

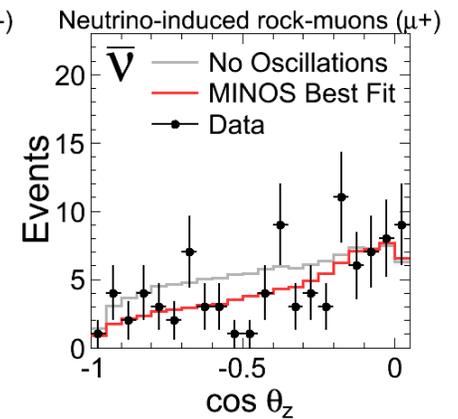
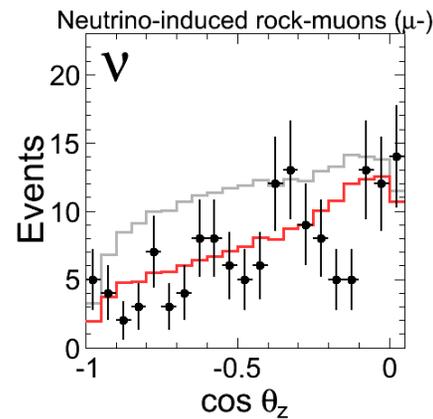
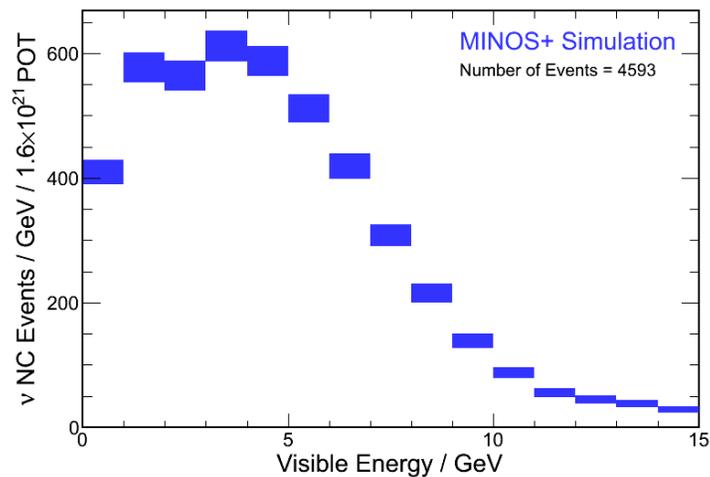
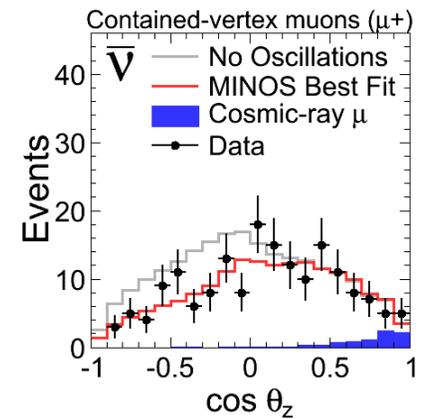
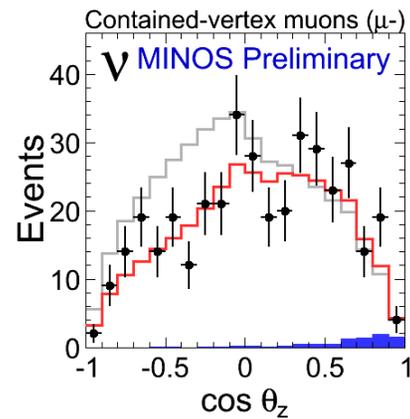
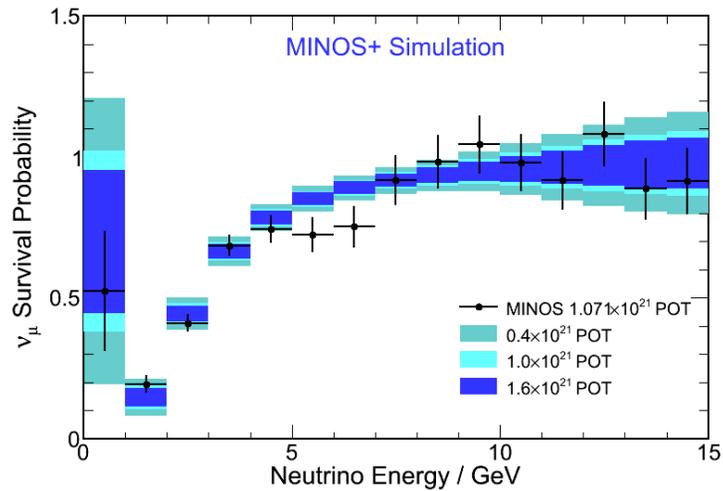
MINOS+

Physics in the first year
Neutrino 2014 in Boston
J.Thomas

- Measurement of Δm^2 and $\sin^2 2\theta_{23}$ via ν_μ CC disappearance
- θ_{23} octant via disappearance and appearance
- Sterile neutrino searches
- Non-Standard interactions
- Extra-dimensions
- Tau appearance

