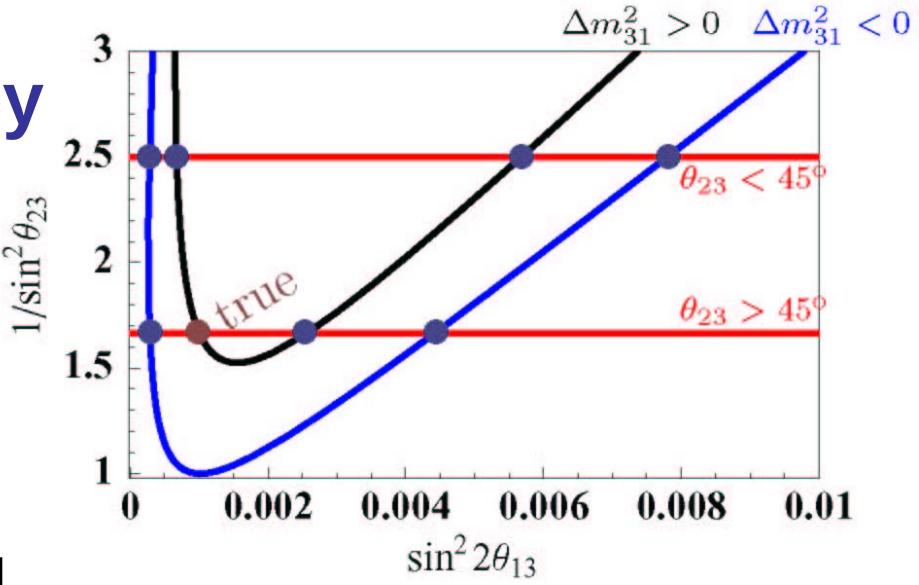
Summary of WG1
– Phenomenological issues

Osamu Yasuda (TMU)

Various proposals to resolve 8-fold degeneracy



Schwetz	**ATM+LBL**
Nunokawa	**T2K-II ($\nu + \bar{\nu}$) +a detector in Korea**
Okamura	**T2K-I (ν) +a detector in Korea**
Palomares-Ruiz	**two detectors for Nova**
Ota	**possibility to use polarized μ**
Donini	**importance of energy resolution**
Meloni	**Precision measurements of θ_{23} and Δm^2_{32}**

