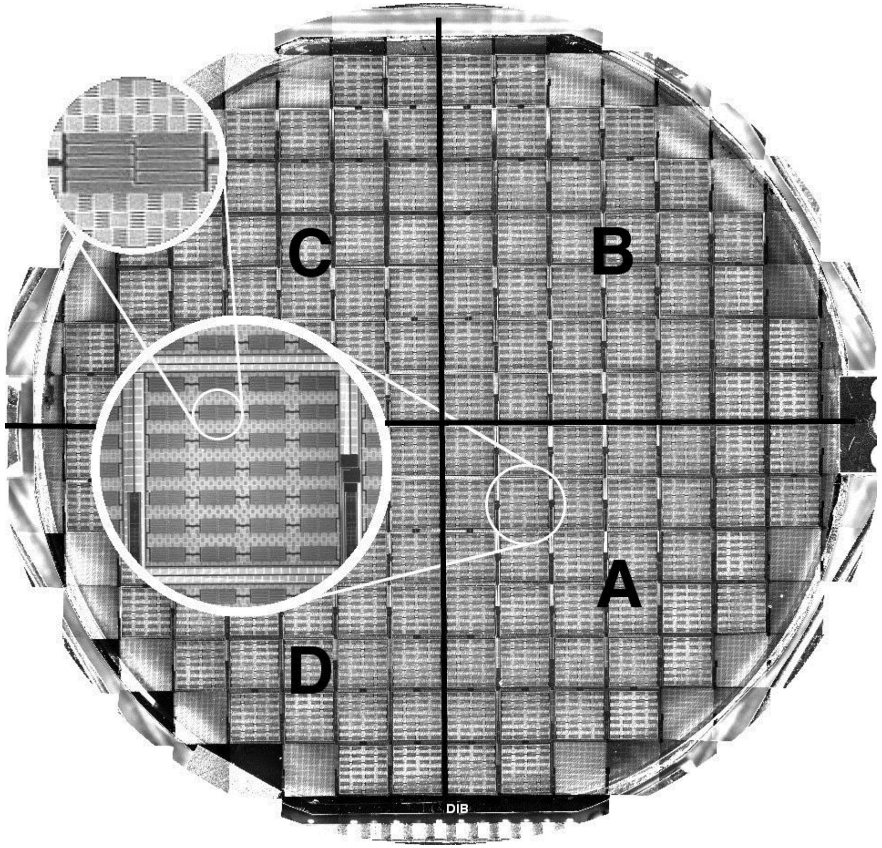
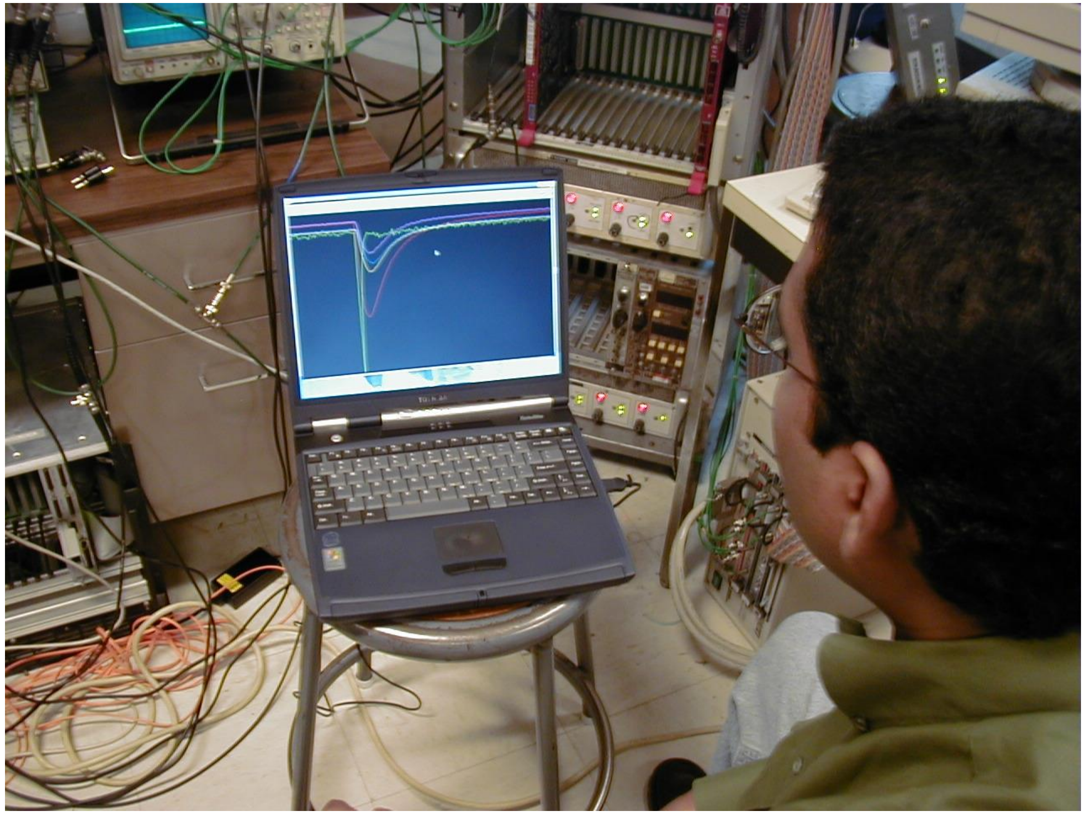
Understanding the CDMS detectors: Choose a power supply for your TES

