The observation of neutrino from J-PARC in Korea

Kenichi SENDA (GUAS/KEK)

Based on works with Kaoru Hagiwara(KEK)

Naotoshi Okamura(KIAS)

Contents

- 1,Introduction
- 2,T2K experiment
- 3,Observation at KOREA
- 4,Summary

1.Introduction

Many experiments observed neutrino oscillation!

- Solar neutrino ------ Super-Kamiokande, SNO etc
- Atmospheric neutrino ---- Super-Kamiokande
- Reactor neutrino ----- CHOOZ,KamLAND etc
- Accelerator neutrino --- K2K

3 neutrino model (with Majorana masses)

has 9 parameters.

3 masses : m_1 m_2 m_3

3 mixing angles and 3 CP phases

$$U_{MNS} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{i\delta} & 0 & \cos\theta_{13} \end{pmatrix}$$

$$\begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & & \\ & e^{i\varphi_2} & \\ & & e^{i\varphi_3} \end{pmatrix}$$

Neutrino oscillation experiments observe 6 parameters

$2\ \text{mass squared difference}: \delta m^2_{12}, \delta m^2_{13}$

$3\ \text{mixing angles}: \theta_{12}, \theta_{13}, \theta_{23}$

$1\ \text{CP Phase}: \delta$

Present parameter constraints

$$6.1\times10^{-5}\,\text{eV}^2 \le \delta m^2_{12} \le 8.4\times10^{-5}\,\text{eV}^2$$

$$1.7\times10^{-3}\,\text{eV}^2 \le \left|\delta m^2_{13}\right| \le 3.5\times10^{-3}\,\text{eV}^2$$

$$0.9 \le \sin^2 2\theta_{23} \le 1.0$$

$$0.33 \le \tan^2 \theta_{12} \le 0.49$$

$$\sin^2 2\theta_{13} \le 0.2$$

δ is unknown

2.T2K experiments

- T2K is neutrino Long base line experiments from J-PARC(Tokai village) to SuperKamiokande

- Neutrino beam flux is about 50 times of K2K
- Detector : Super-Kamiokande(22.5kt)
- Start experiment in 2009 (5 years)

- They search $\nu_\mu \rightarrow \nu_e$ mode.

$$(\sin^2 2\theta_{13} > 0.006)$$

- Some parameters are measured more precisely.

$$\delta(\delta m^2{}_{13}) \sim 0.1\times 10^{-3}\,\mathrm{eV}^2, \delta(\sin^2 2\theta_{23}) \sim 0.01$$

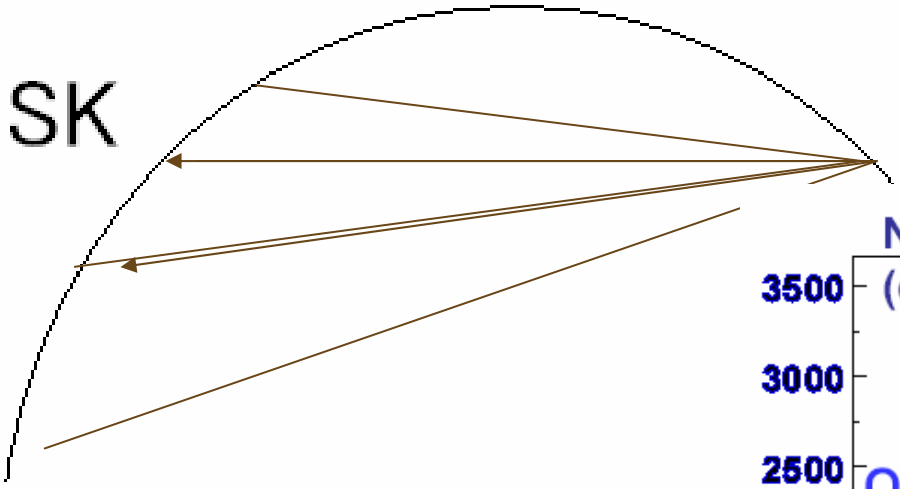
$$P(\nu_\mu \to \nu_e) \cong \sin^2 2\theta_{13} \sin^2 \theta_{23} \sin^2 \left(\frac{\delta m^2_{13}}{2E_\nu} L\right)$$

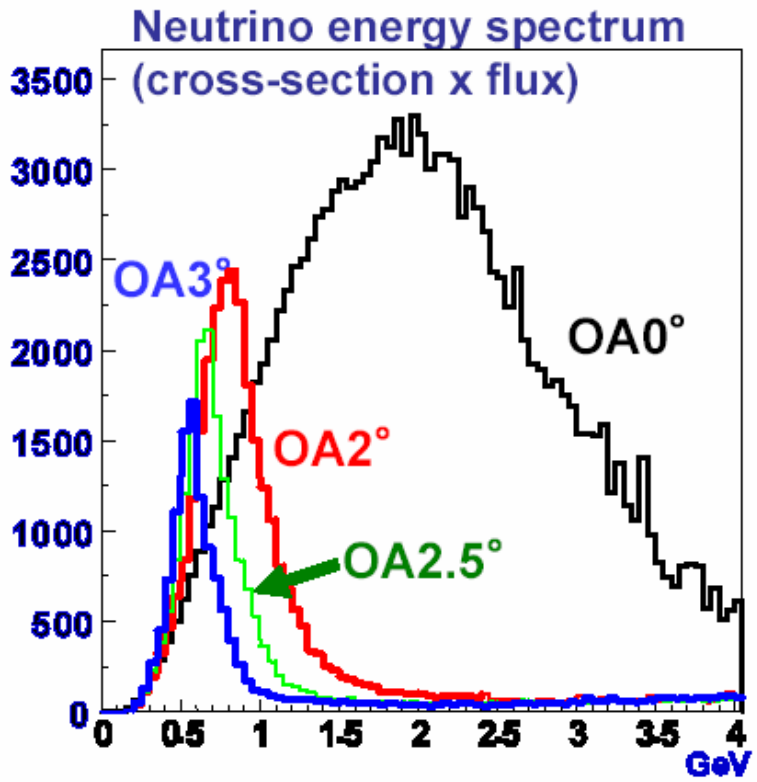
L and E are choose to be oscillation maximum.

- $L = 295$ km
- $1.7 \times 10^{-3}\,\mathrm{eV}^2 \le \left|\delta m^2_{13}\right| \le 3.5 \times 10^{-3}\,\mathrm{eV}^2$

