

Possible DOE Contributions To CMB-S4

Julian Borrill – Berkeley Lab

Clarence Chang – Argonne

Bradford Benson – Fermilab

Chao-Lin Kuo/Sarah Kernasovskiy – SLAC

P5 Recommendations

- “Particle physics groups at the DOE laboratories have unique capabilities, *e.g.*, in sensor technology and production of large sensor arrays that are essential to future CMB experiments”
- “substantially increased particle physics funding of CMB research and projects is appropriate in the context of continued multiagency partnerships.”
- **Recommendation 18: Support CMB experiments as part of the core particle physics program. The multidisciplinary nature of the science warrants continued multiagency support.**

DOE Context

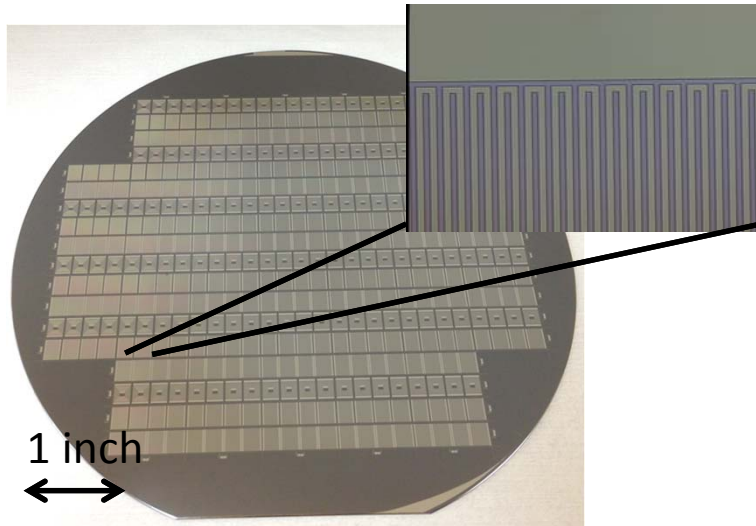
- Mixed history supporting CMB science
 - Cautious about committing to a field
- Existing commitments to DES, DESI, LSST
 - Funding not likely before FY18
- Project funding
 - Clear division between project and general work
- Inter-agency collaborations
 - Strong preference for distinct, well-defined roles
- Lehman Review process
 - Series of 4 Critical Decision reviews
 - CD-0 establishes science need

Berkeley

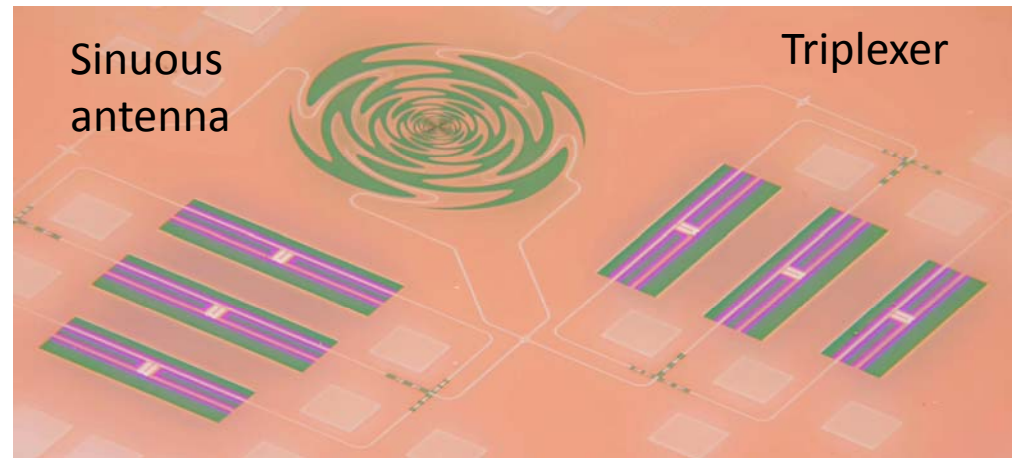
Hardware Design, Fabrication & Assembly

Personnel at LBNL: Chris Bebek, Steve Holland, Maurice Garcia-Sciveres, Akito Kusaka, Adrian Lee (joint with UCB), Nick Palaio, Aritoki Suzuki, and Rhonda Witharm

