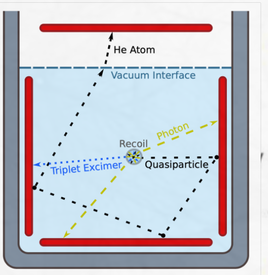
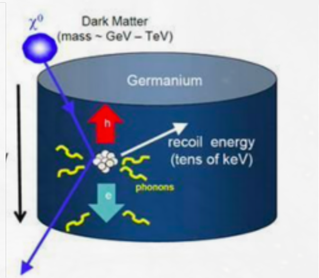
Tsinghua University

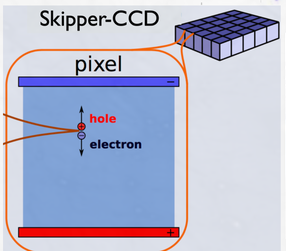
WINDOWS ON THE UNIVERSE
30th Anniversary of the Rencontres du Vietnam
August 6-12, 2023, Quy Nhon, Vietnam

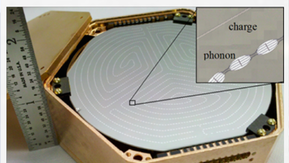
Dark Matter Search Experiments

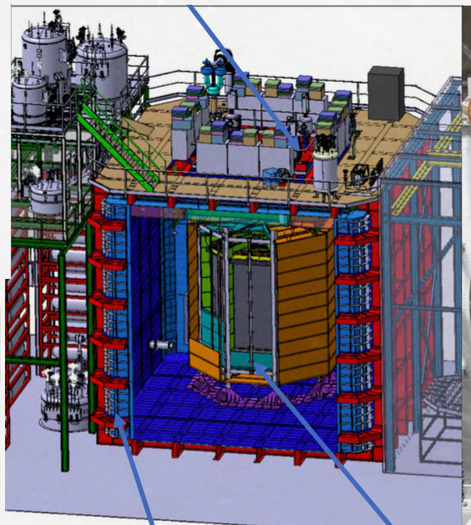
Fei Gao
Tsinghua University

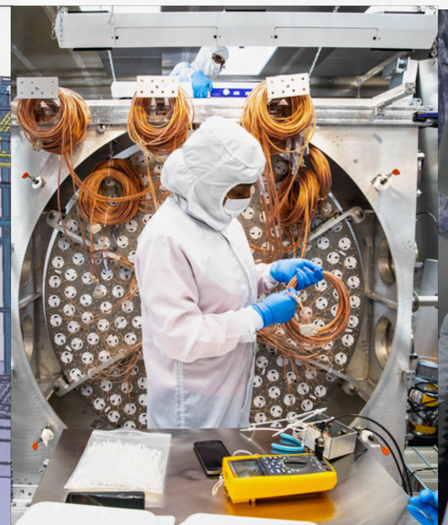


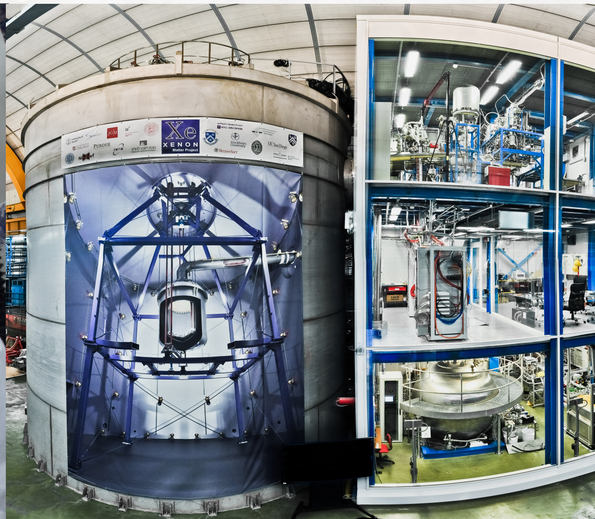




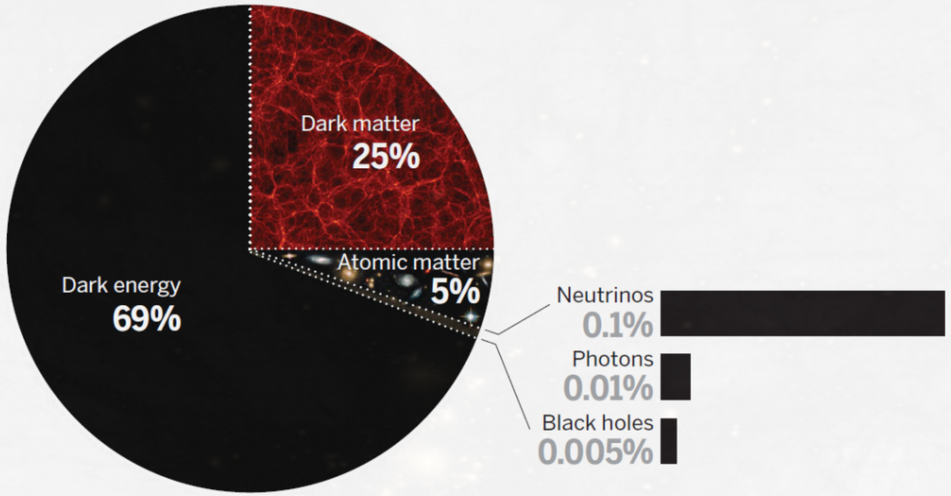




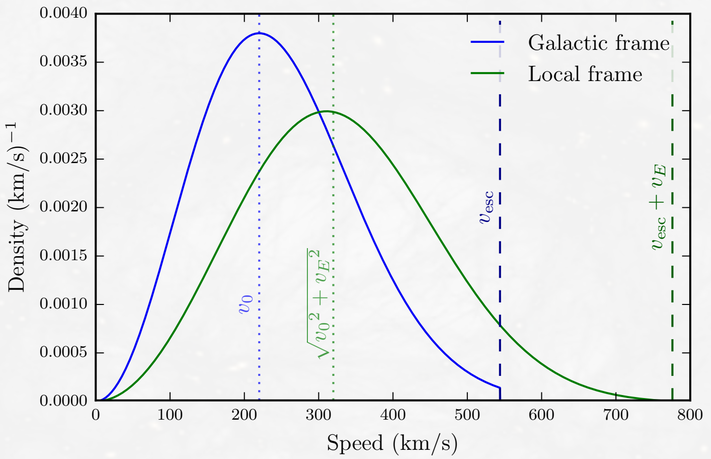


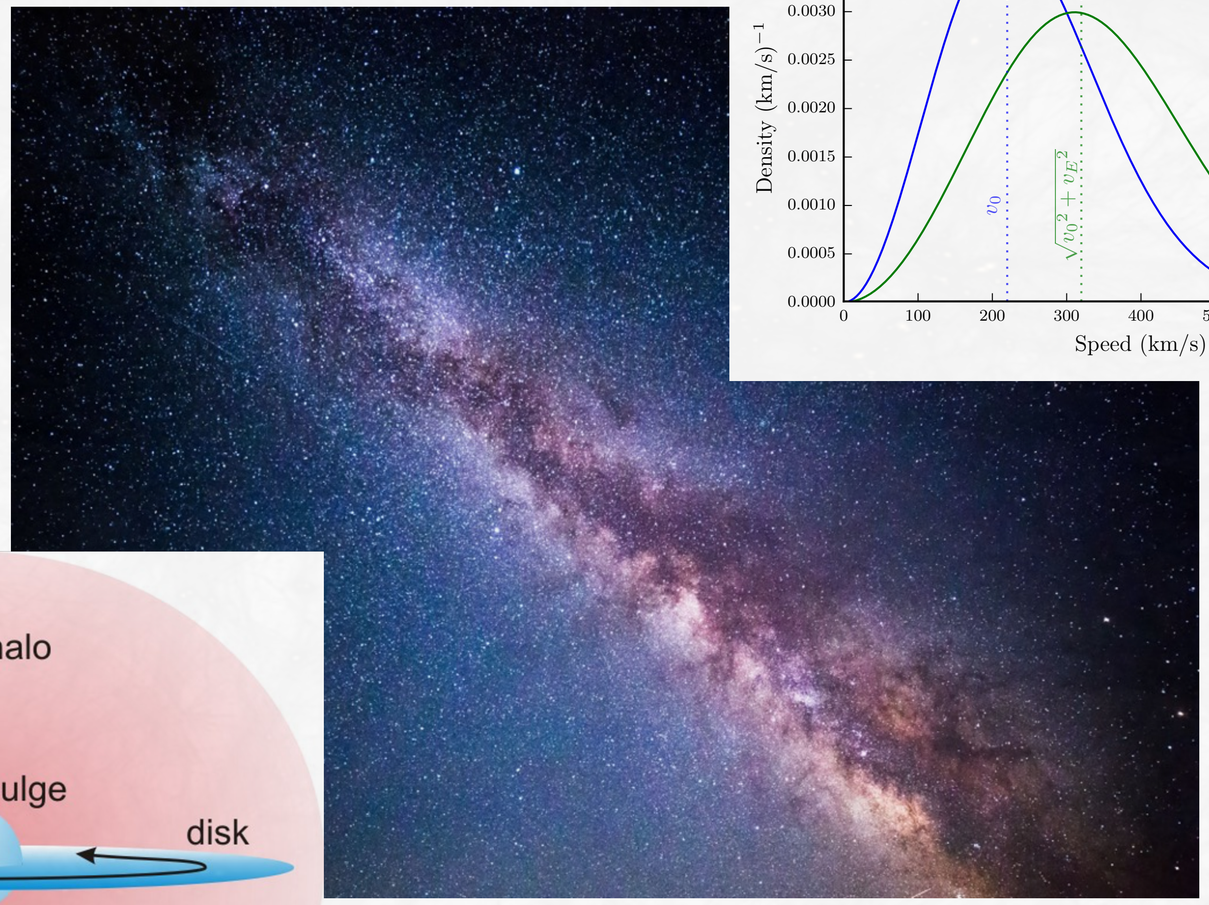


Dark Matter

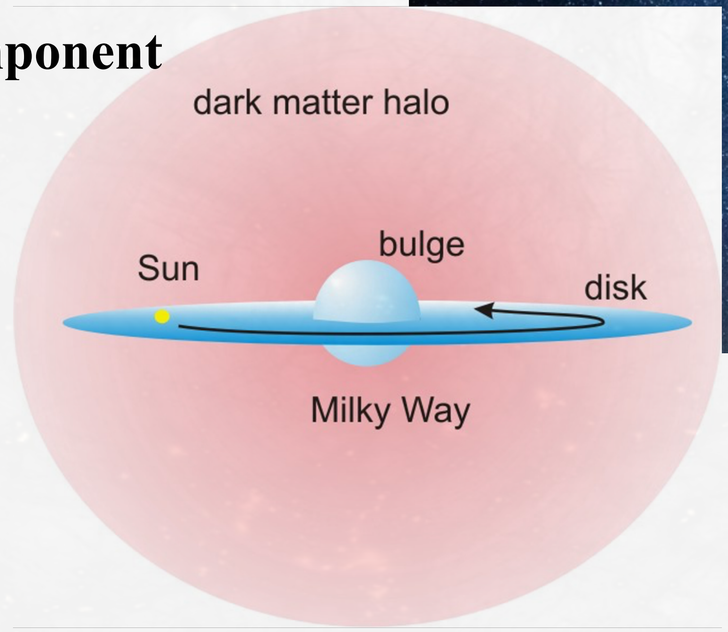


Constant flux of dark matter.





Dark Matter is a Major Component of the Universe



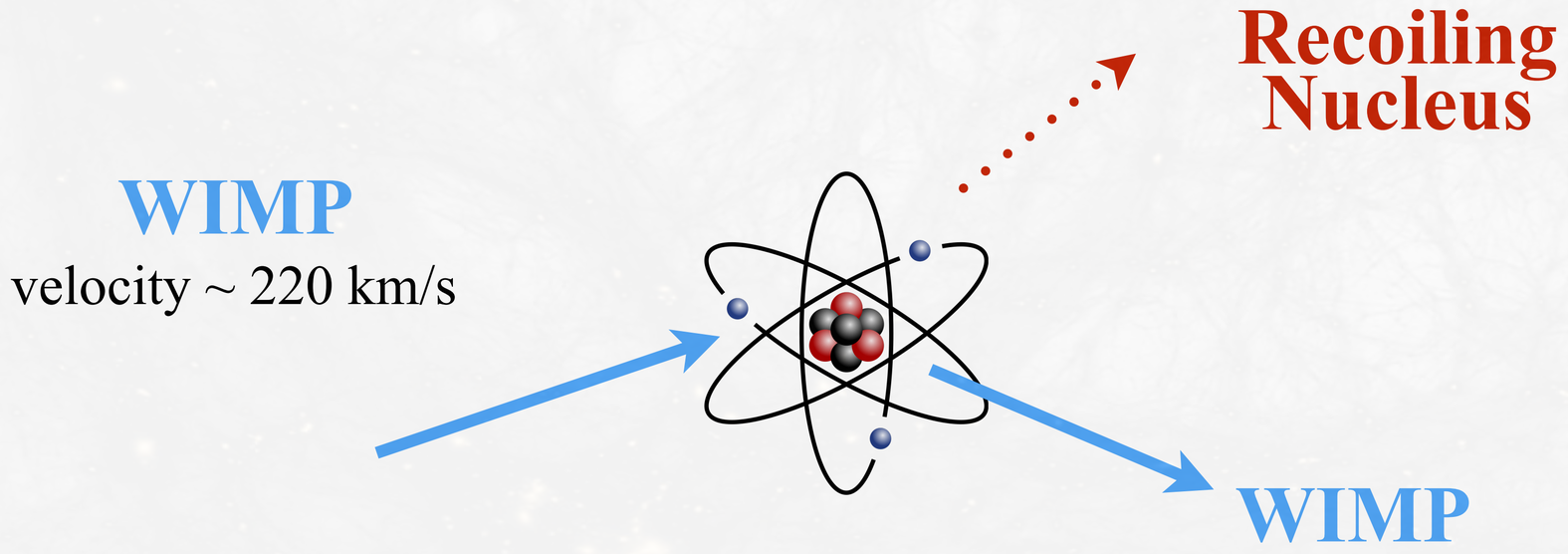
The local dark matter density is around 0.3 GeV/cm^3

PHYSICAL REVIEW D VOLUME 31, NUMBER 12 15 JUNE 1985

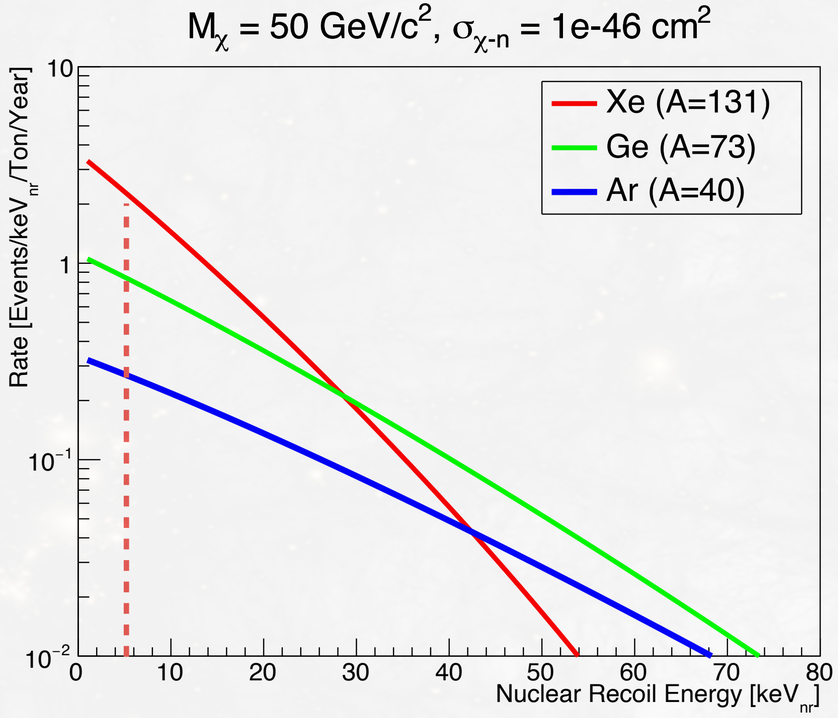
Detectability of certain dark-matter candidates