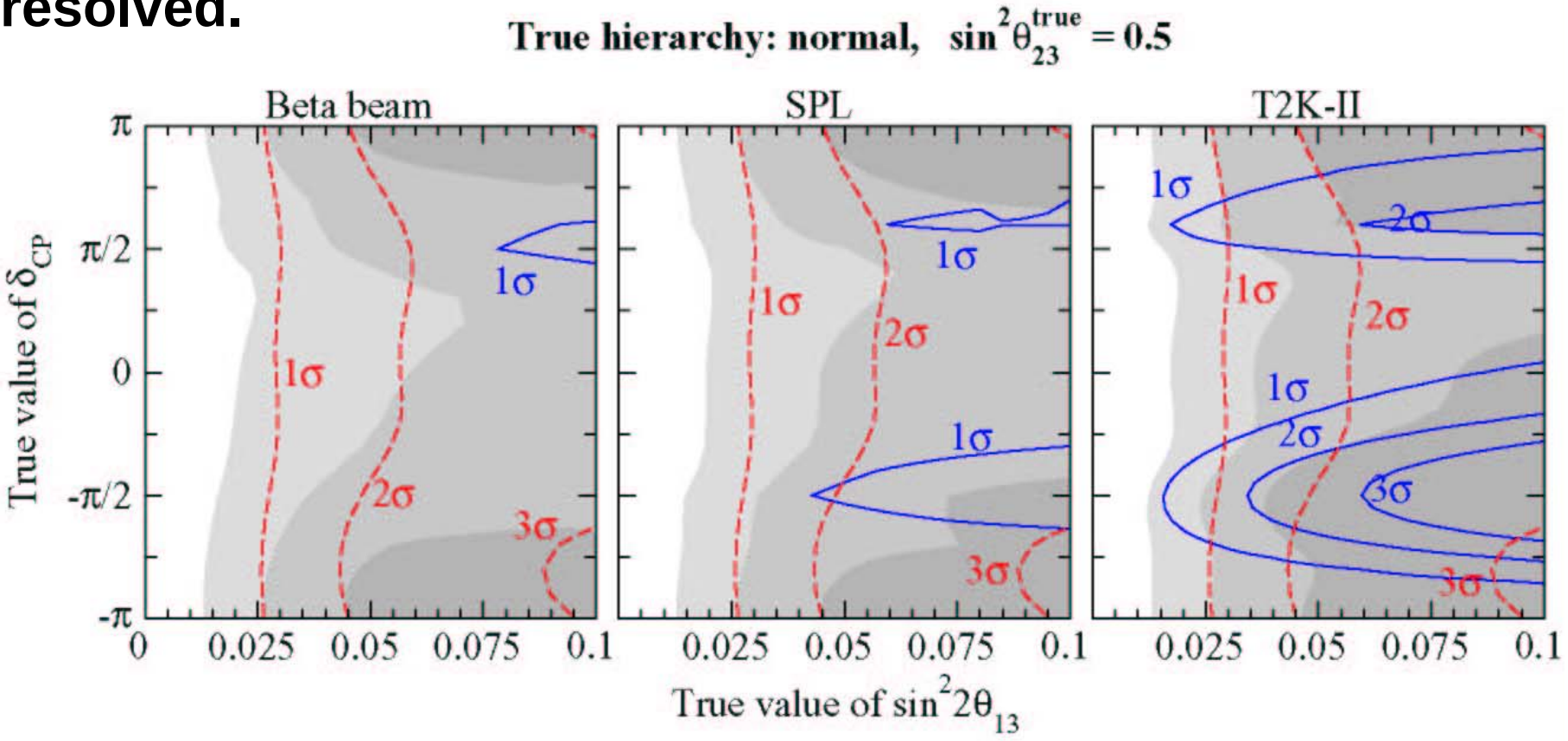
Miscellaneous topics

Blennow	**Phenomenology with the modified probability**
Winter	**Applications of very long baseline experiments**
Takamura	**Analytical treatment of 3-flavor oscillation probability**
Romanino	**Predictive models for θ_{13} and m_{ee}**

Thomas Schwetz

Atmospheric neutrinos are sensitive to mass hierarchy.

Combining ATM and LBL → sign(Δm^2_{32}) ambiguity is resolved.



solid: LBL-only, dashed: ATM-only, shading: LBL+ATM

Hiroshi Nunokawa

- We propose to determine mass hierarchy and CP phase at the same time by using Two Identical Detectors with Different Baselines
- As a concrete example, we consider JPARC Phase II 4MW Beam Power and 0.54 Mt Detector at Kamioka and other 0.54 Mt one at Korea
- 4 + 4 yrs runs of $\nu+\bar{\nu}$ modes, it is possible to determine mass hierachy for $\sin^2 2\theta_{13} > 0.03$ (0.055) at 2 (3) σ CL for any value of δ
- At the same time, good sensitivity to CP violation

K←J experiment

- T2K phase I + Korea (1.OAB - 2.Detectors)
  - L=295km OA:3.0 and L=1000km OA:0.5
  - with reactor experiment

- we get them
  - mass hierarchy : $\chi^2 > 9$ $(\sin^2 2\theta_{13} \sim 0.06)$
  - CP phase : $0 \Leftrightarrow 180$ $(\sin^2 2\theta_{13} \sim 0.06)$

Sergio Palomares-Ruiz

- Super-NOνA: 2 off-axis (LAr) detectors with same L/E using the NuMI beam → determination of sign(Δ m^2_{31}) free of degeneracies

- Only need of 5 years of neutrino run to resolve the type of hierarchy down to $\sin^2 2\theta_{13} = 0.02$ with Proton Driver (for all values of δ)

