Physics Working Group

Status and Charge

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Fermilab

All plots in this talk taken from the IDR

Outline

1. Standard 3-flavor oscillations
   - Optimization for small θ_{13}
   - Optimization for large θ_{13}
2. Near detector physics
   - Cross section measurements
   - Electroweak precision measurements
3. ν_τ contamination
4. New physics in the neutrino sector
   - Sterile neutrinos
   - New interactions
   - Time-of-flight measurements
5. Summary

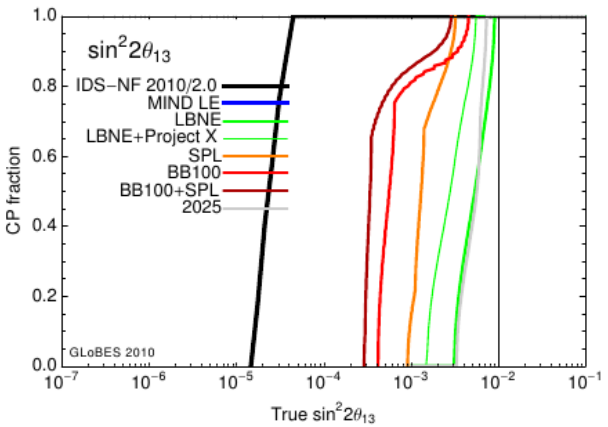
Outline

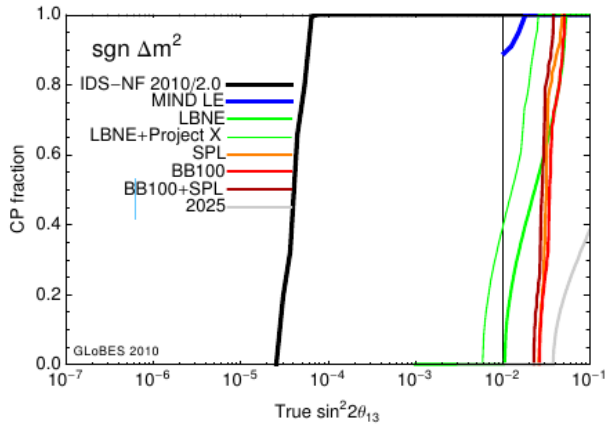
Oscillation physics — Small θ_{13}

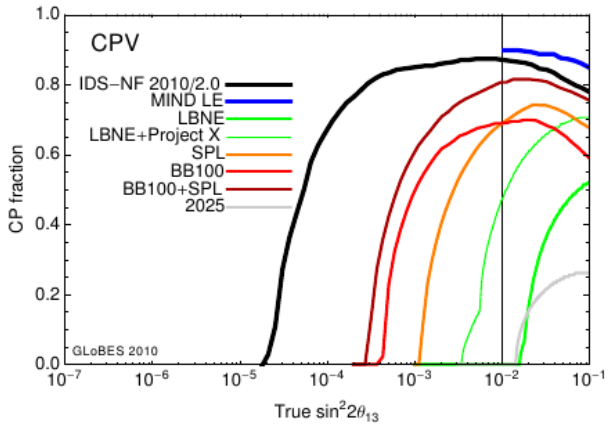
- Physics and optimization well understood
- Sensitivity to θ_{13}, mass hierarchy, CPV down to $\sin^2 2\theta_{13} \sim$ few $\times 10^{-5}$
- Parameter correlations and degenerate solutions are a problem
  - Can be controlled by using two detectors @ $L_1 \sim 4000$ km, $L_2 \sim 7500$ km
- Optimum muon energy: 25 GeV
- Neutrino factory is superior to all other proposed experiments
  (high-γ β-beam could be competitive for some measurements)

Things to do:

- Mostly fine-tuning
- New ideas? Bimagic baseline?







