ions produce radiation whose wavelength is 18.2 nm. A similar method creates lithium-like ions.

In recombination schemes the electron temperatures and densities required for lasing are lower for the same wavelength region than those in the collisional-excitation method used at Livermore. These schemes are thus more adaptable to much smaller-scale facilities. Furthermore, the wavelengths at which lasing is predicted to occur decreases more rapidly as the atomic number of the target material increases.

In the Princeton experiment a 10–20-GW carbon dioxide laser is focused[5] onto a 200- to 400-micron-diameter spot size to produce energy densities on the order of 10^{13} W/cm^2. Suckewer and his colleagues measured the enhancement of the axial emission at 18.2 nm by comparing its intensity to that in the transverse direction. They also compared the ratio of axial to transverse intensities of this line with that of a nonlasing line. Using a solid carbon target, they obtained a product of gain coefficient and length equal to 6.5.

The geometry of the Princeton experiment prevents one from varying the length of the plasma to observe the growth in gain with length. Since the Boston meeting, the Princeton group has acquired from Barbee a spherical x-ray mirror with a radius of curvature of 2 m, to increase effectively the length of the target region. Although the Princeton workers feel they have not yet optimized the mirror arrangement, they observe that their enhancement is 2.0 times greater with the mirror in place, consistent with what they expect for stimulated emission with a mirror of the given reflectivity and small angle of acceptance. They plan further experiments with different targets, with an x-ray mirror of shorter radius, with lithium-like neon ions and with schemes to go to shorter wavelengths.

The x-ray laser schemes described so far have been pursued by others as well. In 1975 Elton suggested[6] a collisional excitation scheme for vacuum ultraviolet light. Later, A. Zherikin, K. Koshelev and V. S. Letokhov (Institute for Spectroscopy, Moscow) described[7] methods of obtaining population inversion between the 3p and 3s levels in neon-like ions. About the same time, A. V. Vinogradov, I. Sobelman and E. Yukov of the Lebedev Physics Institute in Moscow were very active in investigating[8] several x-ray lasing schemes, including collisional excitation. More recently, Elton's colleagues at NRL, some in collaboration with Suckewer and Anand Bhattia (NASA Goddard), and, independently, Hagelstein from Livermore, have extended[9] this work with calculations of the shorter wavelengths expected from neon-like systems at higher atomic numbers. In 1977 a team headed by A. Ilyukhin claimed[10] to have achieved a laser cavity at 60 nm. According to Elton, their claim was never substantiated and the Russians have not published any results on this device since then.

Several experiments in Europe are based on the recombination scheme. Geoffrey Pert and his colleagues at the University of Hull (England) have a setup similar to that of the Princeton group, but with a thin carbon fiber as the target. They reported gain in 1980 and claimed[11] to have measured a gain–length product of approximately 5 on the 18.2-nm line. For the past two years, Pert and his colleagues have been collaborating with Michael Key and others at Rutherford. They are currently planning experiments on a larger scale similar to the Livermore work. At the University of Paris Sud, Orsay, a team led by Pierre Jaeglé is experimenting[12] with a recombination scheme involving lithium-like aluminum, with radiant emission at around 10.5 nm, from which they have reported small gains on the order of one.

There is certainly more than one way to pump a laser, and many other candidates are being studied. The recent success with a collisional excitation scheme does not necessarily indicate the way for future experiments to go; this early in the game it simply speaks to the viability of the x-ray laser concept. —BGL

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Zeta revisited: Have we really seen the Higgs?

Much excitement was generated last summer at the XXII International Conference on High Energy Physics in Leipzig by the Crystal Ball collaboration's report of evidence for a curious new particle, the 8.32-GeV "zeta" boson, that might well have been the long-sought-after Higgs particle. In October (PHYSICS TODAY, page 18) we reported that this hint of the Higgs had set in motion considerable activity among particle theorists, because these data were not entirely consistent with the simplest Higgs particle one might have expected.

It now appears, however, that the experimental signal is going away. At the beginning of November the Crystal Ball group reported at the Santa Fe meeting of the APS Division of Particles and Fields that the partial analysis of their 1984 data sample had failed to confirm the zeta signal discovered in their 1983 data. "The potential physics impact of the zeta is so great," the group declares, "that experimenters bear the burden of proof to show that it reproduces in every valid data set."

The Crystal Ball data were taken at the DORIS e^+e^- storage ring at DESY in Hamburg. At Leipzig, the Columbia–Stony Brook CUSB detector group had reported that their preliminary data, taken at the Cornell CESR e^+e^- ring, gave no indication of a new particle near 8.3 GeV. At the November meeting in Santa Fe, the CUSB group reported that additional data had not revealed a zeta signal. Two other detector groups have also joined the search—ARGUS at DORIS and Cleo at CESR. Both groups reported at the

Morionde conference in January that they have as yet seen no indication of such a particle.

The original zeta signals observed by the Crystal Ball group were based on about 100 000 decays of the 9.46-GeV upsilon meson, created in 9.46-GeV e^+e^- collisions in the DORIS collider ring. These data, taken in 1983, exhibited statistically significant peaks in the photon-energy distribution of two distinct data subsets, suggesting that about 114 upsilons had decayed radiatively to a new particle with a mass near 8.3 GeV. In the "multihadron" data subset—characterized by more than eight particles observed in the final state—there appeared to be about 90 such decays to the zeta, with a statistical significance of 4.2 standard deviations (90% confidence level). The corresponding peak in the alternative "low-multiplicity" subset suggested perhaps two dozen additional zetas decaying to a less flamboyant final state, with a statistical significance of 3.3 standard deviations. The combined statistical significance of the two peaks, the group reported at Leipzig, exceeds five standard deviations.

