Cosmic inflation and Neutrino masses at POLARBEAR and Simons Array

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on behalf of POLARBEAR/
Simons Array collaboration

Outline

- POLARBEAR
  - Motivation : Inflation and ν masses
  - Instruments and observation
  - Recent results
- Status and Prospects
  - POLARBEAR2 and Simons Array

POLARBEAR Collaboration

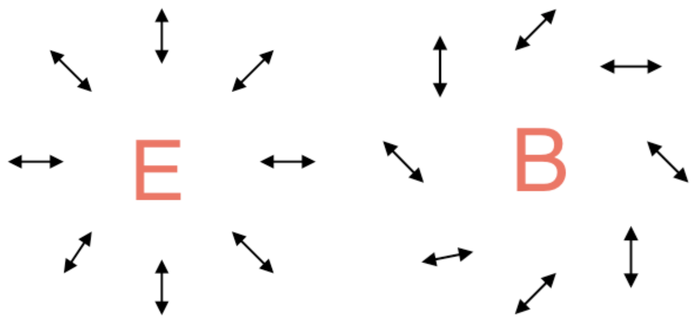
What's POLARBEAR ?

- CMB Polarization Experiment in Chile.
- Measuring the *B*-modes in CMB polarization
  - Inflationary gravitational waves
  - Gravitational lensing: Neutrino masses

Shed light on fundamental problems in cosmology and particle physics !

CMB polarization

- Polarization field can be decomposed into *E* and *B*-mode

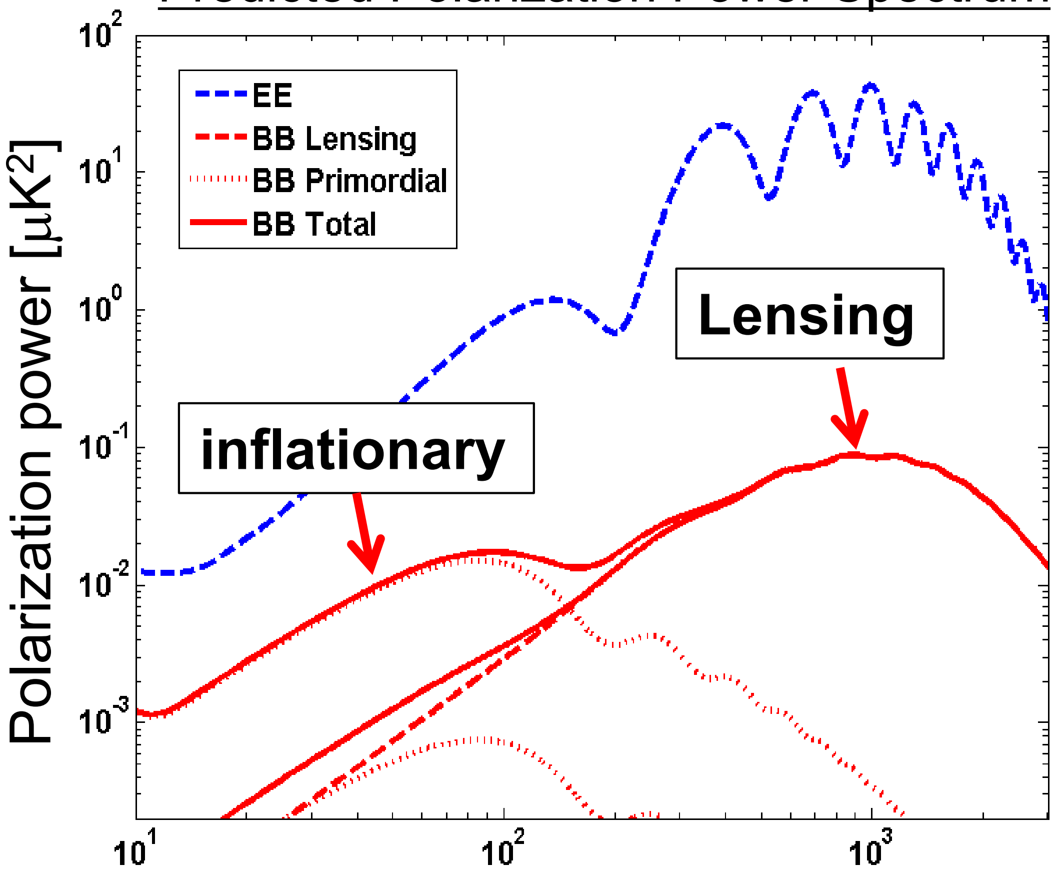


- Typical size of polarization pattern

  ~2deg. (inflation *B*-mode)

~0.2deg. (lensing *B*-mode)

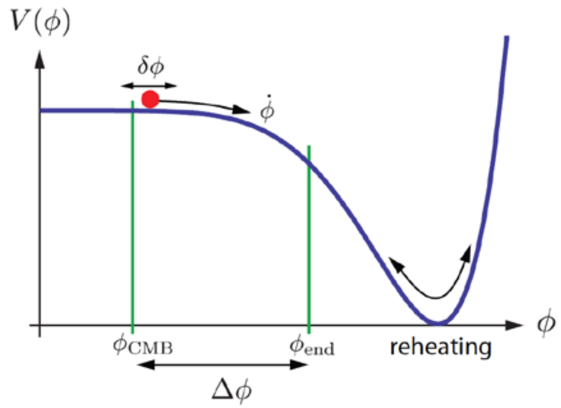
Predicted Polarization Power Spectrum

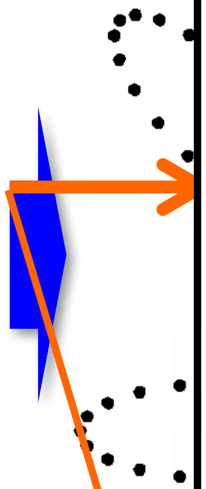


Multipole Moment ell = 180/θ (Size of polarization pattern)

Science with CMB B-mode

Inflation **Gravitational Wa** **Thomson** ***B*-mode**





10^{12} x LHC (13TeV)

