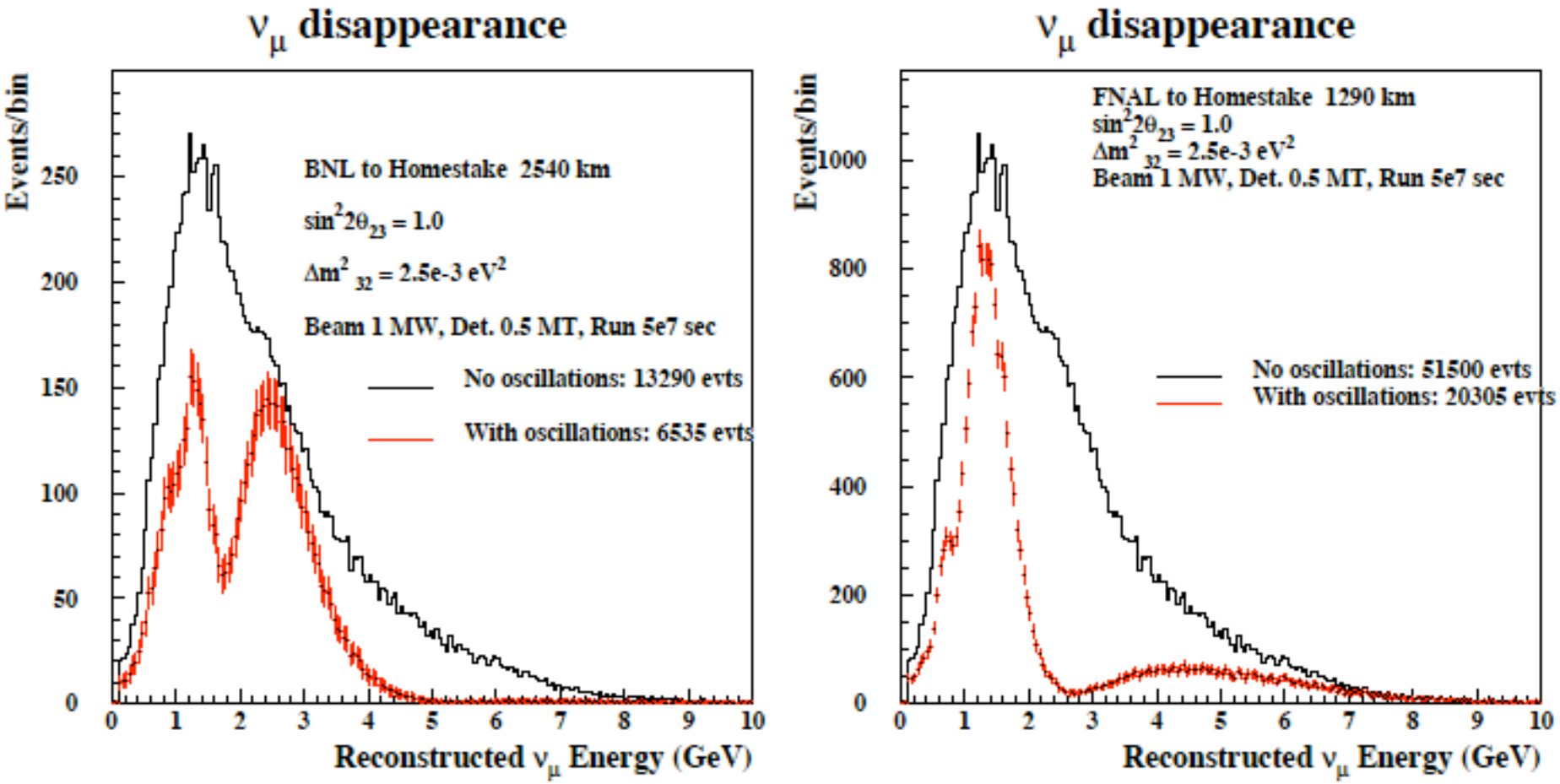


Figure 2: *Simulated spectrum of detected muon neutrinos for 1 MW beam and 500 kT detector exposed for* 5×10^7 *sec. Left side is for baseline of 2540 km, right side for baseline of 1290 km. The oscillation parameters assumed are shown in the figure. Only clean single muon events are assumed to be used for this measurement (see text).*

