# DAMIC-M activities at LSM in 2022 and 2023

## Dark Matter In CCDs at Modane

DAMIC-M detector

Activities in 2022

- Low Background Chamber (LBC),
- First science results.

Plans and requirements for 2023

**R. Smida for the DAMIC-M Collaboration**

# DAMIC-M at LSM

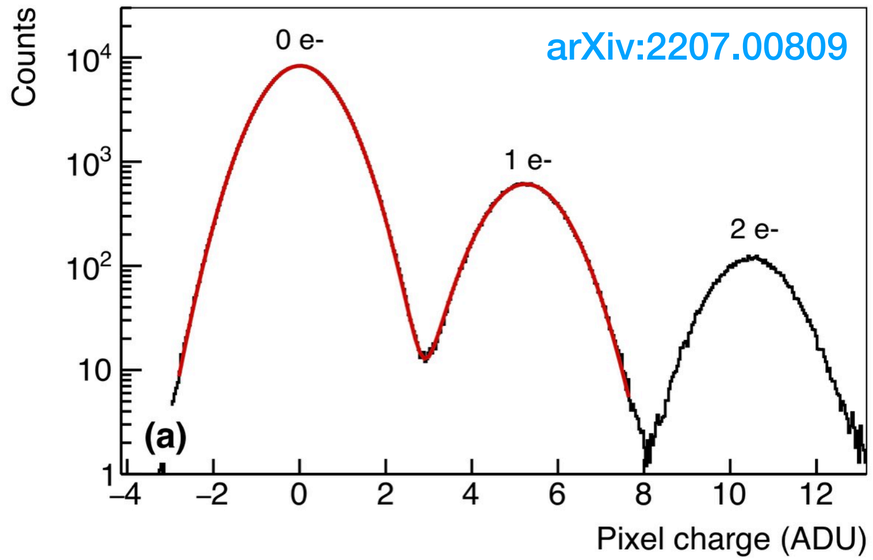
Goal: Detect nuclear and electron recoils to search for light dark matter candidates (eV to GeV).

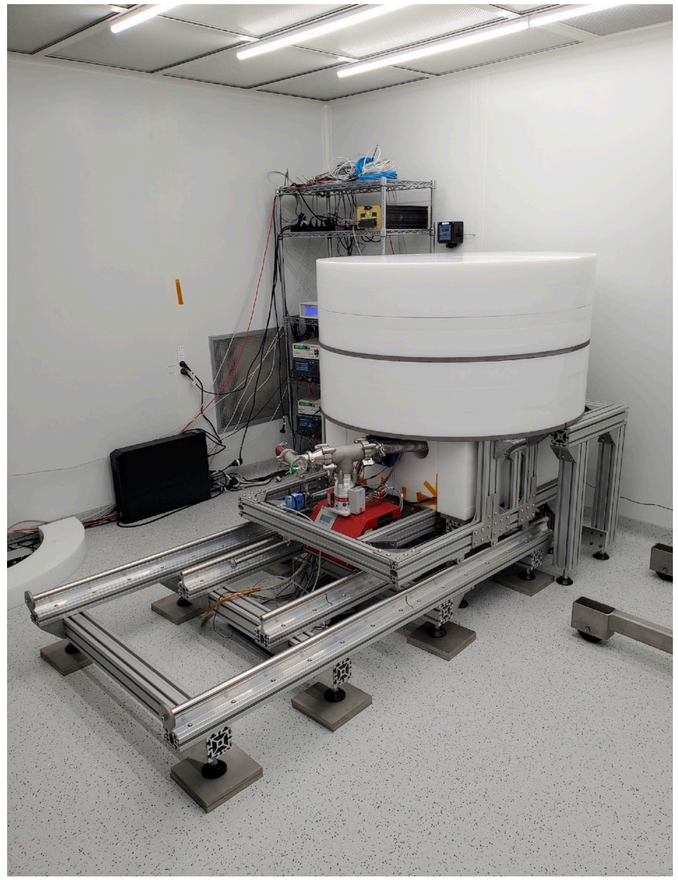
Detector with ~200 CCDs

- CCDs made from high resistivity, n-type, high purity Si,
- 9M pixels, 670 μm thickness, ~3.5 g mass,
- single-electron resolution CCDs, called skipper CCDs,
- the energy threshold of 2-3 electrons (~10 eV),
- the total exposure of 1 kg-year.

Low background rate of $\mathcal{O}$(0.1) dru

- Clean materials (Si, electro-formed copper (EFC), ancient Pb),
- mitigate the cosmogenic activation and surface deposition (Rn or dust),
- use pixelization for background rejection.