- Better capabilities than NOνA + T2K at HK for determining the type of mass hierarchy

Toshihiko Ota

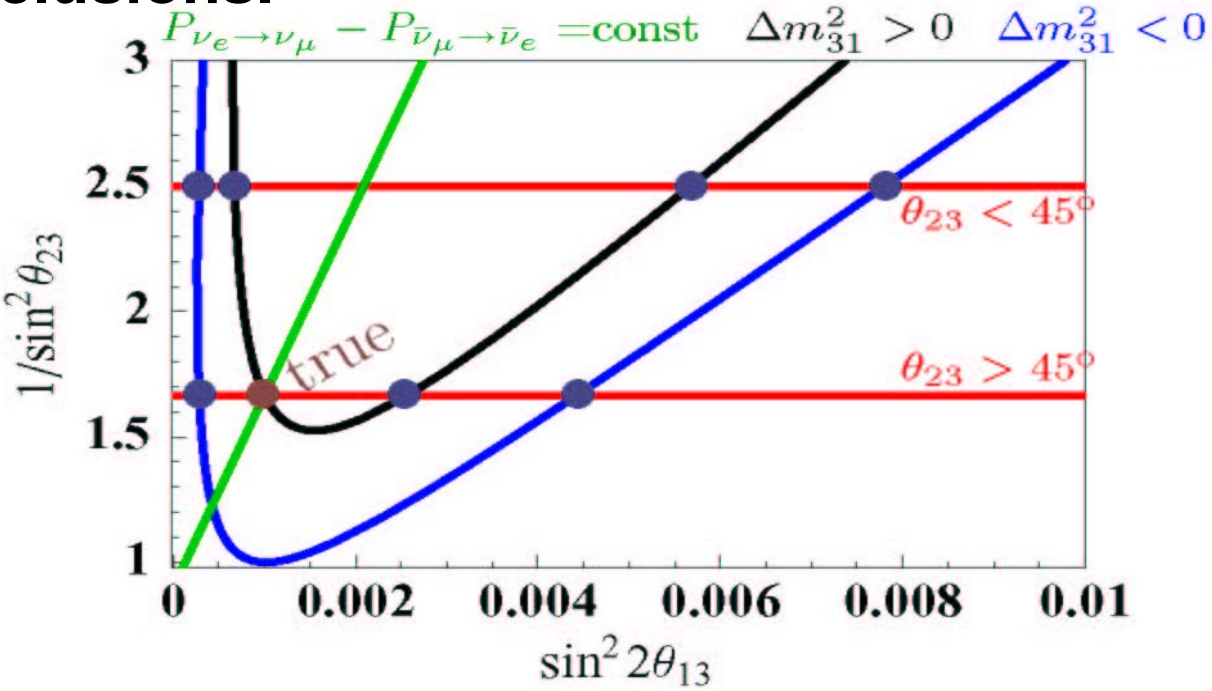
Polarized μ^- with $P_\mu = -1$ (μ^+ with $P_\mu = +1$) gives exclusively ν_μ ($\bar{\nu}_\mu$)

