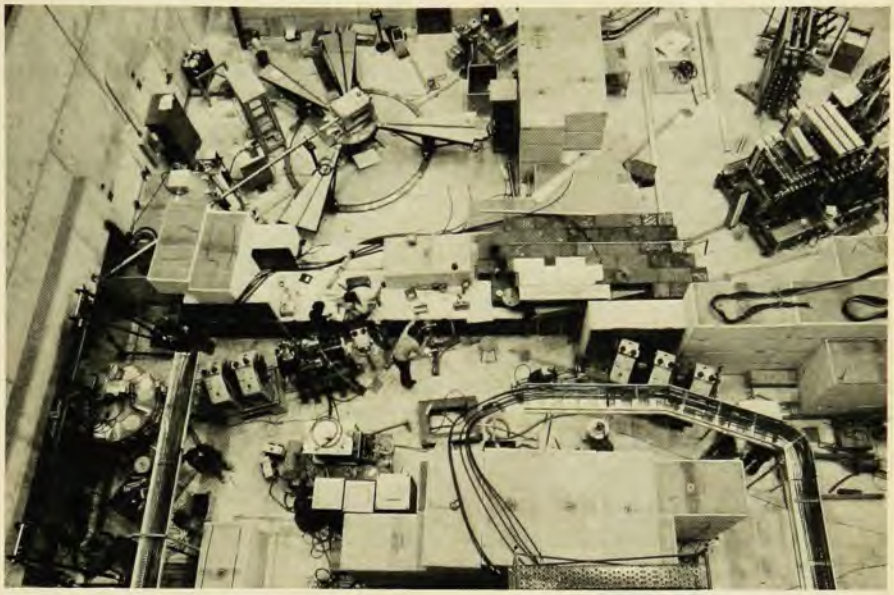
search & discovery

TRIUMF becomes world's third operating meson factory

Champagne flowed in Vancouver, British Columbia recently as the TRIUMF cyclotron yielded its first extracted full-energy beam. With the production of 500-MeV negative hydrogen ions, the Tri-University Meson Facility (TRIUMF) thus joined the other two new meson factories—the Clinton P. Anderson Meson Facility (LAMPF) in Los Alamos, New Mexico and the Swiss Institute for Nuclear Research (SIN) in Villigen; both of these have already achieved external beam production, have begun their experimental programs and are busy building up beam intensity. The TRIUMF cyclotron, part of a meson factory that has been under construction since 1971, will eventually furnish intense secondary beams of pions, muons and neutrons to experimental areas. The impetus behind the meson factories has been the need for sufficiently intense beams of these particles to act as probes for the otherwise unobtainable details of nuclear structure. Intensities are typically 10^3–10^4 times that available at existing machines, and energy resolution is 100 times better. Some particle physics is also possible, as is a program of applied research, notably pion radiation therapy.



Proton hall at TRIUMF will have two beam lines (entering from lower left). This is part of a Canadian meson factory in Vancouver run by a four-university consortium. The other experimental area is a meson hall with two meson-producing targets and four experimental channels.

Meson factories are being produced not only by the construction of these new laboratories in Los Alamos, Villigen and Vancouver but also by the conversion of existing synchrocyclotrons at Columbia University's Nevis Laboratories in Irvington, N.Y., at the Joint Institute for Nuclear Research in Dubna and at CERN in Geneva. (See table on page 19.) Although the broad aim is the same at all the meson factories, each has approached the beam-production problem in a slightly different way; each one is particularly suited to certain kinds of experiments and each has overcome its unique set of financial and technical obstacles.

The Vancouver facility, which received initial funding in 1968, is operated by a consortium of four universities—the University of Alberta, Simon Fraser University, the University of Victoria and the University of British Columbia. Reginald Richardson is the director. Construction of TRIUMF has been

continued on page 19

New techniques advance hypernuclear spectroscopy

A feasible and fruitful way to study the spectroscopy of hypernuclei has been demonstrated by two experiments that applied counter techniques to measure hypernuclear reactions induced by K^- mesons in flight. Such studies have been made possible in recent years by the development of intense, low-momentum K^- beams. They were further stimulated by the suggestions of theorists that production of hypernuclei by K^- mesons in flight might favor the formation of states in which a nucleon of the parent nucleus is replaced by a lambda hyperon without otherwise changing the wave functions. Comparison of such a hypernuclear state with the corresponding nuclear state could yield useful information about the lambda–nucleon interaction.

