LENF to HENF: Physics with an Incremental Approach

Tracey Li
IFIC/ CSIC, Valencia

IDS-NF meeting
Virginia Tech Research Center
17th October 2011

Talk outline

- A staged approach for NF - large θ_{13}
- LENF vs HENF performances
- Moving from LENF to HENF
- Summary.

Why stage?

- Building a neutrino factory (LE or HE) is challenging(!)
- Starting 'small' (LE) and working up to 'big' (HE) is a safer option:

  - Proof of principle

  - Can optimize each stage based on results from previous stage

  - Don't need all the money in one go.

- BUT it's only appealing if each stage can produce physics results.
- References: J. Tang, W. Winter, arXiv: 0911.5052;
  S. Agarwalla, J. Tang, W. Winter, arXiv: 1012.1872.

LENF vs HENF

- The HENF was originally designed with the scenario of small θ_{13} ($< 10^{-3}$) in mind.

  Original HENF idea: $E \sim 25$ GeV, 2 baselines of ~ 3000 and ~ 8000 km, 2×100 kt MIND.

  ISS report, arXiv: 0710.4947.

- The LENF was originally designed with the scenario of large θ_{13} ($> 10^{-3}$) in mind.

  Original LENF idea: E$\sim$ 4 GeV, 1 baseline of ~ 1500 km, 20 kt TASD (or 100 kt LAr).

  S. Geer, O. Mena, S. Pascoli, hep-ph/0701258;

  E. Fernandez Martinez, O. Mena, T.L., S. Pascoli, arXiv: 0911.3776

Original LENF idea

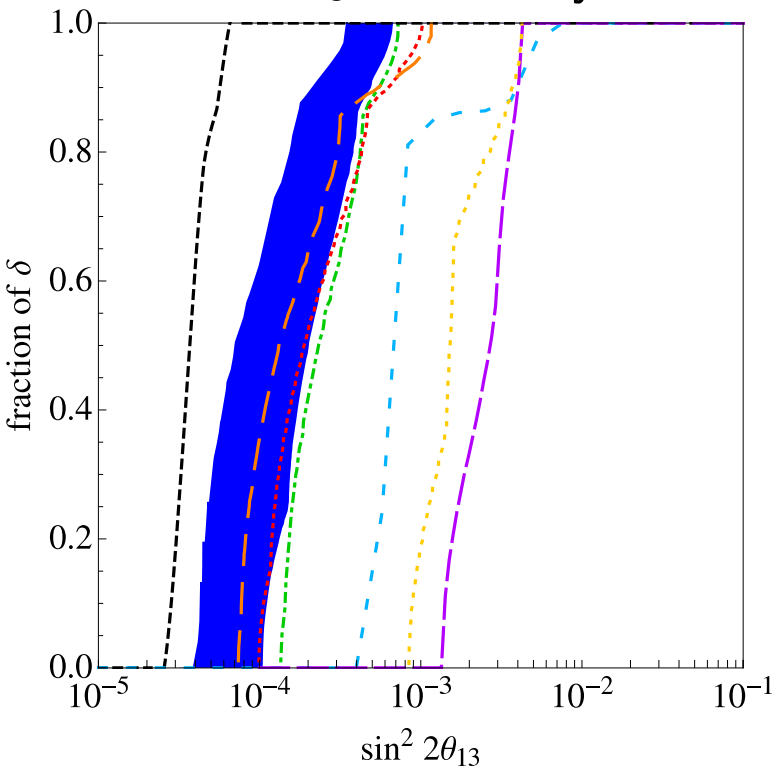
- Very long baseline necessary for small θ_{13} (determine mass hierarchy, resolve degeneracies, magic BL).
- For large θ_{13}, very long baseline isn't necessary.
- For E $\sim$ 4 GeV and L $\sim$ 1500 km, oscillation spectrum is very rich.
- A magnetised detector with good energy resolution could enable all oscillation parameters to be measured in this energy region.

Original LENF sensitivities

Current bound on θ_{13} is $0.004 < \sin^2 2\theta_{13} < 0.150$ (3σ C.L.).

