UNIVERSITEIT VAN AMSTERDAM

Nikhef

Direct dark matter searches

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CAN symposium, Soesterberg, Netherlands
June 20, 2023

Astronomical observations consistently indicate that ~83% of the mass in the universe seems to be made of (an) unknown particle(s).

Blue: Gravitational potential inferred from micro lensing

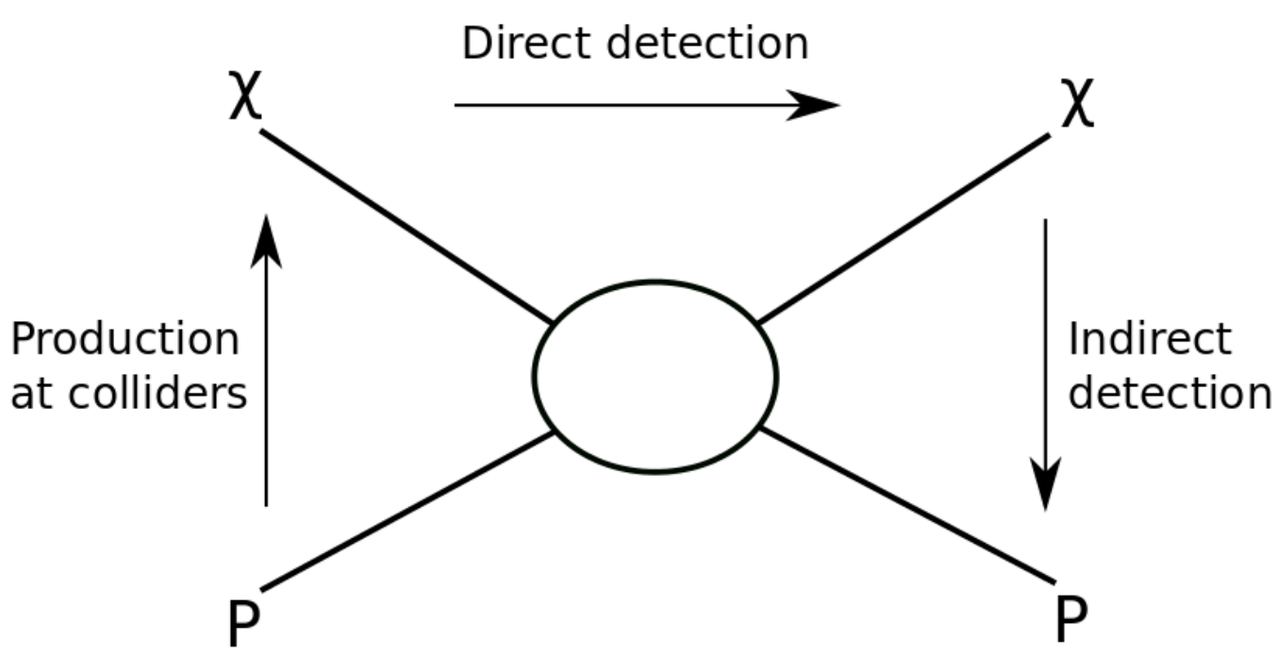
Pink: X-ray emission from hot gas

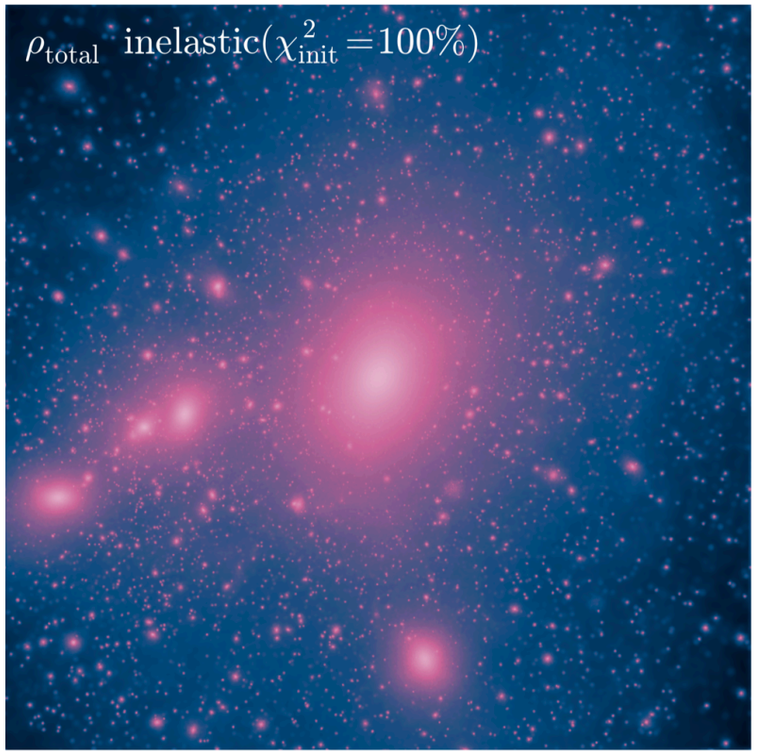
What we know about this new 'Dark Matter' particle so far:

At least one particle beyond the standard model exists	?
mass	?
interaction cross sections	upper limits in some mass ranges
lifetime	> age of universe
electric charge	0
weak charge	maybe
color charge	0

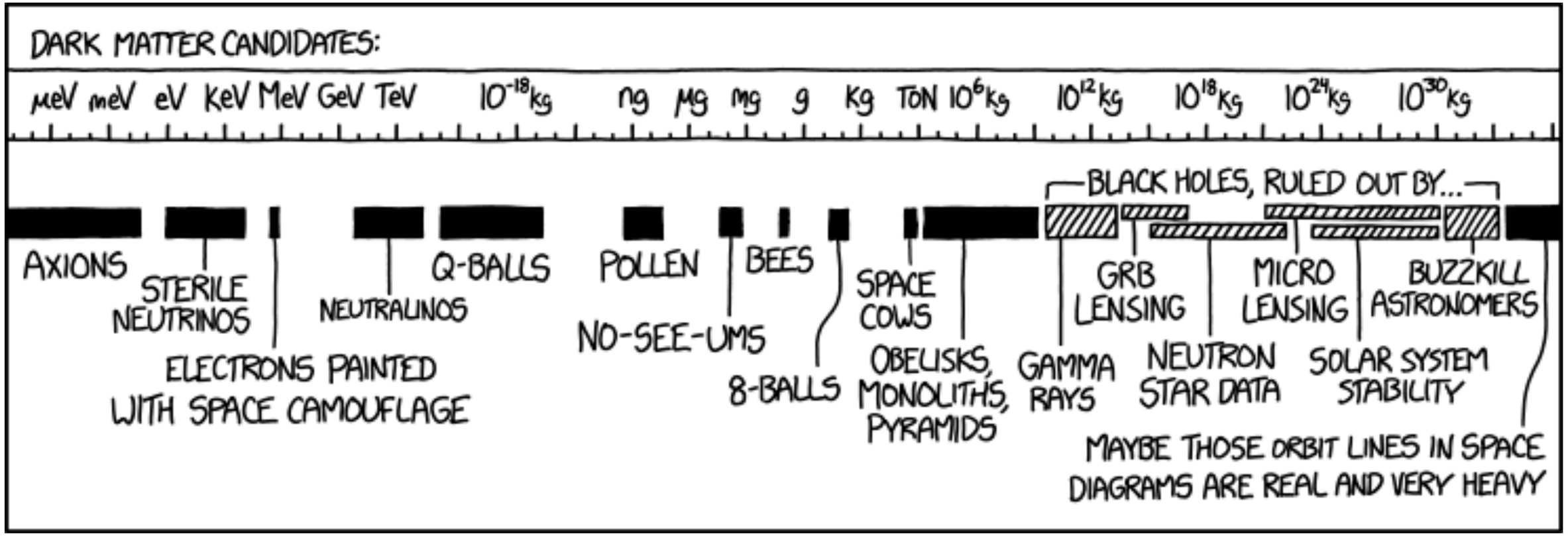
We employ many strategies to pin down this new particle

direct detection	indirect detection	collider production	astrophysical/ cosmological
interactions between galactic DM and terrestrial SM particles	excess particle flux in cosmic rays from DM annihilation or decay	excess of 'invisibles'	model effect of DM on observable astrophysical objects

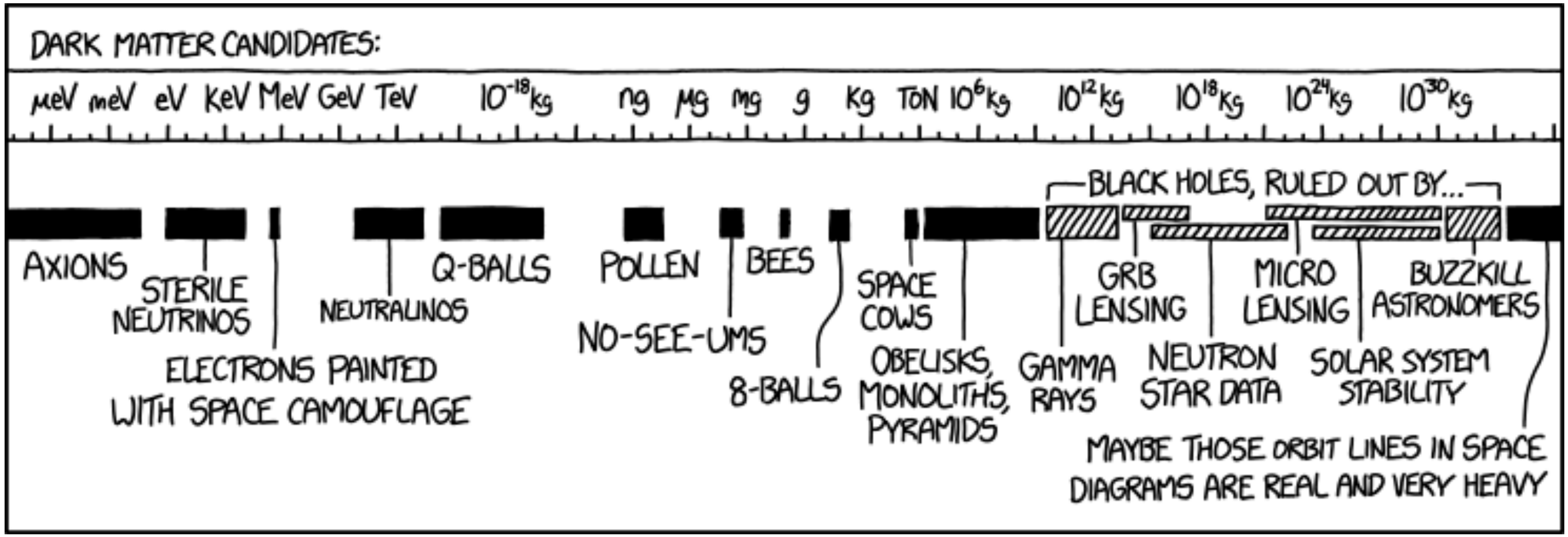




arxiv:1805.03203



https://xkcd.com/2035/



https://xkcd.com/2035/

astrophysical

indirect detection

direct detection

nuclear scattering (standard)

nuclear scattering (quantum materials)