Low Background Chamber (LBC) in the DAMIC-M detector cleanroom at LSM (26.7 m$^2$, ISO 5, Rn (7±1) Bq/m$^3$)

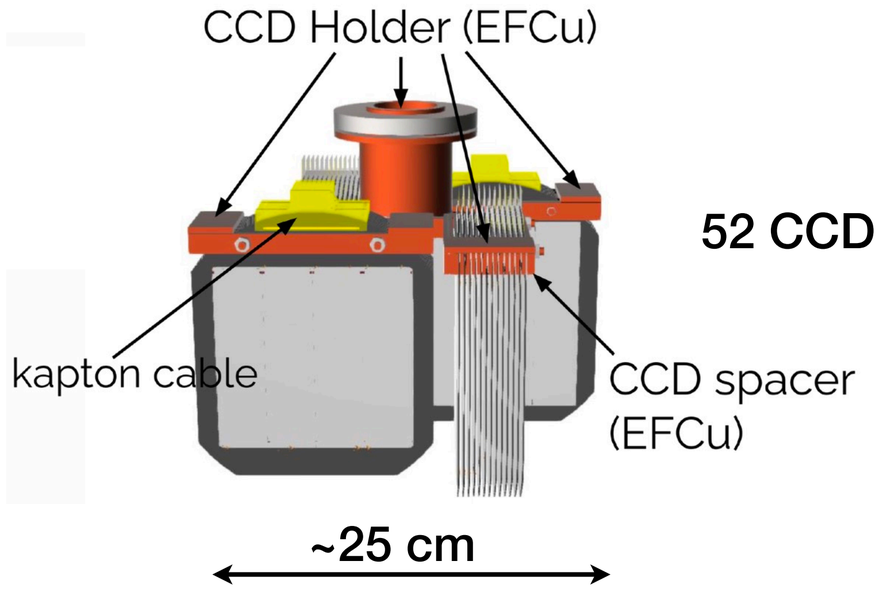
# Detector design

A compact array of 52 CCD modules, i.e. a Si pitch adapter frame with four skipper CCDs.

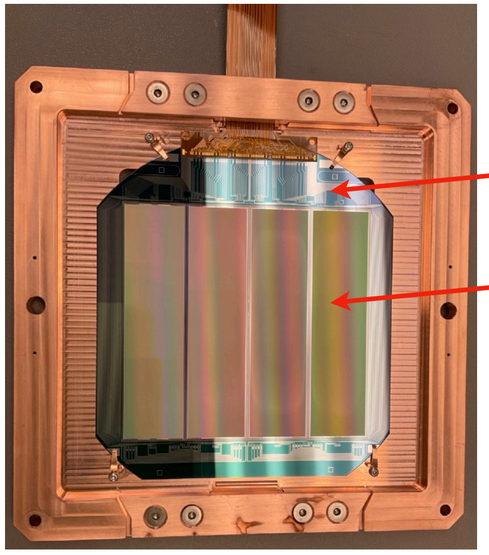
We will use science-grade CCDs carefully selected from ~750 devices. All devices will be packaged and tested in **a dedicated cleanroom (ISO5, ~30 m²)** at LSM. They must be kept in clean environment, flushed with **either $N_2$ or Rn-free air**, and **controlled humidity (50±10)%.**

Voltages and signals will be carried by specially developed low-background flex cables of ~1.5 m length.

Two CCD module prototypes will be characterized in LBC at LSM during next months.




