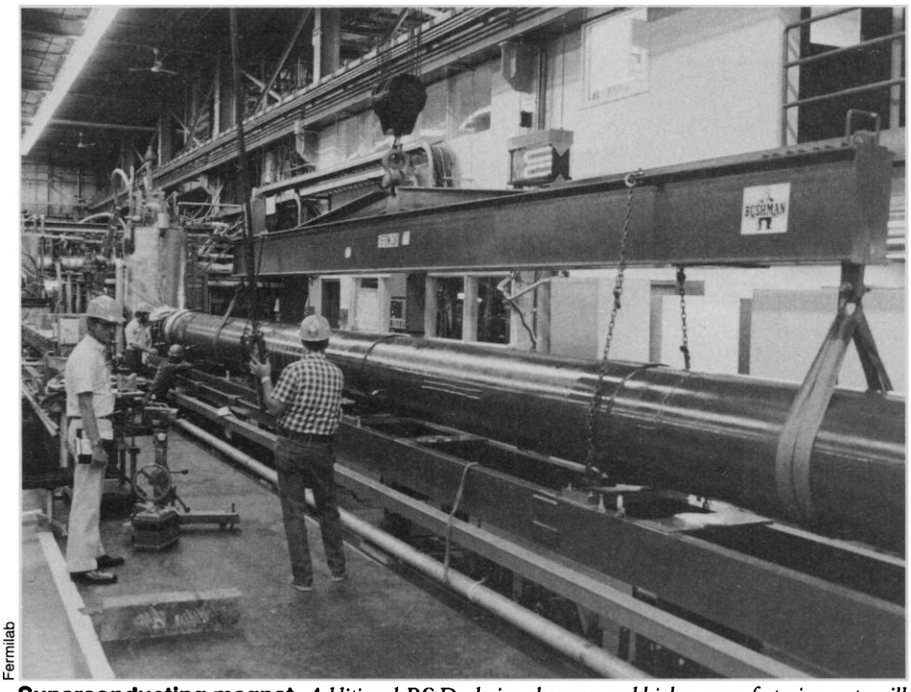

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Superconducting magnet. *Additional R&D, design changes, and higher manufacturing costs will add about $390 million to the accelerator project's price tag. One change would cut the length of the SSC's helium-cooled magnets like the one shown above from 17 meters to 15 meters.*

Super Collider Advocates Tangle with Cost Cutters

As the Secretary of Energy tries to trim costs, a panel of physicists warns that he may be limiting future research

FOR SEVERAL MONTHS NOW Energy Secretary James Watkins and the managers of the Superconducting Super Collider (SSC) project have been at odds over the rising cost of the mammoth particle accelerator. Watkins wants to keep the collider's costs down and is looking for ways to scale back the project. But leading U.S. physicists are warning the Department of Energy (DOE) that tinkering with the performance specifications to save money could prevent researchers from exploring some pressing questions in particle physics.

The focus of the dispute is a set of new cost estimates being assembled by SSC Laboratory officials in Waxahachie, Texas. Their conclusion: The final price tag for the SSC could jump from $6 billion to about $7.2 billion (constant dollars). The cost escalation is largely attributable to increased labor charges, a sharp rise in the expected costs of the superconducting magnets, and design changes in key accelerator systems to make sure the machine performs properly. But Watkins' staff has been reluctant to support some of these price changes and has been looking for ways to save money by relaxing the SSC's performance requirements.

The original design calls for accelerating two beams of protons in opposite directions to an energy of 20 trillion electron volts (TeV) and then smashing bunches of protons together at a combined energy of 40 TeV—more than two orders of magnitude higher than the energy of the world's most powerful accelerator, the 2-TeV Tevatron, at Fermi National Accelerator Laboratory.

On its face, the idea of lowering the maximum collision energy of the SSC from 40 to, say, 36 TeV seems reasonable given that the machine would still be far more powerful than any other accelerator now being planned. Indeed, as recently as last summer, DOE officials and SSC Laboratory researchers were suggesting that this might be a way to cope with weaknesses in the design and performance of the SSC's magnets, which steer protons around the 53-mile accelerator loop.

