Results on Low-Mass WIMPs from a 11 kg d Target Exposure of DAMIC at SNOLAB

International Cosmic Ray Conference 2021

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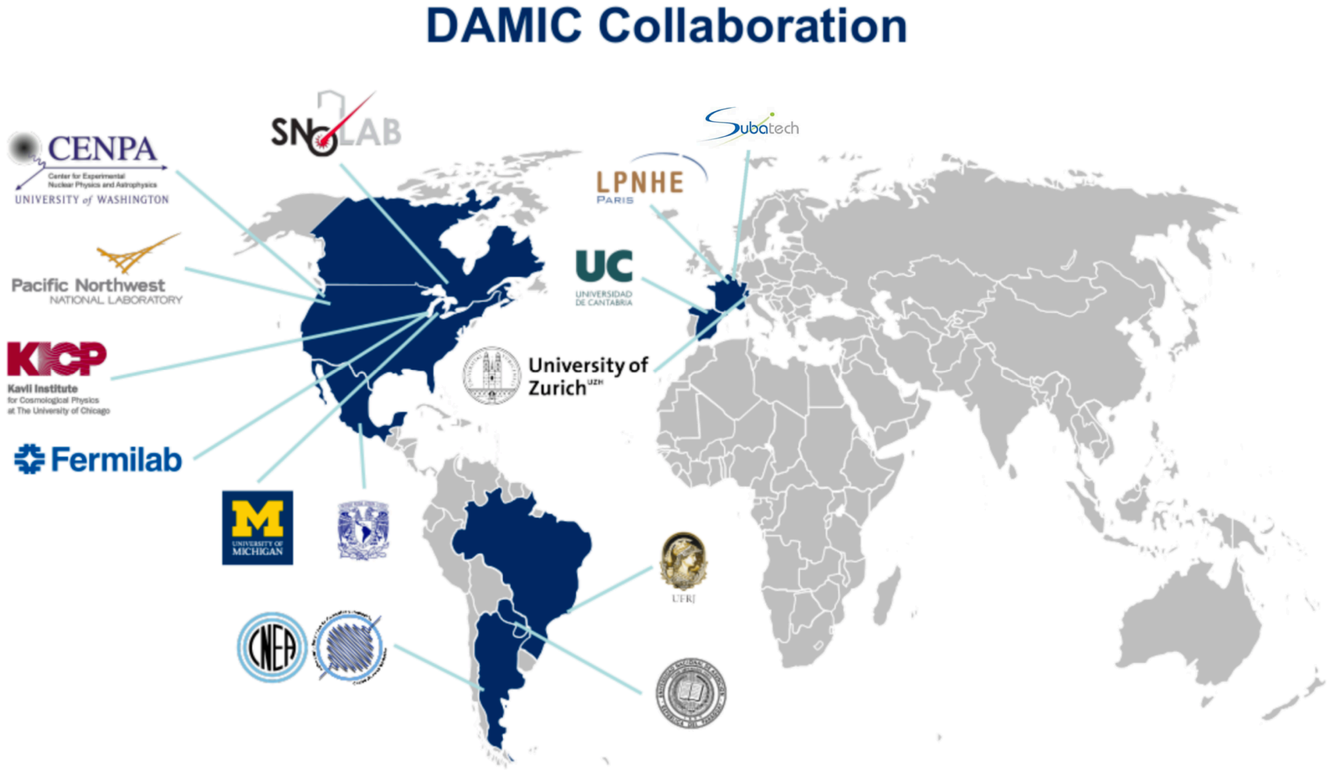
Outline:

1. DAMIC at SNOLAB
2. Background Rejection
3. Background Model
4. WIMP Search
5. Future Plans



DAMIC AT SNOLAB

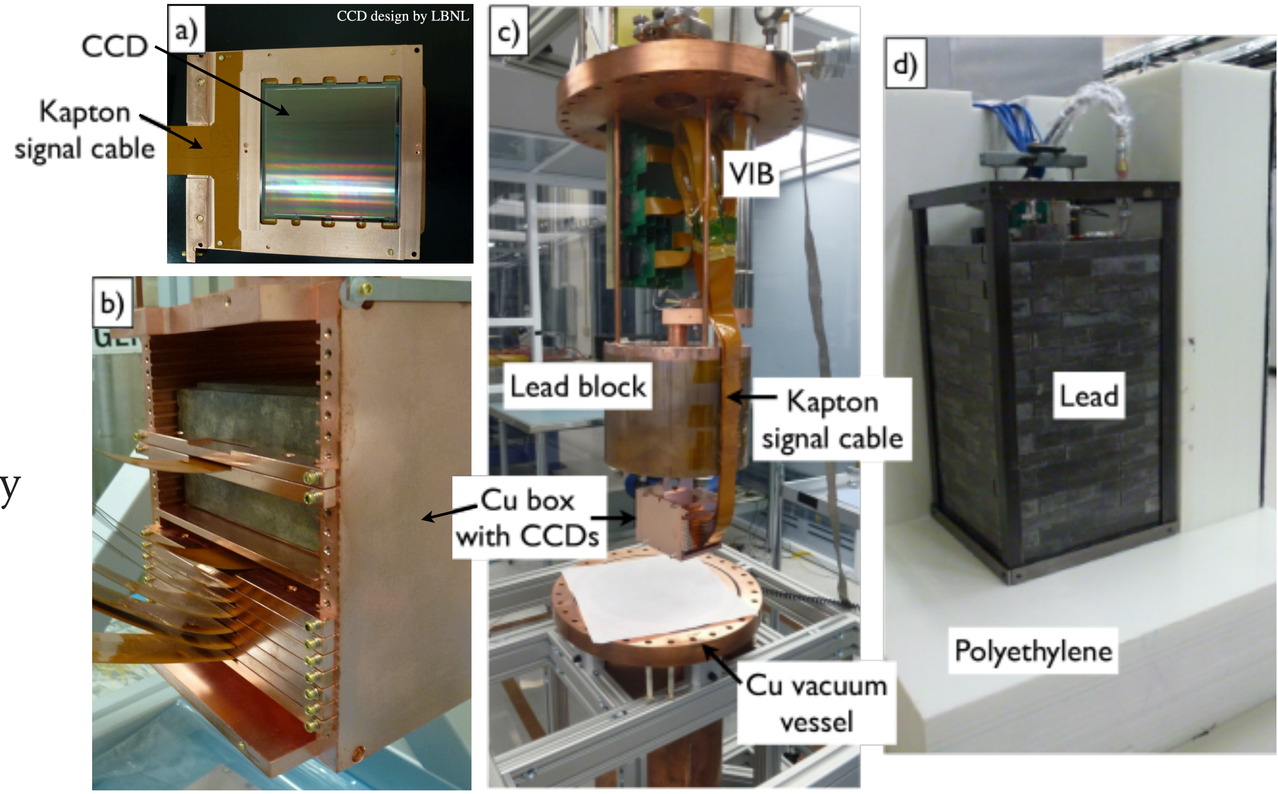
- **DArk Matter In CCDs** collaboration (since 2011)
- Setup beneath 2 km of granite **at SNOLAB** (Canada)
  (6 km water equivalent)