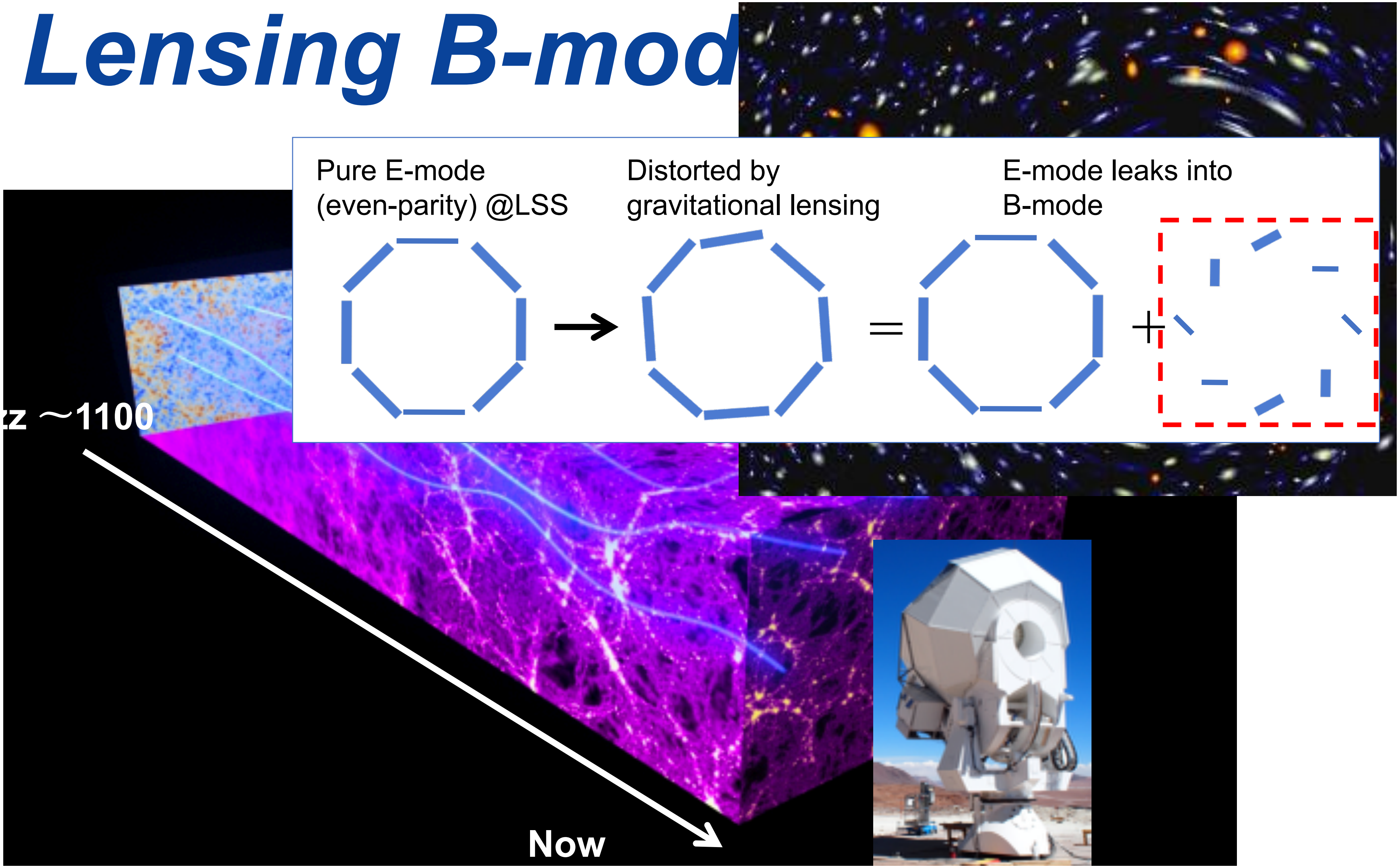
10^{5} x GZK cut-off (10^{20}eV)

→ CMB B-mode is a potential window to the truly-unexplored ultra-high energy phenomenon

B-mode power is characterized with tensor-to-scalar ratio, r

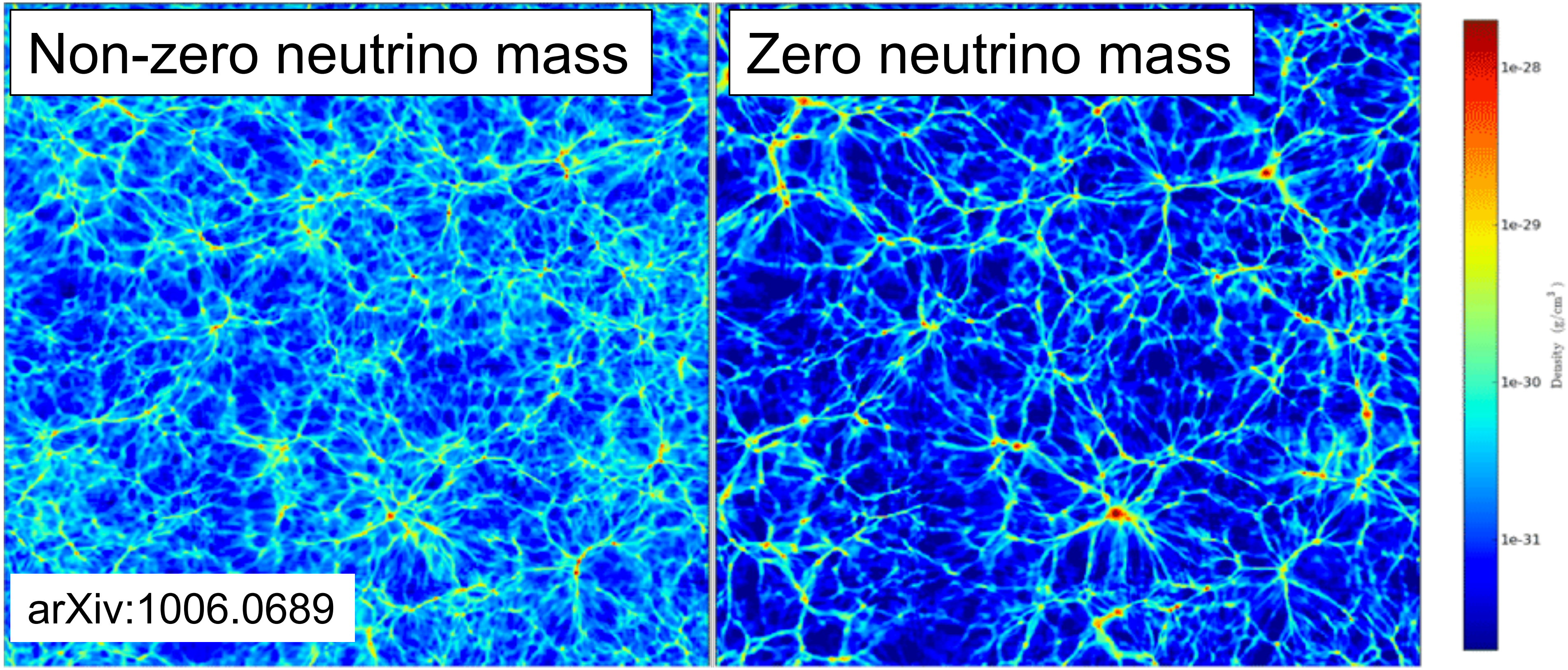
$$\boxed{V^{1/4} = 1.06 \times 10^{16} \times \left(\frac{r}{0.01}\right)^{1/4} \mathrm{GeV}}$$

Lensing B-mod



- Small angular scale *B*-mode is the signature of lensing
- Probe of physics affecting structure growth at ~1<z<3.

