Overview of Dark Matter Searches in France

17th Workshop of the

FCPPN/L 2026, IP2I, Lyon, France

Luca Scotto Lavina

LPNHE, CNRS, Paris

GDR DUPhy

Deep Underground Physics

GDR = Groupement de Recherche

DUPhy = Deep Underground Physics

https://gdrduphy.in2p3.fr/

WP1	WP2	WP3	WP4	WP5	WP6
Physics of rare events	**Low radioactivity techniques**	**Detectors**	**Analysis and Simulation**	**Theory and phenomenology**	**Outreach and Open Science**
Present and future experiments	Link with DULs	Technology, link with GDR DI2I	Microphysics	Links with IRNs Terascale and Neutrino	Link with IN2P3 Comm
Mariangela Settimo (SUBATECH)	Maryvonne De Jesus (IP2I)	Valentina Novati (LPSC-LSM)	Davide Franco (APC)	Julien Masbou (SUBATECH)	Xavier Bertou (IJCLab)
Sara Diglio (SUBATECH)	Silvia Scorza (LPSC-LSM)	Andrea Jeremie (LAPP)	Emmanuel Chauveau (LP2iB)	Salvador Rosauro-Alcaraz (LPC Clermont)	Olivier Dadoun (LPNHE)
Claudia Nones (CEA)	Jose Busto (CPPM)		*Cloé Girard-Carillo (LPSC-LSM)*		Corinne Augier (IP2I)
Maxime Pierre (Nikhef)	*Hichem Tedjditi (CPPM)*	*Yuwei Zu (LPNHE)*	*Claudia De Dominicis (LPNHE)*	*Arpan Car (LPTHE)*	*Maria Belen Lovino(IJCLab)*

High IN2P3 participation
(11 laboratories)

APC (Paris)
CEA (Saclay)
CPPM (Marseille)
IJCLab (Orsay)
IP2I (Lyon)
LAPP (Annecy)
LP2IB (Bordeaux)
LPC-Clermont (Clermont)
LPNHE (Paris)
LPTHE (Paris)
LPSC-LSM (Grenoble)
SUBATECH (Nantes)

Direction :
Christine Marquet (LP2IB)
Luca Scotto Lavina (LPNHE)

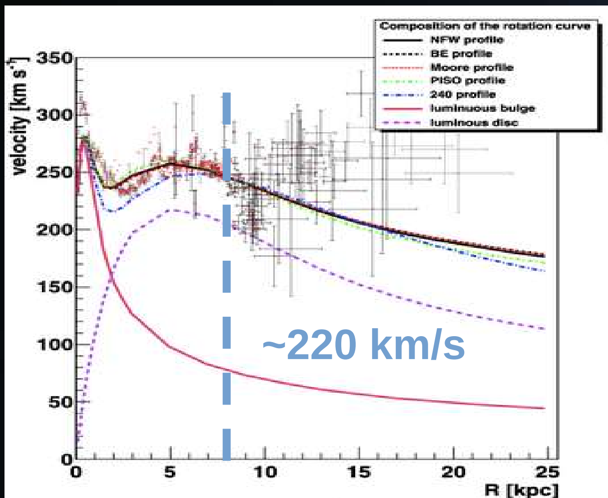
Scope : Underground Physics of rare event (Dark Matter and Neutrinoless Weak Decays)

Indico with Plenary Meetings:
https://indico.in2p3.fr/category/987/

Mailing list:
https://listserv.in2p3.fr/cgi-bin/wa?A0=GDRDUPHY-L

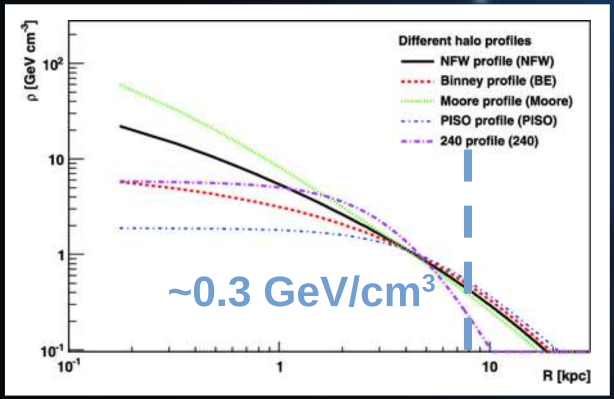
Next meeting:
19-22 October 2026 LPNHE, Paris

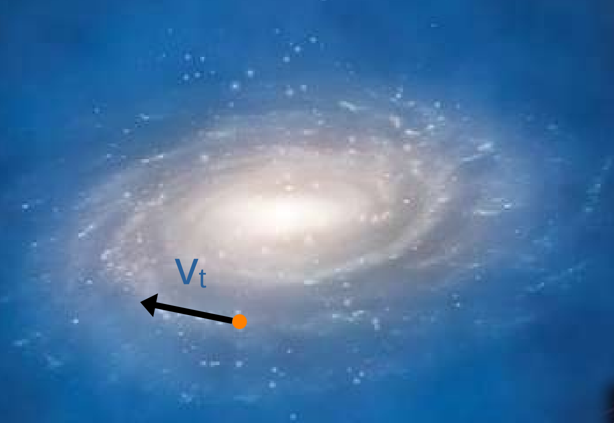
Assumptions of Direct Dark Matter search



Its velocity against us
and its density

M. Weber, W. de Boer, Astron.Astrophys.509:A25,2010

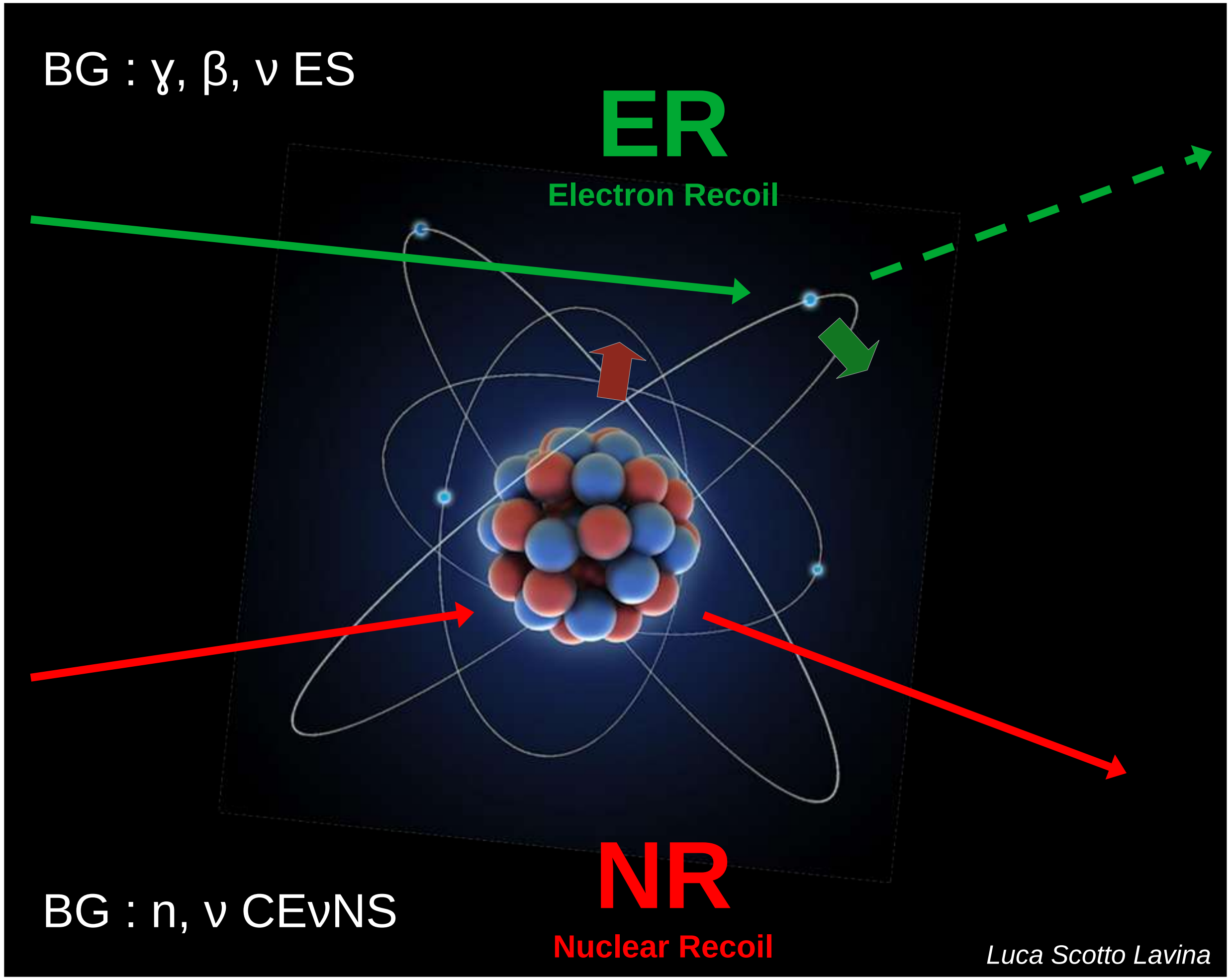




Dark
Matter
Halo

Dark Matter "wind" coming
from a well defined
direction (Cygnus
constellation)

Which target and which mechanism ?

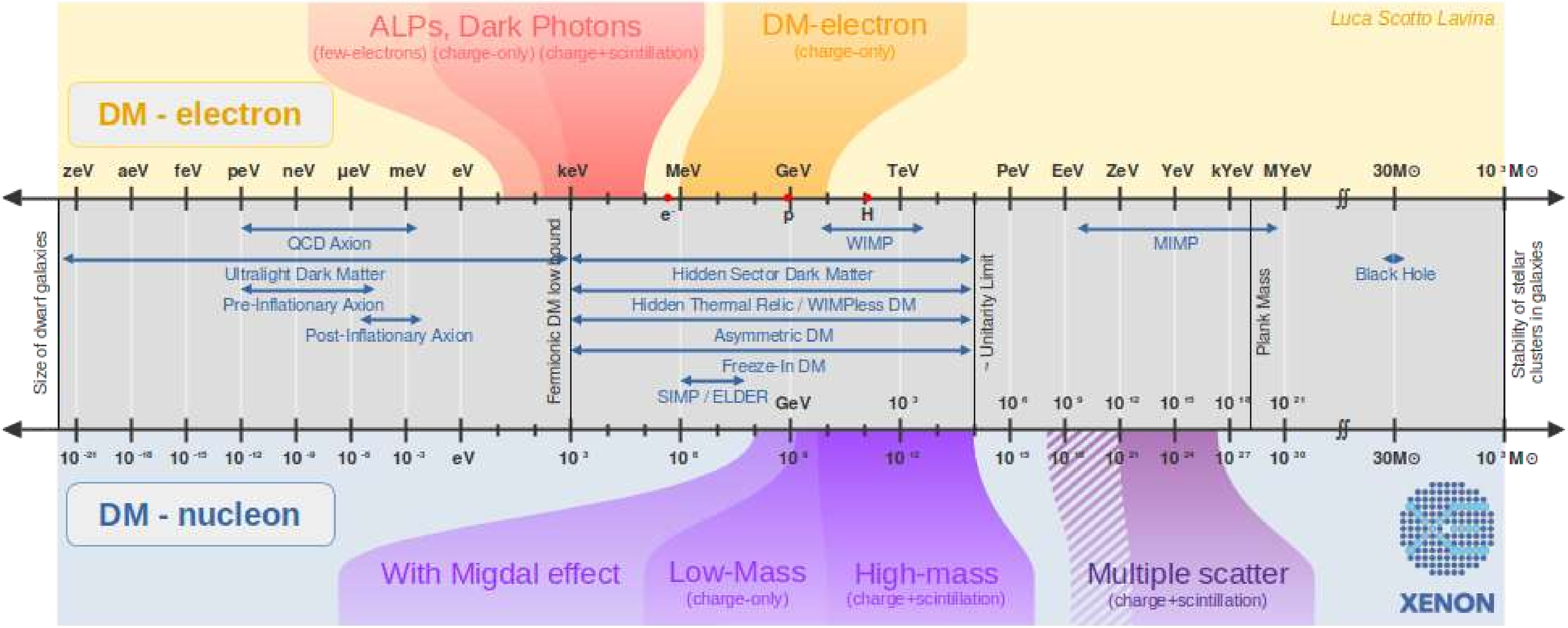


- DM-e
- ALPs
- Dark photons
- ...

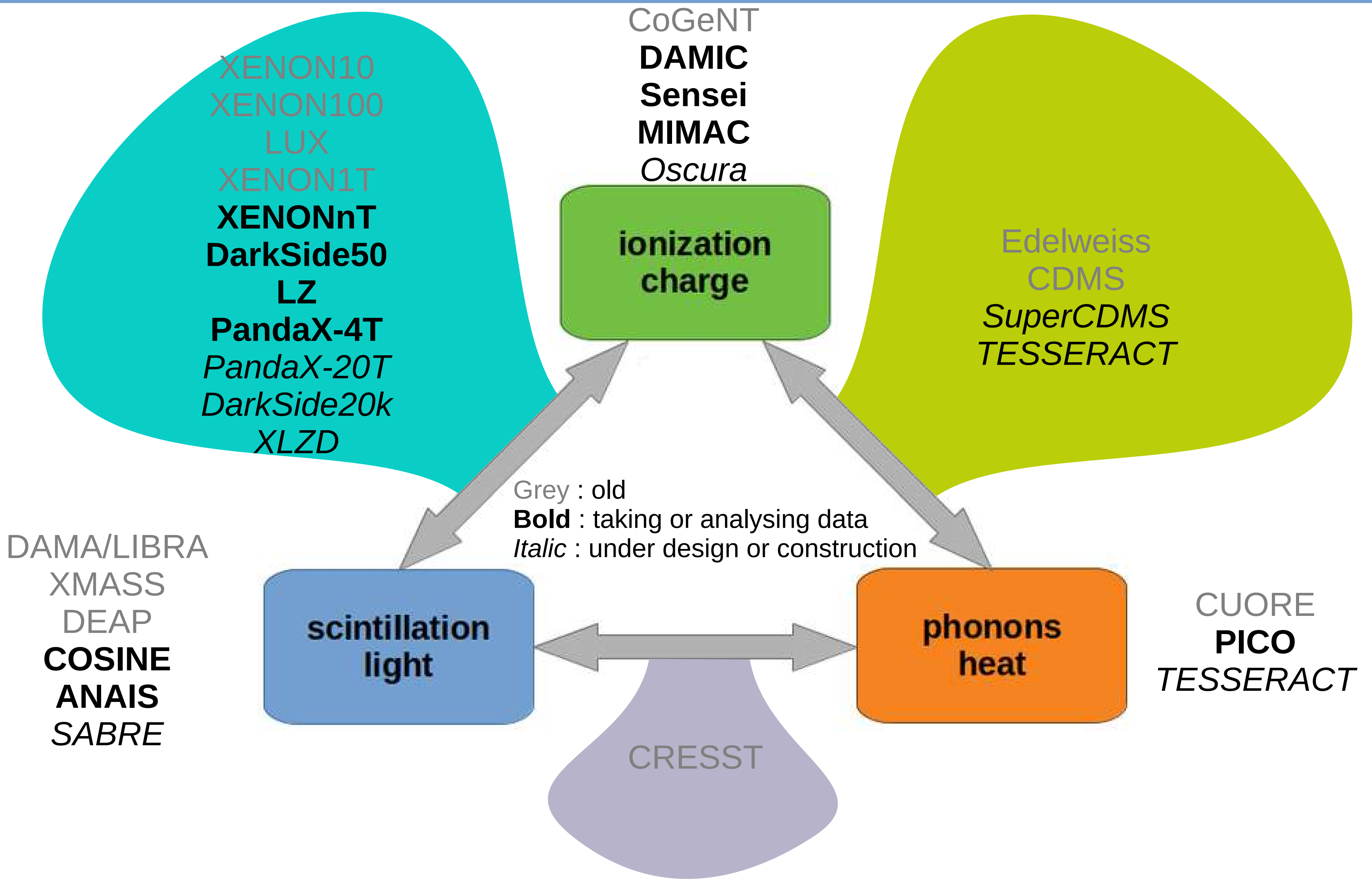
- WIMPs
- MIMPs
- ...

Also :
- SD vs SI
- Elastic vs inelastic
- Light vs heavy mediator
- With/without Migdal

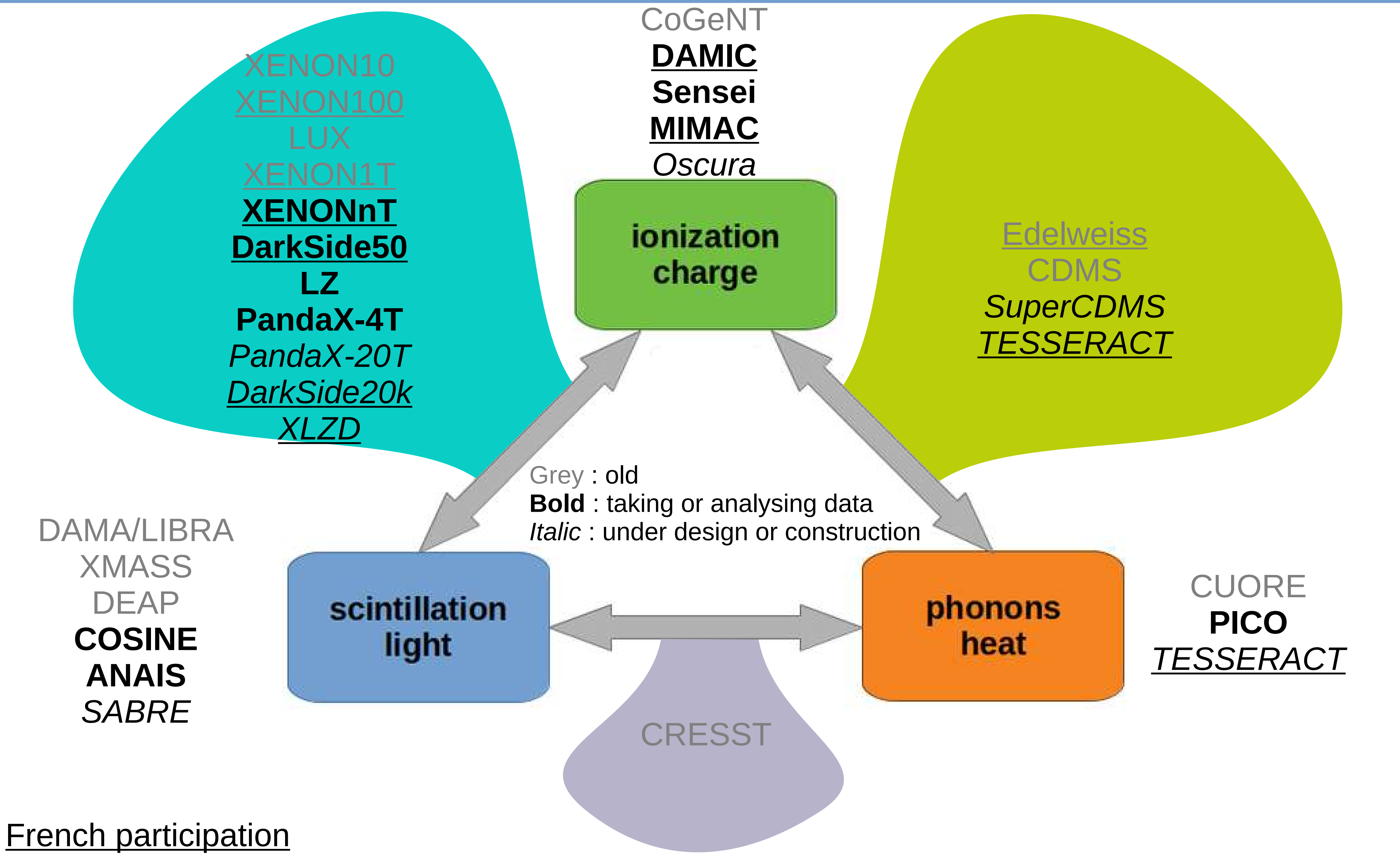
Example of scoped energy domains



Energy recoil : the observables



Energy recoil : the observables



Direct Dark Matter experiments in France

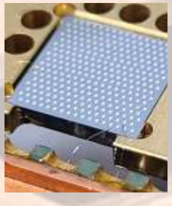
WIMPs, Bosonic DM, Neutrinos

Noble liquids TPCs:
- Xenon : XENON100, XENON1T, **XENONnT** → *XLZD*
- Argon : **DarkSide50** → *DarkSide-20k*

