Retrospectives on Inter

IN THE NEXT FEW PAGES we present four different perspectives on international collaboration in high energy physics:

- Gordon Fraser highlights the origins of pan-European cooperation at CERN and DESY.
- Hirotaka Sugawara frankly appraises the Japanese experience and plans for future colliders.
- Alexander Skrinsky reviews the increasing reliance on international exchanges in the Russian program.
- Zhou Guangzhao explains how international collaboration has been the key to China's emergence as a prominent contributor to the field.

Taken together, these articles show how international collaboration has increasingly knit the community together. It has indeed become, in Peter Rosen's apt phrase, "the sine qua non of high energy physics."

All four articles begin on these two pages, 12 and 13. Then they continue as separate columns on pairs of facing pages through page 19 (look for the relevant author's picture at the top of each column).

Gordon Fraser, Editor, CERN Courier, Geneva, Switzerland

AS THE ECHOES of World War II died away, physicists returned to traditional research and teaching interests. In the United States, federal scientific research expenditure had increased tenfold during the war and maintained this growth over the next decade. In war-torn Europe, postwar funding was less generous, but scientists—with Niels Bohr in Copenhagen as a father figure—had immense prestige. Spurred by fresh cosmic-ray discoveries and with strong political and scientific motivation for particle accelerators, France and the United Kingdom pushed ahead with flagship proton machines, culminating with the 3 GeV Saturne synchrotron in 1958 and the 8 GeV Nimrod machine in 1963.

Postwar Europe was in transition. The militant national pride that had

ational Collaboration

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I AM WORRIED. I am worried about the future of high energy physics. I am worried about the future of international collaboration in high energy physics. Paradoxically, I am also feeling confident about the future.

The cost of high energy physics is ever increasing and the only way out is to share it among interested countries. However, some physicists accept this idea rather reluctantly and only when it is convenient for their purposes. The failure of ICFA evidently demonstrates the unwillingness of physicists to clearly define mechanisms to promote world-wide collaboration.

High energy physics has a clearly defined set of research tasks to pursue for the next 10 to 15 years. The most important issues in high energy physics in the next few decades will be to establish the Standard Model

WORLD WAR II, the Cold War, and a very real possibility of World War III loomed over the intellectual climate of the mid-1950s, when the first postwar east-west contacts between scientists began. Nuclear and elementary particle physicists played the leading role in this process. At the time it was hardly a trivial matter to discuss interesting and intriguing problems in fields so close to the bomb. But many physicists on both sides of the “Iron Curtain” understood—perhaps better than anybody else—that international collaboration is vitally important both for healthy progress in understanding Nature, and for eliminating the historical, artificial divisions, and confrontations among the nations of the world.

Contacts and collaboration with foreign physicists became part of

CHINA’S HIGH energy physics was developed with the aid of international collaboration. During the 1950s, the country was a member of the Joint Institute for Nuclear Research in Dubna, where Chinese physicists worked with foreign colleagues and obtained many interesting results. Beginning in the late 1970s, following the “Open Door” policy established by Deng Xiaoping, international cooperation in high energy physics entered a new era. In 1979 China and the United States established the PRC/U.S. Joint Committee for Cooperation on High Energy Physics. The Chinese Academy of Sciences has since entered cooperative agreements with high energy physics laboratories all around the world. Hundreds of Chinese physicists, engineers, and students have worked in these labs and

engendered two world wars had given way to a new humility and a desire for international cooperation. In 1946, Churchill spoke of a "United States of Europe." Under the new United Nations, specialized agencies were also fostering international cooperation. Subnuclear physics, riding the crest of a wave in the United States and with Europeans anxious to make up lost ground, was an obvious focus. At a 1950 general meeting in Florence of UNESCO, the new United Nations' Educational, Scientific and Cultural Organization, Isidor Rabi was a U.S. delegate. Recently an instigator of the Brookhaven National Laboratory (BNL), run by a consortium of East coast U.S. universities, he saw that it could serve as a role model for Europe.

But the idea of a European laboratory already had two selfless champions—Pierre Auger, French scientist and UNESCO's Director of Exact and Natural Sciences, and Italy's Edoardo Amaldi, a former colleague of Enrico Fermi. So thoroughly did they do their work that only a few months later, an ambitious resolution for the nascent European laboratory aimed to build an accelerator more powerful than the Cosmotron and Bevatron then under construction. As astute diplomatic moves made the Conseil Européen pour la Recherche Nucléaire—CERN—a reality, European accelerator experts faced the challenge of building a world-class accelerator in Geneva. In August 1952 a small party went to admire Brookhaven's progress towards a successor to the Cosmotron.