Charge-Coupled Devices

- Extremely low noise and dark current ⇒ sensitive to ~e^-
- 3D track reconstruction and particle discrimination capability

...for Dark Matter?

- Record thickness + several CCDs ⇒ massive target (~40 g)
  675 μm 7 operational
- Different DM search options:
  - WIMP-nucleus coherent scattering
  - Hidden sector light DM-e^- interactions



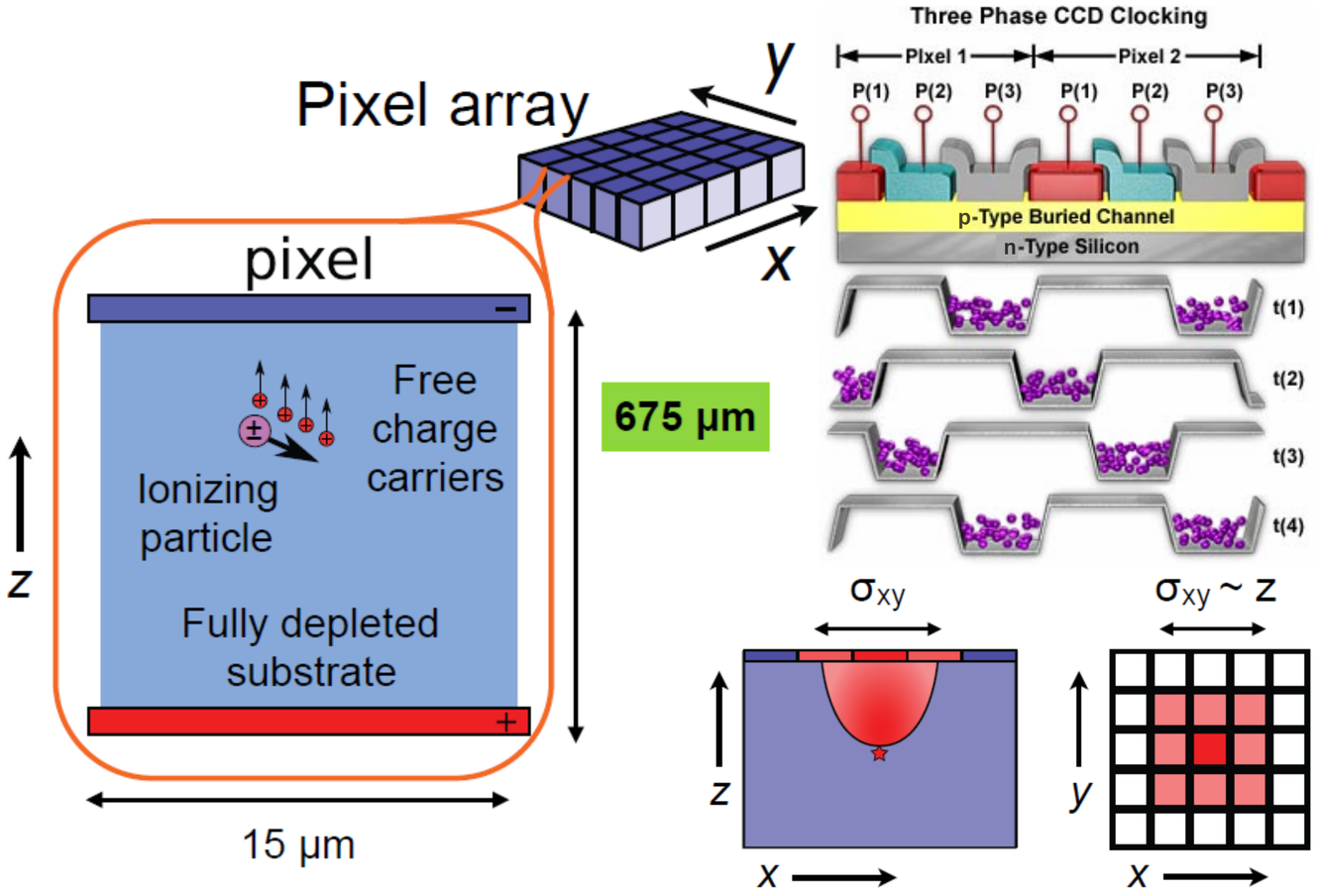
a) Packaged DAMIC CCD

b) Copper CCD housing

c) In-vacuum setup

d) Pb and polyethylene outer shielding

CHARGE-COUPLED DEVICES



DAMIC science-grade CCDs:

