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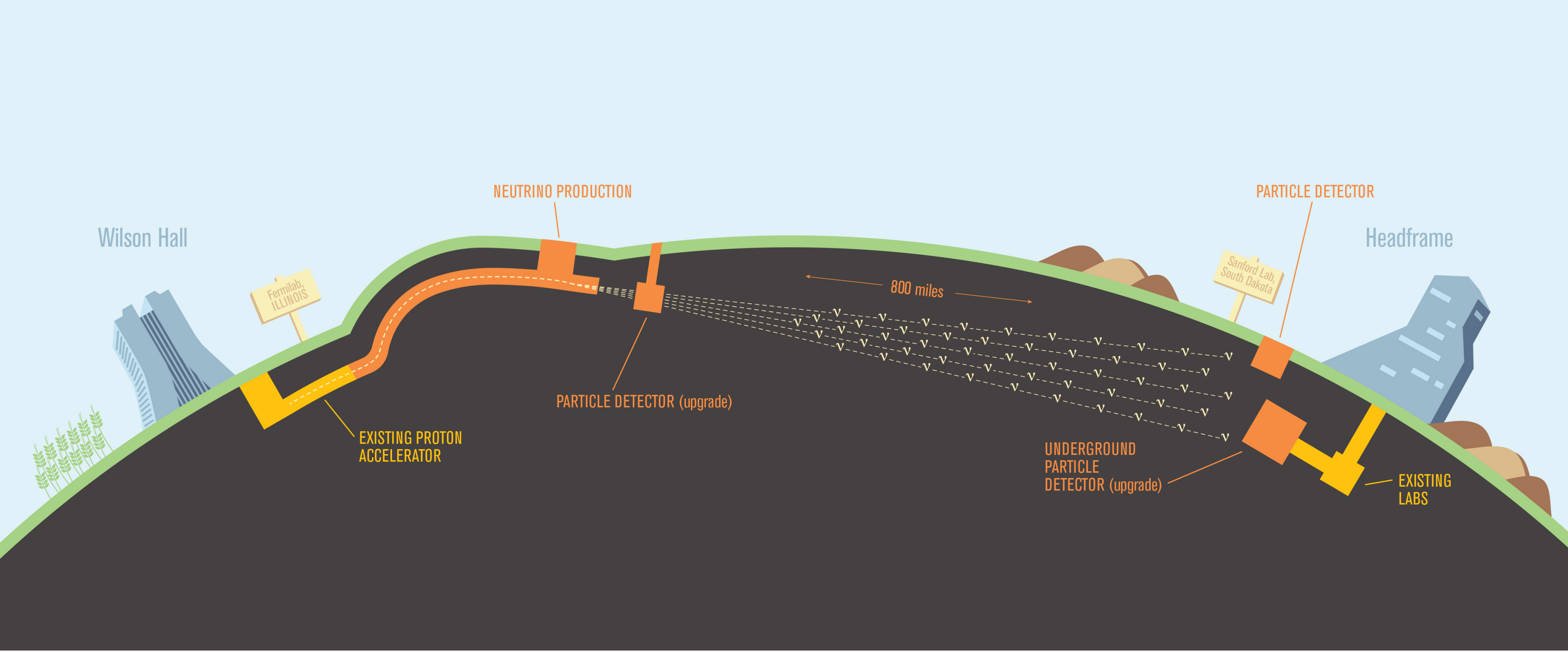
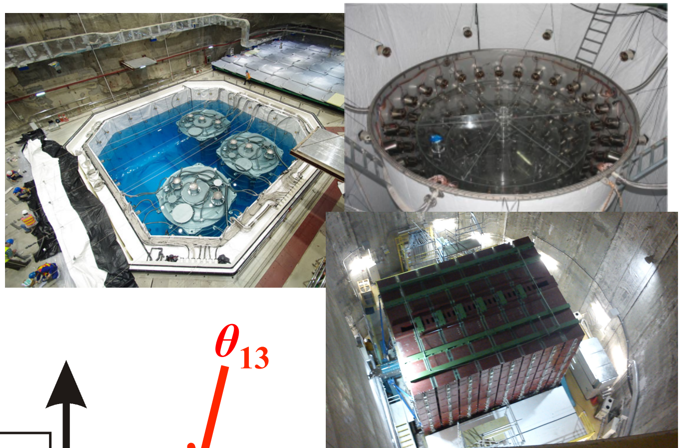
LBNE

