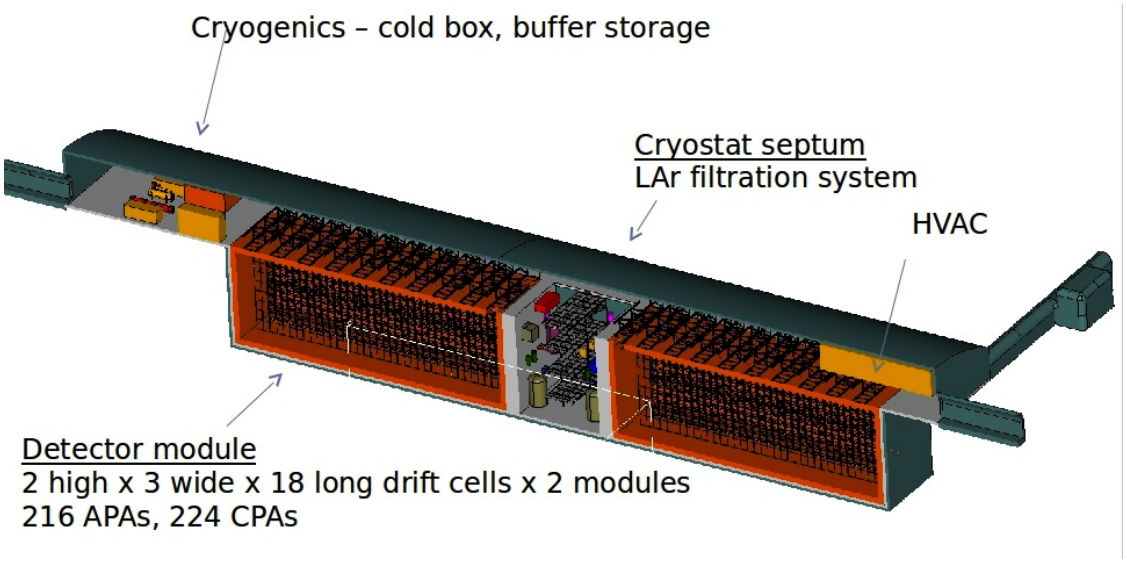
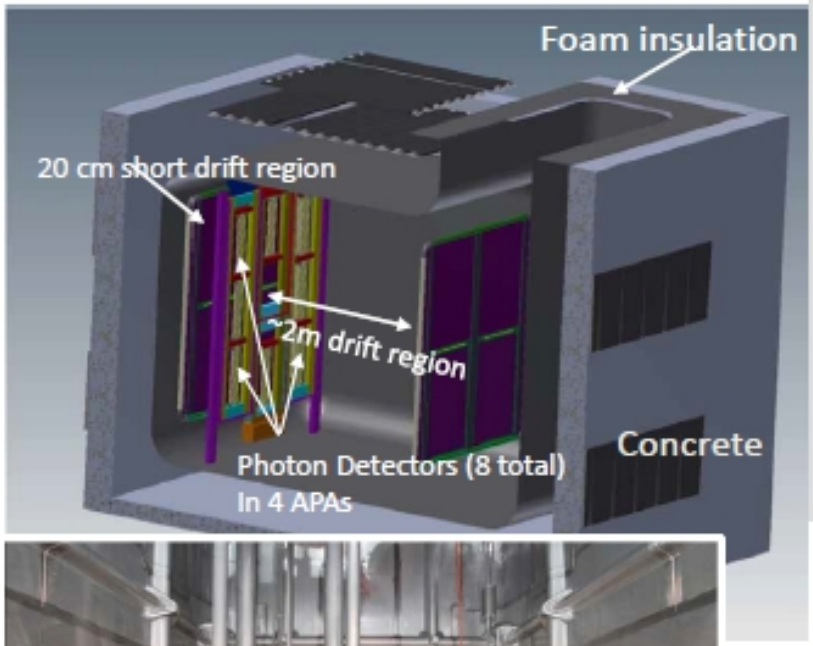
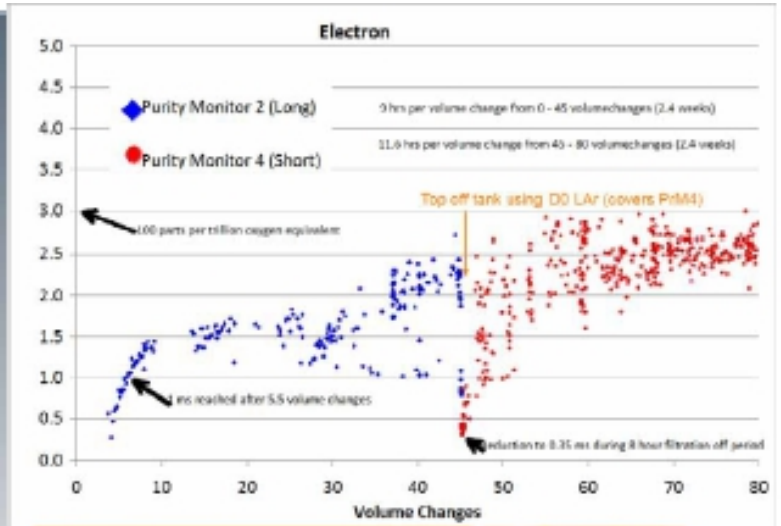
The Far Detector: 34kton single-phase LArTPC

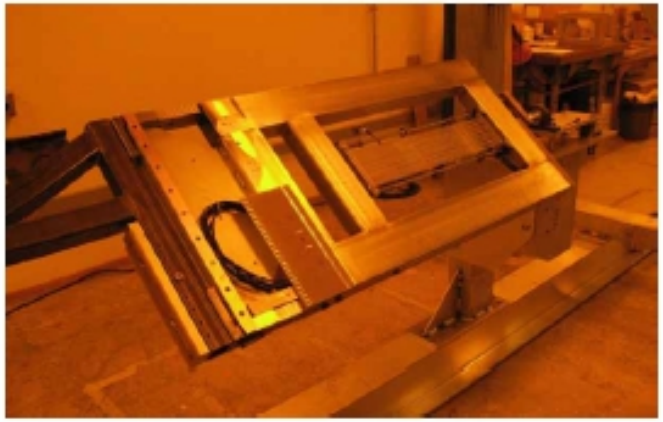


Parameter	Value
Total/Active/Fiducial Mass	50/40/34 kt
Number of Detector Modules (Cryostats)	2
Drift Cell Configuration within Module	3 wide $\times$ 2 high $\times$ 18 long drift cells
Drift Cell Dimensions	2 $\times$ 3.7 m wide (drift) $\times$ 7 m high $\times$ 2.5 m long
Detector Module Dimensions	22.4 m wide $\times$ 14 m high $\times$ 45.6 m long
Anode Wire Spacing	~5 mm
Wire Planes (Orientation from vertical)	Grid (0°), Induction 1 (45°), Induction 2 (-45°) Collection (0°)
Drift Electric Field	500 V/cm
Maximum Drift Time	2.3 ms

