The Elbe Maidens of Physics

Experiments at DESY, Hamburg's synchrotron, take high-energy physics higher and higher

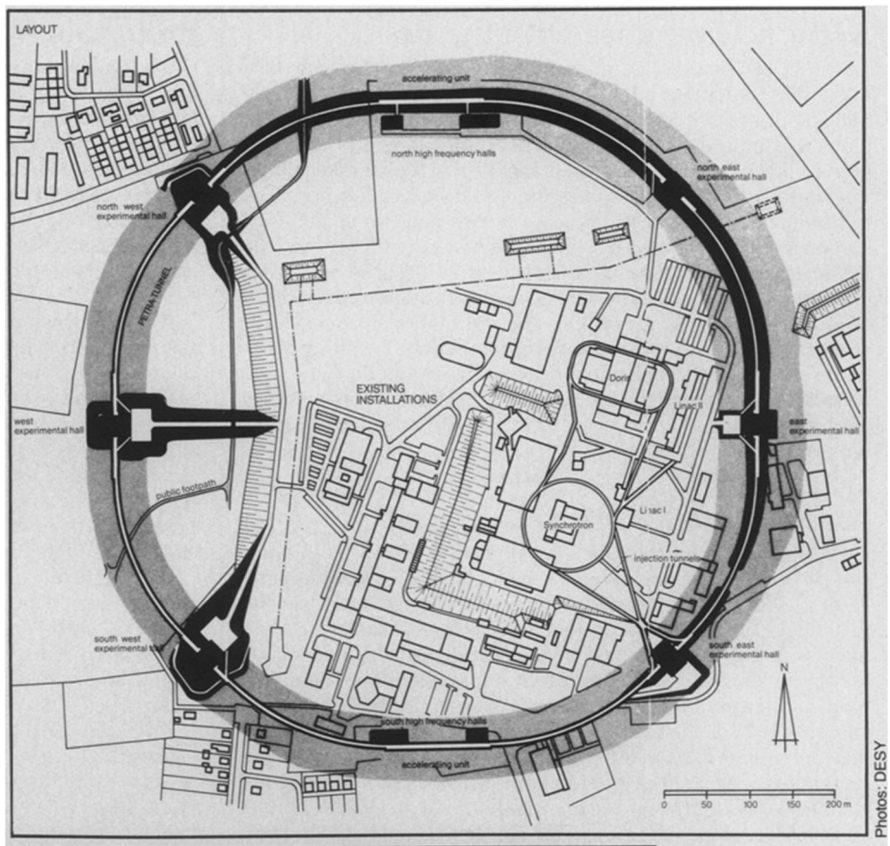
BY DIETRICK E. THOMSEN

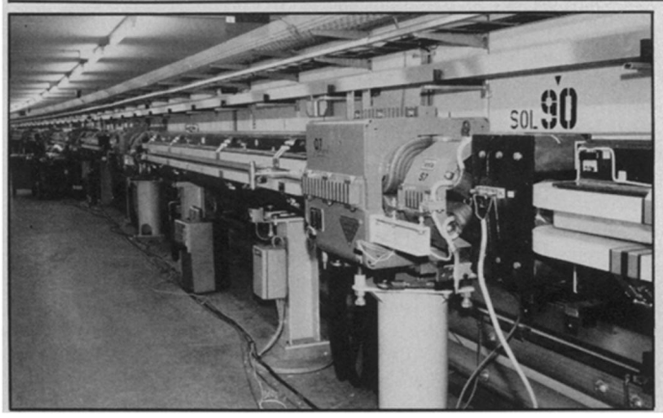
"Und wenn man einst in Hamburg war, das kann man gut verstehn." These lines from a song — "if you've been in Hamburg, you can well understand it" — actually refer to certain characteristic phrases in the Hamburger dialect. To one who sat through a certain session at the recent meeting of the American Physical Society they could easily refer to the building of colliding-beam apparatus or to the physics that comes out of such apparatus. Near Hamburg is the laboratory with the world's most advanced assortment of equipment for colliding energetic electrons with energetic positrons. Experimentation has just begun in the world's most energetic installation of this kind, the PETRA storage rings and colliding beam facility.

