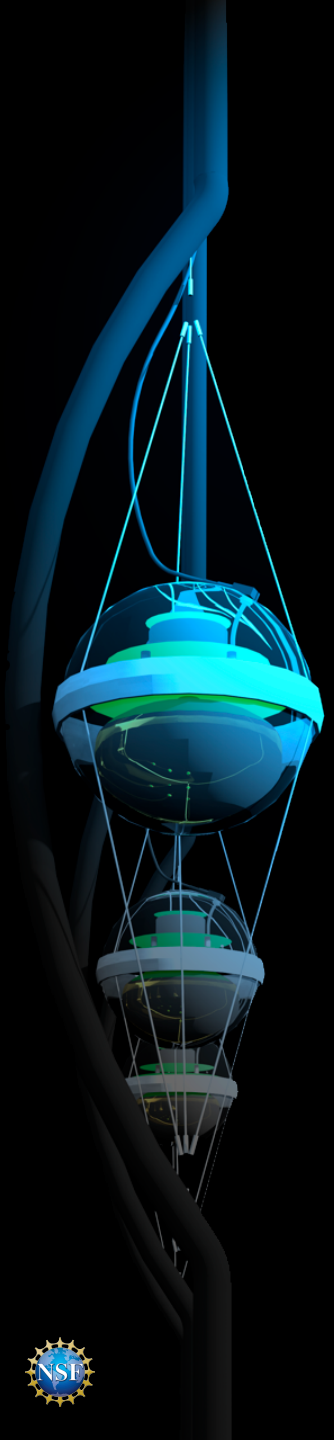
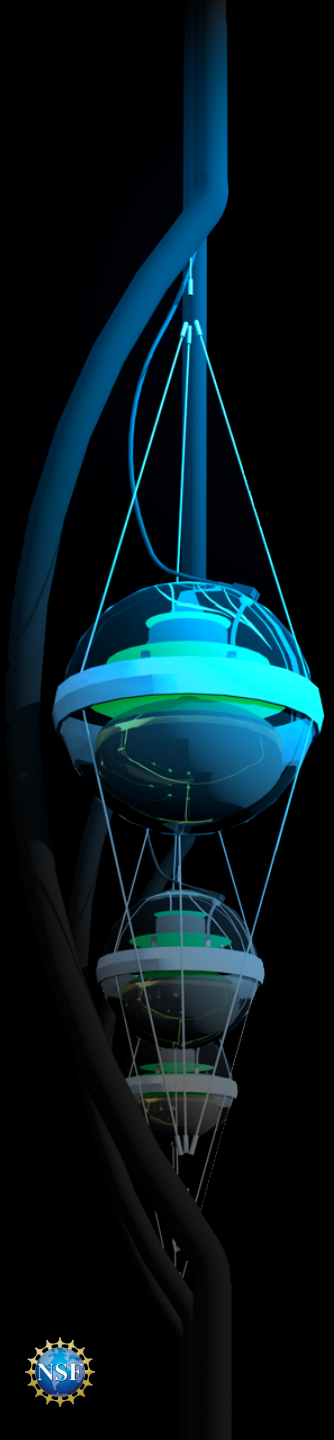


Erasing the Picture:

Non-Standard Neutrinos

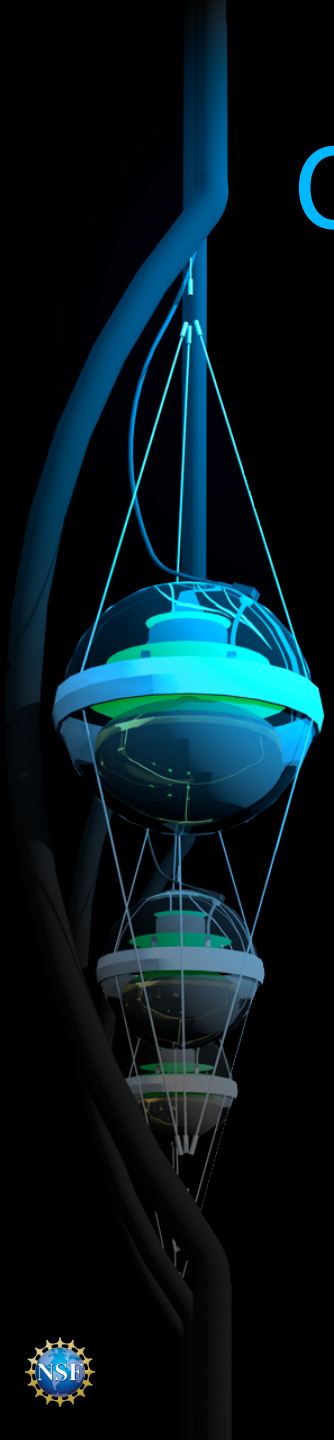
SLAC Summer Institute
Philipp Sicking, Victor Genty, Miguel Campos, Moriah Tobin, Maximilian Totzauer, Pascal Humbert, Ian Mitchell
8.20.2015



Drawing The Picture

- 3 neutrinos
- 2 Δm^2
- 3 mixing angles

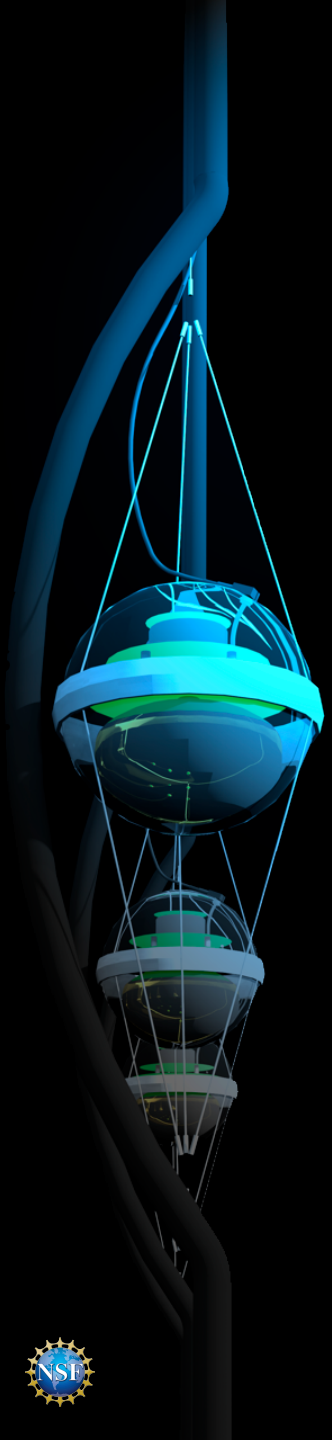
  $+\delta_{CP}$ phase
- Dirac/Majorana



Commissioning a New Picture

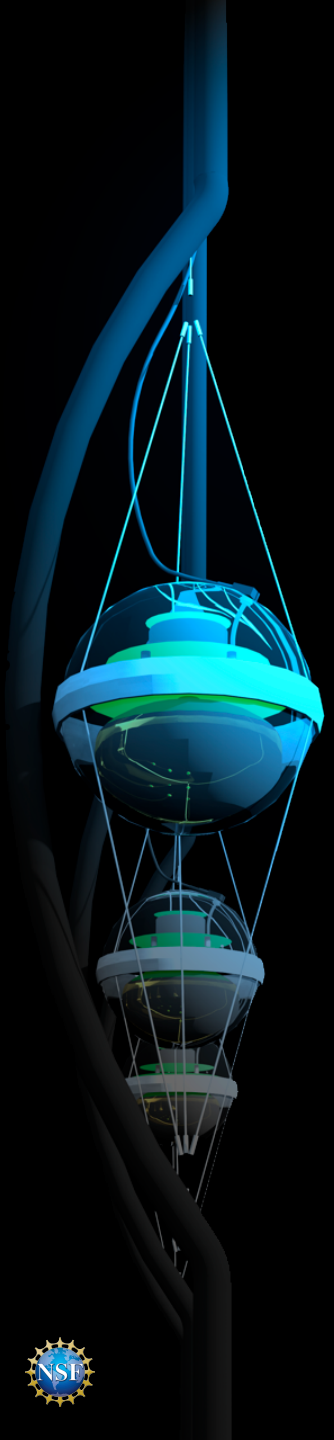
- With the coming precision oscillations measurements, how could this picture be broken?

Sketching the New Picture

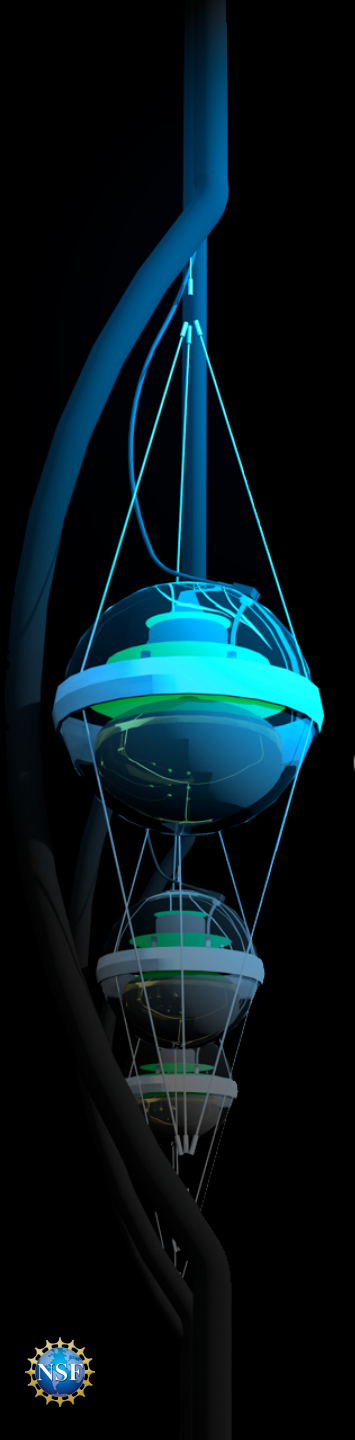


Non-Standard Interactions
Sterile Neutrinos
Lorentz Violation

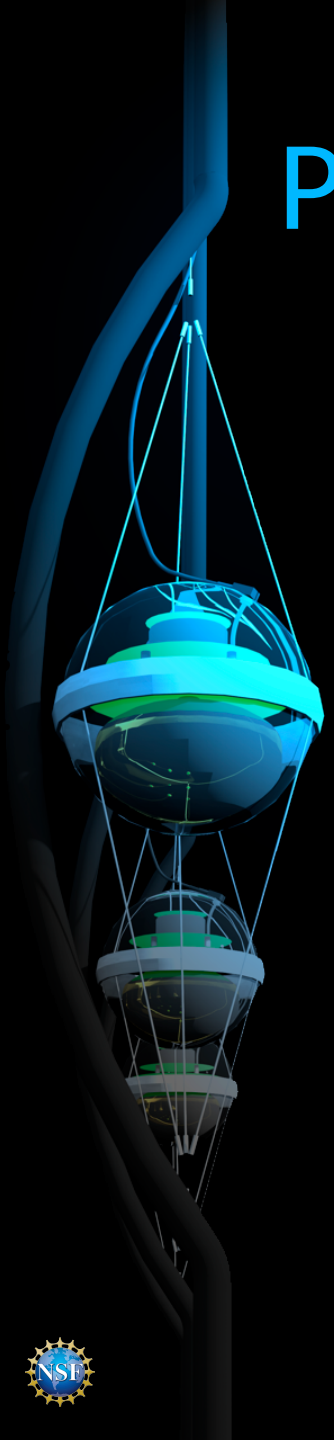
Sketching the New Picture



Sketching the New Picture



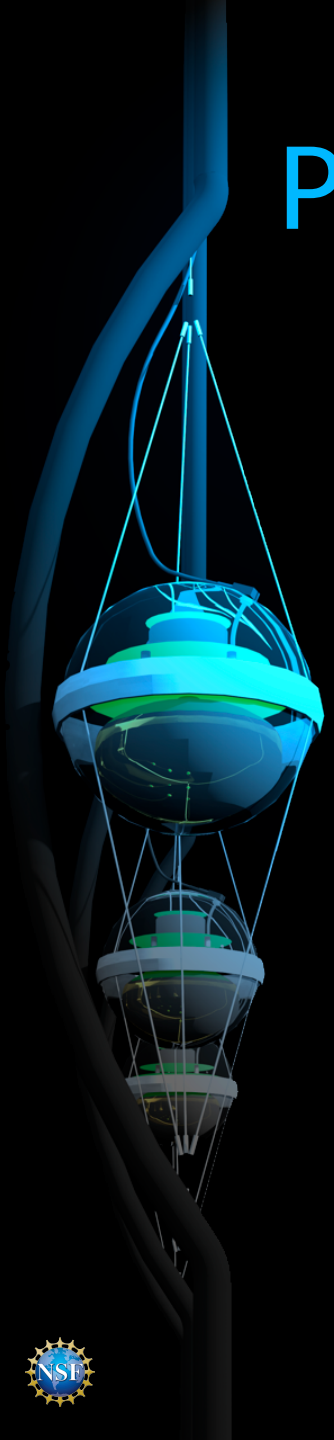
Painting the Sterile Neutrinos



- Electrically neutral fermion.
- Lepton.
- Right-handed.