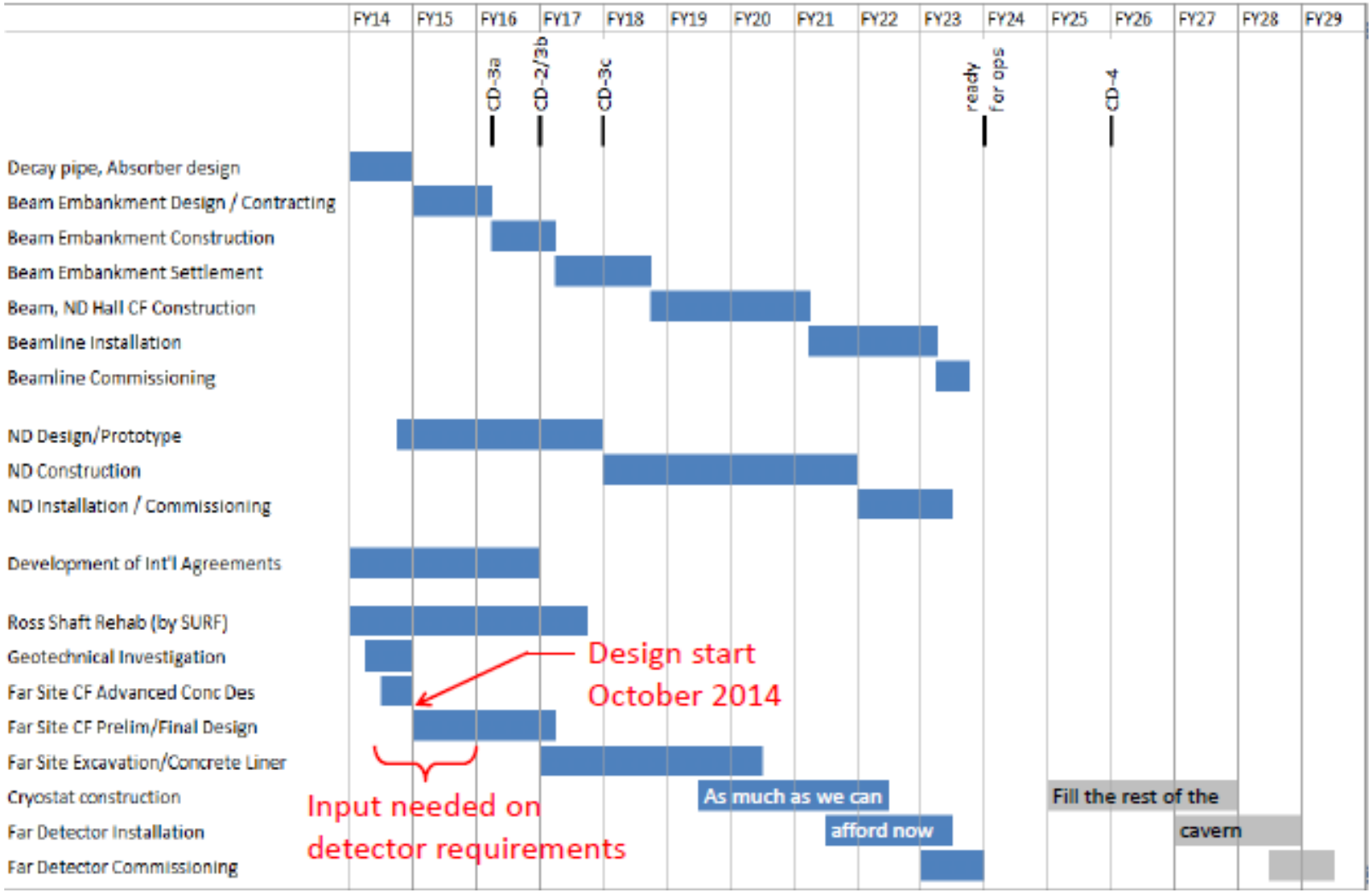
35-ton Prototype Detector





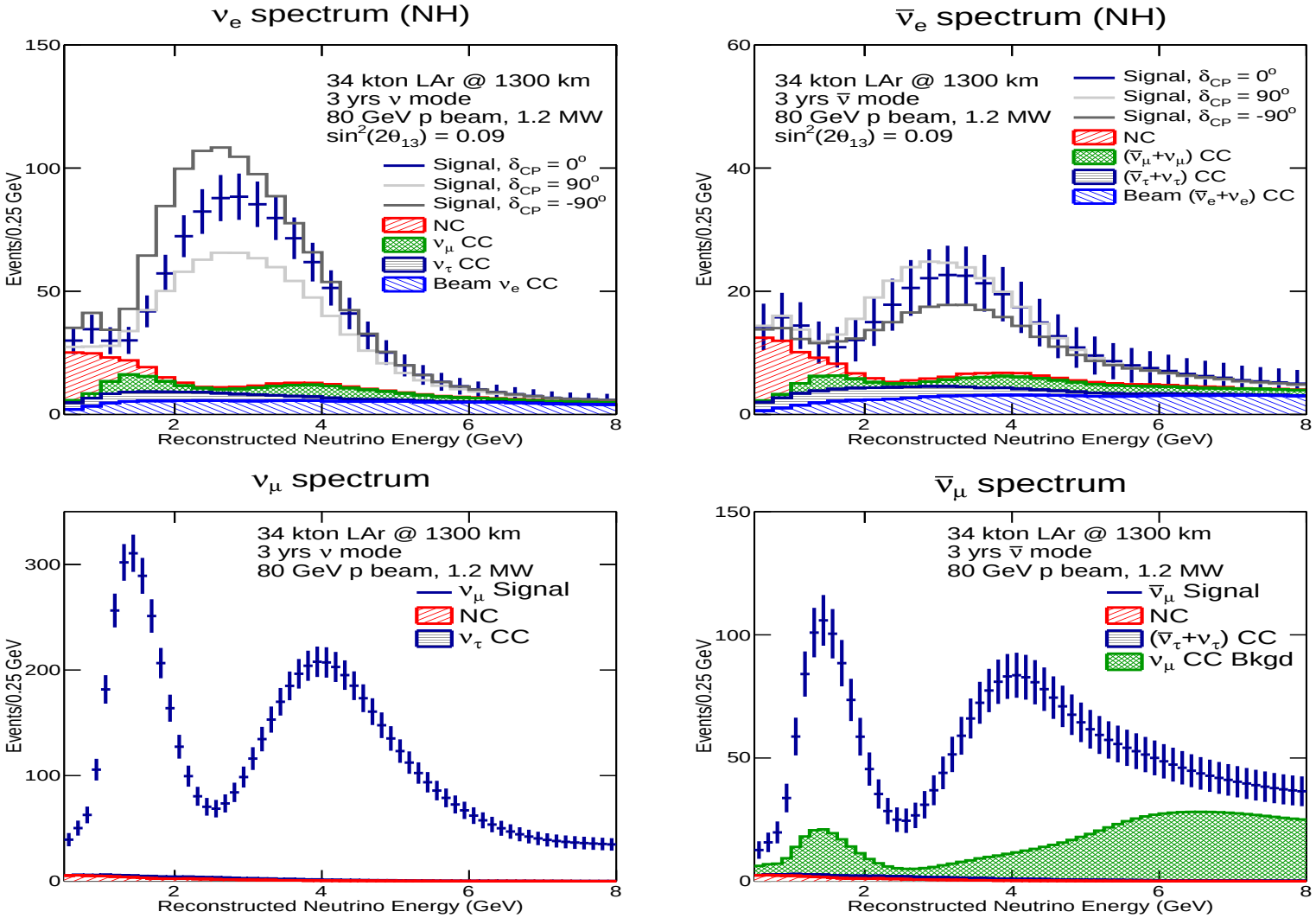


Technically Driven Schedule for International LBNE



Oscillation signals

Exposure: 34 kton, 3 ν + 3 $\bar{\nu}$ MW.yrs. 1MW.yr = 1×10^{21} p.o.t at 120 GeV. ($\sin^2 2\theta_{13} = 0.09$, $\sin^2 \theta_{23} = 0.38$, $\delta m^2_{31} = 2.47 \times 10^{-3}$ eV^2)



Simultaneous fit to all four samples to determine osc. params

Oscillation signals

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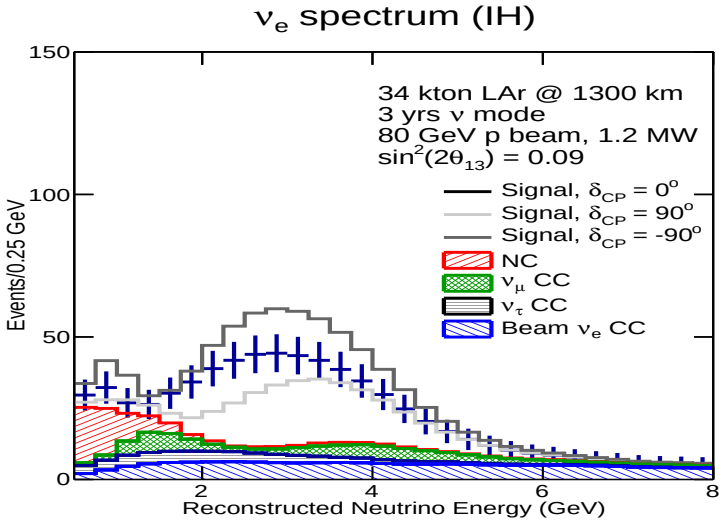

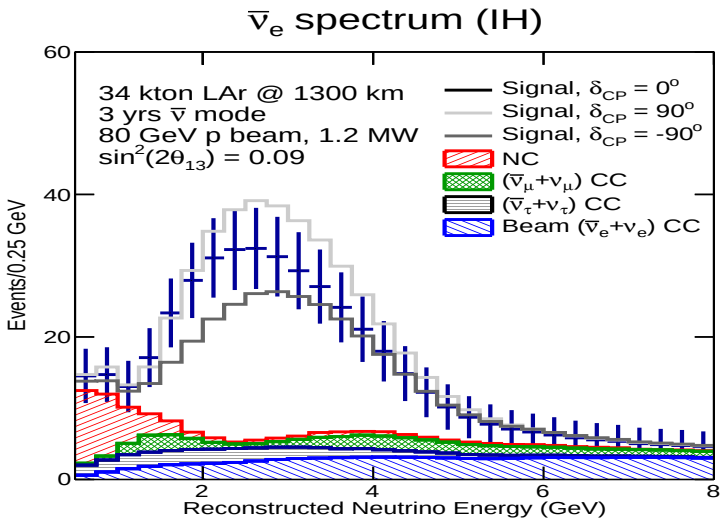

Event rates per 10 kton 3 MW.yr

Beam	Hierarchy	Signal Events	Background Events				
		$\nu_x/\bar{\nu}_x$ CC	ν_μ NC	ν_μ CC	ν_e Beam	ν_τ CC	Total
$\nu_\mu \to \nu_{x=\mu}$ (disappearance)							
Neutrino	-	2056/96	23	N/A	-	18	41
Antineutrino	-	280/655	10	N/A	-	10	20
$\nu_\mu \to \nu_{x=e}$ (appearance)							
Neutrino	Normal	229/3	21	25	47	14	107
Neutrino	Inverted	101/5	21	25	49	17	112
Antineutrino	Normal	15/41	11	11	24	9	55
Antineutrino	Inverted	7/75	11	11	24	9	55

Current LBNE Systematics Estimates

Source of Uncertainty	MINOS Absolute/ν_e	T2K ν_e	LBNE ν_e	Comments
