

The Ali CMB Polarization Telescope

Maria Salatino
Stanford University/KIPAC
on behalf of the AliCPT-1
Collaboration

Towards Coordination of
the European CMB Programme
Paris - September 13, 2019

Outline

- The collaboration
- The science
- The observable sky
- The instrument design



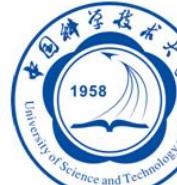
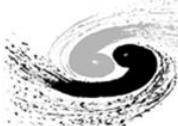
The AliCPT-1 Collaboration

PI Xinmin Zhang
US PI Chao-Lin Kuo



Collaboration Meeting
Beijing, April 12-16 2019

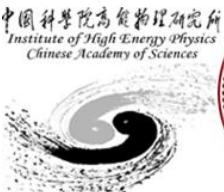
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



The AliCPT-1 Collaboration

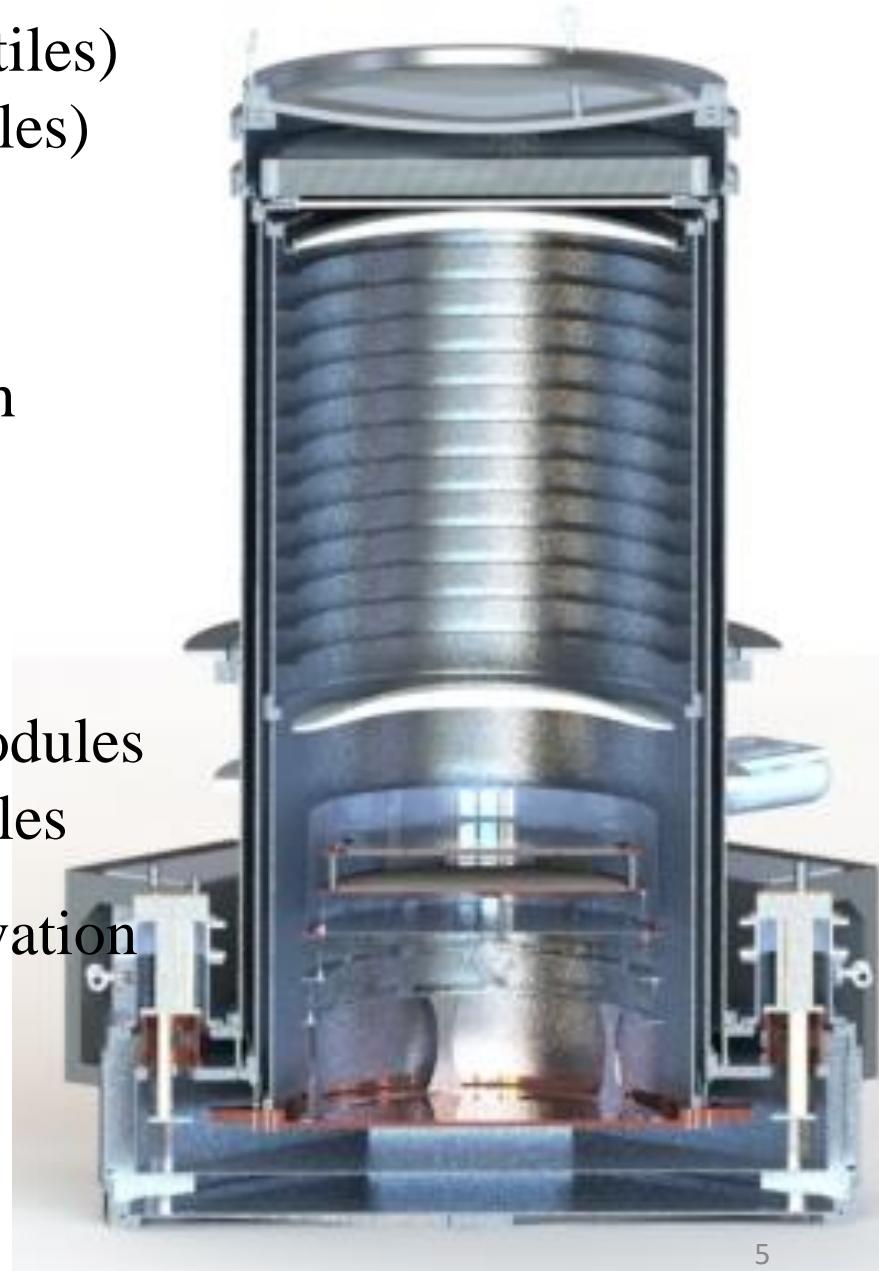
IHEP	pipeline, data analysis, scan strategy, control system, site, mount, test/integration
Stanford	cryostat receiver, optics/AR, focal plane module
NAOC	logistics, site
NIST	det arrays and modules, feedhorns and readout components
ASU	LNAs, cryogenic harness, readout electronics
NTU	scan strategy, calibration
CNRS	science, data analysis
USTC	CMB science
SJTU	foregrounds, cross-correlations
BNU	foregrounds, lensing

