Results from a Blinded Maximum Likelihood Analysis of CDMSlite Run 3

[1808.09098]

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for the SuperCDMS Collaboration

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CDMS low ionization threshold experiment (CDMSlite)

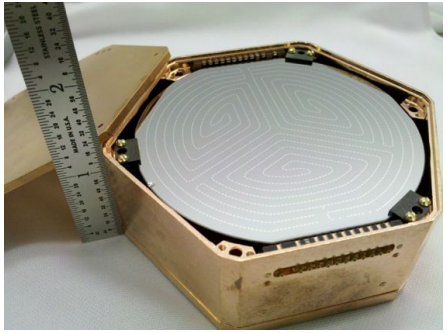
Interacting particle creates charge pairs and phonons (lattice vibrations)

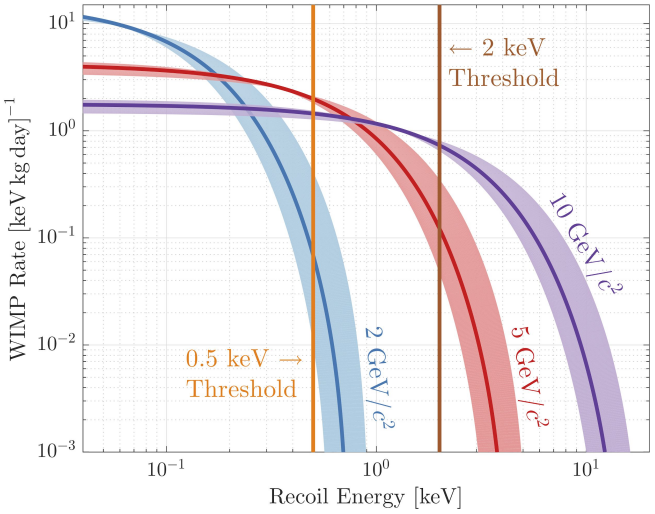
- Ionization: $E_{\mathrm{q}} = \epsilon \times N_{e/h}$
- Recoil Phonon: E_{r}

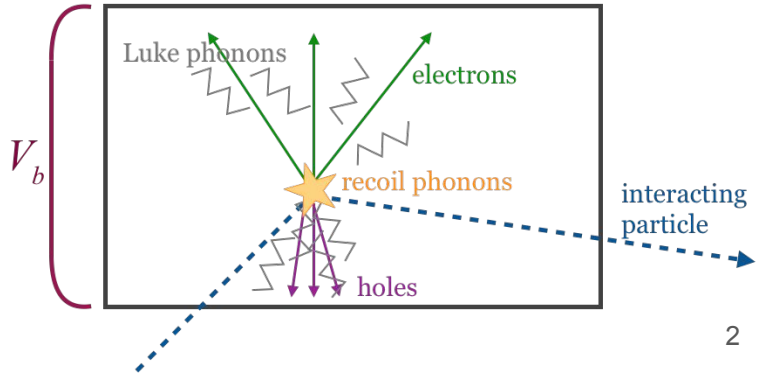
Drifting charges create additional phonons through Neganov-Trofimov-Luke effect, amplifying ionization signal

$$E_{\mathrm{total}} = [E_{\mathrm{r}}] + [E_{\mathrm{q}} \times eV_b/\epsilon]$$

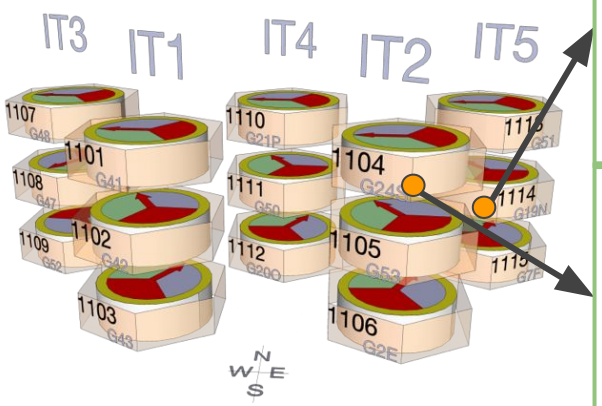
- Increase ionization signal through bias voltage
- Lower threshold







