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Inflation-era High Energy Physics via CMB Measurements at the SPT using ANL/KICP Detectors

Volodymyr Yefremenko, Gensheng Wang, Aaron Datesman, John Pearson, and Valentyn Novosad

Materials Science Division (Argonne TES Development Project)

COLLABORATORS:

Clarence Chang, Jeff McMahon, Lindsey Bleem, Abigail Crites, Jared Mehl, Stephan Meyer, and John Carlstrom

Kavli Institute for Cosmological Physics, University of Chicago

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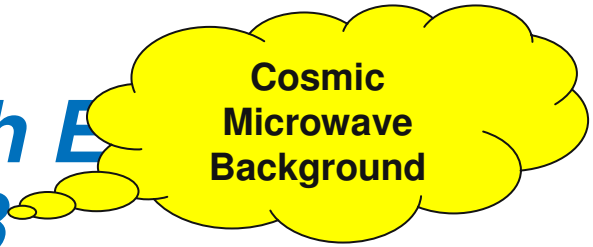

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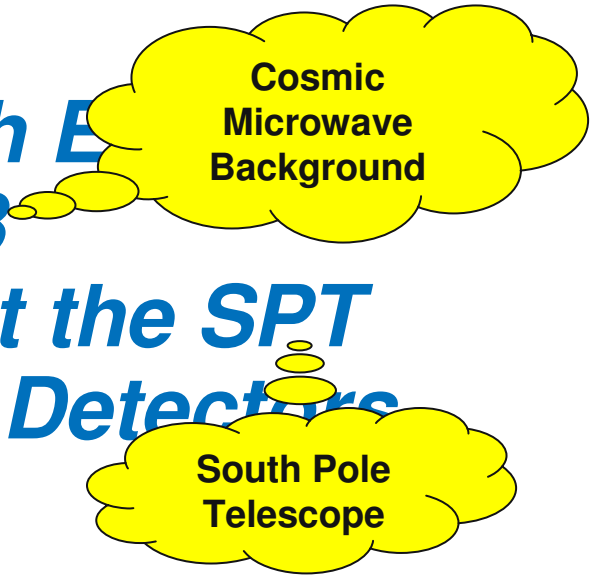

