Physics Potential of NuMI Off-Axis Beam

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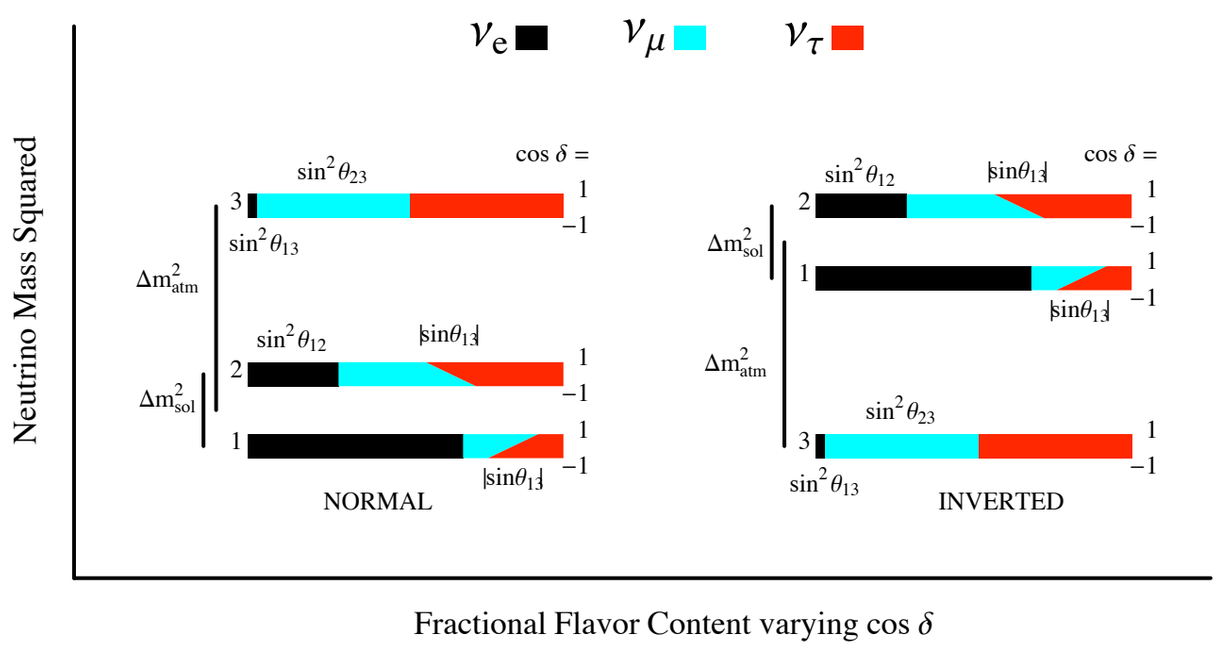
Fermilab

