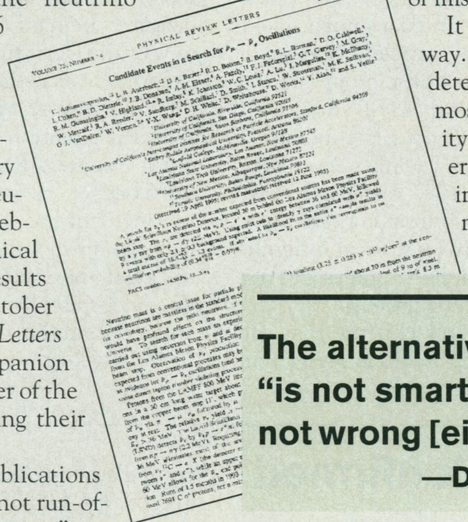
PHYSICS

Papers Face Off Over Claim Of Neutrino Mass Detection

Veteran physicists know that if you ask a simple question, nature by no means guarantees a simple answer. But even the most case-hardened researchers may be taken aback by the answer—or answers—that their field's most prestigious journal will soon report for the question "Does the neutrino have mass?" More than 6 months after newspaper and magazine accounts reported that researchers working at Los Alamos National Laboratory had detected hints of neutrino mass (*Science*, 10 February, p. 789), a technical paper reporting their results is due out in the 2 October issue of *Physical Review Letters* (*PRL*). And so is a companion paper by a former member of the group, flatly contradicting their conclusion.


PHYSICAL REVIEW LETTERS
2 OCTOBER 1995
Candidate Events in a Search for $\bar{\nu}_\mu \to \bar{\nu}_e$ Oscillations

The rare duel of publications caps an episode that is "not run-of-the-mill in any of its aspects," says *PRL* editor Robert Garisto. The original claim promised to shake up everything from physicists' Standard Model of particles and forces to cosmologists' picture of how the universe is structured. But before the result could be published in a technical journal, the uncertainties that attend any research on this elusive particle tore apart the Los Alamos collaboration. The result is that one paper, signed by 39 researchers collaborating at the Liquid Scintillator Neutrino Detector (LSND) at Los Alamos, suggests that neutrinos can "oscillate," or transmute from one kind into another, a process that implies at least a trace of mass. In the other paper, a lone author—recent Ph.D. James Hill of the University of Pennsylvania—presents a simpler analysis, throws out some data Hill believes were contaminated by cosmic rays and other effects, and finds no statistically significant evidence for oscillations.

Debate about the episode isn't limited to scientific issues, however. "I don't think the editors [at *PRL*] have done their job," fumes Leonard Auerbach, a group member at Temple University who is upset that data collected by the entire group should be published under Hill's name. But Garisto explains that "the referees thought equally highly of both [papers]." Physicists are also debating the dangers of the kind of early publicity that greeted the neutrino results, which Hill believes made the group less willing to moderate their claims later on. D. Hywel White, co-spokesperson for the experiment at Los Alamos, dismisses that view. But he says the months since the original announcement "will go down in the annals of misery."

It didn't start out that way. By adding a neutrino detector to the Los Alamos Meson Physics Facility (LAMPF), an accelerator that produces an intense beam of 800-million-electron-volt protons, White and his colleagues thought they might shed light on some long-standing mysteries. Experiments have shown that the three "flavors" of neutrinos—electron, muon, and tau—have at most a tiny mass, and physicists' Standard Model of particles and forces takes neutrino mass to be zero. But doubts began to crop up in about 1970 when measurements of the flux of electron neutrinos reaching Earth from the sun fell well short of the expected number. The doubts grew when researchers found an unexpectedly low ratio of muon to electron neutrinos in the debris from cosmic rays that smash into Earth's atmosphere.

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> **—D. Hywel White**

These results might be explained if a neutrino's flavor, instead of remaining fixed, could oscillate among the three possibilities. But "it's very difficult to see how you can have oscillations without mass," says Wayne Vernon, a group member at the University of California, San Diego. If neutrinos do have mass, the Standard Model will have to give way to new physics, and neutrinos could account for some of the "dark matter" that cosmologists believe must permeate the universe.


