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# CMB Halo Lensing for Cosmology

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(with Nick Battaglia, Hironao Miyatake, Neelima Sehgal)

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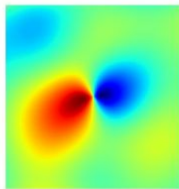
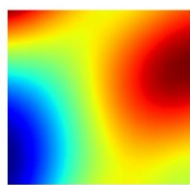
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Princeton University

# Cluster mass scales from lensed CMB

Large-scale gradient    Small-scale dipole

$$\hat{\kappa} \propto \vec{\nabla} \cdot \left[ \left[ \vec{\nabla} T \right]_{\text{low}} \left[ T(\vec{\theta}) \right]_{\text{high}} \right]$$

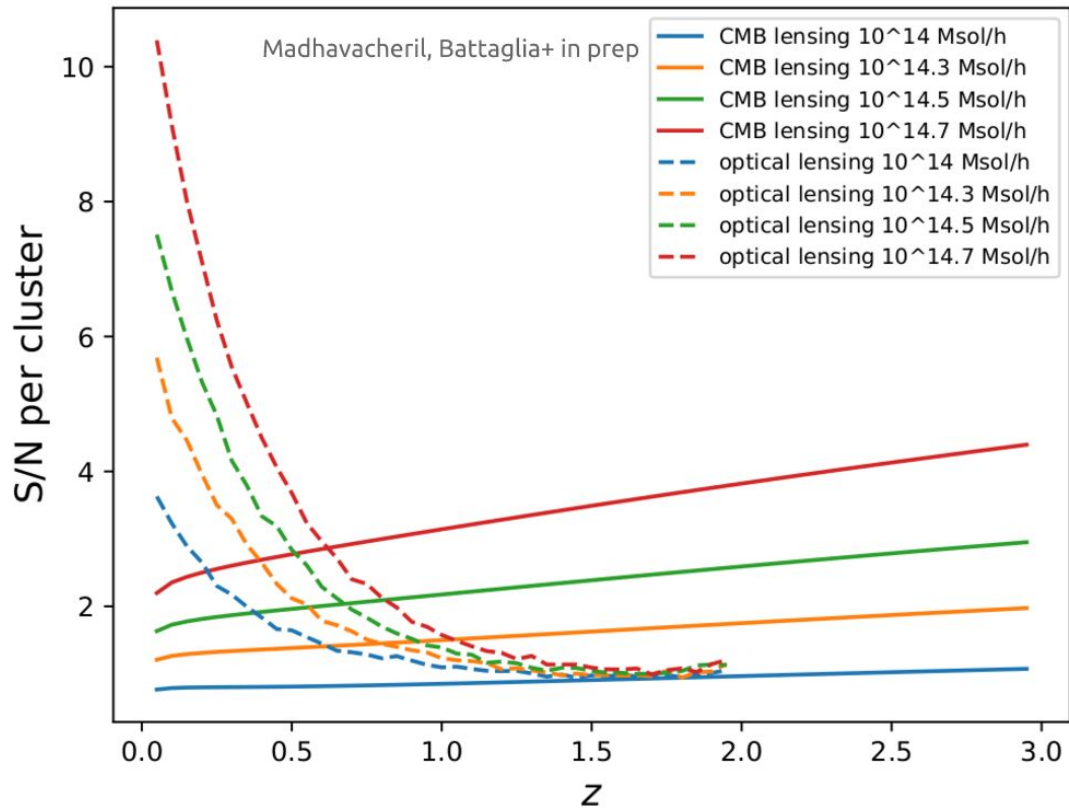


Hu, DeDeo, Vale 2007

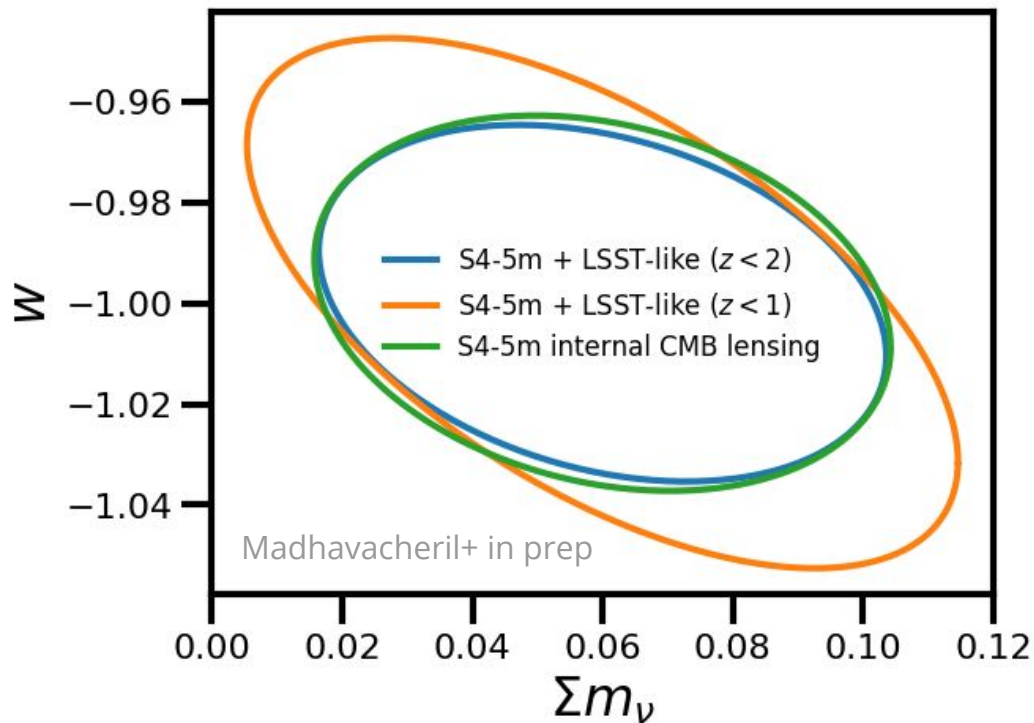
Optimal mass scale estimation with a matched filter on the reconstructed convergence map.

Foregrounds (tSZ, dust) can be dealt with either using cleaned gradients, or polarization only estimators.

# Optical vs. CMB S/N



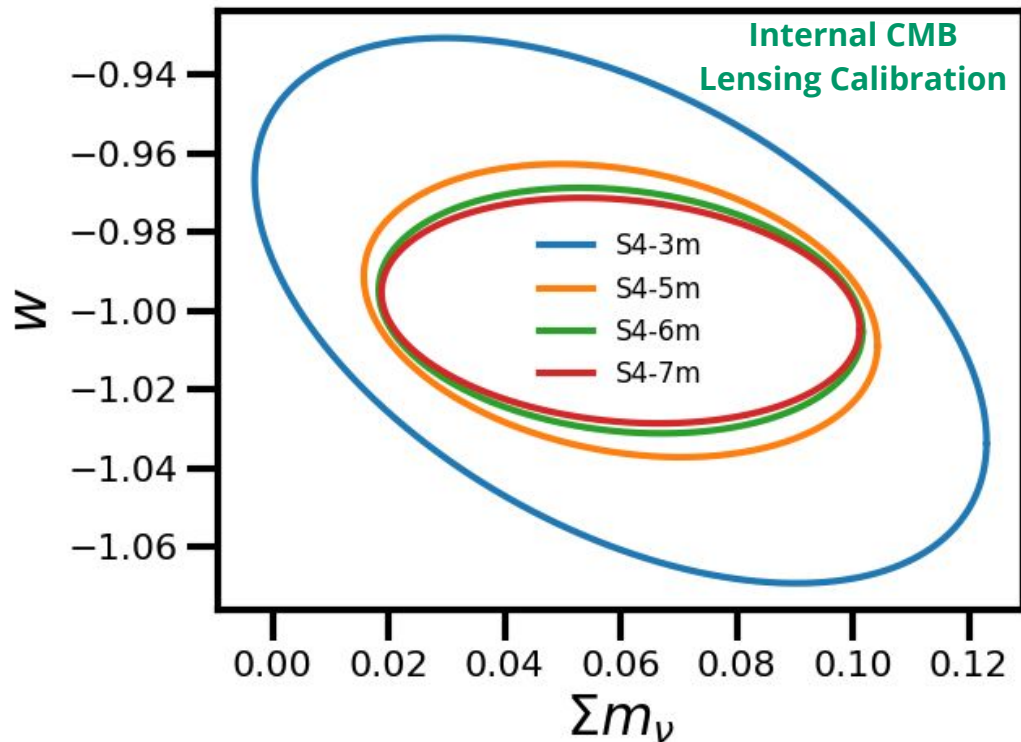
# CMB lensing: a competitive internal calibration