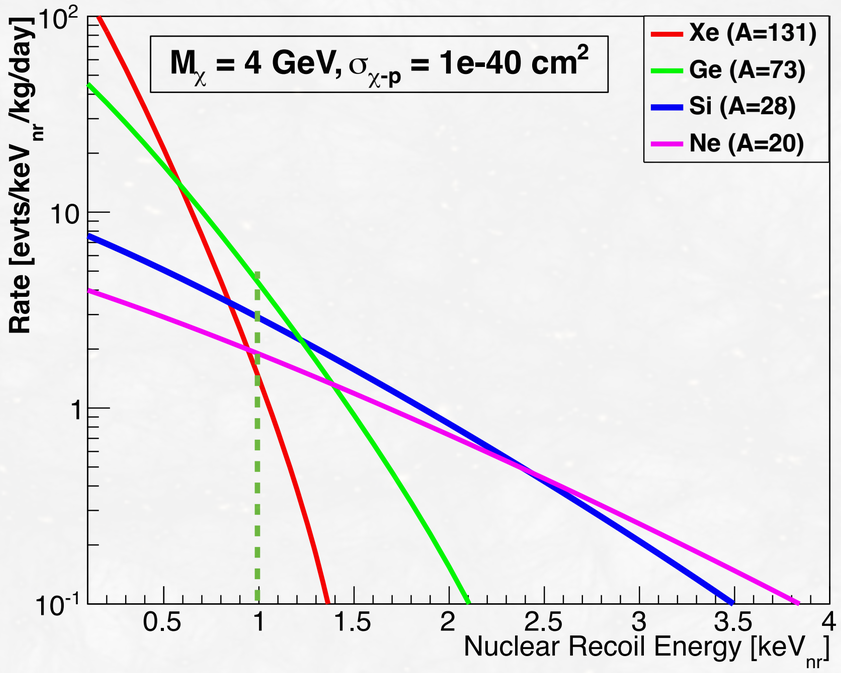
Mark W. Goodman and Edward Witten
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08544
(Received 7 January 1985)

We consider the possibility that the neutral-current neutrino detector recently proposed by Drukier and Stodolsky could be used to detect some possible candidates for the dark matter in galactic halos. This may be feasible if the galactic halos are made of particles with coherent weak interactions and masses $1-10^6$ GeV; particles with spin-dependent interactions of typical weak strength and masses $1-10^2$ GeV; or strongly interacting particles of masses $1-10^{13}$ GeV.



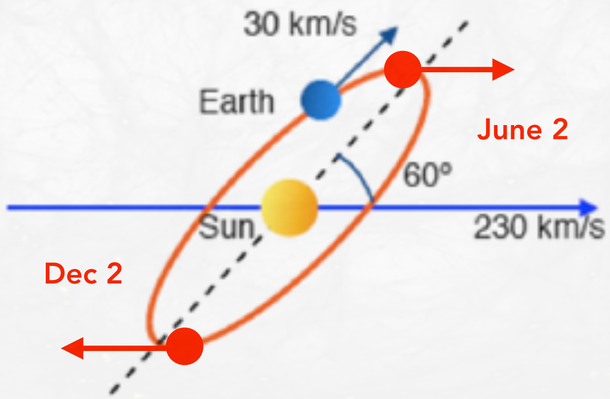
Signatures of Dark Matter Interactions





1. Exponentially falling nuclear recoil energy spectrum

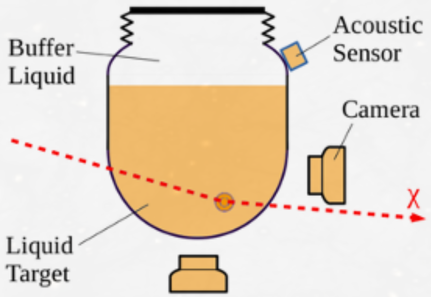
2. Annually modulating signal rate



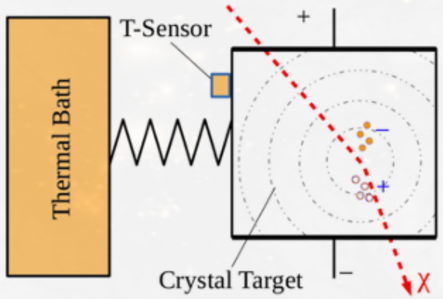
see Federico's talk this Thursday afternoon!

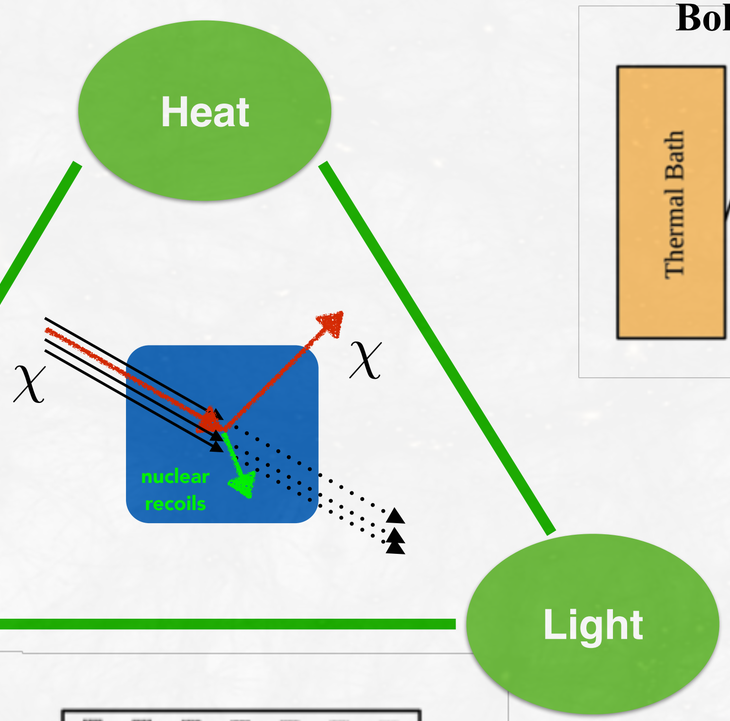
Detection Techniques

Bubble Chamber

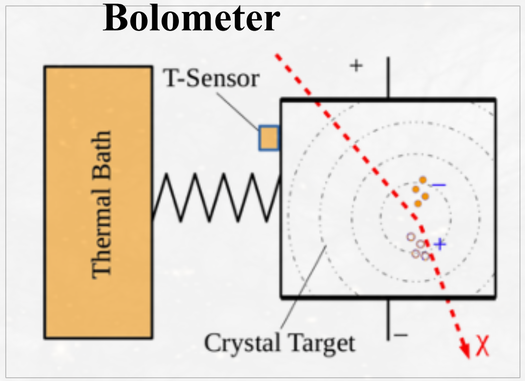


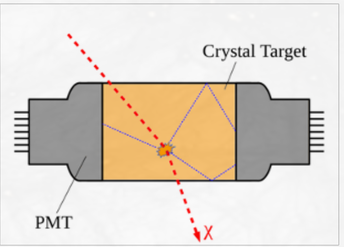
Bolometer



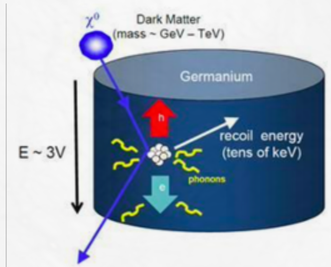


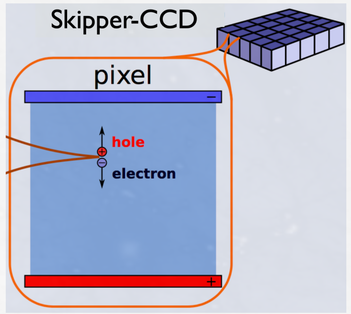
Bolometer

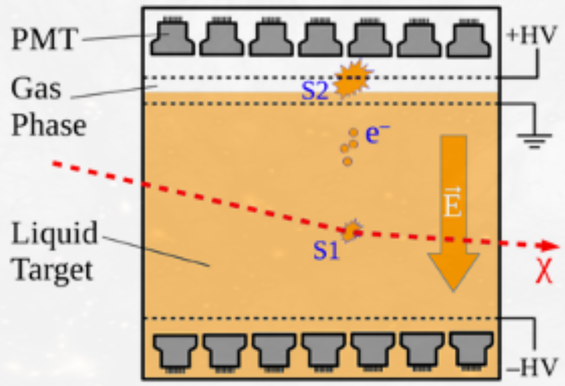




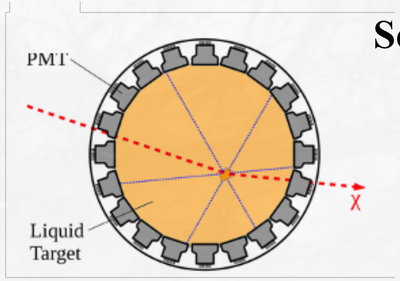
Point Contact Ge





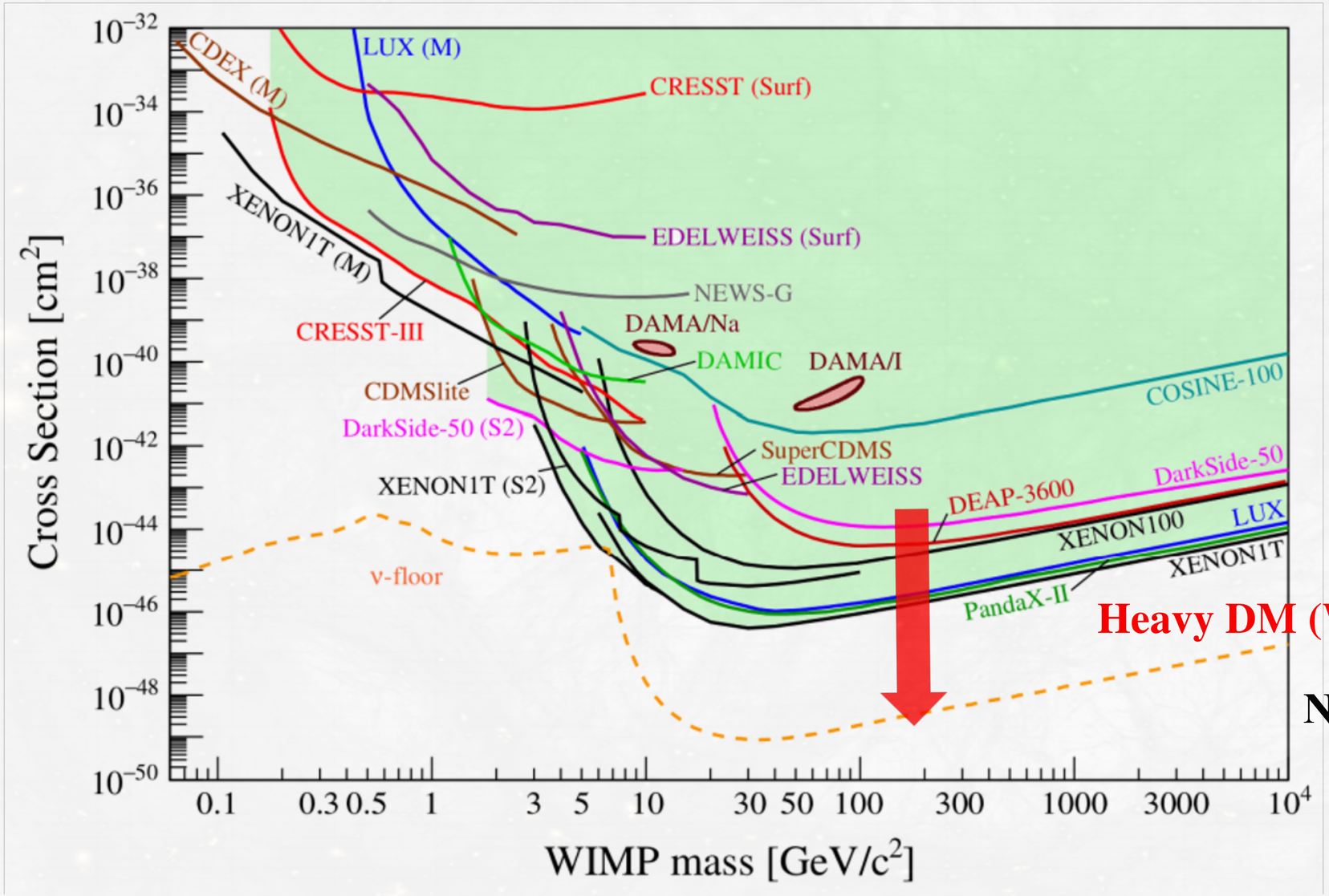


Scintillator



2104.07634, APPEC report (2021)

Status of Dark Matter Searches

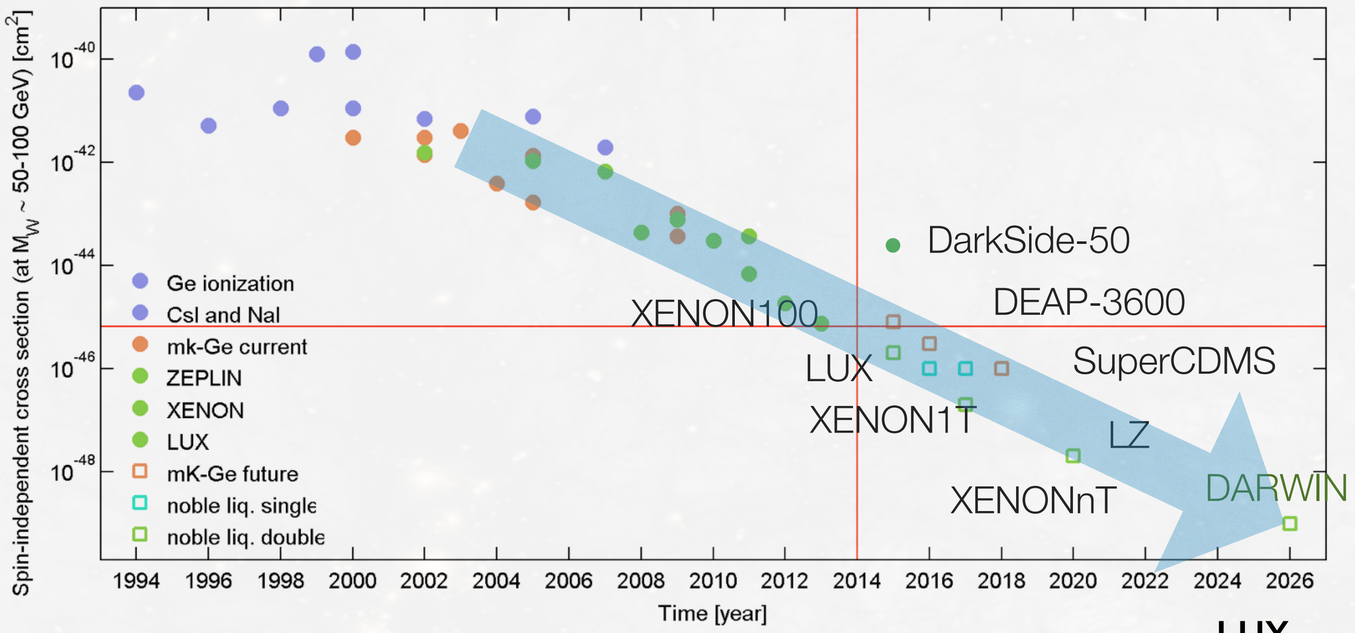


Heavy DM (WIMPs)

