Probing the depths of the nucleus

A new generation of machines, called meson factories, should yield a sharper dimension in the study of what goes on in atomic nuclei

by Dietrick E. Thomsen

The physics of objects smaller than an atom was once a single specialty. It was called nuclear physics because its main concern was the nature and structure of atomic nuclei. But in the last decade or so a separation has taken place between the physicists who studied subatomic matter at very high energies, the so-called particle physicists, and nuclear physicists proper.

The particle physicists took as their domain the nature and behavior of individual particles, rather than collective entities like a nucleus. They have gone on to higher and higher energies and ever more startling discoveries in their search for the most fundamental constituents of matter.

Lately the particle physicists have experienced a certain frustration. They have been having a hard time trying to mate theory and experiment, and many of the objects they have discovered are so ephemeral that some of them are beginning to wonder whether they have anything to do with the structure of stable matter.

The structure of nuclei is fundamental to the structure of stable matter, and if it ever becomes well understood, the age-old dream of making the elements one desires instead of depending on what nature gives might be a step nearer. And among the nuclear structure physicists, there is a feeling of hope and an expectation that old frustrations are about to be relieved.

The nuclear physicists are building a new generation of particle accelerators, which, they expect, will give them an entirely new dimension of information about nuclear structure. Heretofore their experiments have concerned the nucleus as a whole. Now they want to study the nucleus in more detail. They want to see how small regions of it look and how individual nuclear particles behave and interact with each other within the nucleus.

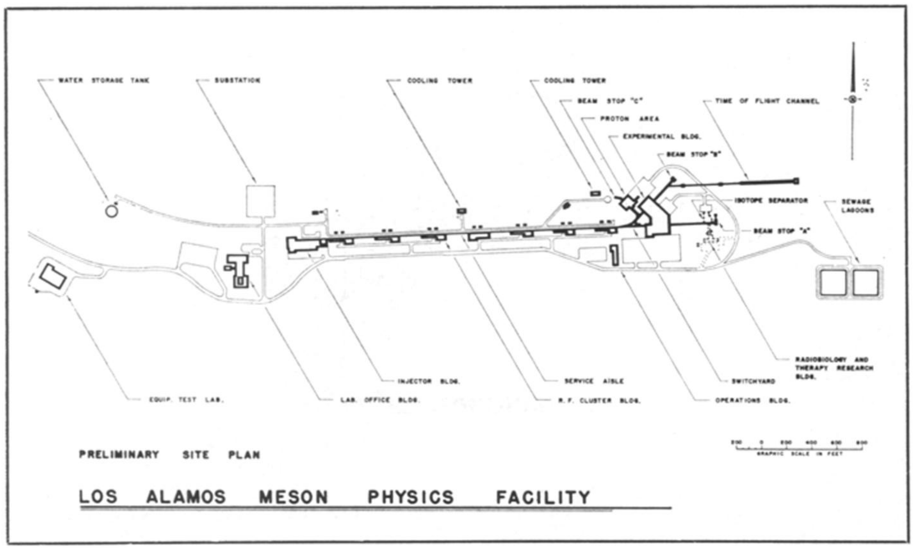
So far they have not had the energy available to get such data. Technology is now allowing them to build the machines that will do it. And those are now being built at several sites in the U.S., as well as in the Soviet Union, Switzerland and Canada.

The machines are commonly called meson factories because one of their primary functions is the production of copious beams of pi and mu mesons with which to probe nuclei. In some cases they also yield protons and negative hydrogen ions, hydrogen atoms with an extra electron each. Each of these particles interacts in a different way with the particles in the nucleus, and each gives a different perspective on nuclear structure. Putting the perspectives together, physicists hope, will give a comprehensive picture.

The meson factories bring nuclear structure physics into an energy range, hundreds of millions of electron volts, where the physics has not usually been done. The energy is necessary to get the detailed information, but achieving the energy was not the major technological stumbling block in the construction of meson factories; intensity was the problem.

The particle beams have to be very intense—contain a large number of particles—to make enough of the desired reactions happen to get meaningful data. Gradual improvements in beam handling techniques have made the management of very intense beams possible, but they still give designers problems with radioactivity.

