Core constraints on “small scale” parameters

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Technical Details

Channel [GHz]	FWMH [arcmin]	ΔT [μK arcmin]	ΔP [μK arcmin]
LiteCORE-80, $l_{\max} = 2400$, $f_{\rm sky} = 0.7$			
80	20.2	8.8	12.5
90	17.8	7.1	10.0
100	15.8	8.5	12.0
120	13.2	6.7	9.5
140	11.2	5.3	7.5
166	8.5	5.0	7.0
195	8.1	3.6	5.0
LiteCORE-120, $l_{\max} = 3000$, $f_{\rm sky} = 0.7$			
80	13.5	8.8	12.5
90	11.9	7.1	10.0
100	10.5	8.5	12.0
120	8.8	6.7	9.5
140	7.4	5.3	7.5
166	6.3	5.0	7.0
195	5.4	3.6	5.0
CORE+, $l_{\max} = 3000$, $f_{\rm sky} = 0.7$			
100	8.4	6.0	8.5
115	7.3	5.0	7.0
130	6.5	4.2	5.9
145	5.8	3.6	5.0
160	5.3	3.8	5.4
175	4.8	3.8	5.3
195	4.3	3.8	5.3
220	3.8	5.8	8.1

No foregrounds
No delensing

LiteBIRD-ext specifications http://ltd16.grenoble.cnrs.fr/IMG/UserFiles/Images/09_TMatsumura_20150720_LTD_v18.pdf						
frequencies [GHz]	fractional bandpass [%]	sensitivities [μK-arcmin]	$f_{\rm sky}$ [%]	FWHM [arcmin]	$\ell_{\rm min}$	$\ell_{\rm max}$
40.0		42.5		108		
50.0		26.0		86		
60.0		20.0		72		
68.4		15.5		63		
78.0		12.5		55		
88.5		10.0		49		
100.0		12.0		43		
118.9	30.0	9.5	70.0	36	2	1350
140.0		7.5		31		
166.0		7.0		26		
195.0		5.0		22		
234.9		6.5		18		
280.0		10.0		37		
337.4		10.0		31		
402.1		19.0		26		

$$\tilde{C}_\ell^{TT} = C_\ell^{TT} + N_\ell^{TT},$$
$$\tilde{C}_\ell^{EE} = C_\ell^{EE} + N_\ell^{EE}$$
$$\tilde{C}_\ell^{TE} = C_\ell^{TE}$$

$$N_\ell^{X,chan} = \left(\frac{w_{X,chan}^{-1/2}}{\mu\text{K-rad}}\right)^2 \exp\left[\frac{\ell(\ell+1)(\theta_{\rm pix}/\text{rad})^2}{8\ln 2}\right]$$

$$N_\ell^X = \frac{1}{\sum_{chan}\{1/(N_\ell^{X,chan})\}}$$

$$w_X^{-1} = \{(\Delta X/T)\times T_{CMB}\times\theta_{\rm pix}\}^2[\mu K^2]$$

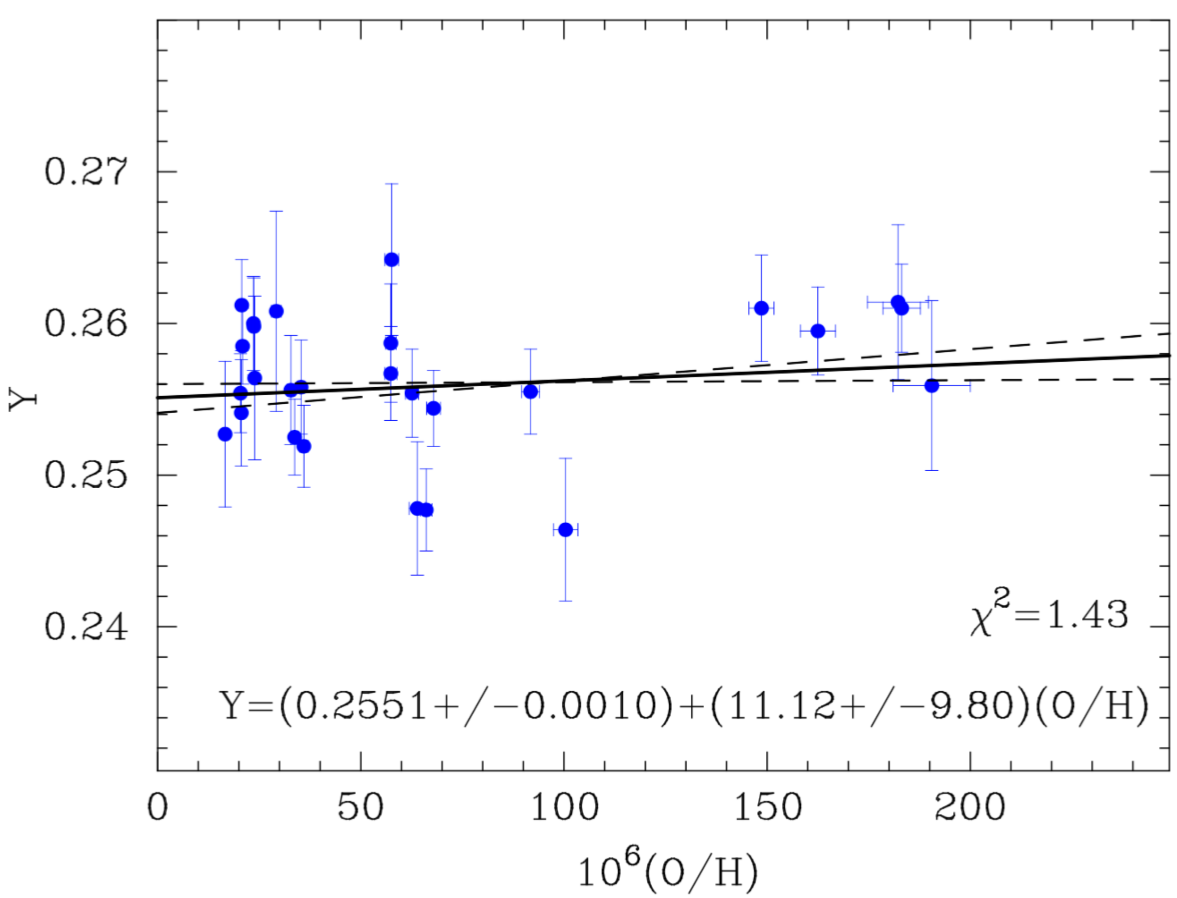
$$T_{CMB} = 2.725K$$

Helium Abundance

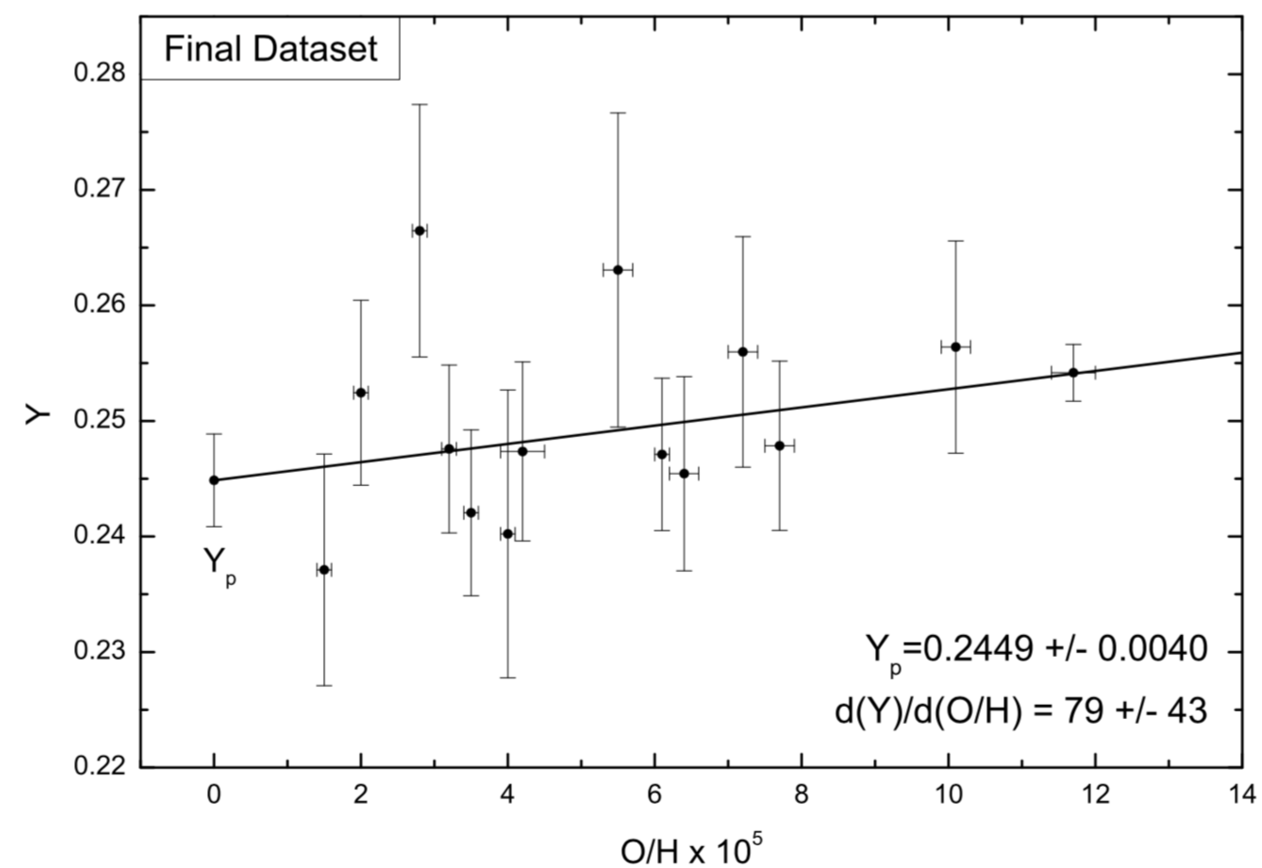
Measuring Primordial Helium vs baryon densities is a crucial test for Big Bang Nucleosynthesis.

