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## What is DarkSide-20k?

- ~50-tonne dual-phase liquid-argon TPC
- Direct dark-matter detector at LNGS
- Underground argon target
- S1/S2 event reconstruction

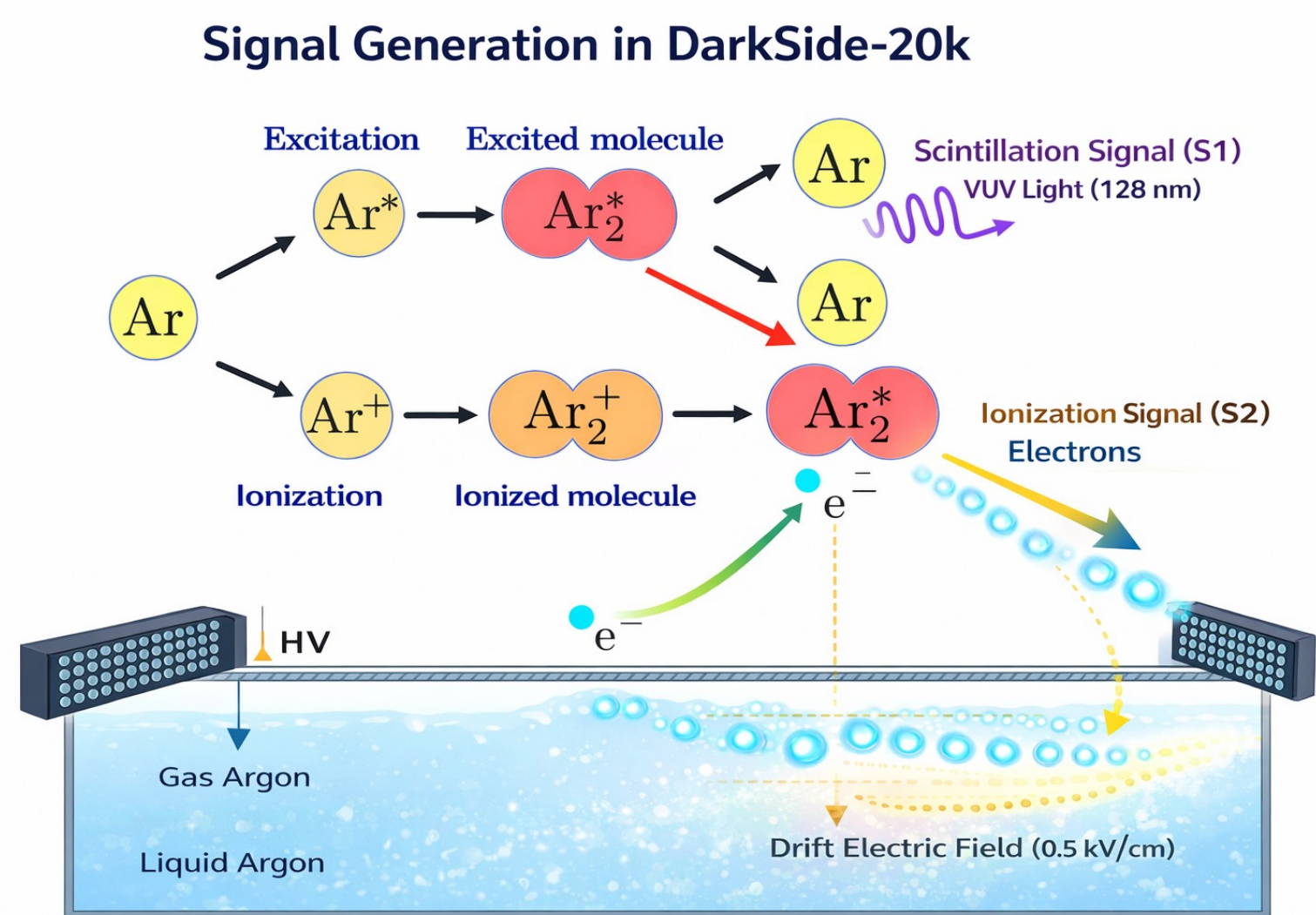


Figure 1: Signal formation in liquid argon.