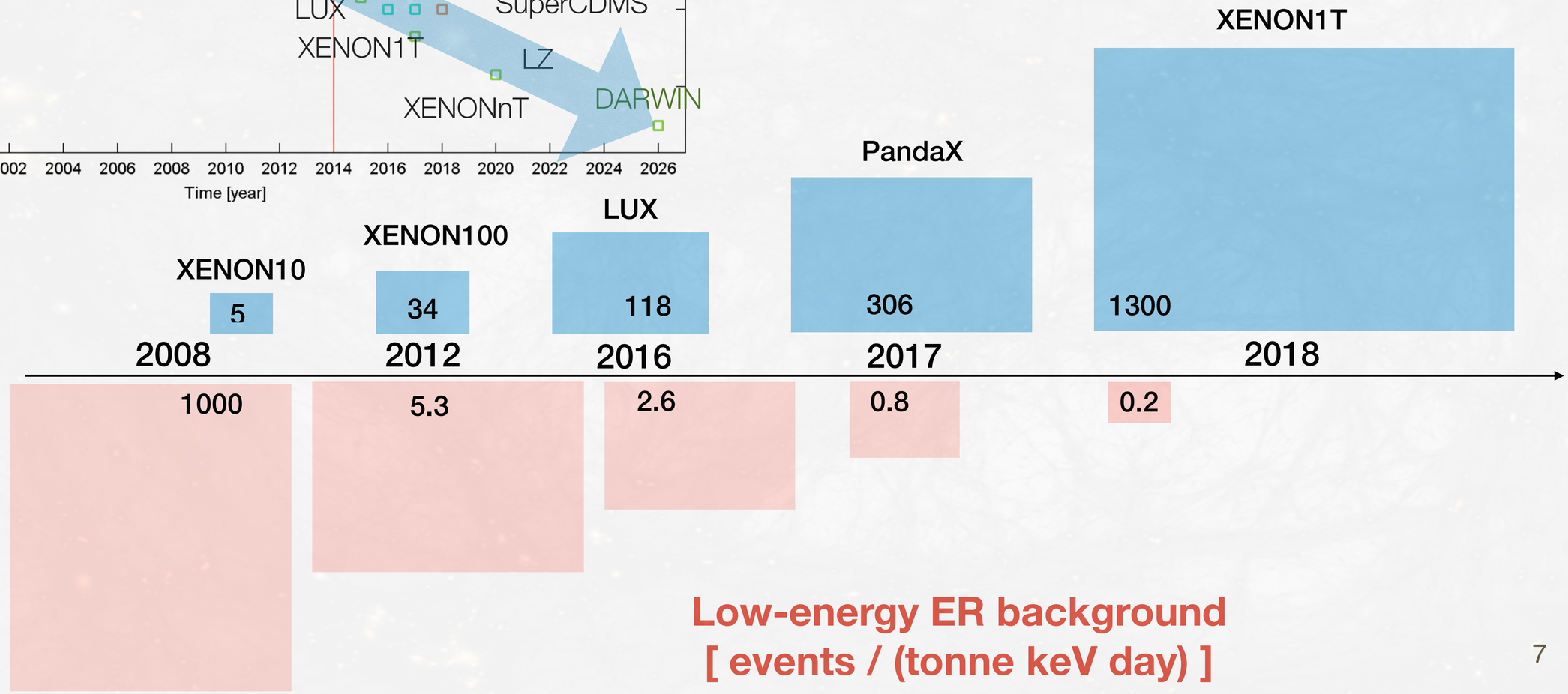
Noble Liquid TPC

2104.07634, APPEC report (2021)

heavy WIMPs searches: sensitivity vs time

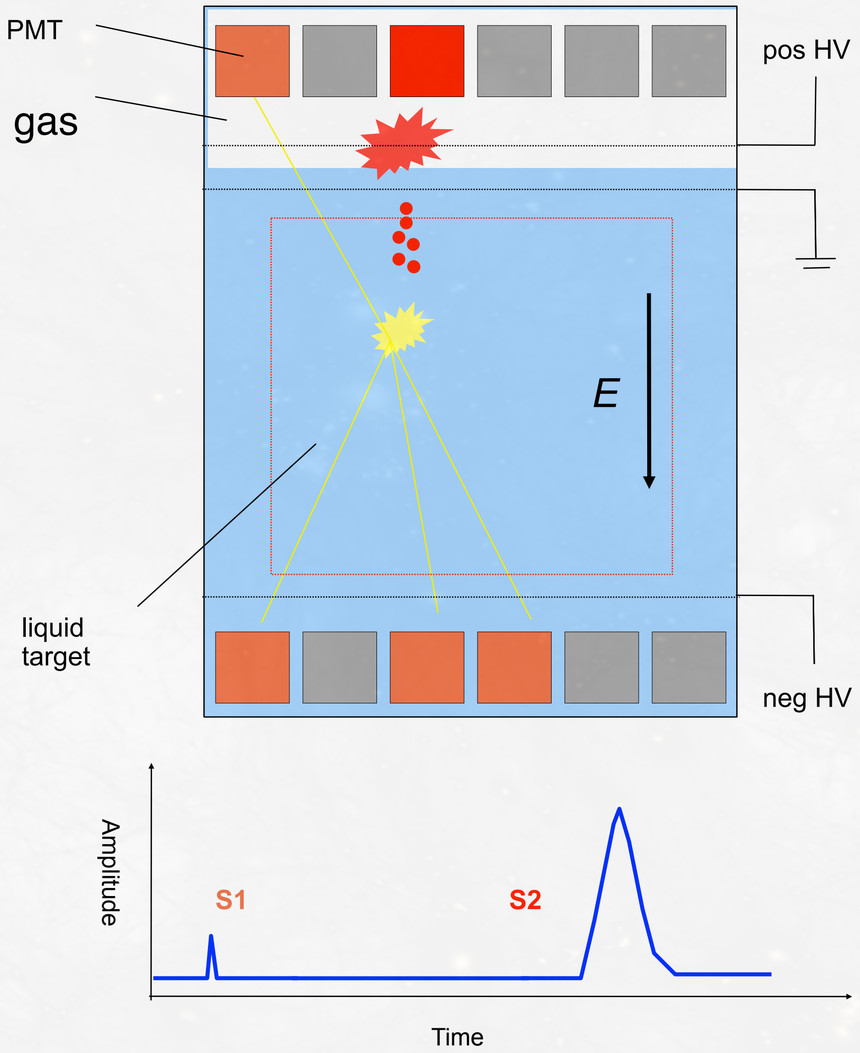


Fiducial mass [kg]

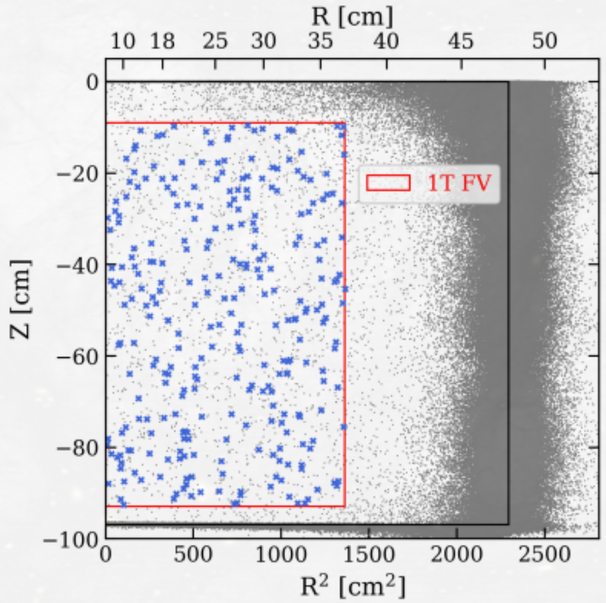


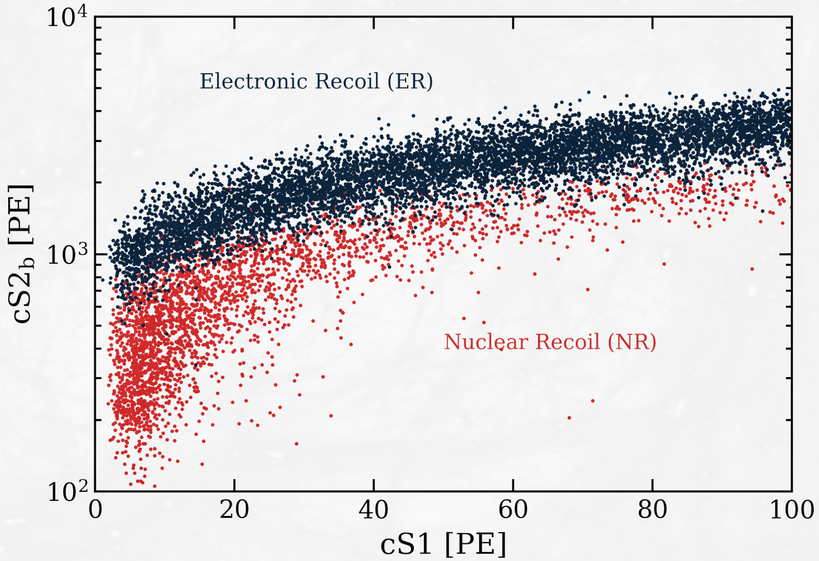
Low-energy ER background
[events / (tonne keV day)]

Dual-phase Noble Liquid Time Projection Chambers



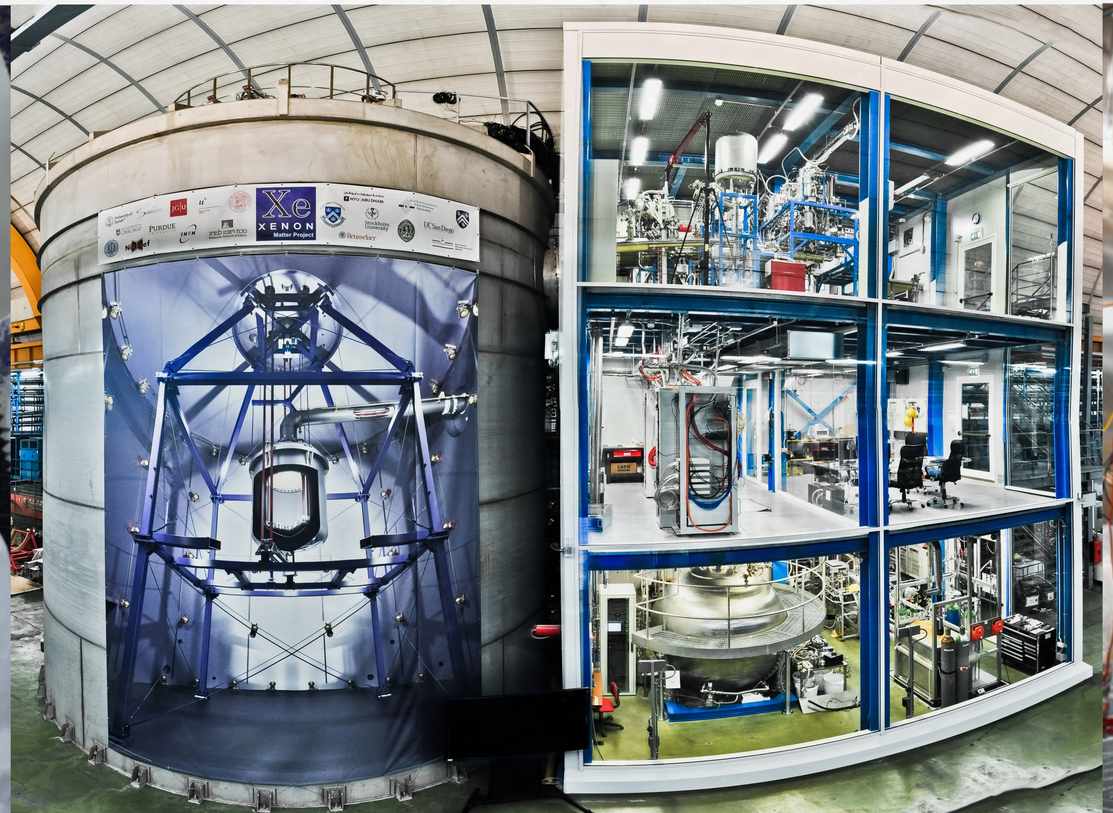
- two signals for each event:
  - 3D event imaging: x-y (S2) and z (drift time)
  - Recoil type discrimination from ratio of charge (S2) to light (S1)

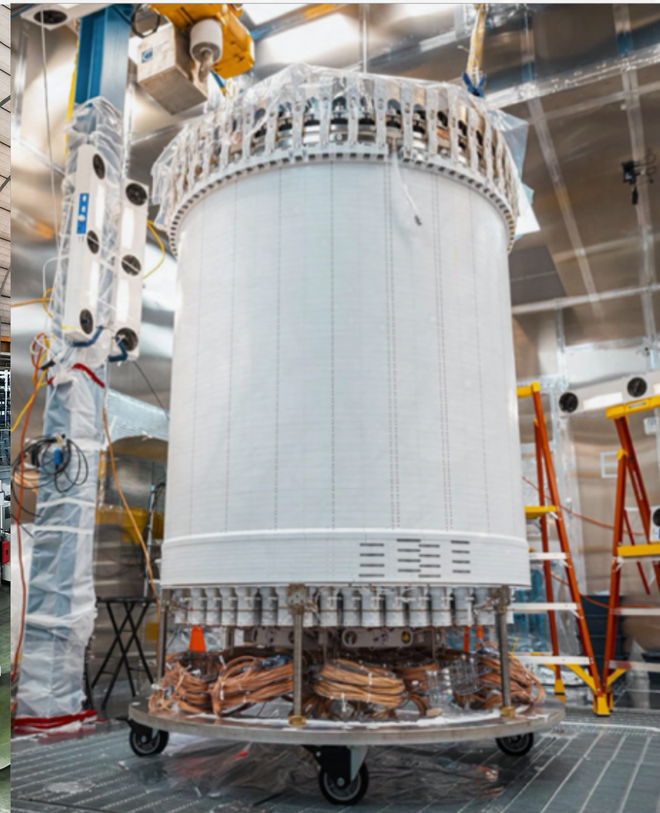




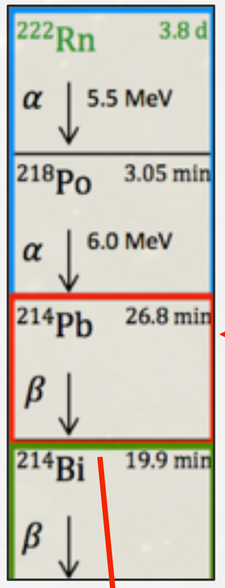
“G2” LXeTPCs for Dark Matter Search

Experiments	Location	Sensitive Mass [t]	Fiducial mass [t]	Radon reduction	Neutron veto	Data taking	First Results
PandaX-4T	CJPL (China)	4.0	2.8	Y	N	2021	2021
XENONnT	LNGS (Italy)	5.9	4.0	Y	Y	2021	2023
LZ	SURF (US)	7.0	5.6	Y	Y	2022	2022

