Majorana Neutrino Searches at ILC

1. Japanese HEP Roadmap
2. ILC Activity in KEK
3. ILC: First Priority for Next Lepton Collider
4. Majorana Neutrino Searches at ILC
5. Summary

Atsuto Suzuki
1. Japanese HEP Roadmap

in 2007
In 2008

Birth-Evolution of Universe

International Linear Collider (ILC)

Scientific Activities
- Technology Innovation
- Talented Human Resources

Beyond Standard Physics
- Lepton CP Asymmetry
- Beam Power-Upgrade
- J-PARC

Operation Power-Upgrade
- LHC

Quest for
- Neutrinos
- 6 Quarks
- 3

Higgs Particle [Origin of Mass]

[Origin of Force]

[Origin of Matter]
In 2009

SuperKEKB vs. SuperB in Italy

“matter-dominated universe plan”
or
“β vs. VHS plan”
Early Universe

```
<table>
<thead>
<tr>
<th>matter</th>
<th>anti-matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000,000,001</td>
<td>1,000,000,000</td>
</tr>
</tbody>
</table>
```

Present Universe

```
<table>
<thead>
<tr>
<th>matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>q</td>
</tr>
</tbody>
</table>
```
“β vs. VHS plan”

Early Stage of Market Share for Video-Tapes

Anti-Darwinism Evolution

Final

10,000,000,001

VHS

10,000,000,000

β
“SuperKEKB vs. Italian Super-B plan”

Present Super-B Factory

Early Approval of Budget

10,000,000,001

10,000,000,000
In 2010

**KEKB to SuperKEKB: current status**

- KEKB operation finished at 9:00 am June 30, 2010

SuperKEKB budget is partially approved:
- Damping ring: 580M yen (~5.8M$) (FY2010)
- Special budget "Very Advanced Research" 1B yen (~100M$) (FY2010-2012)

⇒ Start construction (FY2010-2012)

KEKB to be upgraded to SuperKEKB with $\mathcal{L} = 8 \times 10^{35} \ (40 \times \mathcal{L}_{\text{KEKB}})$

$\int \mathcal{L} = 50 \text{ ab}^{-1}$

To get x40 higher luminosity
Luminosity upgrade projection

Milestone of SuperKEKB

9 month/year
20 days/month
We will reach 50 ab\(^{-1}\) in 2020-2021.

Commissioning starts mid of 2014

Shutdown for upgrade
Recovery Plan

2011

[Diagram showing timelines for APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC, JAN, FEB, MAR for Tokai Campus, Infrastructure, LINAC, RCS/MR, MLF/Hadron/Neutrino with respective inspection, repair, power test, and beam tuning & delivery dates in 2011 and 2012]

2012

[Dates include 12/12 for specific tasks]
Power Upgrade Plan of RCS/MR

- **Power Achieved:**
  - 200 kW (achieved)
  - 145 kW (achieved)

- **Shutdowns:**
  - Shutdown due to the earthquake
  - 3 month summer shutdown

- **Improvements:**
  - New injection kicker
  - Ring collimator shields
  - RF (6th fundamental, 2nd higher harmonics)

- **Upgrade Plans:**
  - Original power upgrade plan of RCS:
    - 7 month summer/autumn shutdown for installation of ACS, new RFQ and IS.
  - Expected MR power

- **Graph:**
  - J-PARC Power Expectation
  - MR improvements
  - RCS power

- **Timeline:**
  - 2008 to 2014
  - 2011 to 2013

- **Additional Notes:**
  - 3 month summer shutdown
  - 2012
  - 2013
2. ILC Activity in KEK

International Linear Collider

~ 1km

30~50 km

Cheer - Party
**ATF: Accelerator Test Facility for ILC**

- Generate Low Emittance Beams
- Handle Nano-Size Beams
Plug compatibility of SCRF system was successfully demonstrated by international collaboration.
Two Candidate Sites in Asia/Japan

- Japanese Mountainous Sites -

- GDE-CFS group visited two sites, Oct., 2011
ICFA Point of View of Situation and Plans for Period 2011-2012-Post for ILC

Atsuto Suzuki

(KEK: High Energy Accelerator Research Organization)
Biggest decision of the decade!

- ILC Enough
  - By far the easiest!
  - A Global program

- LHC Results

- ILC not enough

- CLIC

- Muon collider

P Oddone, Fermilab Users Meeting, June 3, 2010
Biggest decision of the decade!