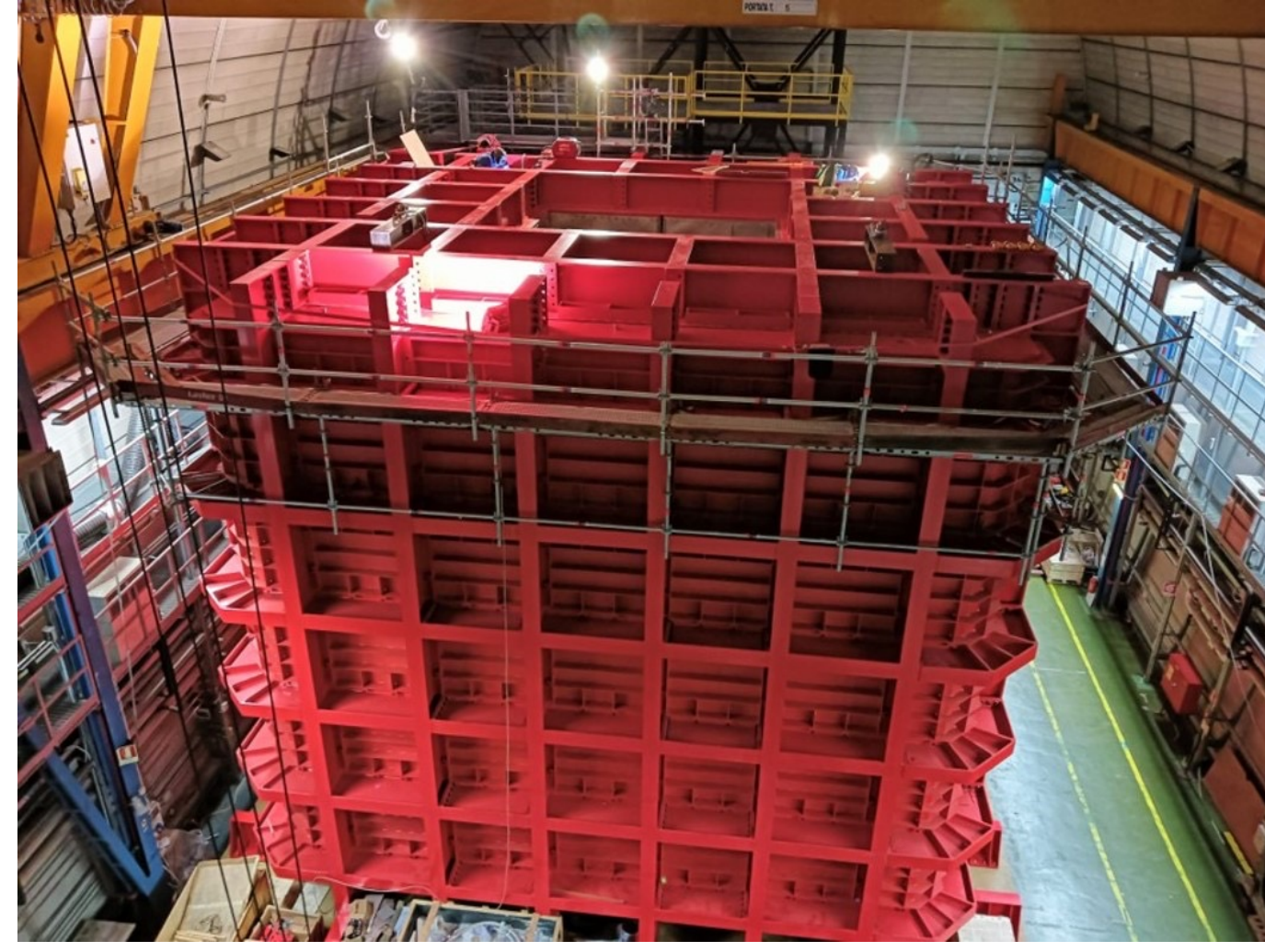


Figure 2: DarkSide-20k at LNGS

## Key Features

- 49.7 t active mass
- 20.2 t fiducial mass
- 32 t inner neutron veto
- Large 3.5 m × 3.5 m drift volume
- Cryogenic SiPM optical planes

## Background Control

- UAr suppresses <sup>39</sup>Ar backgrounds
- ER/NR separation from pulse shape and S2/S1
- Inner veto + outer muon veto
- Shielding and deep-underground siting

