SuperCDMS IMPACT: Measuring the sub-keV Ionization Yield in Cryogenic Solid-State Detectors

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FNAL New Perspectives 2.0

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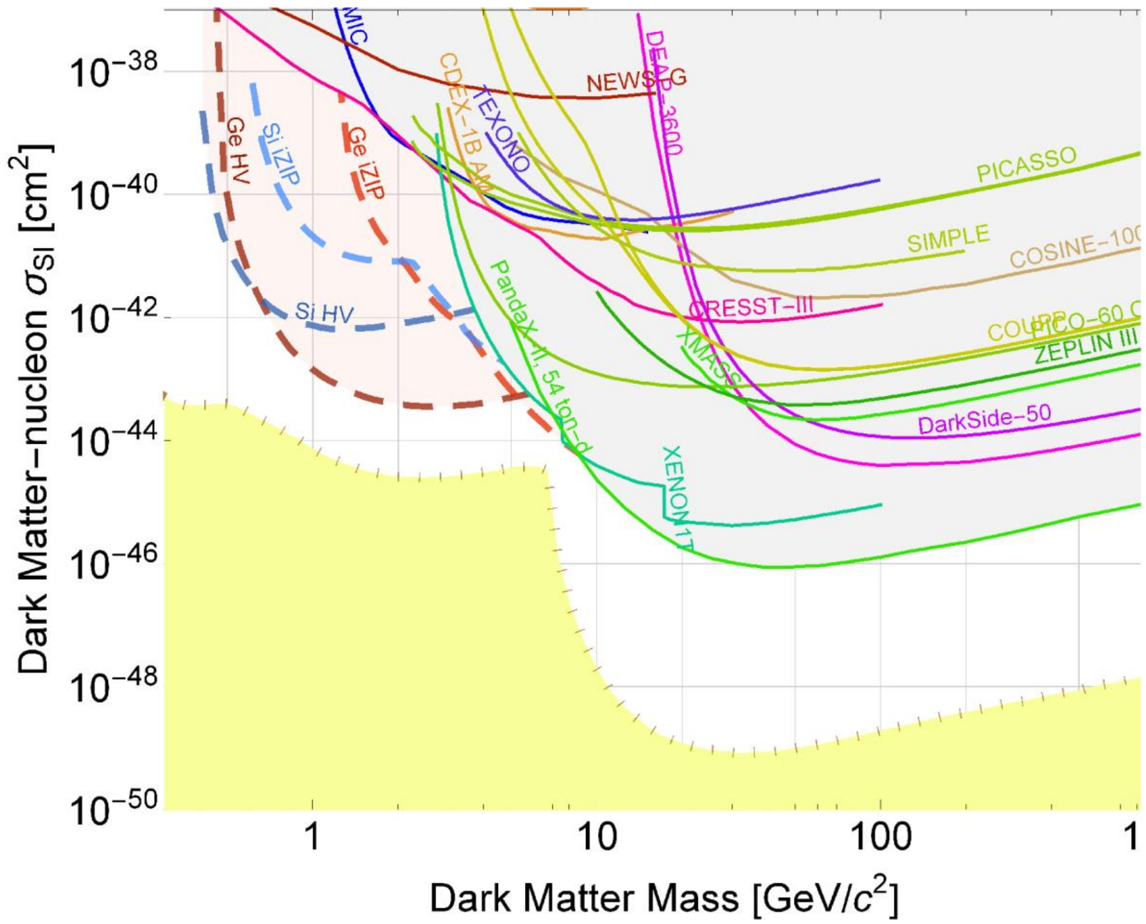
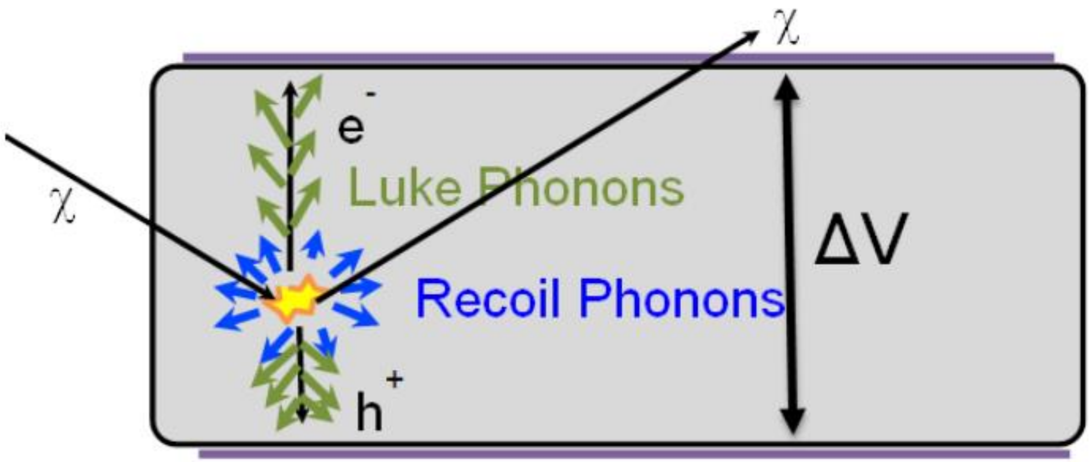
Motivation

- SuperCDMS seeks to directly detect dark matter through their interactions in Ge and Si detectors
- Lighter dark matter candidate masses produce smaller recoil energies



