Introduction

$\sin^2 2\theta_{13} \sim 0.1$ ***is observed***

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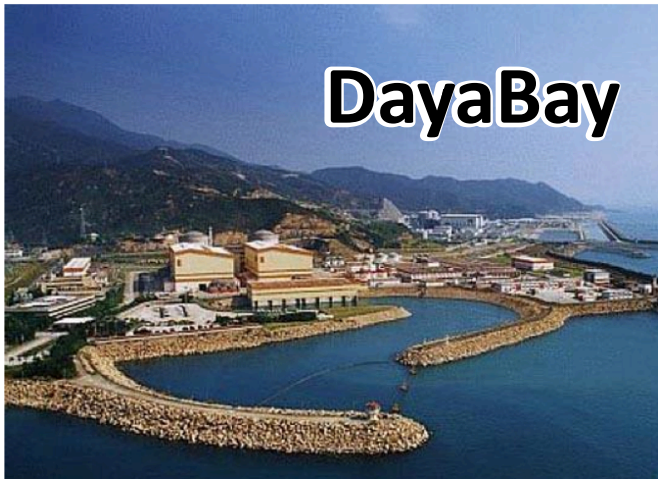
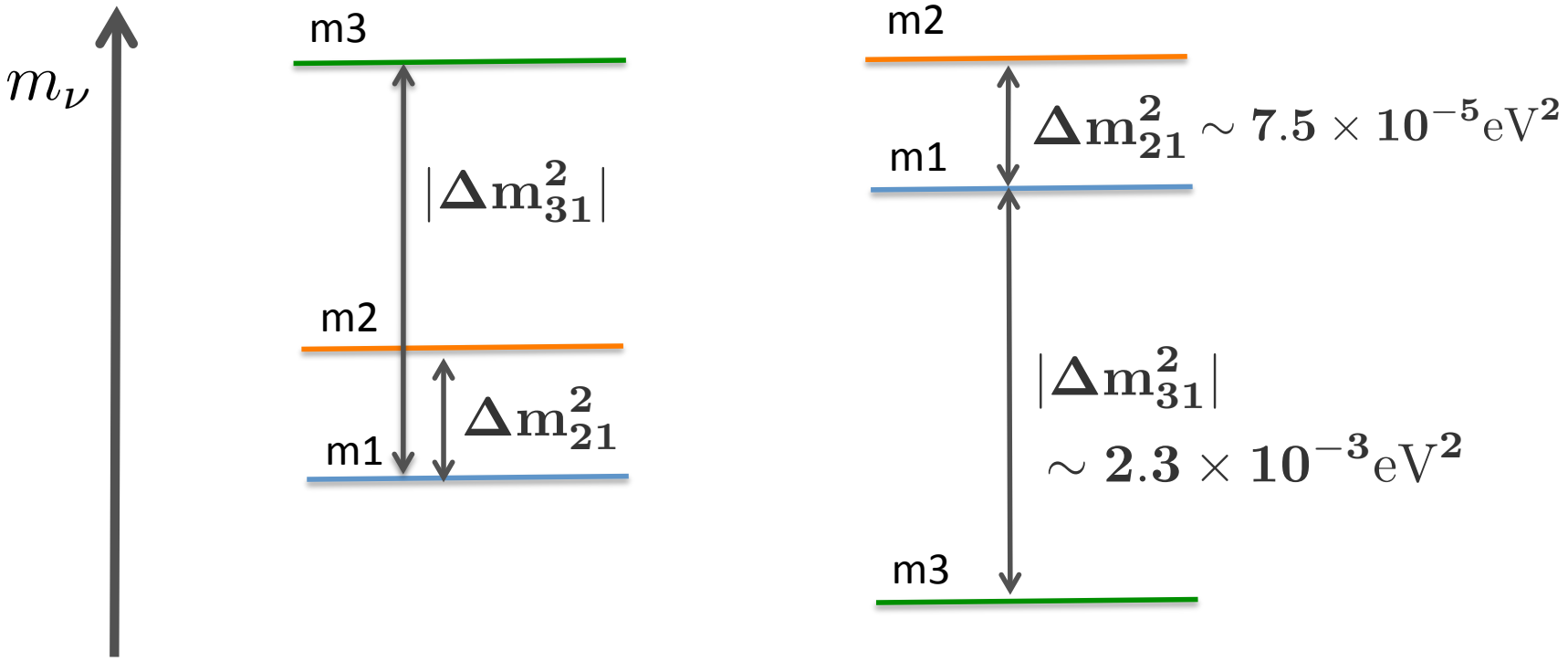
Reactor Experiments (Medium Baseline)
will determine the ***Neutrino Mass Hierarchy*** .

We ***study the sensitivity***
of such future Experiments.



