Confirmation of the spectral excess in DAMIC at SNOLAB with Skipper CCDs

EXCESS23@TAUP - University of Vienna

Michelangelo Traina, on behalf of the DAMIC(-M) collaborations
CENPA, University of Washington, Seattle (US)

Outline:

1. DAMIC at SNOLAB
2. Background model
3. Low-energy excess
4. SNOLAB skipper upgrade
5. Science data and selections
6. Confirmation of the excess

CENPA
Center for Experimental Nuclear Physics and Astrophysics
UNIVERSITY of WASHINGTON

DAMIC AT SNOLAB

DArk Matter In CCDs collaboration

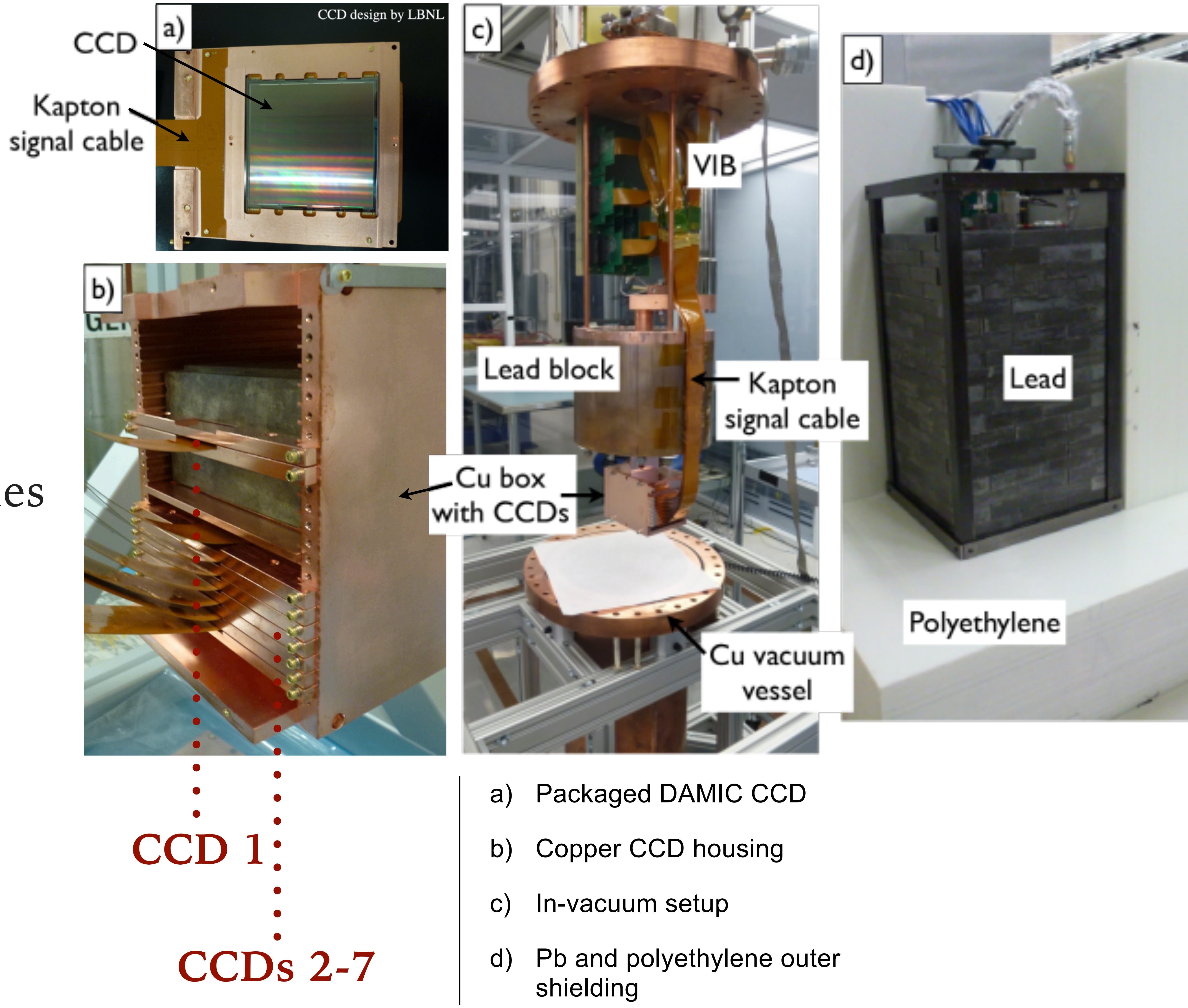
- Setup beneath 2 km of granite **at SNOLAB** (Canada)
- Sensors in cryogenic conditions (10^{-6} mbar, 140 K)

Charge-Coupled Devices

- Very low noise and leakage current: sensitive to e⁻
- 3D track reconstruction and particle identification capabilities

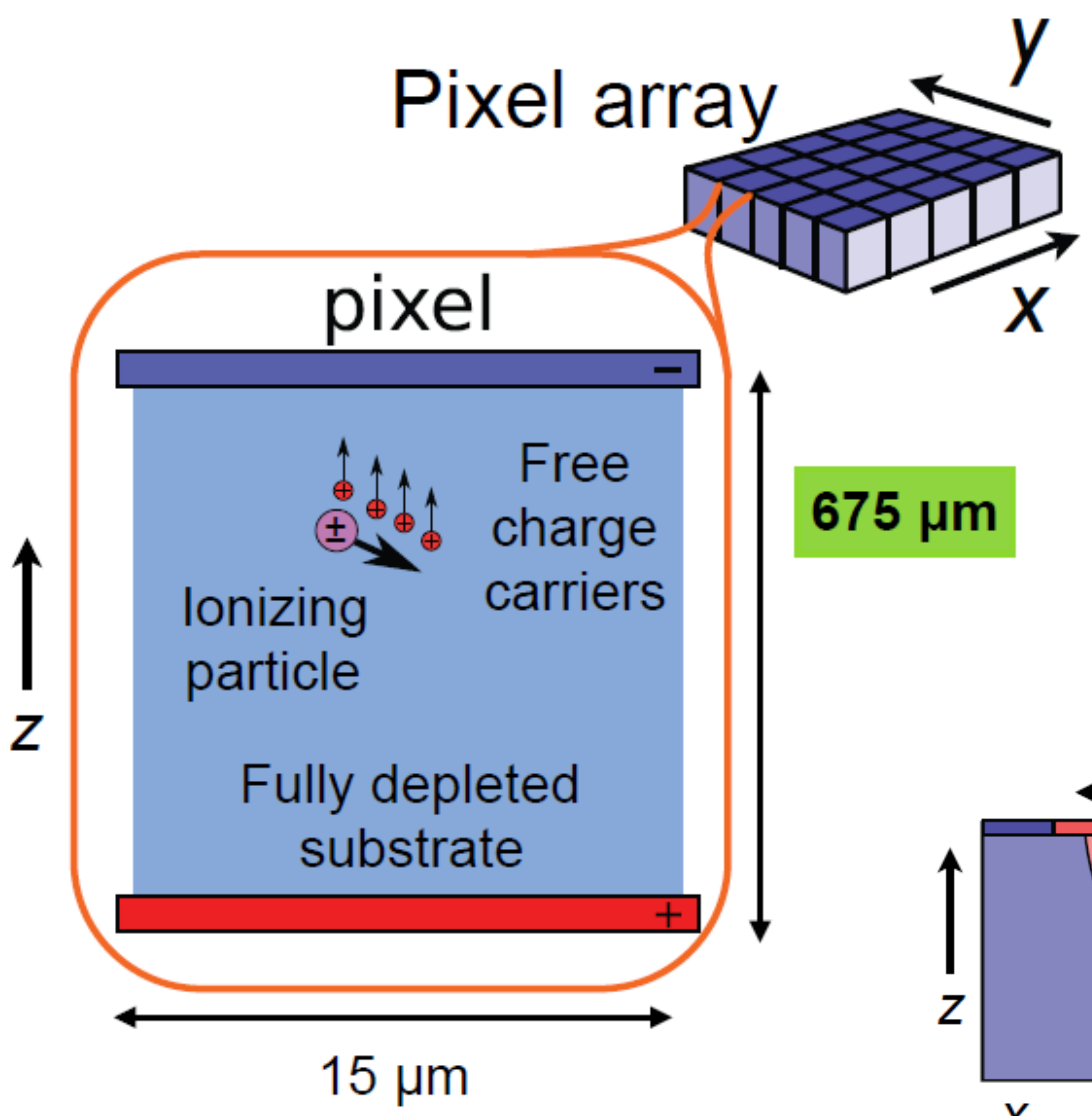
DAMIC apparatus in 2018:

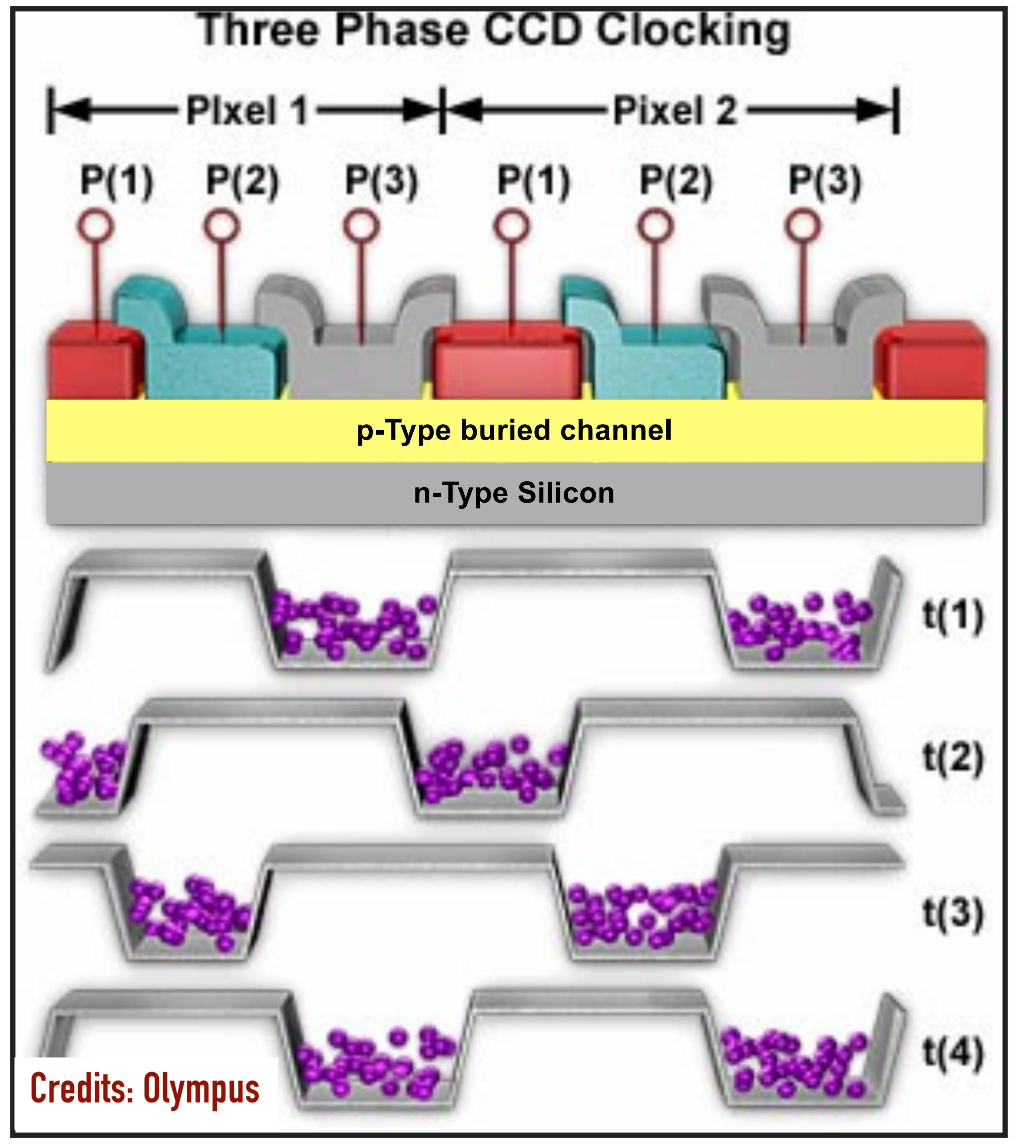
- Several thick CCDs $\Longrightarrow$ massive target
  $7\times$ 675 μm ~ 40 g
- Sensitive to:
  - WIMP-nucleus coherent scattering
  - Hidden sector light DM-e⁻ interactions

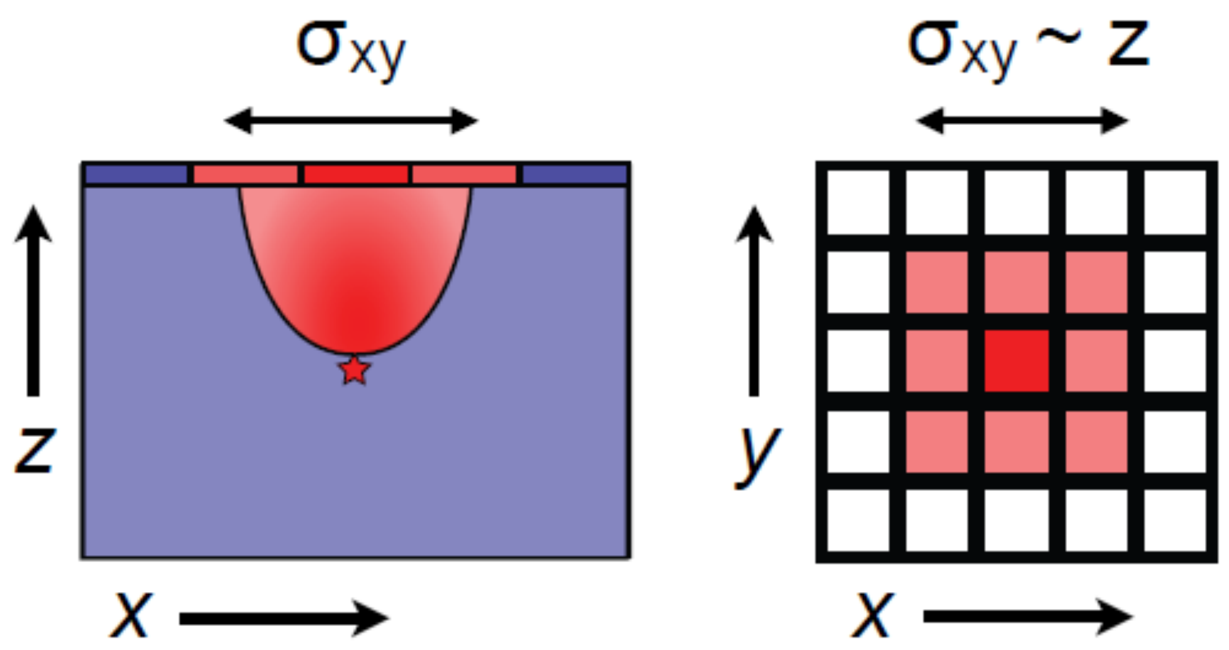


a) Packaged DAMIC CCD
b) Copper CCD housing
c) In-vacuum setup
d) Pb and polyethylene outer shielding

CHARGE-COUPLED DEVICES

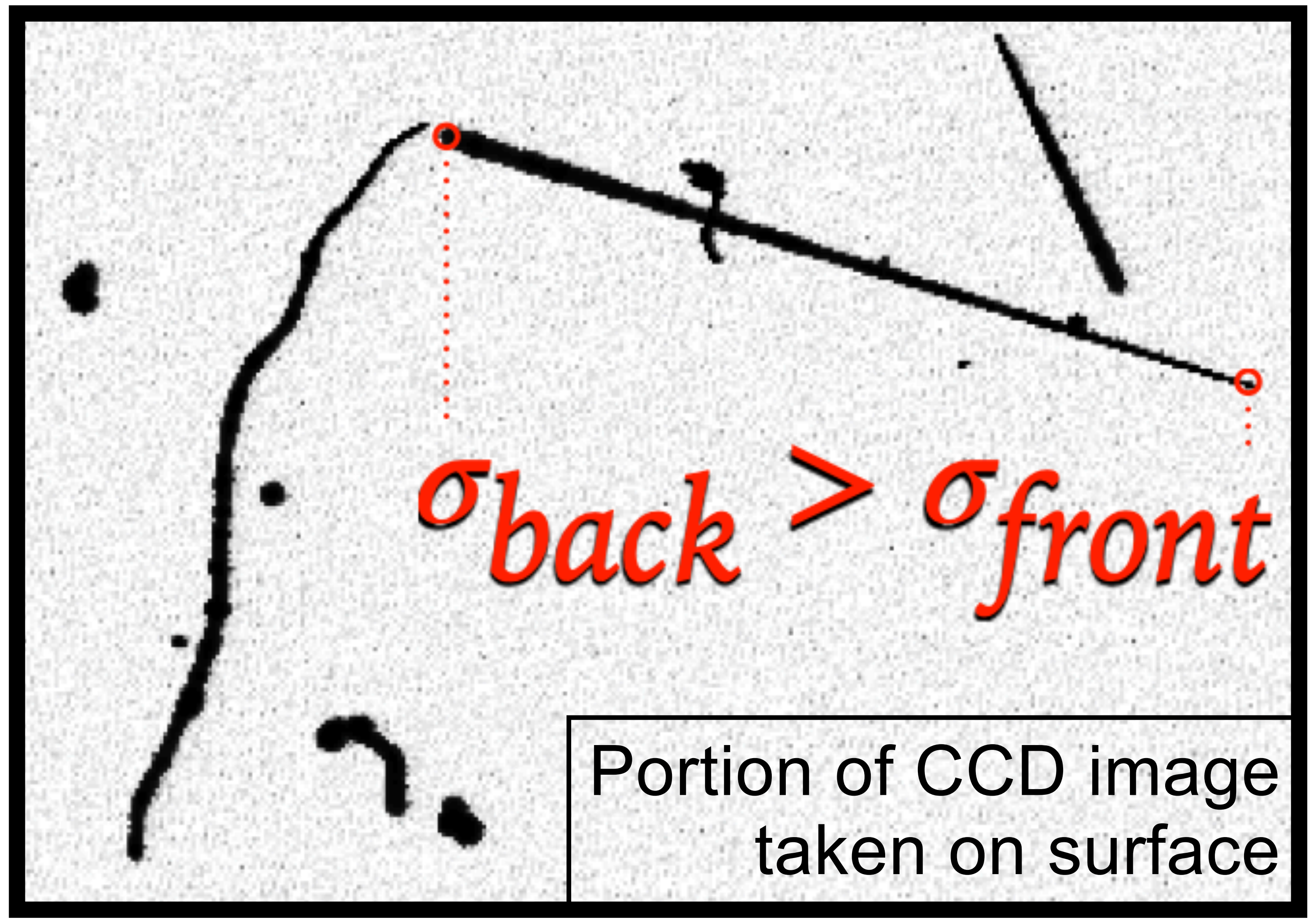






DAMIC science-grade CCDs

- PolySi gate, p-type buried channel structure
- Fully depleted at 40 V ($\sim$ 10 k$\Omega \cdot$ cm)



BACKGROUNDS IN DAMIC

DAMIC

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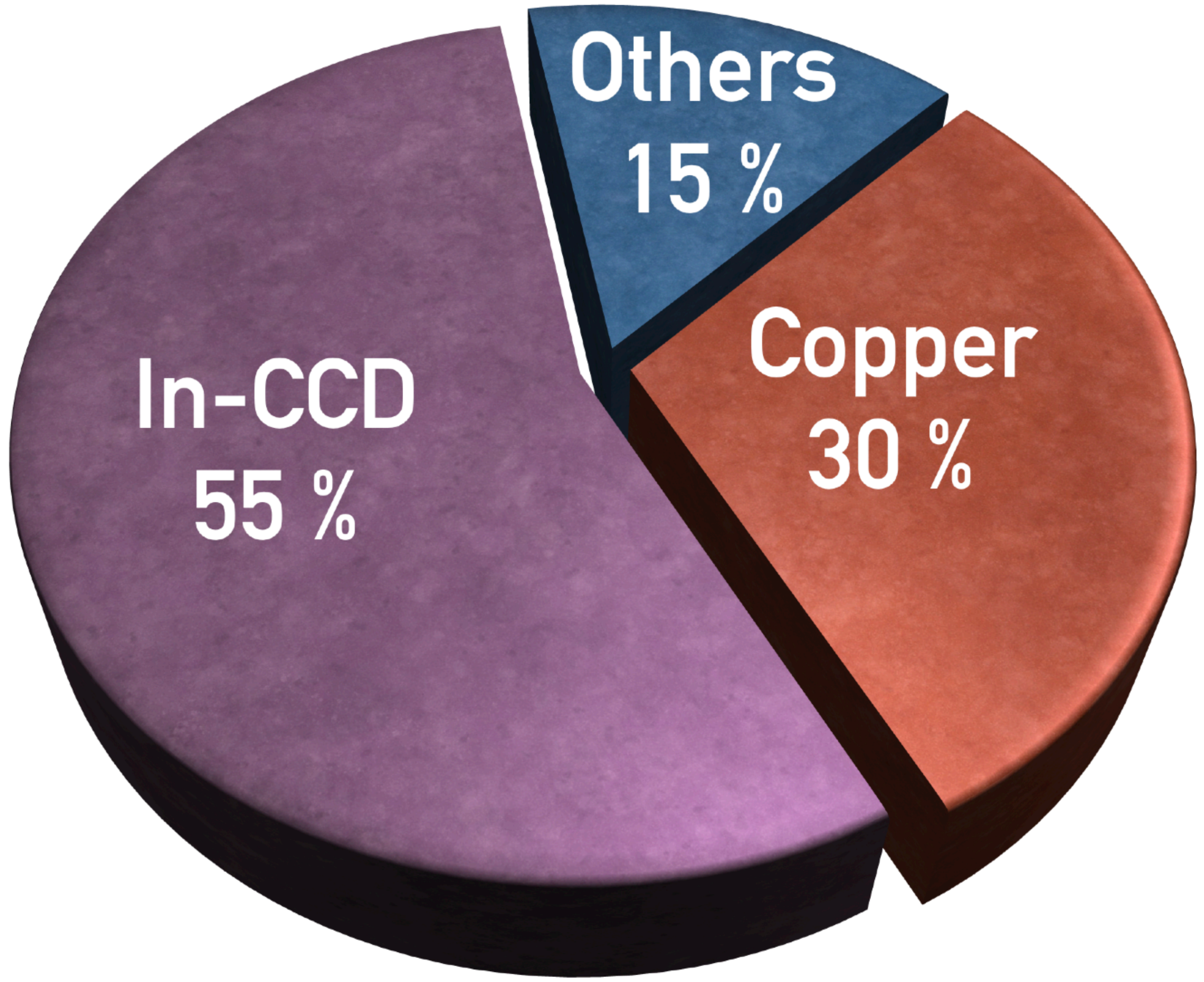
How we deal with backgrounds:

- Underground operation: ~~cosmic radiation~~
- Material selection (assays): ~~apparatus radioactivity~~
- In situ shielding: ~~environmental radioactivity~~
- Discrimination and quantification of residual contaminants $\Longrightarrow$ radioactive background model

Background contributions:

- $\sim 55\,\%$ in-CCD contaminants
  - Surface ^{210}Pb from Rn deposition
  - Bulk ^{3}H from cosmogenic activation
- $\sim 30\,\%$ OFHC copper
  - Bulk ^{210}Pb in copper
  - Cobalt isotopes from cosmogenic activation
- $\sim 15\,\%$ from various detector materials (lead, flex cables, etc.)

~ 12 **dru**

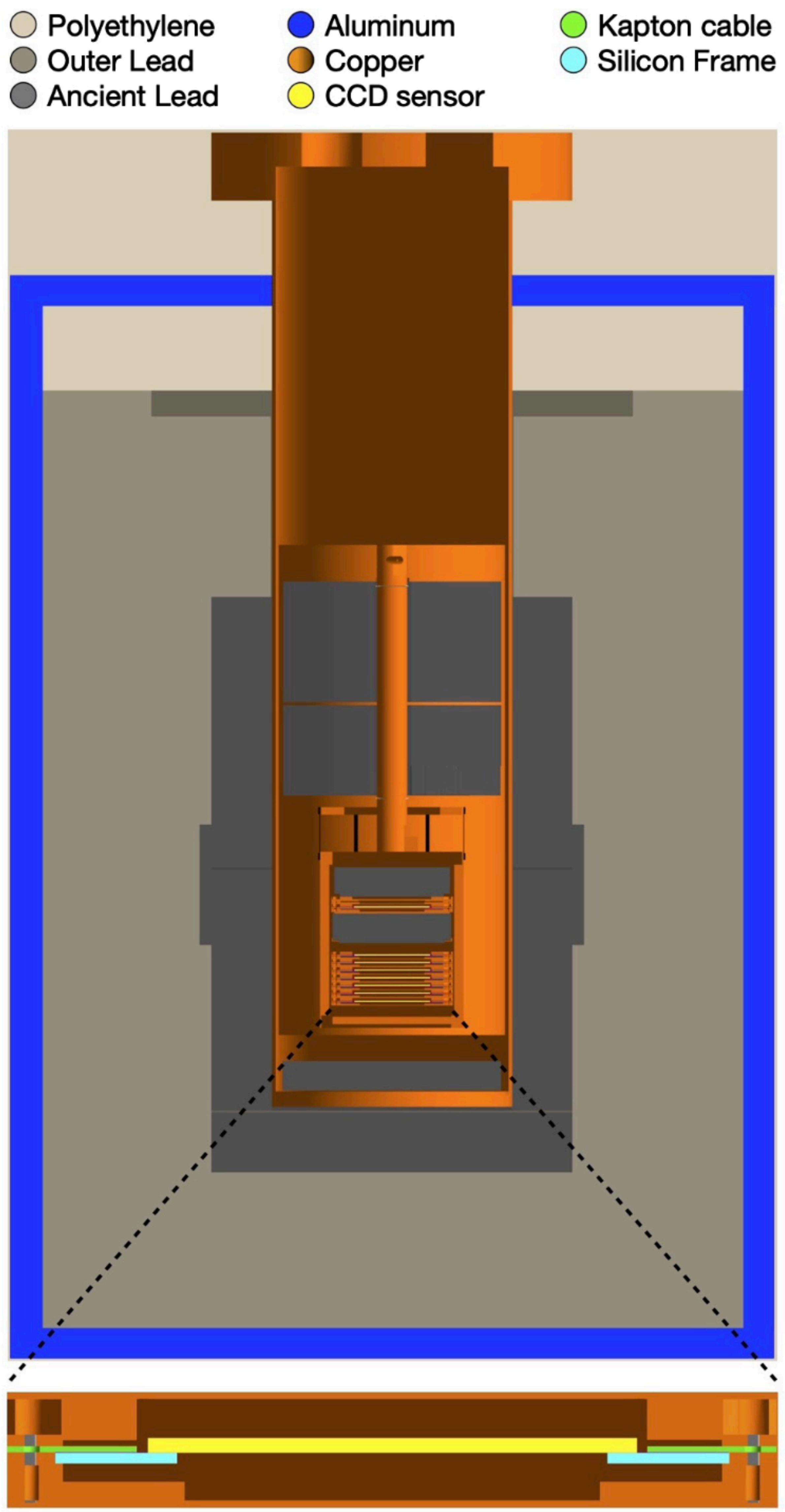


$1\ \mathbf{dru} = 1\ \mathbf{event} \cdot (\mathbf{keV} \cdot \mathbf{kg} \cdot \mathbf{d})^{-1}$

BACKGROUND MODELING

Background model construction: Phys. Rev. D **105**, 062003 JINST **16** P06019

- Decay and tracking across detector geometry with GEANT4
- CCD response simulation

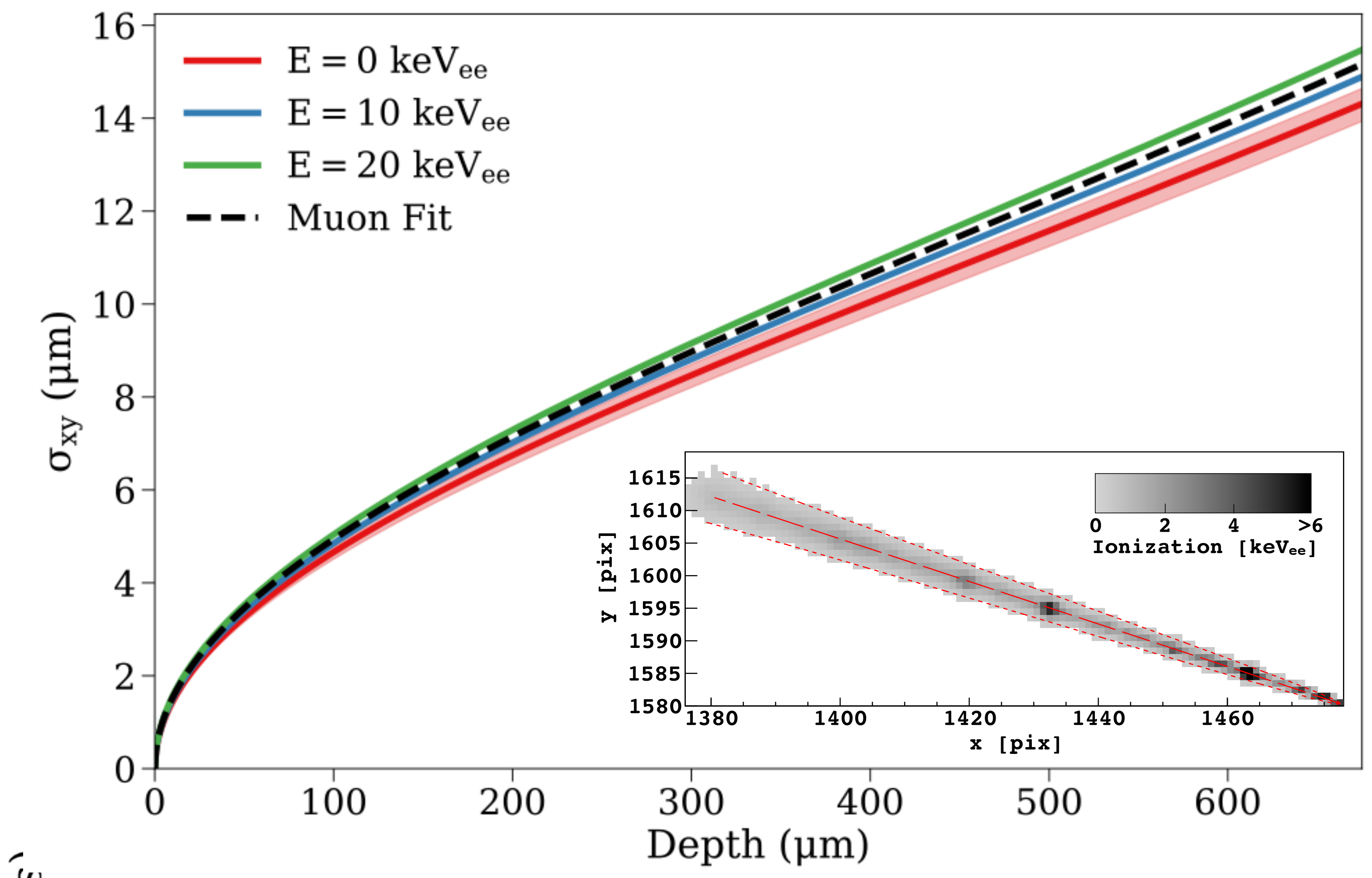


DETECTOR RESPONSE

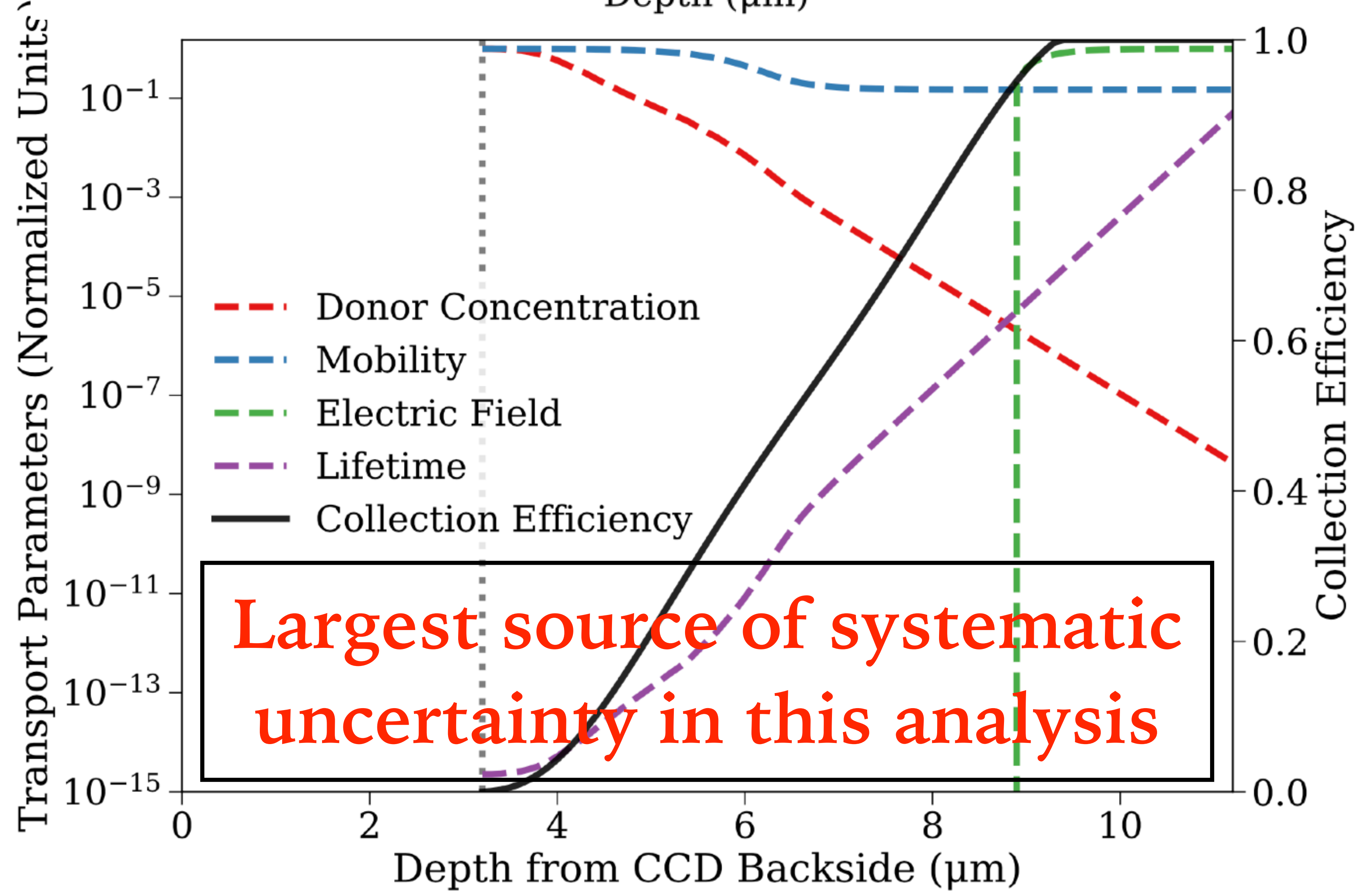
$$\sigma_{xy}(z,E) = \sqrt{-A\ln(1-bz)(\alpha+\beta E)}$$

- Charge generation: $\langle E_{eh} \rangle = 3.8\ \mathrm{eV}_{ee}$ j.nima.2021.165511

- Diffusion model calibrated on muon surface data



- Charge collection efficiency based on secondary ion mass spectrometry measurements (SIMS)
  - Consistent with later calibration
    Phys. Rev. Applied **15**, 064026