WIMPs, Bosonic DM

CCD Cameras:
- Silicium : DAMIC-SNOLAB, **DAMIC-M** → *Oscura*

WIMPs, Bosonic DM

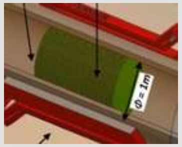


Bolometers:
- Germanium : Edelweiss, **Tesseract**

DM Directional Detection

Gaseous TPC:
- C_4H_{10} / CHF_3 : **MIMAC**

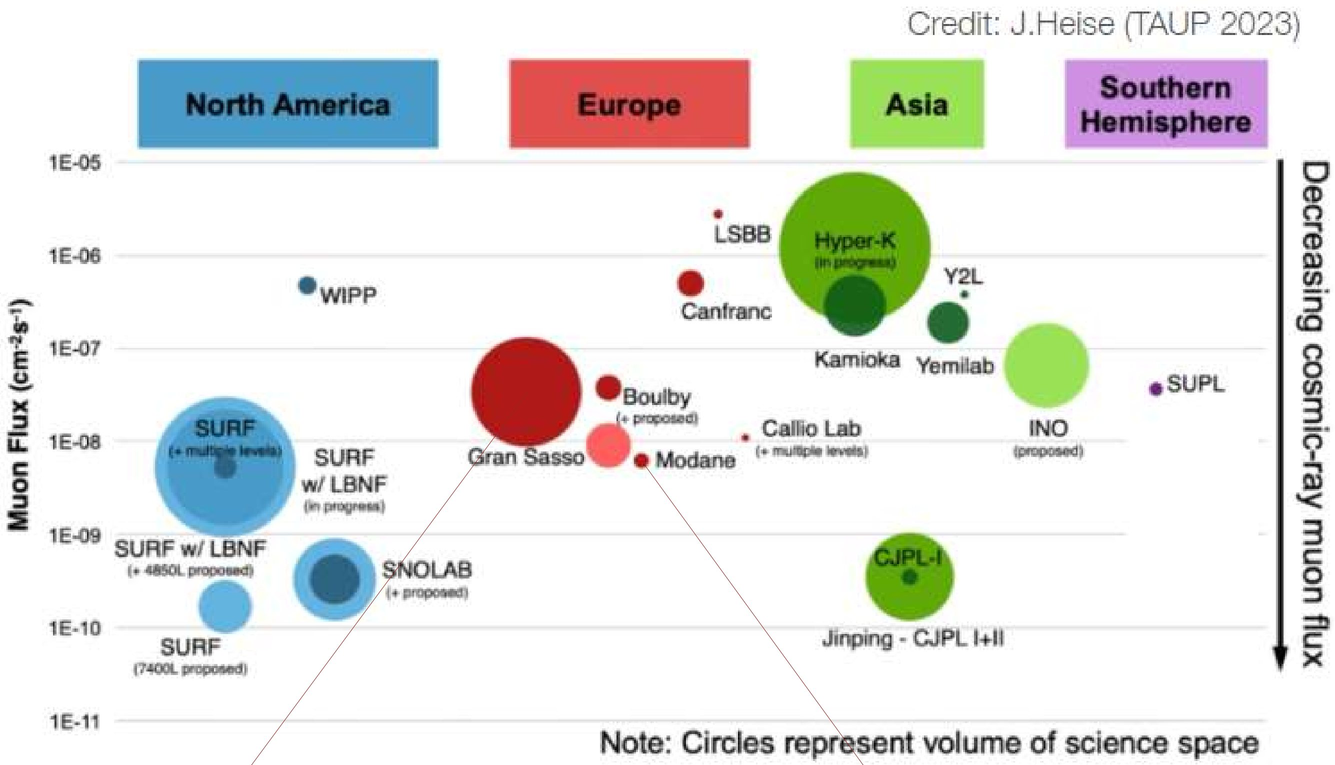
Axions



Dielectric Haloscope:
- Cavity : *MadMax*

Grey : old
Bold : taking or analysing data
Italic : under design or construction

Underground Laboratories



Noble liquids TPCs:
Xenon : XENON100, XENON1T, **XENONnT**
Argon : **DarkSide50** → *DarkSide-20k*

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Bolometers:
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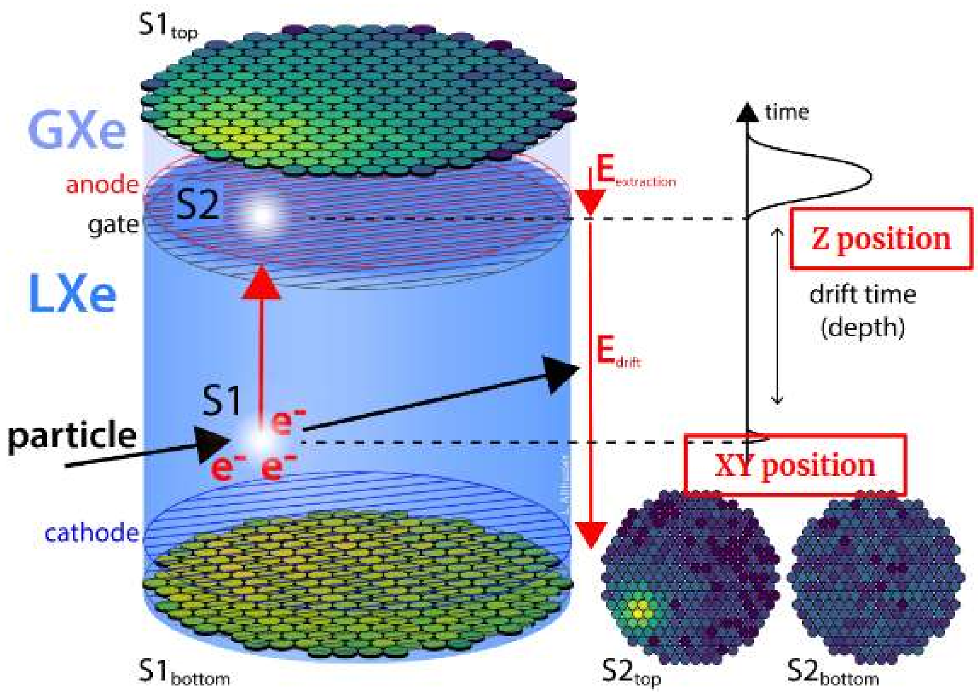
Gaseous TPC:
- C_4H_{10} / CHF_3 : **MIMAC**

WIMPs domain (>10 GeV)

High WIMP mass : the three leading experiments

Working principle of a LXe TPC



Dual phase Xe TPC (Time projection chamber)

- **S1:** Prompt scintillation light
- **S2:** Secondary scintillation light by ionized electrons

- **3D Position reconstruction:** Drift time + PMT pattern
- **Energy reconstruction:**

$$E = W\left(\frac{cS_1}{g_1} + \frac{cS_2}{g_2}\right)$$

W: Average energy to produce a quanta
cS1, cS2: Corrected area of S1 and S2
g1, g2: Gain of S1 (~0.1) and S2 (~15)

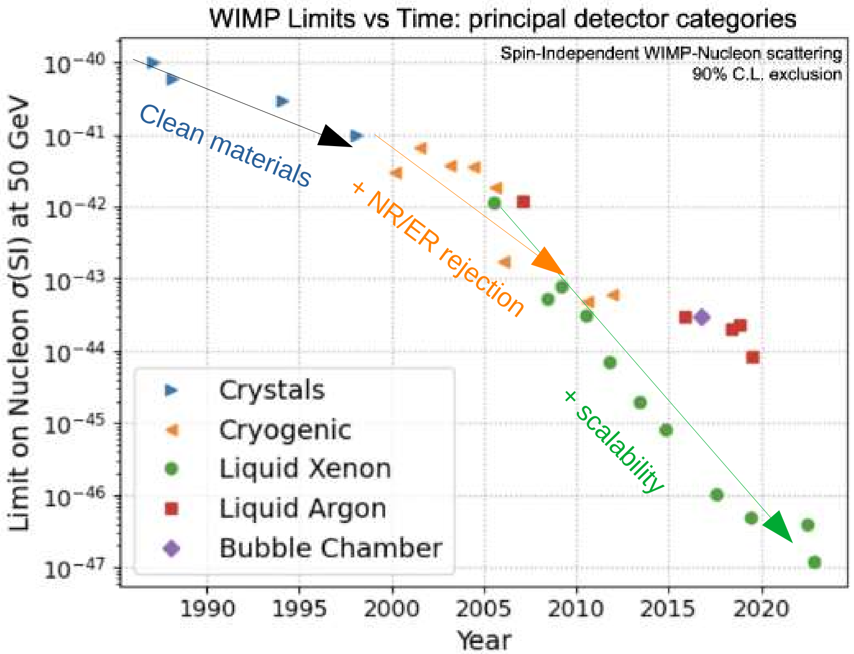
Small S1
Low detection effciency
Photon ✖100 ⇨ S1 = **10 PE** (1)

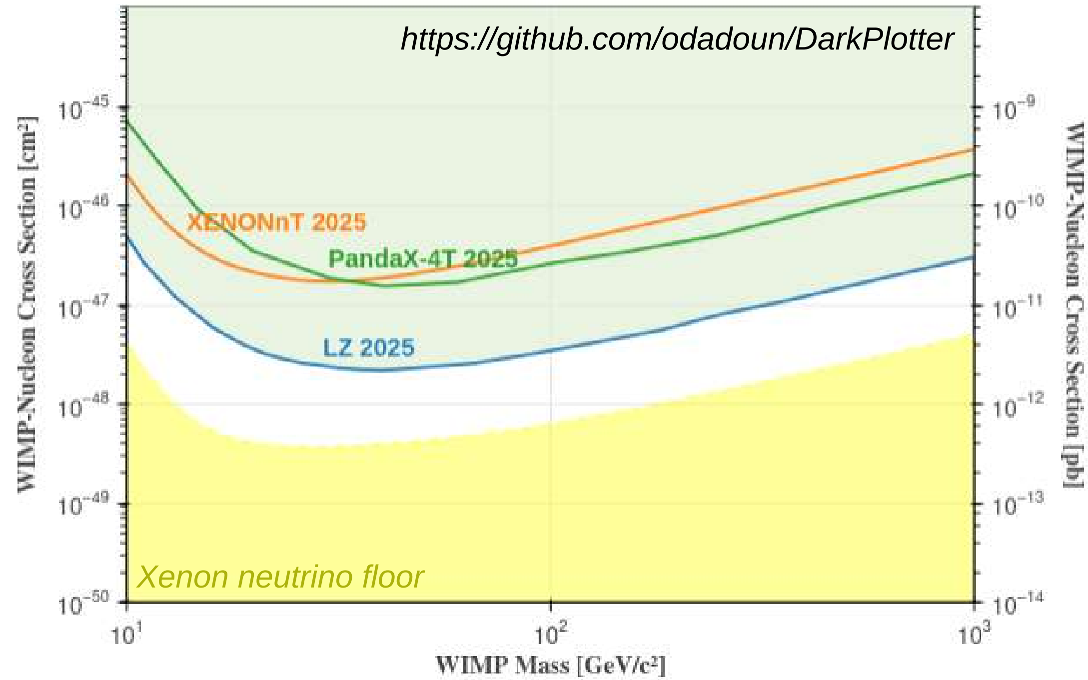
Large S2
Strong scintillation in gas
e− ✖100 ⇨ S2 = **1500 PE**

⇒ Motivation of **S2-only** analysis

(1) Detected Photoelectron [PE]

High WIMP mass (m>10 GeV) : LXe TPCs rule





LZ : *PRL 135, 011802 (2025)*
- @SURF, US
- 10t total Xe mass
- 4.2 t y exposure

XENONnT : *PRL 135, 221003 (2025)*
- @LNGS, Italy
- 8.6t total Xe mass
- 3.1 t y exposure

PandaX-4T : *PRL 134, 011805 (2025)*
- @JinPing, China
- 6t total Xe mass
- 1.54 t y exposure

- No long-lived isotopes (Xe only)
- Odd and even isotopes (Xe only) → SD
- Self-shielding
- Recoil discrimination

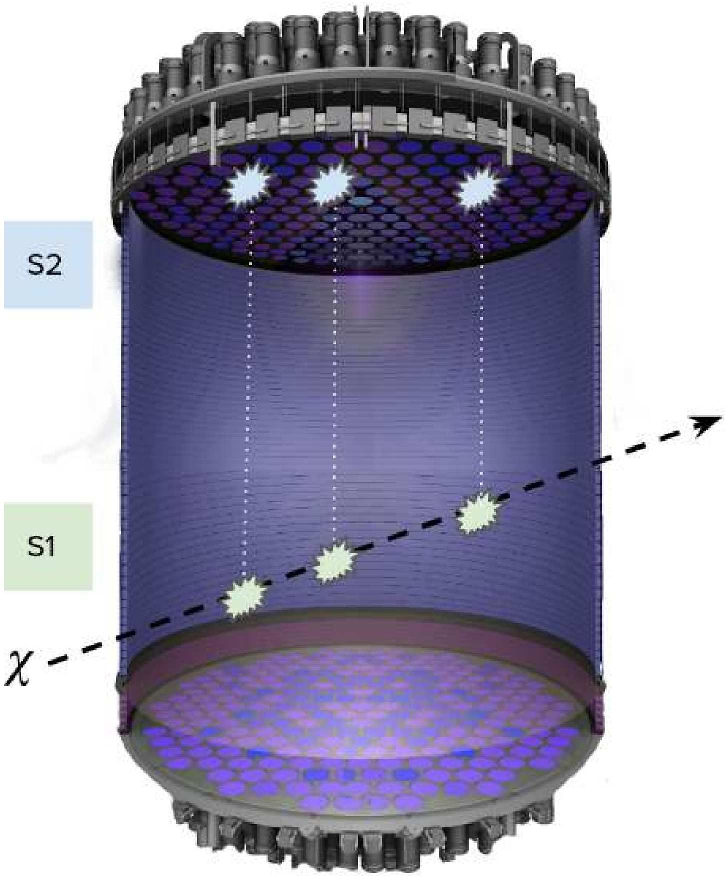
- S1, S2 → event energy
- S2 image → xy coordinate
- S1-S2 timing → z coord.
- S2/S1 → recoil type

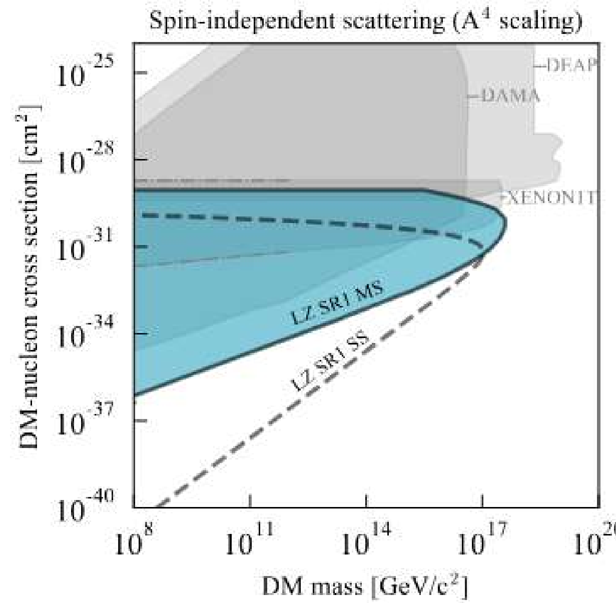
MIMPs domain

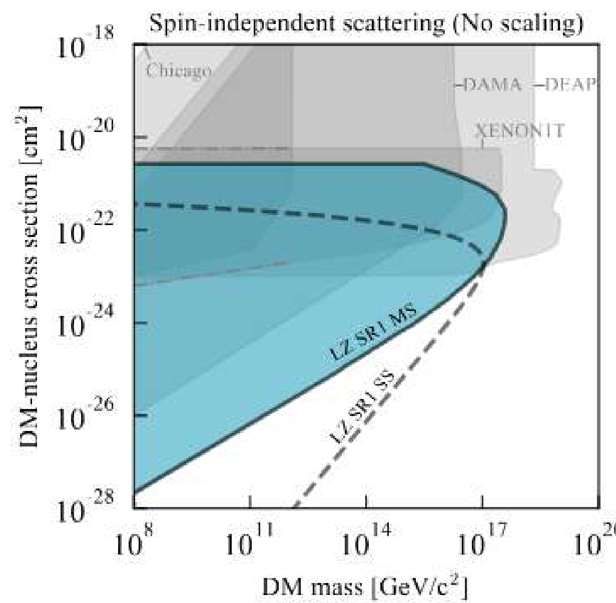
Even higher masses : MIMPs

Mass close to the Planck mass

→ Multiply-Interacting Massive Particles (MIMPs)







XENON1T : Phys. Rev. Lett. 130, 261002, arXiv:2304.10931

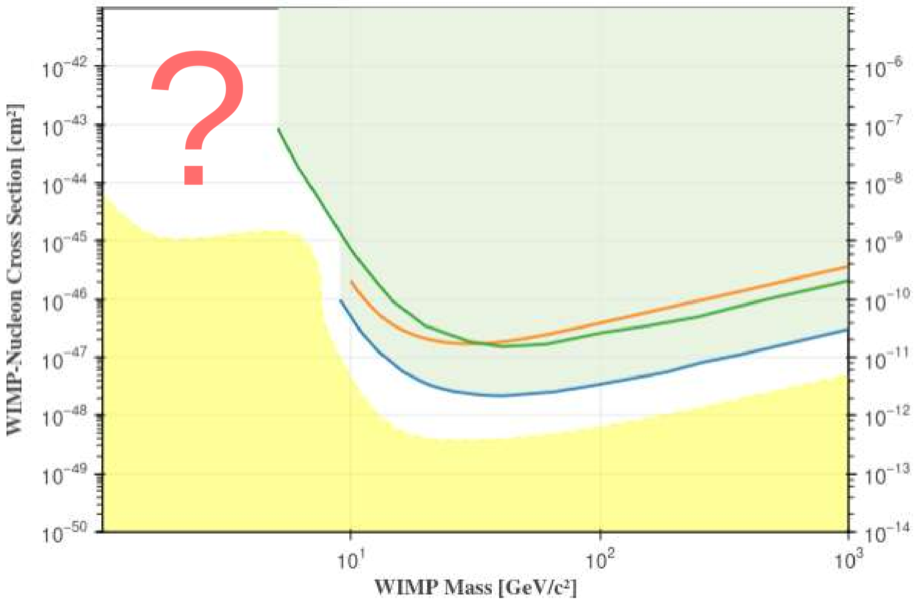
LZ : Phys. Rev. D 109, 112010, arXiv:2402.08865v1

« WIMPs » close to ^8B neutrino floor

(1 to 10 GeV)

Lowering the energy threshold

How an experiment, conceived to look for high WIMP masses, can lower its energy threshold and reach **low WIMP masses** ?



