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May 30, 2001
@JHF-SK ν workshop

Physics reach of JHF-Kamioka ν experiment
- Summary and Discussions -

- Physics goals of future neutrino experiments
- Examination of the experimental approach

  Background suppression (S/N ratio)

  Statistical sensitivity

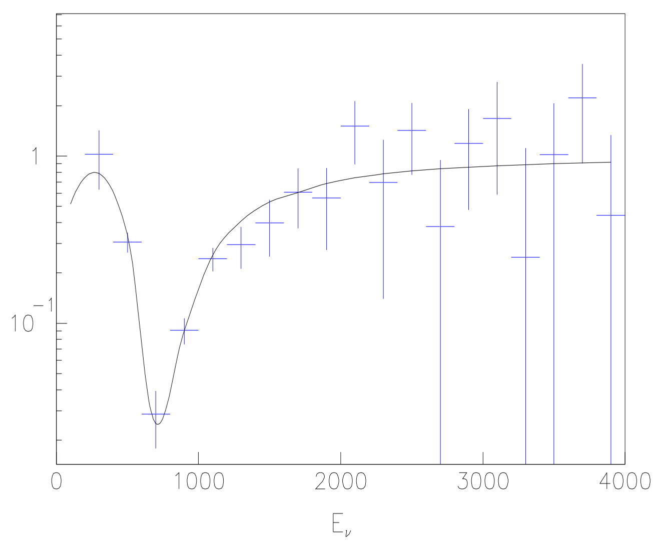
  Systematic Uncertainties

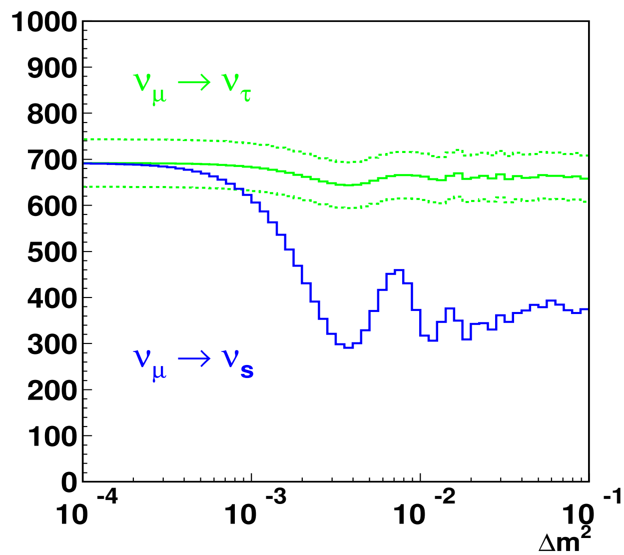
  Feasibility
- Physics requirements

  Introduction to the discussions tomorrow

Physics goals of future neutrino experiments

- **Establish the neutrino oscillation or discover physics beyond MNS (sterile ν)**
  - Oscillation pattern measurement **JHF-SK**
    ν_μ **disappearance-reappearance pattern**
  - ν_τ appearance (direct) e.g. OPERA
  - ν_τ appearance (NC measurement) **JHF-SK**



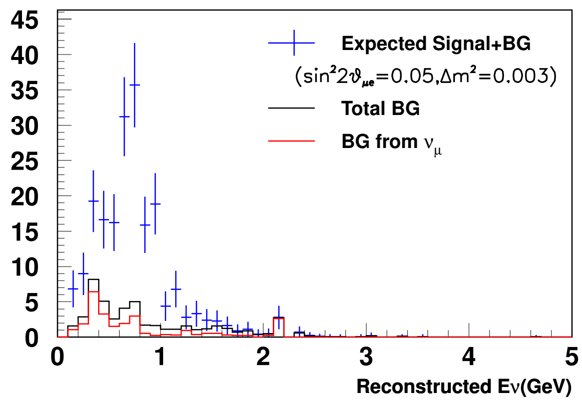


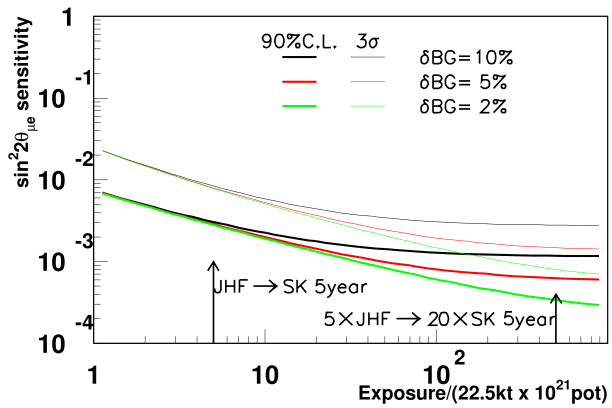
- **Atmospheric neutrino oscillation** $(\theta_{23}, \Delta m^2_{23})$
  - Precision measurement of the parameters **JHF-SK**
    An order of magnitude better precision:
    $\delta(\sin^2 2\theta_{23}) \sim 0.01$, $\delta(\Delta m^2_{23}) \sim 1 \times 10^{-4} eV^2$
  - Sign of Δm^2_{23} Future very long baseline experiment
    Measurement of the matter effect

