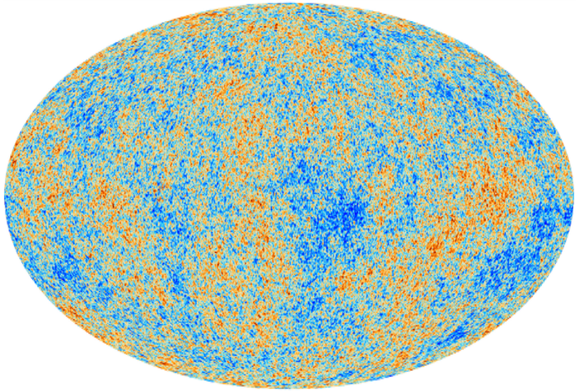
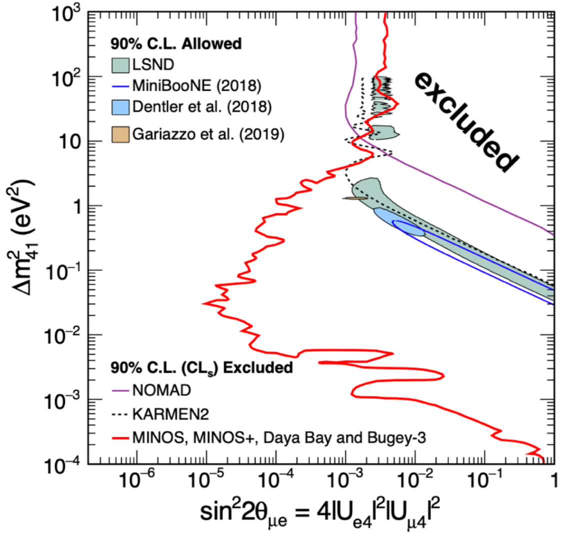
MANCHESTER 1824

The University of Manchester

https://inspirehep.net/literature/1781295

Direct comparison of sterile neutrino constraints from cosmological data and oscillation data in a 3+1 model

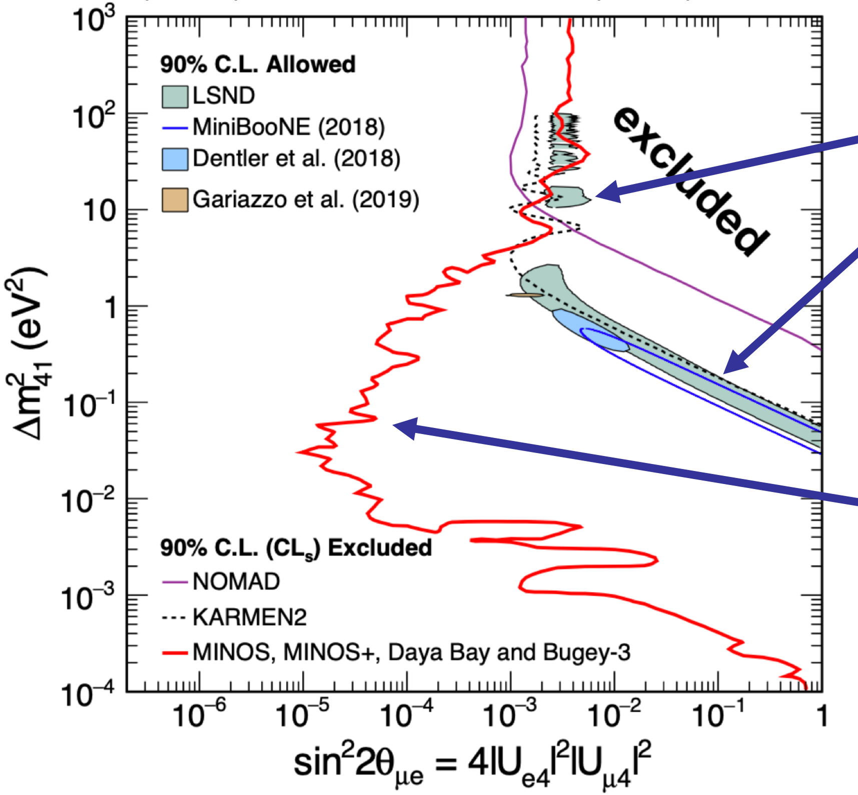




Matthew Adams, Fedor Bezrukov, Jack Elvin-Poole, **Justin Evans**, Pawel Guzowski, Brían Ó Fearraigh, Stefan Söldner-Rembold