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Cosmic Microwave Background

South Pole Telescope

Kavli Institute for Cosmological Physics, University of Chicago

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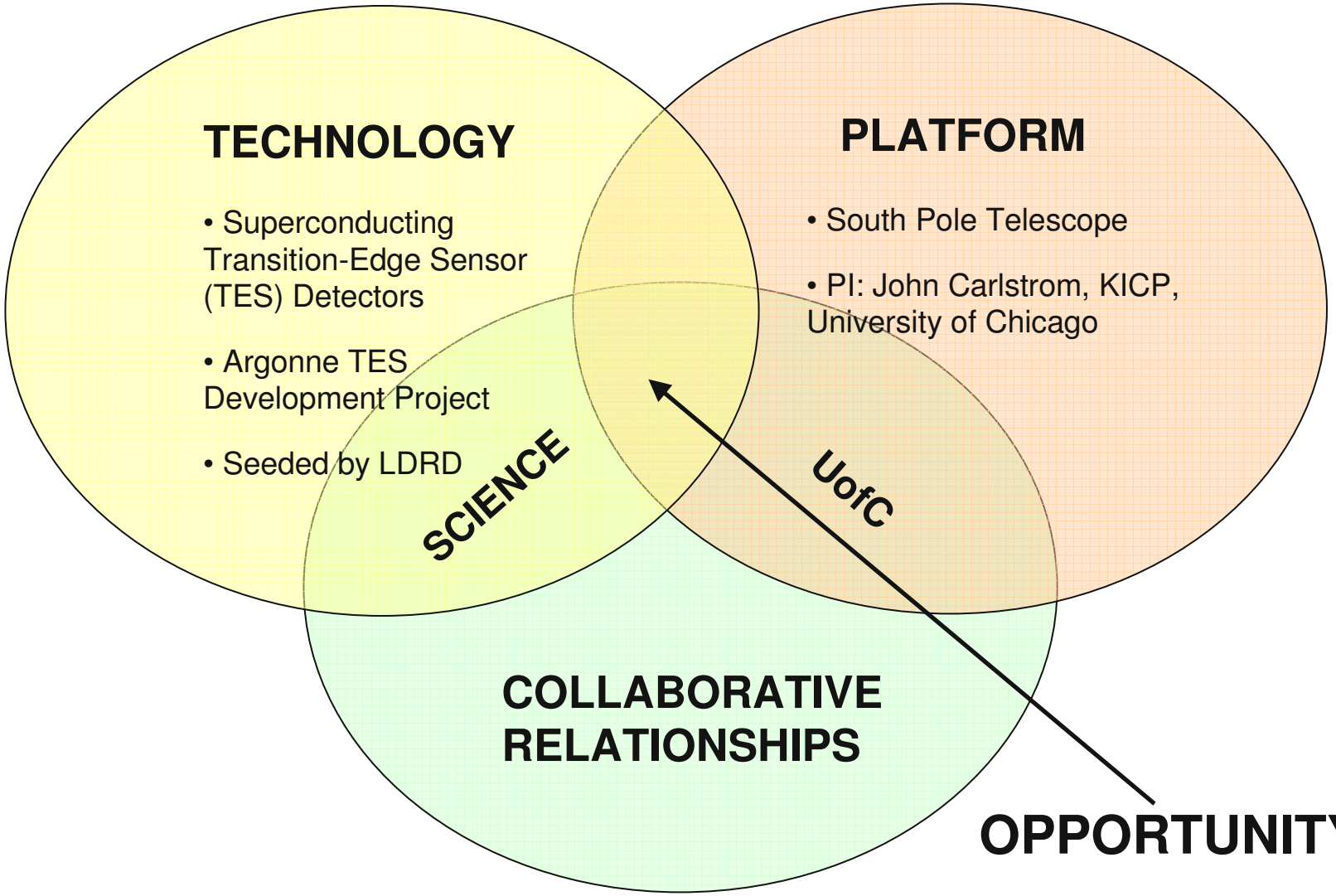
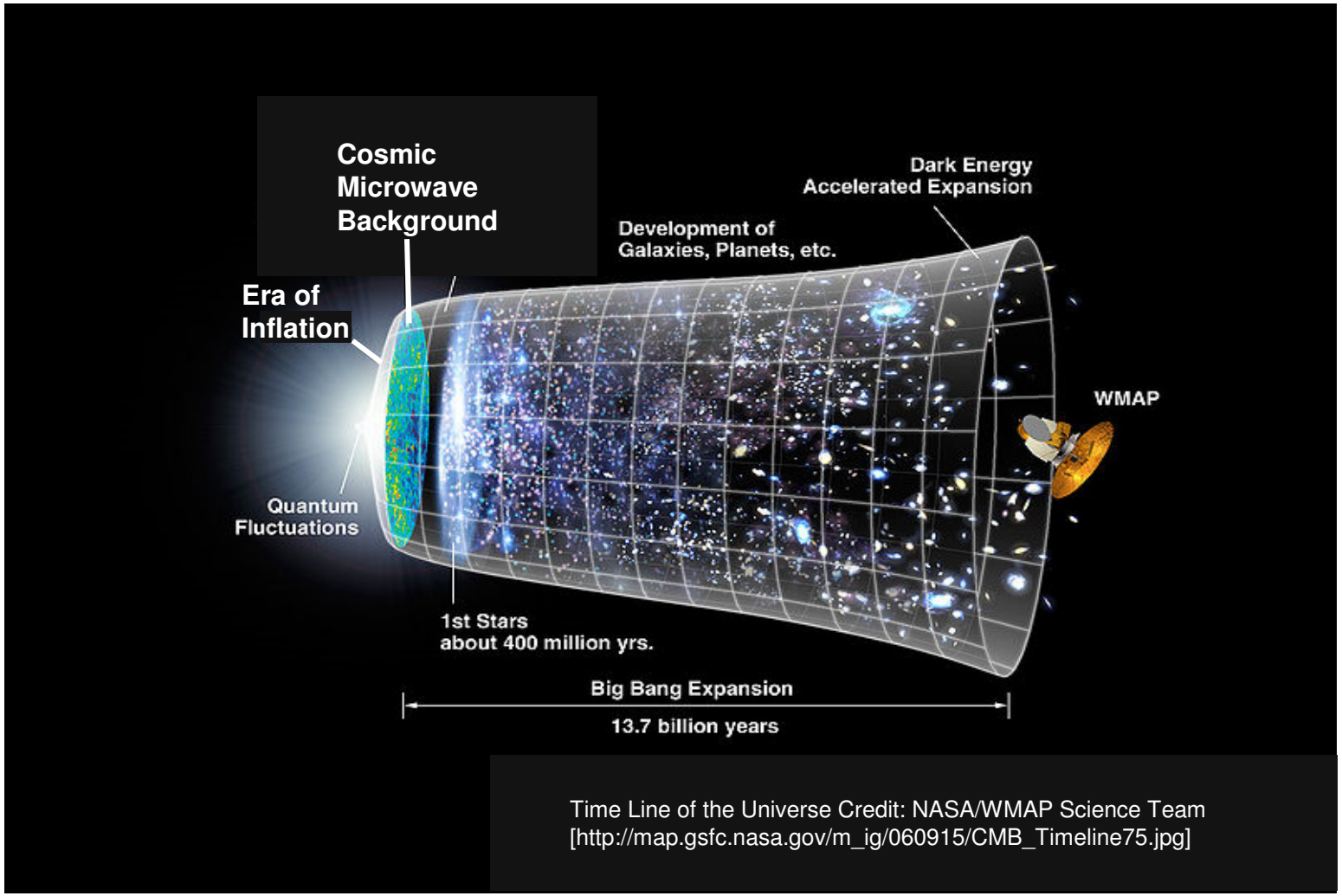
Opportunity for HEP to provide enabling technology for frontier research