Ionization Yield

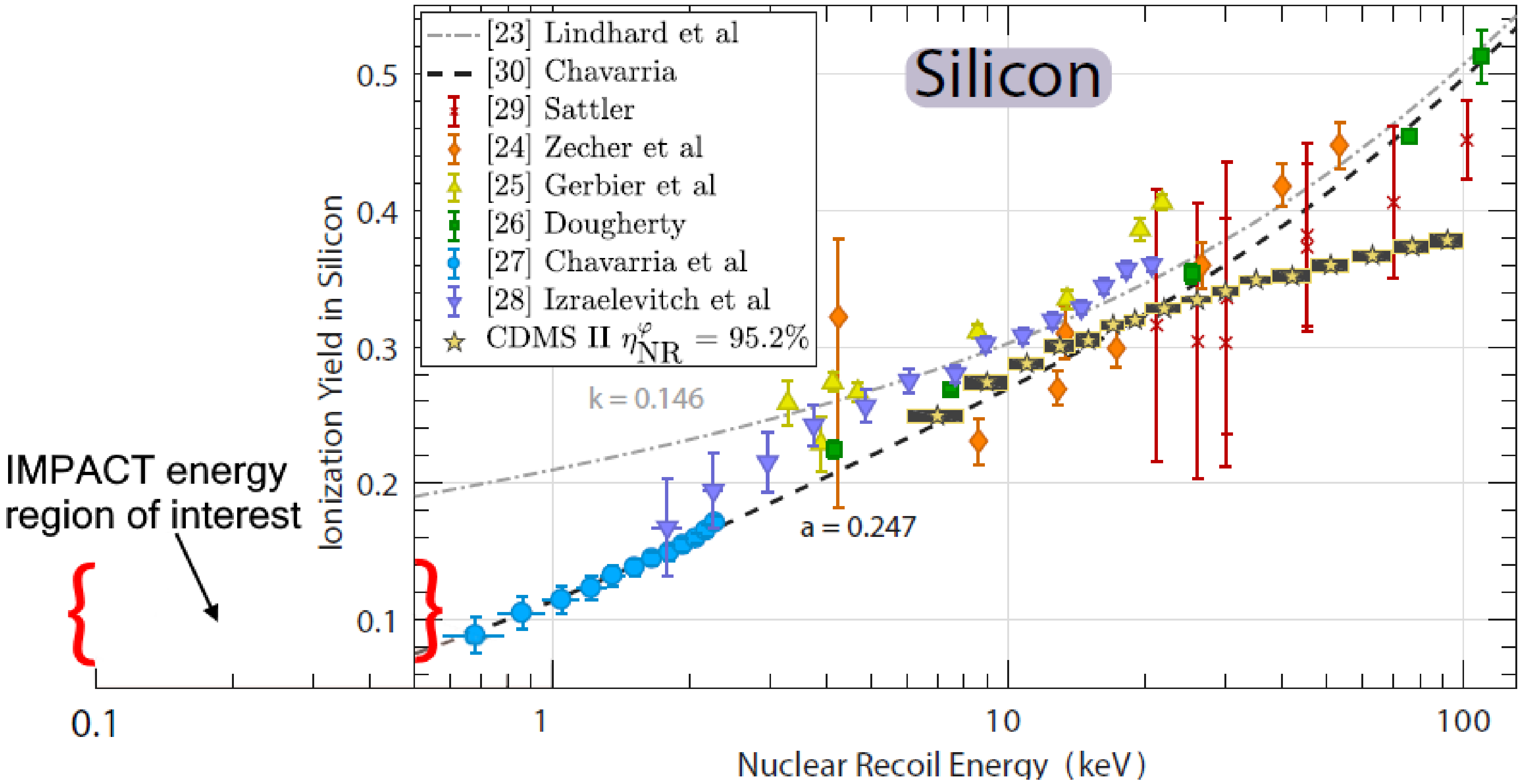


$$E_{phonon} = E_{recoil} + n_{eh} e \Delta V$$

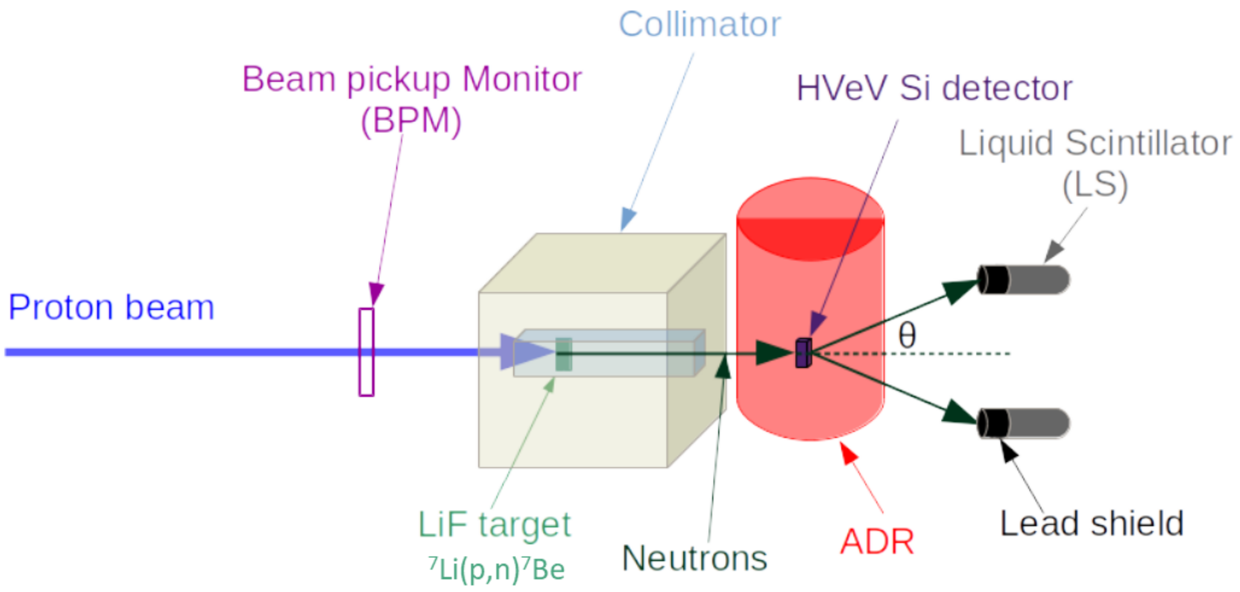
$$n_{eh} = Y(E_{recoil}) \frac{E_{recoil}}{\varepsilon}$$