Oscillation physics — Large θ_{13}

After T2K+MINOS, this may be the relevant case

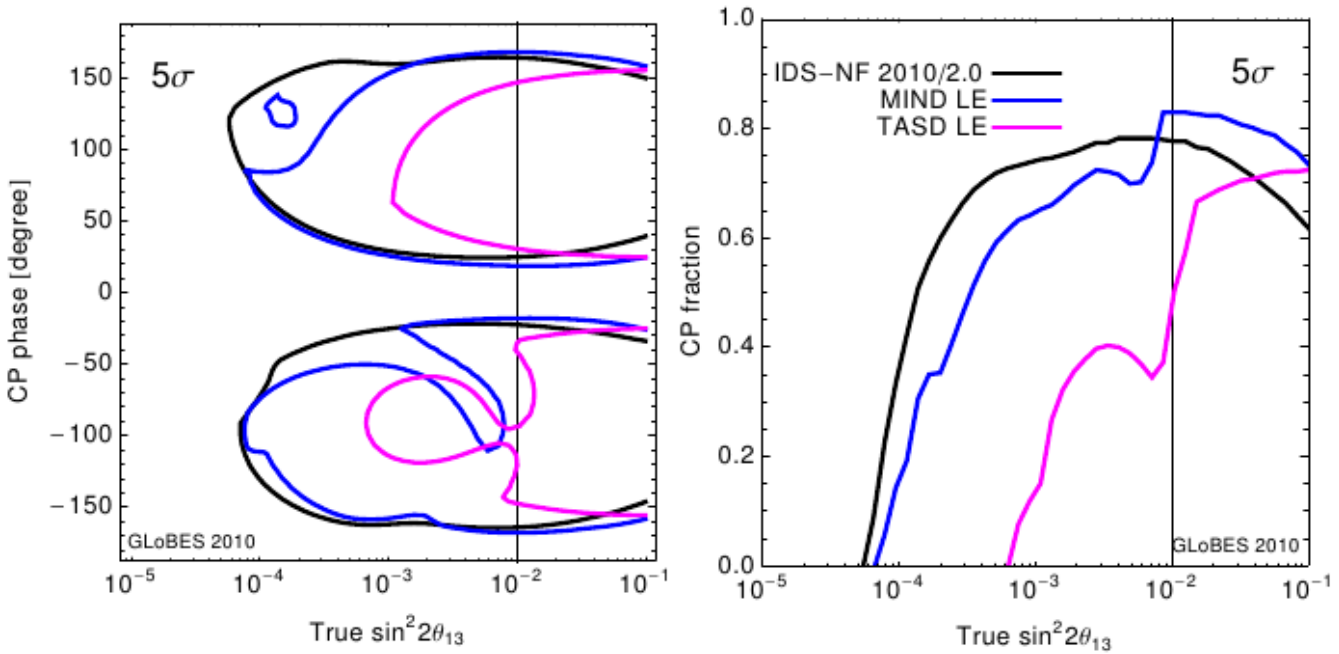
- Double Chooz + Daya Bay + Reno can confirm this soon (in time for RDR)

If θ_{13} is large . . .

- CPV measurement suffers from background due to CP conserving ν_μ appearance $\longrightarrow$ sensitivity drops
- Low-E NuFact (LENF) seems to be best option
- Great progress in LENF studies over past couple of years

Things to do:

- Careful comparison of LENF to other experiments (β-beam, WBB, . . .)



Outline

Cross section measurements

- Questions to be answered
  - What are the next steps after Minerνa?
  - What precision can be reached (systematic uncertainties in near detectors)?
  - Near detector optimization for x-section measurements?
  - What can we learn from precise x-section measurements (about neutrino physics, hadron physics, nuclear physics)?

Other near detector physics

- Precision measurement of $\sin^2\theta_W$
- Parton distribution functions
- Other ideas?