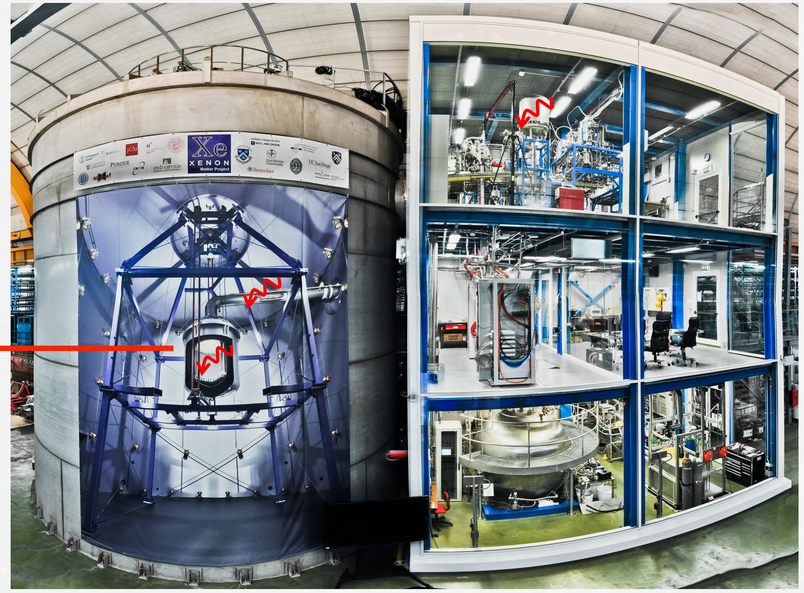


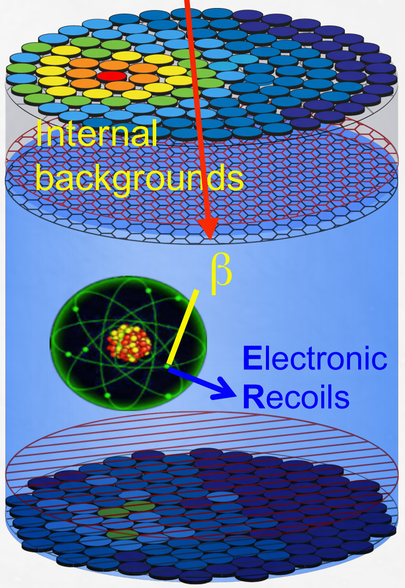


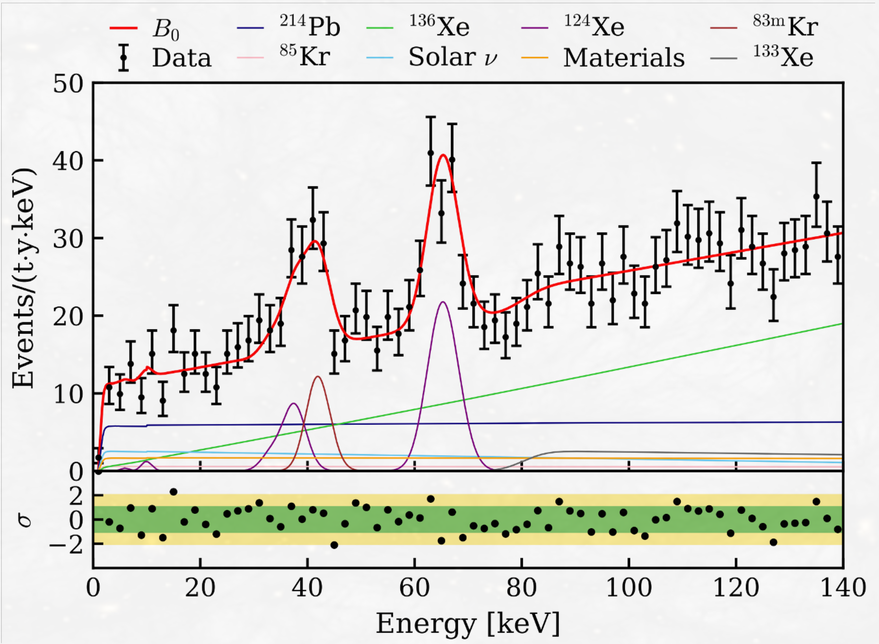
Background Challenge: Kr and Rn

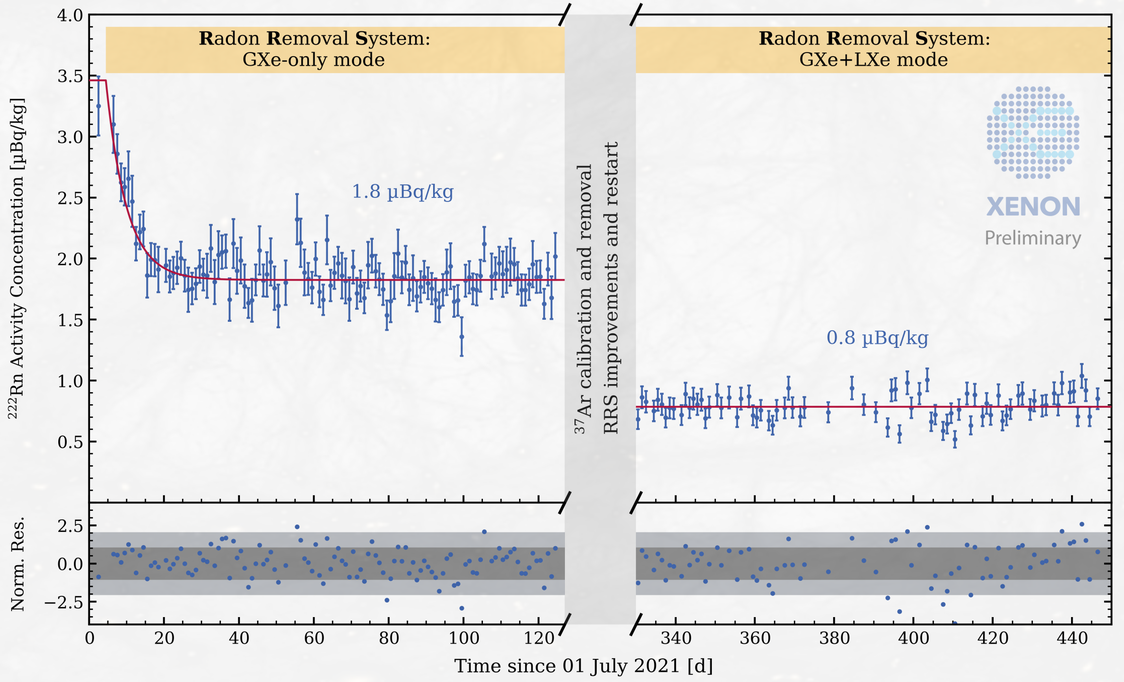


222Rn

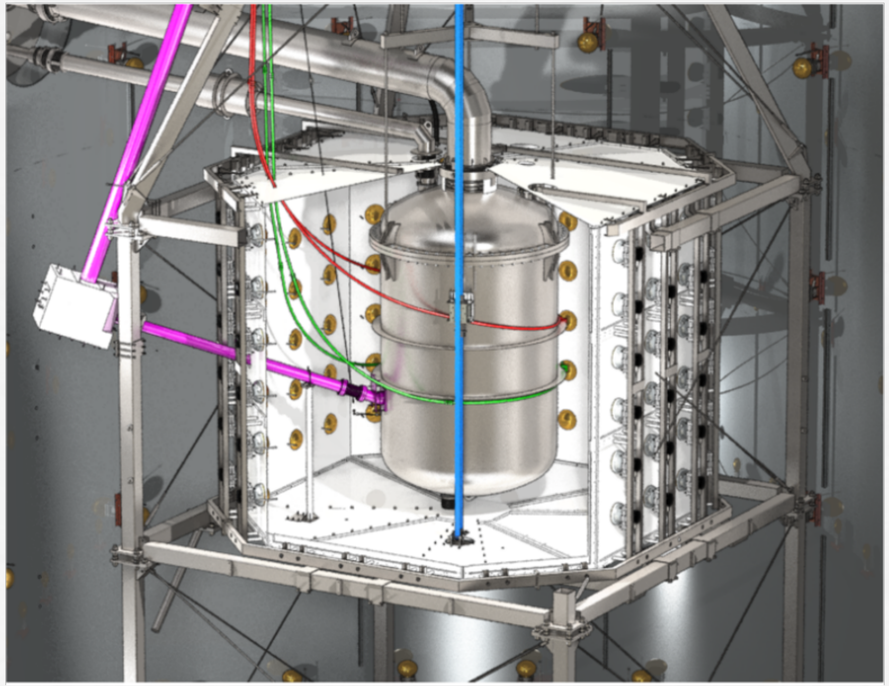








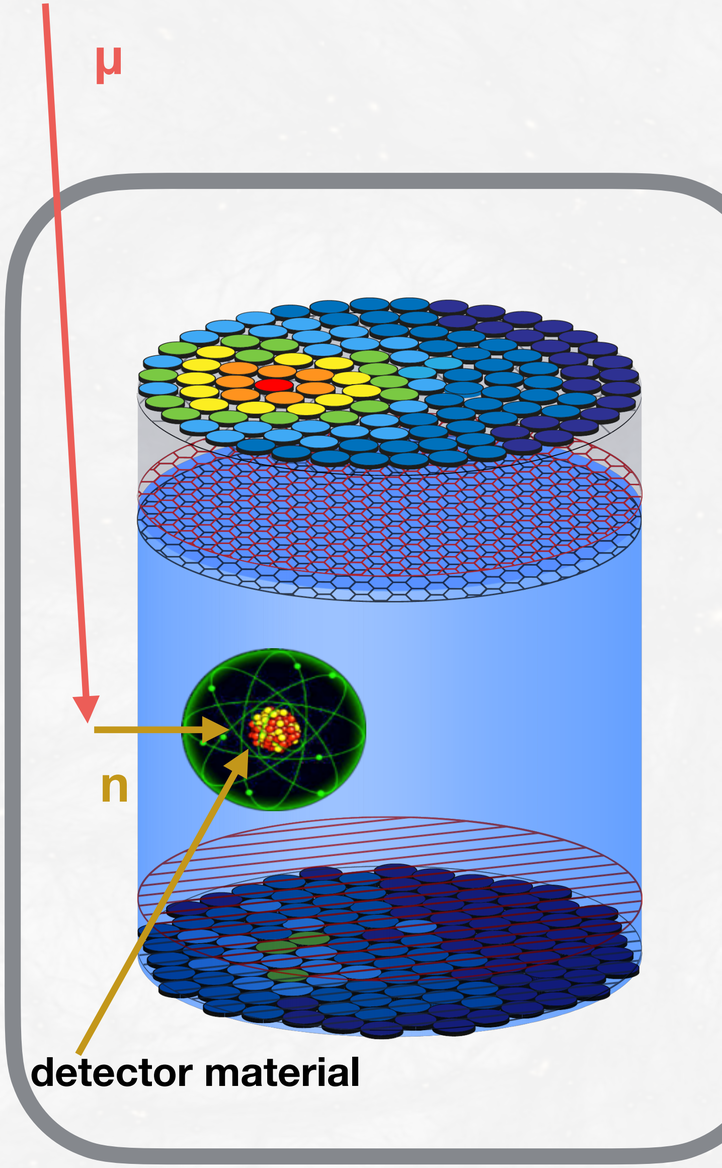
Background Challenge: Neutrons



XENONnT

LZ

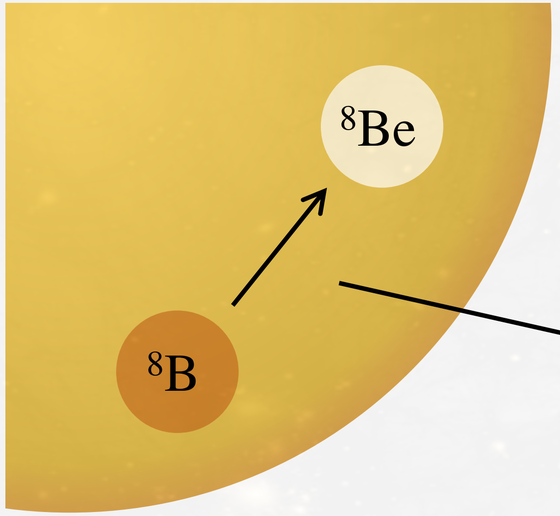
Neutron background reduced to < 1 events / (20 tonne-year)



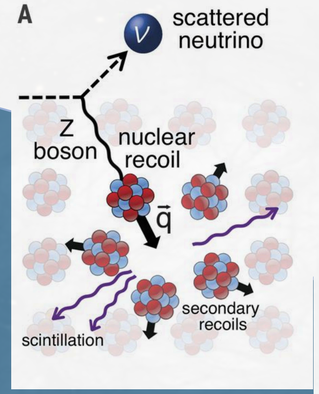
Background Challenge: Irreducible Neutrinos

PRL 126, 091301 (2021)

$$R = \phi(\nu) \times \sigma_\nu \times N_{Xe} \times \text{exposure}$$
$$\simeq 600\,\text{events}/(\text{tonne} \times \text{year})$$

