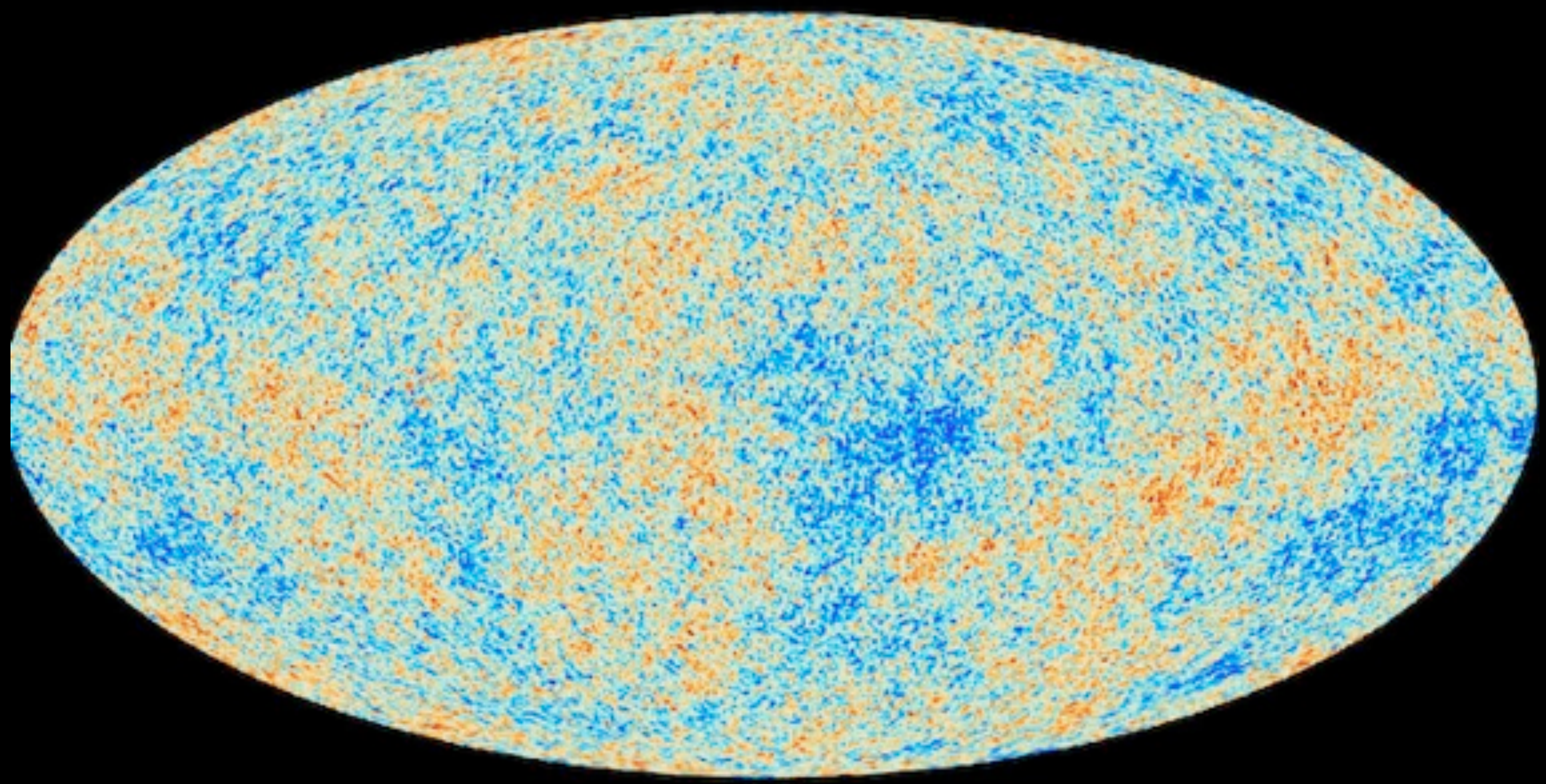
UCSB

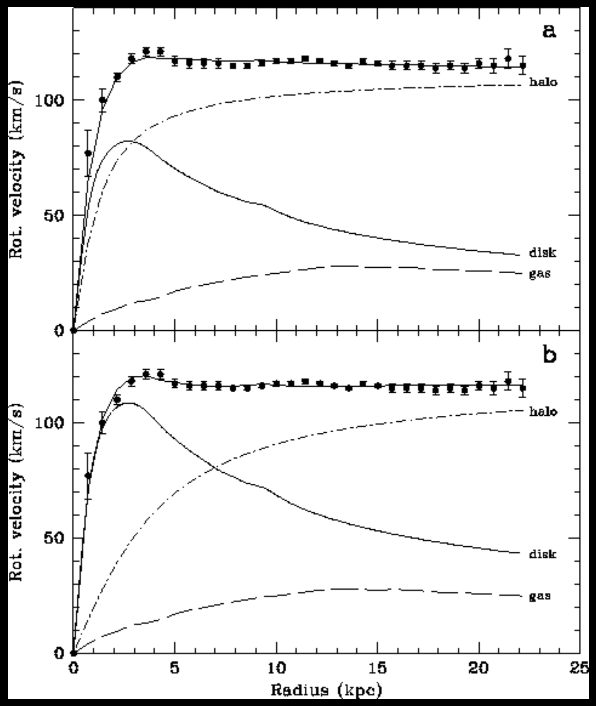
Dark Matter with Liquid Nobles
Where are we and what comes next?

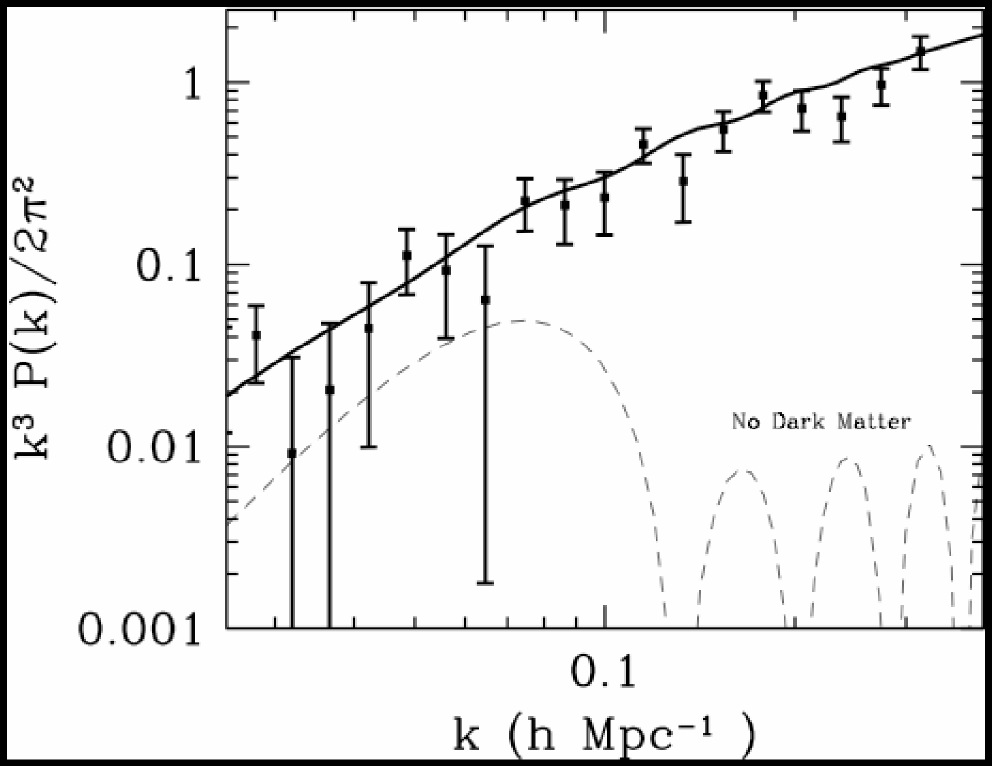
Hugh Lippincott, UCSB
CIPANP, Madison
June 9, 2025

Dark matter - evidence?



- Galaxy rotation curves
- Galaxy clusters and collisions
- Large scale structure
- Cosmic microwave background





Dark Matter 25 years ago

2001 Snowmass report - single 3 page section on dark matter and relic particles

Particle Astrophysics and Cosmology: Cosmic Laboratories for New Physics
(Summary of the Snowmass 2001 P4 Working Group)

Daniel S. Akerib*
Department of Physics, Case Western Reserve University, Cleveland, OH 44106

Sean M. Carroll†
Department of Physics and Enrico Fermi Institute,
University of Chicago, 5640 South Ellis Avenue, Chicago, IL 60637

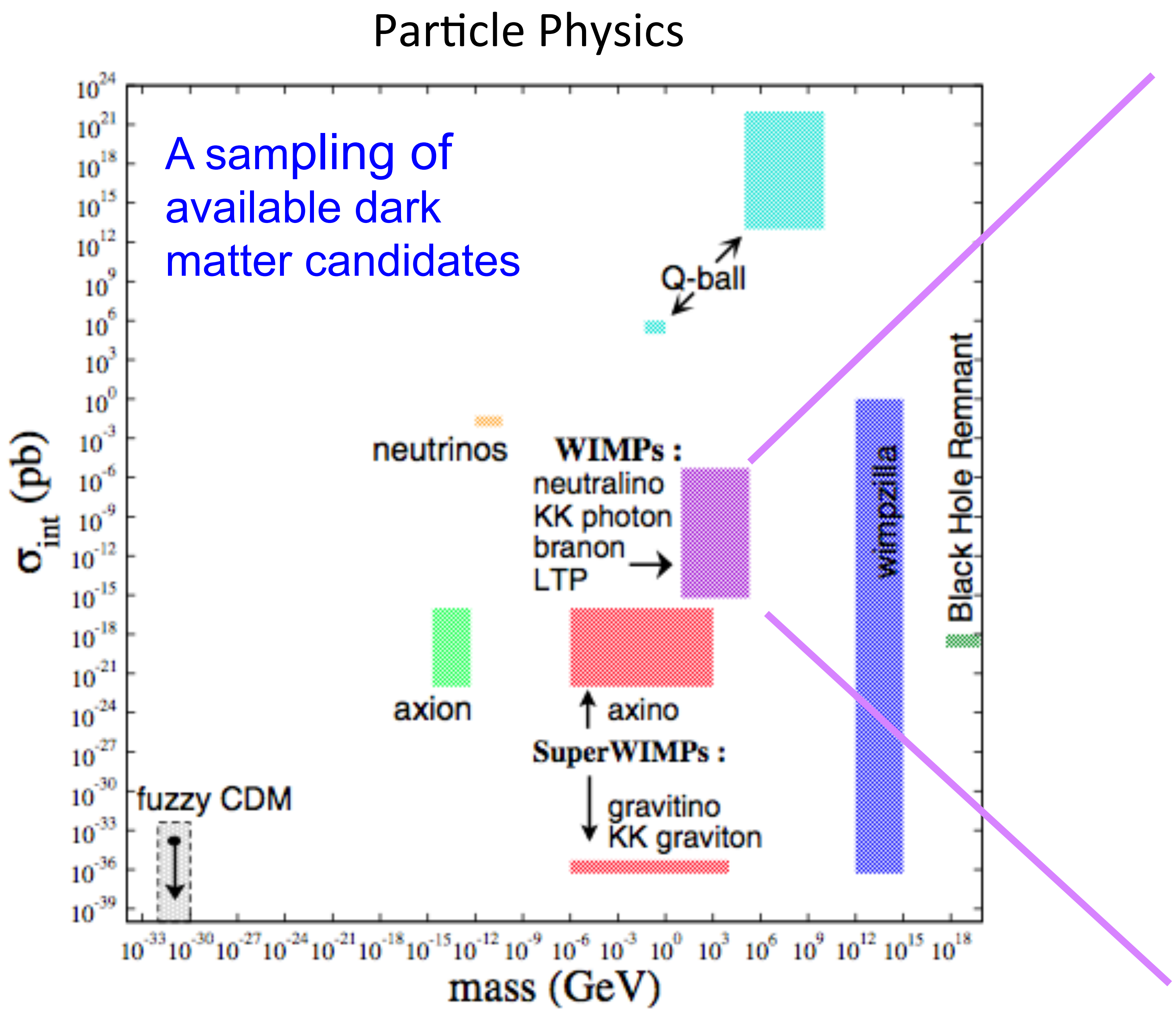
Marc Kamionkowski‡
California Institute of Technology, Mail Code 130-33, Pasadena, CA 91125

Steven Ritz§
NASA/Goddard Space Flight Center, Mail Code 661, Greenbelt, MD 20771
(Dated: October 30, 2018)

III. DARK MATTER AND RELIC PARTICLES

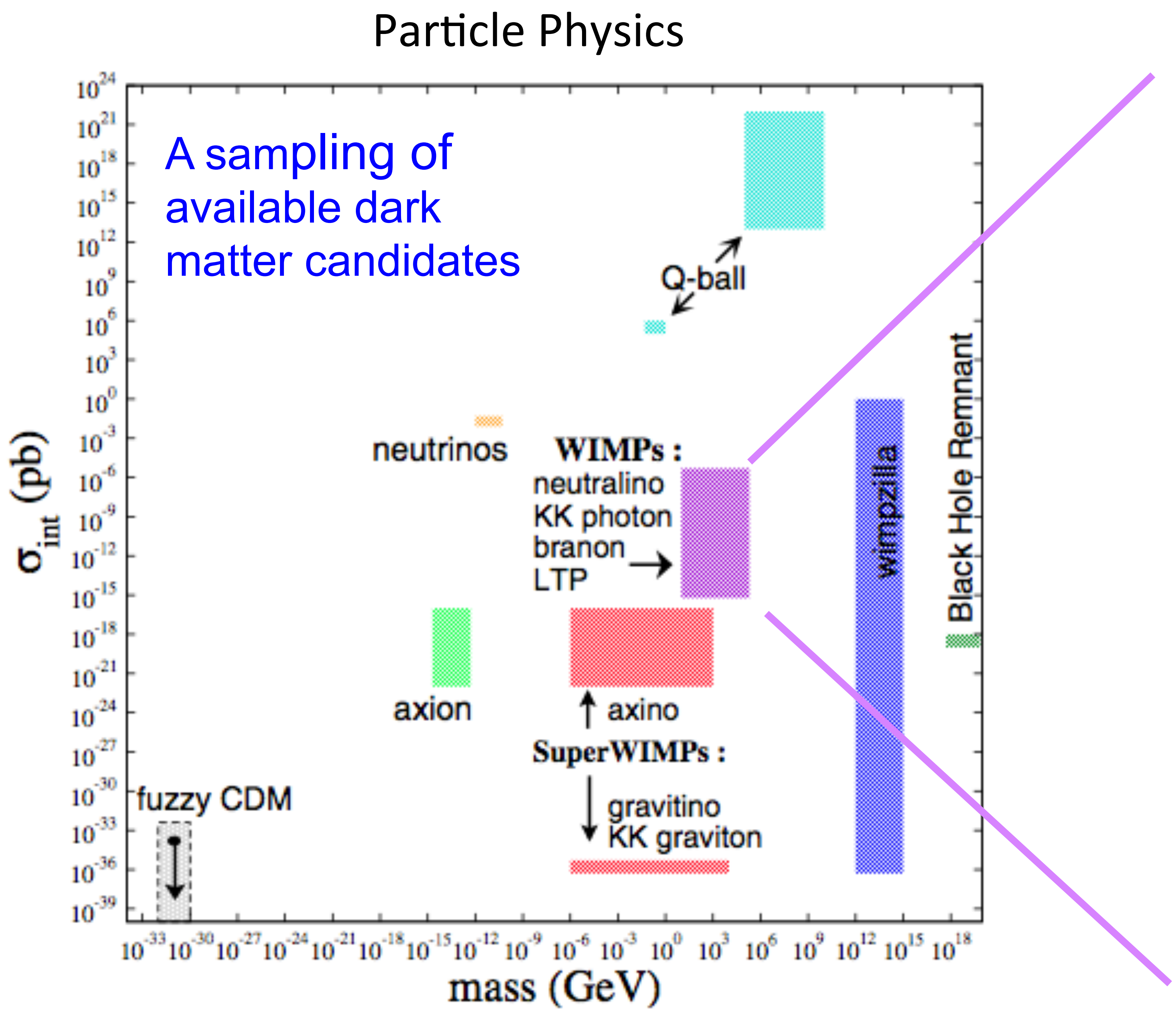
"Particle physics offers two different hypotheses for the dark matter—WIMPs and axions…"

Dark Matter



It's probably WIMPs, right?

Dark Matter

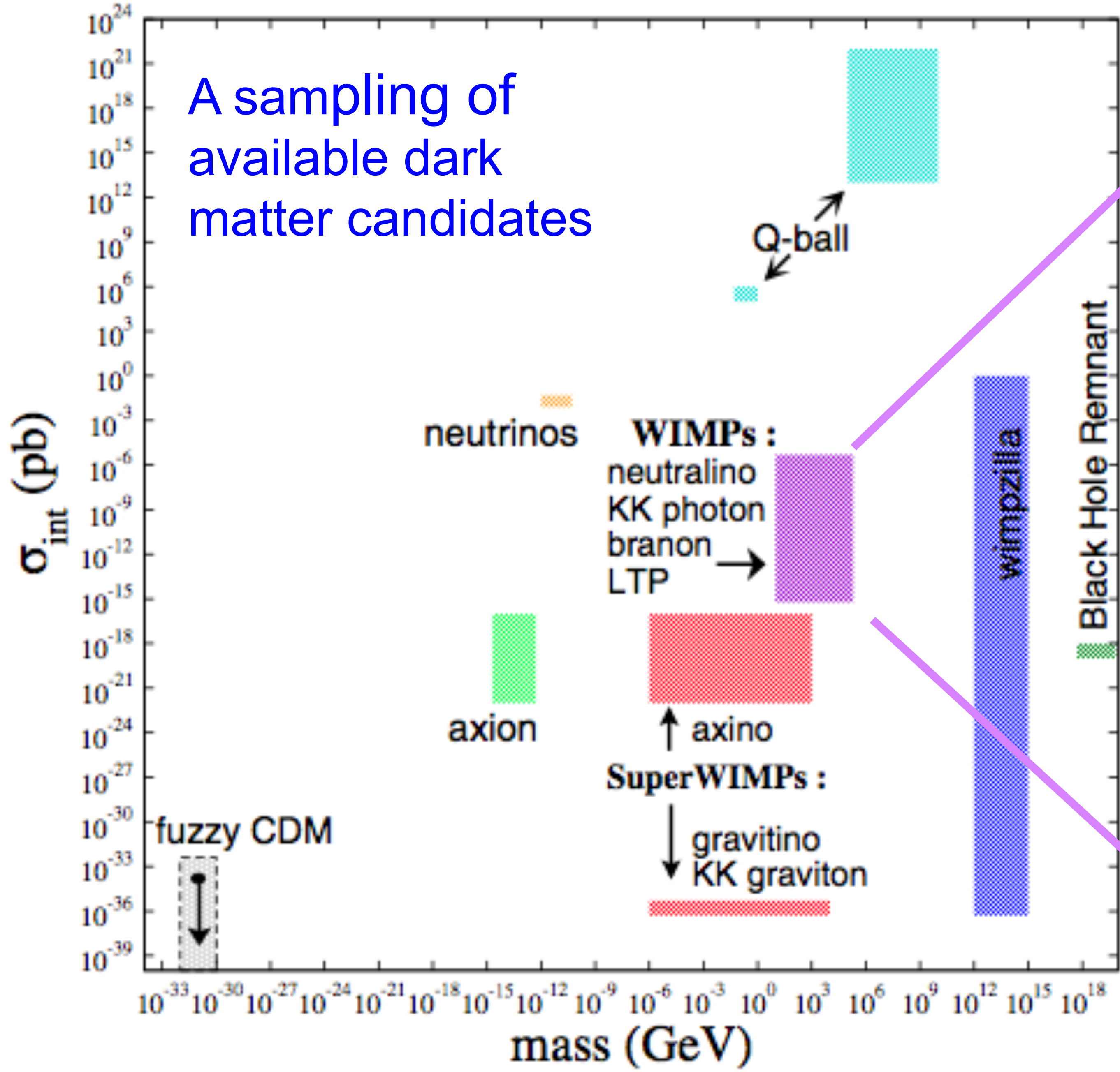


It's probably WIMPs, right?

(I'm serious)

Dark Matter

Particle Physics



It's probably WIMPs, right?

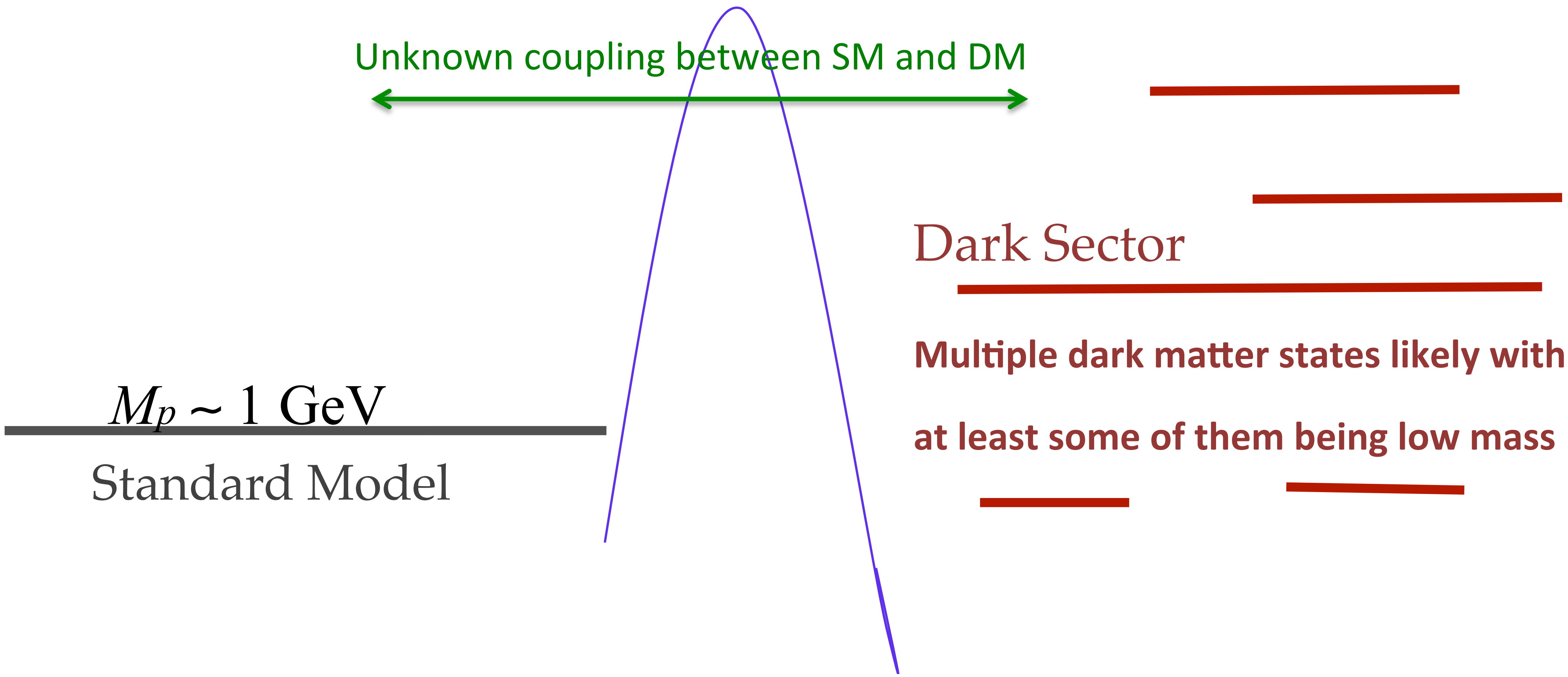
(I'm serious)

(Sort of)

WIMPs as Thermal Relics

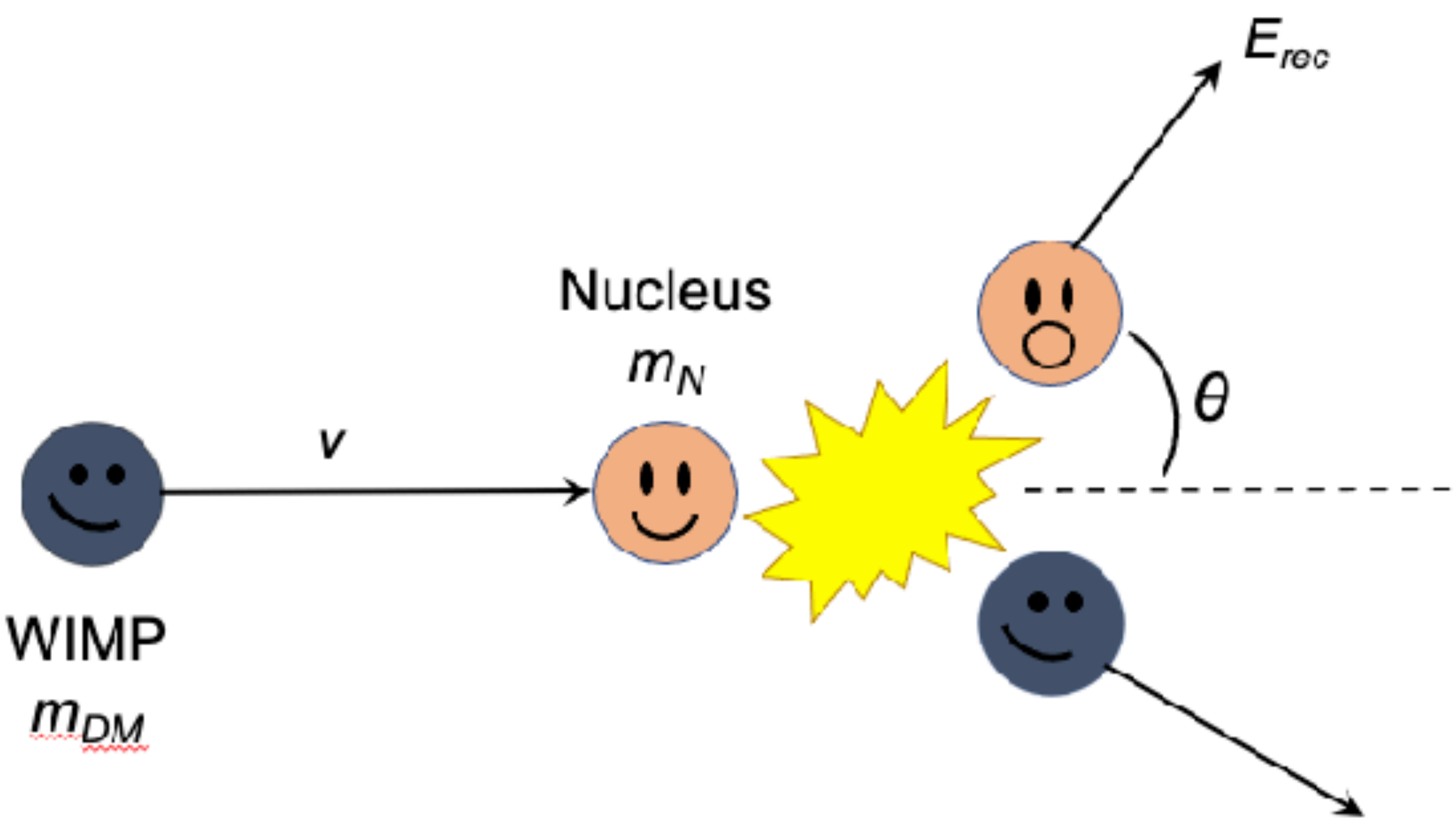
- When I say WIMP, I basically mean a thermal relic
  - Paradigm inherently includes the possibility of detection (DM was once in thermal equilibrium with Standard Model)
  - Don't have to worry about initial conditions

- But it's true, WIMP candidates come out of several theoretical extensions to the Standard Model (Supersymmetry being a prominent example)



Searching for WIMPs with Direct Detection

Fill a detector with your favorite material and wait for WIMPs to scatter off it



Non-relativistic elastic scattering

$$\mu = \frac{m_{DM} m_N}{m_{DM} + m_N}$$

$$E_{rec} = \frac{\mu^2 v^2}{m_N}(1 - cos\theta)$$

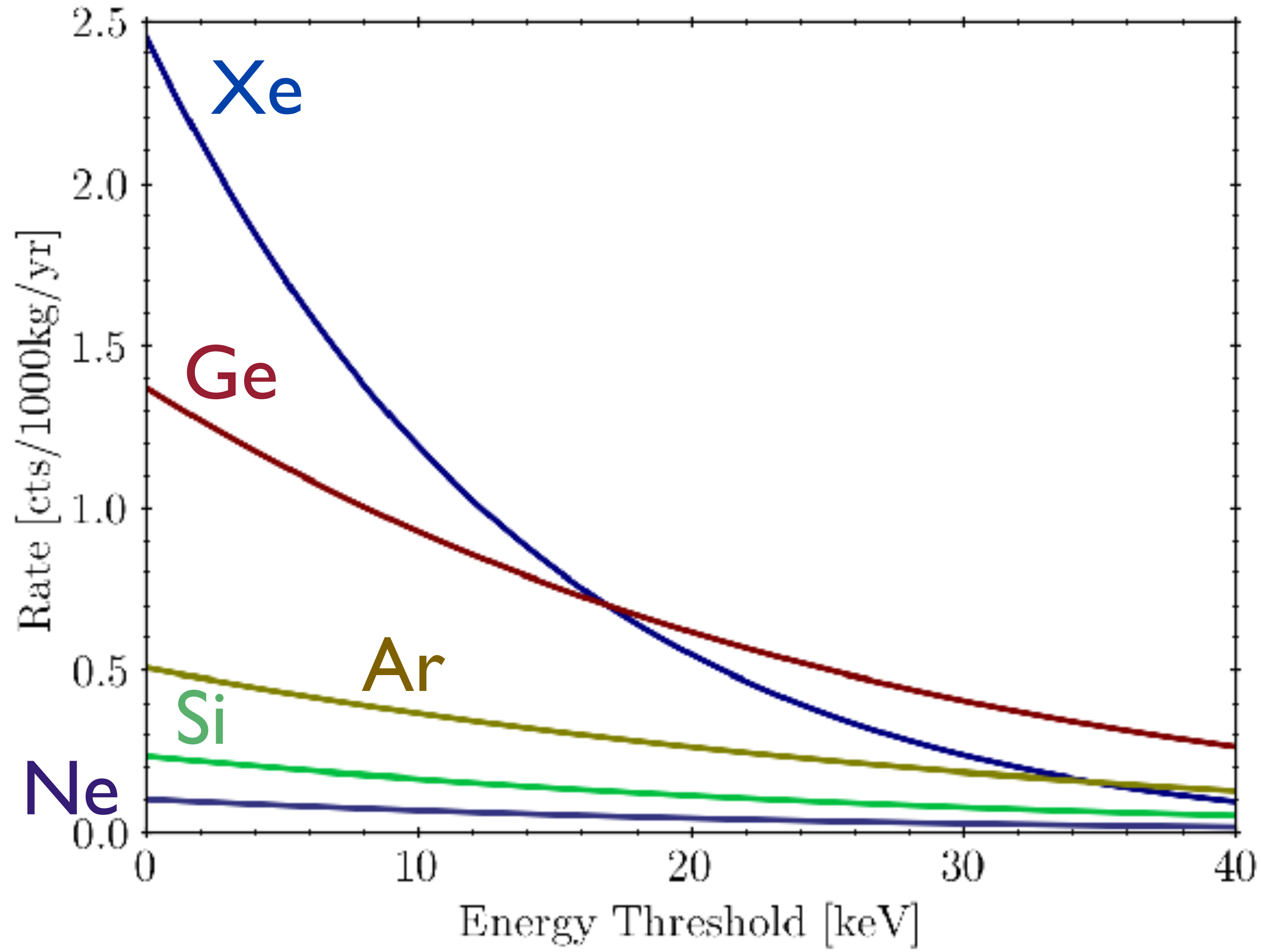
m_{DM} = 100 GeV/c^2
m_N = 131 GeV/c^2
v = 220 km/s
E_{rec} = 3 keV

- Historically sensitive to >GeV particles by kinematics and technology

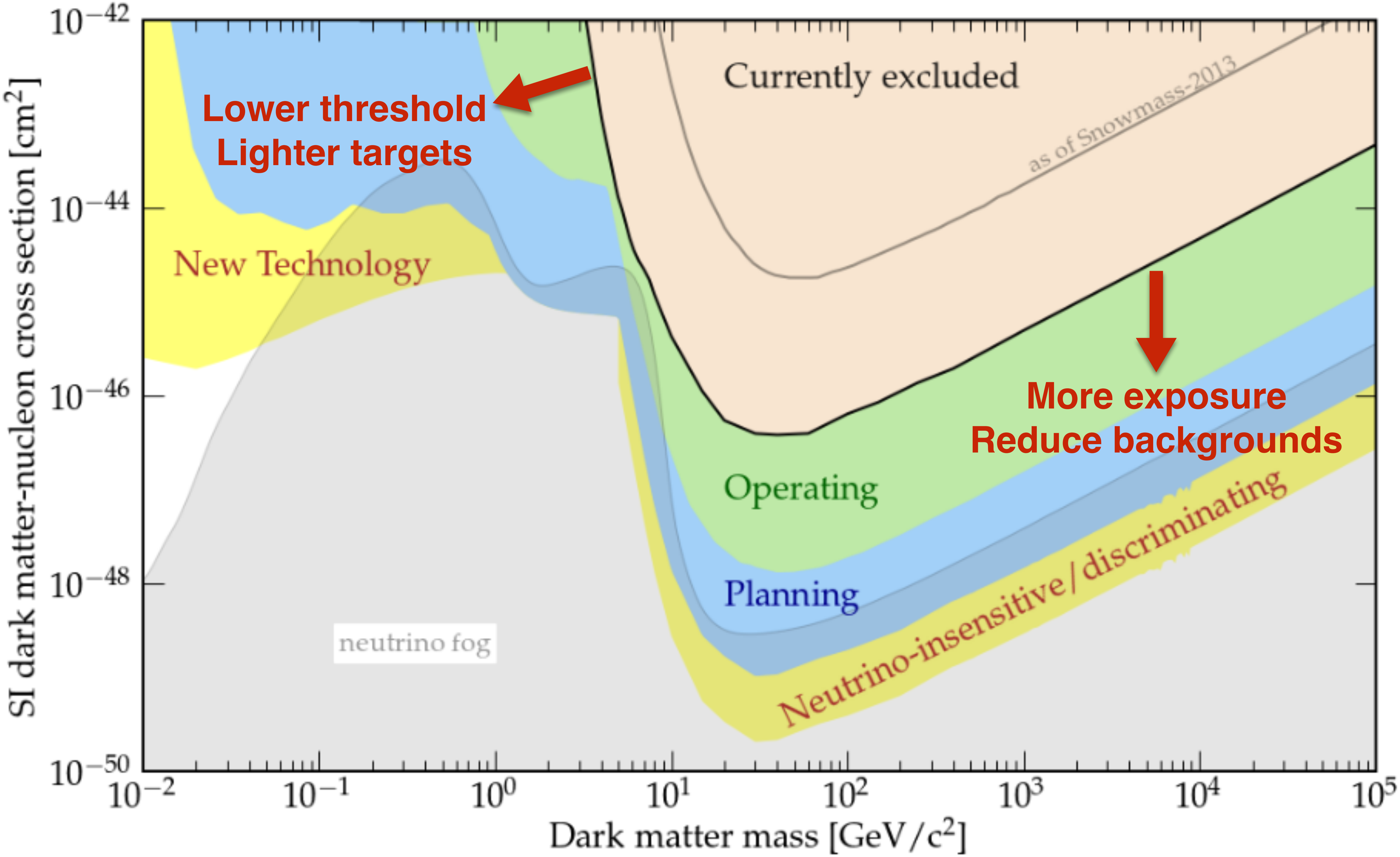
Direct Detection

- Very rare process
  - Current best limits $<10^{-47}$ cm^2
  - Path length in lead of ~10 million light years
- Luckily, there are lots of particles flying around (in theory)
  - Can look for a few counts in a detector per year
- Backgrounds, backgrounds, backgrounds
  - 10^{12} per tonne/year on surface