- **Solar neutrino oscillation** $(\theta_{12}, \Delta m^2_{12})$
  - Establish the oscillation and fix parameters e.g.SK,SNO,Kamland

- **Search for θ_{13}**

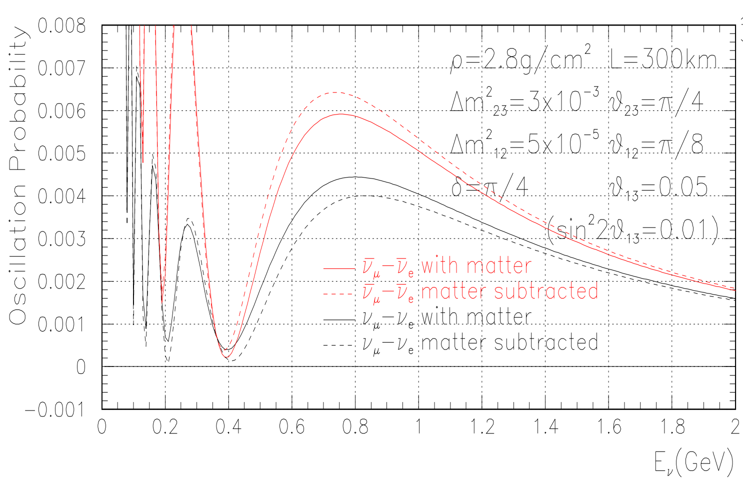
  – $\nu_\mu \to \nu_e$ appearance **JHF-SK**
  A factor of 20 improvement beyond CHOOZ limit
  $\sin^2 2\theta_{\mu e} \simeq 0.5 \sin^2 2\theta_{13} \simeq |U_{e3}|^2 > 0.003$

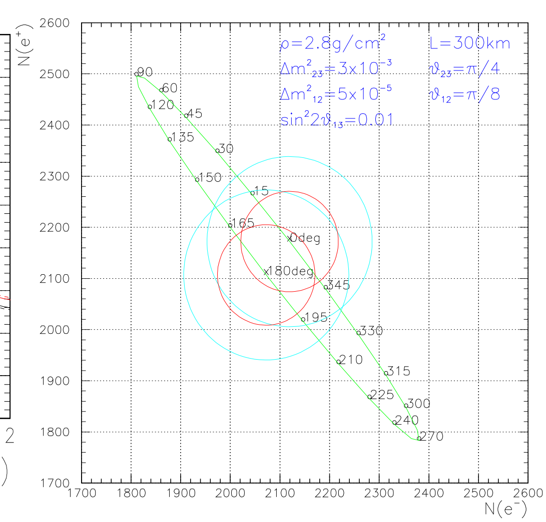




- **CP violation search**

  – $\nu_\mu \to \nu_e$ vs. $\bar{\nu}_\mu \to \bar{\nu}_e$ **JHF-HyperK**
  $|\delta| > 10 - 20°$ for most of the LMA parameter region.





- **LSND type neutrino oscillation**

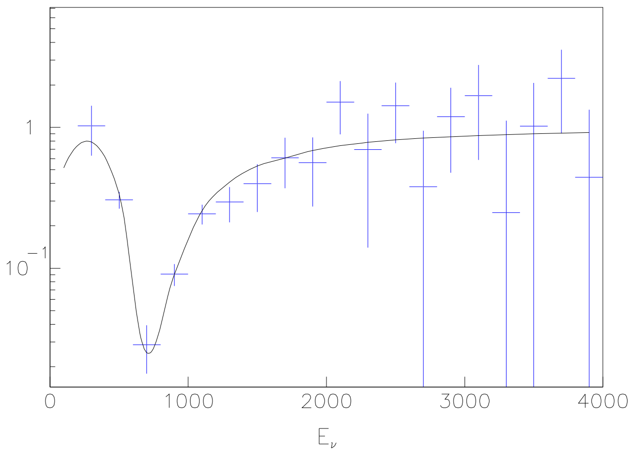
  – Short baseline $\nu_\mu \to \nu_e$ appearance miniBooNE

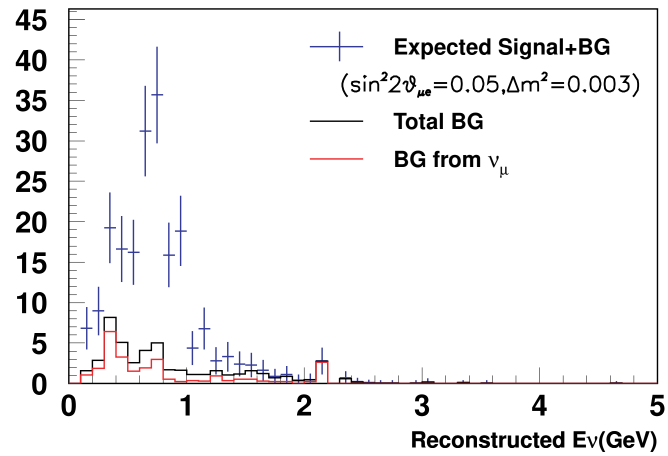
  – Detailed parameter studies if discovered **JHF-SK** ?