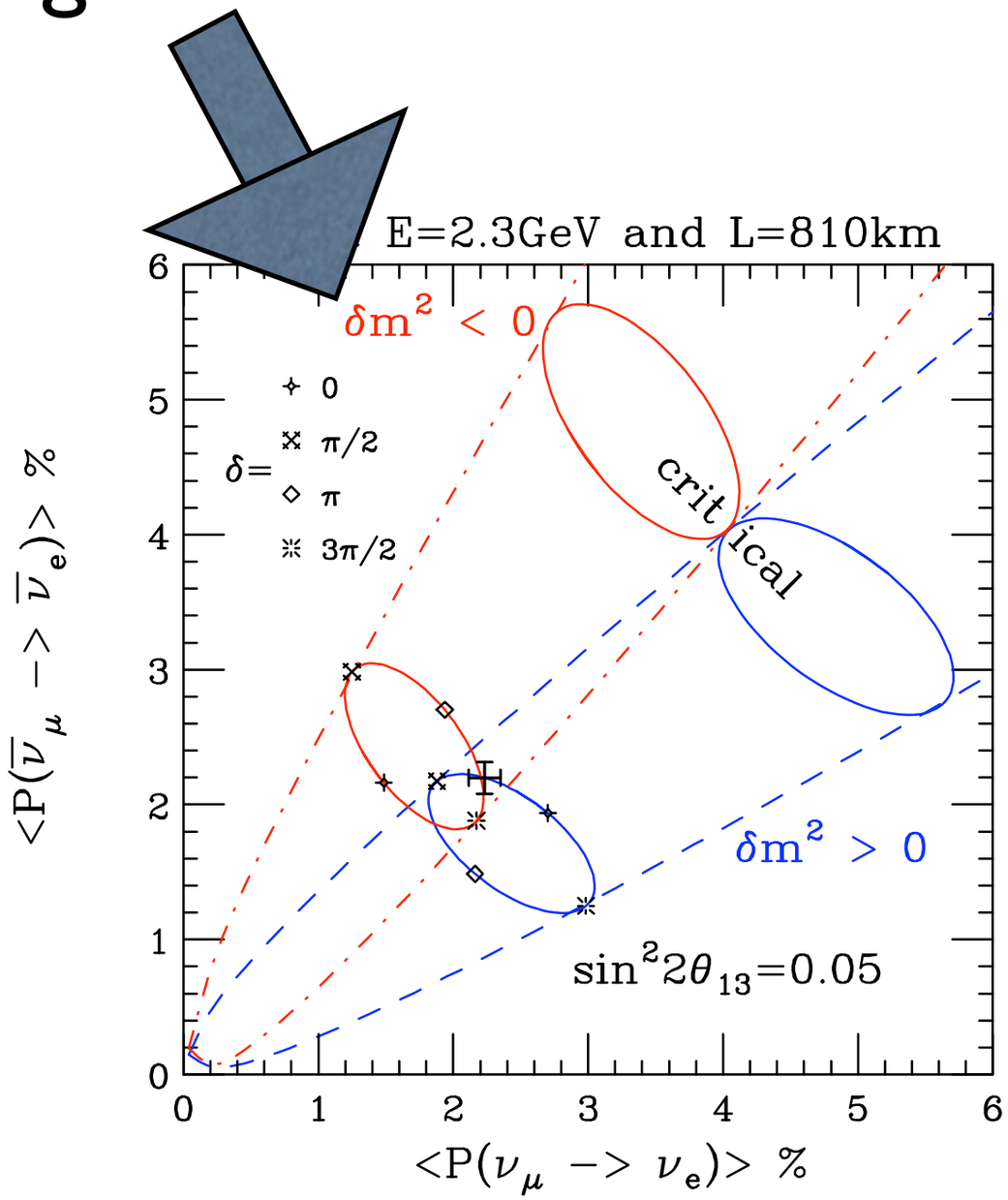
IMPORTANT PHYSICS:

- approximate value of $\sin^2\theta_{13}$
- hierarchy (normal/inverted)
- CP violation ($\sin\delta \neq 0$)



