third running period of the $p\bar{p}$ collider, from early in April until early in July, 1983, integrated luminosity was six times greater than the run at the end of 1982. This time the Z turned up, and on 1 June the UA1 group announced[4] it had found five events. Four of them were $Z \to e^+e^-$ and one was $Z \to \mu^+\mu^-$. On 15 July the UA2 group also reported[5] finding the Z. The Z mass value reported by UA1 was 95.2 ± 2.5 GeV/c^2, and by UA2 was 91.2 ± 1.7 GeV/c^2. The electroweak theory with radiative correction predicted 94.0 ± 2.5 GeV/c^2.

Biographies. Rubbia, who is 50, earned his physics degrees at the Scuola Normala Superiore of Pisa and at the University of Pisa. He spent a couple of years at Columbia University as a postdoc and from there returned to Europe. He joined the staff of CERN in 1961, where he is a senior physicist. In addition, since 1970 he has been a professor in the Harvard University physics department.

Van der Meer, who is 59, attended the Technische Hogeschool in Delft, and received a Dutch diploma in physical engineering. He worked for N.V. Phillips in Eindhoven before joining CERN in 1956, where he has been ever since. He was leader of the power supply group for the ISR and for the SPS, and then was joint project leader for the Antiproton Accumulator. —GBL

References

1. S. van der Meer, "Stochastic damping of betatron oscillations in the ISR," CERN/ISR-PO/72-31, August 1972.
2. G. Arnison *et al.*, Phys. Lett. **122B**, 103 (1983).
3. M. Banner *et al.*, Phys. Lett. **122B**, 476 (1983).
4. G. Arnison *et al.*, Phys. Lett. **126B**, 398 (1983).
5. P. Bagnaia *et al.*, Phys. Lett. **129B**, 130 (1983).

Briefings point out special, low-cost research opportunities

In an effort to highlight for government funding officials "areas in which incremental funding may lead to major advances," a research briefing panel headed by Hans Frauenfelder (University of Illinois) and APS president Mildred Dresselhaus (MIT) conducted a series of briefings in Washington last Fall on "Selected Opportunities in Physics." At the request of the President's Office of Science and Technology Policy and the NSF, the panel had selected emergent fields of physics research in which, they felt, modest additional funding would exert "high leverage toward rapid progress." Large facilities and well-established research programs were explicitly excluded from consideration.

The briefing report on selected opportunities in physics is one of nine such briefings on various research topics in science and technology requested by OSTP director George Keyworth as input for the preparation of the FY1986 budget. The briefing panel reports were prepared under the auspices of COSEPUP (the Committee on Science, Engineering and Public Policy) and published in November by the National Academy Press. The only other physics topic among the nine chosen by Keyworth for the 1984 briefings was solar–terrestrial physics. That briefing was prepared by a panel headed by Charles Kennel (UCLA).

This is the third consecutive year that Keyworth has asked for such briefings. The selection of topics for FY1987 by OSTP, NSF and COSEPUP was to be completed last month, with briefings due for presentation next June, four months earlier in the budget cycle than has been the practice until now.

Selected Opportunities in Physics. In addition to the Keyworth briefing in October, Dresselhaus, Frauenfelder and panel member William Brinkman (Sandia) conducted additional briefings in Washington for agency representatives from DOE, DOD and NASA; NSF director Erich Bloch and his colleagues; and DOE Office of Energy Research director Alvin Trivelpiece. Brinkman is chairman of the National Academy of Sciences Physics Survey Committee. The Committee's much anticipated report, of which the briefing panel made extensive use, should be released early this year.

From among 20 suggested fields of physics research, the panel, with the aid of other experts, had chosen six "areas of special opportunity." As one panel member put it, "we were looking for embryonic, undernourished areas of special promise." The six areas chosen were:

- physics at the laser–atomic frontier
- relativistic plasma waves
- physical properties of deliberately structured materials
- biomolecular dynamics and intercellular cooperativity
- cosmology
- nuclear matter under extreme conditions

These six areas, the panel's report tells us, "promise to yield fundamental results of great interest. Many . . . are likely to advance technology . . . [and] all six cut across lines of narrow specialization." Cosmology, for example, has lately forged intriguing links between astronomy and particle physics.

