SENSITIVITY OF COSMOLOGICAL DATA TO THE NEUTRINO MASS HIERARCHY

Martina Gerbino

Oskar Klein Centre
for Cosmoparticle Physics
Stockholm University

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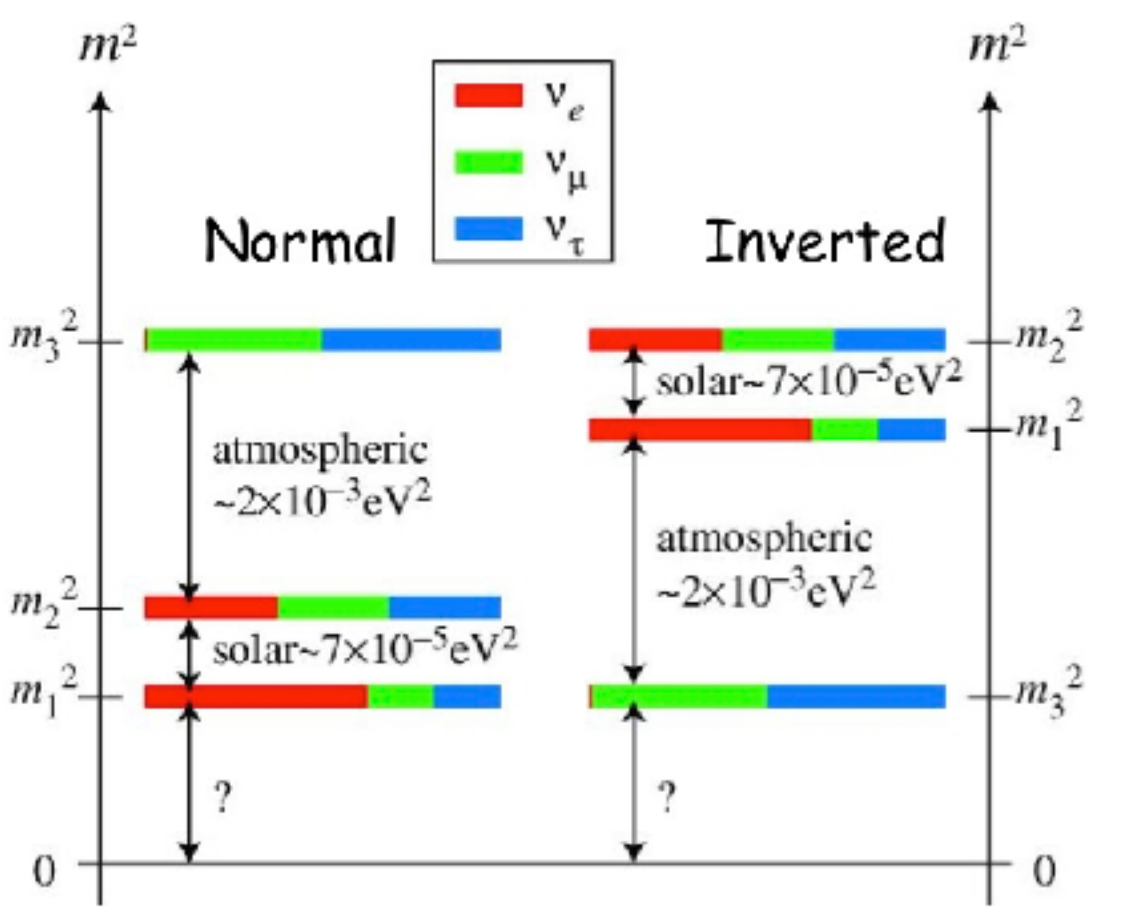
based on Gerbino,Lattanzi,Mena,Freese,2017

What we know, from the outside

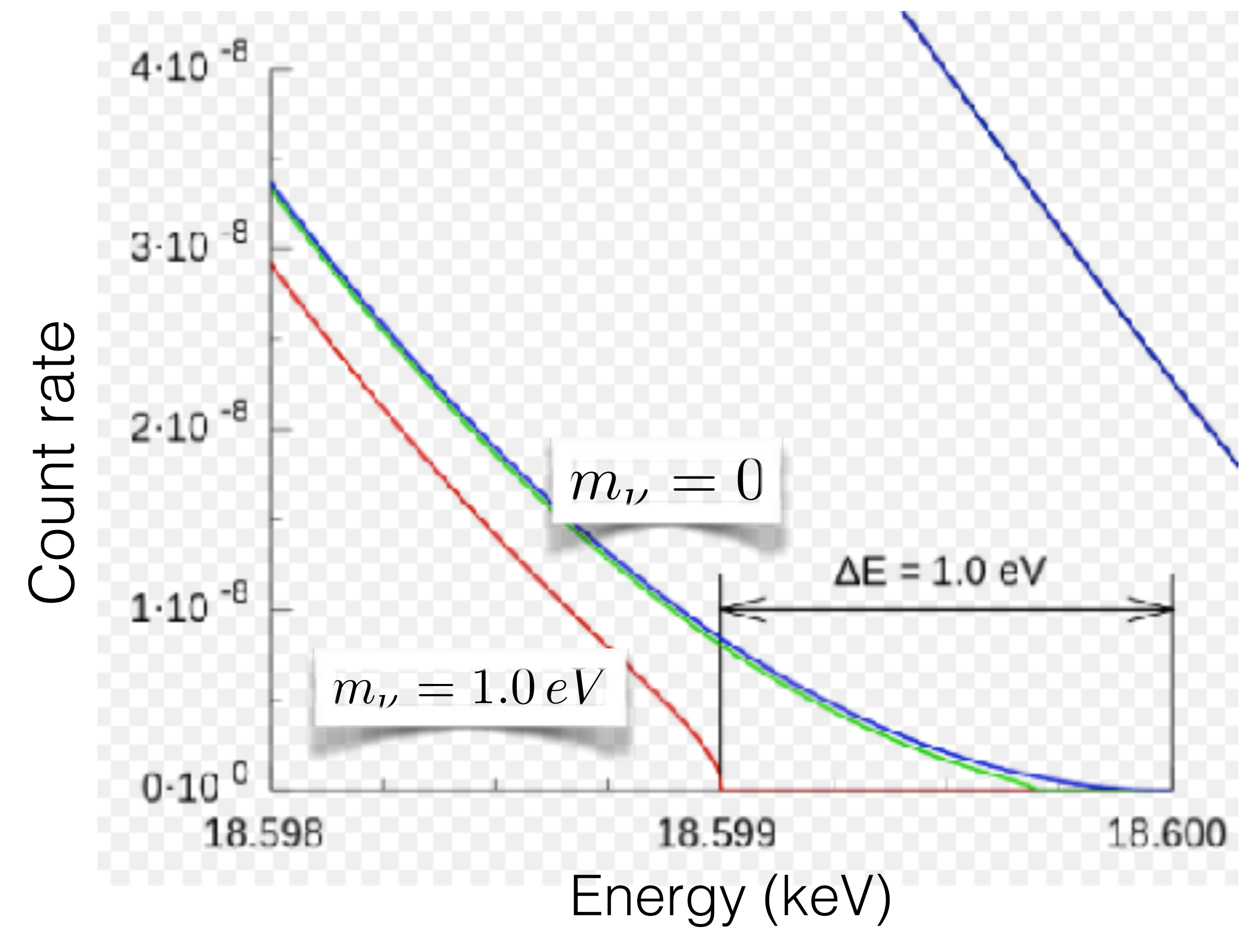
How do they behave?