- ε is average electron-hole pair production energy for electron recoils
  - 3.82 eV in Si
- Y is ionization yield
  - 1 for electron recoils by definition
  - Depends on energy for nuclear recoils

Ionization Yield



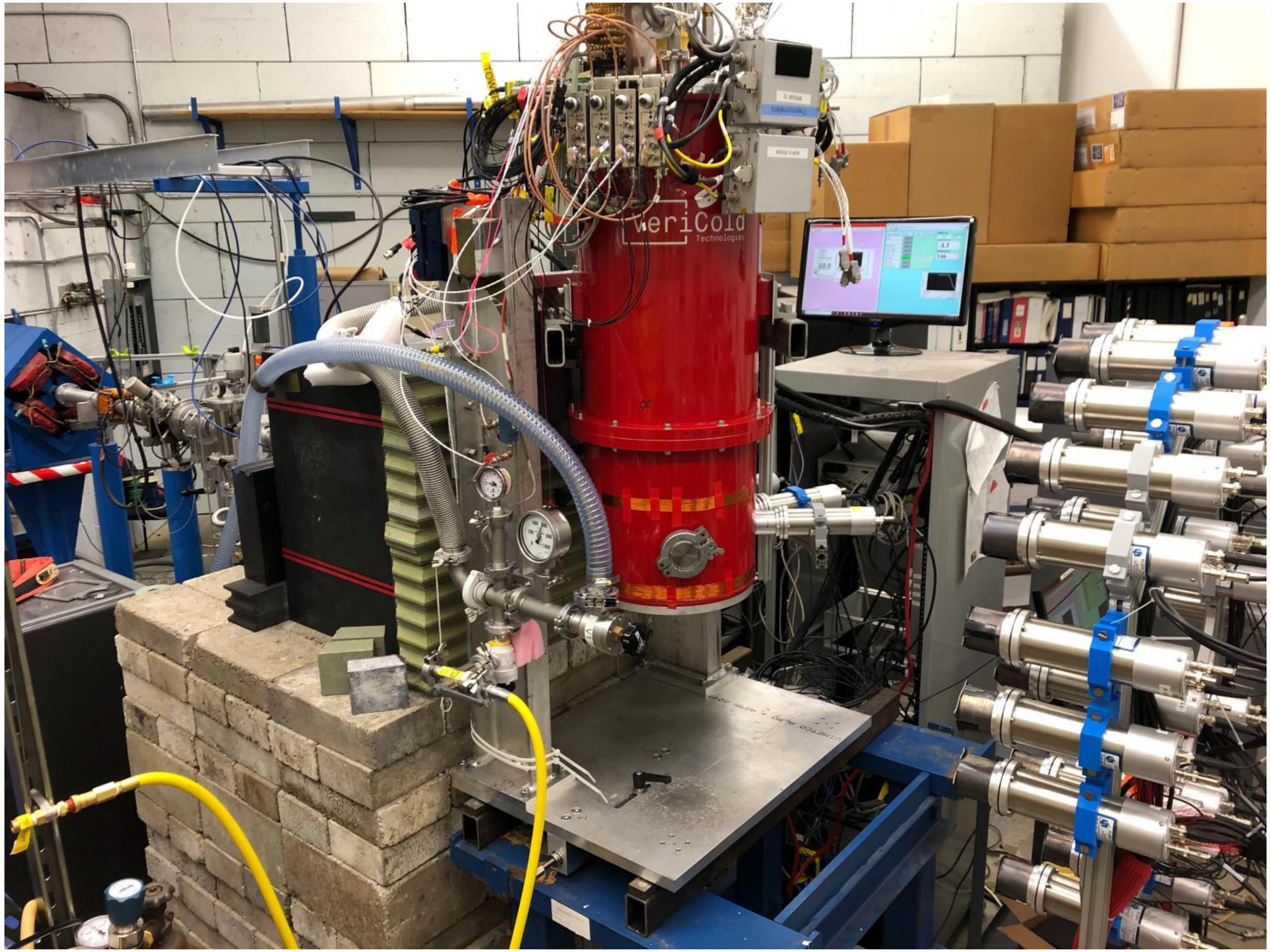
Measuring the Ionization Yield



$$Y = \frac{\varepsilon}{eV}\left(\frac{E_{phonon}}{E_{recoil}} - 1\right)$$

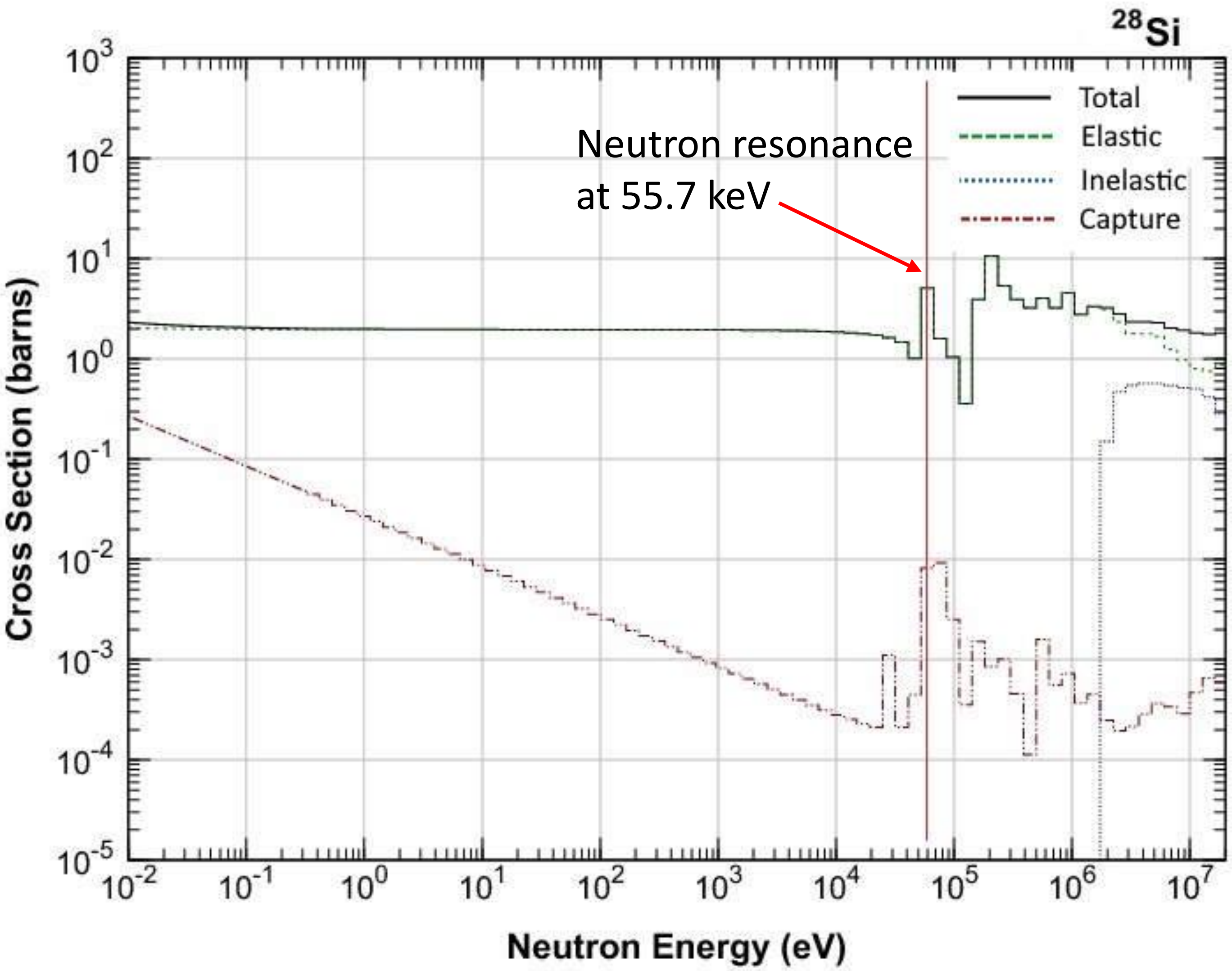
- Determining the recoil and phonon energies can get you the yield
