Nov.9, 2001 梶田

いろいろなニュートリノ振動実験におけるθ_{13}とΔm^2の符号の測定の現状と将来の可能性

- はじめに
- θ_{13}の測定の現状と将来の可能性
  - CHOOZ (Palo Verde)
  - Kr2Det
  - MINOS
  - Off-axis NuMI
  - CERN-super-beam
- Δm^2 の符号のの測定の現状と将来の可能性
  - MONOLITH
- まとめ

はじめに

- JHF neutrino experiment (Phase I) の頃、技術的に実現しそうな実験のみを考える。

  → Neutrino factory は考えない。

  ↓

  吉村さんの話

- $\Delta m_{12}^2 = 0$ とする。 → CPは考えない。
- SK、JHFは言わない。→ 大林さん、小林さん

$\sin^2\theta_{13}$ の測定の現状と将来

3 flavor oscillations

★Approximation

———— $m_{\nu 3}$

$$\Delta m_{23}^2 = \Delta m_{13}^2 \equiv \Delta m^2$$

════ $m_{\nu 2}$, $m_{\nu 1}$

$$\Delta m_{12}^2 = 0$$

⬇

$$\theta_{13},\ \theta_{23},\ \Delta m^2$$

$$P(\nu_\alpha \rightarrow \nu_\beta) = 4|U_{\alpha 3}|^2 |U_{\beta 3}|^2 \sin^2(1.27 \Delta m^2 L/E)$$

$$P(\nu_\alpha \rightarrow \nu_\alpha) = 1 - 4|U_{\alpha 3}|^2 (1 - |U_{\alpha 3}|^2) \sin^2(1.27 \Delta m^2 L/E)$$

$$|U_{e3}|^2 = \sin^2\theta_{13}$$

$$|U_{\mu 3}|^2 = \cos^2\theta_{13} \sin^2\theta_{23}$$

$$|U_{\tau 3}|^2 = \cos^2\theta_{13} \cos^2\theta_{23}$$

Reactor and accelerator experiments

Reactor experiments:

$P(\bar{\nu}_e \rightarrow \bar{\nu}_e)$ ➡ disappearance exp. : more difficult

$= 1 - \sin^2 2\theta_{13} \sin^2 (1.27 \Delta m^2 L/E)$

bigger effect

Accelerator experiments:

$P(\nu_\mu \rightarrow \nu_e)$ ➡ appearance exp. : easier

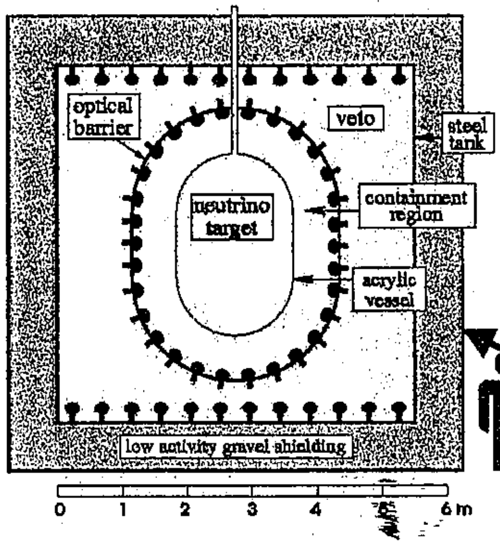
$= \sin^2 \theta_{23} \sin^2 2\theta_{13} \sin^2 (1.27 \Delta m^2 L/E)$

$\sim 0.5 \sin^2 2\theta_{13} \sin^2 (1.27 \Delta m^2 L/E)$

smaller effect

Reactor experiments

CHOOZ (5ton)



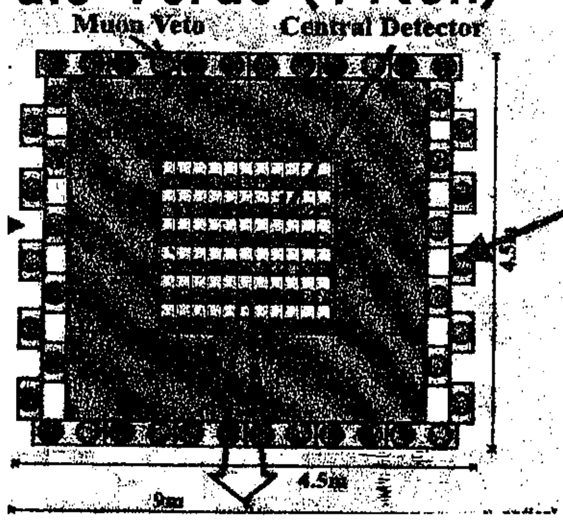
1km

$\overline{\nu}_e$

$\overline{\nu}_e$

890m

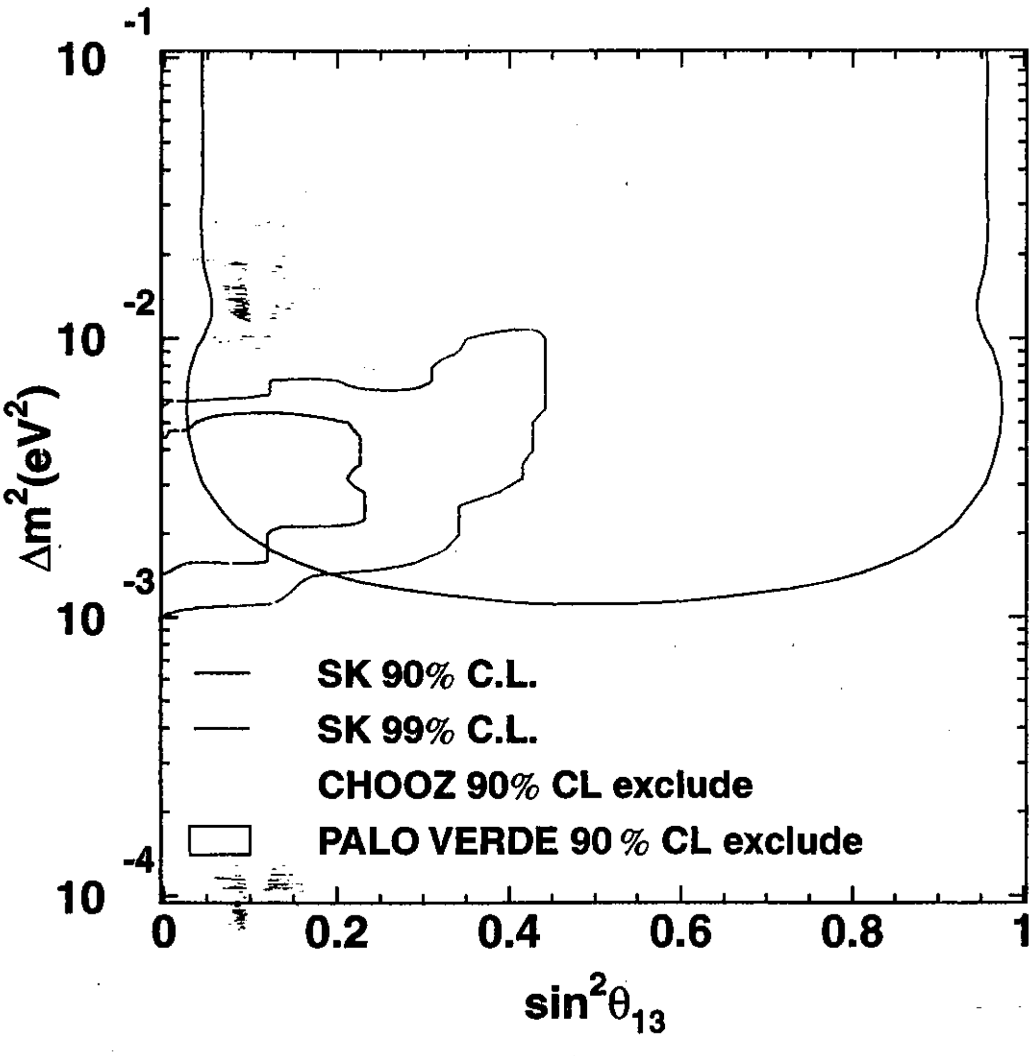
Palo Verde (11ton)



L/E $\sim$ 300 ⟹ sensitivity: $\Delta m^2 \gtrsim 10^{-3}$

Information on θ_{13}

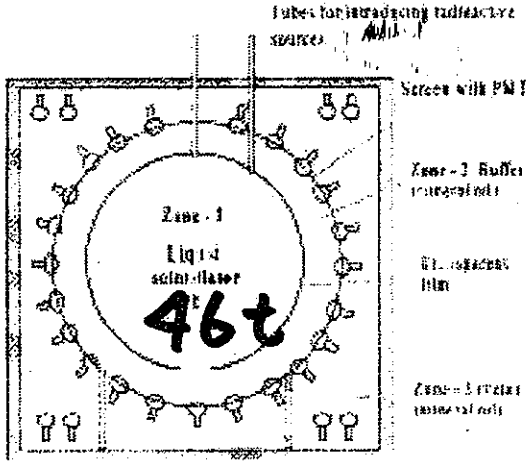
3 flavor analysis and reactor experiments



