The DAMIC-M CCD Array

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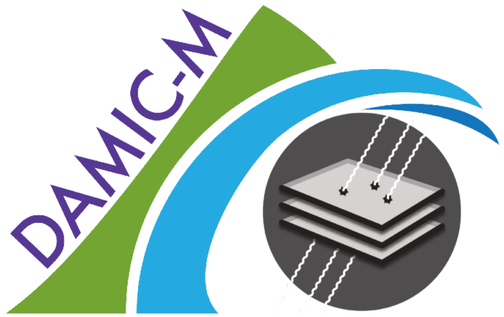
University of Washington



Outline

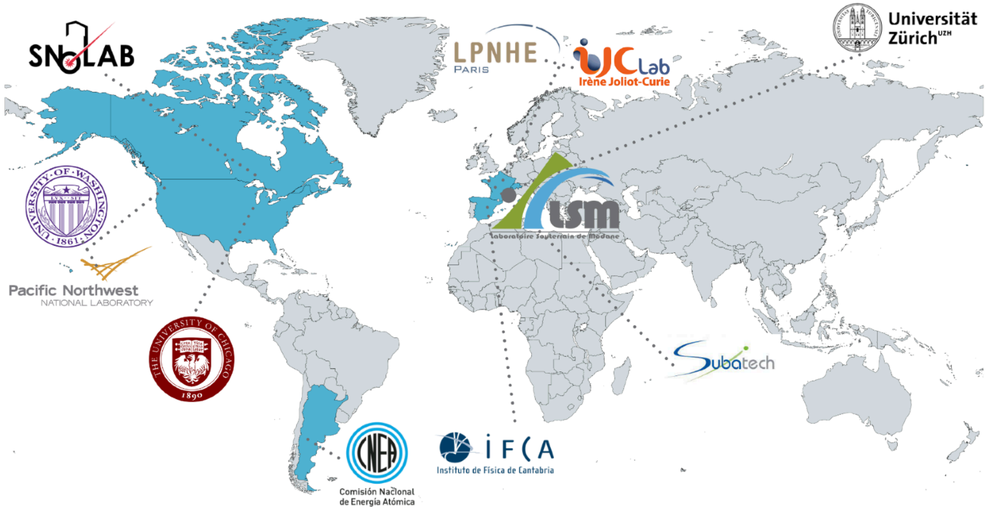
- Dark matter particles and skipper CCDs.
- DAMIC-M’s Low Background Chamber (LBC).
- DAMIC-M detector design and construction.
- Radioactive-background targets and status.

DAMIC-M

CENPA
Center for Experimental
Nuclear Physics and Astrophysics

UNIVERSITY of WASHINGTON

The DAMIC-M Collaboration



Dark matter particles

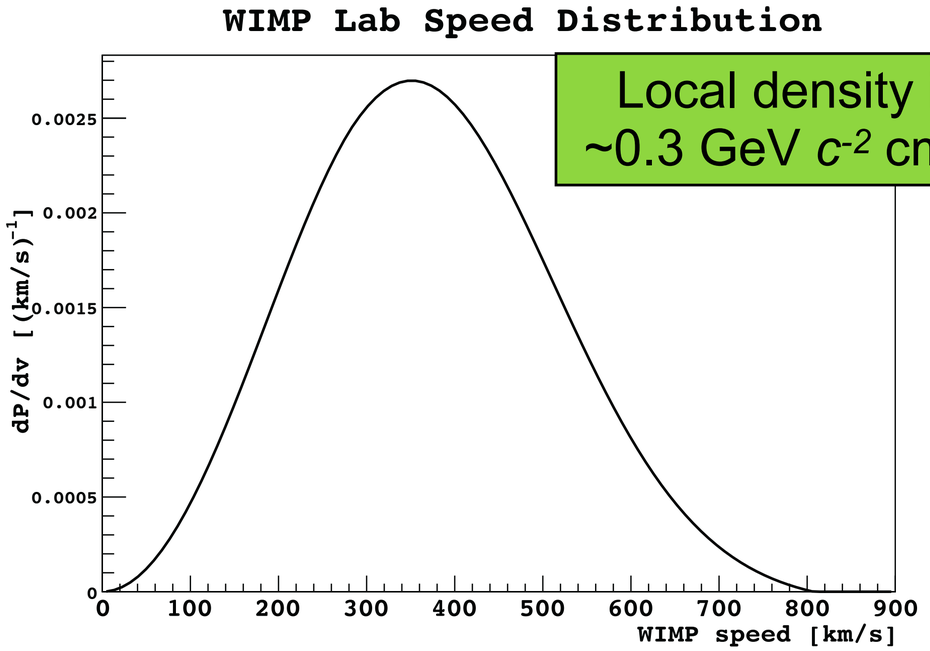
Dark matter is *cold*, i.e., it is bound to the galaxy.

Hence, the dark matter particle speed is ~the same as stars: 100s km/s.

$$E_\chi = \frac{1}{2} M_\chi v^2$$

$$E_\chi = \frac{1}{2} M_\chi c^2 \beta^2 \qquad \beta \approx 10^{-3}$$

$$E_\chi \approx \left(\frac{M_\chi c^2}{\mathrm{GeV}} \right) \mathrm{keV}$$

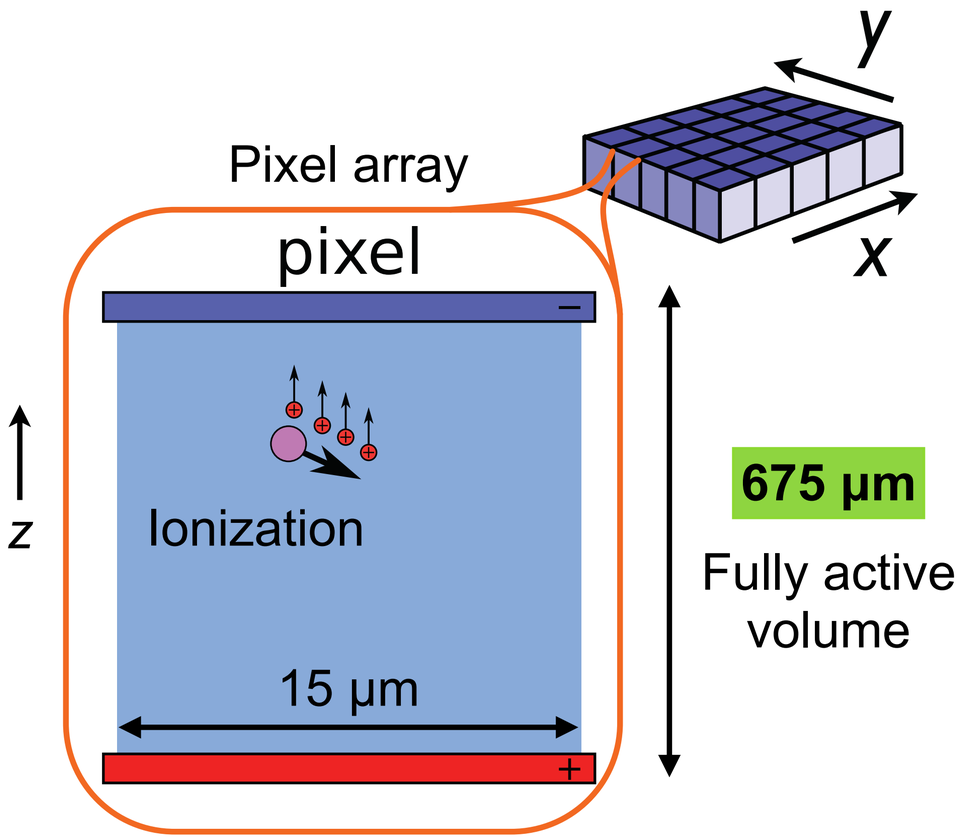


Local density is ~0.3 GeV c^{-2} cm^{-3}.

