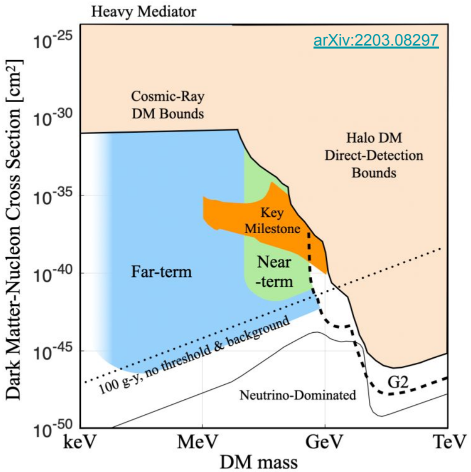
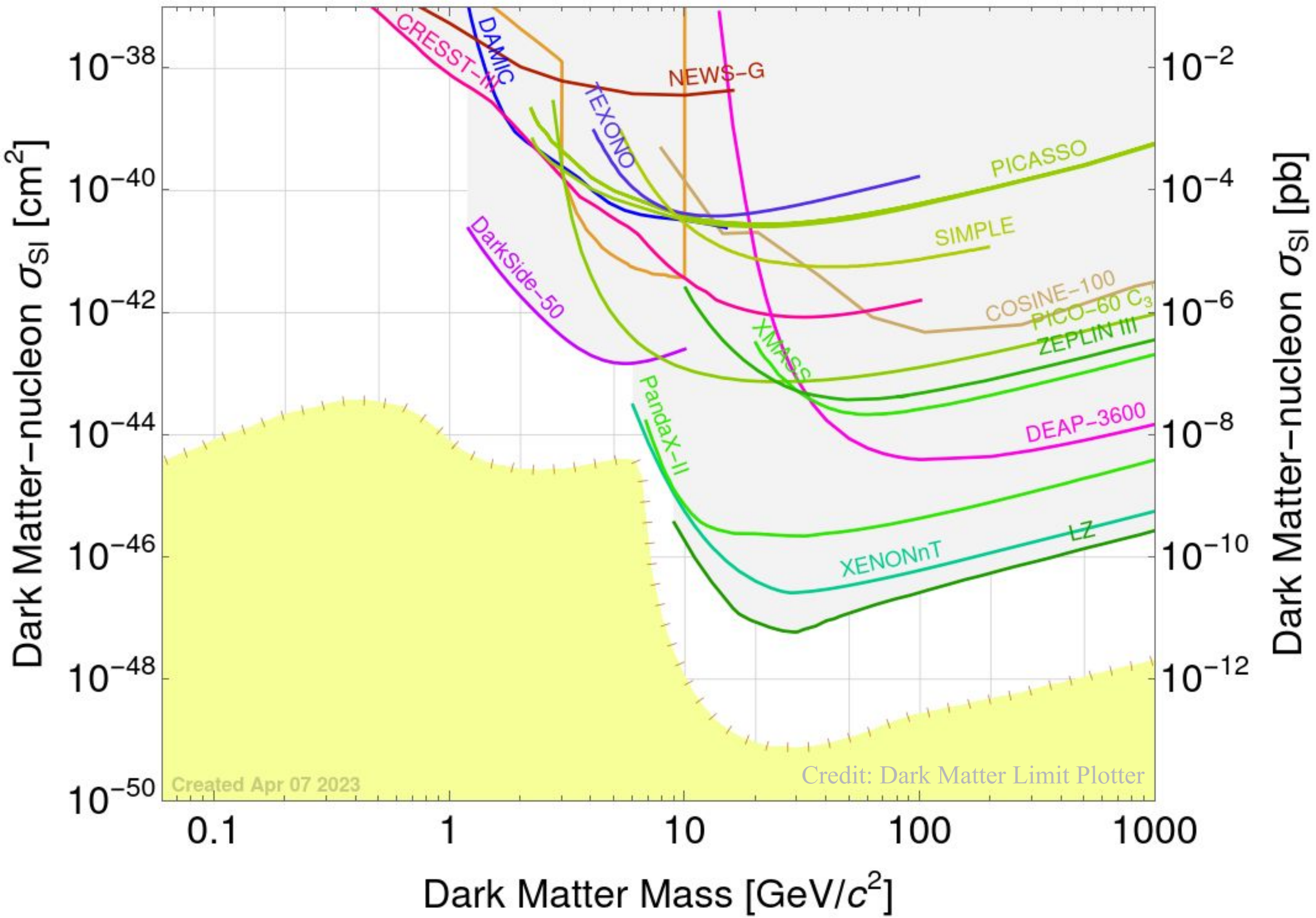
universität freiburg

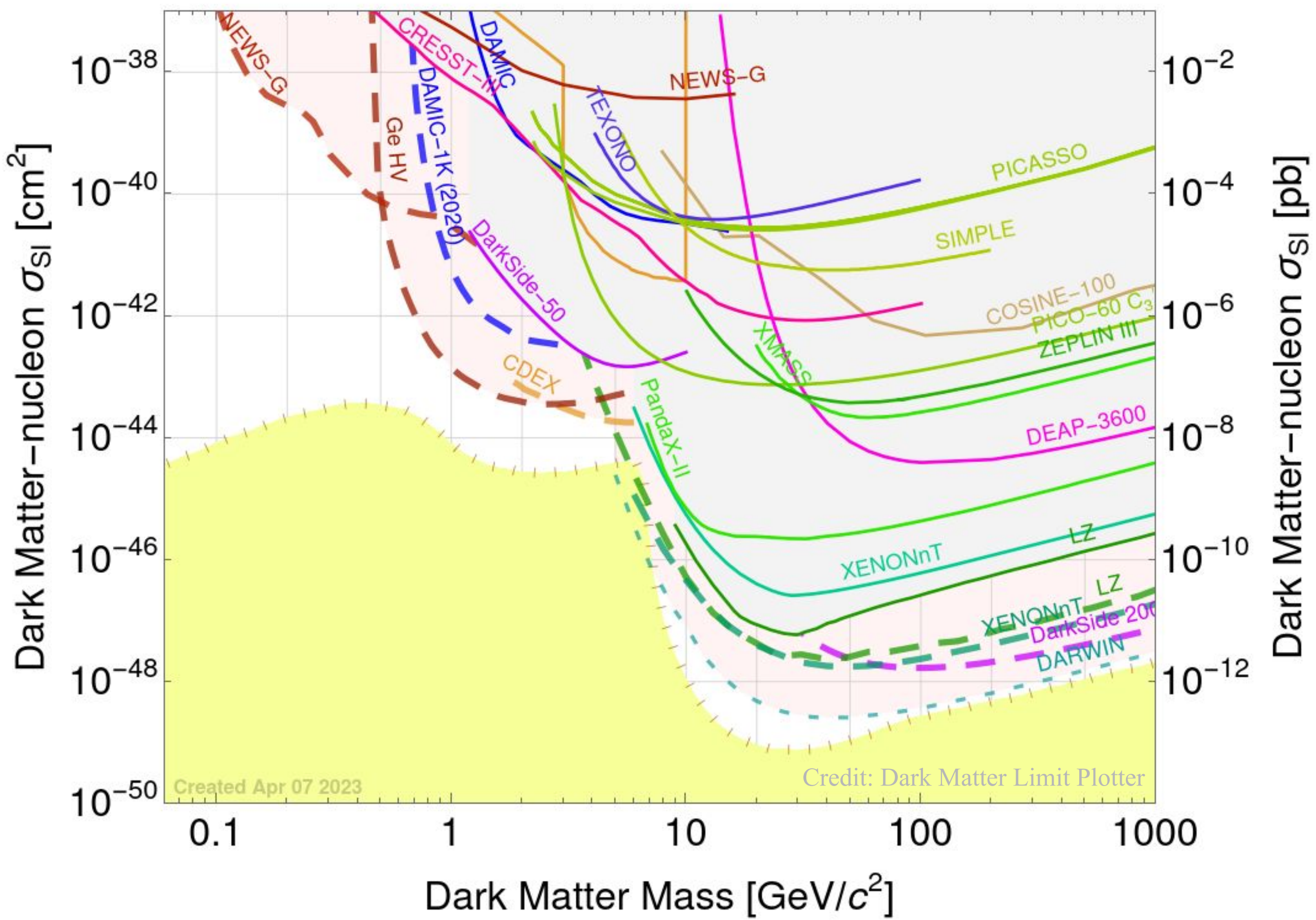
WIMP direct detection experiments

18th PATRAS Workshop, Rijeka



Sebastian Lindemann | University of Freiburg | July 6, 2023


Dark Matter–nucleon σ_{SI} [cm^2]
Dark Matter–nucleon σ_{SI} [pb]
Dark Matter Mass [GeV/c^2]
10^{-38}
10^{-40}
10^{-42}
10^{-44}
10^{-46}
10^{-48}
10^{-50}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
0.1
1
10
100
1000
CRESST-III
DAMIC
NEWS-G
TEXONO
PICASSO
SIMPLE
COSINE-100
PICO-60 C_3
ZEPLIN III
DarkSide-50
XMASS
PandaX-II
DEAP-3600
XENONnT
LZ
Created Apr 07 2023
Credit: Dark Matter Limit Plotter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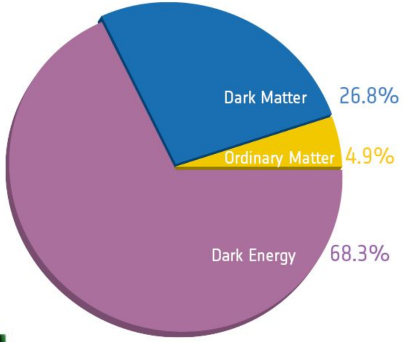
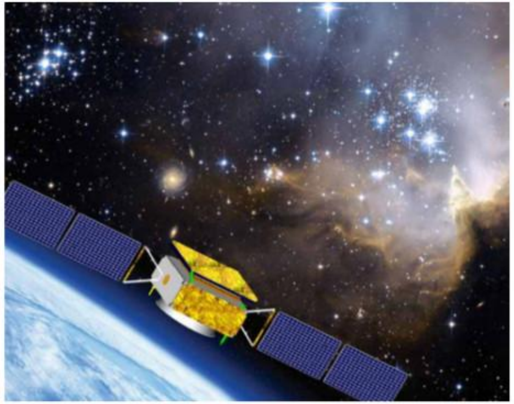
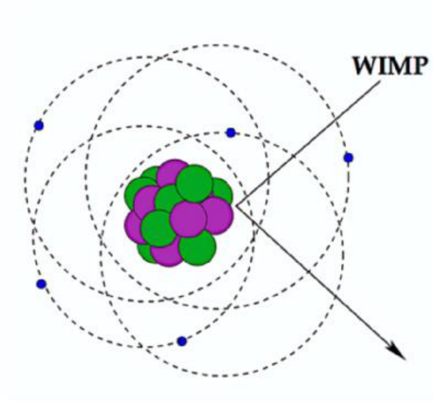
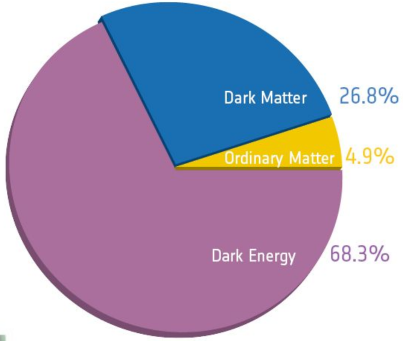
Dark Matter–nucleon σ_{SI} [pb]
Dark Matter Mass [GeV/c^2]
NEWS-G
CRESST-III
DAMIC
DAMIC-1K (2020)
Ge HV
TEXONO
PICASSO
SIMPLE
COSINE-100
ZEPLIN III
XMASS
DarkSide-50
CDEX
PandaX-II
DEAP-3600
XENONnT
LZ
DarkSide 20k
DARWIN
Created Apr 07 2023
Credit: Dark Matter Limit Plotter

Direct detection of dark matter



Indirect detection	Direct detection	Particle colliders
		
DM annihilation into SM particle	DM scattering off SM particle	Direct or by decay production DM
$\chi\bar{\chi} \to q\bar{q}, \gamma\gamma, \ldots$	$\chi N \to \chi N$	$pp \to \chi\bar{\chi} + X$

Direct detection of dark matter



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	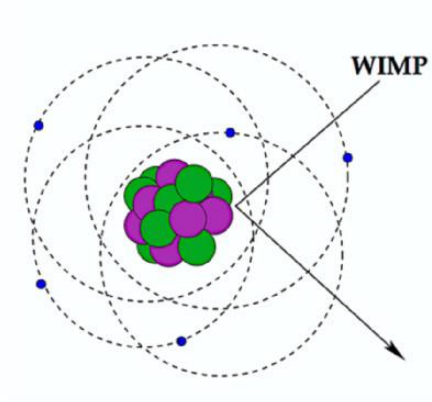	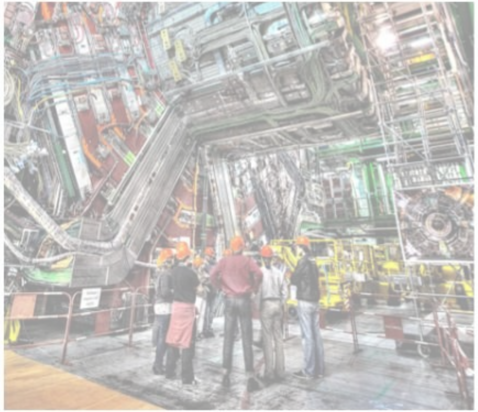
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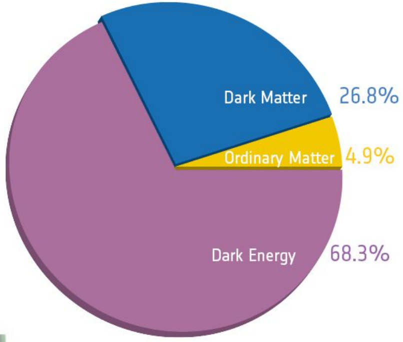

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	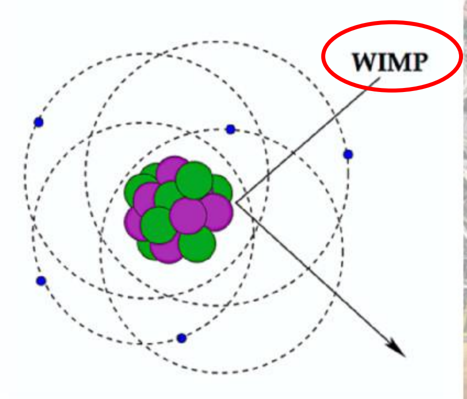	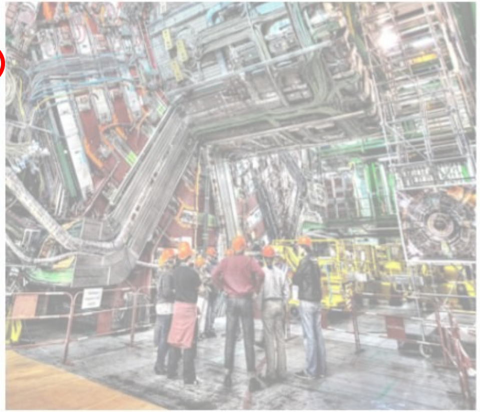
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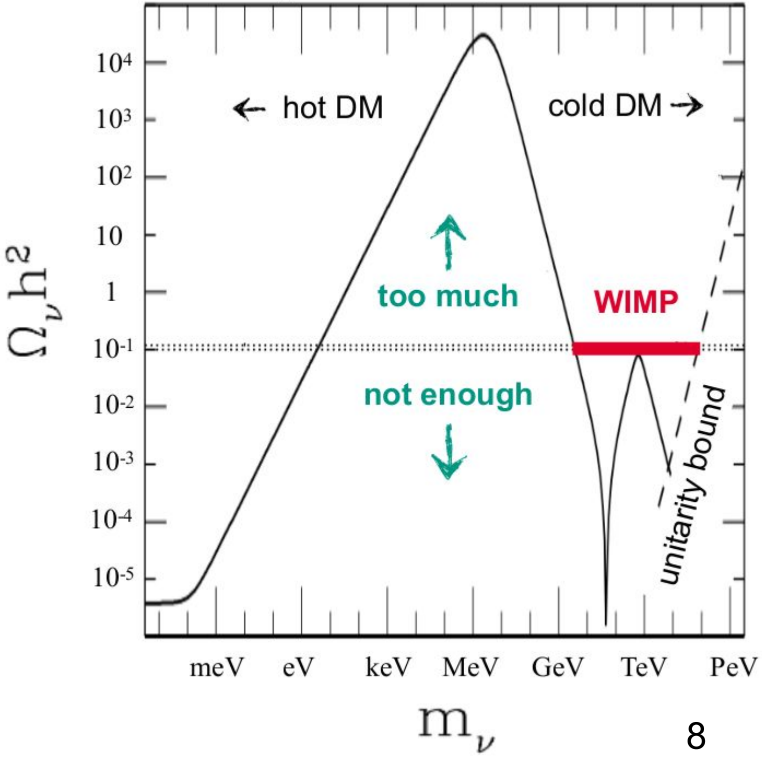
What is a WIMP?

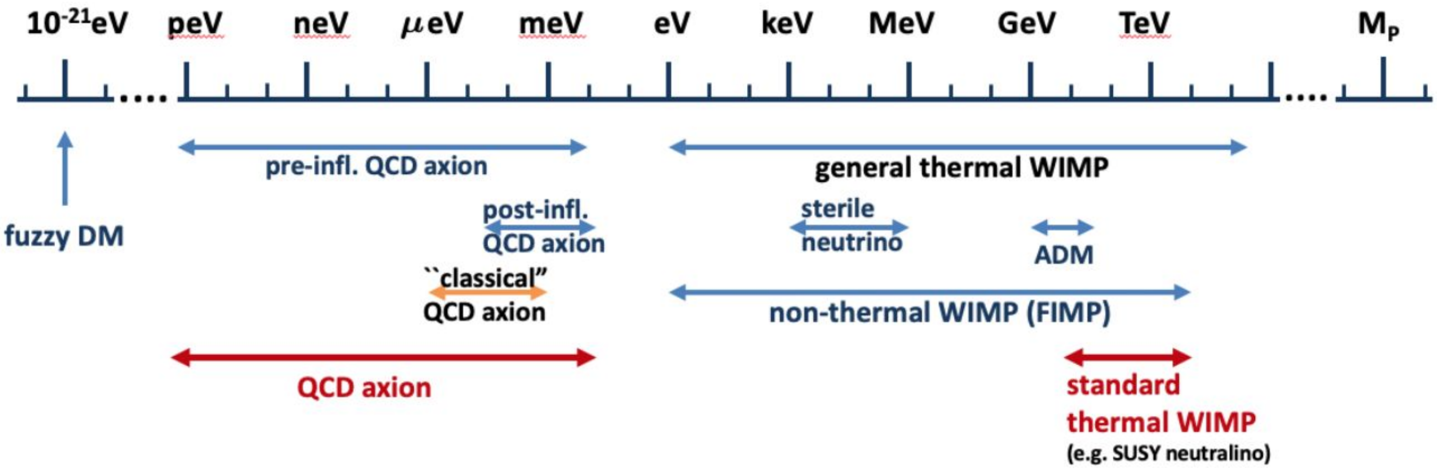
Vanilla (= standard thermal) WIMP

- Not a specific elementary particle, but a broad class of possible particles.
- Introduced by Lee and Weinberg in 1977 as stable, massive left-handed neutrinos (long ruled out by LEP and direct detection experiments).
- Masses above O(1GeV) (to not overclose the universe) and below O(100TeV) (from unitarity constraints).

adapted from: G. Gelmini, P. Gondolo, arXiv:1009.3690

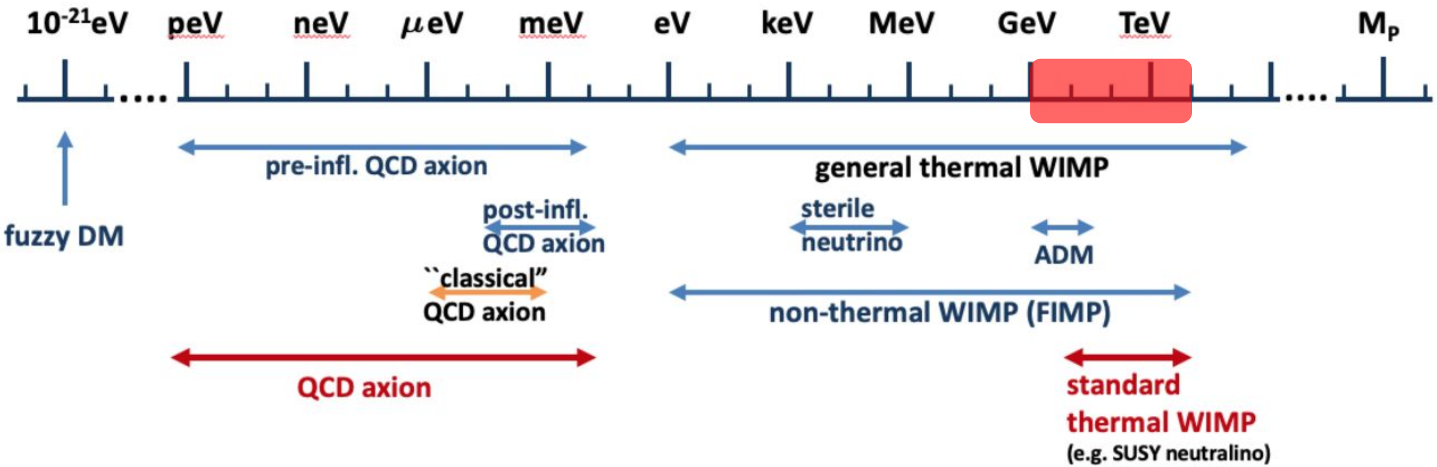


The broader view: general thermal WIMPs and beyond



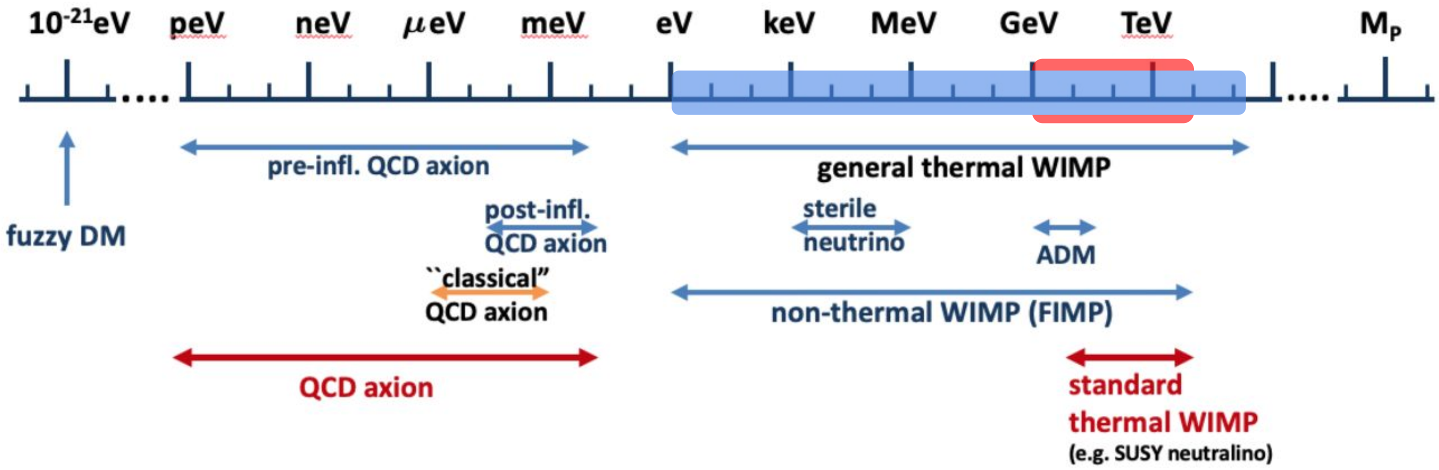
Rep. Prog. Phys. **85** 056201

The broader view: general thermal WIMPs and beyond



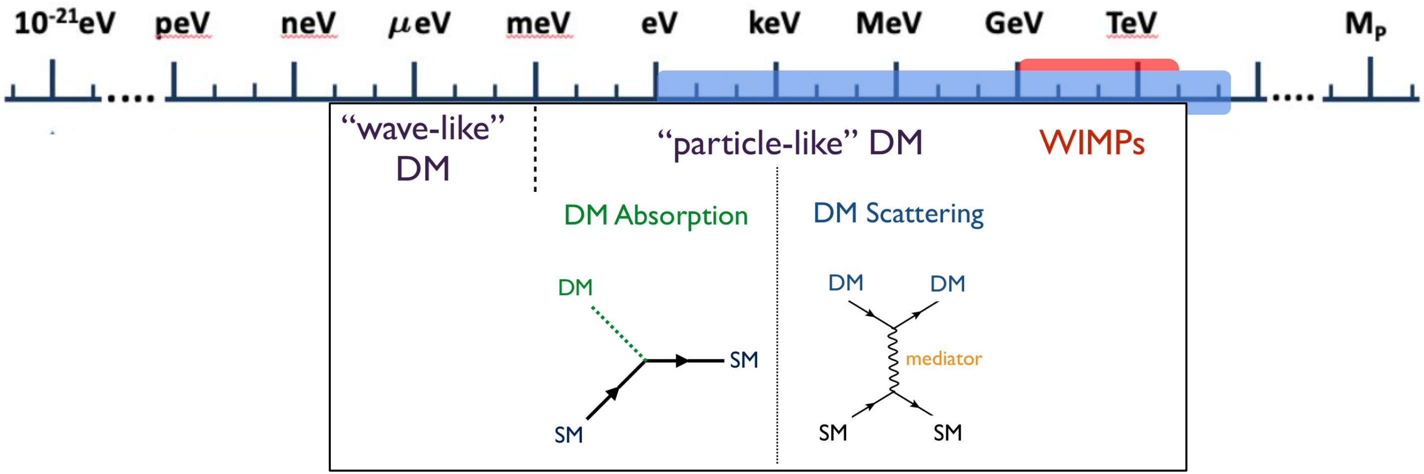
Rep. Prog. Phys. **85** 056201

The broader view: general thermal WIMPs and beyond



[Rep. Prog. Phys. **85** 056201]

