QG-MM

Low Energy neutrino Experiments

Marina Manganaro
(University of Rjeka) for WG4

-- COST Action CA18108 02/10/2019 Barcelona ---

WG4 contributions at the present meeting

2nd of October:

neutrinos: phenomenology
-Mariam Tortola (LE)
-Guenter Sigl (HE)

3rd of October:

neutrinos: experiments
-Marina Manganaro (LE)
-Bruny Baret (HE)

W4 contributions at the present meeting

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Review talks

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Anti-Review talks

Bonus: where are neutrinos coming from?

Neutrinos: protagonists of the multi-messenger era

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Neutrinos: kittens of the multi-messenger era

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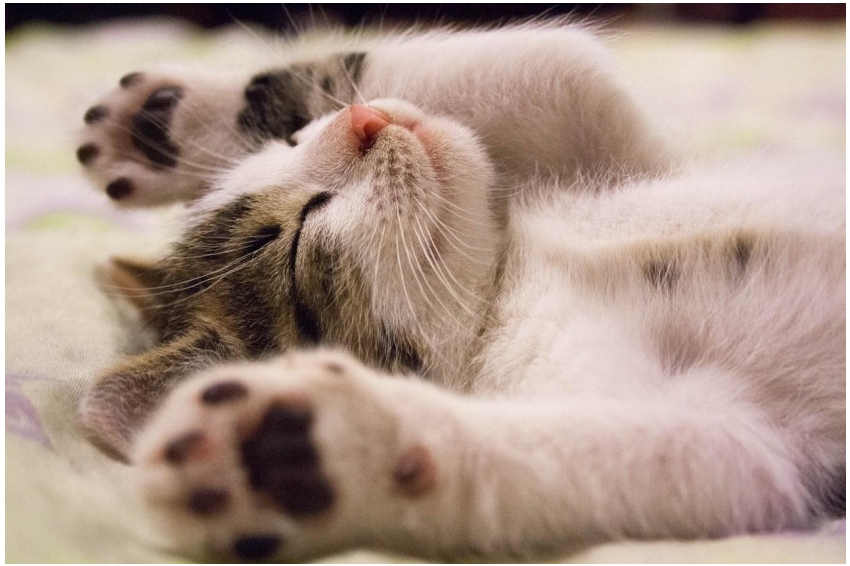
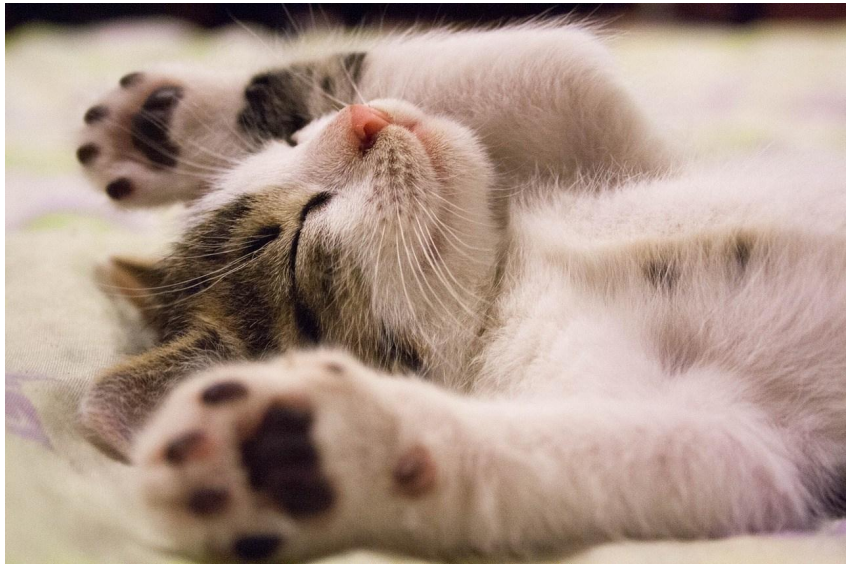
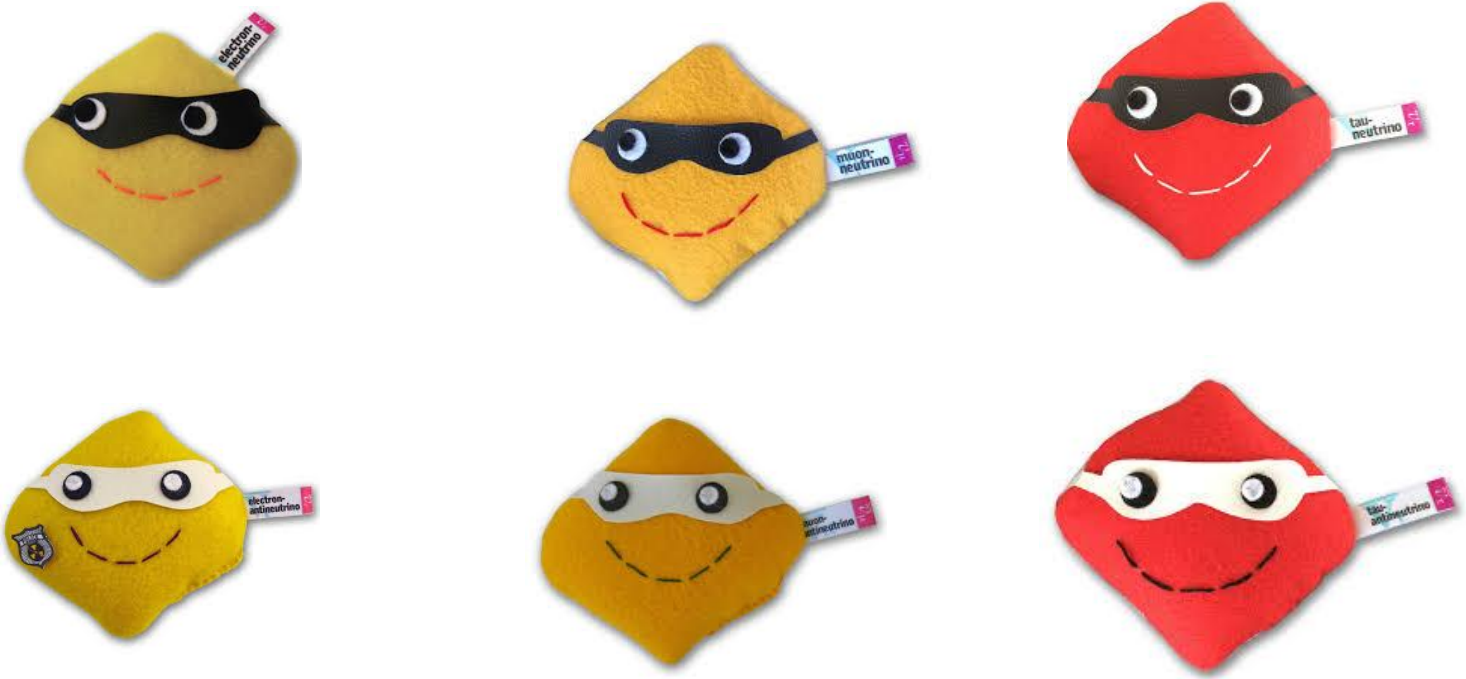


Neutrinos: kittens of the multi-messenger era



Neutrinos experiments: so challenging!



Where are neutrinos hiding?

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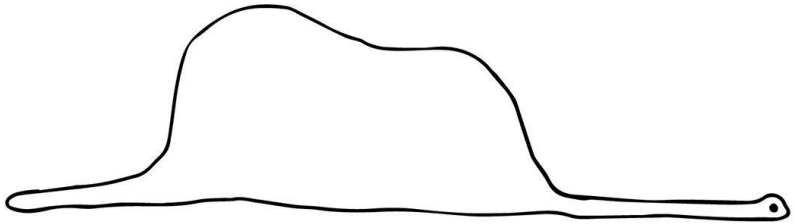

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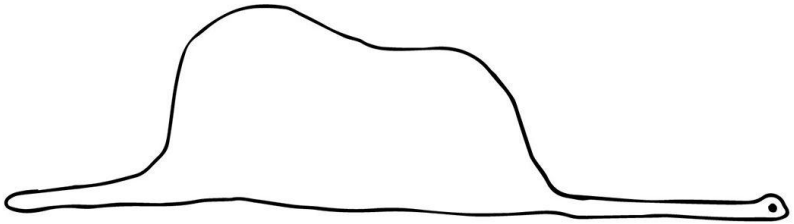

