NEWS

search & discovery

Peking group discusses plans for 30–50-GeV accelerator

The Institute of High-Energy Physics in Peking plans to build a proton synchrotron, 30–50 GeV in energy, roughly five years from now. This summer a ten-man delegation spent three months in the US, first at Fermilab, then at Brookhaven. They came with a preliminary design in mind and hoped to improve on that design after discussions with US accelerator designers. Meanwhile other groups from the Peking Institute of High-Energy Physics are at KEK in Japan and at CERN in Geneva.

While the delegation was at Brookhaven, we discussed the Peking Institute's plans for the accelerator with Hsieh Chia-lin, chief of the Accelerator Division at the Institute of High-Energy Physics and head of the delegation, Sui Ching-yi (whose present position is chief engineer at the Peking Broadcasting Equipment Factory) and other members of the group.

For several years, high-energy physicists in China had been talking about the possibility of building an accelerator there. Various leaders in high-energy physics in the US and abroad were consulted about the best possible choice. Early this year, the People's Republic of China decided to build a 30–50-GeV proton synchrotron as part of its policy of promoting basic research.

GLORIA B. LUBKIN

Four members of delegation from the Institute of High-Energy Physics in Peking stand in front of a C magnet at the Brookhaven Accelerator Department, where they recently spent a month discussing the design of a 30–50-GeV proton synchrotron to be built near Peking. From left are: Chen Sen-yu, Sui Ching-yi, Hsieh Chia-lin (chief of Accelerator Division) and Hsiao Yi-hsuan.

In the late 1950's, Chinese physicists had participated in research at the Joint Institute for Nuclear Research in Dubna, USSR. Since 1973, three different groups of Chinese scientists have visited CERN. And since last year, a number of physicists from China have been working at DESY in Hamburg. Hsieh, who specializes in accelerators, was at Stanford for several years in the late 1940's.