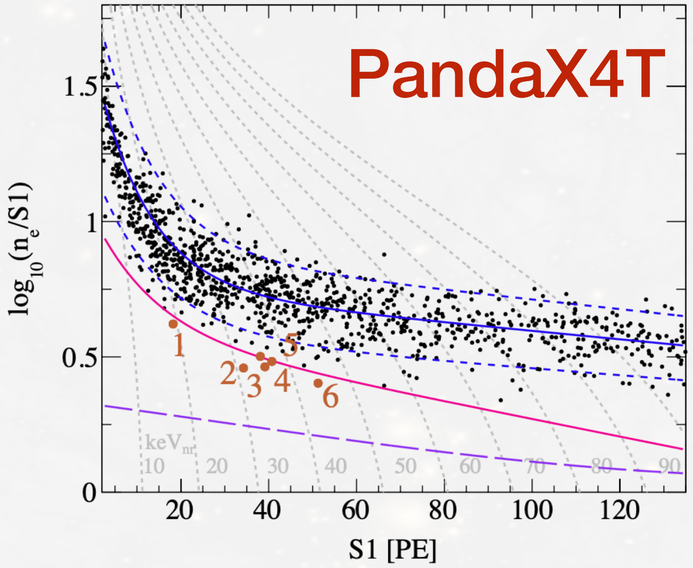


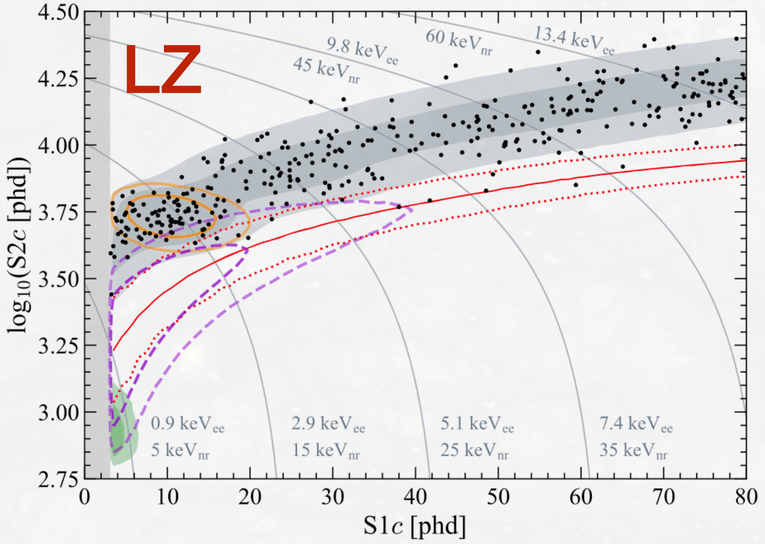
ν

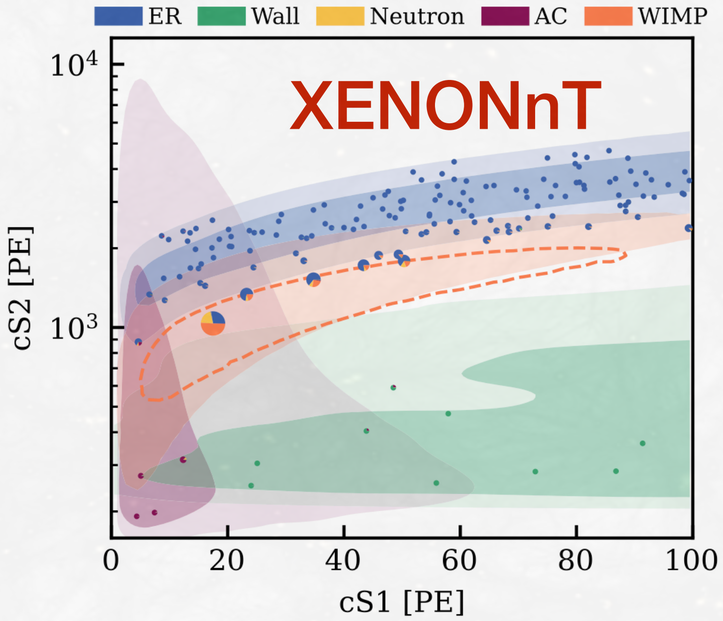


Dark Matter

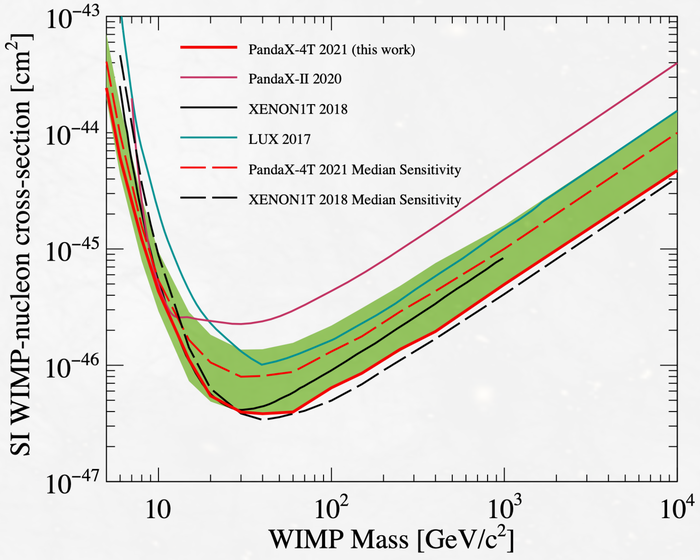
Dark Matter Search Results



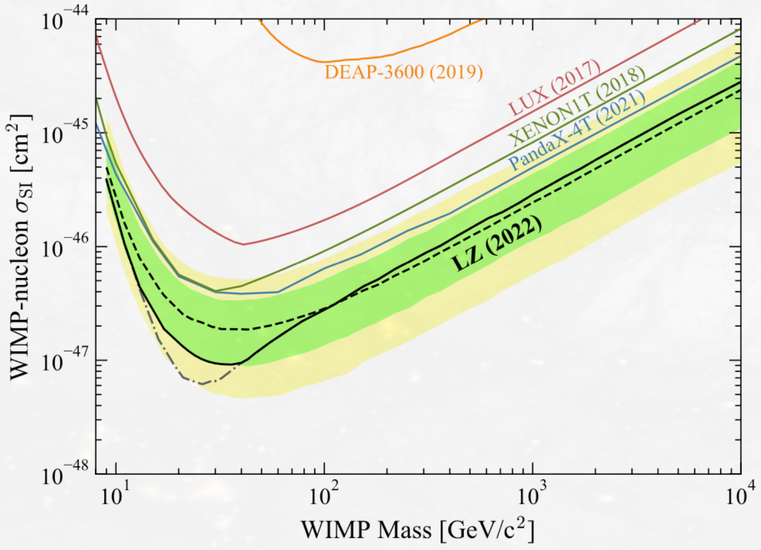




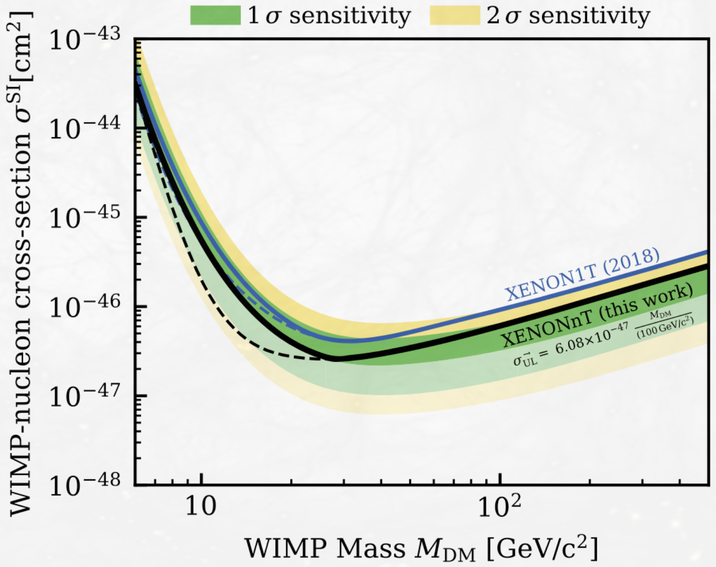
PRL 127, 261802 (2021)



PRL 131, 041002 (2023)

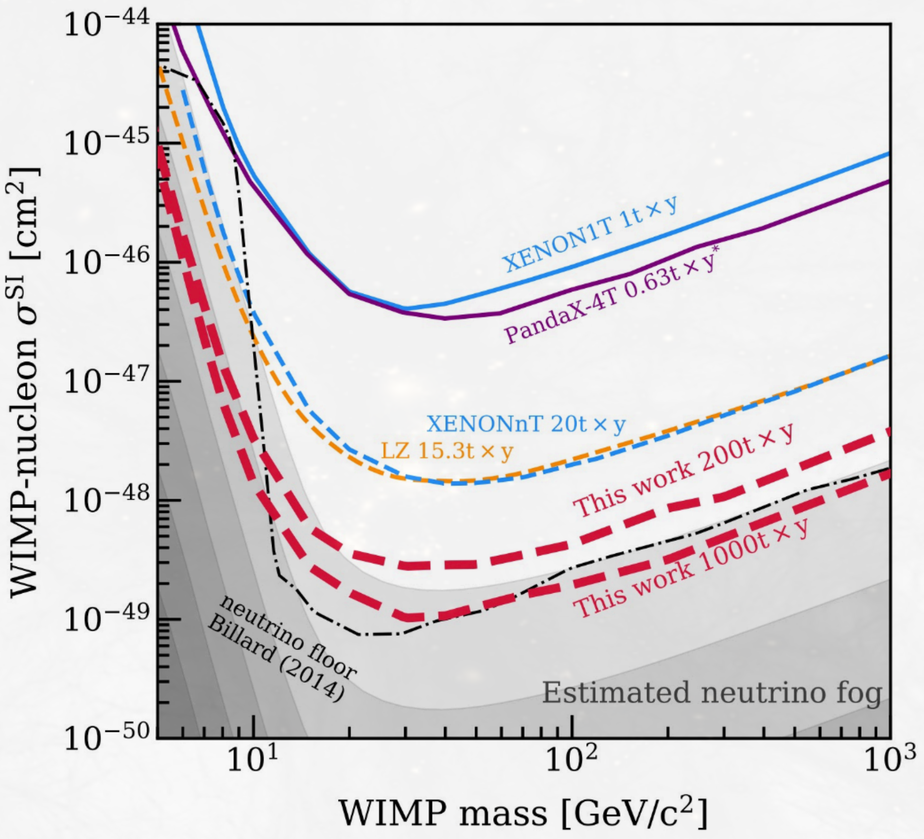


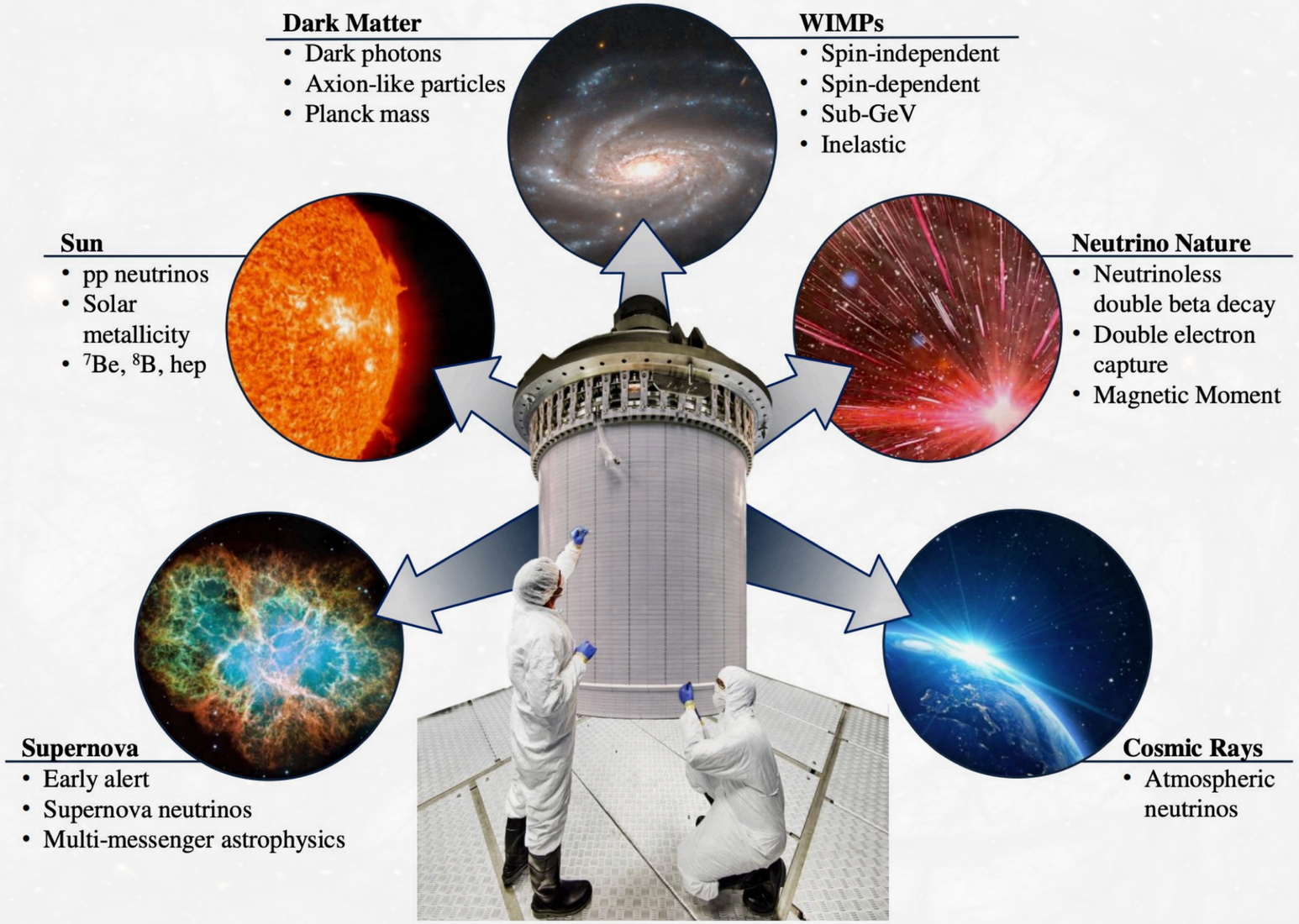
PRL 131, 041003 (2023)



