Neutrino Factory
The Physics Program

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Status quo

A common framework for all the neutrino data is oscillation.

- $\Delta m^2_{21} \sim 8 \cdot 10^{-5}\,\mathrm{eV}^2$ and $\theta_{12} \sim 1/2$
- $\Delta m^2_{31} \sim 2 \cdot 10^{-3}\,\mathrm{eV}^2$ and $\theta_{23} \sim \pi/4$
- $\theta_{13} \lesssim 0.15$

This implies a lower bound on the mass of the heaviest neutrino

$$\sqrt{2 \cdot 10^{-3}\,\mathrm{eV}^2} \sim 0.04\,\mathrm{eV}$$

but we currently do not know which neutrino is the heaviest.

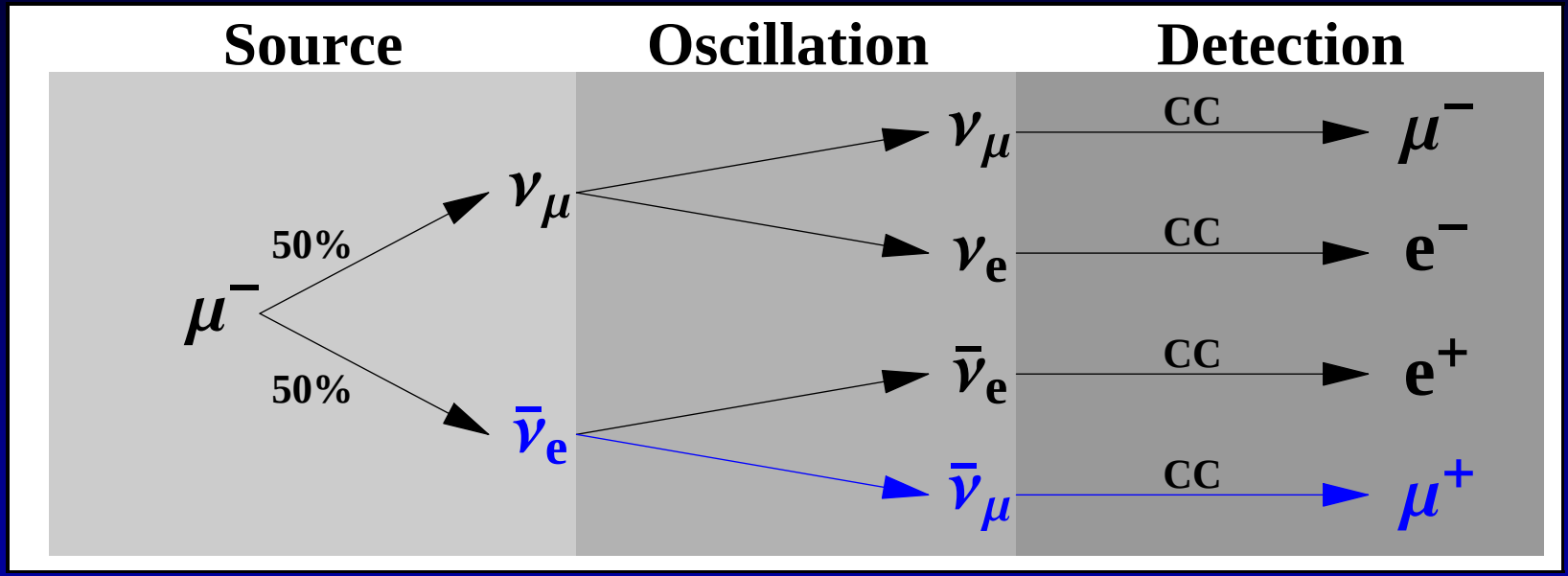
Open Questions

- Majorana vs Dirac mass – $0\nu\beta\beta$
- Absolute m_ν – Katrin, Cosmology
- How large is θ_{13}? – Oscillation
- Which one is the heaviest neutrino? –$0\nu\beta\beta$, Katrin, Oscillation
- Is θ_{23} maximal? – Oscillation
- Is there leptonic CP violation? – Oscillation
- Are there only 3 light neutrinos? – Oscillation

Neutrino oscillation measurements will play a central role.