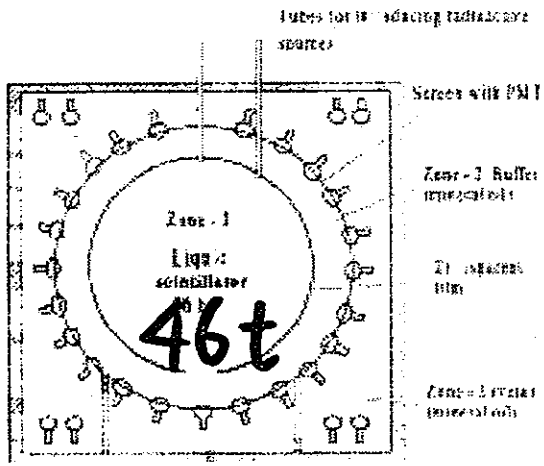
Future reactor exp. (Kr2Det)
(Krásnoyarsk reactor)

Nucl. Phys. (Proc. Suppl.) 91(2001)120
hep-ph/0109277

150m

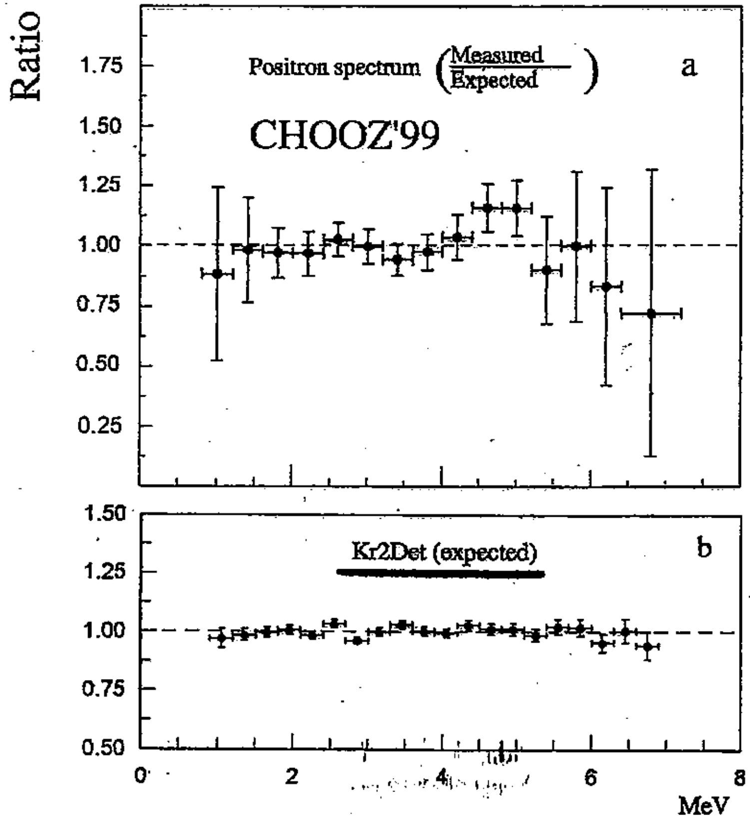


1100m

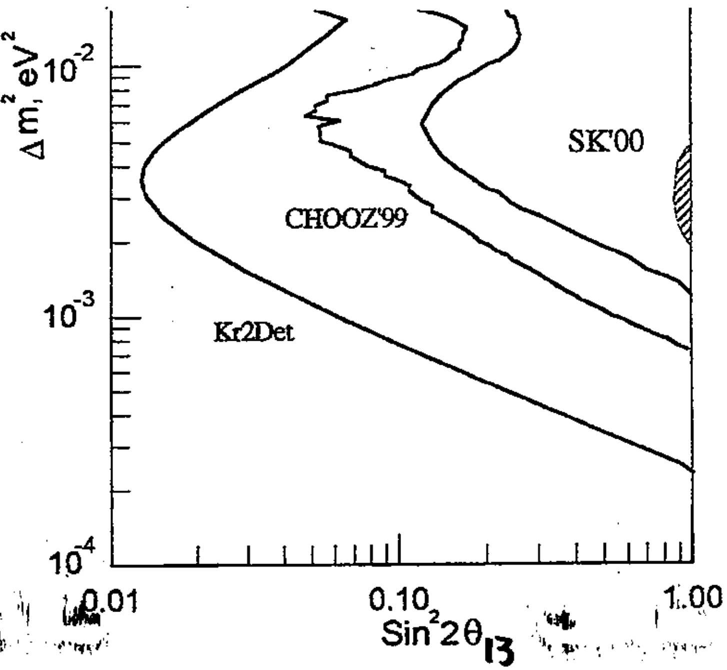


Kr2Det sensitivity

detector	Distance (m)	Depth (m.w.e.)	mass	Rate (/day)	BG (/day)
Kr2Det Far	1100	600	46	46	5
Kr2Det Near	150	600	46	2500	5
CHOOZ	1000	300	5	25	1.2

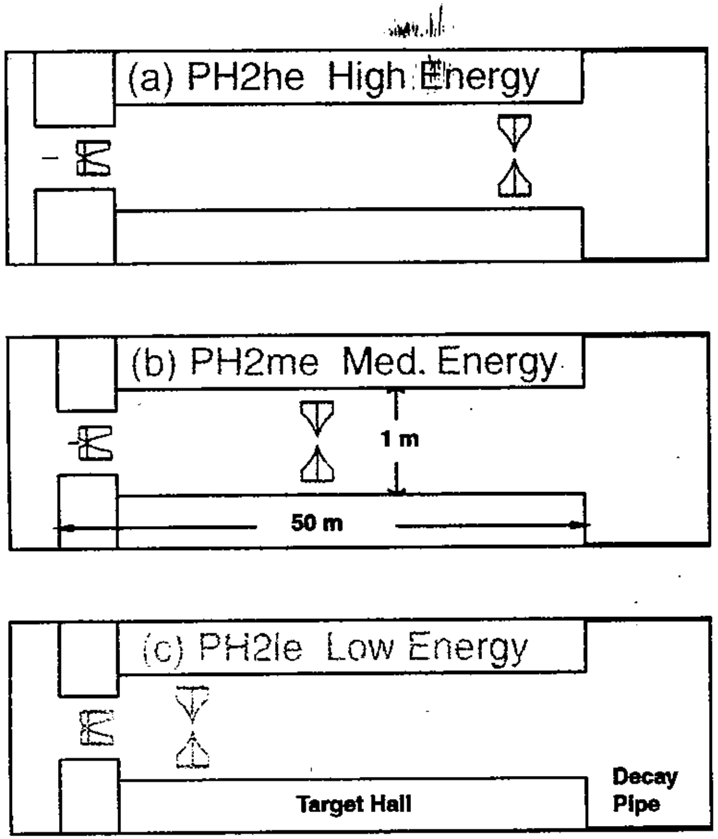


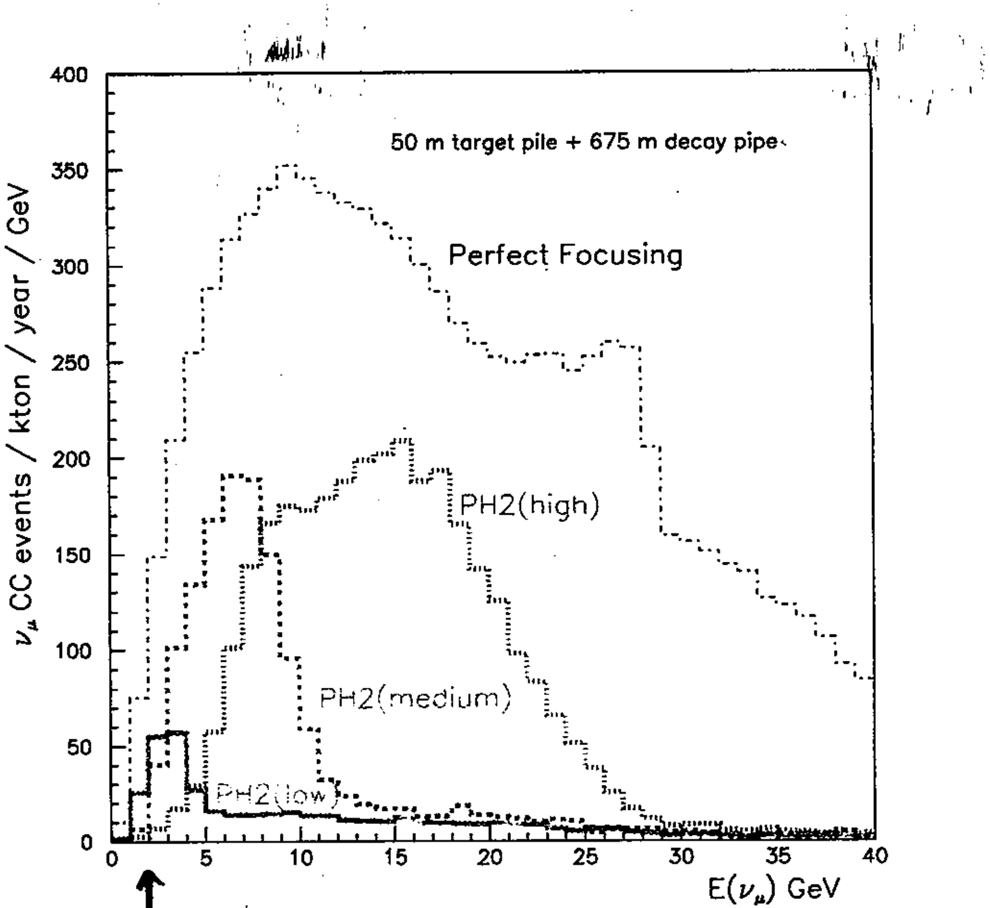
Sensitivity (after 3 years, 0.5% far-near syst.)