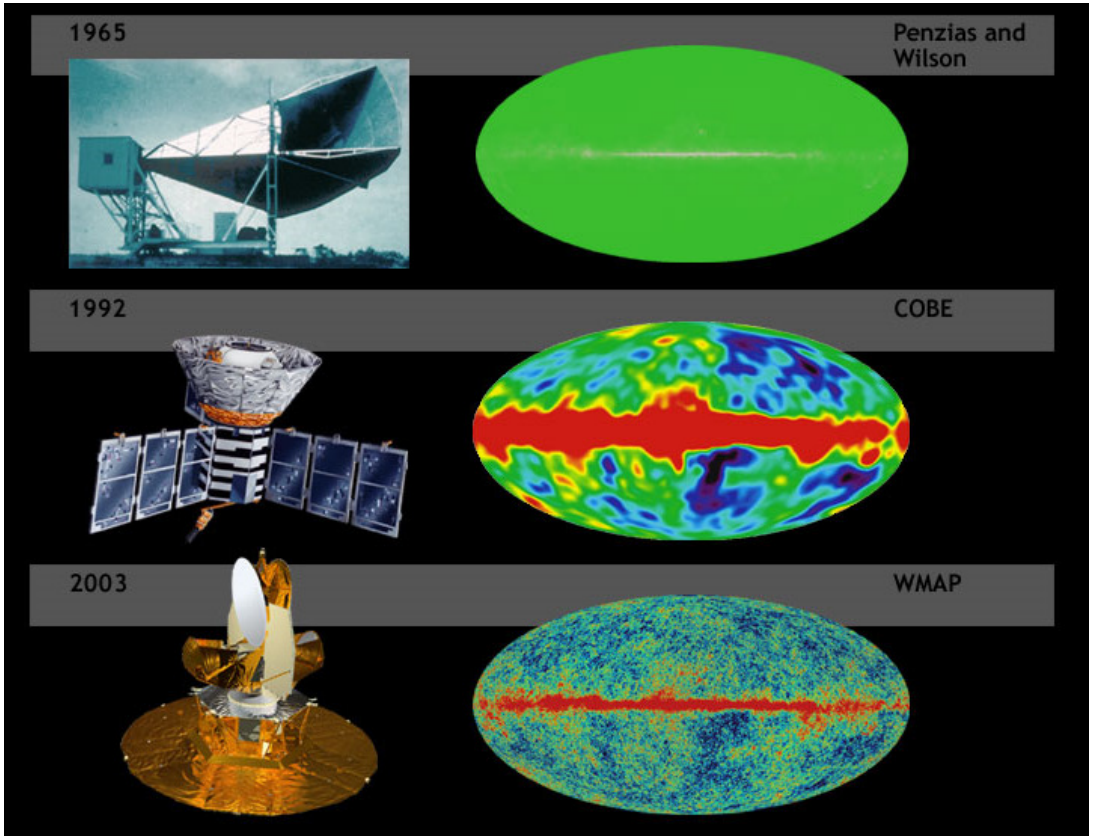


Scientific Motivation: The History of Everything in Just One Slide – the Wilkinson Microwave Anisotropy Probe (WMAP)



Time Line of the Universe Credit: NASA/WMAP Science Team
[http://map.gsfc.nasa.gov/m_ig/060915/CMB_Timeline75.jpg]

