Dark Matter Detector Development

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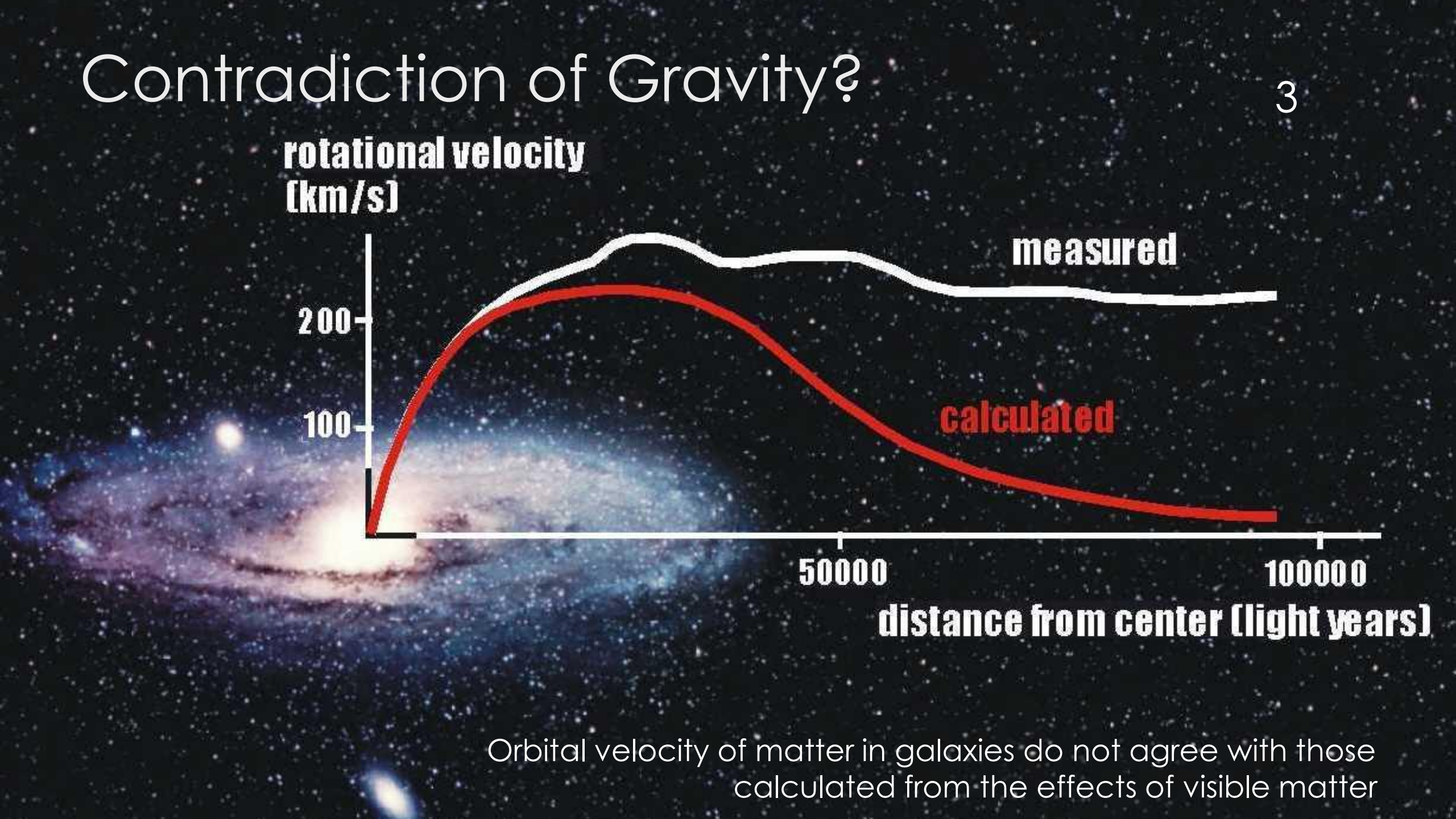
Overview

1. Dark Matter

2. Dark Matter Detector
    1. DAMIC
3. Summer Work
    1. Commissioning Cryocooler
    2. Image Testing
    3. Noise

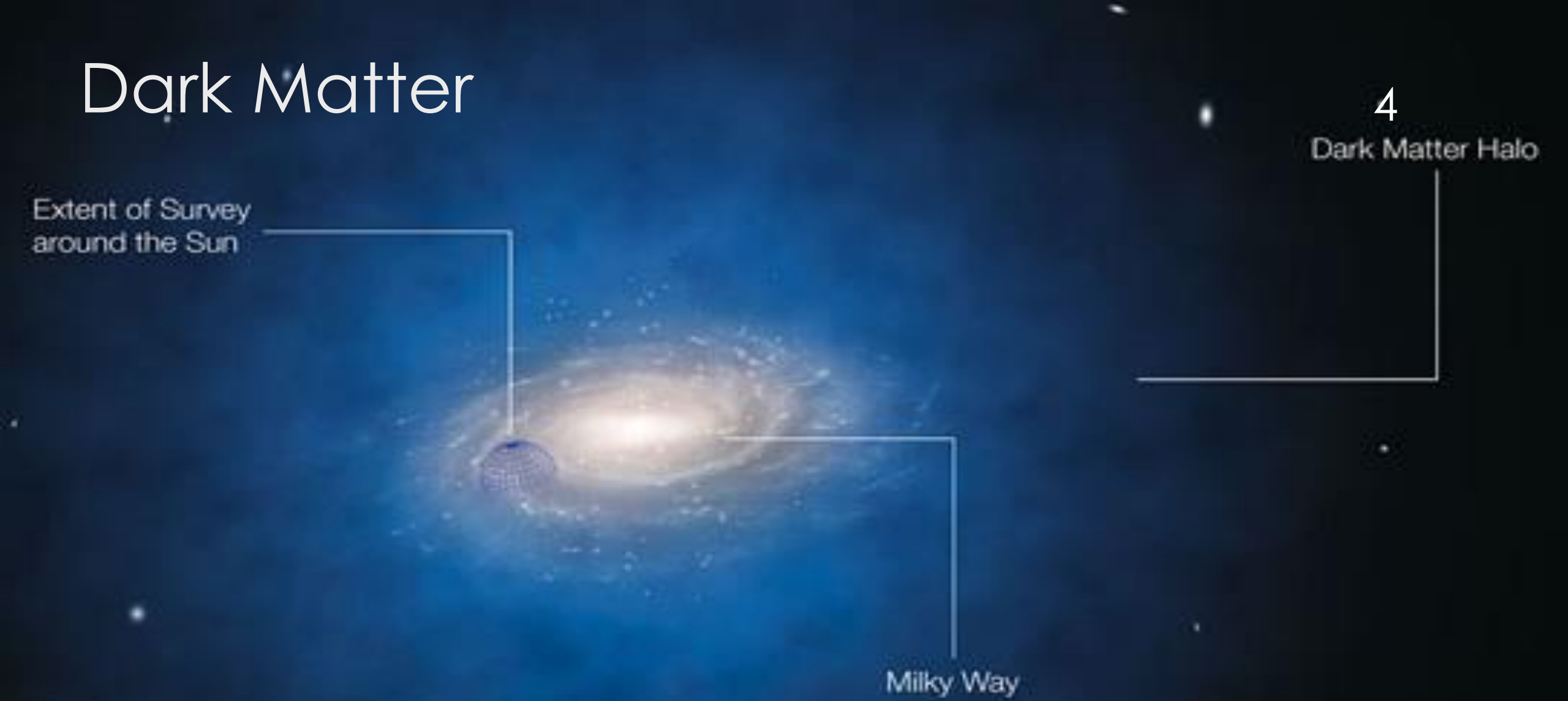
4. Future Work

Contradiction of Gravity?