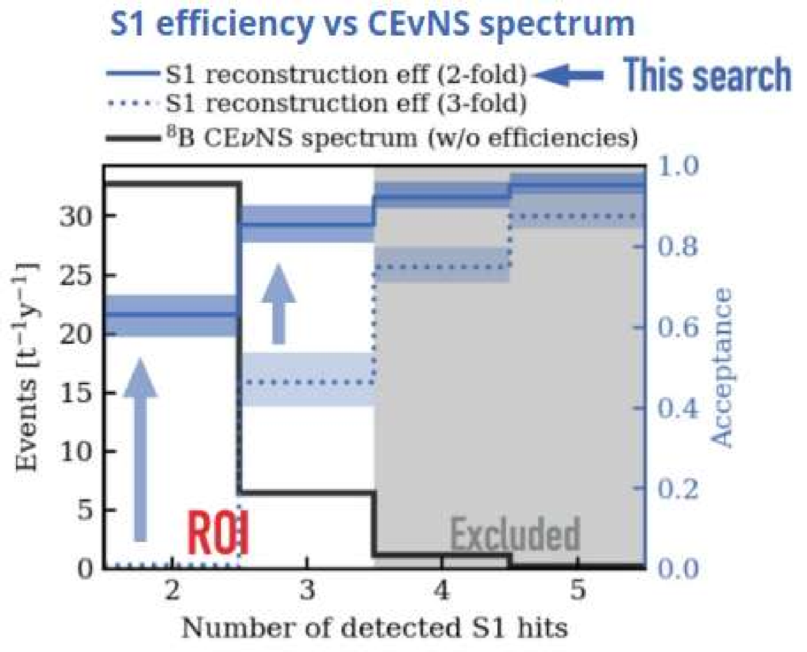
Lower the constrains on the **PMT signal hit coincidences**

Drop the S1 signal, keeping the **S2 only**

Lowering the energy threshold

Lower the constrains on the
PMT signal hit coincidences

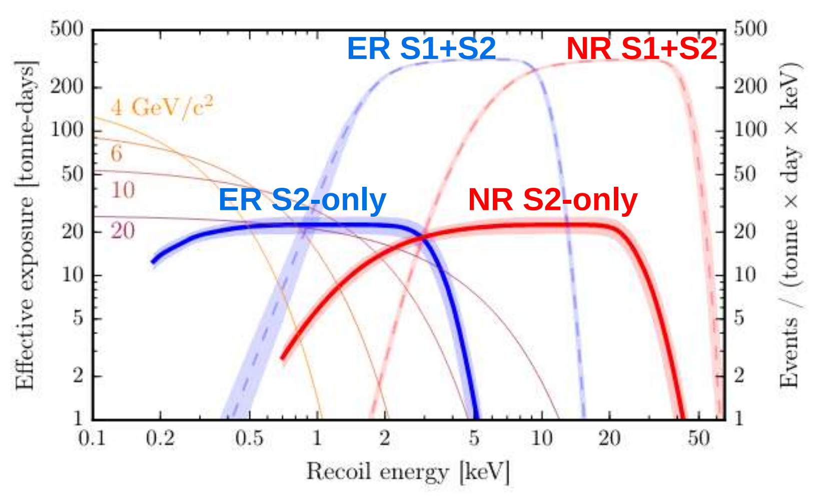
- **S1** : *requiring at least two hits from two different PMTs within 50 ns* (**2-fold PMT coincidence**)



Case of XENONnT data, S. Shi, TAUP 2025

Drop the S1 signal,
keeping the **S2 only**

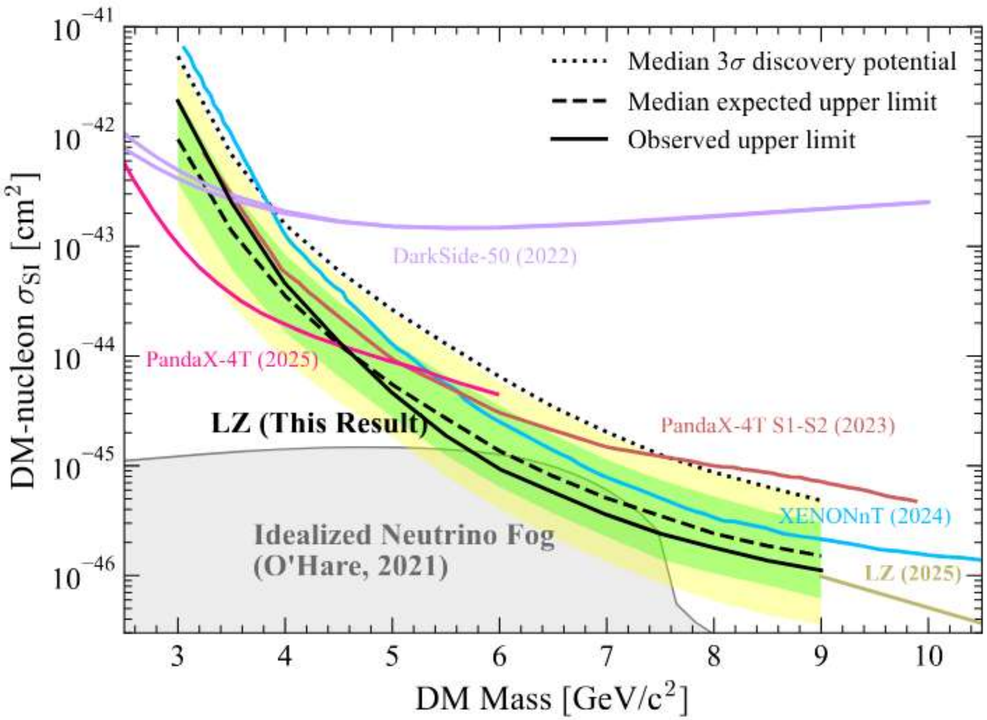
- **Standard** approach (stay away from the few-electrons background)
- Dedicated analysis on the **few-electrons** range
- Focus on **1 to 3 electrons** range (highest background)



Case of XENON1T data, PRL 123, 251801

Low masses close to ^{8}B neutrinos

LZ results (2025) :
5.7 tonne-years



Statistical significances of observations of a signal consistent with ^{8}B **CEνNS** events :

XENONnT (2026) : 3.3 σ
PandaX-4T (2024) : 2.64 σ
LZ (2025) : 5.7 σ

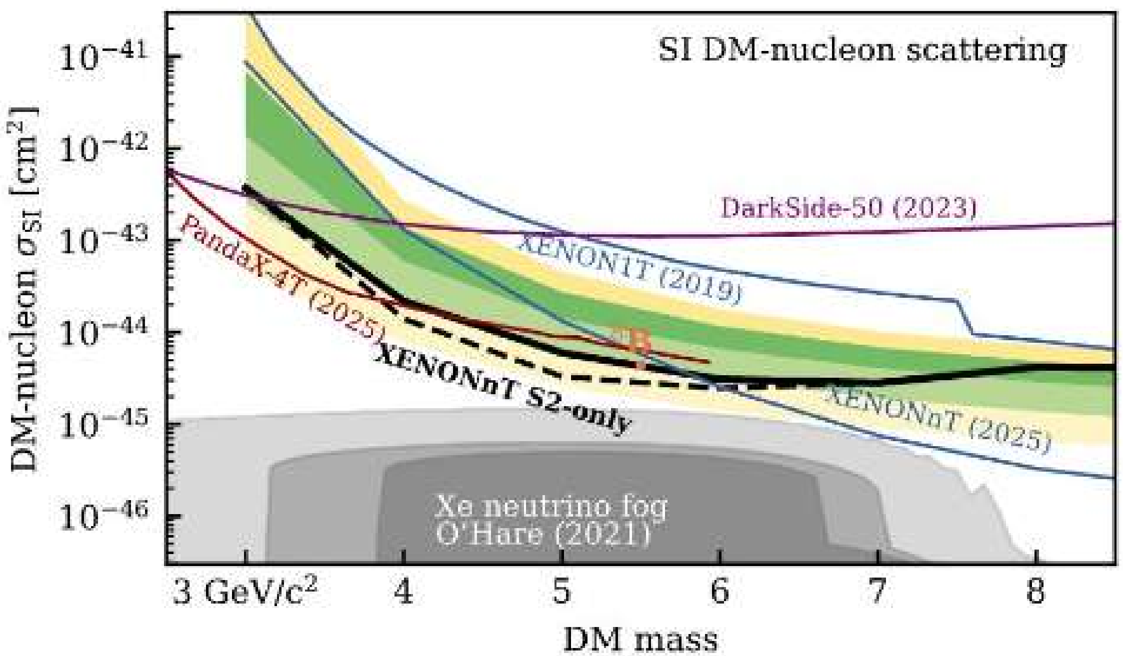
Detected astrophysical ν in a **dark matter detector**
Measured CEνNS signal from an **astrophysical source**
Measured CEνNS signal on a **Xe target**

S2-only : case of XENONnT (2026)

Good agreement between the background predictions and observed events

Science run (exposure)	SR0 (1.50 t · y)		SR1 (2.44 t · y)		SR2 (3.89 t · y)	
Component	Expectation	Best fit	Expectation	Best fit	Expectation	Best fit
Cathode	480 ± 70	477^{+25}_{-24}	660 ± 70	726^{+28}_{-27}	1210 ± 90	1080 ± 30
Delayed electron	1.3 ± 0.5	1.3 ± 0.5	0.34 ± 0.07	0.34 ± 0.07	17.2 ± 2.3	17.1 ± 2.3
Accidental electron	97 ± 17	89 ± 13	108 ± 8	106 ± 8	–	
^{8}B CEνNS	21 ± 5	18^{+5}_{-4}	29 ± 7	26^{+7}_{-6}	32.3 ± 8	29^{+8}_{-6}
Total background	600 ± 80	586 ± 28	800 ± 80	858^{+30}_{-29}	1260 ± 100	1130 ± 30
Observed	583		864		1107	

Most stringent limit set on ~5 GeV light WIMPs



4-years long PhD thesis funded by China Scholarship Council

First time a full background model on this mass range

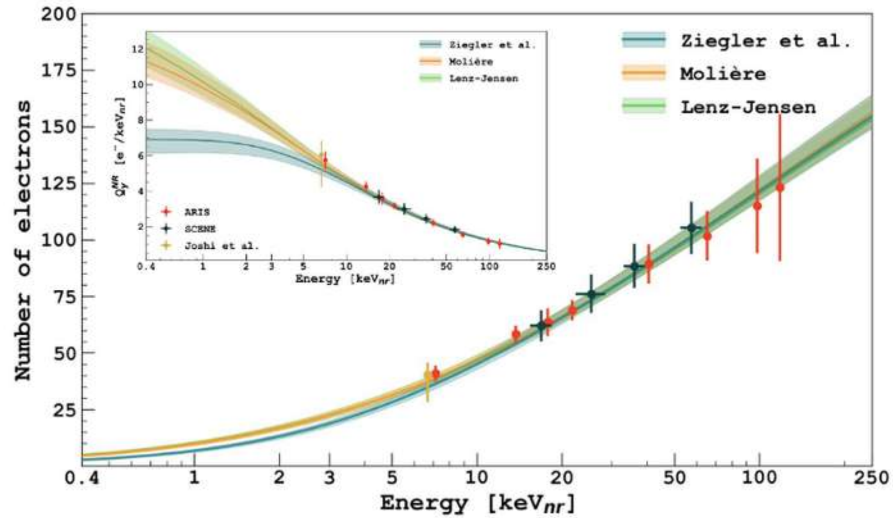
Y. Pan, La Thuile 2026, PRL, arXiv:2601.11296

Argon : change of the nuclear response

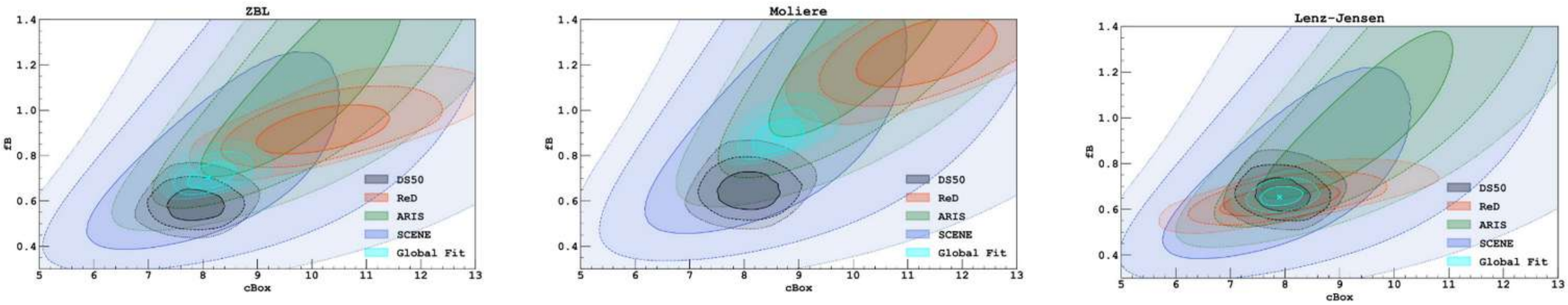
DarkSide used so far ZBL to model the response of Argon to NR :
most conservative choice

Screening Potential Models

- **ZBL** (Ziegler, Biersack, Littmark)
  - Defined from total energy difference of 2-atom system
  - Universal fit (522 potentials) → basis of SRIM
- **Molière**
  - Analytical approximation of Thomas-Fermi potential
  - Widely used in multiple scattering
- **Lenz-Jensen**
  - Modified Thomas-Fermi model with shell corrections
  - Improved accuracy at small radii

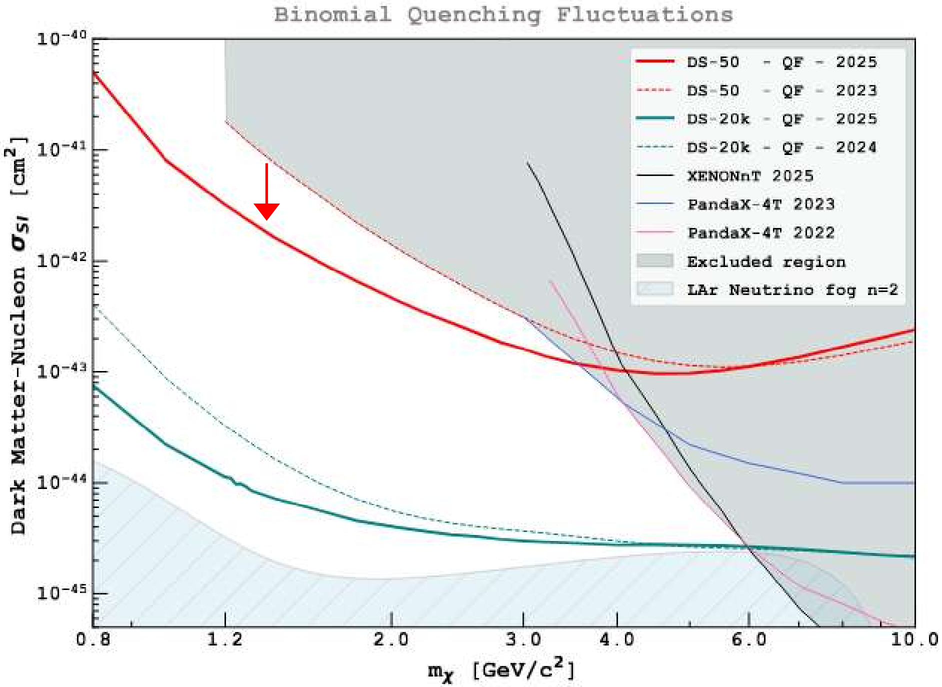


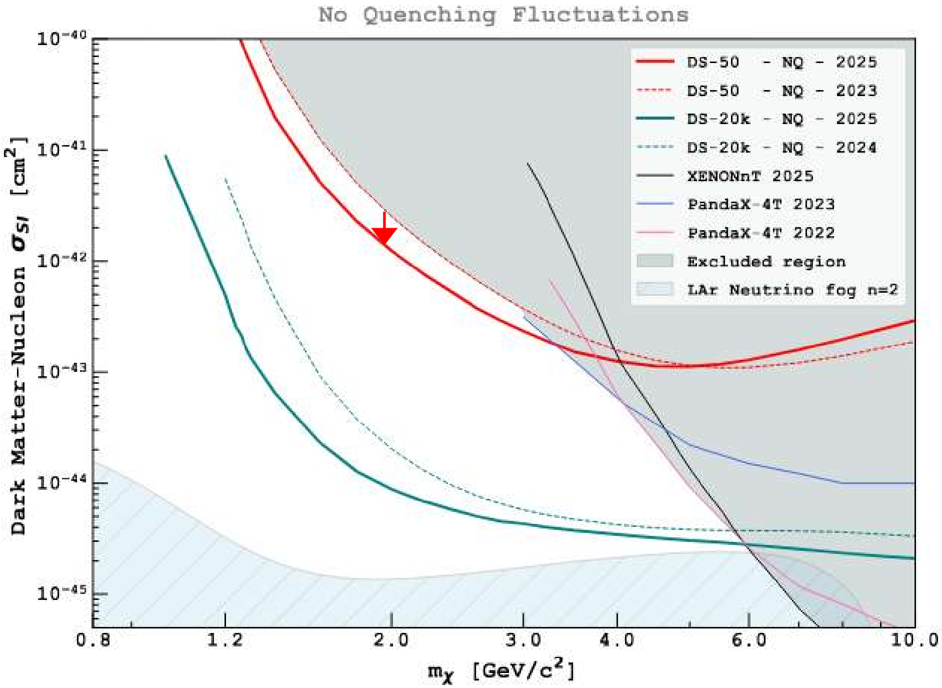
Now they moved to the Lenz-Jensen one, supported by a global fit of the independent measurements ARIS, SCENE, ReD, together with DarkSide50 data



