search & discovery

X-ray parametric conversion—two photons for one

Nonlinear optical effects with visible light have long been known; the first laser was developed 12 years ago. Now Peter Eisenberger and Samuel McCall of Bell Telephone Laboratories have demonstrated[1] nonlinear optical effects at x-ray frequencies. In an experiment that verifies the calculations of Isaac Freund and Barry F. Levine,[2] Eisenberger and McCall have achieved the x-ray analog of optical parametric conversion. They have shown that a single x-ray photon of frequency ω_p incident on a crystal can result in the coincidental emission of two x-ray photons ω_1 and ω_2, where $\omega_1 + \omega_2 = \omega_p$, and the crystal as a whole takes up the recoil, so that both energy and momentum are conserved. A prime reason for interest in the result is the anticipation[3] that the work might be extended to a mixed x-ray–visible experiment that could reveal microscopic details of the behavior of outer-shell electrons in these nonlinear interactions.

X-ray parametric conversion is observable because the interaction cross section depends both on the magnitude of the nonlinear susceptibility of the crystal and the strength of the zero-point fluctuations in the electromagnetic field. Although the nonlinear susceptibility for x rays is only about 10^{-8} of the value for visible light, the strength of the zero-point fluctuations is correspondingly greater.

McCall and Eisenberger aimed a 17-keV x-ray beam at a beryllium crystal oriented slightly (about 15 minutes of arc) off the Bragg scattering angle. They analyzed the emitted radiation for coincident 8.5-keV pairs in the directions consistent with momentum conservation, and found a conversion efficiency of about 10^{-8}. (Typical optical parametric oscillators can have an efficiency of about 10^{-1}.) Beryllium was used because, with its low atomic number, it has a low x-ray absorption constant and allows a large volume for

continued on page 20

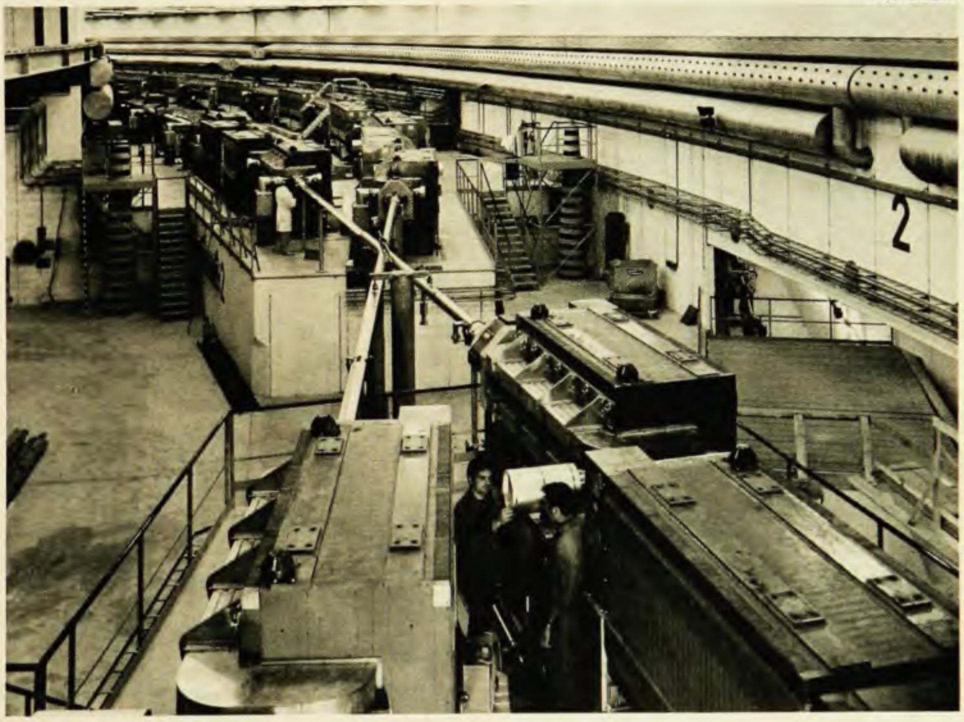
ISR collisions at CERN; experiments start this summer

CERN's Intersecting Storage Rings have produced collisions between protons several months ahead of schedule, and experiments are scheduled to begin with the rings around the middle of the year. The first successful collisions occurred on 27 January with 15-GeV protons, and by 17 February the energy had been boosted to 22.5 GeV. When operated at the full energy of 28 GeV, the collisions will correspond to a beam of 1700 GeV hitting a stationary target.