Sterile neutrino tensions

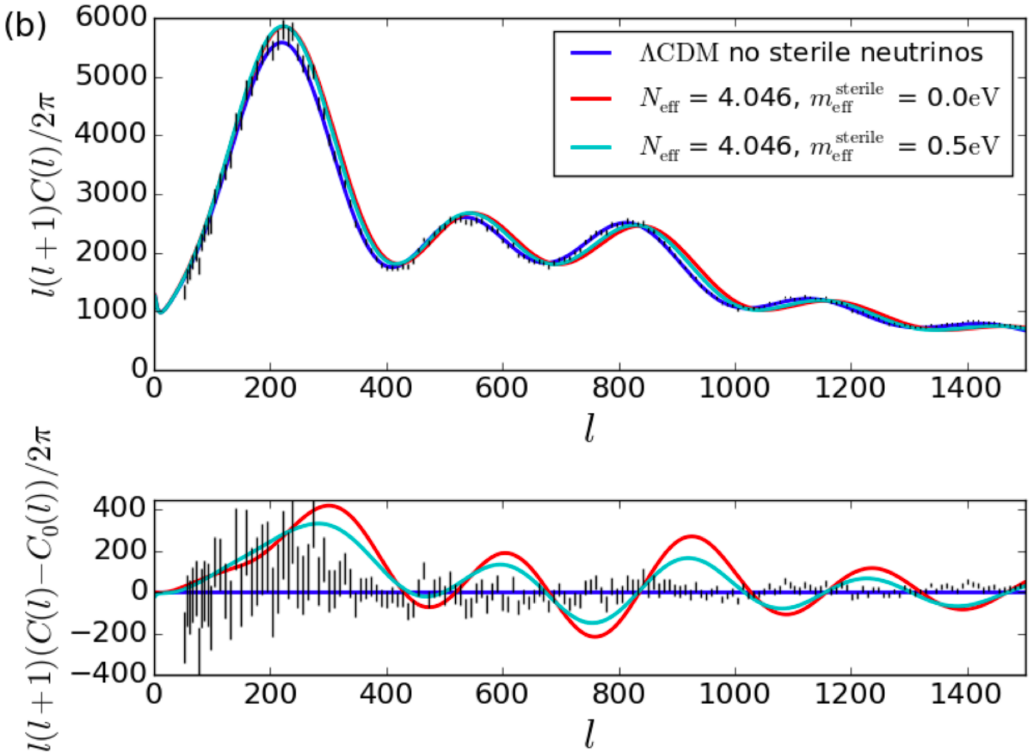
arXiv:2002.00301, PRD **95**, 072006 (2017) & PRL **122**, 091803 (2019)



$\nu_\mu \rightarrow \nu_e$ appearance seen by LSND and MiniBooNE consistent with a sterile neutrino

MINOS, Daya Bay and Bugey exclude most of the allowed parameter space with ν_μ and ν_e disappearance

Cosmology and sterile neutrinos



Thermalised sterile neutrinos add an extra relativistic degree of freedom observable in the CMB power spectrum

$$m_{\rm eff}^{\rm sterile} = \left(\frac{T_s}{T_\nu}\right)^3 m_4^{\rm thermal} = (\Delta N_{\rm eff})^{3/4} m_4^{\rm thermal}$$

