Searching For Vibrations Created by Dark Matter

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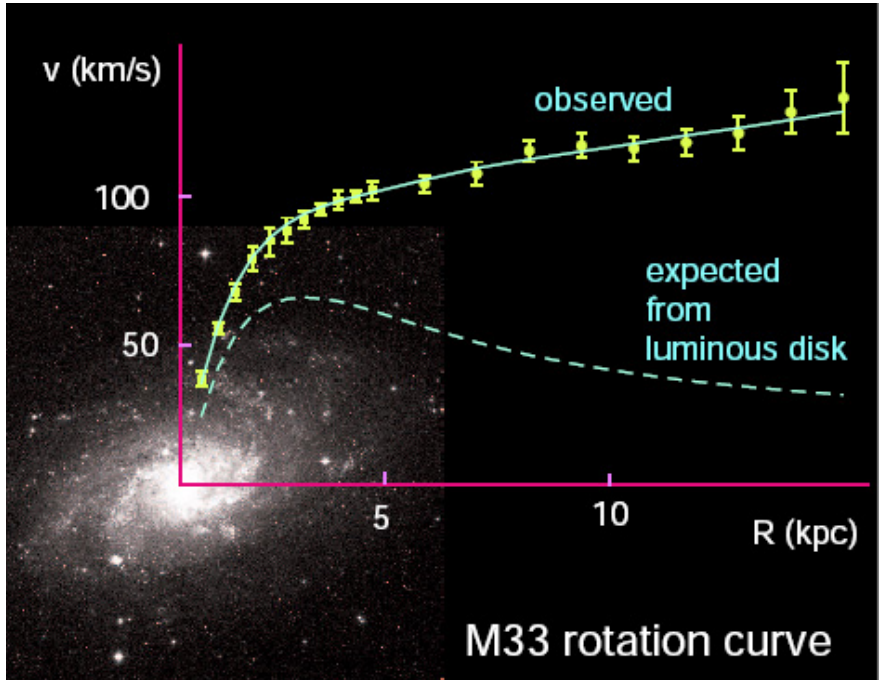
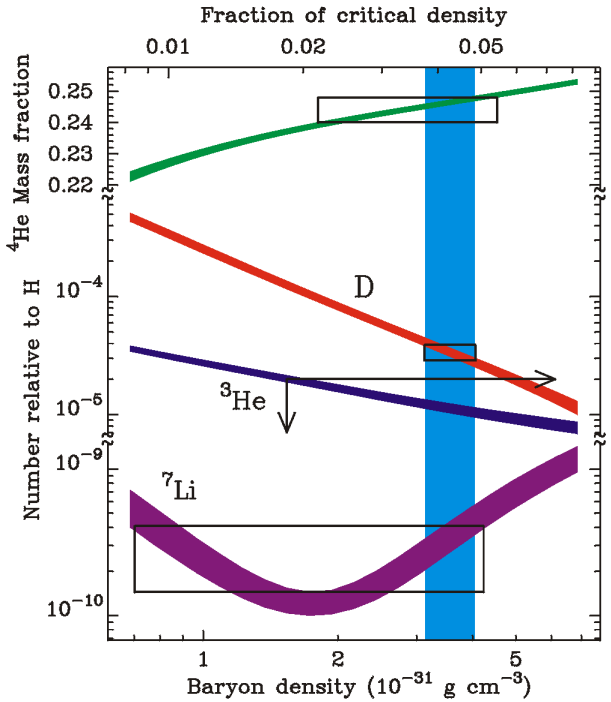
UC Berkeley