52 CCD modules



CCD module prototype

Si pitch adapter

CCD

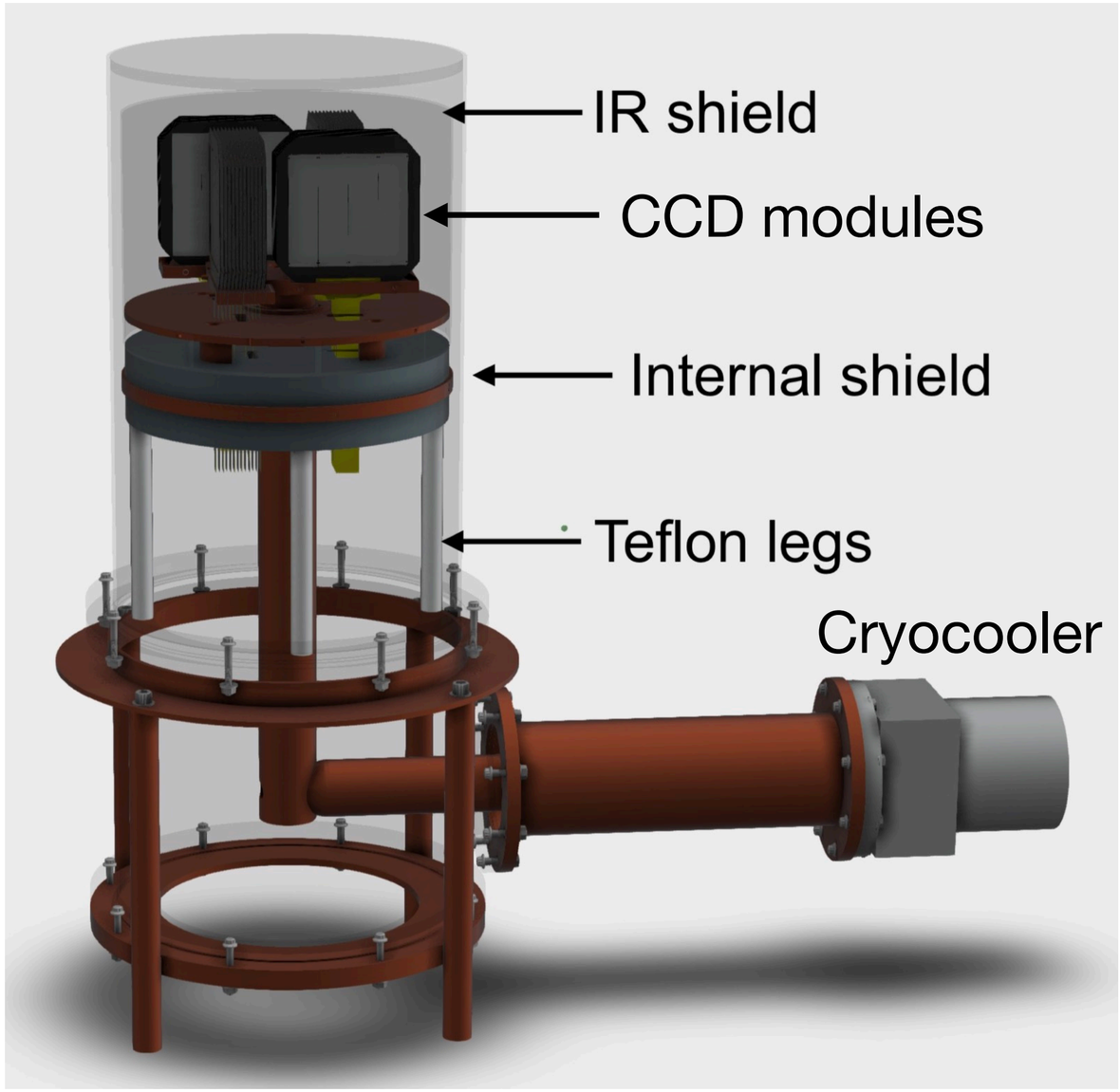
# Detector design

CCD modules are connected to a cold copper hanger and encapsulated in an IR shield. Flex cables bring voltages and signals to a feedthrough flange (not shown).

Parts above the internal shield and the cryostat, are from copper electro-formed and machined at LSC. Other cryostat parts are from OFHC copper.

Ancient Pb plate inside and 5 cm cylinder around the cryostat. In this configuration, we require **~700 kg of ancient Pb.**

Cooling with a cryocooler ($T_{CCD}$ ~ 125 K) and will **not need to have a supply of $LN_2$.**




- External shield (Pb, HDPE) and support structure,
- Custom electronics for fast readout and low noise,
- DAQ system (PCs, remote connection, etc.).

# Background

Getting close to 0.1 dru level.