MANCHESTER 1824 The University of Manchester

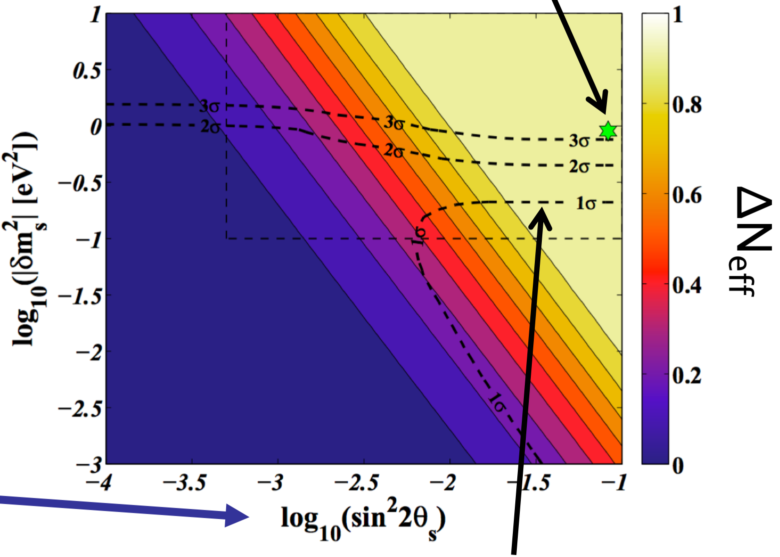
Relating particle physics to cosmology

Graph from S. Hannestad *et al.*, Cosmol Astropart. Phys. **2012**, 025 (2012), arXiv:1204.5861
Code available as LASAGNE

Larger sterile mass splitting increases temperature of thermalization ⇒ greater ΔN_{eff}

Larger mixing angle allows a higher thermalisation rate ⇒ greater ΔN_{eff}

Giunti & Laveder 3+1 best fit (Phys Lett B706, 200 (2011))