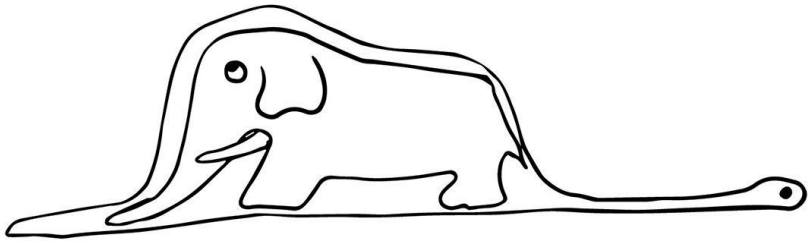

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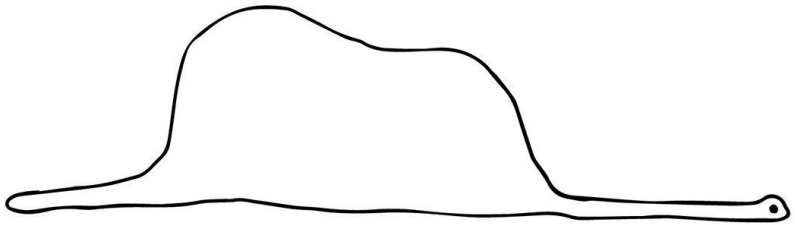
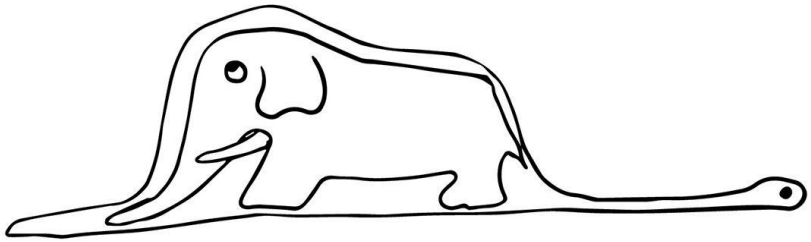
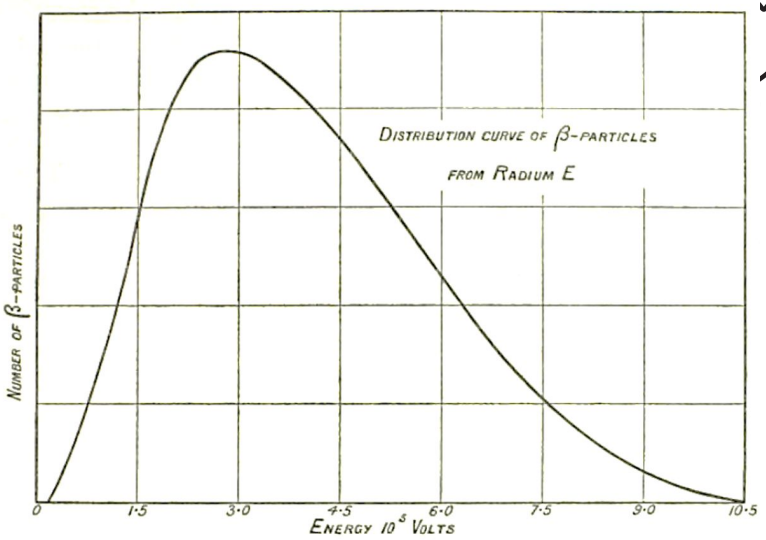
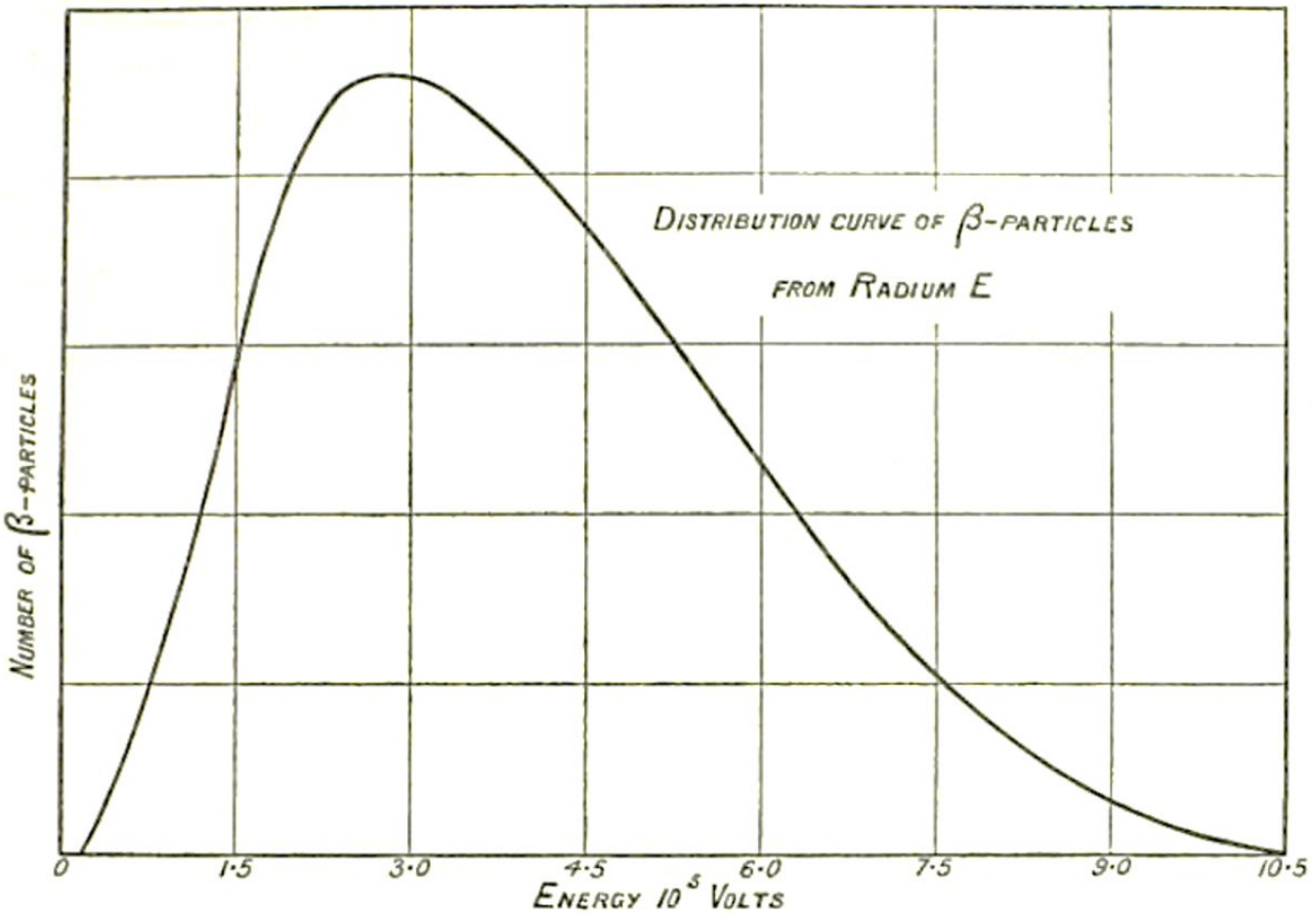






Where are neutrinos hiding?



KATRIN (KArlsruhe TRItium Neutrino)

First KATRIN Neutrino Mass Run Sensitivity Figures

Sensitivity

Statistics dominated

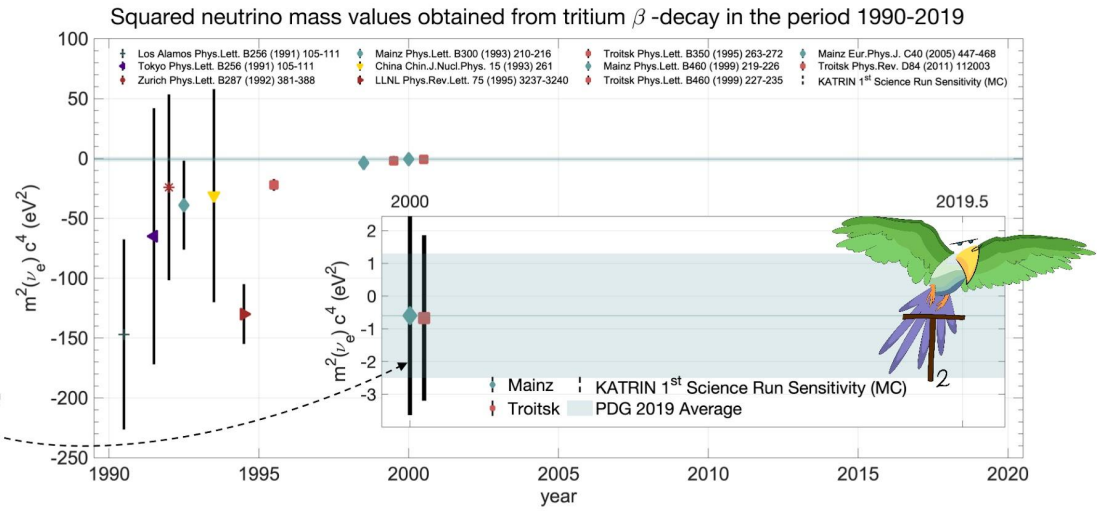
1σ on $m^2 = 0.8\ eV^2$

$m_\nu < 1.1$ eV (90% CL)

Statistics improved x2

~5 days of KATRIN nominal

Systematics reduced x6



From TAUP 2019 talk by T. Lasserre . for details on the set up: arXiv:1909.06069

KATRIN (KArlsruhe TRItium Neutrino)

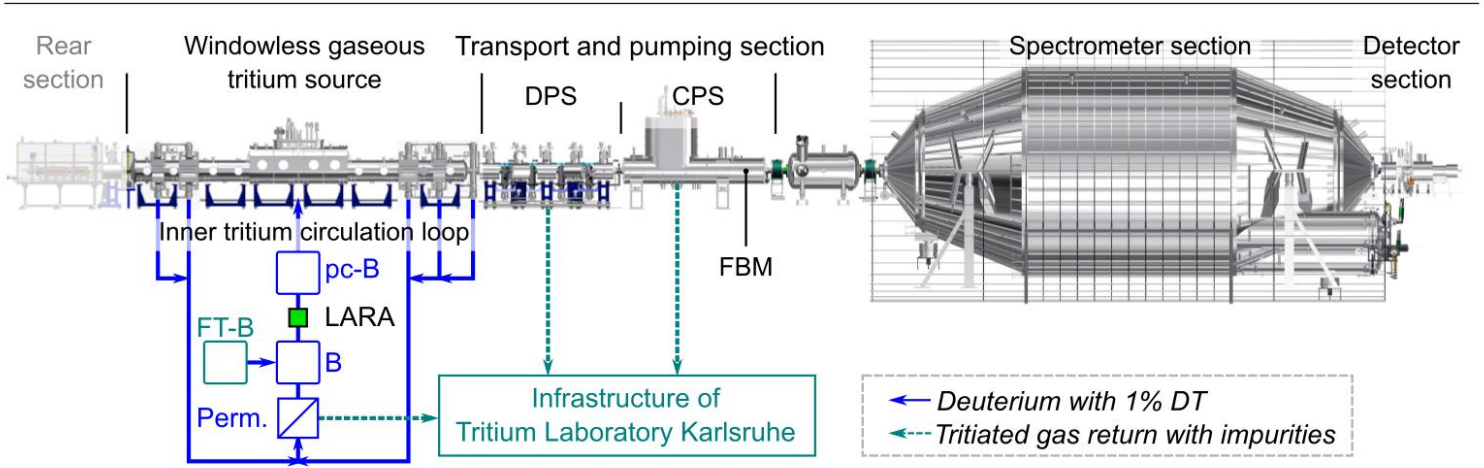


Fig. 1 The experimental setup of the 70-m-long KATRIN beamline with a conceptual sketch of the tritium loop in the configuration during the First Tritium campaign. FT-B: Gas buffer with pre-defined gas mixture: 1 % DT in D_2. pc-B, B: (pressure-controlled) buffer vessels. LARA: compositional monitoring by Laser Raman spectroscopy. Perm.: Permeator for hydrogen purification. FBM: Forward Beam Monitor. DPS: Differential Pumping Section. CPS: Cryogenic Pumping Section. The rear section (grayed out) was not used during the FT campaign.

