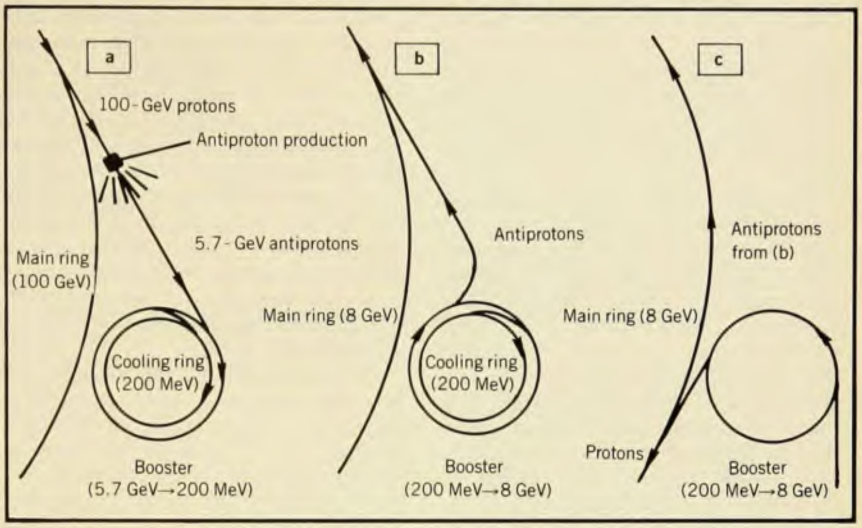
search & discovery

Electron cooling offers high-luminosity antiproton beams

An old idea in accelerator design, called "electron cooling," has been demonstrated to work in experiments over the last two years at the Nuclear Physics Institute in Novosibirsk. The Siberian success has inspired groups at CERN and Fermilab to start experiments on electron cooling with the hope that these might lead to high-energy colliding-beam experiments involving protons and antiprotons.

The electron-cooling idea was first proposed by Lyman Spitzer (Princeton University) about 20 years ago. At that time C. Tsao and Gerard K. O'Neill (Princeton University) did a theoretical analysis, and verified that the idea should work. In 1966 Gersh I. Budker (Novosibirsk) independently developed the electron-cooling idea, reporting on it that year at the Paris particle-accelerator conference. He and Alexander Skrinsky (Novosobirsk) then proposed building a proton–antiproton colliding-beam device using electron cooling (PHYSICS TODAY, August 1969, page 62).



Proposed plan for antiproton–proton colliding beams at Fermilab. In (a) antiprotons are produced, decelerated, cooled (60 millisec) and stored (3 hours). In (b) antiprotons are accelerated and transferred to main ring (60 millisec). In (c) protons are accelerated and transferred to main ring (60 millisec). Then both beams are accelerated to full energy and allowed to collide.

To cool a proton or antiproton beam, one allows an electron beam to travel in the same direction at almost the same velocity. The antiprotons or protons tend to lose their transverse momentum to the electrons by Coulomb scattering, and the entire system tends toward equipartition of energies. Over a large number of turns the oscillation amplitudes and momentum spread of the protons or antiprotons gradually are reduced, and the electron oscillations grow. The net effect is that the volume of phase space occupied by the baryon beam is drastically reduced, making the beam denser and giving it higher luminosity.

Novosibirsk work. Budker's Nuclear Physics Institute has so far done all the experimental work on electron cooling, using a storage ring called NAP-M (Accelerator and Accumulator of Protons). It was designed and built by Skrinsky, Nikolai Dikansky, I. Meshkow, V. Parkhomchuk and their colleagues. First experimental results were reported at the National Particle Accelerator Conference

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The case of the vanishing superconductivity

A ternary superconductor, $ErRh_4B_4$, does an astonishing thing as its temperature is reduced: Although at 8.6 K it becomes superconducting, as the temperature is reduced further, to 0.9 K, the superconductivity disappears. This discovery was scheduled to be reported by Bernd T. Matthias (University of California, La Jolla and Bell Labs) in a postdeadline paper at the March meeting of The American Physical Society in San Diego. Matthias says that this is the first time an ordered crystal has lost its superconductivity as the temperature is lowered.

