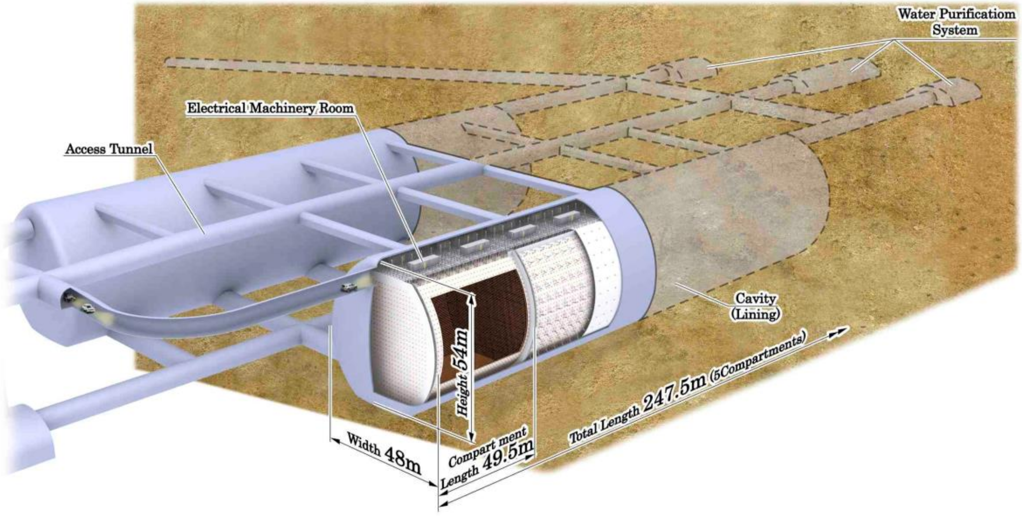
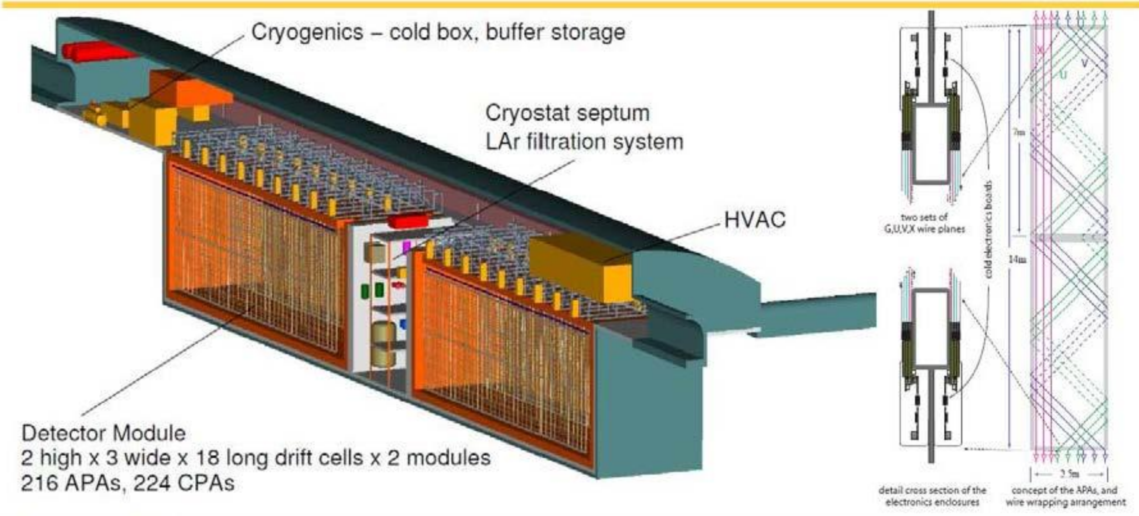
On the complementarity of HK and Dune