From Aker M. et al., arXiv:1909.06069

Reactor neutrino experiments

Accelerators experiments

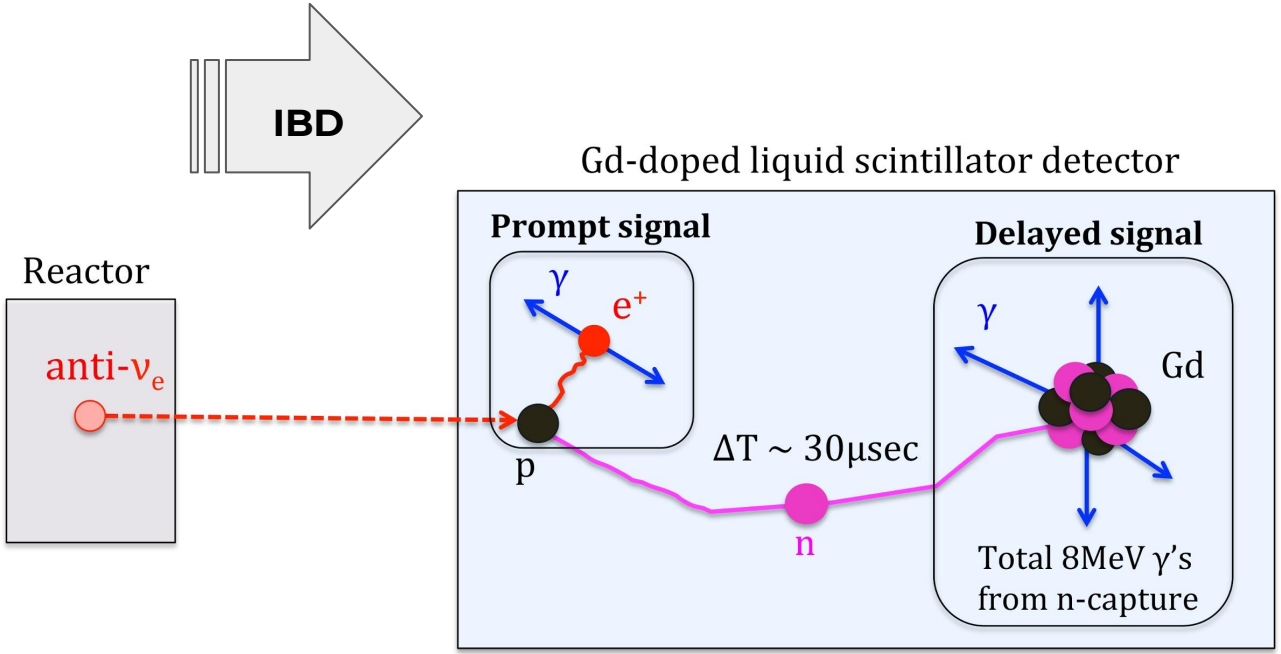
Neutrino telescopes

Solar neutrinos

Neutrino oscillations

Double Beta Decay

Reactor neutrino experiments



Double Chooz

$$U_{3\times3} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} *$$

atmospheric + accelerator disapp

SBL reactor + accelerator app

solar + KamLAND

Δm^2_{31} Δm^2_{31} Δm^2_{21}

* Stolen from Mariam's talk

Double Chooz

MESSENGER · MULTI · QUANTUM · GRAVITY ·

Double Chooz

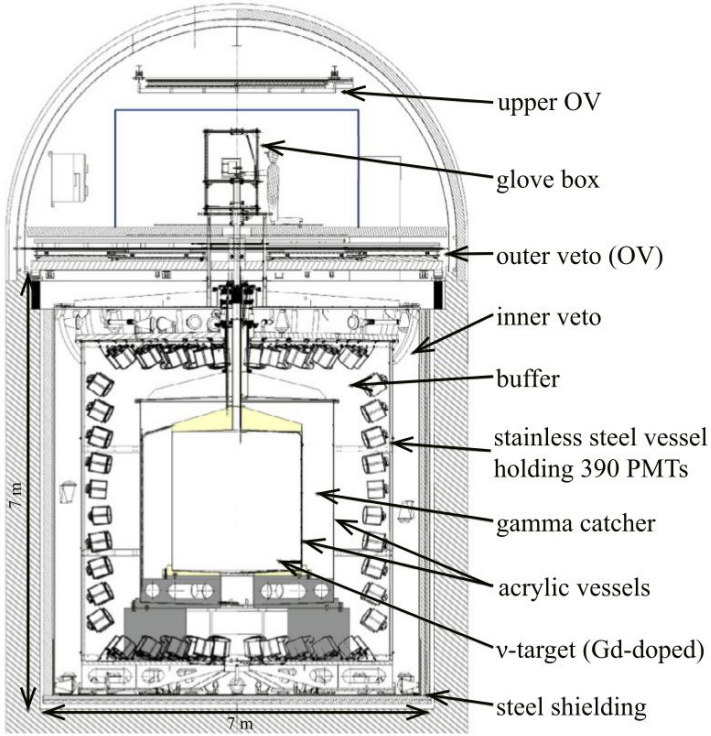
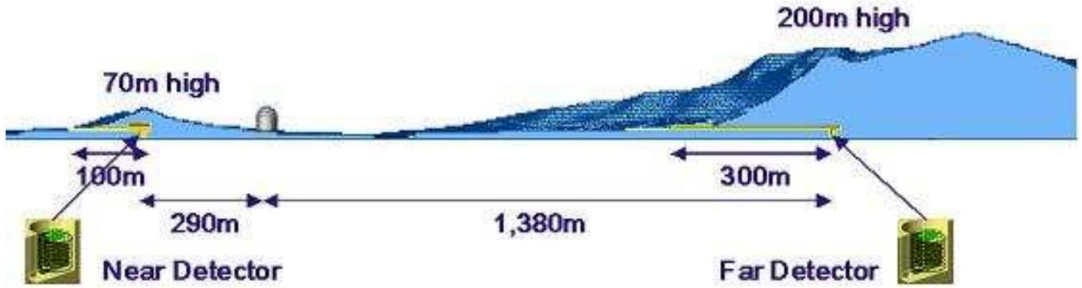
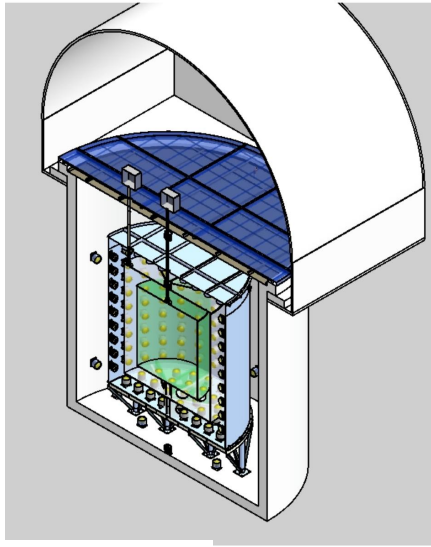


Fig. 4. Double Chooz detector. From inner to outer, (i) Neutrino target scintillator, (ii) γ-Catcher scintillator, (iii) Buffer oil, (iv) PMT array, (v) Inner muon veto scintillator and (vi) Outer muon veto counter.

From Suekane F. et al. (2016), NPB 908, 74

RENO (Reactor Experiment for Neutrino Oscillation)