- PolySi gate, buried channel structure
- Fully depleted (40 V substrate)
- High resistivity ~ 10 kΩ·cm
- Record thickness: 675 μm

Performance:

- Charge transfer inefficiency < 10^{-6}
- Readout noise ~1.6 e- (6 eV)
- Dark current < 10^{-3} e^-/pix/day

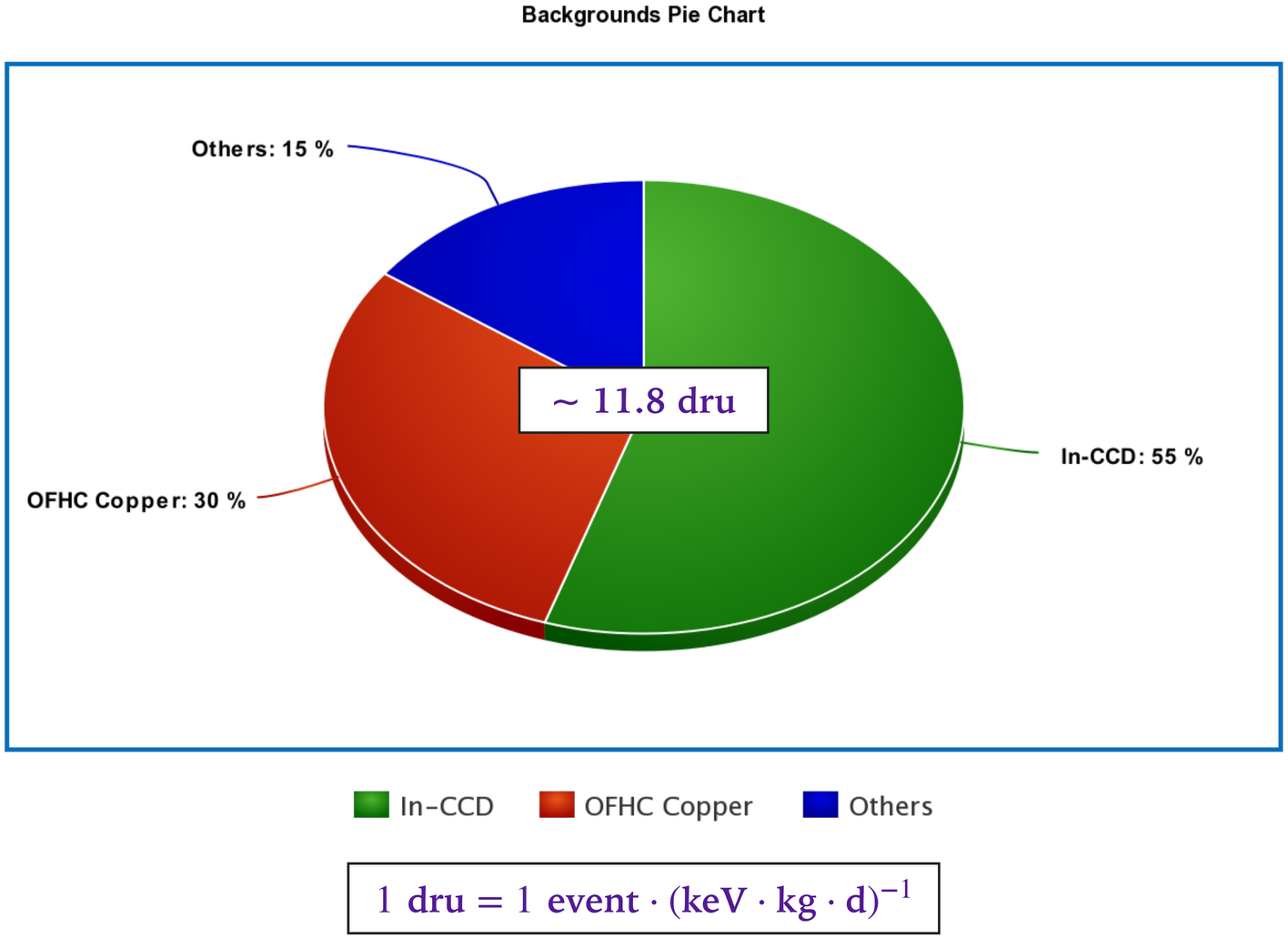
BACKGROUNDS AT DAMIC

How we deal with backgrounds:

- Underground operation
- Material selection (assays)
- In situ shielding
- Discrimination and quantification of contaminants → bkg model