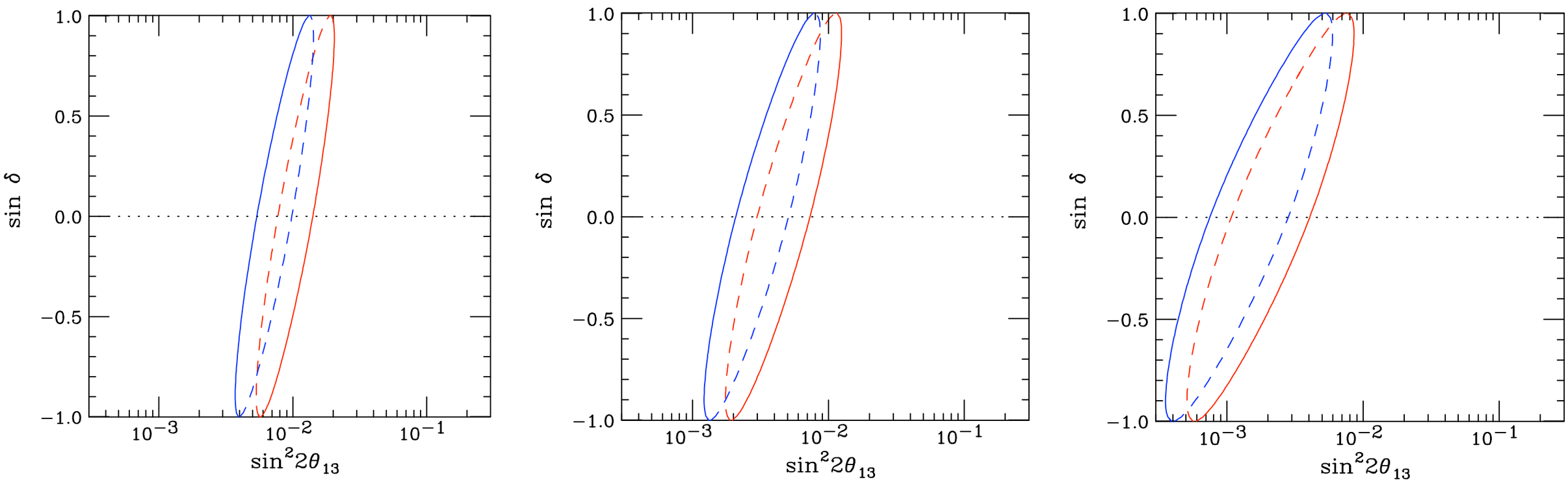
hep-ph/0312131

Bi-Probability Figure:



10 km OA (2.3 GeV) at 820 km
99% sensitivity
only Neutrino Running

eff = 80%



10x5 kt-yr | 50x5 kt-yr | 50x5x5 kt-yr

blue=normal | red=inverted

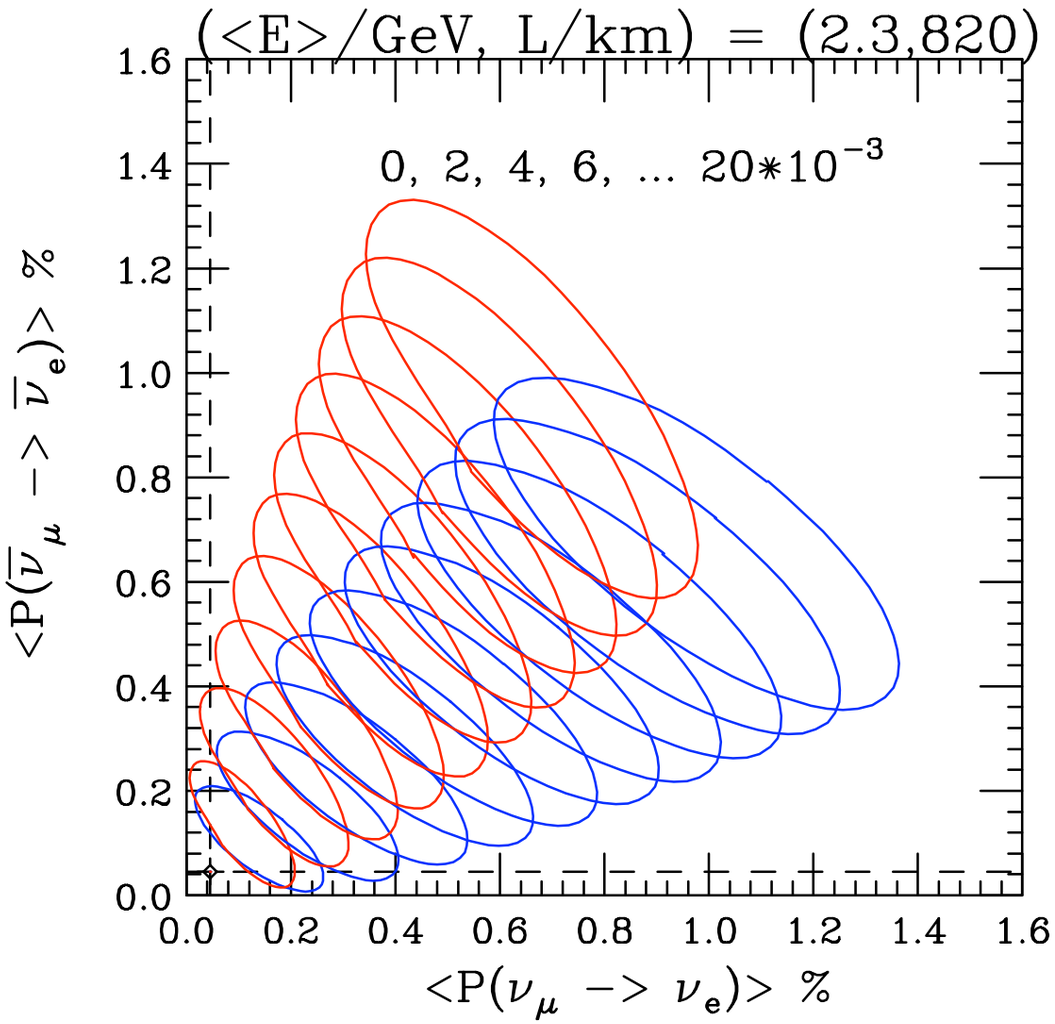
solid (dashed) cos delta > 0 (<0)