Future LXeTPCs

J. Phys. G: Nucl. Part. Phys. 50 (2023) 013001



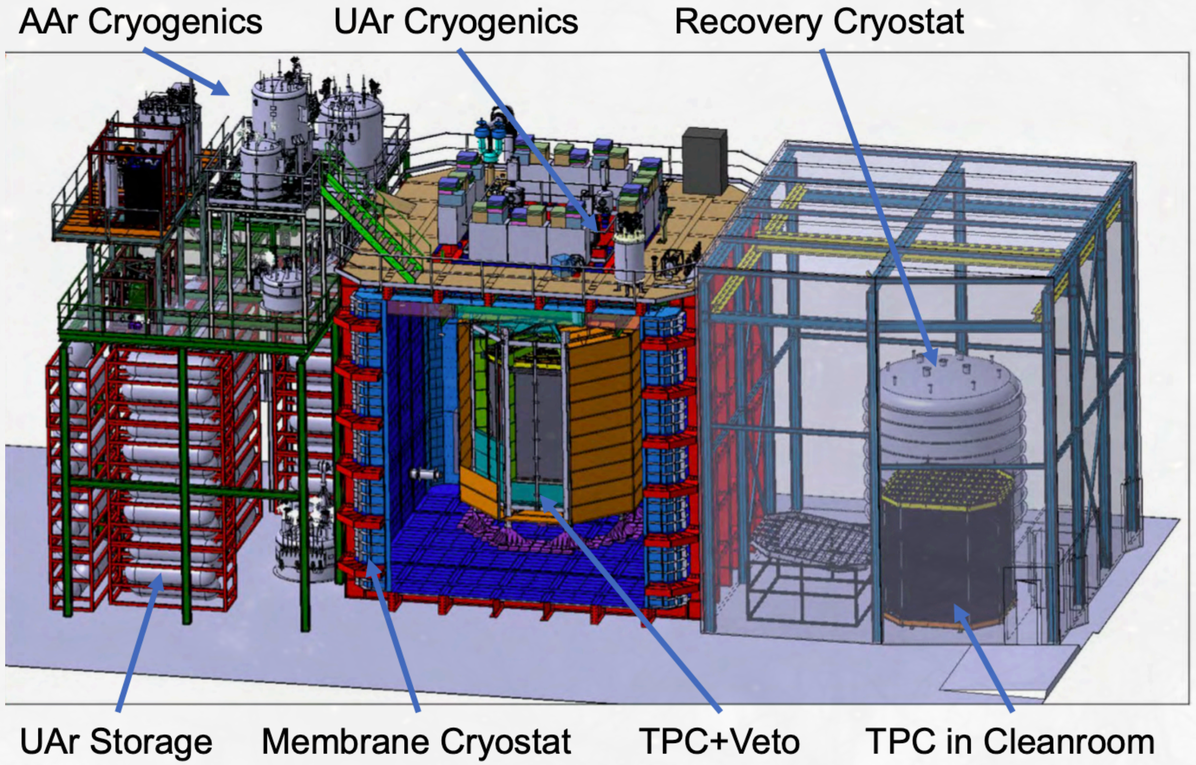


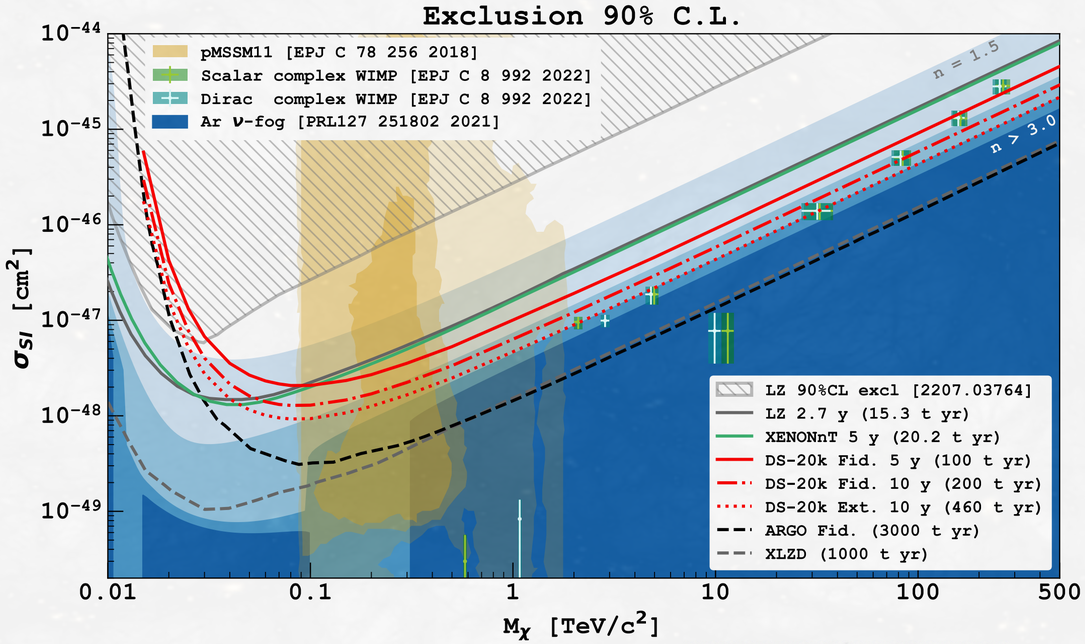
PandaX-xT: ~50t @ CJPL

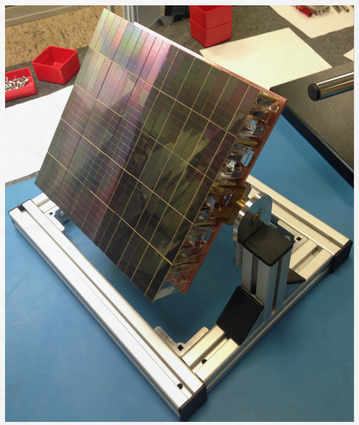
DARWIN: ~50t @ Gran Sasso

XLZD (XENON/LZ/DARWIN): ~100t @ ?

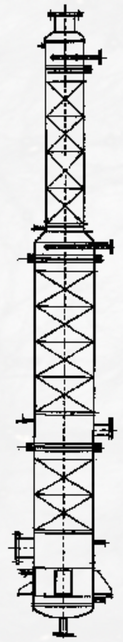
LArTPCs: DarkSide-20k and the Global Argon Dark Matter Collaboration







- Officially supported by underground labs: LNGS, LSC, and SNOLAB
- 50 tons total mass, 20 tons fiducial
- Underground Ar with distillation
- SiPM as photosensors
- To start in 2026

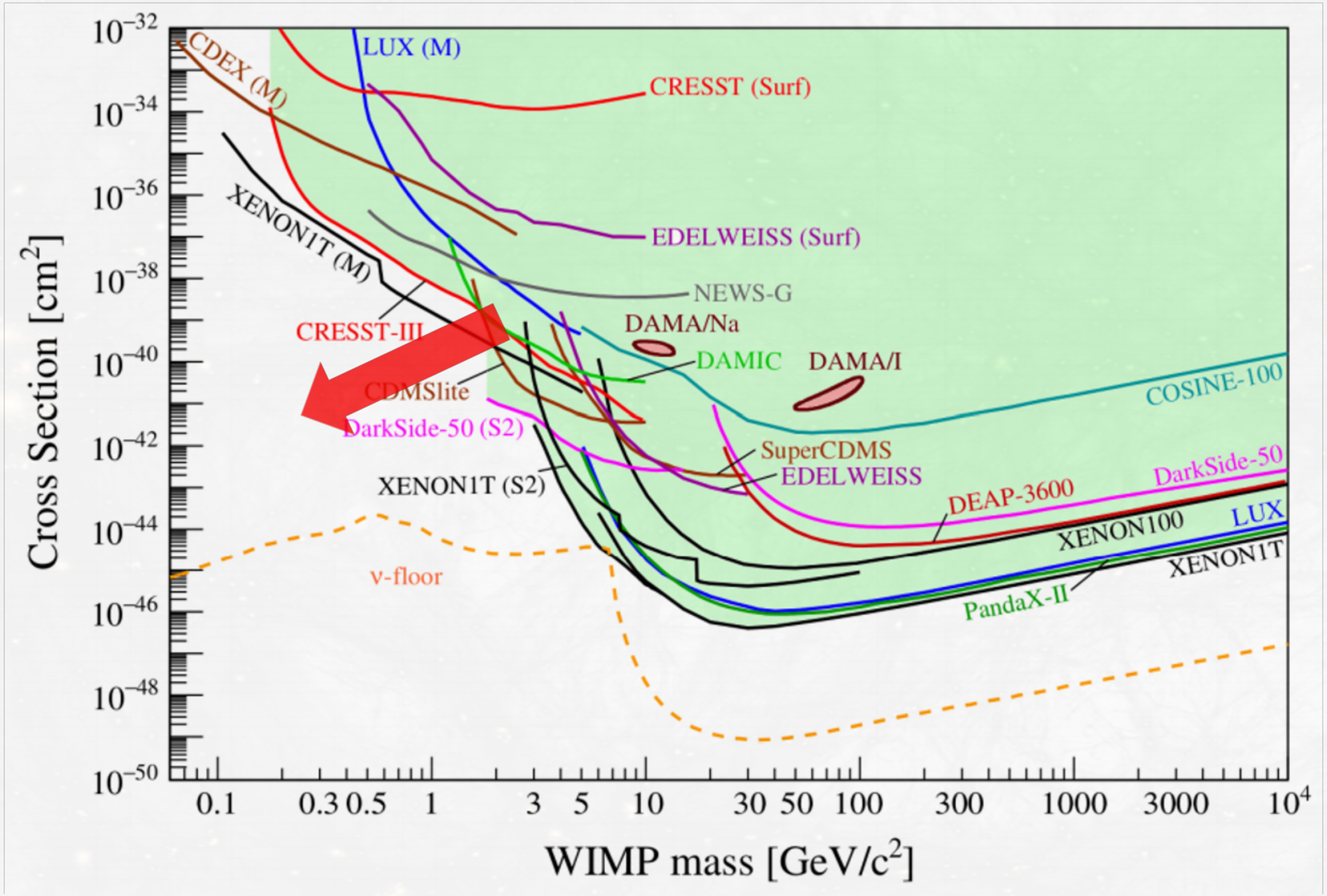


from Y. Wang

Status of Dark Matter Searches: Low Mass

Light DM

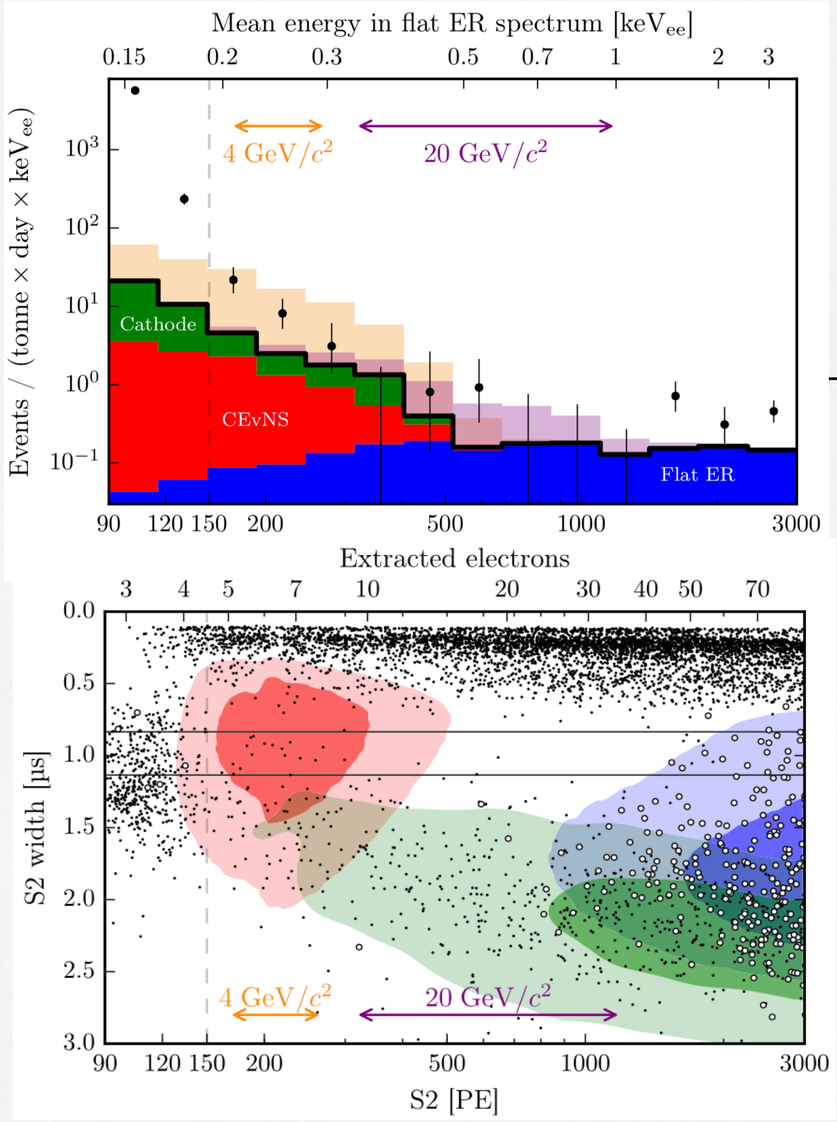
New Technology, lower energy threshold



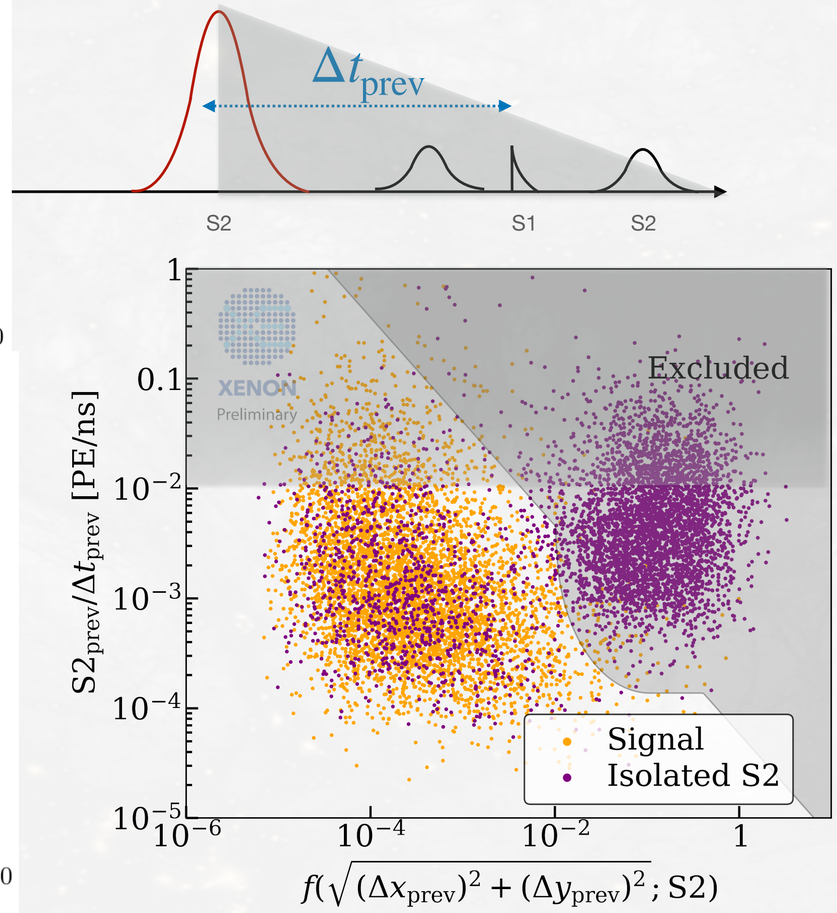
2104.07634, APPEC report (2021)

Light Dark Matter Searches: LXeTPCs

XENON1T: PRL 123, 251801 (2019)

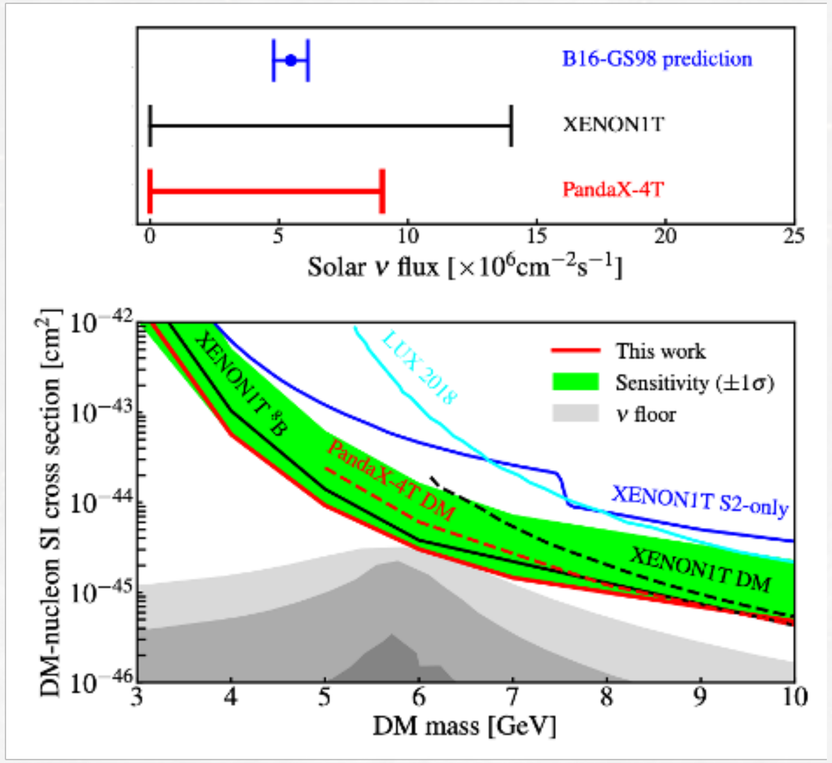


New backgrounds at the energy threshold: surface radioactivity and instrumental effects

