DAMIC-M Project

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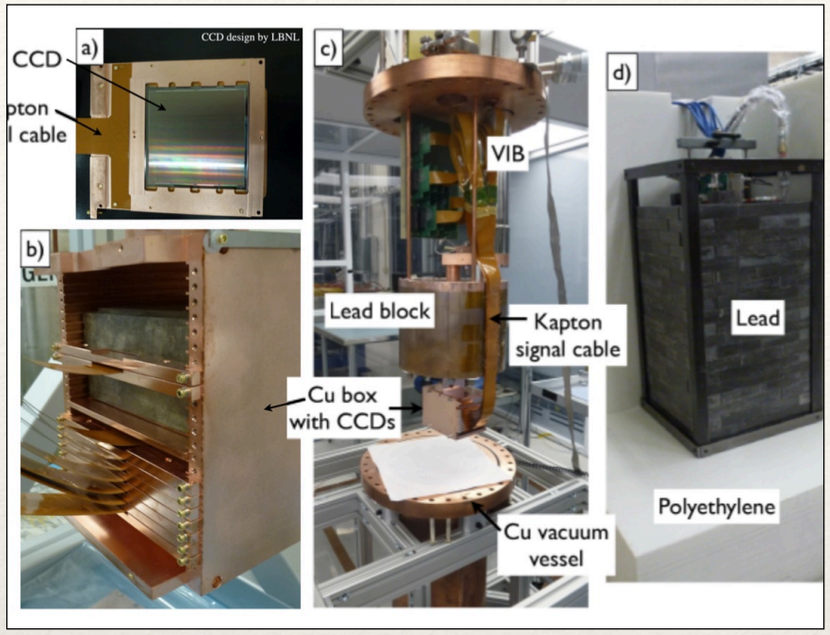
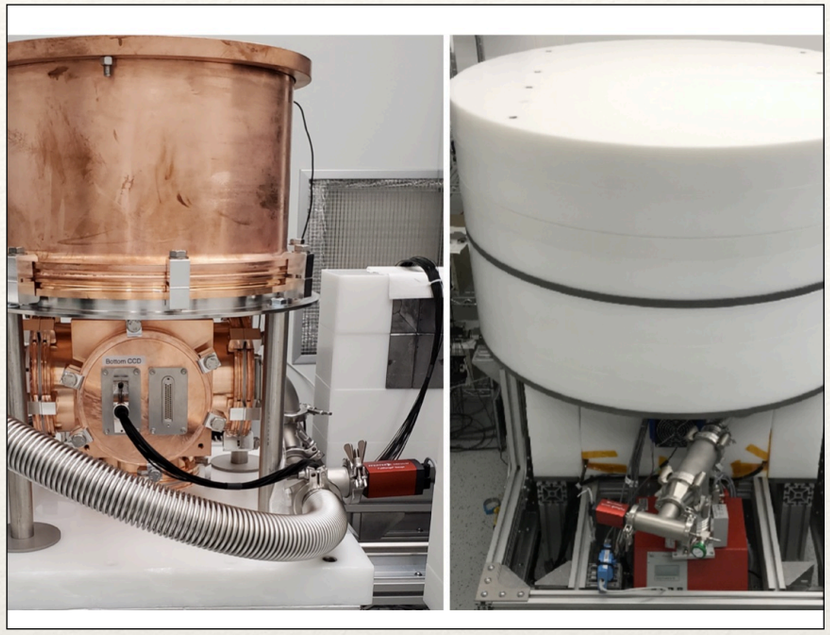
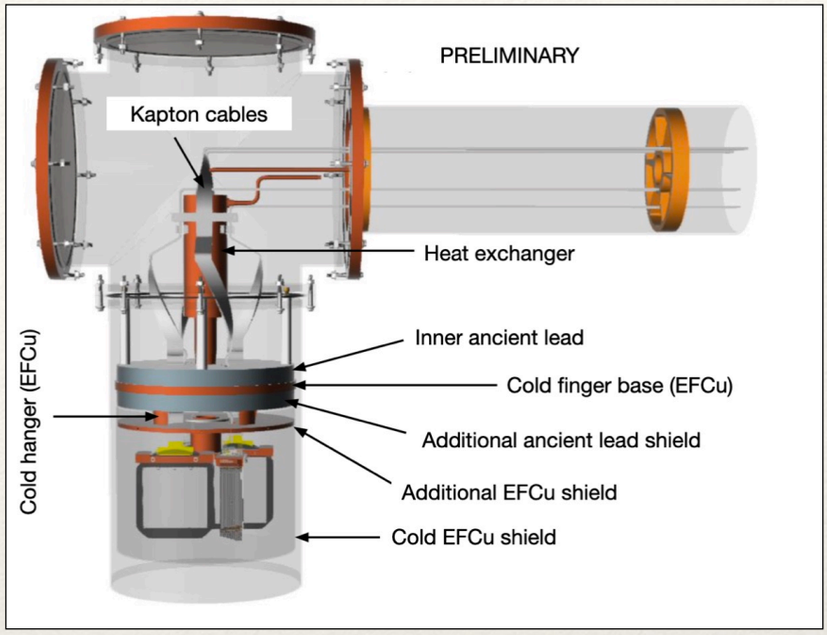
Research team : **C. De Dominicis, R. Gaïor, A. Letessier Selvon, P. Privitera, J-P. Zopounidis**.



DAMIC @ SNOLAB



La LBC à Modane.