A neutrino factory

Put muons in a storage ring and let them decay



- 6 out of 9 possible transition channels can be observed
- Not shown here: ν_τ final states, since difficult to observe
- Charge identification mandatory

Choice of Energy and Baseline

Oscillation physics sets the value of L/E to be in a given, usually the first, oscillation maximum.

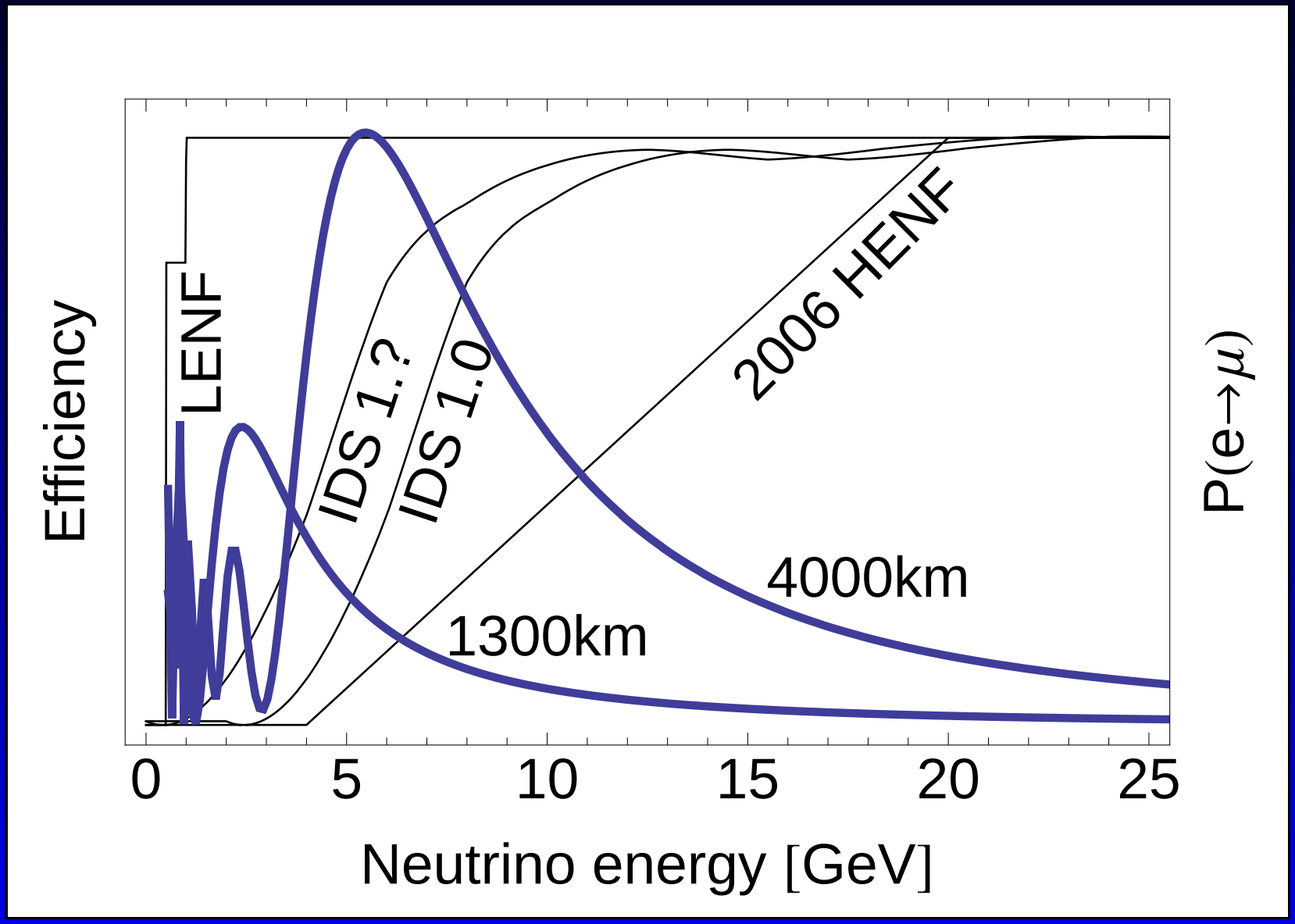
- Energy is set by the requirement for muon charge identification
  - MIND – 2-3 GeV neutrino energy threshold
  - TASD – $\ll$1 GeV neutrino energy threshold

Thus different baseline ranges are possible.