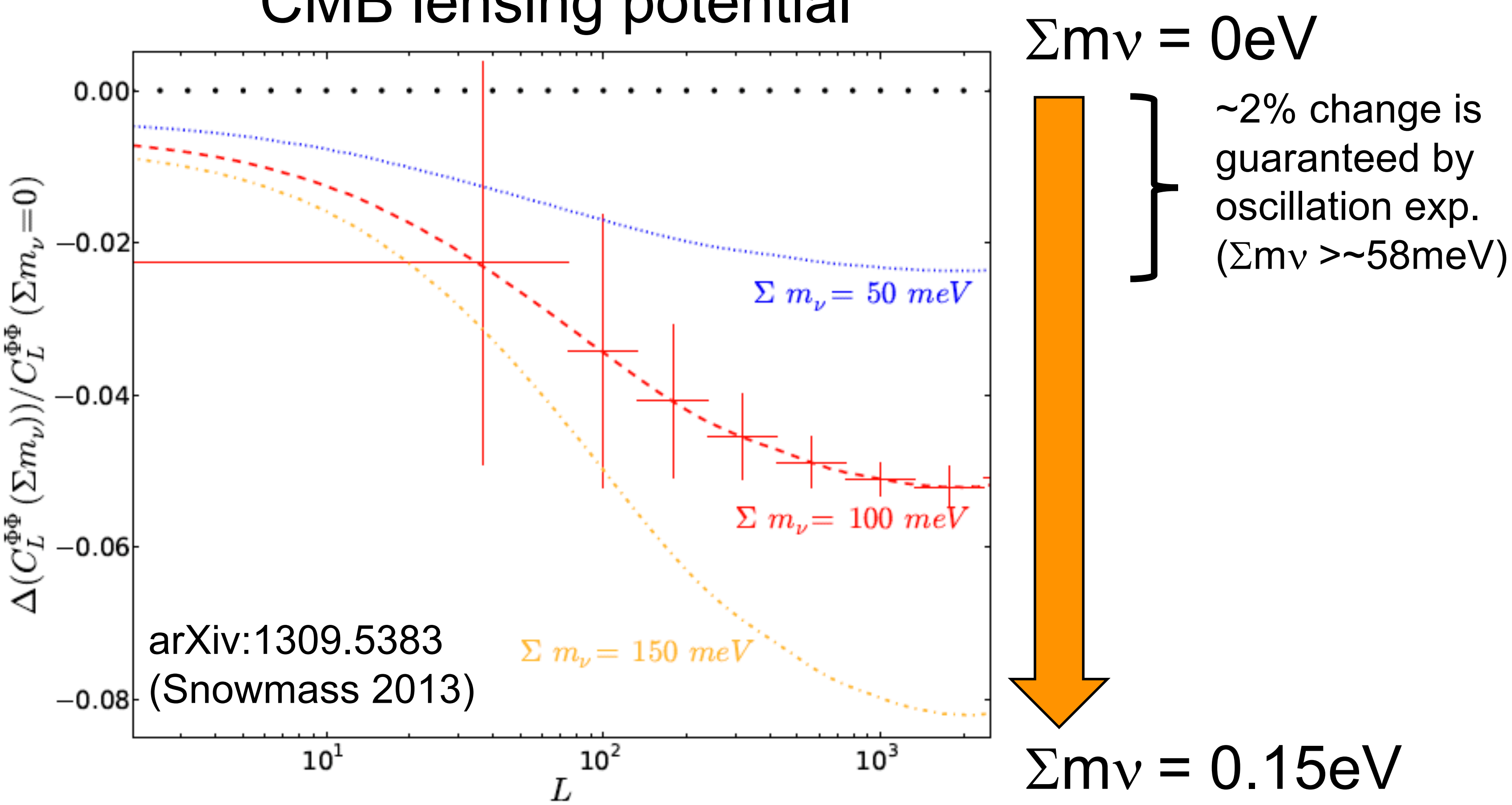
Application: Neutrino mass



- Signature of "finite neutrino mass" is suppression of structure growth.

Application: Neutrino mass

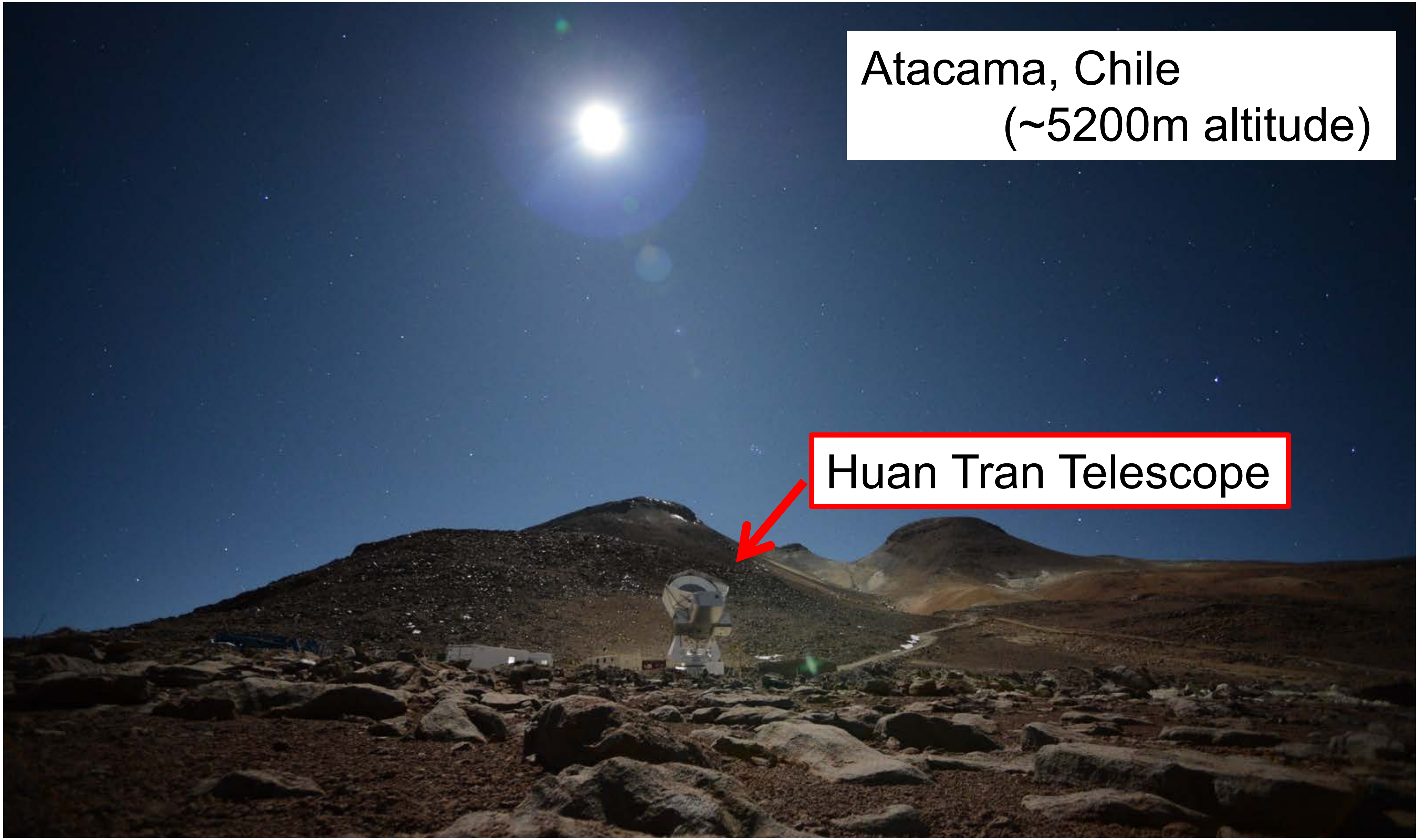
CMB lensing potential



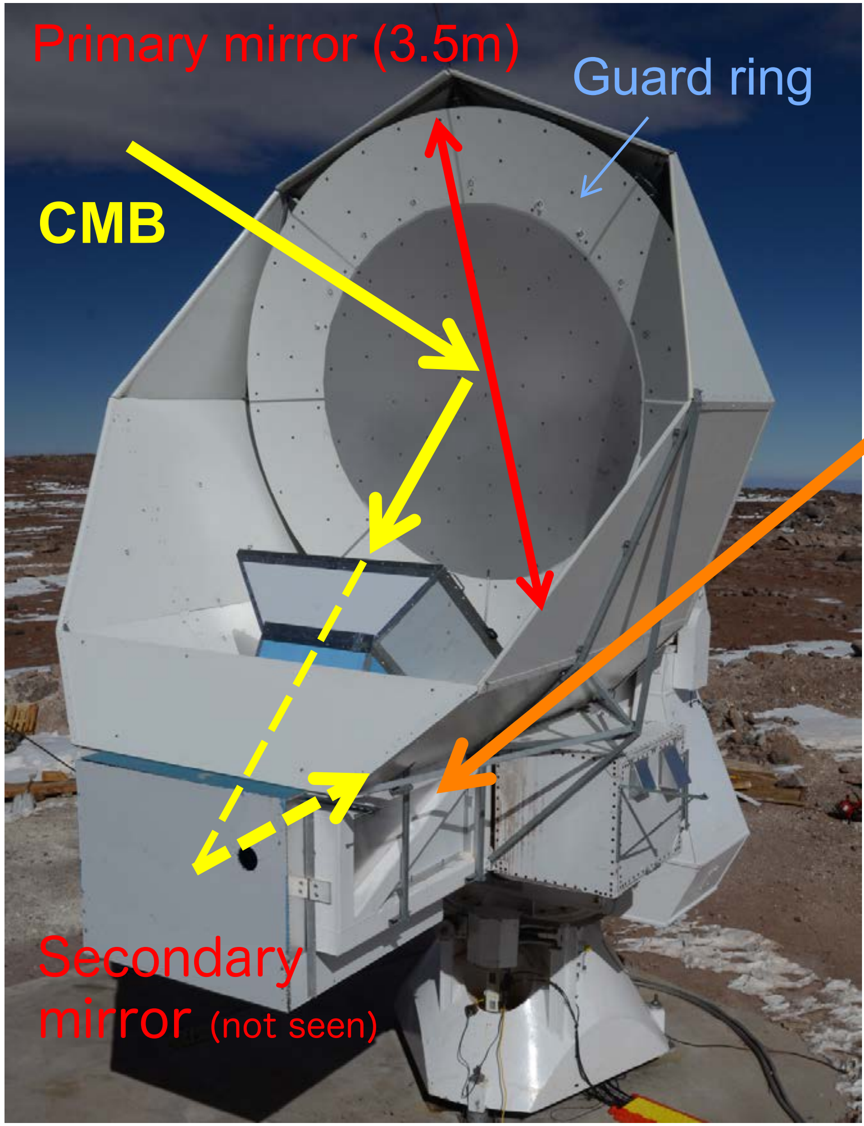
- Signature of "finite neutrino mass" is suppression of structure growth.
- Detectable in coming CMB pol. experiments.