But particle physicists and key SSC supporters in Congress are now sending Watkins a strong message that they would oppose shaving expenses by compromising on performance criteria such as maximum collision energy and luminosity—the number of collisions that occur at any one time. In an internal SSC Laboratory report* prepared for director Roy Schwitters in early December, for example, an ad hoc committee of 13 physicists advised against lowering the collision energy. They backed 40 TeV, the standard adopted by DOE's now defunct Central Design Group in March 1986, stating that "within our present knowledge of physics, there are no indications that would point toward a lower energy machine."

"If you want to revitalize the United States' physics program, 40 TeV is really the minimum you need," says Samuel Ting, a Massachusetts Institute of Technology physicist who was not part of the SSC laboratory's review group. At this energy level, physicists generally believe they can produce the kind and quantity of events necessary to search for new particles predicted by the standard model of the structure of matter—or, perhaps, particles that reveal a more complex order. "High energy is the most important factor" in the machine's design, says Ting.

If the center-of-mass collision energy is lowered, says the SSC Laboratory's ad hoc review committee, there is an increased risk that the accelerator will not produce critical events with enough frequency to enable researchers to confirm the existence of long-sought particles. The Higgs boson, for example, could help explain such phenomena as electroweak symmetry breaking—the process by which quarks, leptons, W, and Z particles are thought to acquire mass. But confirming the existence of the Higgs particle might not be possible if the SSC's collision energy drops much below 40 TeV.

Nevertheless, Watkins has asked the department's High Energy Physics Advisory Panel (HEPAP) to convene a blue-ribbon group of physicists to assess the option of going to a lower collision energy. One possibility under consideration is to offset a lowered collision energy with an increased number of proton collisions. This higher luminosity might allow researchers to see particles produced by events that would be much rarer at the lower energy.

But the SSC's luminosity is already expected to be ten times higher than that of current-generation accelerators, and researchers are struggling to design detectors

**Report of the Ad Hoc Committee on SSC Physics*, SSC Laboratory, 11 December 1989.

and data systems that can handle the additional volume of events. Increasing luminosity yet another order of magnitude does not appear to be practical in the near future because of limitations in detector technology.

Because of such uncertainties, the DOE panel is expected to advise against lowering the SSC's collision energy, *Science* has learned. Its report is slated to be delivered to the department on 12 January. Nobel laureate Leon Lederman, a member of the HEPAP review group who spoke with *Science* before the panel was convened, says that reducing the SSC's operating specifications could jeopardize the project's success. "It would be a tragedy to build this machine and not get some of the key information we are after," he says. That view is echoed by another accelerator physicist and panel member, Robert Palmer of Brookhaven National Laboratory, who notes that some theories suggest that an even higher collision energy of about 45 TeV could be required.

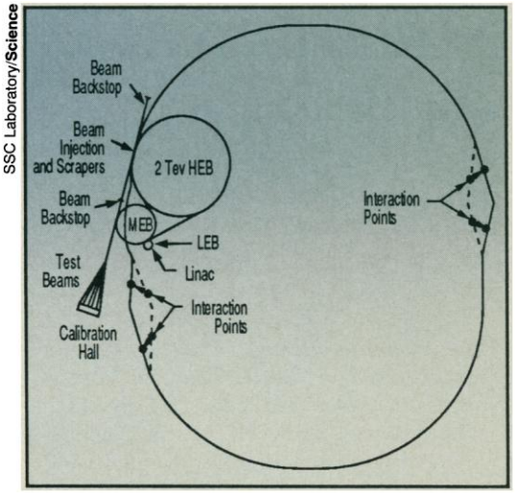
Not only are physicists resisting a move to scale back the accelerator's collision energy, but SSC Laboratory officials are also pushing DOE to accept major performance-boosting changes in the machine's design. Modifications being proposed for the superconducting magnets, additional research and development needs, and higher magnet manufacturing expenses, may add about $390 million to the project's cost. Physicists are also urging the addition of a more powerful proton injection ring, which would cost another $260 million.

A more powerful injector is being proposed in response to concerns that the SSC's magnets may be unable to keep protons in a tight focus as they are injected into the main accelerator storage ring. A degradation in the beam focus could severely reduce the number of observable events and erode the experimental productivity of the SSC. Increasing the final injection energy from 1 TeV to 2 TeV will solve part of this problem. In addition, the machine's designers have proposed increasing the diameter of the hollow bore that runs down the center of the SSC magnets by 1 centimeter to 5 centimeters. That would produce a more uniform field at low energy and would make it easier to keep protons bundled together and on course until they are accelerated and drawn off for collision experiments.