Conception de DAMIC-M

3 experiments with thick CCDs

The DAMIC program

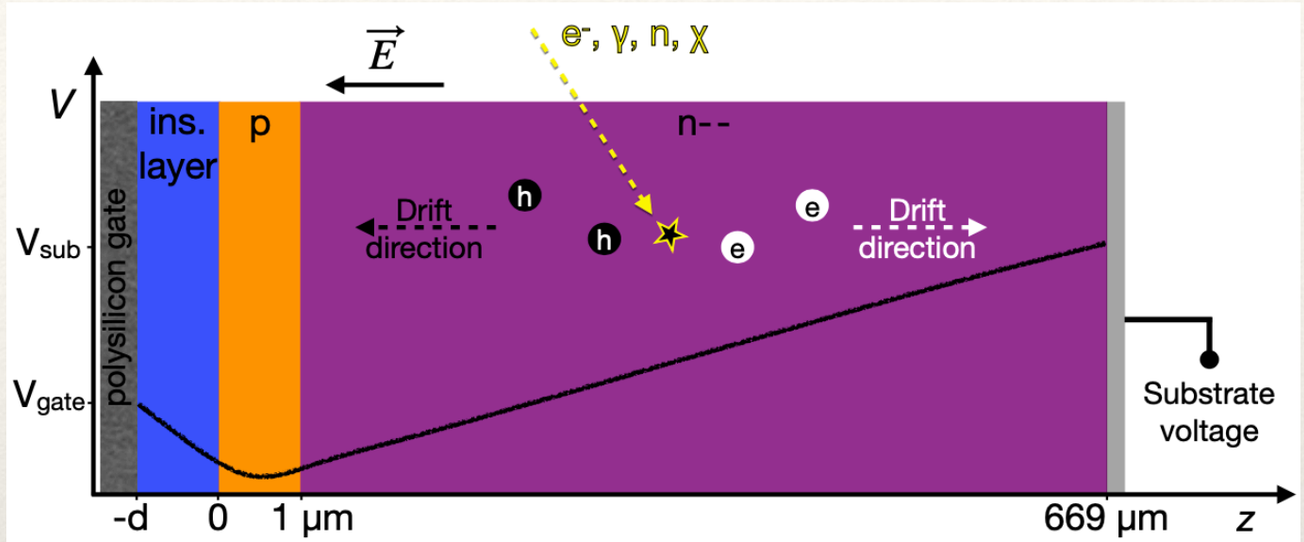
DAMIC@SNOLAB

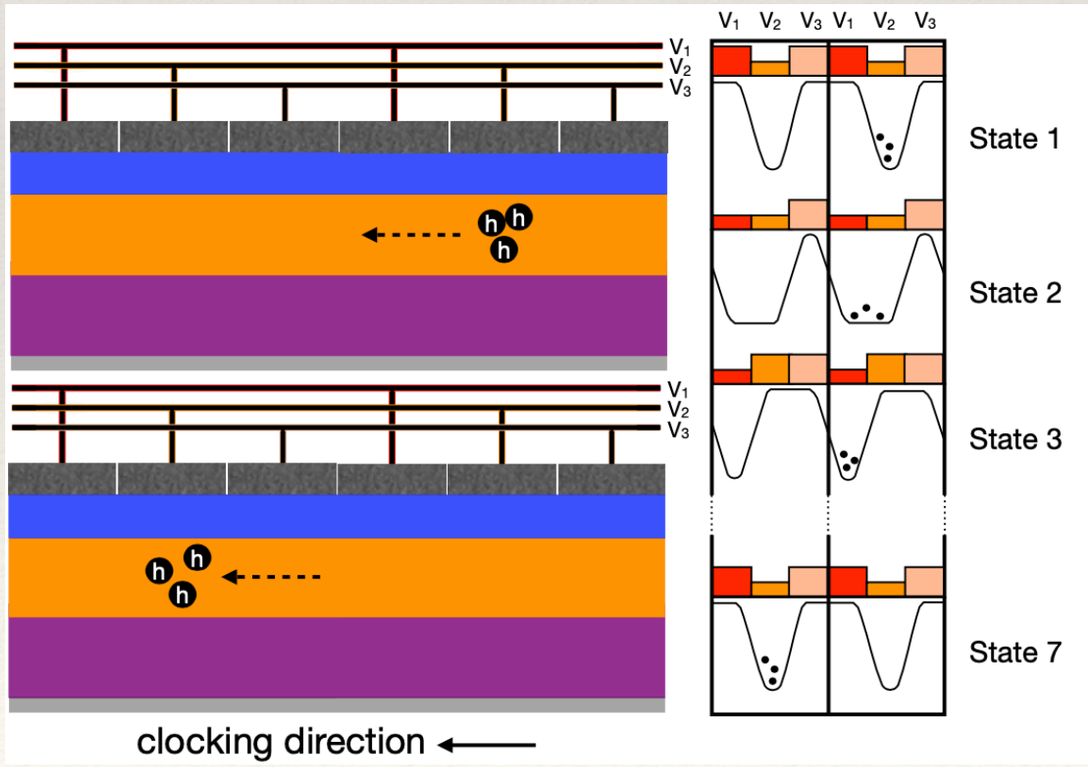
LBC

DAMIC-M

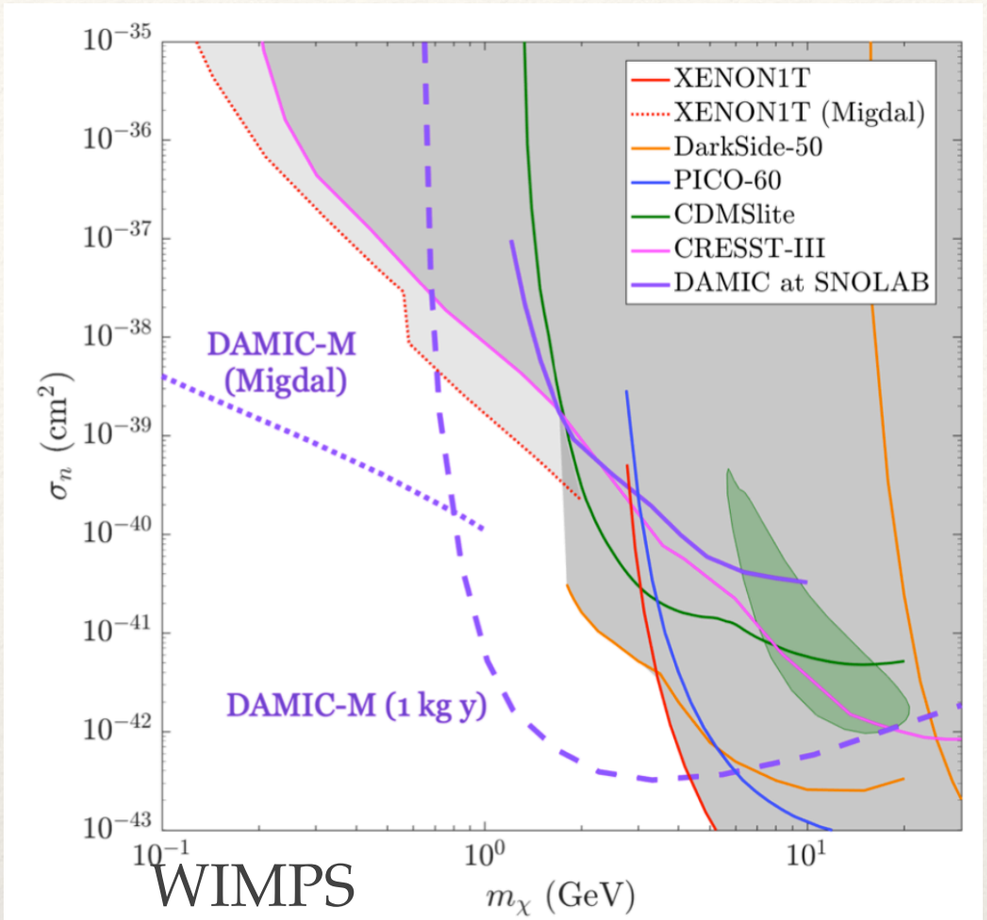
Principle of detection

- Energy deposition by nuclear or electron recoil
- Reading after exposure or continuous
- Cluster search (WIMPS)
- Analysis of charge distribution (dark sector)