The laser–atomic frontier generates research opportunities by applying advanced laser technology to fundamental problems in atomic and molecular physics. The briefing report stresses a number of such research opportunities and their possible applications:

- Trapped particles. Using laser light, one can trap ions and neutral atoms, and cool them to very low temperatures. This opens the way to ultra-high-precision measurements of frequencies, masses, the possible anisotropy of space, and collective motion in plasmas and gases.
- New spectroscopies. Femtosecond light-pulse generation (PHYSICS TODAY, December 1982, page 19) now make possible "snapshots" of atomic collisions, molecular reactions and fast surface phenomena. Femtosecond spectroscopy has applications in fast circuitry and instrumentation. Another new high-resolution spectroscopy of atoms, ions and molecules involves the use of relativistic particle beams to Doppler-shift highly stable visible laser output into the ultraviolet. One can thus investigate QED effects in highly charged ions and make new kinds of photoejection measurements.
- New and previously inaccessible species such as multiply excited atoms, molecular ions and clusters can be created by lasers. One can thus study correlated electron motion, catalysis, and the evolution from single atoms to condensed matter.
- Matter in intense fields produced by high-power lasers will permit the study of nonlinear phenomena and multiphoton processes (PHYSICS TODAY, November 1984, page 21), perhaps opening the way to novel photochemical processing and isotope separation techniques
- New light sources include excimer lasers and the generation of extreme ultraviolet and soft-x-ray light in supersonic atomic beams. Such techniques may provide small-scale alternatives to accelerator-based light sources.

Relativistic plasma waves involve electrons and ions at high velocities. Exploration of such waves could elucidate exotic astrophysical objects and the sources of cosmic rays. Understanding relativistic collective electromagnetic phenomena may lead to novel accelerators and radiation generators.

- Particle accelerators. The long-range future of high-energy physics may well depend on novel acceleration schemes such as plasma accelerators, grating accelerators and free-electron-laser accelerators (PHYSICS TODAY, February 1983, page 19). These schemes exploit the high charge densities that can be achieved in plasmas and the high energy densities made possible by lasers. They will require the development of terawatt lasers with good optical quality and sub-picosecond pulses. The report recommends an appropriate laser development program.

▶ Generation of electromagnetic radiation in plasmas—the inverse of these particle acceleration schemes—may be involved in poorly understood radiation bursts from astrophysical sources. In the lab, the injection of relativistic electron beams into plasma has produced copious radiation at high harmonics of the plasma frequency. Theory predicts that energetic electrons traversing plasmas with strong density fluctuations should yield radiation similar to that from conventional free-electron lasers. Good experiments and computational tools accessible to university researchers are at present lacking, the briefing report tells us.

Deliberately structured materials address issues of scientific as well as technological interest. Three areas of particular promise emphasized in the report are: surfaces and interfaces between specifically designed microscopic structures; tailoring materials to facilitate the study of disorder in condensed matter; and the study of novel phenomena in "exotic materials."

▶ Surfaces, interfaces and thin films. One can now deposit monatomic layers on sufficiently clean crystal surfaces, perhaps modified by pattern etching as fine as 10 Å. Epitaxial deposition of metallic, insulating or semiconducting layers can yield atomically sharp interfaces, and doping profiles can be controlled on a layer-by-layer basis. The physics of these low-dimensional systems is of fundamental interest. They are also potentially useful for computer and solar-cell applications.

▶ Disorder in matter can be created in controlled ways—for example, random dispersion of small particles in a host matrix, or an ordered arrangement of alternating amorphous layers. Spin glasses (with lattice order and random spin orientation) and metastable disordered structures are further examples. Aside from its intrinsic interest, the study of ordered arrangements of disordered components promises to facilitate the understanding of polymers, glasses, composite materials and perhaps even neurobiology.

▶ Exotic materials include arrays of alternating layers called superlattices. Condensed-matter theory must be extended to account for the new size scales or lower dimensionality of such systems. New, quite unexpected phenomena discovered in such tailored structures include the fractional quantum Hall effect (PHYSICS TODAY, October 1984, page 24). Exotic materials are being examined worldwide for computer and communications applications.

Most universities, the briefing report points out, do not possess the necessary technological infrastructure to carry on frontier work in the study of deliberately structured materials. "The intellectual concepts are there to be exploited, if the university infrastructure can be enhanced."

Biomolecular dynamics and intercellular cooperativity. The detailed description of biological phenomena in physical terms "promises rich dividends." The briefing report cites a number of examples where the physicist's approach "is beginning to bear fruit."