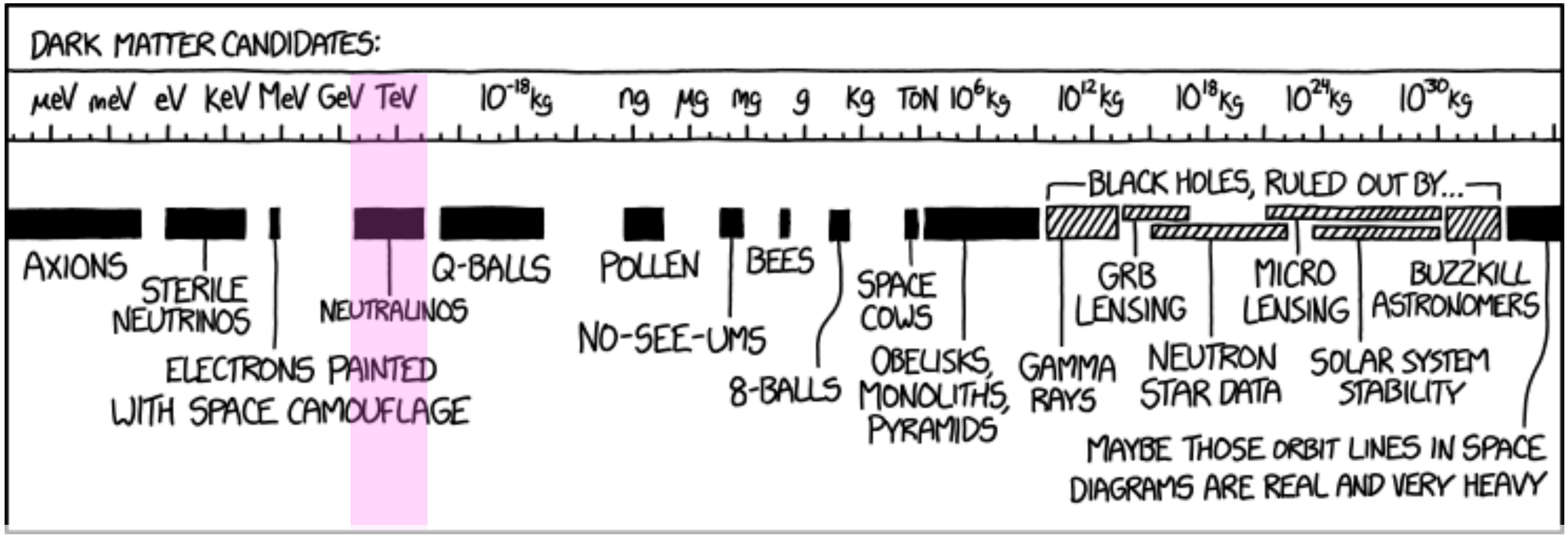
DM absorption

SM particles out of thin air

collider production

proton-proton

beam dump



https://xkcd.com/2035/

astrophysical

indirect detection

direct detection

nuclear scattering (quantum materials)

DM absorption

SM particles out of thin air

nuclear scattering (standard)

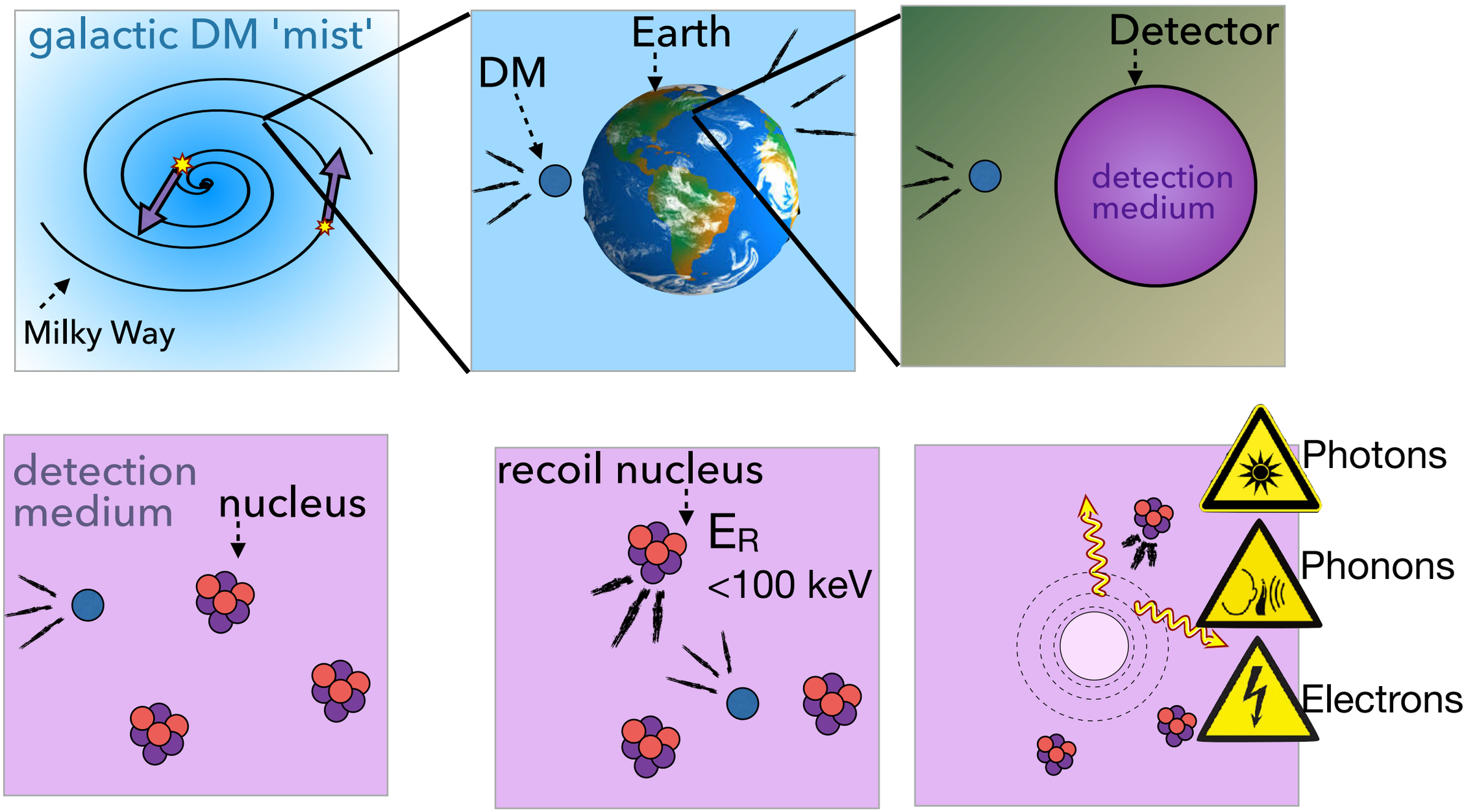
Purpose-built detectors for galactic WIMP dark matter