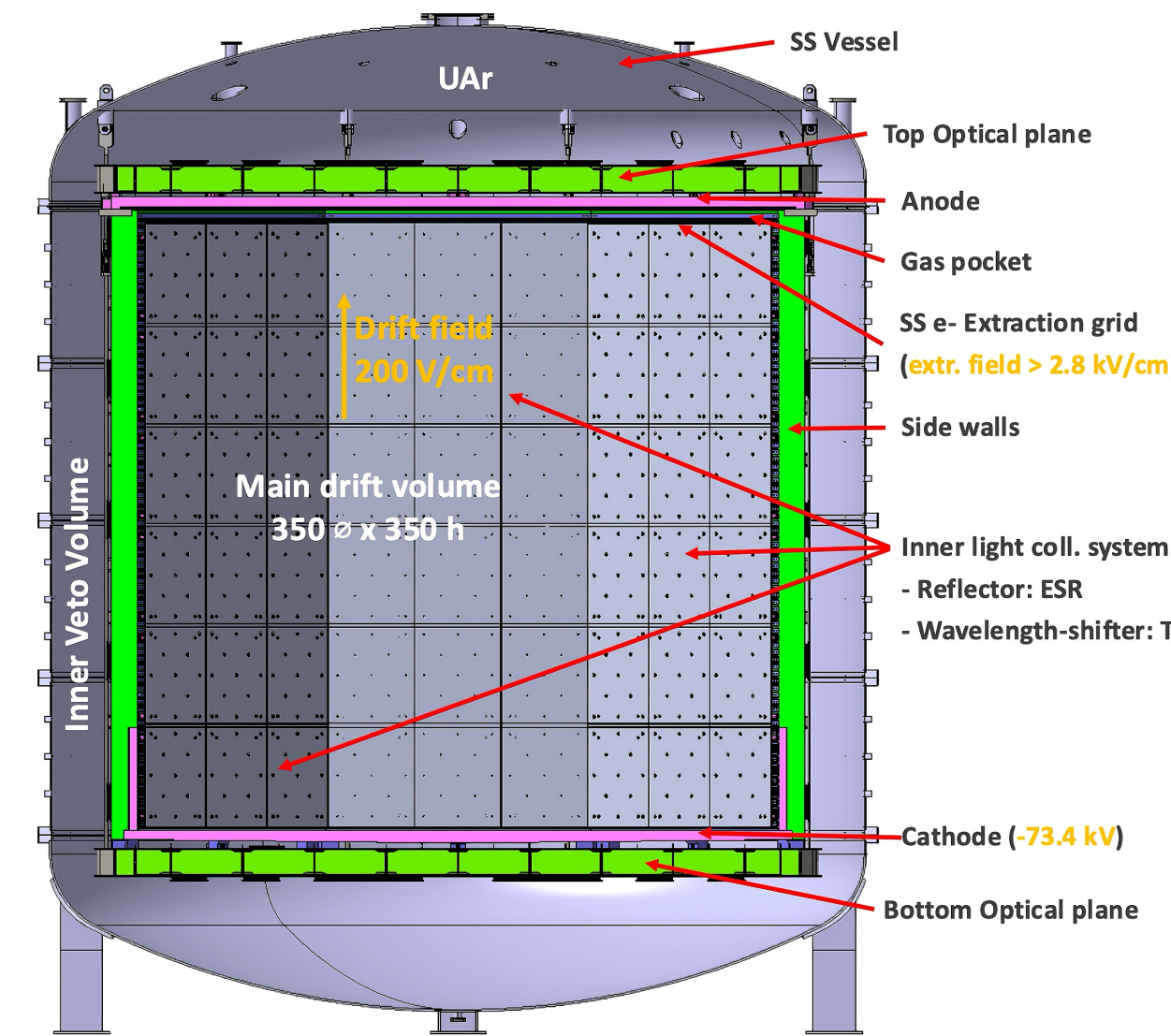


Figure 3: Schematic of the DarkSide-20k dual-phase TPC.