There are early results to report from PETRA as well as new results from the older and less energetic DORIS facility, which has been studying the heaviest particles known to physics, the upsilons, in part with the hope of finding evidence of the binding that holds their structure and similar structures (nearly all the subatomic particles known) together. Meanwhile there are plans for the future that are extremely ambitious. Most of the people involved are not native Hamburgers, but they seem to have taken the spirit of the place. It always was a pushy city.

The laboratory began with a fairly standard kind of electron accelerator, the synchrotron that gives the institution its name, Deutsches Elektronen-Synchrotron or DESY. When colliding beams became feasible, DORIS was built. Now there is the more energetic PETRA. DORIS operates from fairly low energies to a maximum of 10 billion electron-volts (10 GeV). PETRA's operating range is from 5 GeV to 17 GeV per beam with design expectations to 19 GeV.

A billion electron-volts is the energy that would be gained by an electron (or a proton) moving between the terminals of a billion-volt battery. (No such battery can exist, but there are other ways to impart the energy.) A billion electron-volts is about enough to make a proton or a neutron if all of it can be transmuted into mass. Such is the purpose of these experiments: To transmute the energy imparted to the electrons and positrons by the accelerating devices into particles to study, not neutrons and protons, which are readily available elsewhere, but more exotic varieties. The electron and positron, being matter and antimatter, annihilate each other when they collide, and all the energy they bring can then be transmuted into the mass of new particles, and watching what happens to these gives important information about the basic structure of matter and the forces that animate it.





Photos: DESY

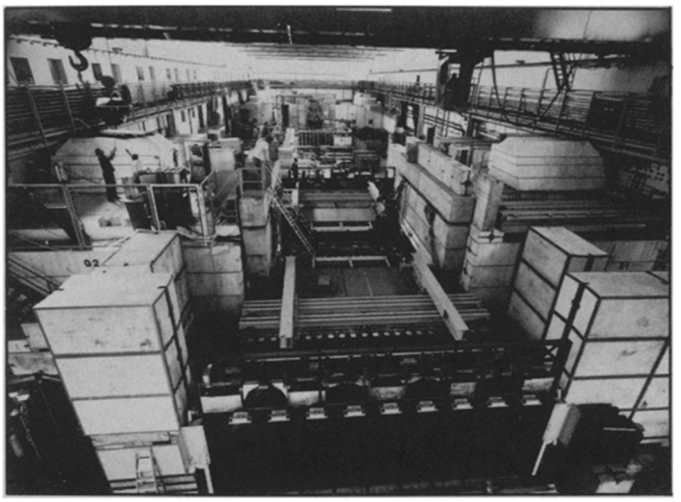
Layout of the German Electron Synchrotron (DESY) shows PETRA ring accelerator connected to existing synchrotron by injection tunnels. Recently completed PETRA tunnel is seen at left.

In the history of physics higher energy has usually meant the discovery of new things. In the case of electron-positron collisions the process is almost simple minded. Tune the energy of the device upward, and when it reaches a threshold corresponding to the mass of a particle (expected or unexpected), lo, it appears. Of course, when the physicists reach the top of the range, they want to go higher. There is every reason to expect that important things will be found if they do. (Somewhere there ought to come an end, but not yet at this level.) So the decision to build PETRA was made (and the decision to build PEP, an American equivalent).

PETRA was built in what must be record time for a project of this sort. Those who see and hear Gustav Adolph Voss, who supervised the construction, will understand some of the reasons why. The proposal went in in 1974. Construction began in the spring of 1976, and on July 15, 1978, the ring had been completed, and the first beams of electrons were run through it. During construction five experiments were selected. Some of them are already in

place; the others are being moved in. Their names would make an interesting study: Mark J, JADE (for Japan-Deutschland-England, appropriate), PLUTO (which has also worked at DORIS), CELLO (for music lovers, apparently), and TASSO (for literary types). Although, as Voss remarks, everything at the DESY laboratory so far has been built on a national basis, the participants in these experiments have home bases ranging from Japan to California and from Norway to France. Voss says there is a rule that experimental apparatus must be built so that it can be moved in and out in one week. Things are intended to move.

Right now, after the first few physics runs in October, December and January, PETRA is shut down. This is in part to enable the installation of the third and fourth of the high-frequency radio transmitters that supply the waves that energize the electrons and positrons and 28 more of the cavities in which the energizing is done. The other reason for the shutdown is to allow DORIS to complete an important series of experiments. According to the original plans, DORIS was to function as an electron accumulator and injector for PETRA. "But the high-energy physics looked so exciting with DORIS that we decided to free DORIS from accumulation duties." A new ring will be built solely to serve as accumulator for PETRA. It will be called PIA, thus continuing the Hamburg tradition of feminine-sounding names.