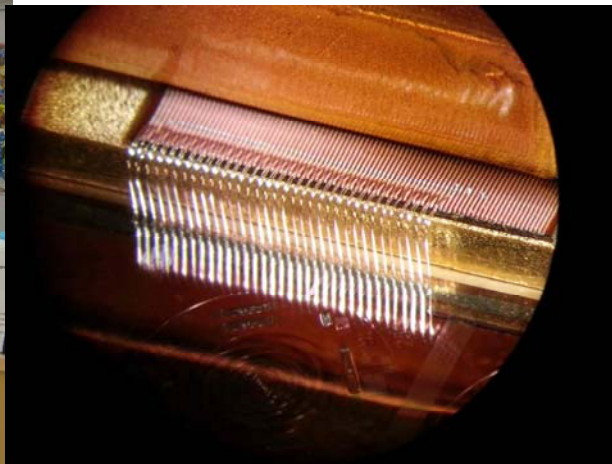
Superconducting Readout Component Fabrication



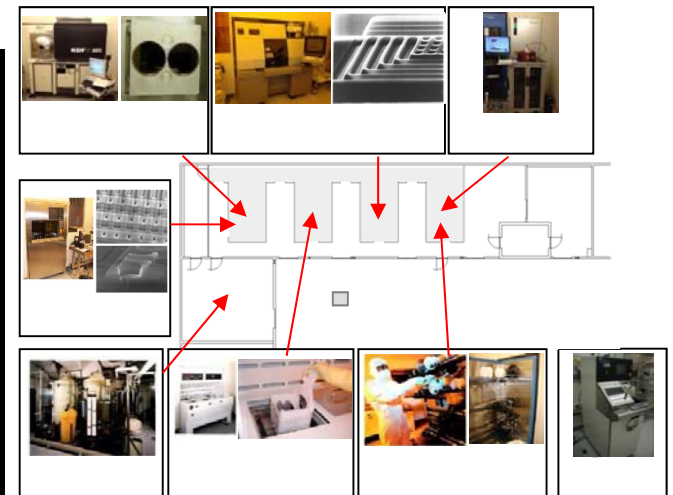
Detector Design and Development



Array assembly and robotic 3D bonding



MSL: Class 10 cleanroom



Theory & Data

- Physics Division (McDonald, Seljak, White; Schlegel etc)
 - CMB theory & cross-correlation with other datasets
 - DESI
- Computational Cosmology Center (Borrill, Keskitalo, Kisner)
 - Joint initiative between Physics & Computational Research Divisions
 - Develops massively parallel algorithms & implementations for most computationally intractable cosmology problems
 - eg. Planck simulations

High Performance Computing

- NERSC
 - DOE's flagship general purpose HPC center
 - Fields a new top-10 supercomputer every ~2 years
 - Keeps 2 systems on the floor at any time
- ESNNet
 - Provides reliable high-bandwidth networks linking national laboratories & universities
 - Feb 10th-11th : Cross-Connects Workshop on Managing Cosmology Data

