33rd Rencontres de Blois - "Exploring the Dark Universe" - 22nd - 27th May 2022

The DAMIC-M Experiment: Status and First Results

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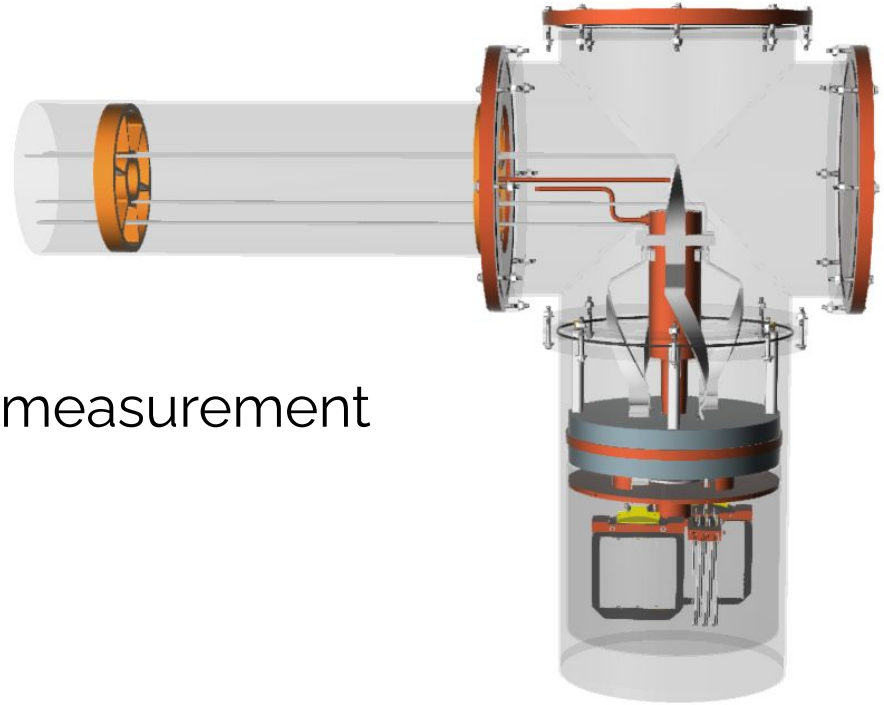
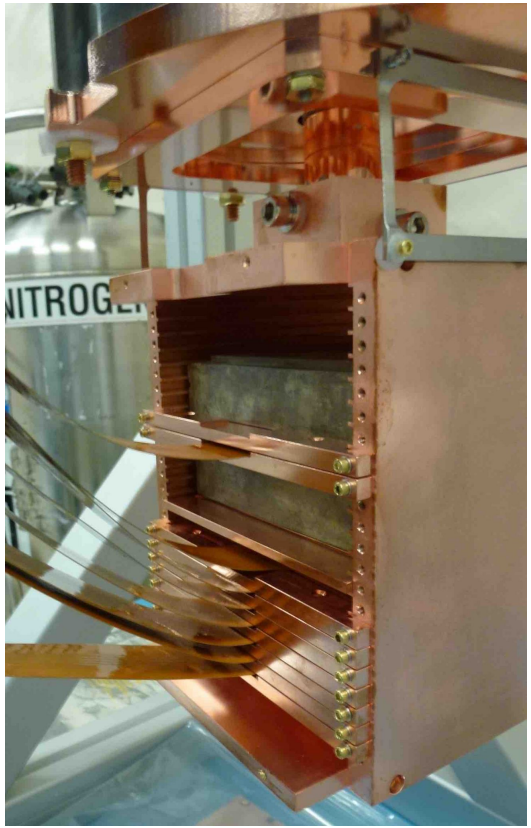
SUBATECH, Nantes Université,IMT Atlantique, CNRS-IN2P3

Outline

- DAMIC@SNOLAB results
- The DAMIC-M experiment
- DAMIC-M calibration: Compton measurement
- Low Background Chamber



DArk Matter In CCDs: DAMIC and DAMIC-M



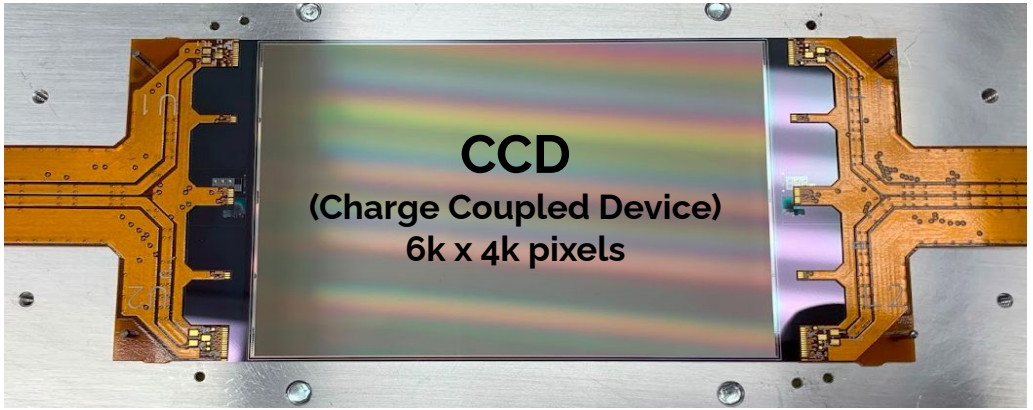
DAMIC@SNOLAB

DAMIC experiment
at SNOLAB (Canada)

DAMIC-M experiment
at LSM (France)

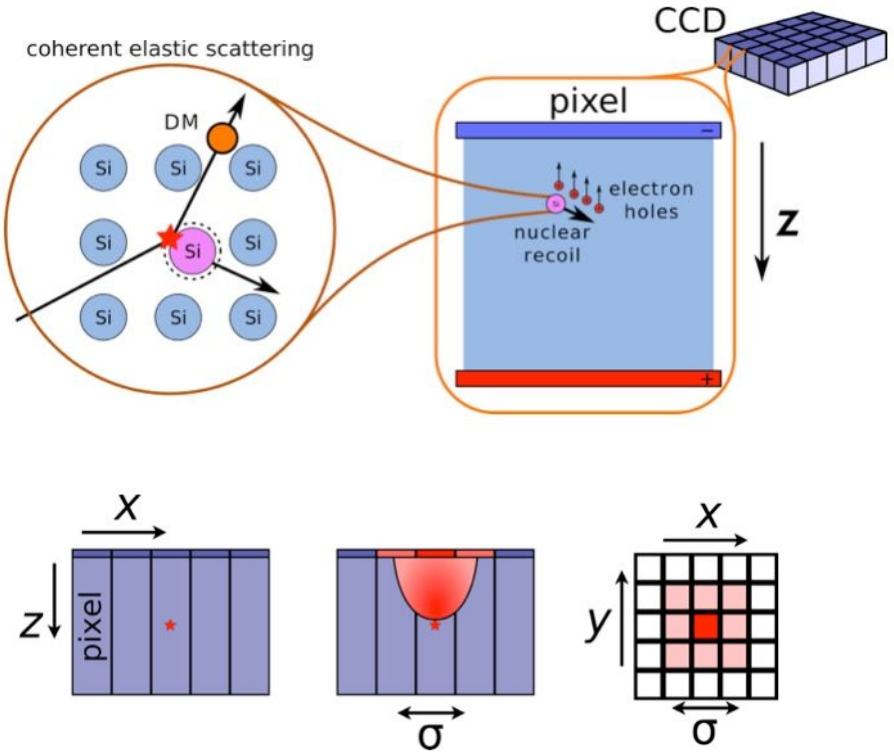
2017 → 2024

Aim: detect **Light DM** (WIMP, Hidden Sector) signals via interaction with Si e- or nucleus in the bulk of **CCDs**



