Sterile Neutrino Global Context and nuSTORM Short-Baseline Sensitivity

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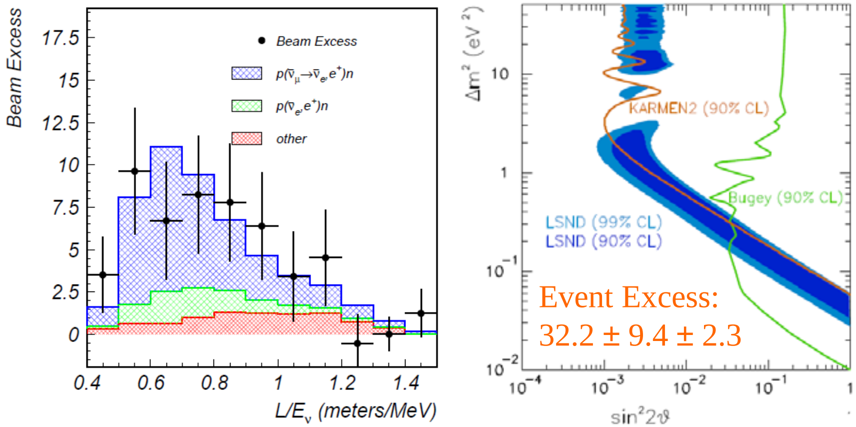
Center for Neutrino Physics
Virginia Tech

νSTORM Informational Meeting

Snowmass, July 3, 2013

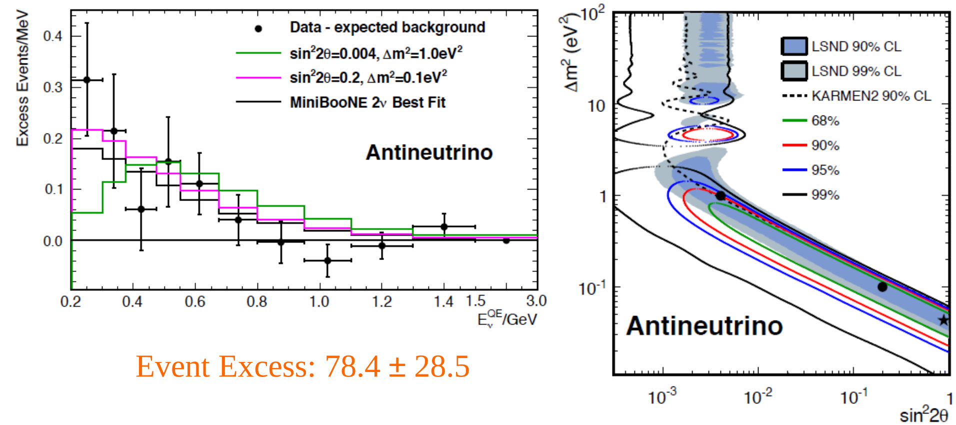
The Evidence for Sterile Neutrinos

LSND ($\bar{\nu}_\mu \rightarrow \bar{\nu}_e$)



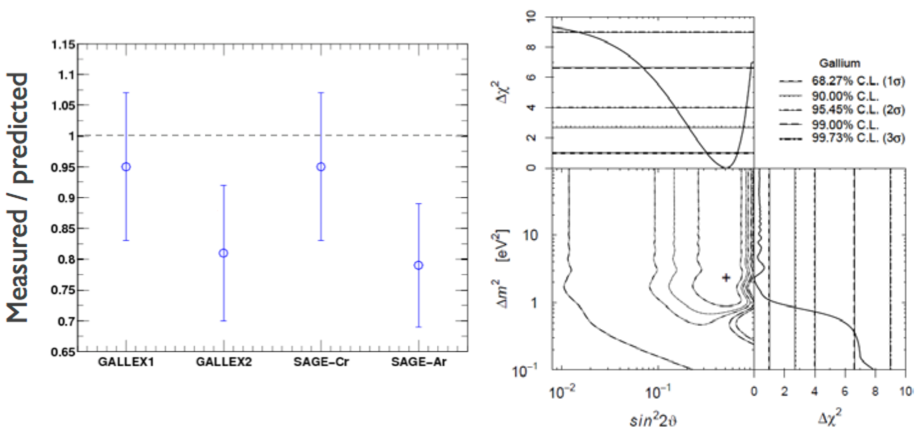
Aguilar-Arevalo *et al.*, Phys.Rev.D64, 112007 (2001)

MiniBooNE ($\bar{\nu}_\mu \rightarrow \bar{\nu}_e$)



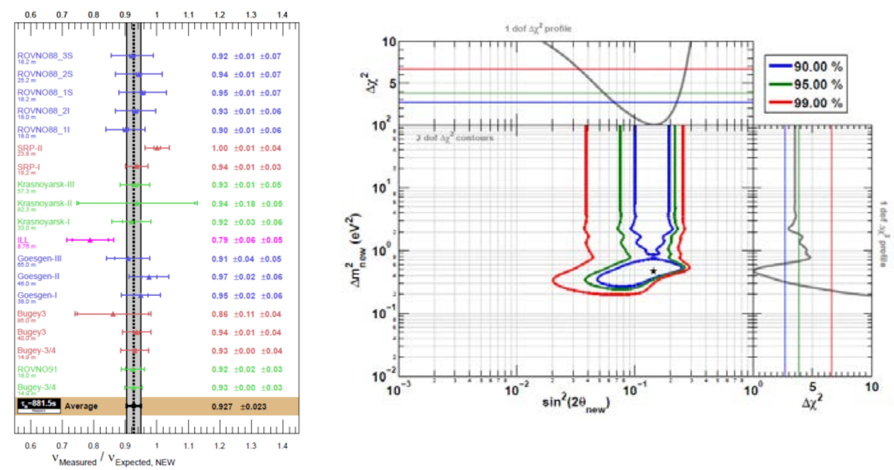
Aguilar-Arevalo *et al.*, Phys.Rev.Lett. 110, 161801 (2013)

Gallium Anomaly (ν_e Disappearance)



Giunti and Laveder, Phys.Rev.C83, 065504(2011)

Reactor Anomaly ($\bar{\nu}_e$ Disappearance)



Mention *et al.*, Phys.Rev.D83 073006 (2011)

Evidence from Cosmology

Cosmological data like CMB, Baryon Acoustic Oscillations (BAO), Large Scale Structure, Big-Bang Nucleosynthesis and the Hubble Constant (H_0) are sensitive to the effective number of light degrees of freedom (N_{eff})

