DOE boosts particle-physics funds

Particle physics has fared reasonably well in the Administration's proposed budget for FY 1983. The total amount in the Department of Energy budget (see page 55)—$429 million—is below the figure at which the Trilling report said the US should build Isabelle. Indeed construction funds for Isabelle in FY 1983 would drop to zero. But Brookhaven would get $23 million for research and development on superconducting magnets and alternative accelerator designs. For several months some insiders have proclaimed Isabelle dead. However, one noted particle discoverer has predicted that in a couple of years, a new accelerator will be built in the empty tunnel at Brookhaven. The machine will have 399-GeV protons colliding with 399-GeV protons. Its name—Maybelle.

The big boost in the particle-physics budget is for operating expenses. William Wallenmeyer, who heads the DOE high-energy physics division, told us that SLAC, Fermilab and Brookhaven have been running their accelerators at only about 40% of their operating capacity because of funding restrictions. Such a utilization rate is very disruptive and is not cost-effective. Instead, with a 20% increase in operating budget for FY 1983, he expects the accelerators to have a utilization rate of 60–70%.

When the Reagan economic message of September called for a 12% additional budget cut, DOE significantly reduced funding for particle physics at Argonne National Laboratory and Lawrence Berkeley Laboratory. A special panel, headed by Charles Baltay (Columbia University), has been convened to assess the role of Argonne and Berkeley and to compare their contributions to the overall US high-energy physics program with those of four large university research groups—at MIT, Yale University, the University of Pennsylvania and the University of Hawaii. The panel, whose report was due in mid-March, was asked to evaluate the relative merits, quality and efficiency or cost effectiveness in the research of the Laboratory and university groups.

The $331 million budgeted for operating expenses (see the table) allocates $106.0 million for Fermilab, $65.0 million for Brookhaven, $76.0 million for SLAC and $84.0 million to be distributed among Berkeley, Argonne and university groups. Although at present the $84.0 million is split as shown in the table, the distribution is subject to change, depending on the outcome of the Baltay panel's evaluations.

Isabelle. The preliminary report of the subpanel headed by George Trilling (PHYSICS TODAY, January, page 51) said that "Isabelle construction and the other essential components of the US program require a minimum annual level of support that averages $440 million (FY 1982 dollars) in DOE funds per year. If support at this level cannot be made available in time for Isabelle completion within this decade, the Isabelle project cannot be continued." The final report of the subpanel, produced in January, was approved by the High-Energy Physics Advisory Panel at its meeting 19–20 February. Jack Sandweiss of Yale is succeeding Sidney Drell of SLAC as HEPAP chairman.

Among the subpanel members there was a difference of opinion as to where the line should be drawn for abandonment of Isabelle. As the final report notes, "some members felt that inclusion of Isabelle construction even at [$440 million from DOE and $35 million from NSF in FY 1982 dollars] would jeopardize funding for the other elements of the national program. Others felt that the project must be sustained even at [$395 million from DOE and $34 million from NSF in FY 1982 dollars]. The majority was of the opinion that it should be included at the higher level and not at the lower."

The White House Office of Science and Technology Policy, according to informed sources, said that particle-physics budget prospects for FY 1984 are at the same level as FY 1983 and accordingly, Isabelle cannot proceed. Although construction funds will continue in FY 1982, the FY 1983 budget request contains no funds for Isabelle construction.

Brookhaven's acting director, Nicholas Samios, is submitting a request to DOE for restoration of $10 million in Isabelle construction funds for FY 1983. That budget *does* give Brookhaven $23 million for R&D on superconducting magnets and alternative accelerator designs. One possible design Brookhaven is considering is a two-coil one-core magnet; that is, the coils for each of the two storage rings would be contained in a single iron core.