(e.g. CMB-S4 + DESI : σ(Σmν)~15meV)

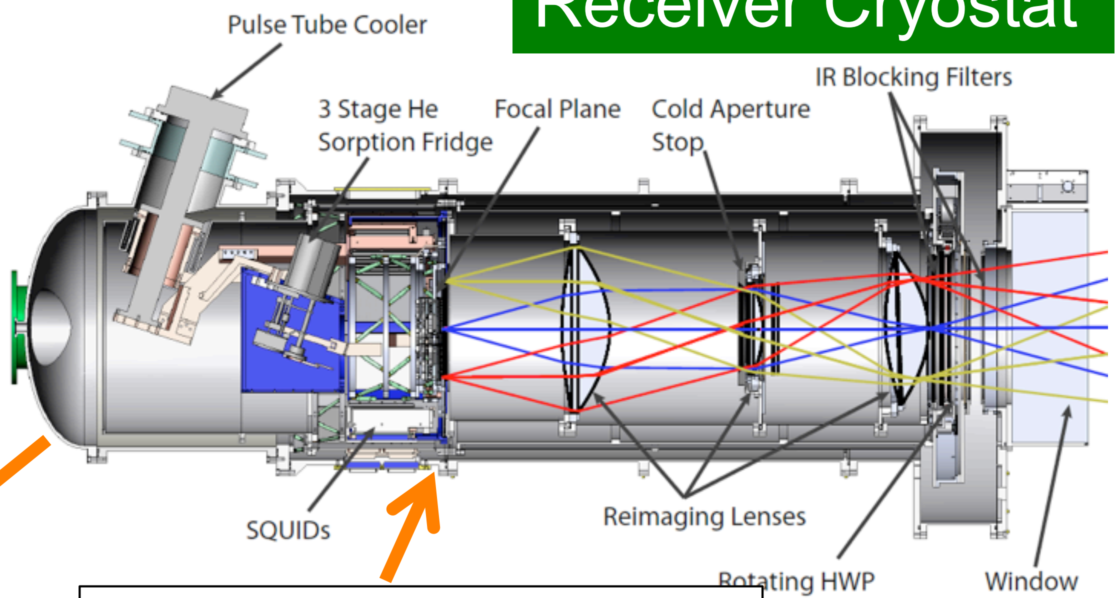
POLARBEAR Site



POLARBEAR Optics



Receiver Cryostat



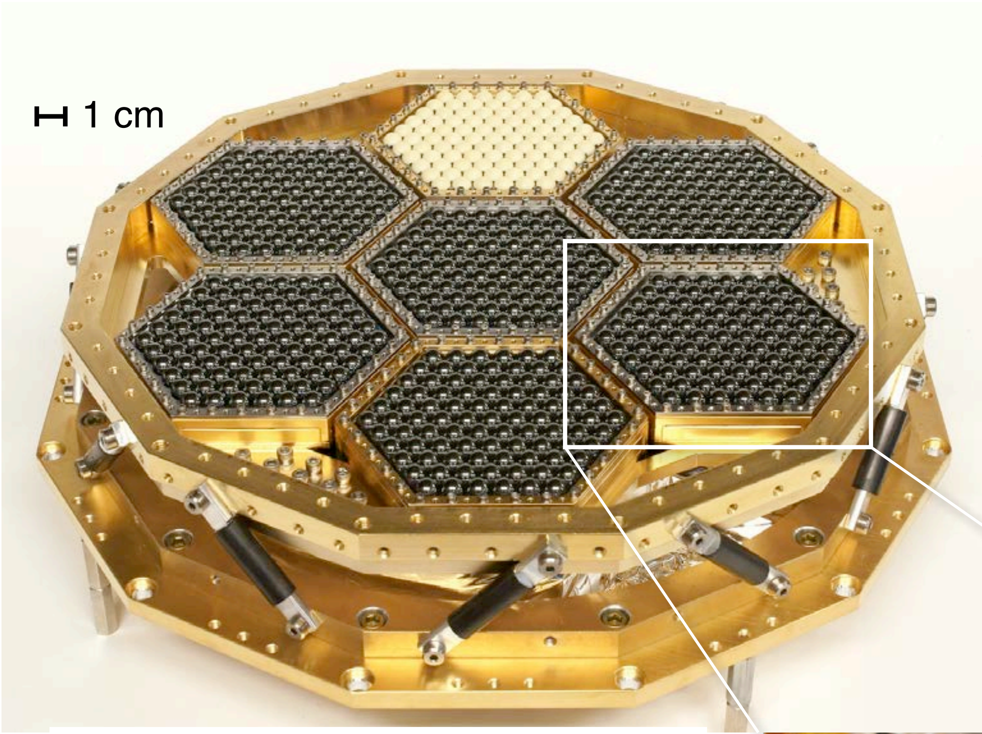
Focal plane (250mK)

- Off-axis Gregorian-Dragone
- 2.5m primary

  → FWHM = 3.5' achieved

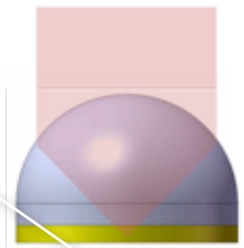
Angular resolution to measure the lensing B-modes.

POLARBEAR-1 Focal Plane

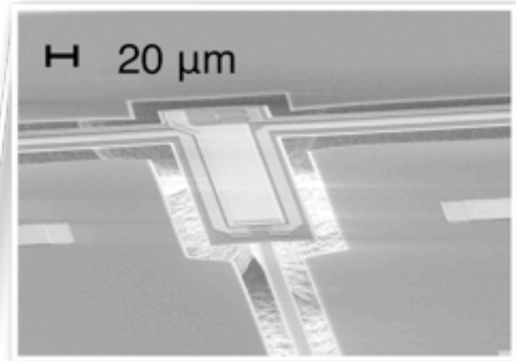


91 pixels (182bolometers) per wafer under AR-coated lenslet.