Current direct measurements from extragalactic HII regions are in tension: systematics play a relevant role.

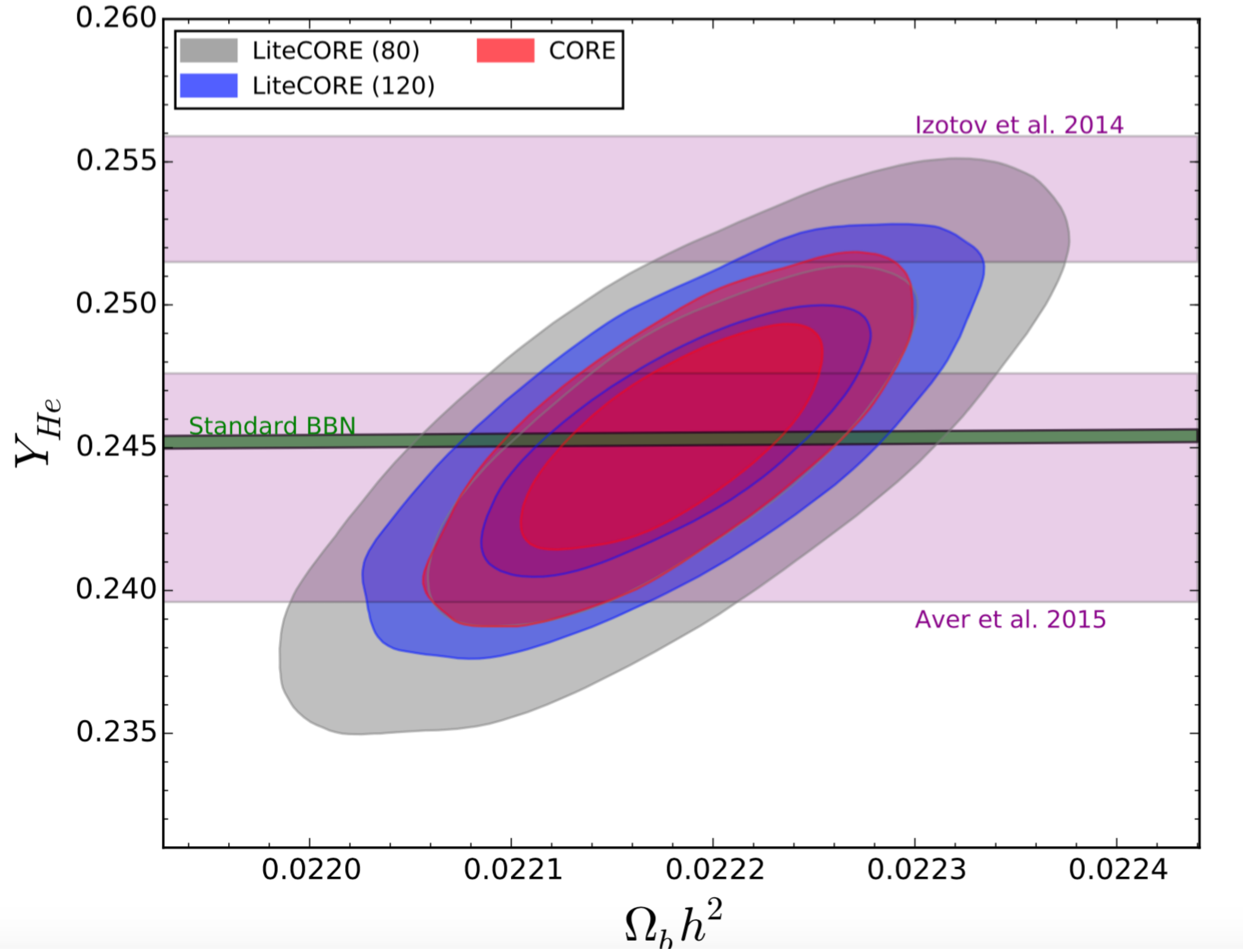
Izotov et al., 2014



Aver et al. 2015



Helium Abundance

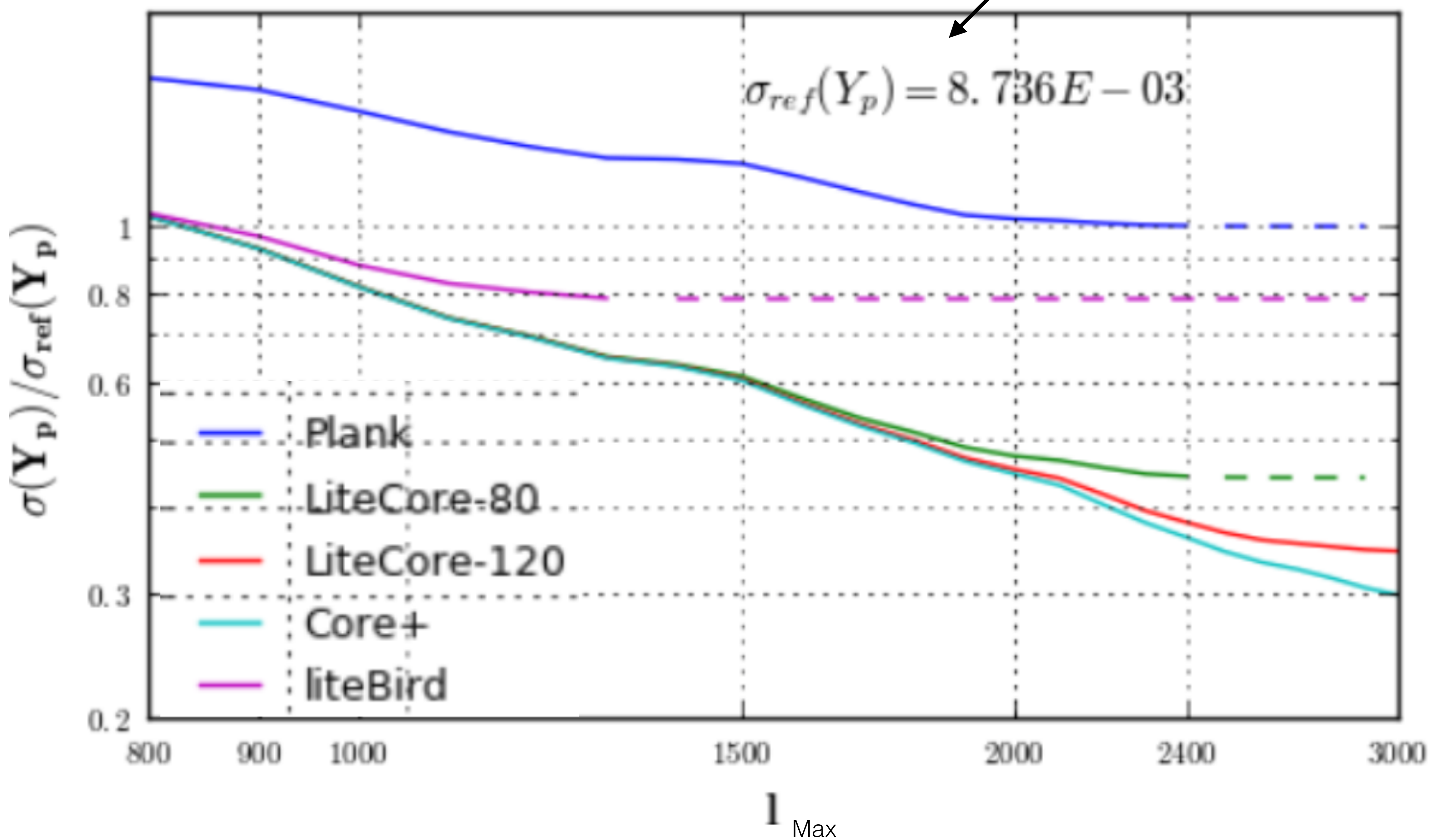


CORE or CORE 120 can discriminate at 95% c.l. between the two measurements.