Neutrinos oscillate, so they are massive

$$0.06\,\mathrm{eV} < \Sigma m_\nu < 6\,\mathrm{eV}$$

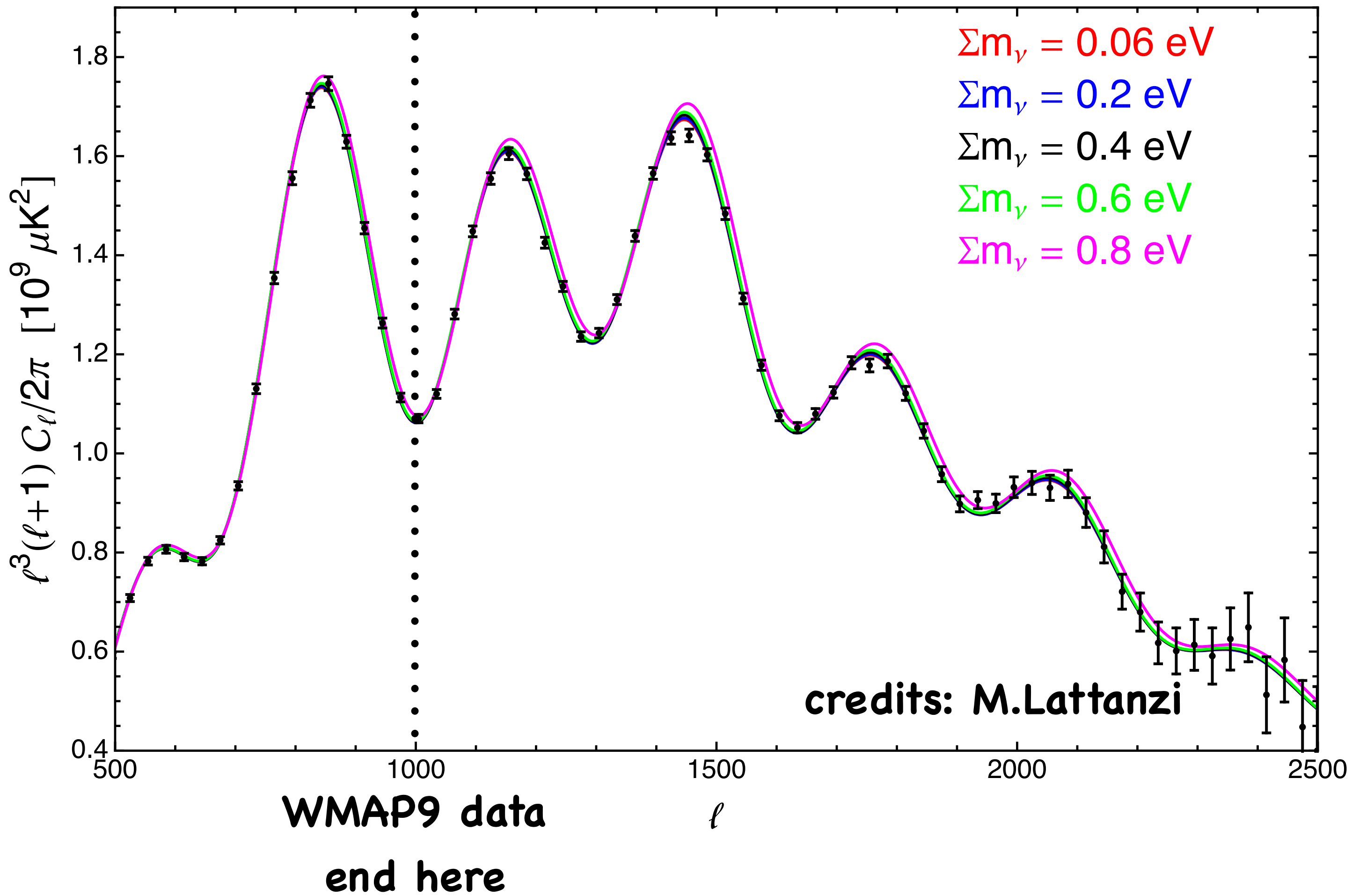


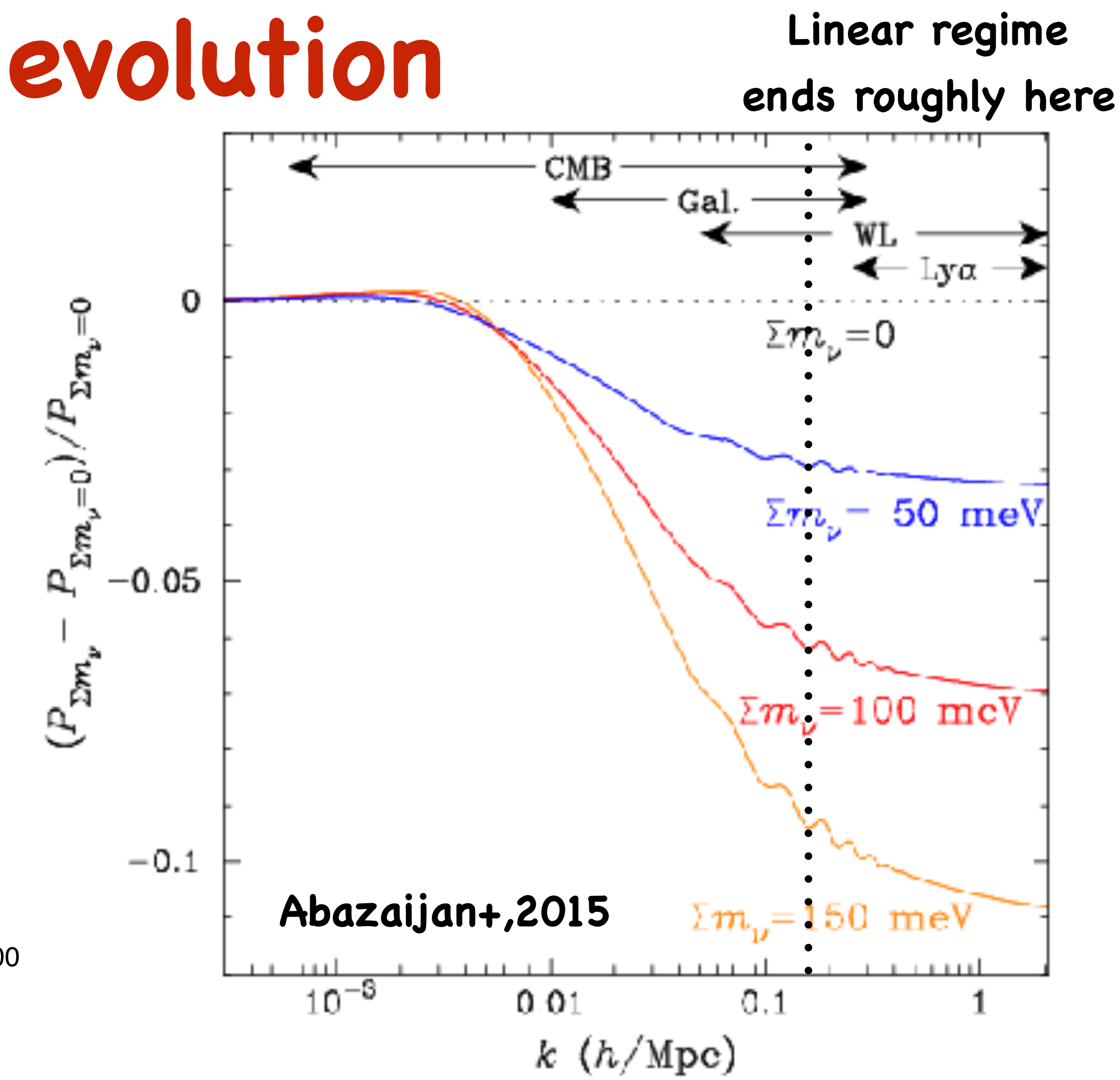
Lower bound
from oscillation experiments