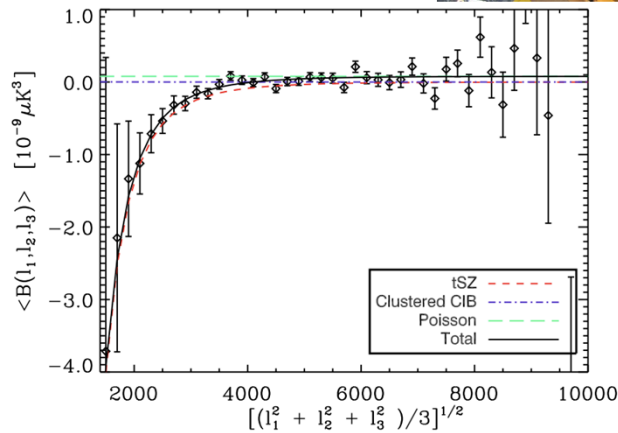
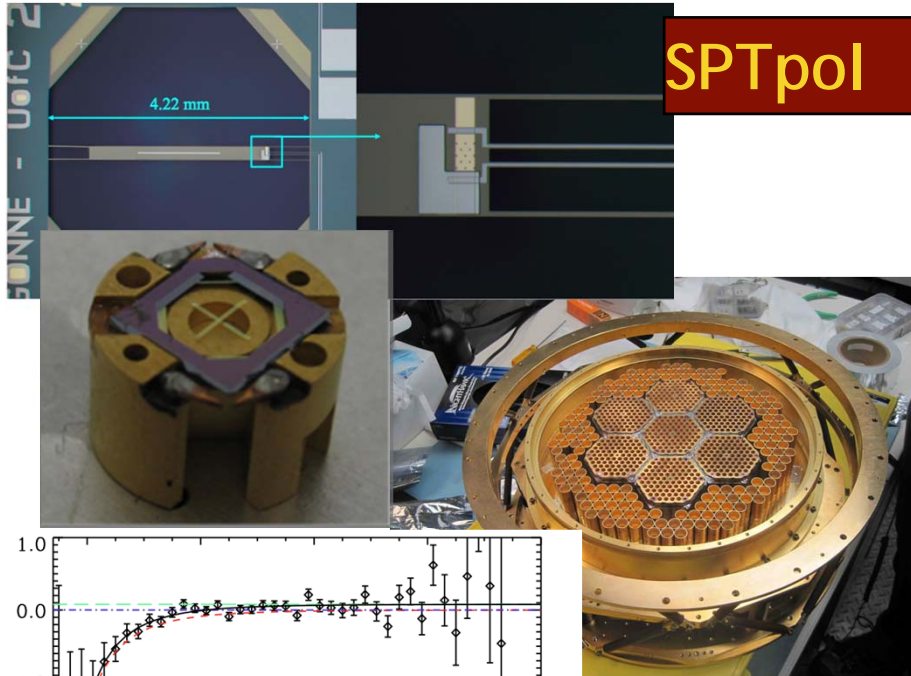
HPC for CMB

- Community CMB allocation at NERSC
 - Almost 20 years (BOOMERanG-98/Maxima1)
 - $O(10)$ experiments, $O(100)$ CMB analysts continuously
- Planck at NERSC: “Mission class supercomputing”
 - Unique NASA/DOE MOU guarantees Planck access
 - $\sim 1\%$ of NERSC cycles every year for 15 years
 - Exceptional level of service agreements
 - 1 cabinet of *Carver* (640 cores)
 - 240TB of global project disk
 - $O(200)$ Planck scientists
 - Data distribution within & outside Planck

Argonne

CMB@Argonne

- ▶ CMB is a priority at ANL. **Lab is committed to CMB science.**
- ▶ Ongoing activities provides foundation for future participation



