been accumulated. Also, the SLAC Hybrid Bubble Chamber Facility has been operating in a laser backscattered gamma-ray beam, and these runs have been extremely successful. Some of this work will continue into the next fiscal year.

There is also a beam dump experiment that is currently being installed and tested which will be ready for data-taking next year. When an intense beam of high-energy electrons strikes a target, new particles might be produced. A detector weighing 20 tons is being installed on the embankment near PEP Interaction Region 2 to register such particles. This, like the quark-search experiment, is one of the 'long shot' experiments which SLAC is engaged in. In general, we like to balance our programme between such 'long shots' and 'sure things', where the experiments exploit phenomena which are already known to exist.

At this time we are not quite sure whether experimentation in End Station A will resume next year. Under financial pressures we had suspended End Station A operations last year. The final decision whether to reactivate End Station A will depend upon what new experimental proposals may be accepted, and upon the financial outlook of the Laboratory once the proposed budget has jumped more hurdles.'

In conclusion, Panofsky said that continued innovation was vital despite the unpredictability of the present course of high energy physics. 'The whole progress of this field has been nurtured by a succession of new inventions. As any one invention has run out of steam, a new one has followed, and it is the result of all these inventions that has led high energy physics to the succession of spectacular revelations of the nature of matter.'

## Linear collider studies

*Although the SLAC Linear Collider (SLC) project has yet to receive official funding, initial studies are already under way at SLAC, and a new front end for the two-mile linac is in the final stages of assembly. Using a recently developed high current photoemission electron gun and a new subharmonic buncher together with a standard SLAC injector section, it is hoped that intense bunches of electrons (containing over $10^{10}$ particles per 30 pseconds) will be available for subsequent acceleration in the main linac.*

# Physics with low energy antiprotons

This year, the CERN proton-antiproton project should bear fruit and experimenters should see the world's first collisions of high intensity beams of antimatter. While the 540 GeV collisions in the SPS and the search for the elusive intermediate bosons of weak interactions will be the natural focus of world attention, at the other end of the antiproton energy scale, preparations are under way which could also provide a rich harvest of new physics.

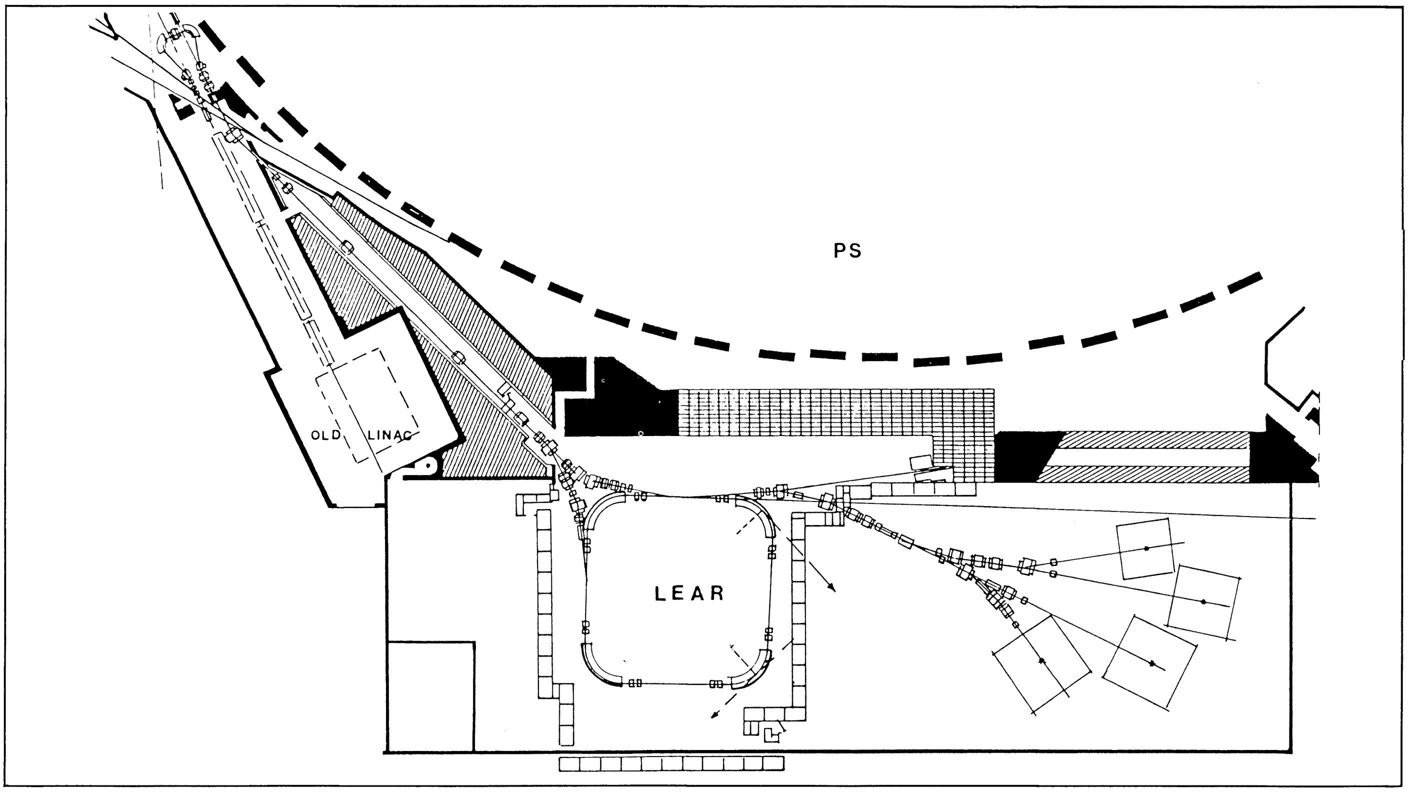
The Low Energy Antiproton Ring (LEAR), to be constructed in the South Experimental Hall at the PS, will provide intense beams of antiprotons in the energy range 0.1 to 2 GeV (see June 1980 issue, page 150). While nucleon-nucleon interactions have been studied in detail over the years, data on low energy nucleon-antinucleon interactions is less complete, although some fine work has been carried out.