Neutrino Mass Hierarchy

Normal Hierarchy (NH) ***Inverted Hierarchy*** (IH)



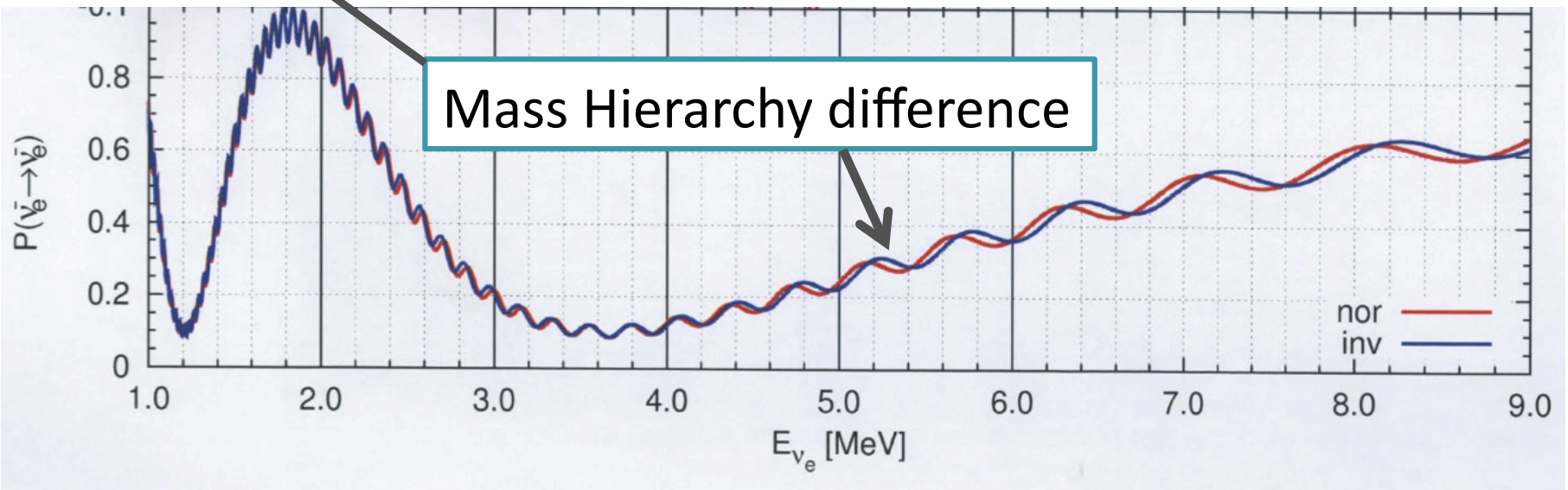
Which **Hierarcy** is realized in Nature?

How to distinguish MH ? (theory)

$\overline{\nu}_e \rightarrow \overline{\nu}_e$ Oscillation

$$P_{ee} = 1 - \cos^4\theta_{13}\sin^2 2\theta_{12}\sin^2(\Delta_{21}) - \sin^2 2\theta_{13}\sin^2(|\Delta_{31}|) - \sin^2\theta_{12}\sin^2 2\theta_{13}\sin^2(\Delta_{21})\cos(2|\Delta_{31}|) \pm \frac{\sin^2\theta_{12}}{2}\sin^2 2\theta_{13}\sin(2\Delta_{21})\sin(2|\Delta_{31}|)$$

$$\Delta_{ij} \equiv \frac{\Delta m^2_{ij} L}{4E_\nu}, \quad (\Delta m^2_{ij} \equiv m^2_i - m^2_j)$$



How to distinguish MH ? (experiment)

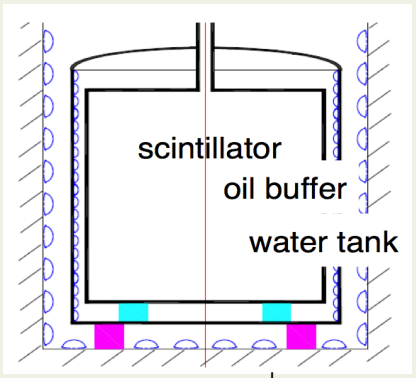
Reactor neutrino experiment

Reactor

$\overline{\nu}_e$

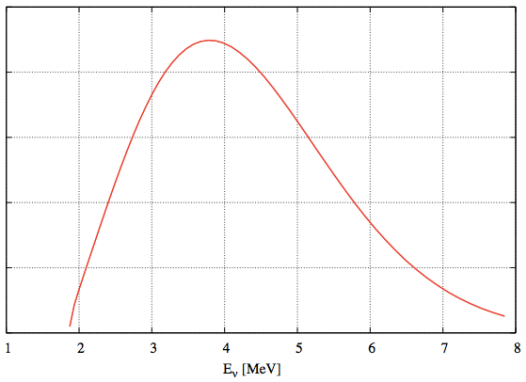
Baseline (L km)