Upper bound
from kinematic measurements

Massive neutrinos alter background and perturbation evolution





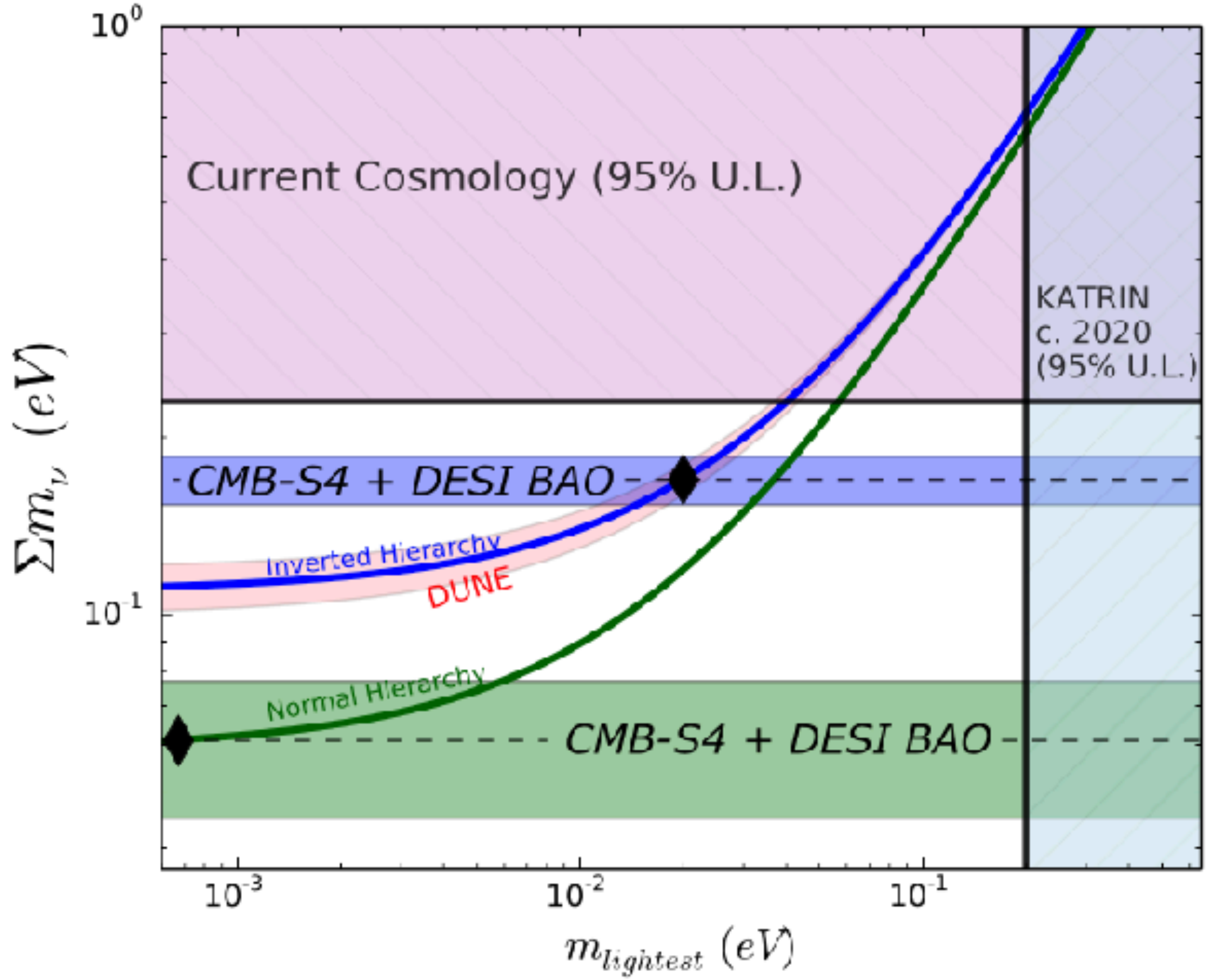
3 active families, sub-eV masses

Relativistic at early times, non-relativistic today

(Almost) peculiar effects on cosmological observables

See M. Lattanzi & A. van Engelen's talks

Joint constraints on Mnu - future

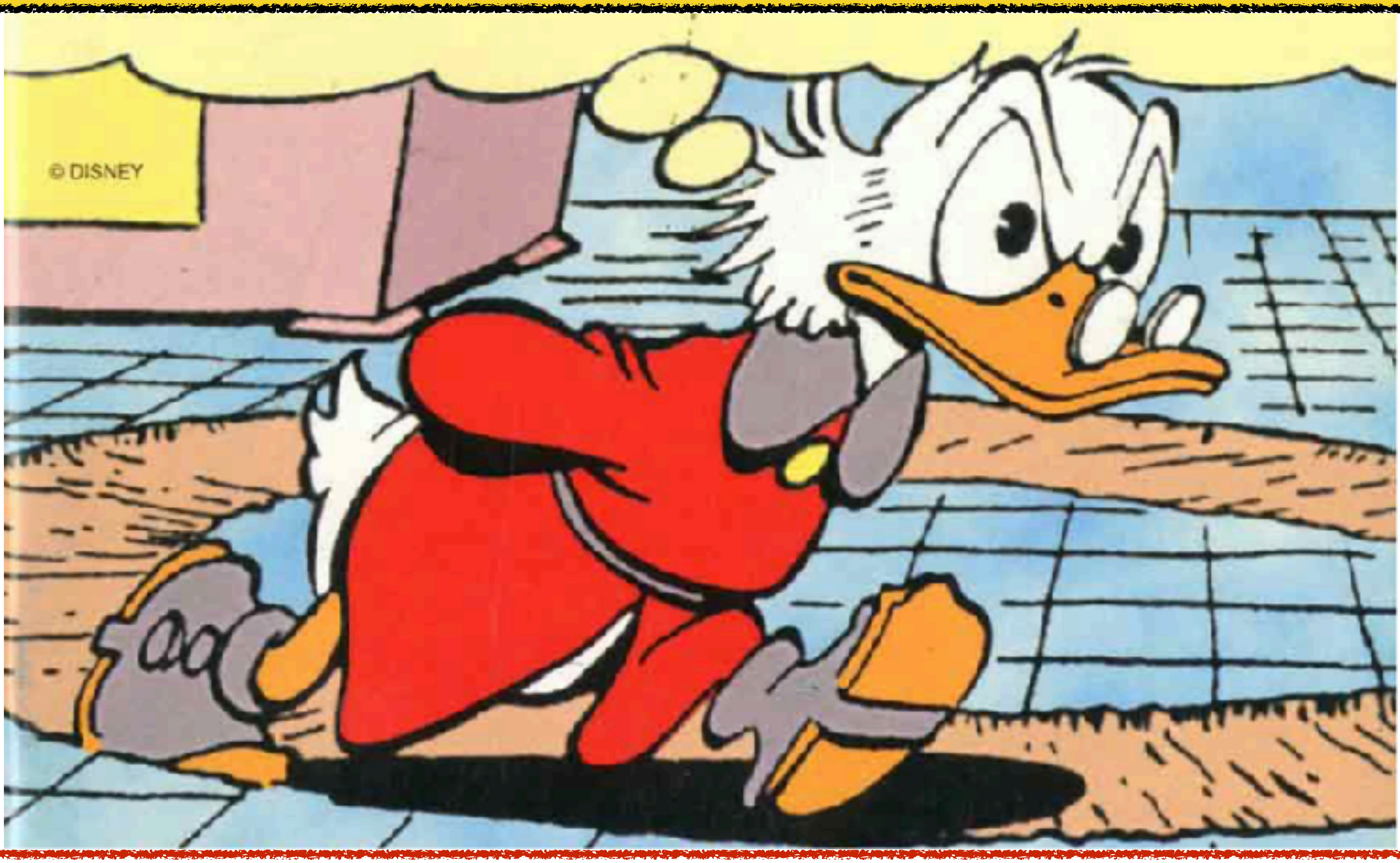


CMB-S4 Science Book

~3sigma detection

in the minimal mass scenario with S4 surveys