New for Run 3

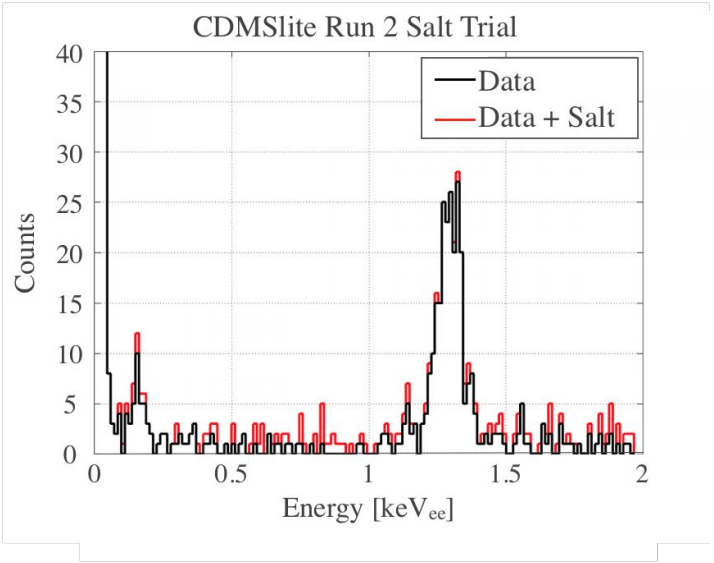


CDMSlite Run 2

- 70 V across T5Z2
- 70 kg-days
- ~56 eV_{ee} threshold

CDMSlite Run 3

- ~75 V across T2Z1
- 35 kg-days
- 70 eV_{ee} threshold



Different Detector

Fiducial Volume Modeling

Blinding by Data Salting

Background Modeling

"Instrumental Background" Discrimination

Profile Likelihood Dark Matter Search

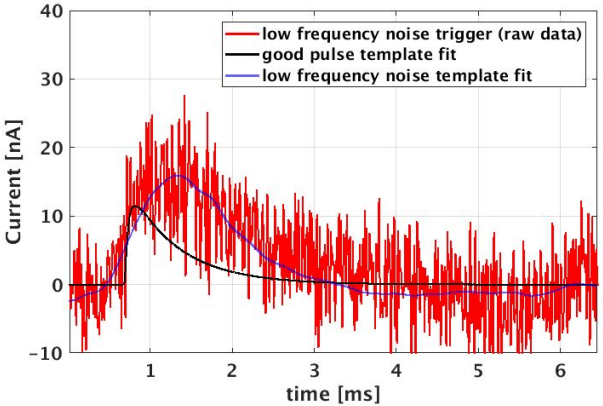
Low Frequency Noise Rejection

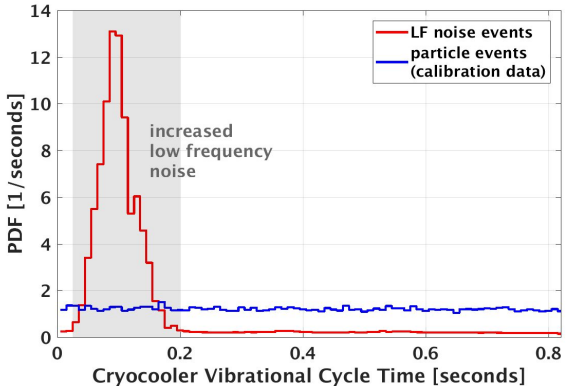
Unrealistic to simulate/model for likelihood fit. Must be efficiently discriminated and cut