- CMB lensing better if you only trust  $z < 1$
- Comparable for optical  $z < 2$
- Self-contained internal calibration
- Independent cross-check

See **Louis & Alonso 2016** for CMB halo lensing  $m_{\nu}$  constraints; we've compared with them

# Mnu-w: resolution dependence

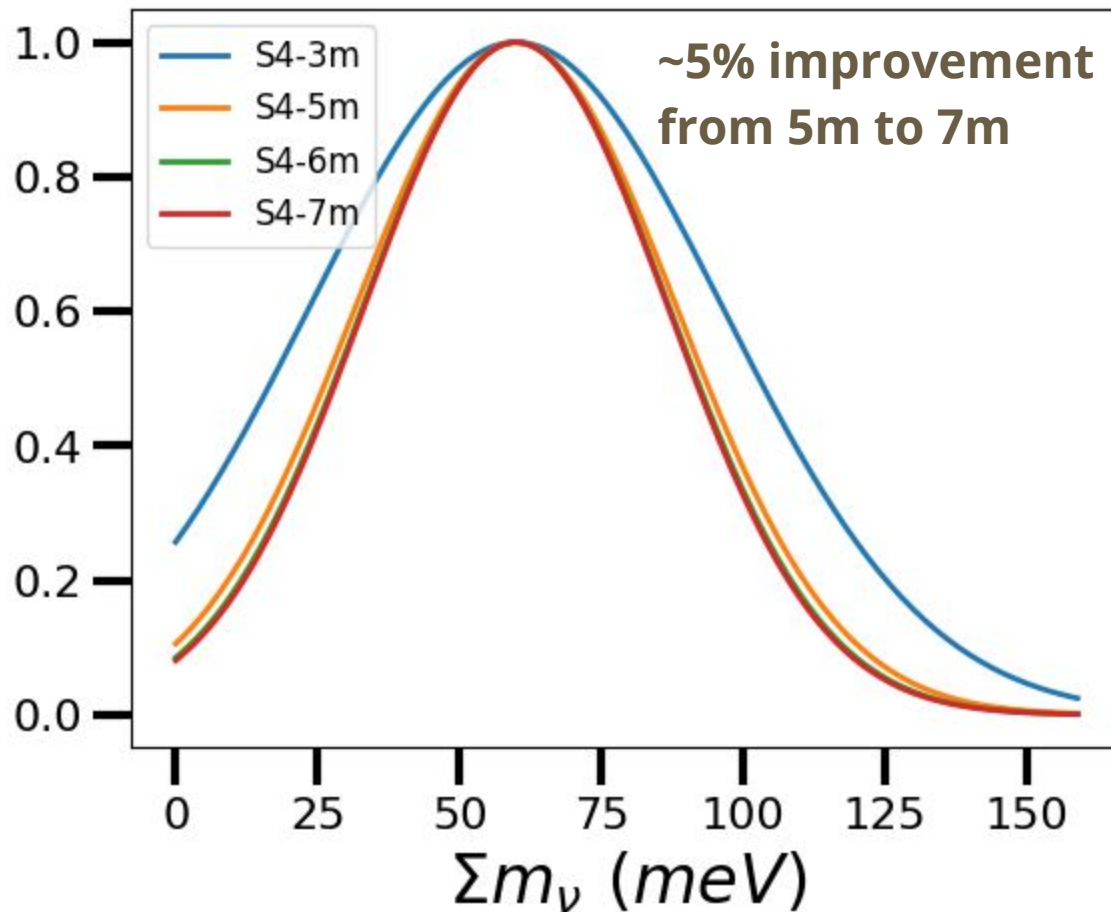


Need >5m!

Not much  
improvement above  
5m.