The first of these two experiments was conducted by a group from the University of Torino and the National Institute of Nuclear Physics in Torino, Italy.[1] A subsequent experiment was performed by a team from the Max-Planck Institute for Nuclear Physics and the University of Heidelberg, Germany.[2] Both groups used separated K^- beams at CERN. They detected the incoming K^- and the outgoing π^- from the strangeness exchange reaction

$$K^- + A \rightarrow A_\Lambda + \pi^-$$

where A_Λ is the hypernucleus resulting from the transfer of a unit of strangeness from the projectile to the nucleus. The energies of the hypernuclear states were determined by a missing-mass technique.

Before the more intense beams became available, most studies of hypernuclei with kaons were measurements of the binding energies of the Λ^- hyperon with emulsion and bubble-chamber techniques. With the advent of the new K^- beams, two experiments used counter techniques to study hypernuclei with stopped K^- mesons. In such reactions, the momentum transfer to the Λ is fixed at 250 MeV/c.

Some years ago, Herman Feshbach and Arthur K. Kerman (MIT) pointed out that the kinematics of the reaction

$$K^- + n \rightarrow \Lambda + \pi^-$$

were such that a Λ hyperon of nearly zero momentum would be formed if the incident K^- were in the momentum range from 300 to 700 MeV/c and if the outgoing π^- were in the forward direction in the lab. A lambda at rest is most likely to replace one of the nucleons without otherwise disturbing the nucleus. Several theorists have been interested in such a reaction and have proposed the existence of strangeness analog states, similar to the nuclear isobaric analog states. The strangeness analog states would be linear combinations of single strangeness exchange resonances that would be described by wave functions that are antisymmetric with respect to the interchange of any neutron and the hyperon.

The production rate for strangeness analog states should be enhanced, some feel, as a consequence of collective coherent effects and would be preferentially excited by reactions induced by K^- in flight. However, other theorists feel that this coherence effect does not exist.

The Torino group studied reactions induced by 390 MeV/c K^- mesons with the π^- detected at a lab angle of less than 10°. Their targets were C^{12}, O^{16} and Al^{27}; the hypernuclear spectrum of the latter two had never before been observed. The target was placed in the middle of a non-focusing, wide-angle double-magnet spectrometer. Trajectories of the incoming K^- and π^- were measured by six pairs of multiwire proportional chambers.

The Heidelberg team worked at a higher K^- momentum—900 MeV/c—and observed hypernuclear states in Be^9, C^{12} and O^{16}. This team consisted of W. Brückner, M. A. Faessler, K. Kilian, U. Lynen, B. Pietrzyk, B. Povh, H. G. Ritter, B. Schürlein, H. Schröder and A. H. Walenta. They too used a double magnetic spectrometer to measure the momenta of the K^- and π^- and ten planes of drift chambers to determine the particle trajectories. This second experiment had an energy resolution of 2 MeV compared to the resolution of 6 MeV for the Torino experiment.

A major problem in both experiments was the large background, primarily from K^- decays and from π^- contamination of the beam. Both groups tried to reduce the background by selecting the $K^-(A,A_\Lambda)\pi^-$ events, using Cerenkov and $\Delta E/\Delta x$ detectors, on the basis of time-of-flight requirements and by making certain cuts on the coordinates of the trajectories. They furthermore studied the background by comparison with the spectrum from K^+ reactions, which do not form hypernuclei.

The Heidelberg trigger was sufficiently clean that their spectra did not require a subtraction of the background.