With 3 ν, $N_{eff} = 3.046$

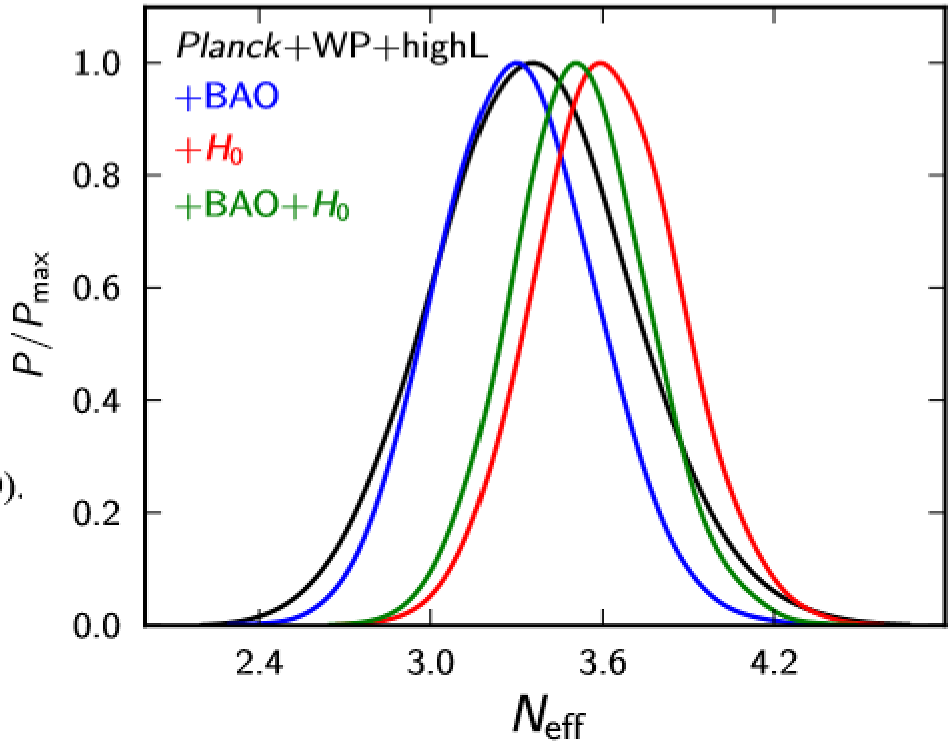
$$N_{eff} = 3.36^{+0.68}_{-0.64} \quad (95\%;\ Planck\text{+WP+highL}).$$

$$N_{eff} = 3.30^{+0.54}_{-0.51} \quad (95\%;\ Planck\text{+WP+highL+BAO})$$

$$N_{eff} = 3.62^{+0.50}_{-0.48} \quad (95\%;\ Planck\text{+WP+highL+}H_0).$$

$$N_{eff} = 3.52^{+0.48}_{-0.45} \quad (95\%;\ Planck\text{+WP+highL+}H_0\text{+BAO}).$$

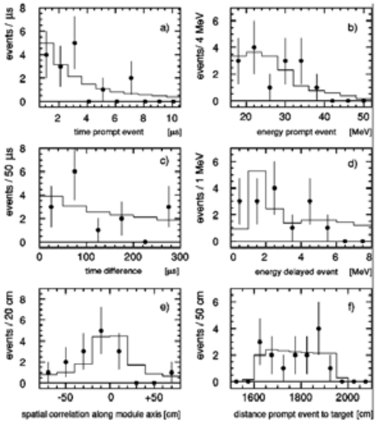
Ade *et al*, arXiv:1303.5076 [astro-ph.CO] (2013)

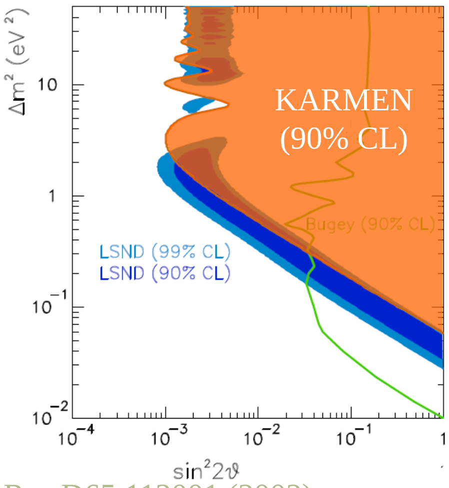


$N_{eff} > 3.046$ may be evidence of a one or more sterile neutrino states

The Evidence Against Sterile Neutrinos

KARMEN ($\bar{\nu}_\mu \rightarrow \bar{\nu}_e$)





No $\bar{\nu}_e$ Excess

Armbruster *et al.*, Phys.Rev.D65 112001 (2002)

The Evidence Against Sterile Neutrinos

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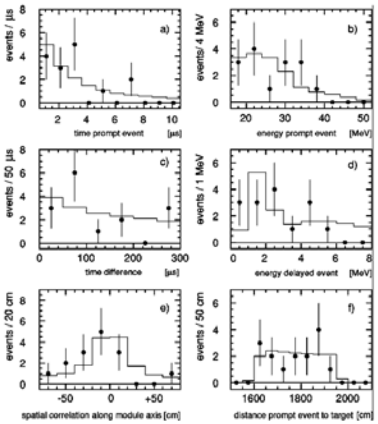

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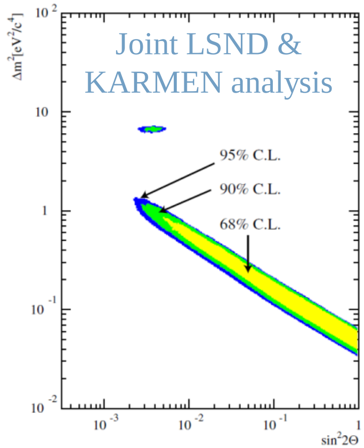
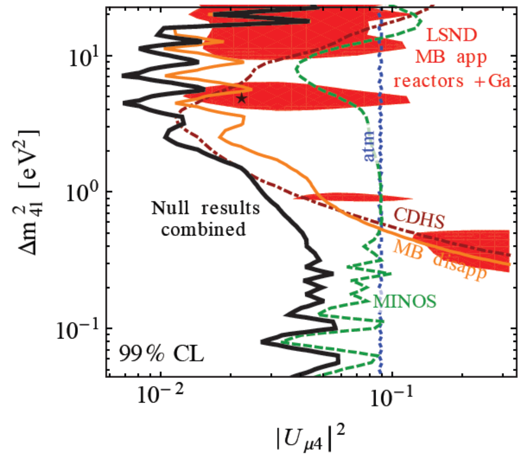