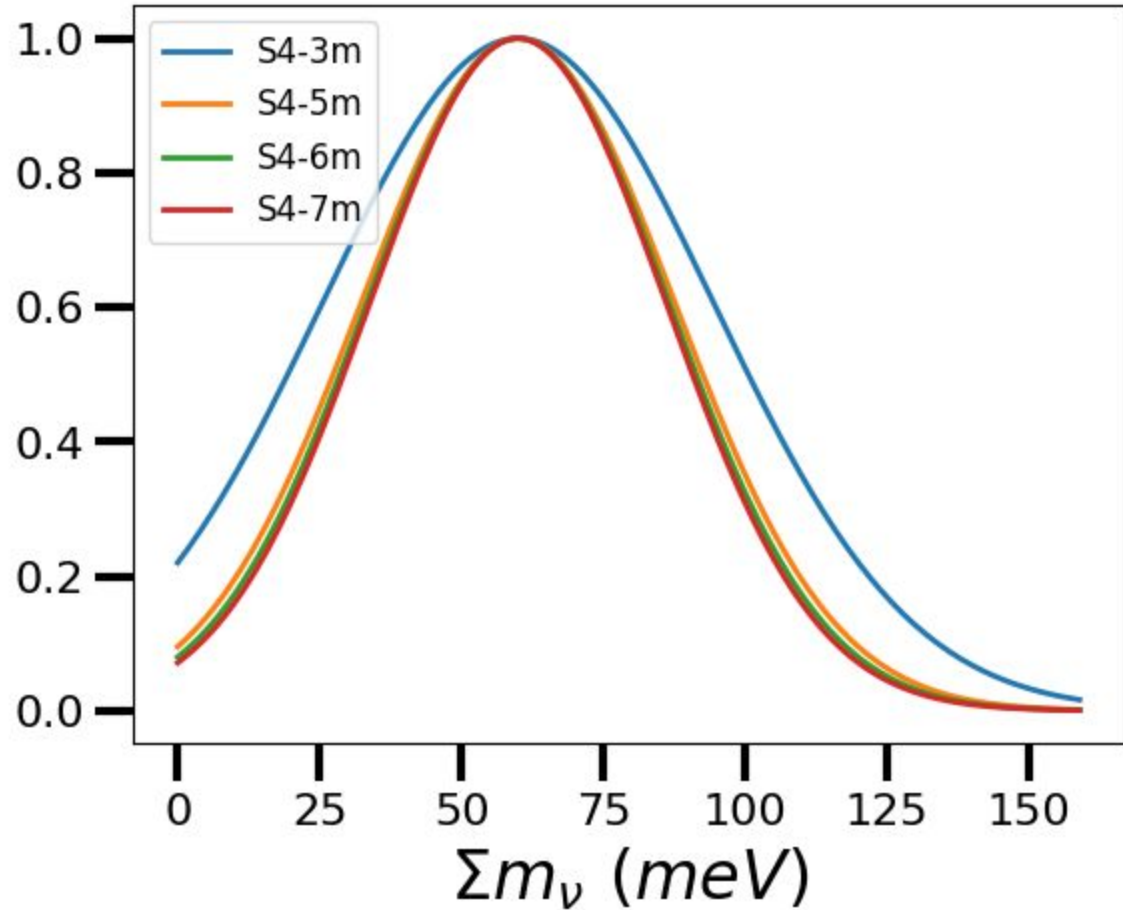
**Tau limited?**  
**Worked**  
**example**  
**with  $m_{\nu}$**