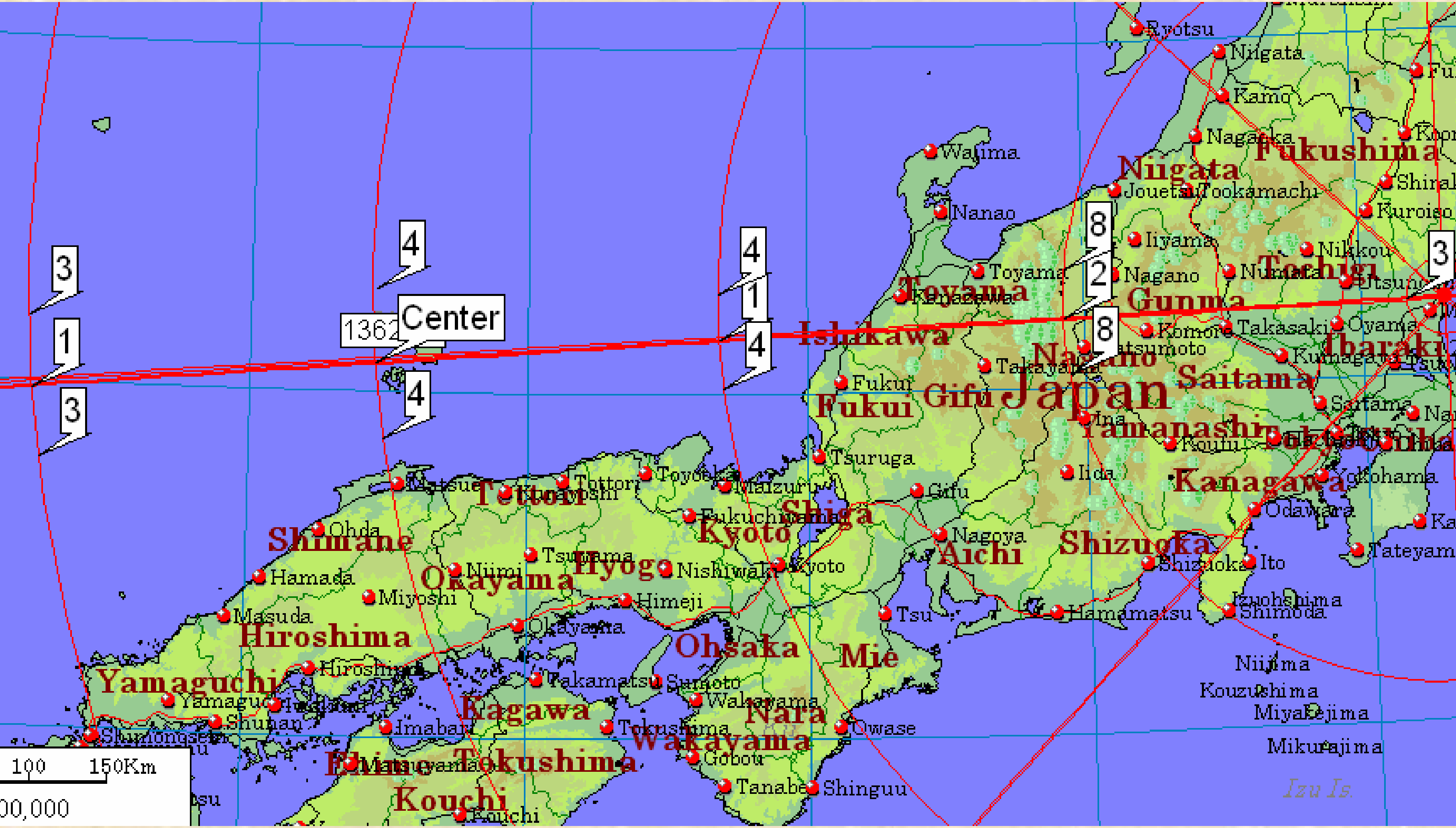
$$0.4GeV \le E_\nu \le 1.0GeV$$

•Off-Axis beam

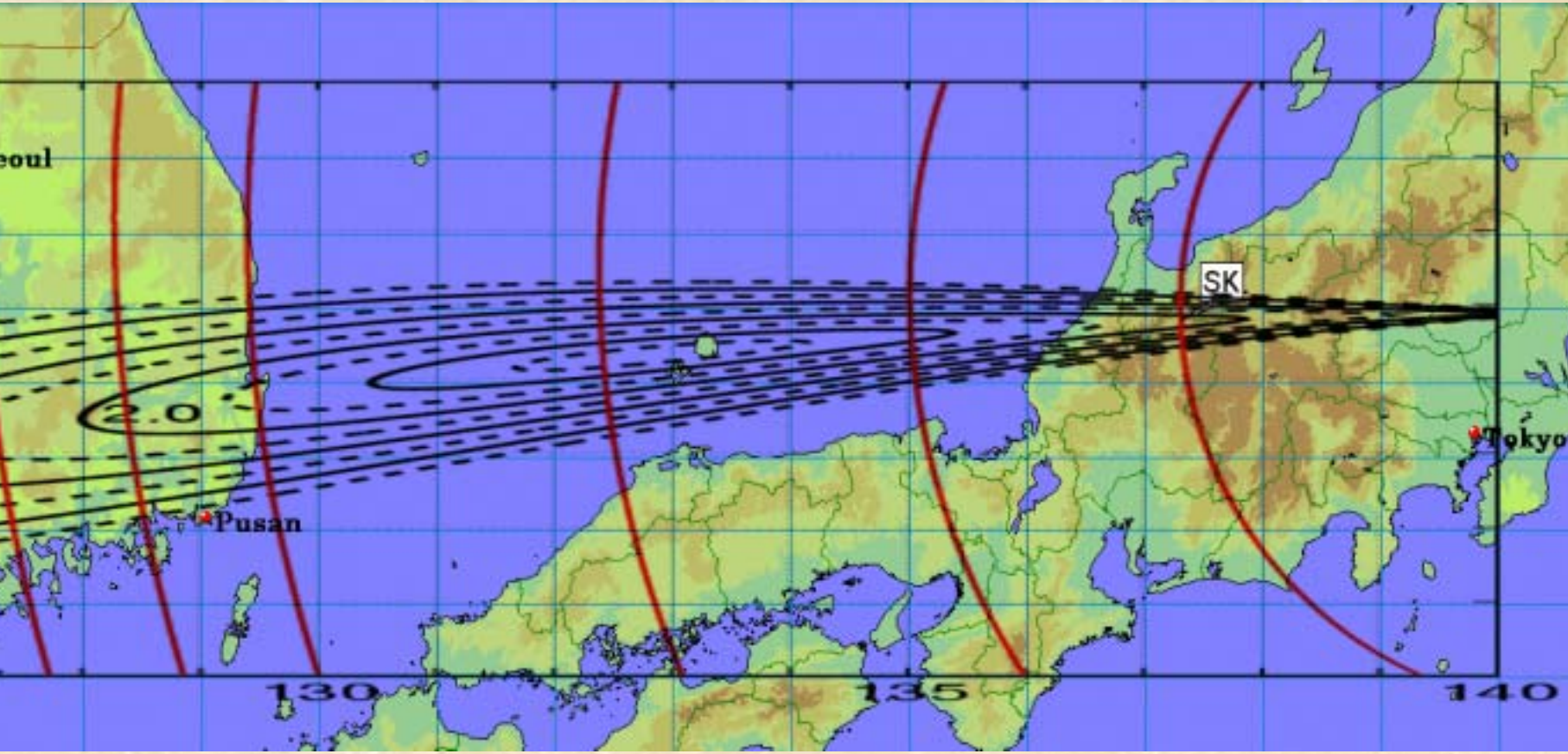




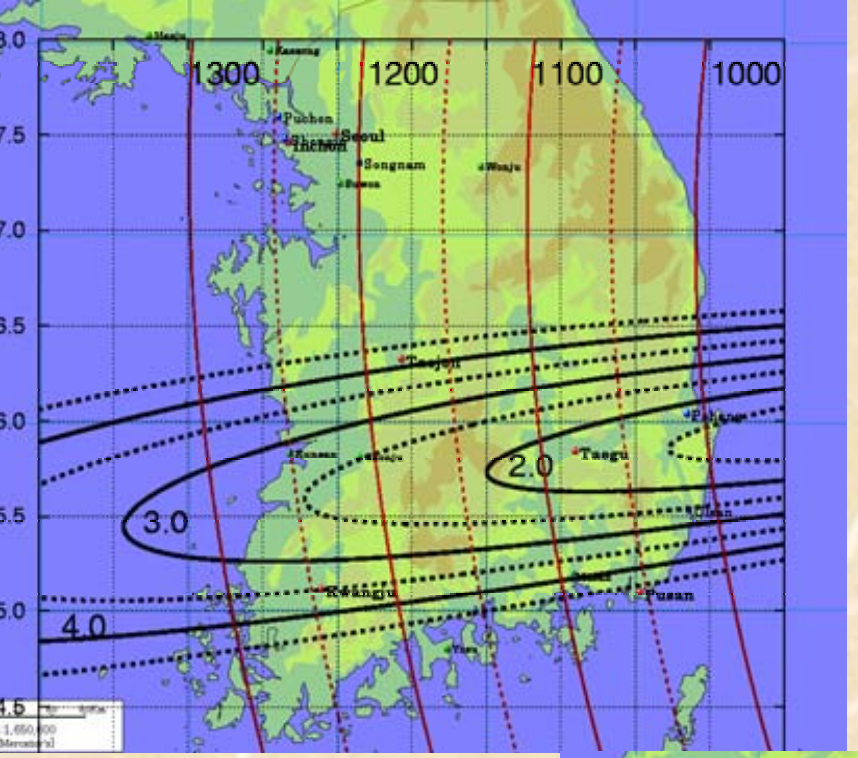
OAB 2 degree



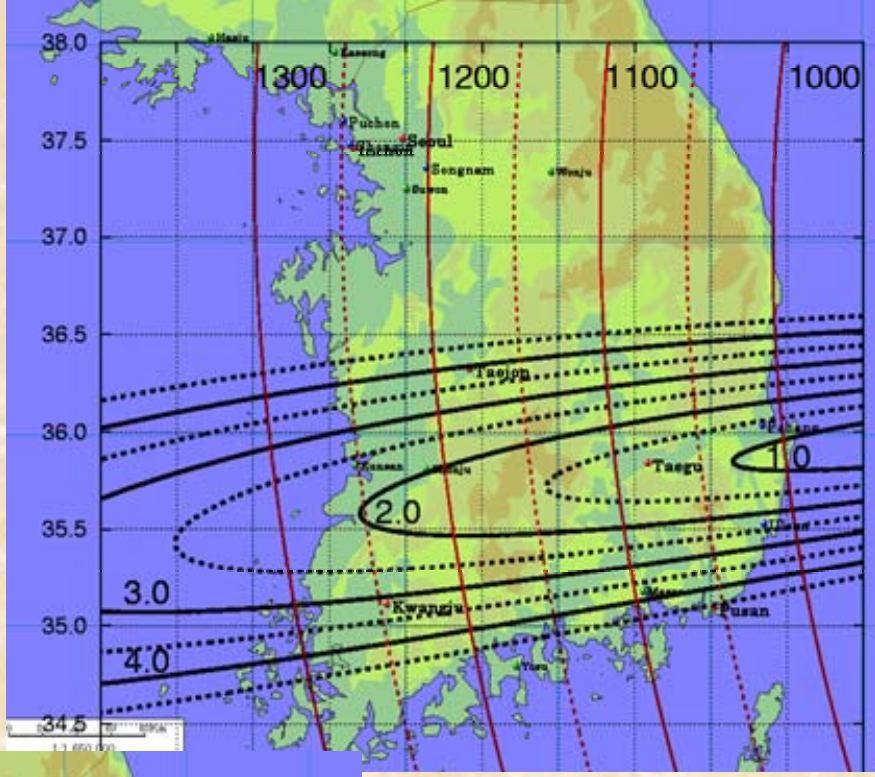
Center
1362
3
1
3
4
4
4
1
4
8
2
8
3
Japan
Niigata
Fukushima
Toyama
Gunma
Tochigi
Ishikawa
Nagano
Ibaraki
Saitama
Fukui
Gifu
Yamanashi
Kanagawa
Shiga
Kyoto
Aichi
Shizuoka
Shimane
Okayama
Hyogo
Hiroshima
Ohsaka
Mie
Yamaguchi
Kagawa
Nara
Wakayama
Tokushima
Kouchi
Ryotsu
Niigata
Kamo
Nagaoka
Wajima
Nanao
Iiyama
Toyama
Nagano
Komoro
Takasaki
Oyama
Takayama
Fukui
Ina
Kouhu
Iida
Tsuruga
Gifu
Nagoya
Yokohama
Odawara
Ito
Shimoda
Tateyama
Hamamatsu
Tsu
Owase
Shinguu
Tanabe
Gobou
Wakayama
Sumoto
Tokushima
Takamatsu
Okayama
Himeji
Nishiwaki
Maizuru
Toyooka
Tottori
Ohda
Hamada
Miyoshi
Masuda
Niimi
Tsuyama
Hiroshima
Shunan
Imabari
Kouchi
Niijima
Miyakejima
Mikurajima
Izu Is.
100
150Km