    - Measure phonon energy using detector
    - Determine recoil from the scattering angle of neutrons via PMTs
    - Look for coincidence between these two detectors and a proton beam bunch

IMPACT@TUNL



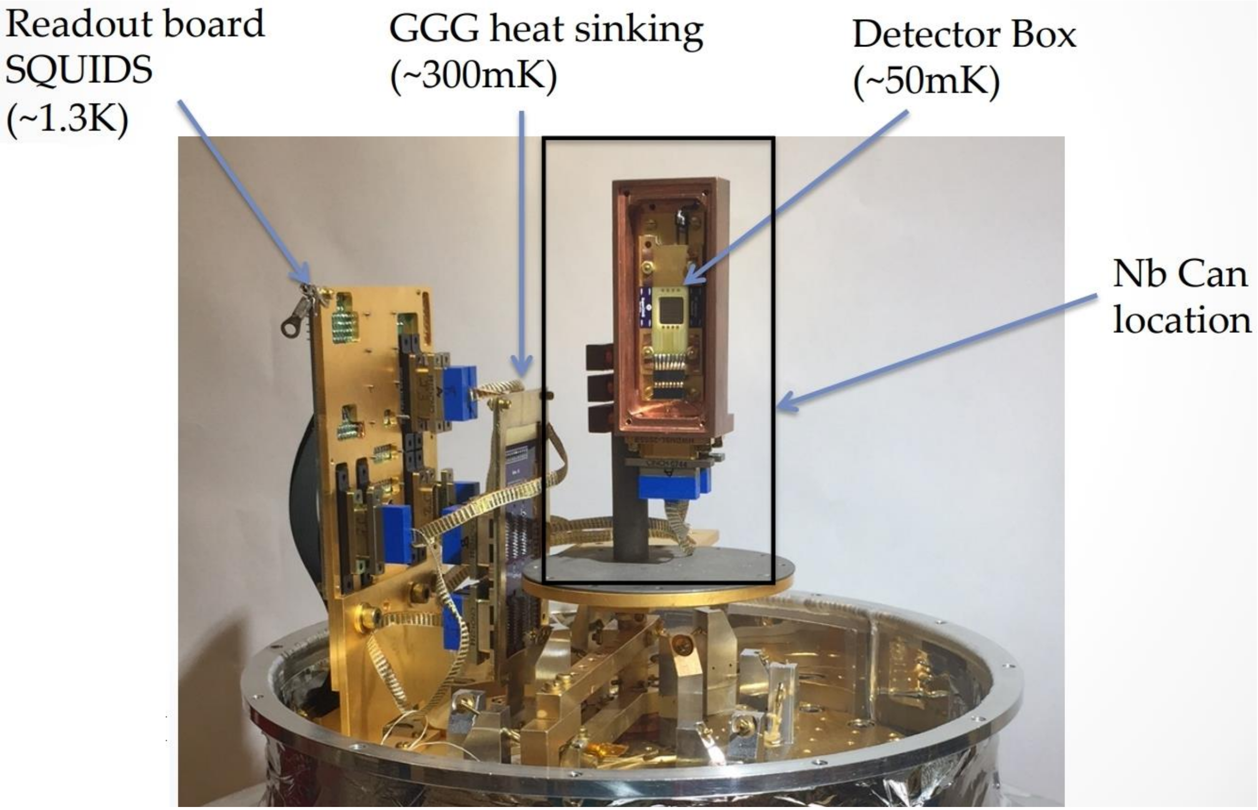
Neutron Beam

- Proton beam at Triangle Universities Nuclear Laboratory (TUNL)
  - 1.889 MeV protons with 2.5 MHz pulsing
  - LiF-on-Ta target
  - Aim for 55.7 keV neutrons
- Beam collimated by HDPE/BPE/lead to reduce background