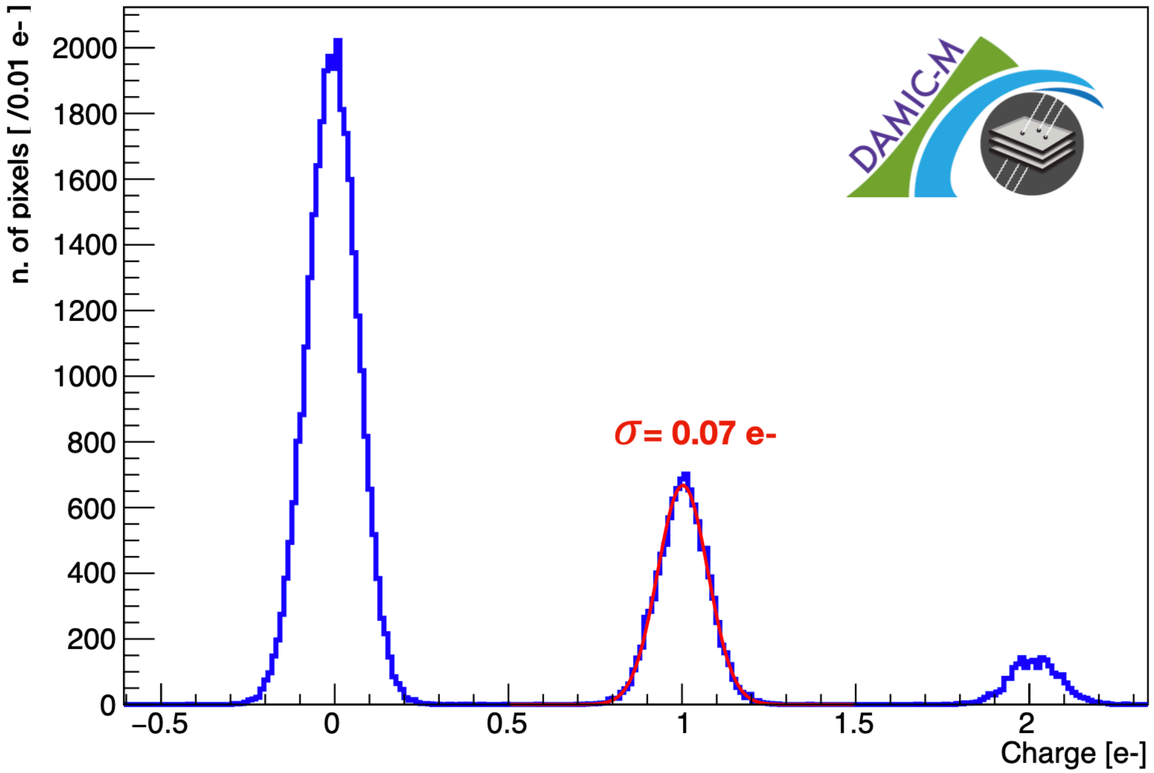
We do not know the particle mass (M_χ)

A 1 GeV (proton-mass) particle has 1 keV of kinetic energy (very little).

Skipper CCDs



Pixel charge



Silicon band-gap: 1.2 eV
Dark current: 40 e^-/gram/day

PRL134(2025)161002

Most sensitive device to the interactions between sub-GeV DM and atoms

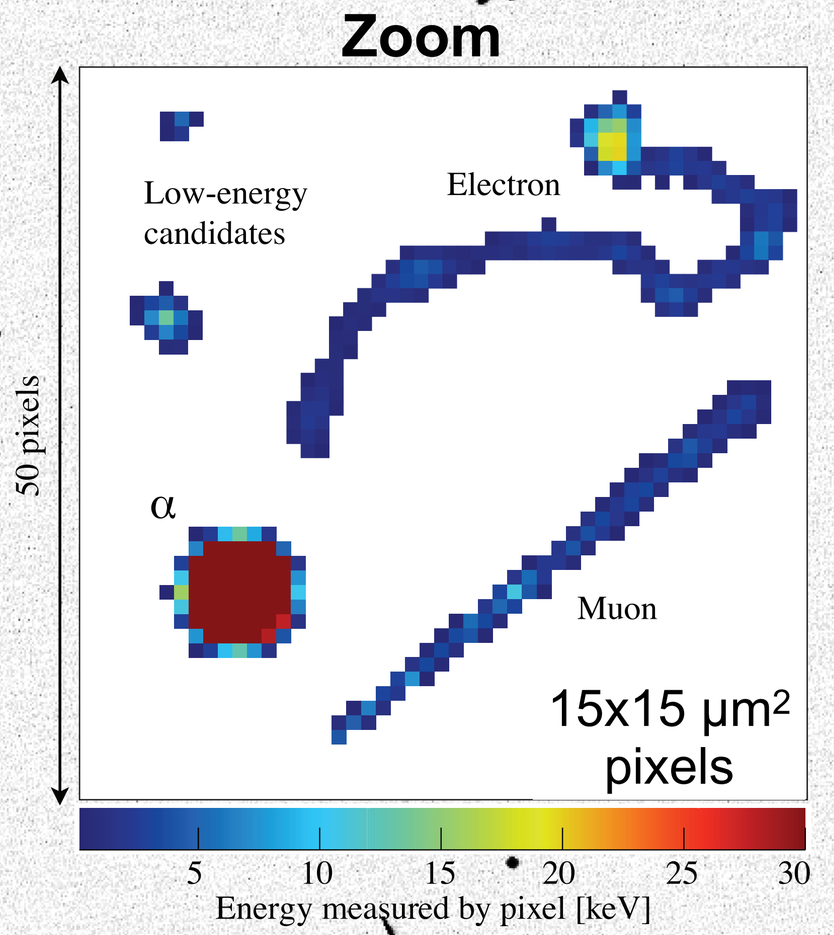
Sample CCD image (~15 min exposure) segment in the surface lab.

~1 cm

Cosmic muon

Point-like

β particle



Spatial resolution

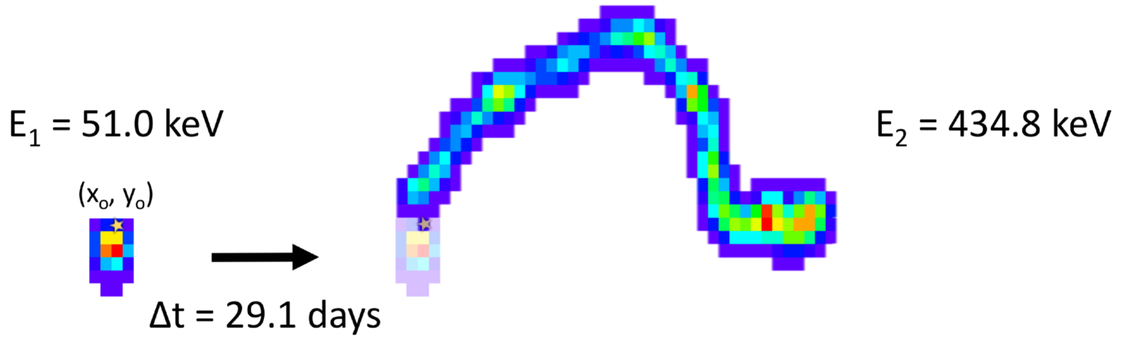
- Surface background rejection by depth (z) reconstruction, and classification (α, β, NR) by track topology (at high E>80 keV_{ee}).

- Spatial coincidence searches to identify decay sequences: JINST16(2021)P06019

- **Cosmogenic ^{32}Si:** ^{32}Si ($T_{1/2}$= 150 y, β) ➔ ^{32}P ($T_{1/2}$= 14 days, β)

  140 ± 30 μBq / kg

- Also upper limits on every β emitter in the U/Th chain.

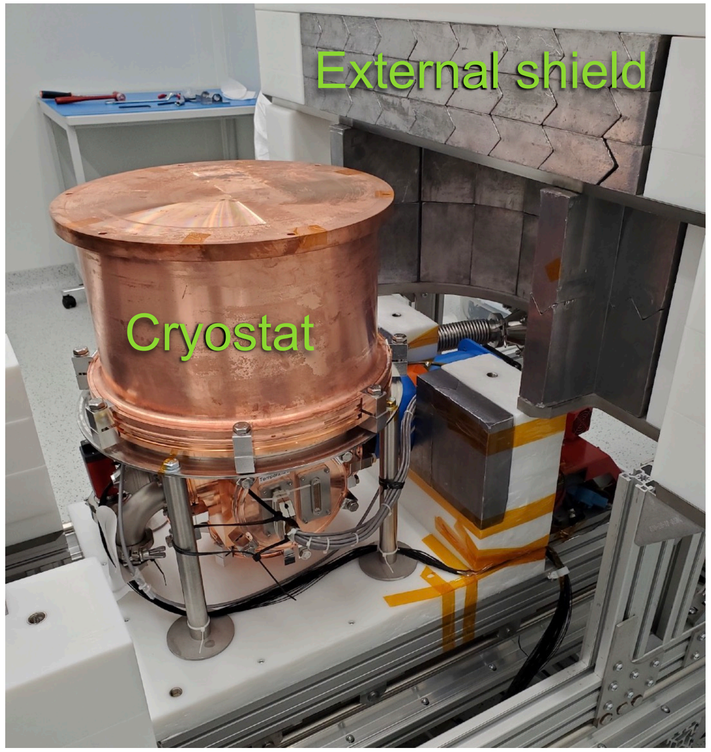


- Reject crystal defects “hot spots” that dominate device leakage current.