35

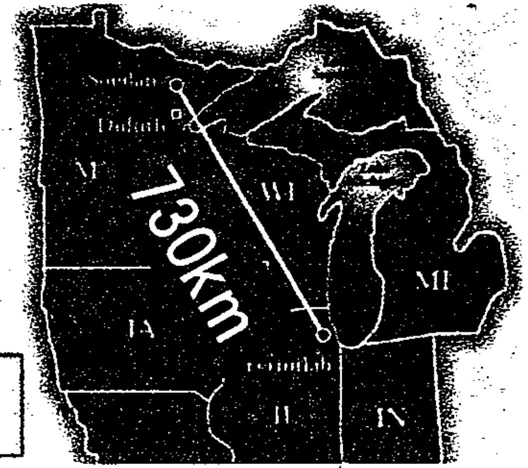
Tuning Neutrino Spectra by Horn/Target Reconfiguration





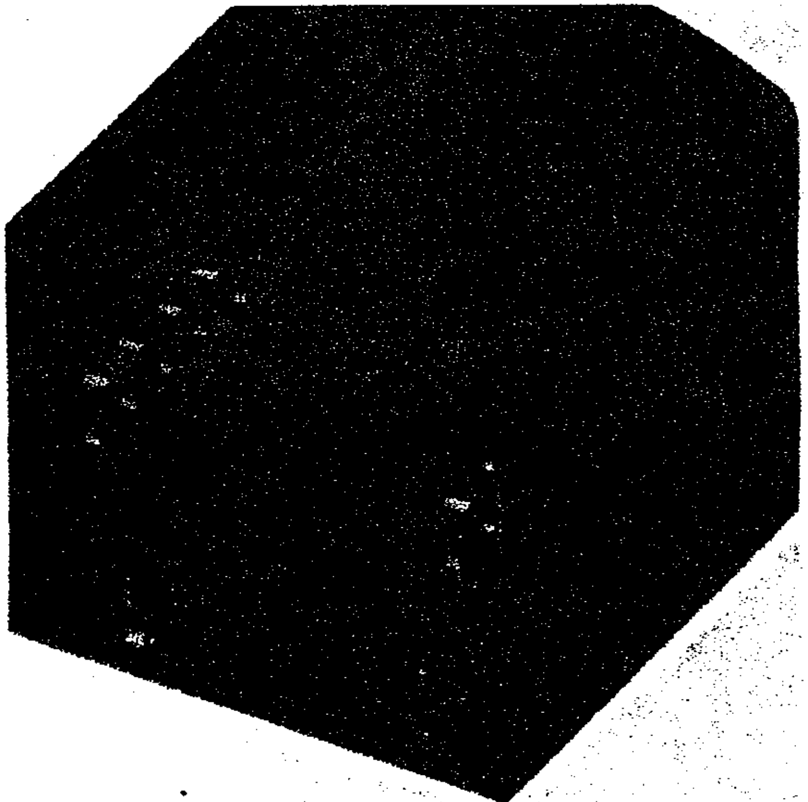
↑ Oscillation max.

Status of future LBL ν osc. exp's (1)



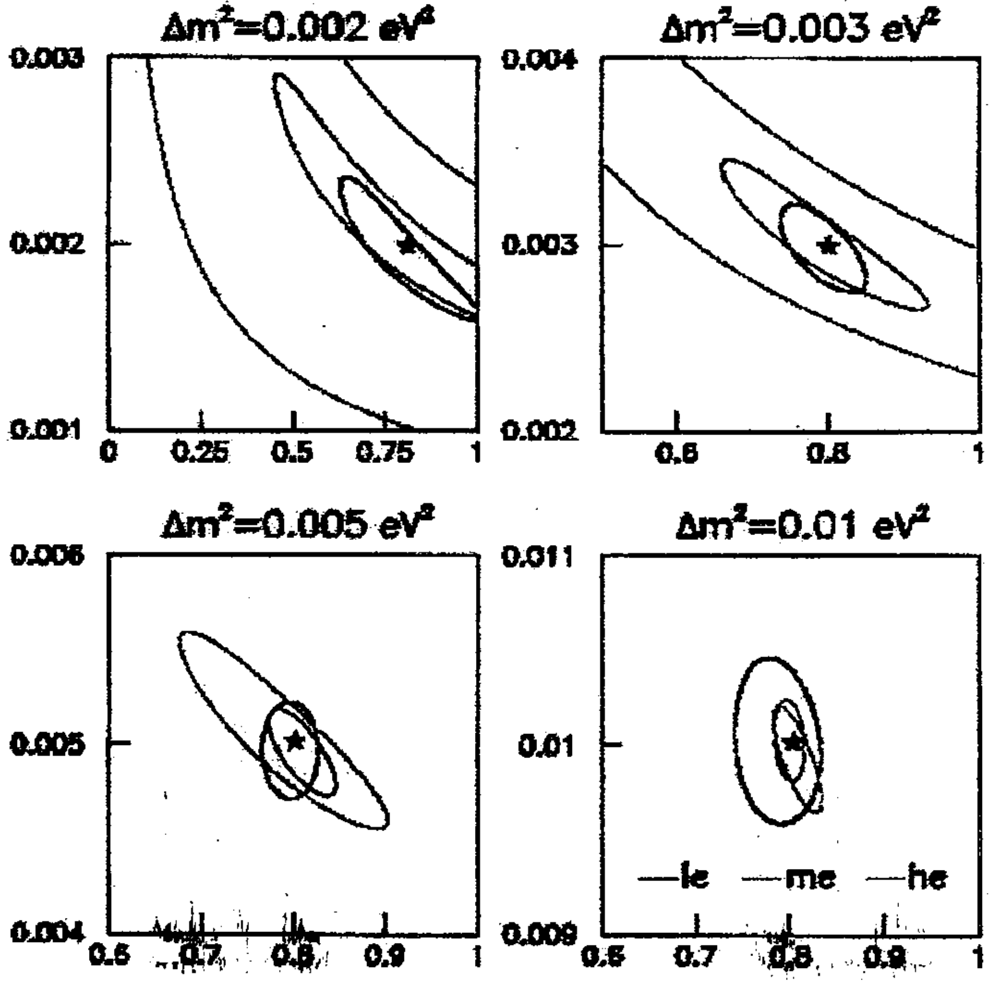
MINOS Fermilab → Soudan (start: 2004 ?)
5 ?

5.4 kton Fe/Plastic scinti. (w/ WLS) detector



Half of the MINOS Far Detector

Sensitivity (2yrs)