collider production

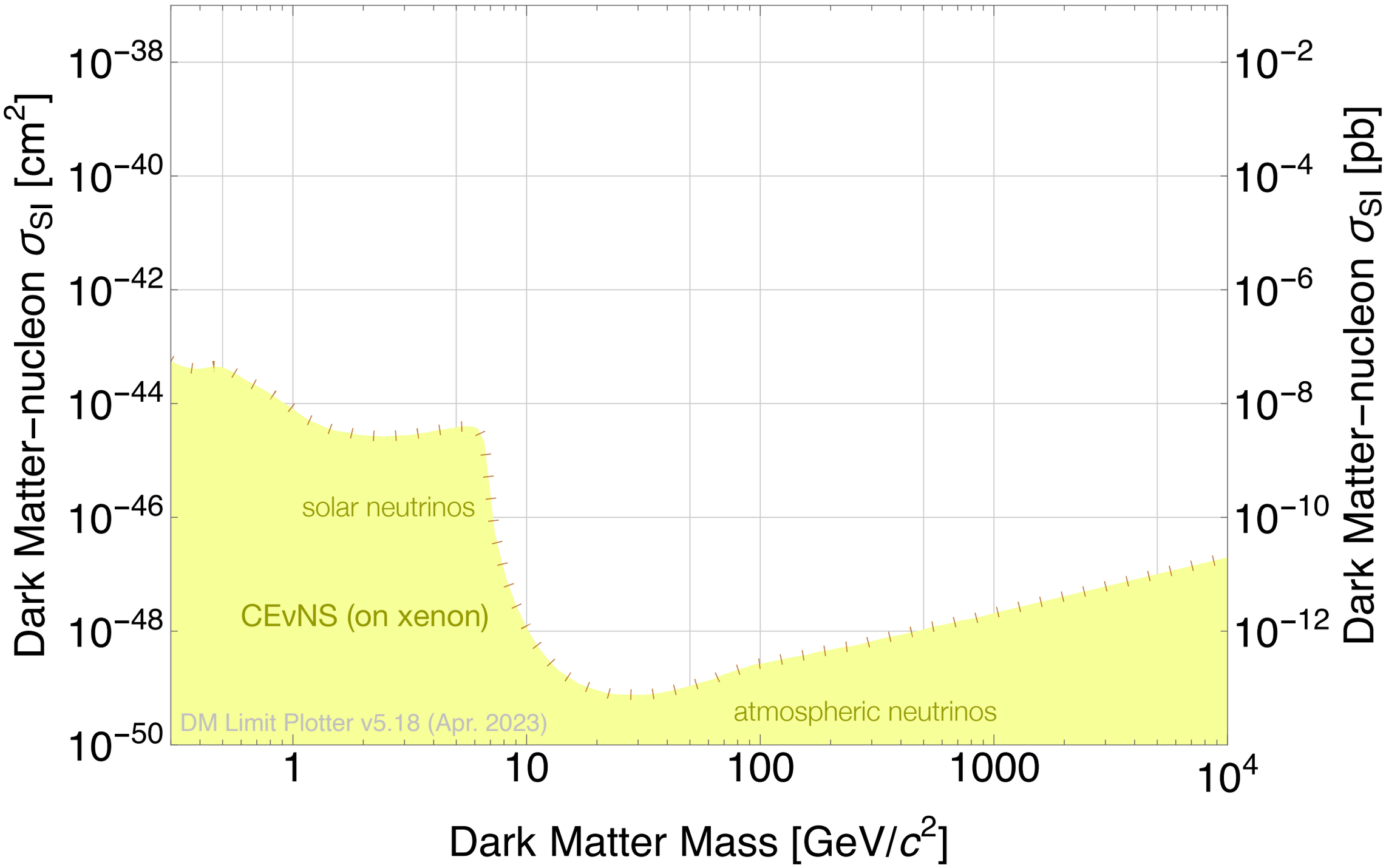
beam dump

proton-proton

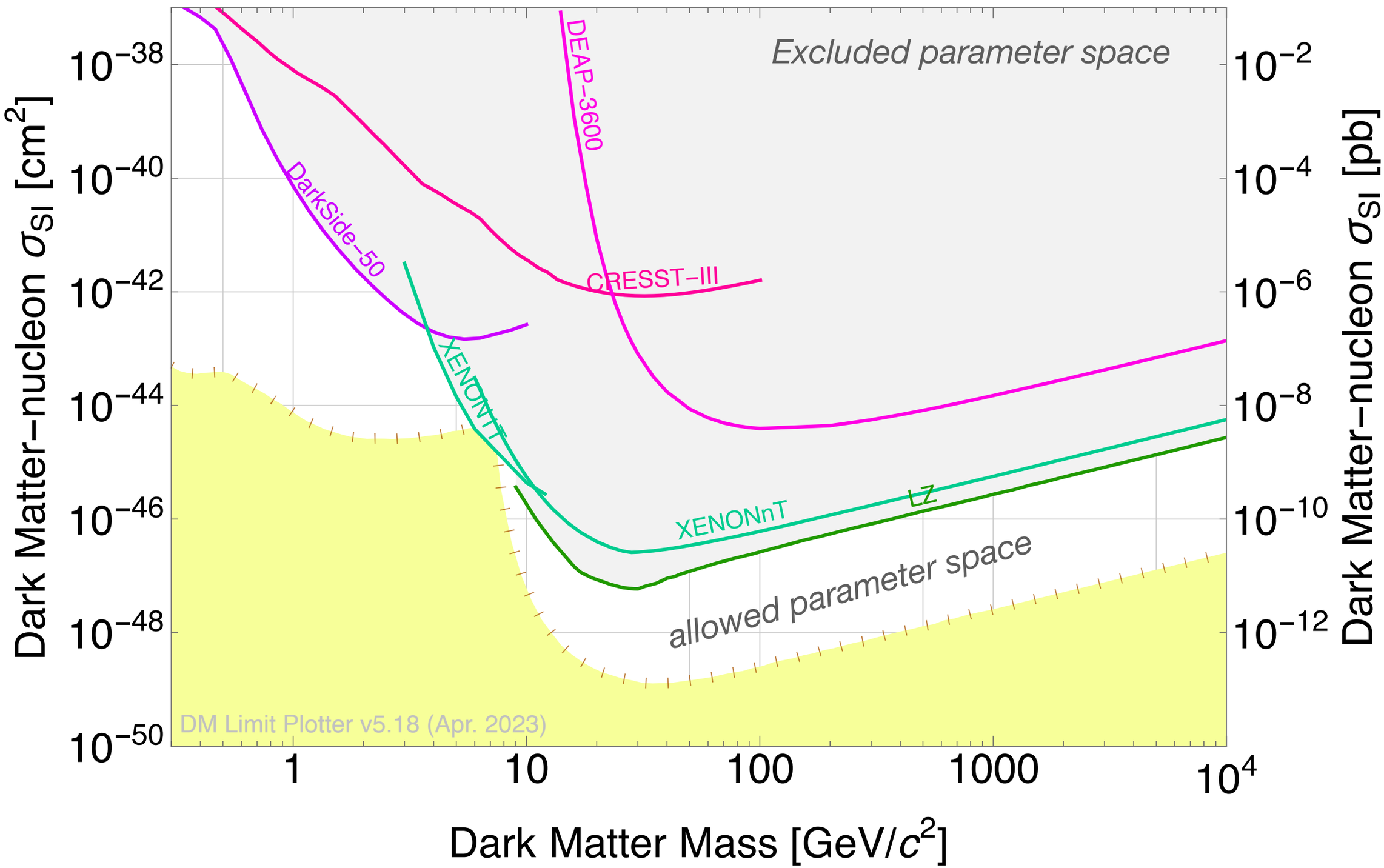
Direct detection with nuclear scattering: detecting WIMP-induced nuclear recoils



A direct detection signal constrains the DM mass and interaction cross section.

