International Context

Patrick Huber

Center for Neutrino Physics at Virginia Tech

Intensity Frontier Workshop: neutrino working group pre-meeting

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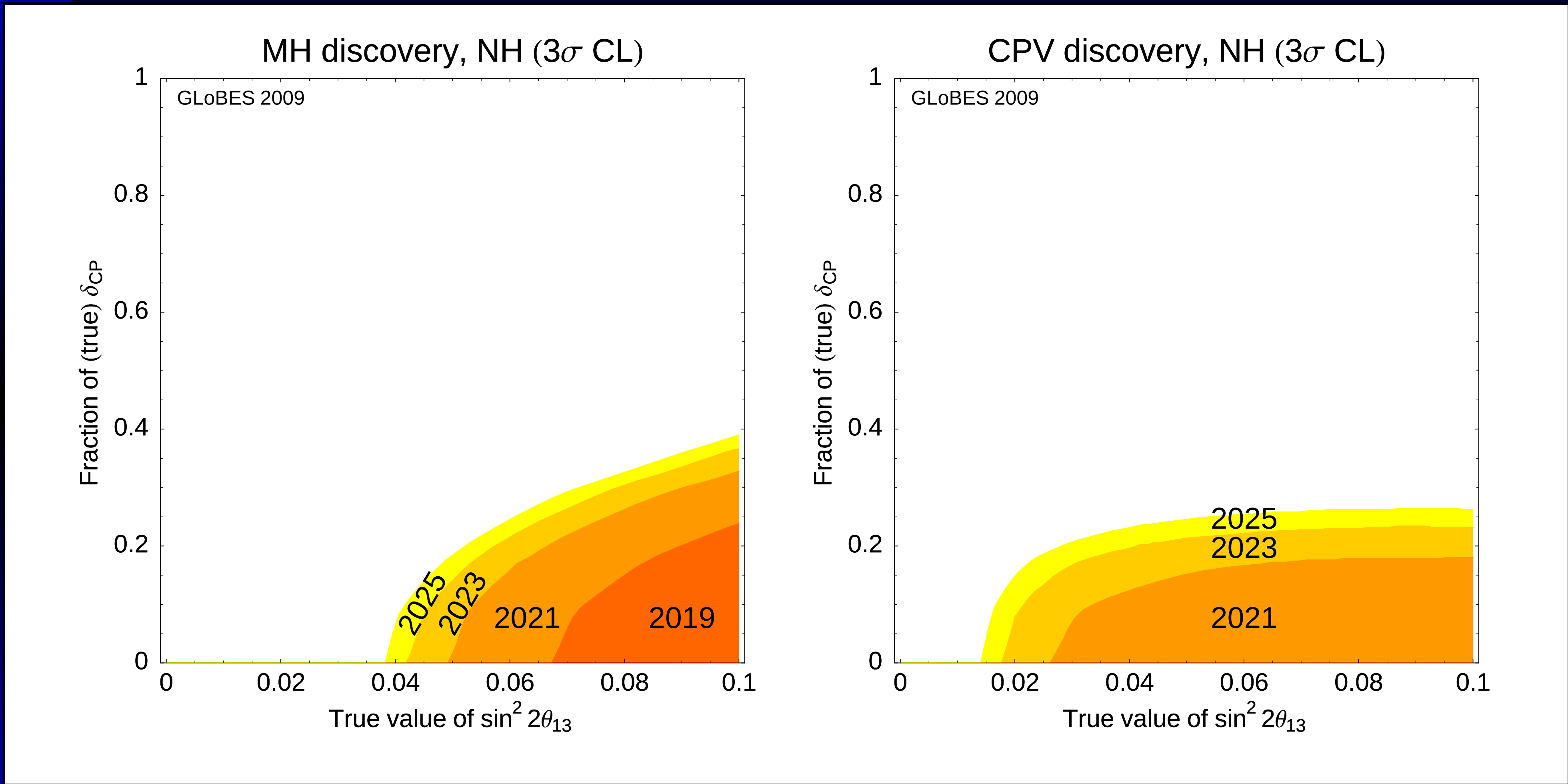
The Issue

If $\sin^2 2\theta_{13} > 0.02$, as hinted by recent data *e.g.* Fogli *et al.*, what are the implications for future facilities?

- Are new experiments beyond NOνA and T2K necessary?
- Will the mass hierarchy have been determined by someone else?
- Will the CPV have been discovered by someone else?
- Are superbeams sufficient?

NB – large θ_{13} also implies that new physics will sit on top of a large SM background, thus systematics will be a key issue for BSM searches

MH & CPV w/o new exps.?