Lenslet

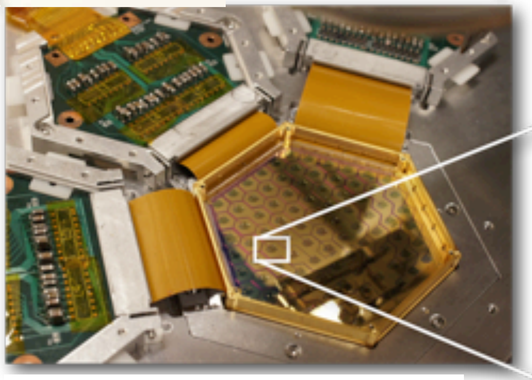


TES bolometer

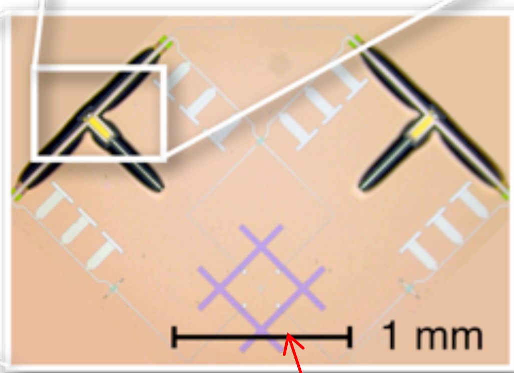


637 pixels
(91 pixels/wafer x 7wafers)
1274 TES bolometers

Array sensitivity : 23µK√s

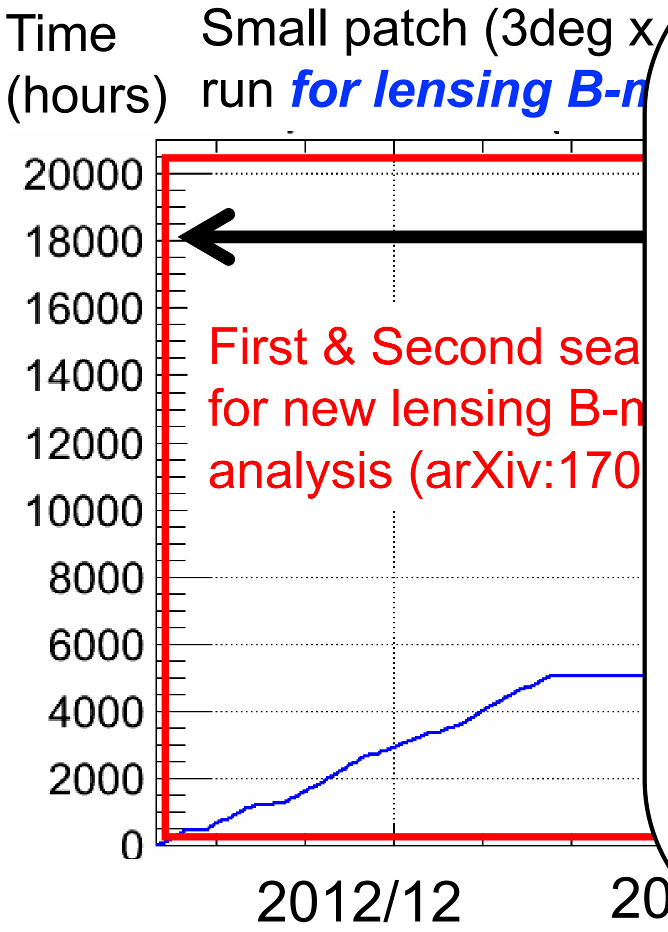


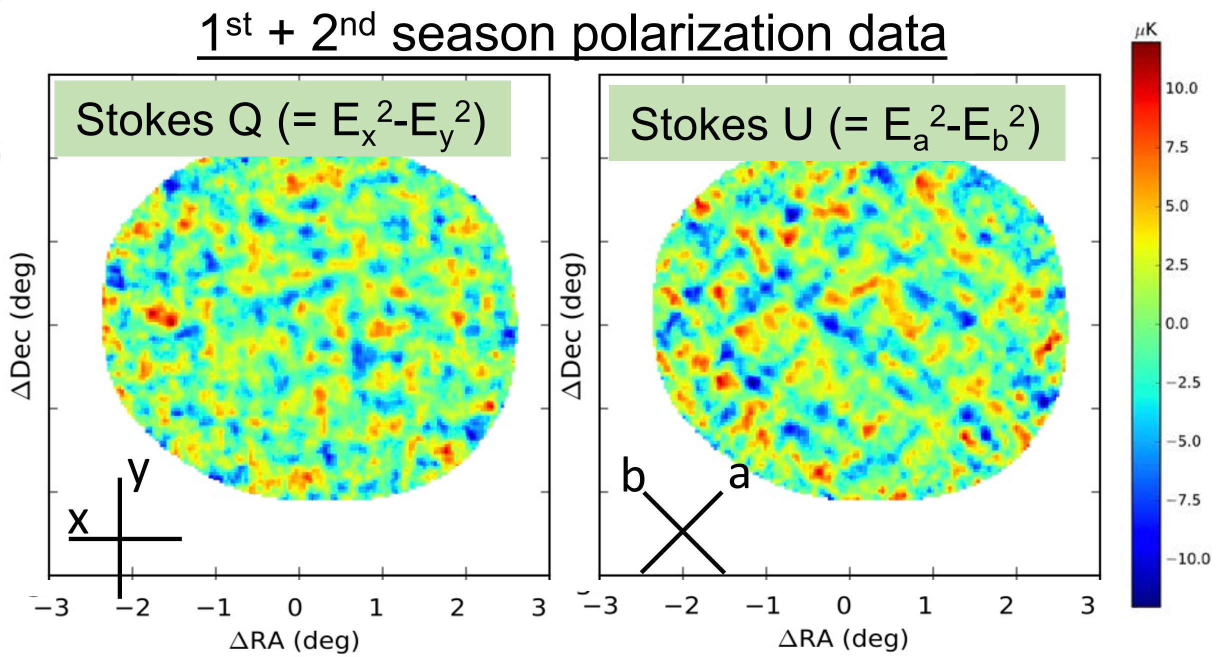
Wafer module



2 TES bolometers/pixel
with dual-polarization
double-slot dipole antenna

Observation

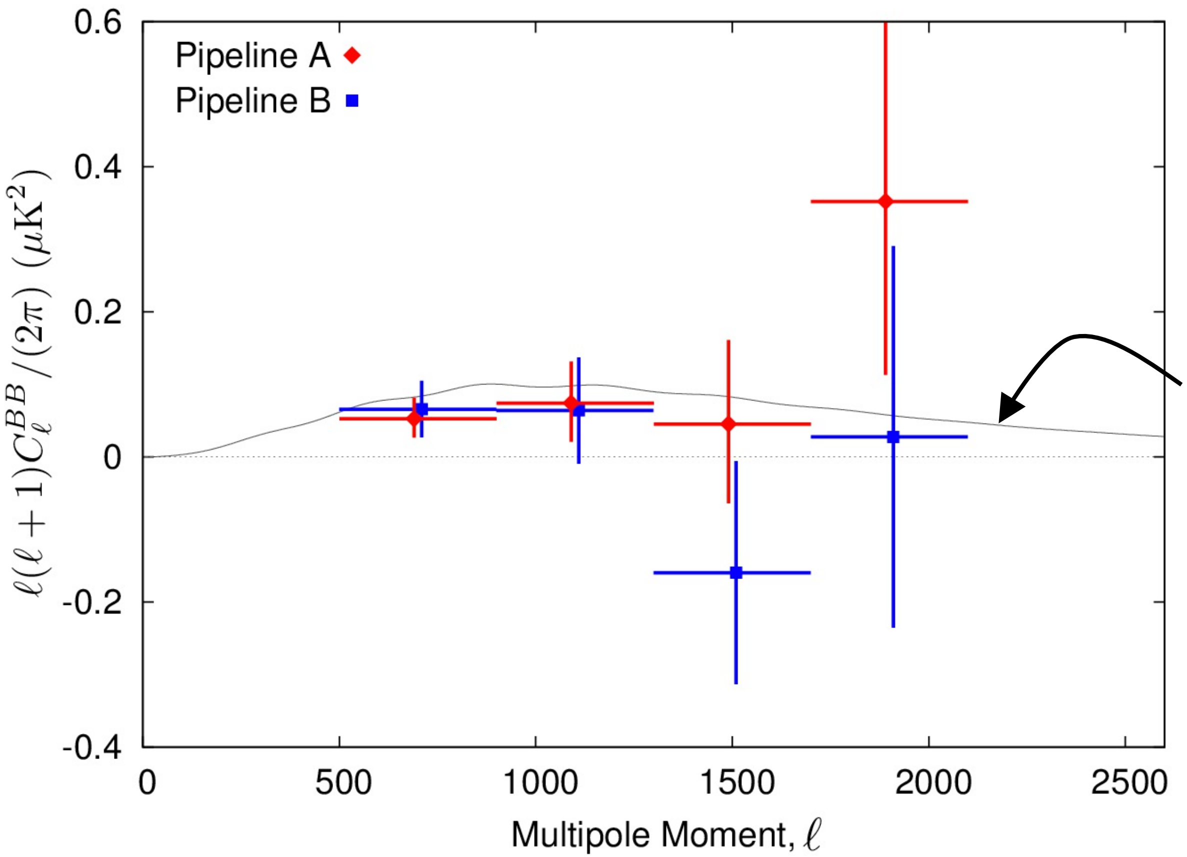




- Three fields, 24.5 deg^2 total sky area
- Map depth : ~5μK-arcmin (deepest patch)
  The cosmological polarized signal (E-mode) is visible in the map domain.