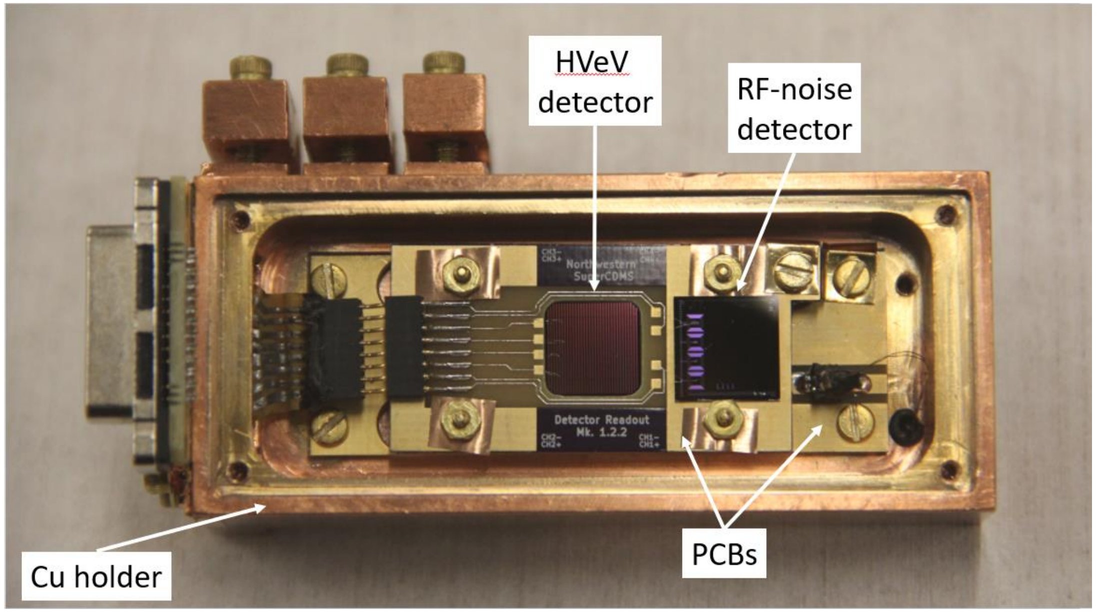
Fridge

- Adiabatic demagnetization refrigerator
- Operated at 52 mK
- Cycled every day (12 h live time daily)

