energy electron diffraction (LEED) apparatus.

Auger emission is not the only process producing secondary electrons at the surface, as can be seen in the figure, which shows curves for 1910-, 1310- and 695-eV electrons incident on pure beryllium. The major process, elastic scattering with little or no loss of energy, yields the very big peaks, which are useful in defining the energy scale of the spectrum. Reflection with energy loss caused by plasma oscillations of valence electrons in the crystalline solid gives rise to peaks that appear at characteristic energies below each large peak. Auger emission can be easily identified as the peaks show up at energies that depend only on the material being studied and not on the bombarding energy.

In this way the presence of surface contaminants introduced on silicon and germanium has been confirmed, and sulfur has been detected on the surface of nickel samples at a bulk concentration of less than 10 ppm. Conventional x-ray analysis becomes more difficult with light elements because there is a decrease in x-ray fluorescence compared with heavier ones. This decrease is due to a parallel increase in Auger emission, and Harris's method is superior to x-ray analysis for these lighter elements, from lithium to oxygen. The apparatus is claimed to be both simpler and cheaper than the equivalent x-ray spectrometer.

New CP-Violation Experiments Reported: Theory Still in Doubt

Since the discovery three years ago (by James Christenson, James Cronin, Val Fitch and Rene Turlay) that the product of the charge conjugation operator (C) and the parity operator (P) is not conserved in the weak interaction, particle physicists have been trying to find out how and why this occurs. The latest experiments on the decay of the K_2^0 meson, reported in *Phys. Rev. Letters*, 23 Oct., seem to show a charge asymmetry in the leptonic decay of K_2^0.

In an experiment at the Brookhaven AGS Jack Steinberger and his collaborators (Sheldon Bennett, David Nygren, Harry Saal and John Sunderland of Columbia University) found the decay rate of $K_2^0 \to \pi^- + e^+ + \nu$ was a trifle larger than that of $K_2^0 \to \pi^+ + e^- + \nu$. The difference between the two rates divided by the sum of the two rates was $(2.24 \pm 0.36) \times 10^{-3}$.

In an experiment at the Stanford Linear Accelerator Melvin Schwartz and his collaborators (D. Dorfan, J. Enstrom, D. Raymond and S. Wojcicki of Stanford University and D. H. Miller and M. Paciotti of the University of California, Berkeley) the decay rate of $K_2^0 \to \pi^- + \mu^+ + \nu$ was somewhat larger than $K_2^0 \to \pi^+ + \mu^- + \nu$. The same ratio in this case was $(4.05 \pm 1.3) \times 10^{-3}$.

The Steinberger and Schwartz experiments are the last in a series of experiments to complete the phenomenological description of CP violation in K-meson decay. As a noted theorist told PHYSICS TODAY, "In a certain sense the experimental physicist has now delivered the theorist the finished product, and the theorist must formulate a behind-the-scenes theory to explain it."

After CP violation was uncovered in K_2^0 decay, people started looking for violations in other weak decays, such as that of the lambda or sigma. None have been found so far. Many theories have been advanced, but they were necessarily speculative since details of the K_2^0 decay were largely unknown.

One such theory, proposed by Jeremy Bernstein, Gerald Feinberg and T. D. Lee, says that the electromagnetic interaction strongly violates both C and T (time reversal) invariance, and this shows up as a small CP violation in K_2^0 decay. The theory suggests that the neutron has an electric dipole moment. Both Norman Ramsey and Clifford Shull recently reported their attempts to find such an electric dipole moment, but within experimental error the value was zero (PHYSICS TODAY, Sept., page 64). The theory, however, may still be viable.

Neutral K mesons exist in two states: K^0 with positive strangeness and $\bar{K}^0$ with negative strangeness. In decays, however, one sees K_1^0 (short lived) and K_2^0 (long lived). Until the Christenson experiment it was believed that K_2^0 was a 1:1 mixture of K^0 and $\bar{K}^0$. The experiment found that a decay forbidden by CP invariance, namely $K_2^0 \to \pi^+ + \pi^-$, did in fact occur, but only weakly. This meant that K_2^0 was actually some more complicated mixture of K^0 and $\bar{K}^0$, but the deviation from 1:1 was not known.

Phenomenology. Shortly afterward C. N. Yang and T. T. Wu developed a phenomenological framework for describing the CP-violating decay. A parameter ϵ describes the composition of K_1^0 and K_2^0 in terms of K^0 and $\bar{K}^0$; ϵ measures the extent to which K_2^0 is not an eigenstate of CP. Two other parameters η_{+-} and η_{00} measure relative decay rates. $|\eta_{+-}|^2$ is the ratio of the probability for $K_2^0 \to \pi^+ + \pi^-$ to the probability for $K_1^0 \to \pi^+ + \pi^-$. $|\eta_{00}|^2$ is the same ratio, except that it is for decays into two neutral pions. If CP violation were due only to the composition of K_2^0 then $\eta_{+-} = \eta_{00}$.