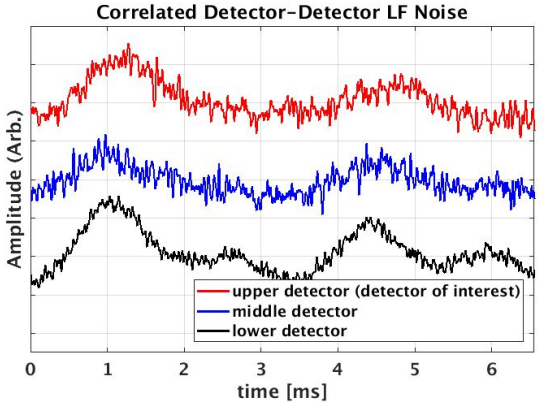
Three Handles on LF Noise:

1. Pulse Shape Discrimination
2. Cryostat Vibration Intensity
3. Detector-Detector Raw Data Correlations

Multivariate Discrimination with Boosted Decision Tree (BDT) Cut

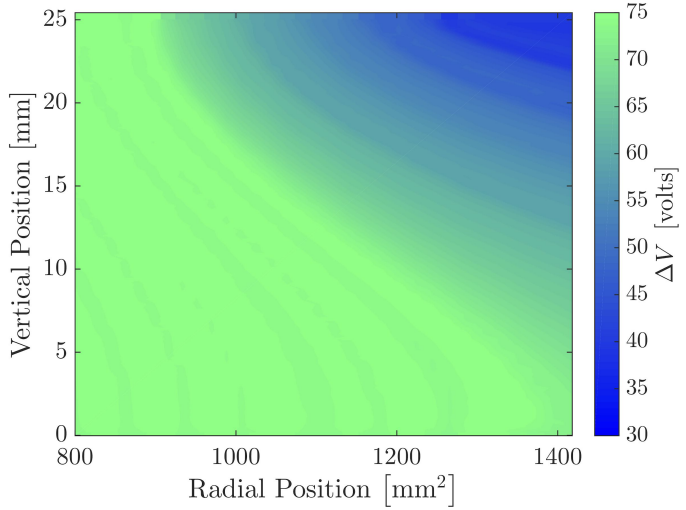


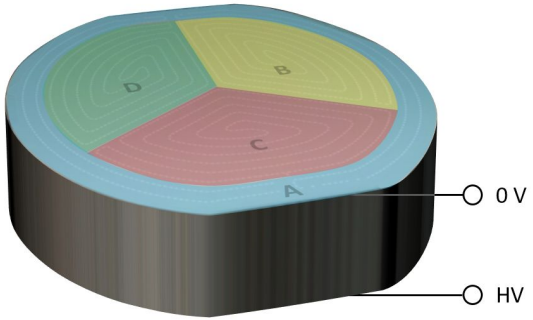


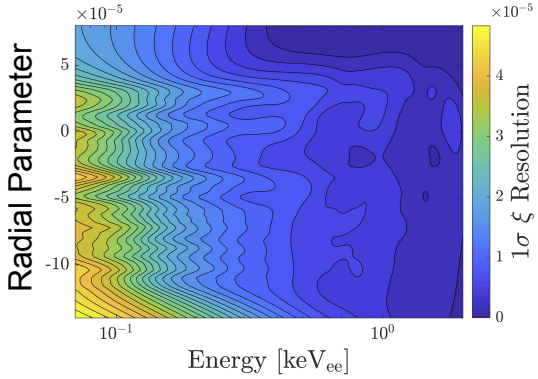


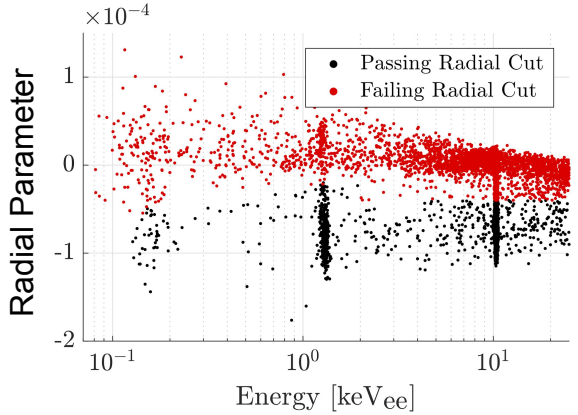
Fiducial Volume

- Events at high radius receive reduced amplification, are reconstructed at lower energy. Must remove for likelihood fit
- Model reduced amplification events' radial distribution using data below calibration lines
- Model reduced amplification events' energy distribution with voltage map
- Design cut to remove radial regions where reduced amplification events fall