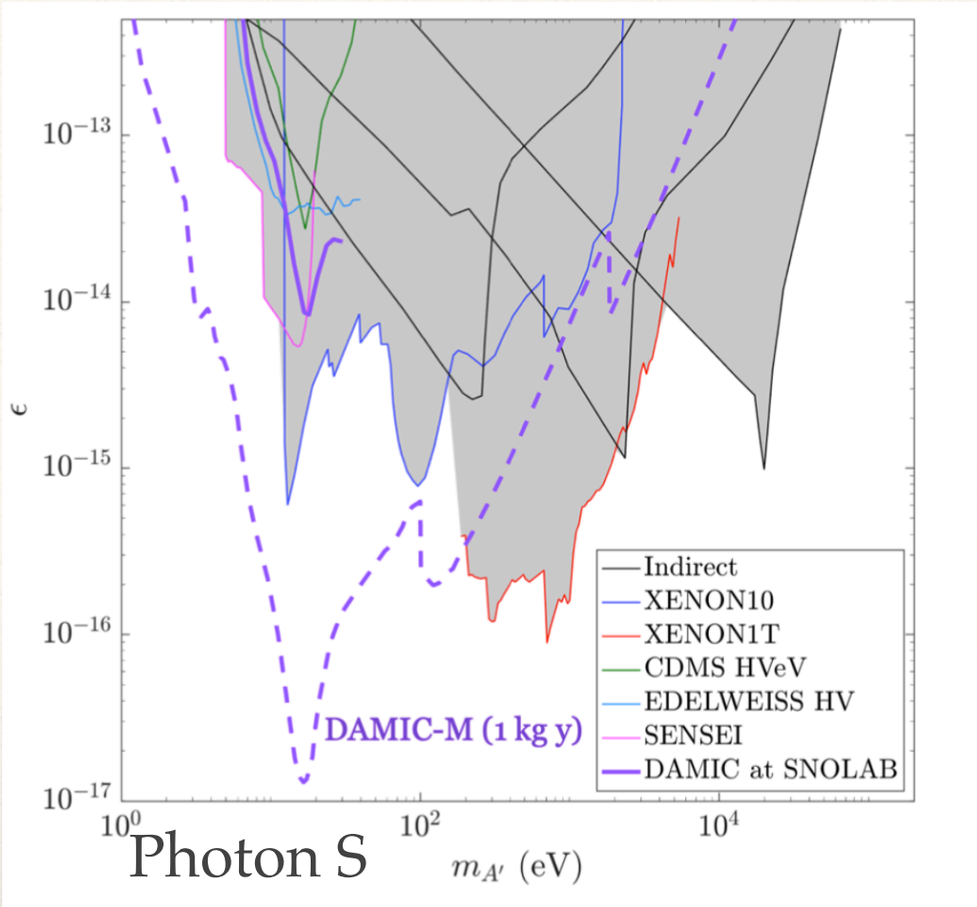




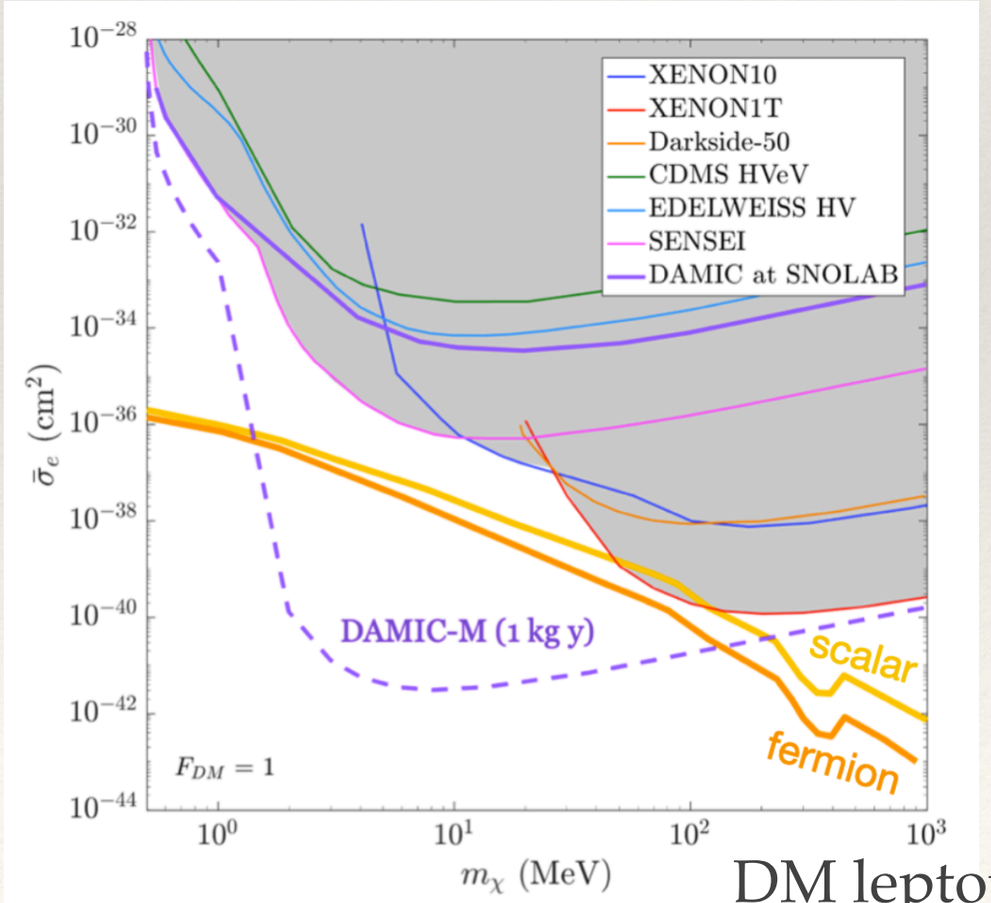
OBJECTIFS

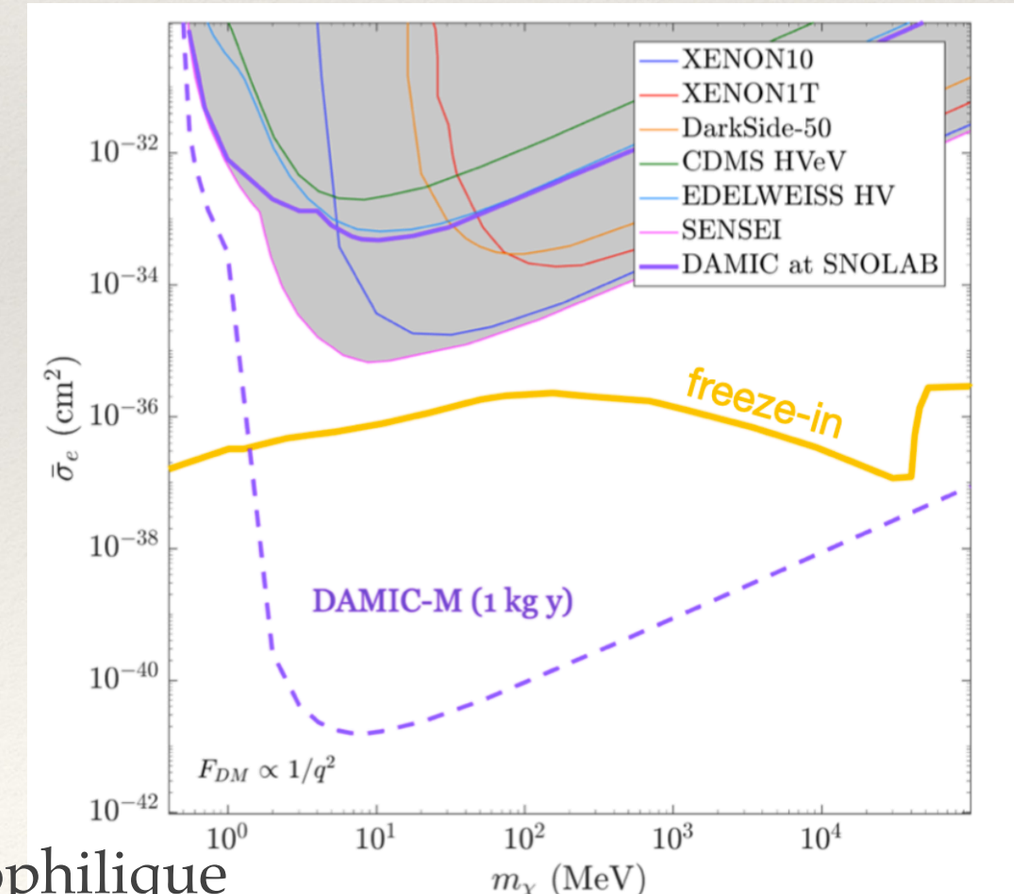


WIMPS



Photon S

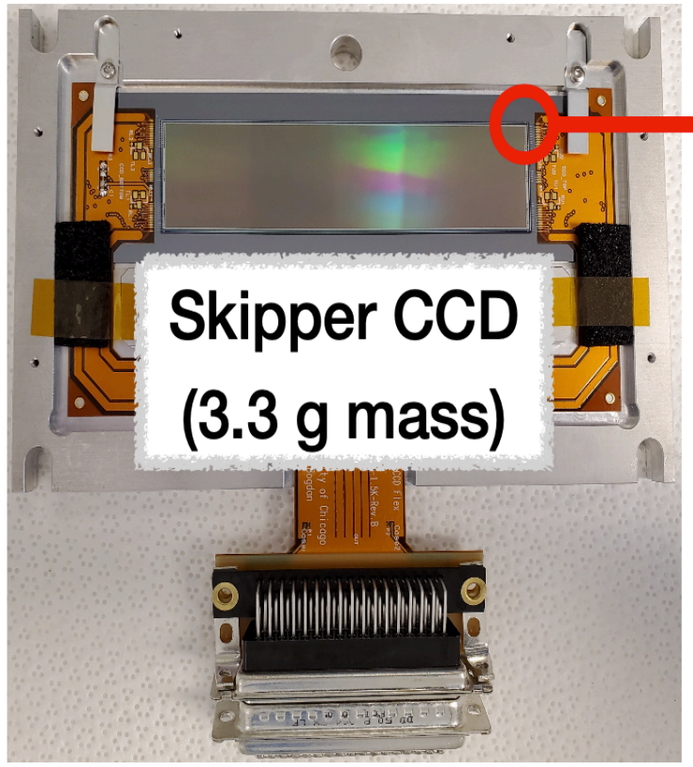


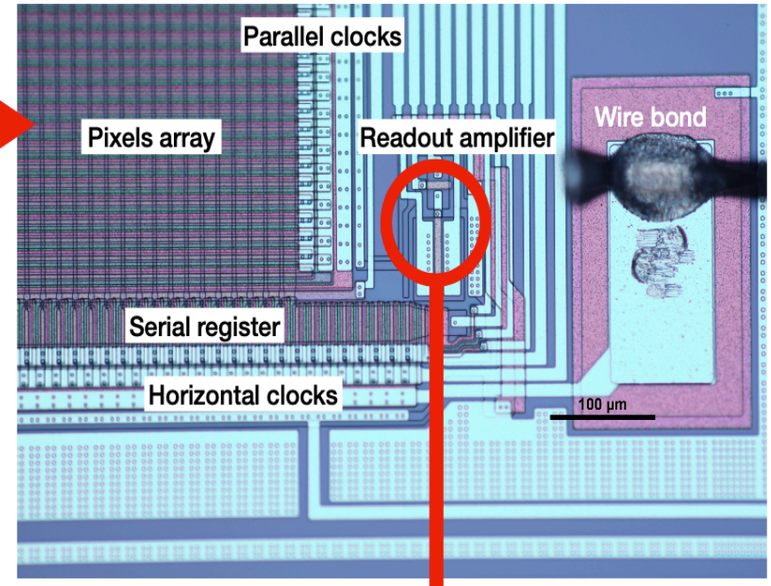


DM leptophilique

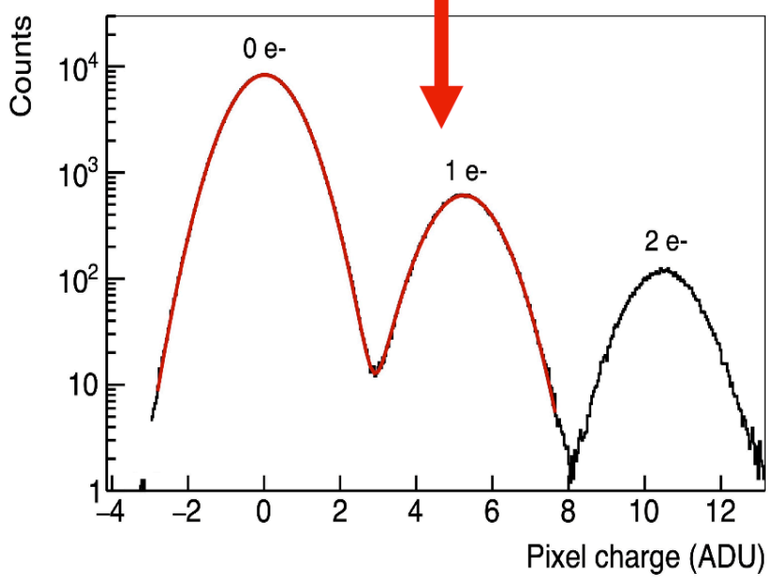
Key points for performance

- Background noise < a few tenths of DRU
- Energy resolution < 1 e-
- Mass ~ 1 kg
- Exposure ~ 1 kg.year