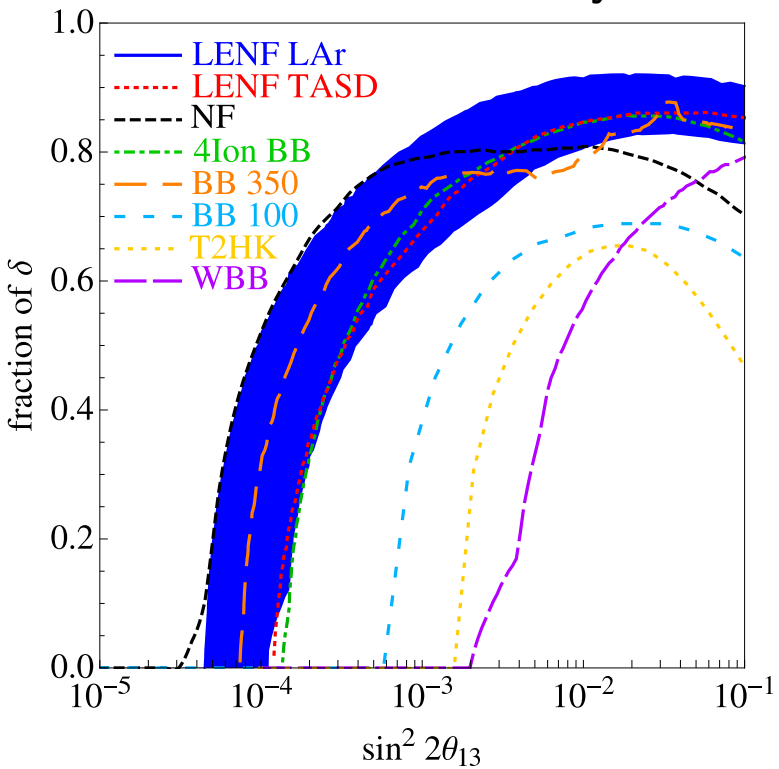
T. Schwetz, M. Tórtola, J. Valle, arXiv: 1108.1376.

3σ θ_{13} discovery:



arXiv: 0911.3776

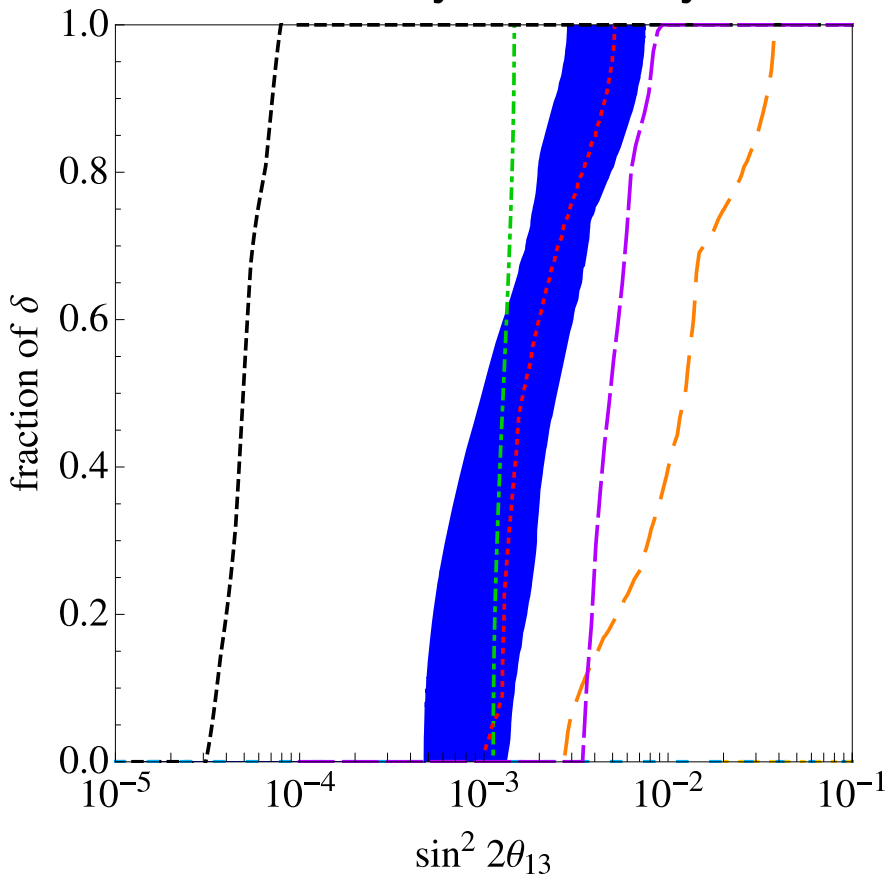
3σ CPV discovery:



arXiv: 0911.3776

Original LENF sensitivites

3σ hierarchy discovery:



arXiv: 0911.3776

Current bound on θ_{13} is $0.004 < \sin^2 2\theta_{13} < 0.150$ (3σ C.L.).

