Large θ_{13} – impact on IDS-NF

Patrick Huber

Center for Neutrino Physics at Virginia Tech

8th IDS-NF plenary meeting

April 18-20, 2012, University of Glasgow, UK

Large θ_{13} – implications

The Daya Bay result is

$$\sin^2 2\theta_{13} = 0.092 \pm 0.016(\mathrm{stat}) \pm 0.005(\mathrm{syst})\,,$$

which translates into a 5.2 σ exclusion of $\theta_{13} = 0$. What are the implications for future facilities?

In general, this raises the following questions

- Will the mass hierarchy have been determined?
- Are new experiments beyond NOνA and T2K necessary?
- Are superbeams sufficient?

Large θ_{13} – implications

For the IDS-NF, this raises the following questions

- Baseline change
- New optimization
- Staging

which we will discuss in part II of this talk in the afternoon...

θ_{13}

FAPP θ_{13} will be known to very high accuracy

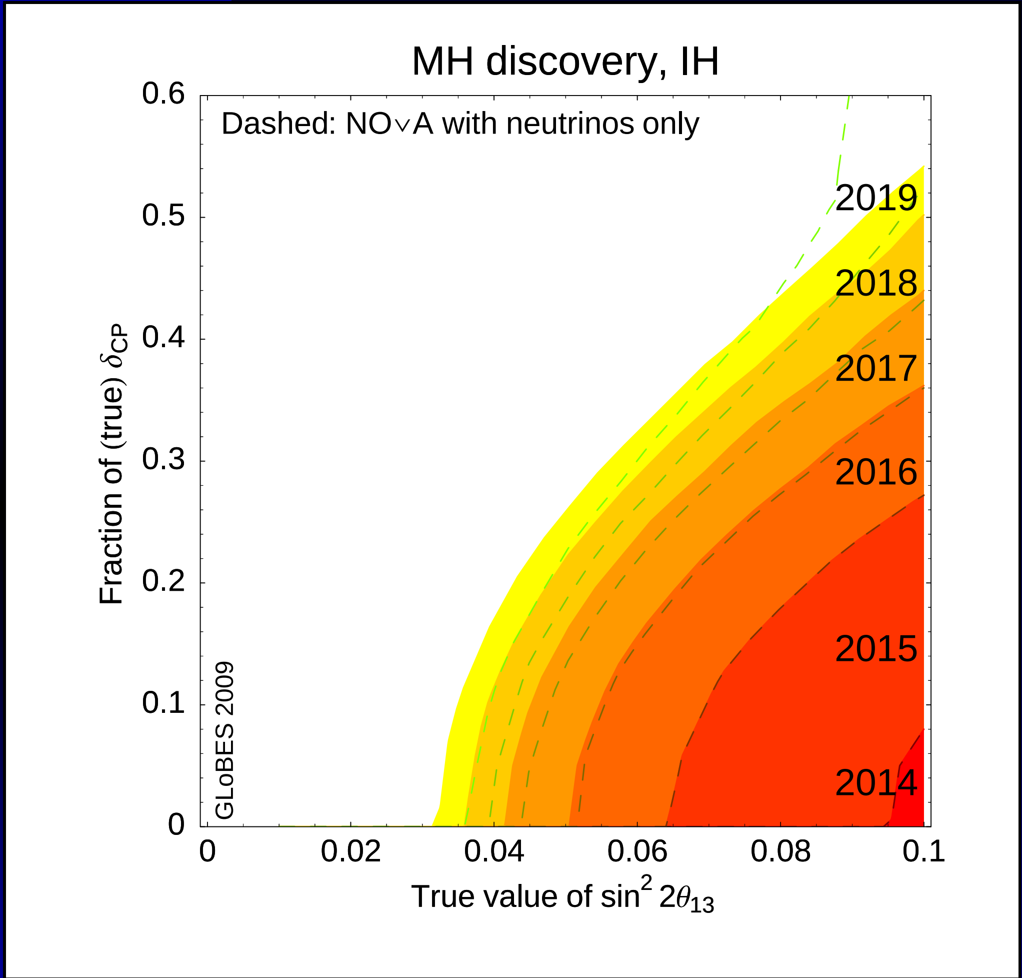
At $\sin^2 2\theta_{13} = 0.1$ the measurement error at T2K will be 10%

At $\sin^2 2\theta_{13} = 0.1$ the measurement error at Daya Bay will be <5%

Can beams improve this result? – not any time soon

See talk by A. Donini in PPEG parallel

Mass hierarchy

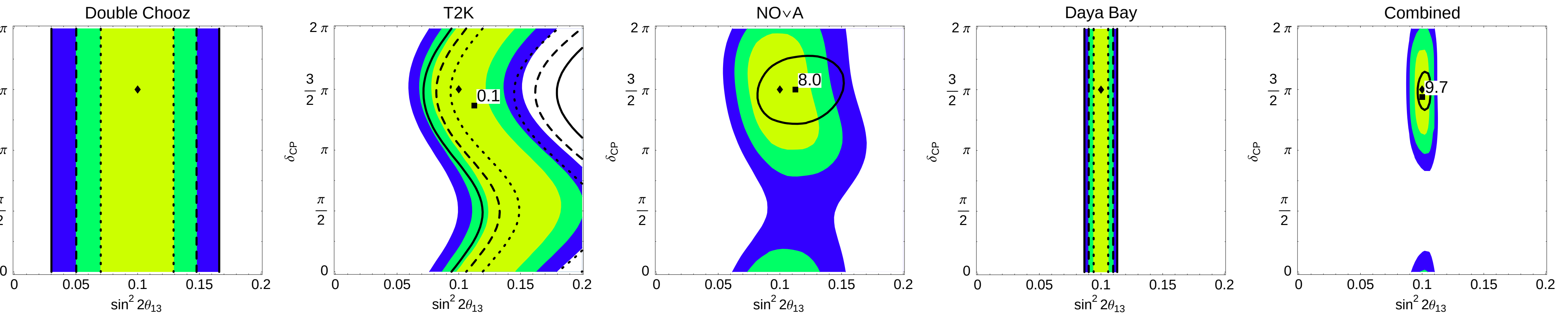


90% CL, combines T2K, NOνA, Daya Bay, Double Chooz and RENO At this CL MINOS and T2K have discovered $\theta_{13} \neq 0$!

At $3\,\sigma$ this plot would be essentially empty!

PH, M. Lindner, T. Schwetz, W. Winter, JHEP 11 044 (2009), arXiv:0907.1896.