Jacques Delabrouille



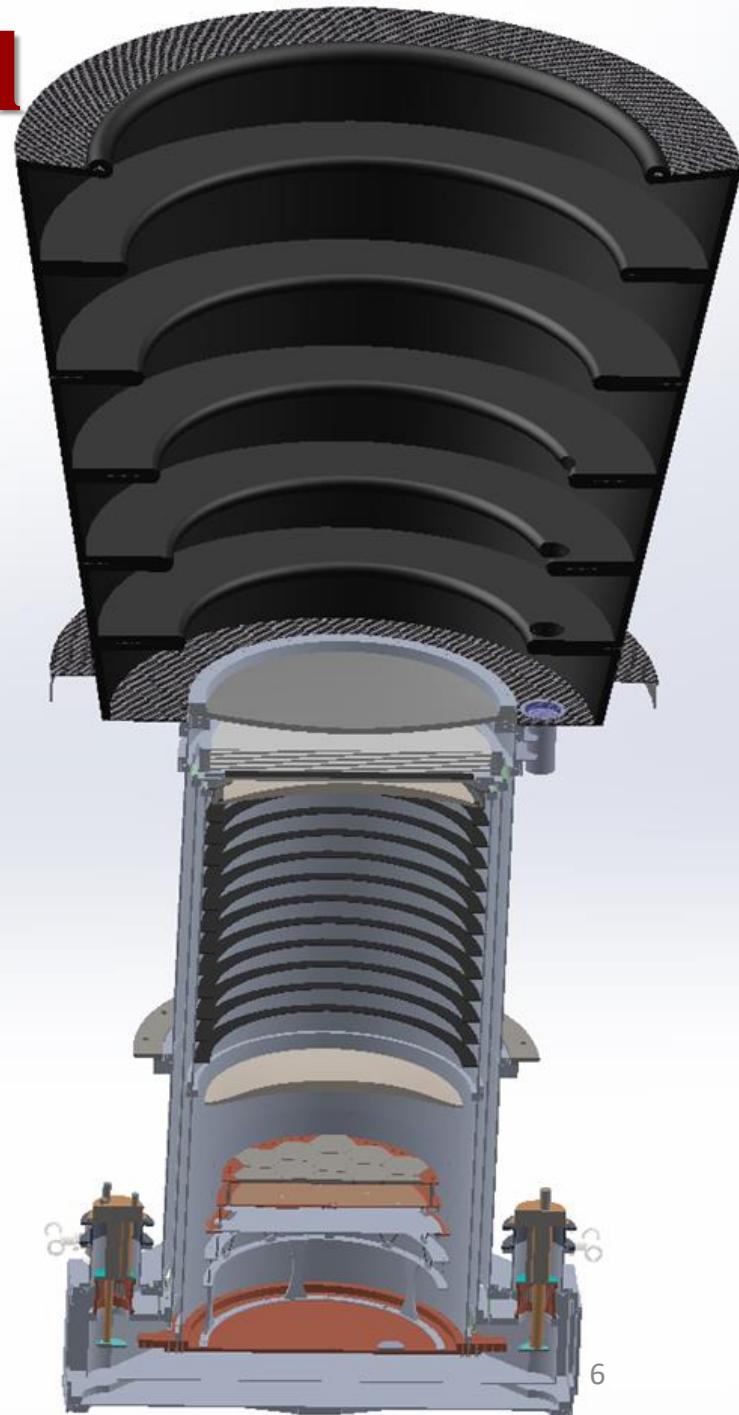
AliCPT-1 in a nutshell

- 72cm aperture, FOV 20.8° (4-7det tiles)
FOV 33.4° (19det tiles)
- 95/150GHz, 27/19% bandwidth
- 19' and 11'
- 1704 pol-sensitive, optical dichroich
TESes per tile
- 280mK, NEP $3\text{-}5 \times 10^{-17}\text{W}/\sqrt{\text{Hz}}$
- 4 detector modules
- Cryostat and optics: up to 19 det modules
- Forebaffle design: up to 7 det modules
- scanning in azimuth at constant elevation
- (45°-70°) elevation range
- up to 4°/s scanning speed
- Instrument design heritage BICEP3



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2014 – Project proposed

Timeline

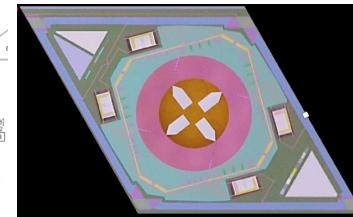
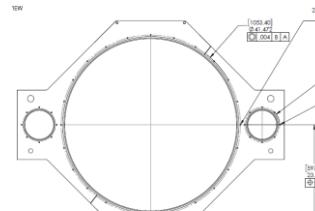
2017 – Site construction starts



2018 – Site construction ends



Sept 13 2019 – cryostat under fab
design single pixel det
mount under test
pipeline development



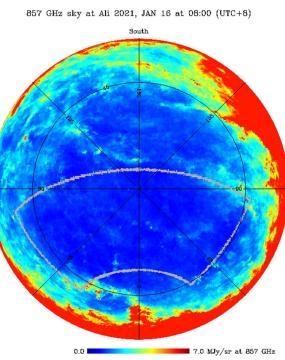
2019 – mount commissioning on site
cryostat delivery at Stanford