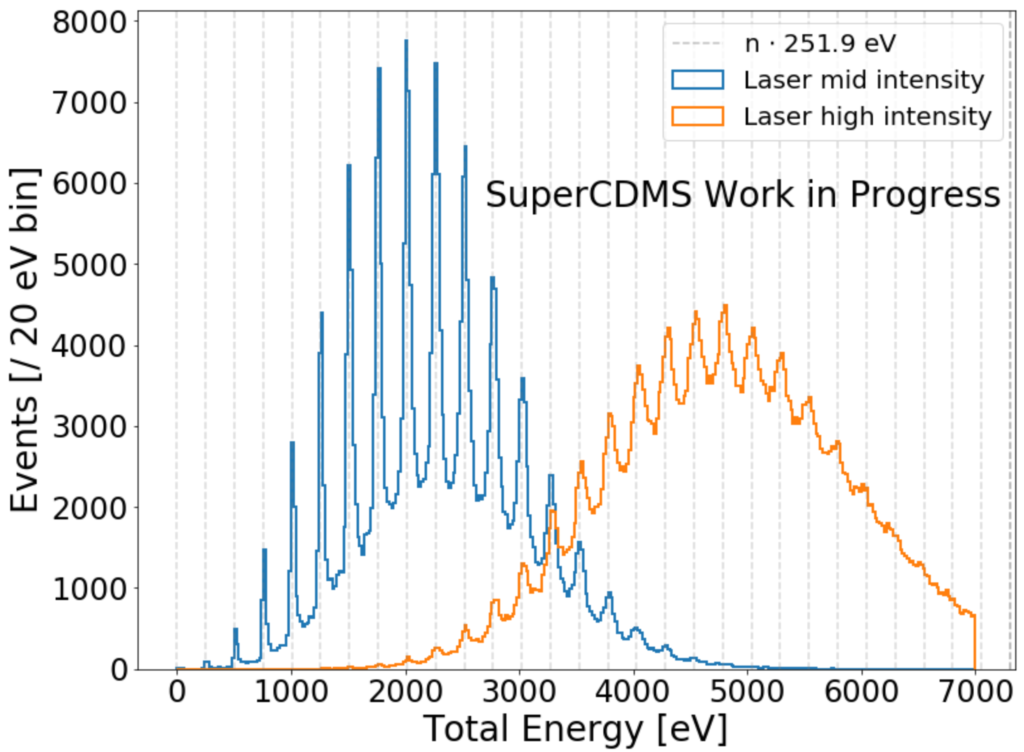


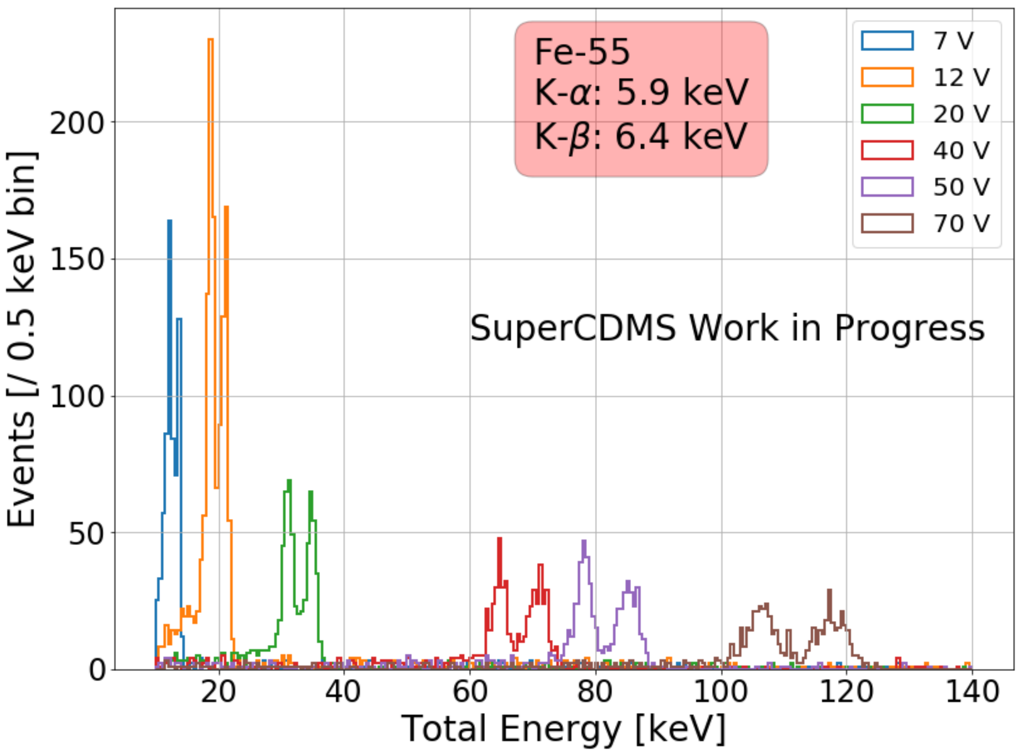
Detector

- 1 g Si detector, 4 mm x 1 cm^2
- Transition edge sensors
- 3 eV resolution
- > 100 keV dynamic range