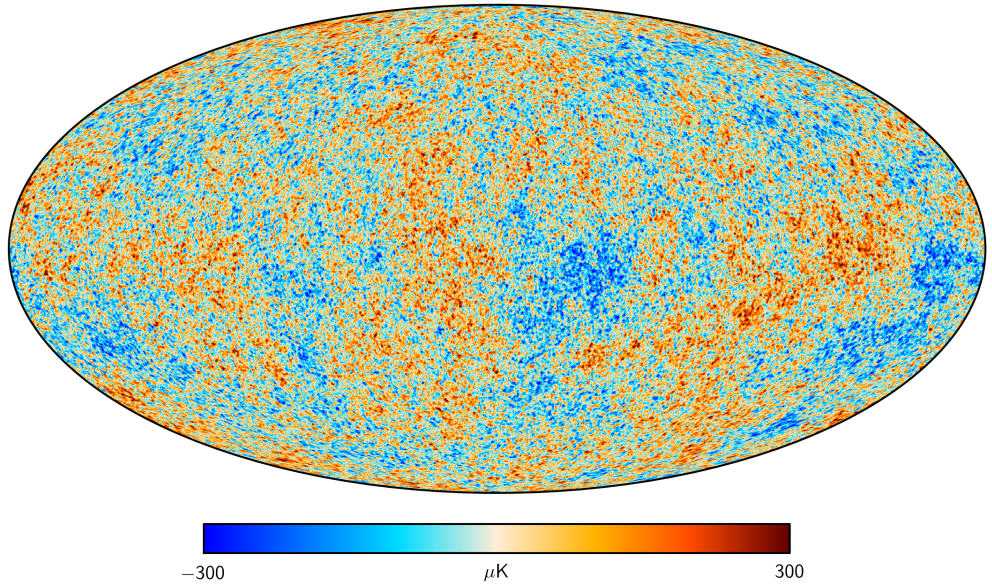
TRIUMF Science Week

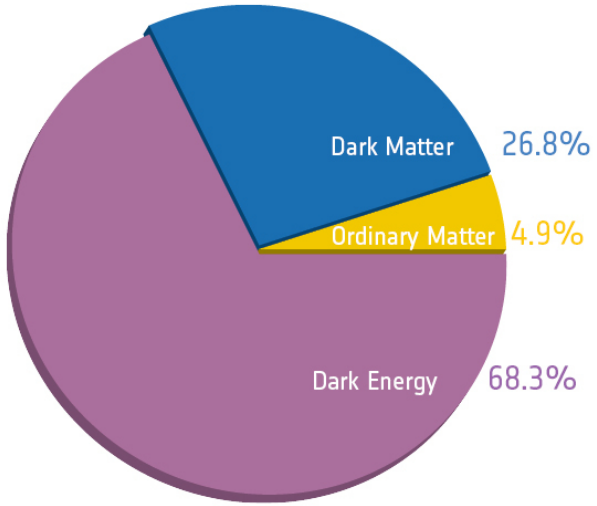
8/20/2020

Observational Evidence for Dark Matter



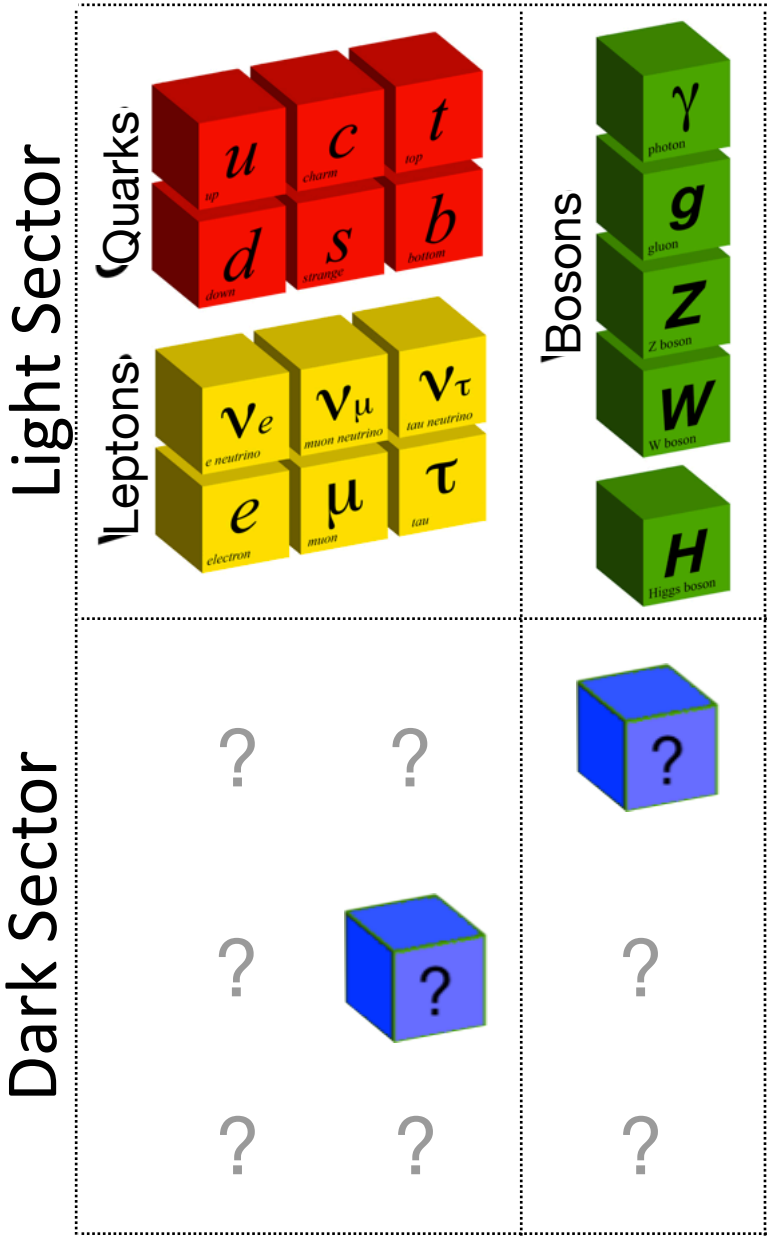






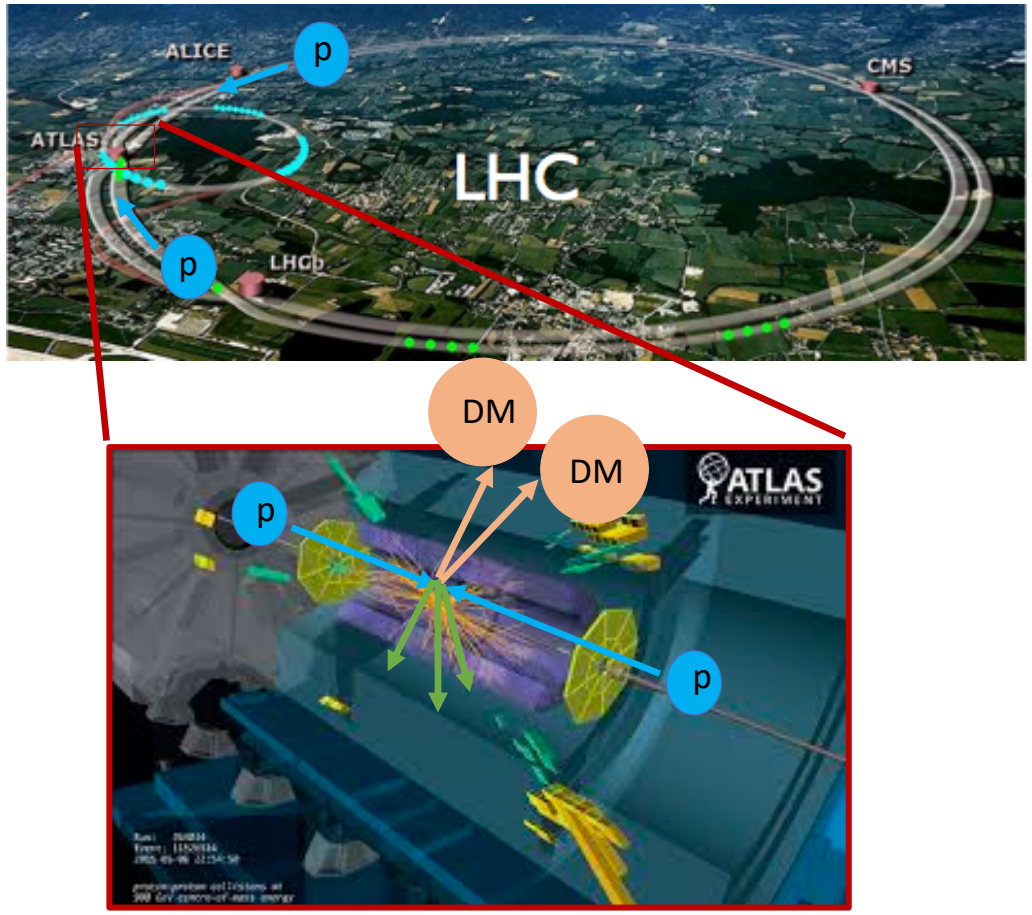
Dark Matter & Particle Physics

- What are its properties?
  - mass
  - Is it charged under a new force(s)?
  - How does it interact with the visible world
- Can this knowledge help us understand the laws of physics at high energies?