As well as proton-antiproton annihilation and antiproton elastic scattering, LEAR physics will cover the spectroscopy of protonium — atoms composed of a proton and an antiproton. LEAR could also provide a definitive answer on baryonium —states expected on certain grounds to be formed from baryons and antibaryons. In addition, there will be other mesonic states to look for in proton-antiproton annihilations, and the properties of the antiproton itself will be accurately measured.

It is hoped that together these experiments will enable nucleon-nucleon and nucleon-antinucleon interactions to be compared, providing a better understanding of hadrons. In addition, LEAR should improve our knowledge of quark behaviour, especially through the investigation of the dynamics of the proton-antiproton annihilation mechanism.

Ten experiments have been approved for LEAR, including four rela-

A plan of the LEAR low energy antiproton ring to be built in the South Hall of the CERN PS, showing the transfer lines and the experimental area.




tively major installations and four studies of exotic atoms. The allocation of available beam time between these experiments has yet to be decided, but the antiproton yield should be so high that some detectors will have only a small requirement for beam time, allowing different experiments to be mounted in parallel, and with a beam splitter allowing simultaneous operation of different experiments.

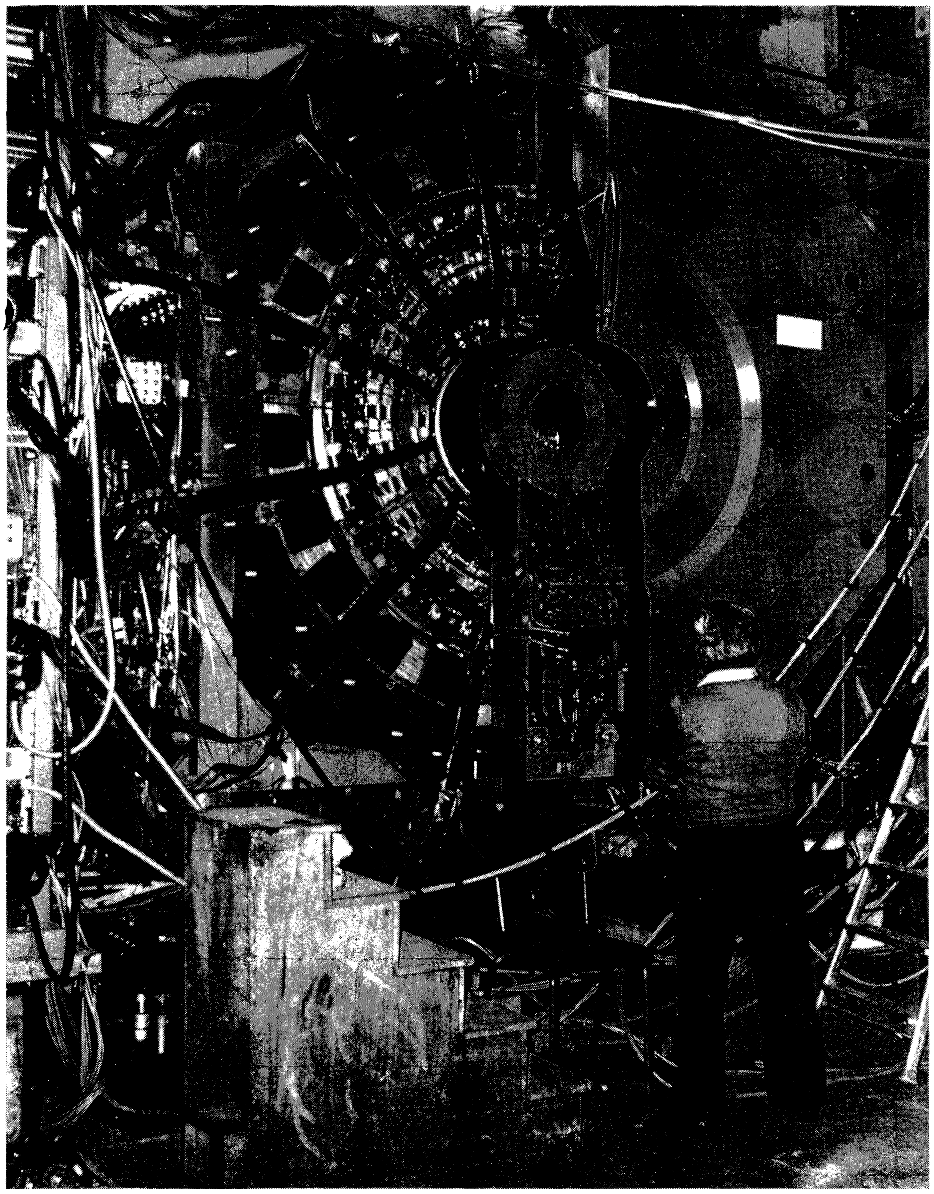
The first LEAR experiment to be approved involves an Annecy / Padova / Saclay / Torino collaboration for 'precision measurements of the proton electromagnetic form factors in the time-like region, and vector meson spectroscopy'. By looking at the annihilation of protons and antiprotons into electron-positron pairs, physicists can compare the behaviour of the electromagnetic form factor of the proton under these conditions (the time-like region) with the precision data obtained from electron-proton scattering (the space-like region). Previous experiments at the CERN PS and at low energy electron-positron rings were able to monitor about one proton-antiproton annihilation into electrons per day, but this experiment hopes to be able to have ten thousand times this event rate. In addition, the electron-positron spectrum could be used to study vector mesons in the mass range below the J/psi.