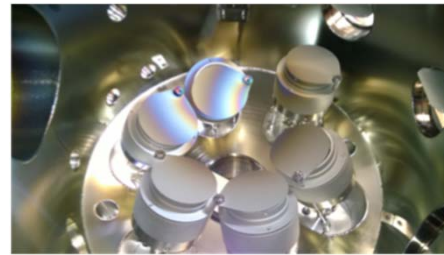
**CMB+LSS
(clusters)**

Cosmology with the CMB and its Polarization, MN, Jan 2015



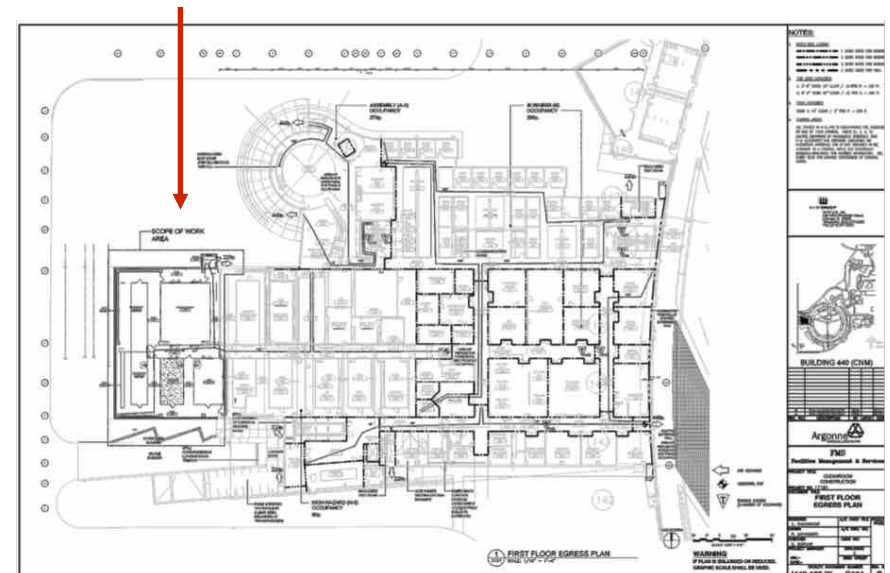
Detectors@Argonne

- Received new tools for detector fabrication & testing
 - stepper, etcher, sputtering (x2), cryostat



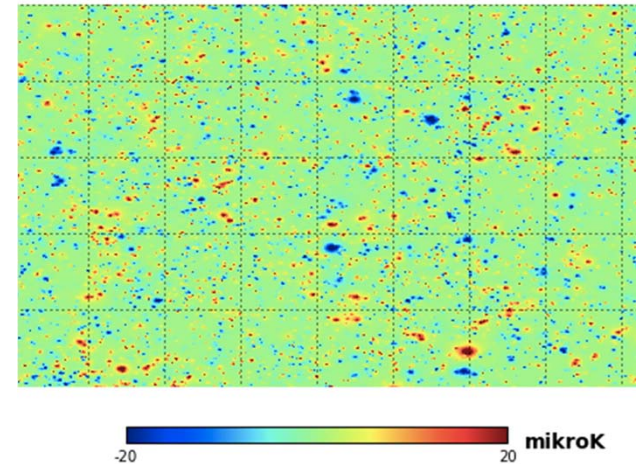
- 5000 sq ft expansion of Argonne cleanroom (complete ~2016)
 - space & tools are dedicated for detector projects

- ANL-UChicago detector center
 - collaboration between ANL and UChicago on detector development
 - leverages new 11,000 sq ft cleanroom on UChicago campus (complete ~2015)



Computing@Argonne

- ▶ Computational Cosmology program (Habib & Heitmann) provides connection between CMB, LSS, & computing
- ▶ Natural science program with CMB analysis, LSS+CMB simulation, and CMB-LSS cross-correlation
- ▶ Computing resources
 - “computing intensive” - Mira (10 PFlops) with a new 200 PFlop system on the floor in 2018/19
 - “data intensive” - Magellan (1 PB dedicated storage)
- ▶ Relevant cross-lab computing focused programs
 - EXDAC -- Extreme Data Analysis for Cosmology
 - Joint computing award w/ LBNL