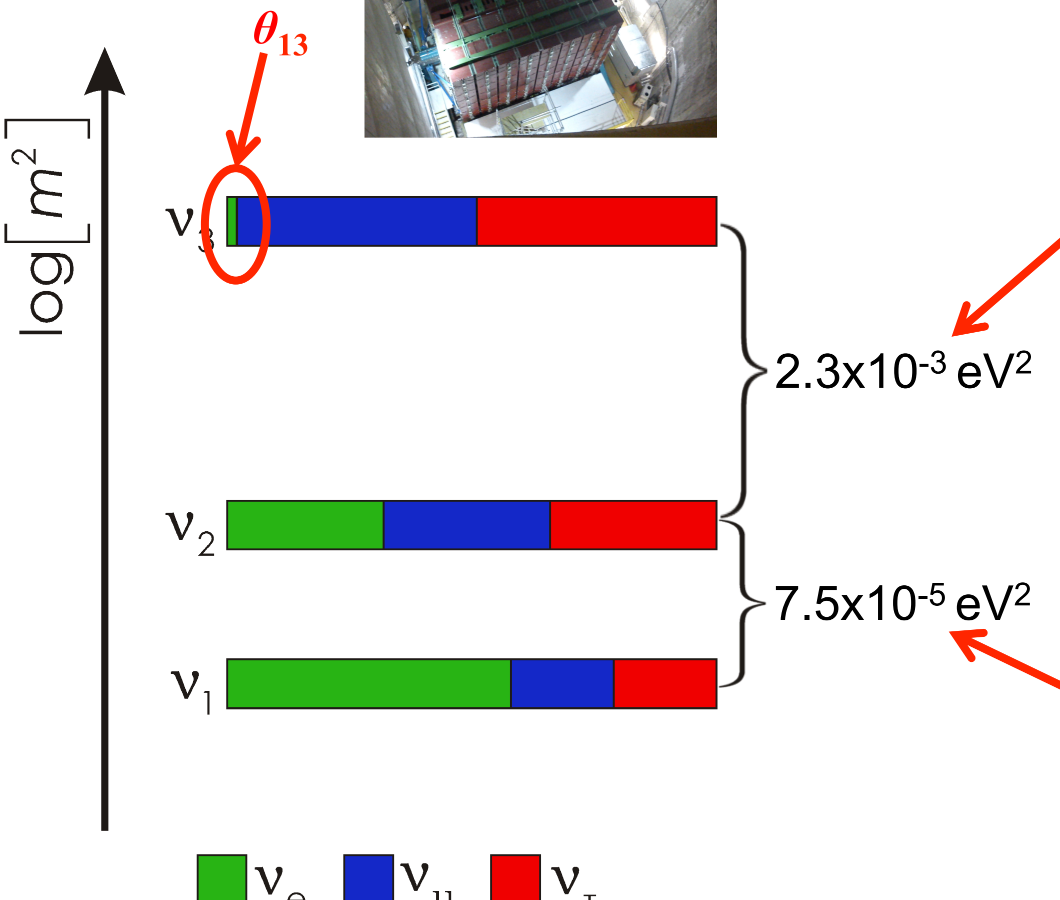


Justin Evans
University of Manchester

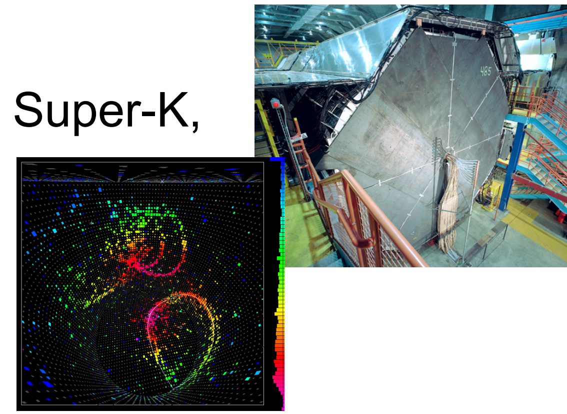
Neutrino oscillations



Daya Bay, Reno, T2K…

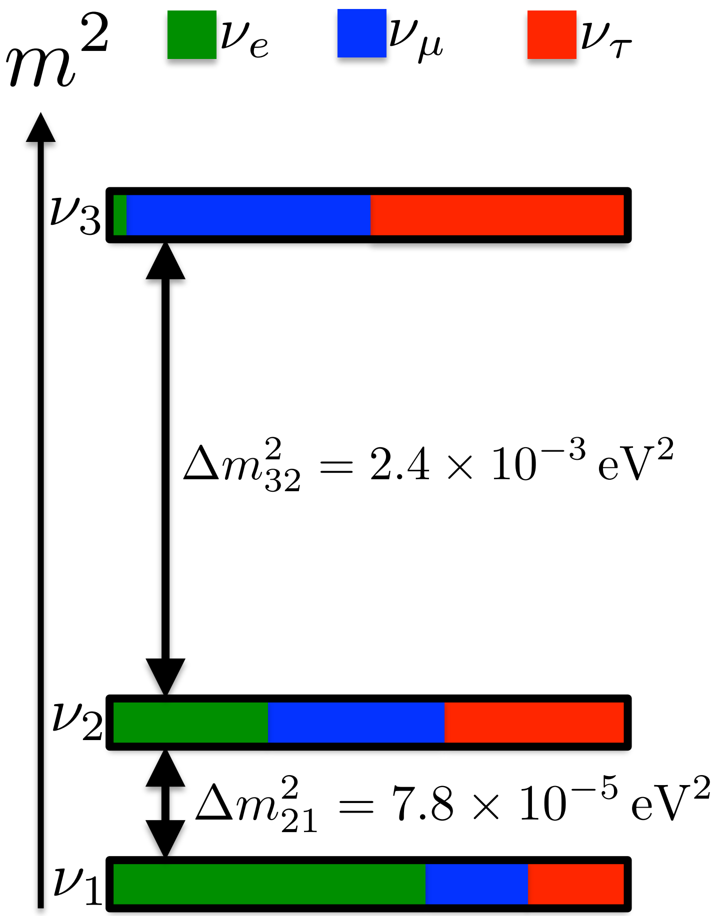


MINOS, Super-K, T2K…

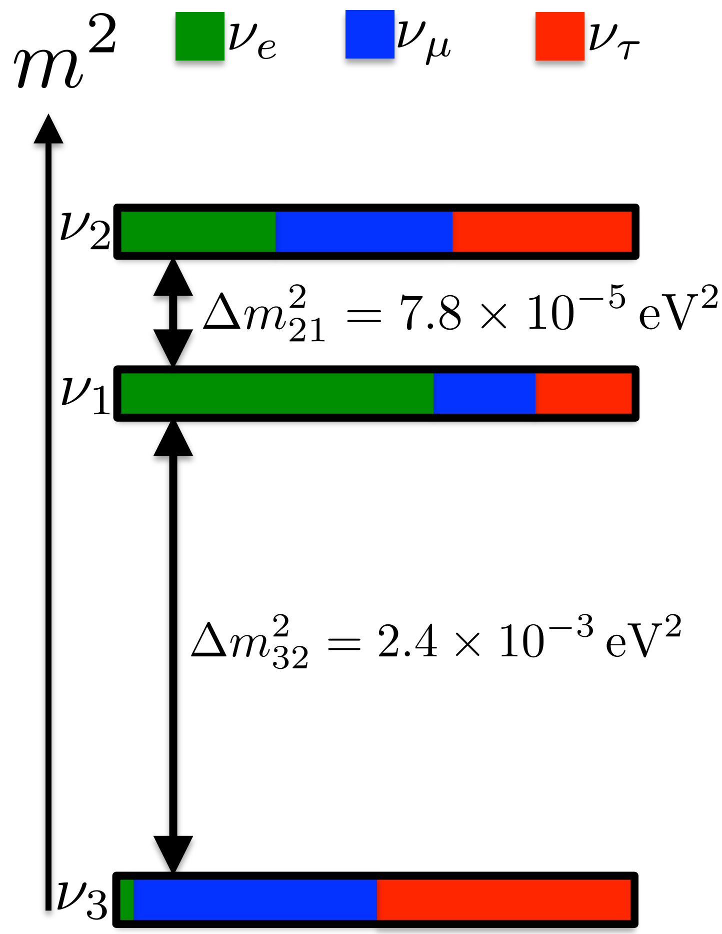


SNO, Borexino, KamLAND…

The mass hierarchy



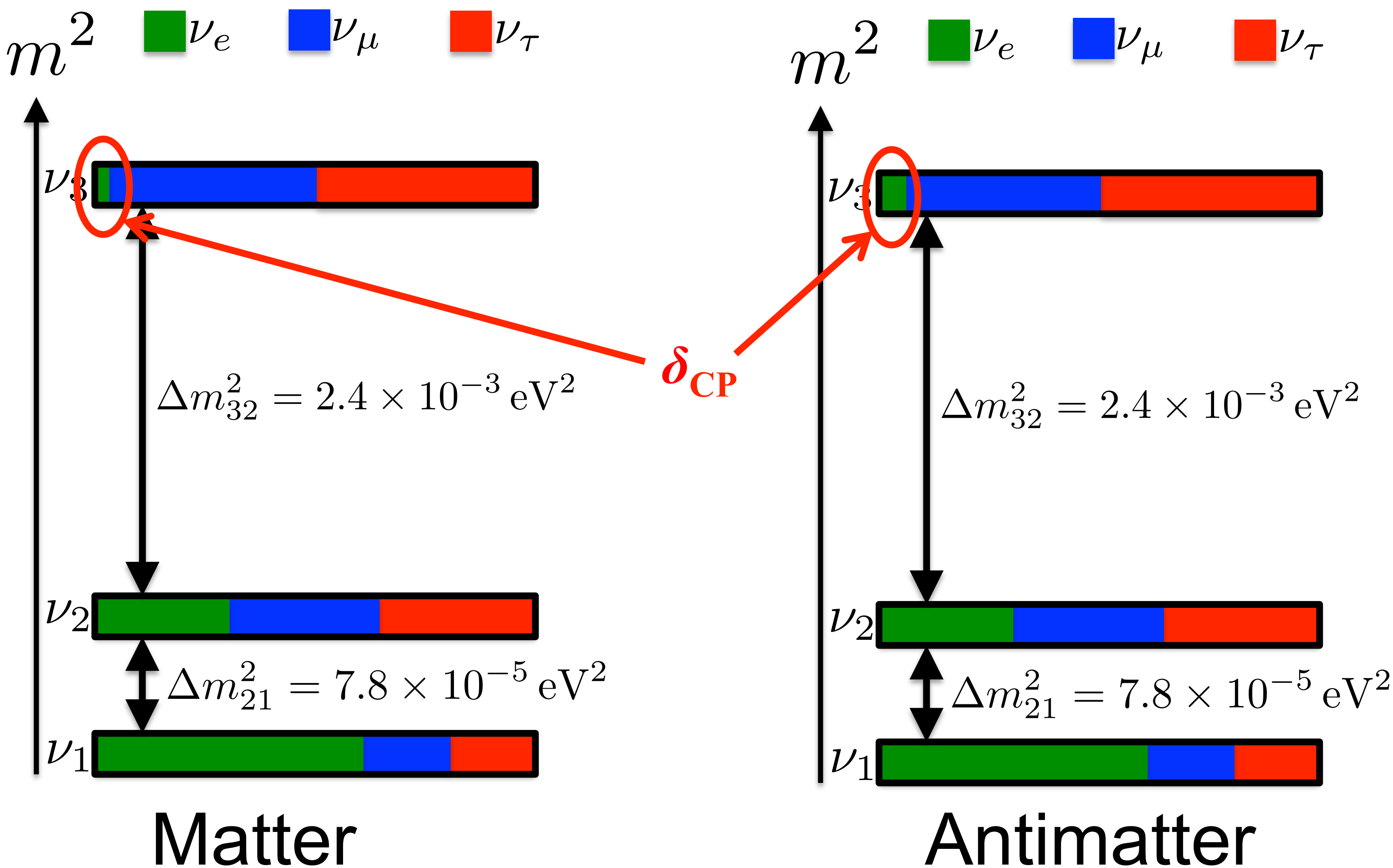
Normal



Inverted

CP violation

Can leptogenesis explain the matter-antimatter asymmetry?