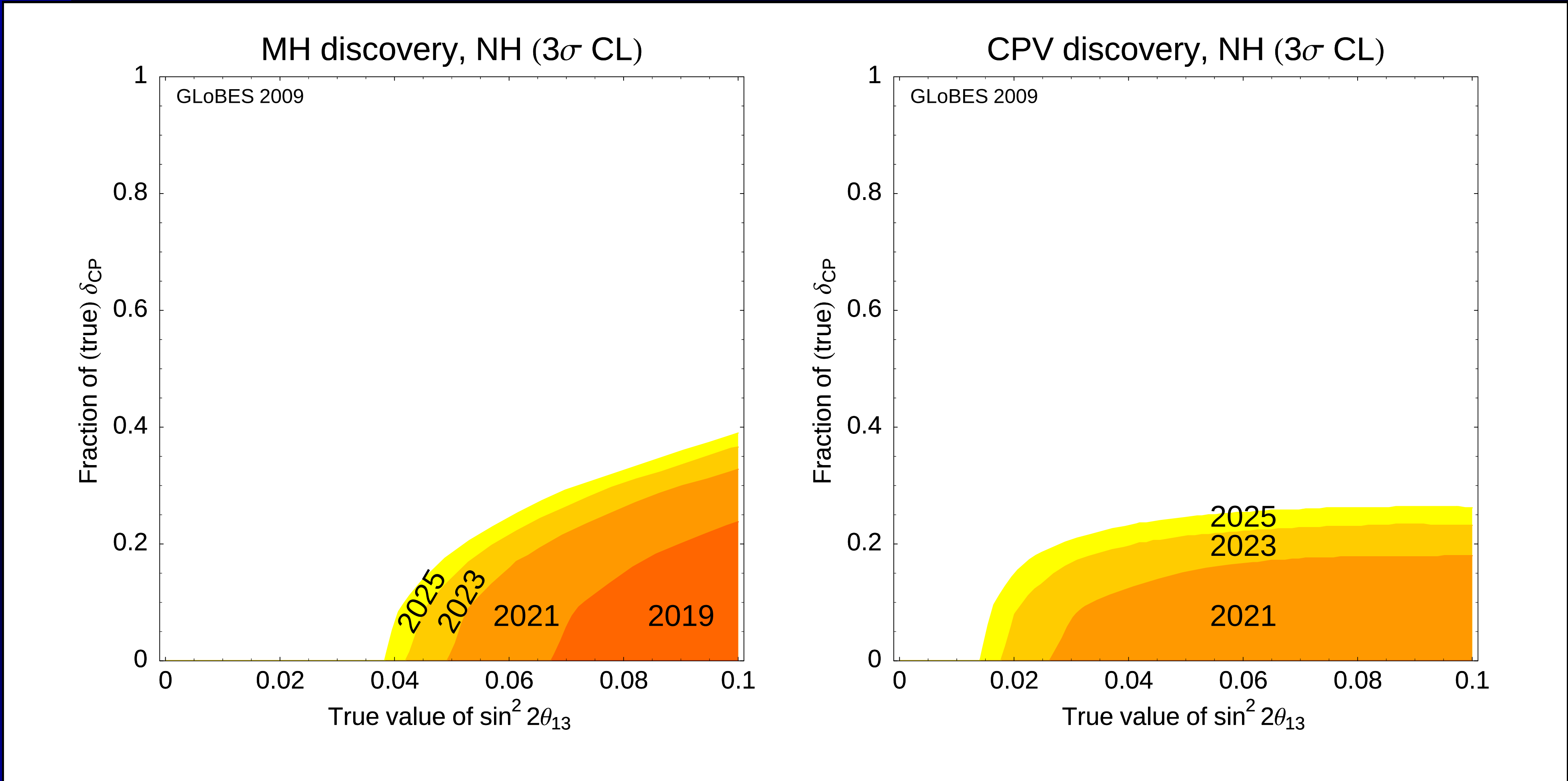
CPV without new experiments?



PH, M. Lindner, T. Schwetz, W. Winter, JHEP 11 044 (2009), arXiv:0907.1896.

Barely reaches $3\,\sigma$ for mass hierarchy, and this is the most favorable δ_{CP}!

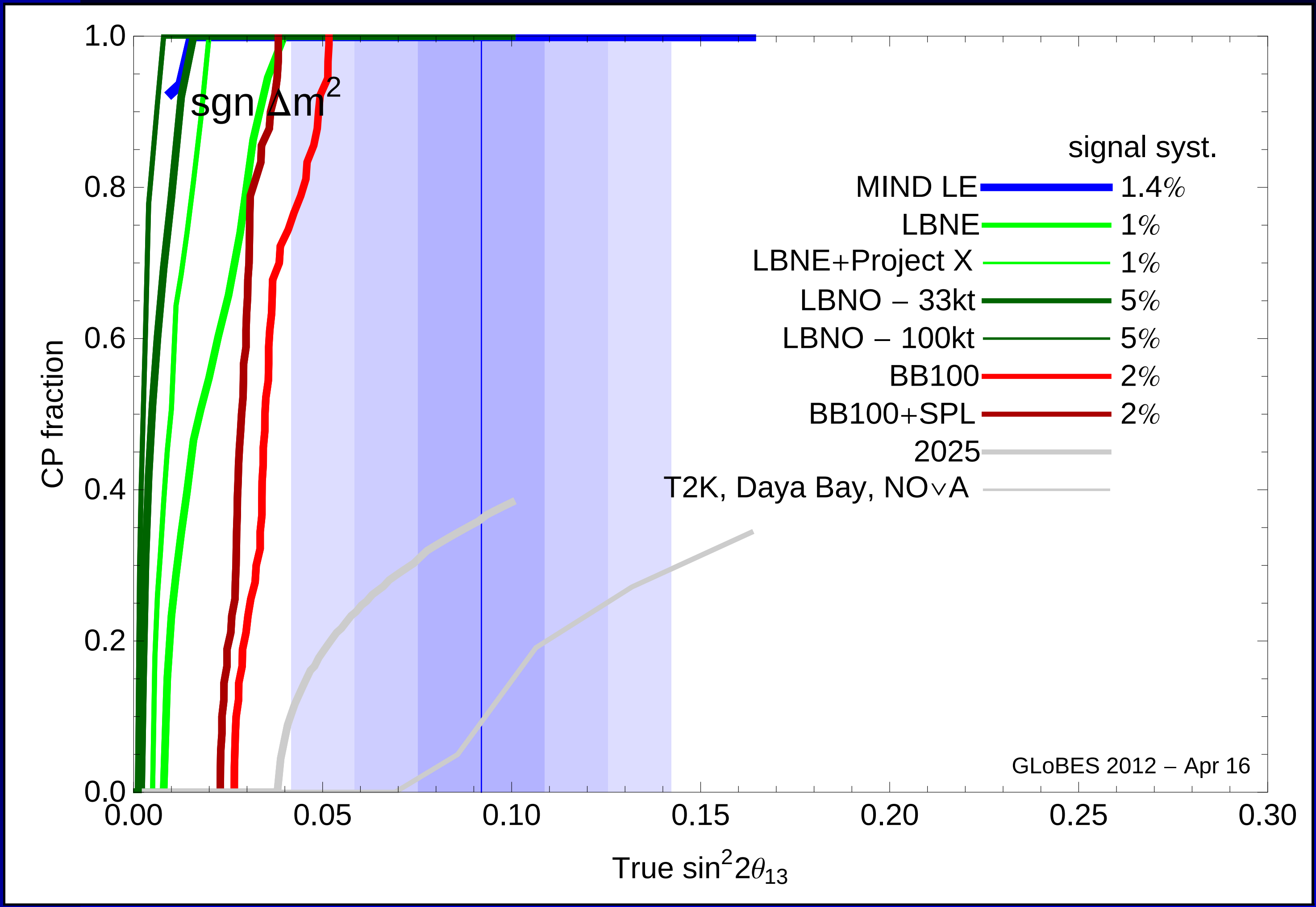
CPV without new experiments?