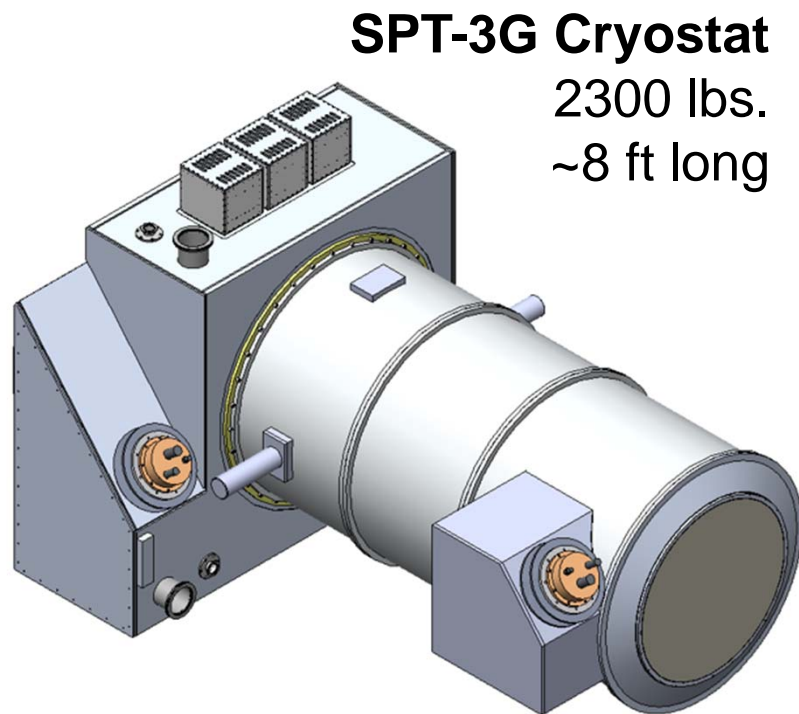


Fermilab



SPT-3G Cryostat Design and Assembly

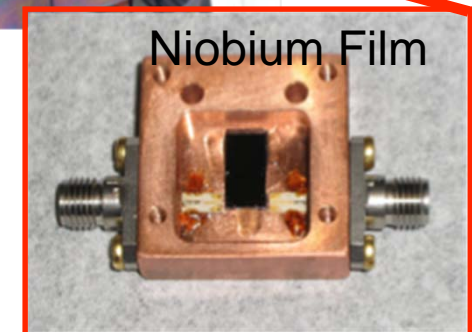
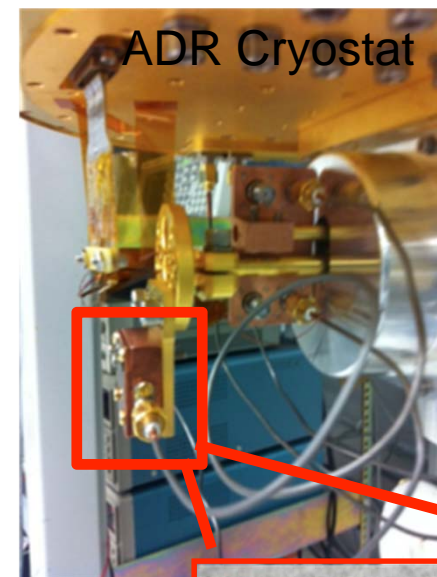
- Fermilab is leading the design, assembly, and integration of the SPT-3G receiver cryostat
- **Personnel:** Brad Benson (Scientist), Hogan Nguyen (Scientist), Sasha Rahlin (Postdoc), Donna Kubik (Technician)





Detector Module Assembly and Testing

- Detector module assembly and packaging for SPT-3G (including wire-bonding, wafer alignment,
- Adiabatic de-magnetization and He4/He3/He3 cryostats to characterize superconducting films and 6" detector wafers.