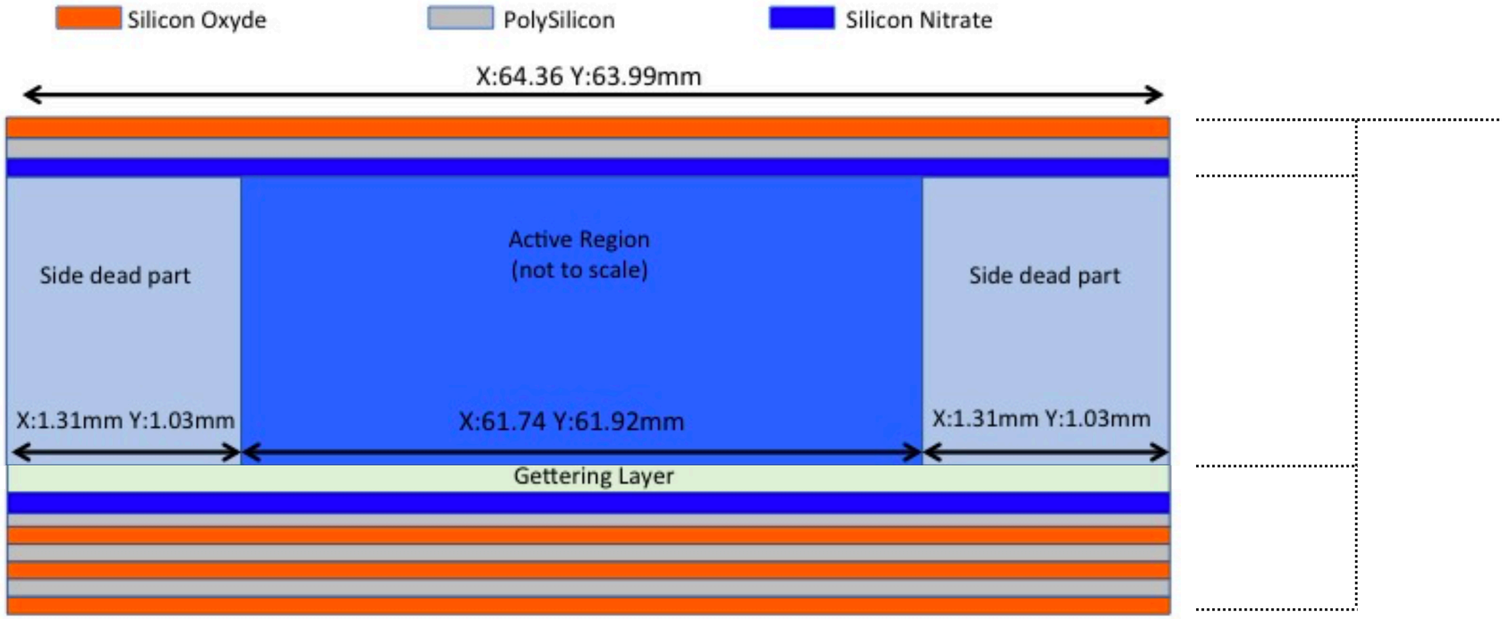
Background contributions:

- ~ 55% in-CCD contaminants
- ~ 30% OFHC Copper
- ~ 15% from various detector materials (lead shielding, flex cables, etc.)



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

SPATIAL COINCIDENCE ANALYSIS



Main Surface Contaminants

Decay Sequence	$t_{1/2}$	Q-value
$^{210}\mathrm{Pb} \longrightarrow {}^{210}\mathrm{Bi} + \beta^- + \mathrm{IC}/\gamma$	22.3 y	63.5 keV
$^{210}\mathrm{Bi} \longrightarrow {}^{210}\mathrm{Po} + \beta^-$	5.01 d	1.16 MeV

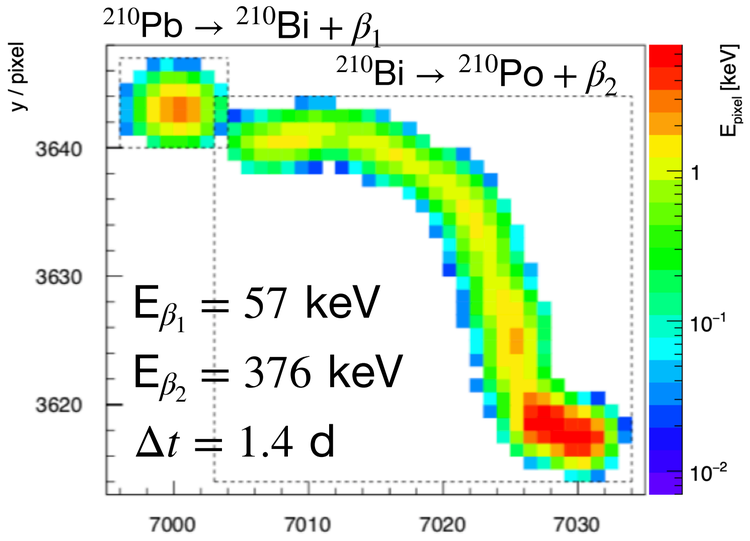
deposition

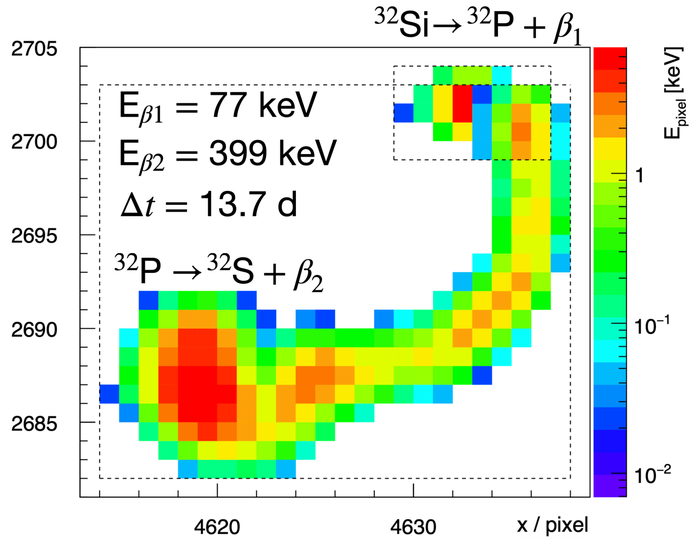
Main Bulk Contaminants

Decay Sequence	$t_{1/2}$	Q-value
$^{32}\mathrm{Si} \longrightarrow {}^{32}\mathrm{P} + \beta^-$	150 y	225 keV
$^{32}\mathrm{P} \longrightarrow {}^{32}\mathrm{S}\,(\mathrm{stable}) + \beta^-$	14.3 d	1.71 MeV

Decay	$t_{1/2}$	Q-value
$^{3}\mathrm{H} \longrightarrow {}^{3}\mathrm{He} + \beta^-$	12.3 y	18.6 keV