→ in principle $P(\bar{\nu}_\mu \to \bar{\nu}_e)$ can be measured

Theoretically

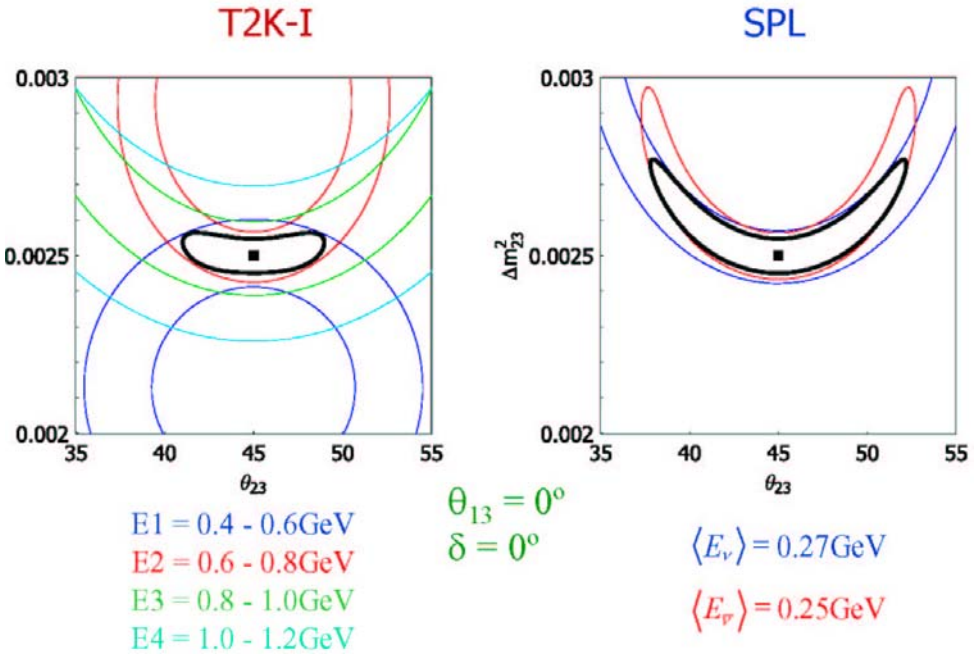
$$P(\nu_e \to \nu_\mu) - P(\bar{\nu}_\mu \to \bar{\nu}_e) = \text{const}$$

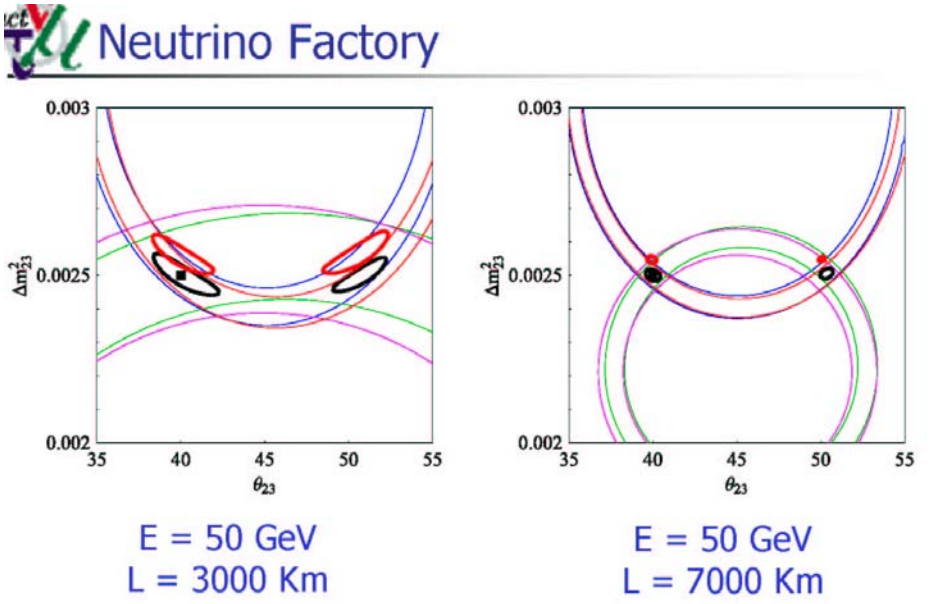
seems to resolve degeneracy, but detailed studies are needed to draw definite conclusions.