Cleanest way to measure primordial Helium abundance and to test BBN !

	CORE	LiteCORE (80)	LiteCORE (120)
$Y_{\rm He}$	0.2454 ± 0.0025	$0.2450^{+0.0042}_{0.0041}$	0.2454 ± 0.0030

Sigma of reference from
Planck (simulated)



Litebird will improve Yp from Planck just by 20%
Differences between different Core configurations
starts at about lmax=2000

Neff
relativistic degrees of freedom at recombination

This parameter essentially measures the entropy density at recombination.

Standard model (3 active neutrinos) predicts $N_{eff}=3.046$.

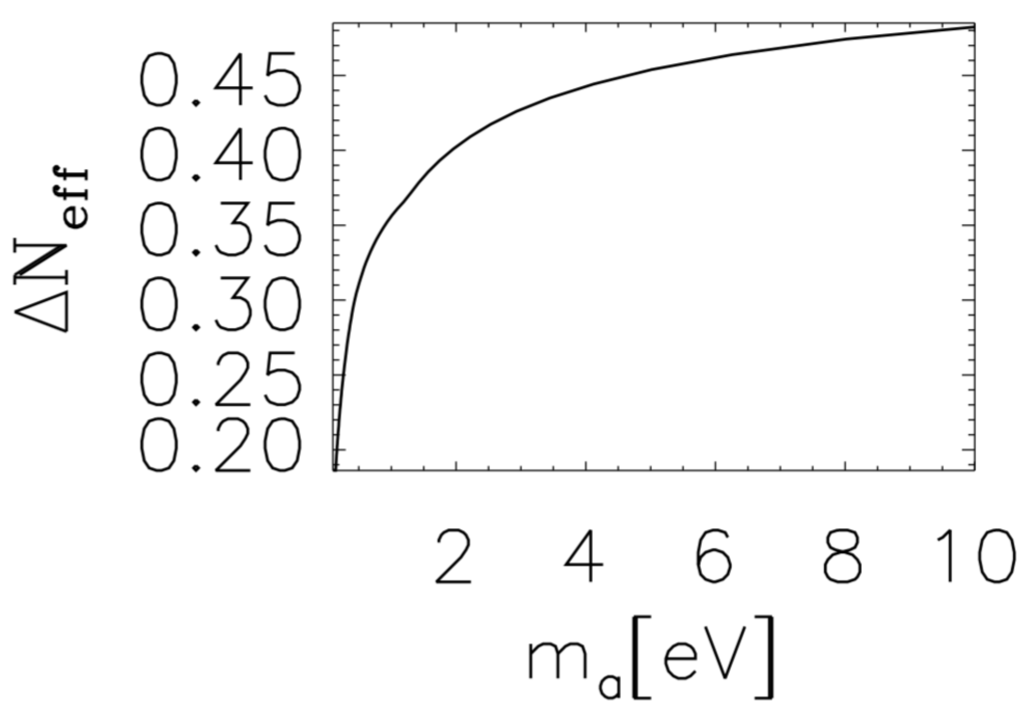
Having a sensitivity of $\Delta N_{eff} \approx 0.023$ could test the neutrino decoupling at 95% c.l..

Extra light particles as thermal axions can produce $N_{eff}>3.046$.

Reheating at low temperatures can give $N_{eff}<3.046$.

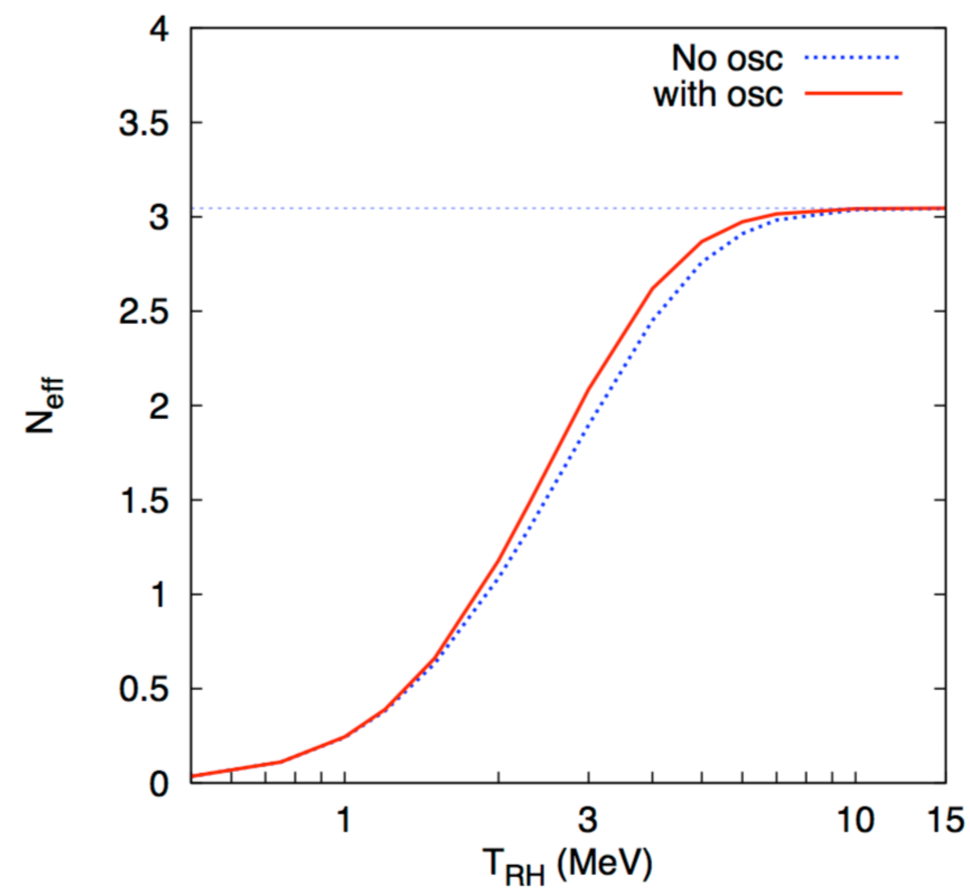
Neff >3.046 Neff <3.046

Example: thermal axions



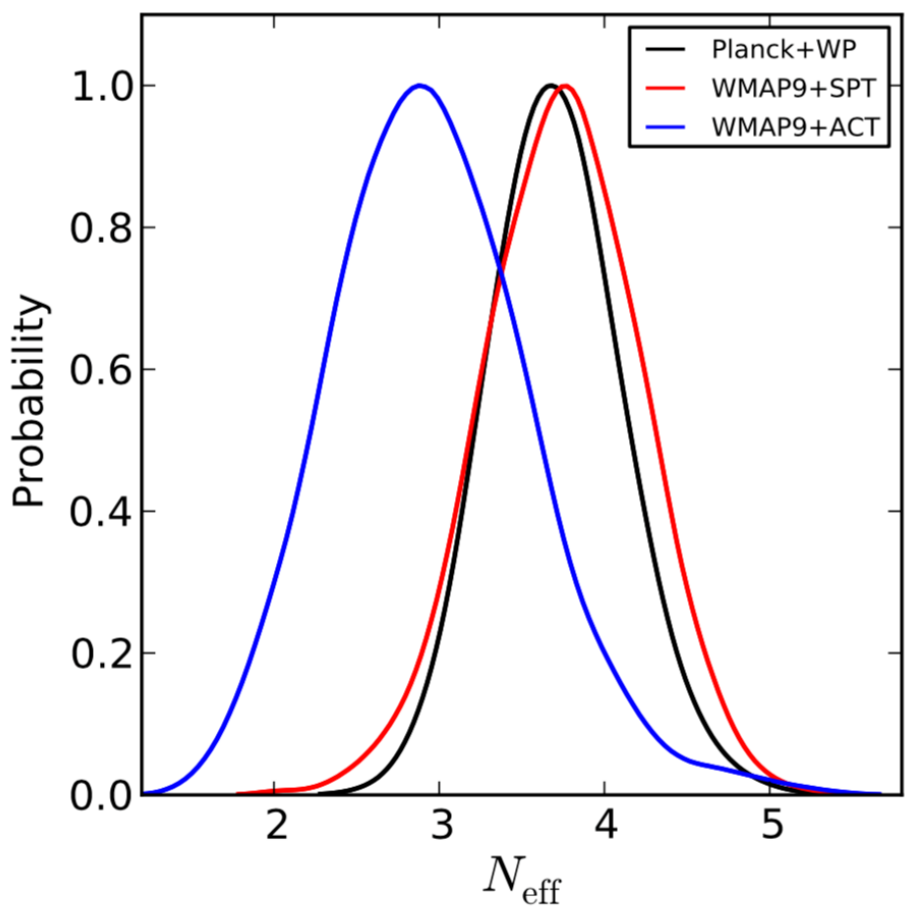
Please note:
we need ΔNeff>0.18 !!