- We started observation in May. 2012, and have collected more than 10000 hours data.
- Released lensing *B*-mode results using small patch data (1st + 2nd season data)

New C_l^{BB} results (1st+2nd season data)

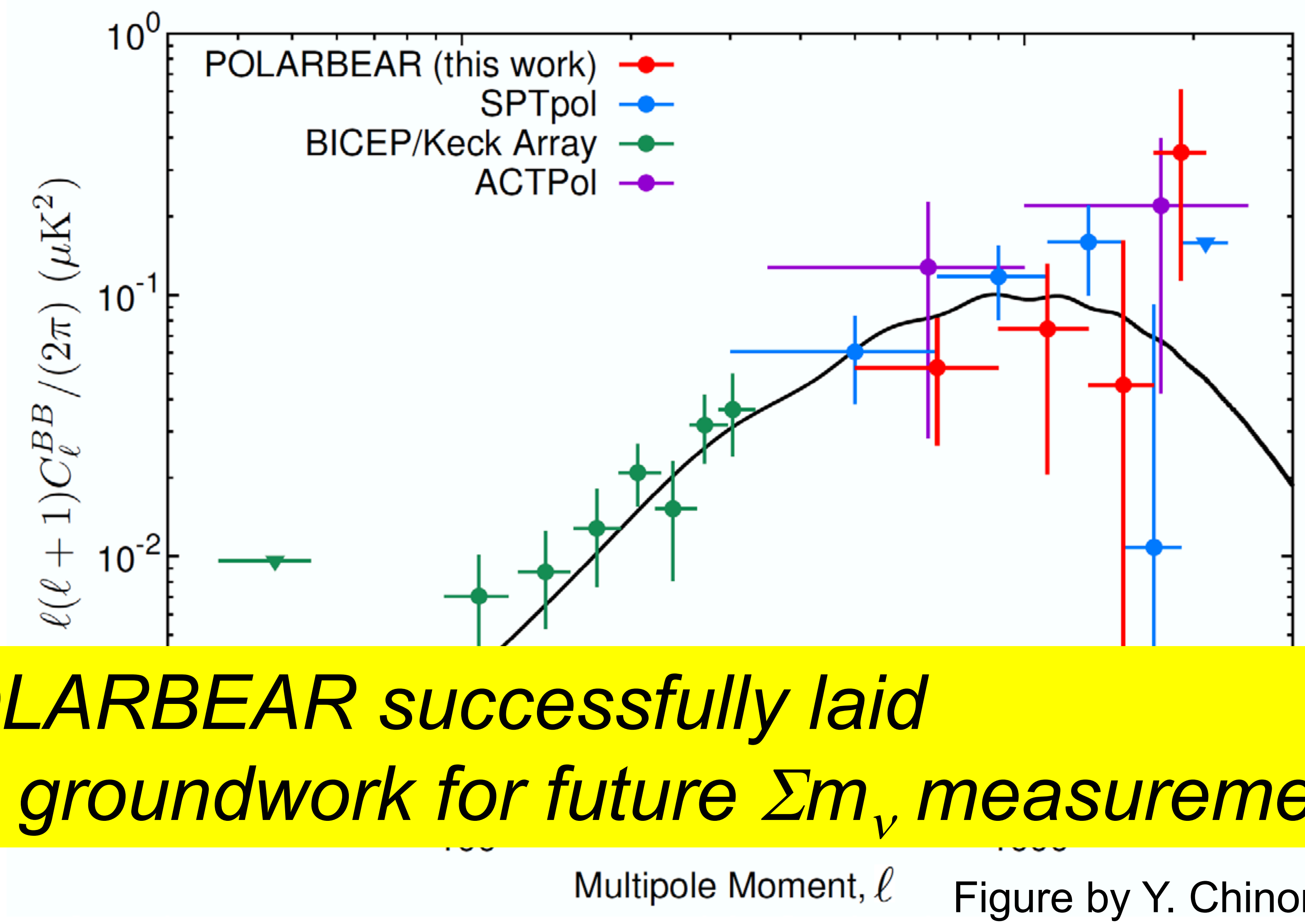


arXiv:1705.02907
(submitted to ApJ)

- Improved measurement of lensing B-mode spectrum
  - Null hypothesis of "B-mode" is rejected more than 3 sigma.
  - Lensing amplitude is consistent with ΛCDM expectation.

$$A_L = 0.60^{+0.26}_{-0.24}(\text{stat.})^{+0.00}_{-0.04}(\text{inst.}) \pm 0.14(\text{FG}) \pm 0.04(\text{multi})$$

Current status of B-mode measurement



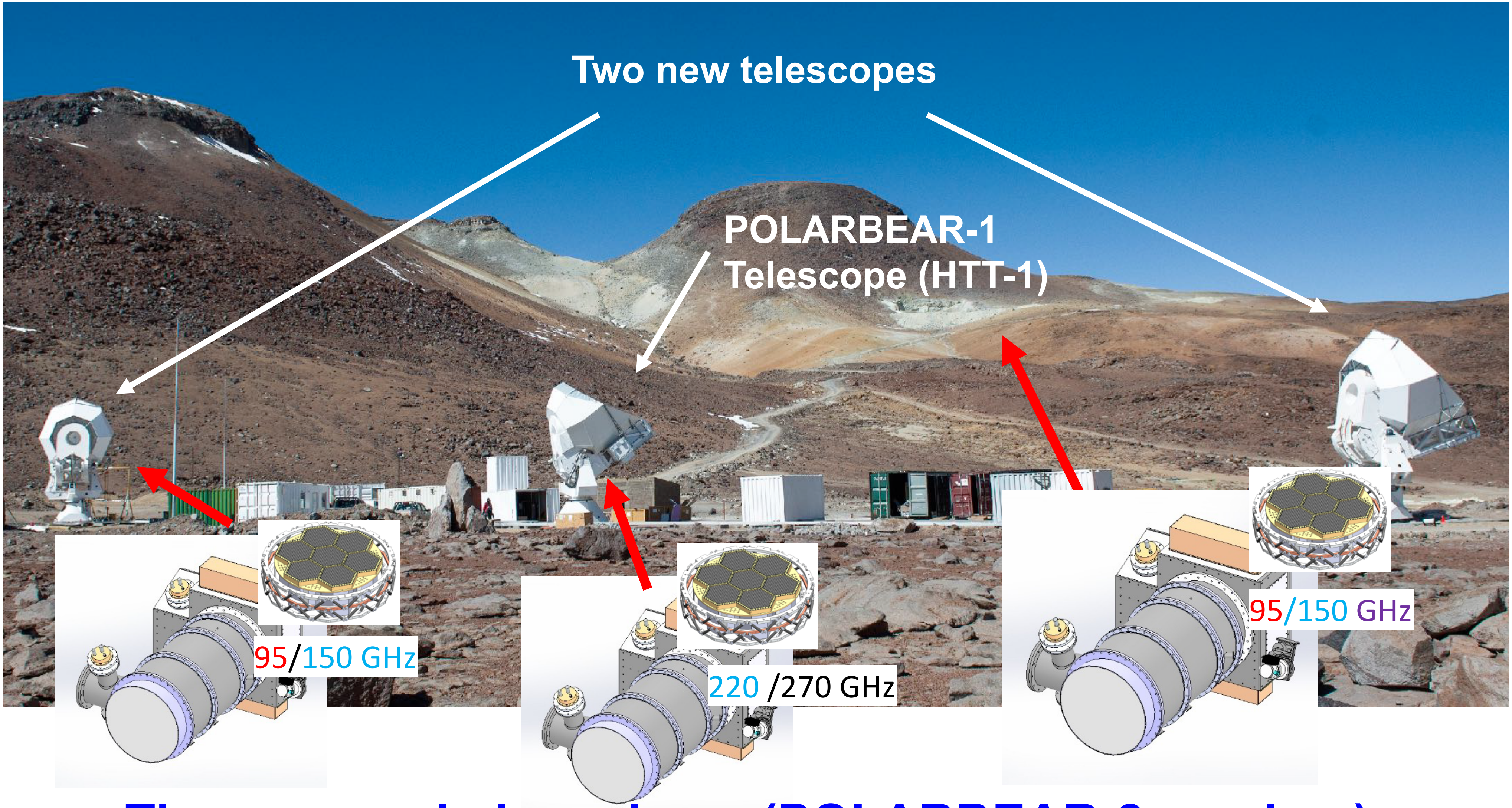
POLARBEAR successfully laid the groundwork for future Σm_ν measurement !