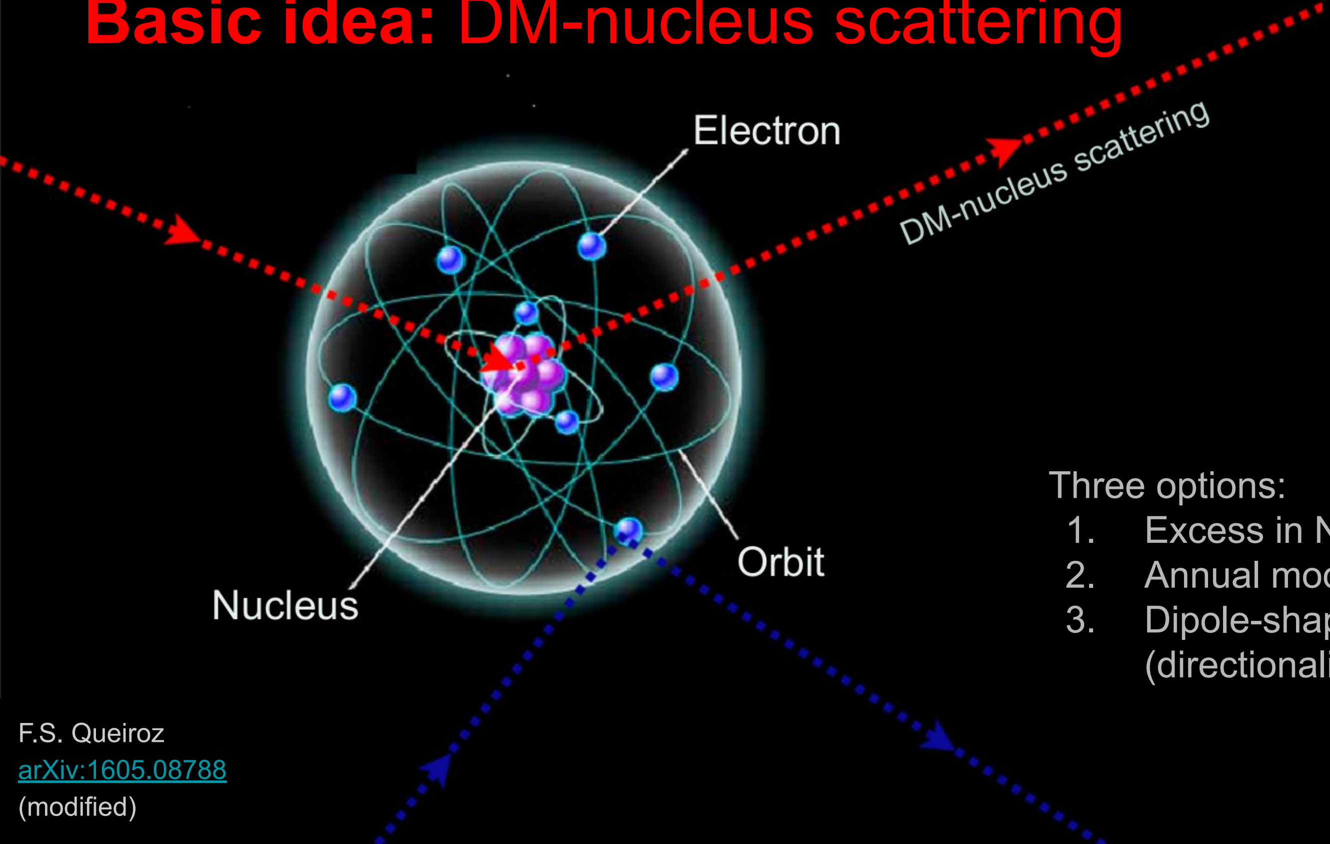
The broader view: general thermal WIMPs and beyond



[Rep. Prog. Phys. **85** 056201]

How to search for WIMPs?

Basic idea: DM-nucleus scattering



Three options:

1. Excess in NR rate
2. Annual modulation of NR rate
3. Dipole-shaped recoil distribution (directionality)

F.S. Queiroz
arXiv:1605.08788
(modified)

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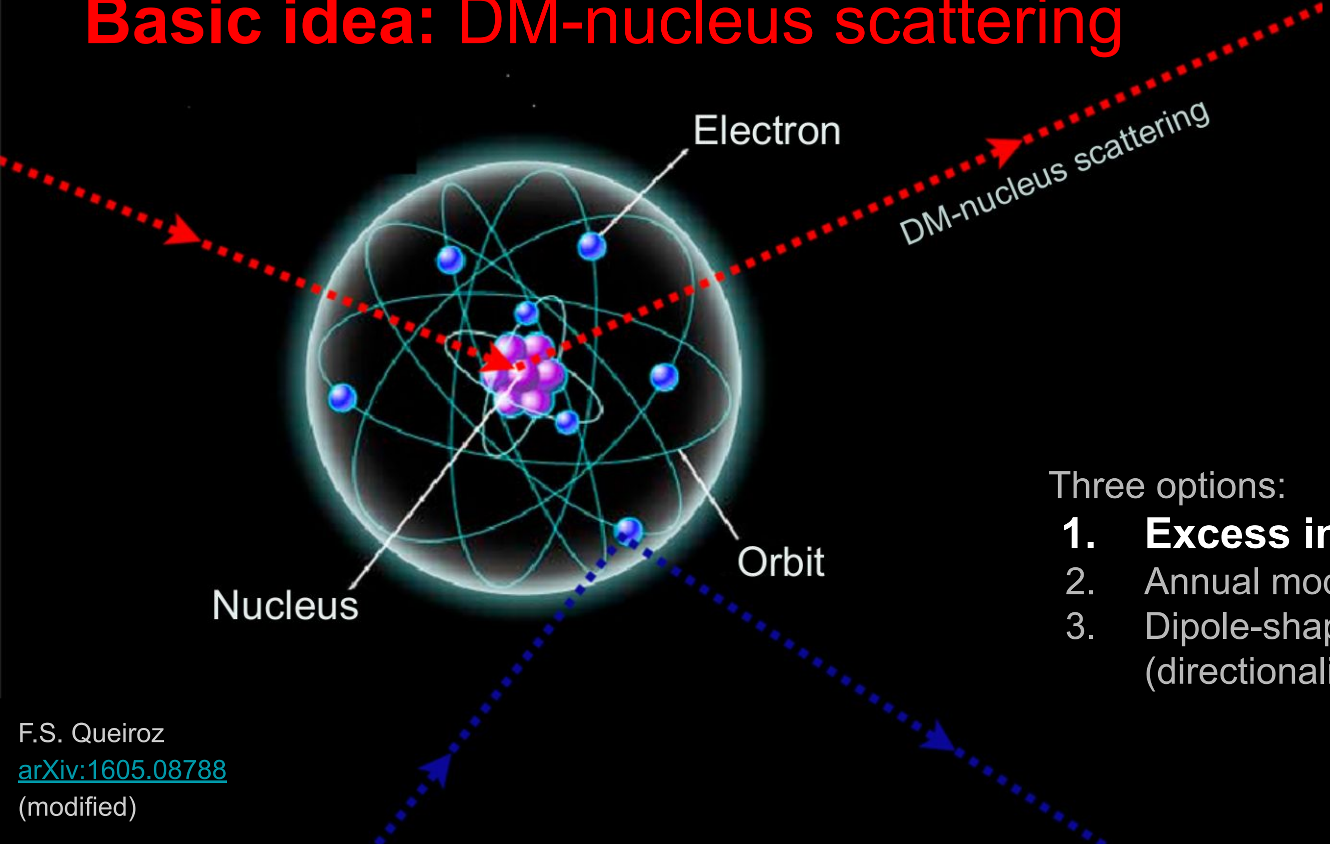

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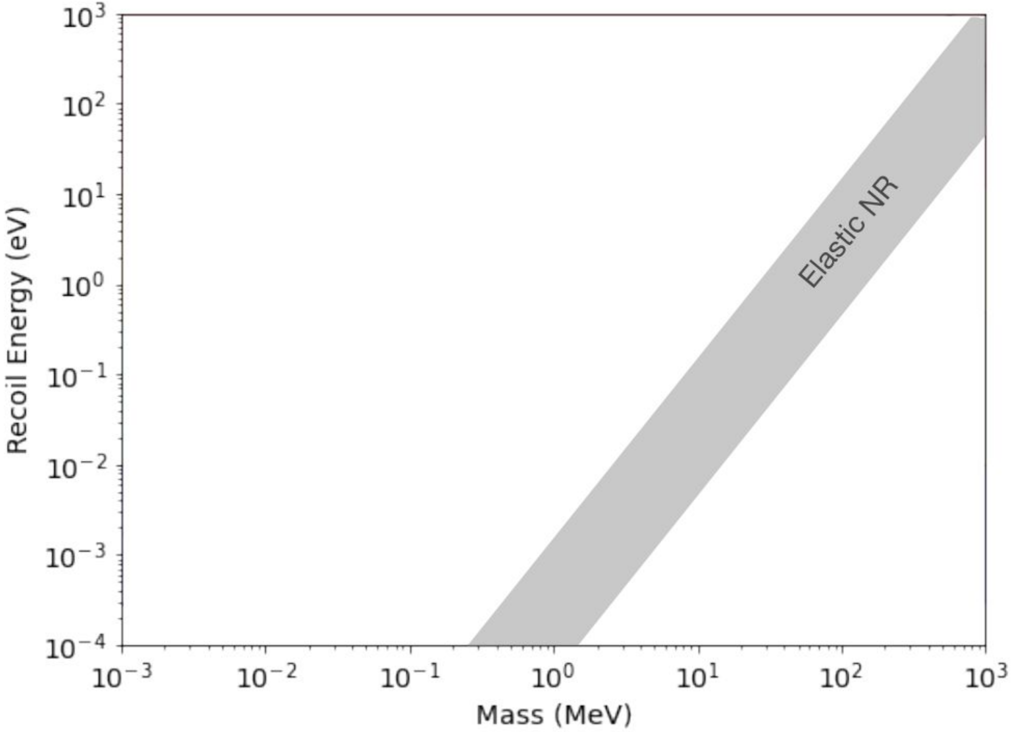
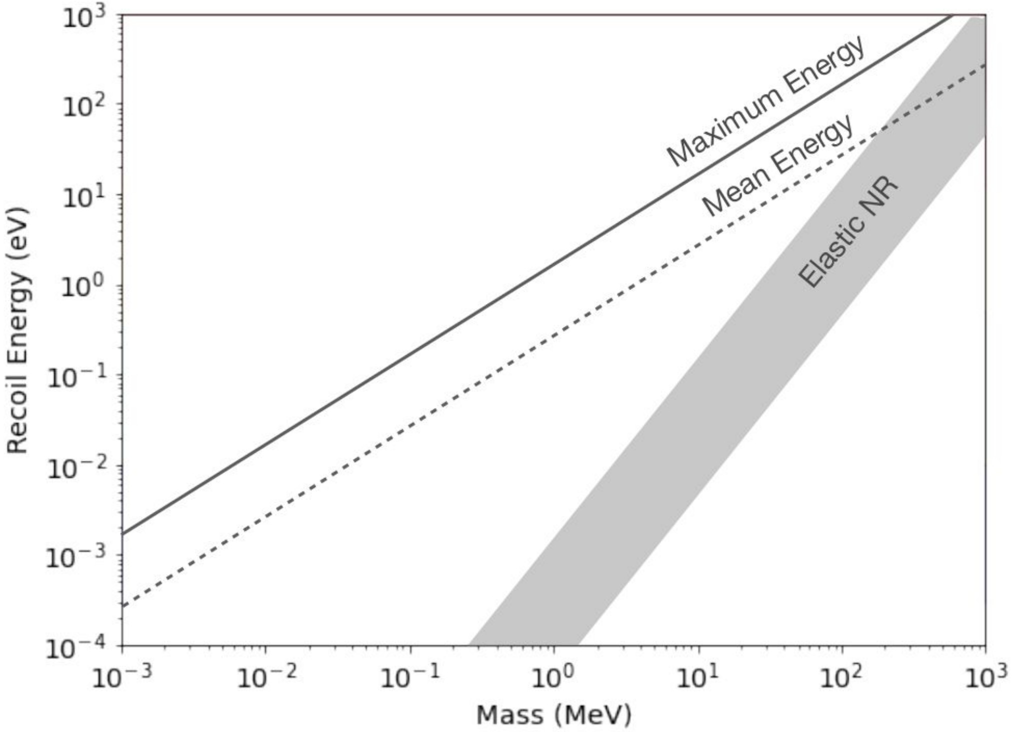


Slides from R. Essigs talk at UCLA Dark Matter 2023

elastic DM-nucleus scattering:

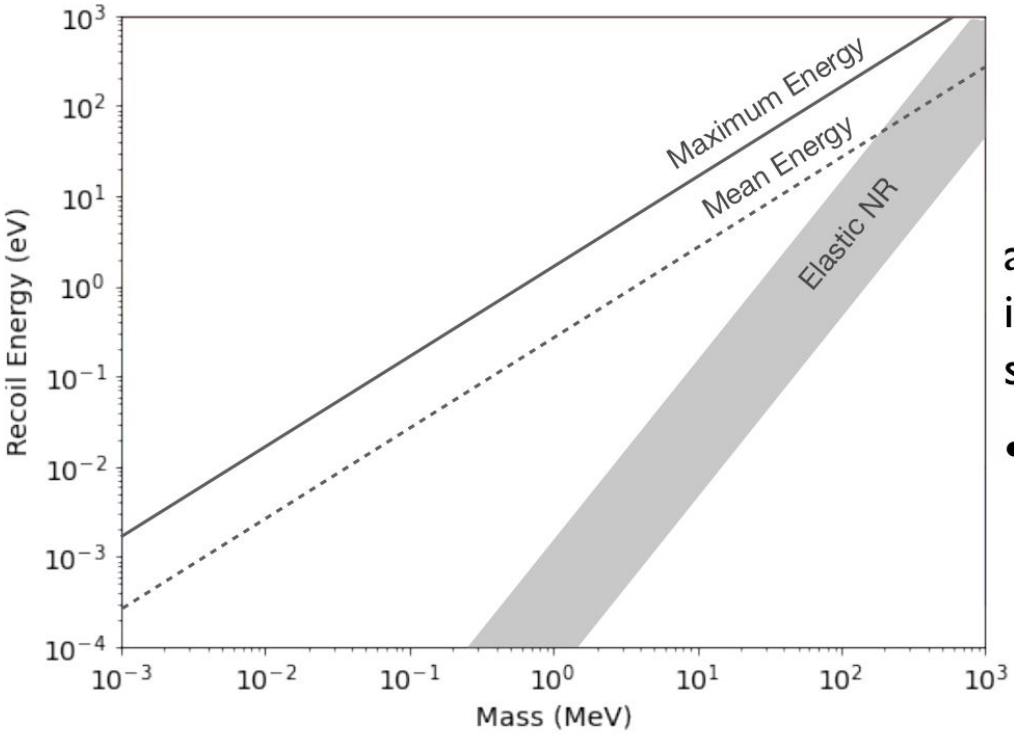
$$E_{\rm NR} = \frac{q^2}{2m_N} \sim 1 \text{ eV} \left(\frac{m_{\rm DM}}{100 \text{ MeV}}\right)^2 \left(\frac{28 \text{ GeV}}{m_N}\right)$$



Slides from R. Essigs talk at UCLA Dark Matter 2023

DM kinetic energy

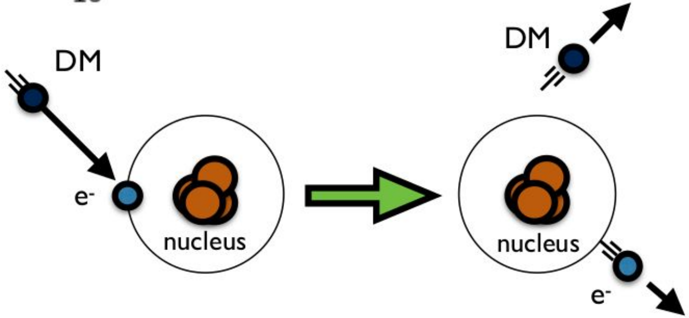
$$E_{\rm kin} = \frac{1}{2} m_{\rm DM} v_{\rm DM}^2 \sim 1 \text{ eV} \left(\frac{m_{\rm DM}}{1 \text{ MeV}} \right)$$



Slides from R. Essigs talk at UCLA Dark Matter 2023

accessible through <u>inelastic</u> interactions (sometimes w/ suppressed rate), e.g.:

- DM-e scattering



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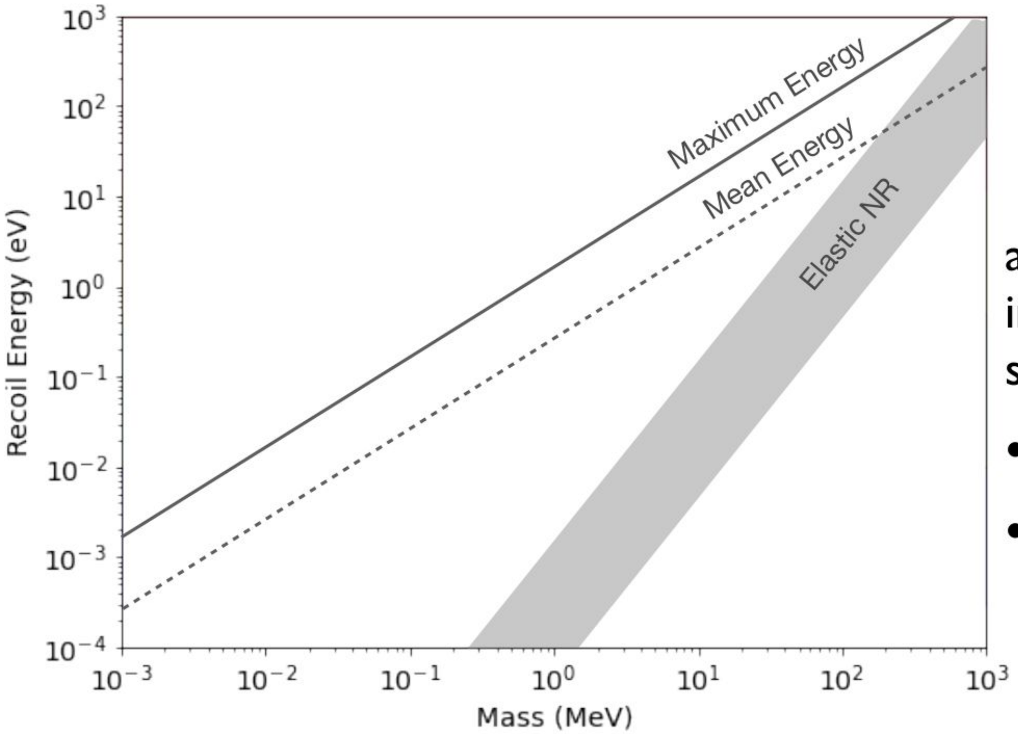
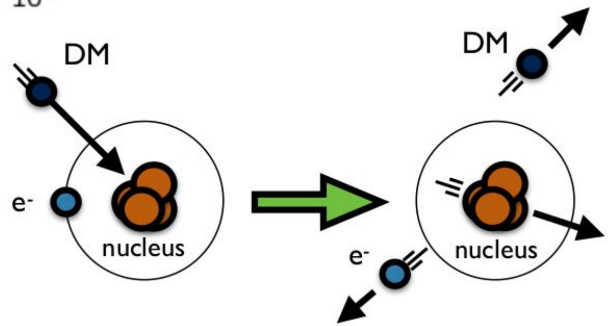


accessible through <u>inelastic</u> interactions (sometimes w/ suppressed rate), e.g.:

- DM-e scattering
- DM-N scattering w/ Migdal



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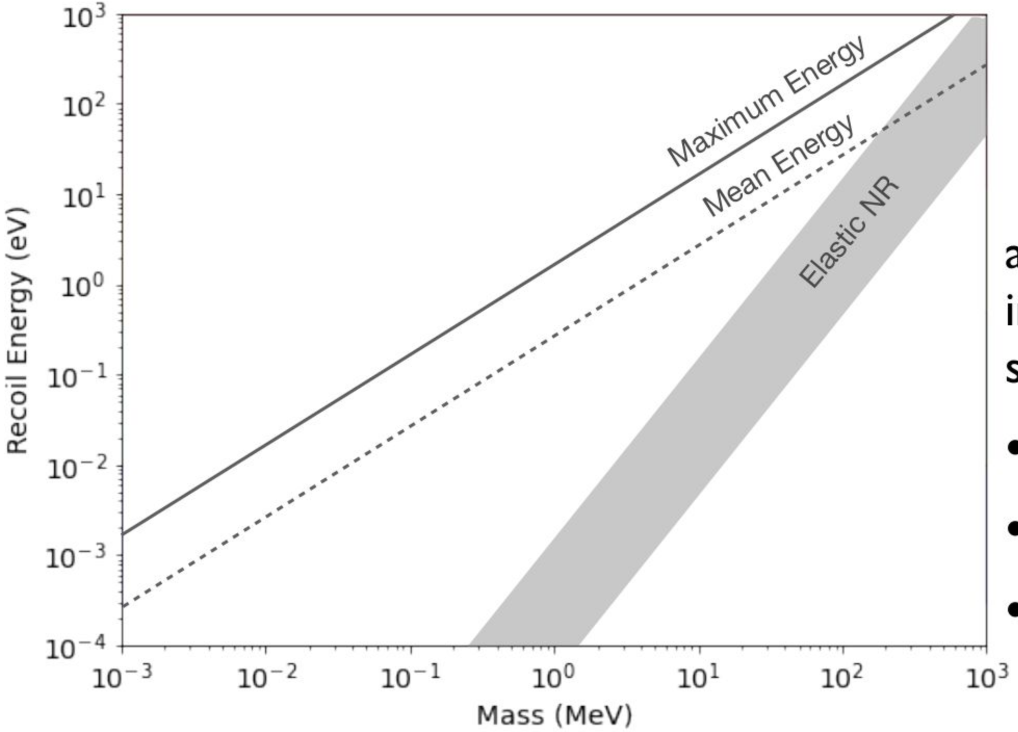
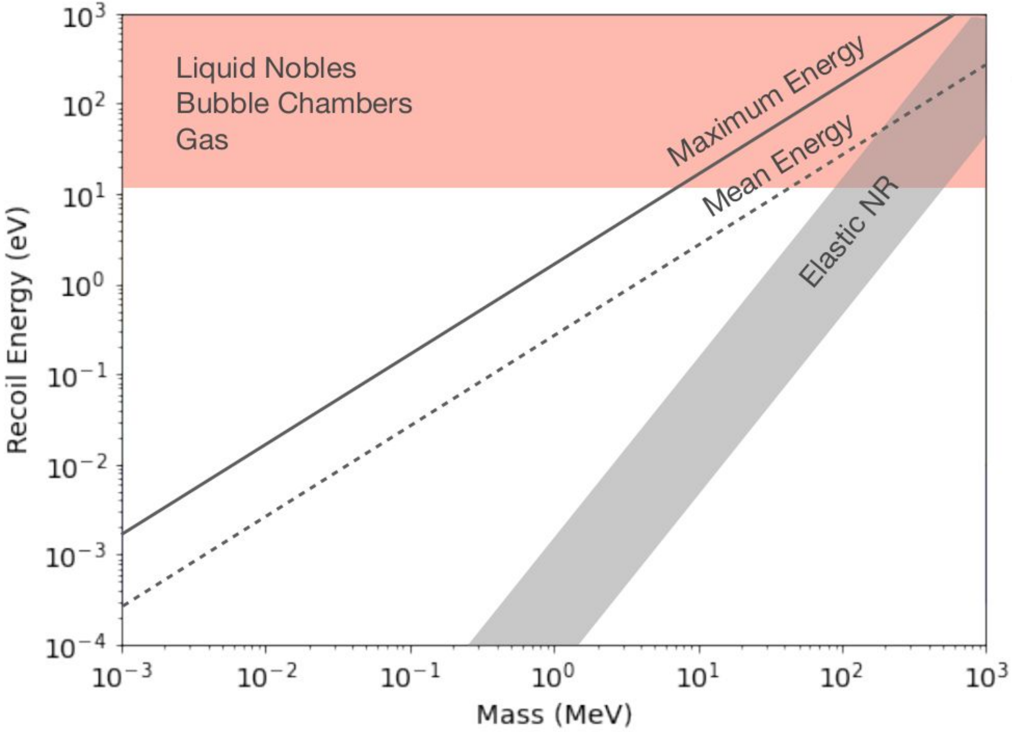


accessible through <u>inelastic</u> interactions (sometimes w/ suppressed rate), e.g.:

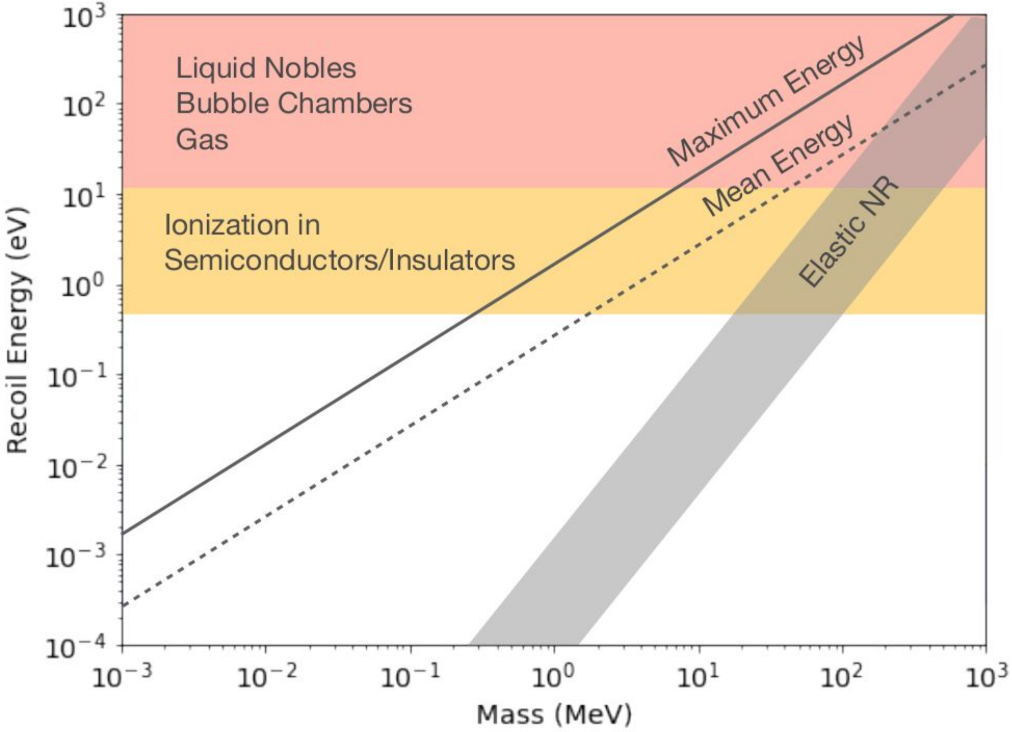
- DM-e scattering
- DM-N scattering w/ Migdal
- DM scattering w/ collective modes (e.g. phonons, magnons)



$\Delta E \sim 10$ eV

e.g. Xe, Ar, He

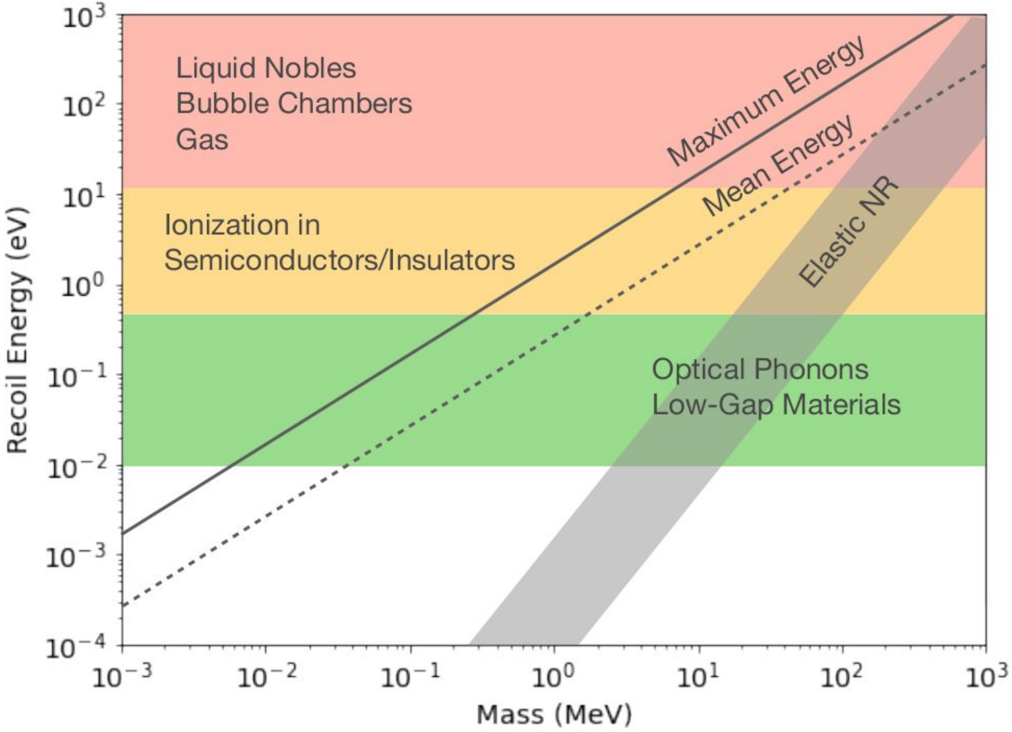
Slides from R. Essigs talk at UCLA Dark Matter 2023



Slides from R. Essigs talk at UCLA Dark Matter 2023

$\Delta E \sim 1$ eV

e.g. Si, Ge, GaAs, diamond, Quantum Dots, organic scintillators…



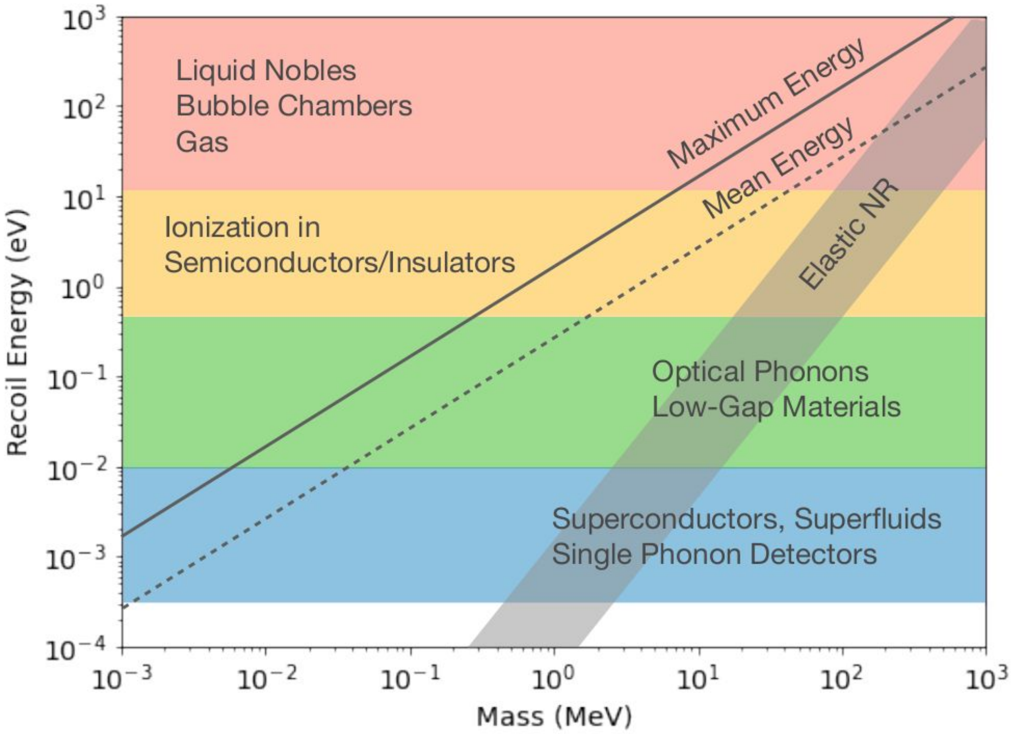
Slides from R. Essigs talk at UCLA Dark Matter 2023

$\Delta E \sim 10 - 100$ meV

e.g. GaAs, sapphire, Dirac materials, doped s/c, …

Check: optical phonons

Slides from R. Essigs talk at
UCLA Dark Matter 2023

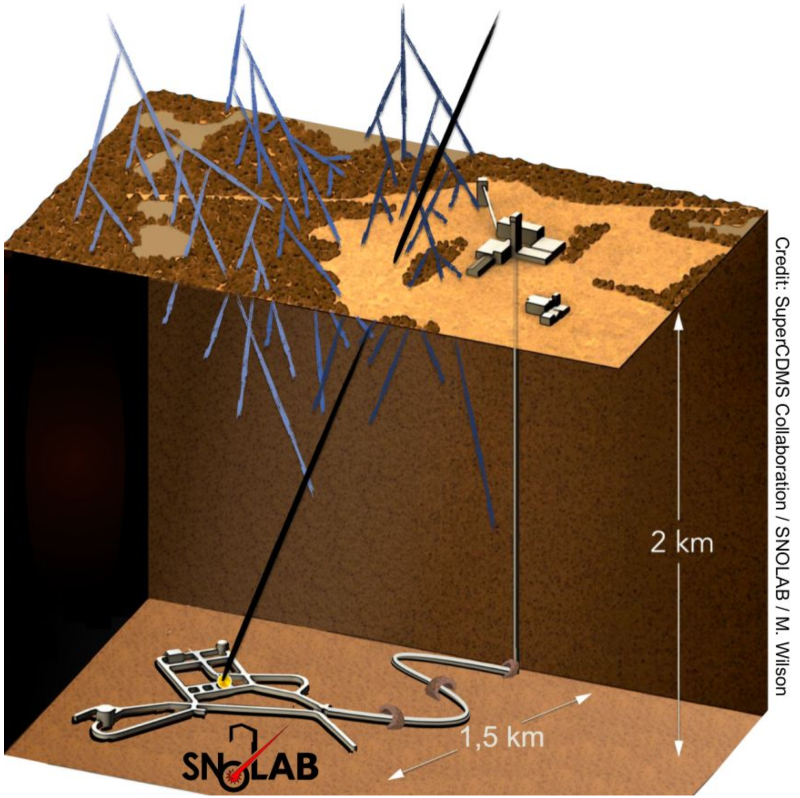


$\Delta E \sim 1 \text{ meV}$

e.g. superfluids,
superconductors

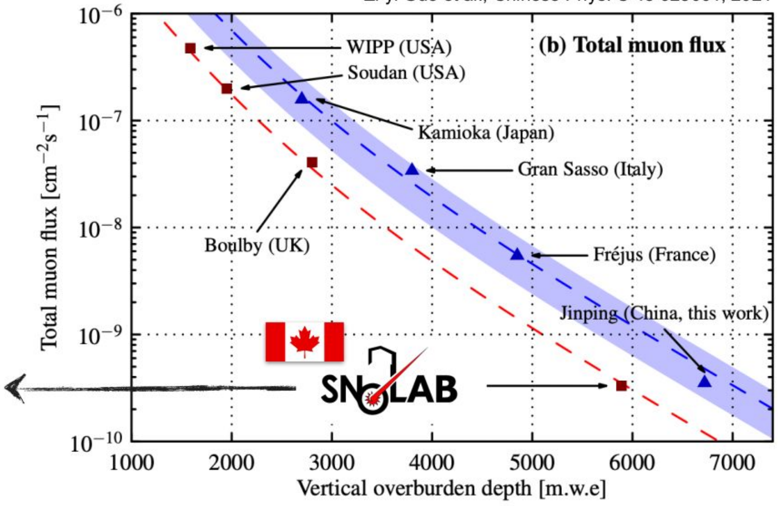
Fighting backgrounds

Shielding against cosmics

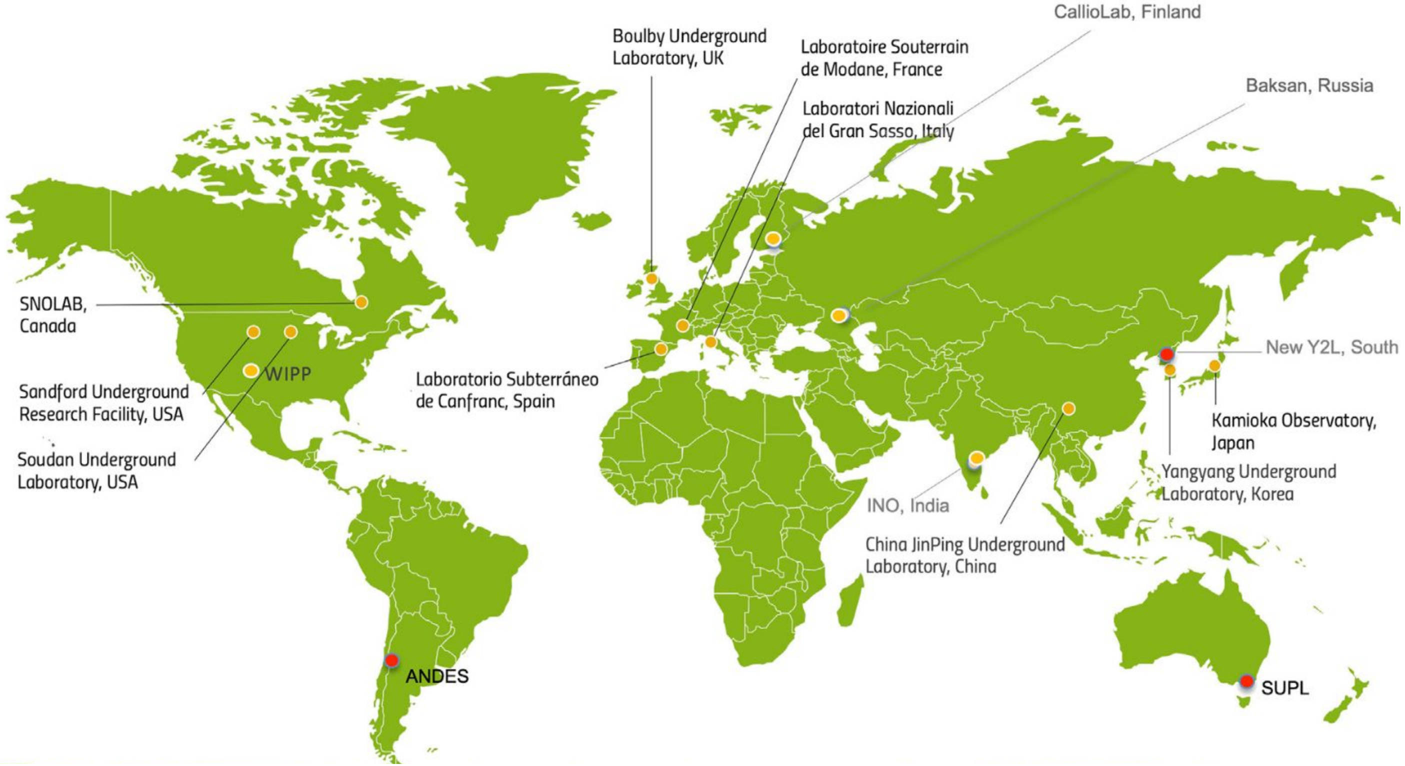


- Going underground to mitigate cosmic and cosmogenic backgrounds

Zi-yi Guo et al., Chinese Phys. C 45 025001, 2021

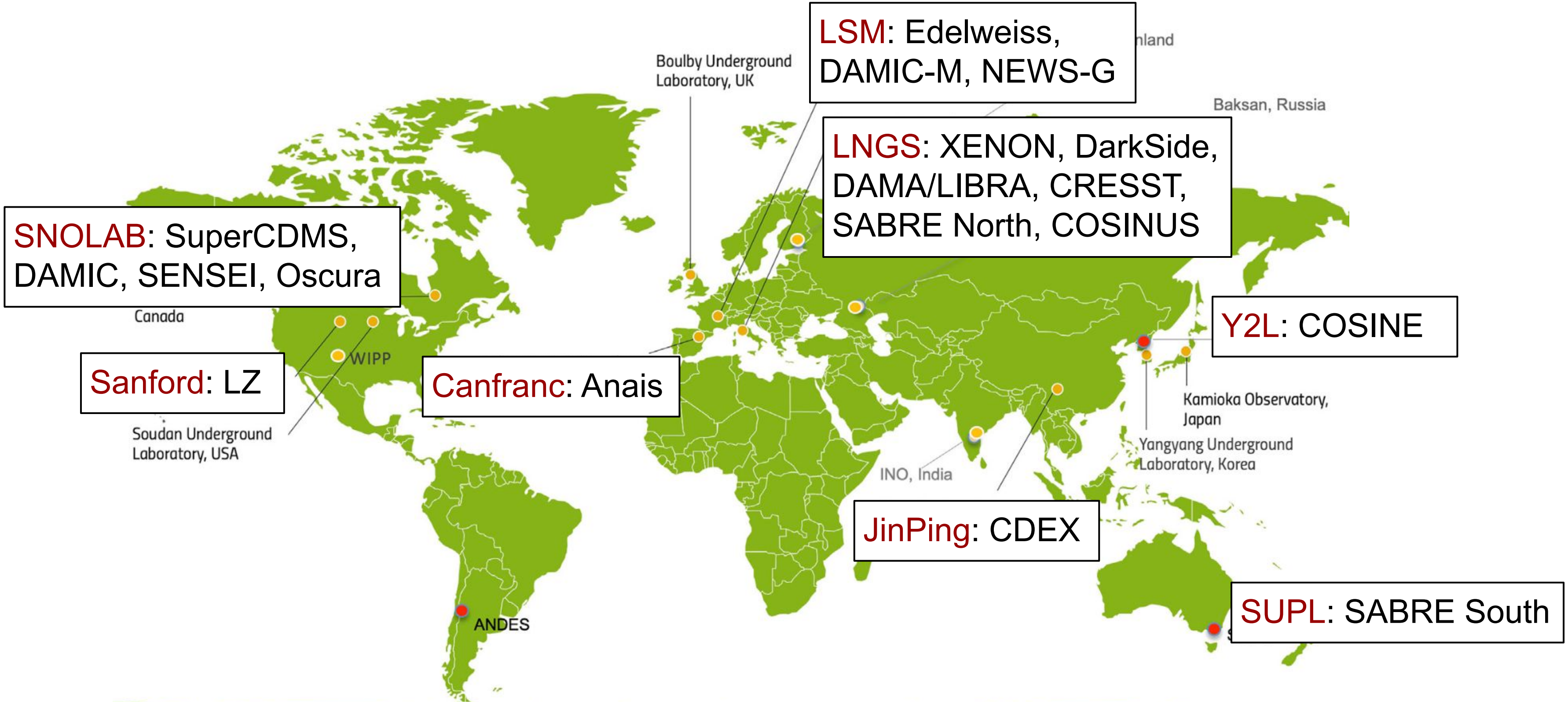


World map showing labs and experiments



[Front. Phys., 23 February 2021](#)

World map showing labs and experiments



Front. Phys., 23 February 2021

Radio assay techniques for bulk contamination screening

(HR)-ICP-MS: Atom counting (^{232}Th, ^{238}U and ^{40}K @pg/g ≃ 1e-5 Bq/kg sensitivities)
High Resolution Inductively Coupled Plasma – Mass Spectrometry

-> early part of chains

HPGe: Gamma spectrometer (^{226}Ra, ^{228}Th @ (high) 1e-5 Bq/kg sensitivities)
High Purity Germanium