**INCLUDES**  
**ATMOSPHERE**



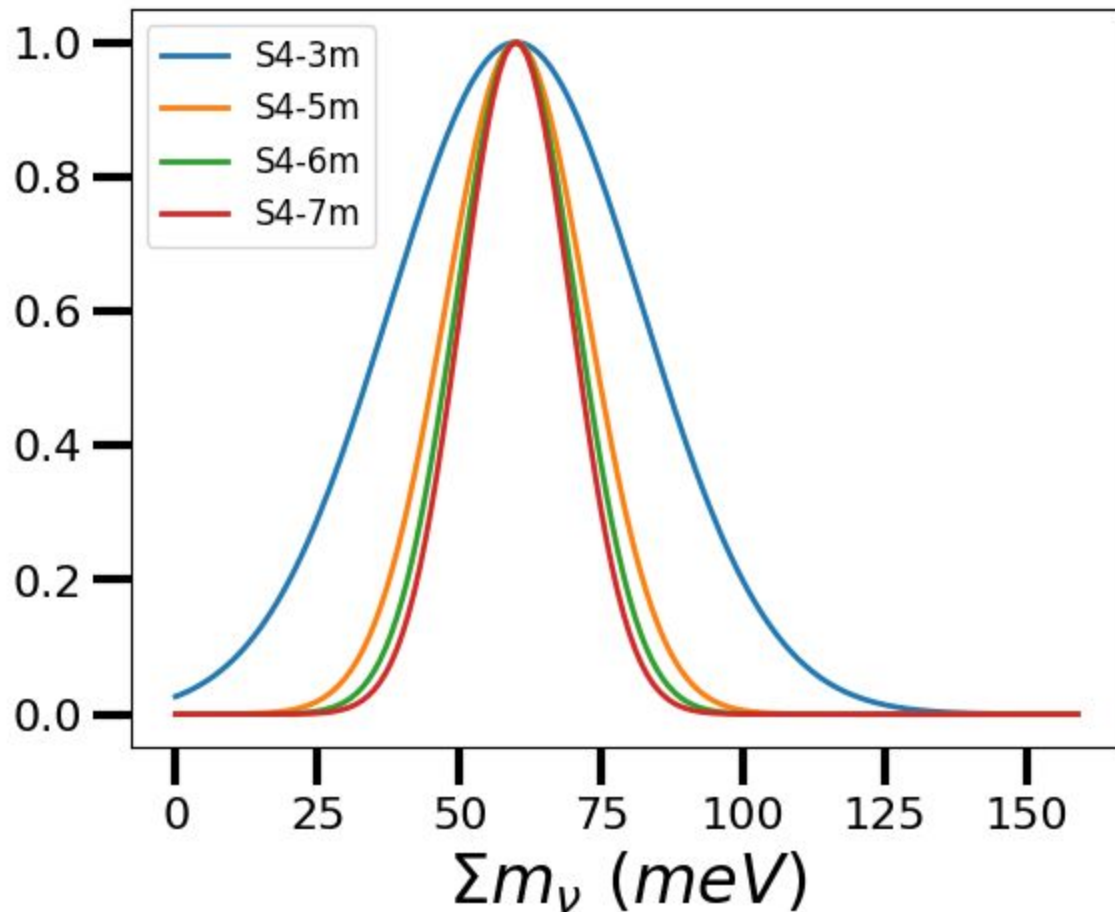
**Tau limited?  
Worked  
example  
with mnu**