  (I. e. new neutrino without weak interactions)

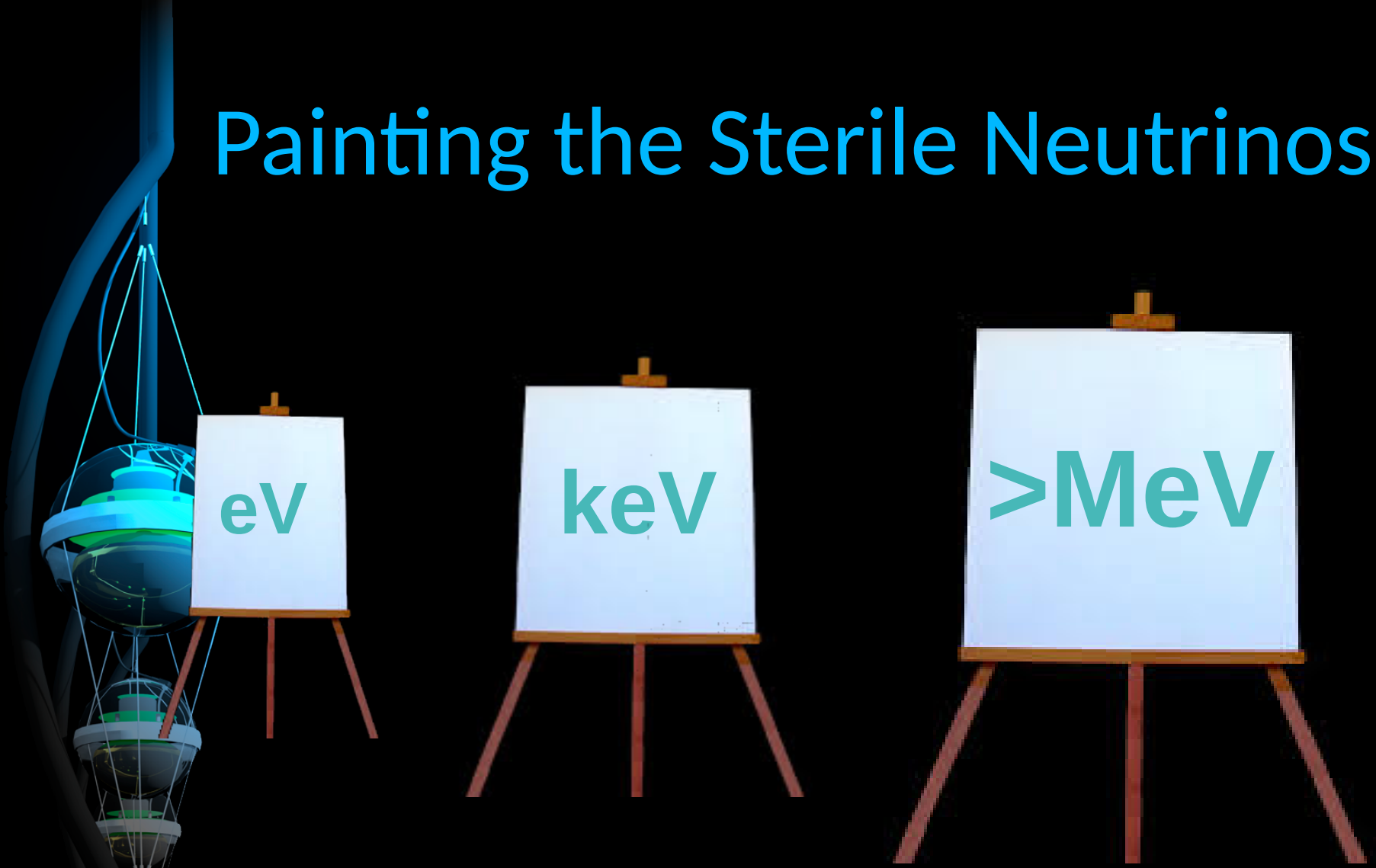
Painting the Sterile Neutrinos



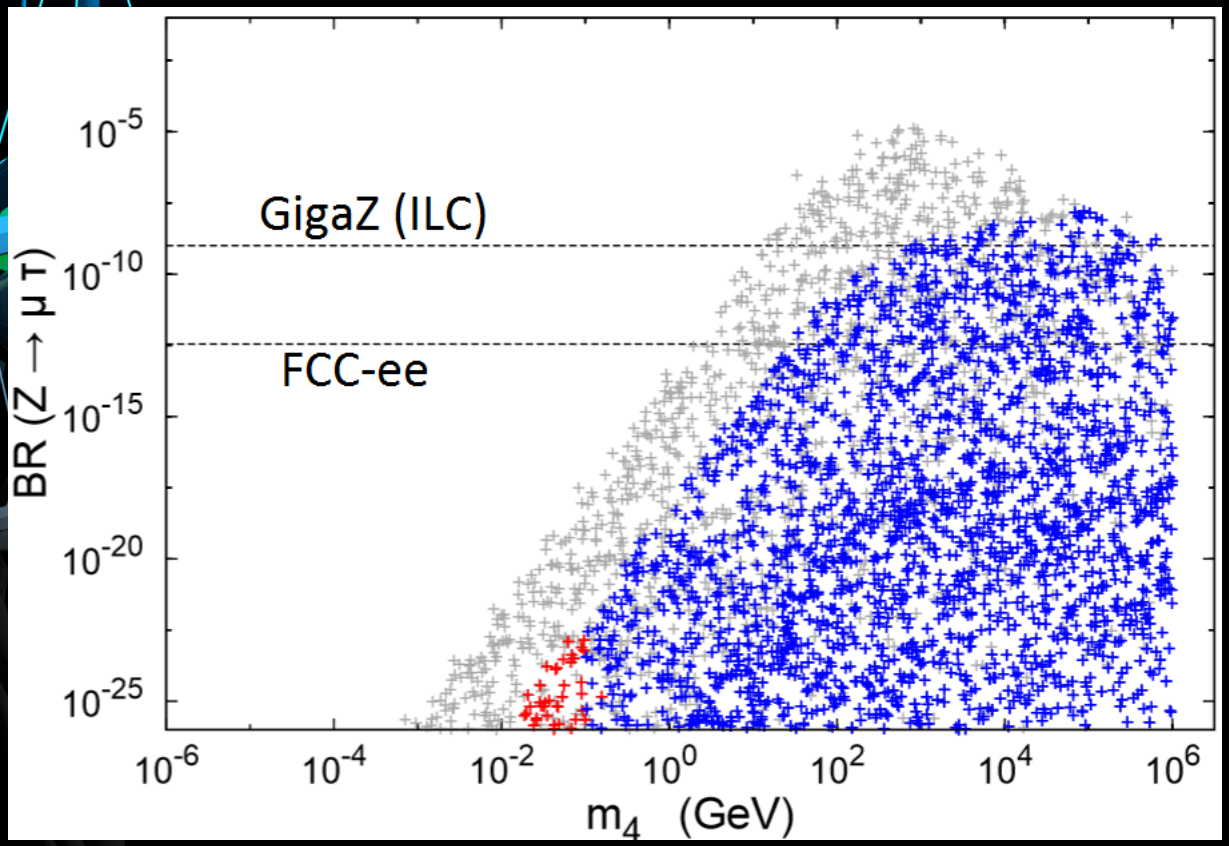
- Why are they interesting?

  They have very good connections:
  - Dark Matter
  - Leptogenesis
  - Neutrino Masses
  - Scale of New Physics

Painting the Sterile Neutrinos



Study of very massive Sterile Neutrinos



*Edited Image from: http://arxiv.org/pdf/1412.6322v1.pdf

Study of very massive Sterile Neutrinos

$0\nu\beta\beta$-decay with

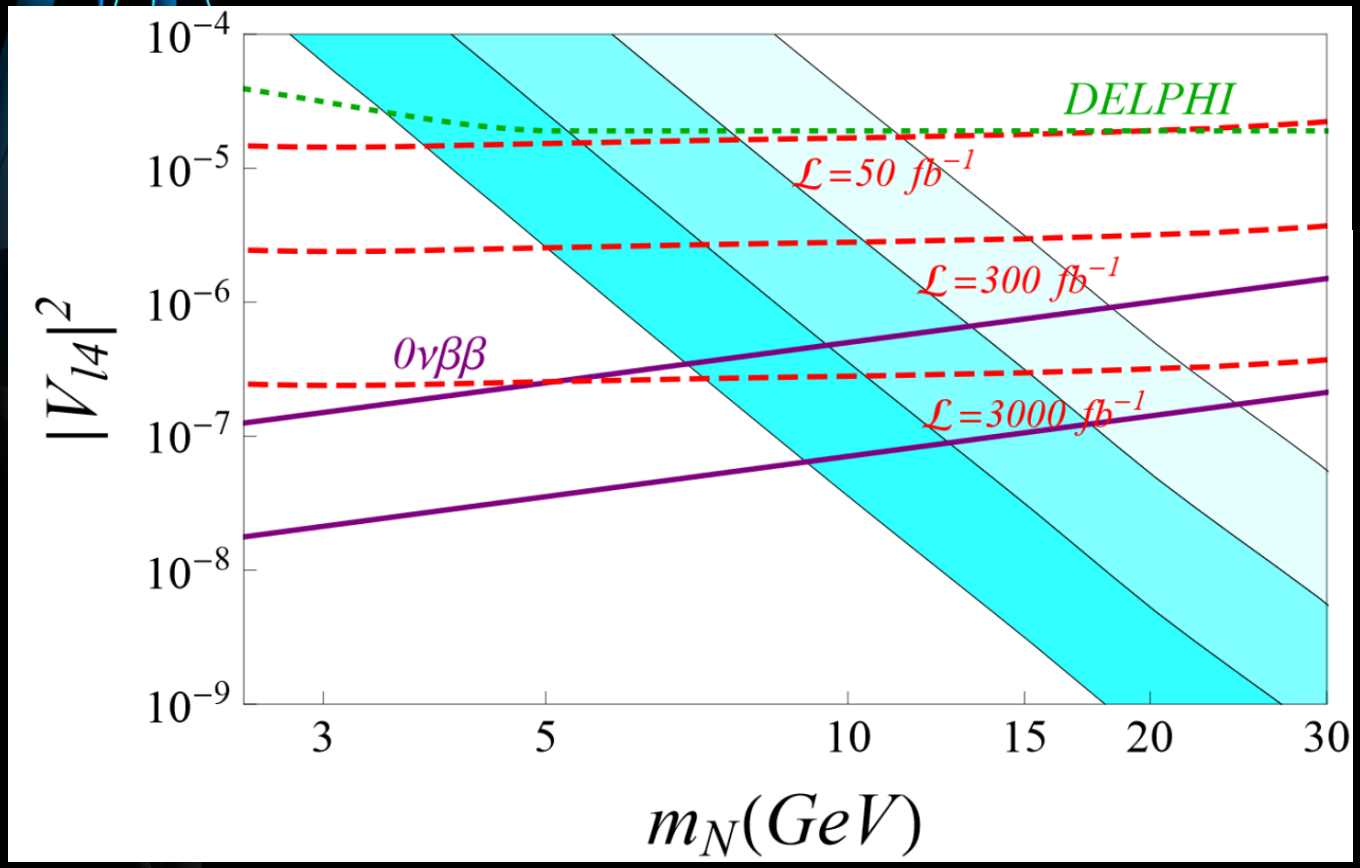
$T_{1/2} \leq 10^{25}$ and $\leq 10^{27}$ yrs

