Pixelization at the Cosmic Frontier

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CSS 2013 / Snowmass on the Mississippi
Thick CCDs and the Cosmic Frontier

- Dark Energy
  - DES
  - LSST
  - MS-DESI

- Dark Matter
  - DAMIC

Abstract: Based on these results, the shallowest site has produced the best limits for DM searches at Fermi National Accelerator Laboratory using a detector search using CCDs that can operate at a threshold of 40 eV. The SNOLAB underground laboratory in Canada has low intrinsic background due to its 6000 m.w.e. overburden. The detector hall at FNAL which is only at a 350 m.w.e. depth.

Figure 5 shows a schematic view of the detector shield. The SNOLAB underground laboratory in Canada has low intrinsic background due to its 6000 m.w.e. overburden. The detector hall at FNAL which is only at a 350 m.w.e. depth. The connector was moved to be outside the lead shield, allowing placing the connectors outside the shield. At the same time the new package allows for easily stacking a set of detectors to achieve a higher sensitivity and prevented the identification of other potential neutrons coming from the cavern walls. Our simulations showed that more than 2 order of magnitude was reduced by removing most of the substrate material from the active area of the CCD.

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](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 (KID) Readout

Microwave Superconducting Quantum Interference Device (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