“Scales beyond 1 TeV”
P3 Plenary Meeting

Subgroup Summary Reports

Snowmass, July 18, 2001

Few points on $n \rightarrow \bar{n}$

Alternative search for baryon instability

- So far, experimental searches for baryon instability have been pursued mainly through the GUT and SUSY–GUT motivated nucleon decay modes, e.g. $p \rightarrow e^{+} + \pi^{0}, p \rightarrow \bar{\nu} + K^{+}, p \rightarrow \mu^{+} + K^{0}$, etc. where (B–L) is conserved.

- As a result of experimental efforts of IMB, Fréjus, Kamiokande, Soudan-2, and Super-K impressive limits on nucleon lifetime have been established that excluded original SU(5), SUSY SU(5), and almost ruled out SUSY SO(10) models of the proton decay.

- Although it is important to continue searches for the nucleon instability in the traditional way with the next generation large-mass detectors, it is also essential to explore alternative processes where (B–L) is NOT conserved, in particular the $n \rightarrow \bar{n}$ transitions with Δ(B–L)=–2.

- Baryon asymmetry of the universe could be naturally explained if (B–L) non-conservation takes place at the energy scale above the electro-weak scale where *sphalerons* mechanism is active.

- (B–L) non-conservation arises in Left–Right super-symmetric unification models and relates massive neutrinos and 2β0ν decay to $n \to \bar{n}$ transitions and $N \to lepton + X$ decays. Certain class of super-symmetric seesaw models for m_ν predict observable upper limit for $n \to \bar{n}$ transitions. In some models with low quantum gravity scale the $n \to \bar{n}$ transitions can be less suppressed than the proton decay. Experimental observation of either proton decay or $n \to \bar{n}$ transition would be crucially important for the understanding the physics above 1 TeV scale.

- In the past $n \to \bar{n}$ transitions were searched for with free neutrons from the reactors (at ILL/Grenoble); they were also searched inside the nuclei as $nn \to pions$. Both methods presently give the same limit that corresponds to the nuclear stability lifetime $>6.5 \cdot 10^{31}$ yr.

- New search can be performed, for example, at the existing High-Flux Isotope Reactor at ORNL in a new experiment employing neutron-focusing technique (major source of improvement), cold neutron moderation, long flight path, and detector similar to one used in the experiment at ILL/Grenoble. For three-four years of operation sensitivity can be increased by a large factor of ~1,000 and reach an equivalent nuclear $n \to \bar{n}$ lifetime limit of 10^{35} yr. Anticipated cost of such an experiment should not exceed ~ $50M.

- New $n \to \bar{n}$ experiment will allow to extend the searches for (B–L) violating processes of the matter instability up to 10^{35} years and either will find the baryon violation or will set a new limit competitive to the limits of the new proposed proton-decay experiments UNO, Hyper-K, LANNDD for a small fraction of cost of the latter.

Conclusion

Thinking of early 2000's is different from early 1980's:

1980's	2000's
• Proton decay with Δ(B–L)=0 as explanation of BAU	• Δ(B–L)≠0 as more natural for BAU
• No indications for neutrino mass	• $m_\nu \neq 0$ and Majorana nature of neutrino
• Great Desert from SUSY scale to GUT scale	• Possible unification with gravity at ~ 10^5 GeV scale
▶ $p \to e^+\pi^0,\ p \to \bar{\nu}K^+,\ etc.$	▶ $n \to \bar{n},\ \nu_R,\ 2\beta 0\nu,\ n \to 3\nu,\ etc.$

Reflecting these changes, future HEP program should include experimental searches for $n \to \bar{n}$