-> later part of chains

NAA: activation and gamma counting
Neutron Activation Analysis

Alpha/beta counting: probing surfaces; **late part of chain**, e.g., ^{210}Pb daughters
e.g., radon emanation and XIA or beta cage

Radio assay techniques for bulk contamination screening

(HR)-I ...ities)

High Resolu

HPGe

High Purity G

NAA:

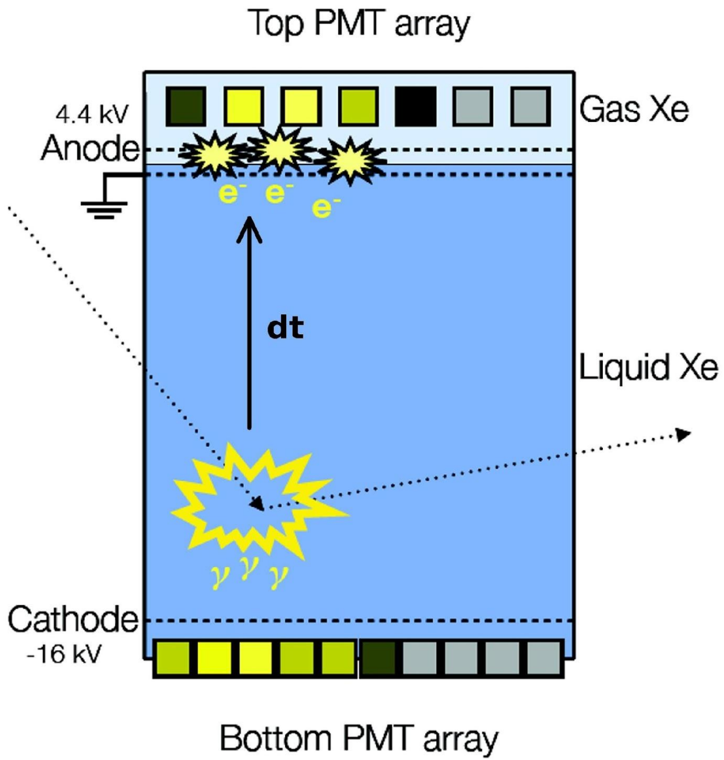
Neutron Acti

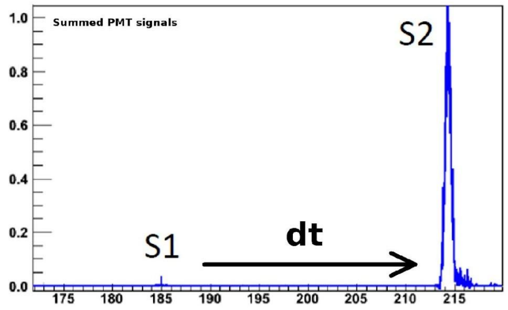
Alpha/ ...s

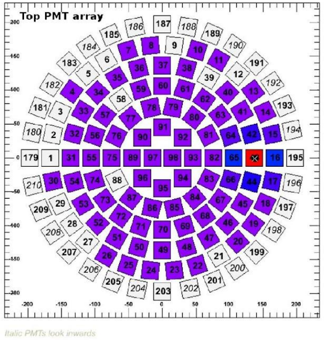
e.g., radon e

XENON TPCs

Liquid xenon (argon) TPCs: detection principle



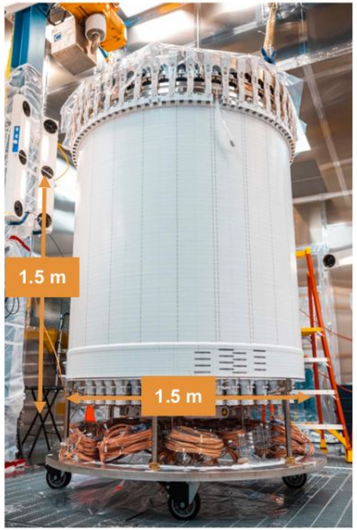




Liquid xenon TPCs: state of the art

XENONnT@LNGS

LZ@SURF



PandaX-4T@JinPing

	XENONnT	LZ	PandaX-4T
Total (sensitive) mass	8.5 (5.9) tonnes	10 (7) tonnes	5.6 (3.7) tonnes
3-inch PMTs	494	494	368
Drift Field	23 V/cm	193 V/cm	93 V/cm

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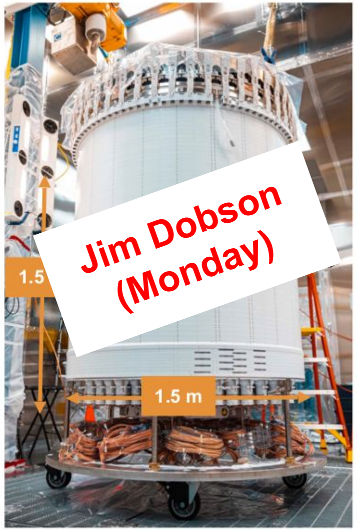

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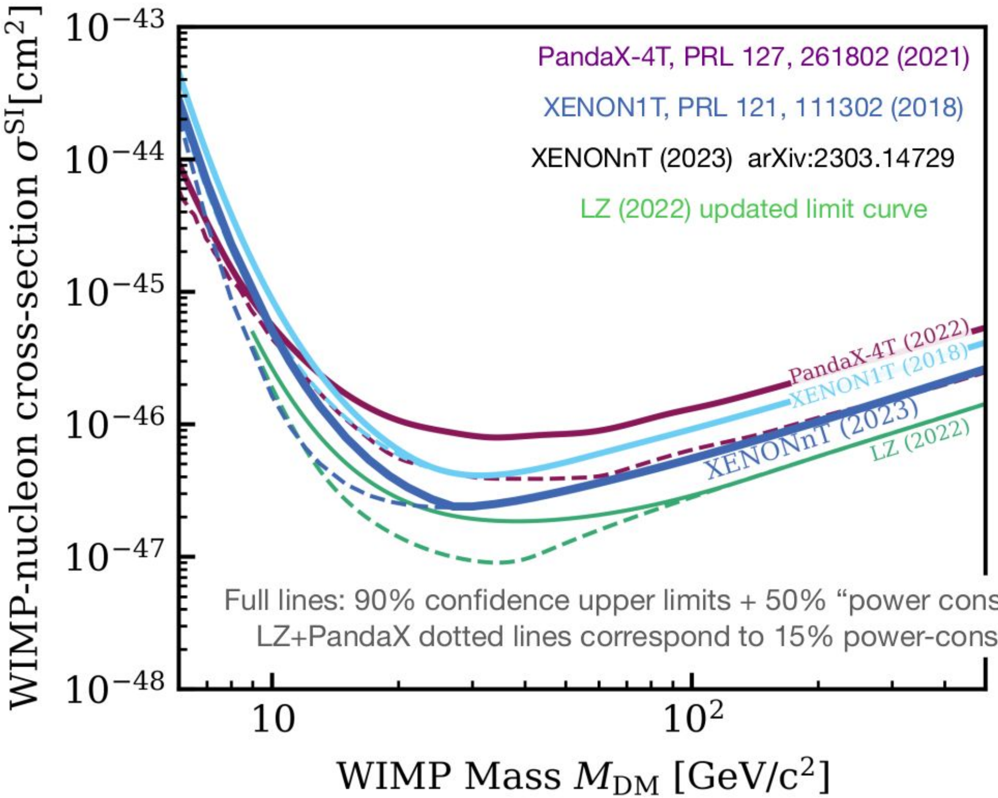
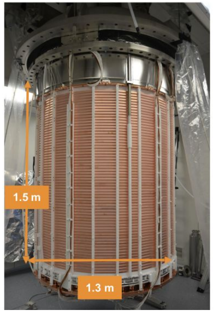


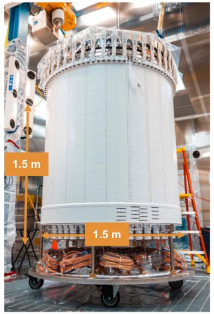
Full lines: 90% confidence upper limits + 50% “power constraint”.
LZ+PandaX dotted lines correspond to 15% power-constraint

XENON Collaboration arXiv:2303.14729

XENONnT@LNGS



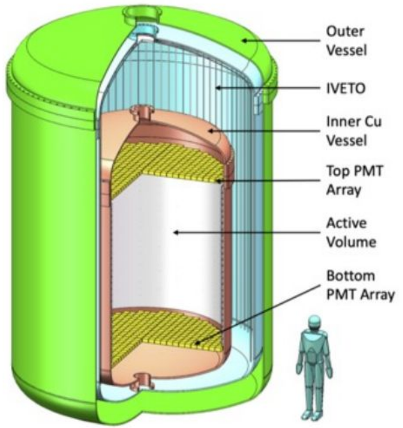
LZ@SURF

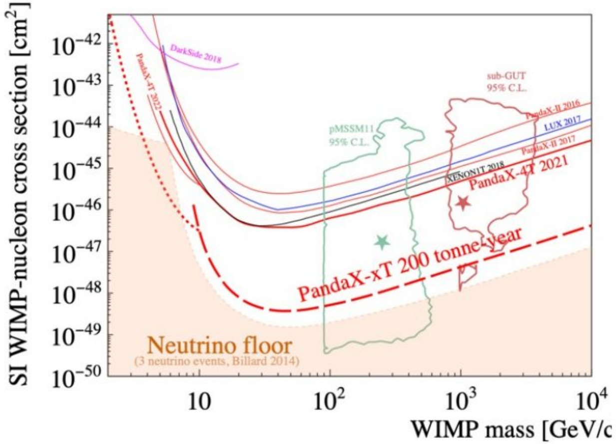


PandaX-4T@JinPing

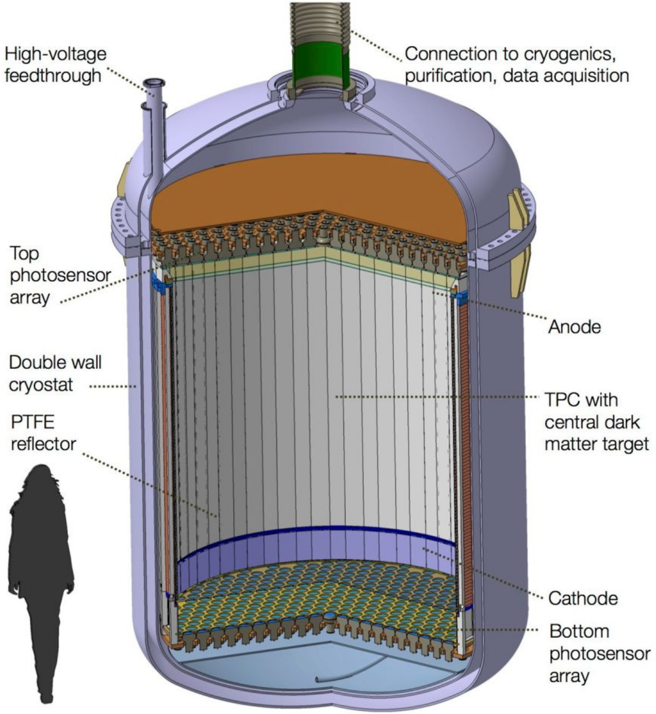
What's next – Future liquid xenon TPCs at the 50+ tonne scale
PandaX-xT

- With >30 tonne sensitive volume
- Letter-of-interest sent to Chinese funding agency
- Decisive test on WIMP and key test on Dirac/Majorana neutrino





What’s next – Future liquid xenon TPCs at the 50+ tonne scale
DARWIN



arXiv.:1606.07001

Benchmark Configuration:

- 1,910 3” PMTs
- 50t LXe detector volume
- 0.1 µBq/kg Rn-222
- Gran Sasso National Laboratory
- Exposure goal: **200 t x y**

Bottleneck: xenon procurement

- Current overall (world-wide) xenon production: ca. **65 t / year**

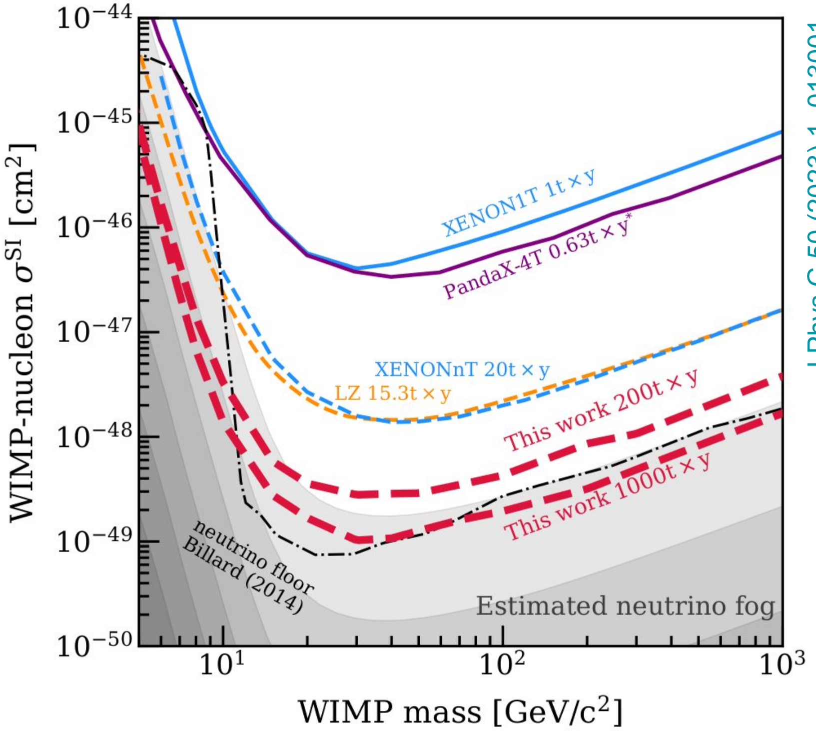
What's next – Future liquid xenon TPCs at the 50+ tonne scale

XLZD (xlzd.org)

Consortium of XENON, LUX-ZEPLIN & DARWIN

→ MOU signed July 2021

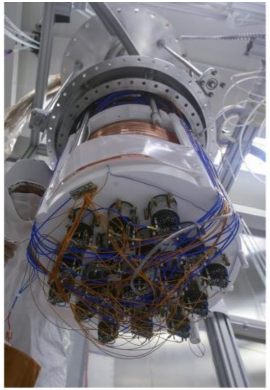
Explore to neutrino fog in the 2030s



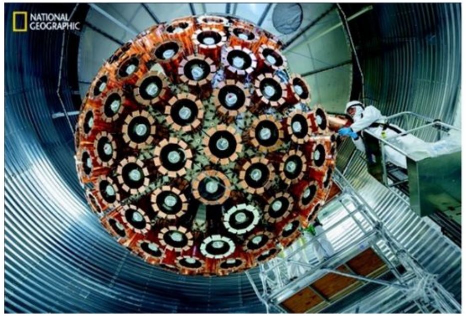
J.Phys.G 50 (2023) 1, 013001

ARGON TPCs

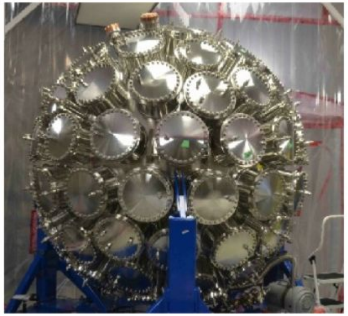
The Global Argon Dark Matter Collaboration (GADMC)



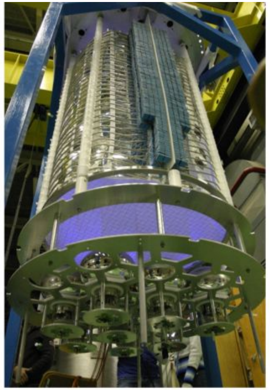
DarkSide-50
@ LNGS



DEAP-3600
@ Snolab



MiniCLEAN
@ Snolab



ArDM
@ Canfranc

GADMC

- ≈ 100 institutions w/ ≈ 500 members
- Exploiting LAr knowledge from multiple experiments to maximize exposure and WIMP sensitivity

DarkSide-20k @ LNGS →
- Under construction
- Start of operations in 2026
- 20 t fiducial volume

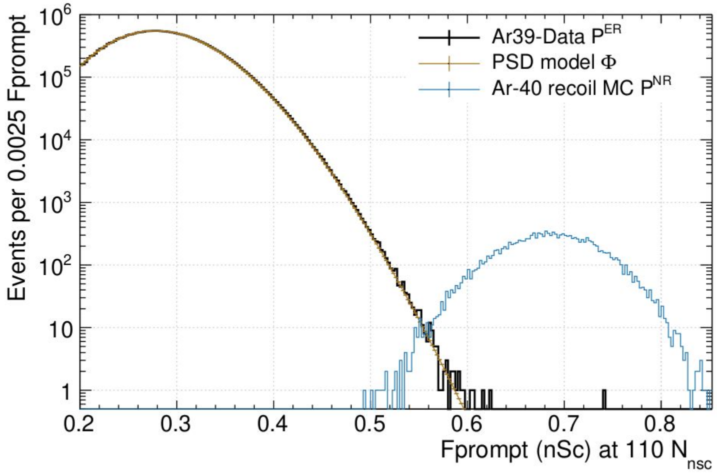
ARGO →
- Future LAr DM detector – 2030 and beyond
- 300 t fiducial volume

Liquid argon TPCs

- 8 - 10 orders of magnitude suppression of ER backgrounds using pulse shape discrimination (PSD)
- **BUT:** Ar39 rate sufficiently low (pile up)

  -> Underground argon (UAr)

  -> Cryogenic Ar39/Ar40 distillation

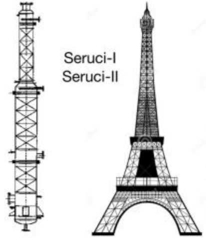


Eur. Phys. J. C 81, 823 (2021)

Large-scale underground argon (UAr) production

Production – URANIA – Cortez, CO, US

- Industrial scale extraction plant
- Extraction rate: 250-330 kg/day
- Production capability ≈ 120 t over two years for DS-20k
- UAr purity: 99.99%



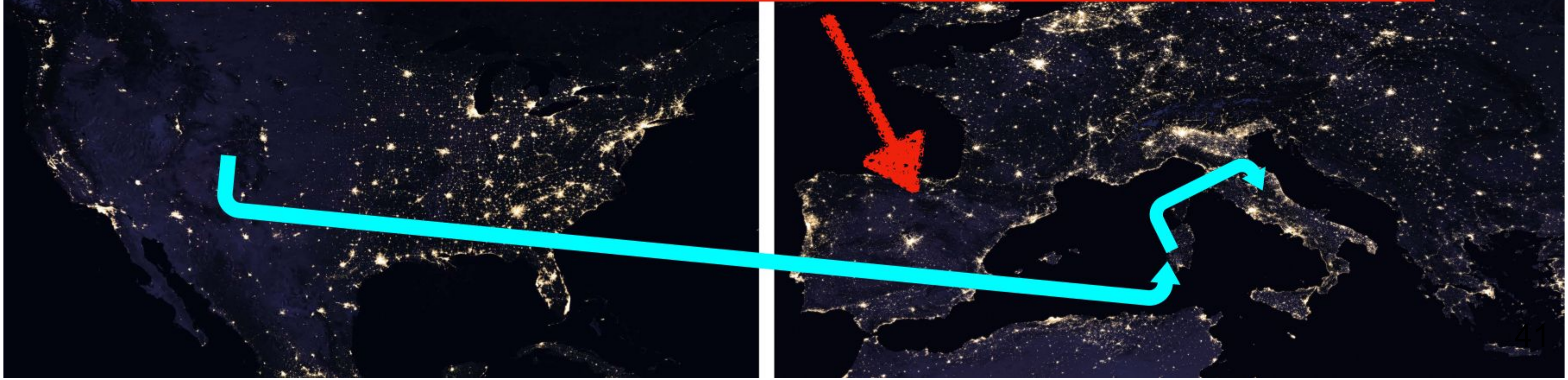
Purification – Aria – Sardinia, IT

Eur. Phys. J. C (2021) 81:359

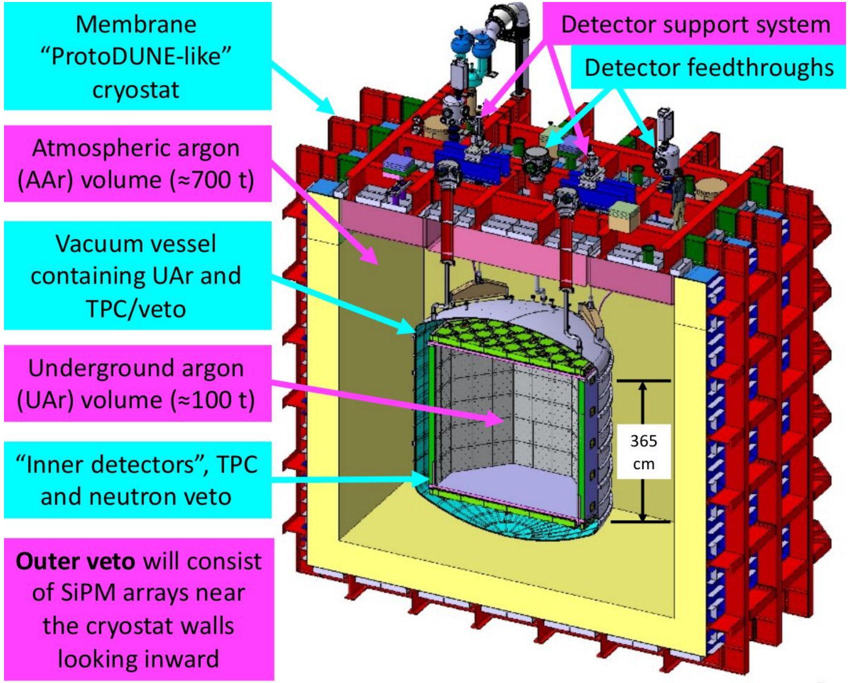
- Seruci-0 (demonstrator) tested
- 350 m cryogenic distillation column
- O(1 tonne)/day capability
- Resulting UAr purity: 99.999%

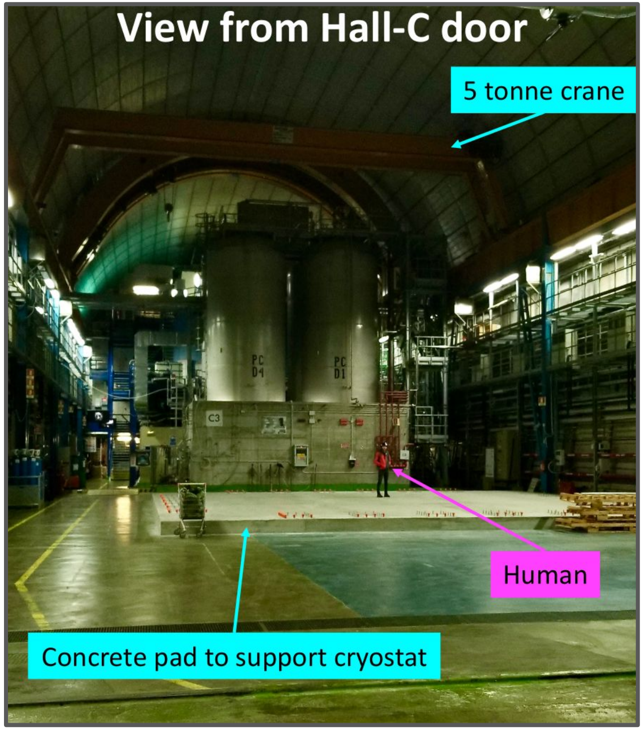
Seruci-0

DArtInArDM: LSC-supported facility of qualification of UAr in ^{39}Ar and ^{42}Ar