PH, M. Lindner, T. Schwetz, W. Winter, JHEP 11 044 (2009), arXiv:0907.1896.

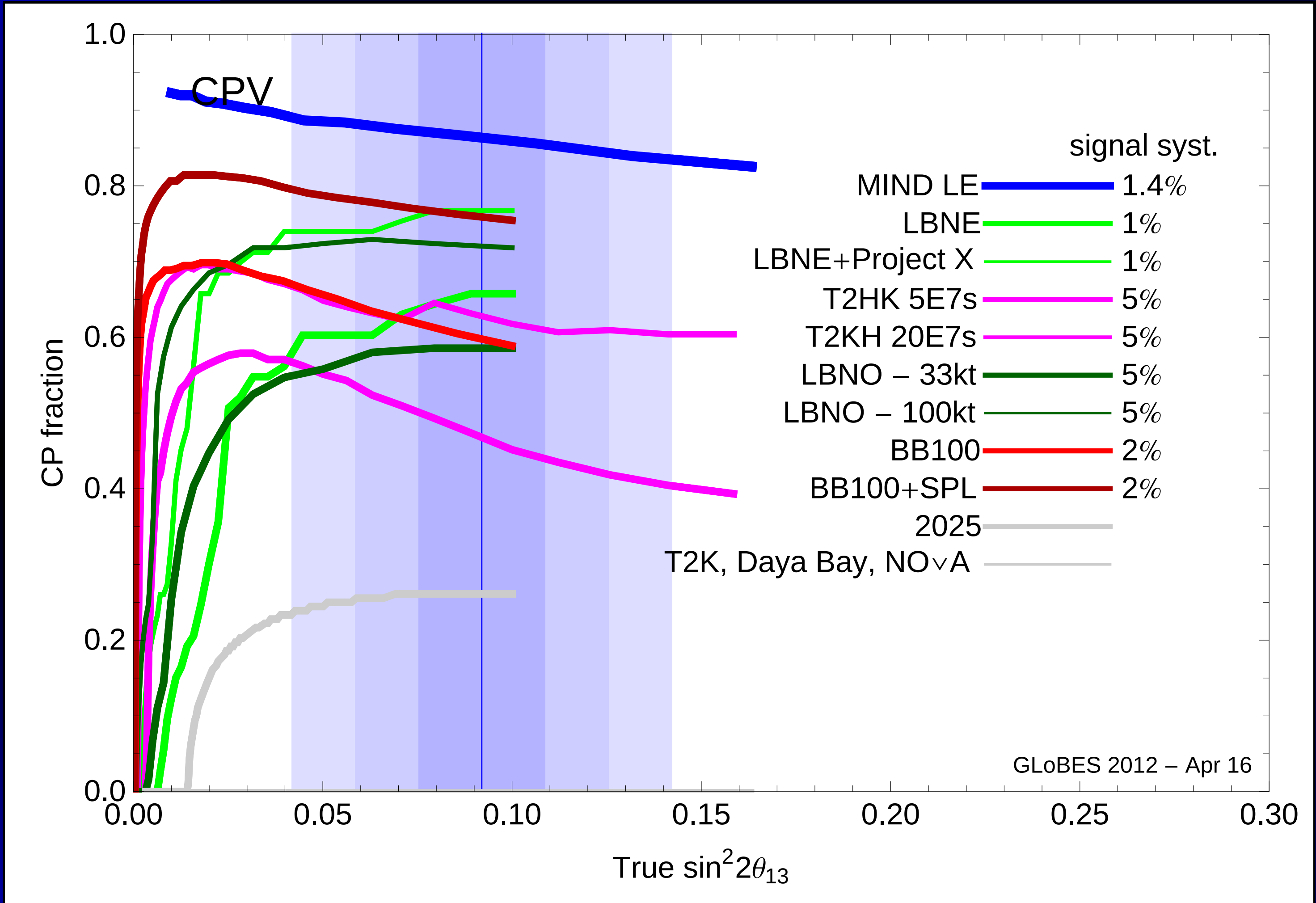
Includes Project X and T2K running at 1.7 MW.

Are superbeams enough?



Mass hierarchy will be resolved by most approaches!

Are superbeams enough?