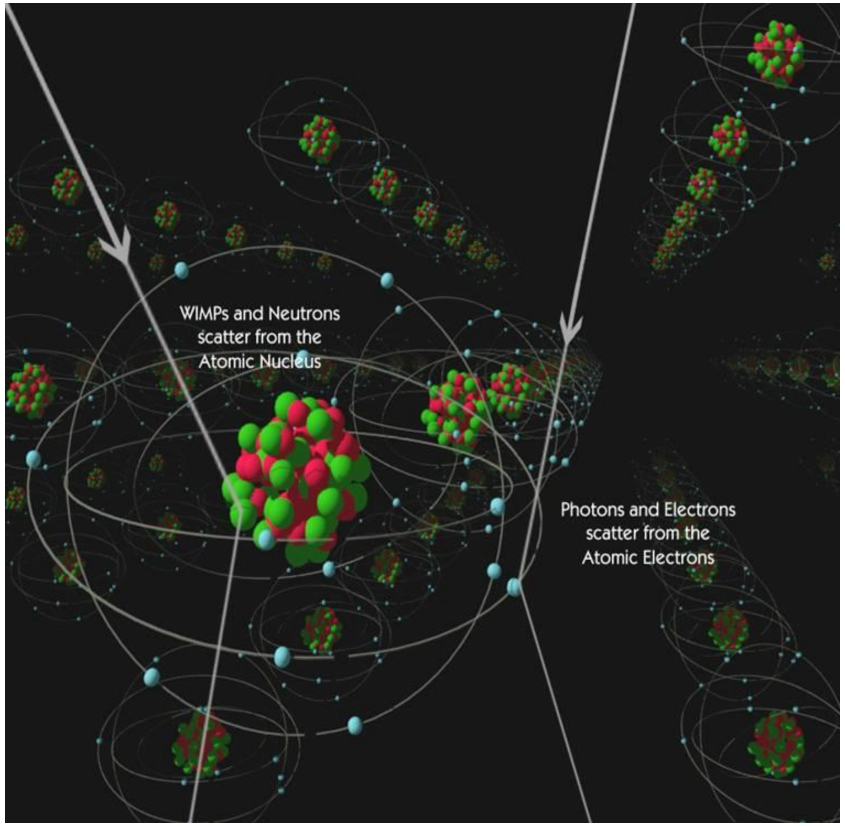




Outline

- Energy deposition in CDMS detectors
- Sensing the energy deposition
  - Transition Edge Sensor (TES)
  - Making the TES human-readable: the TES circuit I
  - Keeping the TES working: the TES circuit II
  - Requirements on circuit stability: the TES circuit III
  - Using an off-the-shelf current source: the TES circuit IV

Energy deposition: an energetic particle interacts within the CDMS crystal



At the moment of the interaction

A particle can deposit energy in a CDMS crystal in two ways:

1. Create phonons (vibrations in the crystal lattice)
2. Create ionization (electron-hole pairs)

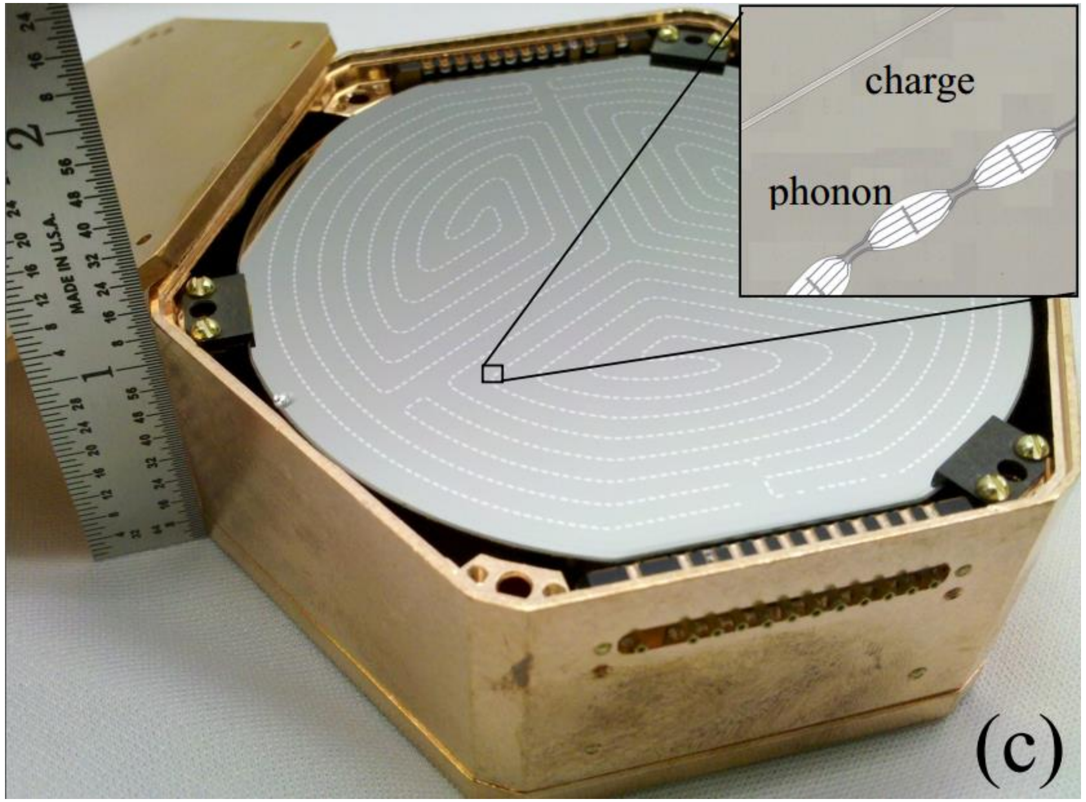
Slightly after the interaction

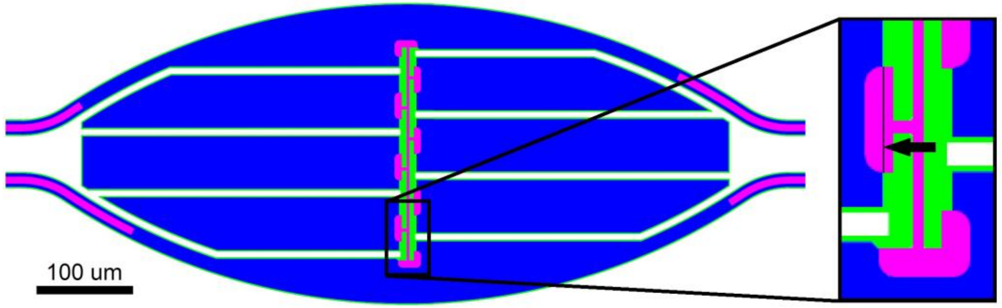
More phonons: if the electrons and holes feel an electric field, they'll accelerate and produce more phonons via the Luke-Neganov effect.