Start in mid-1980s. The Trilling subpanel recommended that if Isabelle is terminated because of inadequate funding for particle physics, a new high-energy construction project of more modest financial scope should start by the mid-1980s. The subpanel felt it premature to suggest a specific approach but urged "intensified discussion, development and R&D aimed at selection and authorization by the middle of the decade." Among the possible new projects given were: an electron–proton collider or a less expensive high-luminosity hadron–hadron collider built in the Isabelle tunnel; a second proton collider ring at Fermilab dedicated to $p\bar{p}$, pp or e^-p collisions; an e^+e^- collider using superconducting rf cavities (as proposed for CESR II); or a combination of smaller facilities, one of which might be a major non-accelerator facility.

Wallenmeyer explained that the R&D funds for Brookhaven, in addition to seeking accelerator-quality superconducting magnets, are also to be used for studying lower-cost alternative faciilties including an e^-p collider and perhaps a reduced-scope pp collider. DOE or its successor agency would take a look at accelerator candidates for FY 1985. Wallenmeyer said they assume that any alternative Brookhaven candidate would use the Isabelle tunnels and that the design would include at least one superconducting ring of magnets.

Fermilab. Tevatron I and II are alternative modes of operating the upgraded Fermilab accelerator, which has a ring of superconducting magnets that produces 1000-GeV protons. Construction of Tevatron II was started in FY 1982; for FY 1983 an additional $18.0 million is requested. The Tevatron II project extracts the 1000-GeV protons and upgrades the Fermilab experimental areas for the higher-energy beams.

Tevatron I is a proton–antiproton collider with 1000 GeV in each beam; it will have two interaction regions and is scheduled to operate in 1985. For this

DOE particle-physics budget

	FY 1981	FY 1982 (in millions of dollars)	FY 1983
Construction	65.3	54.6	50.5
Equipment	37.5	40.7	47.5
Operating			
Fermilab	76.6	87.5	106.0
Brookhaven	49.1	52.0	65.0
SLAC	57.2	60.5	76.0
Other labs	57.2	69.5	84.0
Argonne	6.8	5.8	5.5
Berkeley	12.6	11.5	13.0
Universities	44.1	51.9	65.5
Total	352.2	364.5	429.0

project, which was initiated in FY 1981, the budget calls for an additional $18.0 million in FY 1983.

The Trilling subpanel had recommended implementation of the Tevatron II program in all three experimental areas and completion of Tevatron I with one major detector facility.

SLAC. DOE plans to support R&D on the Stanford Linear Collider with about $11 million in FY 1983. The subpanel recommended "construction of associated conventional facilities to begin in FY 1984 such that the R&D phase can be completed in FY 1986." SLC would collide 50-GeV electrons with 50-GeV positrons; initially it would have only one interaction region. "Funding of major new detectors and provision of a second beam–beam intersection region could occur once the R&D program has demonstrated adequacy for physics research," the subpanel says.

At the HEPAP meeting in February, the panel drafted a submittal letter to Alvin Trivelpiece, director of energy research at DOE. It said that SLC is an accelerator research project central to the long-term development of a very high-energy e^+e^- collider and at the same time offers the opportunity to do exciting physics in timely fashion. However, the transmittal letter says that SLC is not the major new facility that would begin construction in the mid-1980s and be available for research in the 1990s, as recommended by the Trilling subpanel and endorsed by HEPAP. SLC is an example of the type of relatively large R&D project now necessary in developing new accelerator systems, the letter says.

Other recommendations. The subpanel also recommended "adequate utilization and maintenance of existing accelerator and storage-ring facilities, and support of important non-accelerator particle-physics projects."

Fermilab magnet-assembly facility. A superconducting magnet is moved towards its installation in the iron yoke assembly. When upgrading is done, the accelerator will produce 1000-GeV protons for fixed-target and proton–antiproton experiments.