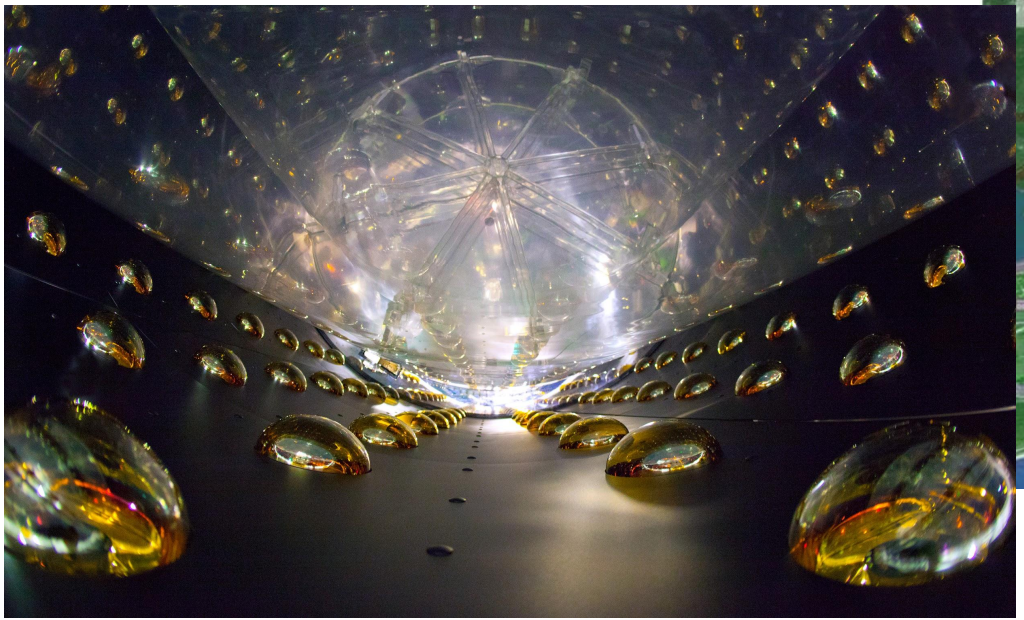


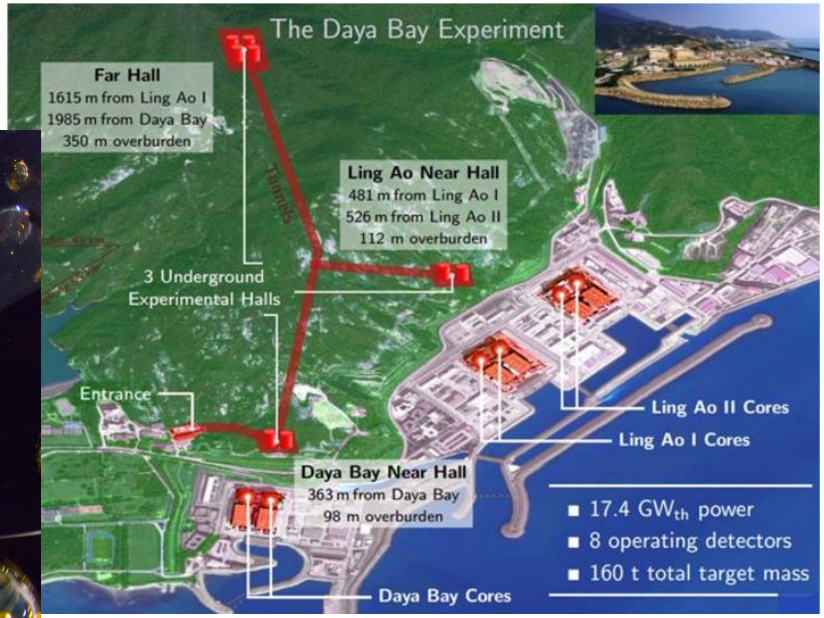


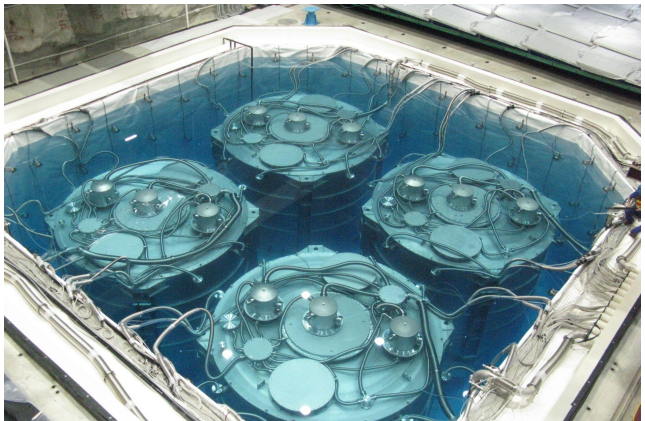
Experiment	Location	Total Reactor Thermal Output (GW_{th})	Detector Distance Near/Far (m)	Overburden Near/Far (mwe)	Target Mass (Near/Far) (tons)
Double Chooz	France	8.7	410/1067	115/300	10/10
Daya Bay	China	11.6(17.4)	360(500)/1985(1613)	260/910	40×2/10
RENO	Korea	16.4	292/1380	110/450	16.1/16.1

From Ahn J. K.. et al. (2010), arXiv: 1003.1391

Daya Bay

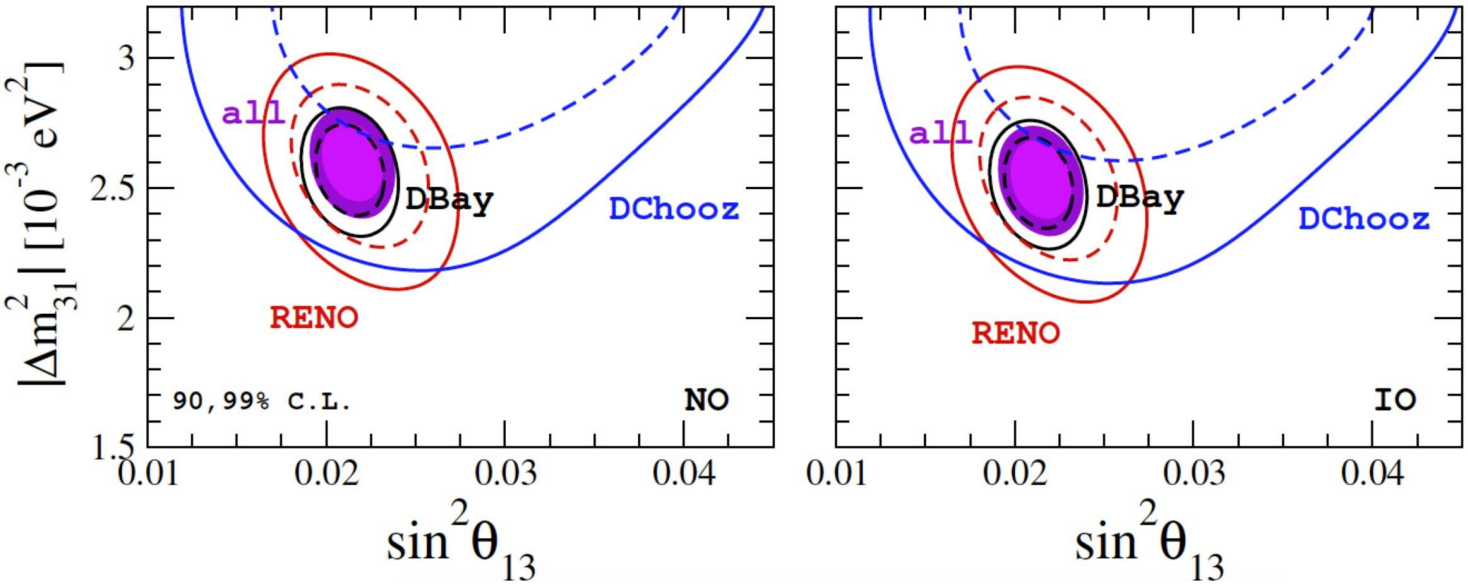






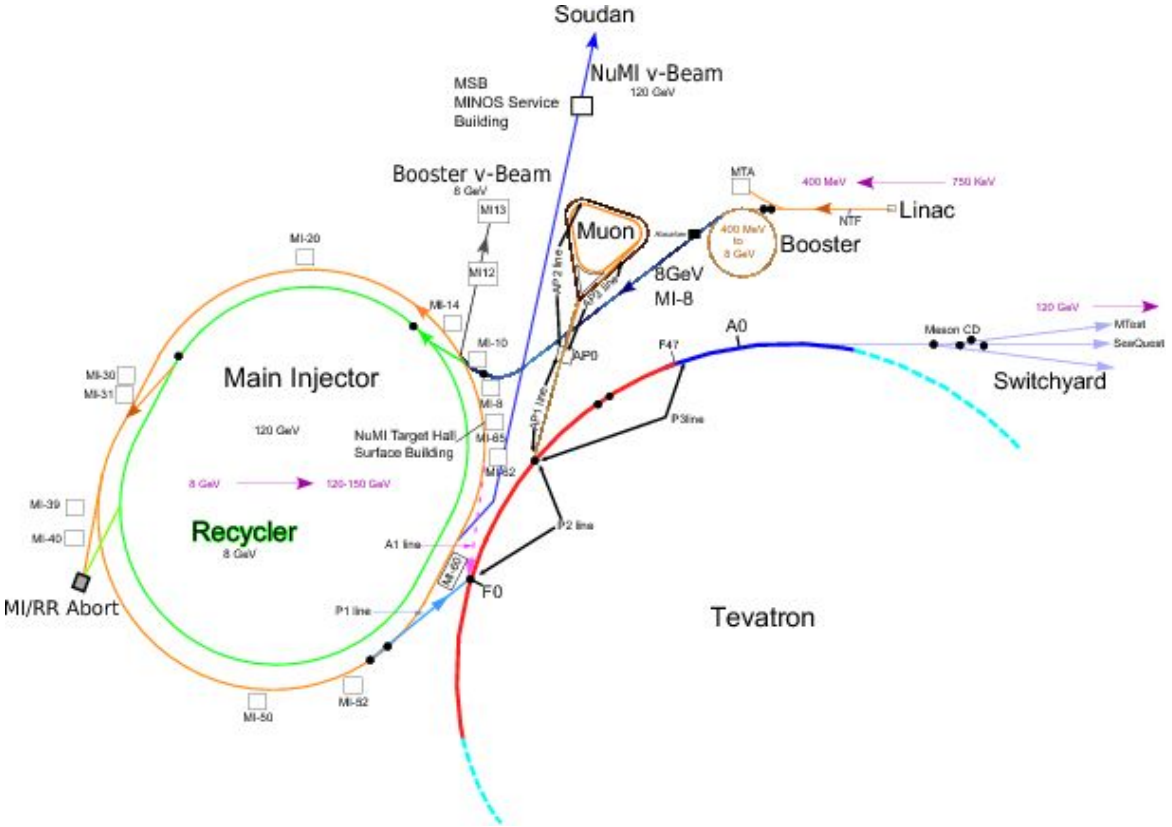
lts from Daya Bay in Adamson P. et al. (2016), arXiv: 1607.01177

Combined results from reactors



De Salas et al., PLB 782,633 (2018)

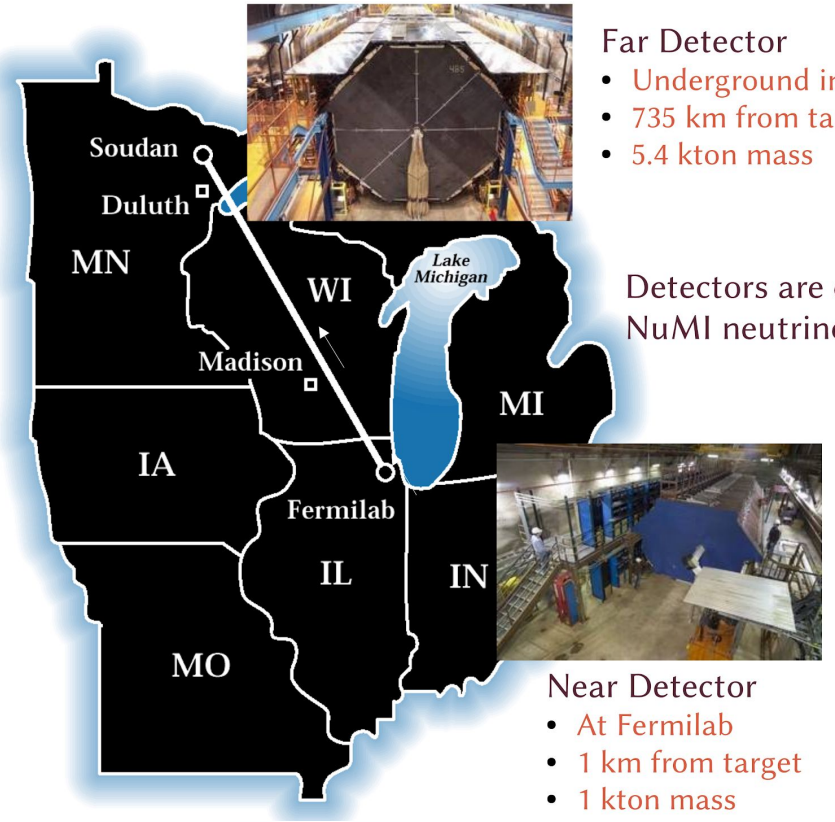
Accelerators experiments



MINOS and MINOS+ (Main Injector Neutrino Oscillation Search)

MINOS and MINOS+ (Main Injector Neutrino Oscillation Search)

- MINOS and MINOS+ were designed to study neutrino oscillations over long baselines using two detectors that are:
  - Iron-scintillator tracking calorimeters to contain muons
  - Functionally identical for systematic uncertainty reduction
  - Magnetized for sign selection and energy estimation



