

## Research Report

### ICRR Inter-University Research Program 2022

Research Subject: Search for the nucleon decay including multi pions in Super-Kamiokande

Principal Investigator: Jee-Seung Jang (Gwangju Institute of Science and Technology)

Participating Researchers:

1. Ryeong-Gyoon Park (Chonnam National University)
2. Dong-Ho Moon (Chonnam National University)
3. Min-Cheol Jang (Chonnam National University)

Summary of Research Result: For this research, proton decay to e or muon plus two neutral pions were searched in Super-Kamiokande detector. There is no report for the lifetime of these after IMB-3 experiment. Since neutral pions decay to two gamma, we should find the signal maximum 5 cherenkov rings. We finalized the event selection for this search as follows and we doesn't observe significant data excess beyond expected atmospheric neutrino MC background. The results are summarized the following table.

Cut parameter	Cut condition	
	$p \rightarrow e^+ \pi^0 \pi^0$	$p \rightarrow \mu^+ \pi^0 \pi^0$
FCV	wall $\geq$ 200 cm evis $\geq$ 30 MeV nhitac $\leq$ 15 ( $\leq$ 9 for SK1)	
Number of rings	nring = 3, 4, 5	
PID	All e-like ring	1 $\mu$ -like ring
Michel electron	No Michel electron	1 Michel electron
Tagged neutron	No tagged neutron (for SK4 and SK5)	
Total invariant mass	$800 \leq M_{\text{tot}} \leq 1050 \text{ MeV}/c^2$	
Total momentum	$P_{\text{tot}} \leq 200 \text{ MeV}/c$	

[table 1] Event selection criteria for proton decay to e or muon and neutral pions.

$p \rightarrow e^+\pi^0\pi^0$	SK1	SK2	SK3	SK4	SK5	SK1-5
Livetime [days]	1489.2	798.6	518.08	3244.4	461.02	6511.3
# of candidates	0	1	0	0	0	1
Signal eff. [%]	19.16	16.43	19.80	18.27	19.08	18.45
Signal syst. err [%]	9.9	12.2	13.5	8.9	13.1	10.3
Bkg. rate [exposure]	0.17	0.10	0.07	0.13	0.02	0.49
Bkg. syst. Err [%]	42.7	48.6	34.0	45.7	53.1	45.2
Lifetime limit	7.2×10 <sup>33</sup> years (90% C.L.)					
$p \rightarrow \mu^+\pi^0\pi^0$	SK1	SK2	SK3	SK4	SK5	SK1-5
Livetime [days]	1489.2	798.6	518.08	3244.4	461.02	6511.3
# of candidates	0	0	0	1	0	1
Signal eff. [%]	11.69	9.84	11.66	13.89	14.13	12.8
Signal syst. err [%]	12.3	13.2	11.2	12.4	12.7	12.4
Bkg. rate [exposure]	0.41	0.19	0.11	0.17	0.02	0.9
Bkg. syst. Err [%]	22.7	29.1	26.3	30.2	28.3	28.1
Lifetime limit	4.5×10 <sup>33</sup> years (90% C.L.)					

[Table 2] The results for lifetime calculation of proton decay.

No. A002