Another recommendation was "pursuit of other advanced accelerator R&D activities on items such as high-field superconducting magnets, high-gradient accelerating structures, superconducting rf cavities and novel means of acceleration." The final recommendations of the subpanel do not specifically mention CESR II, which would be an electron–positron storage ring with 50 GeV in each beam, using superconducting rf cavities. Trilling, at the San Francisco APS meeting in January, said CESR II was not viewed as an alternative to SLC, which has an ongoing proposal. Cornell anticipates submitting a firm proposal this year for funding CESR II in FY 1985. —GBL

Microscopy by vacuum tunneling

The earliest work on quantum tunneling in solid-state physics, more than fifty years ago, dealt with electron tunneling through a vacuum barrier. But for the next half century we had no clear experimental demonstration of this conceptually simplest of tunneling phenomena. Spectroscopic and technological exploitation of quantum tunneling was developed only with solid tunnel barriers. Metal–vacuum–metal tunneling requires a gap held constant at a few angstroms. At such small distances—just a few atomic widths—it is extraordinarily difficult to control the gap size and insure that surface contamination layers or irregularities do not result in an unwanted contact across the gap.

Theory predicts that the tunnel resistance across the vacuum barrier will increase exponentially with gap size, with a logarithmic slope proportional to the square root of the mean work function of the two tunneling surfaces. Thus the most direct evidence of successful metal–vacuum–metal tunneling would be the observation of such an exponential resistance curve with an exponent appropriate to the work functions.

A recent *Applied Physics Letter*[1] by Gerd Binnig, Heinrich Rohrer, Christof Gerber and Edmund Weibel of the IBM Research Laboratory in Zurich reports just such an observation. This has been accomplished with a novel tunneling instrument that makes it possible to control the distance between tunnel electrodes with a precision of one or two tenths of an angstrom. Furthermore, the ability of their three-legged piezoelectric support system to control precisely the lateral position of the electrodes has enabled the group to exploit vacuum tunneling for scanning surface microscopy with a resolution of 5 to 20 Å in the surface plane.

Earlier attempts[2,3,4] to demonstrate and exploit vacuum tunneling were plagued by insufficient suppression of vibrations in the experimental apparatus. Binnig and his colleagues achieved the necessary protection against external vibrations by placing their tunneling experiment on a heavy stone slab resting on inflated rubber tires. Vibrations internal to the apparatus were suppressed by magnetically levitating the tunneling unit on a superconducting bowl of lead cooled by liquid helium.

The Zurich group stresses that its primary purpose was not simply to observe vacuum tunneling, but "to demonstrate its feasibility . . . with modest means . . . in a configuration that simultaneously allows spatially resolved tunneling spectroscopy and other surface spectroscopic methods." Aside from the superconducting lead bowl, they point out, the apparatus is near room temperature and it requires only moderate vacuum. Vacuum-tunneling spectroscopy has a number of evident advantages for the study of surfaces: It is conceptually simpler; the vacuum is obviously easier to characterize than any solid-state barrier layer. Furthermore, one has the advantage of free access to the surfaces between which the electrons are tunneling.

The Zurich vacuum-tunneling junction described in their *Applied Physics Letter* consists of a tungsten needle point separated from a platinum plate by a few angstroms of moderate vacuum (down to 10^{-6} torr). Both electrodes were held in piezoelectric mounts that could be moved in any direction with extreme sensitivity—only two angstroms per volt. This, together with the suppression of vibration, permitted the gap length and position of the needle in the plane of the platinum surface to be controlled with high precision.

A microtorr vacuum is insufficient to keep the electrode surfaces free of contaminants. But the group employed a self-cleaning procedure that kept the surfaces sufficiently clean so that no change in the work function (which is very sensitive to contamination) was observed over tens of minutes. The application of a 10-kilohertz voltage to the piezoelectric mounts generates ultrasonic vibration that appears to rid the surface of contaminants.

(The Zurich group is now doing vacuum tunneling between gold electrode surfaces in a 5×10^{-10} torr vacuum; in so high a vacuum, Rohrer told us, surface contamination is no longer a problem.)

The tunnel resistance curve at 10^{-6}