Orbital velocity of matter in galaxies do not agree with those calculated from the effects of visible matter

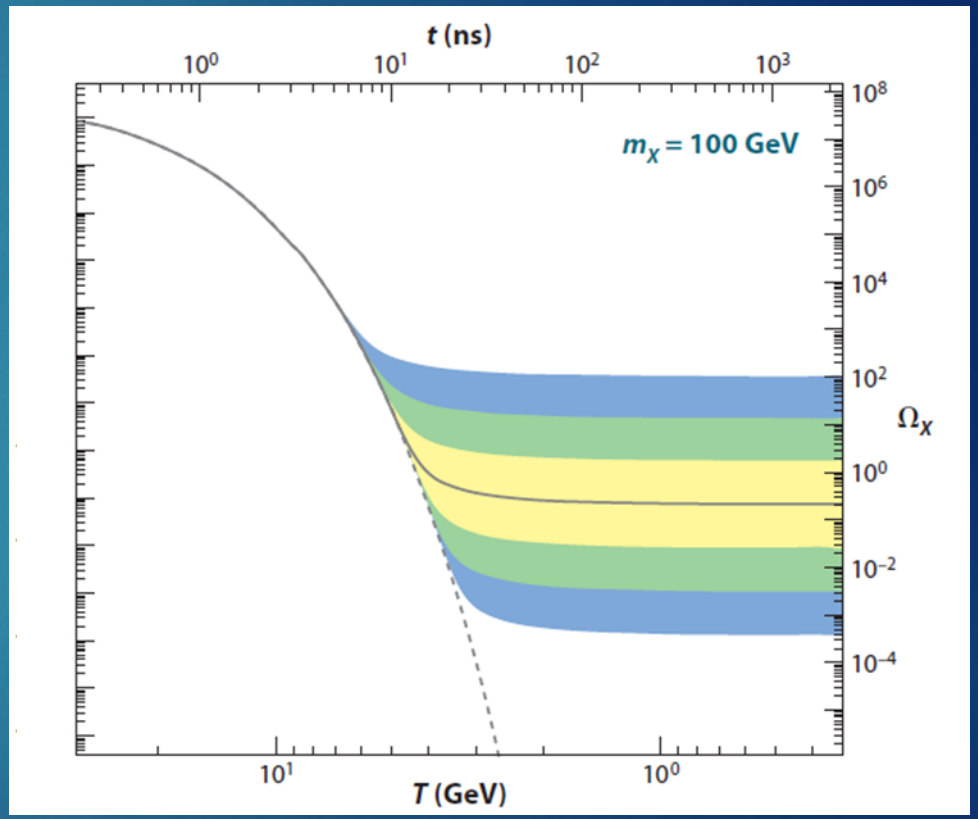
Dark Matter



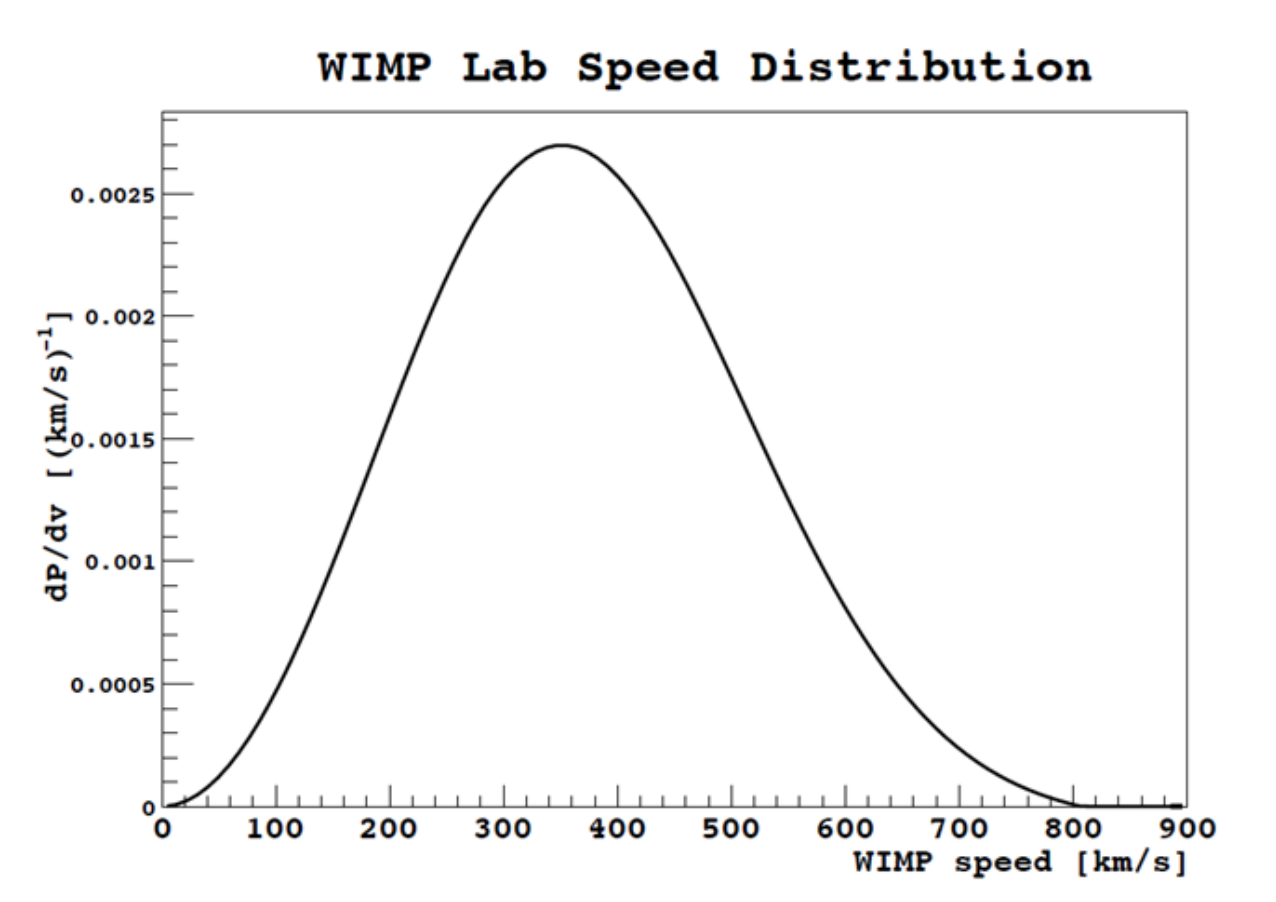
- Source of gravity like normal matter
- Does not interact electromagnetically with normal matter

