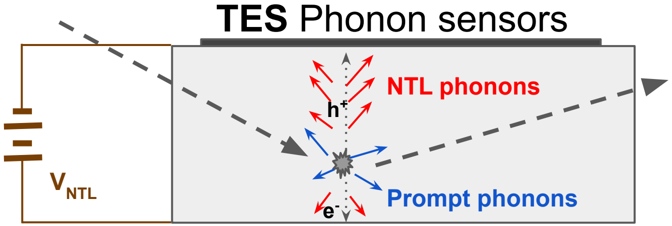
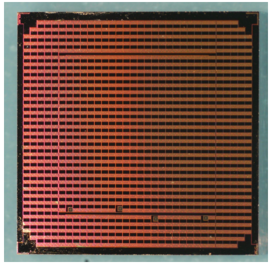
Low-energy background in a SuperCDMS HVeV detector

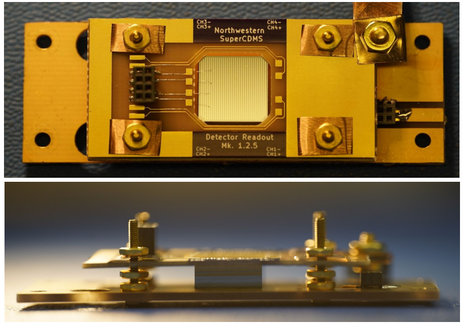
Runze (Tom) Ren, SuperCDMS collaboration

SuperCDMS HVeV detector

Phonon sensors on silicon/germanium crystal







$$E_{phonon} = E_{recoil} + n_{eh} e V_{NTL}$$
$$= E_{recoil} \cdot (1 + \frac{eV_{NTL}}{\epsilon_{eh}} \cdot Y)$$

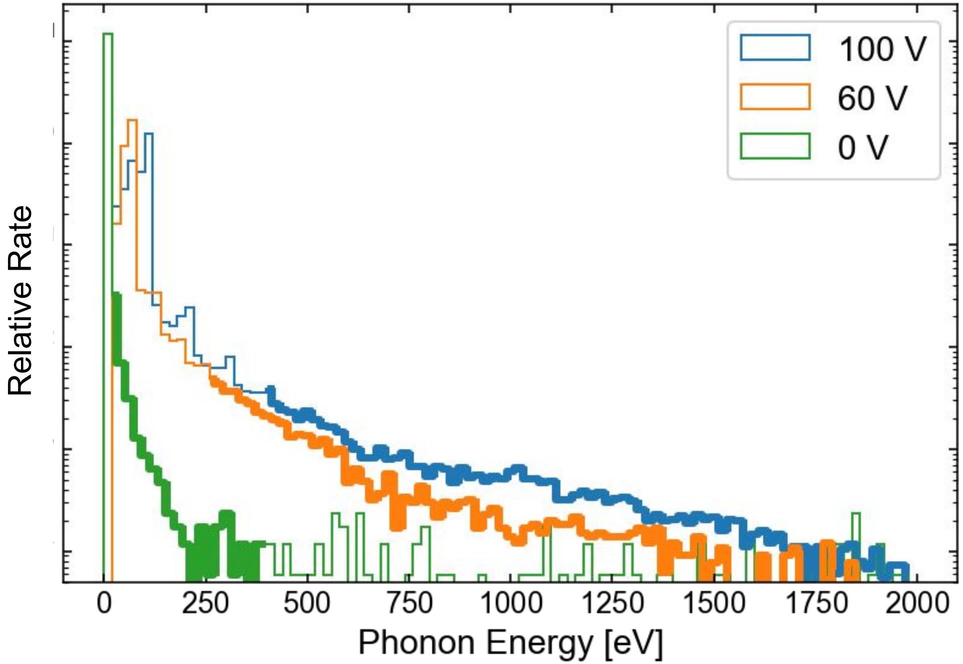
- **0V mode (V_{NTL}=0):** Phonon energy = recoil energy
- **HV mode (V_{NTL}≠0):** Phonon energy = recoil energy + NTL phonon energy

* B.S. Neganov and V.N. Trofimov, Otkrytia i Izobret. 146, 215 (1985).
P.N. Luke, J. Beeman, F.S. Goulding, S.E. Labov, and E.H. Silver, Nucl. Instrum. Meth. Phys. Res. A 289, 406-409 (1990).