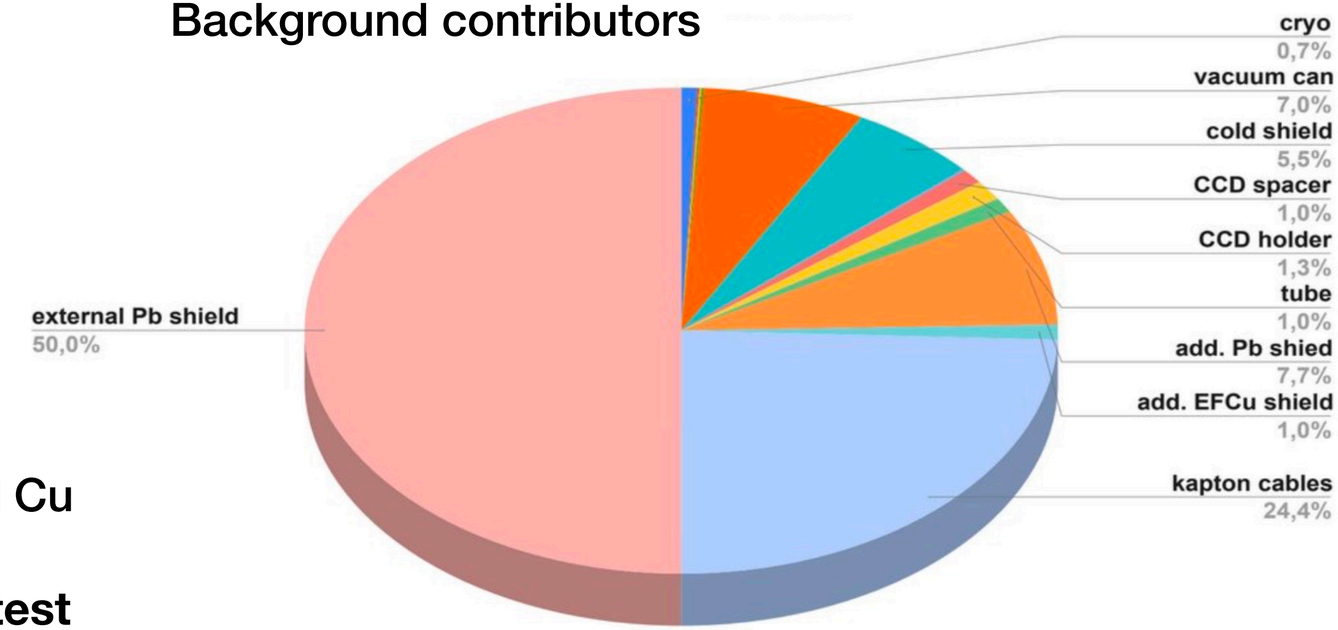
Guided by results of DAMIC at SNOLAB (arXiv: 2110.13133) and extensive Geant4 simulations.

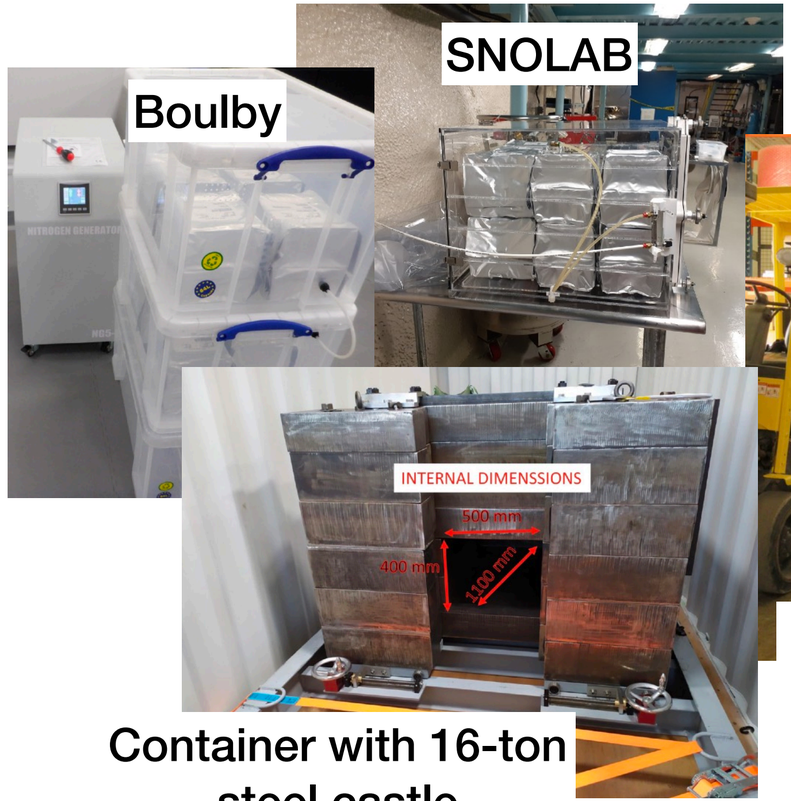
Efforts dedicated to

- Minimize the cosmogenic activation of Si and Cu (shielding, underground storage, expedite processing, etc.). **Critical is to package and test CCDs at LSM.**
- Limit the exposure of CCDs to the air and dust.
- Only electro-formed copper parts close to CCDs.
- Newly developed clean CCD flex (kapton) cables.
- Sufficient thickness of ancient lead. **Precise measurement of $^{210}$Pb in the bulk of LSM ancient lead is missing.**
- Assay of all materials.
- Proper cleaning procedures.

Some of the above was already implemented for LBC.

