Expanding the reach of argon-based dark matter searches

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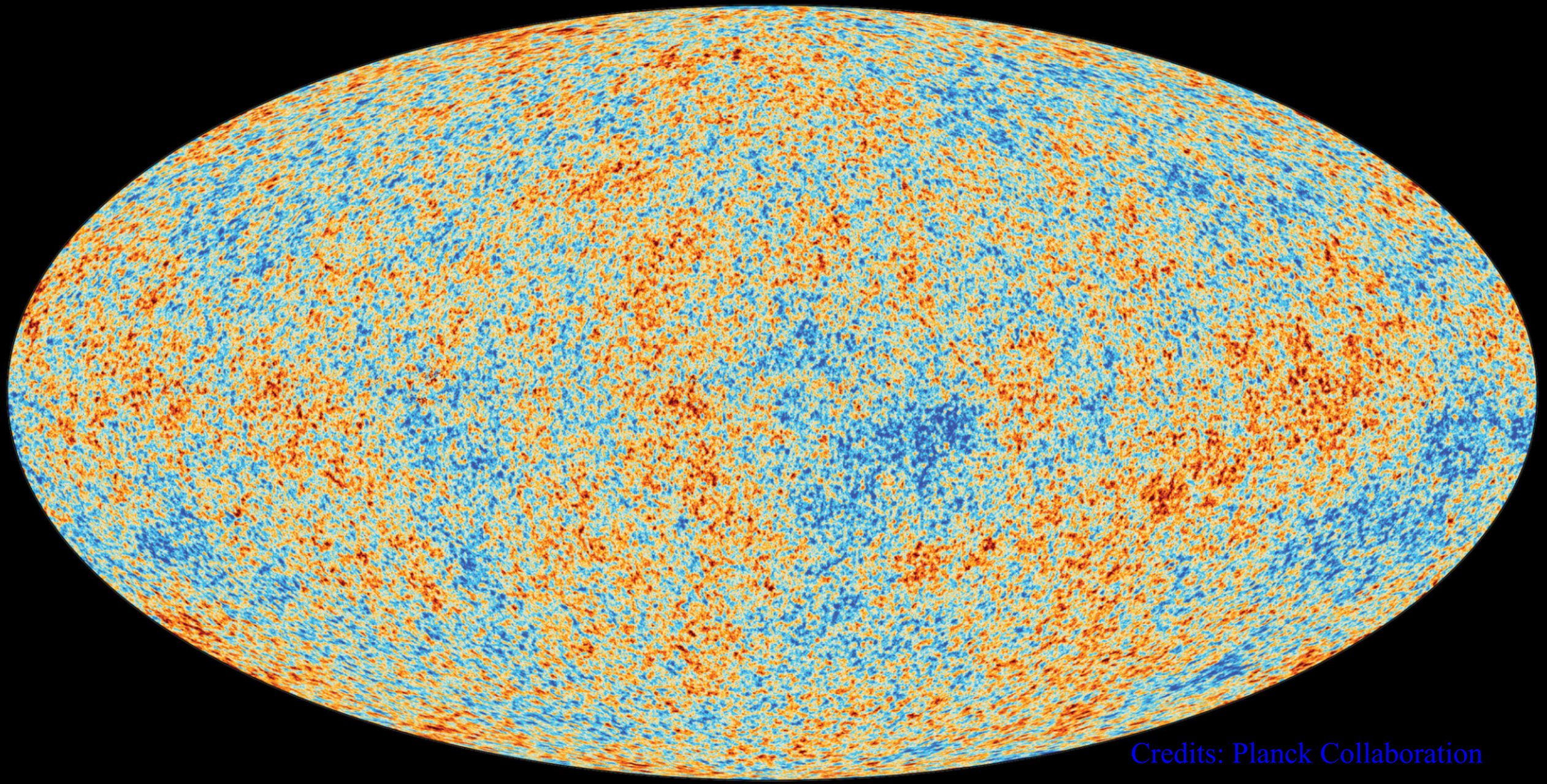
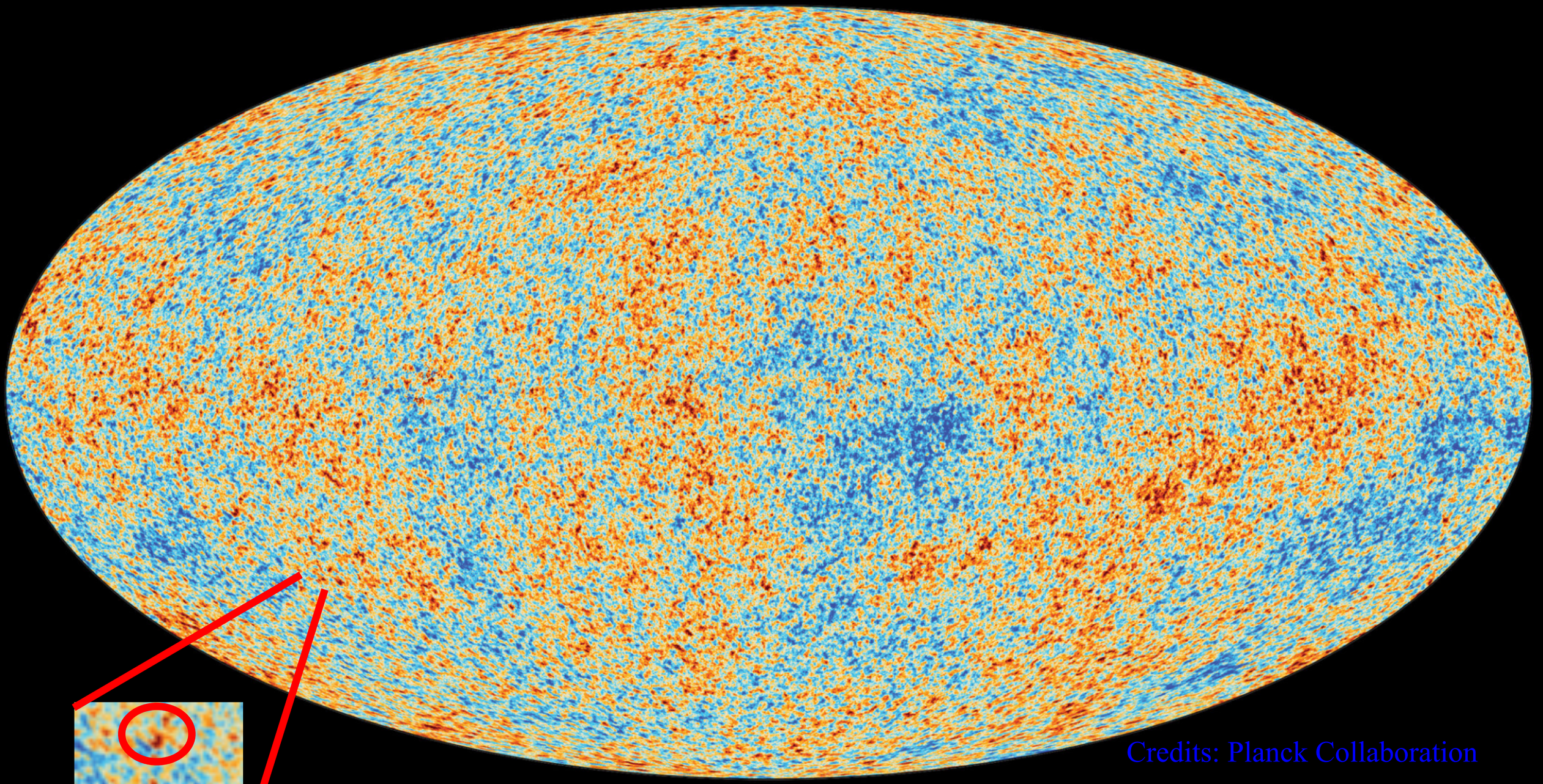
Queen's UNIVERSITY

Winter Nuclear and Particle Physics Conference 2026



Credits: Planck Collaboration



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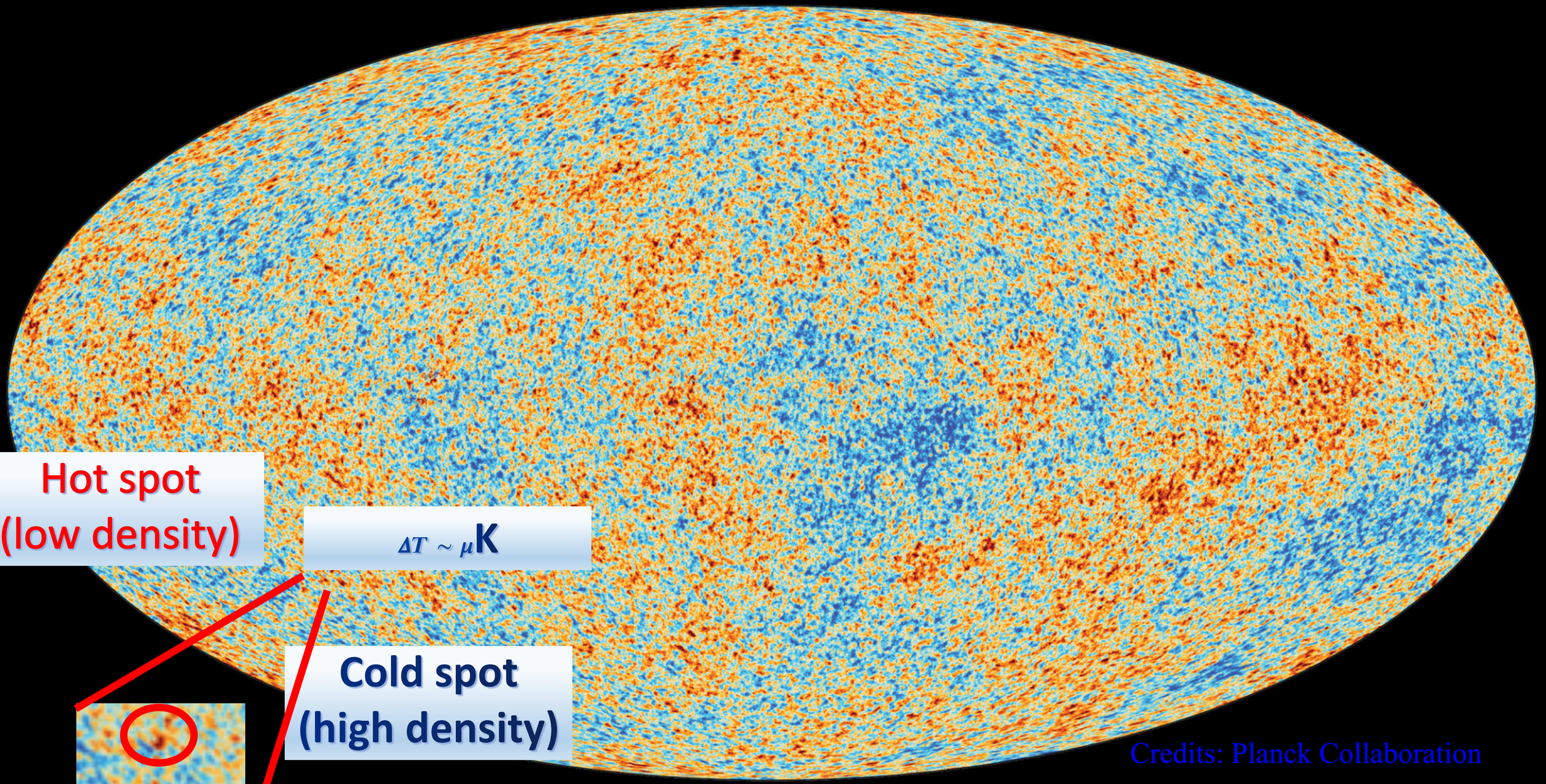

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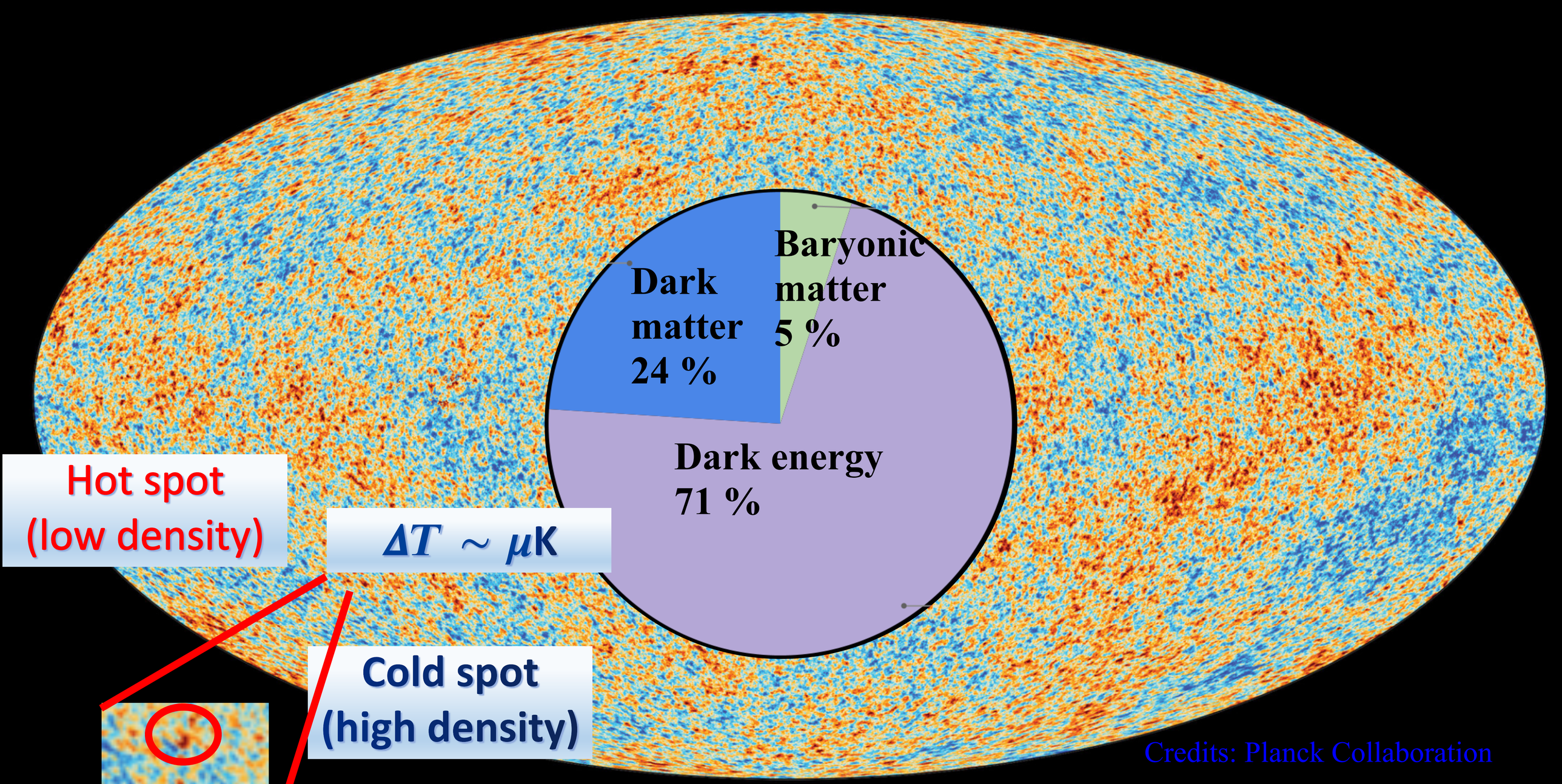

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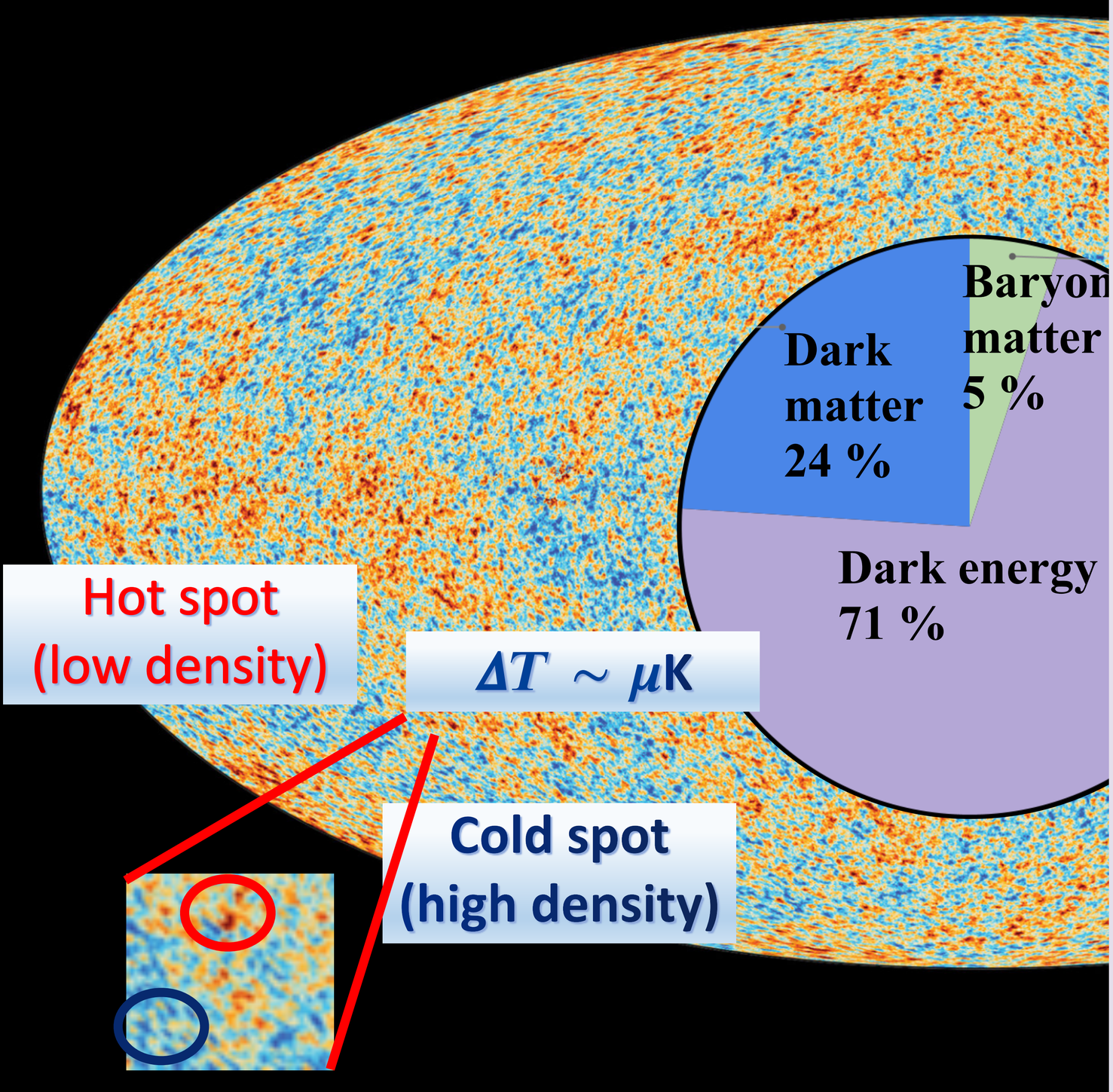

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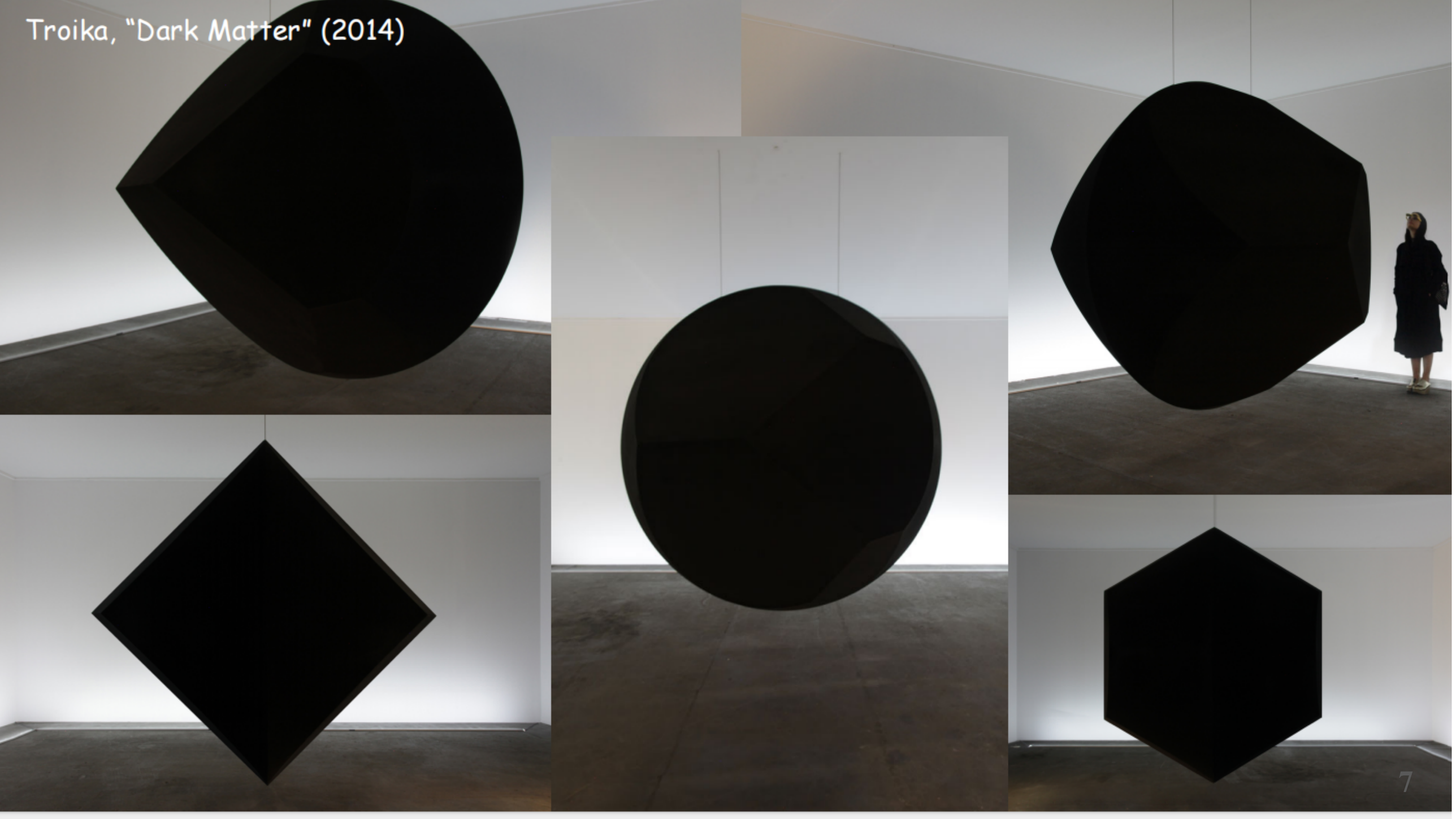
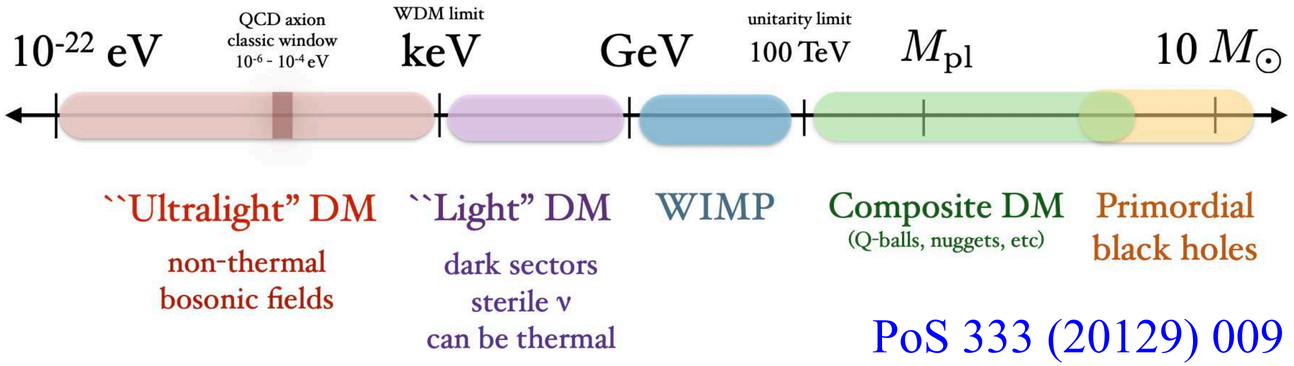

Troika, "Dark Matter" (2014)



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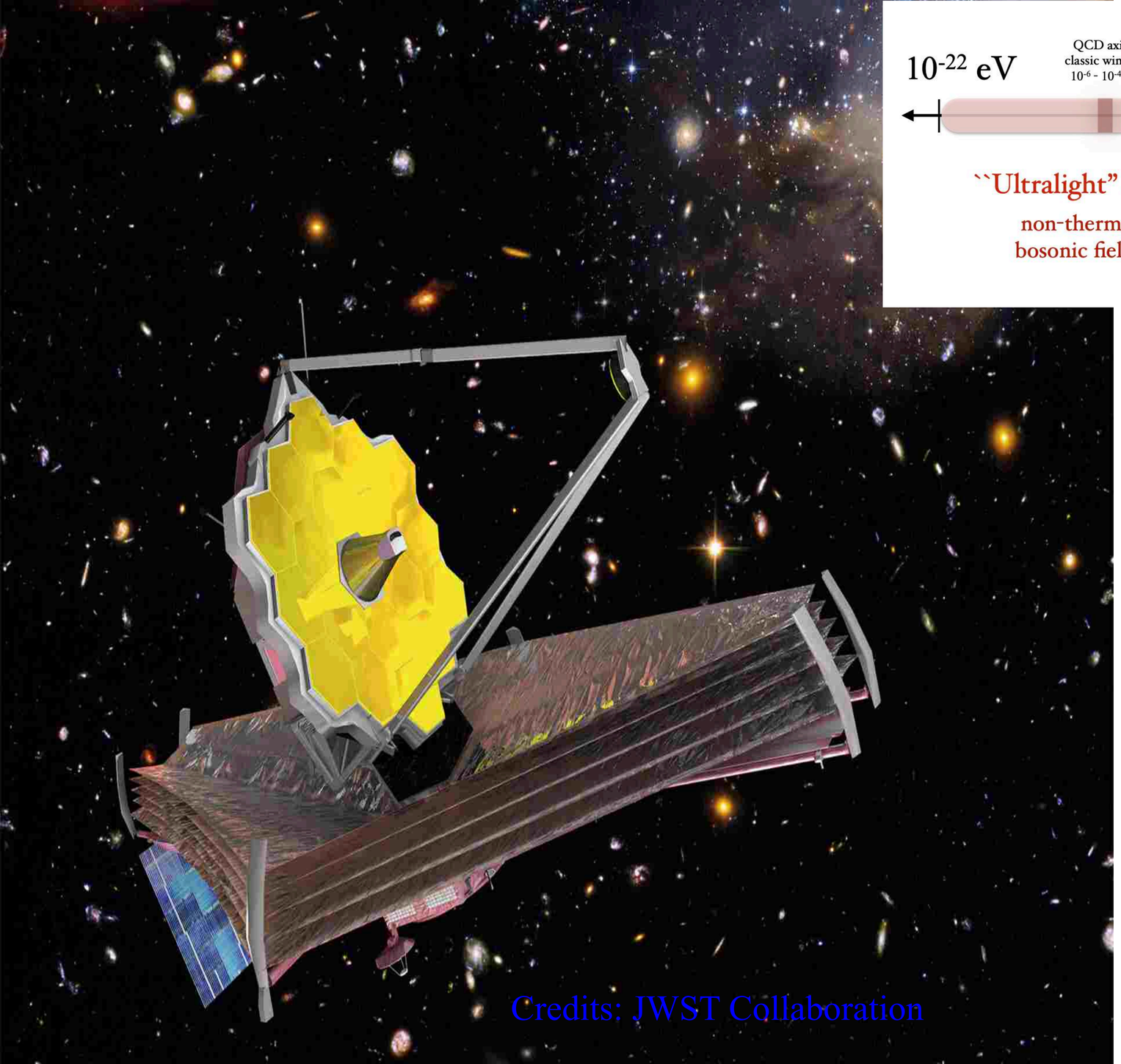
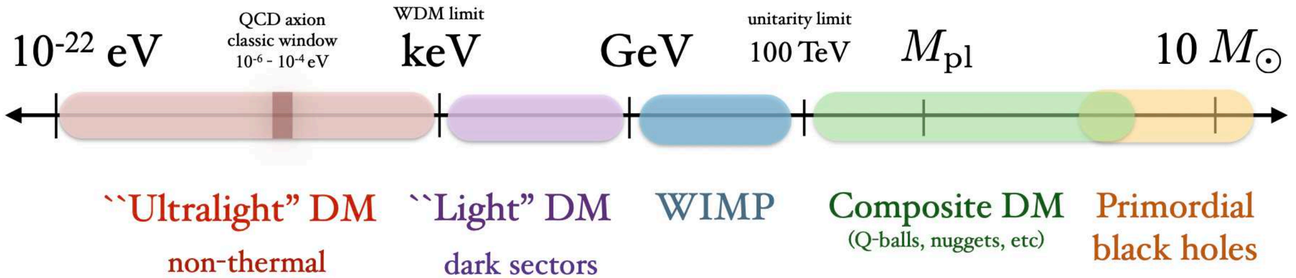


Credits: JWST Collaboration



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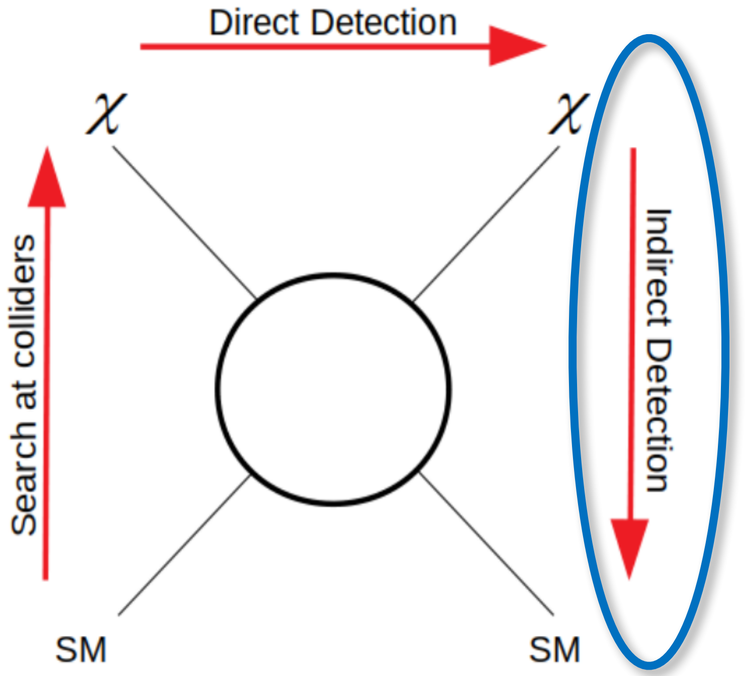