Based on arXiv:1501.03918 by ICFA Neutrino Panel



M.Mezzetto, INFN Padova

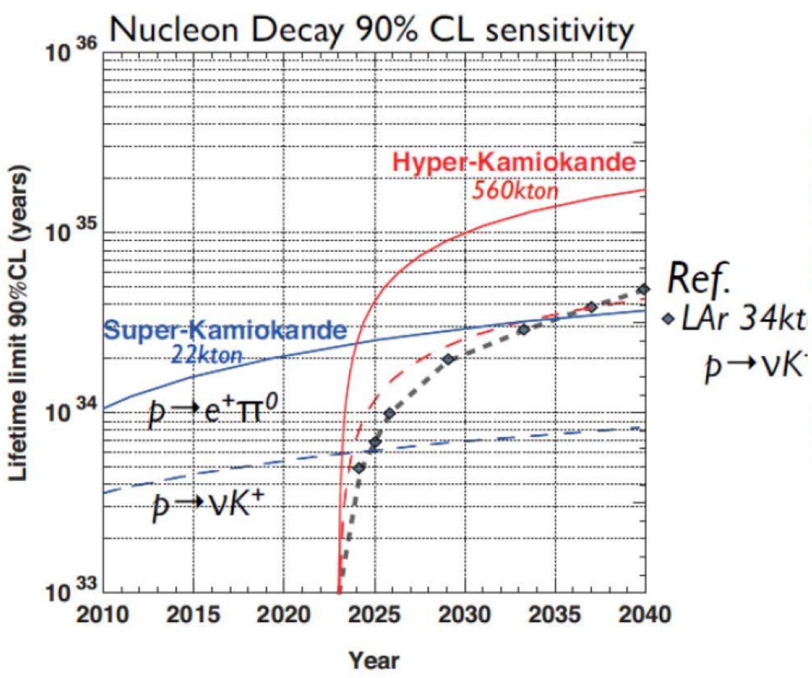
- HK: 560 kton fiducial, 0.75 MW beam power
- Dune (former LBNE, former ELBNF): 40 kton fiducial, 1.2 MW beam power
- Both setups still haven’t been compromised with budget constraints
- I’ll try to compare both astroparticle and beam performances
- Please note that complementarity is not synergy and is not necessity
- The paper of ICFA Neutrino Panel (where both HK and Dune are represented) have been committed by P5 at the Paris neutrino meeting of June 2014.

Proton Decay

HK

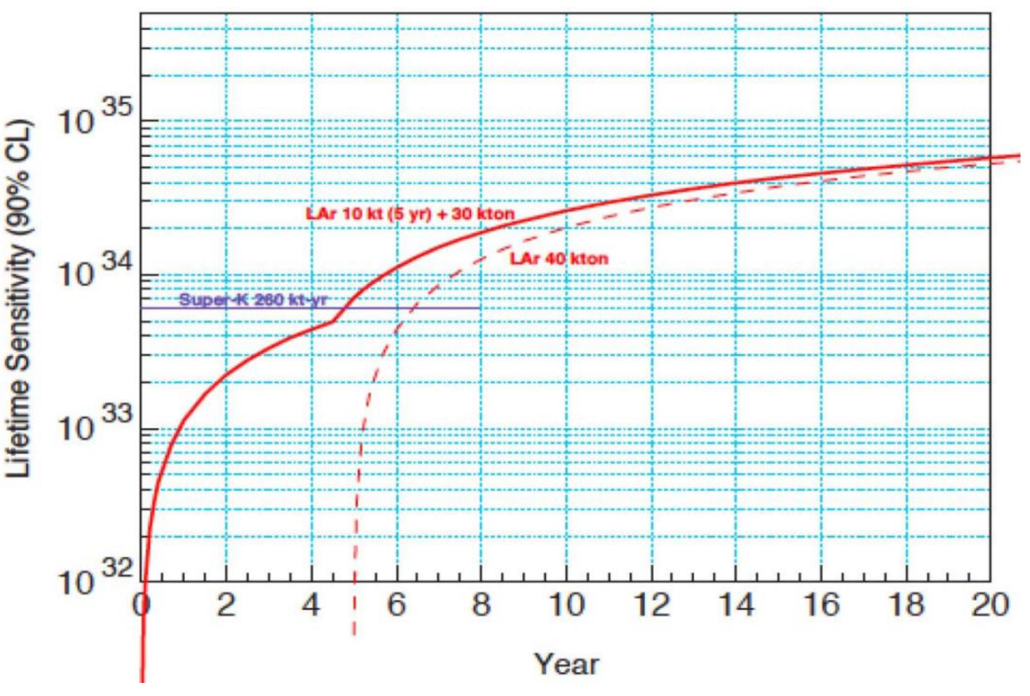
$- p \to e^+ + \pi^0$ — 1.3×10^{35} yrs (90% CL UL); 5.7×10^{34} yrs (3σ discovery)

