Appearance Physics with a 2 GeV Muon Storage Ring

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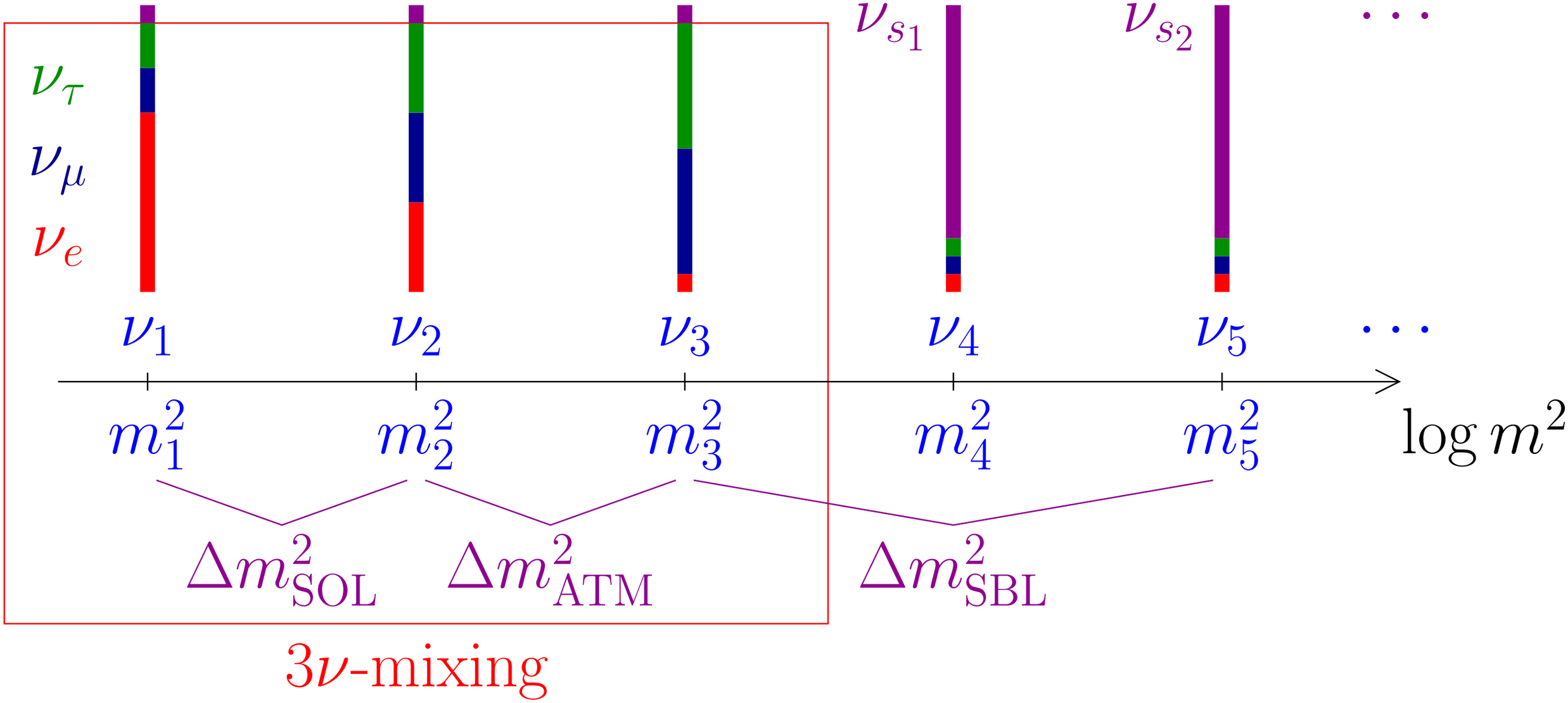
Review