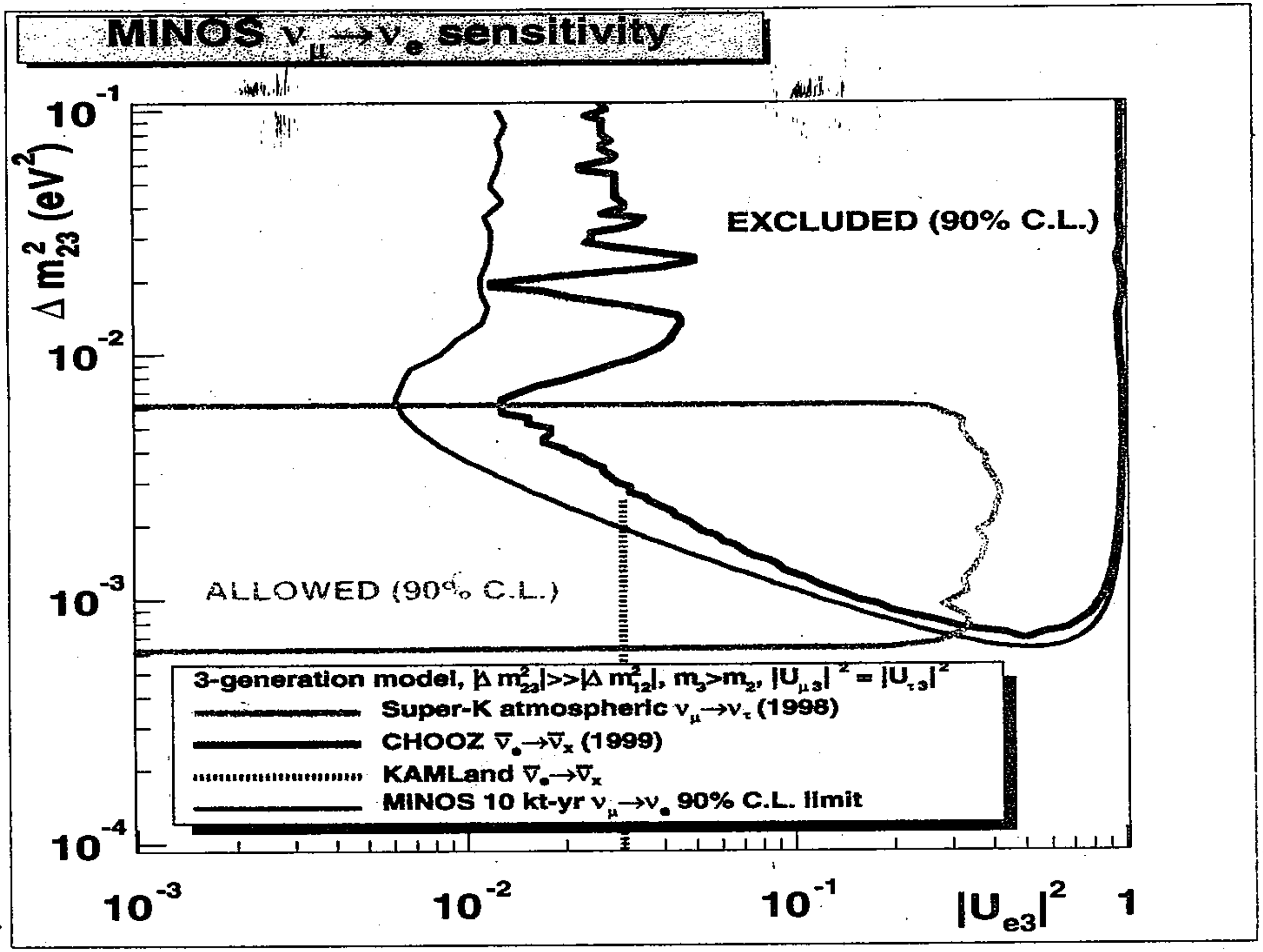


37

NUMI

MINOS

ν_μ—>ν_e Sensitivity



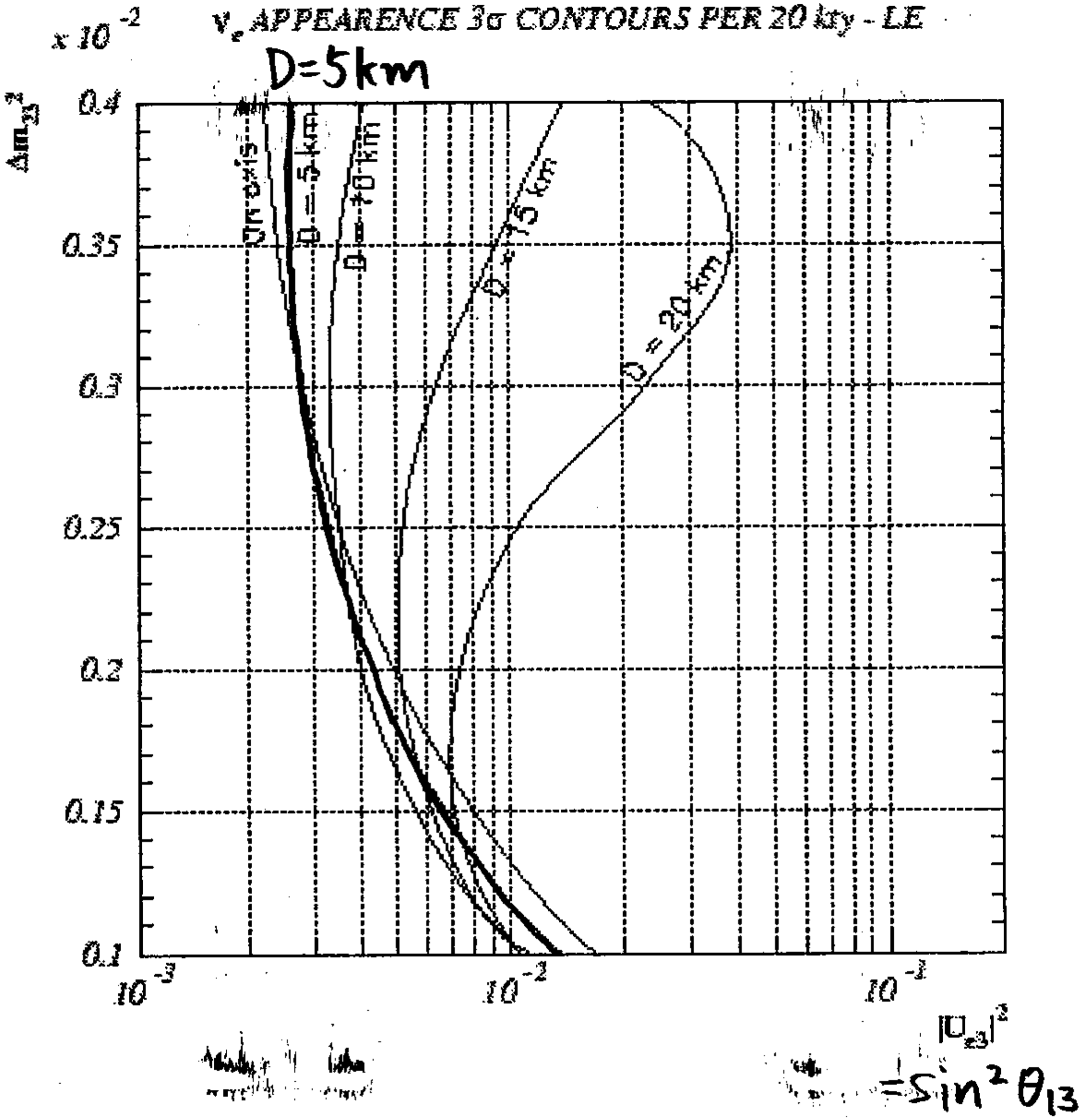
$= \sin^2 \theta_{13}$

Off-axis NuMI sensitivity

Assume:

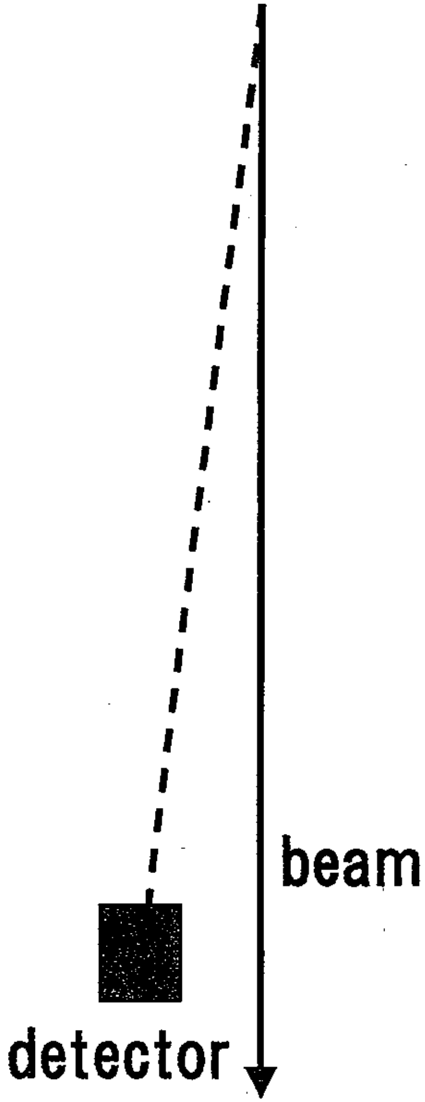
- Good π^0 rejection
  - (NC BG << ν e BG)
- 20kton・yr
- 100% electron ID
- ν_e/ν_μ flux ratio = 0.5%
- 3σ BG fluctuation

