Large Nucleon Decay and Neutrino Detectors in Asia

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Motivation of Nucleon Decay Searches



Ultimate Goals:

- ▶ Origin of the SM group structure $SU_C(3) \otimes SU_L(2) \otimes U_Y(1)$
- Origin of particle structure (quarks and leptons, 3 generation structure)

Strategy of nucleon decay exps

Theorists never guarantee the nucleon decays

1. find signal

1. hopefully find indications in Super-K, or next water Cherenkov detectors.

- 2. Measure branching ratio of various decay modes1. to identify details of unification picture, i.e. GUT scale, gauge group, other symmetries2. by fancy detectors?
- 3. Need bread and butter in each step
 - 1. neutrino oscillation experiment
 - 2. astro-particle physics

Detector requirement 1. Big, Big, Big (w/ reasonable cost) 2. high resolution, tracking capability



Activities related to nucleon decay searches in Japan

- Water Cherenkov
 - Super-Kamiokande (running)
 - Hyper-Kamiokande
- Liq. Argon TPC

Ongoing experiment Super-Kamiokande



$ve + N \rightarrow = + N'$



$\nu\mu + N \rightarrow \mu + N' + \pi$



Detector performance

- good tracking especially at 1GeV or less
 - nucleon decays
 - accerelator v (ex ~0.6GeV in T2K)
- particle identification capability > 99%
- Energy resolution for e and $\mu \sim 3\%$
- Energy threshold ~5MeV
 - solar v, Supernova v, muon decay electrons, nuclear de-excitation γ

Advantage of nucleon decay source

- 20% protons are Hydrogen
 - Free from nuclear binding energy, Fermi motion, pion's final state interaction
 - High, accurate efficiency for free proton decay!
- Construction, Operation, Performance are well established
 Rich physics topics

$p \rightarrow e^+ + \pi^0$ searches



 $p \rightarrow e^+ + \pi^0$

- detection efficiency = 45%
- atmospheric v BG = 2.1 ± 0.3 (stat.) ± 0.8 (syst.) (Mton×years)⁻¹
- $\tau_{proton}/Br > 1.3 \times 10^{34}$ years @ 90%CL
- ▶ For Future
 - ▶ PMT coverage can be reduced to 20% (half of SK)
 - ▶ Further reduction (optimization) is under way.

Other lepton+meson modes

- many models predicts braching ratio of $p \rightarrow e^+\eta$, $e^+\rho$, $e^+\omega$ are 10~20%
- Flipped SU(5) (Ellis) predicts $Br(p \rightarrow e^+\pi^0) \sim Br(p \rightarrow \mu^+\pi^0)$



TABLE V. Summary of the nucleon decay searches



 $p \rightarrow v + K^+$

- 220 kton×years exposure (SK-I+II+III+IV)
- $\tau_{proton}/Br > 4.0 \times 10^{33}$ years @ 90%CL

Experimental limits



Schematic view of Hyper-Kamiokande



Hyper-Kamiokande candidate site



- ♦ 8km south from Super-K
 - ✦ same T2K beam off-axis angle
- \blacklozenge 2.6km horizontal drive from entrance
- ♦ under the peak of Nijuugo-yama
 - ♦ 648m of rock or 1,750 m.w.e. overburden
 - \bigstar 508m above sea level

✦ dominated by Hornblende Biotite Gneiss and Migmatite

 \Rightarrow 2.3km from waste rock disposal place

♦ 13,000 m³/day or 1megaton/80days natural water







Hyper-K timetable



Feasibility Study

- Extensive Feasibility Study is going on
 - Global geological survey for rock/fault distributions, rock properties
 - Analysis for twin cavities
- Optimization/Confirmation is necessary for other components
 - water sealing, PMT support structure, PMTs, DAQ, water, purification system

- to make a realistic design, construction cost and period estimation

Proton Decay

- explore quark/lepton unification -



x20 Larger Target

Photo-Detectors

Quest for CPViolation in lepton sector

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JPARC

<u>36°24'46.66" N 139°18'01.27" E 標高 214 メートル</u>

Hyper_K

Super-K

~0.6GeV

295km

Higher Intensity

COOSIC COOSIC

Compare electron appearance (number and spectrum) in ν and anti- ν beam



CPV discovery potential

CP δ value for which we can exclude CP conserving hypothesis.



Mass hierarchy is assumed to normal, and known.

MR Power Improvement Scenario toward MW-class power frontier machine — KEK Roadmap —

	Day1 Achieved ! (up to Mar.2011)	Next Step	KEK Roadmap
Power(MW)	0.145	0.45	>1.66
Energy(GeV)	30	30	30
Rep Cycle(sec)	3.04	2.2	1.92~0.5
No. of Bunch	8	8	8
Particle/Bunch	1.2×10 ¹³	2.5×10 ¹³	4.1~8.3×10 ¹³
Particle/Ring	9.2×10 ¹³	2.0×10 ¹⁴	3.3~6.7×10 ¹⁴
LINAC(MeV)	181	181	400
RCS	h=2	h=2	h=2 or 1

Combination of **High rep. cycle** and **High beam density R&D for Power Supply, RF, and funding are necessary**



Hyper-K years

Good chance if θ_{23} and θ_{13} are large

Other Physics

- high statistical solar ν
 - short term time variation?
 - solar physics
- Supernova v
 - >100,000 ν events for SN at Galactic center
 - stellar collapsed, explosion mechanism
 - mass hierarchy?
 - relic SN v (w/ Gd?)
- indirect WIMP search, solar flare v...

Gigantic Liq. Argon TPC detector



• on-axis of JPARC ν beam



 \rightarrow Extract δ_{CP} from fit of Ist & 2nd maximum



R&D toward realizing 100kt LArTPC



Summary

- Next generation nucleon decay and neutrino detectors will cover rich physics topics
 - Nucleon Decay to explore unification
 - full picture of ν masses and mixings
 - various astroparticle physics objects
- Two directions under discussions in Japan
 Hyper-Kamiokande to achieve Megaton mass w/ improved efficiency and BG rejection
 Liq. Argon TPC to achieve excellent tracking and resolution