explain some of the things that happen to nuclei.

What is needed, according to Argonne National Laboratory's Dr. S. Bradley Burson, is a theory that would start from a given nuclear state and predict its future. "You want to be able to assemble a system and know how it will behave," he says.

Such a theory would be esthetically and intellectually satisfying. It might also be of technological benefit to replace empirical engineering rules with exact knowledge in the nuclear power technology that is becoming of greater and greater economic importance.

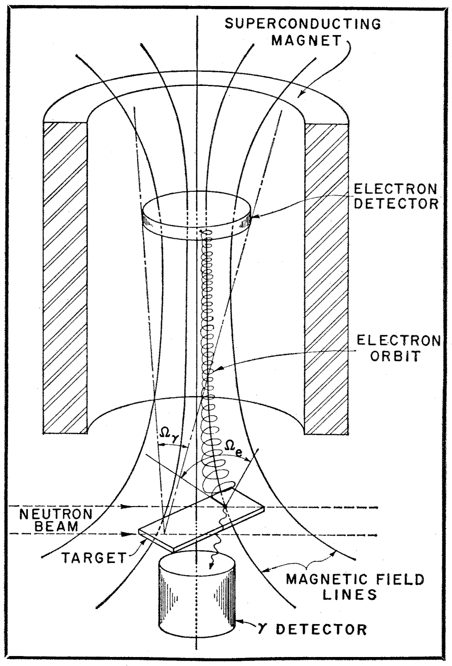
And a good theory could shed light on new possibilities. One that is intriguing physicists at present is the possibility of creating super-heavy atoms (SN: 12/14/68, p. 593) in which the configuration of the nuclear particles could allow for a stable balance between electromagnetic forces pushing them apart and nuclear forces holding them together, so the nucleus won't blow apart.

To get a stable nucleus to yield information on what is going on inside it, one has to disturb it somehow.

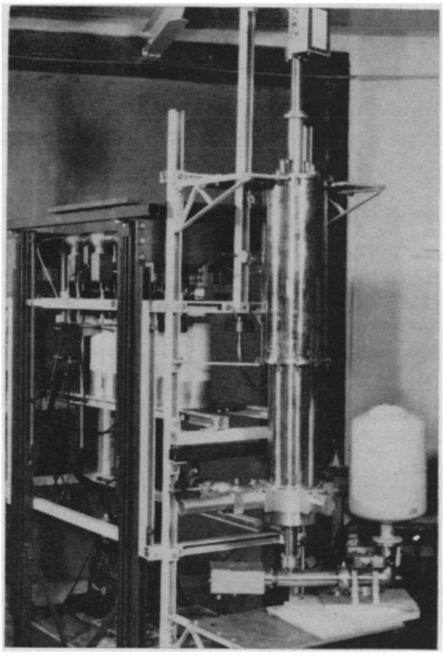
One way is to blow it apart by bombardment with high-energy particles and study the fragments. Accelerators do this.

Information about lower energy states, however, has to be gotten without disrupting the nucleus. It is this that a new and perhaps unique machine, Argonne's superconducting internal conversion electron spectrometer, is expected to do.

If a nucleus captures a sufficiently slow-moving neutron, it can become highly excited without coming apart. It then simmers down to its original



Schematic of components.



The spectrometer fully assembled.

state in a sequence of steps, at each of which it can emit gamma rays and electrons. The cooling-off process is called internal conversion.

There are hundreds of possible states that the nucleus can go through—different combinations of energy, spin and parity for each of its particles—and the research aims to find which ones occur at what stage of the process.

It is not a leisurely form of data gathering; the time scale for internal conversion is counted in billionths of a second.

Internal-conversion gamma rays have been studied for the last two decades and, says Dr. Burson, have been "our largest source of information."

Study of the electrons is just beginning. There are four spectrometers in the world specifically designed to study electrons emitted after capture of a slow neutron: Argonne's, one in Germany, one in Russia, and one in Latvia. Argonne's is unique so far as Argonne knows, however, in simultaneously counting the gamma rays as well as the electrons.

The main part of the instrument, which would take up the corner of a large room, is a strong, superconducting magnet whose construction has been made possible by advances in solid-state technology in the last few years. The magnet sits just above a target, a thin foil of the material to be studied.

The target is irradiated with slow neutrons from a reactor, and the electrons are caught by the magnetic field and focused onto a counter that enumerates them individually. Meanwhile the gamma rays are measured by a counter located below the target.

Being able to study the electrons gives the physicists the ability to gain information about all three of the important factors in the internal conversion process: energy, spin and parity.

The gamma rays give information about the energy but they say nothing about the spin of the objects they have left behind. Electrons do carry such information. Furthermore, says Dr. Burson, if you get enough spin measurements you can draw conclusions about the parity—the right- or left-handedness of the particles involved.

As an added bonus, the strength of the magnet in the Argonne spectrometer will allow study of many materials that give off few internal-conversion electrons. Other studies have had to content themselves with materials that have a particular affinity for absorbing several slow neutrons and thus give off enough electrons for less sensitive equipment to count.

The work, Dr. Burson says, is the purest of pure physics. It is aimed at a satisfying theory of nuclear dynamics, not at engineering convenience.

Yet whatever its long-term effects it might even have fairly immediate practical spin-off. The situation, slow neutron capture, that is set up for the study is just what happens in many cases in objects surrounding nuclear installations, and the design of reactor shielding could conceivably be affected by what is learned. ◇

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