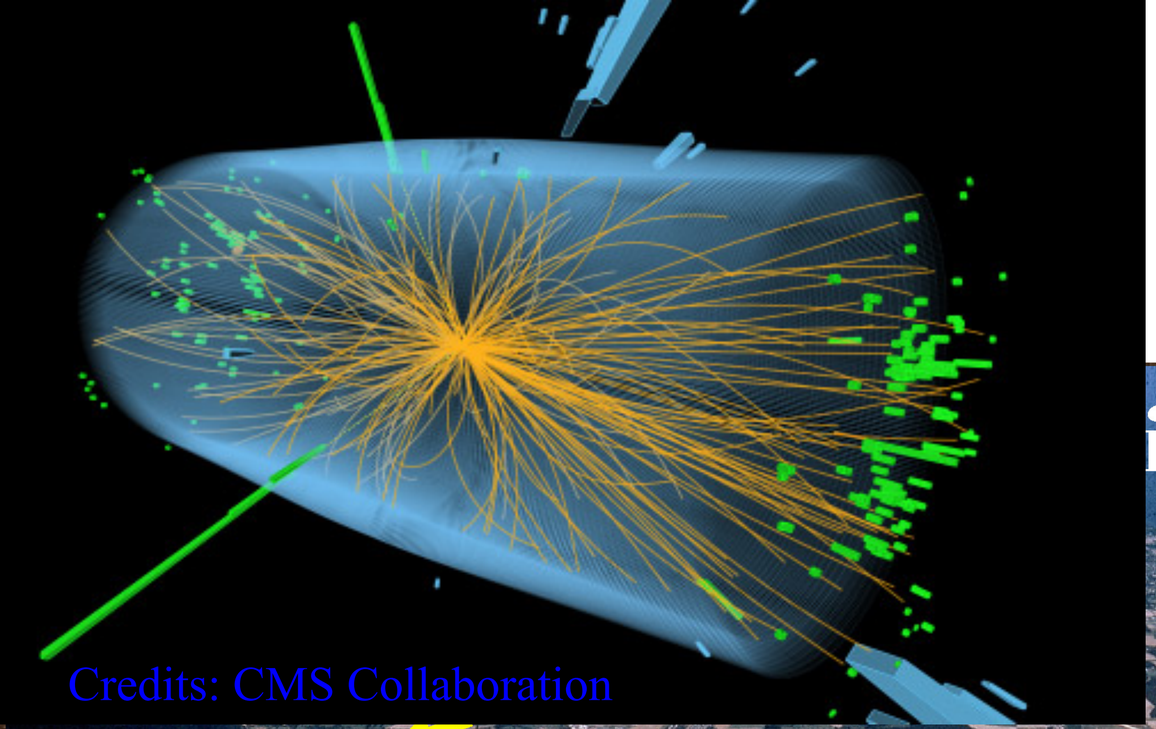

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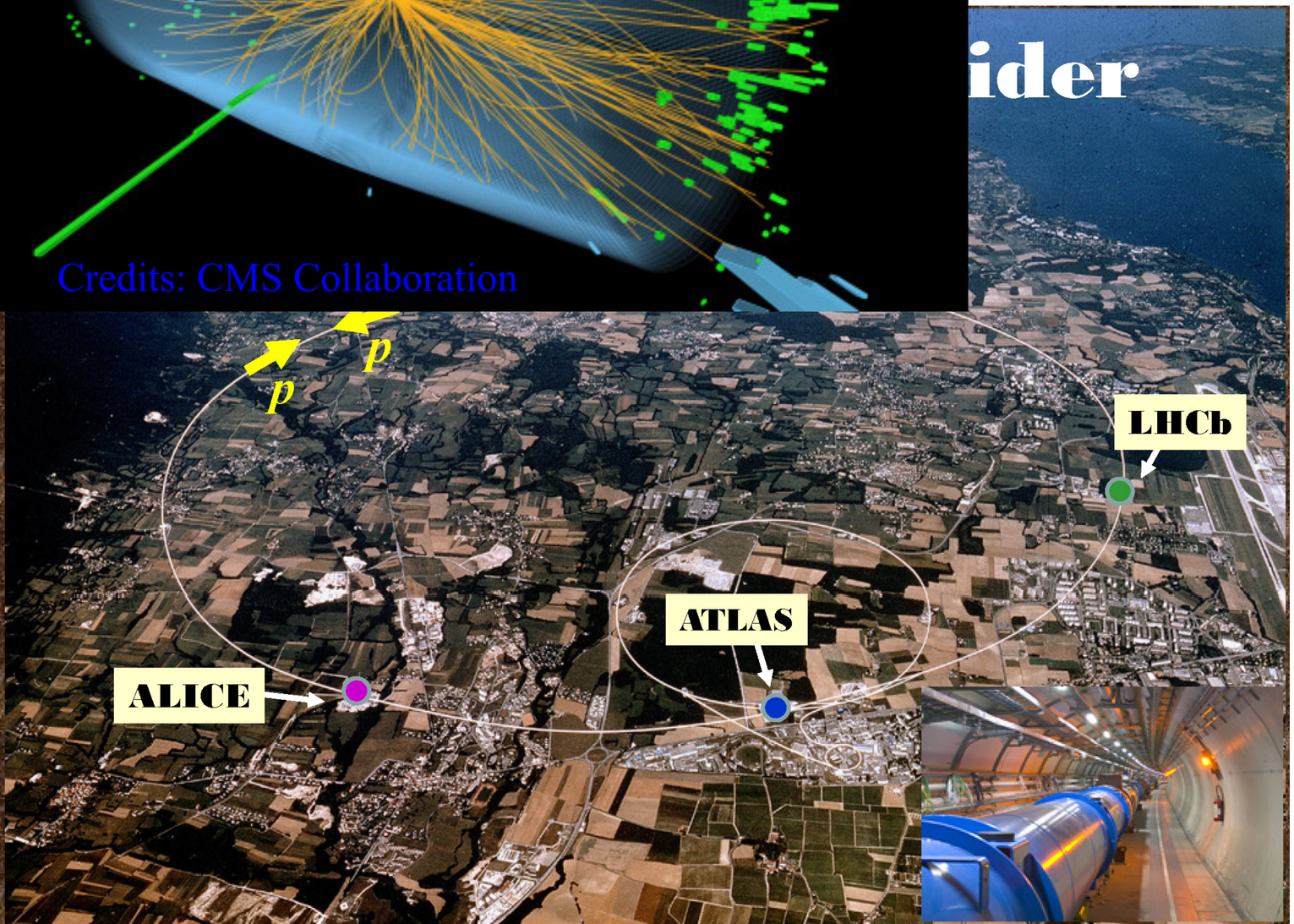

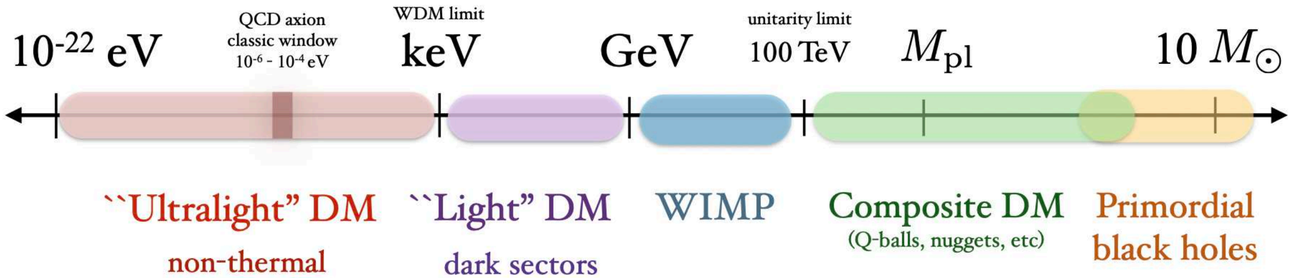

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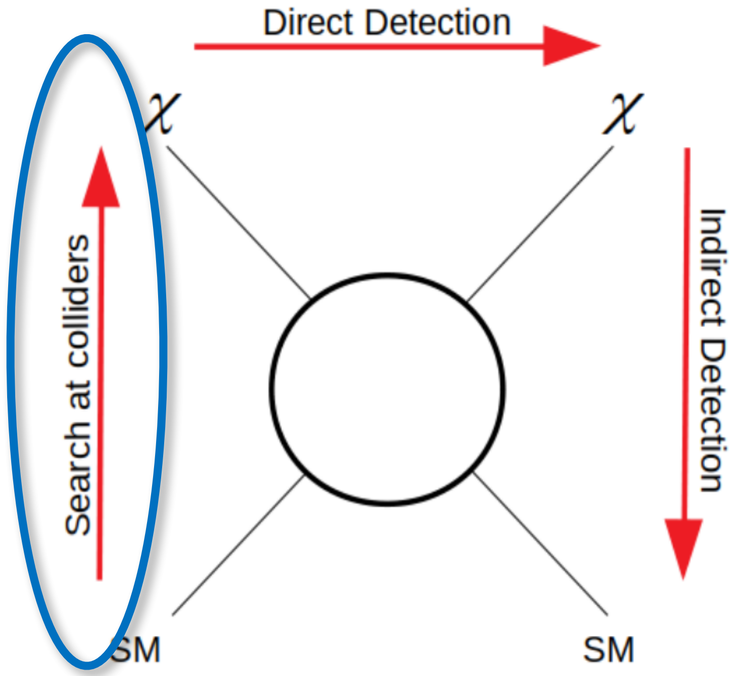

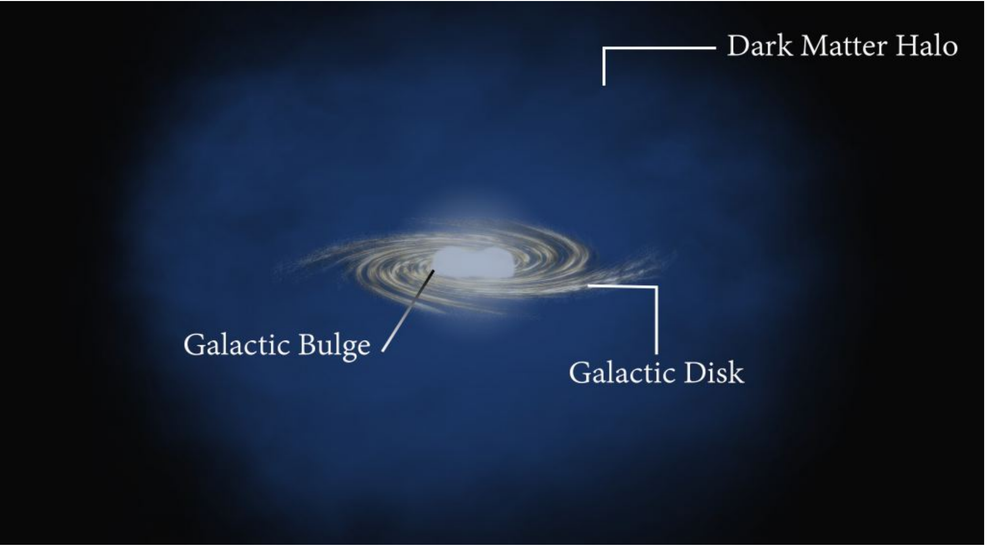

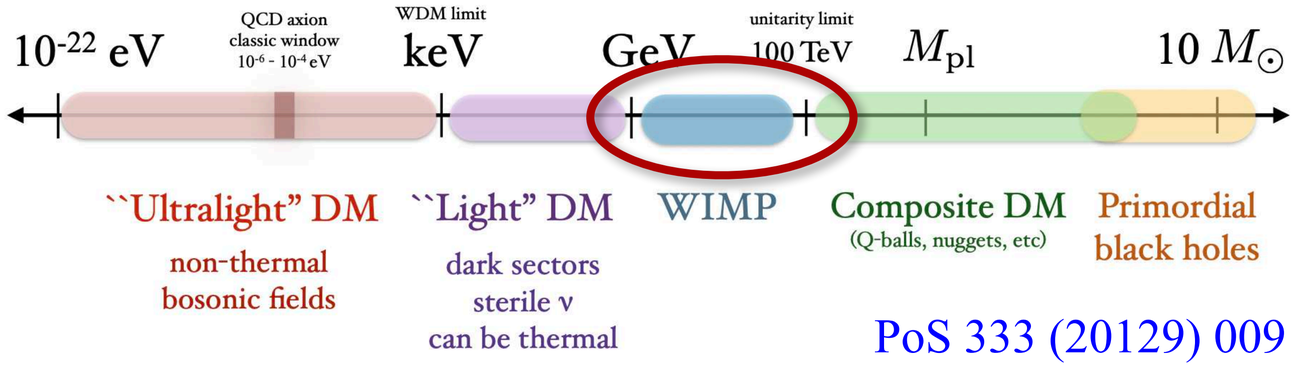

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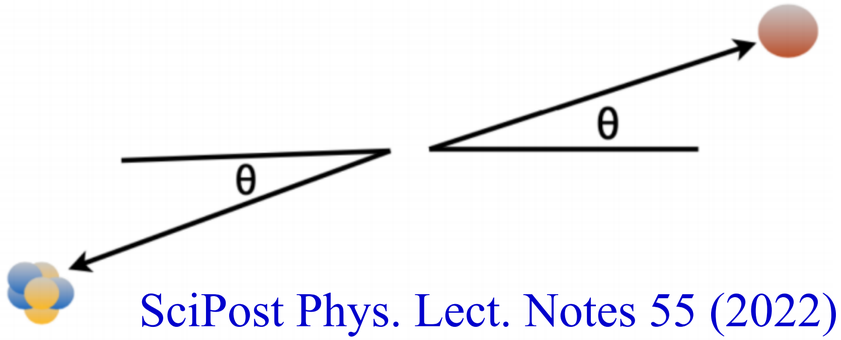
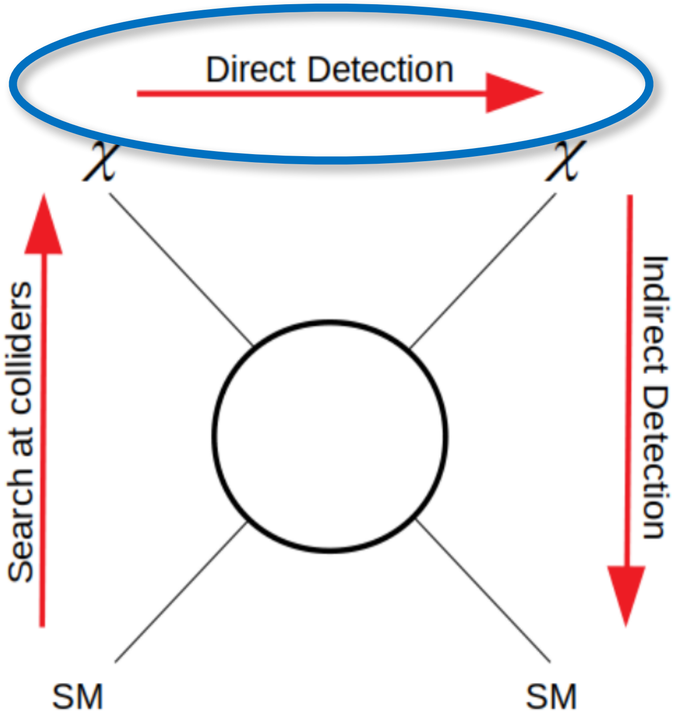
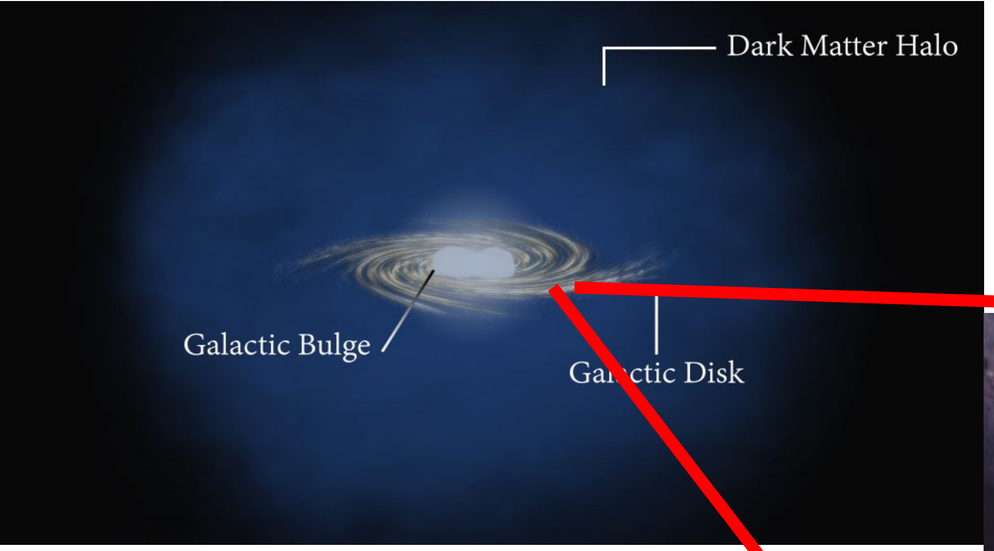


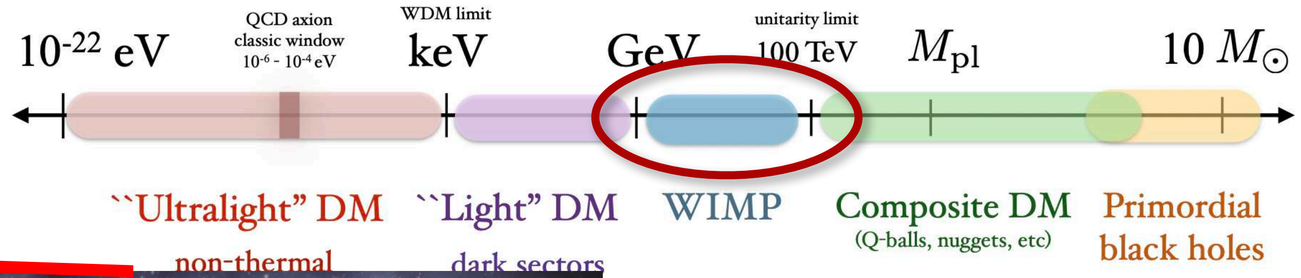
SciPost Phys. Lect. Notes 55 (2022)

- **Maximum recoil energy on SM nuclei!**
- **Weak-like interaction**
- **Multiple theoretical models would match a WIMP**



$$E_R^{max} = \frac{1}{2} m_\chi v^2 \frac{4 m_\chi m_N}{(m_\chi + m_N)^2}$$





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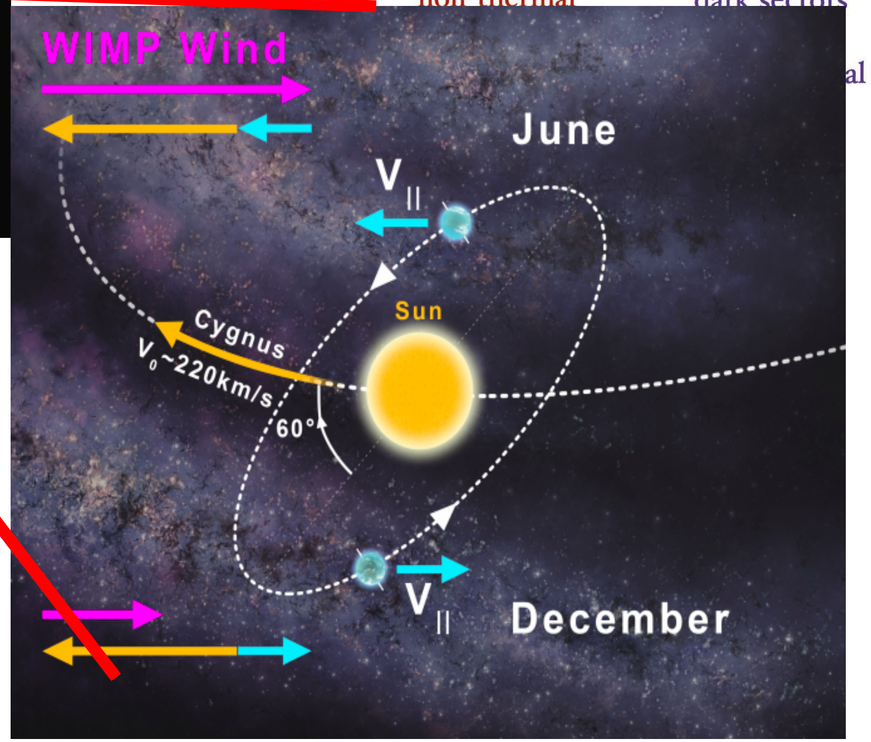

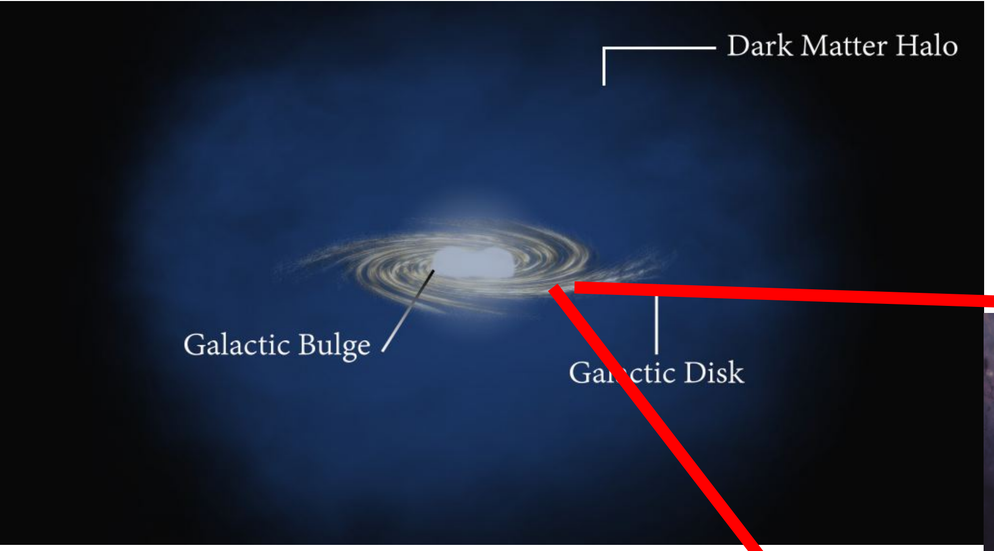

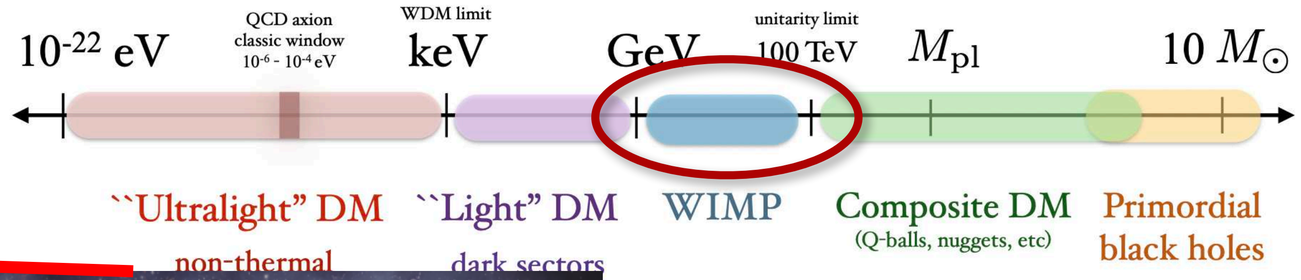

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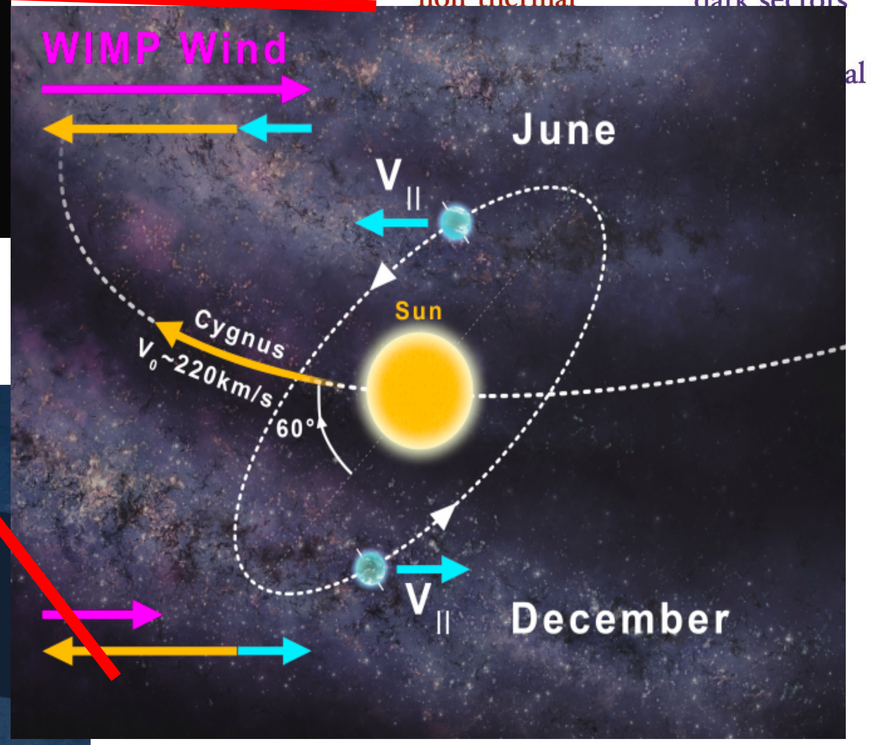

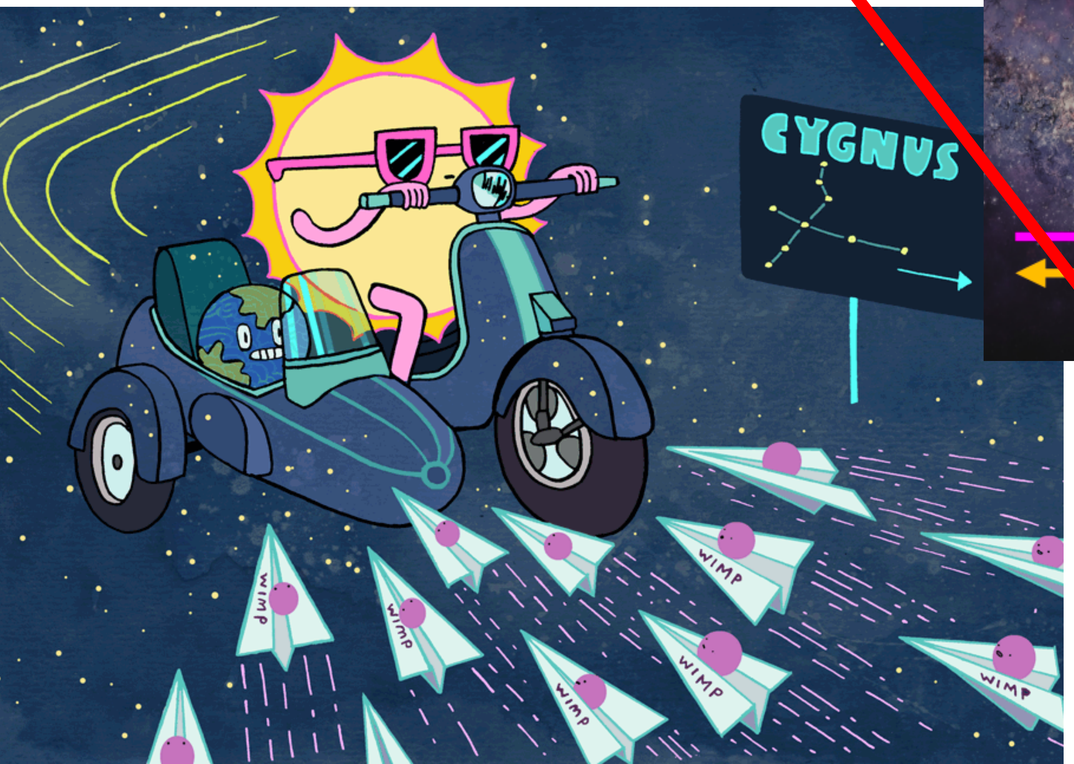

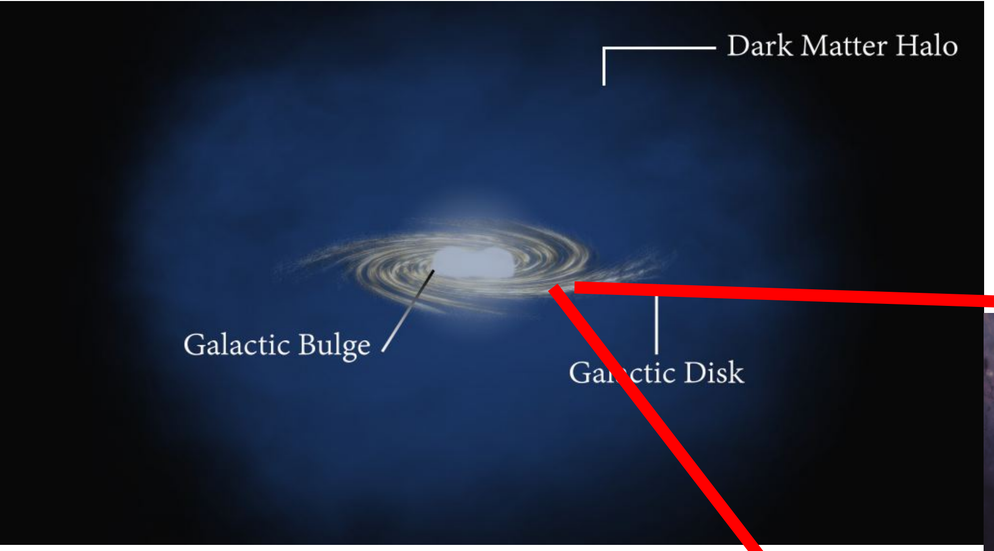

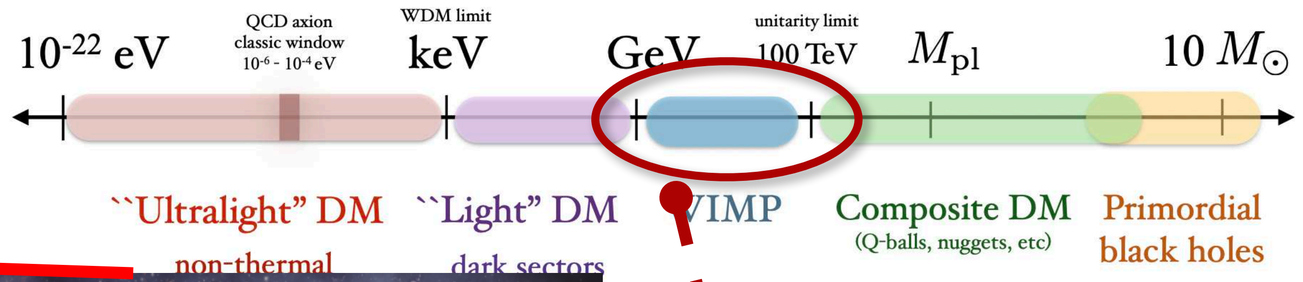

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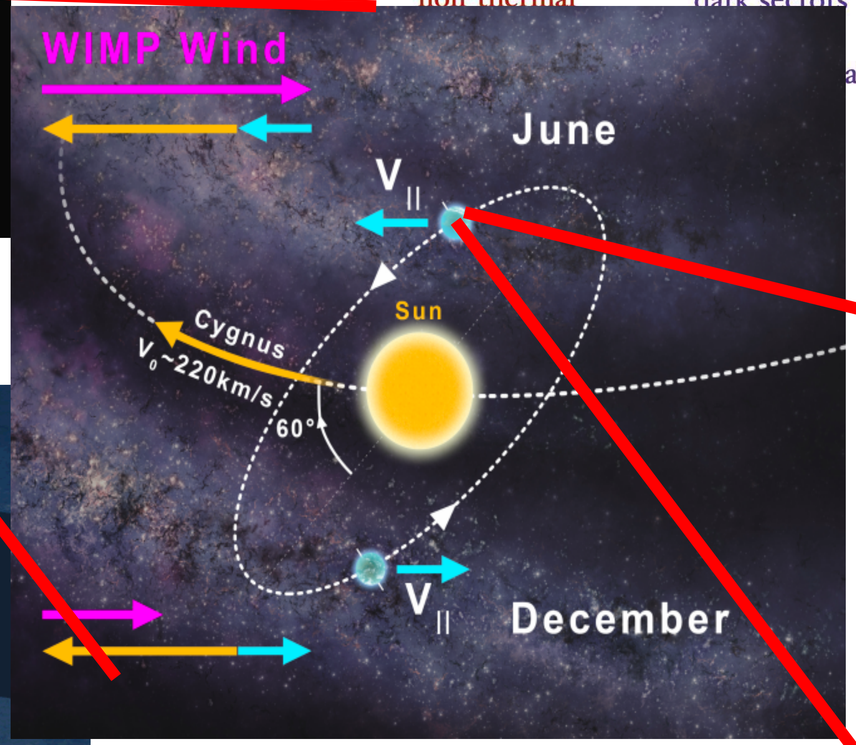

