Pixelization at the Cosmic Frontier

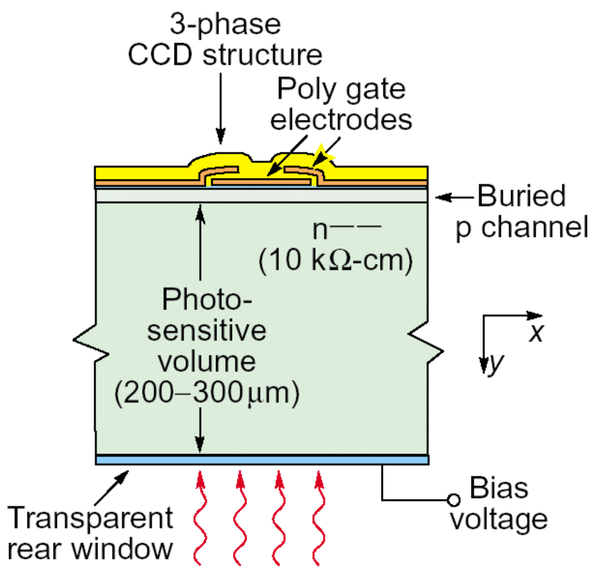
Clarence Chang
Argonne National Lab

CSS 2013 / Snowmass on the Mississippi

Argonne NATIONAL LABORATORY

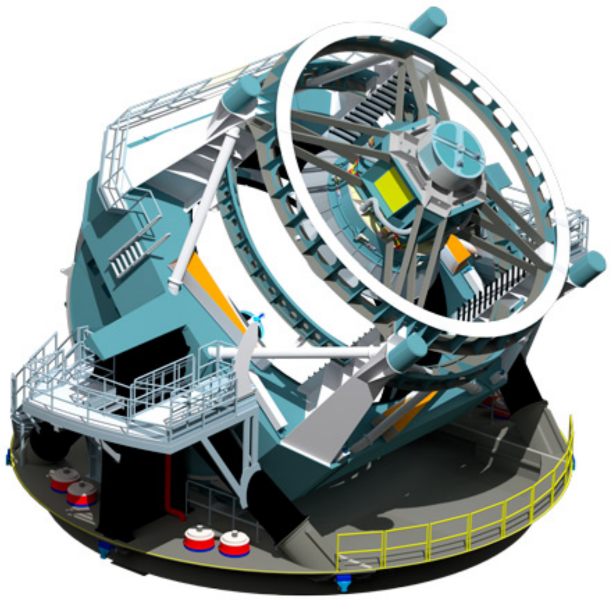
Thick CCDs and the Cosmic Frontier

- Dark Energy

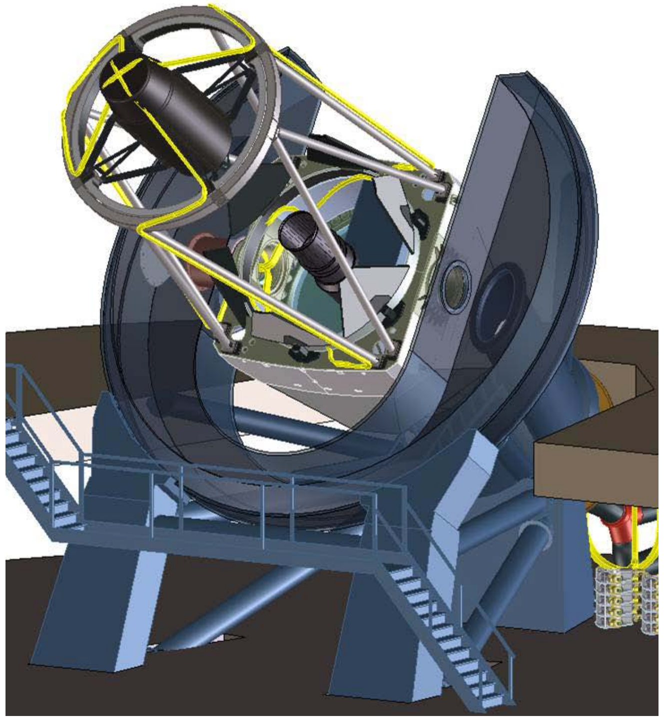


DES

LSST

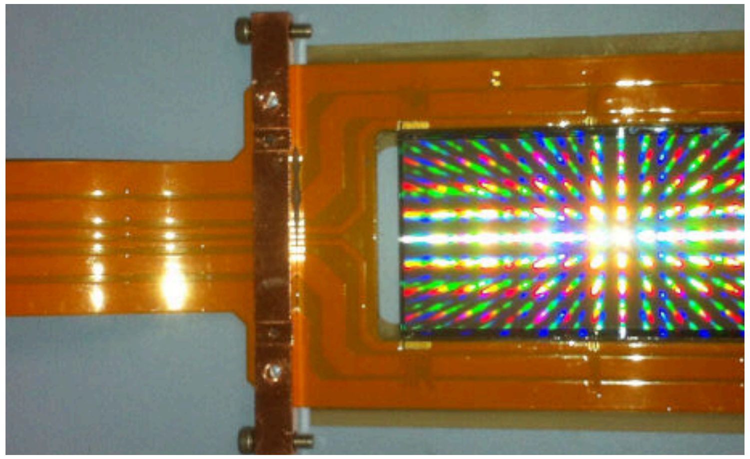


MS-DESI

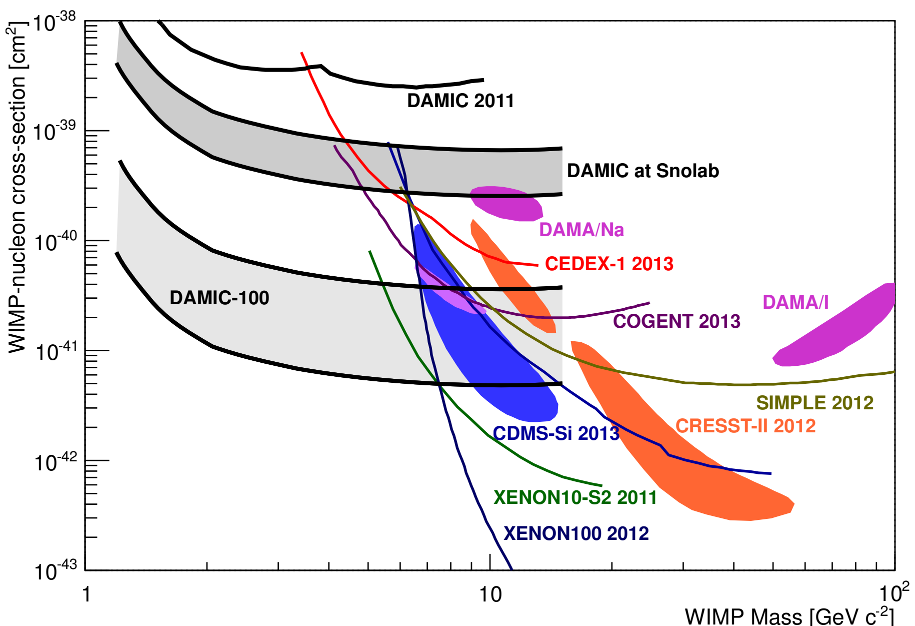


- Dark Matter

DAMIC



http://www.cbpf.br/~icrc2013/papers/icrc2013-1243.pdf



Needs at the Cosmic Frontier

- **Can't change flux of energy from the cosmos!**
- Can only change how (and how much) is measured
- Three ingredients:
  - Increasing spatial instrumentation (larger volumes/areas, increased granularity)
  - Increasing energy bandwidth
  - Increasing readout throughput

New ideas for Instrumentation R&D

- New technology with superconducting detectors
- Commercially available cryogenics (especially cryogen free systems), “worry free” operation
- Long history of R&D. Understanding of the fundamental of the technology is “mature”
- Focus on HEP applications... large and very large arrays of superconducting detectors