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



The proposed method

Bayesian MCMC, Mnu + other cosmo params

+ h → **Discrete Hyper-parameter h**

h=NH | **h=IH**

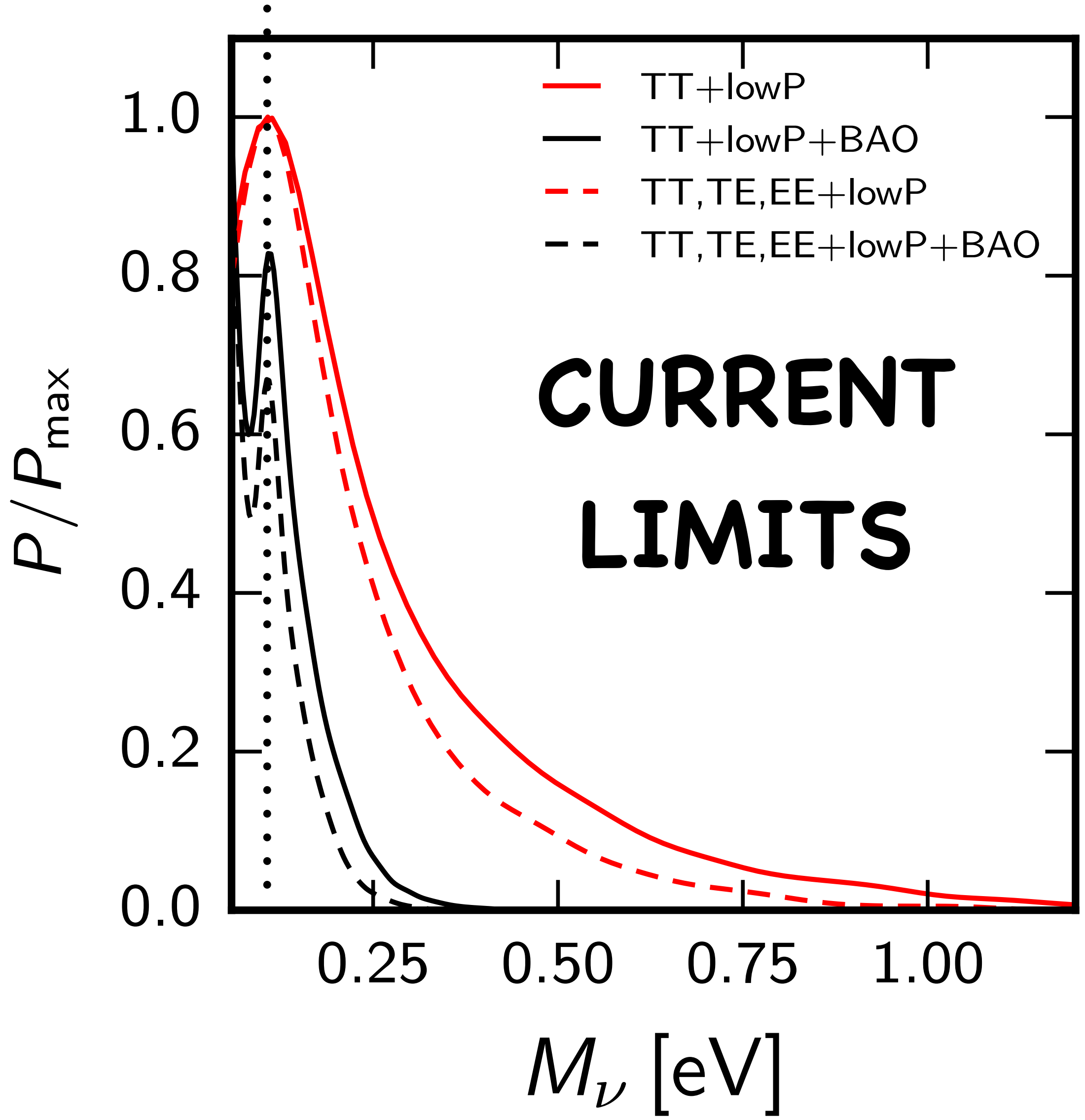
NORMAL HIERARCHY	INVERTED HIERARCHY
$m_{\nu,1} = m_{\text{light}}$	$m_{\nu,3} = m_{\text{light}}$
$m_{\nu,2} = \sqrt{m_1^2 + \Delta m_{12}^2}$	$m_{\nu,1} = \sqrt{m_3^2 + \Delta m_{13}^2}$
$m_{\nu,3} = \sqrt{m_1^2 + \Delta m_{13}^2}$	$m_{\nu,2} = \sqrt{m_1^2 + \Delta m_{12}^2}$