The storage rings consist of two interlaced rings of magnets, each 300 meters in diameter, which enclose doughnut-shaped, highly evacuated vacuum chambers. Protons from the 28-GeV proton synchrotron are injected into a transfer channel and guided into one of the two rings. An rf system allows the pulses to be stacked. At full intensity the ISR is expected to have circulating currents in each ring of about 20 amps.

In commissioning the ISR the big question was what effect the two beams would have on each other. Beams were first circulated and stored in ring no. 1 at the beginning of November. On 11 January lifetimes of several days were recorded. Trials on ring no. 2 began on 25 January, and soon beams were accumulated with currents of up to 1 amp. Although not all the components were connected nor all of them baked

PHOTO CERN



Intersection point I-2 at the CERN Intersecting Storage Rings, where some of the first experiments are now being installed. Here and at point I-8, the tunnel is widened on the inside (left) by 3 meters, and the floor is lowered by 2.4 meters to accommodate experimental equipment. At center right is the end of one of the beam-transfer tunnels, which brings protons from the synchrotron to the ISR. The injection point for one of the rings is at the next crossing point, 100 meters off the bottom of the photograph. The striped towers on either side in the rear are survey monuments, which are used for high-precision alignment of the ISR magnets and other equipment.

out, the average vacuum was better than the design figure. So the ISR builders decided to make the crucial tests on beam interference earlier than planned.

On 27 January, beams were stacked in both rings, and the protons were allowed to collide in the eight interaction regions. Counters showed that proton–proton reactions were occurring. No interference of one beam with the other was found; that is, the beams showed no tendency to increase in size. Under the best conditions the current in ring 1 was over 2 amps while the current in ring 2 was over 1 amp.

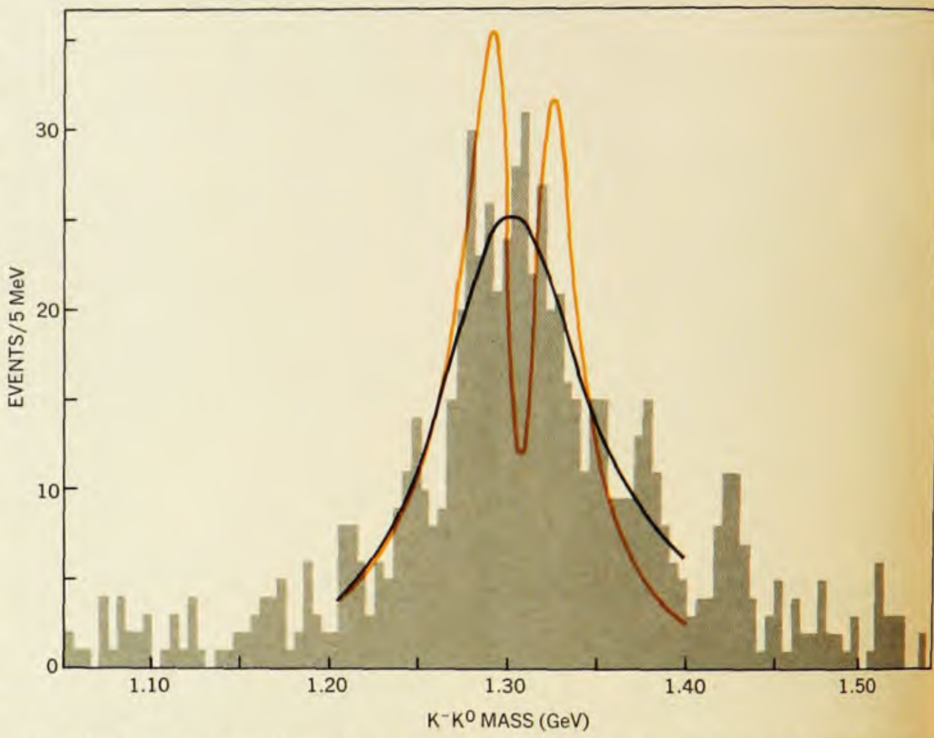
By 17 February the ISR was receiving 22.5-GeV protons. Beams were successfully stored and brought into collision, with intensities of over 2.5 amps in ring 1 and about 1.5 amps in ring 2. Emphasis in these early colliding-beam runs is on achieving the best signal-to-background ratio rather than shooting for the highest possible current.