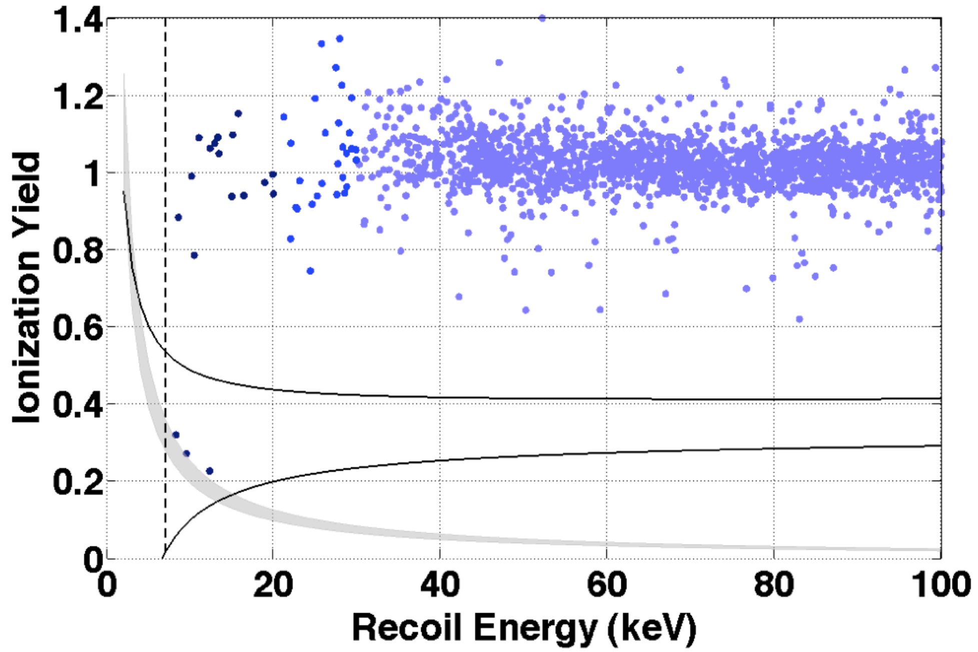
Superconducting detectors and Dark Matter

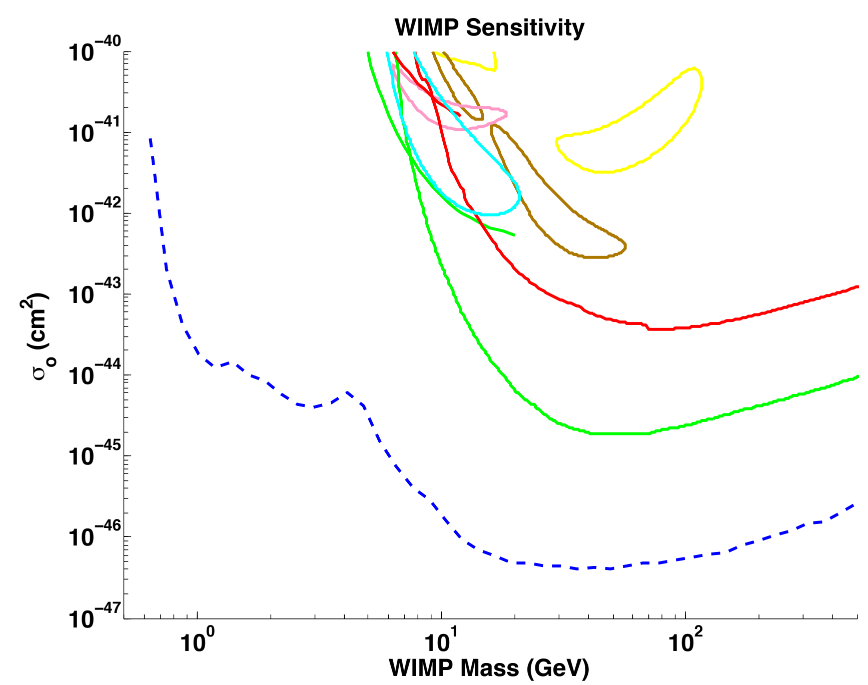
- Transition Edge Sensor (TES) invented by HEP for Dark Matter

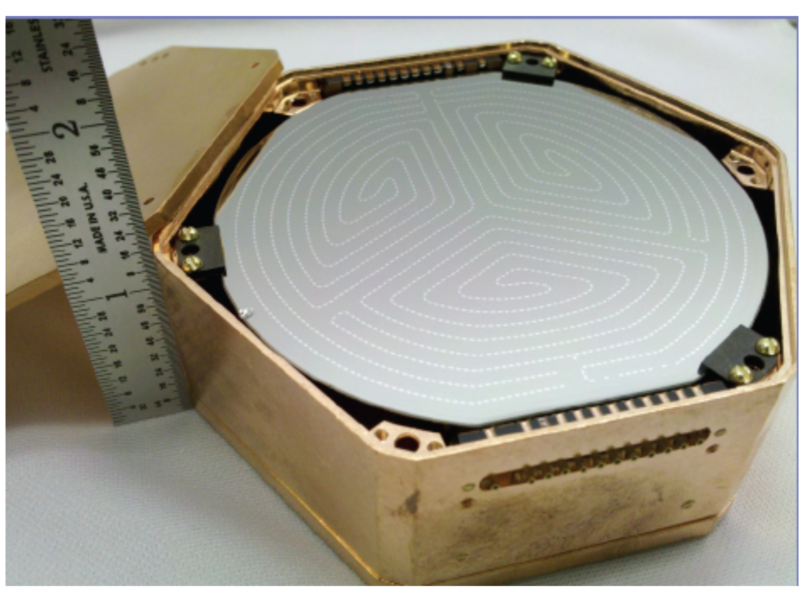
- Future R&D involves:

  - Increasing target mass (bigger detectors, more detectors)

  - Lowering energy threshold

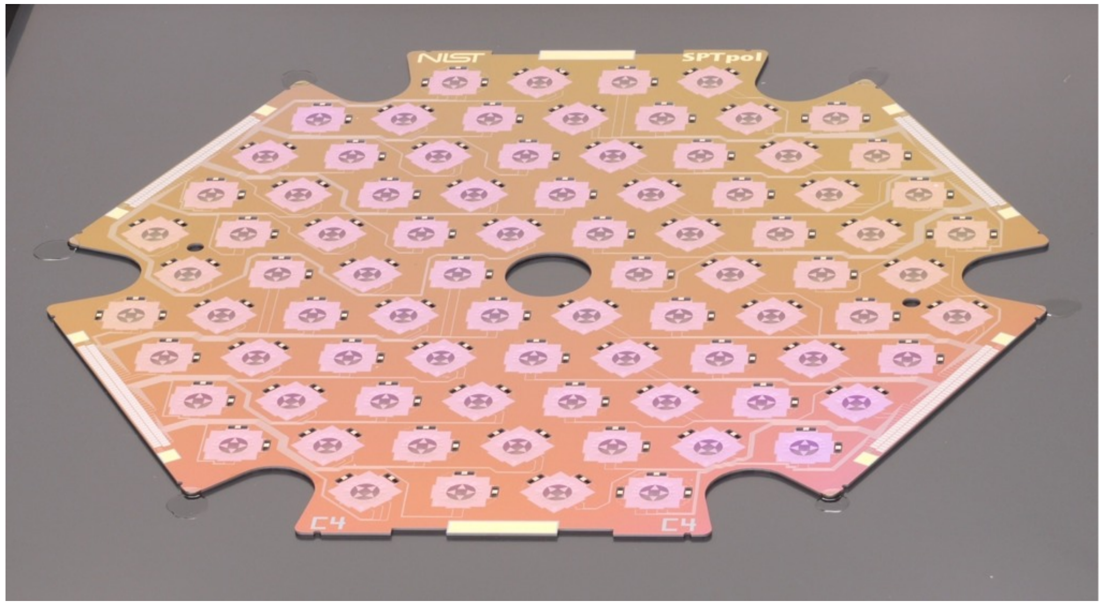


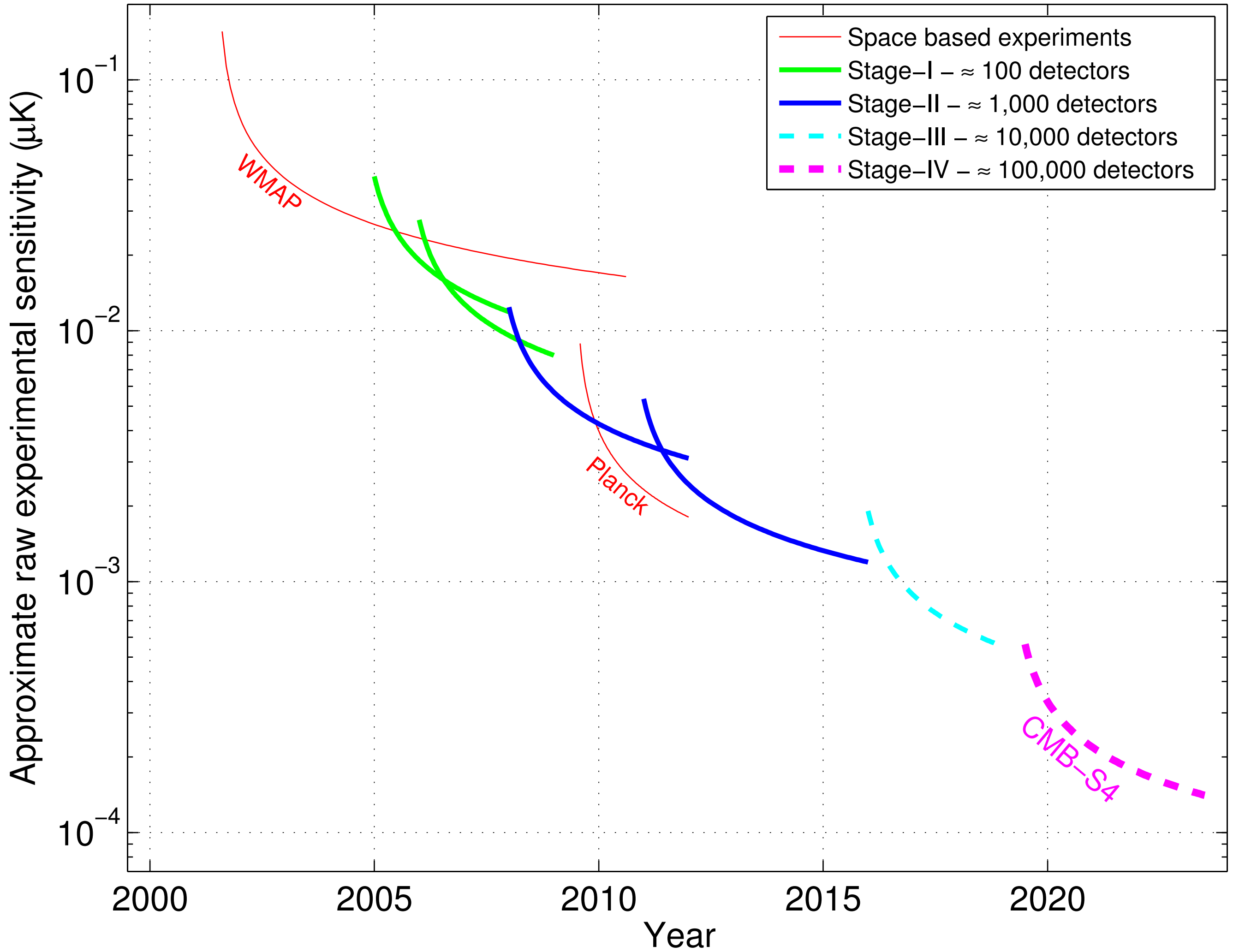




Superconducting detectors and CMB