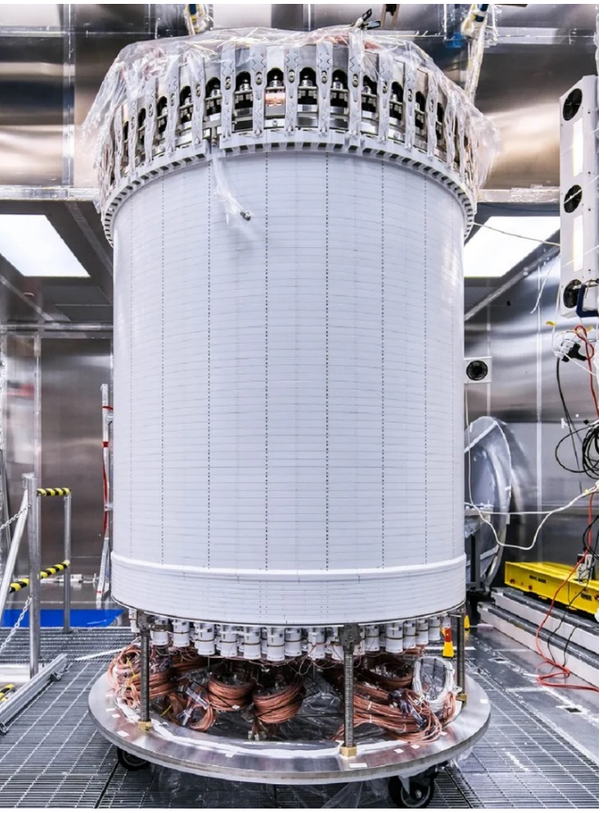


No credible signal has been observed so far



'Standard WIMP' detectors currently operating

LZ



XENONnT

PandaX-4t

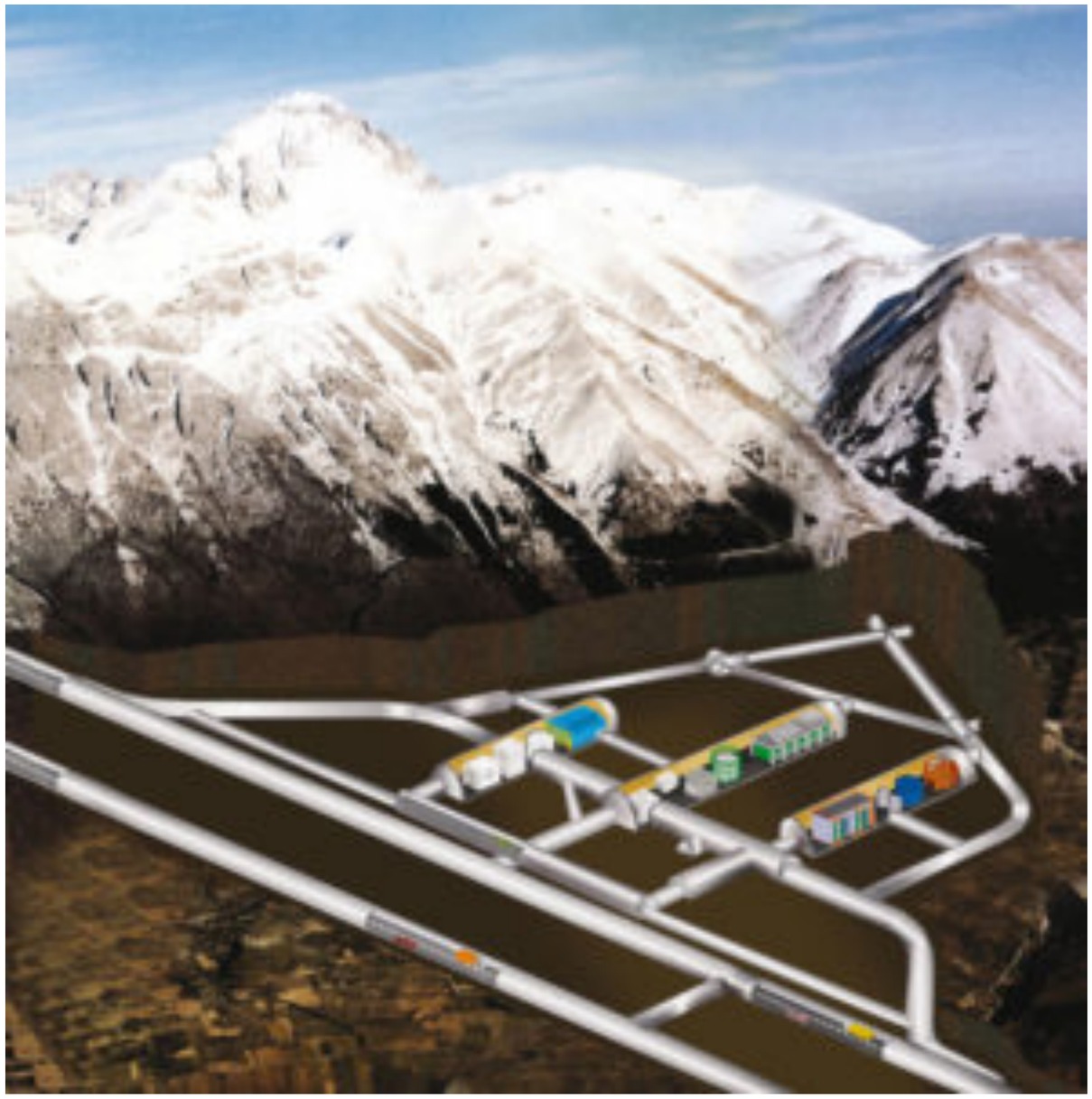
DEAP-3600

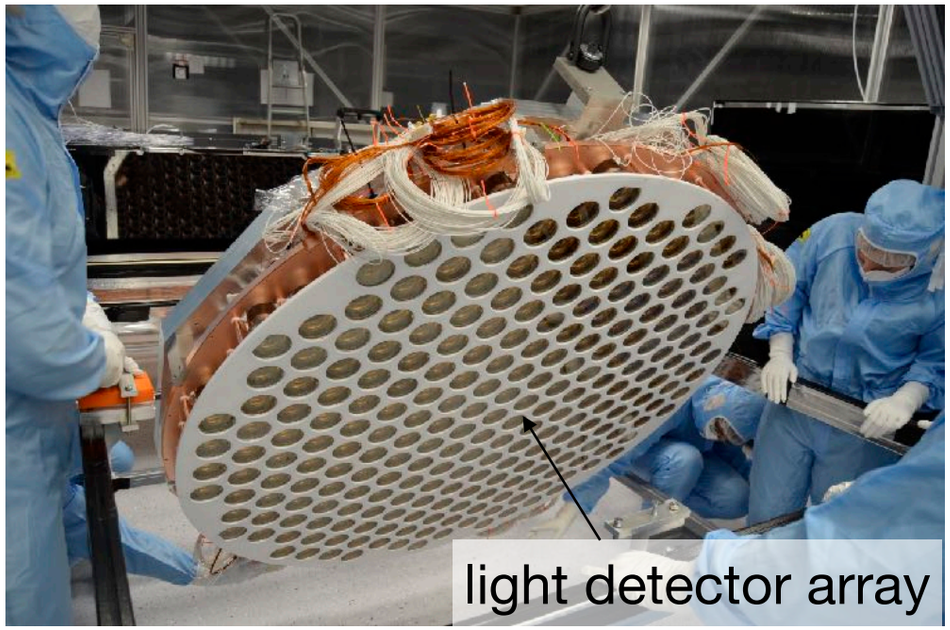
Nikhef

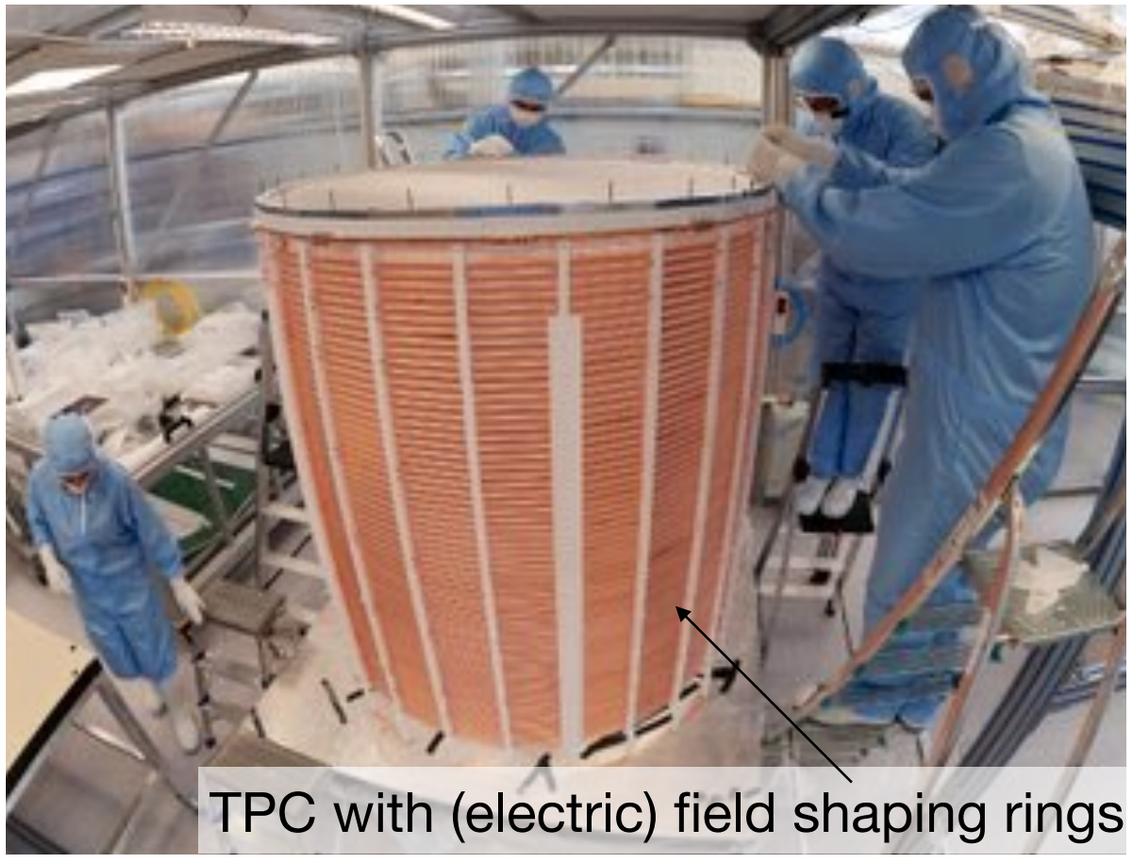
Images courtesy of the respective collaborations

The Netherlands (Nikhef) are contributing to XENON and DARWIN/XLZD.