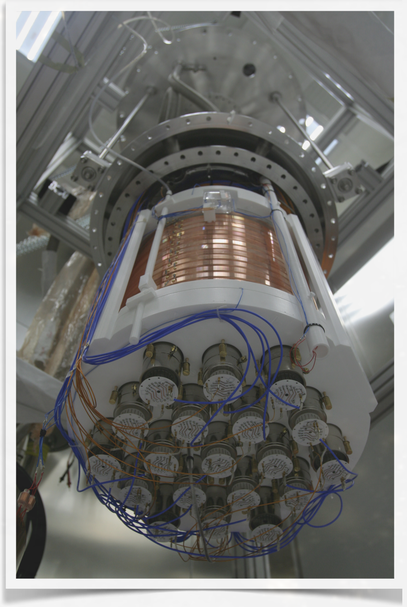


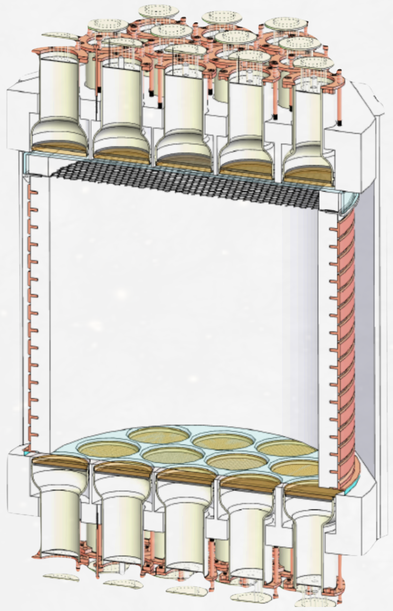
XENON1T: PRL 126, 091301 (2021)

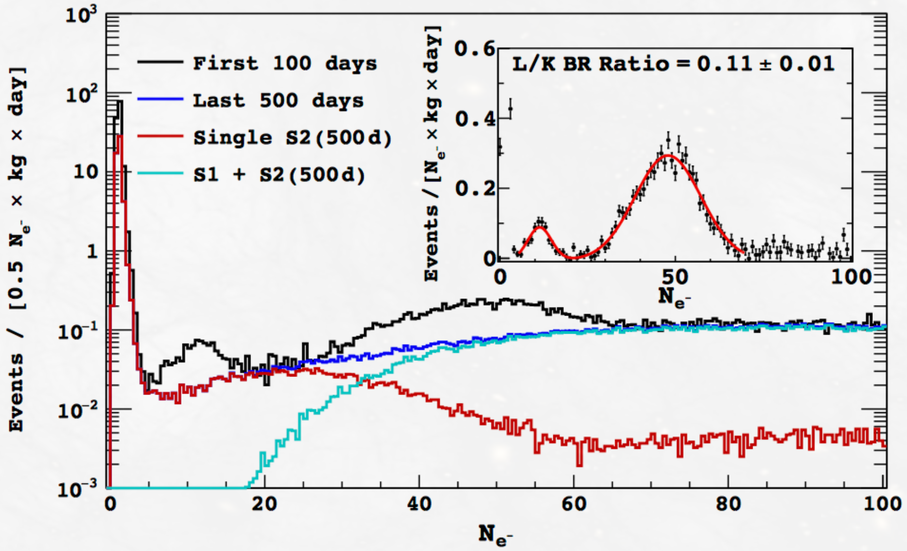
PandaX4T: PRL 130, 021802 (2023)