Matter effects single out one particular baseline – the so called magic baseline

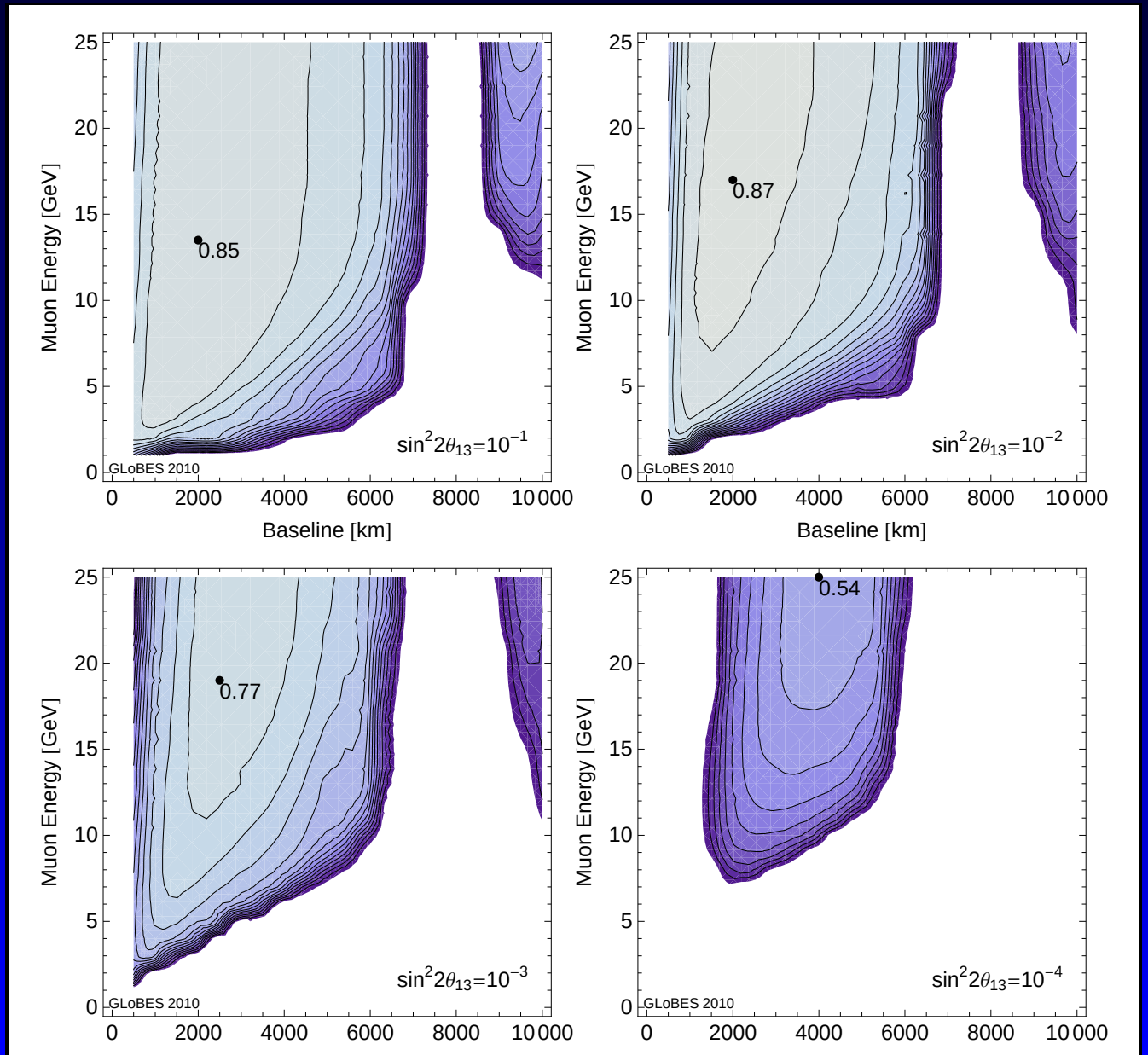
$$L \simeq 7\,500\,\mathrm{km}$$

Thresholds

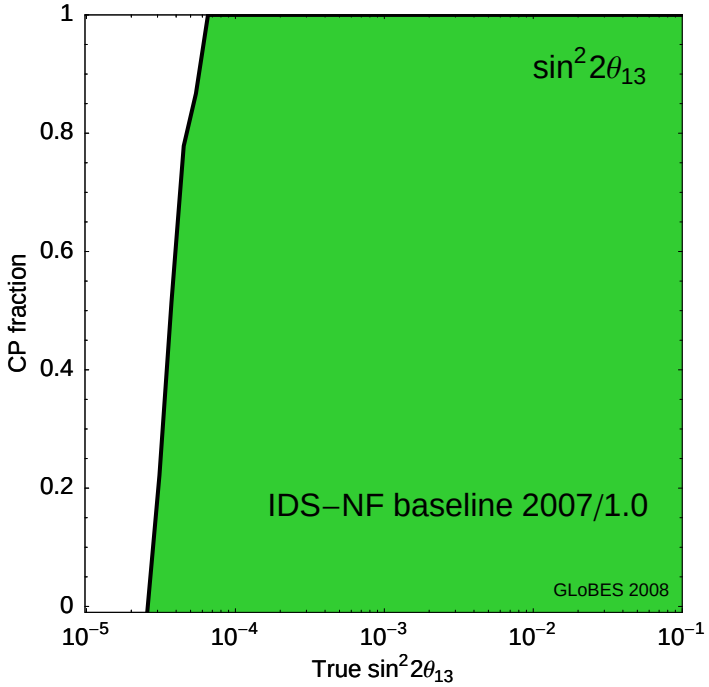

Efficiency
LENF
IDS 1.?
IDS 1.0
2006 HENF
4000km
1300km
P(e→μ)
0
5
10
15
20
25
Neutrino energy [GeV]