Cosmic Microwave Background (CMB) Discovery



<T> = 2.725 K

Verification of the Big Bang Theory

Isotropic to 1:10^5

Nobel Prize 1978

ΔT = 18 μK

Confirmed black body spectrum to within 50 ppm

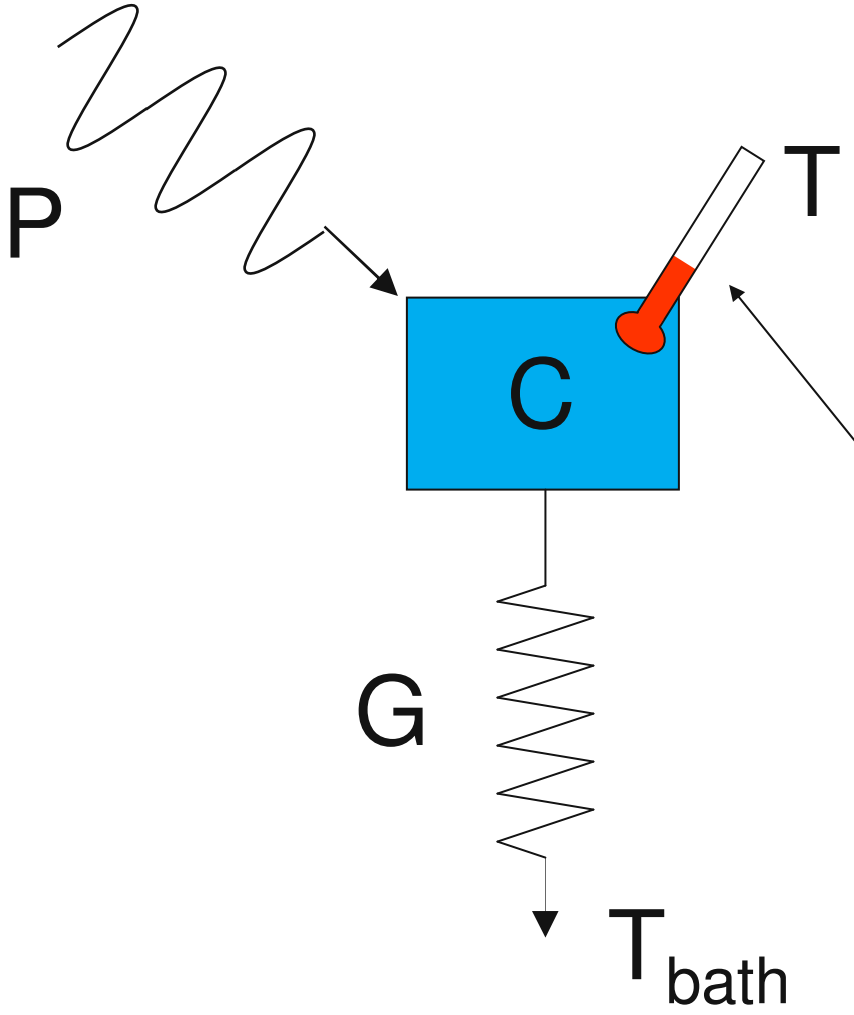
Nobel Prize 2006

ΔT_E ~ 2 μK

***Science* Breakthrough of the Year, 2003**

What's next? B-mode polarization measurements will provide the first experimental probe of Inflation-era HEP. The data from SPTpol will set the energy scale of Inflation and constrain the mass of the neutrino.