CCD activation





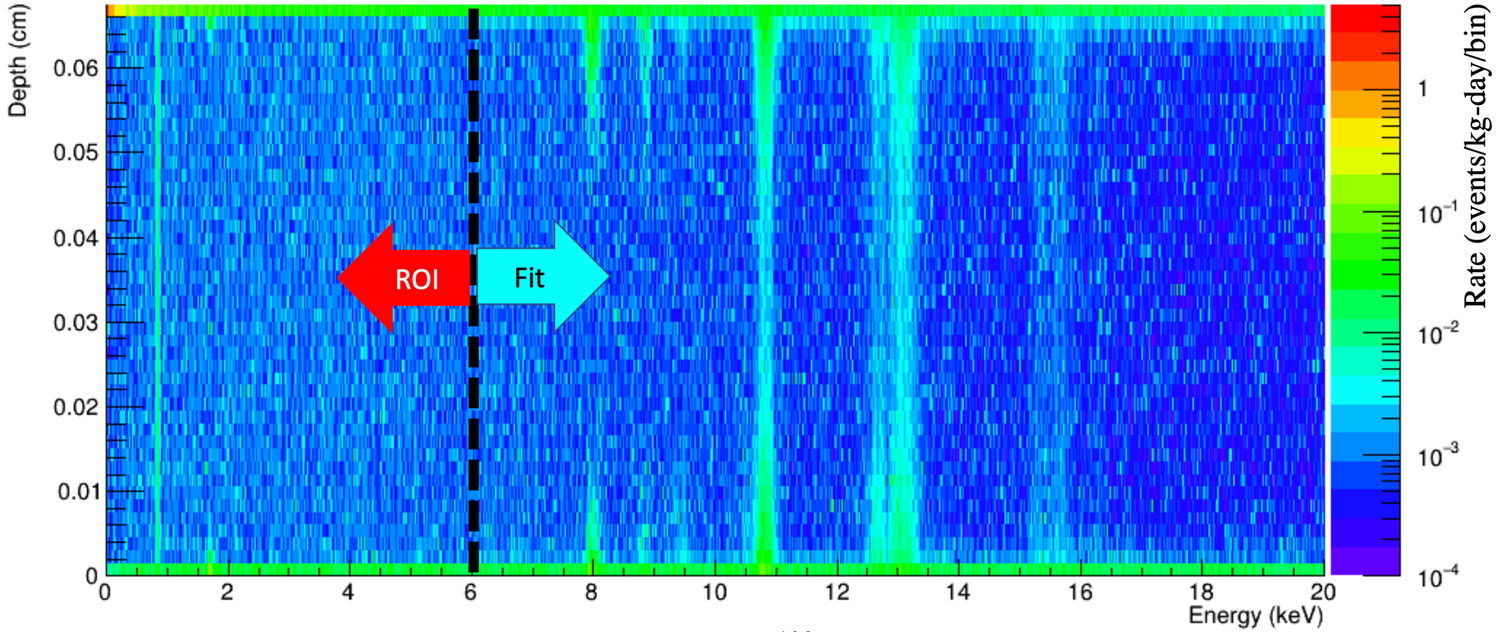
Limits on radioactive contaminants:

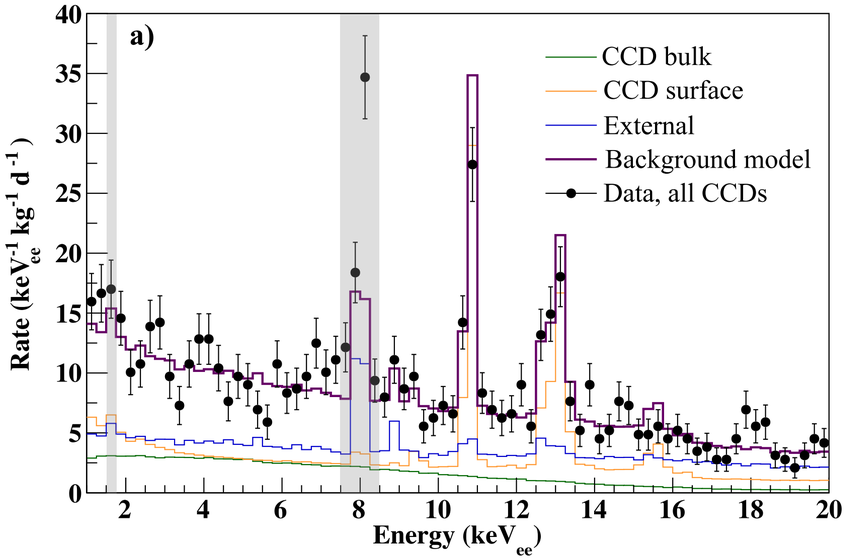
- ^{210}Pb: < 160 μBq/kg
- ^{32}Si: 140±30 μBq/kg
- ^{238}U: < 11 μBq/kg
- ^{232}Th: < 7.3 μBq/kg

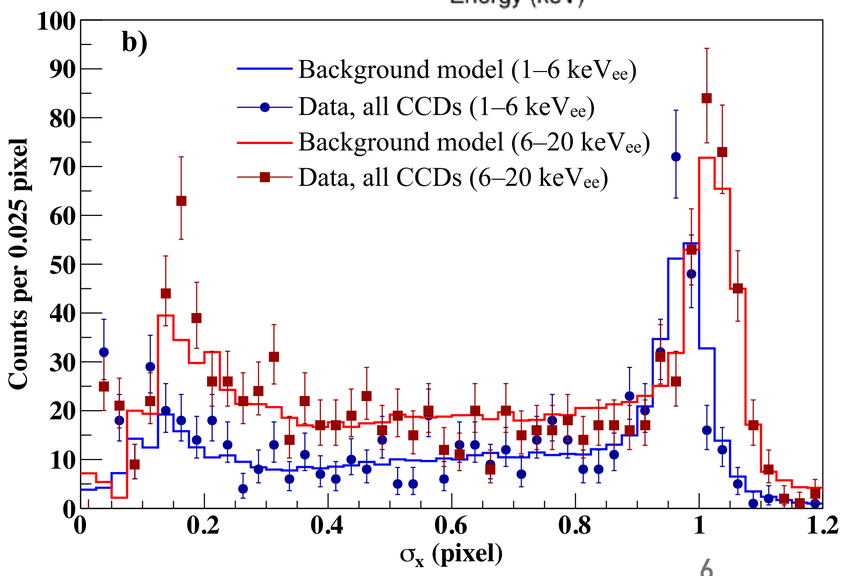
BACKGROUND MODELING

Background model construction:

- **Decay+tracking** across detector geometry with Geant4
- **CCDs response simulation**: charge generation and (partial) collection/transport, pixelation, binning and readout noise
- **Clustering** → **E,σ_x** distribution
- Binned **likelihood fit** in WIMP-safe region (6-20 keV) ⟹ extrapolate in ROI (0-6 keV)

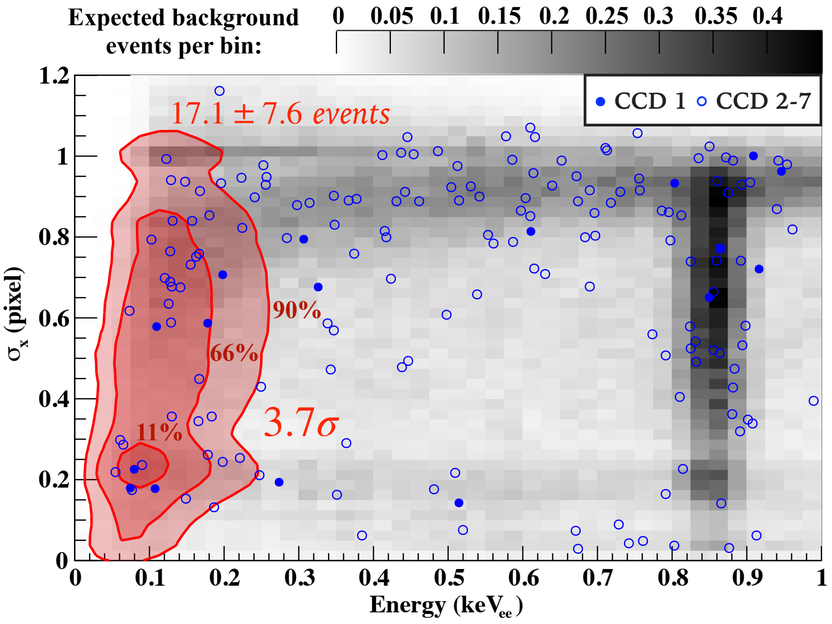


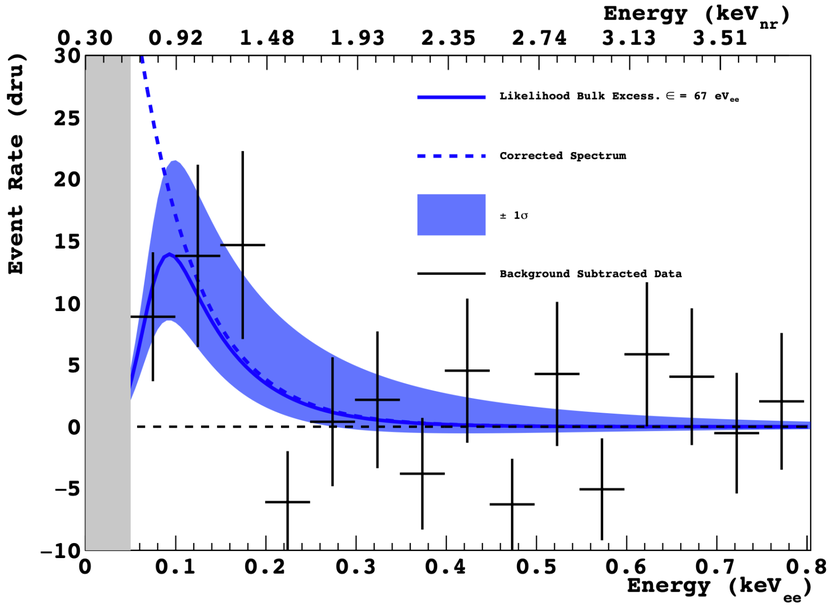


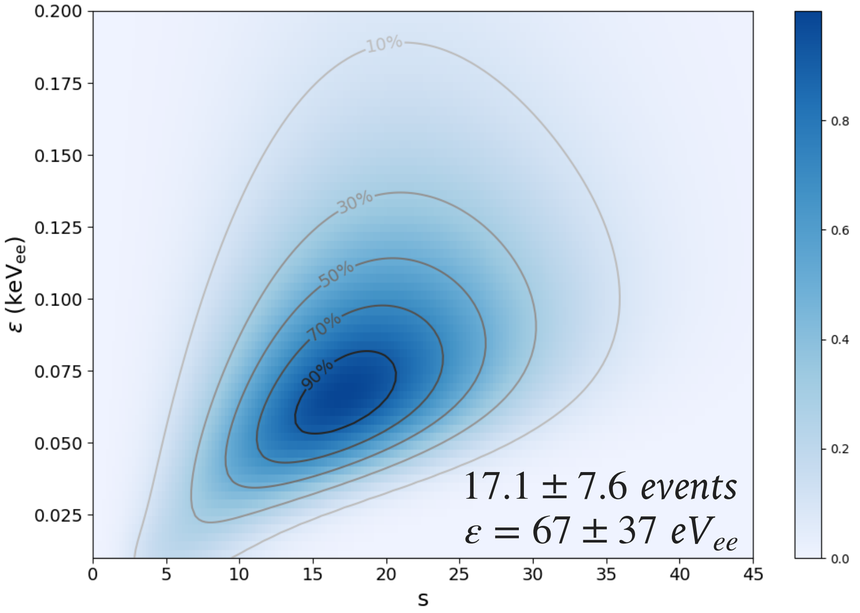