Steriles: in pictures



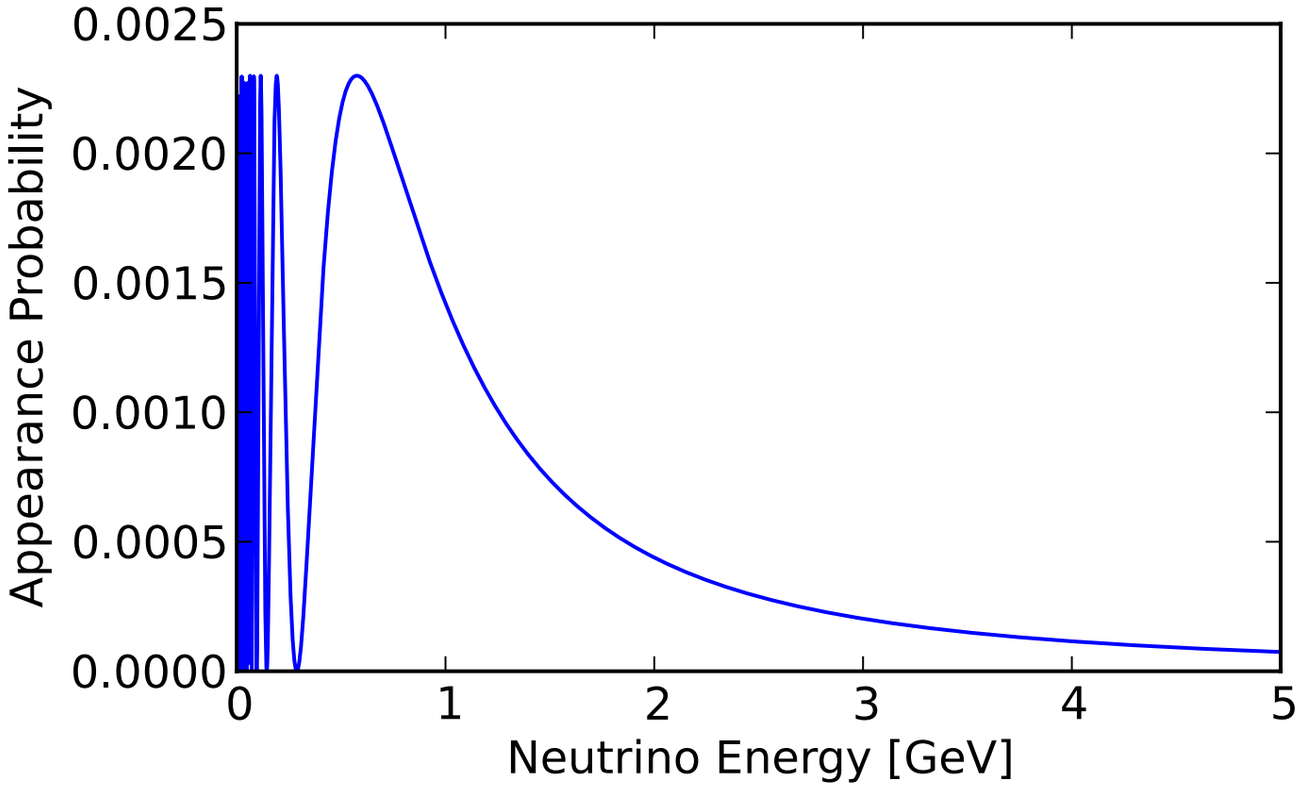
Right handed neutrinos (since neutrinos have mass)?
Dark matter?

Review

Steriles: in math

$$U = R_{34} R_{24} R_{14}$$

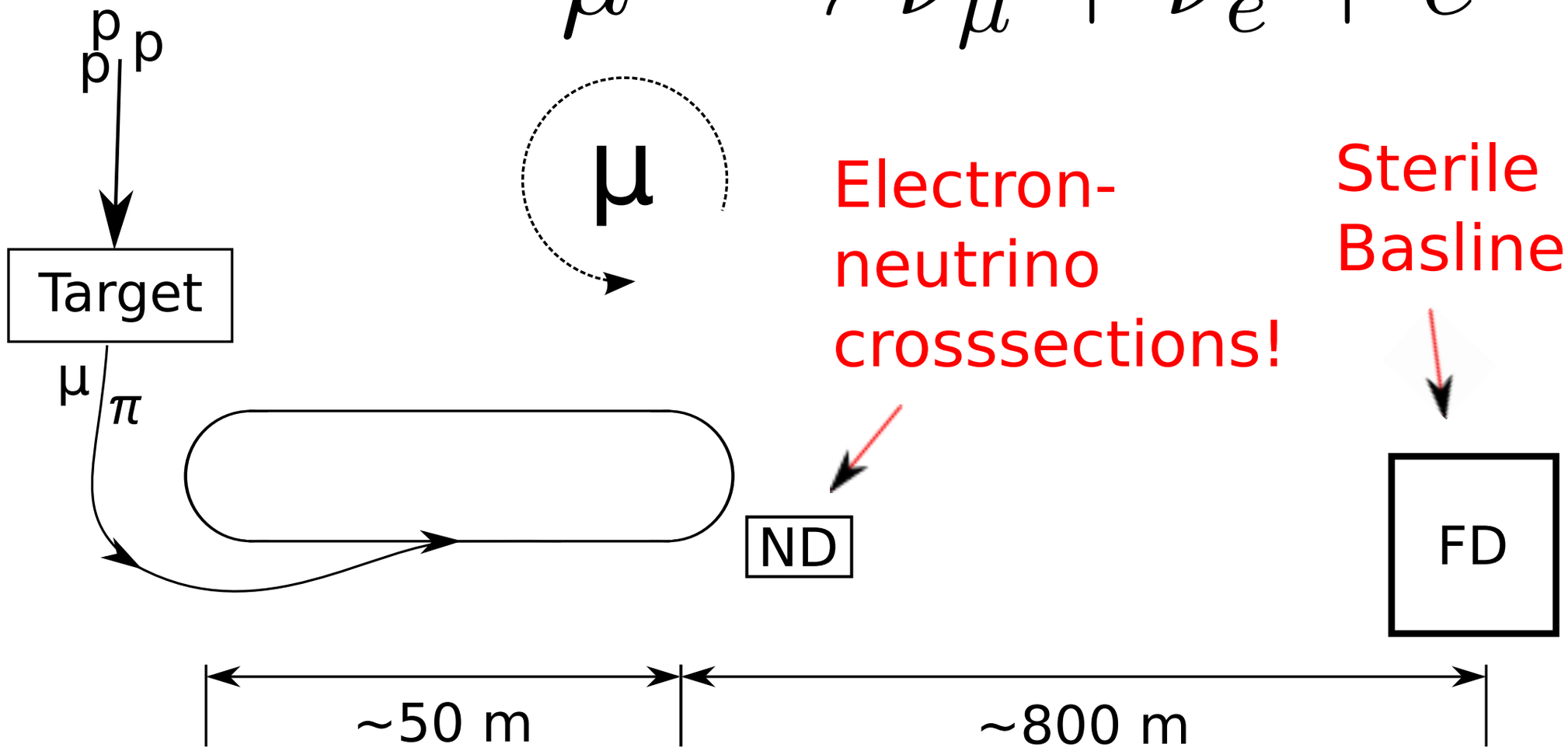
$$\begin{pmatrix} \cos(\theta_{14}) & 0 & 0 & \sin(\theta_{14}) \\ -\sin(\theta_{14})\sin(\theta_{24}) & \cos(\theta_{24}) & 0 & \sin(\theta_{24})\cos(\theta_{14}) \\ -\sin(\theta_{14})\sin(\theta_{34})\cos(\theta_{24}) & -\sin(\theta_{24})\sin(\theta_{34}) & \cos(\theta_{34}) & \sin(\theta_{34})\cos(\theta_{14})\cos(\theta_{24}) \\ -\sin(\theta_{14})\cos(\theta_{24})\cos(\theta_{34}) & -\sin(\theta_{24})\cos(\theta_{34}) & -\sin(\theta_{34}) & \cos(\theta_{14})\cos(\theta_{24})\cos(\theta_{34}) \end{pmatrix}$$