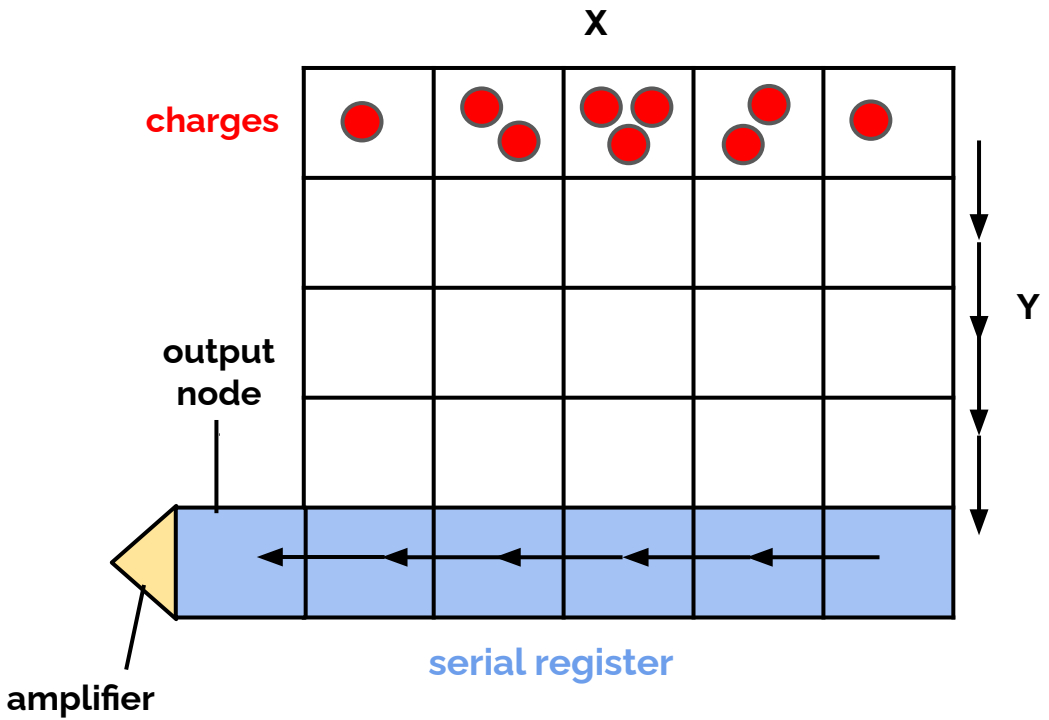
CCDs operation and 3D reconstruction

- CCD: n-type silicon (thickness: 0.675 mm)
- Creation of a depletion region (active volume) in the CCD (full depletion)
- DM interaction causes creation of e-/h pair (3.77 eV required on average) in depletion region
- **3D reconstruction:**
  - z position: diffusion of charges during drift
  - x-y position: Precise spatial resolution (0.015 mm x 0.015 mm pixels)



CCD readout

- charges in a row moved in the following row
- charges in serial register moved pixels by pixels in X direction
- charges in output node read by amplifier
- In DAMIC-M: Skipper Amplifier

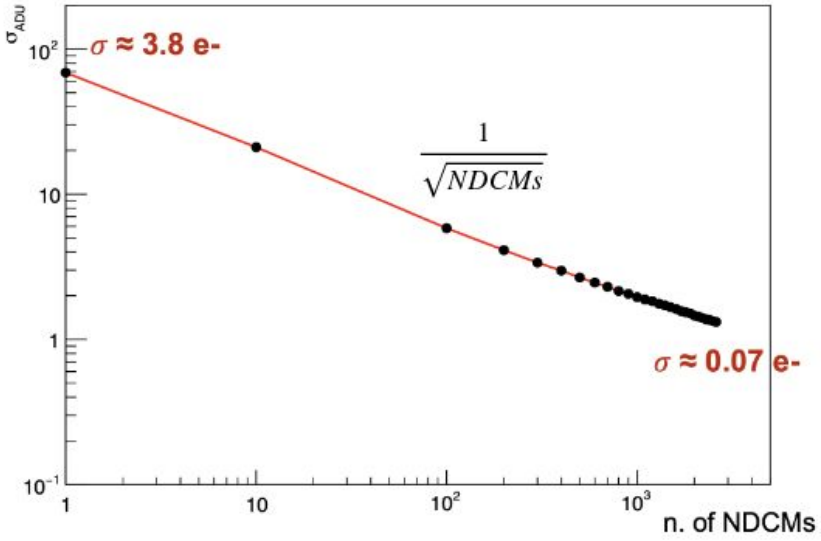


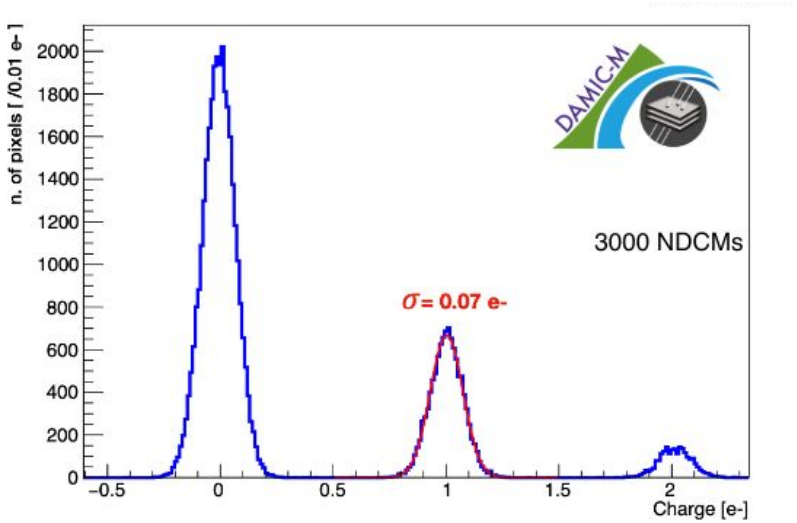
Skipper CCDs for sub-electron resolution

Skips = Non Destructive Repetitive Charge Measurements (NDCMs)

Charges in output node read by amplifier N times

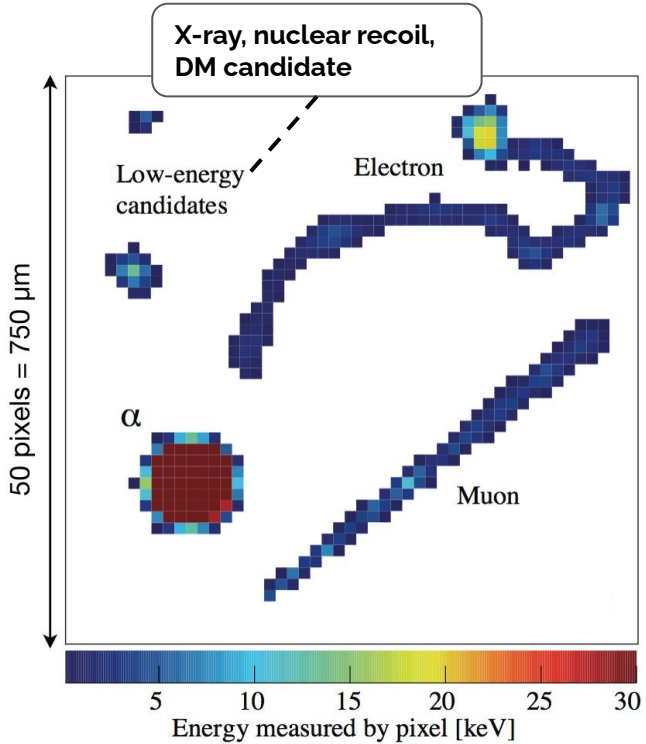
Readout noise decrease by a factor 1/sqrt(N)