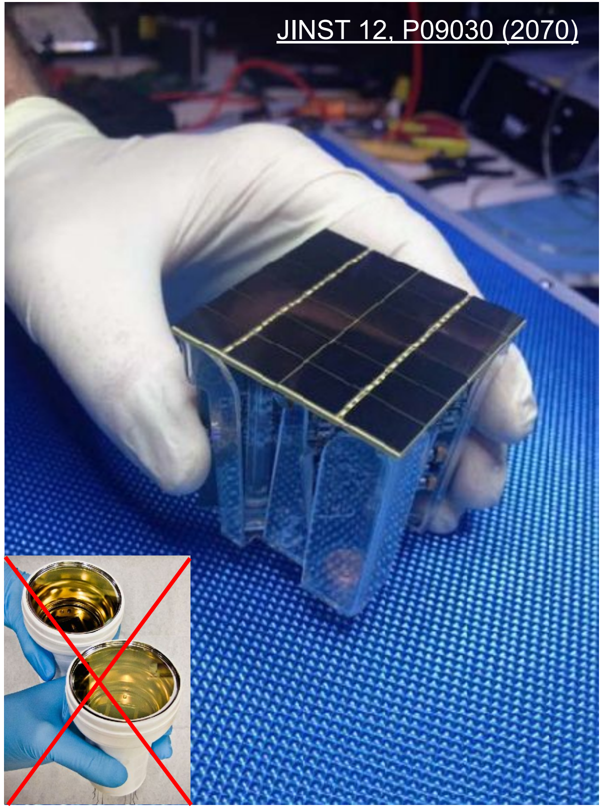


DarkSide-20k @ LNGS

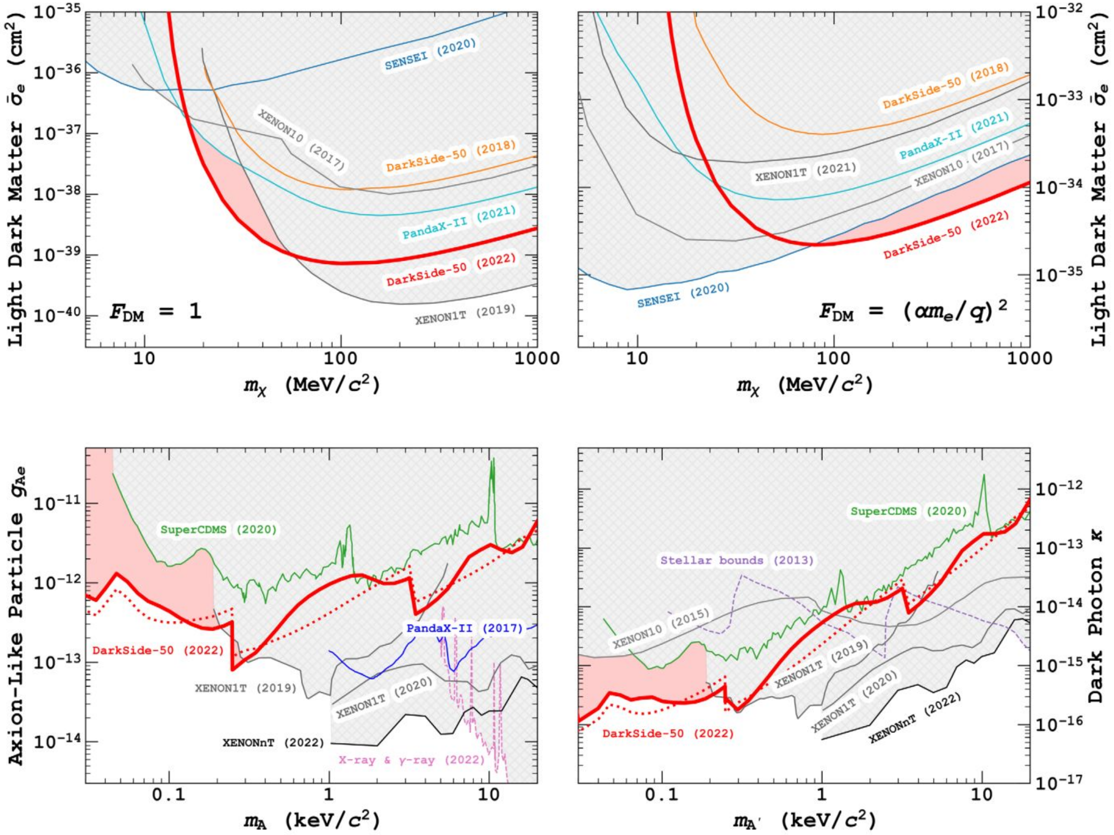




DarkSide-20k @ LNGS

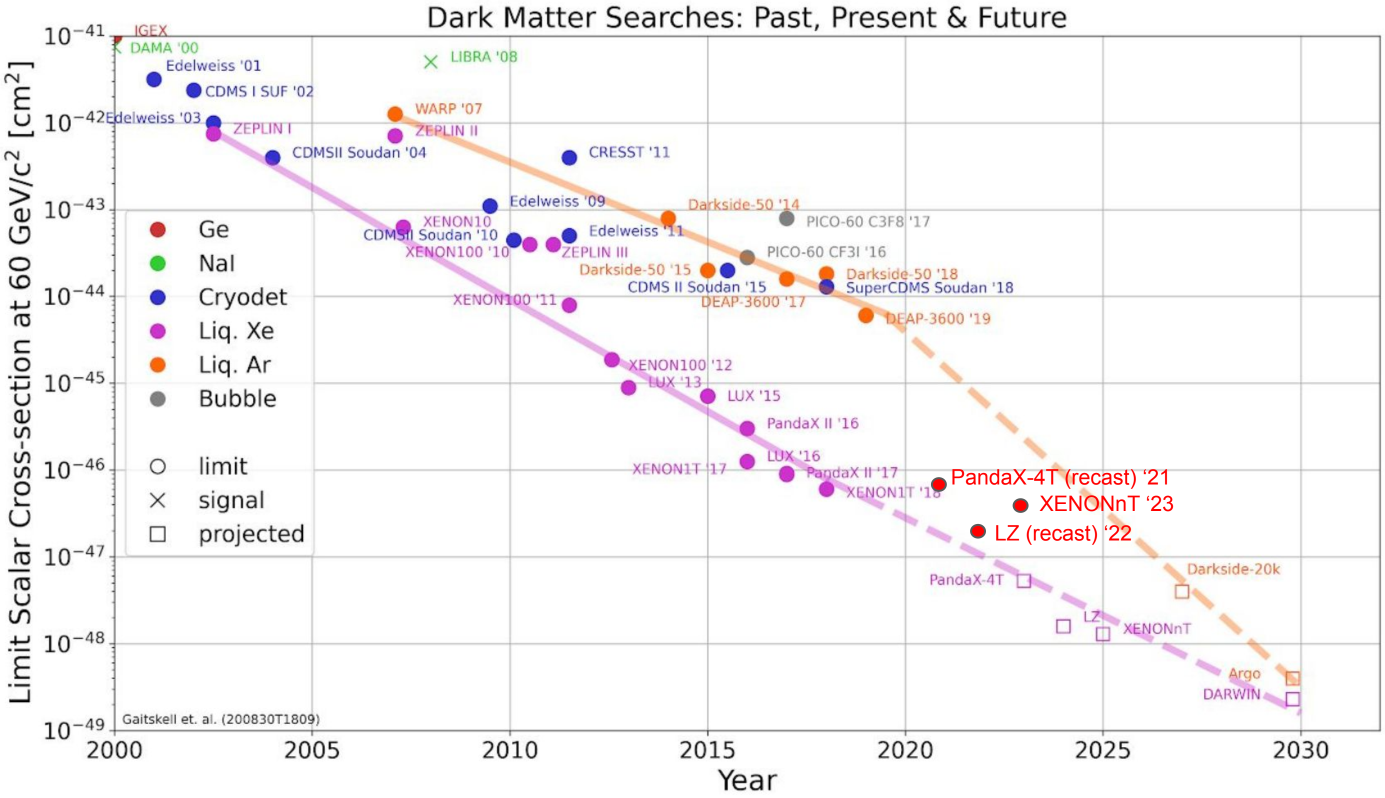


DarkSide-50 (ionization signal-only analysis)



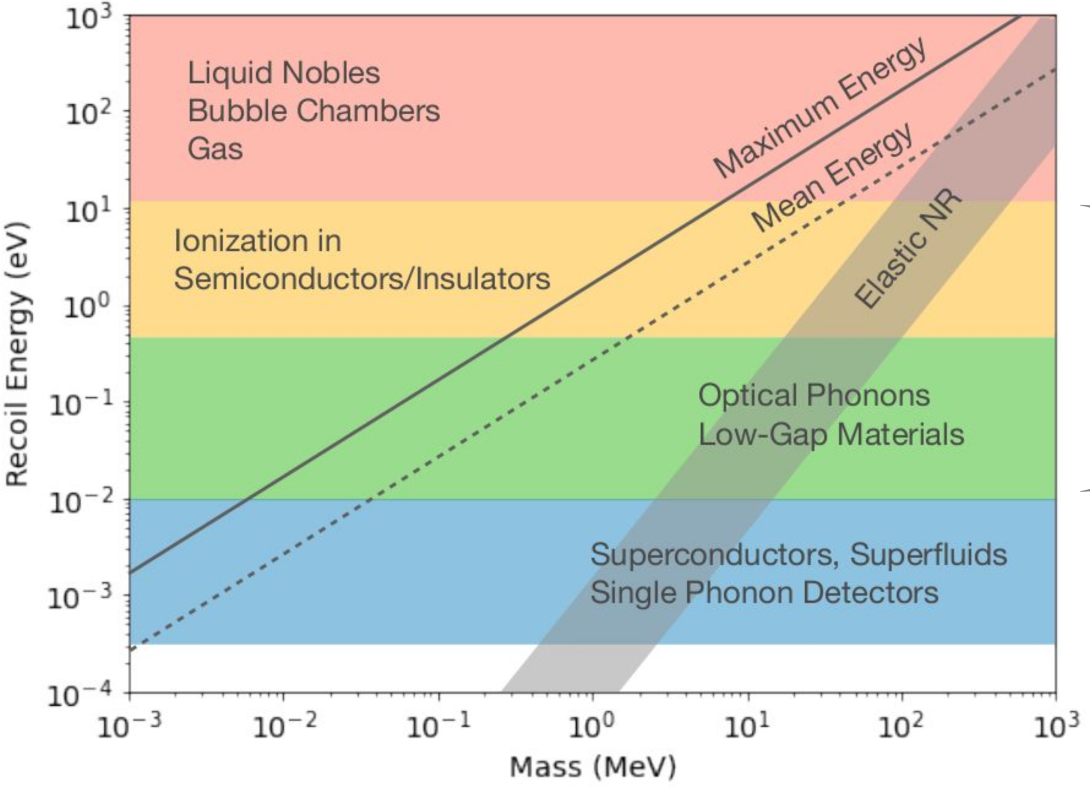
Phys. Rev. Lett. 130, 101002 (2023)

Liquid-gas TPCs summary



The broader view – going sub-GeV

Reminder



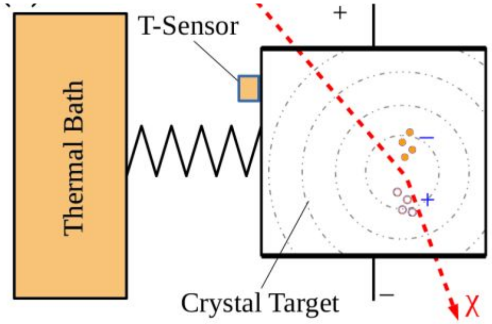
Cryogenic bolometers
(SuperCDMS, CRESST, EDELWEISS)

Skipper CCDs
(SENSEI, DAMIC, OSCURA)

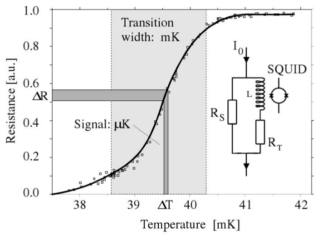
Cryogenic Bolometers

SuperCDMS, CRESST, EDELWEISS

Heat + Light/Charge readout

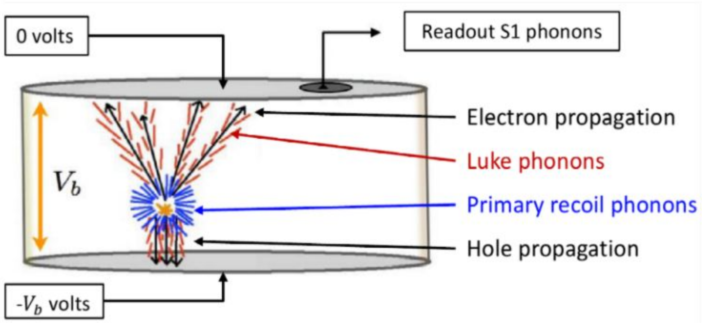


Phonon readout e.g. using TES



Lite/HV-mode

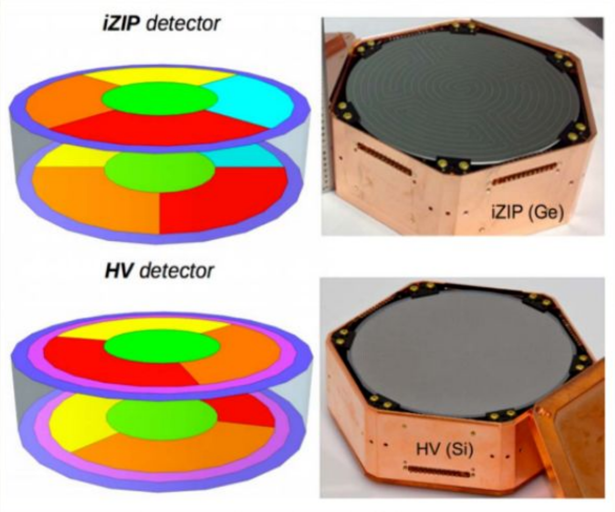
Charge mediated phonon amplification (Neganov-Trofimov-Luke Effect)

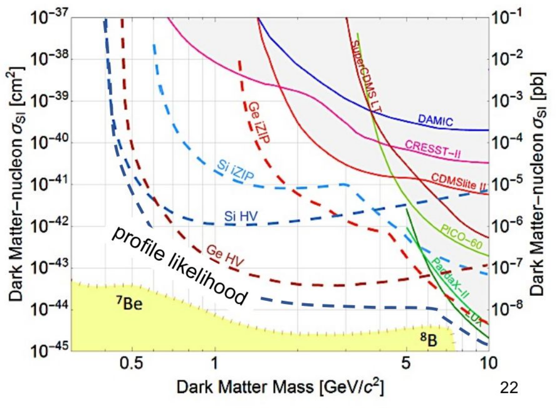


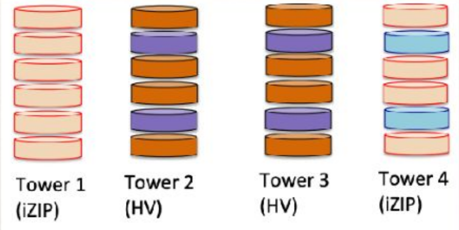
SuperCDMS @ SNOLAB

- Cryogenic thermal phonon technology
  - iZIP (phonon and ionization) and HV sensors
  - Ge $(1.4\ \text{kg})$ and Si $(0.6\ \text{kg})$
- Under construction at SNOLAB
- Operations beginning Fall 2023

	Germanium	Silicon
HV	Lowest threshold for low mass DM Larger exposure, no ^{32}Si bkgd	Lowest threshold for low mass DM Sensitive to lowest DM masses
iZIP	Nuclear Recoil Discrimination Understand Ge Backgrounds	Nuclear Recoil Discrimination Understand Si Backgrounds



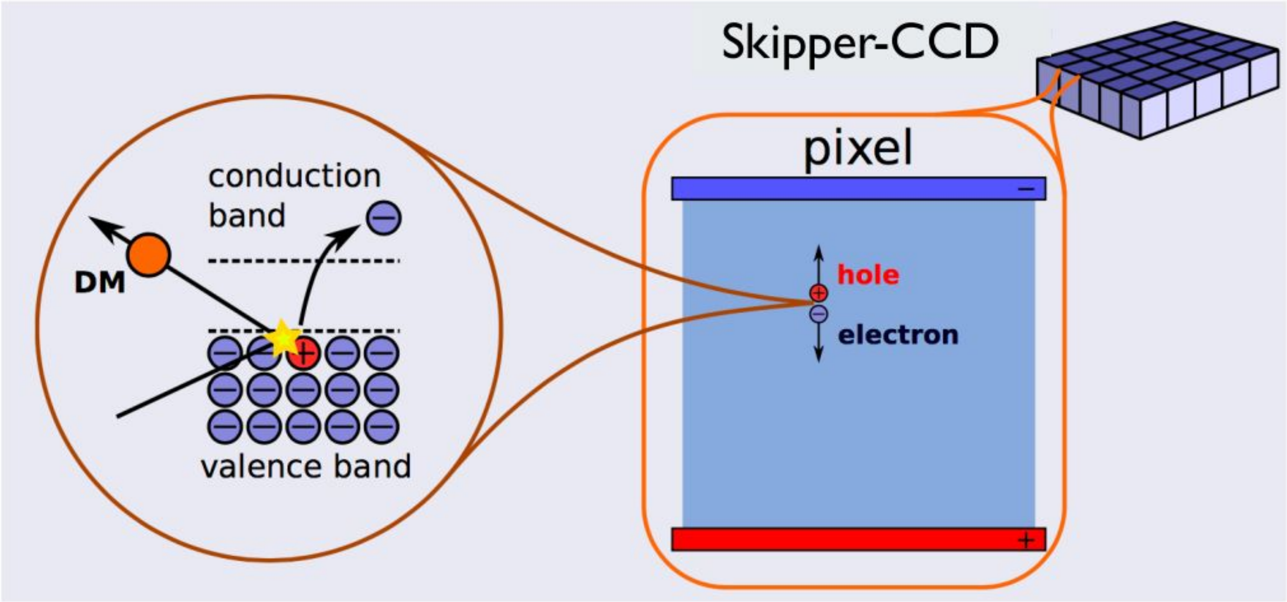




SUPER CDMS
Cryogenic Dark Matter Search

Skipper-CCDs

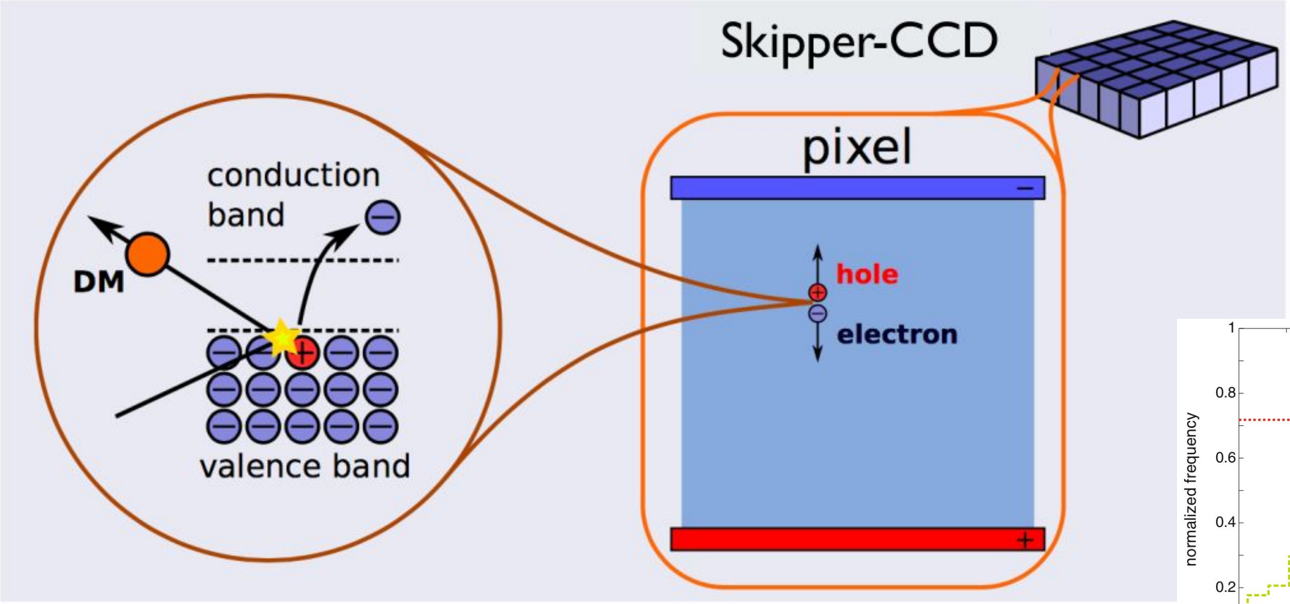
SENSEI, DAMIC, OSCURA



DM would create <u>one</u> or a <u>few</u> electrons in a pixel

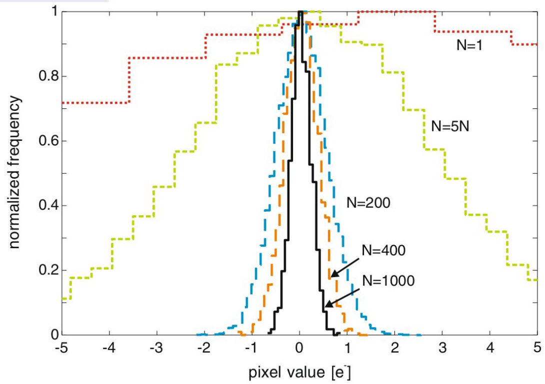
Skipper-CCDs

SENSEI, DAMIC, OSCURA



Readout noise < 1e$^-$

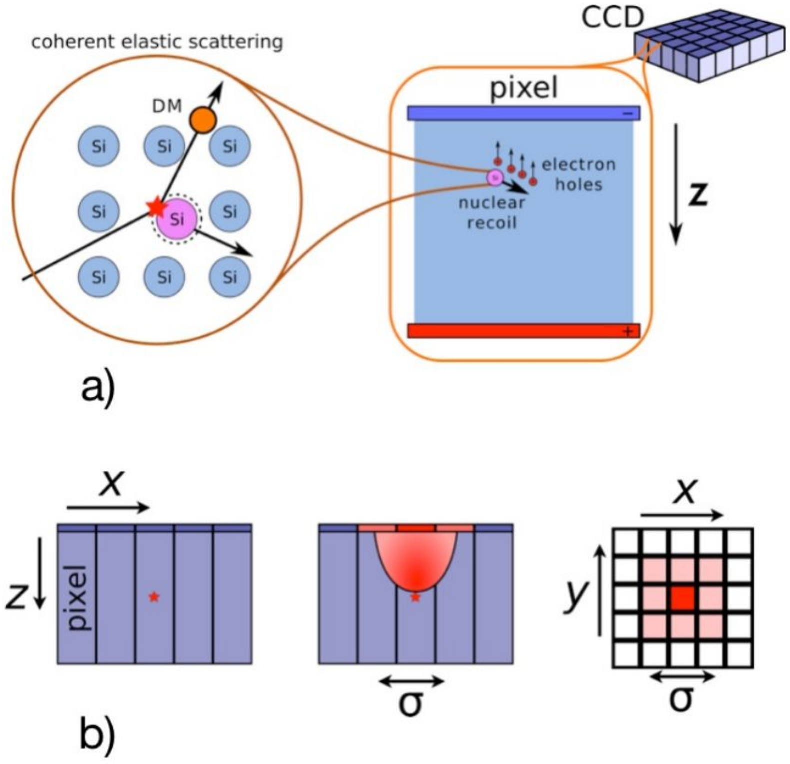
Exp Astron 34, 43–64 (2012)