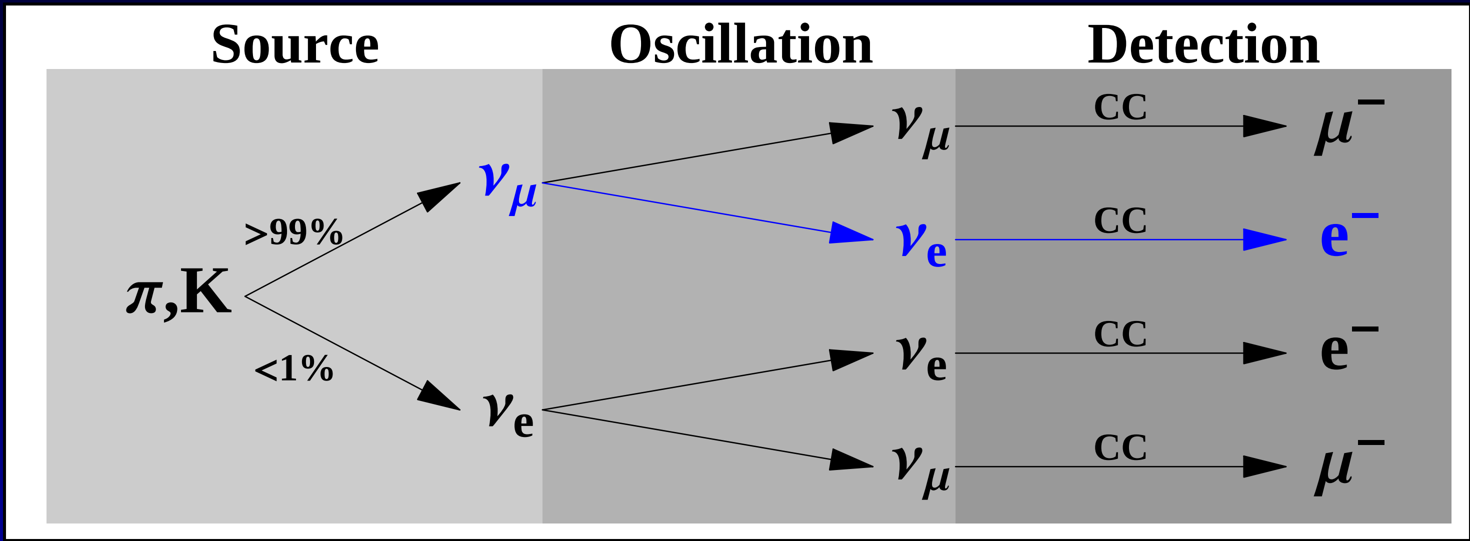


PH, M. Lindner, T. Schwetz, W. Winter, JHEP 11 044 (2009), arXiv:0907.1896.

Includes Project X and T2K running at 1.7 MW.

Superbeams

Neutrino beam from π-decay



They are called 'super'

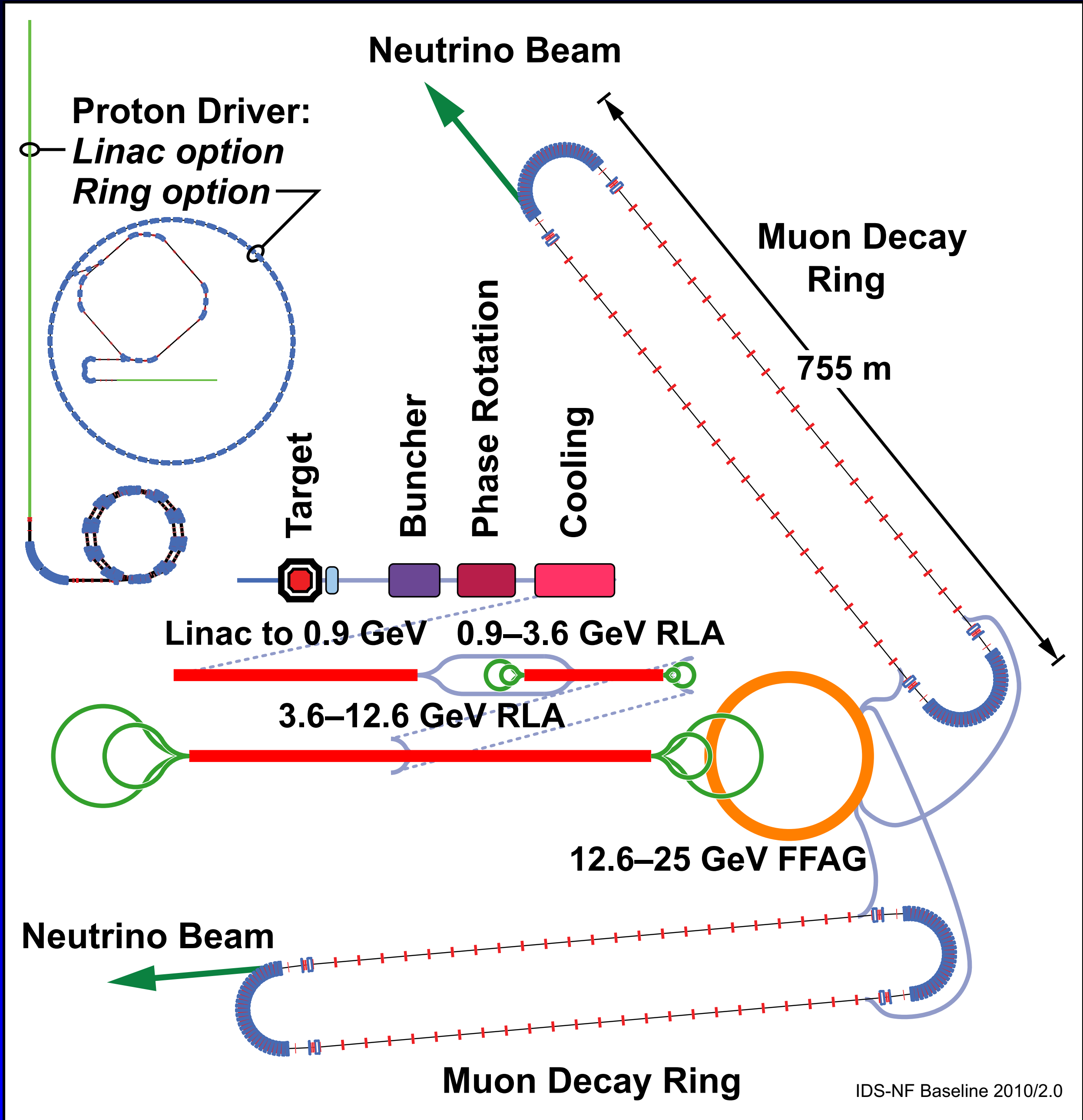
- beam power $> 1\,\mathrm{MW}$
- detectors mass $> 100\,\mathrm{kt}$
- running time of the experiment $\sim$ 10 years
- price