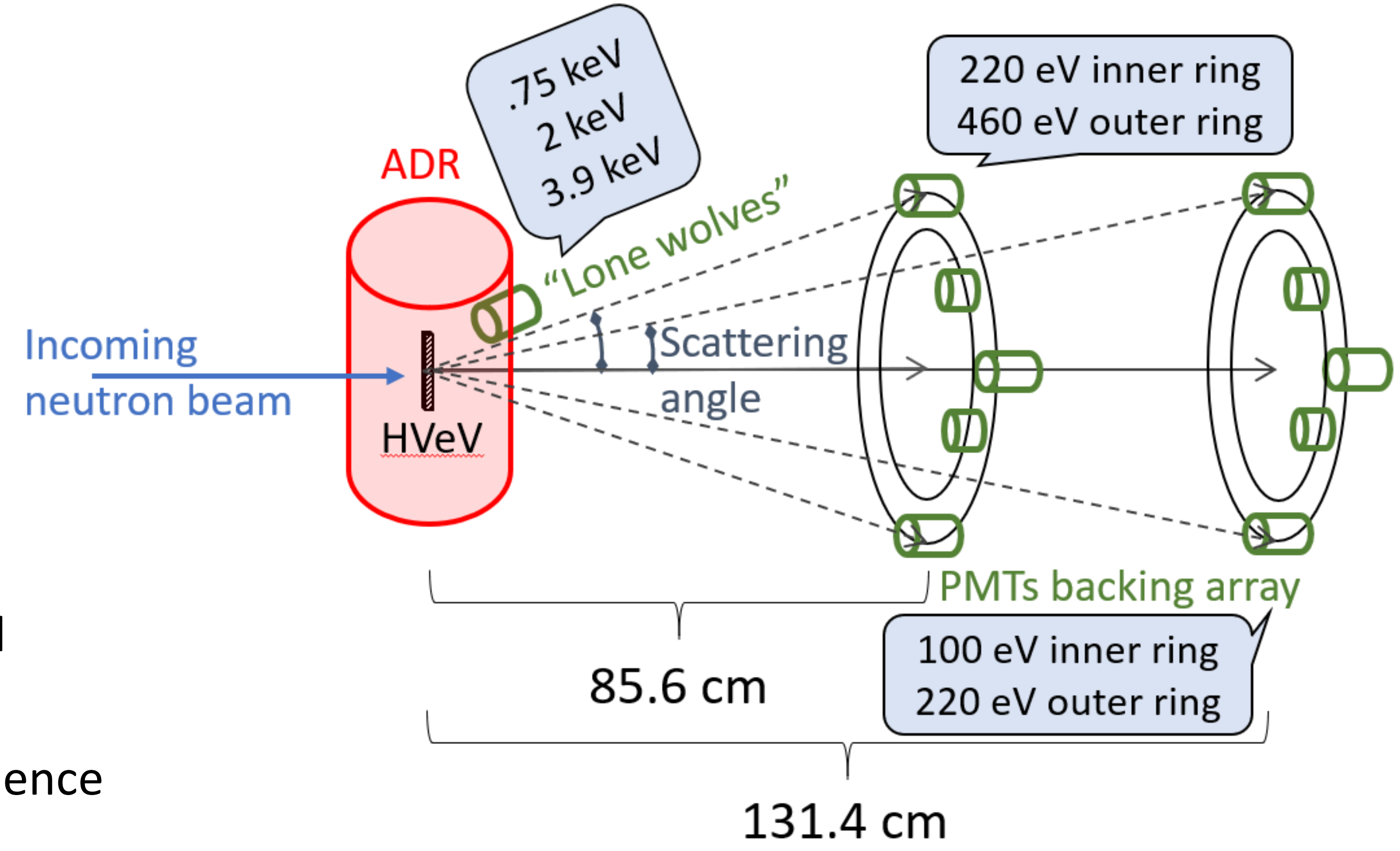
Detector Calibration



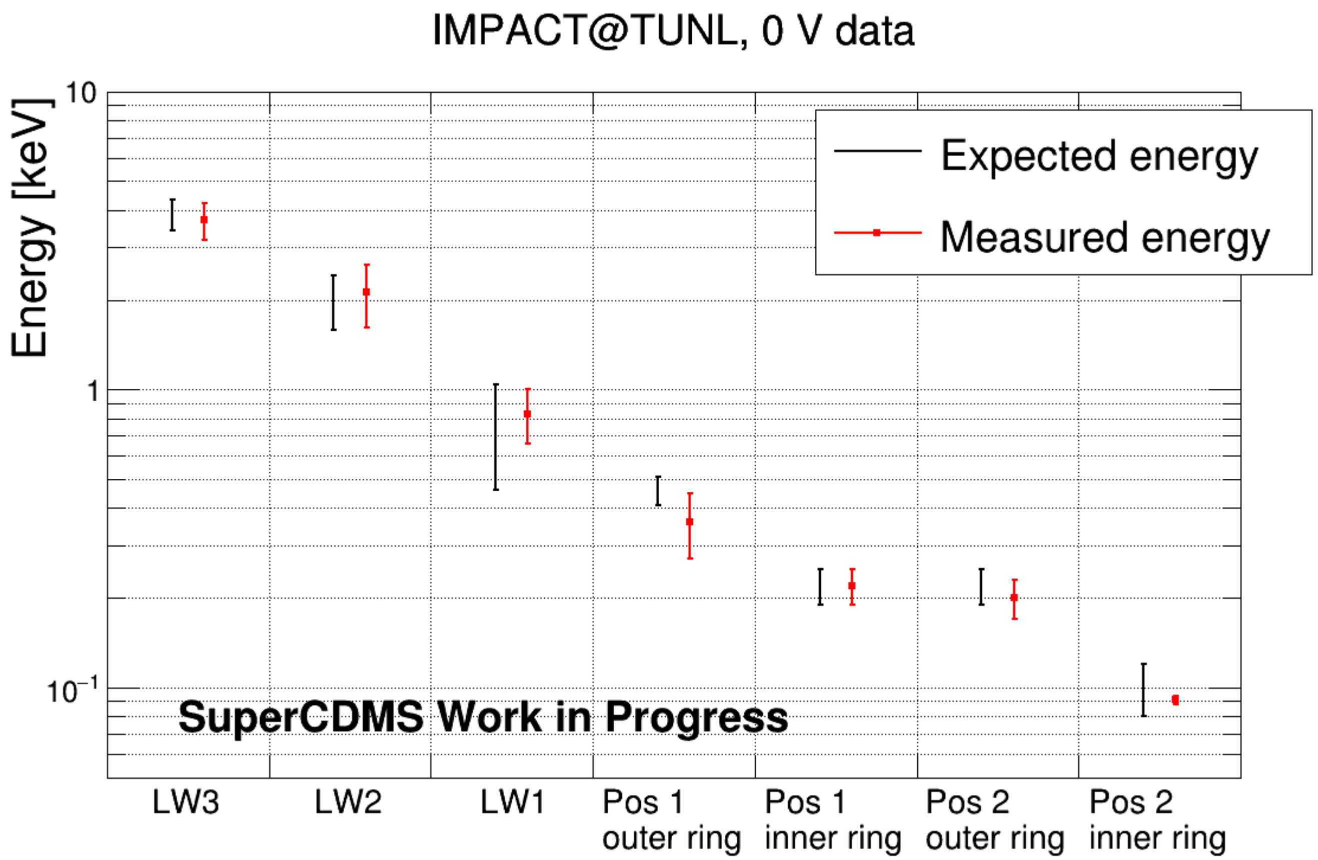


Coincidence Measurement

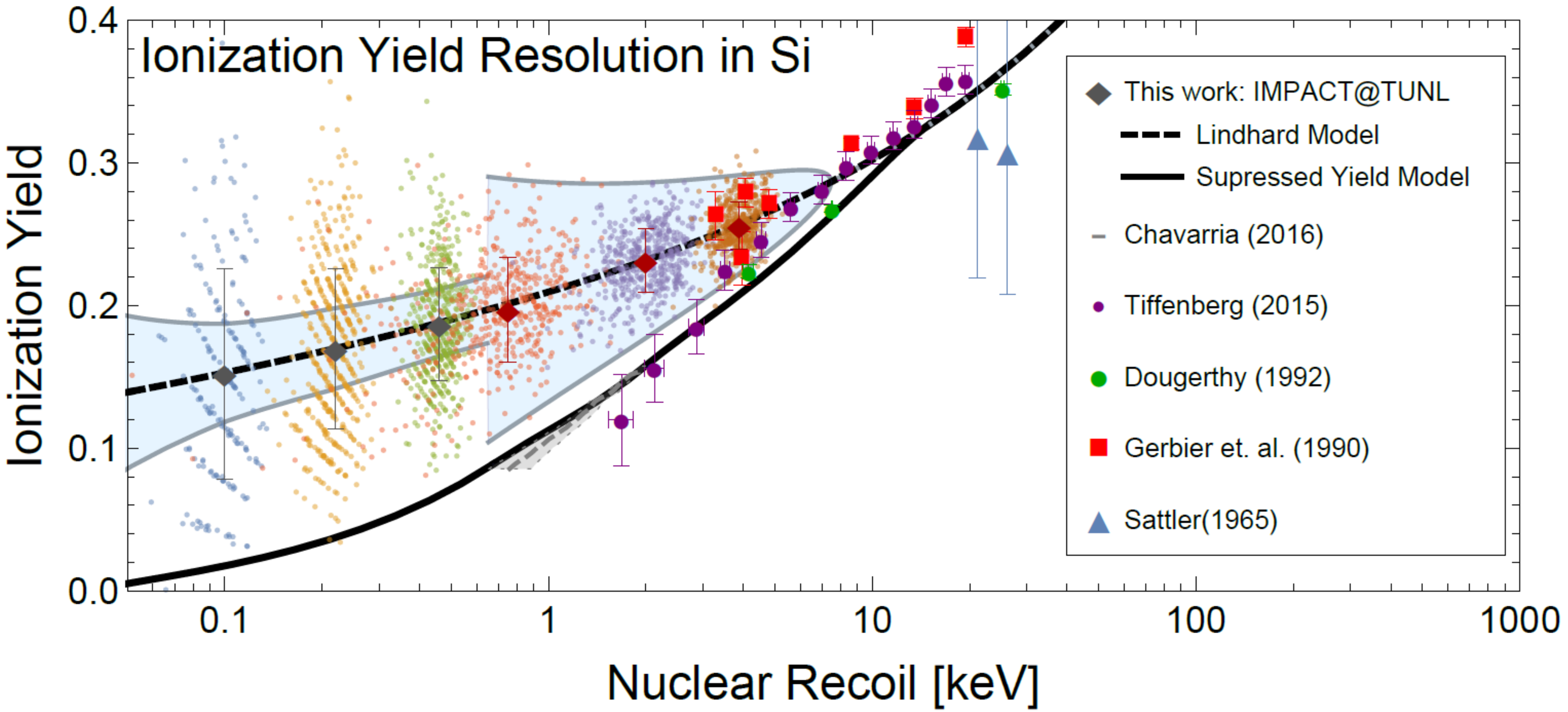
- EJ-301/309 liquid scintillators
  - Three lone wolves to measure Y in a region overlapping with existing recent measurement
  - 26 for new parameter space
- Signal identified by triple coincidence between BPM, detector and PMTs
- 3 weeks of data taking at 50% duty cycle
  - Two days at 0 V for tuning cuts and validating coincidence code
  - 20, 100, and 180 V for data taking and exploring electric field dependence on the yield