$$\begin{aligned} \Pr.[\nu_\alpha \to \nu_\alpha] &= 1 - \left[4|U_{\alpha 4}|^2(1-|U_{\alpha 4}|^2)\right]\sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right) \\ &= \sin^2(2\theta_{\alpha\alpha})\sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right) \\ \Pr.[\nu_e \to \nu_\mu] &= 4|U_{e4}|^2|U_{\mu 4}|^2\sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right) \\ &= \sin^2(2\theta_{e\mu})\sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right) \end{aligned}$$

Review

$$\mu^+ \rightarrow \bar{\nu}_\mu + \nu_e + e^+$$



Electron-neutrino crosssections!

Sterile Basline

Appearance-only (though disappearance good too!)

$$Pr[e \rightarrow \mu] = 4|U_{e4}|^2|U_{\mu 4}|^2 \sin^2(\frac{\Delta m^2_{41} L}{4E})$$

Raw Event Rates

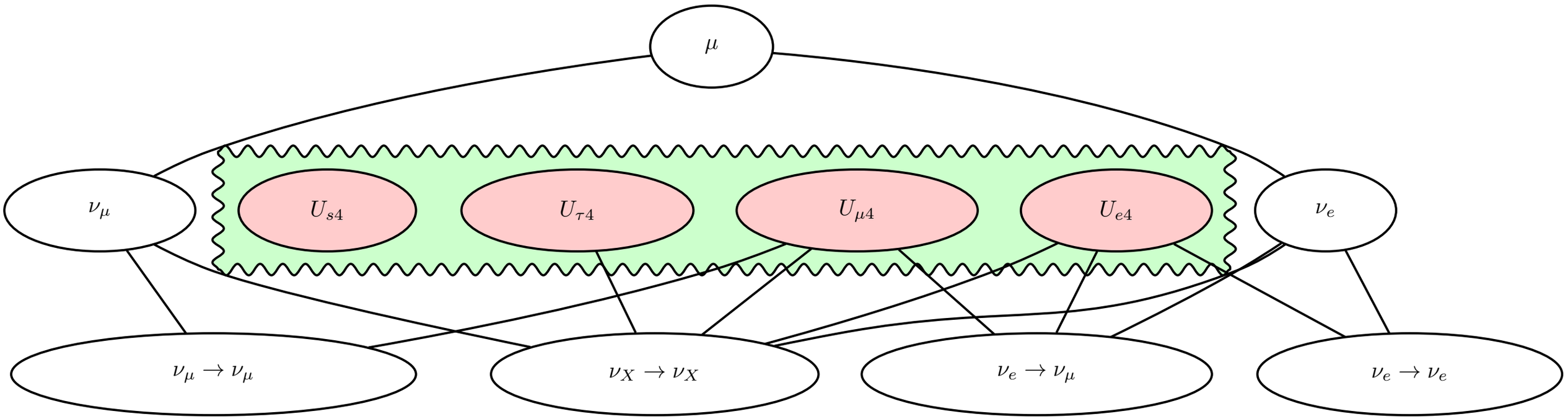
μ^+

Channel	$N_{\text{osc.}}$	N_{null}	Diff.	$(N_{\text{osc.}} - N_{\text{null}})/\sqrt{N_{\text{null}}}$
$\nu_e \to \nu_\mu$ CC	191	0	∞	∞
$\bar{\nu}_\mu \to \bar{\nu}_\mu$ NC	34817	35993	-3.3%	-6.2
$\nu_e \to \nu_e$ NC	65393	68552	-4.6%	-12.1
$\bar{\nu}_\mu \to \bar{\nu}_\mu$ CC	85117	87943	-3.2%	-9.5
$\nu_e \to \nu_e$ CC	171196	179223	-4.5%	-19.0
NC sum	-	-	-	13.4

μ^-

Channel	$N_{\text{osc.}}$	N_{null}	Diff.	$(N_{\text{osc.}} - N_{\text{null}})/\sqrt{N_{\text{null}}}$
$\bar{\nu}_e \to \bar{\nu}_\mu$ CC	72	0	∞	∞
$\bar{\nu}_e \to \bar{\nu}_e$ NC	28325	29613	-4.3%	-7.5
$\bar{\nu}_e \to \bar{\nu}_e$ CC	68065	71105	-4.3%	-11.4
$\nu_\mu \to \nu_\mu$ NC	75742	78457	-3.5%	-9.7
$\nu_\mu \to \nu_\mu$ CC	204381	211490	-3.4%	-15.5
NC sum	-	-	-	12.1

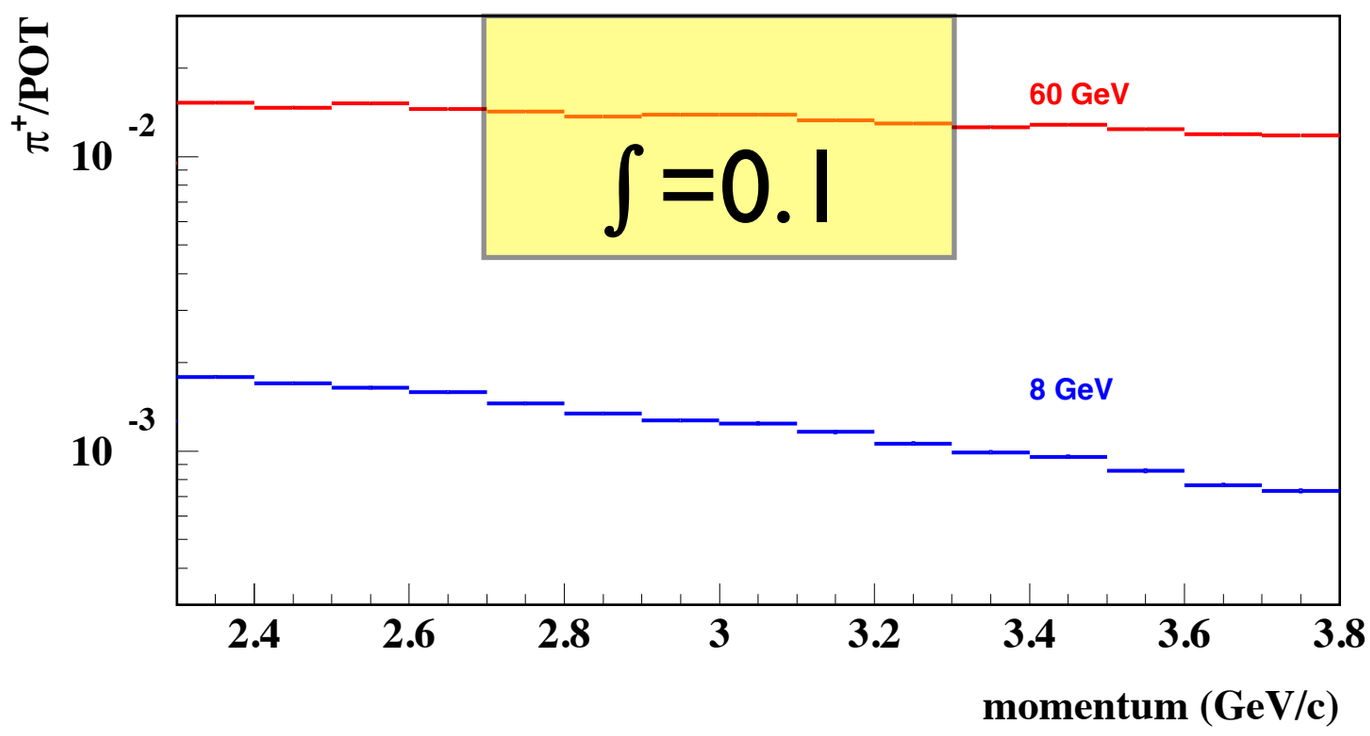
Fun cartoon, if visible?