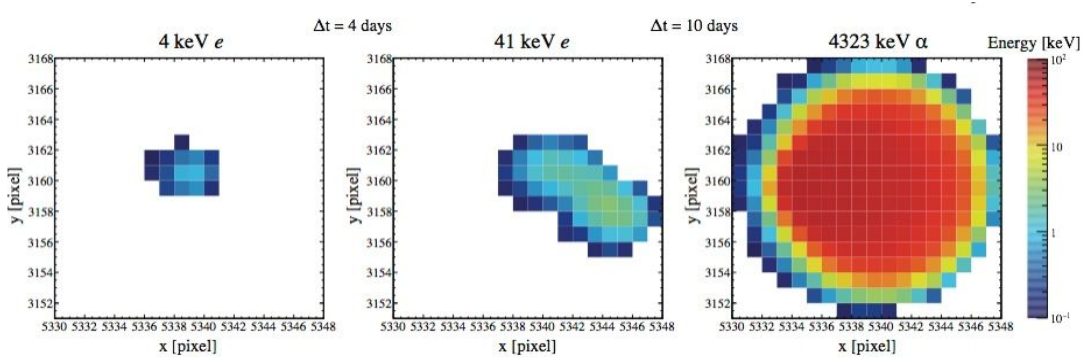
Single electron resolution

Particle identification



Signatures of different ionizing particles in a CCD

Identification of decay chains

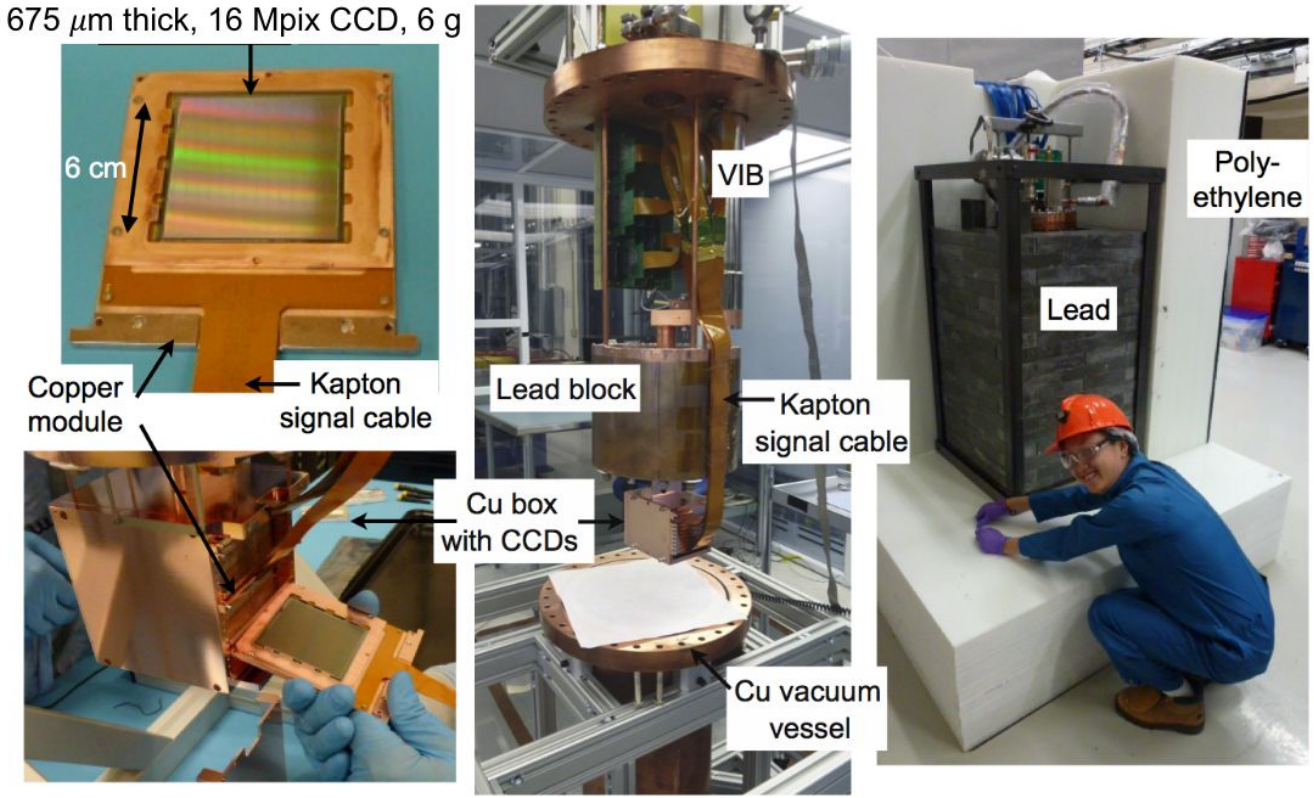


Decay chain of a ^{210}Pb nucleus on the CCD surface [1]:

Pb210 → Bi210 + e- with t1/2= 22y, Q-value = 63.5 keV
Bi210 → Po210 + e- with t1/2= 5d, Q-value = 1.16 MeV
Po210 → Pb206 + α with t1/2 = 138 d, Q-value = 5.41 MeV

[1] A. Aguilar-Arevalo et al. [DAMIC], Measurement of radioactive contamination in the high-resistivity silicon CCDs of the DAMIC experiment, JINST **10** (2015) no.08, P08014, [arXiv:1506.02562 [astro-ph.IM]].

DAMIC at SNOLAB



Detector: 7 CCDs, 4kx4k pixels, 0.675 mm thick, 6g/CCD

Temperature: ~140 K

Location: SNOLAB (Canada)

Resolution: 1.6 e-

Dark current:
< 0.001 e–/pix/day

Background: ~12 d.r.u*

Operation: 2017-2019, upgrade in 2021, data taking ongoing

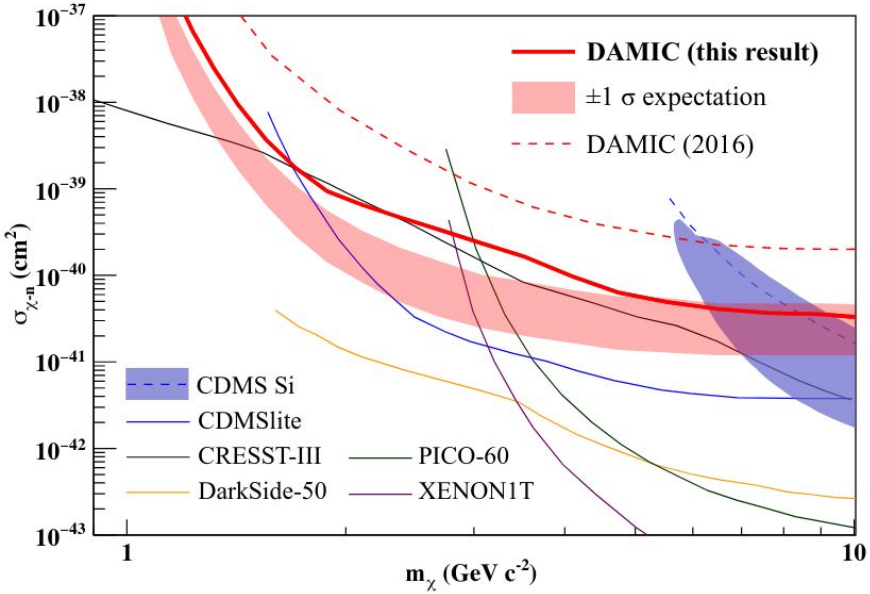
(*) 1 d.r.u = 1 event/kg/day/keV

DAMIC at SNOLAB - WIMP search

Upper limit (90% C.L.) on WIMP-nucleon cross section

Phys. Rev. Lett. 125, 241803 (2020)

exposure: 10.93 kg-days

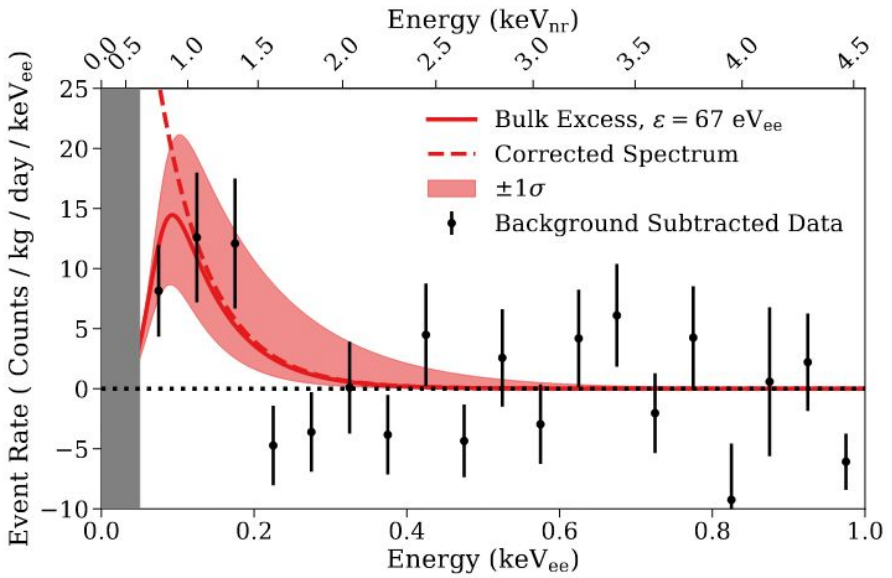


Events excess over background model (3.7 σ):