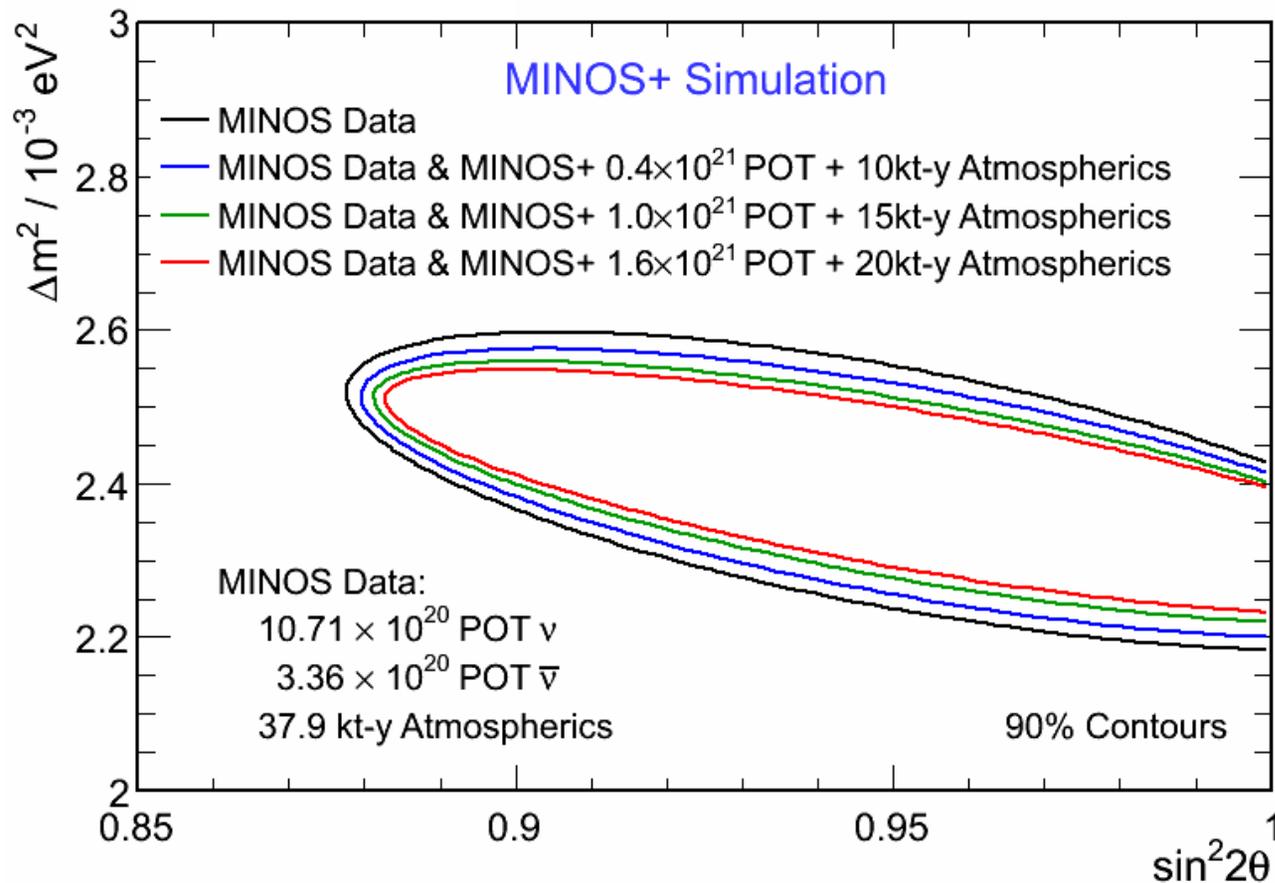
MINOS+

- Most of what MINOS+ will achieve will come from these distributions



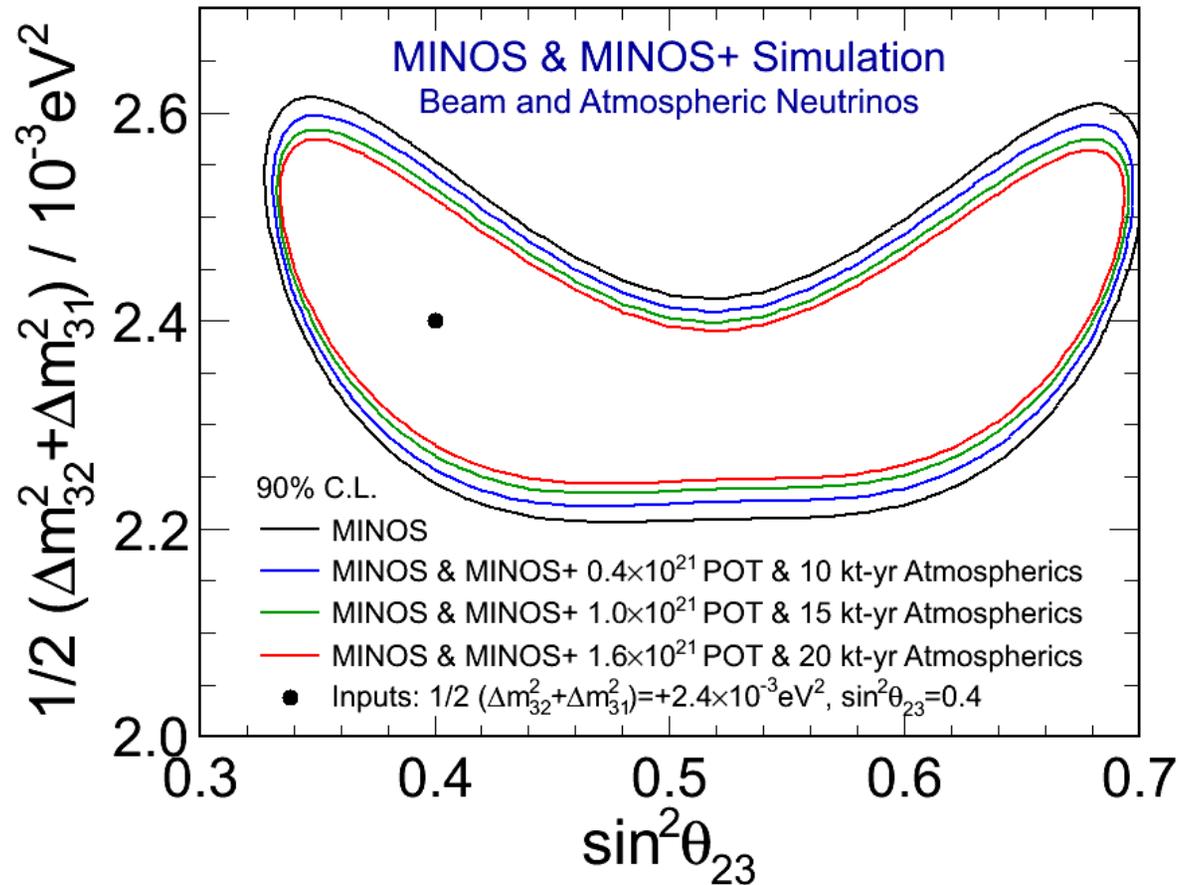
Measurement of Δm^2 and $\sin^2 2\theta_{23}$