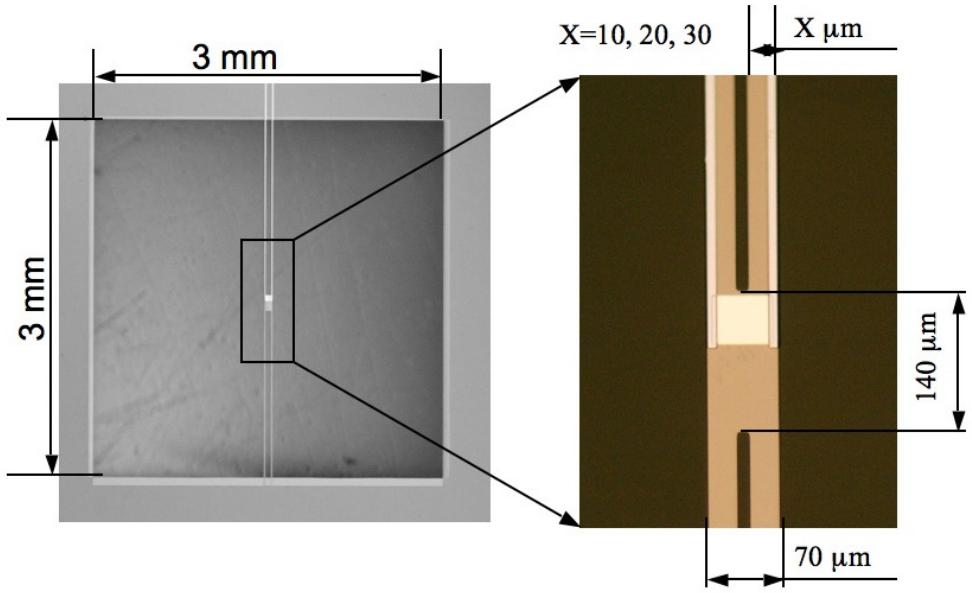
Bolometer Physics: A Broadly Applicable, Ultra-Sensitive Thermal Detection Technique



$$\tau_{th} = C/G$$

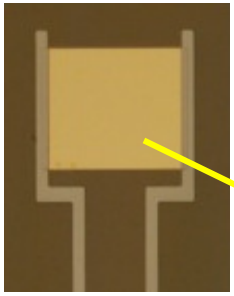
Thermometer:
Superconducting Transition-Edge Sensor (TES) under voltage bias

Perforated approach to the thermal conductance

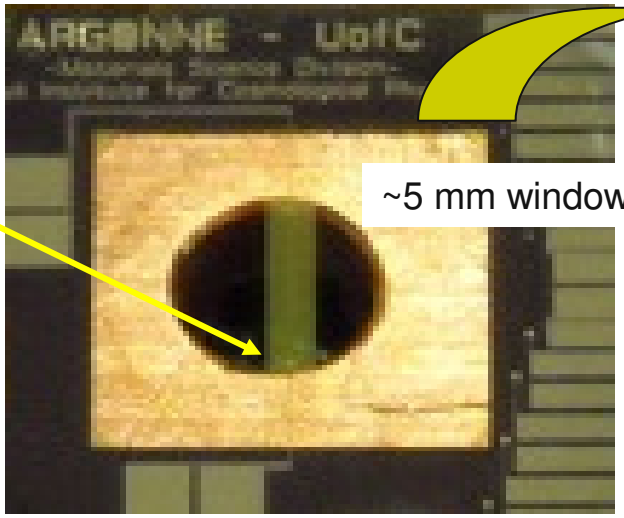


w (μm)	T (K)	κ (nW/K^n)	n	G(0.5 K) (pW/K)
30	0.492	0.259	2.73	213
20	0.499	0.171	2.95	131
10	0.428	0.023	1.8	24

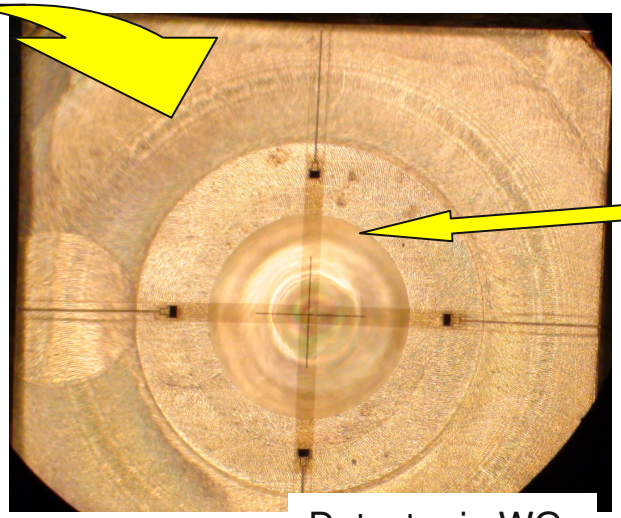
Design of the Dual-Polarization TES Detector