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The Long-Baseline Neutrino Experiment

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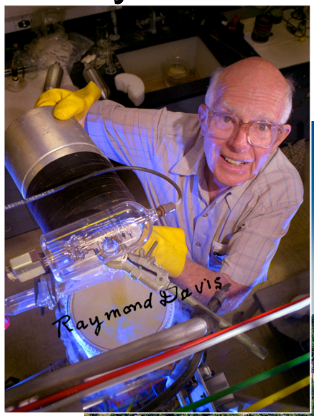
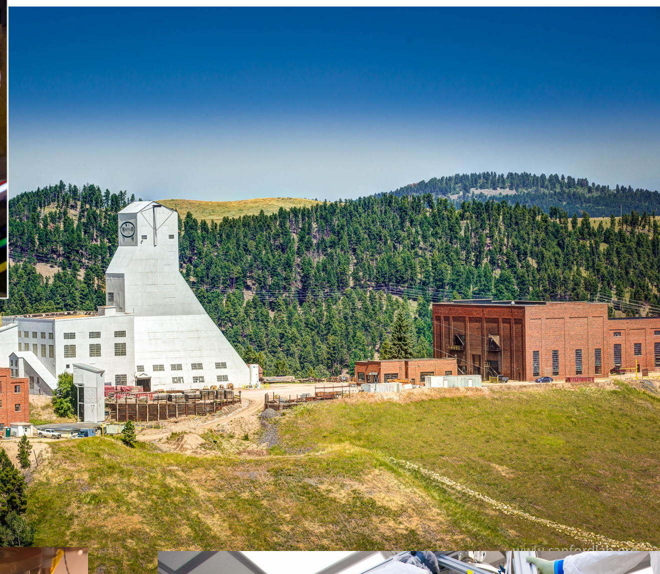
Sanford Underground Research Facility

Ray Davis



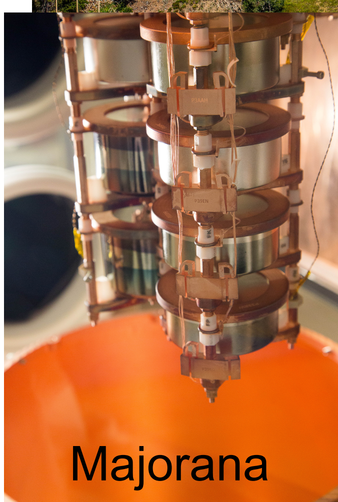


The Homestake Mine

- South Dakota

Formally home to Ray Davis's solar neutrino detector

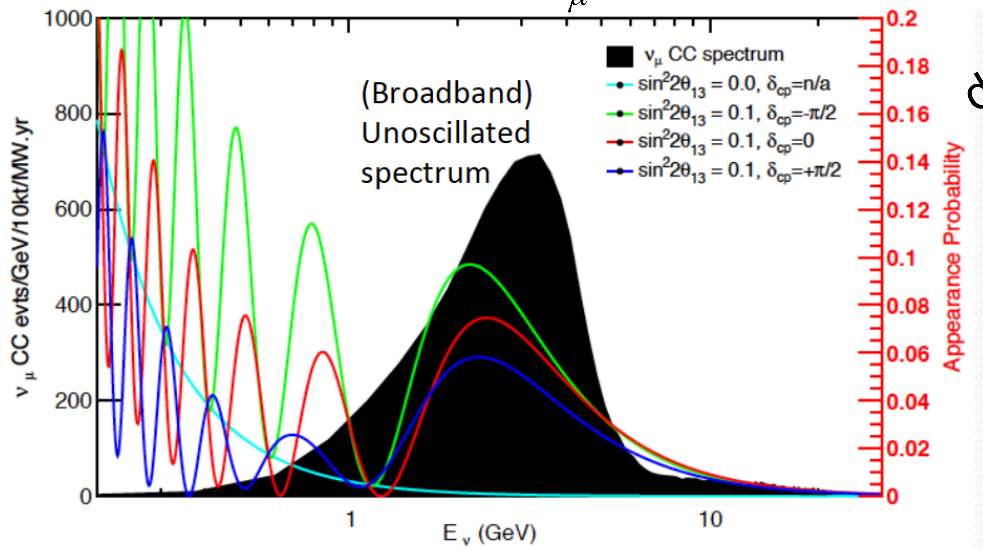
Now a highly active particle physics laboratory


