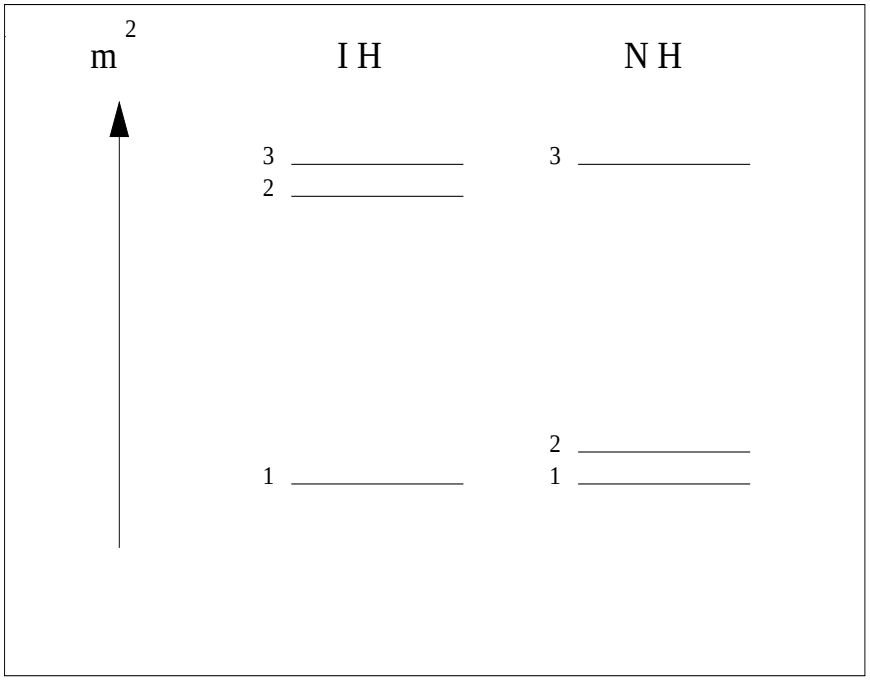
Determining the $\nu-$Mass Hierarchy (sgn($\Delta m^2_{\rm atm}$)



- Reactor $\bar{\nu}_e$ Oscillations in vacuum.
- Atmospheric ν experiments: subdominant $\nu_{\mu(e)} \to \nu_{e(\mu)}$ and $\bar{\nu}_{\mu(e)} \to \bar{\nu}_{e(\mu)}$ oscillations (matter effects).
- LBL $\nu-$oscillation experiments (T2KK, NOνA); $\nu-$factory.
- ^{3}H β-decay Experiments (sensitivity to 5×10^{-2} eV).
- $(\beta\beta)_{0\nu}-$Decay Experiments (ν_j- Majorana particles).

Reactor $\bar{\nu}_e$ Oscillations in vacuum

$$P_{\rm NH}(\bar{\nu}_e \to \bar{\nu}_e) = 1 - \tfrac{1}{2}\sin^2 2\theta_{13}\left(1 - \cos\tfrac{\Delta m^2_{\rm A} L}{2E_\nu}\right) - \tfrac{1}{2}\cos^4\theta_{13}\sin^2 2\theta_\odot\left(1 - \cos\tfrac{\Delta m^2_\odot L}{2E_\nu}\right)$$
$$+ \sin^2 2\theta_{13}\sin^2\theta_\odot \sin\tfrac{\Delta m^2_\odot L}{4E_\nu}\sin\left(\tfrac{\Delta m^2_{\rm A} L}{2E_\nu} - \tfrac{\Delta m^2_\odot L}{4E_\nu}\right),$$

$$P_{\rm IH}(\bar{\nu}_e \to \bar{\nu}_e) = 1 - \tfrac{1}{2}\sin^2 2\theta_{13}\left(1 - \cos\tfrac{\Delta m^2_{\rm A} L}{2E_\nu}\right) - \tfrac{1}{2}\cos^4\theta_{13}\sin^2 2\theta_\odot\left(1 - \cos\tfrac{\Delta m^2_\odot L}{2E_\nu}\right)$$
$$+ \sin^2 2\theta_{13}\cos^2\theta_\odot \sin\tfrac{\Delta m^2_\odot L}{4E_\nu}\sin\left(\tfrac{\Delta m^2_{\rm A} L}{2E_\nu} - \tfrac{\Delta m^2_\odot L}{4E_\nu}\right),$$