The design of the 30–50-GeV proton

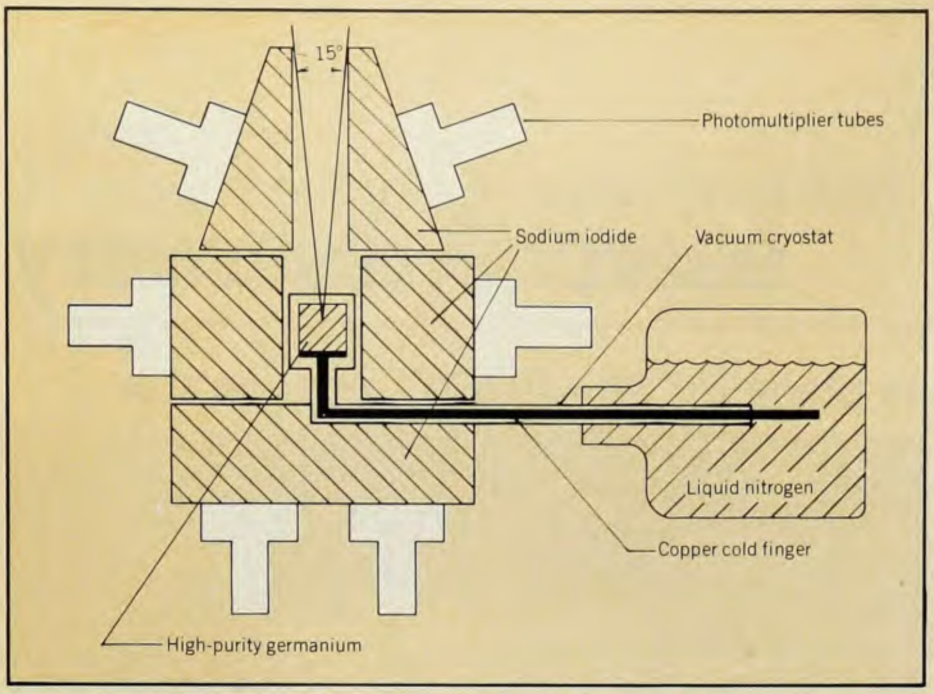
continued on page 19

Germanium detector sees galactic gamma-ray line

A two-day balloon flight over Alice Springs, Australia, has brought some good news for the budding field of gamma-ray line astronomy. The balloon carried a high-resolution germanium detector, which found a narrow 511-keV positron annihilation line coming from the direction of the Galactic center. Because positrons are produced in many of the high-energy processes believed to be occurring in the Galaxy—such as cosmic-ray induced interactions and explosive nucleosynthesis—the 511-keV annihilation is one of the most obvious gamma-ray lines to look for as evidence of these processes. Until these observations, described at the April meeting of The American Physical Society in Washington, D.C. and just published in the 1 October issue of *Astrophysical Journal Letters,* there had been no unambiguous evidence of a steady, nonsolar gamma-ray line.

The two-day flight last November was part of a joint Bell Labs–Sandia Labs project, and the participants were Marvin Leventhal (Bell), Crawford MacCallum and Paul Stang (both of Sandia). They flew a large (130 cm^3) high-purity germanium detector in a telescope with a 15-degree field of view, collected a total of 17.3 hours of Galactic center data and, after careful correction for background effects and instrumentally induced lines found a 511-keV line flux of 1.21×10^{-3} photons per cm^2 per sec. Their evidence for the 511-keV line is significant at the 4.5 σ level in the raw data, and, when they weight the data in a way appropriate to an extraterrestrial source, the statistical significance increases to the 5.6 σ level.

Earlier searches for the 511-keV line have met with less definitive results. In 1971, Robert Haymes and his colleagues at Rice University flew the first of several balloon-borne telescopes. They used sodium-iodide scintillation counters, which have fairly low resolution (about 100 keV at 1 MeV, compared with 2.5 keV for the germanium detectors). The first two flights detected features at about 470–480 keV, outside the predicted gamma-ray range. Among the interpretations of these results were gravita-



Gamma-ray telescope used by Bell Labs–Sandia group to observe 511-keV gamma rays. The high-purity germanium single crystal has a volume of 130 cm^3, the largest existing crystal of this type. It must be operated at liquid-nitrogen temperature. The three sections of sodium iodide, which together weigh 400 pounds, serve as an active anticoincidence shield and collimator.

tionally redshifted photons from e^+ annihilation, and positron annihilation via the intermediate formation of the hydrogen-like species, positronium. (The Bell–Sandia observers also explain their present result, which is within the predicted 511-keV range, in terms of positronium formation.) Haymes then flew a third balloon in 1974, with a larger, more sensitive telescope, and found a feature at 530 ± 11 keV, a feature that could not be interpreted in the same way as the results of the earlier two flights. The line flux reported by Haymes from the 1974 flight is, however, consistent with that now reported by the Bell–Sandia group.

The Bell–Sandia results can be fully interpreted only when the source of the positrons and the mode of annihilation are clear. Leventhal, whose interest in astrophysical positron annihilation evolved through laboratory work with positronium, explained to us that the observations are consistent with annihilation of the e^+e^- bound state. He believes that, in the dilute interstellar gas, the bound state should form nearly all the time. Positronium exists in the singlet (25%) and triplet (75%) states. The singlet state decays into two antiparallel 511-keV photons, whereas the triplet decays via a three-photon continuum, which has no precisely defined energy but is a monotonically decreasing function from 511 keV down to zero. However, although the data suggest positronium, they do not definitely establish the positronium decay mode over free annihilation.

What about the origin of the positrons? As Leventhal pointed out to us, a gamma-ray line "telescope" is simply a detector and an anticoincidence shield, and has no mirrors or focussing devices, so that the field of view is very large: "We don't know if it's a point source or a distributed source. We have 15-deg angular resolution, and that's a big piece of the sky." They are, however, certain that the source is in the direction of the Galactic center.