heavy neutrino decay

length $L = 0.001$ to 1 m

LHC nuclear recoil study

sensitivity for different $\mathcal{L}$



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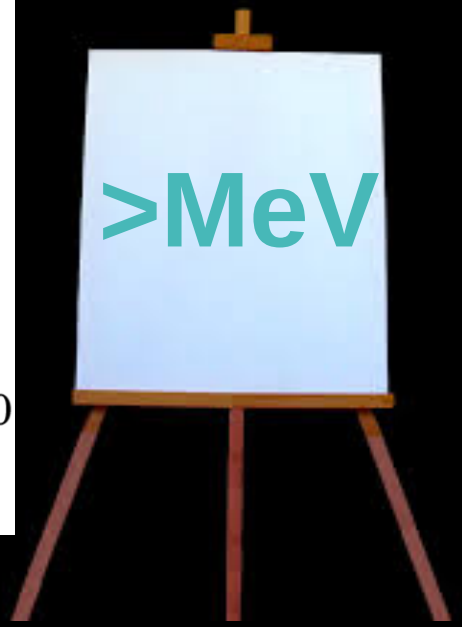
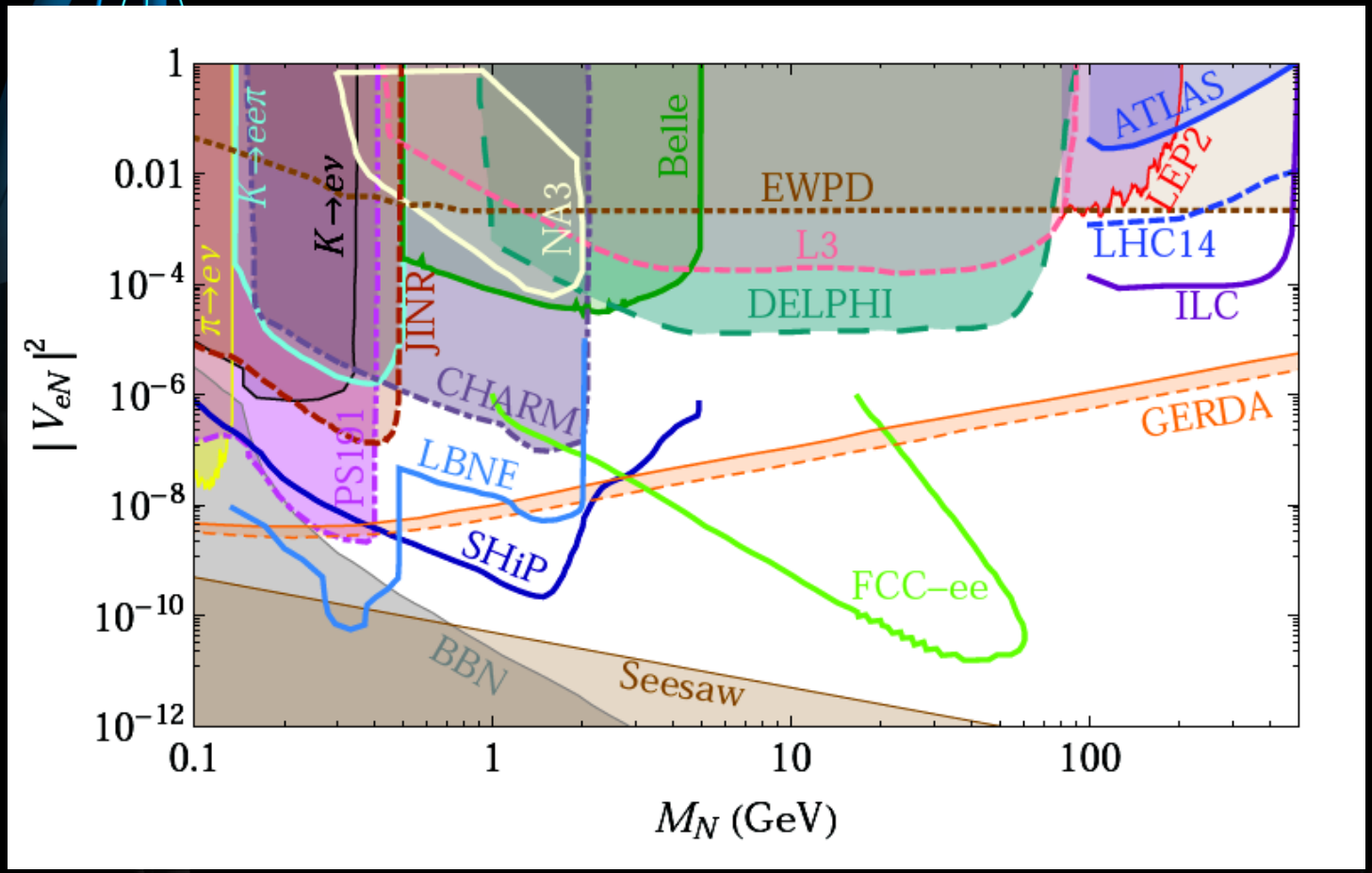
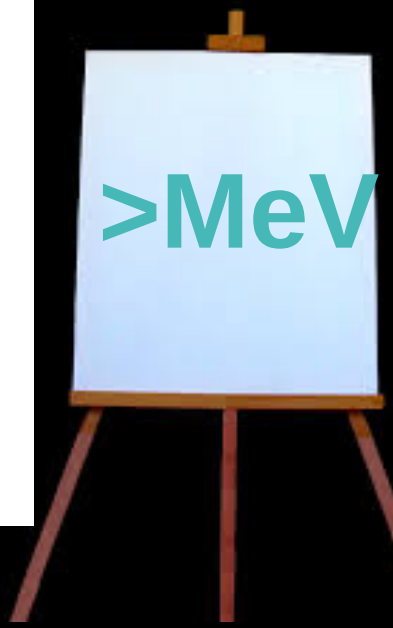


Study of very massive Sterile Neutrinos

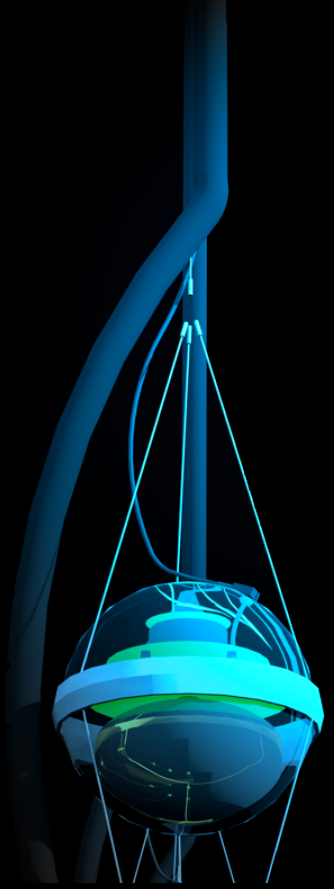


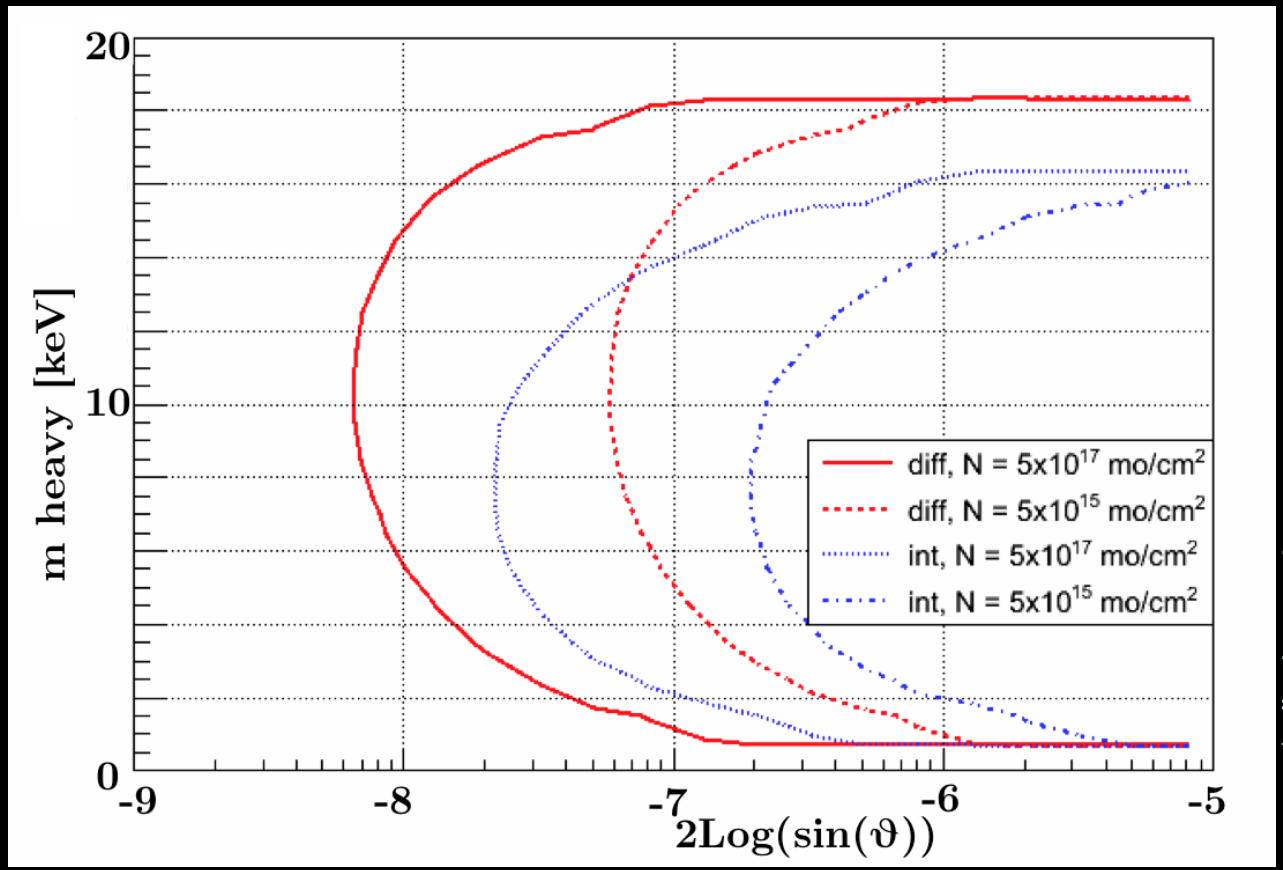
*Edited Image http://arxiv.org/pdf/1502.06541.pdf



Study of keV Sterile Neutrinos

- KATRIN+
- X-ray Astronomy





*Edited Image from: doi:10.1016/j.phpro.2014.12.043

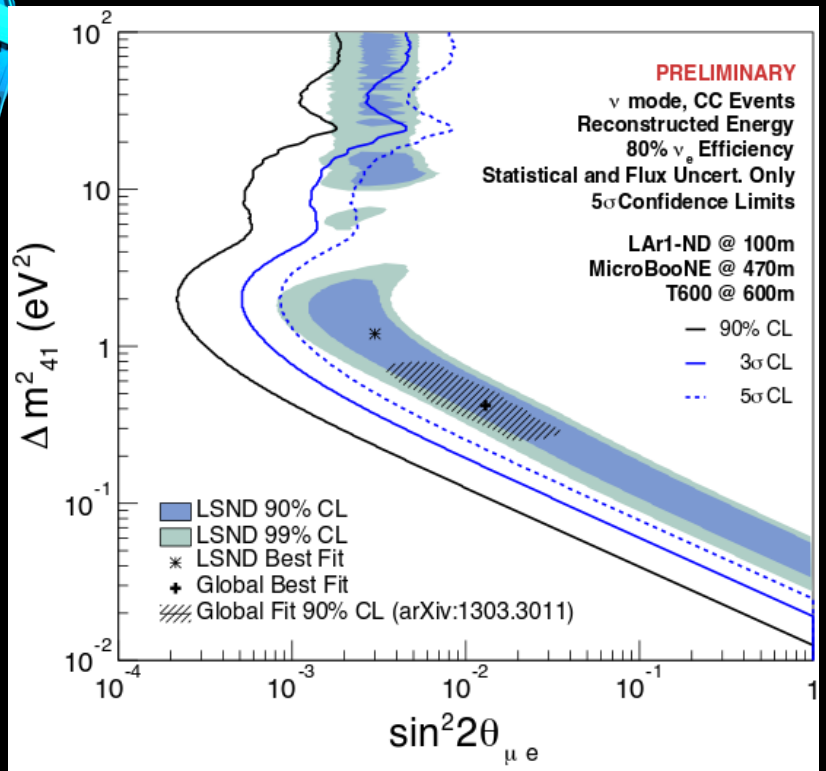
Painting eV Sterile Neutrinos

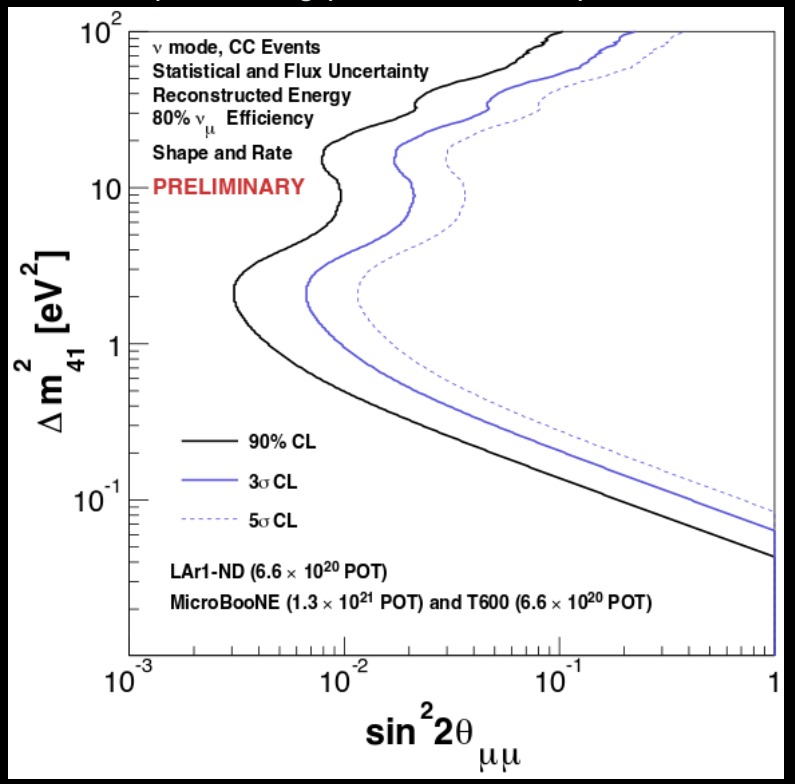
- SBL accelerator
- SBL reactors
- Source Experiments
- IceCube