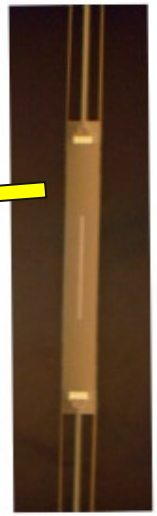


Mo/Au proximity effect bilayer TES

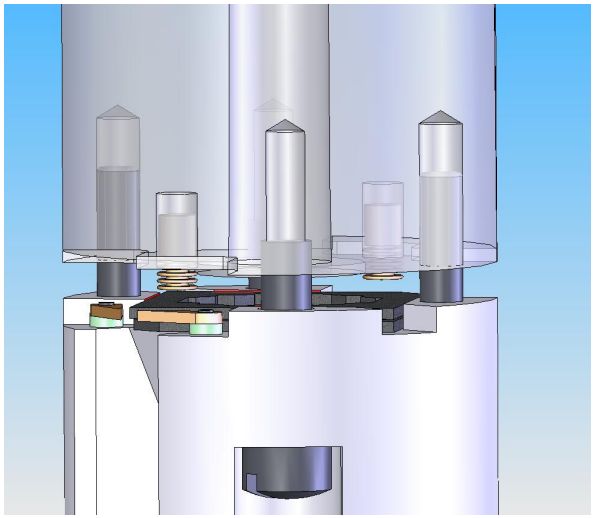


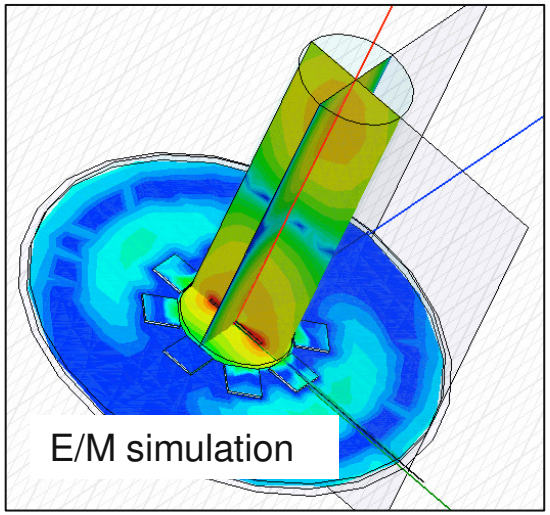
~5 mm window



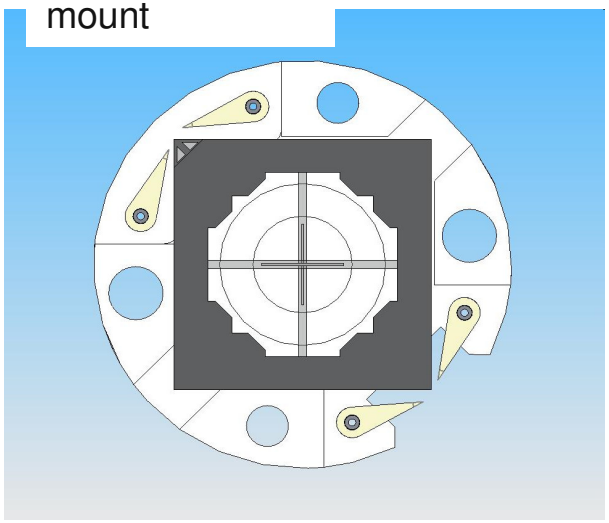


Detector in WG mount



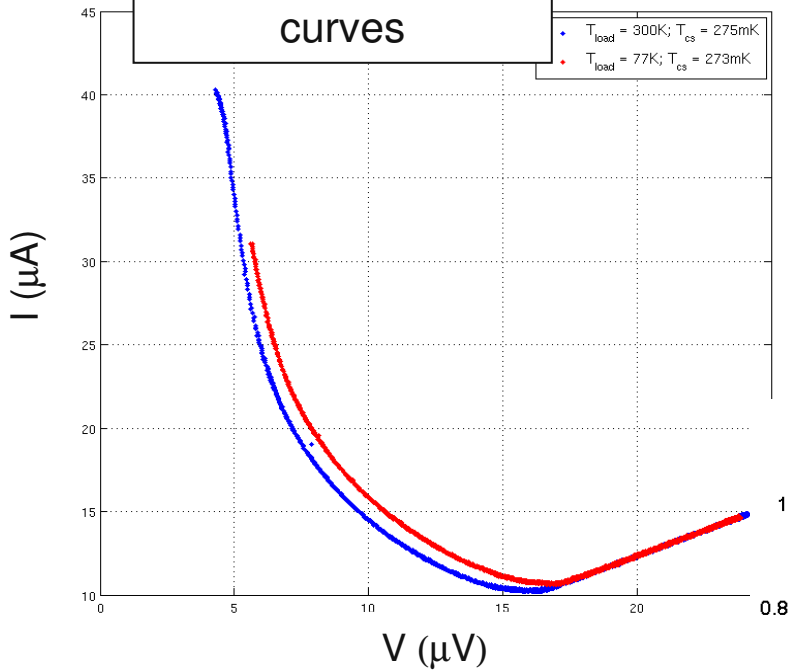


E/M simulation

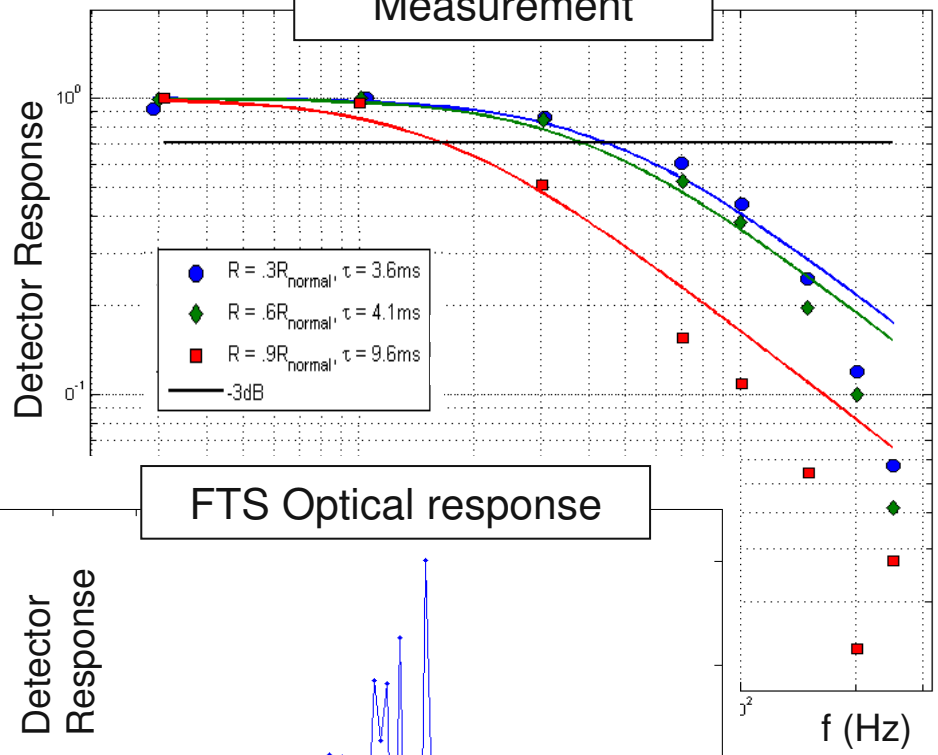