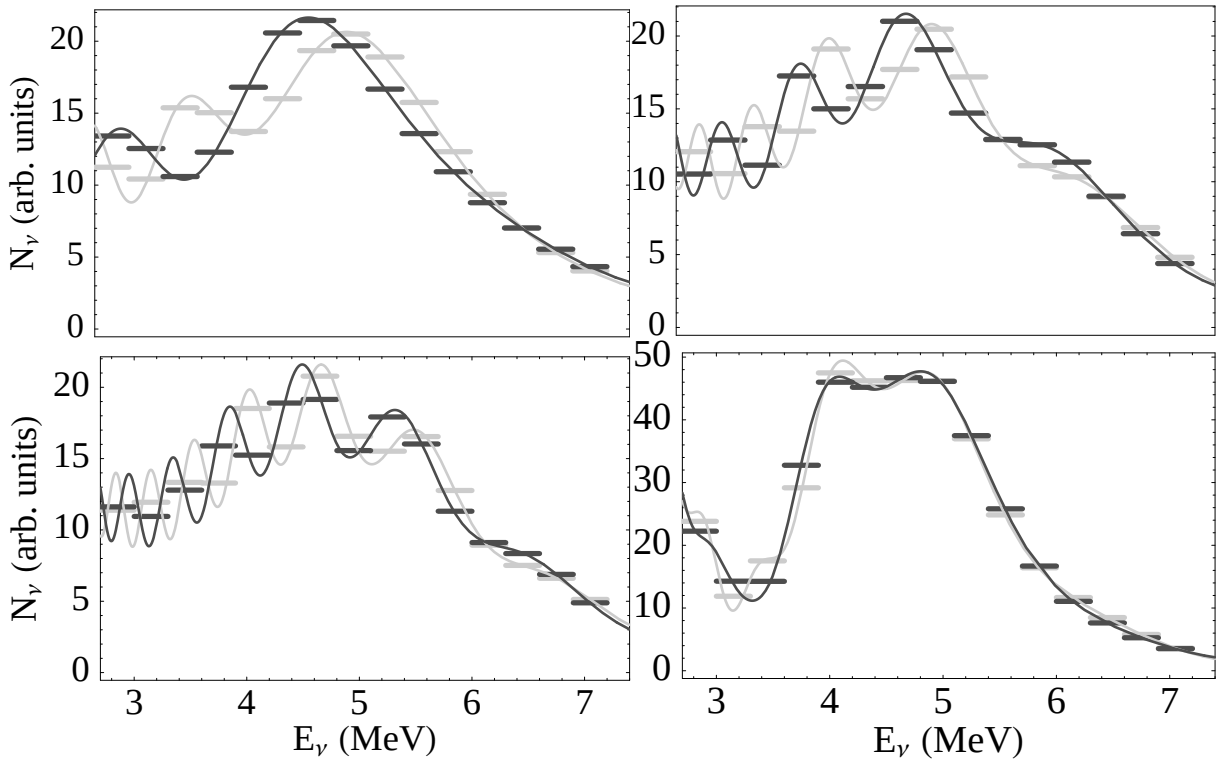
$\theta_\odot = \theta_{12}\,, \Delta m^2_\odot = \Delta m^2_{21} > 0\,;\ \ \sin^2\theta_{12} \leq 0.38$ at 3σ;

$\Delta m^2_{\rm A} = \Delta m^2_{31} > 0\,,$ NH spectrum,

$\Delta m^2_{\rm A} = \Delta m^2_{23} > 0\,,$ IH spectrum

S.M. Bilenky, D. Nicolo, S.T.P., hep-ph/0112216;