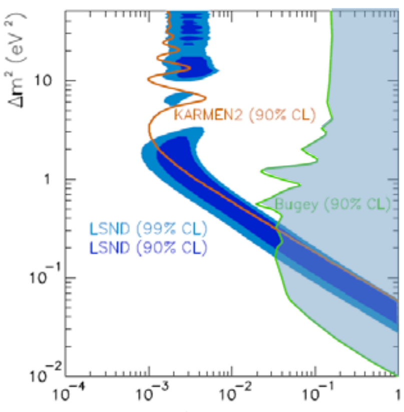
Church *et al.*, Phys.Rev.D66 013001 (2002)

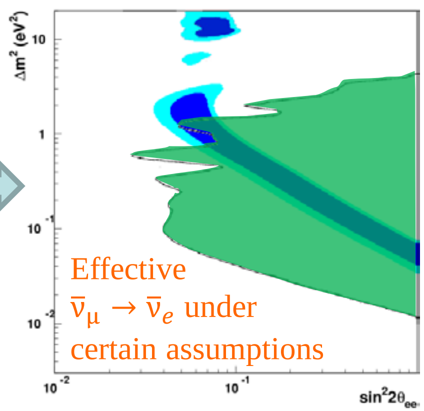
ν_μ Disappearance (where is it?)



Kopp *et al.*, JHEP 1305, 050 (2013)

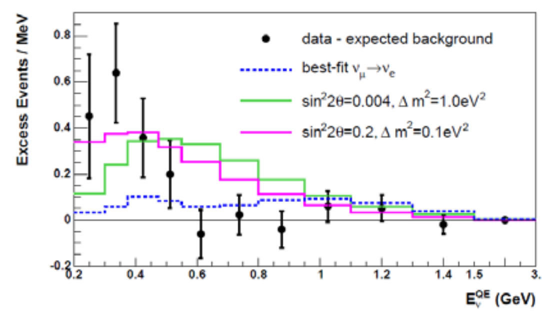
Bugey Reactor ($\bar{\nu}_e$ Disappearance)



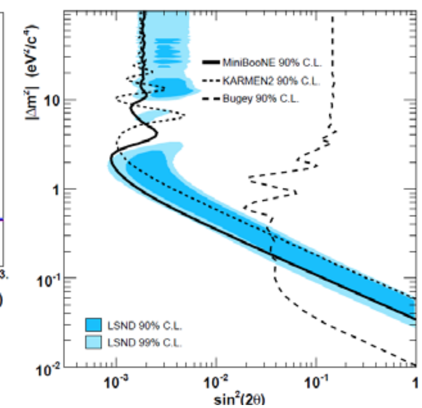


Achkar *et al.*, Nucl.Phys.B434, 503 (1995)

MiniBooNE ($\nu_\mu \rightarrow \nu_e$) 2007



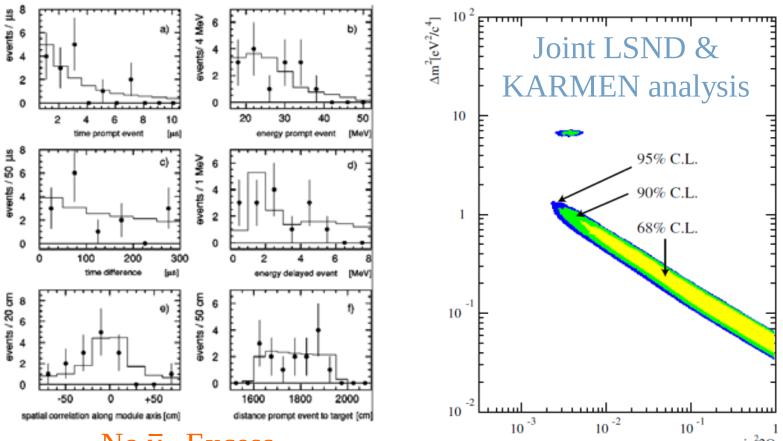
No Excess Above 475 MeV



Aguilar-Arevalo *et al.*, Phys.Rev.Lett. 98, 231801 (2007)

The Evidence Against Sterile Neutrinos

KARMEN ($\bar{\nu}_\mu \rightarrow \bar{\nu}_e$)



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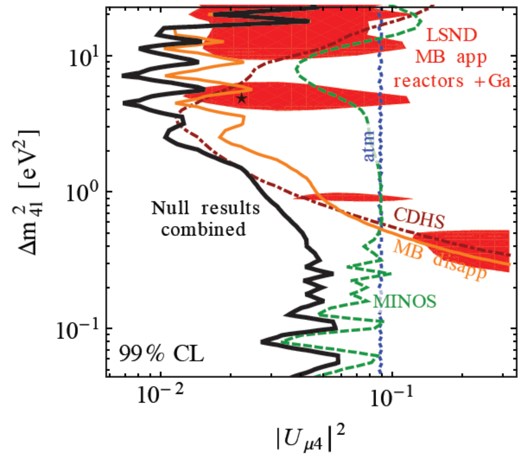
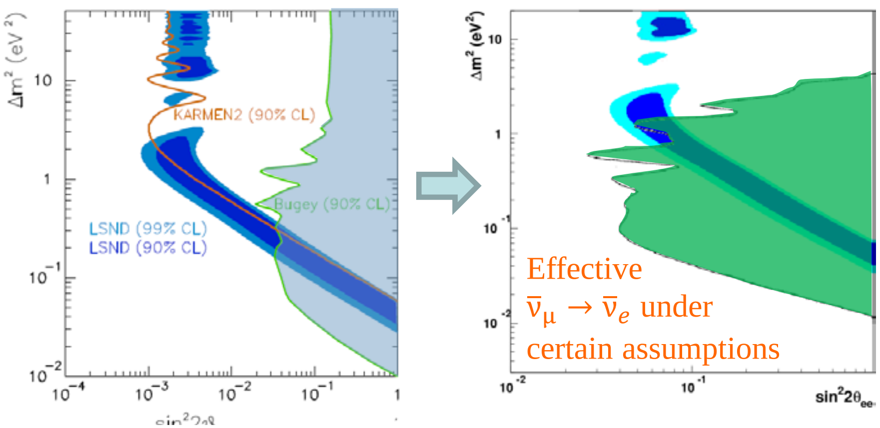