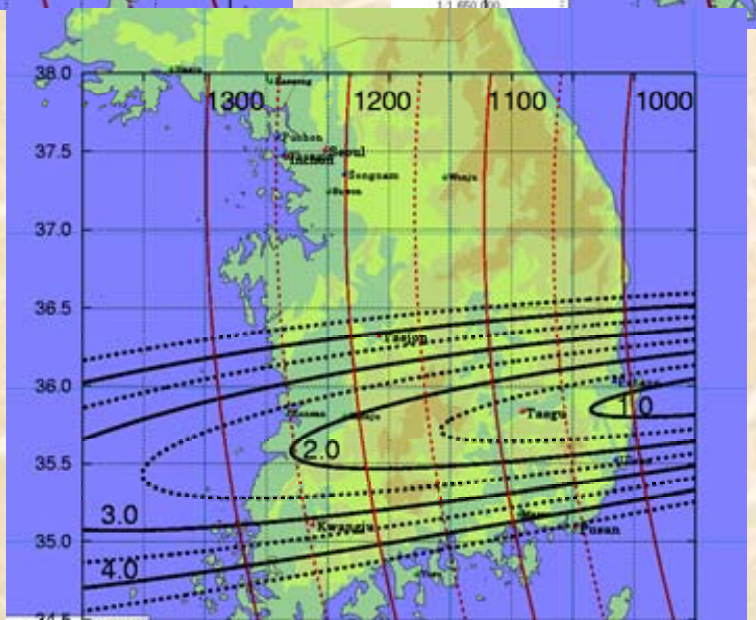
OAB 2.0 deg. @ SK



AB 2.0



OAB 2.5



OAB2.0

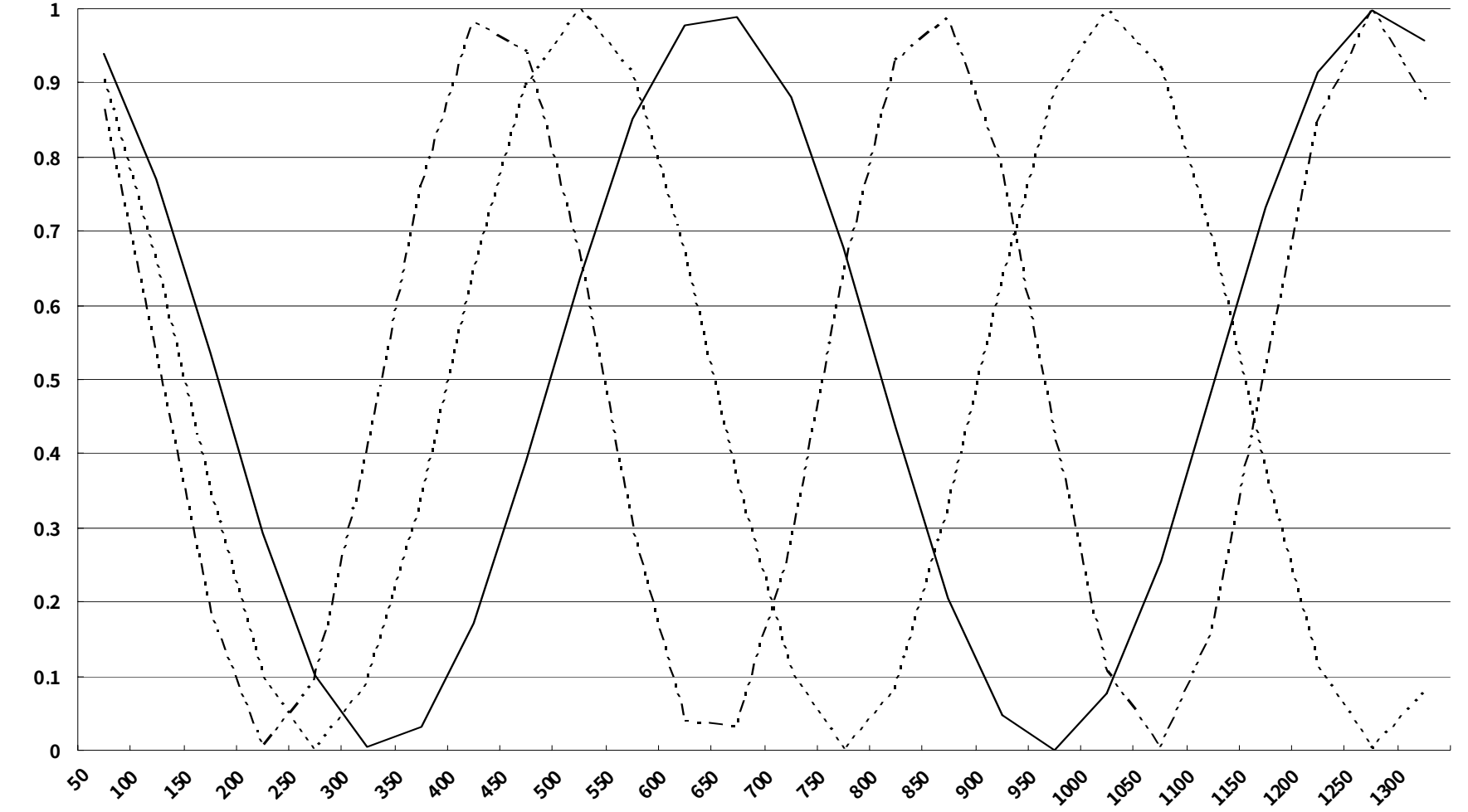
3.Obserbation at KOREA

- Neutrino beam (OAB1.0 deg ~) appeared at KOREA
- If we decide distance from J-PARC,

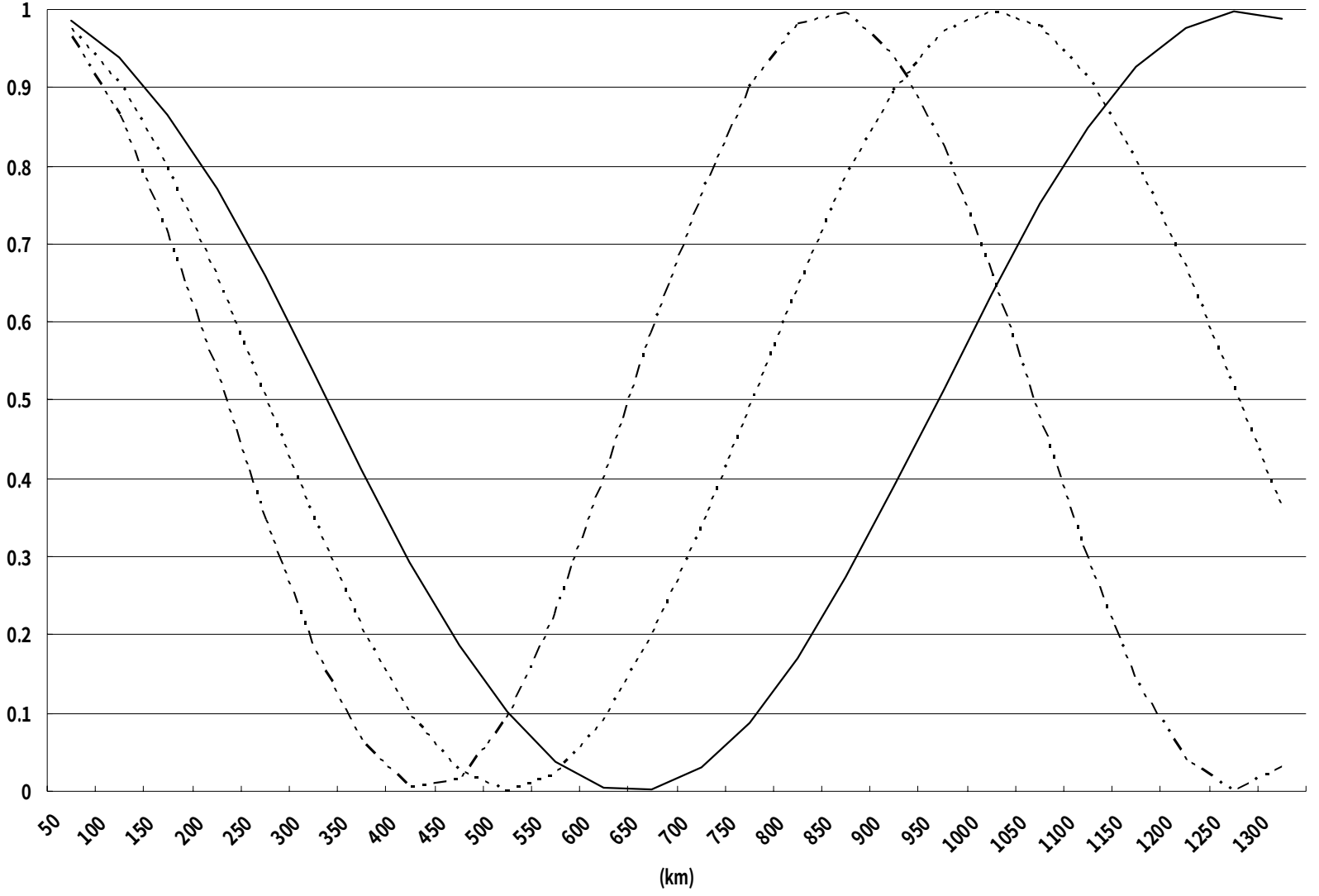
it still remain to decide OAB angle.

What can we measure in Korea?