Challenges

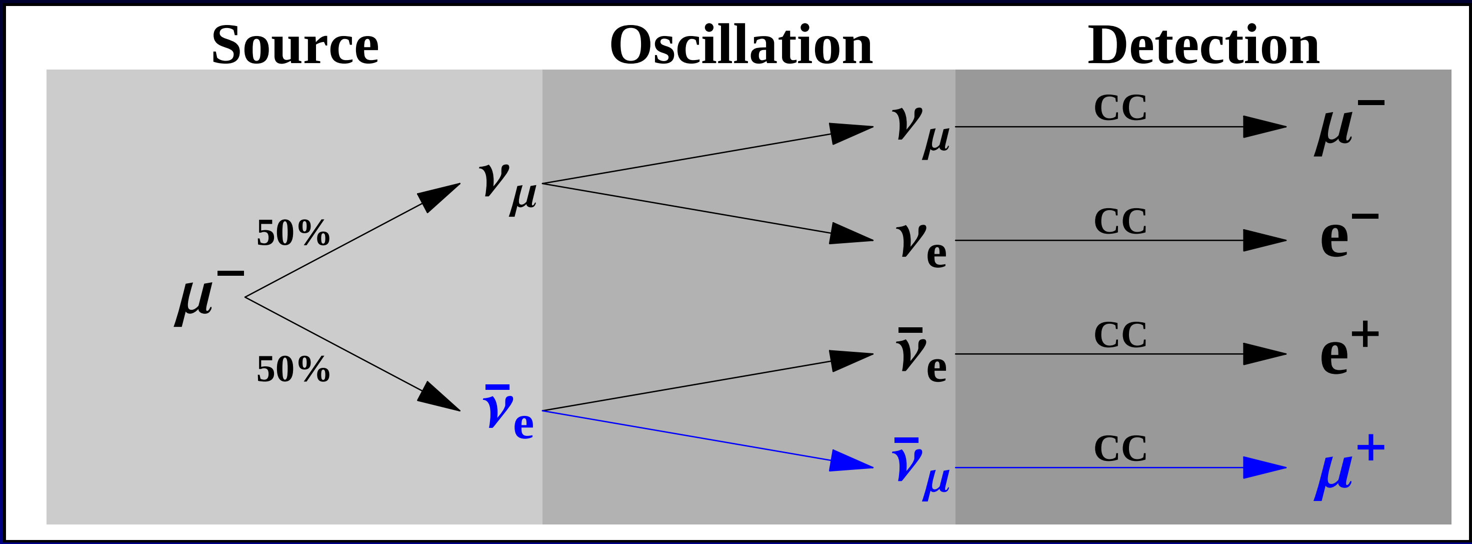
- beam power $\sim 1\,\mathrm{MW}$
- detectors mass $\sim 100\,\mathrm{kt}$
- running time of the experiment ~ 10 years
- price

And at large θ_{13} – systematics & precision

Neutrino Factory



Signal



This requires a detector which can distinguish μ^+ from μ^- $\Rightarrow$ magnetic field of around 1T

- above 3 GeV – iron calorimeter like MINOS
- below 3 GeV – magnetized, totally active, fine grained scintillator