M. Piai, S.T.P., hep-ph/0112074;

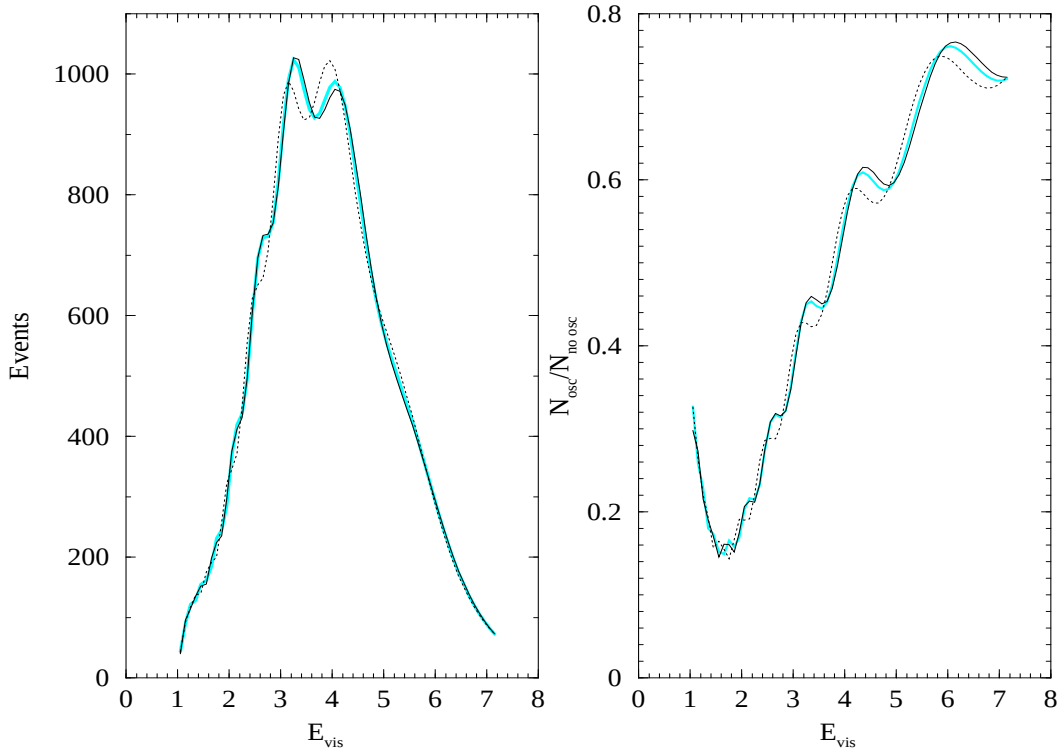


M. Piai, S.T.P., 2001

$\sin^2\theta_{13} = 0.05$, $\Delta m^2_{21} = 2\times10^{-4}$ eV^2; $\Delta m^2_{\rm A} = 1.3;\ 2.5;\ 3.5\times10^{-3}$ eV^2

$L = 20$ km; $\Delta E_\nu = 0.3$ MeV

NH – light grey; IH – dark grey

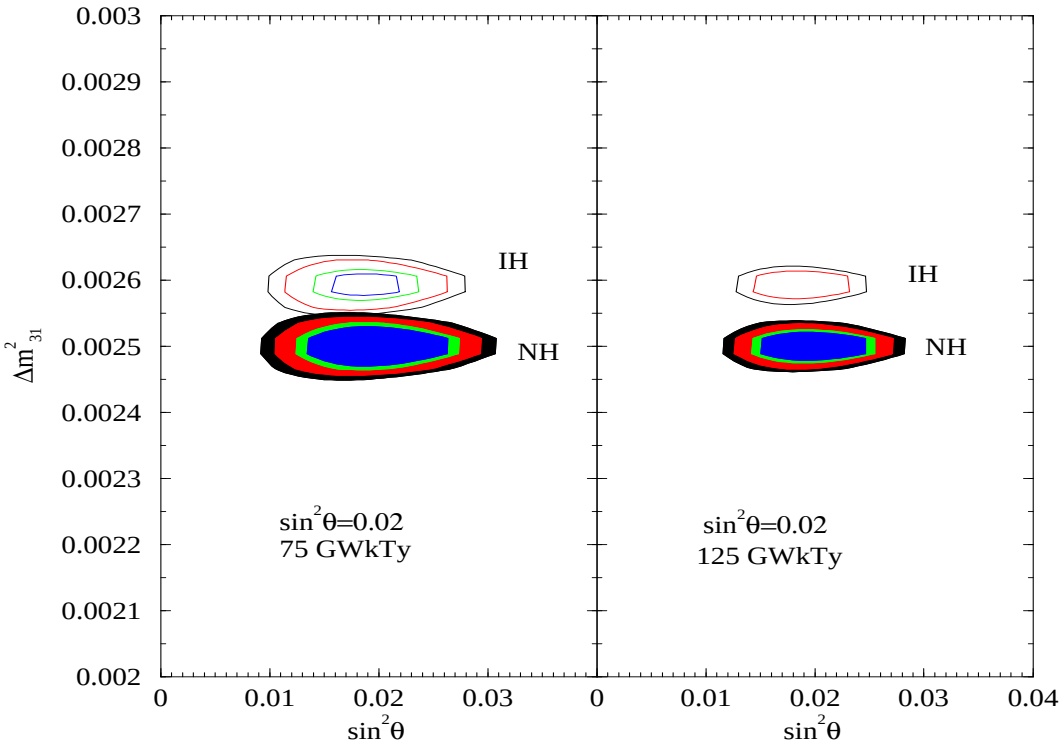


S. Choubey, S.T.P., 2003

$\sin^2\theta_{13} = 0.03$, $\sin^2\theta_{\odot} = 0.30$, $\Delta m^2_{21} = 1.5 \times 10^{-4}$ eV^2, $\Delta m^2_{\rm A} = 2.5 \times 10^{-3}$ eV^2