- TES bolometers have led to a milestone achievement, first observation of CMB B-mode polarization (http://arxiv.org/abs/1307.5830)





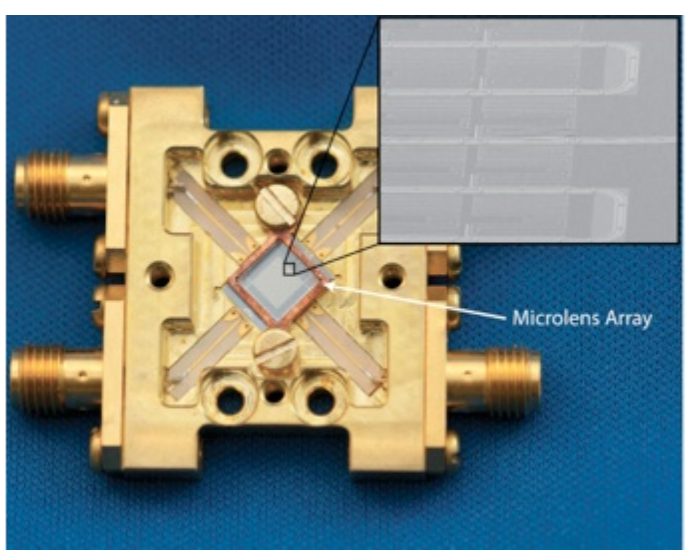
- Larger focal planes

- Expand optical bandwidth to 3 octaves (vs 45%)