Background contributors



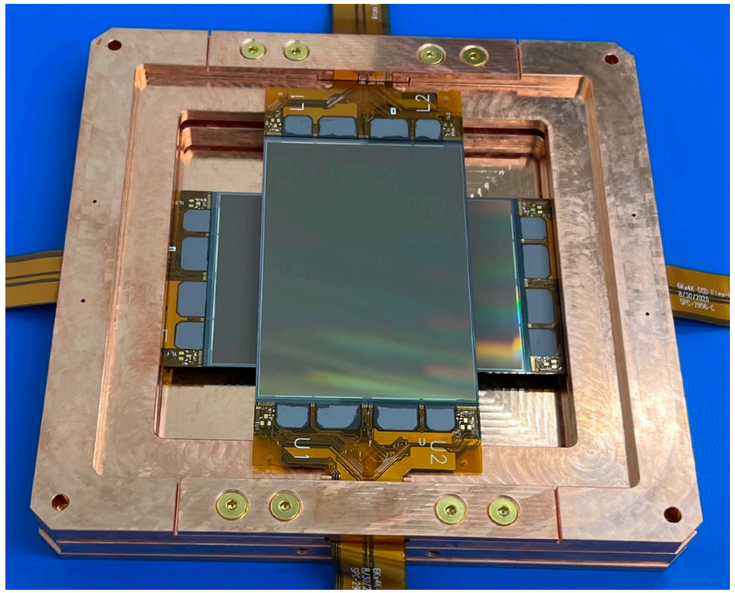

Container with 16-ton steel castle

Enclosure for the CCD production

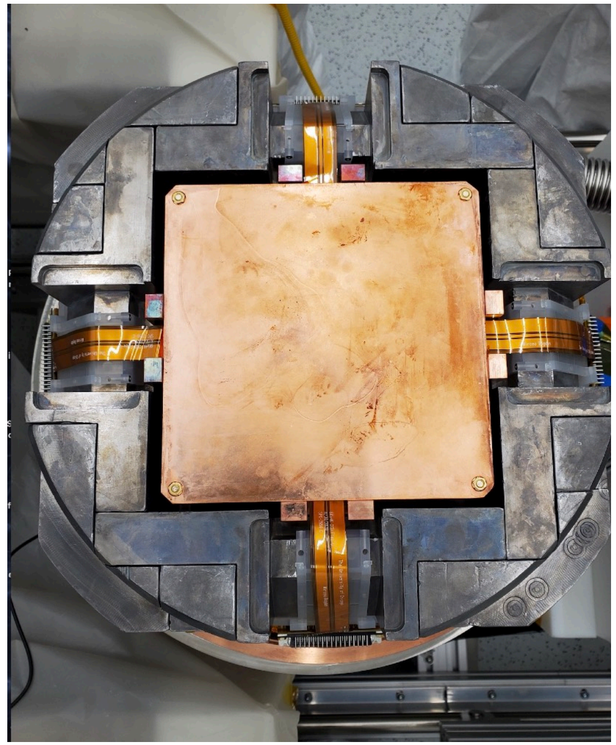
# Low Background Chamber

A prototype detector at LSM with four objectives, built in the winter 2021 and successfully running since Feb 2022. Two upgrades in 2022 and one more starting next week (Jan 30 - Feb 17, 2023).

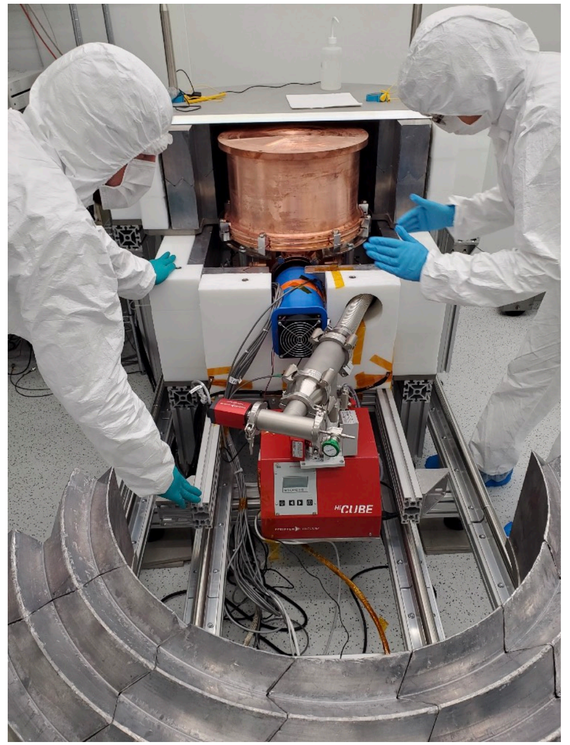
1. Characterize DAMIC-M components in a low background environment (CCD dark current, noise level, radioactive background of materials, etc.), (✔)



- Two skipper CCDs, each with 24M pixels and mass 9.1 g,
- no material between CCDs,
- two-layer flex cable.



- EFC lids from LSC,
- inner 2 cm LSM ancient lead, then TFA lead.