amplitude s = 17.1 ± 7.6 events and

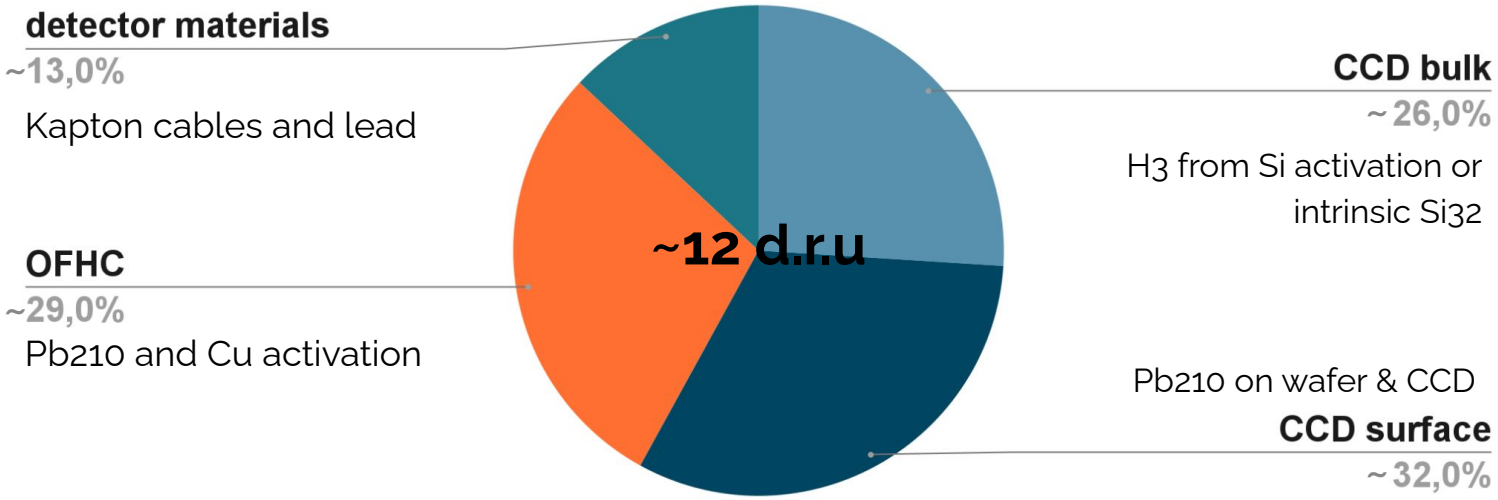
decay energy ε= 67 ± 37 eVee

Phys. Rev. D 105, 062003 (2022)



Unknown origin of the excess. Taking data NOW with skipper CCDs (DAMIC-M CCDs) to understand it.

DAMIC at SNOLAB - Background

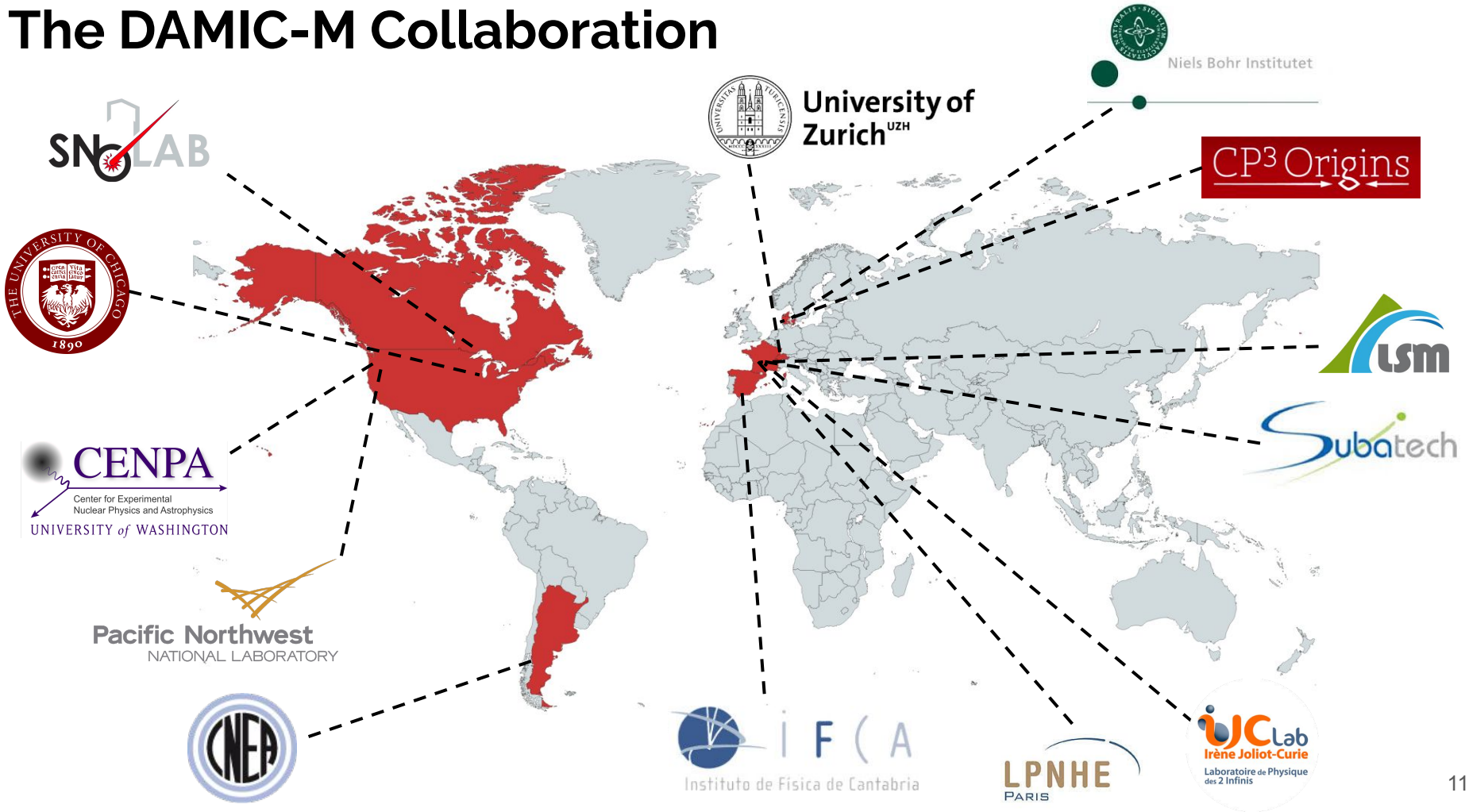


Phys. Rev. D 105, 062003 (2022)

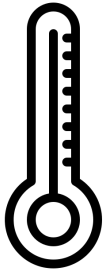
for DAMIC-M better material selection and handling:

- Limit exposure time to cosmic rays (mostly Cu and Si)
- Limit the detector surfaces' exposure to radon (also of Si wafers prior CCD fabrication)
- Remove Si wafer surface (to reduce surface Pb210 and Partial Charge Collection region in backside)
- New materials: Electro-Formed copper, low-background cables