$- p \to \bar{\nu} + K^+$ — 3.2×10^{34} yrs (90% CL UL); 1.2×10^{34} yrs (3σ discovery)



DUNE

- Will improve Super-Kamiokande limits in very few channels, notably in the p→K⁺ν channel



Supernova Neutrinos

HK

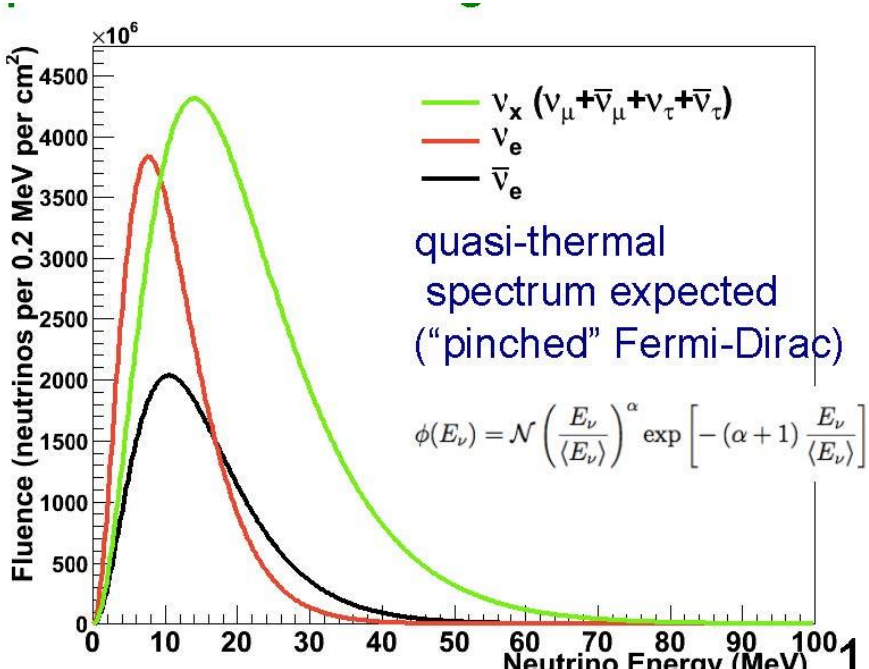
Mainly $\bar{\nu}_e$ from $\bar{\nu}_e\, p \rightarrow e^+\, p$

- Burst from galactic center (10 kpc)
  170,000 – 260,000 ν's
- Burst from Andromeda Galaxy
  30 – 50 ν's
- Supernova relic ν
  890 in 10 years