$$P(\nu_\mu \to \nu_e) = P_{atm} + 2\sqrt{P_{atm}}\sqrt{P_\odot}\cos(\Delta + \delta) + P_\odot$$

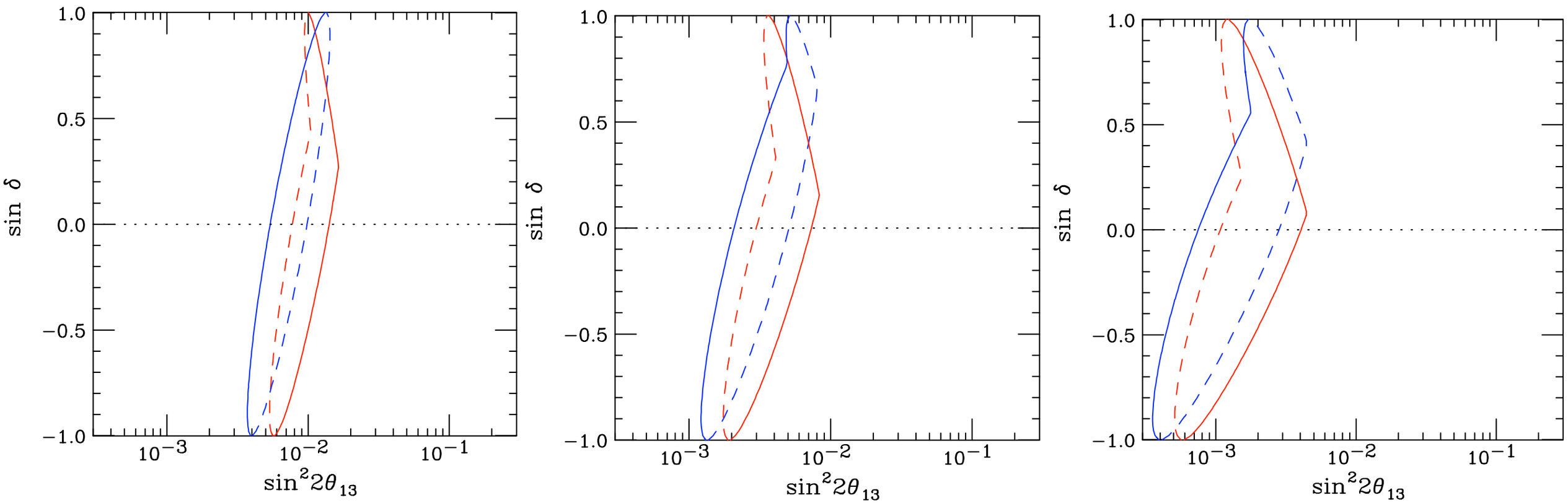
if $\boxed{\sqrt{P_{atm}} = -2\sqrt{P_\odot}\cos(\Delta + \delta) \quad = \quad 2\sin\delta\sqrt{P_\odot}}$ when $\Delta = \pi/2$

then $P(\nu_\mu \to \nu_e) = P_\odot$

same as $\theta_{13} = 0$!