The DORIS *facility, even though less energetic than* PETRA, *has yielded such exciting results in the study of upsilons that it will continue doing physics experiments instead of being used as an electron accumulator for* PETRA.

By the last quarter of 1979, PIA should be built, and DORIS will be free to do high-energy physics full time. More accelerating cavities will have been installed in PETRA, to bring it up to its design energy of 19 GeV per beam. Both machines will then be free to do physics full time. There have been some reports of difficulties in PETRA (SN: 1/6/79, p. 8). Voss acknowledges these, but in public at least he doesn't act bothered by them. He treats them as bugs to be worked out.

"We can do elegant physics in PETRA." The quote is from G. Zech of the University of Siegen, a member of the 60-person consortium that operates the PLUTO experiment. The first runs in PETRA were dedicated to finding that out. Among other things they found, according to J. Duinker of NIKHEF in Amsterdam, representing the Mark J group of 37 physicists, is that the high-energy showers of particles that come out when electrons meet positrons at energies of 2 × 17 GeV act according to quantum electrodynamics, the well-established theory of the behavior of electri-

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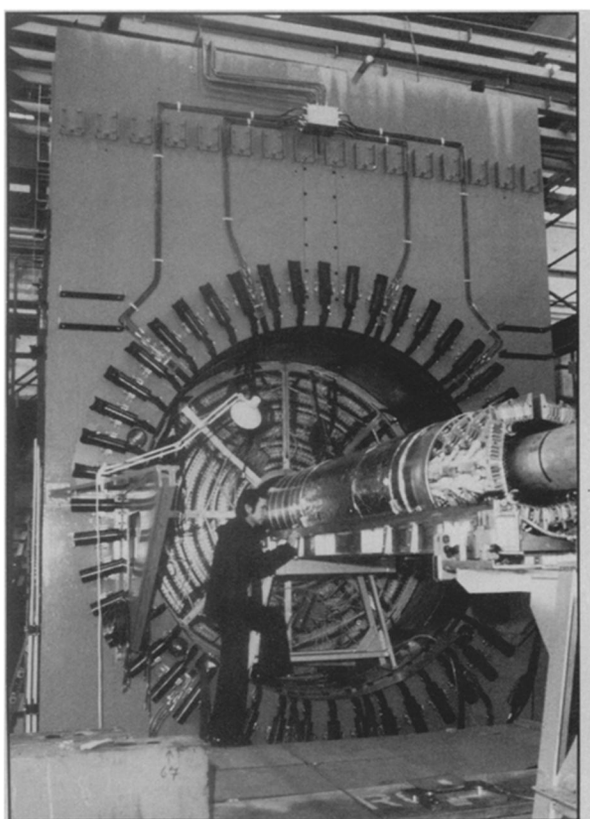