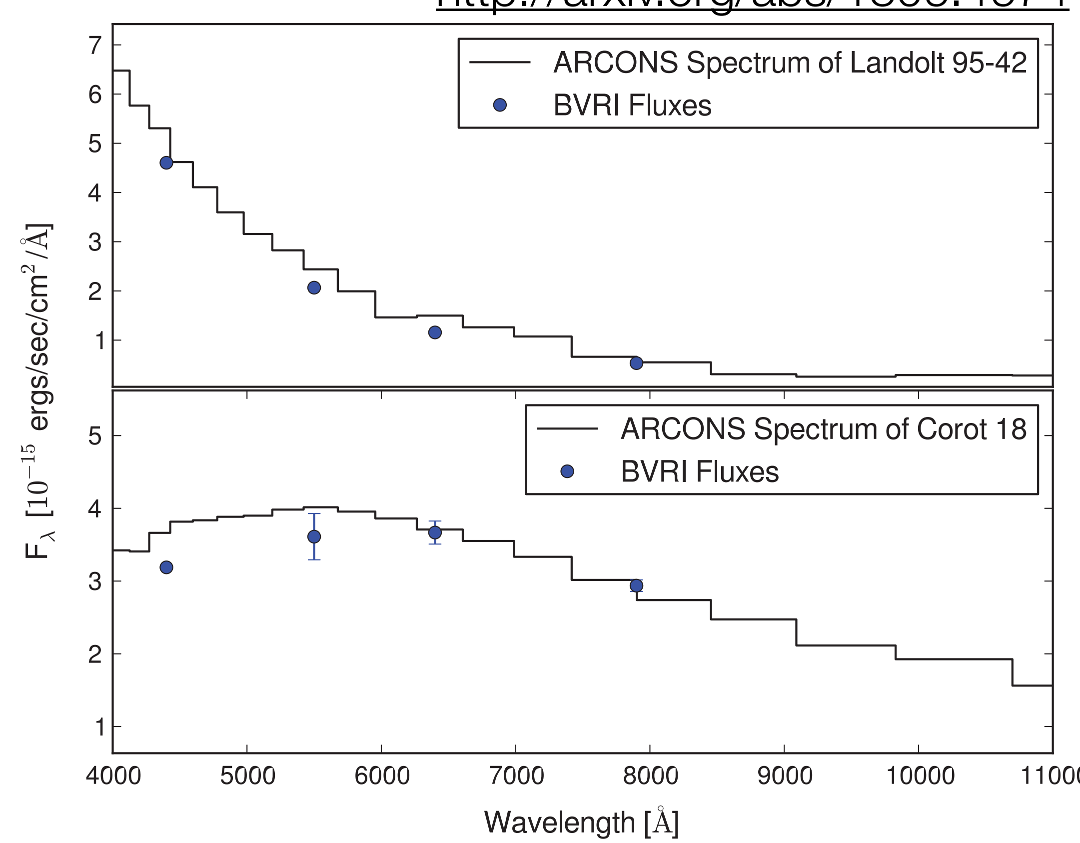
Superconducting detectors and Dark Energy

- Kinetic Inductance Detectors for simultaneous imaging and spectroscopy (spectrophotometry)

- Potential to extend to longer wavelengths (0.1 meV quanta vs 1.1 eV for semiconductor)

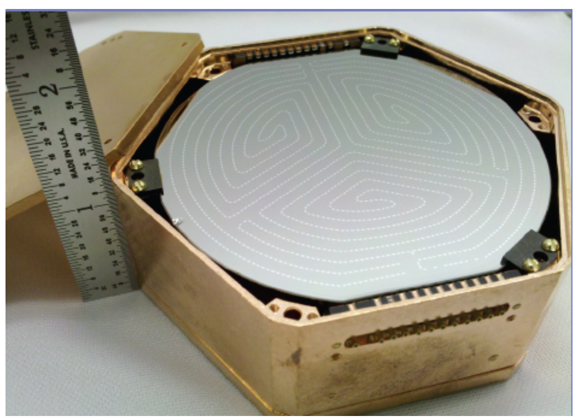


http://arxiv.org/abs/1306.4674



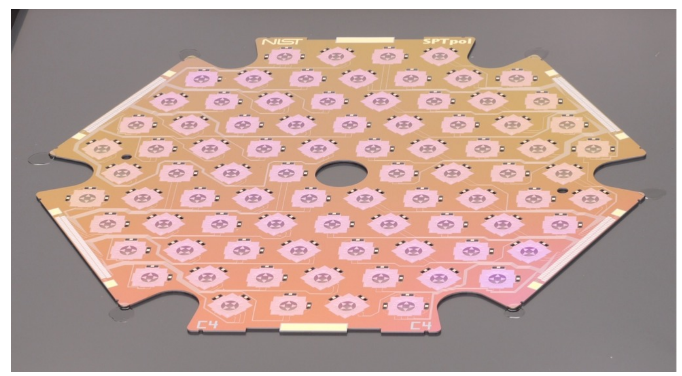
A new and broader approach?