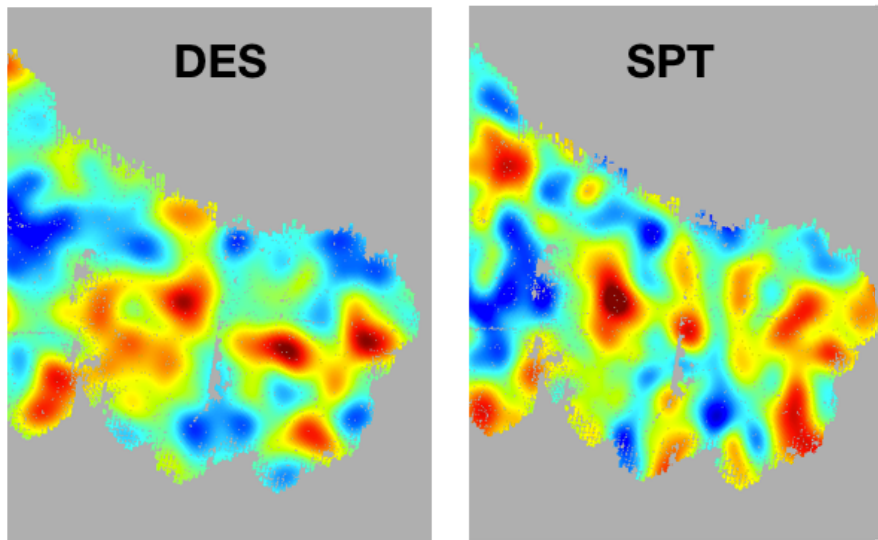




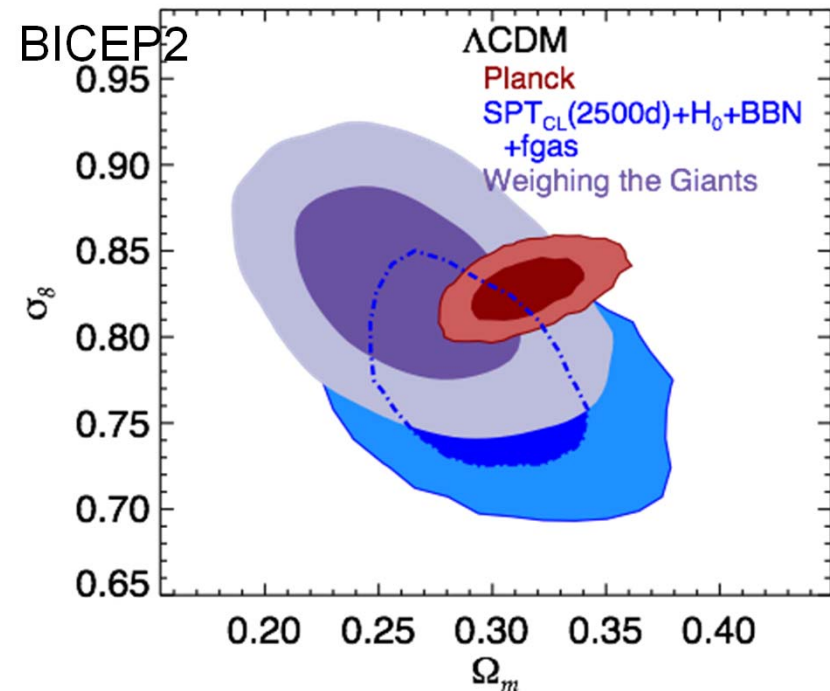
Cosmology from Large-Scale Structure (LSS)

- Cosmology from LSS probes using Dark Energy Survey and the South Pole Telescope: CMB lensing cross-correlations, cluster cosmology
- **Personnel:** Dodelson (Scientist), Benson (Scientist), Soares-Santos (Scientist)