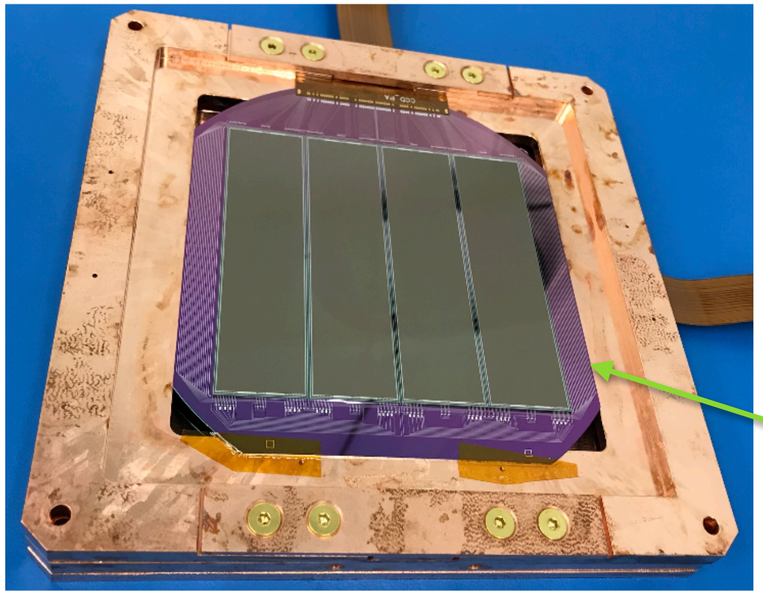
- NR identification by spatial correlation between ionization event and defect left behind in the crystal (R&D): PRD110(2024)043008

Low Background Chamber

- Low Background Chamber (LBC) test setup for DAMIC-M at LSM for performance and background studies.
- Operating in LSM clean room since 2022.
- Latest DM search from 2025, data consistent with background (mostly dark current) in 1.3 kg-day. **PRL132(2024)101006**

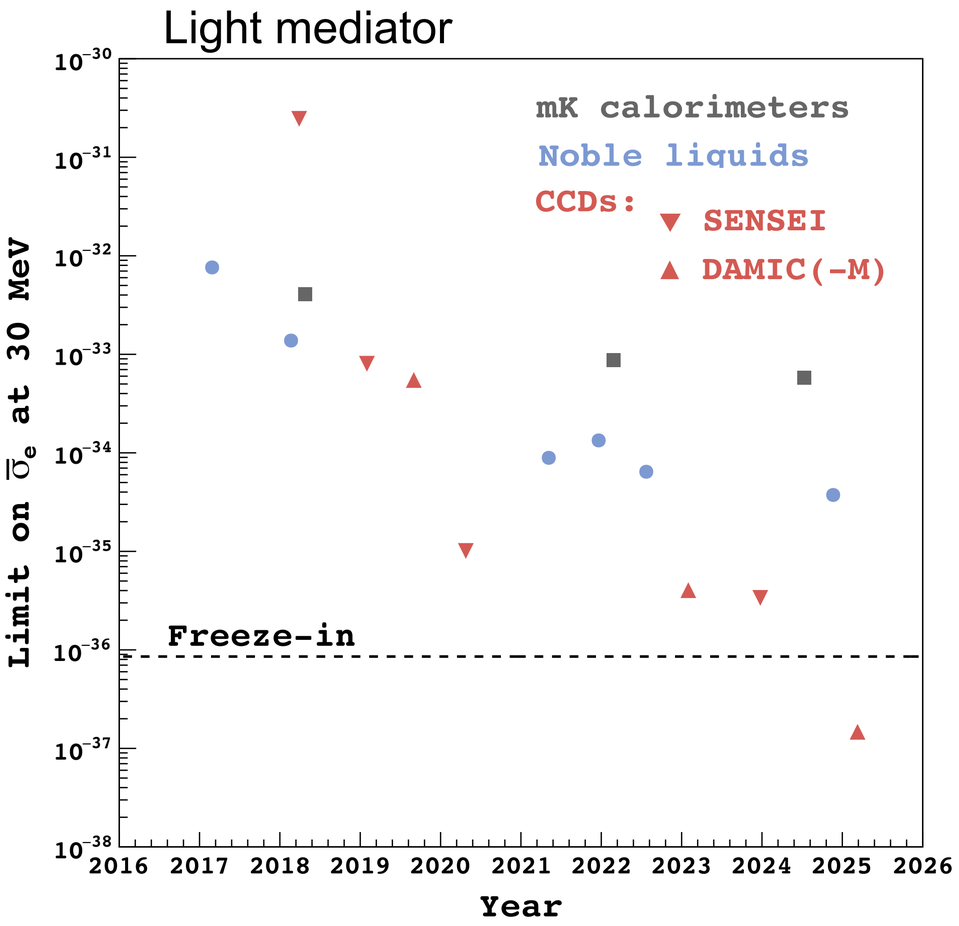


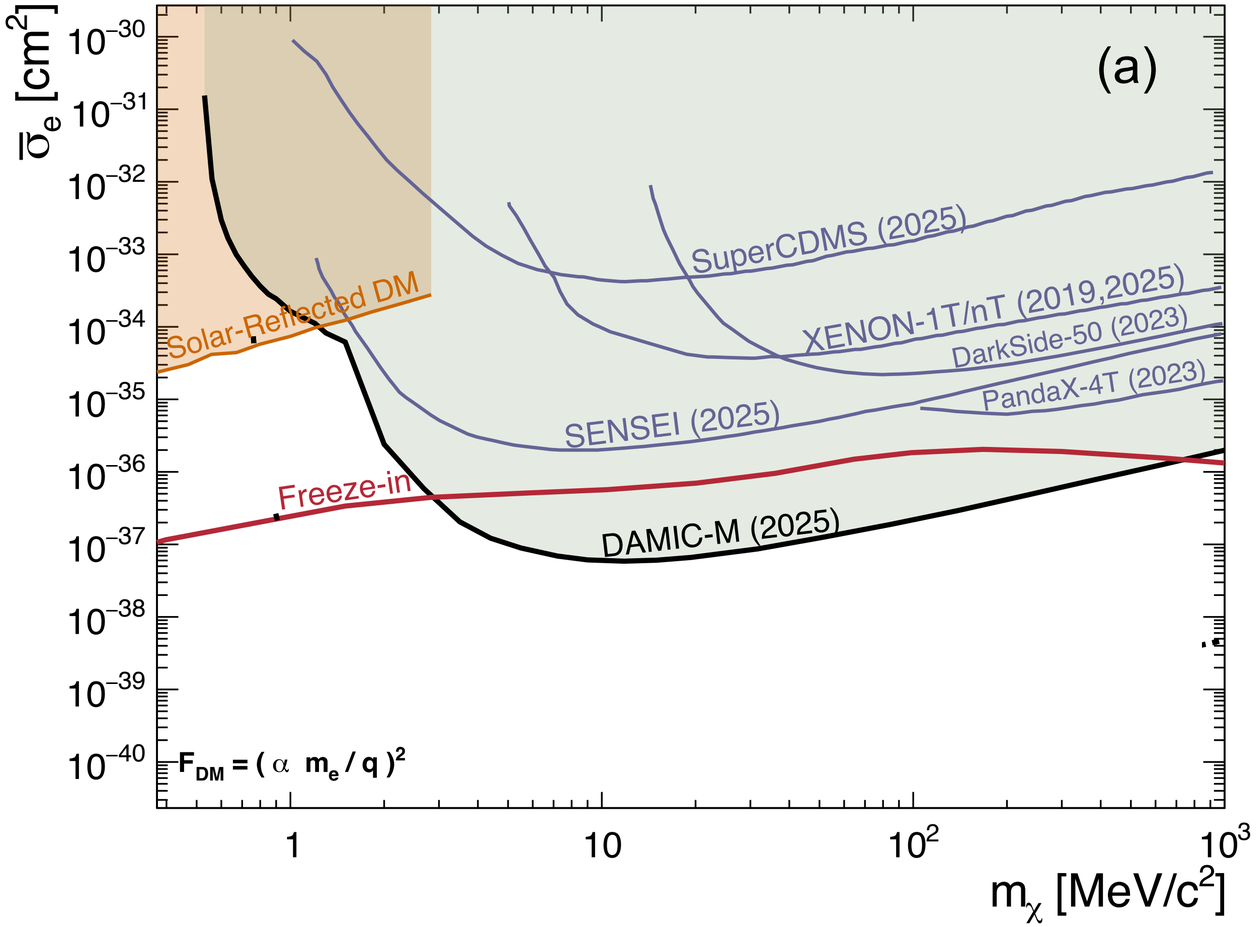
-0.15	0.11	0.10	-0.14	-0.05	0.24	0.07	0.11	0.03	-0.06	-0.11	0.16
0.08	-0.29	-0.15	0.02	0.21	0.21	-0.09	0.01	0.01	-0.03	0.13	-0.14
-0.09	0.01	-0.15	-0.02	-0.02	0.26	0.13	0.09	0.23	0.18	-0.17	0.33
0.10	0.42	-0.10	0.10	0.11	0.08	0.26	0.21	0.29	0.14	0.06	0.35
-0.17	-0.13	-0.17	0.26	0.14	0.33	-0.21	0.11	0.02	-0.15	0.07	-0.14
0.24	0.06	-0.13	0.12	0.29	2.99	1.36	0.12	-0.04	0.03	0.07	0.18
0.08	-0.12	0.09	-0.10	0.10	0.24	0.21	0.13	0.09	0.08	0.07	0.15
-0.22	-0.30	0.05	0.17	-0.23	-0.18	0.17	-0.36	-0.37	-0.33	-0.31	-0.19
0.08	-0.13	-0.02	0.02	-0.29	-0.05	-0.16	0.10	0.09	0.27	0.08	0.08
0.14	0.19	0.08	-0.12	0.20	0.21	-0.03	0.42	-0.10	-0.16	0.30	-0.03
0.01	0.08	-0.13	-0.09	-0.36	-0.18	-0.18	0.16	0.26	0.19	-0.11	0.10