Rate(cts/tonne/yr) for 10^{-47} cm^2, 100 GeV

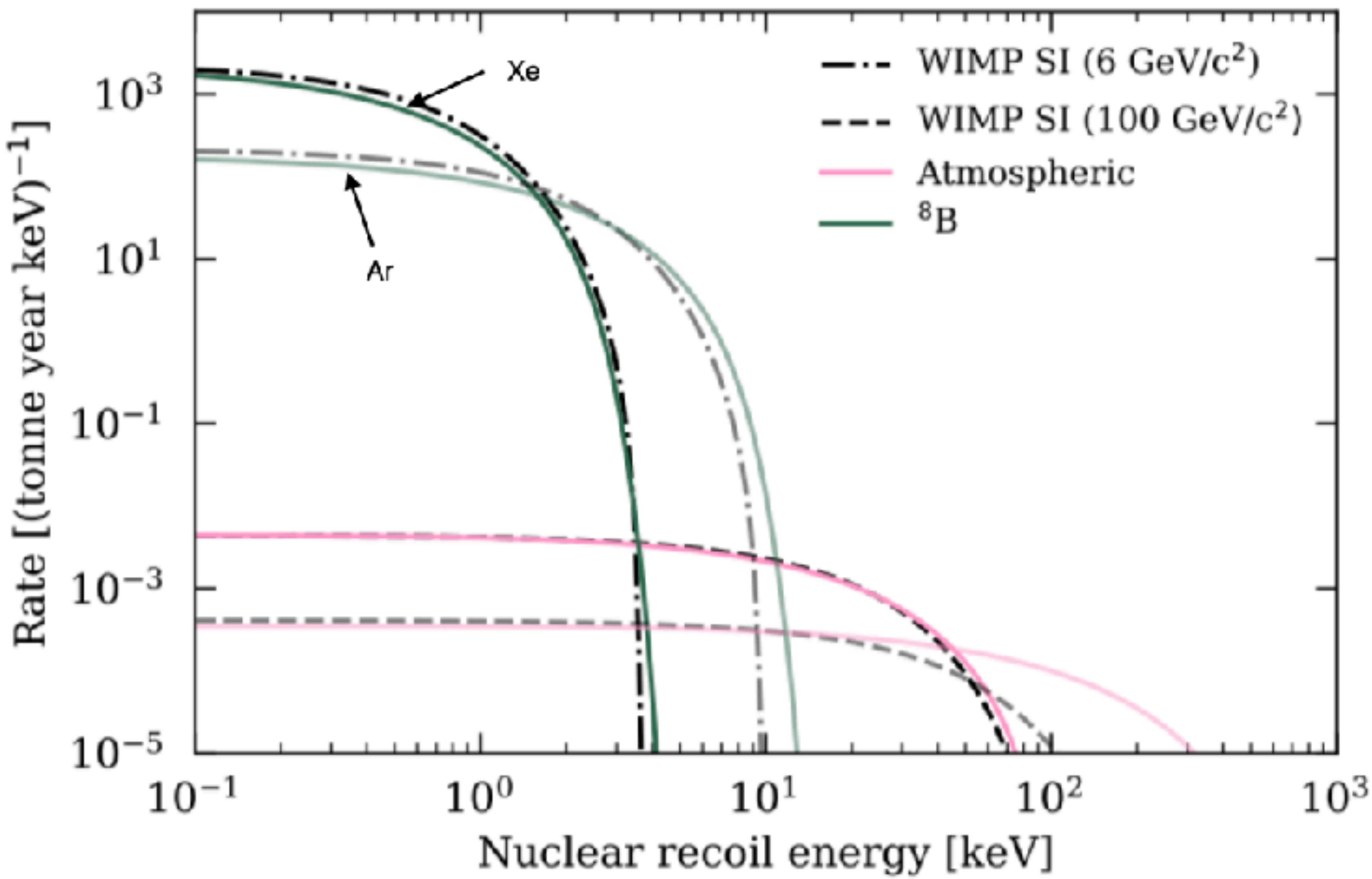


- Goal: Maximize sensitivity to DM while minimizing backgrounds



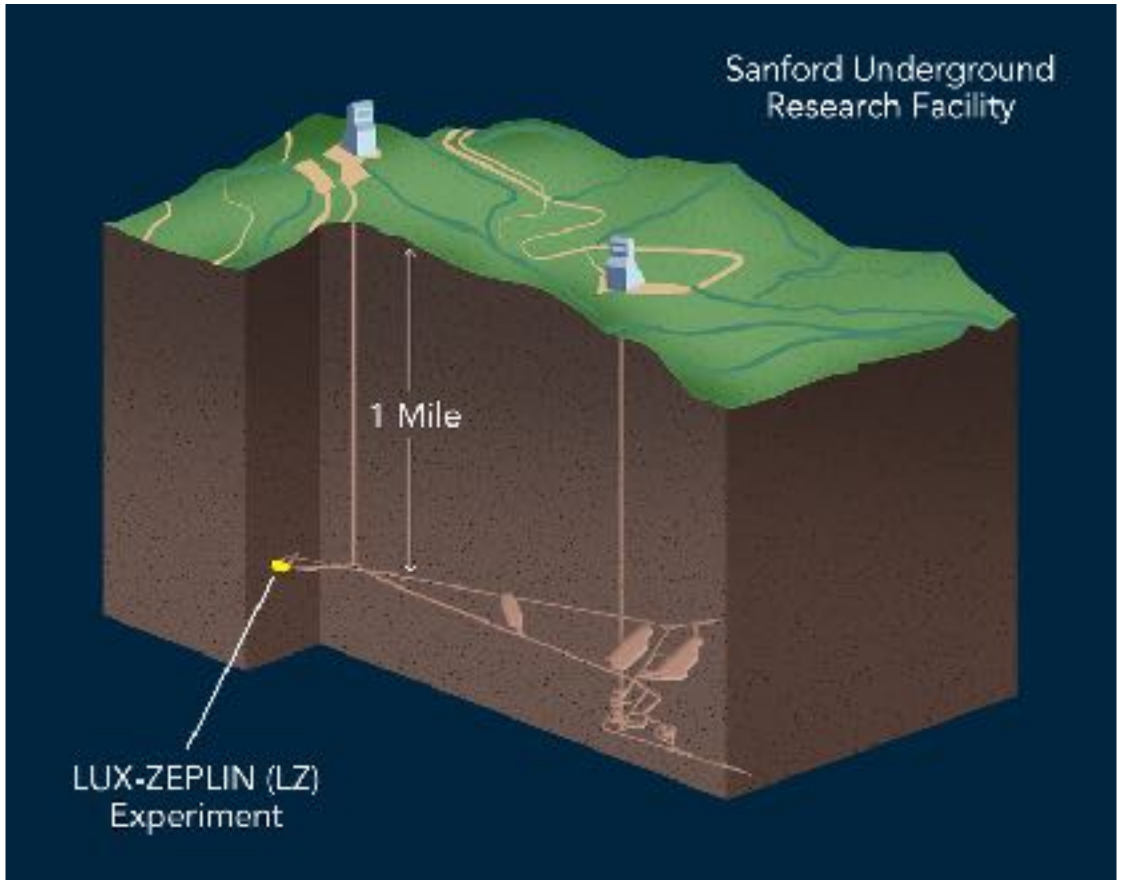
- Limited at low mass by detector threshold
- Limited at high mass by density
- Eventually limited by neutrinos

Neutrino Fog



- Atmospheric and solar neutrinos can interact coherently with nuclei
- Indistinguishable from dark matter -> Neutrino Fog (TM)

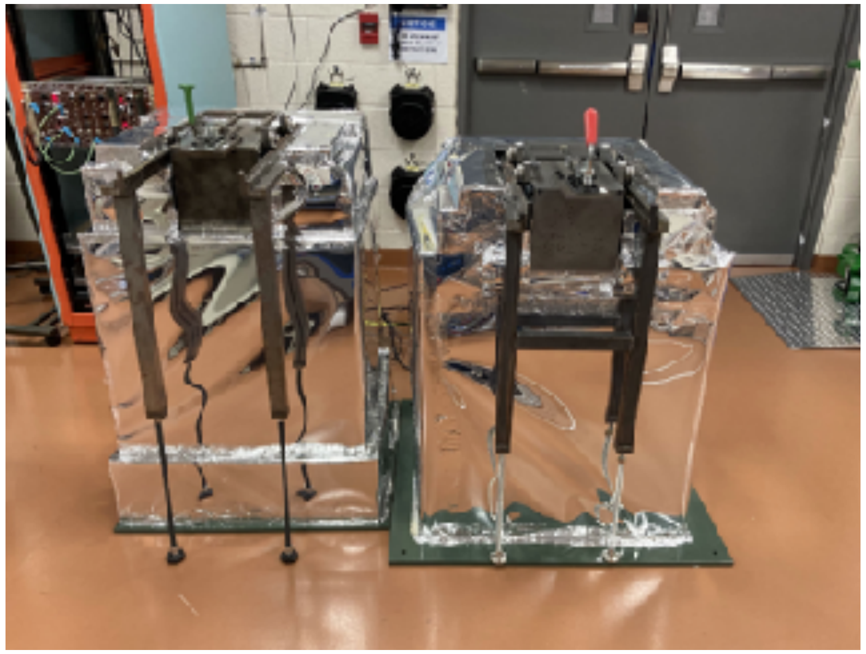
Direct Detection

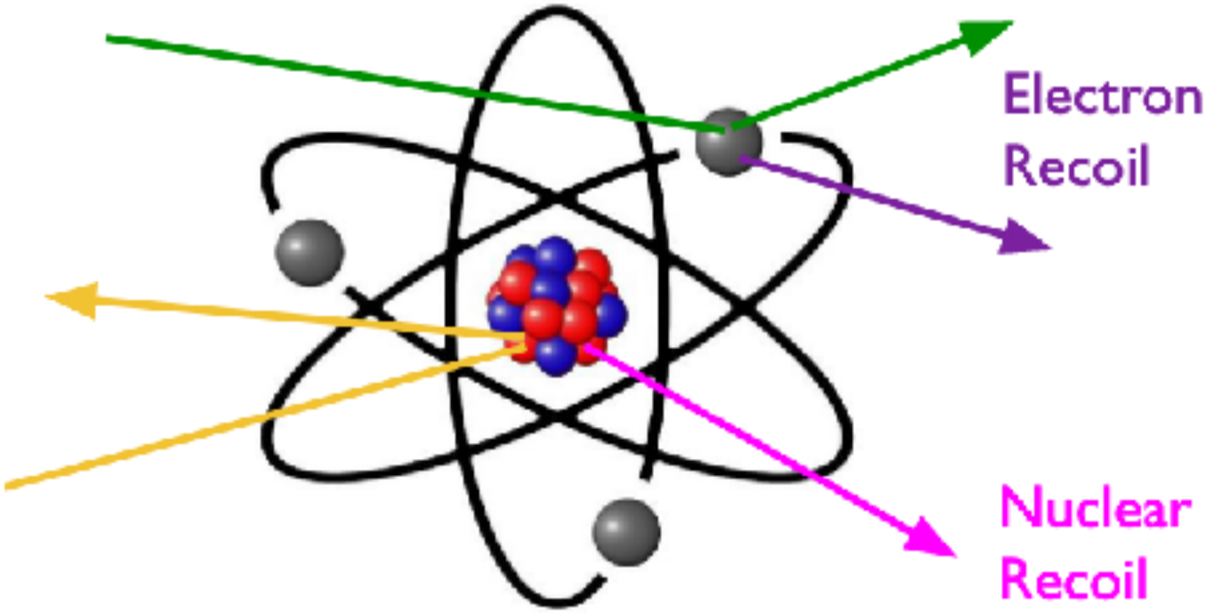


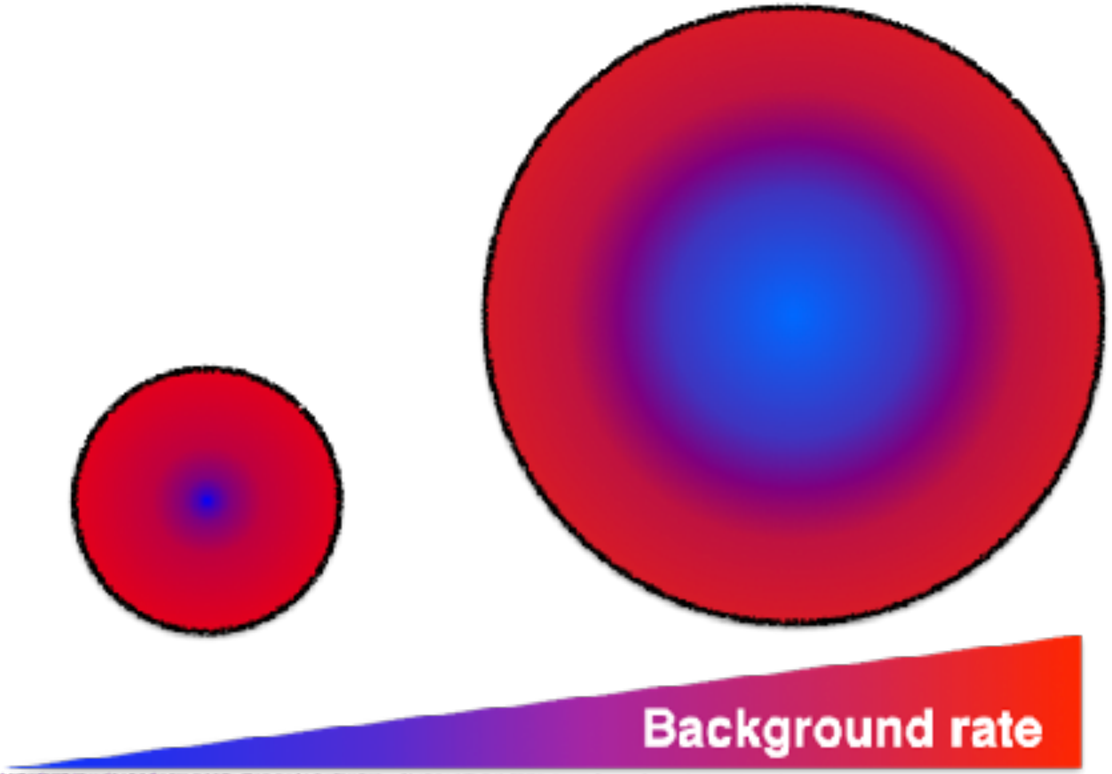
- Must go underground to evade cosmic rays
- Several labs around the world

Direct Detection

- More sensitivity -> scale up target…
  - Now into multi-tonne scales
- …while reducing backgrounds
  - Radiopurity
  - Self shielding (size helps!)
  - Discrimination (nuclear vs electron recoils)
- Explore as many interactions as possible (e.g. SD/SI/EFT)







Custom Dark Matter Detectors

Challenge	Solution
Extremely rare interaction	Large target mass - scalable
Energy depositions of ~10 keV or below	Low energy thresholds
Backgrounds - Impurities	Purification
Backgrounds - Detector	Self shielding
Backgrounds - Internal/Detector	Discrimination
Unknown particle physics	Sensitivity to multiple types interaction

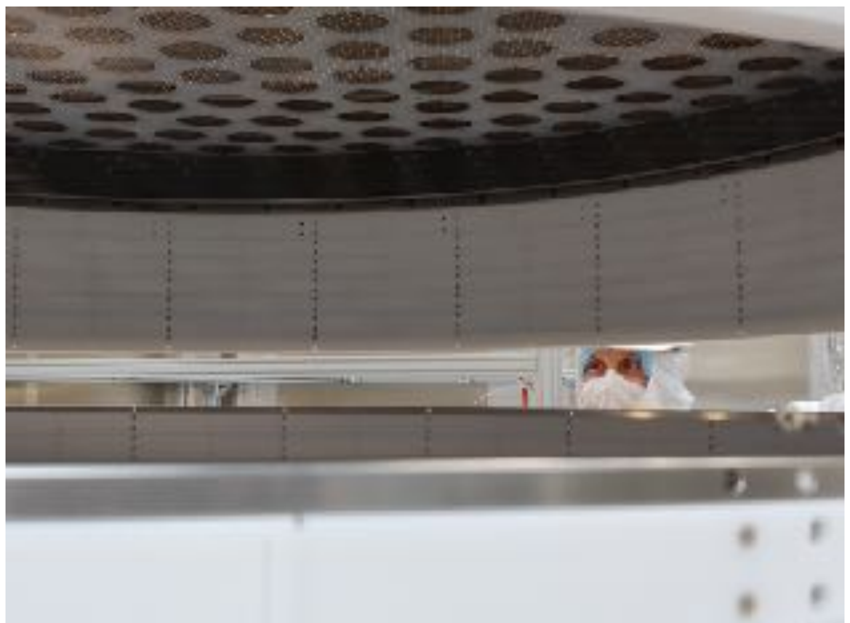
Custom Dark Matter Detectors

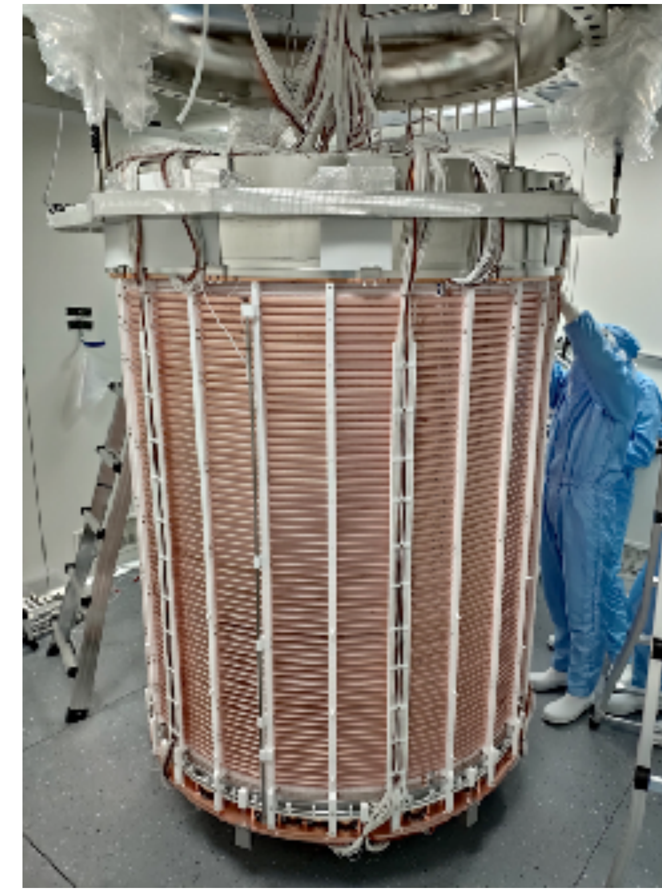
Challenge	Solution
Extremely rare interaction	Large target mass - scalable
Energy depositions of ~10 keV or below	Low energy thresholds
Backgrounds - Impurities	Purification
Backgrounds - Detector	Self shielding
Backgrounds - Internal/Detector	Discrimination
Unknown particle physics	Sensitivity to multiple types interaction

Noble Liquids!

Direct Detection with liquid nobles

- Liquid Xenon (LZ, XENONnT, PandaX, XLZD)
- Liquid Argon (DEAP, DarkSide, Argo, SBC)
- Liquid Helium (HERALD/TESSERACT,…)

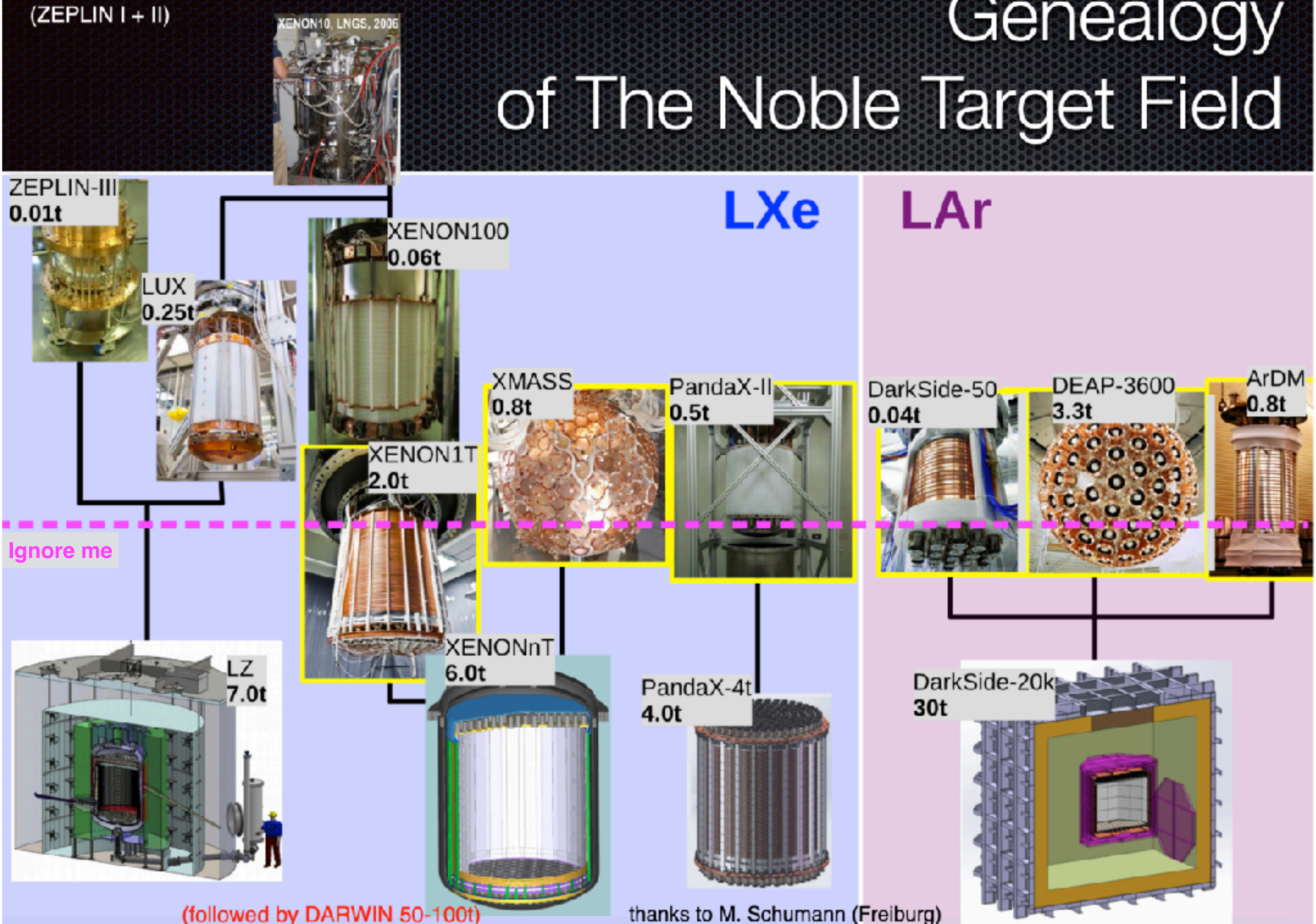




- Things they (mostly) share
  - Liquids - scalable (get a bigger bucket)
  - 3D position reconstruction
    - Surfaces are the enemy
  - ER/NR discrimination

Images from LZ/XENONnT

Genealogy of The Noble Target Field



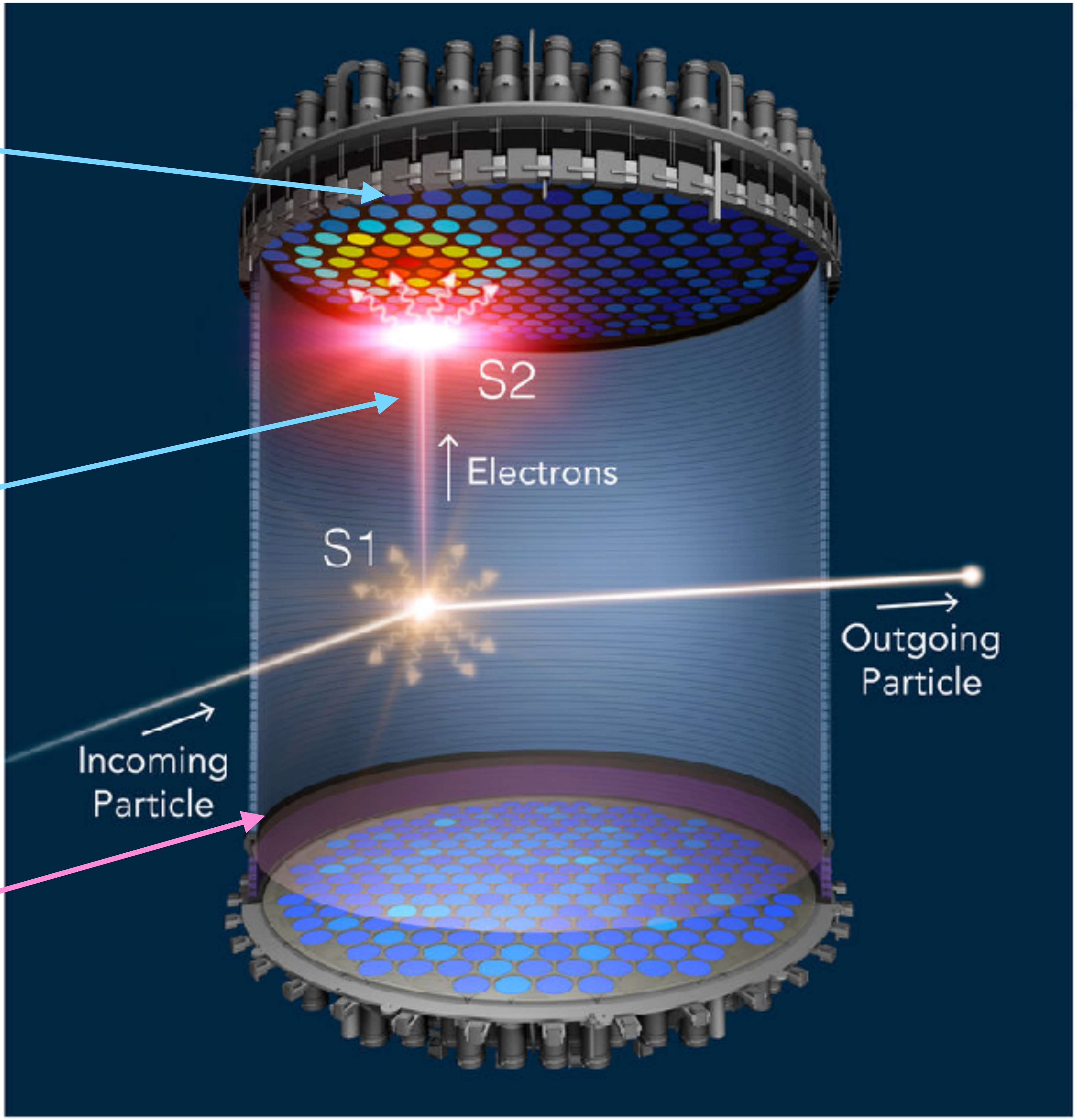
thanks to M. Schumann (Freiburg)

Liquid Noble TPCs

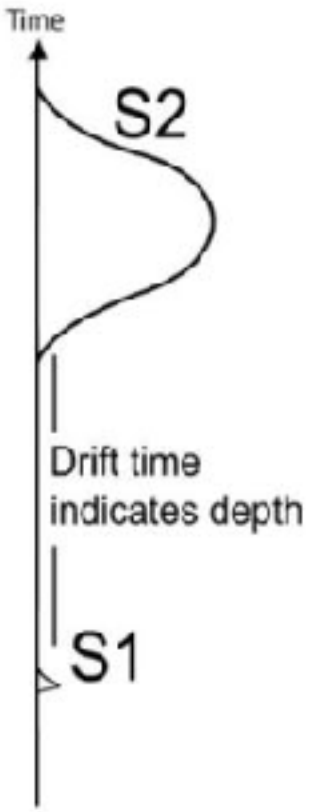
S2 light pattern gives x-y position
(~few mm resolution)

Drift time gives z position
(~0.5 mm resolution)

Cathode

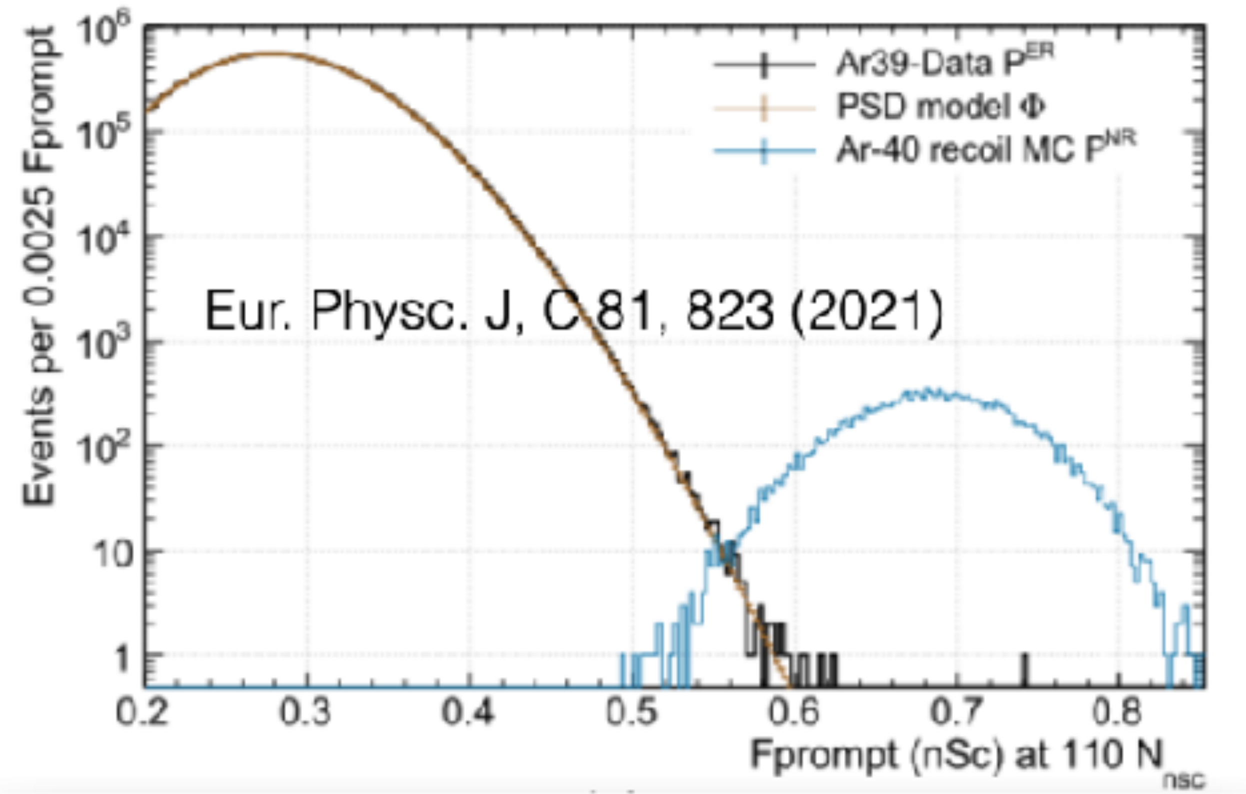


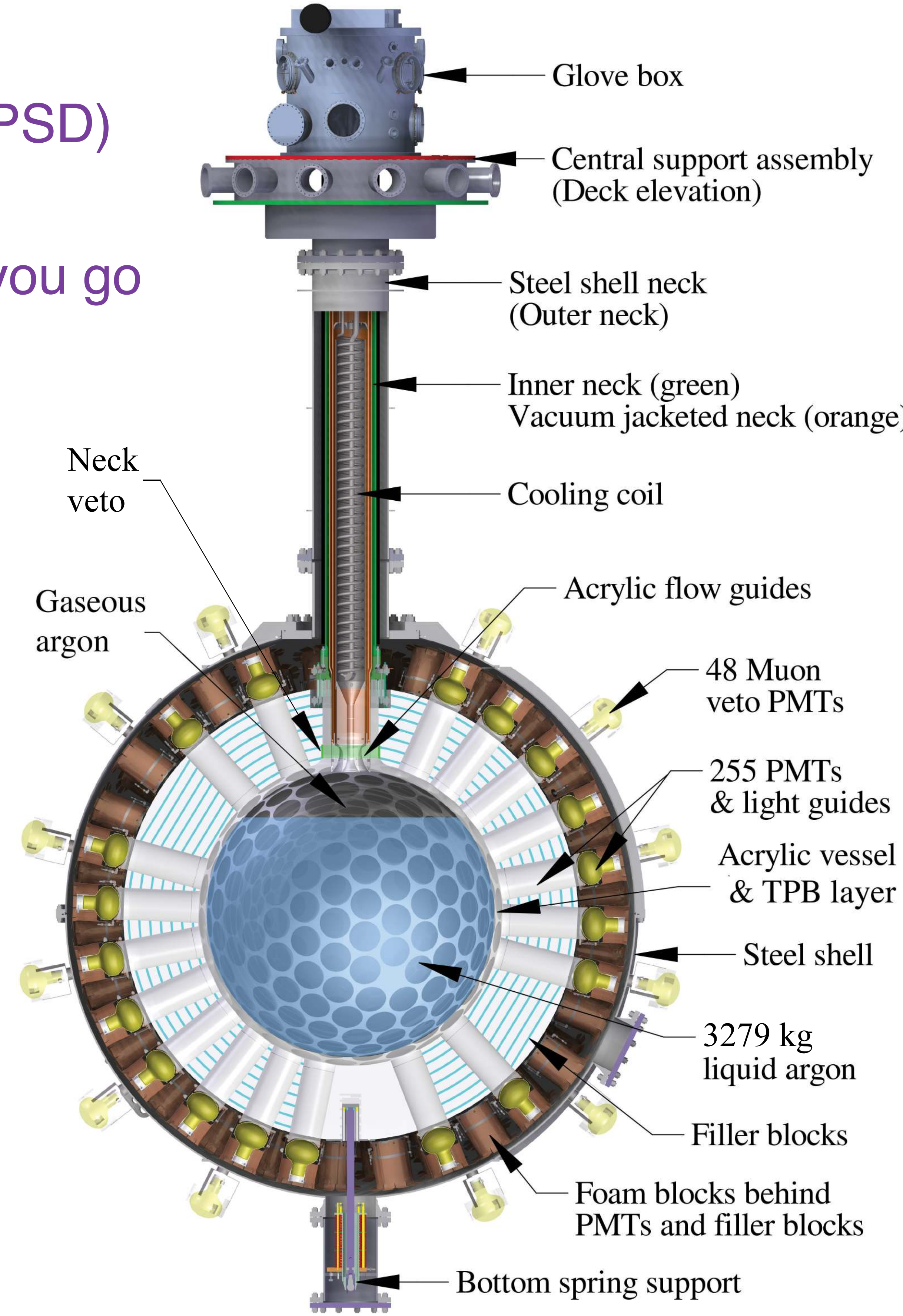
S1-S2 relative size gives event-type discrimination



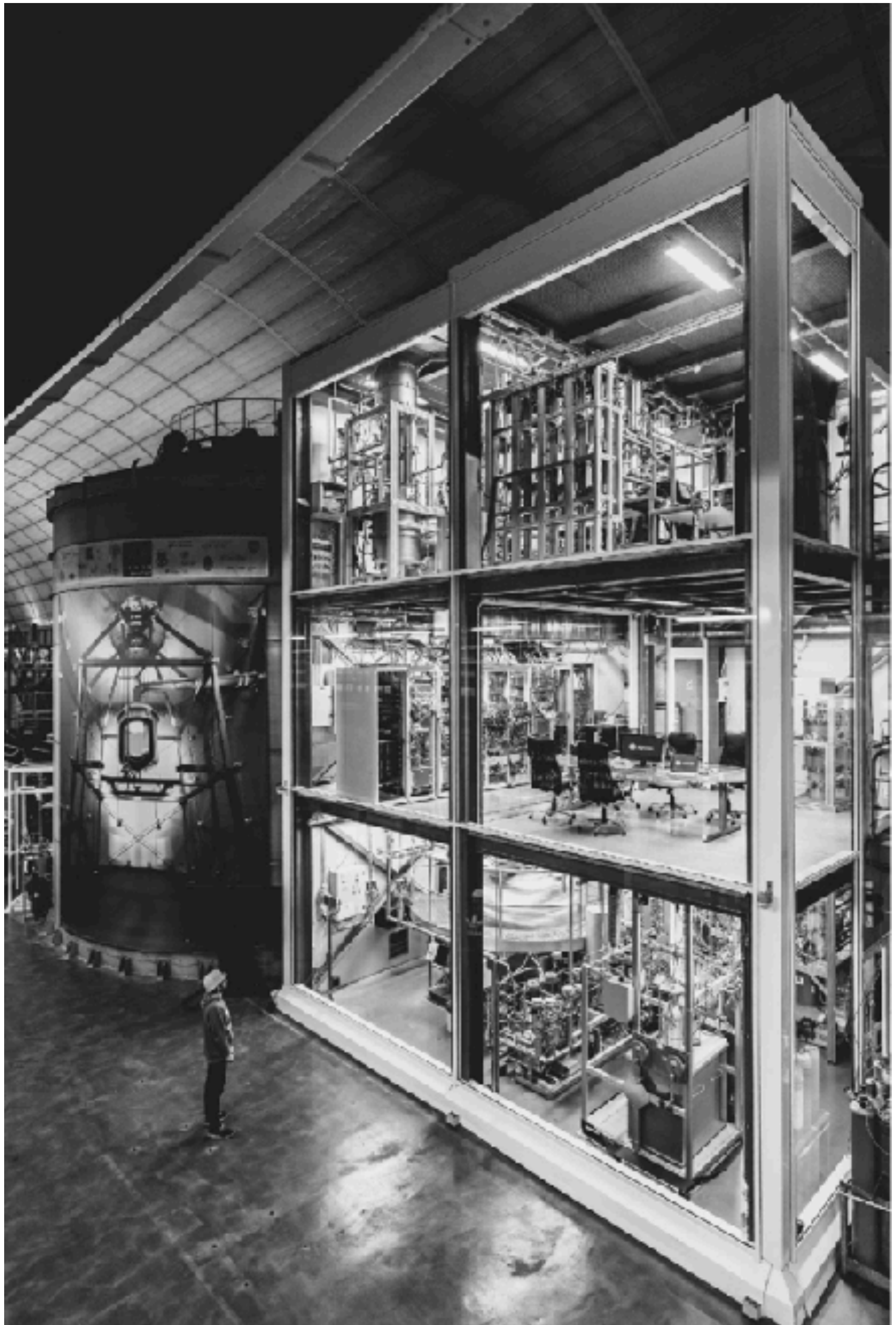
LAr Single Phase

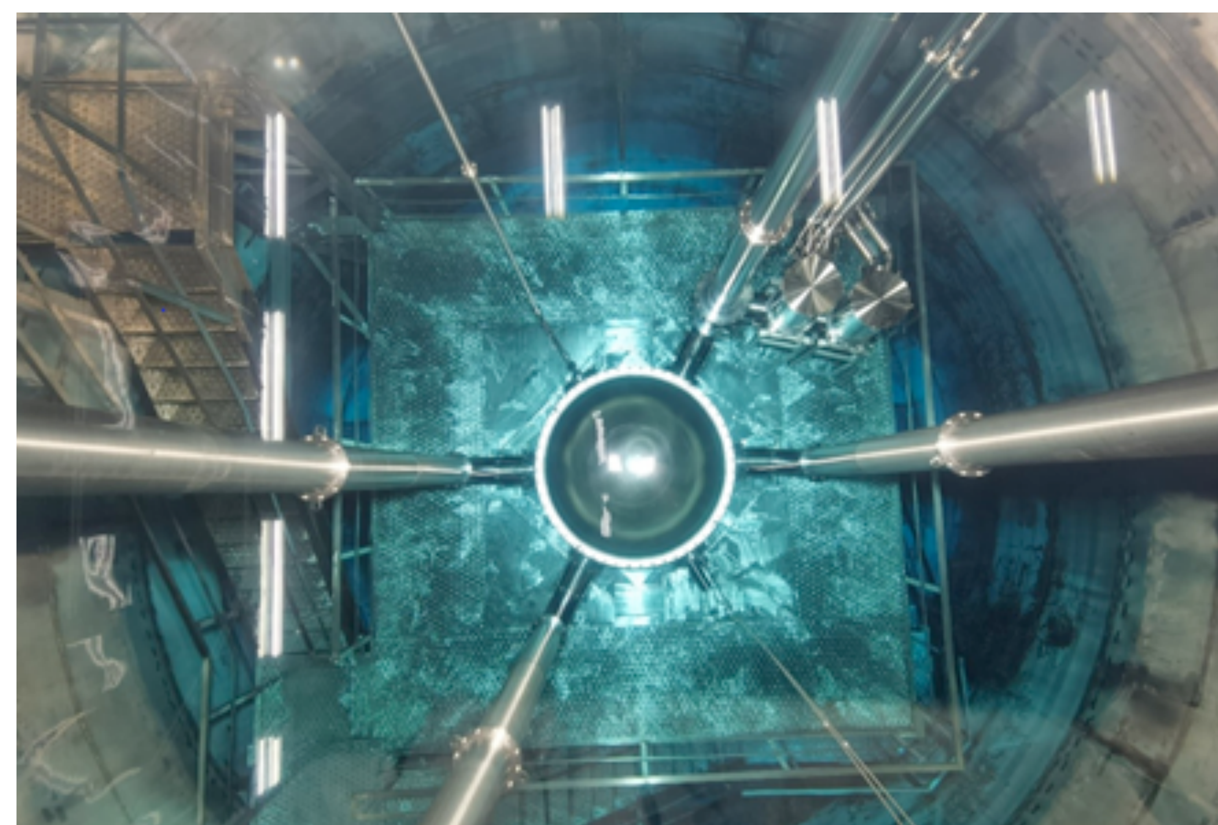
- Exquisite pulse shape discrimination (PSD) ER from NR using timing of light
- 3D reconstruction possible, easier as you go bigger