DES galaxy - SPT Lensing potential Cross-Correlation



SPT Cluster Cosmology



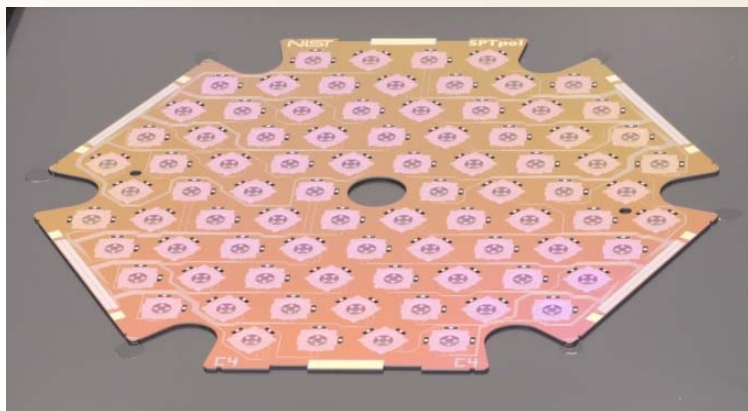
SLAC

CMB-s4: a SLAC perspective

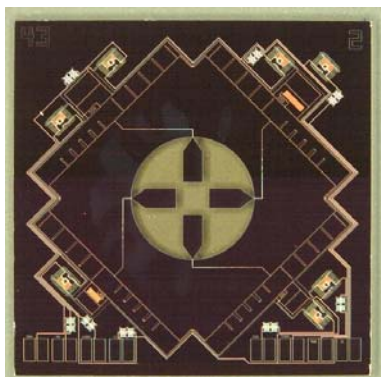
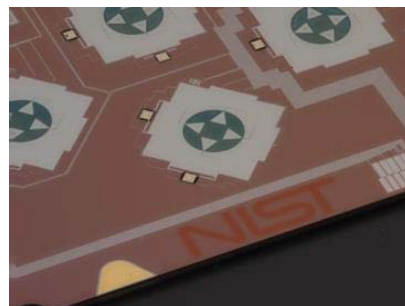
- **SLAC management strongly supports the vision of CMB-s4**
 - » Hiring of Kent Irwin, Sherry Cho, and Dale Li
 - » Strategic LDRD funding to BICEP3 and SPT-3G
- **SLAC CMB activities in the three areas**
 - » **Detectors and SQUIDs**
 - CMB polarimeter arrays
 - *Past*: Arrays for SPTpol and ACTpol
 - *Current*: fabrication at Stanford & (collaborators) at NIST
 - *Future*: Dedicated fab facilities (These capabilities will also support X-ray detectors for LCLS-2 and SSRL)
 - SQUID multiplexers
 - Continuing development of TDM in collaboration with NIST
 - Microwave SQUIDs R&D at Stanford/SLAC, fabrication at NIST
 - » **Cold optics**
 - Delivered BICEP3 lenses & IR filters
 - Working on three SPT-3G lenses and filters
 - » **CMB Science**
 - BICEP/Keck analysis/observation, leading BICEP3 development/deployment
 - Cluster cosmology SZ/X-Ray/weak lensing (SPT/DES)

Future Plans: TES Polarimeters and SQUIDs

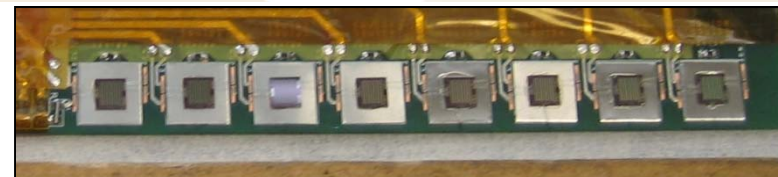
SLAC



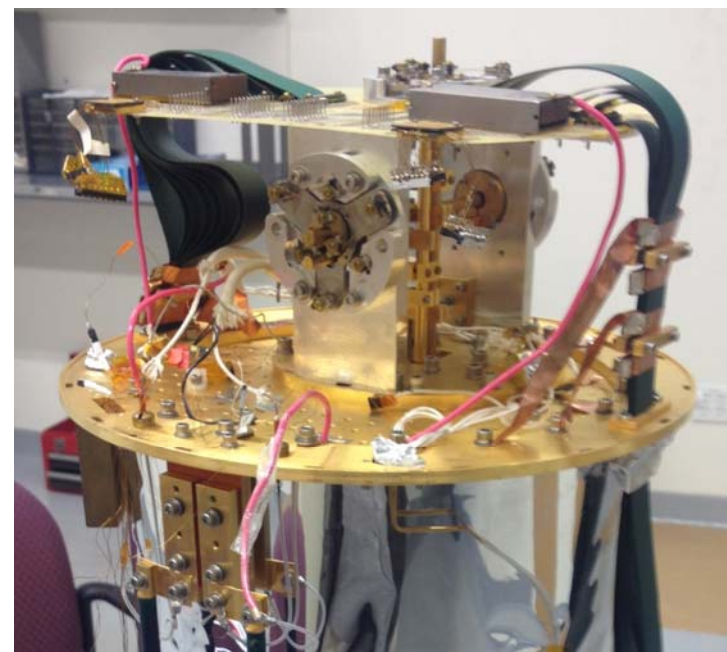
150-GHz feedhorn-coupled TES polarimeters deployed at the South Pole and in the Atacama



Multichroic feedhorn coupled polarimeter



SQUIDs for SPTpol and **SPT-3G**



Janis ADR (<50 mK) + VNA, GHz eq. for microwave SQUID testing

optics

SLAC

60cm BICEP3 alumina lens

SLAC metrology
AR coating
Laser dicing

(baseline for SPT-3G: 72cm)



Laser machined IR filters

24" diameter
15 μ m features

Mm/IR
properties verified