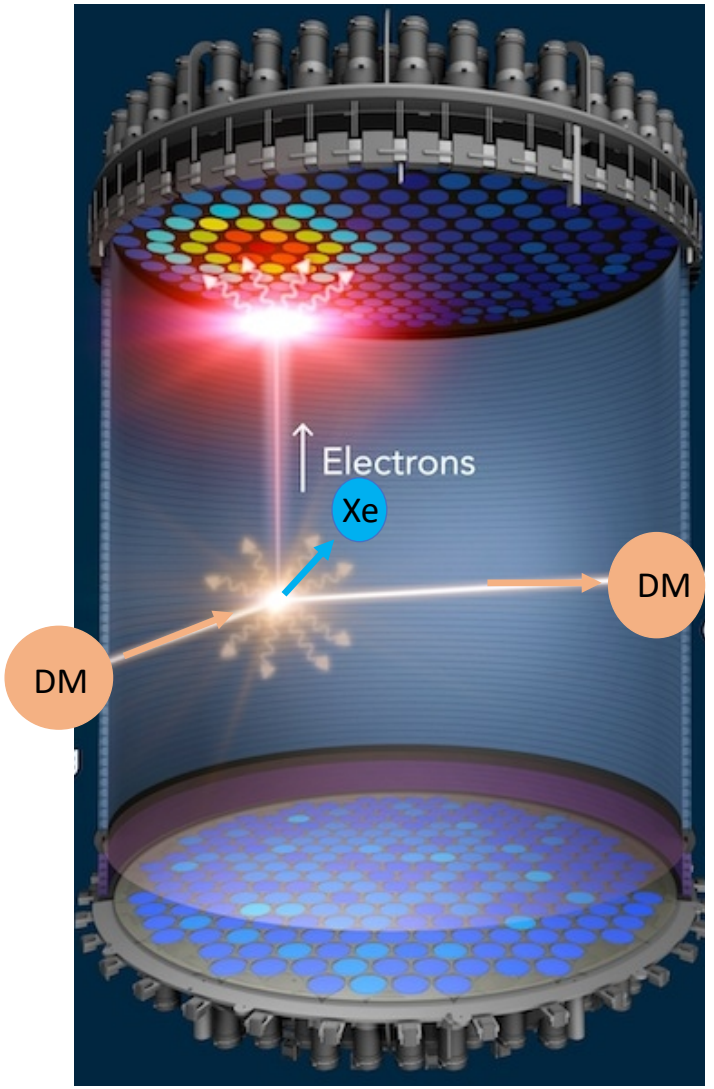


Ways to Search for Dark Matter Searches

Collider Production

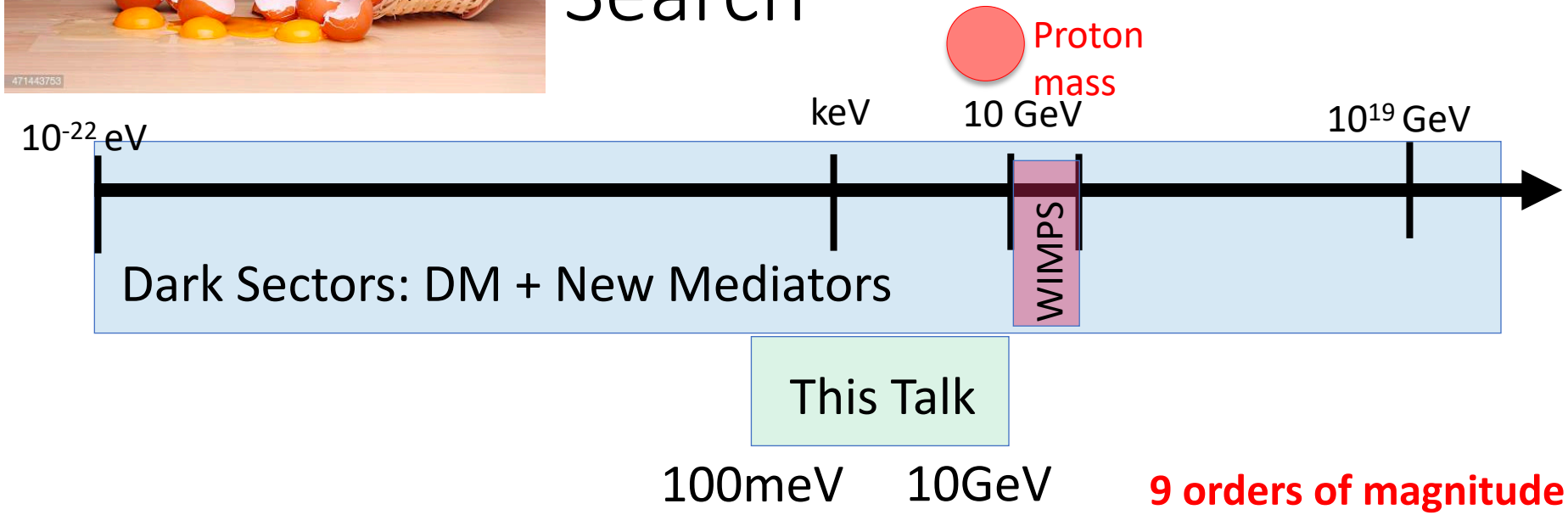


Direct Detection



WIMPs haven't yet been seen ... we continue to search in this mass range

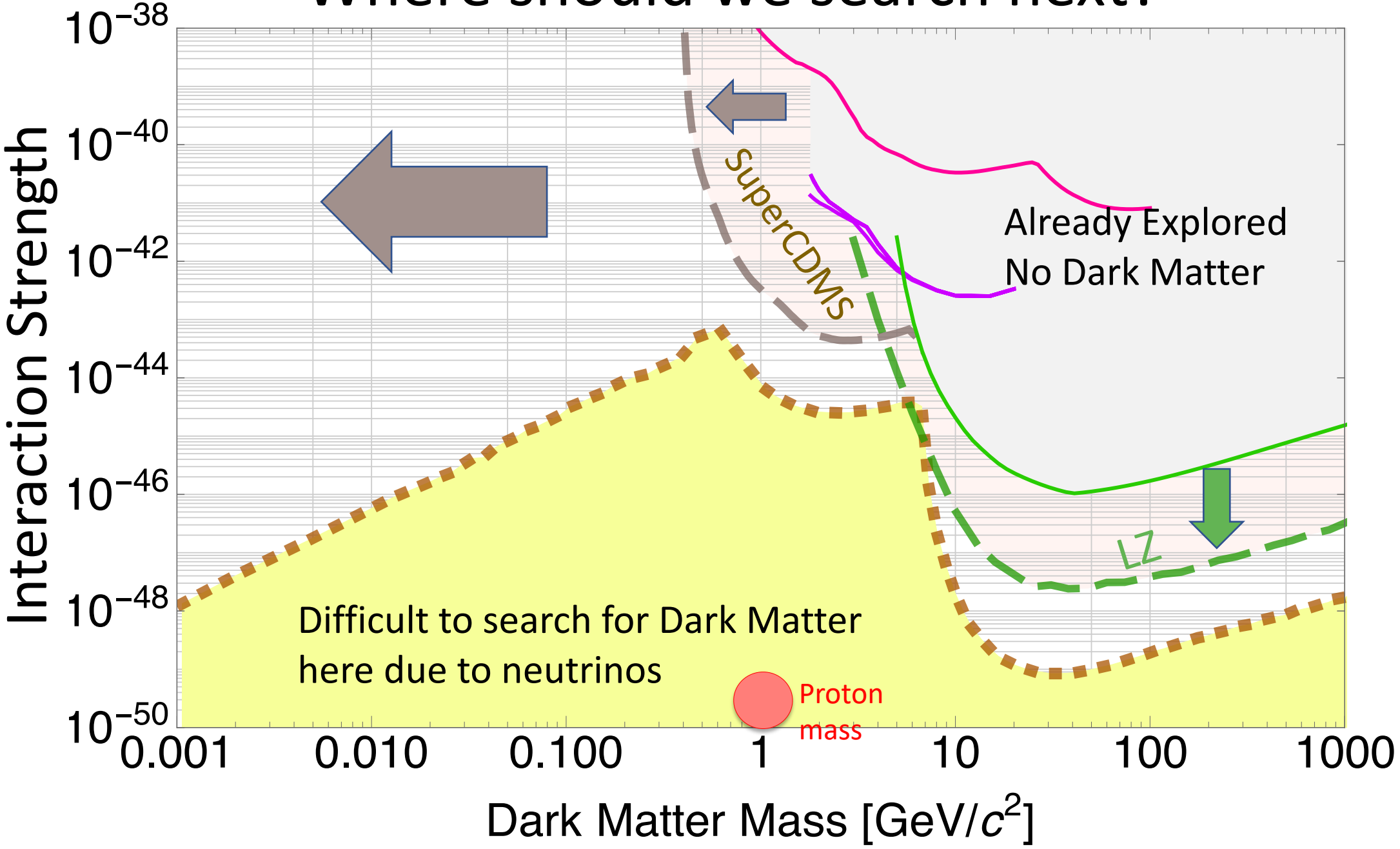
Don’t Put All Your Eggs in One Basket: Broaden the Search