T. Schwetz, M. Tórtola, J. Valle, arXiv: 1108.1376.

So this LENF setup has 100% CP coverage to θ_{13}, the mass hierarchy (nearly) and $\sim 80\%$ coverage for CPV for the 3σ range.

Evolution of LENF

E$\sim$ 4 GeV, L$\sim$ 1500 km, 20 kt TASD/ 100 kt LAr.

$\Downarrow$

E$\sim$ 8 GeV, L$\sim$ 2500 km, 20 kt TASD/ 100 kt LAr.

$\Downarrow$

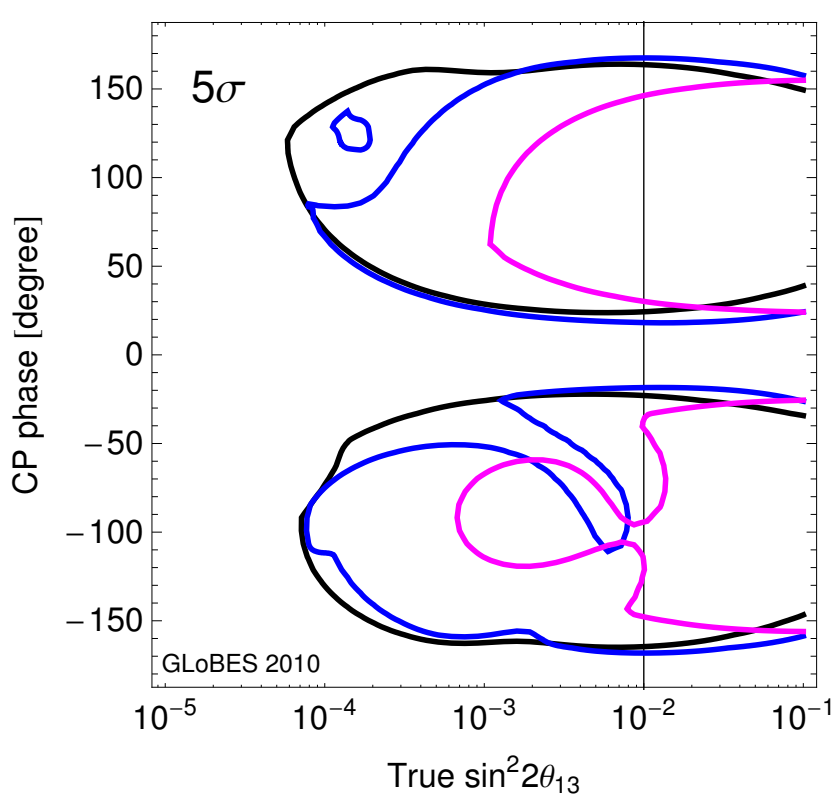
E$\sim$ 8 GeV, L$\sim$ 2500 km, 100 kt MIND.

