

several of the ternary compounds in pulsed magnetic fields up to 350 kG and steady fields up to 50 kG and extrapolated to higher fields. Some of their extrapolations (notably that for $\text{Pb}_{0.9}\text{Mo}_{0.1}\text{S}_6$) appear compatible with the subsequent measurements at the National Magnet Lab, whereas others (for tin-aluminum compounds) do not.

At the National Magnet Lab measurements were made over a wide range of applied fields—pulsed fields up to about 500 kG and steady fields of over 200 kG—and the higher-field superconductors were found by concentrating on the lead ternary compounds. For the best lead ternary compound, $\text{Pb}_{1.0}\text{Mo}_{0.1}\text{S}_6$, the pulsed magnetic field was as high as 495 kG; at this field value the superconducting-normal transition for the material was not yet complete and the experimenters estimate, from the behavior of other lead compounds with slightly lower values of T_c , that the transition occurs slightly above 510 kG at 4.2 K. They note that for the ternary compounds, their values of H_{c2} (4.2 K) appear to agree with predicted values of $H_{c2}(T)$ that are calculated assuming a type-2 superconductor with no paramagnetic limiting. Using this assumption, they predict that $H_{c2}(0)$ is 600 kG. Foner comments that even higher values of H_{c2} may be expected because the National Magnet Lab group has indications that some of their material has a higher critical temperature than 14.4 K, and their data shows that H_{c2} is proportional to T_c for the lead compounds.

Odd behavior of giant quadrupole resonance

Intensive study of an isoscalar giant electric quadrupole resonance in nuclear spectra, stimulated by its apparent discovery several years ago at a position just below the well established giant dipole resonance, has produced a modified—and puzzling—picture of its behavior. Stanley Hanna of Stanford University summarized the current experimental status of the giant quadrupole resonance (GQR) at a conference on Nuclear Structure and Spectroscopy held in Amsterdam, 9–13 September.

Any giant multipole resonance should exhibit three properties: it should be a general feature of all nuclei, it should be localized in a fairly narrow region of the spectrum and its strength there should exhaust a considerable fraction of an appropriate sum rule. The earlier evidence for the GQR, from inelastic scattering of electrons, protons, He^3 nuclei and alpha particles, showed it to have these properties. (See *PHYSICS TODAY*, September 1973, page 18.) It was centered, at an energy of $63/A^{1/3}$, quite close to the position predicted theoreti-

Will the lead-molybdenum sulfide, or any of the other ternary compounds, be able to carry the high current density needed for a dc magnet? This question must be answered experimentally before the practical value of the alloy can be known. Myron Strongin (Brookhaven National Laboratory) points out to us that there is reason for some caution in estimating the prospects for high current density. From the Abrikosov relation we have

$$H_{c2} = (2)^{1/2} \kappa H_{c1}(\text{bulk})$$

where κ is the Ginzburg-Landau parameter and $H_{c1}(\text{bulk})$ is the bulk critical field. Because $H_{c1}(\text{bulk})$ increases with T_c , we would expect a comparable or lower value for this alloy than for Nb_3Sn , which has a higher T_c . The value of κ then must be extremely high, and a very large κ usually indicates lower ultimate values of the flux pinning forces, which could imply a small useful current density. For different reasons, namely those of stability, Matthias also doubts the value of these sulfides for any future magnet.

—MSR

References

1. R. Chevrel, M. Sergent, J. Prigent, *J. Solid State Chem.* 3, 515 (1971).
2. B. T. Matthias, M. Marezio, E. Corenzwit, A. S. Cooper, H. E. Barz, *Science* 175, 1465 (1972).
3. R. Odermatt, Ø. Fischer, H. Jones, G. Bongi, *J. Phys. C Solid State Phys.* 7, L13 (1974).

cally for an isoscalar quadrupole resonance. (The GDR is at $(70-80)/A^{1/3}$.)

However, the recent data have shown that the GQR becomes quite spread out for nuclei with mass number A less than 40. These experiments show that the electric quadrupole (E2) strength in the lighter nuclei, summed over all energies, appears to exceed the sum rule, most probably, asserts Hanna, because it consists of a mixture of isoscalar and isovector strengths.

This new picture of the GQR has been compiled by a variety of experiments. The heavier nuclei have been studied primarily by inelastic scattering of electrons, protons, He^3 nuclei, deuterons and alpha particles. Recently, a group at Texas A&M University did a study of inelastic alpha scattering on a number of nuclei from Pb^{208} down to N^{14} . Their data show a systematic broadening of the GQR until, at Al^{27} , it is completely absent from the spectrum.¹ One advantage of alpha-particle scattering is that it selectively excites the isoscalar strength.