The detector was operated in a surface lab at Northwestern University. O(1) gram-day exposure acquired at **0 V, 60 V and 100 V**

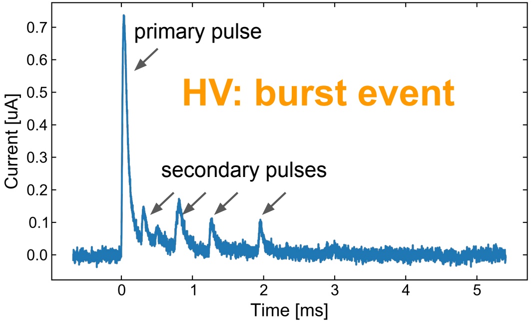
We see low-energy excess (compared to the flat high-energy background) **in both 0V and HV mode.**

1. They are not compatible with DM/neutron signal due to anomalous pulse shape, see next slide
2. They can be partly removed with event selection. However in this study we keep all of them to investigate their origin.

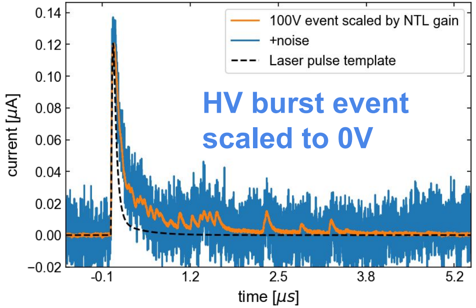


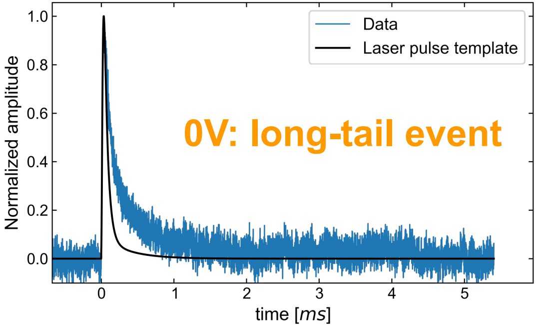
1) Pulse shape

We see anomalous pulse shapes in events from the excess in 0V and HV mode



÷ G_{NTL} + Noise at 0 V →