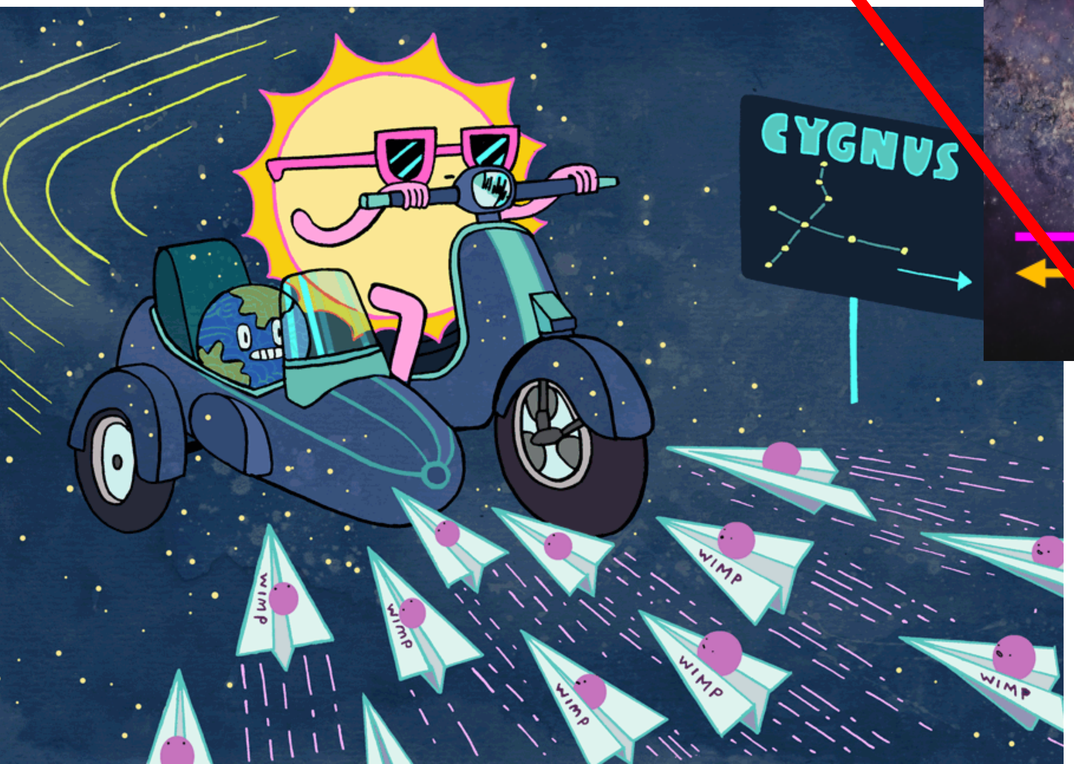

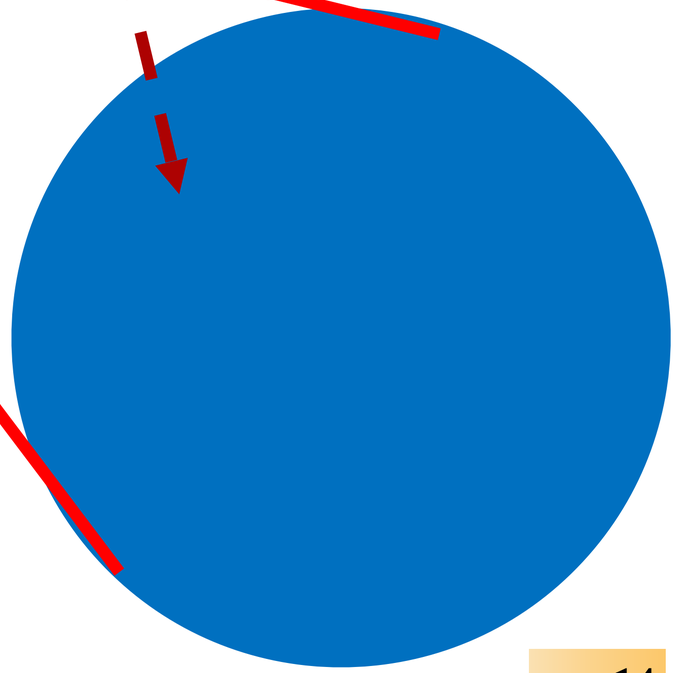

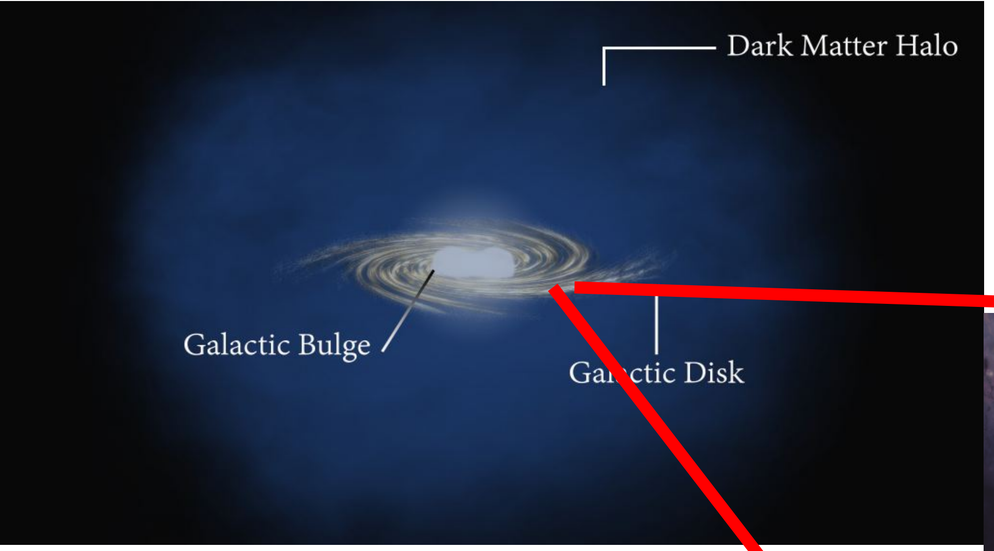

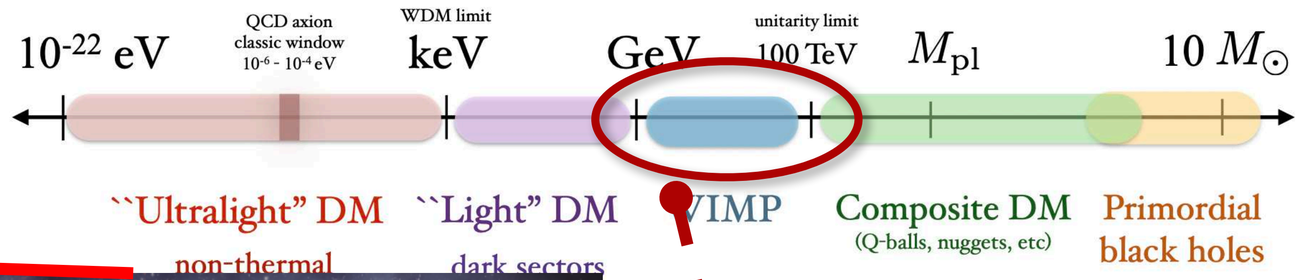

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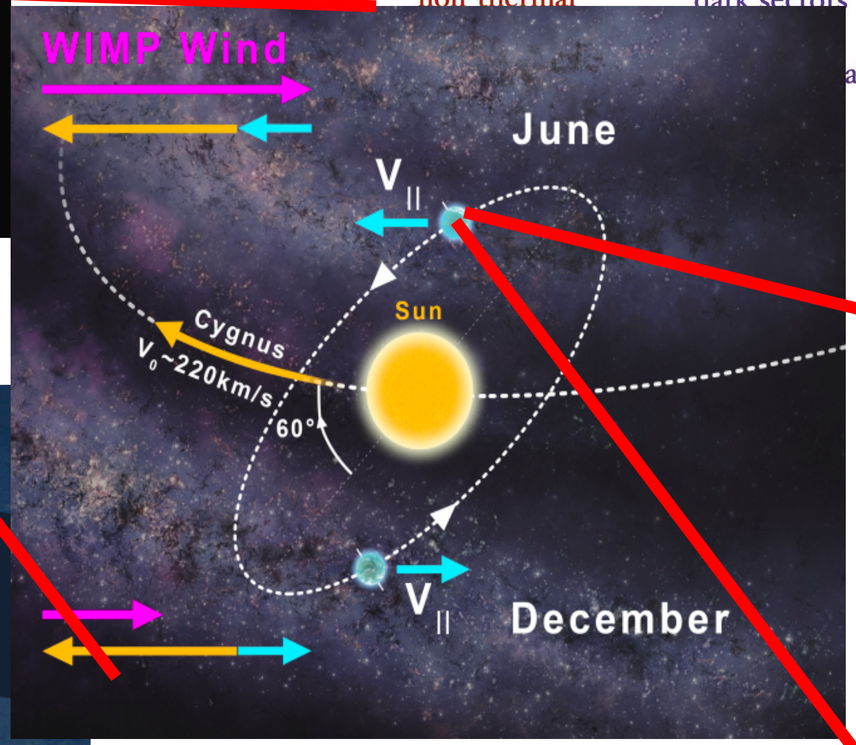

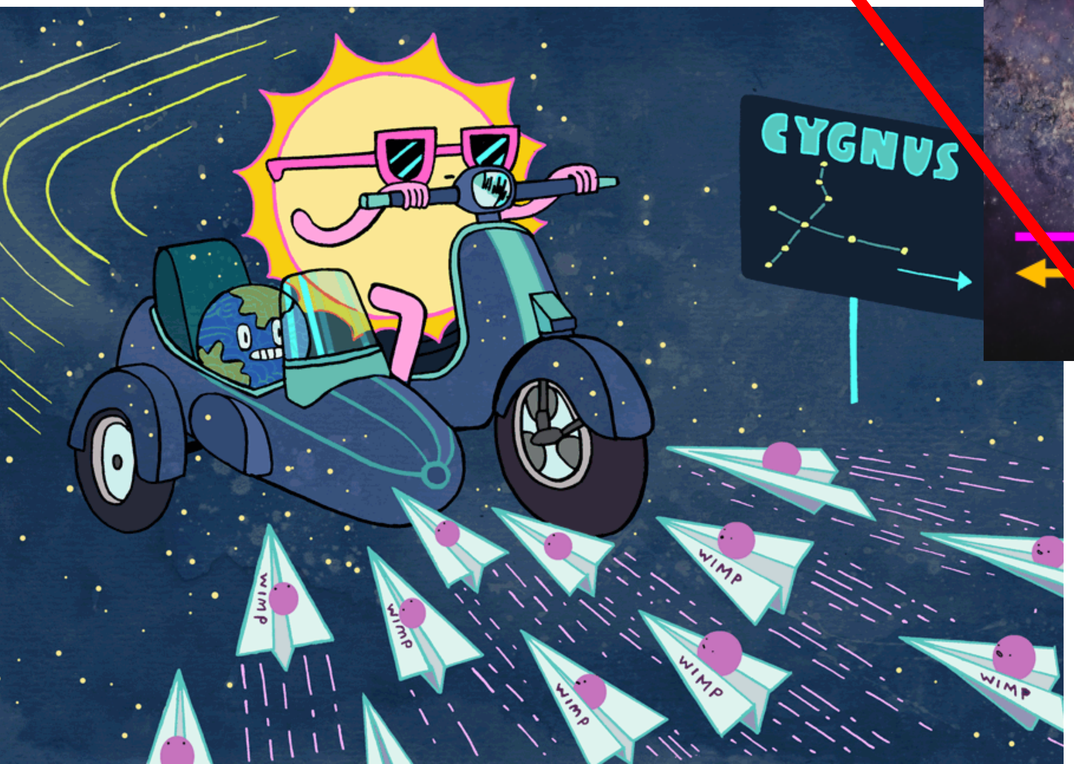

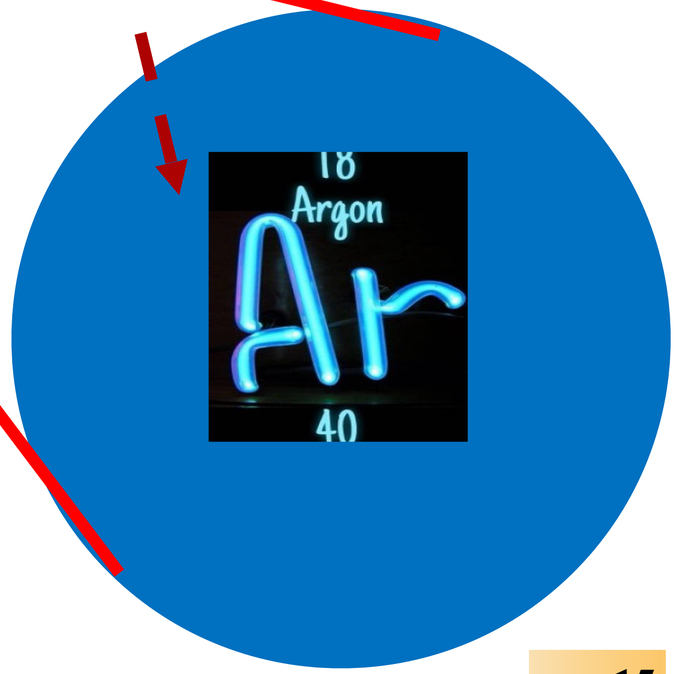

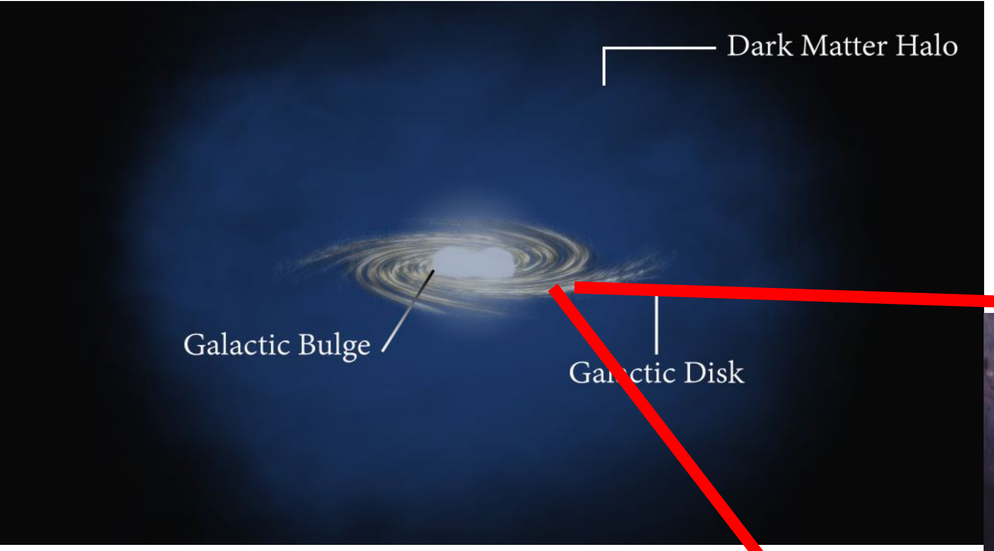

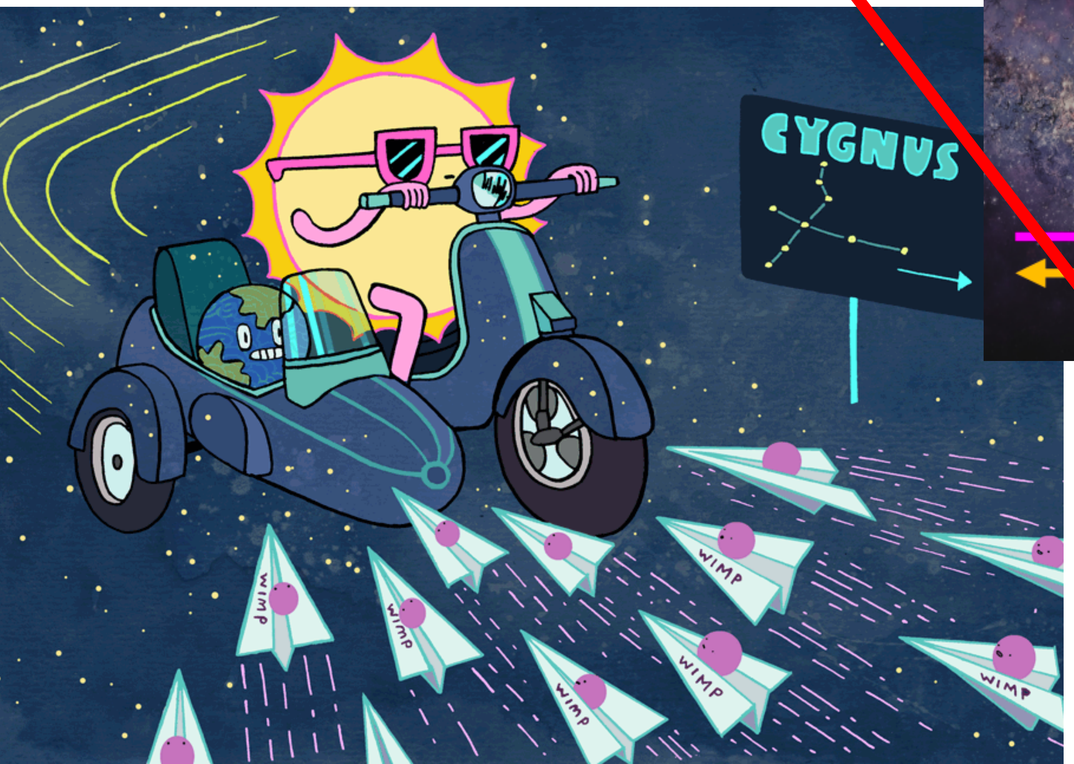

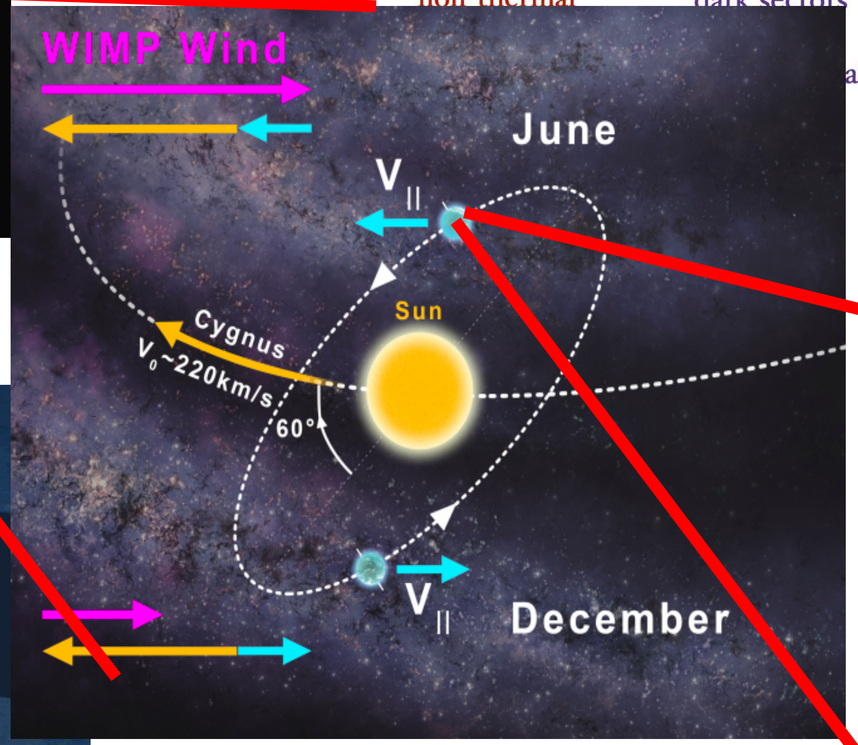

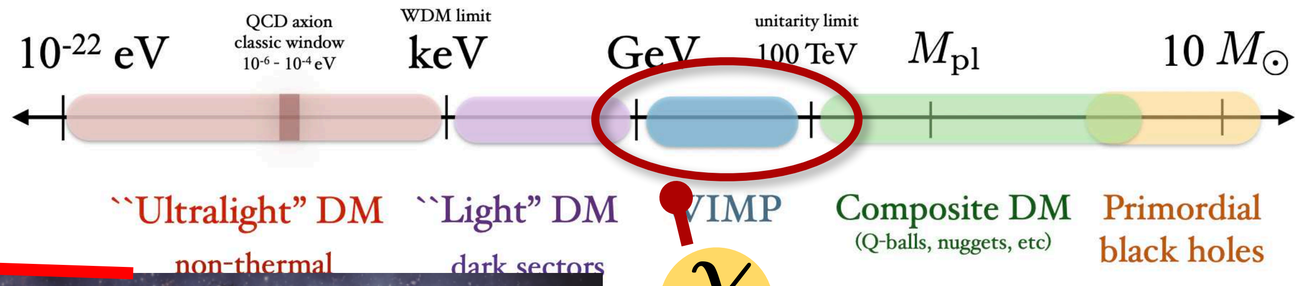

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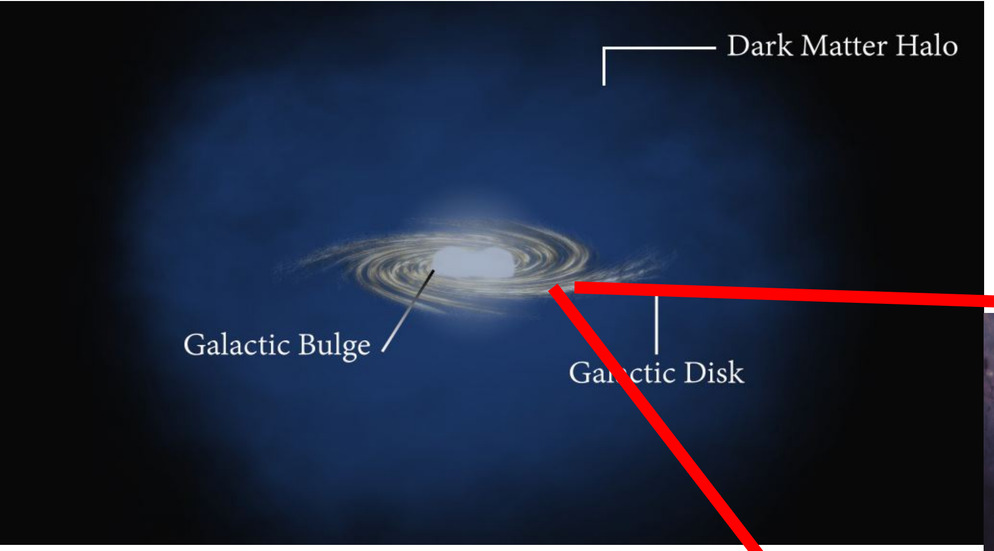

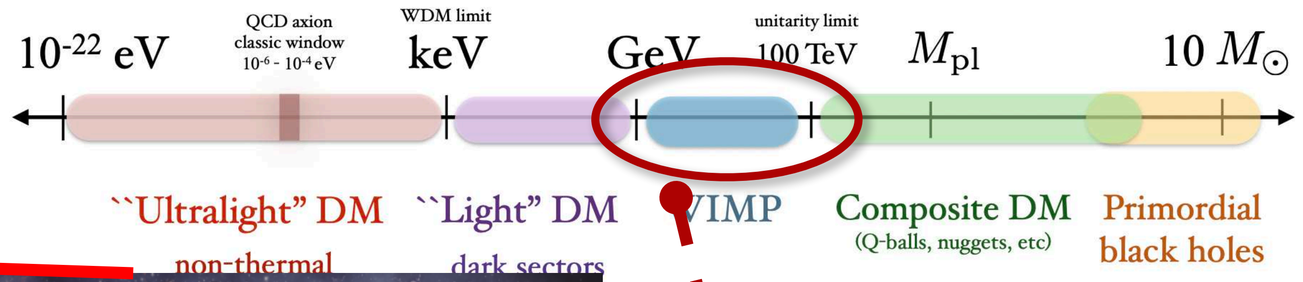

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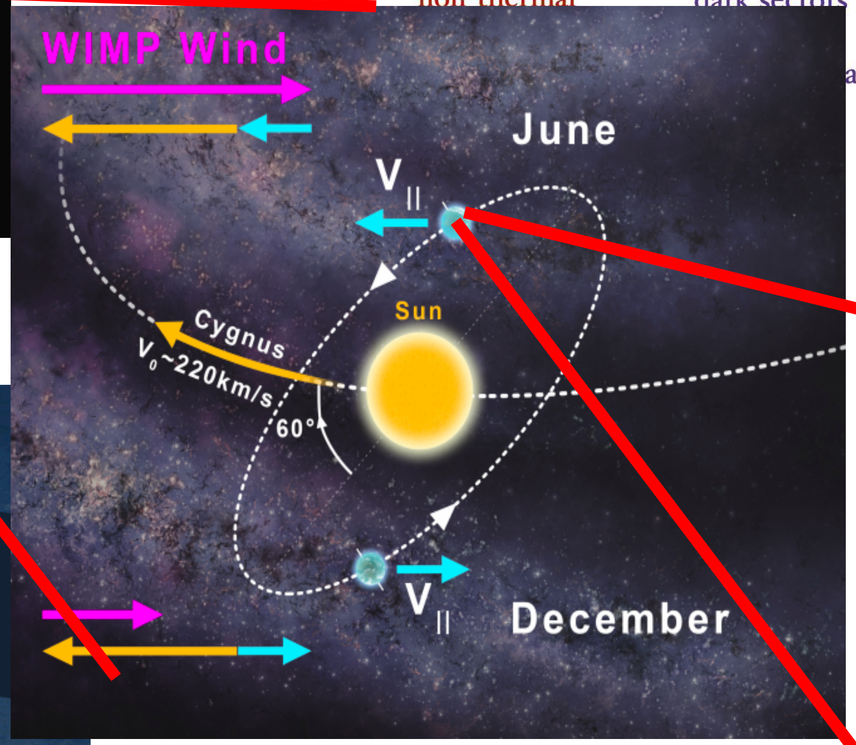