Study of eV Steriles: Accelerators

*http://arxiv.org/pdf/1503.01520v1.pdf

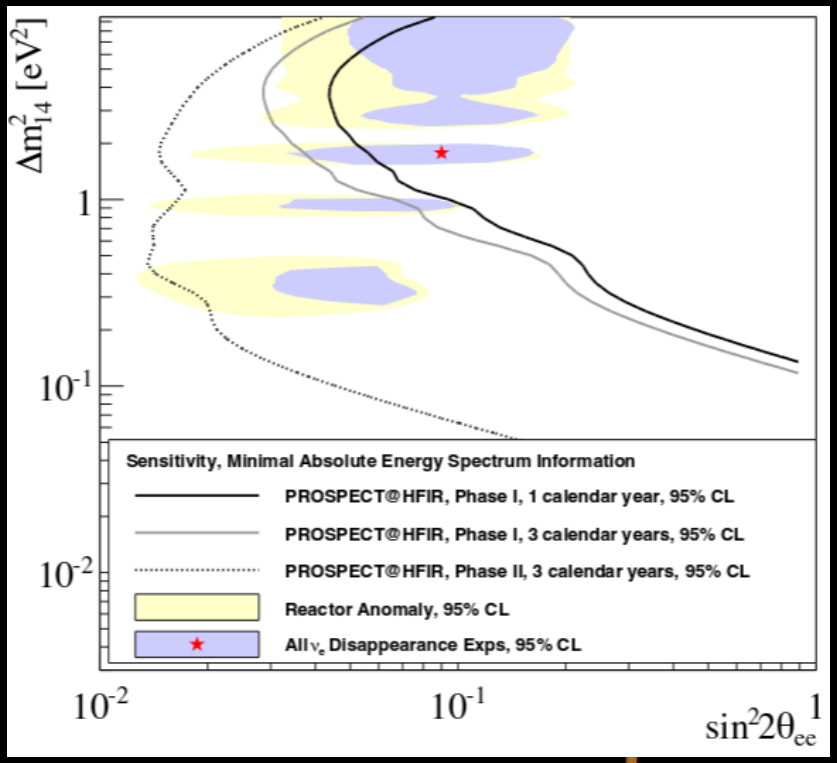
- MicroBooNE
- T2K
- OPERA



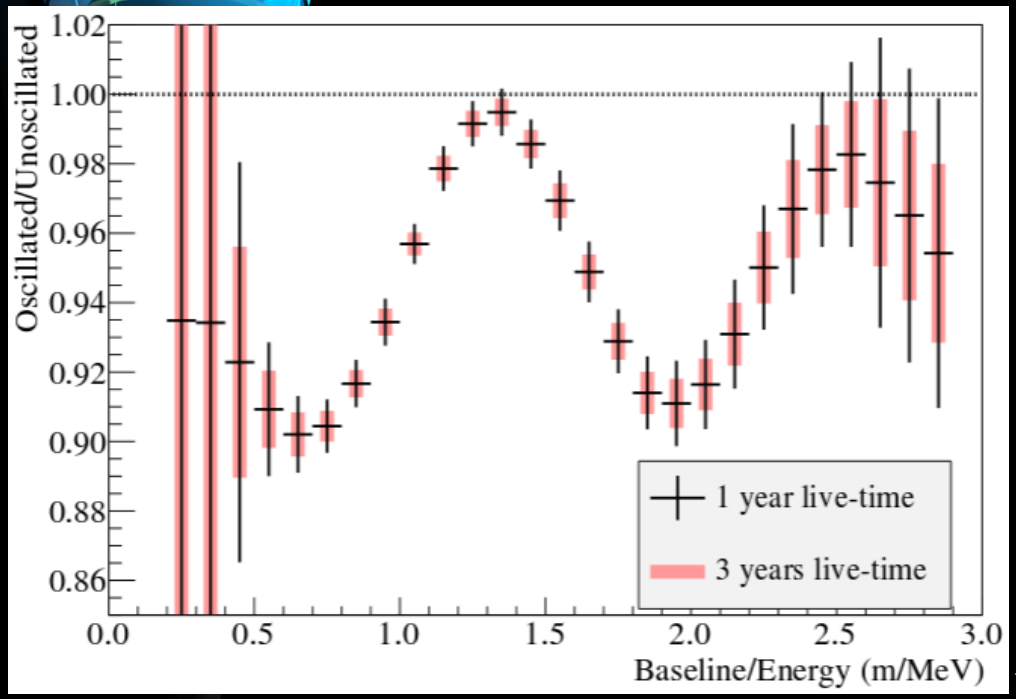


Study of eV Steriles: Reactors

- PROSPECT
- SoLid
- HANARO
- STEREO



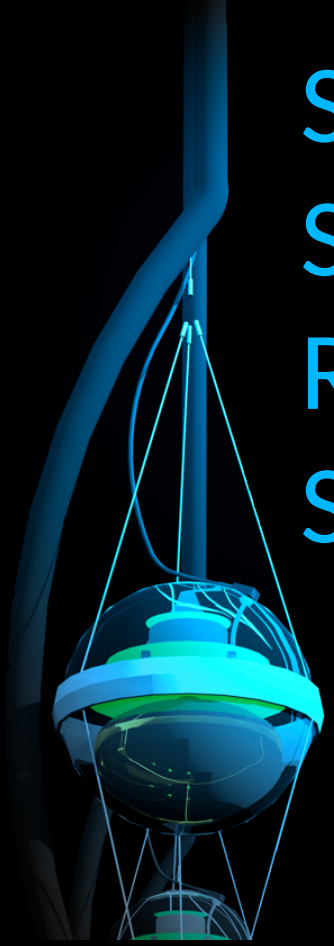
*http://arxiv.org/pdf/1501.00194v1.pdf

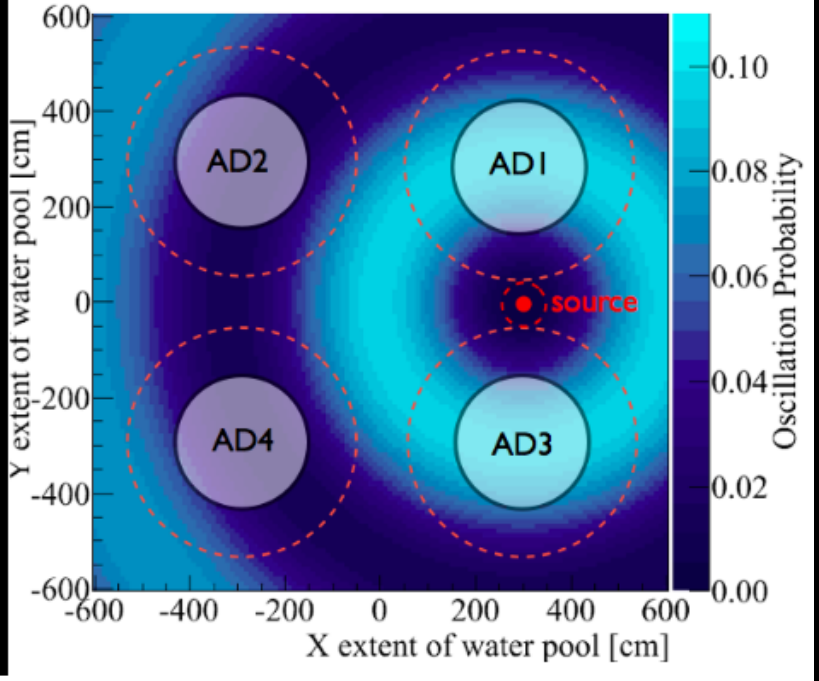


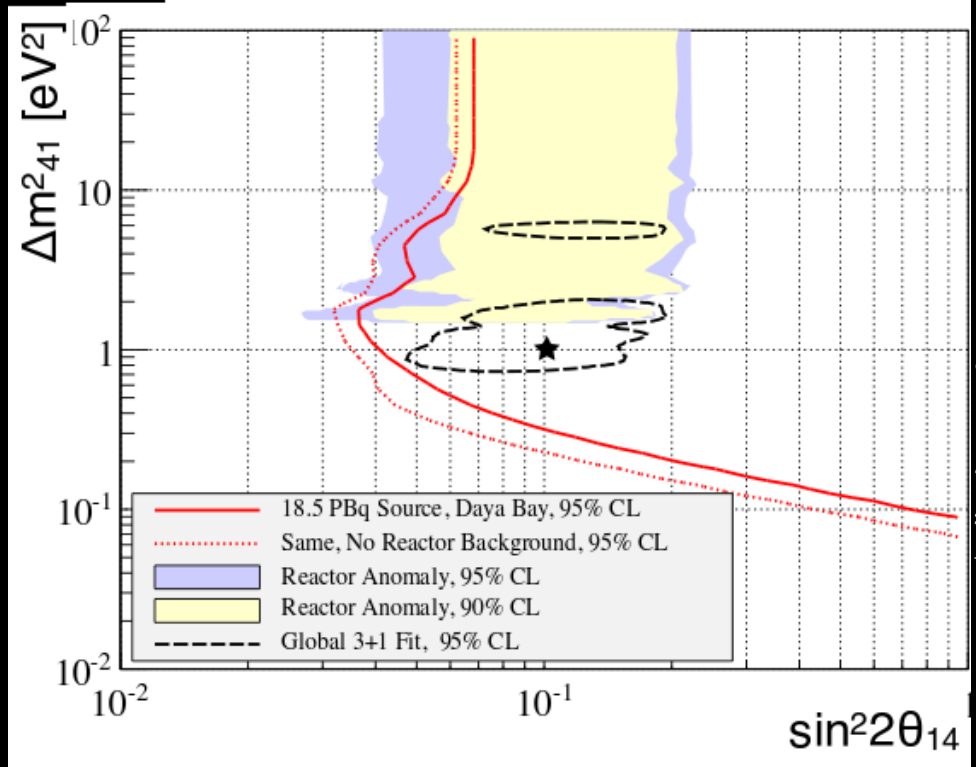
*http://arxiv.org/pdf/1212.2182v1.pdf

Study of eV Steriles: Radioactive Sources

- Daya Bay
- SOX
- CeLand

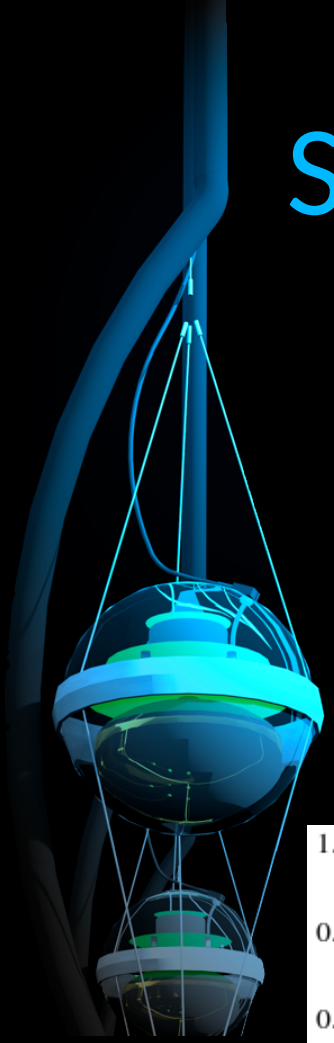






*Edited Image from: http://arxiv.org/pdf/1204.5379v1.pdf

Study of the eV Steriles: IceCube



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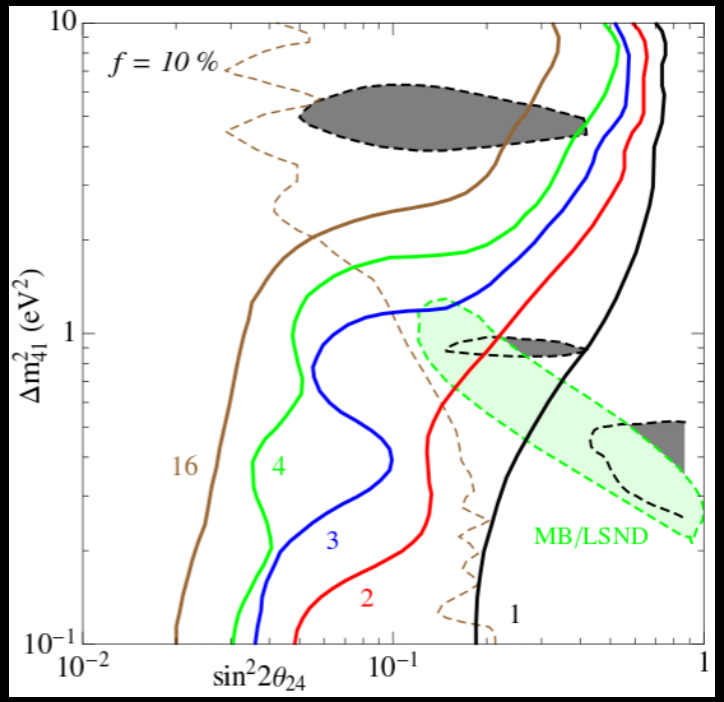
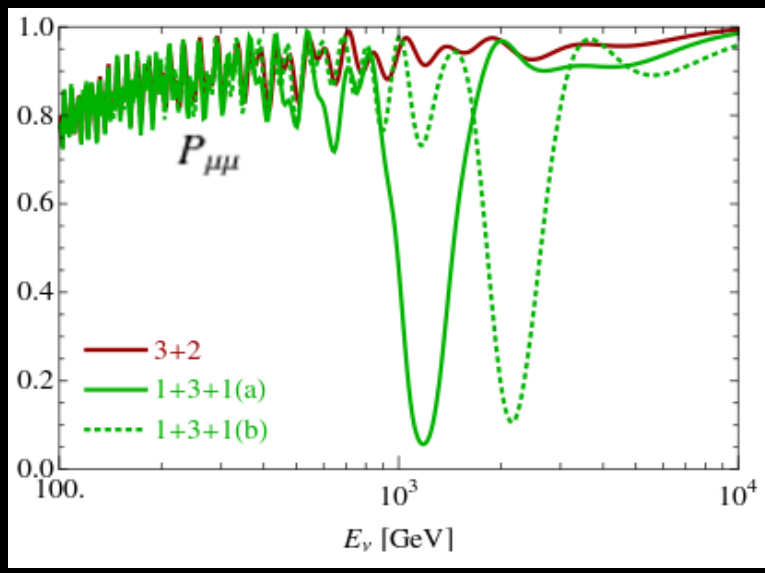