- ILC Enough
  - By far the easiest!
  - A Global program
- LHC Results
  - or
- ILC not enough
  - ILC: First Priority!

LHC Results: Just Highlighting ILC Physics
Discoveries:
Higgs, ....... from LHC

There is luck in leisure.

果報は寝て待て
Luck comes during sleeping
Discoveries:
Higgs, ....... from LHC
Nothing from LHC

No New Physics from LHC

World Theorists

theory

rush heading at

LHC
theory

LHC

Physics in $E < \text{TeV}$
ILC : First Priority for Next Lepton Collider

No Higgs !

No !

No SUSY !

No !

No !

No !

ILC : Indirect option

ILC : Z₀ factory (GigaZ option)

ILC : Top factory
4. Majorana Neutrino Searches at ILC

Monte Carlo Program: GRACE

Majorana Neutrinos

1. Model

- $SU(2)_L \times SU(2)_R \times U(1)_{B-L}$
- Gauge boson masses on $SU(2)_L \times SU(2)_R$ are degenerated: $m_{W^\pm} = m_{W'^\pm}$.
- Neutrinos are Majorana particles.
- A mass of left-handed neutrino is light: $m_{\nu_L} \ll \mathcal{O}(\text{eV})$.
- A mass of right-handed neutrino is heavy: $m_{\nu_R} \geq \mathcal{O}$(weak scale).
- A $W^-$ pair-production occurs through a right-hand electron-neutrino.
- A CM-energy is 200 GeV.
- Cut: $30^\circ < \theta_\mu < 150^\circ$, $E_\mu > 10$ GeV
- We assume a signal is background-free.
- Total cross sections in fb are shown in Figure 1.
- We can expect about 100 events for 1 TeV $\nu_{eR}$-mass after accumulating 100 fb$^{-1}$. 

$E_{CM} = 200$ GeV
A $W^-$ pair-production occurs through a right-hand muon-neutrino.

A mass of a right-hand muon-neutrino is set to be the same as a $W$-boson mass.

Cut: $30^\circ < \theta_\mu < 150^\circ$, $E_\mu > 10$ GeV

We assume a signal is background-free.

Total cross sections in fb as a function of a CM-energy are shown in Figure.

We can expect about 45 events at a CM-energy of 1 TeV after accumulating 100 fb$^{-1}$. 

45 events / 100 fb$^{-1}$
Beam Polarization: Discriminate 2 Reactions

Recent achievement at SLAC
Inverse neutrinoless double $\beta$ decay reexamined

G. Bélanger, 1 F. Boudjema, 1 D. London, 2 and H. Nadeau 3

1 Laboratoire de Physique Théorique ENSLAPP Chemin de Bellevue, Boîte Postale 110, F-74941 Annecy-le-Vieux, Cedex, France
2 Laboratoire de Physique Nucléaire, Université de Montréal, C.P. 6128, Montréal, Québec, Canada H3C 3J7
3 Physics Department, McGill University, 3600 University Street, Montréal, Québec, Canada H3A 2T8

(Received 6 September 1995)

We critically reexamine the prospects for the observation of the $\Delta L = 2$ lepton-number-violating process $e^- e^- \rightarrow W^- W^-$ using the $e^- e^-$ option of a high-energy $e^+ e^-$ collider (NLC). We find that, except in the most contrived scenarios, constraints from neutrinoless double $\beta$ decay render the process unobservable at an NLC of $\sqrt{s} < 2$ TeV. Other $\Delta L = 2$ processes such as $\gamma \gamma \rightarrow \ell^+ \ell^+ W^- W^-$, $e^- \gamma \rightarrow \nu_\ell \ell^- \ell^- W^+$, $e^- e^- \rightarrow \nu_\ell \nu_\ell \ell^- \ell^- (\ell = \mu, \tau)$, and $e^- \gamma \rightarrow e^+ W^- W^-$, which use various options of the NLC, require a $\sqrt{s}$ of at least 4 TeV for observability. [S0556-2821(96)00611-X]
Thinking, Thinking,,,,, Neutrino Physics at ILC

ILC is the next lepton collider option
World $\theta_{13}$ Race: Overheating!

$\sin^2 2\theta_{13}$ sensitivity (90% CL)

$\delta_{CP} = 0$

$\Delta m^2_{31} = 0.0025 \text{ eV}^2$

Time is Money

[Reference]
NOvA: M. Messier, FNAL Director's CD-3b Review, 2009/6/16
Daya Bay: P. Rubin, ibid