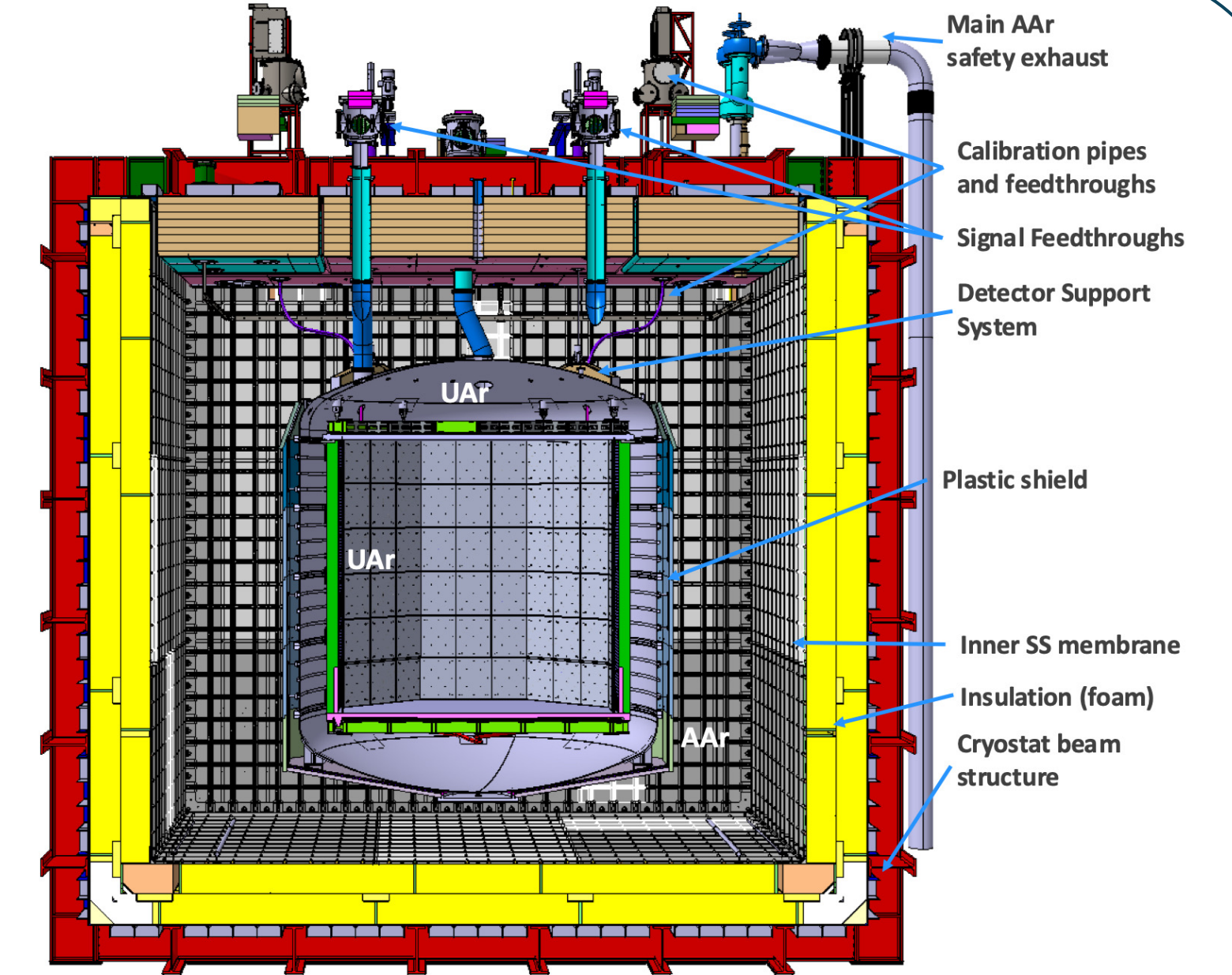


Figure 4: Cross-sectional view of the DarkSide-20k detector assembly.

## Status

- Detector construction underway at LNGS
- Assembly phase in progress
- Commissioning targeted for 2027

## Low-Mass Dark Matter Reach (S2-only)

- S2-only channel (electroluminescence from extracted ionisation electrons) enables sensitivity to low-energy nuclear recoils below the S1 threshold.
- World-leading sensitivity was demonstrated by DarkSide-50 and is expected to be significantly improved by DarkSide-20k.
- Projected sensitivity depends on the assumed dark-matter velocity distribution.
- We tested how the **Large Magellanic Cloud (LMC)** modifies sensitivity by enhancing the high-velocity tail of DM velocity distribution
- This modification is especially important for **Argon targets**, because access to the low-mass regime depends strongly on the highest-velocity DM particles;
- We compare projected **spin-independent** exclusion limits under the **Standard Halo Model (SHM)** and an **LMC-perturbed velocity distribution**.
- We also quantify the additional low-mass sensitivity arising from the **Migdal effect**.