- In the old days, we used to think about plots like this:



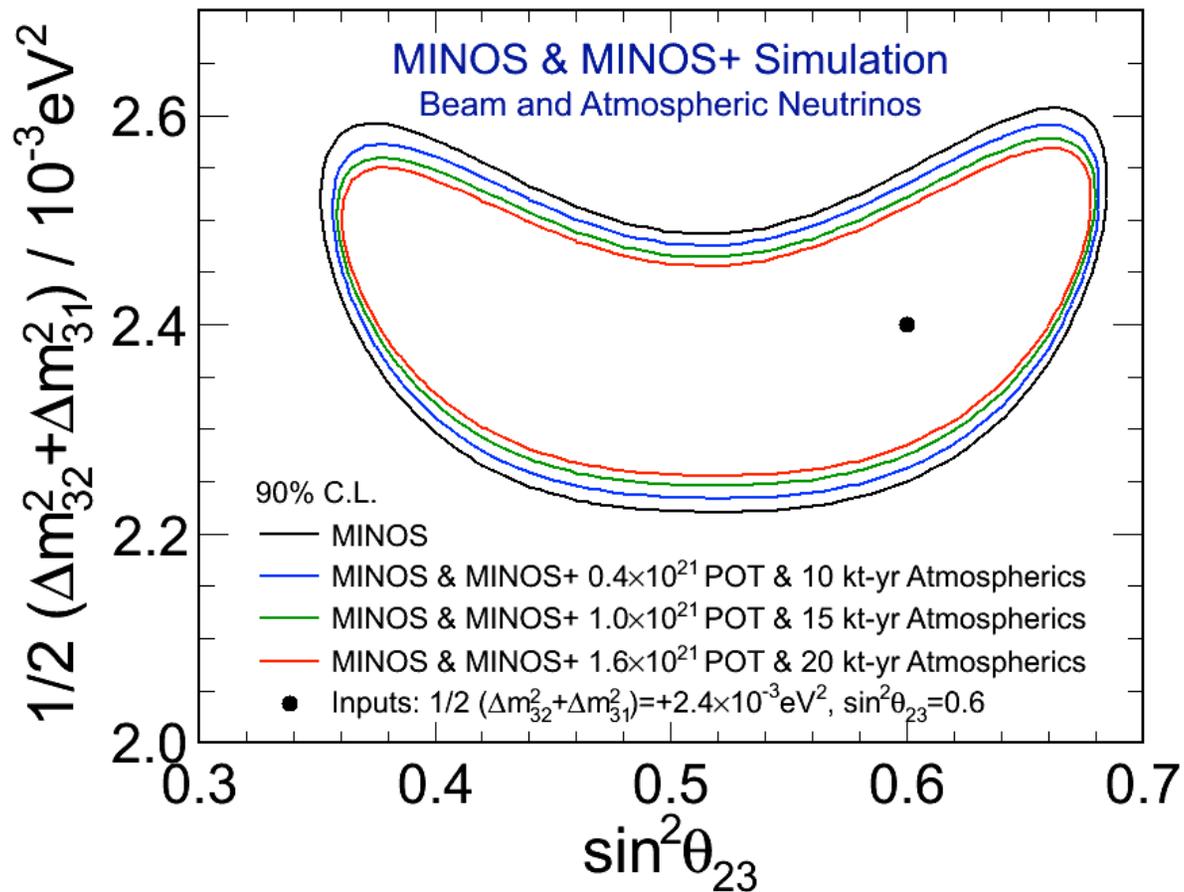
Measurement of Δm^2 and $\sin^2 2\theta_{23}$

- Now we have to think about 3 flavor plots like this:

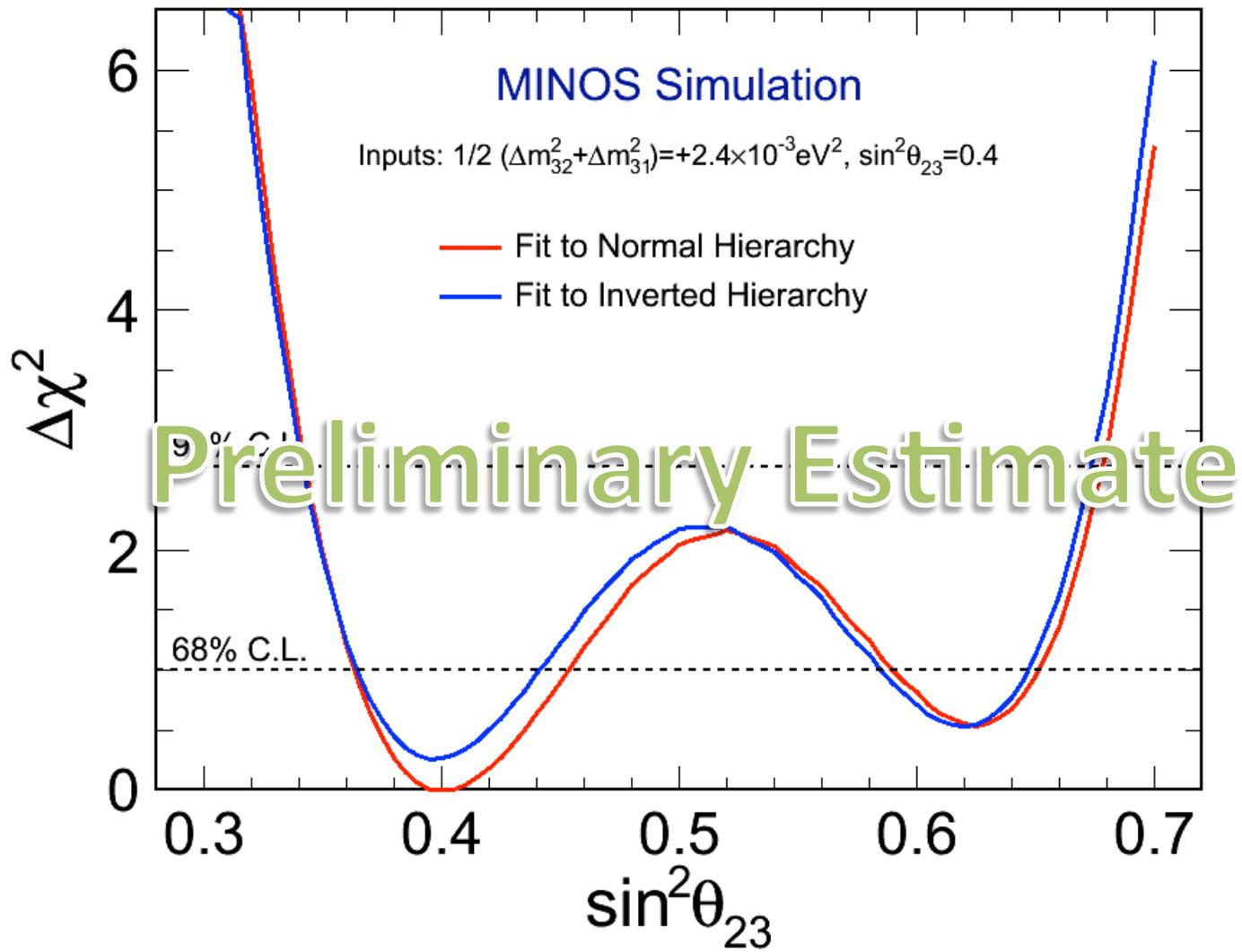


Measurement of Δm^2 and $\sin^2 2\theta_{23}$

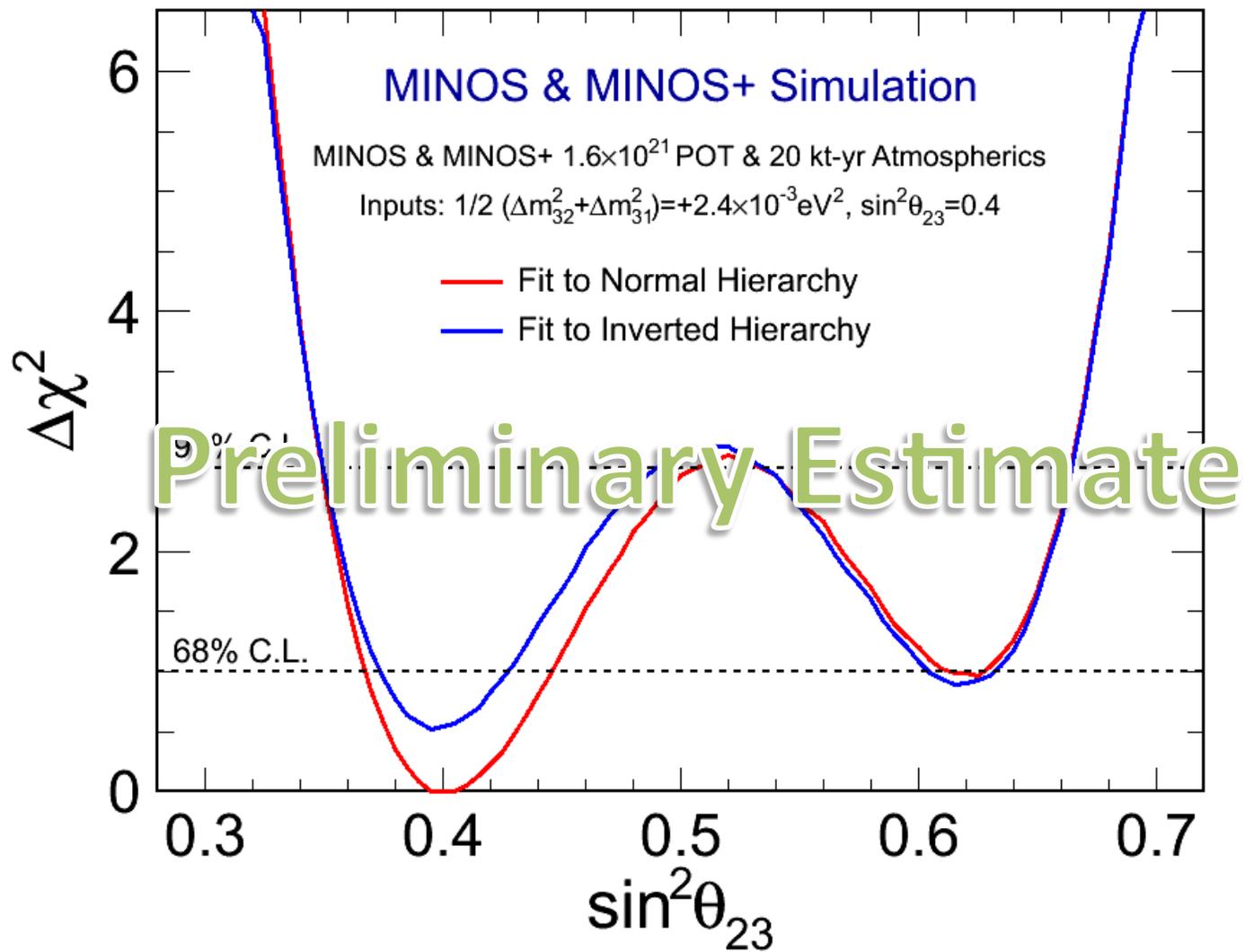