DUNE

Mainly ne from $\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$

- Burst from galactic center (10 kpc)
  ~ 900 ν's in 10 kton detector



Solar Neutrinos

HK

- ^{8}B ν from Sun
  200 ν's/day @ 7 MeV threshold

Allows detailed day/night studies

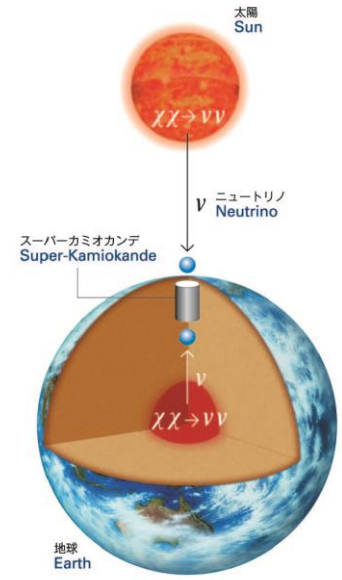
DUNE

In principle sensitive both to

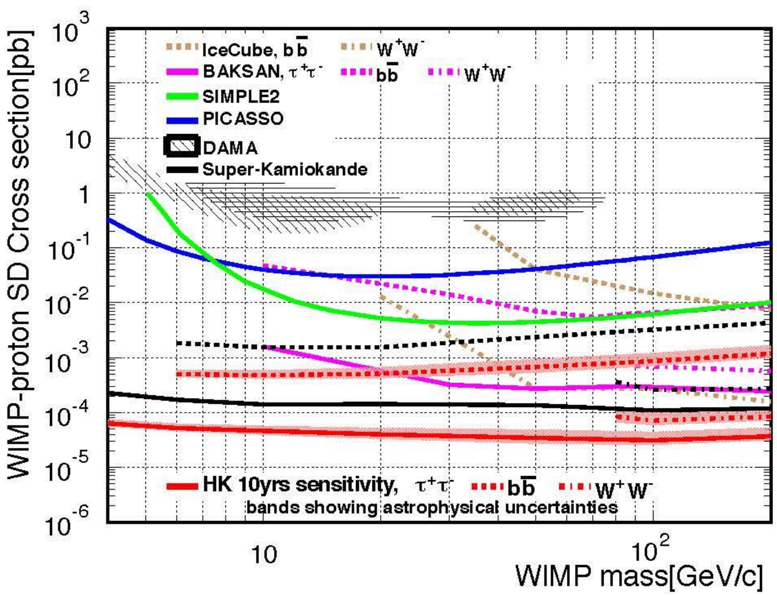
- CC events
  $$\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$$
- ES events
  $$\nu_e + e^- \rightarrow \nu_e + e^-$$

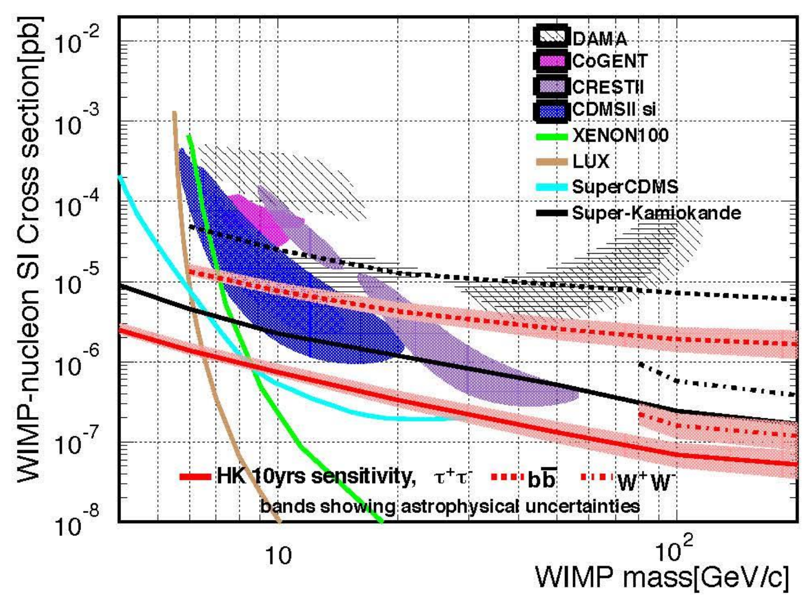
Not clear to which value the e^- detection threshold can be set

WIMP annihilation at Sun



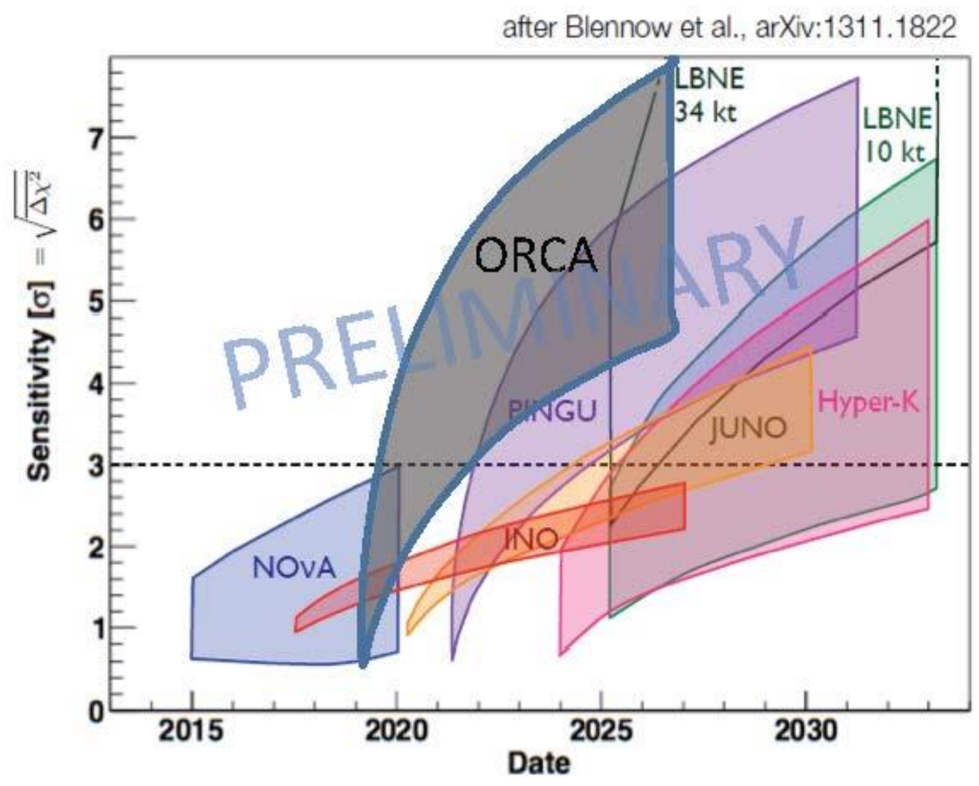
SK updated results recently presented by Nakahata-san at Neutel 2015
HK sensitivity by far the best Spin Dependent (SD) and very competitive in the SI low WIMP mass region