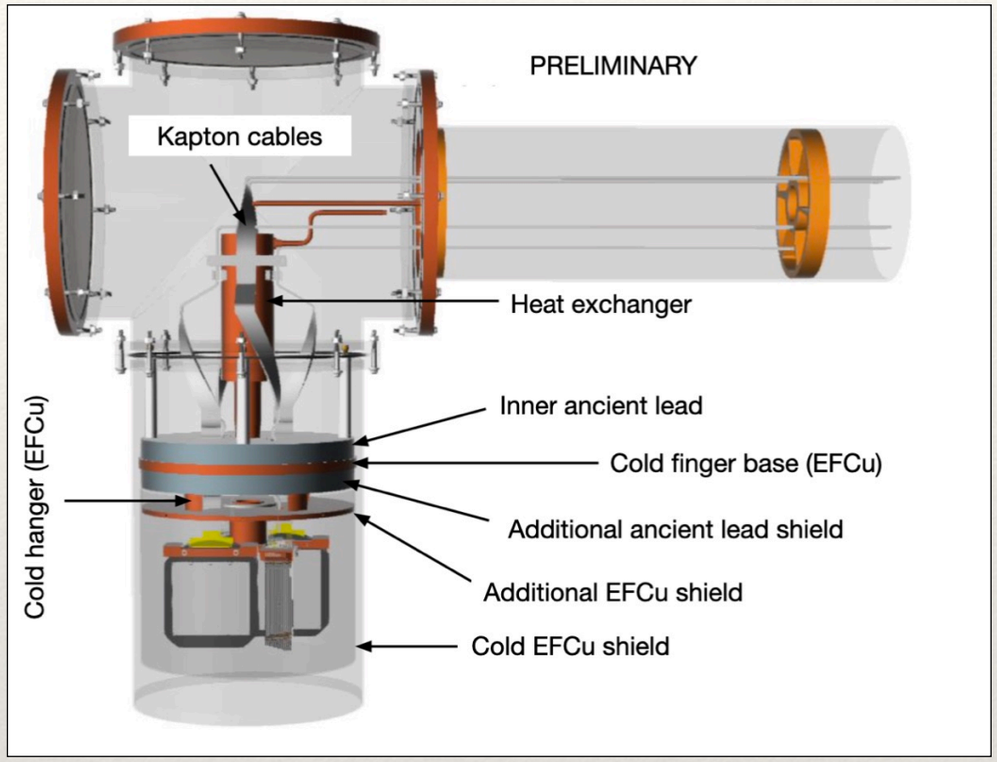


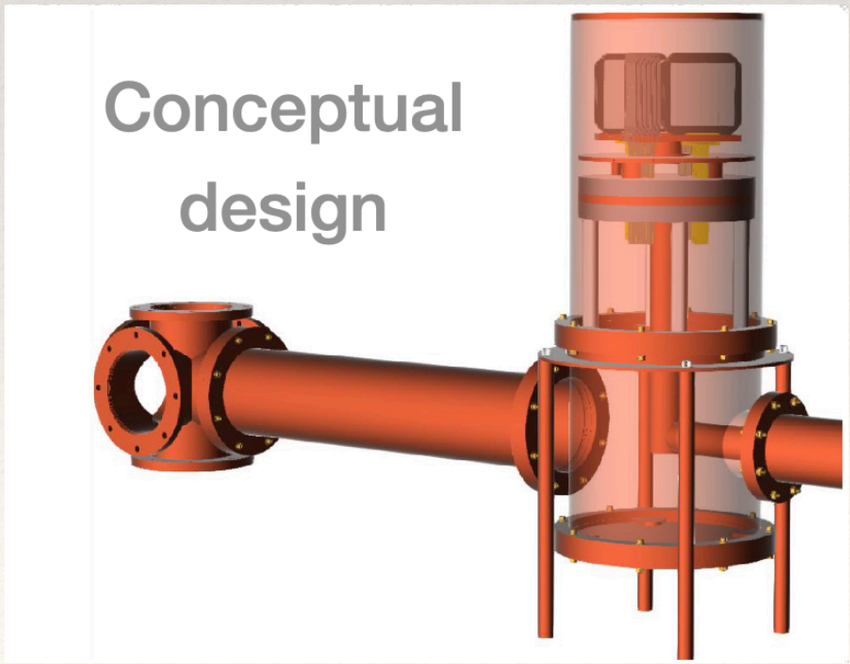
DAMIC-M skipper CCDs measure individual electrons (e^-)



Technical commitments made

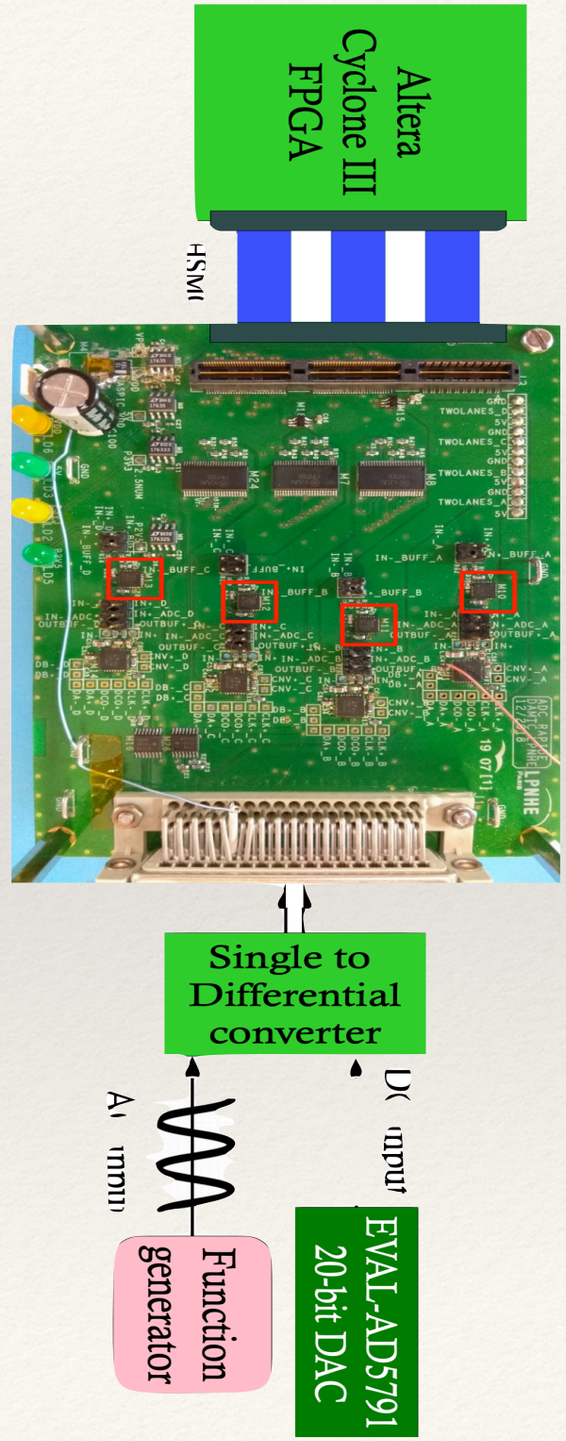
1. Shields (transport + LBC), clean rooms (LPNHE+LSM), cryogenic test benches (3 at the LPNHE)
2. Simulations (detecter optimisation)
3. Cryostat studies
4. The digital conversion card with 4 ADCs of which several versions have been studied and for which the collaboration has chosen the French proposal with an 18-bit ADC of 15 MHz sampling frequency
5. The sequencing firmware, based on that of LSST, the ADC control firmware, the online data processing firmware.
6. The interface middleware with the control board (ACM) for the configuration of sequencing firmware, polarisation voltages and ADC configurations.
7. The acquisition system itself with the control of the 50 CCD modules, image recovery, monitoring, etc.
8. The synchronisation card