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An Alternative Analysis of the LSND Neutrino Oscillation Search Data on $\bar{\nu}_\mu \to \bar{\nu}_e$

> **"Keeping it simple and physical is part of the overall philosophy."**
> **—James Hill**

The LSND group set out to detect neutrino oscillations by generating neutrinos in one place and detecting them in another, which would give them a chance to oscillate along the way. At the neutrino source, protons from LAMPF slam into a water target, producing pions that can continue on until they are stopped in their tracks by a copper beam-stop. At that point, they decay into positive muons and other particles. Among the muons' decay products are muon antineutrinos (muon neutrinos' antimatter counterparts). Thirty meters away, the LSND—a tank filled with 180 tons of mineral oil and lined with 1220 light detectors—is set to detect electron antineutrinos, which would indicate that the muon antineutrinos have oscillated.

But although the logic is simple, actually detecting the electron antineutrinos isn't. Occasionally, one of them should combine with a proton in the oil to produce a positron and a neutron. The positron generates a trail of scintillation; about 200 microseconds later, generally at a different location, another proton captures the free neutron, generating a single photon at a characteristic energy. But cosmic rays and other events can mimic some aspects of this signature. As a result, the LSND's designers armored it in massive shielding and placed a scintillating "veto shield" around the top and sides, which can deliver a warning when certain unwanted particles penetrate the armor anyway. The collaboration also made extensive measurements with the beam off to count background events.

To pick out real events from any remaining "noise," such as background radiation, the group combined the times, locations, and energies of the flashes in each sequence and statistically folded them together into a "likelihood ratio" that an event was in fact caused by an electron antineutrino. In data from 5 months of running time in 1993 and 1994, this analysis revealed nine events, compared to a probable background of two from all sources, including a small number of electron antineutrinos produced by rare processes in the beam. The result implies an oscillation frequency that is probably too large to explain the atmospheric- and solar-neutrino deficits. But it also implies a mass in just the right range for the neutrino to account for at least part of the long-sought dark matter. And if it's correct, says Frank Sciulli of Columbia University, "a whole new field of physics is born."

Hill, however, thinks the data don't warrant such conclusions. His analysis throws away data from areas around the edges of the detector that have the highest concentrations of noise from extraneous effects such as cosmic rays and background radiation, the thickest being at the bottom, where there is no veto shield. Moreover, rather than working with likelihood ratios, he sets independent limits on the energy, timing, and separation of the flashes in a sequence to decide whether the sequence could have originated with a neutrino or not. If the measured energy of a flash is below some cutoff, for example, Hill's analysis strictly rejects the event as spurious. "Keeping it simple and physical is part of the overall philosophy" of the analysis, says Hill. His result: five counts with an estimated background of six, meaning no statistically significant detection of oscillations.

Hill, whose thesis adviser at Penn, Alfred Mann, describes him as "a really self-effacing, charming young man who would be quite happy to compromise," did the analysis as part of his Ph.D. work. When he presented it to his colleagues in the group, he says, they were unreceptive, and he pins some of the blame on the early publicity, especially a 31 January *New York Times* article in which team members described their findings. Having staked their claim, he says, they were unwilling to back away from it. And group member David Caldwell of the University of California, Santa Barbara, who at various times tried to mediate the dispute, acknowledges that publicity could have played a role in the rift. "Some part of the group ... wanted a similar scientific paper [to the *Times* article]," he says.

But other members of the group say the real reason for the rift is that Hill's analysis is misguided. "What Hill does is eliminate a piece of the data," says Temple's Auerbach. "That's already a mistake," because removing so much of the data from consideration dooms the remainder to statistical insignificance. White adds that Hill's analysis "is not smart. But it is not wrong [either]."

Ironically, Mann and Hill say that the early publicity also kept Hill's analysis from languishing in his Ph.D. thesis. Because of the publicity, says Mann, physicists attending Hill's seminar talks "were aware of the other analysis. They said, 'You can't just leave this in your thesis. It has to be published.' " Editors at *PRL* suggested that the two camps reach a compromise, but after initial progress, neither side budged far enough to satisfy the other. In the end, sources say euphemistically, "communication broke down."