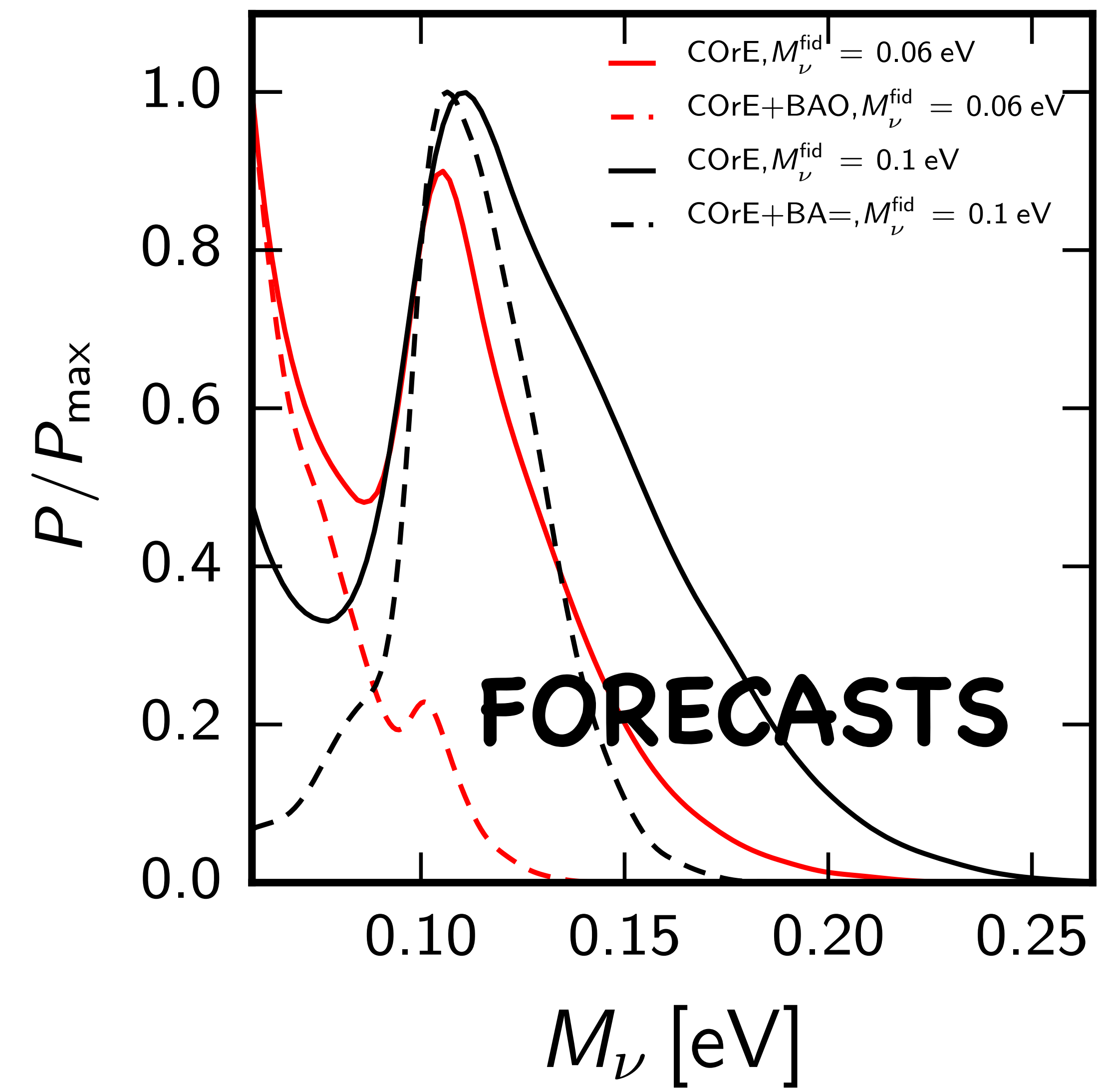
Advantages:

- 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

Gerbino,Lattanzi,Mena,Freese 2017

Sensitivity to the hierarchy





Gerbino,Lattanzi,Mena,Freese 2017

$$\mathcal{P}(h = NH) : \mathcal{P}(h = IH)$$

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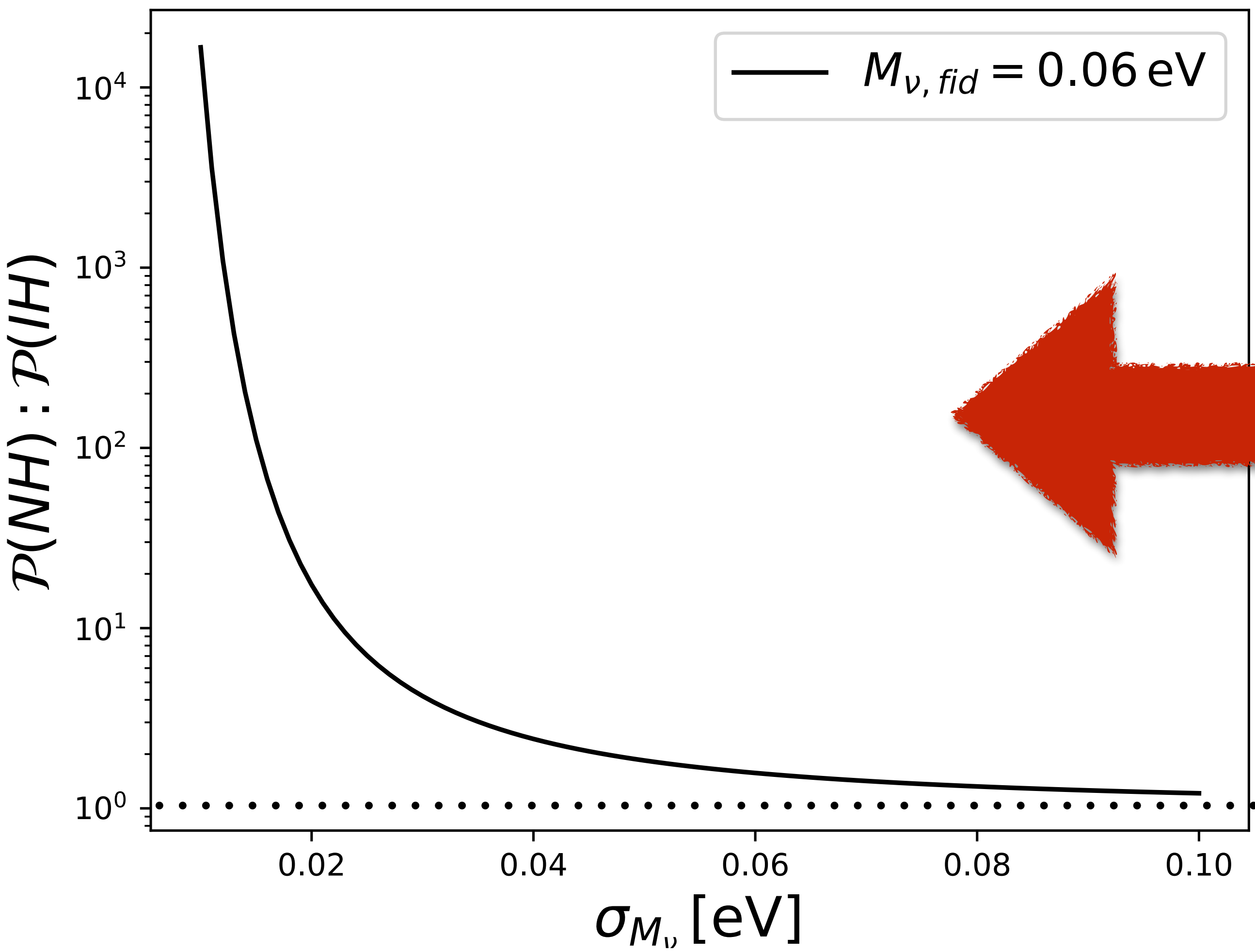
.... **3:2**