Challenges

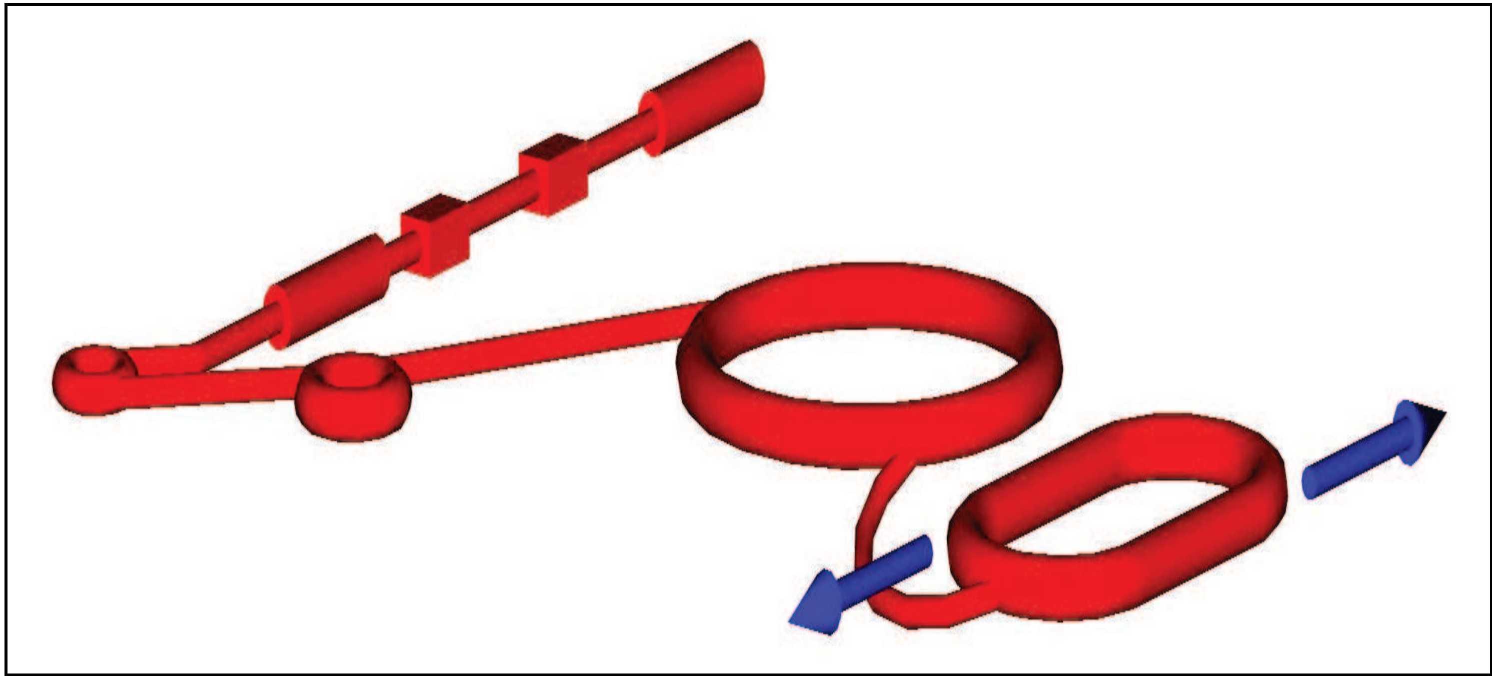
- muon production (MERIT)
- muon cooling (MICE, MuCool)
- muon acceleration (EMMA)

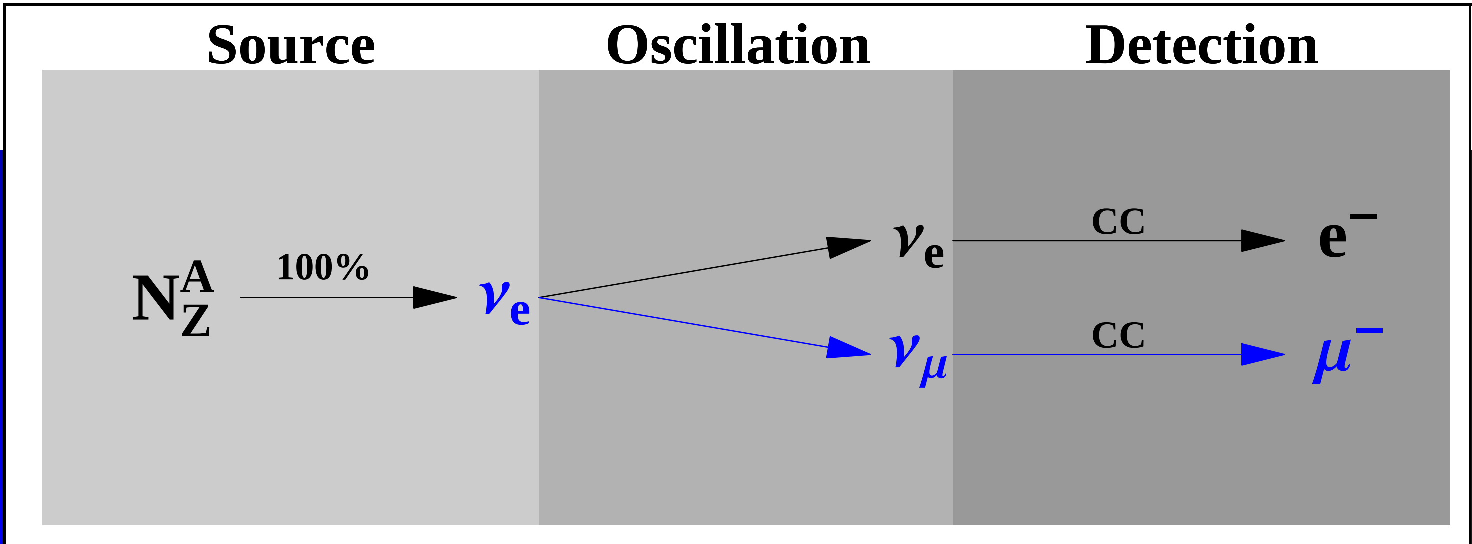
All these steps are necessary for a muon collider, too. Active R&D effort, which will yield a reference design report by 2013.