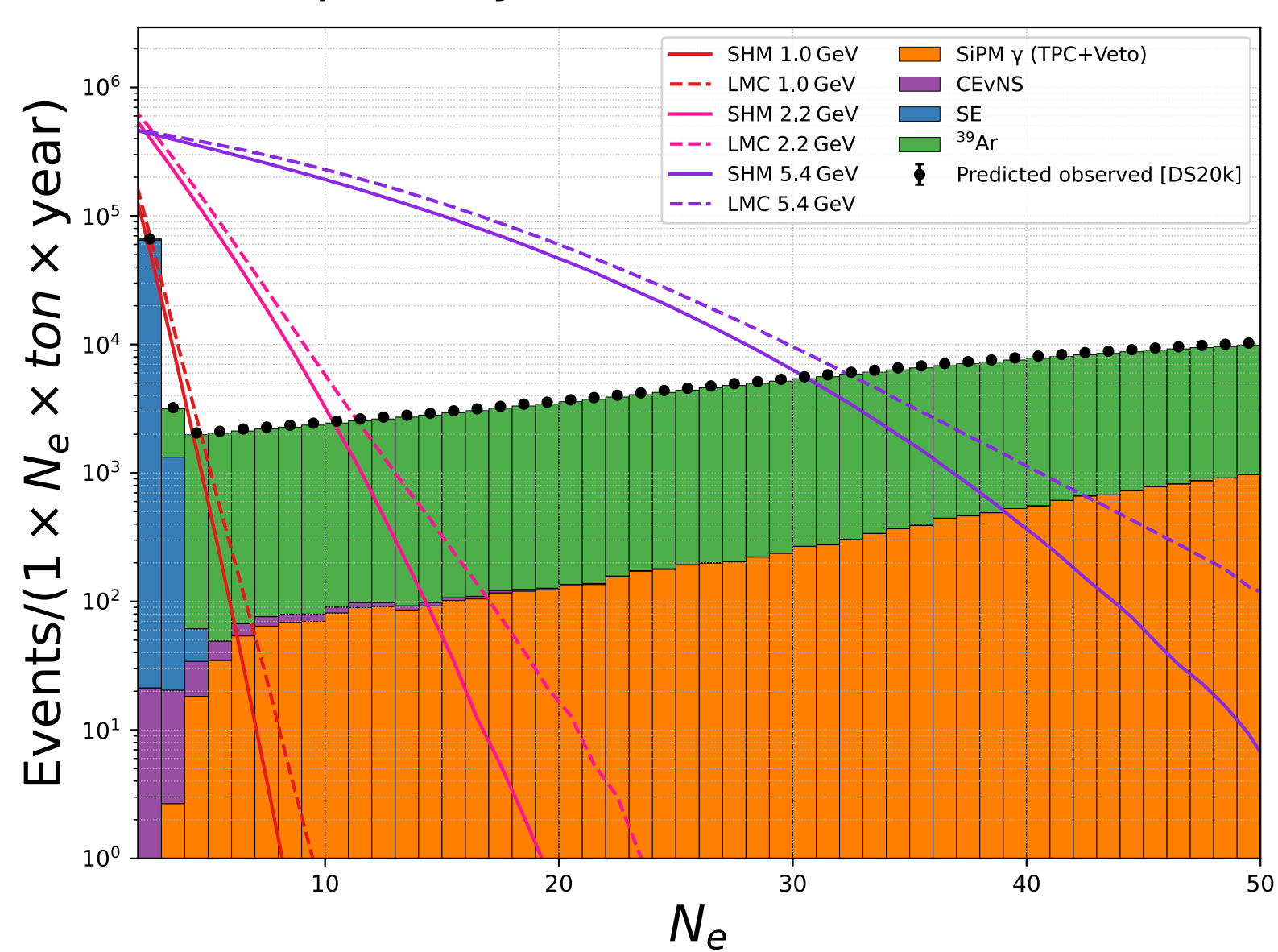


Figure 5: Nuclear-recoil (NR) ionisation spectra—SHM vs LMC for different DM masses.