FastADC board & firmware

- ADC 18 bit, 15 MHz
  - Proposal of the LPNHE alternative to ADC 20 bits 1.5 Mhz
  - Tested and Qualified at the LPNHE
  - Solution adopted by the collaboration (best resolution)
  - Cards produced in Zurich
  - Reading firmware Zurich/Paris/ Chicago

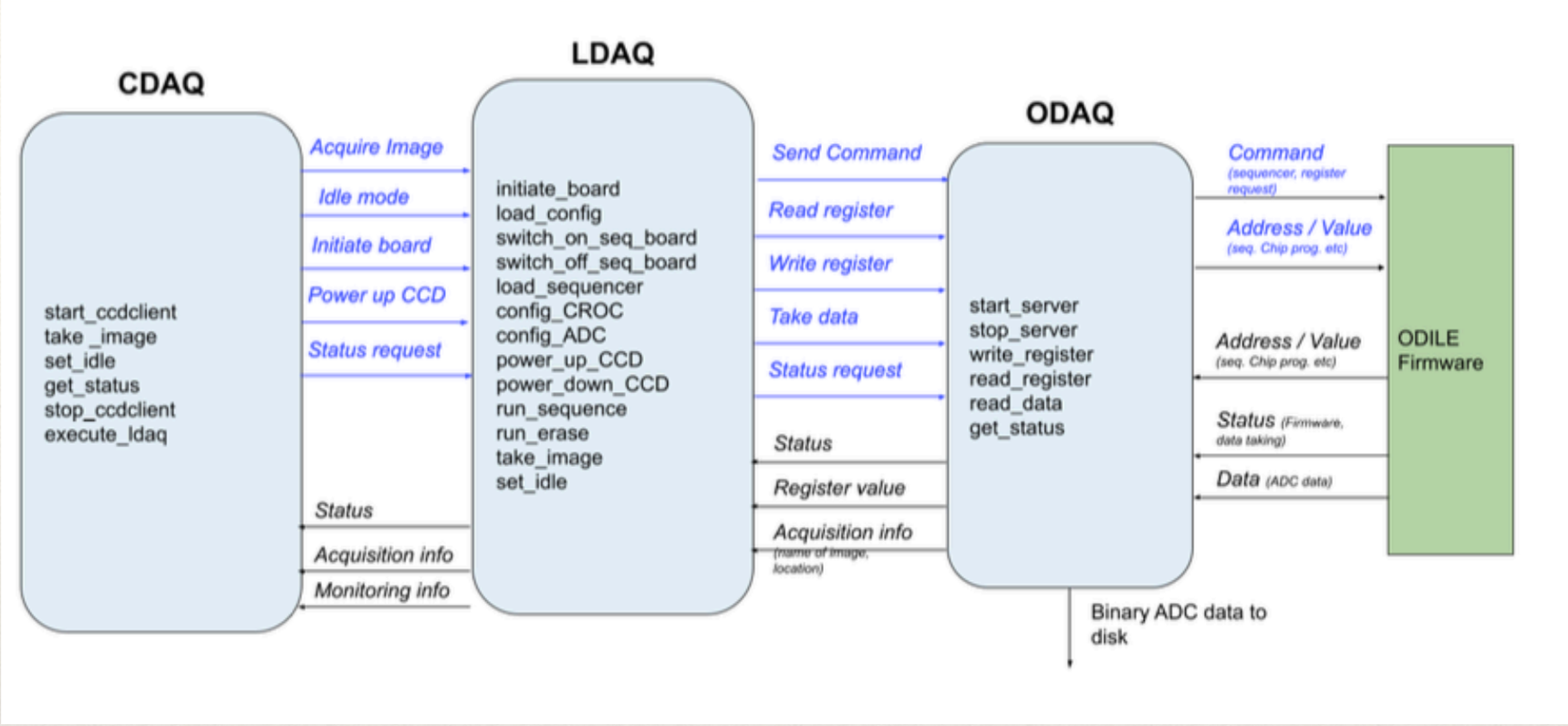


Firmware

```
Vtransfer12:    # One pixel vertical transfer towards both sides 1 and 2
    clocks:     V11, V21, V31, TG1,   V12, V22, V32, TG2
    slices:
        100 ns =  1,   0,   1,   0,     1,   0,   1,   0    # side_1: V2 to V1 to V3 to V2 to V1
        TVpart =  0,   0,   1,   0,     1,   0,   0,   0    # side_2: V2 to V3 to V1 to V2 to V3
        TVpart =  0,   1,   1,   0,     1,   1,   0,   0
        TVpart =  0,   1,   0,   0,     0,   1,   0,   0
        TVpart =  1,   1,   0,   0,     0,   1,   1,   0
        TVpart =  1,   0,   0,   0,     0,   0,   1,   0
        TVpart =  1,   0,   1,   1,     1,   0,   1,   1
    constants: H1L=1, H2L=0, H3L=1, SW1=0, OG1=1, RG1=1, DG1=1,   H1U=1, H2U=0, H3U=1, SW2=0,
    OG2=1, RG2=1, DG2=1
```

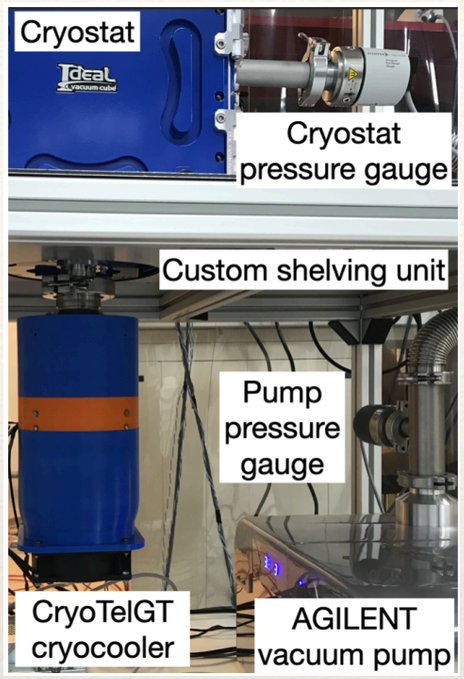
- Sequencing firmware
- Data reduction firmware
- Fast ADC reading firmware