Another major LEAR experiment will be a study of proton-antiproton interactions in a hydrogen gas target by a CERN / Mainz / Munich / Orsay / TRIUMF / Zurich group, also known as ASTERIX (Antiproton STop Experiment with tRigger on Initial X-rays). The experiment will study protonium spectroscopy and proton-antiproton annihilations in different angular momenta, with each event having data on both the initial atomic state and the final annihilation products. Antiprotons will be stopped in a hydrogen gas target at atmospheric pressure. A large-acceptance low-threshold X-ray detector of novel design (see March issue 1979, page 10) will surround the target and count X-rays emitted in transitions to low-lying atomic levels. Final annihilation products will be measured in the DM1 magnetic detector previously used in electron-positron colliding beam experiments at Orsay and now upgraded with gamma detectors. The experiment will have greatly increased abilities for observing any narrow quasinuclear proton-antiproton bound states, and provide valuable comparisons of annihilations with different angular momenta.

Also representing a considerable experimental effort will be an examination of proton-antiproton total cross-sections and spin effects in

*The DM1 magnetic spectrometer being installed in its previous incarnation at the Orsay electron-positron ring. It is now being lengthened to accommodate further multiwire chambers ready for use by the 'ASTERIX' collaboration at LEAR.*

*(Photo Orsay)*



the resultant elastic and charged two-body pion and kaon channels by an Amsterdam / Geneva / London (Bedford and Queen Mary Colleges) / Surrey / Trieste collaboration, using the LEAR beam on a conventional polarized target. This is an attempt to piece together the annihilation mechanism by looking at specific channels. While baryonium is presently out of fashion, it could make a come-back, and this could be one of the experiments to see it. Provided a source of polarized antiprotons can be obtained, another possible objective is to look for spin effects with completely-defined spin states of the incoming particles. Also covering some of this ground will be a Heidelberg group studying the energy variation of proton-antiproton total cross-sections, elastic scattering, and the charge exchange process producing neutrons and antineutrons, down to very low energies.

A precision survey of the X-rays from proton-antiproton (or deuteron-antiproton) exotic atoms is to be carried out by an Amsterdam / Birmingham / Rutherford / William & Mary collaboration. Using a gas target to avoid Stark mixing and achieve good population of low-lying states, the aim is to look harder at the X-rays from simple exotic atoms to search for transitions between low-lying states. While some of these spectral lines have already been seen (see July/August 1978 issue, page 257), the lowest-lying transitions (giving the highest energy photons and corresponding to the Lyman series in ordinary hydrogen) have yet to turn up.

The search for these transitions, which could provide valuable information on proton-antiproton forces, is also the aim of a Karlsruhe group using a novel technique. A superconducting magnet will first make the antiprotons rotate, but subsequent energy losses due to collisions in the very low pressure gas environment will make the antiprotons spiral inwards. In this way low energy antiprotons will accumulate in the central region, equipped with a semiconductor detector. This technique could provide new experimental opportunities.

Another specialist exotic atom group (Basel / Karlsruhe / Stockholm / Strasbourg / Thessaloniki) will look at the characteristics of antiprotonic atoms with heavier nuclei. This will be an extension of the group's previous work on exotic atoms, employing the detector already used in previous experiments at SIN and at CERN.

The relatively high rate of kaon production in proton-antiproton annihilations should provide a source of kaons which compares favourably