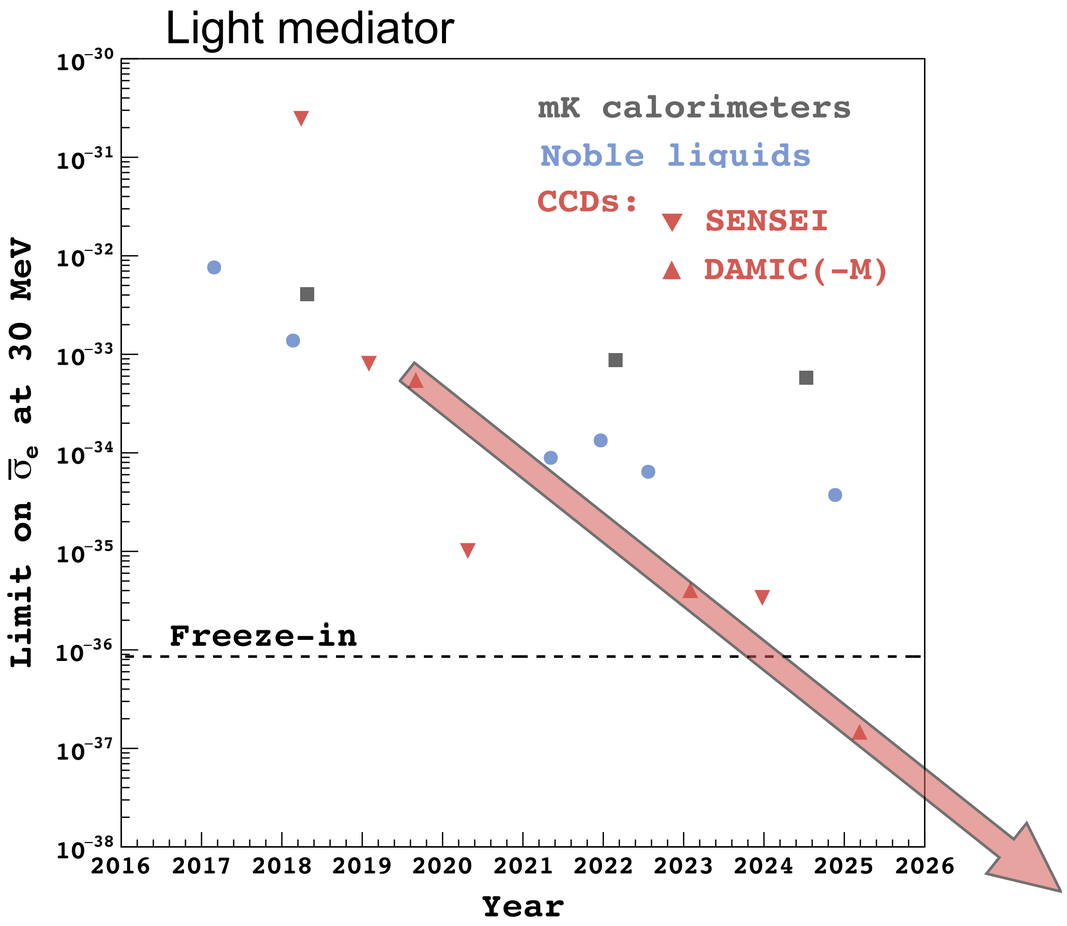
Prototype CCD module packaged and tested at UW

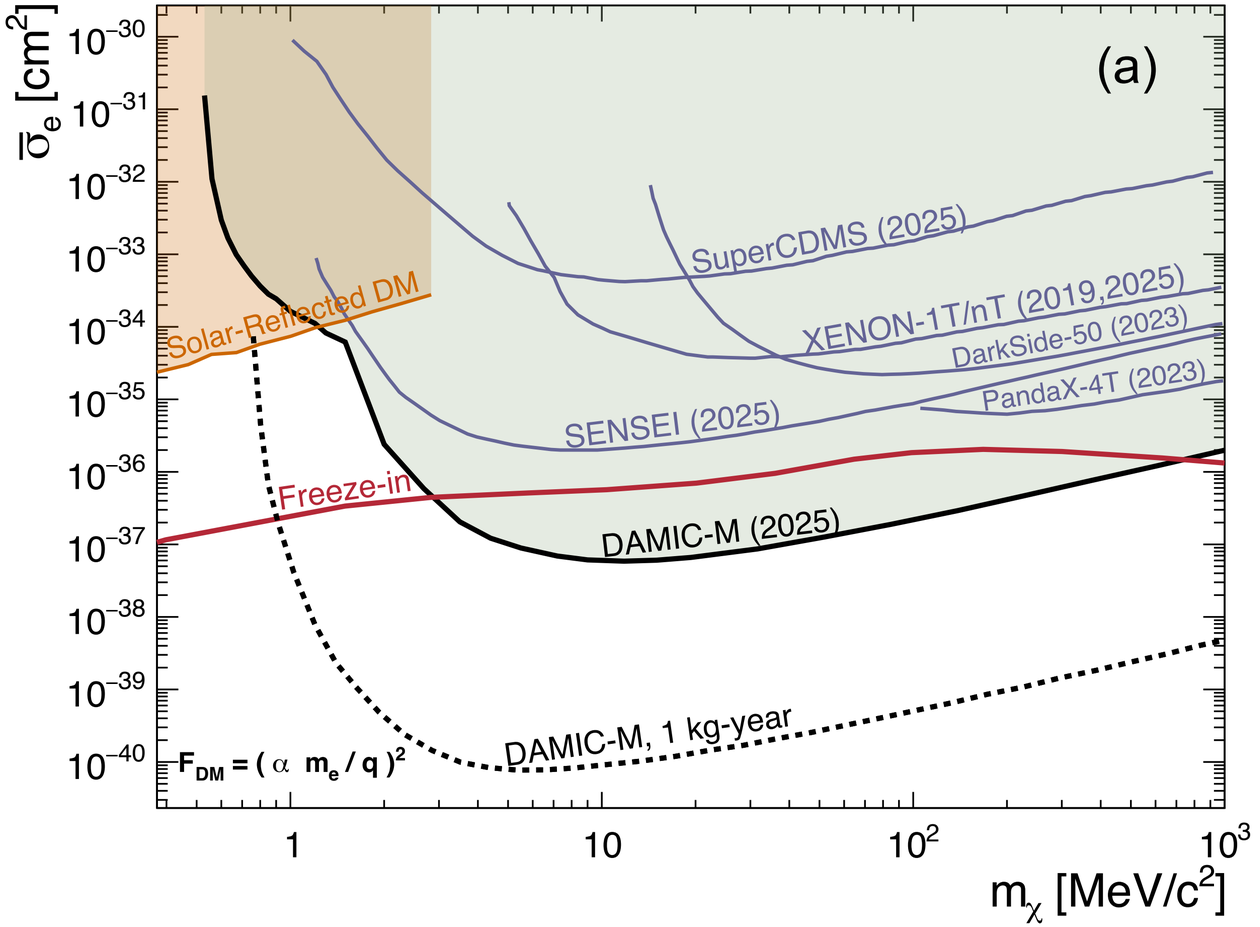
LBC Results


Light mediator
mK calorimeters
Noble liquids
CCDs:
SENSEI
DAMIC(-M)
Freeze-in
Limit on $\bar{\sigma}_e$ at 30 MeV
Year