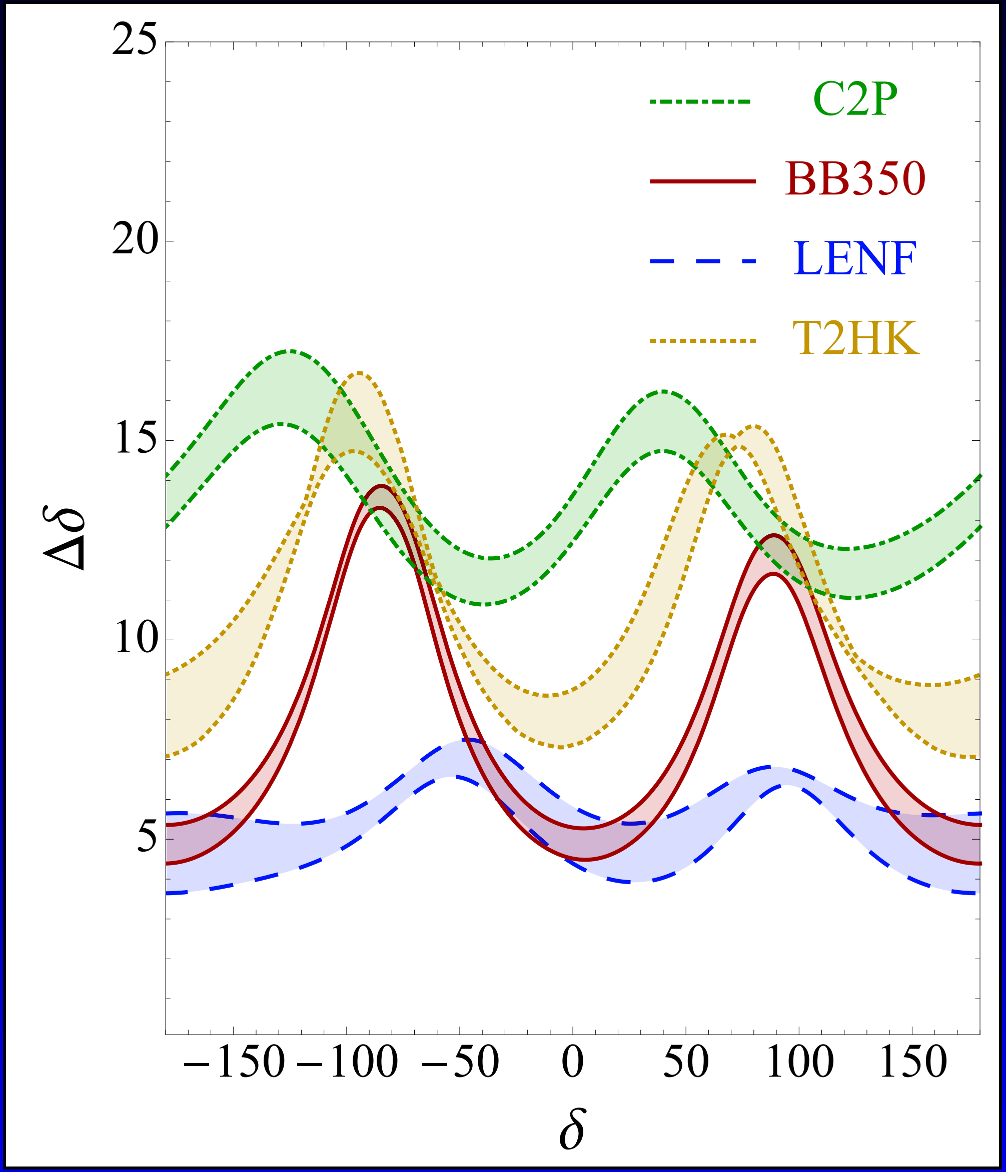


SB reach CPF of 0.7-0.75
NF reaches CPF of 0.85-0.9

MIND LE – 100 kt MIND at 2000km and 10GeV

NF still best for **all** values of θ_{13}!

CP precision

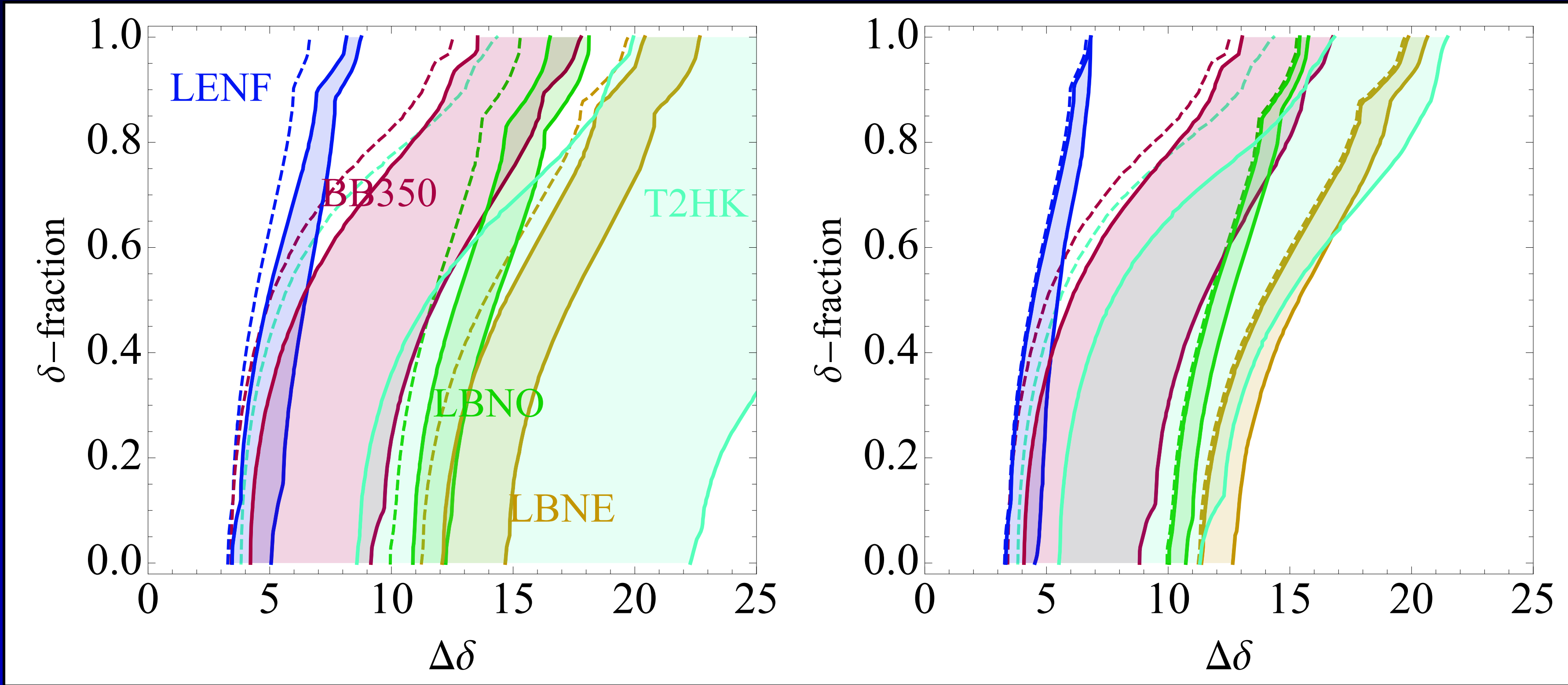


P. Coloma, A. Donini, E. Fernandez-Martinez, P. Hernandez, arXiv:1203:5651

More details from A. Donini in PPEG parallels

CP precision

CAVEAT: highly preliminary!