- Now we have to think about 3 flavor plots like this:



θ_{23} Octant

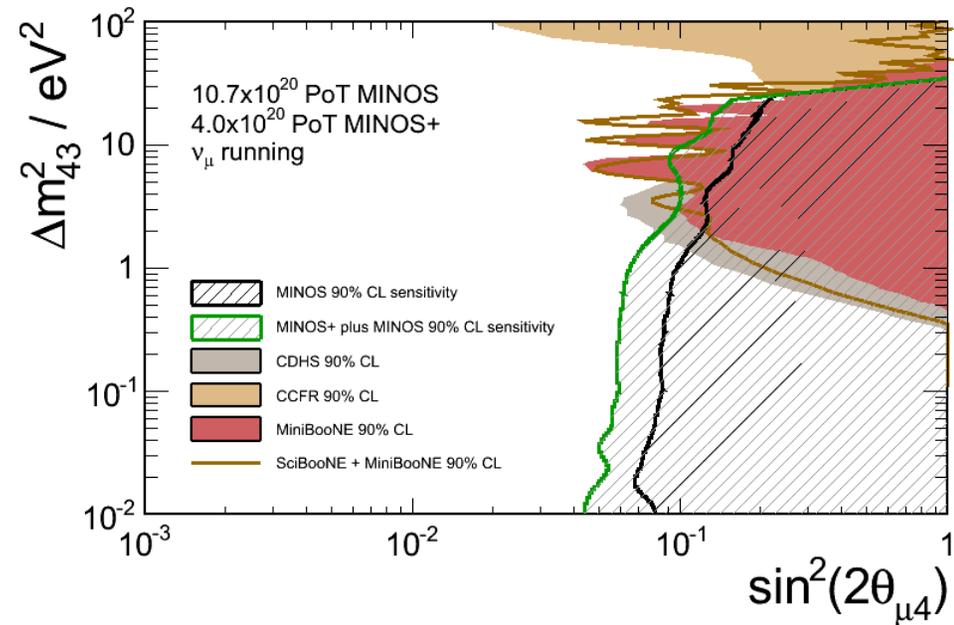
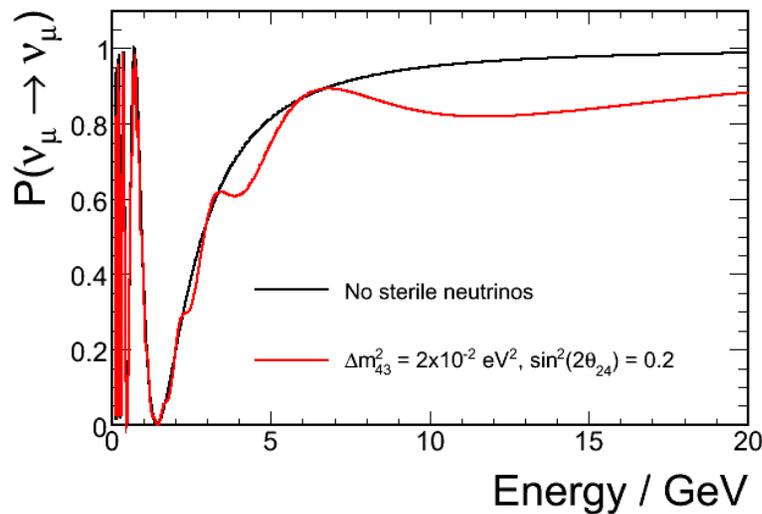


