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Batavia accelerator reaches 200 GeV

Now that the Batavia accelerator has reached its design energy of 200 GeV (on 1 March), physicists can breathe a sigh of relief, although considerable effort remains to be expended before the machine operates at full intensity. Director Robert R. Wilson had hoped to bring the accelerator into operation a year early, in mid-1971 (PHYSICS TODAY, June 1970, page 29) and soon after to raise the energy to 500 GeV at reduced intensity.

But the start-up was beset by many difficulties, most notably from failures in the bending magnets of the main ring and excessive losses in the main-ring circulating beam.

With many of the problems corrected, the National Accelerator Laboratory team was able to achieve 200 GeV with the accelerator operating in the so-called "bimodal condition," that is, running successively for 40 pulses at 30 GeV and one pulse at 200 GeV. This method allows the machine to run without water cooling, thus forestalling difficulties associated with moisture in the magnet insulation.

Despite the unexpected delays, the accelerator did reach 200 GeV four months earlier than its original target date and did not exceed its construction budget of $250 million.

The Batavia group chose to operate at 30 GeV so that the machine could be tuned beyond the 17.4-GeV transition energy (the energy at which the accelerating kick must be reversed in phase) of the main ring. Little additional tuning was needed to carry the beam from 30 to 200 GeV. About 10^{11} protons/pulse were injected into the ring. By holding the injection intensity down to this level, unnecessary radioactive buildup was avoided. Significant beam losses occurred in the cycle prior to reaching 30 GeV, but thereafter the beam was retained quite well. The NAL group believes the losses below 30 GeV were caused by a reduced effective aperture of the vacuum chamber. In these tests a beam intensity of 10^9 protons/pulse was reached. The design intensity is 4×10^{13} protons/pulse.

In the early stages of construction things went very smoothly. Ground was broken for the linac in December 1968,

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Robert R. Wilson, NAL director, celebrates achievement of 200 GeV. The chianti was same brand as that used to salute the first sustained chain reaction in Chicago 30 years ago.

New Mexico site for radio telescope

The National Science Foundation has announced the site for the proposed Very Large Array telescope, preliminary funds for which are included in President Nixon's FY 1973 budget proposal. The telescope would be built on the Plains of San Augustin, near Datil, New Mexico, about 50 miles west of Socorro. It would have from 10 to 100 times the resolution of the next largest instrument, which is at Westerbork in the Netherlands.

The array will cost an estimated $76 million and is expected to be finished in the early 1980's. As proposed, it will consist of a Y-shaped railroad track that would fit inside a circle approximately 26 miles in diameter. The legs of the Y will be 120 deg apart, with one leg four to ten degrees away from true north. There will be nine movable dish antennas 82 feet in diameter on each leg.

Resolution. In order to provide the desired resolution—equal to that of the largest ground-based optical telescopes—a radio telescope 23 miles in diameter is needed. Since it is impossible to build a dish of this size, the technique of interferometry will be used. By interconnecting pairs of antennas spread over the area that the large dish would occupy, it is possible to synthesize the information that would be gathered by it. In addition, the rotation of the earth will continually change the projection of the antenna pairs relative to the radio source during the observation period, an effect that can be used as a means of filling in some of the areas of the 26-mile circle where there are no oscillates at about 5 kHz. Johnson noise on the resistor causes the voltage, and consequently the frequency, to fluctuate. You can relate fluctuations in frequency directly to the absolute temperature of the resistor. In fact, if you use a frequency counter, with gate time τ, the variance σ^2 of the fluctuations in the measured frequency is related to the absolute temperature T by

$$\sigma^2 = 2kTR/\tau\phi_0^2$$

where ϕ_0 is the magnetic flux quantum and R may be measured by noting the bias current and the average frequency of oscillation of the Josephson junction.

Recently Robert Soulen and Harvey Marshak (NBS, Washington) have compared Kamper's noise thermometer with other standard reference thermometers —by measuring the magnetic susceptibility of cerium magnesium nitrate, and by measuring the anisotropy of gamma rays coming from radioactive nuclei. These measurements show that the noise thermometer has an error of less than ±1.0 mK for a temperature of 20.0 mK. To achieve this precision at lower temperature, measurements take many minutes, a time which Kamper feels is about as long as is practicable.

Kamper's thermometer has the resistor connected directly to the junction, whereas Wheatley's is coupled by a superconducting transformer. This gives Wheatley the ability to get a bigger signal and to adjust the bandwith. The statistical rms fractional error in measuring temperature is inversely proportional to the square root of the product of the time you're willing to spend and the bandwidth of the system. Because Wheatley's bandwidth is adjustable (Kamper's is not), he can achieve greater precision. On the other hand, Kamper points out, Wheatley has a calibration problem because he must determine the coupling ratio of the transformer and the bandwidth to specify the temperature. Kamper feels his approach is simpler and more direct.