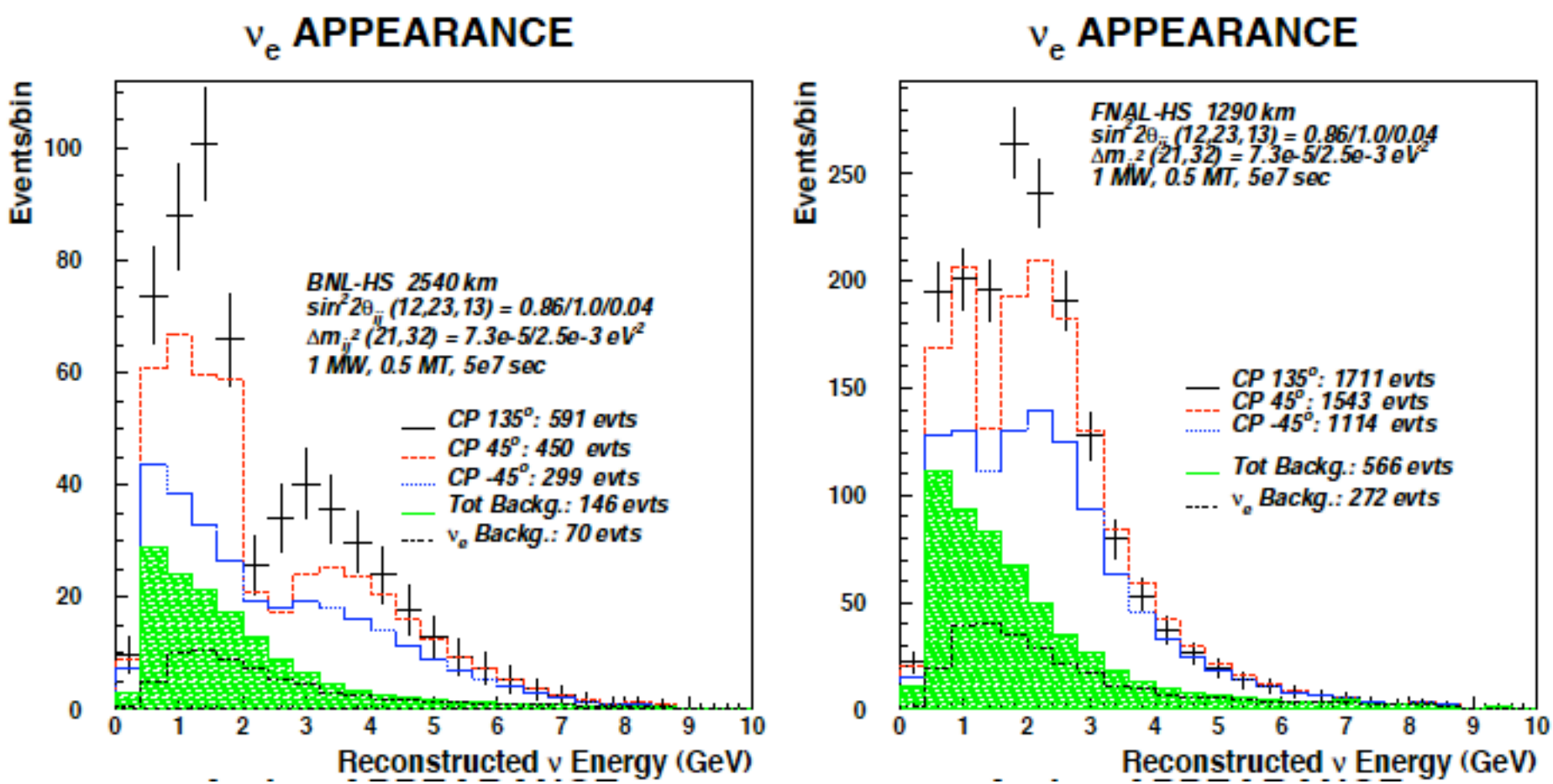


Figure 4: *Simulation of detected electron neutrino (top plots) ~~and anti-neutrino (bottom plots)~~ spectrum (left for BNL-HS 2540km, right for FNAL-HS 1290 km) for 3 values of the CP parameter δ_{CP}, 135°, 45°, and −45°, including background contamination. Obviously, the dependence of event rate on the CP phase has the opposite order for neutrinos and anti-neutrinos. The hatched histogram shows the total background. The ν_e beam background is also shown. The other assumed mixing parameters and running conditions are shown in the figure. These spectra are for the regular mass hierarchy (RO).*