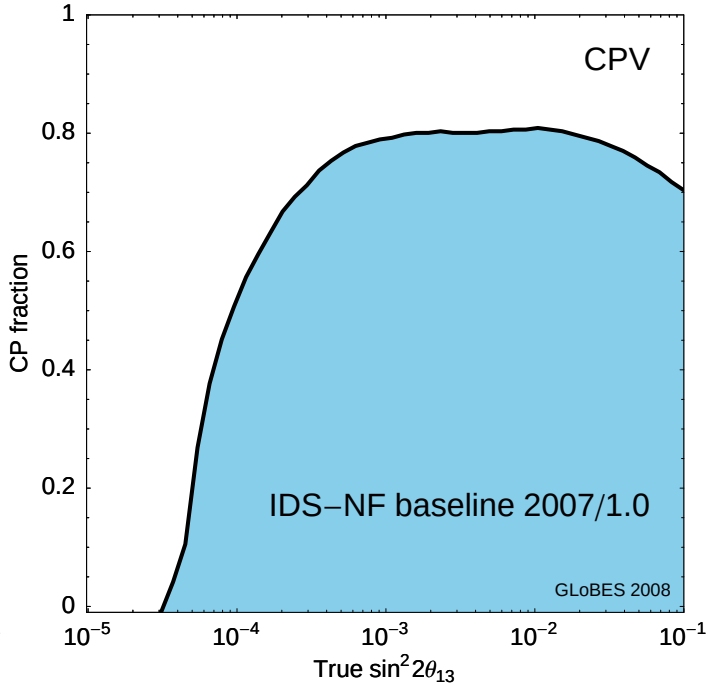
Ideal detector

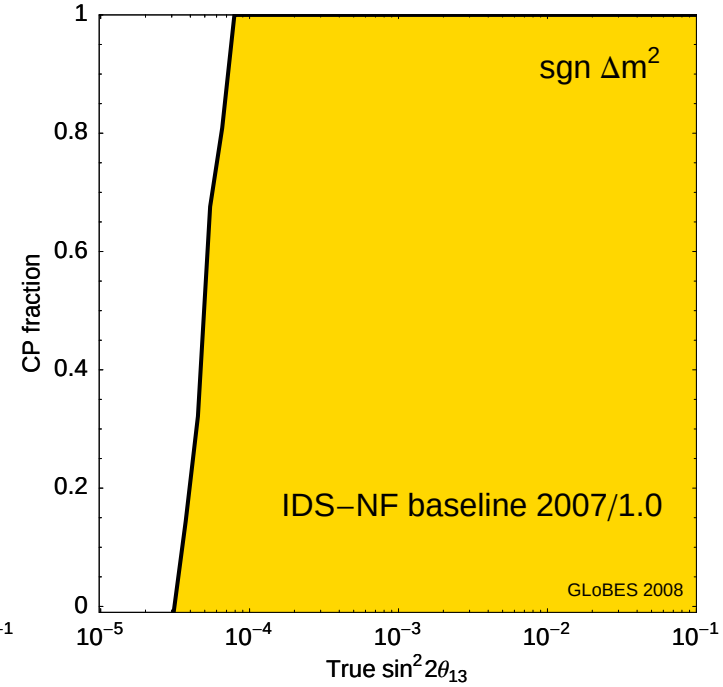
CP violation



IDS-NF baseline







- 25 GeV muon energy
- 2 MIND detectors, 50 kt each
- Baselines 4000km and 7500km
- Results shown a 3σ CL