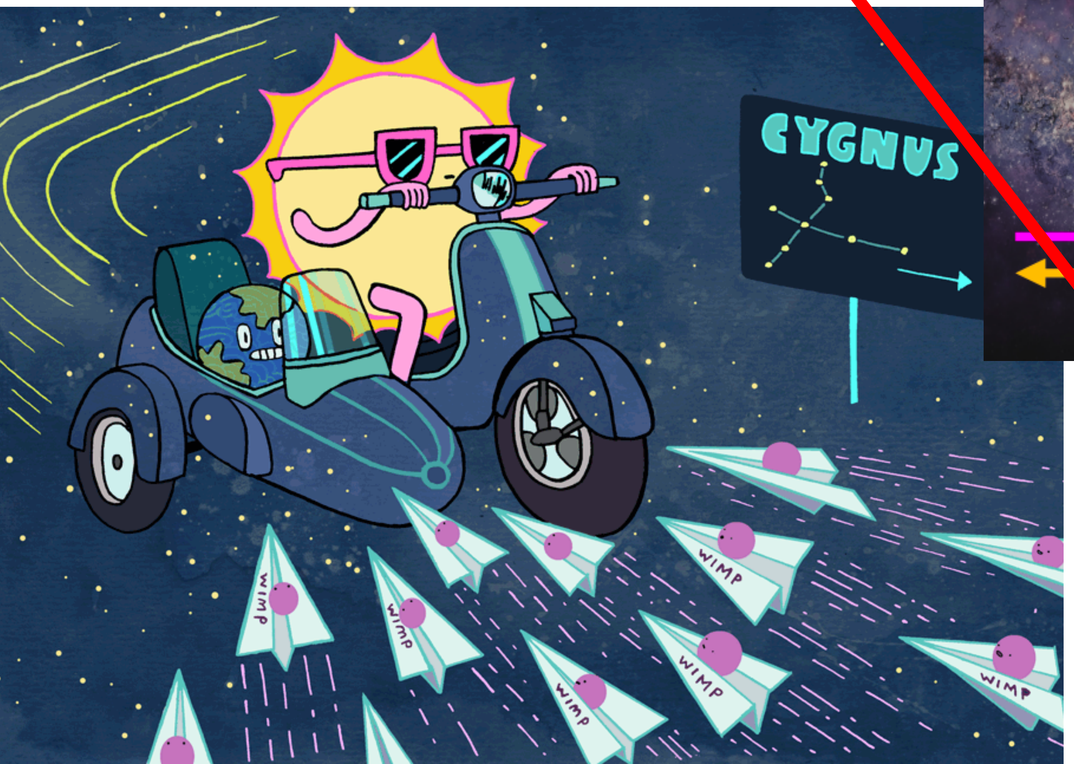

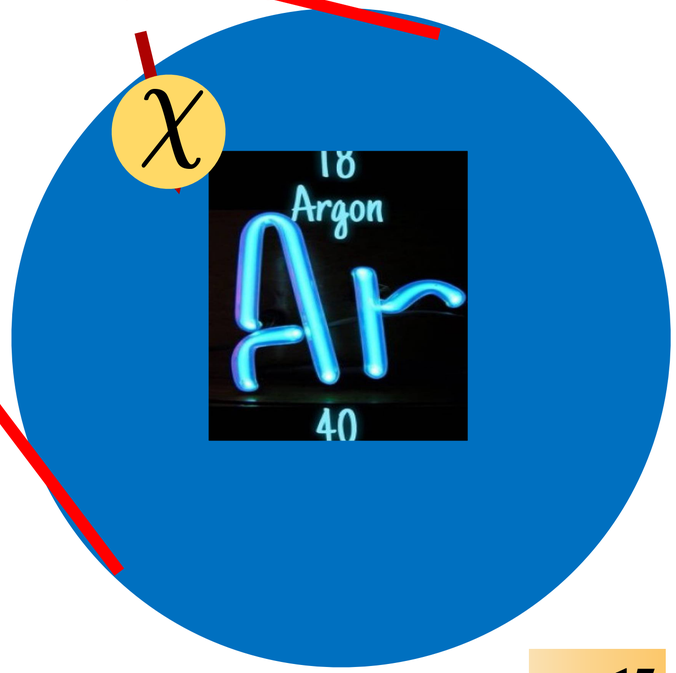

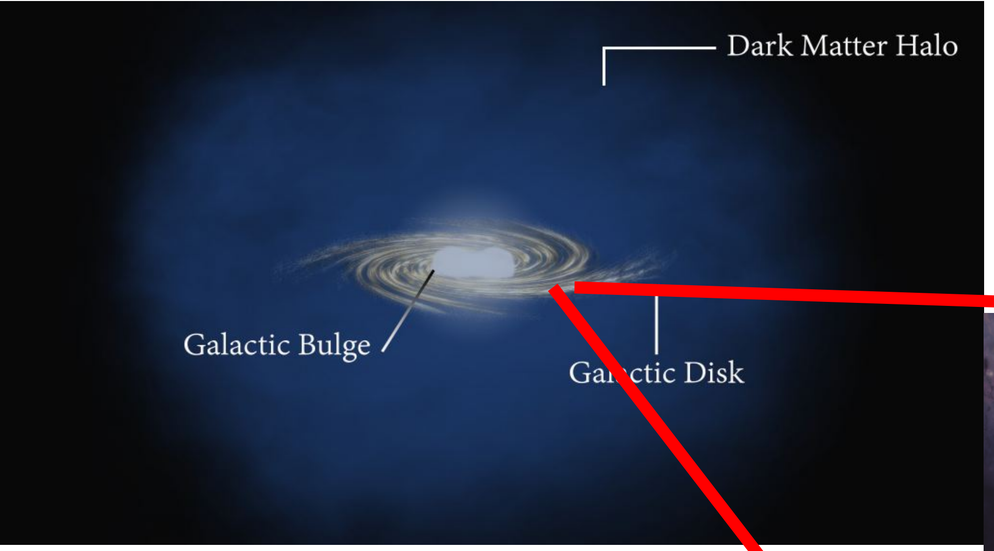

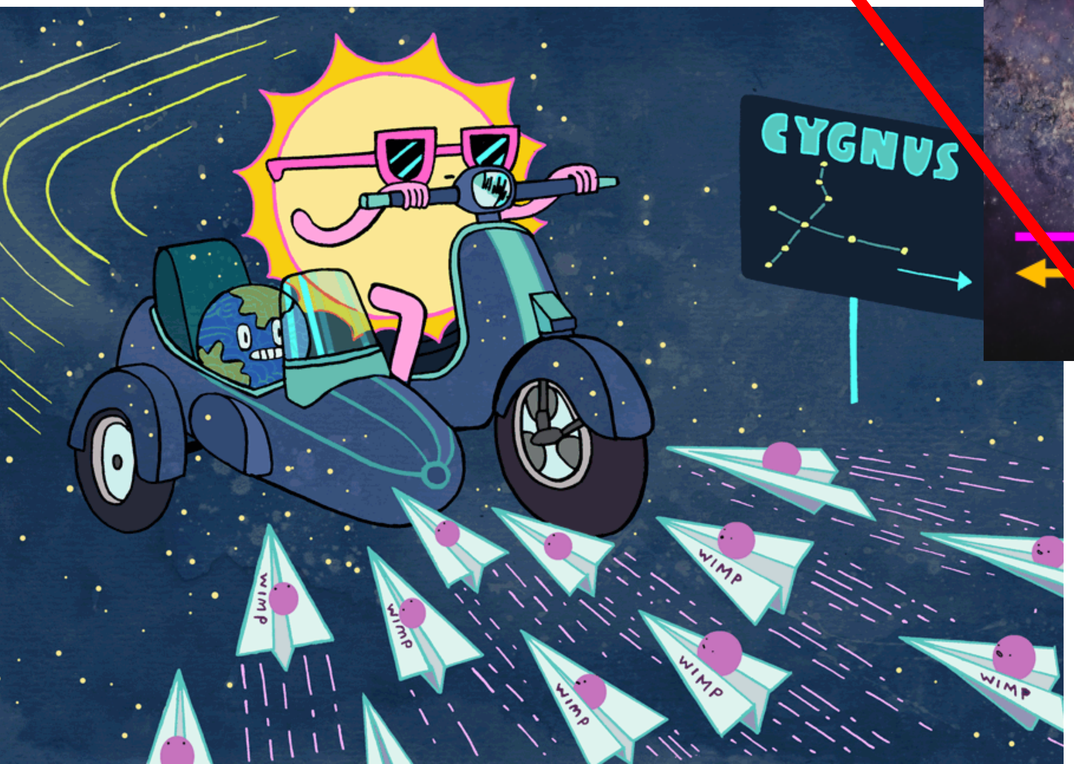

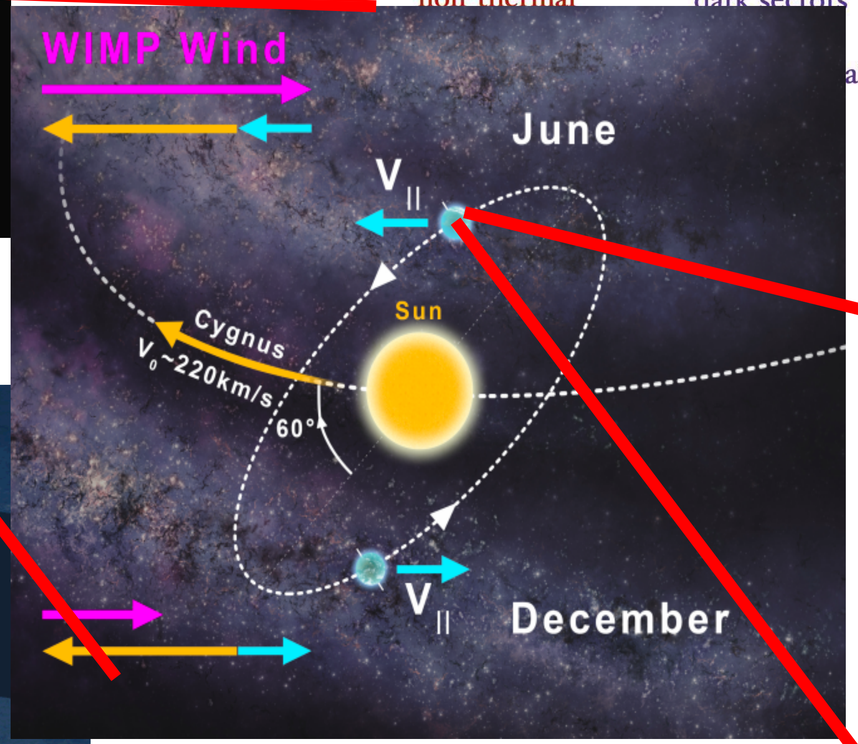

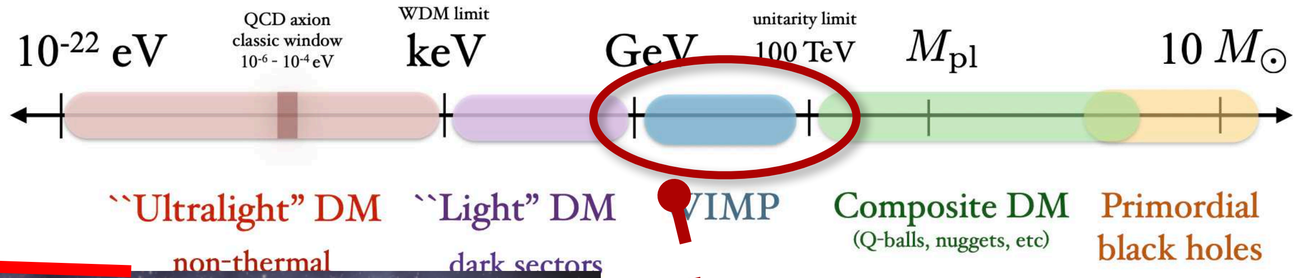

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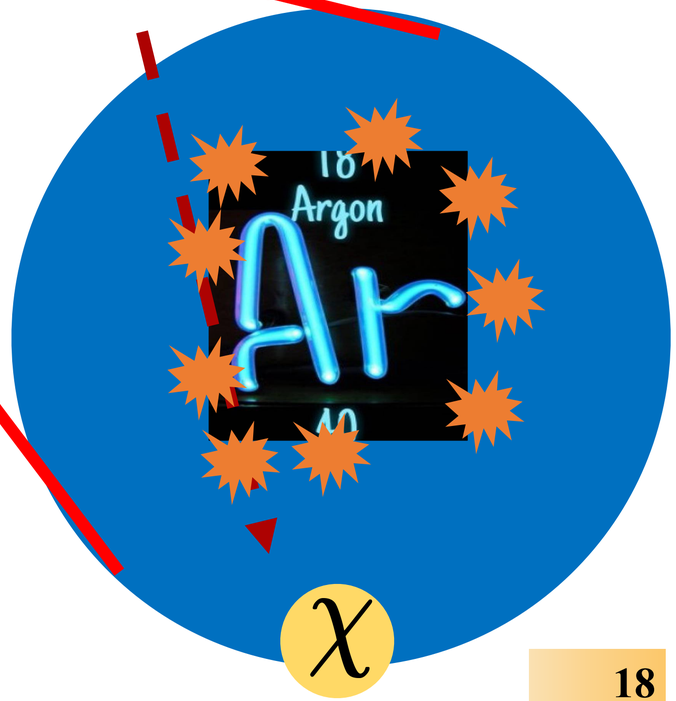
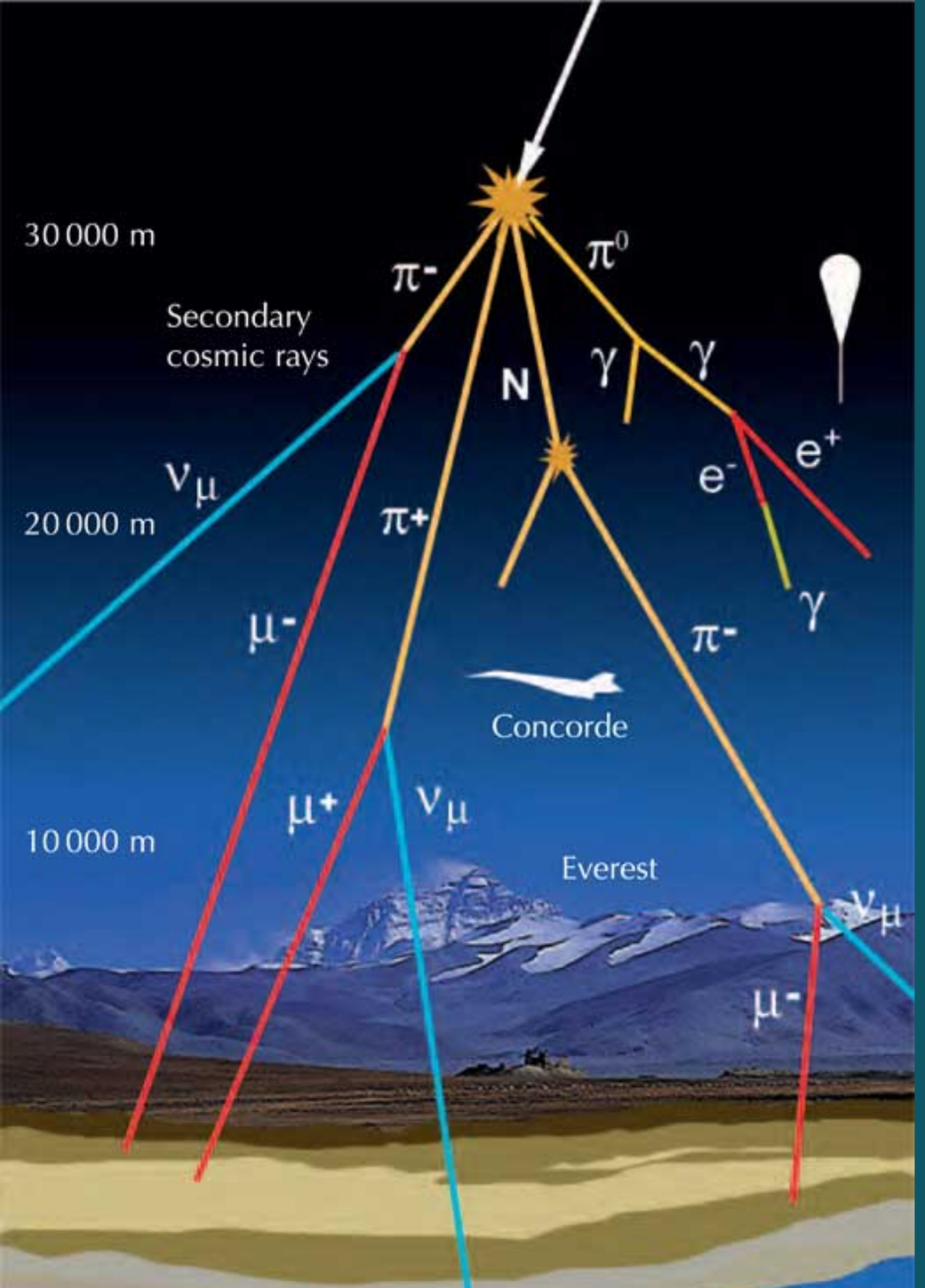
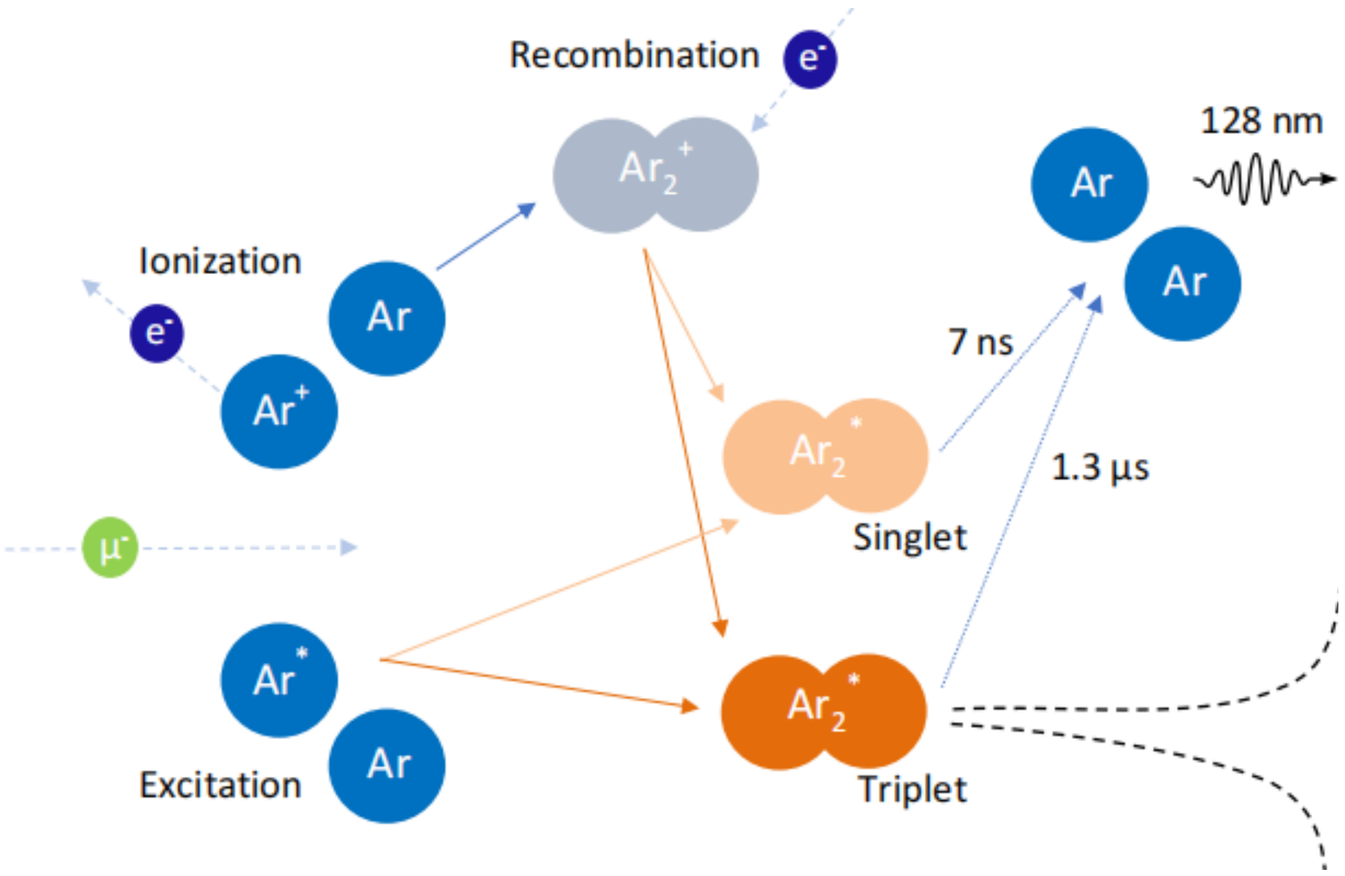


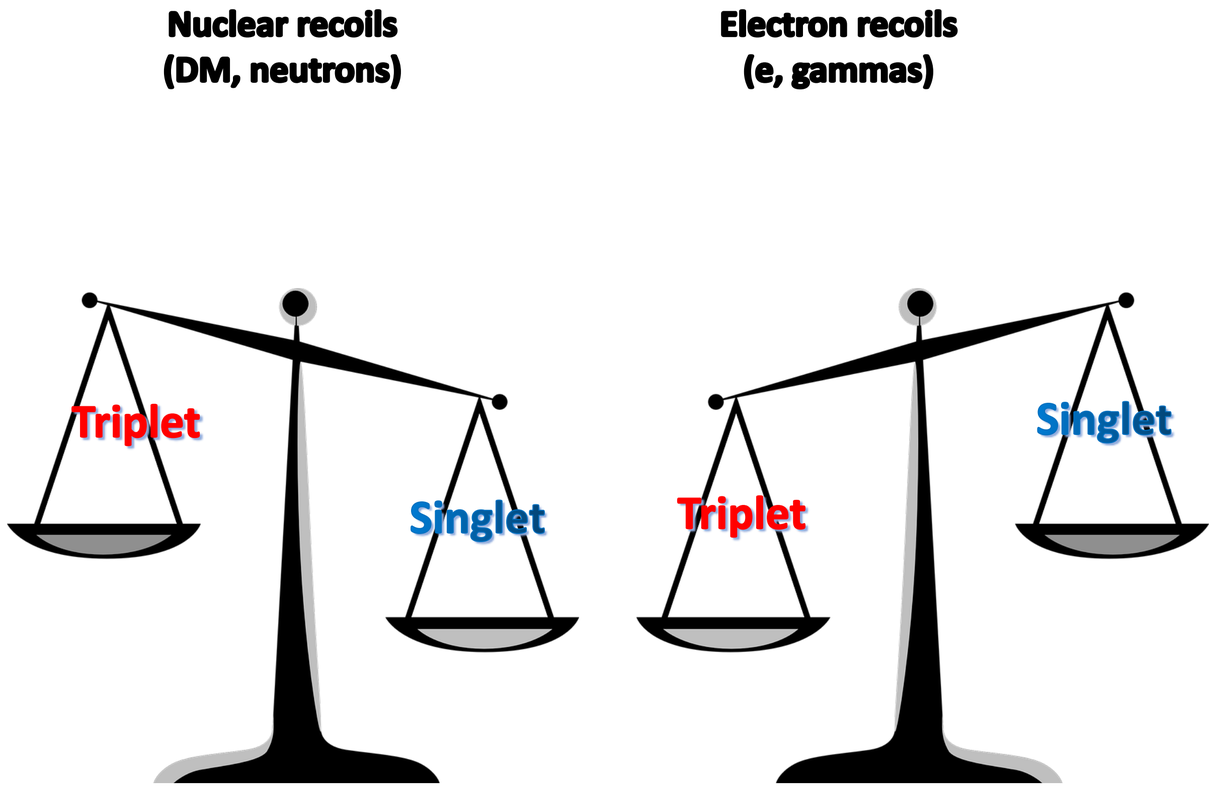

30 000 m
Secondary
cosmic rays
π-
π0
N
γ
γ
e+
e-
νμ
20 000 m
π+
μ-
γ
π-
Concorde
μ+
νμ
10 000 m
Everest
νμ
μ-

SNOLAB

2 km

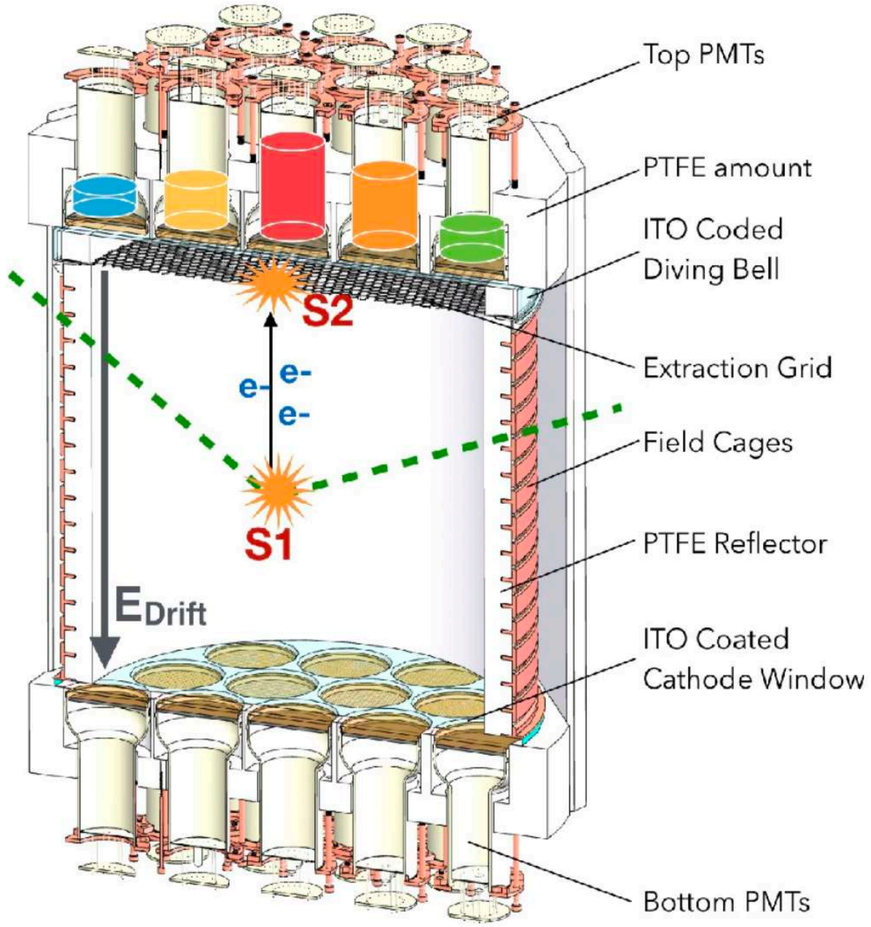
Scintillation in Liquid argon



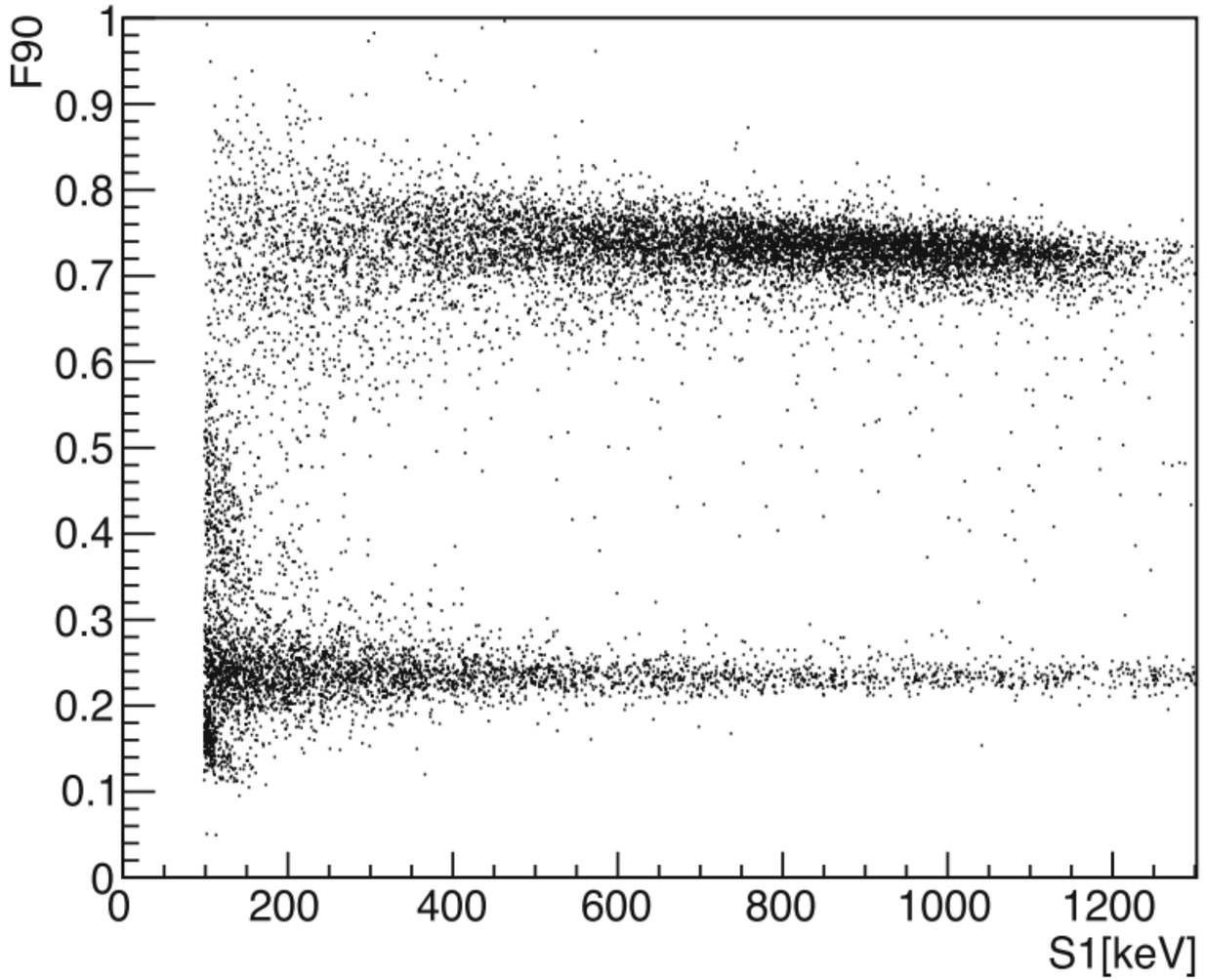


JINST 19 (2024) 08, P08005

High-Mass DM search in a dual-phase Time Projection Chamber (TPC)



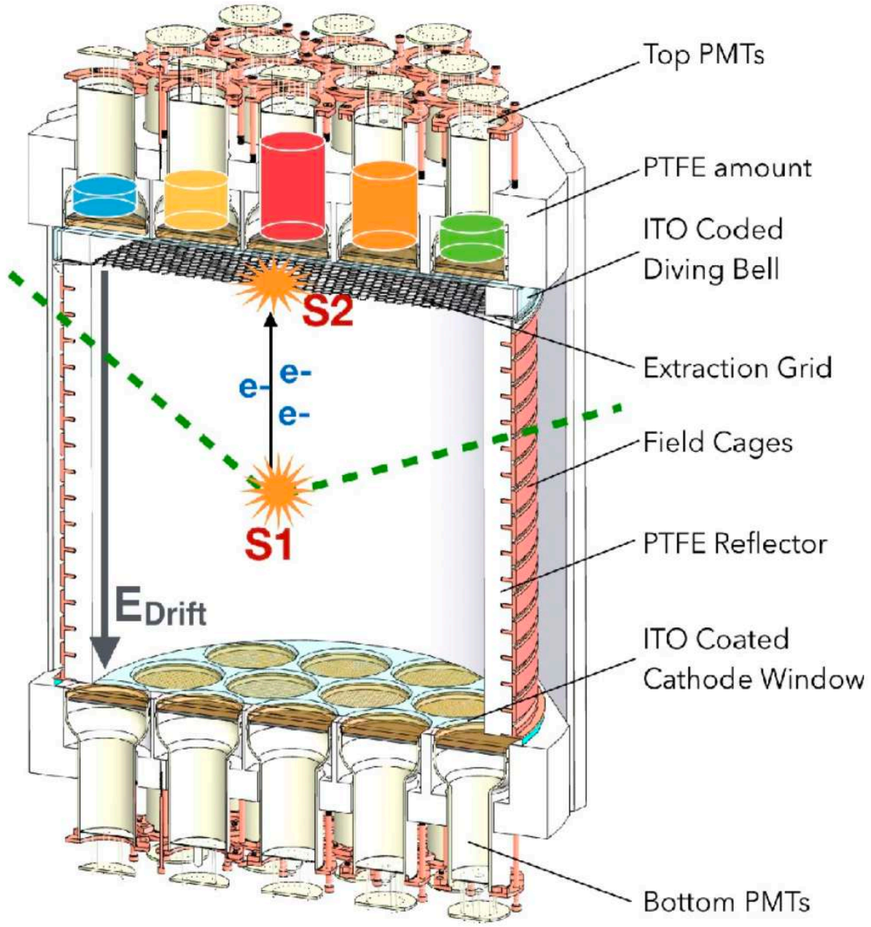
Drawing of DarkSide-50



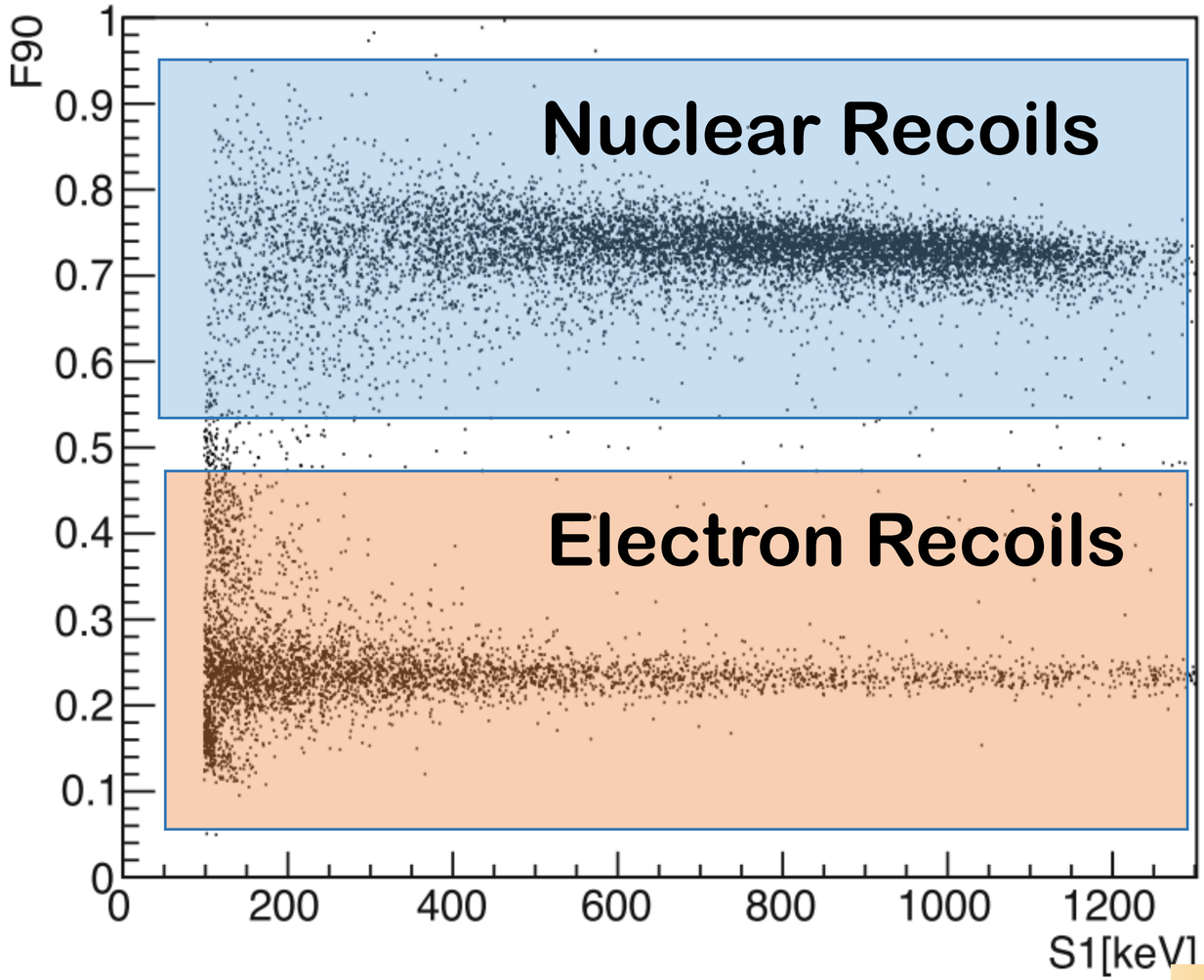
[Radiat Detect Technol Methods (2025)]

High-Mass DM search in a dual-phase Time Projection Chamber (TPC)

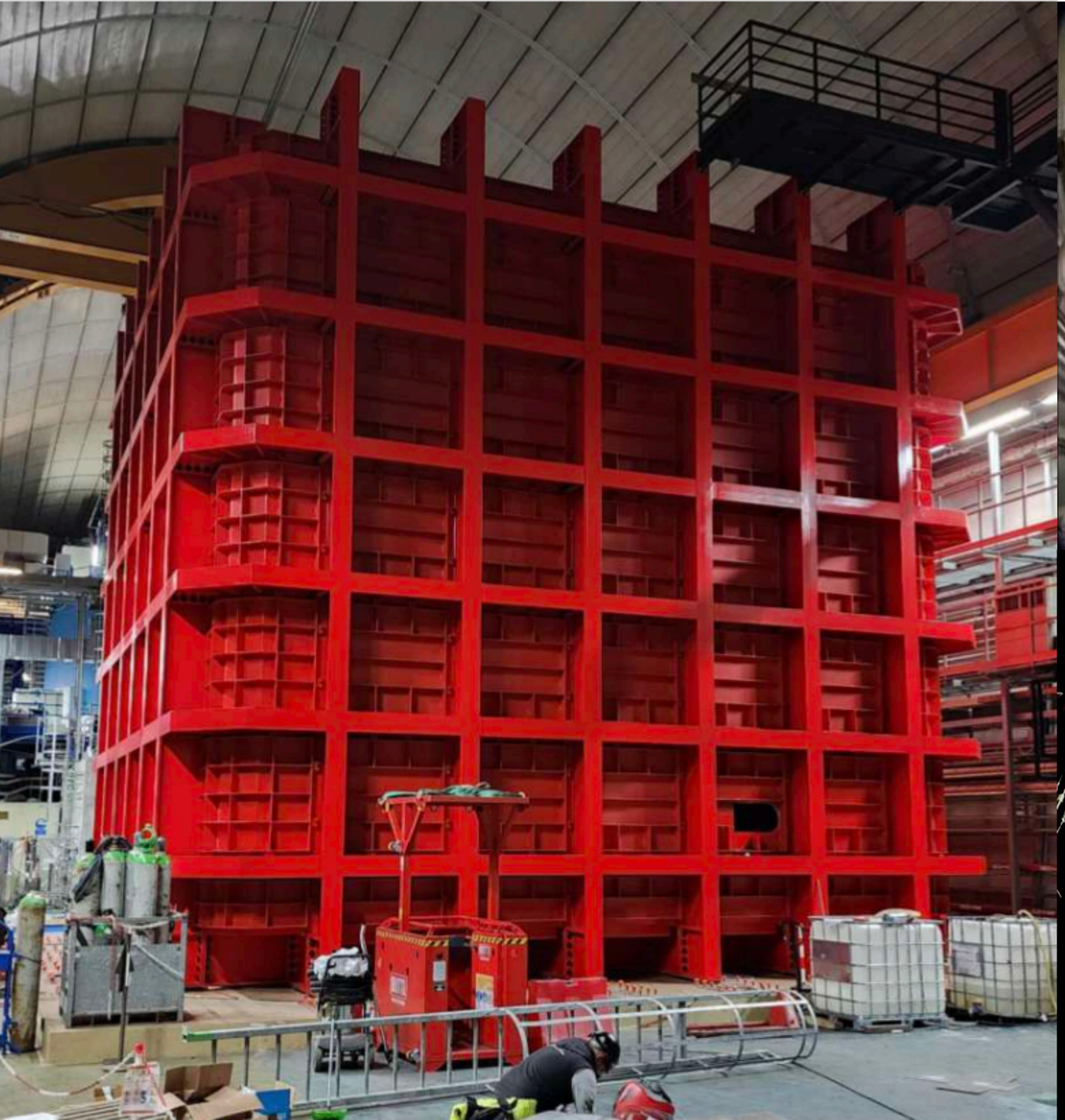
Fraction of the scintillation light in the first 90 ns (F90) in a 2.2 tons LAr chamber + PMTs

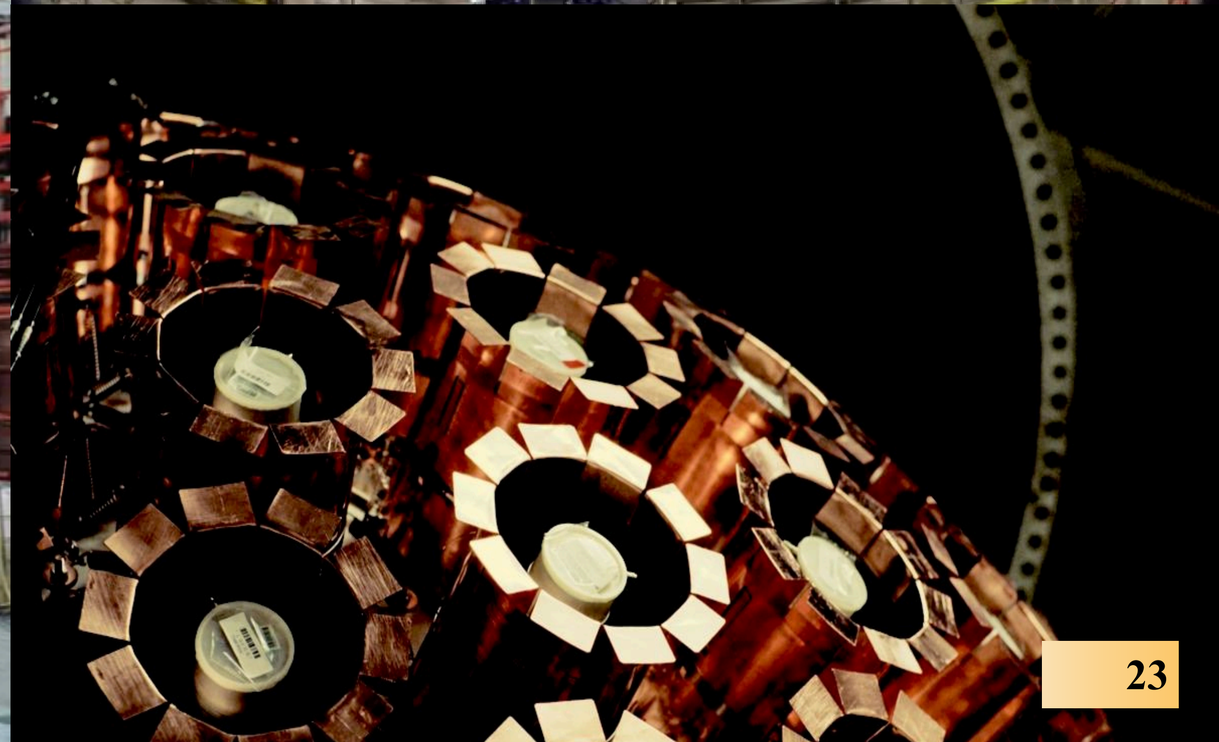


Drawing of DarkSide-50



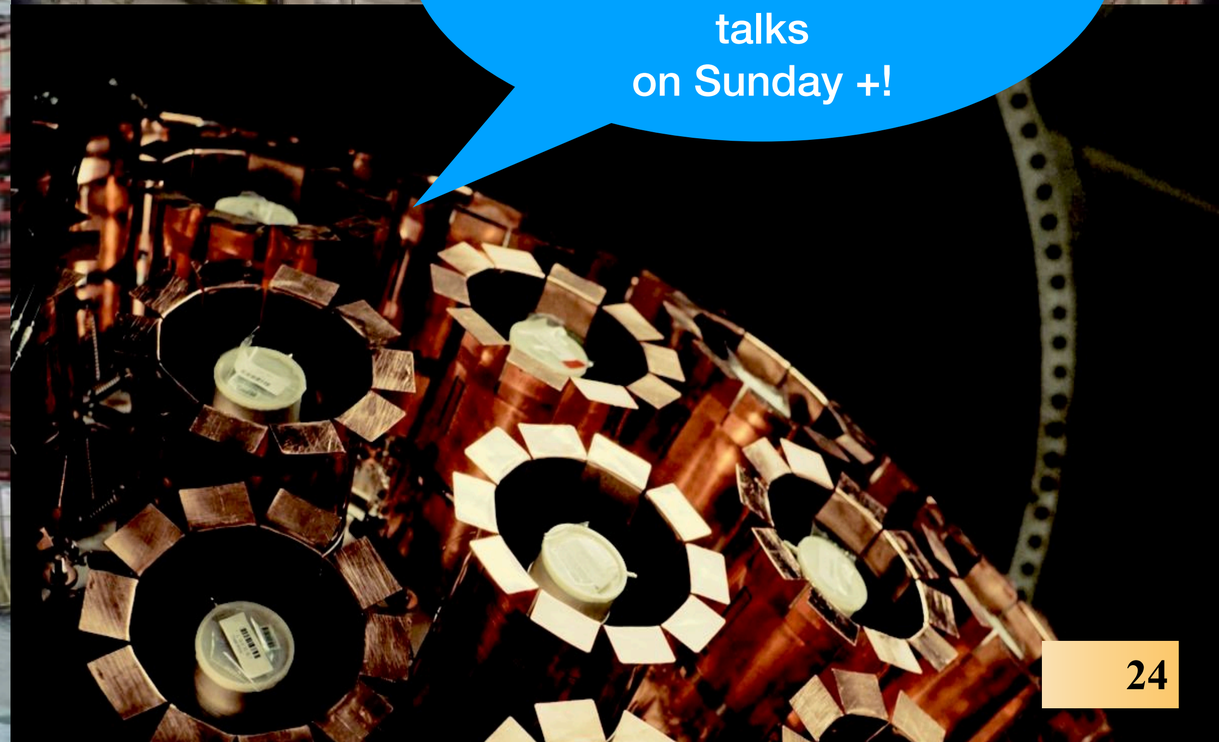
[Radiat Detect Technol Methods (2025)]