Neutrino oscillation

What we know

- $|\Delta m^2_{31}| \sim 2.5 \cdot 10^{-3}\,\mathrm{eV}^2$ and $\theta_{23} \sim \pi/4$
- $\Delta m^2_{21} \sim 8 \cdot 10^{-5}\,\mathrm{eV}^2$ and $\theta_{12} \sim 0.55$

What we don't know

- θ_{13}
- δ
- $\mathrm{sign}\Delta m^2_{31}$

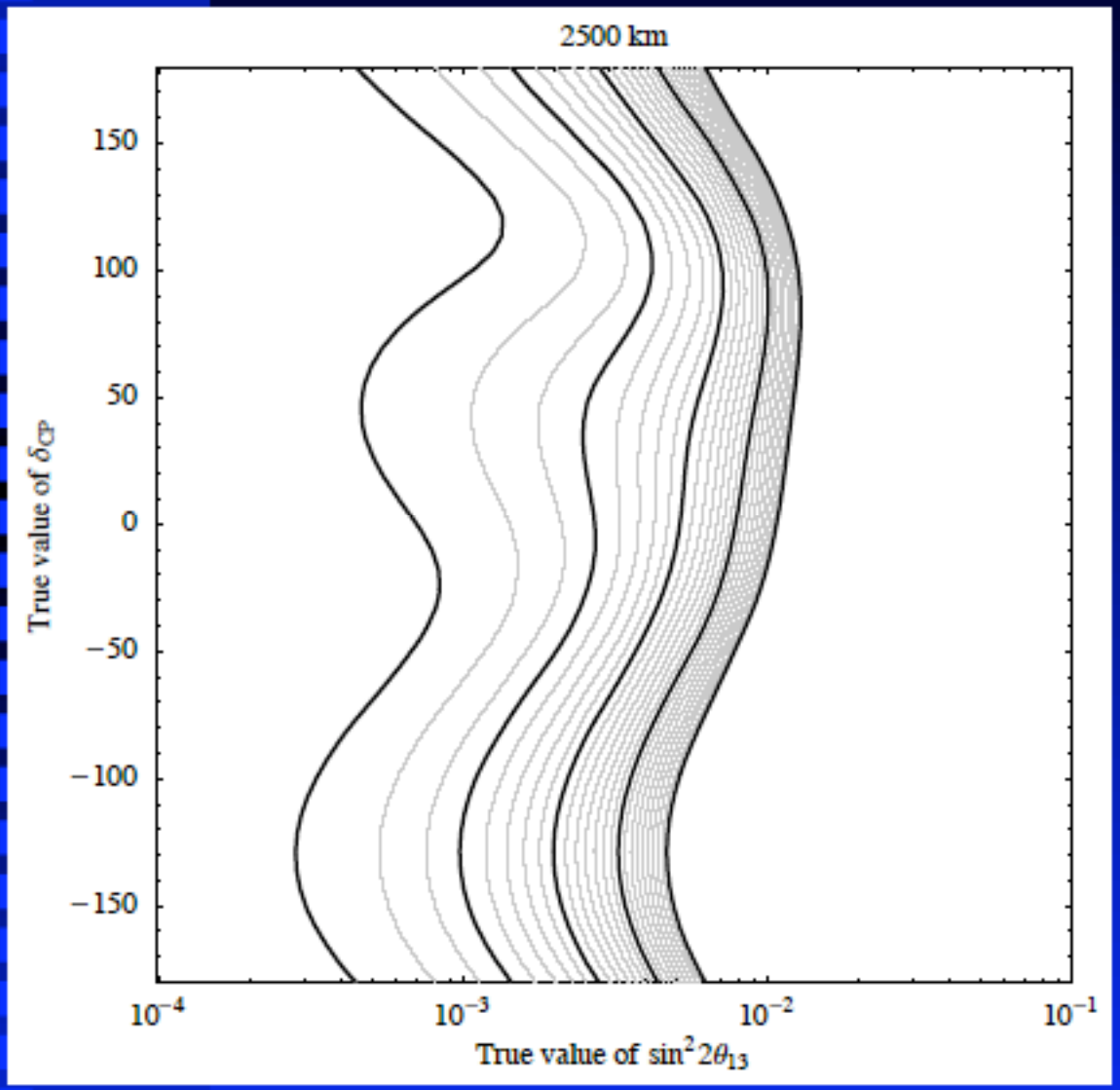
Our study

specifically we assume

- protons with $E = 28\,\mathrm{GeV}$ and $P = 1\,\mathrm{MW}$
- $500\,\mathrm{kt}$ water Cherenkov detector
- π^0 suppression verified by Super-K MC
- $5 \times 10^7\mathrm{s}$ neutrino running
- $5 \times 10^7\mathrm{s}$ anti-neutrino running
- 10% uncertainty on the background
- 5% matter density uncertainty