Majorana


LUX

Neutrino oscillations

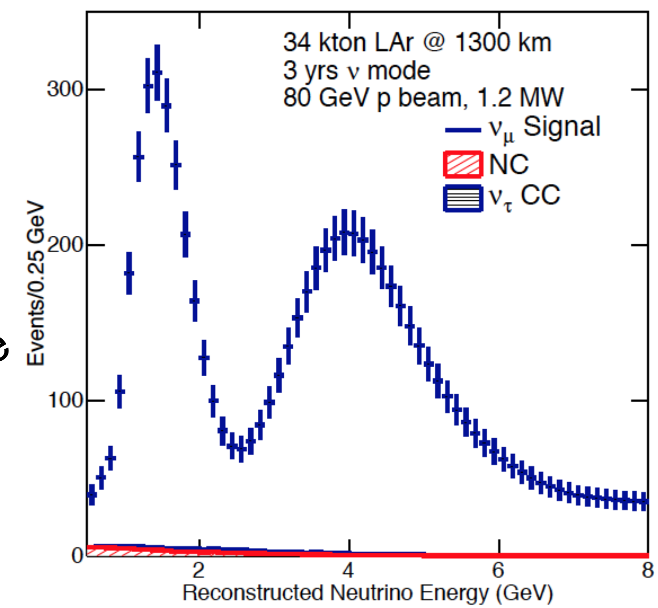
Unoscillated ν_μ beam



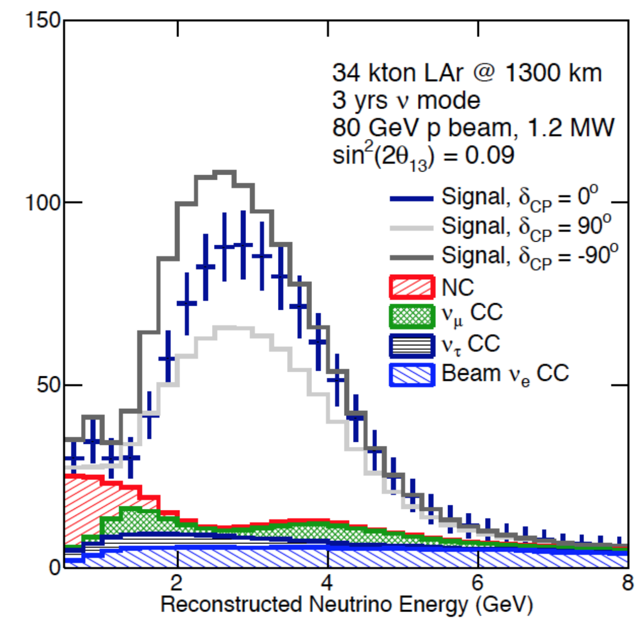
ν_μ disappearance

ν_e appearance

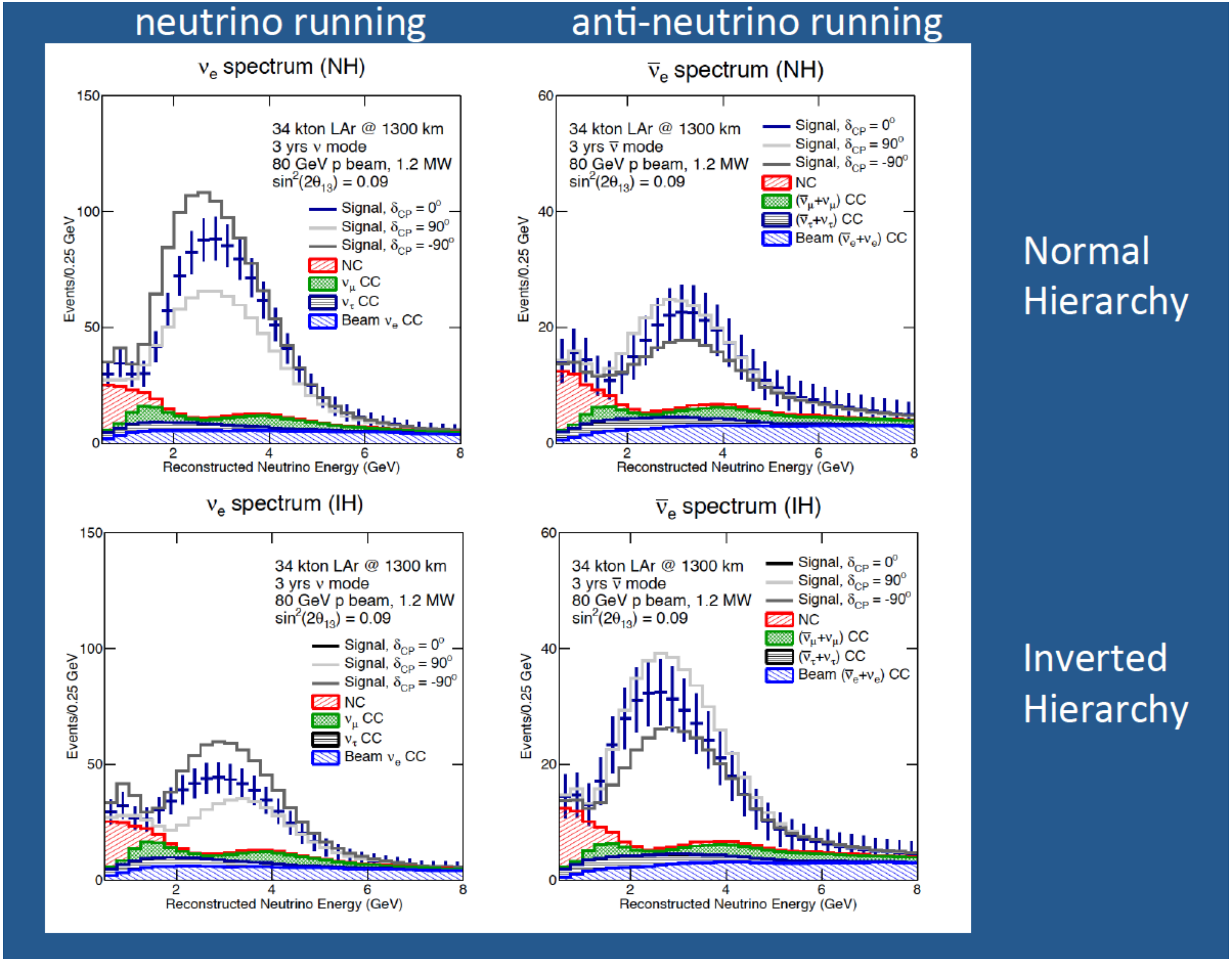
ν_μ spectrum



ν_e spectrum (NH)