One predicted source of positrons is interactions of energetic particles in cosmic rays, such as protons with cold interstellar carbon, nitrogen and oxygen nuclei, to give excited nuclei that themselves decay, yielding positrons. Further evidence for these processes would be observations of gamma-ray lines from excited nuclei, such as the 4.4-MeV carbon line. One of Haymes's spectra has a feature near this energy, and preliminary data from HEAO I, the orbiting high-energy astrophysical observatory, show indications of this line, with a flux consistent with that reported by Haymes's group. The preliminary HEAO I results were described at a recent gamma-ray spectroscopy conference at the Goddard Space Flight Center by Laurence Peterson (University of California at San Diego).

A second possible source of these positrons is the decay of long-lived radioactive nuclei. Theorists have suggested that supernovae or novae explosions could synthesize the heavy elements in their observed cosmic abundances, and some of these nuclei are produced first as beta-unstable species that decay to give positrons; for example supernovae-produced Ni^{56} would decay to Fe^{56}, giving off e^+. Here too, detection of other lines is needed for confirmation. Harder to confirm would be the idea that the positrons are coming from pulsars, although nearly all mechanisms proposed for translating the rotational energies of pulsars involve positrons. More exotic suggestions for the positron origin include evaporation of small black holes and the existence of matter–antimatter symmetry in the Universe. Future experiments with germanium detector systems of greater sensitivity and spatial resolution, such as those planned for HEAO C and for the proposed gamma-ray observatory, should clarify the situation further.

As one astrophysicist described the situation to us: "This is potentially a very

Helicopter prepares to recover the gamma-ray telescope, which had been flown in a balloon for two days over Alice Springs, Australia. The payload landed in the Simpson Desert, 175 miles east.

exciting field, and the Bell–Sandia result is just a first step in showing that one can, in fact, do gamma-ray line astronomy."

—MSR

Peking group

continued from page 17

synchrotron is now under way, Hsieh told us, but many decisions are still being made. The design goal is to achieve an intensity of 1–2 $\times 10^{13}$ particles/pulse, comparable to the intensity of the 33-GeV Alternating Gradient Synchrotron at Brookhaven or the 400–500-GeV Fermilab synchrotron.

Two injector options are being considered. The first, and more likely choice, is a 200-MeV linac injecting into the main ring. The second choice is to use a roughly 50-MeV linac injecting into a booster ring that would accelerate protons to about 1 GeV; then the protons would be injected into the main ring for the final acceleration. The Peking accelerator designers are leaning toward the 200-MeV linac because that would allow them to concentrate more on the main accelerator.

The synchrotron will use separated-function magnets arranged in a simple focus–defocus (FODO) lattice, similar to the Fermilab main ring and the CERN Super Proton Synchrotron. In separated-function proton synchrotons, magnetic field strengths over 20 kG can be used. However, the Peking accelerator will probably have magnets with lower field strength, Hsieh said. The Institute prefers to use low-carbon, low-silicon steel manufactured in China. One of the first measurements to be made is to study the magnetic properties of the available steel.

Magnets will be stamped out of steel and then stacked. Quadrupoles will be of conventional design. Dipoles will be H-shaped rather than picture-frame shape. At this time, superconducting magnets are not being considered, but the group showed interest in its applications for future machines.

The final pulse rate has not yet been decided, but it will be chosen to accommodate their utility system, Hsieh said. The synchrotron will use negative-ion injection as is used at present at Fermilab. The rise time is to be about 1.5 sec and the total pulse period about 4 sec. Hsieh noted that the exact times are not decided yet.

The Peking group will first draw up an initial design, then build prototypes and perform experiments, and then adjust the design accordingly. Already over 100 scientists, engineers and technicians are working in the Accelerator Division at the Institute in Peking. The number of staff members is expected to increase further.

Early on, the group plans to measure the magnetic properties of the steel and start punching magnets. Meanwhile, laboratory buildings are already under construction at the Institute of High-Energy Physics. The site for the accelerator will probably be in the suburbs of Peking.

