Search for Proton Decay via $p \to e^+\eta$ and $p \to \mu^+\eta$ in Super-Kamiokande

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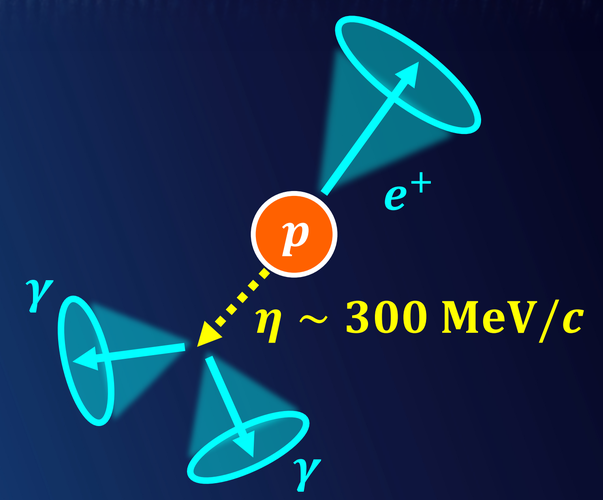
Proton Decay – Key to Probe GUTs

- Grand Unified Theories permit baryon-number-violating proton decay [1].
- Super-Kamiokande (SK), a water Cherenkov detector, leverages numerous proton targets to probe various decay channels [2]:
  $p \to l^+\eta$ $(l^+ = e^+/\mu^+)$ exhibits one of the highest detection efficiencies.
- This work incorporates improved estimations of intranuclear η interaction cross sections and includes ~15% more data than previous analysis [3].