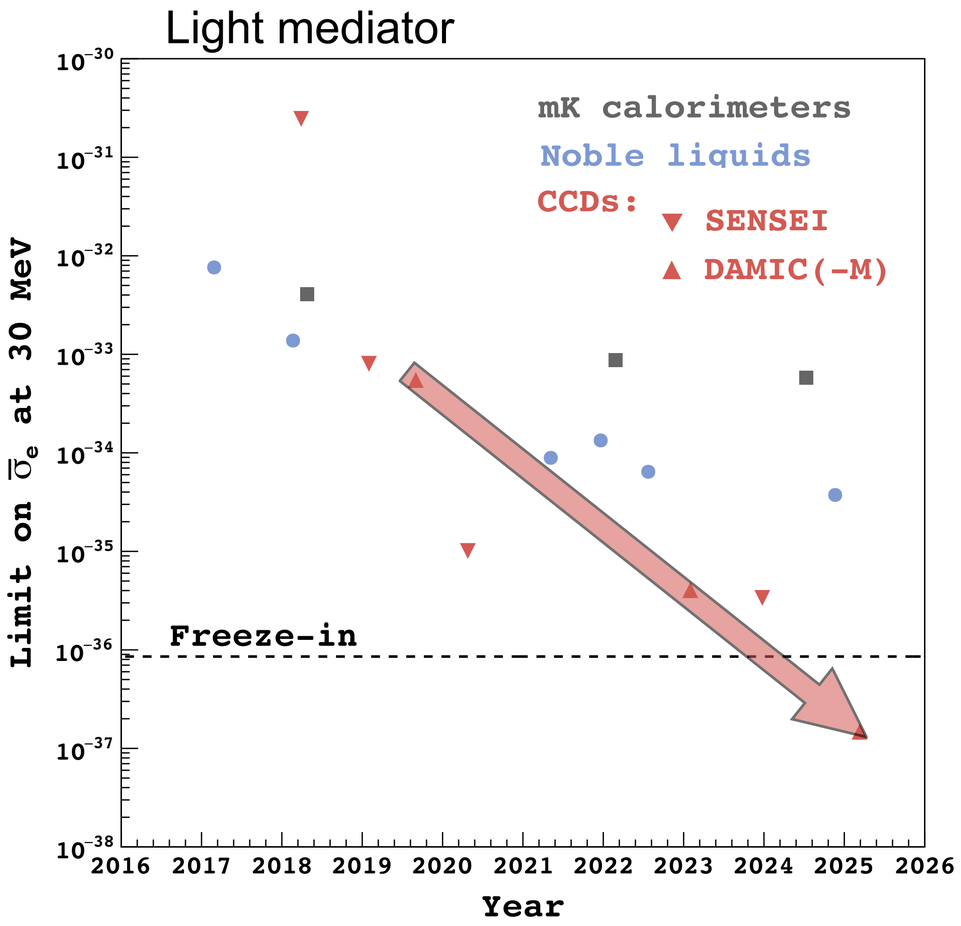

(a)
$\bar{\sigma}_e$ [cm^2]
SuperCDMS (2025)
XENON-1T/nT (2019,2025)
DarkSide-50 (2023)
PandaX-4T (2023)
Solar-Reflected DM
SENSEI (2025)
Freeze-in
DAMIC-M (2025)
$F_{DM} = (\alpha\ m_e / q)^2$
m_χ [MeV/c^2]

DAMIC-M Forecast

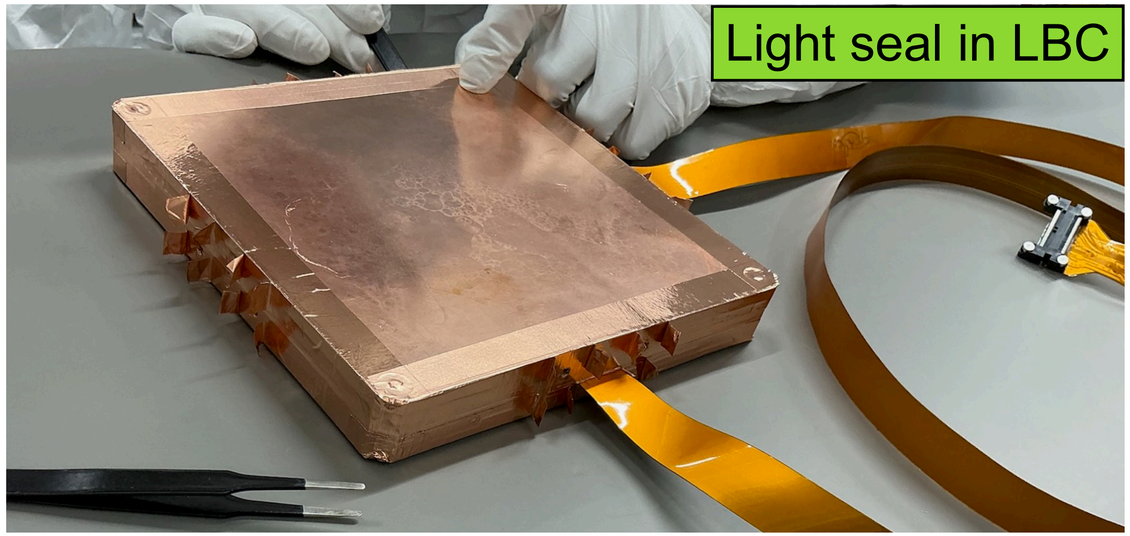




Progress

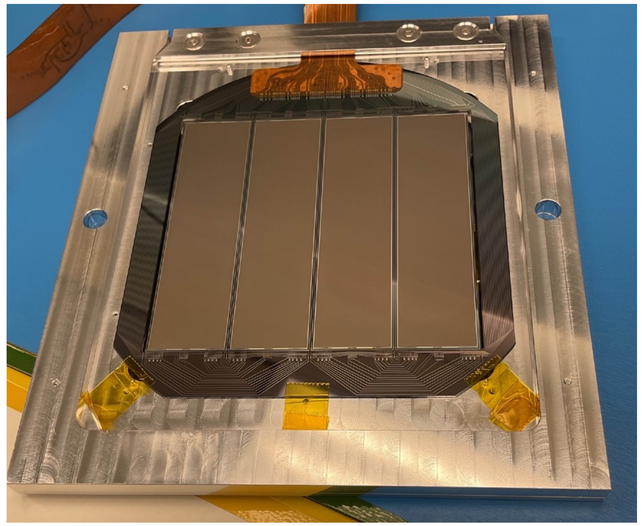


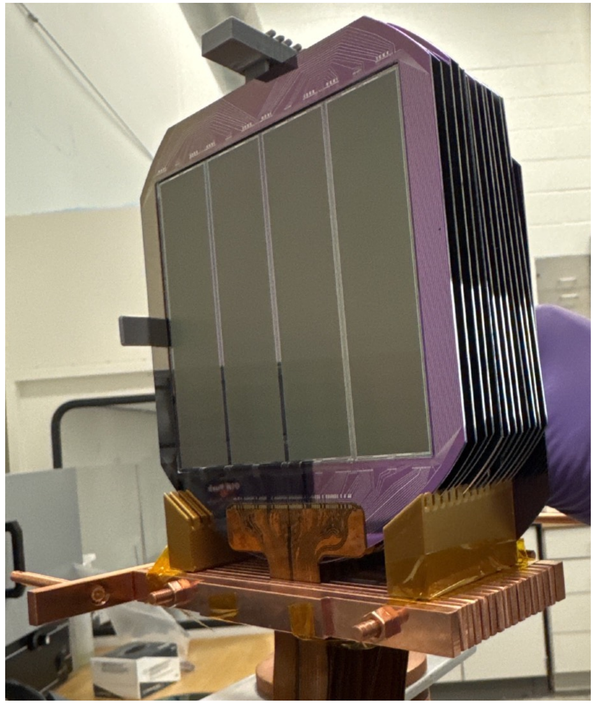
- The radioactive background ~10 dru has not decreased since 2017.
- The improvement is from decreasing single-electron rate and increasing exposure (up to ~1 kg-day).