(<E>/GeV, L/km) = (2.3,820)
0, 2, 4, 6, ... 20*10^-3
<P(ν̄_μ -> ν̄_e)> %
<P(ν_μ -> ν_e)> %
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

Add equivalent Anti-Neutrino Running

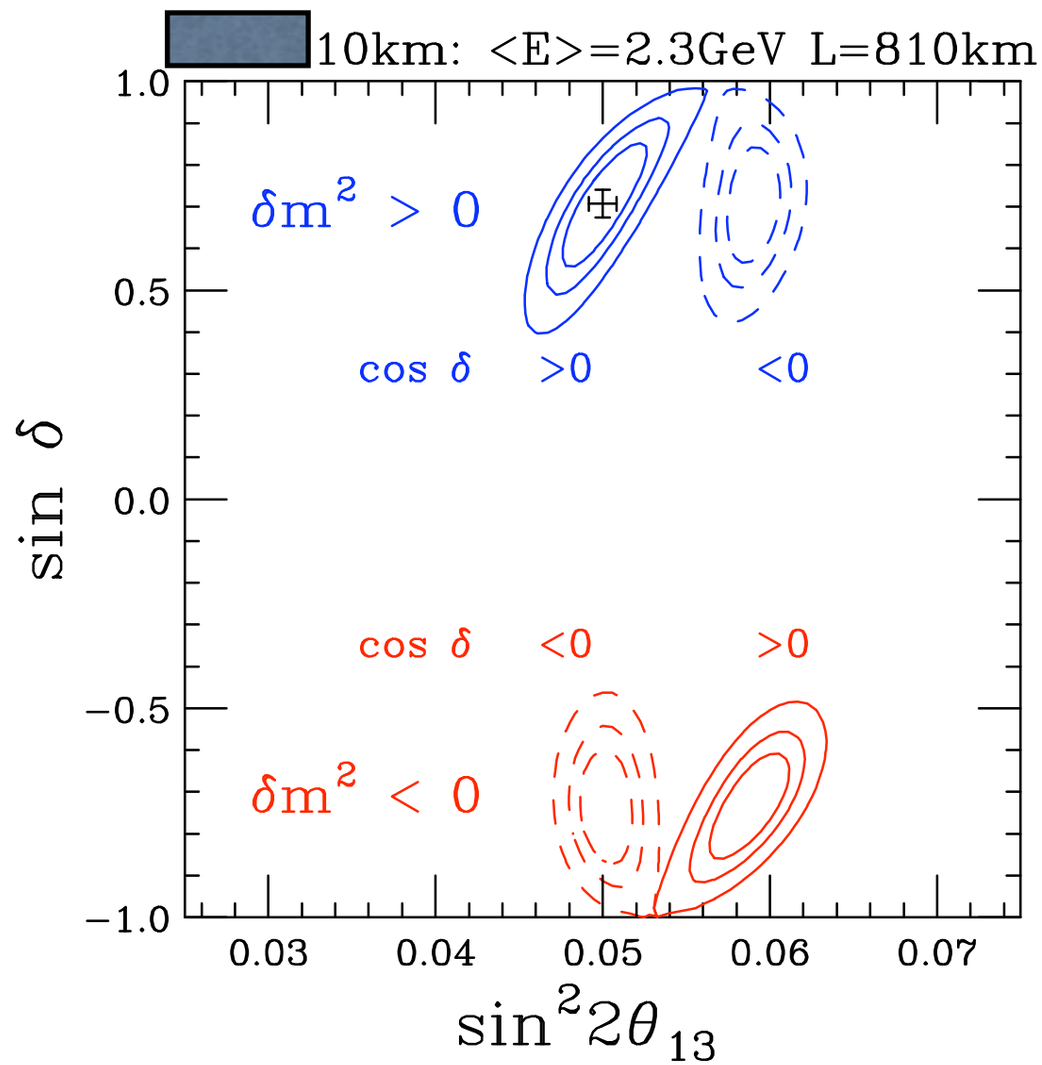


10x5 kt-yr 50x5 kt-yr 50x5x5 kt-yr