**NO  
ATMOSPHERE**



**Tau limited?  
Worked  
example  
with  $m_{\nu}$**

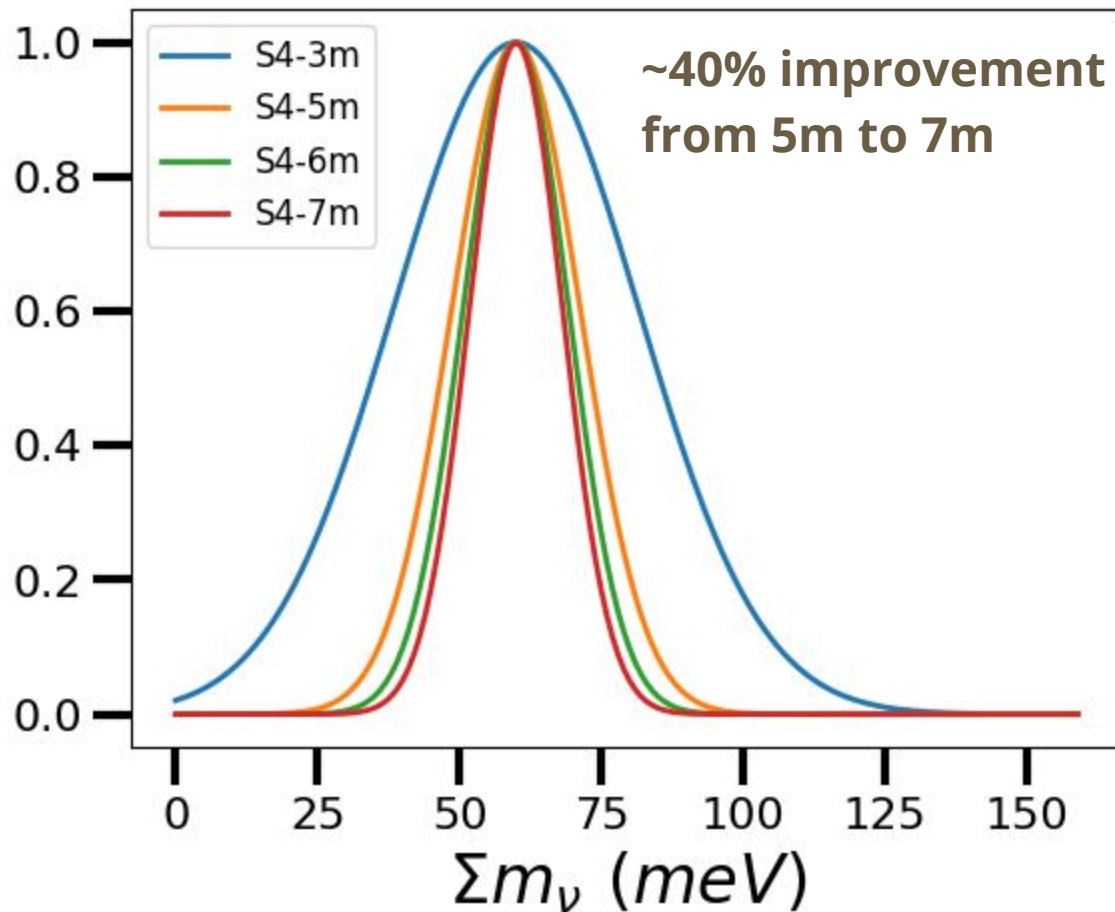
**NO  
ATMOSPHERE  
+  
CVL-TAU**



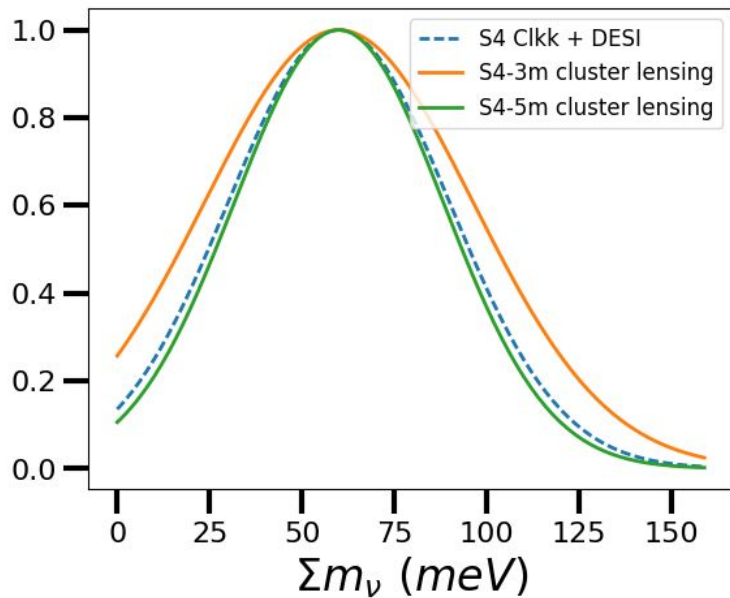


**Tau limited?  
Worked  
example  
with mnu**

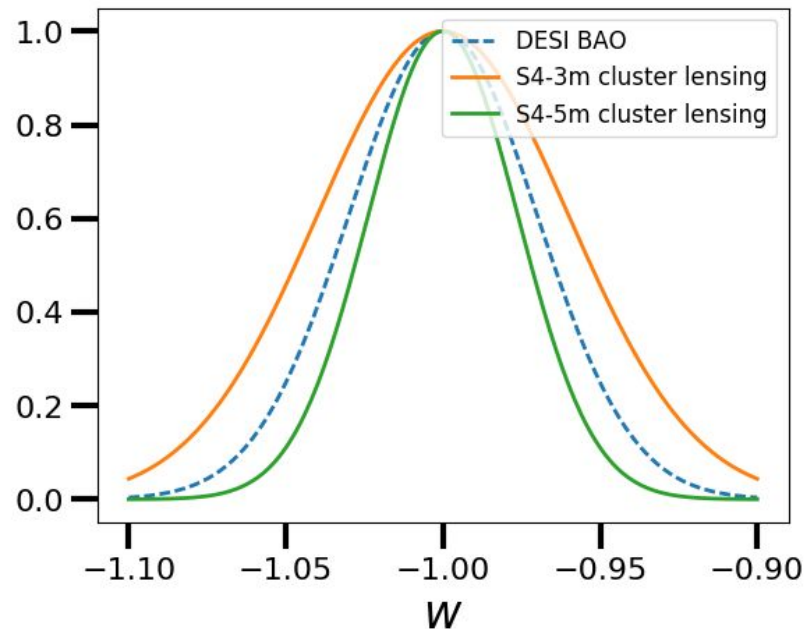
**NO  
ATMOSPHERE  
+  
FIXED TAU**



# Marginalized $m_{\nu}$ and $w$ : requirements

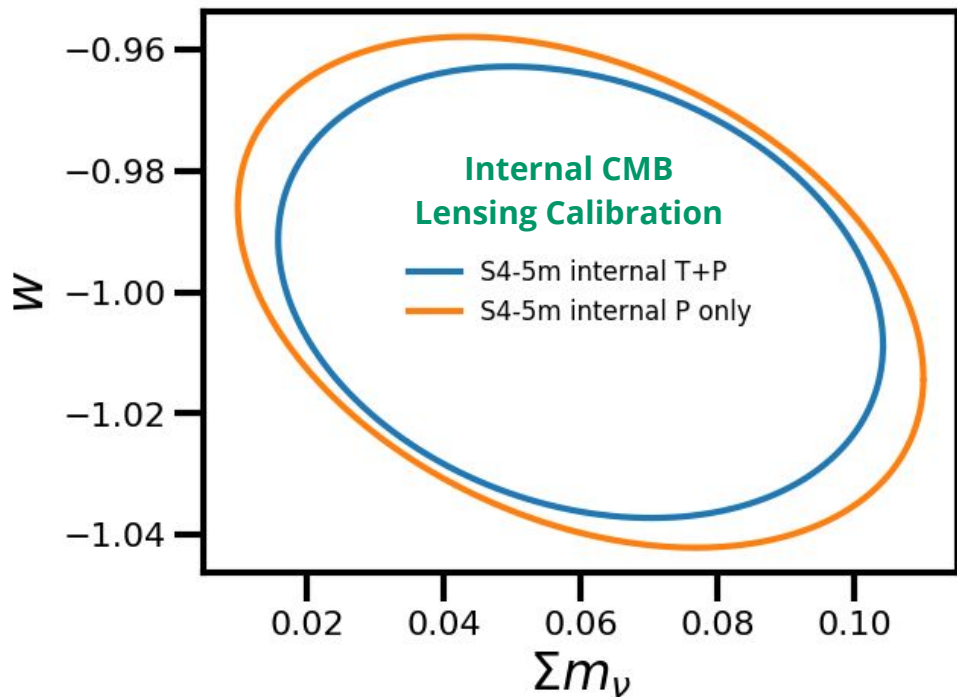


~35 meV



~2.5%

# Robustness to systematics: polarization only



“Polarization-only” has almost no contamination from tSZ and kSZ

P-only increases CMB lensing map noise by factors of 4x - 8x

But that hardly affects parameter inference (lots of self-calibration here)

## In progress

- Include sample variance
- $w_a$  constraints
- $M, Z$ -dependent scatter in scaling relation

## Summary

- Clusters + CMB lensing very competitive for  $m_{nu}$  and  $w$ ! **IF >5m dish**
- Clean measurement possible with polarization with comparable constraints
- Independent cross-check on optical calibration

# Extra: LSST-like robustness to systematics