How many muons?

$$
\begin{aligned}
N_\mu = &\quad (\text{POT}) \times (\pi \text{ per POT}) \times \epsilon_{\text{collection}} \times \epsilon_{\text{injection}} \times (\mu \text{ per } \pi) \times A_{\text{dynamic}} \times \Omega \\
= &\quad 10^{21} \times 0.1 \times 0.9 \times 0.9 \times 0.08 \times 0.9 \times 0.34 \\
= &\quad 2 \times 10^{18} \text{ good muon decays}
\end{aligned}
$$

- 5 years running w/ PIP
- 100 kilowatt target station
- 10% energy spread
- Very conservative
- See my note...



Review

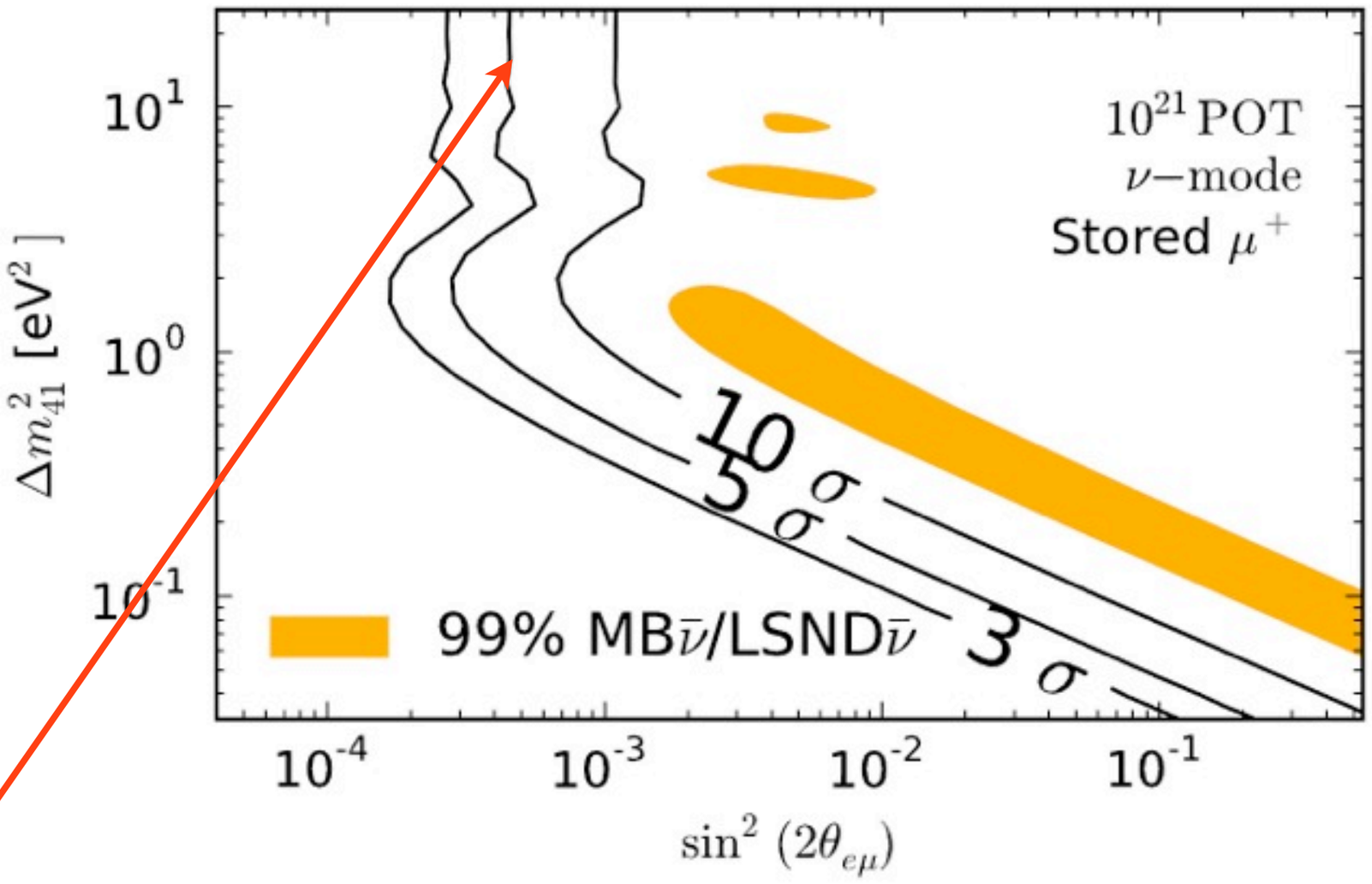
The VLENF Parameterization

Target Fiducial Mass:	1 kt
Muon Energy:	2 GeV
Number of Muons:	2.00E+18
Baseline:	800 m
Detector efficiency	(70 ± 2)%
NC Background Probability	1e-4 ± 35%
Charge Mis-ID	1e-4 ± 35%

can we do this, Ryan?