.... **0.06eV mass -> 9:1**

.... **0.1eV mass -> 1:1**

See also Hannestad&Schwetz 2016,
Couchot et al 2017, Capozzi et al 2017

Sensitivity to the hierarchy



Fixed fiducial

As sigma increases,

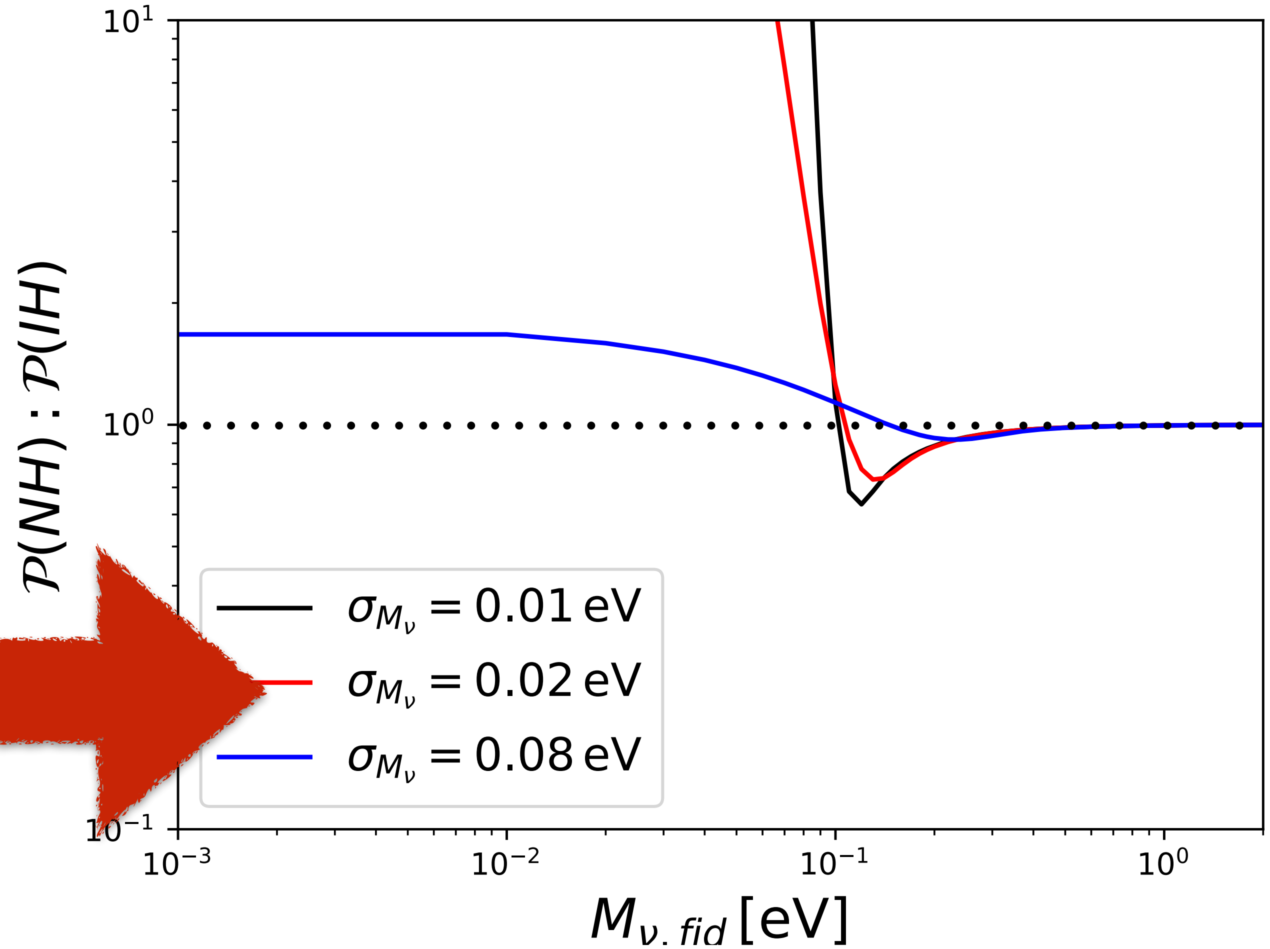
NH is as likely as IH

Fixed sigma

NH favoured for Mnu<0.1eV,

IH favoured for Mnu~0.1eV,

no preference for Mnu>0.1eV



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
- sensitivity driven by prior choice

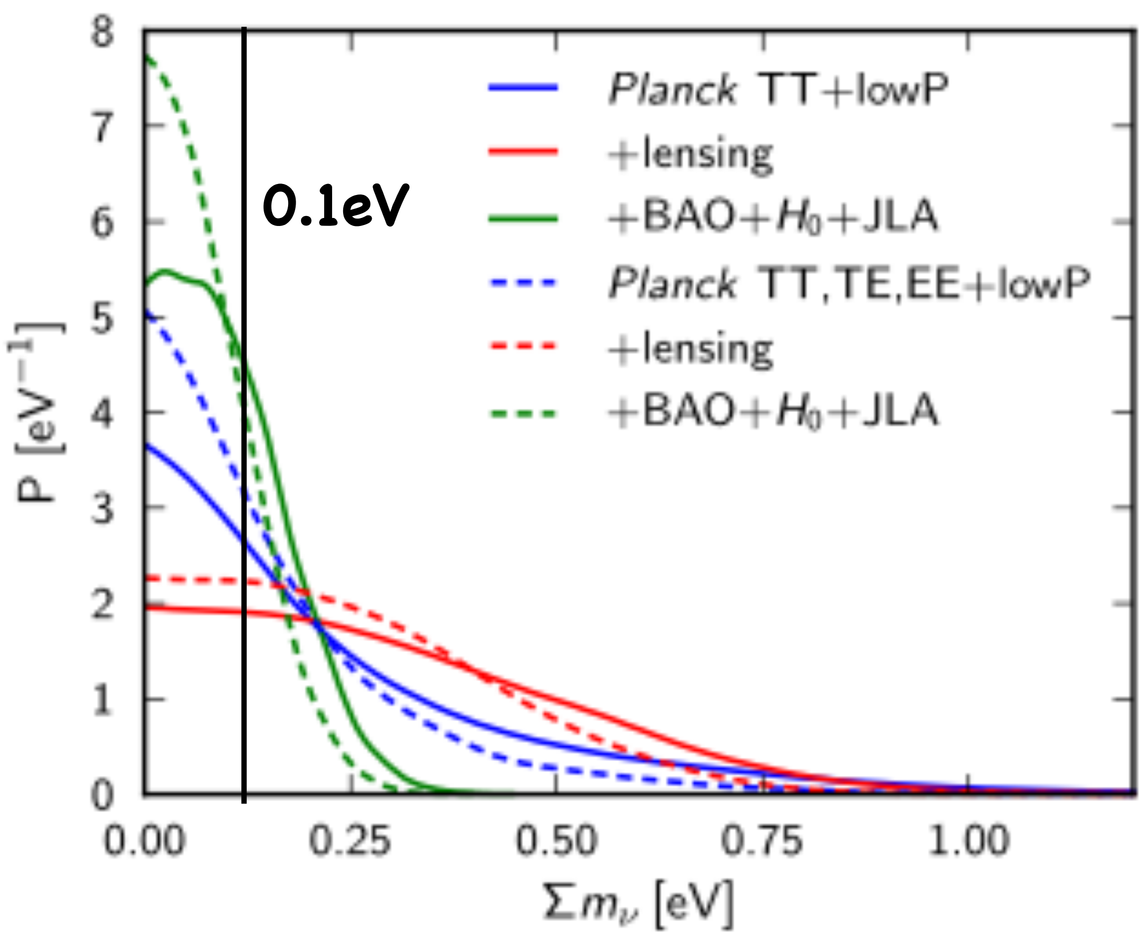
BACK-UP

The standard method

M_{nu}

(+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)

Joint constraints on Mnu - present

Vagnozzi,Giusarma,Mena,Freese,MG,Ho,Lattanzi 2017

$$M_\nu \equiv \Sigma_i m_{\nu,i}$$

Planck TT+lowP+BAO:	Mnu<0.2eV
Planck TT+lowP+Pk:	Mnu<0.3eV
Planck TT+lowP+BAO+Pk:	Mnu<0.25eV