2020 – integration, test, commissioning at Stanford

Deployment and first light with at least one and up to 4 modules by end of 2020

> 2021 – observations and data analysis



Deployment schedule

2020 – integration, test, commissioning at Stanford

Deployment and first light with at least one and up to 4 modules by end of 2020

Year 1 – 4 det modules ~7000 TESes

Year 2 – 10 det modules

Update current
forebaffle design

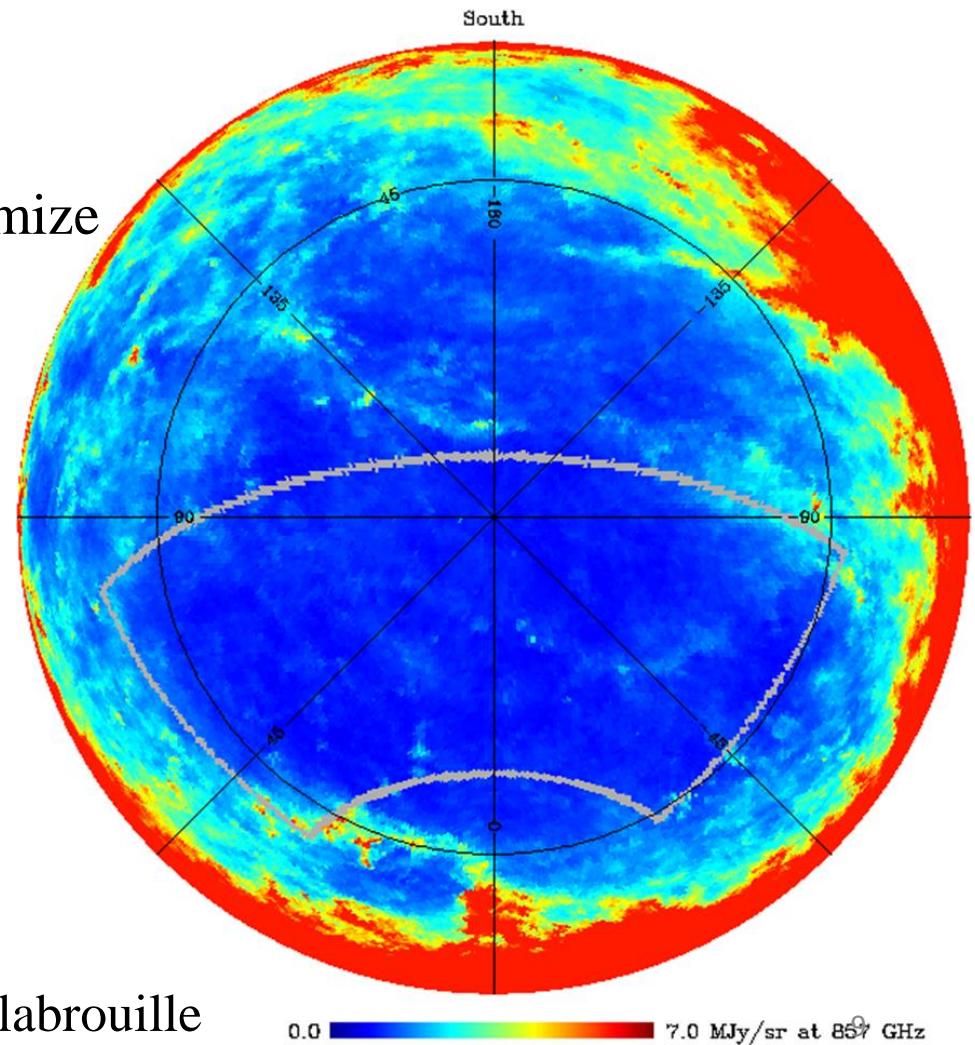
Year 3 – 15 det modules

Year 4 – 19 det modules ~30000 TESes

The observable sky from AliCPT-1

- B1 site $32^{\circ}18'38''$ N, $80^{\circ}01'50''$ E
5,250m a.s.l.
- [45°-70°] elevation
- Work on scanning strategy to optimize the observed sky

857 GHz sky at Ali 2021, JAN 16 at 08:00 (UTC+8)



The AliCPT-1 Science

- Unique mid-latitude site ($80^{\circ} 01' E$, $32^{\circ} 18' N$) @ Northern Hemisphere
- Polarization sensitivity estimates for 10% *northern* sky (with weather)
 - ~15-20 uK.arcmin for combination of channels for 1 year (4 modules.year)
 - ~ 7-9 uK.arcmin for year 4 (19 modules.year)
 - ~ 2-3 uK.arcmin for 4 years (48 modules.year)
- Similar sensitivity in both channels
- Science goals: Primordial CMB (Primordial B-modes, r); lensing spectrum; cosmic birefringence, foreground characterization.
- Angular resolution $\sim 11'$ and $19'$ (intermediate between SO SATs/LATs)
- Joint analysis with other experiments ?
 - common sky with DESI, which is located at $31^{\circ} N$
 - comparisons with SO to be discussed

The AliCPT-1 Site

- 32°18'38" N, 80°01'50" E - 5,250m a.s.l. (B1 site)
- Ngari(Ali) Prefecture of Tibet
- 20km away from the Ngari Gunsa Airport
- 30km away from Shiquanhe City - 4,255m a.s.l.
- Building 850m²
- Weather station
 - pressure, wind speed/direction, temperature
- Oxygen system