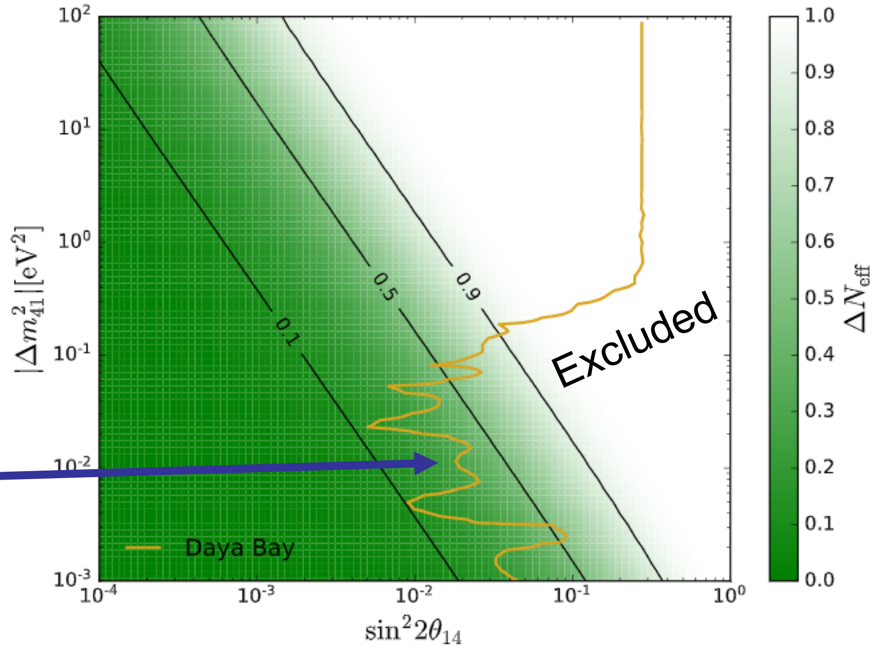


Pre-Planck CMB and large scale structure exclusion region

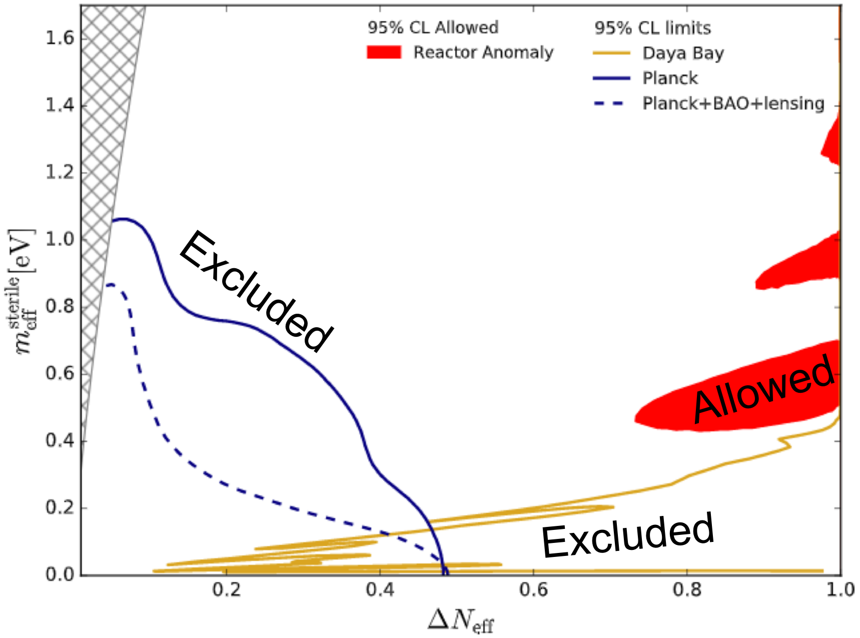
$\overline{\nu}_e$ disappearance

1+1 model.
Only ν_e flavour mixes into m_4.
Only non-zero mixing angle is θ_{14}.

Daya Bay reactor $\overline{\nu}_e$ disappearance search



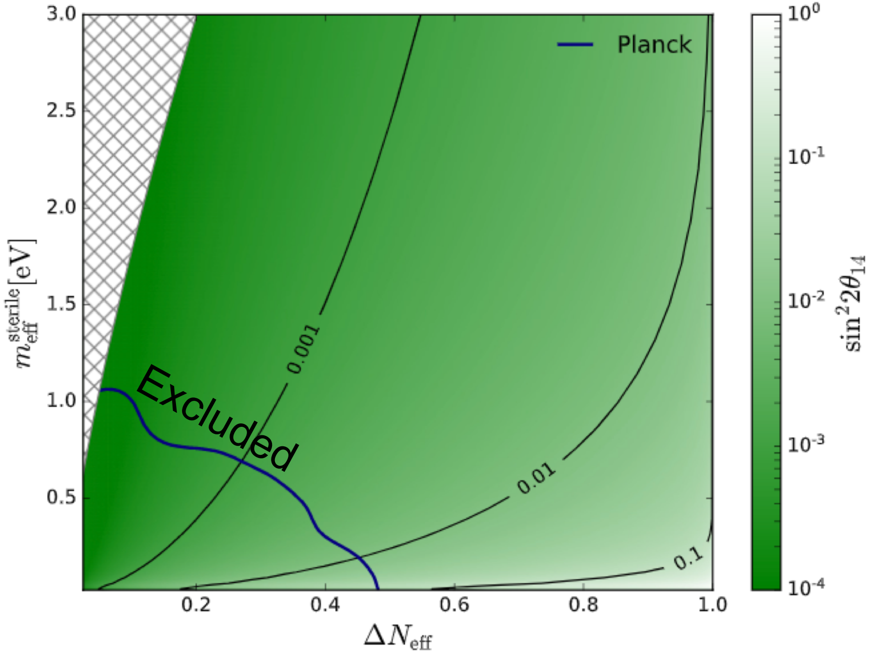
$\overline{\nu}_e$ disappearance



Gallium anomaly allowed region and Daya Bay exclusion region expressed in cosmological parameter space