Compilation of CMB and LSS data

95% CL

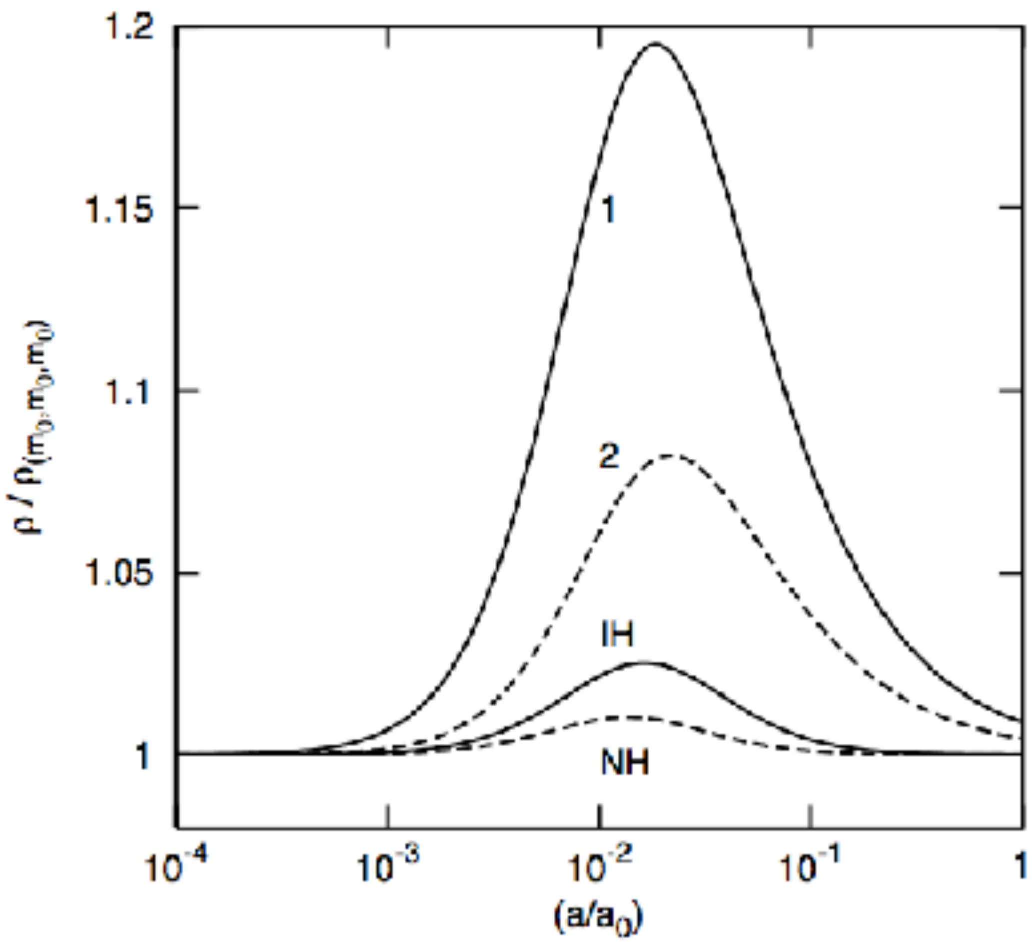
major improvement with a better measurement of the optical depth and/or use of CMB small scale polarisation: wait for Planck legacy release!

Take home message: tight, yet robust bounds

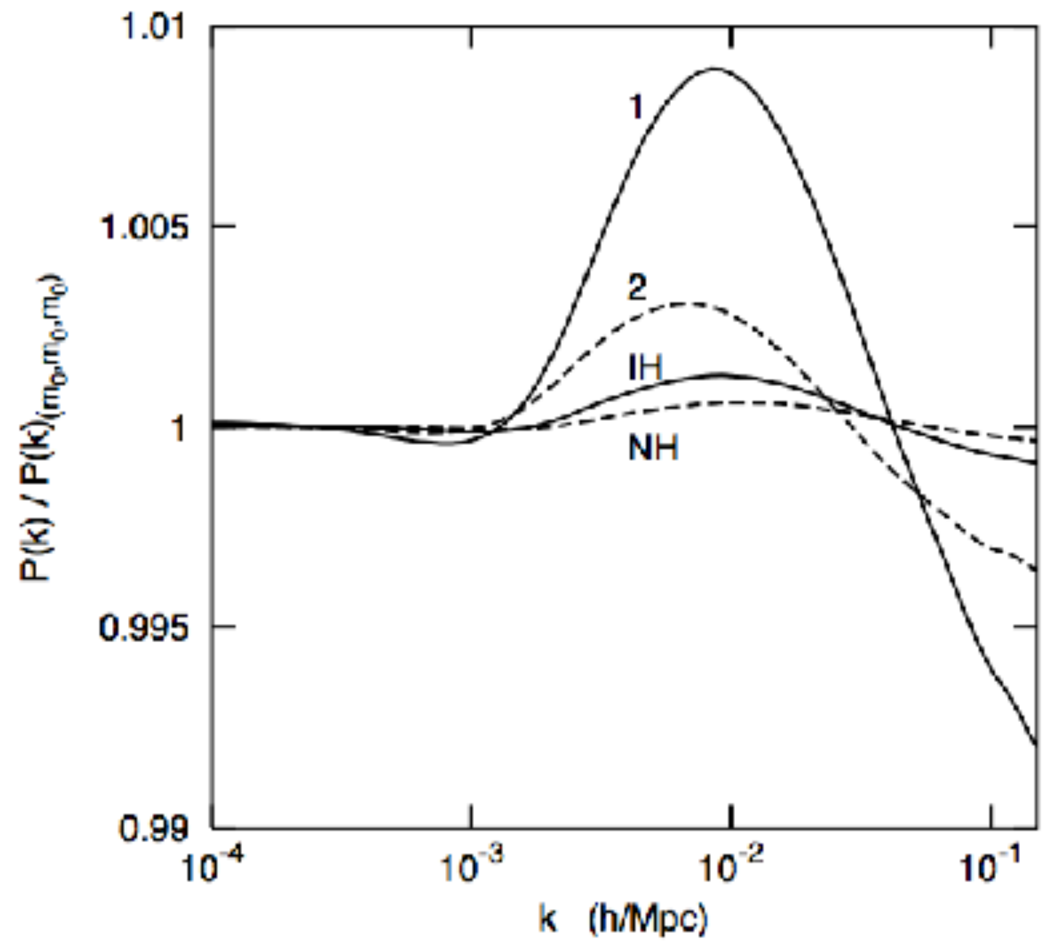
Sensitivity to the hierarchy

Physical effects due to different distribution of the sum of the masses for the 2 hierarchies

