THE HUNT FOR NEUTRINO HIERARCHY

Martina Gerbino
OKC&NORDITA, Stockholm University

Neutrino Oscillation Workshop 2016, Otranto

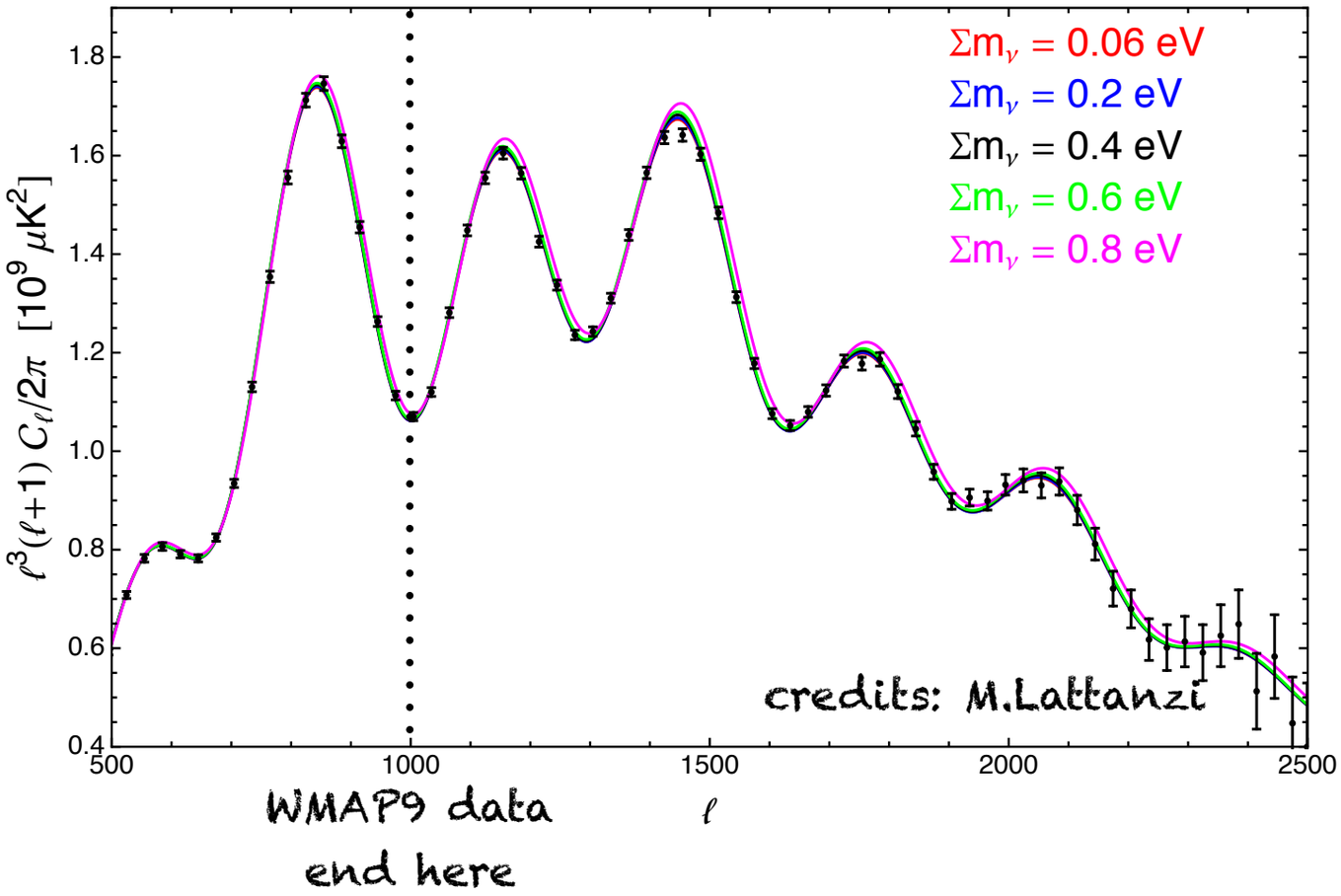
6 Sep 2016

based on Gerbino,Lattanzi,Mena,Freese,in prep

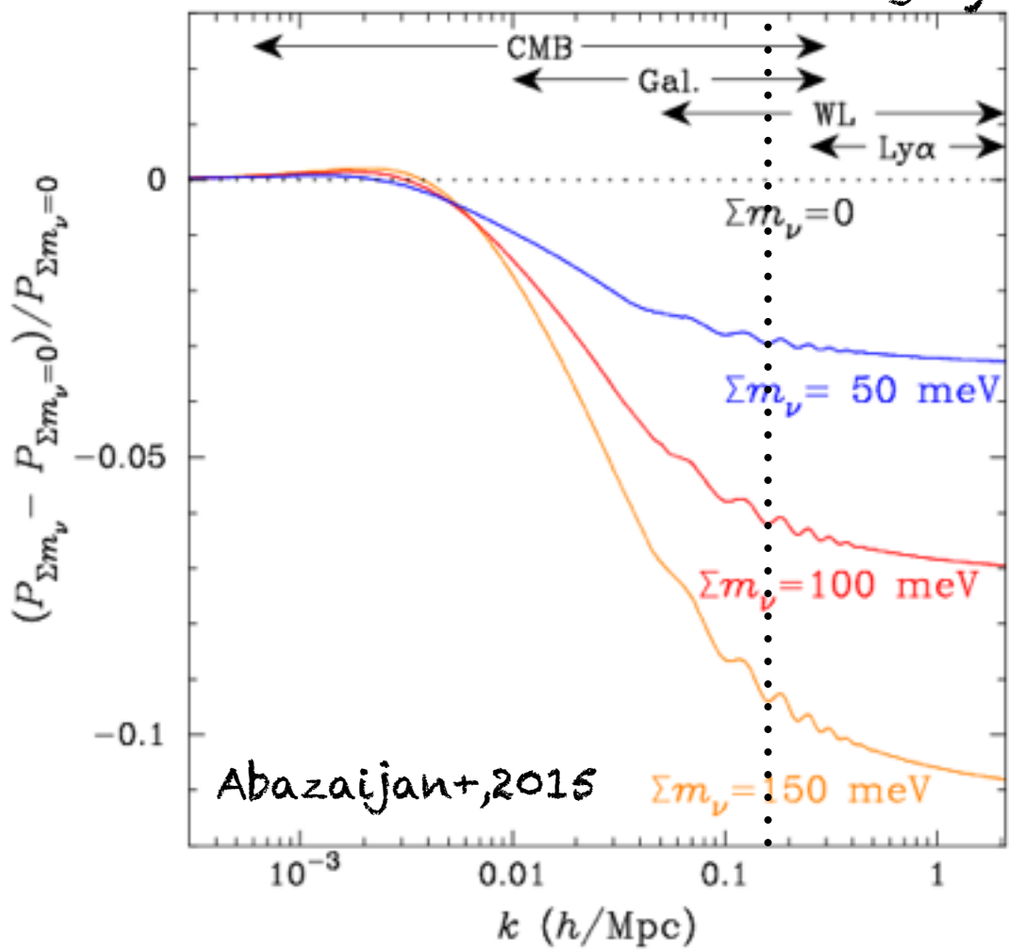
Roadmap

- The characters: neutrinos in cosmology
- A method to quantify cosmological sensitivity to the hierarchy
- Results from current and forecasted data
- Conclusion

Massive neutrinos alter background and perturbation evolution



Linear regime ends roughly here



3 active families, sub-eV masses

Relativistic at early times, non-relativistic today

(Almost) peculiar effects on cosmological observables

Where are we?

Present

Mnu<0.46eV (Planck TT,TE,EE+lowP)

Mnu<0.17eV (Planck TT,TE,EE+lowP+BAO)

(see e.g. Planck collaboration XIII)

Mnu<0.13eV (Planck TT,TE,EE+lowP+BAO+ matter power shape)

(see e.g. Cuesta et al, 2015)

Mnu<0.12eV (Planck TT,TE,EE+lowP+Lya)

(see e.g. Palanque-Delabrouille et al, 2015)

Future

sigma(Mnu)~0.02eV (CORE,Stage4,DESI,Euclid,...)

Where are we?

Questions:

- Will we be able to measure Mnu?
- Will we be able to discriminate the hierarchy?
- Can we provide a statistically robust answer?