Beam Flux after N/F extrapolation	3%/0.3%	2.9%	2%	MINOS is normalization only. LBNE normalization and shape highly correlated between ν_μ/ν_e.
		Detector effects		
Energy scale (ν_μ)	7%/3.5%	included above	(2%)	Included in LBNE ν_μ sample uncertainty only in three-flavor fit. MINOS dominated by hadronic scale.
Absolute energy scale (ν_e)	5.7%/2.7%	3.4% includes all FD effects	2%	Totally active LArTPC with calibration and test beam data lowers uncertainty.
Fiducial volume	2.4%/2.4%	1%	1%	Larger detectors = smaller uncertainty.
		Neutrino interaction modeling		
Simulation includes: hadronization cross sections nuclear models	2.7%/2.7%	7.5%	$\sim$ 2%	Hadronization models are better constrained in the LBNE LArTPC. N/F cancellation larger in MINOS/LBNE. X-section uncertainties larger at T2K energies. Spectral analysis in LBNE provides extra constraint.
Total	**5.7%**	**8.8%**	**3.6 %**	**Uncorrelated ν_e uncertainty in full LBNE three-flavor fit = 1-2%.**

In combined fit, many correlated systematics cancel. Assume independent *uncorrelated* normalization systematics of 5%/10% on ν_μ sig/bkgd and 1-2%/5% on ν_e sig/bkgd.