Gran Sasso national lab (Italy)
3600 mwe shielding against CR secondaries

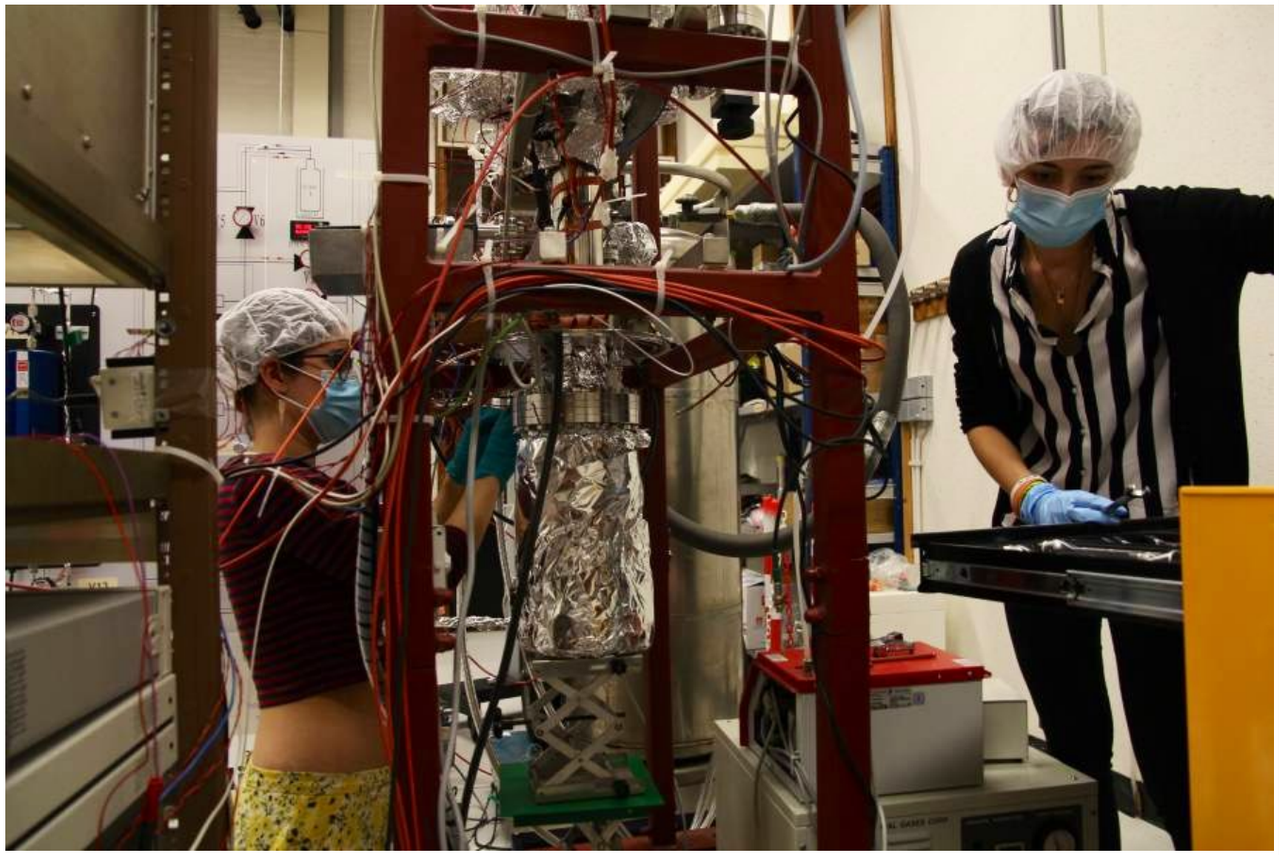






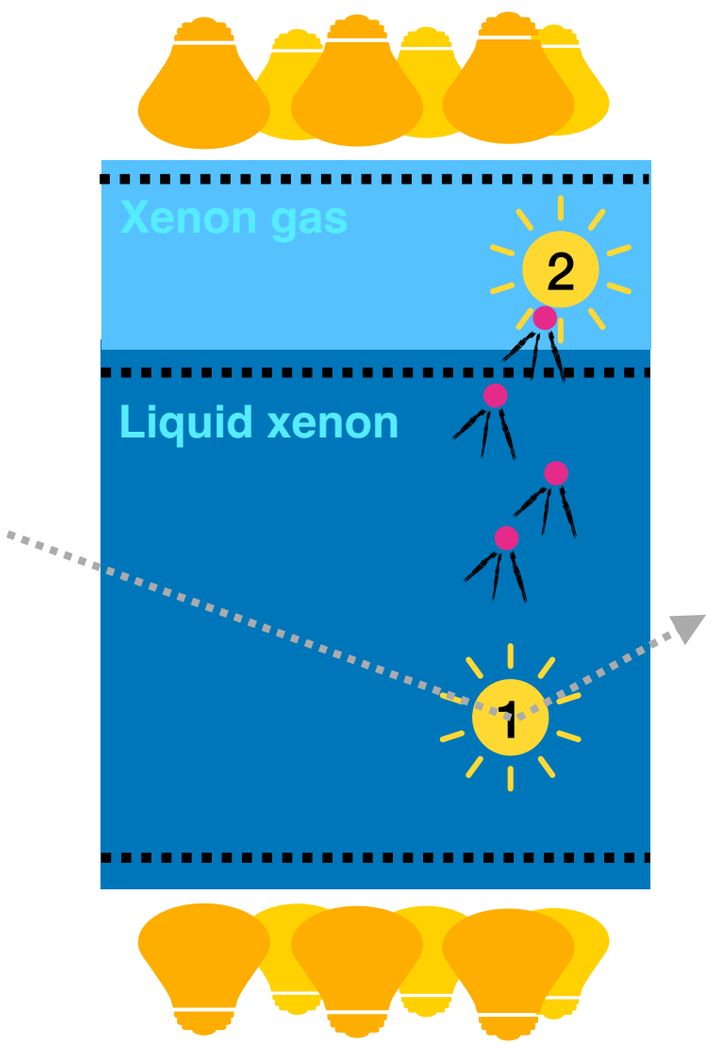
Liquid Xe TPC for R&D at Nikhef

-> Maricke Flierman's talk in the afternoon session

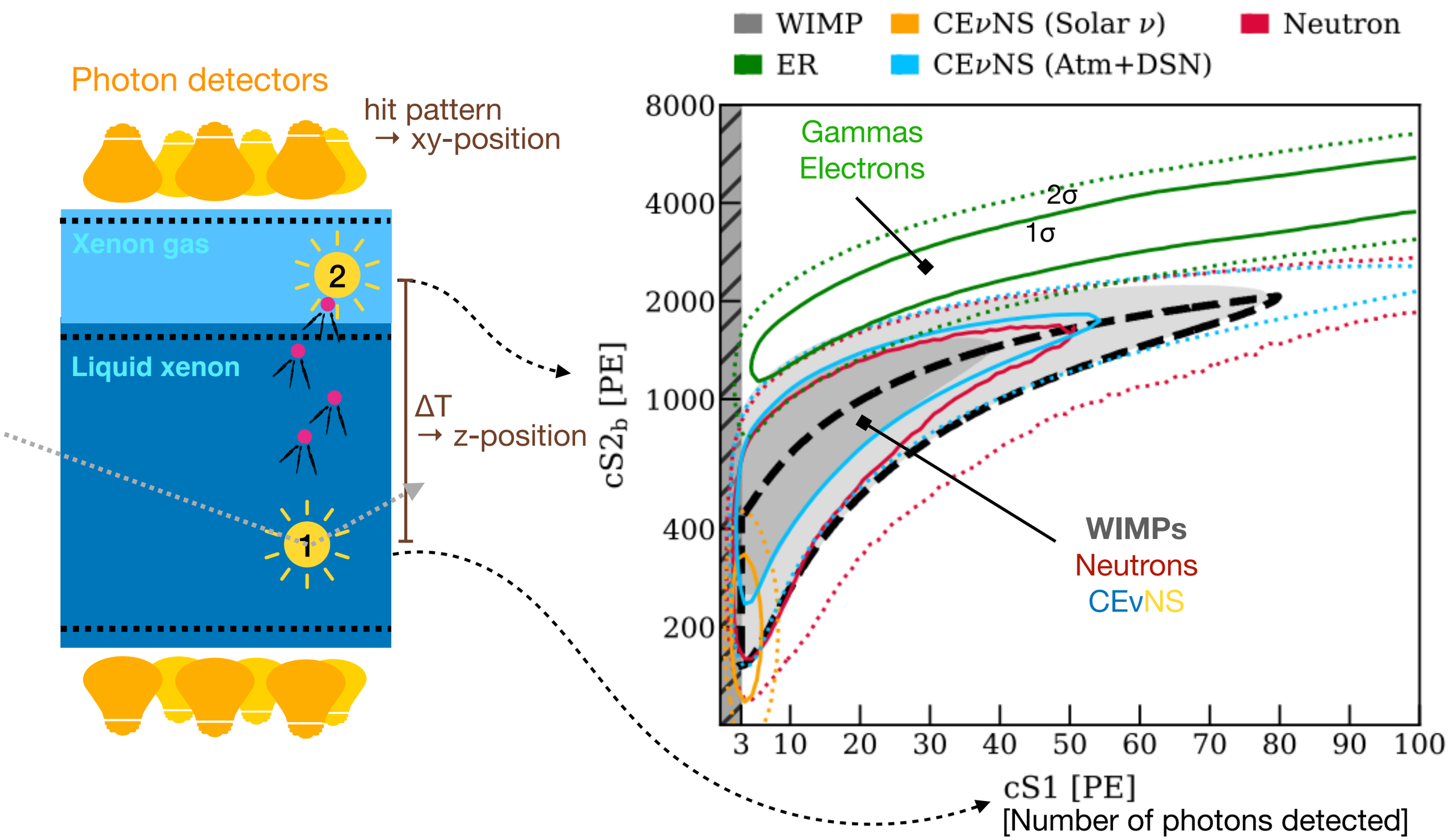


Small single-phase LXe TPC

An interaction in liquid xenon creates scintillation photons and ionization electrons. Both are detected in XENONnT.

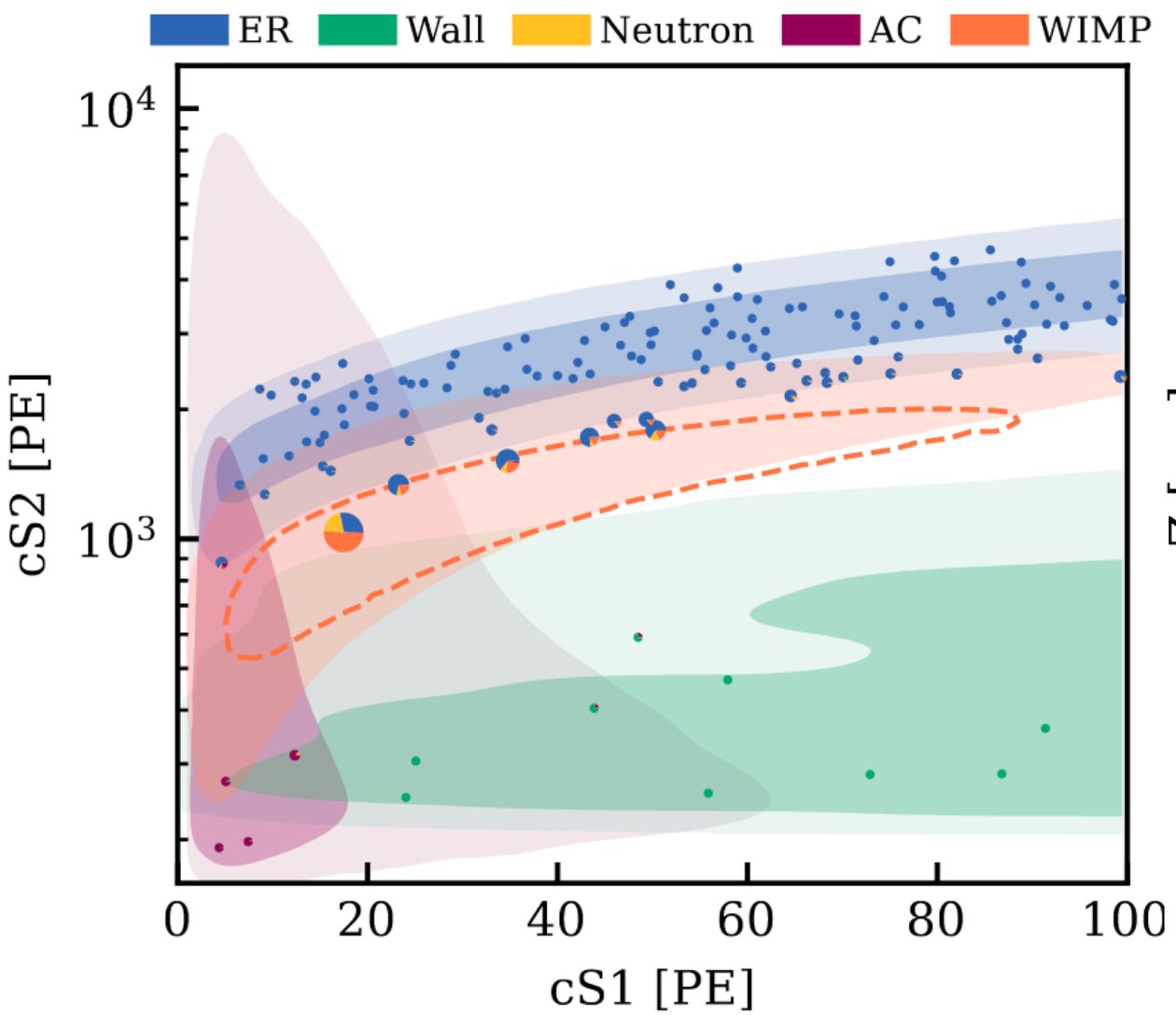


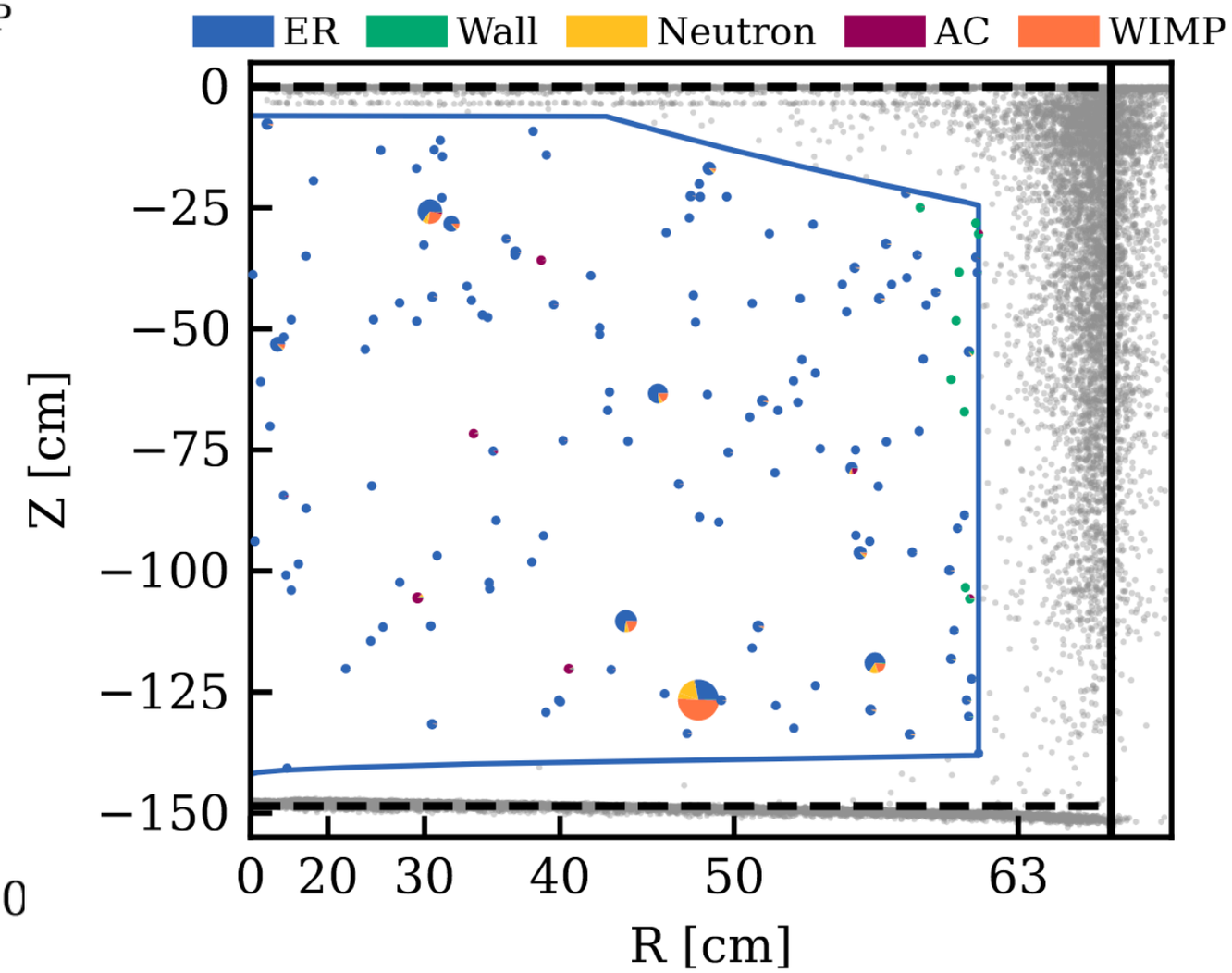
Position and particle ID from the intensity and timing of the light and charge signals.