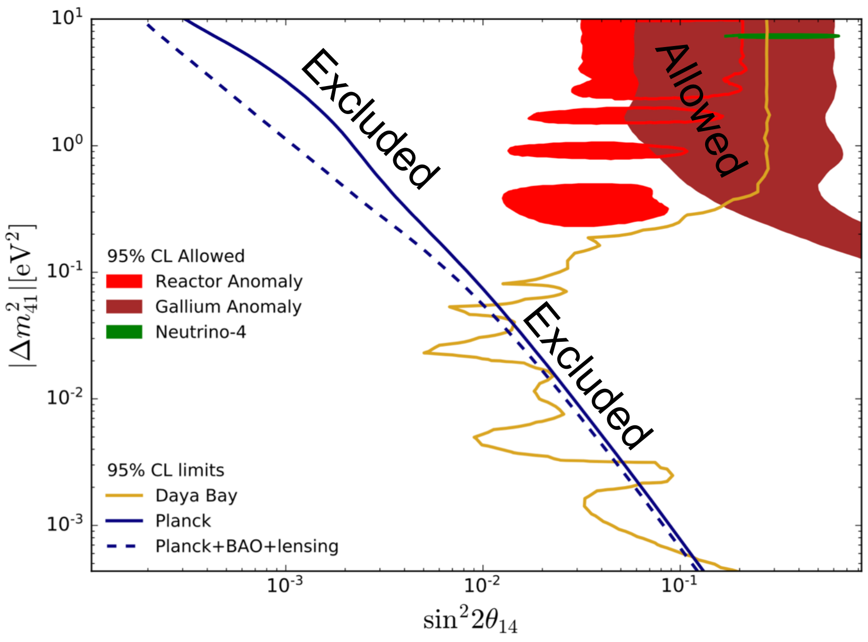
Compared to Planck exclusion

$\overline{\nu}_e$ disappearance



Can also convert the Planck exclusion into neutrino-oscillation parameter space

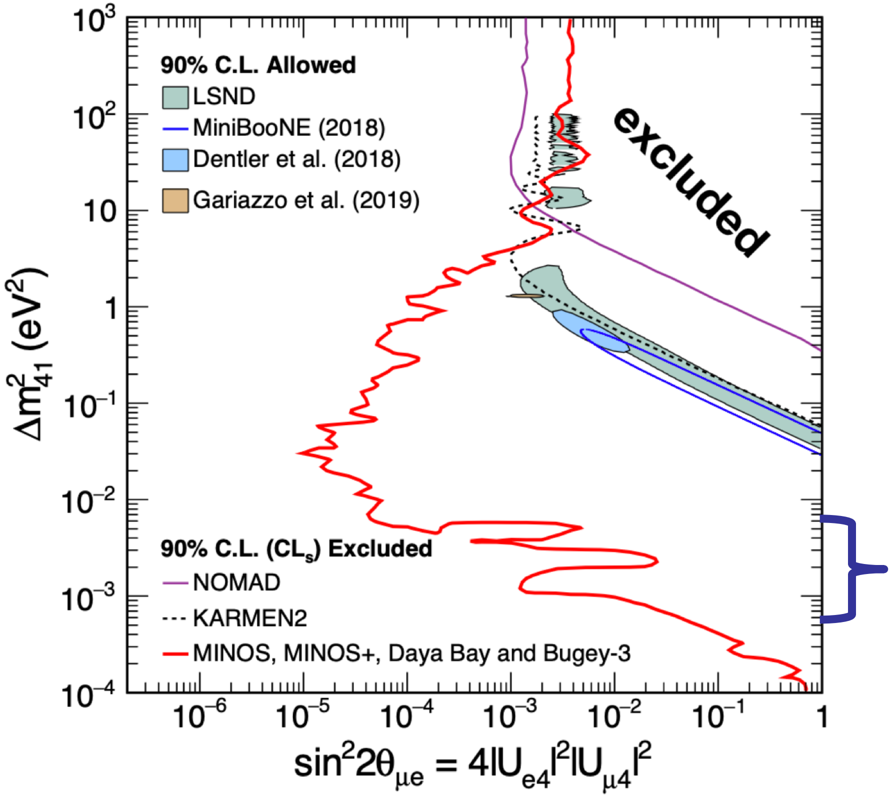
$\overline{\nu}_e$ disappearance



Can also convert the Planck exclusion into neutrino-oscillation parameter space

Including here the Neutrino-4 and gallium anomaly allowed regions