Example: Low Reheating T



Neff >3.046

Mildly suggested by WMAP and Planck 2013

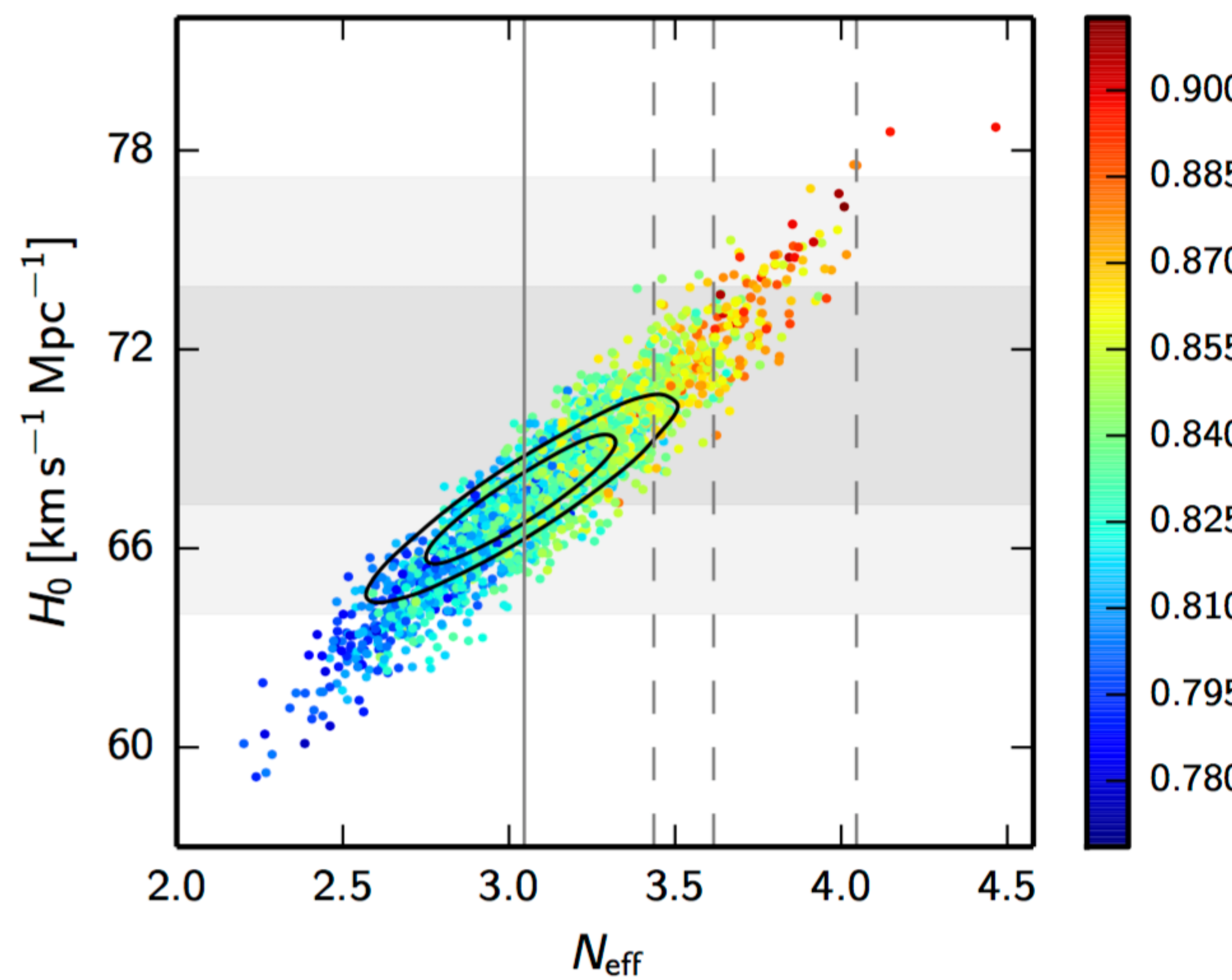


(mainly because of the "high" tau from WMAP9)

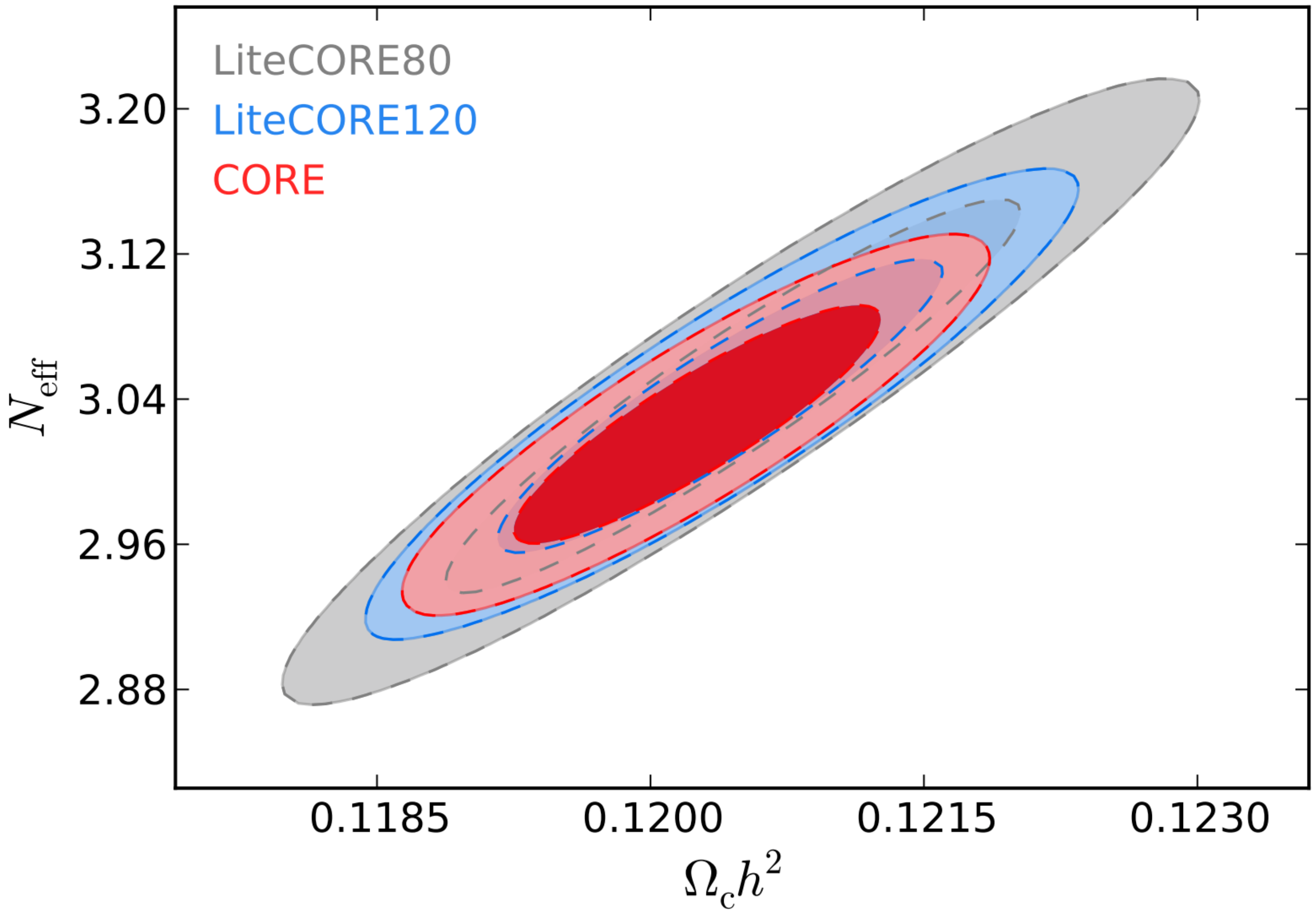
Neff <3.046

Very mildly suggested by Planck 2015 (+ new HFI tau)