Although these zeta signals were widely reported at conferences last summer, the group decided not to submit these early results for publication until they were confirmed by more data. That confirmation still eludes all four collaborations now engaged in the zeta search, much to the regret of the theorists for whom the Higgs boson is the last crucial missing piece in the "Standard Model" unifying the weak and electromagnetic interactions. The regret is, however, tinged with relief. The Standard Model makes no really useful prediction about the Higgs mass. But if the zeta is indeed the Higgs particle, one would expect to see it also in the decay of the Υ' (10.02 GeV), the first *excited* upsilon state. The apparent absence of a zeta signal in the higher-energy Υ' data has been a disturbing challenge to the Standard Model.

In its 1984 run, the Crystal Ball accumulated 210 000 upsilons, but only 60% of this new sample has as yet been analyzed. Like CUSB, the Crystal Ball is a nonmagnetic detector specialized to detect and measure photons produced in e^+e^- collisions with high efficiency and high resolution. It does, however, have tracking chambers inside its spherical igloo of NaI photon-detecting crystals to follow the trajectories of charged particles produced with the photons. A major overhaul of this tracking system between the 1983 and 1984 runs caused startup problems that resulted in the temporary loss of the first 40% of the 1984 data. These data have now been retrieved, but they are not yet fully analyzed.

The remaining 60% of the 1984 data, which has been analyzed (corresponding to 13 events per picobarn), represents a sample 25% larger than the 1983 data in which the strong zeta signal had been found.

The two data sets stand in sharp contrast to one another. Whereas the multihadron subset of the 1983 data showed a prominent 4.2-standard-deviation bump at 8.3 GeV, the 1984 multihadron data exhibit absolutely no enhancement near this mass. The photon energy distribution of the low-multiplicity subsample has not yet been reported because the reconstruction of these events is particularly sensitive to the difficulties the group experienced with the new tracking-chamber system.

"We don't at present understand the origin of this difference," says Elliott Bloom (SLAC), spokesman for the American contingent of the 13-laboratory Crystal Ball collaboration. With so large and far-flung a collaboration, lots of different ideas are floating around. Bloom was reluctant to make a more definitive statement with regard to the existence of the zeta before the collaboration gets together for its next major meeting. In any case, 40% of the multihadron upsilon decays and 100% of the low-multiplicity decays in the 1984 data remain to be analyzed.

The other detector groups have seen nothing of the zeta. At Leipzig, with 100 000 upsilon decays in hand, the CUSB group had given 2×10^{-3} as an *upper limit* (90% confidence level) on the branching fraction for the decay $\Upsilon(9.46\ \mathrm{GeV})\rightarrow\zeta(8.3\ \mathrm{GeV})+\gamma$. At the same meeting, the Crystal Ball group had reported this branching fraction to be 4.7×10^{-3}, clearly in some conflict with the CUSB conclusion. The large systematic uncertainty on this measurement, however, puts it "only in mild disagreement" with the CUSB upper limit, Bloom told us. Dwarfing the statistical uncertainty, the systematic error of ±0.26 reflects one's uncertainty about what the decay of the zeta should look like.

The CUSB group has now gathered an additional 400 000 upsilon decays, this time with one quadrant of their NaI detector array augmented by bismuth germanate crystals. Juliet Lee Franzini (Stony Brook) told us that these new BGO crystals improve the photon energy resolution of this quadrant by a factor of two. Because BGO is considerably denser than the more traditional NaI, and it does not suffer from the latter's hygroscopic affinity for moisture, it was the material of choice for squeezing into the cramped quarters made available by replacing the CUSB detector's tracking chambers with smaller scintillation counters. Combining the new data from the NaI and BGO sectors of the upgraded CUSB detector, the group reported at Santa Fe their conclusion that the branching fraction for radiative upsilon decay to the zeta, if indeed it exists, is less than 1×10^{-3}.

Ironically, even a branching fraction as small as 1×10^{-3} (saying that one upsilon in a thousand decays radiatively to a zeta) is still an order of magnitude *too large* for the "minimal" version of the Higgs symmetry-breaking mechanism in the standard Glashow–Salam–Weinberg theory. If the zeta were indeed this simplest imagined manifestation of the Higgs mechanism, none of the current experiments would yet have detected its very infrequent appearance in upsilon decay. But Frank Wilczek (then at Princeton) pointed out eight years ago that a fairly conservative elaboration of the Higgs mechanism, well within the standard theory, would greatly increase the decay rate of the upsilon to the Higgs, making it quite compatible with the Crystal Ball data. This "two-doublet Higgs" fixup also relieves the theoretical constraint on the mass of the Higgs particle, which had implied that 8.3 GeV was somewhat too light.

The ARGUS and Cleo detectors are more generalized magnetic spectrometers. To join the search for the zeta, these groups had to install lead sheets to convert photons from the collision vertex into electron–positron pairs. These lead converters allow one to see the telltale monochromatic photon energy peak that would signal a two-body radiative decay of the upsilon, but their photon-conversion efficiency is much lower than that of the specialized NaI and BGO crystal detectors. Thus, although the ARGUS and Cleo groups have gathered about as many upsilons as their respective crystal-detector partners, they are able to quote only rather loose upper limits on the Υ-to-ζ branching fraction at this point. —BMS

New hadron naming scheme proposed

In the early 1950s, when the proliferation of "elementary" particles was still quite benign, Enrico Fermi is alleged to have complained, "If I could remember all those names, I would have been a botanist." A decade after Fermi's untimely death in 1954, when the population explosion had engendered a nomenclatural anarchy, Murray Gell-Mann (Caltech) and Arthur Rosenfeld (Berkeley), two of Fermi's former students, set out to impose some order—at least to the naming of baryons.

So long as strangeness was the only