L-E option

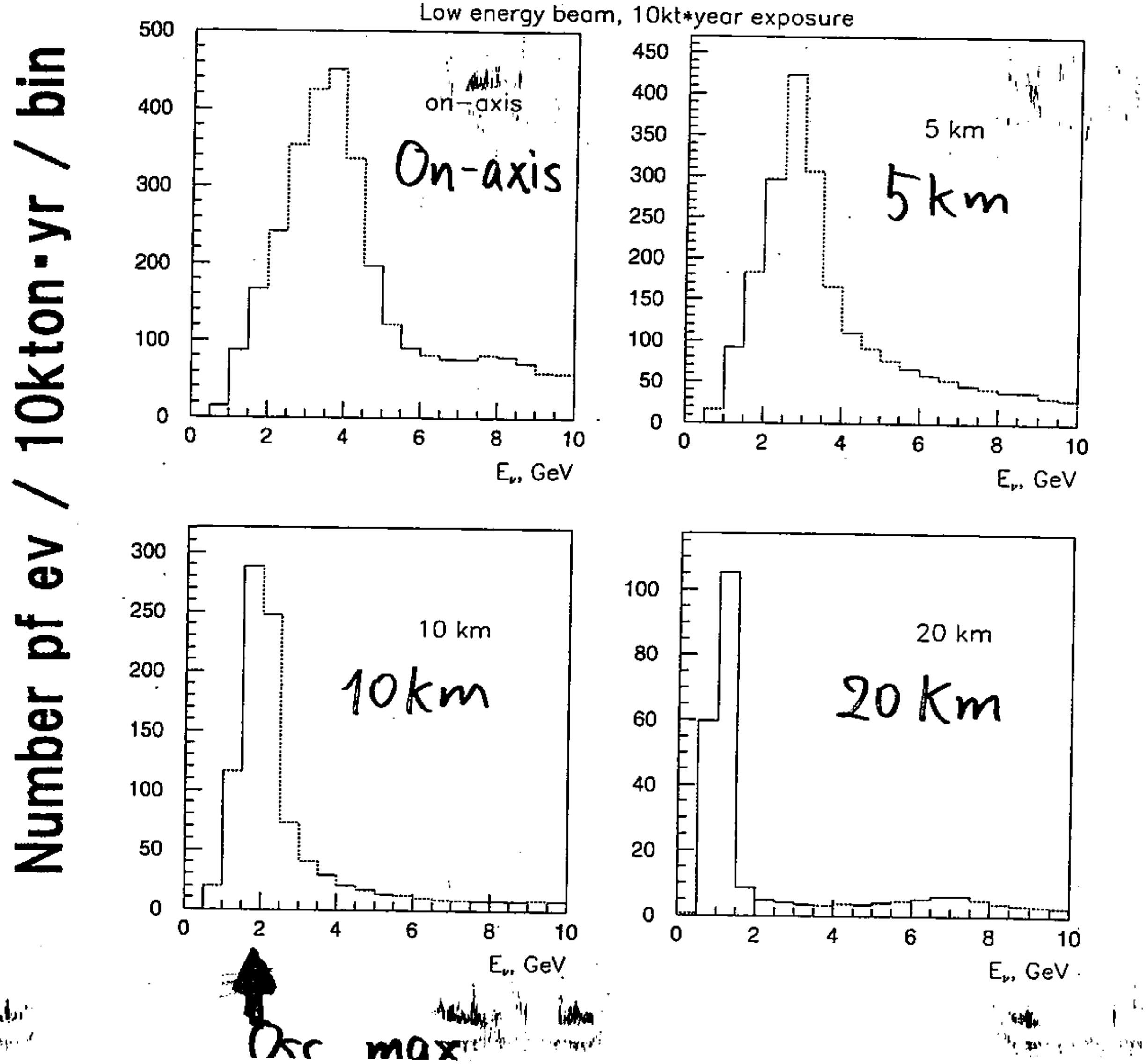


Off-axis NuMI

hep-ex/0110032

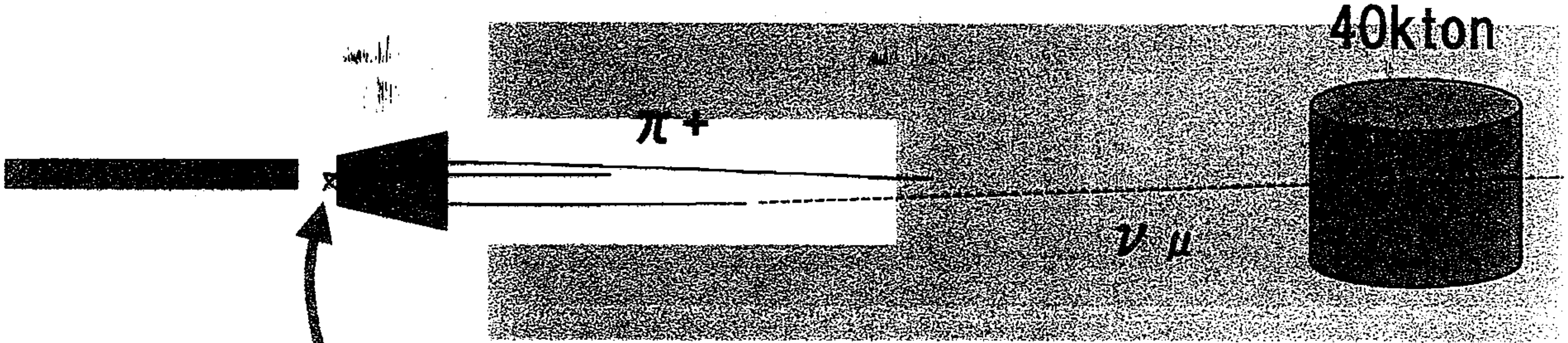


Low-Energy option



hep-ph/0105297

Low-E super-beam (@CERN)



LINAC:

2.2GeV

75Hz

$1.5 \cdot 10^{14}$ppp

4MW

Decay volume:

1m φ

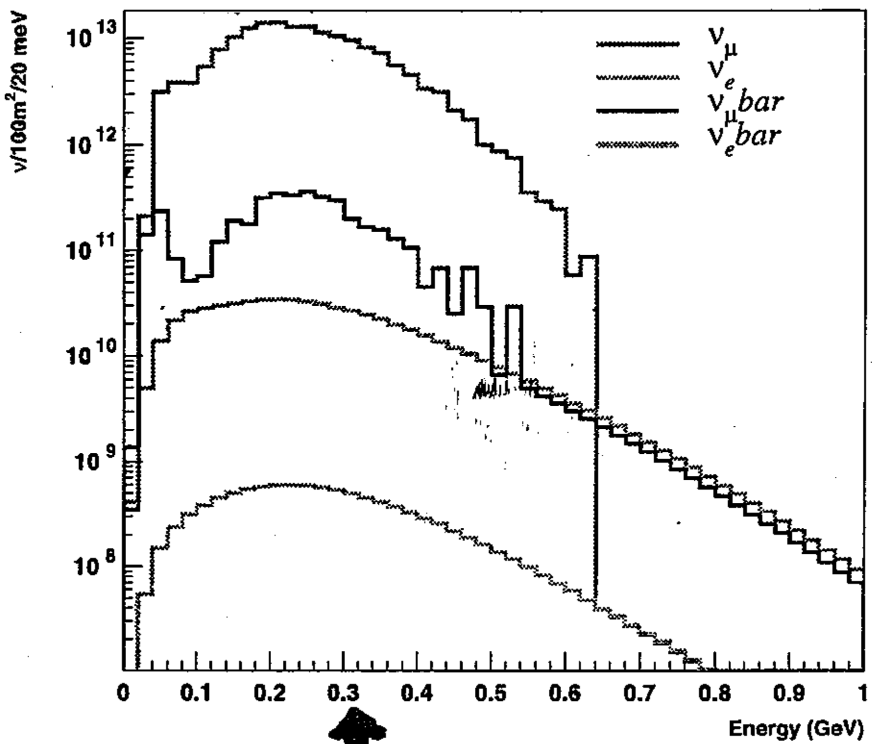
20m length

→ 130km

Small K production

➡ No high E tail

Energy spectra



Osc. max

$\nu N \to \ell^- N'$ dominant

5yr-40kton(Water) @ 130 km

Ve selection

Channel	Initial sample	Visible events	Fit in fiducial volume Single-ring 100 – 450 MeV/c^2	Tight particle ID	No $\mu \to e$	$m_{\gamma\gamma} < 45\,\mathrm{MeV}/c^2$
ν_μ^{CC}	3250	887	578.4	5.5	2.5	1.5
ν_e^{CC}	18	12.	8.2	8.0	8.0	7.8
NC	2887	36.9	8.7	7.7	7.7	1.7
$\nu_\mu \to \nu_e$		82.4%	77.2%	76.5%	70.7%	