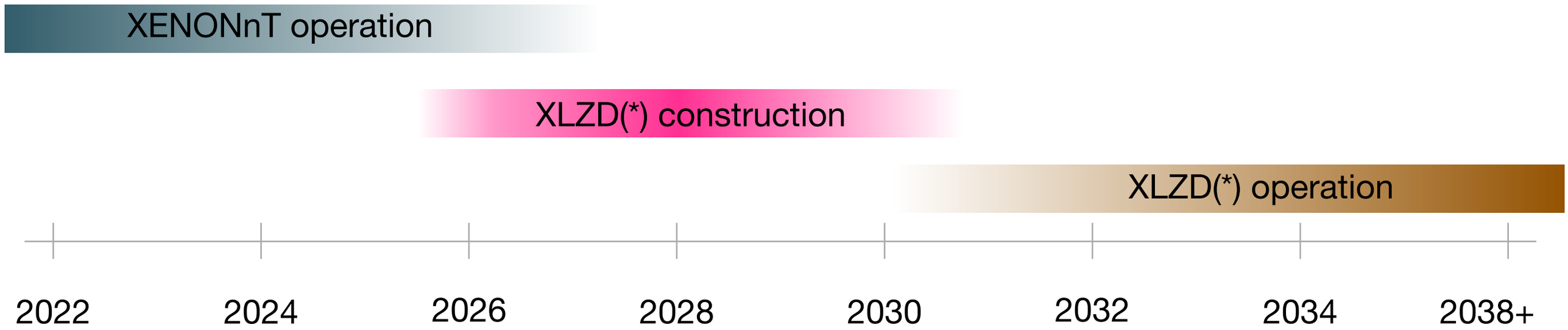
J Cosmol Astropart P **2020**, 031–031 (2020)

Latest result from XENONnT: All events consistent with background





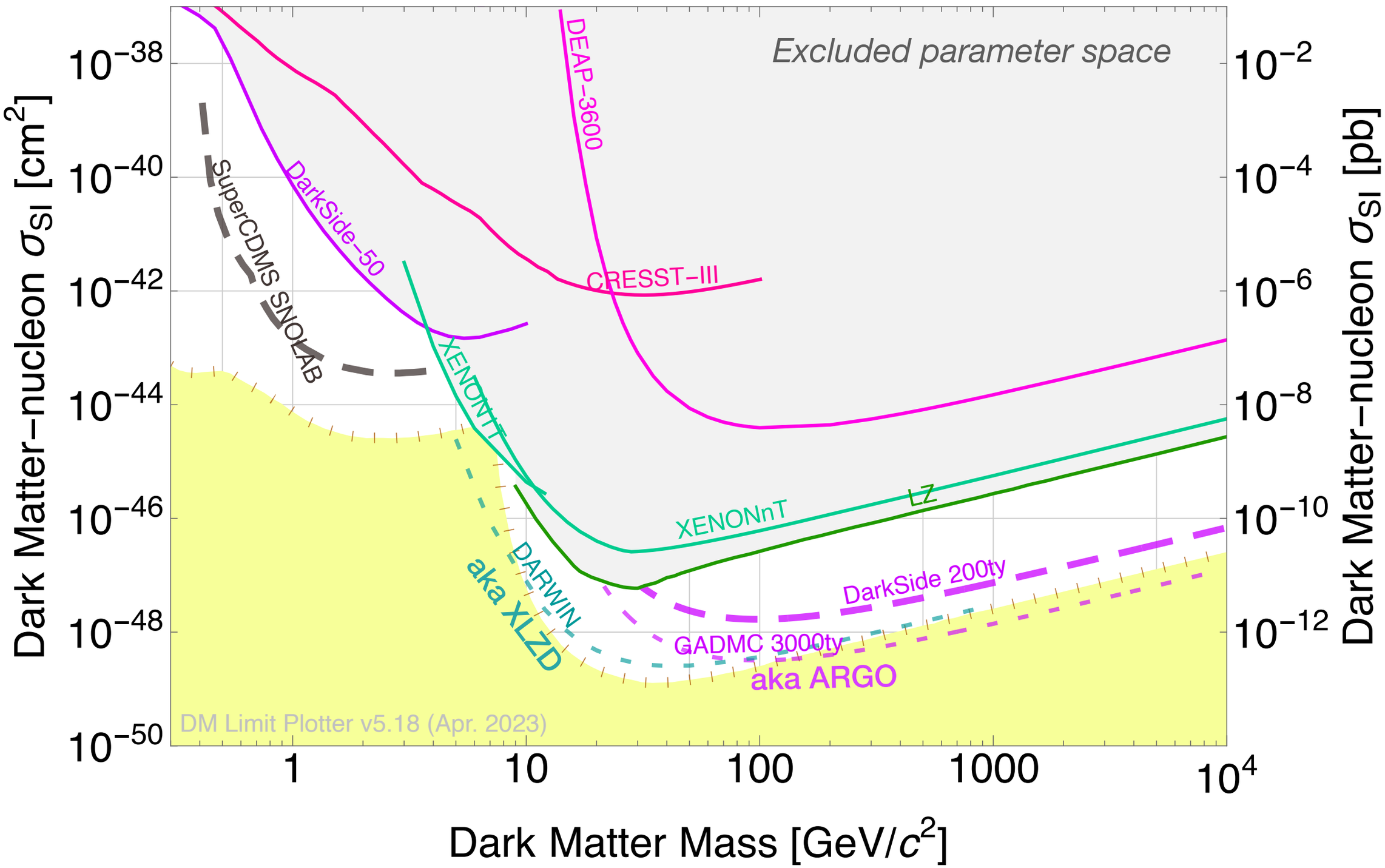
Xenon TPC timeline



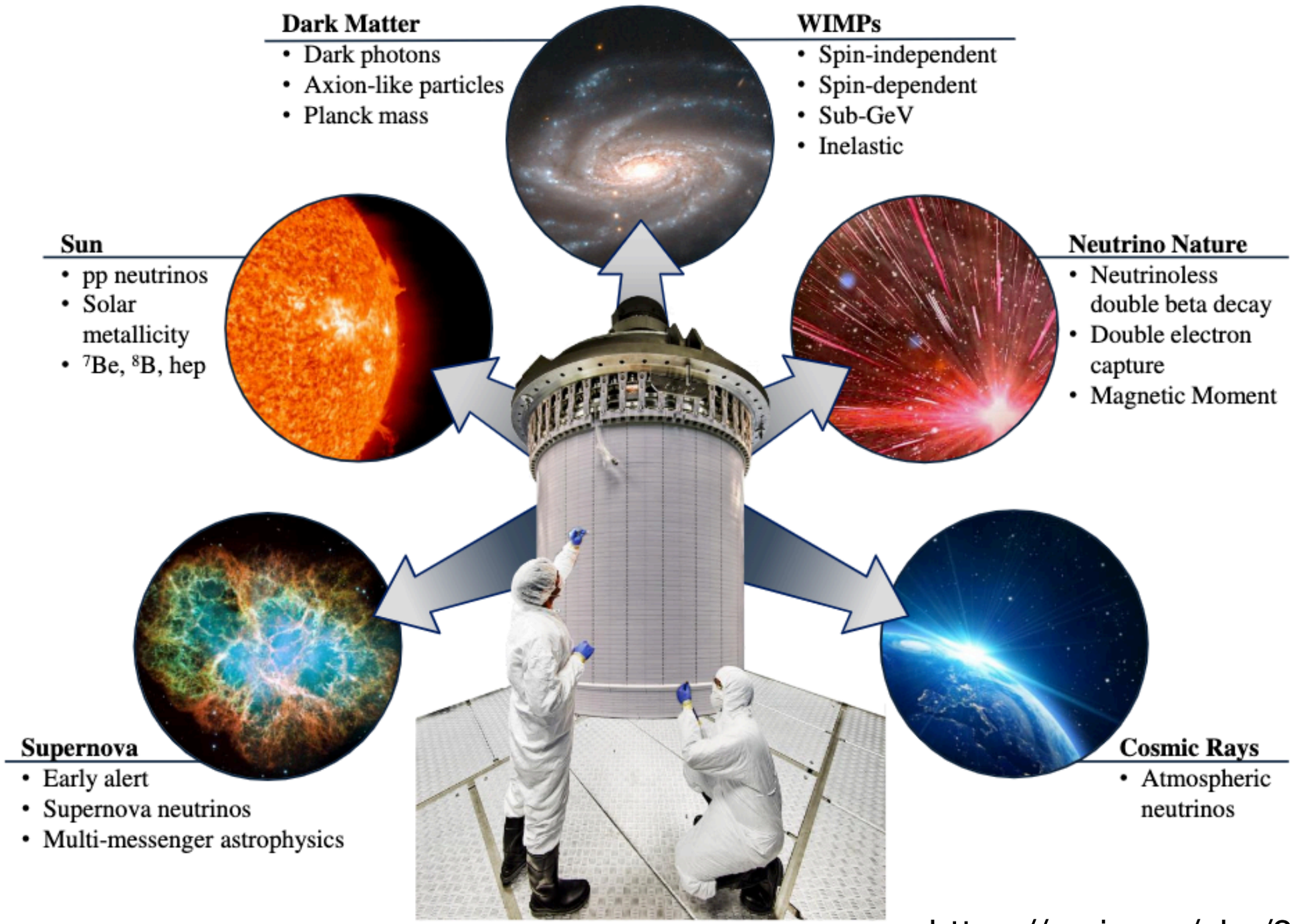
XLZD consortium meeting April 2023

(*) XENON + LZ + DARWIN

XLZD and ARGO will probe the remaining accessible parameter space for standard WIMPs.



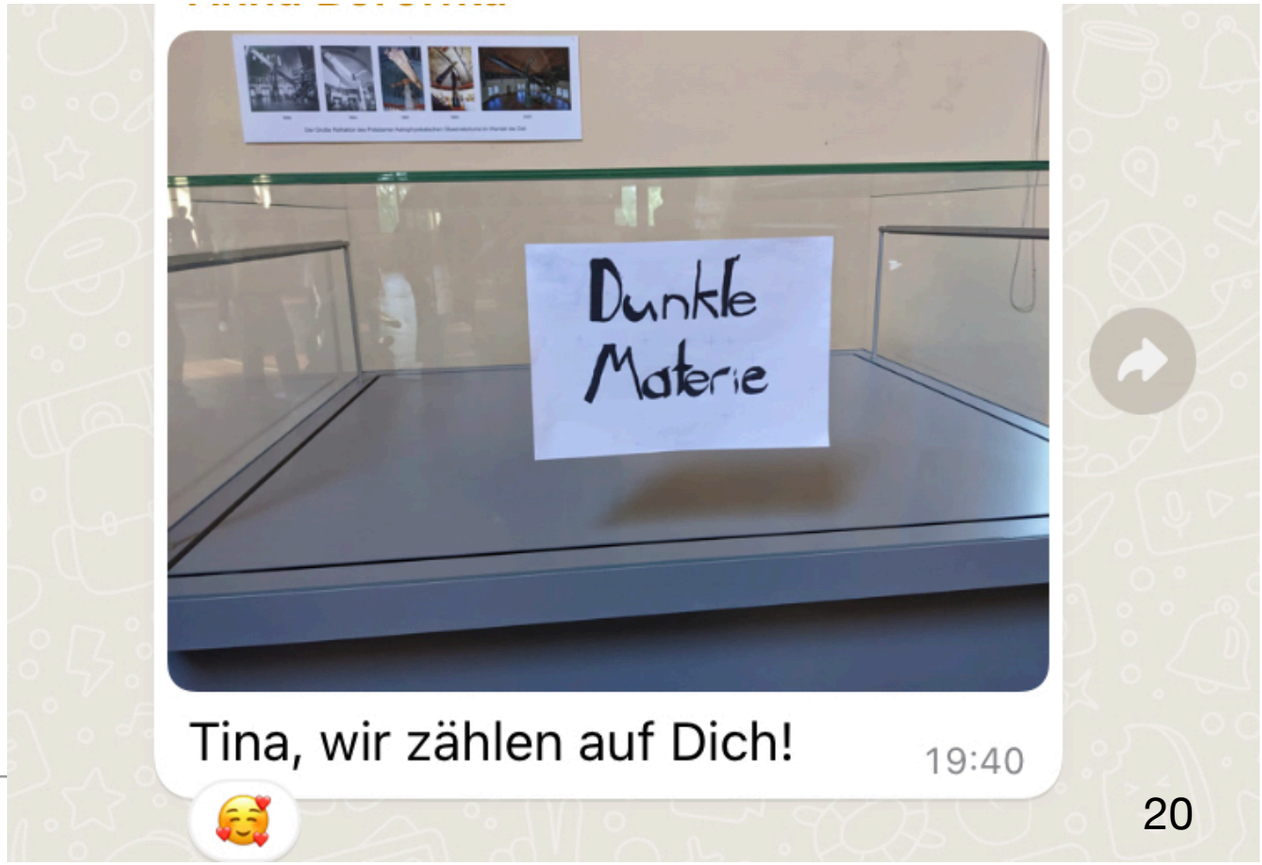
Large sensitive mass, low energy threshold, low background: liquid noble gas detectors turn into observatories for rare processes.