International Design Study for a Neutrino Factory (IDS-NF): www.ids-nf.org

see also Alan's talk

β-beams

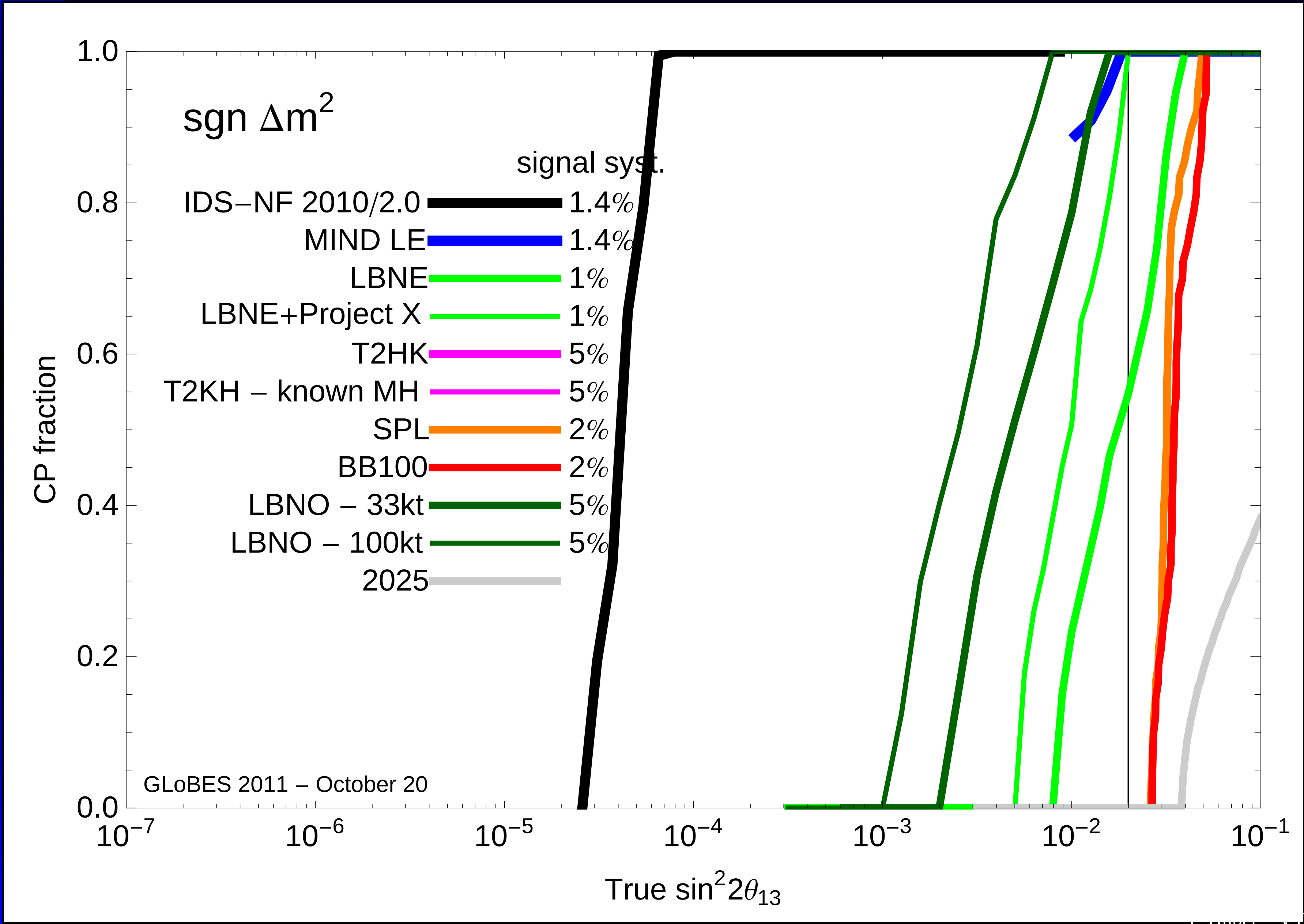




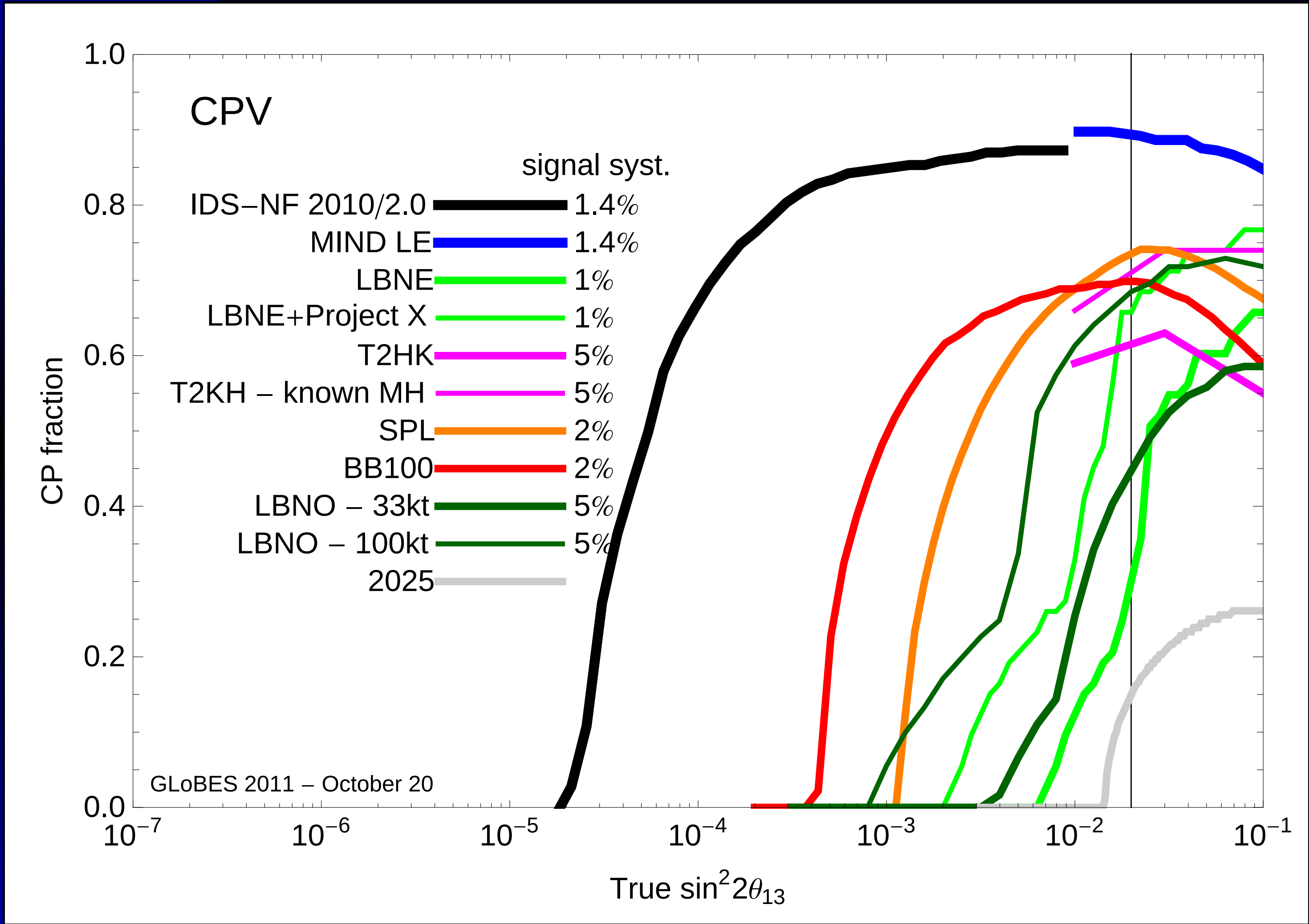
Challenges

- isotope production
- acceleration – sufficiently high neutrino energies
- radioactive beams – activation of equipment
- storage ring – high ion densities, size
- no ν_μ disappearance, thus no θ_{23} measurement

Are superbeams enough?



Are superbeams enough?