- Outer shielding (Pb and HDPE),
- support structure,
- slow control,
- electronics.

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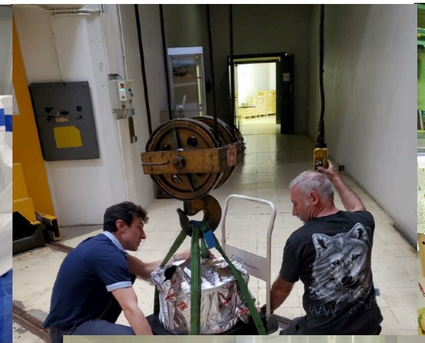
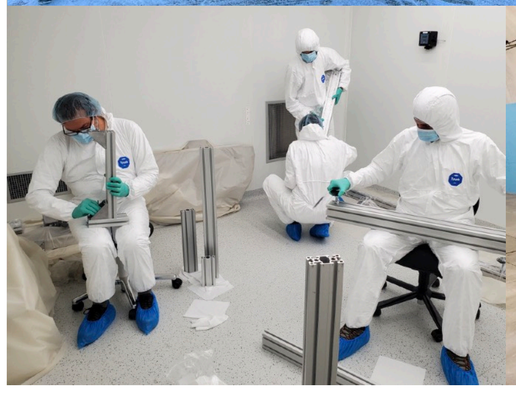
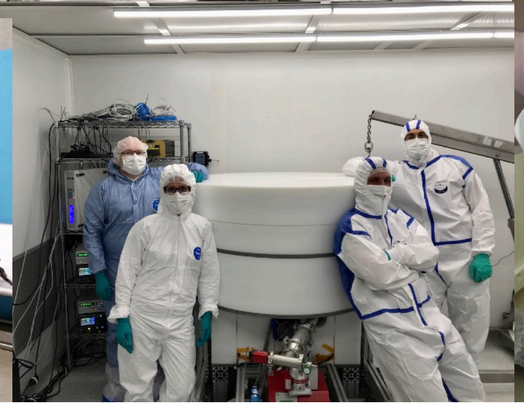
2. Gain working experience at LSM, ✔







**Continuous support by LSM and LPSC, and also other experiments, is highly appreciated!**

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3. Test of other fundamental DAMIC-M components (e.g. Front End electronics, slow control, DAQ software, data transfer and data quality monitoring, remote control), (✔)


Refresh time: 3m | Plots | MPlot | Scatter | Sys Log | Runs | Users | Alarms | Config | Control | LogBook | Cams | You are logged in as smida from 127.0.0.1.

Select All | 2ndPowerSupply: ☑ Cryocooler: ☑ PDU: ☐ PowerSupply: ☐ Pressure: ☐ Radon: ☐ Sys: ☐ Temperature: ☑ UPS: ☐ | Deselect All

Last db update: Jan 25, 2023 @ 16:16:21. Sensors values in yellow are more than 10 minutes old.

| | |
|---|---|
| Current on 2nd system Amplifer+ board (2nd_Current_1)<br>**0.027**<br>(A) | Current on 2nd system Amplifer- board (2nd_Current_2)<br>**0.026**<br>(A) |
| Current on 2nd system Leach board (2nd_Current_3)<br>**0.035**<br>(A) | Voltage on 2nd system Amplifier+ board (2nd_Voltage_1)<br>**5.000**<br>(V) |
| Voltage on 2nd system Amplifier- board (2nd_Voltage_2)<br>**5.002**<br>(V) | Voltage on 2nd system Leach board (2nd_Voltage_3)<br>**25.002**<br>(V) |
| Power output of AVC controller of CryoTelGT (Power_Output_AVC)<br>**190.000**<br>(W) | Reject temperature of CryoTelGT (Reject_Temp)<br>**49.050**<br>(C) |
| Temperature of CryoTelGT cold head (Temp_Cooler)<br>**86.220**<br>(units) | Heater power output percentage (sensor) (Heater_100W)<br>**0**<br>(%) |
| Ramprate of 100W Heater (Ramprate_100W)<br>**0.100**<br>(K/min) | Setpoint of 100W Heater (sensor) (Setpoint_100W)<br>**115.000**<br>(K) |

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2. Gain working experience at LSM, ✔

3. Test of other fundamental DAMIC-M components (e.g. Front End electronics, slow control, DAQ software, data transfer and data quality monitoring, remote control), (✔)