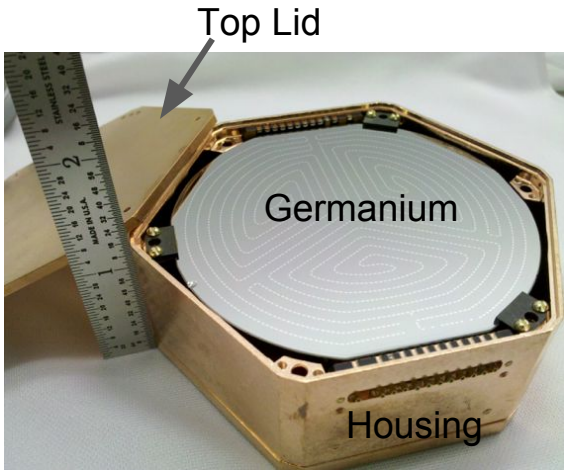


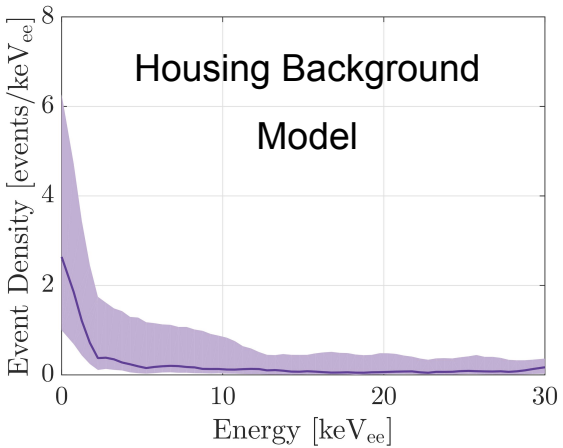


Background Modeling

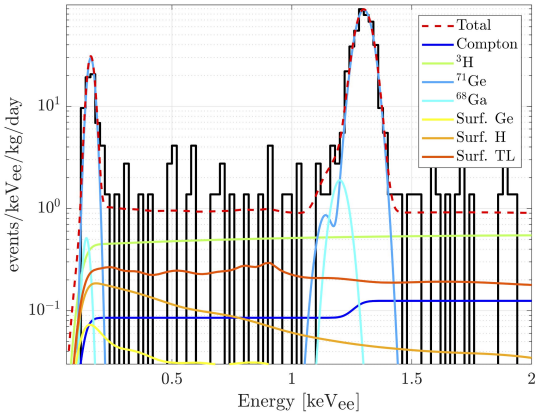
Background events throughout signal region

- ^{71}Ge activation peaks
- Continuum between peaks
  - Cosmogenics, primarily Tritium
  - Compton Scattering
  - Decay products from ^{210}Pb surface contamination