The scaled HV anomalous events resemble the 0V anomalous events

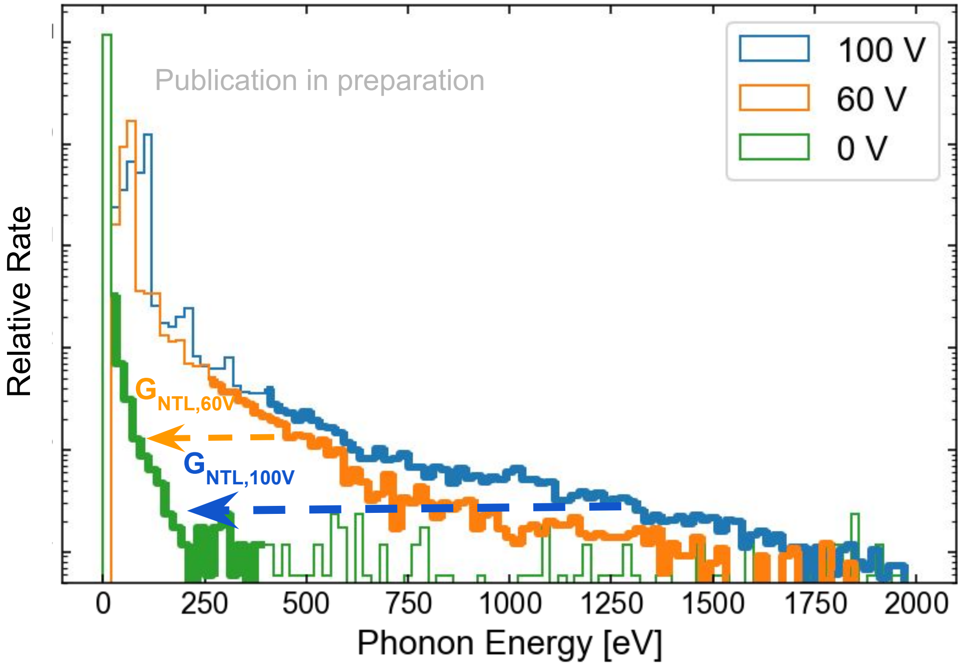
2) Energy spectra

$$\mathrm{E}_{phonon} = \mathrm{E}_{recoil} \cdot \boxed{(1 + e\mathrm{V}_{\mathrm{NTL}}/\epsilon_{eff})}$$

G_{NTL}

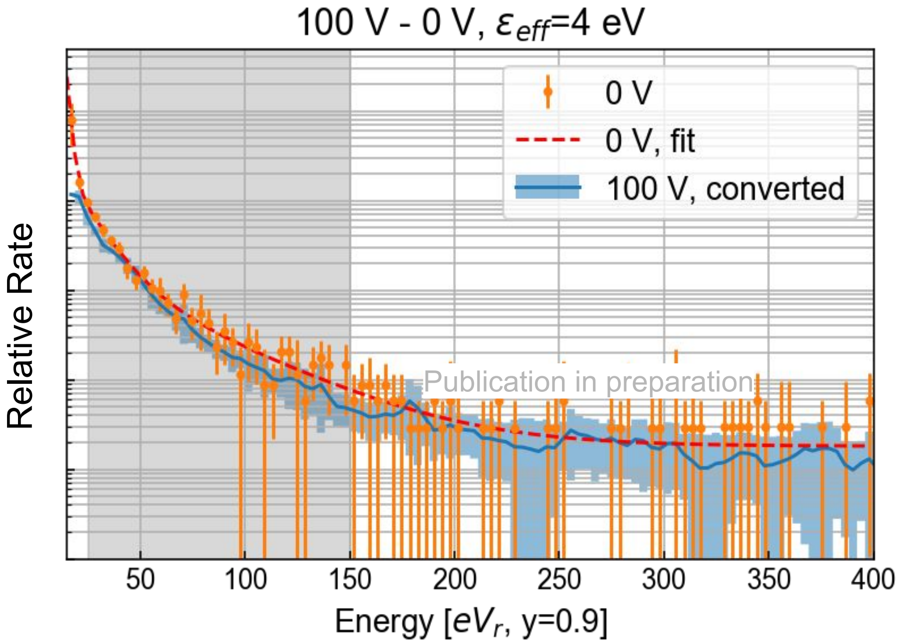
Energy spectrum scales with G_{NTL}.

By looking for the G_{NTL} where the spectra match each other best, we can **measure the effective charge pair creation energy ϵ_{eff}** of the background events.



2) Energy spectra

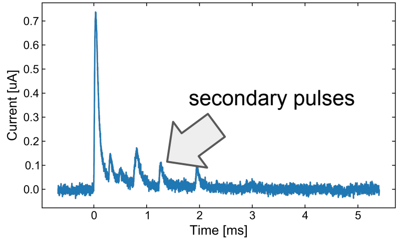
We scale the HV spectra with different $G_{NTL}(\epsilon_{eff})$, and calculate the χ^2 between 0V spectrum and the scaled HV spectrum.