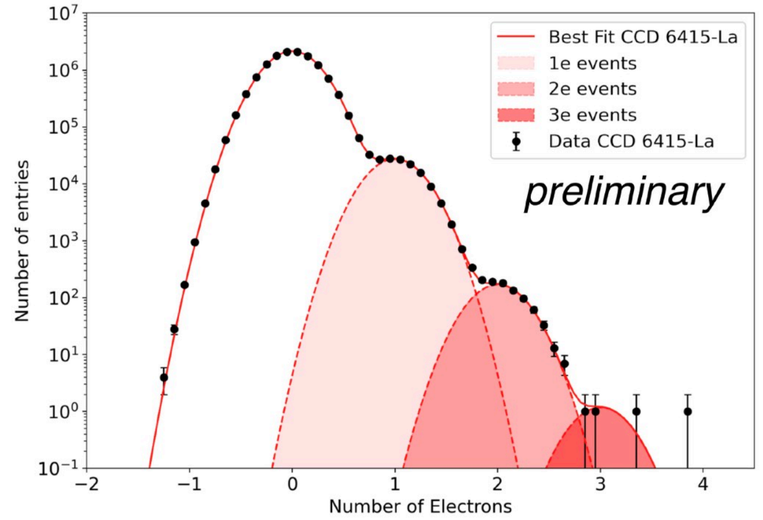
4. Science results with this small detector. ✔