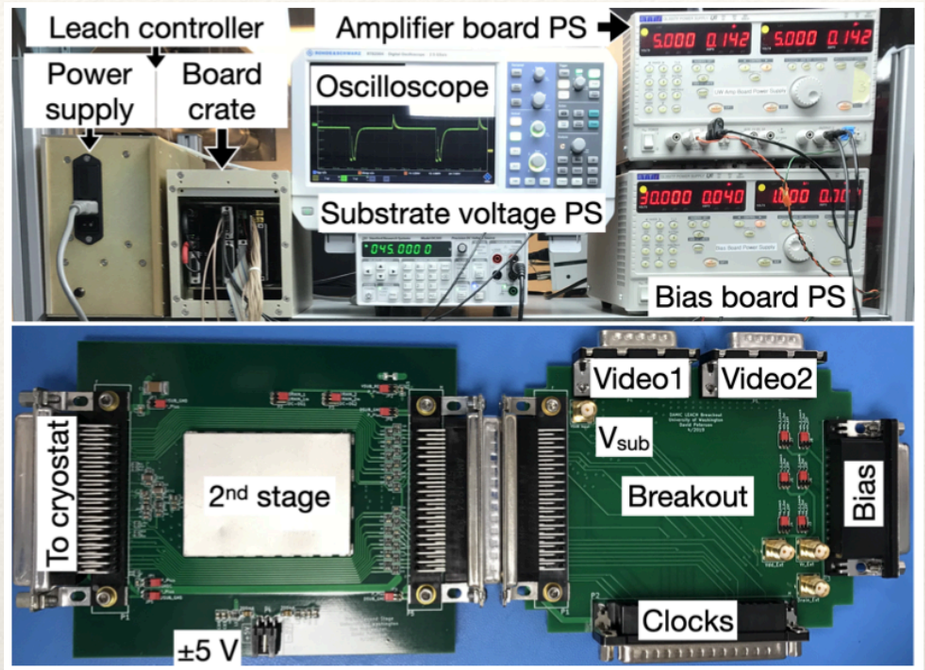
LDAQ & CDAQ

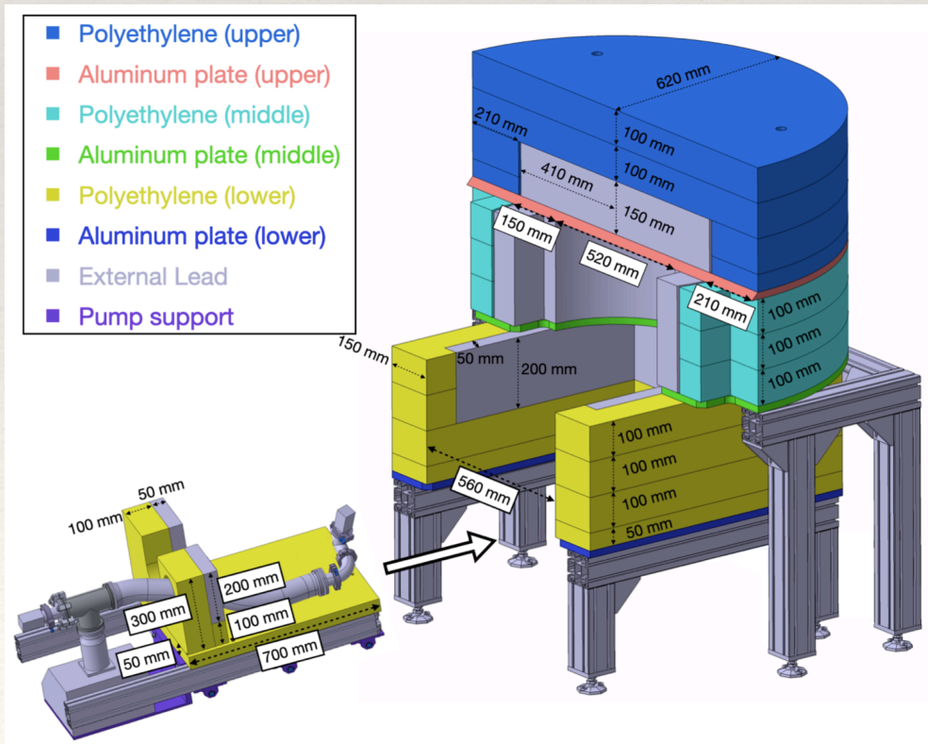


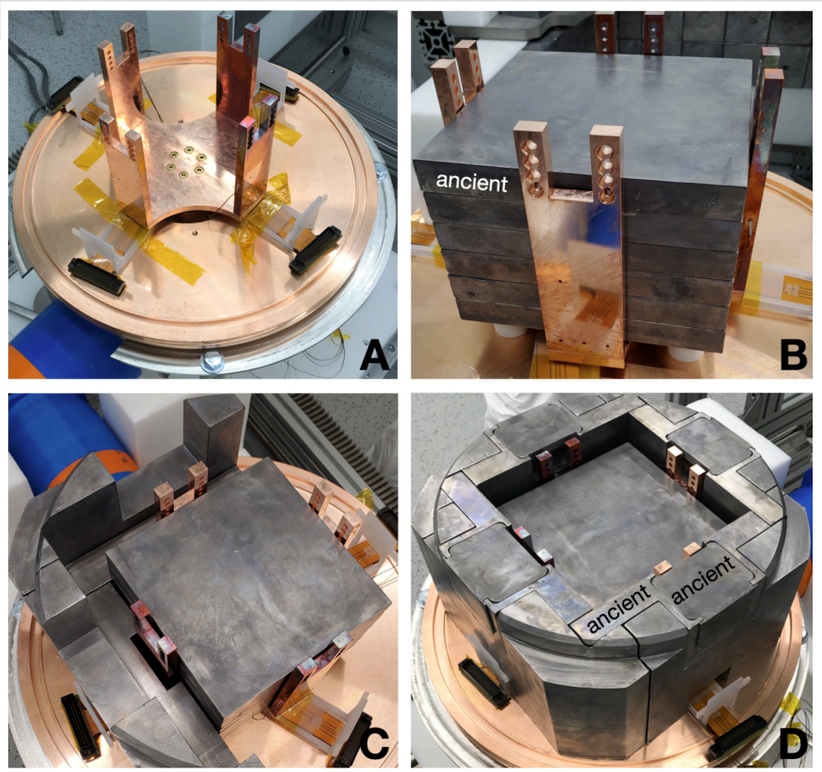
- CDAQ: Central acquisition that controls all LDAQs
- LDAQ: Local acquisition, allows the configuration of electronics and sequencer
- ODAQ: Acquisition Odile/ACM, a communication server that manages exchanges with firmwares via Ethernet.

Test benches and LBC









Some scientific results

- With the skipper CCDs
- With the LBC

Compton studies

Phys. Rev. D 106, 092001

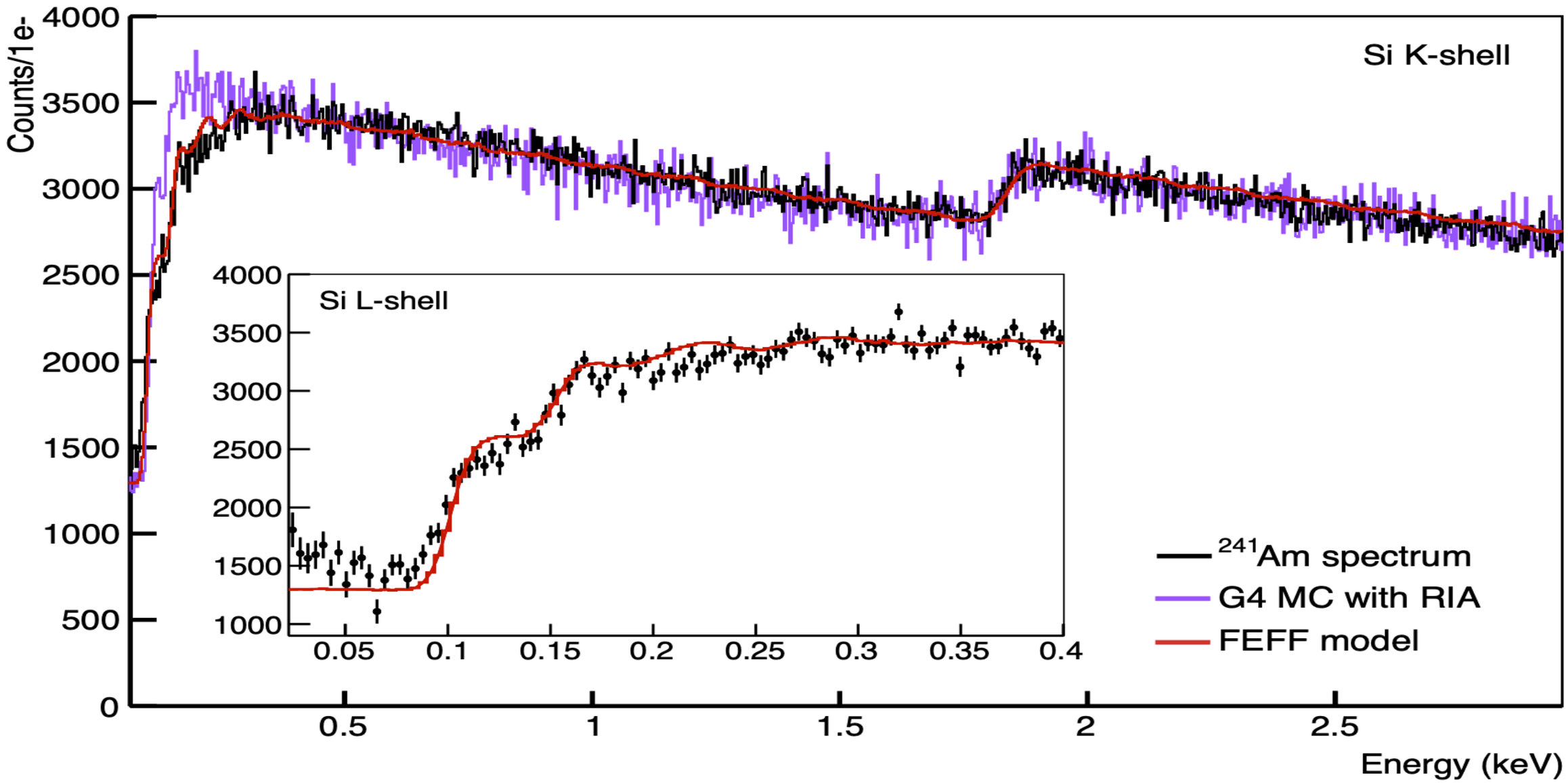
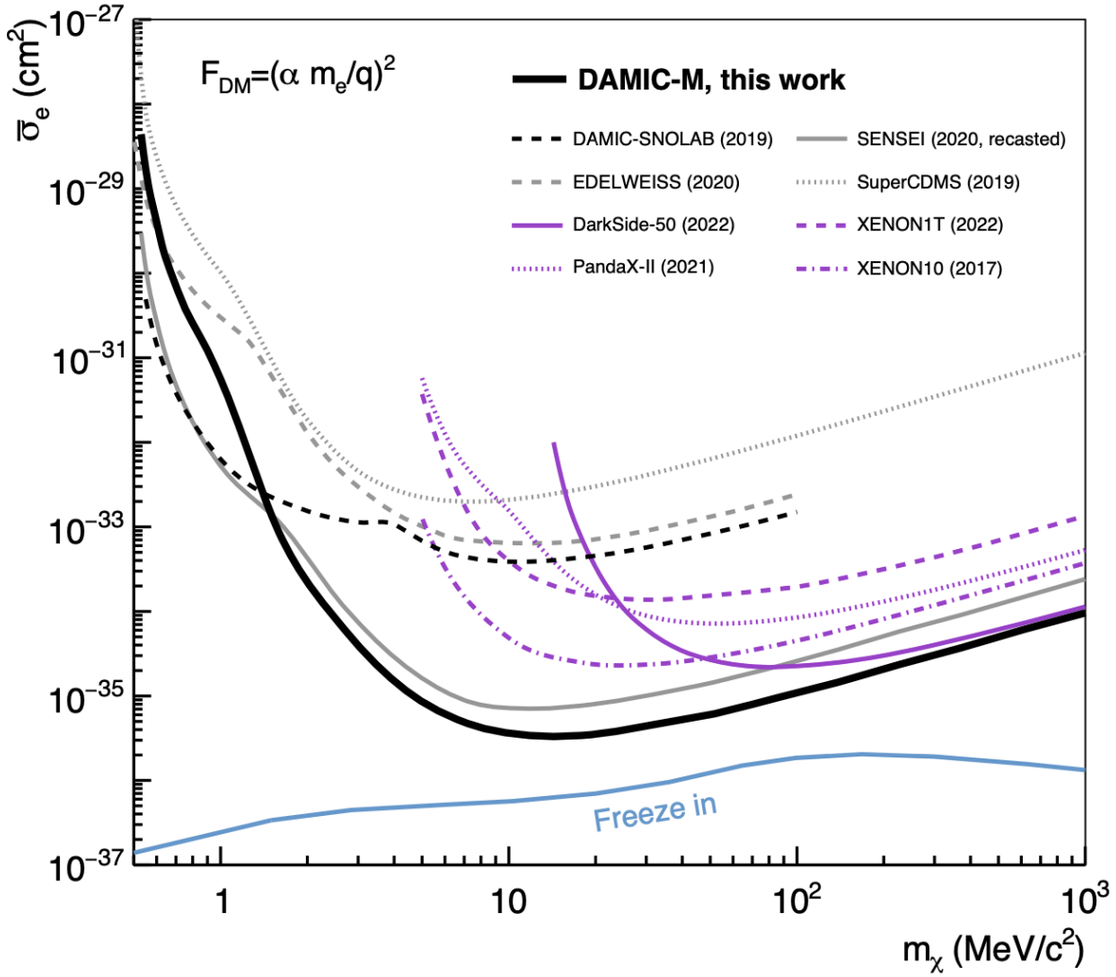