▶ Biomolecules are now seen as dynamic systems representing a state of matter different from solids, liquids and gases. Physicists can study their elementary excitations, motions, transport phenomena and reaction steps. Biomolecular physics overlaps with the physics of glasses and spin glasses, and it complements the biochemist's approach. Understanding the relation between structure and function should facilitate the design of useful synthetic biomolecules and biosensors.

▶ Transmembrane signaling is conspicuous in nerve and muscle tissue. Its molecular basis is newly accessible by recording stochastic electrical conductances of individual molecular channels. Hundreds of distinguishable membrane channels and the neurotransmitters that control their switching have been discovered. Biophysical measurement can address crucial questions of switching, ion selectivity and their relation to pathology.

▶ The molecular basis of information storage is not yet understood. Advanced biophysical instruments such as sensitive optical and electron microscopy probes are promising. Prospects are good, we are told, for understanding the molecular mechanisms of auditory and visual perception, and for the development of novel clinical sensors.

▶ Intercellular cooperative processes such as heartbeat (and its failure during fibrillation) can perhaps be understood in terms of new mathematical ideas involving solitons, limit cycles or chaos. Physicists have generated new, speculative models of distributed memory that may be applicable to computer architecture as well as to the foibles of

Brookhaven will accelerate heavy ions to 15 GeV/nucleon

Construction has started on a 2000-foot-long tunnel that will join the Brookhaven tandem Van de Graaff accelerator with the Alternating Gradient Synchrotron. Wielding the first spades in October are (left to right) Brookhaven director Nicholas Samios, Long Island Congressman William Carney and Alvin Trivelpiece, director of the DOE Office of Energy Research. Their labors are supervised by Herman Feshbach (left) and Robert Hughes, representing Associated Universities Inc. The tunnel will permit the transport of ions as heavy as sulfur from the Van de Graaff to the AGS, where they can be accelerated to 15 GeV/nucleon. At present, no heavy-ion accelerator exceeds 1 GeV/nucleon. When the project is completed in 1986, the AGS, a venerable proton synchrotron serving high-energy physics since 1960, will be given over to heavy-ion nuclear physics for ten weeks a year. With the completion of a synchrotron booster in 1988, the system will be able to accelerate ions as heavy as gold. The Van de Graaff-fed AGS could eventually serve as the injector for an ultrarelativistic heavy-ion collider in the vacant CBA tunnel.

human memory.

Cosmology. Despite its spectacular successes, the Big-Bang model *by itself* fails to explain: the predominance of matter over antimatter in the Cosmos; the observed baryon/photon ratio of 3×10^{-10}; the fortuitous near equality of the kinetic and potential energies of the universal expansion; and the extraordinary isotropy of the 3-K microwave background over regions not causally connected.

Two recent ideas from particle physics promise to reconcile these observations with the basic Big-Bang picture. Applying Grand Unified Theories to the first 10^{-35} sec supplies answers to the first two questions. Thus the report stresses the importance of proton-decay experiments (PHYSICS TODAY, September 1983, page 20) and other laboratory tests of GUTs. The new "inflationary" Big Bang models (PHYSICS TODAY, May 1983, page 17), involving the presumed Higgs mechanism of particle theory, address the two latter questions.

To predict the future of the Universe—the possibility of an eventual contraction and "big crunch"—one might seek to measure the current rate of Cosmic deceleration, or alternatively, look for sources of "dark" mass density in the form of massive neutrinos, axions and other exotic objects put forward by particle theorists. Recent arguments concerning primordial nucleosyntheis appear to militate against this dark matter being baryonic.

Another area of current excitement is the problem of reconciling the observed inhomogeneity of the Universe—galaxies gathered in clusters—with the extreme uniformity of the microwave background. In most present models the two observations remain in conflict.

"Cosmology is at present ripe with opportunity and certain to be full of surprises," the briefing report concludes. The space program, together with major advances in astronomical instrumentation, is rapidly expanding our horizons. Theory, drawing on all areas of physics, is creating testable cosmological models "rich with beautiful physics and unanswered questions."