Detector



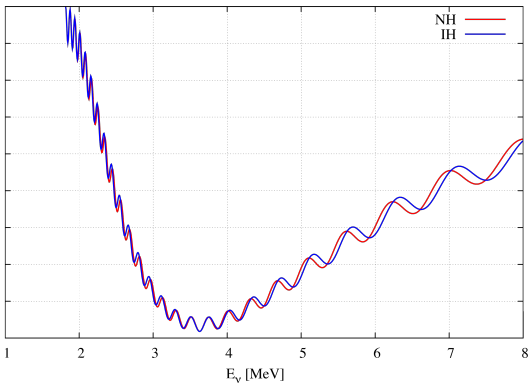
$\overline{\nu}_e + p \rightarrow e^+ + n$

$\overline{\nu}_e$ Flux @ Reactor



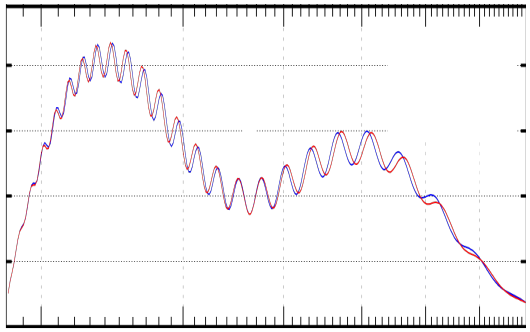
$\otimes$

$\mathbf{P_{ee}}$



$=$

$\overline{\nu}_e$ @ Detector



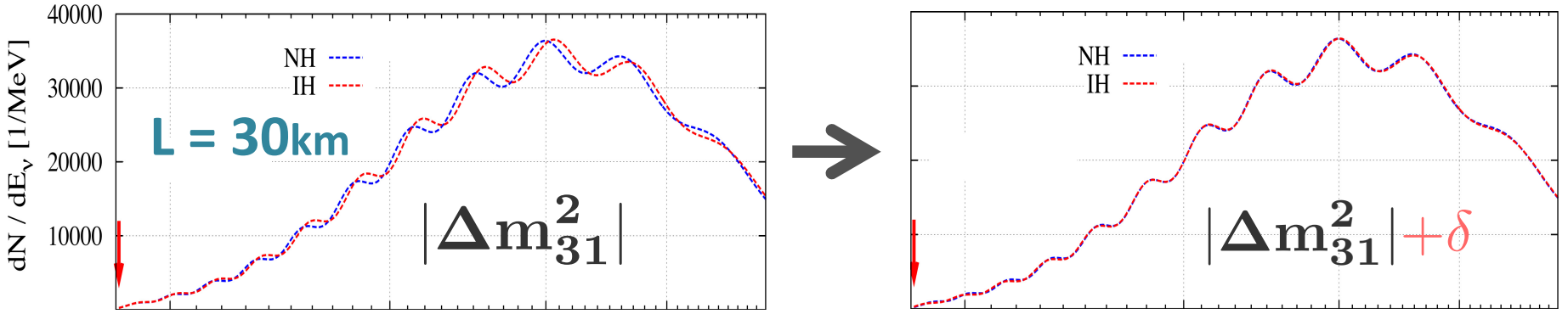
We estimate the **sensitivity** to **distinguish** the **MH difference**.

Method χ^2 analysis

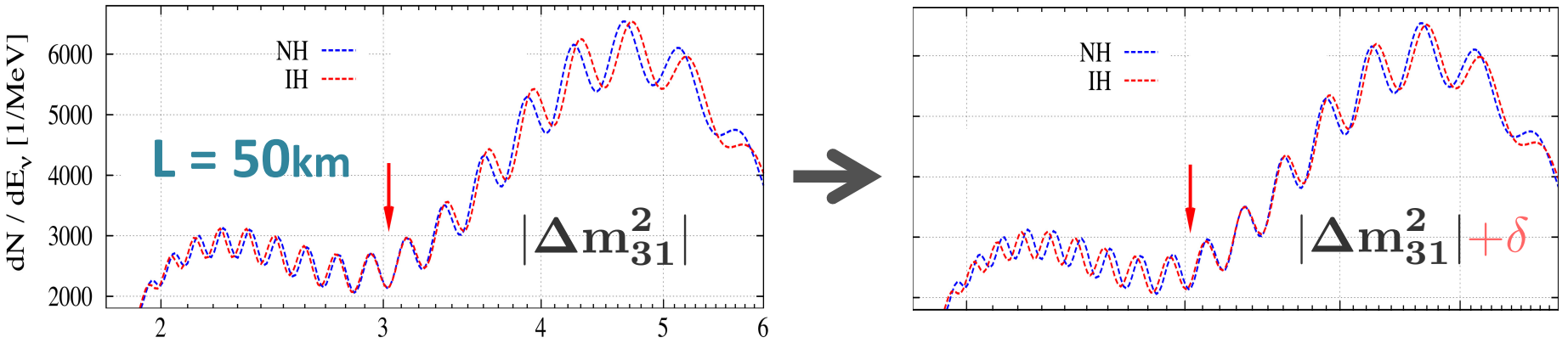
What affects the sensitivity ?