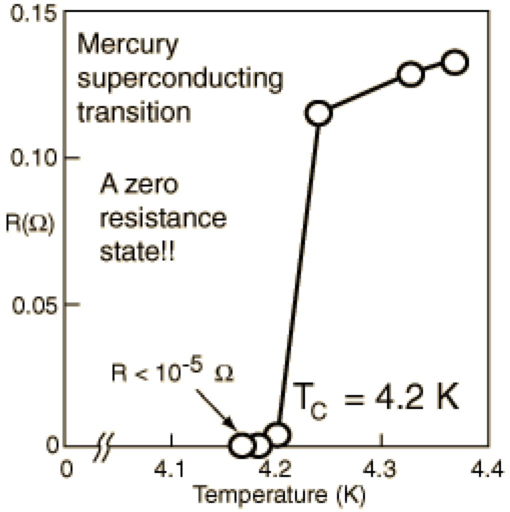
A lucky break

A particle interacting with the detector has two options: (1) interact with a nucleus and (2) interact with an electron. When a particle interacts with a nucleus, the energy preferentially goes into phonon creation; with an electron interaction, the energy preferentially goes to ionization.

See the energy

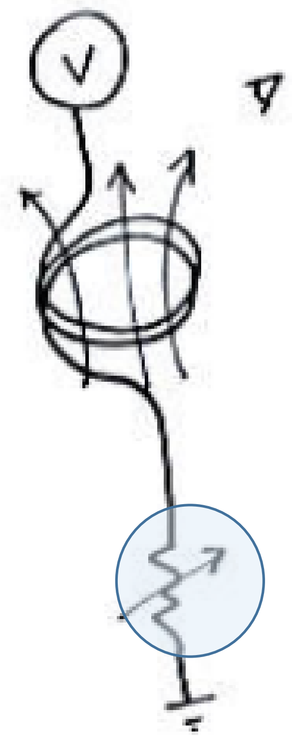






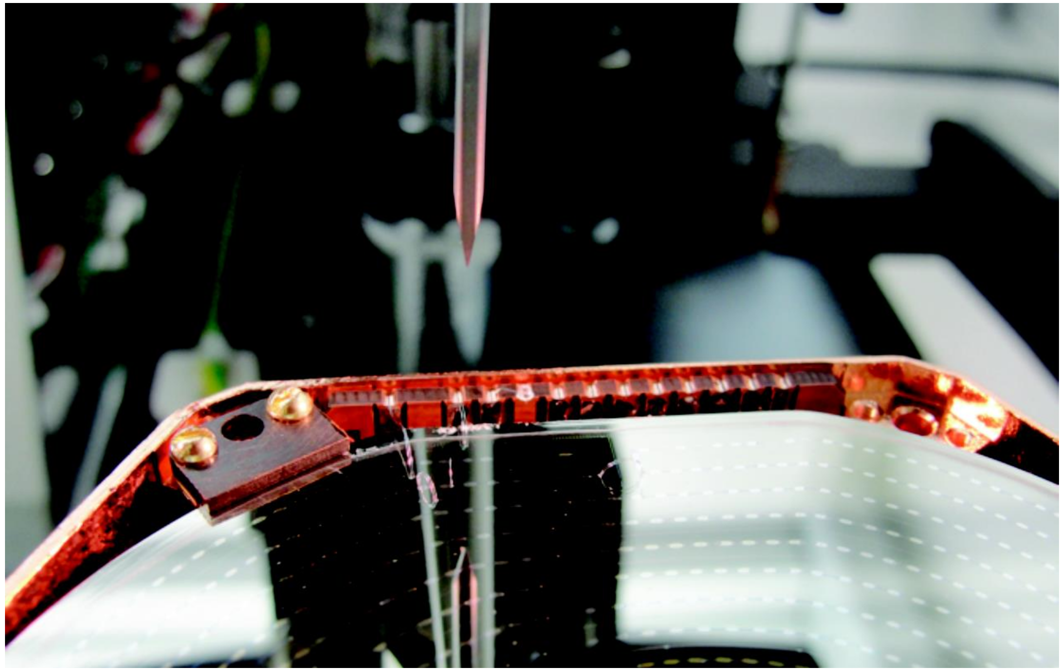
Deposit energy
⇒ Increase TES temperature
⇒ Increase TES resistance

See the energy



We can use SQUIDS to see magnetic fields with very little added noise

The TES is on the crystal



See the energy for multiple events

$$P = I^2 R$$

$$\delta P = 2 I R \,\delta I + I^2 \delta R$$

is $\delta P < 0$?