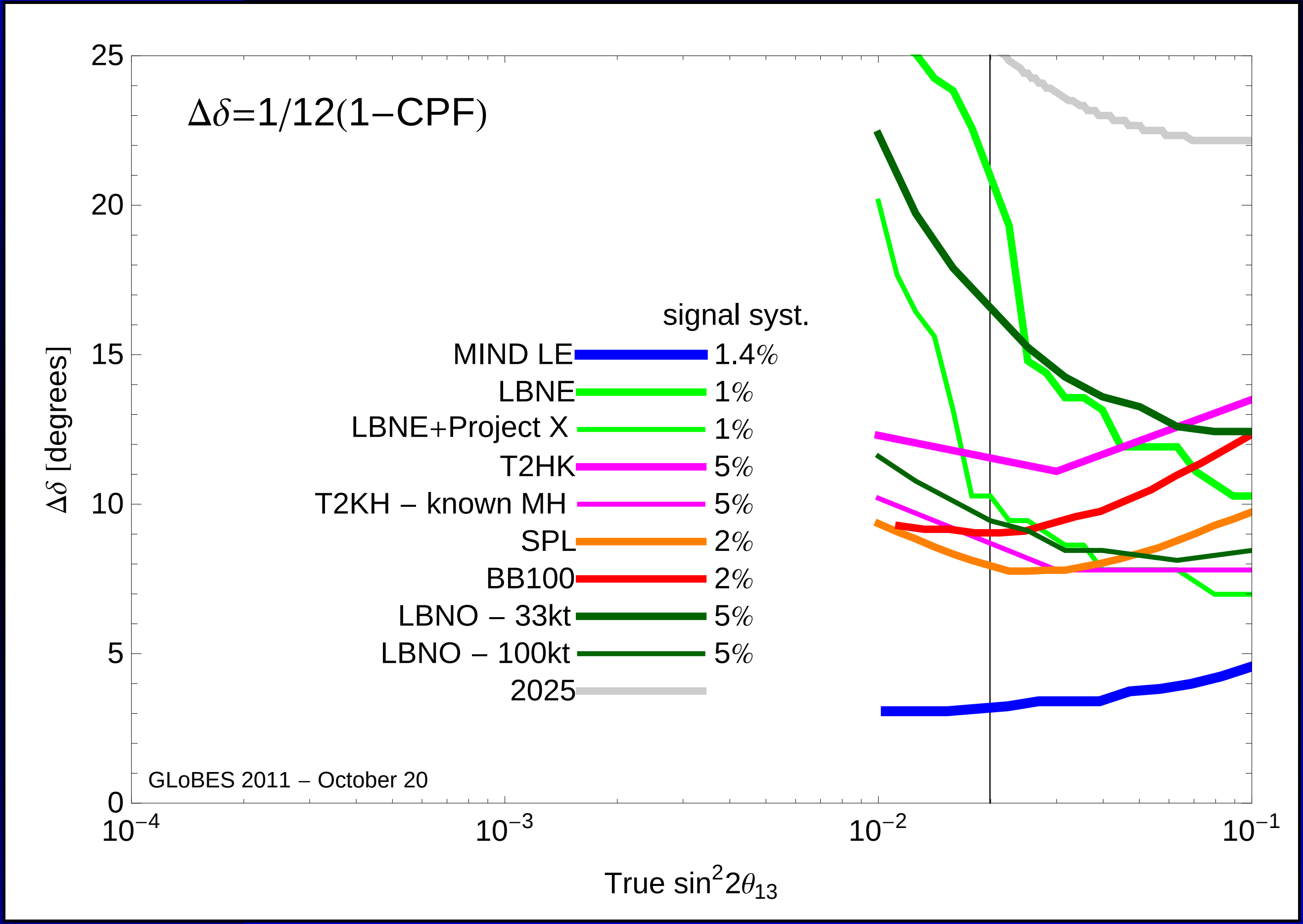
SB reach CPF of 0.15-0.77

BB reach CPF of 0.6-0.75

NF reaches CPF of 0.85-0.9

NF best for **all** values of θ_{13}!

Are superbeams enough?