Additional changes in the superconducting magnets are being urged because, under current design specifications, their top operating fields are dangerously close to the minimum required. A field of 6.6 Tesla (T) is needed to obtain 40-TeV collisions; the magnets are now designed to produce 6.7 T. This would leave virtually no margin for error. If only one of the 10,000 magnets fails to deliver 6.6 T, top collision energies would not be achieved (*Science*, 25 August 1989, p. 809). The proposed solution: Drop the operating temperature below the original specification of 4.35 kelvin, permitting the magnets to carry enough current to increase performance to around 7 T.

These design changes are part of an overall technical plan for the SSC that is in the final stages of completion. DOE is expected to act on the proposal within the next several months. Watkins and Deputy Secretary Henson Moore, who previously had stated that project costs had to be held to $6 billion, are expected to go along with some cost increases. But whether they will accept all the changes being proposed may hinge on what the Office of Science and Technology Policy (OSTP) and the Office of Management and Budget have to say. So far, neither agency has taken any public stand on the cost escalations, but OSTP Director Allan Bromley is said by aides to be unwilling to sacrifice "excellence" in the project's performance goals.

SSC Laboratory/Science



Collider layout. *The use of a larger, 2-TeV injector ring will cost $260 million. To save money, SSC officials will delay installing equipment in tunnels (dotted lines) to divert proton beams around detector halls.*

SSC Laboratory Director Schwitters contends that the revised plan he is discussing with DOE is a bare-bones facility and he says the construction of support facilities and accelerator components is being delayed wherever possible. A case in point is a decision by the laboratory not to install systems in the accelerator rings that would divert the proton beam around detector halls. These bypass loops would enable the collider to be run when a detector is down for maintenance, but officials say they will have to get by without them for a while.

The higher cost, he adds, is "not unreasonable" given the number of refinements in the SSC's original design. Says Schwitters, "The aim here is to make a reliable machine." Indeed, Alvin W. Trivelpiece, the former director of the Office of Energy Research who played a central role in securing former President Ronald Reagan's backing for the SSC, insists that "an adequate margin of safety should be incorporated into the machine."

Even so, some White House officials worry about the project's cost, which initially was estimated at $4.5 billion (inflated dollars) in 1987. Not only may a higher price tag erode support for the SSC, but it may also prompt demands for increased foreign participation in the project. The department is already striving to get other countries to pay for one-third of the project.

Despite these concerns, there are no signs as yet of any serious opposition to the project in Congress. An aide to Representative Robert Roe (D–NJ), chairman of the House Committee on Science, Space and Technology, predicts there will be little or no congressional opposition to an increase on the order of $1 billion to $1.5 billion. Some increase in the collider's funding is to be expected, he says, noting that "this is going to be the first firm, site-specific estimate developed for the SSC." Roe is expected to introduce an authorization bill for the SSC within a few weeks.

Another SSC supporter, Representative Tom Bevill (D–AL), the chairman of the House appropriations subcommittee on energy and water development, plans to hold hearings in February or March to review the project and to scrutinize any effort by DOE to alter the machine's performance specifications. Says Bevill, "If we are going to build it, we are going to build it right."

■ MARK CRAWFORD

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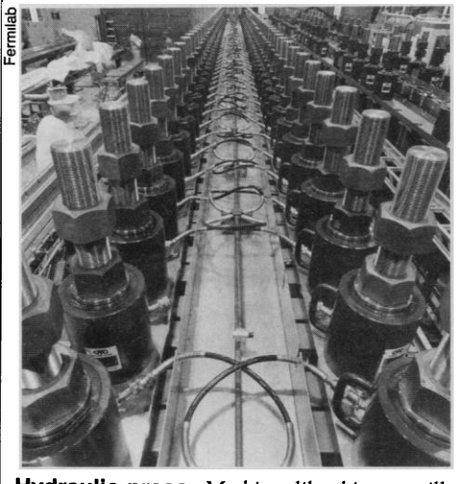

Hydraulic press. *Machines like this one will be used to assemble 15-meter-long SSC magnets.*