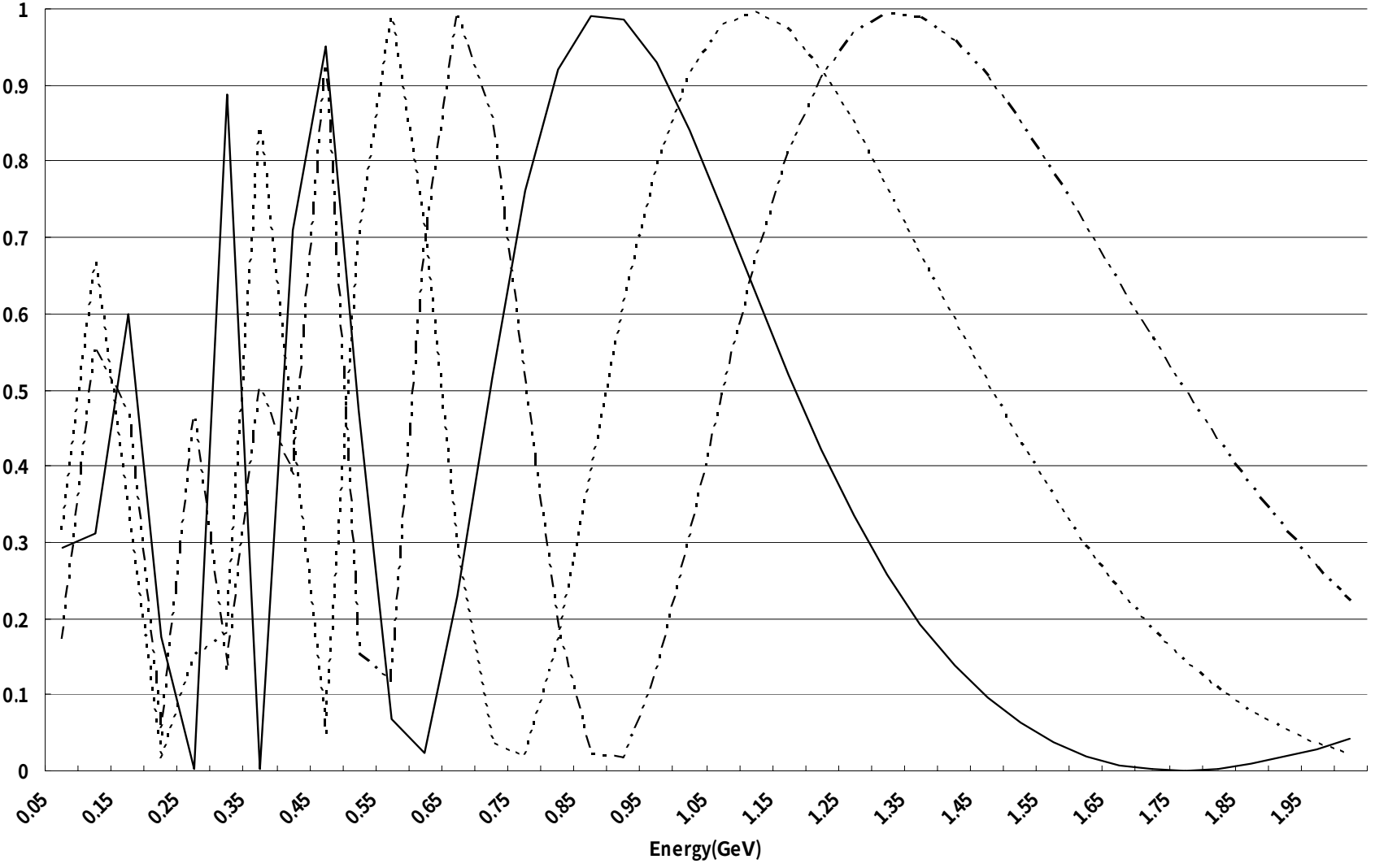
Time evolution of $\nu_\mu \to \nu_\mu$ probability(0.5GeV)



Time evolution of $\nu_\mu \to \nu_\mu$ probability(1.0GeV)