Possible Particles of Dark Matter

- All of normal matter is composed of particles so dark matter could be as well.
- One possible type: Weakly Interacting Massive Particles (WIMPs)
- Created in the Big Bang
- As Universe cooled, they spread out enough to not meet and annihilate with each other
- Relic density determined by the "freezeout" conveniently fits expected density



Energy of Dark Matter



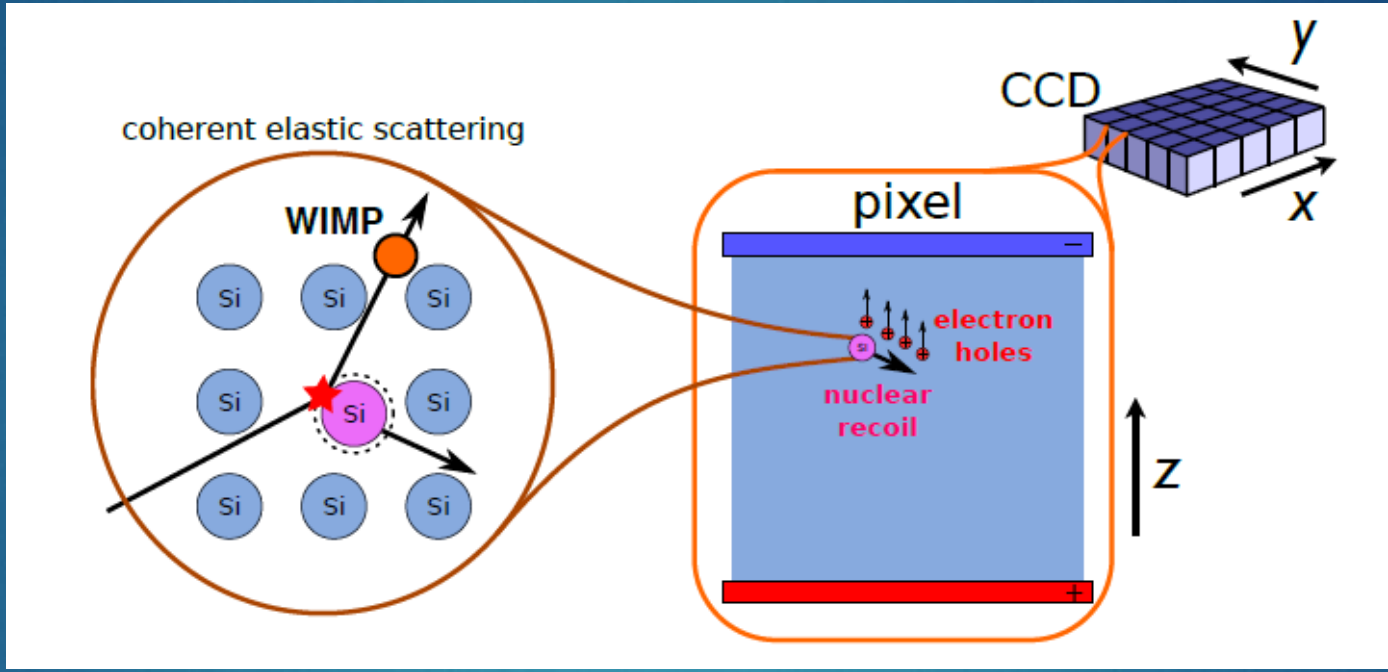
- Bound to galaxies
- From kinetic energy find mass