- Pixelation and noise addition

Reconstruction into (E, σ_{xy}) distribution

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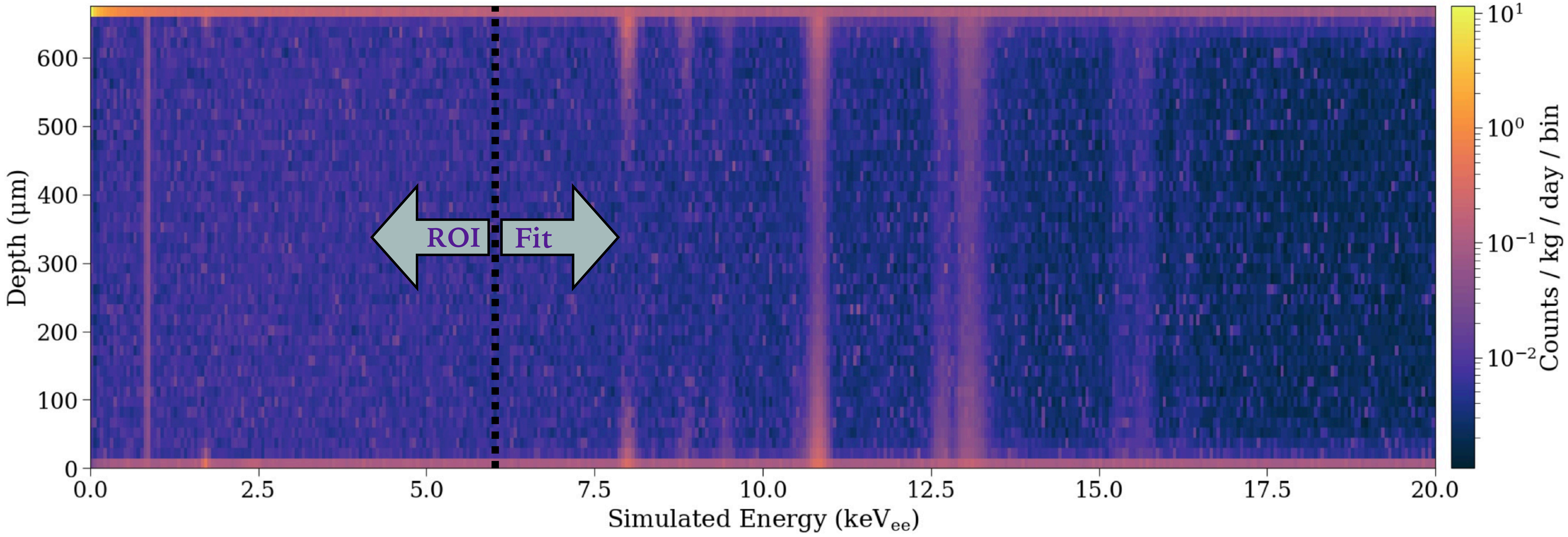
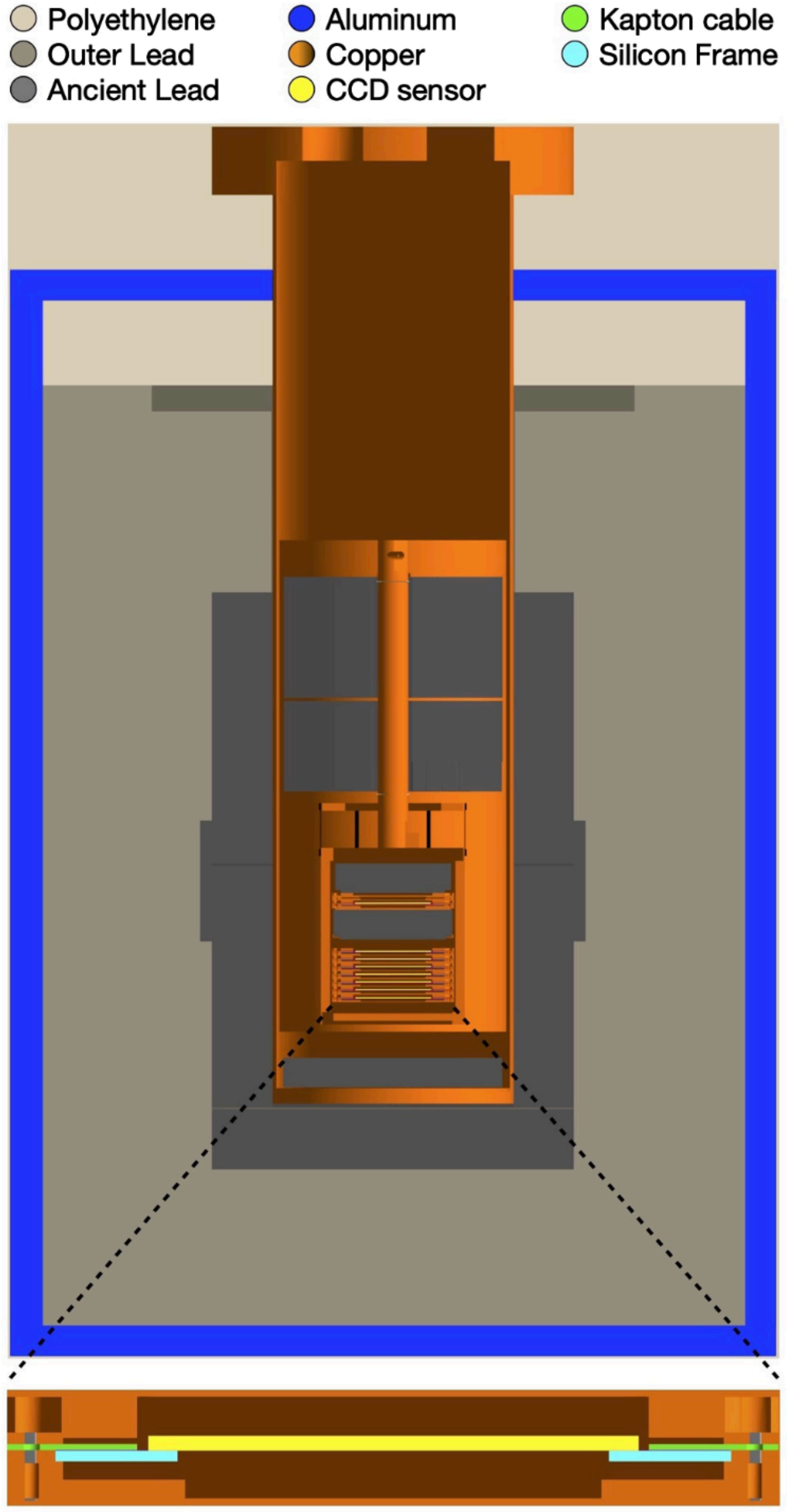
- CCD response simulation
- Reconstruction to (E, σ_{xy}) analysis space
- Likelihood fit to data in WIMP-free region ($6 - 20$ keV$_{ee}$)

$\Longrightarrow$ extrapolate in ROI ($0.05 - 6$ keV$_{ee}$)

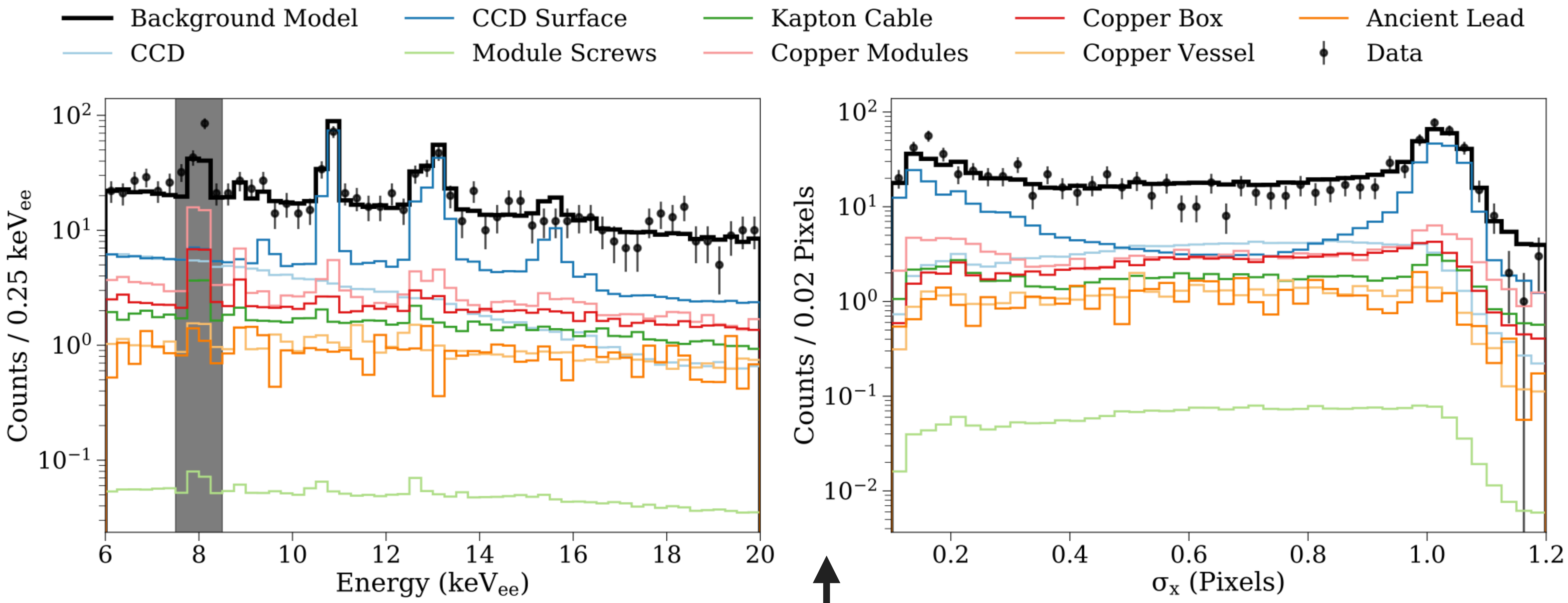
eV$_{ee}$: electron-equivalent energies

Simulated backgrounds for CCDs 2-7 in energy and depth

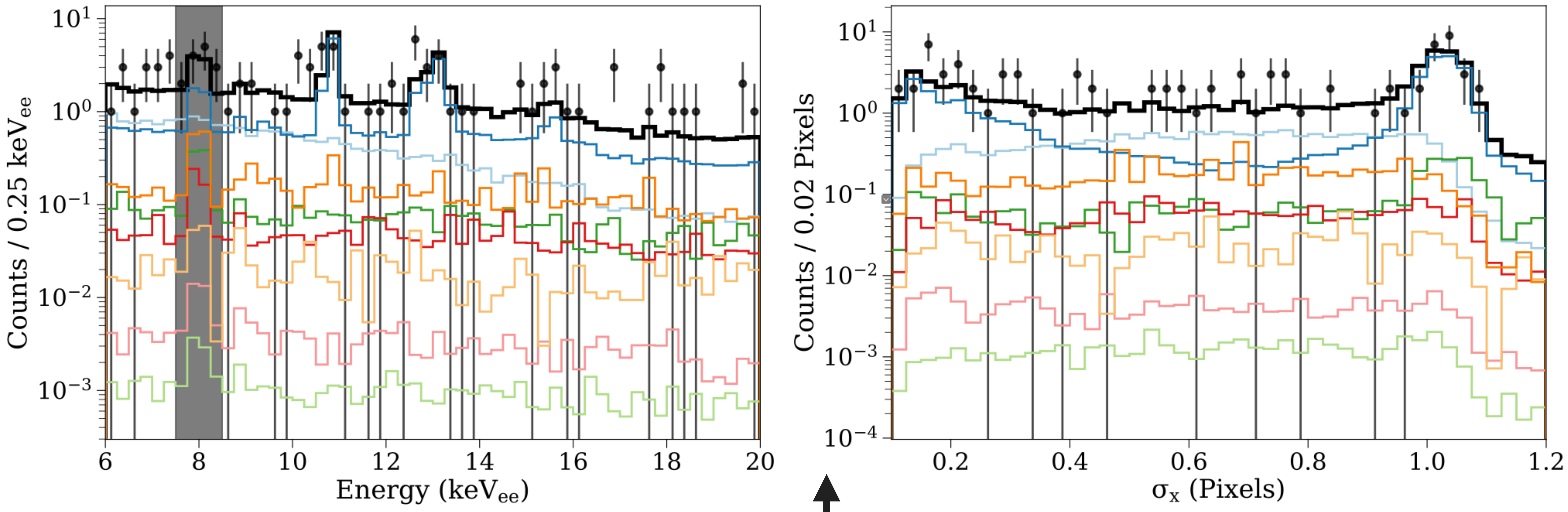




BACKGROUND TEMPLATE FITTING



Fit on CCD 2-7 data



Validation with CCD 1 data

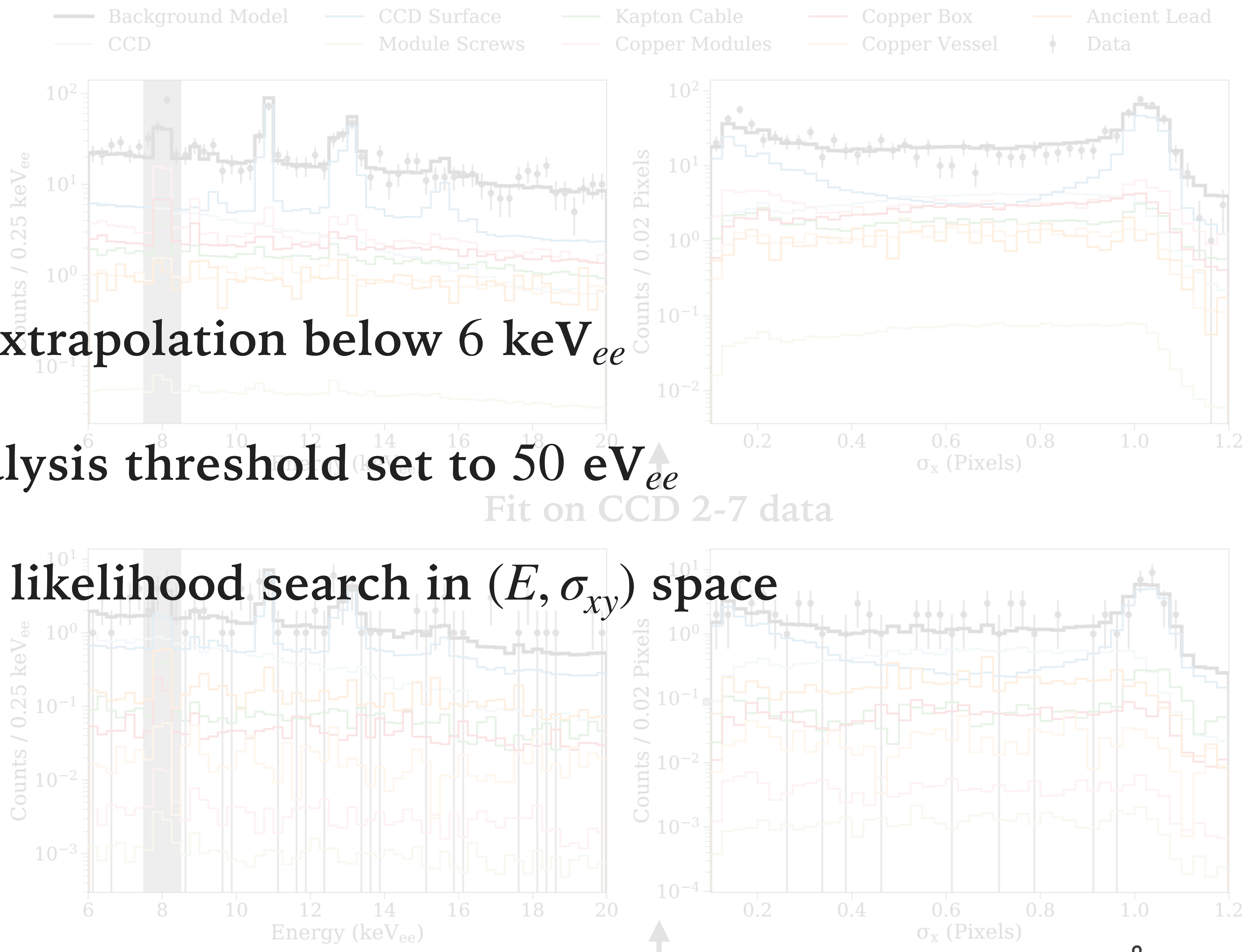
BACKGROUND TEMPLATE FITTING

Construction of Background Templates

- Group simulations up in templates according to material and decay
- Construct number of expected events per bin, ν_{ij}:

$$\nu_{ijl} = \sum_{m=0}^{N_{det.part}} n_{ijm} \times \frac{A_l M_m(\epsilon_{data} t_{run})}{(\epsilon_{sim} N_m)}, \quad \nu_{ij} = \sum_{l=0}^{N_{templates}} C_l \nu_{ijl}$$

- Compare it to data bin content, … Poisson two-dimensional likelihood analysis
  - ➡ Best-fit C_l's characterize bkg model



Fit on CCD 2-7 data

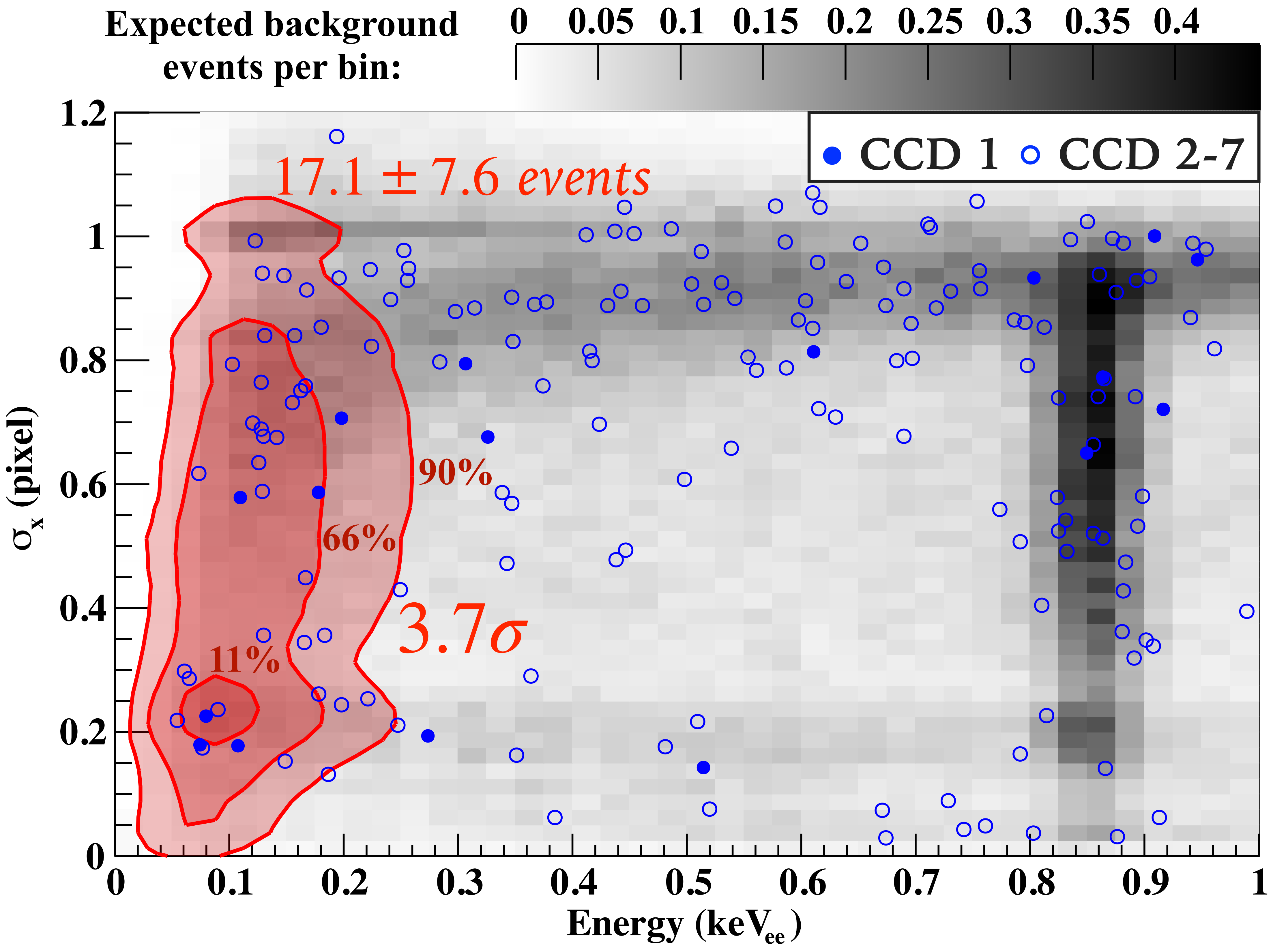
Validation with CCD 1 data

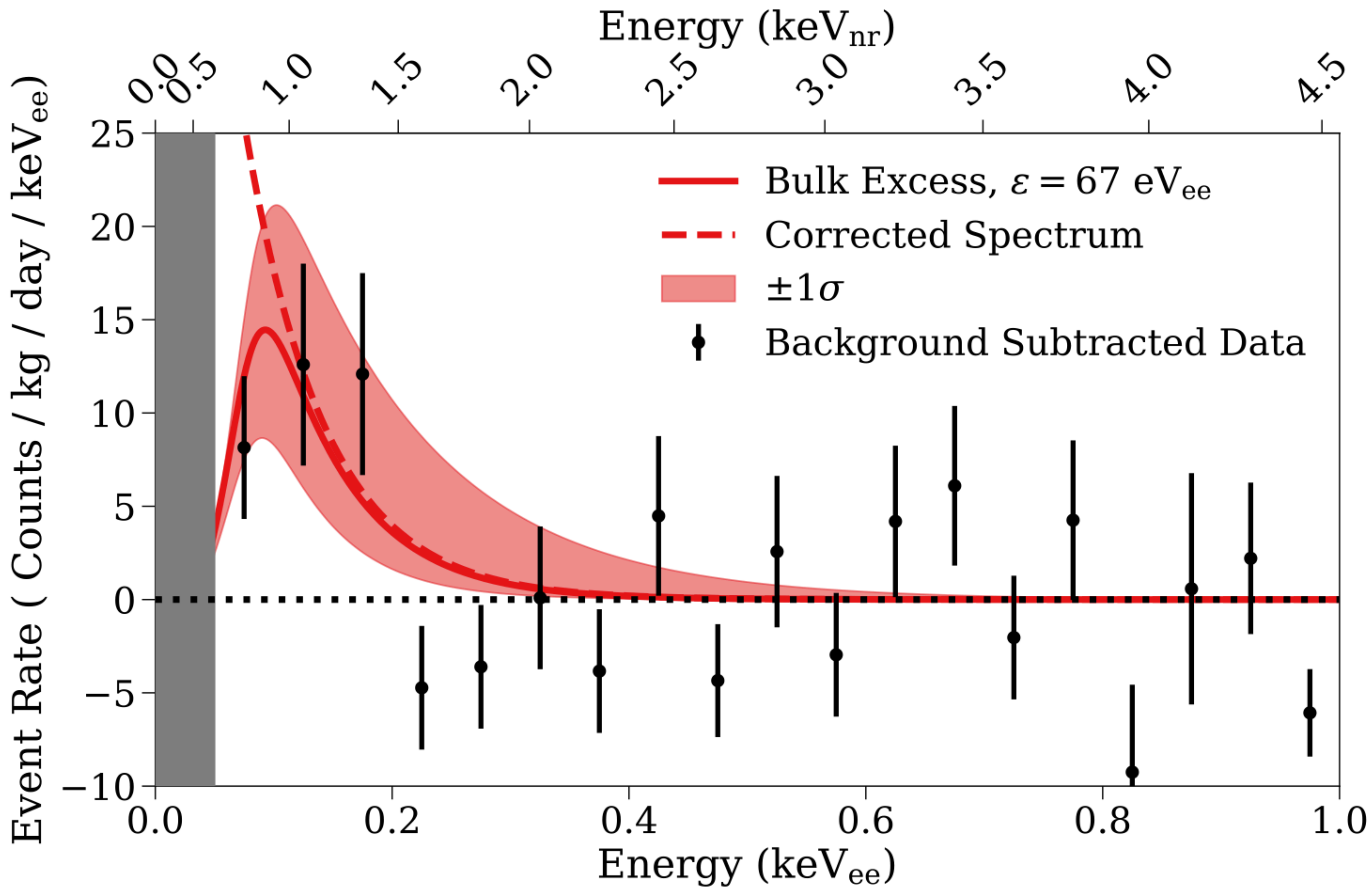
→ Extrapolation below 6 keV$_{ee}$

→ Analysis threshold set to 50 eV$_{ee}$

→ Profile likelihood search in (E, σ_{xy}) space

≤200 eV EXCESS





Phys. Rev. Lett. **125**, 241803

Systematic checks: no issue with analysis

- Fit above 200 eV consistent with null hypothesis
- Independent fit to CCD1 and 2-7 consistent with global result
- PCC systematics cannot account for excess
- Surface events cannot account for excess
- Local vs. global significance: excess by far most significant feature in spectrum
- Excluded CCD artifacts as possible source

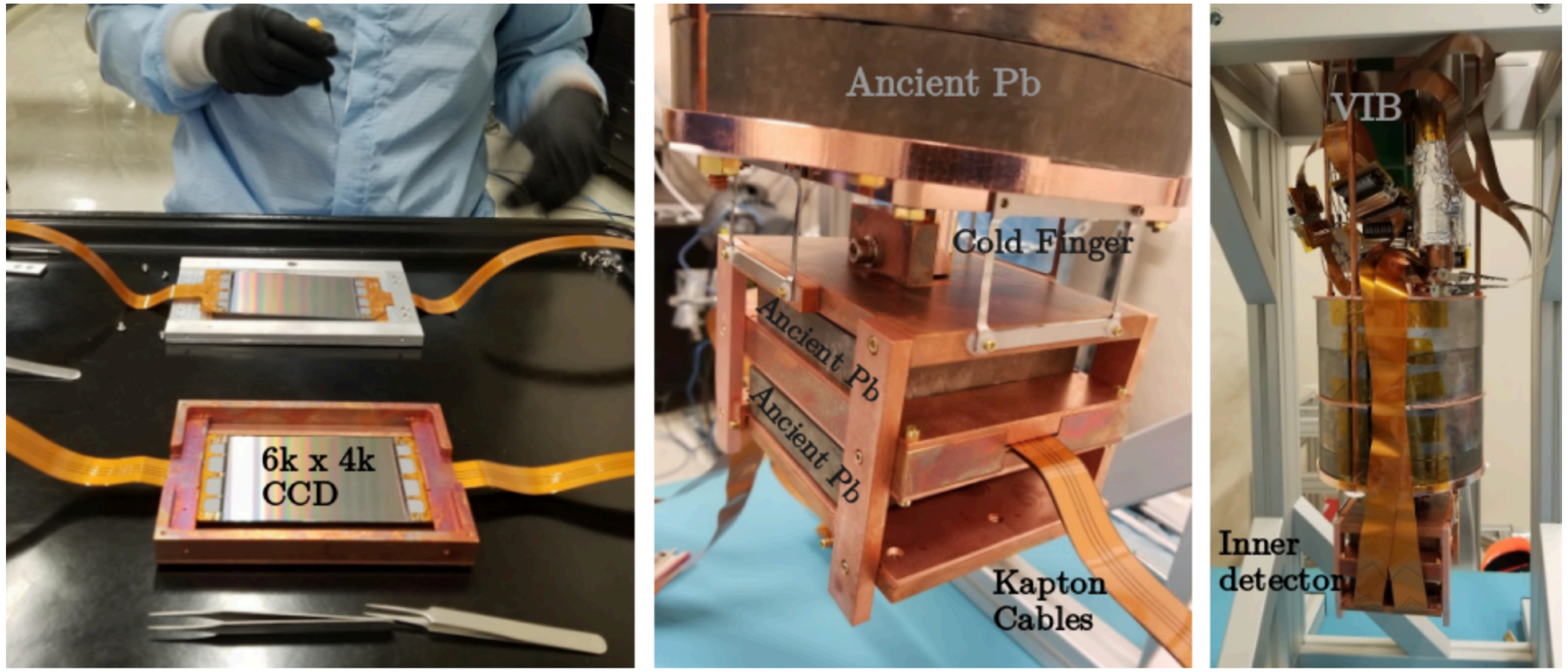
Plausible interpretations:

- Unaccounted detector surface effect
- Missing component in background model

SKIPPER UPGRADE AT SNOLAB

Setup upgraded with two $6k \times 4k$ skipper CCDs

- Same bkg contributions, same rate: ~ 10 dru
- $10\times$ lower noise with skipper readout: $\sim 0.16\ e^-$
- Science run from March 2022 to Jan 2023
  - Different readout → different noise response
  - Improved $\sigma_{xy}(z)$ reconstruction for depth fiducialization
  - 4.8 kg-day total exposure. 3.1 kg-day after selections
- ROI: $E < 500$ eV$_{ee}$ unblinded in Feb 2023



DAMIC, DAMIC-M and SENSEI collaboration

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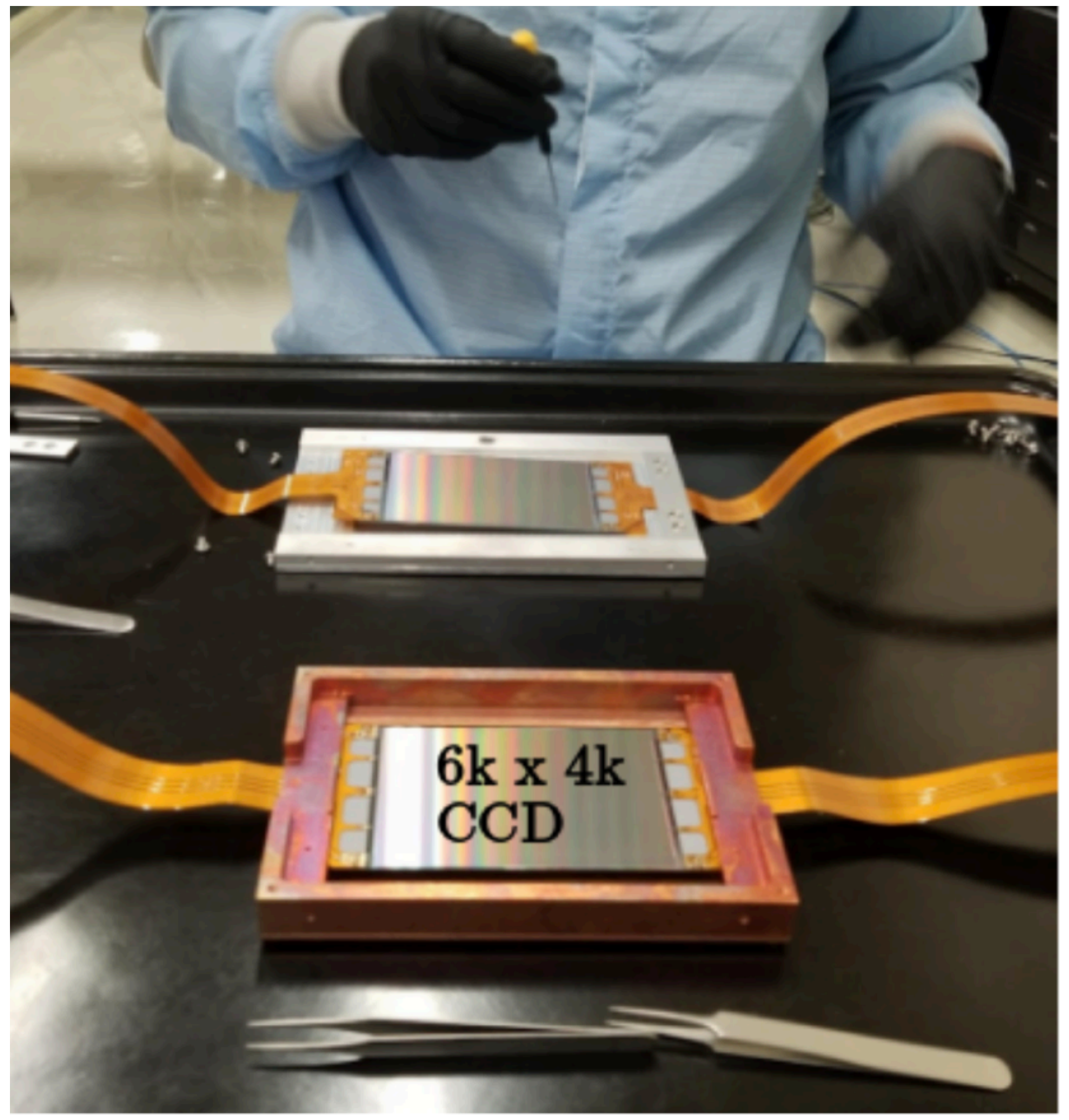
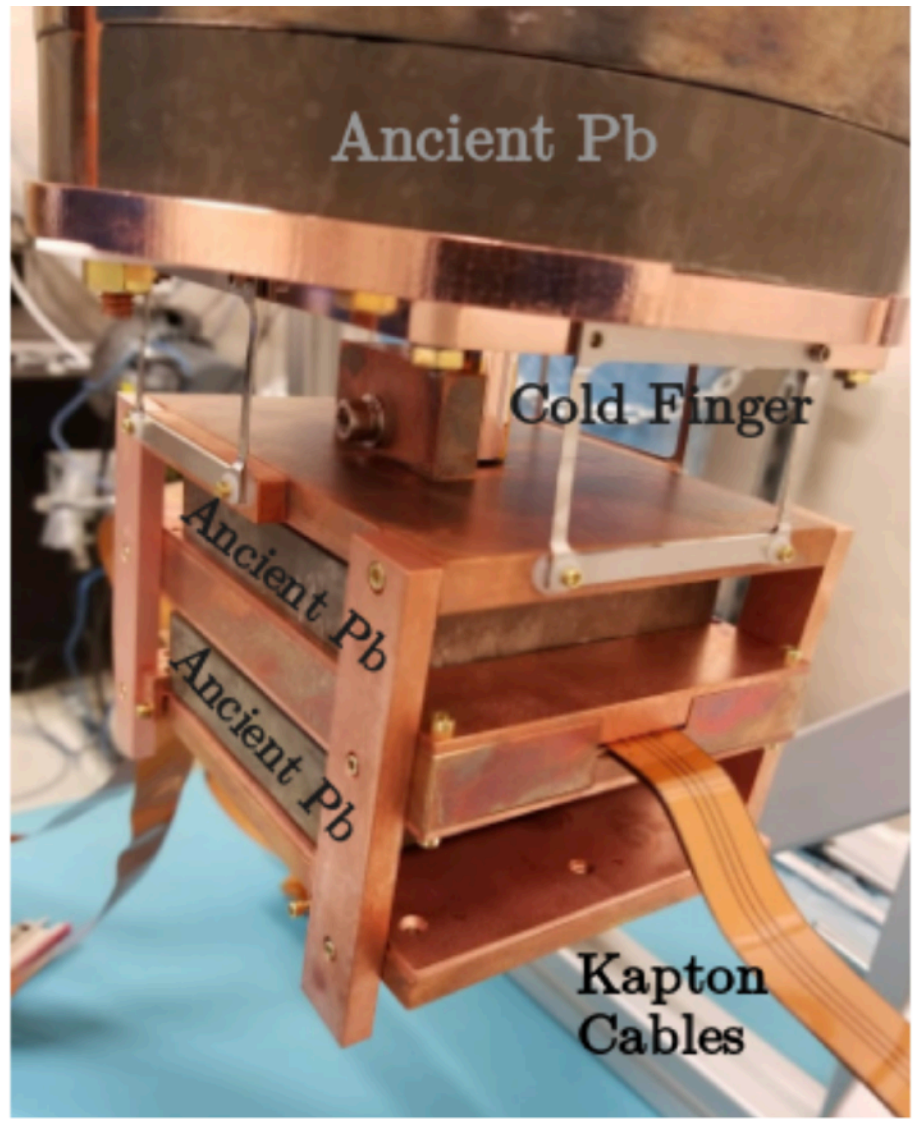
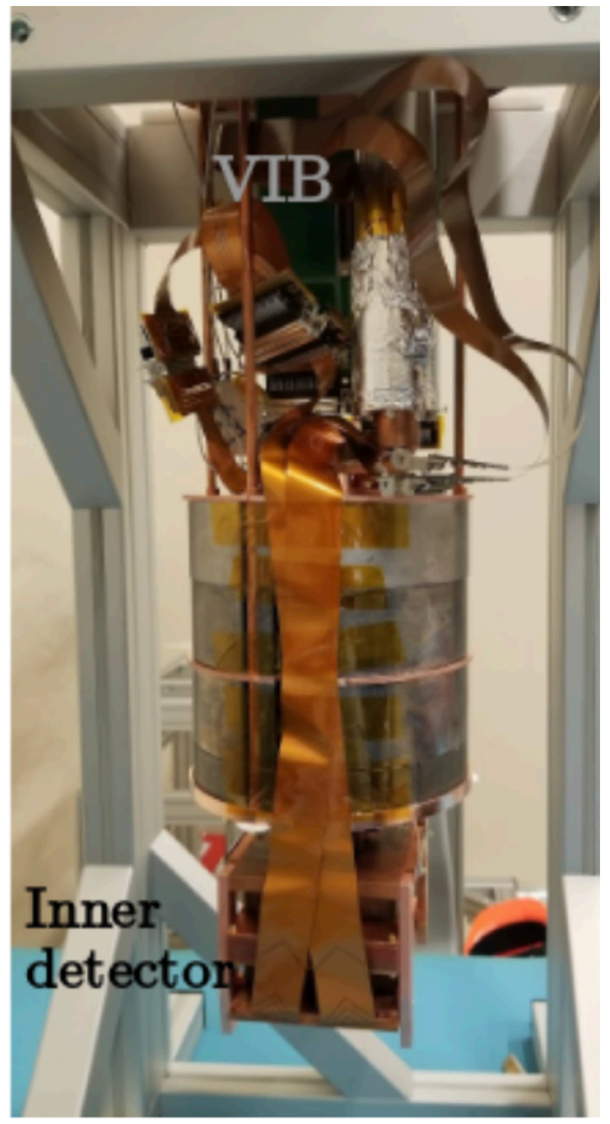