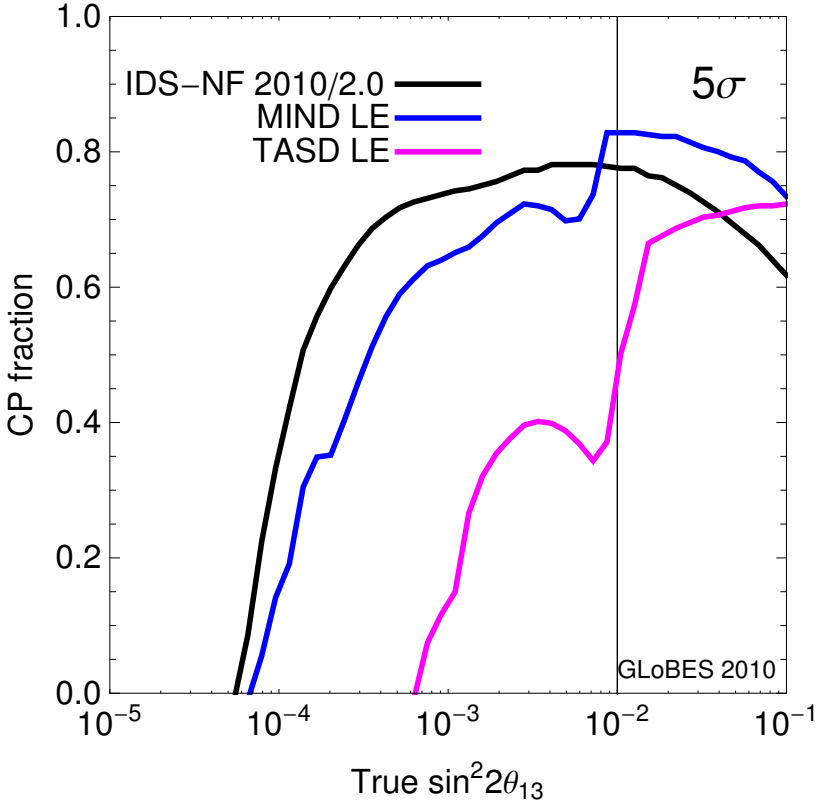
LENF can work with MIND (same detector as HENF).

(Although the completely optimal LENF has a detector with high efficiency at low energies e.g. TASD).

LENF vs HENF

5σ CP violation discovery (from IDR):





IDS-NF: E= 25 GeV, L= 4000 + 7500 km, 100 + 50 kt MIND

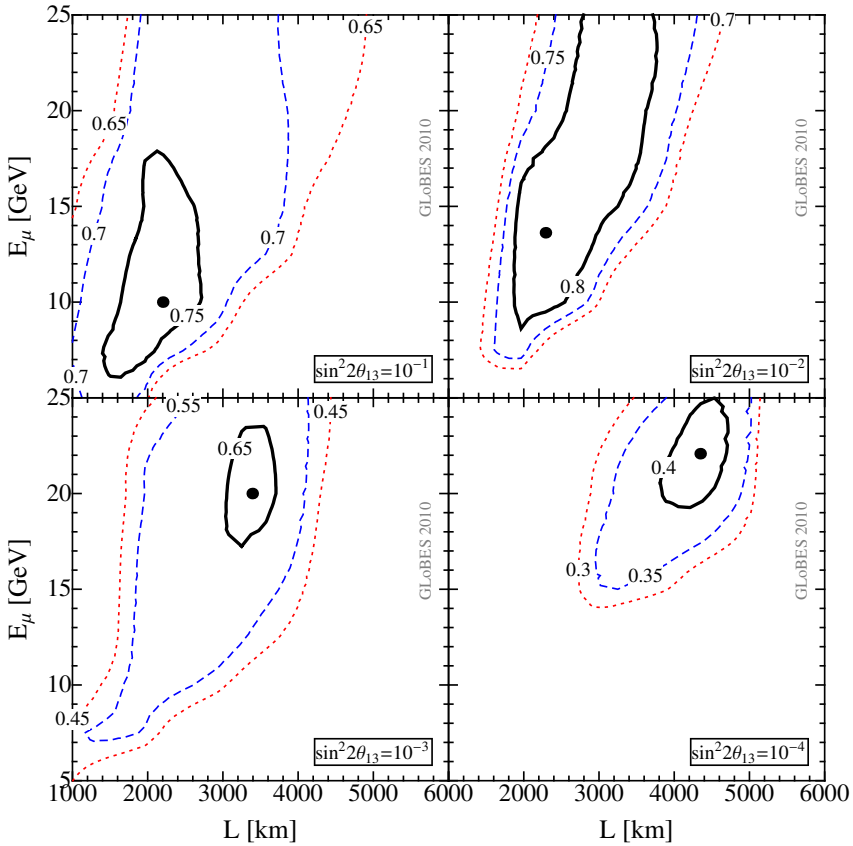
TASD LE: E= 5 GeV, L= 1300 km, 20 kt TASD

MIND LE: E= 10 GeV, L= 2000 km, 100 kt MIND

Given sufficient statistics (100 kt MIND), LENF ∼ HENF.