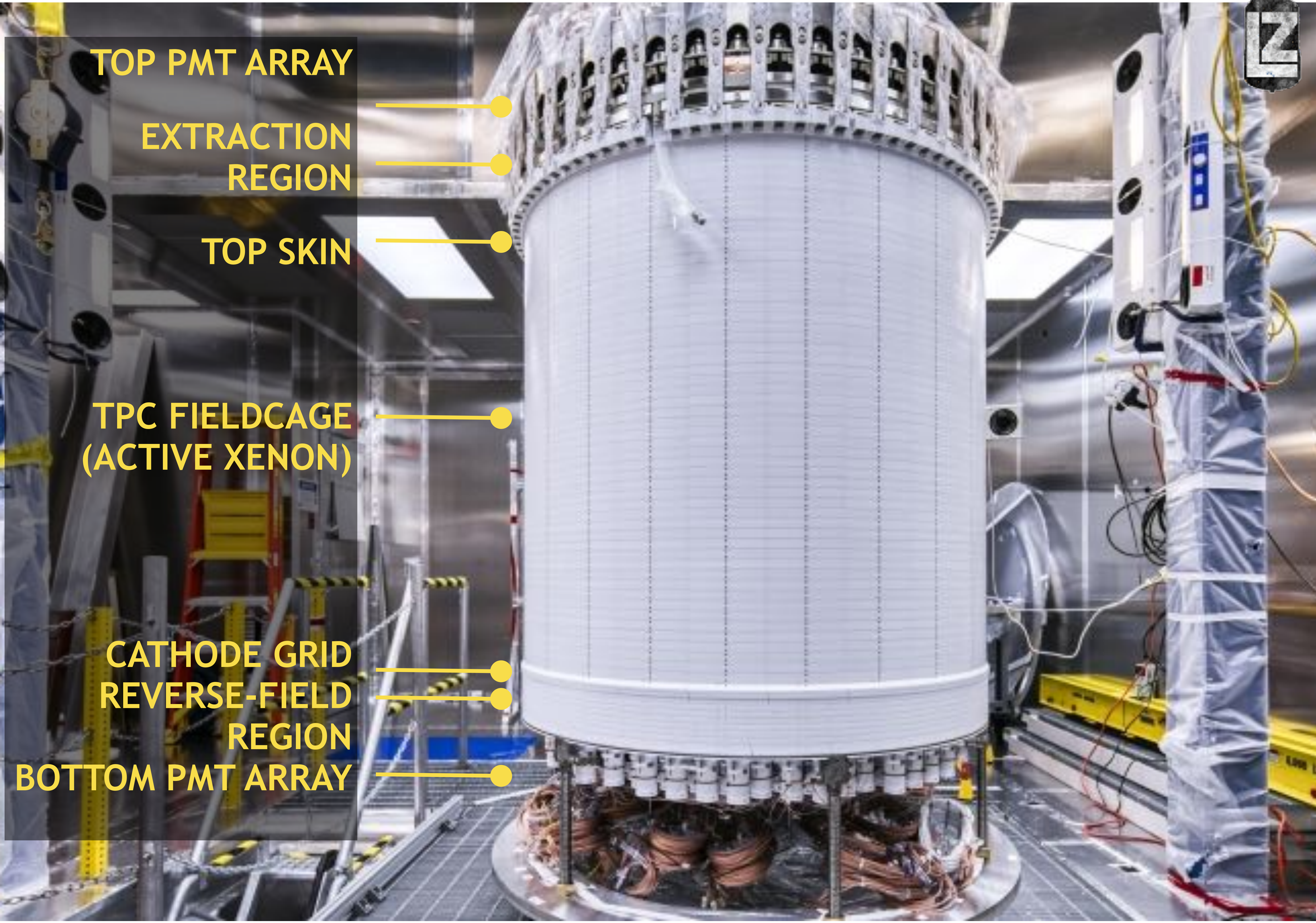


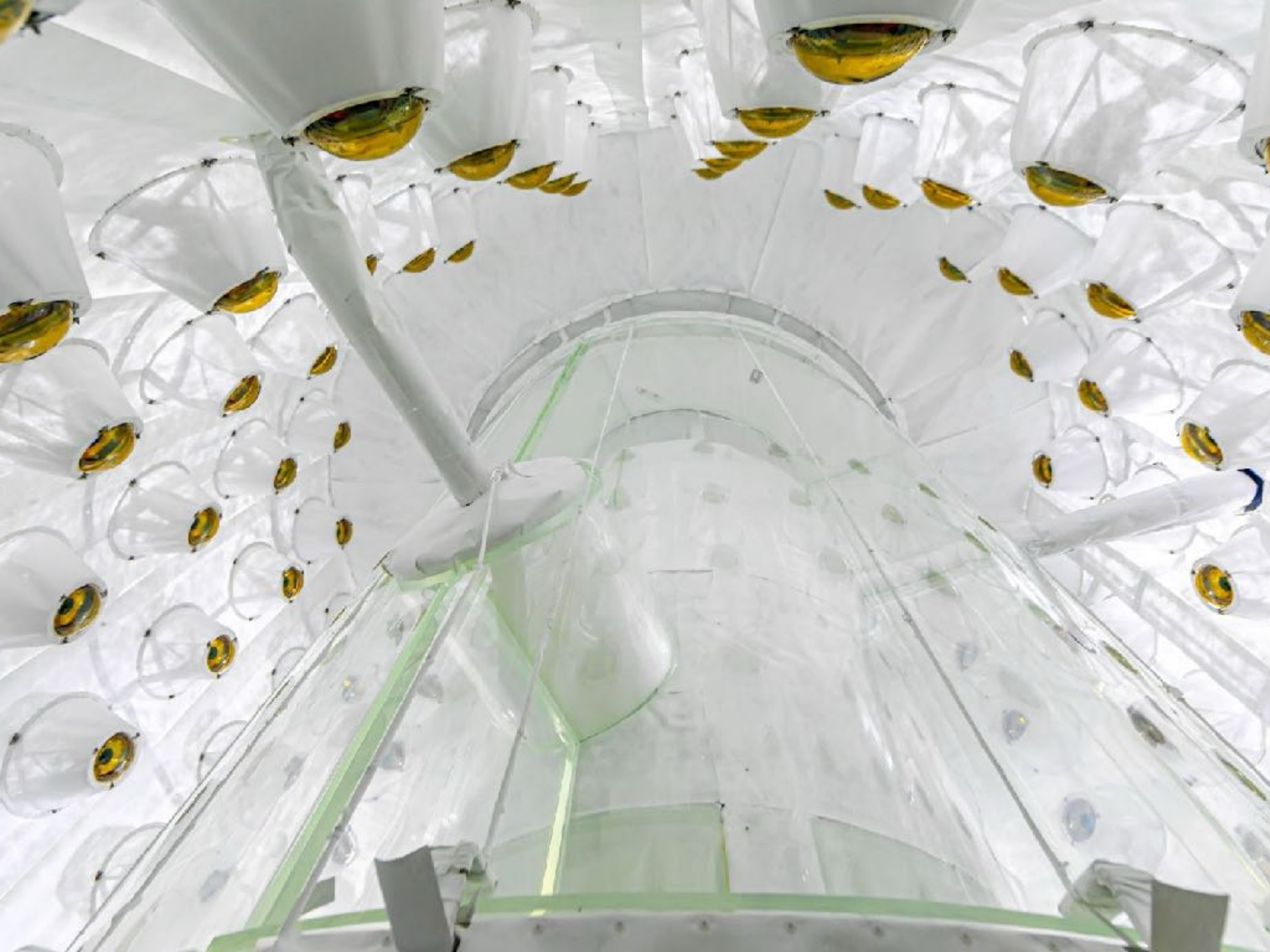


Liquid Xenon Detectors (LZ, XENONnT, PandaX)



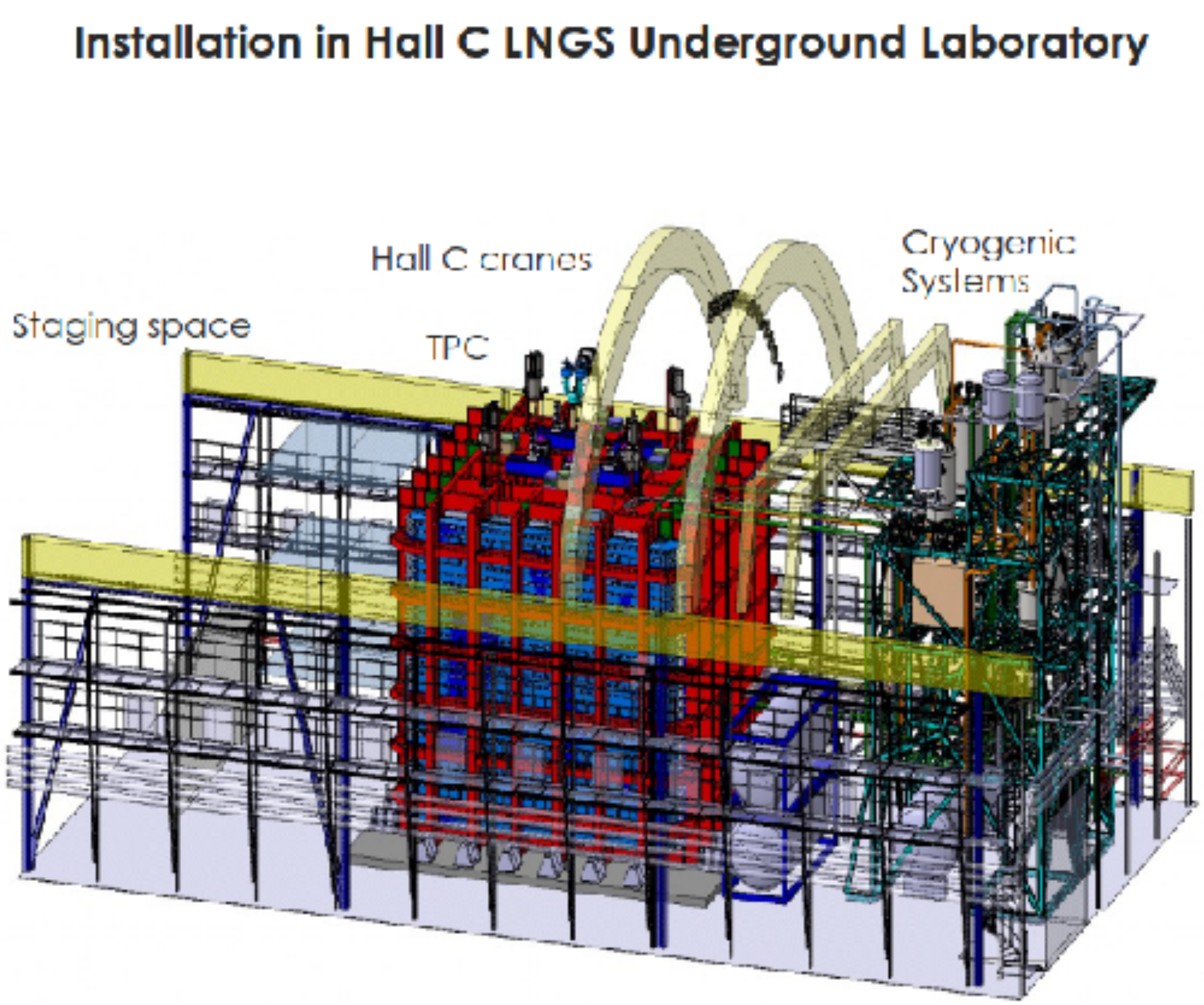



TOP PMT ARRAY
EXTRACTION REGION
TOP SKIN
TPC FIELDCAGE (ACTIVE XENON)
CATHODE GRID
REVERSE-FIELD REGION
BOTTOM PMT ARRAY



LAr Detectors

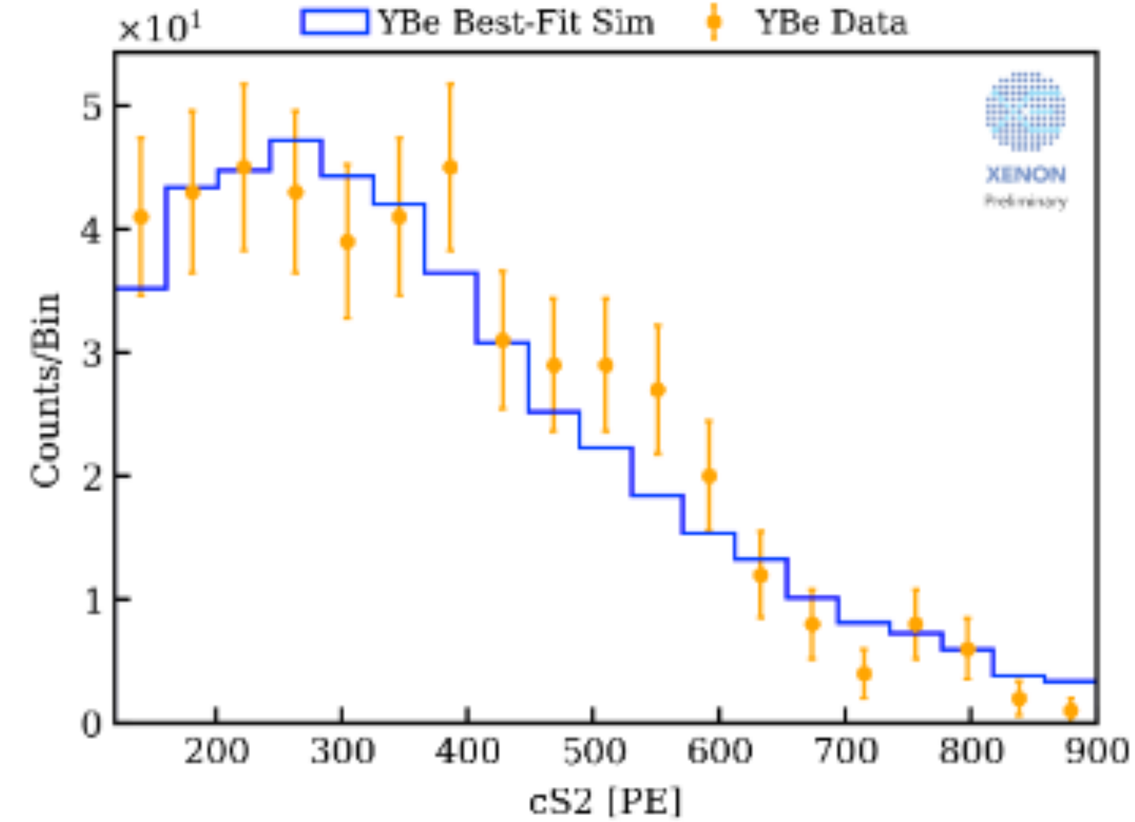
- DEAP-3600 upgrade nearly complete - goal to understand rare neck and dust backgrounds
- DarkSide-20k detector at LNGS under construction
  - 20 tonnes underground argon fiducial, ~700t total Ar
- Installation happening now!

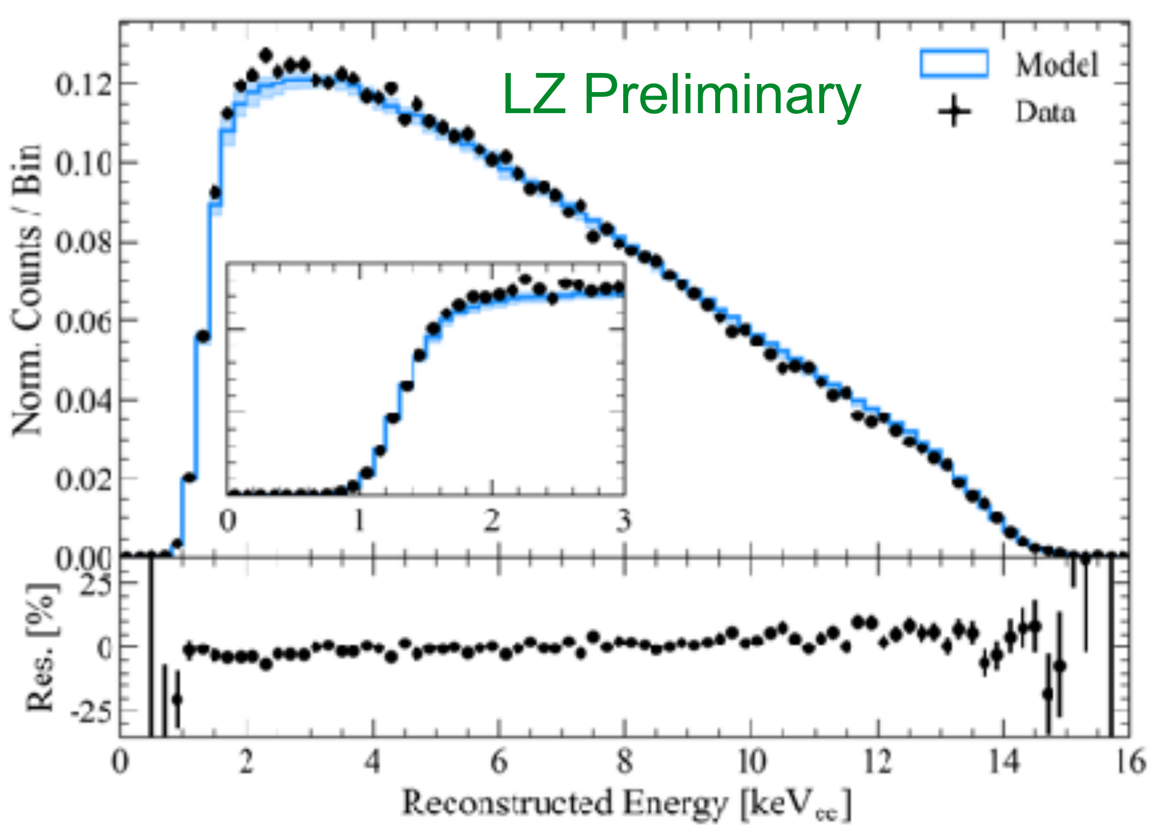


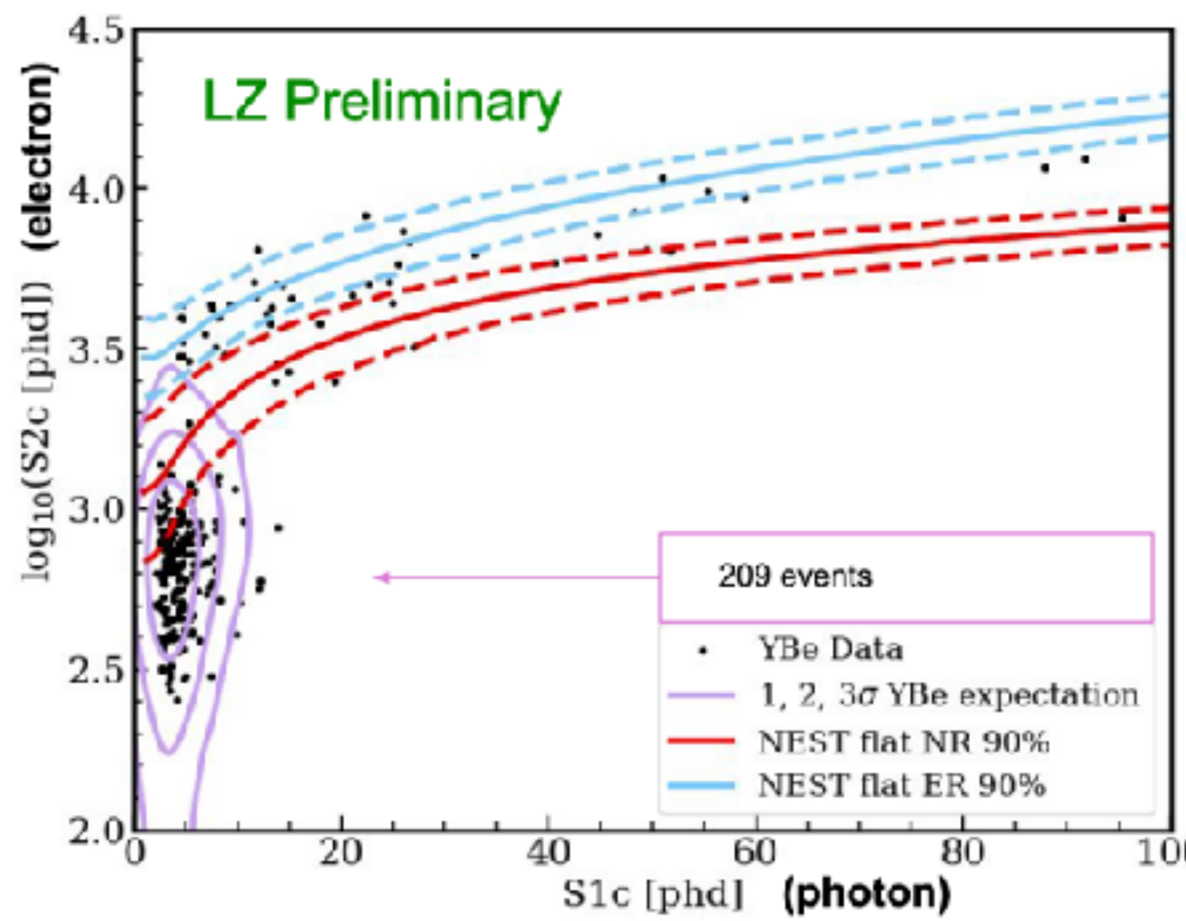
Later today: D. Huff - DM Searches with LAr in DEAP-3600 and DarkSide-20k

Some recent developments

- Calibration is key - e.g.:
  - LZ - High stats of ER (background) distribution using dispersed tritium (CH_3T) - ~160k events!
  - LZ and XENON have now used YBe to calibrate low energy NR
- Allows for precise modeling in final analysis, enables discovery

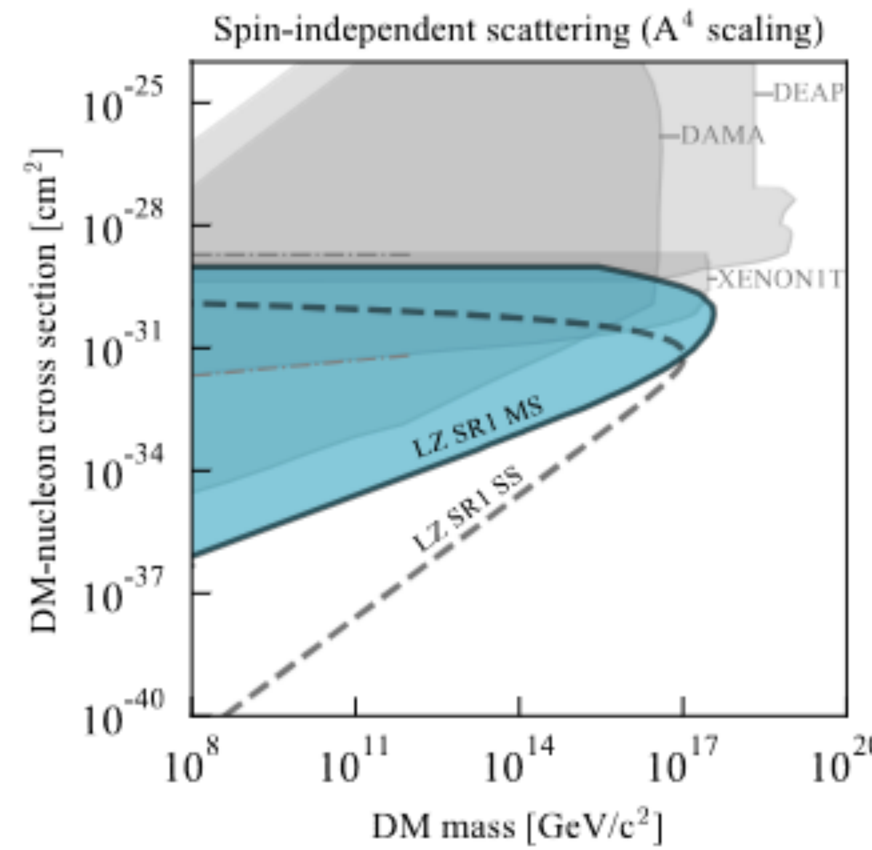


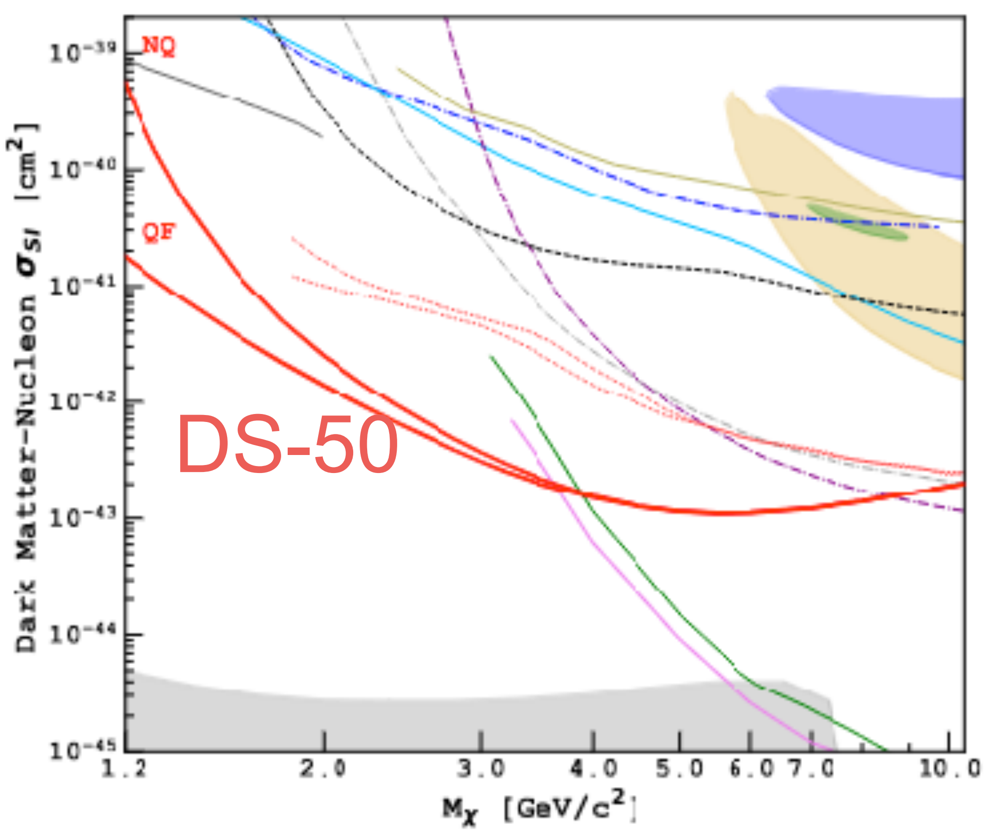




Some recent developments

- Many rare event searches, e.g. (not complete):
  - ~Planck scale DM from DEAP, XENON, LZ
  - EFT and inelastic searches from PICO, XENON, LZ, DEAP
  - Electron recoil searches in XENON, LZ, PandaX
  - Low mass results from DarkSide
  - Lots of models in PandaX
  - E.g. Tomorrow night: A. Garai - DEAP-3600 and charged-current 8B measurements in liquid argon





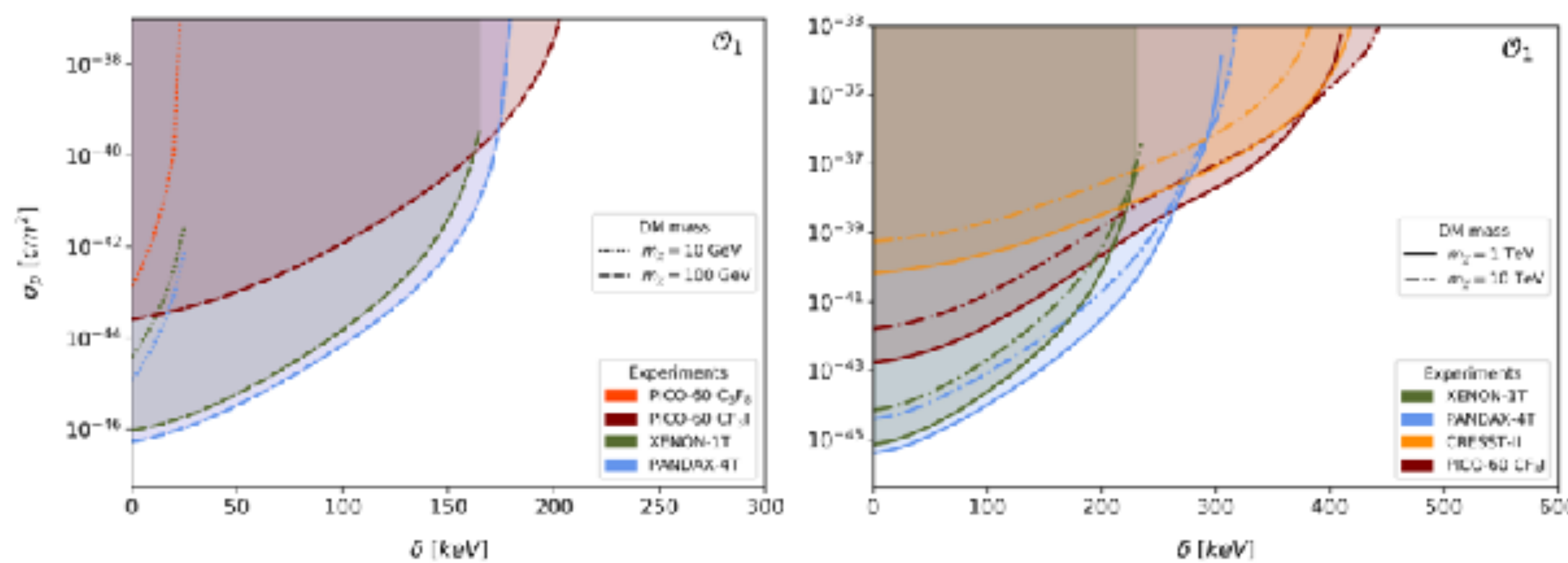
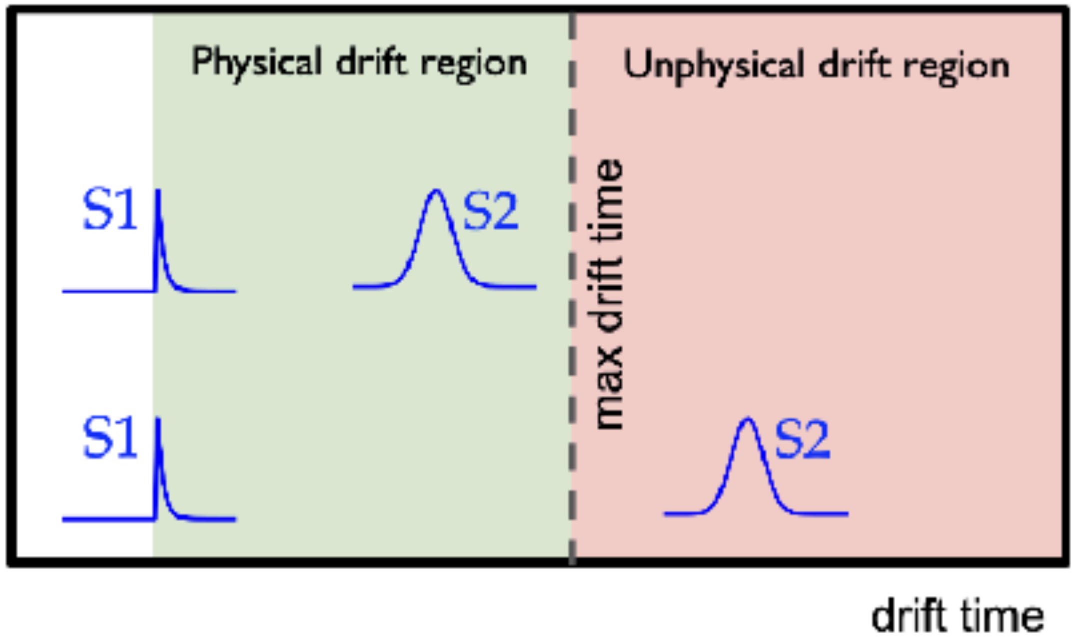
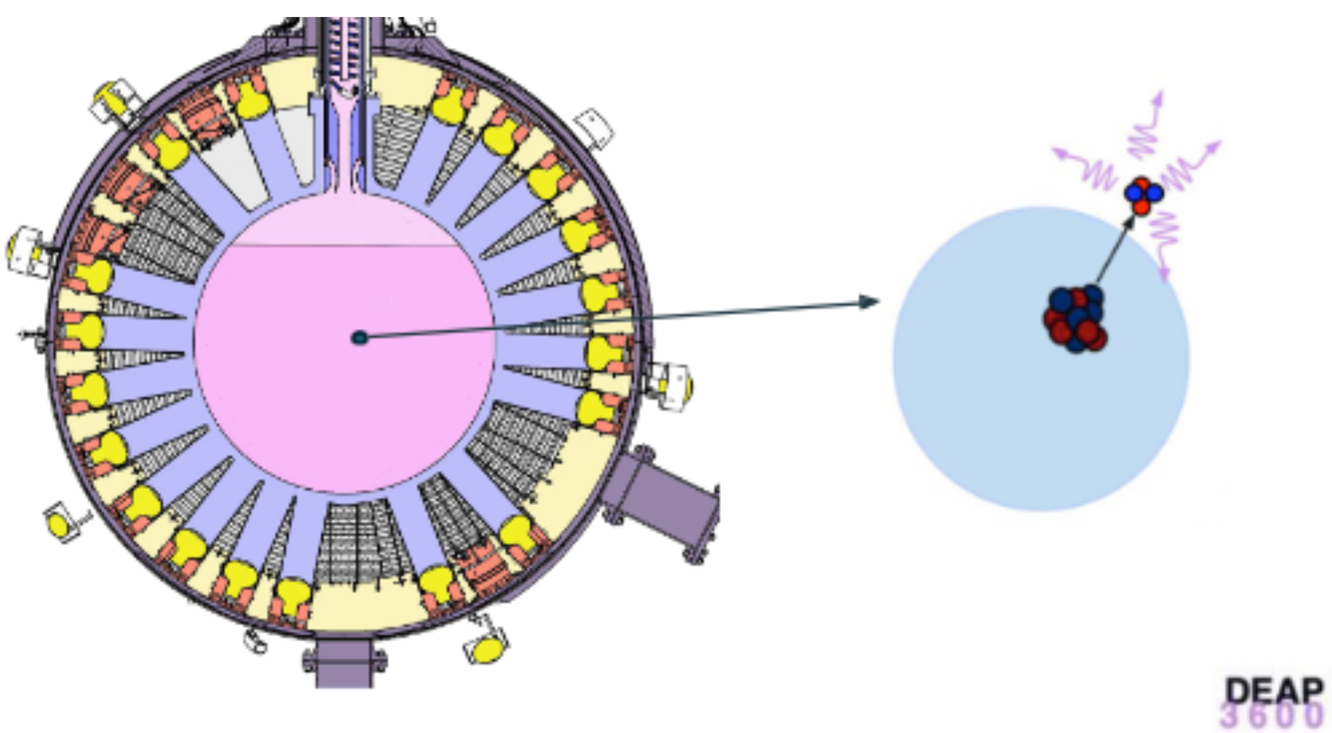


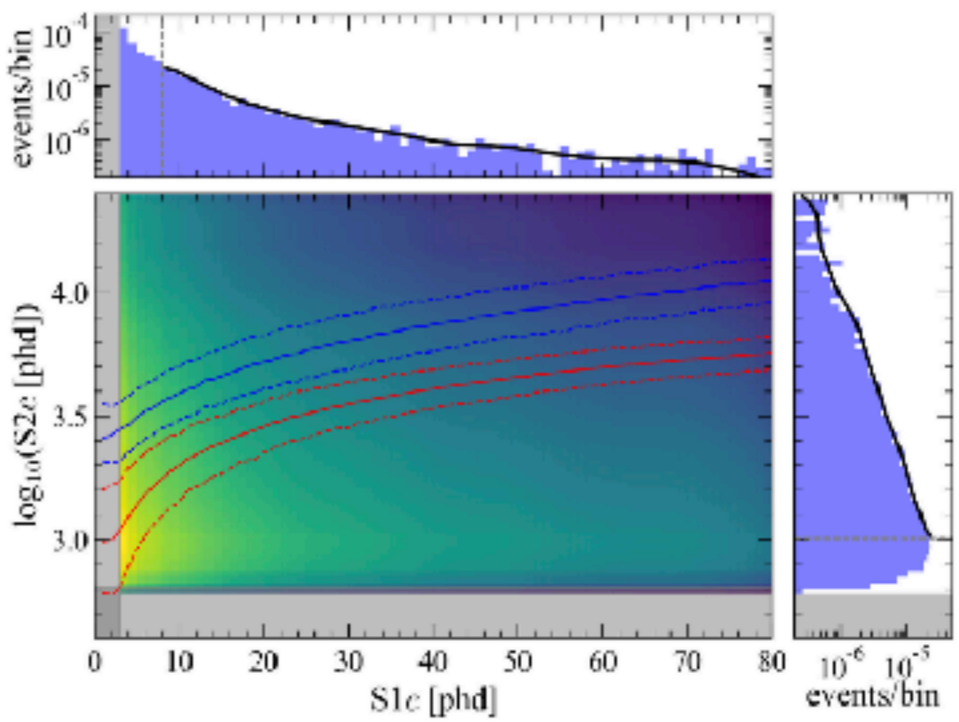
FIG. 1: Upper limits (90% C. L.) on DM-nucleon scattering cross sections as a function of the mass splitting for the effective operator $\mathcal{O}_1$ and DM masses of 10 GeV/c^2 and 100 GeV/c^2 (left), and 1 TeV/c^2 and 10 TeV/c^2 (right), from the analysis of the PICO-60 CF_3I and C_3F_8 experiments. Limits from XENON-1T [12], PANDAX-4T [11], and CRESST-II [16] are also shown.