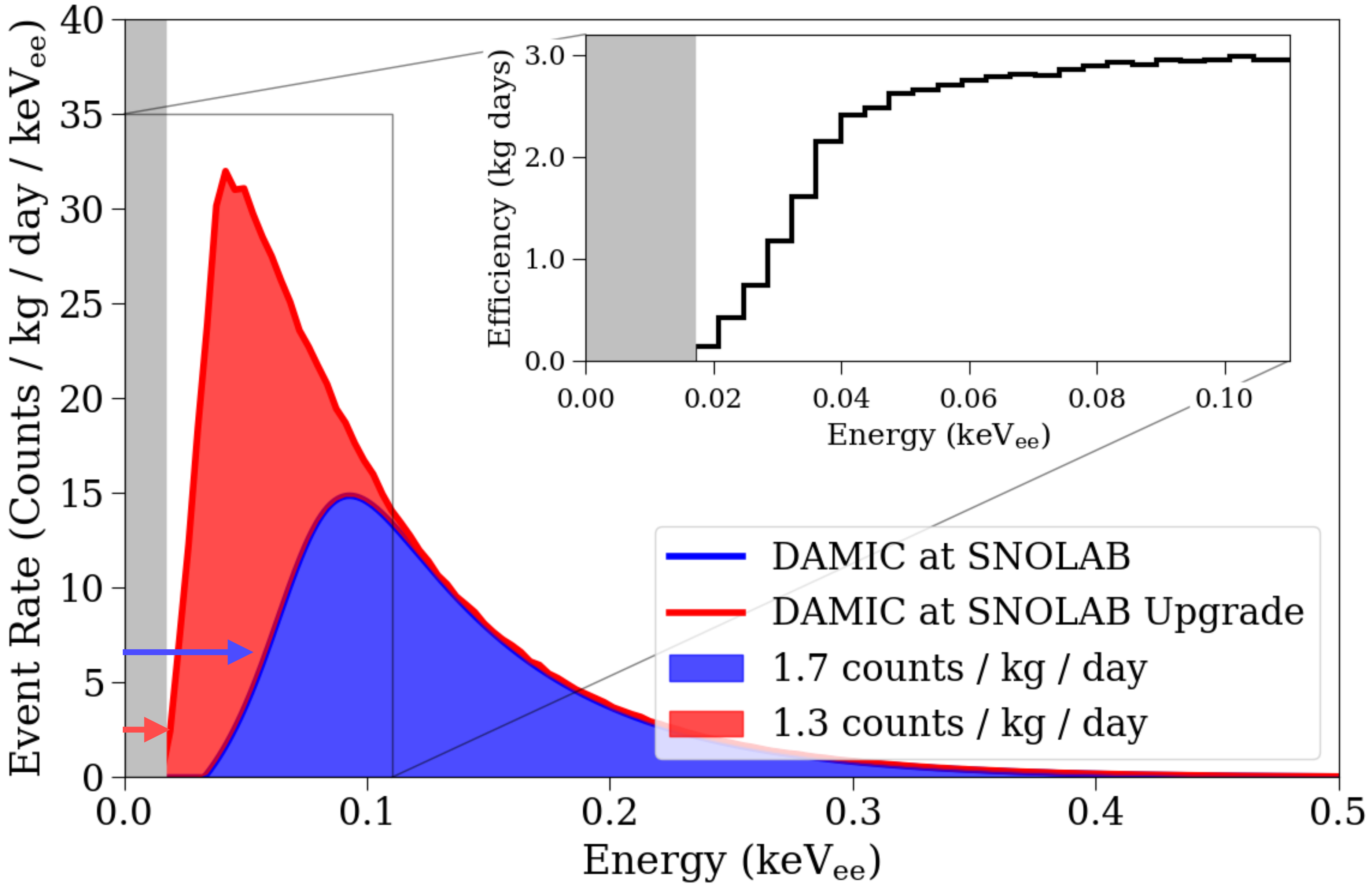




Almost twice as sensitive to previously detected excess

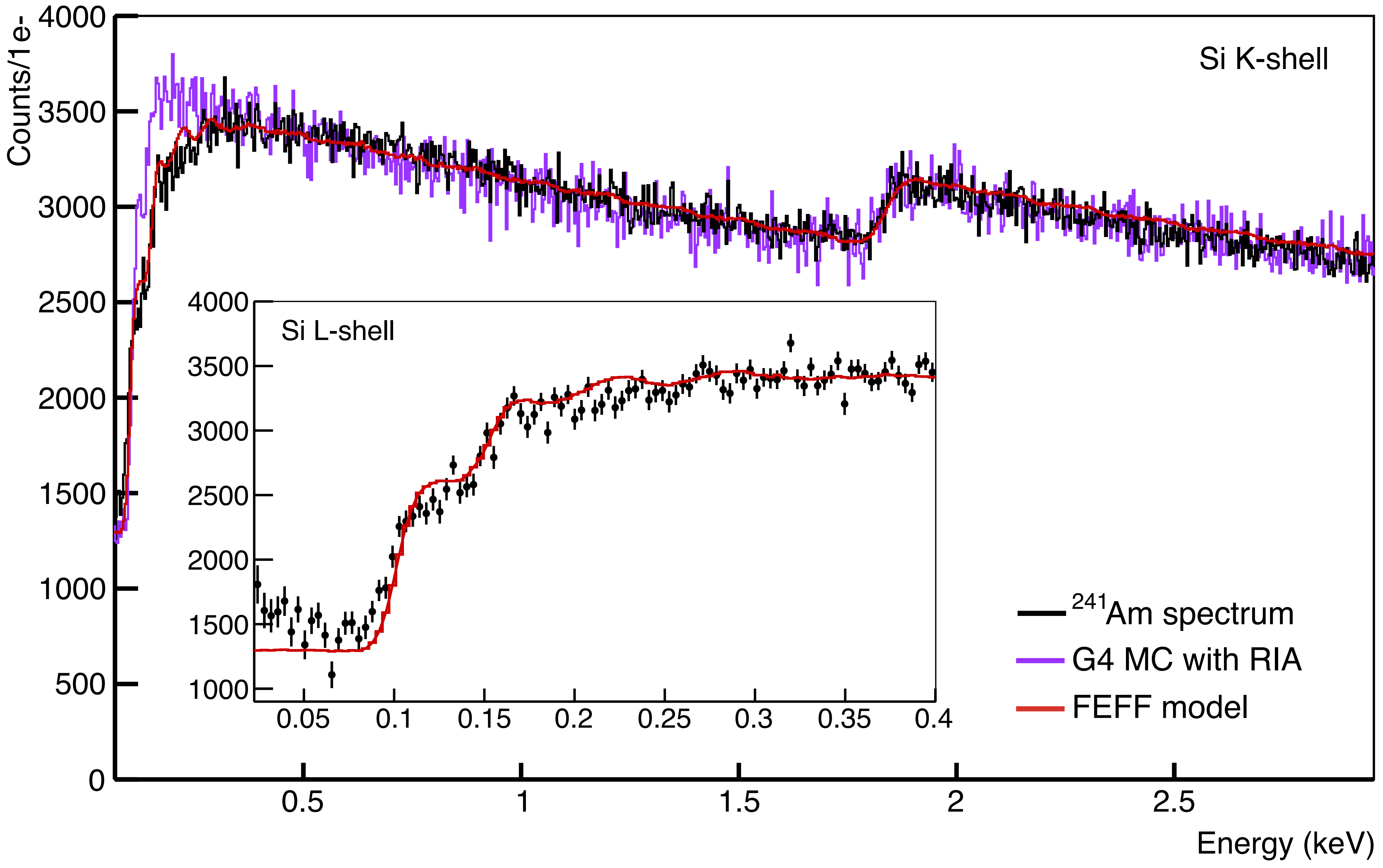
Detected rate in DAMIC at SNOLAB

Expected rate increase in skipper upgrade



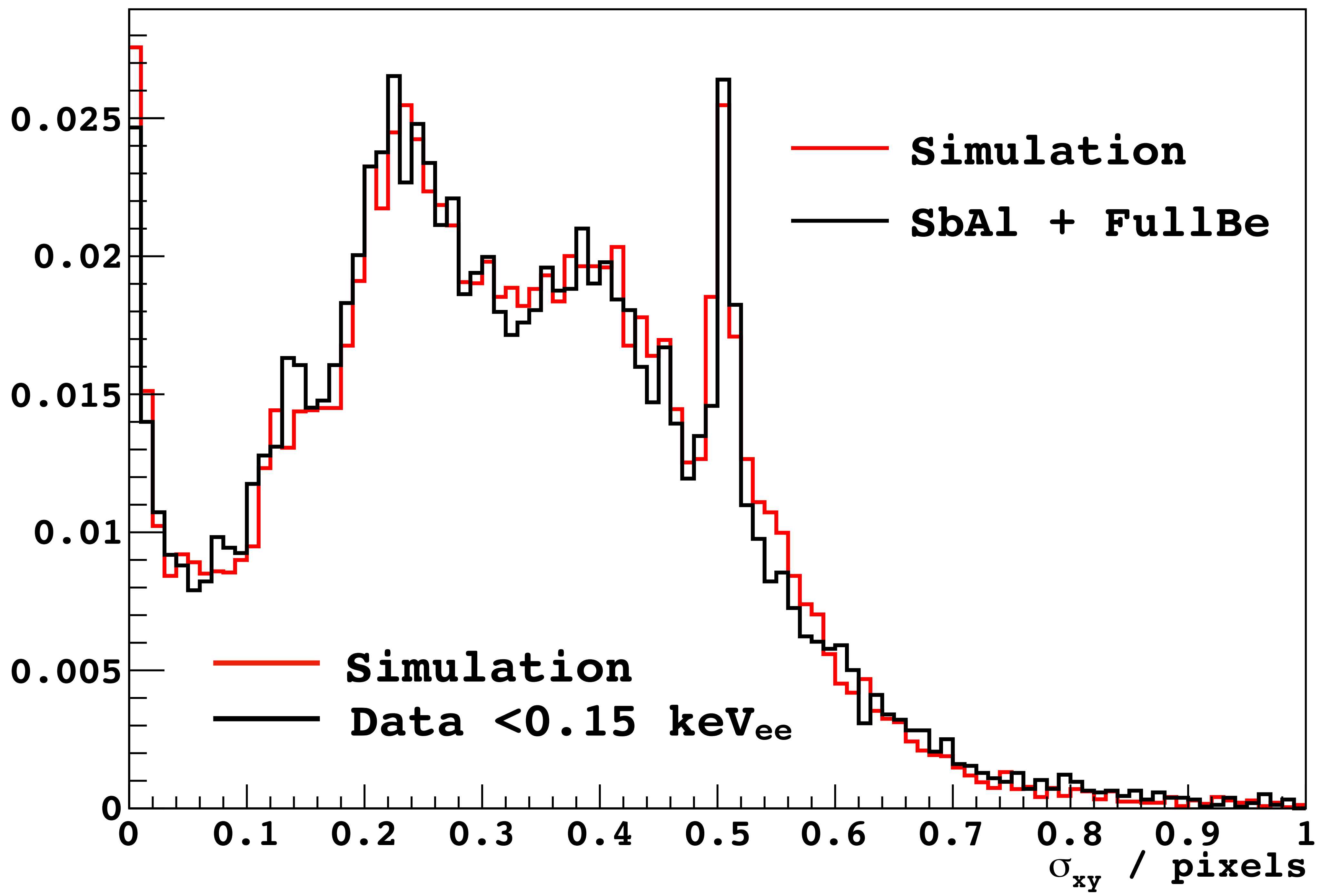
ENERGY AND DEPTH RESPONSE

Energy response validated with Compton scatterings from ^{241}Am down to 23 eV_{ee}



PRD106(2022)092001

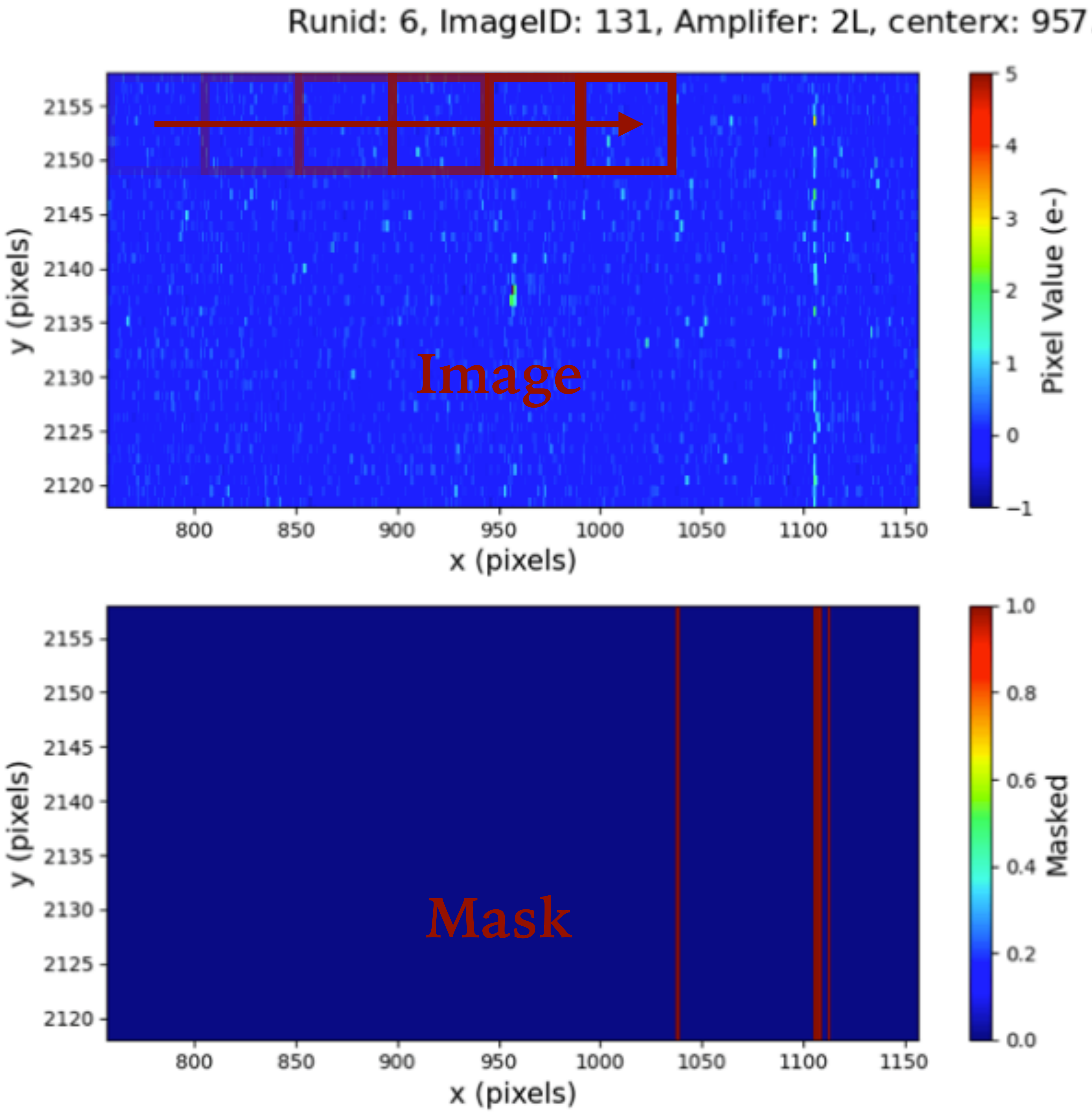
Depth response validated with low-energy neutrons from SbBe

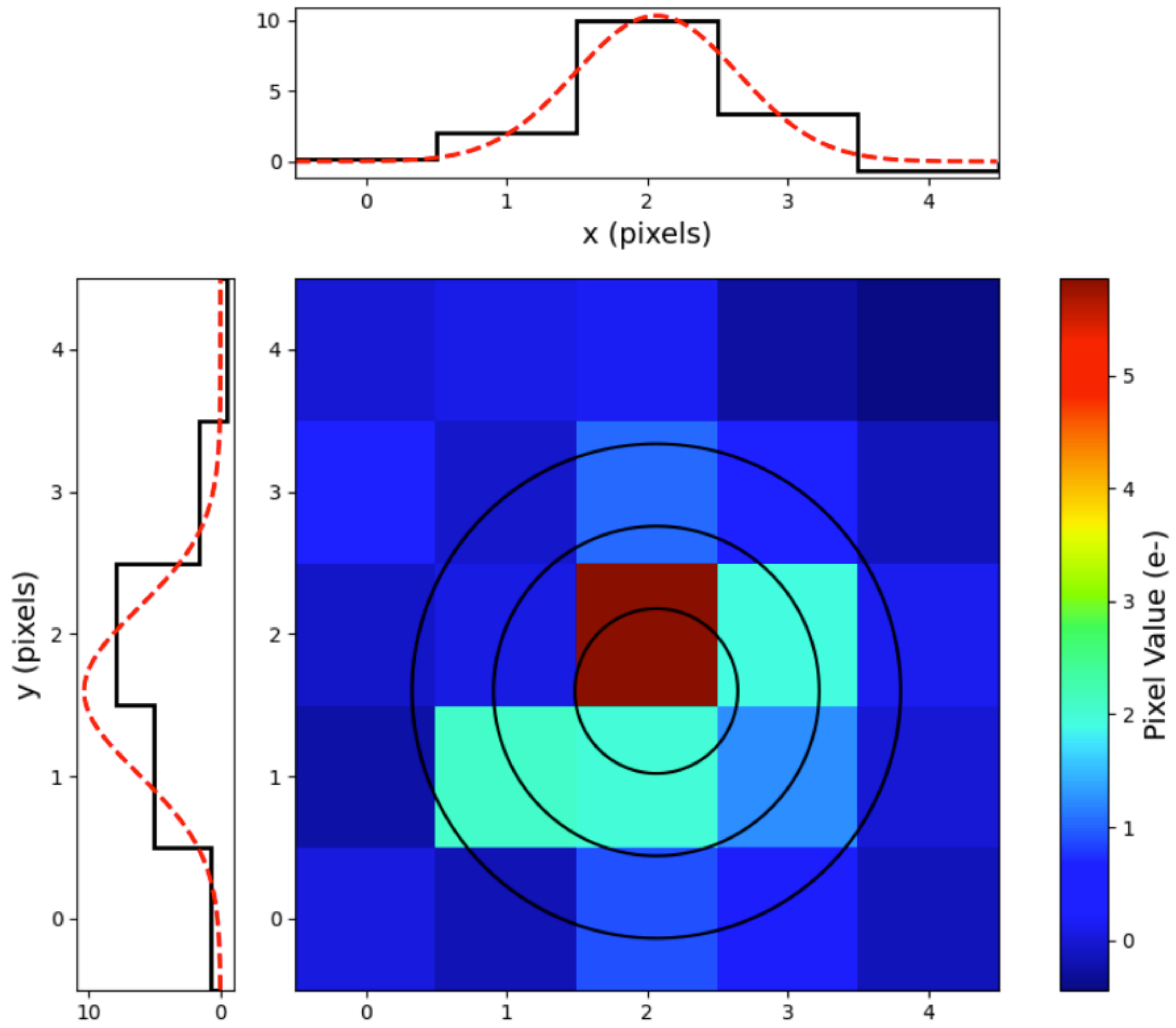


J. Phys.: Conf. Ser. **1468** 012024

LOW-ENERGY CLUSTERS

Likelihood clustering: find low-energy clusters by computing likelihood of ionization event inside moving window… $< 6\ keV$





We expect a 2D Gaussian spatial distribution for ionization events.

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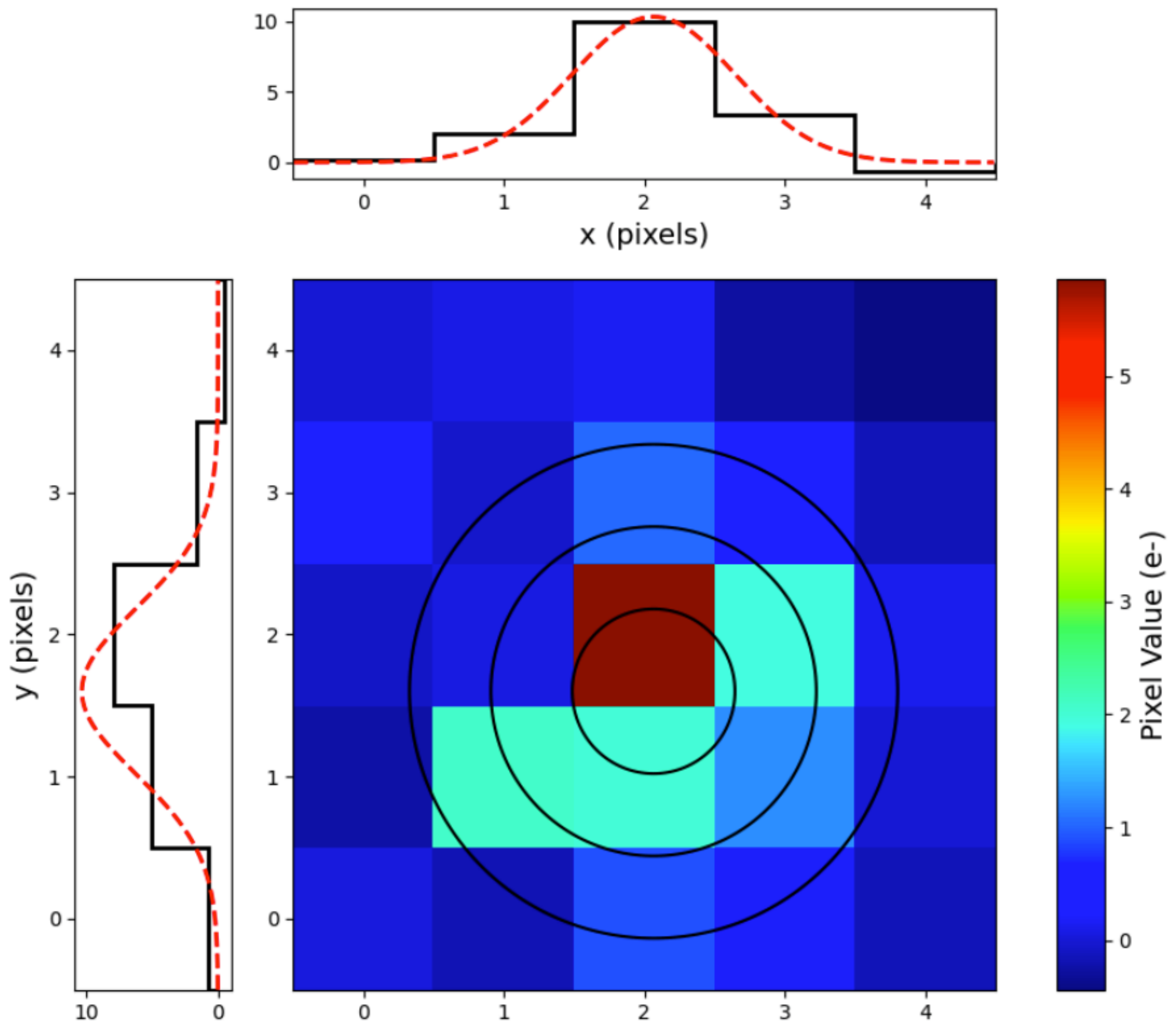
$$\log \mathcal{L}(N, \vec{\mu}, \vec{\sigma}, \lambda, \sigma_r | \vec{q}) = \sum_i \sum_j \left(\sum_k^{\infty} \log \left(\frac{\gamma_{ij}^k \exp(-\gamma_{ij})}{k!} \frac{1}{\sqrt{2\pi\sigma_r^2}} \exp\left(\frac{-(q_{ij}-k)^2}{2\sigma_r^2} \right) \right) \right)$$

$$\gamma_{ij} = \lambda_i + N \int_{i-0.5}^{i+0.5} \int_{j-0.5}^{j+0.5} \mathrm{Gaus}(x, y | \mu_x, \mu_y, \sigma_x, \sigma_y) dxdy$$ **: Noise + Ionization**



DATA SELECTIONS

<u>ΔLL **selection**</u>: …and efficiently reject noise accidentals down to 23 eV_{ee}

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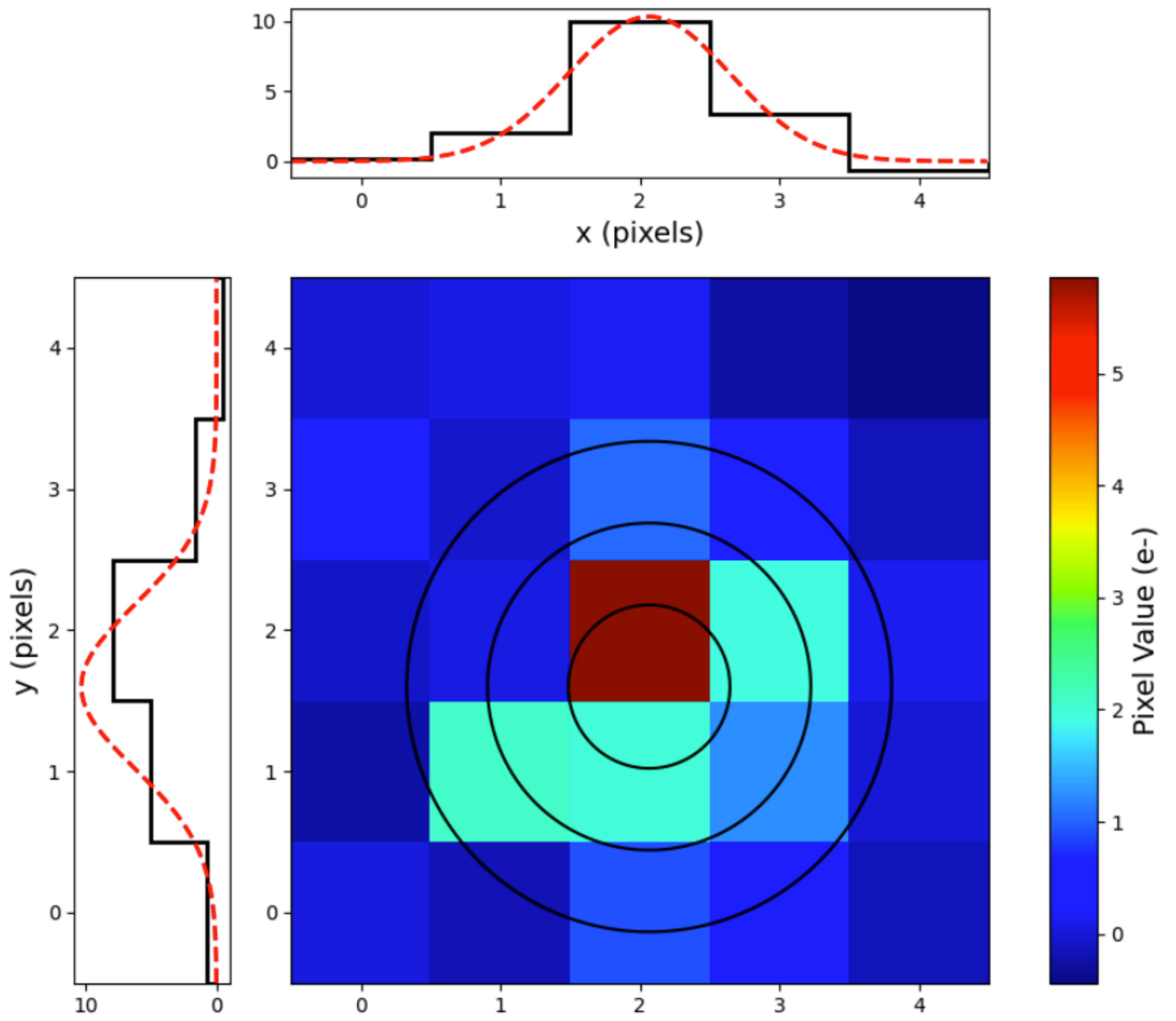
$$\Delta LL = -\log\left(\frac{\tilde{\mathcal{L}}_g}{\mathcal{L}_n}\right)$$ discriminates low-energy events from noise accidentals

$\tilde{\mathcal{L}}_g$: global likelihood under hypothesis of ionization
$\mathcal{L}_n$: local likelihood under noise-only hypothesis



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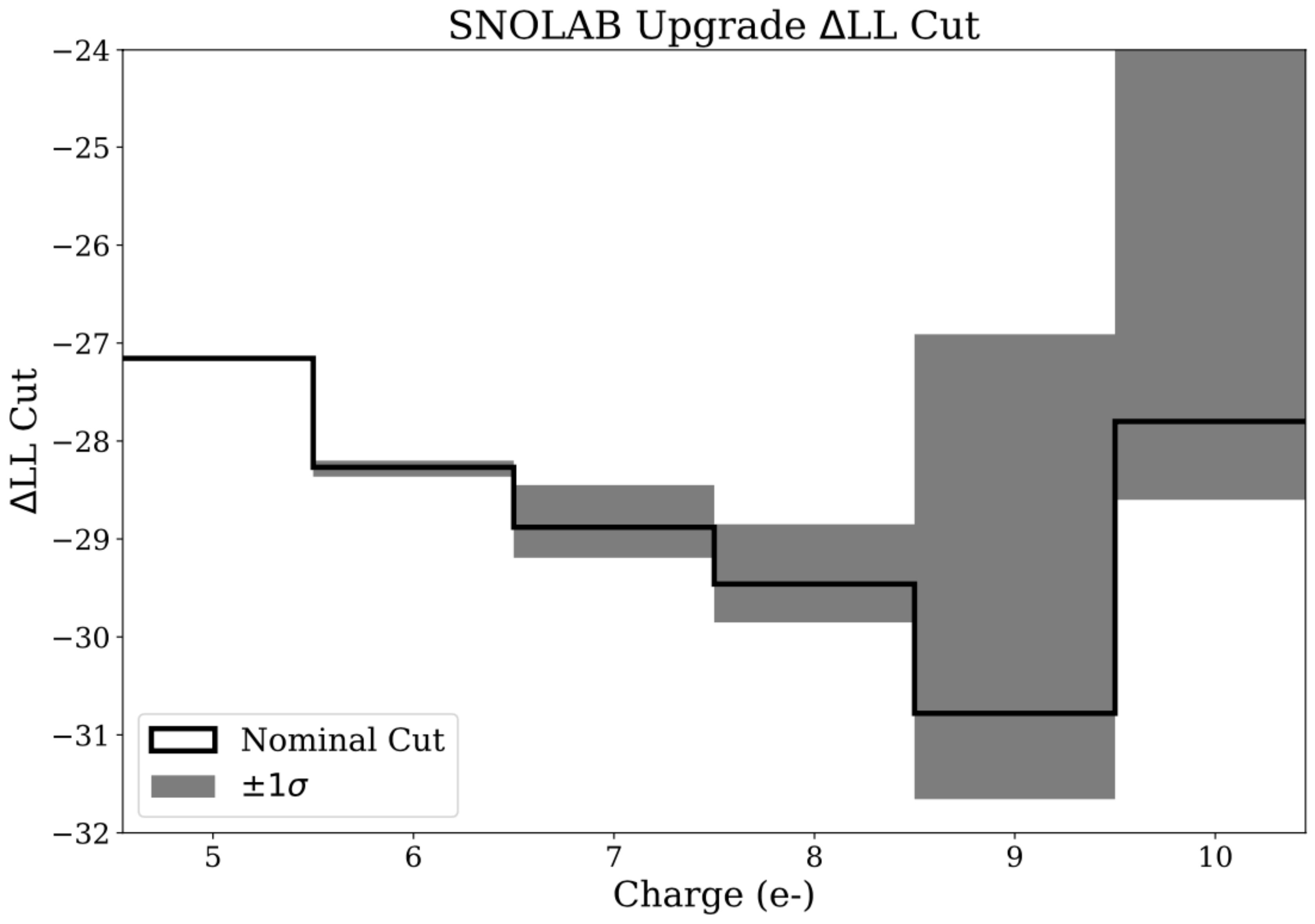

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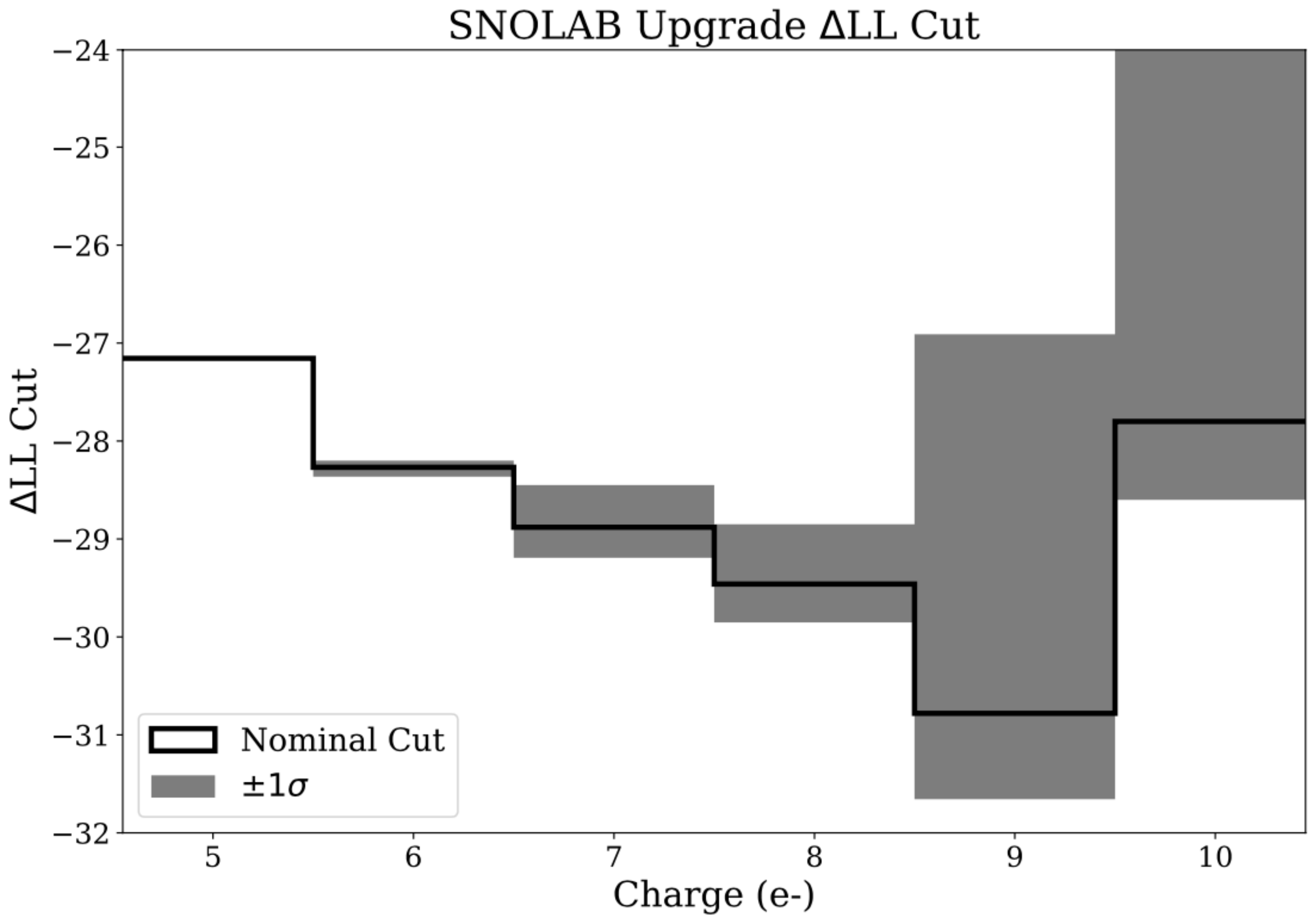

Bulk fiducialization: we also reject CCD surface events, the largest source of systematic uncertainty

We apply a fiducial selection of bulk events, using the diffusion model:

$$\sigma_{xy}(z,E) = \sqrt{-A\ln(1-bz)}(\alpha+\beta E)$$

σ_{xy} : cluster spread z : depth E : energy

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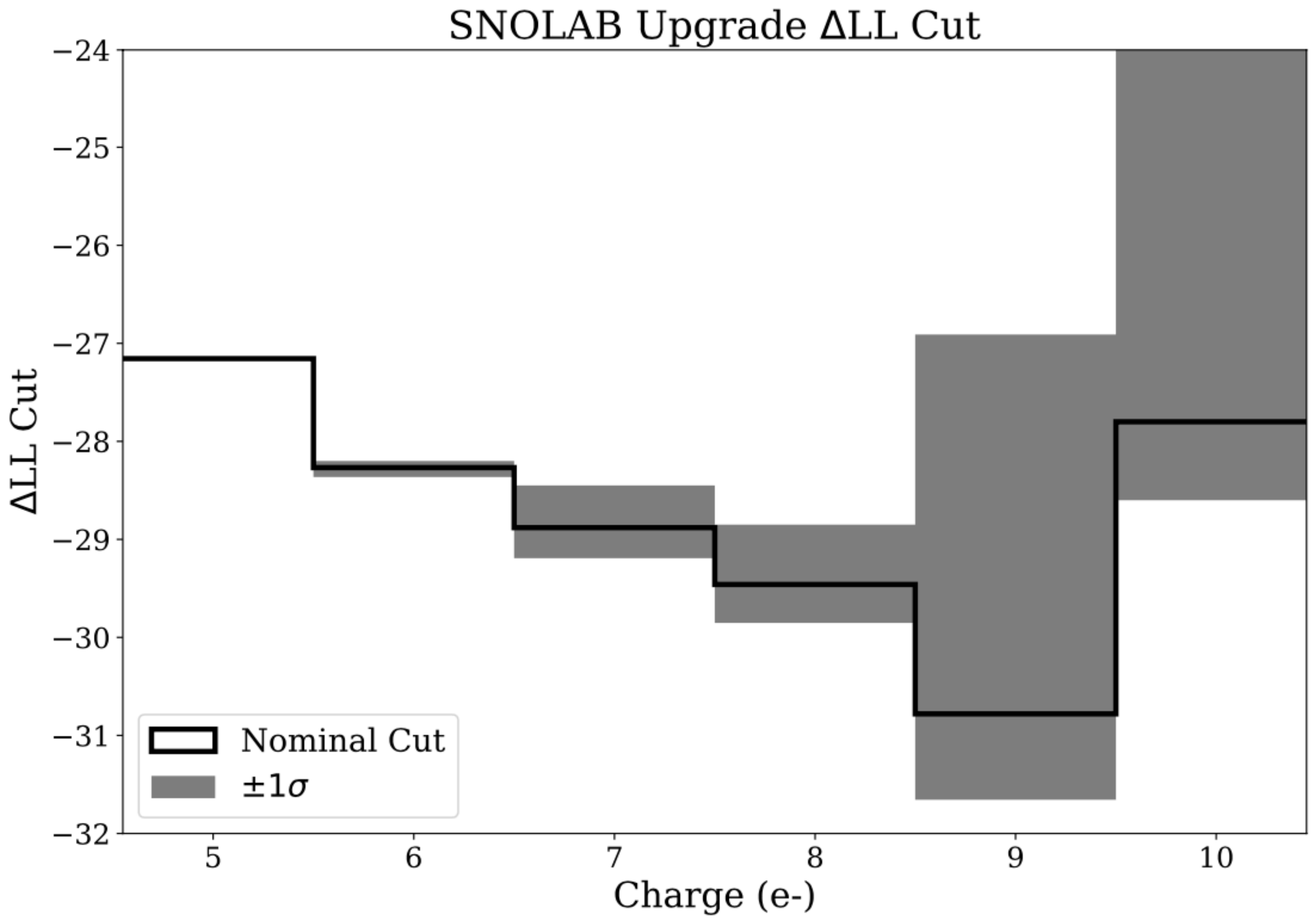