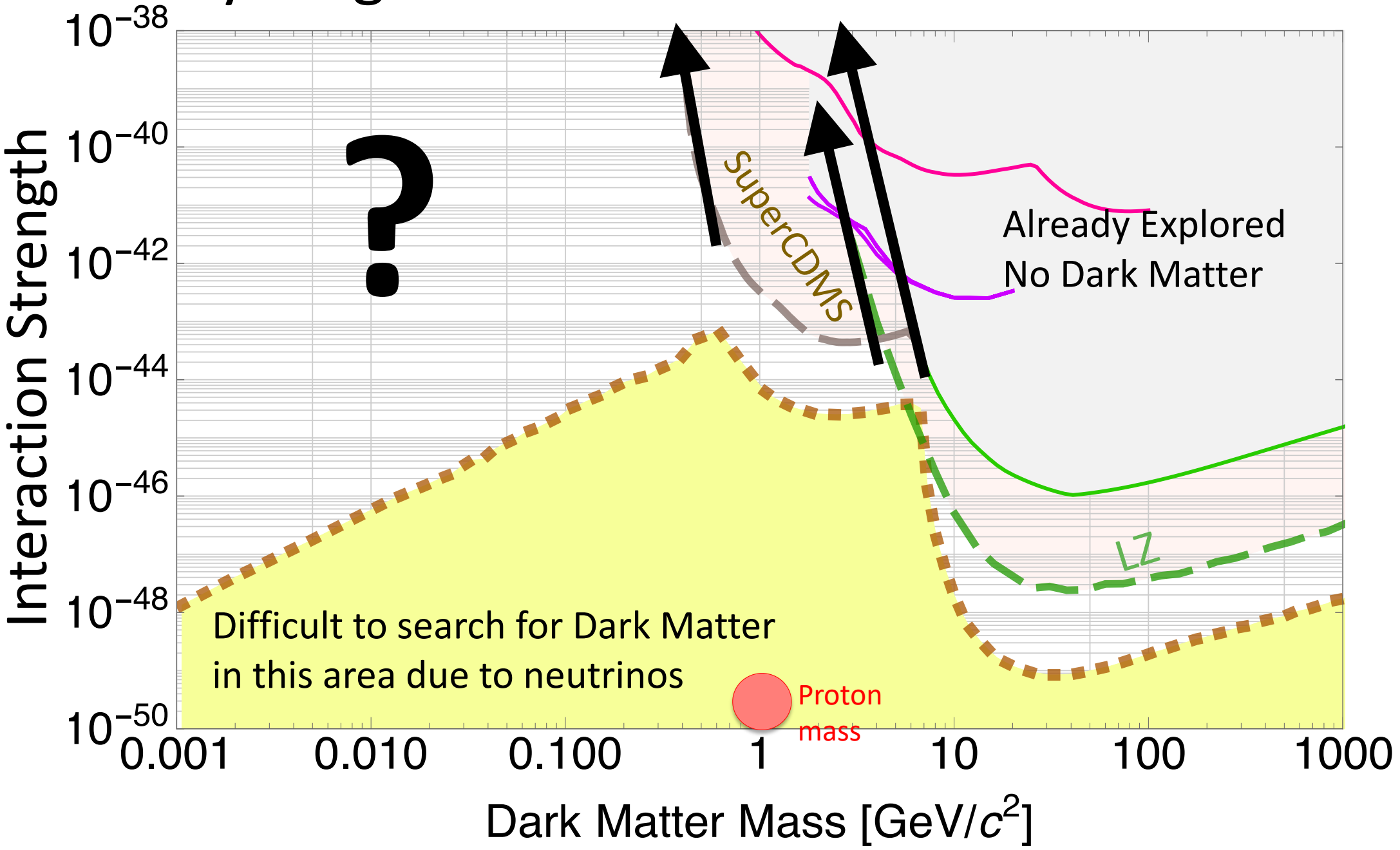
Many Well Motivated and Viable DM Models Developed Over the Last Decade in Light Mass Range

US Cosmic Visions: New Ideas in Dark Matter: 1707.04591

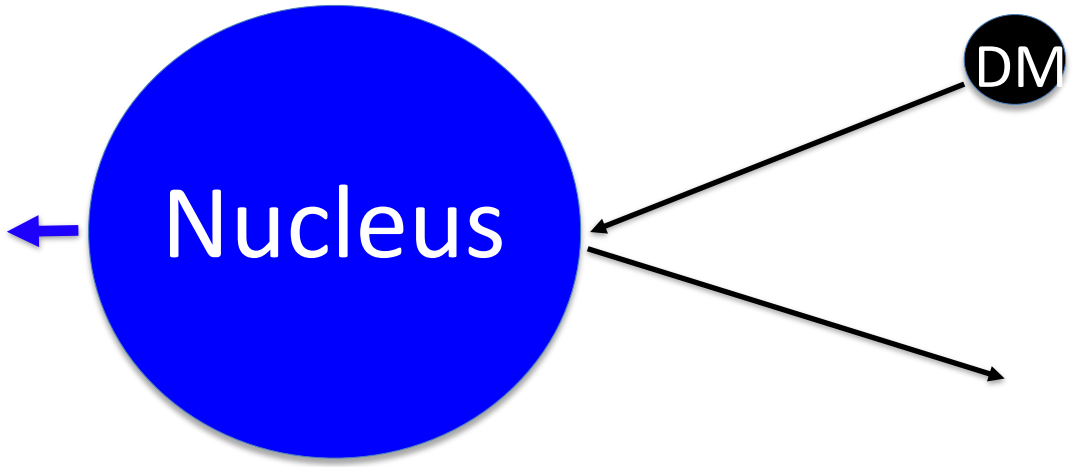
Where should we search next?



Why is light mass dark matter so hard to find?



The Challenge: Really Tiny Nuclear Recoils!



For light mass dark matter scattering off a big nucleus:

$$\Delta E \propto M_{DM}^2$$

$$\Delta E(M_{\text{proton}}) = 10^{-17} J$$

How much is 10^{-17}J ?

1. The amount of energy needed to lift a paperclip 10^{-15}m (1 fm)

2. The random vibrational energy of 1000 atoms at room temperature (1 human cell has 10^{14} atoms!)

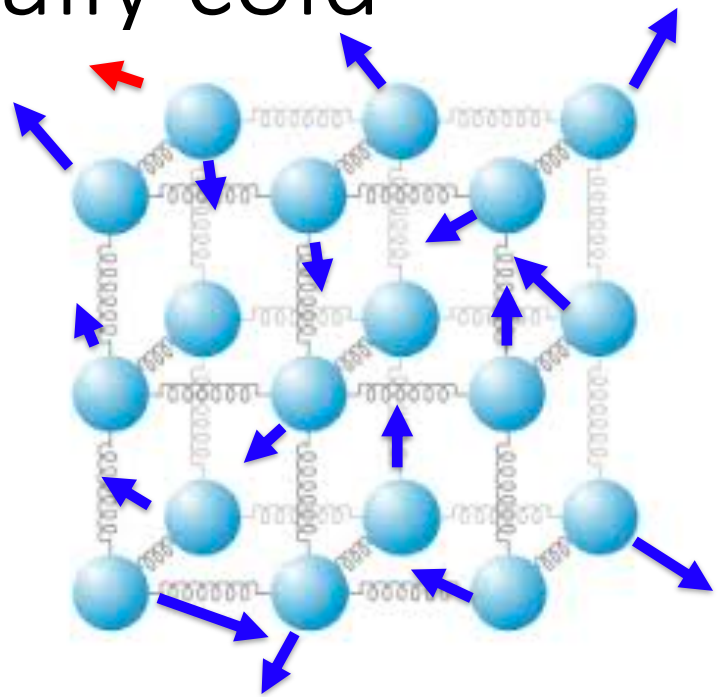
How can you measure vibrations? A Calorimeter