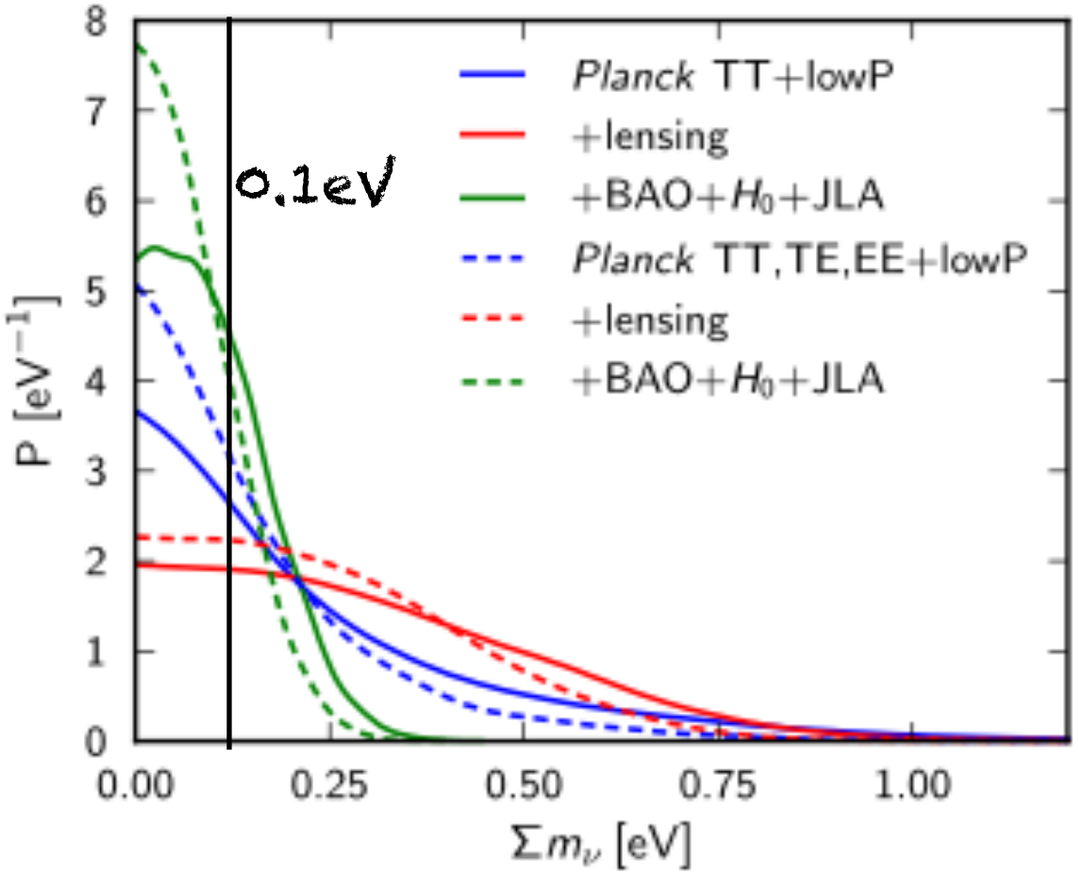
The standard method

Mnu

(+other cosmological parameters)

↓

Degenerate spectrum: $m_{\nu,i} = M_\nu/3,\ i = 1, 2, 3$



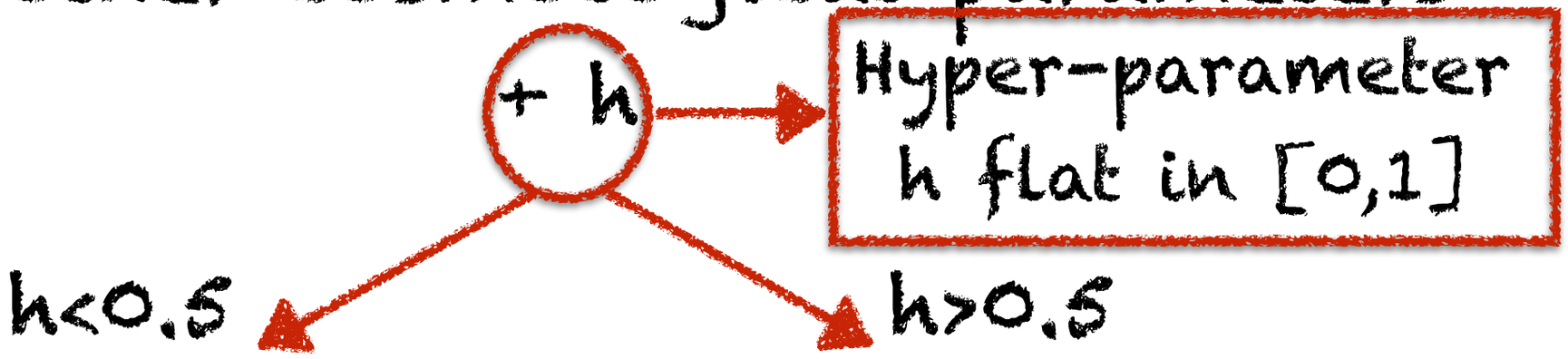
Different authors obtain upper bounds from current data approaching the "critical" value of 0.1 eV. These results suggest that IH starts to get under pressure from cosmology.

[...] Such a claim should be based on a proper statistical analysis. The question to be answered is, whether the hypothesis of IH can be rejected with some confidence against NH.

(Hannestad&Schwetz,2016)