$N_{\rm eff} = 2.91^{+0.39}_{-0.37}$



Constraining Neff with CORE

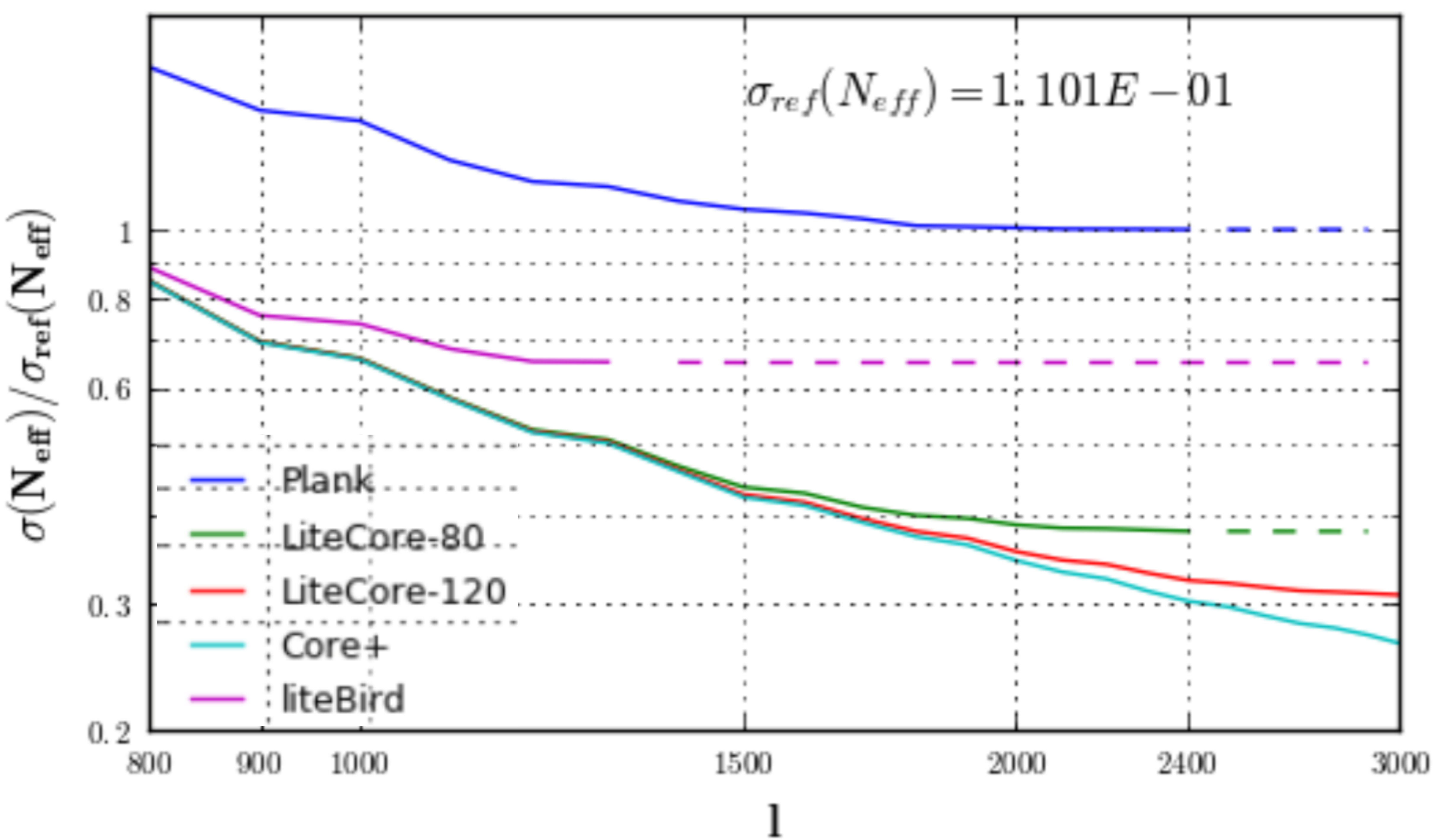


ΛCDM+$N_{\rm eff}$	CORE	LiteCORE (80)	LiteCORE (120)
$\Omega_b h^2$	0.02217 ± 0.00010	0.02218 ± 0.00017	0.02218 ± 0.00013
$\Omega_c h^2$	0.1202 ± 0.0011	$0.12047^{+0.0018}_{-0.0017}$	0.12038 ± 0.0014
$100\,\theta_{\rm MC}$	$1.04070^{+0.00016}_{-0.00017}$	1.04069 ± 0.00025	1.04069 ± 0.00019
τ	$0.0598^{+0.0041}_{-0.0038}$	$0.0597^{+0.0040}_{-0.0039}$	$0.0598^{+0.0040}_{-0.0038}$
$N_{\rm eff}$	$3.026^{+0.073}_{-0.074}$	$3.043^{+0.124}_{-0.119}$	$3.037^{+0.093}_{-0.090}$
σ_8	0.817 ± 0.004	$0.817^{+0.006}_{-0.005}$	$0.817^{+0.005}_{-0.004}$
$H_0[{\rm Km\,s^{-1}\,Mpc^{-1}}]$	66.80 ± 0.58	$67.93^{+0.94}_{-0.90}$	$66.88^{+0.72}_{-0.70}$

:ABLE I. 95% CL bounds on the cosmological parameters for a ΛCDM+$N_{\rm eff}$ model.

$\Delta N_{\rm eff} \approx 0.037$ not enough to test neutrino decoupling but enough to rule out axions at 4 sigma level.

Fisher Matrix forecast for N_{eff}



Neutrino Mass

Very HOT topic.
We have lower limits of:

$$\Sigma m_\nu > 0.096 \ \ eV \ \ \text{I.H.}$$

$$\Sigma m_\nu > 0.06 \ \ eV \ \ \text{N.H.}$$

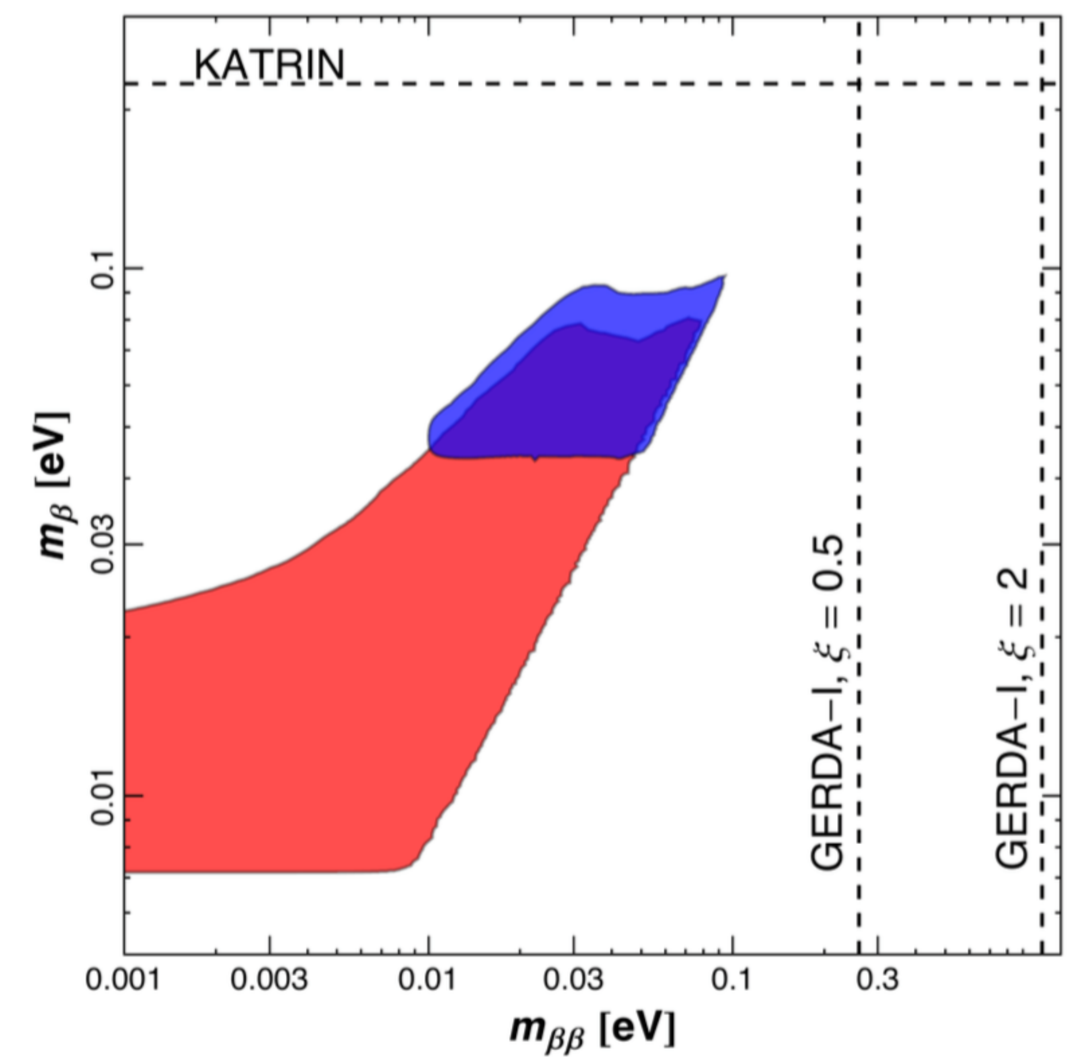
Planck alone provides the 68% limit:

$$\Sigma m_\nu < 0.17 \ \ eV$$

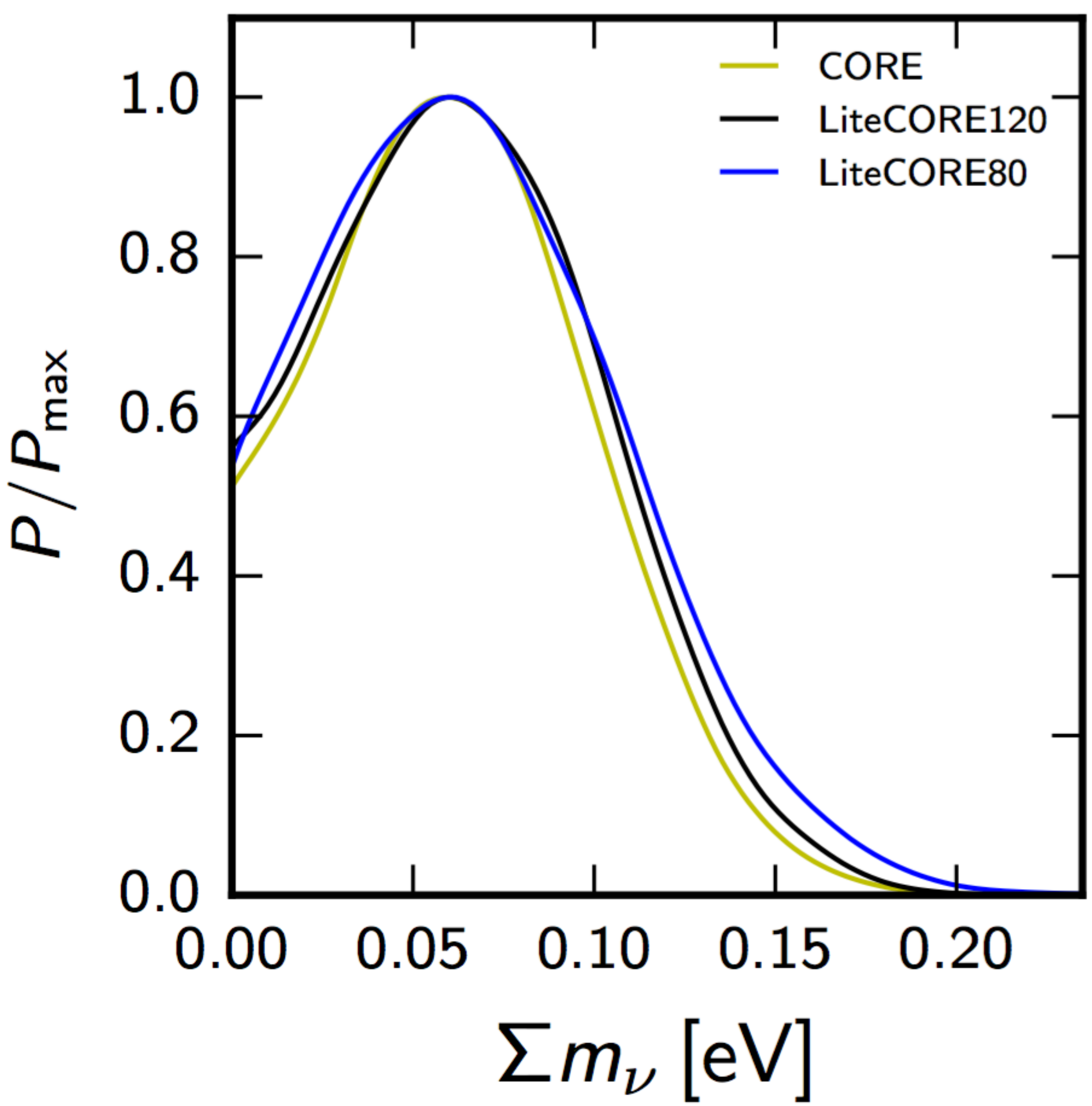
While Planck+BAO gives:

$$\Sigma m_\nu < 0.081 \ \ eV$$

A neutrino mass cosmological detection is possibly around the corner. I.H. can be ruled out soon !