Nuclear matter under extreme conditions. With the acceleration of heavy ions to relativistic energies comes the prospect of delivering unprecedented energy into a nuclear volume (PHYSICS TODAY, January 1984, page 20). With the new generation of heavy-ion accelerators we can thus study nuclear matter under extreme conditions of energy density and compression, crossing traditional boundaries of particle, nuclear and astrophysics. Foremost among these opportunities, we are told, is the possibility of creating quark–gluon plasmas. Theoretical extrapolations suggest that in relativistic heavy-ion collisions we can explore phase transitions to two distinct domains.

▶ At center-of-mass collision energies of a few GeV/nucleon one achieves a baryon-rich state of maximum nuclear compression, with densities 10 times those of normal nuclei.

▶ At several tens of GeV/nucleon, with nuclei passing through one another with relative ease, one should be left in the center of mass with a high-energy-density state with baryon number close to zero; roughly equal numbers of quarks and antiquarks would characterize this mesonic quark–gluon plasma.

Suitable facilities will soon be available for accelerating light ions to the range of 15–225 GeV/nucleon (see box, page 21). The briefing report calls for research and development efforts toward adequate detector systems. In nuclear theory, substantial efforts are required to produce theoretical benchmarks for comparison with the complex experimental results one expects. One needs, for example, lattice-gauge calculations with finite quark masses and baryon densities.

Understanding the transitions between ordinary nuclear matter and a mesonic quark–gluon plasma is important to cosmologists. Data from the baryonic regime of maximum compression are crucial to understanding the interiors of neutron stars. There is no other way, the report tells us, to investigate the equation of state of nuclear matter in the laboratory under such extreme conditions. Such data will facilitate the interpretation of observations from future x-ray telescopes such as AXAF. With regard to particle physics, ultrarelativistic nuclear collisions will provide a unique opportunity to study quark confinement over greater distances than elementary-particle collisions make available.

Summarizing, the briefing report suggests that each of these six areas "is at a stage where incremental funding may produce major progress." This "high leverage" could be achieved through "seed funding to promote new research or new instrumentation, especially medium-cost instrumentation for university laboratories." Several of these fields—plasma accelerators, cosmology and parts of biophysics—do not have established mechanisms for support and review.

The other physics briefing panel reported on solar–terrestial plasma physics—the chain of processes that starts with the generation of the magnetic field in the solar interior and links it to the Sun's surface and ultimately to our ionosphere and atmosphere. Outlining the most important unanswered questions and present research opportunities in this field, the briefing report produced by Kennel and his colleagues makes two strong recommendations:

▶ "The United States should initiate its participation in the International Solar–Terrestrial Physics Program, as scheduled, in FY 1986." It turns out, however, that funding for the ISTP is not included in the President's 1986 budget, which should go to Congress this month. Stanley Shawhan, the solar–terrestrial research coordinator at NASA, told us that NASA is now "restructuring US participation in ISTP to begin somewhat later."

▶ "We recommend a national computational program dedicated to basic plasma physics, space physics and astrophysics, which will provide and maintain state-of-the-art technology appropriate to large-scale theoretical models and simulations. Such a program should ensure ready access to advanced computing on the basis of peer review."

Thus far, the report tells us, solar–terrestrial research has concentrated on elucidating individual links in the causal chain connecting the solar wind to the Earth's magnetosphere and ionosphere. "Our challenge today is to increase our understanding of each of the local plasma processes influencing the magnetosphere's structure and dynamics so that we can begin to create quantitative models that start with the solar wind's observed state and calculate the [terrestrial] response."

"There is remarkable unanimity that we can begin the quantitative study of the solar–terrestrial system as a whole," the report asserts. This unanimity expresses itself in the proposal, currently before the Administration, to initiate US participation in the International Solar–Terrestrial Physics Program. The ISTP envisions simultaneous, coordinated measurements of key links in the solar–terrestrial chain by spacecraft provided by NASA, the European Space Agency and the Japanese Institute for Space and Terrestrial Sciences.

The national computational program envisaged by the Kennel panel's briefing report is intended to enhance the ISTP program and to promote "fruitful interactions with astrophysical plasma physics." There is a growing realization, we are told, of the "essential unity of plasma physics" in the laboratory, the solar system and astrophysics in general. "Solar–terrestrial research has developed plasma-physics problems that are broadly applicable to many astrophysical systems." Many key problems in solar-system and astrophysical plasma research are ready for advanced numerical modeling. "Combining these problems with others in hydrodynamics and general astrophysics . . . . would justify the dedicated effort we propose."

—BMS □