Polarimeter Optical Measurements

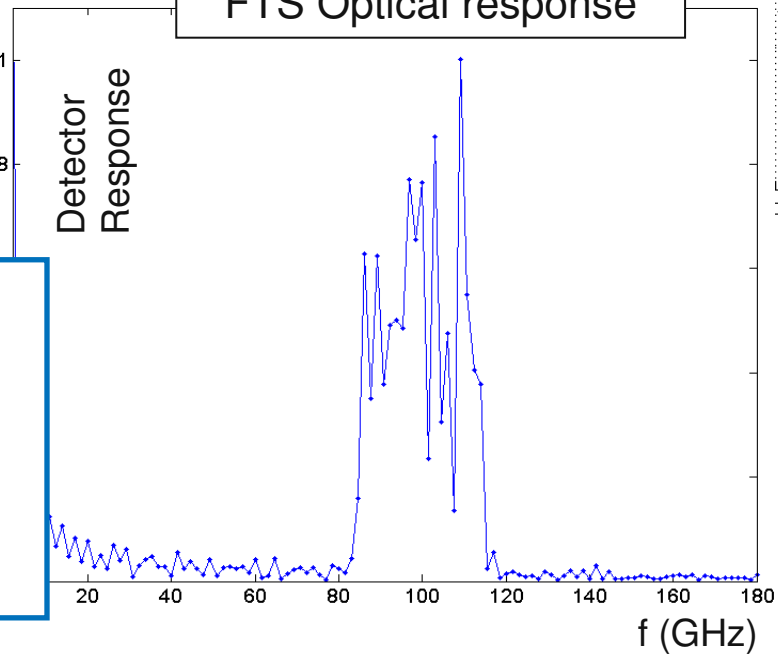
Hot/cold load curves



Time Constant Measurement



FTS Optical response



- Fast bandwidth > 20 Hz
- Low cross-pol <2%
- Meets targets for R_n, T_C, and G

Demonstrated Competencies Required for Success

And this is just what's needed to design and build the detectors!

