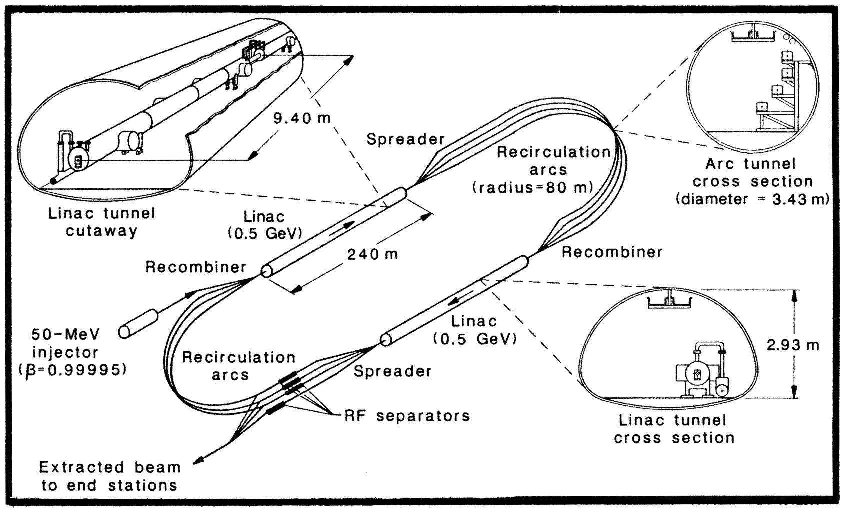
Single-File Electrons

The next machine for nuclear physics is to have a powerful yet precise electron beam designed to study quarks



Each of CEBAF's two linac cavities is to be able to speed electrons by 0.5 GeV. Electrons that circulate through the pair of them four times are to reach 4 GeV.

By MARY MURRAY

Physicists who want to study the way quarks behave inside the nucleus are waiting for the construction of a powerful yet precise new electron accelerator in Newport News, Va. The Continuous Electron Beam Accelerator Facility (CEBAF) is to be the most delicate probe in the world for examining the tiniest particles of matter.

The U.S. Department of Energy (DOE) is asking Congress for $246 million to build the facility. If Congress agrees to start construction as early as next year, CEBAF could be up and running by 1992. And while such an optimistic timetable is unlikely, according to congressional sources, scientists nevertheless are eagerly anticipating the pioneering facility.

Nuclear physicists have wanted an accelerator like CEBAF for more than a decade, ever since particle physicists discovered quarks—the pieces that make up protons and neutrons — and gluons, the particles that hold quarks together. "We want to use what we know from particle physics about quarks and to see what effect that new [knowledge] might have on the understanding of the structure of nuclei," says Peter Barnes, physics professor at Carnegie-Mellon University in Pittsburgh. Barnes chaired a 1982 subcommittee of the DOE's Nuclear Science Advisory Committee, which identified CEBAF as the most needed new tool in nuclear physics.

Although it is to be more powerful than most nuclear physics accelerators, CEBAF is to be much gentler than the giant atom-smashers used in particle physics, because nuclear physicists plan to study quarks more delicately. While particle physicists try to blast quarks and gluons free from their parent neutrons and protons (SN:5/24/86,p.331), nuclear physicists want to watch quark behavior inside intact nuclei.

The electron beam is considered the best tool for this job because it can hit the nucleus with the electromagnetic force, the best-understood force in nature, which will not disturb the entire nucleus. The electromagnetic force will disturb only the specific pieces of the nucleus it penetrates.

"The electron is like a scalpel, excising one part of the nucleus and measuring it with great detail," says David L. Hendrie, director of the nuclear physics division of the DOE Office of Energy Research. "It can go in and scatter off one selected item, such as a quark or perhaps a gluon, and measure the location, charge and motion of that quark inside the nucleus."

The premier feature of CEBAF is to be its powerful yet continuous flow of electrons. Whereas most high-powered electron accelerators hurl "pulses" of electrons, all bunched together, toward the target nucleus, CEBAF is designed to shoot the electrons in a single-file stream. This will allow physicists to perform "coincidence" experiments, in which they can correlate one impact on the target nucleus with one particular electron. Coincidence experiments are needed, physicists say, in order to figure out the exact location, energy and momentum of individual particles within the nucleus.

Although there are two other "continuous wave" accelerators — one at the University of Illinois at Urbana-Champaign and the other at the University of Meinz in West Germany — neither is powerful enough to probe quarks in the nucleus. Their beams range from 80 to 200 million electron-volts (MeV), which is strong enough to bounce electrons off neutrons and protons, but not off quarks. To reach the quark level of detail requires a beam with at least 1 billion electron-volts (GeV).

CEBAF is to have a capacity of up to 4 GeV, plus the potential of being upgraded to about four times that power if scientists eventually see the need. At 4 GeV, an electron beam can examine quark clusters to a resolution of about one-tenth the diameter of a neutron or proton, according to Hermann A. Grunder, a physicist who recently left Lawrence Berkeley Laboratory in Berkeley, Calif., to become director of CEBAF.