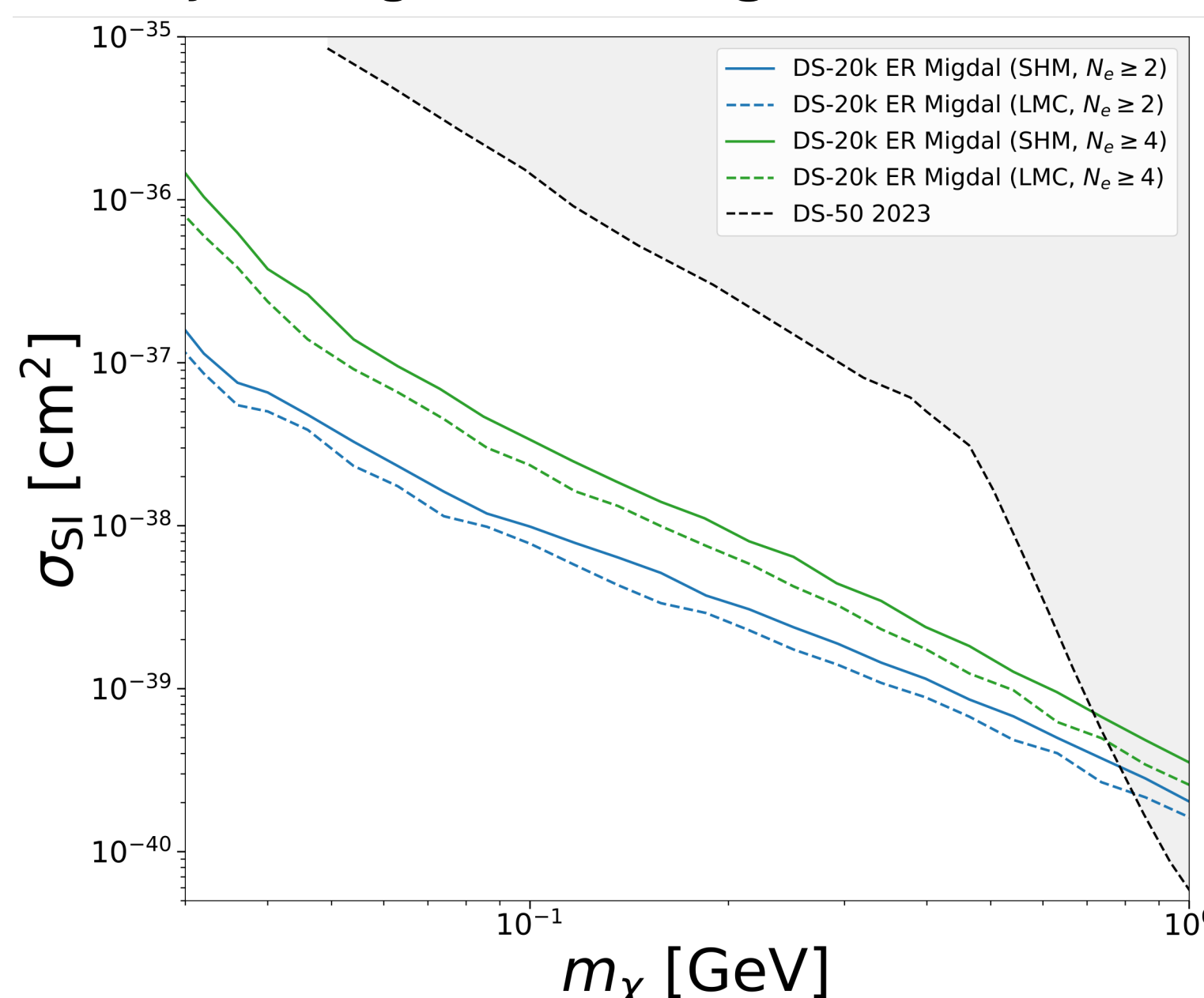


Figure 6: Projected DS-20k S2-only exclusion limits for the Migdal channel (1 year).

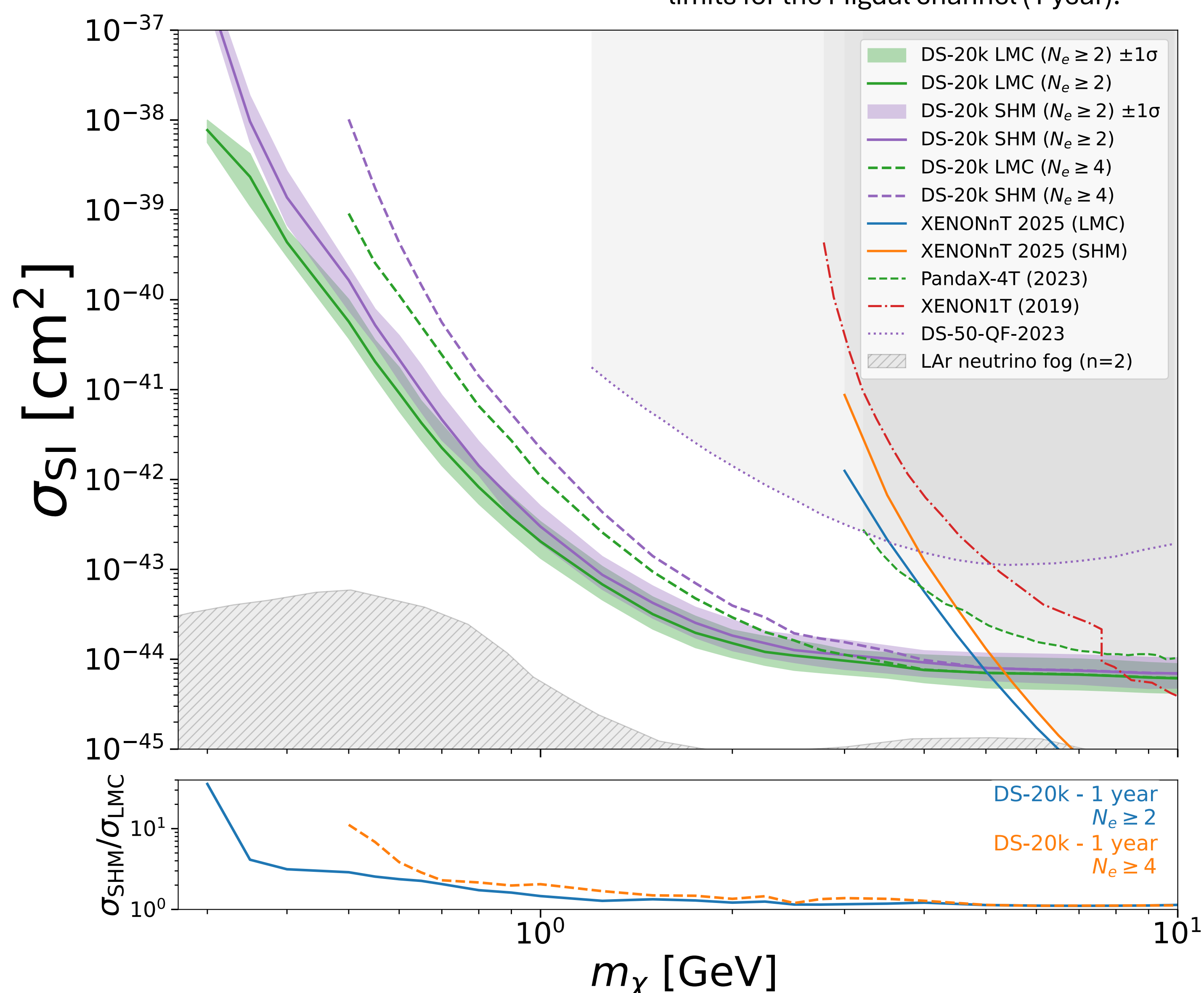


Figure 7: 90% CL S2-only exclusion limits: DS-20k (SHM vs LMC,  $\pm 1\sigma$ , 1 year) with DS-50 & existing xenon-based exclusion limits. [1,2,3]

## From a Projected DarkSide-20k Null Result to the 5 $\sigma$ Discovery Probability of XLZD

**Question:** If **DS-20k** sees a **null result after 10 years**, can a larger-scale experiment like **XLZD** (a proposed future liquid xenon detector) coming online at that time still achieve a **5 $\sigma$  discovery** (in **standard SI WIMP benchmark**)?