$$E = \frac{1}{2}Mv^2 = \frac{1}{2}Mc^2\beta^2$$

$$E \approx \left(\frac{Mc^2}{GeV}\right) keV$$

- 1 keV of kinetic energy for 1 GeV massive particle

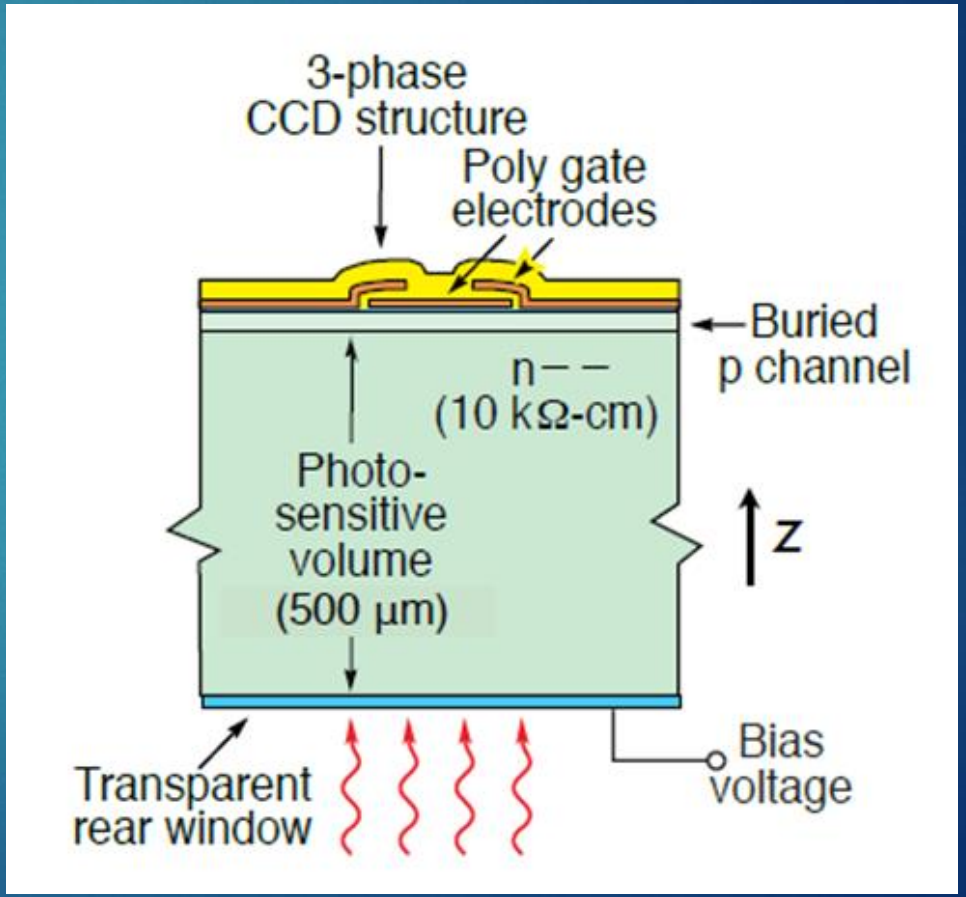
WIMP Scattering Interaction



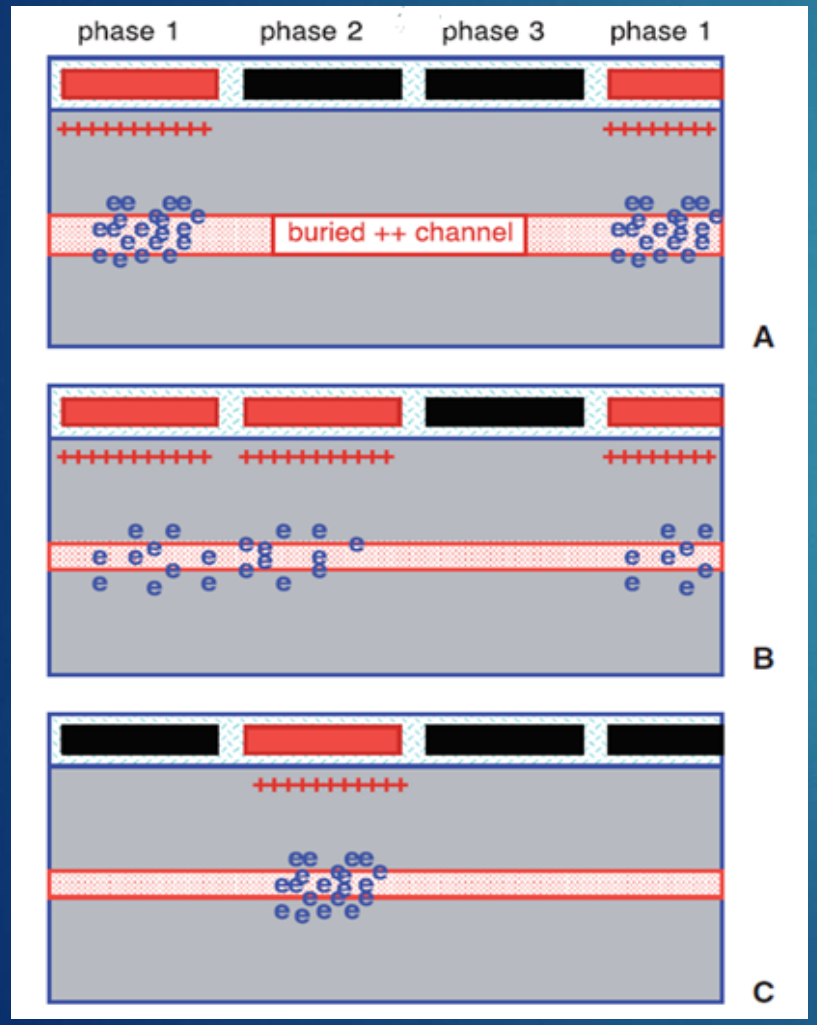
- Dark matter particles recoil off nuclei
- Nuclei deposit some of transferred kinetic energy as ionization

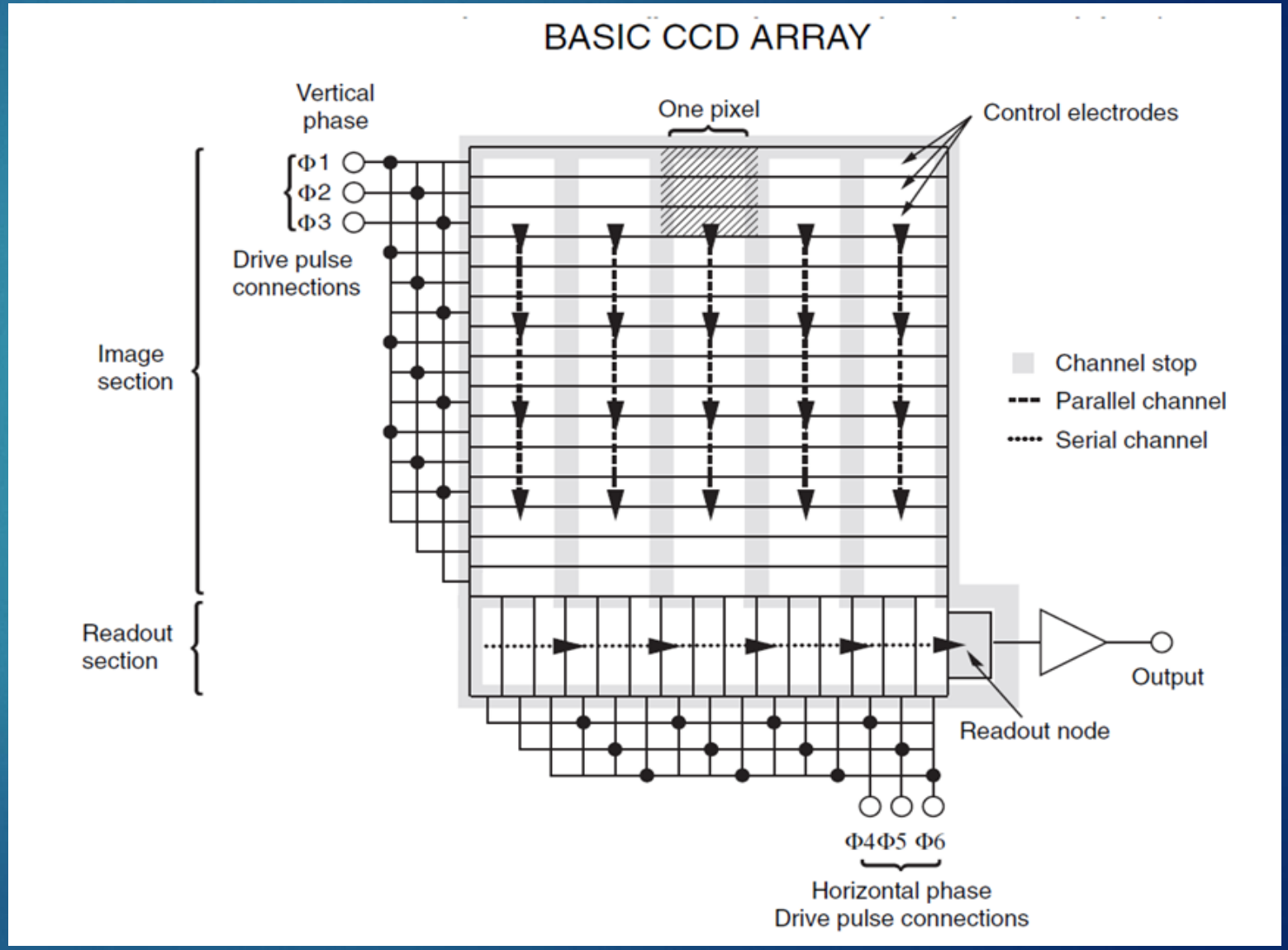
Charged-Coupled Device (CCD)

- Used in wide variety of fields for high quality imaging
- Silicon wafers divided into pixels
- Charged particles cause ionization