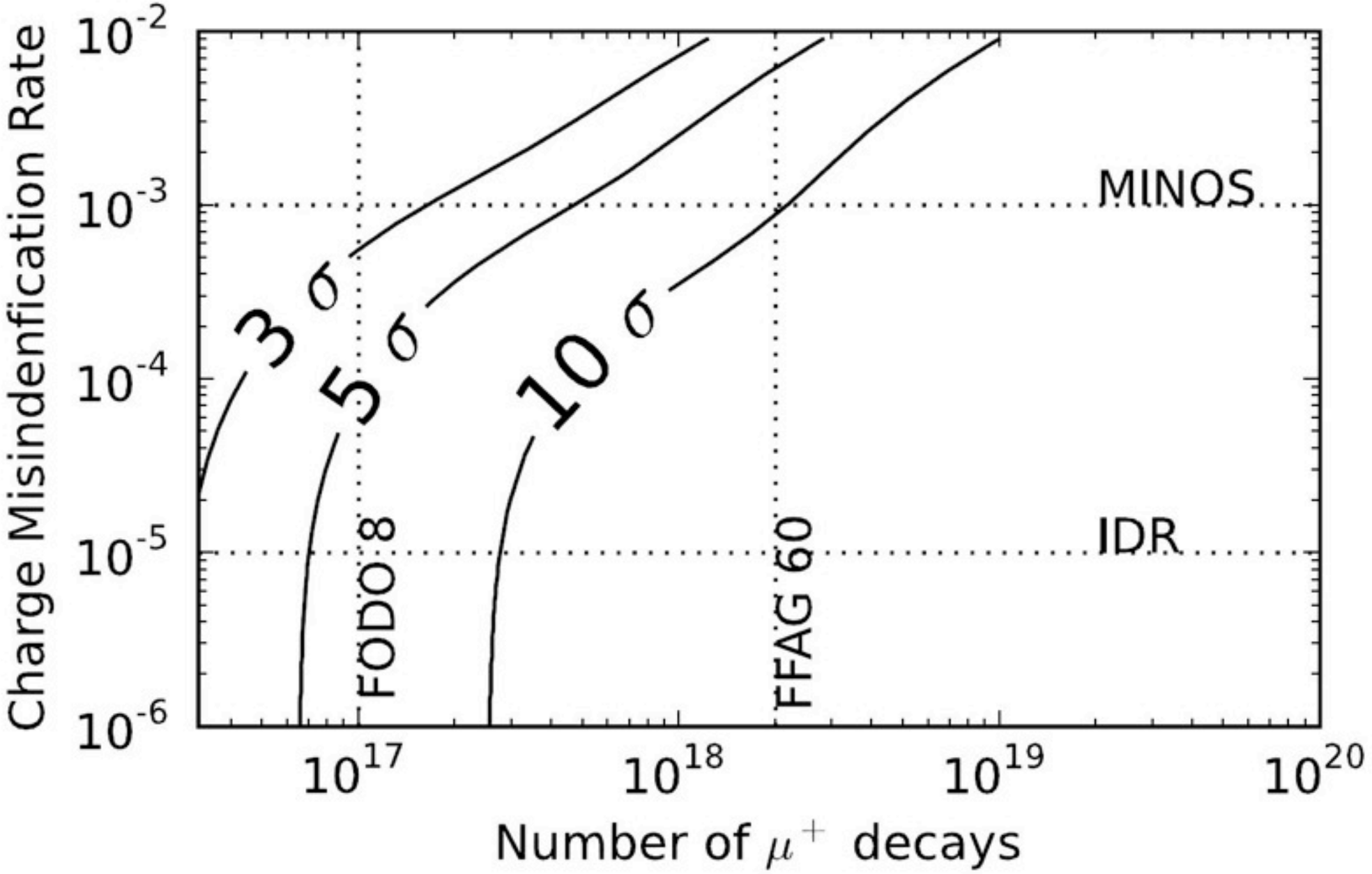
"Golden Channel"/ CPT(LSND)

$$\mathrm{Prob}[\mu \to e] = \sin^2 2\theta \sin^2 \left(\Delta m^2 L/4E\right)$$



No upper limit if we use a BCT rather than a near detector; can probe keV dark matter candidates