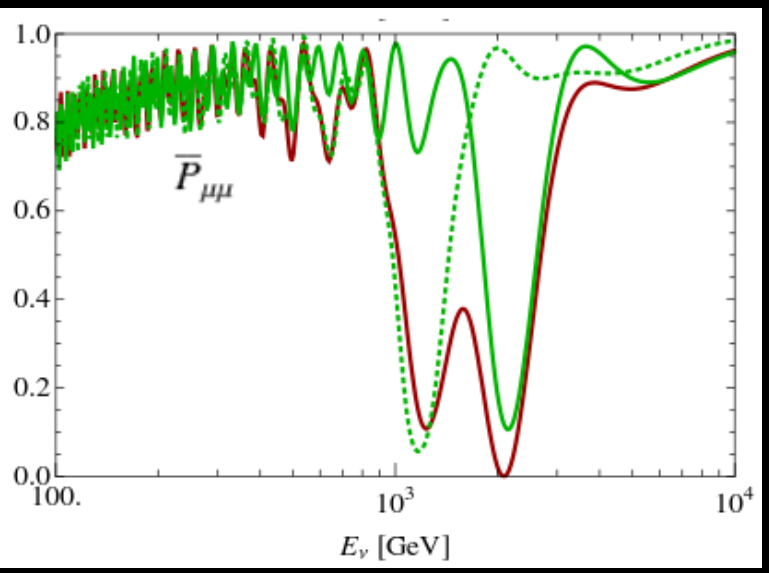


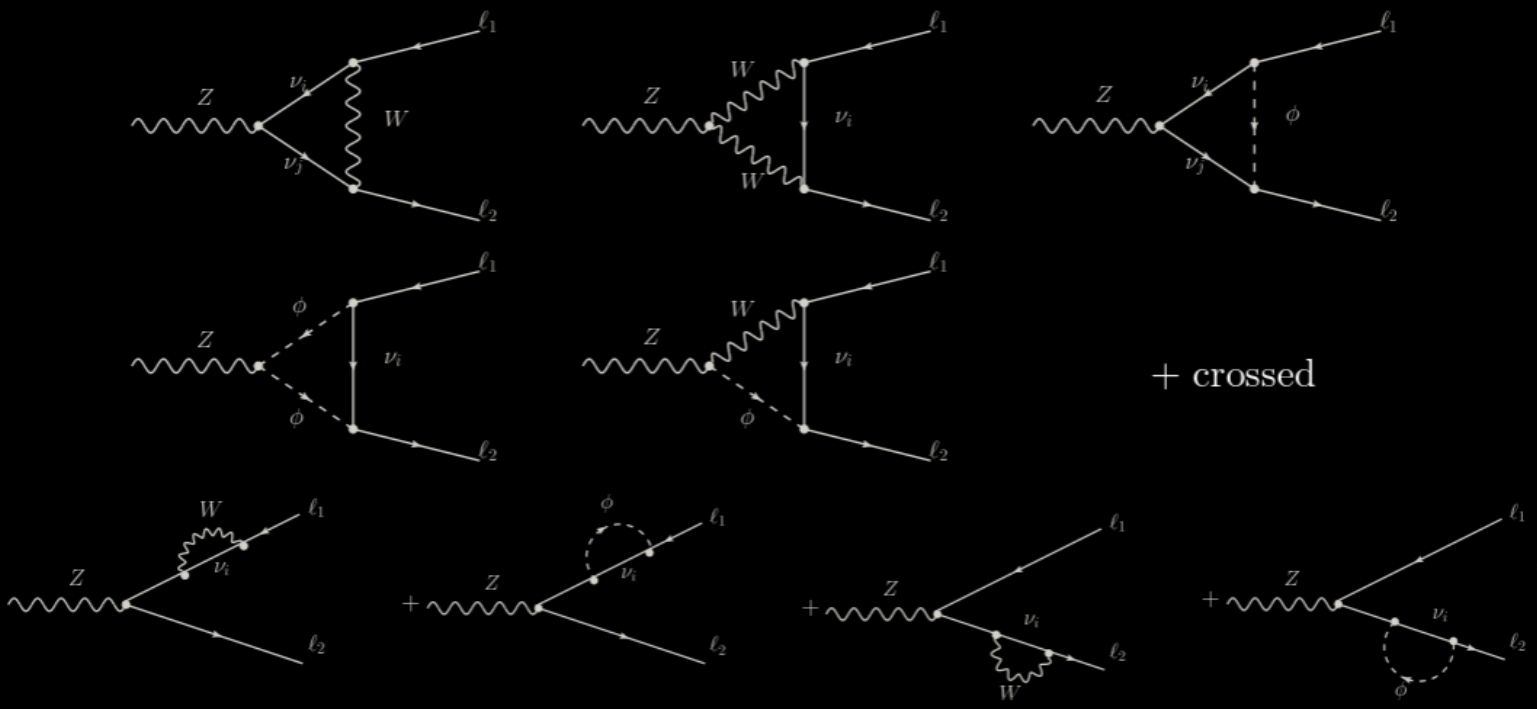
*Image Edited from: http://arxiv.org/pdf/1109.5748v2.pdf

Conclusion

- Lots of Exciting Possibilities
- But We Must Wait

Fin

Very Massive Steriles: ILC Diagrams



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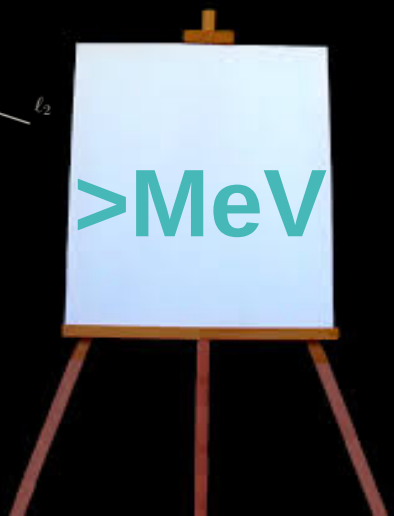
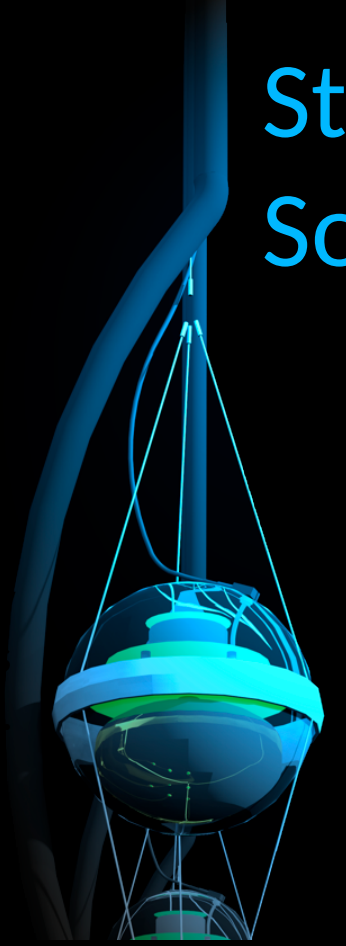


Study of eV Steriles: Radioactive Sources

- SOX @ Borexino



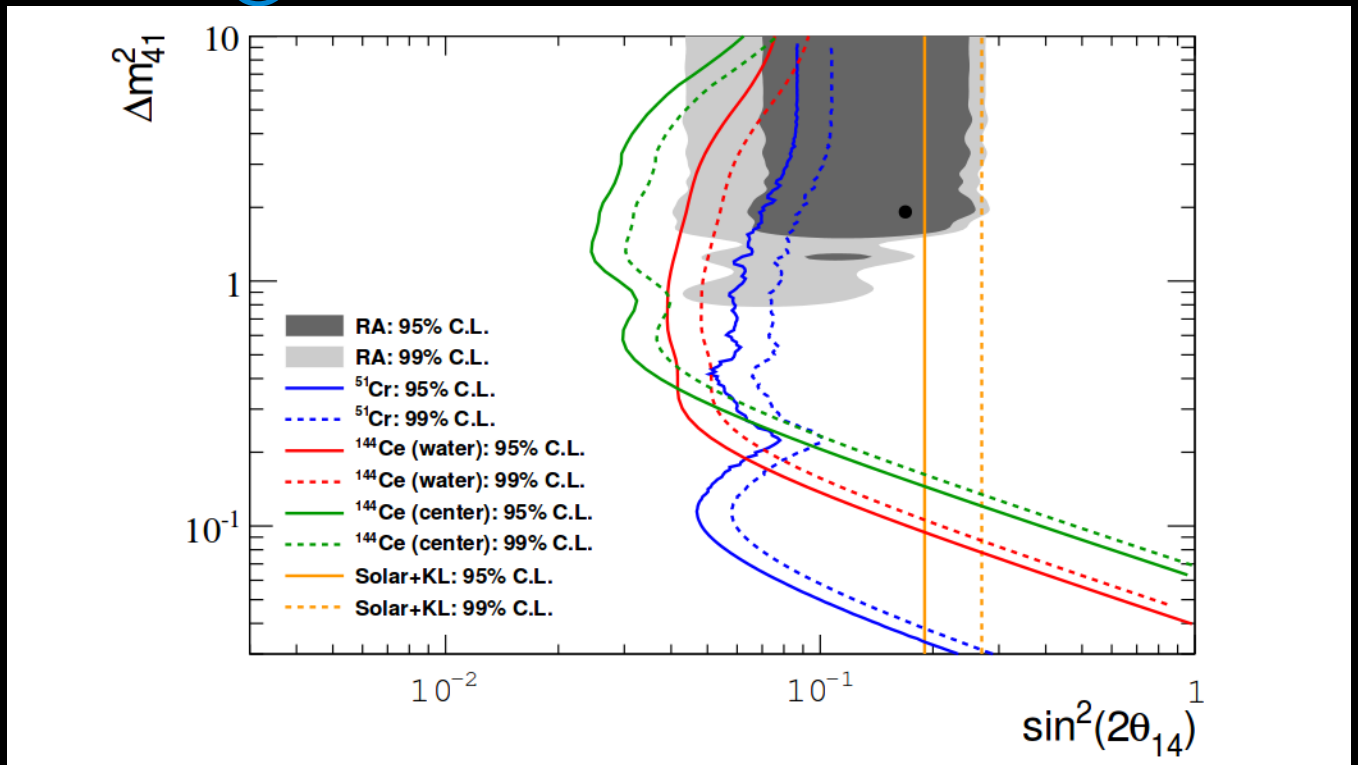
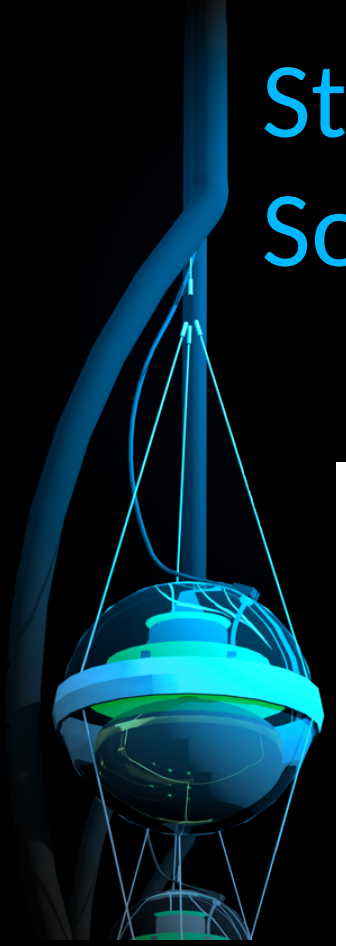


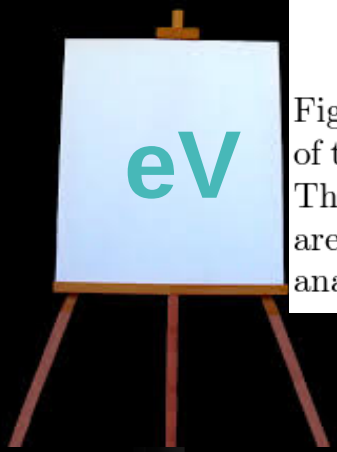
Figure 5. Sensitivity of the Phase A (^{51}Cr external, blue), of Phase B (^{144}Ce-^{144}Pr external, red) and Phase C (^{144}Ce-^{144}Pr center, green). The grey area is the one indicated by the reactor anomaly, if interpreted as oscillations to sterile neutrinos. Both 95% and 99% C.L. are shown for all cases. The yellow line indicates the region already excluded in [40].