Progress is hard!

- Each detector must grapple with a new set of backgrounds e.g.
  - Accidentals in LXe-TPCs
  - Dust and geometry in DEAP-3600
  - Neutrinos…?







But we're into the fog!

- XENONnT and PandaX reported "Indications of Solar ^{8}B neutrinos" last year

PandaX, PRL 133, 191001
2.64 sigma

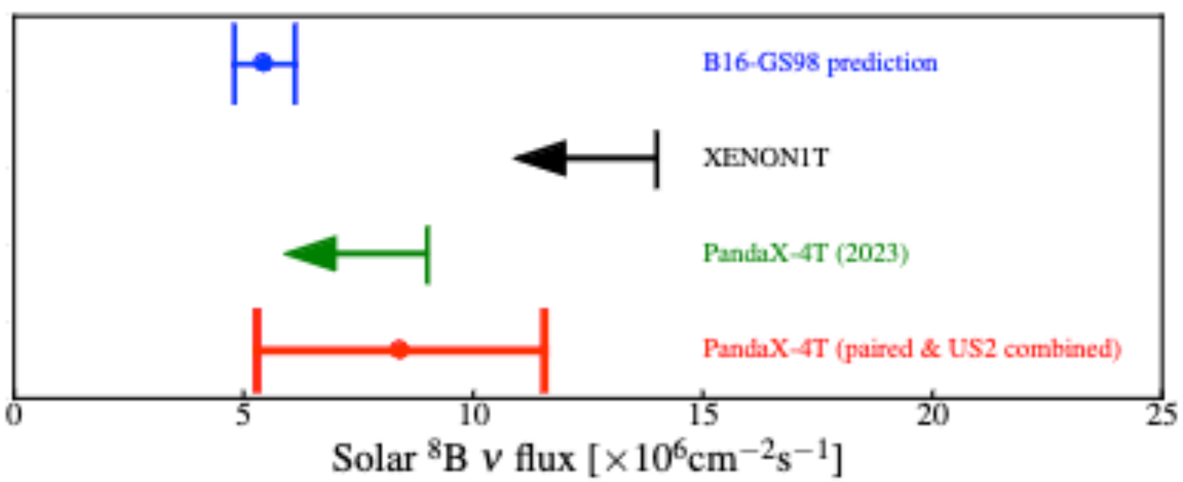


FIG. 6. The best-fit ^{8}B solar neutrino flux and 1σ uncertainty from this work (red), together with 90% C.L. regions of the PandaX-4T previous constraint [33] (green), XENON1T constraint [31] (black), and 1σ of the theoretical prediction from the standard solar model [45] (blue).

XENONnT, PRL 133, 191002
2.73 sigma

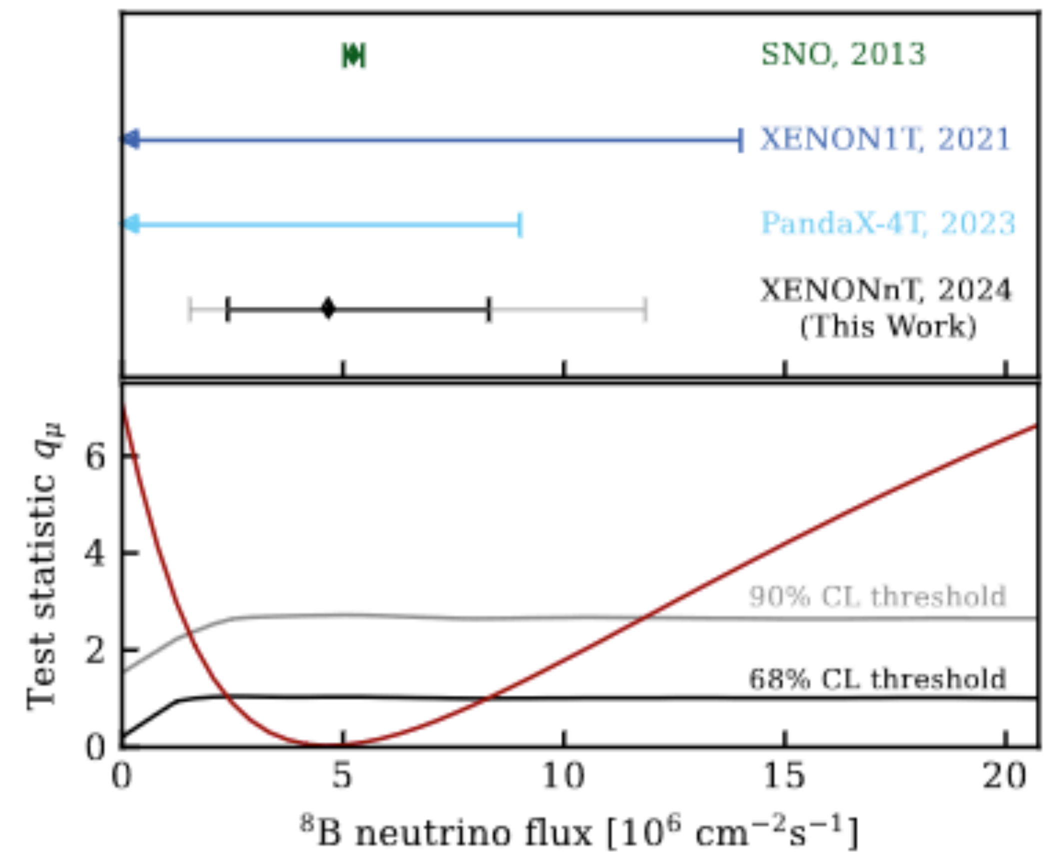
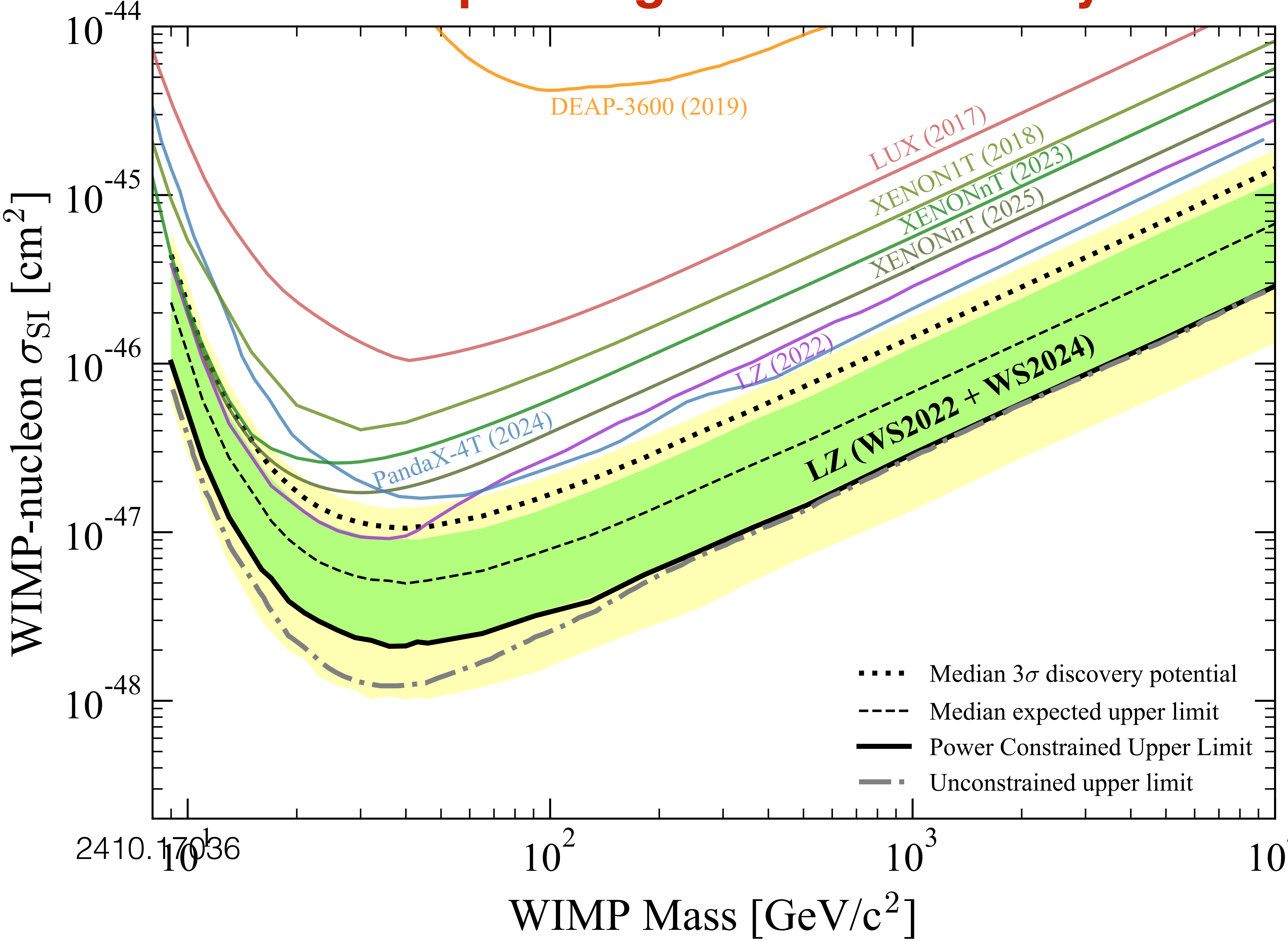


FIG. 3. Constraints on solar ^{8}B neutrino flux. Top: the 68% (90%) measurement of solar ^{8}B neutrino flux from this work is shown in black (gray). The 68% CL measurement from SNO [22], and 90% CL upper limits from XENON1T [6] and PandaX-4T [7] are also shown. Bottom: the solid red line shows the profile likelihood ratio test statistics q_μ as a function of solar ^{8}B neutrino flux. The constraints are derived with Feldman-Cousins construction at 68% (90%) CL, indicated by the black (gray) curve.

Tomorrow night: D. Wenz - The first measurement of CEvNS of solar 8B neutrinos in the XENONnT experiment

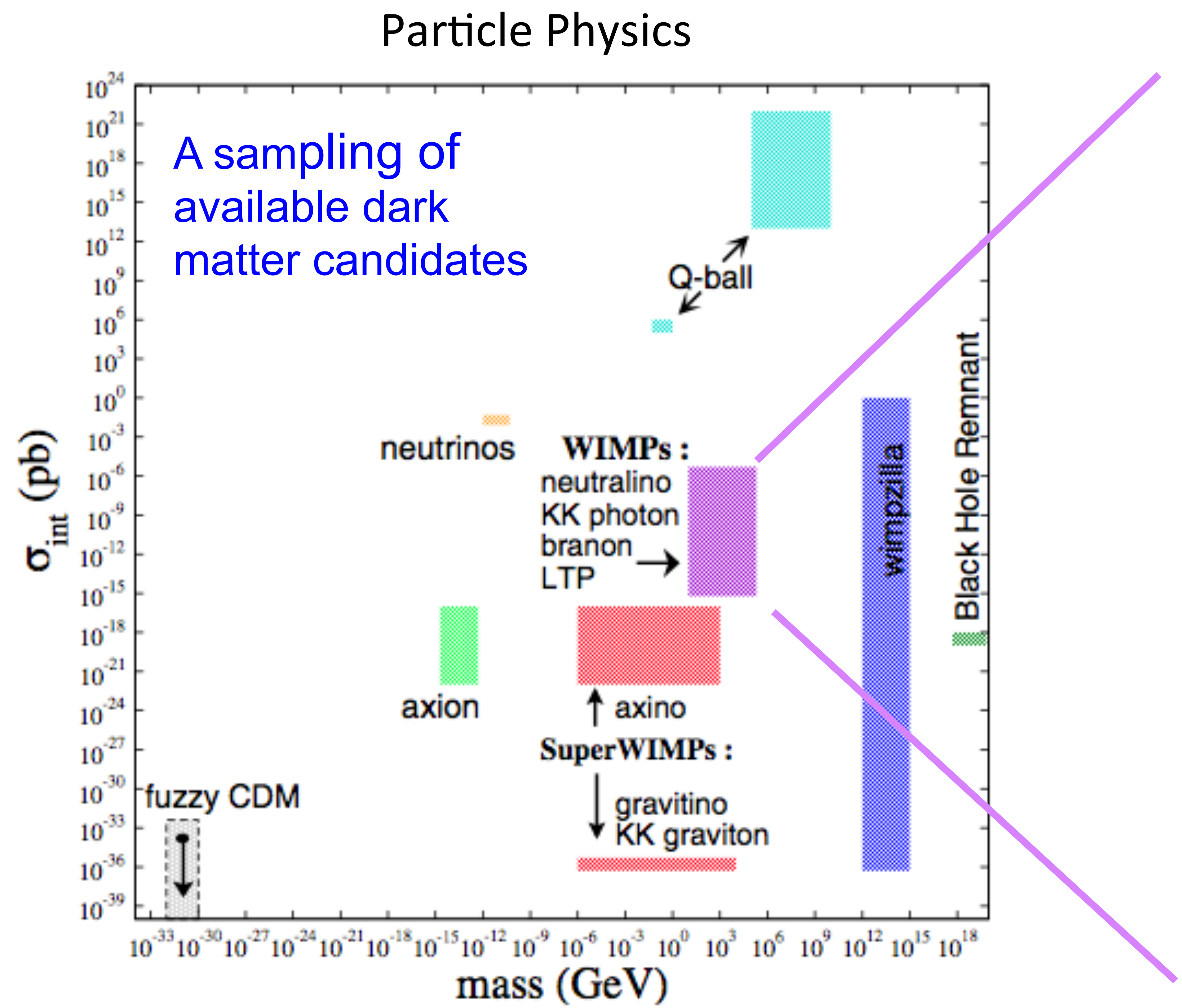
And still pushing WIMP sensitivity!



2410.17036

Later today: C. Amarasinghe - Results and status of the LZ experiment

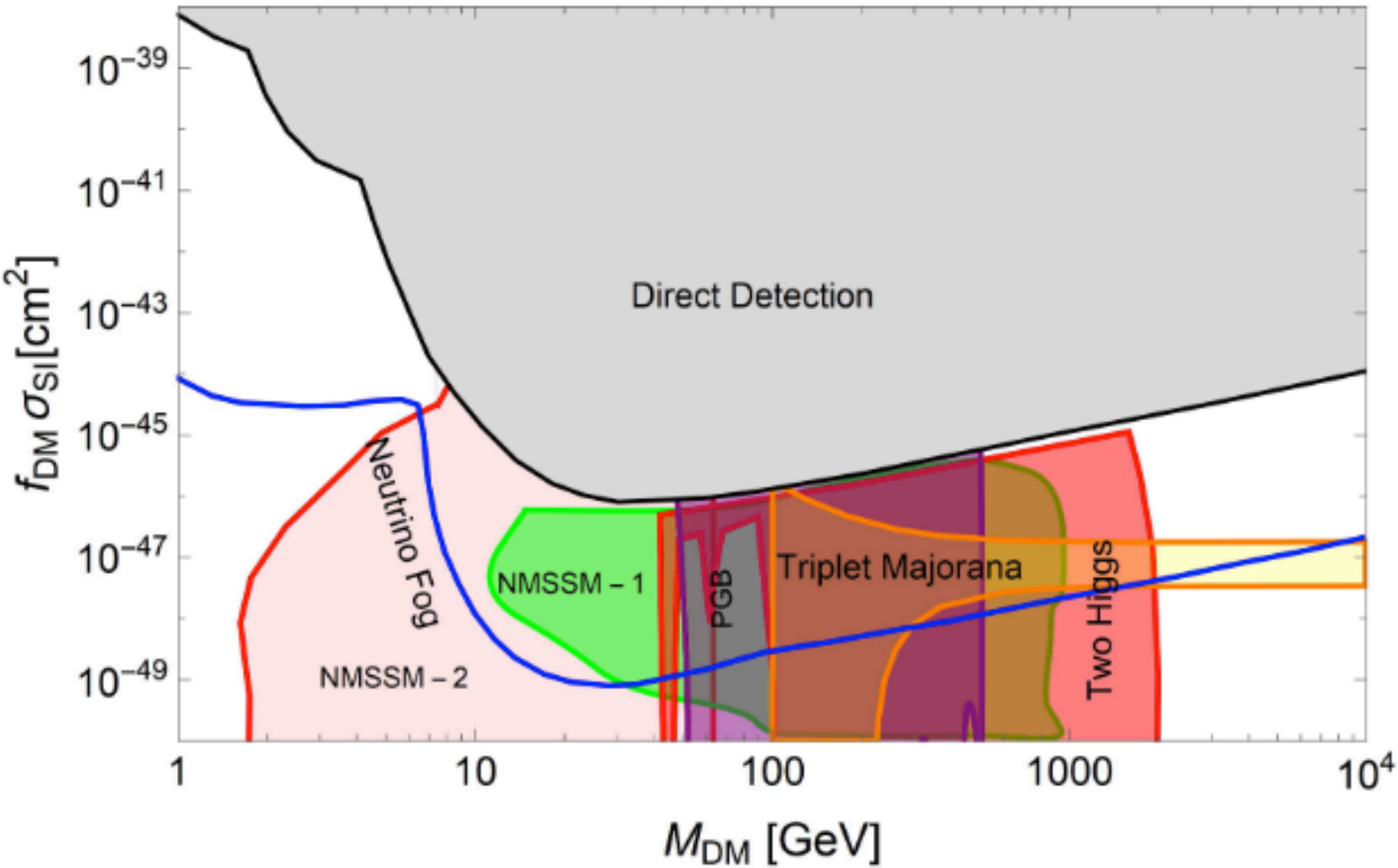
Dark Matter



It's probably WIMPs, right?

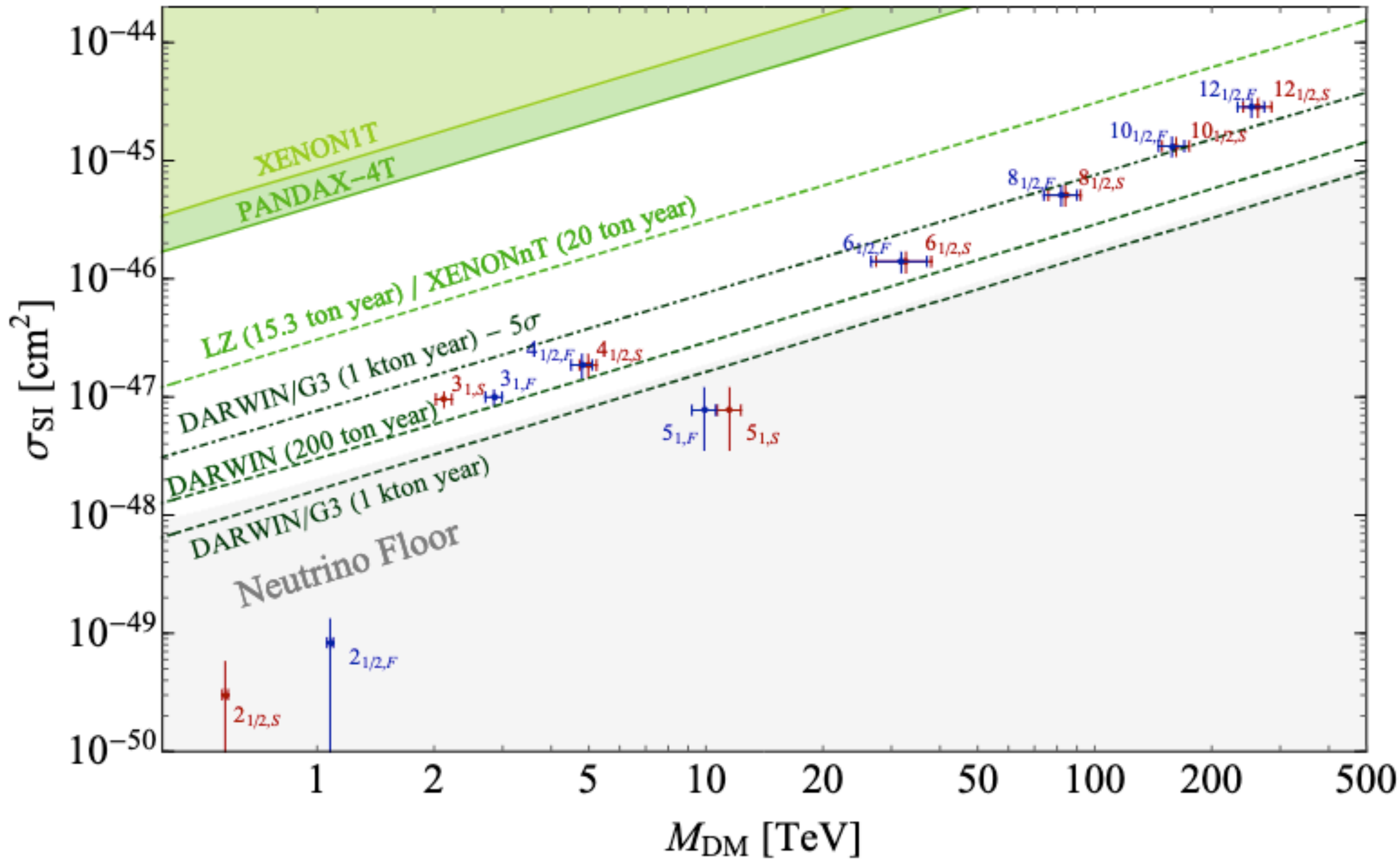
(I'm serious)

What are we looking for?

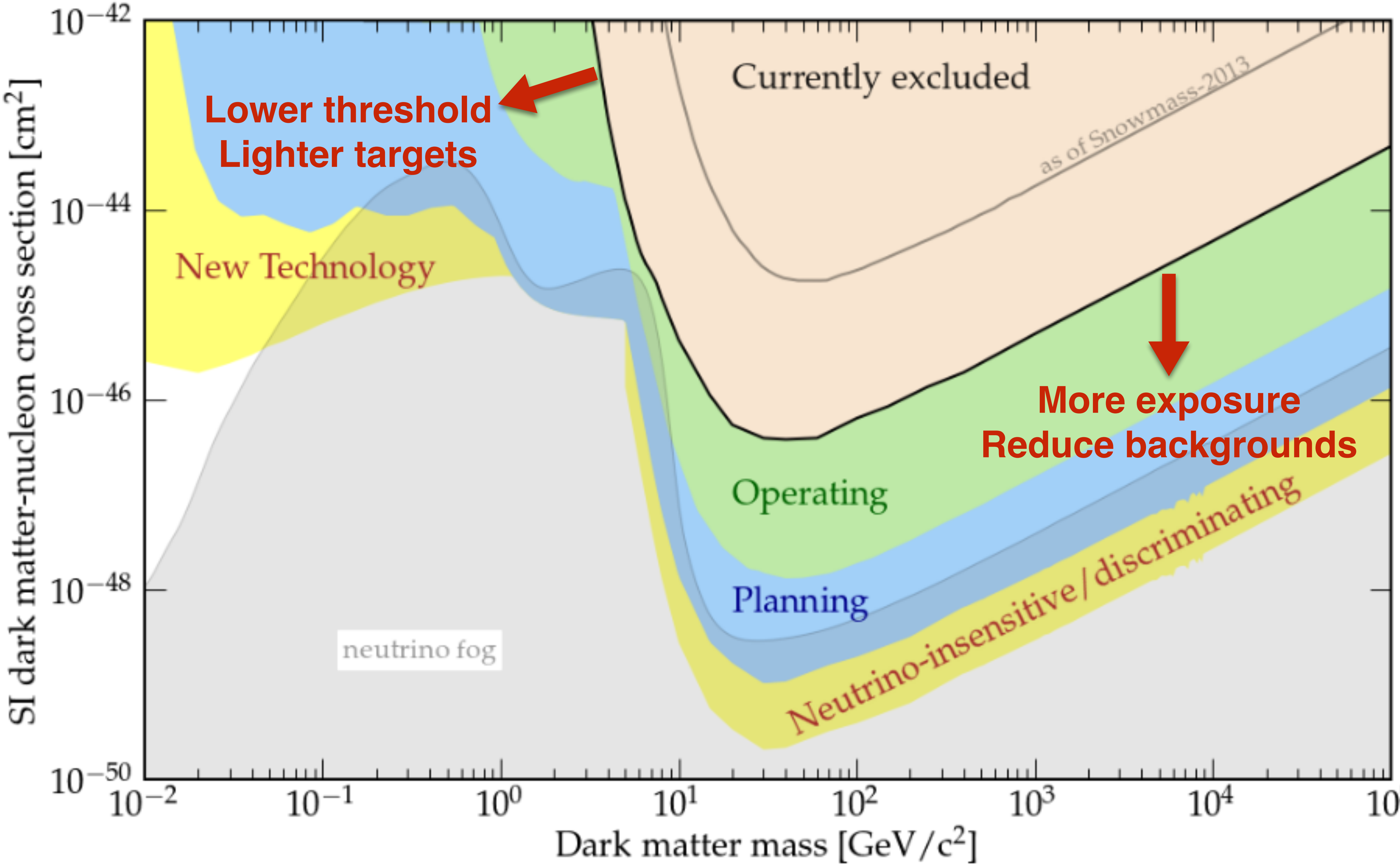


CF Snowmass 2203.08084

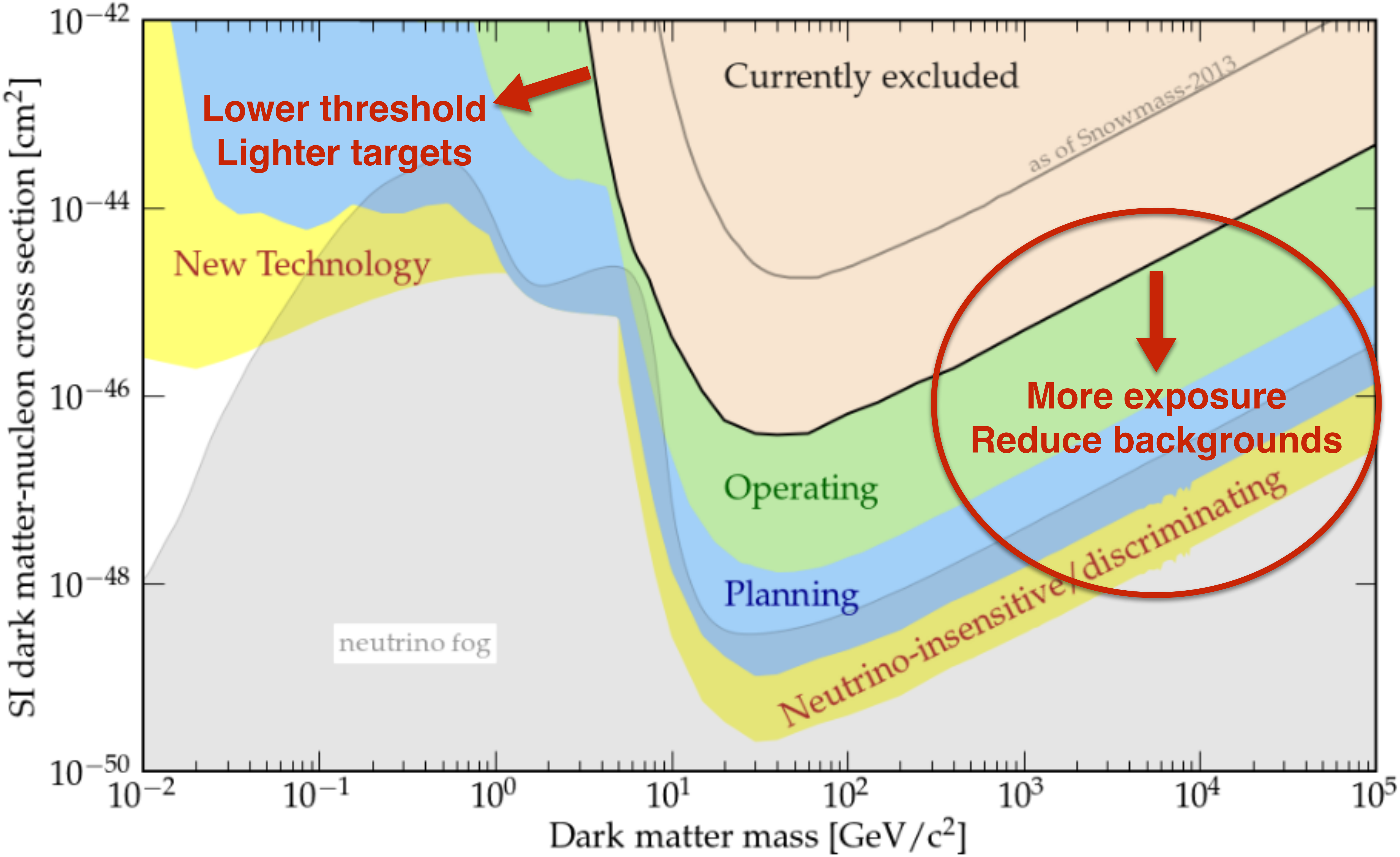
What are we looking for?



From Bottaro et al, 2205.04486 - Electroweak WIMP candidates - tree-level Higgs process vanishes -> small cross sections



- Limited at low mass by detector threshold
- Limited at high mass by density
- Eventually limited by neutrinos



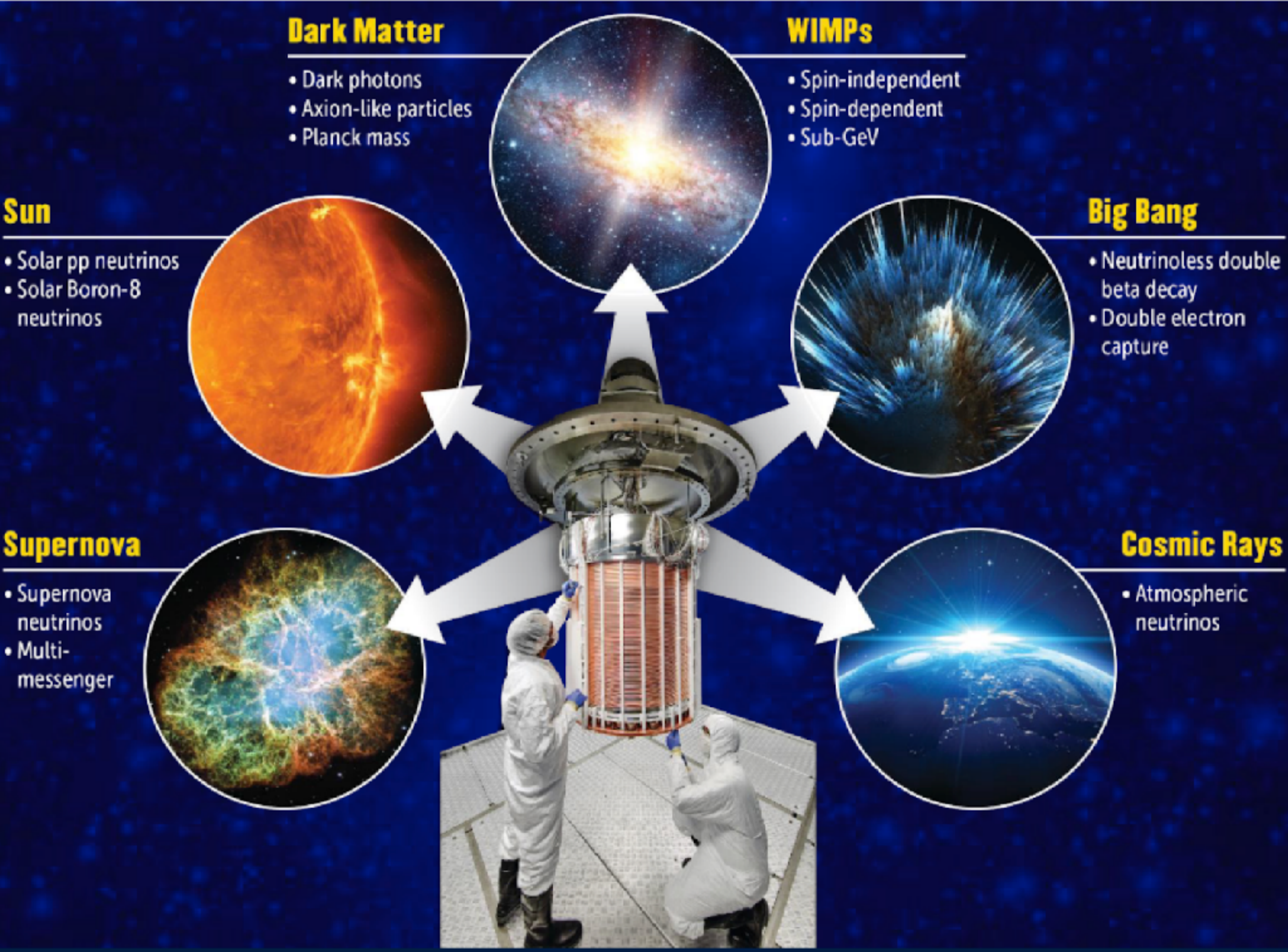
- Limited at low mass by detector threshold
- Limited at high mass by density
- Eventually limited by neutrinos

XLZD Collaboration

Leading Xenon Researchers unite to build next-generation Dark Matter Detector

SURF is distributing this press release on behalf of the DARWIN and LZ collaborations