θ_{23} Octant



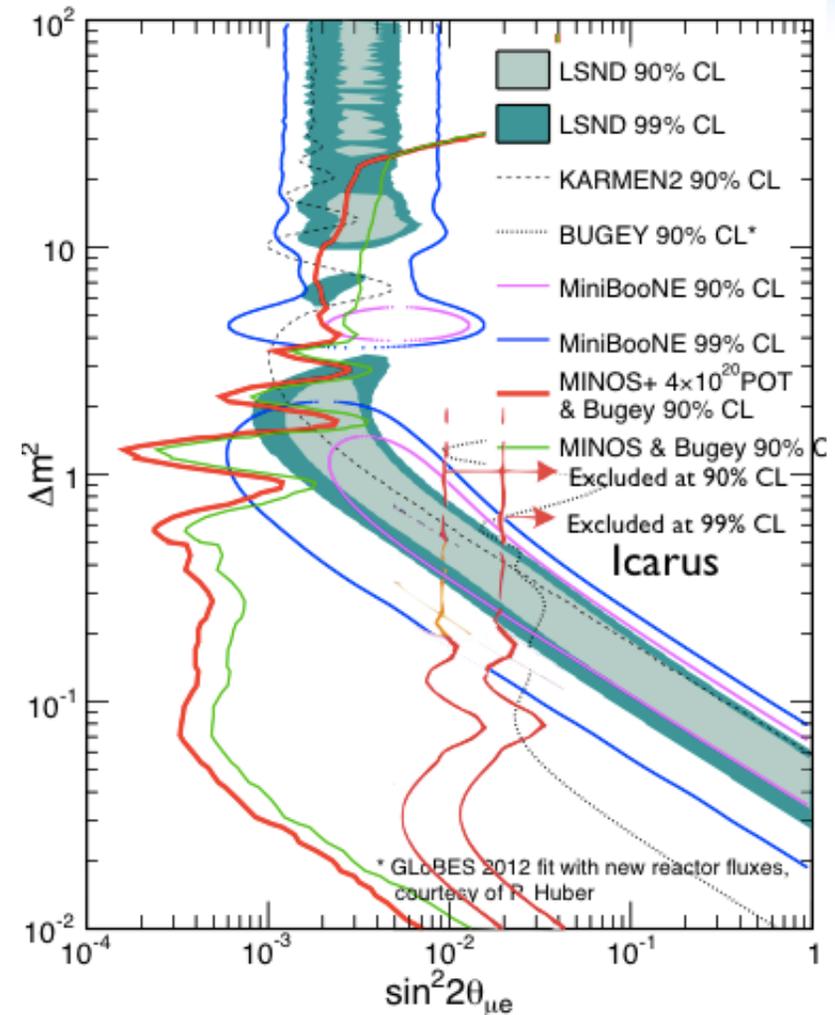
Sterile Neutrino Search

- After the first year, visible improvement on sterile limit



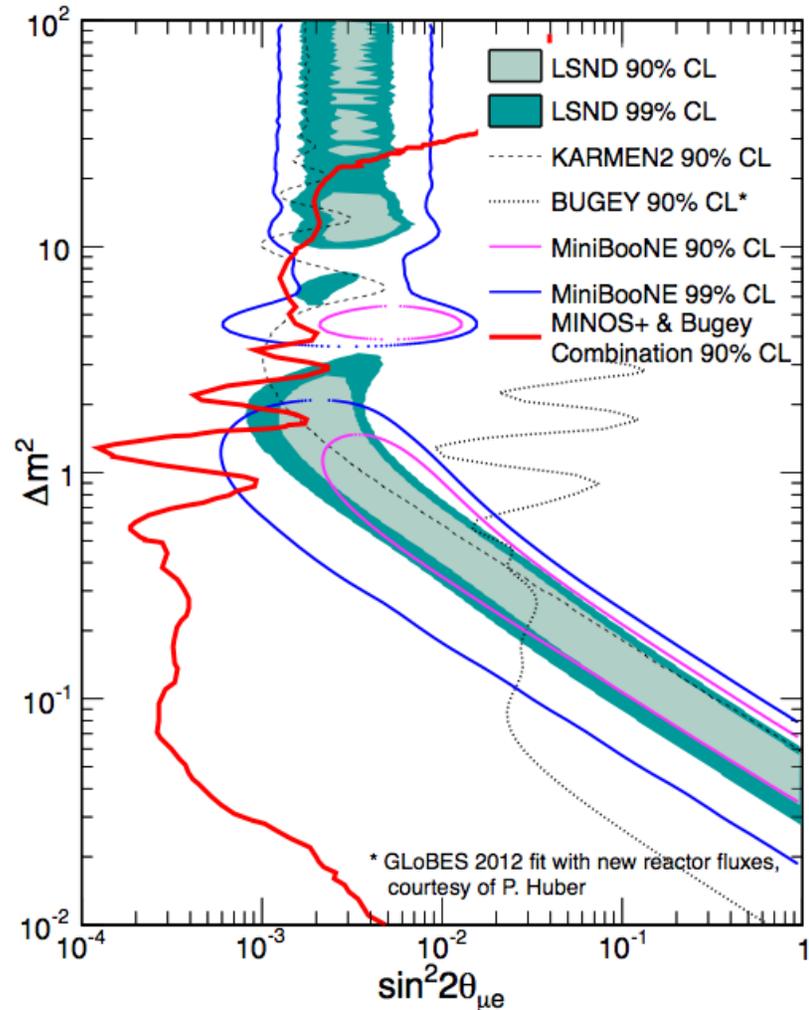
Sterile Neutrino Search

- Also note: $\sin^2 2\theta_{\mu e} = 4 |U_{e4}|^2 \times |U_{\mu 4}|^2$
- Combining the disappearance constraints from MINOS+ with complementary disappearance constraints from reactor experiments, MINOS+ can constrain large portions of the LSND appearance signal