In August 1952, a visit to Brookhaven National Laboratory by a group from an embryo CERN helped bring about the development of the strong focusing technique which revolutionized the design and construction of synchrotrons. Left to right are George Collins, Chairman of BNL's Cosmotron department; Odd Dahl, in charge of CERN's synchrotron project; accelerator pioneer Rolf Wideröe of Brown Boveri, and Frank Goward of CERN.

on a firm ground and then to find evidence for or against supersymmetry. It will also be very important for non-accelerator physics to search for a possible grand unified scale or even the Planck scale.

We will need a linear collider to complement the LHC, a 100 TeV scale *pp* collider, and perhaps a muon collider to complement the *pp* collider; we also need several large scale non-accelerator devices. The problem is to allocate these facilities in a reasonable way among the countries or the regions willing to share the cost. Due to current economic conditions, together with technological capabilities, these countries are most likely to be in Europe, North America, or Asia. However, there is no agreed upon mechanism by which physicists can decide the countries or the regions.

My worry is not just about high energy physicists' reluctance to engage in genuine international collaboration in accelerator management, but also about the attitude of scientists outside high energy physics. Everywhere I hear the cry of anti-big-science mobs. High energy physicists are partly responsible; there has been a lack of effort to communicate well with their neighboring scientists. I find in many cases well established scientists in other fields are envious of us. I believe that good scientists are interested not only in the success of their own field, but also in the advancement of related or even unrelated fields.

Another worry is about our relationship with politicians and government officials. Obviously, in democratic systems we must respect decisions made by our elected representatives; it is also our task to work hard to see that these decisions are made on their scientific merits. The same applies to our interactions with officials in governmental bureaucracies. There are some international organizations that can potentially have a real influence on science policy, such as UNESCO and OECD; however, both have real limitations. First, the U.S. does not belong to UNESCO. Secondly, the OECD was first created to protect the interests of postwar western European nations, so European countries are over-represented and Asian countries are under-represented for discussing big-science matters.

Let me turn to the linear collider issue. In 1986 the Japanese high energy physics community decided that it would participate in a foreign hadron collider project

daily life for Russian high energy physicists and laboratories after the 1963 International Accelerator Conference at Dubna. At this meeting, colliding-beam activities were presented globally for the first time. And friendly collaboration began between the Princeton/Stanford and Novosibirsk groups. Two years later this rivalry led to the world's first experimental results from electron-electron colliding beams at Stanford and Novosibirsk, followed shortly by the world's first electron-positron experiments at Novosibirsk.

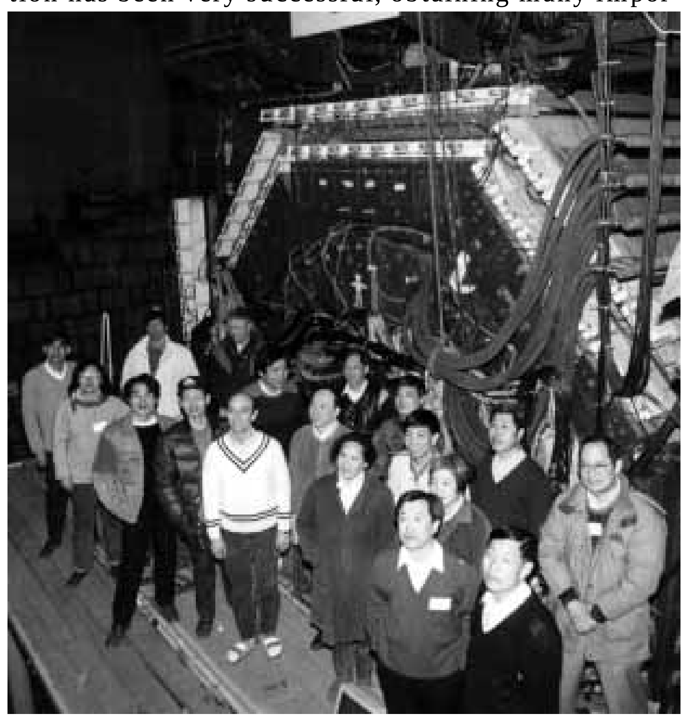
Beginnings of the long-term collaboration between SLAC and the Institute of Nuclear Physics. Gersh Budker, right, and Wolfgang Panofsky at the INP in Novosibirsk, 1975.

This was the real beginning of the now-dominant collider era in particle physics. Wolfgang (Pief) Panofsky and Gersh Budker contributed much effort and enthusiasm to increase the scope of this cooperation. During the 1960s, however, their efforts were not completely successful—mostly because of political reasons. But, unfortunately, even now, when almost all external political obstacles have disintegrated, the Novosibirsk-SLAC collaboration is far smaller in scale than the Budker Institute of Nuclear Physics collaboration with CERN, DESY, and KEK. We could definitely do much more together.