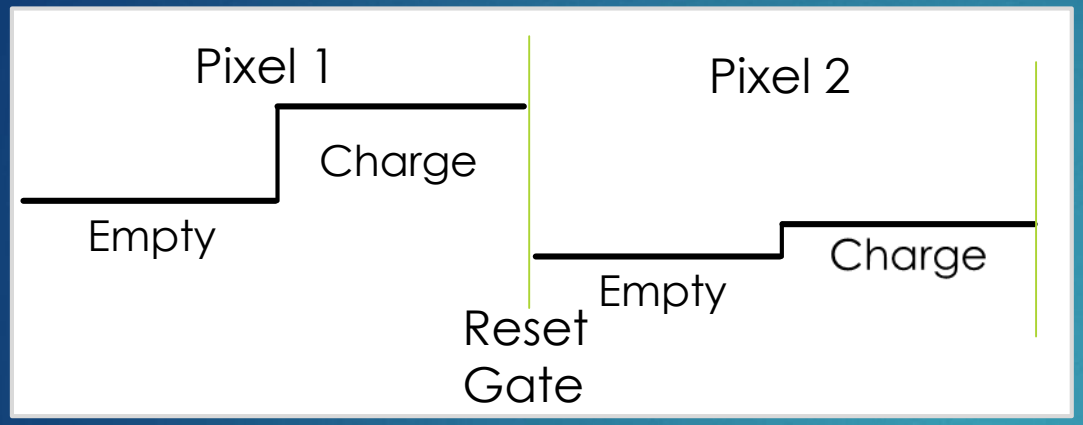


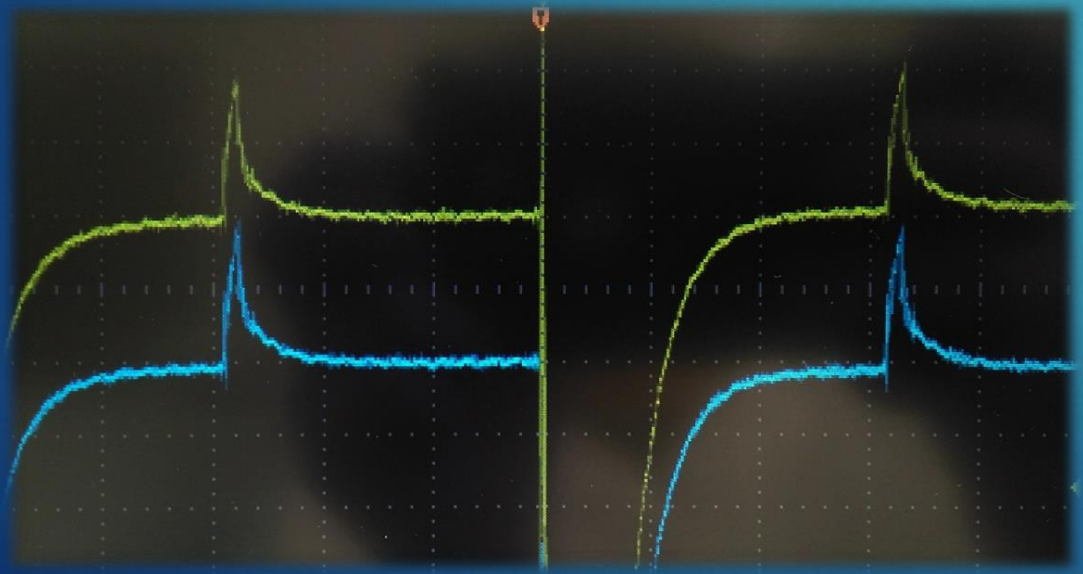
Readout Operation





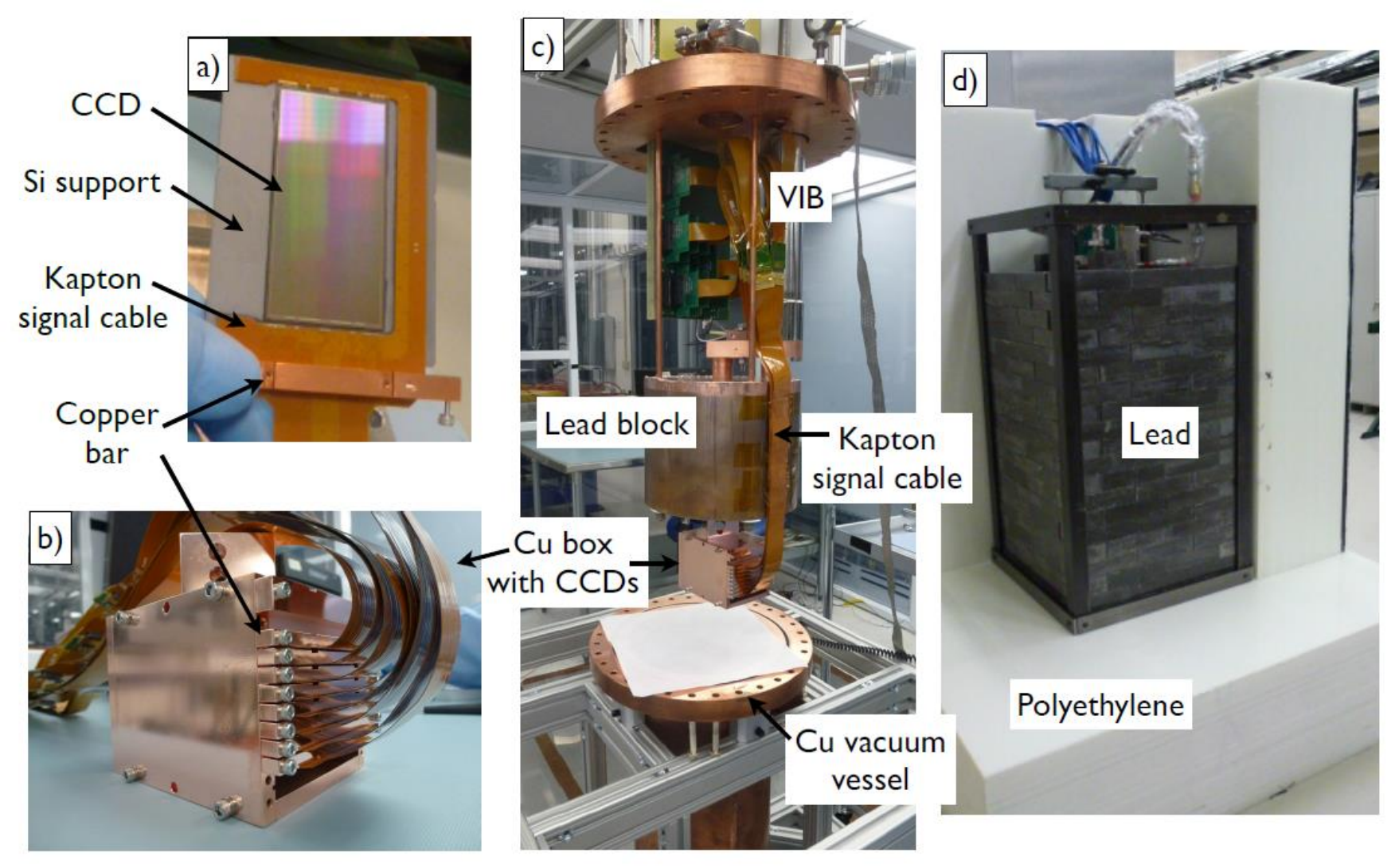
Measuring the Charge





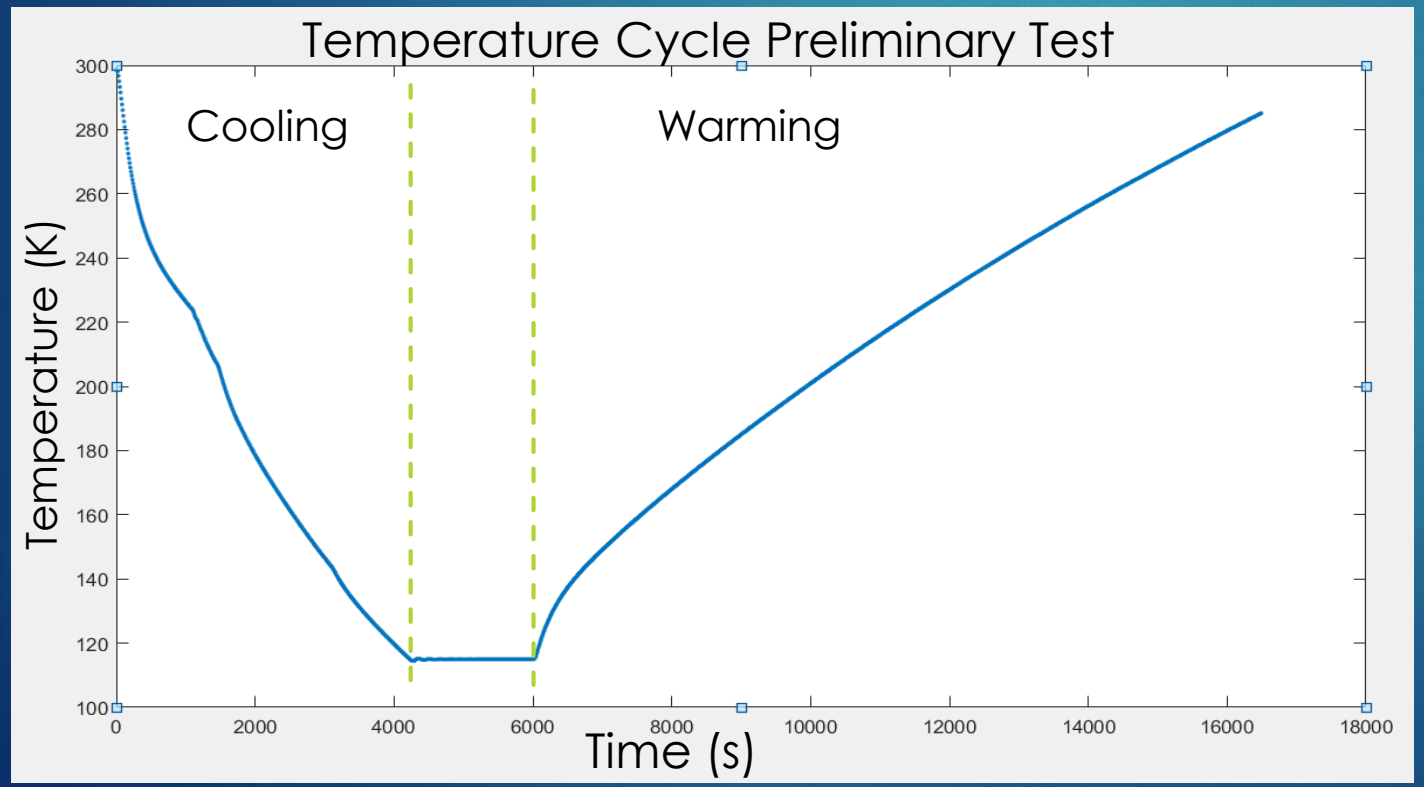
- Correlated double sampling
- Sample by integrating over measurement period
- 40 µs total integration time per pixel