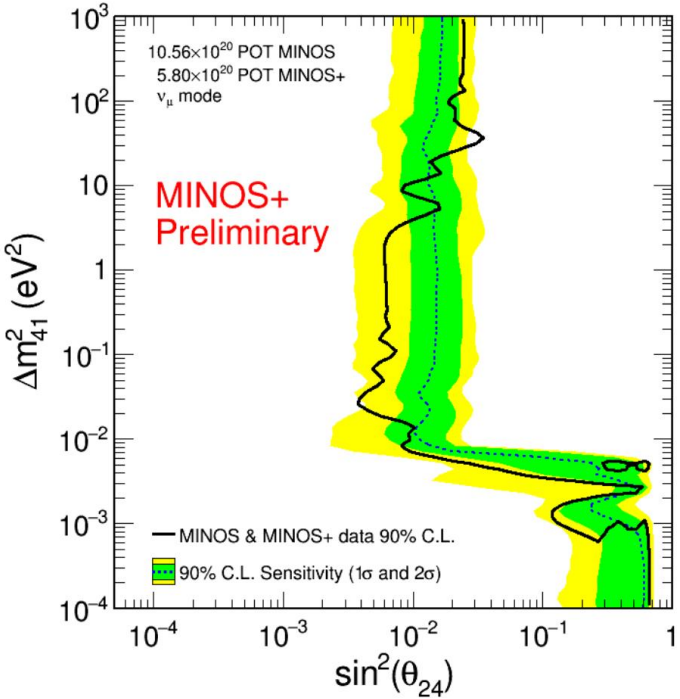
Far Detector
- Underground in Soudan mine
- 735 km from target
- 5.4 kton mass

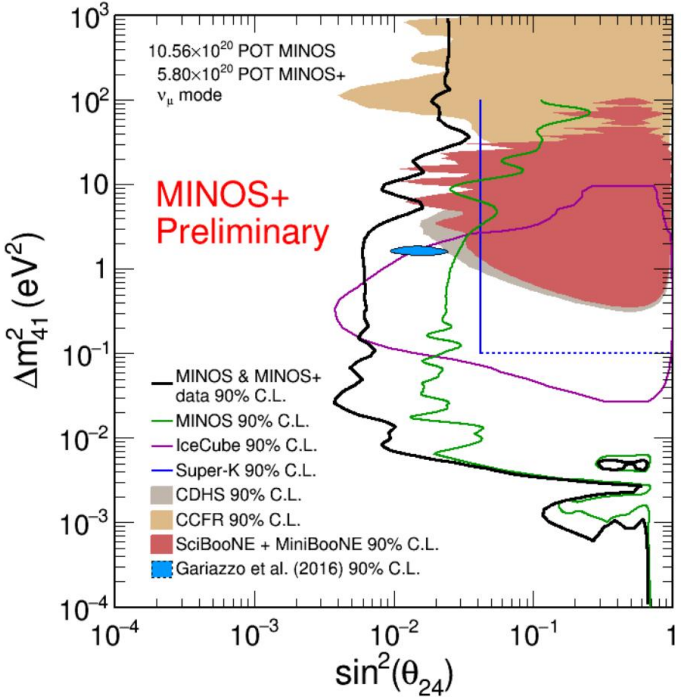
Detectors are on-axis for NuMI neutrino beam

Near Detector
- At Fermilab
- 1 km from target
- 1 kton mass

isano, talk at Neutrino 2018

MINOS and MINOS+





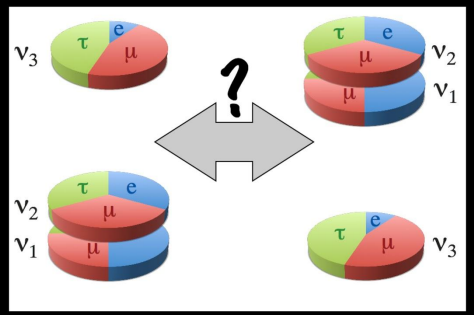
J.Todd, Nufacts 2018

NOvA

NOVA'S PHYSICS GOALS

THE NOVA PROGRAM SEEKS TO ANSWER KEY UNKNOWNS

- What is the mass hierarchy or ordering for atmospheric neutrinos?
- Is there a ν_μ - ν_τ symmetry (is the large mixing angle maximal; if not, what is the octant)?
- Is CP violated in the lepton sector?
- Are there other neutrinos beyond the three known active flavors?



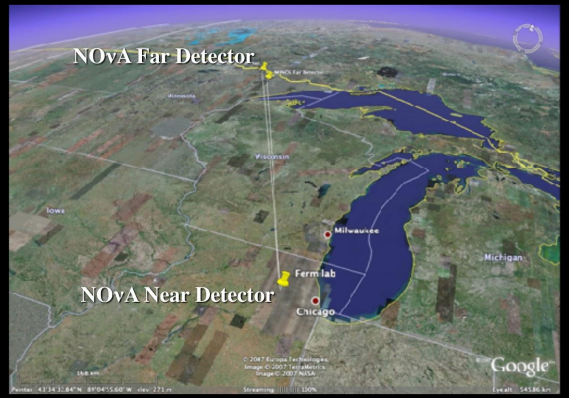
In addition, cross section analyses, searches for exotic phenomena and non-beam physics

From Neutrino 2018 conference, "Nova results and prospects" by M. Sanchez et al.

NOvA

THE NOVA EXPERIMENT IN A NUTSHELL

- Upgraded NuMI **beam of muon neutrinos or antineutrinos** at Fermilab running at 700kW.
- Highly active liquid scintillator **14-kton detector** off the main axis of the beam.
  - Functionally identical detectors: Near Detector (ND) site at Fermilab and Far Detector (FD) 810 km away at Ash River, MN.
- NOvA observes **disappearance of muon neutrinos and antineutrinos, appearance of electron neutrinos and antineutrinos** and potential suppression of neutral current interactions.

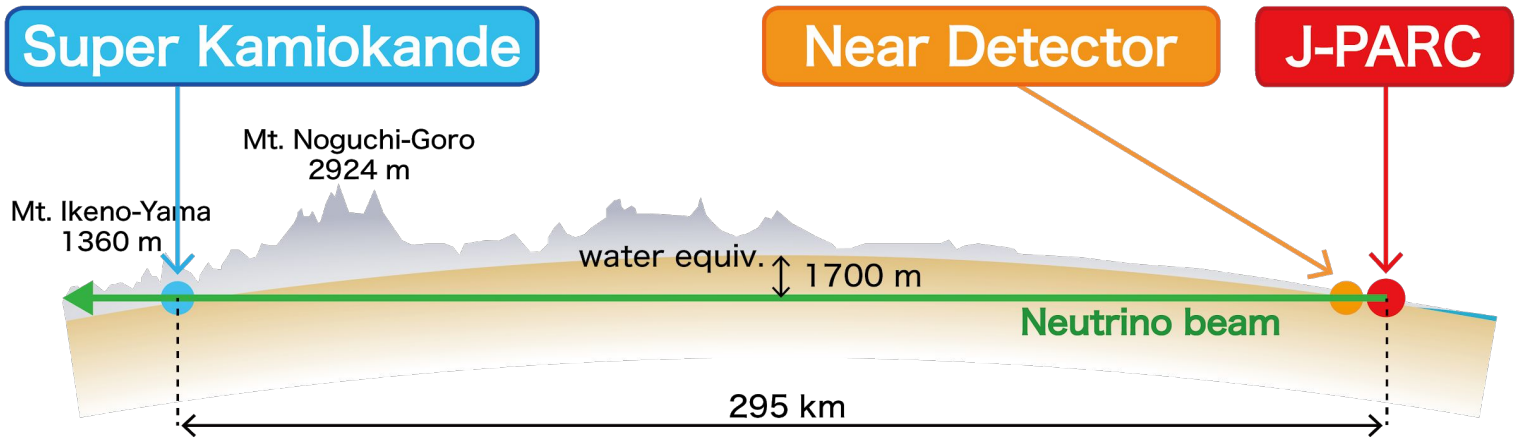


← longest baseline →

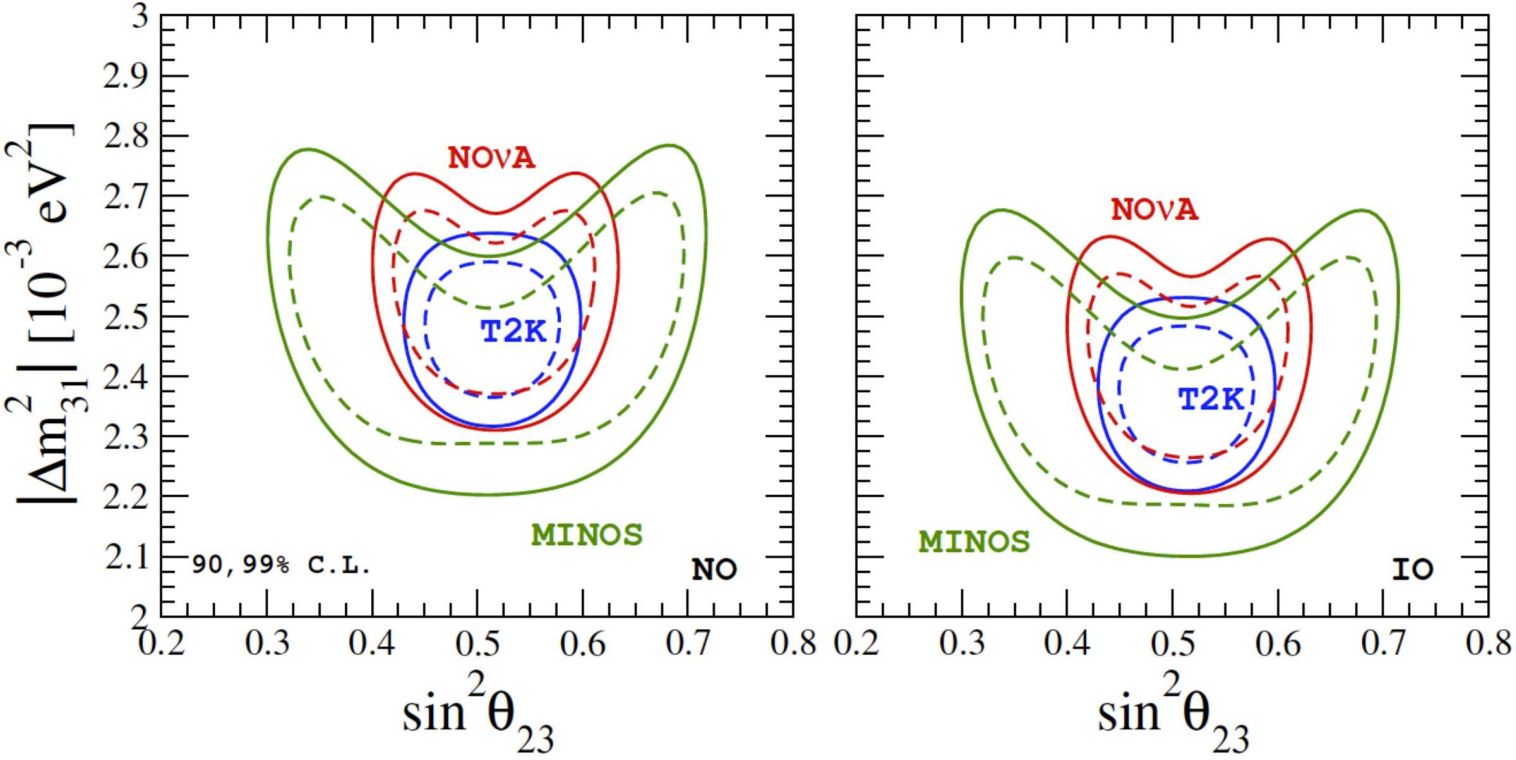
Mayly Sanchez - ISU 5

From Neutrino 2018 conference, “Nova results and prospects” by M. Sanchez et al.