https://arxiv.org/abs/2203.02309

Summary

- The Netherlands contributes to the global liquid-xenon DM programme
- 'neutrino fog' to be reached by at least 2 experiments within ~15 years, which will either lead to detection, or put strong pressure on supersymmetric models.
- We plan for the Xe-based direct detector programme to continue for the next ~20 years
- Large WIMP detectors are observatories sensitive to rare interactions with neutrinos and alternative dark matter candidates



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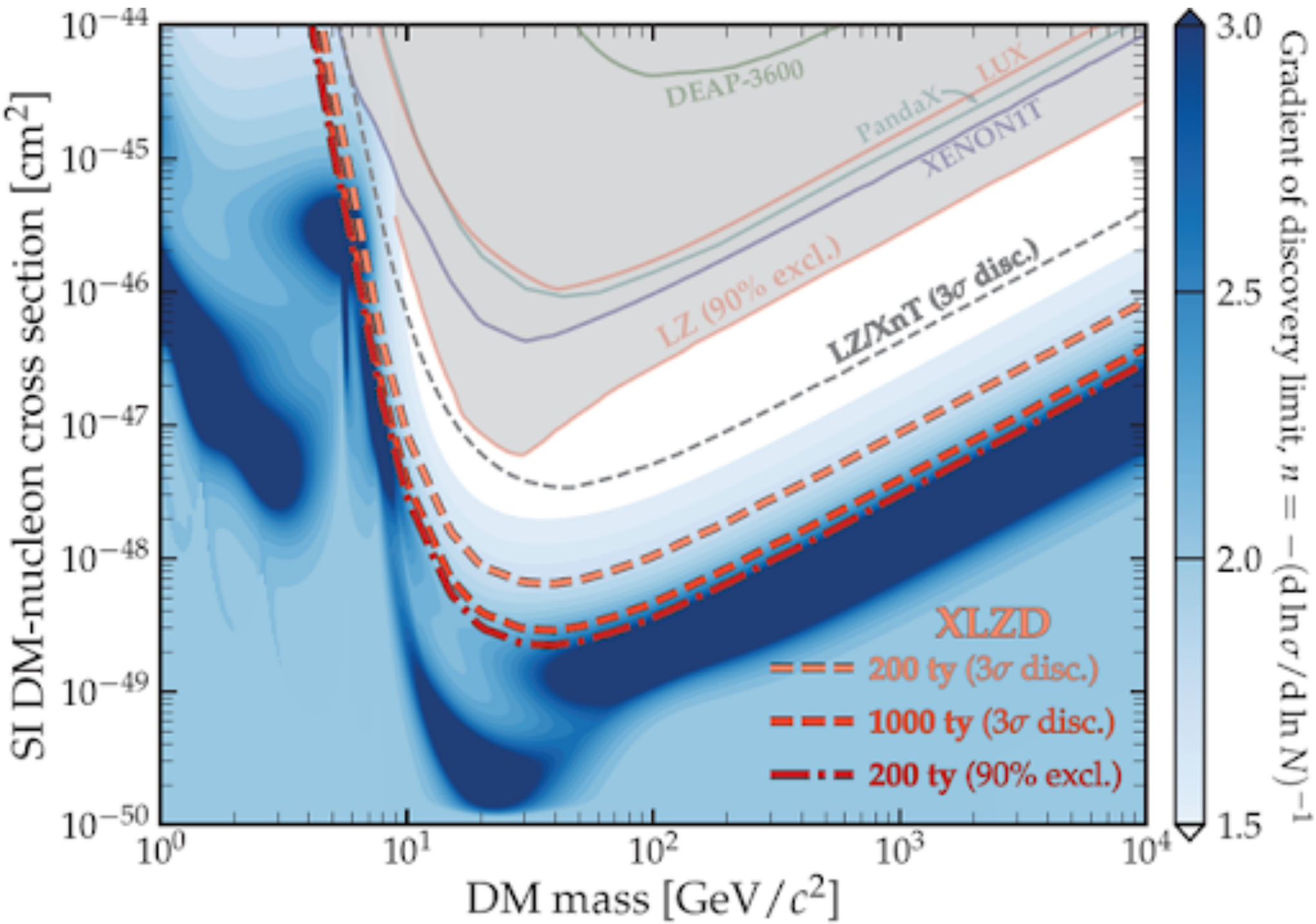
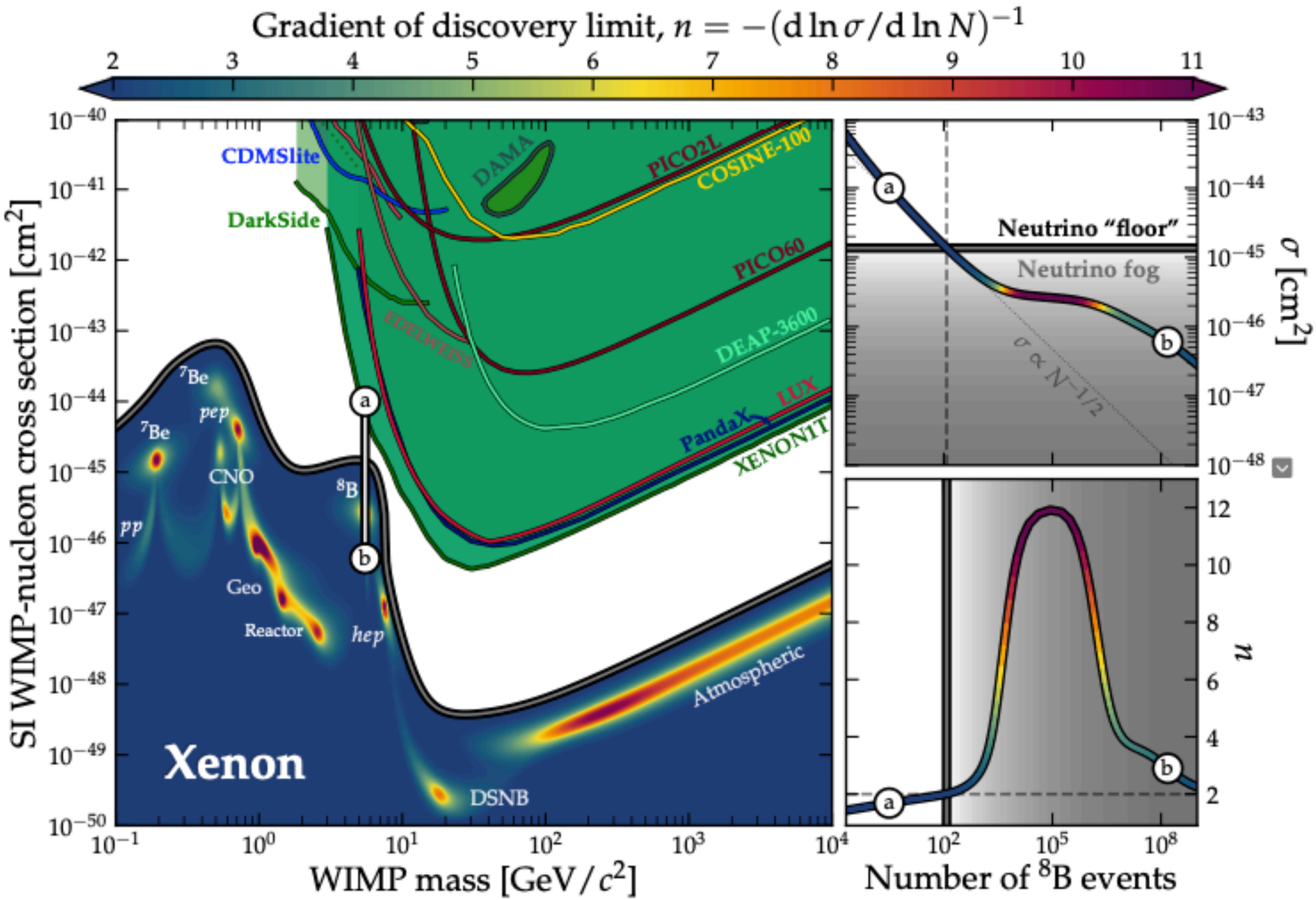
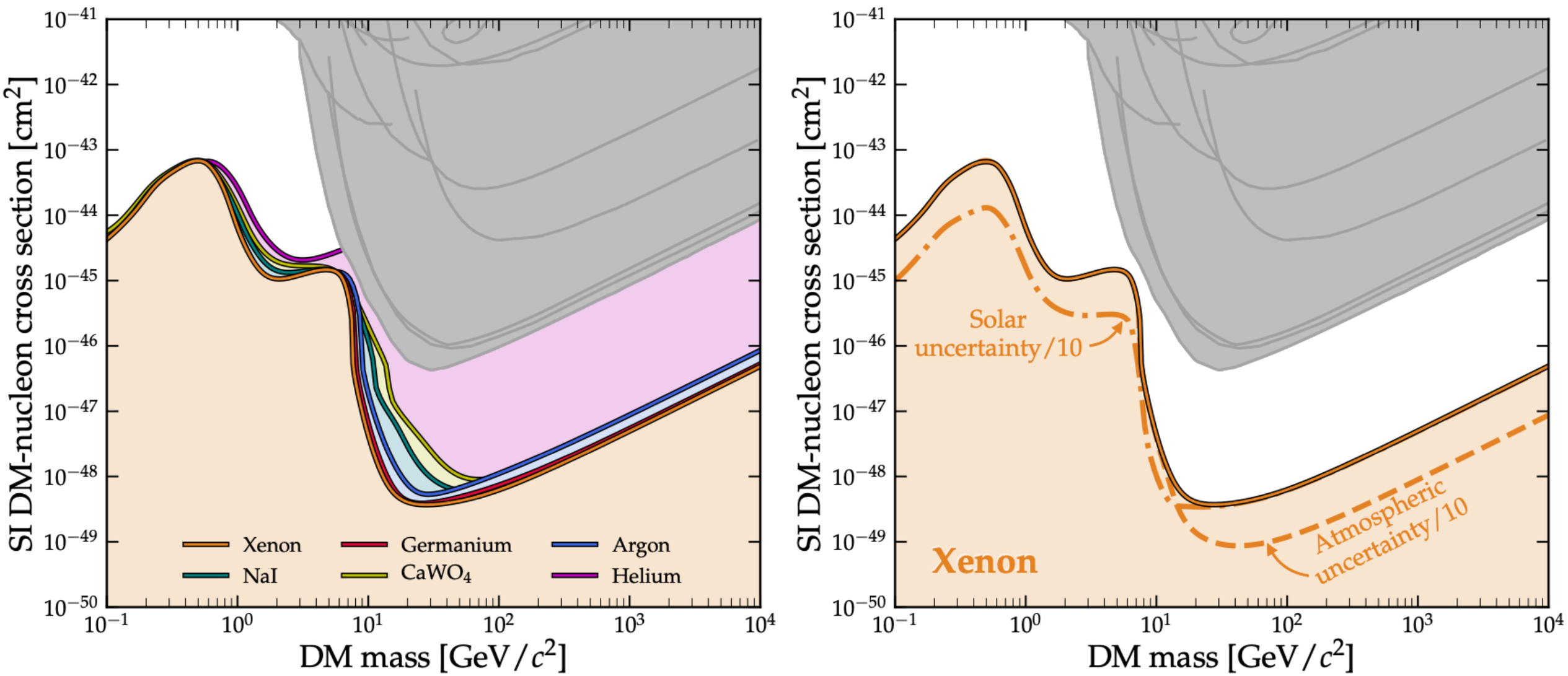