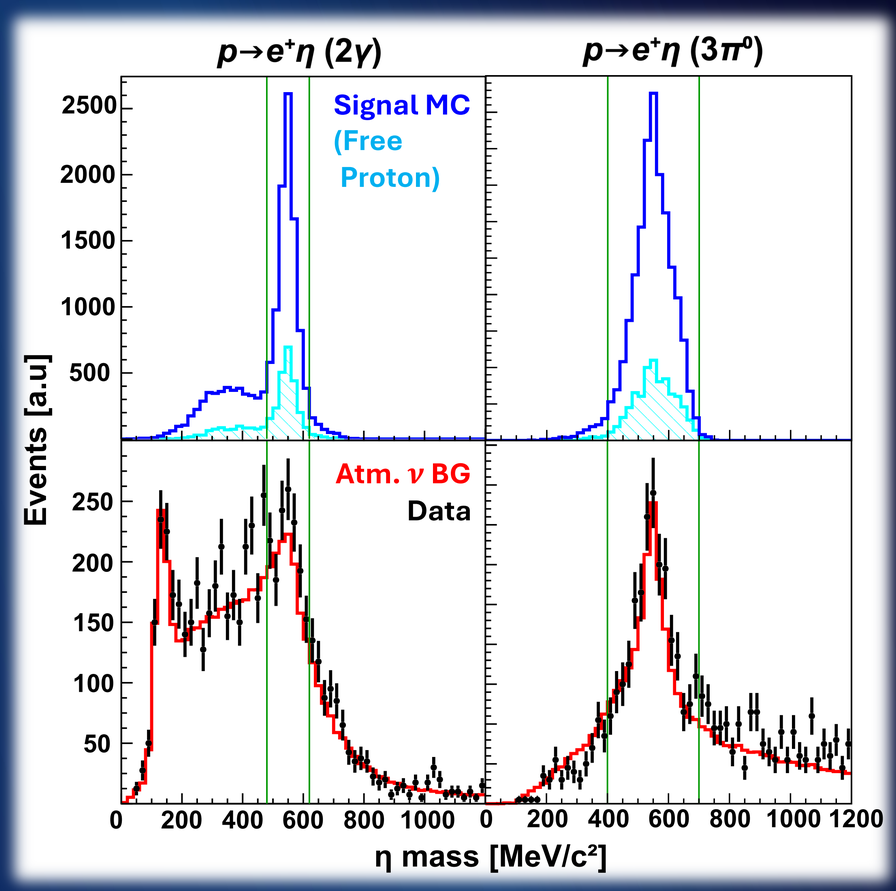


Event Selections at Water Cherenkov Detector

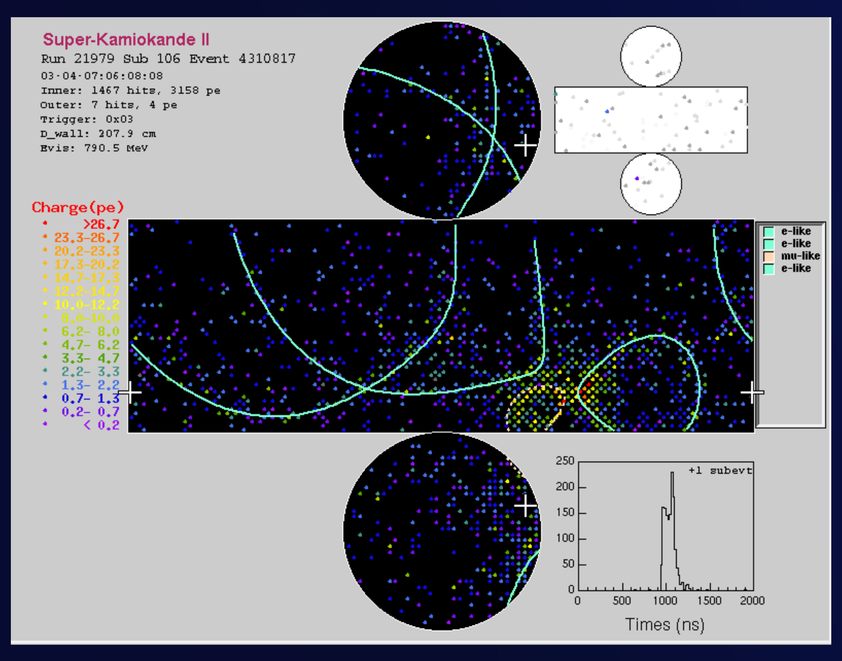
- η Decay Modes: $\eta \to 2\gamma$ (39%) & $\eta \to 3\pi^0$ (33%).
- SK detects e/γ as fuzzy rings, and μ as a ring with sharp edges.
- **Event selection cuts on reconstructed invariant masses of η and p, and p momentum** effectively identify signals from BGs.
- Backgrounds: π^0/η via atmospheric ν interaction on ^{16}O.