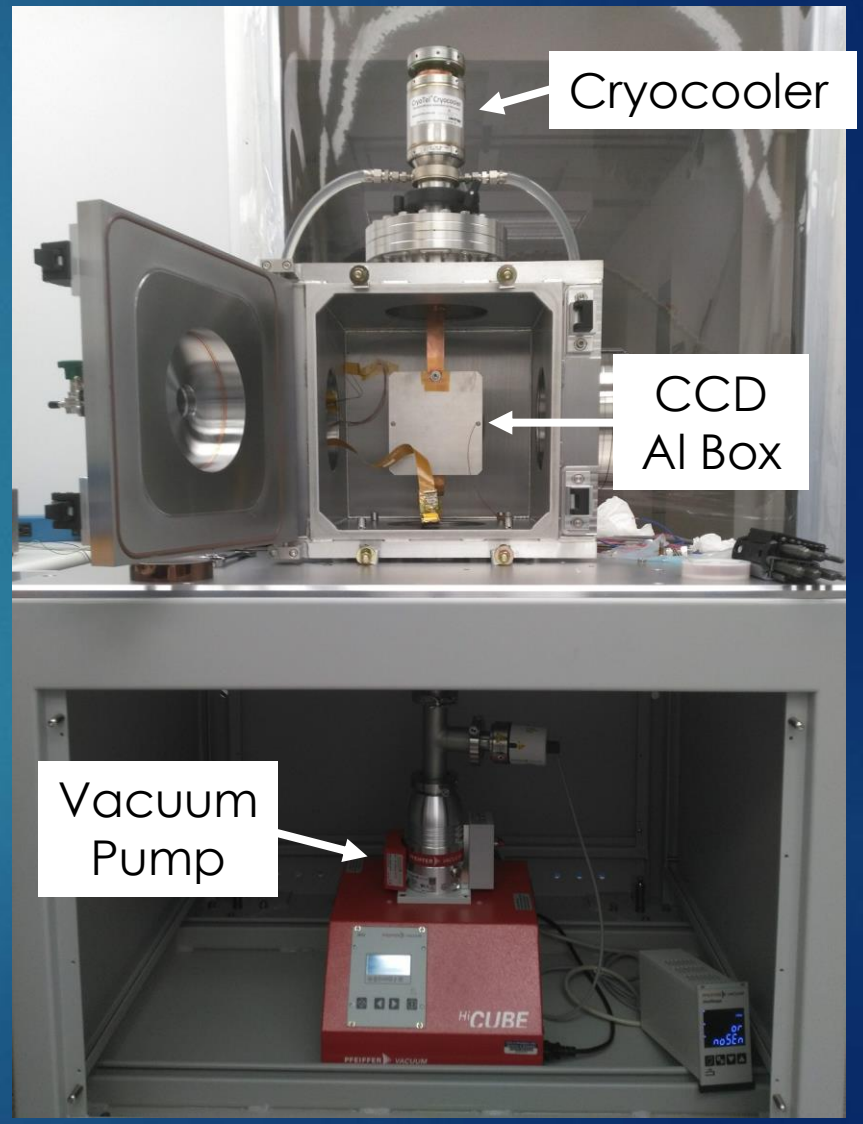
DAMIC Search Focus



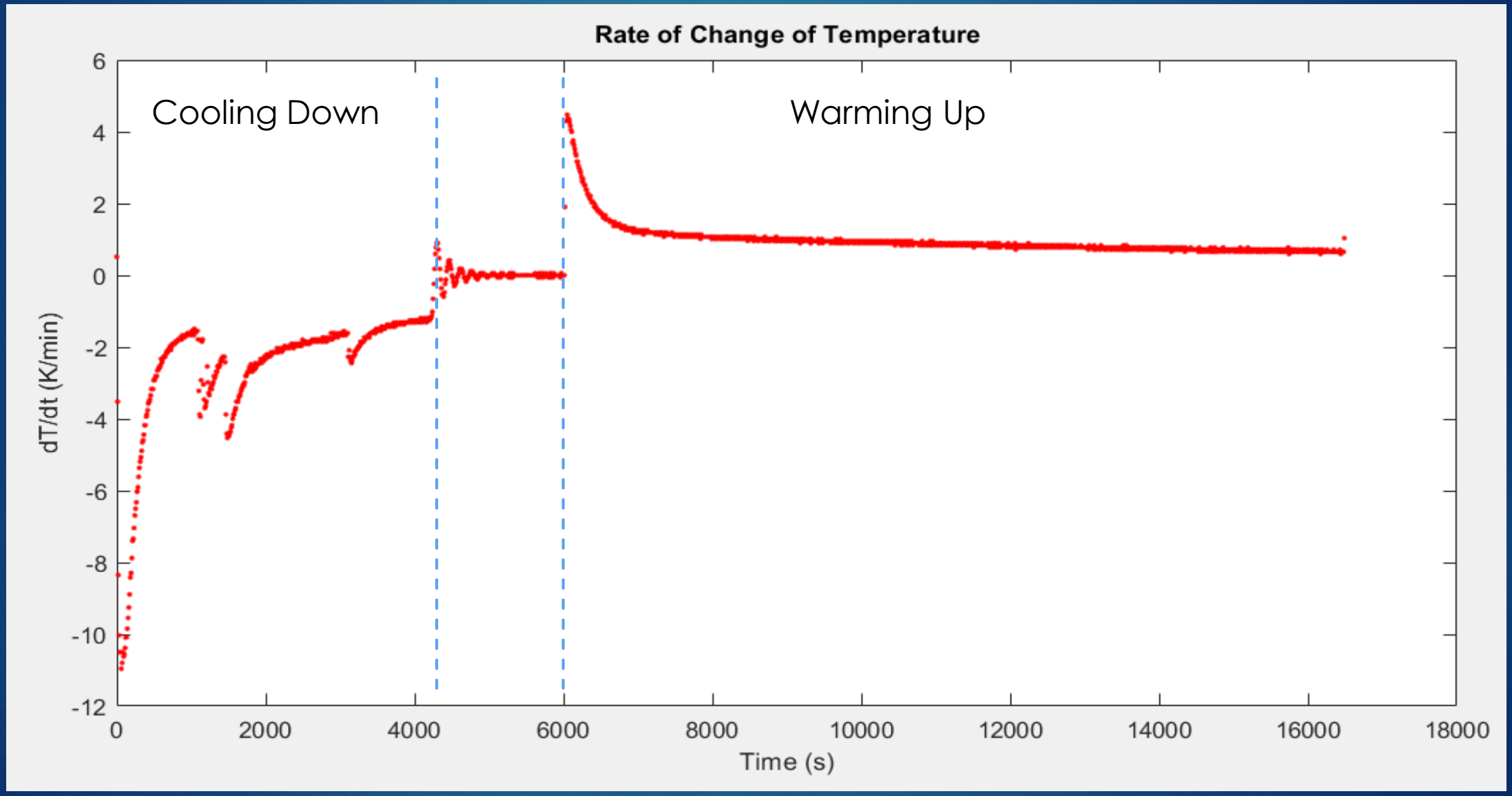
Summer Work: Commissioning a Testing Chamber