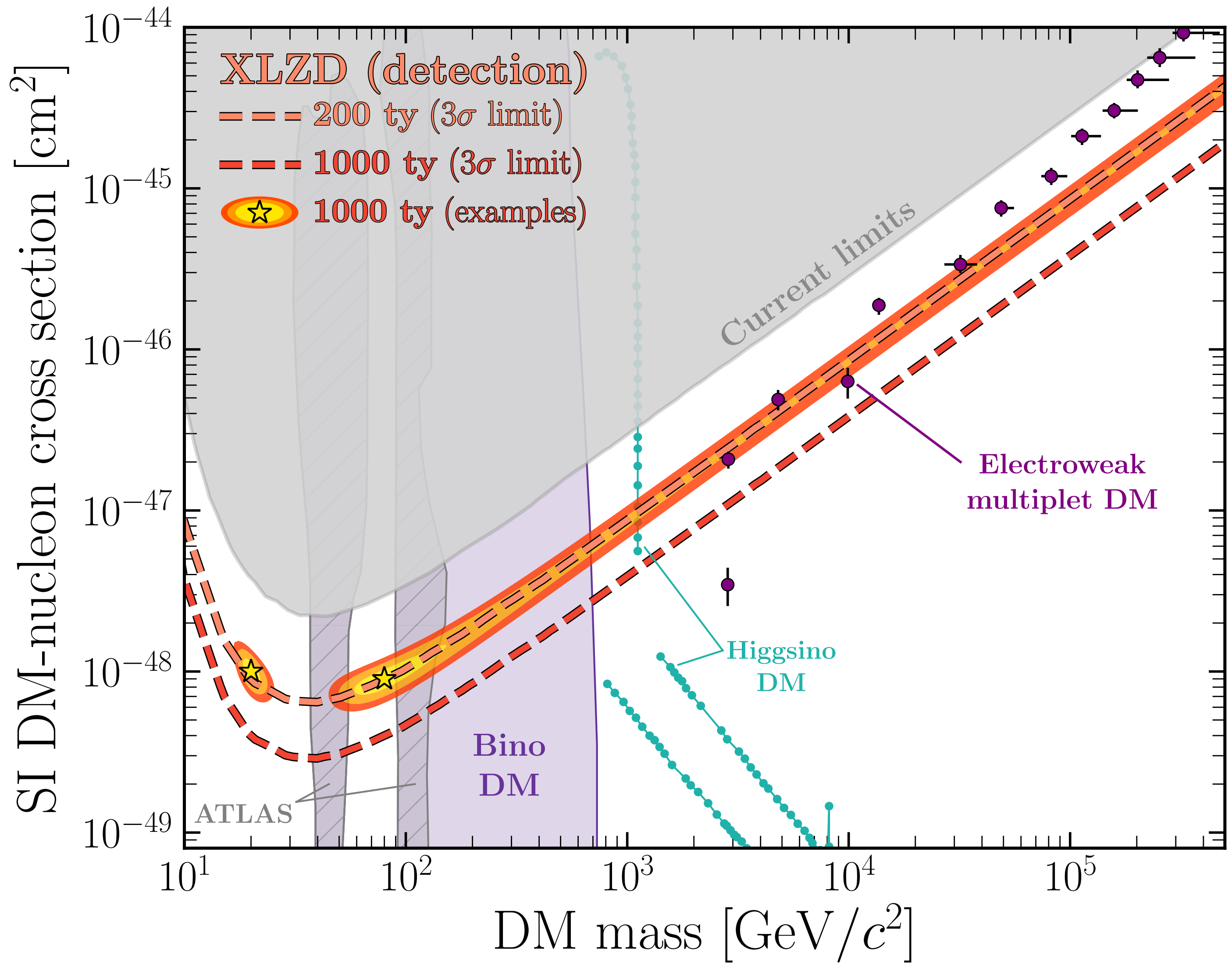
July 20, 2021

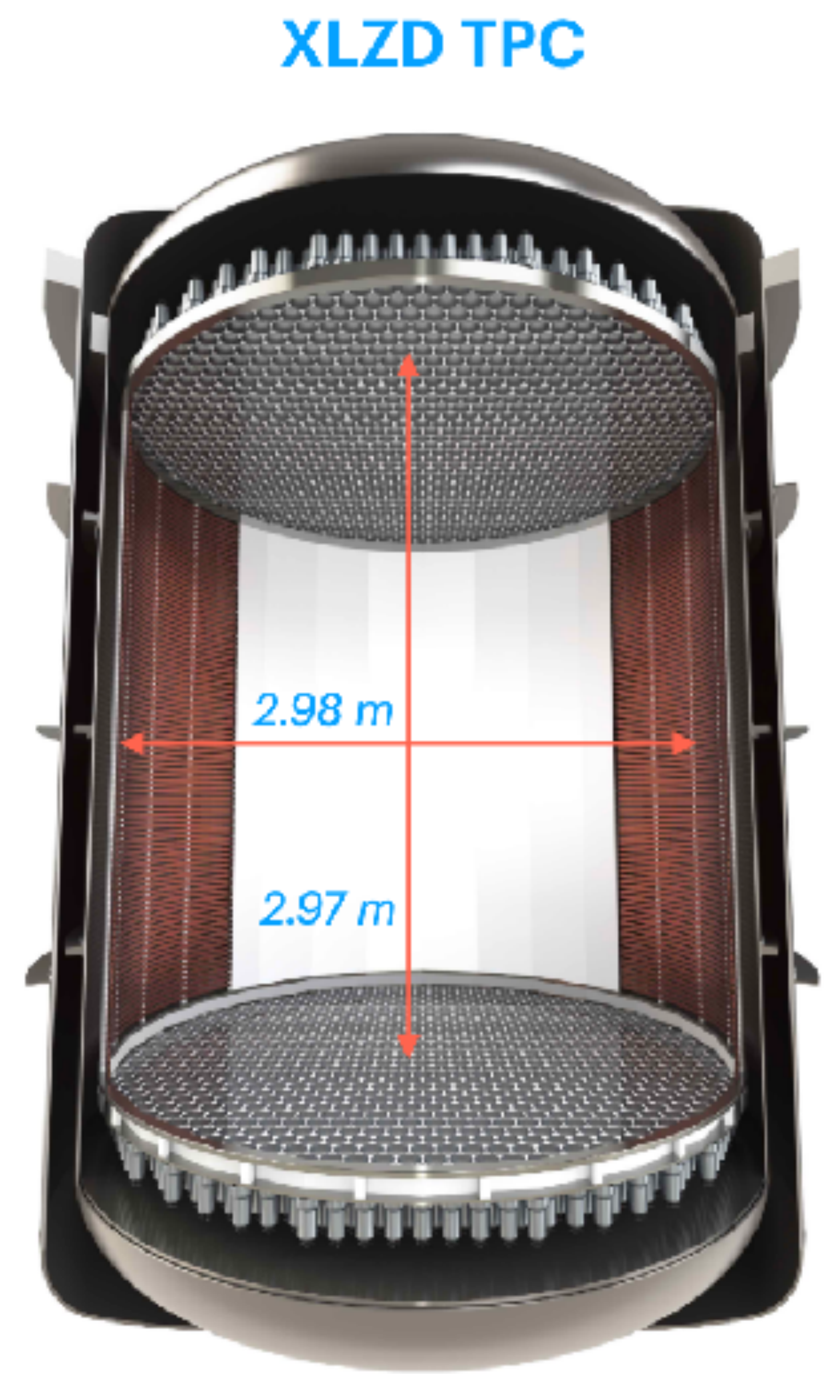


Dark Matter
• Dark photons
• Axion-like particles
• Planck mass
WIMPs
• Spin-independent
• Spin-dependent
• Sub-GeV
Sun
• Solar pp neutrinos
• Solar Boron-8 neutrinos
Big Bang
• Neutrinoless double beta decay
• Double electron capture
Supernova
• Supernova neutrinos
• Multi-messenger
Cosmic Rays
• Atmospheric neutrinos

XLZD Collaboration

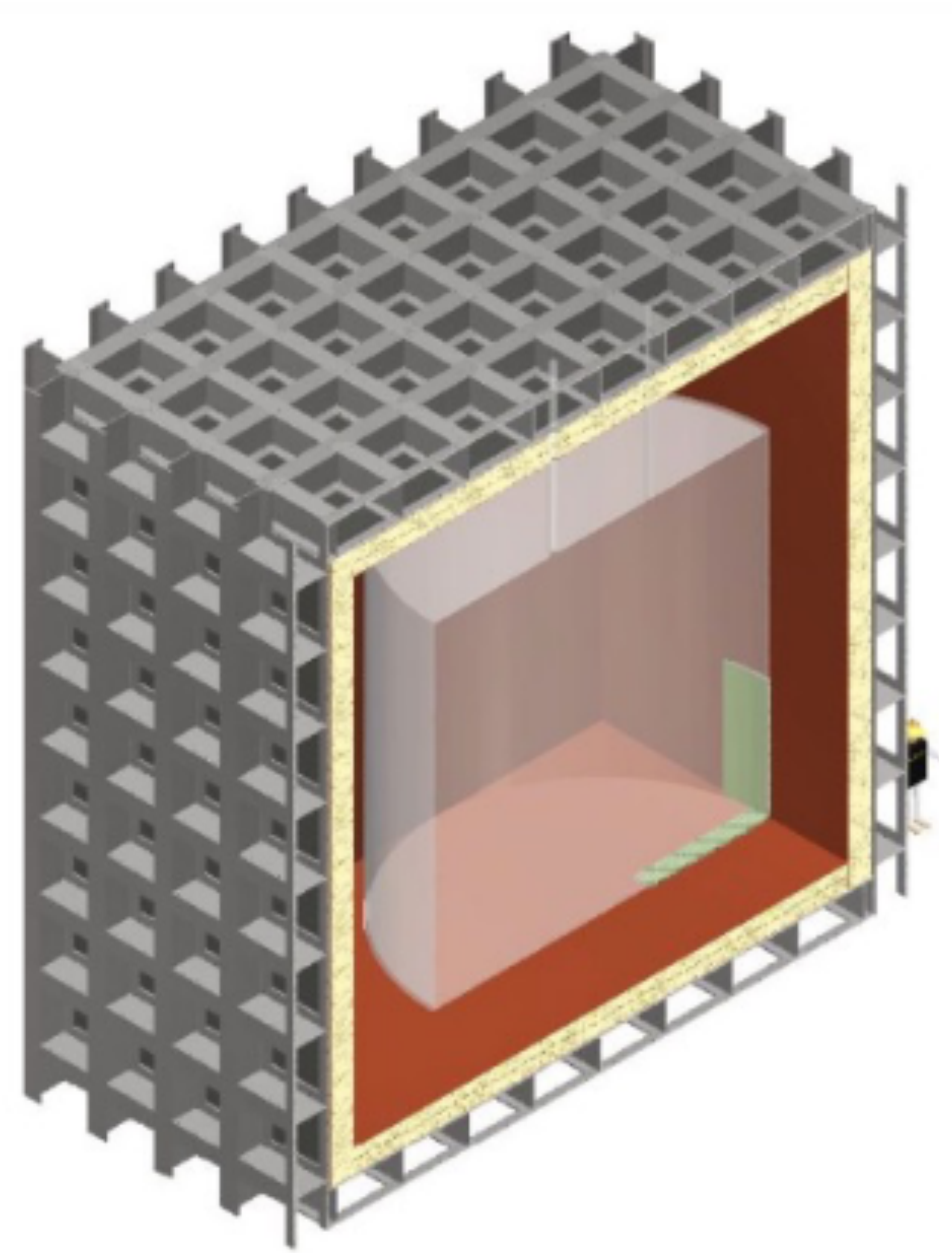
- 60-80 tonne LXe-TPC, 3 m x 3 m (x2 scale up from LZ/XnT)
- Neutron and muon vetoes
- Site - several options (LNGS, Boulby, SURF, SNOLAB)
- Physics case: 2203.02309
- Design book: 2410.17137

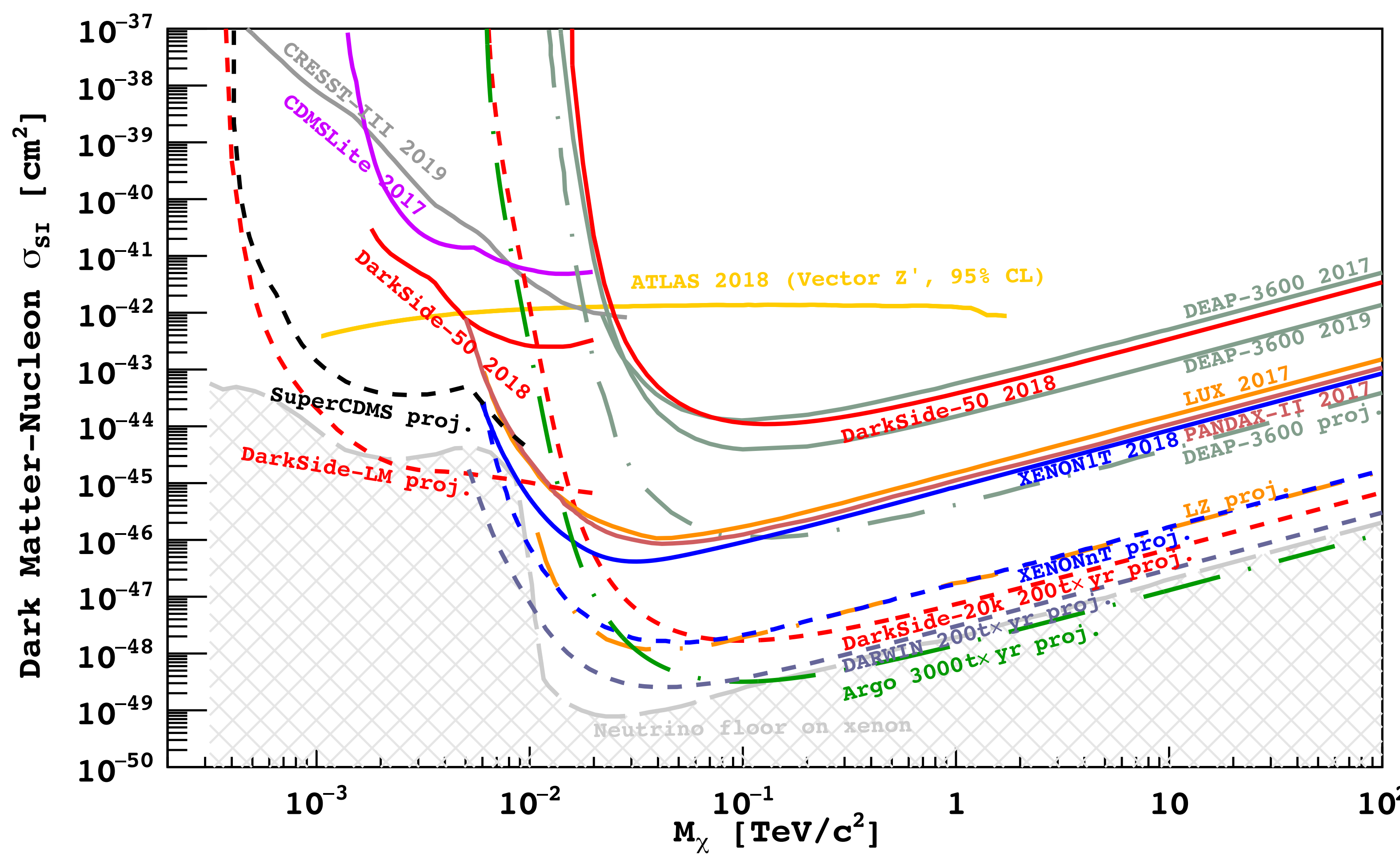




ARGO

- ArDM, DS-50, DEAP-3600, and MiniCLEAN jointly formed the Global Argon Dark Matter Collaboration (GADMC)
- A 300-tonnes fiducial argon detector filled with underground argon
- 3000 tonne×year exposure to reach into the neutrino fog





Dark Matter 25 years ago

2001 Snowmass report - single 3 page section on dark matter and relic particles

Particle Astrophysics and Cosmology: Cosmic Laboratories for New Physics
(Summary of the Snowmass 2001 P4 Working Group)

Daniel S. Akerib[*]
Department of Physics, Case Western Reserve University, Cleveland, OH 44106

Sean M. Carroll[†]
Department of Physics and Enrico Fermi Institute,
University of Chicago, 5640 South Ellis Avenue, Chicago, IL 60637

Marc Kamionkowski[‡]
California Institute of Technology, Mail Code 130-33, Pasadena, CA 91125

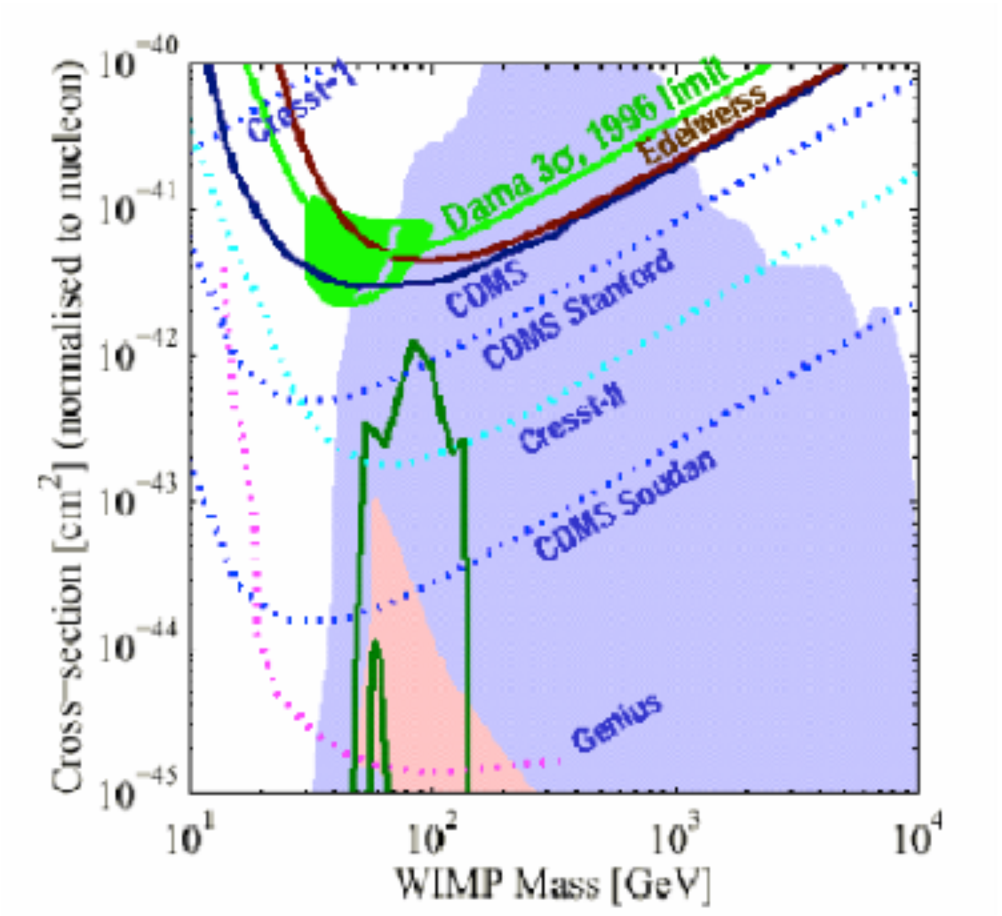
Steven Ritz[§]
NASA/Goddard Space Flight Center, Mail Code 661, Greenbelt, MD 20771
(Dated: October 30, 2018)

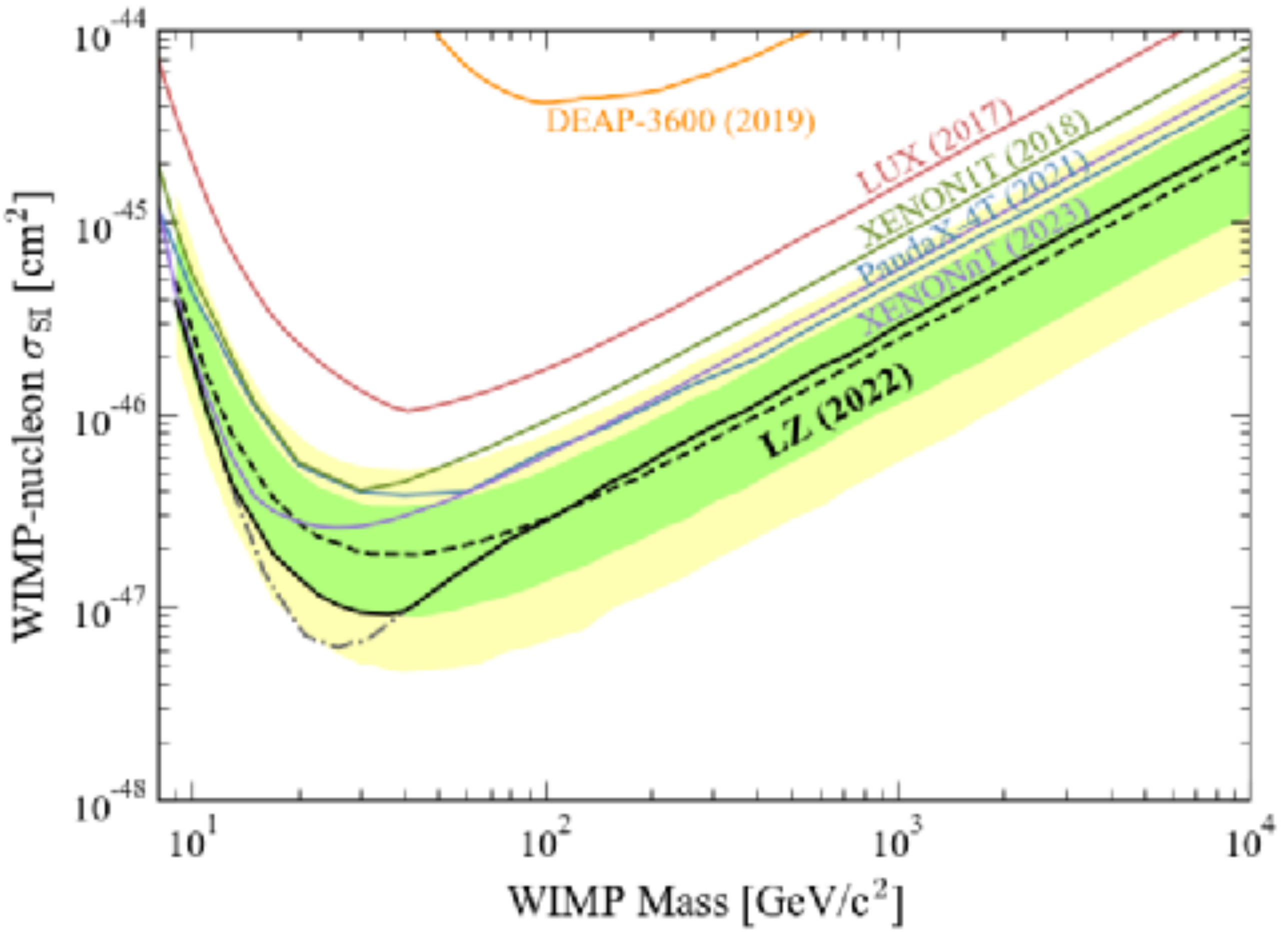
"Current searches are already exploring the parameter space of supersymmetric WIMPs [10-1000 GeV], with prospects for a factor of a hundred improvement in the coming years."

WIMPs

- CDMS PRL 84: 5699, (2000)
- Best limit at 3 x 10^{-42} cm^2

- LZ, 2410.17036 (2024)
- Best limit at 2.2 x 10^{-48} cm^2

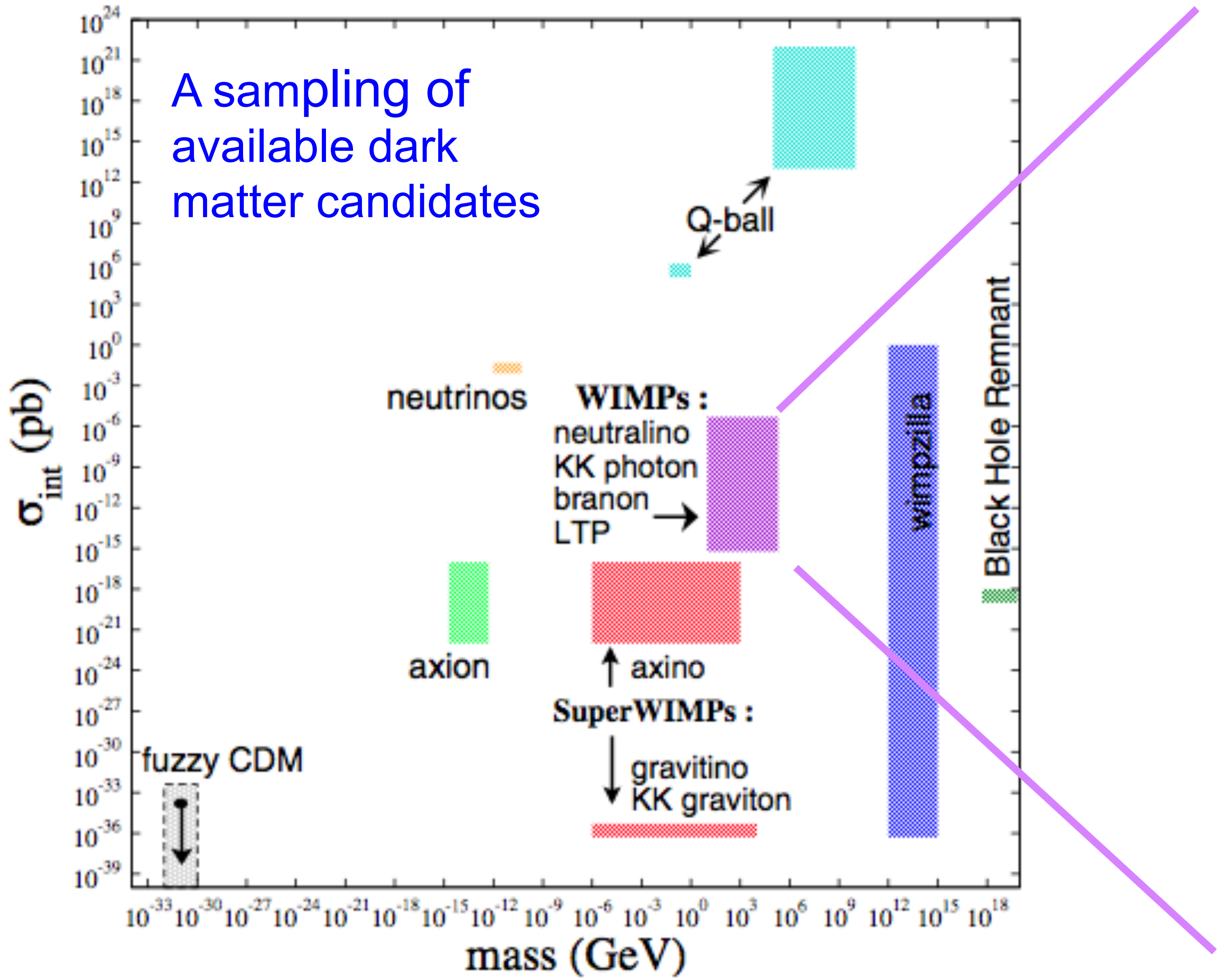




- Factor of >1,000,000 improvement in <25 years! Doubling every 1.2 years!
- Much faster than Moore's Law! A triumph of experimental physics!
- No WIMPs :(

Dark Matter

Particle Physics

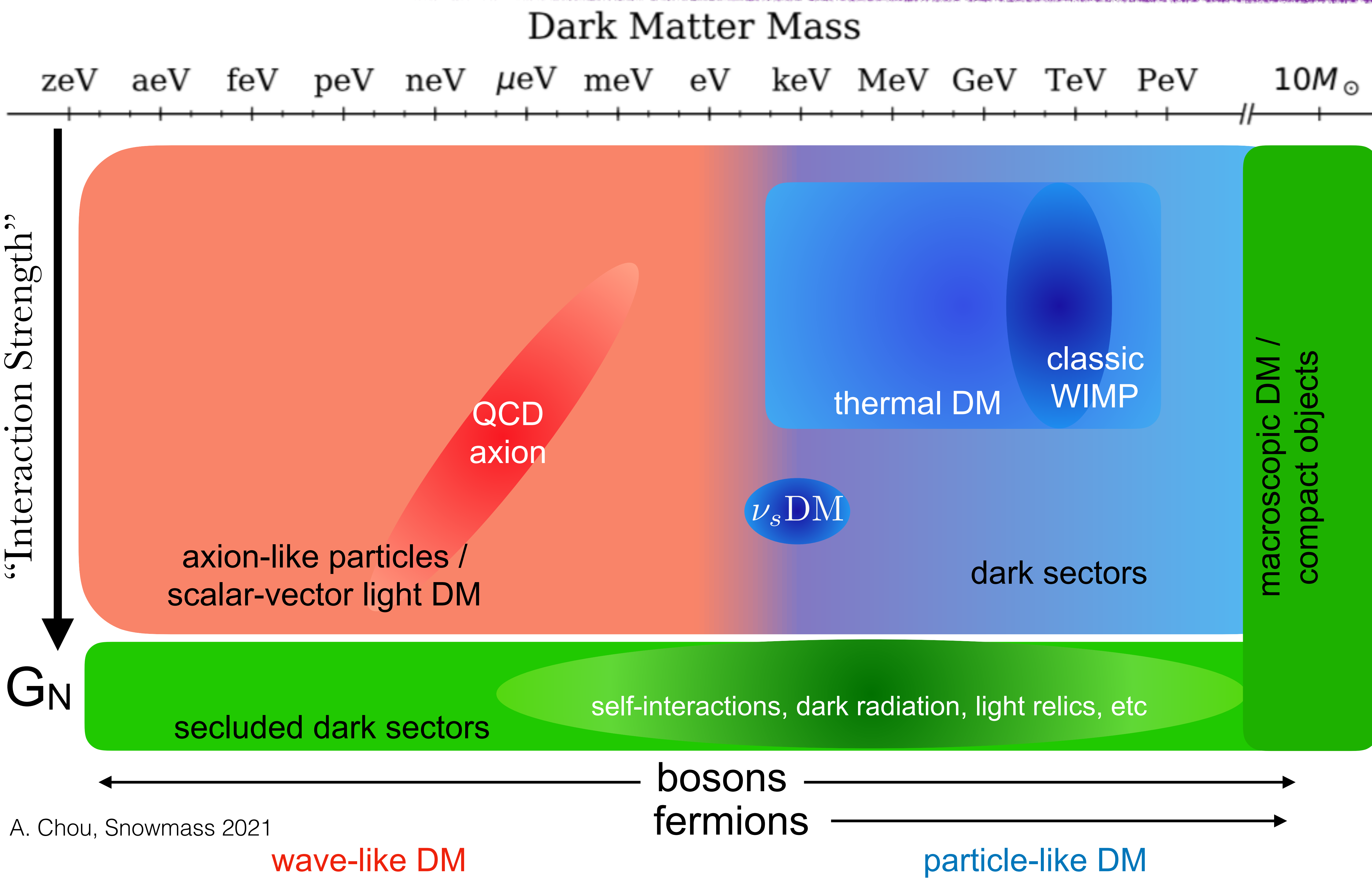


It's probably WIMPs, right?

(I'm serious)

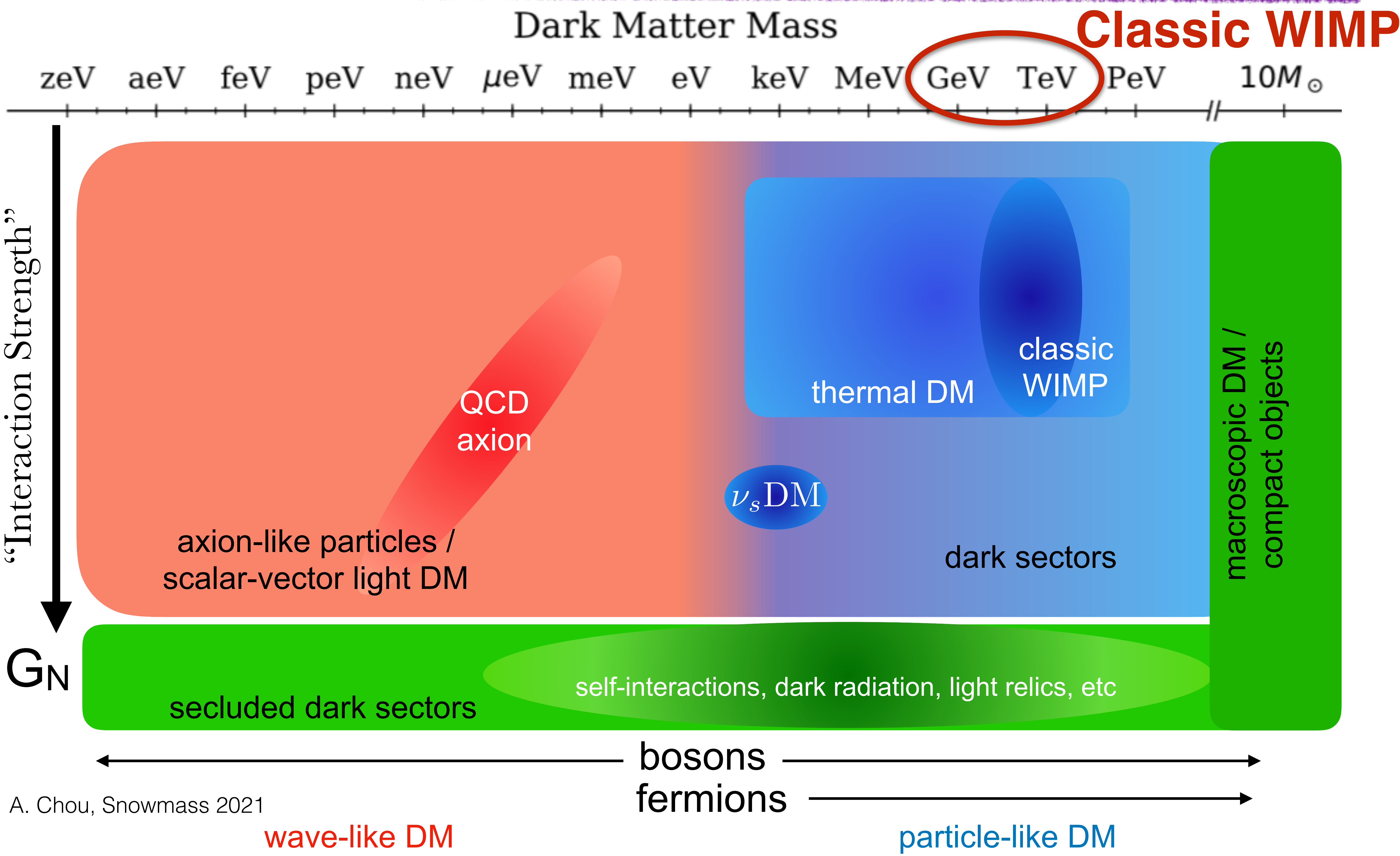
(Sort of)