Dark Matter



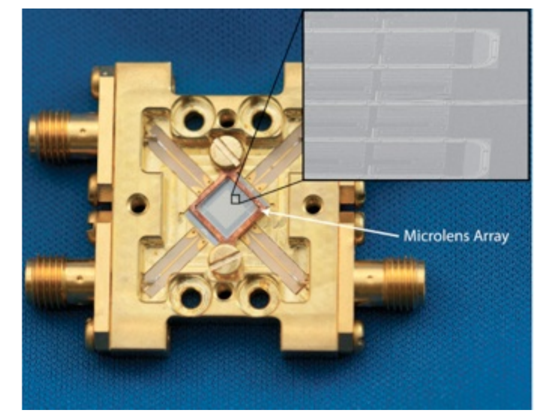
- Reduce threshold
- Increase mass

CMB



- Larger focal plane
- Increase optical bw

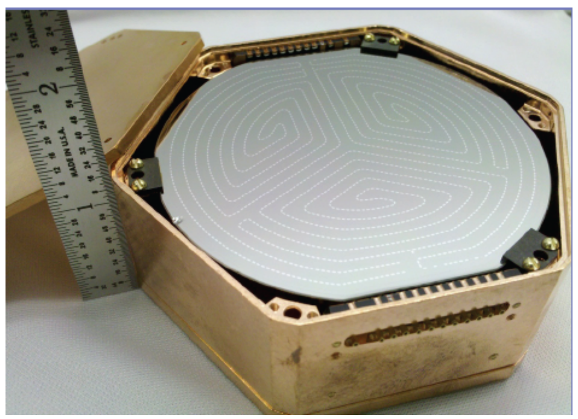
Dark Energy



- Imaging & Spec.
- Extend IR sensitivity

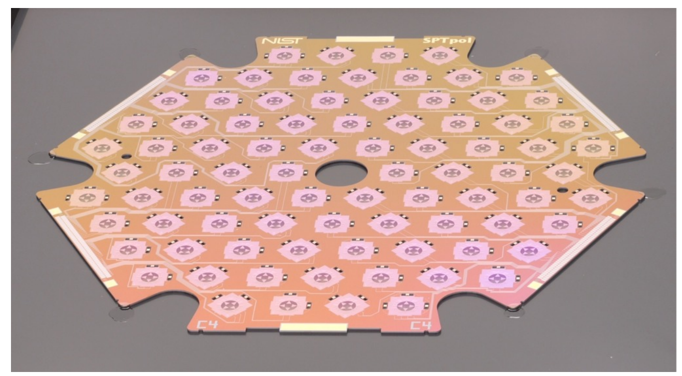
Cross-cutting resources

Dark Matter



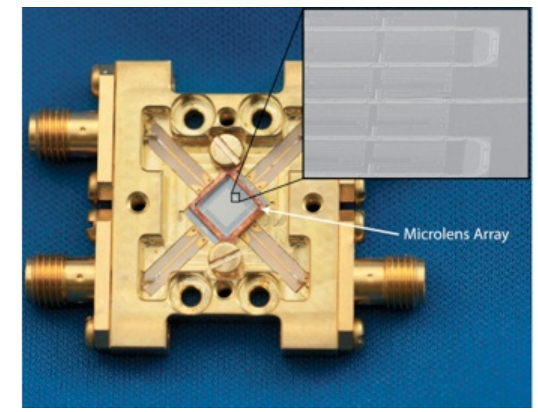
- Reduce threshold
- Increase mass

CMB



- Larger focal plane
- Increase optical bw

Dark Energy



- Imaging & Spec.
- Extend IR sensitivity

Cryogenic systems

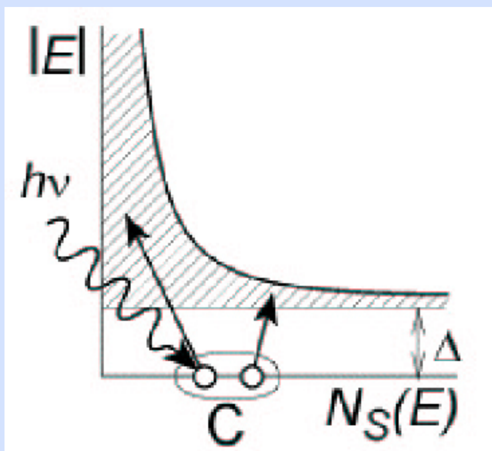
Thin film deposition

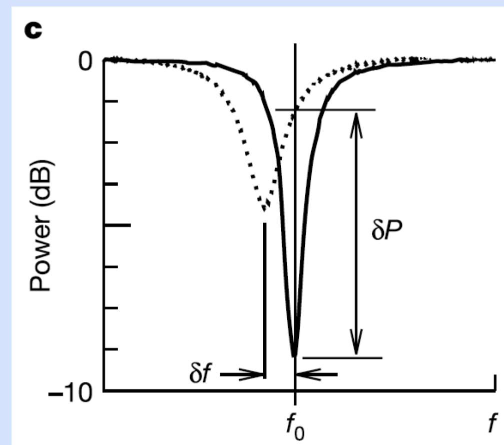
Micromachining

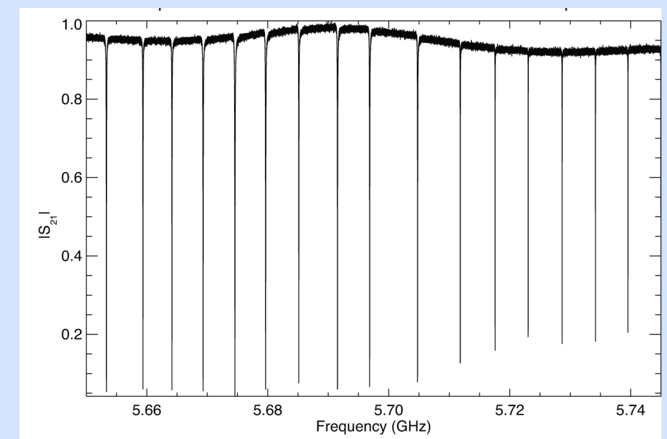
Microwave electronics

Cross-cutting applications and solutions

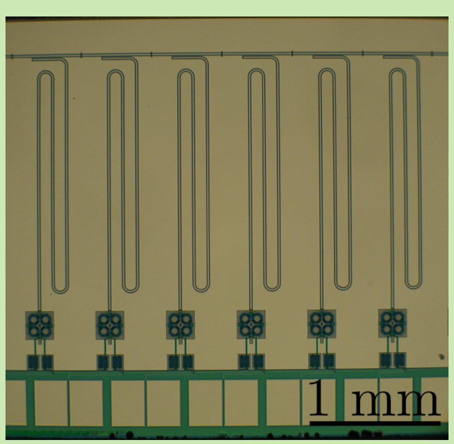
Microwave Kinetic Inductance Detector Readout

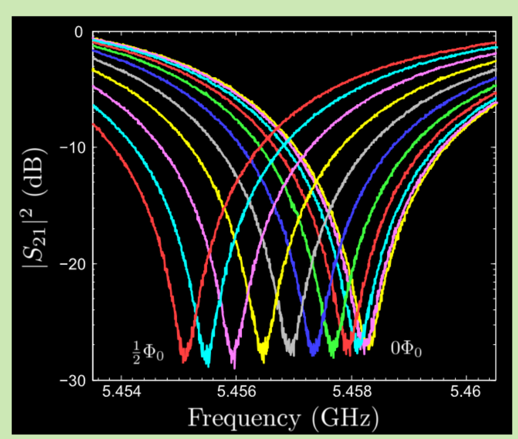






Microwave SQUID Multiplexer Readout





New opportunities

- Combine CDMS-type detectors with mKID technology for a “CDMS-inspired” GX? detector
  - Fully exploit phonon-based event reconstruction
  - Maybe cheaper fab?
- Build CMB bolometer technology into beta-decay micro-calorimeter for Cosmic Neutrino Background detection
- Extend low-threshold CDMS detectors to coherent neutrino scattering

Superconducting Detector Instrumentation R&D

- Cosmic Frontier needs new detectors with increased spatial instrumentation, increased energy bandwidth, and increased readout throughput

- Superconducting detector technology has matured where R&D of large superconducting detector arrays can address these needs for DM, CMB, and DE

- Benefits from sharing limited access/expensive resources (reduced cost), diversified applications (reduce risk and new opens new opportunities), exchange of ideas (improved problem solving)

- There is no other program like this for HEP. Success with any single application would provide unique HEP leadership for that application. Resonates with similar programs for NASA.

Other ideas?

- SiPM arrays
  - potential applications for UHECR and gamma rays
  - need large arrays with low power and high bandwidth DAQ
  - ASIC readouts