Neutrino Mass

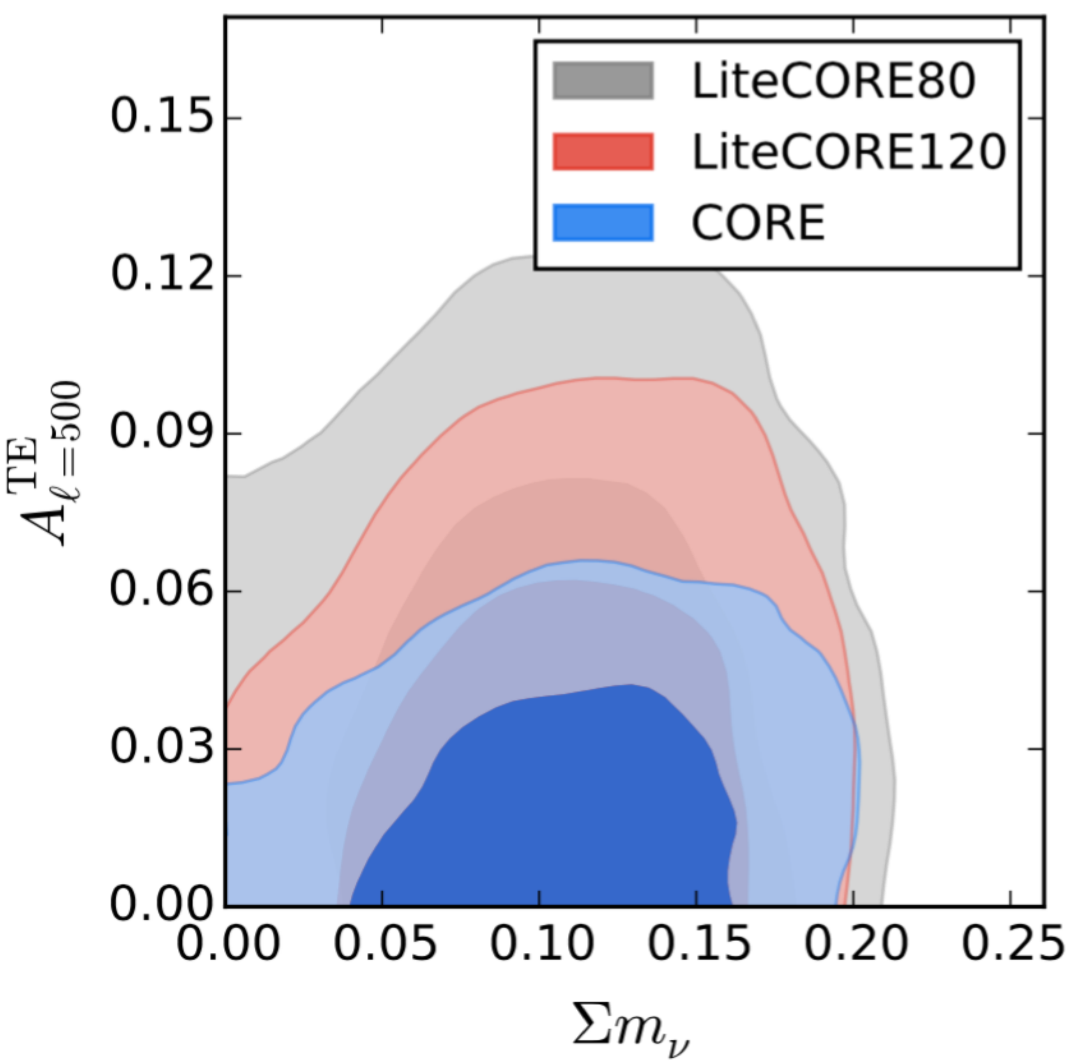


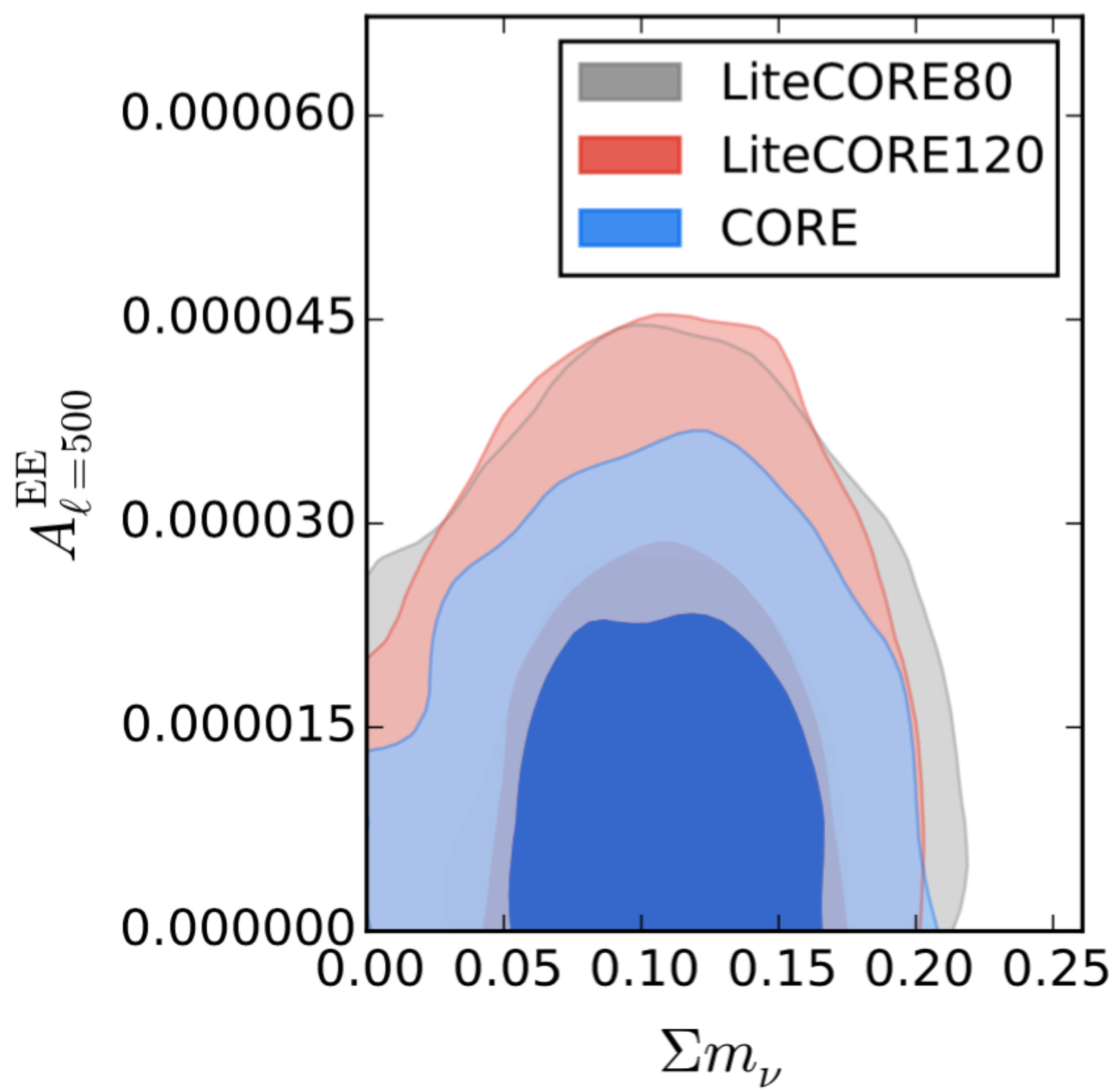
	mnu(eV)
CORE	0.063^{+0.032}_{-0.043}
LiteCORE120	0.065^{+0.033}_{-0.045}
LiteCORE80	0.068^{+0.031}_{-0.051}

In the “worst case" scenario we can measure a neutrino mass just very marginally at 1 sigma with CORE.

Neutrino mass vs unresolved pol. foreground

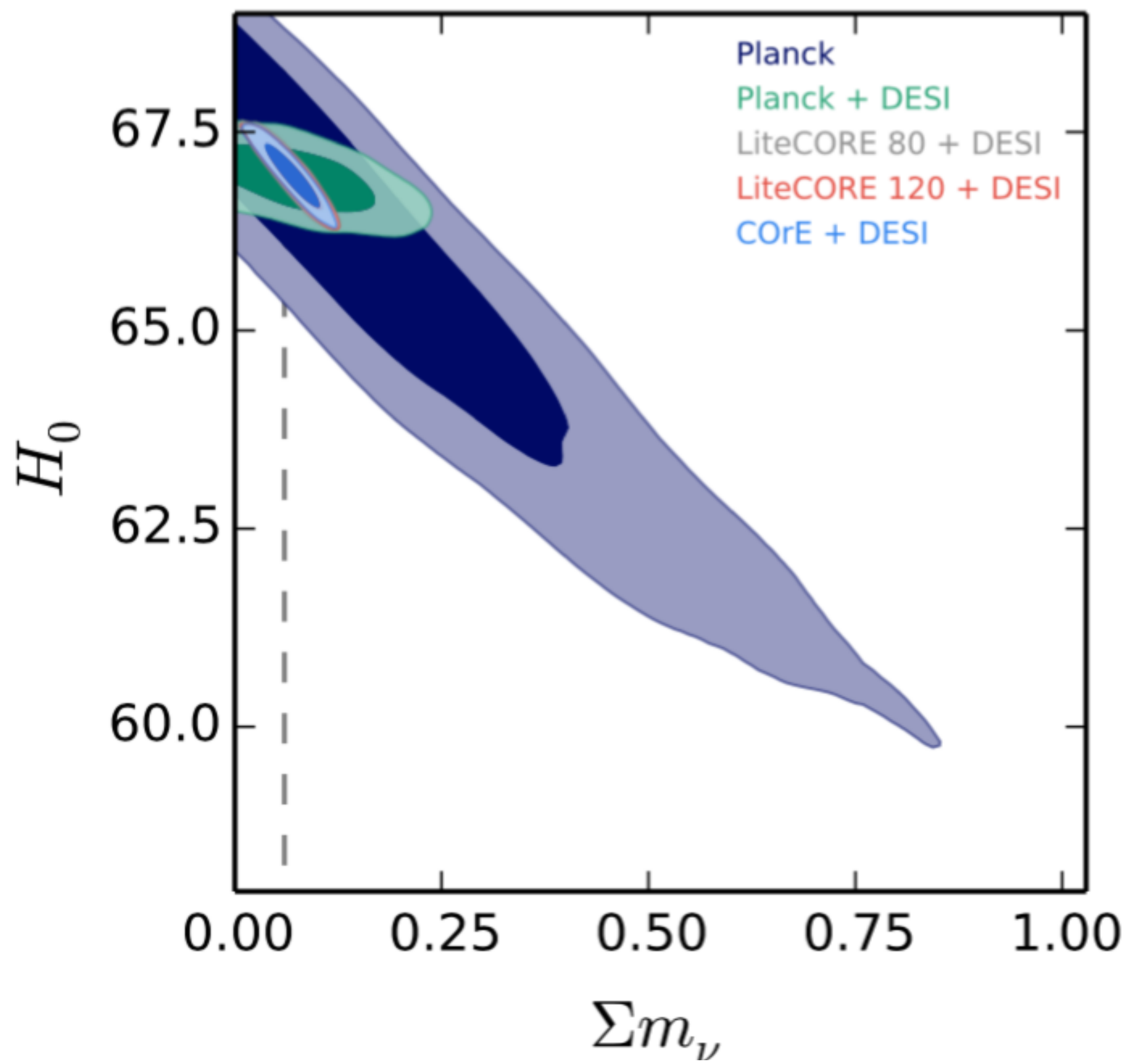
$$C_l^{dust} = A^{TE,EE}\left(\frac{l}{500}\right)^{-0.4}$$





