slowly than do other particles when they traverse matter; this property is the basis for detecting them, and at Brookhaven it was sufficient that the particles penetrate a concrete wall for them to be detected as muons. The Berkeley muon detector measured the range of the stopping muons with a segmented absorber and compared the range with the measured momentum. Other dissimilarities in the two experiments were the chambers (ten spark chambers at Berkeley and three multiwire proportional chambers at Brookhaven) and different trigger requirements.

Kerth told us that his group at Berkeley has reanalyzed their data, essentially assuming that their experiment was done with apparatus like that at Brookhaven; that is, with fewer constraints on the events (such as no measurement of range and by using a chi-squared analysis). They still found no events.

The Columbia-CERN-NYU group is planning further experiments to improve their statistics, changing the apparatus a bit and attempting to eliminate any unusual kind of background signal, although they don't believe any such signal is present. But, as Nygren sums it up, "We now have a first-class controversy in physics: two very nice experiments that give totally incompatible results. Where will it lead and who's right? Probably a third experiment to verify one of the two experiments—or give a third result—is necessary." —MSR

Josephson-junction method detects nmr transitions

In nuclear-magnetic-resonance work, the detection of broad lines such as those from solid samples has usually been done by observing a pulse in a radiofrequency pickup coil while carrying out a procedure known as "adiabatic fast passage." A new technique, in which detection during adiabatic fast passage is by a Josephson-junction magnetometer, does the same job but with considerably less radiofrequency power.

E. P. Day of Stanford University reports the new method in *Physical Review Letters* **29**, 540 (1972). In the paper he quotes data for protons in water and Li^7 and F^{19} lines in lithium fluoride, taken on a preliminary version of the apparatus. A reduction of 40 dB in rf power is reported for the lithium fluoride lines. Possible applications of the new method will be to most aspects of nmr studies of broad resonance lines; examples are isotope trace analysis, geological dating, thermometry and biochemistry.

Adiabatic fast passage. Most nmr work has been done with liquid or gaseous samples, for which the resonance line is very narrow. For protons in water the natural linewidth is one part in 10^8. In these cases you can tune right to the point of resonance and detect the full signal in a transverse rf coil arranged to pick up the power loss at resonance.

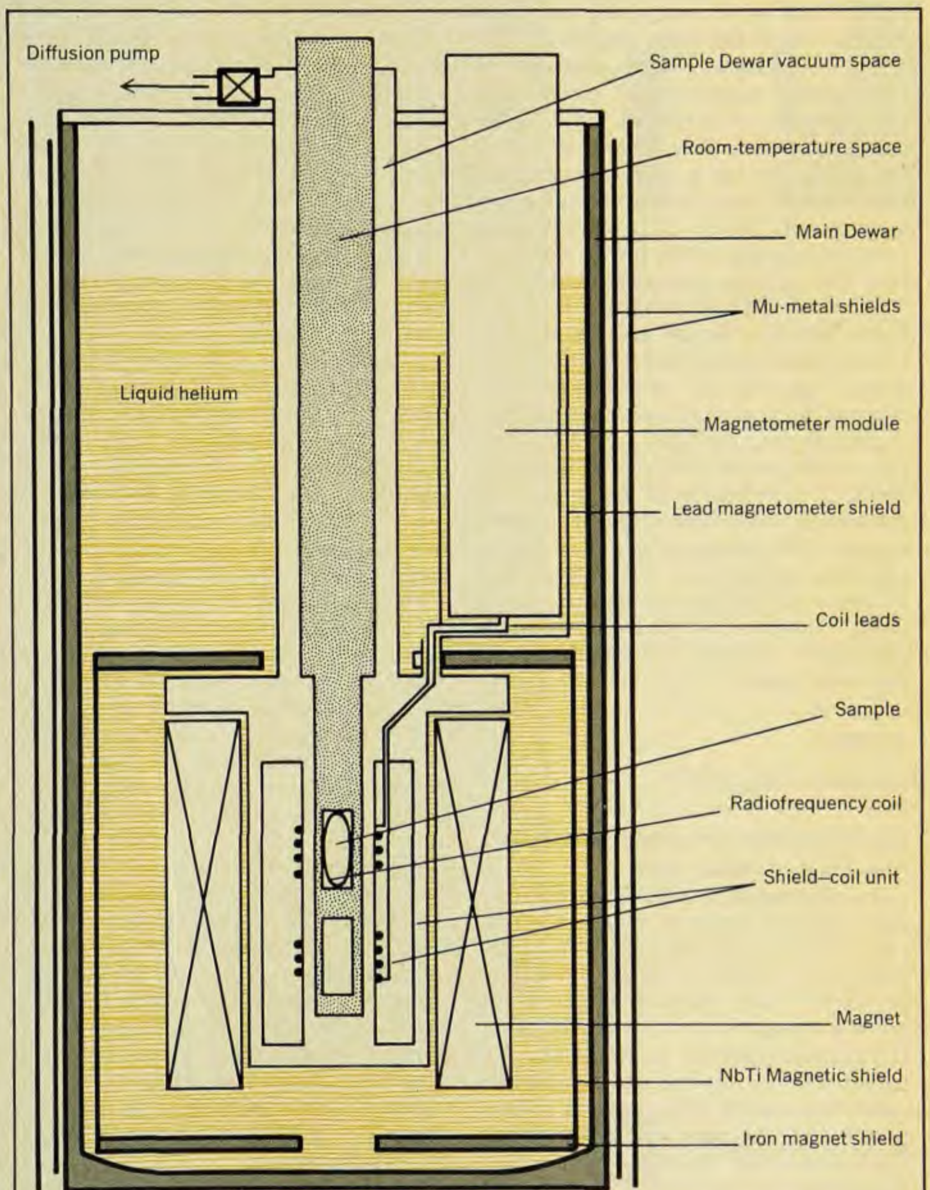
In solids, however, the natural linewidth is broad. Then only a small fraction of the total nuclear population is resonant at the "center" frequency, and the usual rf detection doesn't work. Instead, the frequency of the rf field is swept right through the broad resonance line. As the spins flip over during this sweep, the transverse pickup coil detects a pulse when the nuclear spins pass through the midpoint of their 180-degree inversion.