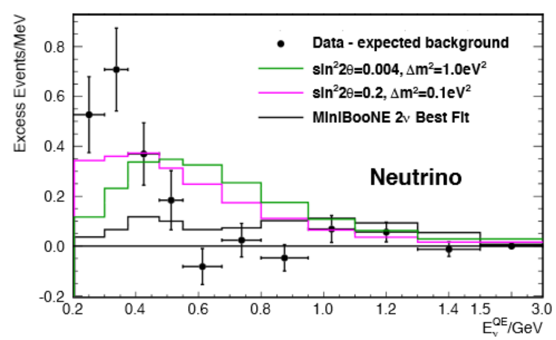
Kopp *et al.*, JHEP 1305, 050 (2013)

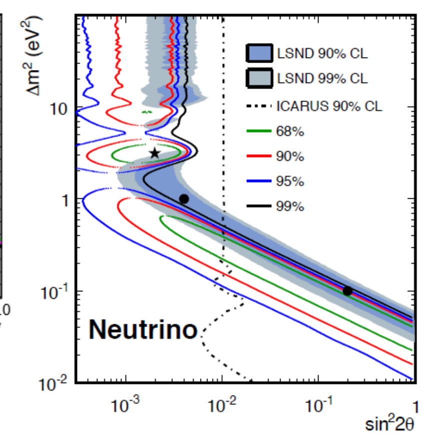
Bugey Reactor ($\bar{\nu}_e$ Disappearance)



Achkar *et al.*, Nucl.Phys.B434, 503 (1995)

MiniBooNE ($\nu_\mu \rightarrow \nu_e$) 2013





Event Excess: 162.0 ± 47.8

Aguilar-Arevalo *et al.*, Phys.Rev.Lett. 110, 161801 (2013)

What Might We Know by Snowmass 2023?


SNOWMASS
CSS
2023
IN THE
BLUE RIDGE
JULY 26 – AUGUST 2, 2023
ORGANIZED BY THE DIVISION OF PARTICLILES AND FIELDS OF THE APS
HOSTED BY THE CENTER FOR NEUTRINO PHYSICS AT VIRGINIA TECH
STUDY GROUPS
Energy Frontier
Luis Alvarez (UC Berkeley)
Henry Kendall (MIT)
Intensity Frontier
Fred Reines (UC Irvine)
Melvin Schwartz (BNL)
Cosmic Frontier
Raymond Davis (U Penn)
Hans Bethe (Cornell)
Instrumentation Frontier
Simon van der Meer (CERN)
Georges Charpak (CERN)
Computing Frontier
Richard Feynman (CalTech)
Eugene Wigner (Princeton)
Education and Outreach
Emilio Segre (UC Berekeley)
Maria Goeppert-Mayer (UCSD)
Theory Panel
Julian Schwinger (UCLA)
LOCAL ORGANIZING COMMITTEE
Donald Duck(University of Virginia)
Daisy Duck(Virginia Tech)
Huey Duck (University of North Carolina)
Dewey Duck (Virginia Tech)
Louie Duck (Virginia Tech)
Minnie Mouse (William and Mary)
Mickey Mouse (Virginia Tech, Chair)
Peter Pan (Duke)
Captain Hook (Virginia Tech)
Wendy Darling (Duke)
Pinocchio (University of Virginia)
Geppetto (University of Tennessee)
Jiminy Cricket (Virginia Tech)
Cheshire Cat (North Carolina State)
DPF EXECUTIVE COMMITTEE
Chair: Albert Einstein
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Vice Chair: Max Planck
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• James Chadwick
• Erwin Schrodinger
APS physics
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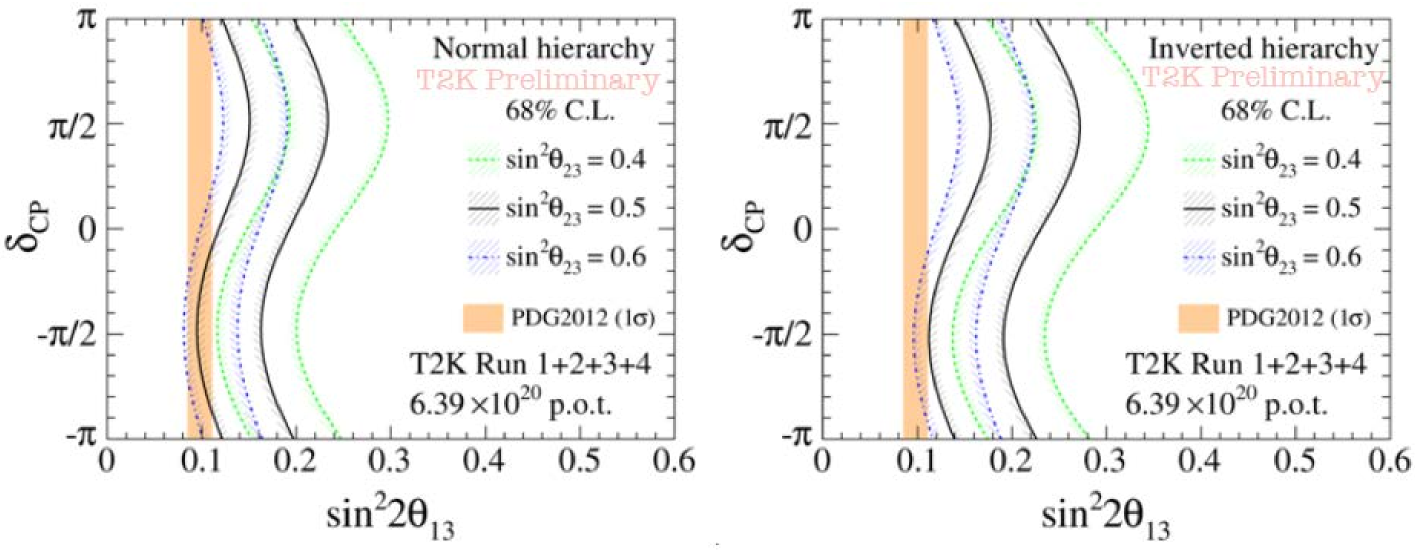
What Might We Know by Snowmass 2023?