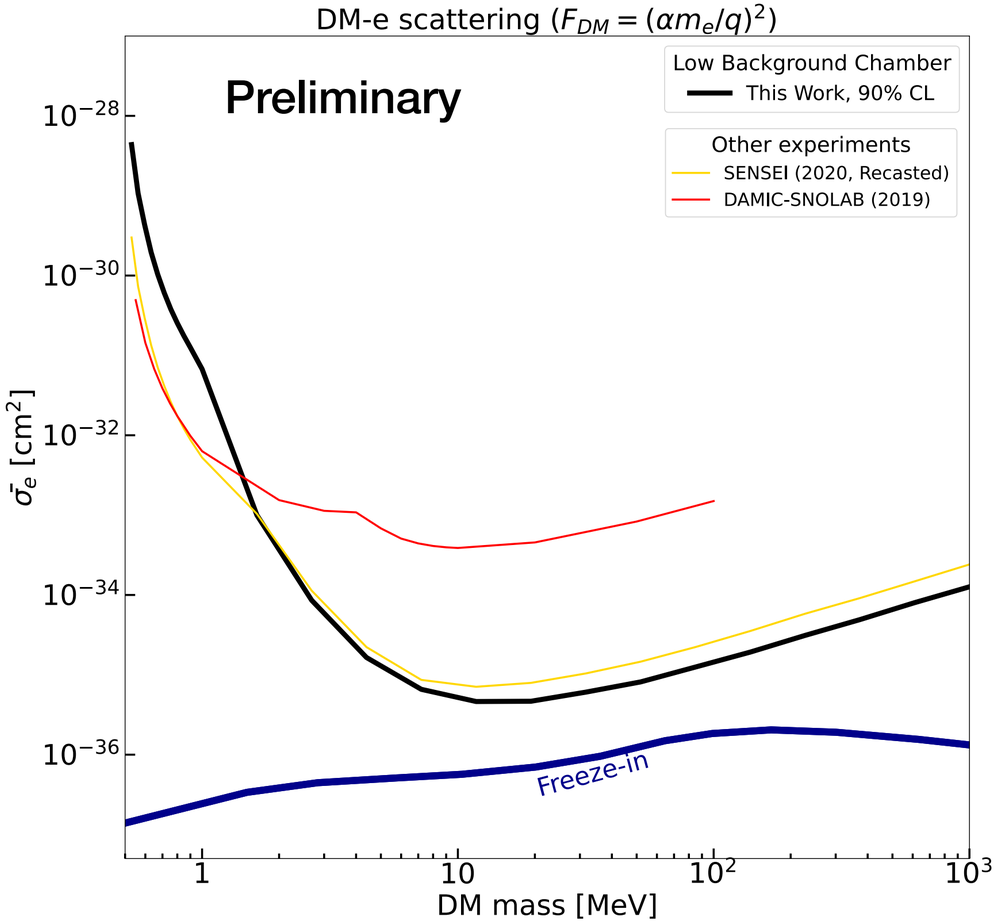
# First science results

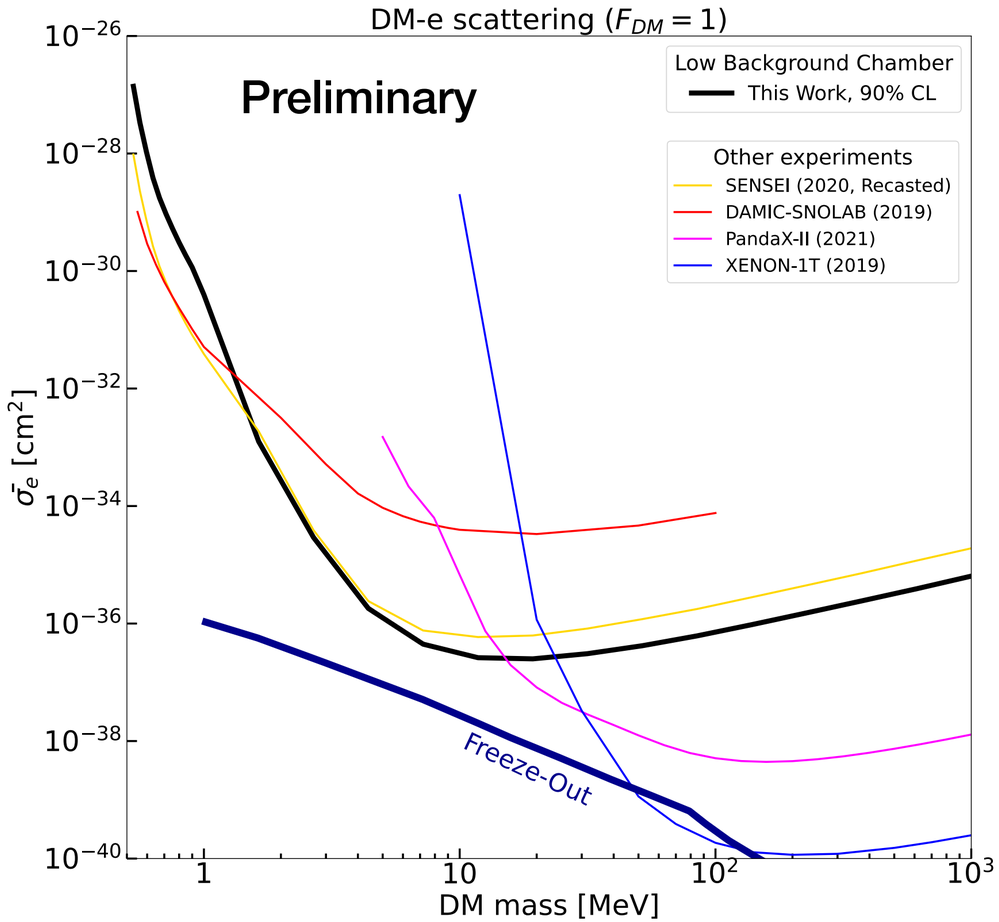
The analysis of the pixel-charge distribution (right figure) measured by LBC gives the world-leading limits on DM-electron scattering (figures below).

Preliminary results have been presented at conferences, arXiv:2210.12070. A journal Letter paper reporting an improved limit is written and under the Collaboration review.

Other analysis are ongoing.



# DAMIC-M at LSM in 2023

| | |
|---|---|
| Q4 2022 | Background data with LBC.<br>CCD pre-processing phase has started. |
| Q1 2023 | **Work on LBC** (Jan 30 - Feb 17), installation of open-shield mechanism and CCD modules.<br>Start taking data with the new CCD modules.<br>The CCD production phase.<br>Finalize the detector design.<br>Start electro-forming copper at LSC. |
| Q2 2023 | Shipment of CCDs to LSM. **Clean and Rn-free storage space for CCDs.**<br>Production of Si pitch adapters. Ideally, in a fab in or close to Grenoble.<br>**A cleanroom for probing, packaging and testing CCDs** (~30 $m^2$, ISO 5, humidity 40-60%).<br>Delivery of instruments (cold probing setup, wire bonder, two test chambers). |
| Q3-Q4 2023 | Cold probing and packaging of CCDs at LSM.<br>Tests of CCD modules, some of them with **radioactive source(s)**. Select the best science-grade detectors (defects, amplifiers, dark current, single electron resolution).<br>Disassemble/relocate LBC start preparing this cleanroom for the full-scale DAMIC-M detector. |

Our goal is to complete installation in Q3 2024 and start data taking by the end of 2024.
One year minimum of science data taking.

# Required infrastructure/support from LSM

1. A dedicated cleanroom (ISO5, ~30 $m^2$, humidity (50±10)%) for packaging and testing CCDs at LSM.

2. Supply of Rn-free air and $N_2$.

3. Clean and Rn-free storage cabinets for Si and Cu parts.

4. Ancient lead (~700 kg). Precise measurement of $^{210}Pb$ in LSM ancient lead is still missing.

5. Radioactive sources for CCD tests. (If feasible, we will be interested in using activated source(s) for photo-neutron measurement.)

6. Support with shipments, construction and chemical cleaning.

For a successful completion of the DAMIC-M program is essential that adequate space and infrastructure is allocated to the experiment in 2023 and 2024. The ERC Advanced Grant ends in 2024.