Fiducial
∑m=0.1 eV

Neutrino mass CMB+ext



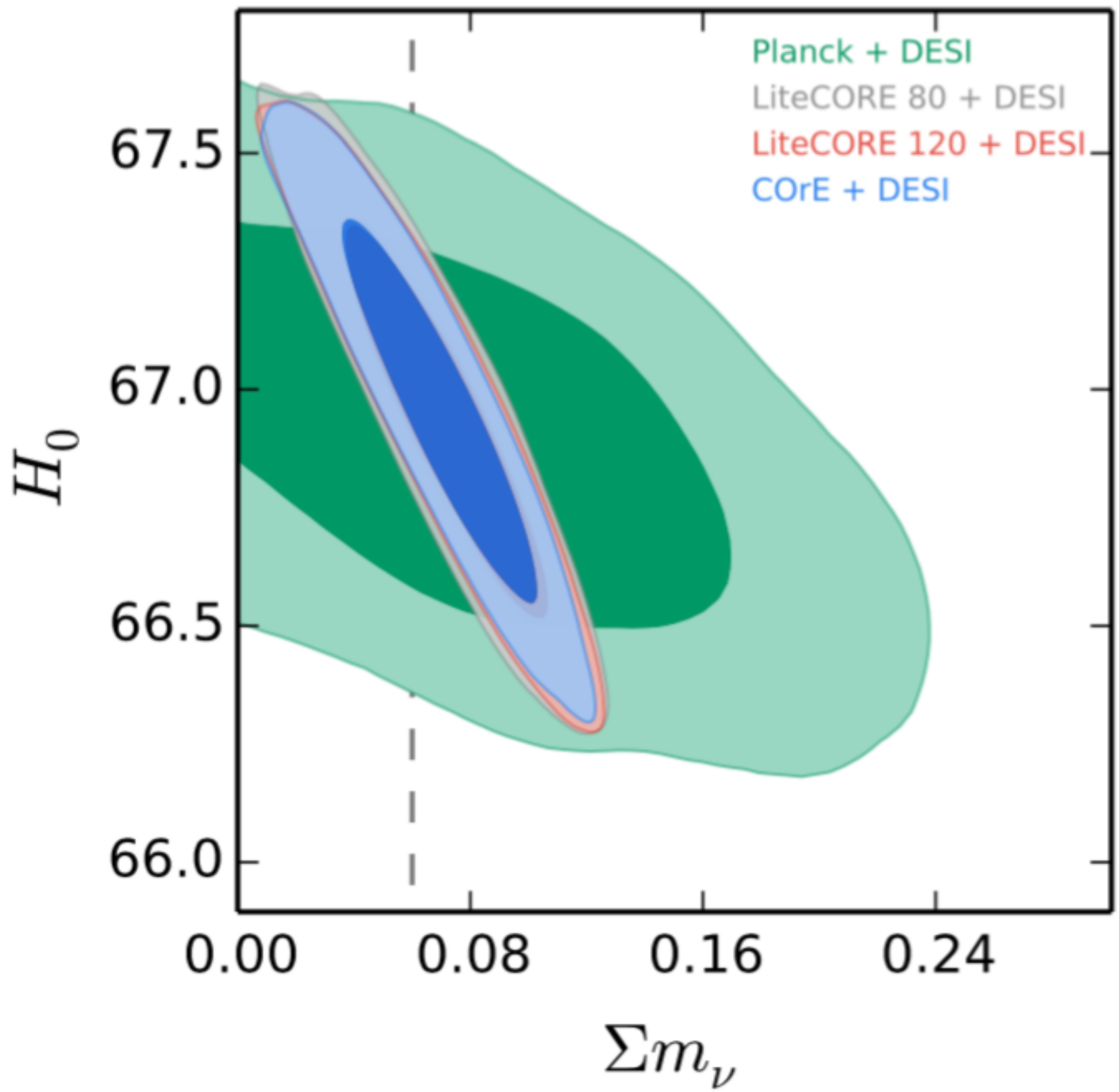
(Planck simulated not real data)

Fiducial has ∑m=0.066 eV

Not enough to have guaranteed discovery !

68% c.l.		Planck +DESI	LiteCORE 80 +DESI	LiteCORE120 +DESI	COrE+ +DESI
	Σm_ν [eV]	$0.093^{+0.042}_{-0.070}$	0.071 ± 0.022	$0.071^{+0.024}_{-0.021}$	$0.069^{+0.023}_{-0.019}$

Any CORE configuration will be OK for discovery!



We need improved CMB data to measure neutrino mass even after combination with BAO surveys as DESI

Alens

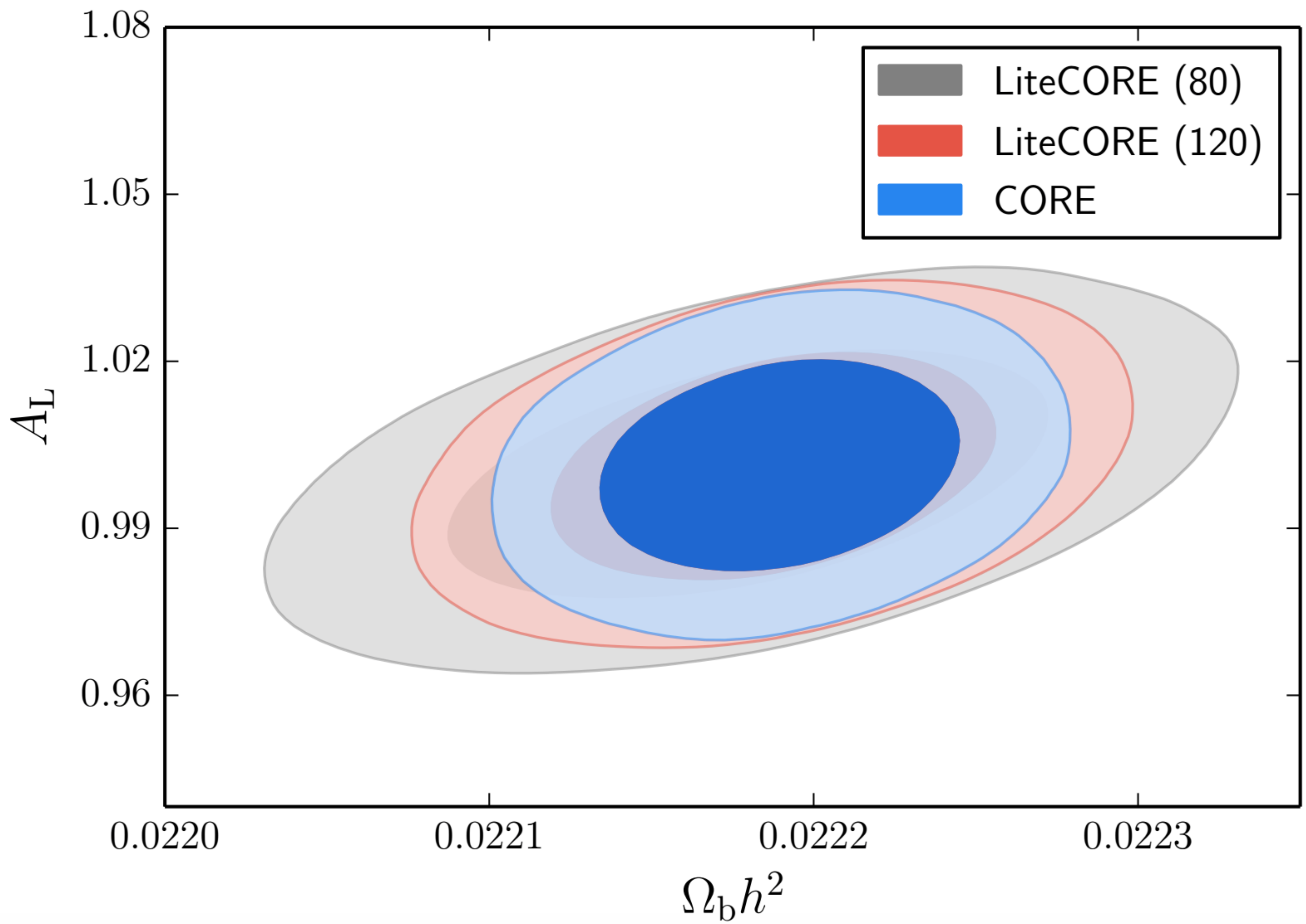
In Planck we see in the angular power spectra a larger amplitude for lensing:

$$A_{\rm L} \; . \; . \; . \quad 1.15^{+0.13}_{-0.12}$$

PlanckTTTEEE+SIMlow
95 % limits

The nature of this “anomaly" is still unclear.
Most probably is not related to the true lensing since we don’t see in the Planck trispectrum.

We have this anomaly since the 2013 release, it may well go away in future analyses but how much we can constrain it with CORE ?



$\Lambda CDM + A_L$	CORE	LiteCORE (80)	LiteCORE (120)
A_L	1.001 ± 0.012	1.000 ± 0.014	1.001 ± 0.013

If we don't have A_L=1.15, we could rule it out at 10 sigmas

Conclusions

Interesting parameters constrained by CORE

Helium abundance

+ Cleanest way to measure it
+ Beautiful test of BBN from CMB only
+ Discriminate between tensions in current HII data.
- Final constraints not significantly better in precision than current direct measurements.

Neff

+ Crucial test for BBN and exotic physics
- No evidence for non-standard values from Planck
- CORE not enough to test neutrino decoupling

Conclusions

Neutrino mass

+ Guaranteed discovery for CORE+DESI
+ Tremendous implications for general physics
- No guaranteed discovery for CORE alone
- Discovery is near the corner ! (S3+DESI could be enough)

A_{lens}

+ CORE can improve constraints by a factor 10.
+ Hint for new physics ?
- What is that ?
- Could be just due to a systematic

ECO Parameters Paper

Send a mail to alessandro.melchiorri@roma1.infn.it and lesgourg@physik.rwth-aachen.de if you like to be included.

Suggestions for extra parameters are most welcome.

Work on the paper will start full steam ahead in the next days (when we will know the core specifications).

No degeneracy between Neff and neutrino masses