Mass Hierarchy

- The Dune baseline is a clear premium
- Maybe arrives too late
- HK sensitivity is not null and can be corroborated by atmospheric neutrinos



CP violation: general considerations

- HK:
  - short baseline →no matter effects: pure CP but reduced MH
  - Off axis → reduced intrinsic ν_e contamination, reduced NC backgrounds
- DUNE:
  - Long baseline → sensitive to matter effects: good performances in MH
  - On axis: second oscillation maximum and sensitive to ν_τ appearance
  - On axis: Extended lever of arm for measurement of parameters

CP violation: just event numbers

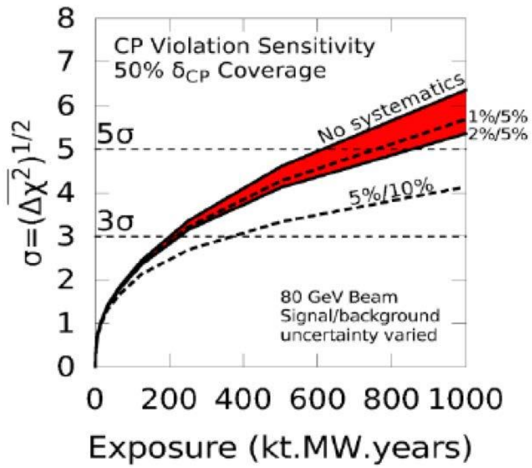
Courtesy by Gabriella: note that S/N of HK is better than Dune

HYPERK , $\delta_{CP}=0$, and NH

	Signal ($\nu\mu \to \nu e$ CC)	Wrong sign appearance	$\nu\mu/\bar{\nu}\mu$ CC	beam $\nu e/\bar{\nu}e$ contamination	NC
ν	3,016	28	11	523	172
$\bar{\nu}$	2,110	396	9	618	265

ELBNF 40KT

Run Mode	Signal Events δ_{CP}			Background Events			
	$-\pi/2$	0	$\pi/2$	ν_μ NC	ν_μ CC	ν_e Beam	ν_τ CC
Neutrino	1068	864	649	72	83	182	55
Antineutrino	166	213	231	41	42	107	33



CP violation: systematic errors

A crucial factor in CP sensitivity

HK: third generation close detector system (after K2K and T2K)

Uncertainty on the expected number of events at Hyper-K (%)

	ν mode		anti-ν mode	
	νe	νμ	$\bar{\nu}$e	$\bar{\nu}$μ
Flux&ND	3.0	2.8	5.6	4.2
XSEC model	1.2	1.5	2.0	1.4
Far Det. +FSI	0.7	1.0	1.7	1.1
Total	3.3	3.3	6.2	4.5