The speed at which the applied field is swept through resonance is important; it must be fast enough to beat the natural relaxation time during which the spins would revert to their original direction, and slow enough to give the spins time enough to make several Larmor precessions about the direction of the changing effective field.

The trouble with the conventional adiabatic-fast-passage technique is that, for a broad line, the spins are not completely in phase in the transverse direction, and the observed pulse is reduced by a factor

$$\frac{\text{rf field amplitude}}{\text{line width}}$$

To overcome this reduction in signal the amplitude of the rf field must be increased resulting in a requirement for



Nuclear-magnetic-resonance apparatus at Stanford. Originally designed for static-susceptibility measurements, the design includes a superconducting shield between the magnet and the pickup coil, rigidly attached to the coil ("shield-coil unit"), to reduce the effects of noise and vibration. An rf coil (ellipse in upper sample chamber) coupled to a Josephson-junction magnetometer was added later to be used for the nmr measurements.

high radiofrequency power levels.

Josephson-junction magnetometer. In the Stanford system a superconducting pickup coil, coaxial with the sample, coupled to a Josephson-junction magnetometer detects the total change in longitudinal magnetization. This change is twice the steady-state magnetization, 2 M_0, during a frequency sweep that inverts the magnetization M_0 of the whole sample. In Day's experiments the steady field H_0 was 7.47 kilo-oersteds, provided by a superconducting persistent-mode solenoid coaxial with the sample. He obtained maximum signals at power levels more than 40 dB down from the rf power required for maximum signal in a conventional fast-passage detector. Lines 8 gauss wide showed at full intensity with only about 50 milligauss rf amplitude.

The trick is to mount the sensitive pickup coil in the large magnetic field of an nmr magnet, while providing a sufficiently magnetically clean and vibration-free environment for it. The figure shows how Day does it: the sample holder lies in a room-temperature Dewar finger inside the superconducting pickup coil, which is itself within a superconducting shield inside the solenoid that supplies the steady field.

Currently Day is rebuilding his magnet for better resolution and his apparatus for higher sensitivity. "What we're doing," he told us, "is improving our magnet homogeneity to meet normal standards for nmr work. At the same time we expect to achieve and improvement of two orders of magnitude in sensitivity over our present performance. We have a long way to go before this method is as sensitive as conventional techniques applied to narrow lines. However, we are working on this and expect to make considerable progress very soon." —JTS

CERN

continued from page 17

least 20 million SF should be available from the contingency fund.