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Source of Uncertainty	MINOS Absolute/ν_e	T2K ν_e	LBNE ν_e	Comments
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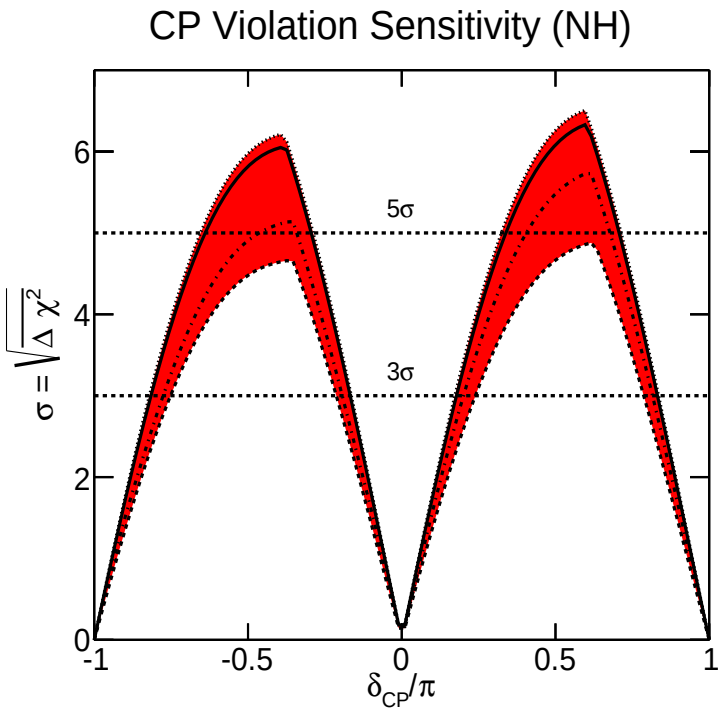
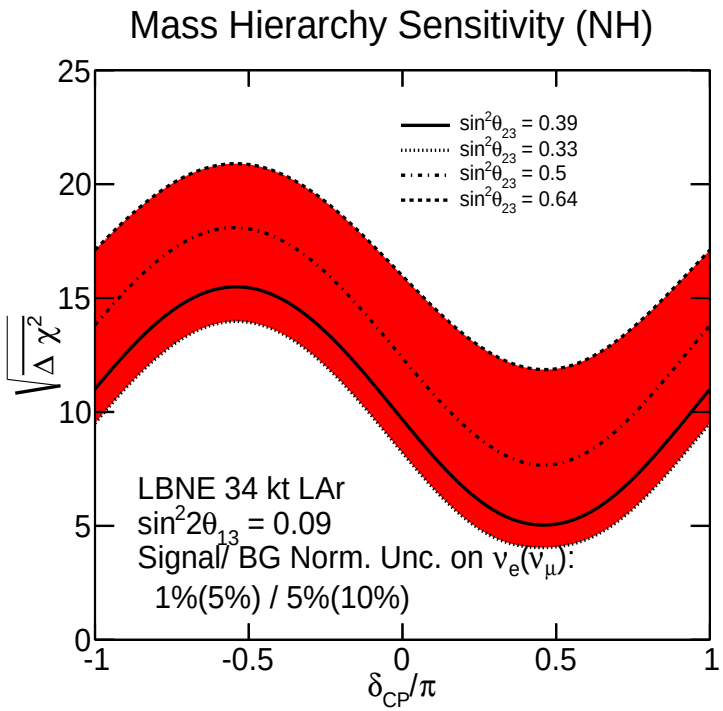
Total	**5.7%**	**8.8%**	**3.6 %**	**Uncorrelated ν_e uncertainty in full LBNE three-flavor fit = 1-2%.**

A FastMC has been developed to enable the estimation of detailed neutrino interaction and beam flux shape and normalization systematics. Studies are ongoing.