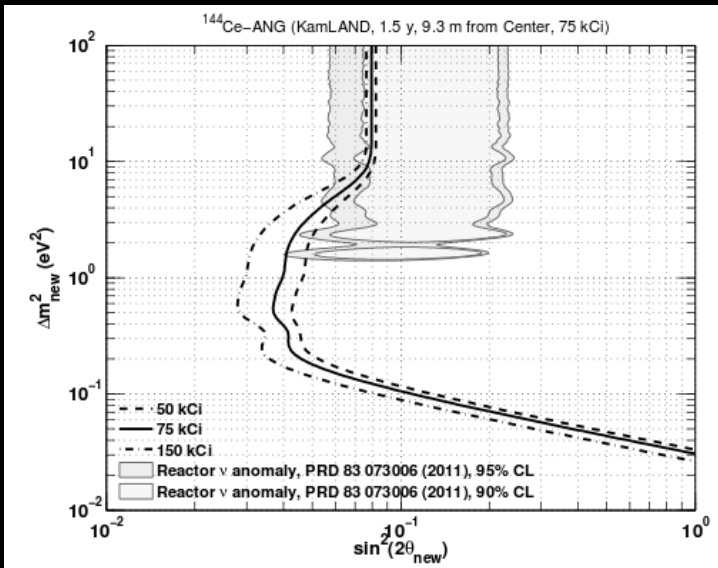
*Edited Image from: http://arxiv.org/pdf/1304.7721v2.pdf

Study of eV Steriles: Radioactive Sources

- CeLand







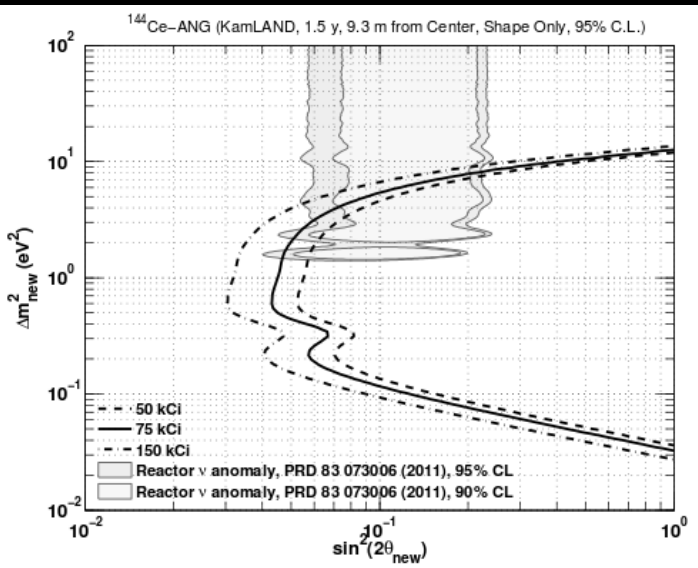
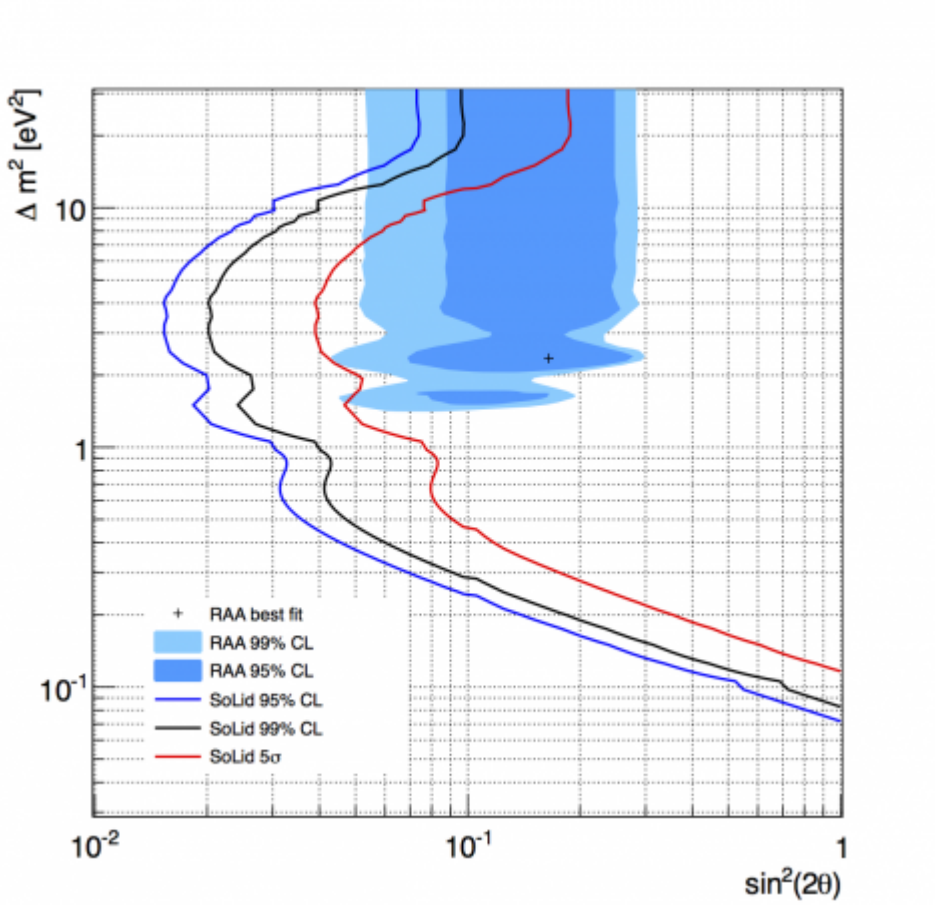


Figure 41: 95% C.L. expected sensitivity to exclude the non-oscillation, as a function of the activity of the source. We assume the antineutrino generator to be places at 9.3 m from the detector center. The fiducial volume is starting from the detector center and extends to a radius of 6.5 m. Results are given for 1.5 year of data taking for a rate+shape analysis (left panel), and for a shape only analysis (right panel). The normalization uncertainty is taken at 1.5%.