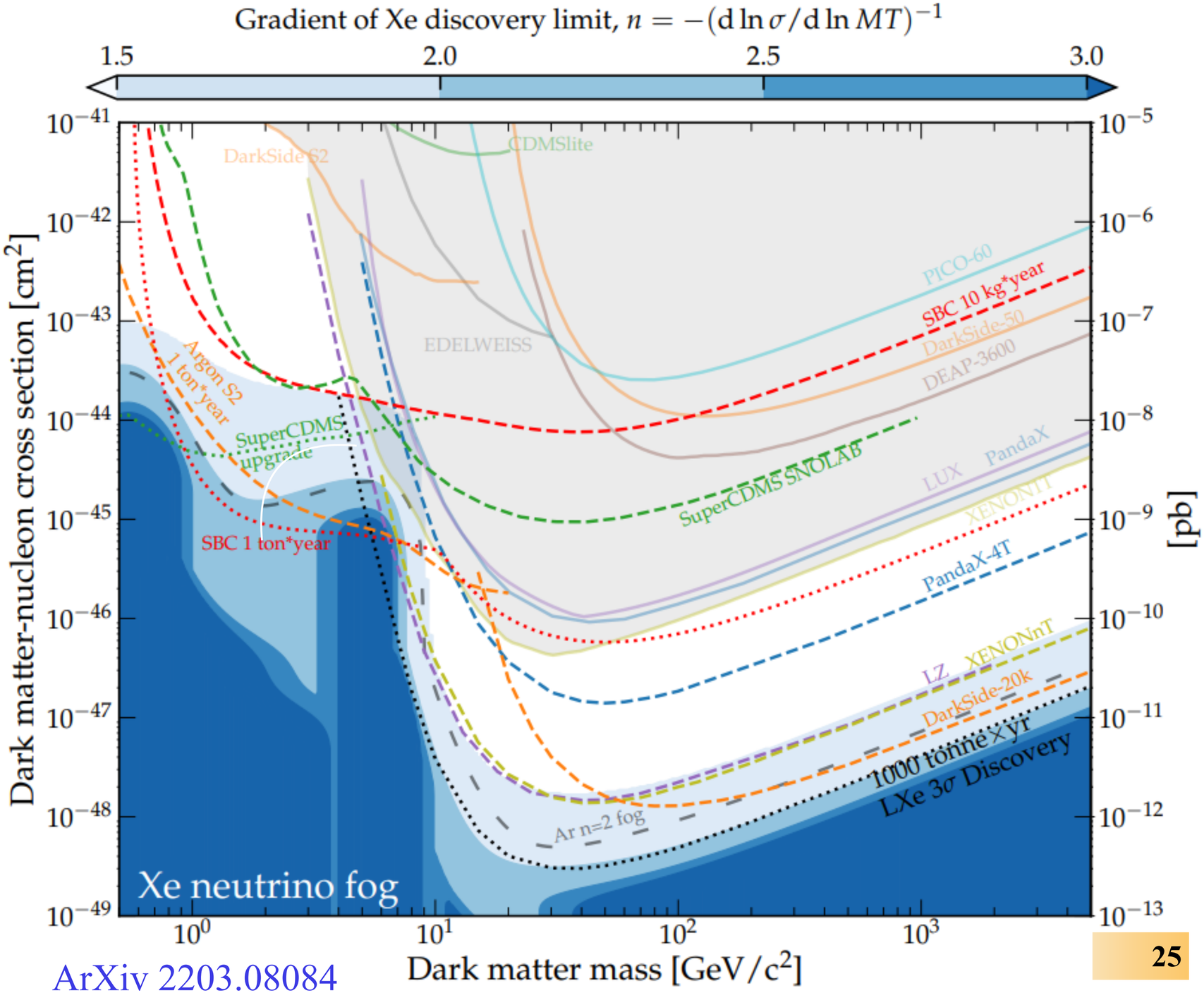
See R. Curtis talk on DarkSide-20k on Sunday!

See J. Hu's poster, P. Taylor and S. Haskins talks on Sunday +!



Whenever WIMPs are searched for and (so far) not found, exclusion plots like these are set at 90% Confidence level

Not an endless game: neutrino fog, so far, represents a pragmatic limit to our searches



ArXiv 2203.08084

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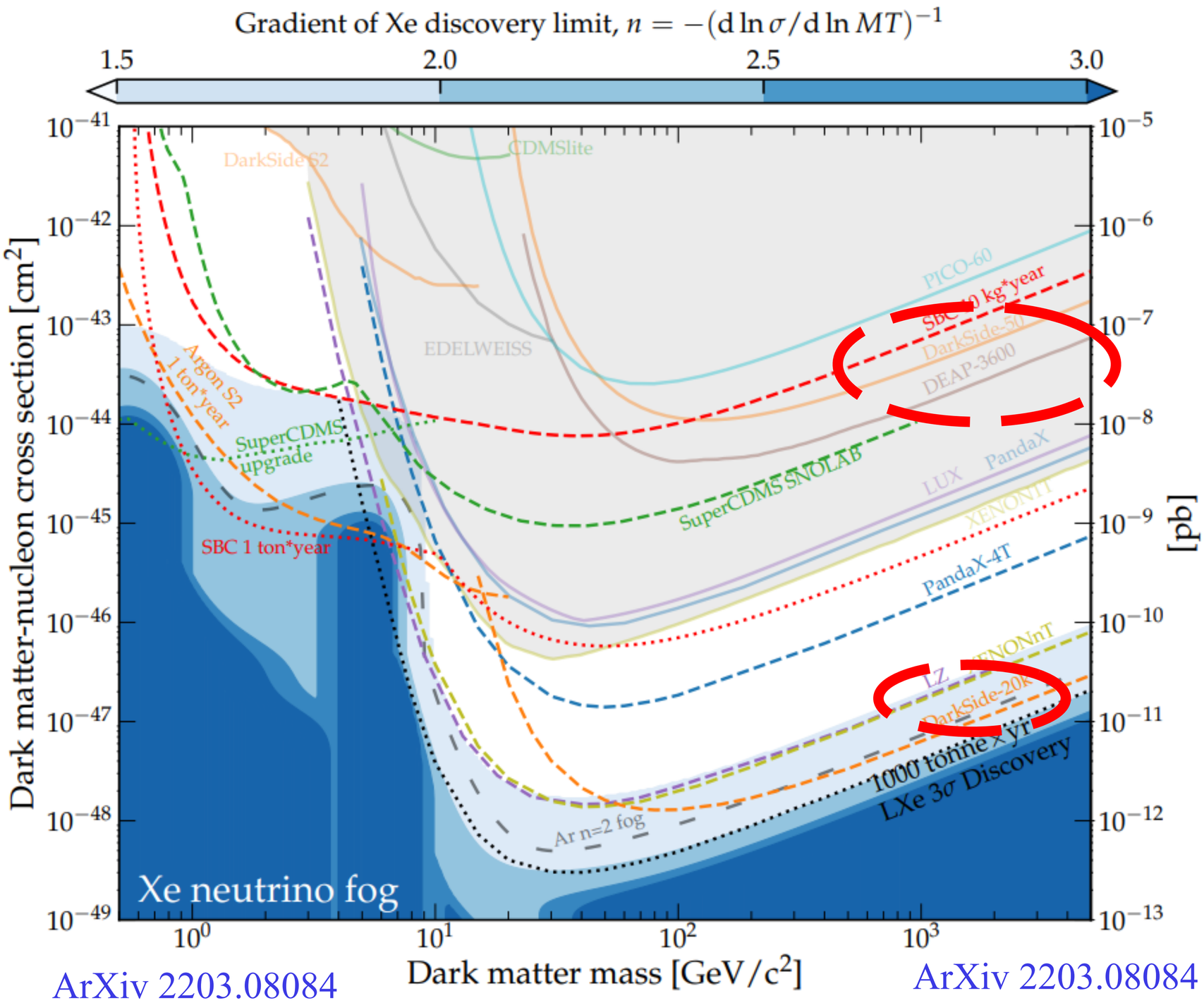


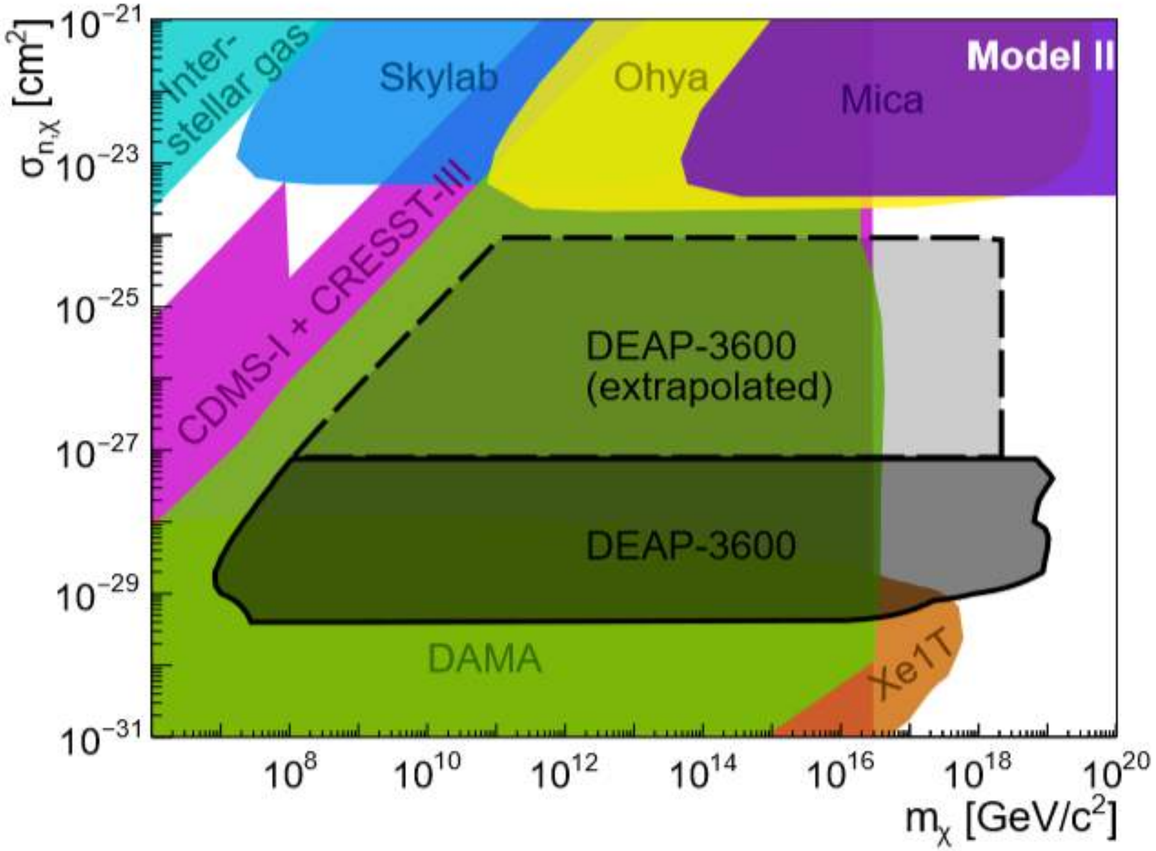
ArXiv 2203.08084

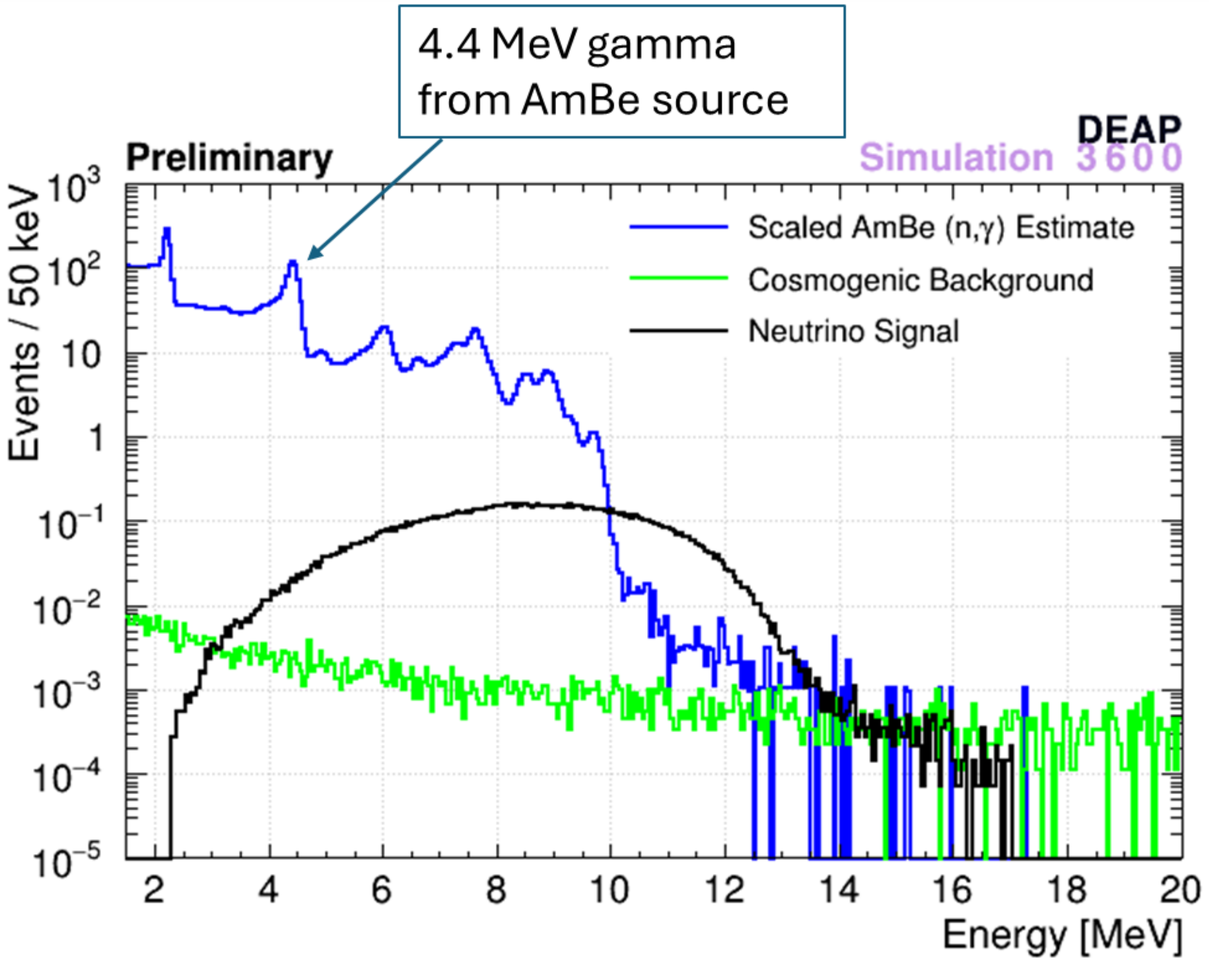
ArXiv 2203.08084

From the WIMP search to multi-purpose Dark matter experiments and neutrino observatories

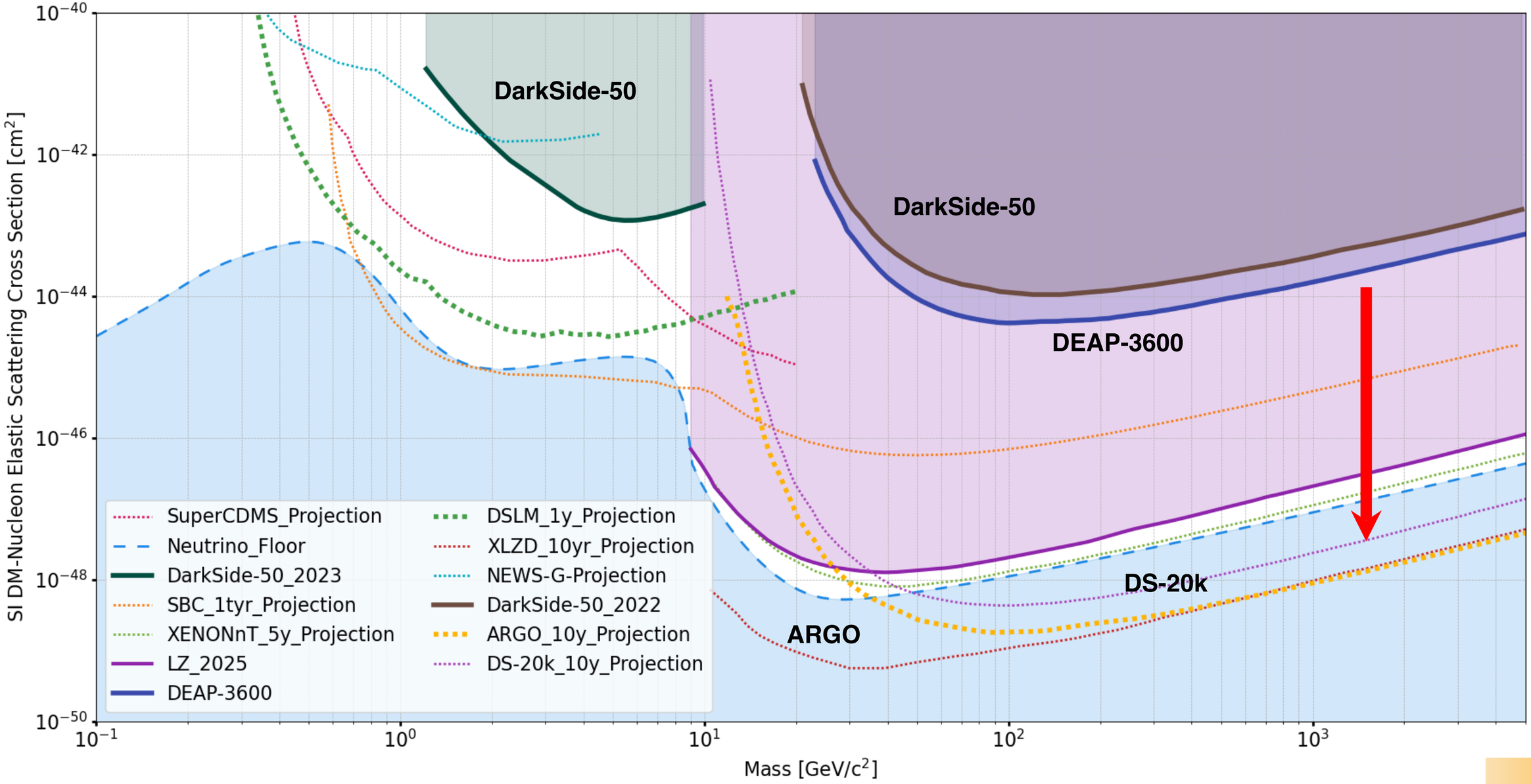
JCAP 03 (2021) 043

Phys. Rev. Lett. 128, 011801 (2022)

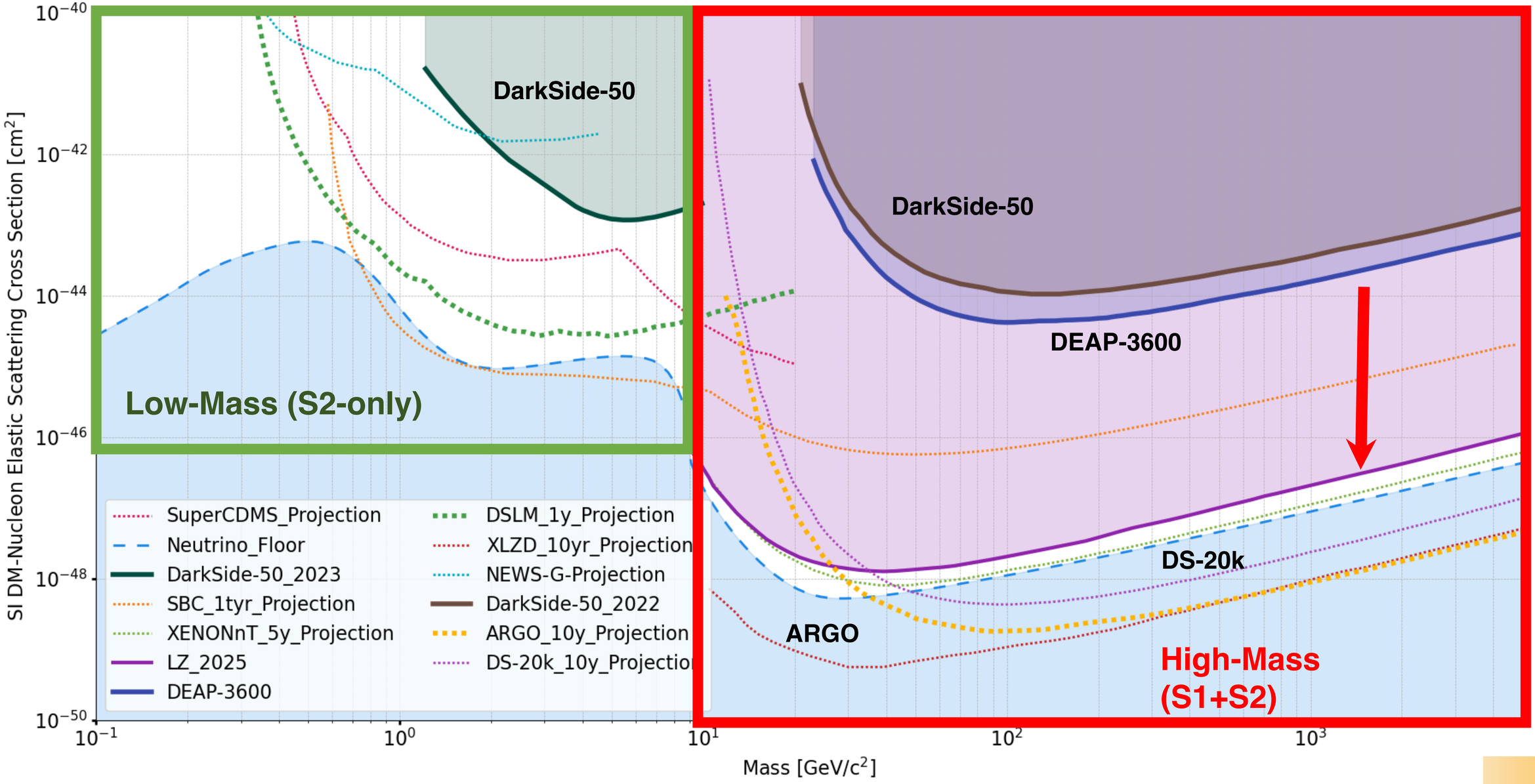




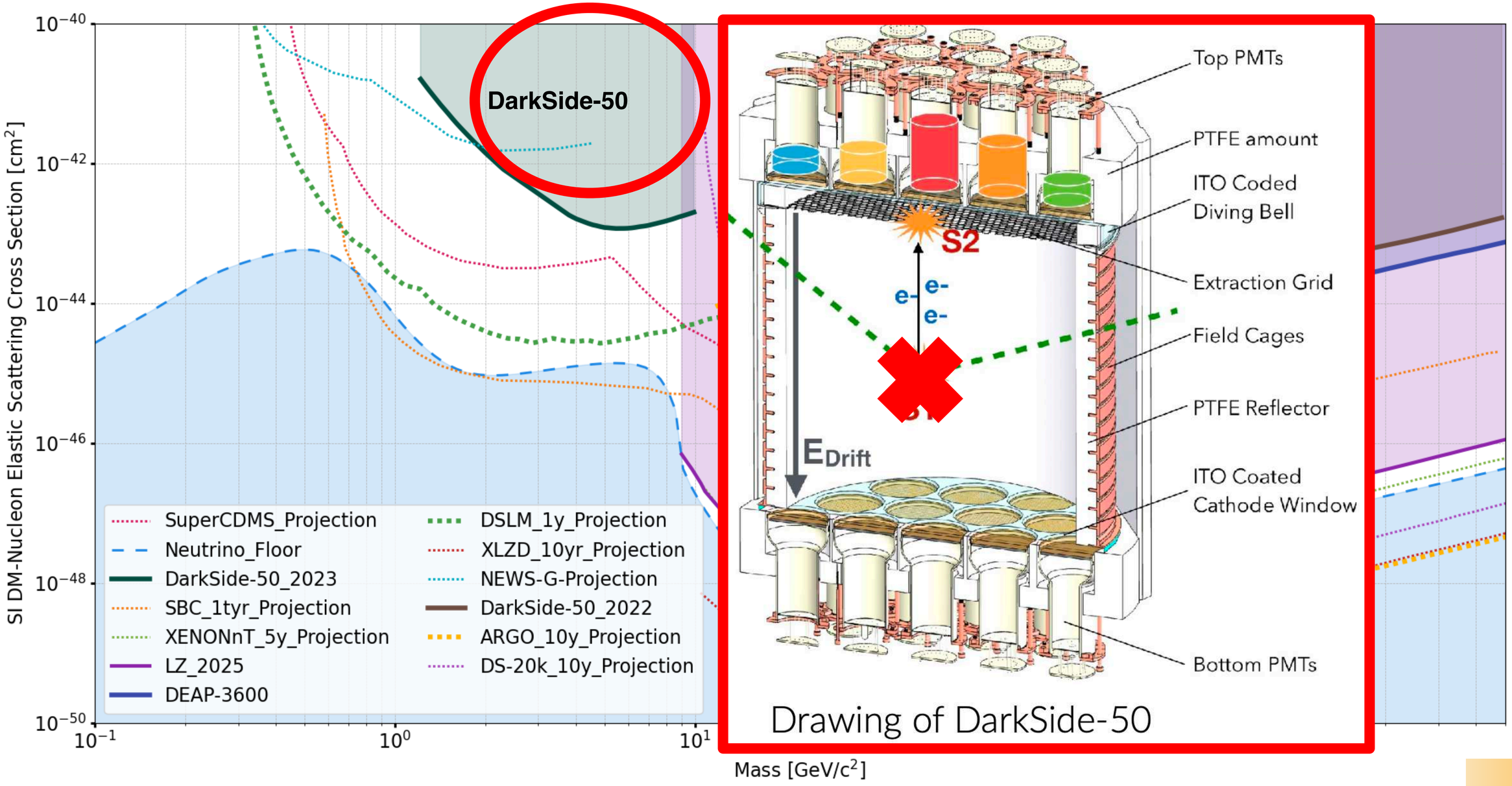
DS-20k (and ARGO, 300 t LAr) Projected Sensitivity



DS-20k (and ARGO, 300 t LAr) Projected Sensitivity

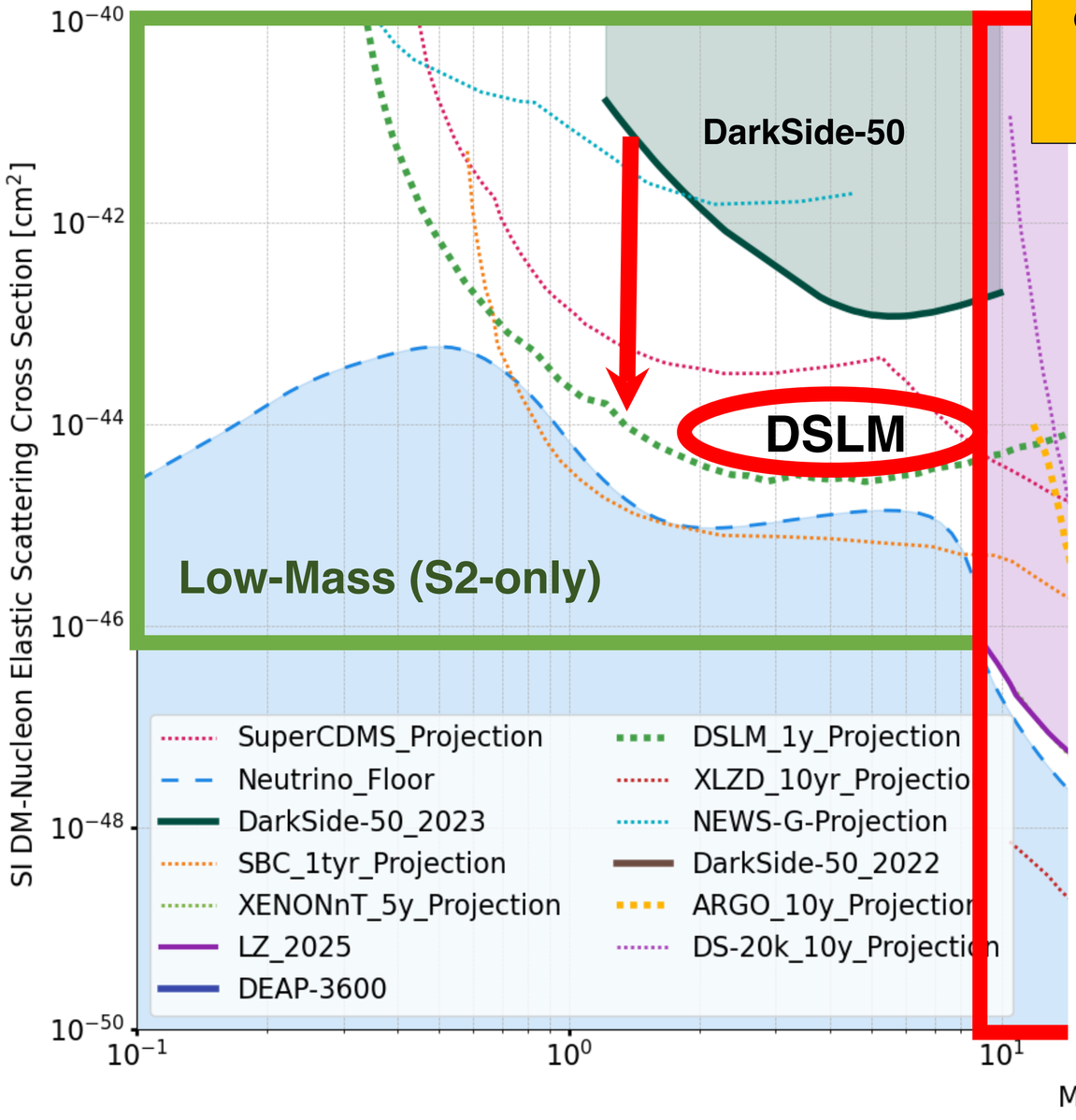


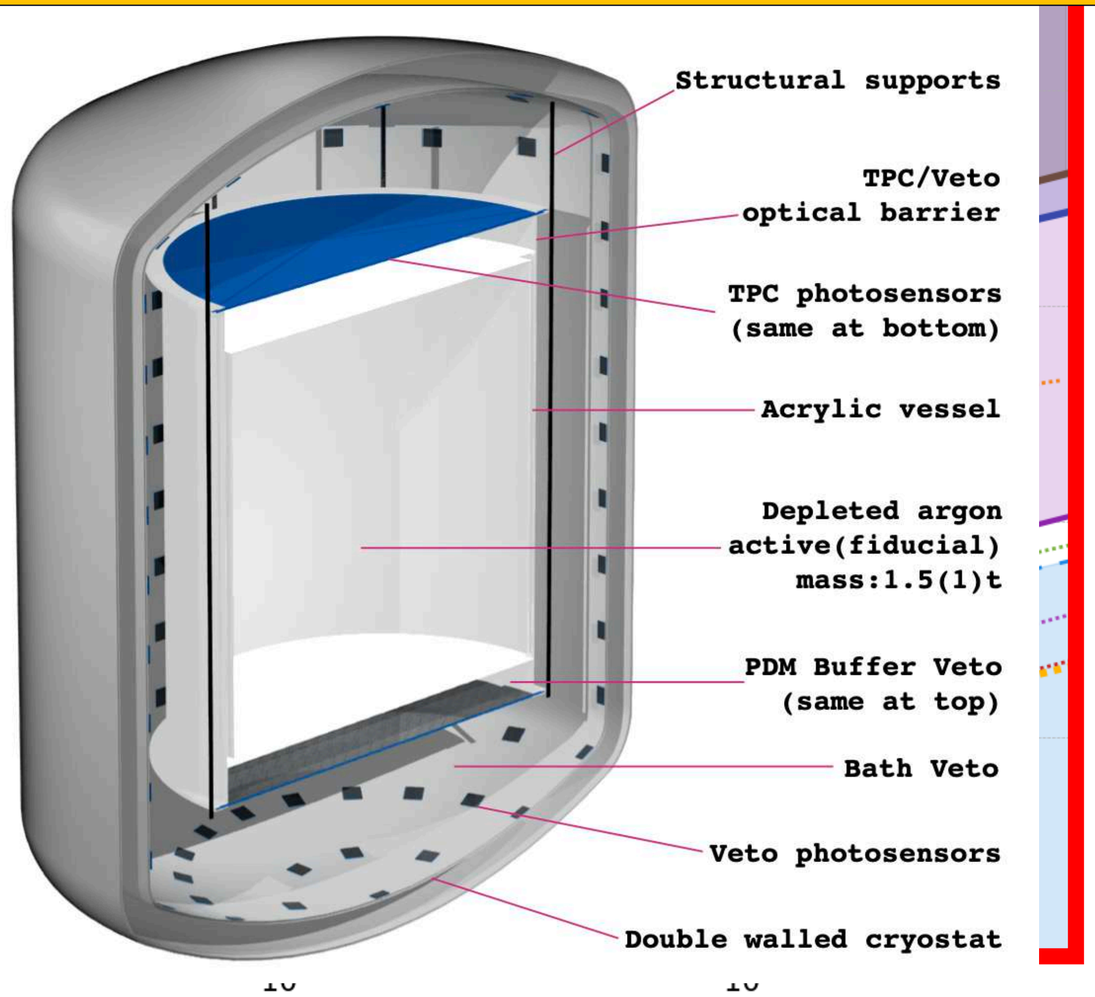
DS-20k (and ARGO) Projected Sensitivity



DarkSide-LowMass (?)