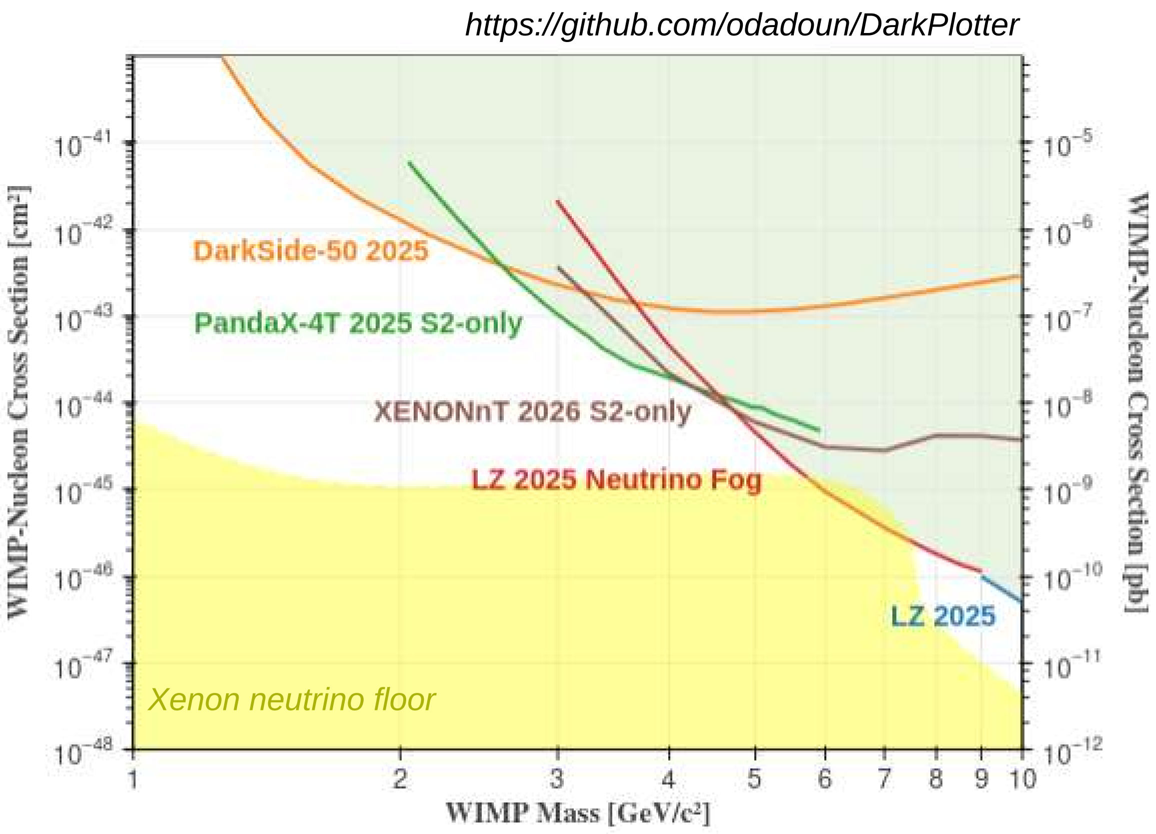
Low masses < 3 GeV : DarkSide-50

The effect is an improvement of sensitivity at low WIMP masses





Summary for WIMP masses between 1 and 10 GeV

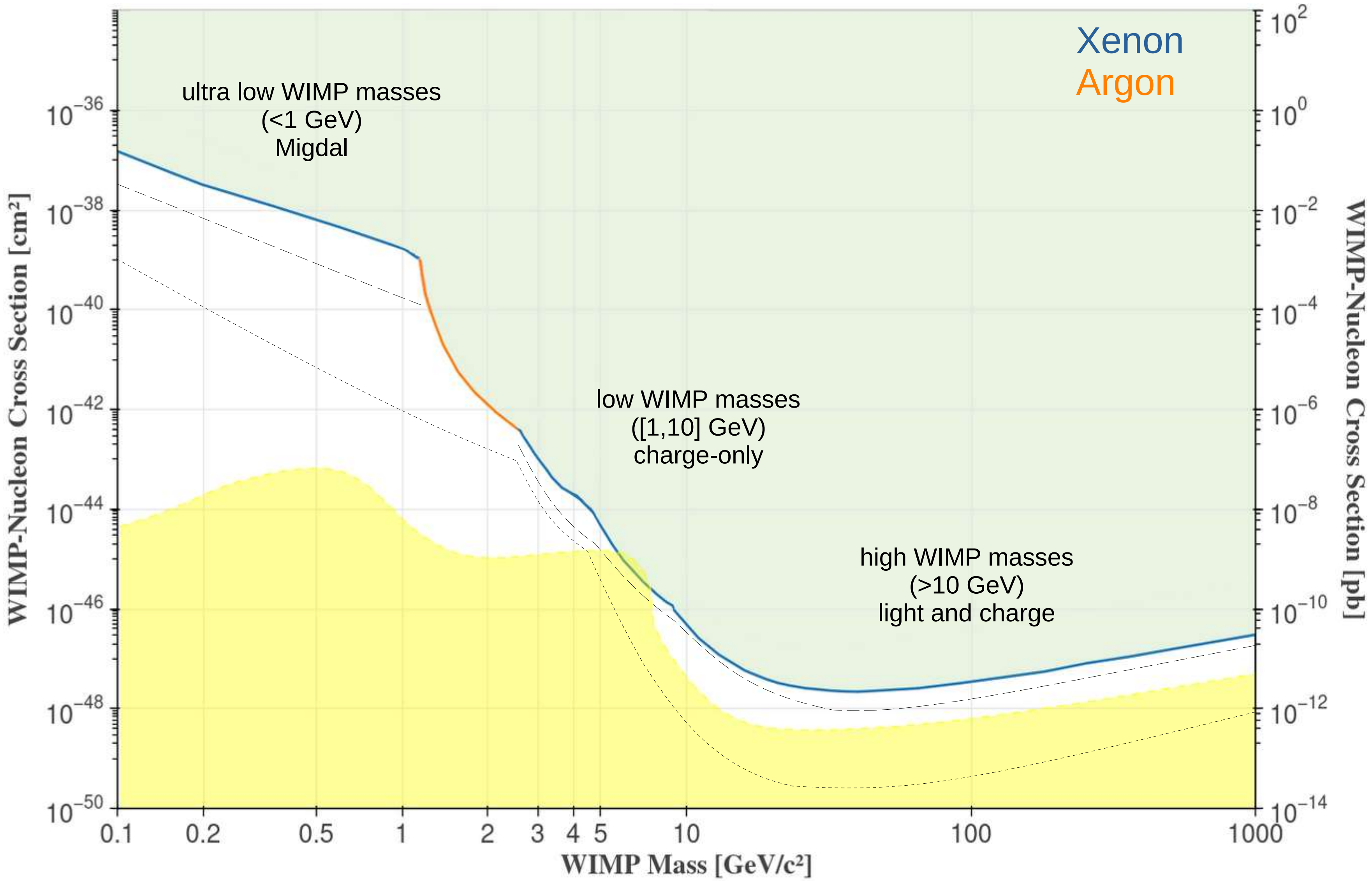


Liquid **Xenon** rules at any WIMP mass starting from ~2.5 GeV

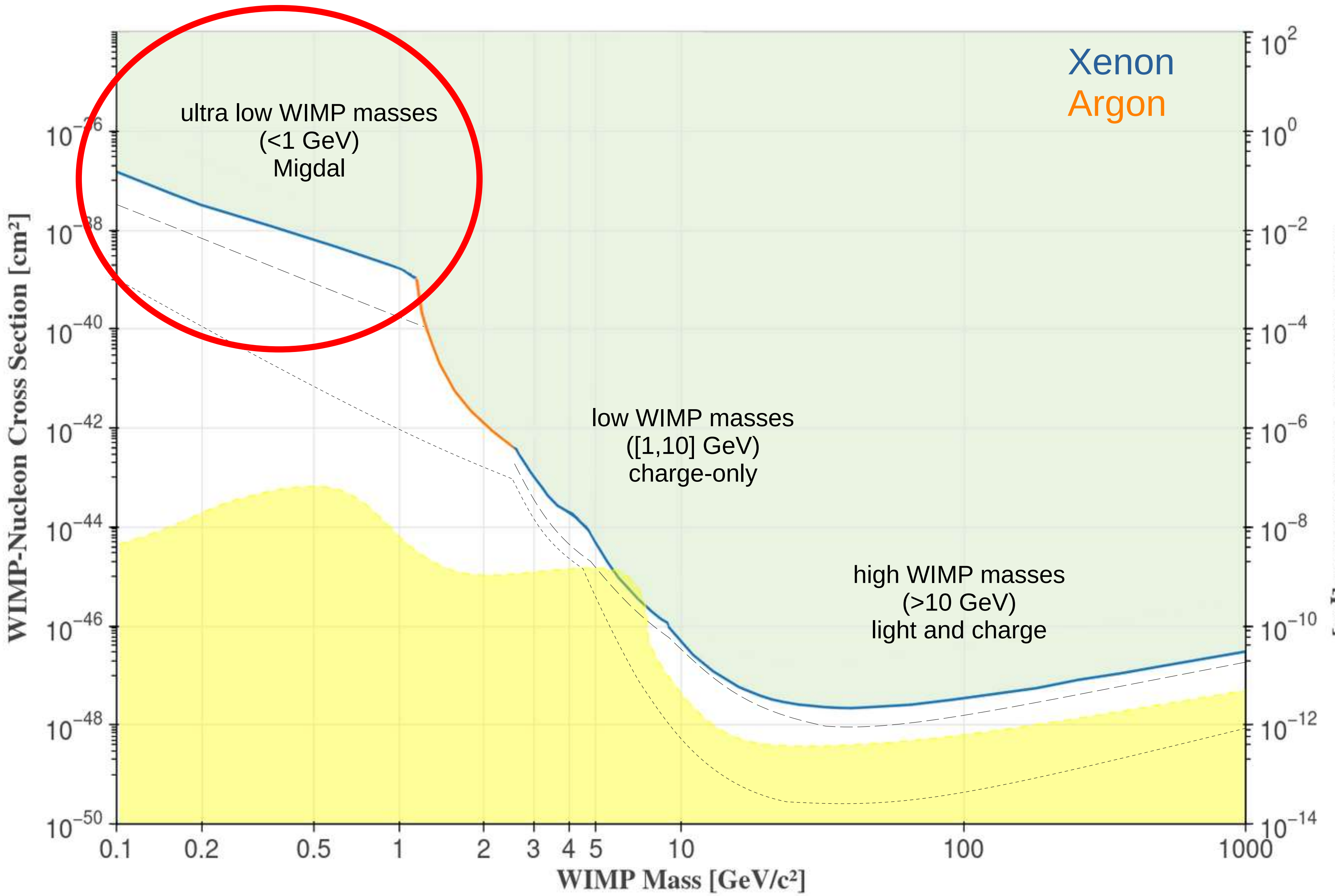
Liquid **Argon** rules below ~2.5 GeV (lighter nuclei)

Currently no other technique challenges noble liquids TPCs

Best limits and perspectives at M > 0.1 GeV



Best limits and perspectives at M > 0.1 GeV

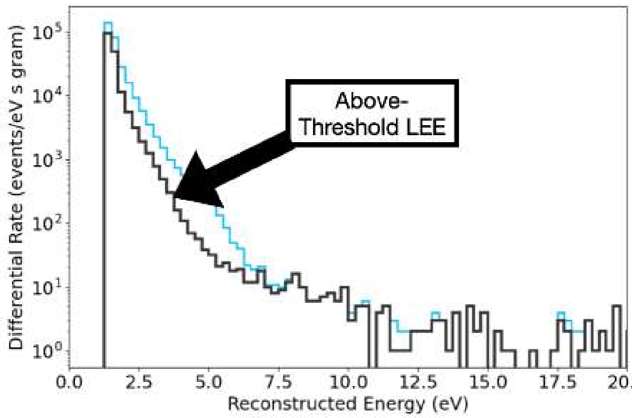


TESSERACT

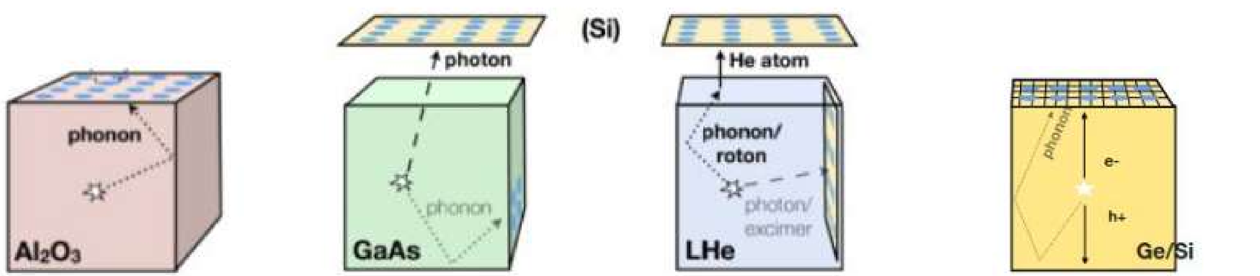
Observation of a strong Low Energy Excess (LEE) of events in ALL low-threshold cryogenic experiments limiting their DM sensitivity

The LEE is both :

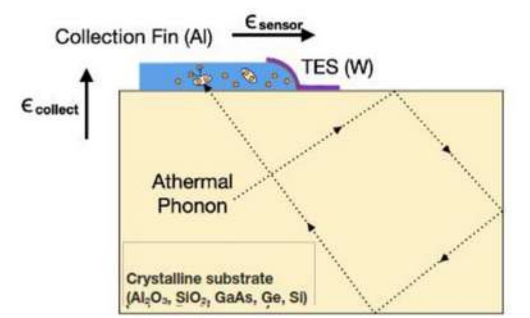
- the largely dominating background at the lowest energies
- limiting the phonon baseline energy resolution



ER : 100 meV – MeV No PID, SP	ER : eV – MeV NR : MeV - GeV PID : photon - phonon	NR : MeV - GeV PID : PSD	NR : 100 MeV – 10 GeV PID : PSD



SPICE (Al_2O_3 and GaAs) HeRALD (LHe) TES4DM (Ge/Si)



$$\sigma_E \sim \frac{\sqrt{4k_b T_c^2 G(\tau_{collect} + \tau_{sensor})}}{\epsilon_{collect}\epsilon_{sensor}}$$

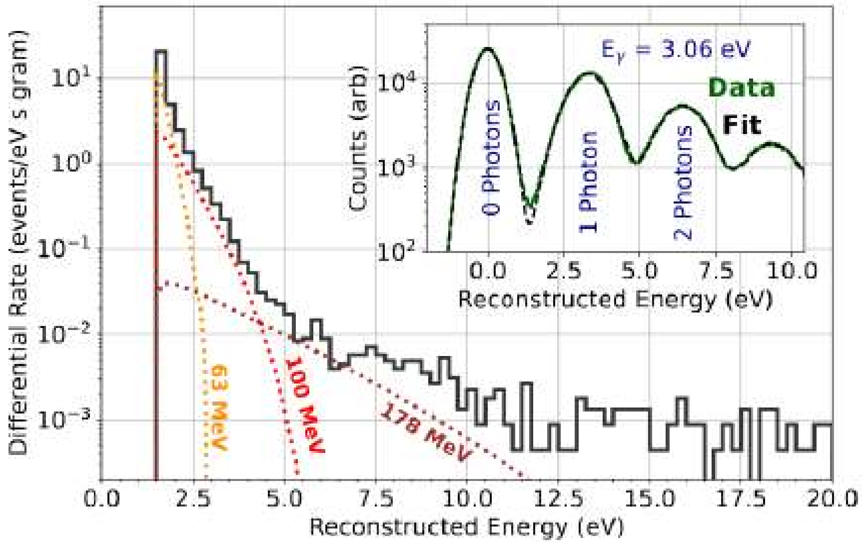
$$\sigma_E \propto V_{det}^{1/2} T_c^3$$

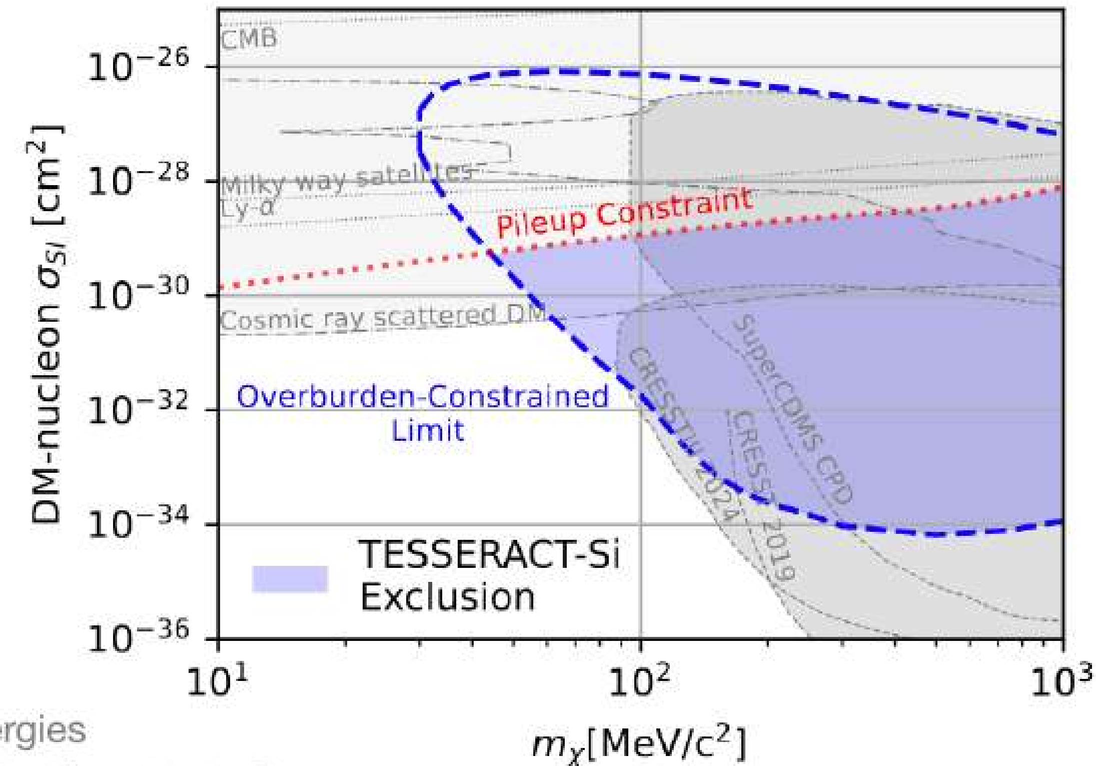
Energy threshold decreases with detector mass

Energy threshold decreases very quickly with Tc

TESSERACT

First surface Dark Matter search



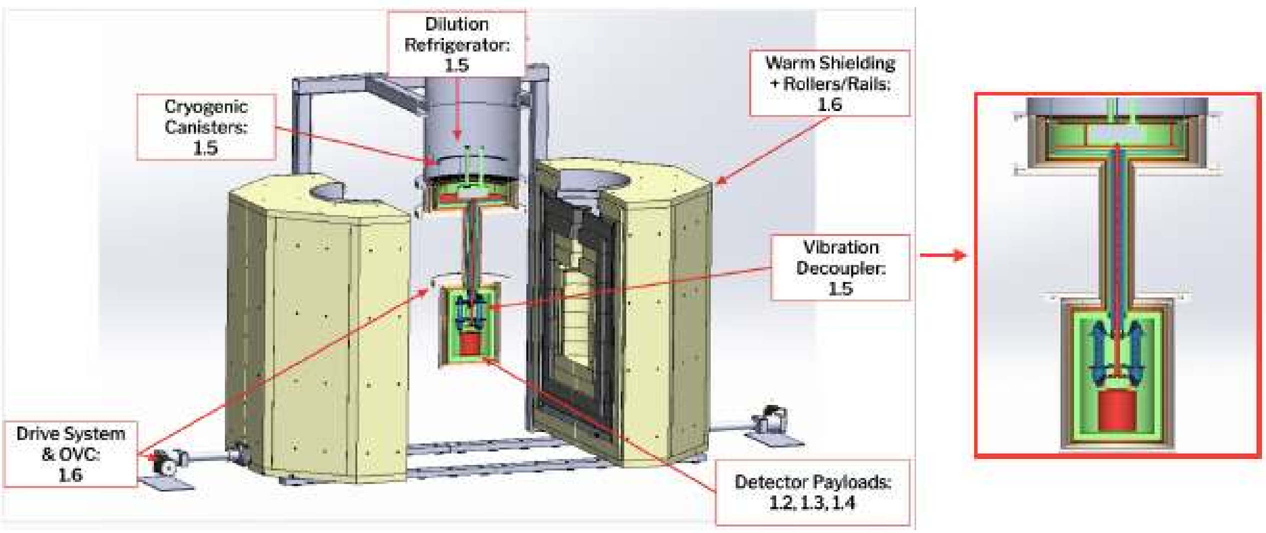


First TESSERACT DM limit — arXiv:2503.03683

- World-leading 1.45 eV energy threshold !
- Leading between 44 MeV and 87 MeV
- Limited by the overwhelming LEE at the lowest energies
  - **Need LEE discrimination techniques and mitigation strategies**

TESSERACT : getting ready for LSM

- TESSERACT is designed for flexibility and straightforward detector replacement, with a common infrastructure of shielding, cryostat, vibrational decoupler, cold electronics, and DAQ.
- Dedicated clean room at LPSC ready to host the first TESSERACT fridge for its surface commissioning including: cryogenics, vibration levels, EMI mitigation, detector integration operation and optimisation, and **surface DM science !**

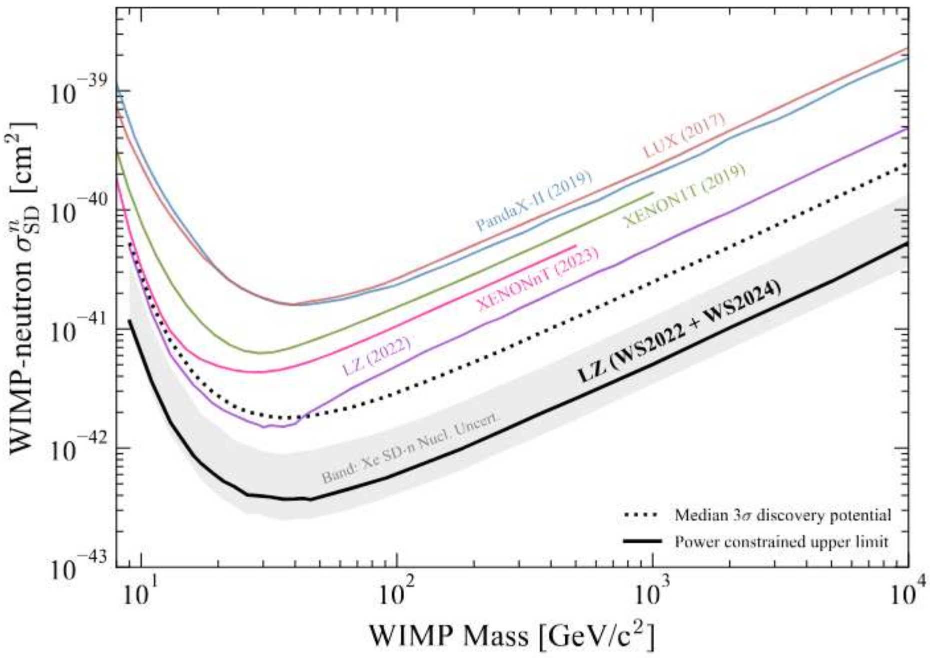


Spin-Dependent interactions

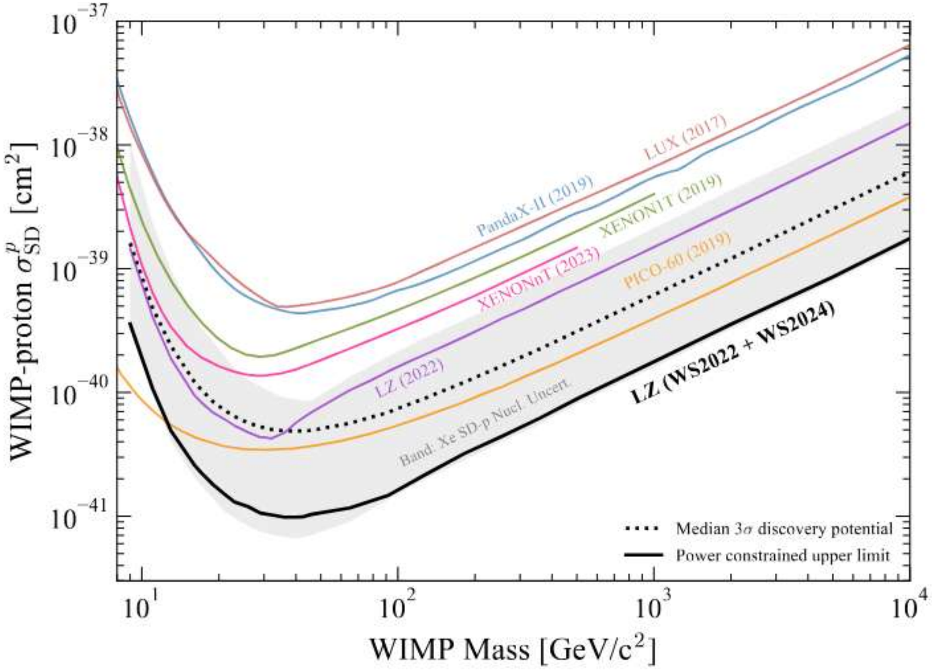
Spin-Dependent Interactions

LZ results (2025) :
4.2 ± 0.1 tonne-years from 280 live days

Coupling with neutron



Coupling with proton

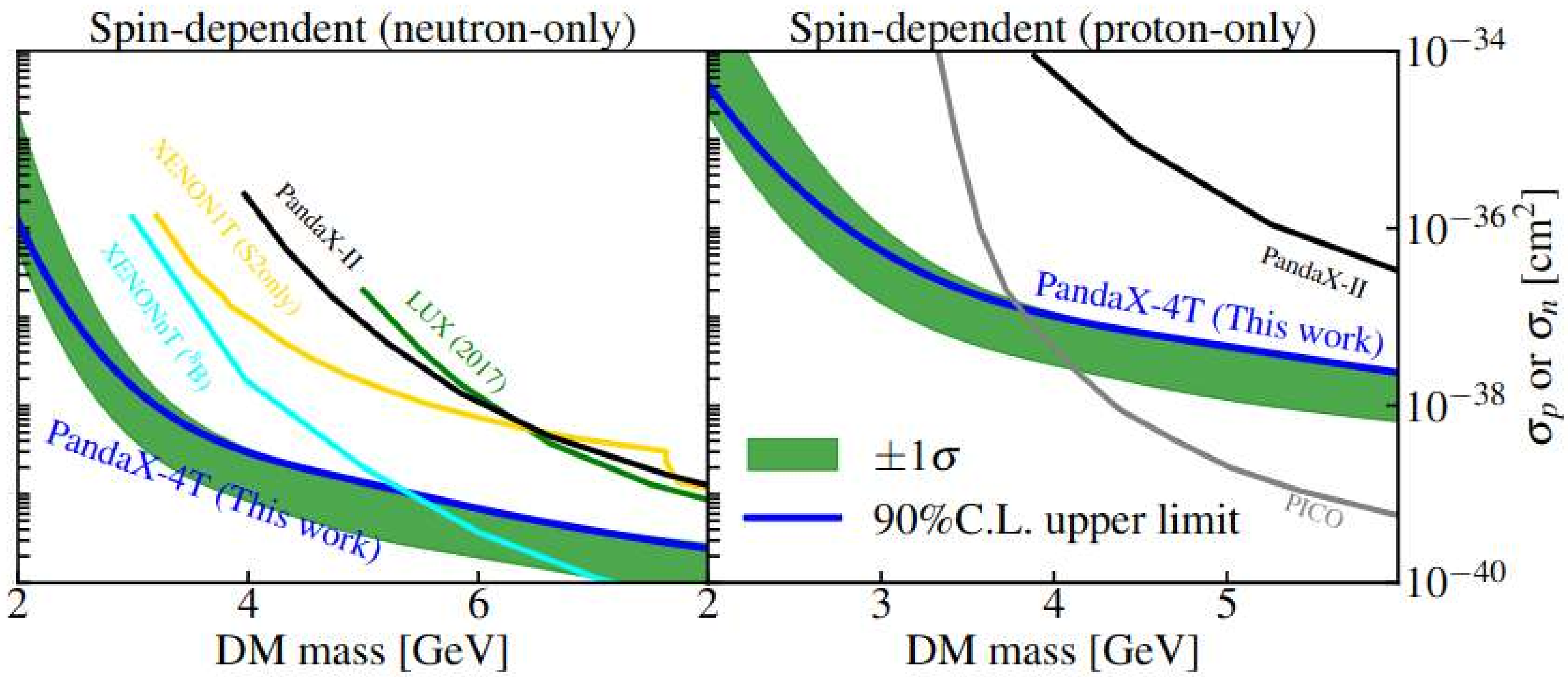


First time LXe explored
new territory after PICO
(bubble chambers)