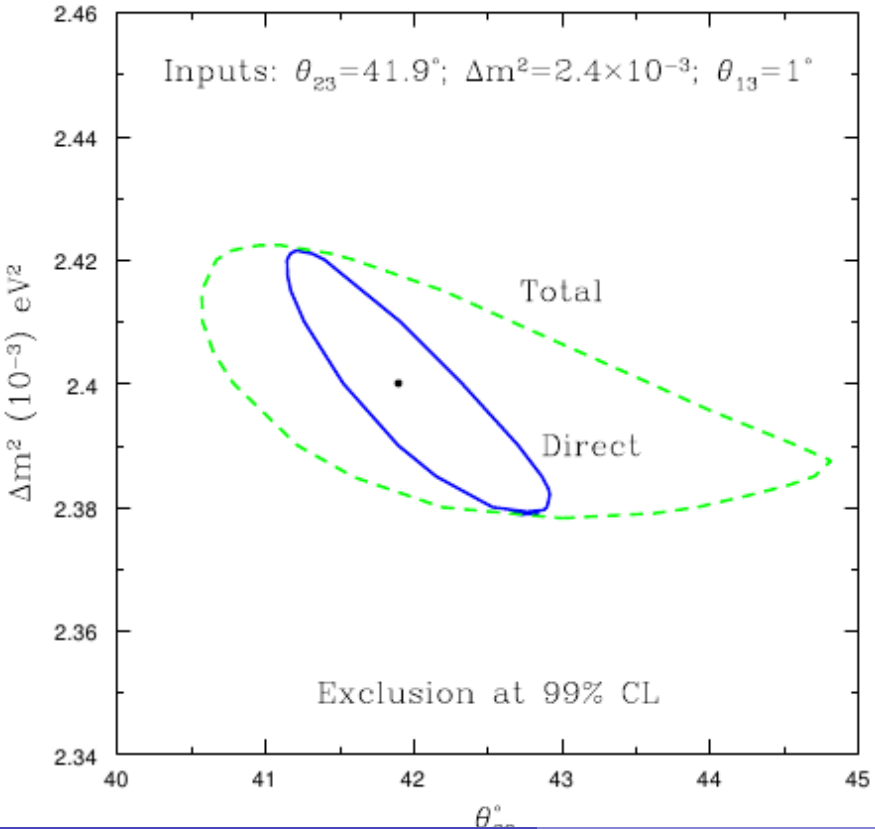
Outline

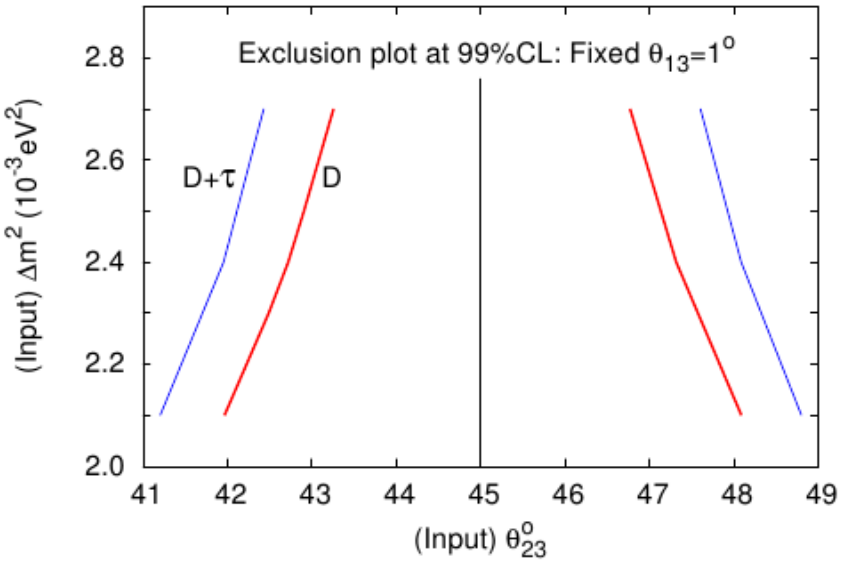
ν_τ contamination

- Effect of muons from $\nu_e, \nu_\mu \rightarrow \nu_\tau \rightarrow \tau \rightarrow \mu$ can be relavant in appearance and disappearance measurements

Things to do:

- Investigate impact on LENF
- Investigate impact on New Physics searches
- Should be taken into account in all future simulations