The DAMIC-M Collaboration



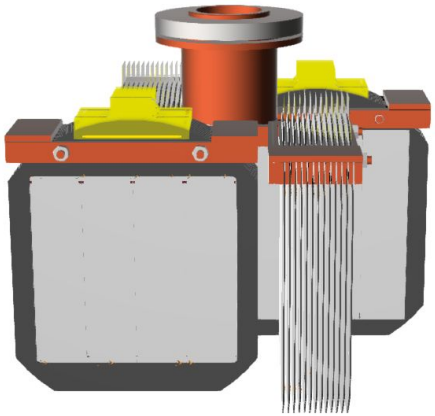
DAMIC-M detector features



~100 K

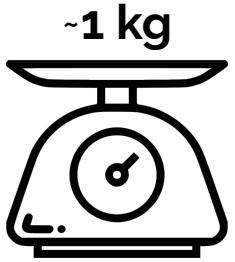
Temperature

DAMIC-M CCD stack



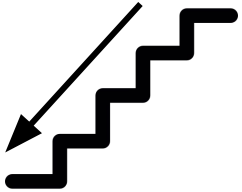
~200 SKIPPER CCDs

6000 pix x 1500 pix



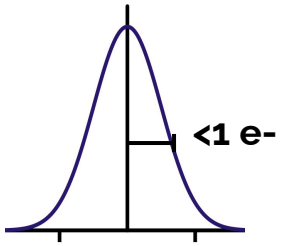
~1 kg

Sensitive Mass



1 d.r.u*

Background Level
O(0.1) d.ru

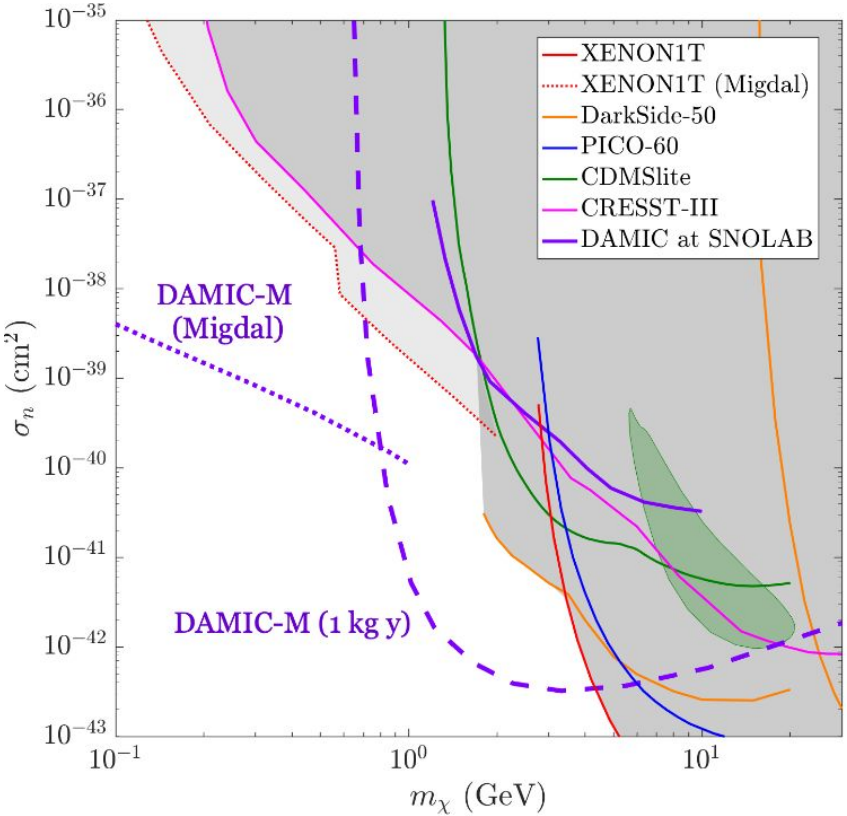


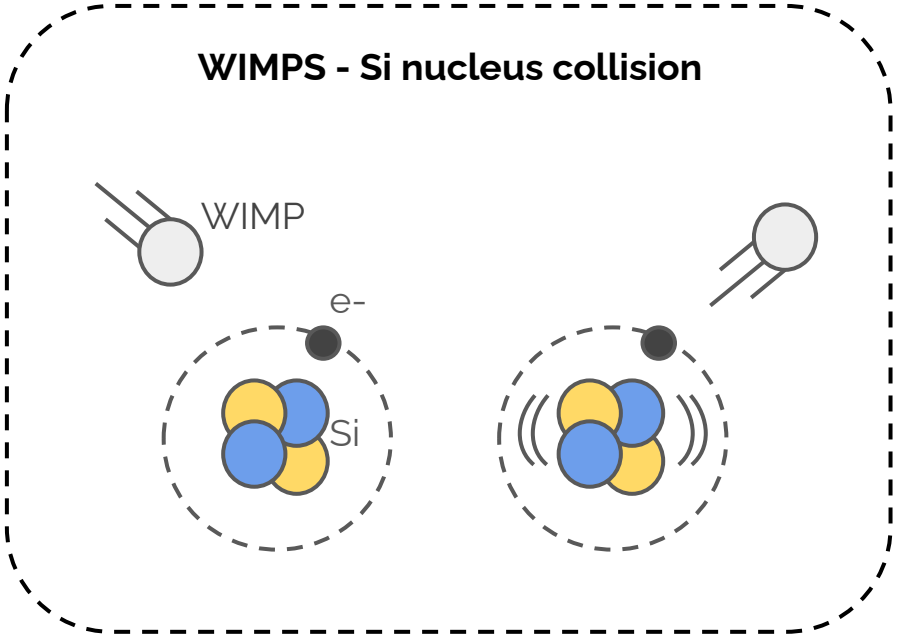
<1 e-

Resolution (readout noise)
~0.1 eV

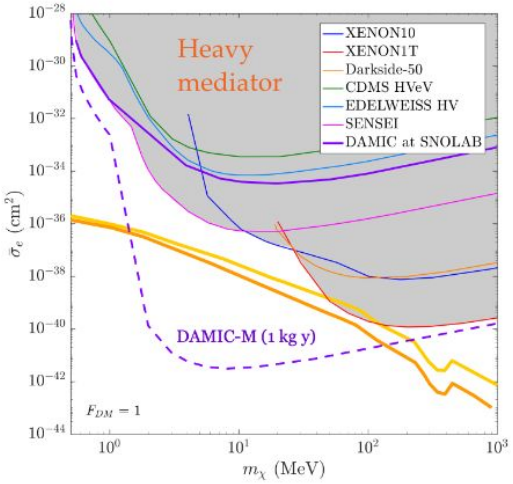
(*) 1 d.r.u = 1 decay/kg/day/keV

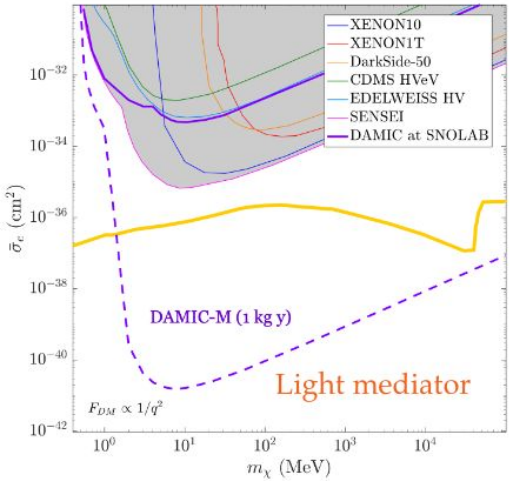
Physics reach - Light WIMPS

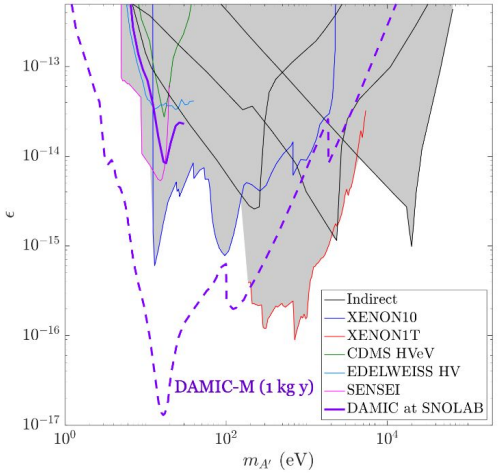




Physics reach - Hidden sector

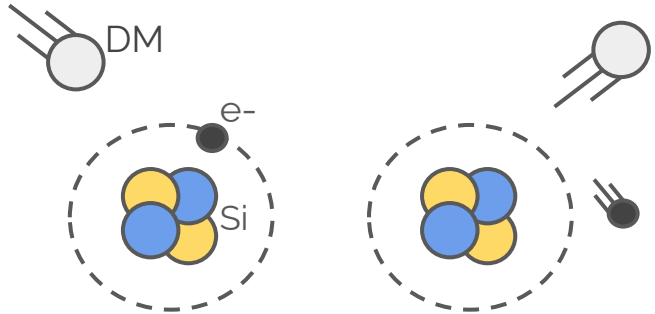