PRL 135, 011802 (2025), arXiv:2410.17036

Spin-Dependent Interactions at low masses

PandaX-4T results (2025) :
1.04 tonne-years from 259 live days



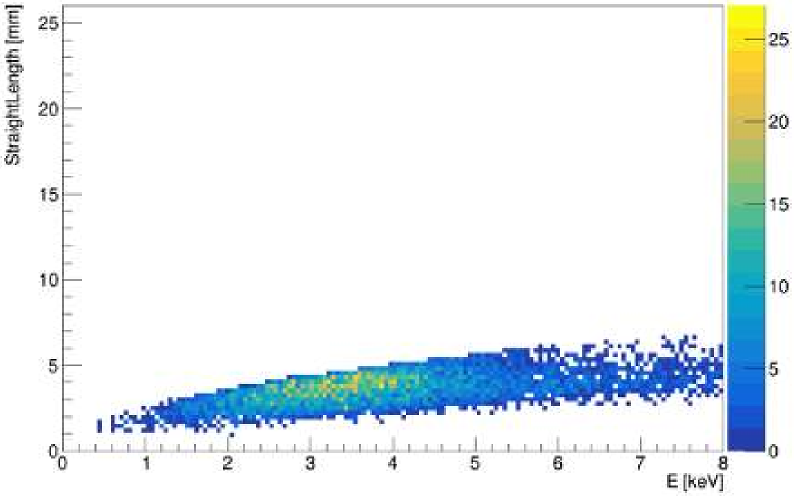
arXiv:2507.11930

Directional detection with MIMAC

See talk of Olivier Guillaudin, LPSC, Grenoble
for the detector details

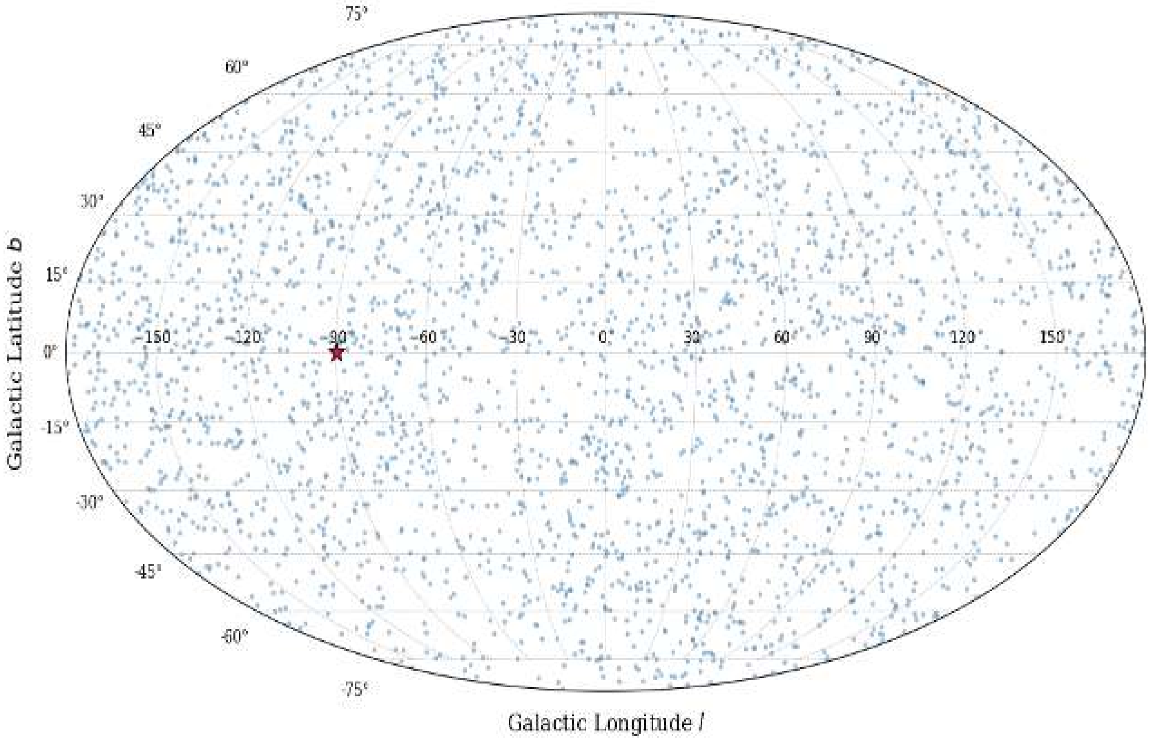
MIMAC Results: Event Analysis

Identification of Nuclear Recoils



The two-dimensional diagram shows that the hydrogen recoil branch dominates. The contributions of the other nuclei (carbon and fluorine) are negligible.

Galactic Projection



Talk of Ilias Ourahou, LPSC, Grenoble

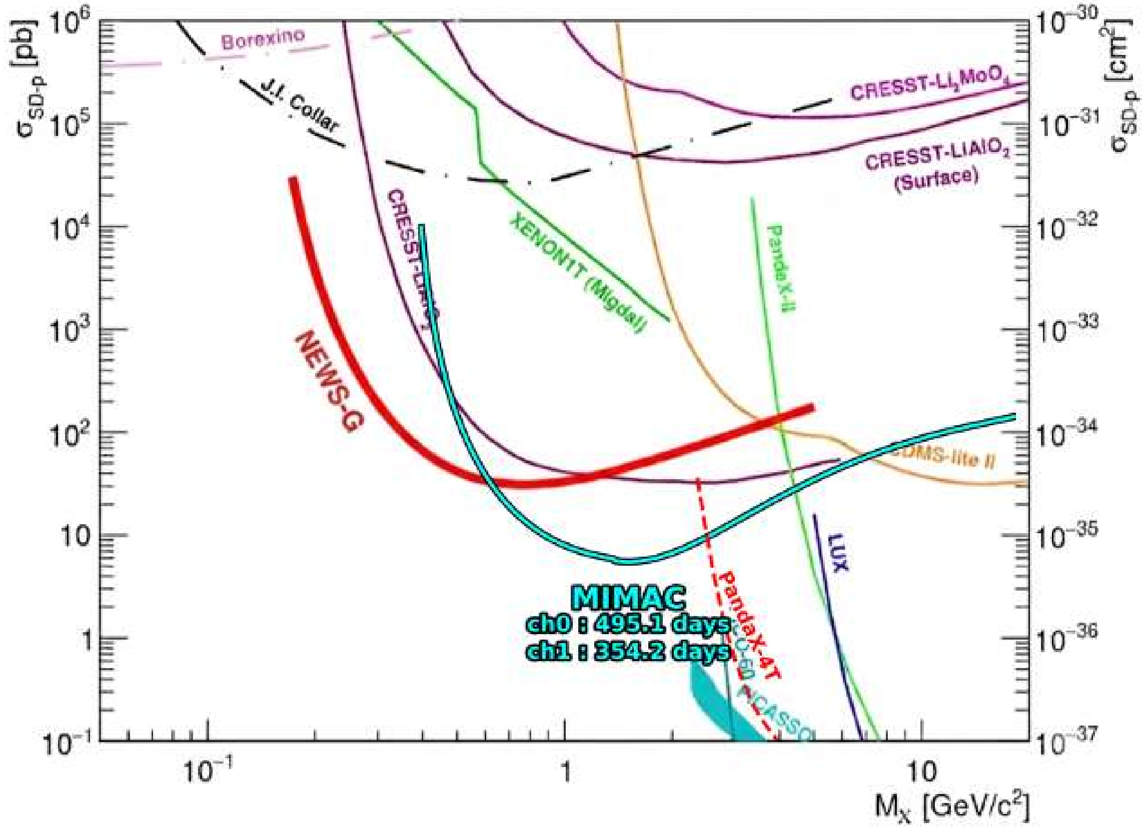
Spin-Dependent proton-coupling with MIMAC

MIMAC Results: Exclusion Curve and Cross Section limit

With a kinetic energy threshold of 0.94 keV, we obtain the following exclusion curve.

Limit reached without any shielding

The limit on the cross section obtained is: $\sigma < 5\,10^{-36}$ cm^2

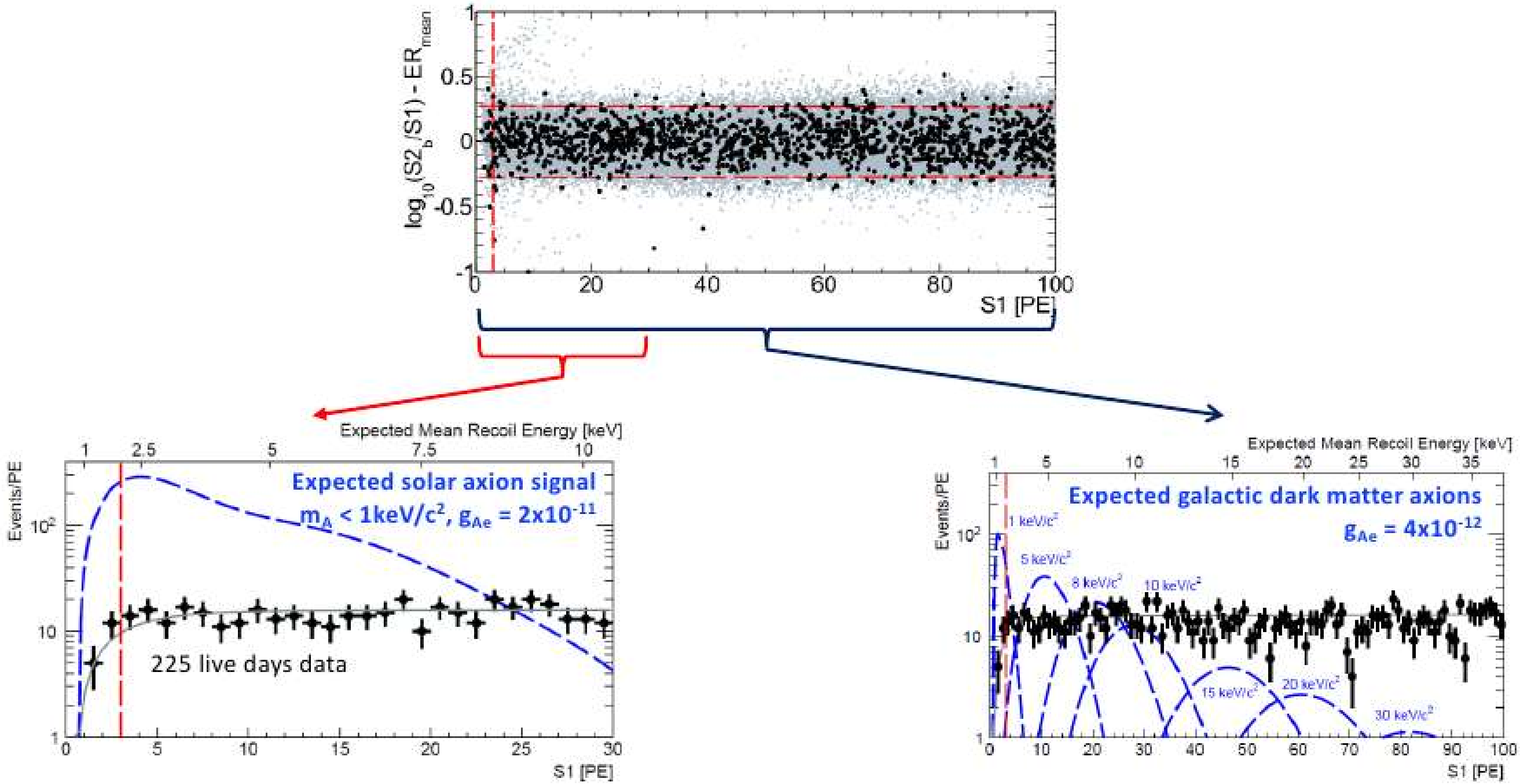


Talk of Ilias Ourahou, LPSC, Grenoble

sub-GeV Dark Matter

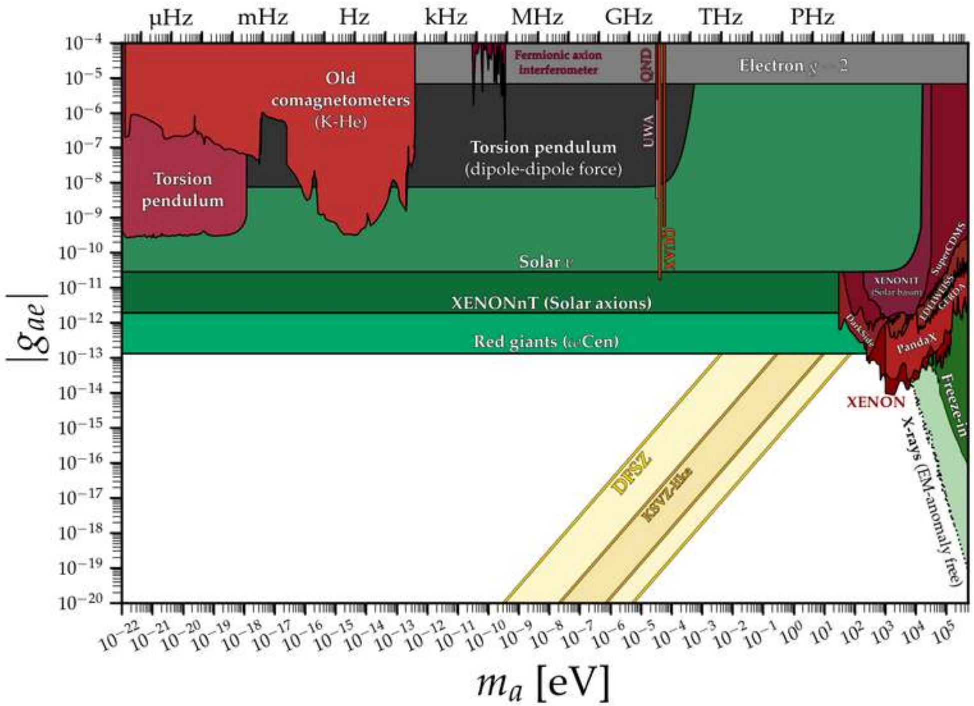
Axions search

- Origins of axion type particles: galactic dark matter and production in the Sun
- Coupling of axions and axion-like dark matter particles (ALP) to LXe target medium via axio-electric effect („absorption“ of axion and emission of electron from the atomic shell)
- Signal expected to appear in the electronic recoil band (as opposed to WIMPs)



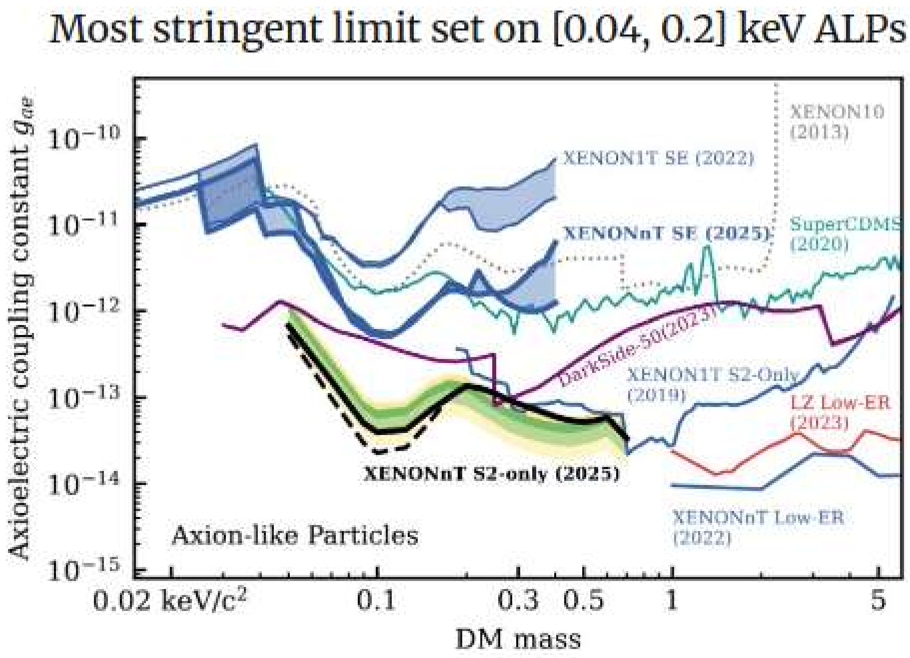
Axions search

Solar axions



Galactic ALPs

XENONnT: Y. Pan, La Thuile 2026, PRL, arXiv:2601.11296



For noble liquids, curves are a combination of several analyses :

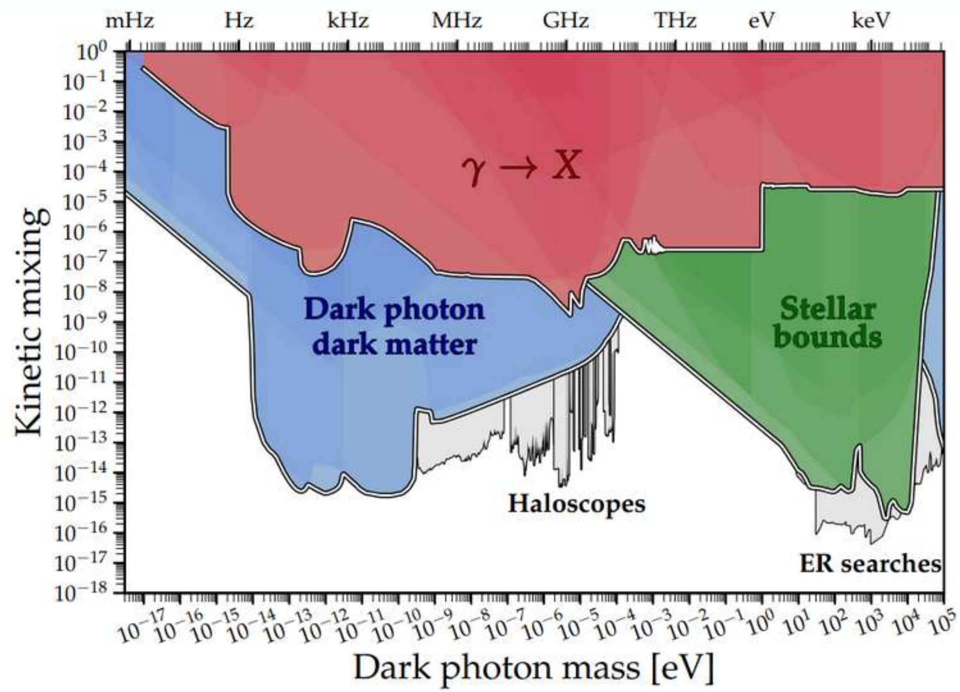
- Standard S1+S2
- S2-only analysis
- 1-to-few electron analysis

Dark Photons

- Arise from a U(1) extension of the Standard Model
- A dark electromagnetic field mixes with the SM photon
- Dark Matter searches exploit the fact that dark photons can oscillate into regular photons, producing luminous signals

"Kinetic mixing"

$$\mathcal{L} \supset -\frac{\chi}{2} F_{\mu\nu} X^{\mu\nu} \qquad (\chi \ll 1)$$