MH and CPV Sensitivities

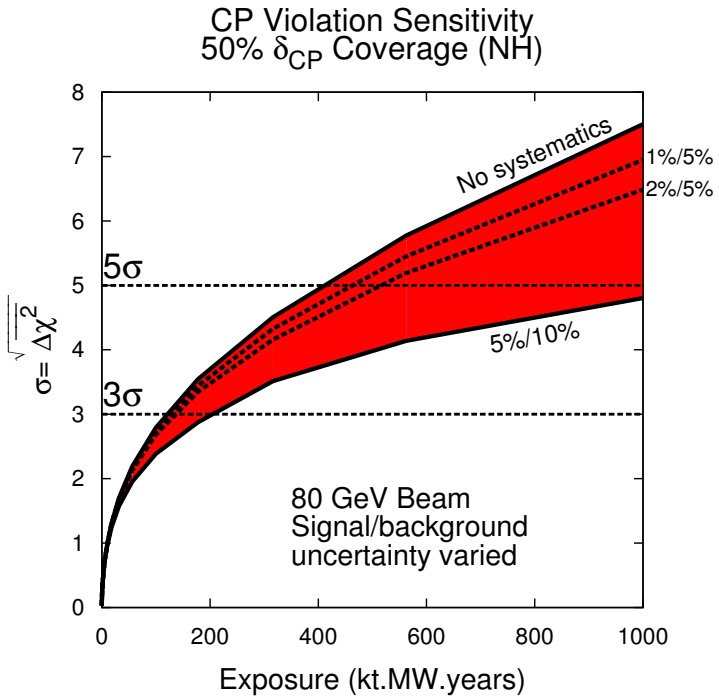


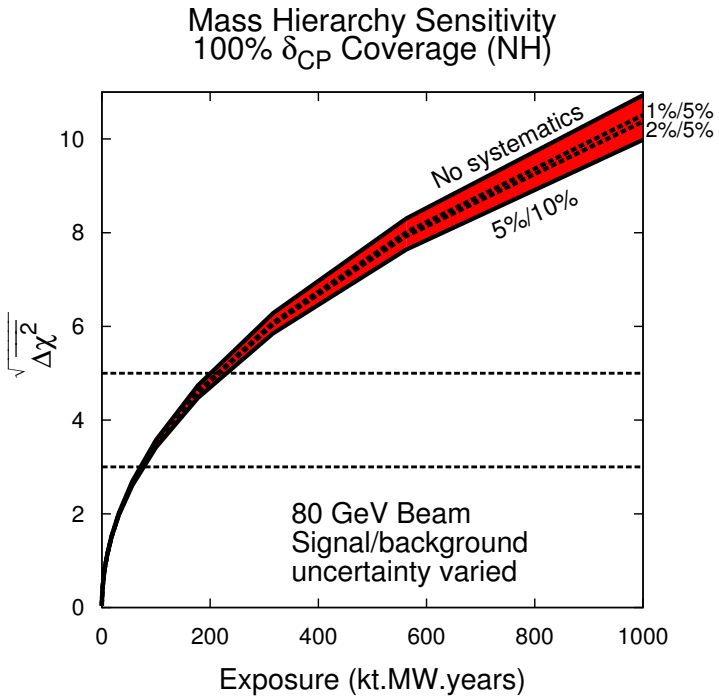


In LBNE with a 34-kton LArTPC operating for six years in a 1.2-MW beam ($\sin^2\theta_{23} = 0.39, \sin^2 2\theta_{13} = 0.09$):

- **The CPV sensitivity is $\geq 3,5\sigma$ for 60%,35% of $\delta_{\rm CP}$.**
- **At the *worst sensitivity point* the MH $|\Delta\chi^2|$ value obtained in a typical data set will exceed 25, allowing LBNE on its own to rule out the incorrect mass ordering at a confidence level above $1 - 3.7 \times 10^{-6}$.**

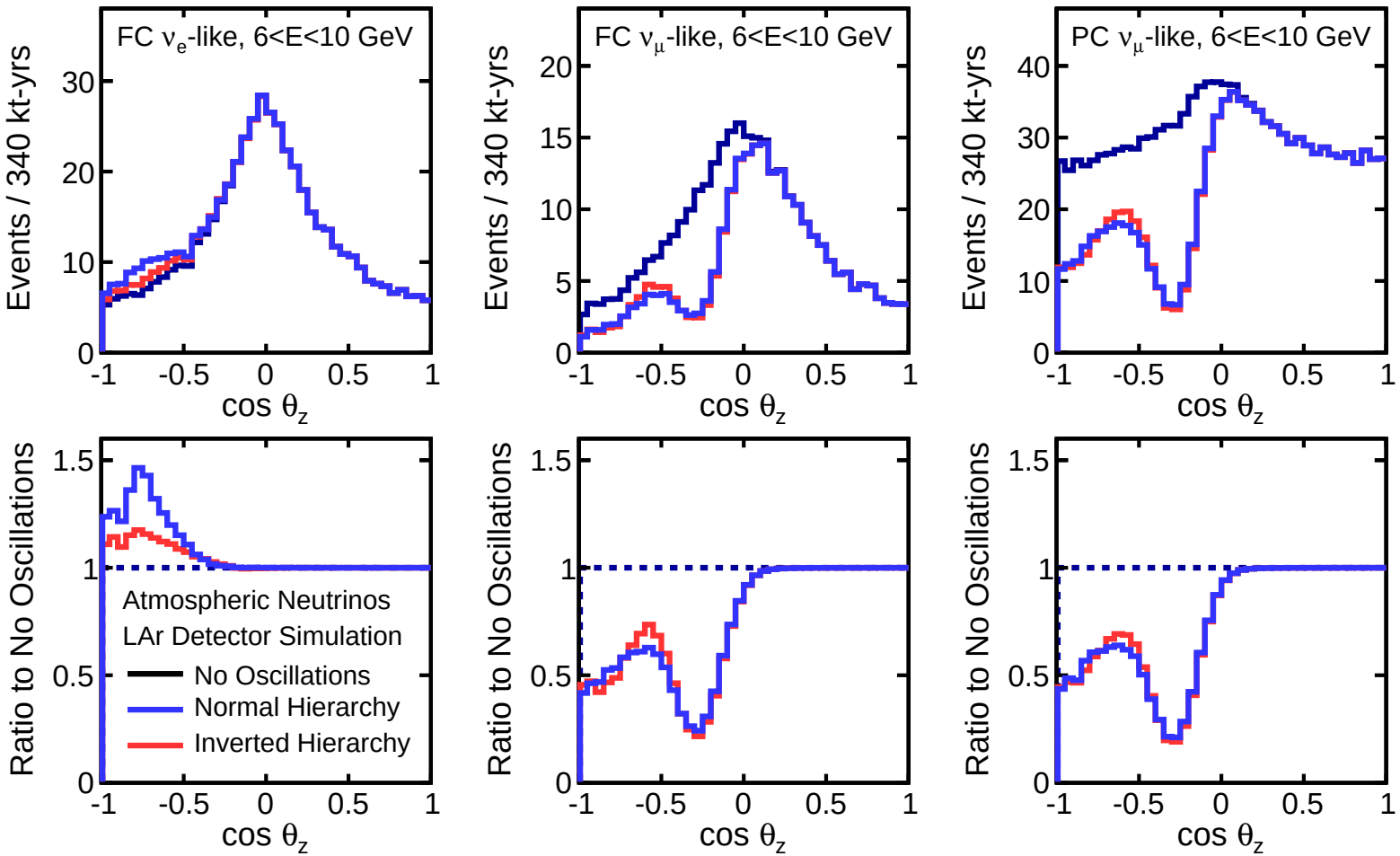
Sensitivities with varying ν_e uncorrelated systematics