SI DM-nucleon cross section [cm^2]
DM mass [GeV/c^2]
Gradient of discovery limit, $n = -(\mathrm{d}\ln\sigma/\mathrm{d}\ln N)^{-1}$
DEAP-3600
PandaX
LUX
XENON1T
LZ (90% excl.)
LZ/XnT (3σ disc.)
XLZD
200 ty (3σ disc.)
1000 ty (3σ disc.)
200 ty (90% excl.)

The neutrino fog

https://arxiv.org/pdf/2109.03116.pdf

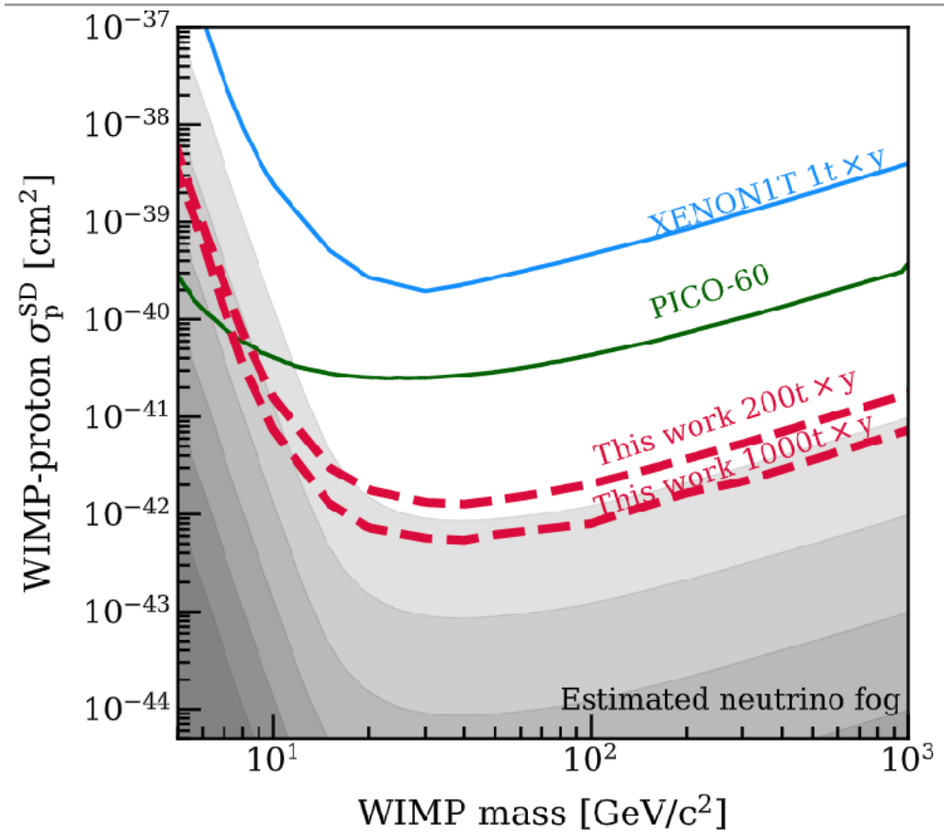


The neutrino fog

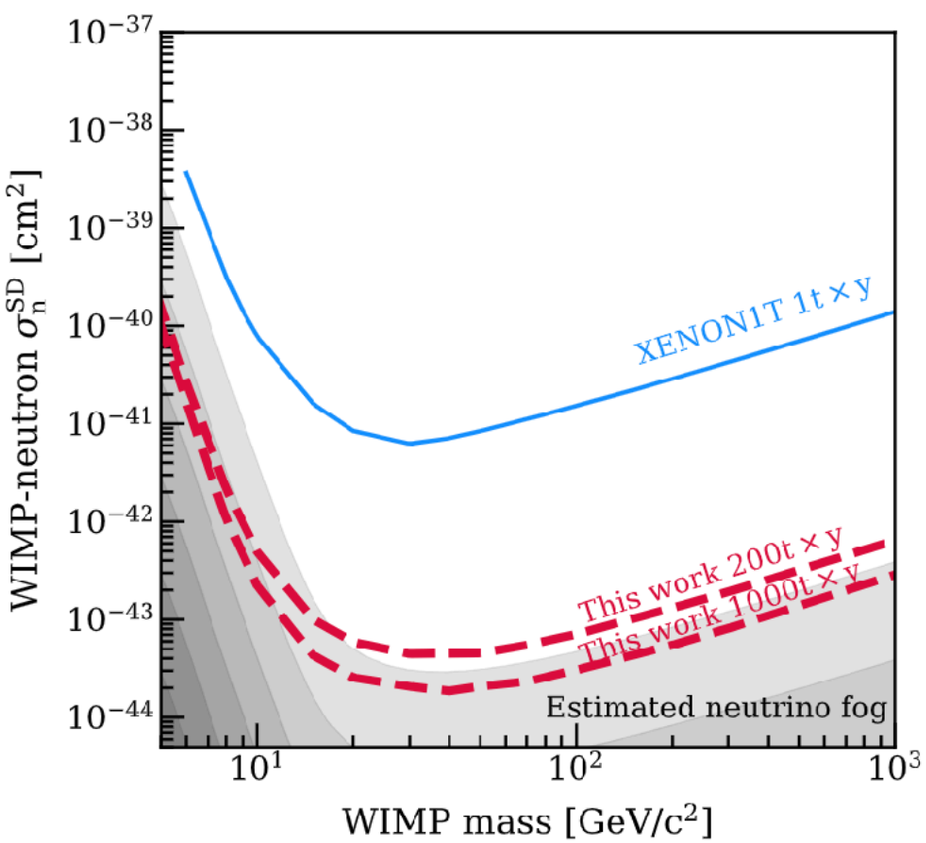


https://arxiv.org/pdf/2109.03116.pdf

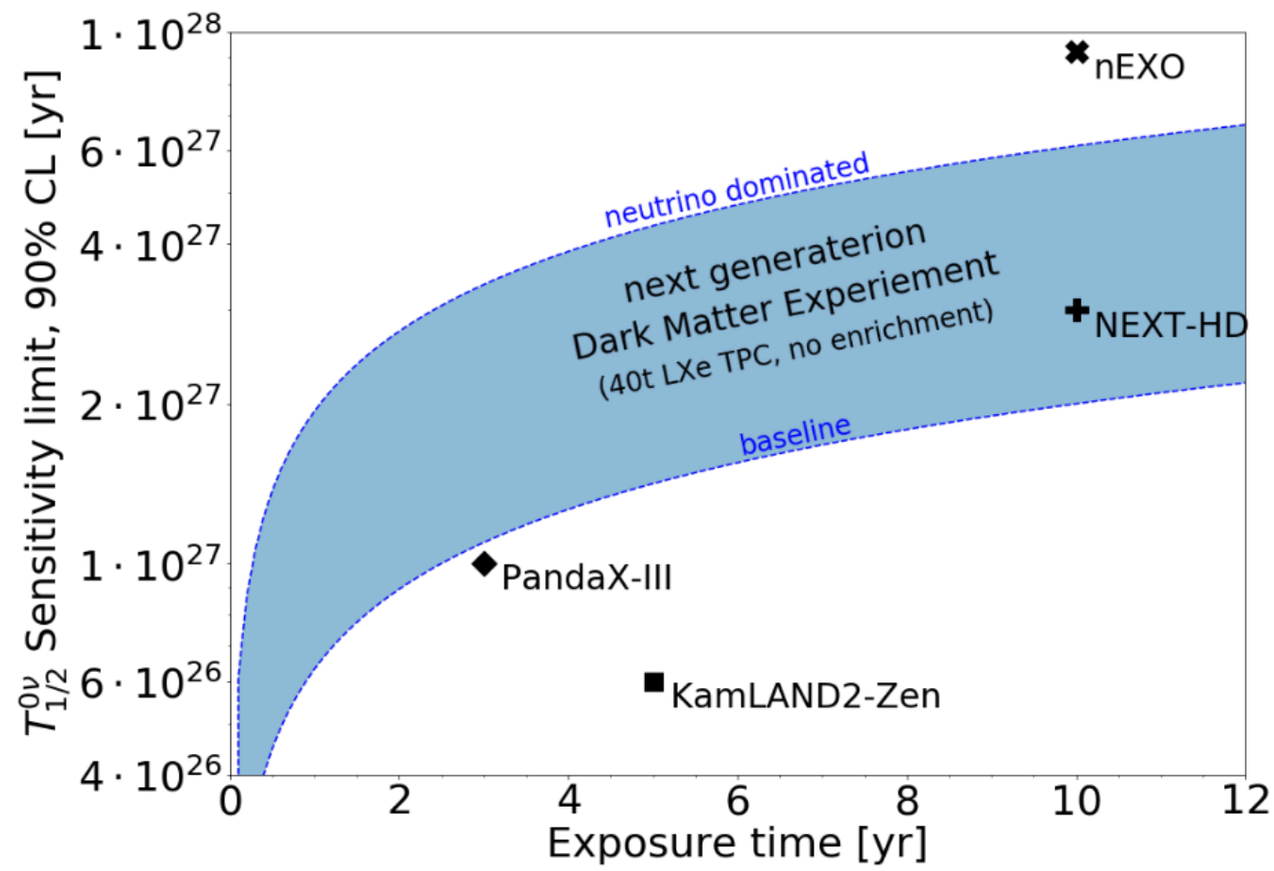
'G3' detectors additional physics reach: non-standard WIMP couplings, solar neutrinos, solar axions, rare decays (0νββ), ...



Sensitivity to spin-dependent WIMP cross sections



Sensitivity to 0νββ (Xe-136)



Aalbers, J. *et al.* A Next-Generation Liquid Xenon Observatory for Dark Matter and Neutrino Physics. *Arxiv:2203.02309* (2022).

Competitive limits already from XENON1T: 0νββ (limit) and ECEC (rarest measured decay)