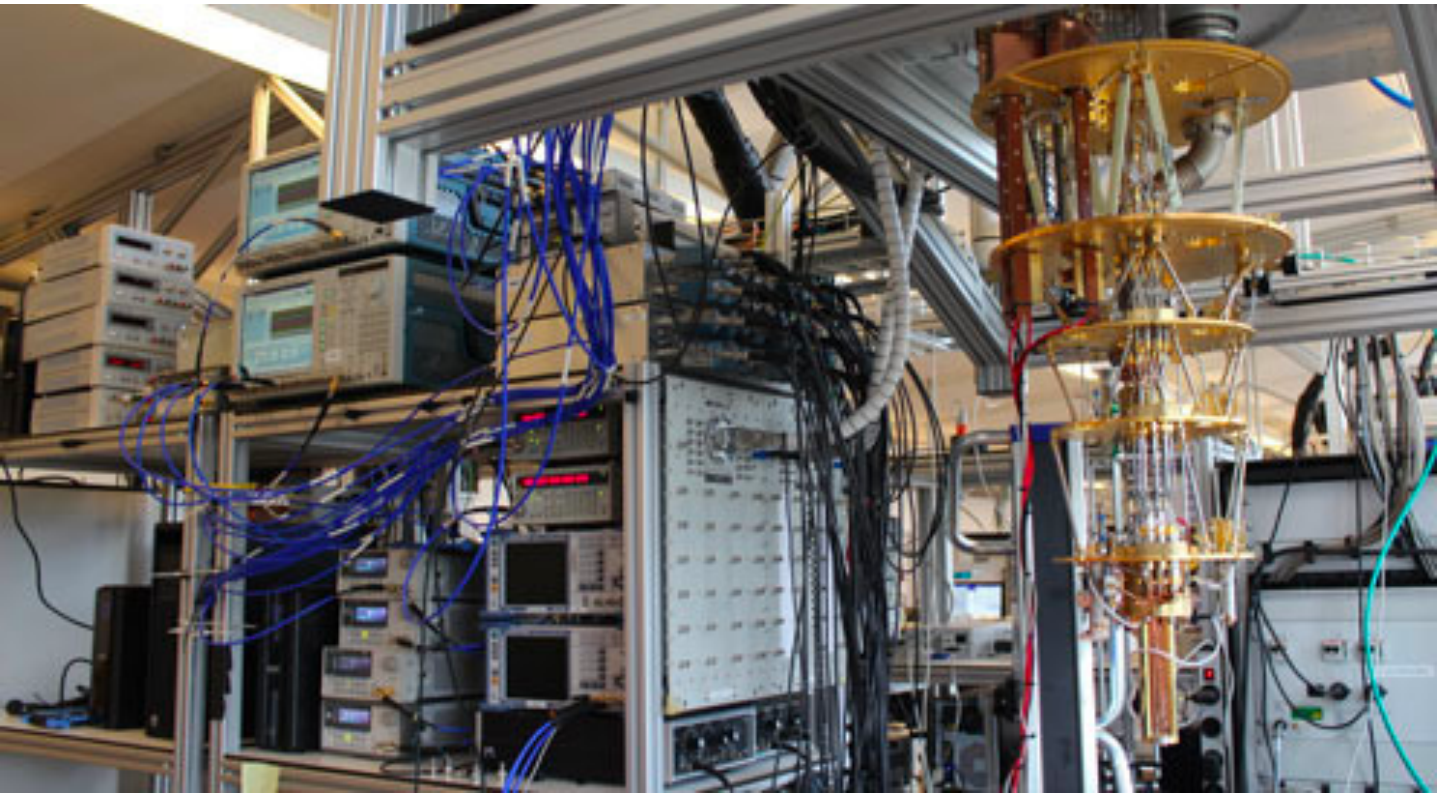
$$\delta T = \frac{\delta E}{C}$$

To measure the tiny amounts of vibrational energy produced by light mass dark matter, we need to make the worlds most sensitive calorimeter!

Step 1: The calorimeter must be really cold

- Temperature = random vibrational energy
- To see Dark Matter: Random vibrational energy << vibrational energy from DM interaction