FIG. 10. The measured ^{241}Am Compton spectrum (black) from the 23 eV detection threshold to 2.1 keV. The K-step is observed at 1.8 keV. The GEANT4 simulated spectrum (purple) that is based on the relativistic impulse approximation is also shown. In red is the *ab initio* calculation from the FEFF code, with detector response taken into account. The inset shows the data comparison to the FEFF prediction in the L-shell energy range.

LBC leptophilic limits

Phys. Rev. Lett. 130 171003



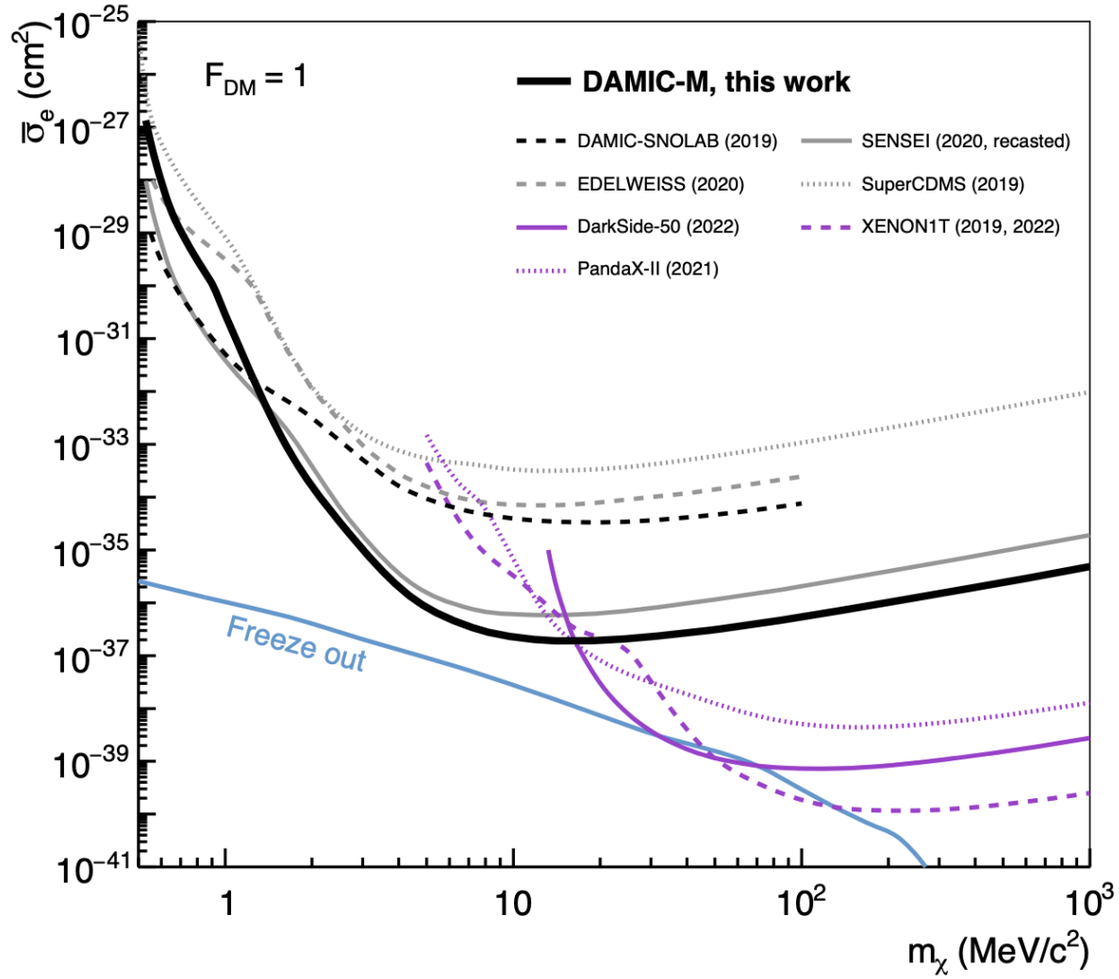
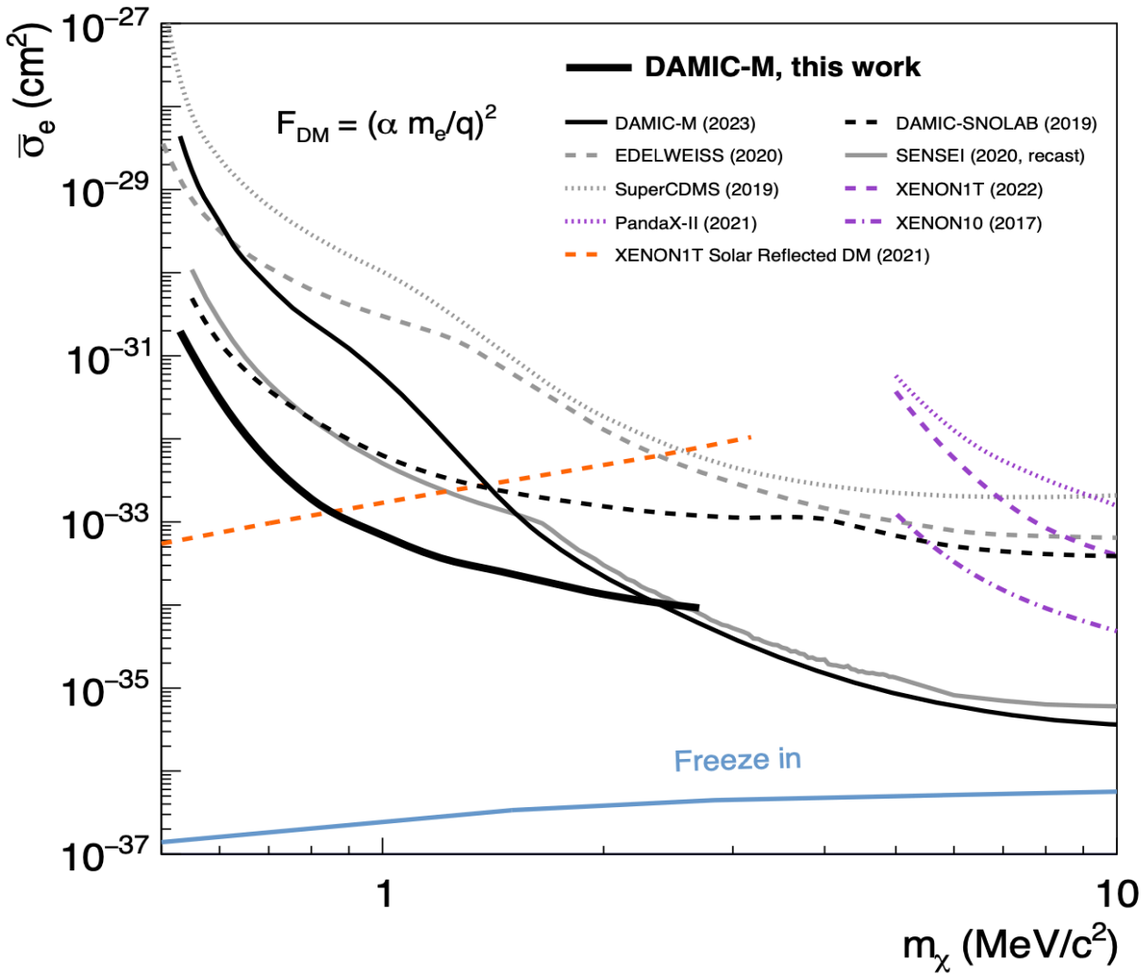