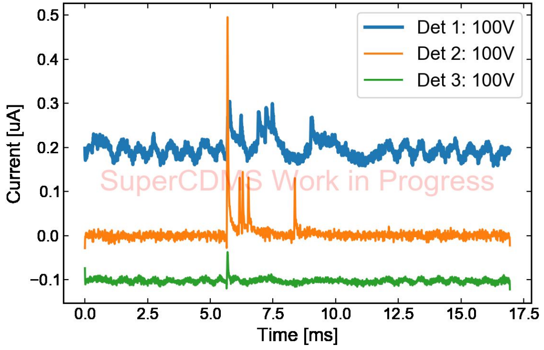


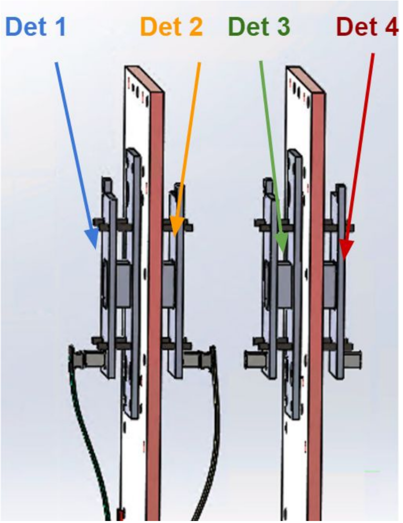
→ Data is in favor of **ϵ_{eff}~4-5 eV** (just a rough estimation, not a confidence interval)

Other properties of HV burst events

1. Secondary pulses have recoil energy of ~2 eV
2. Burst events are seen in multiple detectors in another experiment setup of 4 HVeV detectors.

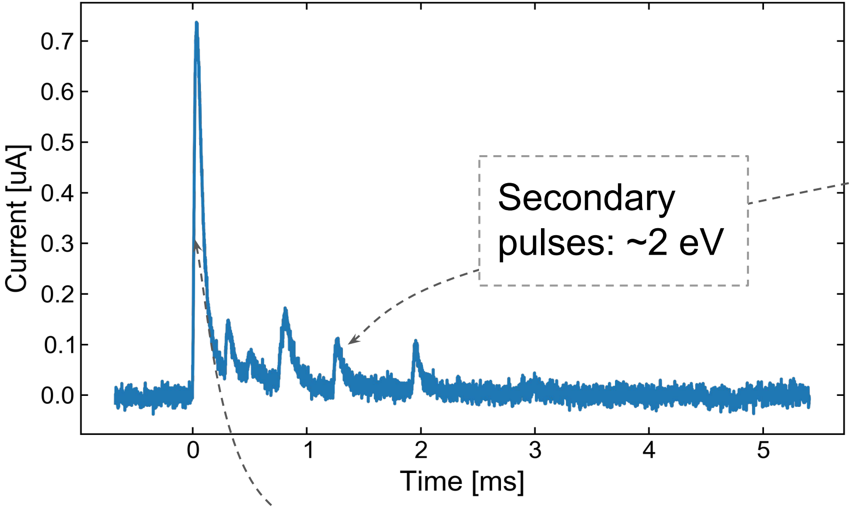






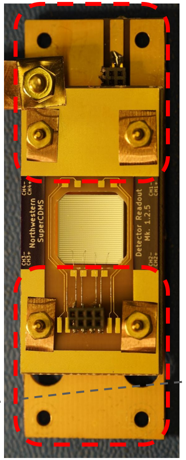
A hypothesis of HV burst events

Luminescence of SiO_2 (from the detector holder G10 PCB)