- Setting up cryocooler in vacuum chamber

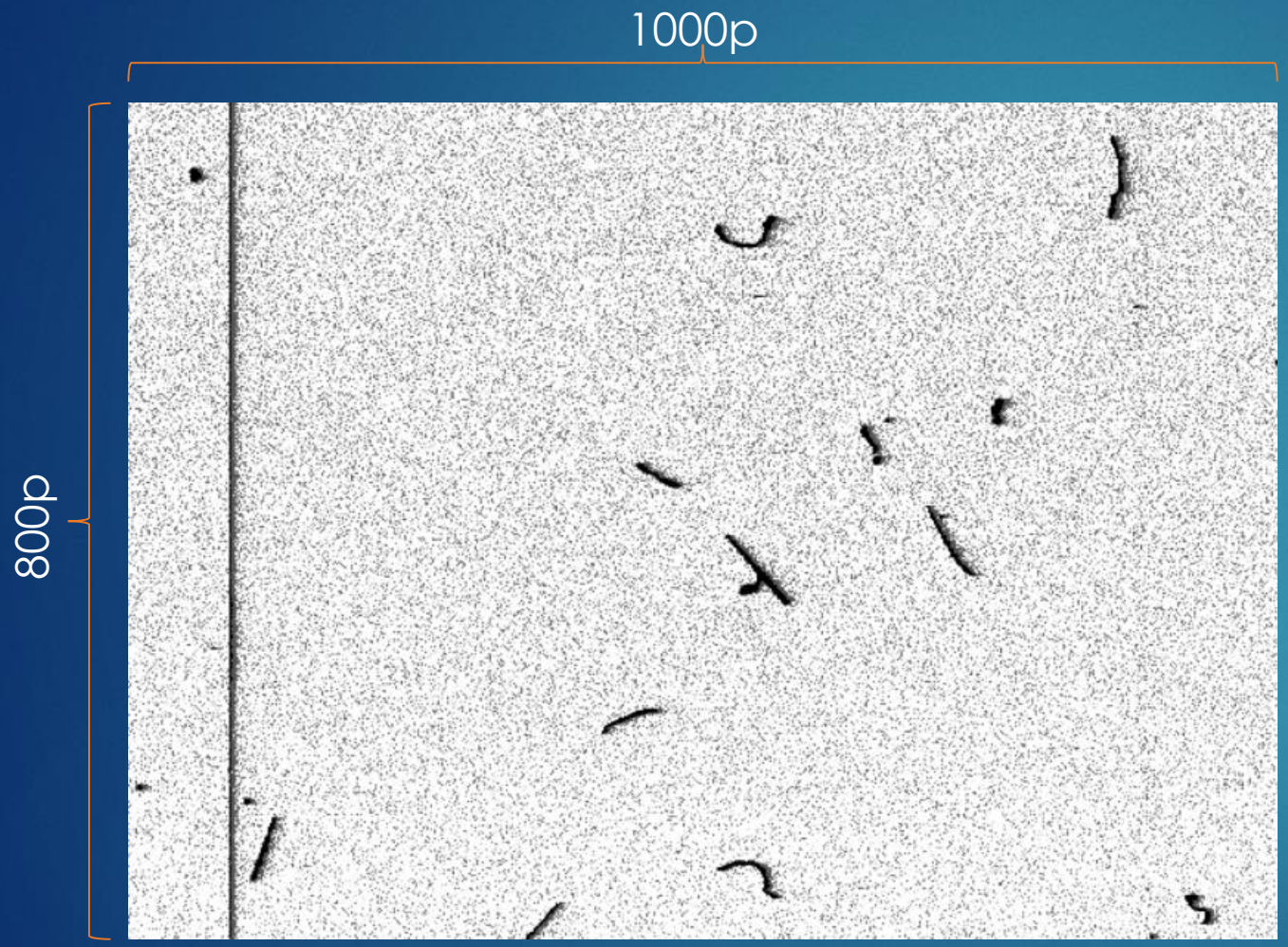


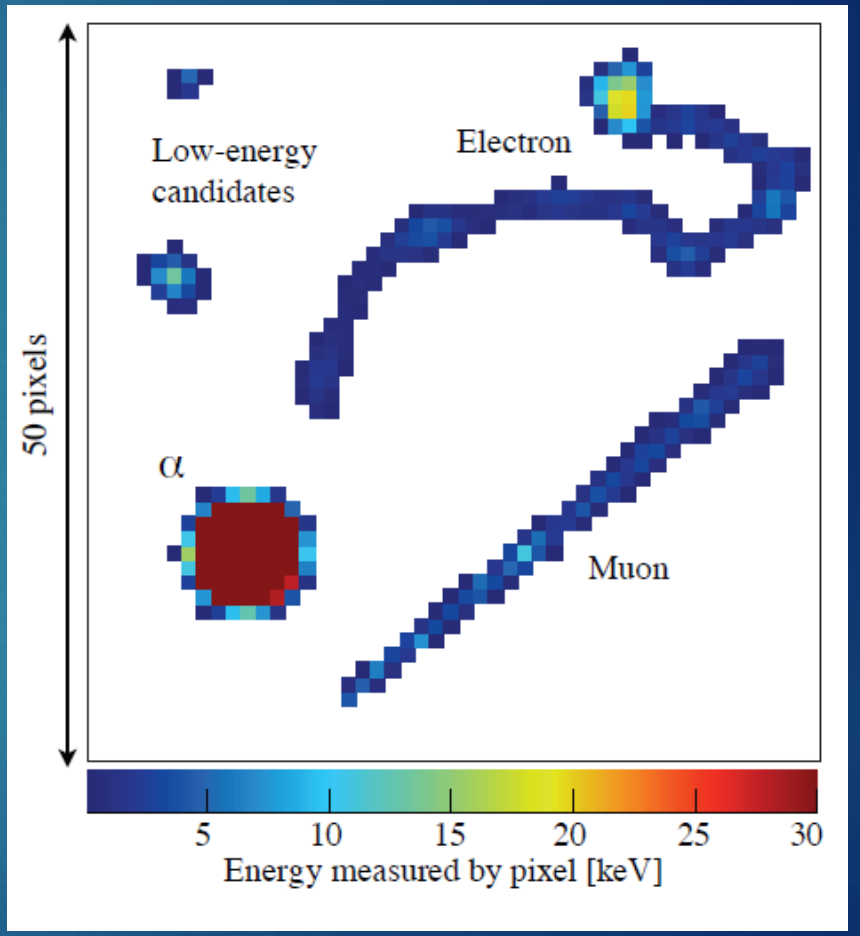


Limiting Thermal Stress



Tracks and Defects





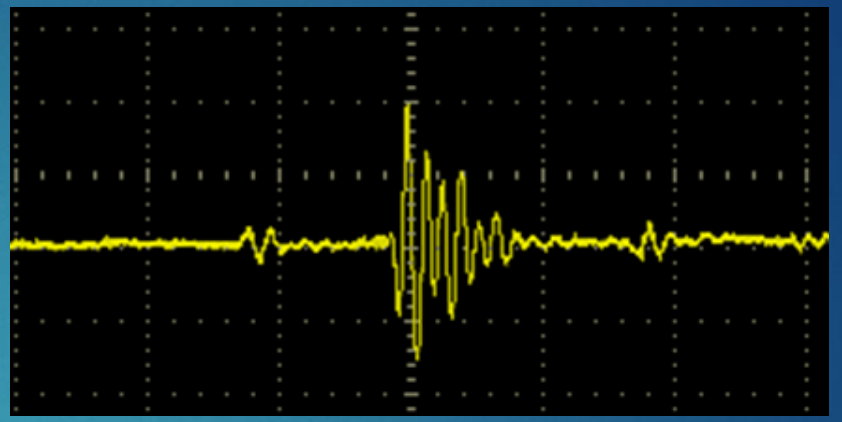
Current Obstacle: Background Noise

Image taken with cryocooler on

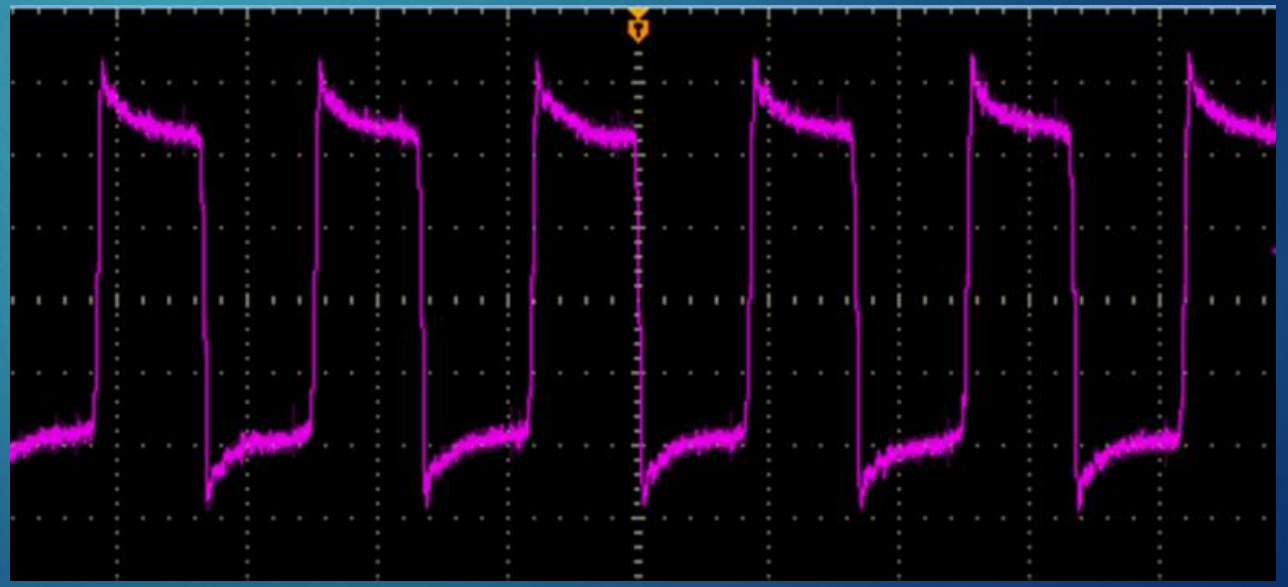
Image taken with cryocooler off

Noise

- 1 µs, 25 mV wave packet bursts
- 28 kHz 15 mV square wave
- 1 MHz 8 mV sine wave
- 156 Hz 2.6 mV sine wave



1 µs burst



28 kHz ‘square’ wave

Noise – Sources

- General Noise Level – Weak electrical connection between readout controller and chamber
- 1 μs wave packet bursts – Switching 48V DC power supply
- 28 kHz waves – RF signal from cryocooler controller
- 1 MHz wave – Ground loop

Mitigating Noise: Sequence of Attempts

- Testing different grounding configurations
- Using different outlets for the CCD readout controller and cryocooler power supply
- Replacing switching power supply with linear power supply
- Electrically and vibrationally isolating CCD from cryocooler cold tip
- Adding grounding wire between CCD box and chamber

Successes & Future Steps

- Stable vacuum at desired pressure
- Safe temperature control
- Working readout system

- Further reduce noise
  - Design cryocooler controller
  - Construct frequency filter
- Calibrate energy readings
  - Radioactive source
- Develop next generation of CCDs

Thank you

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