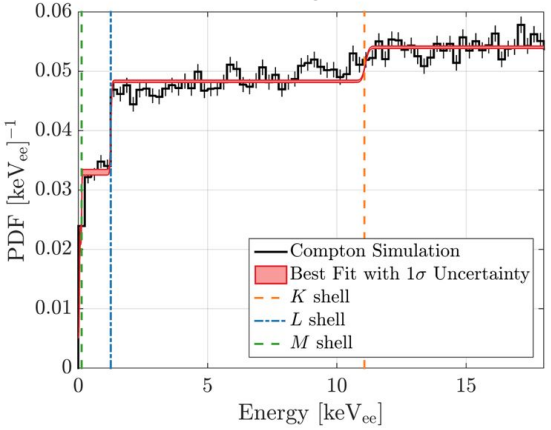




Run 3 Final Spectrum



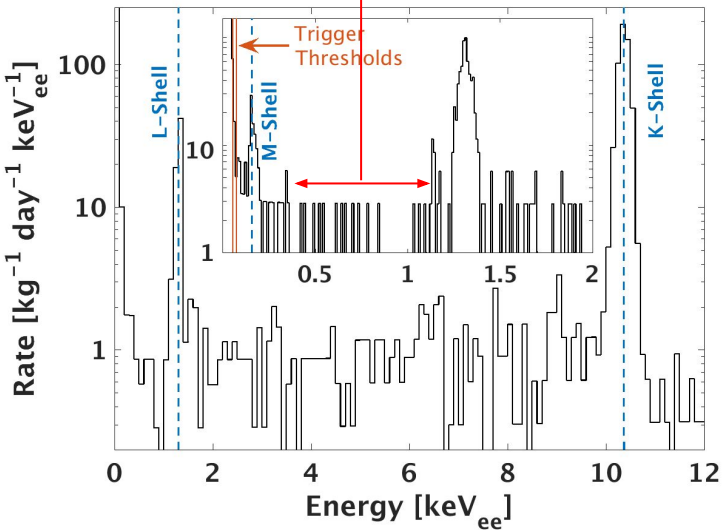
Compton Background Model



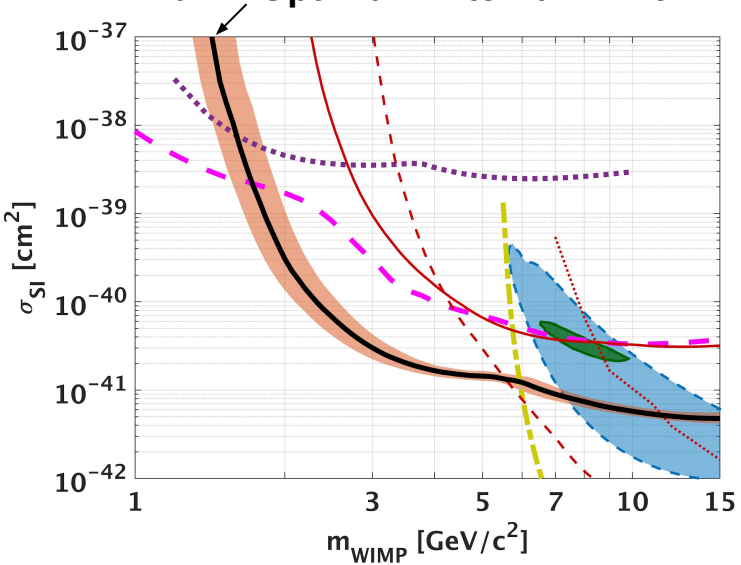
From Optimum Interval To Profile Likelihood

- Intervals between events used to set limit at WIMP σ_X incompatible with data
- Optimum Interval method interprets every event as a potential WIMP event ➡ exclusion-only analysis