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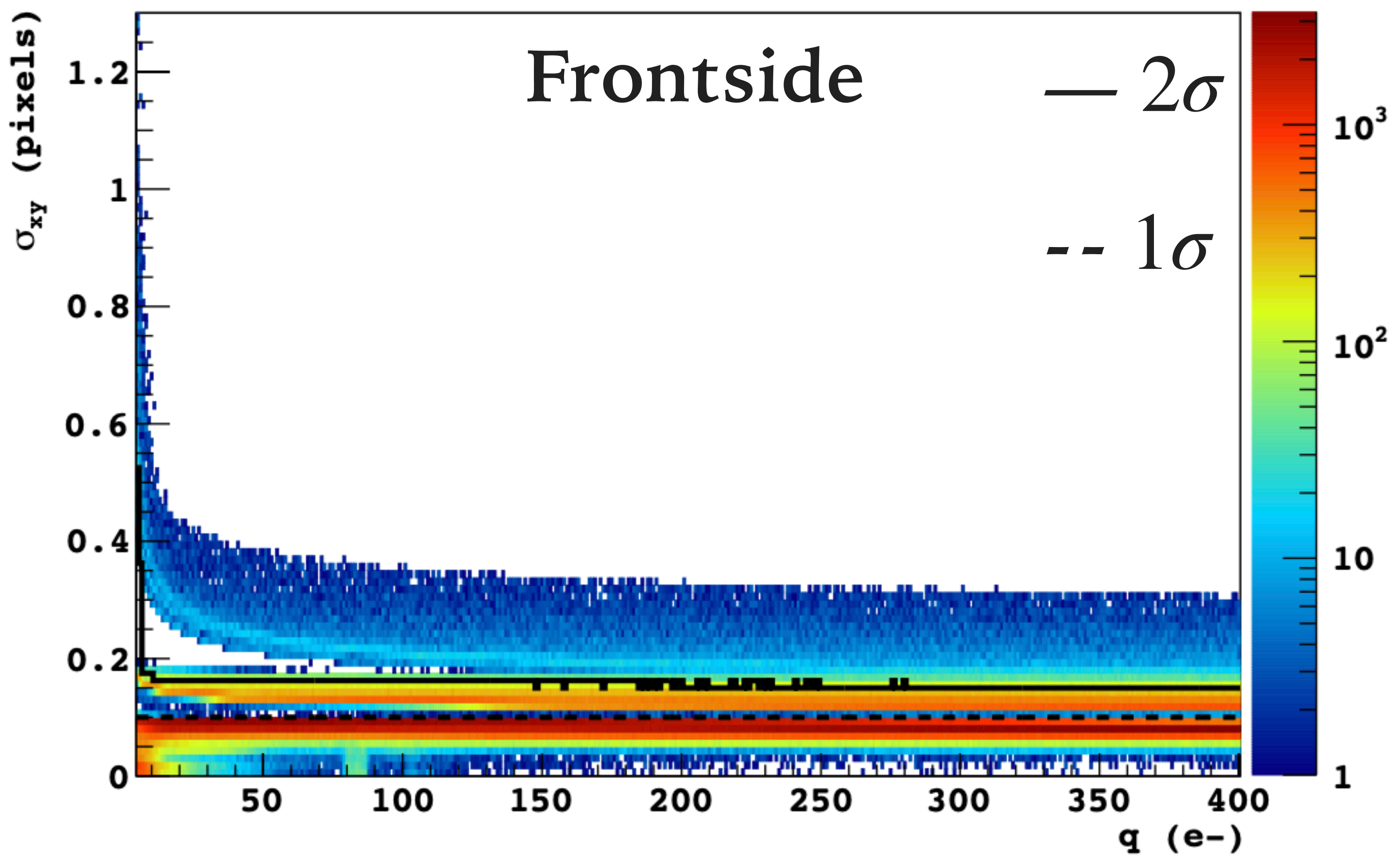

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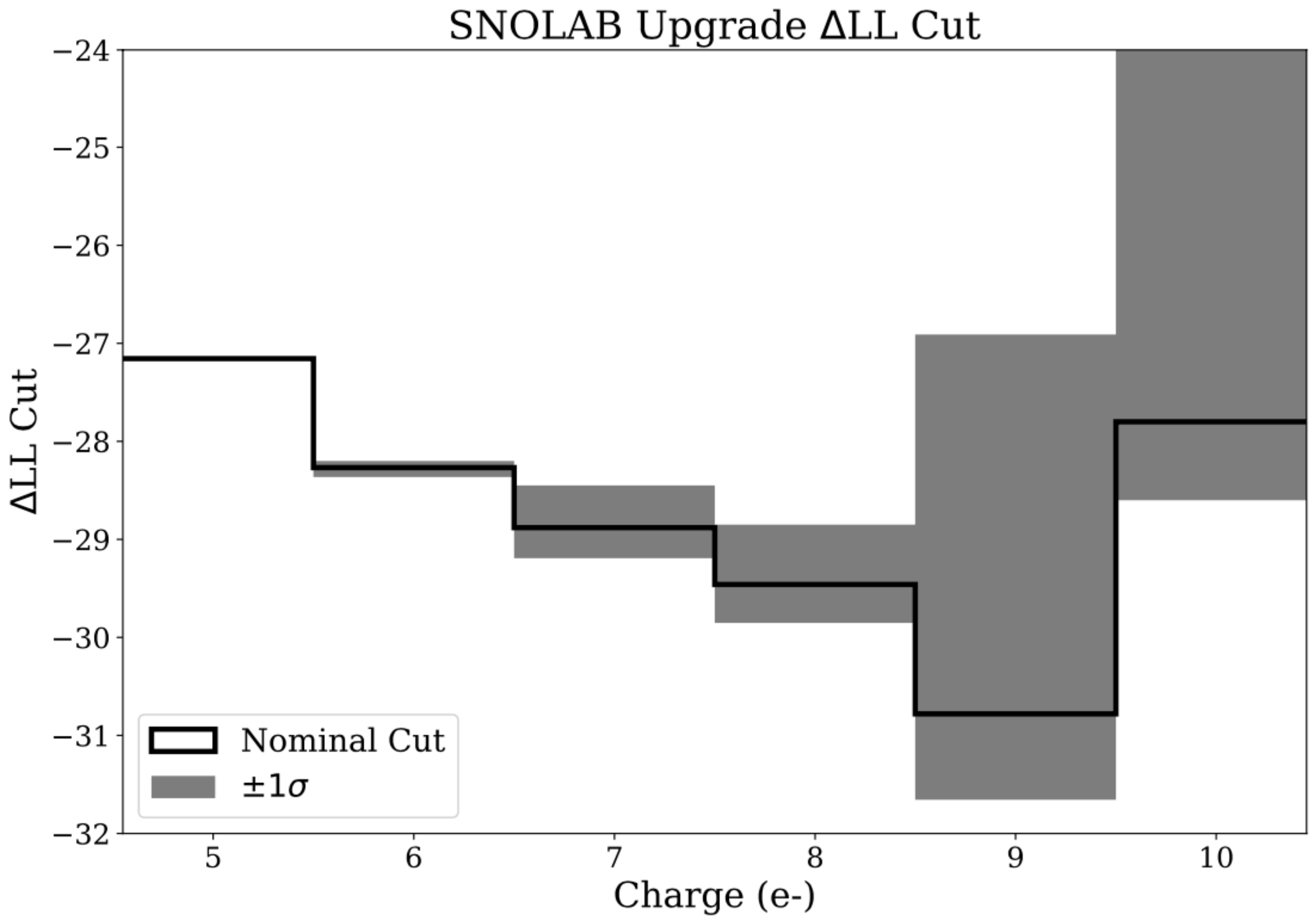

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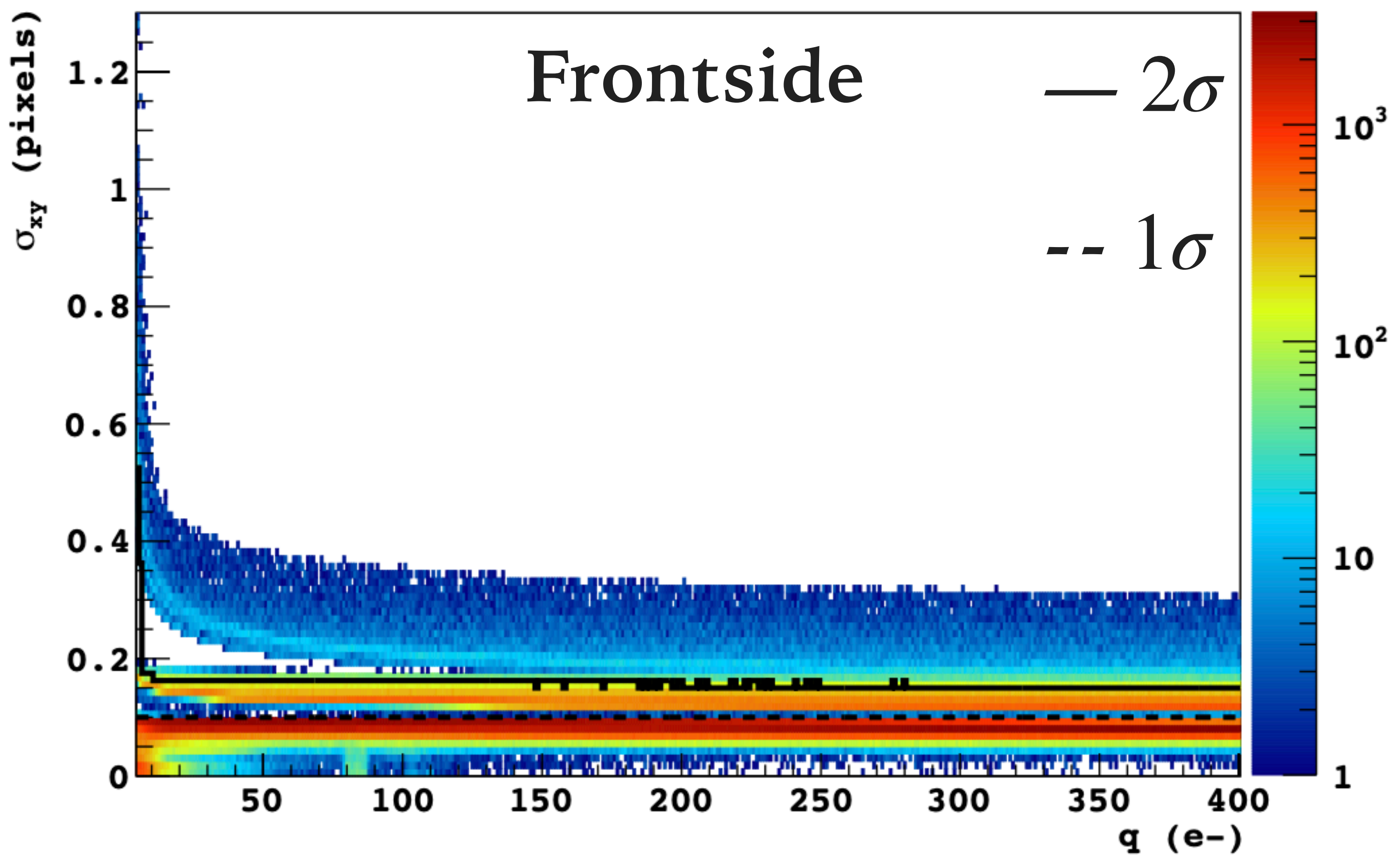

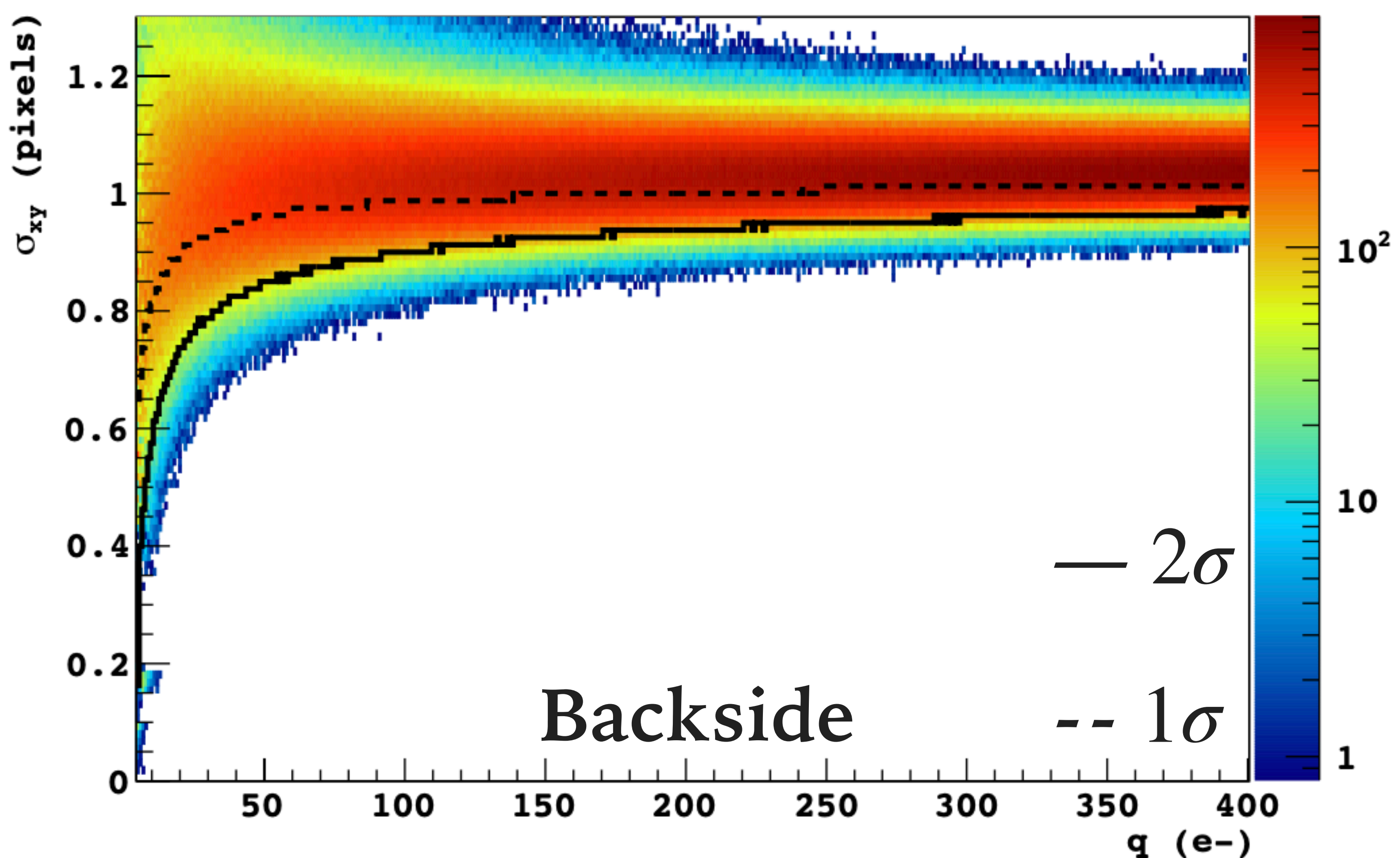

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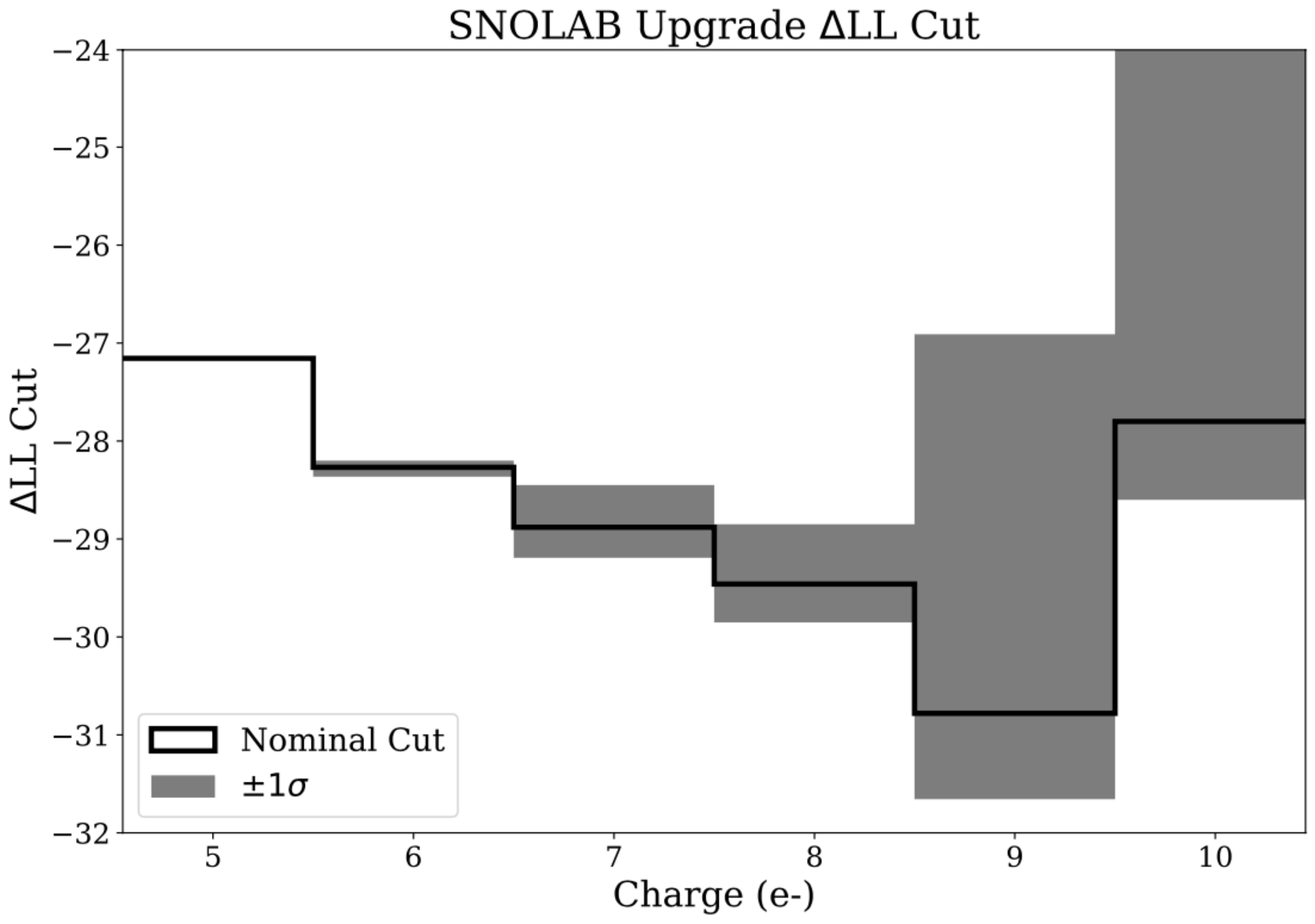

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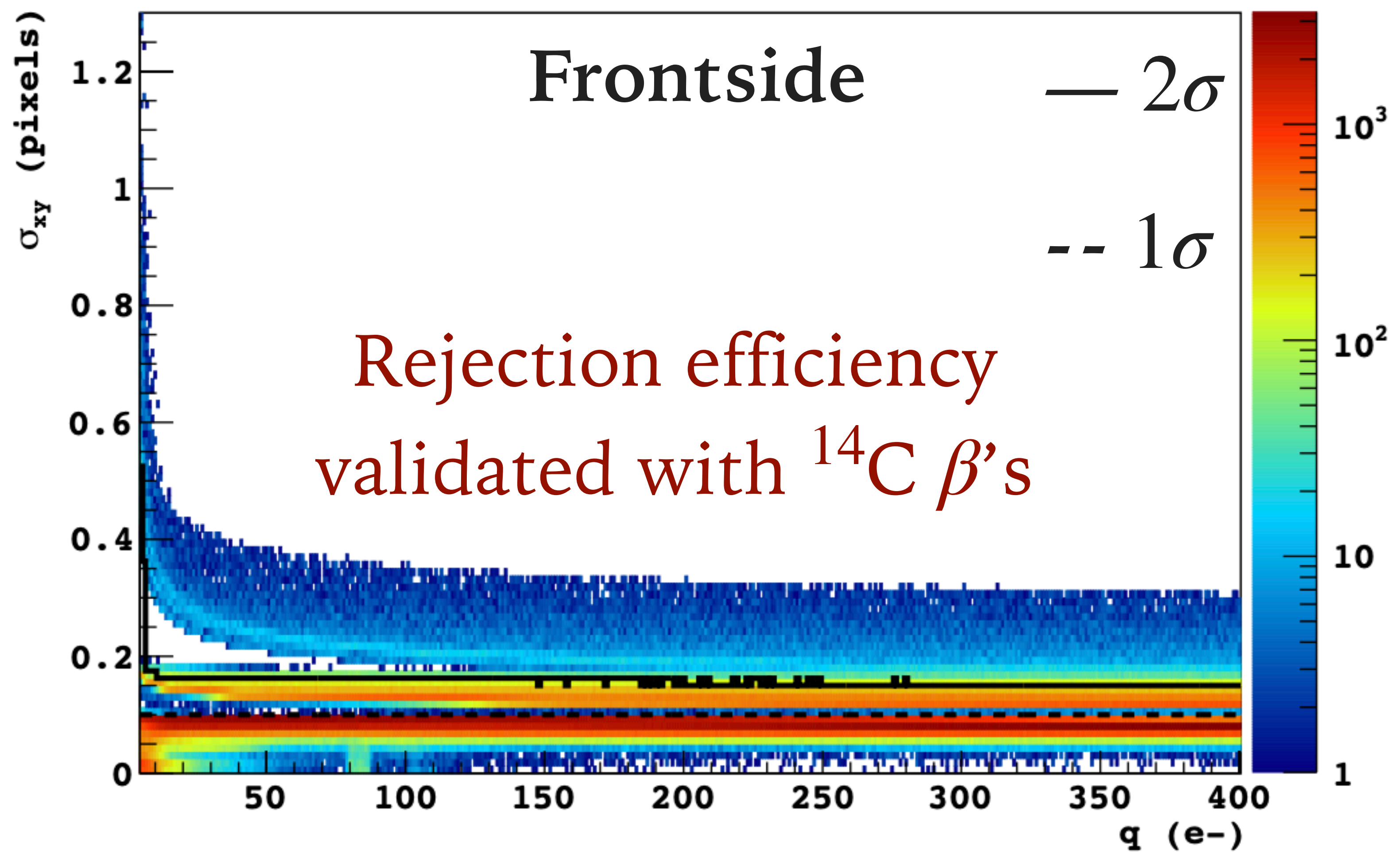
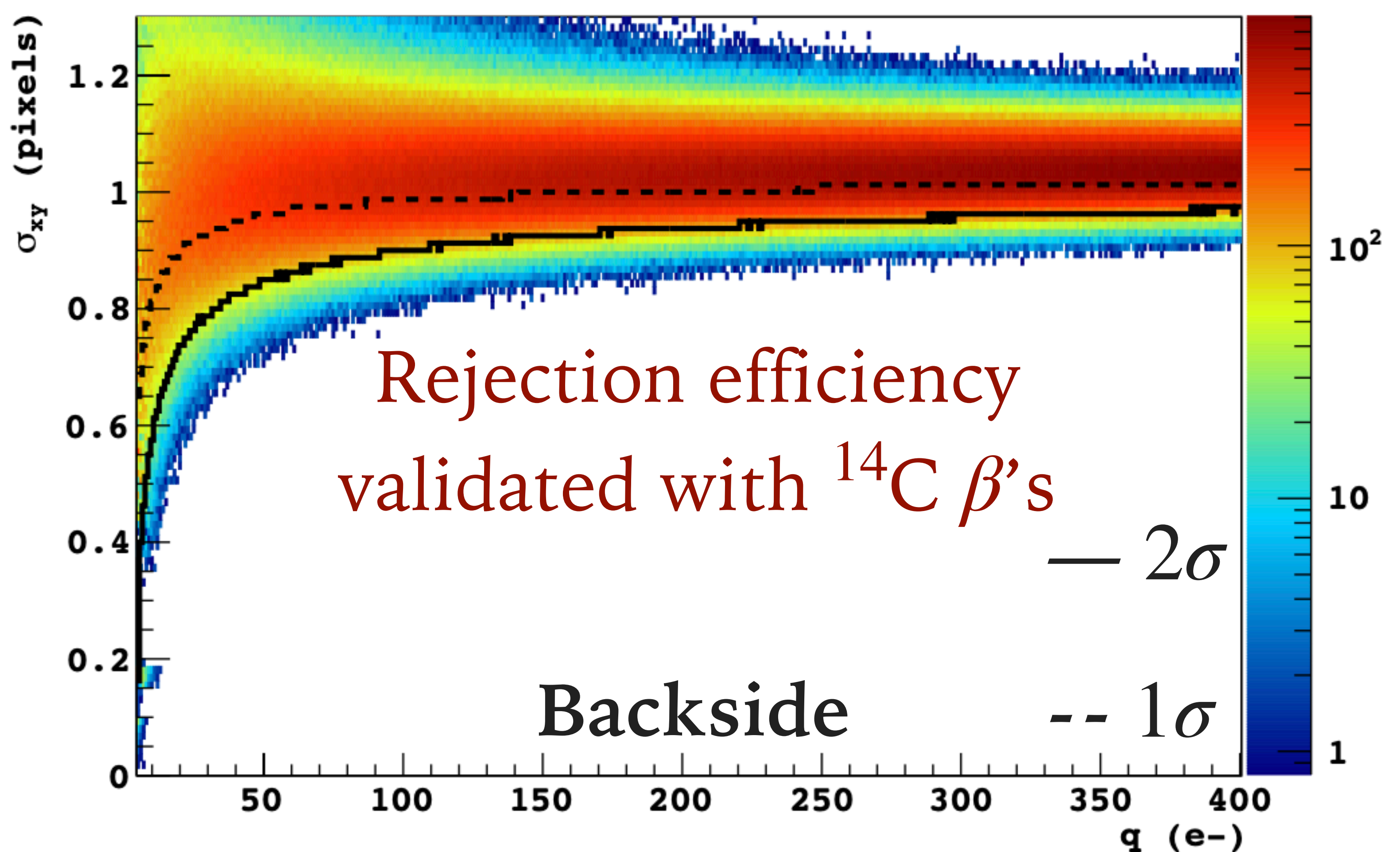
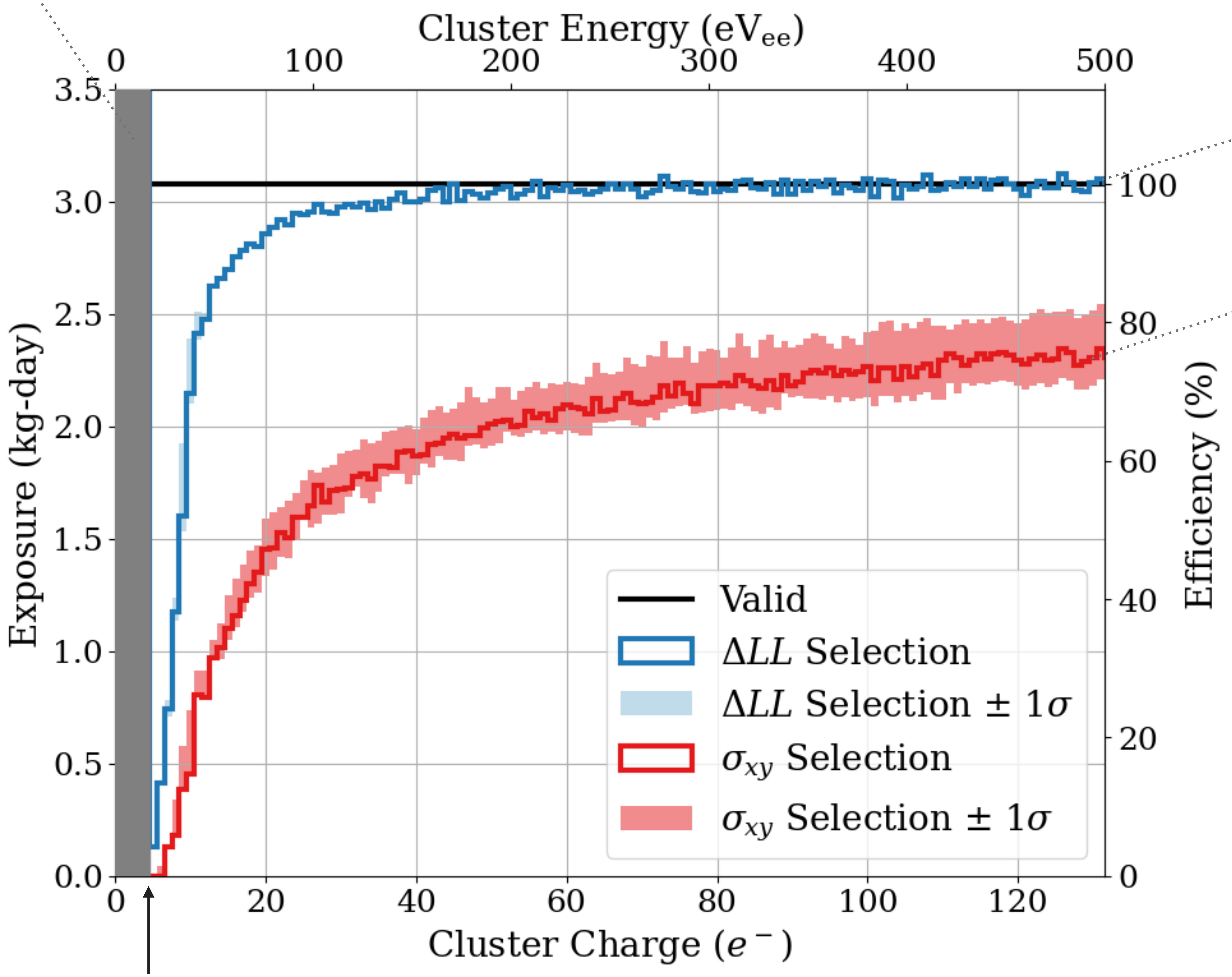




DATA SELECTIONS

Valid clusters: from 4.8 to 3.1 kg-day

- discard bad images
- mask high-energy clusters
- mask defects, hot regions and instrumental artifacts

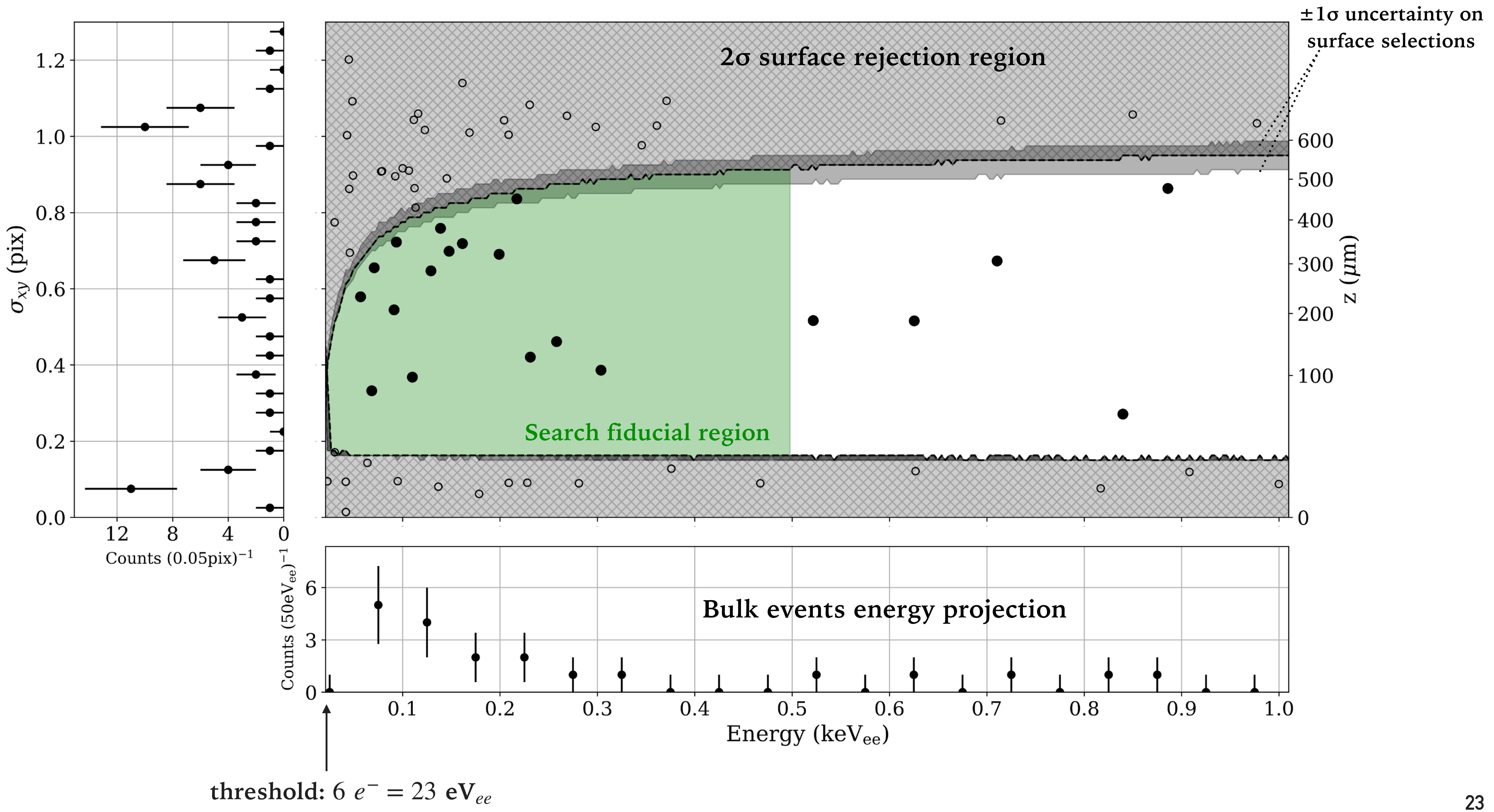


Ionization acceptance

Bulk acceptance

threshold: 6 $e^- = 23$ eV$_{ee}$

FIDUCIALIZED SCIENCE DATA

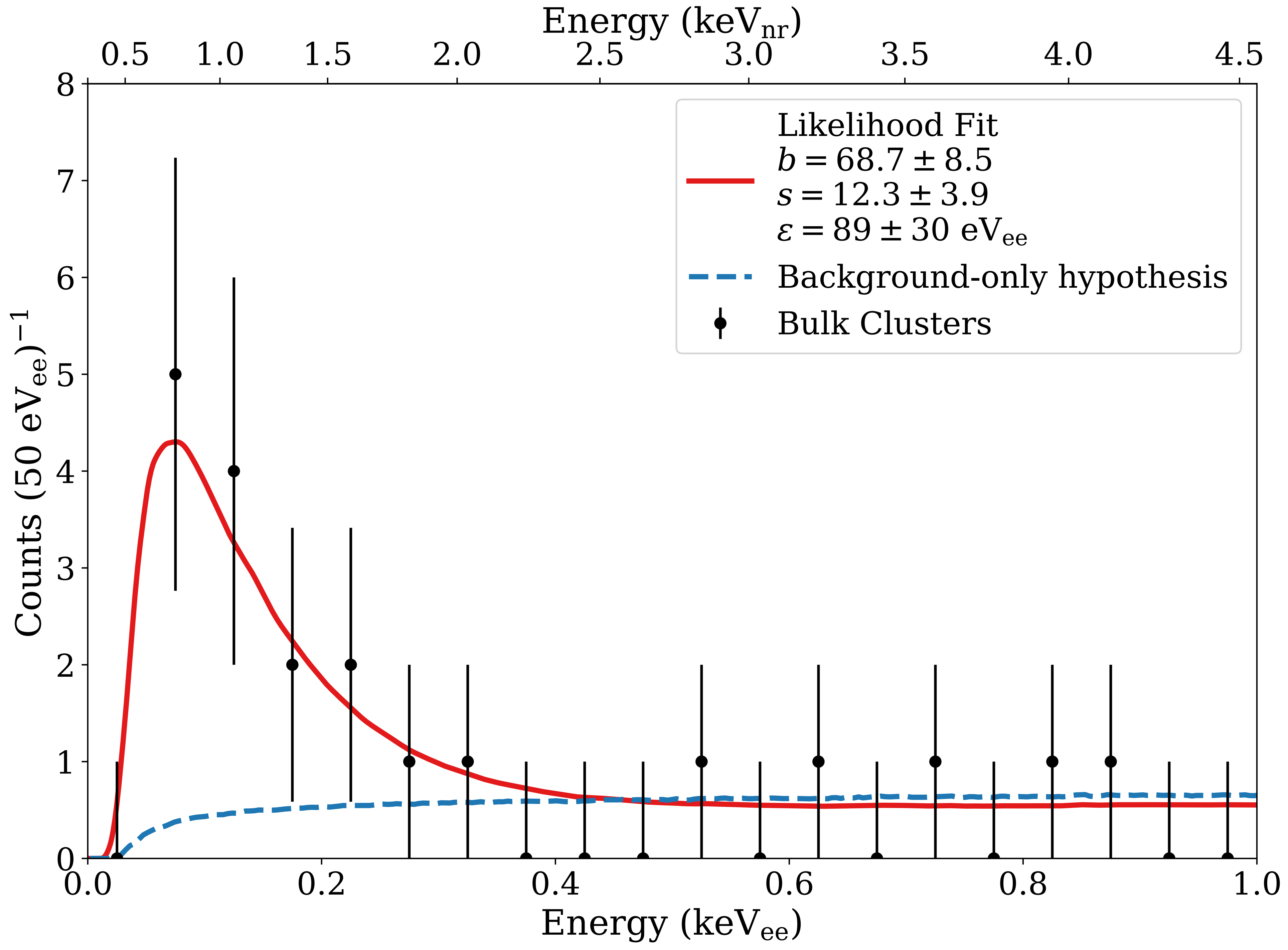


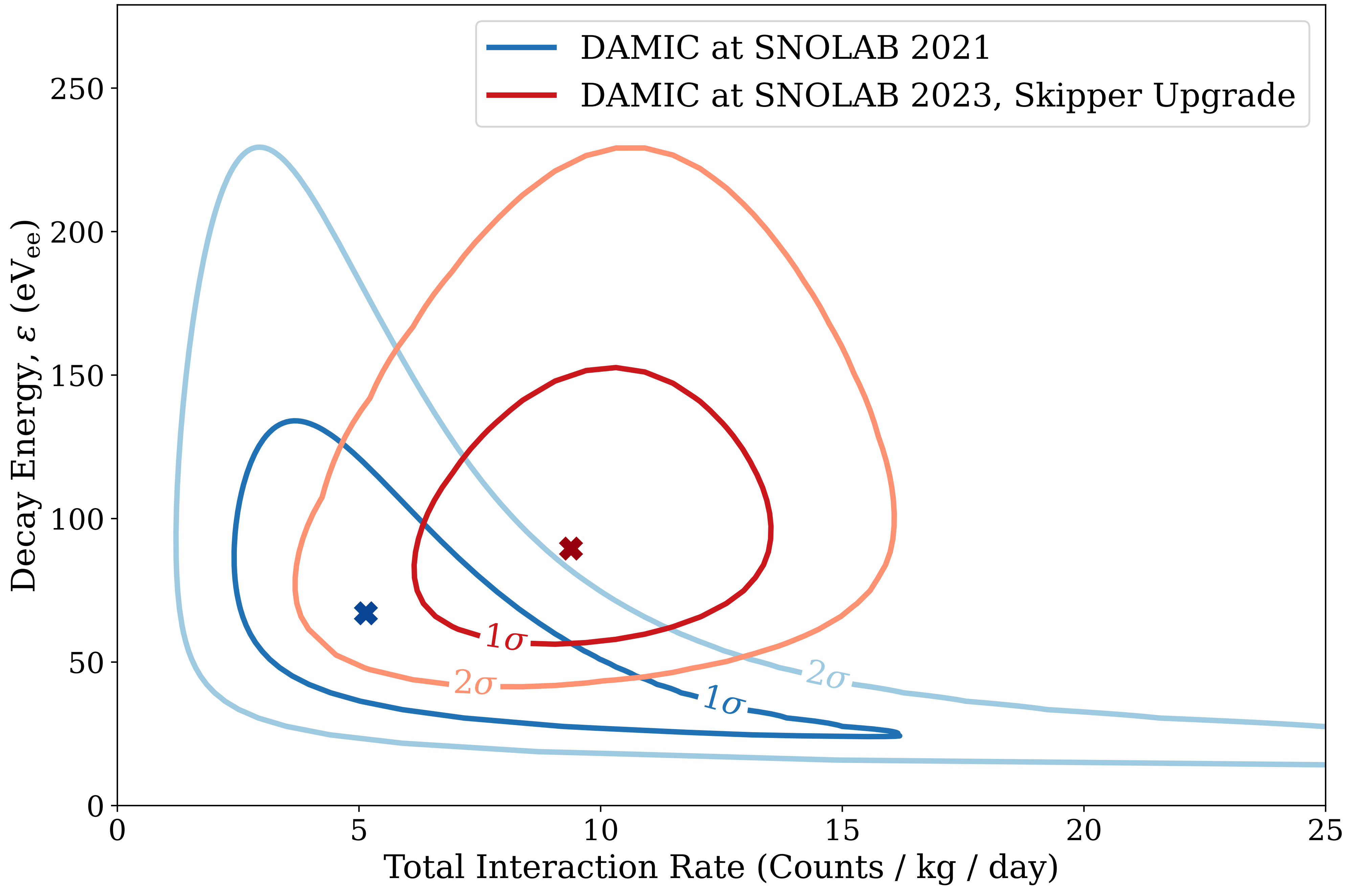
RESULTS

- Fit flat* bkg+exponential signal between 23 eV_{ee} and 6 keV_{ee}

The excess is still there. arXiv:2306.01717

- Increased significance: 5.4σ (expected from lower threshold)
- Statistically compatible with old excess (see contours)