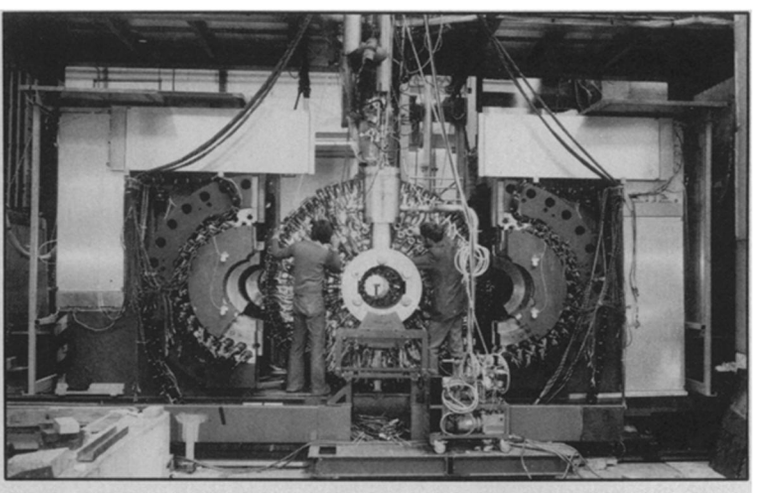

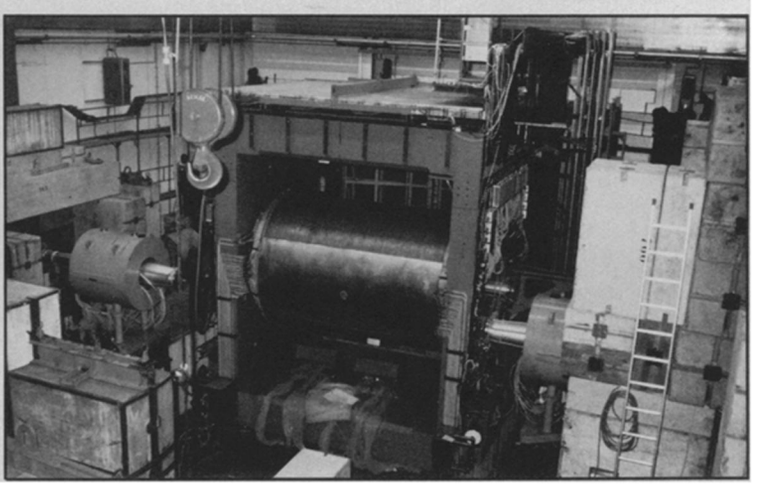

JADE, PLUTO *and* TASSO *(clockwise from left) are among the five experiments already selected for* PETRA.

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THE EARTHQUAKE HANDBOOK — Peter Verney — Paddington, 1979, 224 p., illus., $10.95. Explains in nontechnical language how earthquakes happen, where they occur and why. Traces the development of seismology, describes and illustrates many famous earthquakes and makes suggestions for safety for those in earthquake-prone areas.

HANDBOOK OF NOISE CONTROL — Cyril M. Harris, Ed. — McGraw, 2nd ed, 1979, 720 p., illus., $39.50. Today there are many people in widely diverse fields whose work requires some knowledge of noise control. This edition is written so as to make technical information on noise control accessible to these nonspecialists without diminishing its value to the acoustical engineer. Contributions from 53 experts in the field.

THE HIDDEN COSTS OF REWARD: New Perspectives on the Psychology of Human Motivation — Mark R. Lepper and David Greene, Eds — LEA (Wiley), 1978, 262 p., charts & graphs, $16.50. These papers are intended to acquaint the reader with the most recent theory and research concerning the conditions under which rewards may have detrimental, as well as beneficial, effects, and the processes that may underlie such effects.

HOW TO PATENT WITHOUT A LAWYER — Albert Thumann — Fairmont Pr (Van Nos Reinhold), 1978, 163 p., illus., $14.95. Provides answers to patent law problems using actual case studies. The book does not advocate that everyone with a patentable product should patent without a lawyer, but rather that by understanding the principles of self-patenting the best course of action can be chosen.

LAUGH AFTER LAUGH: The Healing Power of Humor — Raymond A. Moody, Jr. — Headwaters Pr (Lippincott), 1978, 128 p., $7.95. An M.D. writes about the medical implications and uses of laughter and the sense of humor.

MAKING MEDICAL CHOICES: Who is Responsible? — Jane J. Stein — HM, 1978, 270 p., $10.95. Technological advances in medicine have created a multitude of choices for each individual — choices that can influence how we live and how we die.

MALNUTRITION, ENVIRONMENT, AND BEHAVIOR: New Perspectives — David A. Levitsky — Cornell U Pr, 1979, 295 p., illus., $15. Papers concerned with the effects of malnutrition on behavior and brain development that were presented at the Cornell Conference on Malnutrition and Behavior, November 1975.

MURMURS OF EARTH: The Voyager Interstellar Record — Carl Sagan et al — Random, 1978, 273 p., color and b&w illus., $15. Written by those chiefly responsible for the content of the Voyager Record that is affixed to each Voyager spacecraft as a message about earth to possible extraterrestrial civilizations. An account of why the Record was done, how the material was selected and what it contains.

POLLUTION: The Neglected Dimensions — Denis Hayes — Worldwatch Inst, 1979, 32 p., paper, $2. Long-lived pollutants, such as CO_2, toxic substances and nuclear wastes, are examined. These pollutants, the author feels, can pose dangers for thousands of years, or even forever.