1. Background suppression (S/N ratio)

"Background" statistics limits at the sensitivity limits

$\Rightarrow$ Improvements in S/N linearly enhace the sensitivities:





+ non-QE backgr. (peak): 3%

+ resolution tail (peak): 3%

10% measurement

$\Rightarrow$ 0.6% in $\sin^2 2\theta_{\mu\tau}$

+ ν_e contamination: 0.2%

+ NC-π^0 background: 0.3%

50% measurement

$\Rightarrow$ 2.5×10^{-3} in $\sin^2 2\theta_{\mu e}$

How are these achieved?

- Signal enhancement: Oscillation maximum
- Excellent particle ID by water Čerenkov
  R(e/μ)∼500, R($NC(\pi^0)/e$)∼100
- E_ν reconstruction and the narrow band beam
  Background suppression by the E_ν window
- CP measurement: additional advantages at low energy
  - Enhancement of the asymmetry

$$A_{CP} = 1.27\Delta m^2_{12}\frac{L}{E}\cdot\frac{\sin 2\theta_{12}}{\sin\theta_{13}}\cdot sin\delta$$

  - Fake asymmetry due to matter effect is small

2. Statistical Sensitivity

- **Neutrino beam**
  High intensity narrow band beam at low energy

- **Neutrino yield** Y_ν: small dependence on E and L

$$Y_\nu = \Phi_{\nu flux} \cdot P_{\pi decay} \cdot \sigma_\nu \cdot P_{oscil}$$
$$\propto \frac{E^2}{L^2} \cdot \frac{1}{E} \cdot E \cdot \sin^2 \frac{1.27 \Delta m^2_{atm} L}{E}$$

- **Signal enhancement** at the oscillation maximum

Equivalent statistics for 10^{21} 50GeV-POT per 1kton detector

Beam	(GeV, km)	$\Phi_{\nu flux} \cdot P_{\pi decay} \cdot \sigma_\nu$	P_{oscil}	Y_ν	$Y_\nu \cdot P_{oscil}$
OAB2°	(0.7, 295)	100	1.0	100	100
WBB	(1.1, 295)	230	0.7	161	112
MINOS LE	(3.5, 730)	500	0.5	250	125
MINOS ME	(7.0, 730)	1830	0.15	274	41
MINOS HE	(15.0, 730)	3555	0.034	120	4

Further advantages:

- **Excellent background suppression** (good S/N)
- **Large fiducial mass** with Water Čerenkov
- **CP asymmetry** enhancement at low energy

3. Systematic Uncertainties

- **Signal enhancement and backgr. suppression**

  ν_μ disapperance: Systematics in normalization

  10% uncertainty $\Rightarrow 6\% \cdot 0.1 = 0.6\%$ in $\sin^2 2\theta_{\mu\tau}$

  ν_e disapperance: Systematics in BG subtraction

  20% uncertainty $\Rightarrow 0.25\% \cdot 0.2 = 5\times 10^{-4}$ in $\sin^2 2\theta_{\mu e}$

- **Cancellation of systematics**

  Far/near ratio (signal, background)

  Double ratio in CP measurement: $\frac{P_{\nu_\mu\to\nu_e}(far)}{P_{\nu_\mu}(near)} / \frac{P_{\bar\nu_\mu\to\bar\nu_e}(far)}{P_{\bar\nu_\mu}(near)}$

- **Monitorings and Checks of syetematics**

  Muon beam monitor: beam stability checks

  Monitor ν flux as a function of E_ν and θ_ν

  Constrain systematics in Far/near ratio

  BG estimation by events outside E_ν window.

- **Additional studies on syst. uncertainties**

  Hadron production measurements (HARP3?)

  ν cross section measurements using NBB

- **Redundancy**

  Positive ID of the signal by the oscillation pattern

4. Feasibilities

- JHF approved and in construction
- Far detector(Super-K) exists
- Existing beam technology (conventional ν beam)
- Full simulation/analysis proven by SK/K2K
- Realistic experimental requiements
  Systematics and background rejection
- Staging to Hyper-K/upgraded JHF
- Redundancies (oscillation pattern measurement)
- Step towards neutrino factory

Physics requirements

Excellent physics opportunity in the JHF-Kamioka project, yet studies of practical issues towards proposal has just started.

- High intensity primary proton
  - **Production target**
  - **Superconduction magnet**
  - **Transport beam optics**
- Optimization of the experiment (statistics,systematics)
  - **Near detector**
  - **Beam monitors**
  - **Beam configurations:** WBB,NBB,OAB
  - **Upgrade of the Super-Kamiokande**
  - **Constraining Far/near ratio**

There will be review and introductory talks in the morning followed by open discussions on these item tomorrow.

Please participate discussion during coffee breaks, dinner, and the open discussion session (1:30pm-4:00pm)