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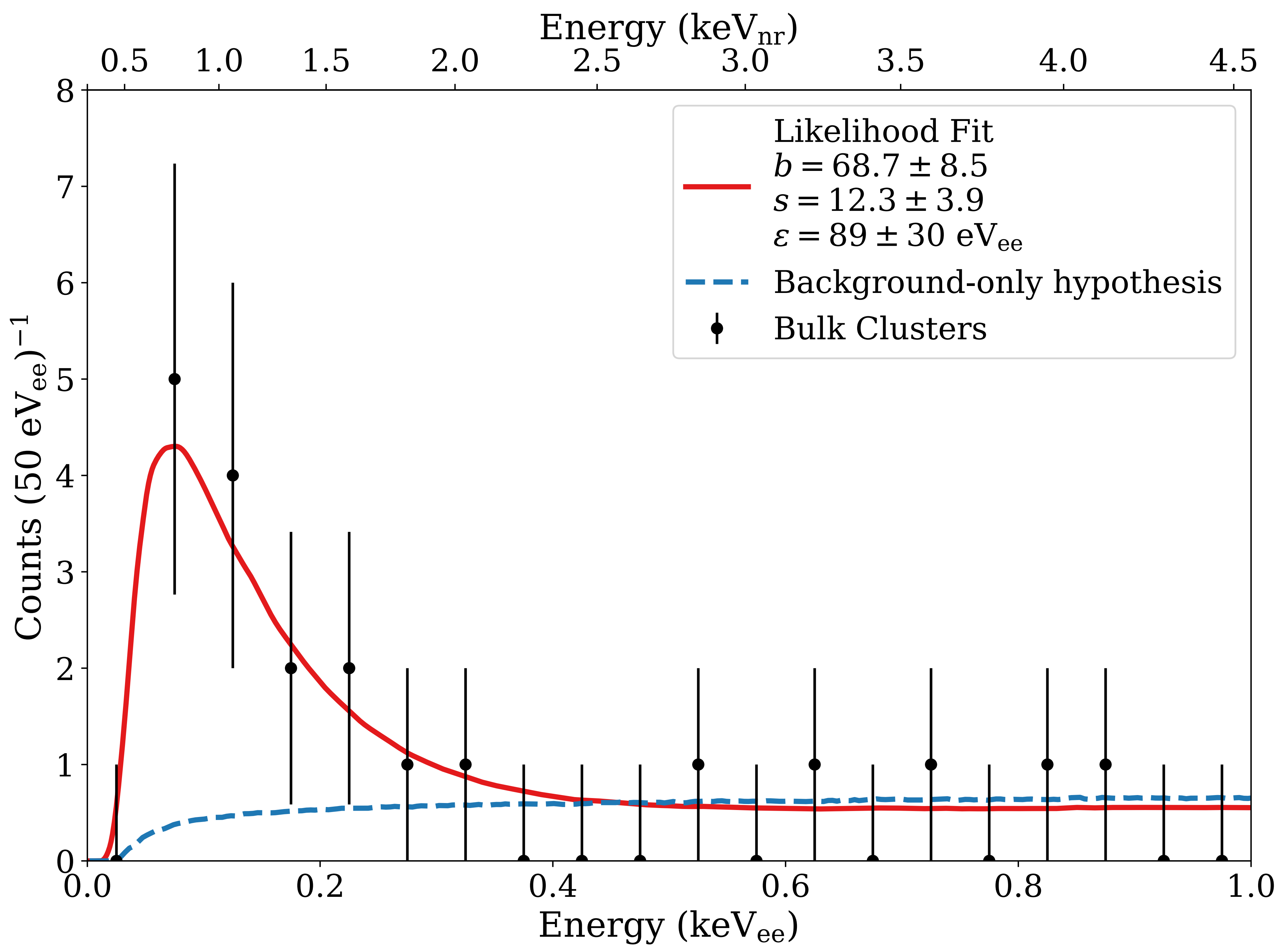
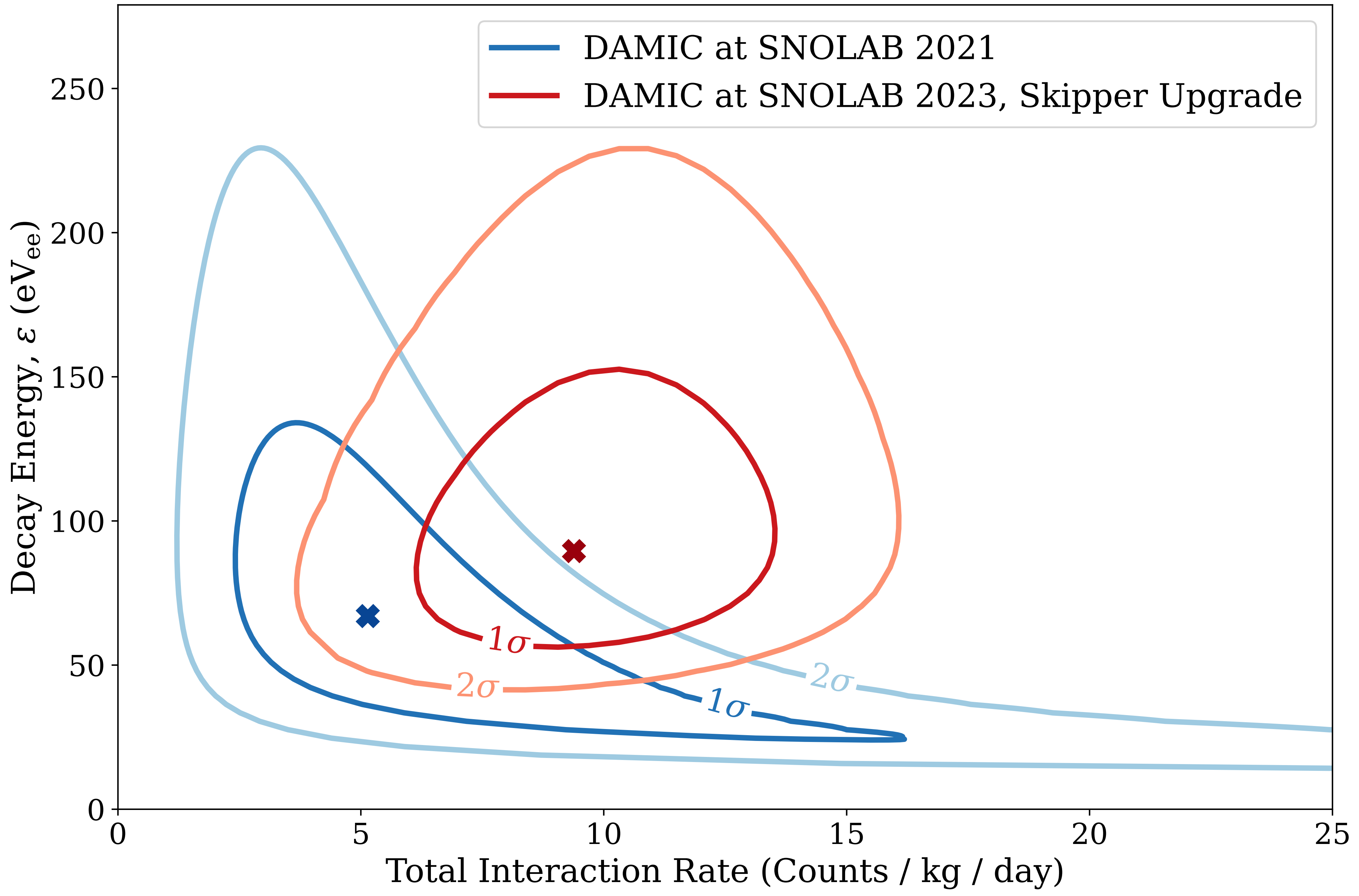
***Flat background**: conservative assumption. Low-energy drops expected in ROI from Compton and tritium β^- events. Data consistent with background model above 0.5 keV





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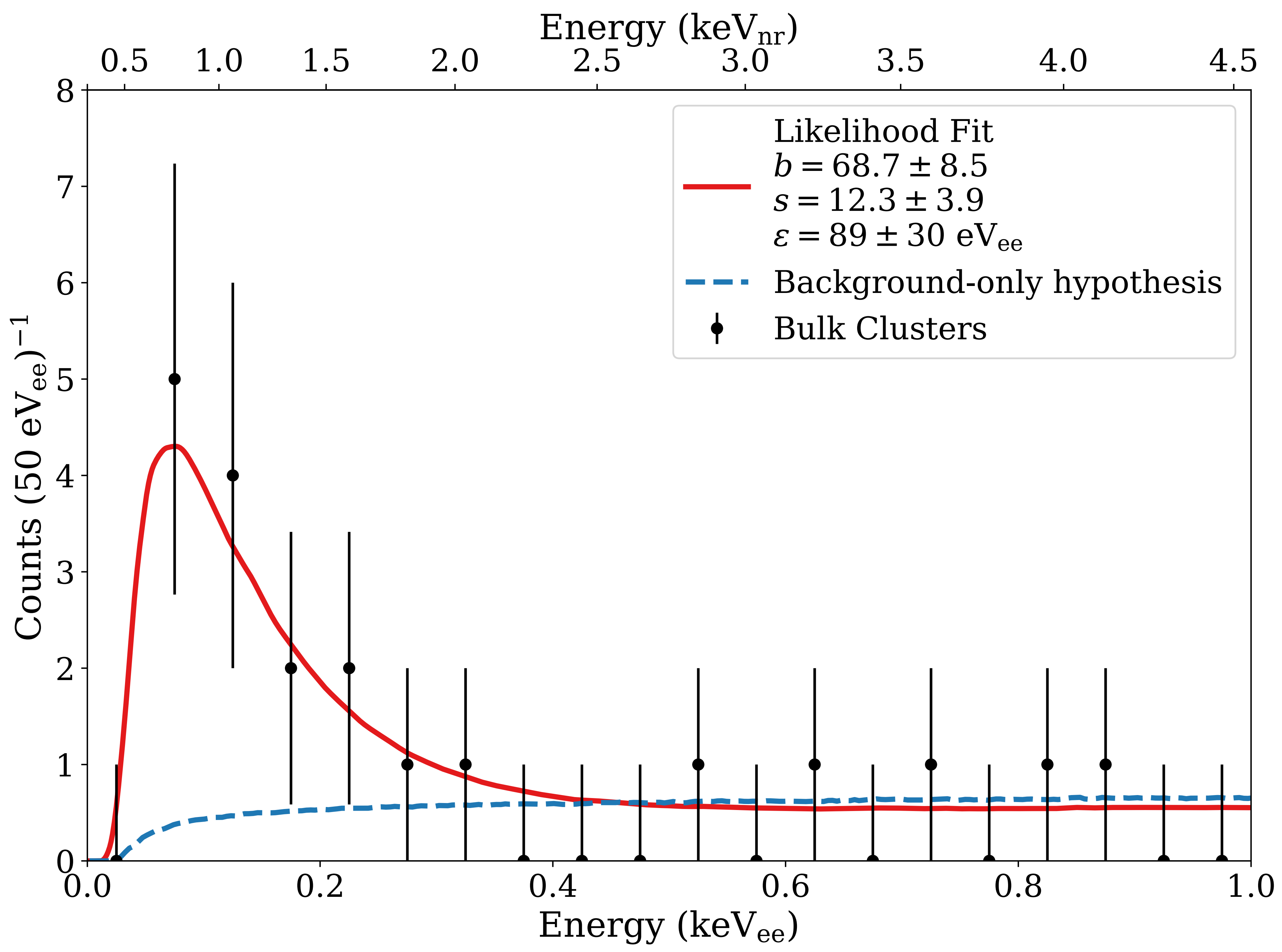
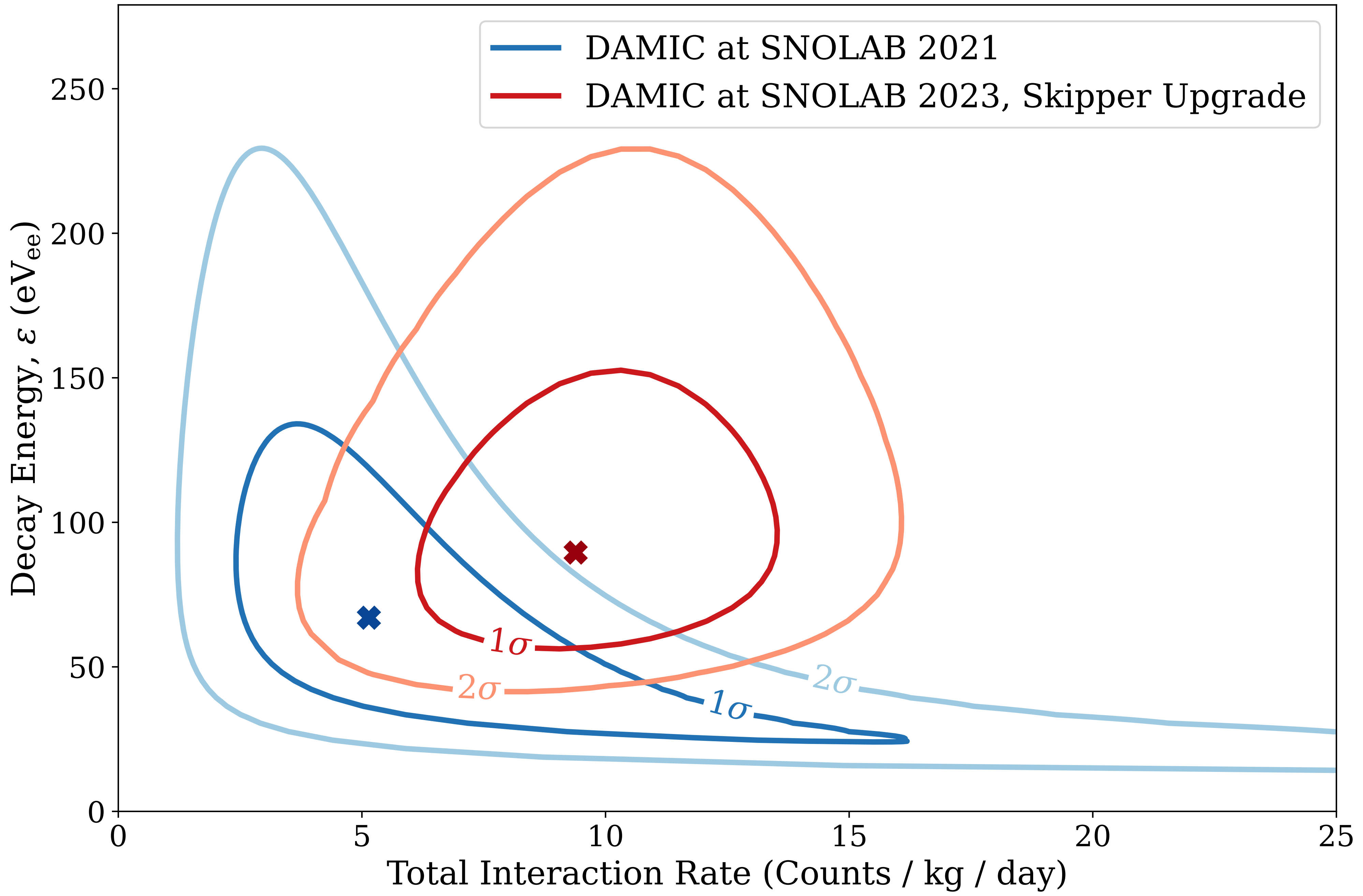
What is it?

- Probably a source of radiation. Neutrons?

  Required flux: 0.2 $cm^{-2}\,day^{-1}$ ~ total flux in SNOLAB cavern.

  We expect ~ 100 × lower from simulations.





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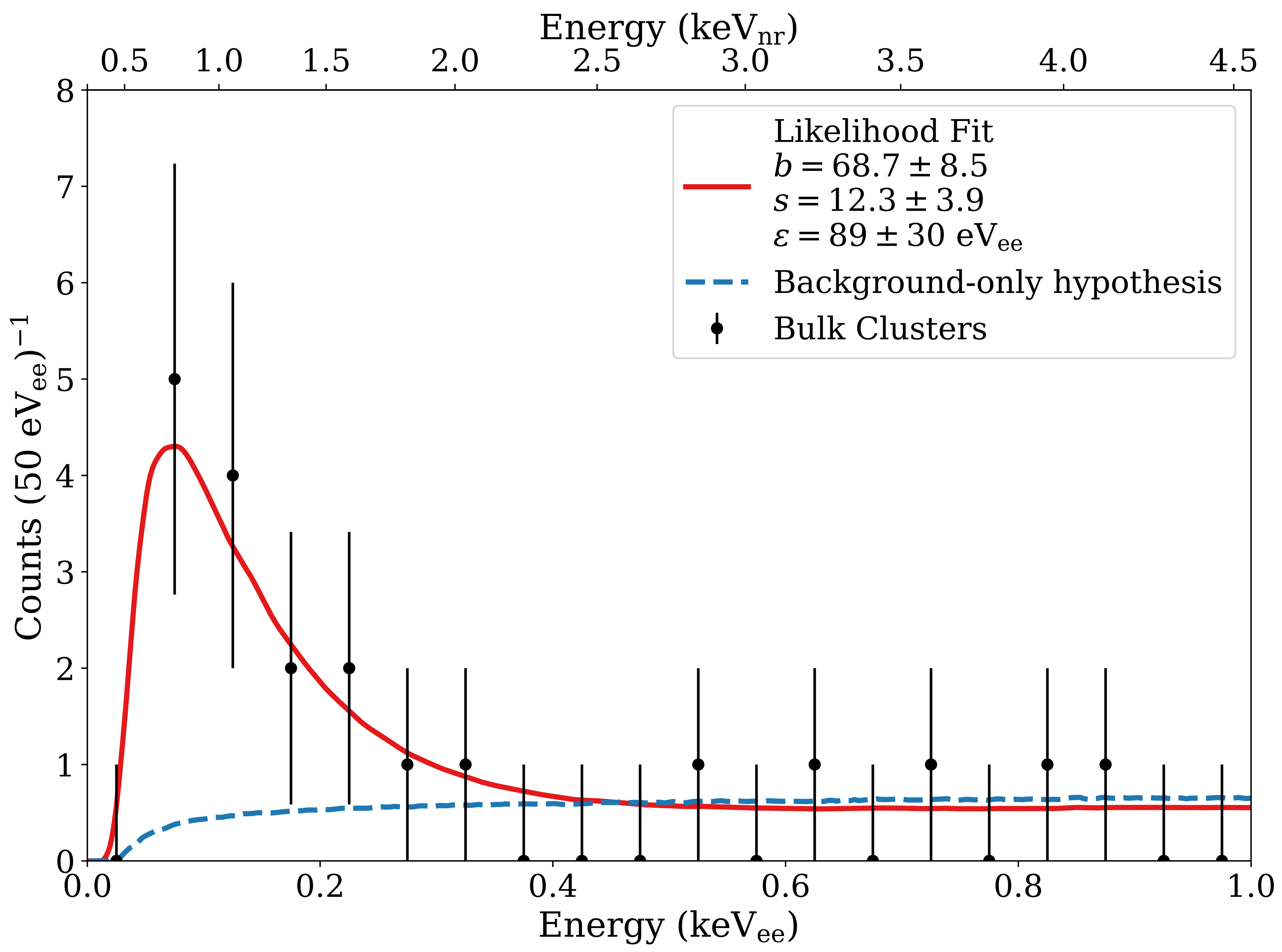
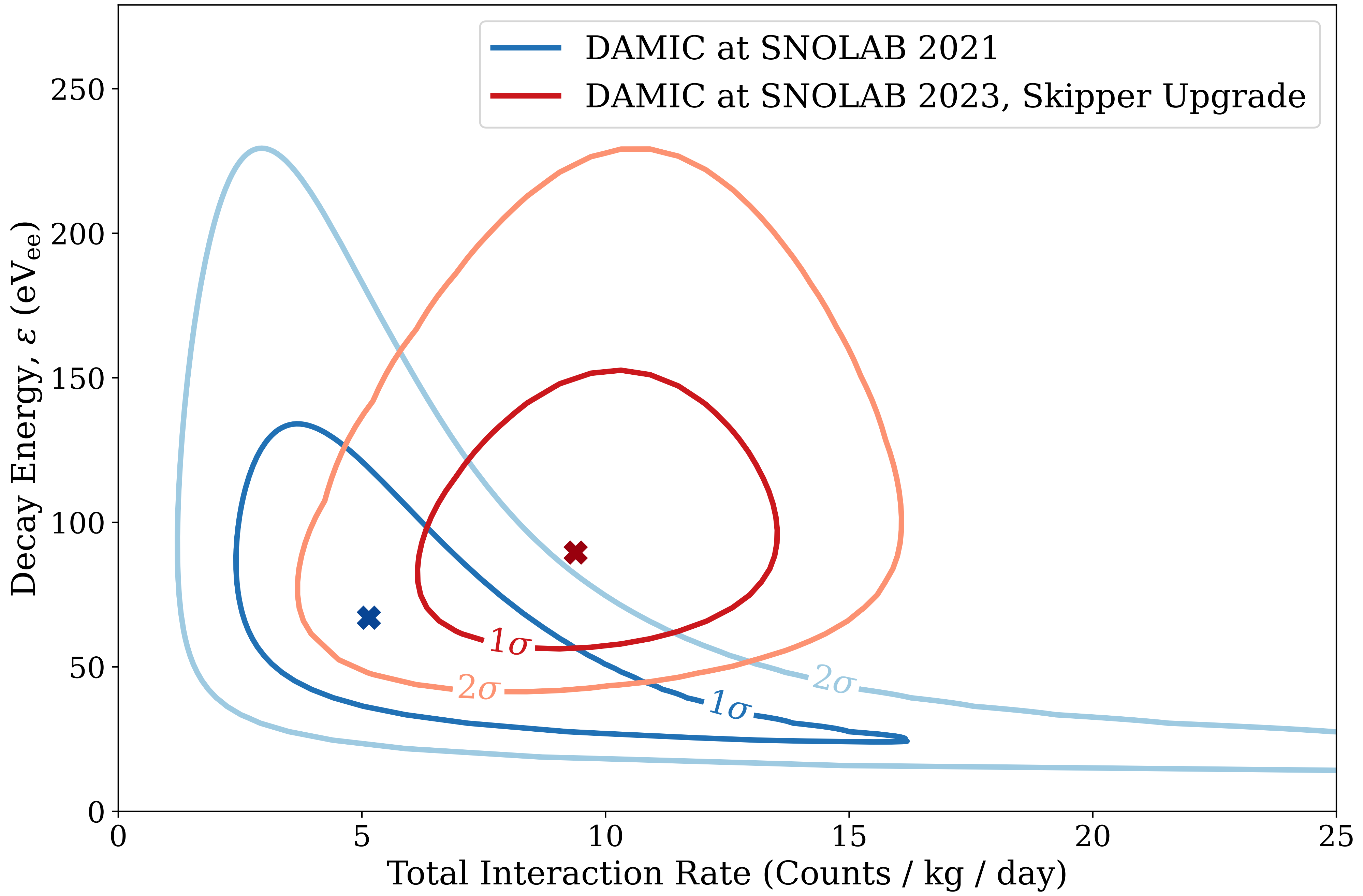


What is it?

- Probably a source of radiation. Neutrons?
  Required flux: 0.2 $cm^{-2}\,day^{-1}$ ~ total flux in SNOLAB cavern.
  We expect ~ 100 × lower from simulations.
- The finding is in tension with experimental results from CDMSlite and DarkSide-50

$m_\chi \sim 2.5\ GeV/c^2,\ \ \sigma_{\chi n} \sim 3 \times 10^{-40}\ cm^2$

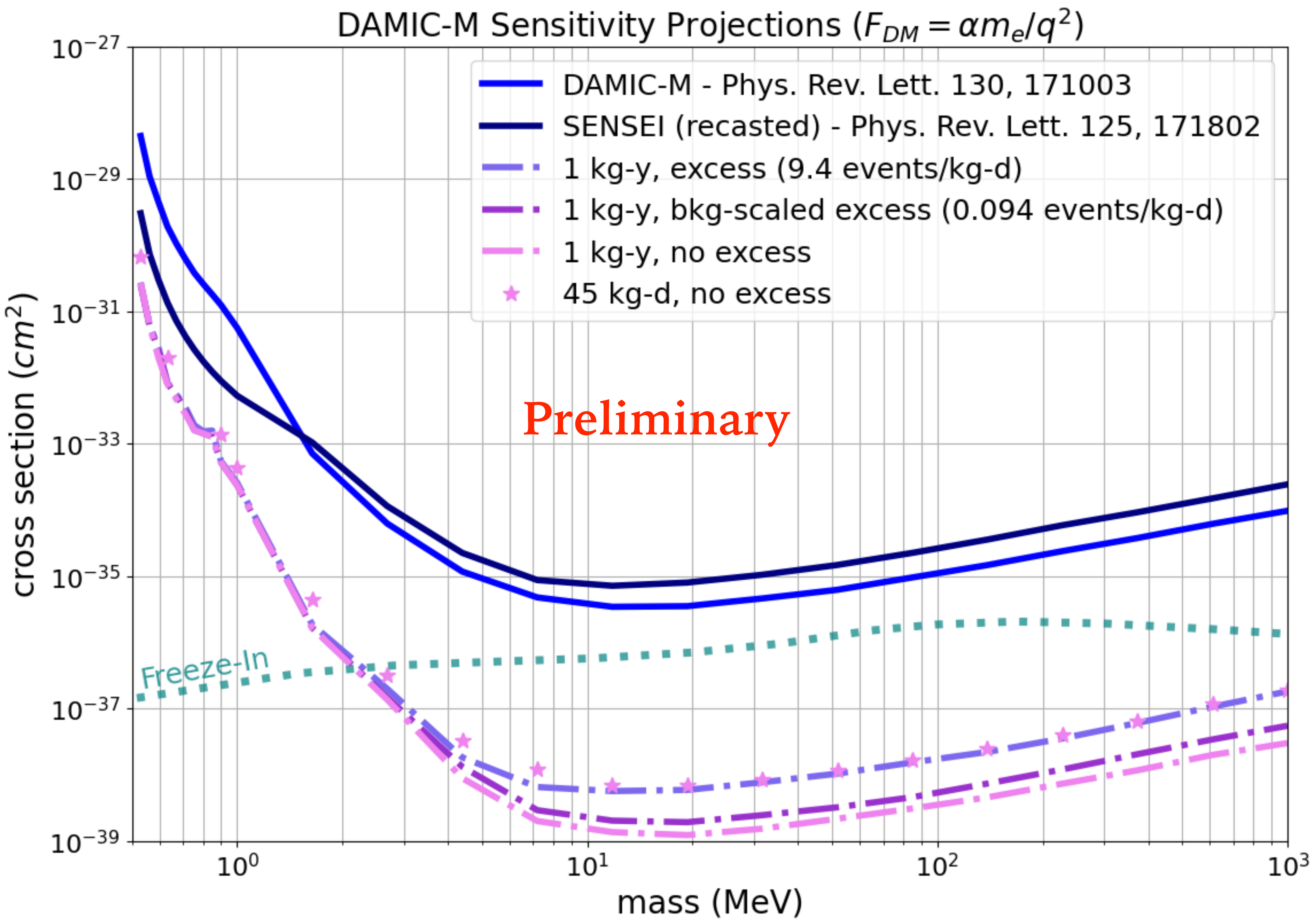


EXCESS AS A BACKGROUND

Sensitivity projections for DM-e^- scattering:
How the excess might affect DAMIC-M sensitivity.

- We extrapolate the exponential physical signal down to $1e^-$ and simulate it as a background for hidden sector DM searches
- Conservative assumptions on noise and leakage current ($\sigma = 0.23\ e^-$ and $\lambda = 10^{-3}\ e^-$/pix/day), and readout strategy (continuous)
- We consider two scenarios:
  - The excess event rate is fixed to 9.4 (kg-d)$^{-1}$ and does not depend on the total background rate
  - The excess event rate scales with the background rate

    ➡ 2 order of magnitude reduction in DAMIC-M



CONCLUSIONS

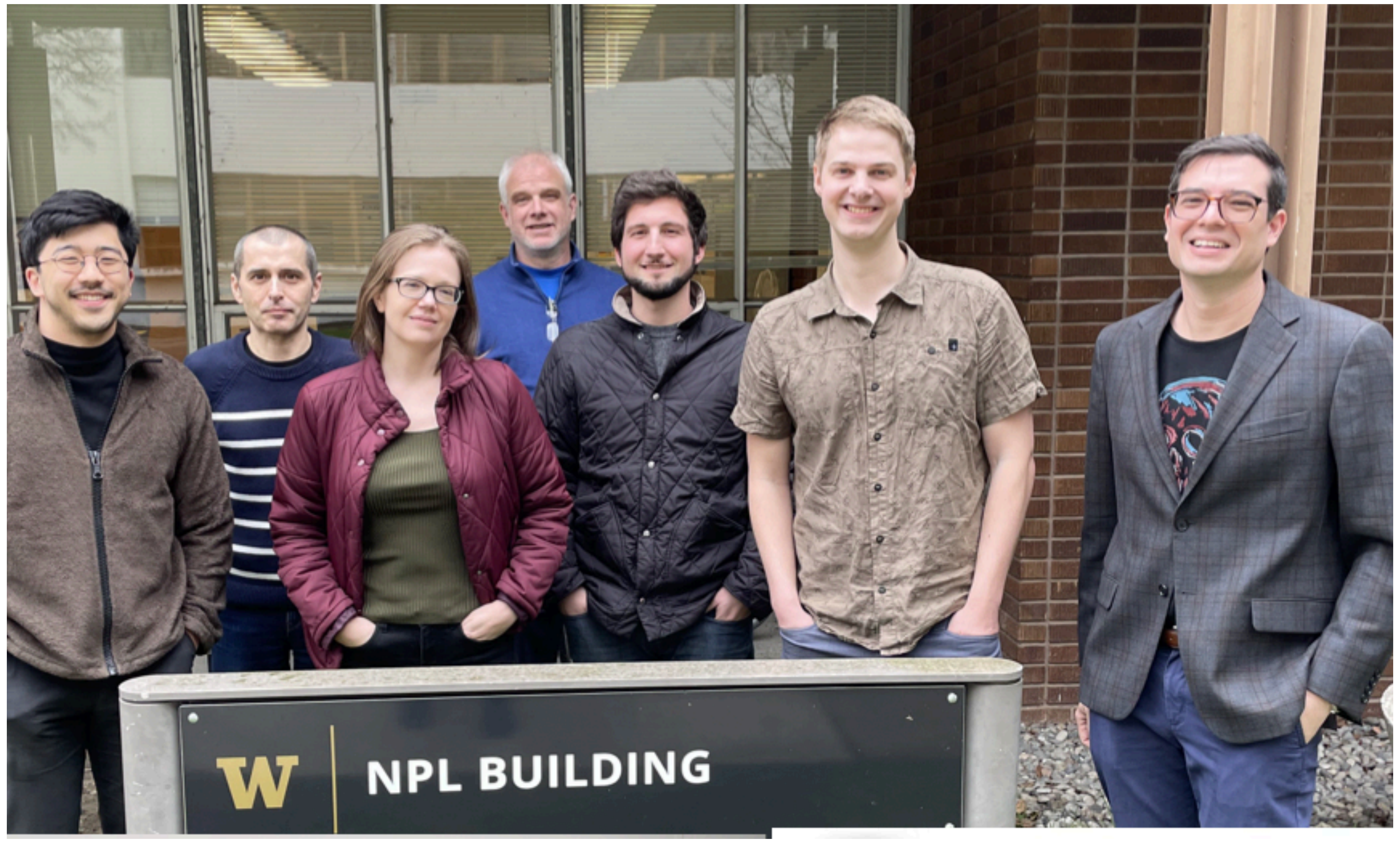
- DAMIC at SNOLAB pioneered CCDs as Dark Matter detectors:
  - Constructed first comprehensive CCD background model
  - Detected low-energy excess below 500 eV_{ee}
- DAMIC-M will be deployed in 2024
  - $\sim$200 skipper CCDs: $\mathcal{O}$(kg) detector
  - Low-energy excess confirmed with DAMIC-M skippers at SNOLAB arXiv:2306.01717
    - Lower threshold with sub-electron noise
    - Different readout strategy, different noise response
    - Rejected most prominent systematic: surface events
    - Unchanged background environment
  - Will investigate excess in DAMIC-M (different) ultra-low background environment, much higher statistics and NR/ER discrimination See TAUP talks from R.Smida and P.Privitera on Aug 28th and 31st
    - If confirmed, excess will have significant implications on the next generation of CCD dark matter experiments

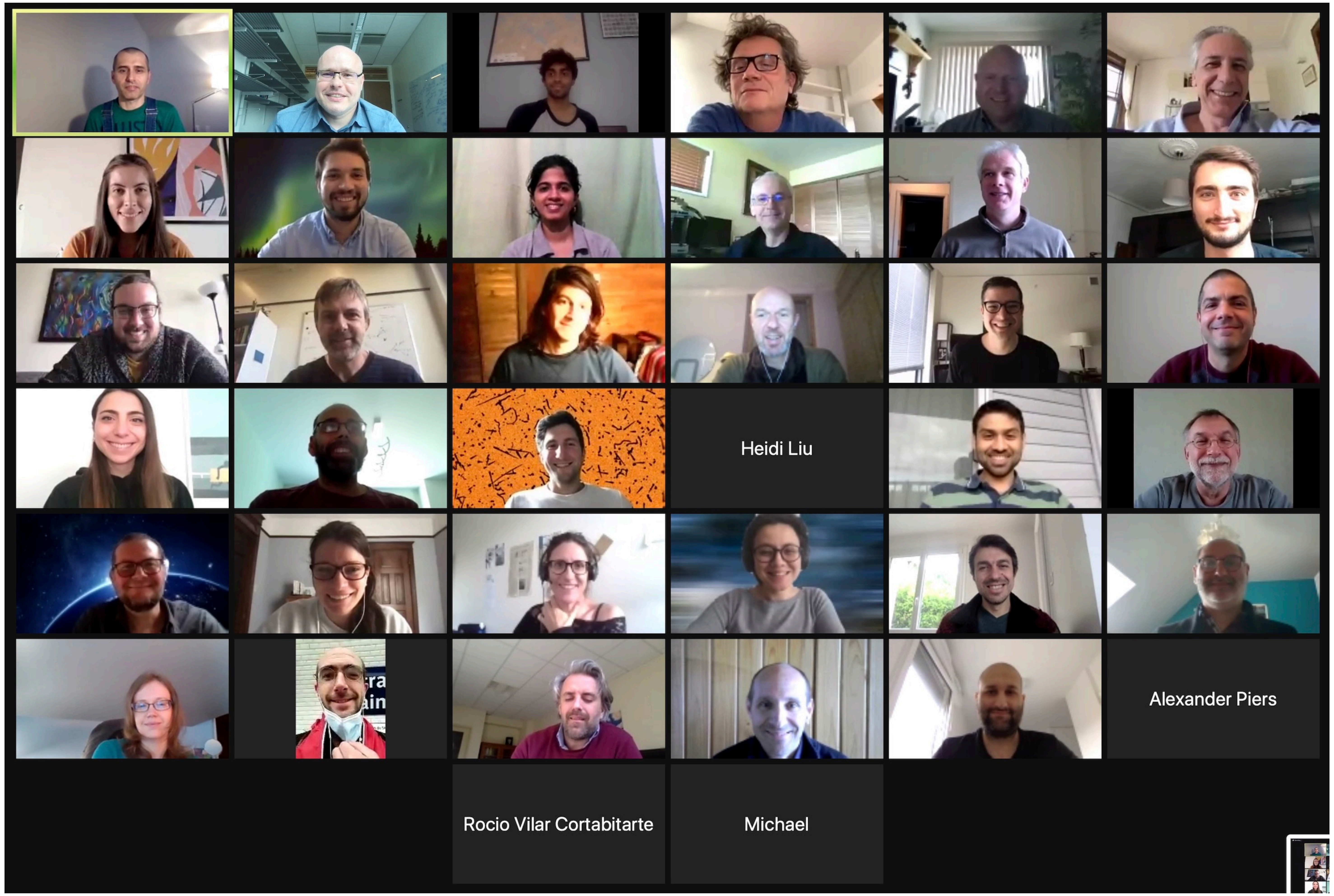
DAMIC-M

CENPA

Center for Experimental Nuclear Physics and Astrophysics

UNIVERSITY of WASHINGTON



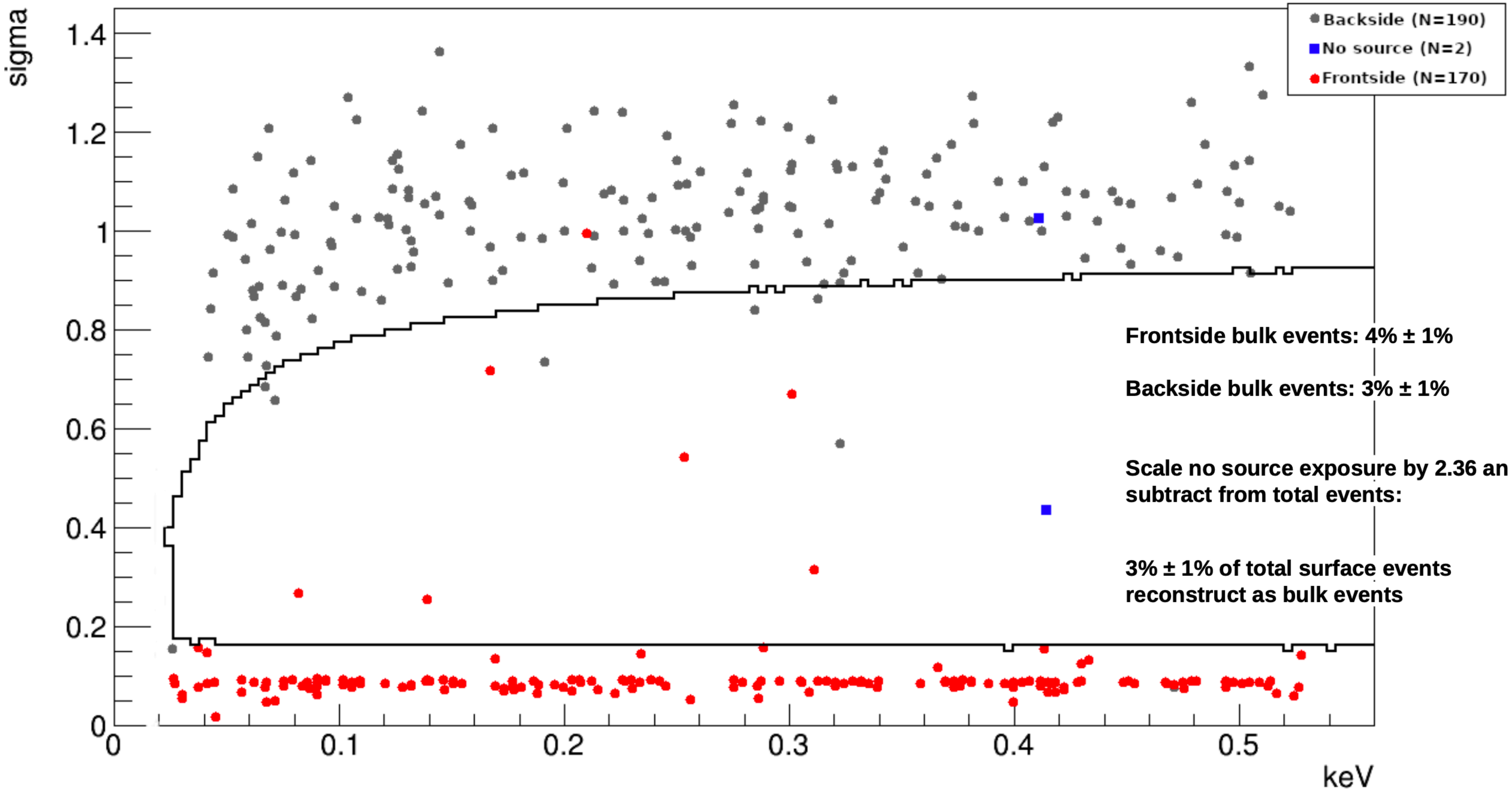


The DAMIC-M Collaboration

erc
European Research Council
Established by the European Commission
NSF
DAMIC-M

DIFFUSION SYSTEMATICS

Validation of surface rejection with ^{14}C pure β source (Q_β = 156.476 keV)