A question of interpretation

The hypernuclear structure of carbon-12 as measured by both the Torino and Heidelberg groups shows clear structure, but the experimenters differ somewhat on their interpretation of the results. The Torino group sees two peaks, which they interpret to be most probably a ground state and an excited state. They feel that their results, especially the enhancement of the excited state near 10 MeV, are consistent with the predictions of Harry J. Lipkin (Argonne National Laboratory and the Weizmann Institute) and Arthur K. Kerman (MIT), based on the ideas of strangeness analog resonances.[4]

The Heidelberg data, which has higher resolution, shows two peaks that this group interprets as two excited states—one around 11 MeV in which a $p_{3/2}$-state neutron is replaced by a $p_{3/2}$-state lambda and another near 22 MeV in which an $s_{1/2}$ neutron is replaced by a $s_{1/2}$-state lambda. According to the Heidelberg group they do not see the hypernuclear ground state.

No firm conclusions can yet be drawn (see box), but clearly the two experiments have opened a promising source of information on hypernuclear states that should add to our knowledge of nuclear states and of nucleon-hyperon interactions. —BGL

References

1. G. C. Bonazzola, T. Bressani, R. Cester, E. Chiavassa, G. Dellacasa, A. Fainberg, N. Mirfakhrai, A. Musso, G. Rinaudo, Phys. Letters **53 B** (1974).
2. K. Kilian, B. Povh, CERN Internal Report CERN/EEC-74/33.
3. H. Feshbach, A. K. Kerman, *Preludes in Theoretical Physics* (A. DeShalit, H. Feshbach, L. VanHove, eds), North Holland, Amsterdam (1966), page 260.
4. A. K. Kerman, H. J. Lipkin, Ann. Phys. **66**, 738 (1971).

Fermi Lab produces a 225-GeV electron beam

The Fermi National Accelerator Laboratory has produced a 225-GeV electron beam, a record energy for electrons. According to Thomas Nash, the NAL physicist responsible for the beam's development, beam intensity in the 100–150-GeV range was about 4 × 10^5 electrons per pulse, in agreement with predicted values for 2 × 10^{11} protons injected per pulse. Intensity is expected to be over 10^7 electrons per pulse for a full intensity proton beam of over 10^{12} protons per pulse. Of course, intensity at 225 GeV is much lower but is also within the range predicted. The electrons will be used as a source of "tagged" photons, rather than for themselves; NAL already has a muon beam for doing lepton physics, but the ability to produce photons of known energy is unique. Before the NAL beam was produced, the highest energy electron beams were at Serpukhov, USSR (35 GeV) and at the Stanford Linear Accelerator Center (20 GeV).

At NAL, which is primarily a proton accelerator, electron-beam production begins in a 40-cm beryllium target in the Proton Area. Here the neutral pions resulting from proton interaction decay to photons, which are converted to electrons in a lead-sheet radiator about three millimeters (half a radiation length) thick. A 290-meter beam transport system, consisting of 15 major magnets and three additional steering magnets, focusses the beam. In the recent tests that produced the 225-GeV beam, roughly two thirds of the beam was installed, with the last six magnets missing. For 300-GeV incident protons, the resulting beam had about 2 × 10^{-6} electrons per proton, at an energy of 115 GeV. In these tests, pion contamination (the major concern when using a proton accelerator to produce electrons) was 0.3 percent of the electron intensity, an acceptable value for the kinds of experiments planned. However, a two-stage extension of the electron beam further downstream has been designed by Zaven Guiragossian (Stanford) to improve the electron purity such that there will only be 1 part in 10^6 pion contamination. With a beam of this purity, electron physics can be performed at NAL to complement the existing muon beam for lepton physics, comments Guiragossian.

Working with Nash on the beam tests and installation have been Bradley Cox and Roy Rubinstein of NAL; John Cumalat, Rollin Morrison and Frederick Murphy of the University of California, Santa Barbara and Philip Davis, Roland Egloff, George Luste and James Prentice, of the University of Toronto.

Additional tests of the beam are scheduled for this month, with all magnets in place. During tests scheduled for May, Nash tells us, they expect to get the tagging system working. To produce the tagged photons, a 1% radiator will be installed in the electron-beam path, about 25 meters before the final focus. A lead-glass array, acting as a Cerenkov radiation counter, in combination with three magnets that bend the interacting electron beam, will allow the momentum of the recoiling electrons to be measured, thus "tagging" the energy of the photons. Since any pions present will deposit much less energy than the electrons in the lead-glass array, and the array essentially integrates the total energy deposited, it acts as an additional pion-rejection scheme. The noninteracting electrons