FIG. 3. DAMIC-M 90% C.L. upper limits (solid black) on DM-electron interactions through a ultra-light mediator (left) and heavy mediator (right). Also shown are current best direct-detection limits from other experiments, DAMIC-SNOLAB [35] (dashed black), SENSEI [20] (solid gray), EDELWEISS [36] (dashed gray), SuperCDMS [37] (dotted gray), DarkSide-50 [38] (solid violet), XENON1T combined result from [39, 40] (dashed violet), PandaX-II [41] (dotted violet), and a limit obtained from XENON10 data in Ref. [42] (dash-dotted violet). Theoretical expectations assuming a DM relic abundance from freeze-in and freeze-out mechanisms are also shown in light blue [11].

LBC leptophilic limits
Daily modulation analysis

https://arxiv.org/abs/2307.07251



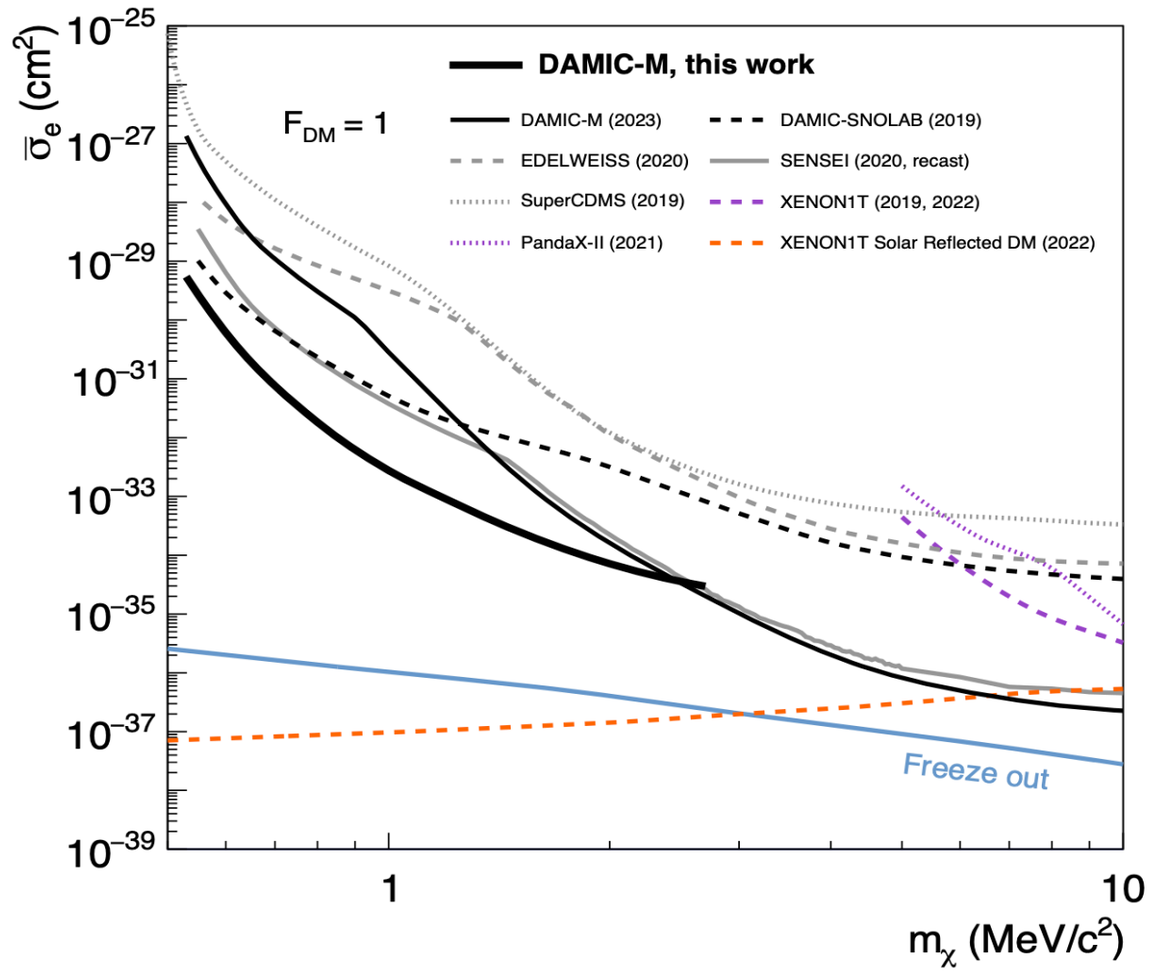


FIG. 4. DAMIC-M 90% C.L. upper limits (solid thick black) on DM-electron interactions through an ultralight (left) and heavy (right) dark photon mediator obtained from the daily modulation analysis. Also shown are previous limits from DAMIC-M [16] (solid black) and other experiments: DAMIC-SNOLAB [13] (dashed black); SENSEI [14] (solid gray); EDELWEISS [15] (dashed gray); SuperCDMS [12] (dotted gray); XENON1T combined result from [66, 67] (dashed violet); PandaX-II [68] (dotted violet); a limit obtained from XENON10 data in Ref. [69] (dash-dotted violet); and a limit obtained from XENON1T data considering "solar reflected DM" (dashed orange) from Ref. [70] (left) and Ref. [71] (right). Theoretical expectations assuming a DM relic abundance from freeze-in and freeze-out mechanisms are also shown in light blue [72].

Scientific training

- 6 PhDs since 2017
  - Joao Da Rocha, DAMIC@SNOLAB, background noise studies, GEANT4 simulations
  - Latifa Khalil, DAMIC-M, electronics for DAMIC-M, ADC qualification
  - Ariel Matalon, DAMIC, Franco-American thesis, installation and qualification of CCDs at the LPNHE, background noise measurement DAMIC@SNOLAB
  - Giorgos Papadopoulos, DAMIC-M, DAMIC-M electronics, CROD qualification, DCA, CABAC
  - Michelangelo Traina, DAMIC-M, LPNHE test benches, LBC installation and analysis
  - Lounes Iddir, Electronics and low background noise reading of CCDs

Work Plan & Perspectives

- Electronics test with the DAQ - 2023
- Qualification of CCD and packaging -2024
- Installation DAMIC-M 2024
- Data taking 2025-2026, 1kg.year of exposure
- Scientific analyses and publications 2026-2028
- Oscura? 2024…

- From September 2024 the scientific team will be greatly reduced due to the end of the ERC program
  - ALS(80%), Romain Gaior (decreased to 30%), + 1 year of PhD and 1 year of fixed-term researcher on equity funds