Accelerator v.s. Detector



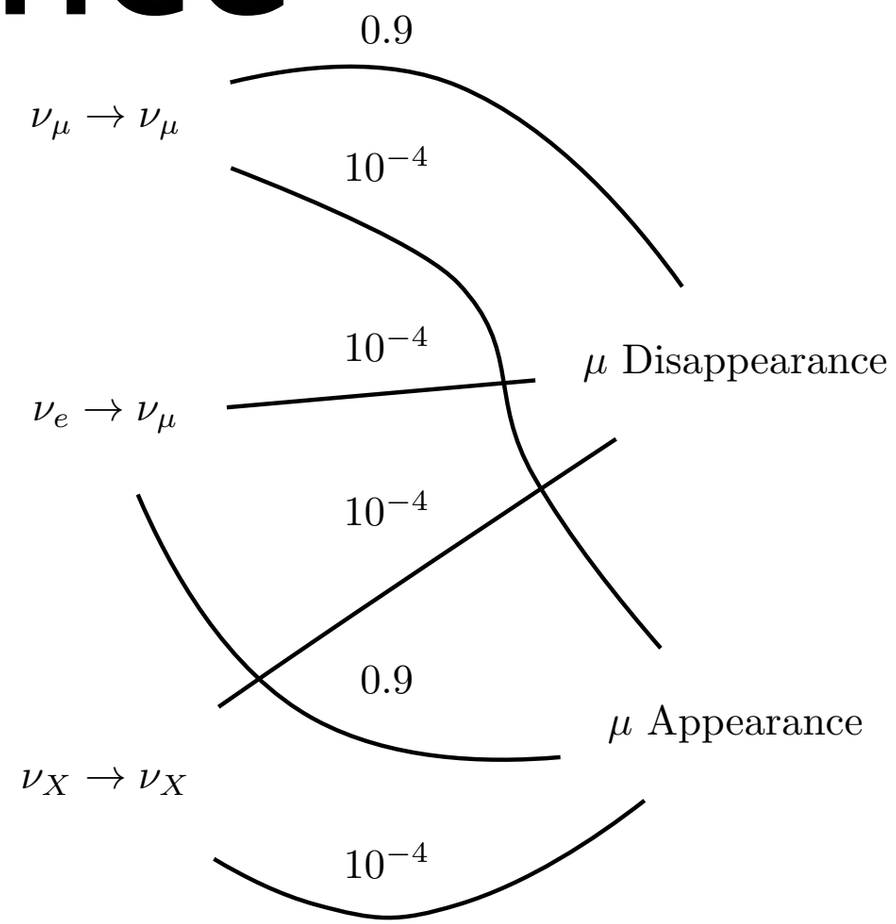
Disappearance

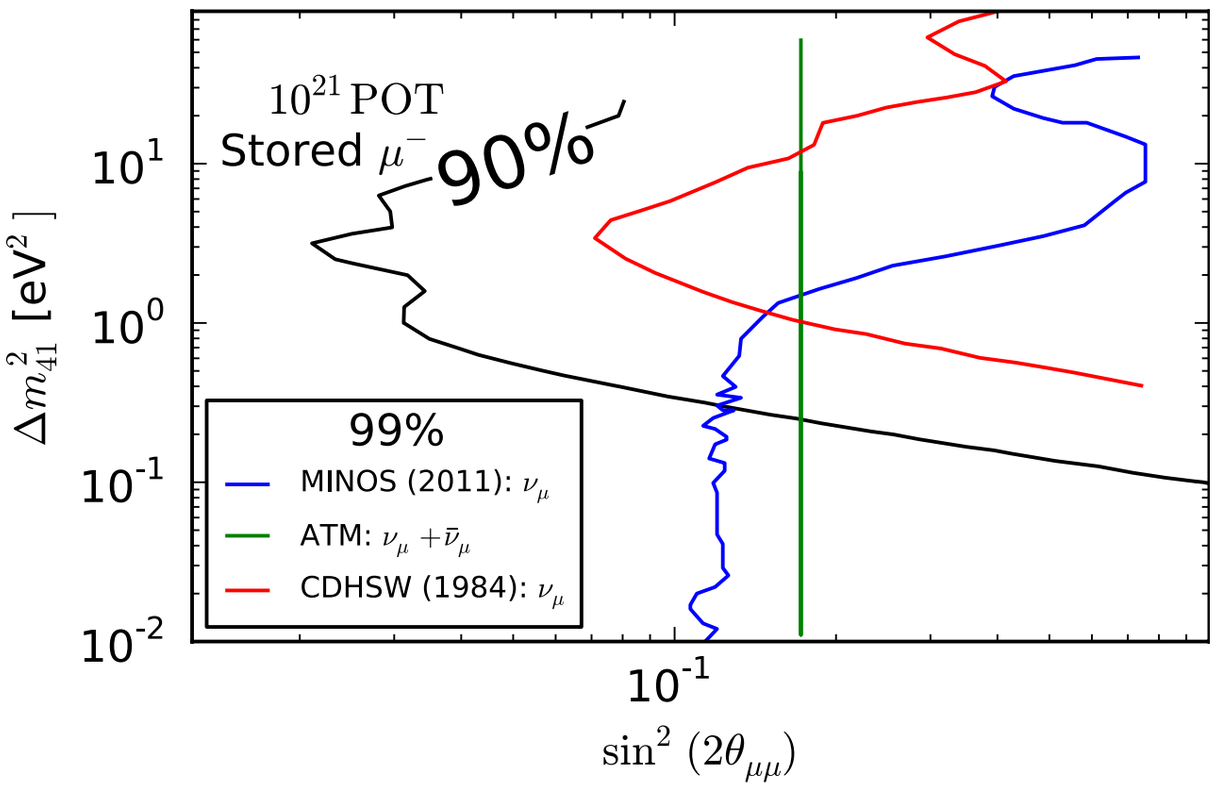
$$\Pr.[\nu_\alpha \to \nu_\alpha] = 1 - \left[4|U_{\alpha 4}|^2(1-|U_{\alpha 4}|^2)\right]\sin^2\left(\frac{\Delta m^2_{41}L}{4E}\right)$$