Frontside bulk events: 4% ± 1%

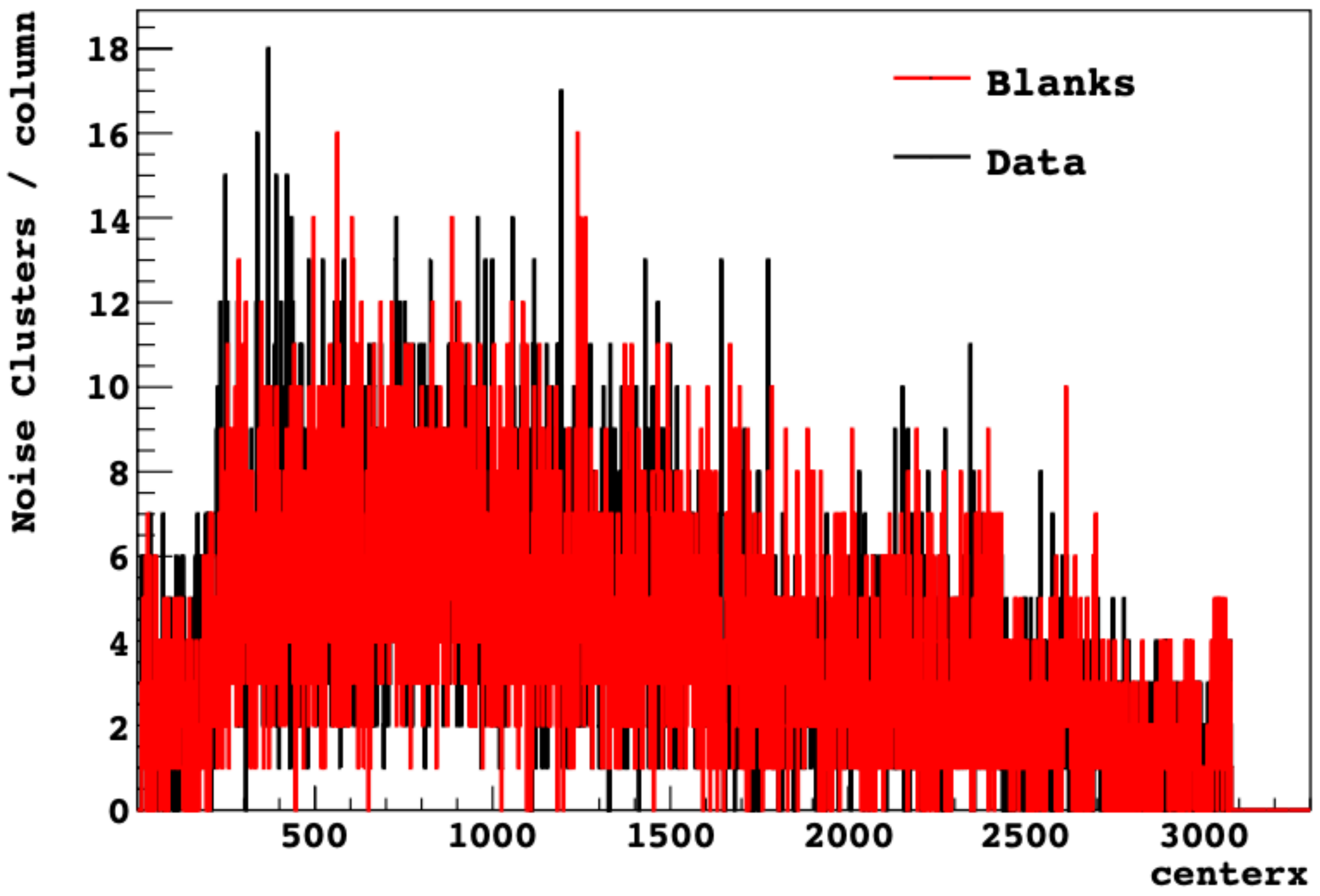
Backside bulk events: 3% ± 1%

Scale no source exposure by 2.36 an subtract from total events:

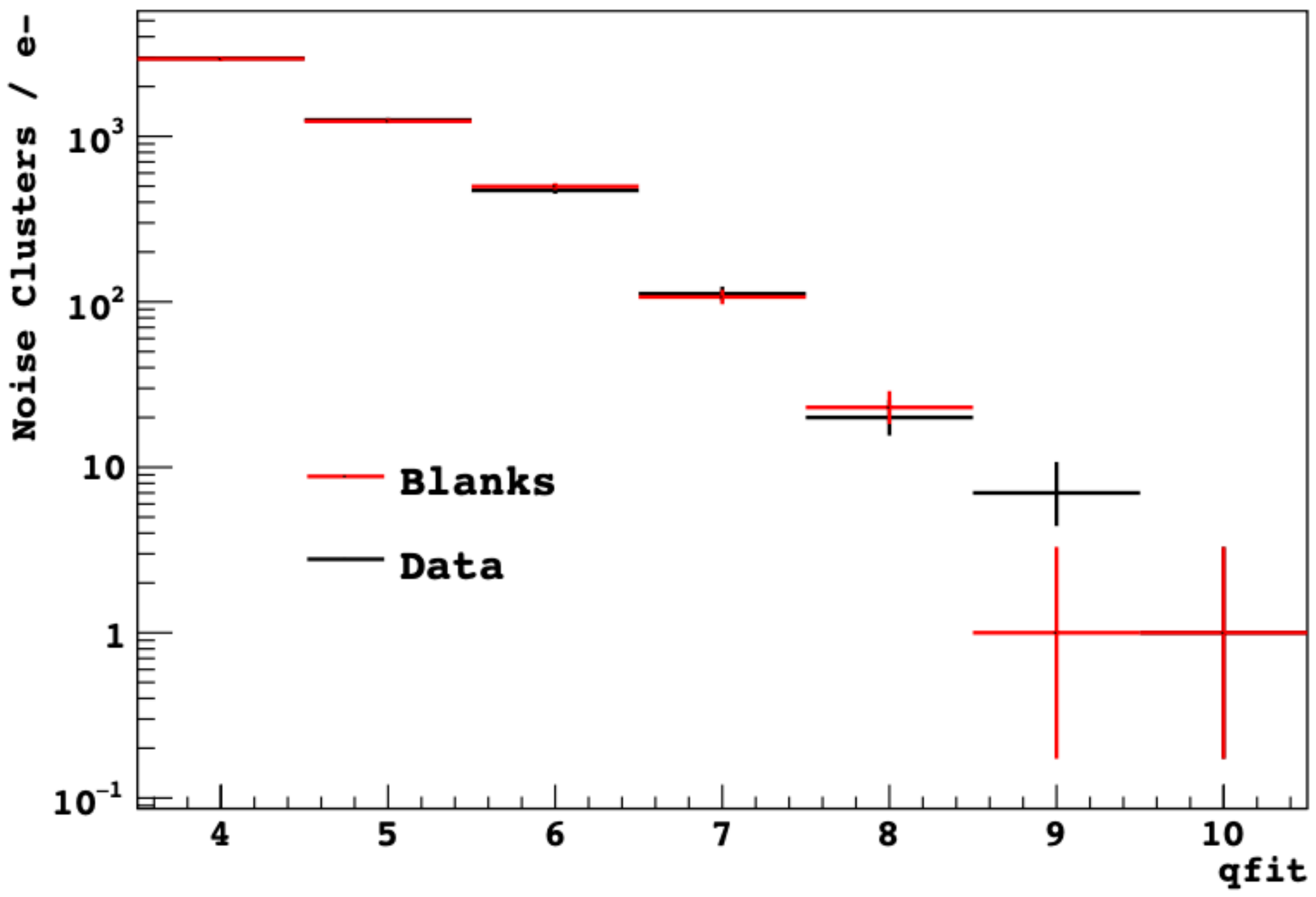
3% ± 1% of total surface events reconstruct as bulk events

ALL CUT SYSTEMATICS

Validation of likelihood clustering selections: comparing data and noise simulations



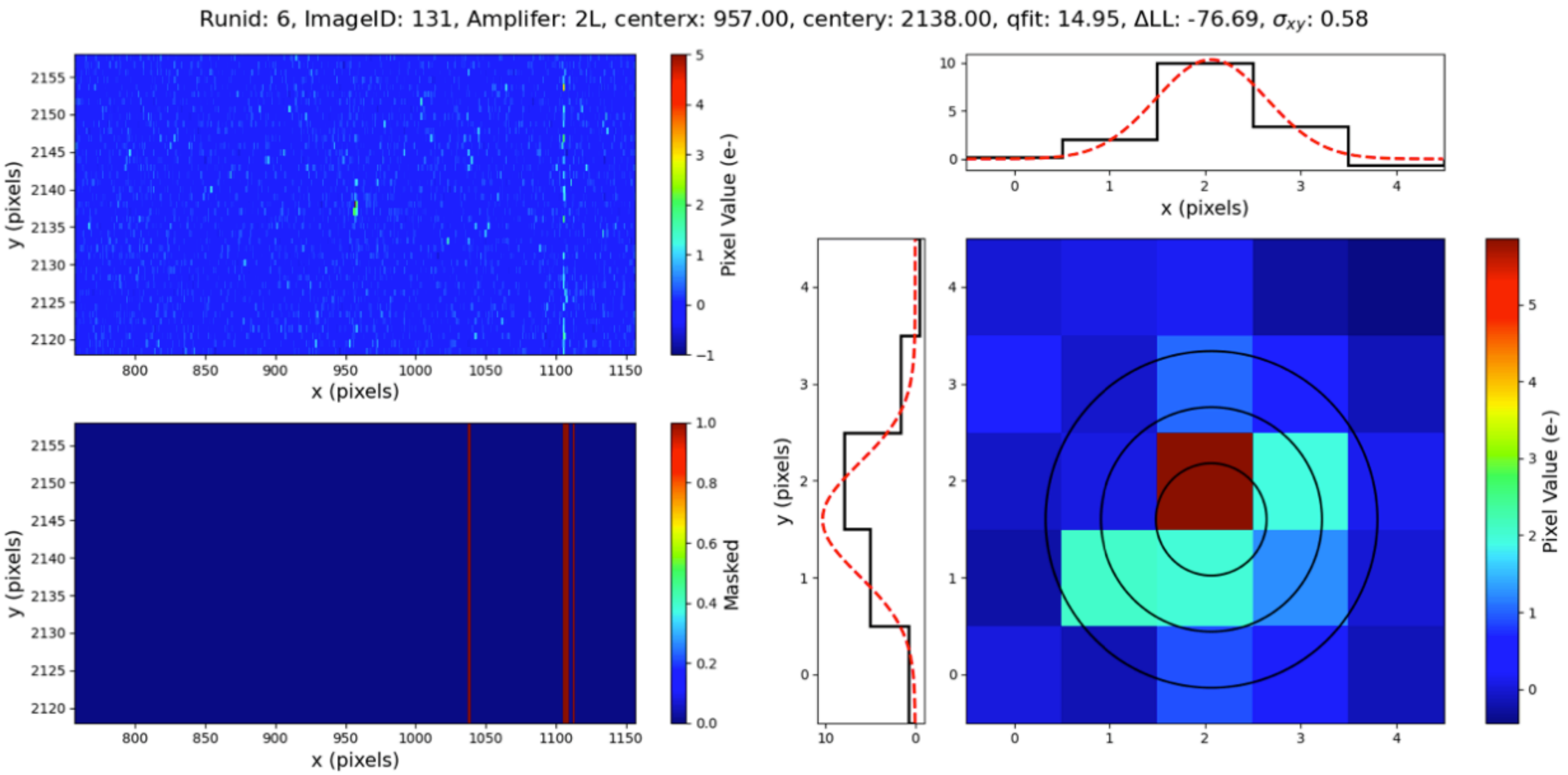
(a) Cluster `centerx` comparison.



(b) Cluster charge comparison.

LOW-E CLUSTERS

Visual inspection event by event for quality assessment



ΔLL CUT INGREDIENTS

Figure 3.12: Components needed to compute the ΔLL cut values. (a) The accidental rate, $R_a(q, \lambda)$, of clusters (in counts / kg / day) as a function of the local λ value from the blank images. We simulated ~ 30 kg days of images. (b) The CDF, $\alpha(\Delta LL, \lambda|q)$, of the ΔLL distribution for $q = 7$. (c) The distribution of λ values across all images. We convert the exposure to a probability distribution $P(\lambda)$. (d) Finally the ΔLL cut as a function of charge to allow < 0.01 accidental event / kg / day. The uncertainty in the shaded band comes from the uncertainty of the bin content in (a).

MAIN BACKGROUNDS

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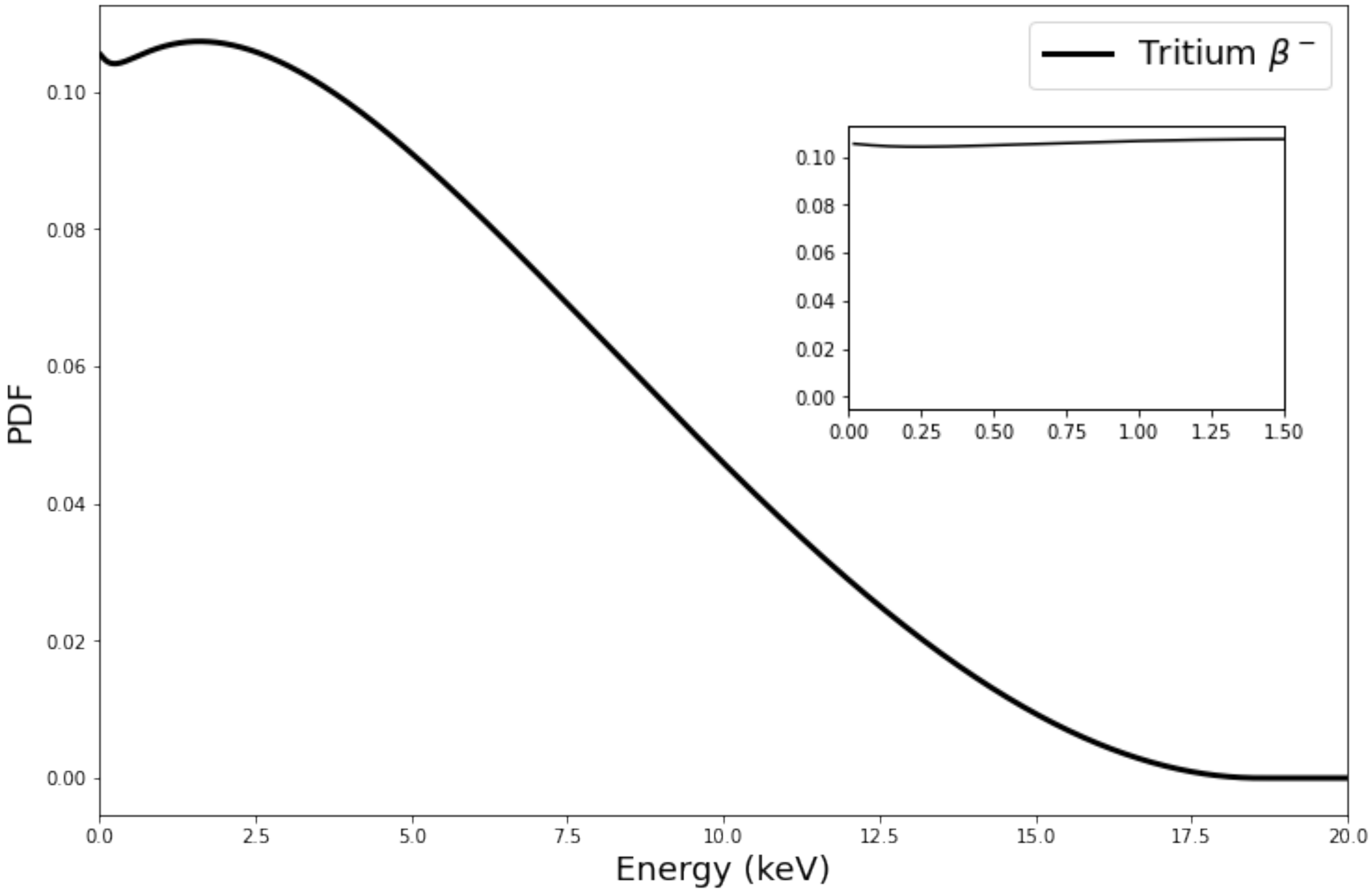
	Detector part	Chain	C_l	Best-fit activity	Rate (dru): CCDs 2–7 1–6 keV$_{ee}$	Rate (dru): CCDs 2–7 6–20 keV$_{ee}$	Rate (dru): CCD 1 1–6 keV$_{ee}$	Rate (dru): CCD 1 6–20 keV$_{ee}$
1	CCD	^{238}U	0.897	$\lesssim$9.86 μBq/kg	0.01	0.01	<0.01	<0.01
2	CCD	^{226}Ra	0.900	$\lesssim$4.79 μBq/kg	0.01	0.01	<0.01	<0.01
3	CCD	^{232}Th	0.900	$\lesssim$6.56 μBq/kg	0.01	0.03	0.01	0.02
4	CCD	^{40}K	0.910	$\lesssim$0.42 μBq/kg	<0.01	<0.01	<0.01	<0.01
5	CCD	^{22}Na	1.066	340 $\pm$ 60 μBq/kg	0.17	0.16	0.10	0.09
6	CCD	^{32}Si	1.042	150 $\pm$ 30 μBq/kg	0.19	0.17	0.15	0.13
7	CCD	^{3}H	1.131	330 $\pm$ 90 μBq/kg	2.86	0.78	2.40	0.66
8	CCD (front surface)	^{210}Pb	1.658	69 $\pm$ 12 nBq/cm^2	1.45	1.67	0.53	0.88
9	CCD (back surface)	^{210}Pb	<10^{-4}	<0.1 nBq/cm^2	<0.01	<0.01	<0.01	<0.01
10	CCD (wafer surface)	^{210}Pb	1.343	56 $\pm$ 8 nBq/cm^2	2.43	1.84	1.98	1.18
11	Copper Box	^{238}U	0.900	$\lesssim$110 μBq/kg	0.01	0.01	<0.01	<0.01
12	Copper Box	^{226}Ra	0.900	$\lesssim$120 μBq/kg	0.19	0.15	0.03	0.02
13	Copper Box	^{210}Pb	0.380	10 $\pm$ 6 mBq/kg	0.33	0.20	0.02	0.01
14	Copper Box	^{232}Th	0.900	$\lesssim$36 μBq/kg	0.08	0.06	0.01	0.01
15	Copper Box	^{40}K	0.900	$\lesssim$28 μBq/kg	<0.01	<0.01	<0.01	<0.01
16	Copper Box	Act.	1.015	280 $\pm$ 30 μBq/kg	0.63	0.49	0.10	0.08
17	Copper Modules	^{238}U	0.900	$\lesssim$110 μBq/kg	0.05	0.03	<0.01	<0.01
18	Copper Modules	^{226}Ra	0.900	$\lesssim$120 μBq/kg	0.21	0.17	<0.01	<0.01
19	Copper Modules	^{210}Pb	0.557	15 $\pm$ 4 mBq/kg	1.18	0.71	<0.01	<0.01
20	Copper Modules	^{232}Th	0.900	$\lesssim$36 μBq/kg	0.10	0.08	<0.01	<0.01
21	Copper Modules	^{40}K	0.900	$\lesssim$28 μBq/kg	<0.01	<0.01	<0.01	<0.01
22	Copper Modules	Act.	1.006	130 $\pm$ 10 μBq/kg	0.30	0.23	0.01	0.01
23	Kapton Cable	^{238}U	1.016	59 $\pm$ 5 mBq/kg	0.51	0.30	0.23	0.11
24	Kapton Cable	^{226}Ra	1.362	7 $\pm$ 5 mBq/kg	0.24	0.18	0.05	0.03
25	Kapton Cable	^{232}Th	1.010	32 $\pm$ 0.5 mBq/kg	0.17	0.13	0.04	0.02
26	Kapton Cable	^{40}K	1.003	29 $\pm$ 2 mBq/kg	0.09	0.05	0.04	0.02
27	Kapton Cable	Act.	1.000	140 $\pm$ 10 μBq/kg	0.01	0.01	<0.01	<0.01
28	Ancient Lead	^{238}U	0.911	$\lesssim$21 μBq/kg	<0.01	<0.01	<0.01	<0.01
29	Ancient Lead	^{226}Ra	0.900	$\lesssim$230 μBq/kg	0.44	0.36	0.21	0.18
30	Ancient Lead	^{210}Pb	1.000	~33 mBq/kg	0.04	0.03	0.24	0.18
31	Ancient Lead	^{232}Th	1.000	~2.3 μBq/kg	<0.01	<0.01	<0.01	<0.01
32	Ancient Lead	^{40}K	0.916	$\lesssim$5.3 μBq/kg	<0.01	<0.01	<0.01	<0.01
33	Outer Lead	^{238}U	0.916	$\lesssim$12 μBq/kg	<0.01	<0.01	<0.01	<0.01
34	Outer Lead	^{226}Ra	0.909	$\lesssim$190 μBq/kg	<0.01	<0.01	<0.01	<0.01
35	Outer Lead	^{210}Pb	1.000	18 $\pm$ 5 Bq/kg	<0.01	<0.01	<0.01	<0.01
36	Outer Lead	^{232}Th	0.907	$\lesssim$4.2 μBq/kg	<0.01	<0.01	<0.01	<0.01
37	Outer Lead	^{40}K	0.906	$\lesssim$200 μBq/kg	<0.01	<0.01	<0.01	<0.01
38	Module Screws	^{238}U	1.000	20 $\pm$ 40 mBq/kg	<0.01	<0.01	<0.01	<0.01
39	Module Screws	^{226}Ra	0.900	$\lesssim$1.4 mBq/kg	0.01	0.01	<0.01	<0.01
40	Module Screws	^{210}Pb	1.000	27 $\pm$ 8 mBq/kg	<0.01	<0.01	<0.01	<0.01
41	Modu le Screws	^{232}Th	1.024	2.4 $\pm$ 1.6 mBq/kg	0.02	0.01	<0.01	<0.01
42	Module Screws	^{40}K	1.000	28 $\pm$ 15 mBq/kg	<0.01	<0.01	<0.01	<0.01
43	Module Screws	Act.	1.000	89 $\pm$ 9 μBq/kg	<0.01	<0.01	<0.01	<0.01
44	Copper Vessel	^{238}U	0.903	$\lesssim$110 μBq/kg	<0.01	<0.01	<0.01	<0.01
45	Copper Vessel	^{226}Ra	0.900	$\lesssim$120 μBq/kg	0.10	0.09	0.01	0.01
46	Copper Vessel	^{210}Pb	0.731	20 $\pm$ 8 mBq/kg	0.06	0.03	<0.01	<0.01
47	Copper Vessel	^{232}Th	0.900	$\lesssim$36 μBq/kg	0.04	0.03	<0.01	<0.01

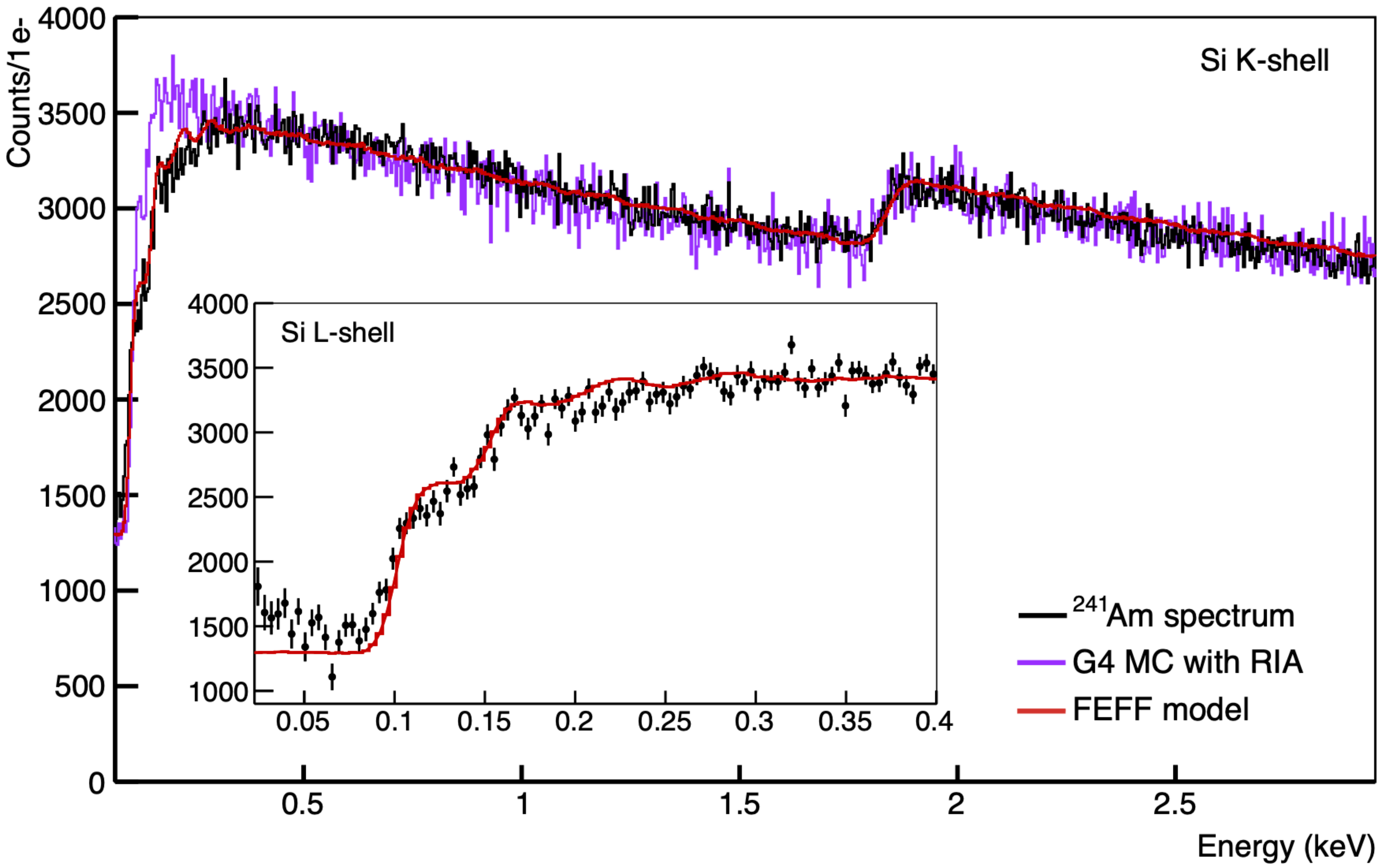
(Table continued)

	Detector part	Chain	C_l	Best-fit activity	Rate (dru): CCDs 2–7 1–6 keV$_{ee}$	Rate (dru): CCDs 2–7 6–20 keV$_{ee}$	Rate (dru): CCD 1 1–6 keV$_{ee}$	Rate (dru): CCD 1 6–20 keV$_{ee}$
48	Copper Vessel	^{40}K	0.901	$\lesssim$28 μBq/kg	<0.01	<0.01	<0.01	<0.01
49	Copper Vessel	Act.	0.486	400 $\pm$ 440 μBq/kg	0.33	0.27	0.05	0.04
	Total				12.28	8.29	6.22	3.70

MAIN BACKGROUNDS: TRITIUM



MAIN BACKGROUNDS: COMPTON



BKG MODEL VALIDATION

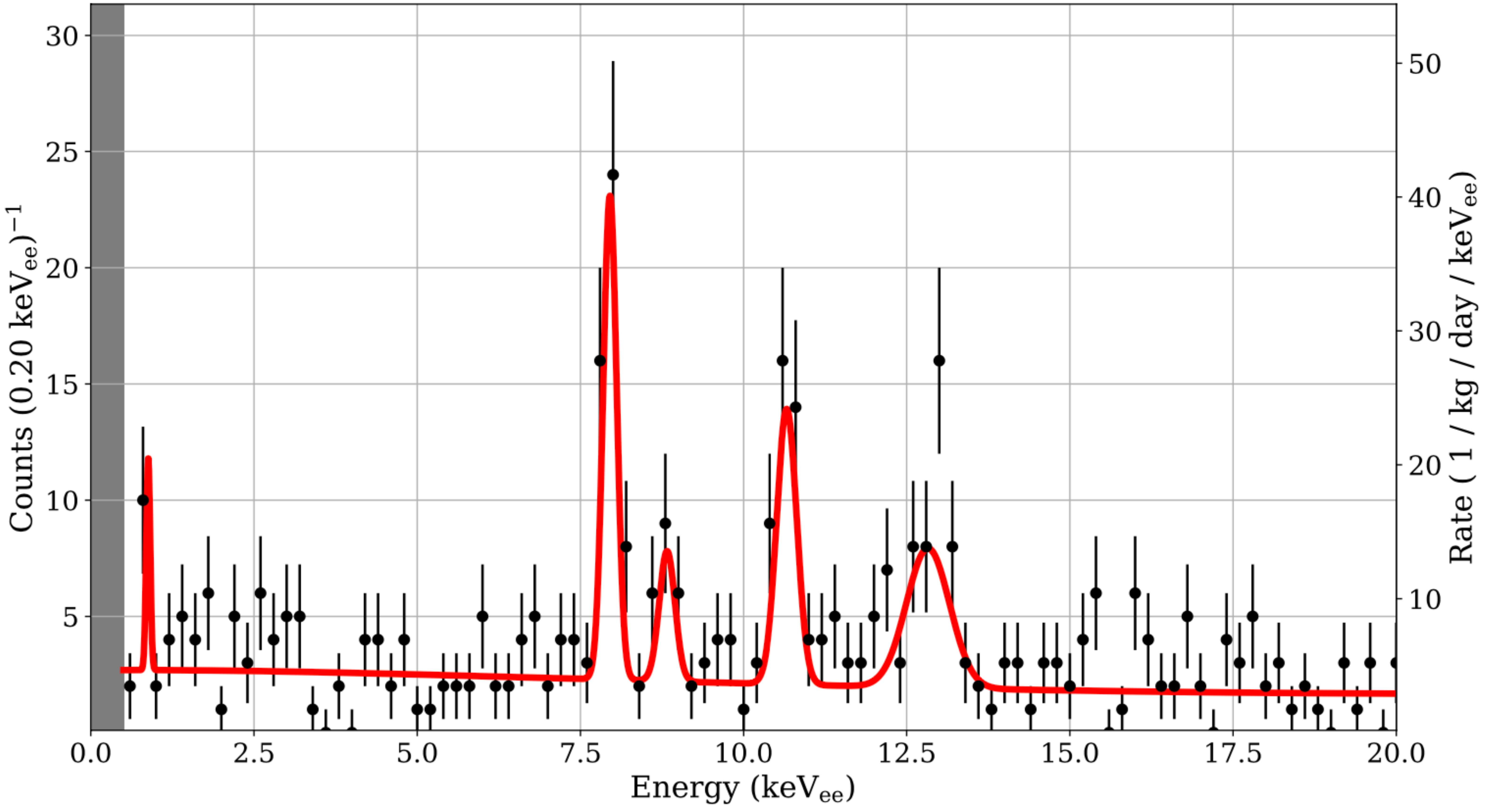
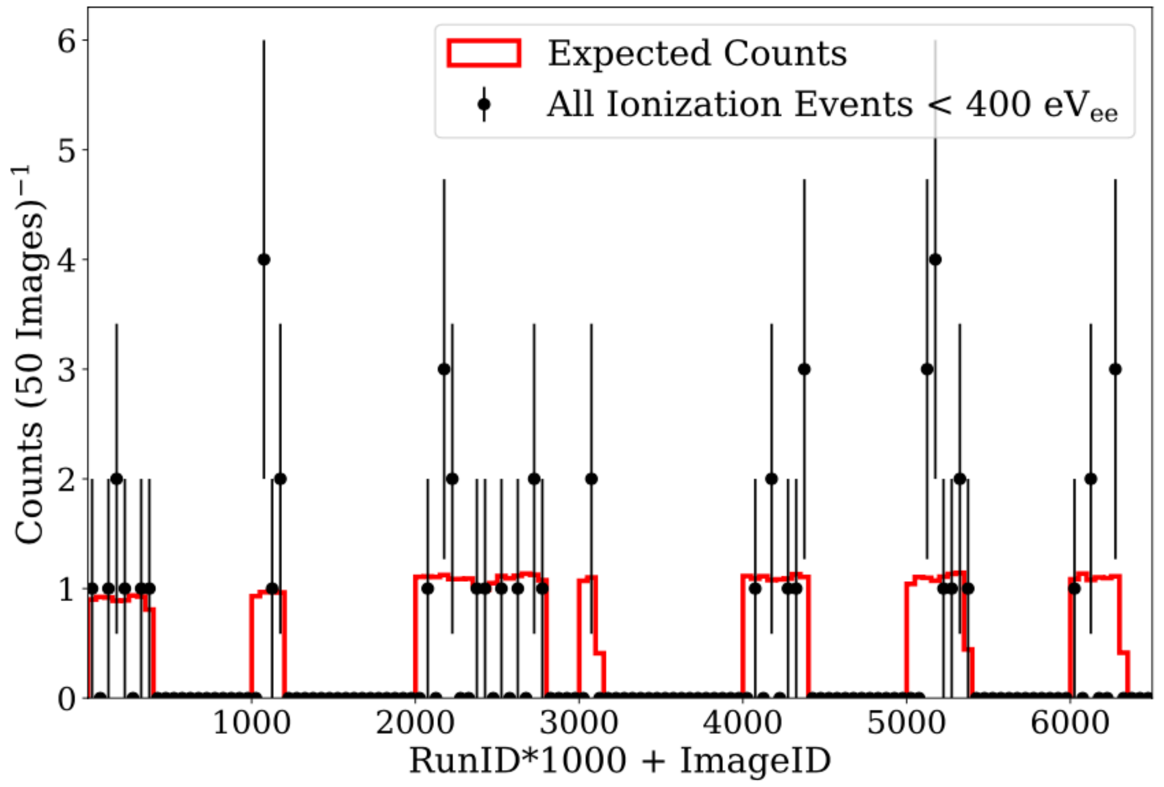


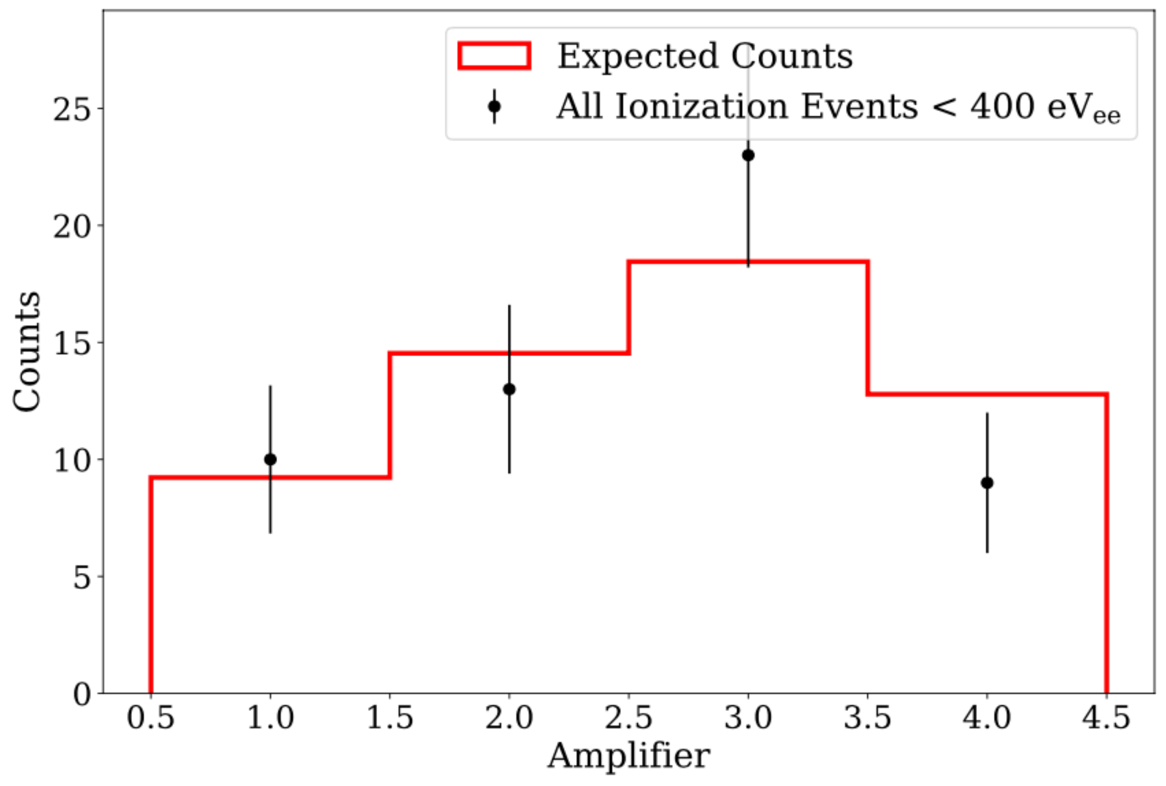
Figure 3.9: The bulk (after σ_y cuts) background rate above 0.5 keV$_{ee}$ for a bulk exposure of $\sim$ 3 kg days.