Sterile Neutrino Search

- Also note: $\sin^2 2\theta_{\mu e} = 4 |U_{e4}|^2 \times |U_{\mu 4}|^2$
- Combining the disappearance constraints from MINOS+ with complementary disappearance constraints from reactor experiments, MINOS+ can constrain large portions of the LSND appearance signal. Note: (limit on the plot assumes 2 years of MINOS+ running)

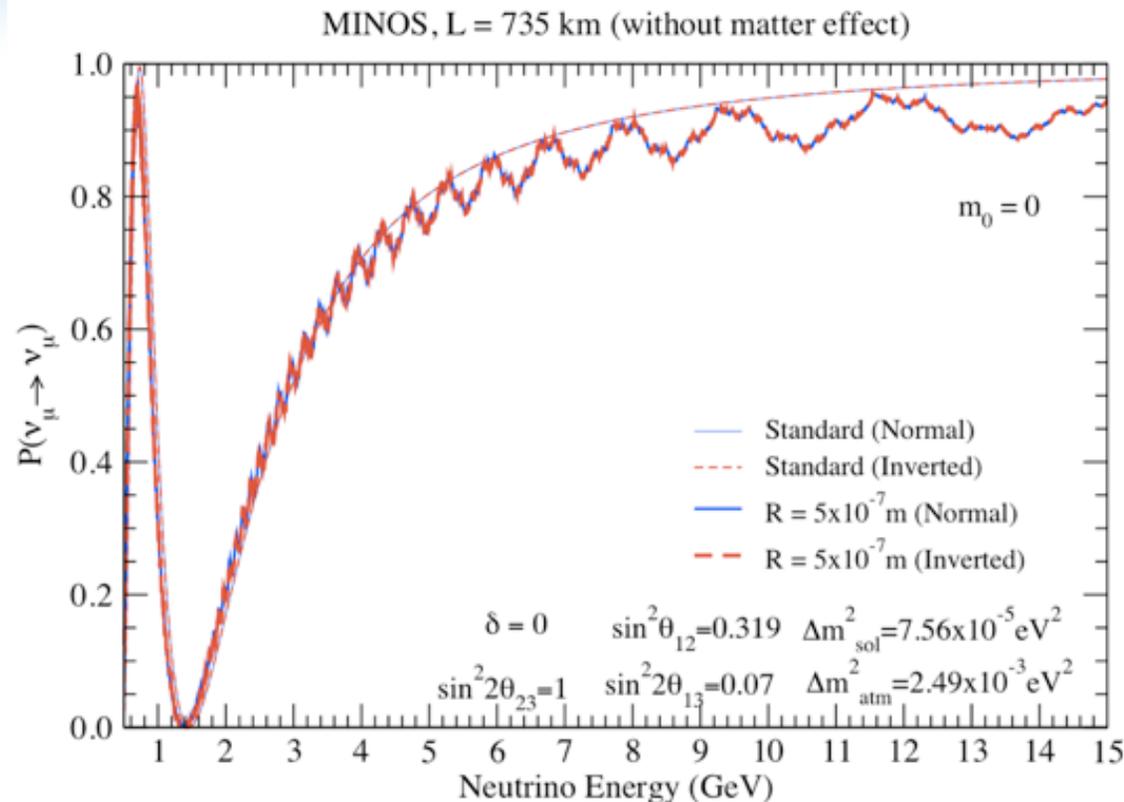


Tau Events

- In the first $4e20$ POT we expect about 60 tau events
 - ANN analysis being set up, huge backgrounds to contend with

Stage	2-4 GeV	4-8 GeV	8-12 GeV
Total	9.1	167.2	59.6
Fiducial	6.5	112.0	43.3
Nue Preselection	4.3	84.5	30.5
Nue Preselection (NC)	200.2	1474.2	716.4
Nue Preselection (CC numu)	201.1	895.8	273.4