→ Profile likelihood ratio search

WIMP SEARCH







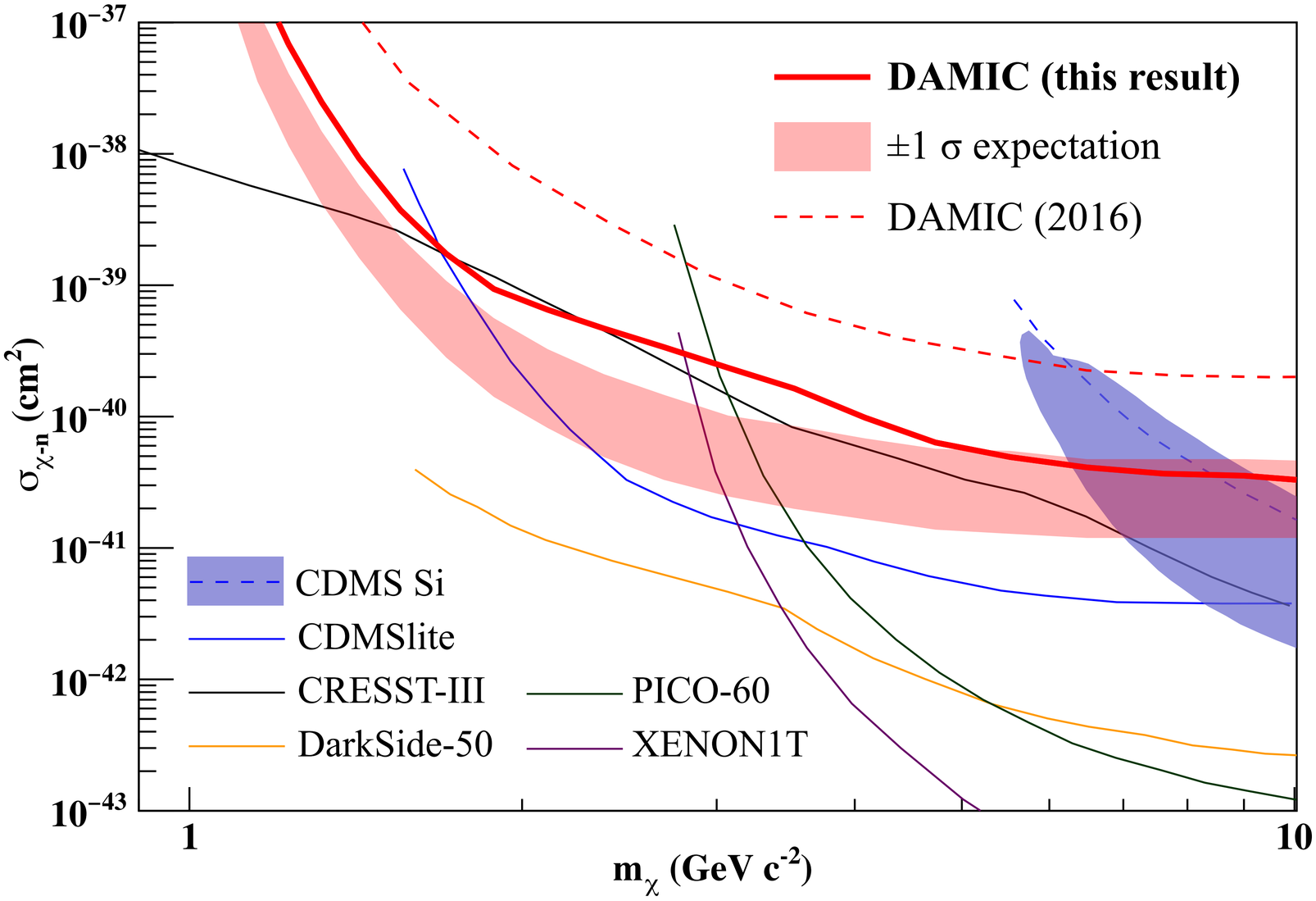
Possible Interpretations of the Excess

- Missing front component in bkg model
- Unaccounted detector front-side effect
- New physics (e.g., dark matter?)

Systematic Checks

- Front- and back-surface events assessment
- Likelihood fit with known input parameters
- Parallel Markov Chain MC analysis
- Local vs Global significance tests