Figure by Y. Chinone (UCB)

Lensing B-mode is now firmly confirmed by POLARBEAR and the following experiments.

Next: The Simons Array

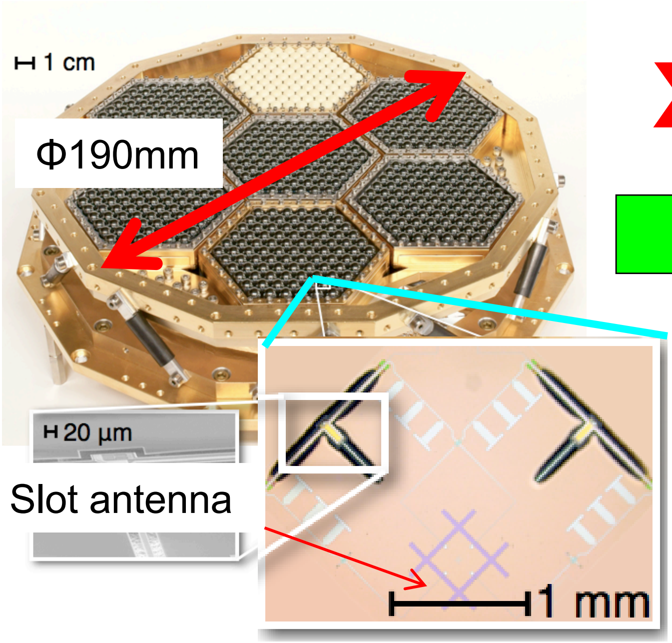
Expanding POLARBEAR to three multi-chroic telescopes



Three upgraded receivers (POLARBEAR-2 receiver), observing at 95, 150, 220, 270 GHz

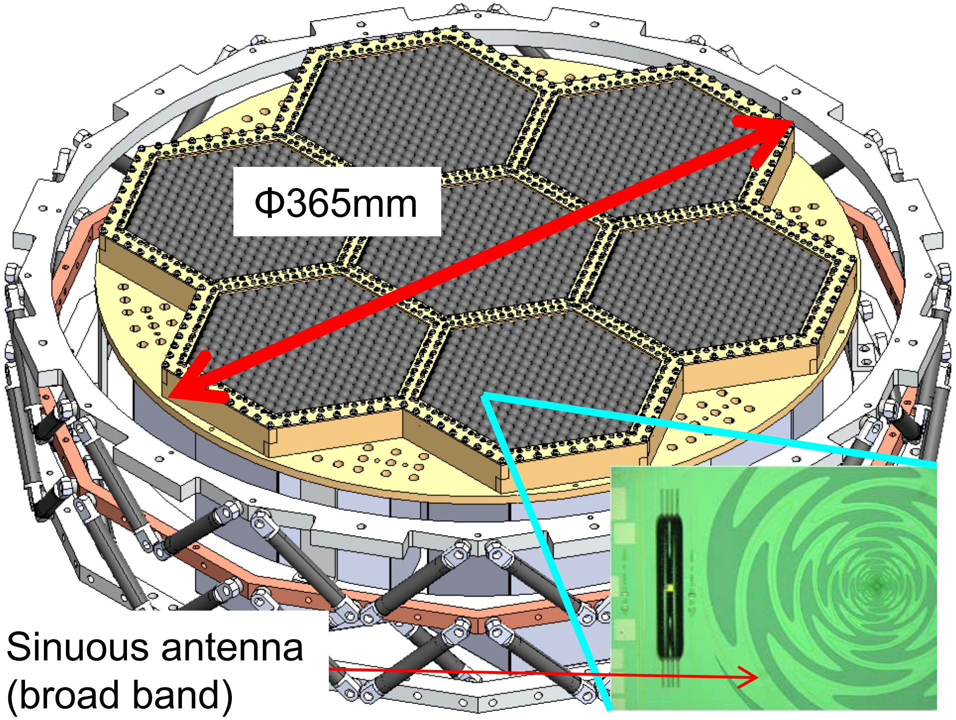
POLARBEAR to Simons Array

POLARBEAR-1
1274 detector array



x6

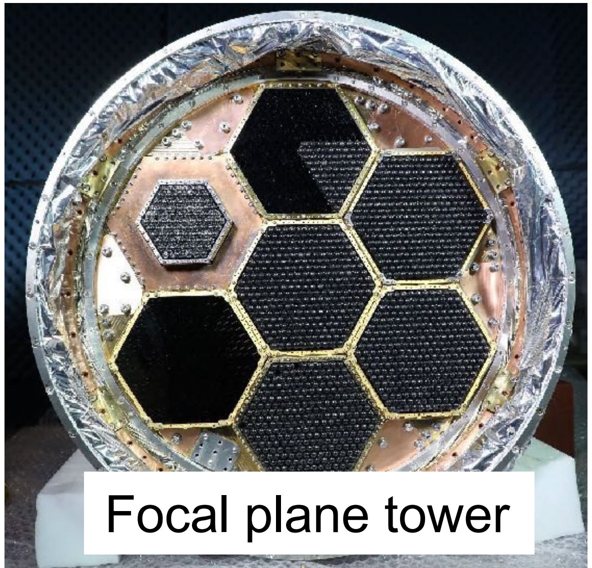
POLARBEAR-2 focal plane

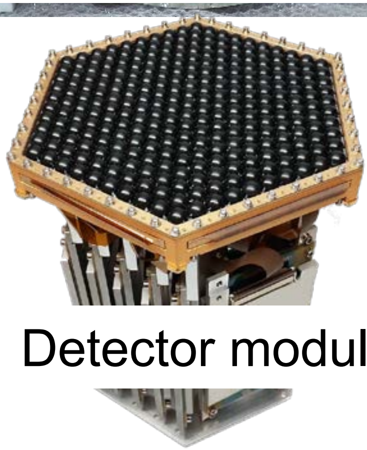


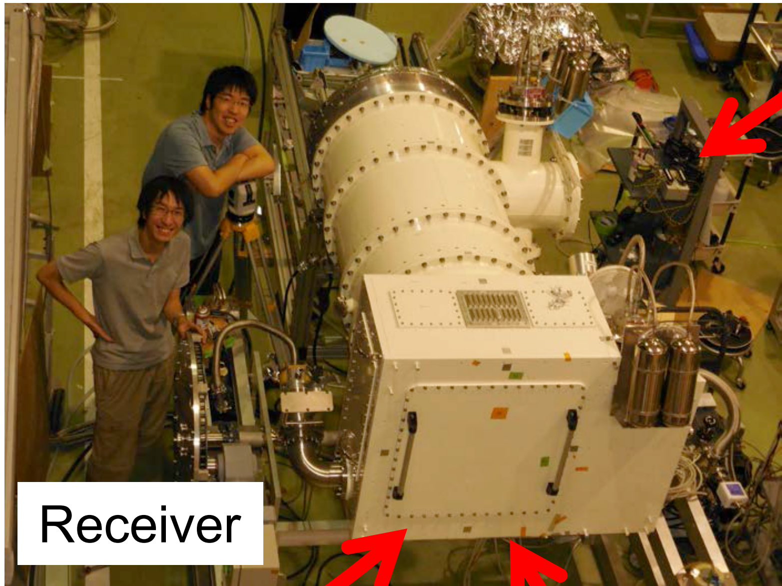
- Three larger focal plane (7588 TES / focal plane)
- Multi-chroic pixels with 95/150, 220/270GHz frequency coverage.