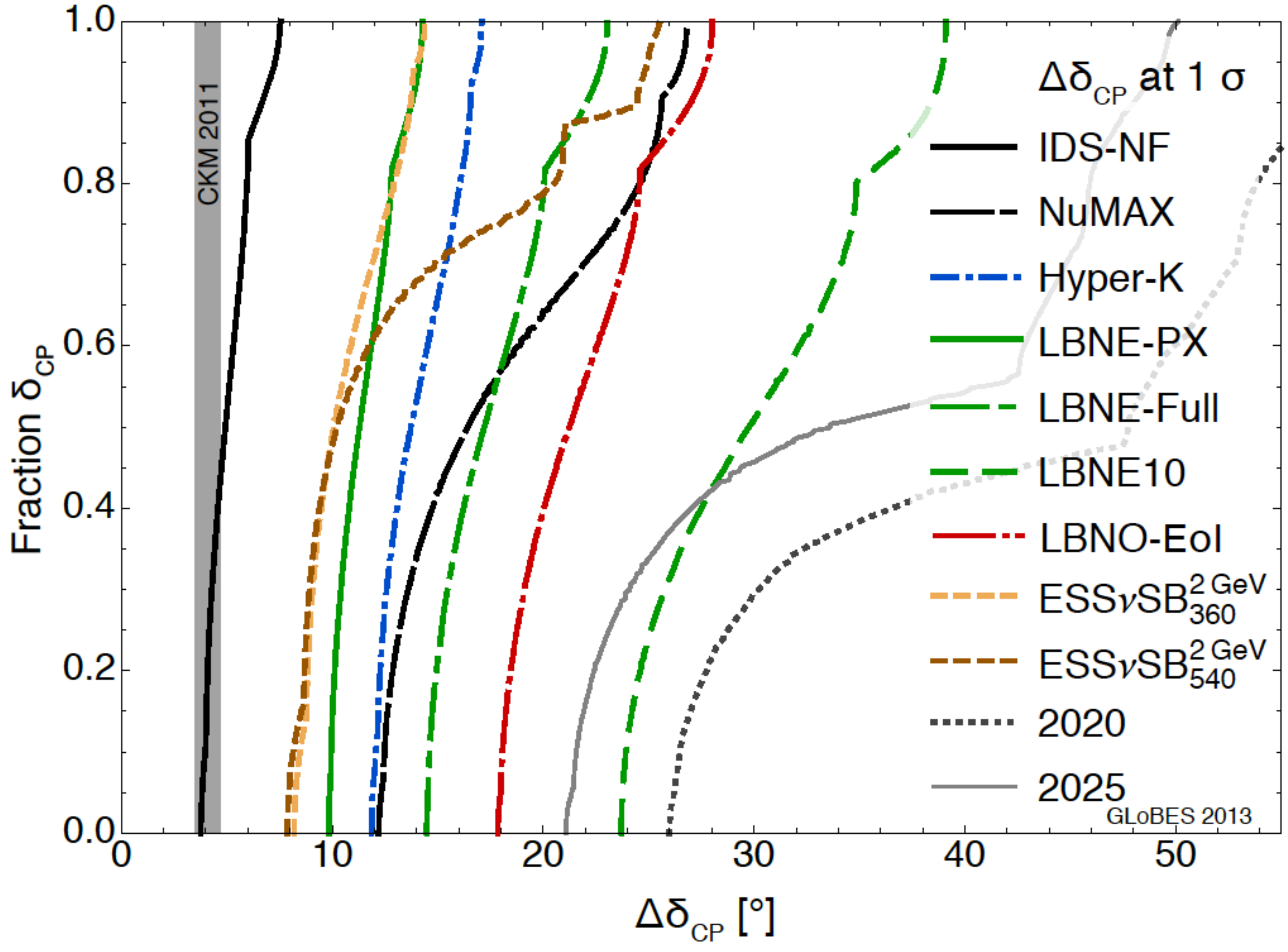
(T2K 2014)	
νe	νμ
3.1	2.7
4.7	5.0
3.7	5.0
6.8	7.6

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

Dune prediction follows MINOS (no experience on ν_e appearance or LAr)
Beam slope will prevent medium distance close detectors
LAr FSI more severe than water

CP violation: performances

(USA snowmass process, P. Coloma)



Conclusions

- ICFA neutrino panel: «… given the challenging nature of the measurement and the importance of the discovery (CP violation), independent confirmation by a qualitatively different experiment is likely to be essential»
- My personal point of view: if the fate of the entire high energy physics community depends from the construction of Dune at Fermilab, let’s do it. But then physics desperately calls for HK.