Total nu energy density



Matter power spectrum

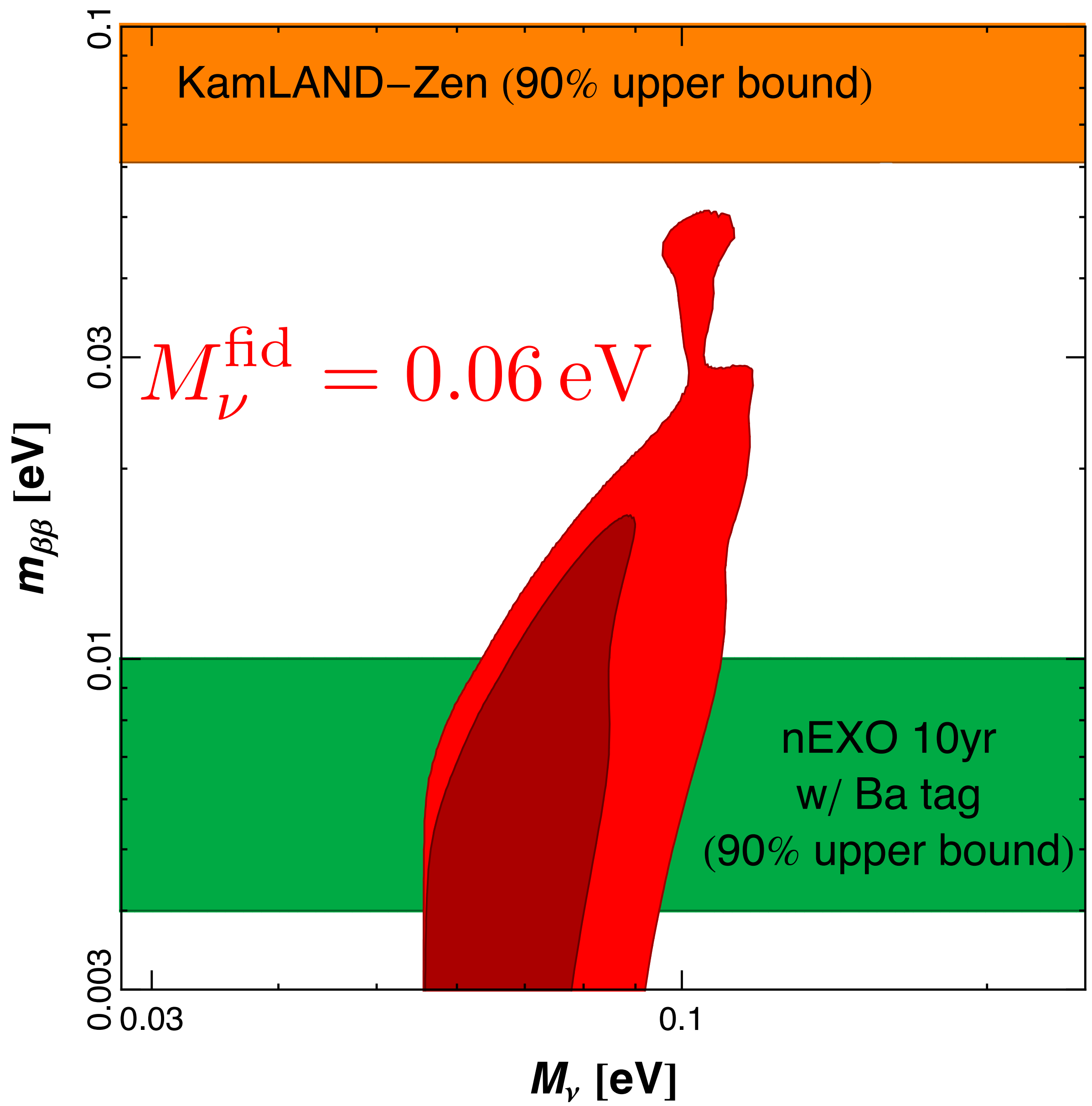


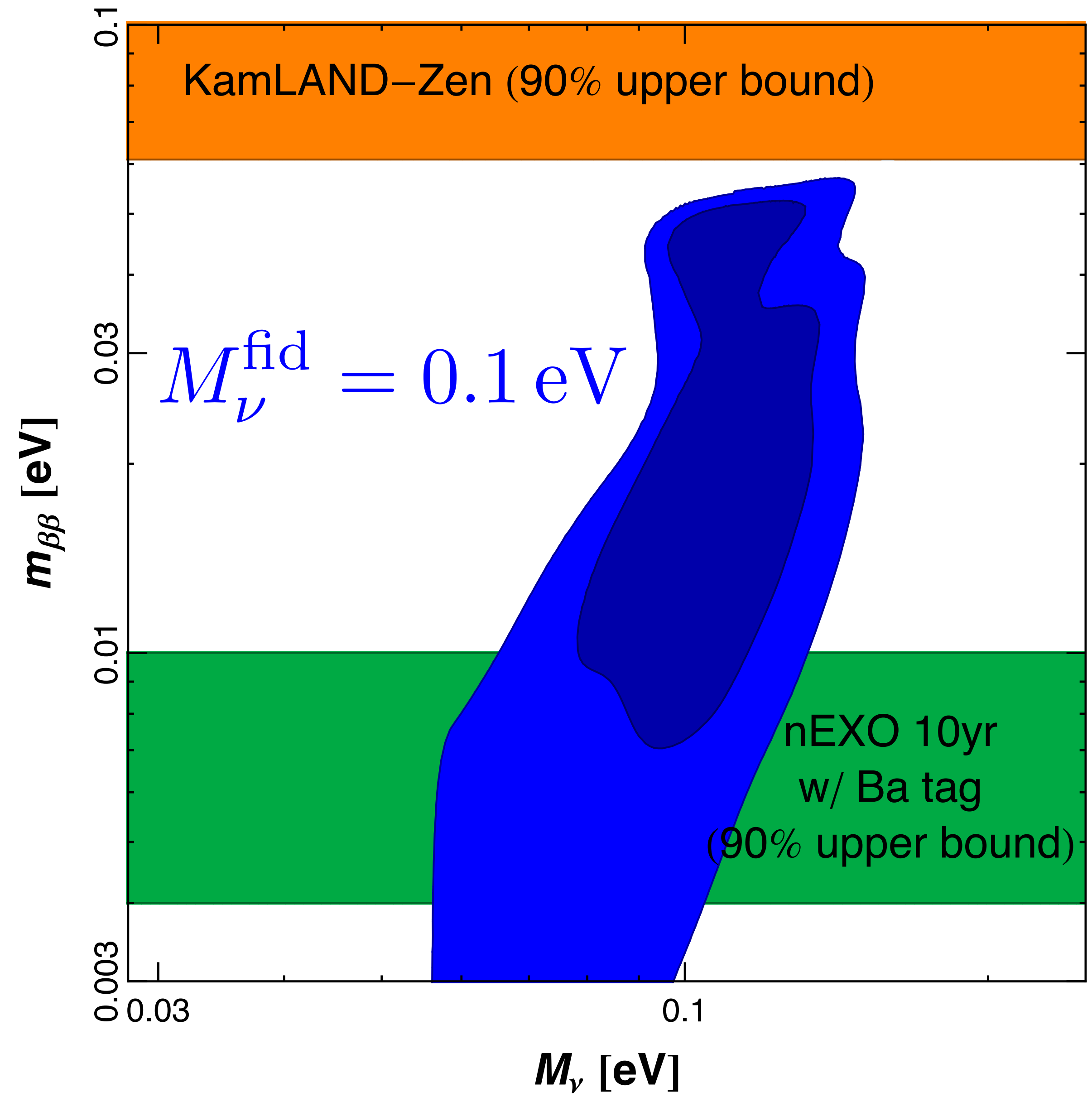
Lesgourgues&Pastor, 2006

Are current (and future) data sensitive to these effects?

How much?

Sensitivity to the hierarchy





Gerbino,Lattanzi,Mena,Freese 2017

If Mnu=0.1eV, sigma(mbb)~10meV could guarantee 0n2b measurement

0n2b could in turn helps unravel the hierarchy (wip, extending the results in Gerbino+2015 in the hierarchical bayesian context)