Imagine what we may know just before the turn-on of LBNE in 2023:

- The mass hierarchy – from the combination of Pingu, Juno and Nova
- Majorana vs. Dirac – if the hierarchy is inverted
- The absolute mass scale – from Katrin or $0\nu2\beta$ if the masses are degenerate
- Hints of δ_{CP} and the θ_{23} – look at this cool plot from T2K:



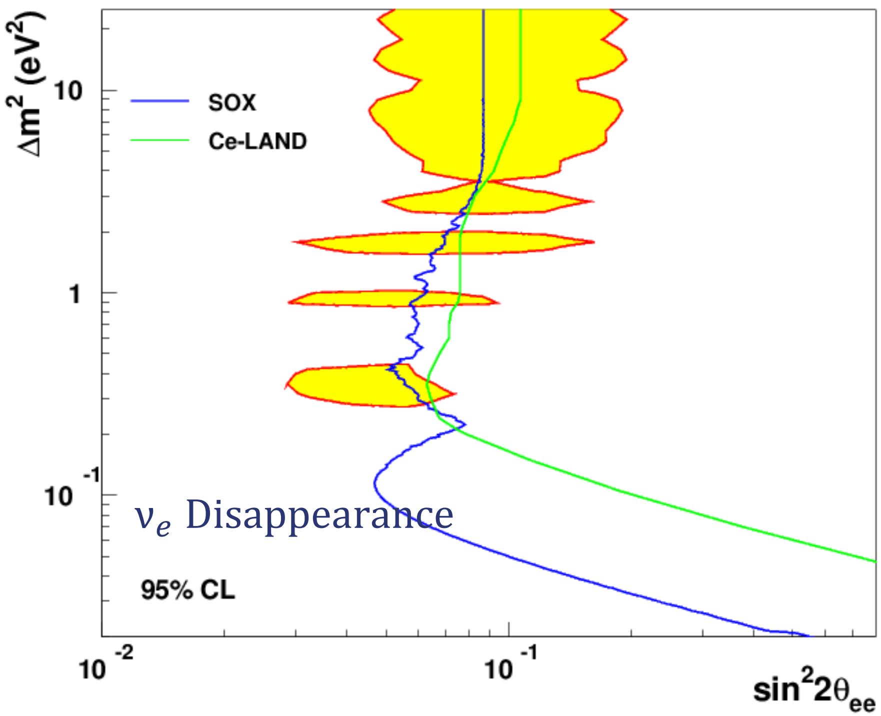
From Mike Wilking's talk at EPS HEP 2013

But we still may not have a resolution of the LSND anomaly.

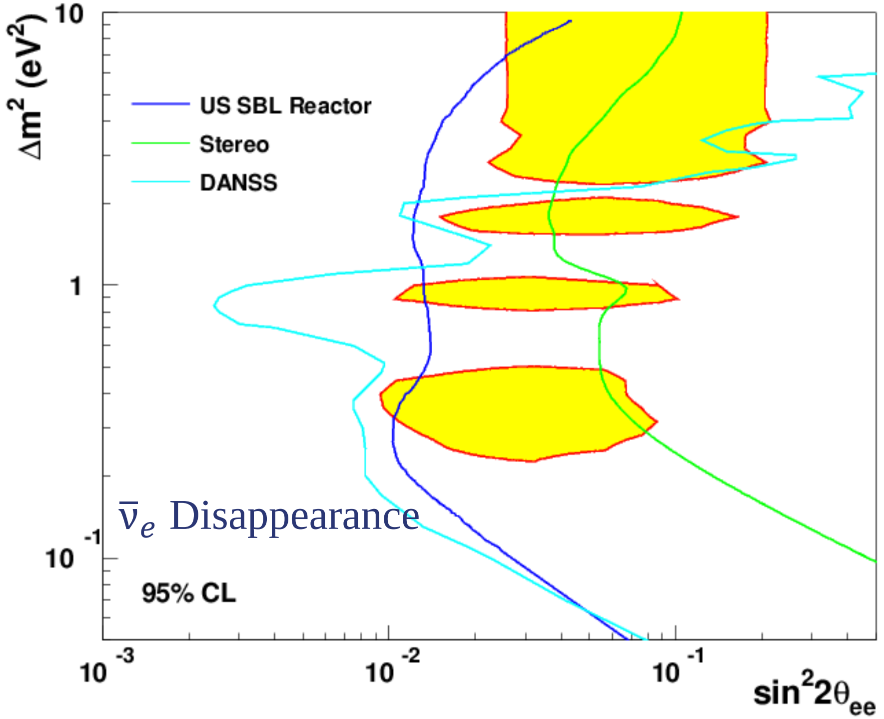
Several Ideas to Search for Sterile Neutrinos

Some have neat signatures and good discovery potential, but most will not be definitive

Radioactive Source Experiments

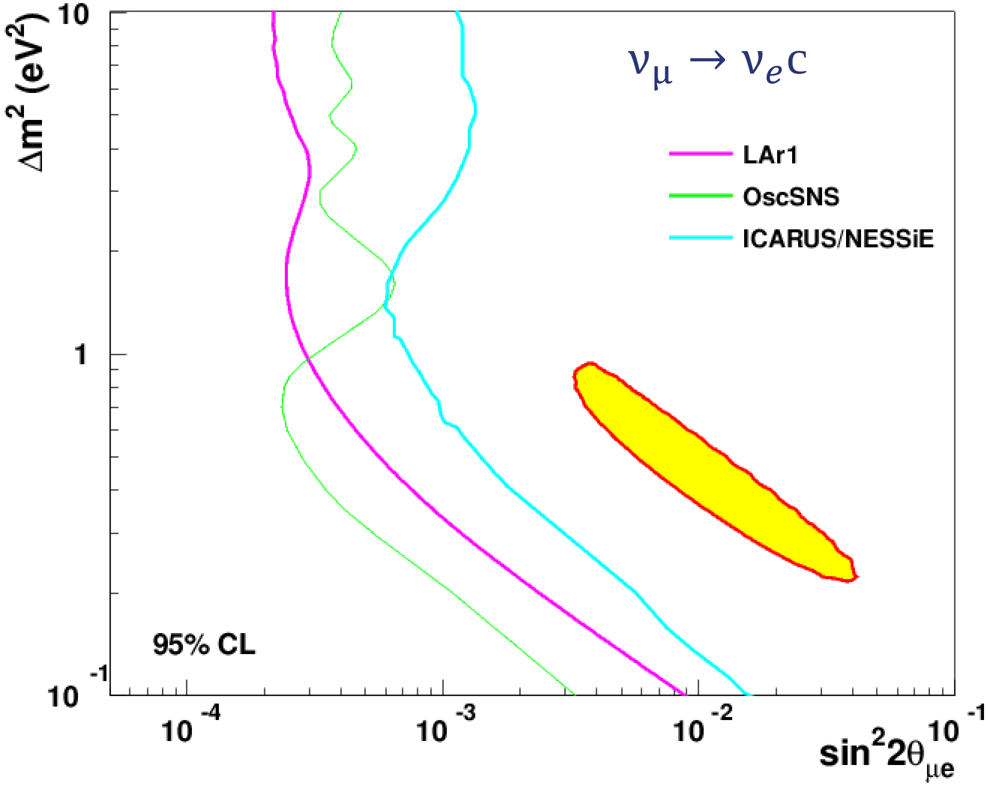


Reactor Short Baseline



(Self reported sensitivities)

Ideas for Appearance Searches



Appearance searches are almost exclusively accelerator based.

