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THE SEARCH FOR PROTON DECAY: INTRODUCTION *

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ABSTRACT

In interpreting contained events observed in various proton decay detectors one can sometimes postulate, though usually not unambiguously, a potential decay mode of the proton, called a "candidate". It is called a candidate, because for any individual event it is not possible to exclude the possibility that it is instead due to cosmic ray background, chiefly atmospheric neutrinos. Some consistency checks are proposed which could help establish proton decay, if it does occur in the presently accessible lifetime window.

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In the particle tables there are nearly thirty particles listed with a mass smaller than that of the proton (if we count both particles and anti-particles and different members of multiplets separately). Ten of these particles are fermions and the remainder protons. If we believe in charge, energy, momentum and angular momentum conservation in proton decay each decay mode has to contain at least one fermion. There are then a great many possible two-body decay modes and an even larger number of three-body etc. decay modes which might occur.

The "decay signature" distributions depend on detector characteristics (the material from which the detector is made, the method of detection, timing information, time resolution, etc.). The background due to cosmic rays, chiefly atmospheric neutrinos, depends also on these factors as well as on the depth of the detector, on the geomagnetic latitude and on the phase of the sun cycle (with which the magnetic field of the sun is correlated and thus the cutoff energy for charged cosmic rays.) For each possible proton decay signature there is a finite, albeit sometimes small, probability of a background event with a similar signature. We cannot claim evidence for the existence of proton decay before we have statistically valid, reproducible results. We must always remember that reproducibility is at the very core of physics.

At the present time it is difficult to reconcile the experimental limit for the decay mode $p \rightarrow e^+ \pi^0$, found by the IMB Collaboration[1)] to be $\tau/B > 2 \times 10^{32}$ years, with the value predicted by minimal SU5 theory. While modifications of the theory might still affect the predicted value, we shall have to see, as both experiment and theory are refined, whether the gap between the minimal SU5 prediction and the experimental limit will decrease or increase in the future. If this gap is not closed, we have at present no other theory which makes a quantitative prediction for the lifetime for a particular decay mode.[2)] Thus the subject is back where it was when we first started working on proton decay thirty years ago: a purely experimental subject with no strong guidance from theory. We must therefore be specially careful. Whenever we find a candidate for proton decay we should remember that this a political term and that the most important thing about a candidate is his background!

Besides reproducibility we can formulate a number of consistency checks (see Fig. 1).

It may be possible to push the limits for proton lifetime branches to $\sim 10^{33-34}$ years. To go much further we may have to go to the moon, where no atmospheric neutrinos are produced, since the moon is a good "beam dump" for cosmic ray protons!

1. R.M. Bionta, G. Blewitt, C.B. Bratton, B.G. Cortez, S. Errede, G.W. Foster, W. Gajewski, M. Goldhaber, J. Greenberg, T.J. Haines, T.W. Jones, D. Kielczewska, W.R. Kropp, J.G. Learned, E. Lehmann, J.M. LoSecco, P.V. Ramana Murthy, H.S. Park, E. Reines, J. Schultz, E. Shumard, D. Sinchair, D.W. Smith, H.W. Sobel, J.L. Stone, L.R. Sulak, R. Svoboda, J.C. van der Velde and C. Wuest.

2. A supersymmetric theory can predict preferred branching ratios in proton decay (B.A. Campbell, J. Ellis, and D.V. Nanopoulos, CERN preprint Th 3787).

CONSISTENCY CHECKS

1) BRANCHING RATIOS OF DECAY PRODUCTS

e.g. $K^0_S \rightarrow 2\pi^0$ 31.4%

$K^0_S \rightarrow \pi^-\pi^+$ 68.6%

$K^0_S / K^0_L = 1/1$

$\eta_0 \rightarrow$

2γ	39%
$3\pi^0$	32%
$\pi^+\pi^-\pi^0$	24%
$\pi^+\pi^-\gamma$	5%

2) IN H_2O:

RATIO OF FREE PROTON DECAY

TO BOUND PROTON DECAY

3) H_2O FE RATIO ETC.

(2, 3: INVOLVES USING CALCULATIONS OF EFFECT OF NUCLEON INTERACTION ON PROTON DECAY)

4) RATIO OF CORRESPONDING p AND n DECAY MODES,

e.g. $e^+\pi^0/e^+\pi^-$, $\bar{\nu}k^+/\bar{\nu}k^0$, etc.

EXPECTED TO VARY BETWEEN 1 AND 2.

5) COMPARISON WITH THEORETICAL BRANCHING RATIOS, WHICH DIFFER FOR DIFFERENT THEORIES,

e.g. $e^+\pi^0/\mu^+\pi^0/\mu^+k^0$, ETC.

Figure 1