Impression of NNN05

Kenzo NAKAMURA
KEK

April 7-9, 2005
NNN05
Aussois, Savoie, France
History of NNN Workshop

- NNN99, Stony Brook: Initiated by CKJ
- NNN00, UC Irvine: mini-workshop
- NNN00, Fermilab: mini-workshop
- NNN02, CERN
- NNN05, Aussois

The NNN steering committee has decided to organize NNN Workshop each year. Announcement of NNN06 and NNN07 at the end of this talk.
Science with large underground detectors

Neutrino physics
- w/ accelerator-produced beam
  - LBNO, VLBNO
  - $\theta_{13}, \text{sign}(\Delta m_{23}^2), \delta_{CP}$, precision measurement of $(\theta_{23}, \Delta m_{23}^2)$
- wo/ accelerator-produced beam
  - solar $\nu$, atm $\nu$, $\nu$ burst from SN, Relic SN $\nu$

Nucleon decay
- $p \rightarrow e^+\pi^0, \nu K^+, \text{other decay modes}$

Most of large detectors are multi-purpose
- Water Cherenkov ($\sim$Mton)
- Liq. Ar ($\sim$100 kton)
- Liq. Scintillator ($\sim$50 kton)
Next-generation water Cherenkov detectors

Conceptual idea of next-generation water Cherenkov detectors

1999: Concept of UNO & Hyper-K
2002?: Concept of the European detector

Time line of each detector

UNO @ Henderson Mine
- DUSEL proposal: 2005
- Construction: 10 years, wish to start as soon as possible

Hyper-K @ Tochibora Mine (Kamioka)
- Some years after start-up of T2K-1
- Construction: 10 years, hopefully 2013 - 2022

European detector @ Frejus Tunnel
- CERN-based Super and beta beams hopefully ready before 2020
- Construction: hopefully 2010 - 2019 (first module 2017)
DUE and TRE have a choice to put Gd in one module in order to enhance the sensitivity to low-energy antineutrino detection.

See, an interesting talk by Vagins on GADZOOKS
LBNO: each detector has its own project
- UNO-BNL or UNO-Fermilab: 1500 – 2800km
- HyperK-J-PARC: 295 km
- European detector-CERN super and beta beams: 130 km
T2K Phase 2

Long baseline neutrino oscillation experiment from Tokai to Kamioka.

Super-K: 50 kton Water Cherenkov

~1GeV $\nu_\mu$ beam ($\times 100$ of K2K)

J-PARC 0.75MW 50GeV PS

Kamioka

295km

Phase2: Hyper-K

Phase2: 4 MW?
CERN to Frejus: Super and Beta Beams


M. Lindroos et al., see http://beta-beam.web.ch/beta-beam
LBNO: each detector has its own right

- UNO-BNL or UNO-Fermilab: 1500 - 2500 km
- HyperK-J-PARC: 295 km
- European detector-CERN super and beta beams: 130 km

Nucleon decay:

- Reach of the lifetime limit improves as the summed fiducial masses of individual detectors.
- Should have at least one detector, if nucleon decay is really around the corner.
- Here, world-wide collaborative effort to realize at least one, hopefully all, next-generation water Cherenkov detectors is very relevant.
Next generation ~100 kton liq. Ar detector

Rubbia
Next-generation liq. Scintillator detector

LENA

A large (~50 kton) liquid scintillator underground detector

Muon veto

~12000 Pms (50cm)

Possible locations

Oberauer

CENTRE FOR UNDERGROUND PHYSICS IN PYHÄSALMI MINE
Back to the Science
Nucleon decay

Reach of partial lifetime

- $p \rightarrow e^+ \pi^0$ up to $\sim 10^{35}$ yrs with $\sim$Mton water Cherenkov (present SK limit: $5.4 \times 10^{33}$ yrs)
- $p \rightarrow \nu K^+$ up to $\sim$ a few $\times 10^{34}$ yrs with $\sim$100 kton liq. Ar and $\sim$50 kton liq. scintillator (present SK limit: $2.0 \times 10^{33}$ yrs)

There is a lot of life in proton decay

It is possible to suppress the decay rate, but in many cases proton decay is just around the corner:

Next step is significant!
Proton Decay in ‘Flipped’ SU(5) × U(1)

- Similar modes to conventional SU(5): different branching ratios, no Higgsino exchange
- SU(3) and SU(2) unify below usual GUT scale
- Enhanced rate in strongly-coupled M theory
Lifetime accessible to Experiment?

Lifetime in benchmark scenarios

Lifetime in best fits

K. Nakamura      NNN05, Aussois, April 7-9, 2005

JE + Nanopoulos + Walker
UNO Proton Decay Sensitivity and Updated Theoretical Predictions ($e^+\pi^0$)

- IMB/Kamiokande
- SuperK in 10 years
- UNO in 10 years

Non-SUSY SU(5)

$10^{30} \rightarrow 10^{31} \rightarrow 10^{32} \rightarrow 10^{33} \rightarrow 10^{34} \rightarrow 10^{35} \rightarrow 10^{36} \rightarrow 10^{37}$

- Two-step Non-SUSY SO(10)
- Complete 5D SU(5)
- String Theory 6D–Branes
- Three Family Heterotic String Model

- MSSM SU(5)
- Flipped SU(5)
- Split multiplets
- MSSM SO(10)
- Fermion mass correlated
- MSSM SO(10)–generic
- Extra dimension at GUT scale

Chang Kee Jung
Neutrino parameters

Recent years have been exciting ...
but our knowledge is still poor:

- kinematical unknowns: $\theta_{13}$, CP violation, mass hierarchy, absolute mass
- dynamical unknowns: new neutrino properties and/or interactions (LSND?)
- theoretical unknowns: making sense of parameters, finding underlying symmetries and scales
Neutrino physics w/ accelerators

News
- MINOS: 1st far detector beam neutrino, March 7, 05. Congratulations!