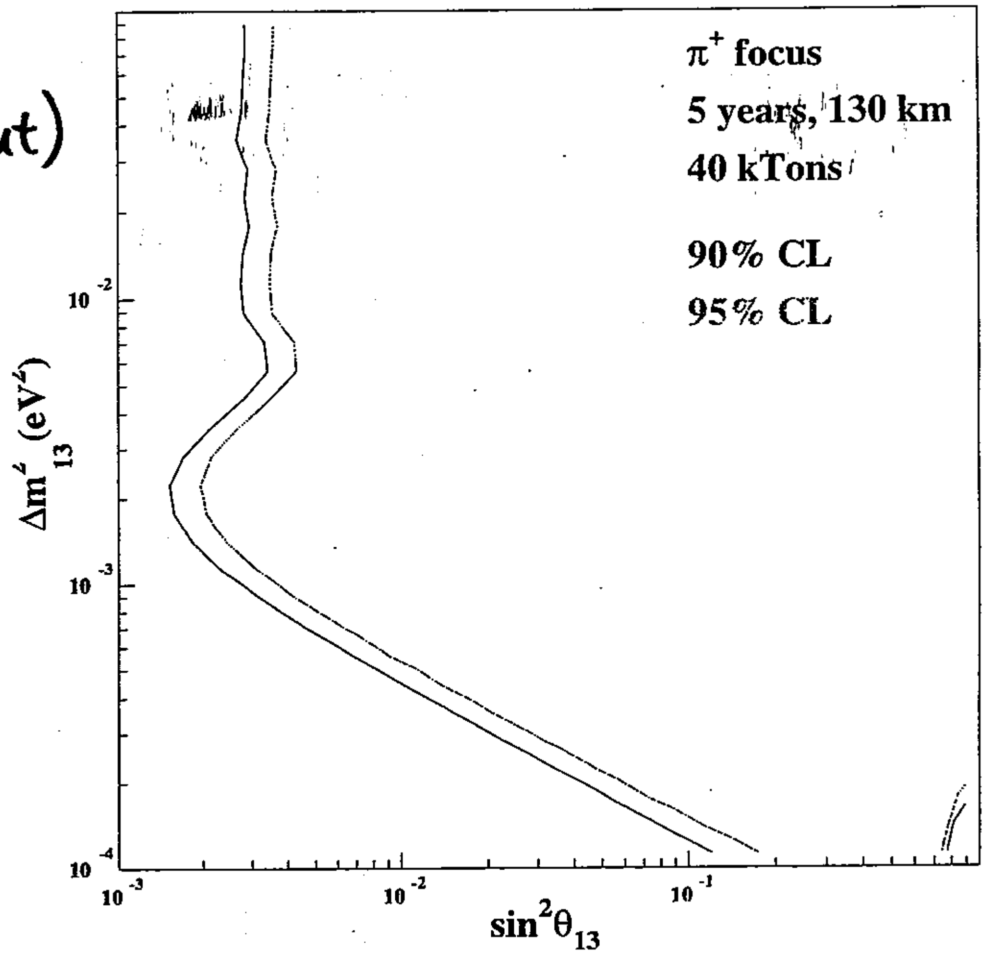
Low-E super-beam @CERN: Sensitivity

Assume:

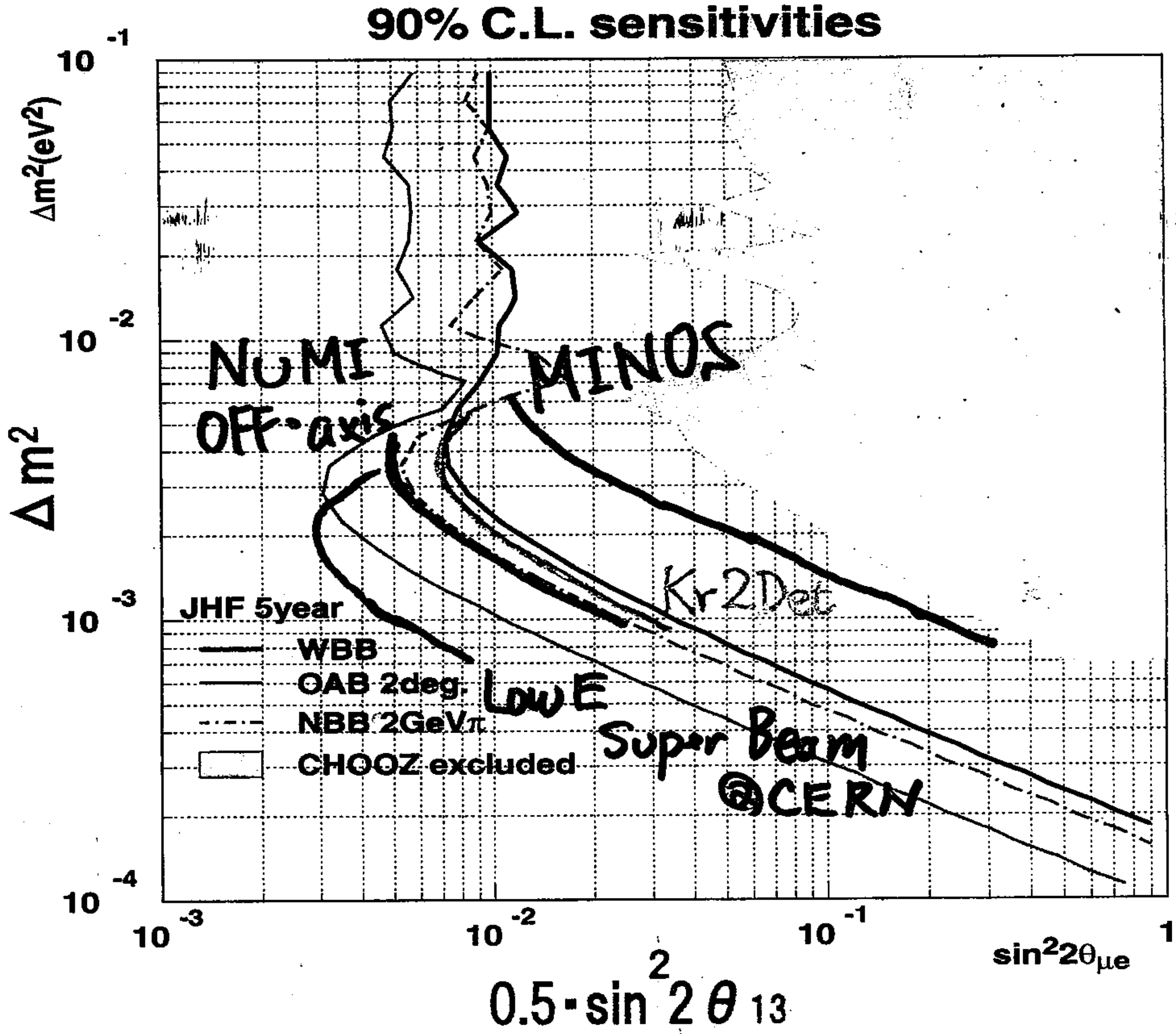
Super-K analysis (+ π^0 cut)

Only stat. Considered

5yr・40kton @130km



Comparison of sensitivities



Δm_{13}^2 の符号の測定の現状と将来

方法： 物質効果をつかう。

$\Delta m_{13}^2 > 0$ ： $P(\nu_\mu \to \nu_e) > P(\bar{\nu}_\mu \to \bar{\nu}_e)$

$\Delta m_{13}^2 < 0$ ： $P(\nu_\mu \to \nu_e) < P(\bar{\nu}_\mu \to \bar{\nu}_e)$