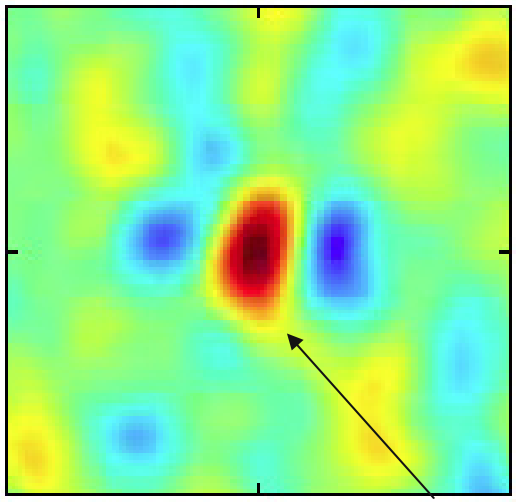
APPLICATION:
Detectors for the South Pole Telescope!

World-class Science

Materials Science

Low-Noise Superconducting Electronics

Advanced Microfabrication



Staniszewski et al.,"GALAXY CLUSTERS DISCOVERED WITH A SUNYAEV-ZEL'DOVICH EFFECT SURVEY", *ApJ*, vol. 701, p. 32, 10 Aug. 2009

Conclusion

- ***There's no better laboratory than Mother Nature!***

  From the Elementary Particle Physics Report:

> This recent history of particle physics underscores the interplay between experiments involving accelerators and those that do not involve accelerators. For instance, nonaccelerator experiments have helped drive the scientific frontiers of particle physics and have brought the field into closer contact with nuclear physics, cosmology, and astrophysics. Historically, many important discoveries first came from nonaccelerator experiments, in some cases simply because appropriate accelerators did not exist at the time. In fact, there is an impressive list of particle physics discoveries that did not involve accelerators. To name just a few:

- ***The world-class capabilities and knowledge in MSD, the closeness of the UofC collaboration, and the commitment the lab has shown by seeding this program, create exciting opportunities for HEP – and for other fields as well.***

Conclusion

- ***There's no better laboratory than Mother Nature!***

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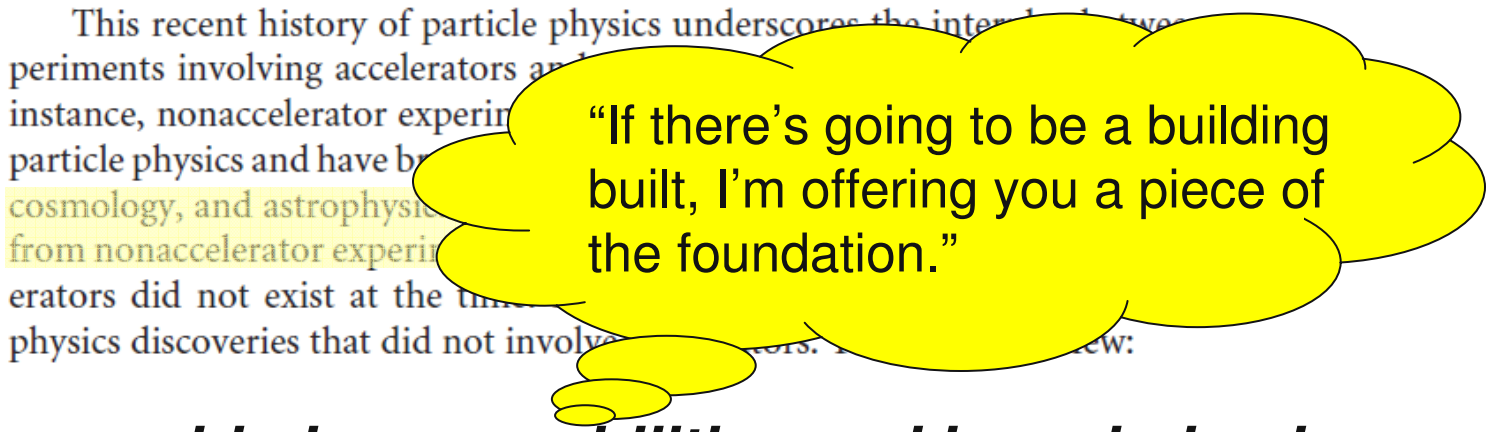

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Focal Plane Array Layout