DM would create one or a few electrons in a pixel

Skipper-CCDs

SENSEI, DAMIC, OSCURA



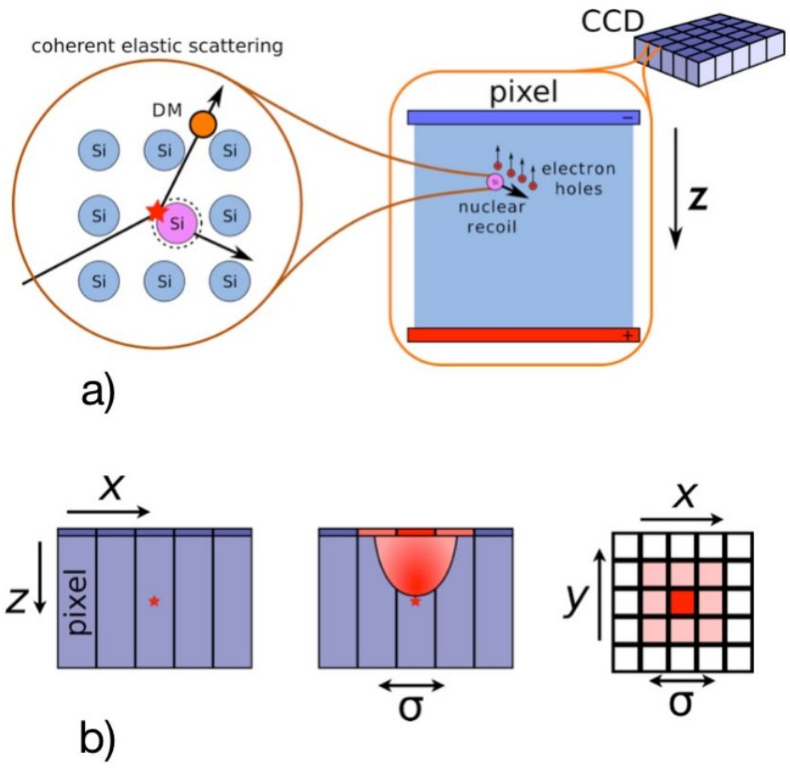
- A DM particle can scatter off a nucleus or a valence electron and create a point-like ionization event
- Charge will be drifted to the pixel array under a voltage bias
- Lateral spread of the charge cloud due to thermal diffusion
- The lateral spread is proportional to the drift time (depth of the interaction)

3D reconstruction of the interaction location	Identification of particle type via cluster pattern

3

Skipper-CCDs

SENSEI, DAMIC, OSCURA



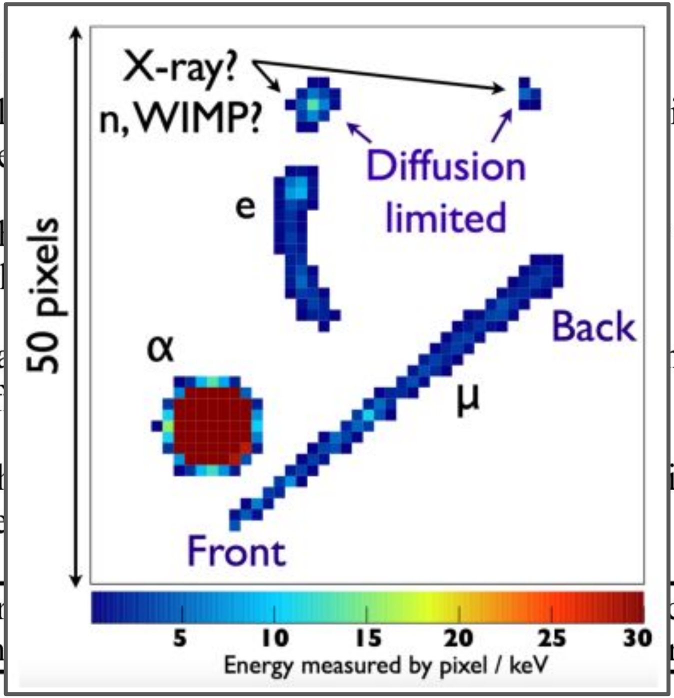
◉A ... ion
val
eve

◉Cl ... a
vol

◉La ... mal
dif

◉Th ... ime
(de

3D r ... cle
in ... rn

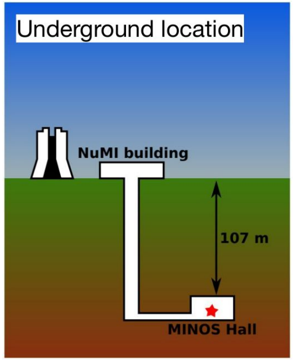


3

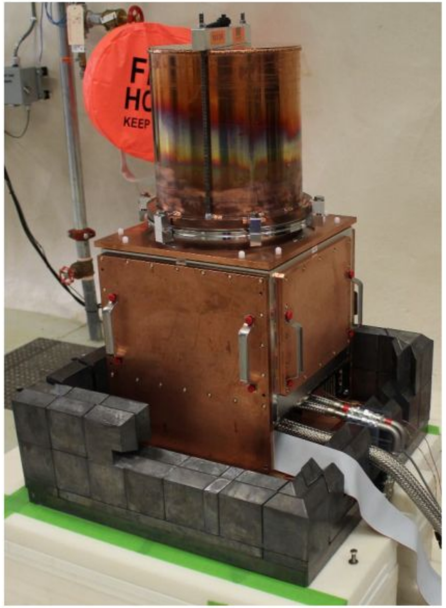
SENSEI

- Detectors operating at Fermilab & SNOLAB

SENSEI@MINOS

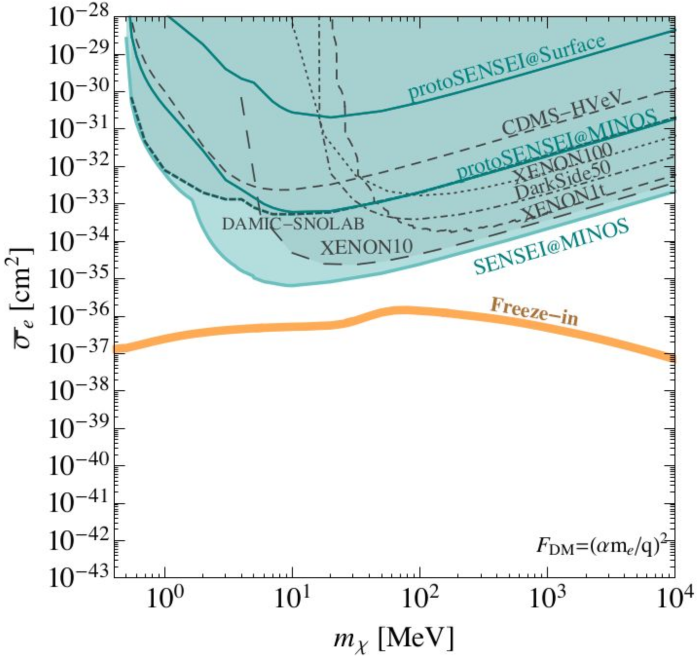


SENSEI@SNOLAB



SENSEI

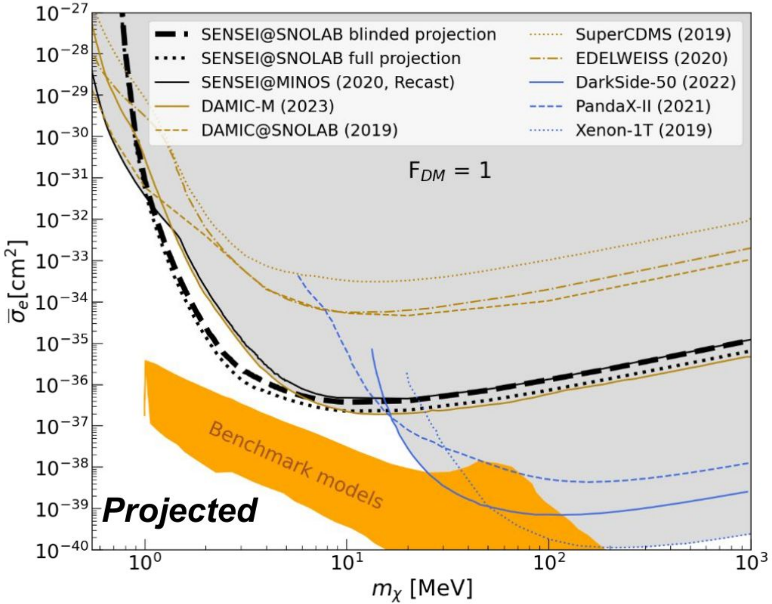
- Detectors operating at Fermilab & SNOLAB
- 3 science results w/ detector at Fermilab



1804.00088, PRL
1901.10478, PRL
2004.11378, PRL

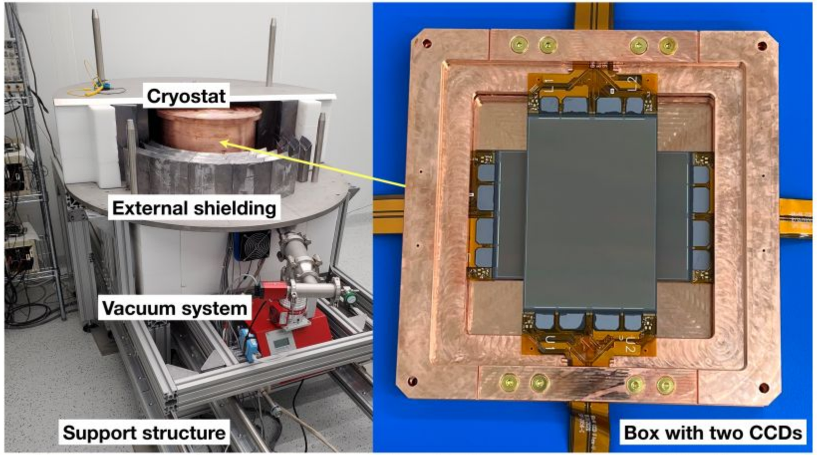
SENSEI

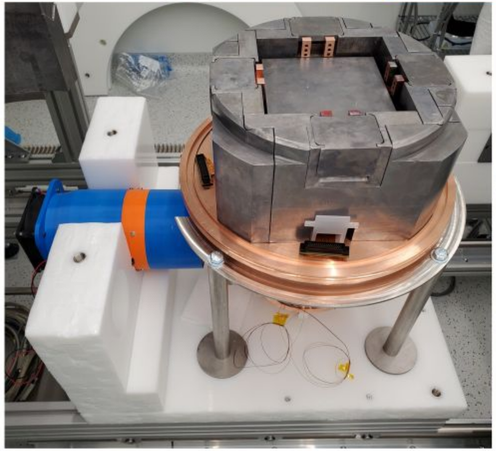
- Detectors operating at Fermilab & SNOLAB
- 3 science results w/ detector at Fermilab
- First results from SNOLAB expected soon



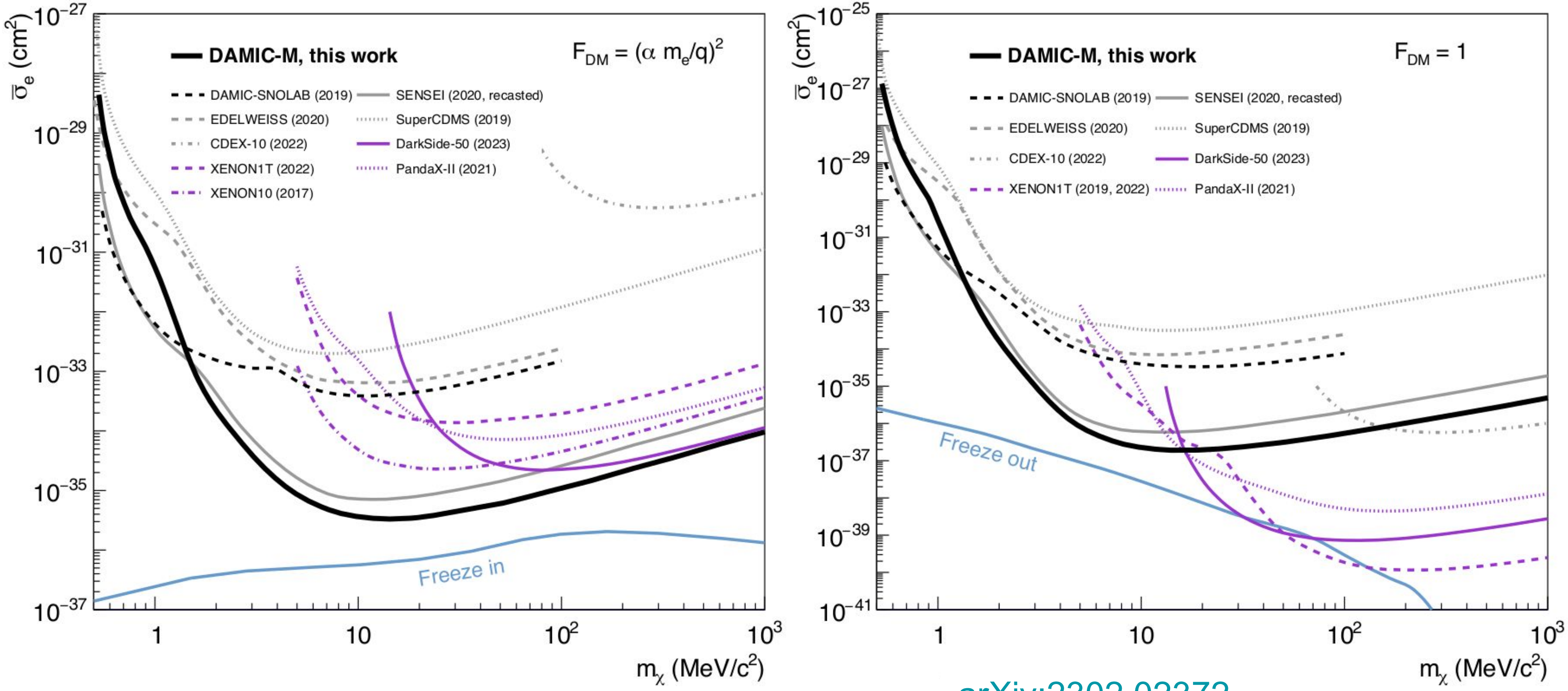
DAMIC-M LBC

- Laboratoire Souterrain de Modane
- Low Background Chamber (LBC)
- 6k × 4k pixel skipper CCDs (× 2)
- Total mass of active target **~18 g**
    - Goal: ~700 g
- Integrated exposure of **85.23 g days**





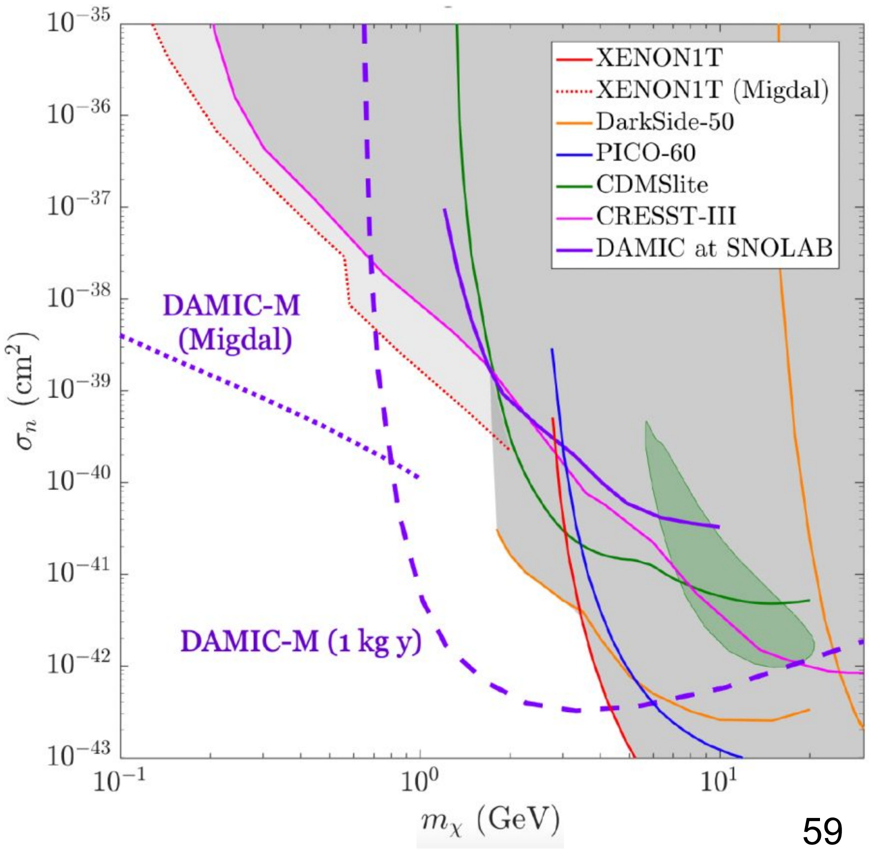
DAMIC-M LBC



arXiv:2302.02372

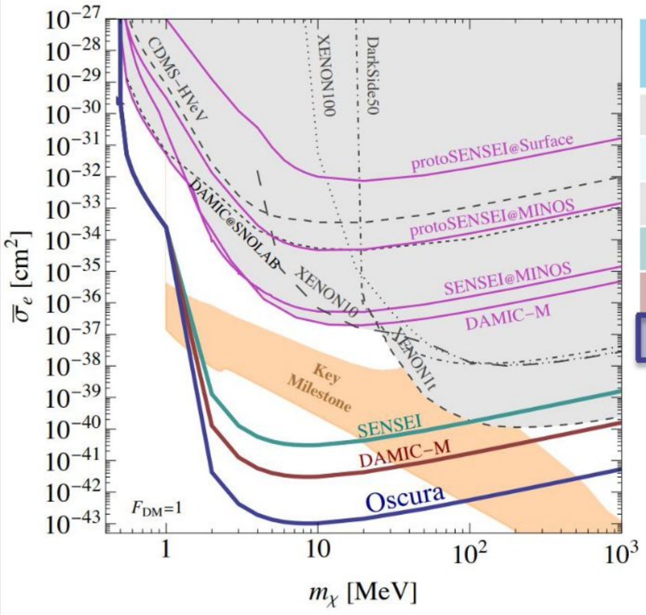
DAMIC-M

- Laboratoire Souterrain de Modane
- Full mass of **~700 g**
- Expected exposure of **1 kg y**



Skipper-CCDs

World best limits for sub-GeV DM candidates with this technology → Ongoing program



Experiment	Mass [kg]	#CCDs	Radiation bkgd [dru]	Instrumental bkgd [e-/pix/day]	Commissioning
SENSEI @ MINOS	~0.002	1	3400	1.6×10^{-4}	late-2019
DAMIC @ SNOLAB	~0.02	2	~10 (exp*)	~3×10^{-4} (exp*)	late-2021
DAMIC-M LBC	~0.02	2	10	3×10^{-3}	late-2021
SENSEI-100	~0.1	50	10 (goal)		mid-2022
DAMIC-M	~1	200	0.1 (goal)		~2023
OSCURA	~10	20,000	0.01 (goal)	1×10^{-6} (goal)	~2028

* expected from DAMIC with standard CCDs [PRL 123, 181802/PRL 125, 241803]

Oscura builds on existing efforts

The challenges are to increase mass (from 10s to 10,000s CCDs) and to reduce the backgrounds (2 orders of magnitude)

Major R&D

From Brenda Cervantes, UCLA Dark Matter 2023

DAMIC @ SNOLAB

Confirmation of the spectral excess in DAMIC at SNOLAB with skipper CCDs

A. Aguilar-Arevalo,[1] I. Arnquist,[2] N. Avalos,[3] L. Barak,[4] D. Baxter,[5] X. Bertou,[3] I.M. Bloch,[6,7] A.M. Botti,[5] M. Cababie,[8,9,5] G. Cancelo,[5] N. Castelló-Mor,[10] B.A. Cervantes-Vergara,[1] A.E. Chavarria,[11] J. Cortabitarte-Gutiérrez,[10] M. Crisler,[5] J. Cuevas-Zepeda,[12] A. Dastgheibi-Fard,[13] C. De Dominicis,[14] O. Deligny,[15] A. Drlica-Wagner,[5,12,16] J. Duarte-Campderros,[10] J.C. D'Olivo,[1] R. Essig,[17] E. Estrada,[3] J. Estrada,[5] E. Etzion,[4] F. Favela-Perez,[1] N. Gadola,[18] R. Gaïor,[14] S.E. Holland,[7] T. Hossbach,[2] L. Iddir,[14] B. Kilminster,[18] Y. Korn,[4] A. Lantero-Barreda,[10] I. Lawson,[19] S. Lee,[18] A. Letessier-Selvon,[14] P. Loaiza,[15] A. Lopez-Virto,[10] S. Luoma,[19] E. Marrufo-Villalpando,[12] K.J. McGuire,[11] G.F. Moroni,[5] S. Munagavalasa,[12] D. Norcini,[12] A. Orly,[4] G. Papadopoulos,[14] S. Paul,[12] S.E. Perez,[8,9,5] A. Piers,[11] P. Privitera,[12,14] P. Robmann,[18] D. Rodrigues,[8,9,5] N.A. Saffold,[5] S. Scorza,[19] M. Settimo,[20] A. Singal,[17,21] R. Smida,[12] M. Sofo-Haro,[5,22] L. Stefanazzi,[5] K. Stifter,[5] J. Tiffenberg,[5] M. Traina,[11] S. Uemura,[5] I. Vila,[10] R. Vilar,[10] T. Volansky,[4] G. Warot,[13] R. Yajur,[12] T-T. Yu,[23] and J-P. Zopounidis[14]

(DAMIC, DAMIC-M and SENSEI Collaborations)