In 1956 the Soviet Union brought scientists together from different socialist countries by organizing the Joint Institute for Nuclear Research at Dubna. Around 1970, CERN and groups from its Member States made important contributions to the Institute of High Energy Physics at Protvino, site of the 70 GeV proton synchrotron—at that time the biggest accelerator in the world. Since

obtained extensive experience, making important contributions to many high energy physics projects.

Without successful cooperation with physicists and laboratories in the United States, Europe, and Japan, the Beijing Electron Positron Collider (BEPC) would not have been built on schedule and within budget. And it would have been impossible to have reached the design luminosity so soon after commissioning it. Physicists from ten American institutions have since been working on the Beijing Spectrometer (BES) at BEPC. This collaboration has been very successful, obtaining many impor-



Chinese physicists with U.S. collaborators working on the Beijing spectrometer.

tant results on tau-charm physics, including a precision measurement of the tau lepton mass and measurements of the D_s and ψ' mesons.

In addition, Chinese high energy physicists have joined international collaborations on experiments all over the world. Our physicists and engineers have made important contributions to the L3, ALEPH, AMS, LVD, and other experiments. They are also making major contributions to the construction of the two *B* factories and other particle accelerators.

While preparing for their visitors, Brookhaven physicists came up with the idea of strong focusing, and magnanimously shared with their European colleagues the insight that synchrotrons could be made more powerful. CERN gratefully took the baton and ran with it. In a startling demonstration of what European collaboration could achieve, CERN's synchrotron began operations in November 1959, several months before Brookhaven's Alternating Gradient Synchrotron; directed by John Adams, the new CERN machine delivered protons at 28 GeV, then the world's highest energy. It was the start of a U.S.-European tradition of close collaboration tempered by friendly rivalry.

Although the young upstart CERN won that race, exploiting the new synchrotrons was a different matter. Within a few years, the Brookhaven AGS produced major discoveries—the muon neutrino, CP violation, the omega minus. Watching enviously from the wings, CERN had to wait until 1973 before its first important breakthrough, the discovery of neutral current. Meanwhile CERN's next big machine, the Intersecting Storage Rings (ISR), the first proton-proton collider, cruised into action in 1971. Although a triumph of machine building that explored promising new horizons, the initial harvests of physics results were again disappointing.

CERN had learned its lesson for its next project, the proton-antiproton collider. A distinguished tradition of machine building, consummate machine expertise gained from the ISR, and the physics vision of Carlo Rubbia set the stage for the historic discovery of the *W* and *Z* particles in 1983. With Simon van der Meer's development of stochastic cooling, a key accelerator technique again crossed the Atlantic, but this time it went from east to west.

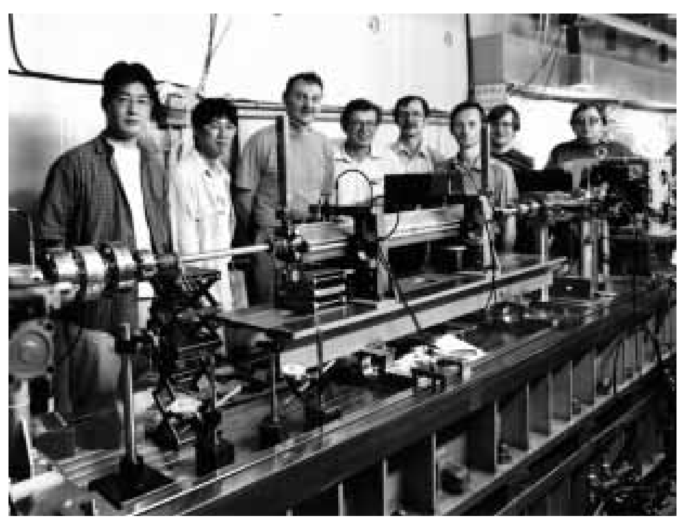
But Europe has more than the CERN string to its bow. In parallel with international efforts, its nations initially continued their individual aspirations. Germany, a CERN founder nation, had no national accelerator. To rebuild a tradition, pioneers such as Wolfgang Paul, Wolfgang Gentner, and Willibald Jentschke pushed for the apparently less glamorous electron synchrotron route.