P. Coloma, PH, J. Kopp, W. Winter, in preparation

LENF consistently superior – more details from P. Coloma in PPEG parallels

Summary

Comparison with SB

- Will the mass hierarchy have been determined w/o new experiments? – not likely (requires Project X)
- SB will measure mass hierarchy (even a phase 1 LBNE may be able to do that)
- Are SB likely to discover CPV – yes, provided they are truly super (which LBNE is not, but T2HK is)
- Can SB do precision measurements – highly dependent on place in parameter space and systematics
- Can NF do significantly better – YES

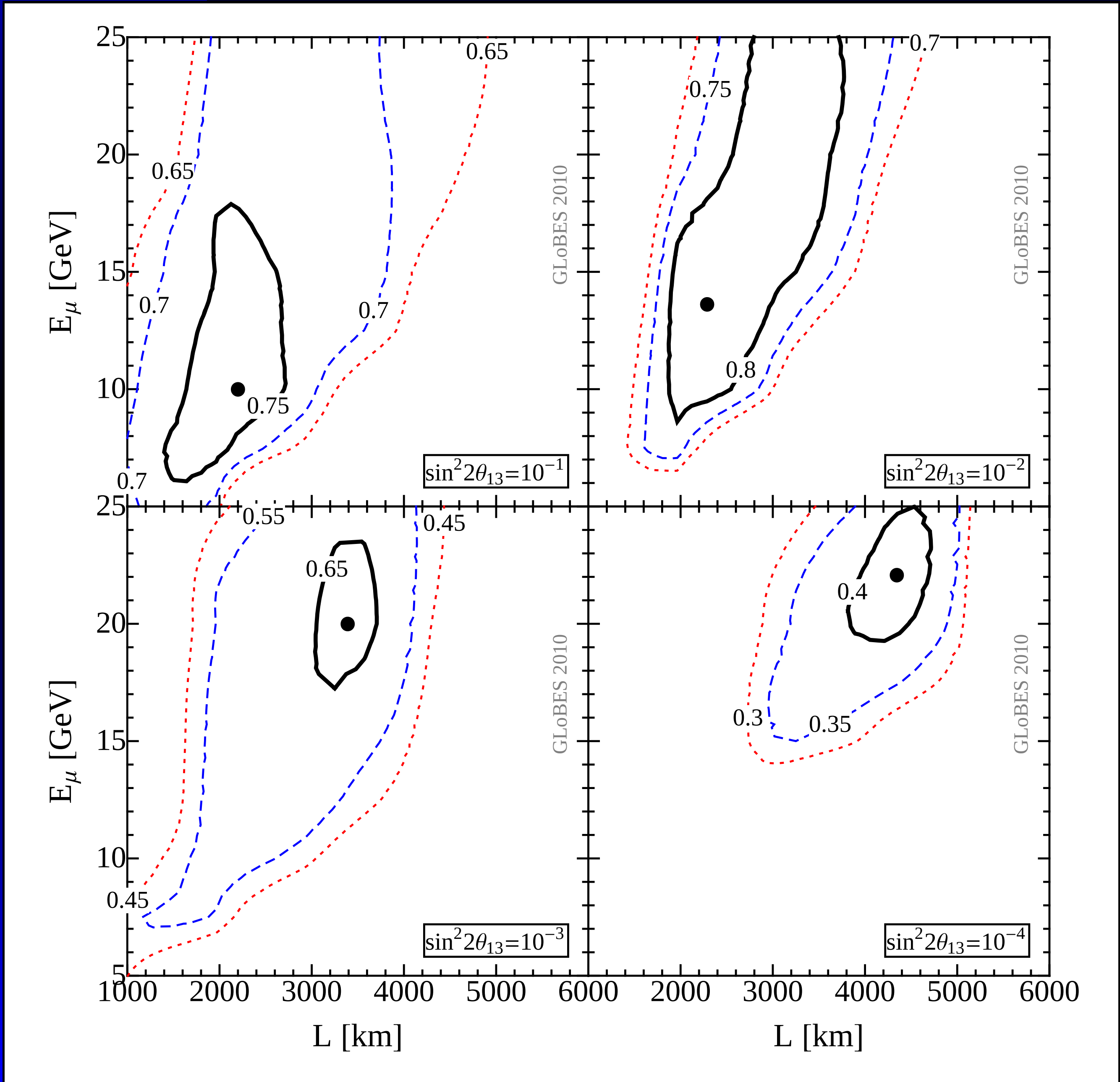
Implications for the IDS-NF

One page summary

- New baseline: 100kt MIND, baseline 1300-2500 km, 5-10 GeV, 1E21 muons per 1E7s
- To stay relevant
  - Make the precision case
  - Exploit all opportunities
  - Be cost aware
  - Do not rely on >10 year projects, ie. Project X


Opportunity doesn't always
arrive gift wrapped.
Today's challenges are different. Talk to us and see how we
can help you turn elusive potential into tangible performance.
• Consulting • Technology • Outsourcing
IDS-NF
High performance. Delivered.