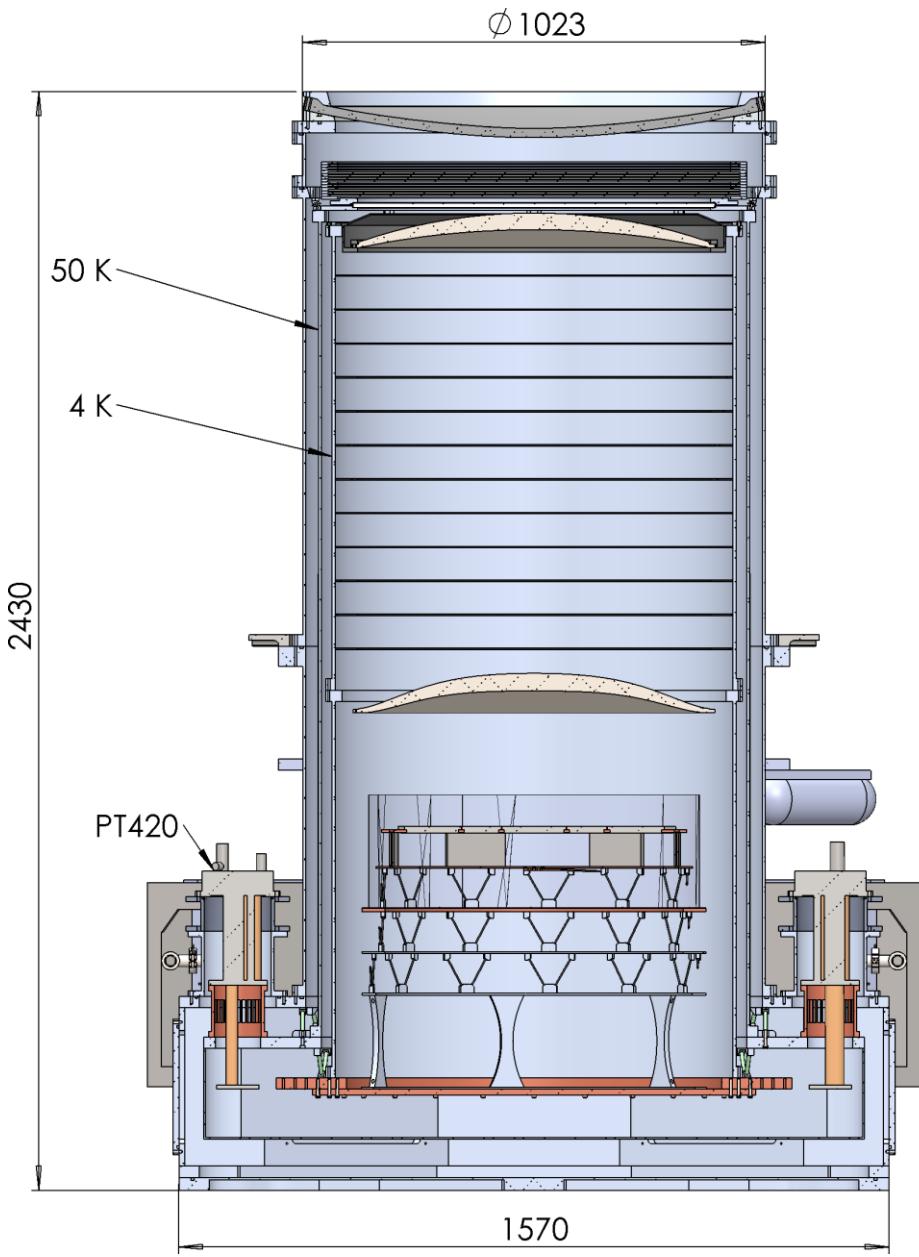


The telescope mount

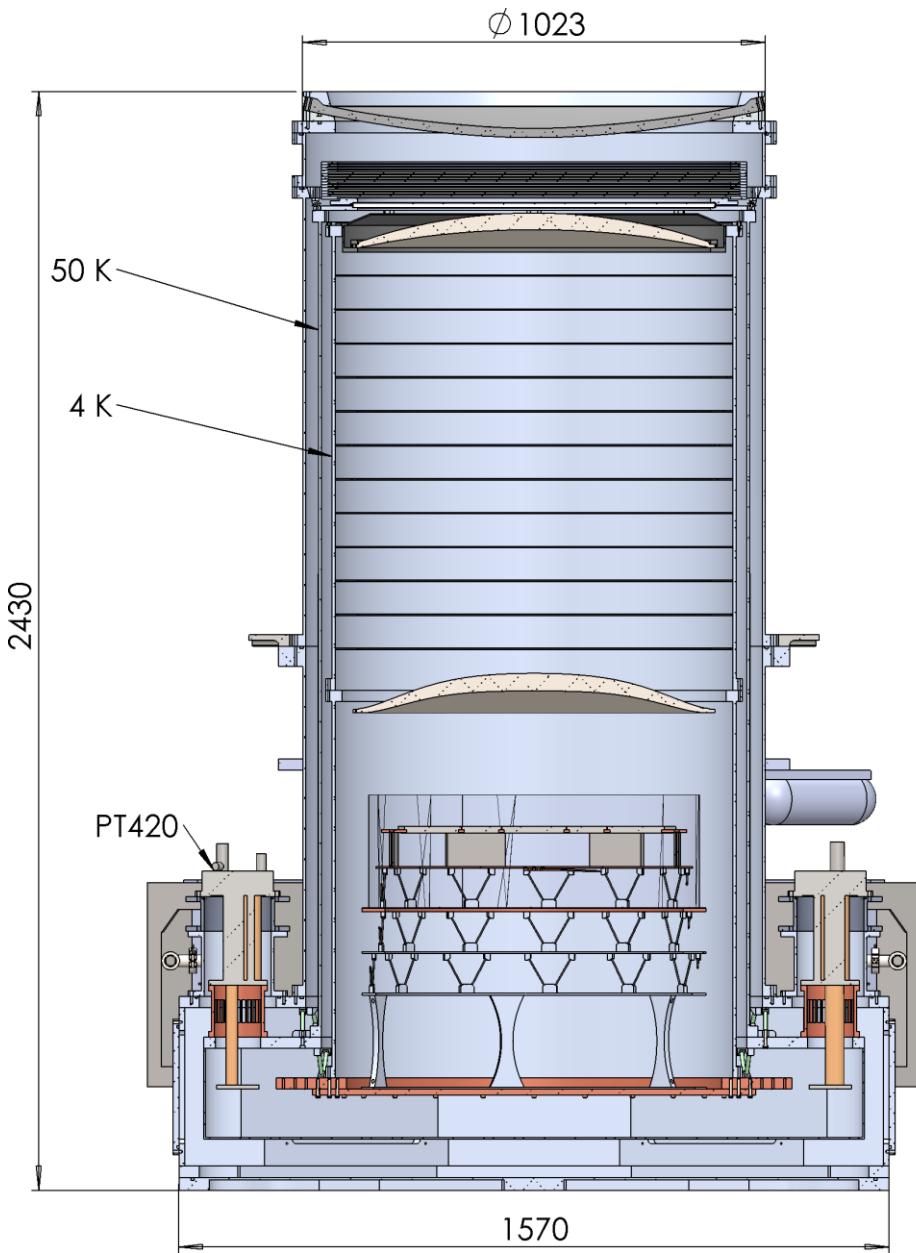


- Azimuth $\pm 270^\circ$
- Elevation [45° - 135°]
- Boresight [0° - 181°]
- Developed by the
54th Research Institute (China)
- Mount currently under test in Beijing