Baseline Length

Short Baseline (L < 50km) is less sensitive

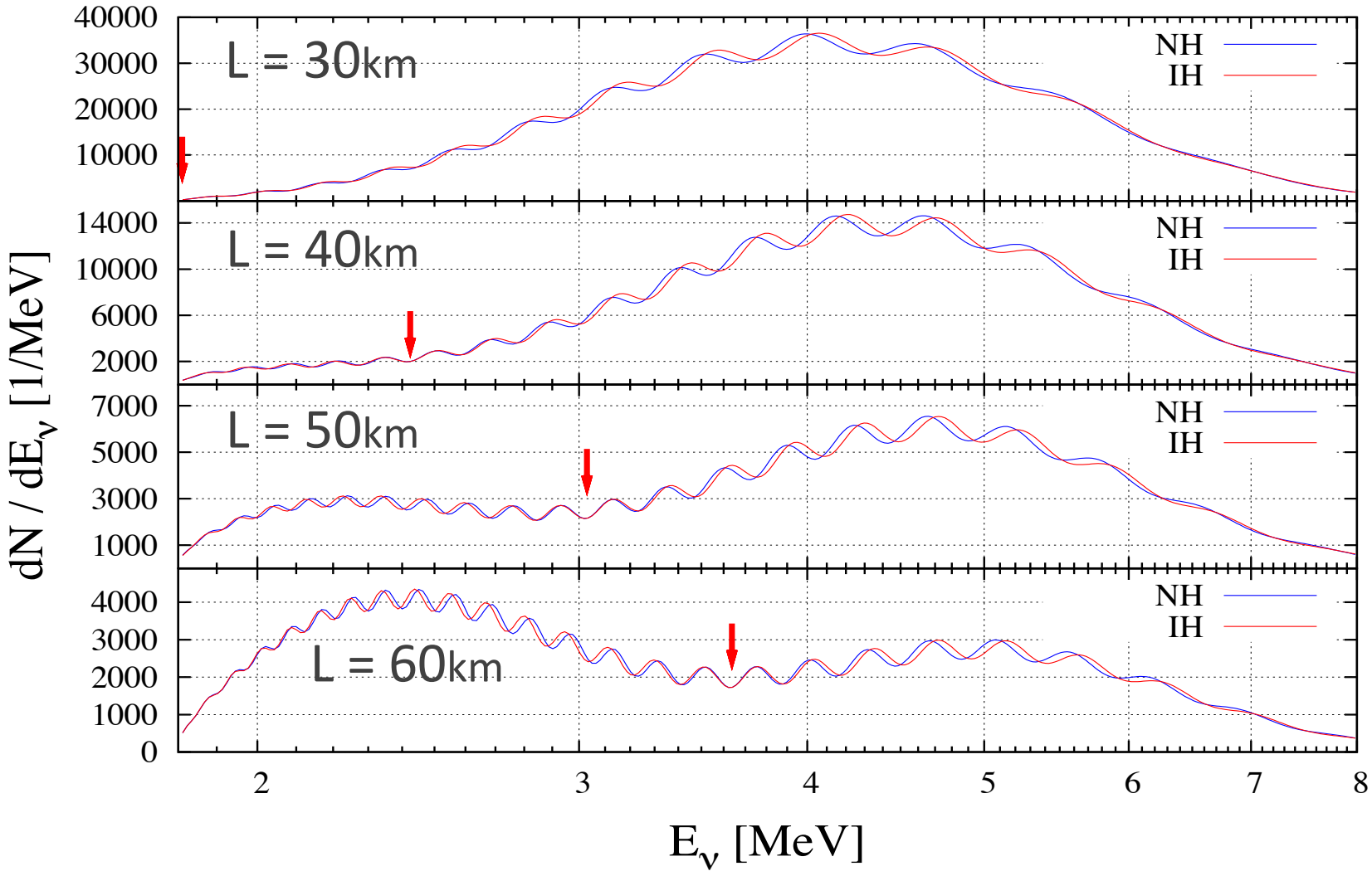


MH difference disappears after shift in $|\Delta m^2_{31}|$ @ **L = 30km**.



MH difference remains after shift in $|\Delta m^2_{31}|$ @ **L = 50km**.