An alternative to filling out the ring with ordinary bending magnets would be to consider putting superconducting magnets in some or all of the empty positions. This scheme might boost the top energy to as high as 700 GeV. Development efforts at a number of laboratories in Europe are expected to yield firm data within the next several months on the costs and reliability of superconducting magnets that would be suitable for the SPS. By the middle of next year the CERN group plans to decide which of the two routes to follow.

With the physical specifications now all determined,. the SPS is turning out to look very much like the Batavia machine—essentially a ring of separated-function magnets almost four miles in circumference.

CERN however points to some detailed differences in magnet design that it hopes will avoid some of the difficulties experienced with the NAL accelerator. For instance, the electrical insulation of the SPS magnets will have a ground voltage rating double that of NAL, thus providing insurance against the shorting-out that plagued the NAL magnets when moisture collected in them during installation.

In general, the SPS magnets are more conservatively designed with investment and operating costs optimized for 400 GeV instead of 200 GeV as at NAL. This means larger copper and iron cross sections for the magnets making possible lower current densities at full field (1.8 Tesla).

Another difference stemming from NAL hindsight is the scheme for synchronizing the 12 rectifier power supplies that feed the bending magnets. Instead of the exclusive digital control used by NAL, CERN will use a digitally generated reference point with analog feedback to fix the firing time for each supply. In this way CERN hopes to avoid the tracking errors between different power supplies that are causing problems for Batavia.

In addition the SPS features a novel rf accelerating system. Instead of the usual resonant cavity system, CERN will use an untuned wide-band travelling-wave system that will operate at 200 MHz—four times the frequency of the NAL rf. Besides eliminating costly and complex tuning equipment, the high-frequency rf makes it easier to deliver the rf power from the surface to the deep underground location of the SPS magnet ring (see figure). Also the 200-MHz system is easily modified to accomodate either higher machine intensity or energy at some time in the future. Disadvantages are the possibilities of more severe problems with synchrotron oscillations and parasitic modes.

Although it now appears that the SPS will be competing with Batavia energywise, the design intensity of SPS is still five times smaller than the Batavia design intensity (10^{13} protons per pulse at 18 pulses per minute compared to NAL's 5×10^{13} ppp at 20 ppm). On the other hand it is less than completely certain when, or if, Batavia (now operating at slightly below 10^{11} ppp) will be able to reach its design intensity.

One area in which the CERN machine will offer a clear advantage—even at lower intensity and energy—is that of experiments with high-energy neutrinos. Wüster points out that because the SPS neutrino facilities are closer to the machine the larger solid angle subtended will provide a counting rate for high energy neutrinos (> 50 GeV/c) that is ten times larger than that available at NAL if both machines were to operate at design intensity.

The first experimental area to be available for SPS will be the existing West Hall now in use with the old 28-GeV Proton Synchrotron (PS). Money from the CERN Laboratory I budget (which operates the PS and the Intersecting Storage Ring) is being used to ready the West Hall for use with SPS in 1976. The West Hall will accomodate experiments with hadrons up to 200 GeV and bubble-chamber experiments with neutrinos up to 400 GeV. SPS funds will be used to construct a brand new North area sometime later that will accomodate high-energy muon and neutrino counter experiments.

The use of Laboratory I funds at CERN for Laboratory II (the official title of SPS) is one of the means employed to cut in half the cost originally proposed for the new machine to the present figure of 1150 MSF (~\$300 million).

A most important factor in achieving this saving was the decision to use the 28-GeV PS itself as the injector for SPS. Laboratory I is bearing the total cost of an improvement program that will upgrade the PS to the intensity of 10^{13} ppp needed to inject into the SPS. A new 800-MeV injector for the PS has been built to replace the old 50-MeV linac. The PS will continue to supply protons for the ISR and directly to experiments while the SPS is under construction. However, as much as 25% of resources previously foreseen for Laboratory I will be invested in the SPS program each year through to 1976.

When the SPS begins operating, alternate pulses from the PS will be received by the SPS and ISR. The two machines require injected pulses of quite dissimilar specifications and it remains to be demonstrated that the PS can actually meet these specifications when it begins switching back and forth between the two machines in this way.

At the time SPS becomes available for experiments in 1976, the total annual budget for the two labs will be 540 MSF (~\$140 million).

What is the long-range future for SPS? The CERN group believes that the SPS has as good a chance as NAL to eventually push its energy up to 1000 GeV. Another possibility is to put superconducting magnets in the ISR rings, enabling them to accept 100-GeV protons from the SPS. These two colliding beams would provide center-of-mass energies equivalent to a single-beam energy of about 20 000 GeV. —HLD□