Optimization – one baseline

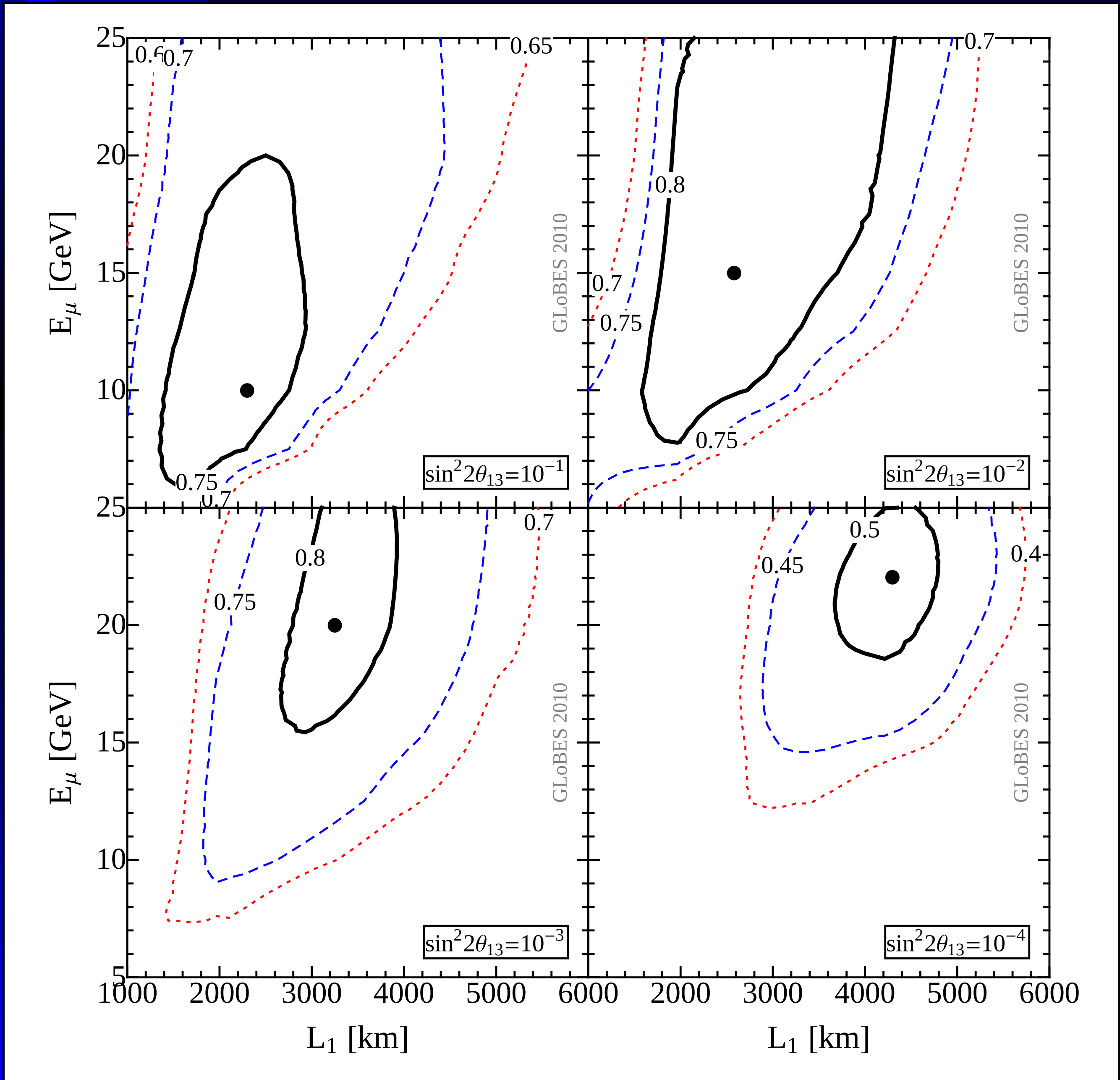


At large θ_{13}, using MIND and one baseline, optimum is at 2200-2300 km and 10-14 GeV.

CPF 0.77-0.84

S. Agarwalla, PH, J. Tang, W. Winter JHEP 1101 120 (2011).

Optimization – 2nd baseline?



At large θ_{13}, using MIND and one baseline, optimum is at 2300-2600 km and 10-15 GeV.

CPF 0.77-0.84 – identical to one baseline setup

Only 1 baseline needed!

S. Agarwalla, PH, J. Tang, W. Winter JHEP 1101 120 (2011).

Case for ν_τ – or lack thereof

Standard physics

- MIND has been re-evaluated and now a has low (few GeV) neutrino threshold, which effectively allows to fully map the 1st oscillation maximum for $L \geq 2000\,\mathrm{km}$
- The current baseline has a MIND at the magic baseline

As a result it was found that no performance is gained from having an ECC measuring $\nu_e \to \nu_\tau$ anywhere between 1000-10000km (PRD **74**:073003,2006.).

Case for ν_τ – or lack thereof

Standard physics result is easy to understand:

- $\theta_{23} \simeq \pi/4$, that is, ν_τ and ν_μ are maximally mixed.
- Within a 3 flavor framework, any change of the ν_τ oscillation probability will show up with similar magnitude in the corresponding ν_μ channel
- Muons are much easier to detect than taus, hence the statistical power of a well designed muon-only experiment always outperforms tau detection

Case for ν_τ – or lack thereof

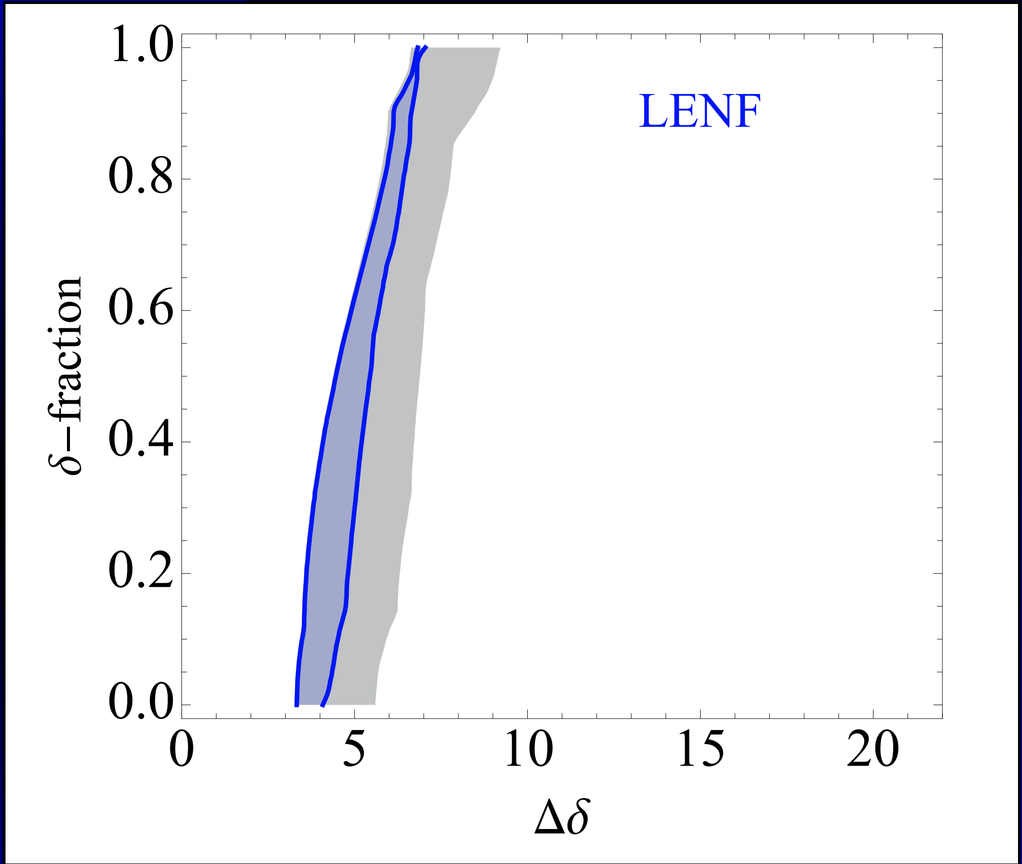
A fully optimized neutrino factory, with 2 low threshold MIND detectors, does not experience a significant increase in its physics reach from tau-detection capabilities at baselines exceeding a few 100km. This statement is true, both for

- Standard 3 flavor oscillation
- Non-standard interactions

All this information has been concisely documented in IDS-NF 008.