LAr1 and ICARUS/NESSiE are both π decay-in-flight beams (so called super beams).

OscSNS is a π decay-at-rest beams and therefore makes a direct test of LSND.

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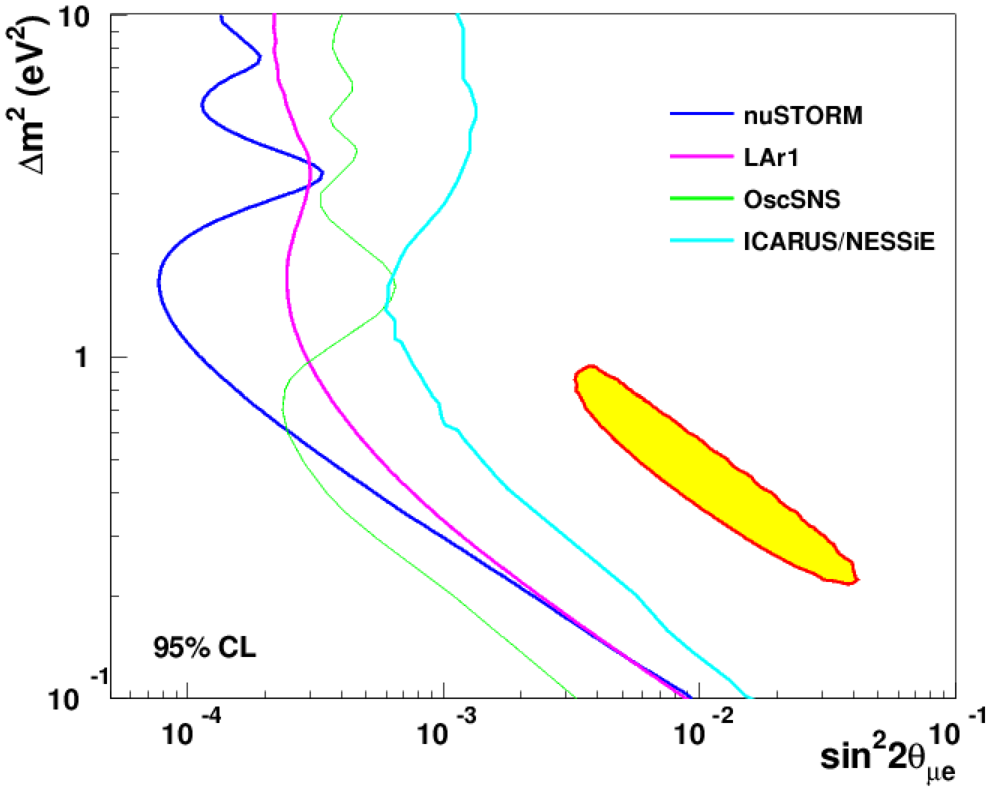

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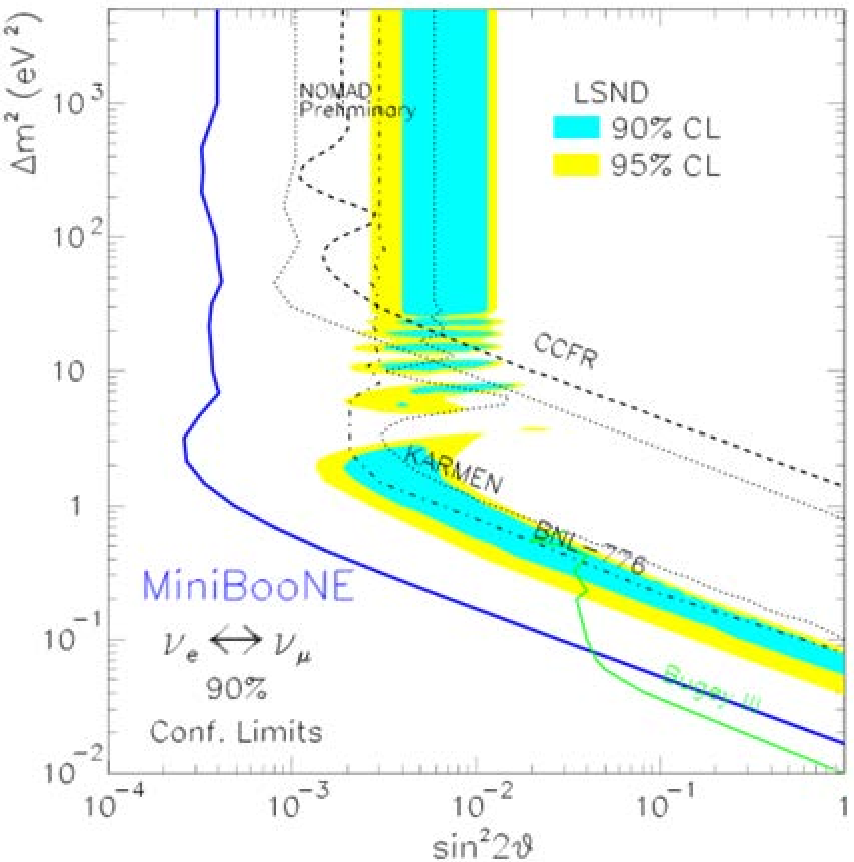
nuSTORM's primary channel is $\nu_e \rightarrow \nu_\mu$, the CPT conjugate to LSND (or $\bar{\nu}_e \rightarrow \bar{\nu}_\mu$ if μ^- are stored)