*Edited Image from: http://arxiv.org/pdf/1312.0896v2.pdf

Study of eV Steriles: Reactors

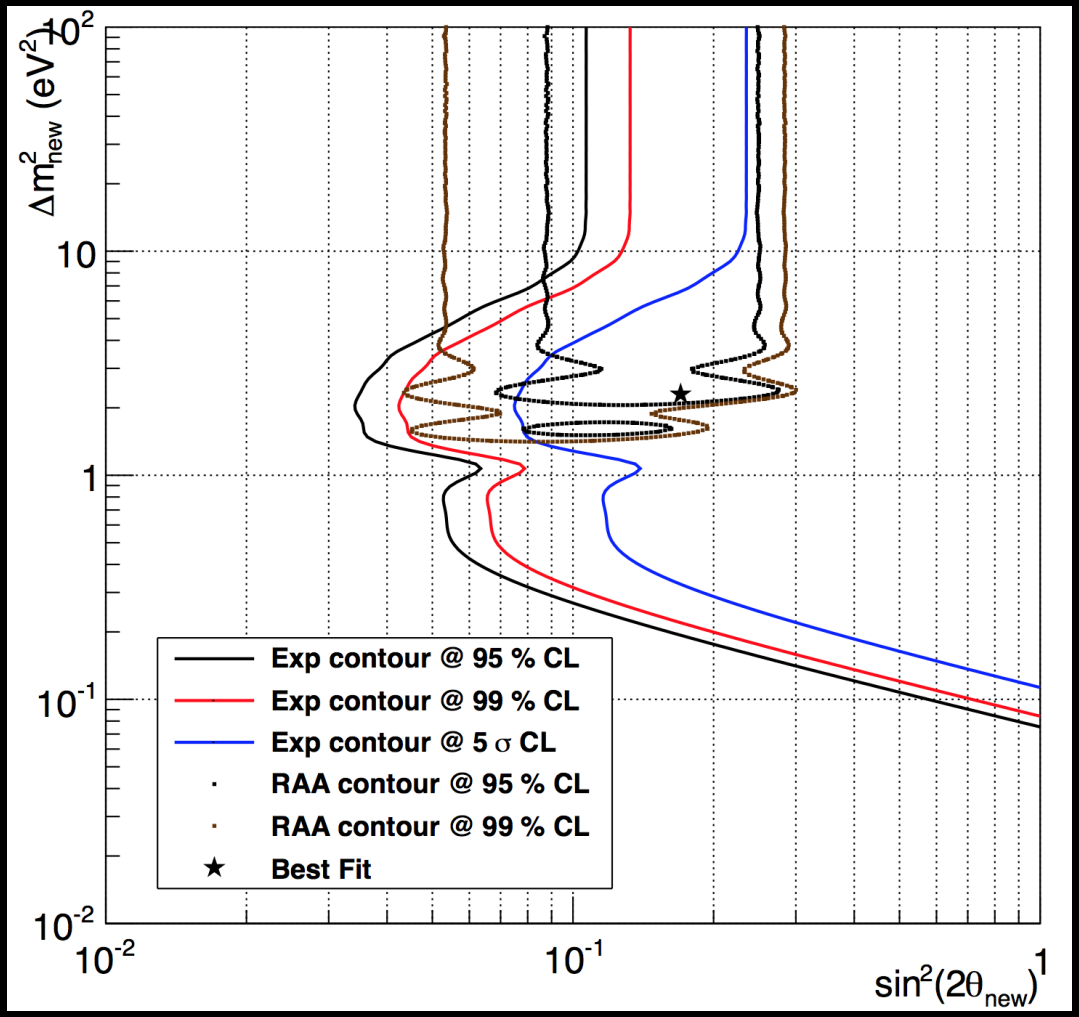
- SoLid – Projected 2017



* https://www2.physics.ox.ac.uk/research/mars-project/solid

Study of eV Steriles: Reactors

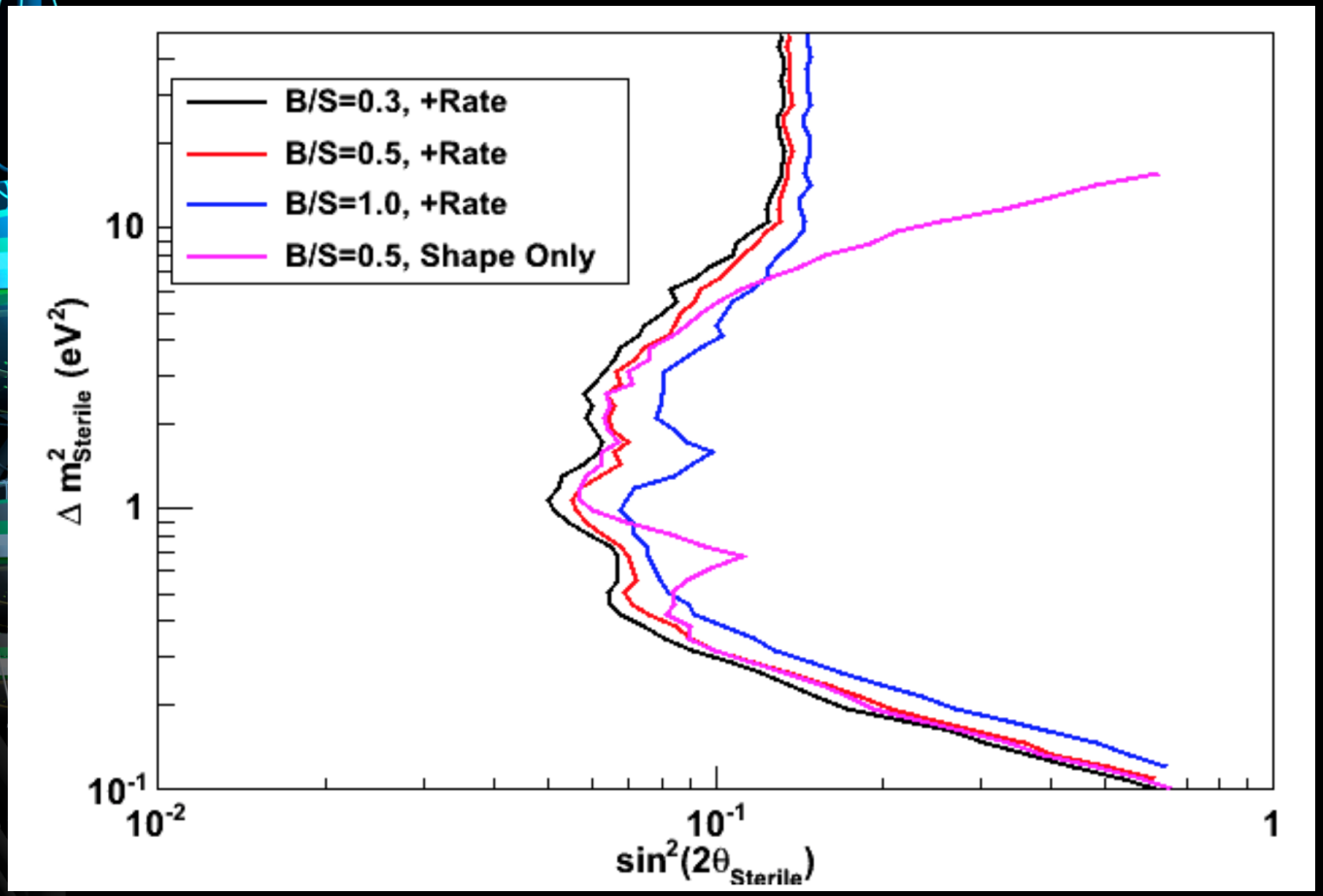
- STEREO



*http://ruphe.fsac.ac.ma/Neutrino_ILL_experiment/STEREO/Stereo_Proposal.pdf

Study of eV Steriles: Reactors

- HANARO



*workshop.kias.re.kr/lownu11/?download=lownu-ydkim.pdf

Study of eV Steriles: Reactors

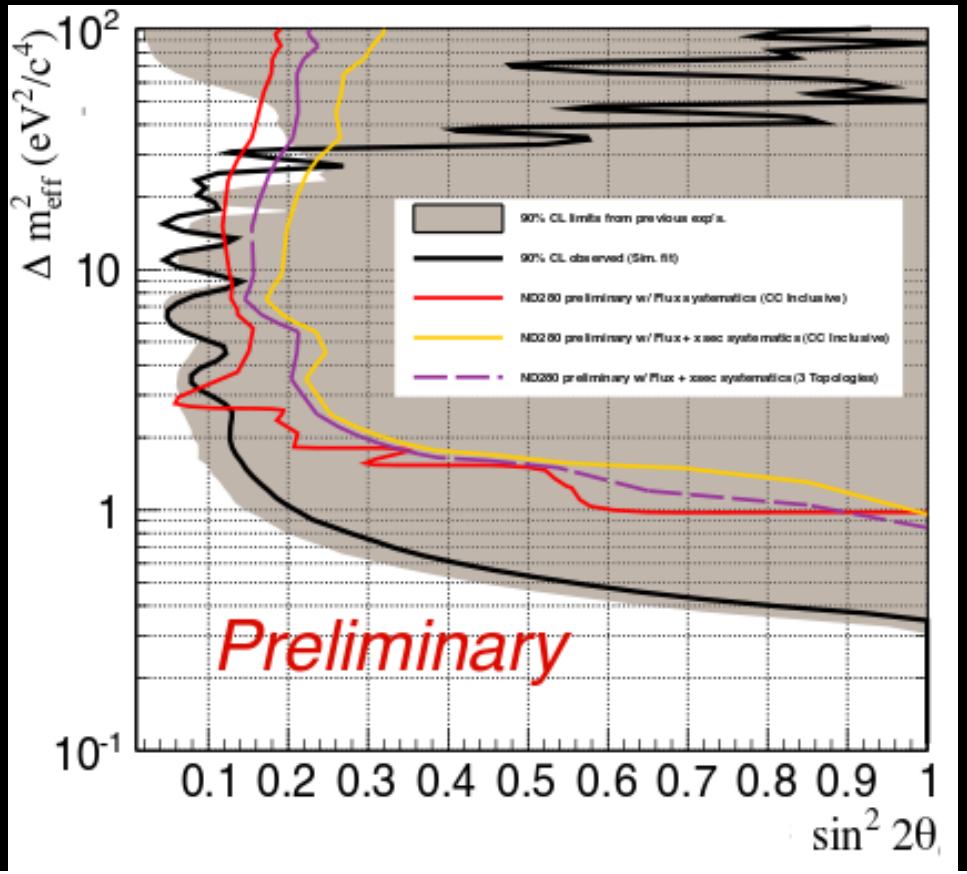
- So Many Experiments

	Power (MW_{th})	Baseline (m)	Mass (ton)	Dopant	Seg.
PROSPECT[118]	85	6–20	1 and 10	^{6}Li	Y
NuLat[119]	1,500	3–8	1.0	^{10}B, ^{6}Li	Y
NUCIFER[120]	70	~7	0.7	Gd	N
STEREO[108]	57	~10	1.8	Gd	N
DANSS[122]	3,000	9–12	0.9	Gd	Y
NEUTRINO-4 (ref. 123)	100	6–12	1.5	Gd	N
POSEIDON[125]	100	5–8	1.3	Gd	N
SOLID[126]	45–80	6.8	2.9	Gd, ^{6}Li	Y
HANARO[127]	30	6	~1	Gd	Y

*Image Edited from: http://www.nature.com/ncomms/2015/150427/ncomms7935/pdf/ncomms7935.pdf

Study of eV Steriles: Accelerators

- T2K near detector



*http://arxiv.org/pdf/1504.08237v1.pdf

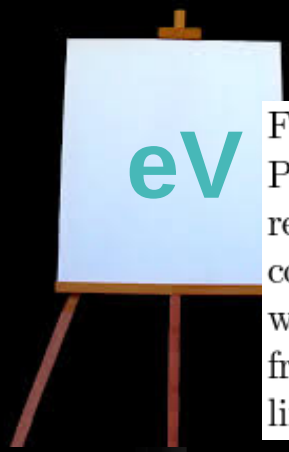
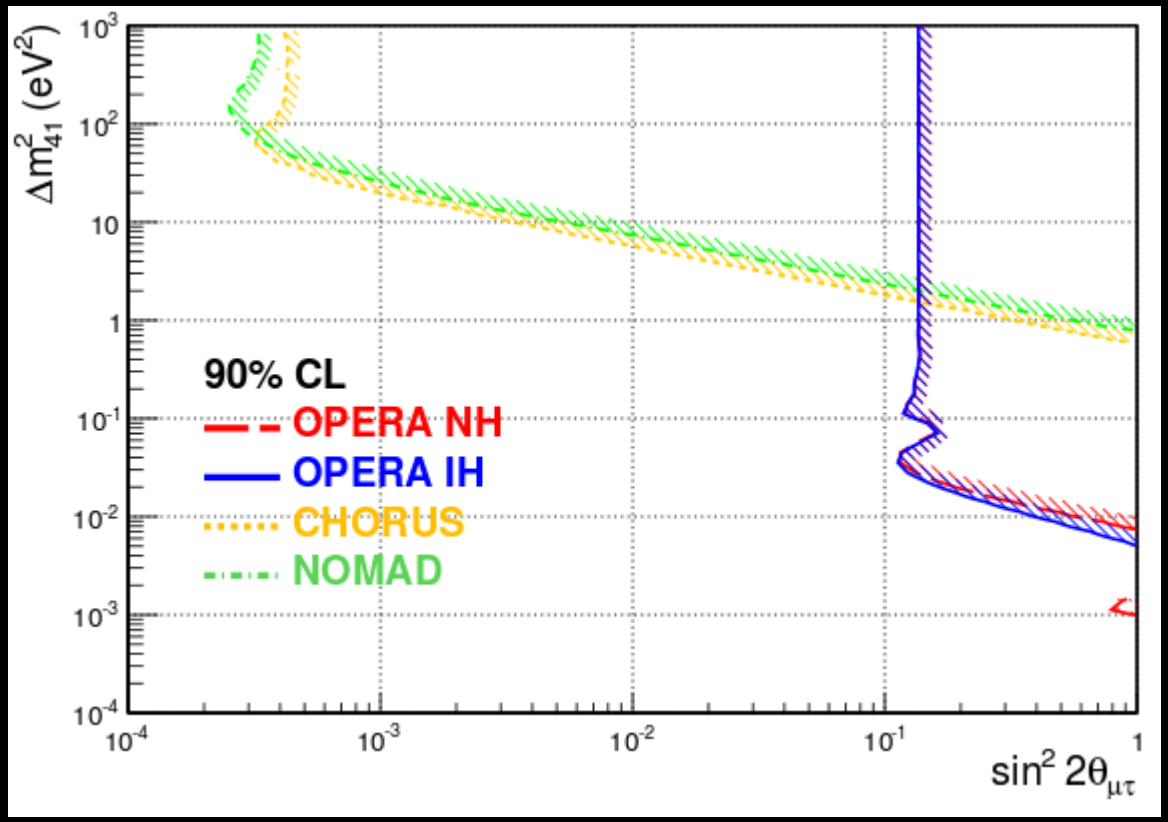


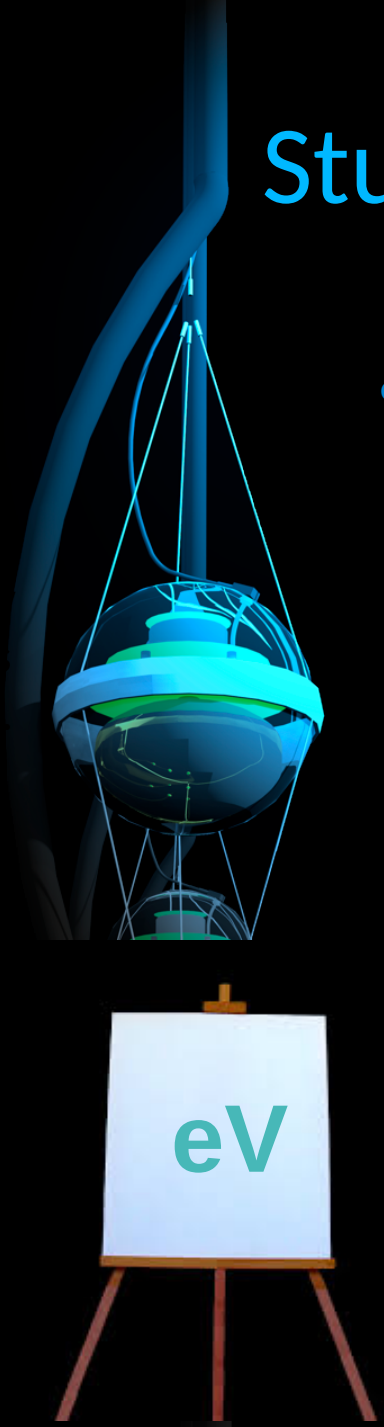
Figure 3: The expected sensitivity for ν_μ disappearance, at 90% CL, based on 3×10^{20} POT of MC scaled to 6×10^{20} POT with flux and cross-section systematics included. The red and the yellow lines show the 90% CL when the CC0π, CCπ^+ and CCOth samples are combined into a single CC inclusive sample. The dashed purple line shows the 90% CL when the three samples are kept separate. The shaded region indicates the 90% CL limits from the CCFR [10] and CDHS [11] experiments. The black line represents the 90% CL limits from MiniBooNE/SciBooNE measurements [12].