Dark Matter today

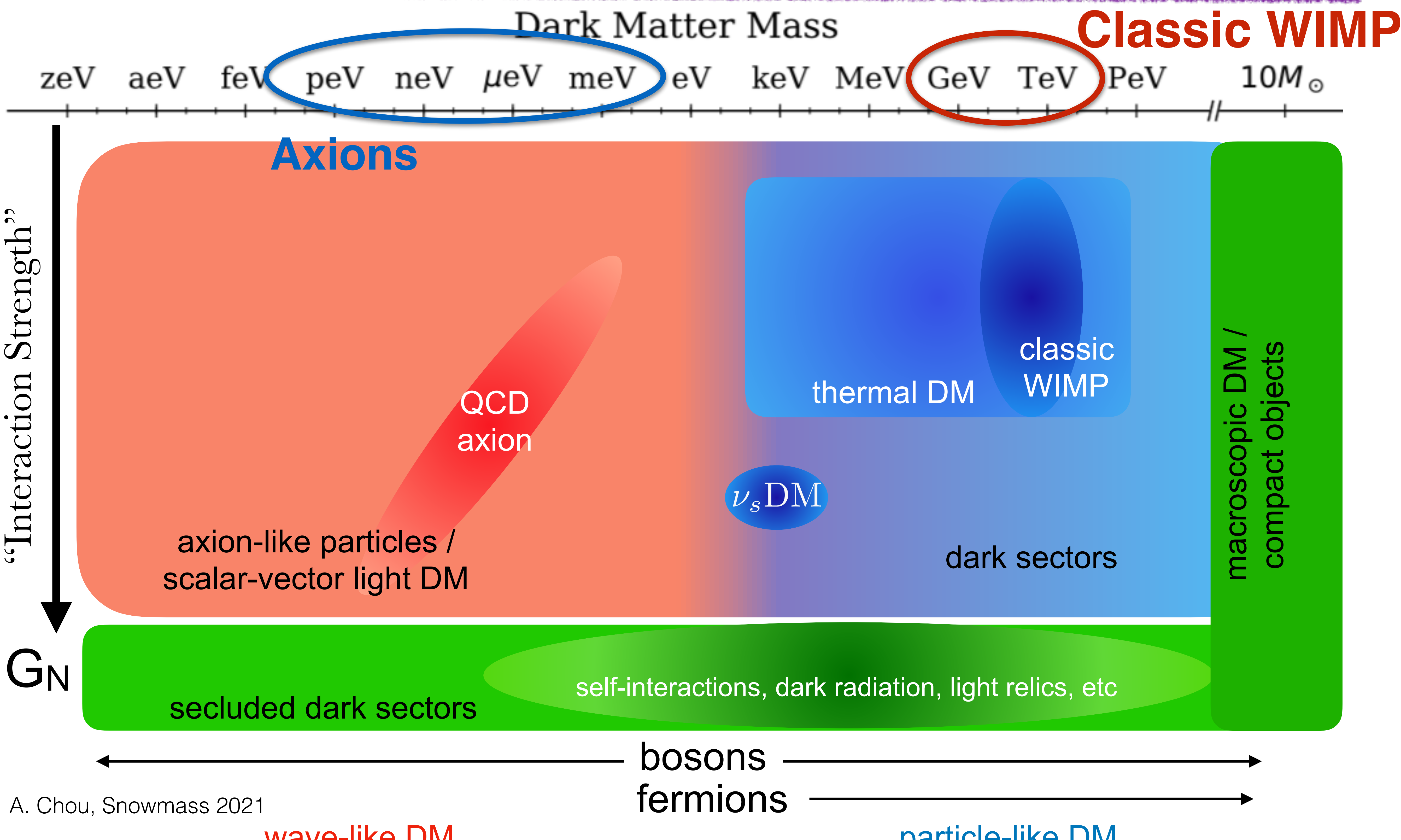


A. Chou, Snowmass 2021

Dark Matter today

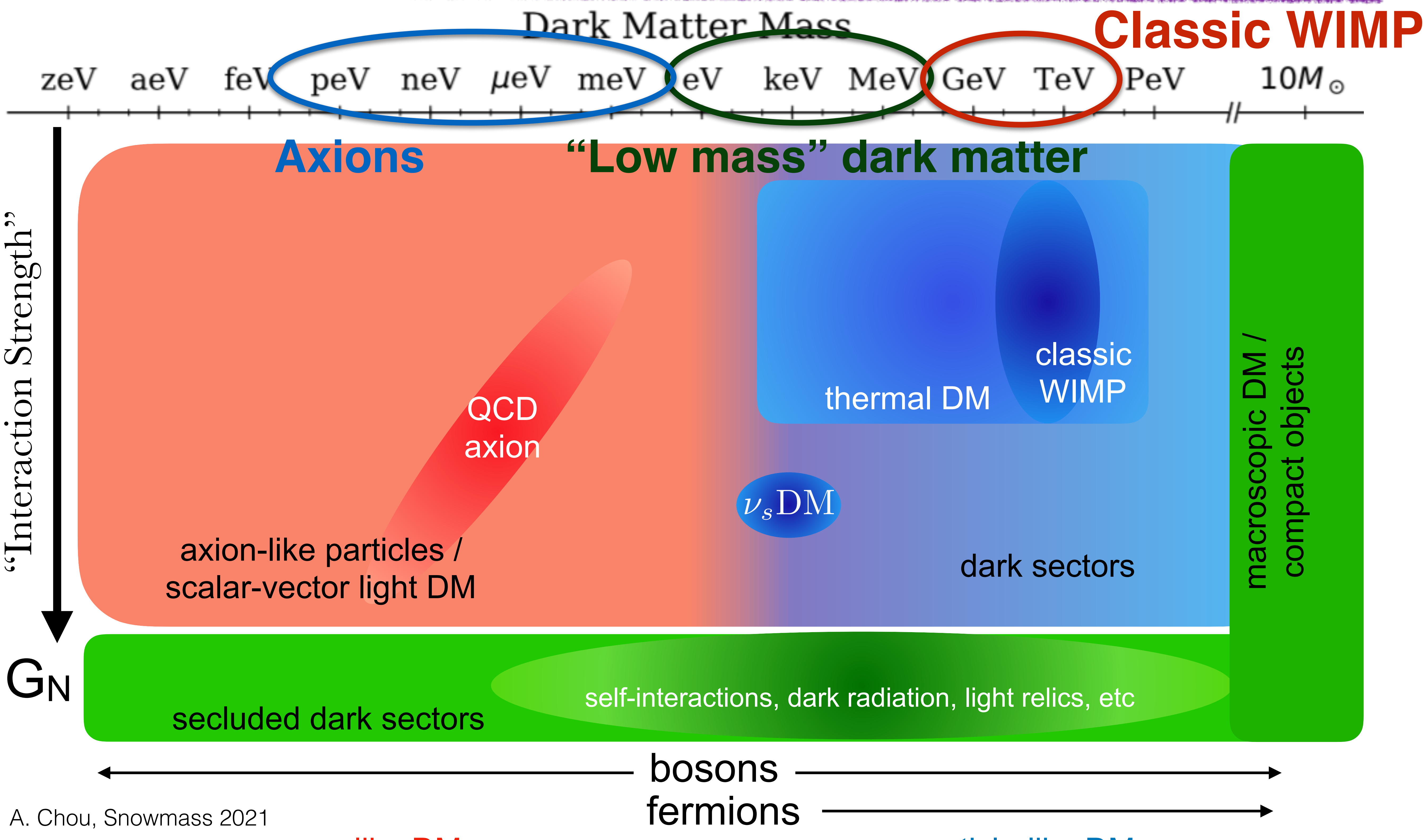


Dark Matter today



A. Chou, Snowmass 2021

Dark Matter today



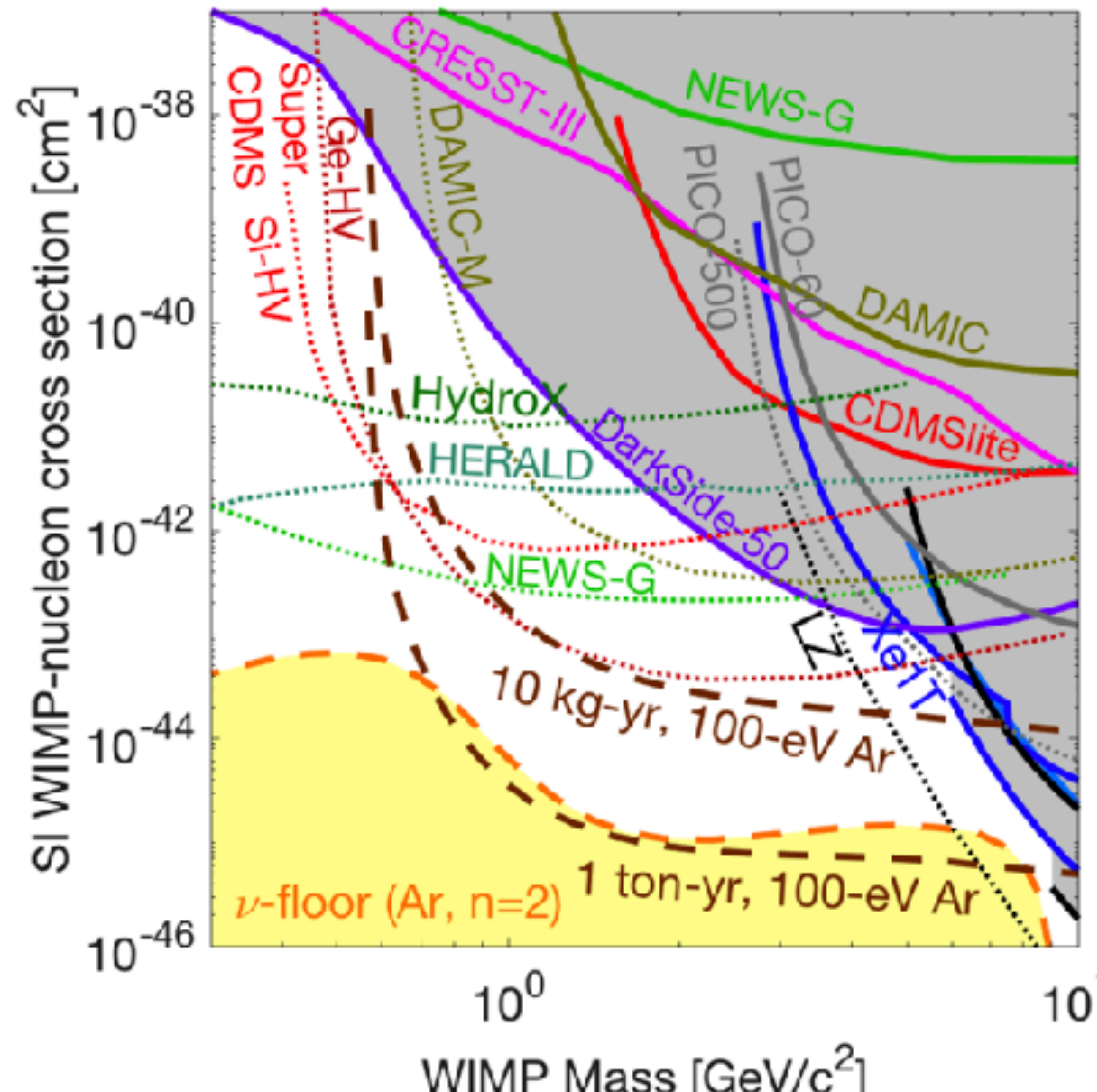
A. Chou, Snowmass 2021

wave-like DM

particle-like DM

Broadening the mass reach (with noble gases)

- **Scintillating Bubble Chamber (SBC)**
  - **Liquid argon bubble chamber**
  - **Goal: ER rejection at ~100 eV threshold**
  - **Calibration run this summer/fall at FNAL**
  - **SNOLAB chamber to follow**

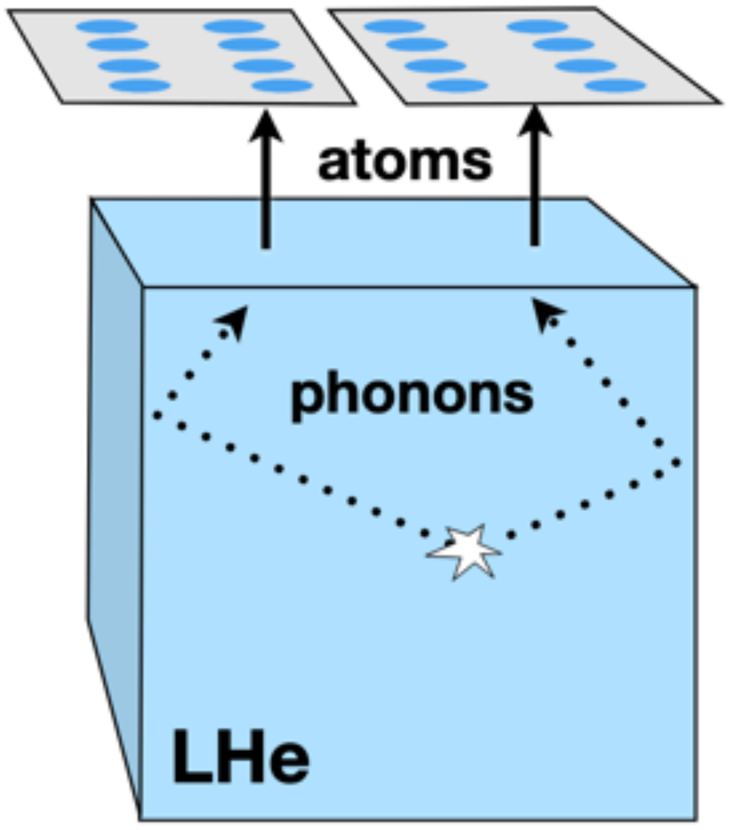


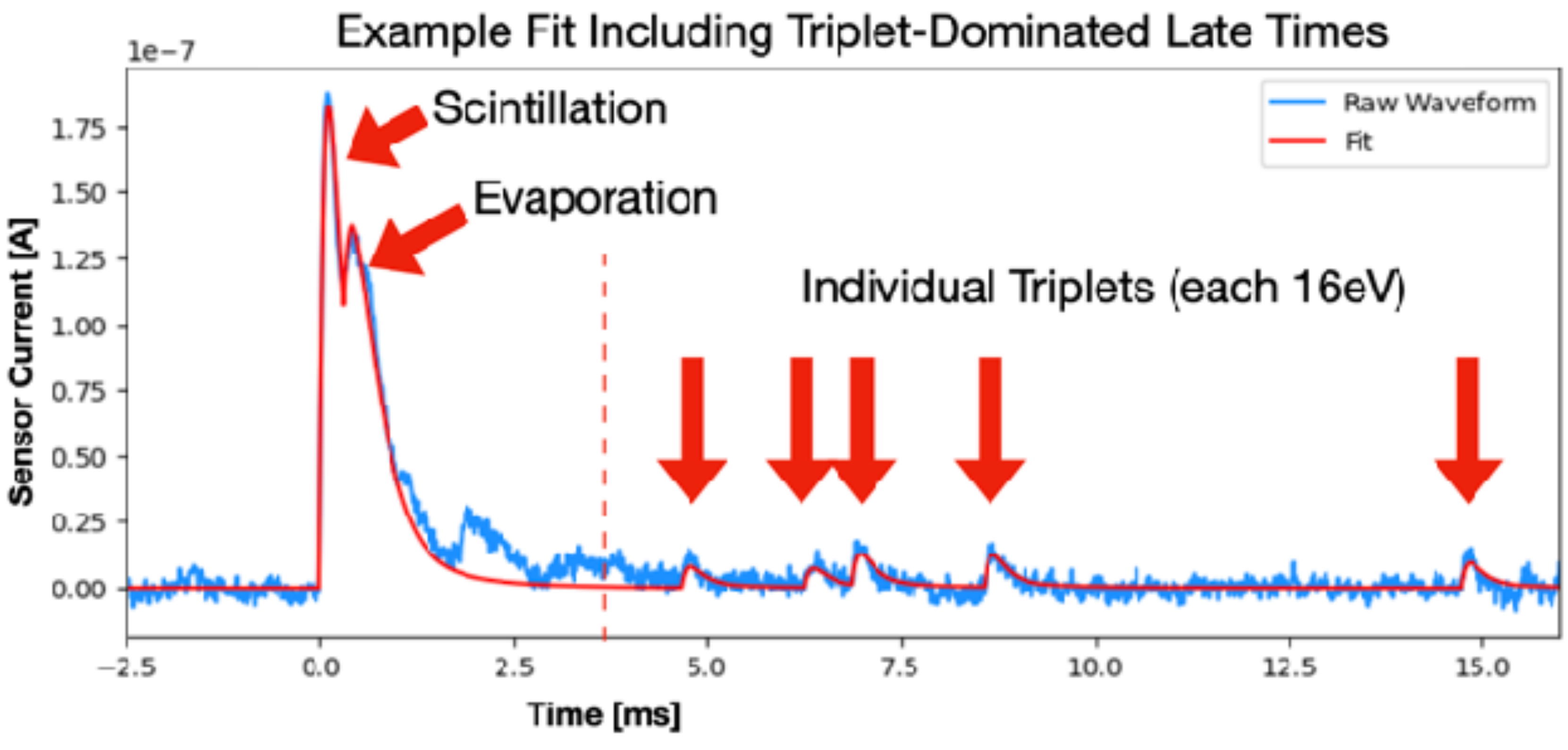
SBC at Fermilab

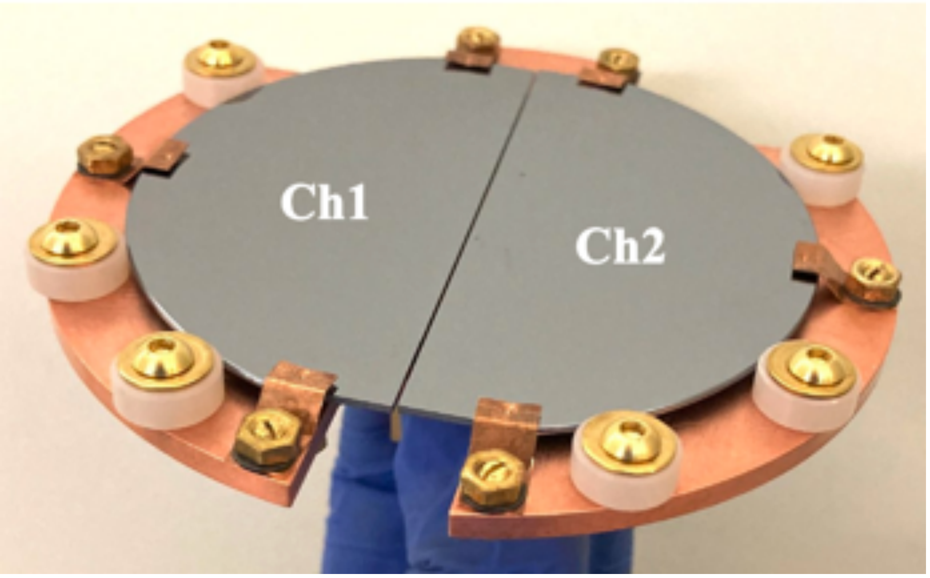
See B. Broerman this afternoon, also G. Putnam, Wed 19:00 neutrino session)

Broadening the mass reach (with noble gases)

- **Down to the MeV region - TESSERACT/HERALD**
  - **TES sensors measuring energy deposition in liquid helium (and other detector media)**
  - **Energy deposition induces phonons induces evaporation at liquid surface**
  - **Superfluid target free of low energy excess (LEE) observed in similar detectors**





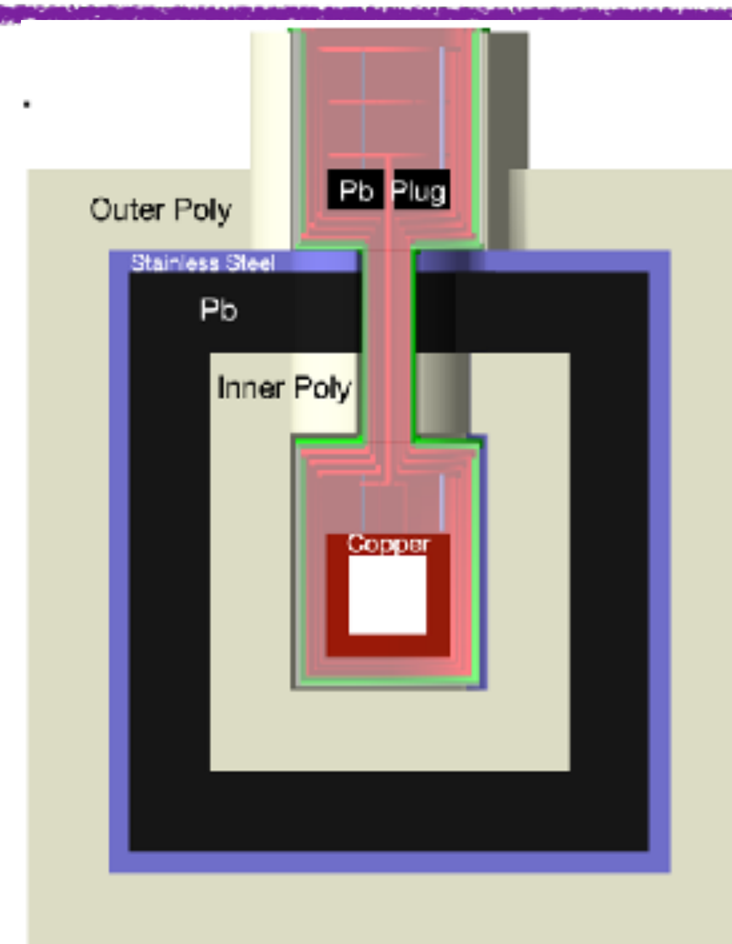


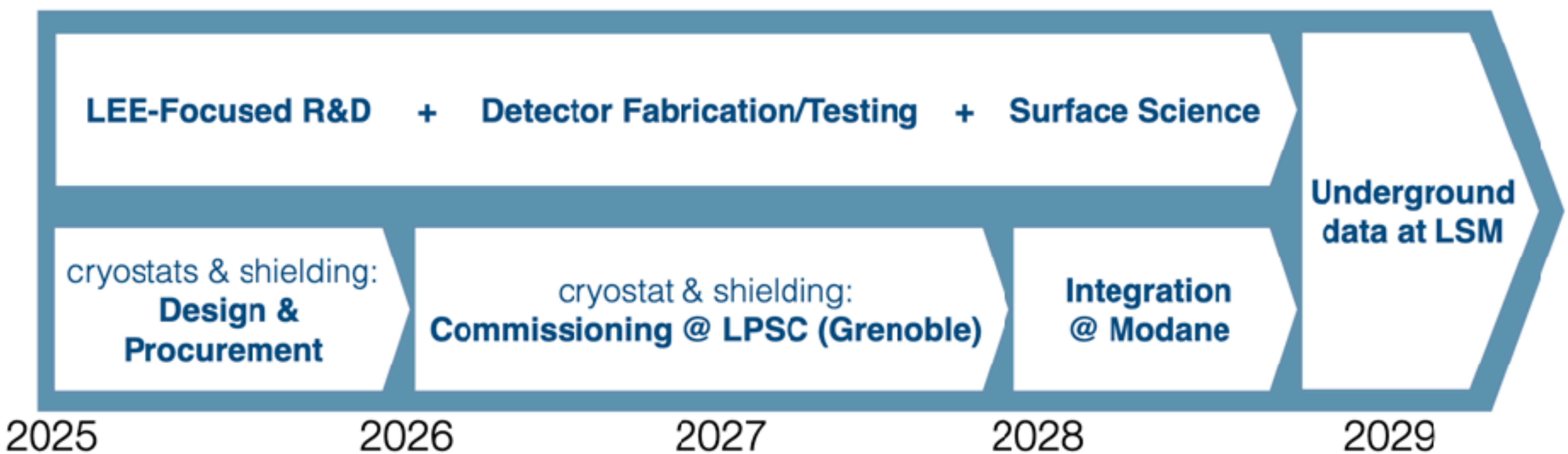
S. Hertel, UCLA DM 2025

Broadening the mass reach (with noble gases)

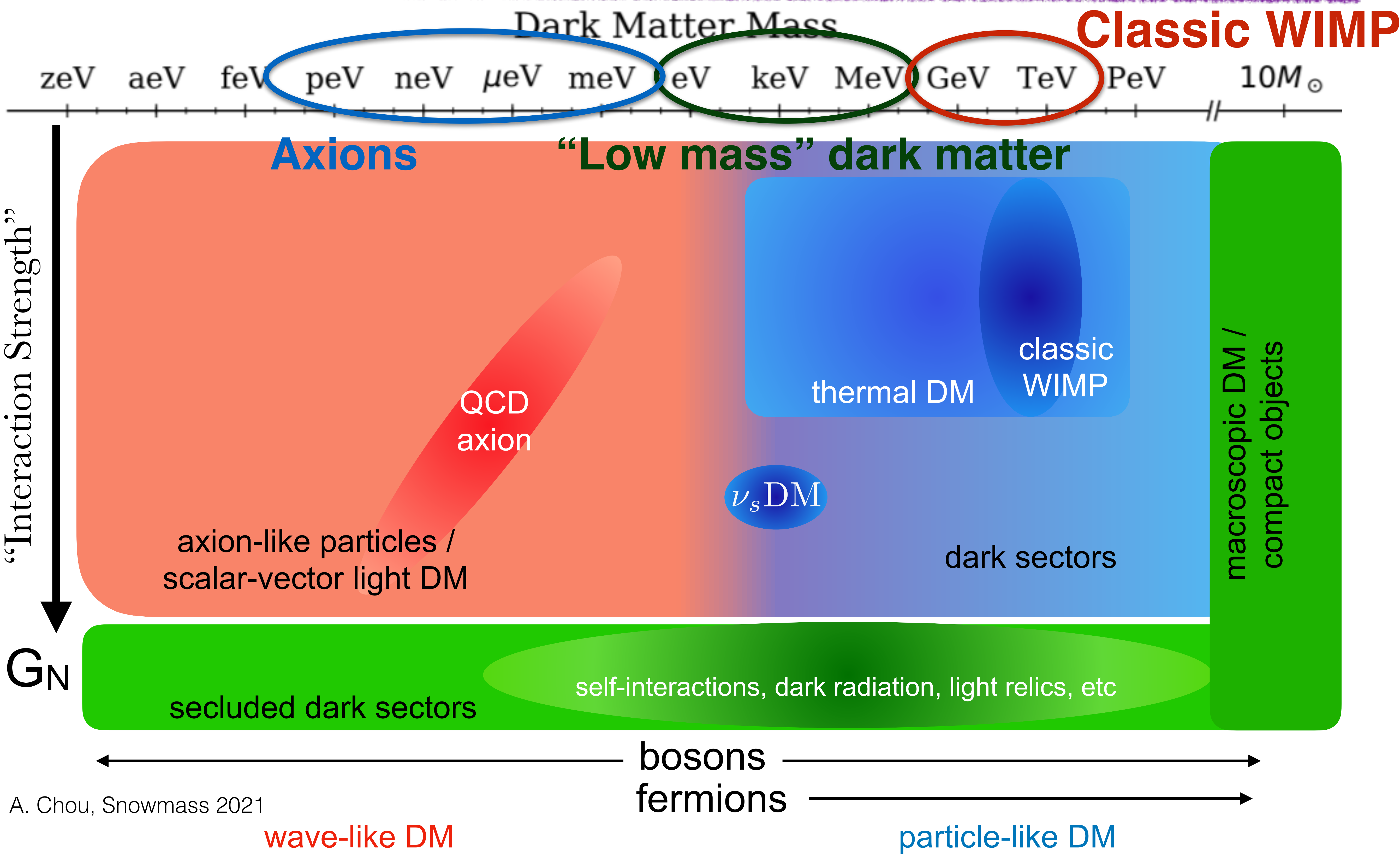
- **Down to the MeV region - TESSERACT Project**
  - **Approved to proceed (Dark Matter New Initiatives)**
  - **Two low background, shielded cryostats at Modane Laboratory in France**
  - **Targets can be swapped between technologies**

S. Hertel, UCLA DM 2025





Dark Matter today



A. Chou, Snowmass 2021

Glass Half Empty?

- It can feel like we know less now than we did before
  - What was “axions or WIMPs” is now 50 orders of magnitude
- No guarantees of discovery


Physicist Claims Universe Has No Dark Matter And Is 27 Billion Years Old

SPACE 18 March 2024 By MIKE MCRAE

(Mark Garlick/Science Photo Library/Getty Images)


Elon Musk
@elonmusk

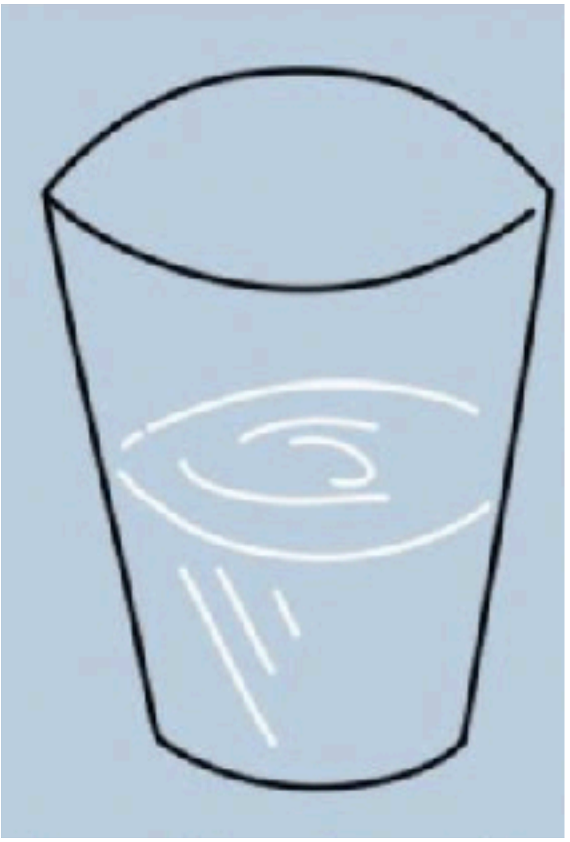
Possibly.

Dark matter is what seems most sketch to me.

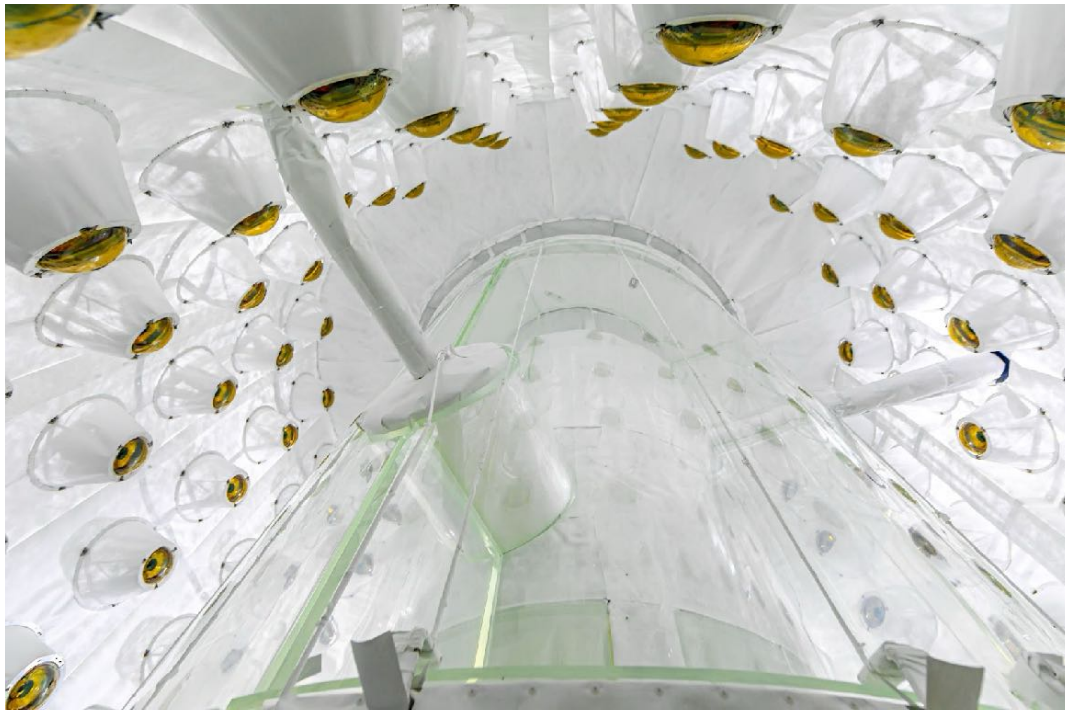
9:02 PM · Jul 16, 2023 · **2.8M** Views

Glass Half Full?

- A factor of a million improvement in sensitivity in 25 years
  - e.g. XENONnT at 15 events/tonne/keV/year
  - Factor of 10^{12} suppression!
- Explosion of ideas to search wide and delve deep!
- These are opportunities!



Part of DS-20k distillation column

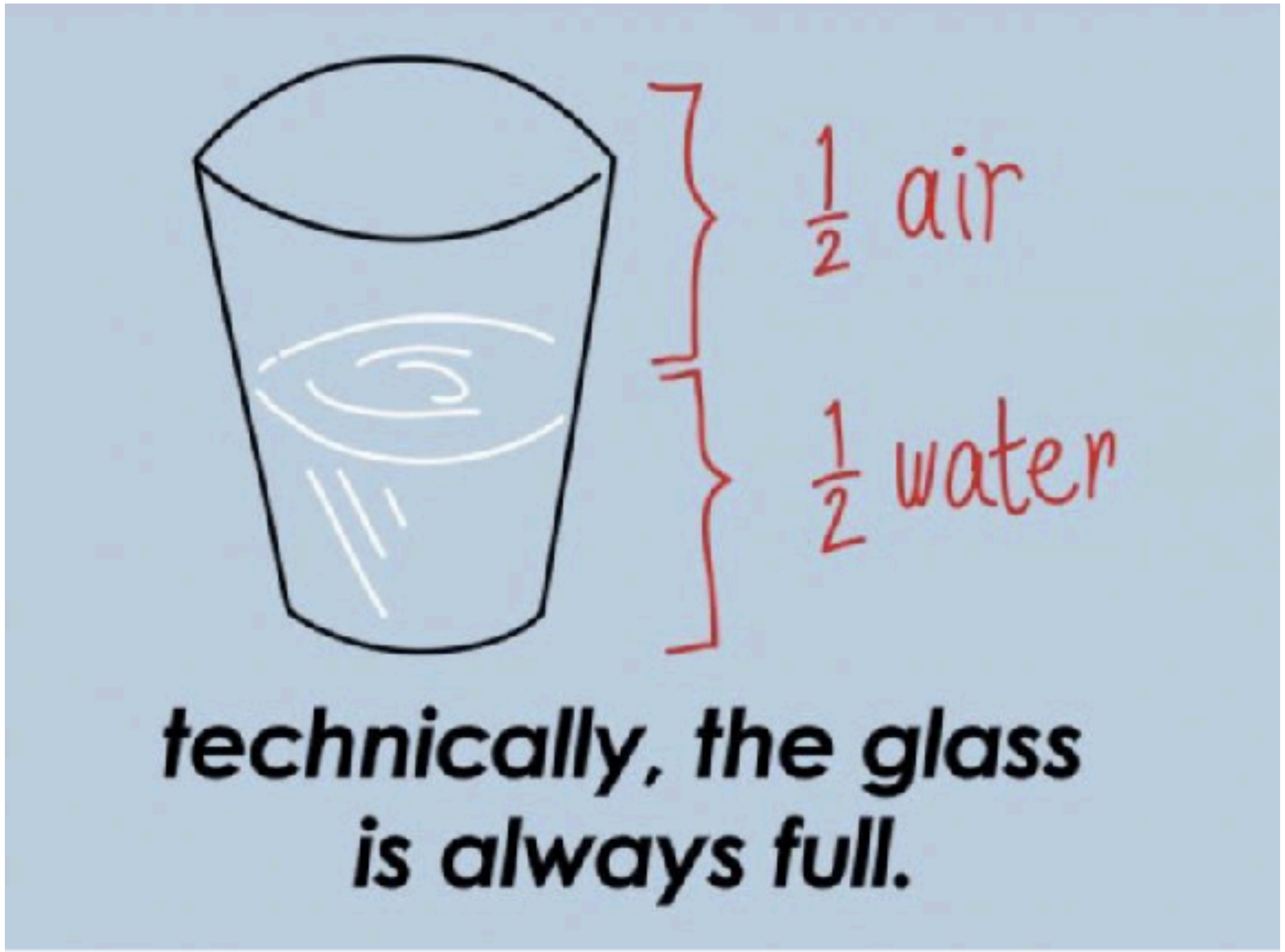


LZ Outer Detector

Glass is always full

- Dark Matter exists
- Without it, we wouldn't be here
- It's worth understanding

- There are no guarantees
- We learn a lot on the way

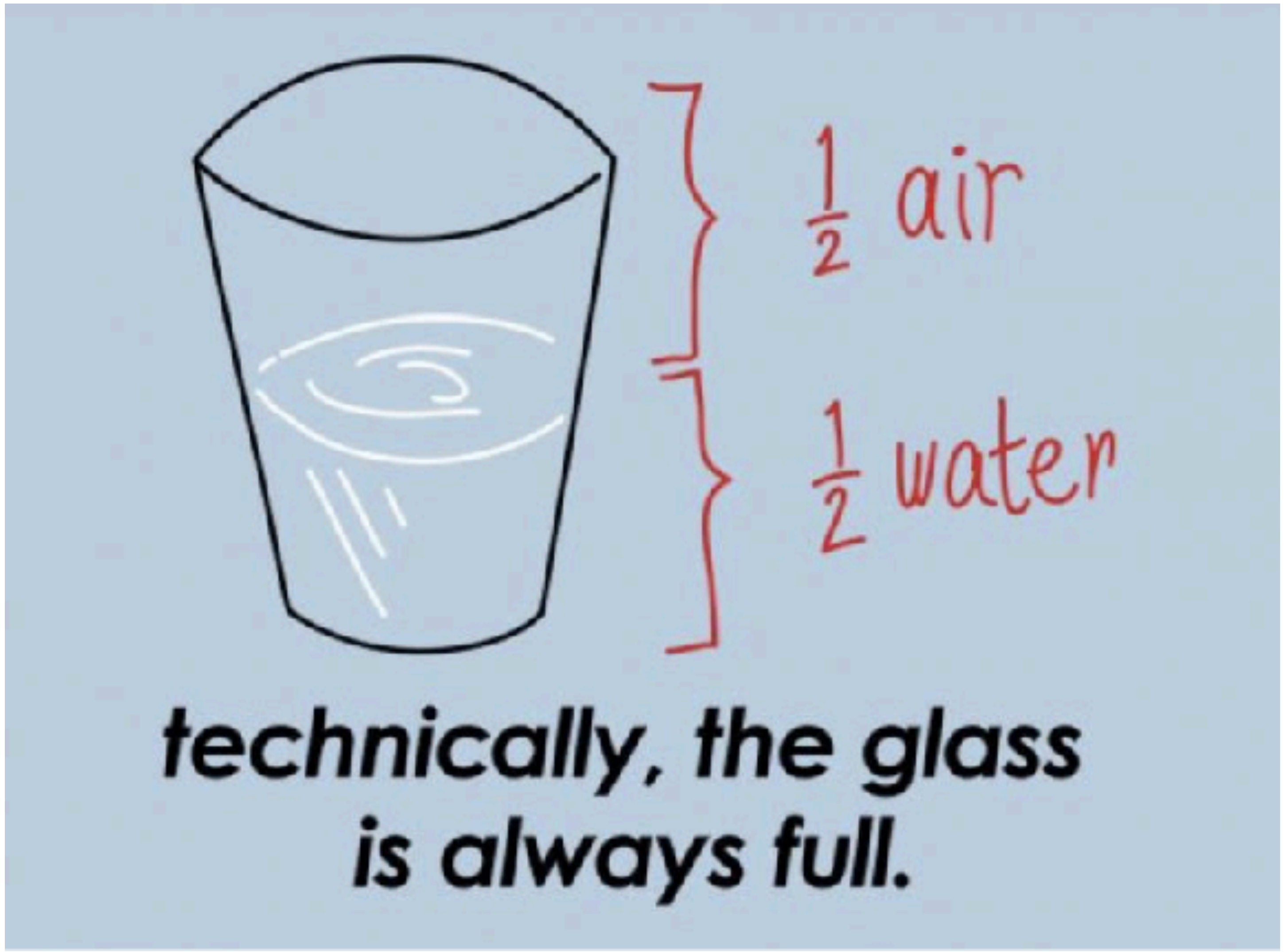


STEAMfest at Woodlawn School, NC

Glass is always full

- Dark Matter exists
- Without it, we wouldn't be here
- It's worth understanding

- There are no guarantees
- We learn a lot on the way



STEAMfest at Woodlawn School, NC

Liquid noble detectors are leading the way at >GeV scales, and pushing the boundaries at MeV scales!