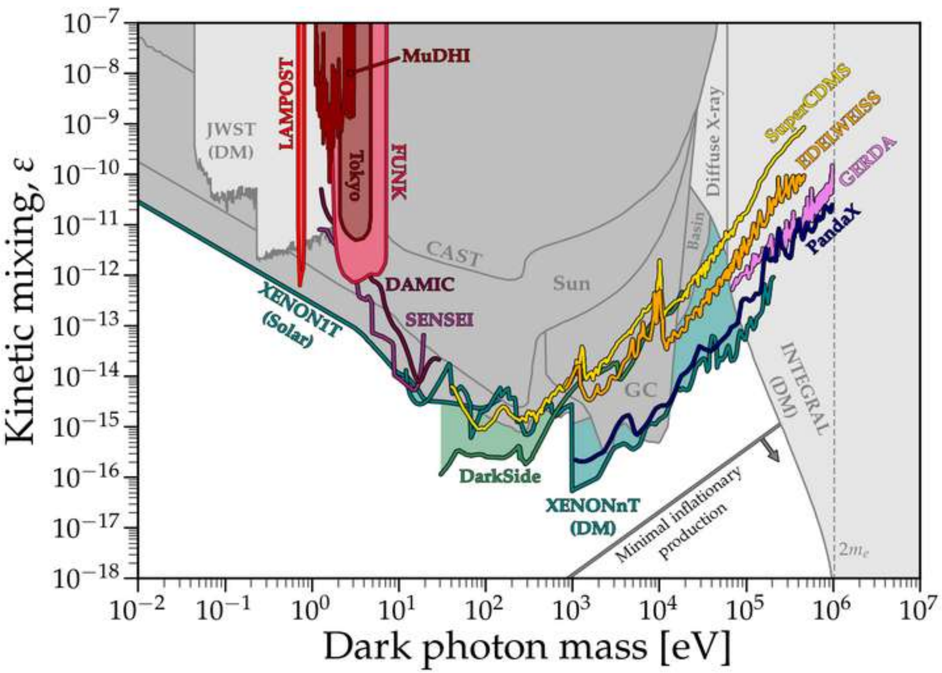
Leading results :

- **From skipper CCDs:**

DAMIC@SNOLAB
SENSEI (2023) *arXiv:2312.13342*
SENSEI (2024) *arXiv:2410.18716*
DAMIC-M

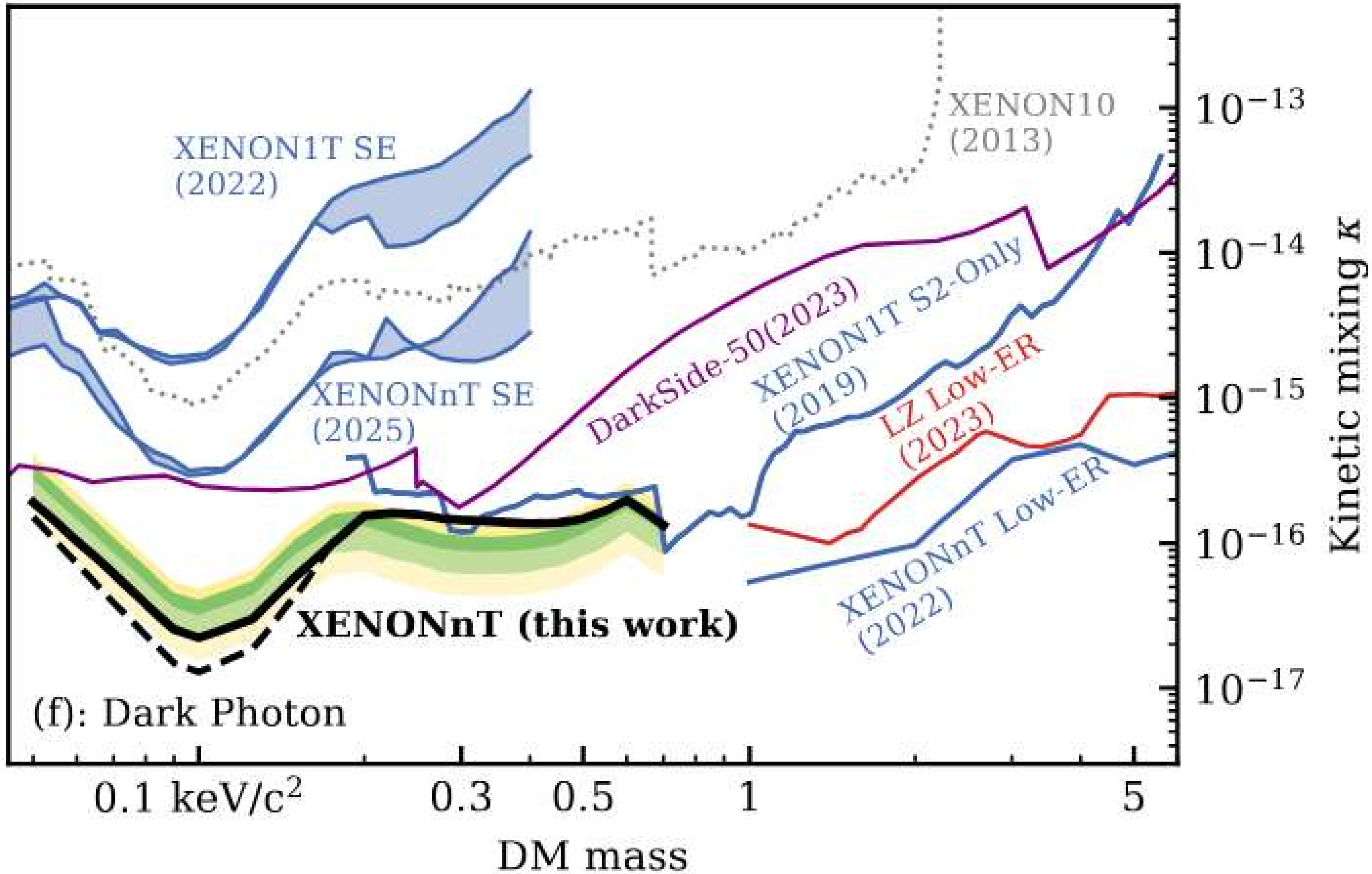
- **From noble liquids:**

DarkSide-50
XENON1T
Panda-X
XENONnT
LZ



Latest results on Dark Photons

XENONnT: Y. Pan, La Thuile 2026, PRL arXiv:2601.11296



DM-electron scattering

At low masses, DM-electron scattering kinematics is more optimal than DM-nucleon scattering for experiments

Leading results :

- **From skipper CCDs:**

DAMIC@SNOLAB
SENSEI (2023) *arXiv:2312.13342*
SENSEI (2024) *arXiv:2410.18716*
DAMIC-M

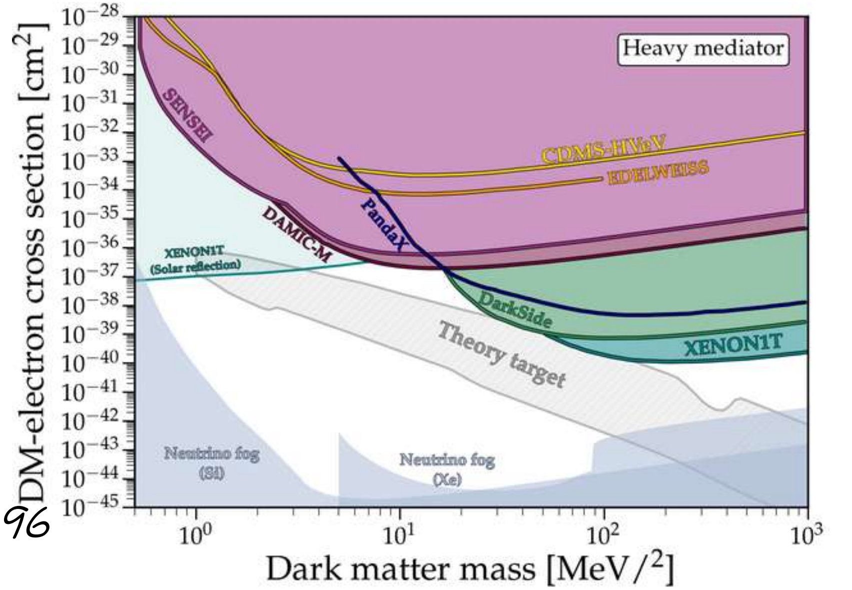
- **From noble liquids:**

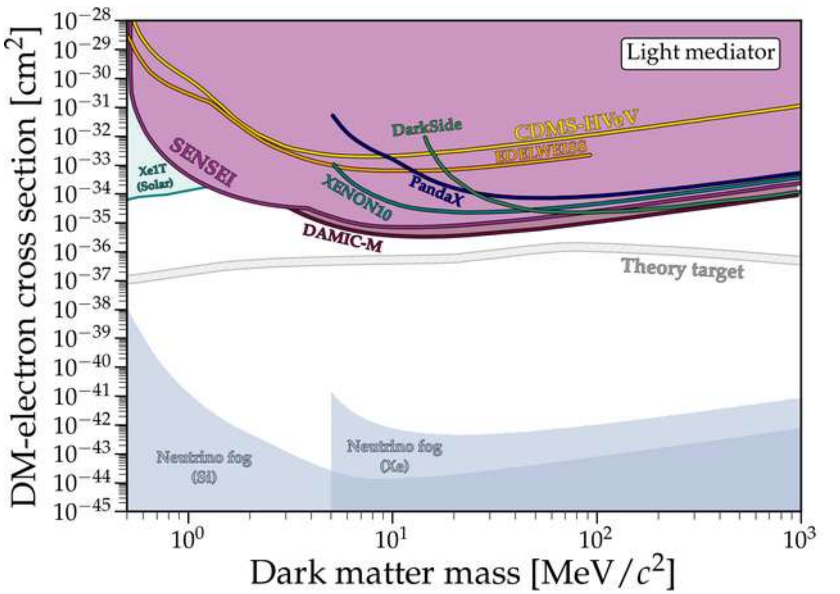
DarkSide-50
XENON1T
Panda-X
XENONnT
LZ

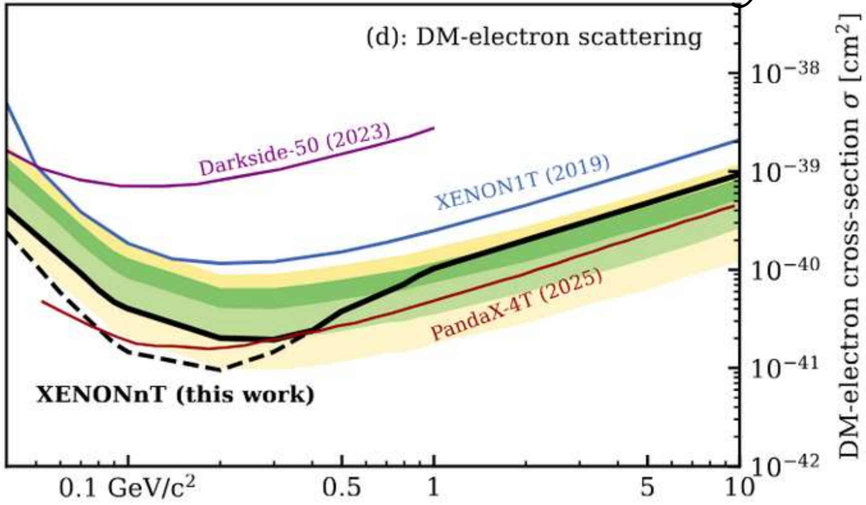
XENONnT: PRL arXiv:2601.11296

PandaX-4T (2025)

See talk of Wei Wang



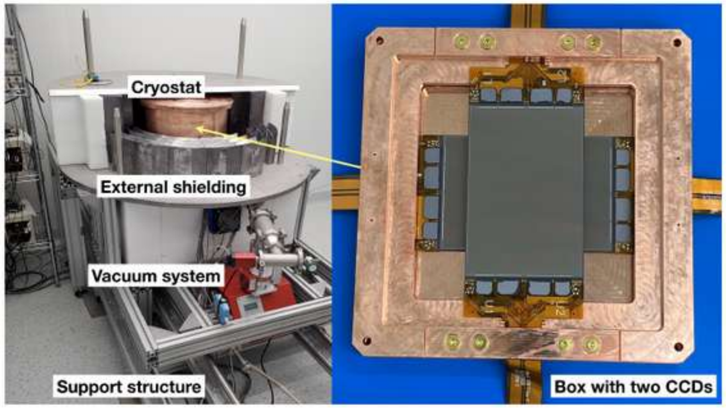




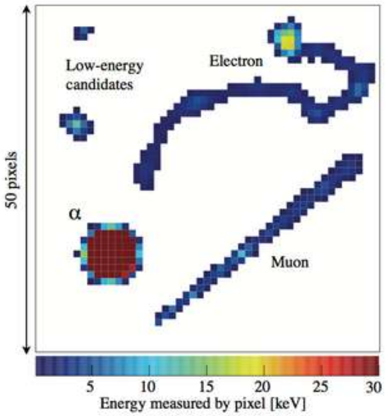
Dark Matter with Skipper-CCDs

Main idea : ultralow-noise electronics in combination with repetitive, nondestructive readout of a thick, fully depleted charge-coupled device (CCD)

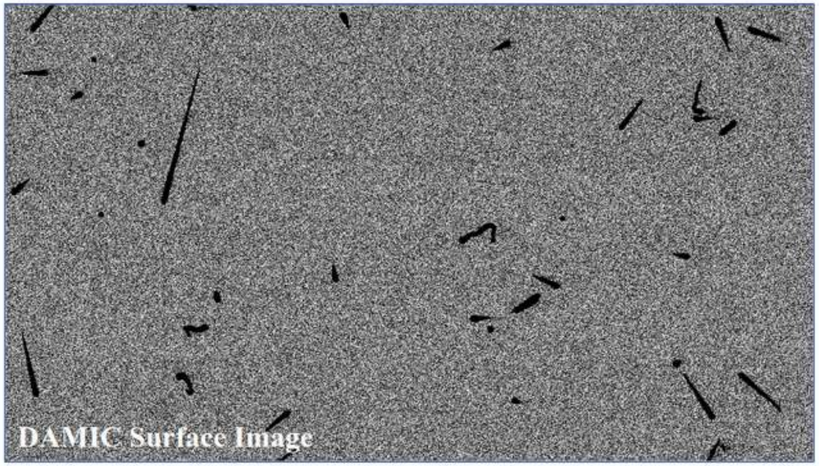
Three detectors : SENSEI, DAMIC @ SNOLAB, DAMIC-M

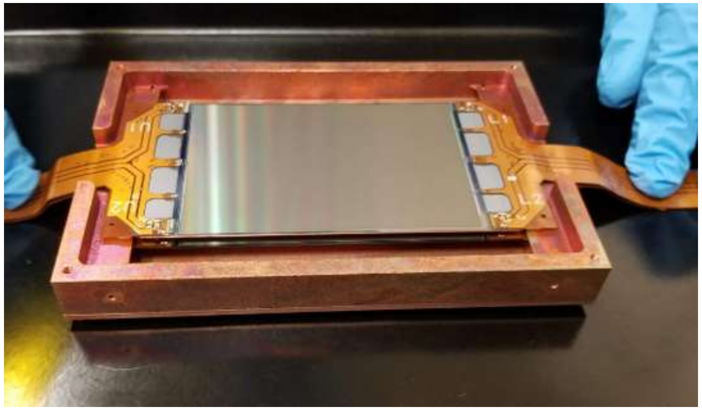


DAMIC-M

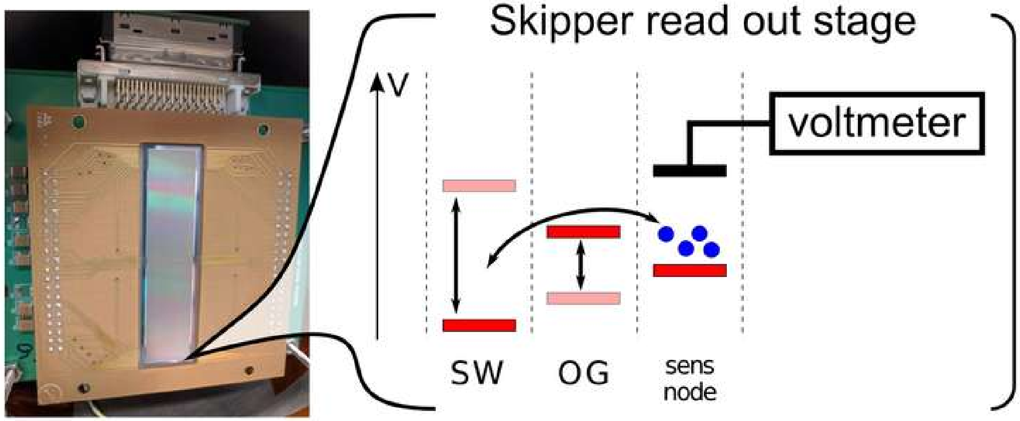


Particle ID



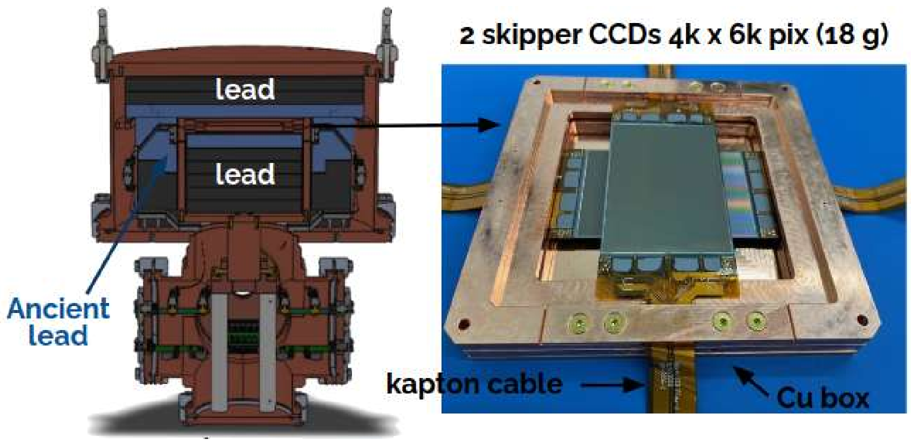


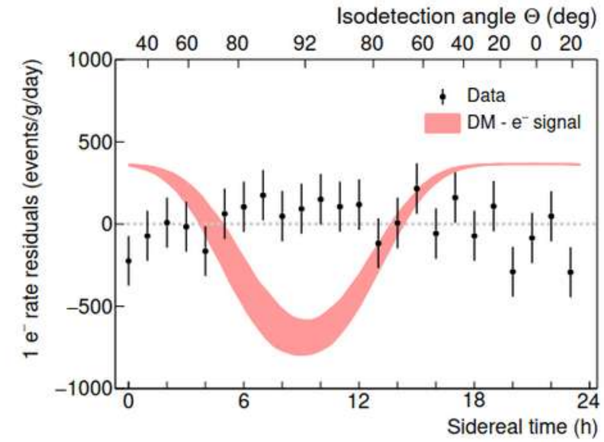
DAMIC @ SNOLAB



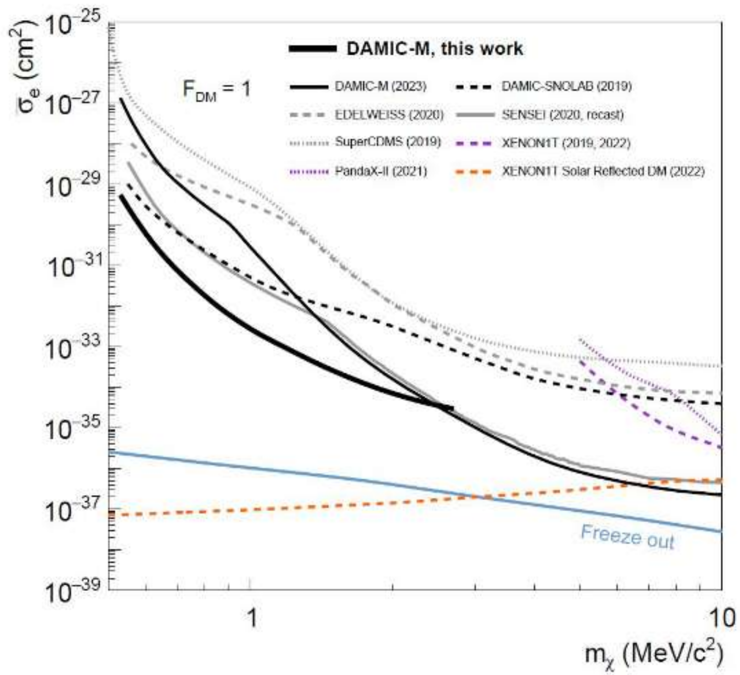
SENSEI

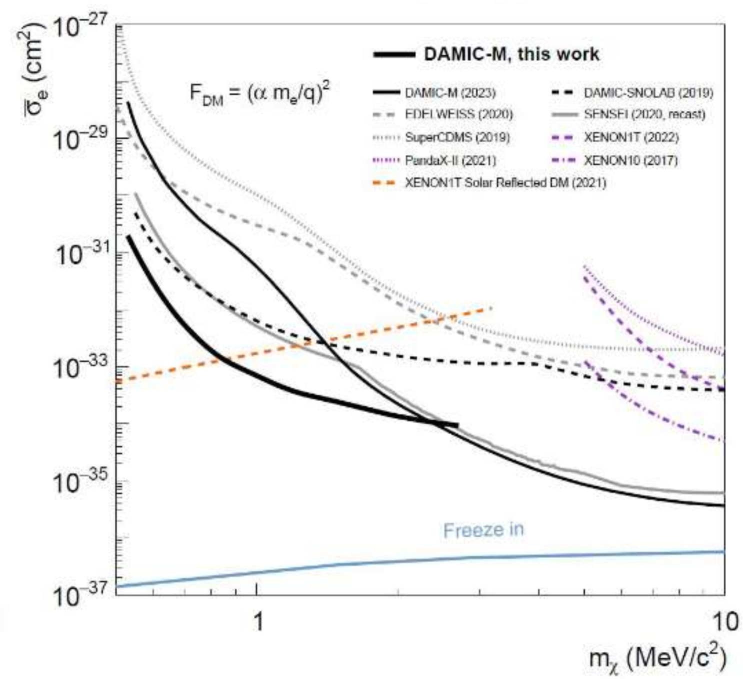
DAMIC-M Low Background Chamber
+ daily modulation analysis