T2K (Tokai to Kamioka)

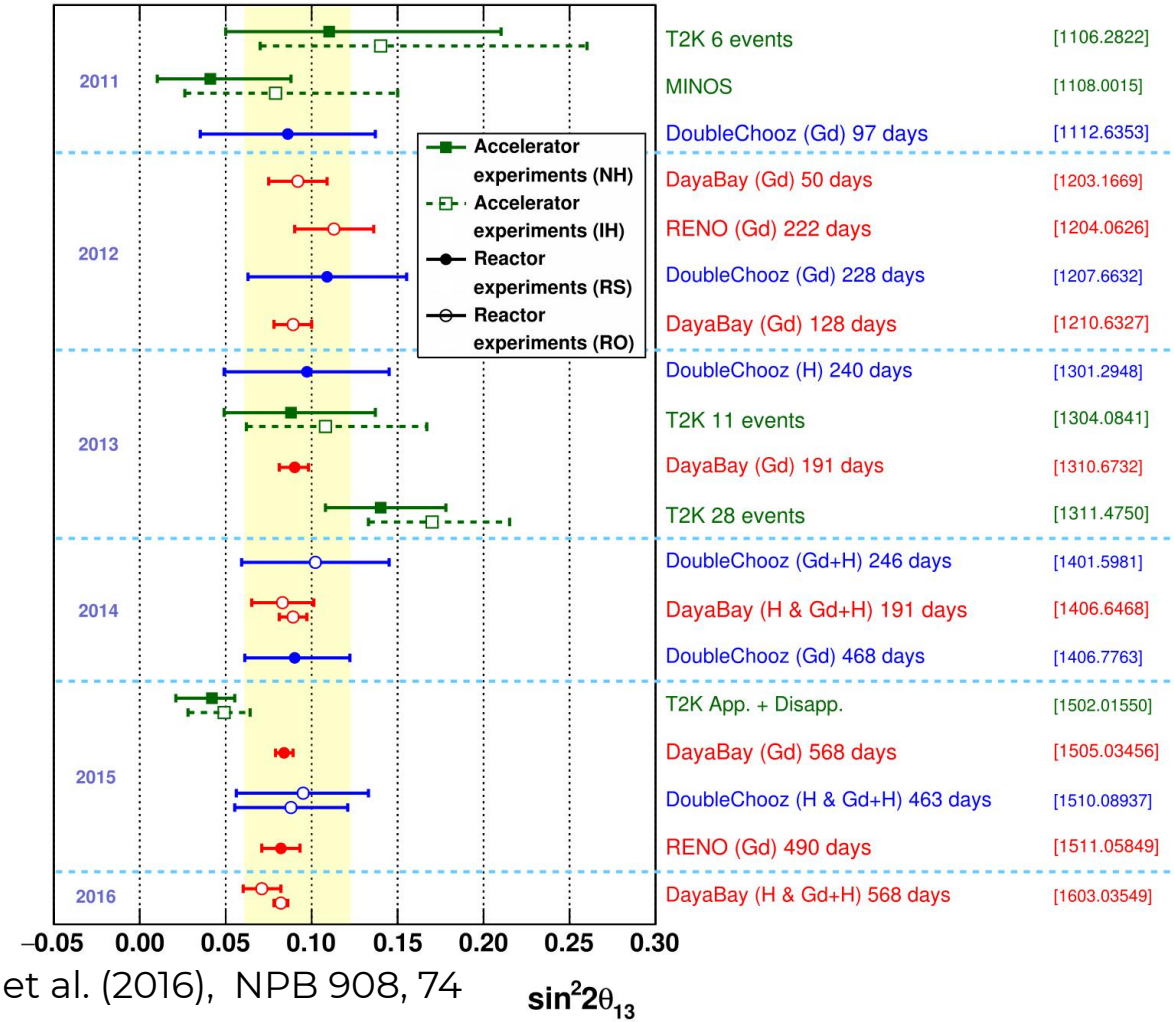


Combined results from accelerators



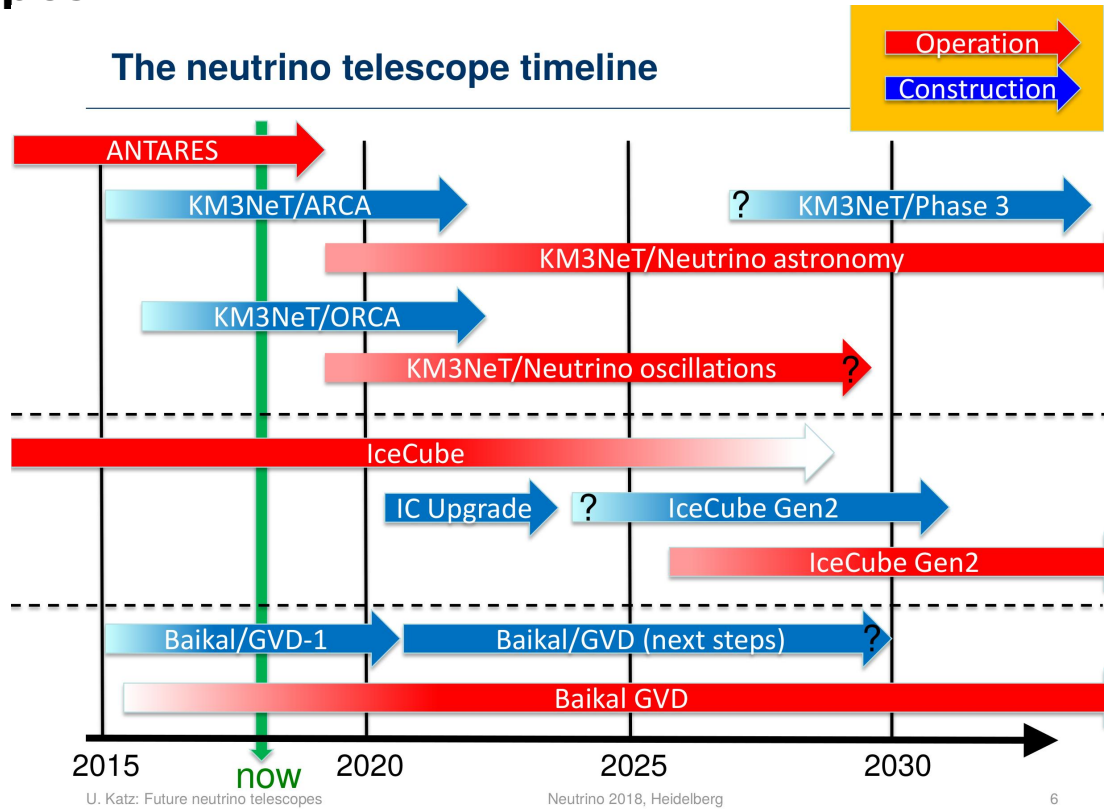
Stolen from Mariam's talk

Combined results from reactors and accelerators



From Suekane F. et al. (2016), NPB 908, 74

Neutrino telescopes



From Neutrino 18 conference, “Future neutrino telescopes” by U. Katz et al.

KM3Net ORCA3

ORCA (Oscillations Research with Cosmics in the Abyss) is the low-energy branch of KM3NeT, the next generation underwater Cherenkov neutrino detector in the Mediterranean.
Interactions of neutrinos in seawater at low (< 100 GeV) energies.
Goals: -to resolve the long-standing unsolved question of whether the neutrino mass ordering (NMO) is normal or inverted by measuring matter oscillation effects with atmospheric neutrinos;
-to study exotic oscillation phenomena such as sterile neutrinos and non-standard Interactions
-astrophysics and supernova neutrinos (reference to multi-messenger astronomy)

KM3Net ORCA

NSI-> Non Standard Interactions

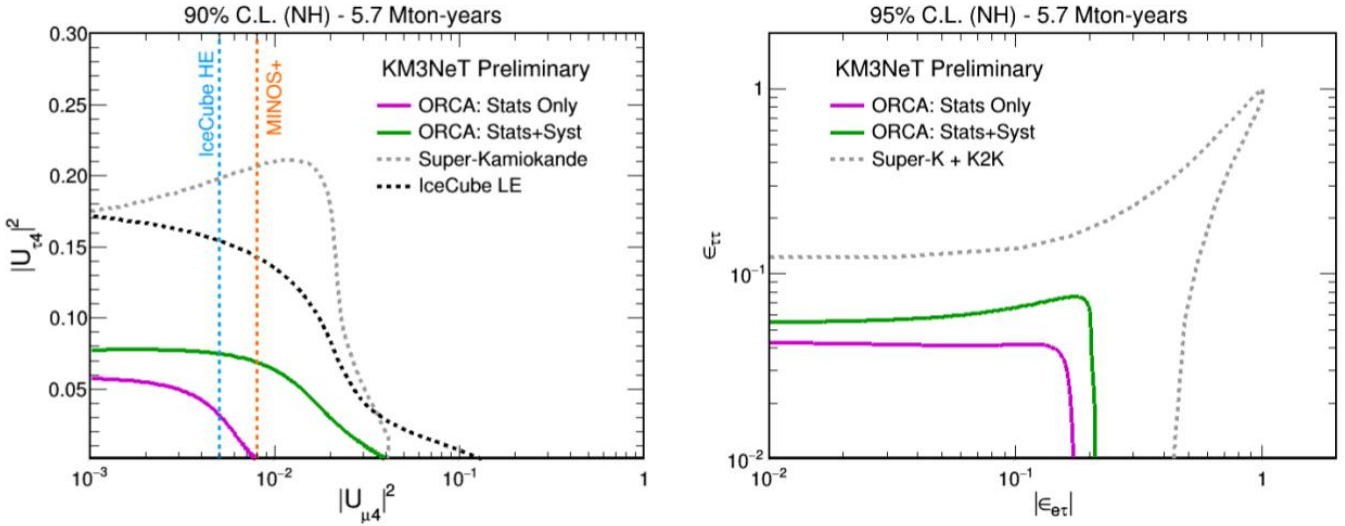


Figure 4: Sensitivity to sterile neutrinos (left) and NSI (right) for the LoI 9 m spacing configuration, including a fit of θ_{23}, ΔM^2, and four other systematics (see text). Sensitivities are for one year of operation time. For comparison, current limits on sterile neutrino mixing from Super-Kamiokande [12], IceCube [13], and MINOS+ [14] are shown as well as limits on NSI from a Super-Kamiokande and K2K analysis [15].