POSITIONAL ASTRONOMY AND ASTRO-NAVIGATION MADE EASY: A New Approach Using the Pocket Calculator — H. R. Mills — Wiley, 1978, 267 p., illus., $22.50. Makes the basic methods of positional astronomy easily accessible with a hand-held scientific calculator and some simple apparatus that is inexpensive to build.

PRACTICAL GEMOLOGY: A Study of the Identification of Gemstones, Pearls, and Ornamental Minerals — Robert Webster — Arco, 6th ed., 1978, 209 p., illus., $7.95. An introduction to the study of gems. Essential methods of gem testing are explained, apparatus is described and gem species are given in semitabular form.

THE PSYCHOPATH: A Comprehensive Study of Antisocial Disorders and Behaviors — William H. Reid, Ed. — Brunner-Mazel, 1978, 349 p., $17.50. Contributors examine the antisocial syndrome, focusing on characteristics that are associated with it and on treatment approaches that have had some degree of success with these most difficult patients.

. . . PETRA

cally charged particles. It would have been a terrible shock if they hadn't.

Another general point reported by Zech from PLUTO is that the total cross section, the over-all probability of producing things, in these collisions, remains at a constant level up to 2 × 17 GeV. In the past when a new variety ("flavor") of quark has entered the picture, the total cross section has taken a stepwise upward move, reached a threshold as they say. The quarks are supposed to be the basic pieces out of which all but a few of the known subatomic particles are built. So it is interesting to know how many they are and how they interact with each other. At the moment theory envisions six varieties or flavors, and there is experimental evidence for five of these.

Zech offers the expectation that at PETRA they will soon find a new flavor threshold, that is, the domain of a sixth quark. Meanwhile, experiments at both PETRA and DORIS are working on the fifth one, called the bottom quark, which appears in the upsilon particles, the heaviest yet discovered. The basic upsilon weighs in at 9.46 GeV, the slightly more energetic (excited) state, upsilon-prime, at 10.02 GeV. DORIS at its top energy can just about make them.

Systematic study by the DASP experiment at DORIS leads to a confirmation that the upsilons are indeed bound states of the fifth or bottom quark and its antiquark, J. K. Bienlein reports. The force that binds them together is a basic concern of the newly developed theory of quantum chromodynamics (QCD). QCD predicts that this force will be materialized or carried by intermediate particles called gluons. A force between two quarks is equivalent to a continual exchange of gluons between them. Are gluons real?

Theory says that when upsilon particles decay, the gluons should manifest their existence by making the decay products come out in three narrow, separated jets. Such jets should be especially distinguishable at high energy. In the general character, nature and distribution of the upsilon decay products, the PLUTO group has found a good agreement with theoretical prediction. That is indirect evidence for gluons since they are a key part of the theory, but the three jets that would be a more direct evidence of the gluons themselves have not yet appeared. They hope to find them in PETRA.

Another aspect of the QCD force is how it operates among different flavors of quark. Electric forces, for example, follow the same law whether the charged particle is an electron, a proton or a pion. Bienlein reports that DASP studies comparing the behavior of upsilons and of psi particles (which are made of a different flavor of quark, the charm quark), indicate that the "interaction is flavor independent." This is as the theory expects. A contradiction would have seriously complicated quark dynamics.

These beginnings can lead to a very full program. Already Voss is talking of adding polarized electrons to PETRA. Polarized electrons would permit experiments that make very sharp distinctions in the study of the newly unified domains of electromagnetism and the weak interaction, another kind of force in the subatomic world (SN: 7/8/78, p. 20).

By 1981 it may be possible to have two more detectors using polarized beams. There could be more transmitters, raising the energy to 23 GeV per beam. Another energy jump (to 2 × 30 GeV) could come in 198X, that is, as soon as superconducting accelerating cavities are tested out. There is a joint DESY-CERN-Karlsruhe project to build one and install it in DORIS by the fall of this year. In 198X it might also be possible to put in superconducting proton rings of about 300 GeV energy in order to study electron-proton collisions. And finally, though he admits that PETRA is as big a ring as can be built on the present DESY site, Voss's plan for 19YZ talks of an electron-positron ring of 100 GeV or so. At this point, if not sooner, he is likely to run into competition from other European laboratories, especially the older and international CERN laboratory — to some extent he already has — but he doesn't act as if it bothers him. □