In February 1964 the new Deutsches Elektronen Synchrotron—DESY—began operations in Hamburg at 6 GeV; until the arrival of the 20 GeV Stanford linear accelerator in 1966, it provided the world's highest energy electrons. DESY capitalized on the trend to electron-

and it also would build a domestic linear collider. The High Energy Committee action plan, issued in 1995, states that Japan wants to be the host country for an international linear collider project. The Asian Committee for Future Accelerators (ACFA) supports this action plan. There seems to be a growing consensus among Asian countries that a linear collider project is an appropriate project for Asian-Pacific countries to participate in and that Japan should take the leadership in this project.

The U.S. failed to build the SSC; a high energy physics facility located in the U.S. is certainly needed. It is up to the U.S. high energy physics community to decide which project is the most suitable, given the present circumstances. If a linear collider is selected, a serious consultation between U.S. and Japan becomes necessary.

SLAC and KEK are now working together in the R&D effort for a linear collider within the framework of worldwide collaboration. We are trying to strengthen the effort of the two laboratories by making it more formal. This initial formal agreement will not be to make a common design, but to study together the problems of designing a linear collider, although I believe that we have to proceed with a common design, eventually. The Japanese high energy community decided recently that it wants to have more time to consider the issue before it makes a final decision on whether or not to proceed to the common design stage.



The linac for the accelerator test facility at KEK.

then, Russian groups have taken an increasing role in experiments at CERN, Fermilab, and other western laboratories. A new scale of collaboration began on the LEP collider at CERN, where several Russian labs and groups made major contributions to the big L3 and DELPHI detectors and played important roles in these experiments.

After Perestroika, which brought many good and bad things to Russian life, all Russian science (including high energy physics) suffers from severe economic difficulty. (See Sergei Kapitza's article, "The Future of Science in Russia," in the Fall/Winter 1993 issue of the *Beam Line*, Vol. 23, No. 3.) International collaboration has become essential to the survival of the existing Russian groups and for attracting bright young people to high-energy physics. Russian physicists now collaborate

SLAC

An international team from Japan, India, the Republic of Korea, and Russia participate in a joint test of the prototype of a cesium iodide electromagnetic calorimeter at the tagged photon beam for a future KEK B factory experiment, BELLE. This photo was taken at the Budker INP in Novosibirsk.

actively at practically all the major high energy physics centers in the world, while foreign scientists are involved in experiments at Novosibirsk and Protvino. And use is made throughout the field of well-known Russian inventions and developments such as electron cooling of proton-antiproton and heavy-ion beams, and high-

One of the most important fundamental research fields, high energy physics is also Big Science, requiring large amounts of manpower and resources, which makes international cooperation essential. The world community is pooling every possible effort to overcome the budget challenges and making great endeavors at both the high-energy frontier, with large colliders such as the LHC, and the high-precision frontier, with high-luminosity particle factories. We are confident that international cooperation in high energy physics will be further enhanced during the next century. The Chinese government has given this research strong support, but as a developing country, China can allocate only limited resources to the field, thus making international cooperation crucial. It allows foreign physicists to do research in China, and our own physicists to work at frontier experiments all over the world, following the latest developments.

Chinese physicists are now discussing further development of the BEPC facilities to do high-precision measurements in the tau-charm energy region from 3 to 5 GeV. Such a Tau Charm Factory with a luminosity of 10^{33} cm^{-2}sec^{-1} would allow very accurate measurements of light-hadron spectroscopy, especially searches for glueballs and quark-gluon hybrid states, as well as searches for CP violation in tau lepton and *D* meson decays. The proposed Beijing Tau Charm Factory (BTCF) will proceed in three steps—feasibility study, research and development, and official construction project. So far the Chinese government has supported a feasibility study on the BTCF, which was reviewed by an international panel at the end of 1996. Another possibility is for us to upgrade BEPC into BEPC II, having a luminosity of 10^{32} cm^{-2}sec^{-1}, which would still be sufficient to do most of the research on light-hadron spectroscopy, including the work on glueballs and quark-gluon hybrids. We will do R&D work for both the BTCF and BEPC II, with a final decision to be made around the year 2000. Foreign physicists are welcome to participate in this project; their experience and technology will prove very useful. And foreign contributions to the accelerator and detector would help to get the project approved by the Chinese government.

Another fruitful international collaboration is taking place in Yangbajing, Tibet, where a large air-shower array is being built at 4300 meters above sea level by

positron colliders, first with DORIS, then with PETRA. Europe's initial wave of postwar machines was the culmination of national aspirations. To coordinate these aspirations with science, the European Committee for Future Accelerators (ECFA) was formed during Victor Weisskopf's mandate as CERN Director General from 1961–1965.