Status
- CNGS (OPERA and ICARUS)
- T2K

Future
- BNL
- Fermilab (NOvA)
- CERN (Beta beams, Super beams)
Physics potential of VLB

MC simulation with fermi motion, detector resolution and physics backgrounds for $L = 2540$ and $1290$ km. M. Diwan, hep-ex/0407047:

**BNL beam $L = 2540$ km**

**BNL beam $L = 1290$ km**

---

K. Nakamura       NNN05, Aussois, April 7-9, 2005
Beta Beam ($\gamma = 100, 100$) performances

$\theta_{13}$ sensitivity (90% CL)

5 years run

- CHOOZ excluded
- CNGS combined
- $\beta\beta$ Disappearance
- BNL
- T2K
- SPL-SB 3.5 GeV
- SPL-SB 3.5 GeV + $\beta\beta_{90,100}$

$\delta_{CP}$ discovery potential (3$\sigma$)

10 years, 5 $\nu_e + 5 \bar{\nu}_e$

$\gamma = 150$ curve with the tentative new $\gamma$-flux relation

- $\gamma=100, L=130$ km
- $\gamma=150, L=300$ km
- $\gamma=100 +$ SPL 3.5 GeV
Combined analysis of LBL and ATM data provides an interesting method to resolve degeneracies

Identifying the mass hierarchy

T2K-2: 2Mt/yr $\nu$ and 6Mt/yr anti-$\nu$
HK 9Mt.yr ATM $\nu$ data assumed

solid: LBL-only, dashed: ATM-only, shading: LBL+ATM
Non-accelerator neutrino physics w/ Mton water Cherenkov

Kajita

- Neutrino oscillation measurements with atmospheric neutrinos: $\theta_{13}, \text{sgn}(\Delta m_{23}^2)$, sub-dominant osc., CP phase

Nakahata

- Measurements of low-energy neutrinos
  - $^8$B Solar neutrino measurements
  - Neutrino burst from Supernova explosion
  - Relic supernova neutrinos
Relic SN neutrinos
--- Very encouraging ---

- SK data \(<1.2 \text{ cm}^{-2}\text{s}^{-1}\) for \(E_{\nu} > 19.3\) MeV
- It is just above the prediction using reasonable models (1.1 cm\(^{-2}\)s\(^{-1}\))!
- 5\(\sigma\) detection would be possible with a Mton water Cherenkov.
- With Gd loaded water, 300 ev/yr expected.
Back to the detector
Detector R&D

- R&D items (for big water Cherenkov)
  - Through physics studies and simulations, identify necessary photocathode coverage for each physics objective.
  - Site study and cavity design
  - Technology of sealing water tanks and supporting photo-sensors
  - Develop low-cost photo-sensors.

- Inter-regional coordination of R&D efforts desirable.

Nakagawa, Petersen (CKJ), Levy, Duffault

Aihara, Ferenc, Pouthas, Birkel, Flyckt, Caracciolo, Wright
Outcome of round-table discussion

- Inter-regional coordination, mostly on R&D.
  - Water-Cherenkov (three regions)
  - Liq. Ar
  - Liq. scintillator
- Try to set collaboration on different items of R&D with common interest.
- Find one person per region to arrange MOU and to connect respective community and agency.
- NNN workshop will be the place for interested community to meet and discuss each year toward realization of next-generation of nucleon-decay and neutrino detectors.
Concluding remarks

- There are a number of exciting physics which can be addressed with the next-generation underground detectors.
- And, there are a number of ideas toward realization of such detectors. All ideas are still at the R&D stage.
- Whichever ideas would be realized in future, some kind of coordination of R&D efforts on items with common interest is very relevant.
- It is a significant outcome of NNN05 that inter-regional coordination in these lines has been agreed.
Next NNN

- We are asked to organize next NNN in Japan. Our proposal is
  - NNN07
    - October 2007, Hamamatsu, Japan
- But, it is 2 years and half ahead from now. Therefore, it is necessary to organize NNN06 in between NNN05 and NNN07
  - Sometime in 2006, in U.S.
  - To be announced later.
Tentative Plan of NNN07 in Japan

Date: October 2 – 5, 2007
Place: Hamamatsu, Japan
  Convention Center “Act City Hamamatsu”

Program
  Oct. 2: Registration and Reception
  Oct. 3 – 5: Academic sessions
  Afternoon of Oct. 5: Visit to a Research Laboratory or a Electron-tube factory of Hamamatsu Photonics Inc.
Message from the Local Organizing Committee

LOC thanks to

- Isabelle, Roxanne, and Sandrine (Secretaries)
- Luigi Mosca for night adventure and
- All speakers for their excellent talks