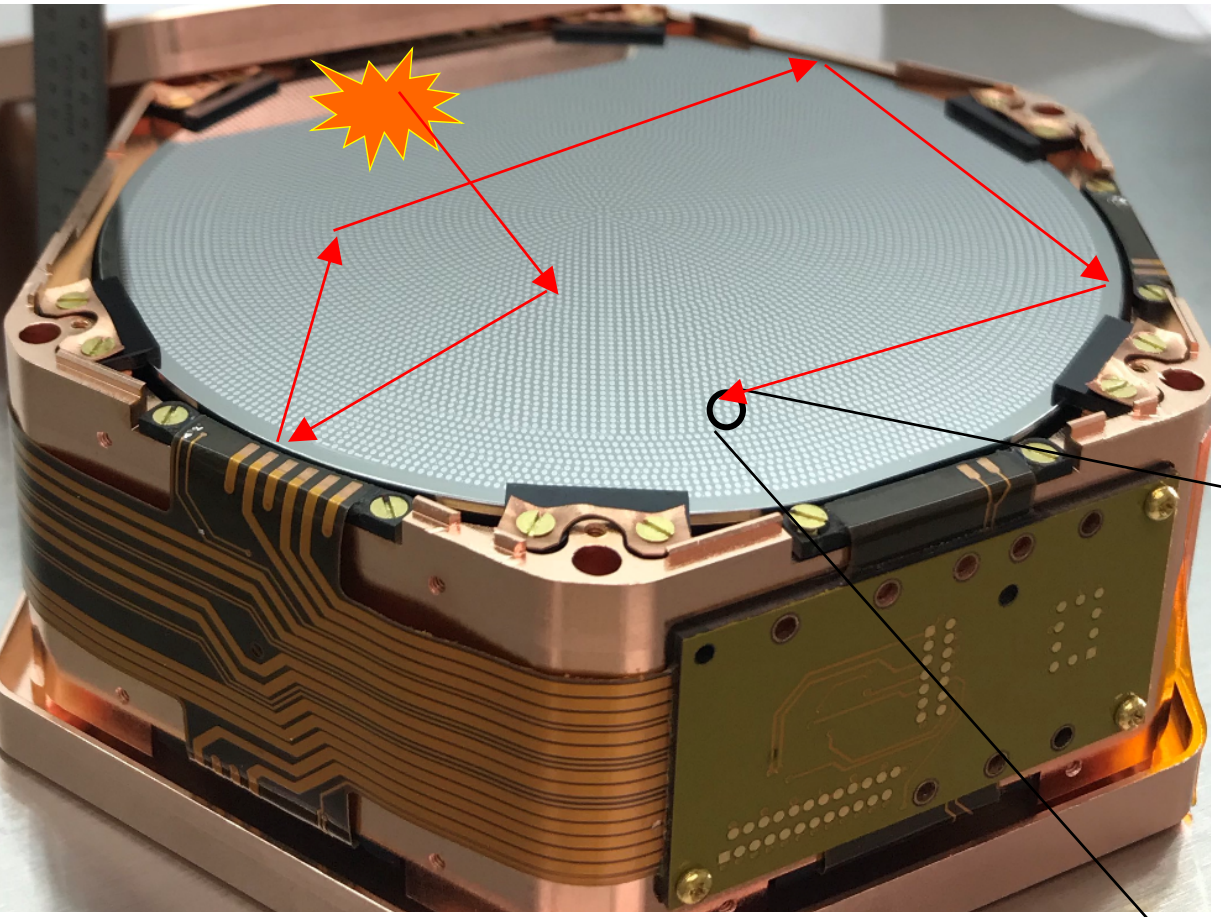


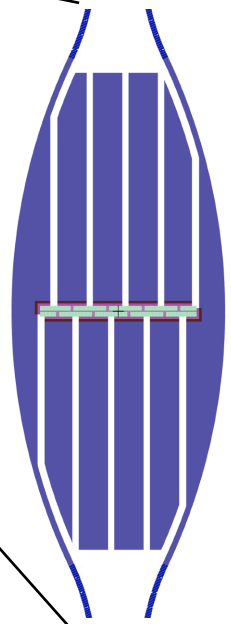


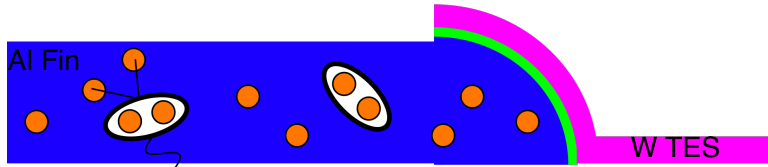
We need to be really cold!
Use special refrigerators that cool detectors to 10 mK (-459.66 F)

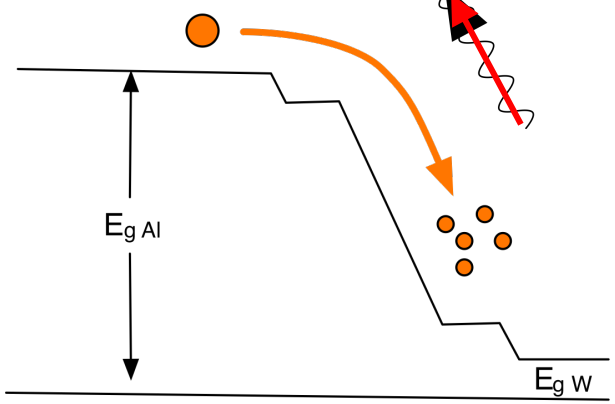
Step 2: Fabricate the calorimeter

1. Take a single crystal
   - 1kg for SuperCDMS
   - 2g when searching for even lighter masses
2. fabricate super-sensitive superconducting thermometers across its surface







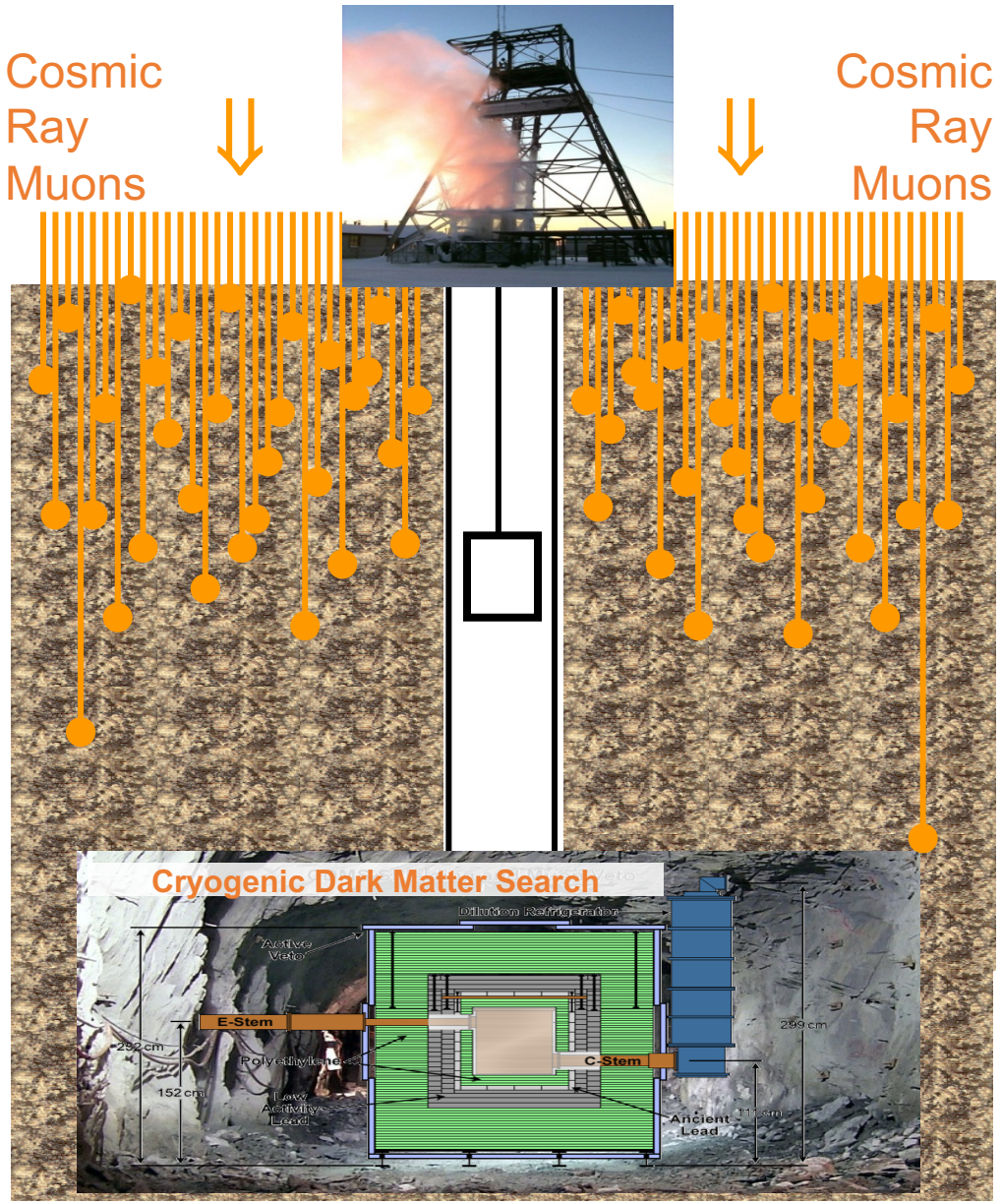


Step 3: Get Rid of Environmental Noise

Detectors that are sensitive to light mass dark matter are sensitive to everything!

Isolate and Dampen!