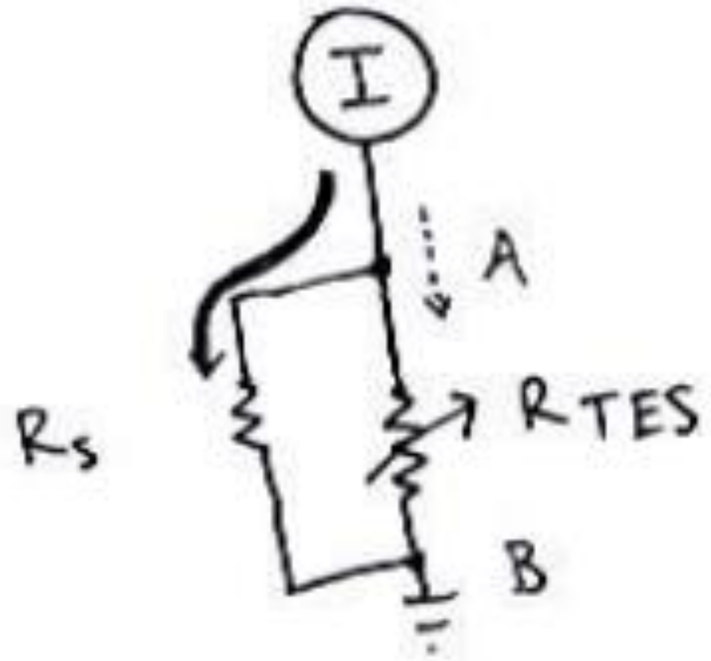
in this circuit the voltage is constant

$$\delta V = I \,\delta R + R \,\delta I = 0$$

$$\delta P = -2 I^2 \delta R + I^2 \delta R$$

$$= -I^2 \delta R$$

See the energy with existing power-supply technology



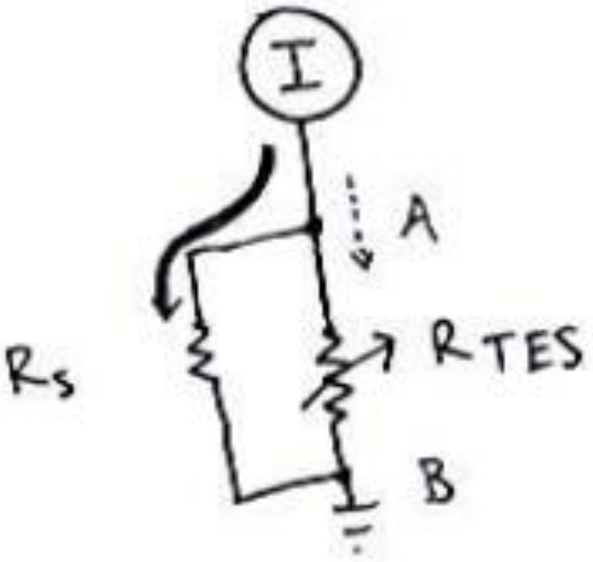
$$V_{AB} = I_{TES} R_{TES} = I_s R_s$$

$$V_{AB} = \underbrace{I \times \frac{R_{TES}}{R_s + R_{TES}}}_{I_s} \times R_s$$

$$= I R_s \times \frac{1}{1 + R_s / R_{TES}}$$

The TES (one channel = an array of sensors hooked up in parallel) ends up being ~ 2 Ohms.
The shunt resistor is ~ 20 milli Ohms.

See the energy with existing power supply technology



$$I_{TES} = V_{AB} / R_{TES} \simeq I \frac{R_s}{R_{TES}}$$

$$\delta I_{TES} = \underbrace{\frac{R_s}{R_{TES}} \delta I}_{\text{current source fluctuations}} - \underbrace{\frac{I R_s}{R_{TES}^2} \delta R_{TES}}_{\text{physics on the crystal}}$$

The TES (one channel = an array of sensors hooked up in parallel) ends up being ~ 2 Ohms.
The shunt resistor is ~ 20 milli Ohms.
Heating the TES into its superconducting transition typically requires ~ 20 micro Amps.