The Christenson experiment determined $|\eta_{+-}|$ but not its phase. Then the phase of η_{+-} was determined in experiments by Val Fitch and his collaborators at the Princeton-Pennsylvania Accelerator, by Carlo Rubbia, Steinberger and others at CERN, and by M. Bott-Bodenhausen and collaborators at CERN.

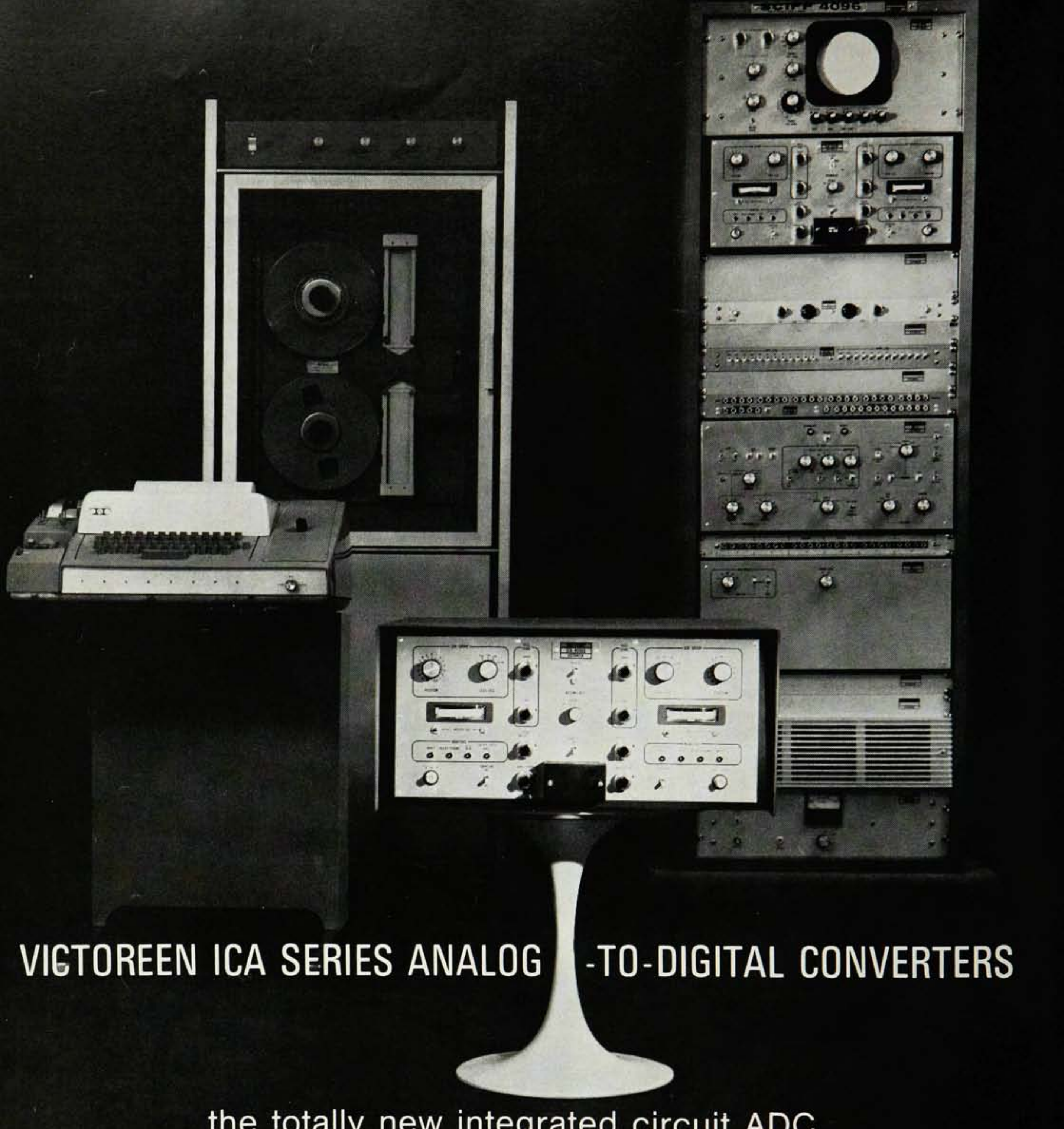
Late last year Jean-Marc Gaillard, E. Manning and collaborators at CERN and James Cronin and collaborators at PPA (PHYSICS TODAY, March 1967, page 83) determined $|\eta_{00}|$.