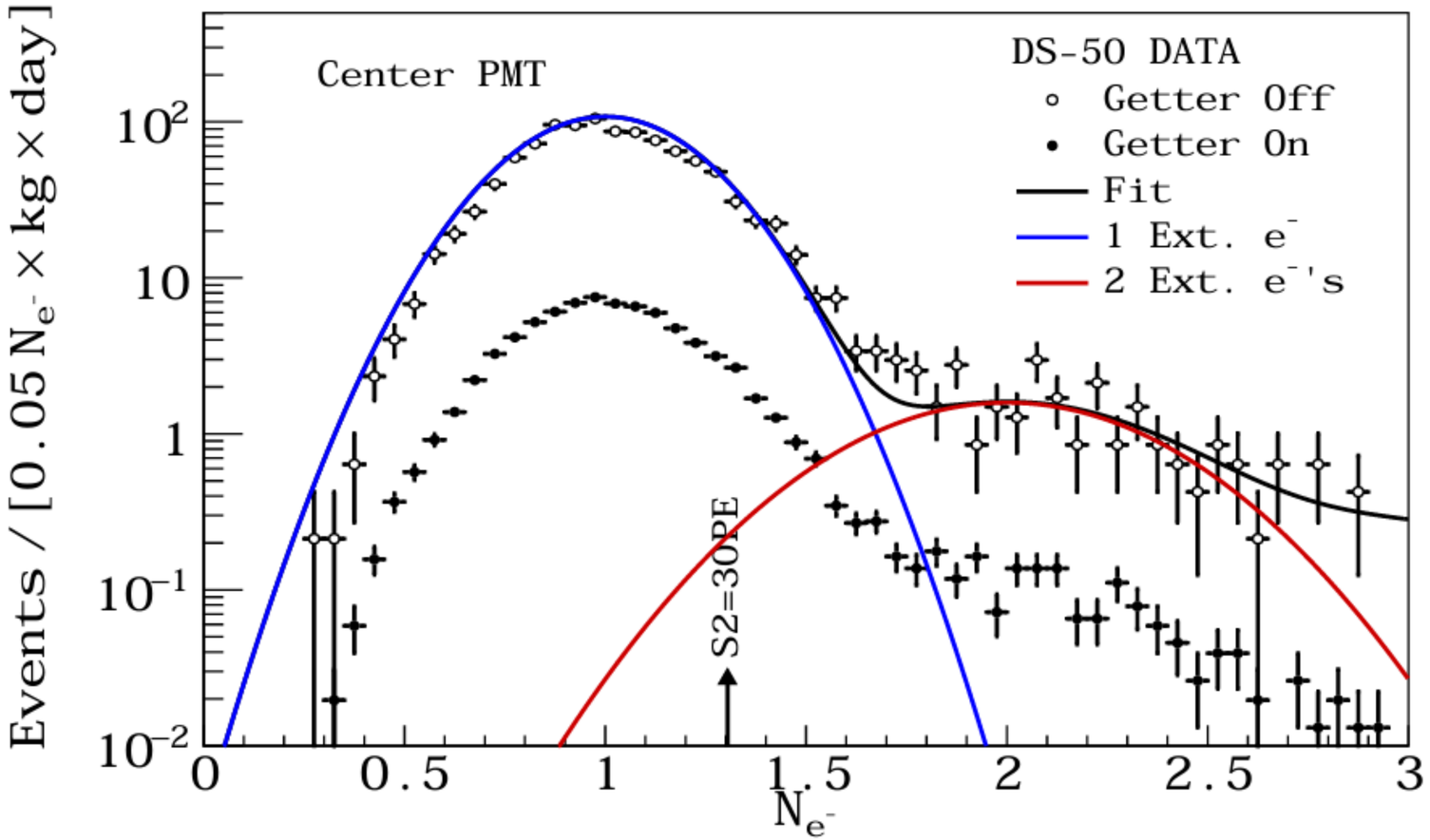
- 1 tonnes of active UAr volume
- Optimized for the S2-only analysis
- Sensitive to the neutrino fog with 1 tonne year exposure

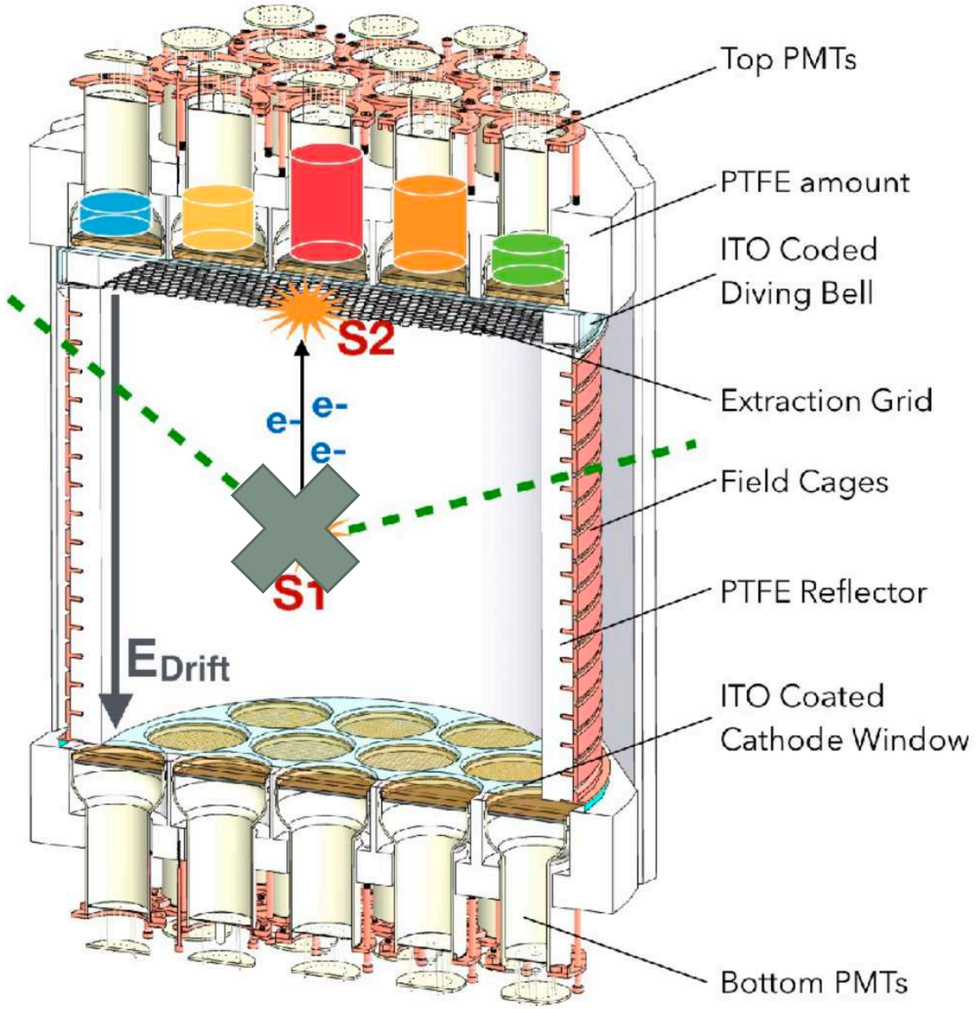




Phys. Rev. D 107, 112006 (2023)

Spurious electrons in double-phase noble liquid TPCs are the major backgrounds for sub-GeV DM searches

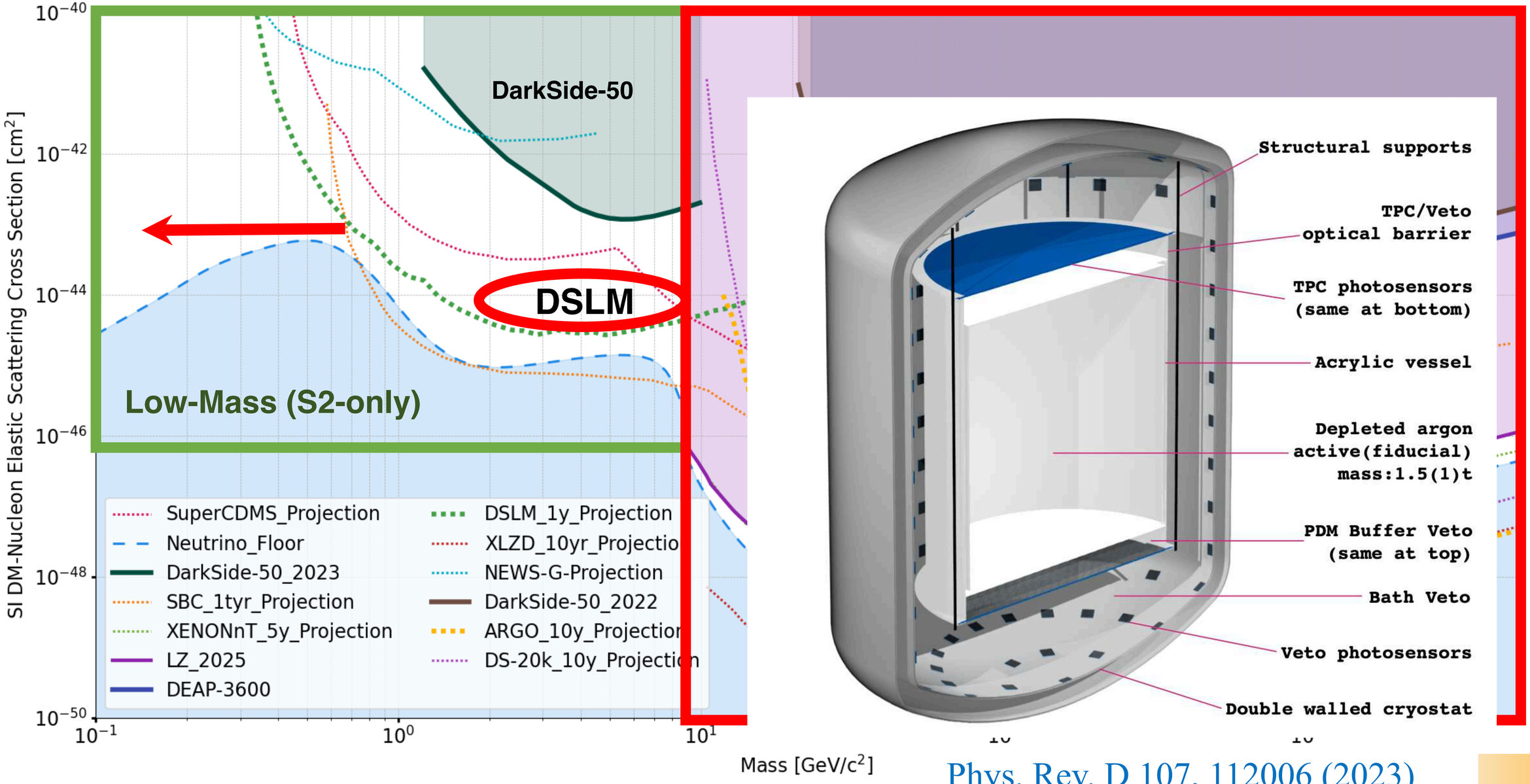




Drawing of DarkSide-50

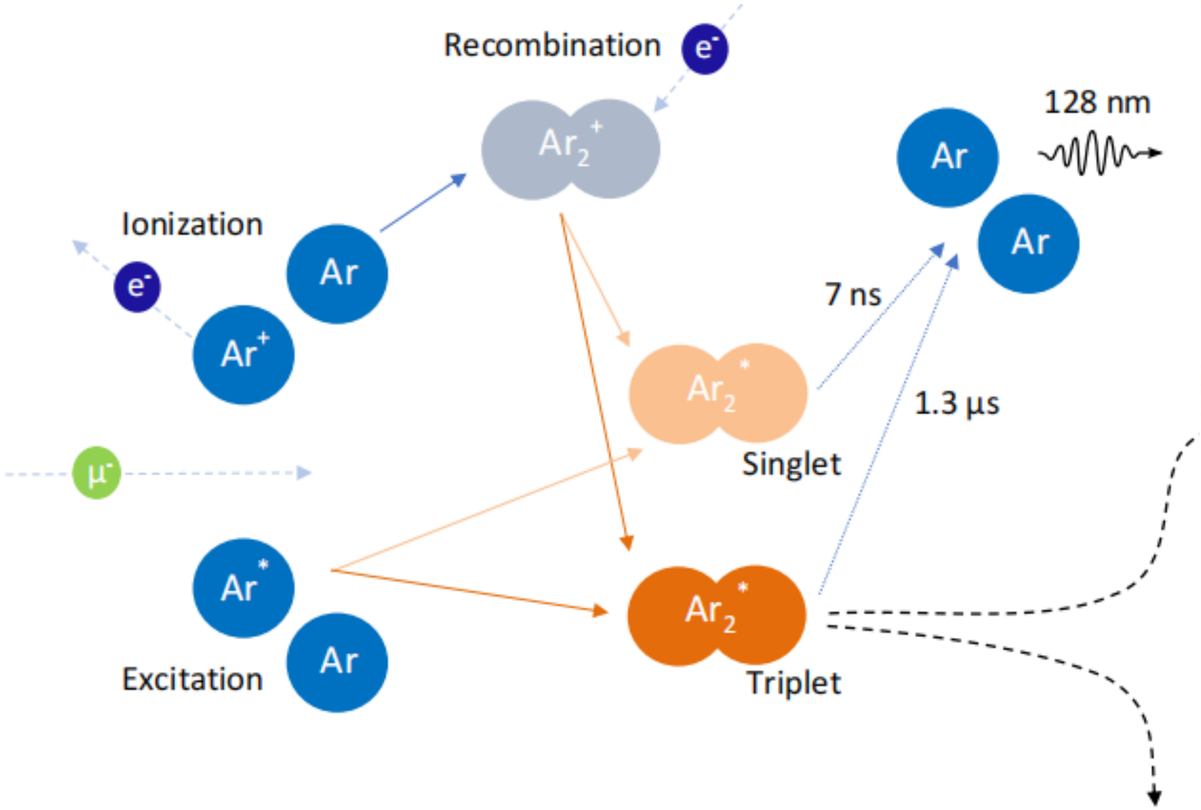
Phys.Rev.Lett. 121 (2018) 8, 081307

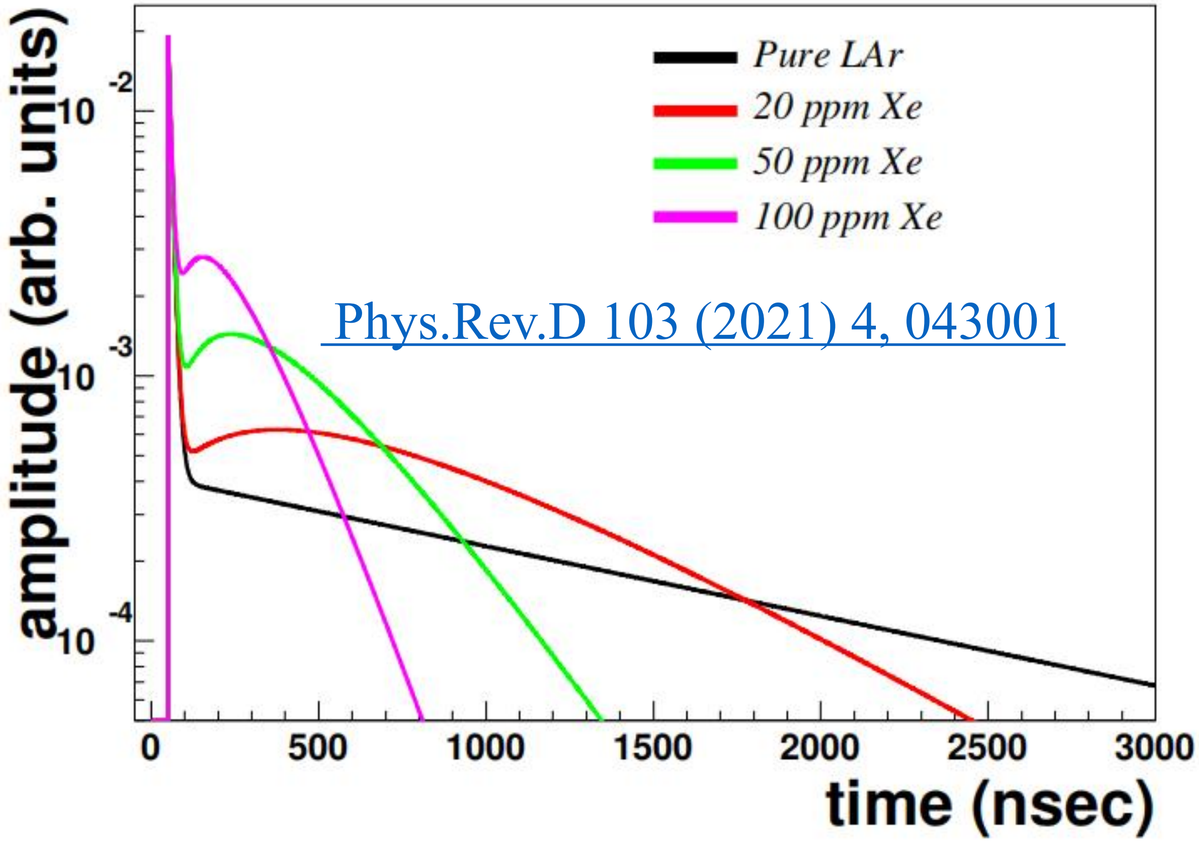
How do we detect even lighter DM candidates?



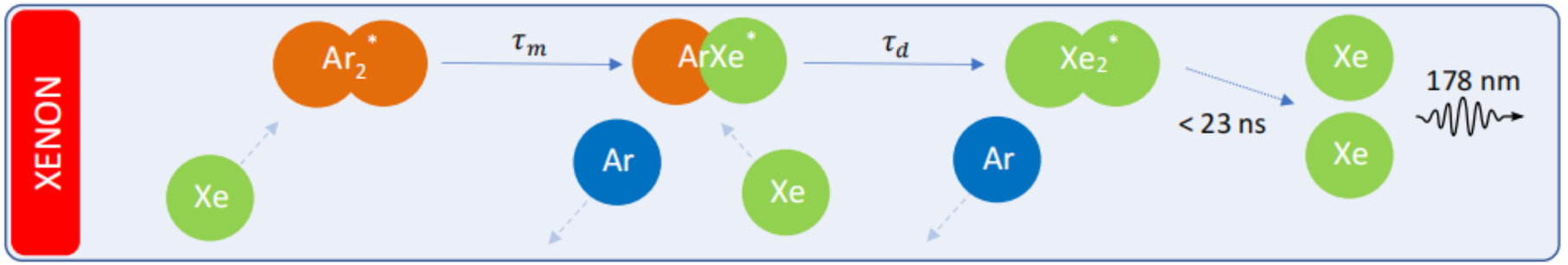
Phys. Rev. D 107, 112006 (2023)

Xenon doped Argon





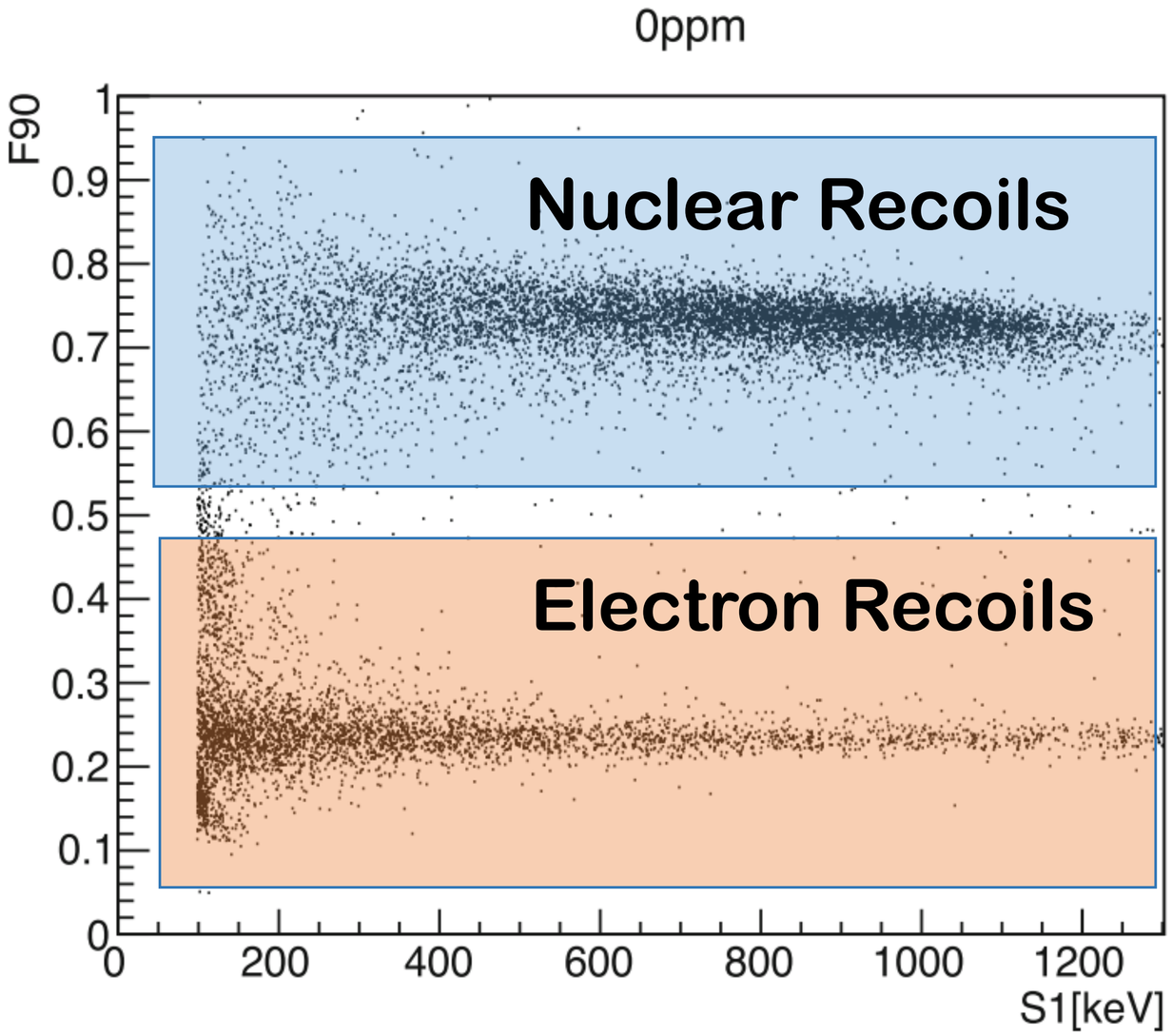
Phys.Rev.D 103 (2021) 4, 043001



JINST 19 (2024) 08, P08005

Huge decrease of the PSD

Fraction of the scintillation light in the first 90 ns (F90) in a 2.2 tons LAr chamber + PMTs



Radiat Detect Technol Methods (2025)

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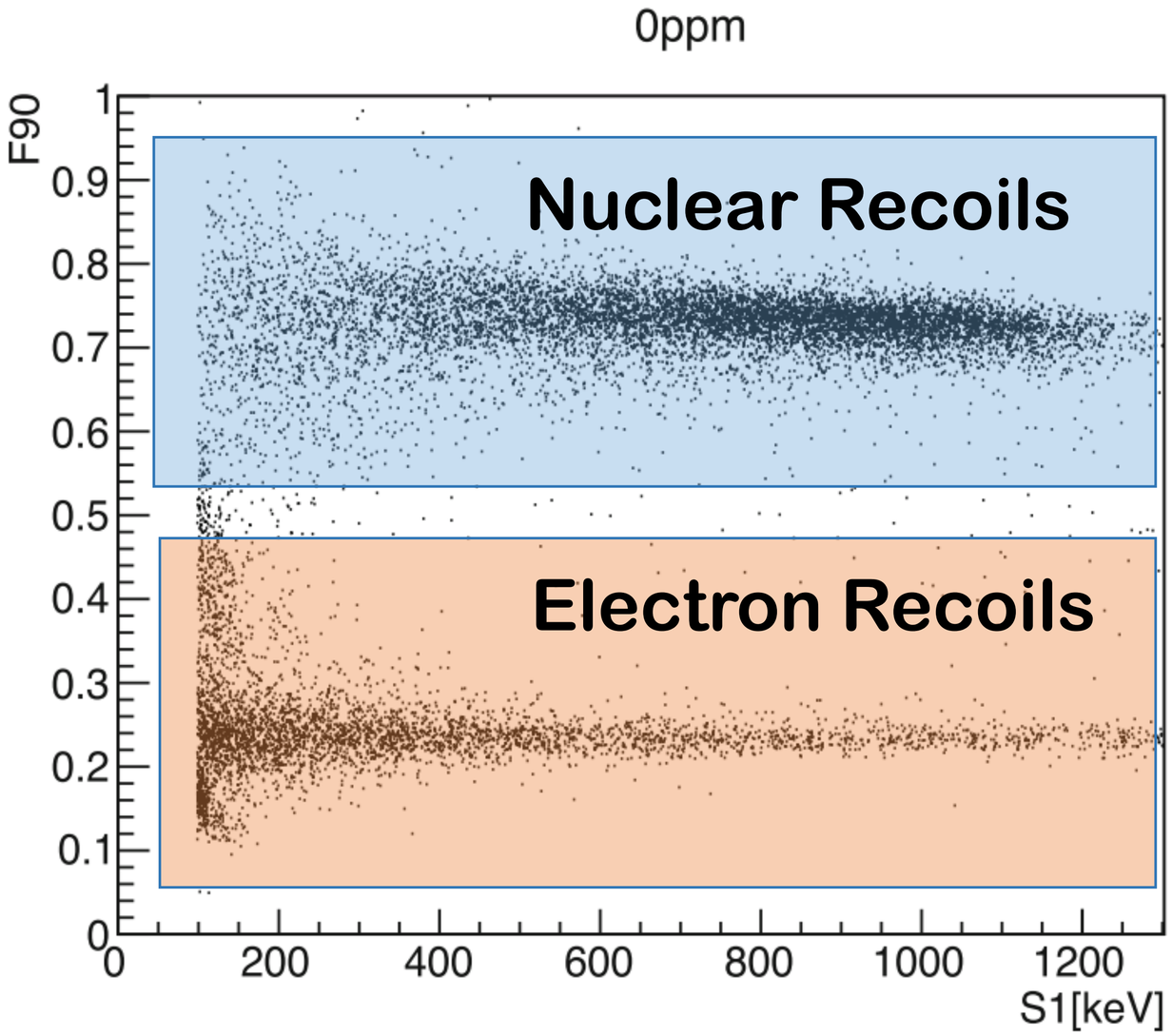
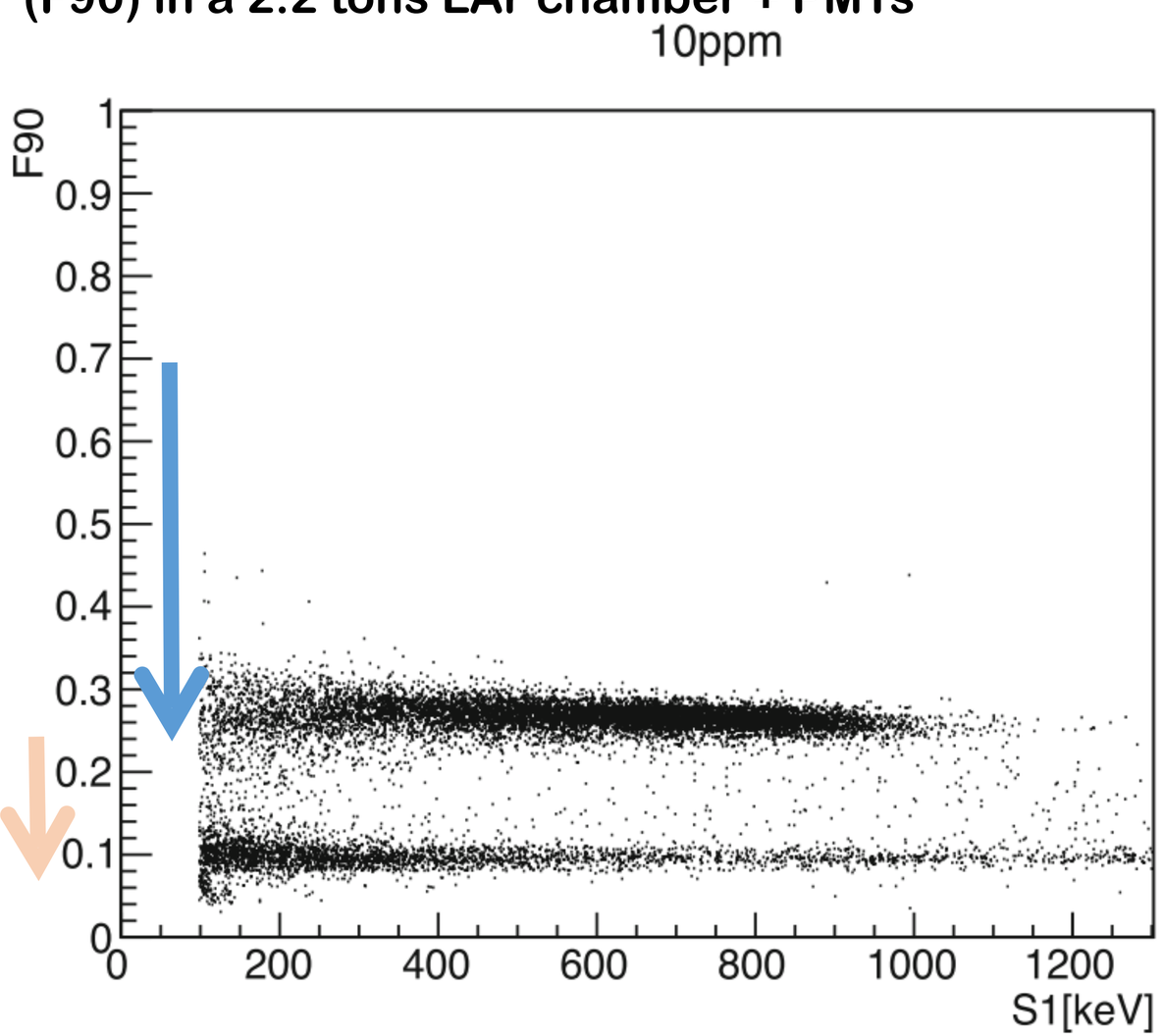
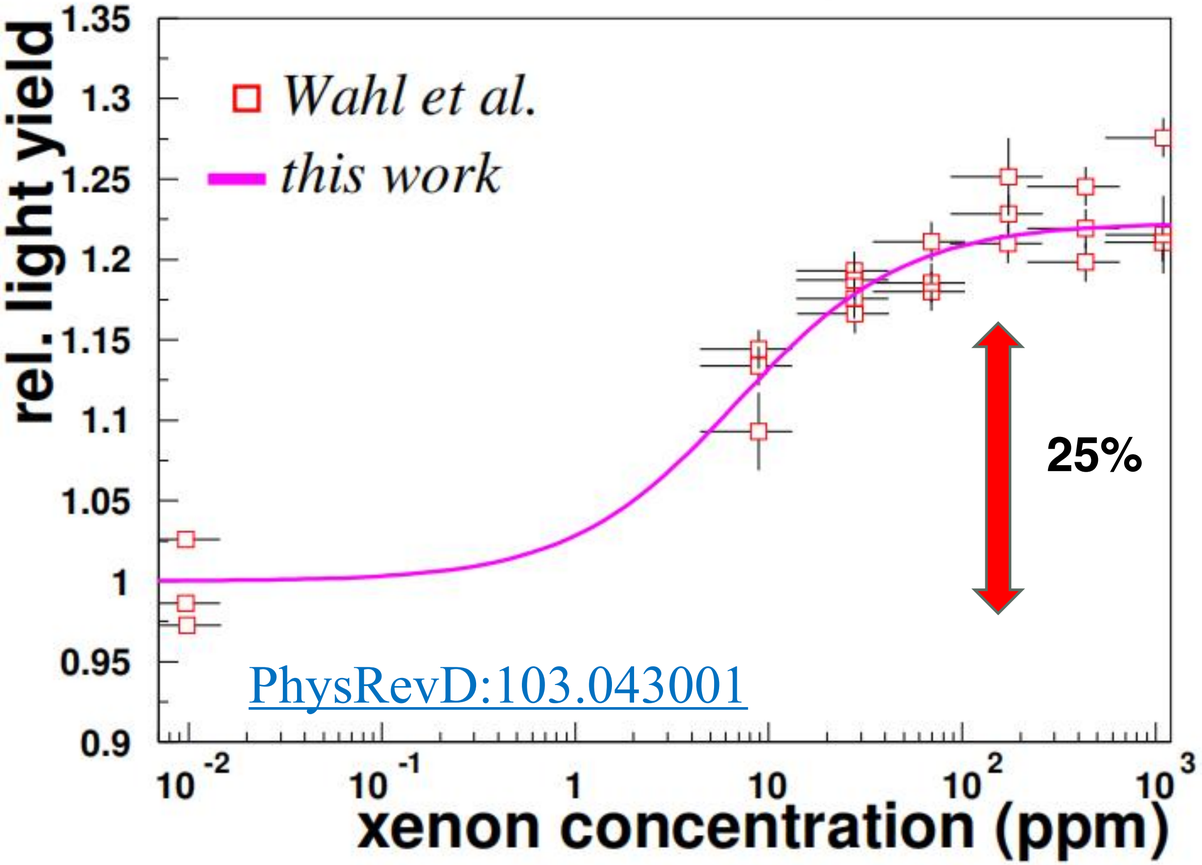