CEBAF's beam will be made possible by its "superconducting" design. Instead of a traditional copper accelerator cavity, CEBAF is to have a niobium cavity that is kept chilled to −455°F, just a few degrees above absolute zero. (The cavity is insulated in a bath of liquid helium.) Niobium cooled to this point loses about 100,000 times less energy (in the form of heat) than copper, says Ronald M. Sundelin, one of the physicists who came up with the CEBAF design at the Floyd R. Newman Laboratory of Nuclear Studies at Cornell University in Ithaca, N.Y.

Because it is more efficient, the supercooled niobium cavity can send out a 4-

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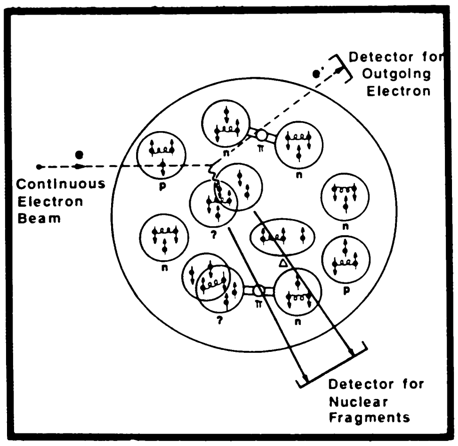
GeV beam with less power than a copper tube would require. And with lower power, physicists can run the beam continuously.

"If you were using a copper structure, you would need a very large amount of power, and you could not run it at that power with a continuous beam because it would crack the copper," Sundelin said. "Besides, you would have an electric bill that your budget would not allow you to pay."

Sundelin estimates that CEBAF's electric bill will be half what it would be for a comparably sized facility with a copper cavity and a pulsed beam.



When electrons hit the nucleus one at a time, each electron can be matched with the fragments it breaks off.

CEBAF is expected to be "unique in the world" and to allow the United States to maintain "leadership in basic nuclear research," Alvin W. Trivelpiece, director of DOE's Office of Energy Research, told the House energy appropriations subcommittee this spring. That is, if the five-year construction period begins soon.

DOE has asked Congress to appropriate $25 million in the 1987 budget to begin building CEBAF next year. But as Congress still struggles to erase the national debt, it may be reluctant to approve a construction start, according to an aide to the Senate energy appropriations subcommittee.

It wouldn't be the first time CEBAF has run into hurdles in Congress. A year ago, Sen. J. Bennett Johnston (D-La.), ranking minority member of the Senate energy appropriations subcommittee, questioned why DOE officials chose to have CEBAF built by the Southeast Universities Research Association (SURA). This consortium of southeastern universities was formed in 1980 for the express purpose of establishing a nuclear physics accelerator in the southeastern United States. The group had no experience operating an accelerator.

At Johnston's request, the General Accounting Office (GAO) investigated the selection process and, in April, issued a report criticizing DOE officials for not first figuring out the best available technology for the accelerator and then formally requesting design proposals that made use of that technology. Instead, DOE simply established the need for a continuous electron beam accelerator with a capacity of at least 1 GeV, and then chose from among five proposals that were sent in unsolicited. The result, according to the GAO report, was the selection of an inexperienced management organization and an accelerator design that had to be updated.

The scientists who helped DOE select from among the five proposals decided the new machine should have the capacity of at least 4 GeV, a requirement that disqualified three of the five plans. Neither of the two that remained — SURA's plan and a proposal submitted by Argonne (Ill.) National Laboratory — included the latest in accelerator technology, the GAO report stated. At the time it was selected, SURA's proposal called for a traditional copper tube accelerator with an attached "pulse stretcher" ring, which was to create the continuous beam.

The GAO found there were "technical uncertainties" in SURA's original design, including the need for a high level of energy from the klystrons — the machines that power the accelerator — which could overheat the copper beam cavity and cause it to fail.

The damage was repaired, however, when CEBAF officials updated the design to include a superconducting cavity, according to the GAO report. The report also praised SURA for hiring experienced accelerator physicists to run the facility. They include Grunder, the director, and J. Dirk Walecka, a Stanford University physicist who became CEBAF's scientific director in July.

Some scientists have questioned the wisdom of building CEBAF in Newport News because there is no university nearby.

"We would have preferred to have it near the facilities of a large university," says Yale University physicist D. Allan Bromley, who headed a panel of scientists that helped DOE officials choose the SURA proposal.

But the City of Newport News had offered to buy a 300-acre site, complete with two existing buildings, for the facility, and the Commonwealth of Virginia offered a $1 million annual contribution to match, so the scientists accepted the site. "It was a trade-off," Bromley said. "We were trying to keep costs down, so we decided we could live with this location."

With congressional budget-cutting threatening to keep CEBAF waiting in the wings another year, location has turned into a minor concern. The main task now facing CEBAF officials, who already have set up shop in Newport News, is to make sure the project gets started soon. □

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