Several years ago Matthias decided that the path to higher superconducting transition temperatures was not via the binary compounds. "After all," he said, "Nb_3Ge has been known for the last 22 years." Instead, he decided to look at ternary superconductors. A true ternary superconductor is a compound of three elements whose properties depend on all three. In 1971 Roger Chevrel, M. Sergent and J. J. Prigent (CNRS, Rennes, France) had found[1] a new rhombohedral system, the double molybdenum sulfides, XMo_6S_8, which turned out to be the first system of ternary superconductors. Matthias and his collaborators at La Jolla and Bell Labs began studying both XMo_6S_8 and XMo_6Se_8. They found superconductivity for X being copper, silver, zinc, cadmium, tin, lead and magnesium, first in sulfides, then in selenides.

In 1975 O. Fischer, A. Treyvaud (University of Geneva), Chevrel and Sergent found that X could also be a rare-earth element. Robert N. Shelton and his colleagues at La Jolla showed that some of the rare-earth molybdenum selenides with lanthanides had superconducting transition temperatures as high as 11 K. For all the rare earths, from lanthanum to lutetium, with the exception of cerium and europium, superconductivity has been found in experiments done by M. Brian Maple, Shelton, David C. Johnston and R. William McCallum (La Jolla). Because the transition temperatures of the tin and lead compounds with molybdenum sulfide were somewhat above 15 K, and their critical fields are in the range 500–700 kG, Matthias believes it will be interesting to check the new compounds along the same lines.

Last spring, at the Second Rochester Conference on Superconductivity in d- and f-Band Metals, McCallum, Johnston, Shelton and Maple discussed specific-heat measurements on $Gd_{1.2}Mo_6Se_8$. They found in the plot of specific heat as a function of temperature that the specific heat showed a jump at 5.5 K associated with the superconducting transition. But of much greater interest was the pronounced lambda-type anomaly that occurred at about 3.5 K, followed by an upturn at lower temperatures. At the time, the group said it was tempting to ascribe the lambda anomaly to long-range magnetic ordering in the superconducting state.

In further studies on the $Gd_{1.2}Mo_6Se_8$ and other rare-earth systems, the group continued to see anomalies in the specific heat at temperatures below the superconducting transition. The group now believes that some of these materials are indeed undergoing a magnetic transition. The temperature at which this occurs is obtained by extrapolating down from Curie–Weiss measurements made above the superconducting range. Thus, the La Jolla group appears to be seeing the coexistence of magnetism and superconductivity, Matthias explained. The experimenters believe they are observing antiferromagnetism, but cannot be sure until a neutron experiment is done.

At Bell Labs Matthias, Ernest Corenzwit, Joanna Vandenberg and Hartmut Barz discovered a new ternary system, XRh_4B_4, in which X is a rare earth and decided to see whether or not each compound was superconducting. Going through the periodic table, they found[2] that lanthanum and praseodymium do not form the compound, neodymium forms it with a superconducting transition temperature greater than 6 K, prometheum is too radioactive, samarium forms it with a superconducting transition temperature at 2 K, and europium does not form it. But gadolinium, terbium, dysprosium and holmium all were ferromagnetic with dysprosium having a Curie point of 12 K and holmium with a Curie point of 4 K. "But wonder of wonders," Matthias explained, "as you went from holmium to erbium, erbium was superconducting at 8.6 K and thulium was superconducting at 9.5 K, temperatures far above anything previously observed for erbium and thulium." The magnetic moment of pure holmium is about 10.4 Bohr magnetons and for pure erbium it is 9.6. "In the past," he went on, "a magnetic moment of 10 was always the kiss of death for superconductivity. It became obvious that either ferromagnetism or superconductivity must be the ground state."

William Fertig at La Jolla studied the XRh_4B_4 system in which the rare earth was gadolinium, terbium, dysprosium or holmium. Down to 60 mK, the materials showed no superconductivity. "As a consequence," Matthias told us, "it seemed to me that ferromagnetism was the ground state. I expected erbium to become magnetic eventually, in spite of its superconductivity."