Radiat Detect Technol Methods (2025)

Clear increase of the scintillation yield in Xenon-doped Argon



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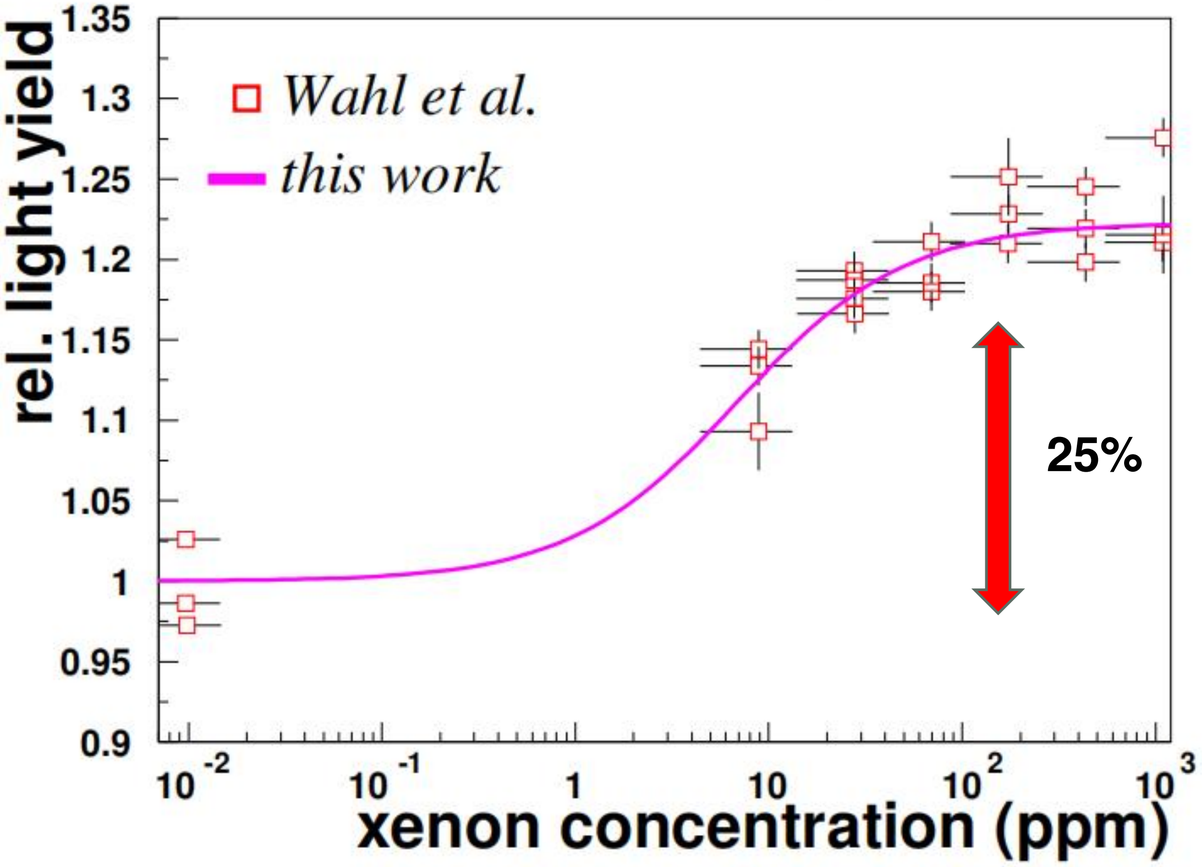
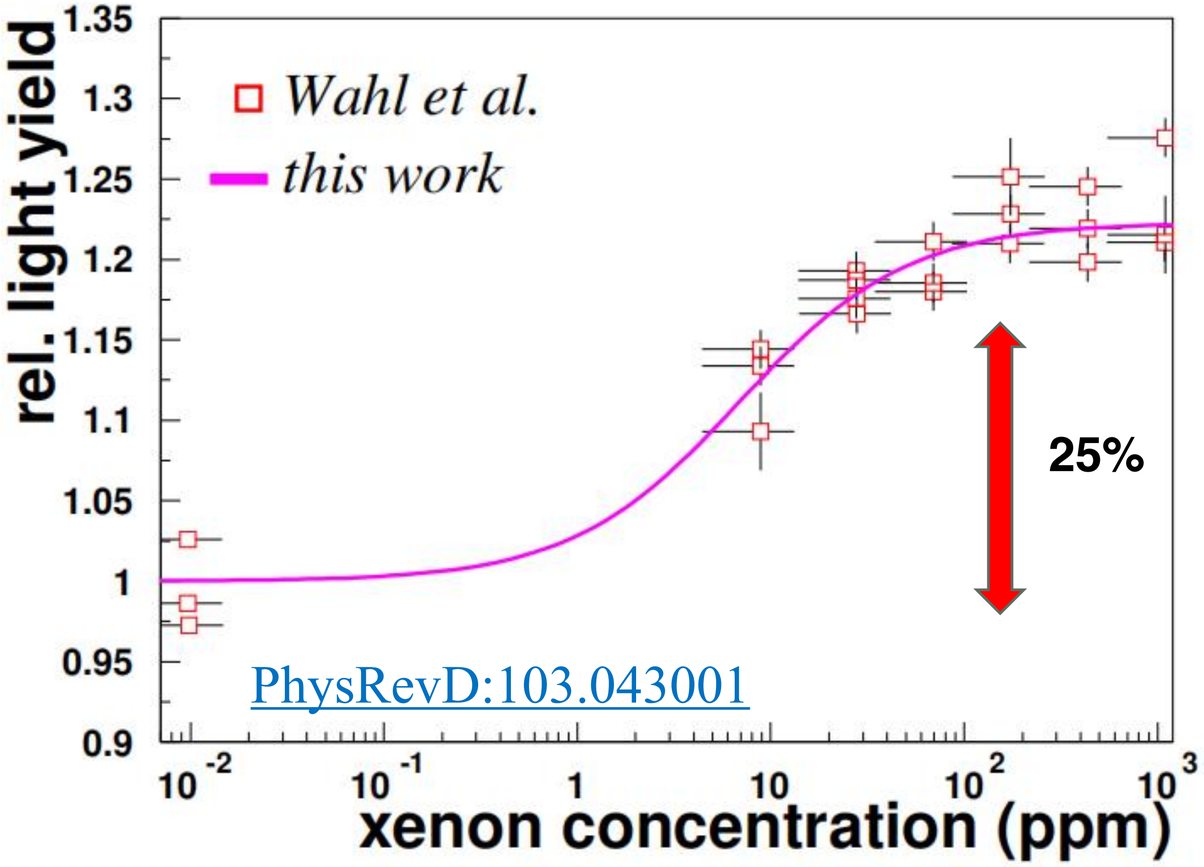


Xenon-doped LAr: does the ionization signal increase too?

Yes, it does!



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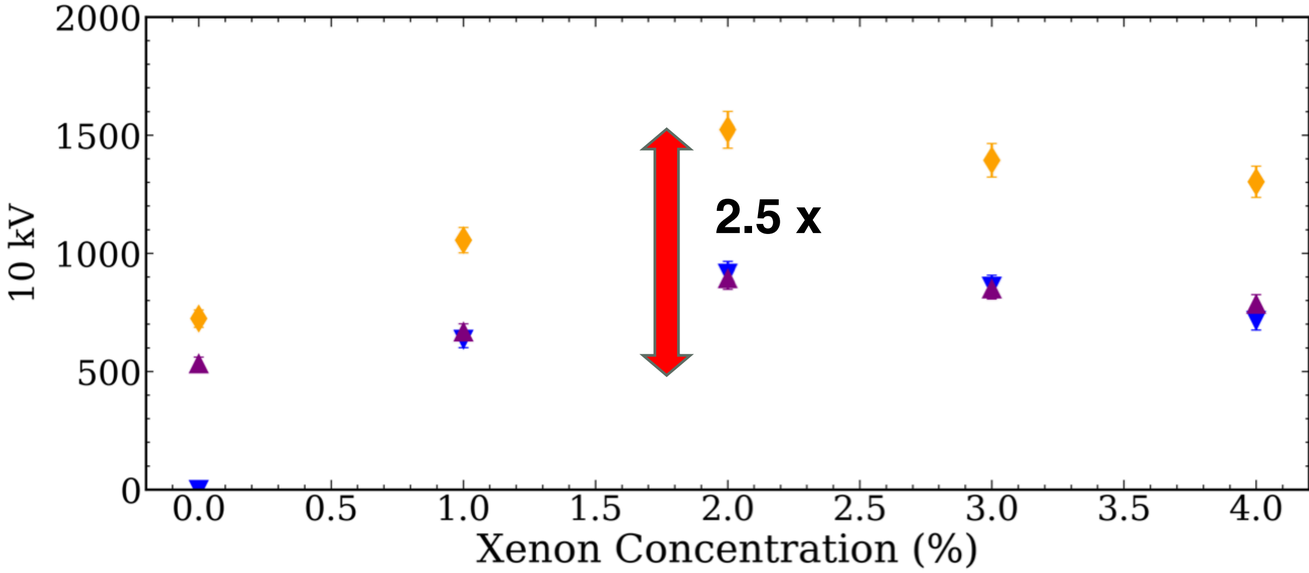
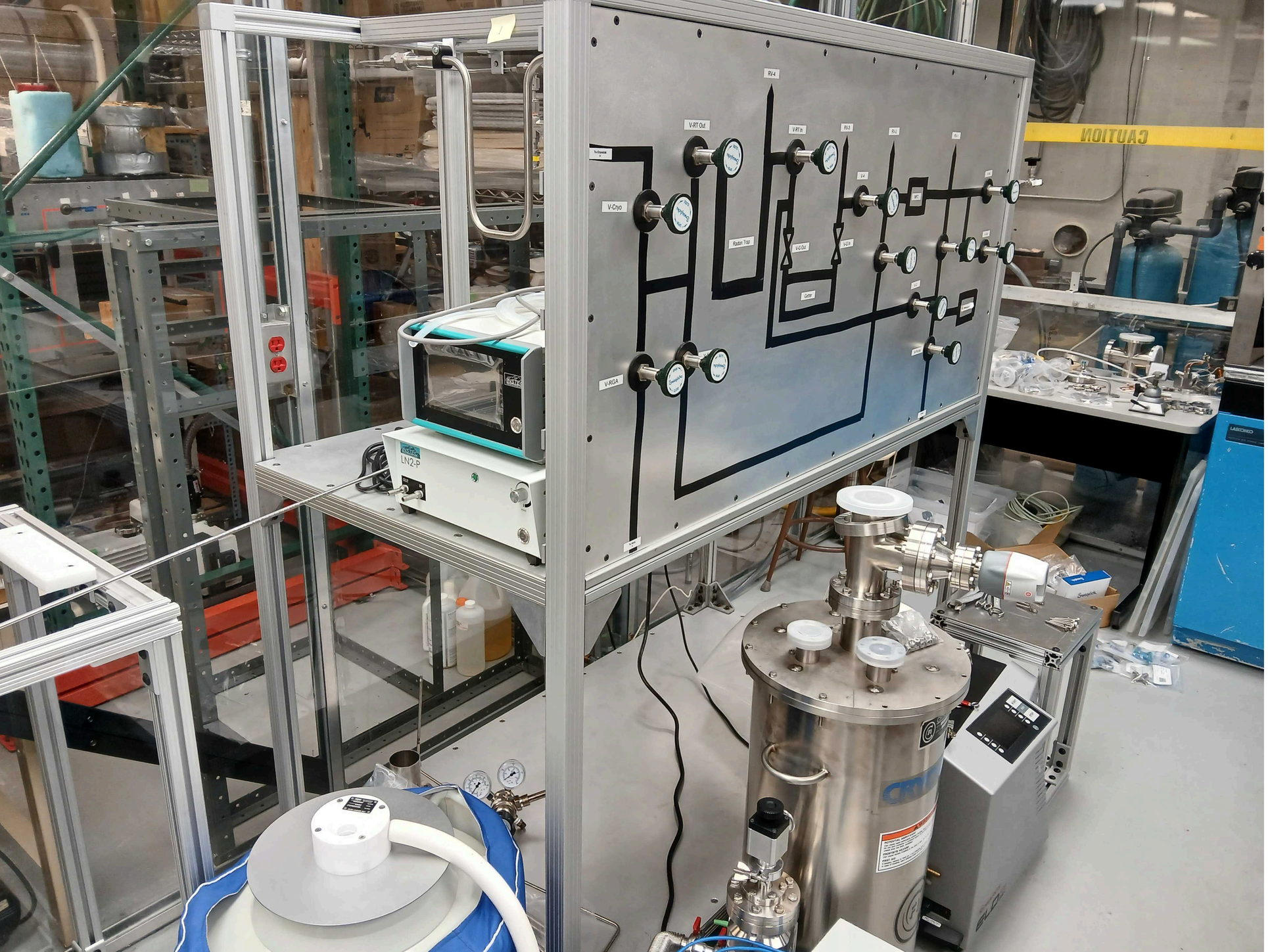


[2510.02261] Gas Electroluminescence in a Dual Phase Xenon-Doped Argon Detector

Soon at Queen's: scalable dual-phase TPC in xenon-doped argon

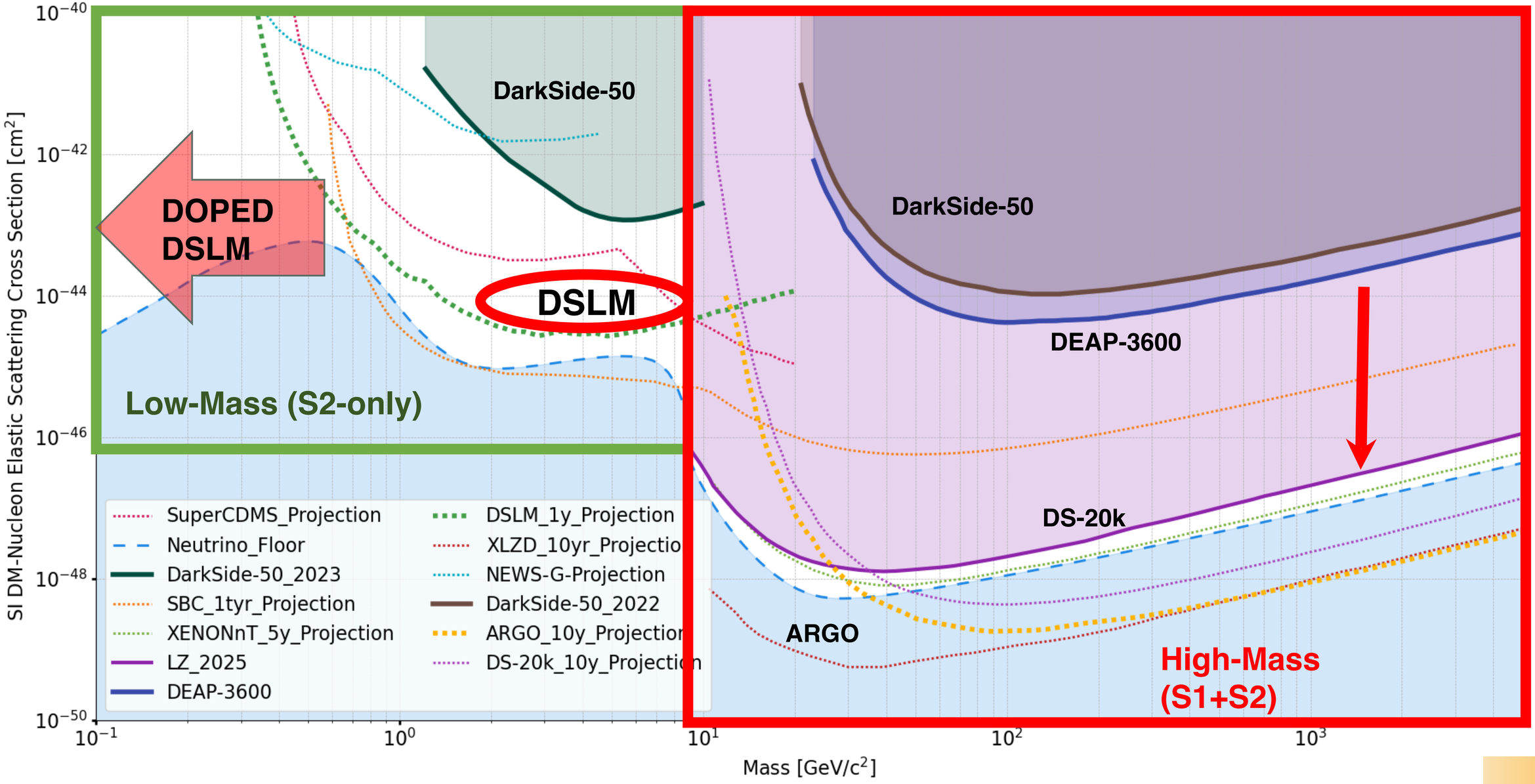


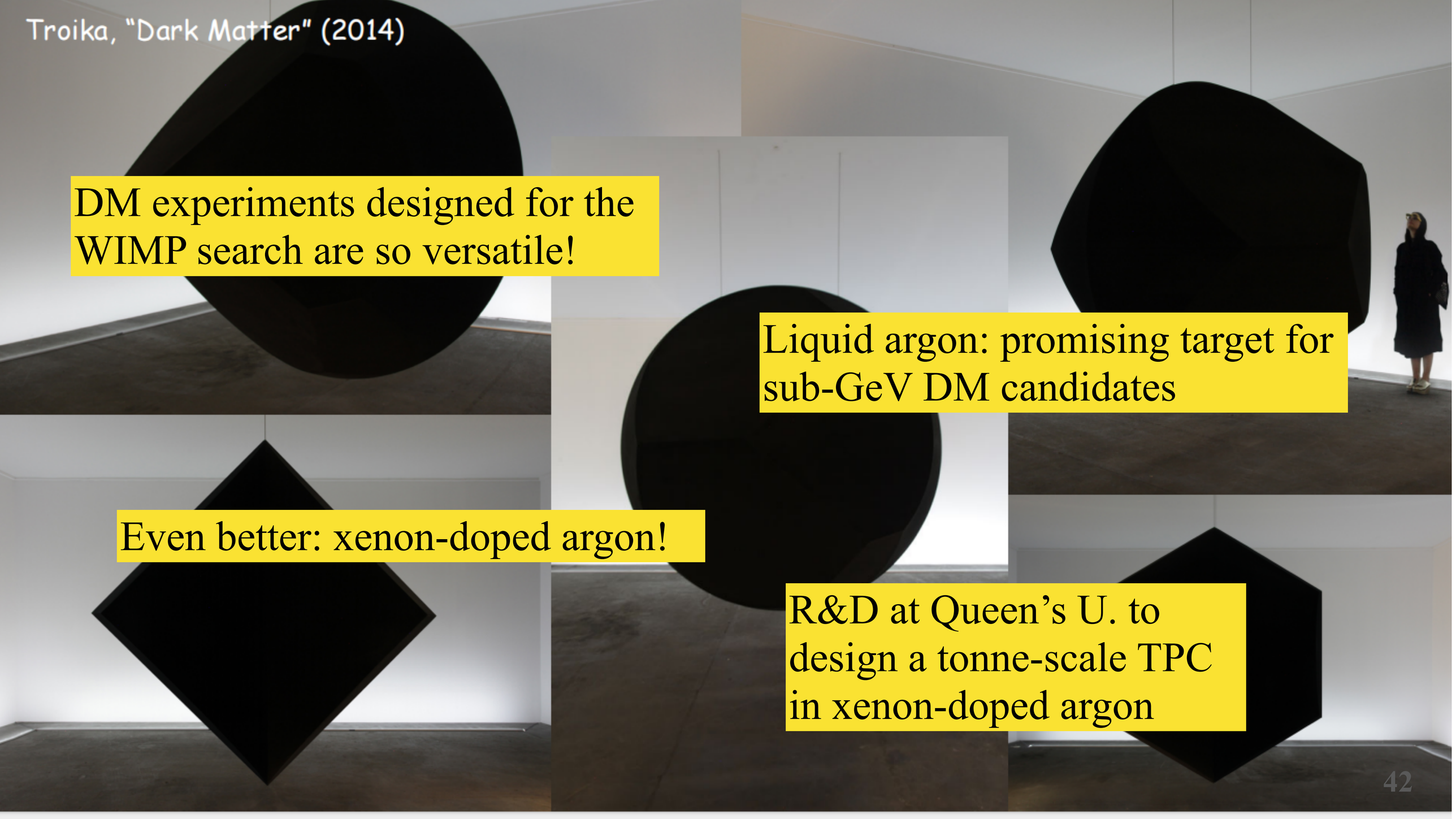
Commissioned cryostat from SNOLAB

We can now (literally, last week) condense and keep liquid argon

Group effort!
Stay tuned!

Low-Background, tonne-scale Doped LAr for sub-GeV DM!



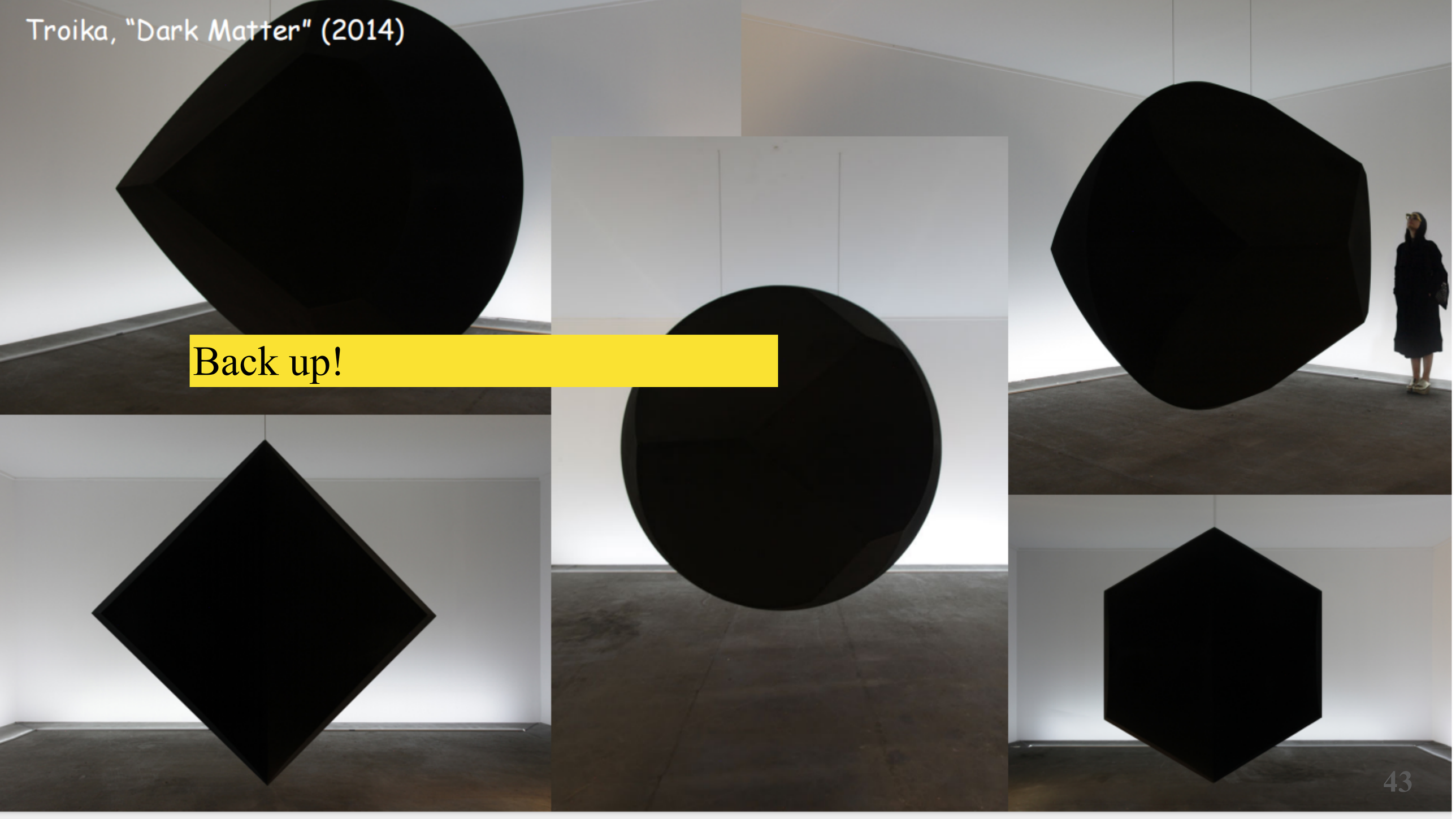


DM experiments designed for the WIMP search are so versatile!

Liquid argon: promising target for sub-GeV DM candidates

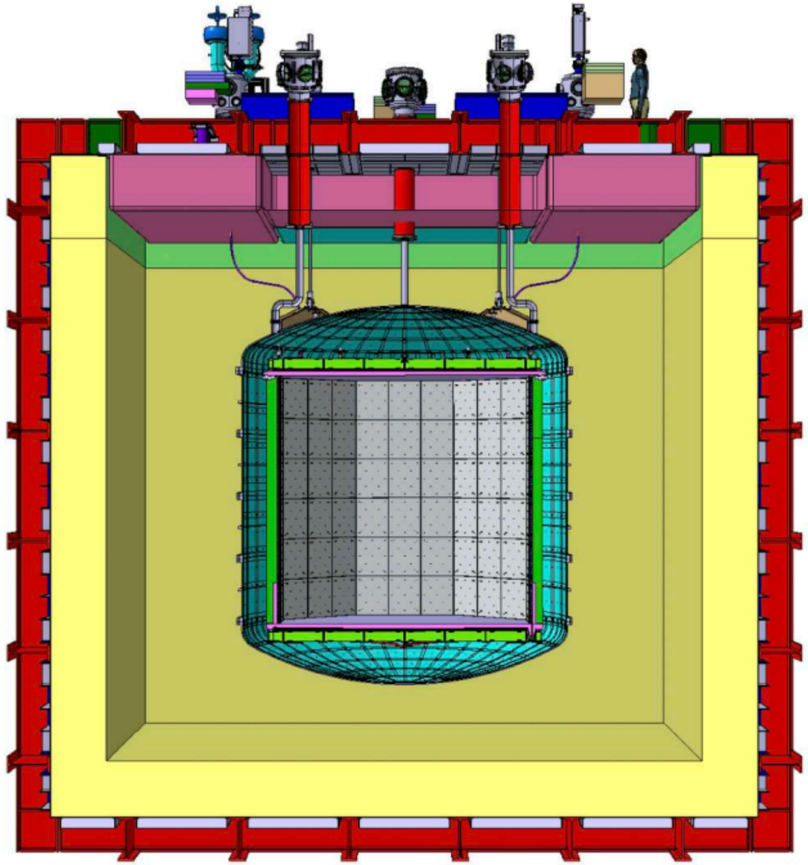
Even better: xenon-doped argon!

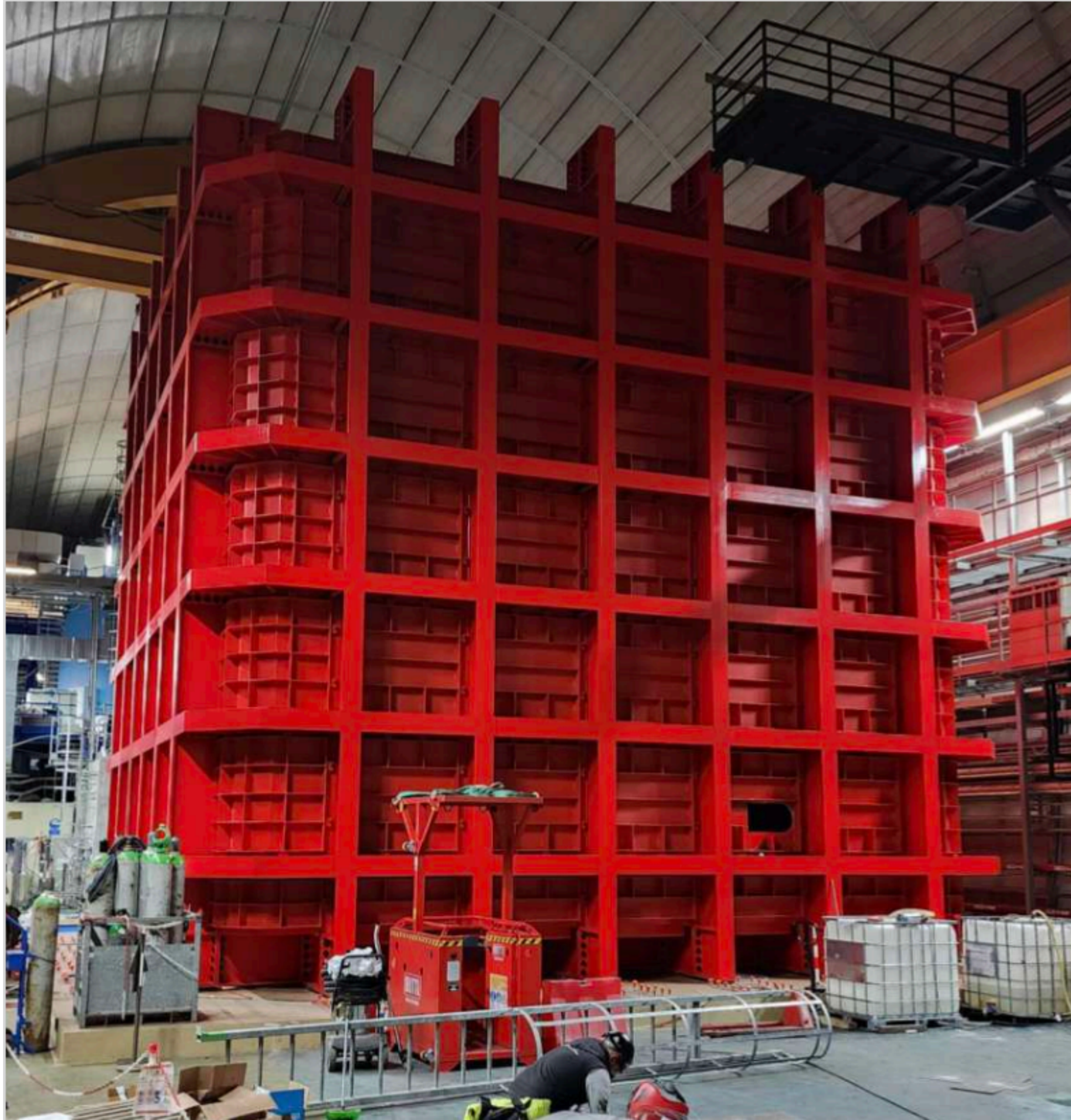
R&D at Queen's U. to design a tonne-scale TPC in xenon-doped argon


Troika, "Dark Matter" (2014)
Back up!

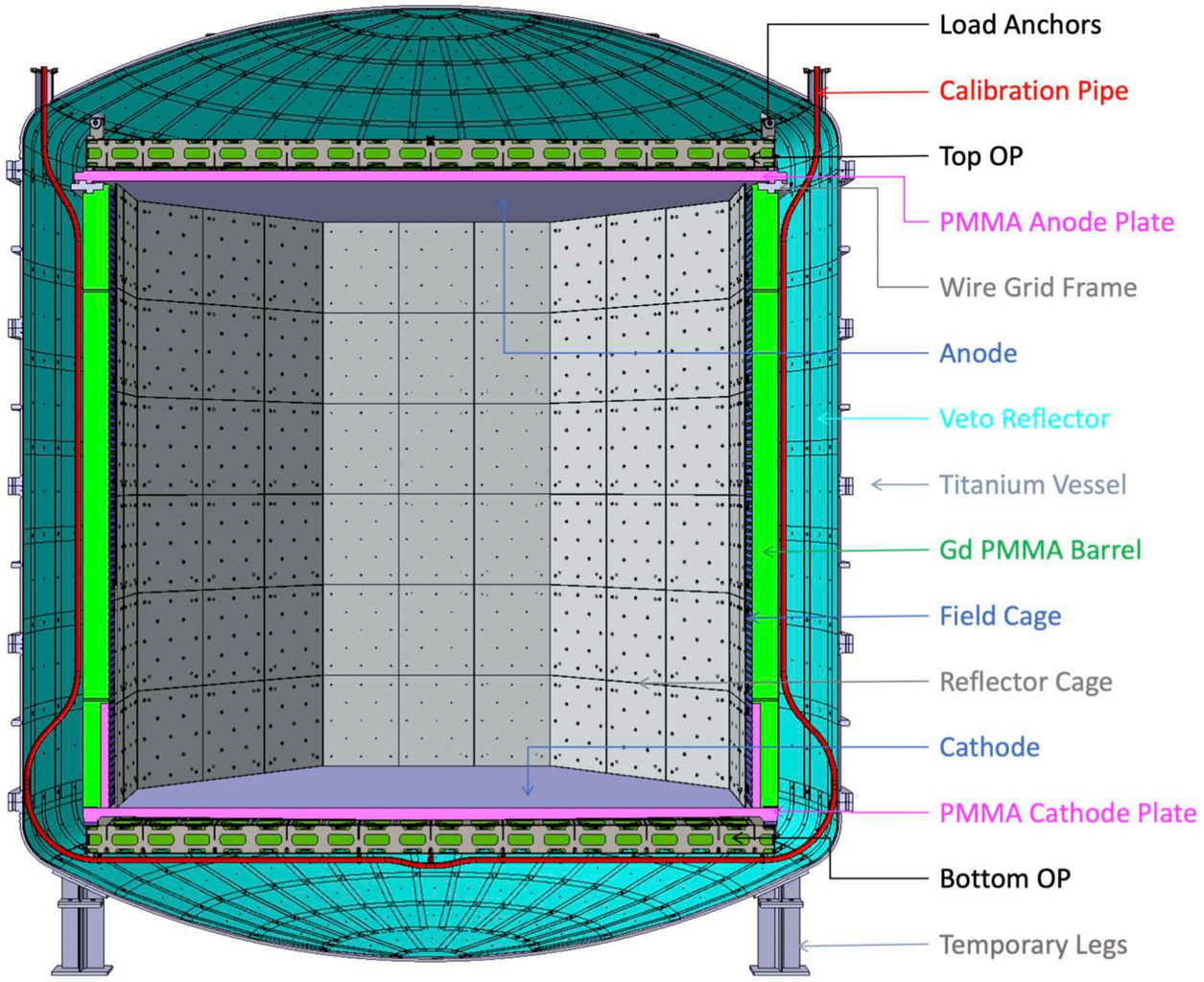
Next step: DarkSide-20k experiment!