From PoS ICRC 2017 by A. Kouchner et al.

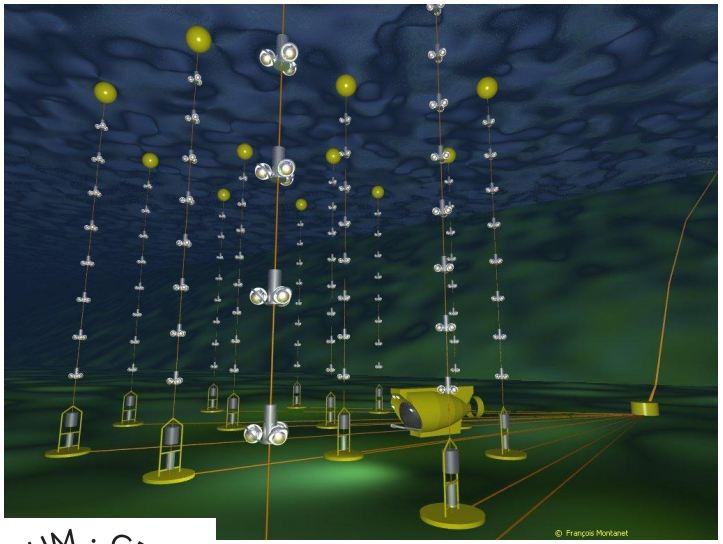
IceCube DeepCore

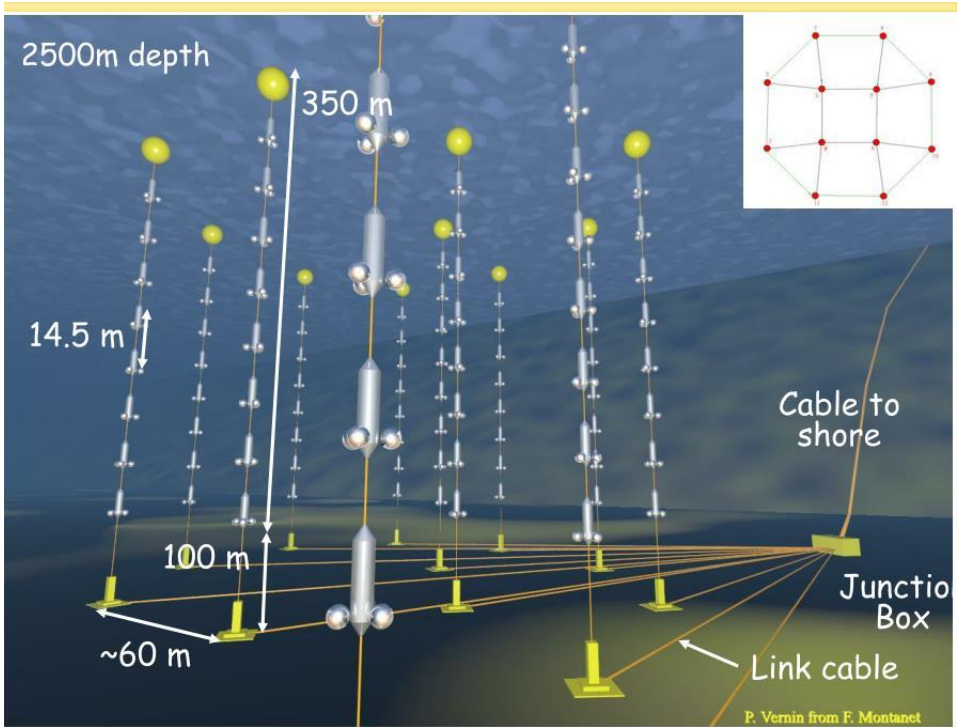
-designed to lower the IceCube neutrino energy threshold by over an order of magnitude, to energies as low as about 10 GeV.
-situated primarily 2100 m below the surface of the icecap at the South Pole, at the bottom center of the existing IceCube array, and began taking physics data in May 2010.
-neutrinos from WIMP dark matter annihilations, atmospheric neutrino oscillations, galactic supernova neutrinos, and point sources of neutrinos in the northern and southern skies.

arXiv: 1109.6096

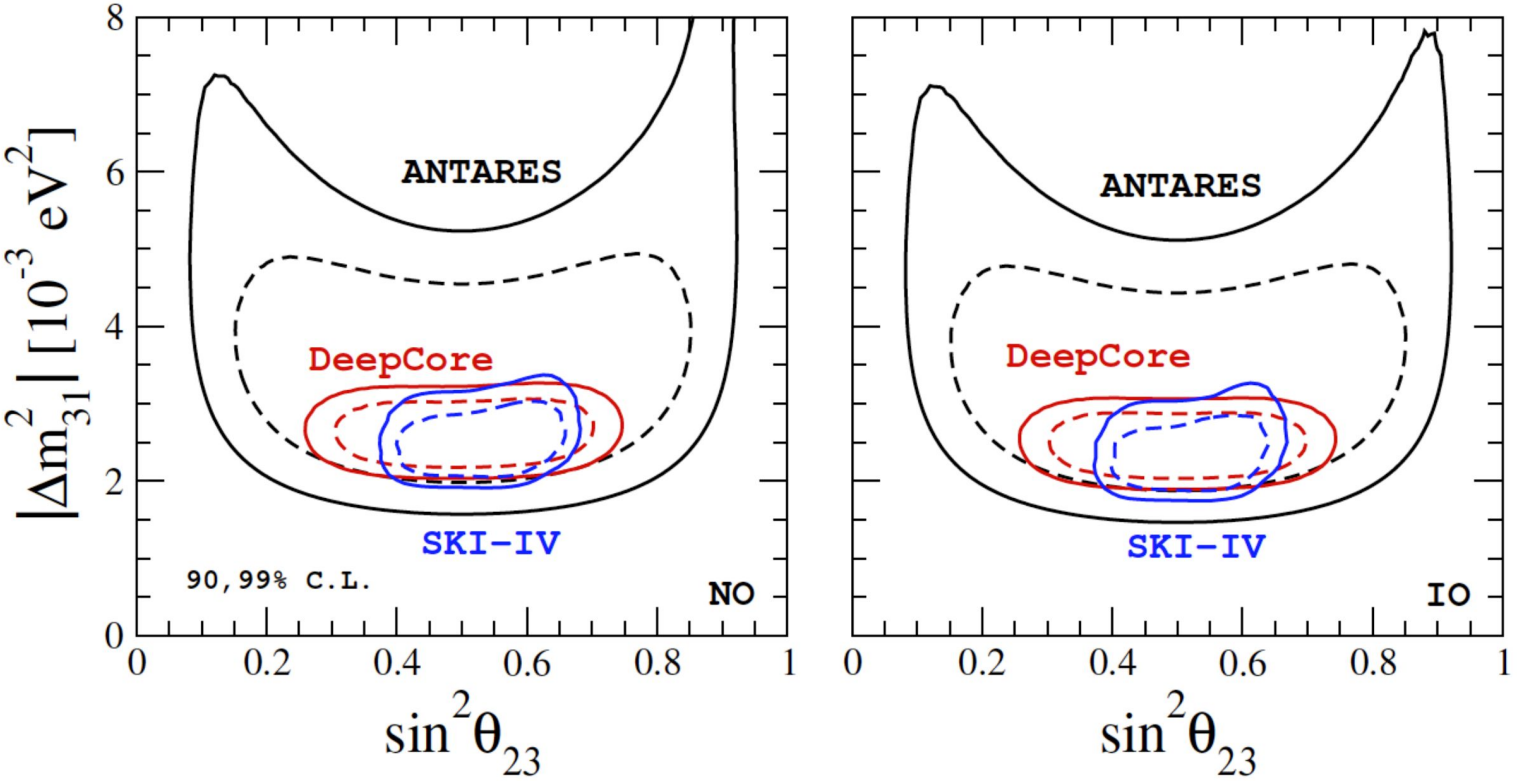
Decoherence in neutrino propagation through matter (arXiv 1803.04438 Coloma et al.)