HENF optimisation vs LENF optimisation

3σ CPV discovery for single-baseline HENF (50 kt MIND):



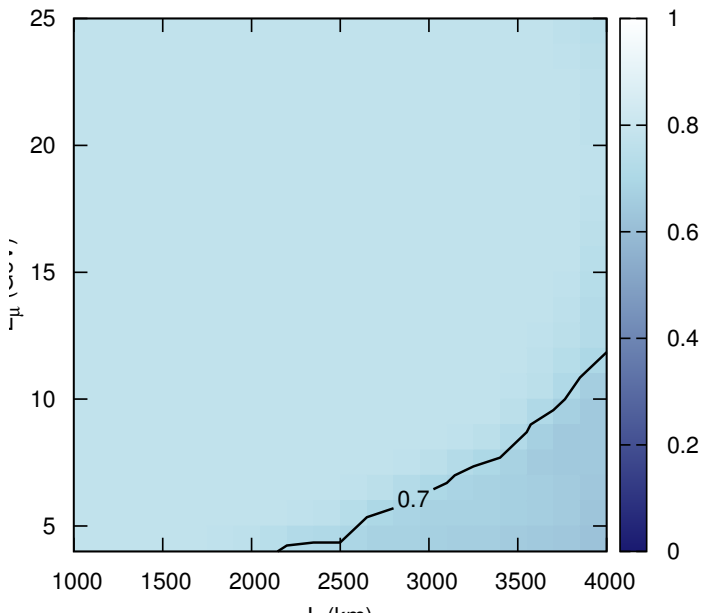
S. Agarwalla, P. Huber, J. Tang, W. Winter, arXiv: 1012.1872.

For large θ_{13}: optimum at L ~ 1500 - 3000 km, E ~ 5 - 15 GeV.

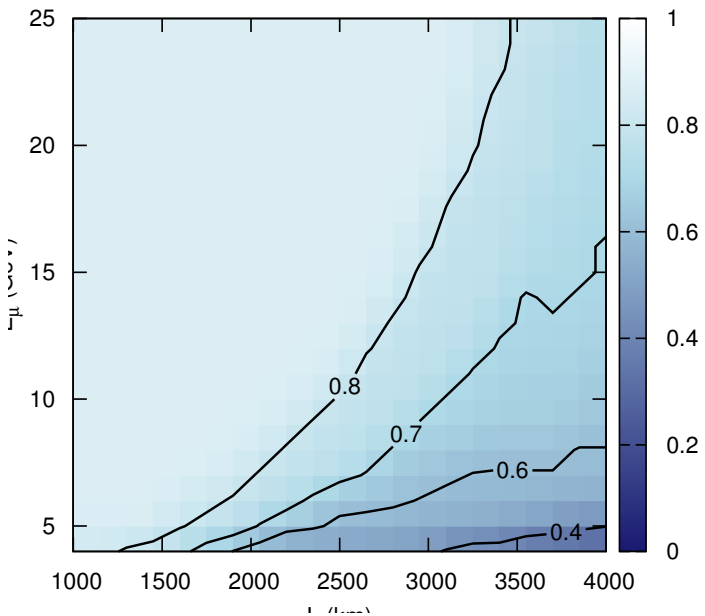
HENF optimisation vs LENF optimisation

3σ CPV discovery for LENF (20 kt TASD):

$\sin^2 2\theta_{13} = 10^{-1}$



$\sin^2 2\theta_{13} = 10^{-2}$



P. Ballett, P. Huber, S. Pascoli, in preparation.

Optimal LENF region overlaps with optimal HENF region.

(Anyone know what mass of MIND is equivalent to 20 kt TASD)?

LENF $\rightarrow$ HENF

- For current 3σ preferred region of θ_{13}, LENF has good sensitivity to all oscillation parameters.
- Have just seen that LENF and HENF optimisations are compatible, in terms of L and E.
- LENF works well with MIND as well as TASD.

  $\Rightarrow$ So start with LE + MIND, and build up to HE (single baseline).
- Also stage the detector...? (Start with smaller mass and build up to 100 kt)?

Why bother with HENF?