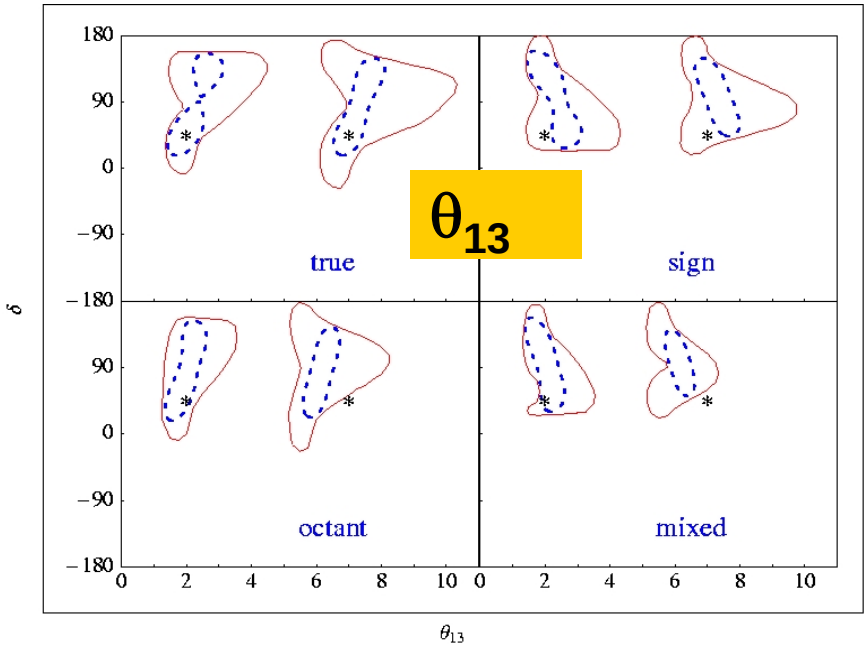
Andrea Donini

- **Precision measurements of θ_{23} and Δm^2_{23} need energy resolution and events above and below the oscillation peak**
- **SPL is clearly inadequate for the task. T2K-I is very good due to energy resolution and it can exclude maximal mixing for θ_{23} <41°**
- **The NuFactory seems extremely promising but more study is needed (a very long baseline?)**





Comparison between 2 and 3 dof`s analysis



- present uncertainties on atmospheric parameters are large enough to modify in a significant way the results of 2-par fits
- If the atmospheric parameters will be measure with the expected precision after T2K-I (Nona) the results of 2-par fits presented in the literature can be considered reliable