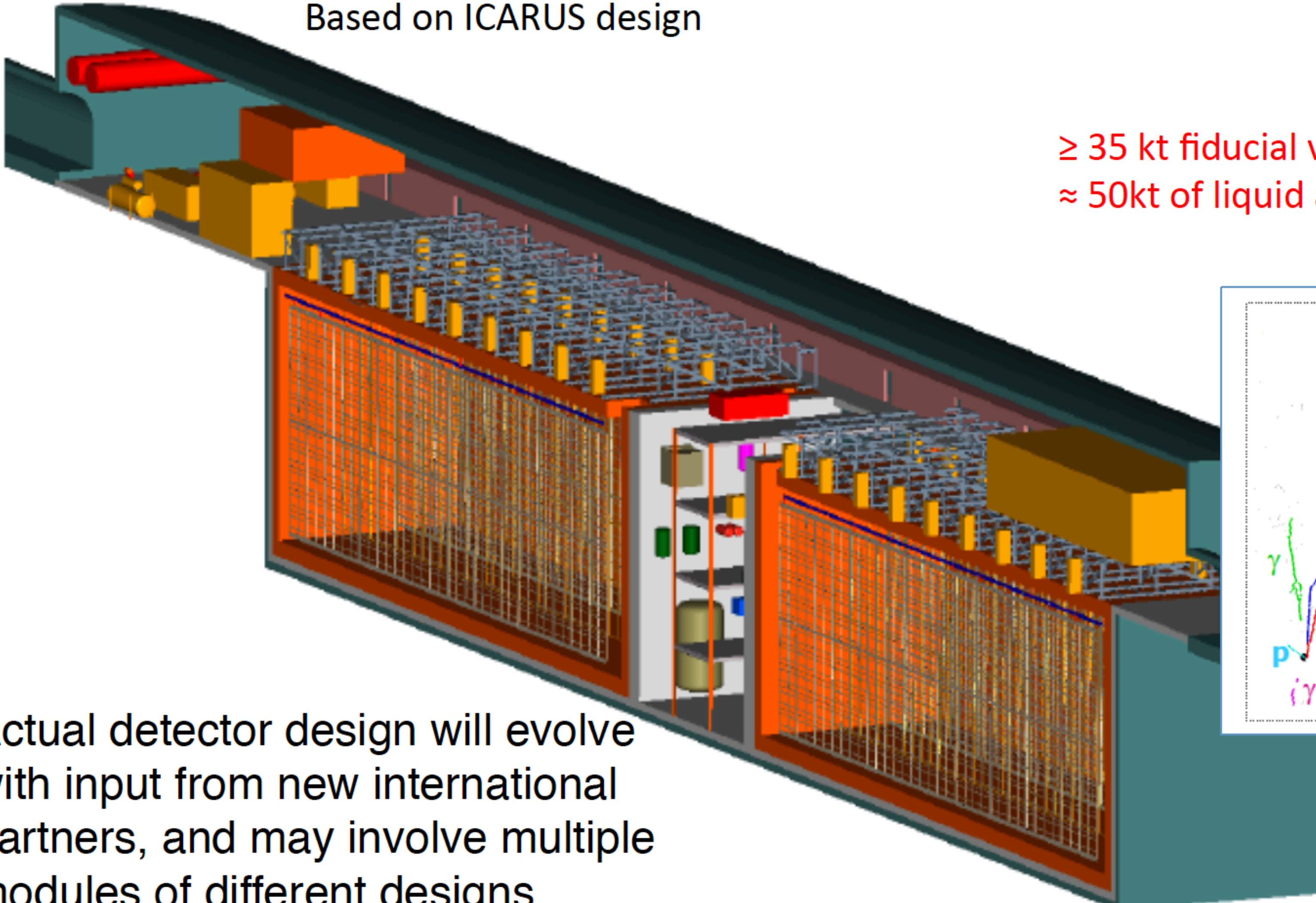


ν_e appearance

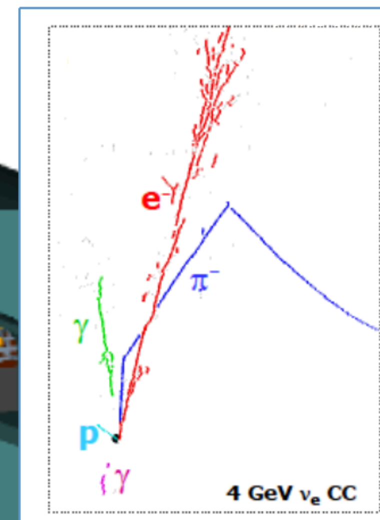


The Far Detector

Based on ICARUS design

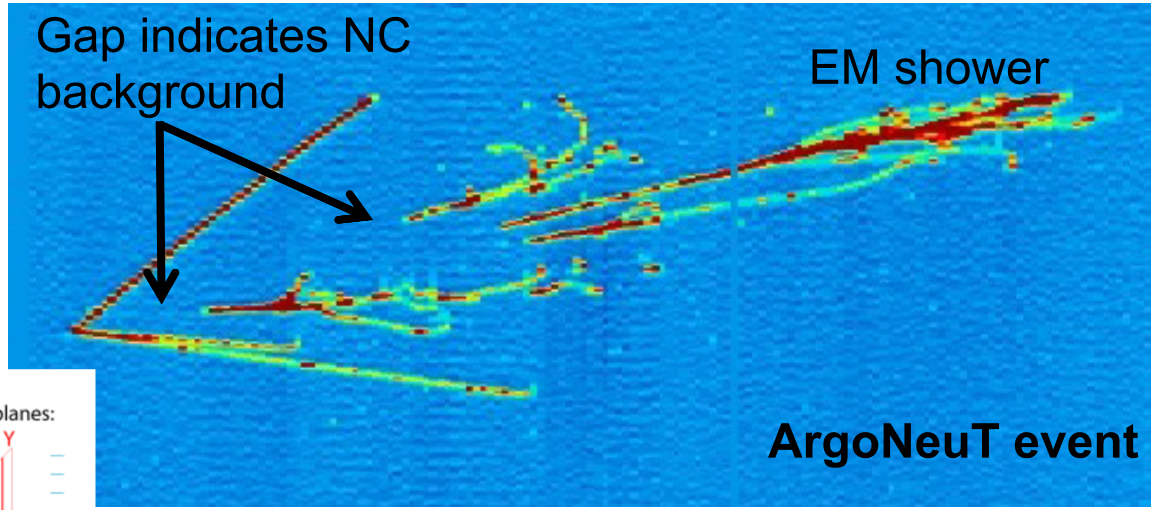


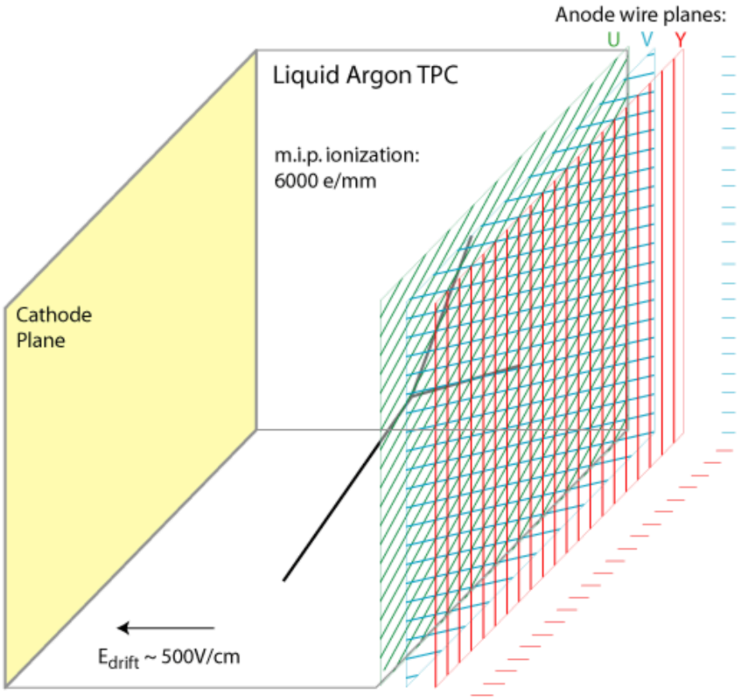
≥ 35 kt fiducial volume
≈ 50kt of liquid argon



Actual detector design will evolve with input from new international partners, and may involve multiple modules of different designs.

The liquid argon TPC

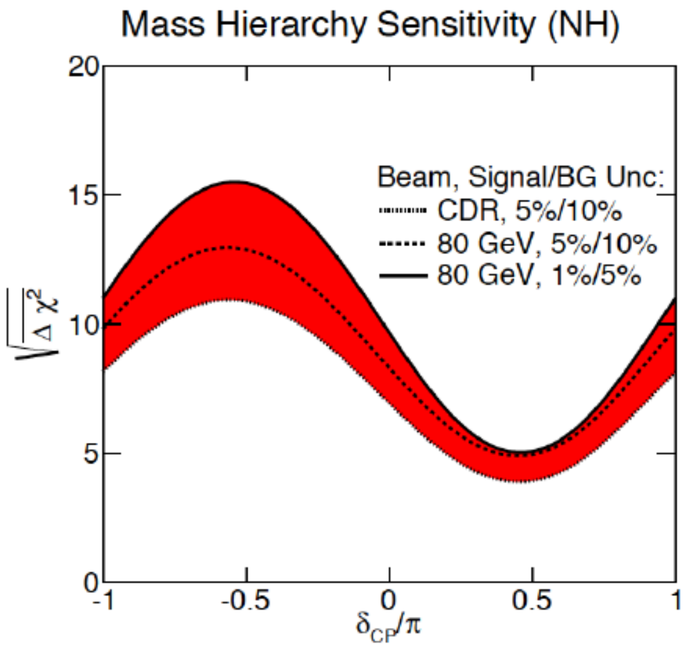


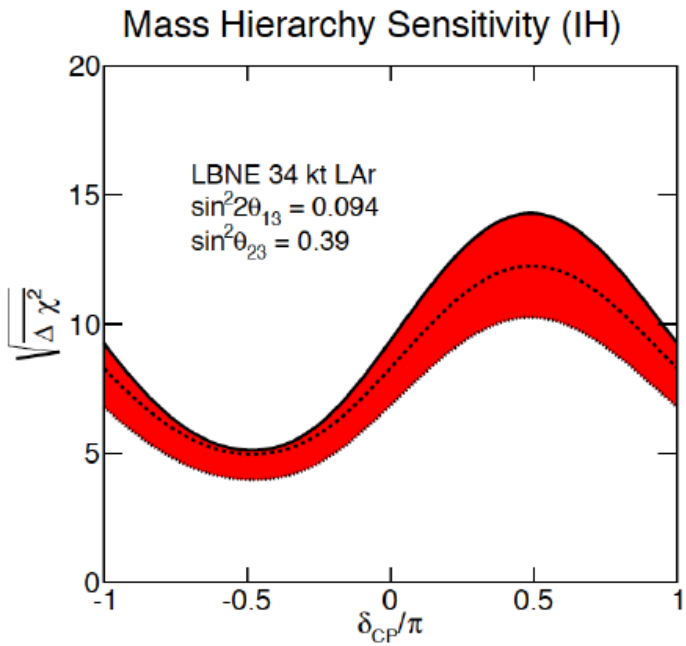


3.45m → 2.16ms

- Millimetre-level spatial resolution
- Superb ability to reject NC-induced electromagnetic activity