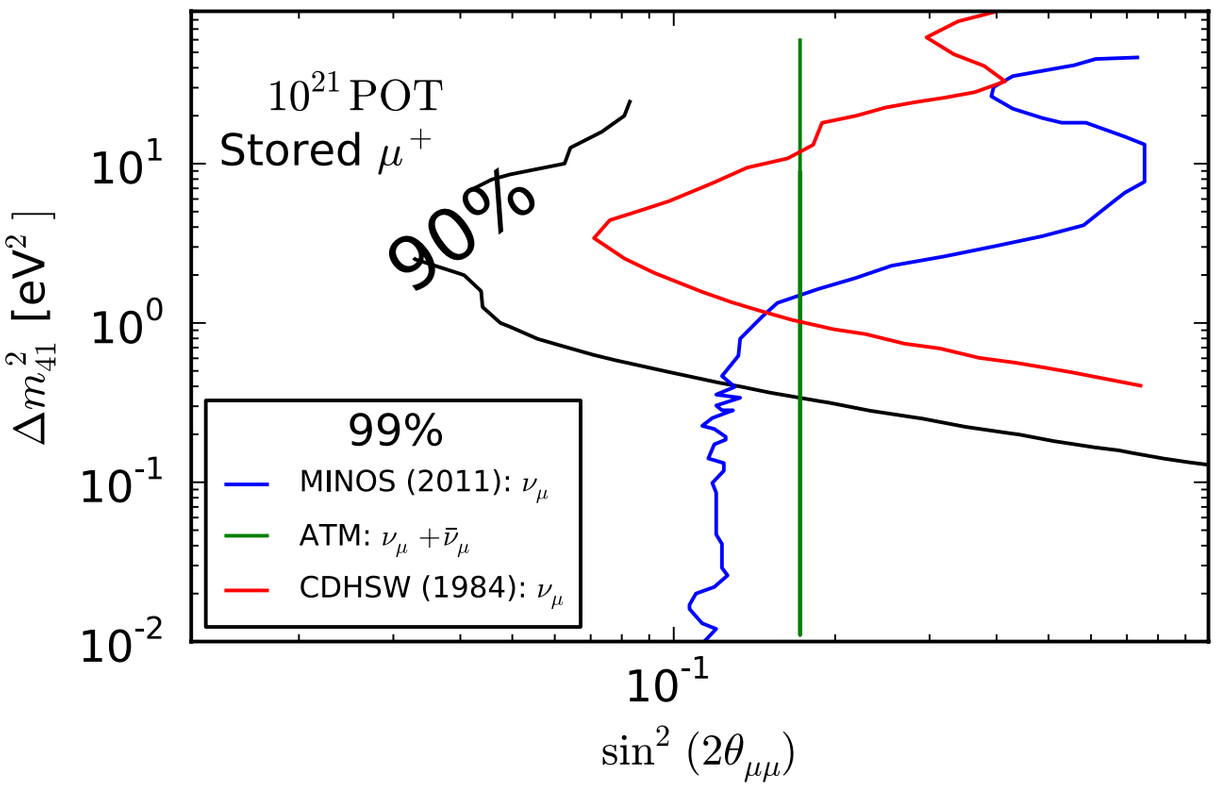
$$= \sin^2(2\theta_{\alpha\alpha})\sin^2\left(\frac{\Delta m^2_{41}L}{4E}\right)$$

$$\Pr.[\nu_e \to \nu_\mu] = 4|U_{e4}|^2|U_{\mu 4}|^2\sin^2\left(\frac{\Delta m^2_{41}L}{4E}\right)$$

$$= \sin^2(2\theta_{e\mu})\sin^2\left(\frac{\Delta m^2_{41}L}{4E}\right)$$







Conclusions

- Lots of theoretical (dark matter, right-handed neutrinos) and even some experimental motivation
- “Double suppressed” golden channel covers LSND range and is able to explore a different mass steriles
- Disappearance, which must be there, good too (See Walter’s talk)
- Comprehensive facility to study steriles