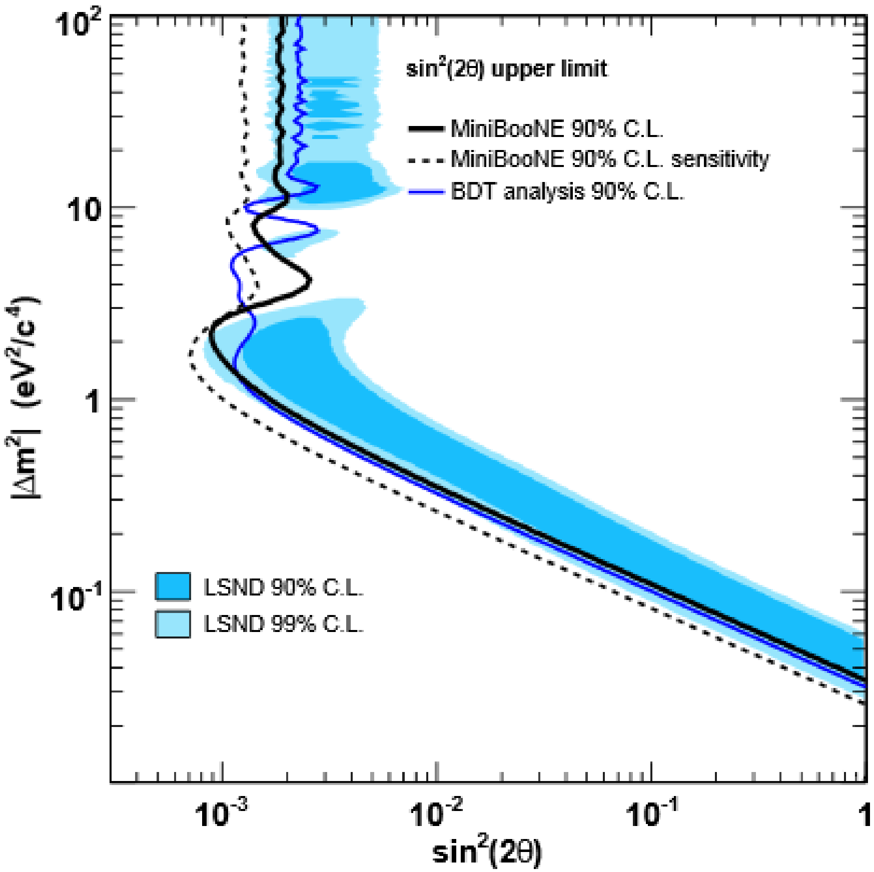
It has the best reach in $\sin^2 2\theta$ over the interesting Δm^2 region.

ν_e are Bad News

Super beam ν_e appearance experiments are very difficult. You've got an ambiguous event signature and beam intrinsic ν_e



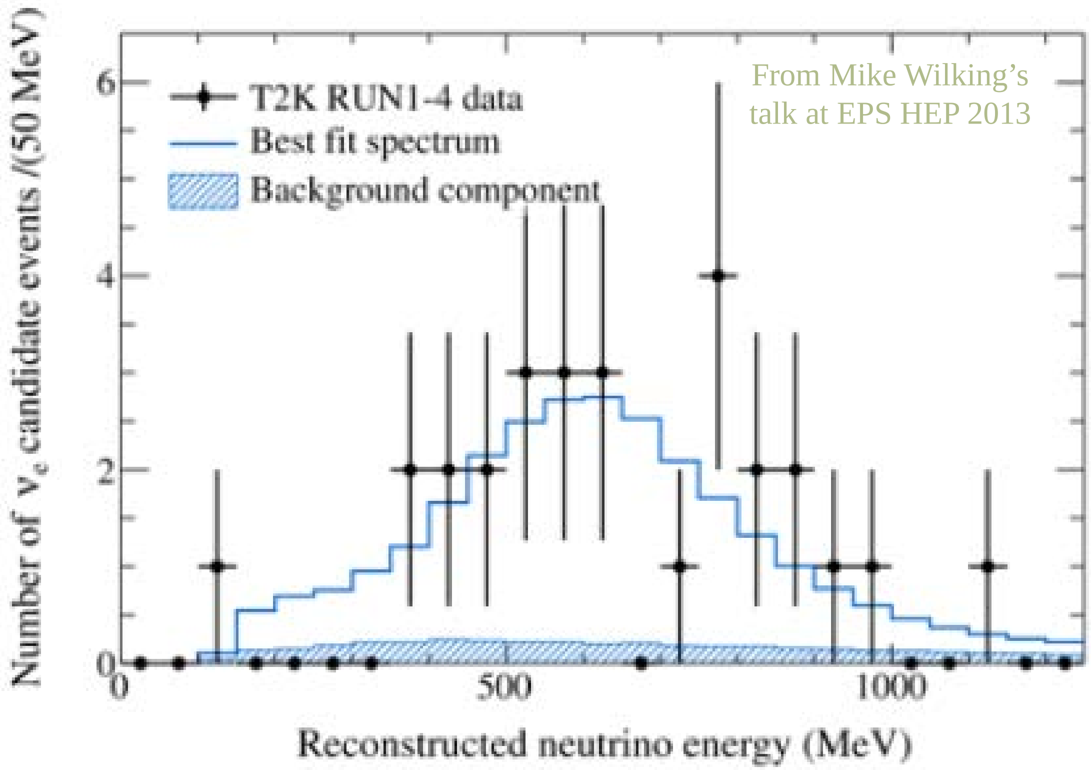
The MiniBooNE Proposal



The MiniBooNE Reality

What About the T2K

T2K demonstrated that a superbeam ν_e appearance experiment can be made to work when the mixing angle is of order 10%.