$\overline{\nu}_e$ Energy Distribution @ Detector



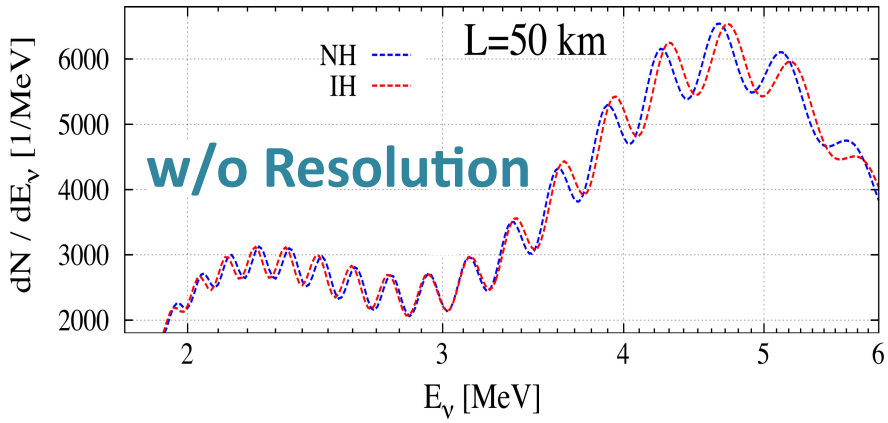
What affects the sensitivity ?

Energy Resolution

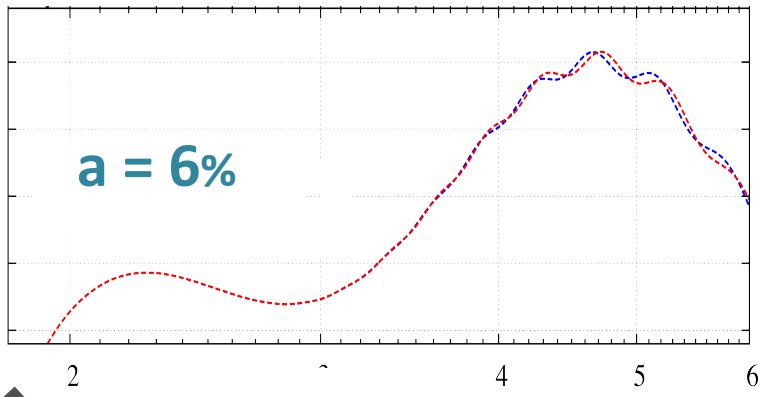
Energy Resolution affects significantly.

$$\frac{\delta E}{E} = \sqrt{\left(\frac{a}{\sqrt{E}}\right)^2 + b^2}$$

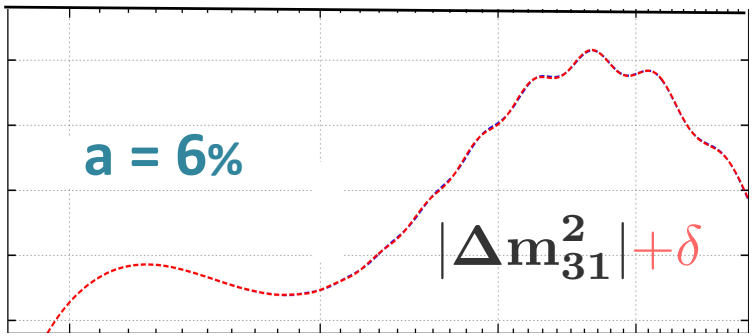
a: statistical error part
b: systematic error part