Run 2 Final Event Spectrum



Run 2 Optimum Interval Limit

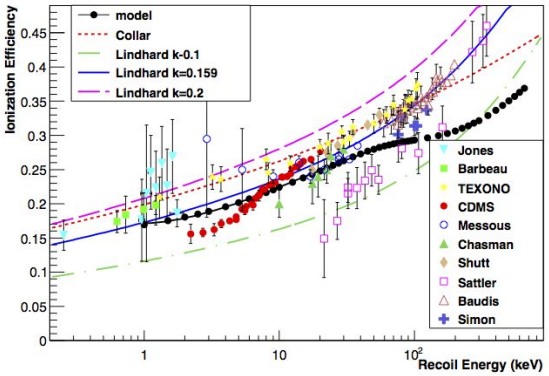


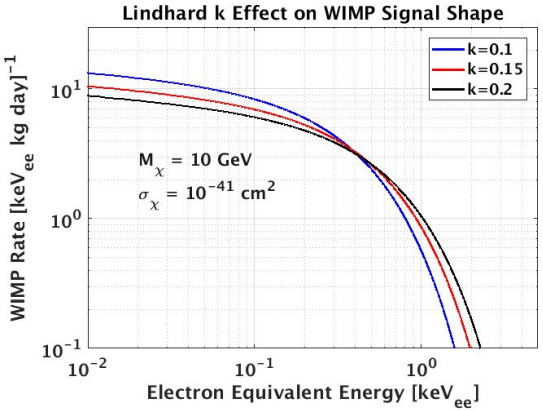
Use particle background models to set profile likelihood WIMP limit. The profile likelihood limit improves WIMP σ_X sensitivity and is not an exclusion only method.

Likelihood Setup

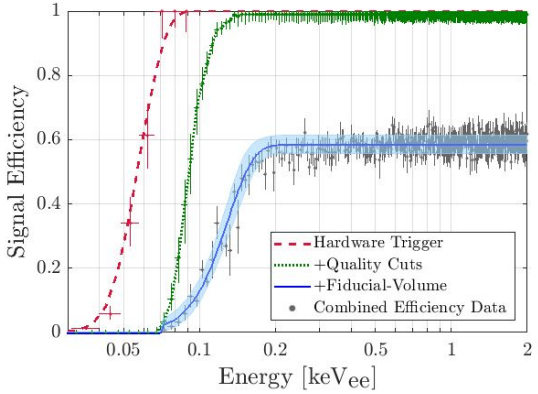
$$\mathcal{L} = \underbrace{\mathcal{L}_1(\sigma_\chi, \vec{N}_b, \vec{\nu}; M_\chi)}_{\text{Likelihood, for a given WIMP mass spectral shape and signal strength } \sigma_\chi, \text{ and nuisance parameters: background spectral shapes, background rates } \vec{N}_b \text{ and systematic uncertainty parameters } \vec{\nu}} \times \underbrace{\mathcal{L}_2(\vec{N}_b, \vec{\nu})}_{\text{Likelihood for constraints on nuisance parameters}}$$

Ionization Yield + Uncertainty





Signal Efficiency + Uncertainty



Results

- P value = 0.988 that data are consistent with background model
- Profile Likelihood 90% CL Limit using CL_s method
- Little to no new parameter space
- < 2.5 GeV gained relative to Run 2 because of comparable analysis thresholds
- Factor of ~2.5 improvement over CDMSlite Run 2 at 5 GeV

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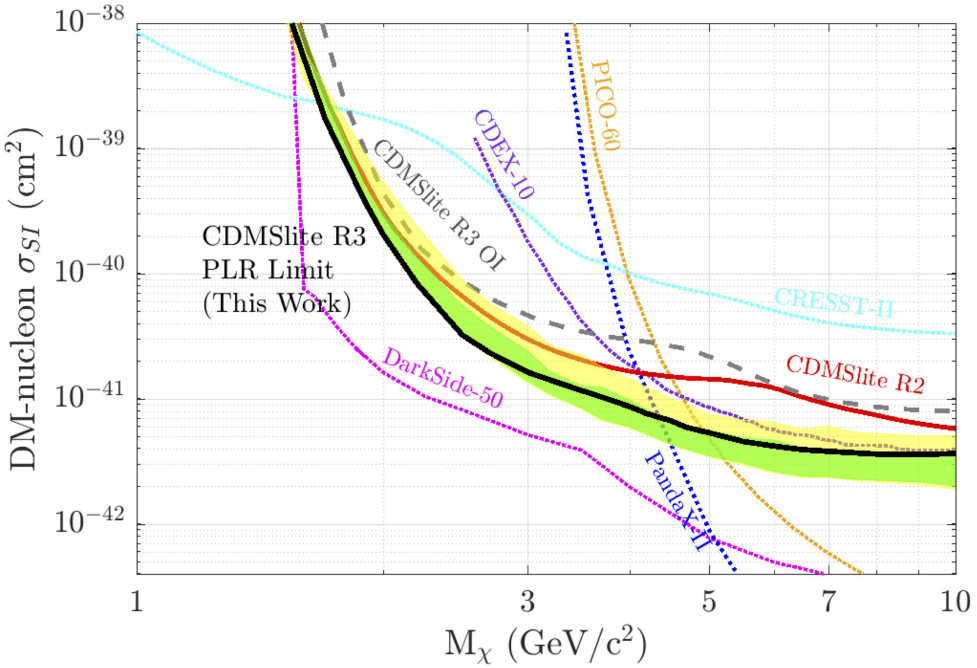