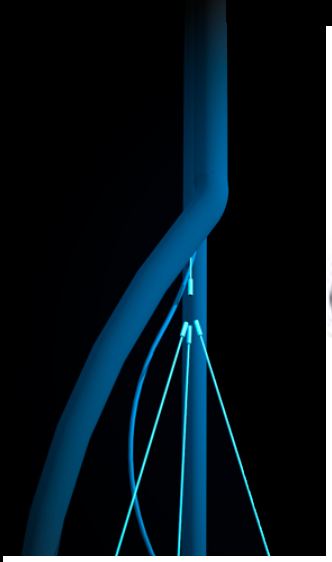
Study of eV Steriles: Accelerators

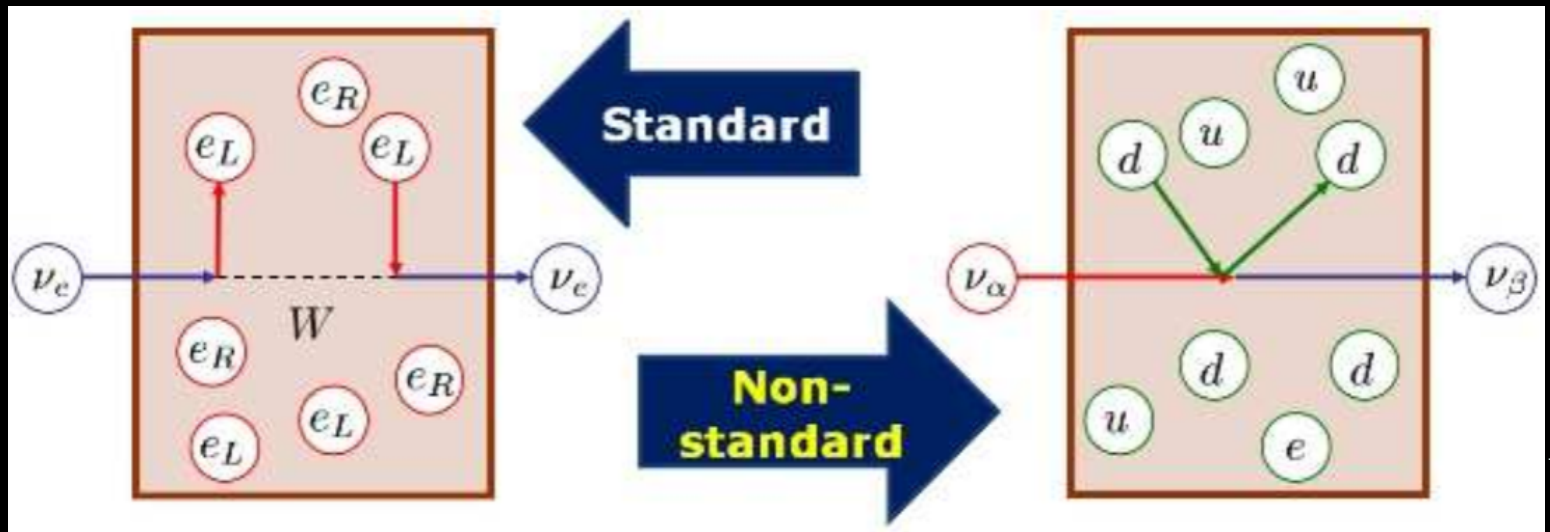
- OPERA: Current constraints



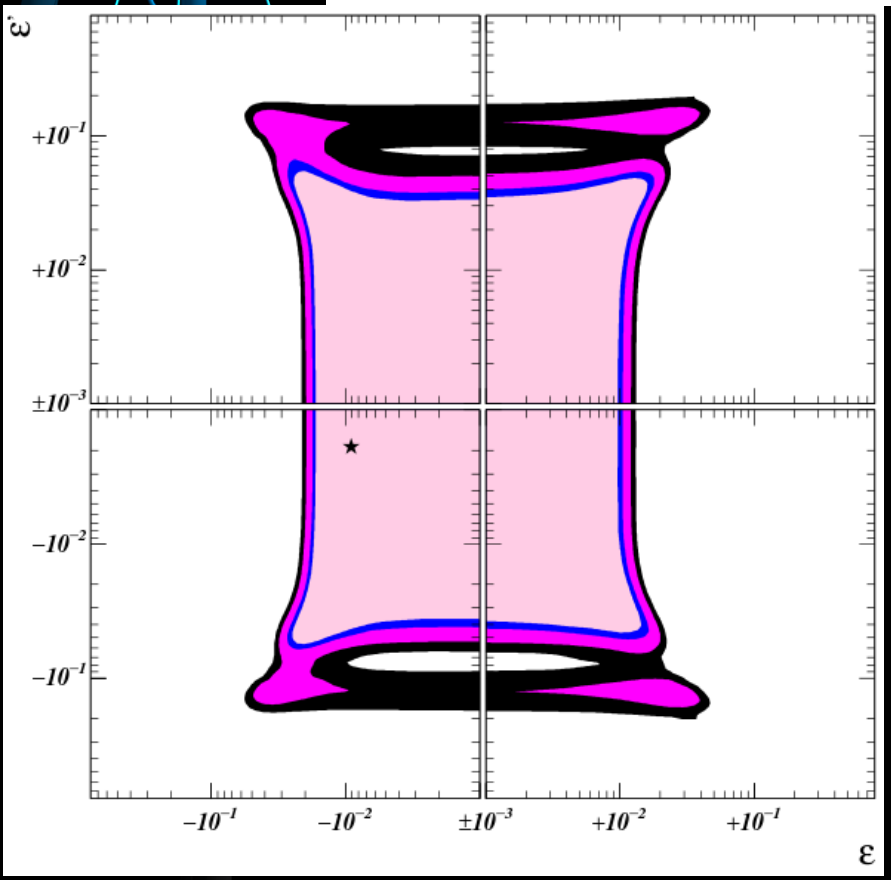
*http://arxiv.org/pdf/1503.01876v2.pdf







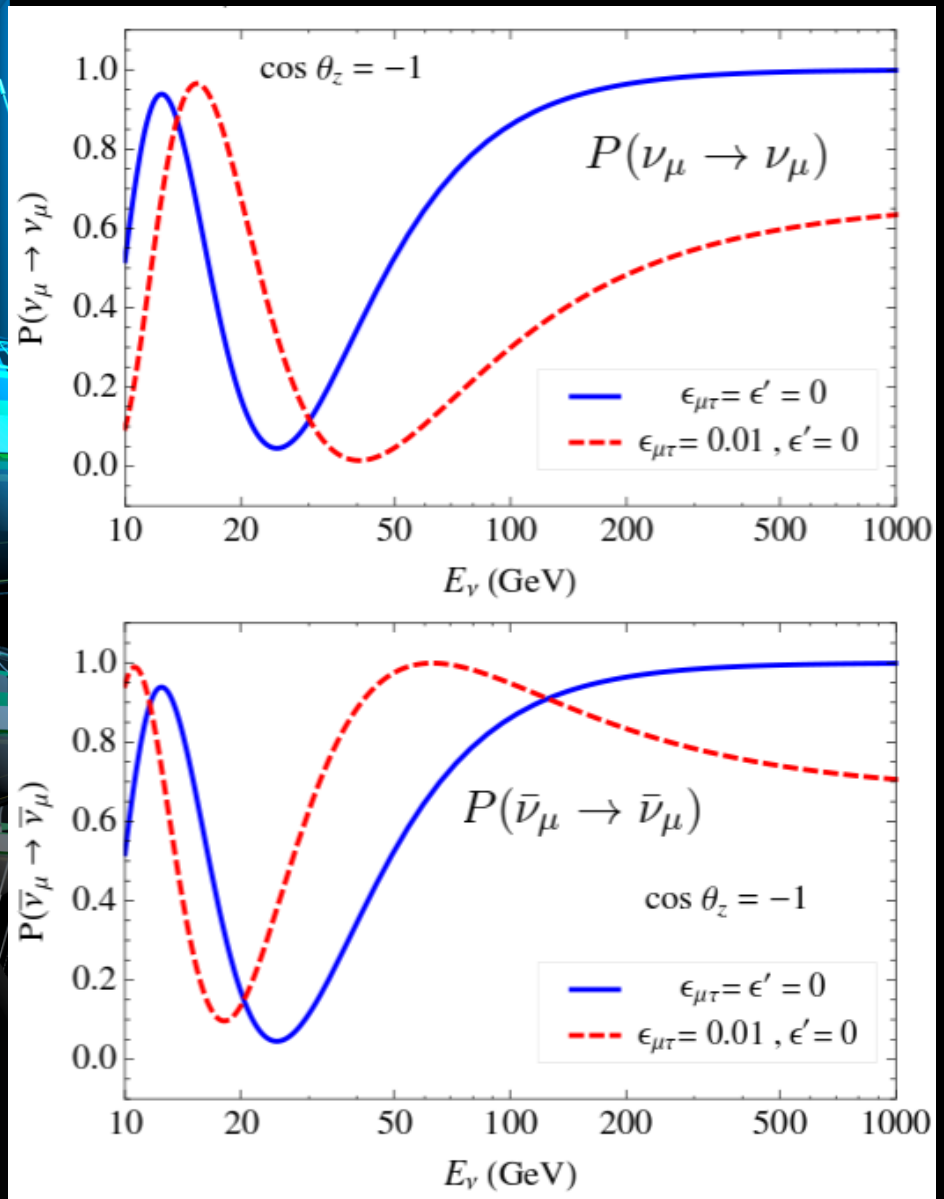
* http://arxiv.org/pdf/1209.2710v2.pdf

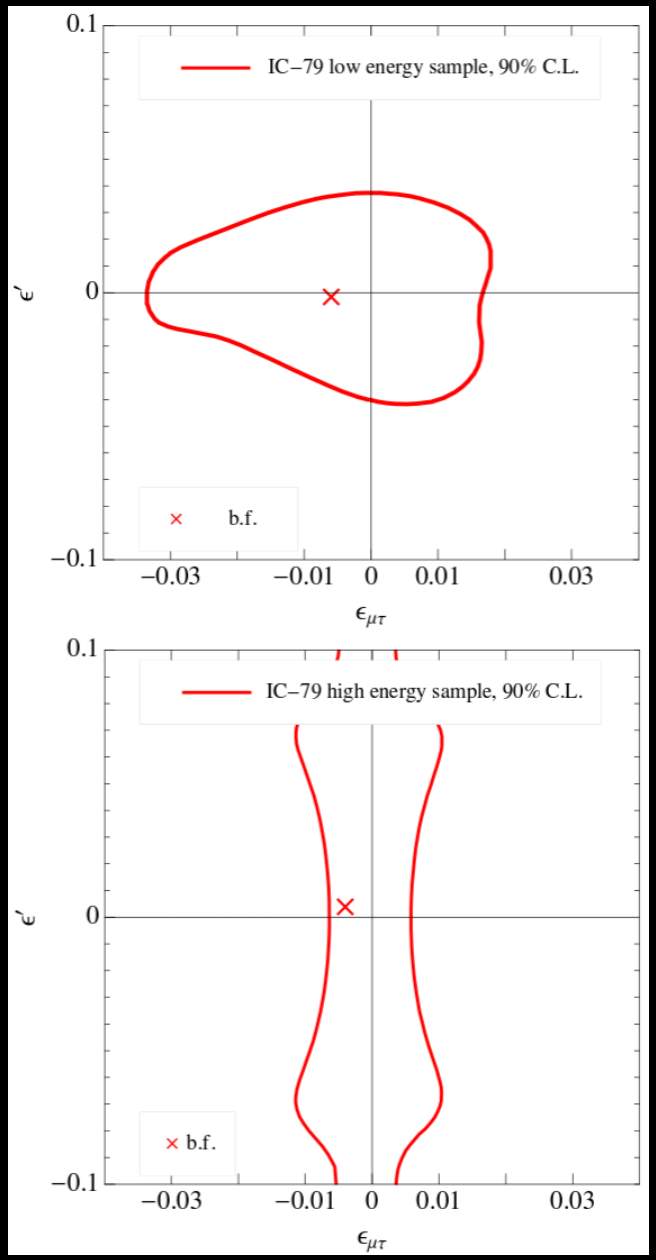


* http://arxiv.org/pdf/hep-ph/0108043v3.pdf

NSI: Non Standard Interactions

NSI with IceCube





*Edited Image from: http://arxiv.org/pdf/1304.1042v2.pdf

Backup Slides

- SBL Oscillation

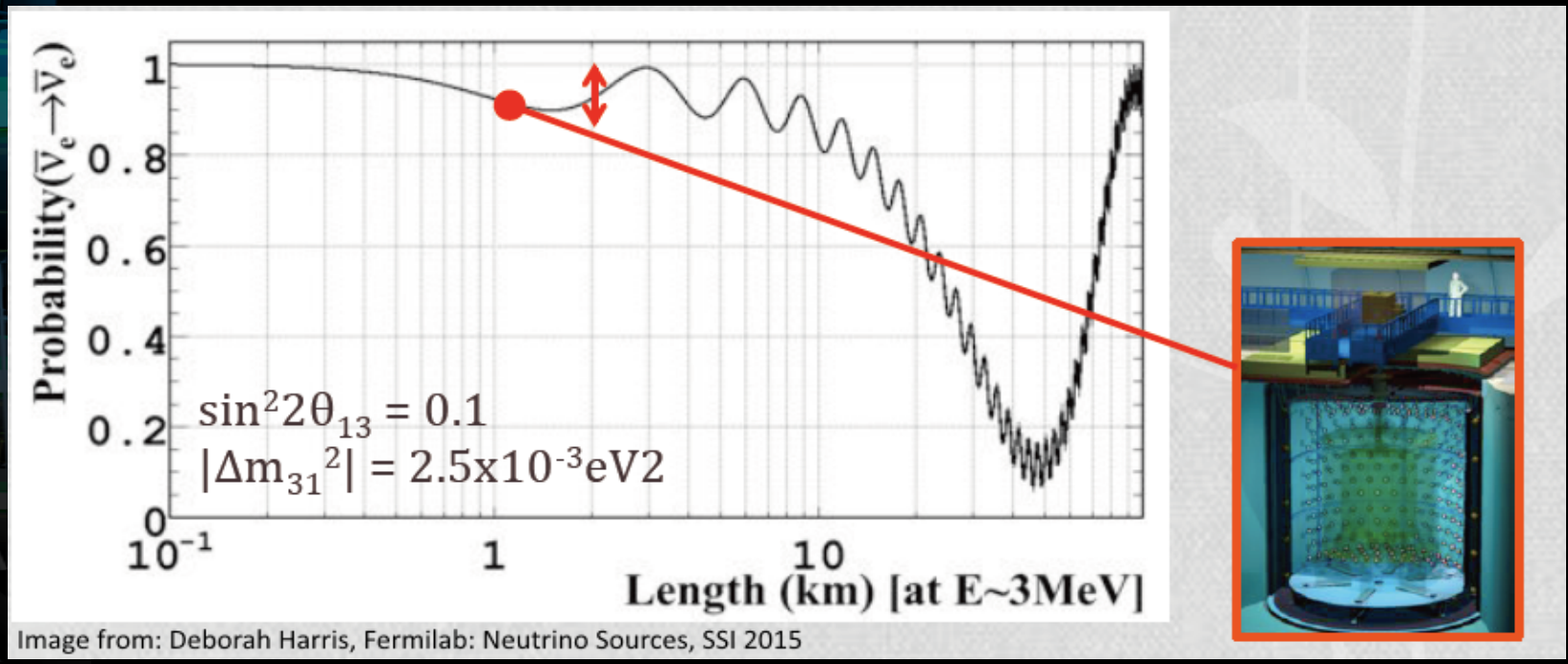


Image from: Deborah Harris, Fermilab: Neutrino Sources, SSI 2015