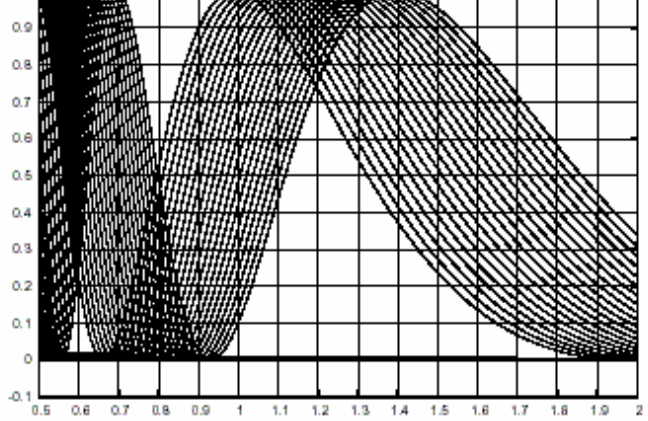


$\nu_\mu \to \nu_\mu$ probability @1100km



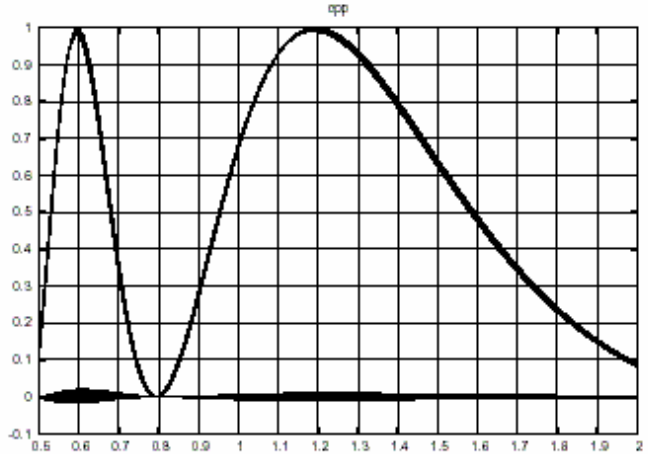
δm_{13}^2

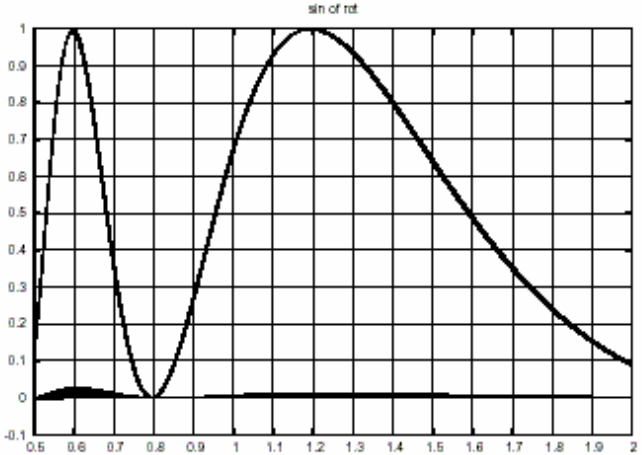
$\sin^2 2\theta$



δ

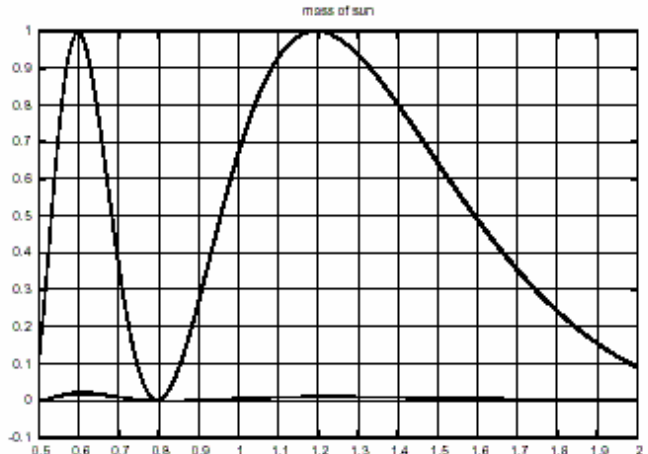
$\sin^2 2\theta$

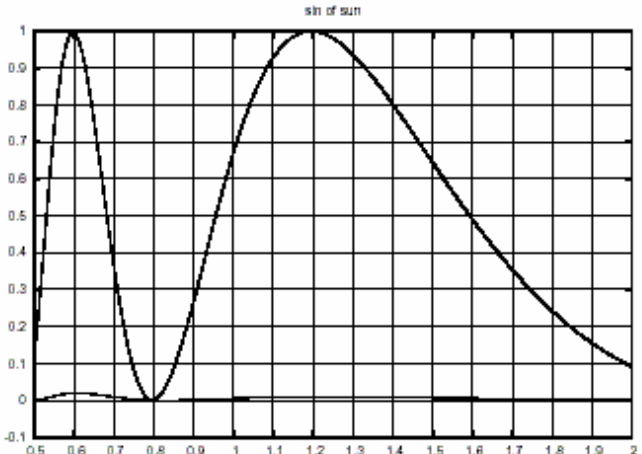




δm_{12}^2

$\sin^2 2\theta$

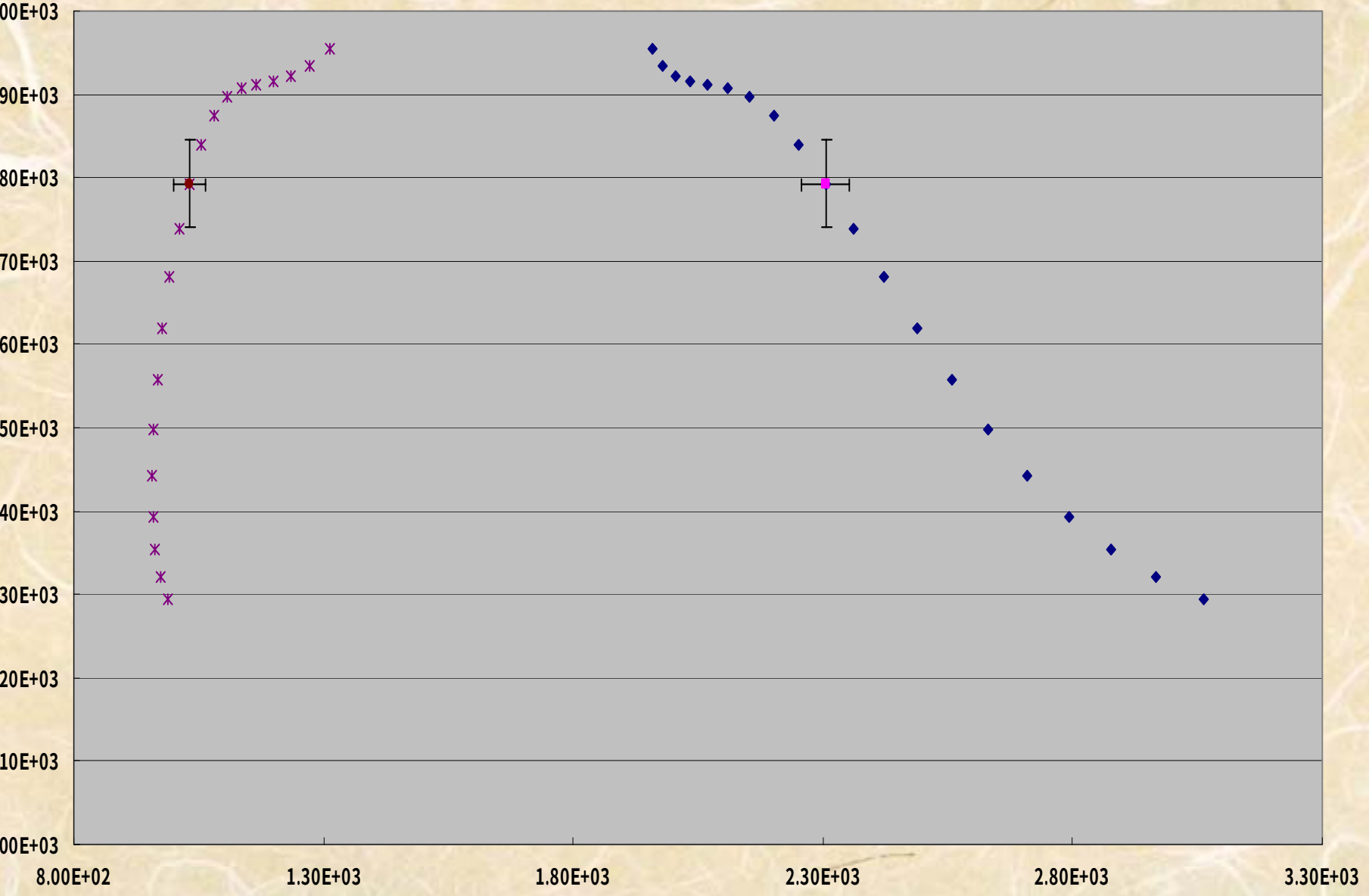




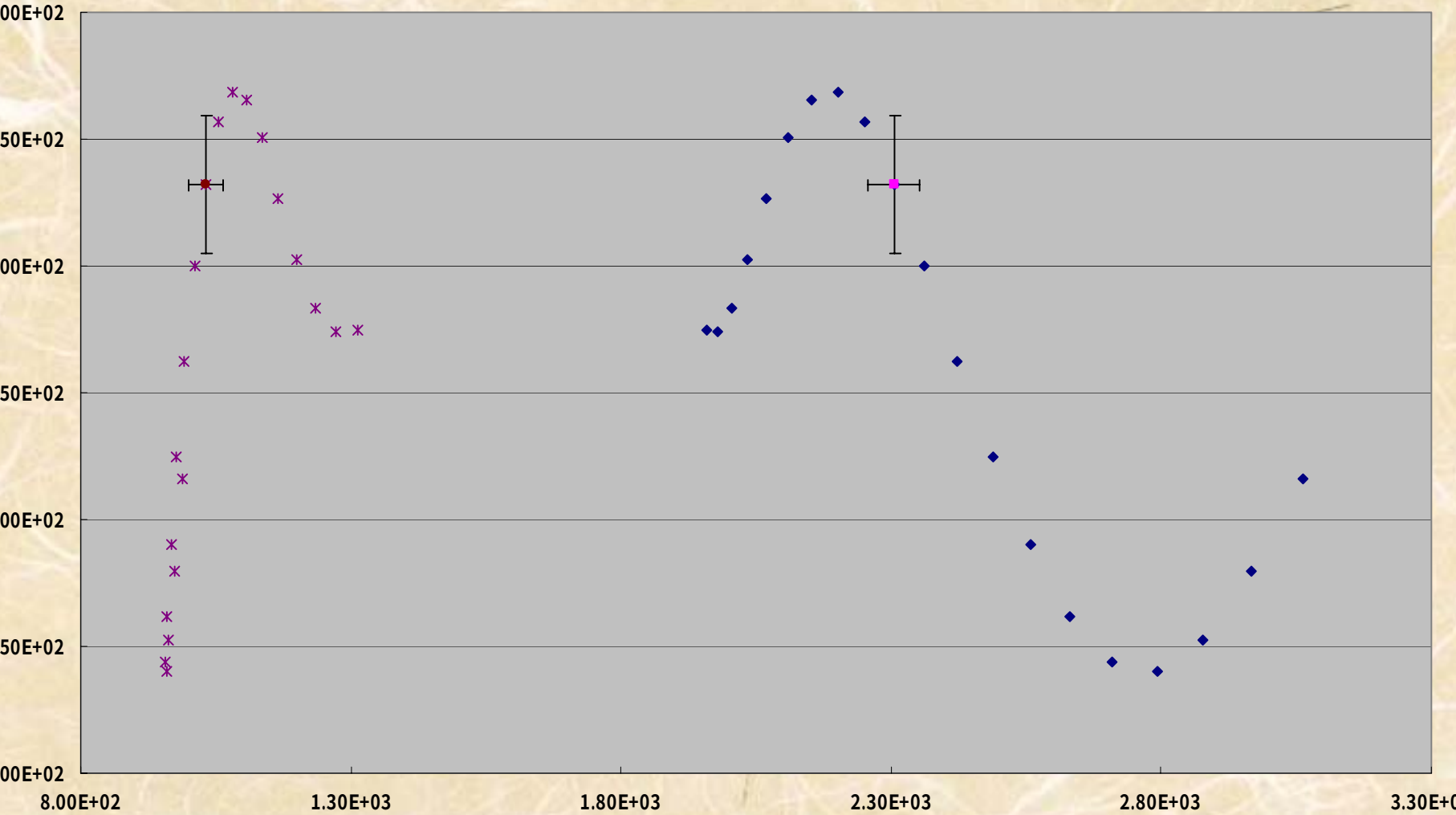
We consider these situation.