Secondary pulses: ~2 eV

Primary pulse: **ϵ_{eff}~4-5 eV**



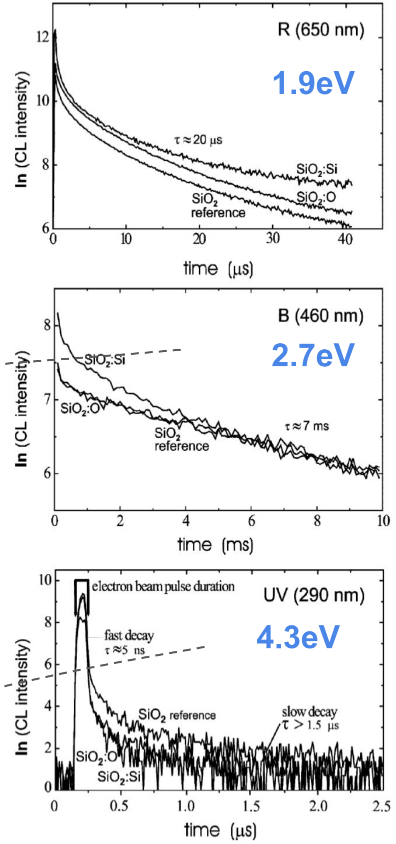


Fig. 3. Decay kinetics of the red R, blue B and UV luminescence in thin SiO_2 films partially doped with Si^+ and O^+ ions and excited by a pulsed electron beam at liquid nitrogen temperature (LNT).

Trukhin, A. N., Jansons, J., Fitting, H. J., Barfels, T., & Schmidt, B. (2003). Cathodoluminescence decay kinetics in Ge+, Si+, O+ implanted SiO2 layers. *Journal of non-crystalline solids, 331*(1-3), 91-99.

- The **HV excess** **in HVeV detector** is dominated by **burst events**
  - Burst events are likely to have an external origin:
    - Most burst events have coincidence events in other detectors
    - Luminescence of SiO_2 in PCB may be one of the origins
- The **0V excess** **in HVeV detector** can be partly explained by burst events seen at HV

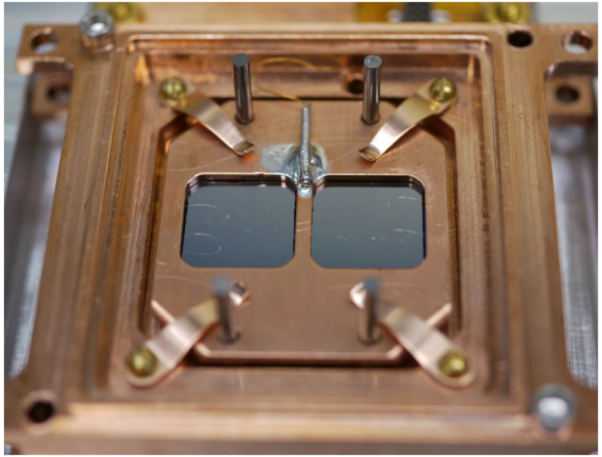
→ **We designed a new detector holder with minimized G10 PCB/insulator**

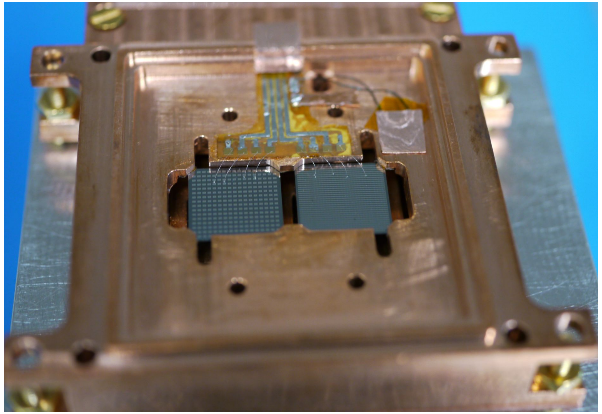
Improved detector holder

The new detector holder is made out of copper.

- No G10 PCB; thin kapton PCB is used for electrical connection
- Two detectors side by side to detect coincidence events

Data-taking and analysis is ongoing. Stay tuned!





This luminescence-like background is the dominating background in SuperCDMS HVeV detectors in HV mode.

It may present in other experiments at a different level.