Mass hierarchy





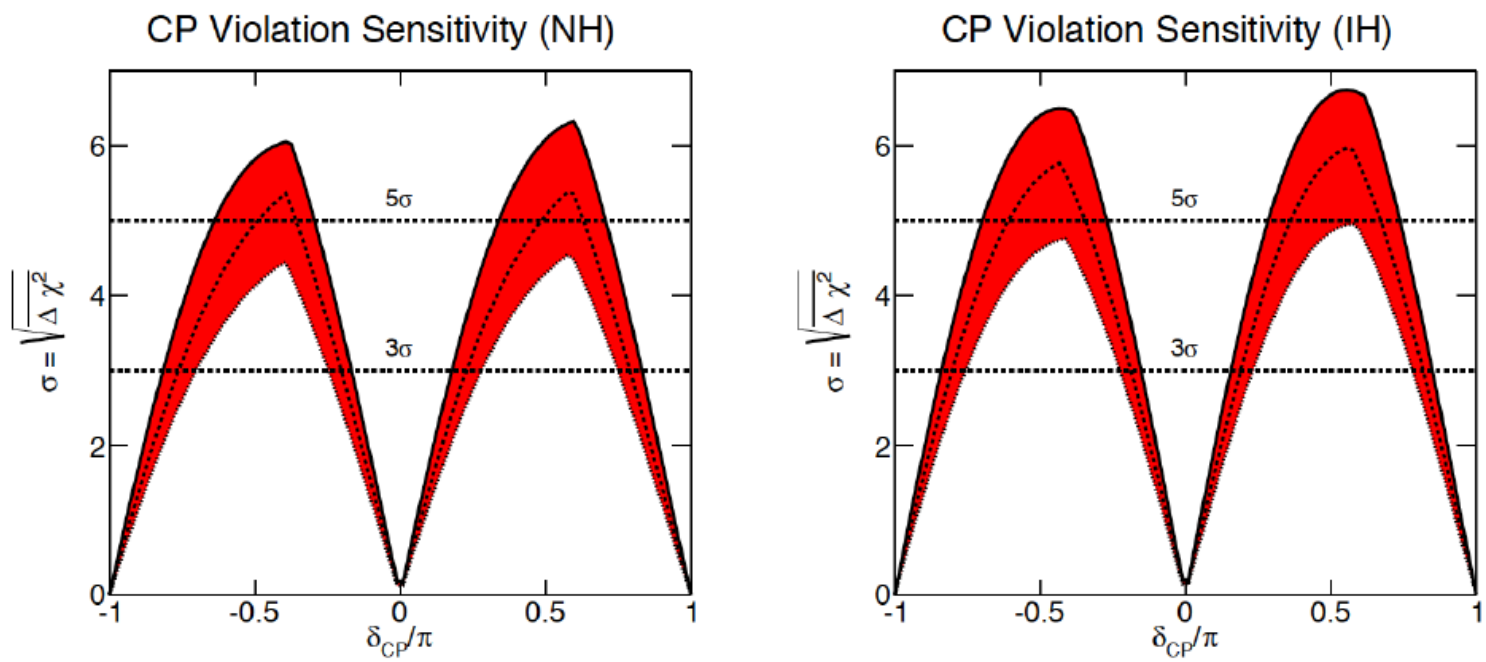
Top of band: optimised beam, small systematics

Bottom of band: unoptimised beam, poor systematics

Exposure: 34 kt x 1.2 MW x 6 years

- (3 years neutrino + 3 years antineutrino)

CP violation



Top of band: optimised beam, small systematics

Bottom of band: unoptimised beam, poor systematics

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- (3 years neutrino + 3 years antineutrino)

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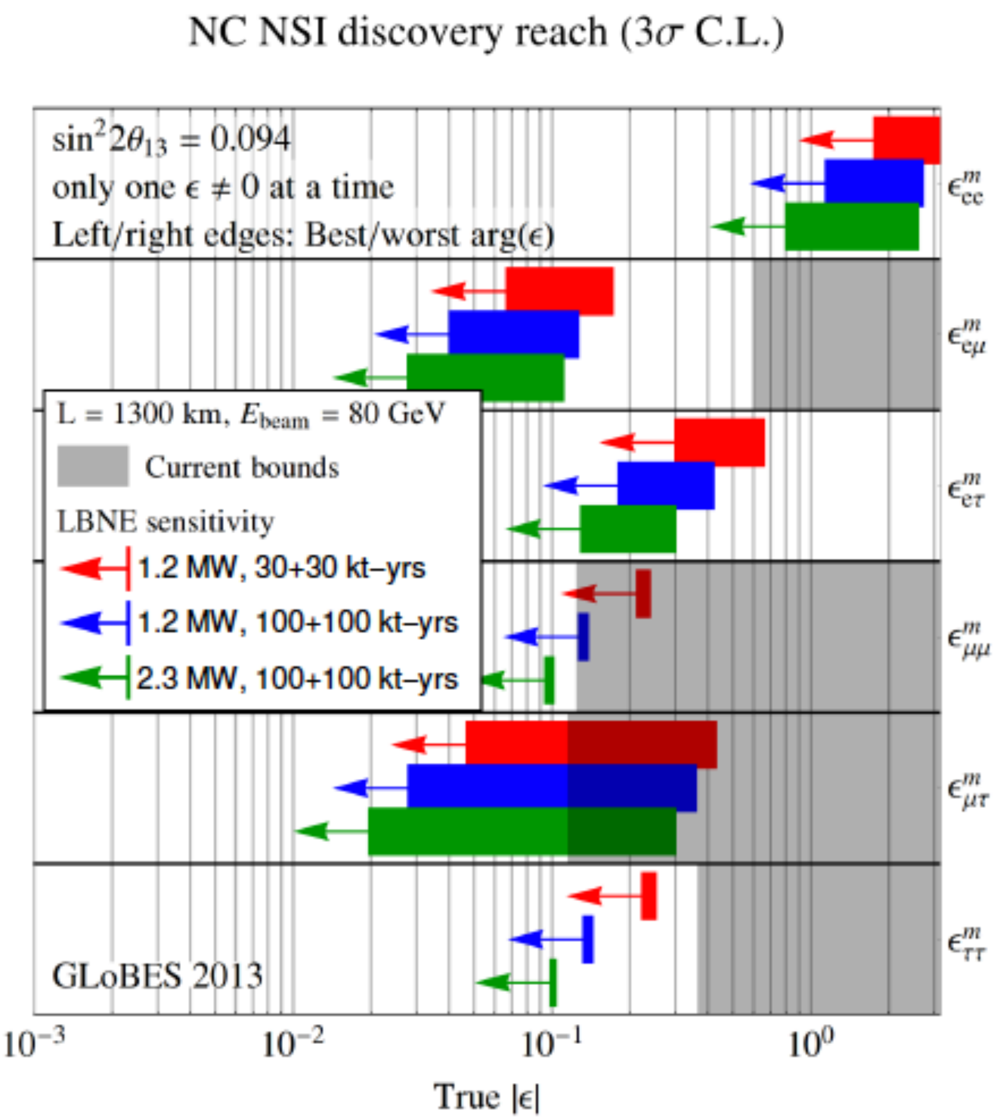
Non-standard interactions