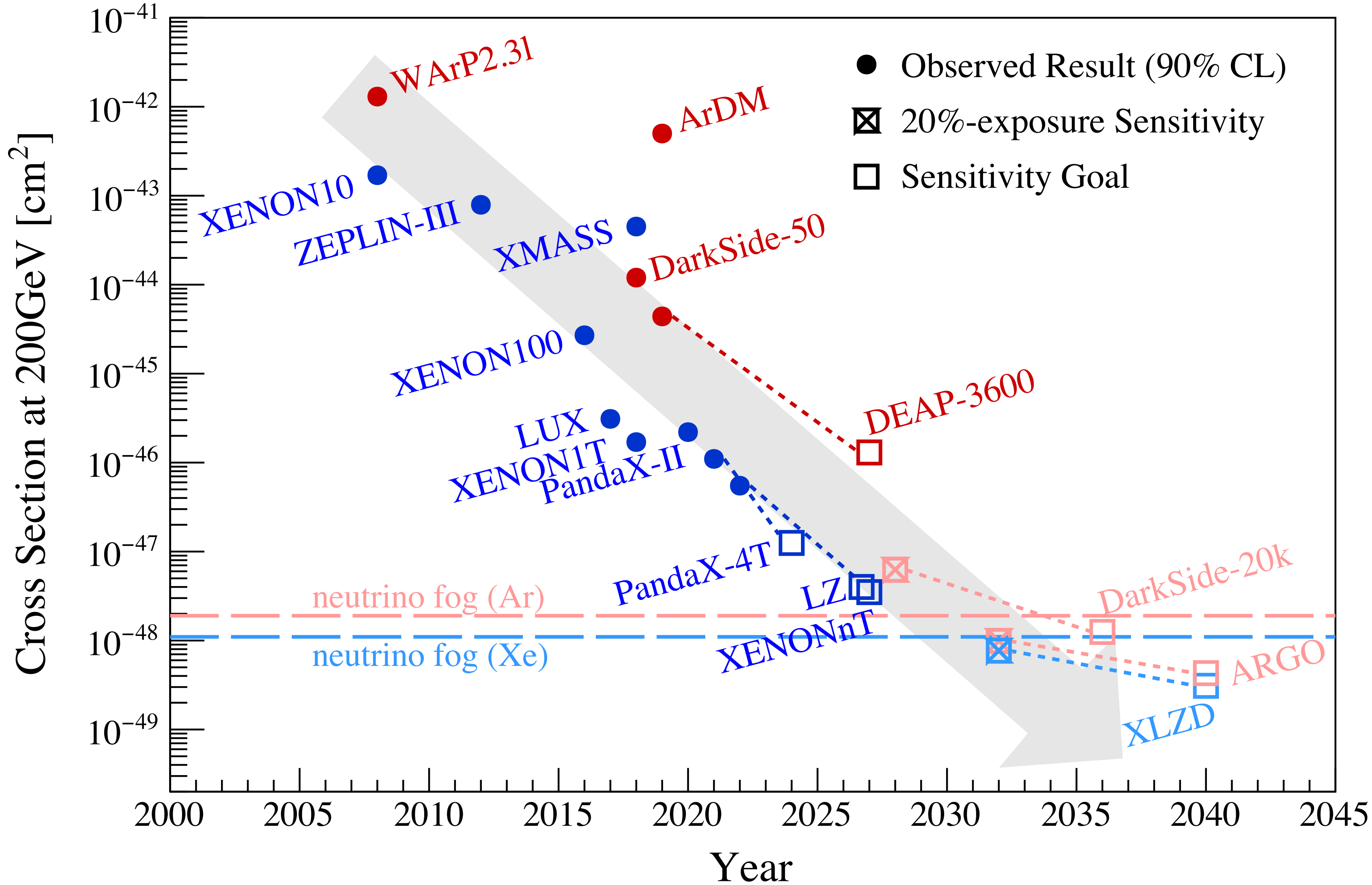

This is a problem worth solving!
I’m eager to see what’s next!

Liquid noble "DM" at this conference…

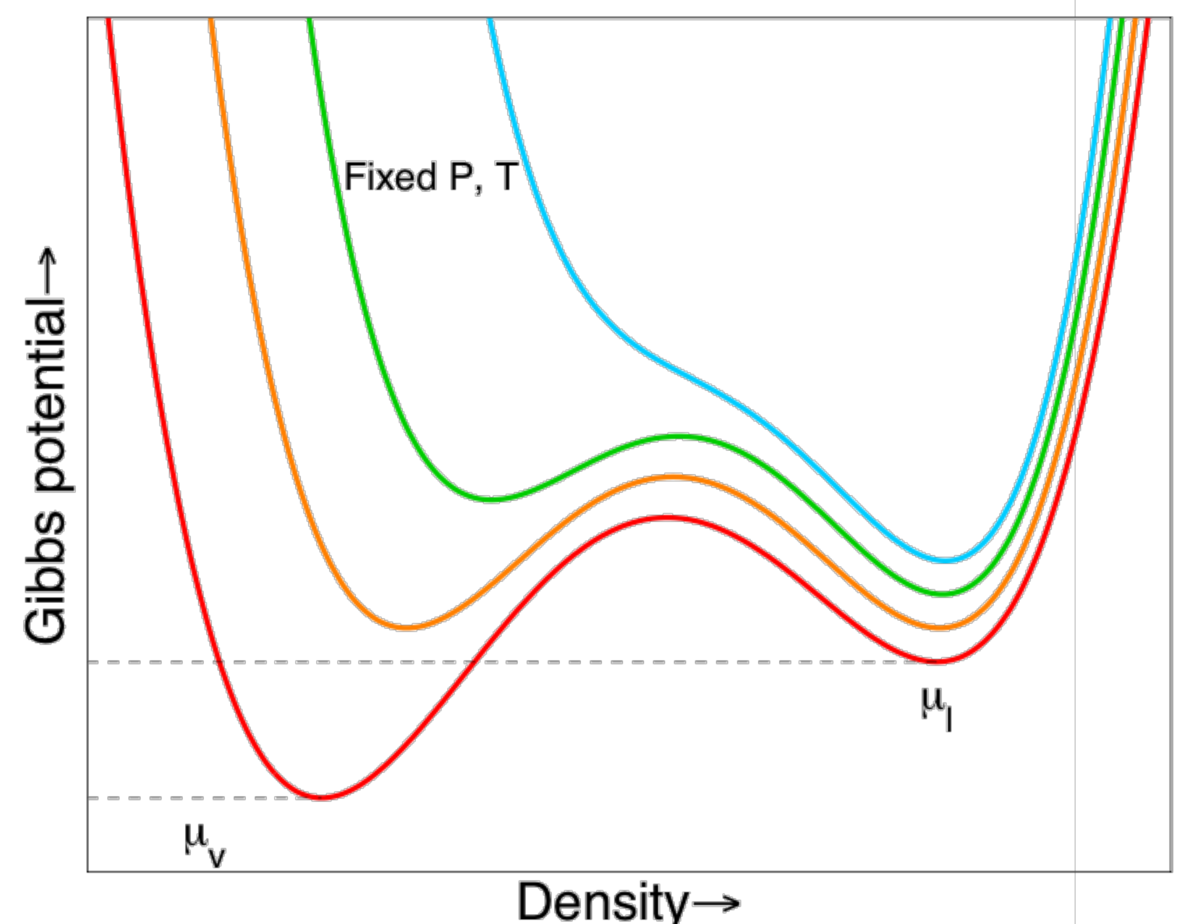
- Monday afternoon, 15:30 session:
  - B. Broerman - Scintillating Bubble Chambers for Rare Event Searches
    - (See also G. Putnam, Wednesday 19:00 neutrino session)
  - D. Huff - Dark Matter Searches with Liquid Argon in DEAP-3600 and DarkSide-20k
  - C. Amarasinghe - Results and status of the LUX-ZEPLIN (LZ) experiment
- Tuesday evening, 19:00 session:
  - A. Garai - The DEAP-3600 dark matter search and charged-current 8B measurements in liquid argon
  - D. Wenz - The first measurement of coherent elastic neutrino-nucleus scattering of solar 8B neutrinos in the XENONnT experiment
- Thursday afternoon, 14:00 neutrino session:
  - A. Schneider - Dark Sector Searches with Coherent CAPTAIN-Mills
- Several double beta decay talks (Monday 15:30 session, Tuesday 13:30 session, 19:00 session)
- Not to mention LAr TPCs for neutrinos
- Apologies if I missed your talk!

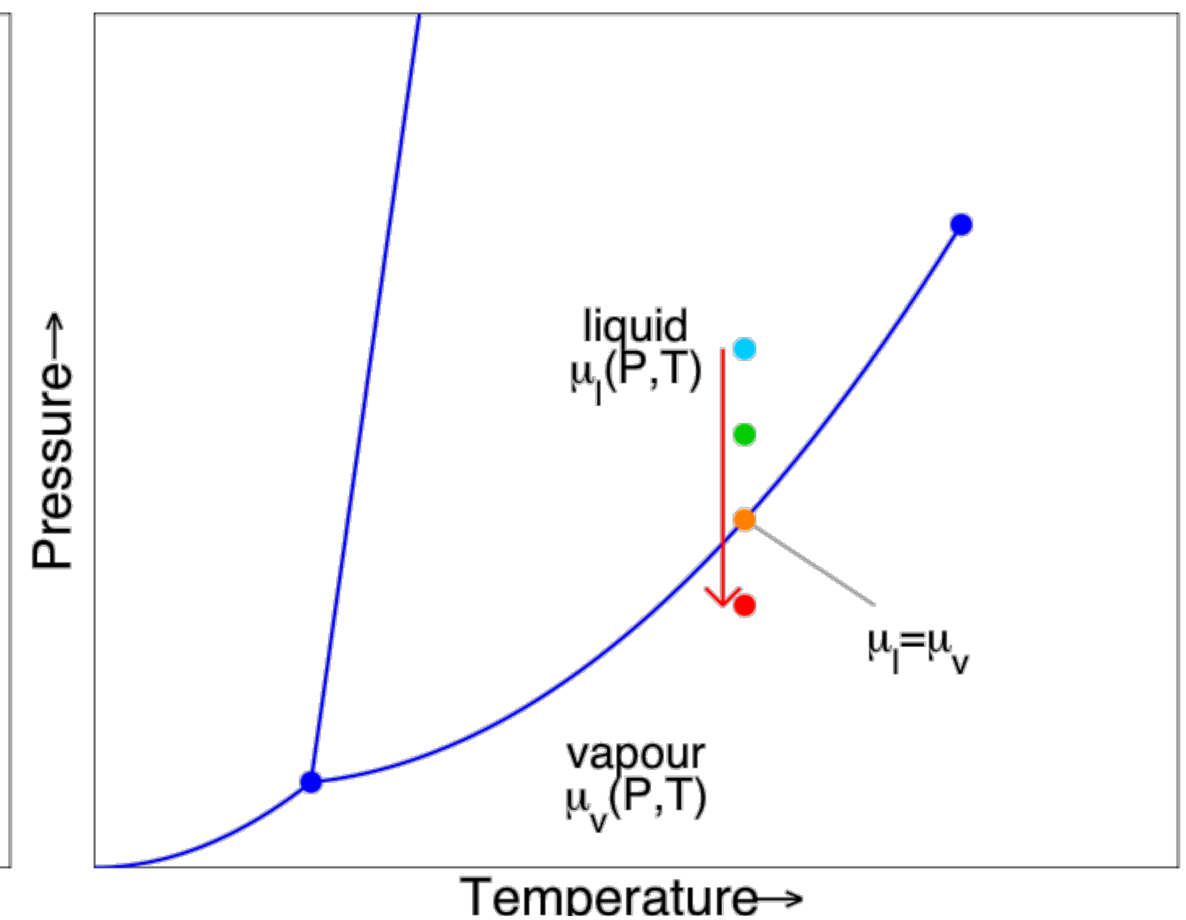
Lights in the dark

- Four multi-tonne detectors operating simultaneously, with more on the way!
- Demonstration of technological maturity
  - Building these detectors is hard!
  - Every time we build one, we find something we want to do better
- Ready for another push

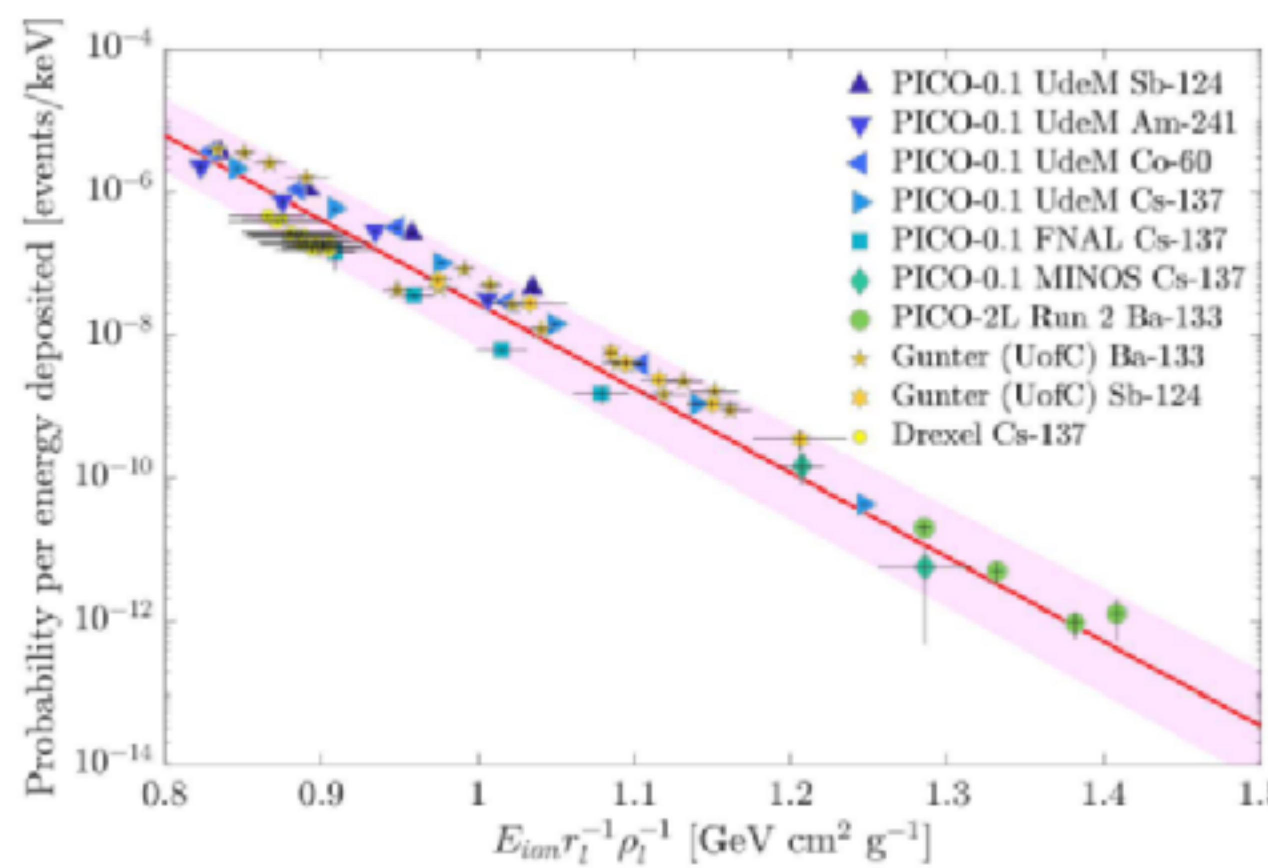


Bubble Chambers



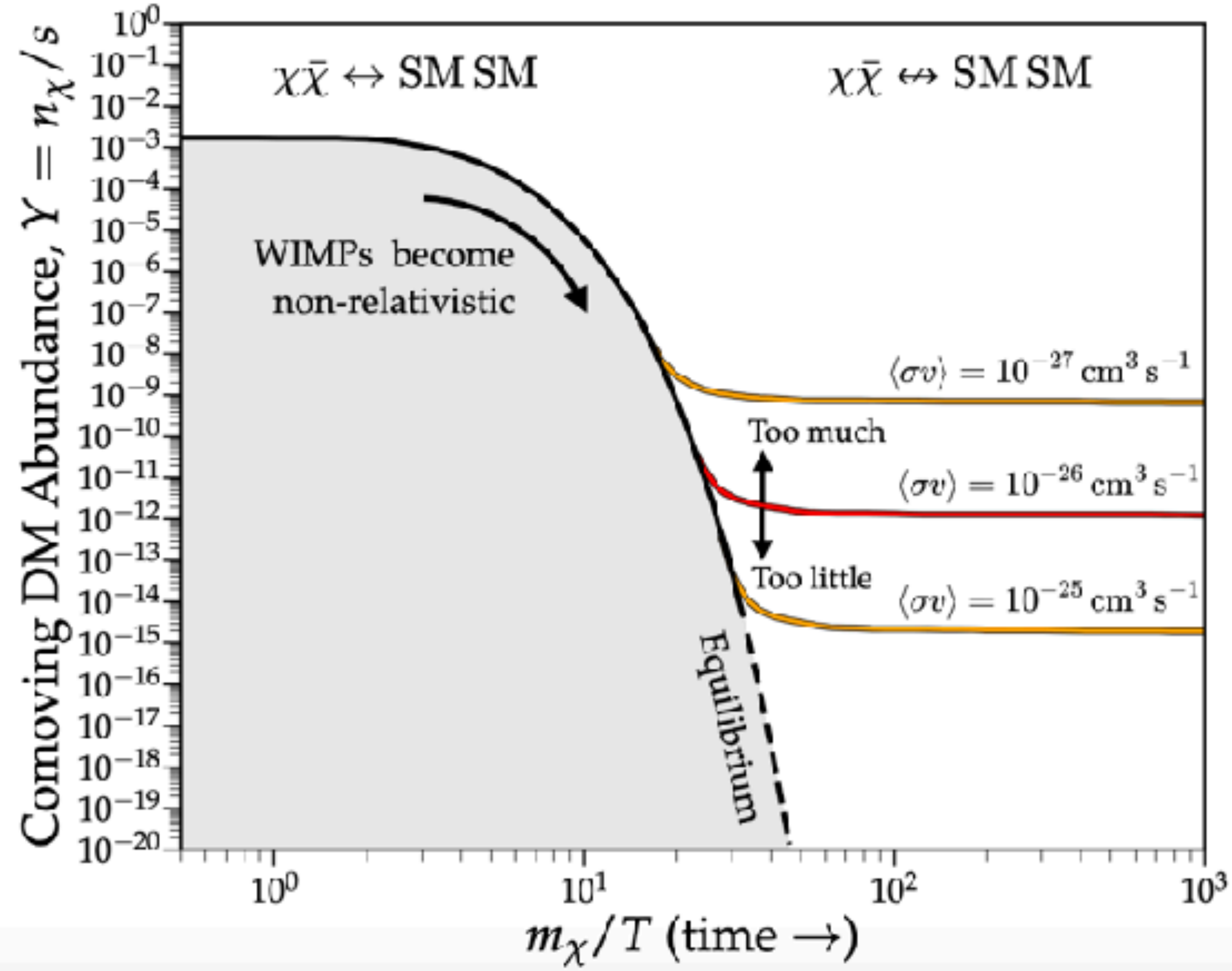


- Thermodynamics set sensitivity
- Need heat (energy) and density to make bubbles
  - ER do not cross density threshold
  - Acoustics provide further rejection
- Fluorine target with ~3 keV threshold



What is a WIMP and why is one attractive?

- Weakly Interacting Massive Particle
  - Subgroup of “Thermal Relic”
- Produced in big bang - initially in thermal equilibrium with normal matter (Standard Model)
  - Decouples from normal matter as universe expands and cools
- Continues self-annihilating until density is too small
  - Density frozen since that time
- Current observed density matches “weak scale” interaction strength

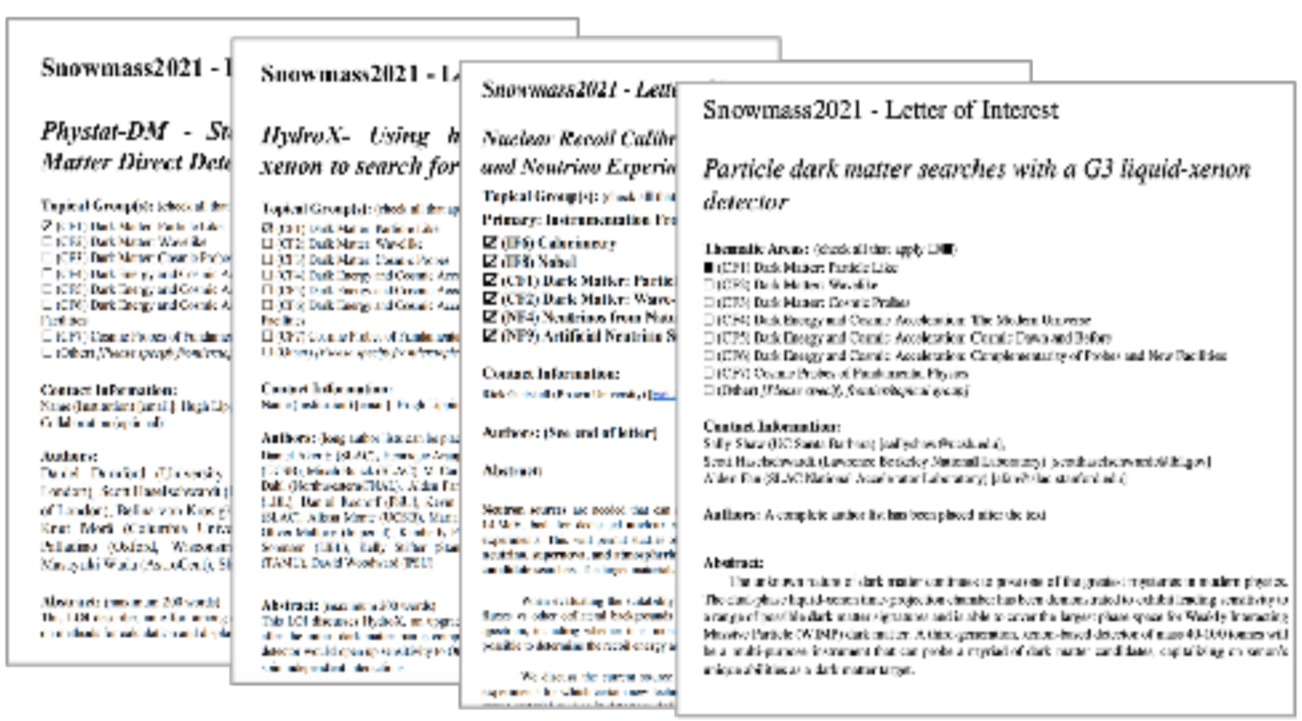


Snowmass and P5

- Today, dark matter is one of the biggest mysteries in particle physics

Illuminate
the
Invisible
Universe

P5 Report December 2023


Snowmass2021 - Letter of Interest

Particle dark matter searches with a G3 liquid-xenon detector

Thematic Areas:

Contact Information:

Authors:

Abstract:

- Most commonly mentioned topic in Snowmass LOIs

Snowmass and P5

- Today, dark matter is one of the biggest mysteries in particle physics today

Report of the Topical Group on Wave Dark Matter for Snowmass 2021

Conveners: Joerg Jaeckel[1], Gray Rybka[2], and Lindley Winslow[3]

[1]Institut für Theoretische
[2]Department of Phys
[3]Laboratory for Nuclear Science,

Report of the Topical Group on Particle Dark Matter for Snowmass 2021

Conveners: Jodi Cooley[1,2], Tongyan Lin[3], W. Hugh Lippincott[4], Tracy R. Slatyer[5], Tien-Tien Yu[6],
Contributors: Daniel S. Akerib[7], Tsuguo Aramaki[8], Daniel Baxter[9], Torsten Bringmann[10], Ray Bunker[11], Daniel Carney[12], Susana Cebrián[13], Thomas Y. Chen[14], Priscilla Cushman[15], C.E. Dahl[16], Rouven Essig [17], Alden Fan[7], Richard Gaitskell[18], Cristano Galbiati[19], Graciela B. Gelmini[20], Graham K. Giovanetti[21], Guillaume Giroux[22], Luca Grandi[23], J. Patrick Harding[24], Scott Haselschwardt[12], Lauren Hsu[5], Shunsaku Horiuchi[25], Yonatan Kahn[26], Doojin Kim[27], Geon-Bo Kim[28], Scott Kravitz[12], V. A. Kudryavtsev[29], Noah Kurinsky[7], Rafael F. Lang[30], Rebecca K. Leane[7], Benjamin V. Lehmann[31], Cecilia Levy[32], Shengchao Li[30], Marloff[33], Gopolang Mohlabeng[34], M.E. Monzani[7,35,36], Alexander St. Nelson[5], Ciaran A. J. O'Hare[39], K.J. Palladino[40], Aditya Parikh[41], Jun Profumo[31,45], Nirmal Raj[46], Brandon M. Roach[44], Tarek Saab[47], Mari Shaw[4], Seodong Shin[44], Kuver Sinha[50], Kelly Stifter[9], Aritoki Suzu Volodymyr Takhistov[51,52], Yu-Dai Tsai[34], S. E. Vahsen[53], Edoardo Gensheng Wang[54], Shawn Westerdale[55], David A. Williams[31]

Cosmic Probes of Dark Matter

Conveners: Alex Drlica-Wagner, Chanda Prescod-Weinstein, Hai-Bo Yu

Contributors: Andrea Albert, Mustafa Amin, Arka Banerjee, Masha Baryakhtar, Keith Bechtol, Simeon Bird, Simon Birrer, Torsten Bringmann, Regina Caputo, Sukanya Chakrabarti, Thomas Y. Chen, Djuna Croon, Francis-Yan Cyr-Racine, William A. Dawson, Cora Dvorkin, Vera Gluscevic, Daniel Gilman, Daniel Grin, Renée Hložek, Rebecca K. Leane, Ting S. Li, Yao-Yuan Mao, Joel Meyers, Siddharth Mishra-Sharma, Julian B. Muñoz, Ferah Munshi, Ethan O. Nadler, Aditya Parikh, Kerstin Perez, Annika H. G. Peter, Stefano Profumo, Katelin Schutz, Neelima Sehgal, Joshua D. Simon, Kuver Sinha, Monica Valluri, Risa H. Wechsler

- Over 100 pages of dedicated Snowmass reports in CF
- High prominence in other frontiers
- Dedicated Complementarity report

P5 Report

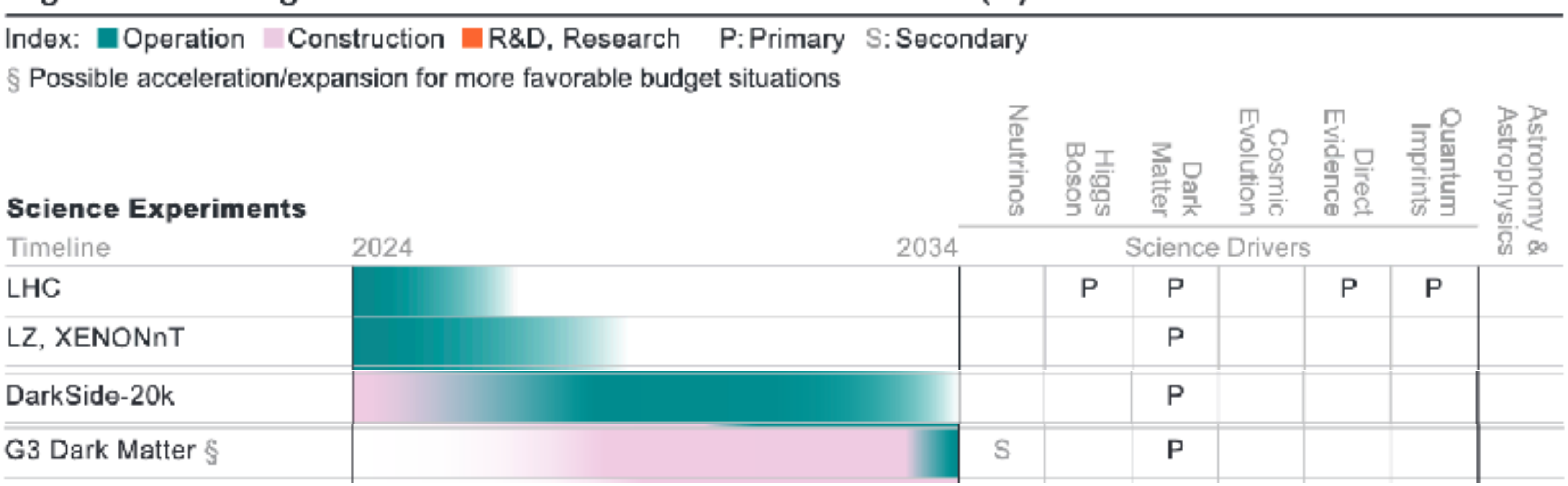
Decipher the Quantum Realm

Illuminate the Invisible Universe

Explore New Paradigms in Physics

- **Recommendation 2d:**
  - **An ultimate Generation 3 (G3) dark matter direct detection experiment reaching the neutrino fog, in coordination with international partners and preferably sited in the US (section 4.1).**

Figure 1 – Program and Timeline in Baseline Scenario (B)



P5 Report

- **DOE response to P5 (M. Procario, DPF, May 2024)**

G3 Dark Matter

- From P5 Recommendation 2, Priority 4 out of 5 :
  - An **ultimate Generation 3 (G3) dark matter** direct detection experiment reaching the neutrino fog, in coordination with international partners and **preferably sited in the US.**
- DOE response and actions:
  - At the present time, based on the Snowmass Community Summer Study, there have been two proposals for G3 Dark Matter detectors : XLZD and ARGO
  - P5 recommended a **domestic site for the experiment in the higher funding scenario** and an international site in the lower funding scenario.
  - Start with site independent R&D as we understand the funding that will be available.
    - Engage with partners who are interested in hosting.
  - DOE will entertain proposals by U.S. groups for pre-project R&D.

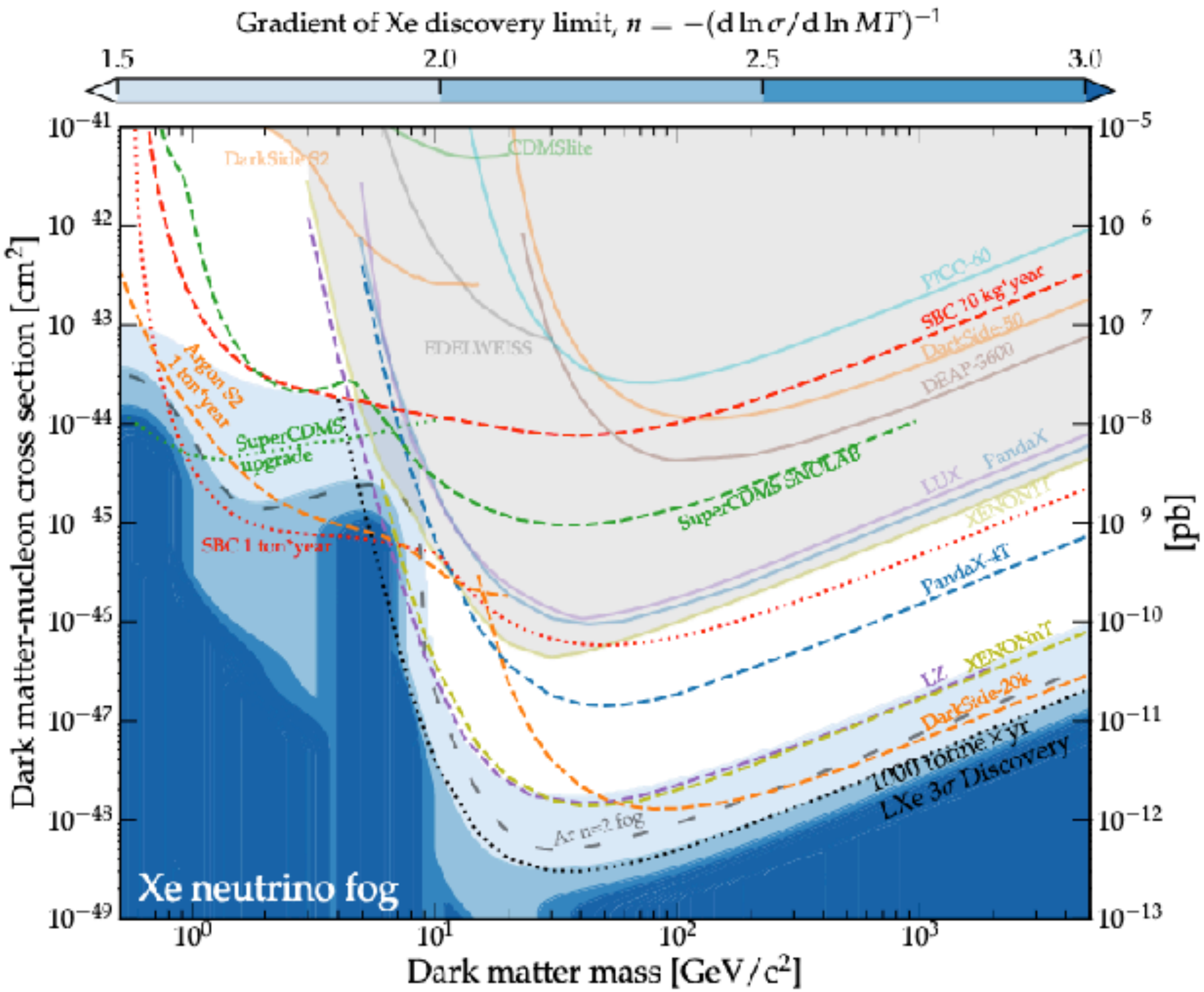
Key endorsements & roadmaps

- Astroparticle Physics European Consortium (APPEC) mid-term roadmap
- Helmholtz roadmap (DE)
- UKRI funds to develop XLZD
- SERI roadmap (CH)

"This improvement in reach would provide coverage of important benchmark WIMP models, such as most remaining potential dark matter parameter space under the constrained minimal supersymmetric extension to the Standard Model."

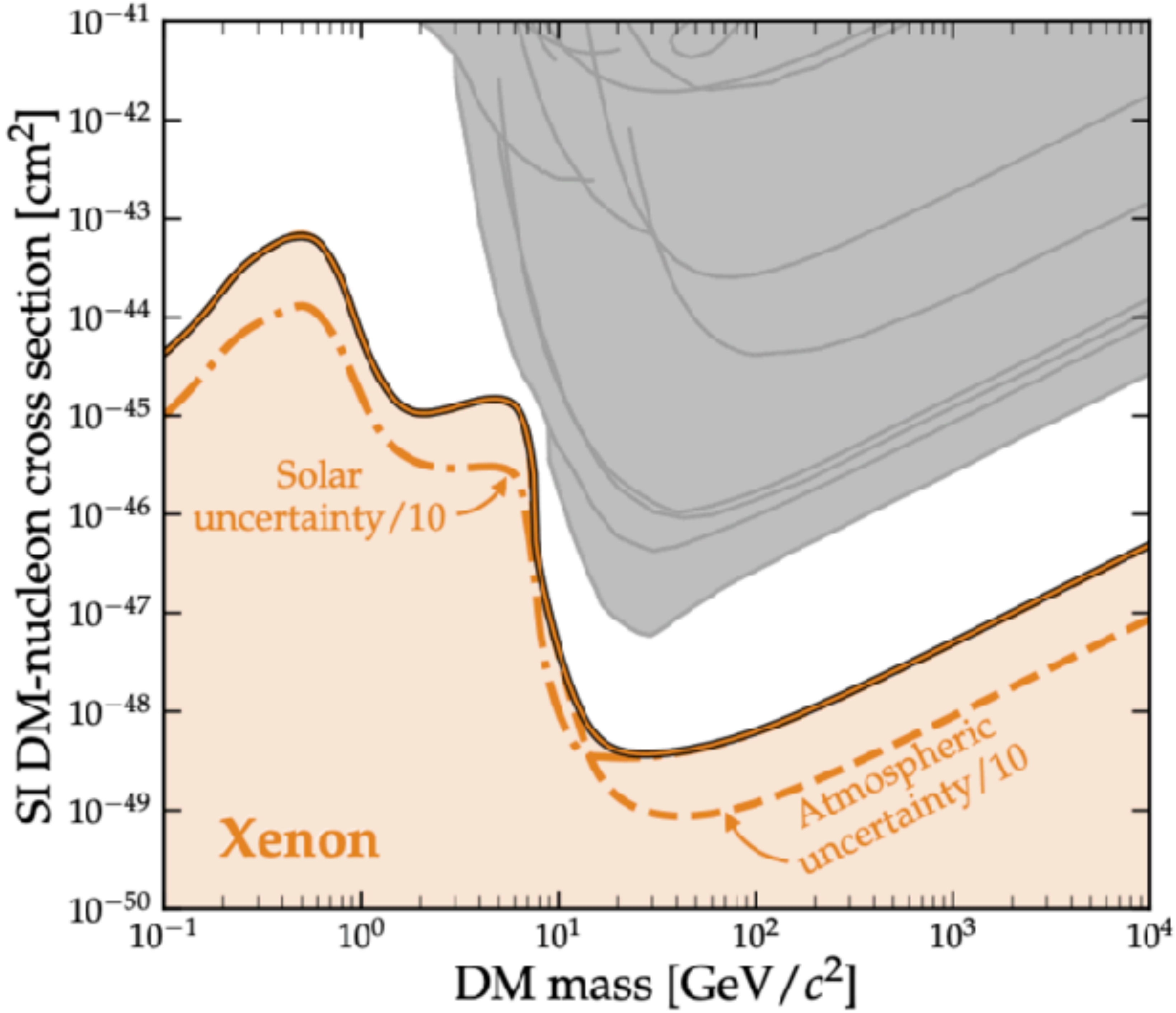
"APPEC strongly supports the European leadership role in Dark Matter direct detection, underpinned by the pioneering LNGS programme, to realise at least one next-generation xenon (order 50 tons) and one argon (order 300 tons) detector, respectively, of which at least one should be situated in Europe. APPEC strongly encourages detector R&D to reach down to the neutrino floor on the shortest possible me scale for WIMP searches for the widest possible mass range."