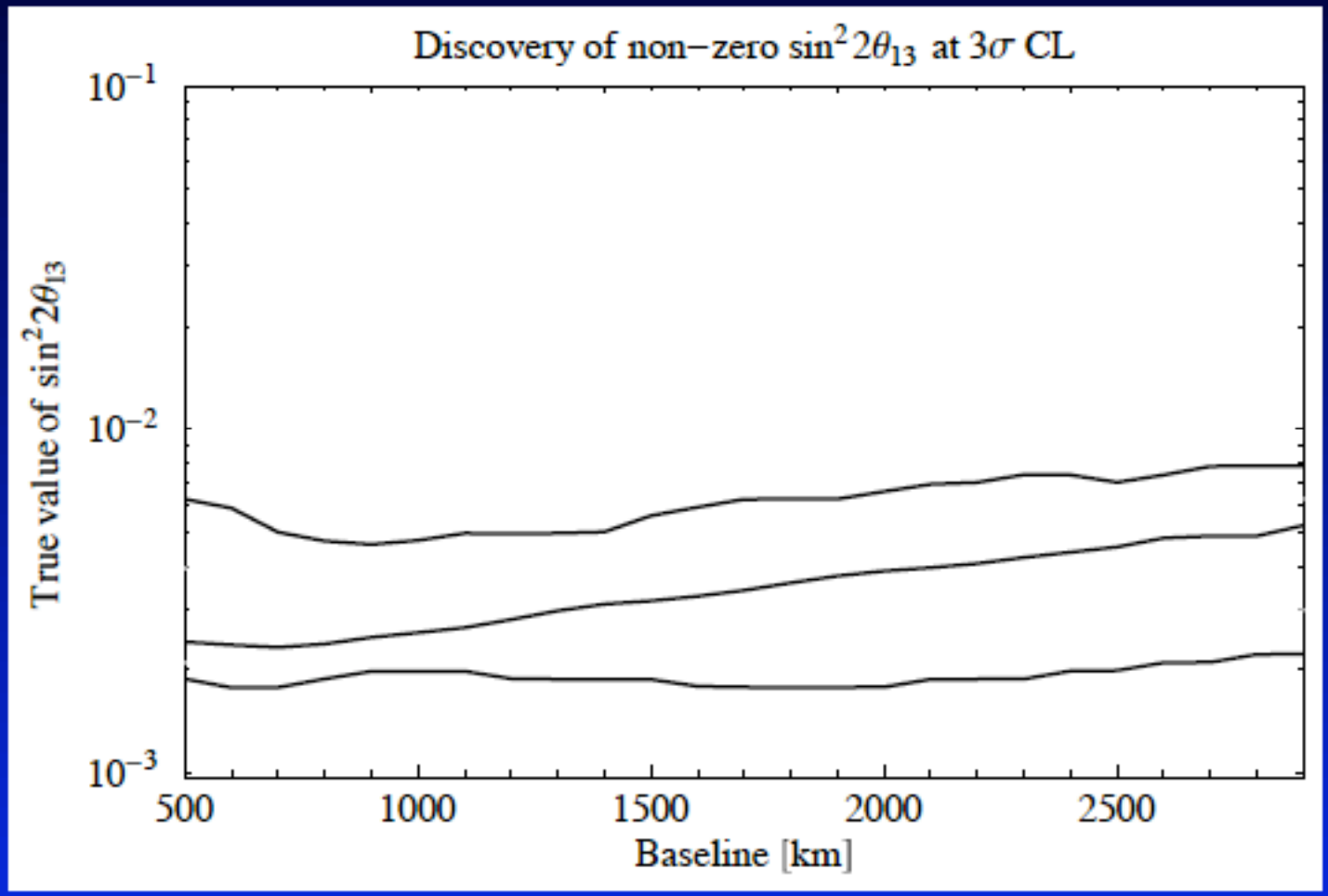
full analysis with GLoBES

Discovery of θ_{13}



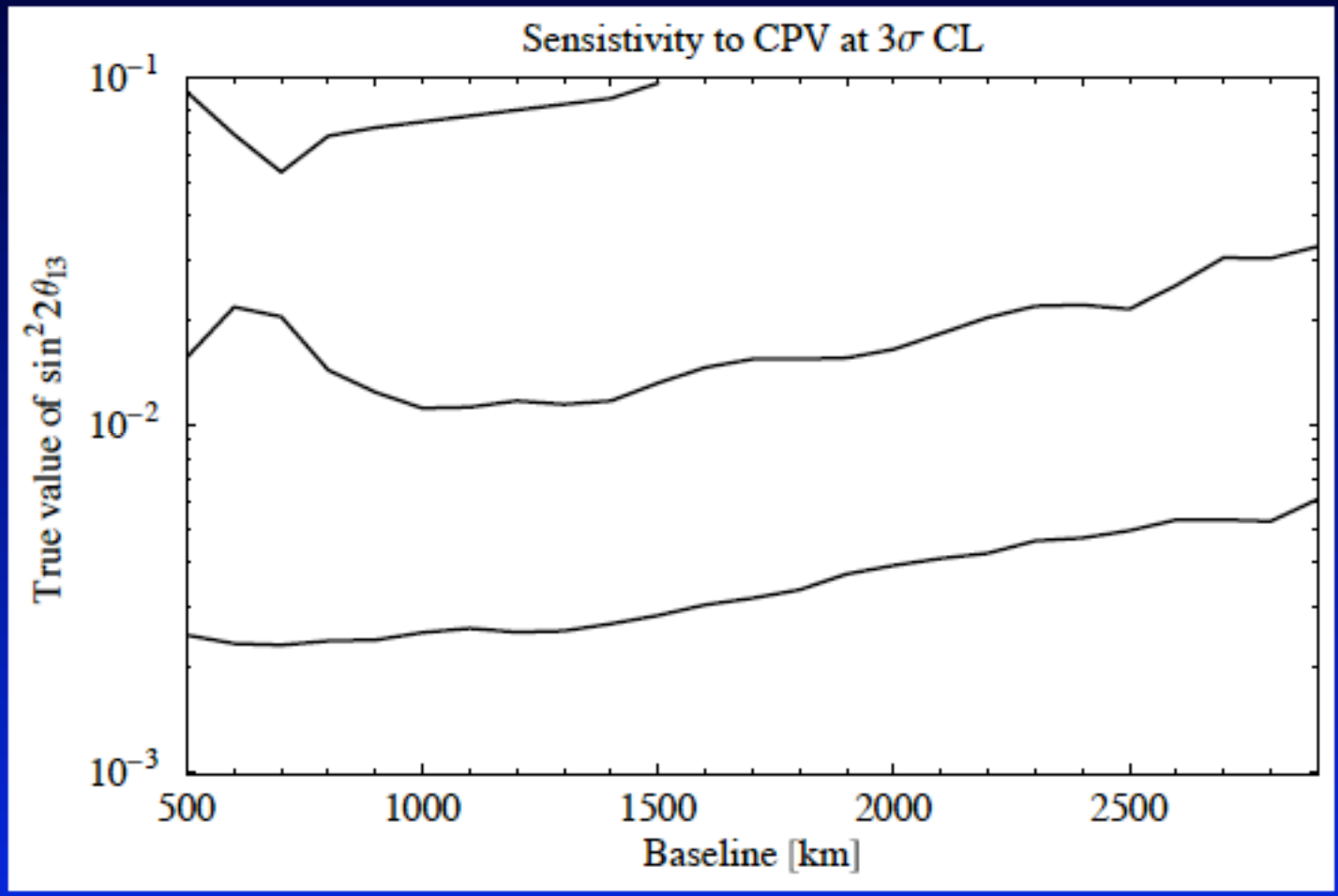
- simulate data for δ and $\theta_{13} \neq 0$
- try to fit them with $\theta_{13} = 0$
- repeat the fit for the wrong hierarchy
- take the smallest χ^2