Cryostat Receiver Overview



Cryostat Receiver Overview



Mechanics

- 300K, 50K, 4K tubes/baserings
- G-10CR structures

Window

IR Filters

- Zotefoam layers
- 50K Alumina/Nylon filters

Cold Optics

- 4K Alumina lenses/AR epoxy mix

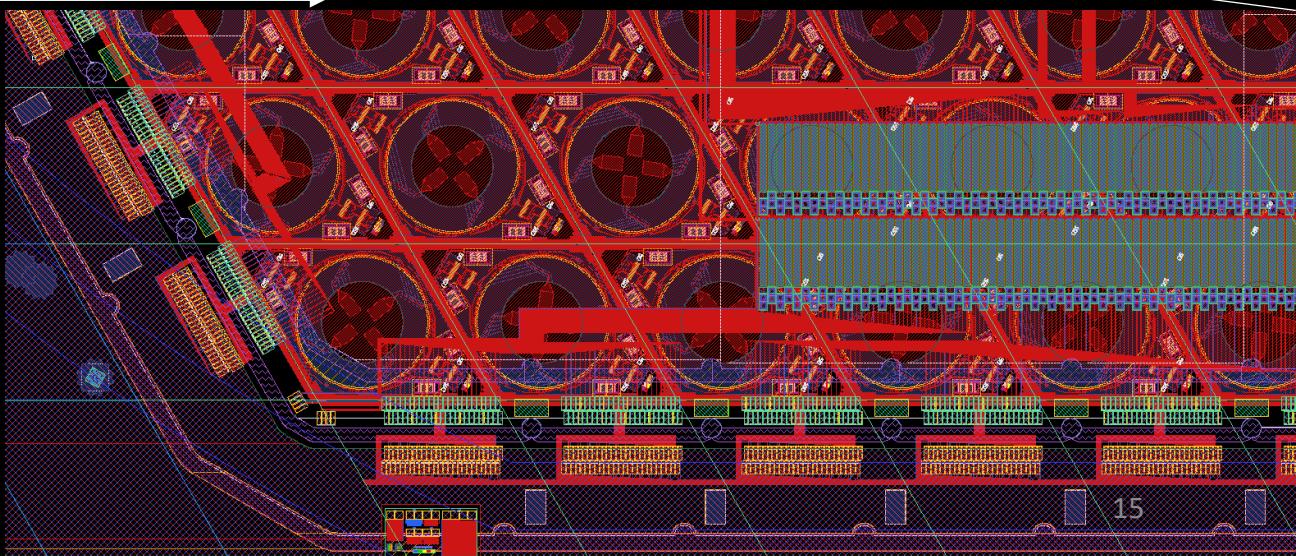
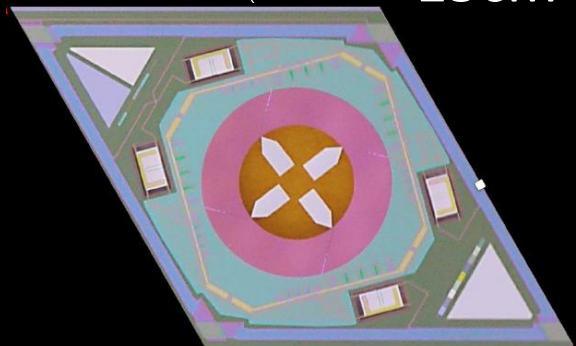
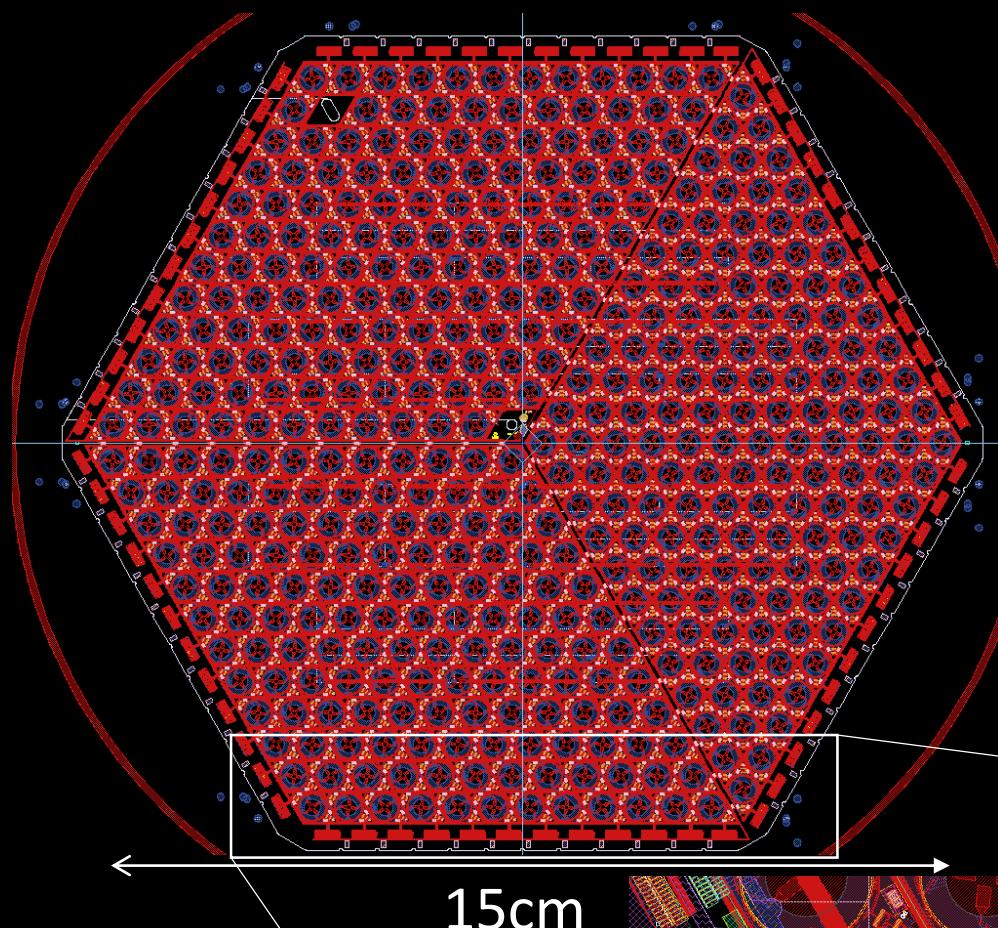
Cryogenics

- 1/2x PT-420
- Custom GL10 absorption fridge

TESes array and μ mux

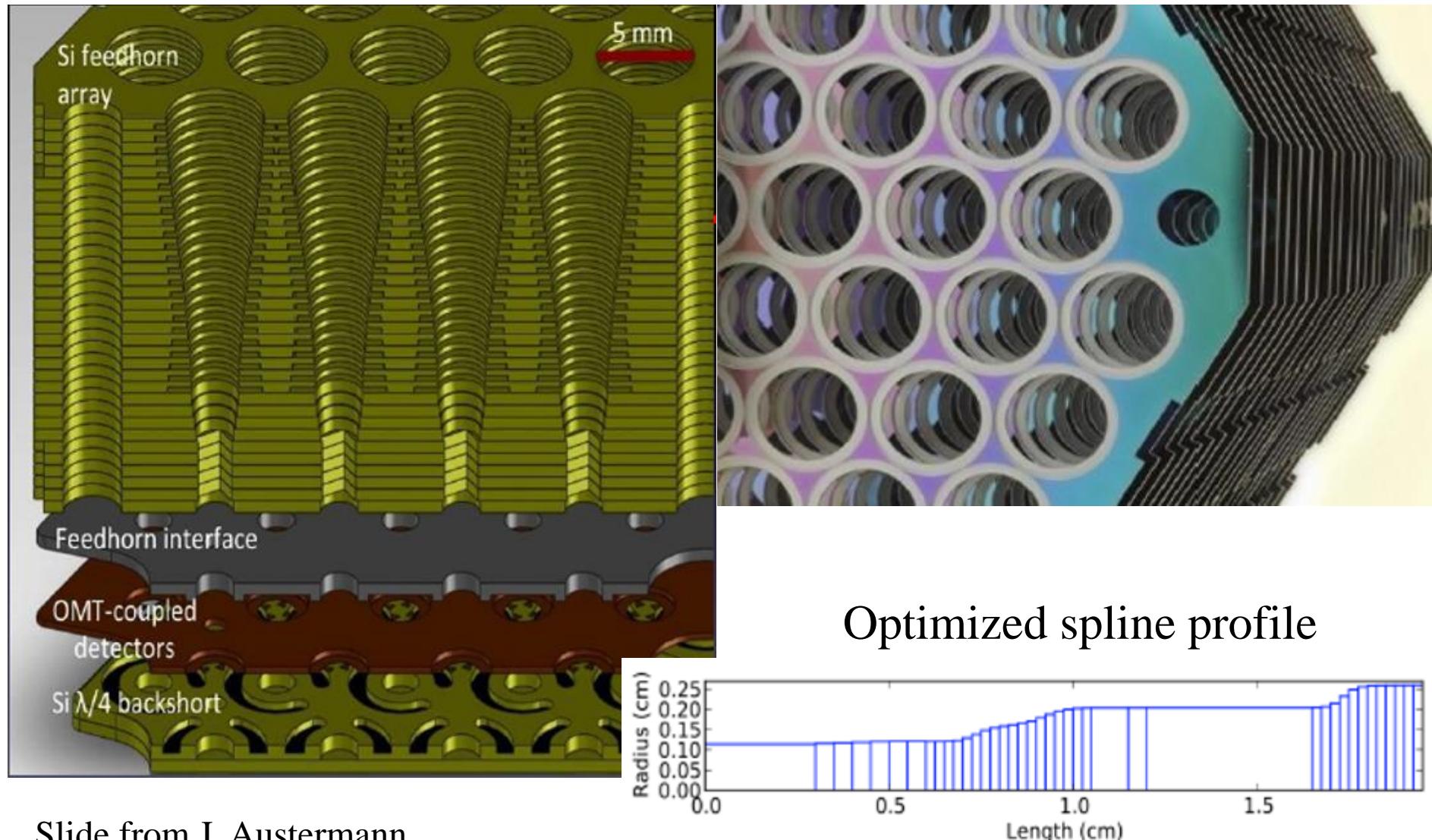
Detectors

- Pol-sensitive dichroic TESes
- 95 and 150GHz
- similar design AdvACT MF
(Duff S. et al. JLTP16,
Henderson S. et al. JLTP16)