$\delta E \neq 0$



Shift in $|\Delta m^2_{31}|$

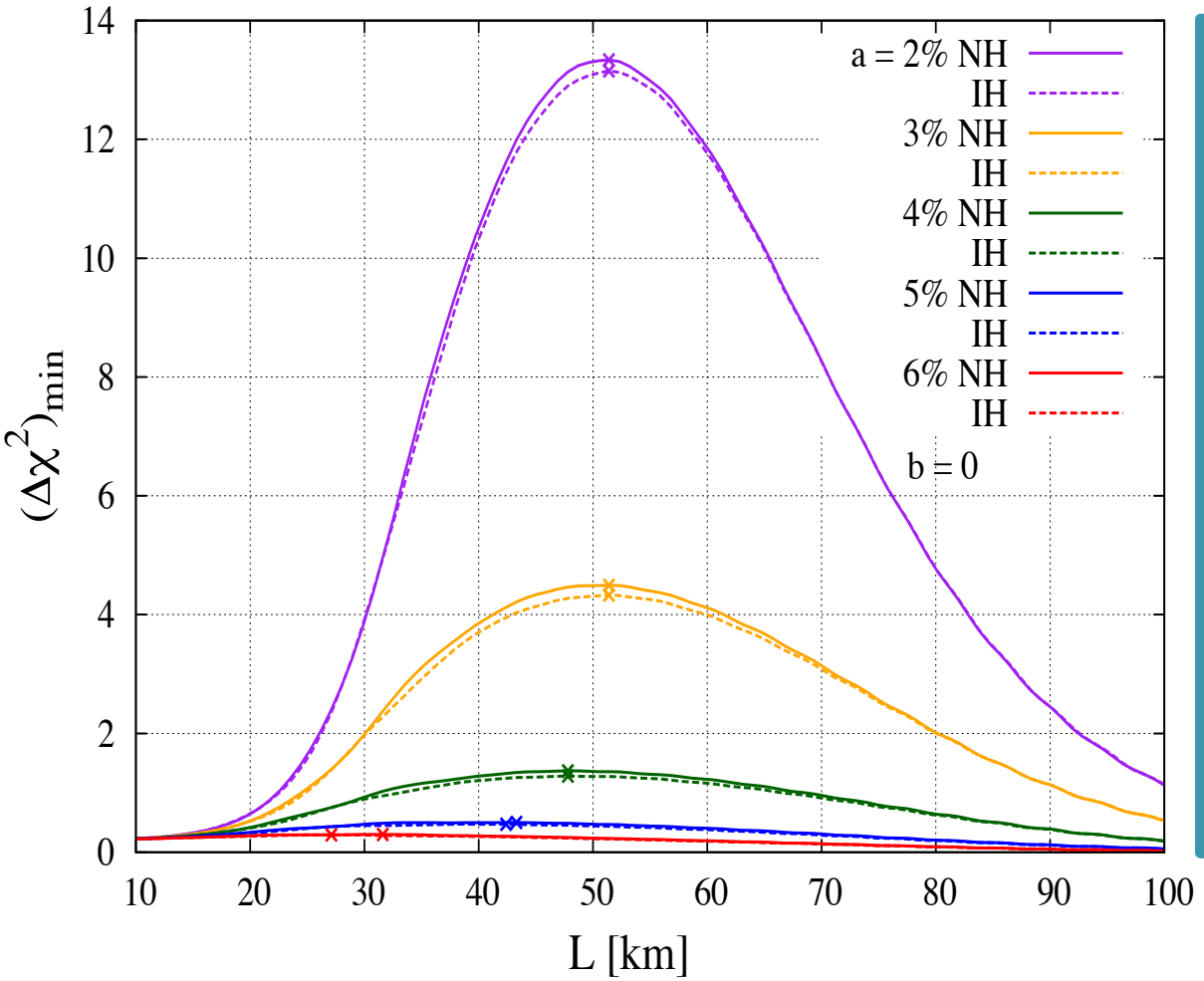


Results 1-a

Sensitivity for Mass Hierarchy

Statistical part of Energy Resolution

20GW 5kton 5yrs



$$\frac{\delta \mathbf{E}}{\mathbf{E}} = \sqrt{\left(\frac{\mathbf{a}}{\sqrt{\mathbf{E}}}\right)^2 + \mathbf{b^2}}$$