"There are unique problems in the handling of intensely radioactive material in targets," says Dr. R. L. Burman of Los Alamos Scientific Laboratory, speaking of the now-building Los Alamos Meson Physics Facility. The solution, he says, is to design a so-called

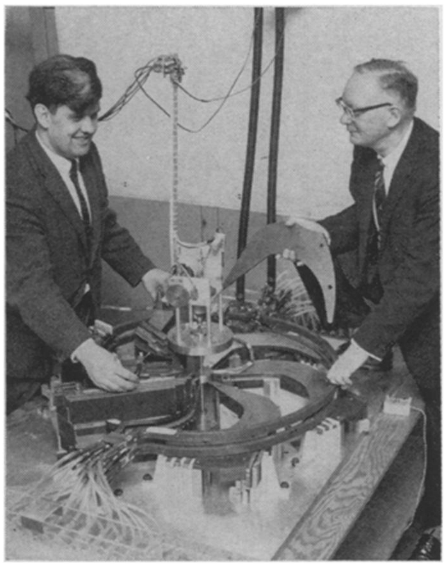


LASL

Meson site plan: Left end of plan is bottom of photo on opposite page.

A. Vorotynsky

Dzelepov: Remodeling one he has.



Univ. of British Columbia

Warren, E. W. Vogt and TRIUMF.

hot cell that could be dropped over LAMPF's target cell to service the components of the target cell by remote control.

The Los Alamos facility is the most energetic of the meson factories now under construction. It will be a linear accelerator, 1,800 feet long, that will accelerate protons or negative hydrogen ions to energies between 100 million and 800 million electron volts (MeV). The protons, striking various targets, will produce pi and mu meson beams.

The total cost of $56 million as estimated by Dr. Burman also makes the Los Alamos machine the most expensive of the current group. Completion is expected in the early 1970's.

At Dubna in the U.S.S.R. an existing machine is to be remodeled into a meson factory. This, the Dubna High Current Phasotron, gives an example of how beam intensities must be increased for the coming class of nuclear structure investigations. As it now exists, according to Dr. V. P. Dzelepov, the phasotron produces a current of protons between 2.3 and 3.5 microamperes at 680 MeV; renovation will provide a current of 50 microamperes.

The phasotron will be shut down in the middle of 1972 to begin the renovation.

Meson factories do not need to be as expensive as LAMPF, and this makes the game one that small nations can play. On the banks of the River Aare in northern Switzerland a machine called SIN-ETH is under construction. (The initials refer to the Swiss Institute of Nuclear Research and the Eidgenössische Technische Hochschule, the Federal Institute of Technology.)

"Some people in Switzerland consider it not only a sin, but a crime, to build this machine," says Dr. J. P. Blaser of ETH. But opposition was overcome, and Dr. Blaser is proud that his machine was the first of the meson factories to be funded. Construction has been delayed, however, and the machine is not expected to operate before the end of 1973.

The Swiss machine will be a 600-MeV cyclotron with beams on the order of 100 microamperes. A cyclotron, says Dr. Blaser, is cheaper than a linear accelerator, "or we couldn't have afforded it in our small country." The total cost will be $22 million.

Another economically small country, Canada, is building a meson factory that will get its particles from negative hydrogen ions accelerated to 500 MeV. The machine was originally the project of three universities in western Canada and is called TRIUMF for Tri-university Meson Facility. Now a fourth university has come into the group, which means the name could become TETRUMF. So far it hasn't.

To produce 500-MeV particles the Canadian cyclotron will have to be 624 inches across. (In the recent past 200 inches was considered large for a cyclotron.) Cyclotrons have large magnets spanning their entire diameter, and "it is pieces of iron of this enormous size that provide the challenge in the design of this type of accelerator," says Dr. J. B. Warren of the University of British Columbia.

The new cyclotron is being built on the university campus in Vancouver.

At the high end of the current energy range, the managers of the Princeton-Pennsylvania Accelerator, a machine originally built for particle physics studies in the billions of electron volts, are seeking money to modify it so that it can participate in high-energy nuclear research.

The plan for PPA is to alter it so that it can accelerate heavy ions, nuclei stripped of their electrons, and study what happens when they collide. The total cost of the modifications would be $4.75 million. The accelerator has already brought doubly ionized helium 4 to an energy of 4 billion electron volts, and PPA's Dr. Milton G. White says he and his associates hope to reach 4.8 billion electron volts by February or March.

Finally, a bridge between the current area of interest, the hundreds of MeV, and the region where work was done in the past, the tens of MeV, is being supplied by Indiana University's 200-MeV cyclotron project. This will produce protons between 15 and 200 MeV and negative hydrogen ions between 15 and 160 MeV. "We're not interested in producing pi mesons as such," says Indiana's Dr. M. E. Rickey, "but there is merit in exploring this transition region between low- and high-energy physics." □