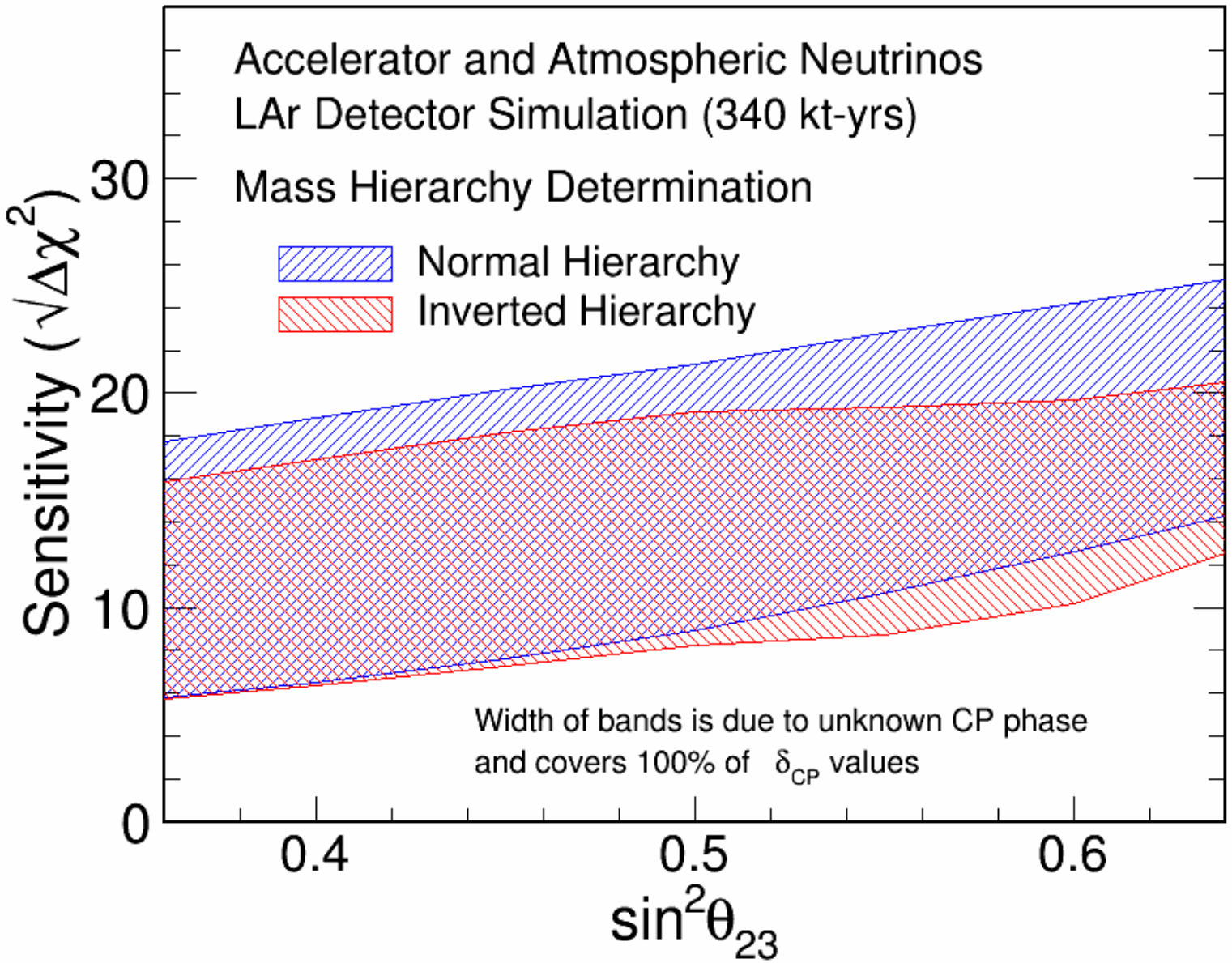


Systematic uncertainty	CPV Sensitivity δ_{CP} Fraction	$(\sqrt{\Delta\chi^2})$	Required Exposure
0 (statistical only)	50% δ_{CP}	3 σ	100 kt · MW · year
	50% δ_{CP}	5 σ	400 kt · MW · year
1%/5% (Sig/bkgd)	50% δ_{CP}	3 σ	100 kt · MW · year
	50% δ_{CP}	5 σ	450 kt · MW · year
2%/5% (Sig/bkgd)	50% δ_{CP}	3 σ	120 kt · MW · year
	50% δ_{CP}	5 σ	500 kt · MW · year
5%/10% (no near ν det.)	50% δ_{CP}	3 σ	200 kt · MW · year