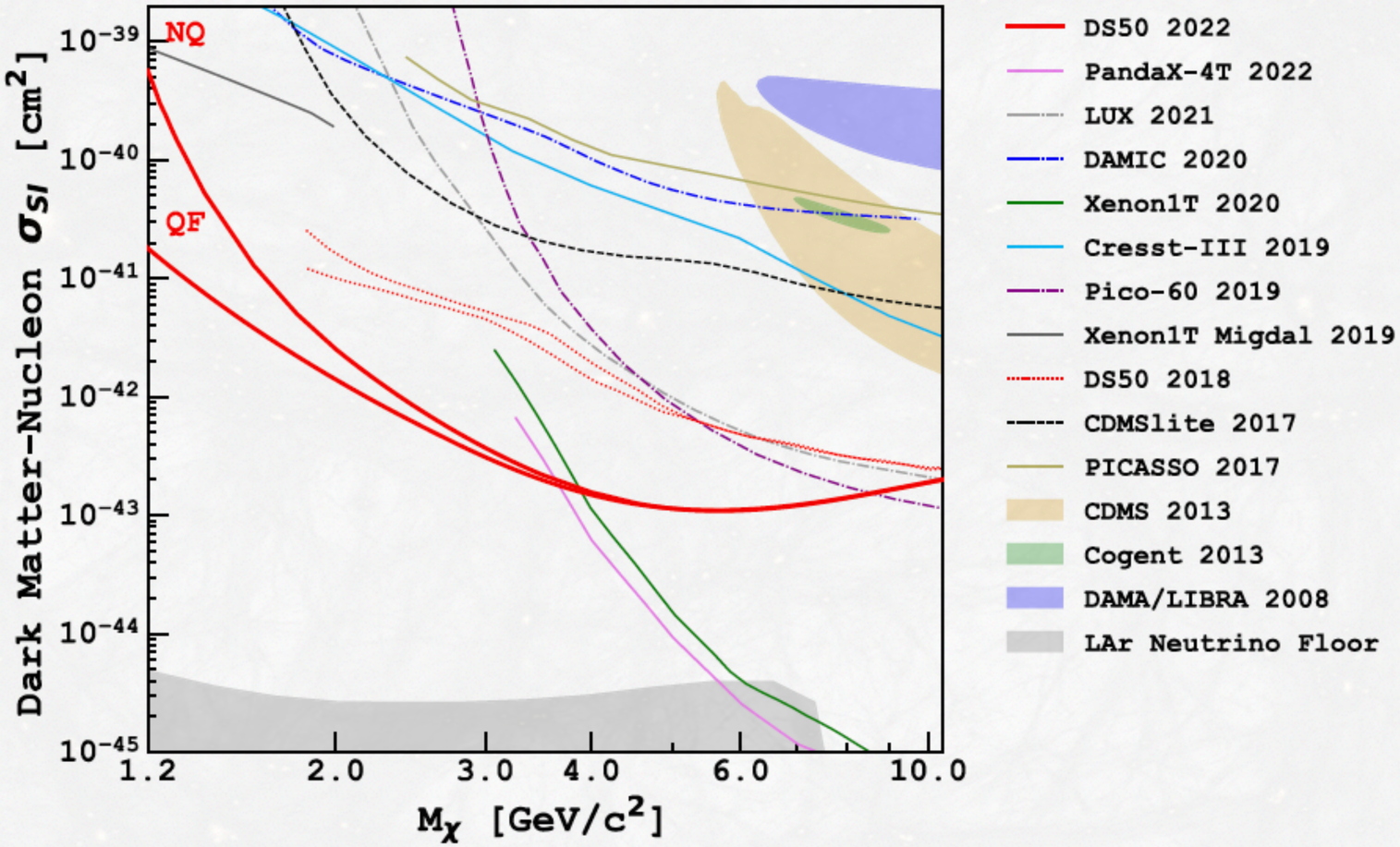


Light Dark Matter Searches: DarkSide-50



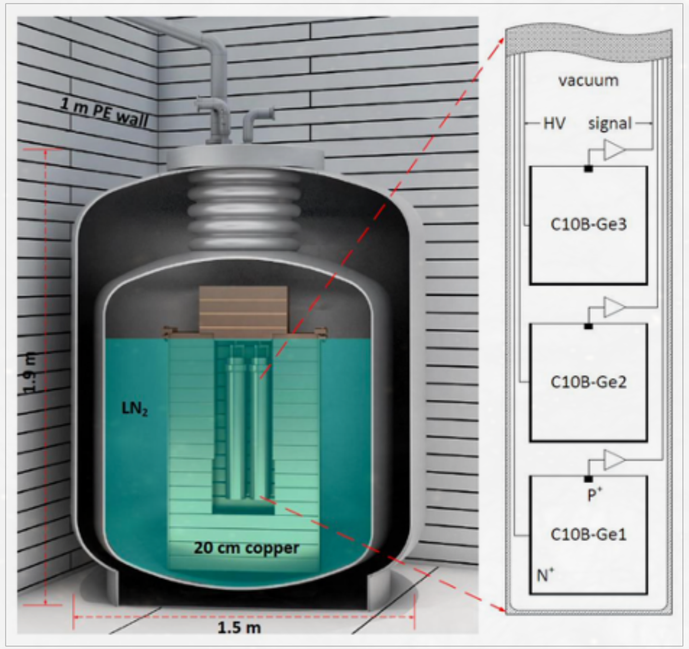


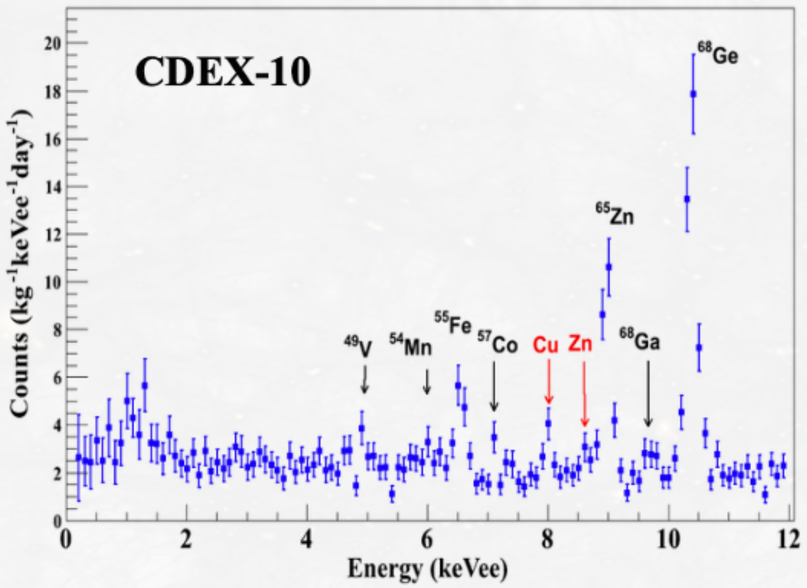


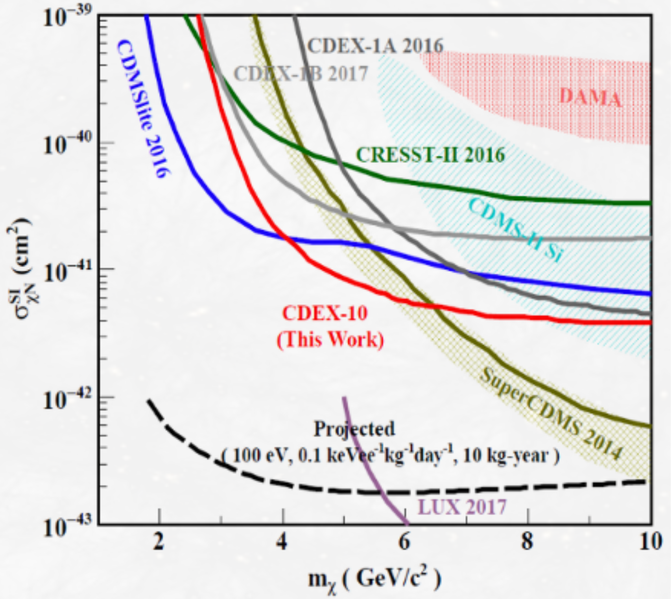


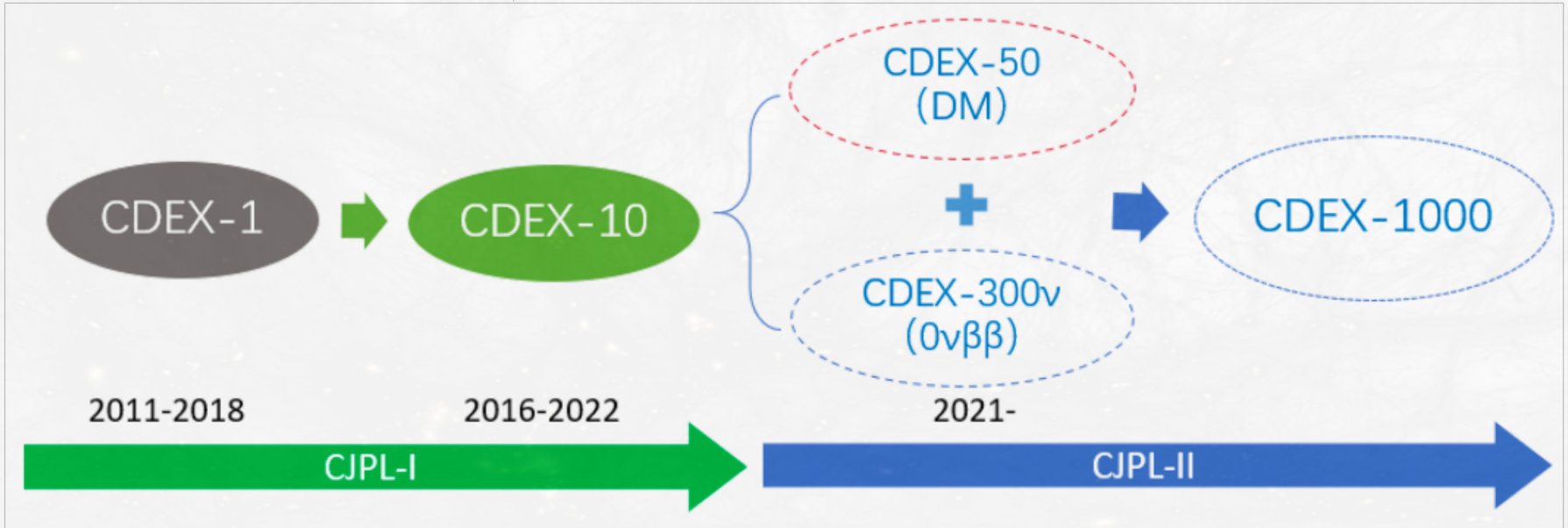
from Y. Wang

Light Dark Matter Searches: CDEX

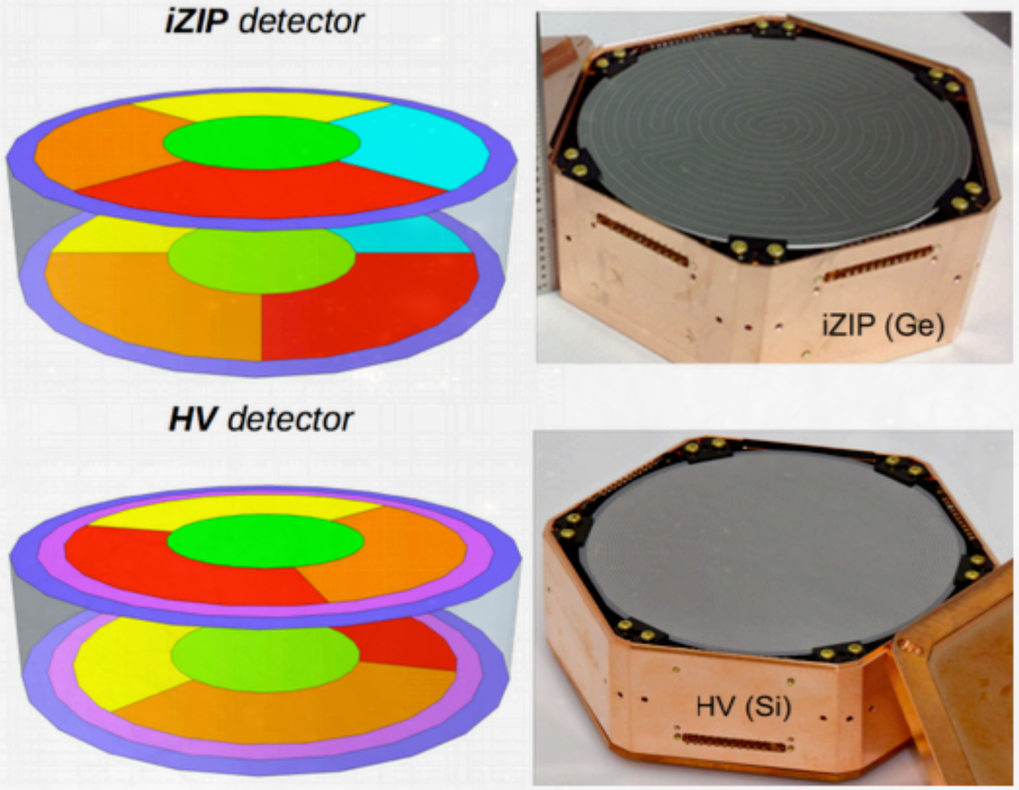


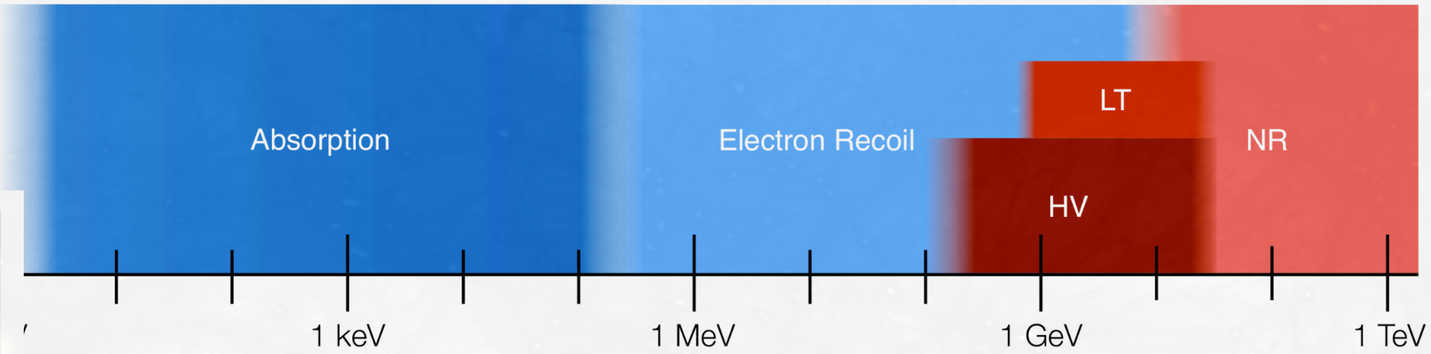


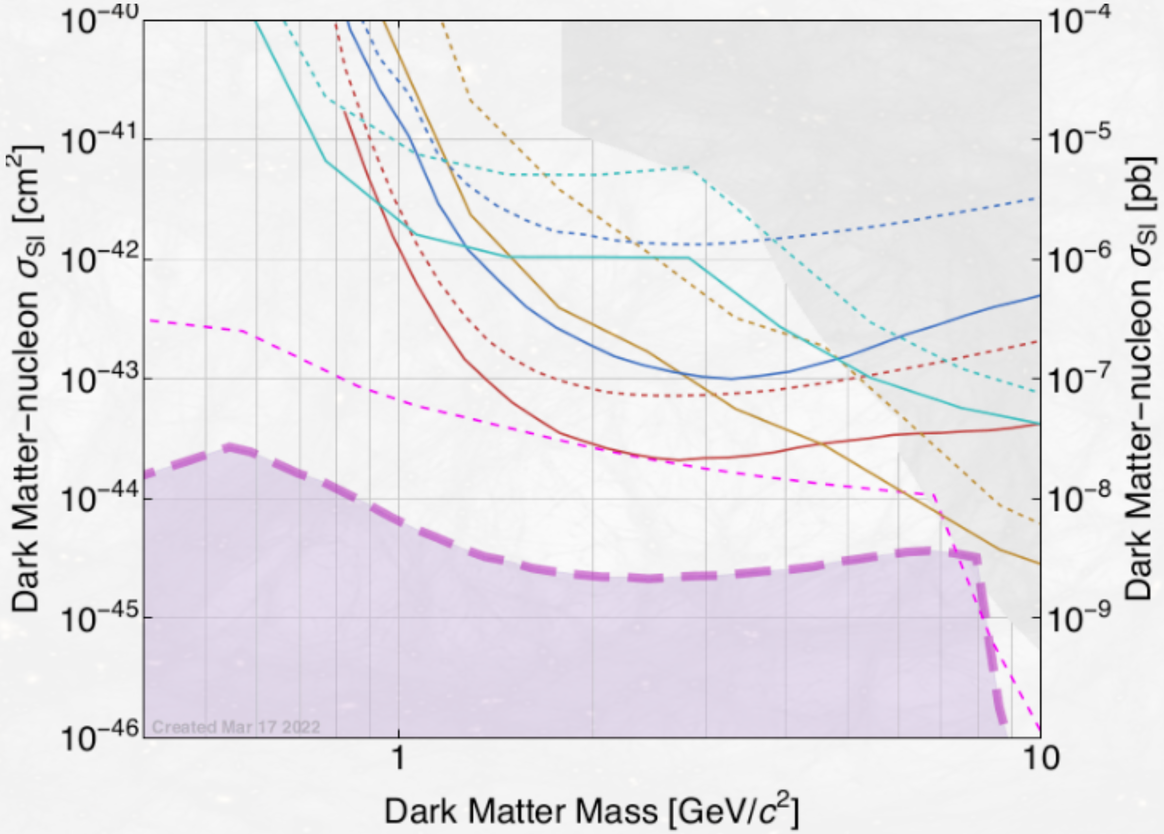




Light Dark Matter Searches: SuperCDMS

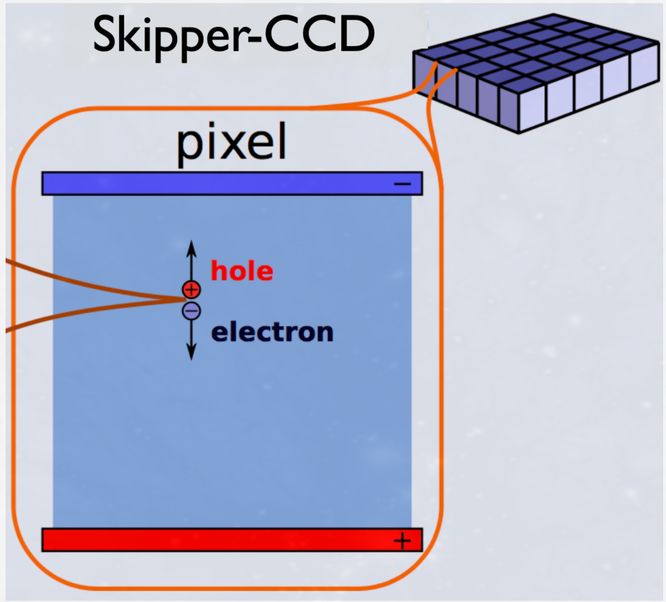


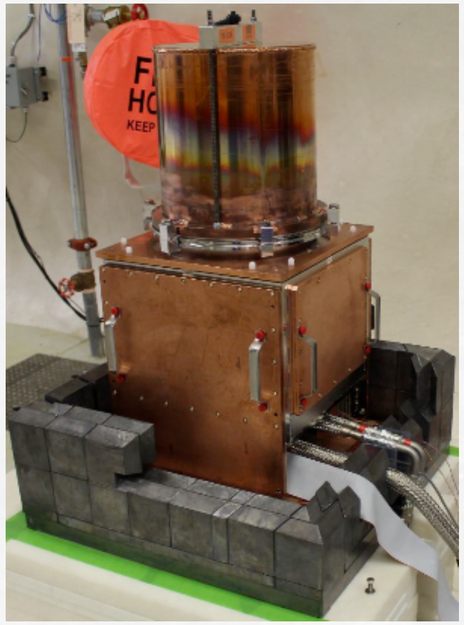


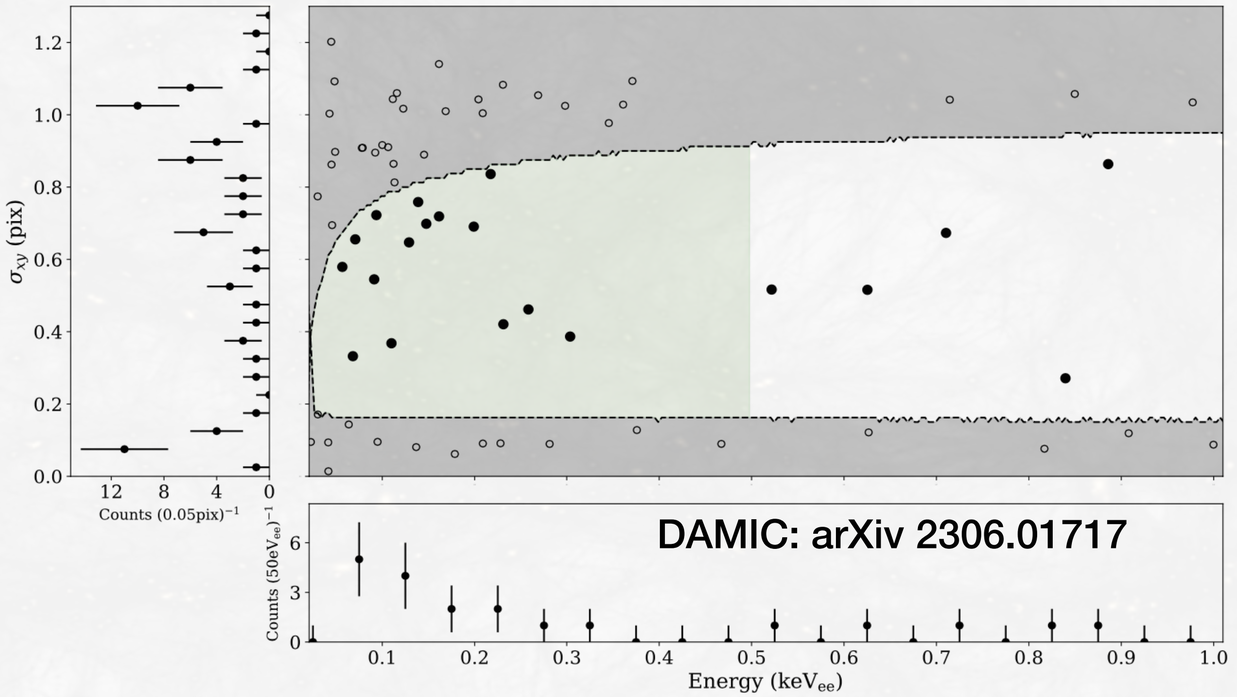


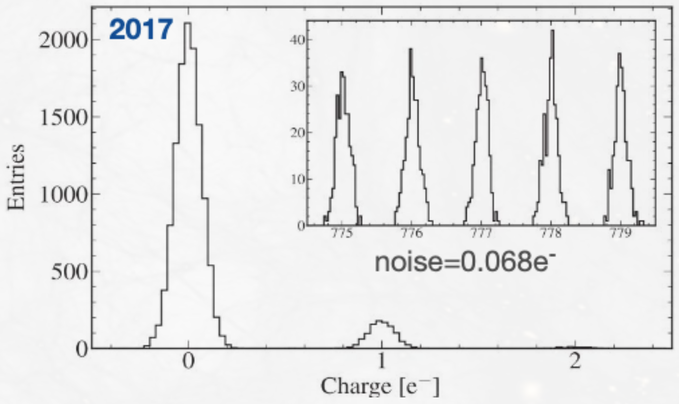
E. Michielin, UCLA DM 2023

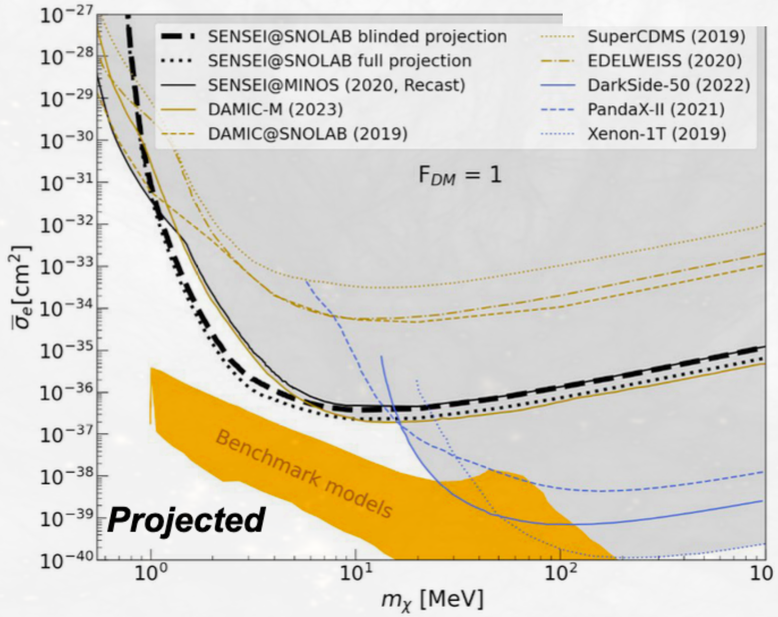
Light Dark Matter Searches: DAMIC & SENSI

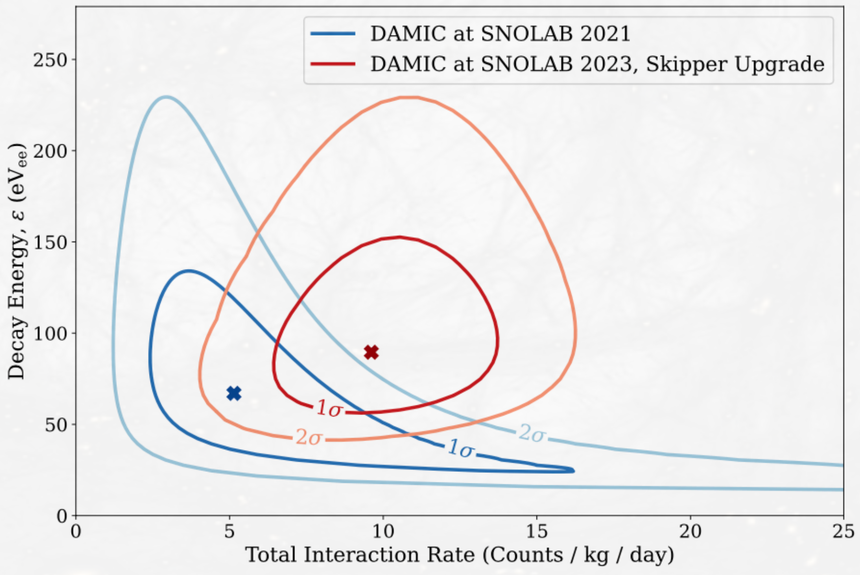












K. Stifter, UCLA DM 2023

Summary

- Significant progress in Dark Matter searches over the past decade
- Scalability and low background of experiments using LXe and LAr have made them the most favorable target for heavy WIMPs.
- Over the next years, massive LXe (PandaX-4T / LZ / XENONnT) and LAr (DarkSide-20K) TPCs, promise another order of magnitude in sensitivity. PandaX-xT / DARWIN / XLZD will go even further on the path to the “neutrino fog”
- There is a paradigm shift towards light-Dark Matter search, mostly with new technologies. Opportunities and challenges are taken by various types of experiments around the world.
- We will finally find Dark Matter or learn what Dark Matter is not.