- 100kt water Cerenkove detector.
- Experiment run for 5 years.
- Counting 1 – ring mu-like events.
- L:1000km ~ 1200km

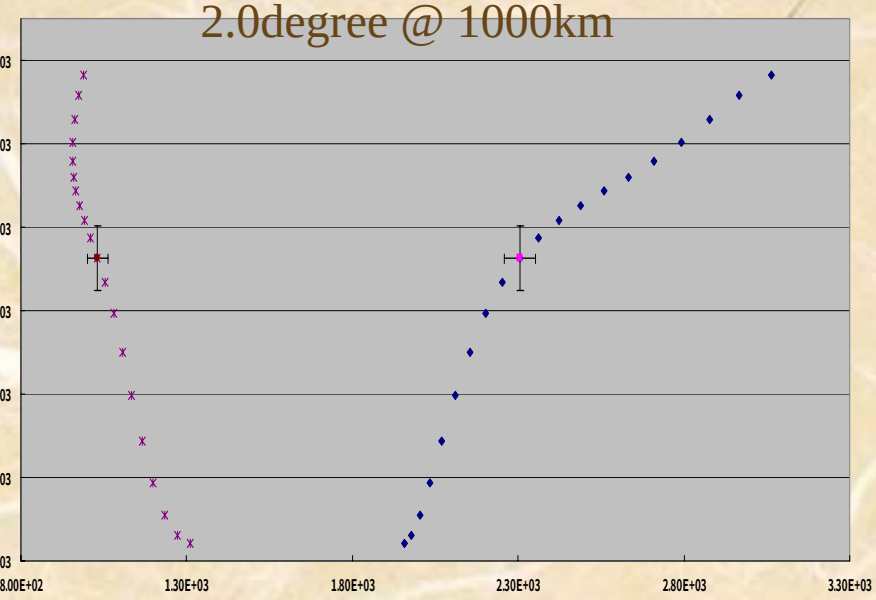
1000 km –OAB 1.0



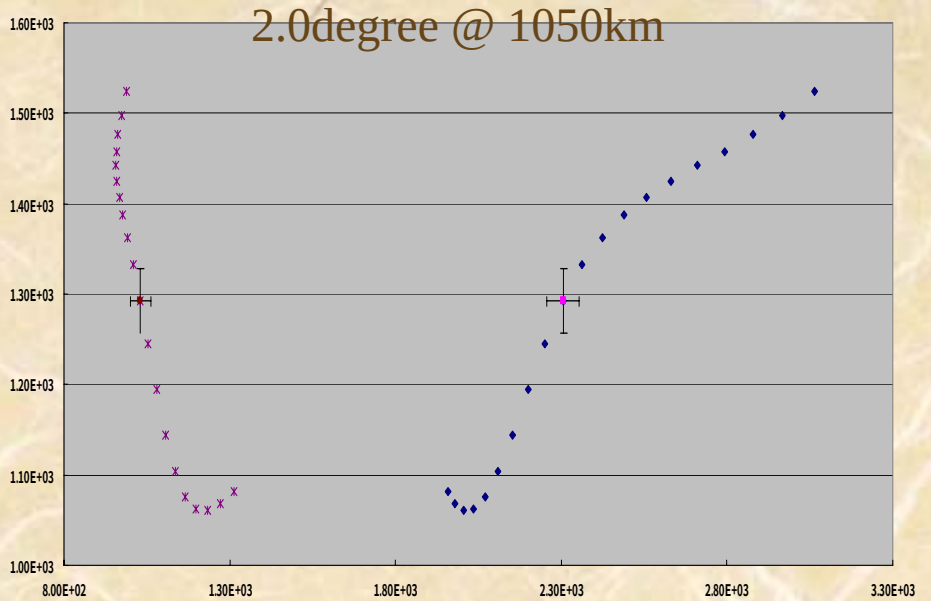
1000km -OAB 3.0 degree



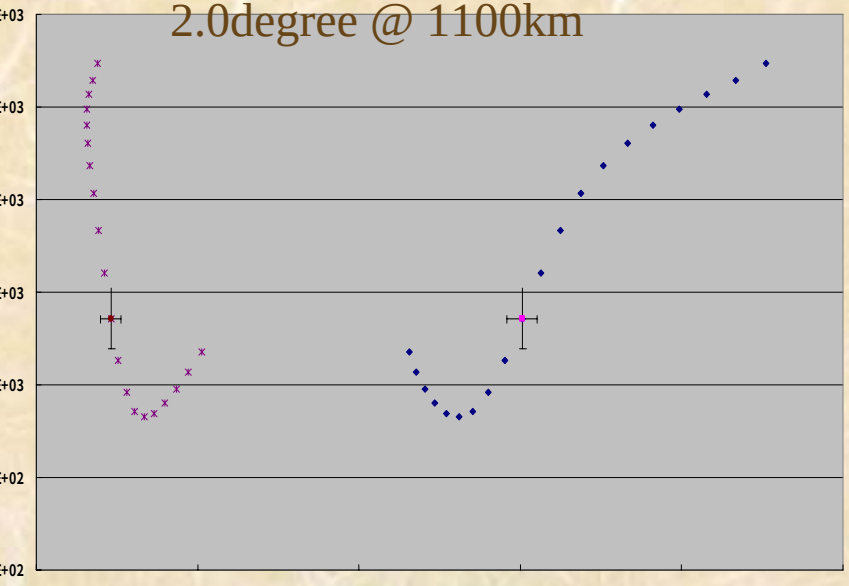
2.0degree @ 1000km



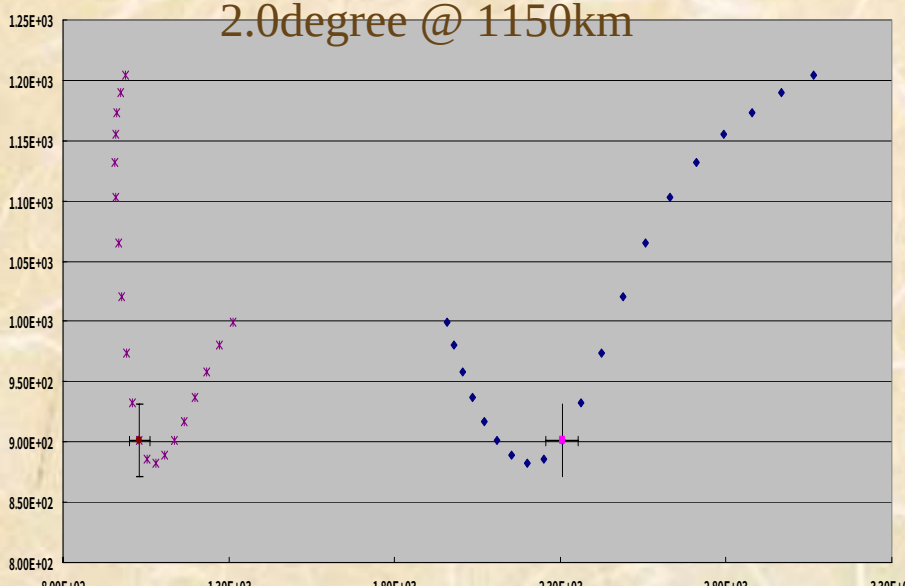
2.0degree @ 1050km



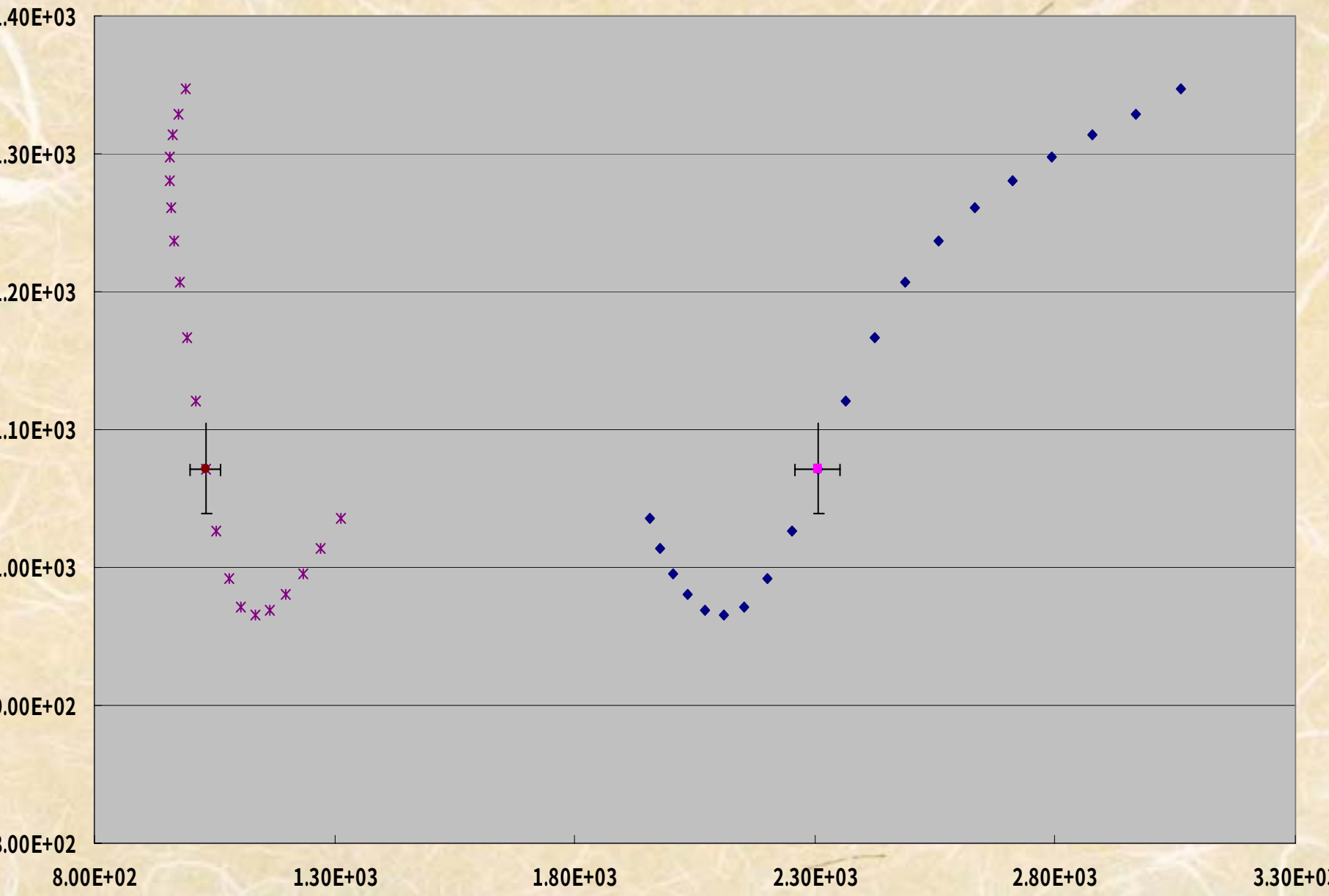
2.0degree @ 1100km

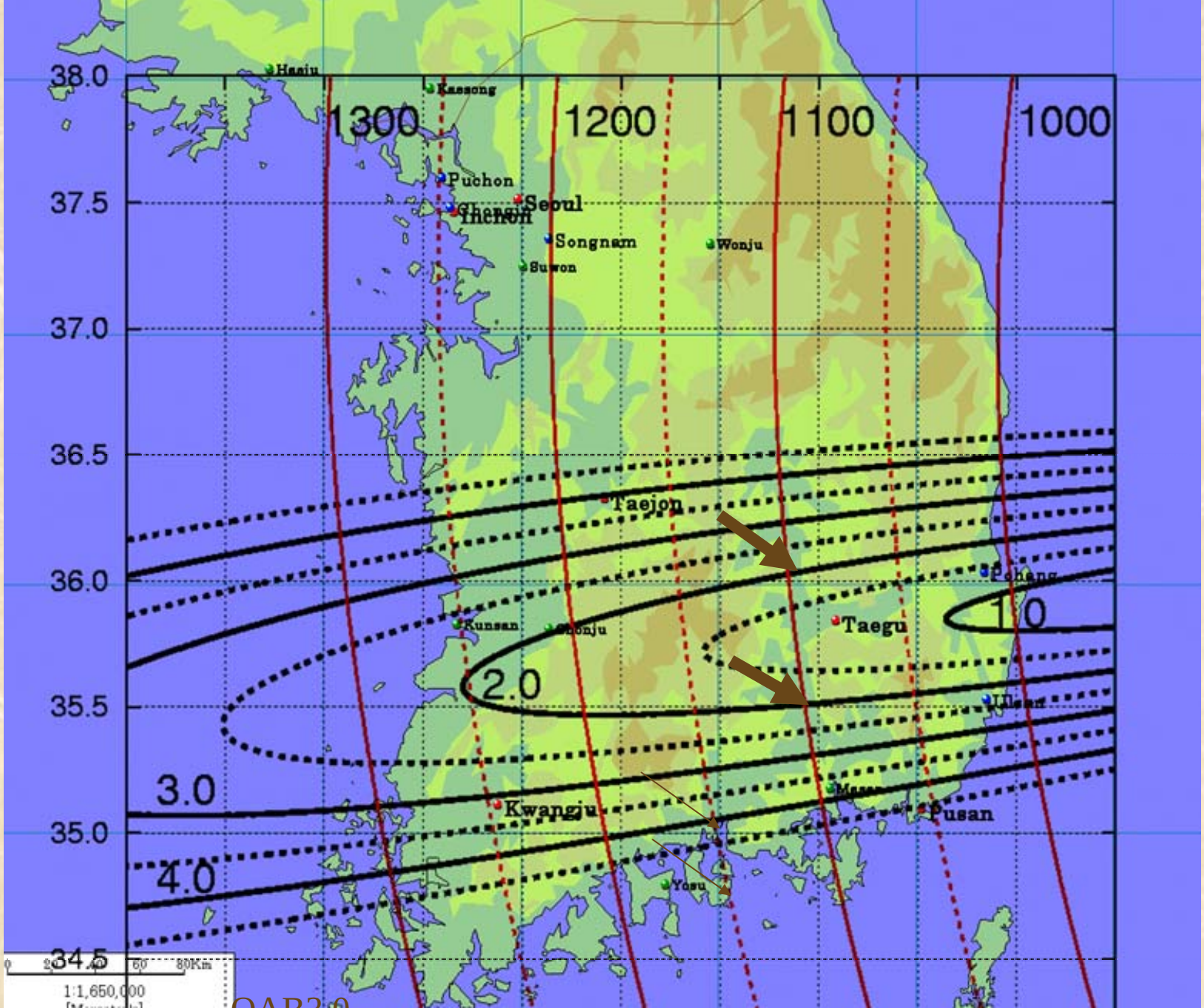


2.0degree @ 1150km



1100km-2.0 degree




38.0
37.5
37.0
36.5
36.0
35.5
35.0
34.5
1300
1200
1100
1000
Haeju
Kaesong
Puchon
Seoul
Inchon
Songnam
Wonju
Suwon
Taejon
Taegu
Kunsan
Kwangju
Pusan
Yosu
1.0
2.0
3.0
4.0
1:1,650,000

4.Summary

- T2K is next generation Long Base Line neutrino experiment!
- Off-axis beam is useful for searching electron neutrino appearance.
- In Korea ,OAB 1 degree ~ neutrino beam appear.
- A few places ,we can measure δm_{13}^{2} more precisely than SK.