MAIN SYSTEMATICS

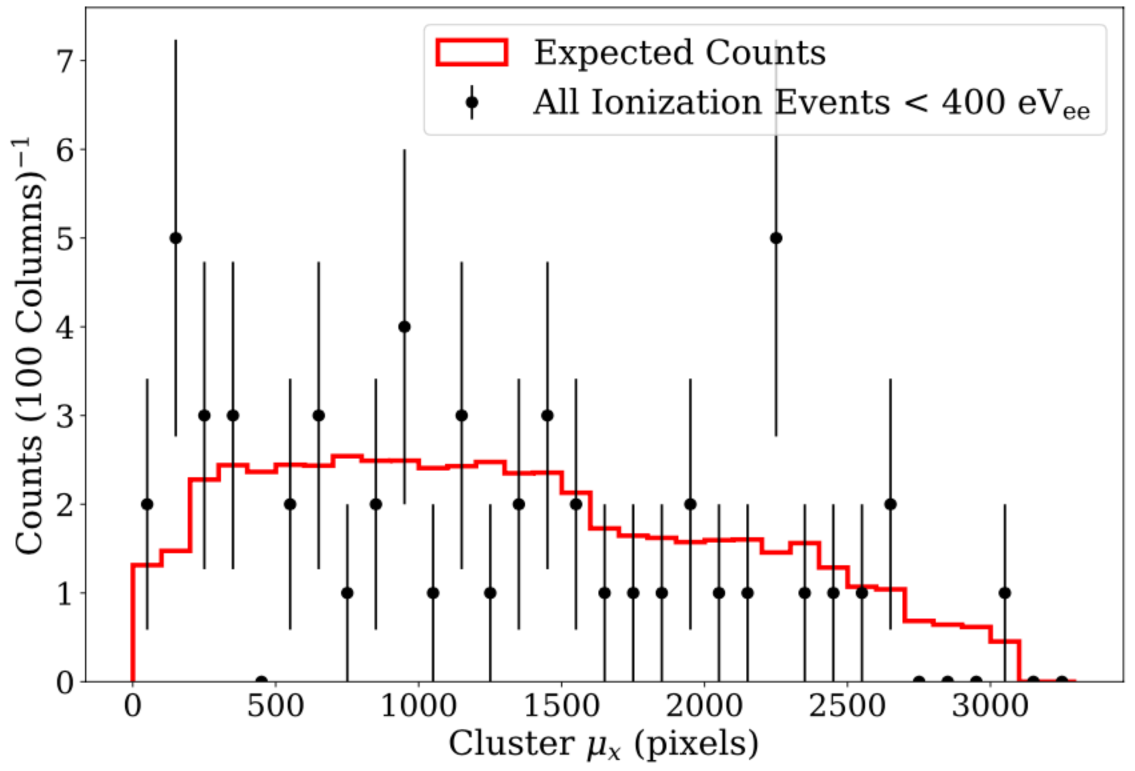
Validation of statistical properties of dataset



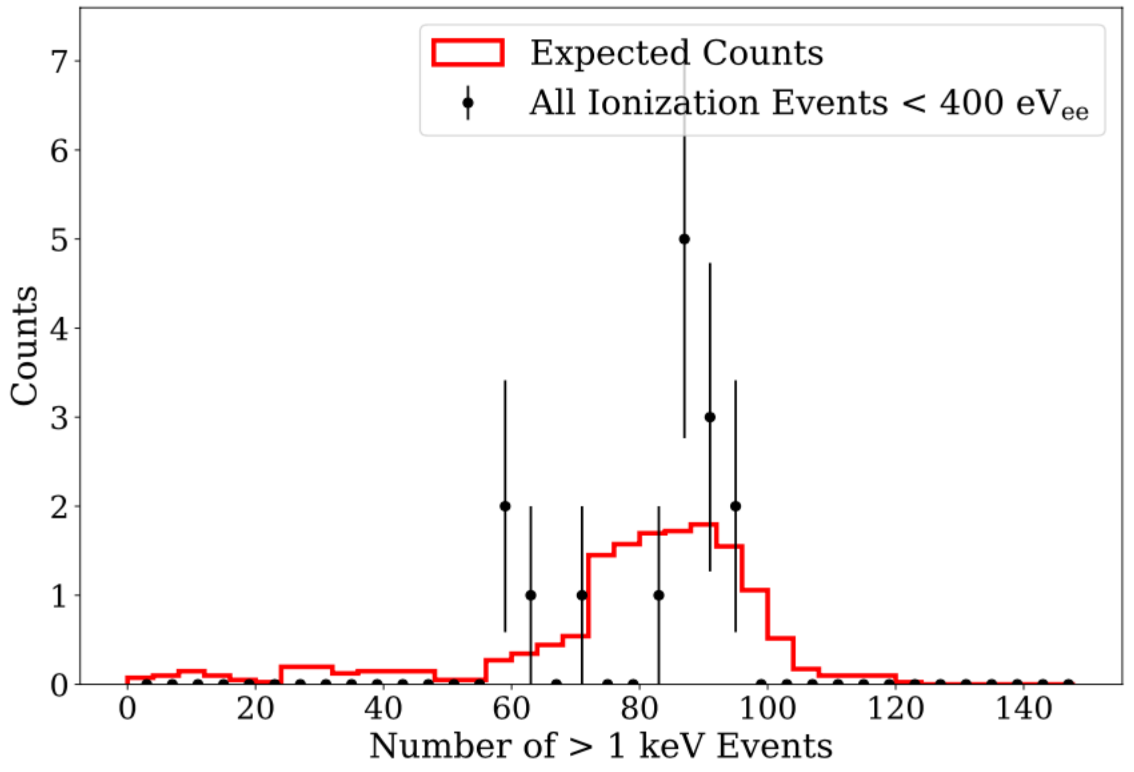
(a) Time distribution of events.



(b) Amplifier distribution.

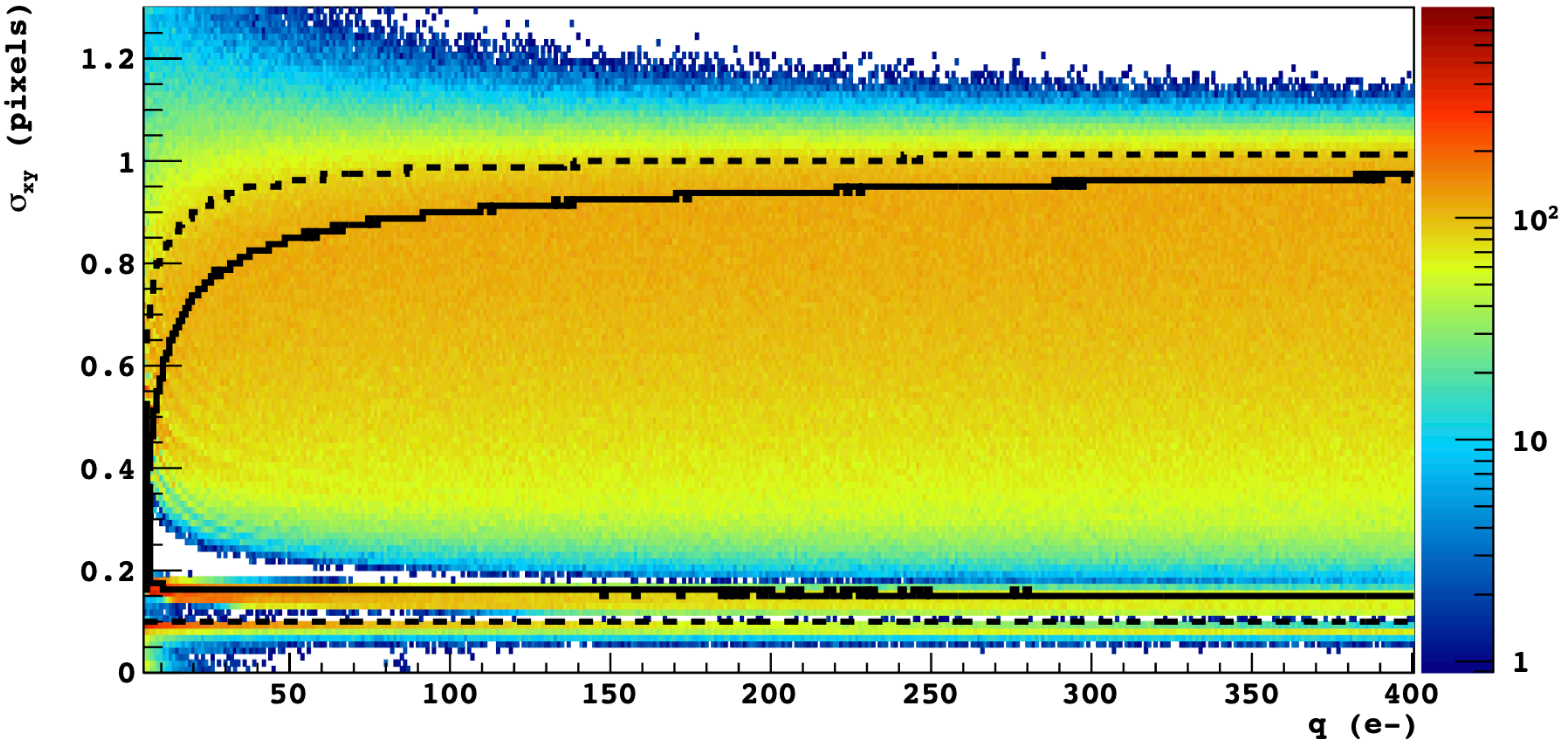


(c) Position distribution.

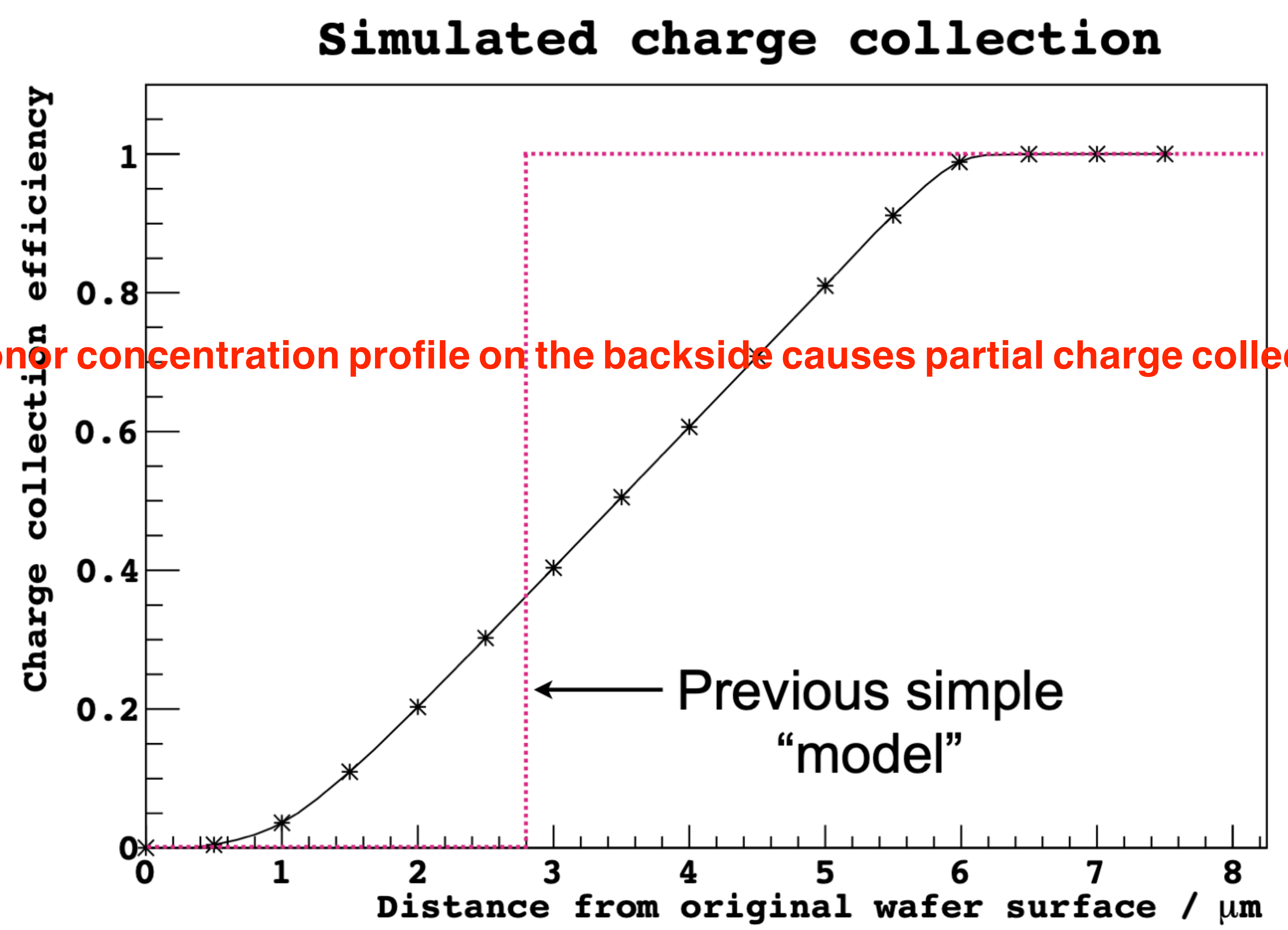


(d) Number of possible time coincident events.

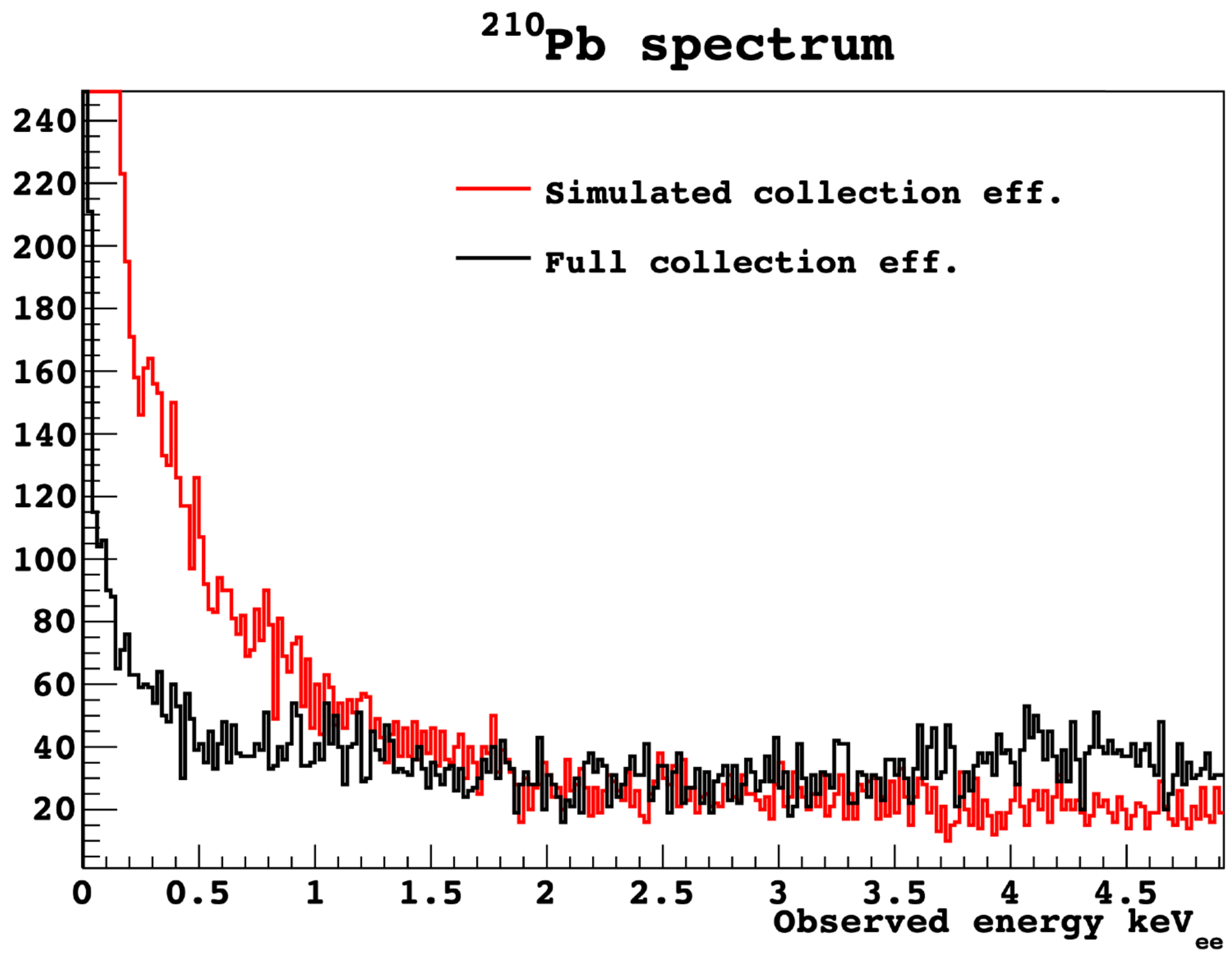
BULK EVENTS SIMULATIONS

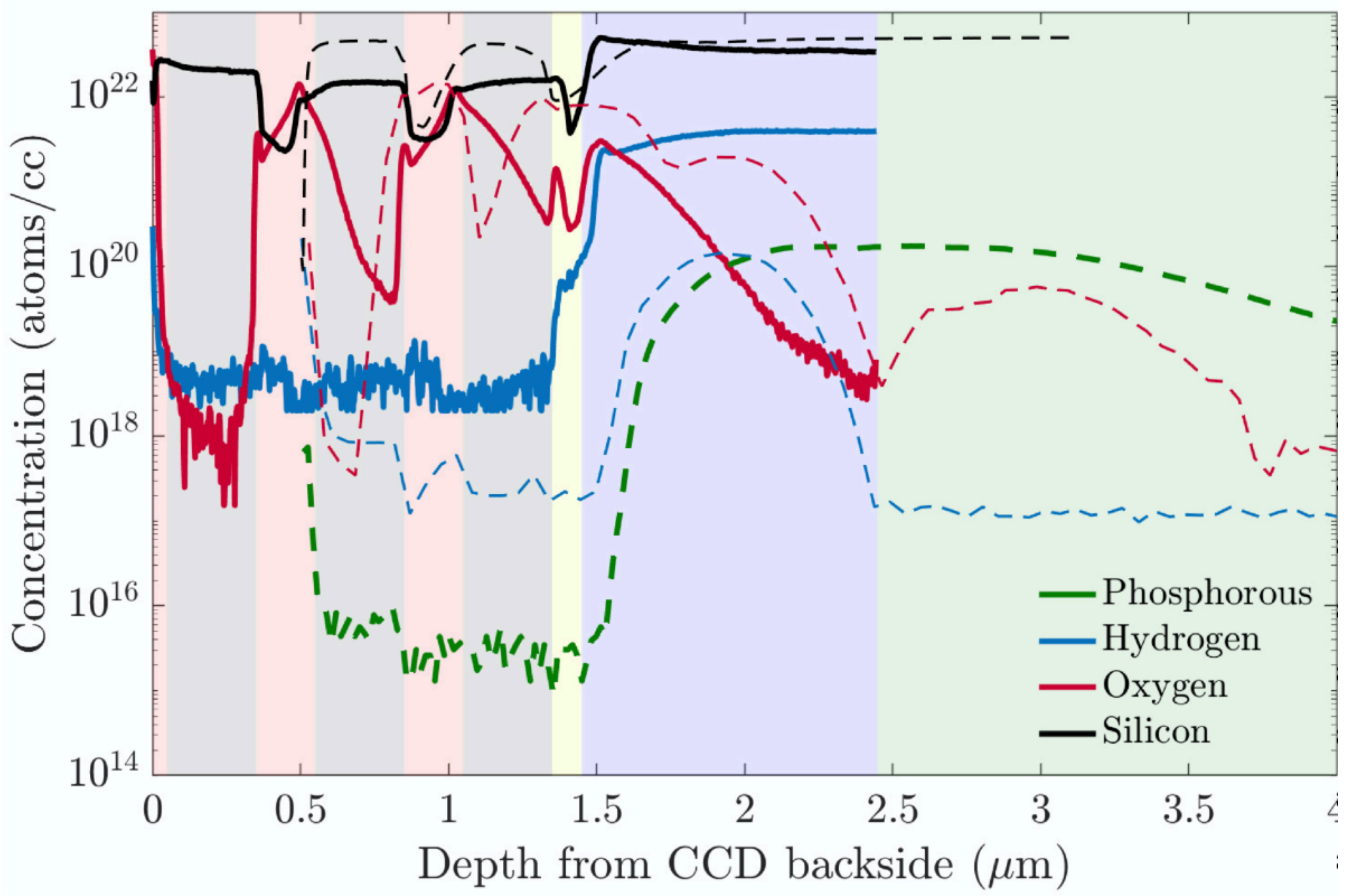


BACKSIDE ANALYSIS: PARTIAL CHARGE COLLECTION



Donor concentration profile on the backside causes partial charge collection





largest uncertainty in our response model

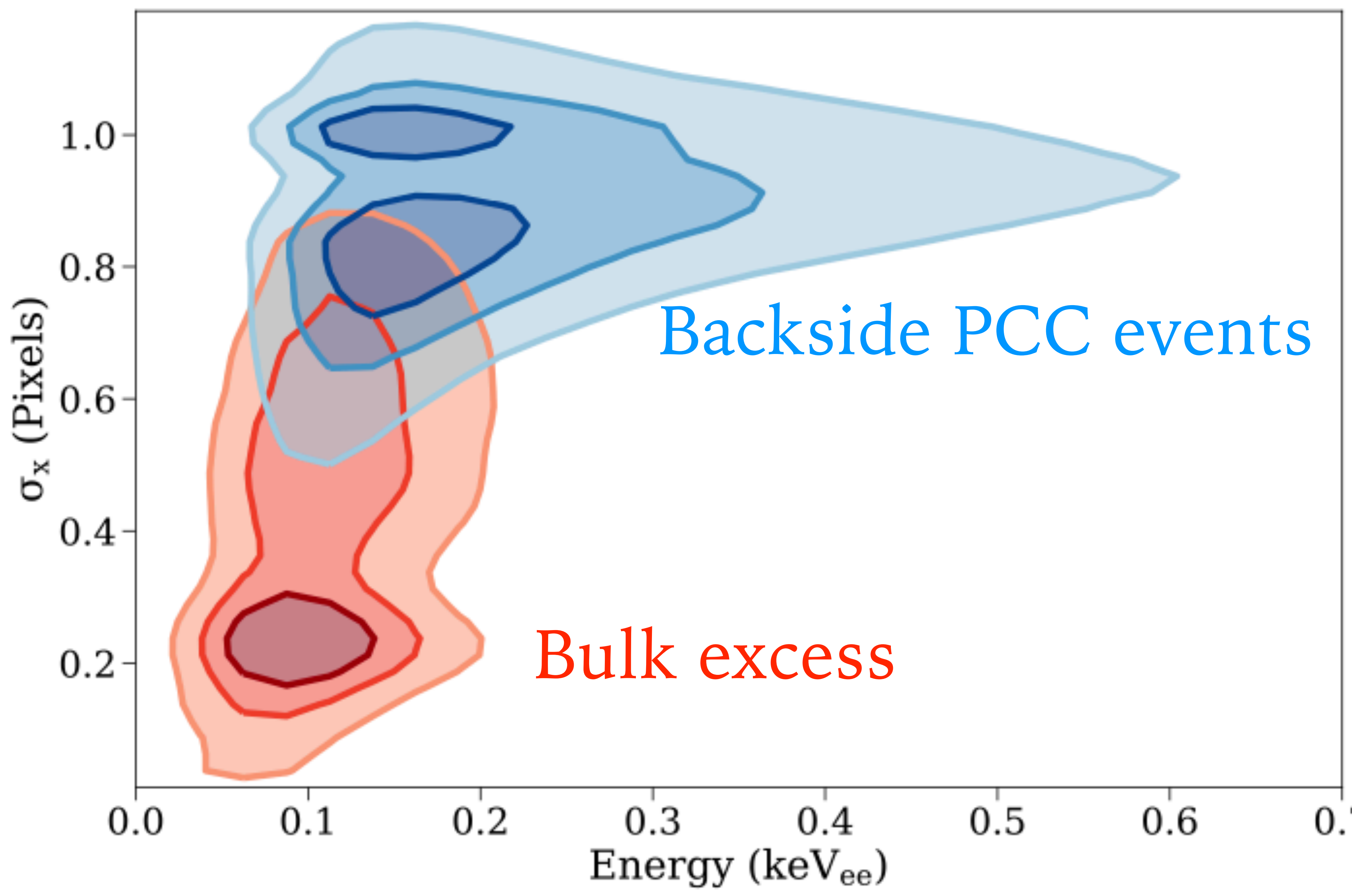
Incorporate it as systematic via back exponential in log-likelihood fit

$$f_{pcc}(E[keV_{ee}];\alpha_{pcc}) = N_{pcc}e^{-\frac{\sqrt{E}}{\alpha_{pcc}}}$$

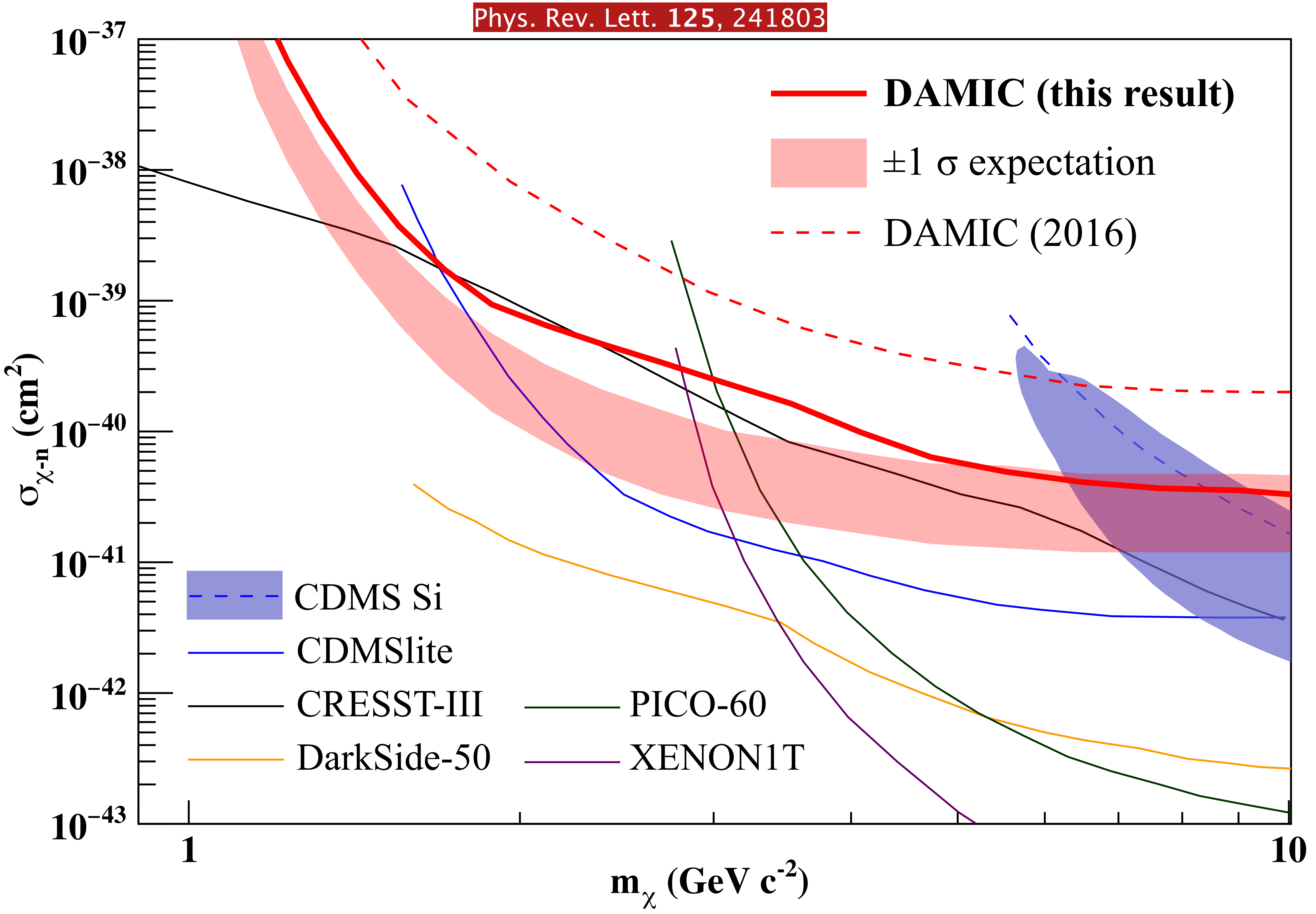
SYSTEMATIC CHECKS

Systematic Checks

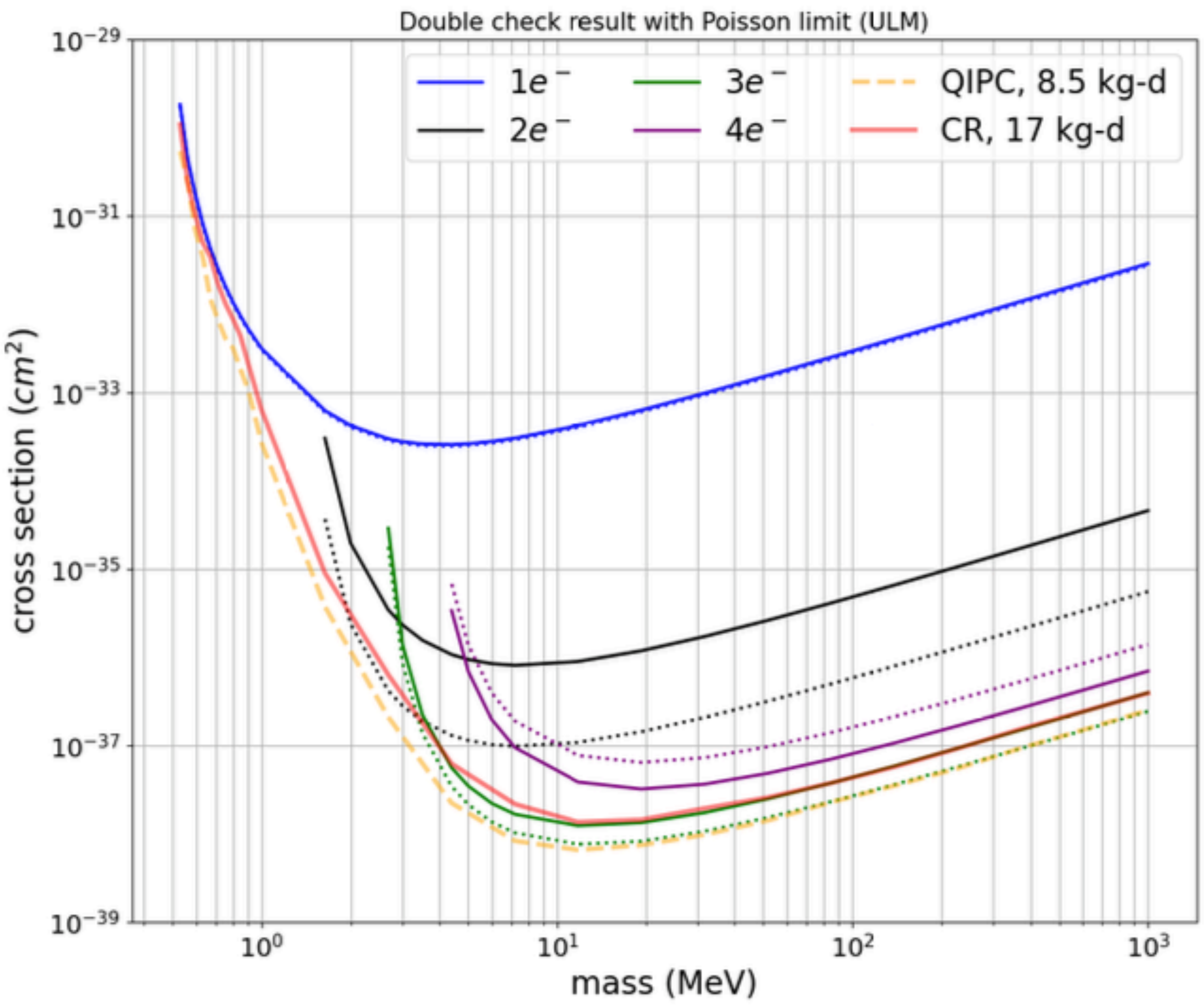
- Fit above 200 eV_{ee} consistent with null hypothesis
- Fit to CCD1 and CCD2-7 data sets separately consistent with joint analysis (excess more significant in CCD 1)
- Partial Charge Collection (PCC) systematic cannot account for the excess
- Front-surface events alone cannot account for the excess
- Local vs Global significance tests: excess is by far the most significant feature in data
- Serial register events excluded as possible source of excess (0.01% of overall exposure)