Extra-Dimensions

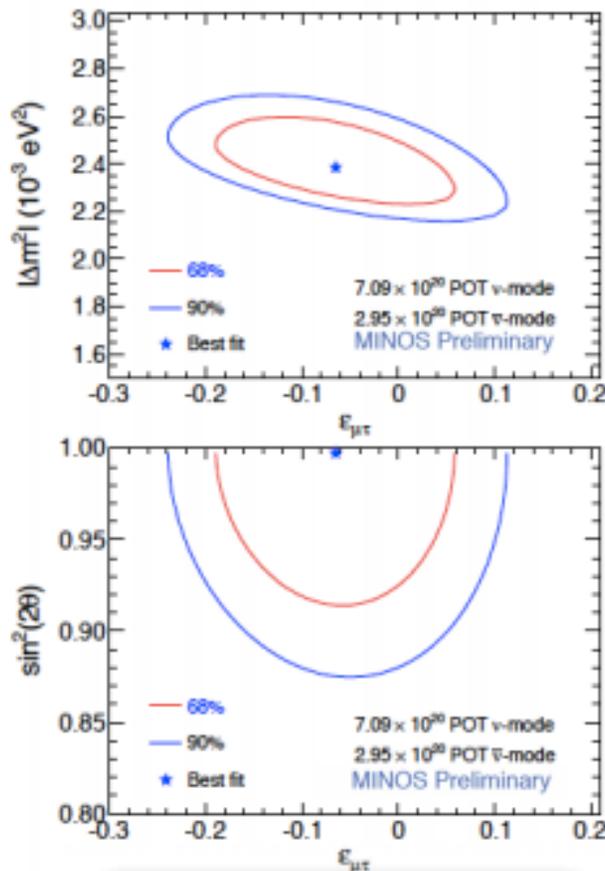


- Machado, Nunokawa, Zukanovich Funchal **Phys. Rev. D** **84**, 013003 (2011)
- Right-handed neutrinos propagate in extra-dimension of size R . Kaluza-Klein modes mix with regular oscillations
- MINOS+ can exclude extra dimensions with $R > 0.1$ micron
- Better than NOvA and T2K due to KK effect mostly at higher energies

Non-Standard Interactions



- Non-Standard Interactions affect neutrino propagation in the same way as MSW matter effects

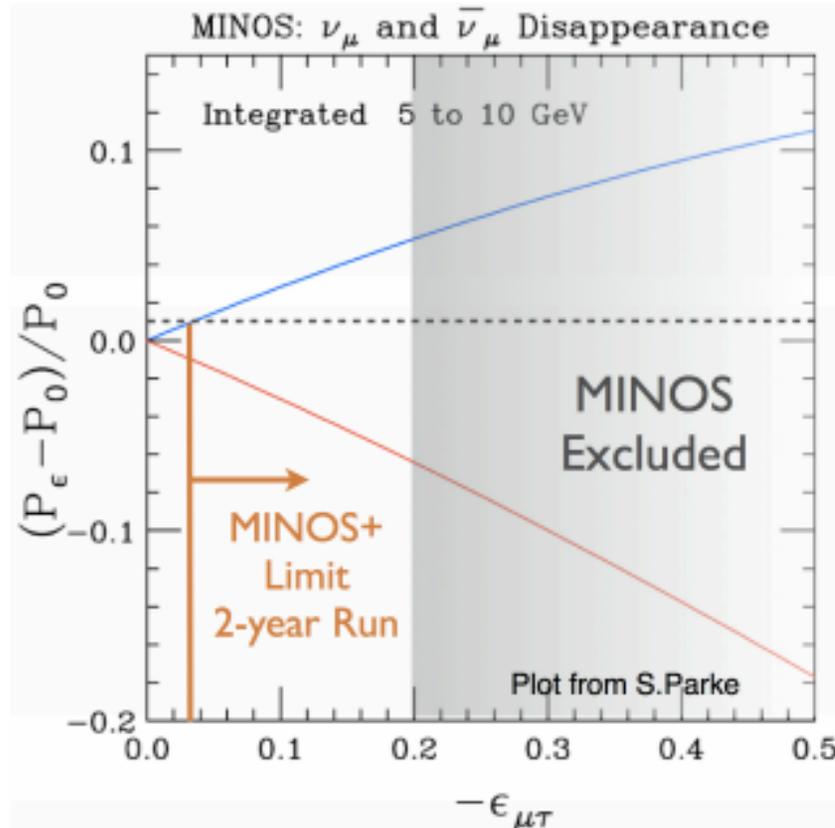


$$\Delta m^2 = 2.39^{+0.135}_{-0.105} \times 10^{-3} \text{eV}^2$$

$$\sin^2(2\theta) > 0.91 \text{ (90\% C.L.)}$$

$$-0.200 < \epsilon_{\mu\tau} < 0.070 \text{ (90\% C.L.)}$$

$$i \frac{d\vec{\nu}}{dt} = \left[\frac{\Delta m_{31}^2}{4E_\nu} \begin{pmatrix} -\cos 2\theta_{23} & \sin 2\theta_{23} \\ \sin 2\theta_{23} & \cos 2\theta_{23} \end{pmatrix} \pm \sqrt{2} G_F N_e(r) \begin{pmatrix} \epsilon_{\mu\mu}^e & \epsilon_{\mu\tau}^e \\ \epsilon_{\mu\tau}^{e*} & \epsilon_{\tau\tau}^e \end{pmatrix} \right] \vec{\nu}; \quad \vec{\nu} = (\nu_\mu, \nu_\tau)^T$$



Alexander Friedland,
Cecilia Lunardini,
Phys.Rev.D74:033012, 2006

J.Kopp, P.A.N. Machado
and S.Parke,
Phys.Rev.D82:113002 (2010)

- NSI parameter $\epsilon_{\mu\tau}$ can be significantly constrained thanks to MINOS+ large statistics. In Year 1, do not expect significant improvements because of nu running only

Publications

- We will have three analysis groups going forward
 - Disappearance
 - Appearance (ν_e , τ ...)
 - UP! (Universal Physics)
- We also have all the “support” groups in place such as Calibration, Reconstruction, Batch Processing, Data Quality Monitoring, etc
- Analysis should be straightforward, although ND reconstruction algorithms must be verified first
- In any case, we will not open the box until we have collected $4e20$ P.O.T which gives us time to have the major analyses ready to go.
- The goal is for first results for Neutrino 2014

Summary

- MINOS+ should be ready to take data on day 1
- There are measurements to be made with first year of data of great interest
 - Push on the octant for θ_{23} (of course NOVA should do better!)
- The main goal of MINOS+, however, is to look for new physics, and this will provide interesting results (one way or the other) in time for Neutrino 2014.
 - Personal favorite is sterile search