—GBL

References

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Liquid-xenon proportional counter

Luis Alvarez and his collaborators[1] at Berkeley have built a proportional counter filled with liquid xenon. When we recently discussed the new counter (while flying over the Bay Area in Alvarez's twin-engine Cessna), he told us that the new counter will be useful for cosmic-ray satellite experiments, for ground-based high-energy particle detection and as a medical gamma-ray camera.

The counter works just like any other proportional counter—the ionizing radiation impinges on the filling material, which is normally a gas, but in the Berkeley device is liquid xenon. Because the xenon is liquid its higher density permits the improvement of spatial resolution by a factor of maybe 100 over that of a gas, Alvarez said. At the present time a spatial resolution better than 10 microns has been observed, and that value is limited by the width of the "signal generator." An advantage over solid-state counters is that because there are no grain boundaries in the liquid xenon, you can make as large a volume of liquid xenon as your pocketbook will stand, he went on. Typical condensed counters of germanium or silicon are limited by the size of the furnaces that do the purification, typically 2–3 inches.

The other very high-class, large-volume condensed-state counting material with good gamma-ray detection properties is cesium iodide, and Alvarez says that the liquid xenon is considerably cheaper in the sizes they want.

The Berkeley group has planned to use spark chambers in a cosmic-ray experiment on HEAO (High-Energy Astronomical Observatory)-B, scheduled for launch about 1976. One of the reasons for studying liquid xenon was to improve upon the spatial resolution of the spark chambers (about a fifth of a millimeter). The experiment is primarily designed to measure the very-high-momentum electrons and positrons in cosmic rays to look for evidence of the inverse Compton effect on the 3-K blackbody radiation. The electrons can be identified, but the positrons have to be distinguished from protons. To do that, the experimenters use the fact that positrons make showers in cesium iodide with a much shorter build-up distance than protons. You measure the particle's energy in a magnetic field (produced by a superconducting magnet) and you remeasure it in cesium iodide; if the two numbers agree there's a good change that the particle is a positron. Now Alvarez feels that the liquid xenon is also a promising substitute for the cesium iodide. He would need 10–20 gallons of it to operate a total absorption shower counter.

Alvarez says that many people think of liquid xenon as being too expensive compared with most materials—it's about a dollar per gram, the same as gold. But this cost is less than that of putting the satellite in orbit in the first place, he points out.

Because the liquid-xenon detector can be used as a high spatial-resolution substitute for a spark chamber, it should be quite effective at the energies at which the Batavia accelerator will be running. This ability to detect and measure very small magnetic deflections should lead to great savings in the cost of bending magnets. In such an application, you would use a thickness of only a few thousandths of an inch over a square meter.

In the early development of the liquid-xenon counter the Berkeley group was troubled with some unknown impurities that had an enormous appetite for electrons. To cure the ailment the experimenters use the central wire with potentials reversed as a very copious supply of electrons (produced by field emission from the very thin wire). These electrons are drawn over to the outside cylinder, which is normally a cathode, but in the clean-up mode acts as an anode. The impurities capture the electrons and are then swept out towards the wall by the electric field. Then the potentials are reversed back to normal counter operations. The ionization electrons can then multiply in the intense electric field, producing an avalanche. The clean-up is so effective that no impurities are normally seen for several hours. An unexpected bonus is that the energy resolution of a liquid-xenon counter in the gamma-ray detecting mode is now better than that of a sodium-iodide crystal.

—GBL

Reference

1. Richard A. Muller, Stephen E. Derenzo, Gerald Smadja, Dennis B. Smith, Robert G. Smits, Haim Zaklad, Luis W. Alvarez, Phys. Rev. Lett. **27**, 532 (1971).

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and the first 200-MeV beam was achieved two years later. The 7-GeV booster became fully operational in May 1971. On 1 July a 7-GeV beam was injected from the booster into the main ring and made to execute one full turn; by early August the beam was able to execute 10 000 revolutions.

Despite these early achievements it became apparent during the second half of 1971 that many modifications and improvements were needed in the main ring and that even minor changes to main-ring components were time-consuming major endeavors because over 1000 magnets were involved.

Problems. After the coils were installed in the main-ring magnets, they were tested at 2500 volts, considerably beyond the 1000-V potential required for 200-GeV operation. But the tests did not require submerging the magnets in water before voltage measurements were made. When summer brought high humidity to the magnets in the cold tunnel, they became saturated with moisture and any small cracks in the epoxy-impregnated fiberglass provided a conduction path to ground that could cause a serious spark discharge. To cure this ailment the Batavia workers started a program of heating and drying the tunnel, retesting the magnets in the tunnel at 500 and later 1000 volts, baking in a vacuum vessel those magnets that showed low resistance to ground, and eventually vacuum impregnating with epoxy all magnets that showed a low resistance to ground.

Another difficulty appeared in the power supplies when the magnets were operated at high field values, a difficulty apparently caused by occasional large voltage pulses that destroyed some of the components.