Baseline dependence



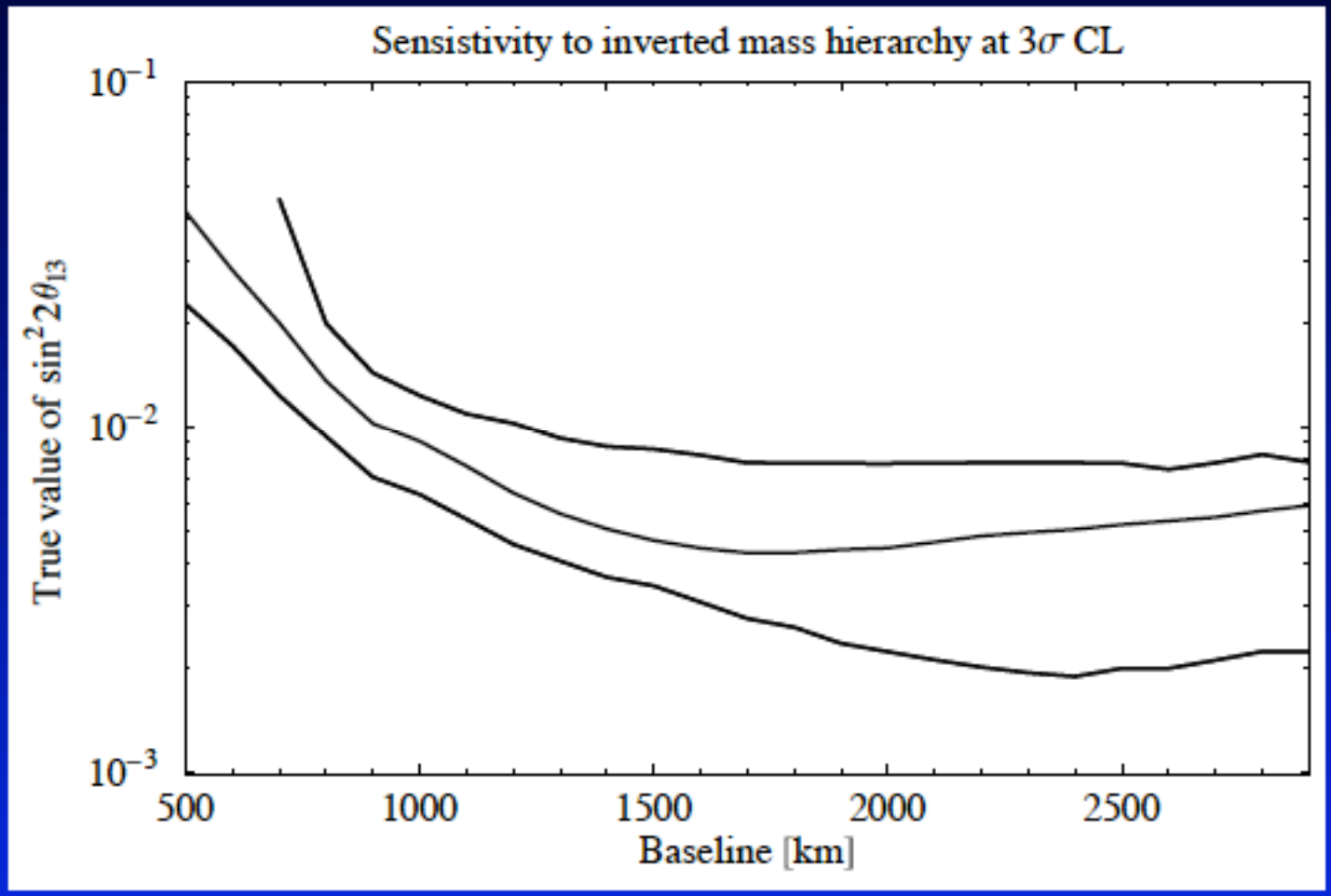
- weak baseline dependence

Baseline dependence



- baselines between 1000 and 2000 km are very similar

Baseline dependence

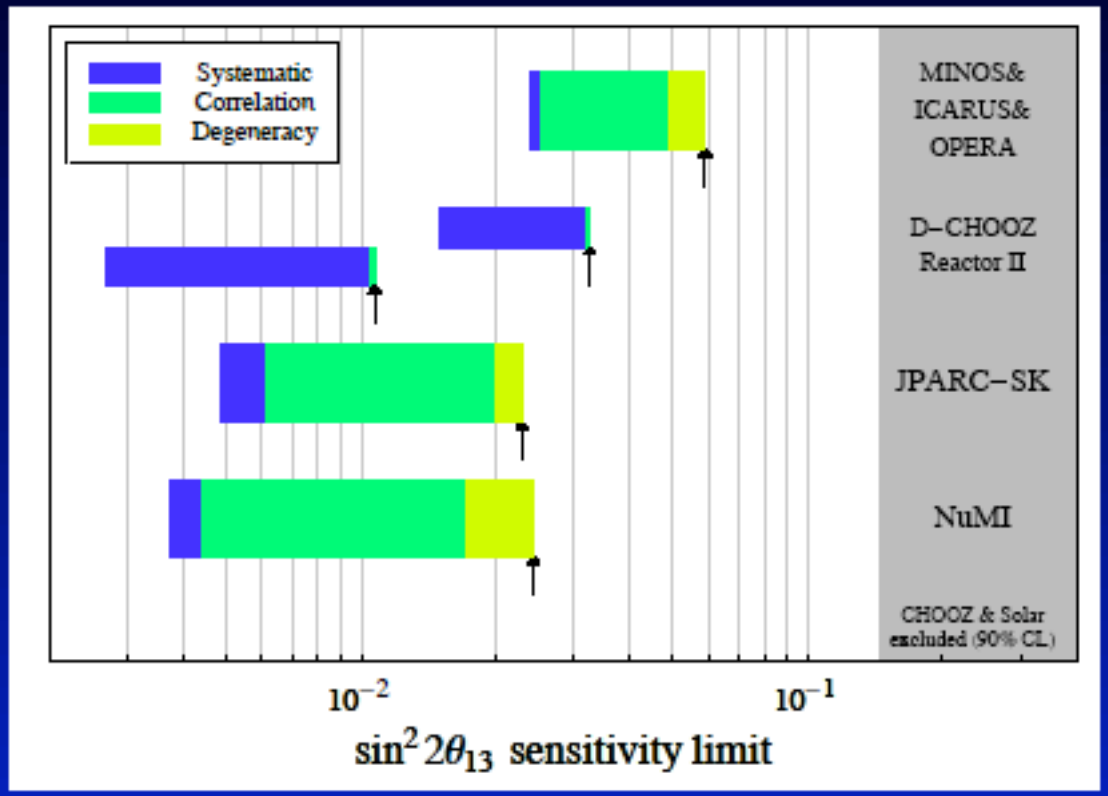


- long baselines are clearly favored

Wide band beam

- backgrounds are under control
- full analysis corroborates earlier findings
- baselines above 1000 km are preferred
- wide band beams are very competitive

$\sin^2 2\theta_{13}$ within the next ten years



true values:

$\sin^2 2\theta_{12} = 0.8$

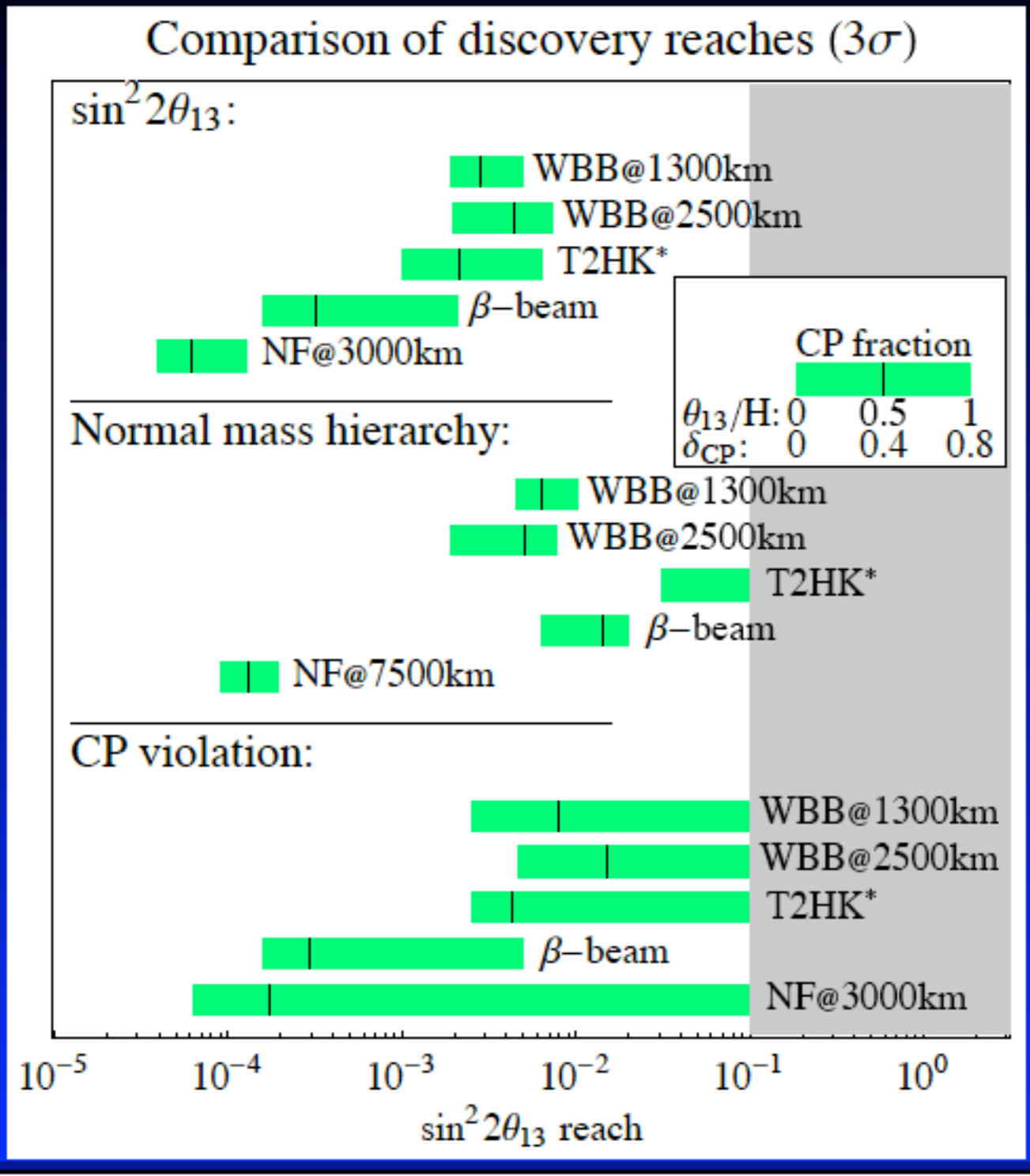
$\sin^2 2\theta_{23} = 1.0$

$\sin^2 2\theta_{13} = 0.0$

$\Delta m^2_{21} = 7.0 \cdot 10^{-5}$ eV

$\Delta m^2_{31} = 2.0 \cdot 10^{-3}$ eV

PH, Lindner, Rolinec, Schwetz, Winter, Phys. Rev. D70 (2004) 073014



β-beam, T2HK* and NF numbers are taken from PH, M. Lindner and W. Winter, JHEP **0505**, 020 (2005)