For now, says Sciulli, "both points of view are defensible"—not a very satisfactory outcome for physicists eager to know the secret of neutrino mass. Everyone agrees that only more data can resolve the issue. But more data may be hard to come by. Funded until now by the Department of Energy, the LSND experiment may survive through November on a patchwork of funding sources. After that, the situation is "opaque," says White, until Congress finishes its debate on the 1996 budget. Meanwhile, *PRL*'s Garisto says the incident has set in motion another debate, on how journal editors should respond the next time nature—and scientific politics—conspire to send them two different answers from the same experiment.

–James Glanz

EARTH SCIENCE

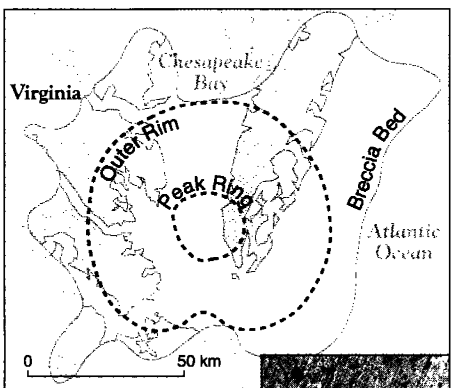
Chesapeake Bay Impact Crater Confirmed

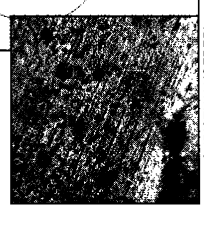
Last year, geologist Wylie Poag and his colleagues presented their opening argument for a vast impact crater 300 meters below the southern end of the Chesapeake Bay, on the U.S. mid-Atlantic coast. Now they have come back with more evidence for the crater, which could explain both the location of the bay and a mysterious layer of 35-million-year-old impact debris found across the southeast United States and the Caribbean Sea—and have clinched their case. "We've put it on our list of known impact craters," says Richard Grieve of the Geological Survey of Canada, the gatekeeper of the community's semiofficial crater database.

Poag, who works at the U.S. Geological Survey in Woods Hole, Massachusetts, had based his original claim on seismic mapping of the rocks under the bay (*Science*, 19 August 1994, p. 1036). It revealed an 85-kilometer-diameter trough of deeply disrupted sediments with a concentric 30-kilometer "peak ring" of uplifted basement rock, a feature typical of impact craters this size. The crater, if that's what it was, appeared to be half the size of the one left by the impact that killed the dinosaurs. If it really were that large, it would be the largest known in the United States.

Crater researchers were intrigued by the possibility of a giant new crater but not convinced. But last week at the annual meeting of the Meteoritical Society in Washington, Poag and his colleagues supplemented that tantalizing evidence with a map of gravity data across the region. It showed a region of reduced gravity—presumably tracing an area where the dense basement rock was blasted away—that neatly fits within the 30-kilometer peak ring.

The actual fingerprints of an impact have also turned up, Christian Koeberl of the University of Vienna announced. He and his colleagues, including Poag, looked at samples from a layer of breccia—jumbled sedimentary blocks—that scientific drill holes penetrated around the southern bay. Under the microscope, bits of quartz, feldspar, and plagioclase minerals from the layer showed the closely spaced, parallel or crisscrossing deformation features that only the intense shock pressures of an impact could have forged. Koeberl also reported that some of the grains had been melted, as if by an impact. "We feel confident this presents unambiguous evidence for an impact origin" of the breccia layer, Koeberl told the audience.





Telltale of an impact. Only impact pressures could have formed this pattern in a mineral grain found beneath Chesapeake Bay.

Its newly awarded credentials make the Chesapeake Bay crater the logical source for the thin layer of glassy spherules, called tektites, that showered the Southeast at the same time as the impact. The resulting crustal depression could have also determined the location of Chesapeake Bay, formed millions of years later by a rising ocean. And the site could be a boon to cratering researchers, because the blanket of sediment, laid down soon after the impact, presumably preserved the crater and its debris largely intact. "We don't really know what controls crater morphology," says cratering specialist Virgil Sharpton of the Lunar and Planetary Institute in Houston, "so having another extremely large and potentially well-preserved crater is tremendous."

Sharpton and his colleagues may soon get another one to study: Poag is now in pursuit of a smaller candidate off Atlantic City, New Jersey, that may have been formed about the time of his first find.

–Richard A. Kerr