- Two-stage posterior-predictive framework** linking a projected DS-20k null result to the future XLZD discovery probability.
- Stage 1:** Construct the DS-20k likelihood under a projected 10-year null result and infer the allowed posterior distribution for the standard spin-independent WIMP–nucleon cross section.
- Stage 2:** Propagate this posterior into an XLZD toy-MC power study to evaluate the probability that a larger future liquid-xenon experiment could still achieve a 5 $\sigma$  discovery [4].

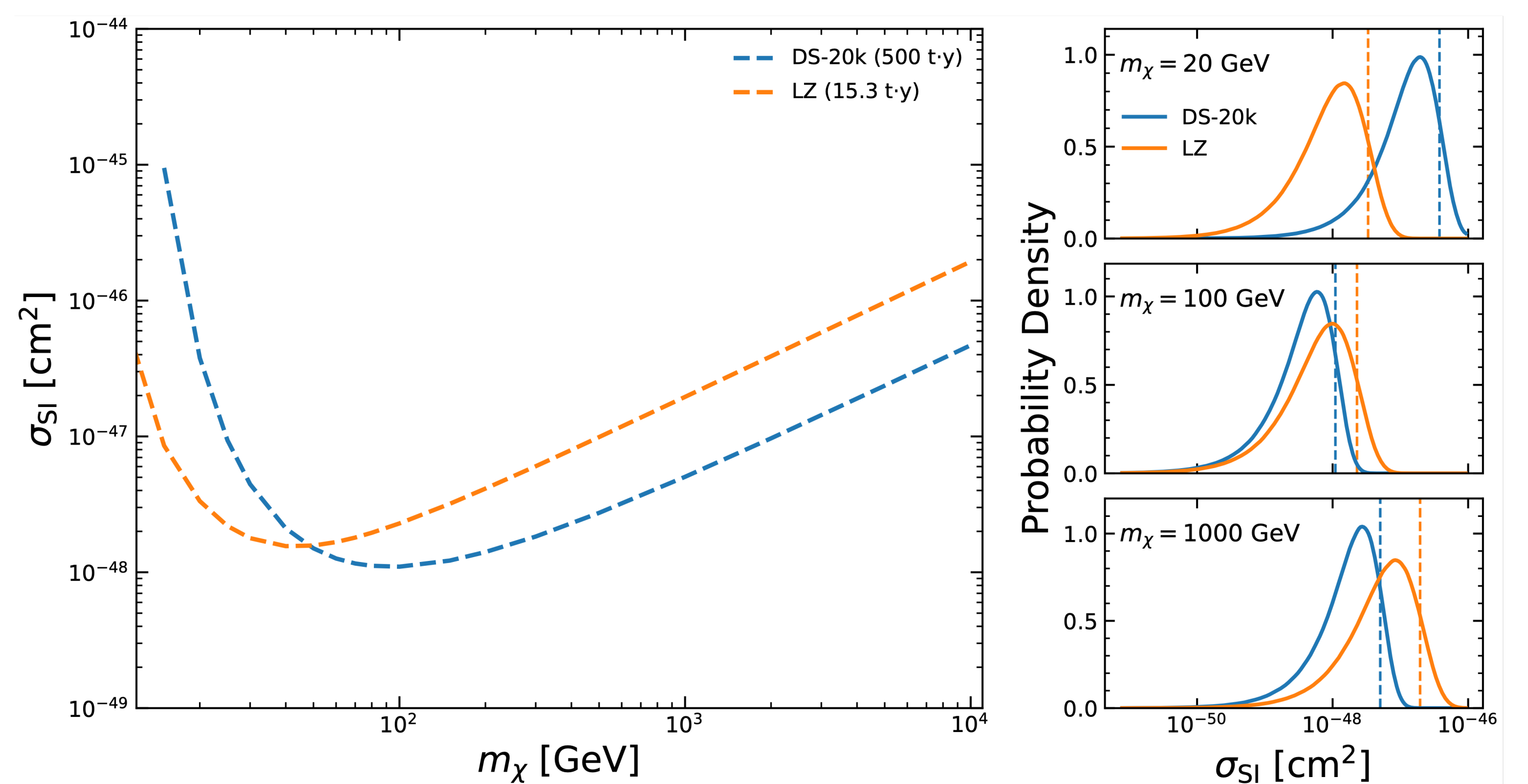


Figure 8. **Left:** one-sided 90% Bayesian upper limits. **Right:** normalized Probability distributions at three representative masses