blue=normal | red=inverted

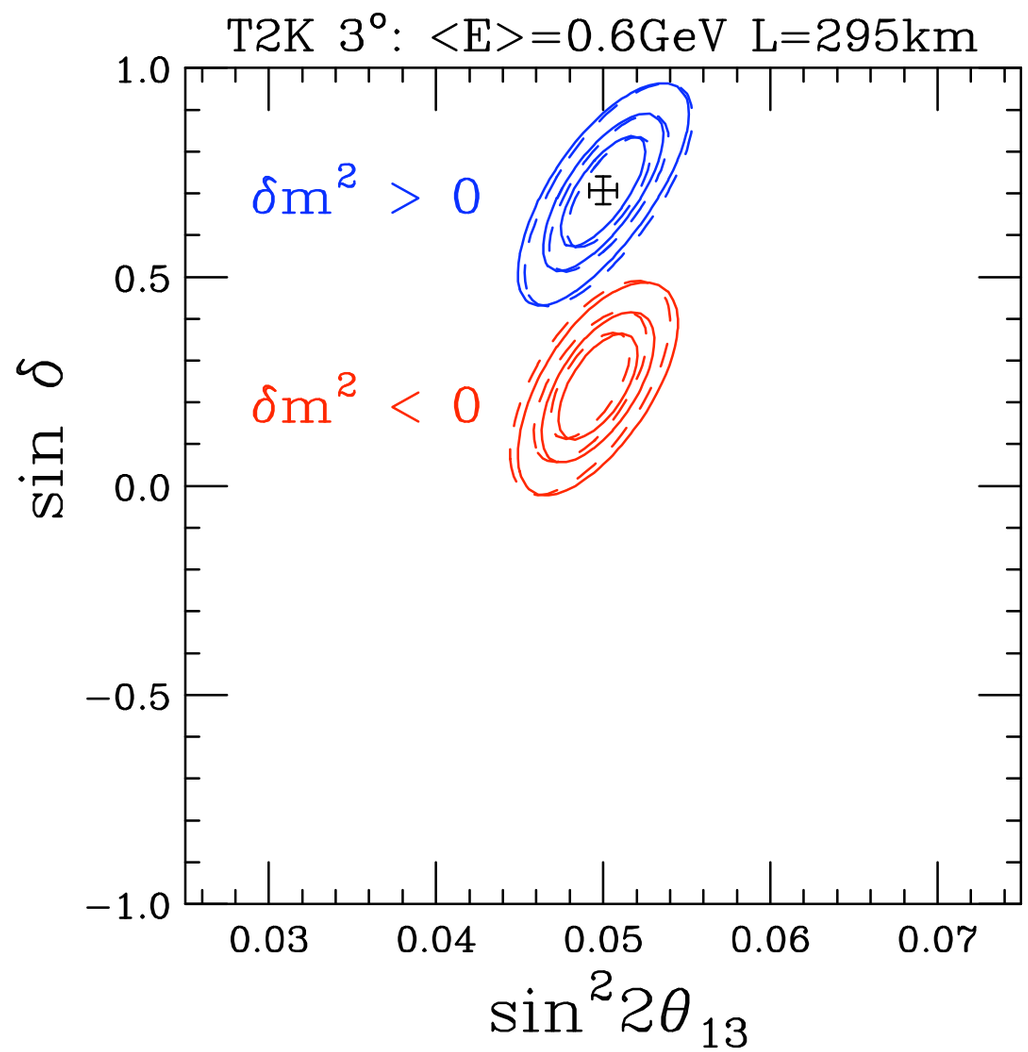
NuMI

OM+SP
hep-ph/0408070



$$\langle \sin\delta \rangle_+ - \langle \sin\delta \rangle_- \approx \sqrt{2}\,\sqrt{\frac{\langle \sin^2 2\theta_{13} \rangle}{0.05}}$$