Although considerable construction remains to be done, experimenters are eagerly readying their apparatus for the beginning of experiments this summer. —GBL

Is the A_2 meson split? Two experiments say no

Two recent experiments have brought new life to the argument about whether the A_2 meson is split—that is, whether it exists as two particles having identical properties except for a 3% difference in mass. The experiments, one performed at CERN by a CERN–Munich group and the other at Brookhaven, both report data indicating the A_2 is *not* split. S. J. Lindenbaum, the leader of the Brookhaven group, presented data at the annual APS meeting in New York that he claims have less than one chance in a million of being consistent with a two-peak (dipole) mass formula. (The group has also published a letter in *Physical Review Letters* **26**, 413, 1971.)

Just last fall (*physics today*, November 1970, page 32) Peter Schübelin had reviewed the five-year experimental history of this question and had concluded that it was all but certain that the A_2 *is* split. He cited a half-dozen independent investigations that had produced data showing a split. The most extensive data had been collected by the CERN missing-mass spectrometer group, which according to Schübelin supports the existence of a split with a probability much smaller than 1 part in 10^4. The "all but" in his conclusion referred to an experiment on the A_2^+ reported last year by bubble-chamber group A at Berkeley, which found only a 0.3% likelihood for a double-pole mass spectrum as opposed to 14% for a single pole.



K^-K^0 effective mass spectrum for all K^-K^0 events with a proton recoil mass between 0.76 and 1.06 GeV. S. J. Lindenbaum and his collaborators use the data to observe the A_2^- mass spectrum via this decay mode. The black line is a single Breit–Wigner fit; the colored line corresponds to a split in the A_2.

The original CERN experiments studied the reaction $\pi^- + p \rightarrow A_2^- + p$ with a spark-chamber spectrometer and used a "missing-mass" analysis to infer the mass of the A_2 from the measurement of the recoil proton. The two new experiments (B. Hyams is the senior member of the CERN–Munich group) claim an improvement over this approach in that they determine the A_2 mass more directly by observing the momentum of each of the decay particles. In particular they look at the decay mode:

$$\begin{aligned} \pi^- + p &\rightarrow A_2^- + p \\ A_2^- &\rightarrow K^0 + K^- \\ &\rightarrow \pi^+ + \pi^- + K^- \end{aligned}$$

and detect both K particles.

Also the two new systems provide a factor of two better resolutions. In particular the system used by Lindenbaum's group is the new general-purpose BNL Double Vee Spectrometer, which can identify events such as $A_2 \rightarrow K^0 + K$ in which a particle pair is produced. The spectrometer consists of a complex array of digitized spark chambers and counter hodoscopes that feed their signals to an on-line computer for immediate determination of particle identity and momentum.

The Lindenbaum group chose to limit observations to the K^0K^- decay mode, rather than also collect data from the $A_2 \rightarrow \rho + \pi$ mode as previous studies had done, because of the very low background possible with the K^0K^- decay. The better than 10:1 signal-to-noise ratio achieved on runs with the BNL system plus the improved resolution yielded data that, according to Lindenbaum, made possible the decisive conclusion quoted in their paper—the A_2 dipole split in the $K\bar{K}$ mode ruled out by the chi-squared test at a risk of less than 10^{-6}.

However, the new experiments differ intrinsically from the original CERN experiment in that the incident pion energy was higher in both cases—20 GeV at BNL and 17 GeV at CERN, as opposed to the energy range 2.5-7 GeV used in the original work. Another difference is that the original data were limited to a narrow region of momentum transfer, whereas the more recent experiments look at a wider band of momentum transfer.

Because of these differences Schübelin feels that there is not necessarily a contradiction between the results of the CERN missing-mass group and the more recent experiments. That is, the splitting might be a function of incident energy, momentum transfer or decay channel. This, however, would rule out a simple, universal split in the A_2 and make the task of devising a theoretical