A further problem is that the main-ring beam decayed rapidly in only a few thousandths of a second, whereas normal operation would require the beam to last for about one second under coasting conditions. This beam loss suggested that there were obstructions in the vacuum chamber, possibly thin stainless-steel shavings left over from cutting operations. These shavings would stand up when the magnetic field was on and lie flat (and thus be difficult to see) when the field was off. Eventually the NAL workers built devices to sweep the vacuum chamber clean.

Agenda. Now that NAL has demonstrated operation at 200 GeV, the next thing on the agenda is to operate the machine with a normal acceleration cycle. As of the beginning of April the cooling system was installed and temporary modifications of the power supplies are being undone.

After that, according to Edwin L. Goldwasser, NAL deputy director, the highest priority is to extract the beam and then to steer it into the neutrino area, where it will go to the old Argonne 30-inch hydrogen bubble chamber. Extraction is expected to be somewhat easier than at other accelerators because of the long straight sections around the ring. Goldwasser believes that by summer most of the present NAL difficulties will be solved.

The intensity will be increased in part by injecting twelve pulses from the booster instead of one. Also, four linac pulses will be injected for each booster acceleration cycle. In addition to this 48-fold increase, it is hoped to diminish the losses now occurring in the early part of the main-ring cycle. An NAL spokesman said they believe this can be done by improving the so-called "20th harmonic tune" of the accelerator, by turning on sextupoles and by tuning the trim steering magnets at low momentum. He said there is no reason to believe that they will be unable to achieve the design intensity.

What about NAL's hopes of achieving 500 GeV? Goldwasser told us he does not anticipate any major difficulty getting to 400 GeV, but he will not venture a prediction as to when that will occur. He does believe that operating the accelerator at 500 GeV will be harder because it is difficult to extract a beam at that energy. —GBL

Alfvén on cosmic rays, sunspots, antimatter

Plasma-physics theories often have had little connection with reality, according to Hannes Alfvén. When we recently chatted with him in his office at the University of California in La Jolla (shortly before he left for his annual six-month stay at the Royal Institute of Technology in Stockholm) Alfvén pointed out that two major confrontations between theory and experiment have occurred. One took place when controlled thermonuclear experiments began. "The result was catastrophic," he said. The second confrontation came when space missions made the magnetosphere and interplanetary space accessible to physical instruments, and some cherished theories became ripe for revision. In the future, Alfvén believes, at least three "sacrosanct" astrophysics theories may be drastically revised.

It is generally believed that the intensity of the common cosmic rays (energy of 10^{10}-10^{11} eV) is essentially the same over the entire galaxy as it is measured near the earth, he noted. Alfvén suggests that there may very well be a magnetic field, for example in the heliosphere, that forms a screen between the solar system and the galaxy. Just as the van Allen radiation in the earth's magnetic field differs by orders of magnitude from the radiation outside, the cosmic-ray intensity between the planets may be orders of magnitude larger than the interstellar intensity. To test the opposing views, we will probably have to wait until spacecraft pass the outer shock front of the solar wind, when we could learn about the structure of magnetic fields in the surroundings of the solar system.

The sacrosanct belief about solar magnetic fields is that the sun's general magnetic field varies in strength and sign from day to day, and that sunspots are produced by mechanisms close to the surface of the sun. Alfvén points out that the readings of "solar magnetographs" do not give the actual magnetic field, but rather a complicated function of magnetic field, turbulence, temperature, and so on. Thus rapid changes in the "magnetograph" readings may be due to factors other than changes in magnetism. The sun may have a dipole field. Sunspots may be caused by disturbances occurring in the core, which travel upwards as hydromagnetic waves. Alfvén feels that new methods of measurement and theoretical analysis of magnetic fields in the solar atmosphere are necessary.

The popular view is that all celestial objects are made of koinomatter (ordinary matter). Alfvén's heretical belief is that some of these objects are made of antimatter (PHYSICS TODAY, February 1971, page 28). To find out whether a certain star is made of koinomatter or antimatter, we would probably have to send a spacecraft there.

Another somewhat heretical suggestion, made by Alfvén and Gustaf Arrhenius (Scripps Institution of Oceanography), is that we send a space mission to an asteroid. Alfvén eloquently argued to us the importance of such a mission, saying that there is no inherent reason why a 2-km-diameter body like Toro (PHYSICS TODAY, December 1971, page 17) should be any less interesting than a 7000-km-diameter body such as Mars. He notes that the stated goal of NASA is to clarify the origin and evolution of the solar system. Such a goal could just as well be served by studying asteroids.

It is a very natural but very regrettable fact in science that before a field is considered important, you have to know enough about it, Alfvén said. Those fields about which we know nothing are considered to be unimportant, and the reason lies in simple psychology, he explained. "If there are a hundred people working in a field, they will automatically constitute a very powerful pressure group. If a single man works on a problem it doesn't matter how important the problem is, he can exert very little pressure. Mars proponents can call a conference and discuss all the maps of Mars, and discuss how many craters there are—there are hundreds of things to discuss, and the more they discuss, the more there is." But an asteroid like Eros, for example, has never been seen. "No one has made a map of it yet. How could you discuss it? But Eros may be much more important." GBL