This does not drive us to higher energies!

Flux measurements



P. Coloma, PH, J. Kopp, W. Winter, in preparation

Gray area – old systematics implementation (ν and $\bar{\nu}$ uncorrelated)

Color area – new systematics implementation plus near detector

Includes a flux error variation from 0.1% – 1%

Does this justify the cost of extra acceleration to be able use inverse μ-decay?

Staging

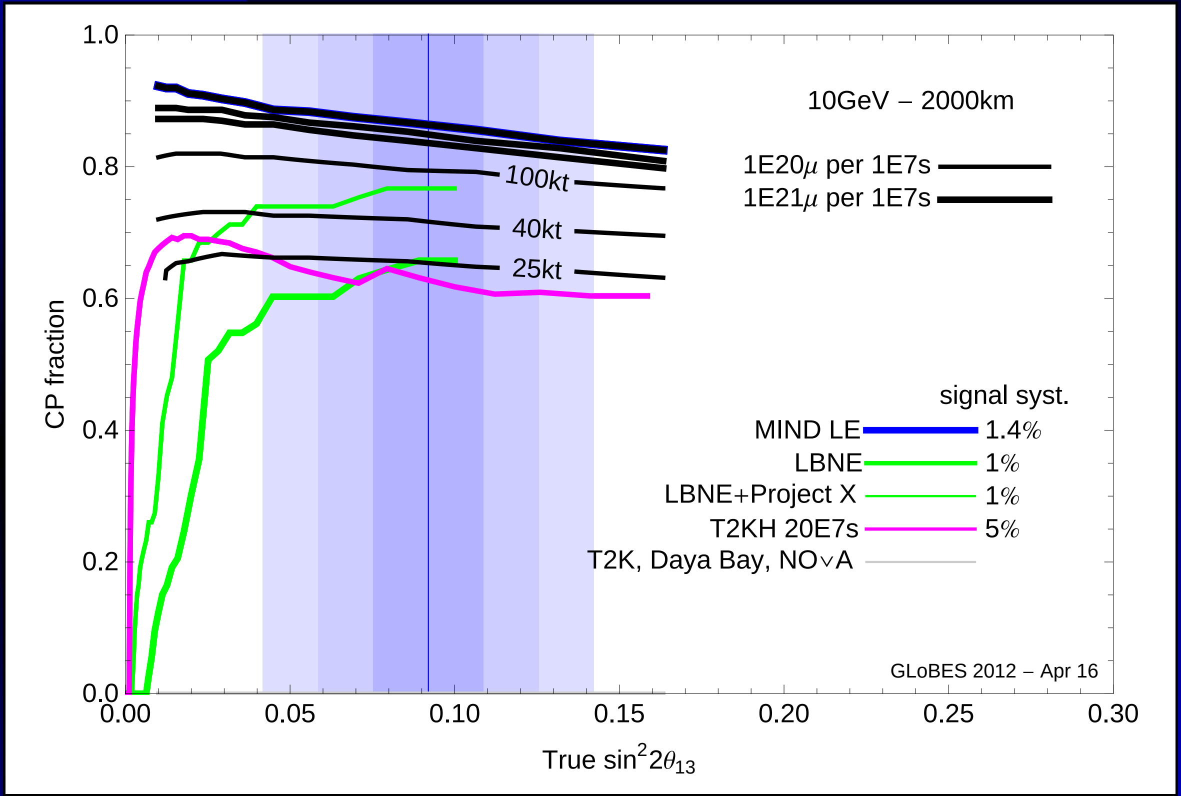
Traditional staging scenarios evolve from low energy, 1 baseline setups to high energy, 2 baseline setups.
e.g. J. Tang, W. Winter, Phys.Rev. D81 (2010) 033005.

At large θ_{13}, we only want low energy and 1 baseline!

Remaining degrees of freedom

- Luminosity
- Detector technology
  - iron vs fully active
  - magnetized vs non-magnetized

Staging – luminosity



1/20-1/10 of luminosity
- NF as good as the best SB

1/50-1/20 of luminosity
- NF on par with LBNE

$\Rightarrow$ Start somewhere between 1/50 and 1/20 and work your way to full luminosity

reduced proton power, 700kW instead of 4MW – no need to wait for Project X
no cooling – reduction of 1.7, but removes technological risk

Staging – luminosity

Assume 1/25 of the default luminosity, gains split equally between detector and accelerator

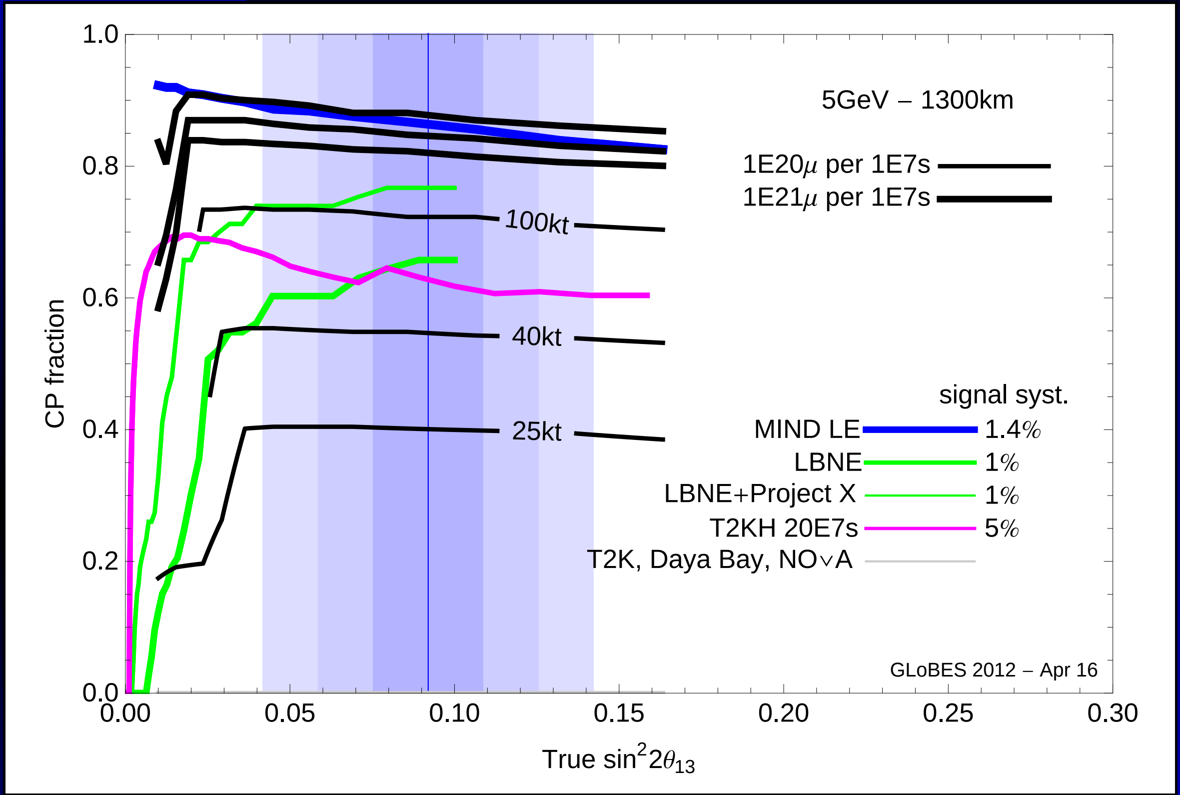
- proton beam power of 4 MW $\rightarrow$ 800 kW
- fiducial mass of MIND of 100 kt $\rightarrow$ 20 kt