[1] *Universidad Nacional Autónoma de México, Mexico City, Mexico*
[2] *Pacific Northwest National Laboratory (PNNL), Richland, WA, United States*
[3] *Centro Atómico Bariloche and Instituto Balseiro, Comisión Nacional de Energía Atómica (CNEA), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Universidad Nacional de Cuyo (UNCUYO), San Carlos de Bariloche, Argentina*
[4] *School of Physics and Astronomy, Tel-Aviv University, Tel-Aviv, Israel*
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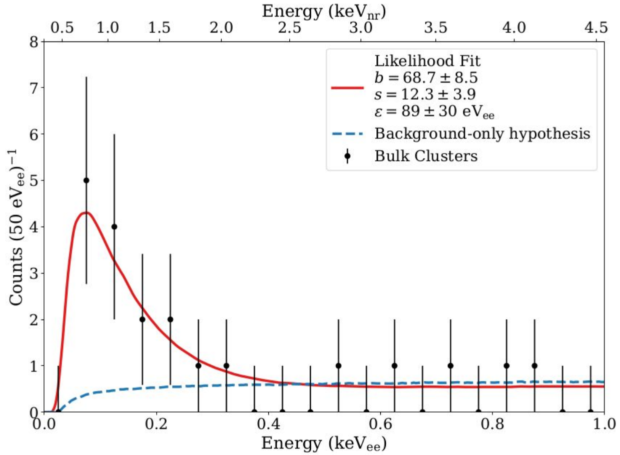
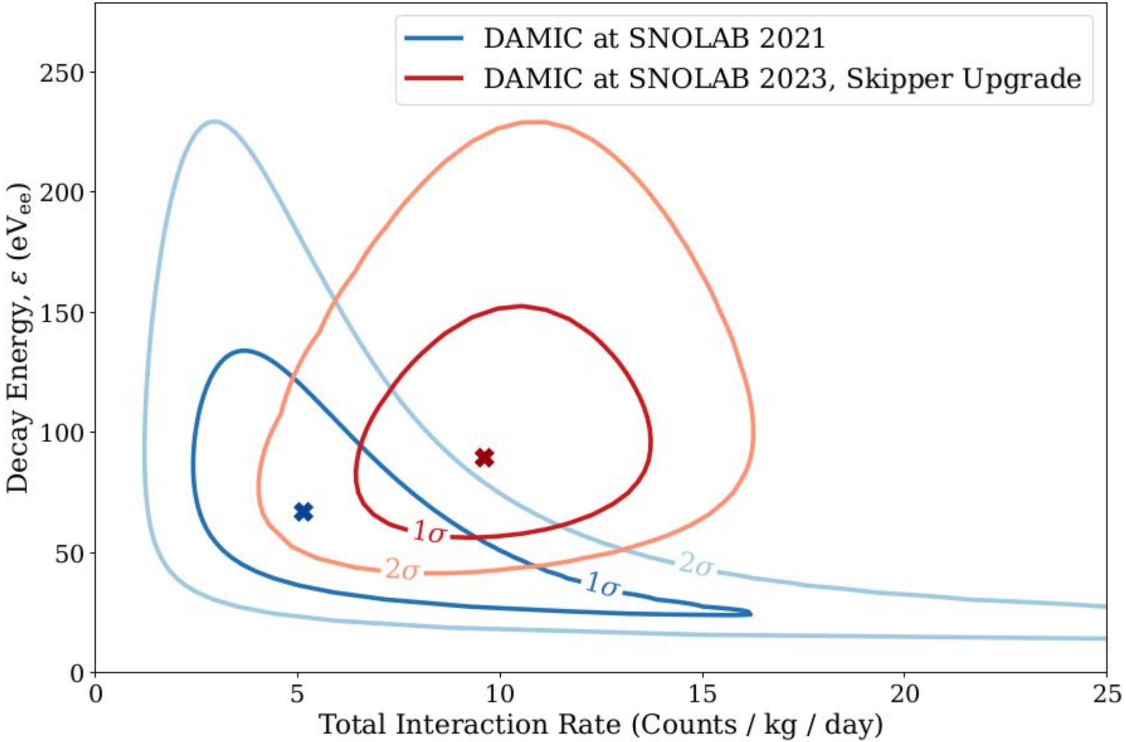
[6] *Berkeley Center for Theoretical Physics, University of California, Berkeley, CA, United States*
[7] *Lawrence Berkeley National Laboratory, Berkeley, CA, United States*
[8] *Universidad de Buenos Aires, Facultad de Ciencias Exactas y Naturales, Departamento de Física, Buenos Aires, Argentina*
[9] *CONICET - Universidad de Buenos Aires, Instituto de Física de Buenos Aires (IFIBA), Buenos Aires, Argentina*
[10] *Instituto de Física de Cantabria (IFCA), CSIC - Universidad de Cantabria, Santander, Spain*
[11] *Center for Experimental Nuclear Physics and Astrophysics, University of Washington, Seattle, WA, United States*
[12] *Kavli Institute for Cosmological Physics and The Enrico Fermi Institute, The University of Chicago, Chicago, IL, United States*



arXiv:2306.01717

DAMIC @ SNOLAB



*"The observed excess ionization events likely arise from an unidentified source of **radiation** …"*

*"The only known interactions that could give rise to the observed excess spectrum are those from **neutrons** …"*

"No such source of neutrons has been identified."

*"… the excess corresponds to a **WIMP** with mass ~2.5 GeV/c2 and a WIMP-nucleon scattering cross section ~$3x10^{-40}$ cm^2. This interpretation is nominally **excluded by** results from **CDMSlite** and **DarkSide-50**."*

arXiv:2306.01717

The EXCESS initiative

15-17 June 2021 Online

Participant List
139 participants

13 talks by 10 collaborations:

CONNIE
CRESST
DAMIC
EDELWEISS
MINER
NEWS-G
NUCLEUS
RICOCHET
SENSEI
SuperCDMS

Chairs of the 1st edition:


Alexander Fuss


Felix Wagner


Florian Reindl


Margarita Kaznacheeva

Advisory Board:
Belina von Krosigk (SuperCDMS)
Dan Baxter (DAMIC)
Federica Petricca (CRESST)
Guillaume Giroux (NEWS-G)
Guillermo Fernandez Moroni (CONNIE/Skipper-CCD)
Jules Gascon (EDELWEISS)
Julien Billard (RICOCHET)
Kostas Nikolopoulos (NEWS-G)
Marie-Cecile Piro (PhyStat DM)
Noah Kurinsky (SuperCDMS)
Raimund Strauss (NUCLEUS)
Rouven Essig (SENSEI)
Rupak Mahapatra (MINER)
Vasile Ghete (NUCLEUS)

SciPost Phys. Proc. 9, 001 (2022)

Contents

EXCESS2023@TAUP coming up!
Aug. 26, 2023
https://indico.cern.ch/event/1213348/

The EXCESS initiative

15-

Particip

139 parti

13 talks b

CONNIE
CRESST
DAMIC
EDELWE
MINER
NEWS-G
NUCLEU
RICOCH
SENSEI
SuperCD

2022)

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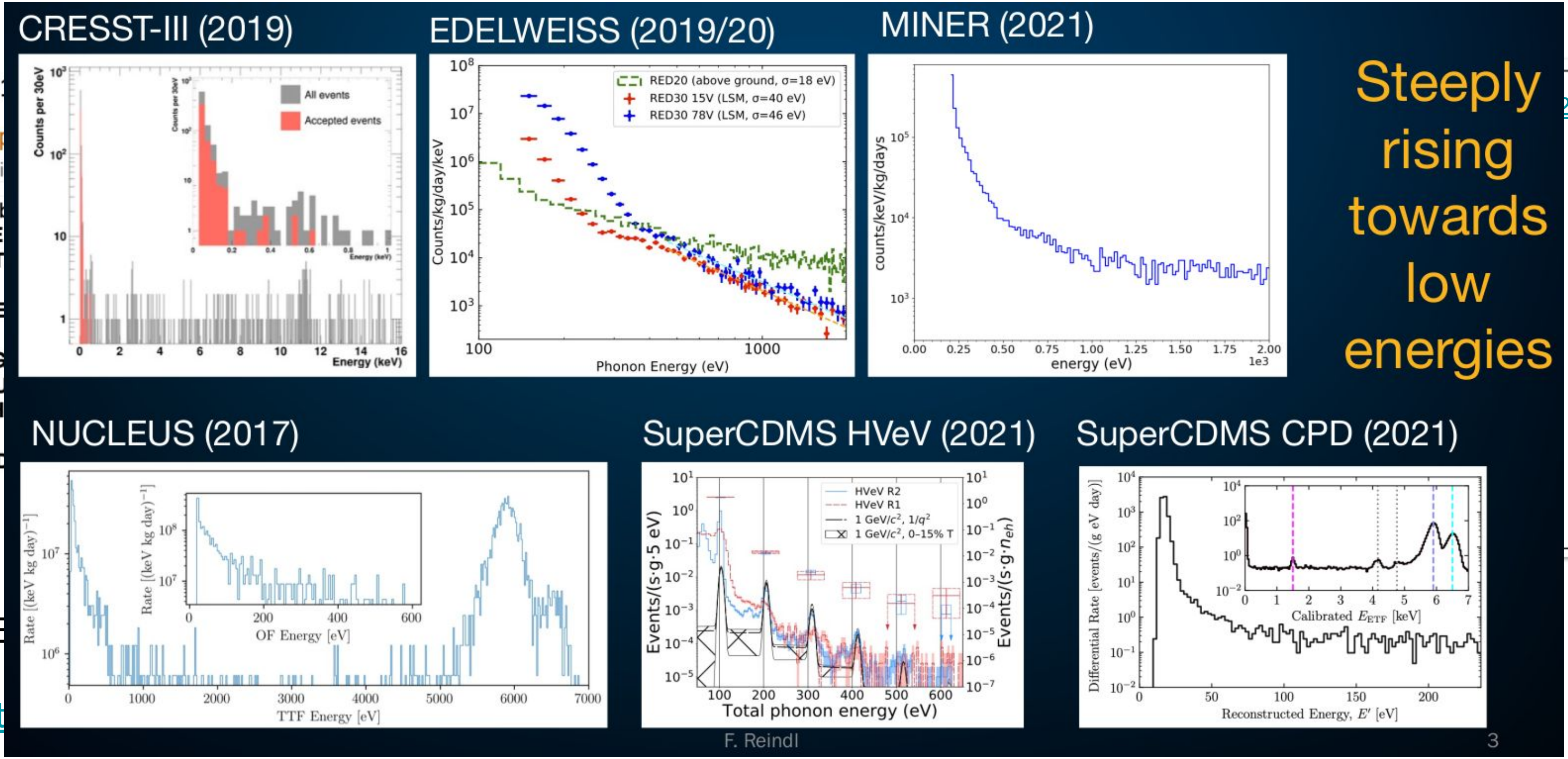

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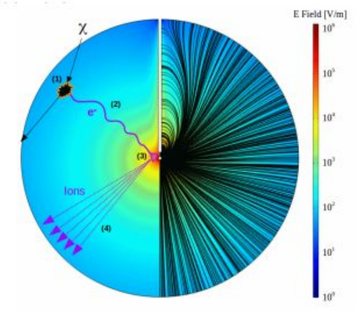
Many more promising technologies/detectors

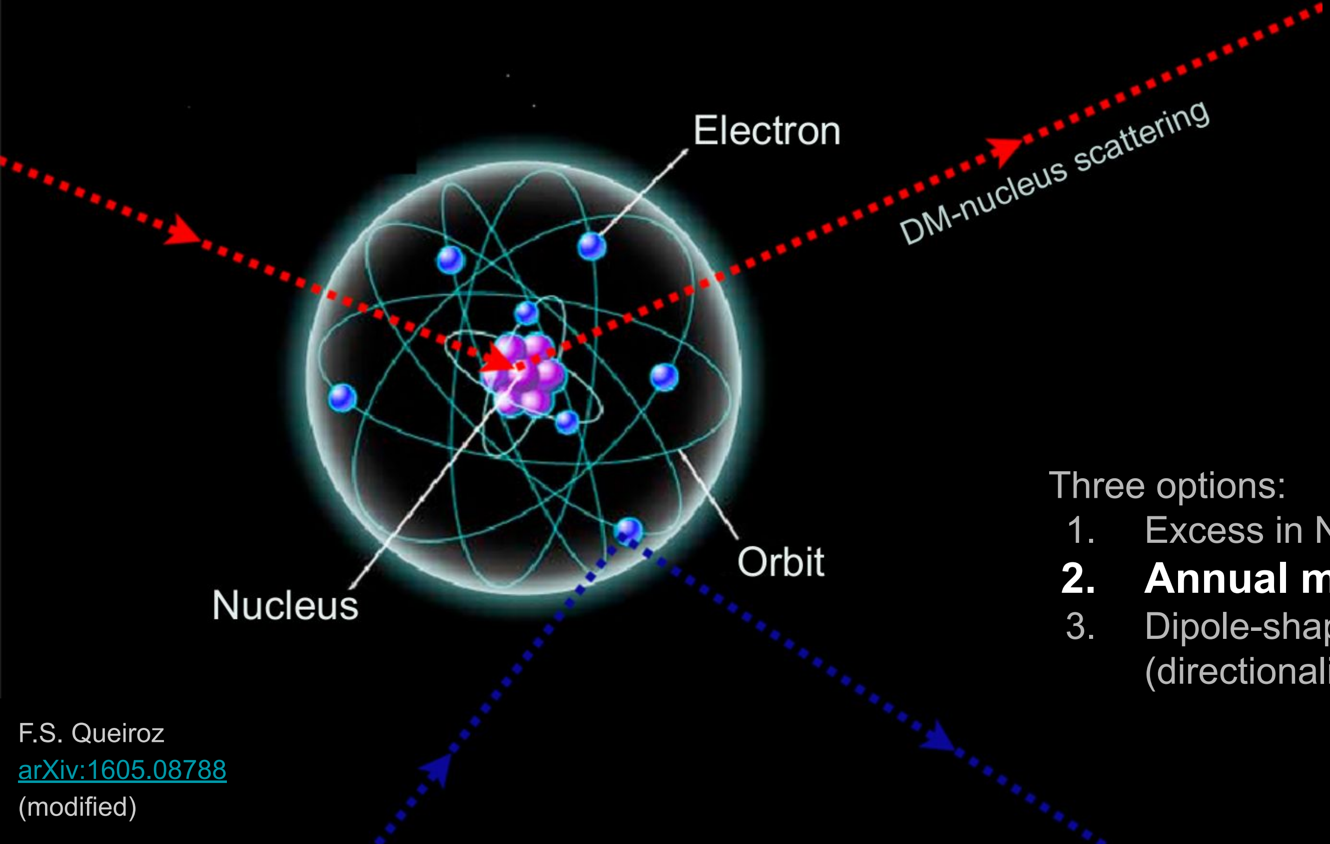
NEWS-G



PICO (PICASSO + COUPP)

- Gas prop. counter (NEWS-G)
- Threshold detectors (PICO)
- Qubits (see poster by Rakshya Khatiwada)
- SNSPD
- Supercooled water (Snowball)
- Superfluid helium (HeRALD)
- HydroX
- …

Resolving DAMA



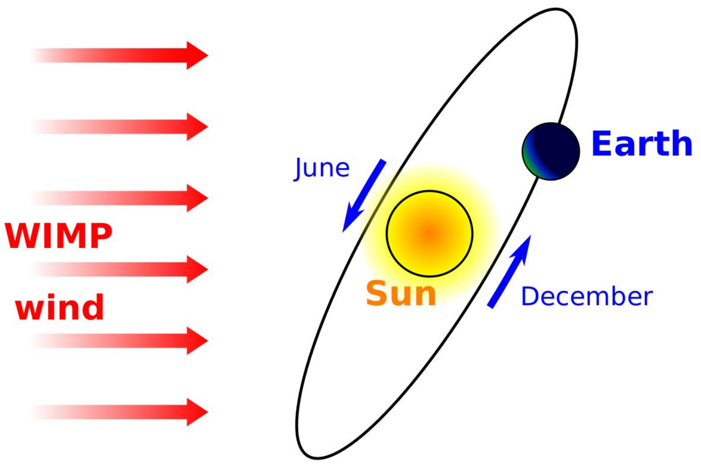
Three options:

1. Excess in NR rate
2. **Annual modulation of NR rate**
3. Dipole-shaped recoil distribution (directionality)

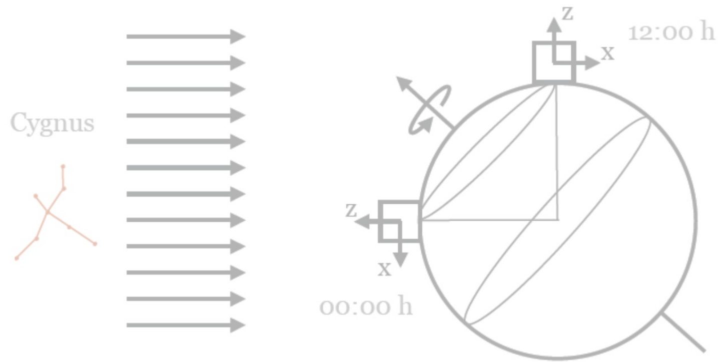
F.S. Queiroz
arXiv:1605.08788
(modified)

Modulation signals

Yearly modulated signal:



Daily modulated signal:



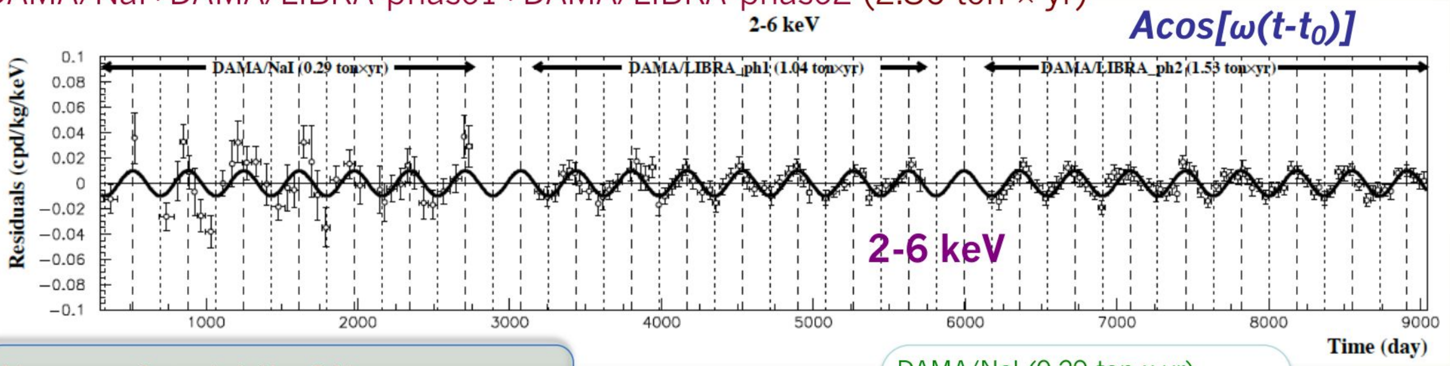
Expected change in rate: **1-10 %**

DAMA/Libra

DM model-independent Annual Modulation Result

experimental residuals of the single-hit scintillation events rate vs time and energy

DAMA/NaI+DAMA/LIBRA-phase1+DAMA/LIBRA-phase2 (2.86 ton × yr)



Absence of modulation? No

χ^2/dof=311/156 ⇒ P(A=0) =2.3×10^{-12}

DAMA/NaI (0.29 ton x yr)

DAMA/LIBRA-ph1 (1.04 ton x yr)

DAMA/LIBRA-ph2 (1.53 ton x yr)

total exposure = 2.86 ton×yr

continuous lines: t_0 = 152.5 d, T = 1.00 y

A=(0.00996±0.00074) cpd/kg/keV

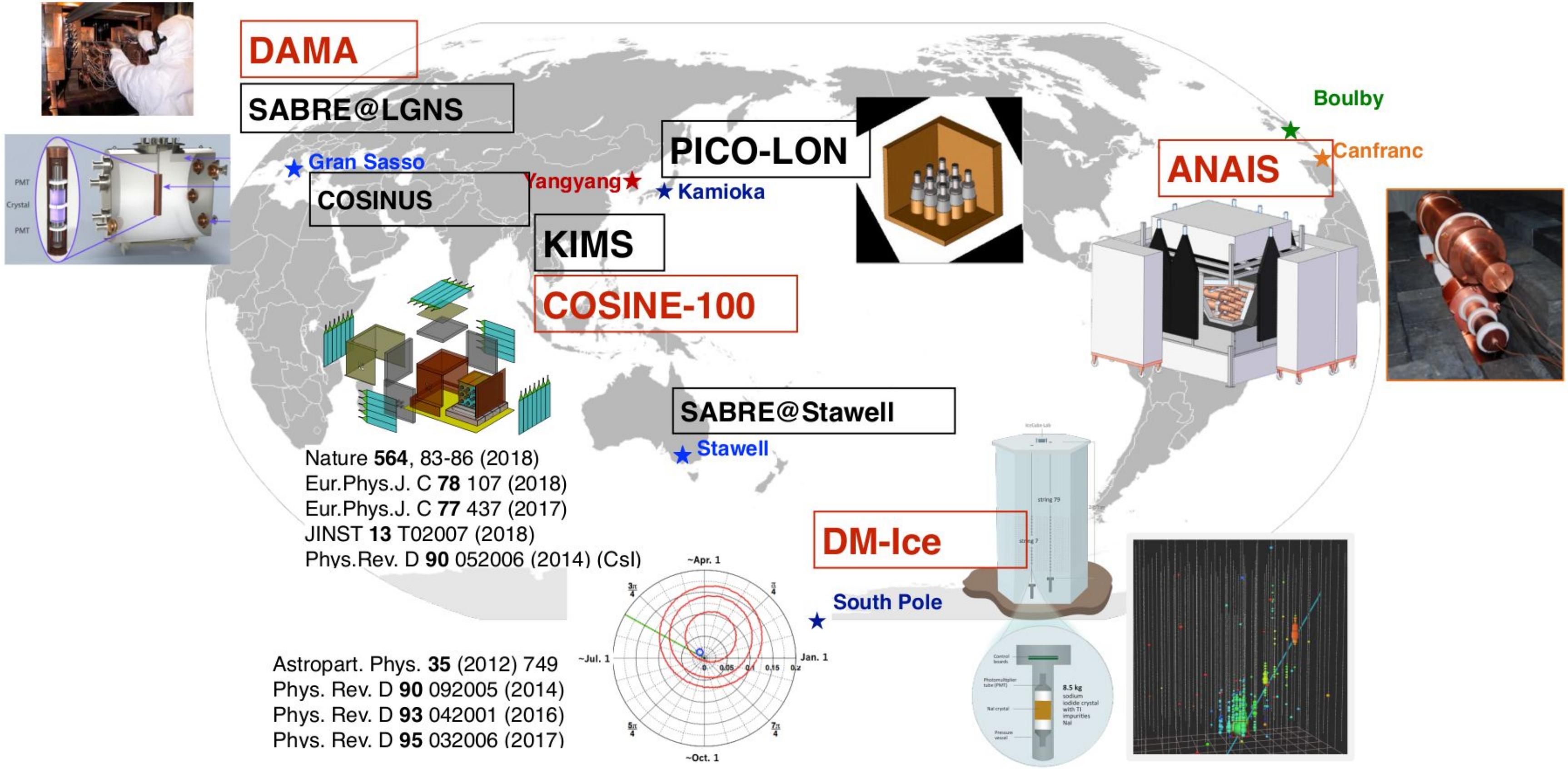
χ^2/dof = 130/155 **13.4 σ C.L.**

Releasing period (T) and phase (t_0) in the fit

from Pierluigi Belli, UCLA Dark Matter 2023

(see also: Nucl.Phys.Atom.Energy 19 (2018) 4, 307-325)

Global NaI(Tl) efforts



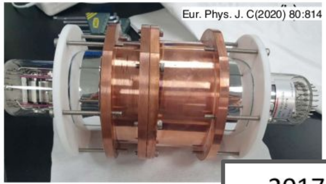
Nature **564**, 83-86 (2018)
Eur.Phys.J. C **78** 107 (2018)
Eur.Phys.J. C **77** 437 (2017)
JINST **13** T02007 (2018)
Phys.Rev. D **90** 052006 (2014) (CsI)

Astropart. Phys. **35** (2012) 749
Phys. Rev. D **90** 092005 (2014)
Phys. Rev. D **93** 042001 (2016)
Phys. Rev. D **95** 032006 (2017)

Are we nearing a solution?