In the new experiments at La Jolla, Matthias, Maple, Johnston, Fertig, McCallum and Lance DeLong studied the behavior of $ErRh_4B_4$. They started with the crystal at 60 mK, where it acts as a normal conductor, whose resistivity was measurable. As they went higher in temperature, at 0.9 K, in an interval of 25 mK, the material becomes superconducting. It stays that way until it reaches the transition temperature of 8.5 K, where it becomes normal again. The transition at 0.9 K appears to be ferrimagnetic at least, but at this writing the La Jolla experimenters were not sure. Similarly to the ternary rare-earth molybdenum selenides, a striking lambda-type anomaly for the specific heat was observed to accompany the transition at 0.9 K.

The explanation for the disappearance of superconductivity has become an attractive mystery to Matthias. However, he feels that "this result will help our understanding of superconductivity and may eventually lead to higher transition temperatures." —GBL

References

1. R. Chevrel, M. Sergent, J. J. Prigent, J. Solid State Chem. 3, 515 (1971).
2. B. T. Matthias, E. Corenzwit, J. M. Vandenberg, H. E. Barz, Proc. Nat. Acad. Sci., April 1977.

2.4-meter telescope could orbit in 1983

If Congress and the President are willing, NASA plans to orbit the Space Telescope some time in the fourth quarter of 1983. The Space Telescope is a complete astronomical facility with a 2.4-meter aperture optical telescope, signal detectors and a number of instruments. NASA is asking for $36 million in fiscal year 1978. The total program cost is expected to be $435 million. In anticipation of approval, NASA recently released an Announcement of Opportunity for proposing instruments. (Copies of this announcement can be obtained from the Project Scientist, C. Robert O'Dell, DS-30, Marshall Space Flight Center, Ala. 35810.)

The 2.4-meter instrument is an f/24 Cassegrain telescope with Ritchey-Chrêtien optics. Mirrors will be made from hollow-construction low-expansion fused silica. The device is 46 feet long and will weigh 17 000 pounds. It is to be equipped with remote detectors to convert photons to electronic signals; these might be detectors such as television, a solid-state array, or one of several electronic detectors now under development. Several detectors could operate in parallel. Data will be transmitted to Earth, and the telescope will be controlled from the Goddard Space Flight Center in Greenbelt, Maryland.

The Space Telescope is to be launched by the Space Shuttle into an orbit 300 nautical miles above Earth with an inclination of 28.8 deg. The shuttle would then return to Earth; every two or three years the shuttle would visit the telescope to make repairs and change or add instruments. At roughly five-year intervals, the shuttle could bring the telescope back to Earth for major repairs as needed, and then the device could be orbited once again. The total design life in orbit is at least 15 years.

The telescope facility has room for five scientific instruments, although five will not necessarily be flown in the initial launch. Two instruments that are definite are a wide-field camera (which is capable of seeing 28th magnitude objects and whose field of view would be several arc minutes) and a faint-object spectrograph (which can be used in both the extreme uv and the visible). A third instrument that has been seriously considered is an infrared photometer, which would make the overall spectral range be 1 mm–1150 Å.

NASA is in the final stages of negotiating an agreement with the European Space Agency for participation in the Space Telescope program. Last October the European agency voted to spend approximately $88 million for participation in the project. The agency would provide a faint-object camera, the solar-power array, and its share of operating the facility while in space.

Many space scientists are advocating that a special institute be established for the Space Telescope. The institute would be responsible for selecting users, scheduling observations, data analysis and so on.

Observations. O'Dell told us that the Space Telescope will be most useful for three kinds of observations. One is the study of active galaxies such as quasars. The instrument would have an image capability ten times better than if it were Earthbound. If the imaging is done down to about Lyman alpha(1150 Å), one can look at nearby quasars in the ultraviolet to study their evolution because this same radiation is what is observed as optical light in the highly red-shifted quasars. John Bahcall (Institute for Advanced Study), a frequent spokesman for the Space Telescope, notes that many absorption lines are seen in the spectra of large red-shift quasars, corresponding to several different red shifts. One school of thought attributes this phenomenon to very high-velocity clouds shot out of the quasar. Bahcall, on the other hand, feels that many of the red-shifts are caused by material along the line of sight, for example, from a number of large galactic