The proposed method

Mnu + other cosmological parameters



NORMAL HIERARCHY

$$m_{\nu,1} = m_{\rm light}$$

$$m_{\nu,2} = \sqrt{m_1^2 + \Delta m_{12}^2}$$

$$m_{\nu,3} = \sqrt{m_1^2 + \Delta m_{13}^2}$$

INVERTED HIERARCHY

$$m_{\nu,3} = m_{\rm light}$$

$$m_{\nu,1} = \sqrt{m_3^2 + \Delta m_{13}^2}$$

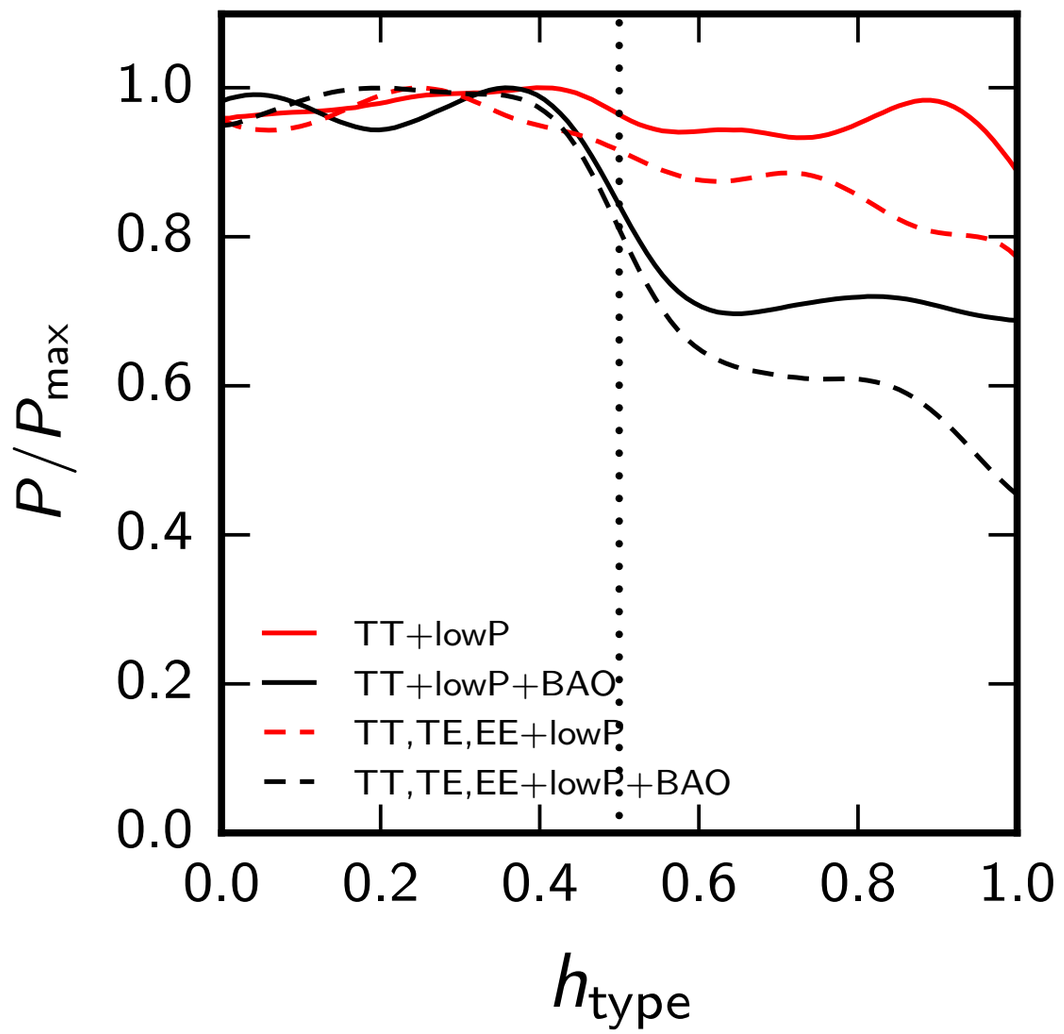
$$m_{\nu,2} = \sqrt{m_1^2 + \Delta m_{12}^2}$$

Advantages:

- neutrinos modelled with exact mass spectrum
- information from oscillations taken into account
- quantifies sensitivity to the hierarchy
- takes into account uncertainties related to the hierarchy

Sensitivity to the hierarchy: current data

Preliminary



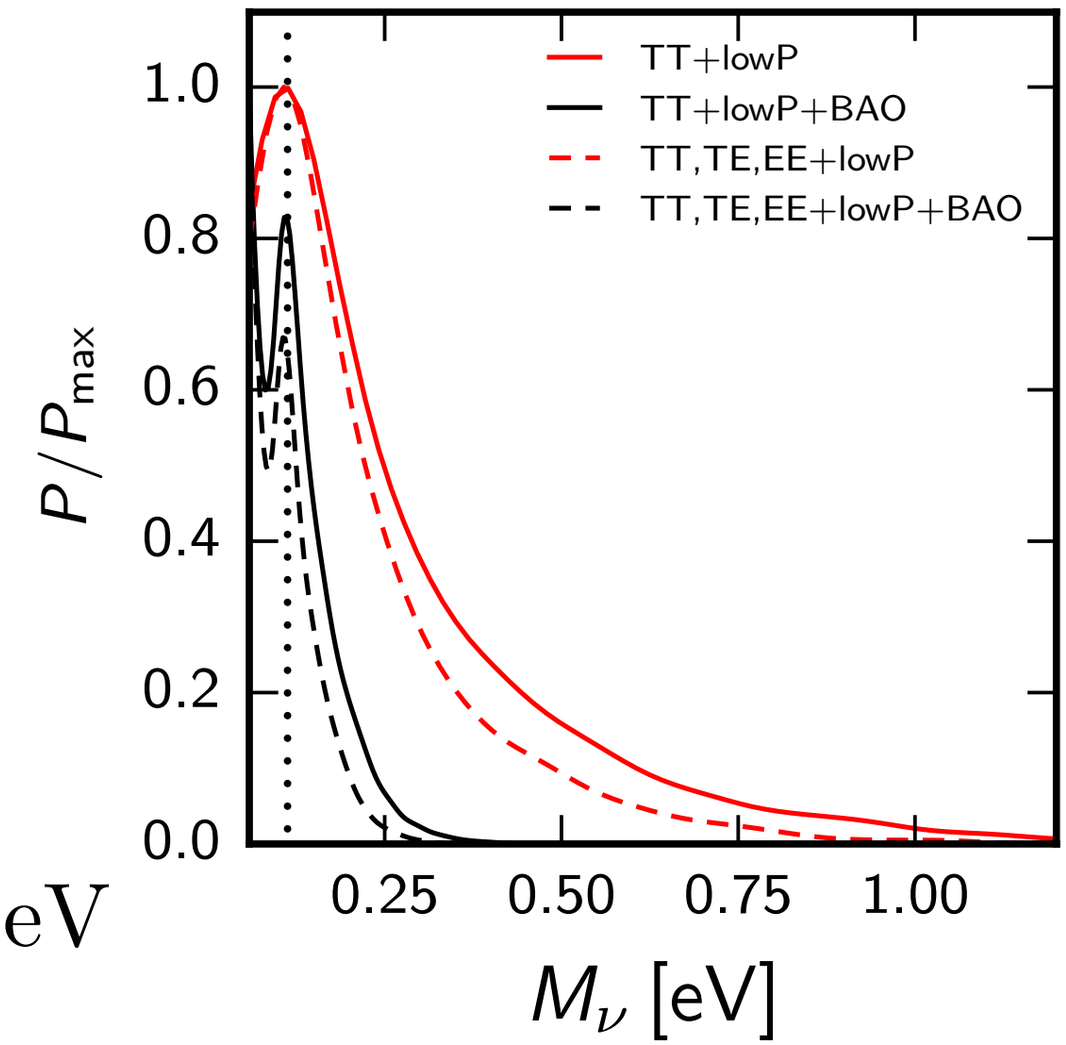
Mild preference for NORMAL HIERARCHY (~5:3)