"Why build this particular type of accelerator?" we asked. For some time, Hsieh told us, there was a debate on the relative merits of electron and proton machines. Because at first China will have only one high-energy accelerator, it was felt that a proton accelerator would be better because one can have a broader range of experiments by using both the primary and secondary beams.

From an experimenter's point of view, the higher the energy the better, Hsieh went on. But considering China's lack of experience and its level of industry, it was felt that starting with a several-hundred-GeV accelerator was unwise. On the other hand, if the energy were too low, say 1–2 GeV, there would essentially be no new physics to be learned. "So finally we settled on medium high-energy physics."

The main purpose of the new proton synchrotron is to do basic research. But another strong goal is "to push our industry to a more advanced level," by bootstrapping. "As is well known, we're under the guidance of the principle of self-reliance." Accordingly, if at all practical, accelerator components will be made in China. However, some of the components might be imported.

Regarding accelerator control, the final decision on the mode has not been made. However, two alternatives are being considered. One is to use computers from the outset, and the other is to use manual control first and switch over to computer control later. However, Hsieh said, once the accelerator is actually being used for experiments, the Institute does expect to use computers for data analysis.

In the Division of Scientific Research at the Peking Institute, the experimenters are already making models of various detectors.

The delegation spent roughly three months in the US, the first two at Fermilab, the last at Brookhaven, discussing accelerator design. This delegation was followed by a five-man group that will stay at Fermilab for six months to a year. Meanwhile four other Peking scientists have been at CERN; two are staying there for about half a year to study magnet and abort techniques. And at the same time, a group is at the 12-GeV proton synchrotron at KEK in Tsukuba, Japan studying magnet and rf cavity measurements.

The first US delegation, in addition to Hsieh and Sui, consisted of Chung Hui who served as deputy head of the group, Hsu Chien-ming, Mao Chen-lung, Pan Hui-pao, Shen Pao-hua, Wang Shu-hung, Hsiao Yi-hsuan and Chen Sen-yu.

The decision to build the new accelerator is related to the new emphasis in China on the so-called "four modernizations," using science and technology to advance agriculture, industry and national defense. To catch up with Western countries in science and technology, the Chinese government has decided to emphasize basic research while at the same time continuing to do applied research. The government plans to emphasize particularly eight disciplines in science and technology: agriculture, energy resources, materials science, computer techniques, lasers, space science, high-energy physics and genetic engineering.

They expect to build the high-energy physics experimental base in ten years, completing the above-mentioned 30–50-GeV proton synchrotron in the first five years and a giant one with considerably higher energy in the second five years.

—GBL

Two groups plan for giant optical telescopes

Astronomers today are pushing existing optical telescopes to their limits: Better optical coatings, sophisticated microelectronics and computer control, and detector quantum efficiencies approaching unity make it possible to wring nearly the last photon of light-gathering capacity from present instruments. To improve optical telescopes still further, it appears, one must produce larger-aperture primaries.

Groups at Kitt Peak National Observatory and the University of California are completing design studies for such supertelescopes. The University of California plan calls for a \$30–50-million observatory package based on a 10-m primary mirror. Kitt Peak is examining several concepts for the equivalent of a 25-m aperture, likely to have a final cost of the order of $\$10^8$. This figure is comparable to the cost of the Very Large Array radio telescope now under construction near Socorro, N.M. Both groups seek to design a large-aperture instrument limited only by atmospheric seeing (except when speckle techniques are used) in the visible and most of the infrared range. Such a telescope should also be capable of making essentially diffraction-limited observations at submillimeter wavelengths.

The challenge. The largest telescopes in the world today are the 5-m equatorially mounted reflector on Mt Palomar in California and a 6-m reflector (alt-azimuth mounted) on Mt Semirodnika in the Soviet Caucasus. Casting one-piece (monolithic) mirrors much larger than these may not be feasible, and the Kitt Peak group estimates that a direct scale-up of such instruments to a 25-m aperture could cost a prohibitive \$2 billion and take 50 years to complete. Application of advanced technology must reduce