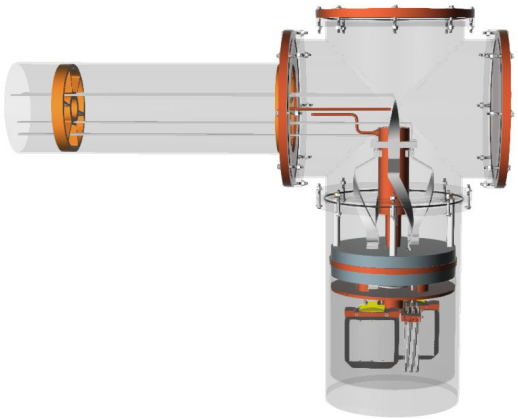


Hidden dark photon

DM - valence e- collision

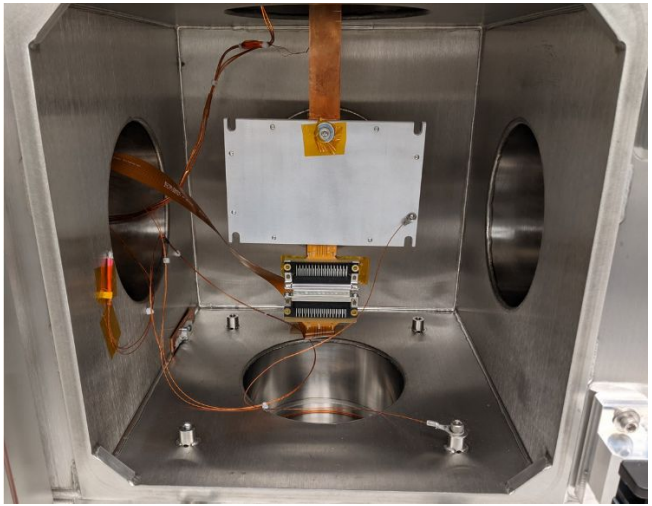


Status of DAMIC-M



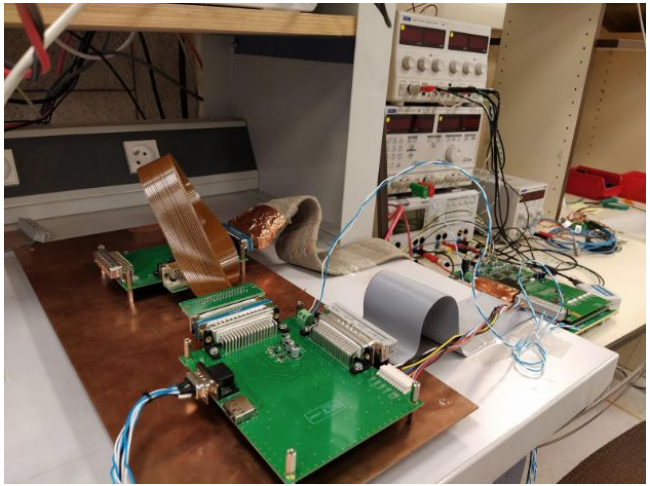
Detector design is under development and some part prototypes are tested

CCD pre-production ongoing

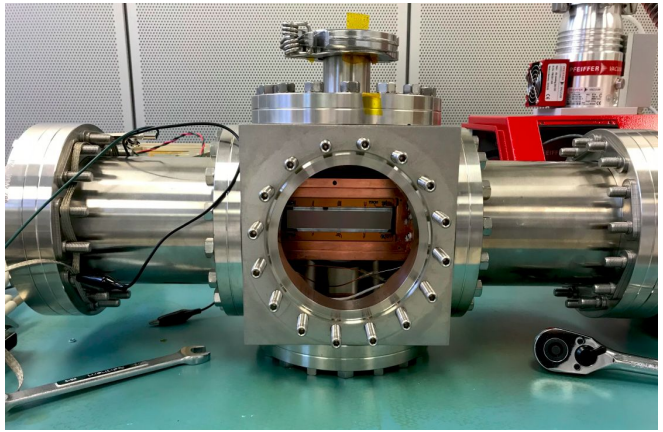


CCD testing ongoing

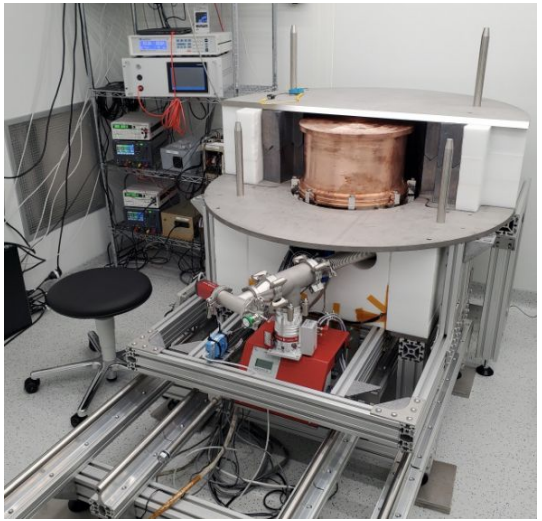
Status of DAMIC-M



Electronics designed, under tests



Calibration with radioactive sources ongoing



Low Background chamber operating at LSM

… DAMIC-M Installation at LSM in 2024

Calibration: Compton measurements

Aim:

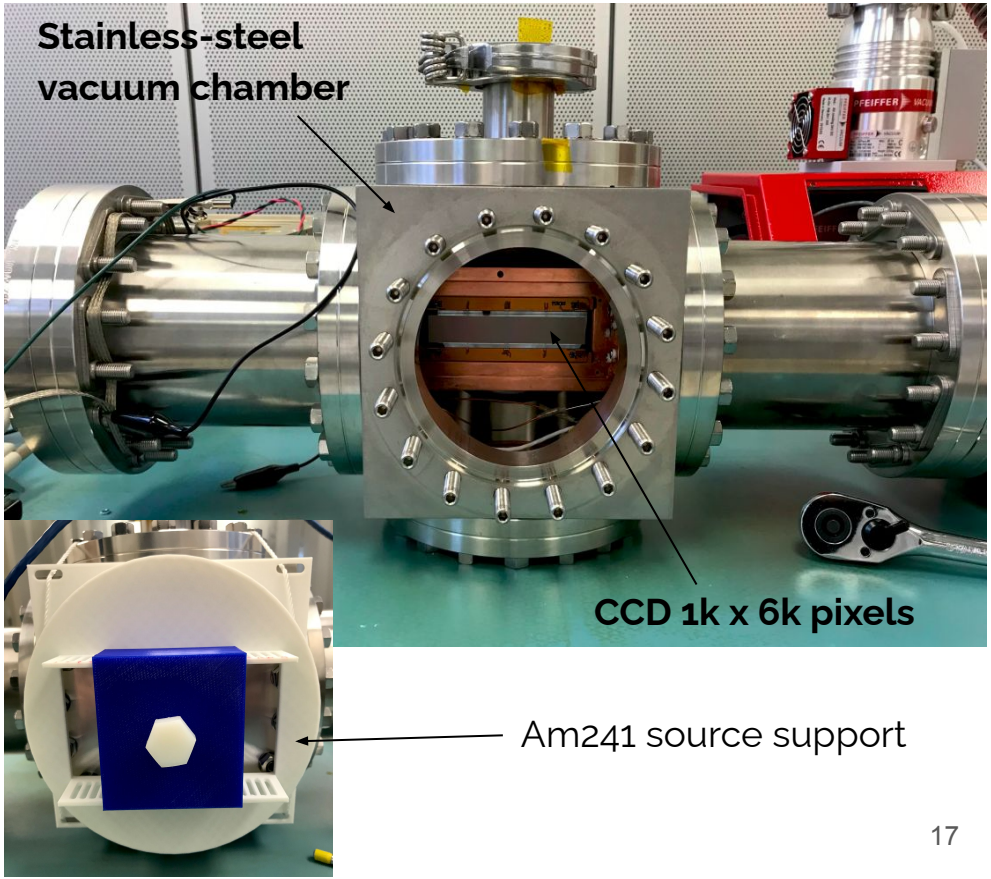
- Parametrize Compton spectrum at low energy (main source of background for DM search)
- Provide detector calibration

Setup:

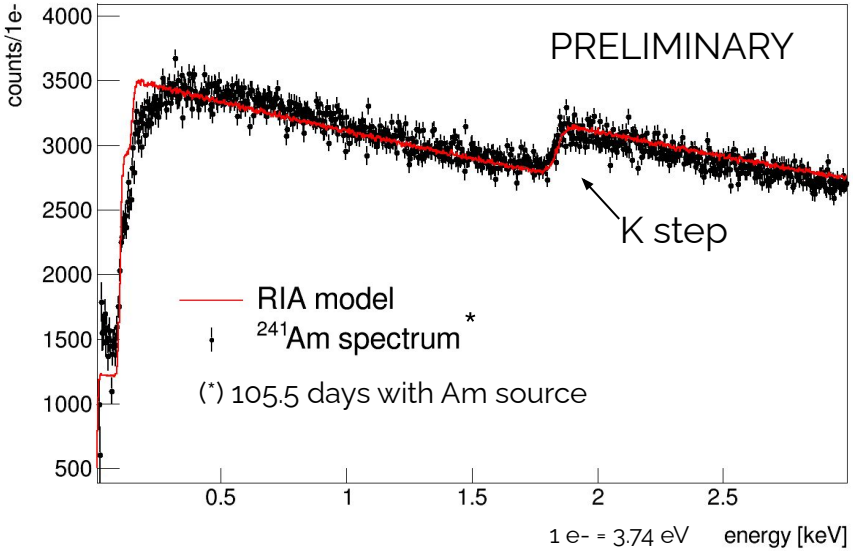
- Temperature: 126 K
- γ source: Am241 (γ Energy: 26.3 keV & **59.5 keV)**
- 1 skipper CCD (1k x 6k pixels)

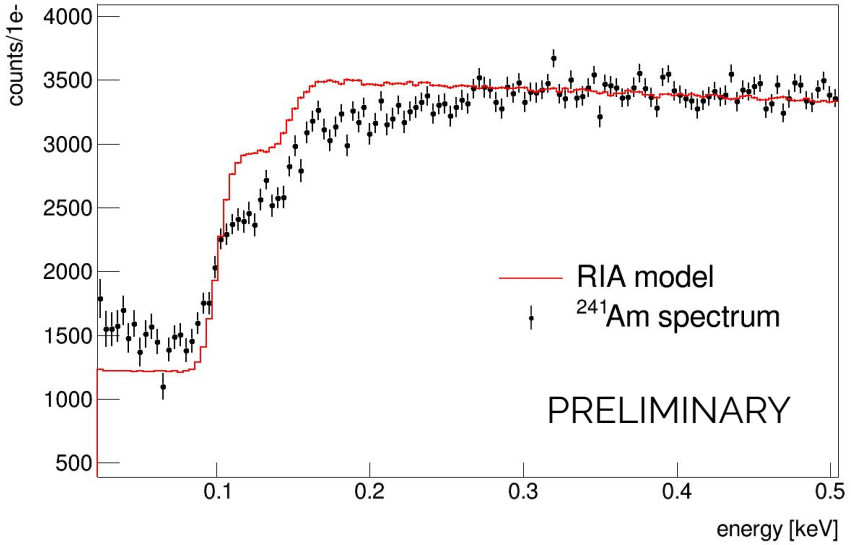
Readout:

- 64 skips
- 0.7 e- readout noise (~2.6 eV)
- binning: 4 pixels x 4 pixels



Compton measurements - Data vs model





Data vs Relativistic Impulse Approximation model:

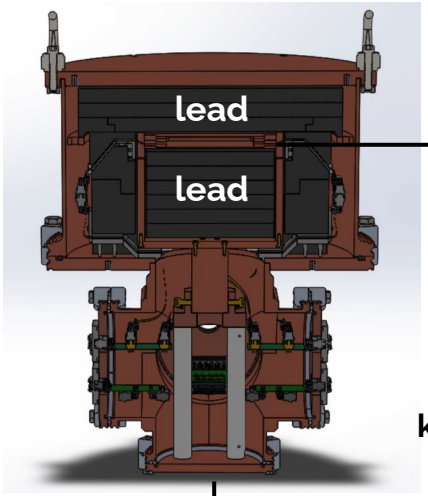
- **agreement in the K-shell region**
- **disagreement at L shell:**
  - softening of the spectrum below 250 eV is observed
  - confirmation of the previous DAMIC measurement

Phys. Rev. D 96, 042002 (2017)

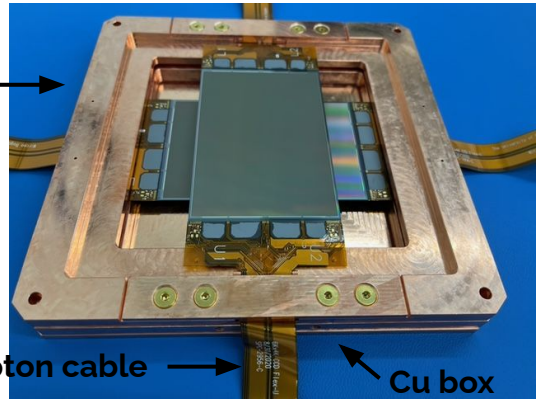
PAPER COMING SOON!

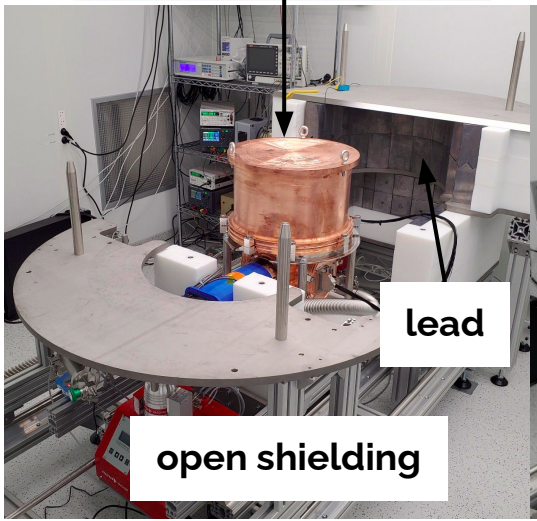
Low Background Chamber

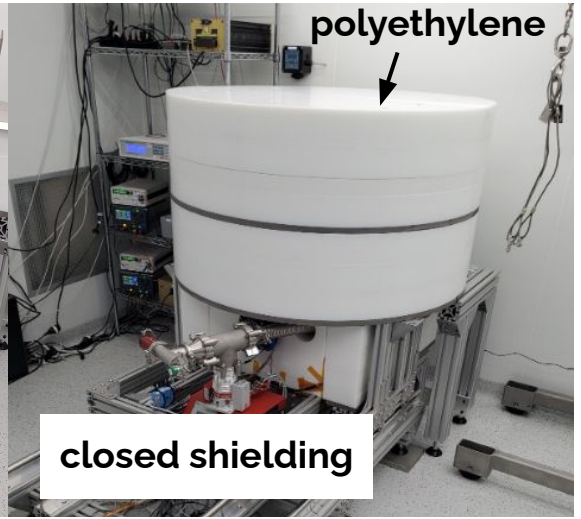
- **Aim:**
  - Demonstrate the ability to control backgrounds for DAMIC-M
  - integration/operation of DAMIC-M electronics
  - first dark matter search
- **Target:**
  - 1 kg-day exposure
  - O(1) dru background
- **Timeline:**
  - Installed at LSM at the end of 2021
  - 1st run collected (with open shielding)
  - 2nd run ongoing! (with closed shielding & 2 CCDs)
  - next runs: swap the OFHC packaging with an EFCu one