Step 4: Go Underground and search for dark matter



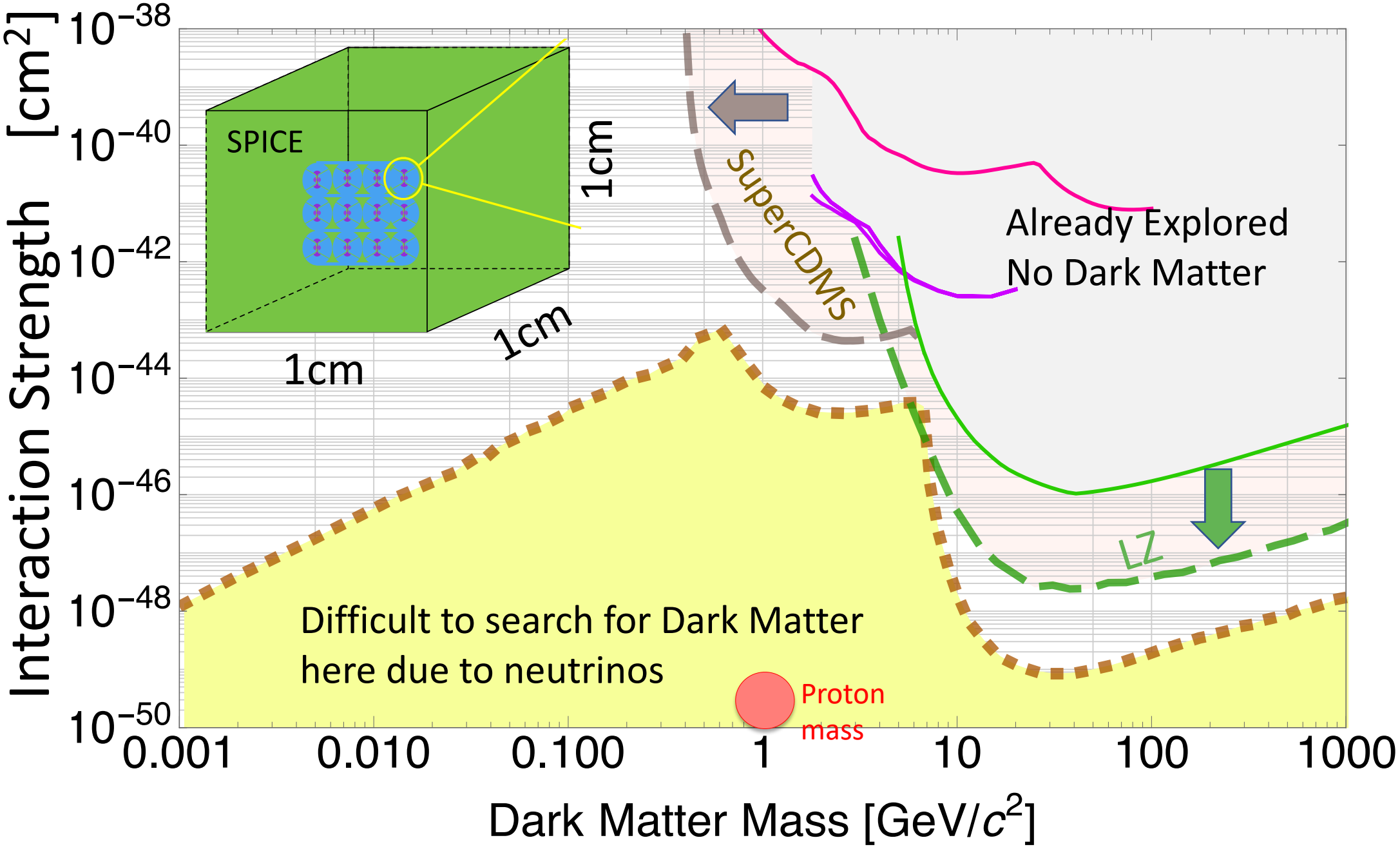
- Go underground to get rid of outerspace backgrounds
- SuperCDMS will start taking data @SNOLAB in Sudbury Canada in 2022

The SuperCDMS Collaboration

California Inst. of Tech.
CNRS-LPN*
Durham University
FNAL
NISER
NIST*
Northwestern
PNNL
Queen's University
Santa Clara University
SLAC
South Dakota SM&T
SMU
SNOLAB
Stanford University
Texas A&M University
TRIUMF
U. British Columbia
U. California, Berkeley
U. Colorado Denver
U. Evansville
U. Florida
U. Montréal
U. Minnesota
U. South Dakota
U. Toronto

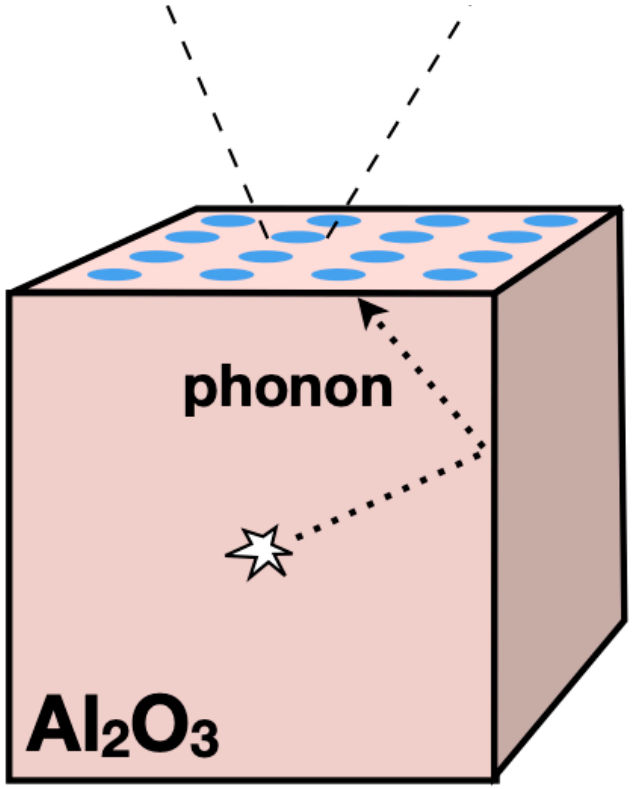
* Associate members

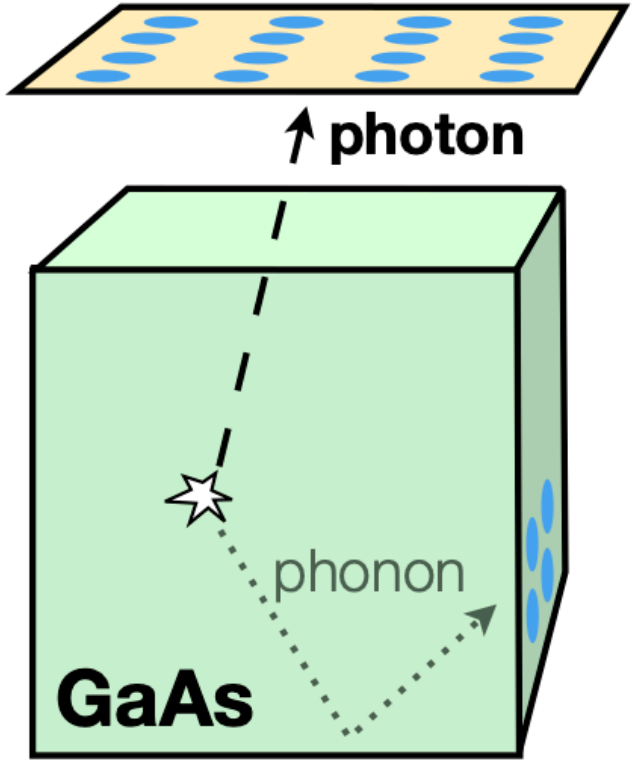
Lower Masses = Smaller More Sensitive Calorimeters!