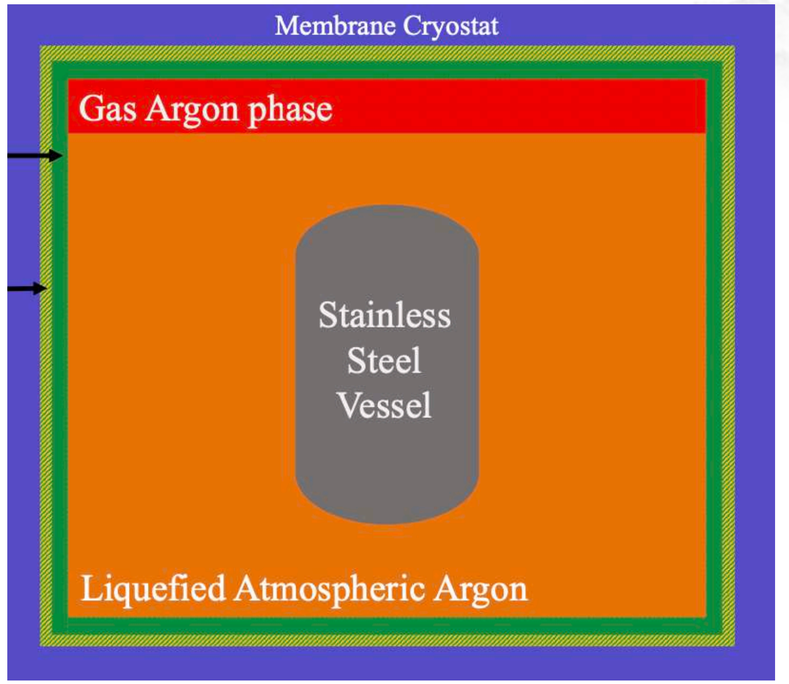
Three nested detectors designed for being instrumental background free in 10 years of data taking

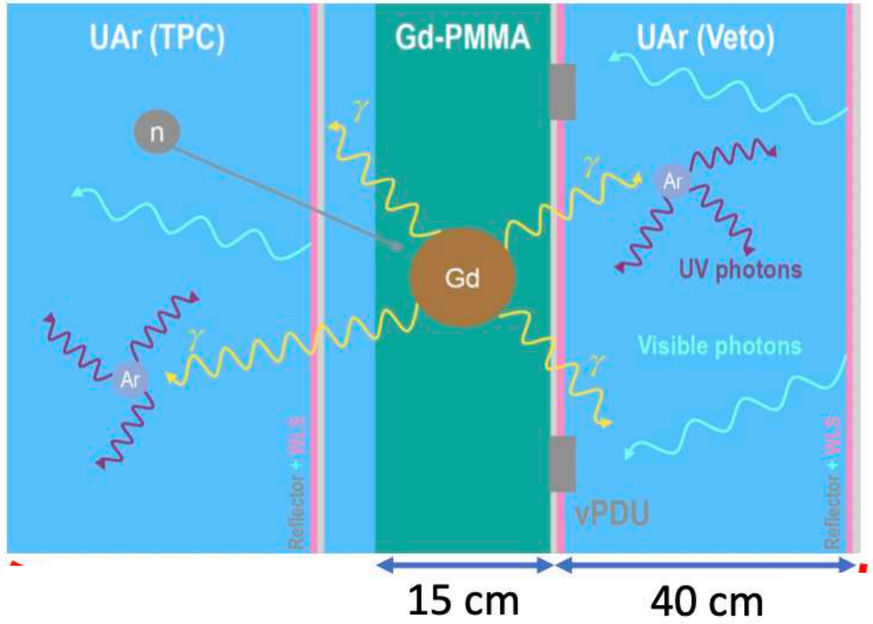


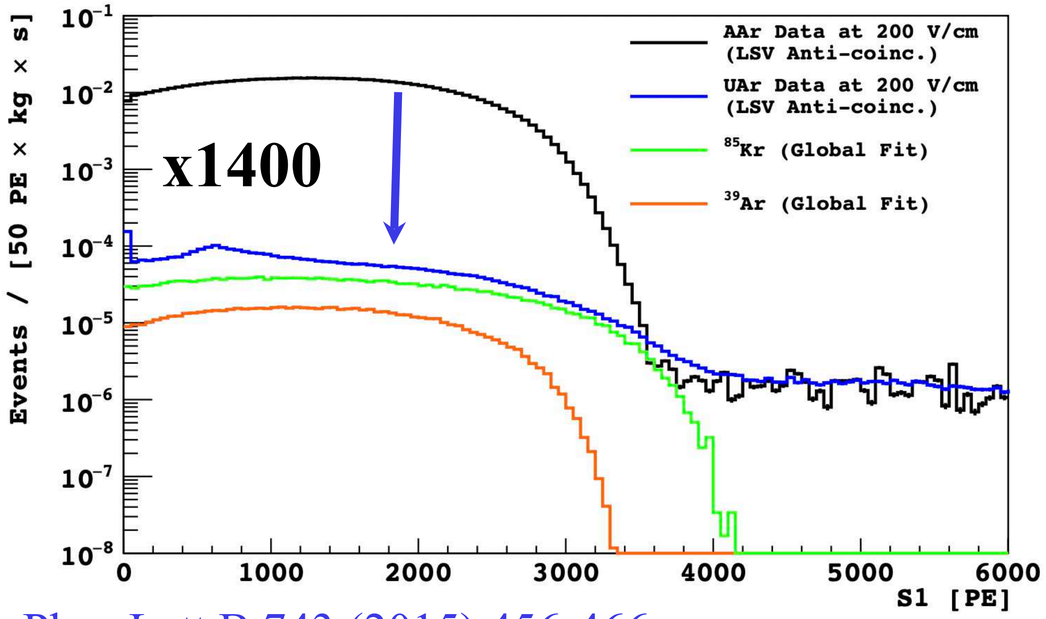


50 tonnes (TPC) of UAr + 27 tonnes of UAr (Inner Veto) + 650 tonnes of AAr (Outer Veto)

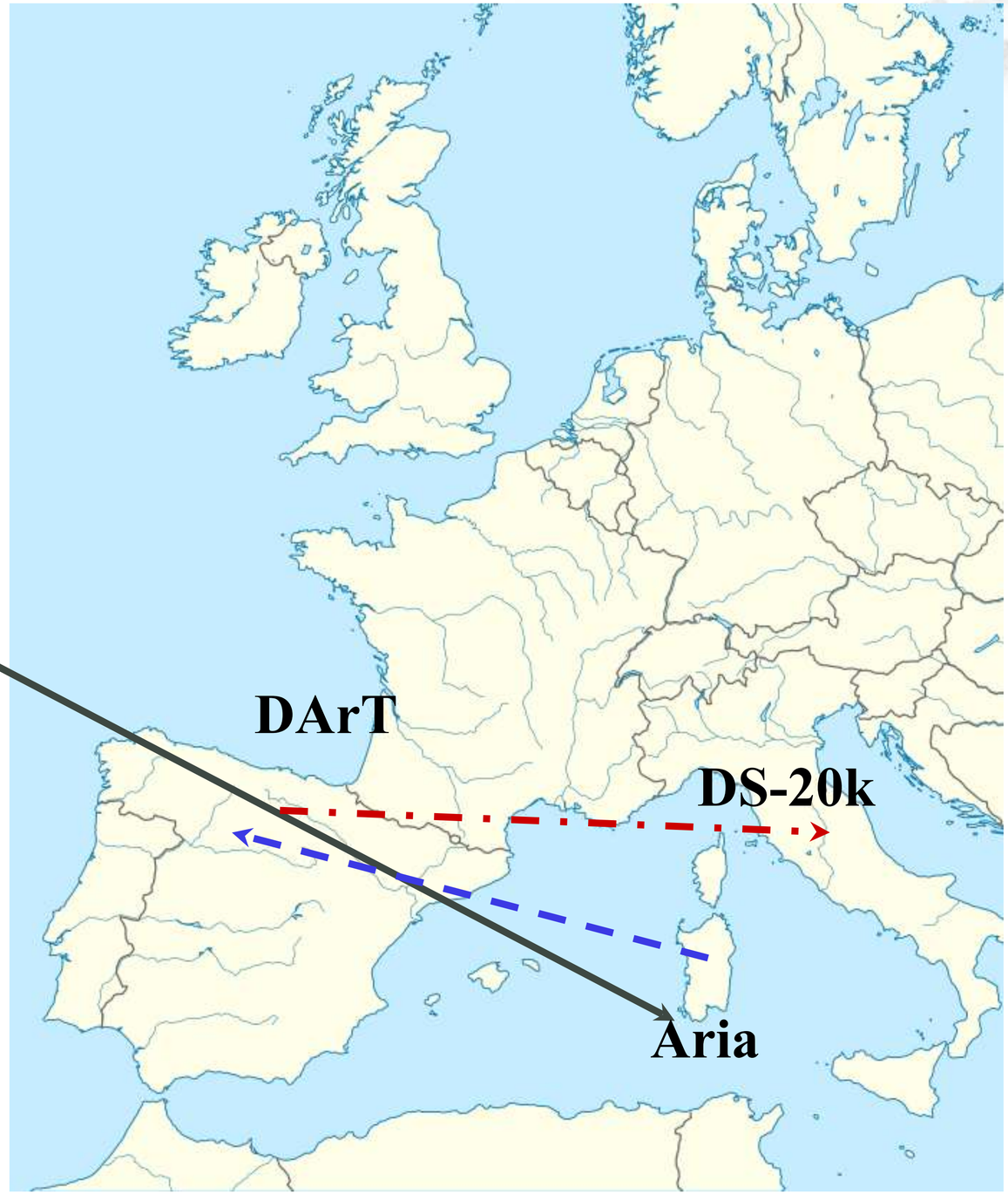


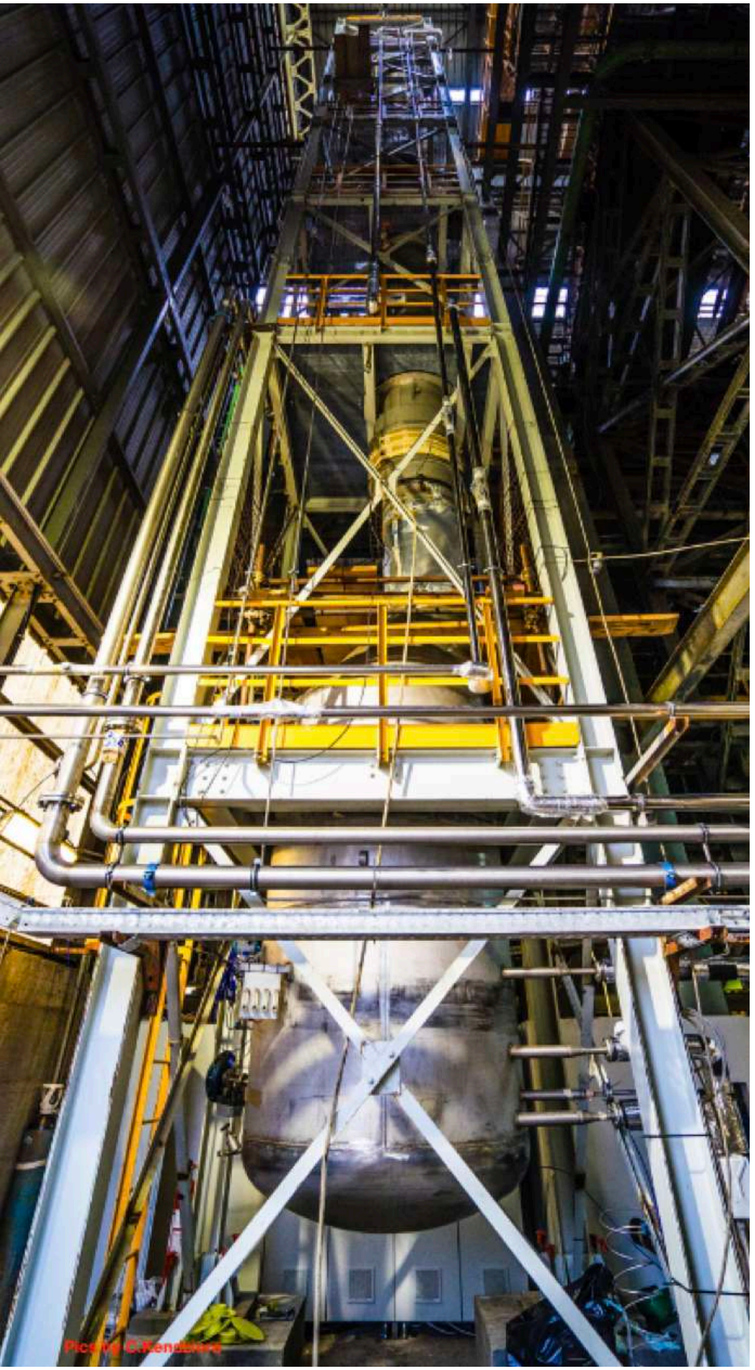




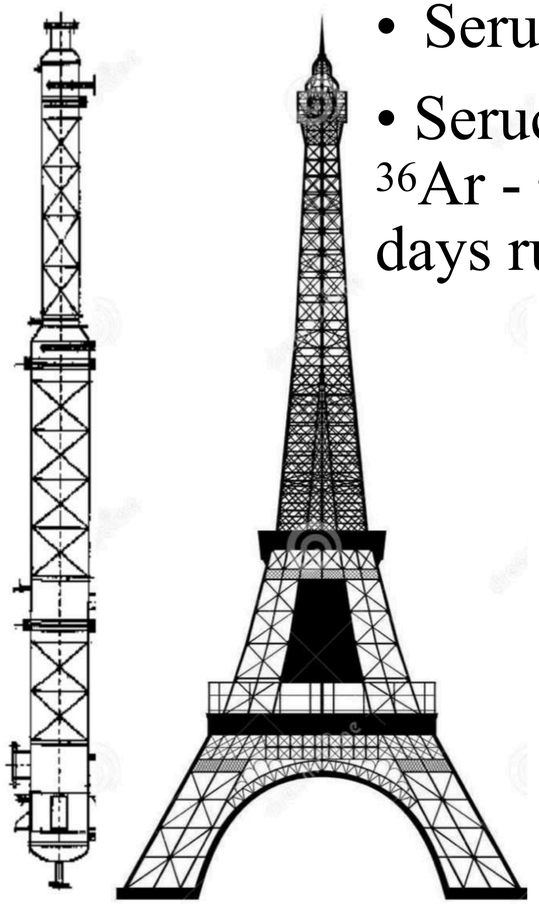


Phys.Lett.B 743 (2015) 456-466

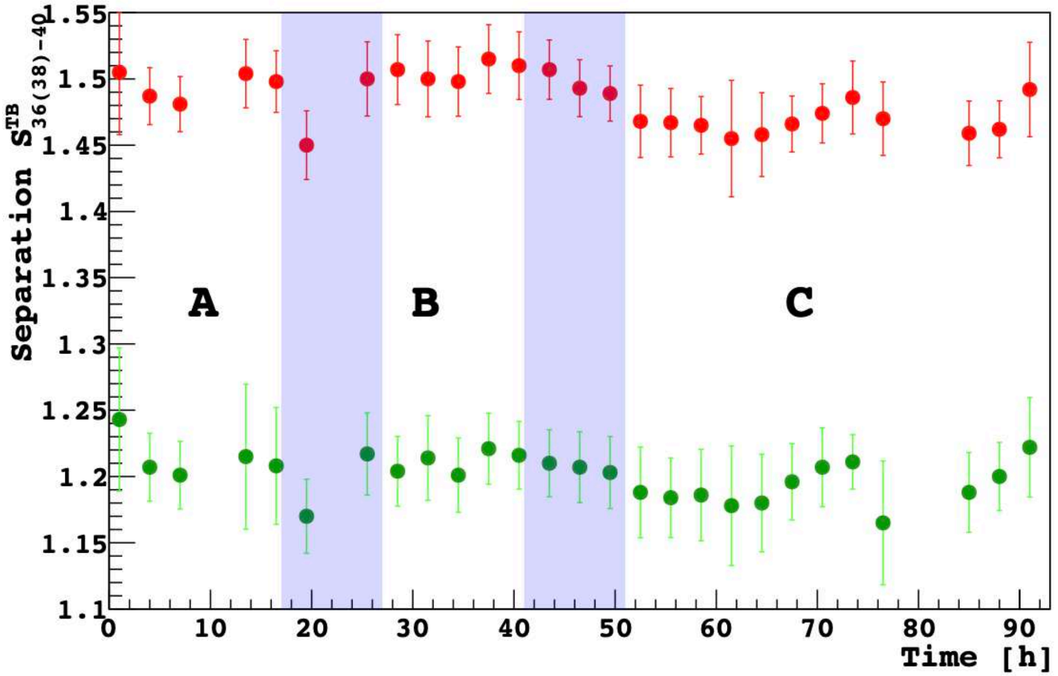




- Expected purity from URANIA: 99.9 %
- At least two more orders of magnitude needed for DarkSide-20k
- **Aria: argon cryogenic distillation plant**
- Seruci-1: 350 m tall distillation column
- Seruci-0: 26 m tall already demonstrated ^{36}Ar - ^{40}Ar separation performances in a few days run

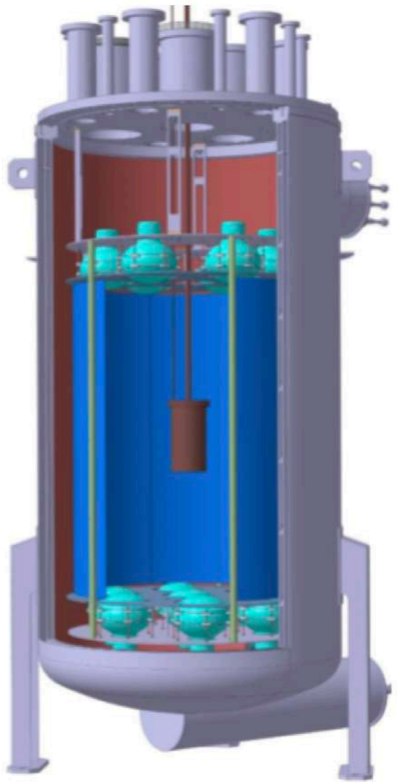


Eur. Phys. J.C 81 (2021) 4, 359



Eur. Phys. J.C 83 (2023) 5, 453

^{39}Ar essay in DArT with ArDM: small low-background detector located at Laboratorio Subterràneo de Canfranc (LSC, Spain), 1400 m.w.e undergound

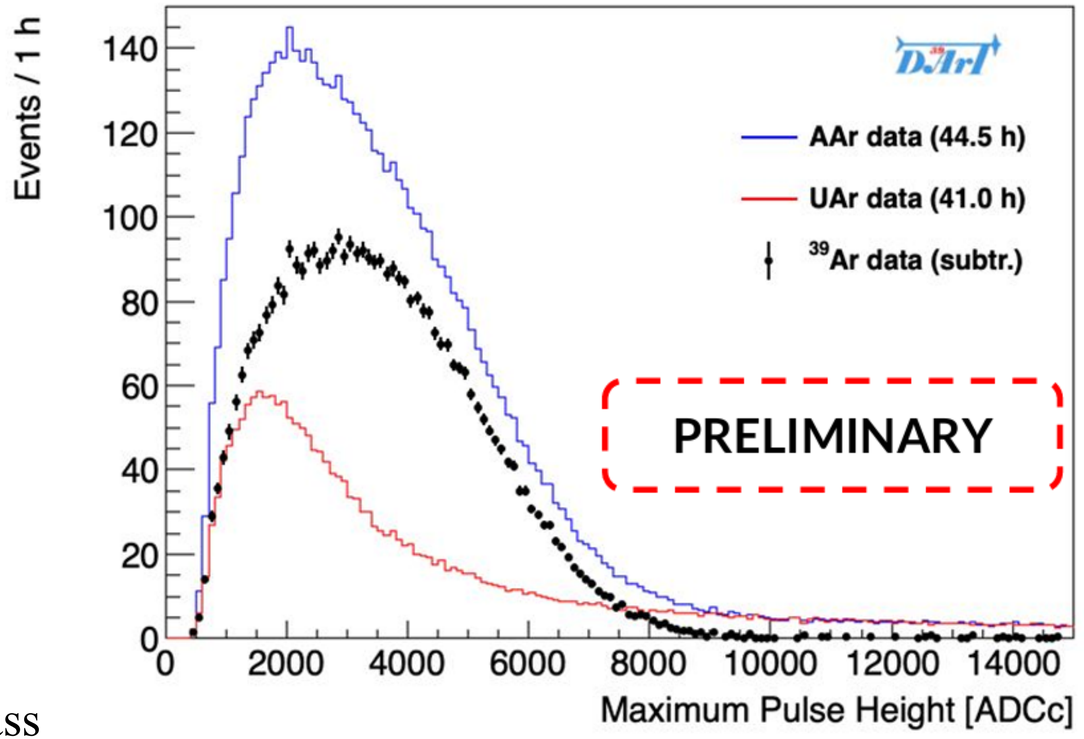


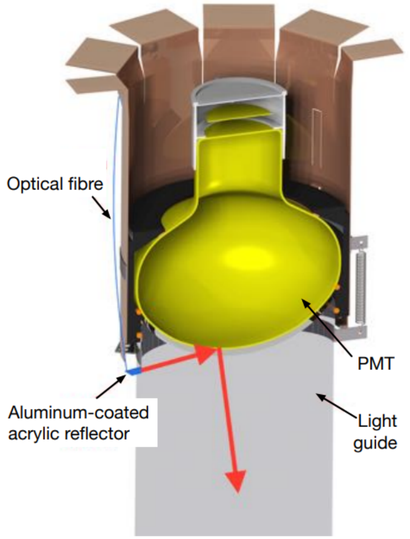
ArDM: 850 kg AAr

DArT: 1.35 kg active mass

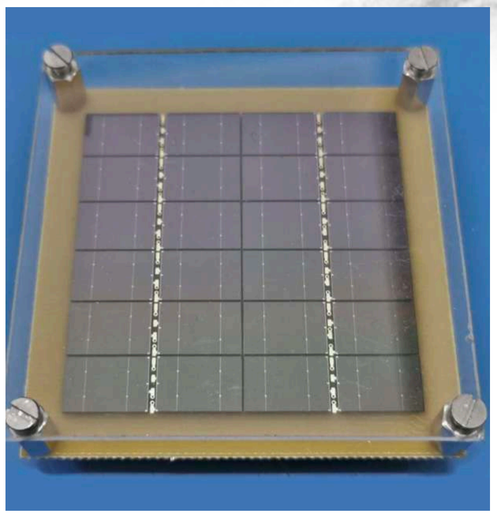
JINST 15 (2020) 02, C02044

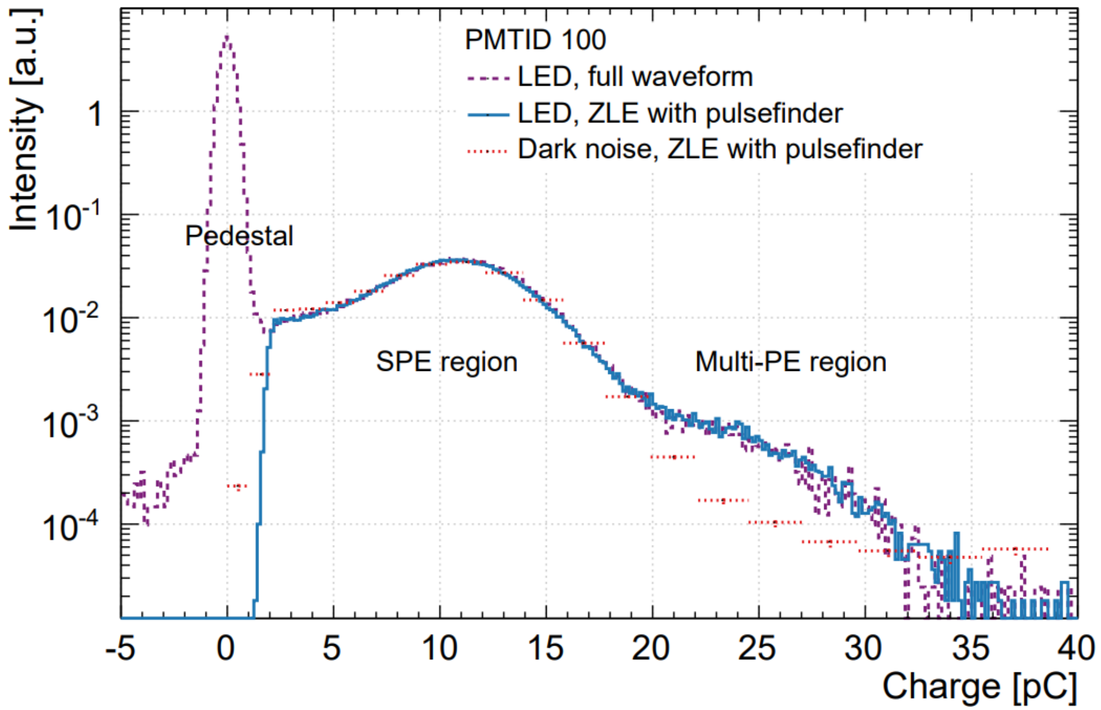
Credits:
D. Gahan - ICHEP 2024



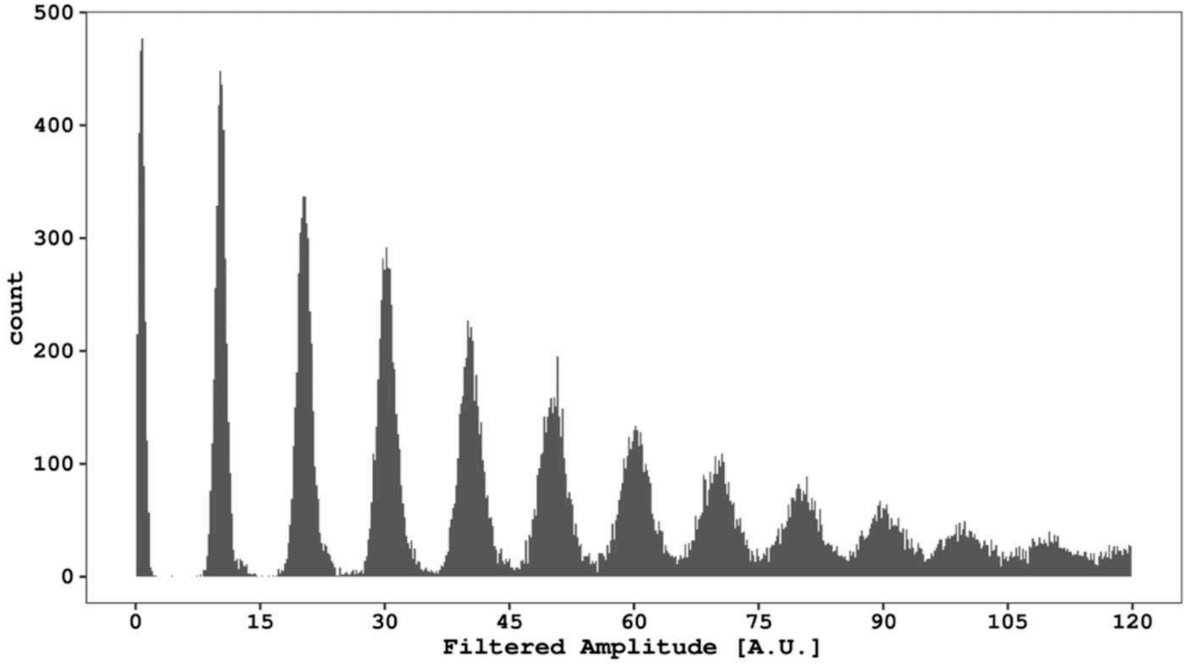


Photomultipliers tubes (PMTs) exchanged for Silicon Photomultipliers (SiPMs) customly developed by Fondazione Bruno Kessler



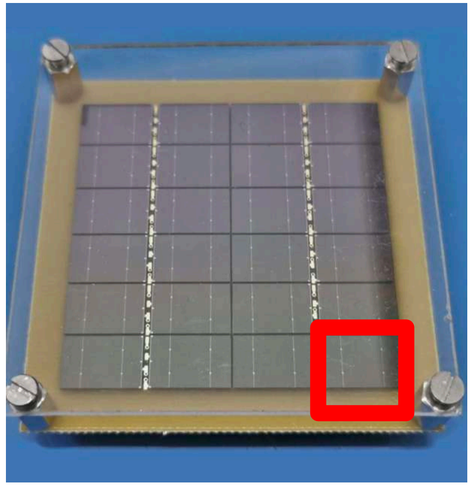


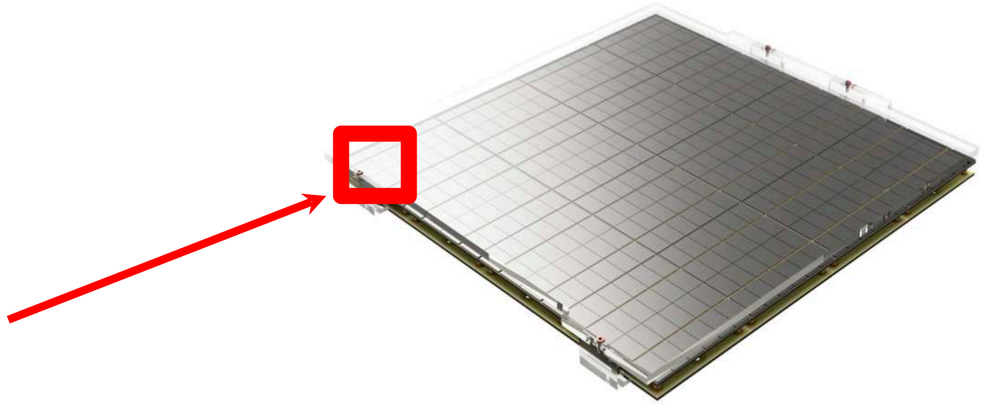
Nucl. Instr. Meth. A 922(2019) 373-384

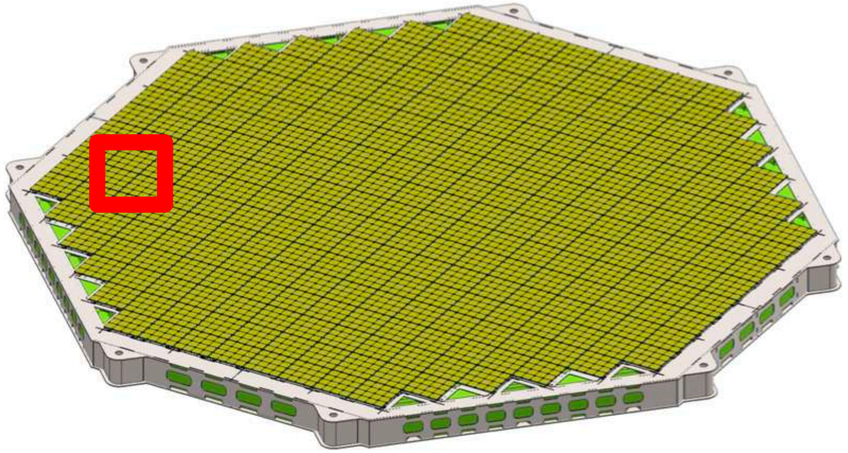


A. Gola et al. Sensors19(2), 308 (2019)

Photosensors have being tested in NOA facility, Italy, while the read-out is developed at TRIUMF





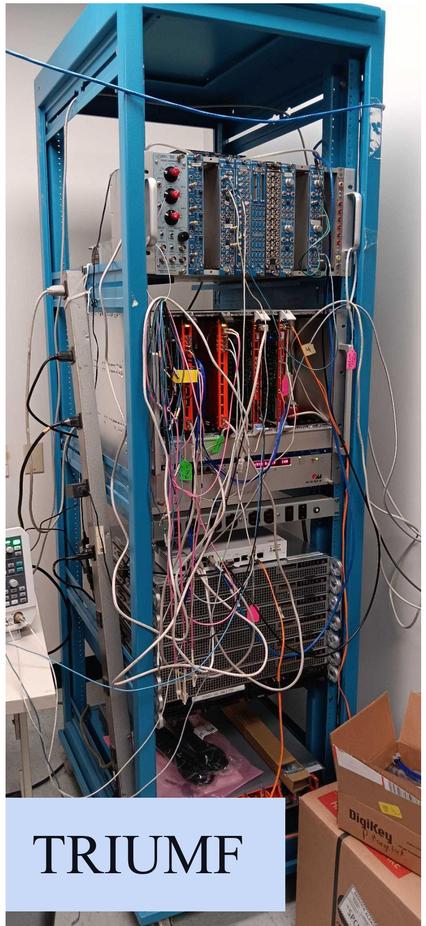


TPC: 525 PDU

IV: 20 vPDU

OV: 32 vPDU

NOA facility



TRIUMF