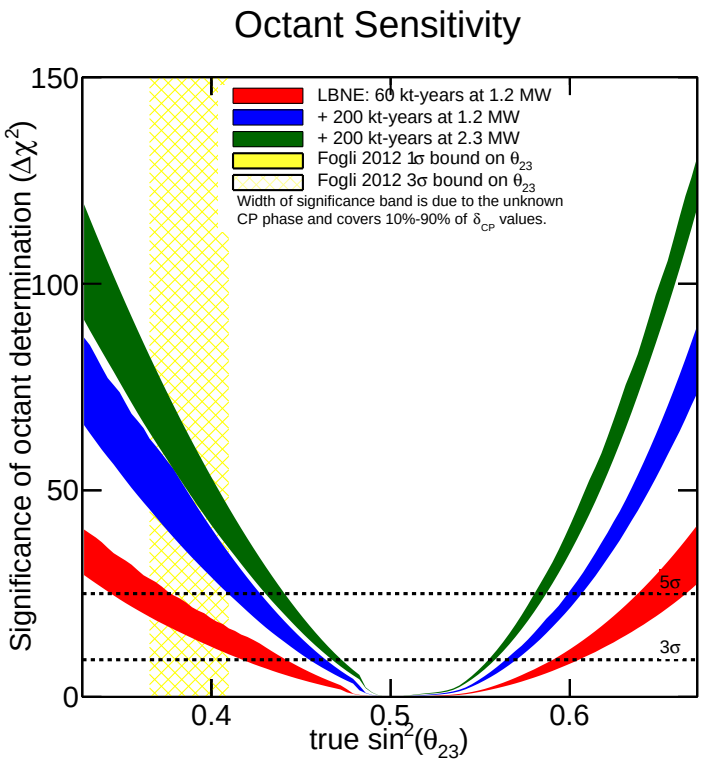
MH with Atmospheric Neutrinos

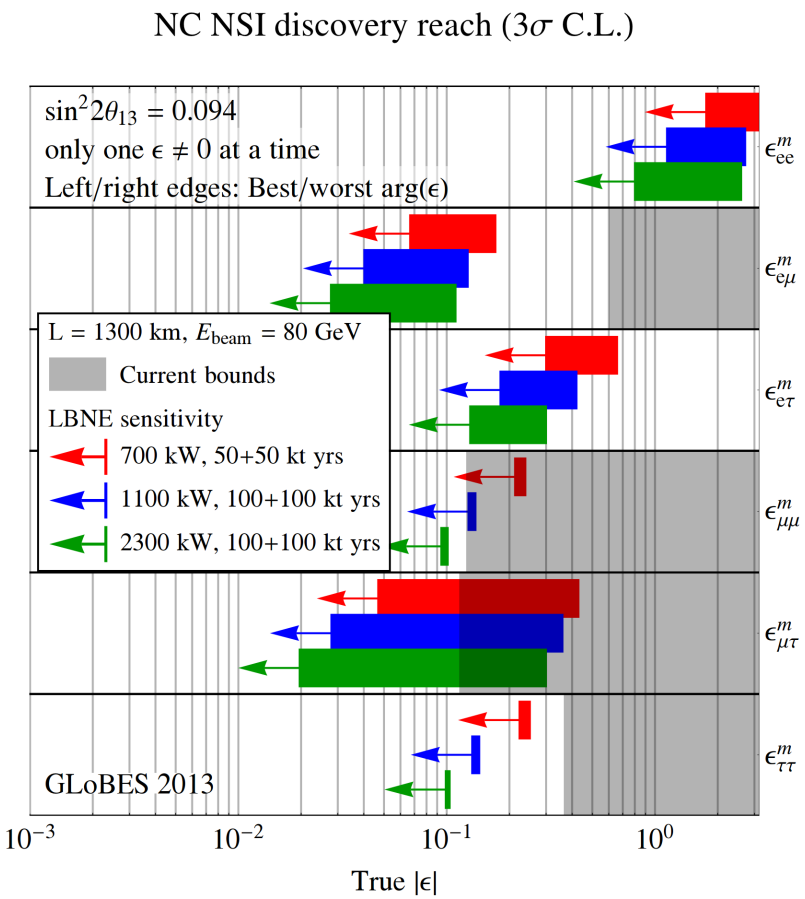


MH with Atmospheric Neutrinos



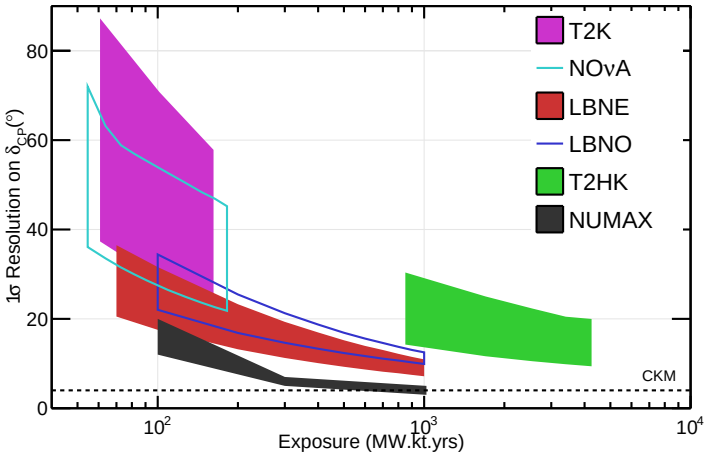
Octant and NSI



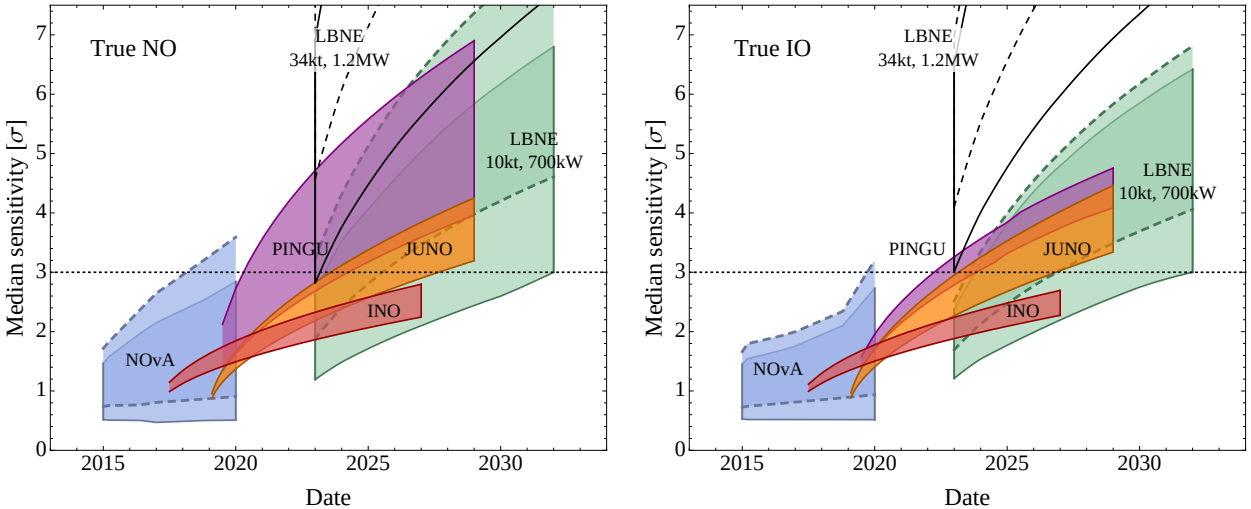


Comparison with other Experiments

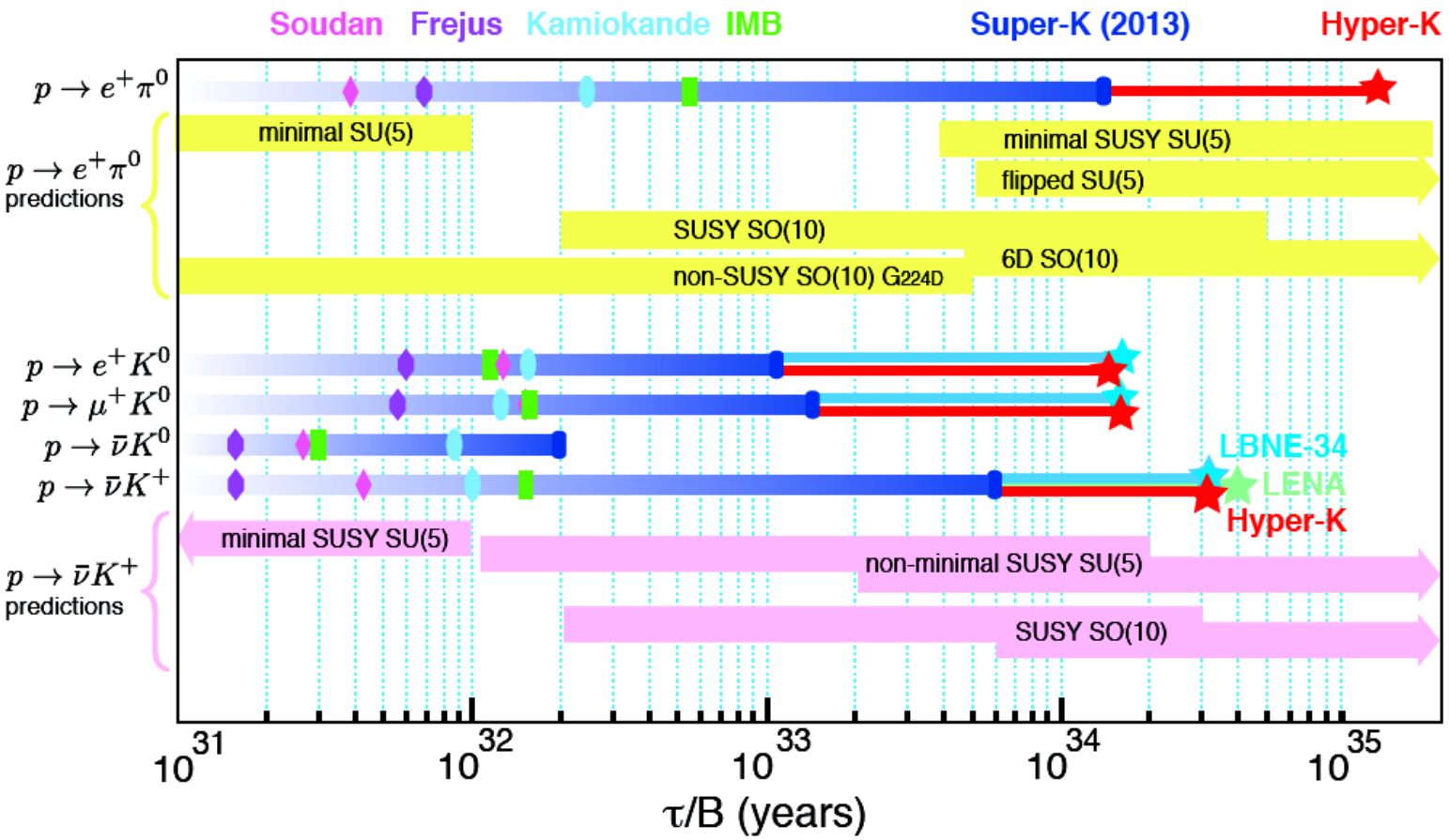
LBNE estimate from public information:



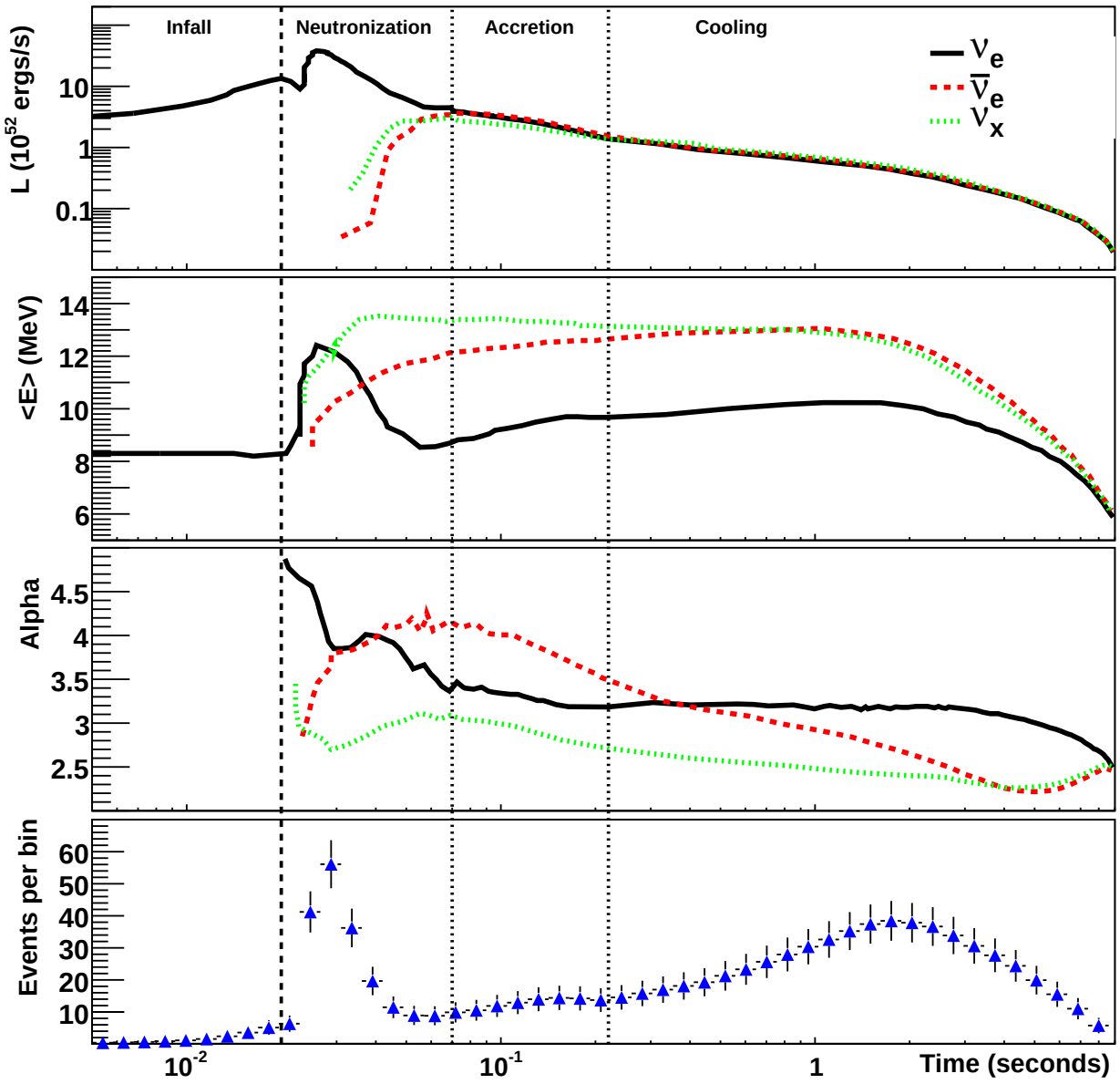
Independent study: M. Blennow *et. al.* arxiv:1300.1822



Proton Decay Sensitivities



Core-Collapse Supernova Signal



LBNE Status Summary

- **The LBNE concept has developed over a decade, with extensive studies of site, technology, physics capabilities.**
- **P5 has endorsed the LBNE vision both in 2008 and 2014!**
- **A large, diverse international collaboration has developed and is continuing to expand.**
- **Designs are being developed incorporating ideas of all partners.** *Input from additional partners is welcome.*
- **The transmogrification of LBNE to LBNF is being conjured up. Process will become clearer in the coming months.**