Neutrino Fog



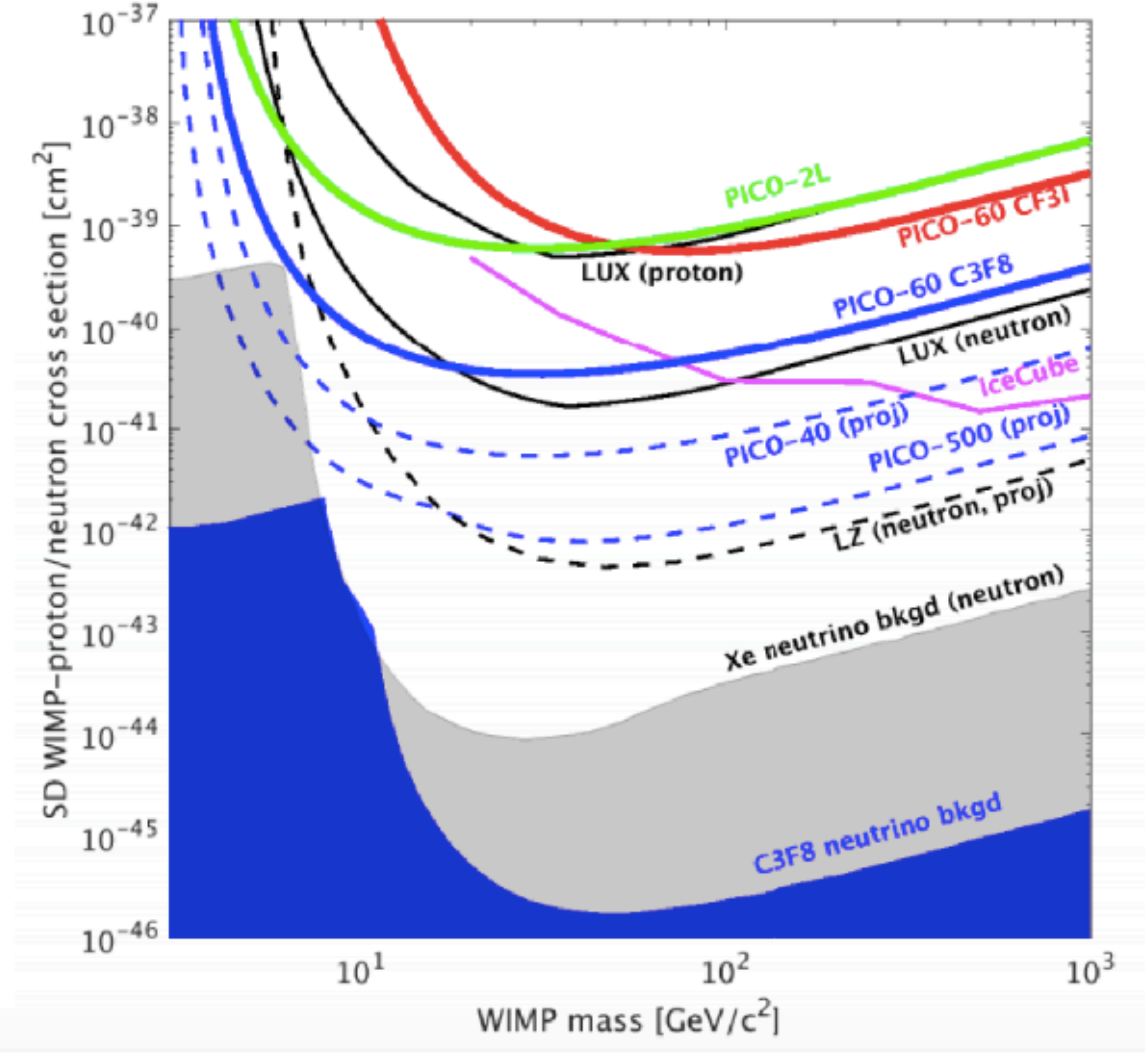
- Index n - how fast one makes progress with respect to background
- Increase in sensitivity by x10 requires 10^n more exposure

Neutrino Fog



- Future progress can be made with better measurements of the atmospheric neutrino flux

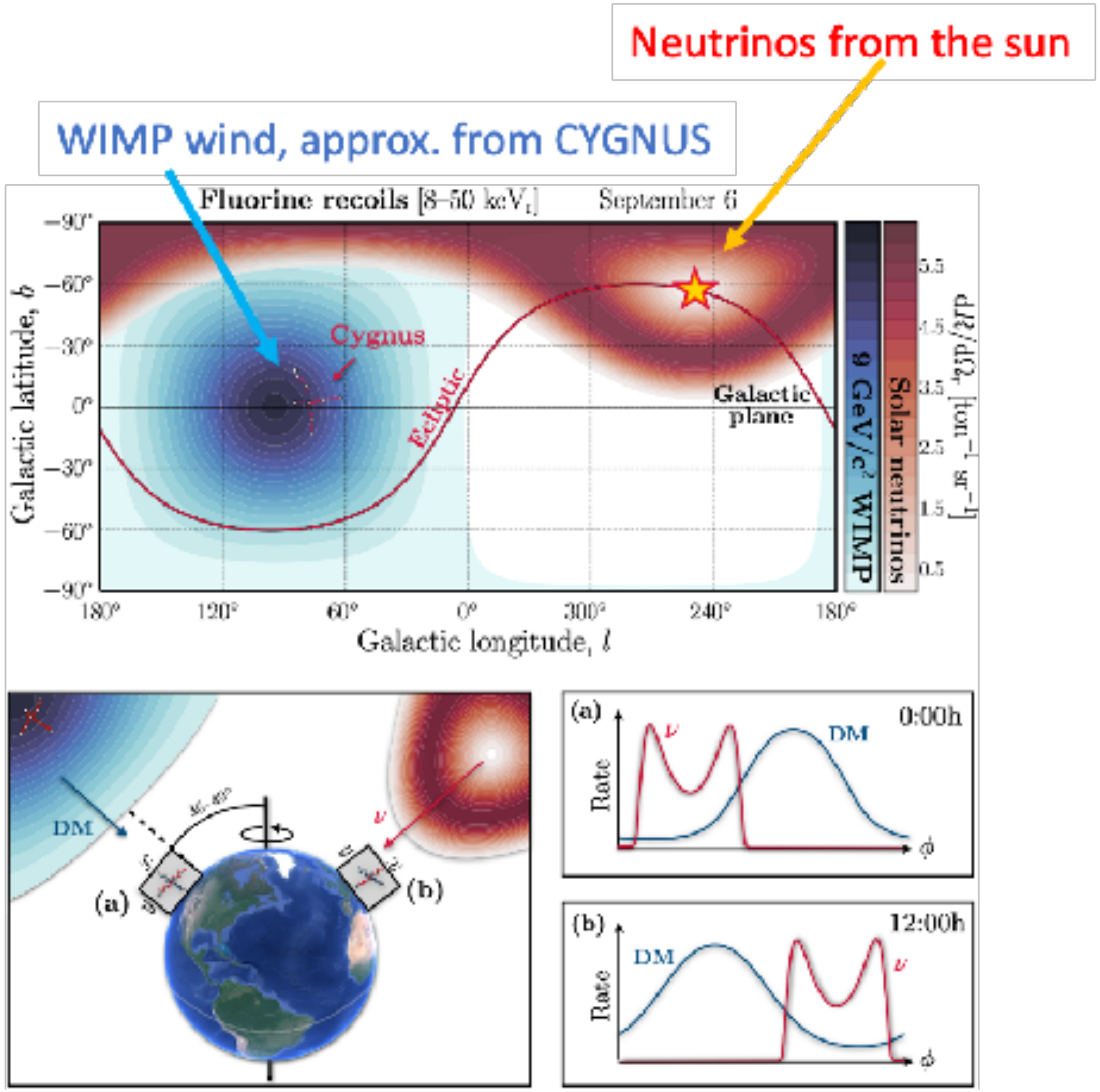
Neutrino Fog

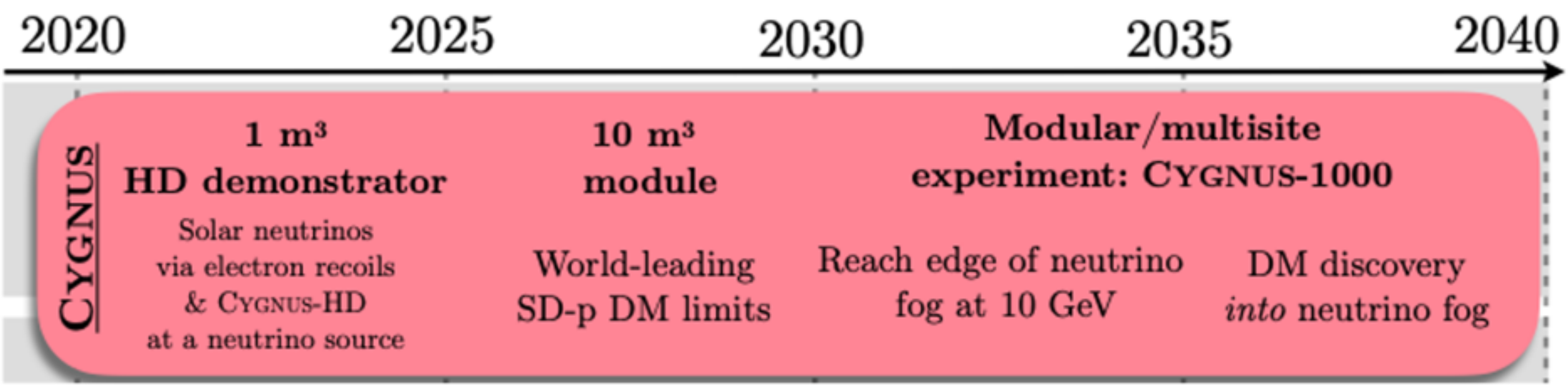


- Future progress can be made depending on target
  - Fluorine based SD detector can go deeper than xenon-based SD detector

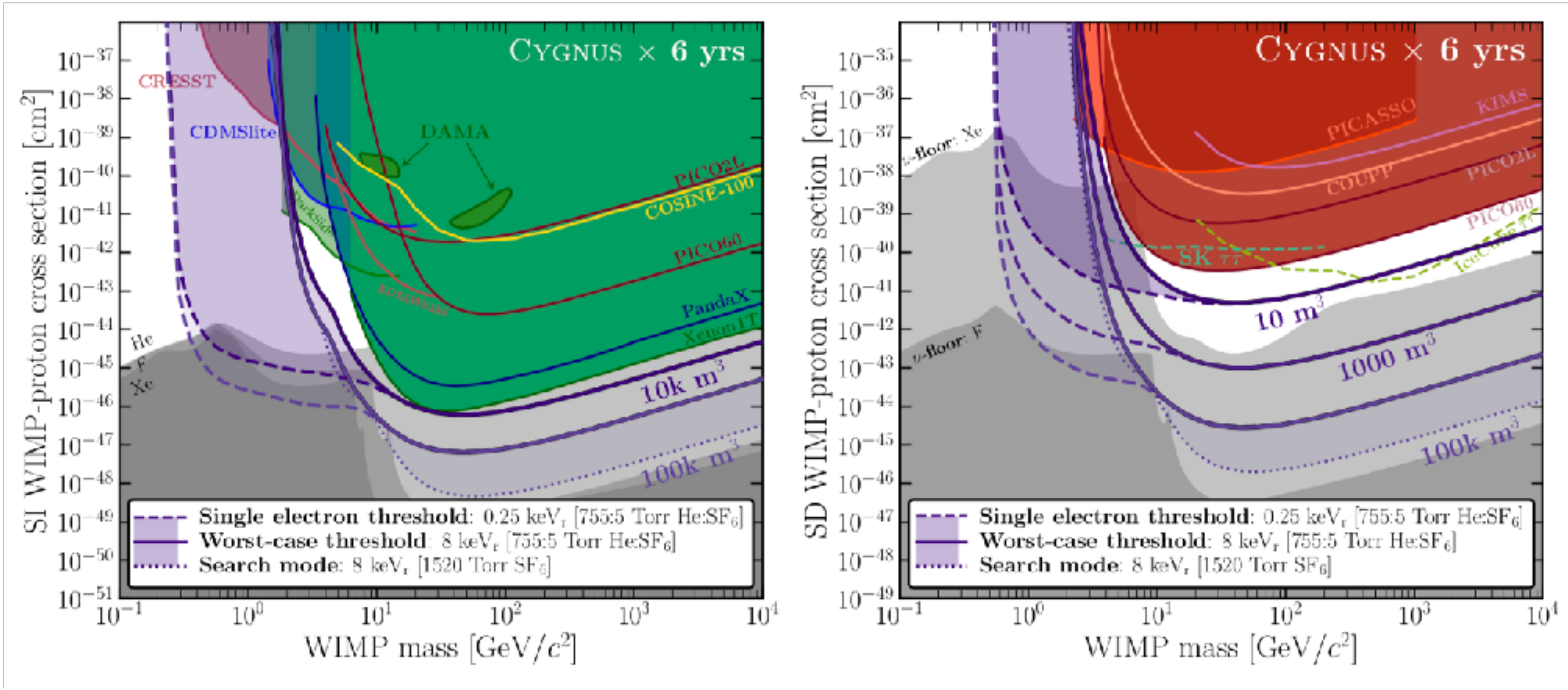
Directionality

- Directionality can identify WIMP wind with only handful of events
  - Ideal case - 3D direction plus energy
  - Experimentally challenging
- Cygnus program doing R&D now to enable large scale directionality
  - Physics program for dark matter and neutrinos described in 2102.04596

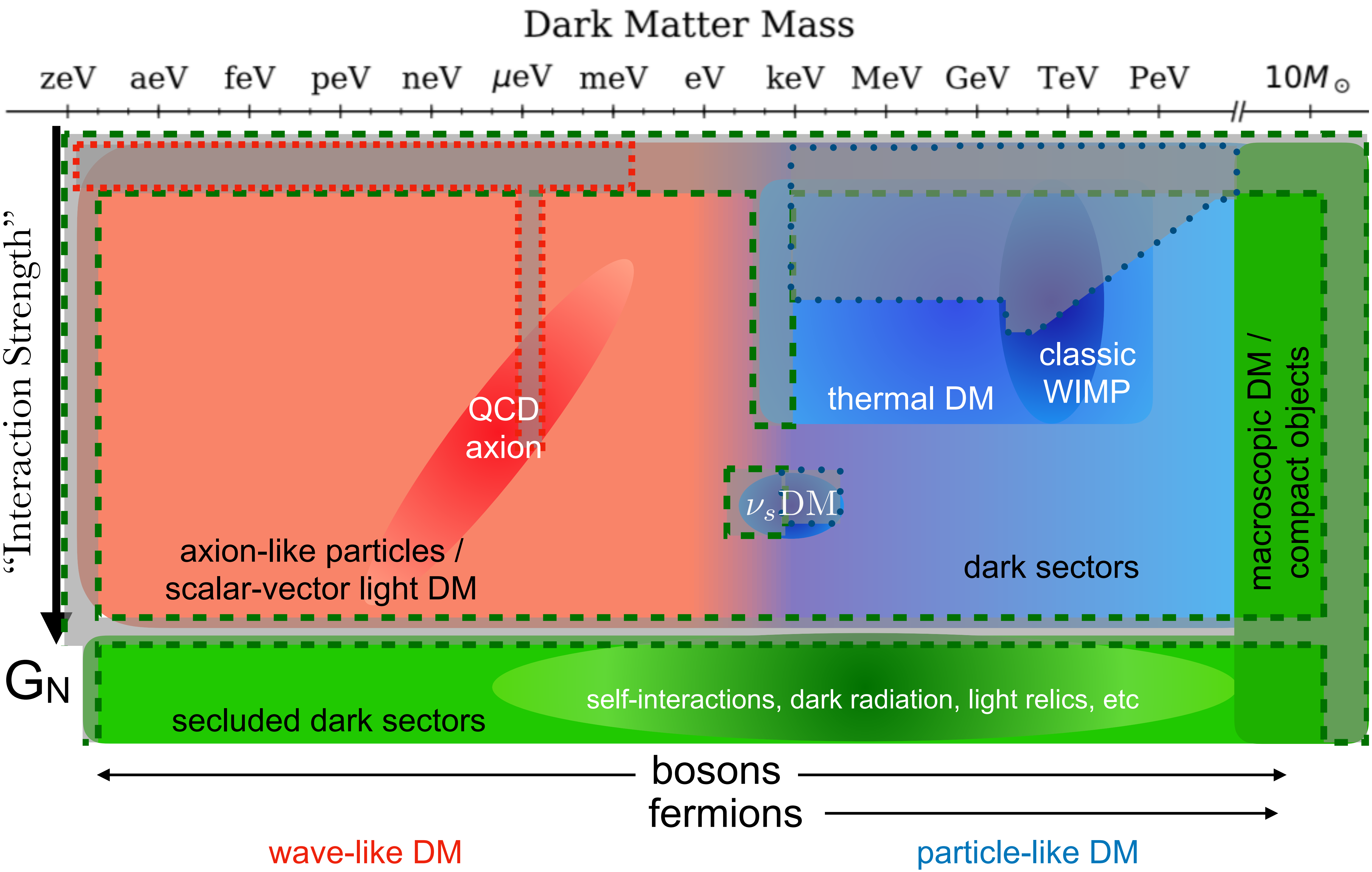




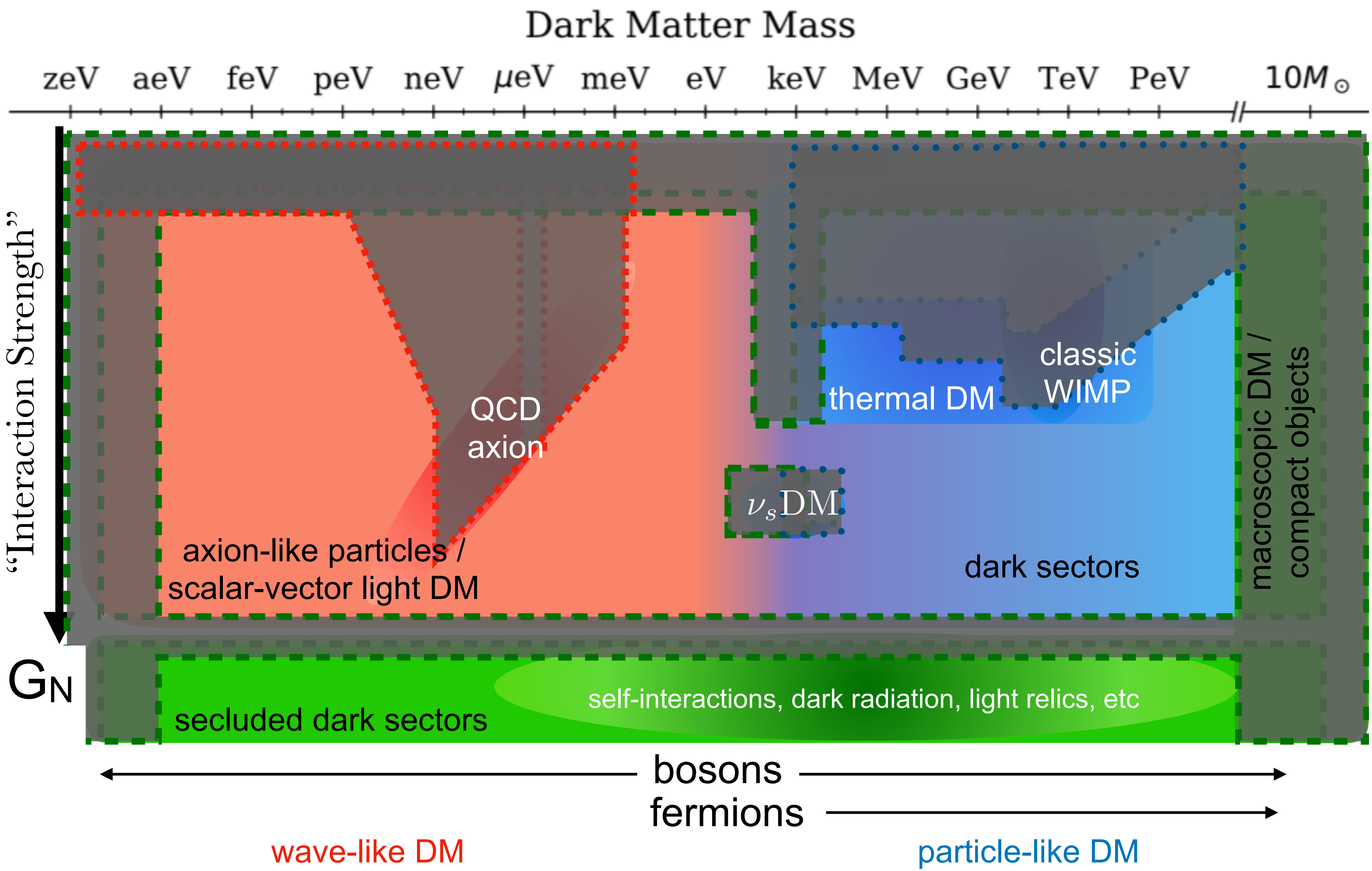
Directionality



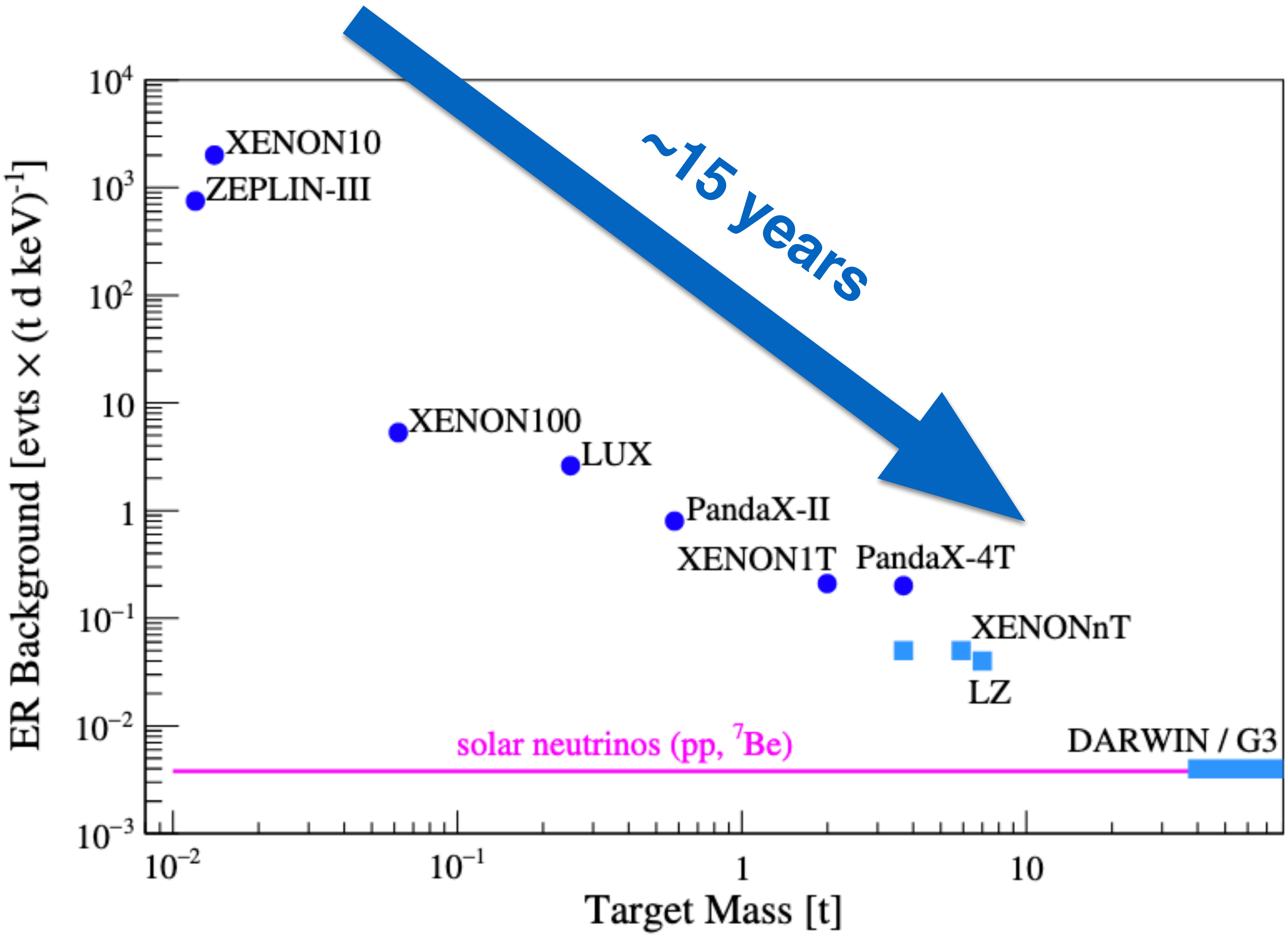
Current status



Plan for next decade

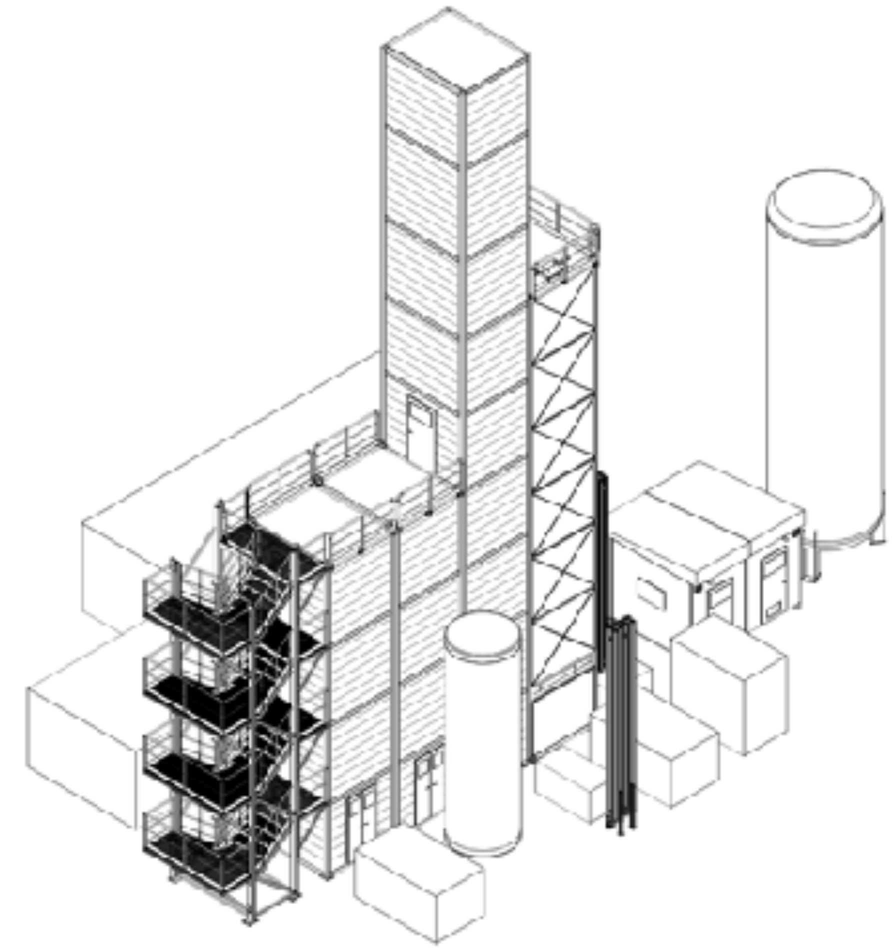


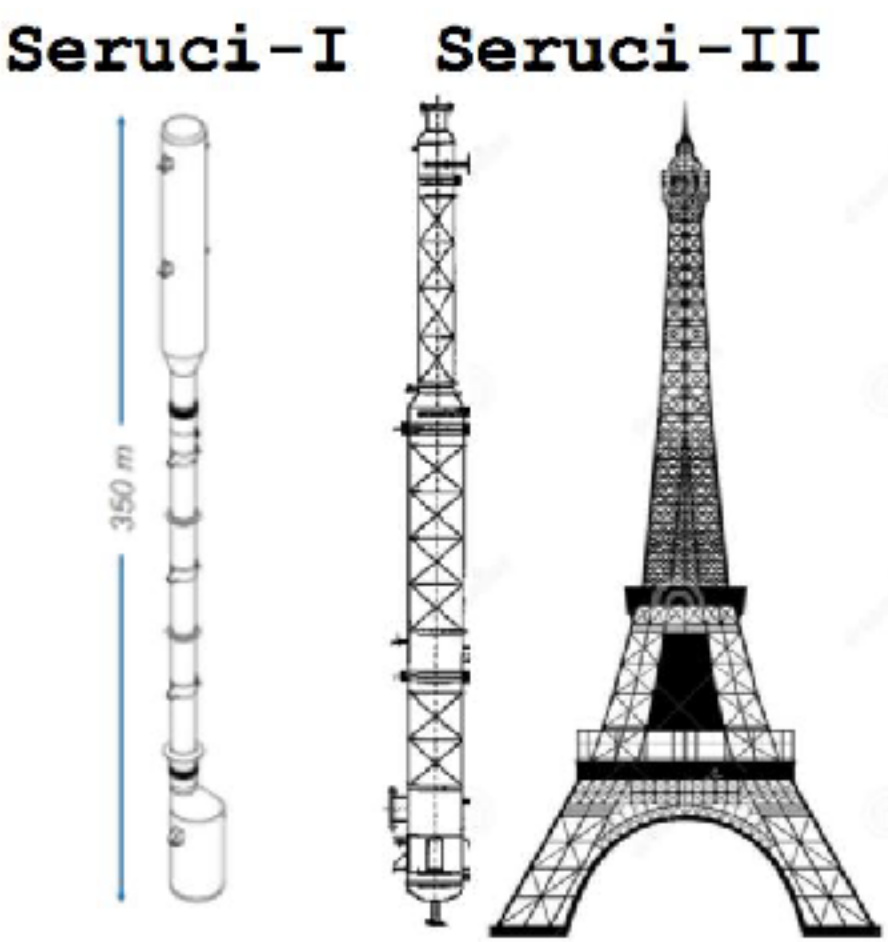
Liquid Xenon TPCs



URANIA

- Procurement of 50 tonnes of UAr from same Colorado source as for DS-50
- Extraction of 250 kg/day, with 99.9% purity
- UAr transported to Sardinia for final chemical purification at Aria



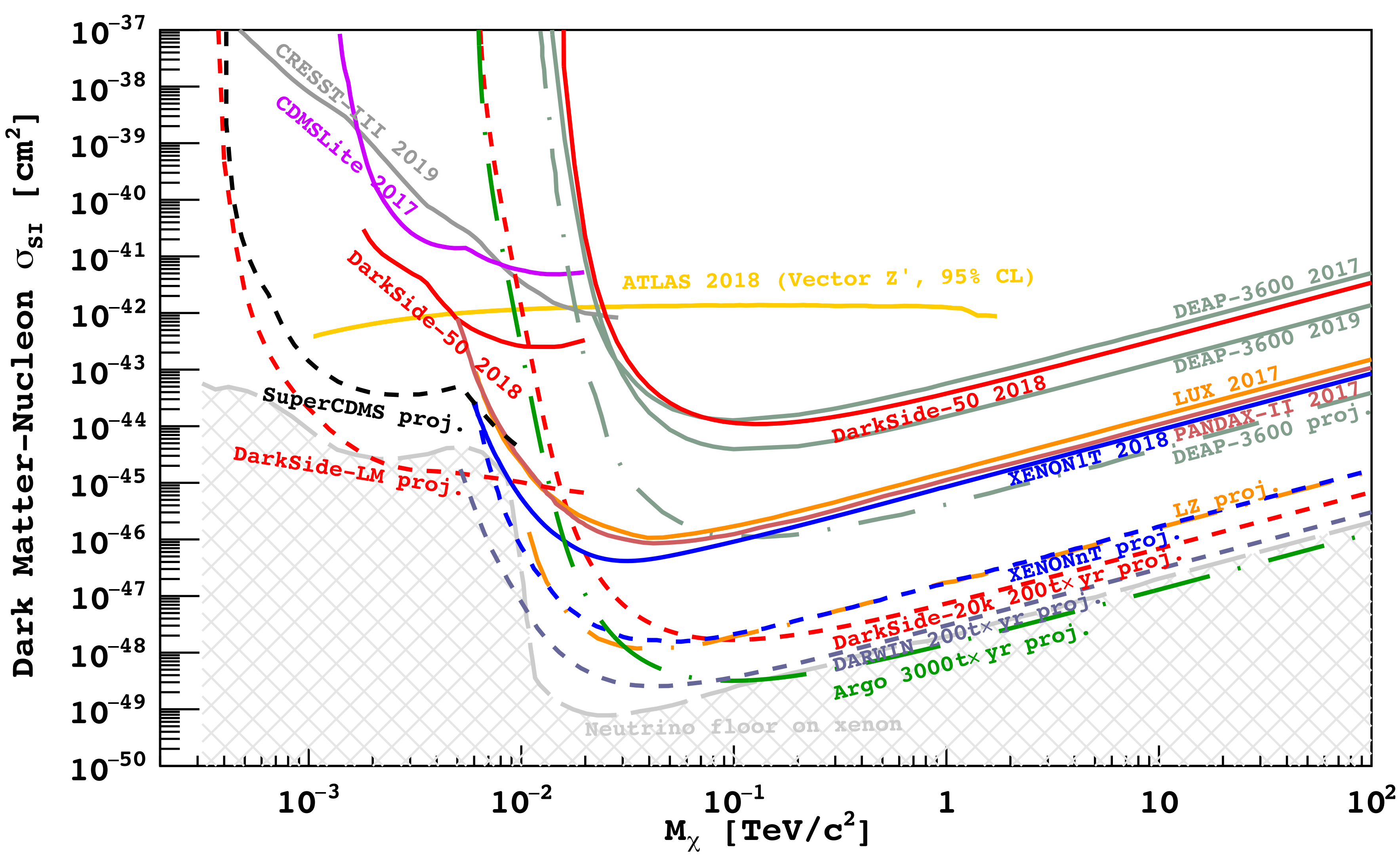


ARIA

- Big cryogenic distillation column in Seruci, Sardinia
- Final chemical purification of the UAr
- Can process O(1 tonne/day) with 10^3 reduction of all chemical impurities
- Ultimate goal is to isotopically separate ^{39}Ar from ^{40}Ar (at the rate of 10 kg/day in Seruci-I)

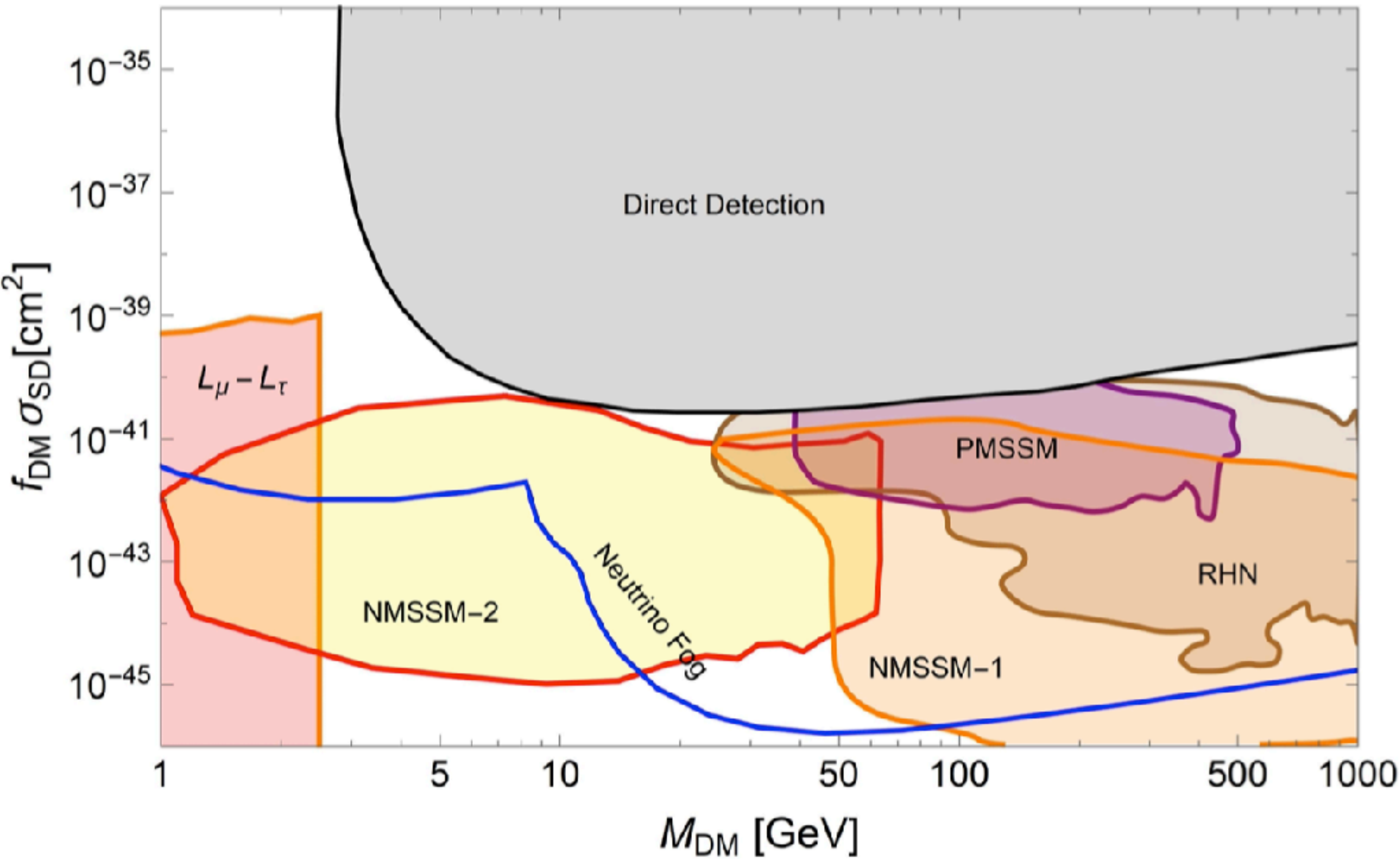
ARGO

- ArDM, DS-50, DEAP-3600, and MiniCLEAN jointly formed the Global Argon Dark Matter Collaboration (GADMC)
- A 300-tonnes fiducial argon detector filled with underground argon
- 3000 tonne×year exposure to reach the neutrino floor



GADMC experiments cover the WIMP hypothesis from 1GeV/c² to several hundreds of TeV/c² masses in the search for spin-independent coupling.

What are we looking for? (Spin Dependent)



CF Snowmass 2203.08084