The Schwartz and Steinberger experiments determine the phase of η_{00} and $|\epsilon|$. The phase of ϵ was previously known quite accurately from theory; so now all the Yang-Wu parameters are available for ambitious theorists.

The experiments of Cronin and Gaillard also showed that $|\eta_{00}| \neq |\eta_{+-}|$; that is, the structure of K_2^0 is not the sole cause of CP violation.

It has been known for almost ten years that in strangeness-changing weak interactions the $\Delta I = 1/2$ rule works pretty well; that is, the change in isotopic spin I during a reaction is at most $1/2$. But even then particle physicists knew that although $\Delta I = 1/2$ decay is dominant, there is some $\Delta I \neq 1/2$ behavior.

Two effects. Thus it now appears that the CP violation in the weak decay of K_2^0 occurs from two effects: (1) K_2^0 and K_1^0 are made up of a peculiar combination of K^0 and $\bar{K}^0$. (2) There is a $\Delta I > 1/2$ weak interaction in the decay of K_2^0 into two



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pions, and this decay shows CP violation.

One might well ask: Does the $\Delta I \neq 1/2$ decay violate CP and not the $\Delta I = 1/2$ decay? Or do both the $\Delta I = 1/2$ and the $\Delta I > 1/2$ decays violate CP? Although some experimental data are now available, nobody knows the answer yet. Particle physicists are looking for experiments that will give the answer, but so far they appear to be too difficult.

The charge asymmetry found by Schwartz and Steinberger has another intriguing aspect. It offers a way to determine, by communication (with an exchange of dots and dashes rather than physical objects) with physicists in another galaxy, whether their galaxy is composed of the same kind of matter as ours. They will be able to make K_2^0 and observe that less negative particles are emitted, as Steinberger did. If these less-favored particles are the common constituent of their galaxy, then it, too, would consist of matter rather than antimatter.

Such a scheme for intergalactic matter identification appeared to be feasible last year (PHYSICS TODAY, Aug. 1966, page 71) when a charge asymmetry in η^0 decay was reported by Paolo Franzini and his collaborators. Subsequent experiments, however (PHYSICS TODAY, Oct. 1966, page 85), found no statistically significant asymmetry. —GBL

Oak Ridge IMP Will Shoot Neutrals at Plasma in a Well

DCX-1, for many years a mainstay of controlled-fusion research at Oak Ridge, is now being replaced by a more broadly based experimental series, known as the "Target Plasma Program." One new experiment in the program, IMP (Injection into Microwave Plasma), is now being designed; neutral atoms will be injected into a target plasma produced by microwave heating.

In the DCX-1 experiment a beam of molecular hydrogen ions, accelerated to 600 keV, is injected into a magnetic field between two mirror coils; by dissociation in that region one obtains a collection of 300-keV atomic ions. Although the plasma is hot enough for fusion, experiments completed last year (by Julian Dunlap, Glenn Haste, Herman Postma, Larry Reber and Carl Nielsen, *Phys. Fluids* **9**, 199, 1966) showed that the hot-ion density could not be increased beyond 2×10^8 cm^{-3} (far from the 10^{14} cm^{-3} usually considered necessary for controlled fusion); losses from the negative mass instability were too high.

In the new approach a steady-state target plasma is generated between magnetic mirrors or in a magnetic well by microwave power applied at a frequency that gives electron cyclotron resonance at appropriate locations in the magnetic bottle. Such a plasma consists of cold ions (H^+ or D^+) and warm electrons. The cold ions cause trapping of an energetic neutral beam, and the warm electrons aid stability of the trapped ions at high densities (by Landau damping of certain critical longitudinal plasma waves).

Trapping occurs because hot (20-keV) neutral particles exchange charge with cold ions in the target. The reaction, which has a large resonant cross section, is $H^0(\text{hot}) + H^+(\text{cold}) \rightarrow H^0(\text{cold}) + H^0(\text{hot})$. This method of trapping, not previously exploited, can be 100 times as efficient as present methods (in which the injected neutral particles are ionized by Lorentz forces), according to

WORK IN PROGRESS. At Los Alamos (left) a cleared area and 0.8-km trench are the start of the meson facility now abuilding. Meanwhile at CERN (right) most of the excavation is complete and concrete work has been started for the 300-meter-diameter tunnel to house intersecting proton storage rings. Beyond are CERN buildings, Geneva, the Alps.