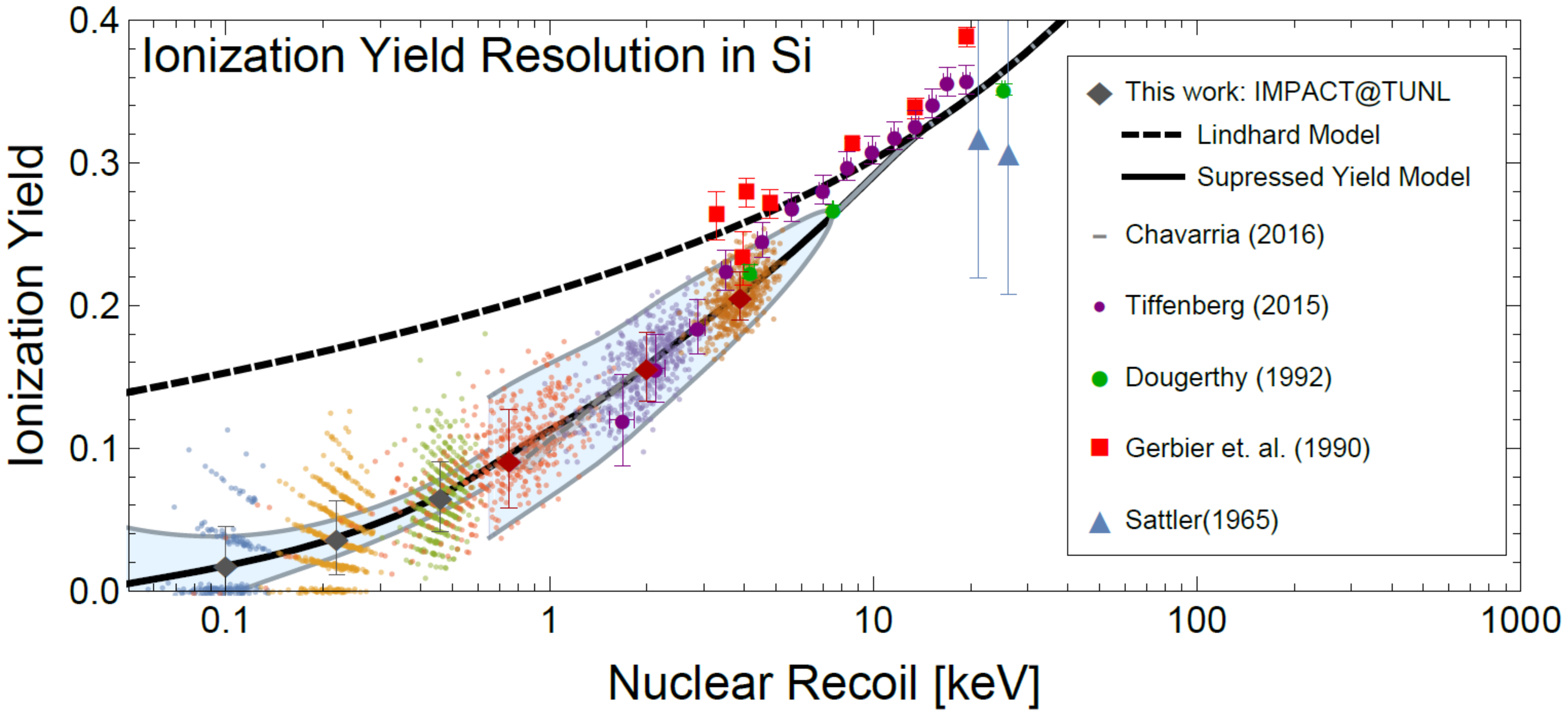
0V Analysis


IMPACT@TUNL, 0 V data
Energy [keV]
10
1
10^{-1}
Expected energy
Measured energy
SuperCDMS Work in Progress
LW3
LW2
LW1
Pos 1 outer ring
Pos 1 inner ring
Pos 2 outer ring
Pos 2 inner ring

Projected Results



Projected Results



Summary

- IMPACT aims to measure ionization yield for nuclear recoils in Ge and Si below 1 keV
- IMPACT@TUNL took data with a gram-scale detector and 55 keV neutron beam
- 0V confirmation of data complete
- Full results coming soon
- Thanks to Phil Barbeau and Long Li at TUNL