2 skipper CCDs 4000 x 6000 pix

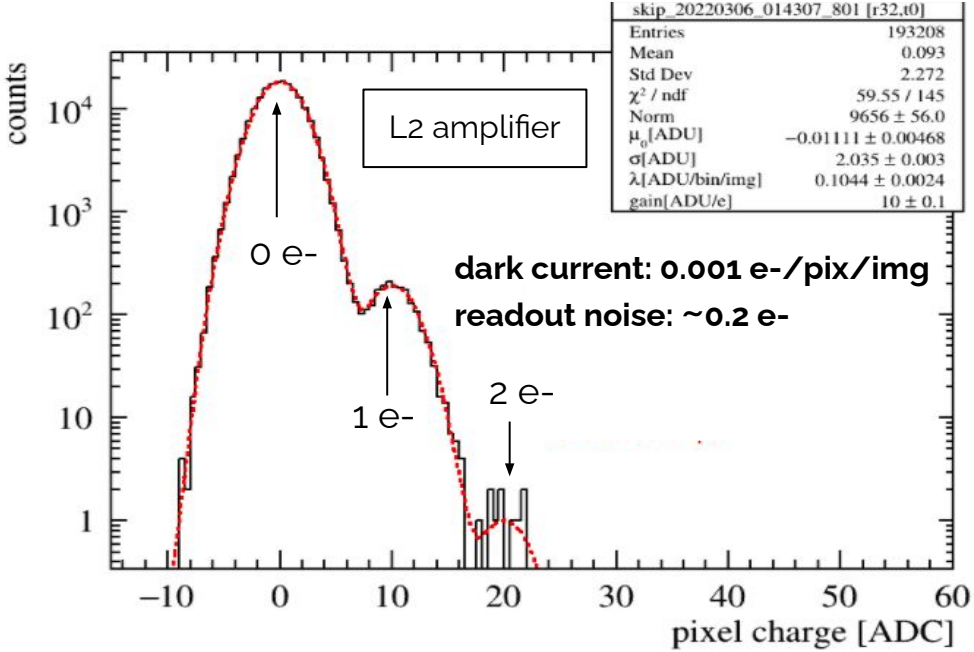


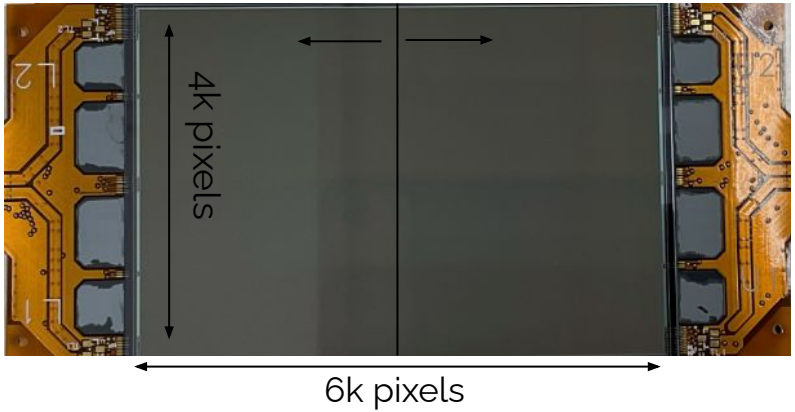


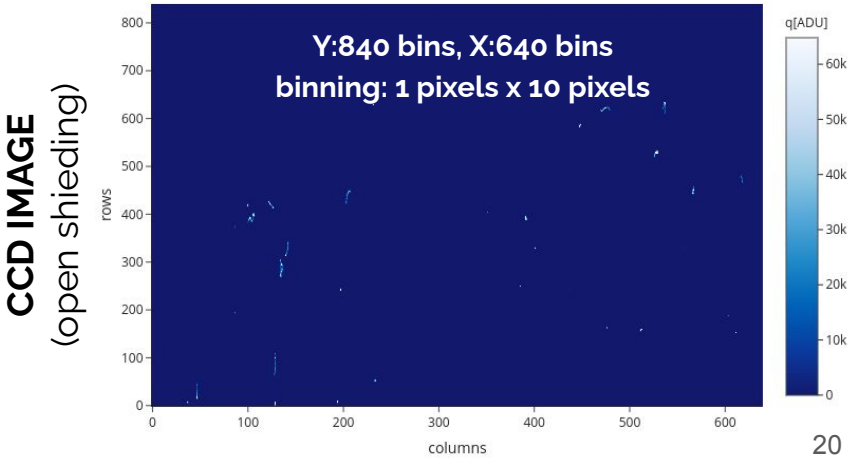


Low Background Chamber - Data taking

- Data taking: 12/02 -7/03 2022, 10/05 2022- now
- Temperature: ~110 K
- 650 skips

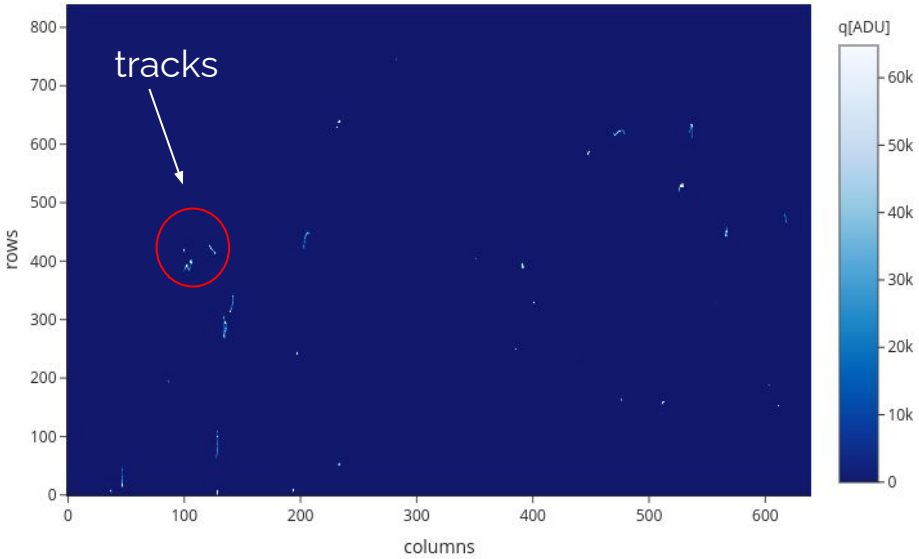






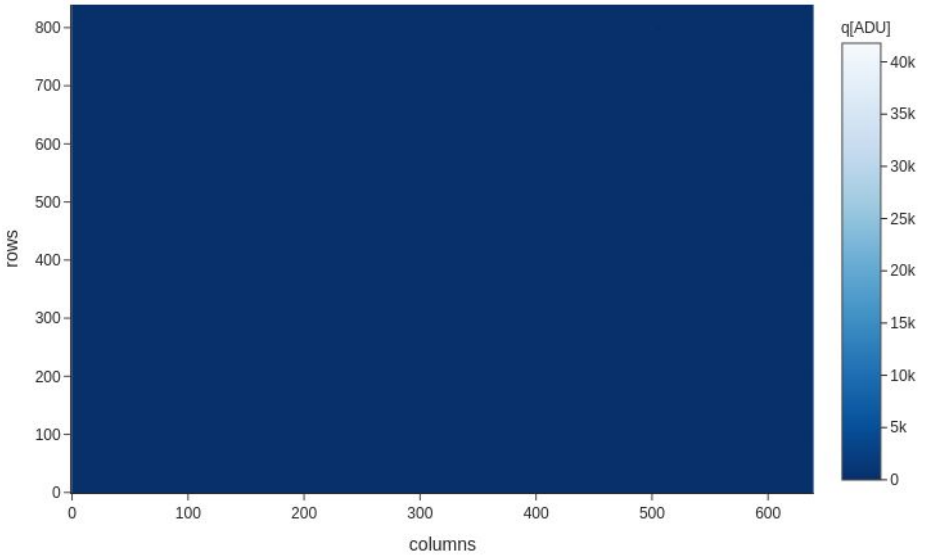
Low Background Chamber - Data

Open shielding



~300 dru

Closed shielding



~10 dru

~rate same level damic@SNOLAB

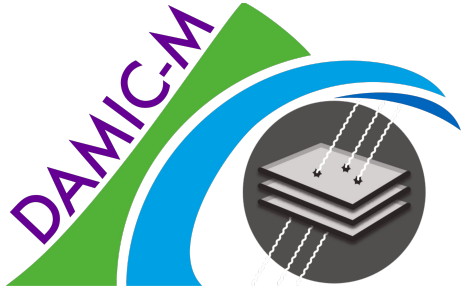
to be reduced by changing OFHC CCD box with an EFCu one

First physics results coming soon…

Conclusions

- **On our way towards DAMIC-M**
  - CCDs are being fabricated and tested right now,
  - Compton spectrum measurements: paper soon,
  - photon-nuclear scattering measurements ongoing,
  - design optimization and finalization,
  - electronics being designed.

- **Low Background Chamber**
  - RUNNING NOW,
  - first physics results expected soon.



Thank you for the attention

European Research Council

Established by the European Commission