Thank You

California Inst. of Tech.
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South Dakota SM&T
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SNOLAB
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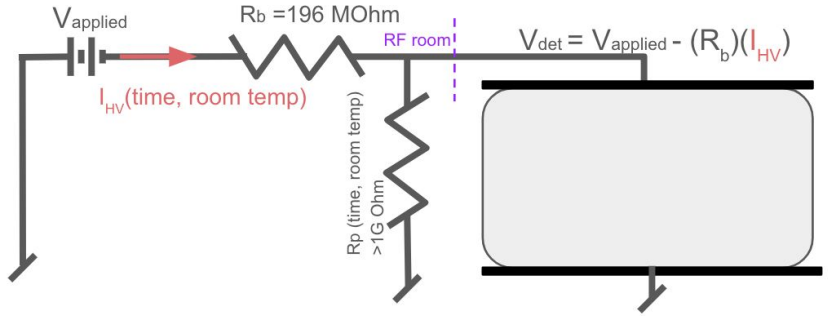
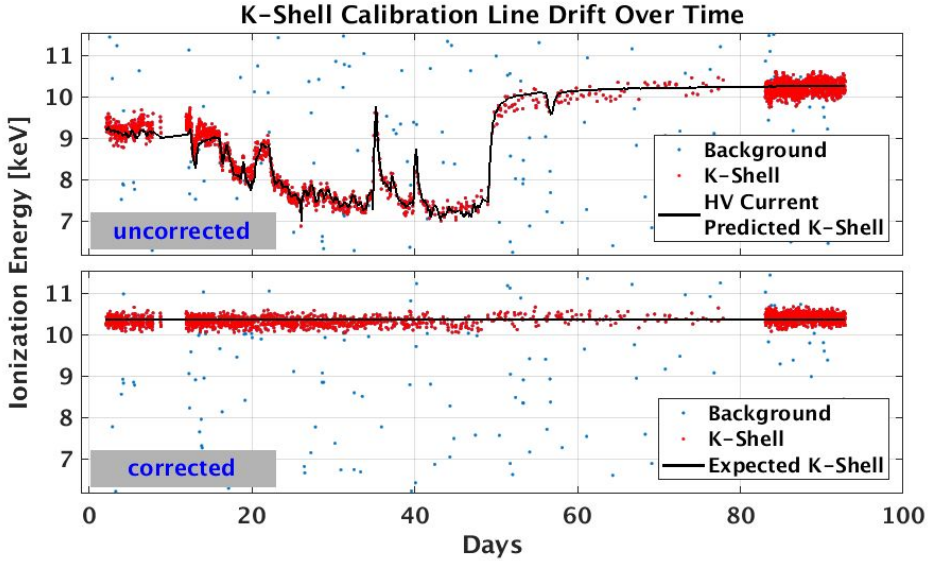
* Associate members

Backup Slides

Energy Scale Calibration and Correction

- Primary calibration feature is the ^{71}Ge electron-capture K-shell decay, producing a 10.37keV electron recoil
- Variable detector gain necessitates calibration + correction
- Majority of energy correction is from variation of detector voltage from current, which was measured
- Small additional energy corrections from base temperature, event position





Bifurcated Analysis

Two uncorrelated BDT variables are formed using the three different handles on discriminating LF noise

- Branch A : primarily pulse shape discrimination information
- Branch B : primarily cryostat vibration and detector-detector correlation information
- Bifurcated analysis indicates 0.4 ± 0.1 LF noise event leaking past cuts