11 KG-DAY WIMP SEARCH LIMITS

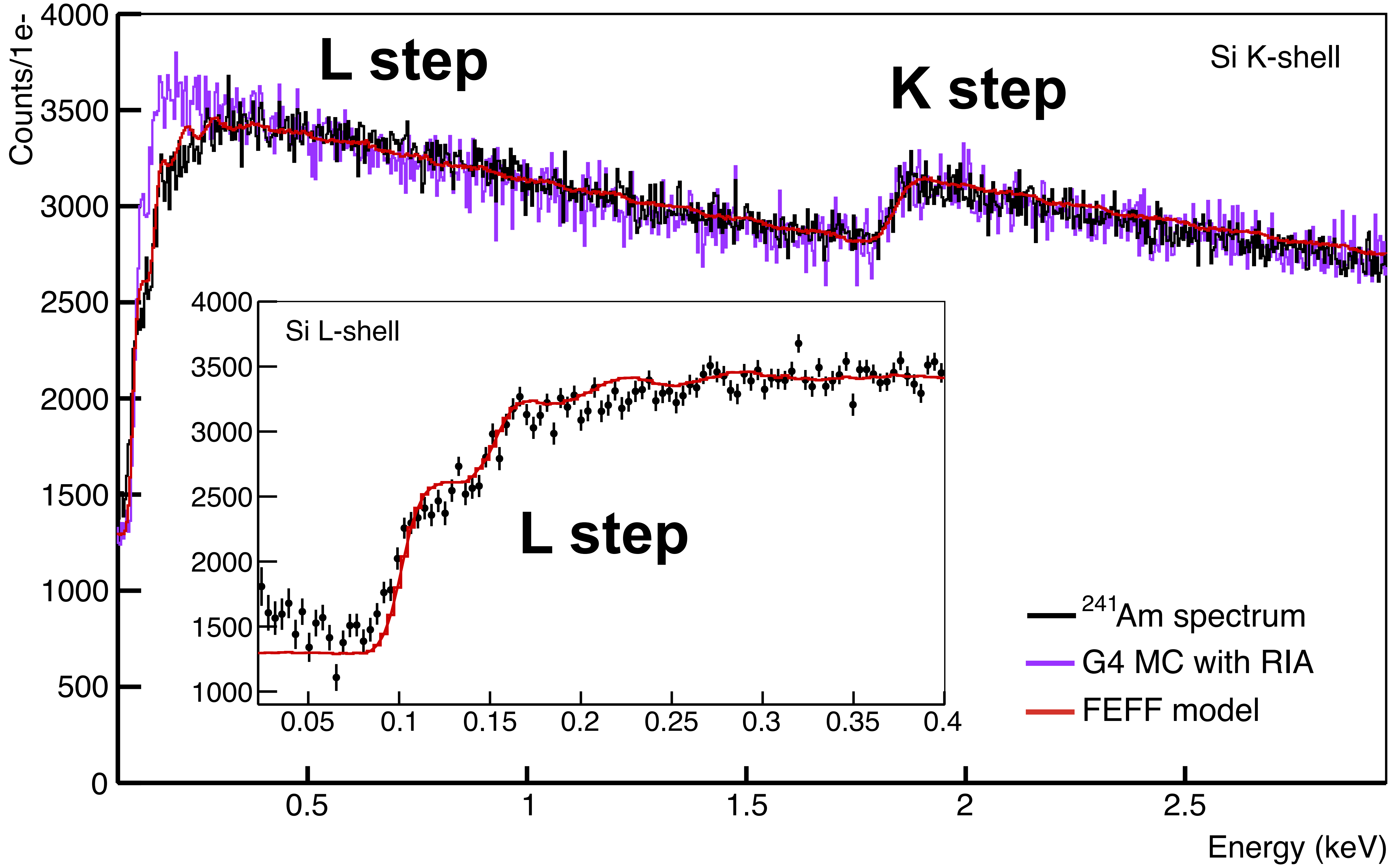


POISSON-PLR LIMITS



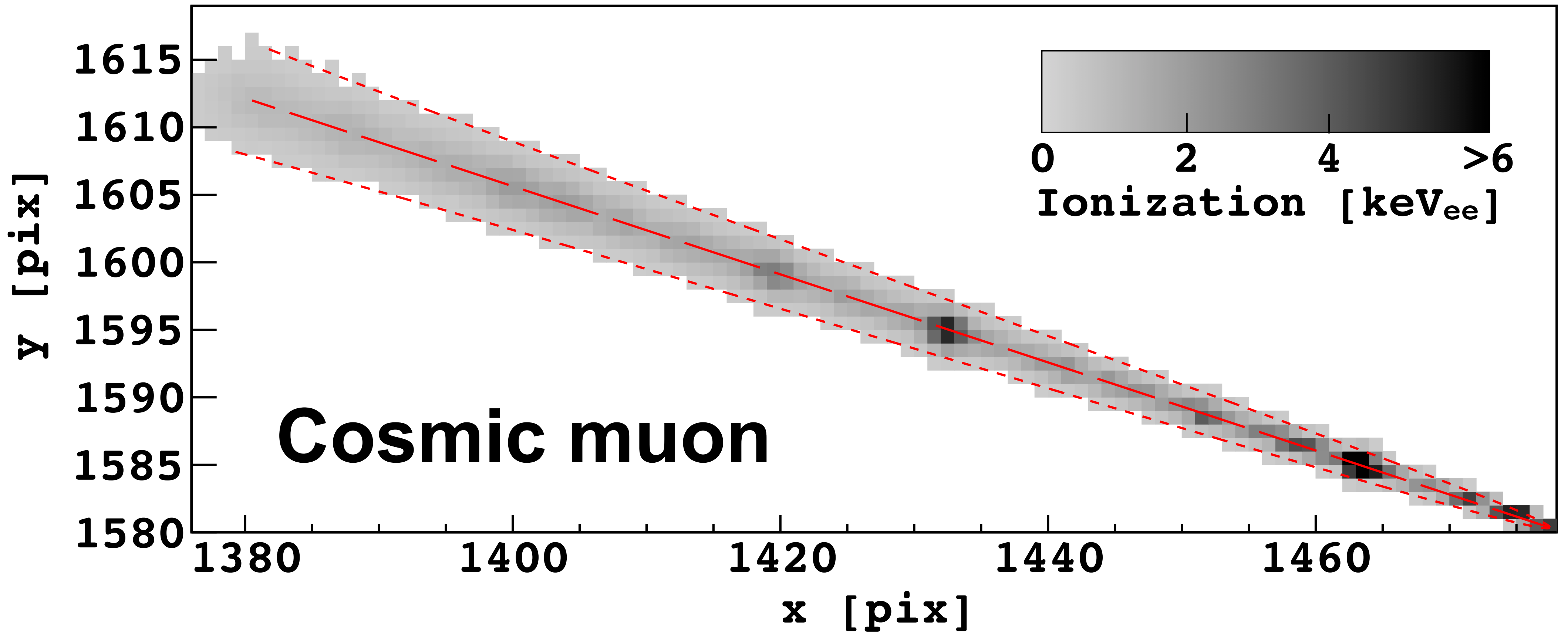
Energy response

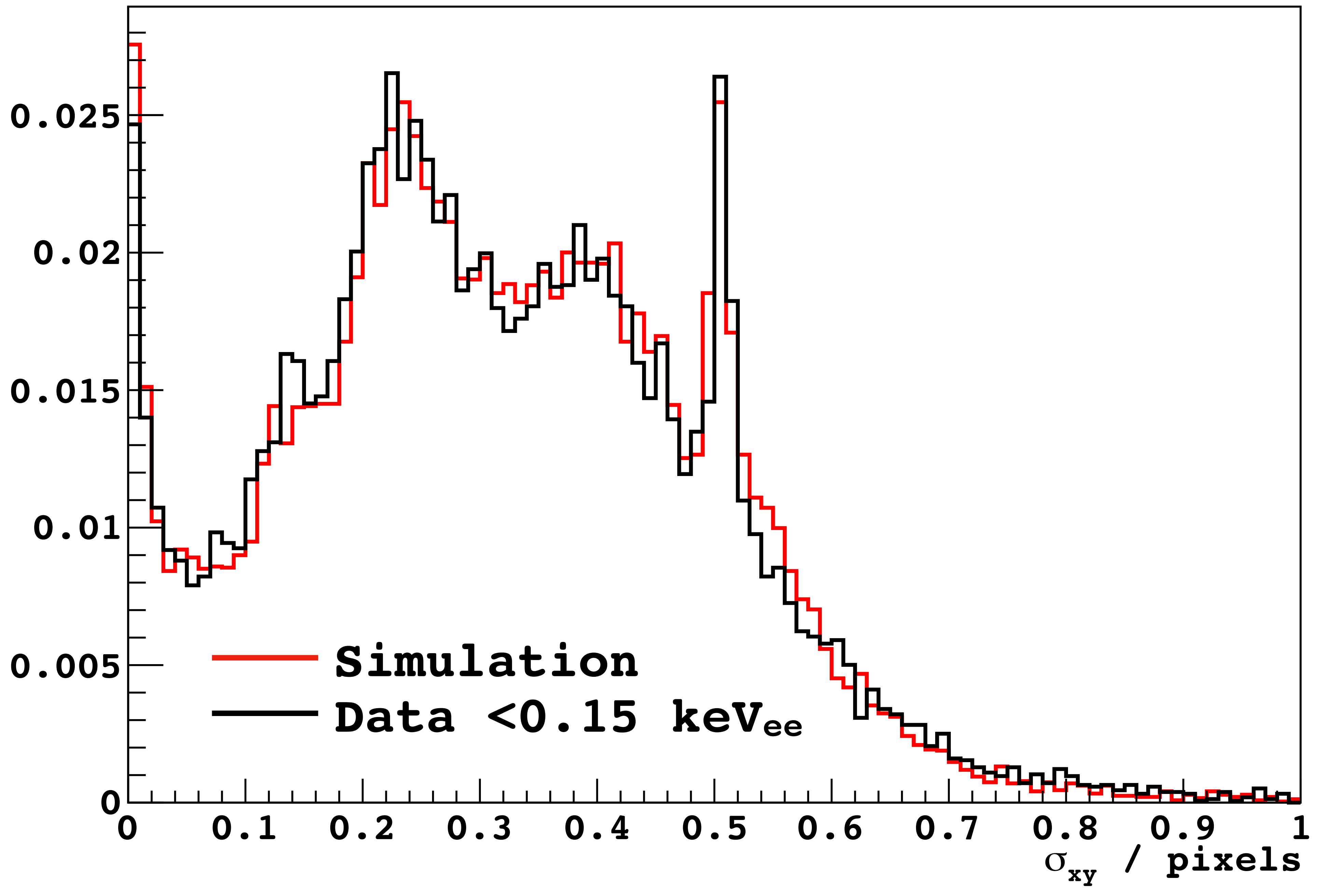
- Precision measurement with a skipper CCD improved energy resolution and decreasing threshold to 23 eV_{ee}: **PRD106(2022)092001**
- Confirmed softening of the L step, observed structure in the L step.
- Detector response model is good!
- Softening reproduced with *FEFF* code, which performs full QM treatment.
- Full QM calculations may be needed to correctly describe electronic recoil spectra.

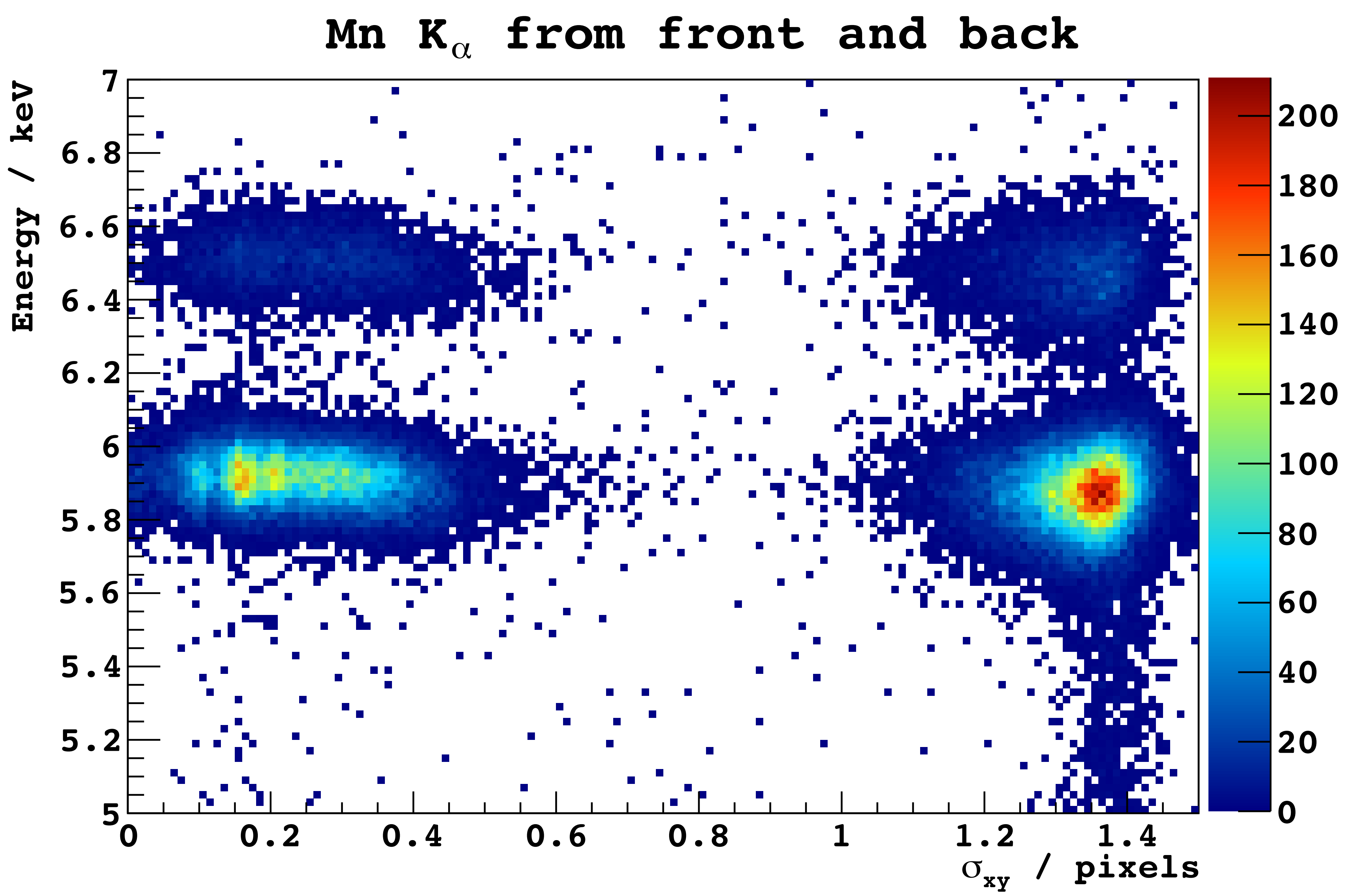


Depth response

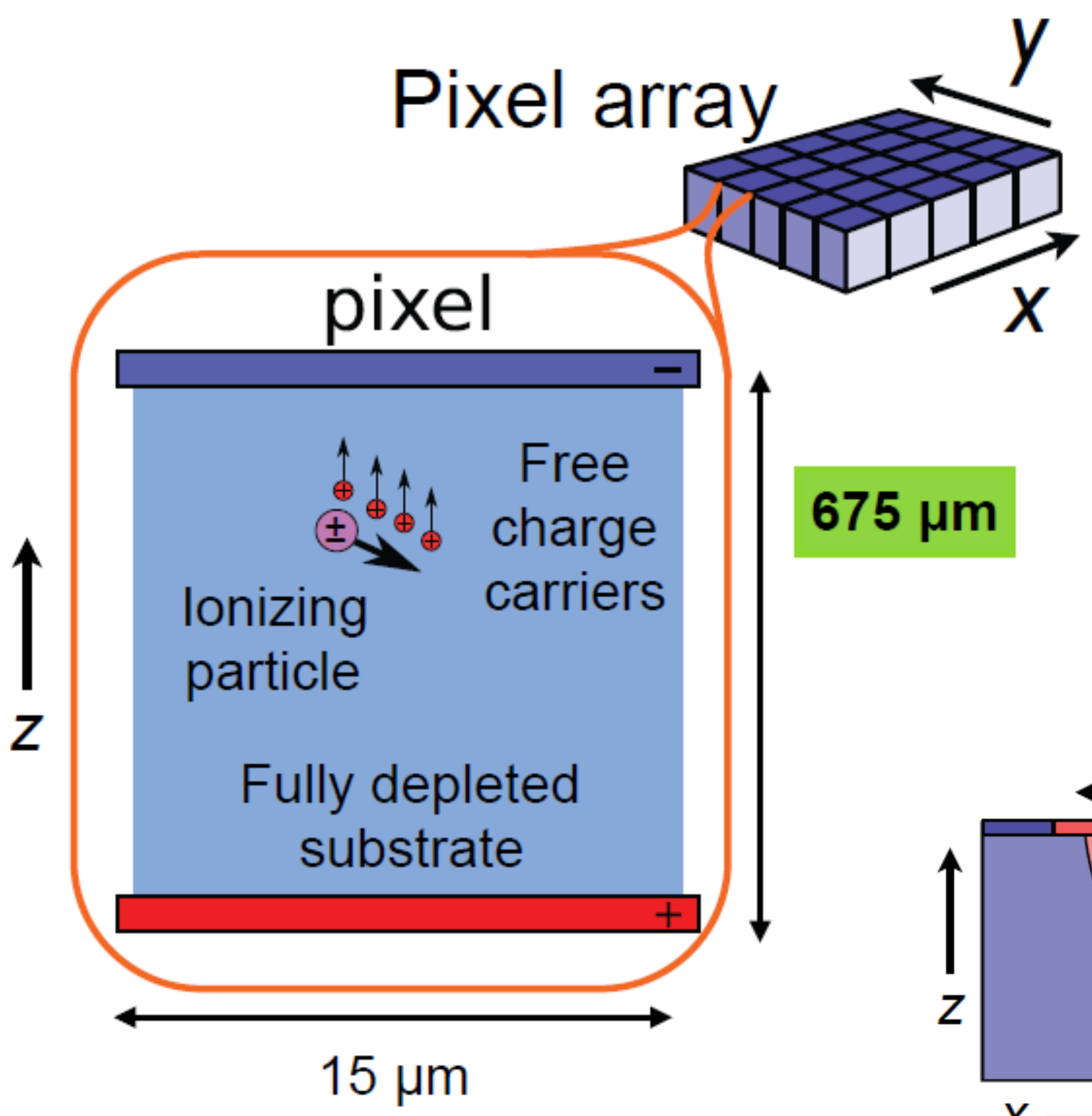
- Diffusion model calibrated with cosmic muons on the surface.
- Validated with low energy neutrons and surface X and β rays.

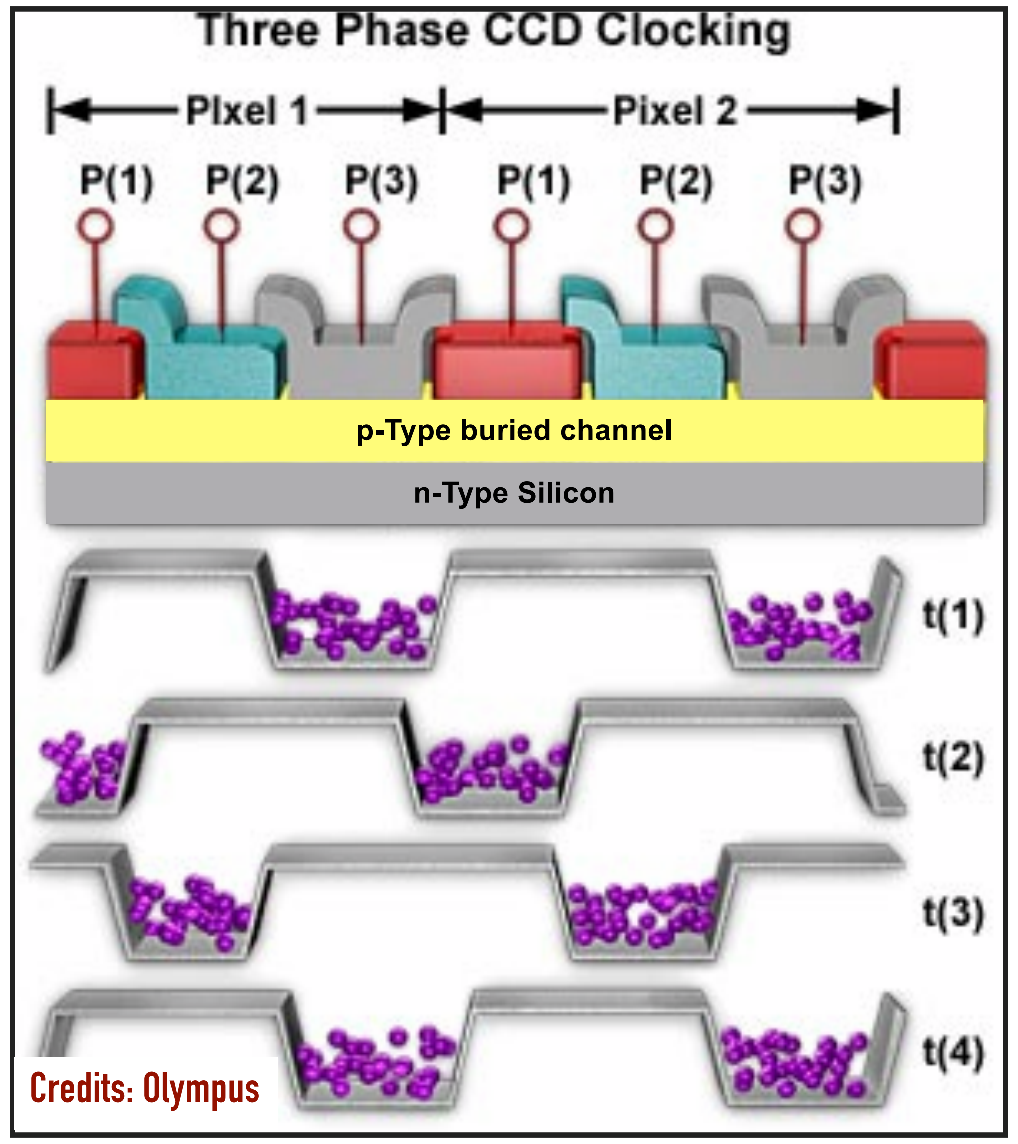


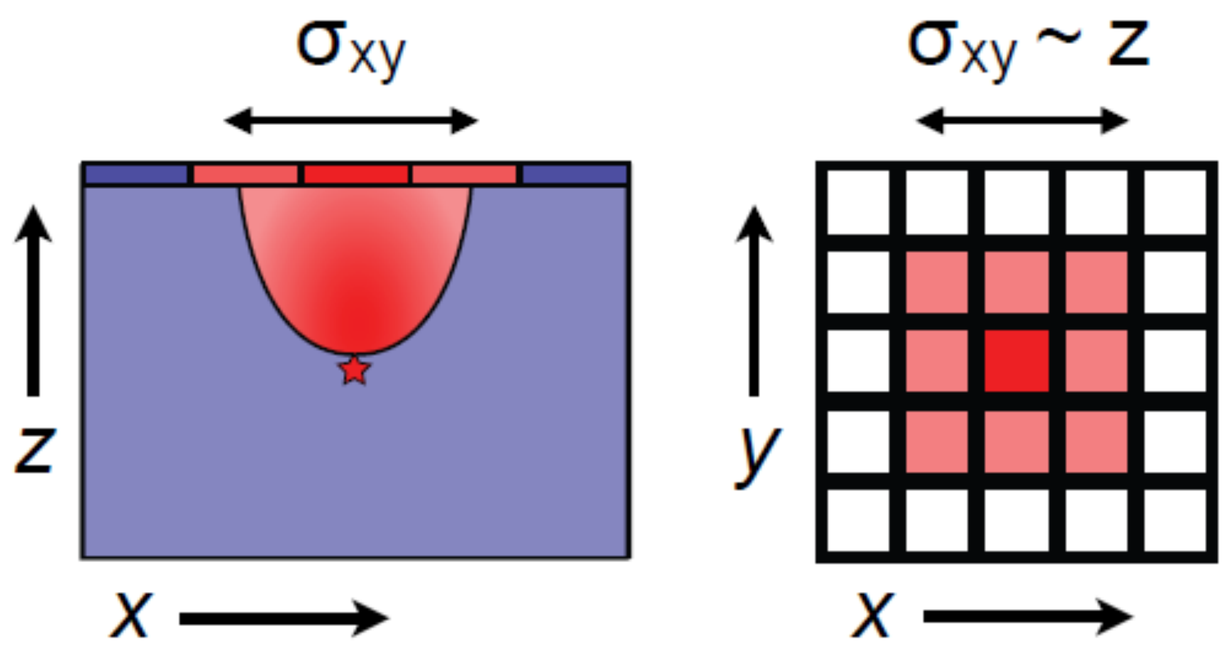




CHARGE-COUPLED DEVICES



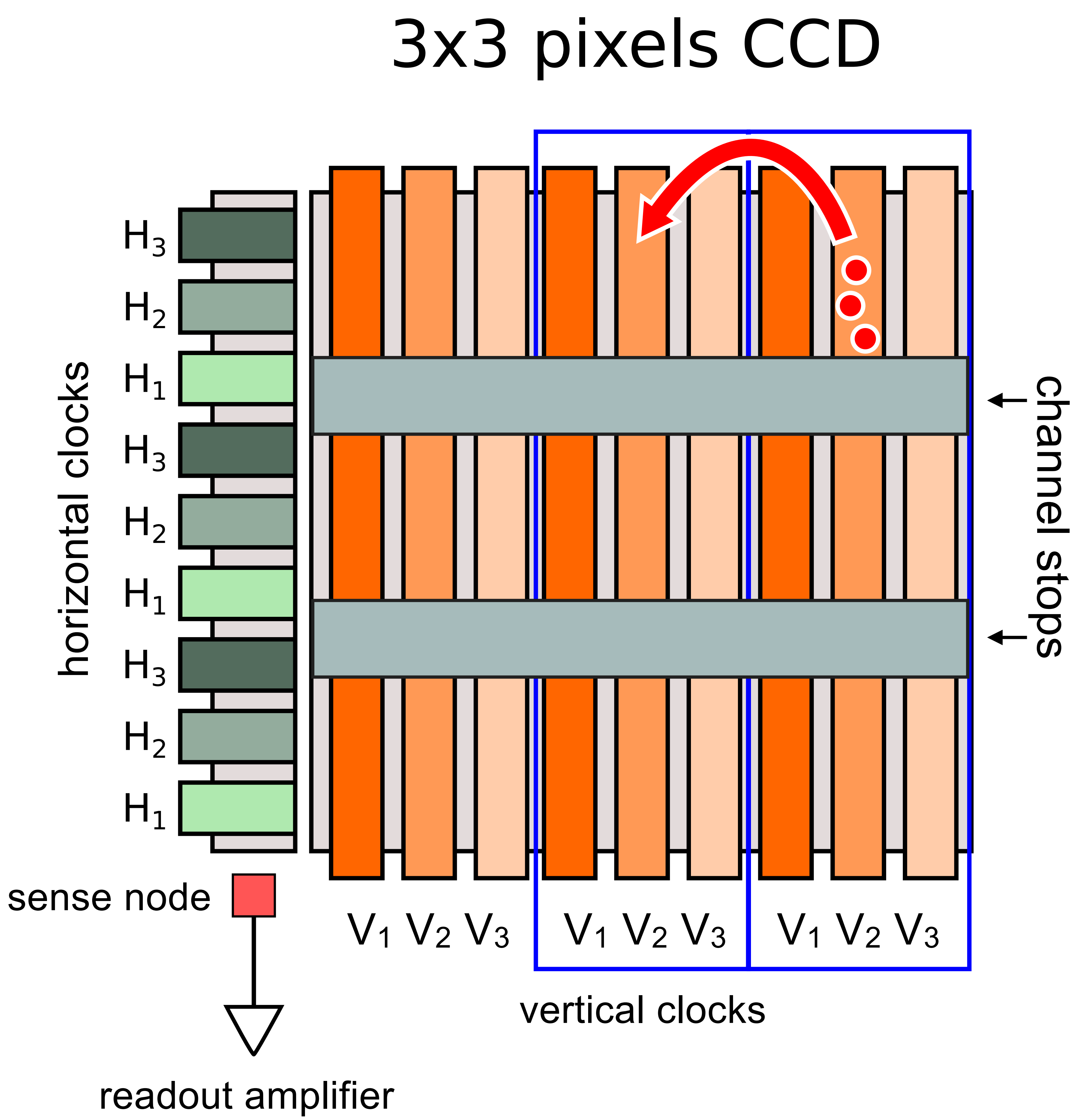




DAMIC science-grade CCDs

- PolySi gate, p-type buried channel structure
- Fully depleted at 40 V ($\sim 10\ \mathrm{k\Omega \cdot cm}$)

CHARGE-COUPLED DEVICES



Performance

- Charge transfer inefficiency $< 10^{-6}$
- Readout noise $< 2\ e^{-}$ (6 eV)
- Leakage current $\sim 10^{-4}\ e^{-}$/pix/day

BACKGROUNDs IN DAMIC

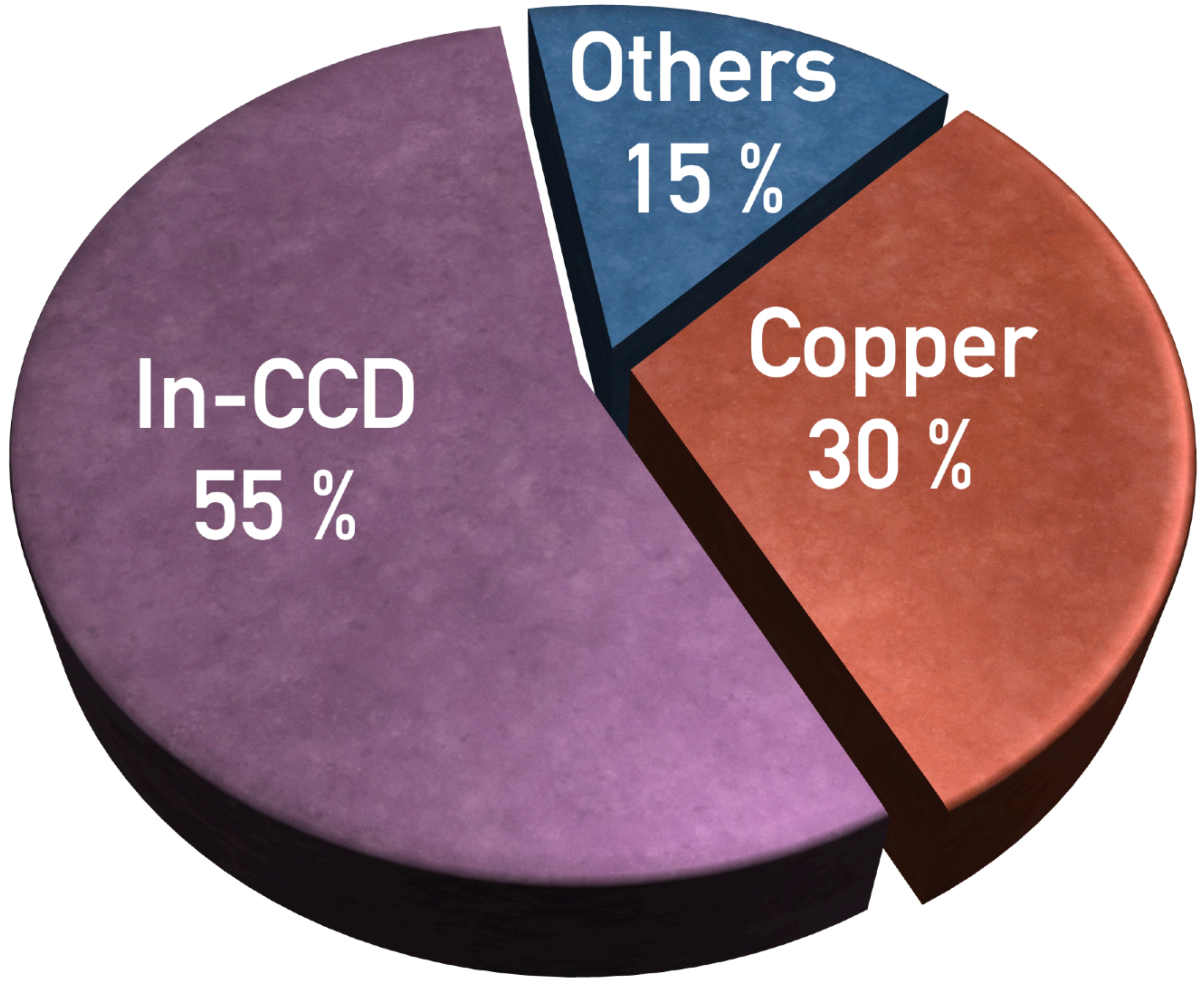
How we deal with backgrounds:

- Underground operation: ~~cosmic radiation~~
- Material selection (assays): ~~apparatus radioactivity~~
- In situ shielding: ~~environmental radioactivity~~
- Discrimination and quantification of residual contaminants $\Longrightarrow$ radioactive background model

Background contributions:

- $\sim 55\,\%$ in-CCD contaminants
- $\sim 30\,\%$ OFHC copper
- $\sim 15\,\%$ from various detector materials (lead, flex cables, etc.)

~ 12 **dru**



$1\ \mathbf{dru} = 1\ \mathbf{event} \cdot (\mathbf{keV} \cdot \mathbf{kg} \cdot \mathbf{d})^{-1}$

Sample CCD image (~15 min exposure) portion in the surface lab.

Image courtesy of Prof. A. Chavarria

DAMIC AT MODANE (DAMIC-M)

CENPA
Center for Experimental Nuclear Physics and Astrophysics
UNIVERSITY of WASHINGTON

Experiment will be deployed at Modane Underground Laboratory (LSM), France.

Main novelties:

- kg-scale detector (~ 200 CCDs)
- Skipper readout: sub-electron resolution $\sim 0.1\ e^-$
- $\sim 100\times$ lower backgrounds: 10 dru $\rightarrow \mathcal{O}(0.1)$ dru

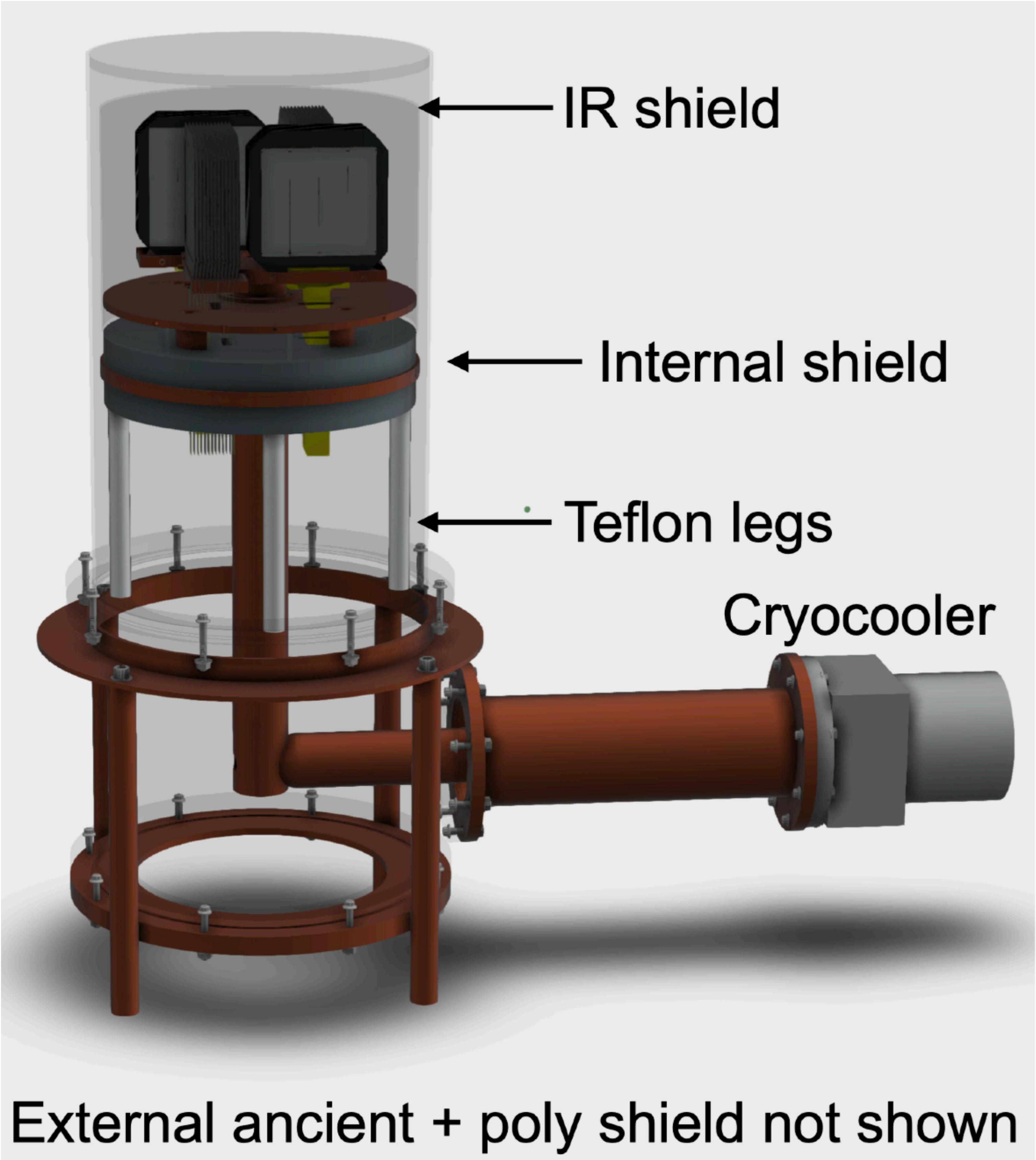
Status:

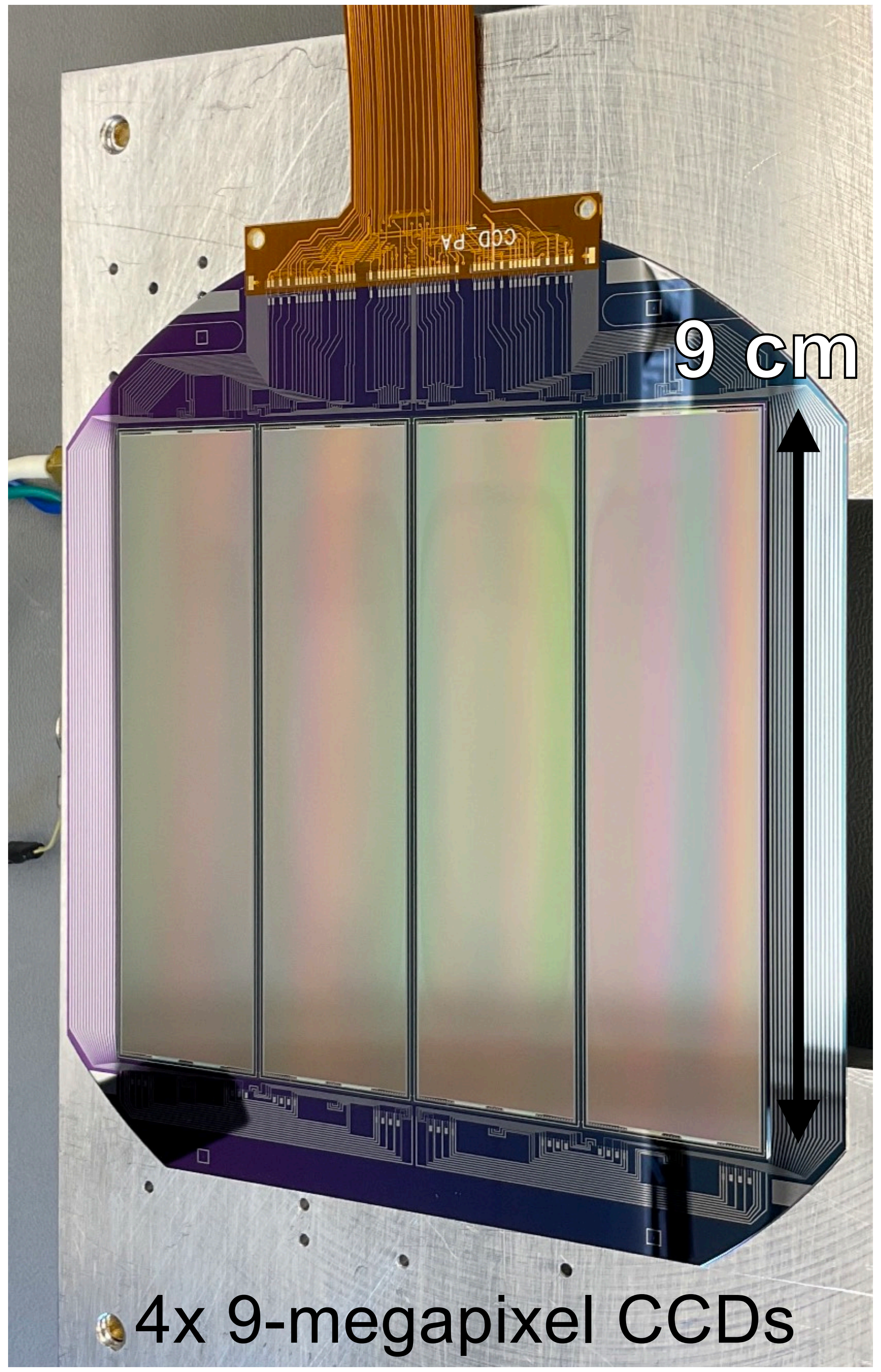
- LBC prototype detector up and running. First DAMIC-M science results published recently

Phys. Rev. Lett. **130**, 171003

- Construction starting in 2024

Nucl.Instrum.Meth.A 958 (2020) 162933





DAMIC-M CCD module packaged at UW