$L = 20$ km; $\Delta E_\nu = 0.1$ MeV; 75 GWkTy

NH – thick cyan; IH – dotted, thin solid ($\Delta m^2_{\rm A} = 2.6 \times 10^{-3}$ eV^2)

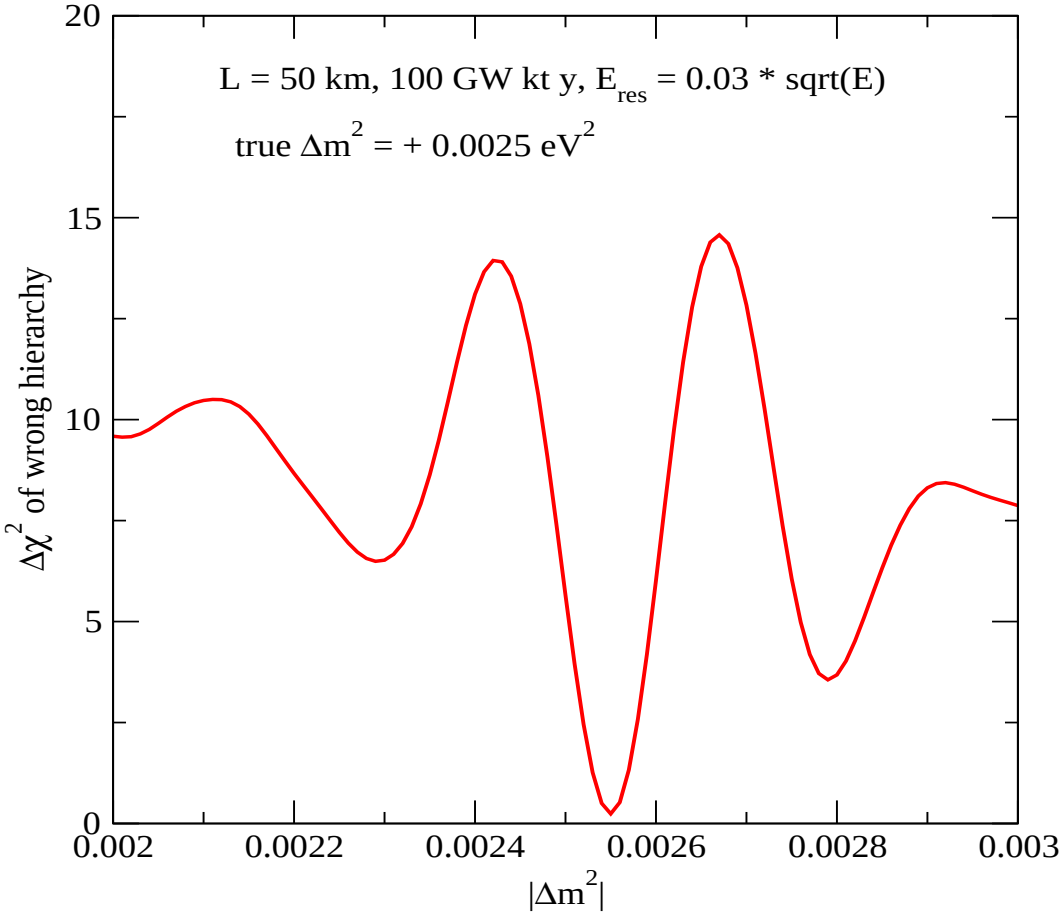


S. Choubey, S.T.P., 2003

$\sin^2\theta_\odot = 0.30,\ \Delta m^2_{21} = 1.5 \times 10^{-4}$ eV^2, $\Delta m^2_{\rm A} = 2.5 \times 10^{-3}$ eV^2

$L = 20$ km; $\Delta E_\nu = 0.1$ MeV; syst. error 2%

"True": NH; 90%, 95%, 99% and 99.73% solution regions



T. Schwetz, September 2006

$\sin^2\theta_\odot = 0.30$, $\Delta m^2_{21} = 8 \times 10^{-5}$ eV^2; "true" $\Delta m^2_{\rm A} = 2.50 \times 10^{-3}$ eV^2 (NH)

Minimum at $\Delta m^2_{\rm A} = -\ 2.55 \times 10^{-3}$ eV^2 (IH)

Precision of $\sim 1\%$ on $|\Delta m^2_{\rm A}|$ required