ANTARES (Astronomy with a Neutrino Telescope and Abyss environmental RESearch)

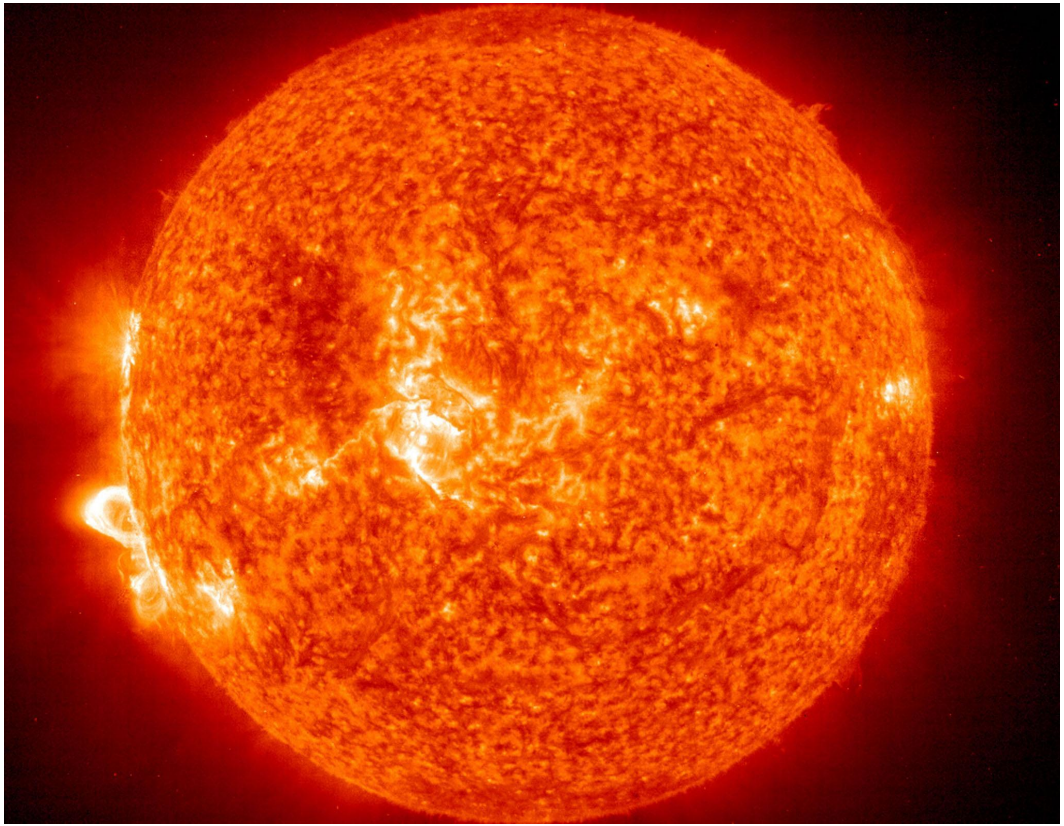




Combined results for atmospheric neutrinos

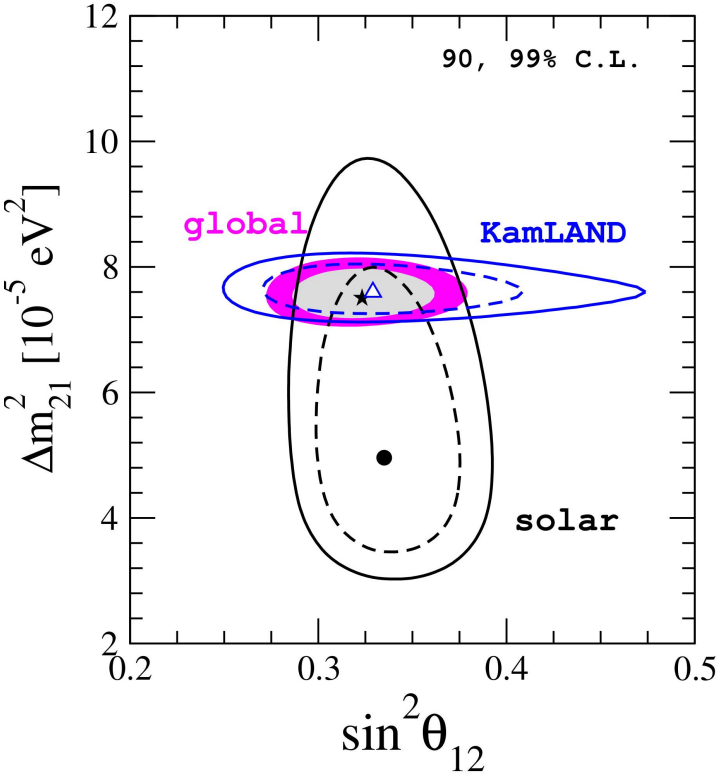


Solar neutrinos



Combined results for solar neutrinos

De Salas et al., PLB 782,633 (2018)

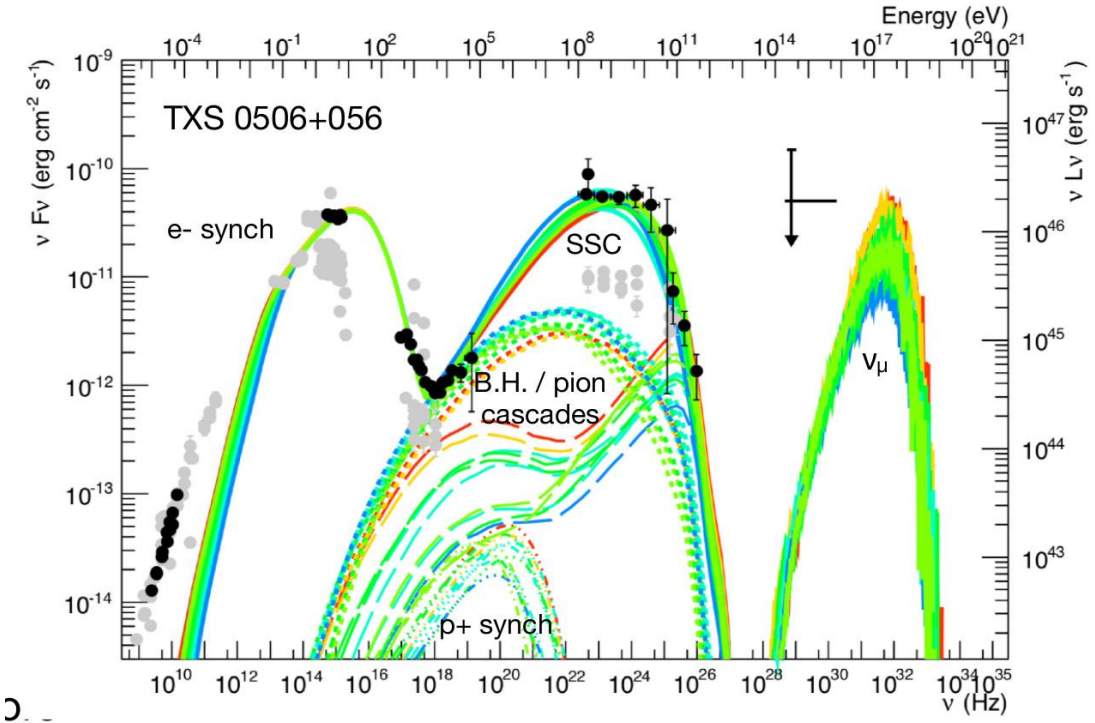


A lot of other experiments could not be mentioned….

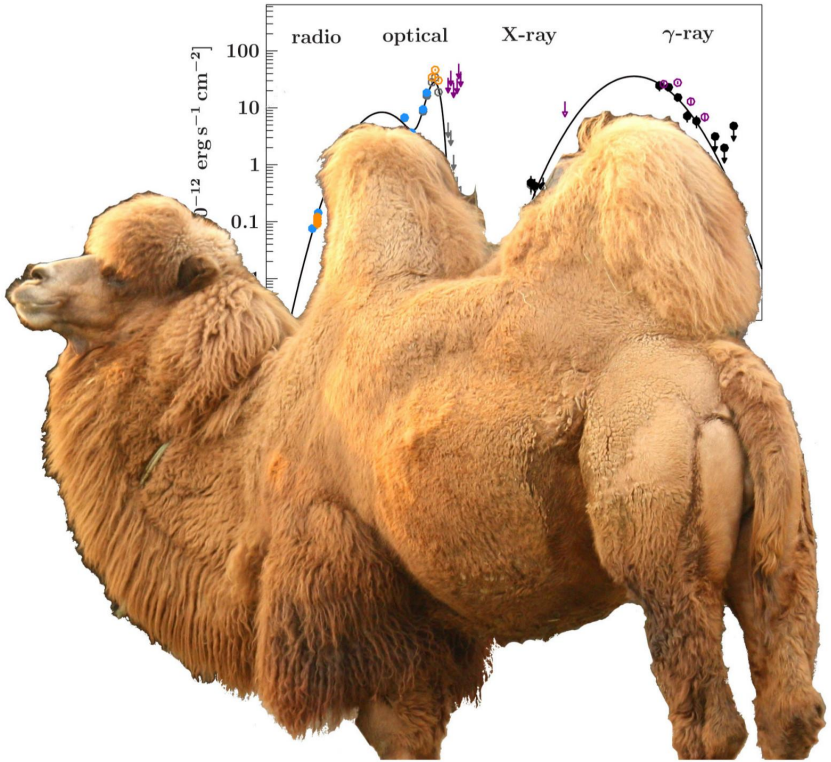
Double beta decay experiments (very important!)

DUne
SuperK
Baikal Deep Underwater Neutrino Telescope
Borexino (BORon EXperiment)
SAGE (Soviet–American Gallium Experiment)
Radioactivity experiments (GERDA, Mayorana demonstrator…)

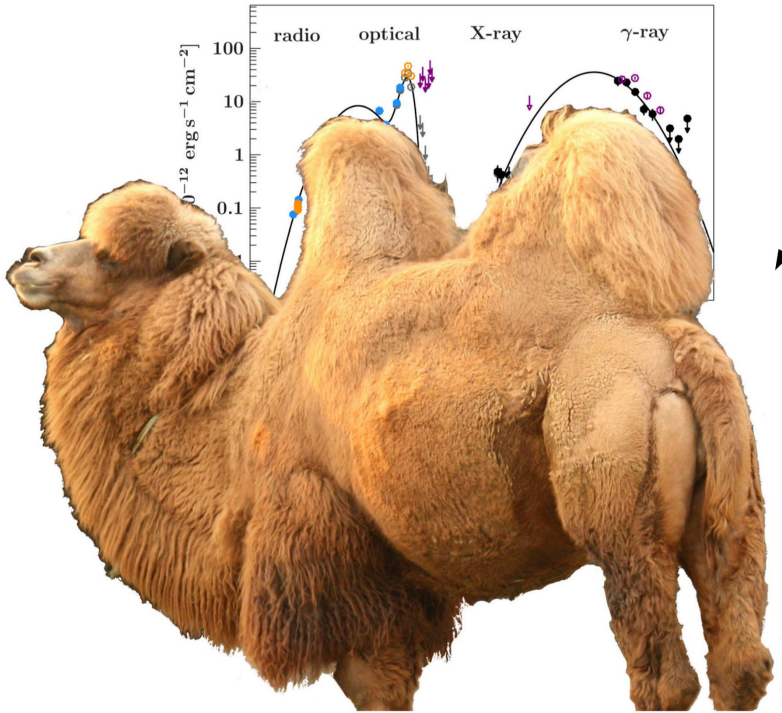
Bonus question: where do neutrinos come from?



Cerruti, AZ et al. 2018



Credit: Krauss et al. 2014, A&A 566, L7 & Wikipedia



neutrinos

Credit: Krauss et al. 2014, A&A 566, L7 & Wikipedia