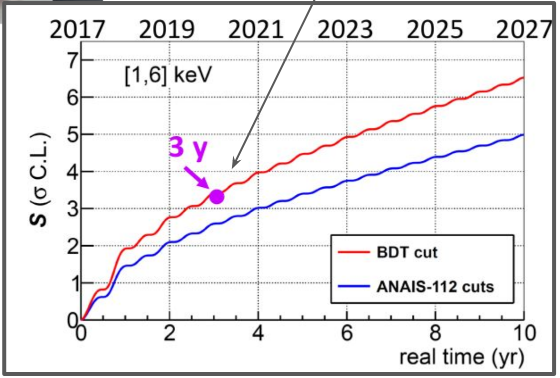
Conclusions



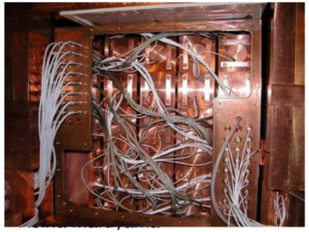


- DAMA sees annual modulation
- No signal from other direct detection experiments
- ANAIS-112 & COSINE-100 offer direct test, no clear observation of modulation
- However, no explanation for DAMA's signal
  - SABRE & COSINUS may offer new information
- NaI to continue with dark matter searches (see G. Adhikari's talk)

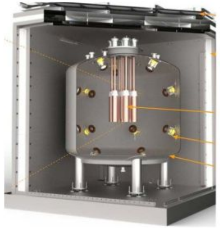
today



from María Martínez, UCLA Dark Matter 2023





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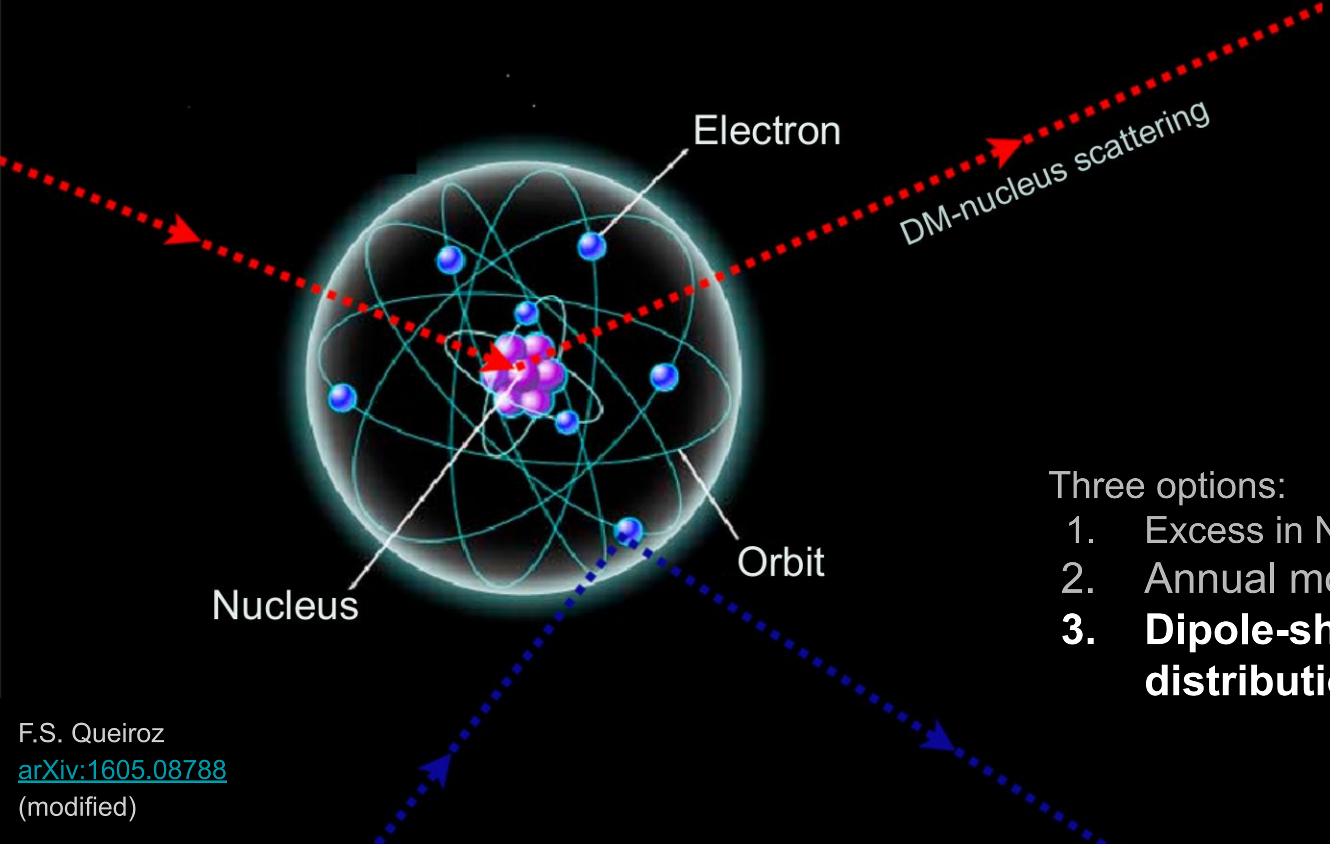
from Reina Maruyama, UCLA Dark Matter 2023

Going beyond the neutrino fog



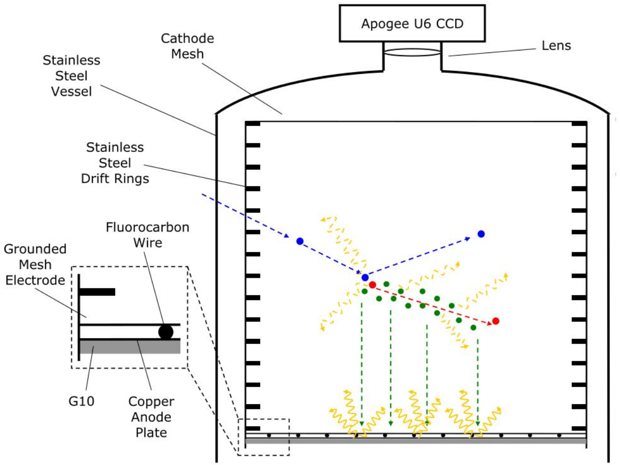
Three options:

1. Excess in NR rate
2. Annual modulation of NR rate
3. **Dipole-shaped recoil distribution (directionality)**

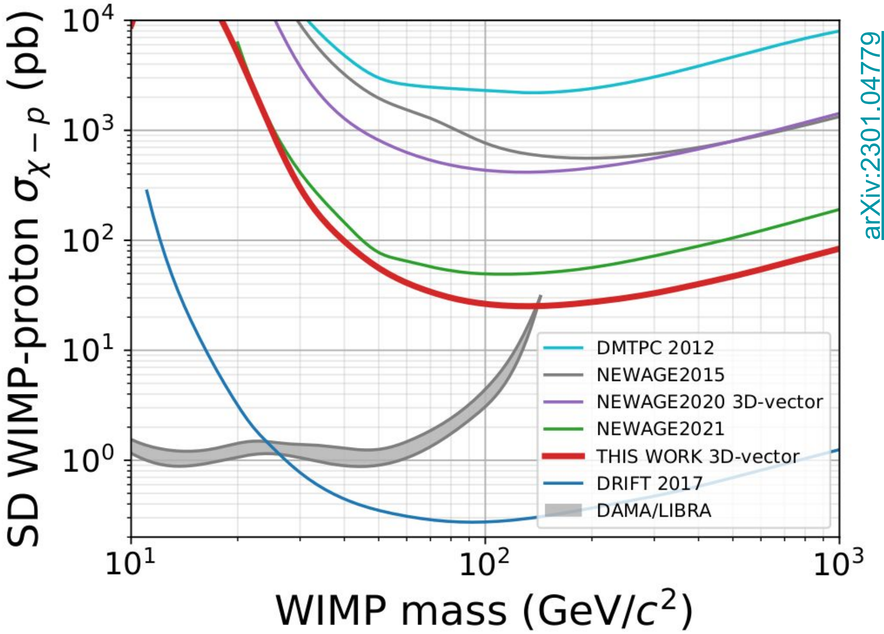
F.S. Queiroz
arXiv:1605.08788
(modified)

Directional detectors

- DMTPC (Phys. Lett. B, 695 (2011), p. 124)
- Drift (Astropart. Phys., 91 (2017), p. 65)
- Newage (arXiv:2301.04779 (2023))
- CYGNO (arXiv:2202.05480 (2022))

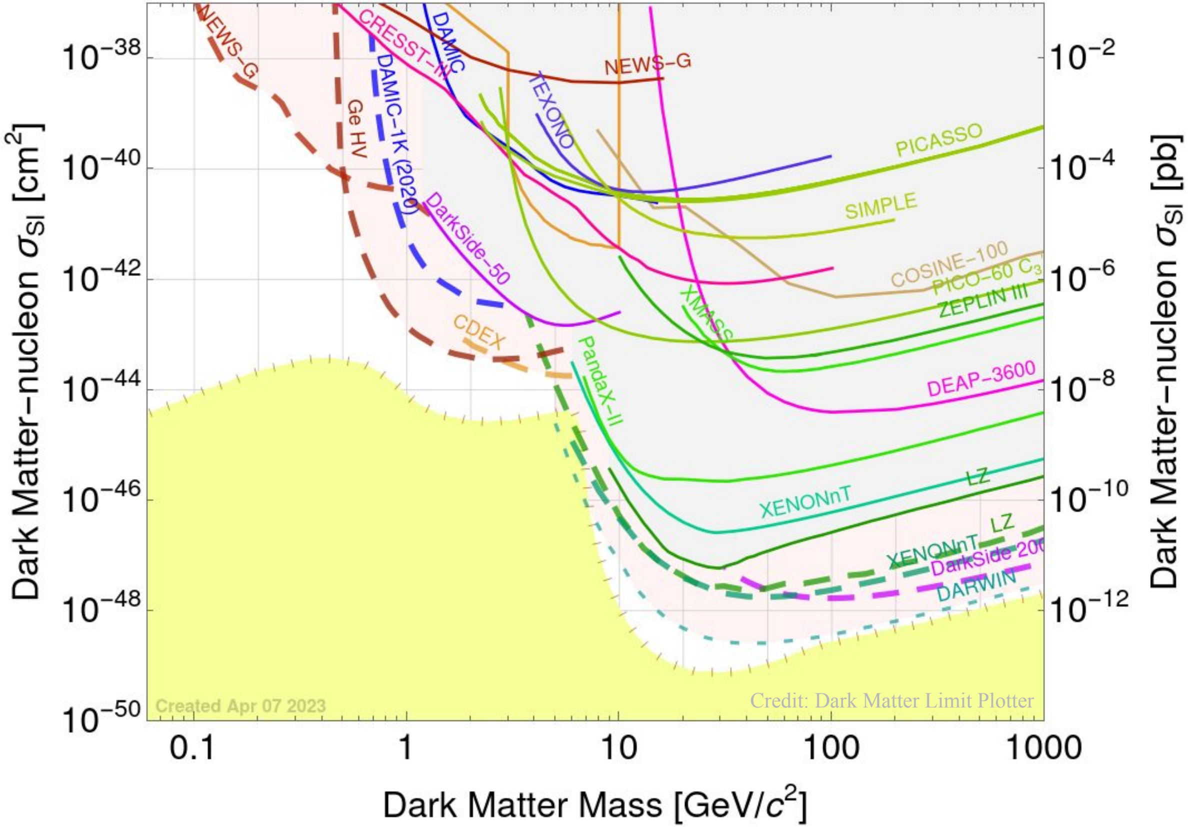


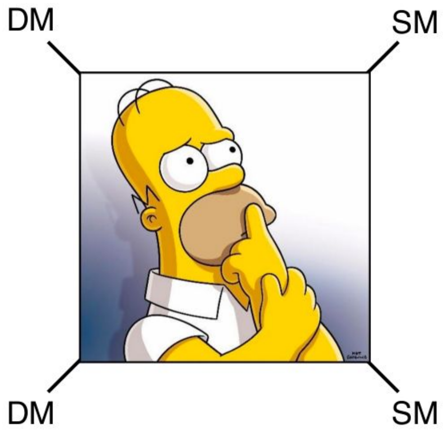
10-L DMTPC directional dark matter detector



arXiv:2301.04779

Delve Deep, Search Wide

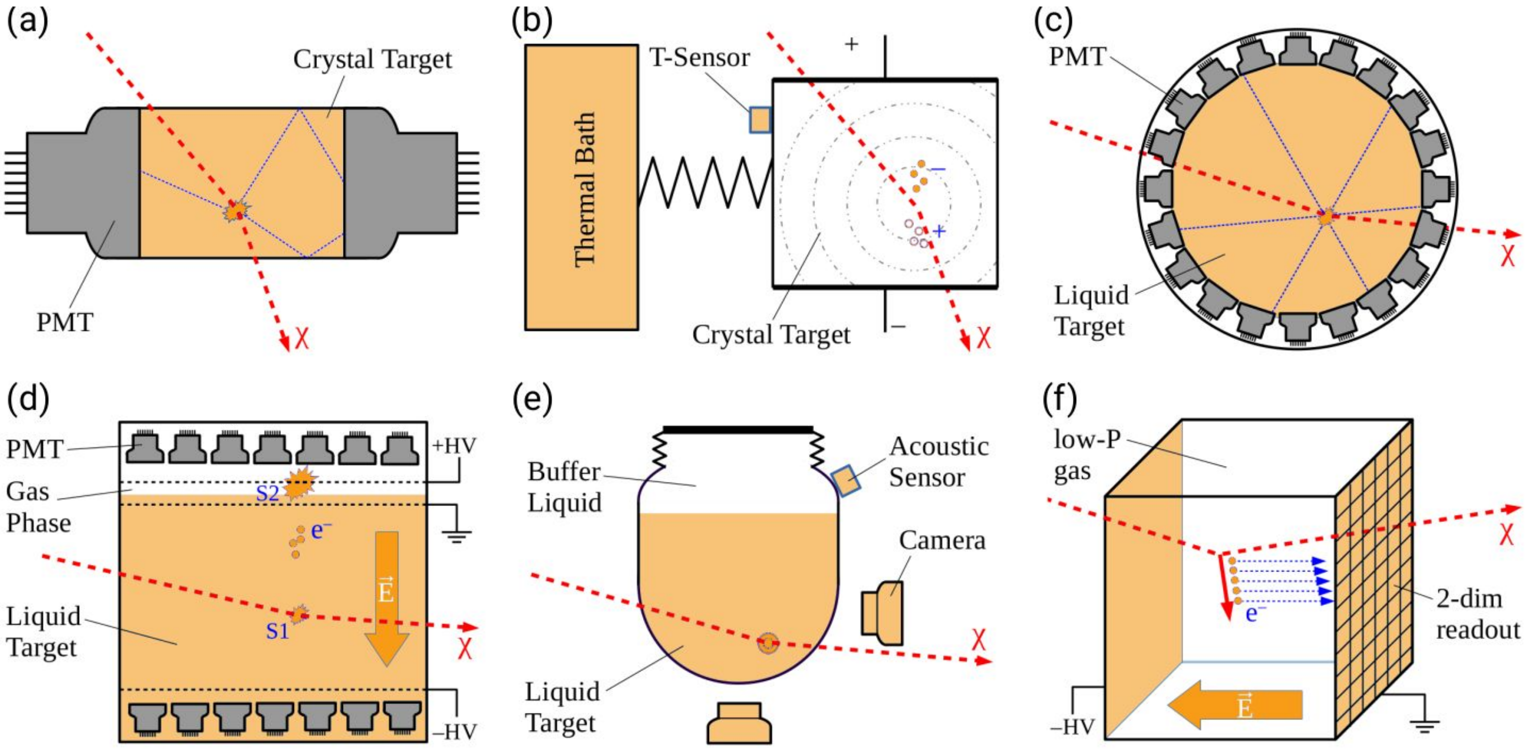




Thank you for your attention!

Backup

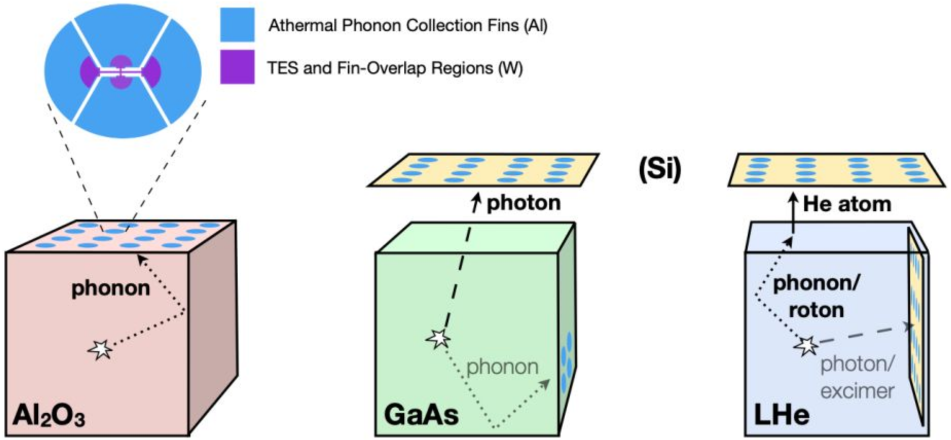
Working principles of direct detection experiments



TESSERACT

Transition Edge Sensors with Sub-EV Resolution And Cryogenic Targets

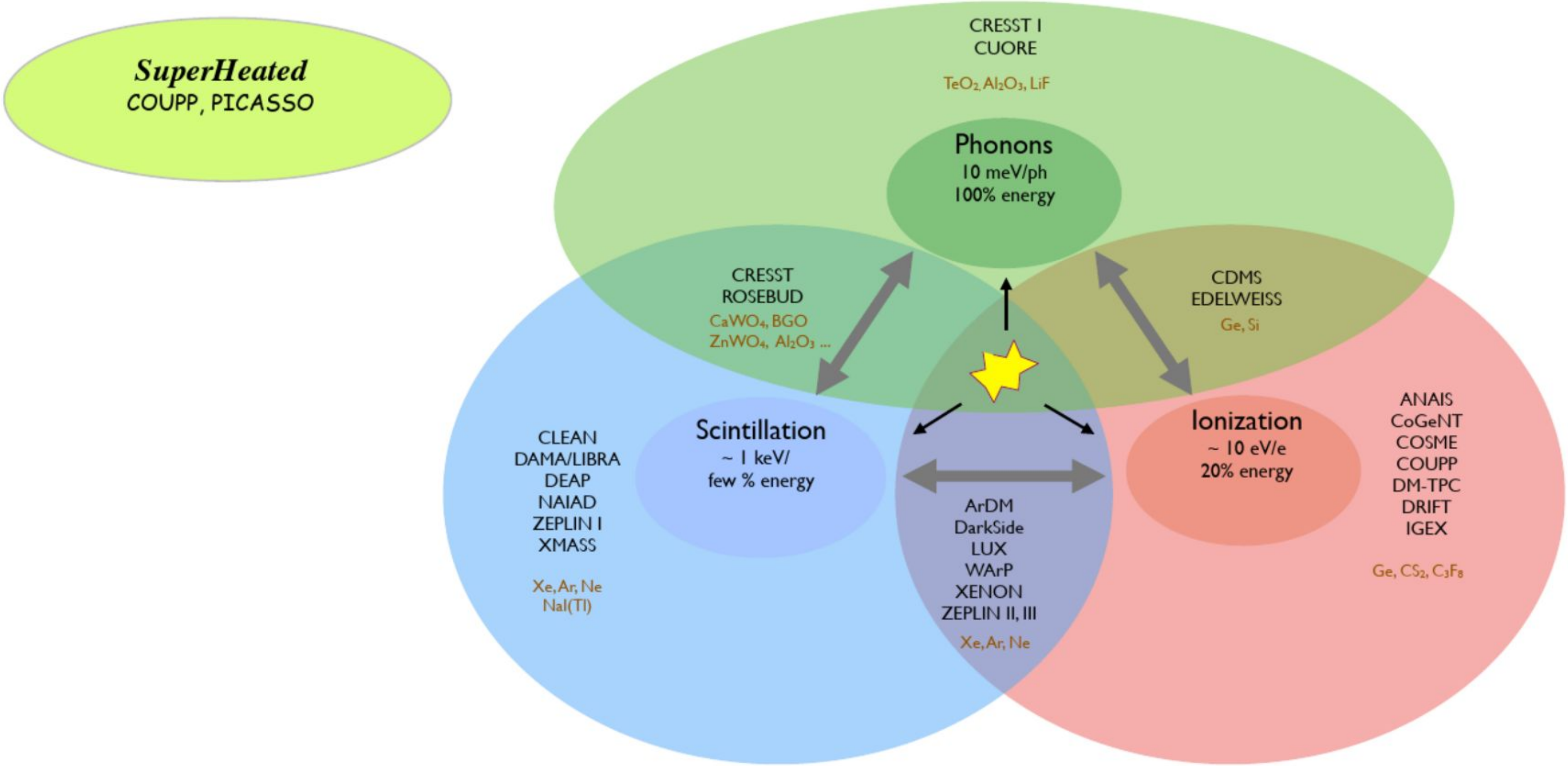
Goal: use multiple target materials + advances in TES sensor technology



Liquid helium experiment (HeRALD)
GaAs and Sapphire-based experiments (SPICE)

Figure from: https://www.snowmass21.org/docs/files/summaries/CF/SNOWMASS21-CF1_CF2-IF1_IF8-120.pdf

Direct detection experiments overview



Modulation introduced with DAMA-like analysis

COSINE-like analysis

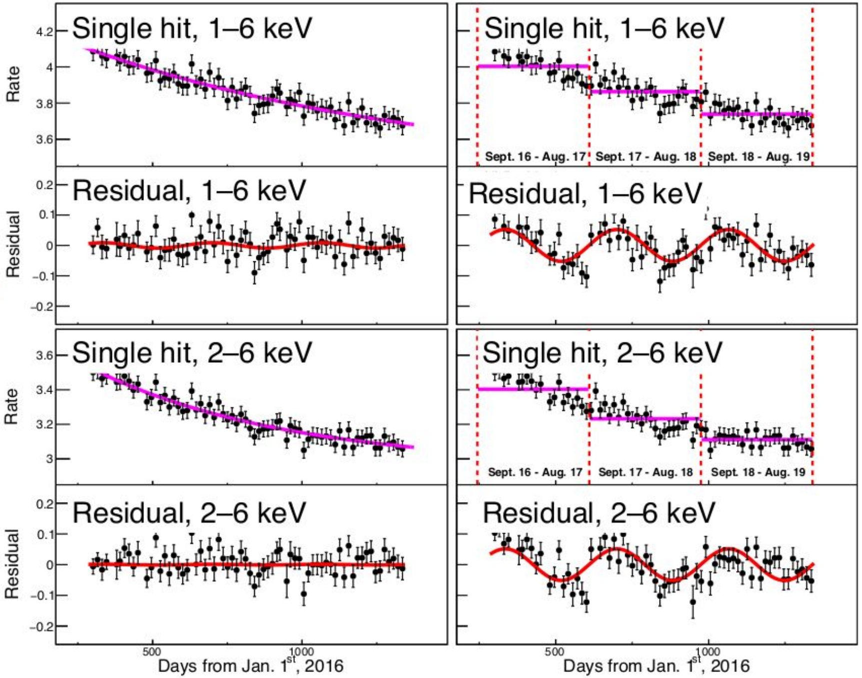
Fit for background,
7 exponentials

Fit residual for modulation

1–6 keV

2–6 keV

COSINE-100 data



DAMA-like analysis

Subtract single average per dataset

Fit residual for modulation

~7σ modulation
opposite phase

Impossible to confirm without rate vs. time