In the minimal SU(5) GUT, nucleon decay is mediated by a supermassive gauge boson, and the dominant decay mode is $p \to e^+\pi^0$. The partial mean life for a particular mode is the total mean life τ divided by the branching fraction B for the mode. The partial mean life for the $p \to e^+\pi^0$ mode is predicted, in the minimal SU(5) GUT, to be $\tau/B = 4.5 \times 10^{29\pm1.7}$ yr [3]. To test this clear and striking prediction, modern nucleon-decay experiments have needed the following: a large mass in order to explore the domain of $\tau/B \gtrsim 10^{30}$ yr, a tracking capability for charged particles, a way to measure visible energy, and particle identification—at least the ability to discriminate between showering (e,γ) and nonshowering $(\mu,\pi^\pm)$ particles.

There are two main techniques. One uses tracking calorimetry with iron plates interleaved by tracking planes; the other uses a water Čerenkov detector. Fig. 1 compares the total and fiducial masses of various nucleon-decay detectors. The 5-year construction schedule of the 50,000-ton water-Čerenkov detector Superkamiokande began in 1991.

Candidate nucleon-decay events are those contained in the detector. Background comes from atmospheric neutrino interactions and has a rate of about 100 kton^{-1}yr^{-1}. The kinematical difference between nucleon decay and atmospheric neutrino interactions provides background rejection. The amount of background contamination depends upon the tightness of the kinematical cuts, which are different for the different decay modes, as well as on detector capabilities such as resolutions of energy and vertex position.

Among the most favorable decay modes to detect is $p \to e^+\pi^0$, because all the final-state particles shower and their energies are well measured. No background contamination is as yet expected for this mode in the current experiments. In the absence of background, the τ/B limit is directly proportional to the detector exposure.

On the other hand, the mode $p \to K^+\overline{\nu}$ is only poorly constrained kinematically. This mode, which unfortunately is the most important one in supersymmetric (SUSY) GUTs, is thus dominated by the atmospheric-neutrino background. In such a background-dominated case, the τ/B limit only improves as the square root of the exposure time.

Fig. 2 summarizes the present limits from the three major detectors (IMB, Kamiokande, and Fréjus) for nucleon partial lifetimes in various modes involving a lepton and a meson. (For limits on other modes, see the Listings.) There is as yet no compelling experimental evidence for nucleon decay, despite the predictions. The observed number of candidate events in each mode is roughly consistent with the atmospheric-neutrino background. For the $p \to e^+\pi^0$ mode, there are no candidate events in the three experiments, and therefore the τ/B limits from these experiments simply add to give the world limit of $\tau/B(p \to e^+\pi^0) > 9 \times 10^{32}$ yr (90% confidence level). Clearly, the minimal SU(5) GUT has already been ruled out. The best background-subtracted limit for the $p \to K^+\overline{\nu}$ mode has been reported by Kamiokande: it is $\tau/B(p \to K^+\overline{\nu}) > 10^{32}$ yr (90% confidence level).

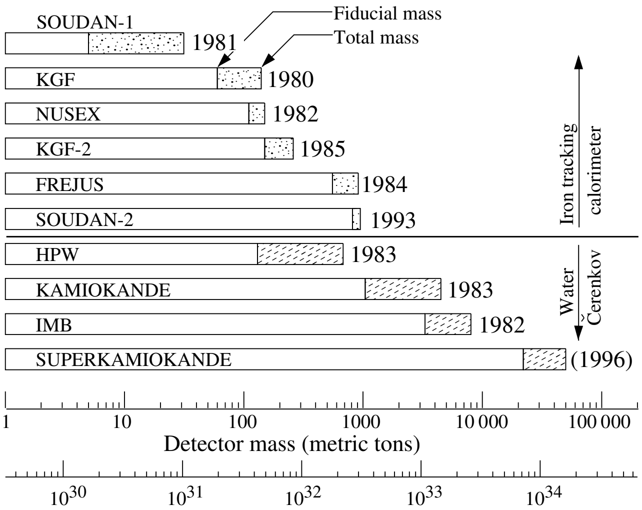

Fig. 1. Nucleon decay experiments. The open bars represent the fiducial masses, while the shaded extensions indicate the total masses. Turn-on dates are at the right. The bottom scale shows the observation limit for the partial lifetime with the assumptions of no background, 50% detection efficiency, and equal numbers of protons and neutrons in the detector material.

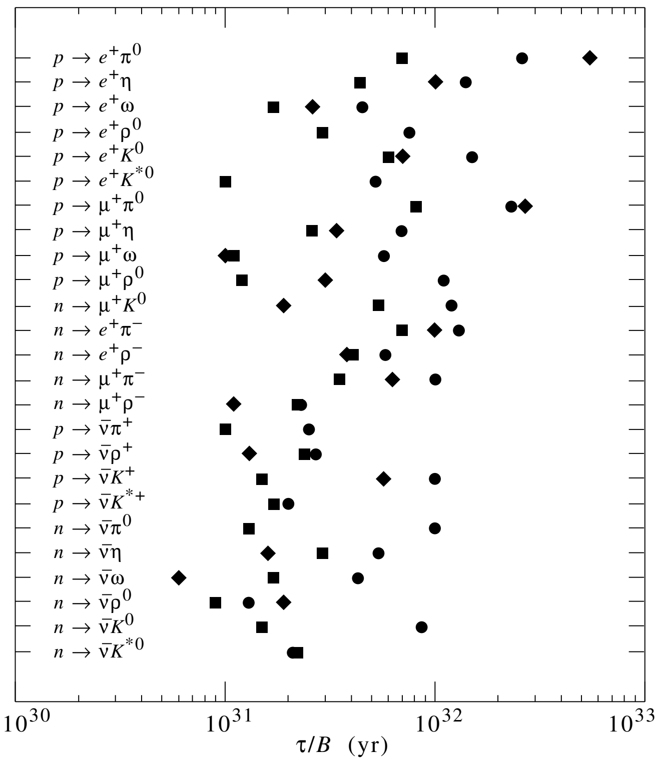

Fig. 2. The 90%-confidence-level lower limits of the nucleon partial lifetime for various nucleon decay modes into lepton + meson, obtained by the IMB (diamonds), Kamiokande (circles), and Fréjus (squares) experiments. For the actual values for these and other modes, see the Listings.