CMB only mildly sensitive (with polarisation)

Sensitivity increases when BAO are added

Constraints on Mnu: current data

Preliminary



$M_\nu^{\rm min} = 0.059\,{\rm eV}$

$M_\nu^{\rm min} \leq M_\nu \leq 0.740\,{\rm eV}$ 95%, Planck TT+lowP

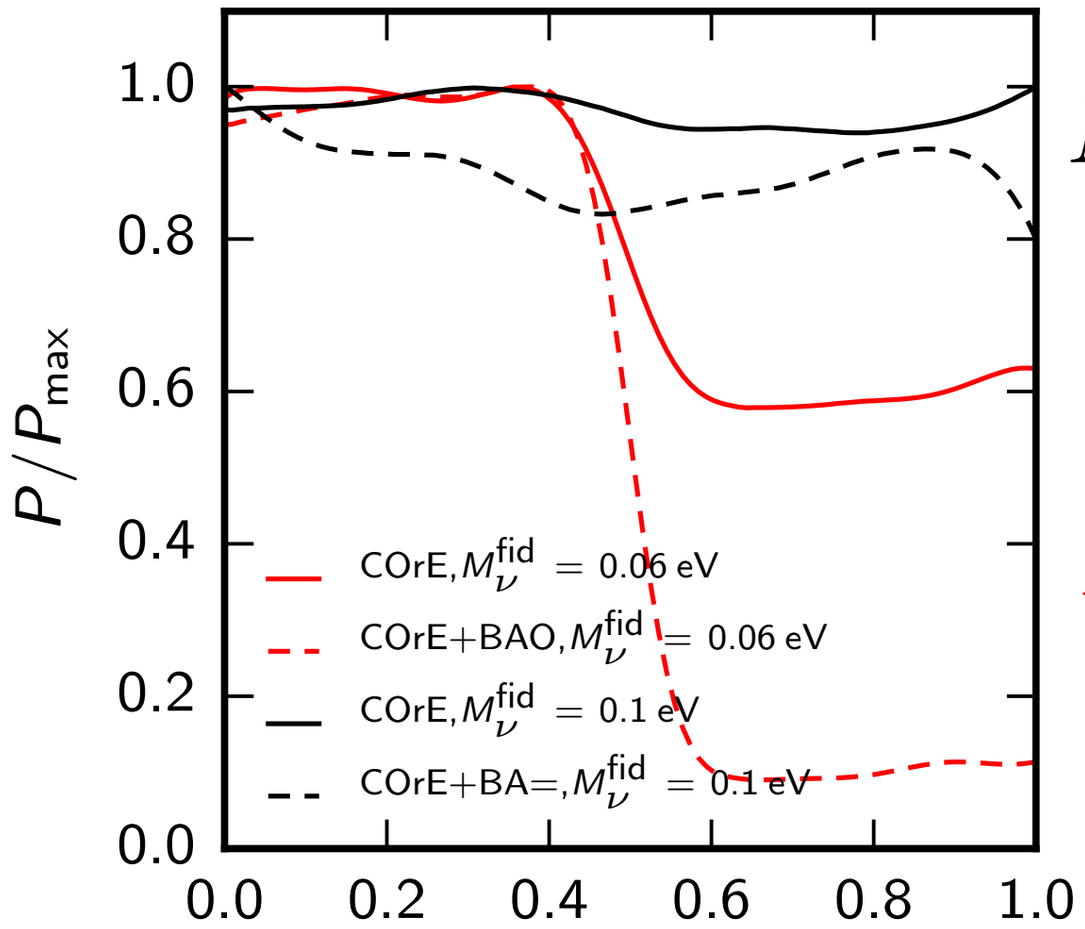
$M_\nu^{\rm min} \leq M_\nu \leq 0.232\,{\rm eV}$ 95%, Planck TT+lowP+BAO

