“Scales beyond 1 TeV”
P3 Plenary Meeting

Subgroup Summary Reports

Snowmass, July 18, 2001
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 \( \Delta(B–L)=-2 \).
• 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 $n \rightarrow \bar{n}$ transitions and $N \rightarrow \text{lepton} + X$ decays. Certain class of super-symmetric seesaw models for $m_\nu$ predict observable upper limit for $n \rightarrow \bar{n}$ transitions. In some models with low quantum gravity scale the $n \rightarrow \bar{n}$ transitions can be less suppressed than the proton decay. Experimental observation of either proton decay or $n \rightarrow \bar{n}$ transition would be crucially important for the understanding the physics above 1 TeV scale.

• In the past $n \rightarrow \bar{n}$ transitions were searched for with free neutrons from the reactors (at ILL/Grenoble); they were also searched inside the nuclei as $nn \rightarrow \text{pions}$. 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 \(n \rightarrow \bar{n}\) lifetime limit of \(10^{35}\) yr. Anticipated cost of such an experiment should not exceed \(~$50M\).

• New \(n \rightarrow \bar{n}\) 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:

<table>
<thead>
<tr>
<th>1980’s</th>
<th>2000’s</th>
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<tbody>
<tr>
<td>• Proton decay with $\Delta (B-L) = 0$ as explanation of BAU</td>
<td>• $\Delta (B-L) \neq 0$ as more natural for BAU</td>
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<td>• No indications for neutrino mass</td>
<td>• $m_\nu \neq 0$ and Majorana nature of neutrino</td>
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<td>• Great Desert from SUSY scale to GUT scale</td>
<td>• Possible unification with gravity at $\sim 10^5$ GeV scale</td>
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<td>$p \rightarrow e^+ \pi^0, p \rightarrow \bar{\nu}K^+$, etc.</td>
<td>$n \rightarrow \bar{n}, \nu_R, 2\beta 0\nu, n \rightarrow 3\nu$, etc.</td>
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Reflecting these changes, future HEP program should include experimental searches for $n \rightarrow \bar{n}$.