Changing the Baseline

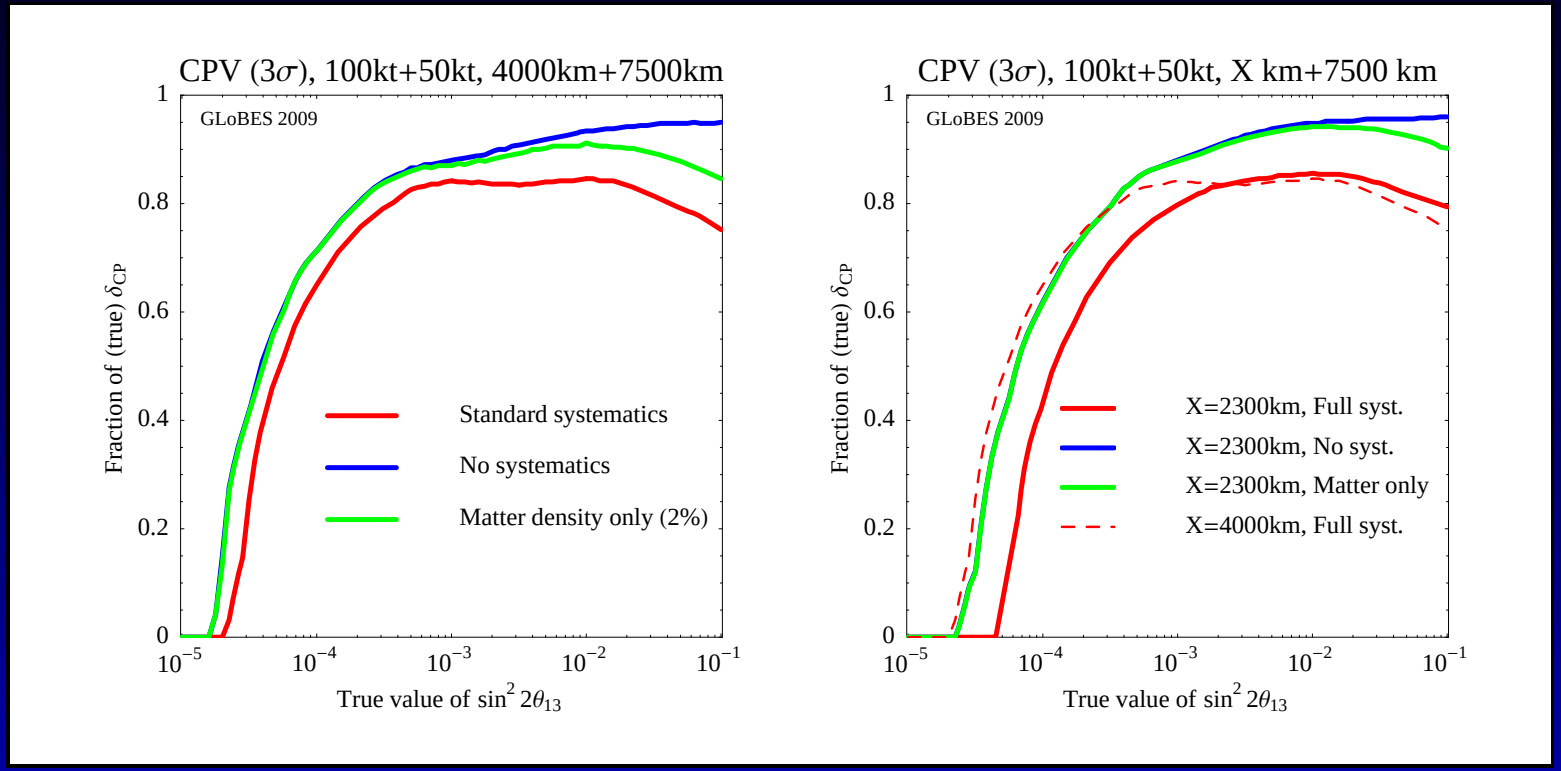
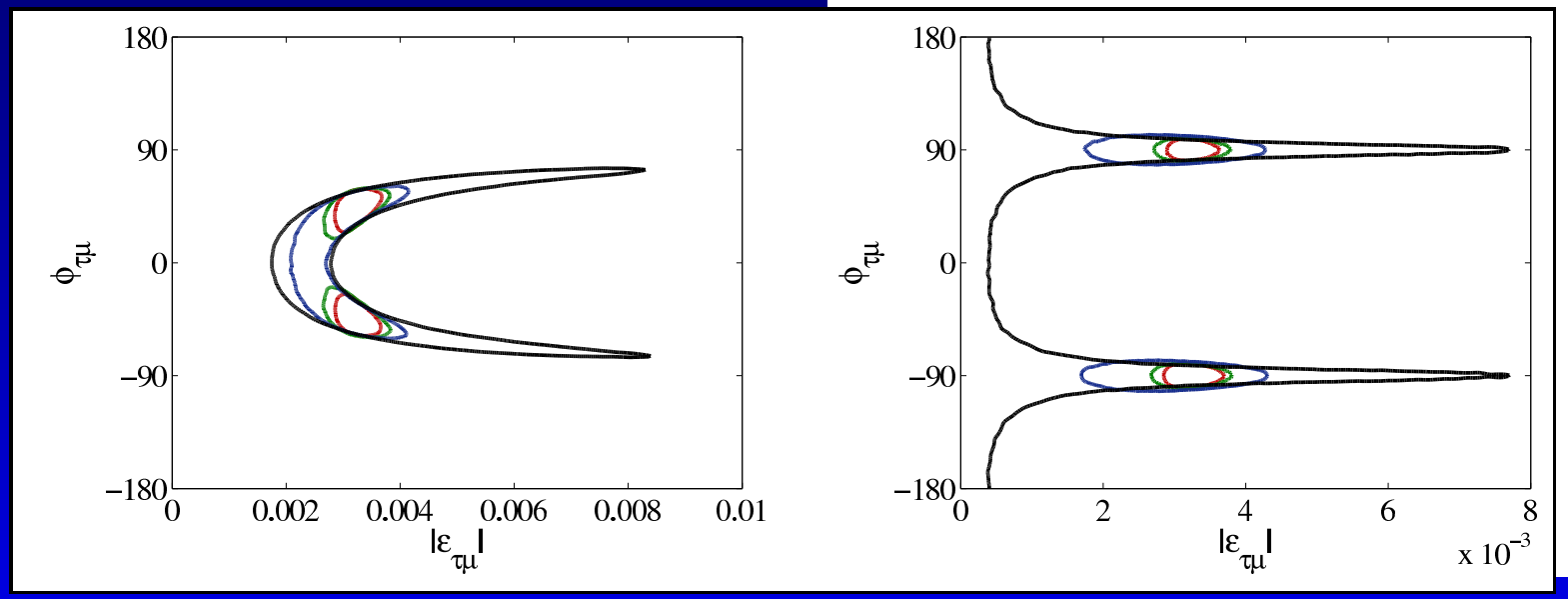


Figure courtesy W. Winter

- Larger detector at 4000km
- Wide range of baselines and energies yield very similar results
- Lower systematics likely – work in progress

New Physics Searches

- new 4-fermion vertices (NSI)
- Unitarity violation
- Connections to LHC
- . . .



S. Antusch *et al.* arXiv:0903.3986

Summary

- Precision neutrino physics is possible
- Neutrino factory is the most versatile tool
- Natural step in muon collider R&D
- Outstanding physics reach
- IDS-NF baseline currently under review
  - Inclusion of near detector(s) improves systematics
  - Larger far detector
  - Lower energy threshold