smaller than 20:1. But the magnetic stresses on the helical coils in the proposed "fat" configuration turned out to be so high that they would have required considerable mechanical buttressing. To avoid the consequent construction delay, the minor radius of the plasma had to be reduced to 10 cm. With a major radius of 2 meters, the Wendelstein VIIA is thus left with an aspect ratio no better than that of the old Model C (though with twice the plasma radius).

But nowadays the aspect ratio is no longer crucial for the achievement of high temperatures. Because it has become clear that tokamaks cannot achieve ignition temperatures by ohmic heating alone, neutral-beam injection has been developed in recent years as an additional source of plasma heating in tokamaks. The Wendelstein VIIA is the first stellarator that incorporates high-power neutral-beam injection. With this second heat source providing up to a megawatt of input power, the plasma current can be shut off after the initial ohmic-heating phase. With the complex stellarator windings making access difficult, it was no mean trick to inject the neutral beam into the plasma at a favorable angle. Although neutral-beam injection has made it possible to operate a stellarator with good confinement even at large aspect ratios, the 20:1 geometry of the Wendelstein VIIA may limit its β (plasma pressure/magnetic field pressure) to about half a percent. The higher pressures and densities necessary for a practical reactor would ultimately require a smaller aspect ratio.

The earlier stellarator project at Princeton having been named "Matterhorn," Grieger and his colleagues called their undertaking Wendelstein, after a modest Alpine foothill outside Munich—a deliberate act of humility. Unlike the racetrack-shaped Model C, the Wendelstein VIIA torus is circular. This avoids the special coils that were necessary in the Model C to smooth the transition between curved and straight sections. These transitional fields are believed by some to have contributed to the poor performance of the earlier machine.

Although the Wendelstein VIIA is significantly smaller than the current generation of large tokamaks, it and its counterparts in the Soviet Union, Britain and Japan have been doing at least as well as tokamaks of comparable size for several years now—without neutral-beam injection. Operating only with ohmic heating, these machines have shown very good values of the confinement parameter (density $\times$ energy confinement time), which now appears to be exhibiting the same favorable scaling behavior as one sees for tokamaks, with respect to temperature, density and size. This improved performance is the cumulative result of numerous small refinements of the stellerator design.

Furthermore, the helical stellarator field appears to prevent the rapid plasma breakup that can occur in tokamaks near the critical ohmic current density. (Such a violent plasma disruption could severely damage a reactor.) All this has generated considerable new enthusiasm for the stellarator concept around the world. But until the recent Garching results, no-one has been able to maintain a plasma of significant pressure in a pure stellarator mode—with the ohmic heating turned off.

Shutting off the ohmic heating has in the past always resulted in the loss of plasma confinement in the stellarator. Last fall, even after they had managed to squeeze their high-power neutral beam into the Wendelstein VIIA, the Garching group found that their plasma invariably got lost in a magnetohydrodynamic resonance as they attempted to reduce the plasma current to zero. But they have now found the trick. Instead of keeping the current in the helical stellarator coils constant as they turn down the plasma current, they gradually increase the helical current in a manner that just compensates for the loss of the plasma current. By keeping the poloidal magnetic field component approximately constant in this way during the transition, so that the offending resonant surface is kept out of the plasma, they find that confinement is maintained as the system goes over to the pure stellarator mode.

In the stellarator mode, with heating provided only by the neutral-beam injection, and the poloidal field component coming only from the helical windings, the energy confinement time of the plasma improves by a factor of four. The confinement time in the Wendelstein VIIA increases from about 5 msec in the ohmic-heating phase to 20 msec in its pure stellarator phase. With a plasma density of 10^{14} cm^{-3}, this represents a confinement parameter of 2×10^{12} sec/cm^3—at least five times as high as attained by tokamaks of comparable size. Of course the plasma temperature achieved in the Garching stellarator is only 700 eV, an order of magnitude below what has been obtained in the Princeton PLT tokamak, with a plasma volume ten times that of the Wendelstein VIIA.

The most attractive feature of the stellarator concept as against tokamaks is that a stellarator reactor would operate in a steady-state mode. Because the plasma current in tokamaks must be induced by the transformer action of external induction coils, it can only operate in a pulsed mode. Even

AGS Celebrates Twentieth Anniversary

Brookhaven celebrated the twentieth anniversary of the Alternating Gradient Synchrotron in May. John Blewett, Ernest Courant (Brookhaven) and Kjell Johnsen (CERN) reminisced about designing and building the machine. Some of the speakers recalled the great physics discoveries made at the AGS. Melvin Schwartz (Stanford) talked about finding the muon neutrino and a "residual level of junk" events that were probably neutral currents. Val Fitch described the discovery of CP violation (an experiment approved on the basis of a two-page proposal with no detailed background calculations). Nicholas Samios (Brookhaven) reviewed the bubble-chamber program, which over the two decades yielded 40 million pictures, including the first Ω^- and the first charmed baryon. Samuel Ting (MIT) described the experiments leading to the J/ψ, which led to a new high-energy era with charm, beauty and other gracious qualities.

The speakers, photographed at the meeting, are (from left): Johnsen, Samios, Fitch, Schwartz, Ting, Courant and Blewett.