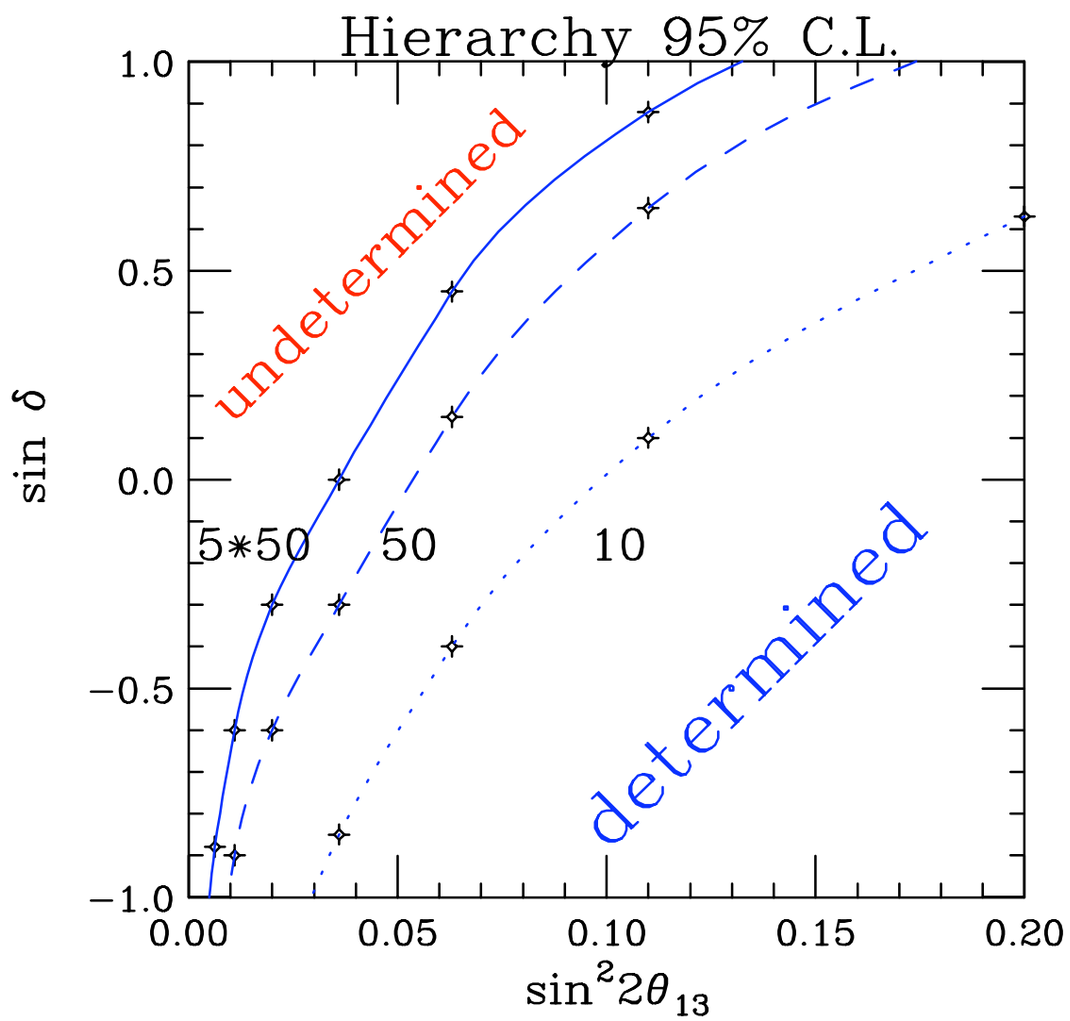
T2K+HK



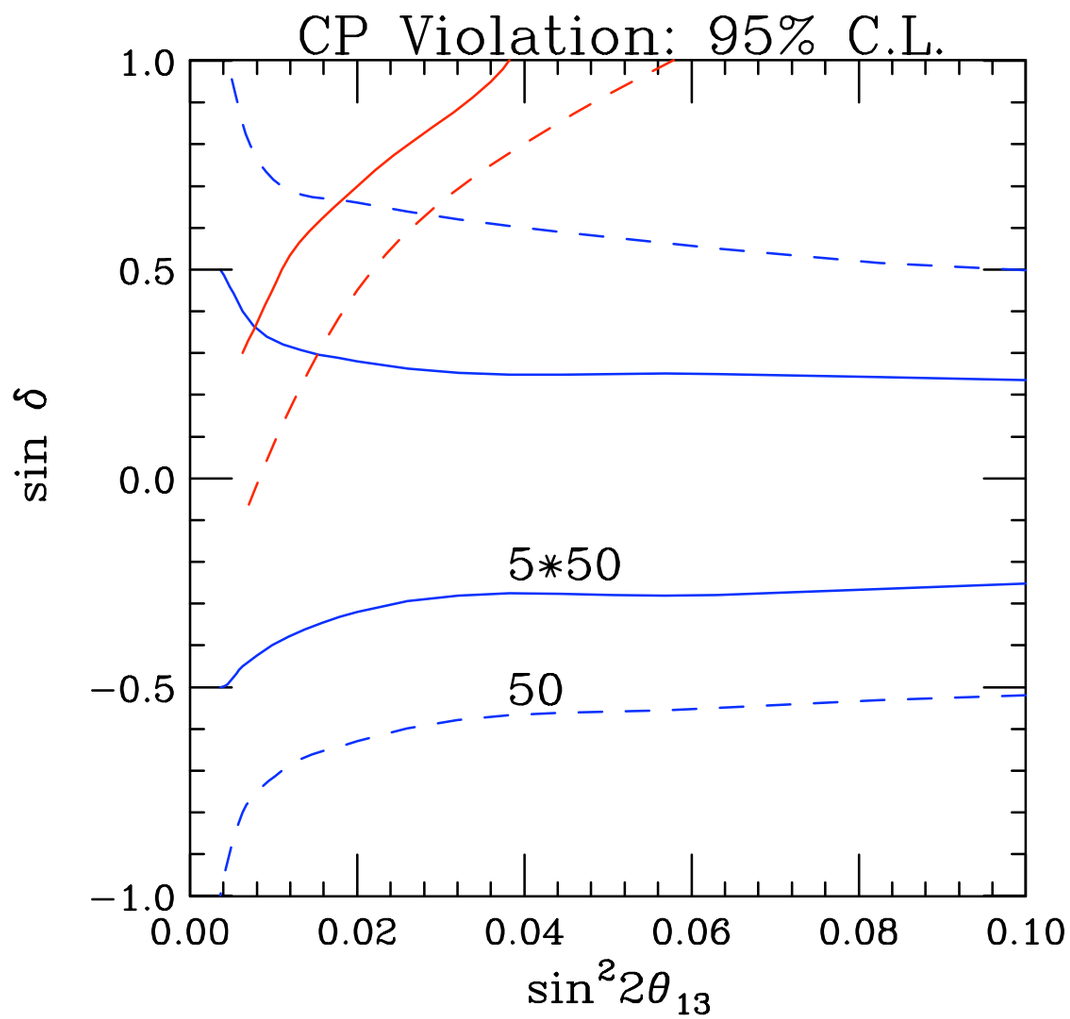
$$\langle \sin\delta \rangle_+ - \langle \sin\delta \rangle_- \approx \frac{\sqrt{2}}{3} \sqrt{\frac{\langle \sin^2 2\theta_{13} \rangle}{0.05}}$$

factor of 3 smaller due to baseline, density and E/L.

Hierarchy:


Hierarchy 95% C.L.
undetermined
determined
5*50
50
10
1.0
0.5
0.0
−0.5
−1.0
0.00
0.05
0.10
0.15
0.20
sin δ
sin²2θ13

CP Violation



Conclusions

- NuMI beamline a Fabulous Physics Opportunity:
- Theta_13, Hierarchy and CP Violation.
- When combined with T2K very powerful at small Theta_13.