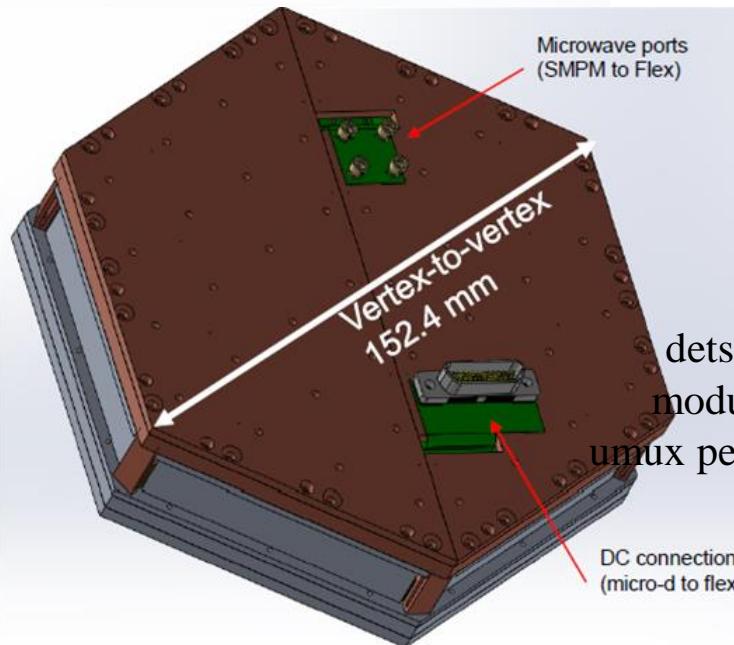
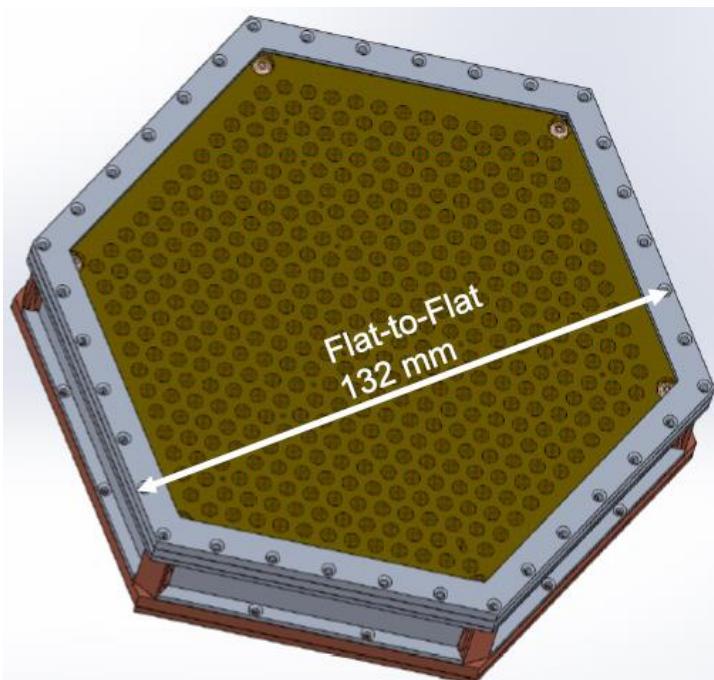
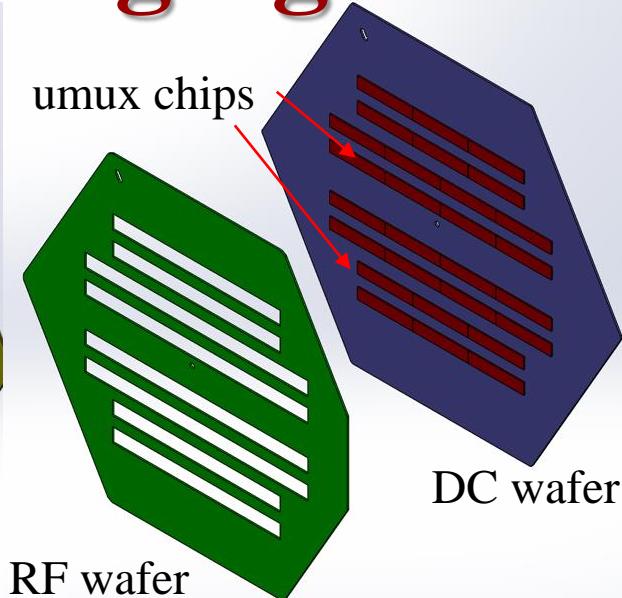
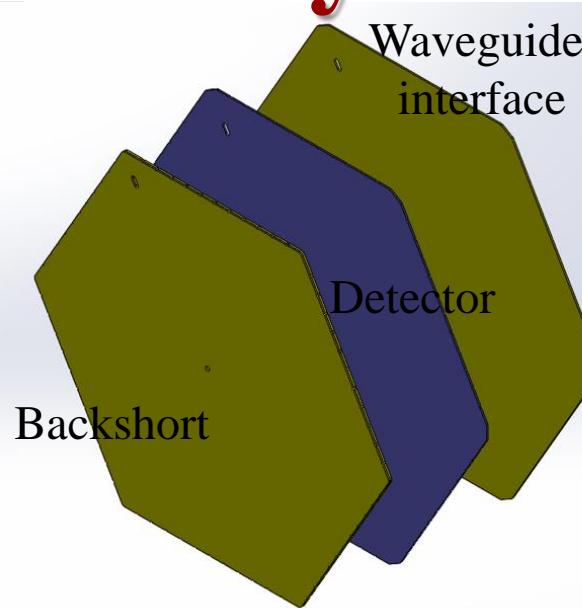
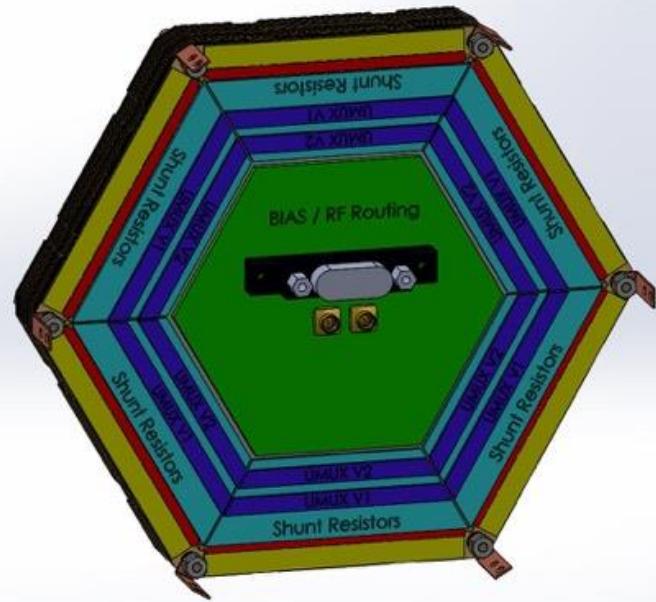
Slide from J. Austermann
and H. Hubmayr