$$\Delta\delta \simeq \frac{1}{12}(1 - \mathrm{CPF})$$

$$\mathrm{SB}\ \Delta\delta = 7^\circ - 25^\circ$$

$$\mathrm{NF}\ \Delta\delta = 3^\circ - 5^\circ$$

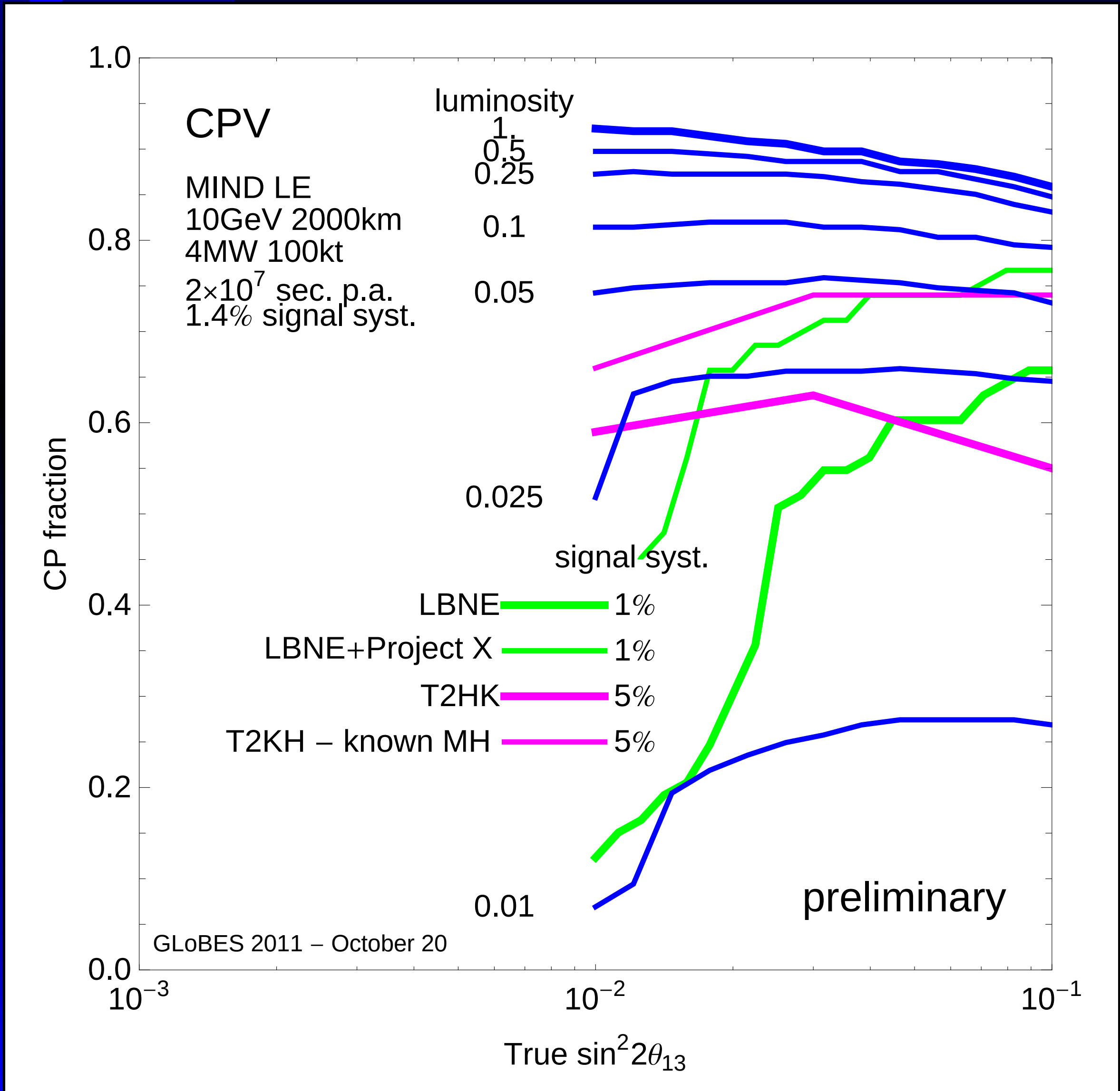
BUT, wildly different assumptions about systematics – still NF outperforms all other options

This requires a MUCH more detailed analysis!

For more on systematics, see Jorge's talk

L^3NF

Low Luminosity Low energy Neutrino Factory



1/20-1/10 of luminosity
- L^3NF as good as the best SB

⇒ Start somewhere between 1/20 and 1/10
⇒ Use existing proton infrastructure
⇒ Upgrade to full luminosity

Summary

- New facilities are indispensable to fully exploit the discovery of neutrino oscillation
- CP violation is never easy to measure – even for the largest values of θ_{13}
- Mass hierarchy needs long baseline and multi-GeV beams
- In the large θ_{13} case – systematics will be key!

All approaches requite multi-MW proton beams!

Given sufficient resources, it seems likely that neutrino mixing can be quantitatively understood at a level similar to the quark sector, which ultimately will allow us to shed light onto the flavor puzzle.

References

- LBNE curves are provided by Sam Zeller as defined by the LBNE physics working group as of fall 2010 and have been computed by Lisa Whitehead
- LBNO curves are taken from Agarwalla, *et al.* arXiv:1109.6526 and have been provided by Tracey Li
- T2HK curves are taken from the T2HK LOI.
- SPL and beta beam curves (BB100) are taken from the Euroν report arXiv:1005.3146
- Neutrino Factory curves are taken from the IDS-NF IDR
- 2025 data from PH, *et al.* JHEP 11 044 (2009).
- current 3σ lower limit on $\sin^2 2\theta_{13}$, Fogli, *et al.* arXiv:1106.6028

Luminosity of the Setups

name	baseline	type	mass	power	sec. in year	years	sig. syst.
LBNE	1300	WC/LAr	200/33	0.7MW	2×10^7	5+5	1%
LBNE+ Pro. X	1300	WC/LAr	200/33	2.3MW	2×10^7	5+5	1%
LBNO 33kt	2300	LAr	33	1.7MW	1.7×10^7	5+5	5%
LBNO 100kt	2300	LAr	100	1.7MW	1.7×10^7	5+5	5%
T2HK	295	WC	560	1.66MW	1×10^7	2.1+2.9	5%
SPL	130	WC	440	4MW	1×10^7	2+8	2%
IDS-NF 2.0	4000+7500	MIND	100+50	4MW	1×10^7	5+5	1.4%
MIND LE	2000	MIND	100	4MW	1×10^7	5+5	1.4%