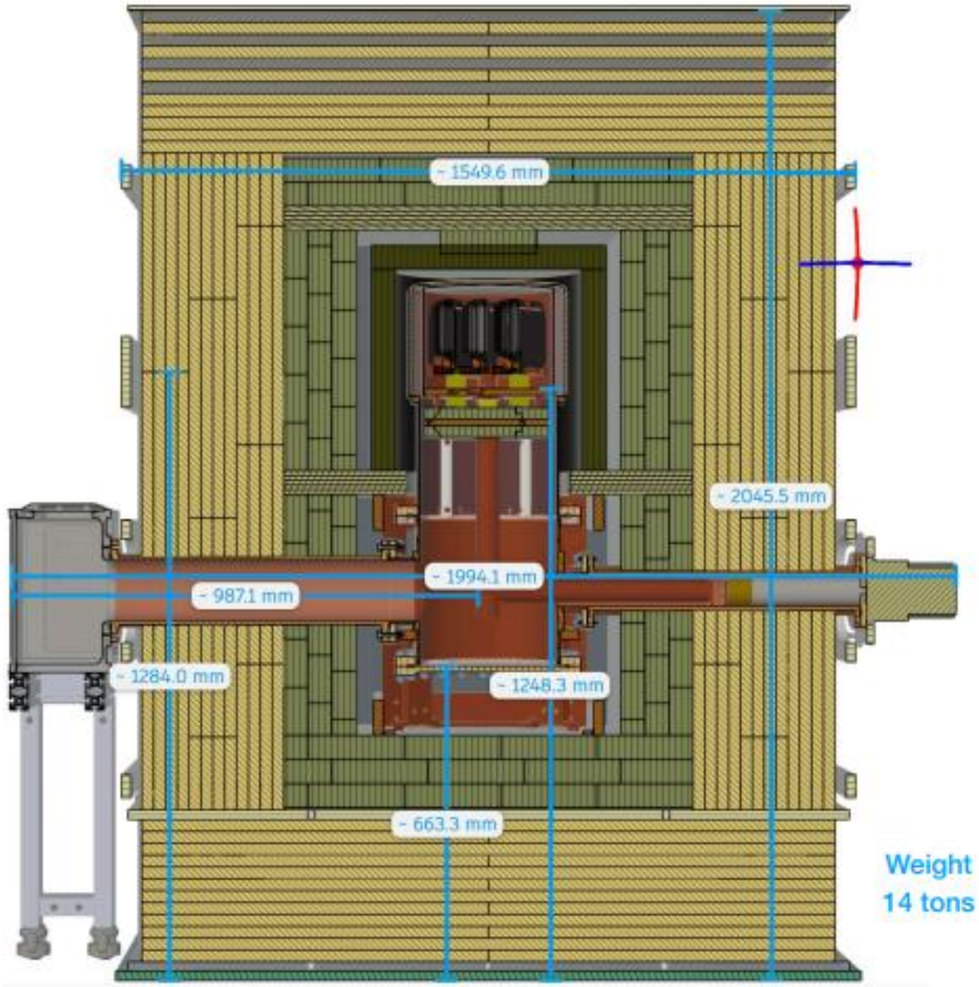


DAMIC-M

- 104 CCDs in LSM (France) for kg-year target exposures.
- ~1 Gigapixel ➡ like a modern astro camera!
- Skipper readout for sensitivity to single charges.
- Background reduction to ~1 d.r.u. (events per kg-day).
- Under construction. Commissioning by end of 2026!







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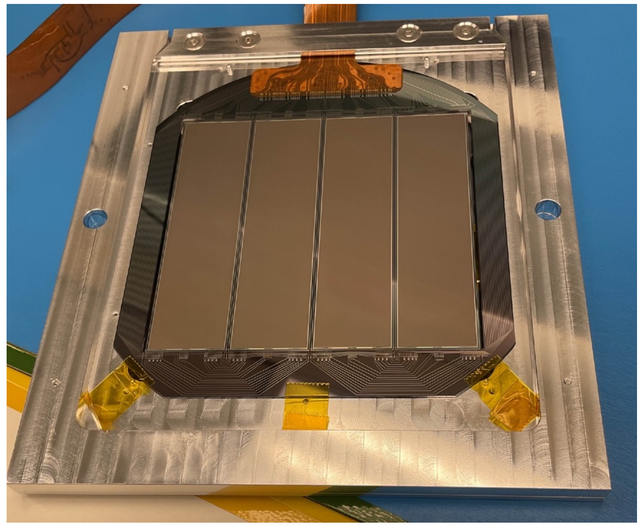
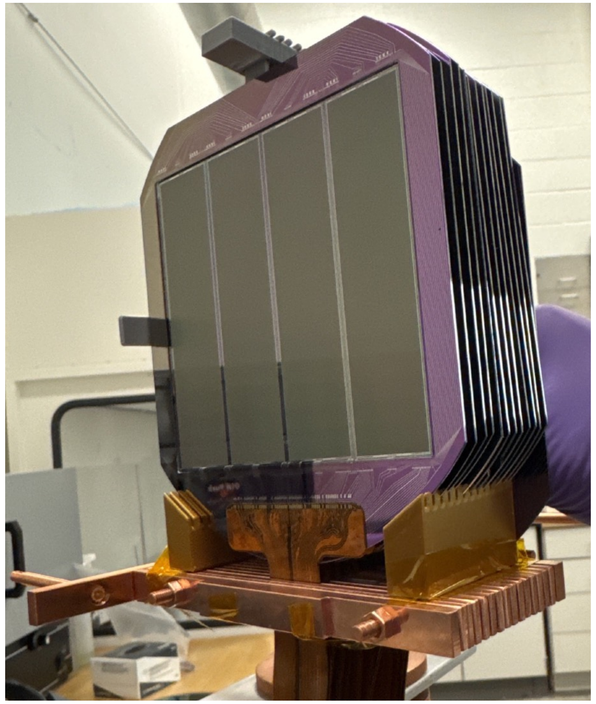


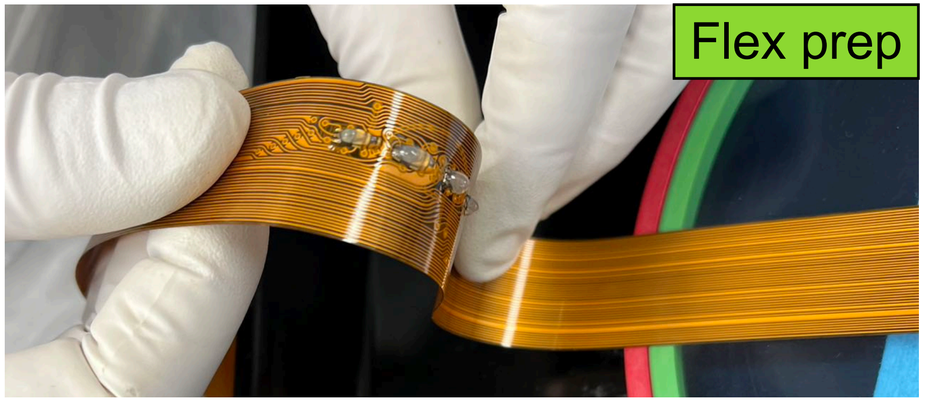


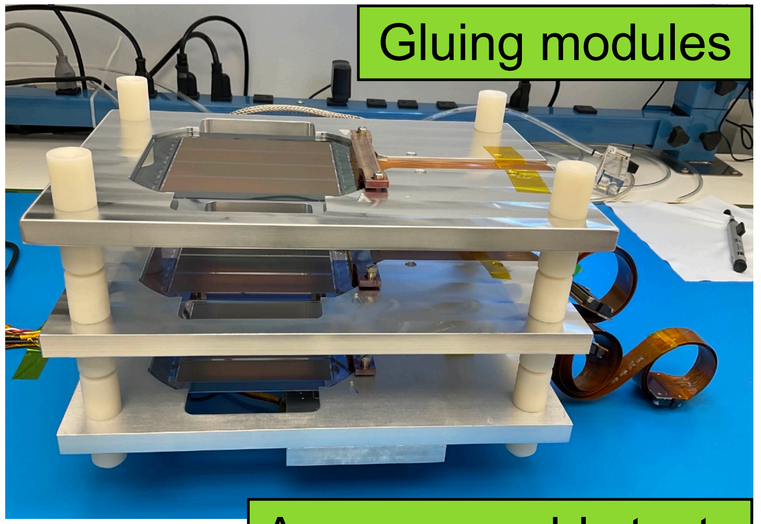
As of end of summer:

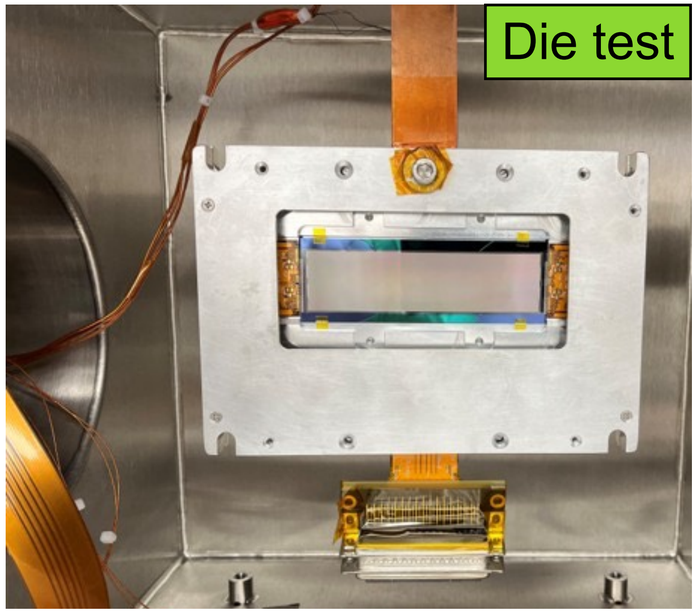
Module Production

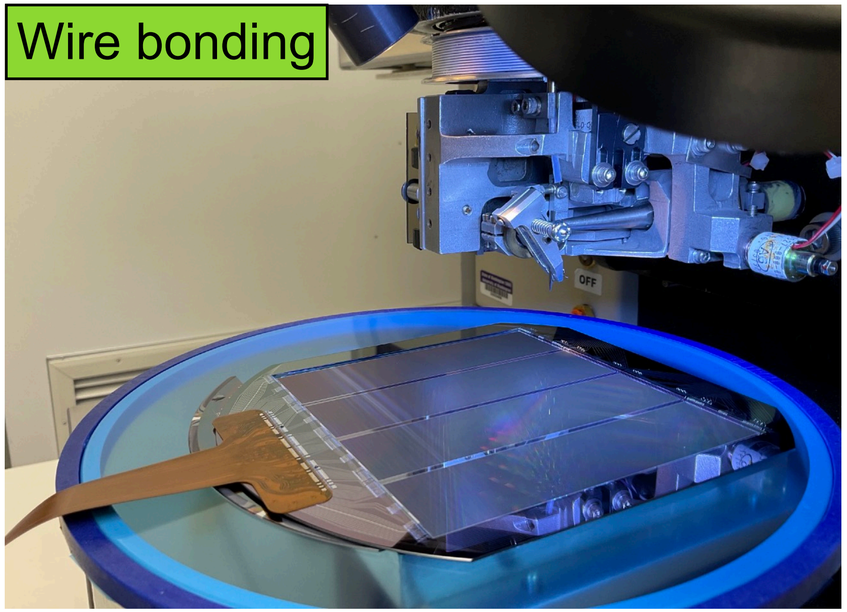
arXiv:2509.06943

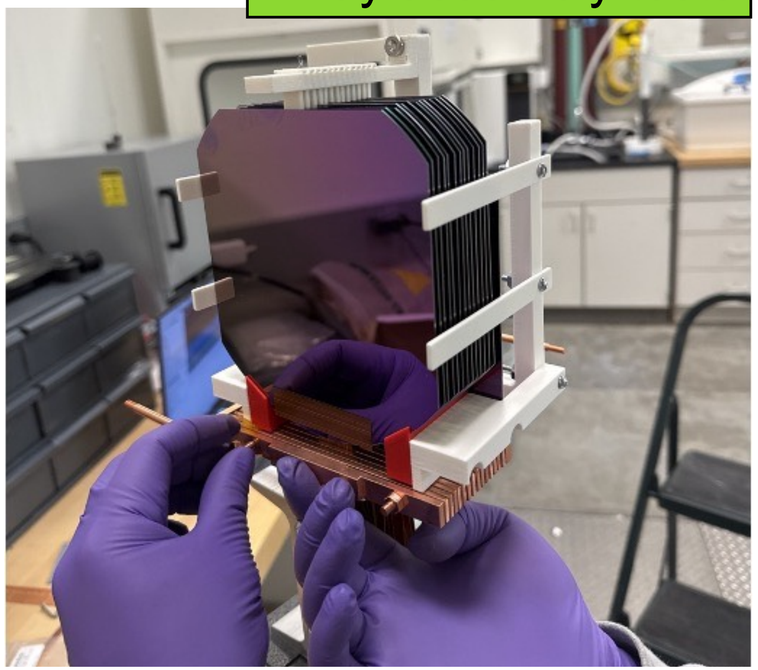
- UW Seattle in Autumn 2024.
- Tested 188 CCDs and selected the best to fabricate 28 modules.
- Modules now at LSM.