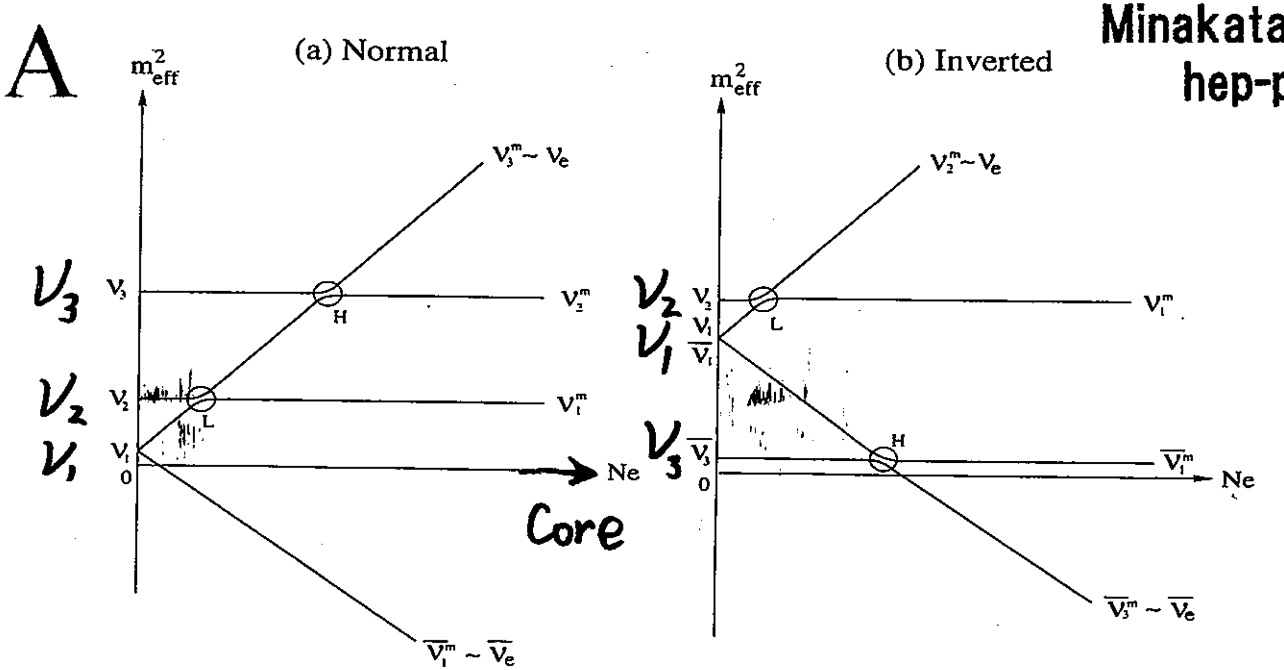
現状： わかってない。

（一つの Indication 以外は、、、）

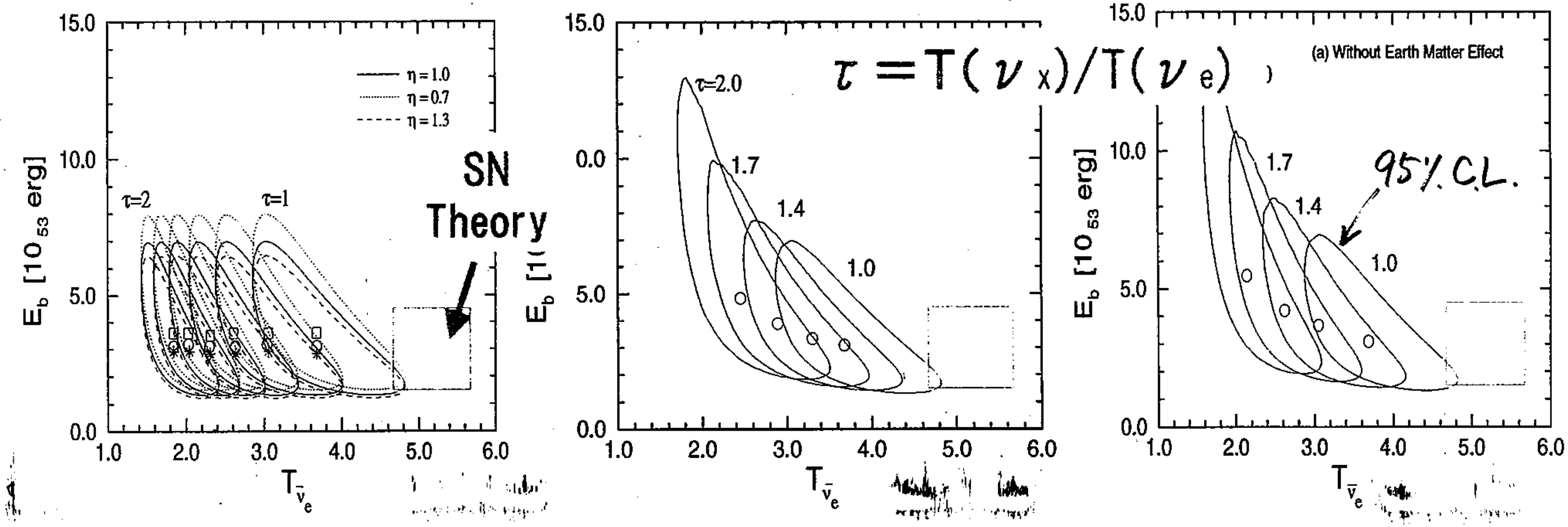
⬇

SN1987A

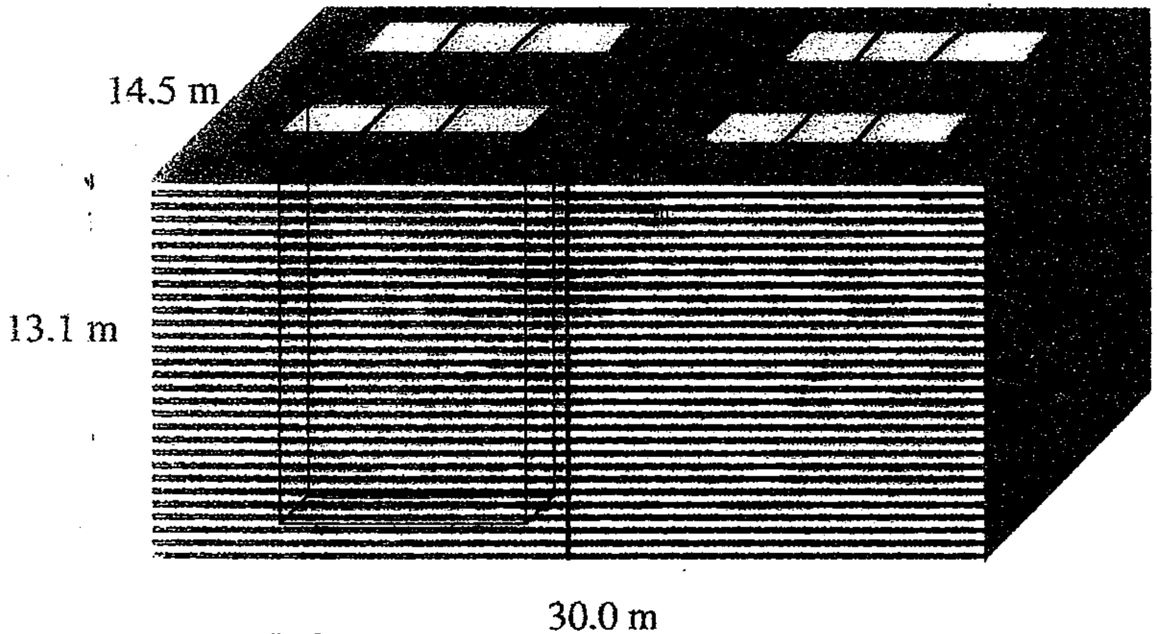
Minakata, Nunokawa
hep-ph/0010240

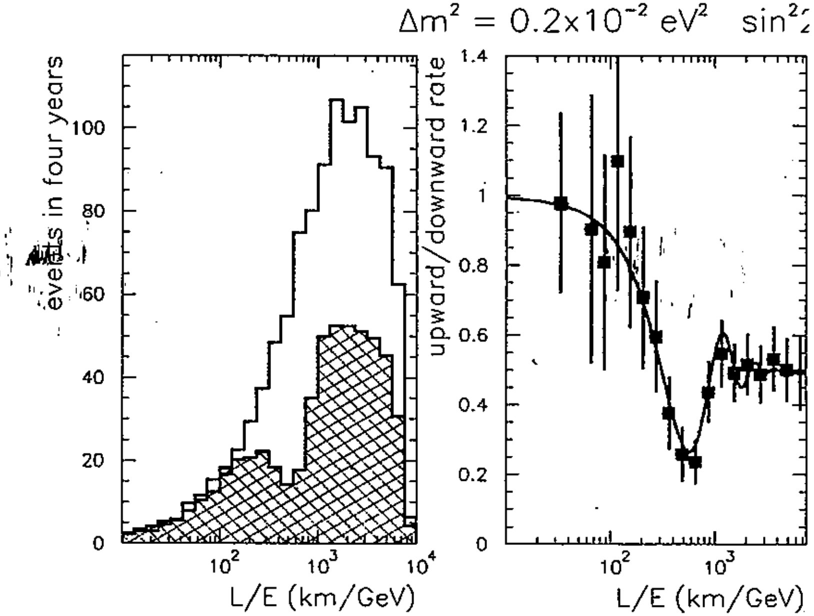


$\Delta m^2 < 0$ | $\Delta m^2 > 0$, LMA | $\Delta m^2 > 0$, LOW



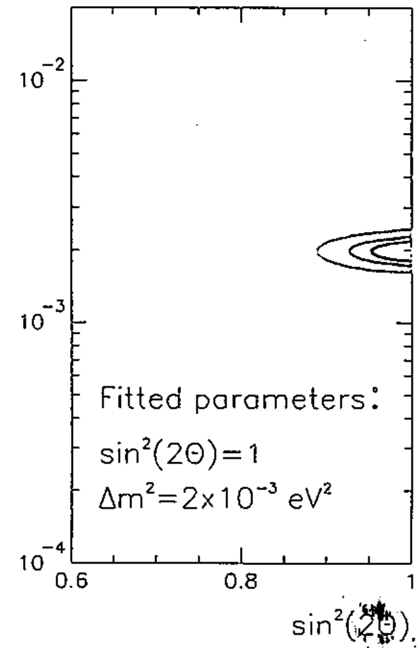
MONOLITH (atmospheric neutrino)