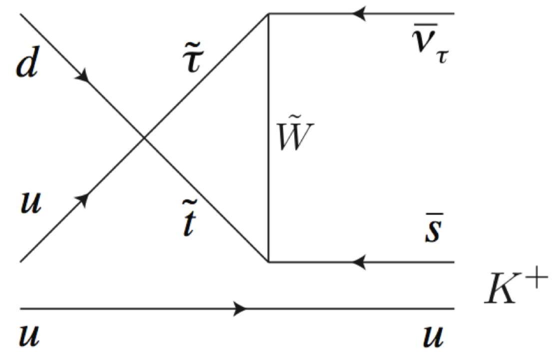


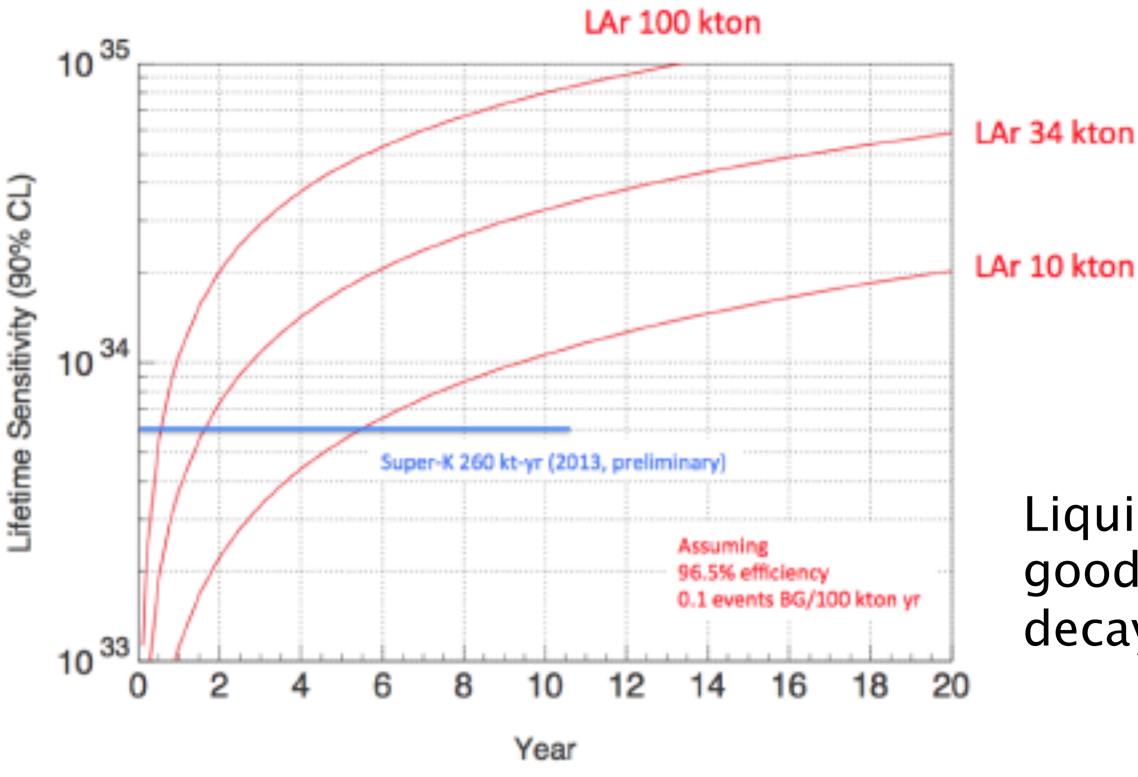
$$\tilde{V}_{\rm MSW} = \sqrt{2} G_F N_e \begin{pmatrix} 1+\epsilon^m_{ee} & \epsilon^m_{e\mu} & \epsilon^m_{e\tau} \\ \epsilon^{m*}_{e\mu} & \epsilon^m_{\mu\mu} & \epsilon^m_{\mu\tau} \\ \epsilon^{m*}_{e\tau} & \epsilon^{m*}_{\mu\tau} & \epsilon^m_{\tau\tau} \end{pmatrix}$$

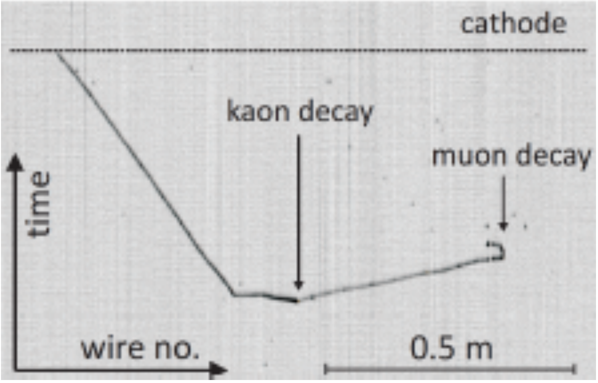
Parameters governing the strength of BSM interactions between neutrinos and the Earth's matter

Proton decay

Decay Mode	Water Cherenkov		Liquid Argon TPC	
	Efficiency	Background	Efficiency	Background
$p \to K^+\overline{\nu}$	19%	4	97%	1
$p \to K^0\mu^+$	10%	8	47%	< 2
$p \to K^+\mu^-\pi^+$			97%	1
$n \to K^+e^-$	10%	3	96%	< 2
$n \to e^+\pi^-$	19%	2	44%	0.8