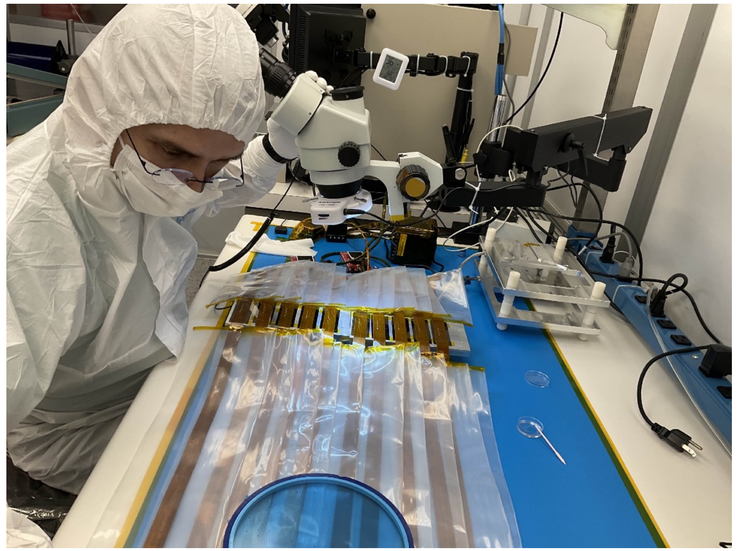






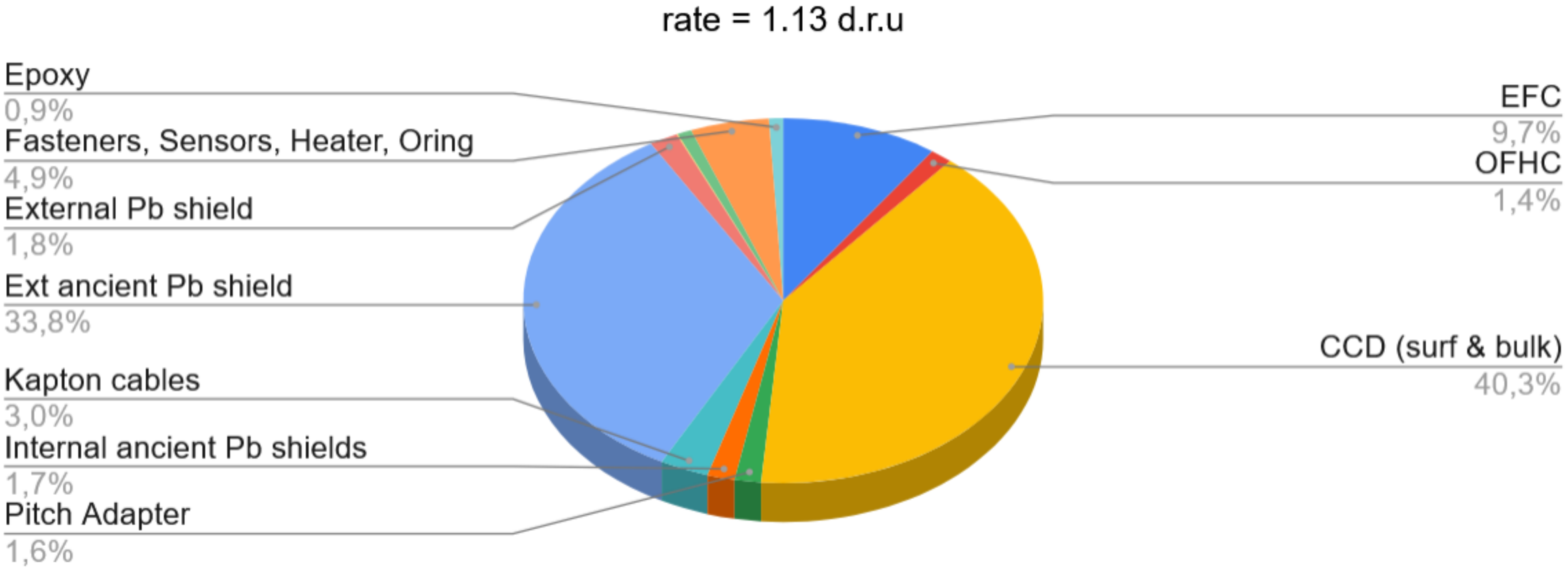


Low-background

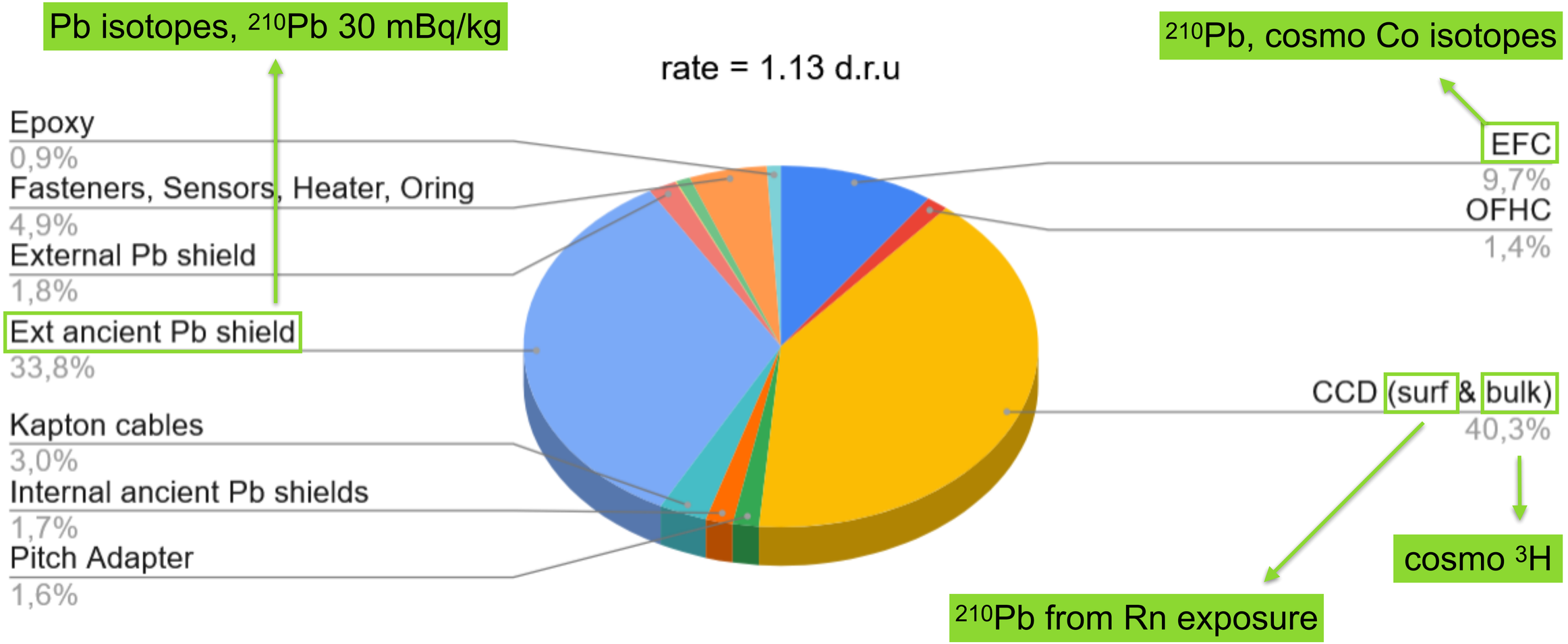


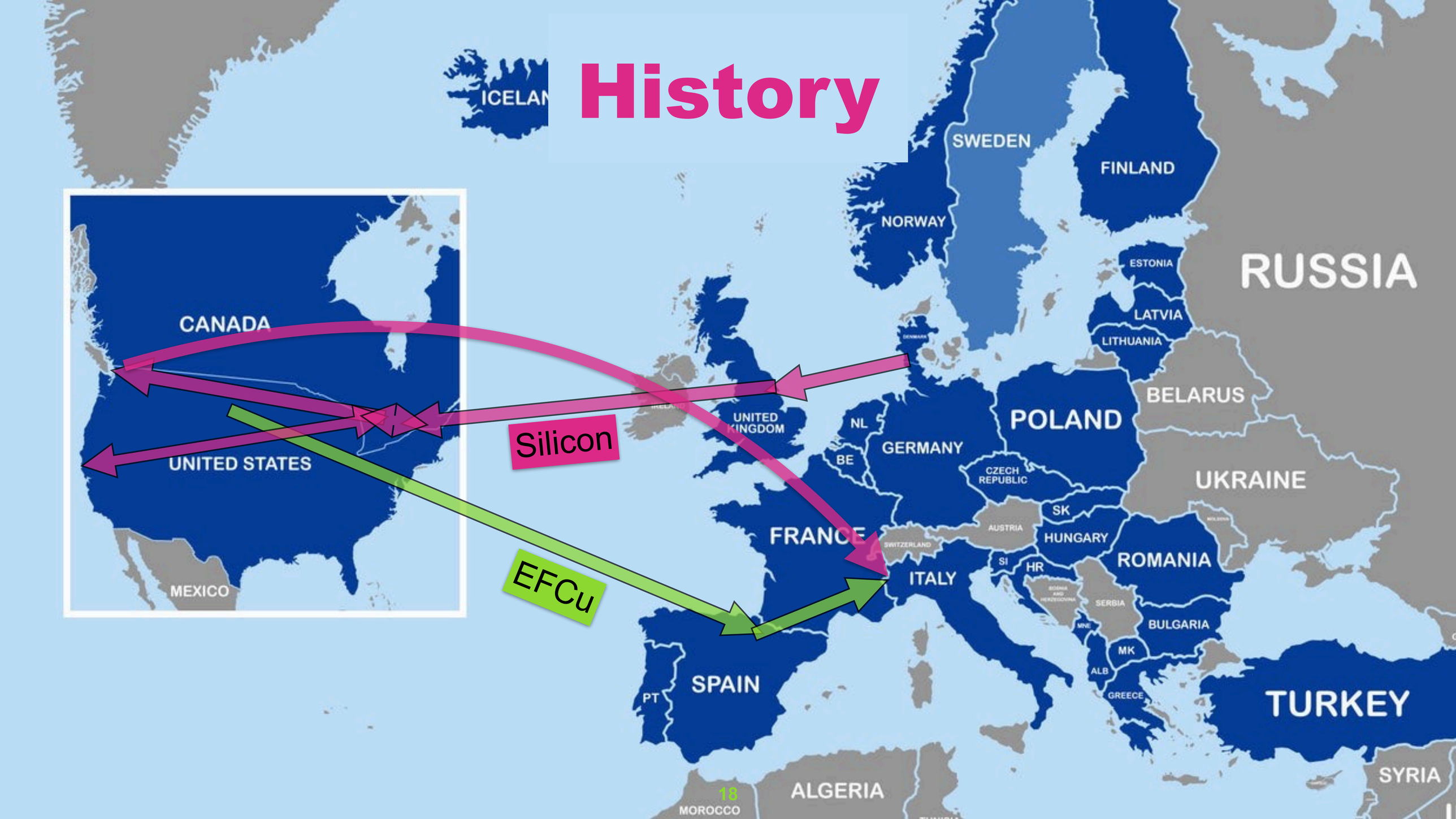
- Transport in shielded container.
- Shielded, Rn-free storage.
- Clean room operations.
- Low-radioactivity flexes. NIMA959(2020)163573
- Copper electroformed underground.
- Light-tight infrared shield.

Backgrounds



Backgrounds




History
ICELAND
SWEDEN
FINLAND
NORWAY
ESTONIA
LATVIA
LITHUANIA
RUSSIA
BELARUS
CANADA
UNITED STATES
MEXICO
Silicon
EFCu
UNITED KINGDOM
IRELAND
NL
BE
GERMANY
POLAND
CZECH REPUBLIC
SK
AUSTRIA
HUNGARY
UKRAINE
FRANCE
SWITZERLAND
SI
HR
ROMANIA
ITALY
SERBIA
BULGARIA
MK
ALB
GREECE
TURKEY
SYRIA
SPAIN
PT
ALGERIA
MOROCCO
18

Cosmogenic

Surface-equivalent exposure

	Target / days	Result
CCD silicon	100	60 or 76 days
EF copper	28	Up to 18
OFHC copper	180	Up to 95

- Storage underground in between production steps: Boulby, SNOLAB, SURF, LSC, LSM.
- Stainless steel shield *in* foundry!
- Shielded room for storage during packaging.

DALSA

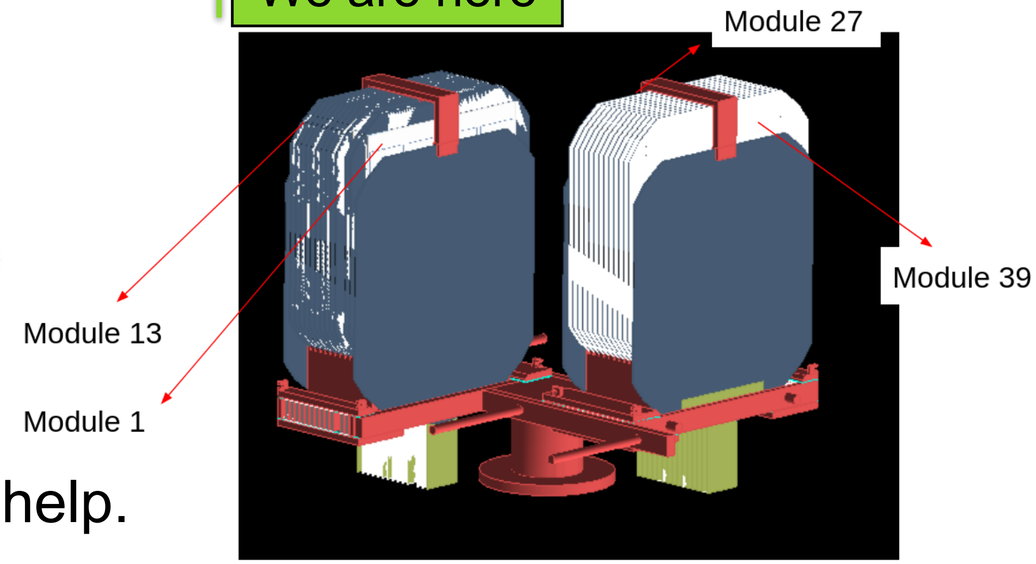
Surface

- Harder to control than cosmogenic exposure since environmental radon levels much more variable and mitigation procedure more prone to error.
- Stored in nitrogen flushed containers and metallized bags whenever possible.

	Before UW	At UW	Ship to LSM	LSM	Total	Target
Accumulated ^{210}Pb [nBq/cm^2]	Small (?)	0.4	7	5	**12**	4

We are here

- Surface ^{210}Pb will be dominant radiogenic background (~1 dru).
- Preliminary MC-based spatial coincidence study shows 60% background reduction with 10% loss of exposure.
- Depth reconstruction by diffusion will also help.



Conclusions

- World-leading sensitivity in the search for sub-GeV dark matter particles with DAMIC-M modules in the LBC.
- The next leap in sensitivity requires significant increase in exposure and reduction in backgrounds.
- Enter DAMIC-M: 104 skipper CCDs with a 10x reduction in background.
- Construction to be completed by the end of 2026.
- First data in 2027, with 1 kg-year exposure by the end of 2029.

Thank you!