A 3+1 model for $\nu_e \rightarrow \nu_\mu$ appearance

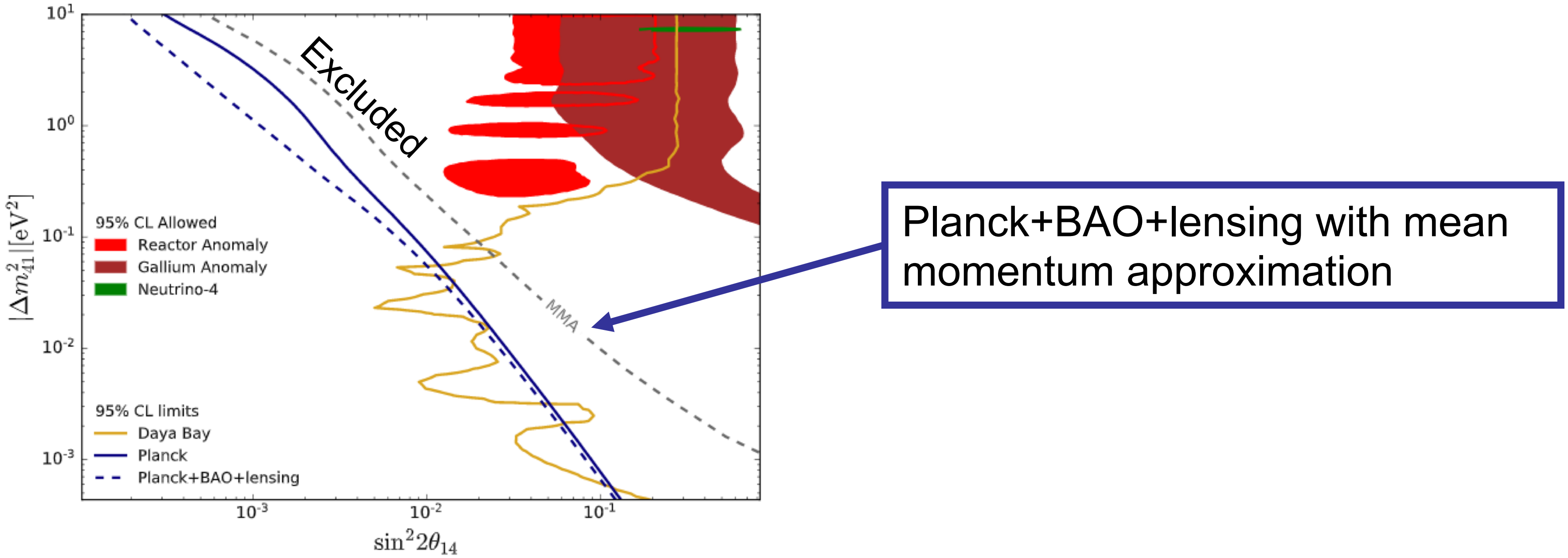


$$\sin^2(2\theta_{\mu e}) \equiv \sin^2(2\theta_{14})\sin^2(\theta_{24})$$

Requirement to solve quantum kinetic equations in four flavours requires simplification: mean momentum approximation

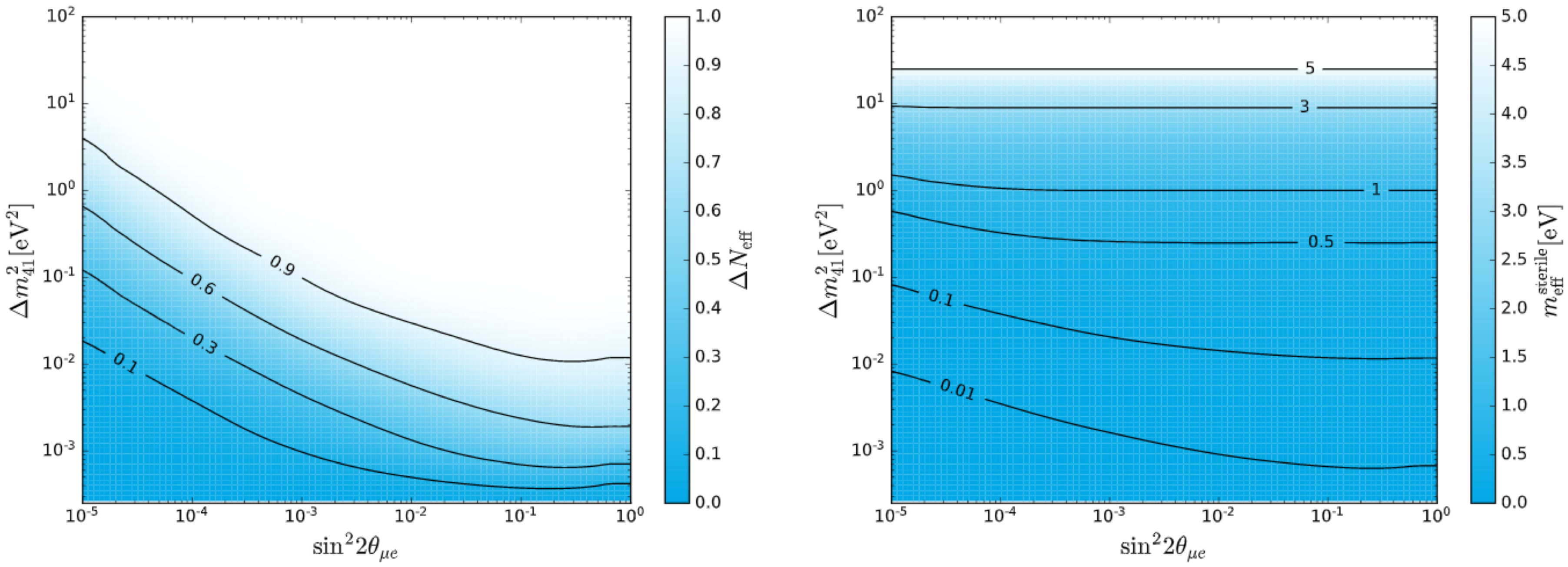
Degenerate region where $\Delta m^2_{41} \sim \Delta m^2_{31}$