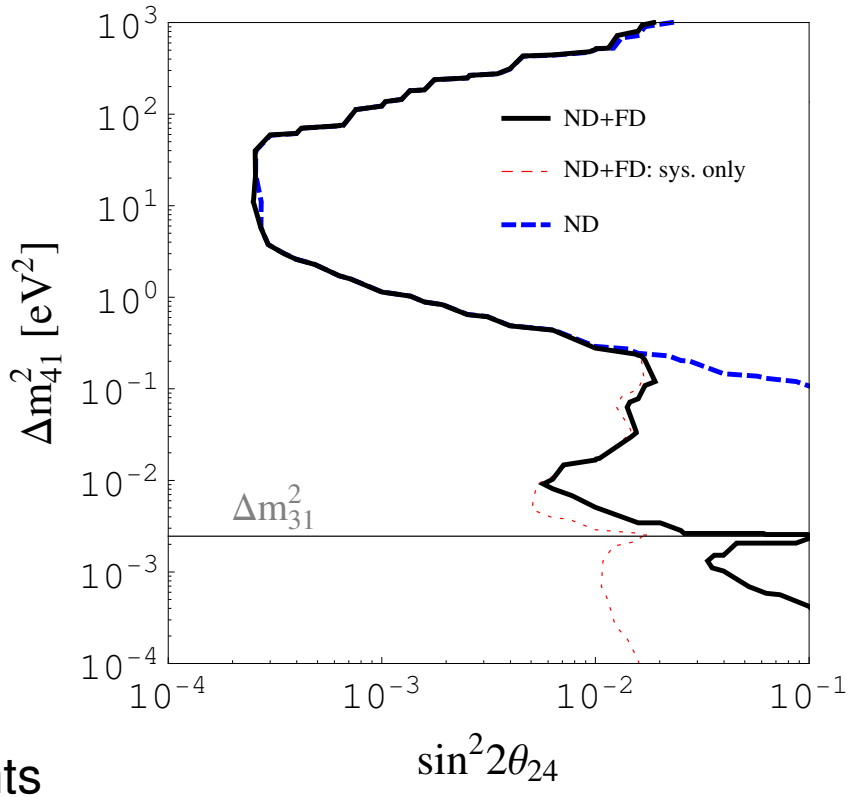




Outline

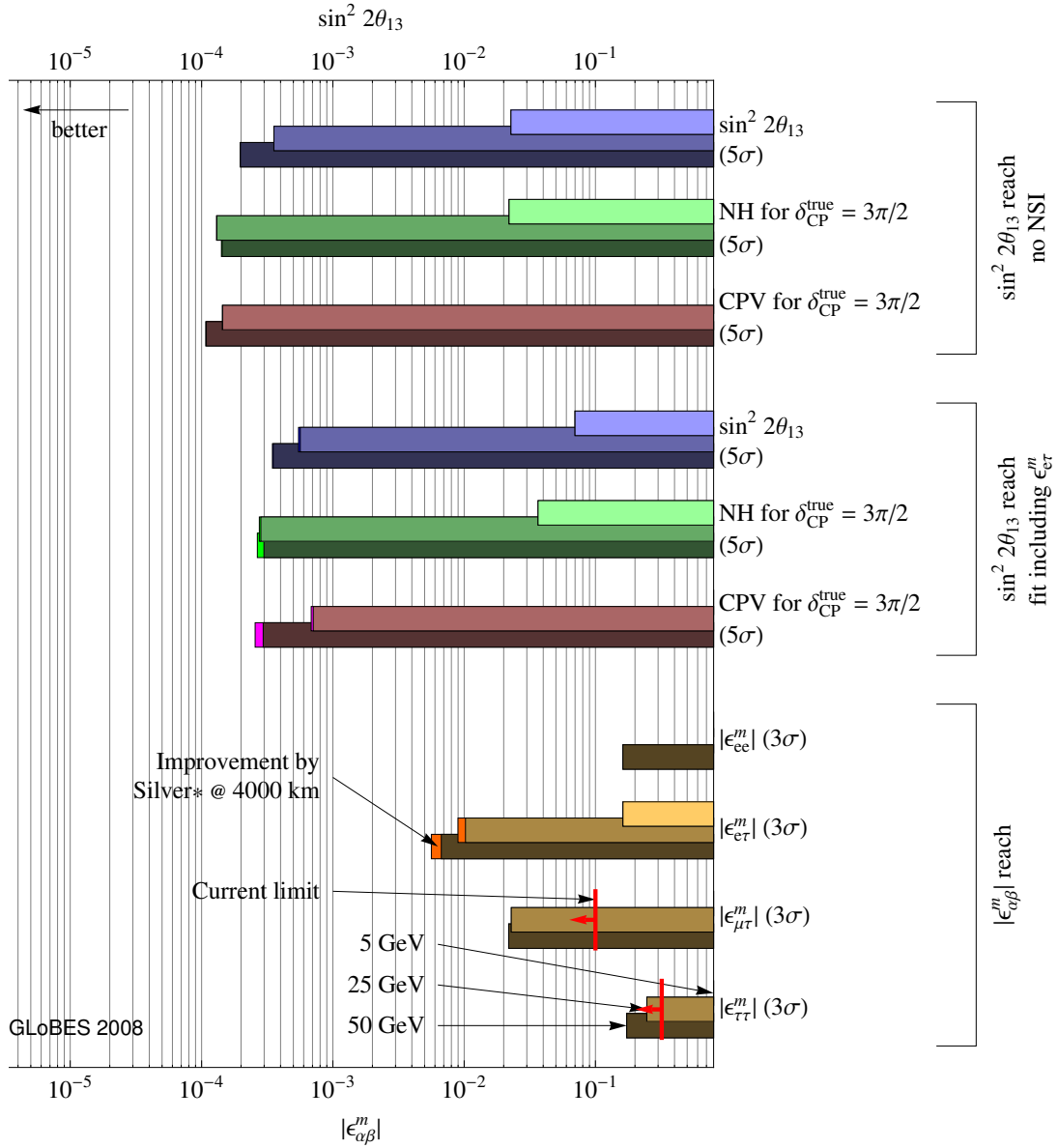
Sterile neutrinos

- Several inconclusive hints
  - LSND / MiniBooNE
  - Reactor anomaly
  - Gallium anomaly
- Global fits in $3+1$ and $3+2$ models have problems
  $\longrightarrow$ some (or all) of the hints, or some of the null results may be wrong
- Many ideas for testing these hints
  - New short baseline reactor experiments
  - Radioactive source experiments
  - New experiments with accelerators (extra ND for NOνA, Daeδalus, . . .)
  - Very Low Energy Neutrino Factory (VLENF)
- We should discuss
  - Prospects and optimization of VLENF
  - Prospects of full NuFact in high E or low E configuration (some studies already exist)
- Any experiment to test the hints must have 5σ sensitivity



New neutrino interactions

- Small in MSSM, ADD, RS . . .
- But could be unique winodw to light ($\lesssim 1$ *GeV*) new states
  - New matter effects mediated by light new particle can be very strong in low-*E* processes such as coherent forward scattering without violating constraints from high-*E* experiments
- Phenomenology of "non-standard interactions" well understood
- Sensitivity best at high *E*
- Are there ways to achieve sensitivity to $\epsilon < 10^{-3}$ (near detector?)



Time-of-flight measurements

The Phantom of the OPERA: ν_μ in OPERA detetced 60 ns ($\sim$ 18 m) too early.

- Innumerable comments / ideas already:
  - Why did neutrinos from SN1987A arrive on time?
  - Spontaneous Lorentz-violation if neutrinos couple to a scalar condensate?
  - Effects should be mediated to electrons through loops ($\rightarrow$ constraints)
  - New decay modes (e.g. $\nu \rightarrow \nu e^+ e^-$, modified pion decay kinematics
  - Are all particles except neutrinos subluminal due to a refractive index of unknown origin?
  - Are neutrinos tachyonic?
  - Extra-dimensional shortcuts for sterile neutrinos?
  - A mistake in modelling the shape and timing of the proton bunch?
- Can be tested by MINOS, T2K, NOνA, LBNE, etc.
- If confirmed, profound implications for all areas of physics
- What can the neutrino factory say?
  - How to configure muon bunches for rime-of-flight measurement?
  - High statistics, long baseline $\rightarrow$ very precise?
  - Most sensitive to any effect related to Earth matter
  - Wide energy range accessible $\rightarrow$ investigate E dependence

Outline

Summary of things to do

- Small θ_{13}: Fine-tuning
- Large θ_{13}: Comparatative study and optimization of LENF
- Cross section measurements: Establish physics case
- ν_τ contamination: Investigate impact on LENF and new physics searches
- Beyond the Standard Model:
  - Sterile neutrinos: Discuss performance of LENF and VLENF
  - New interactions: Discuss physics case (Light new particles?)
  - Time of flight measurements: What can a NuFact say?

Thank you!