$M_\nu^{\rm min} \leq M_\nu \leq 0.558\,{\rm eV}$ 95%, Planck TT,TE,EE+lowP

$M_\nu^{\rm min} \leq M_\nu \leq 0.199\,{\rm eV}$ 95%, Planck TT,TE,EE+lowP+BAO

Sensitivity to the hierarchy: forecasts

Preliminary



$M_\nu^{\rm fid} = 0.1\,{\rm eV}$

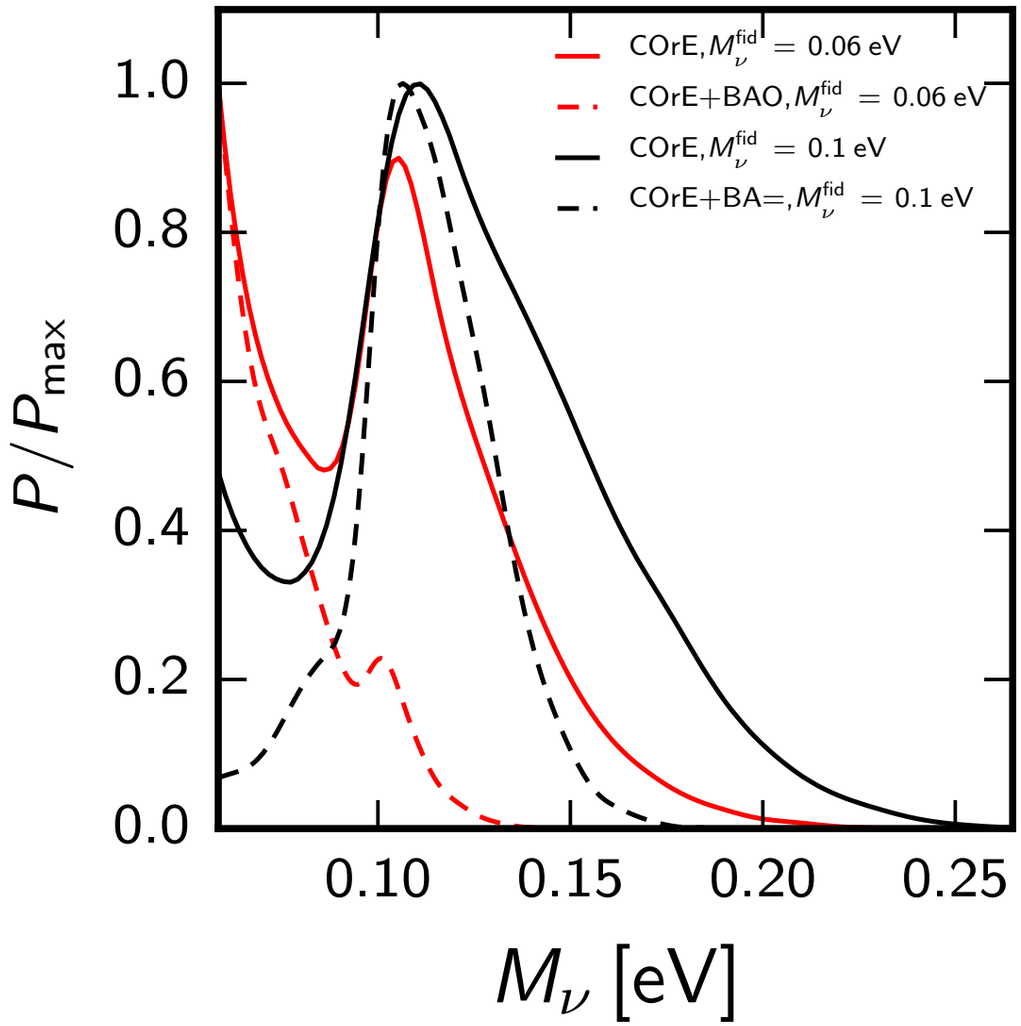
$M_\nu^{\rm fid} = 0.06\,{\rm eV}$

If Mnu is minimal, 10:1 odds for NH!!!