35 kton

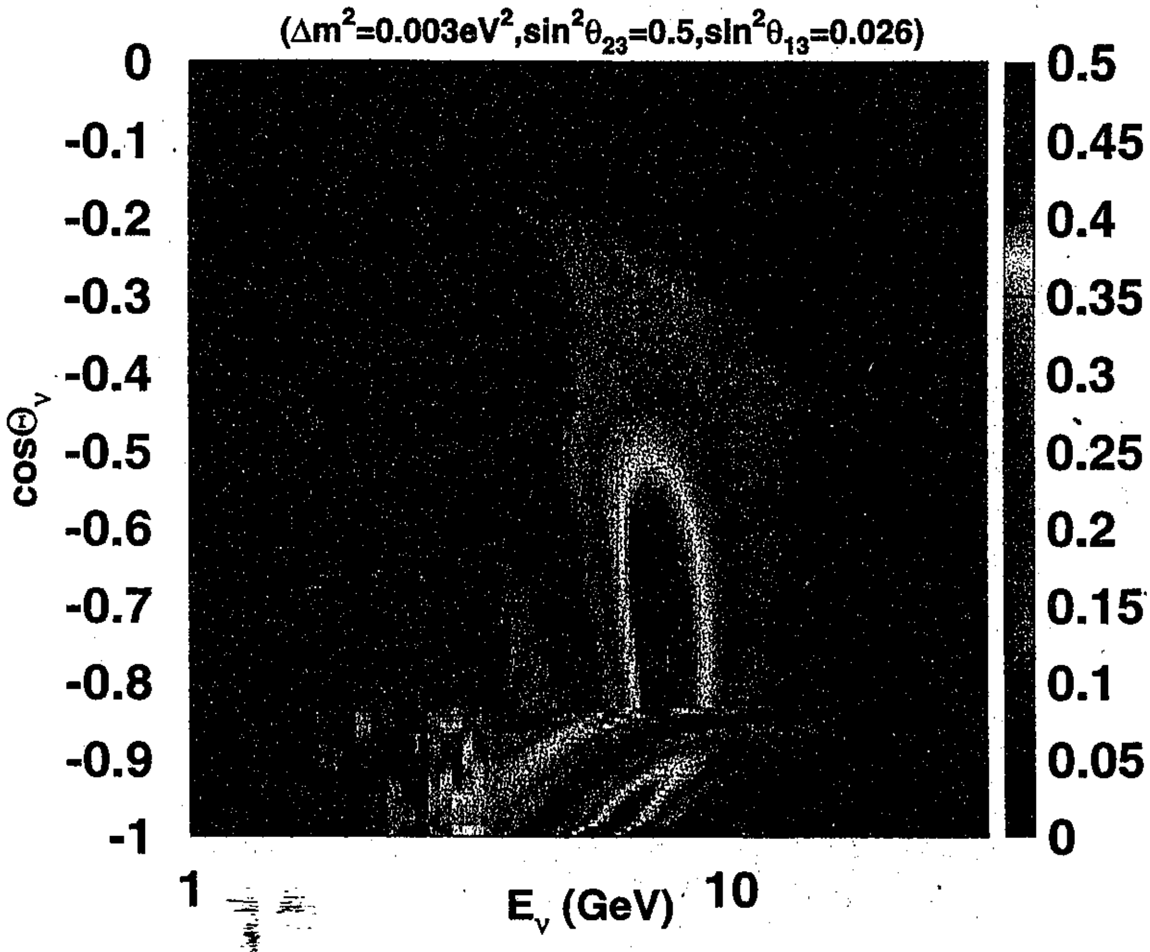
Muon charge measurable.



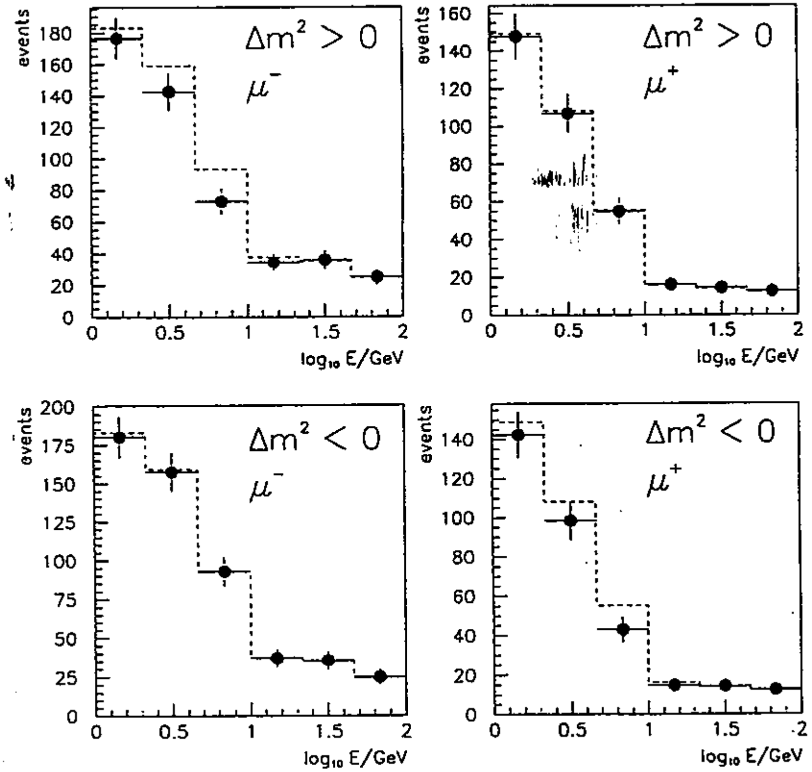
3 flavor analysis

➡ Matter effect $P(\bar{\nu}_e \to \bar{\nu}_\mu)$ for $\Delta m^2 < 0$

$P(\nu_e \to \nu_\mu)$ for $\Delta m^2 > 0$



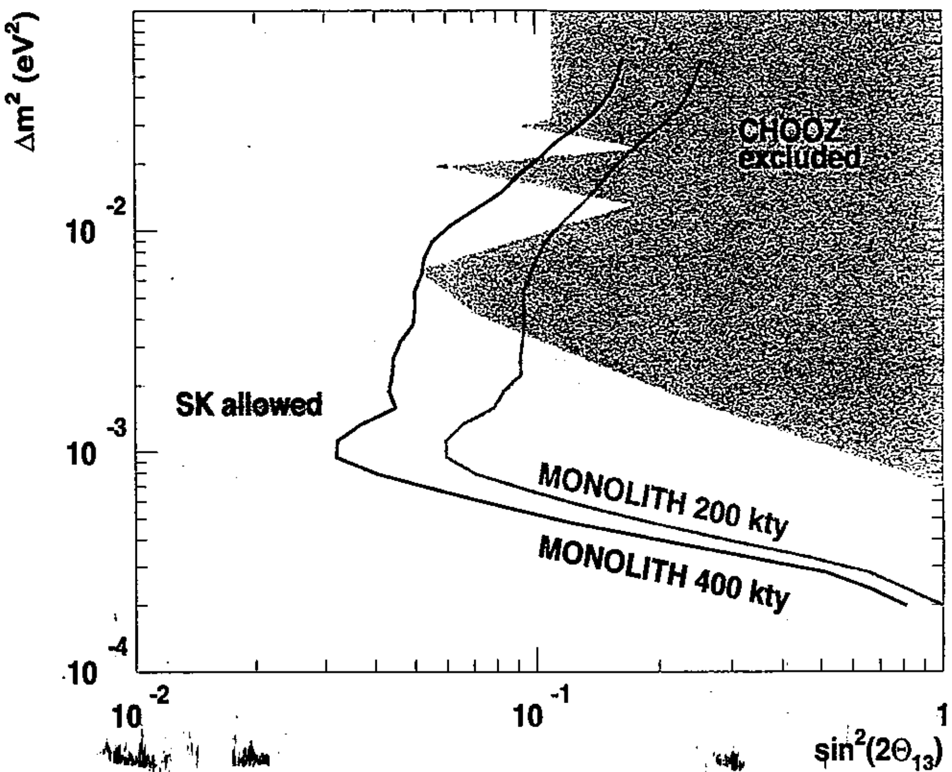
MONOLITH sensitivity



$$\begin{cases} \sin^2\theta_{13} = 0.02 \\ \Delta m^2 = 0.0025 \end{cases}$$

(Dotted line: $\sin^2\theta_{13}=0$)

Parameter region that the MONOLITH experiment is sensitive to the sign of Δm^2 at 90%C.L.



まとめ

- Θ_{13} の測定は、現在実験・建設中の実験ではあまり多くを期待できないが、いろいろな実験が提案されている。

- $\Delta m2$の符号の測定は、もし、θ_{13}がCHOOZのlimitのすぐ近くにあれば、大気ニュートリノで、ミューオンの電荷を測定することで決定できる。