Phenomenology with the modified probability

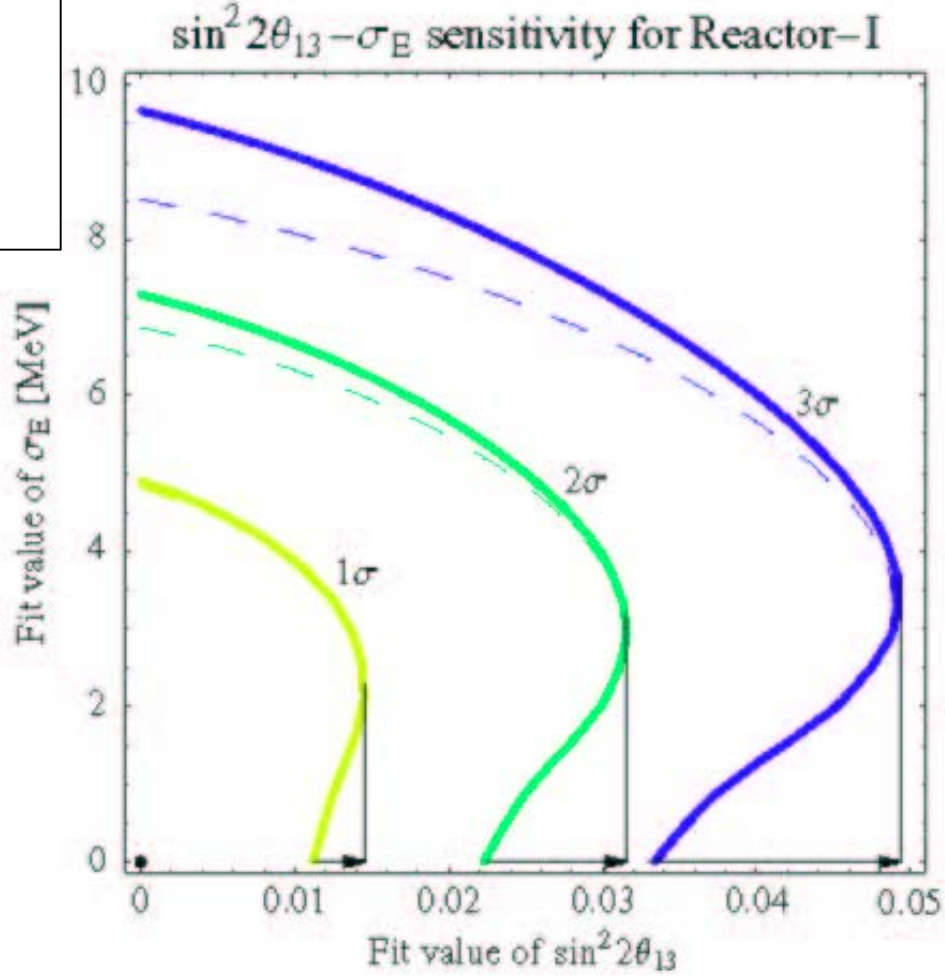
Mattias Blennow

$$P_{\alpha\beta} = \sum_i \sum_j D_{ij} J^{ij}_{\alpha\beta} \exp\left(-\mathrm{i}\frac{\Delta m^2_{ij}}{2p} L\right)$$

$$D_{ij} = \exp\left(-\alpha_{ij} \frac{|\Delta m^2_{ij}|^\xi L^\beta}{E^\gamma}\right)$$

Introduction of an extra parameter σ_E can result in larger θ_{13}

Energy dependence may be useful to discover the new effect



VL baseline applications

Walter Winter

Purpose	Measure density of the Earth's core	Magic baseline: Resolve correlations/ degeneracies	Verify Earth matter effects at high CL
L	L>10 665 km (outer core)	L ~ 7 500 km	L > 6 000 km

- Major challenge: Decay ring/decay tunnel slope
- Open question: Simultaneous or subsequent operation of VL baseline? Feasibility study for storage ring configurations needed!

Akira Takamura

Analytical treatment of 3-flavor probability for non-constant density profile: basically expressed in terms of 2-flavor amplitudes

$$O_{23} \equiv \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & -s_{23} \\ 0 & s_{23} & c_{23} \end{pmatrix}$$

$$S(t) = [O_{23}\Gamma_\delta]S'(t)[O_{23}\Gamma_\delta]^\dagger$$

$$P(\nu_e \to \nu_\mu) = |S(t)_{\mu e}|^2 = A\cos\delta + B\sin\delta + C$$

$$\Gamma_\delta \equiv \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & e^{i\delta} \end{pmatrix}$$

★ Two small parameters

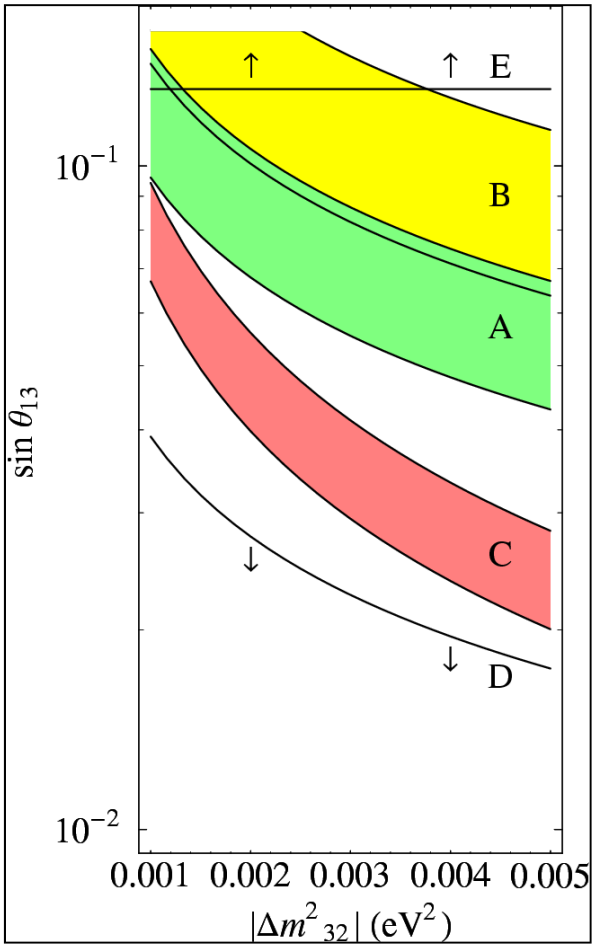
1. $\alpha = \Delta m^2_{21}/\Delta m^2_{31} \simeq 0.03$
2. $s_{13} = \sin\theta_{13} \leq 0.23$