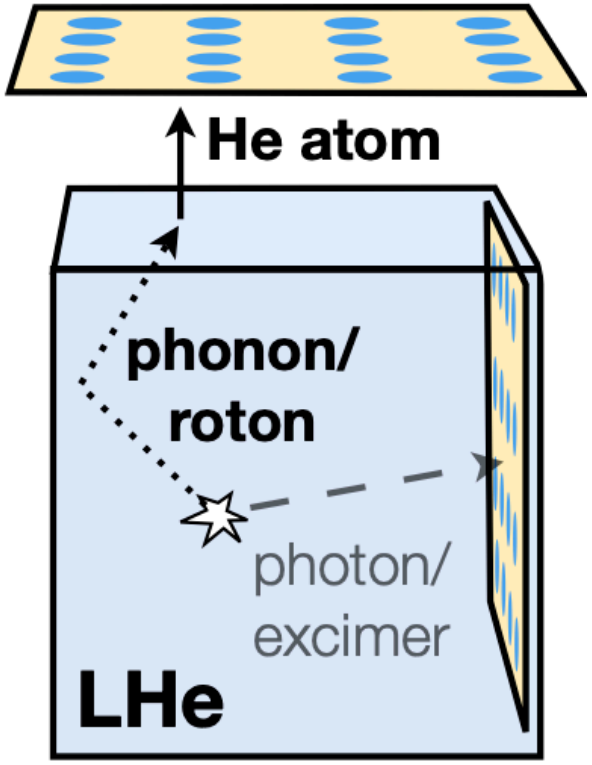
SPICE

HERALD





(Si)



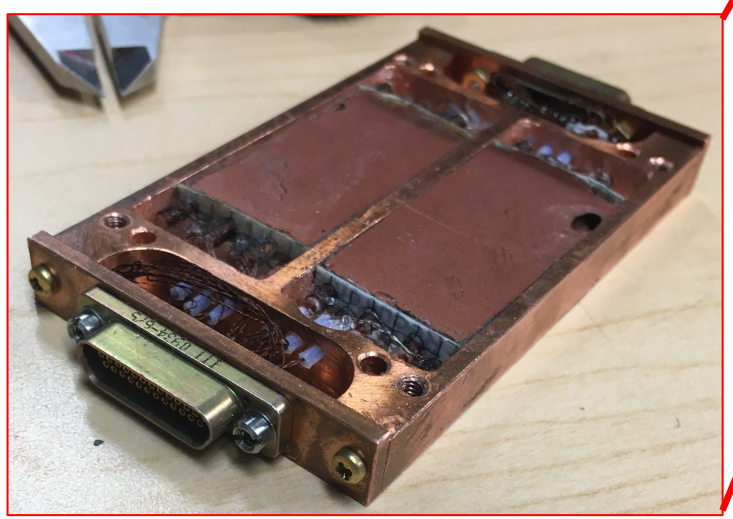
Lawrence Berkeley National Lab, Argonne National Lab, Florida State University,
Texas A&M, U C Berkeley, University of Massachusetts

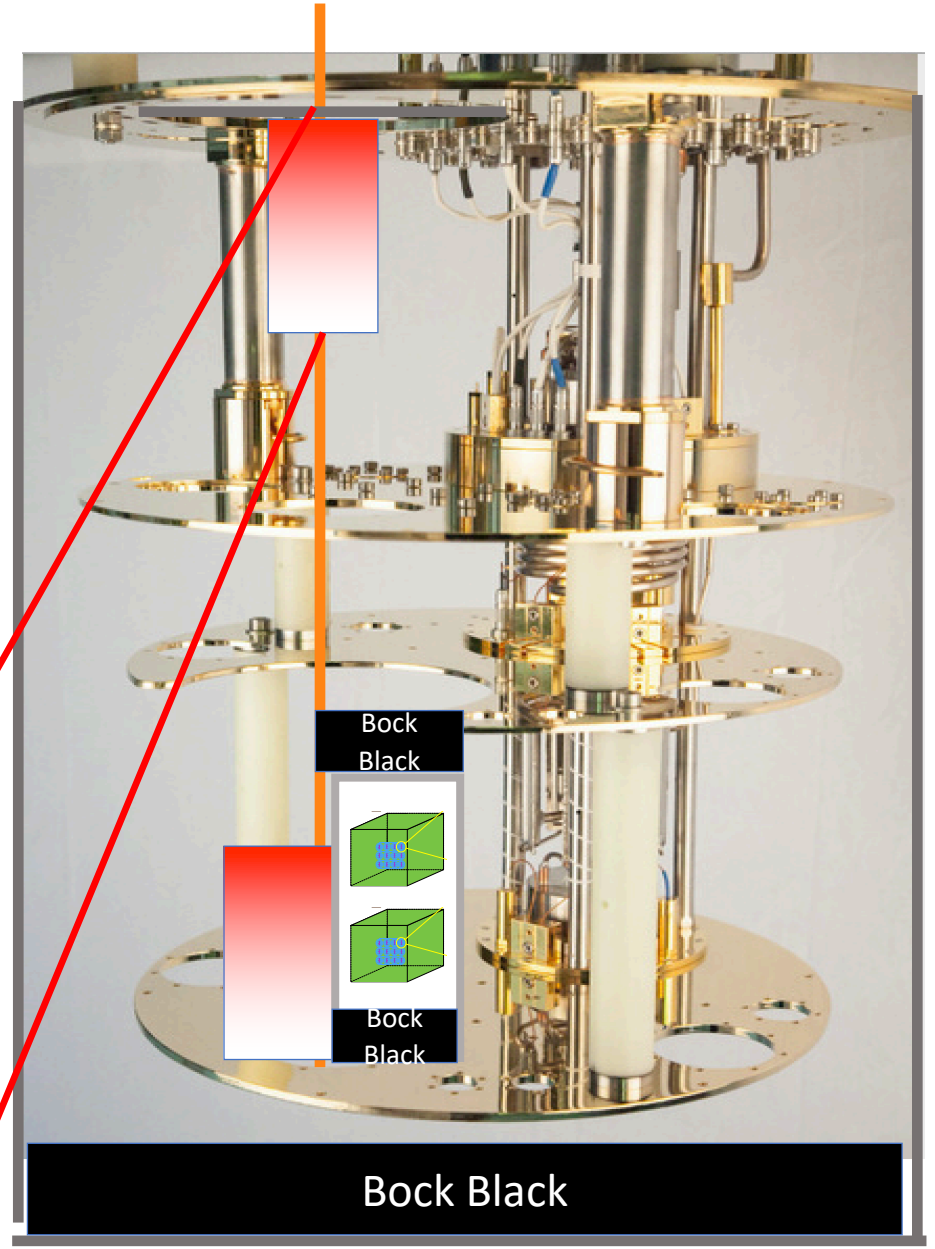
EMI Shielding for SPICE/HERALD

- Inner thermal shields would act as additional Farday Cages … if there were filters on all the lines.

  Bock Black for IR light leaks

  Steal copper powder filter from Martinis, Devoret, Clarke (PRB 35.4682 1987)
  - FY20: design & construction
  - FY21: test





Summary

- Finding Dark Matter is one of our best chances to improve our understanding of the universe
- We don’t know that mass of Dark Matter … searching for dark matter requires many different experimental techniques
- 100meV-10GeV dark matter requires seeing incredibly small energy depositions
  - Detectors at near absolute zero
  - Lots of environmental shielding
    - EMI
    - Vibrations
    - Radiogenics