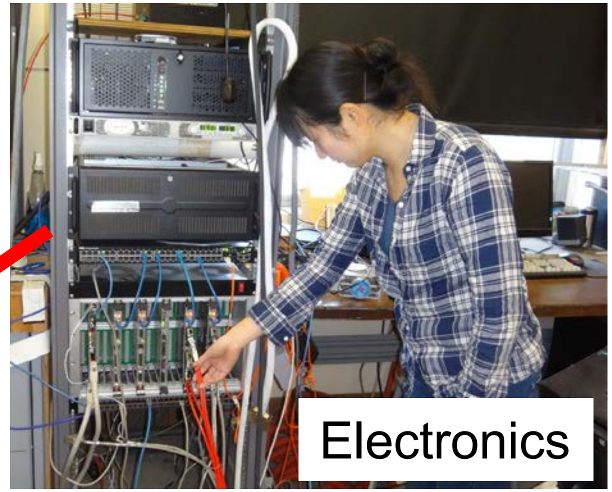
x18 leap with multi-chroic pixels

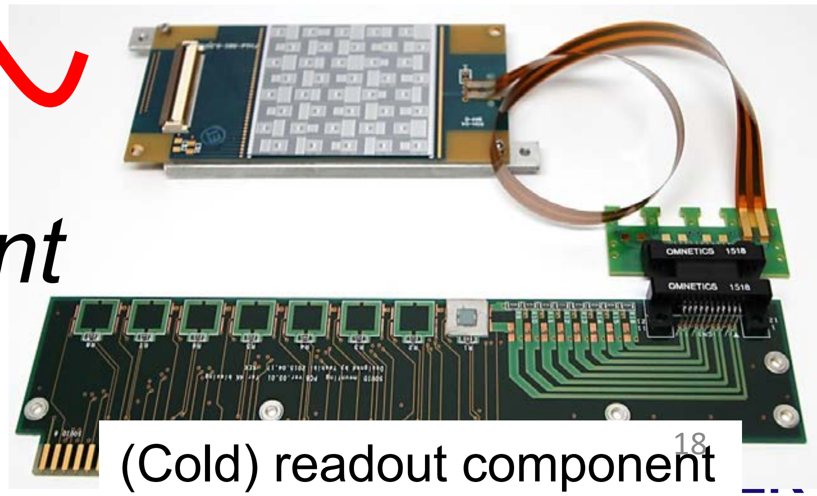
1st receiver assembly at KEK


Focal plane tower


Detector module

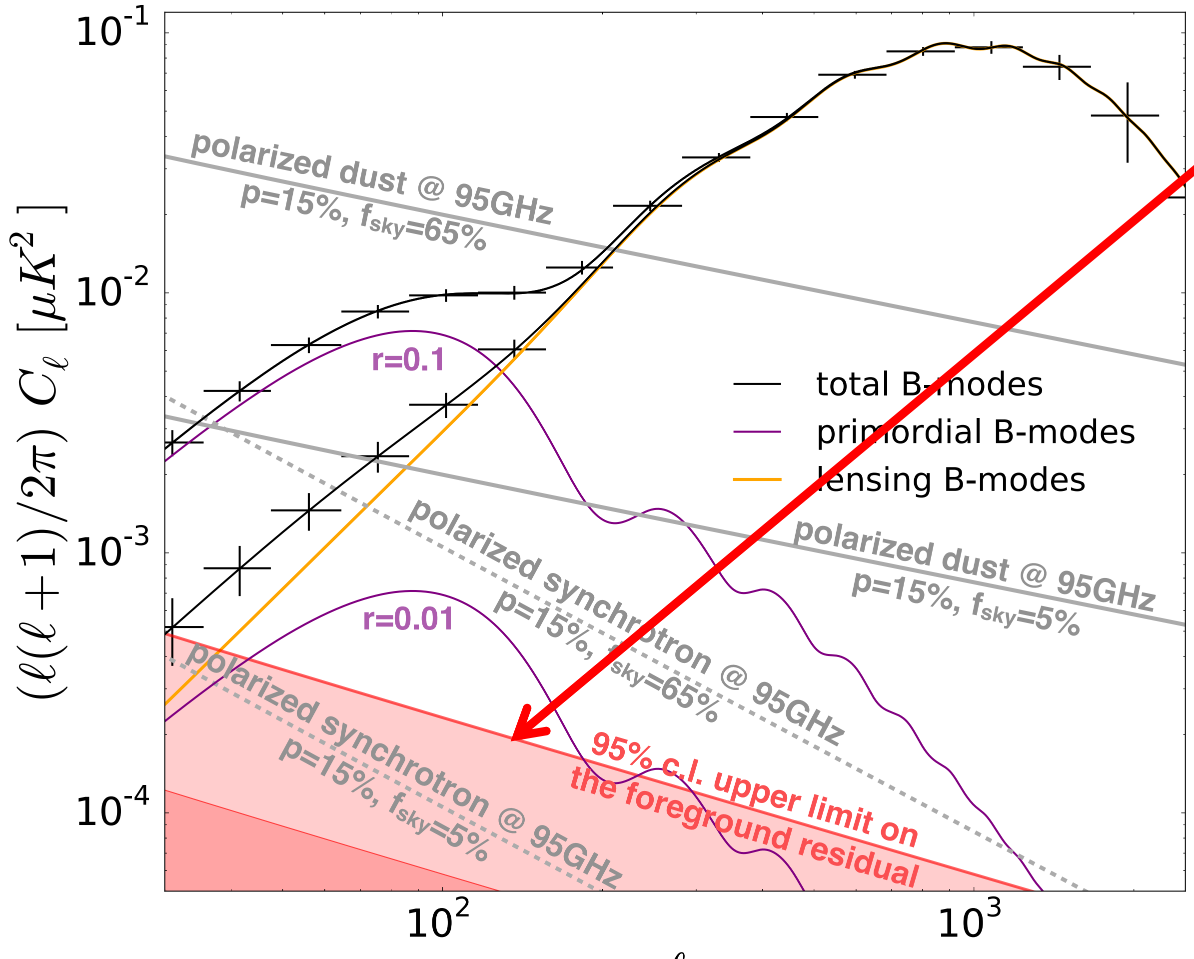

Receiver


Electronics


(Cold) readout component

Lab. testing with full equipment is on-going.

Simons Array (projected) sensitivity



Foreground rejection with 95/150/220 GHz, Planck, & C-BASS data

Inflation

- $\sigma(r=0.1) = 6\text{x}10^{-3}$ $(4\text{x}10^{-3}$ (stat))

Neutrino mass

- $\sigma(\Sigma m\nu)$ = 40 meV (19 meV (stat))

w/ DESI BAO

Simons Array can contribute to cosmology and particle physics significantly.

Summary

- POLARBEAR is a ground-based CMB polarization experiment, aiming to reveal the inflationary universe and neutrino absolute mass scale.
- POLARBEAR-1
  - Established “lensing *B*-mode” with small patch data
    - Laid the groundwork for neutrino mass measurement
  - Started large patch observation for inflationary *B*-mode
- POLARBEAR-2/Simons Array is being prepared.

Stay Tuned !

Acknowledgement

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Core-to-Core Program