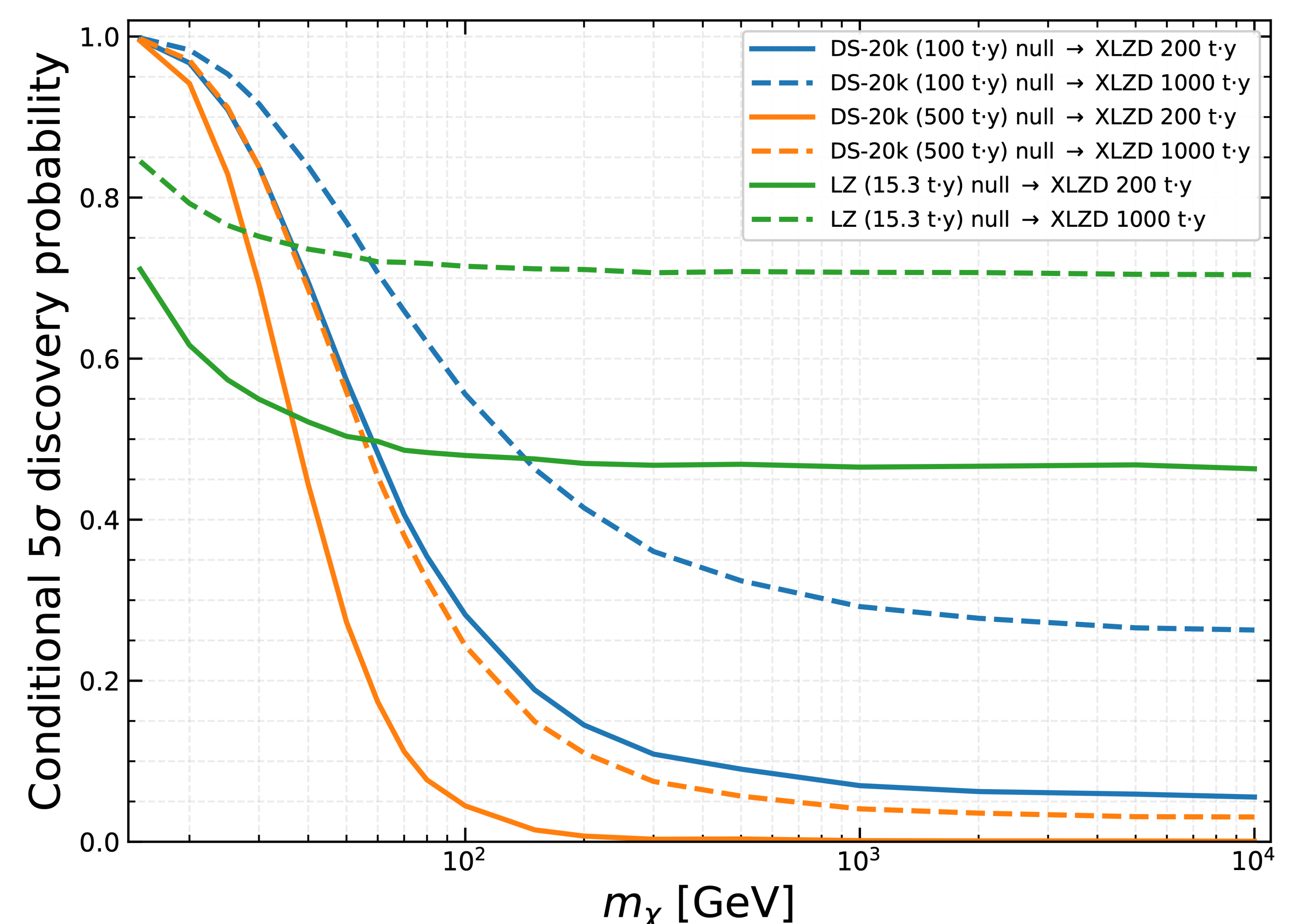


Figure 9: **Conditional XLZD 5 $\sigma$  discovery probability** after projected null results from DarkSide-20k and LUX-ZEPLIN [5].

## References

- The DarkSide-20k Collaboration. DarkSide-20k sensitivity to light dark matter particles (arXiv:2407.05813)
- The first results of PandaX-4T (Int. J. Mod. Phys. A 37, 2230007, 2022).
- First Search for Light Dark Matter in the Neutrino Fog with XENONnT (Phys. Rev. Lett. 134, 111802, 2025; arXiv:2409.17868).
- The XLZD Collaboration. The XLZD Design Book: Towards the Next-Generation Liquid Xenon Observatory for Dark Matter and Neutrino Physics (arXiv:2410.17137, 2024).
- The LZ Collaboration. Dark Matter Search Results from 4.2 Tonne-Years of Exposure of the LUX-ZEPLIN (LZ) Experiment (Phys. Rev. Lett. 135, 011802, 2025; arXiv:2410.17036).