If Mnu=0.1eV, cosmology almost insensitive

Constraints on Mnu: forecasts

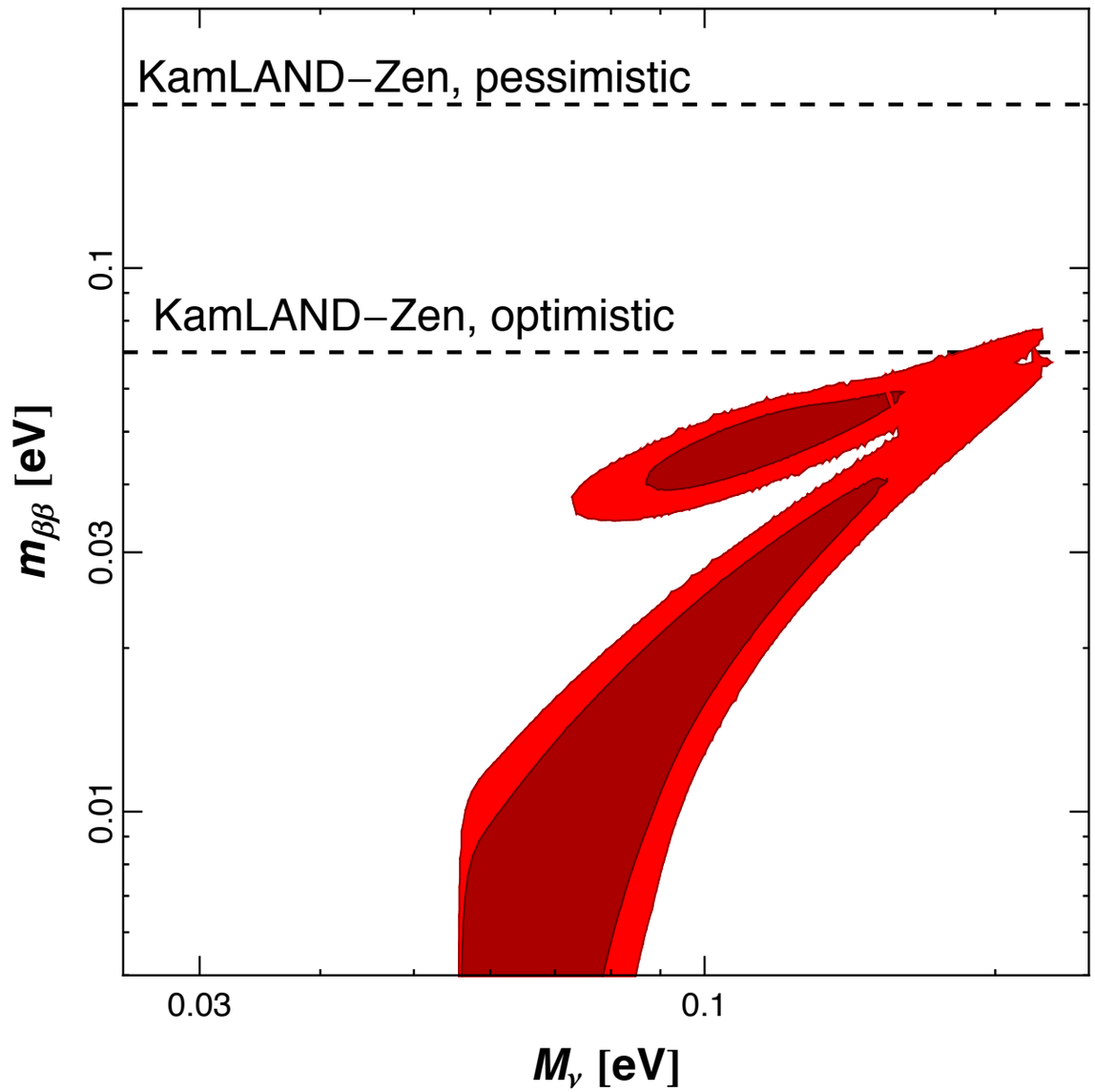
Preliminary



$$M_\nu^{\rm min} \leq M_\nu \leq 0.109\,{\rm eV}$$ 95%, COrE+BAO, minimal mass

$$M_\nu = 0.112^{+0.037}_{-0.040}\,{\rm eV}$$ 95%, COrE+BAO, 0.1eV fiducial

Implications for 0ν2β: present



Preliminary

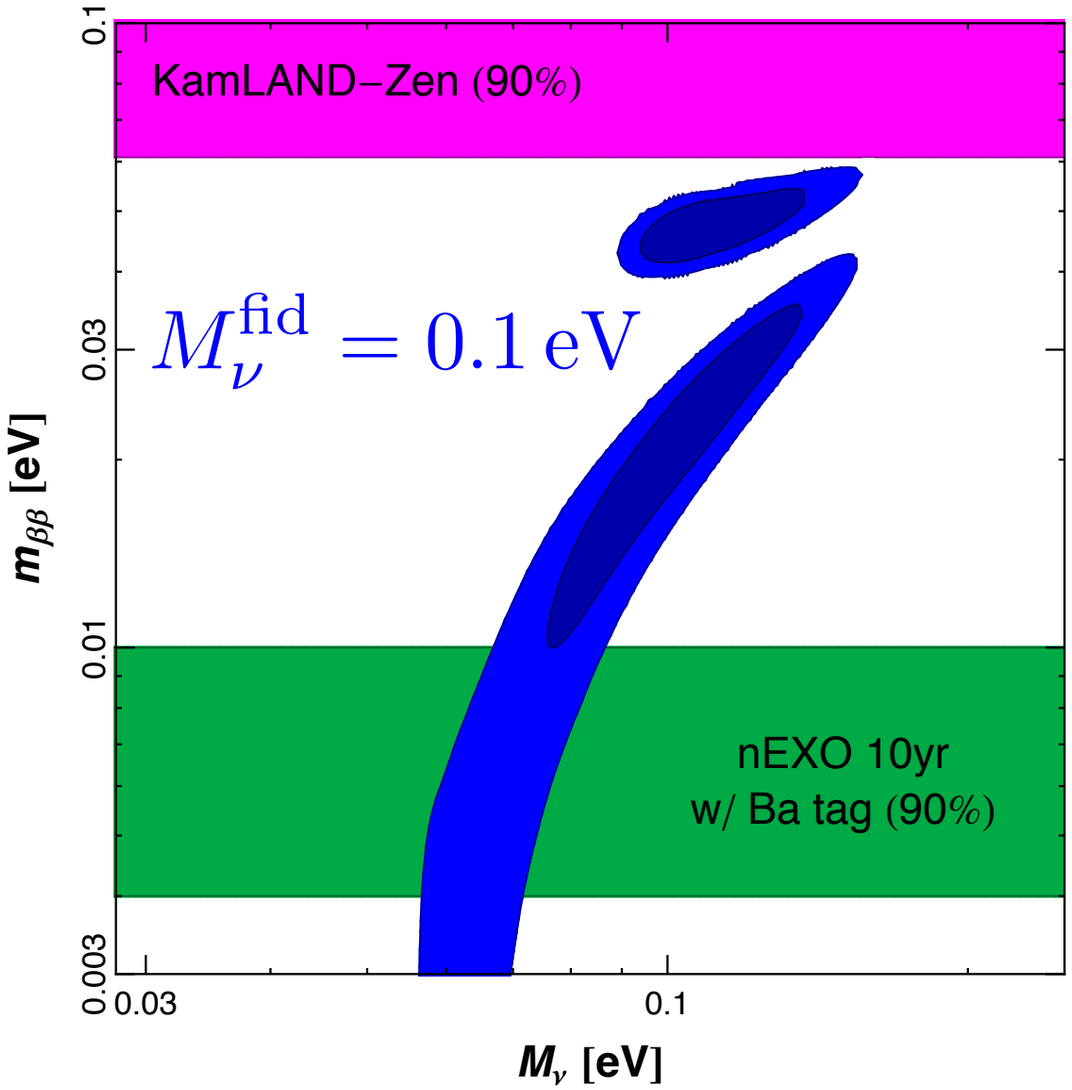
Cosmology+ oscillations only

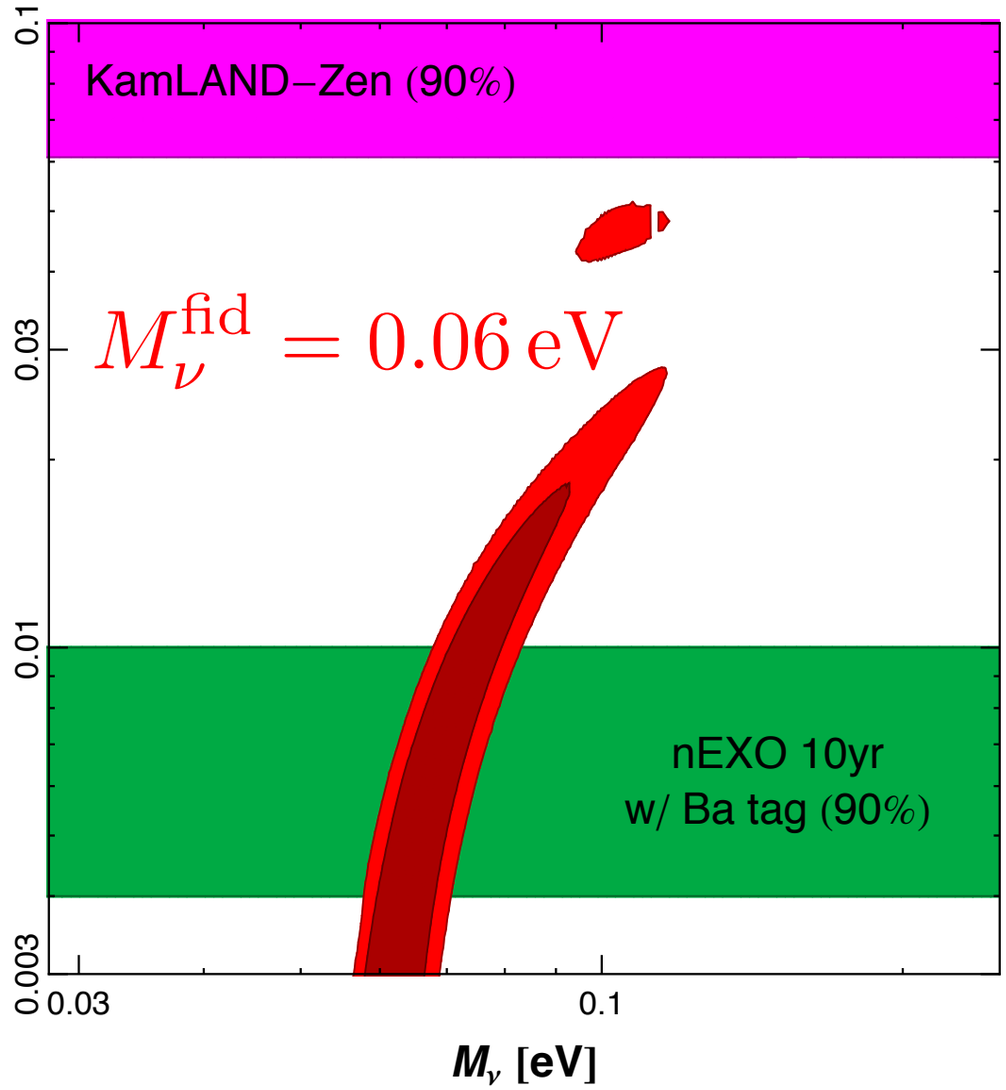
0ν2β searches almost competitive cosmology (provided nuclear modelling under control)

Implications for on2b: forecasts

Cosmology+oscillations only

Preliminary





If Mnu=0.1eV, sigma(mbb)~10meV could guarantee on2b measurement

If Mnu minimal, hard times

CONCLUSIONS

- Tight bounds on neutrino mass from cosmology
- Inverted hierarchy in trouble: how much?
- By introducing an hyper-parameter we can: 1) easily account for exact neutrino mass spectra; 2) quantify sensitivity to the hierarchy; 3) take into account uncertainty due to imperfect knowledge of the hierarchy
- NH favoured 5:3 by current data
- NH favoured 10:1 by future measurements, if the mass is minimal