Radiative-capture experiments have been important largely for studying the lighter nuclei. The radiative capture of

alpha particles was found to have great strength, accounting for 50% of the sum rule when combined with the strength in the bound states. The strength was considerably spread out below the position of the GQR observed in the heavier nuclei. These radiative alpha-capture studies were performed by groups at the Argonne National Laboratory,² at the Australian National University in Canberra,³ at the University of Washington⁴ and at Stanford.

Radiative capture experiments and their inverse have also been done with protons—both (p, γ) and (γ, p) . Studies with polarized protons done at Stanford⁵ have been particularly enlightening because they give unambiguous separation of the E2 from the E1 strengths. These data also fail to show any concentration of E2 strength in a narrow region and add to the evidence that the total observed E2 strength exceeds the sum rule.

No theoretical calculations have yet been carried out to account for the disappearance of the GQR in lighter nuclei. Meanwhile, as Hanna pointed out, experimentalists should continue efforts to measure more accurately the E2 strength, to locate all the strength and to determine the isospin and the decay modes.

—BGL

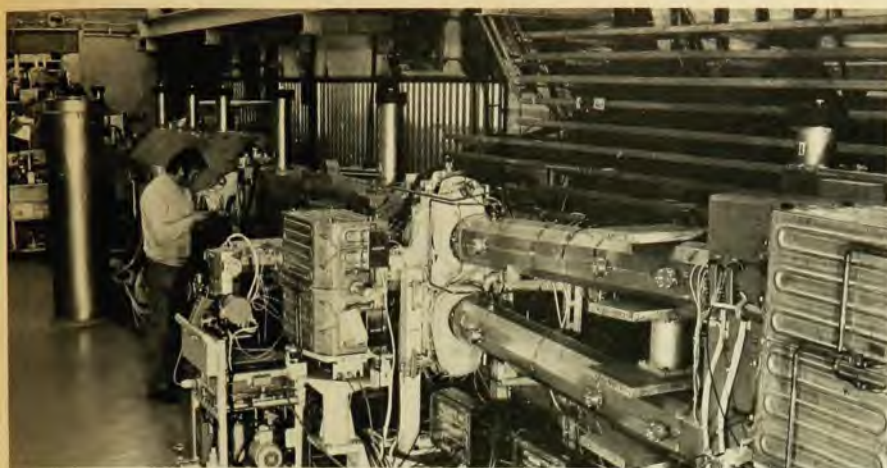
References

1. J. M. Moss, C. M. Rozsa, J. D. Bronson, D. H. Youngblood, *Phys. Letters* 53B, 51 (1974).
2. L. Meyer-Schützmeister, Z. Vager, R. E. Segel, P. P. Singh, *Nucl. Phys.* A108, 180 (1968).
3. R. B. Watson, D. Bradford, J. L. Block, W. A. Caelli, *Nucl. Phys.* A203, 209 (1973).
4. K. A. Snover, E. G. Adelberger, D. R. Brown, *Phys. Rev. Lett.* 32, 1061 (1974).
5. S. Hanna, H. F. Glavish, R. Avida, J. R. Calarco, E. Kuhlmann, R. LaCanna, *Phys. Rev. Lett.* 32, 114 (1974).

New storage rings operate at DESY

DORIS—the electron storage ring facility at DESY (Deutsches Elektronen Synchrotron) in Hamburg—made her debut in early October and by now is supplying beams for two interaction regions. The director of the DESY Laboratory, Herwig F. Schopper, spoke to us about them during a recent visit to the US.

The unique feature of DORIS is that it consists of two rings; thus it can produce electron-electron as well as electron-positron collisions. However, this feature of DORIS will not be developed until later this year, estimates Schopper. The rings are elliptical, with a circumference of about 280 meters, and are situated one above the other, with the beams intersecting twice at a cross-



DORIS storage rings consist of straight sections, (shown here looking toward interaction point) and circular regions at either end. Photograph from DESY, Hamburg.

ing angle of 1.5 deg. (See *PHYSICS TODAY*, August 1970, page 43.)

In physics runs, DORIS produced measured luminosities of about 10^{30} $\text{cm}^{-2} \text{sec}^{-1}$ per intersection at an energy of 2 GeV. (Luminosity is the collision rate per unit cross section.) Beam lifetimes of up to seven hours have been observed. The design current is 0.9 amps at 3 GeV and 0.3 amps at 3.5 GeV. So far DORIS has produced currents of 0.8 amps with one ring filled and currents of 0.3 amps with both rings filled. The main limitations to the current are the beam-beam interactions.