Observed 28 events over an anticipated background of 4.46±0.53

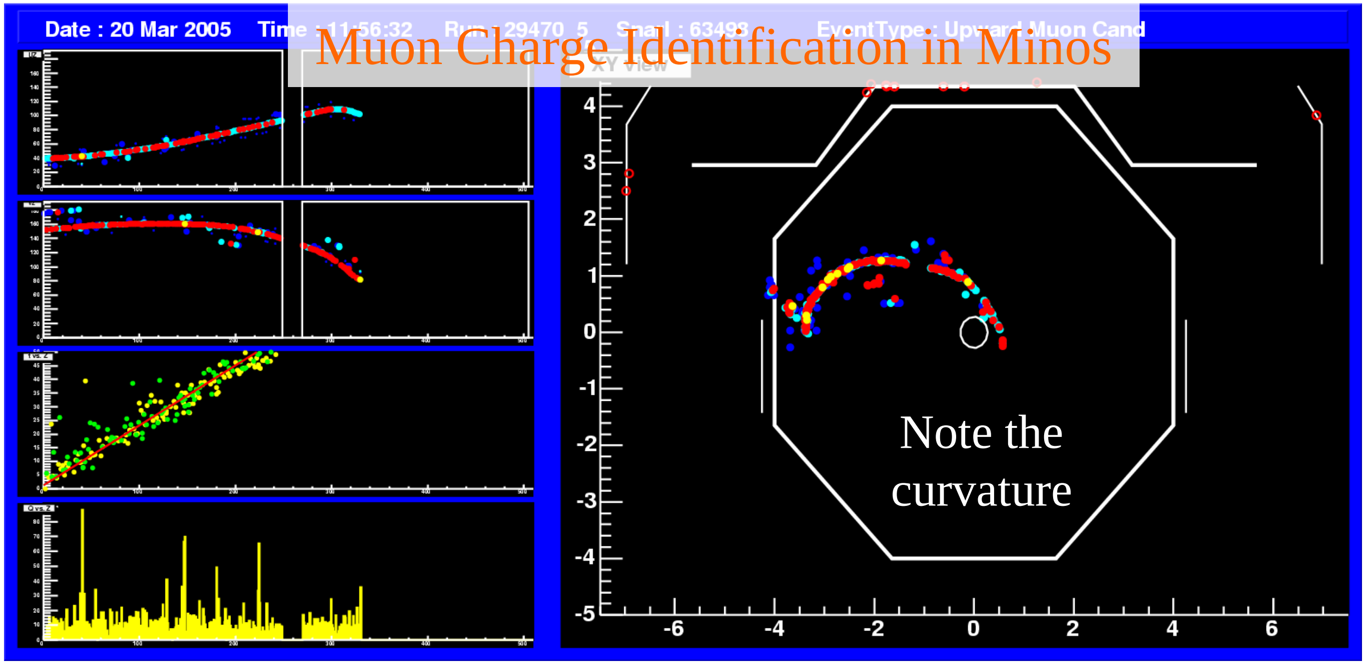
For a mixing angle of 1% for an expected S/N = 0.5

The $\nu_\mu \to \nu_e$ allowed region from global fits extends below 0.4% for S/N < 0.2 ($\approx \sigma_{BG}$).

So T2K: great success, but not a demonstration of feasibility for short-baseline ν_e appearance searches.

The $\nu_e \rightarrow \nu_\mu$ Golden Mode Channel

In nuSTORM, $\nu_e \rightarrow \nu_\mu$ can be cleanly identified by looking at the charge of the produced muon.



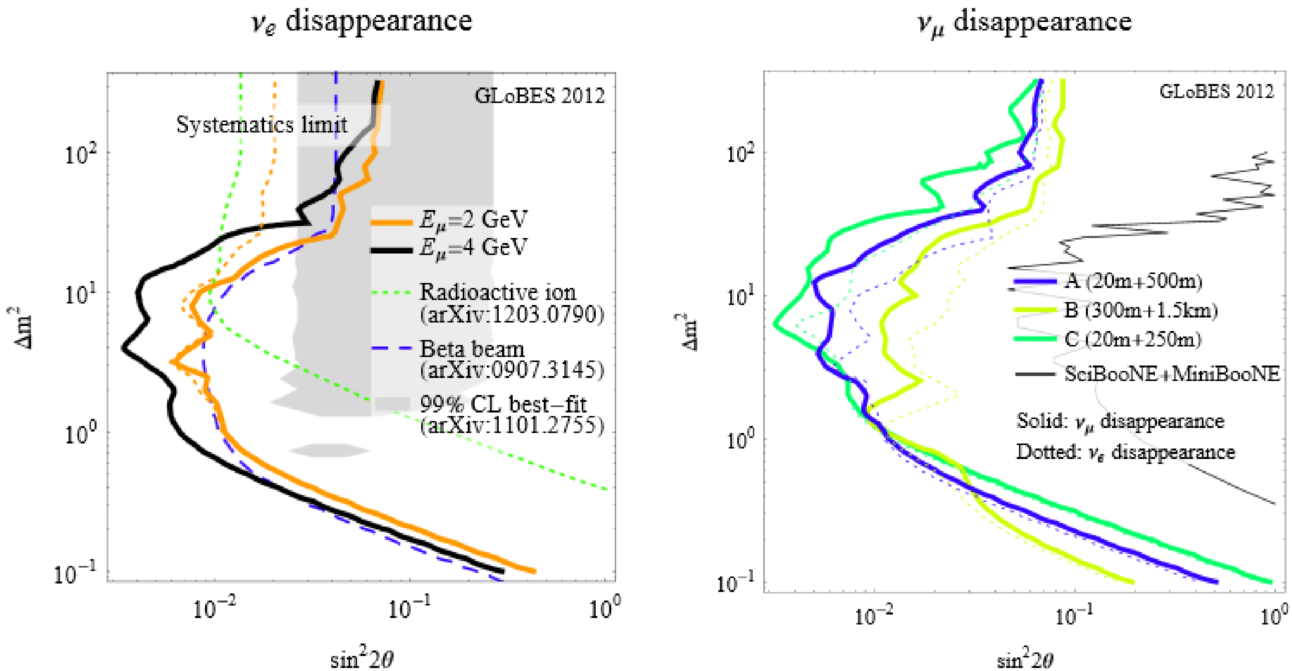
There is no source of intrinsic, wrong-sign muons.

The muon signature in the detector is unique.

6 Oscillation Channels Available to nuSTORM

In addition to the ν_μ and $\bar{\nu}_\mu$ appearance channels, the clean, well-characterized beams of nuSTORM can do:

- ν_μ and $\bar{\nu}_\mu$ disappearance
- ν_e and $\bar{\nu}_e$ disappearance



Winter, Phys.Rev.D85, 113005 (2012)

Final Thoughts

As a machine for short-baseline oscillations, nuSTORM is unique:

1. It produces clean, well-understood beams of ν_e and $\bar{\nu}_\mu$.
2. The signature of the golden mode oscillation channel, $\nu_e \rightarrow \nu_\mu$, is hard to fake in the detector.
3. In addition to ν_μ appearance, ν_μ and ν_e disappearance channels are accessible (in both neutrinos and antineutrinos).
4. nuSTORM is the next step on a path to a full neutrino factory and a muon collider.