If θ_{13} is large, the main motivations for HENF are:

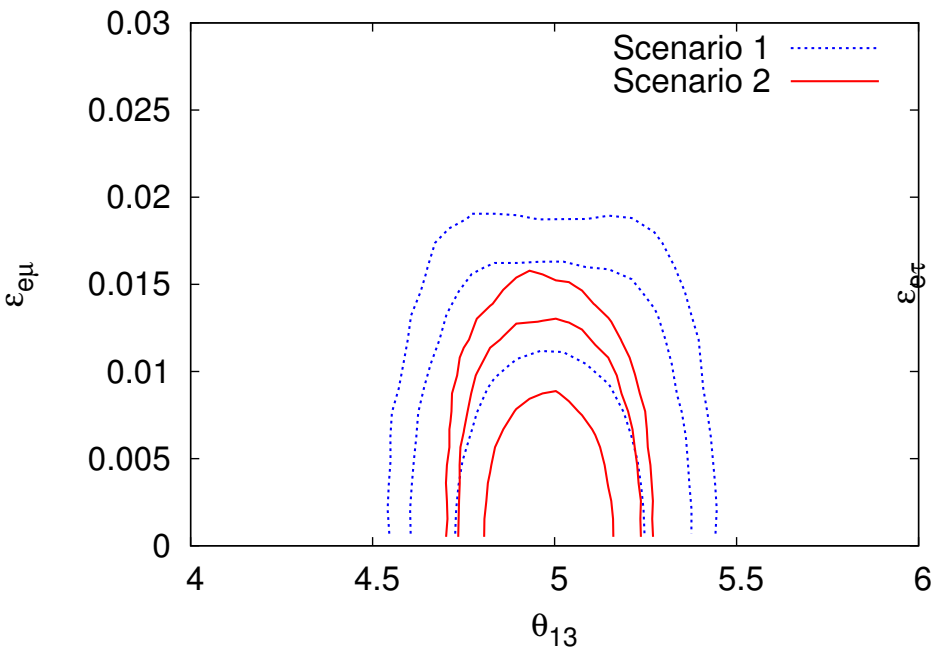
- Precision measurements of oscillation parameters (θ_{13}, δ_{CP}, θ_{23}).
- Non-standard interactions = neutrino interactions not predicted by Standard Model

$\Rightarrow$ search for new physics!

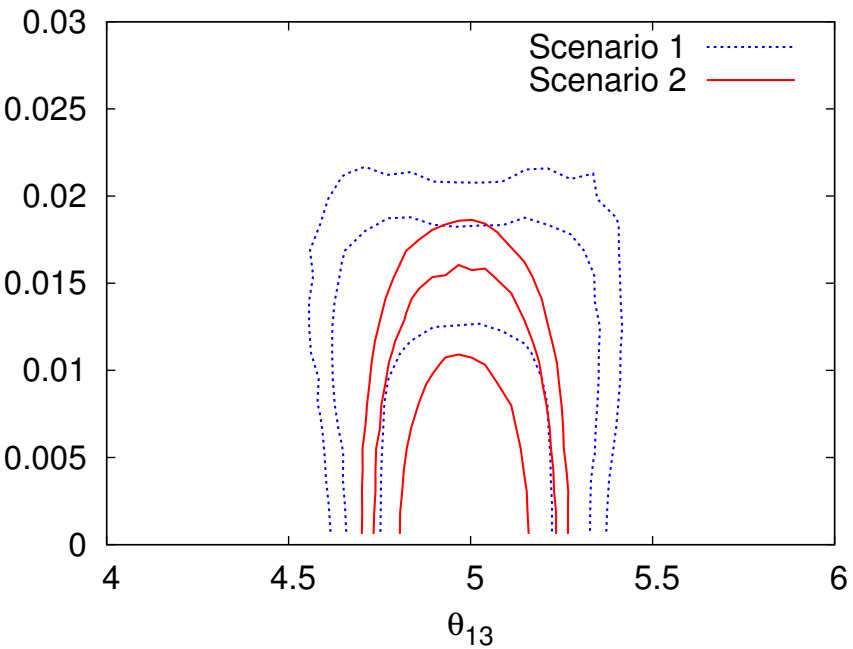
NSI's at LENF

For large θ_{13}, LENF (4.5 GeV, 1300 km, 20 kt TASD) has sensitivity to NSI's down to $\varepsilon \sim 10^{-2}$:

$\varepsilon_{e\mu}$ (68%, 90%, 95%)



$\varepsilon_{e\tau}$ (68%, 90%, 95%)

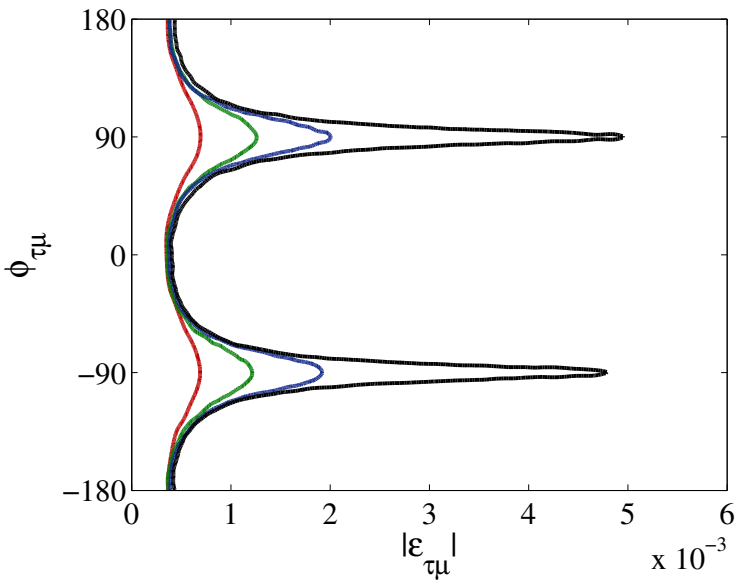


Note that this is only if we include the platinum channel!

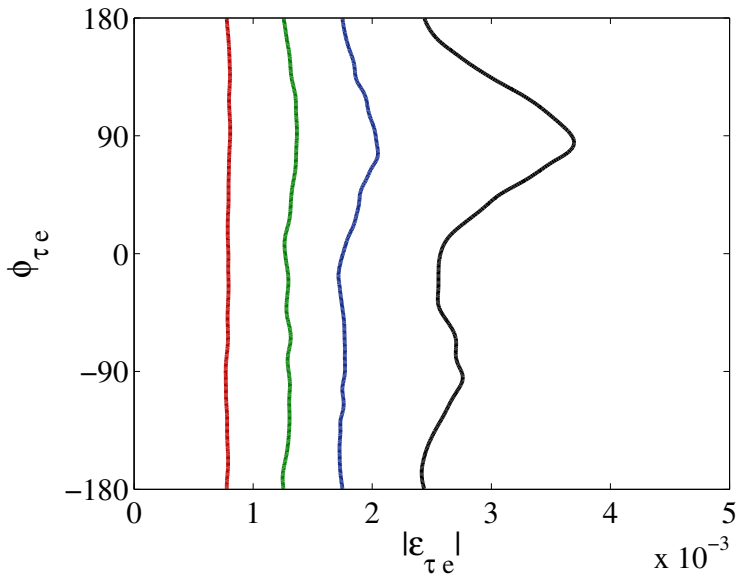
NSI's at HENF

But HENF is much more powerful:

$\varepsilon_{e\mu}$ (90% C.L.)



$\varepsilon_{e\tau}$ (90% C.L.)



Sensitivity down to $\varepsilon \sim 10^{-3}$.

Further LENF work

Need to look at NSI sensitivity of LENF with MIND.

- LENF performance will be improved if E is higher.
- But probably won't have access to platinum channel.
- Although we can include τ's...?

Summary

- For current 3σ best-fit region of θ_{13}, LENF has excellent sensitivity to oscillation parameters and some sensitivity to NSI's.
- LENF works with MIND as well as TASD (need to check NSI's, though) $\Rightarrow$ common detector.
- MIND prefers higher energies than TASD, but still works with lower energies $\Rightarrow$ can start with E $\sim$ 5 GeV, L $\sim$ 1500 km.
- In this case, LENF fits in as the first stage of a single-baseline HENF (same detector, increase energy to $\sim$ 10 GeV).
- HENF still needed for NSI's, and probably precision measurements too.