This opens new possibilities

- Maybe horns instead of solenoids can be used
- Maybe existing proton infrastructure can be used
- Maybe 20 kt of LAr can be magnetized

LBNE + Project X cost about $3.6 billion – can we make a 1/25th-luminosity NF for a similar price? Can we make it for 1/3 the price?

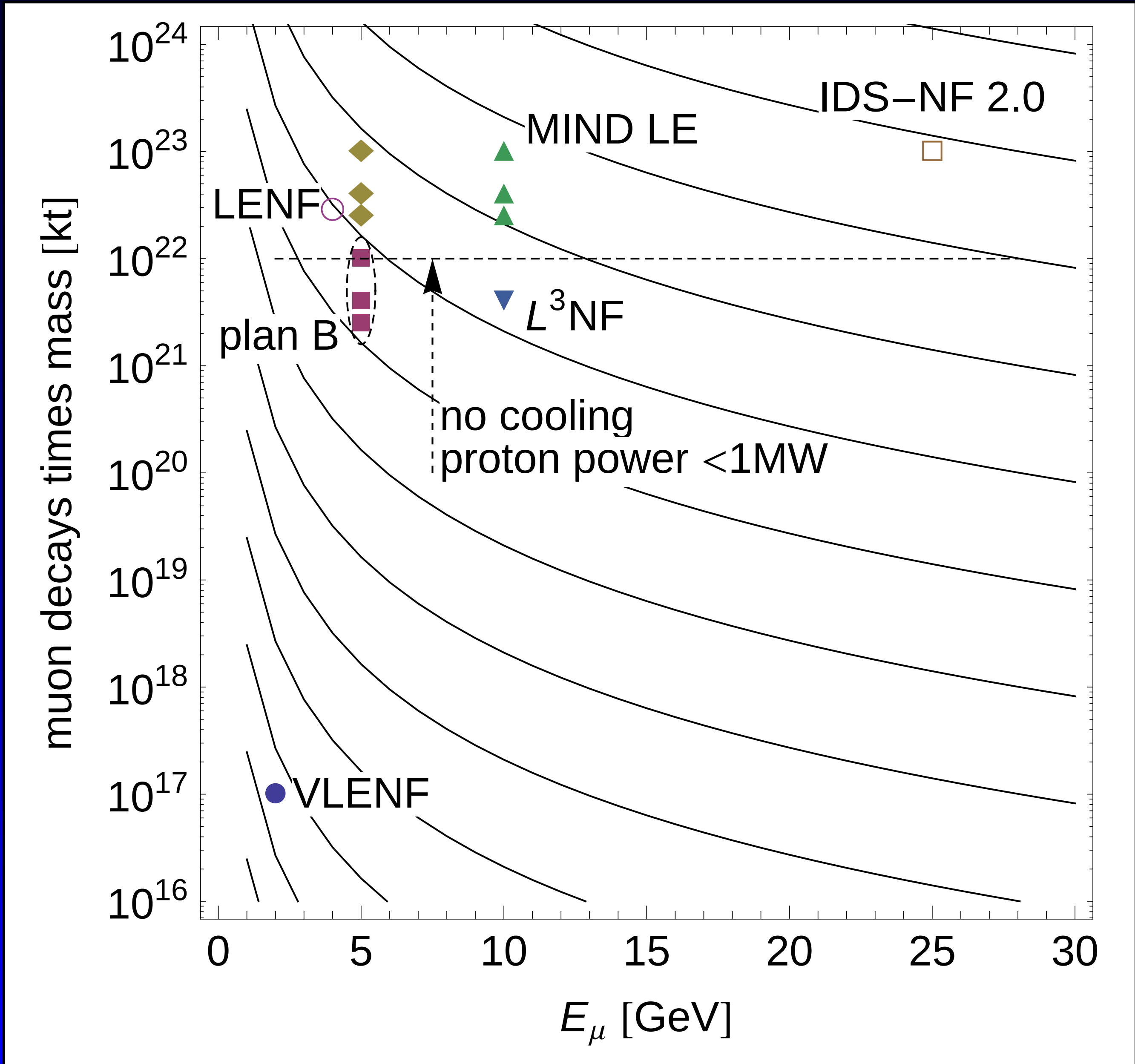
Staging – energy



Lower energy still works with MIND – but need to go to shorter baseline, too

At large θ_{13} final sensitivity at full luminosity very similar to 10GeV option, maybe even slightly better

Staging – in one view



Summary

Consequences for IDS-NF

- MIND LE optimal at large θ_{13}
- 1/25th of the luminosity is sufficient for an entry level facility to match the capabilities of SB
- still lower energies may be feasible using MIND – requites shorter baselines
- totally active detectors (scintillator, liquid argon) seem to be too expensive per kt

Open questions

PPEG & Detector WG

- Study precision
  - Systematics modeling including near detector
  - Select (or develop) performance indicators
  - Optimize for large θ_{13}
- Compare with precision of other facilities

Accelerator WG

- Alternative proton beam scenarios, e.g. 120 GeV
- 1 MW targets
- 5-10GeV muon beam

How cheap and fast can a 1/25th-luminosity NF be?


Who says you can't
be big and nimble?
To see how our research and experience can help you
become a high-performance business, visit accenture.com
• Consulting • Technology • Outsourcing
IDS-NF
High performance. Delivered.