The workers at DORIS are studying these beam-beam interactions and have observed bunch lengthening caused by them. They feel that they may get higher currents by changing their working point on the Q diagram. Earlier, the team had been limited by single-beam instabilities, such as the transverse instability and the head-tail effect, but they have overcome these effects. They have also been able to observe bunch lengthening with large single currents.

Currently, the DORIS rings are filled at 2 GeV by the 7.5-GeV DESY synchrotron, which operates at 50 Hz. The energy is then raised in the storage rings. Beams of more than 100 milliamps have been accelerated and stored at 3.2 GeV, and smaller currents have been stable at 3.45 GeV.

Several pieces of apparatus are in place to study the various aspects of electron-positron interactions. One is a double-arm spectrometer, DASP, which has an excellent momentum resolution; It will measure single-particle spectra and two-body reactions with particle identification with a comparatively large solid angle.

A second detector is a superconducting solenoid called "PLUTO." It is 1.4 meters in diameter, 1.15 meters long and has a maximum field of 20 kG. Experiments have indicated that this field does not disturb the stored beam. In

comparison to DASP, PLUTO has a medium momentum resolution and larger solid angle. It will be used to study high-multiplicity events and to measure total cross sections. Thirdly, there is a sodium-iodide crystal with lead-glass counters that will be used to measure the ratio of charged to neutral particles and to measure correlations between particles. Two other experimental set-ups are under test. Finally, a synchrotron-radiation facility is currently being installed at DORIS and first measurements have been performed.

New particles

continued from page 17

gate the behavior of time-like photons in such reactions. They found a sharp peak in the e^+e^- mass spectrum at 3.1 GeV which had a width consistent with zero, within their mass resolution of 20 MeV. (See left-hand figure.) Their final mass resolution is much smaller, according to Ting. They estimated the yield of this new particle to be about 10^{-34}cm^2 .

In the MIT experiment, protons struck an extended beryllium target, and the electrons were measured with a precise pair spectrometer. The appearance of the narrow peak was so surprising to the MIT group that they made many experimental checks, such as decreasing the magnet currents or reversing the spectrometer polarity, to make sure that it was a real effect.

Ting told us that he and his collaborators were still hard at work trying to answer many questions about the first new particle. Does its decay violate parity? Is its decay into e^+e^- asymmetric? Does it decay into $e\pi\nu$ or $eK\nu$? Are there any more particles of lower mass or other decay modes (K^+K^- , K^-p , $K^+\pi^-$)? Are there charged modes? They have already found that the 3.695-GeV particle is not produced

(to 1% of the level of the 3.1-GeV particle) in pp experiments at the AGS.

The SLAC-LBL/UC collaboration had been studying the reaction $e^+ + e^- \rightarrow$ hadrons in 200-MeV steps; particles were detected in the large solenoidal magnetic detector. The new particle first surfaced as an anomalous value of the cross section at 3.2 GeV that would not go away. When the California team went back to investigate this energy region in very fine steps, with a nuclear magnetic resonance spectrometer to monitor the ring energy, they found a cross section for hadronic production at 3.105 GeV that is more than 100 times the cross section outside the peak. The upper limit to the full width at half maximum is 1.9 MeV. (See figure 2.) Subsequently the team measured enhancements at the same energy in the cross sections for the reaction $e^+ + e^- \rightarrow e^+ + e^-$ and $e^+ + e^- \rightarrow$ collinear pairs other than electrons. (Although their muon detection system was not working at the time, the group feels that this latter reaction is dominated by muon production.)

By now the muon detection system is operational and Richter told us that he and his colleagues are trying to determine the spin and parity of the new particle. One way to do this is to measure the angular distribution for events that decay into muon pairs. A second way is to look at the region just below the peak where the tail of the new particle can interfere with the normal quantum electrodynamical production of muon pairs; the existence of such an interference would prove that the particle has $J^P = 1^-$. This collaboration is also looking for a decay of the 3.695-GeV into the 3.105-GeV particle.

The Frascati team had to push beyond the nominal energy of (2×1.5) GeV for the ADONE storage rings in order to find the new particle. It was seen in three separate experiments, each run by a group that had been set up originally to analyze e^+e^- interactions below 3.0 GeV. The Gamma-Gamma Group used optical spark chambers and wire chambers to measure events with more than three charged particles. The cross section in the region from 3.090 to 3.112 GeV exhibits a sharp peak. The energy resolution of the Adone storage ring allowed them to put a 3-MeV upper limit to the full width at half maximum of the resonance. Interesting features were the presence of kaons and a rather large number of photons per event.

The MEA Group at Frascati studied the same reactions as the SLAC-LBL/UC collaboration. Their apparatus included a large magnet and optical wide-gap spark chambers and narrow-gap shower spark chambers. In addition to the peak in the cross sections, they noted a large multiplicity of charged