a < 3%

is required for

$$(\Delta\chi^2)_{\mathrm{min}} \geq 9\,.$$

optimal Baseline

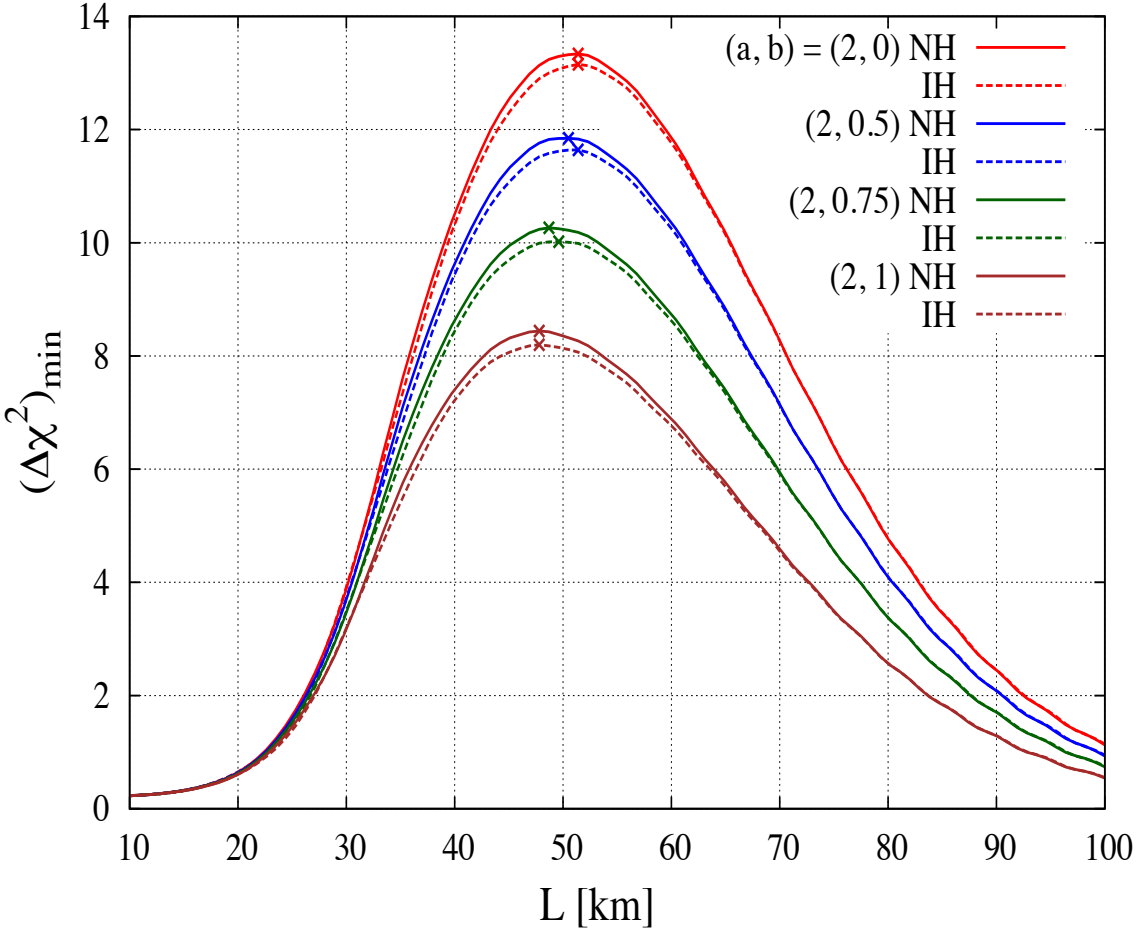
L ~ 50km

Results 1-b

Sensitivity for Mass Hierarchy

Systematic part of Energy Resolution

20GW 5kton 5yrs



$$\frac{\delta \mathbf{E}}{\mathbf{E}} = \sqrt{\left(\frac{\mathbf{a}}{\sqrt{\mathbf{E}}}\right)^2 + \mathbf{b^2}}$$

b < 1%

is required for

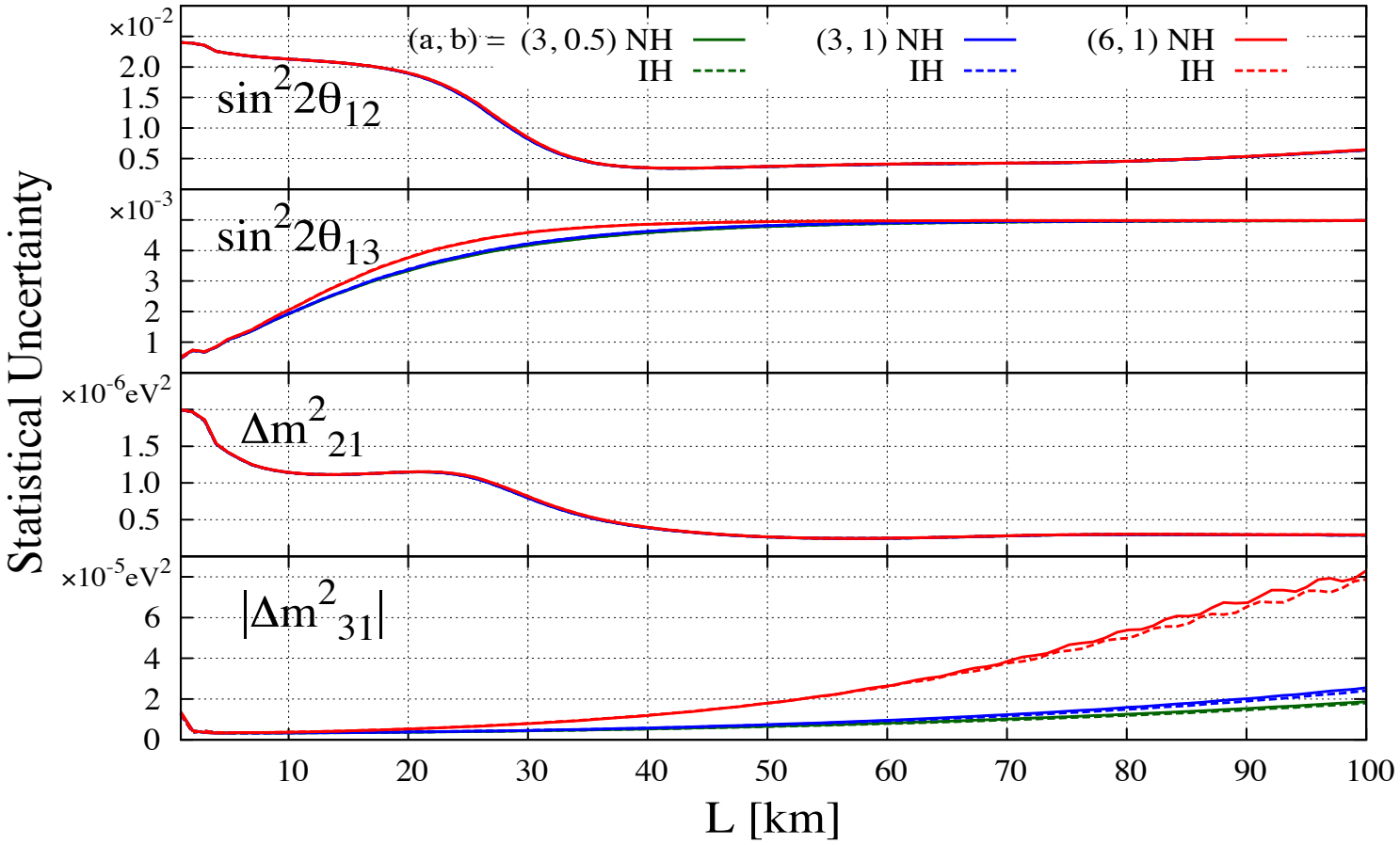
$(\Delta\chi^2)_{\min} \geq 9$.