Daily modulation (due to interactions in the Earth) analysis improves up to ~2 orders of magnitude their analysis with the same dataset

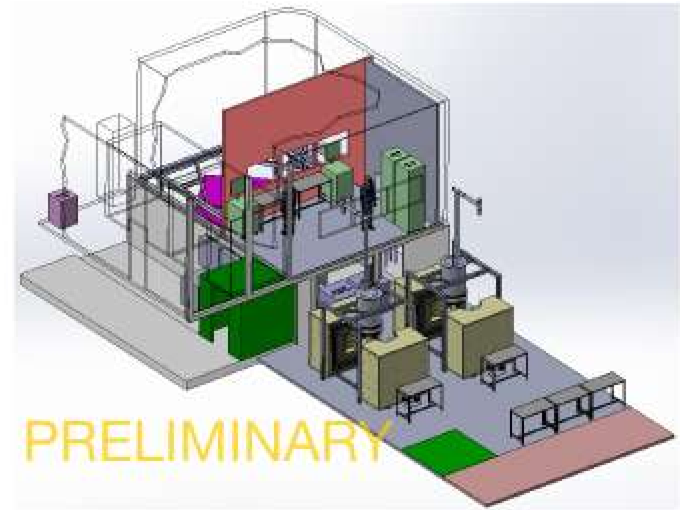




What we should expect in the future

TESSERACT

- Two copies of the setup at LSM, for enabling both:
  - underground R&D and detector optimisation
  - DM science data taking in parallel
- Target background levels < 5 evt/kg/keV/day
- Each detector technologies is designed to achieve major breakthrough in short time scales (few months) hence allowing fast turnarounds
- **Integration at LSM planned in 2028 for first DM science data in 2029**

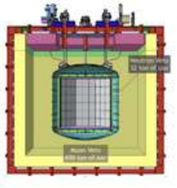


Thanks to Julien Billard (IP2I) for the material

Future at high WIMP masses

DarkSide50 :
@LNGS, Italy
50kg Ar → UAr

DarkSide20k
@LNGS, Italy
50t UAr



PandaX-4T :
@JinPing, China
6t total Xe mass

PandaX-xT :
@JinPing, China
20t → 43t total Xe mass
Approved in China

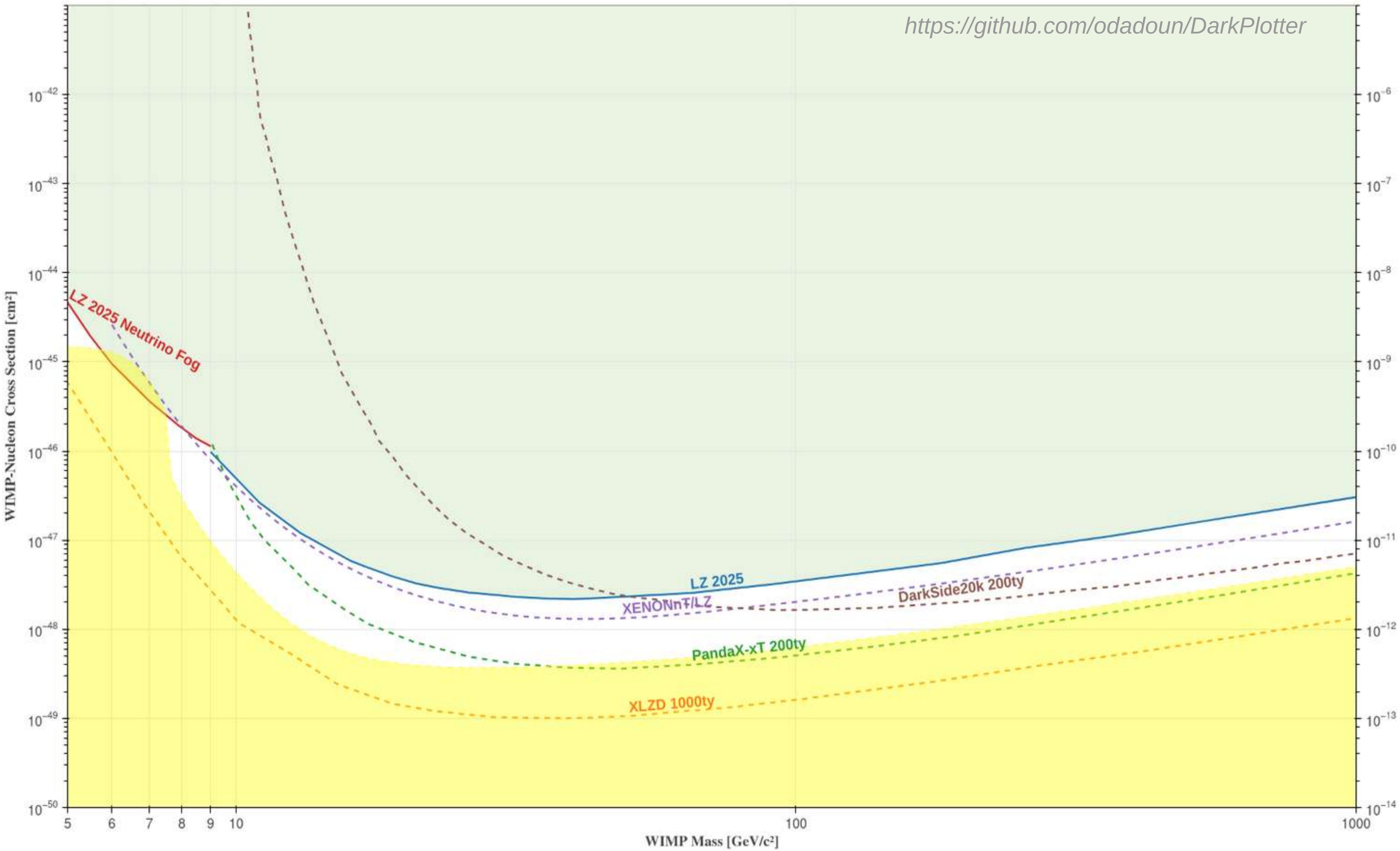
XENONnT :
@LNGS, Italy
8.6t total Xe mass

LZ :
@SURF, US
10t total Xe mass

+ DARWIN
R&D program since a decade
to build a 50t total mass

XLZD (XENON+LZ+DARWIN):
Several sites considered
40t → 80t total Xe mass

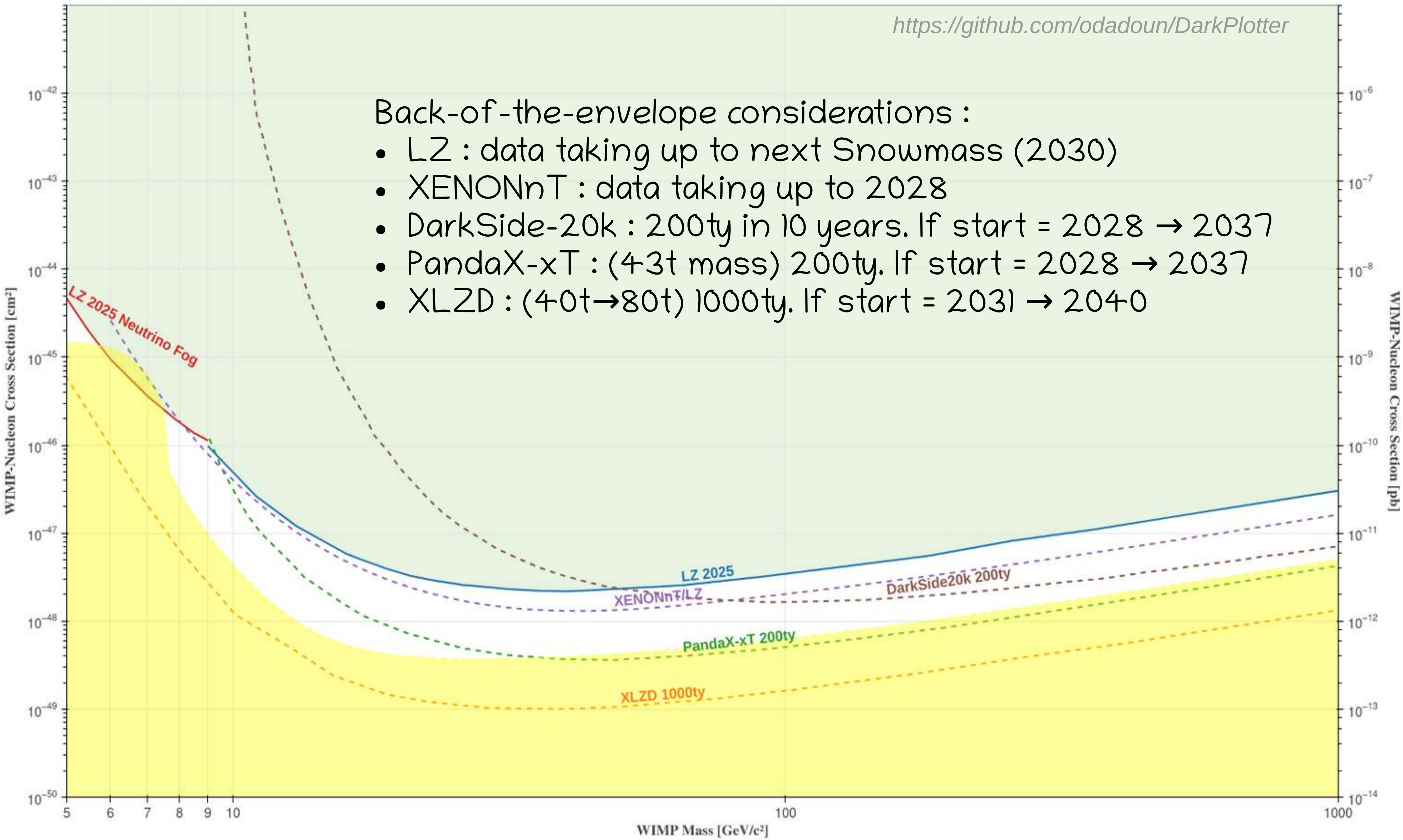
Comparison between future experiments



Timeline of future experiments

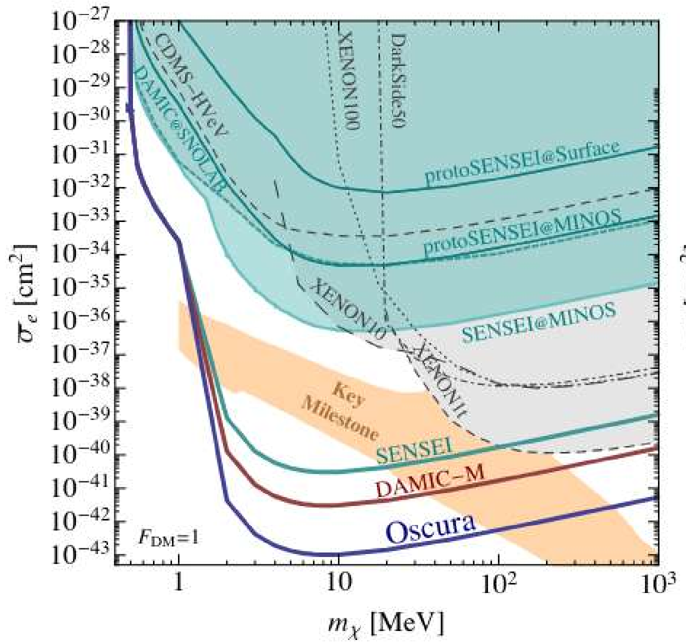
Back-of-the-envelope considerations :

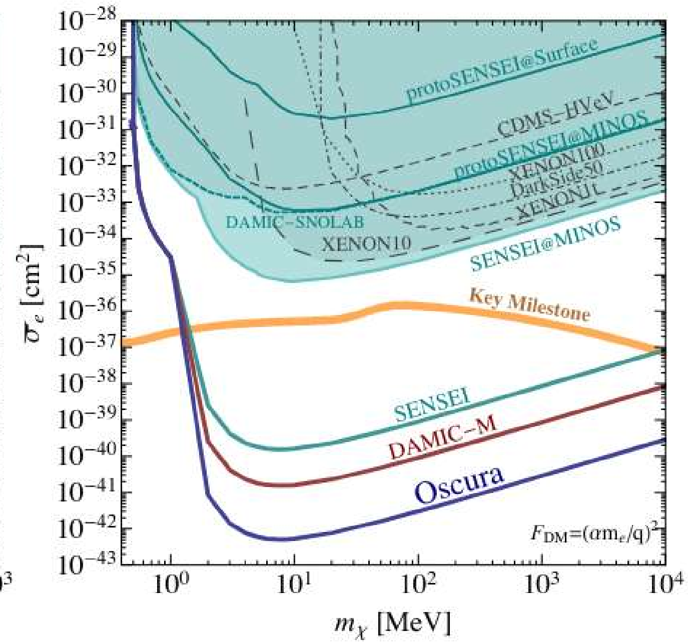
- LZ : data taking up to next Snowmass (2030)
- XENONnT : data taking up to 2028
- DarkSide-20k : 200ty in 10 years. If start = 2028 → 2037
- PandaX-xT : (43t mass) 200ty. If start = 2028 → 2037
- XLZD : (40t→80t) 1000ty. If start = 2031 → 2040



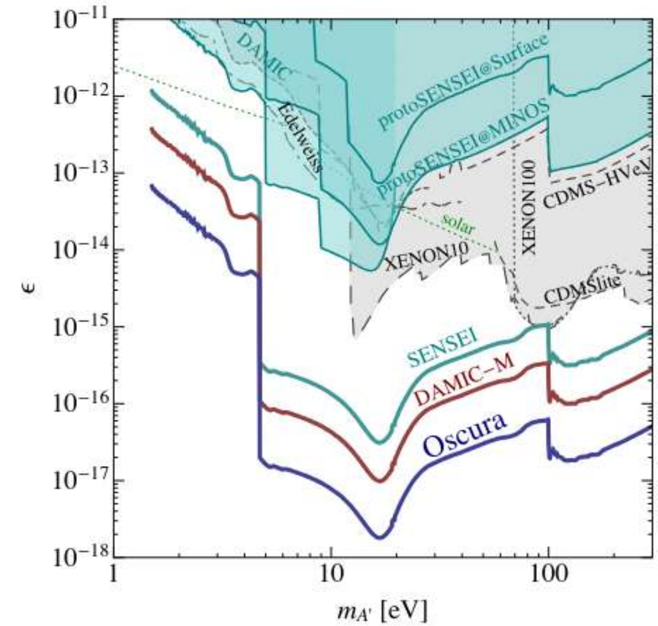
Next generation experiments : Skipper-CCDs

DM-electron scattering





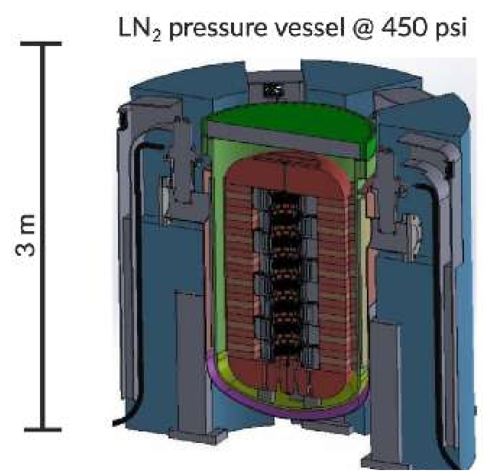
Dark photons

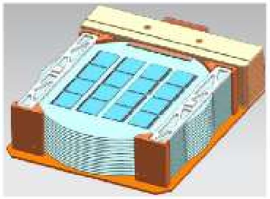


Skipper-CCD is now a well estabilished technology

To gain sensitivity it needs to

- Increase target mass
  - Silicium thickness
  - High number of devices
- Improve background





	SENSEI	DAMIC-M	Oscura
n. of CCDs	50	200	20000
mass (kg)	0.1	1	10
bkg (dru)	10	0.1	0.01
Lab	SNOLAB	LSM	SNOLAB (likely)

OSCURA merges the expertise from the two collaborations DAMIC and SENSEI

The OSCURA experiment : *arXiv:2202.10518v2*

Future on Axions

Axions, coupling to the photon

Haloscopes :

- Lumped element + LC
  - m_a ~ O(10 peV - 100 eV)
  - ν ~ O(MHz)

ABRACADABRA, DMRadio

- Microwave cavities
  - m_a ~ O(10 μeV)
  - ν ~ O(GHz)

ADMX, HAYSTAC, CAPP, GrAHal, ORGAN, QUAX, CAST-CAPP, RADES

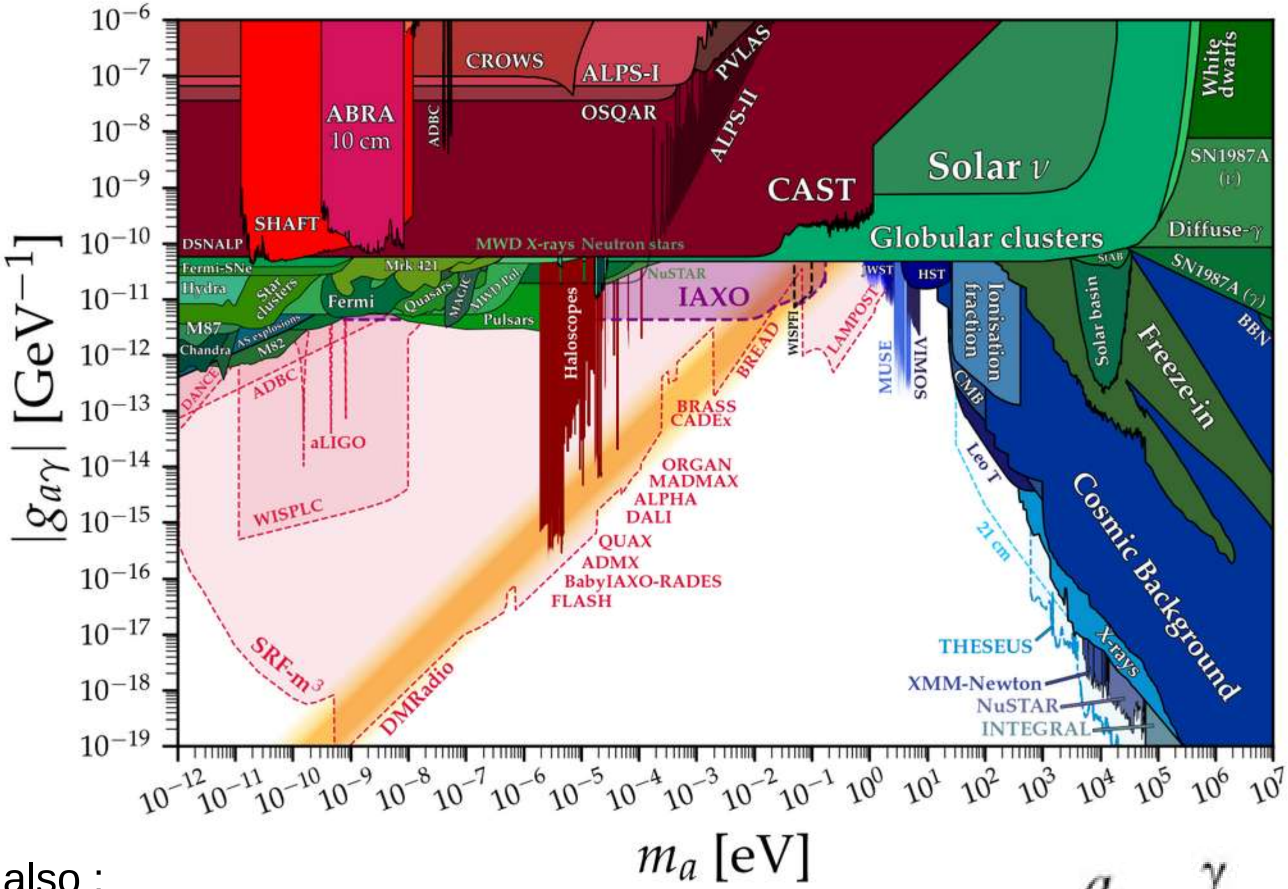
- Dielectric
  - m_a ~ O(100 μeV)
  - ν ~ O(10-100 GHz)