Feedhorn-Coupled Polarimeter Arrays



Slide from J. Austermann

Detector array Packaging



Design
similar to SO

Simons Observatory
submitted to JLTP:
dets module: McCarrick et al.,
module integration: Li Y. et al.,
umux performance: Dober B. et al.

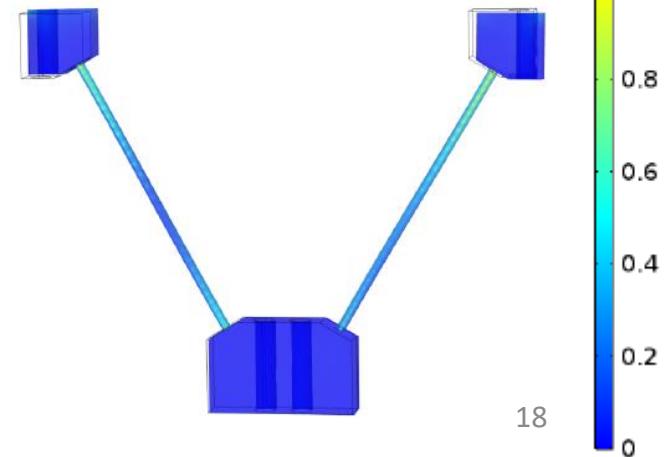
Slide from
J. Austermann &
H. Hubmayr¹⁷

Focal Plane Unit

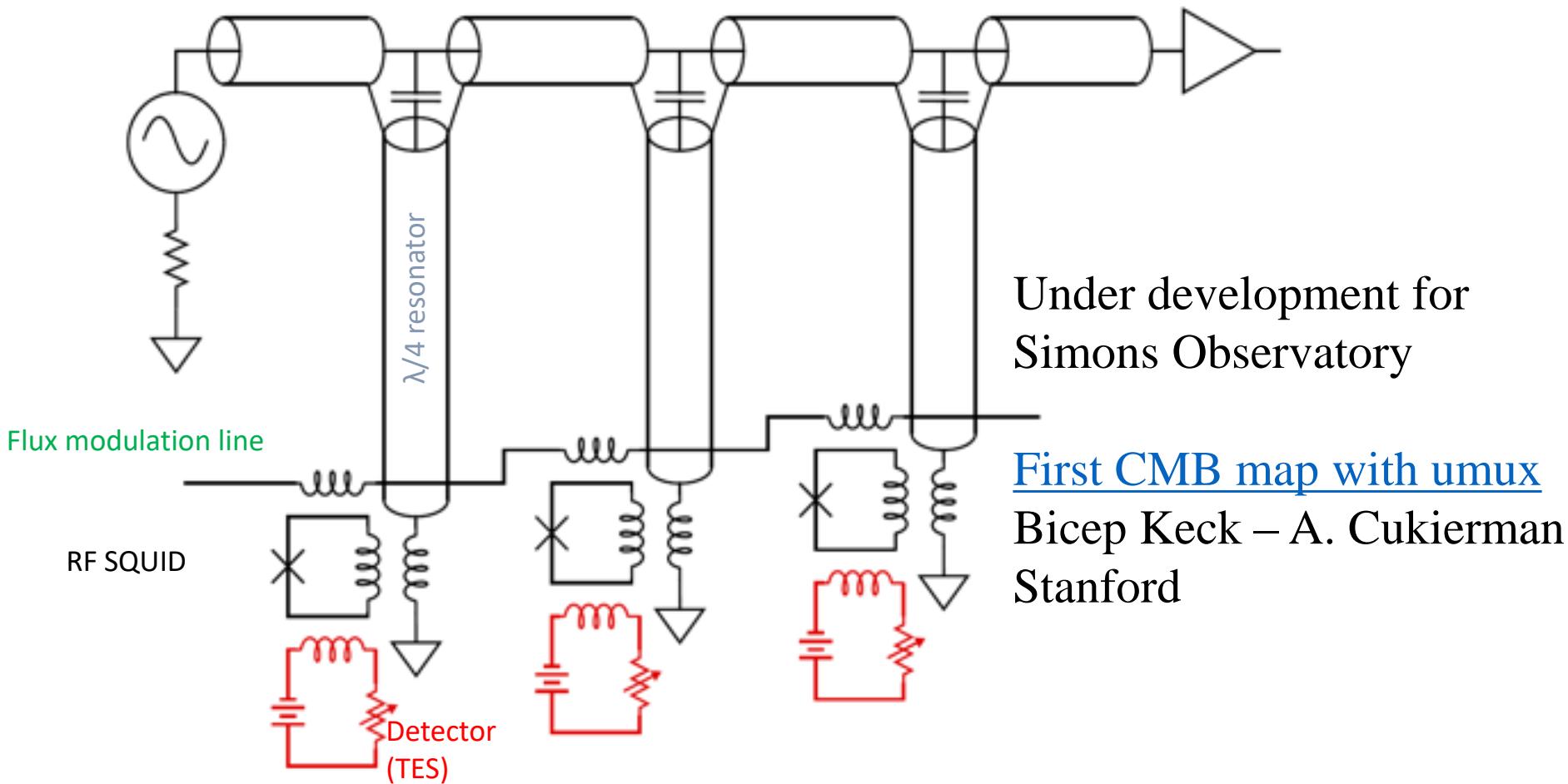


- Magnetic shielding
- Carbon fiber rods

von Mises stress (100 MPa)