WIMP SEARCH LIMITS



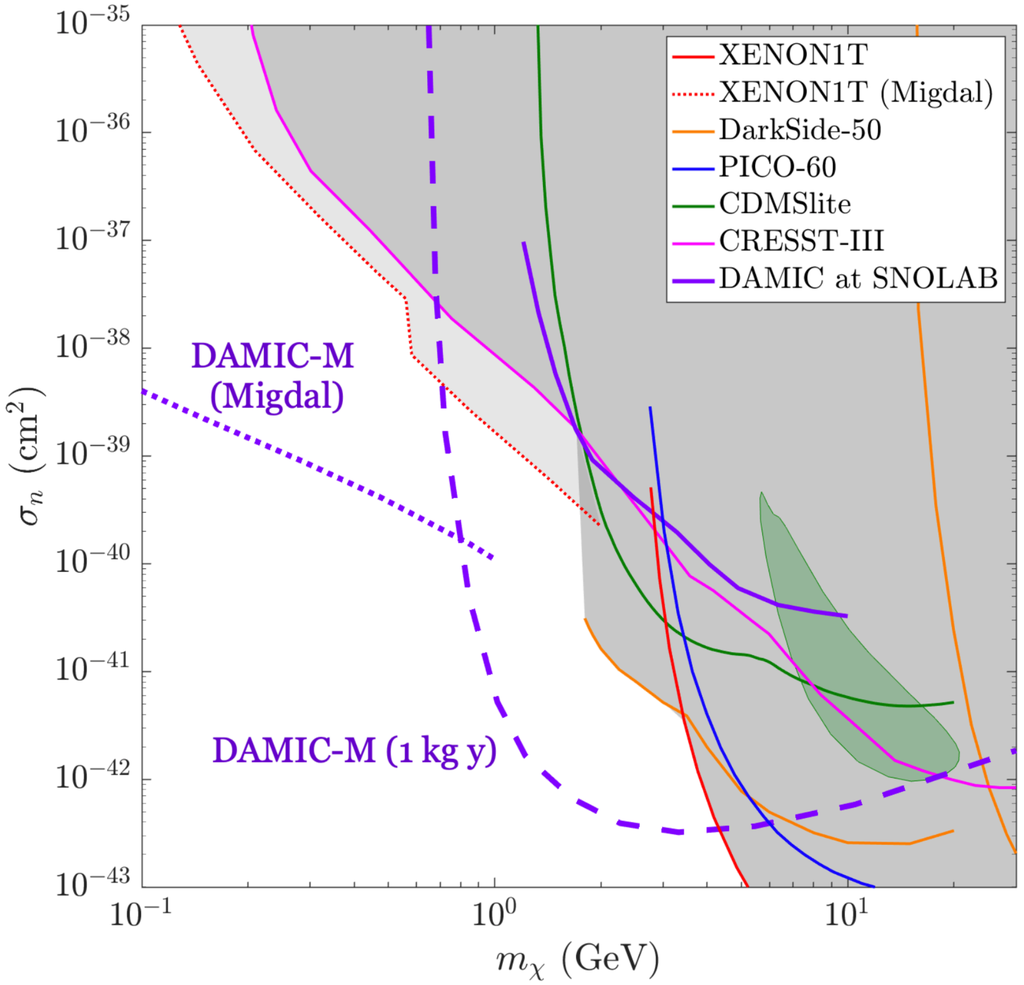
SUMMARY & FUTURE PLANS

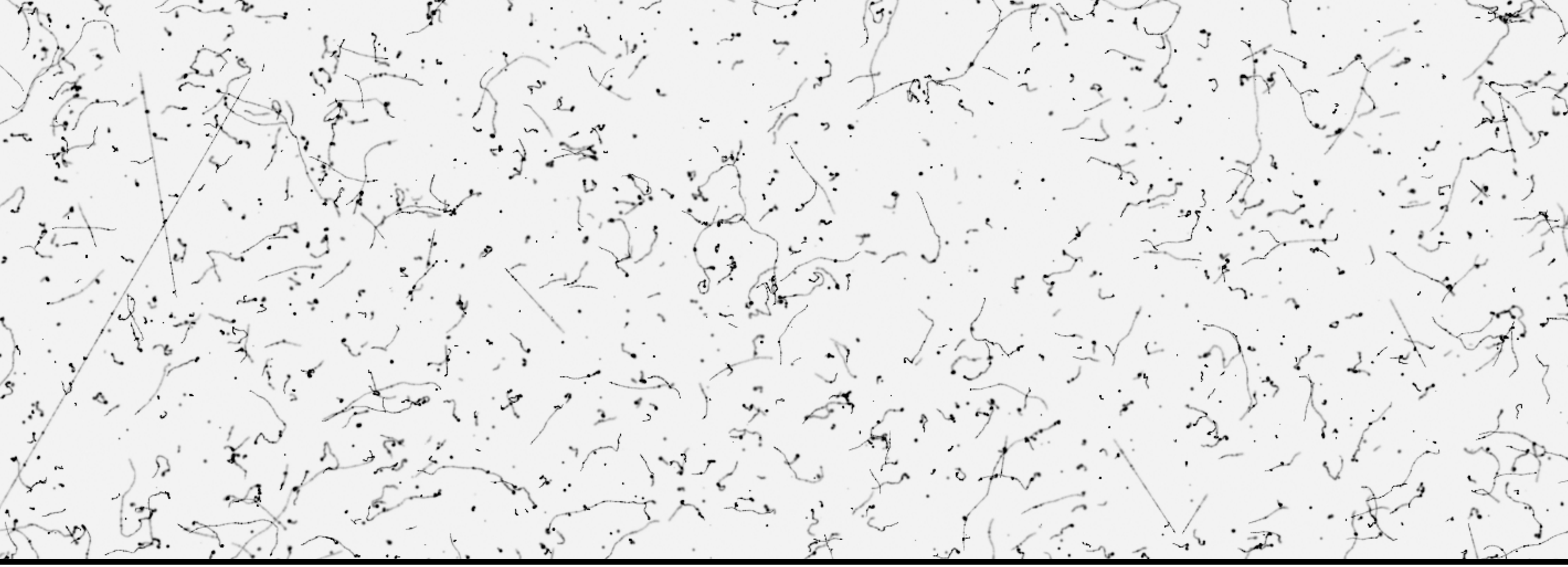
DAMIC at SNOLAB:

- WIMP Search paper published on PRL: Phys. Rev. Lett. **125**, 241803 arXiv:2007.15622
- Spatial coincidence analysis paper published on JINST: *JINST* 16 (2021) 06, P06019 arXiv:2011.12922
- Paper detailing background model construction in the making
- Upcoming setup upgrade to investigate excess: two DAMIC-M 6k×4k and four SENSEI 1k×6k skipper CCDs arXiv:2001.01476 arXiv:1706.00028

DAMIC at Modane:

- Kg-scale skipper CCD detector striving for 0.1 dru background rates
  - See ICRC contribution by Claudia De Dominicis: *Simulations and background estimates for the DAMIC-M experiment*





Thanks for your attention. It was a pleasure to tell you about us!