b↑ → optimal L↓

Results 2
Parameter measurement

Fitted ***parameter values*** are ***not so sensitive*** to the ***Energy Resolution***

~ 0.5% ***accuracy*** can be achieved for $\sin^2 2\theta_{12}, \Delta m^2_{21}, \Delta m^2_{31}$



Summary

We have studied ***the sensitivity*** of
Medium Baseline Reactor Experiments
for ***MH determination***.

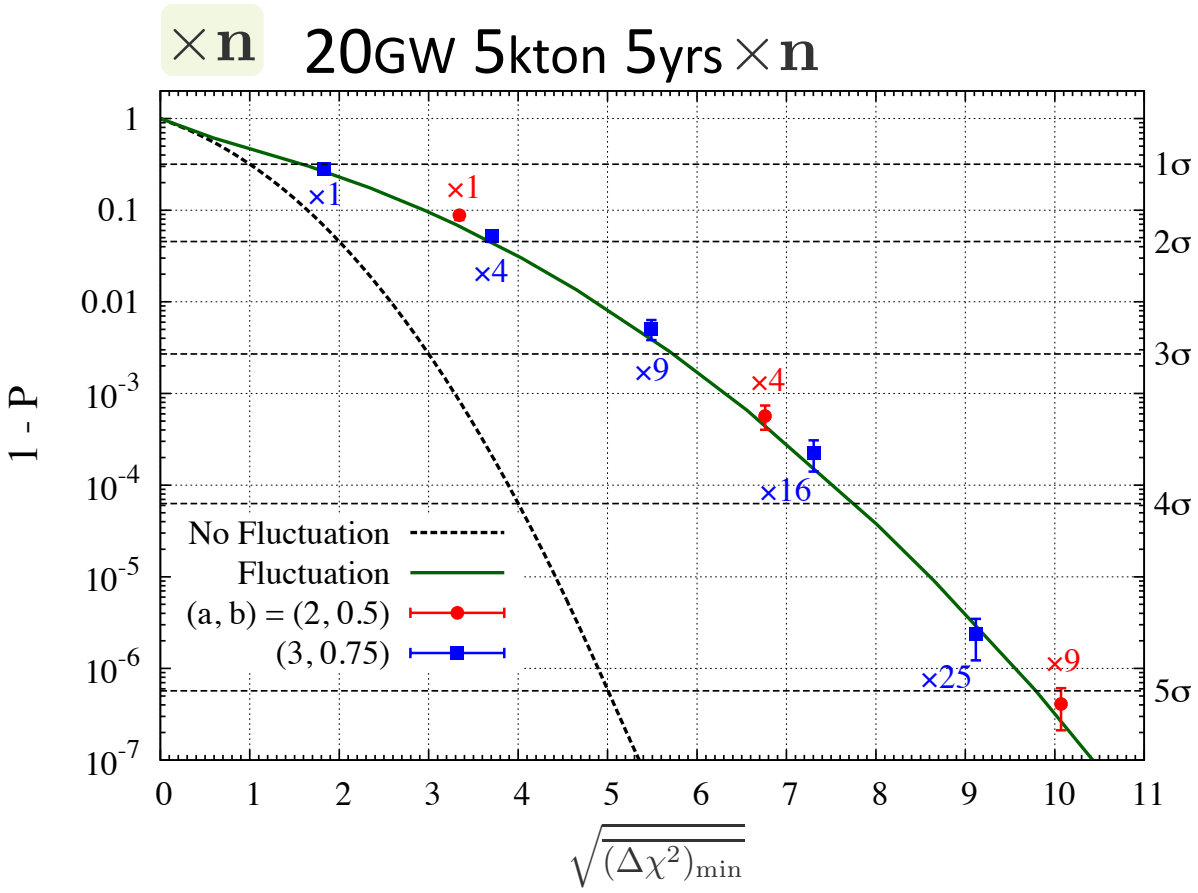
For **20GW 5kton 5yrs** exposure,

50km ***Baseline Length*** is optimal

2-3% ***statistical*** error
1% ***systematic*** error
} of ***Energy Resolution*** is required

0.5% ***accuracy*** is achieved for ***Neutrino parameters***

Expected Sensitivity



Statistical Fluctuation is considered.

We can expect 3σ for

15yrs run | **a = 2%**

50yrs run | **a = 3%**