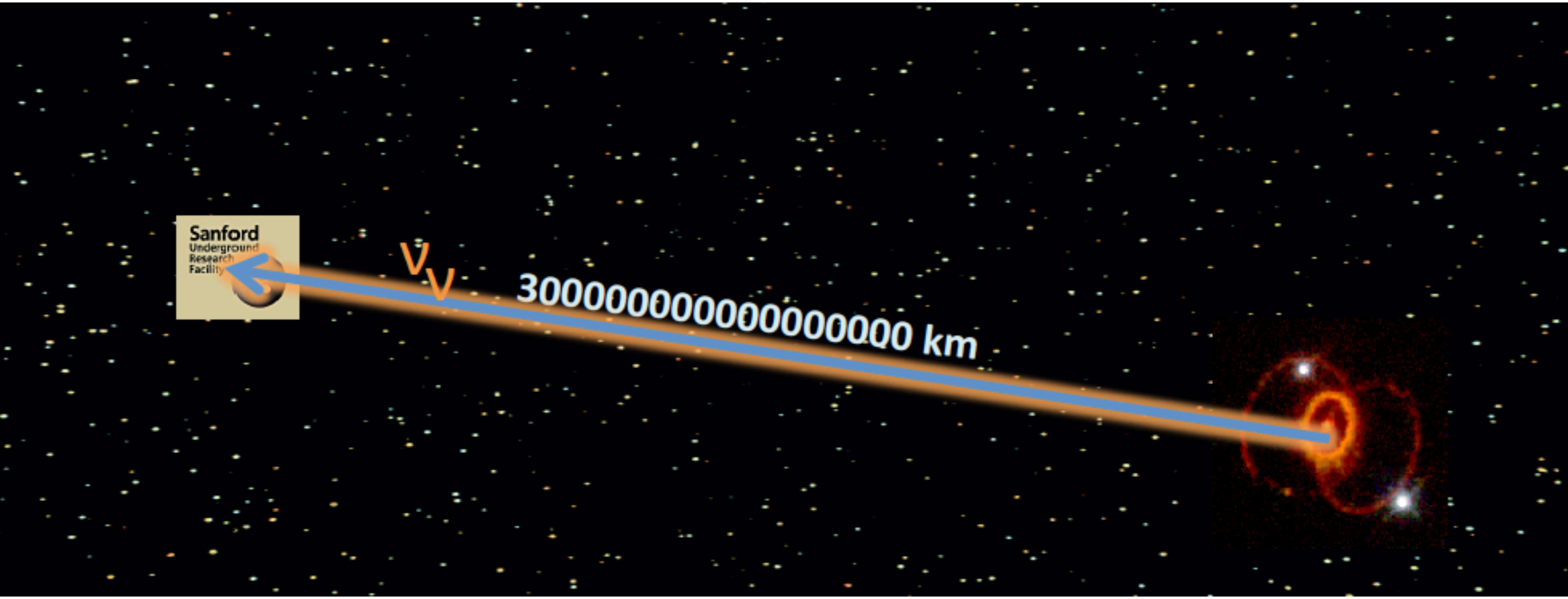






Liquid argon TPCs are particularly good at reconstructing kaon decay modes

Core-collapse supernovae



99% of the proto-neutron star's energy goes into neutrinos

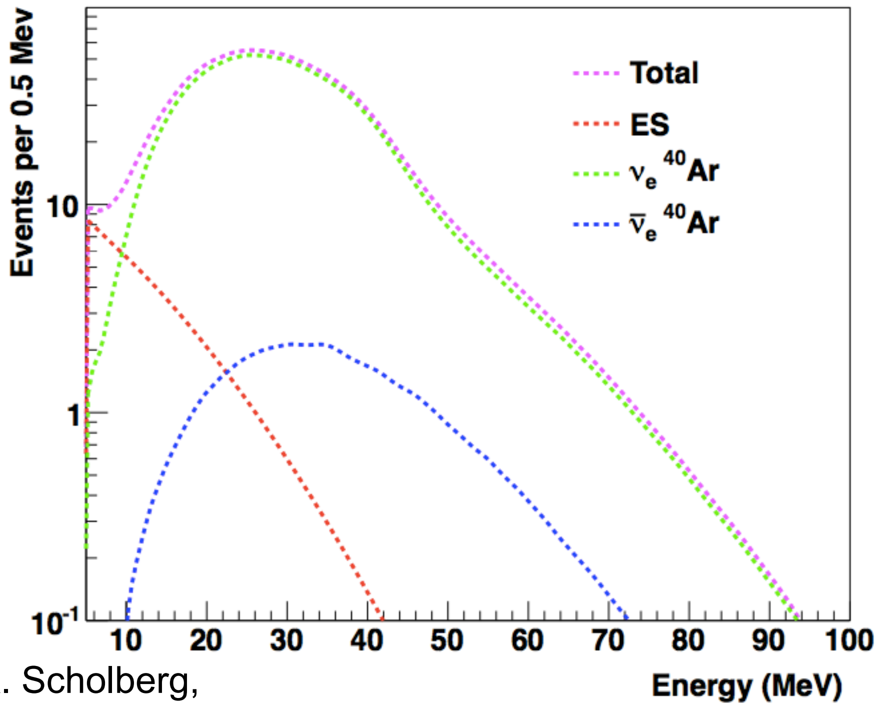
SN at galactic core (10 kpc) gives several thousand interactions in the 35 kt Far Detector in tens of seconds

- ms timing precision on the reconstruction

Neutrinos from ~2000 Milky Way supernovae are already on their way

Supernovae

Events seen in 34 kt argon at 10 kpc



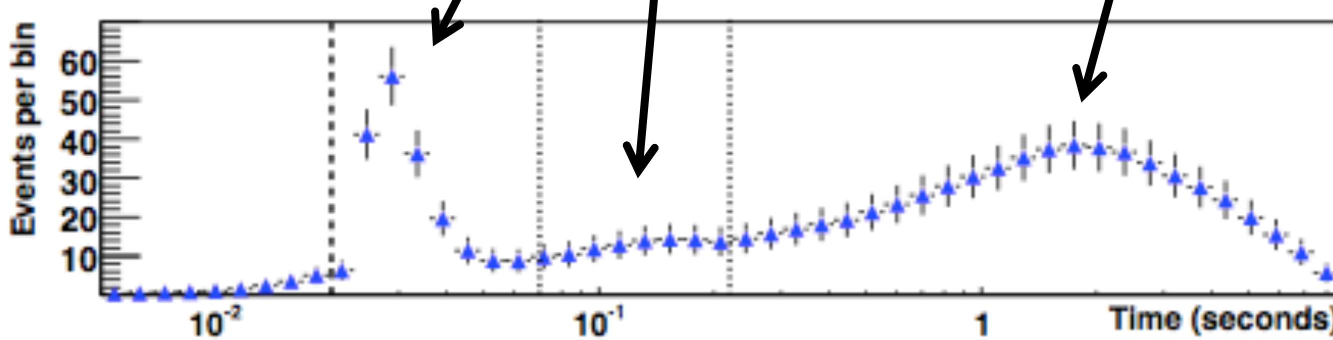
K. Scholberg, Neutrino 2014

Neutronisation

$$e^- + p \rightarrow n + \nu_e$$

Cooling

Accretion



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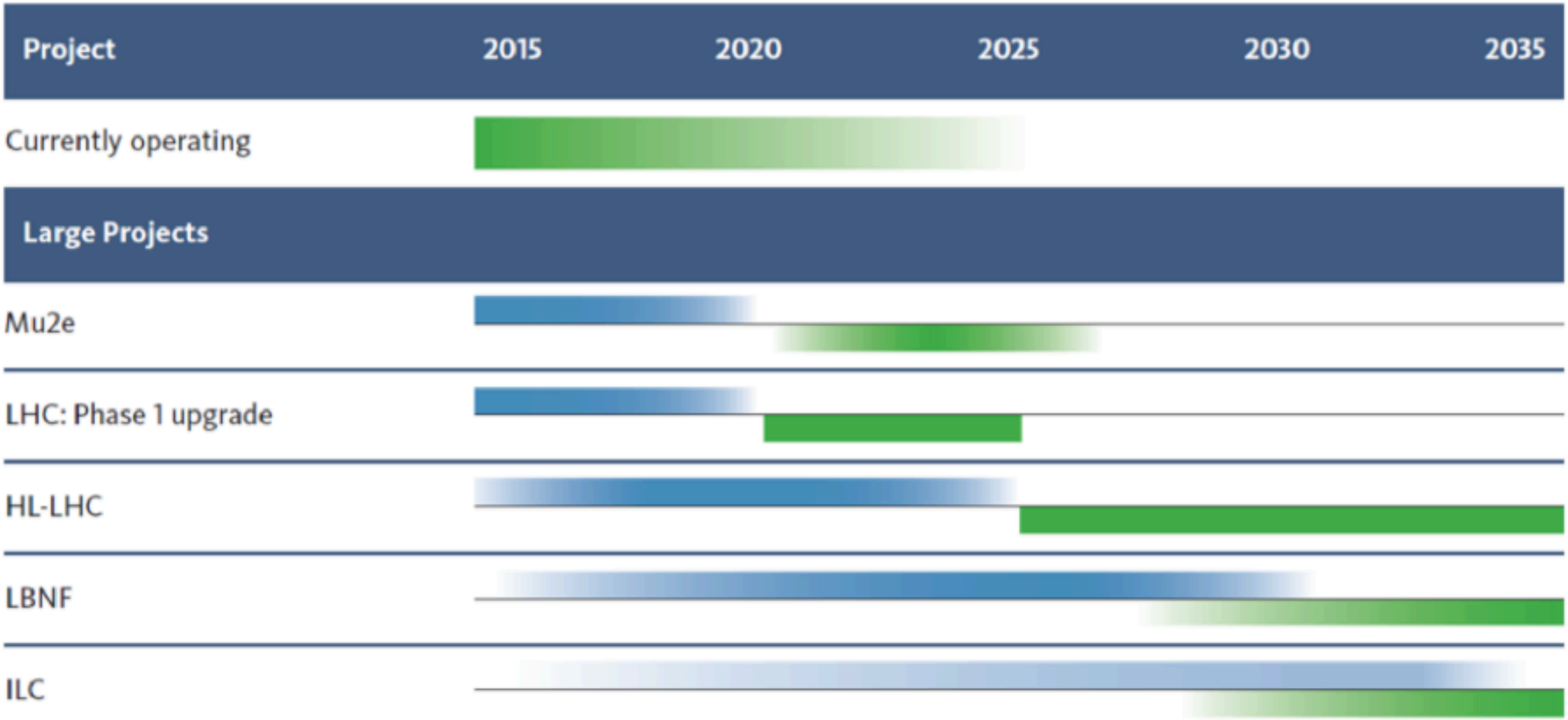
Timescale



DoE timescale created by the P5 panel

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Summary

LBNE is the US's flagship particle physics project for the next decade

- 35 kt, underground liquid argon far detector
- 1.2 MW beam at turn-on

Strong and varied physics programme

- Neutrino mass hierarchy
- CP violation
- Non-standard interactions
- Proton decay
- Core-collapse supernovae
- And much more…