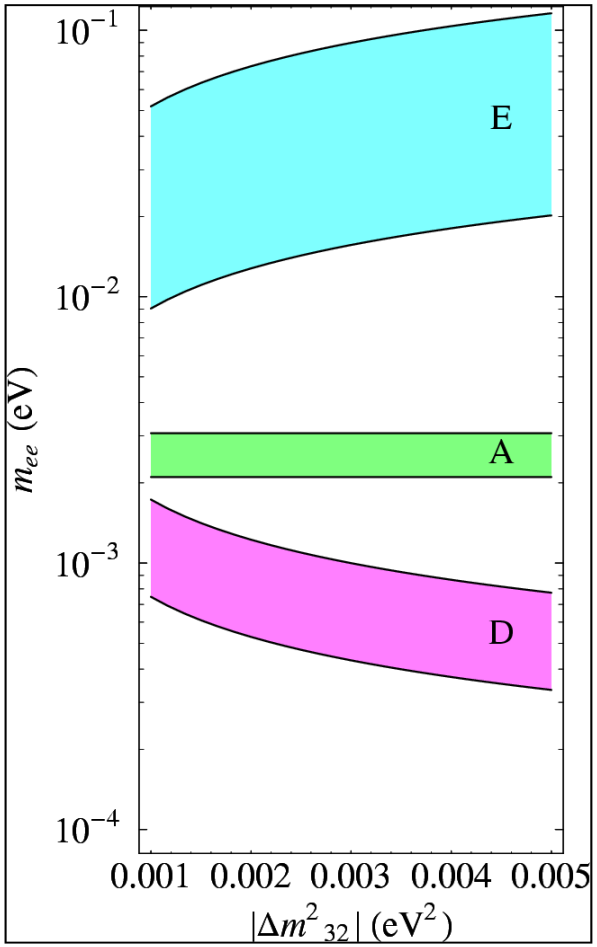
$$S' \sim \lim_{s_{13}\to 0} S' + \lim_{\alpha\to 0} S' - \lim_{s_{13},\alpha\to 0} S'$$

Agreement with numerical results are good

Andrea Romanino

Predictive models





$$R \equiv \Delta m^2_{21} / \Delta m^2_{32}$$

	$\sin\theta_{13}$
A1	$\frac{1}{2}\tan\theta_{23}\sin 2\theta_{12}\sqrt{R}$
B1	$\frac{1}{2}\tan\theta_{23}\tan 2\theta_{12}\,(R\cos 2\theta_{12})^{1/2}$

C	$\frac{1}{2}\tan 2\theta_{12}\,(R\cos 2\theta_{12})^{3/4}$
D	$\frac{1}{2}\frac{\tan 2\theta_{12}}{\lvert\tan 2\theta_{23}\rvert}(R\cos 2\theta_{12})^{1/2}$
E1	$-\frac{\tan\theta_{23}}{\cos\delta}\frac{1-\tan\theta_{12}}{1+\tan\theta_{12}}$

---Phenomenological issues----

Achievements@Nufact05

- **Degeneracies can be resolved by one way or the other (super beams + ν factories + beta beams + reactors) for $\sin^2 2\theta_{13} > 0.03$.**
- **New physics (other than oscillations) or applications of very long baseline experiments have been studied.**

Problems towards Nufact06

- **Look for ways to resolve degeneracies for $\sin^2 2\theta_{13} << 0.03$.**
- **Look for more interesting new physics or more applications of very long baseline experiments.**