BNL--40399

DE88 003546

PROTON DECAY: THE SEARCH GOES ON*

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ABSTRACT: In the search for proton decay the results of the IMB detector taken together with results from other detectors have reached a limit for the proton decay branch $p \rightarrow e^+\pi^0$ which is nearly a thousand times longer than the most probable value predicted by the minimal SU(5) theory. Other grand unified theories give no quantitative prediction, and the search continues now as a purely experimental challenge. In the meantime, supernova explosions in our galaxy could also be recorded.

Until about a third of a century ago it was generally accepted that the proton is absolutely stable. At that time the first test for proton decay was carried out. On very general grounds one could conclude that a proton must live longer than 10^{20} years, no matter how it decays, and if it decayed into charged particles with a minimum energy $\gtrsim$ 100 MeV it had to live longer than 10^{22} years.[1]

These experiments were improved over the years, leading to much longer lifetime limits. Then in 1973 Pati and Salam[2] and in 1974 Georgi and Glashow[3] postulated a grand unification of forces, whereby the strong, electromagnetic, and weak forces are unified at the so-called grand unification mass which was estimated by extrapolation to be around 10^{15} GeV. In particular, the so-called minimal SU(5) theory[3] led to quantitative predictions for the proton lifetime. These theoretical predictions led to a number of efforts to measure the proton lifetime, which appeared to be a not too difficult experiment at the predicted rate. The Irvine-Michigan-Brookhaven collaboration decided to build a very large detector capable of measuring proton decay up to about 10^{33} years, of the order of a thousand times longer than predicted by the minimal SU(5) theory. This experiment has now been going on for several years, and we have achieved a value of 3.1×10^{32} years for the lower limit of the proton branch $p \rightarrow e^+\pi^0$, which is to be compared with the predicted lifetime for this branch of $4.5 \times 10^{29\pm1.7}$ years. If we take into account the other experiments carried out with smaller detectors, which have also not been able to see this particular decay mode, we can say that the limit for this branch is of the order of a thousand times longer than the central value predicted by the minimal SU(5) theory. During the last year we have improved our detector to gather more Cherenkov light and hope to continue the experiment long enough to reach lifetimes close to 10^{33} years. Often, when new detectors were first switched on, a candidate for proton decay was soon found while the calculated background from atmospheric neutrinos was small. But we

*Supported by the U.S. Department of Energy.

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must remember that a candidate's background has a way of catching up with him! Thus we need large statistical samples to be able to subtract neutrino background, a situation which some members of our collaboration believe we have reached.[4] In this field the accumulated "ton-years" are an important figure of merit. Though there is at present no quantitative theory of proton decay, the work is still worth continuing as a purely experimental effort, the way it started before there was any theoretical prediction. But tastes differ, and one can find many different attitudes toward a continuing search for proton decay. The belief in the existence of proton decay is sustained by the beauty of the idea of the grand unification of forces and by the Sakharov-Weinberg-Yoshimura argument which makes a world in which protons are preferred to antiprotons possible, provided the proton decays at a finite rate. If grand unification happens only at the Planck mass the proton would live about 10^{47} years, inaccessible to direct experiments.[5]

Big water Cherenkov counters are good traps for neutrinos, and as luck would have it, neutrinos from a supernova reached our planet last February 23rd. The progenitor of the supernova has been determined to be a previously known star[6], Sanduleak-69° 202, in the galaxy nearest to us, the Large Magellanic Cloud. Neutrinos from this supernova, SN1987a, were observed both by the Kamiokande II[7] and the IMB[8] water Cherenkov detectors and perhaps by smaller scintillation detectors. Within the limits of error of the clocks used, the bursts of neutrinos were recorded essentially simultaneously in the two Cherenkov detectors. From the arrival time of neutrinos of different energies one can make an estimate of the electron-neutrino mass. If one likes to do so, independently of any particular model of neutrino emission from the supernova, one can only conservatively conclude that the neutrino mass limit is in the same ballpark as the limits obtained by experiments on Earth. Some theoreticians have squeezed the data and theory a little further and have obtained smaller limits. It will be worth keeping these and other neutrino detectors going to await a supernova in our own galaxy, as is our intention, and I believe the intention of many other researchers.

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