BREAD, BRASS, **MADMAX**

- Plasma
  - m_a O(100 μeV)
  - ν ~ O(10-100 GHz)

ALPHA

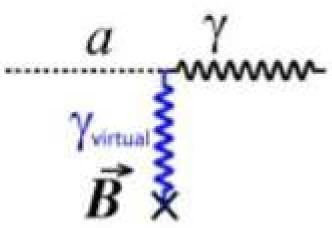
The phenomenology mostly based on the axion coupling with photons



Plot from https://cajohare.github.io/AxionLimits/

But also :

- Light-shining-through-wall (ALPS)
- Helioscopes (CAST)

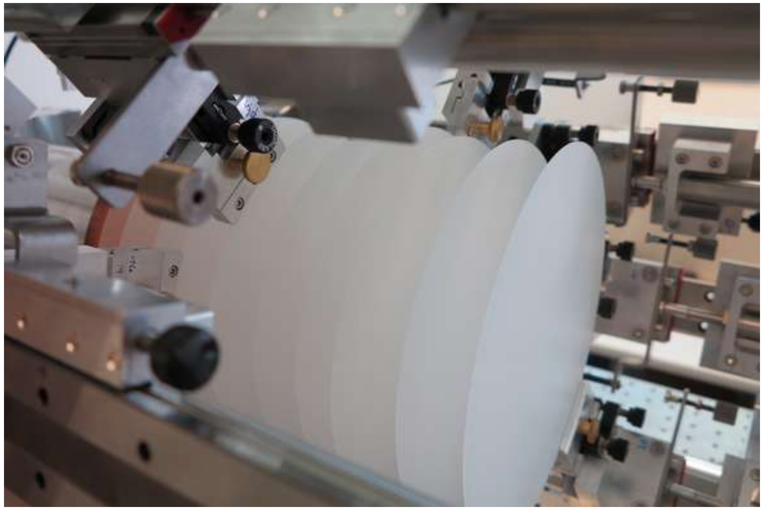


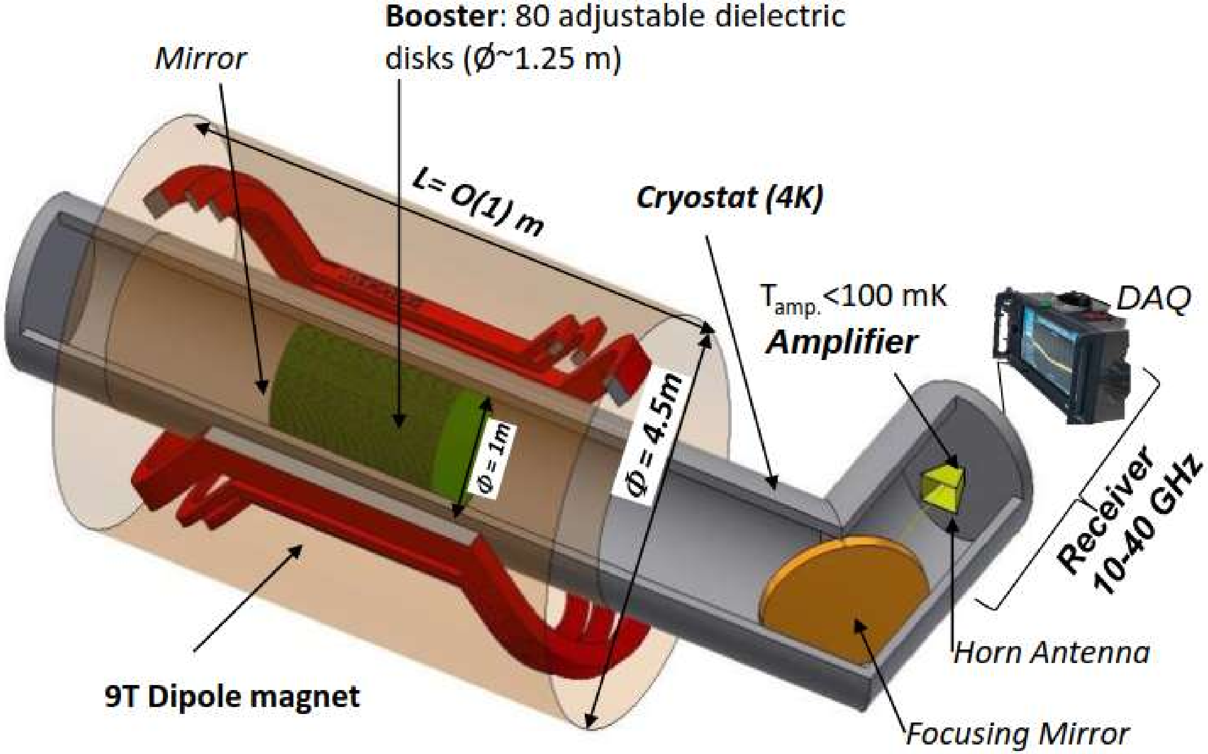
MADMAX

- Constructive interference of coherent photons emitted at the disk surface + resonant enhancement (~leaky resonator cavities) : boost factor β^2 wrt mirror only
- Axion mass scan: by moving discs with piezo motors (μm precision) at 4K under 10 T

$$P_{sig} = 10^{-22}\ \mathrm{W} \times \left(\frac{\beta^2}{50000}\right) \times \left(\frac{B_e}{10\ \mathrm{T}}\right)^2 \times \left(\frac{A}{1\ \mathrm{m}^2}\right) \times C_{a\gamma}^2$$

$$|C_{a\gamma}| = \left(\frac{|g_{a\gamma}|}{2\times 10^{-14}\ \mathrm{GeV}^{-1}}\right)\left(\frac{100\ \mu\mathrm{eV}}{m_a}\right)$$





White Paper, Eur. Phys. J. C (2019) 79: 186

NEXUS project

Call: HORIZON-MSCA-2024-SE-01
Type of Action: HORIZON-TMA-MSCA-SE
Acronym: NEXUS
Number: 101236929
Duration: 48 months
GA based on the: HE Unit MGA — Multi & Mono - 1.2
Estimated Project Cost: €0.00
Requested EU Contribution: €771,540.00
Current Phase: Grant Management
Start Date: 01 Jan 2026
Contact: Amir SPAHIC

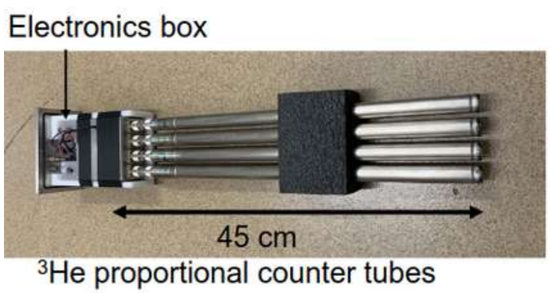
Led by **Fairouz Malek**, LPSC, Grenoble

Working Packages

1	✓	Low background technologies
2	✓	Muography and radiation measurements
3	✓	Modelling, Simulation and Machine learning
4	✓	Quantum science and technology
5	✓	Education and Training Activities
6	✓	Management and Coordination

See talk of Fairouz Malek, LPSC, Grenoble

WP2



Measurement done already at **PAUL** (South Africa)
Will be done also at **CJPL** (China), **LNGS** (Italy), **SUPL** (Australia), **SNOLAB** (Canada)
First time the **same detector** travelling on most of UG laboratories for neutron measurements

Concluding comments

Direct Dark Matter Search is a very exciting branch of astroparticle physics

In **France,** we have a **high complementarity** in terms of:

- **experimental techniques**
- dark matter **mass range**
- **physics models** experimentally accessible

For WIMPs:

- experiments put significant **pressure on WIMP model** (**XENONnT, DarkSide50**) but WIMPs are not yet ruled out **!**
- **neutrino floor** has been already reached by xenon experiments (CEvNS @ ^{8}B)
- we need another generation of experiments to reach it at **high masses** (atmospheric neutrinos) (**XLZD**)

Light Dark Matter:

- We are also seeing the rapid growth of **improved techniques** designed specifically for alternative models (light dark matter) (**TESSERACT, DAMIC**)

For **axions,** France has a flagship experiment (**MADMAX**)

Directional detection for the first time explored a new region of the parameters space (**MIMAC**)

France is strongly active on reinforcing a network including current and emerging **underground labs** (**NEXUS**)

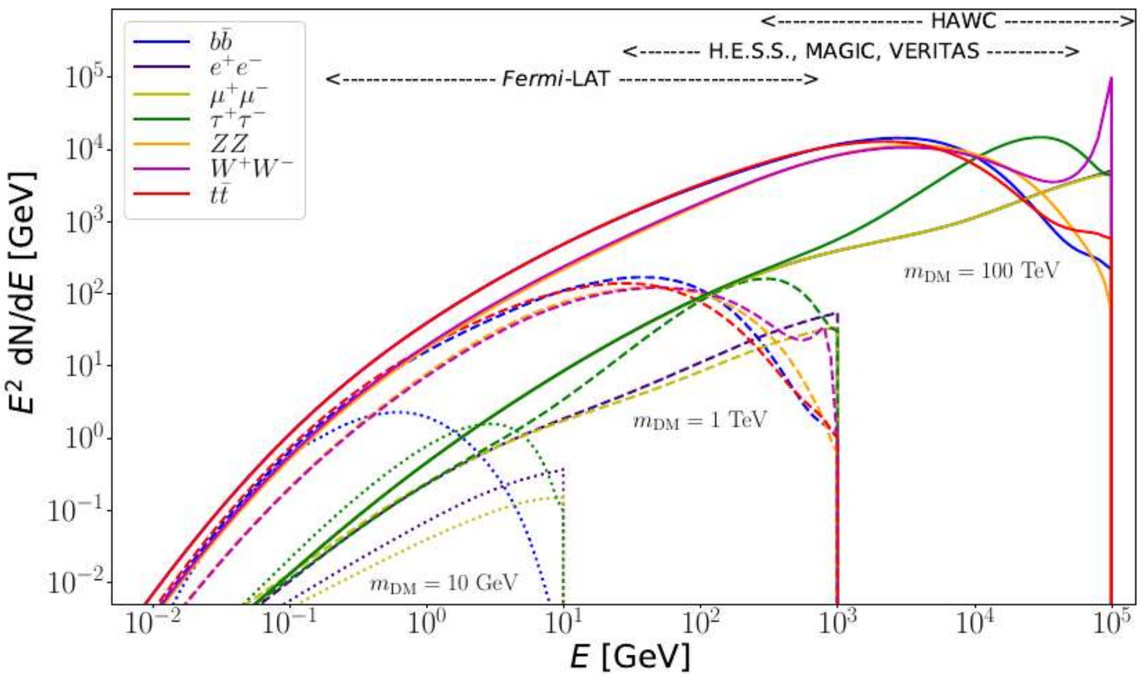
Thank you

Indirect observation : Dark Matter annihilation

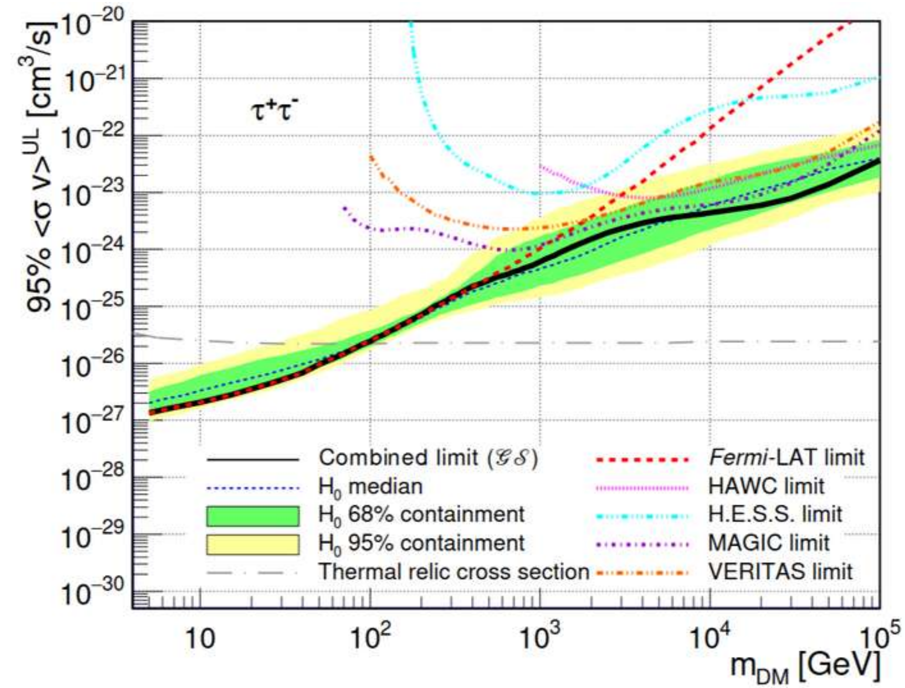
Combination of 5 gamma-ray detectors in observing dwarf galaxies :

Expected dark matter flux

$$\frac{d\Phi(\Delta\Omega)}{dE} = \frac{1}{4\pi}\frac{\langle\sigma_{\mathrm{ann}}v\rangle}{2m_{\mathrm{DM}}^2}\frac{dN}{dE} \times \int_{\Delta\Omega} d\Omega' \int_{\mathrm{l.o.s.}} dl\,\rho^2(l,\Omega')$$



Example of upper limits on <σv> for $\tau^+\tau^-$ channel



Material from Daniel Kerszberg (LPNHE), talk at :
Second International Conference on the Physics of the Two Infinities, Tokyo, 2025

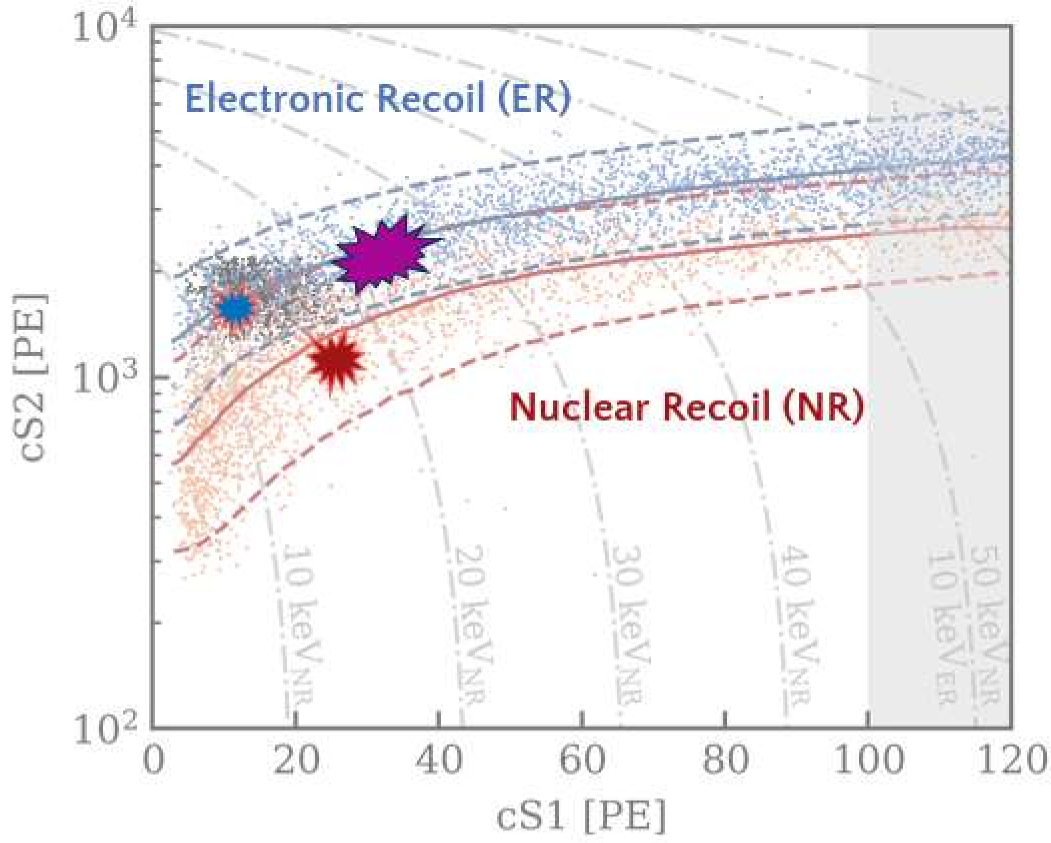
Migdal Effect in Direct Detection

Migdal Effect

Deposited Energy:

- **NR**
- Migdal electron
- Binding energy (X-ray + *Auger e⁻*)

ER {Migdal electron, Binding energy}



First direct evidence of Migdal Effect

Nature volume 649, pages 580–583 (2026)

Article

Direct observation of the Migdal effect induced by neutron bombardment

https://doi.org/10.1038/s41586-025-09918-8

Received: 4 October 2024

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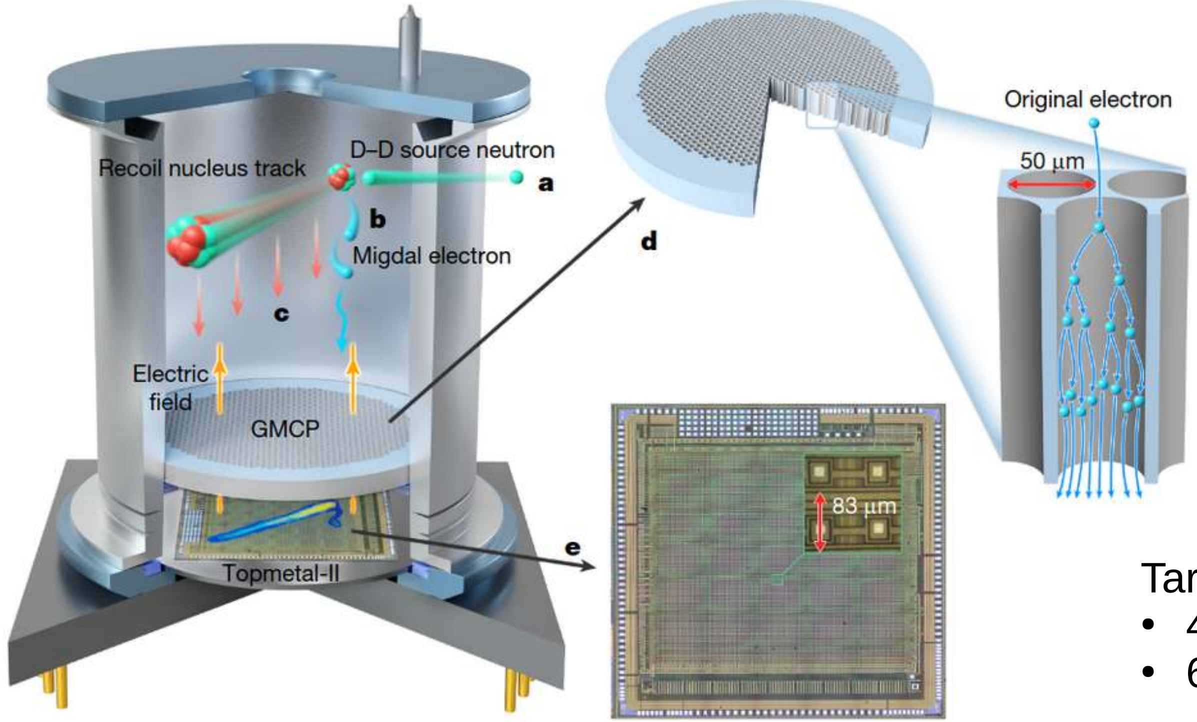
Difan Yi[1,2], Qian Liu[1✉], Shi Chen[1], Chunlai Dong[3], Huanbo Feng[2], Chaosong Gao[3], Wenqian Huang[1,2], Xinmei Jing[1], Lingquan Kong[1], Jin Li[1], Peirong Li[4], Enwei Liang[2], Ruiting Ma[1], Chenguang Su[1], Liangliang Su[5], Junwei Sun[6], Dong Wang[3], Junrun Wang[4], Zheng Wei[4], Zeen Yao[4], Yunlinchen Yu[1], Yu Zhang[4], Shiqiang Zhou[3], Zhuo Zhou[3], Bin Zhu[6], Jie Zuo[1], Hongbang Liu[2✉], Xiangming Sun[3✉], Lei Wu[5✉] & Yangheng Zheng[1✉]



Target :

- 40% helium
- 60% dimethyl ether (DME, CH_3OCH_3)

First direct evidence of Migdal Effect

Phenomenon predicted more than 80 years ago but confirmed only now with a statistical significance exceeding 5σ

Relative cross-section with respect to NR cross section : $(4.9^{+2.6}_{-1.9}) \times 10^{-5}$