For its long-term future, CERN set its sights on a large electron-positron collider. But fertile minds had been exploring a radically different route, electron-proton collisions, to probe the structure of the proton in new depth. Deftly orchestrated by ECFA, CERN got LEP and DESY got HERA. In a curious twist of tradition, CERN, a proton laboratory, had to learn how to handle electrons, while DESY had to take protons on board. Both laboratories took the challenges in stride, adding new depth to Europe's complementarity of particle beams.

CERN had demonstrated the effectiveness of formal international collaboration, with assured funding and guided by vision. In CERN's parliament, or Council, representatives from Member States vote on important issues, such as major new scientific projects, which require prior Council approval before becoming an integral part of the ongoing program. This approved program is then the responsibility of CERN management; CERN's budget, itself governed by a rolling plan periodically updated by Council, finances this program. In this way, approved projects are administered according to their scientific merit and are sheltered from various political pressures in the member States. In building HERA, DESY had taken another approach, inviting international partners to contribute to a shopping list of equipment and resources in return for a research interest in the new facility. There was more than one way of going international.

CERN had written itself a long-lived research ticket by building its LEP tunnel large enough to house a subsequent proton collider, the LHC. LEP is the largest electron synchrotron ever built and may hold that record forever. Crippling losses due to synchrotron radiation mean that higher energy electron machines must be linear colliders. DESY dutifully prepared for the future, pushing accelerator technology on several fronts. Recent achievements using superconducting radiofrequency cavities have shown that this approach may be a prime contender to power a large electron-positron linear collider to complement the LHC in the next century.

International collaboration, whether in accelerator R&D, particle research, or laboratory management, is not just a matter of physics. It is a matter of language, beliefs, education, and daily life. In fact, it is a matter of an encounter of all aspects of different cultures. In this respect I envy California which is already very open, multi-cultural, and multi-racial. I love that aspect of Californian style; I want Japan to be more like that and I am glad that there is a persistent and growing tendency in various sectors of Japanese society to make it more open.

Damping ring in the Accelerator Test Facility at KEK.

What a physics laboratory like KEK can contribute to this end is to build a project like a linear collider with genuinely international management and research programs, inviting people from California and the rest of the U.S., from Asia, from Europe, and from all the rest of the world to participate in the project. This has to be done in such a way that our colleagues at SLAC will feel happy about it. Things also should proceed gracefully. I am confident that it can be done. But I am worried. I am very confident, but I am also very worried.

precision measurements of particle masses—both originated and first applied at Novosibirsk.

Our participation in the LHC project at CERN now plays an especially important role in the future of Russian high energy physics. It is crucial for our physicists to be full partners in these frontier experiments. But under the current circumstances in Russia, it was almost impossible for our laboratories and institutes to obtain additional funds to contribute to the LHC and participate in designing and building its detectors. Aided by the wisdom and openmindedness of Carlo Rubbia, Chris Llewellyn-Smith, and our CERN colleagues, we found mutually beneficial and affordable ways to permit this participation, which is now funded equally by CERN and the Russian government.

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We in the Russian high-energy physics community truly believe that international collaboration is the best way to conduct our science in the future—not only for Russia but for the world in general.

Gabriele Otto

A new electron cooling device for the Heavy Ion Synchrotron being delivered to GSI in Darmstadt, Germany. The device was developed and manufactured at the Budker INP. (Courtesy GSI)

collaborating with Japanese physicists. Meanwhile, Chinese and Italian physicists are proposing another cosmic-ray experiment known as ARGO in the same place. Indeed, we are even considering the possibility of establishing an international center for cosmic-ray physics experiments at Yangbajing; such a center would provide an ideal site for this kind of research, attracting scientists from all over the world.

Early in the next century, Chinese physicists will continue to make their due contribution in key experiments in other countries. We are participating in the construction of both *B* factories and their experimental collaborations, and have joined both the CMS and ATLAS collaborations at the LHC. Our participation will continue in experiments at the Tevatron and DAΦNE, as well as at other laboratories. Chinese accelerator physicists are interested in collaborative R&D work on the technology for future linear colliders. Other physicists are interested in non-accelerator experiments such as AMS and L3 Cosmics. The Chinese Academy of Sciences strongly supports all these collaborations.

As a developing country, China's contributions to international collaborations will however be rather limited during the next few decades. Therefore our physicists need to concentrate their resources and manpower on key collaborations, make good contributions to these projects, and become more visible. They should identify certain work that can be done in China, such as production of new materials, construction of subdetectors, and developing software. By taking advantage of their particular knowledge, plus the special techniques and know-how of Chinese industries and materials sciences, as well as our cheaper labor, our physicists can make major contributions to these collaborations.

China has taken its place in the world in the realm of science and technology. We are certain that during the next century our country will make even greater contributions to the international community of high energy physics.