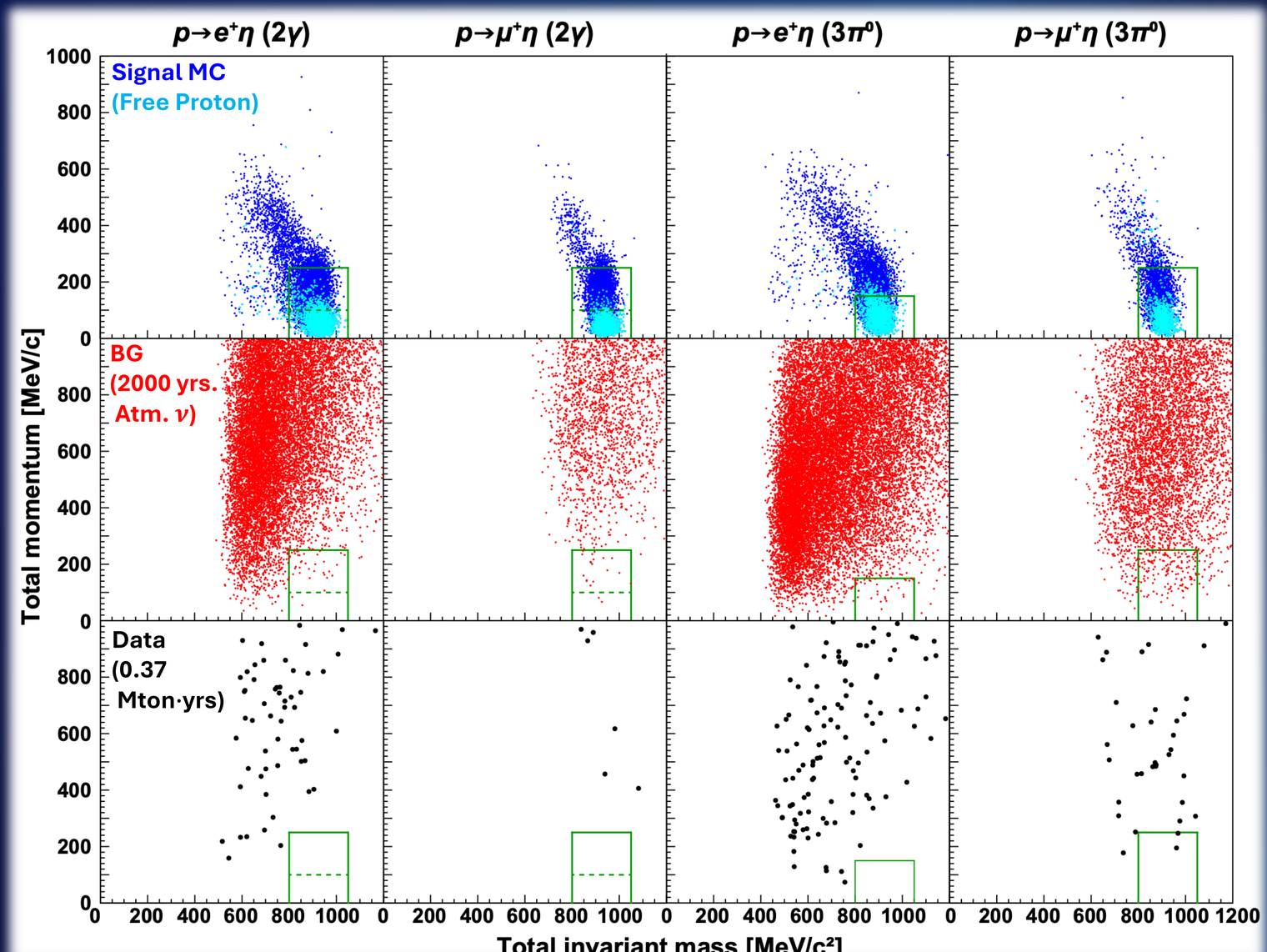
Search Results with World's Best Sensitivity

- Analysed over 0.37 Mton·years exposure of SK data.
- Updated nuclear effect led to improvements in signal efficiency (~10%) and a reduction in systematic uncertainty by a factor of 3.
- **2 candidates remain in the final signal region of $p \to \mu^+\eta, \eta \to 3\pi^0$ search. No significant data excess was observed above the expected background rate.**
- Sets most stringent limits on proton's lifetime for $p \to l^+\eta$ by ~50%.



Modes	$p \to e^+\eta$	$p \to \mu^+\eta$
Efficiency [%]	29.0 ± 4.6	24.2 ± 3.7
#Background	0.42 ± 0.13	0.93 ± 0.25
#Candidate	0	2
Lifetime Limit at 90% C.L.	**1.4×10^{34} years**	**7.3×10^{33} years**





References:

[1] P. Nath and P. Fileviez Perez, Phys. Rep. 441, 191 (2007).

[2] Y. Fukuda et al. (Super-Kamiokande Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A 737, 253 (2014).

[3] K. Abe et al. (Super-Kamiokande Collaboration), Phys. Rev. D 96, 012003 (2017).