Validating the mean momentum approximation



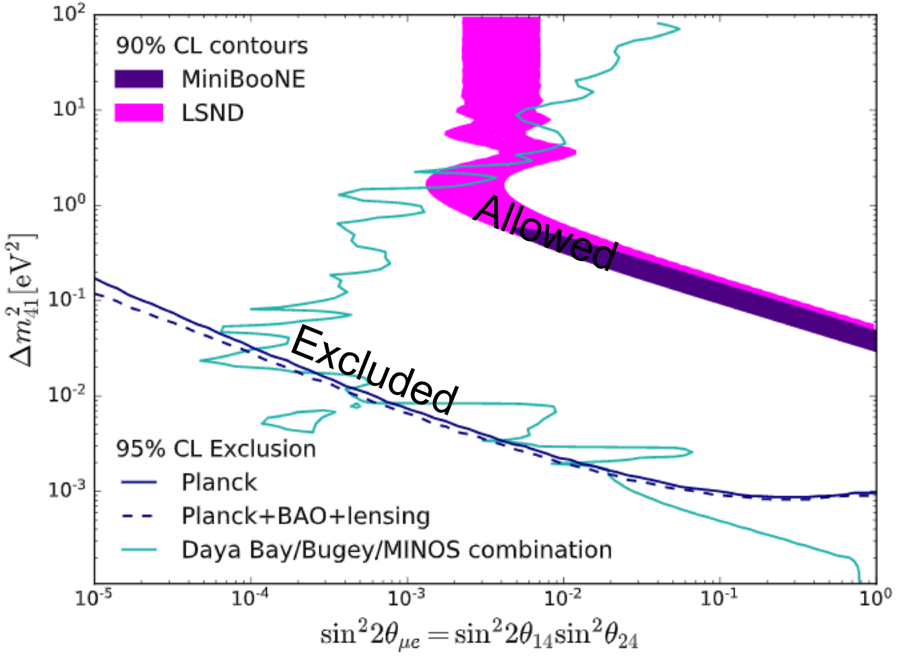
MANCHESTER 1824
The University of Manchester

3+1 model for $\nu_\mu \rightarrow \nu_e$ analysis



Cosmological parameters in the oscillation space of $\nu_\mu \rightarrow \nu_e$

3+1 model for $\nu_\mu \rightarrow \nu_e$ analysis



Daya Bay/Bugey/MINOS combination from PRL **117** 151801 (2016)

MANCHESTER 1824
The University of Manchester

Conclusion

Cosmological and particle physics searches for sterile neutrinos can be compared in the same parameter space

ν_e disappearance

- Cosmological limits are strongest above Δm^2_{41} ~ 0.1 eV^2 and $m_{eff}^{sterile}$ ~ 0.2 eV but are model-dependent
- Daya Bay is more constraining at lower masses

$\nu_\mu \rightarrow \nu_e$ appearance

- Cosmological limits are strongest at mass splittings above Δm^2_{41} ~ 5x10^{-2} eV^2 and $m_{eff}^{sterile}$ ~ 0.2 eV but are model-dependent
- Daya Bay / Bugey / MINOS combination is more constraining at lower masses

https://inspirehep.net/literature/1781295