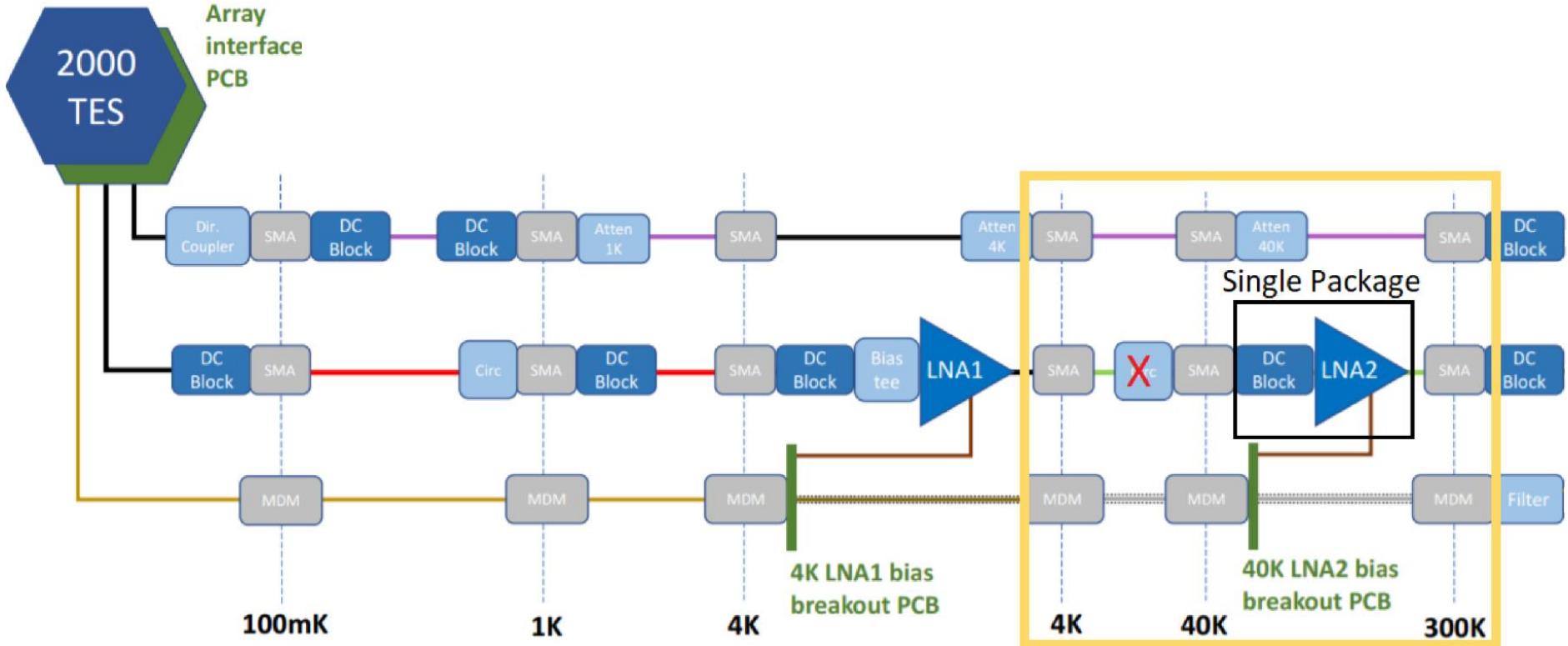


Microwave SQUID Multiplexing



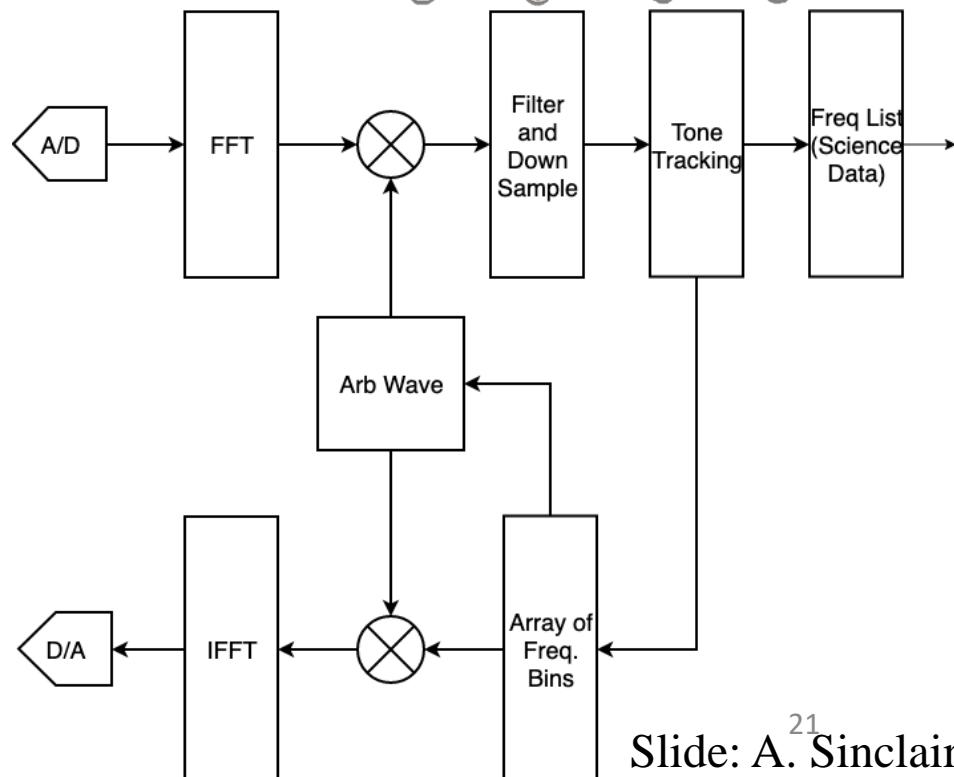
Irwin and Lehnert (2004)
J.A.B. Mates Thesis (2011)

TES μMux Readout Schematic



Multiplexing Readout Software

- Room temperature readout on the Xilinx RFSoC ZCU111
- On chip ADC/DACs, microprocessors, reprogrammable digital logic fabric
- FFT/IFFT + complex mixing for up/down converting bias tones.
- PID style tone tracking on det resonances.
- Open source PYNQ development from Xilinx, Python interface.
- Open source software
<https://github.com/adriankaisinclair>



Summary

- AliCPT-1 will be the first high altitude (>5200m) CMB telescope in Tibet
- Thousands 95/150GHz dichroic/pol-sensitive TESes + μmux
- **Deployment and first light by end of 2020**
- Contribution from Europe started on simulations and data pipeline development
- Additional European contributions welcome