



The XENONnT Dark Matter experiment: results and prospects

1st BiCoQ Conference: from gravity to particles

Milan, 15–19 June 2026

Virginia Mazza
on behalf of the XENON Collaboration



XENON PROJECT

The **XENON** project aims at the **DIRECT DETECTION** of **DARK MATTER** with **Liquid Xenon** deep underground (1.4 km rock → $10^6 \mu$ reduction factor) at the INFN Laboratori Nazionali del Gran Sasso, Italy.

It is operational since 2020, with **5.9 t of LXe** inside the TPC.



200+ members
31 institutes
12 countries



Collaboration Meeting 2025 @LNGS

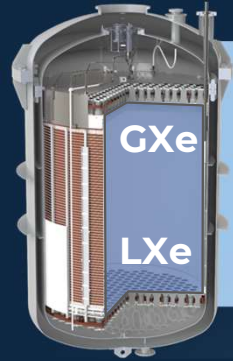


XENON_nT EXPERIMENT

3 NESTED DETECTORS INSIDE
700 t WATER TANK (WT)



XENONnT EXPERIMENT



DUAL-PHASE Xe TIME PROJECTION CHAMBER (TPC)

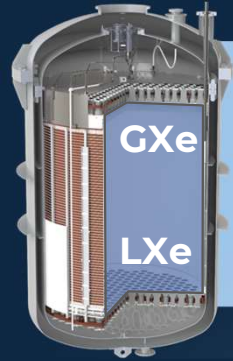
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- 494 3" PMTs
- RARE-EVENTS searches via NUCLEAR/ELECTRONIC RECOILS (NR, ER)

[Eur.Phys.J.C 84 \(2024\) 8, 784](#)

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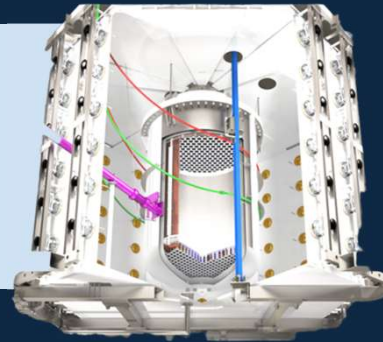
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Gd-WATER CHERENKOV NEUTRON VETO (NV)

- 33 m³ around cryostat, \varnothing 2 m x h 3 m
- 120 8" PMTs
- RADIOGENIC NEUTRONS from materials

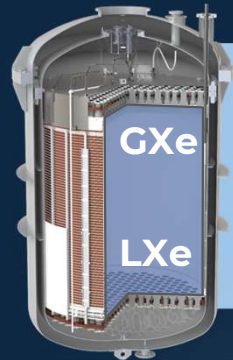
[Eur.Phys.J.C 85 \(2025\) 6, 695](#)



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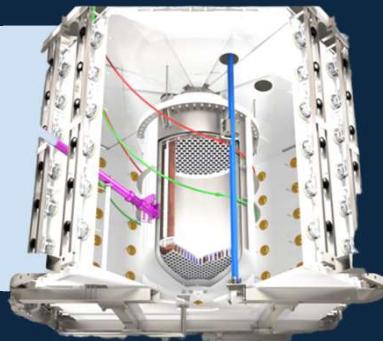
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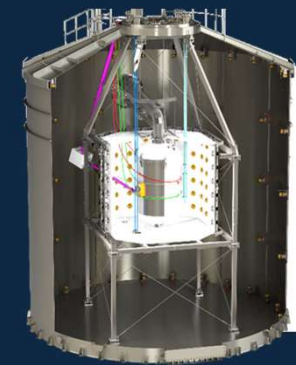
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Gd-WATER CHERENKOV MUON VETO (MV)

- 700 t water, \varnothing 10 m x h 10 m
- 84 8" PMTs
- MUON-induced NEUTRONS (active veto), γ and neutrons from natural RADIOACTIVITY (passive shield)

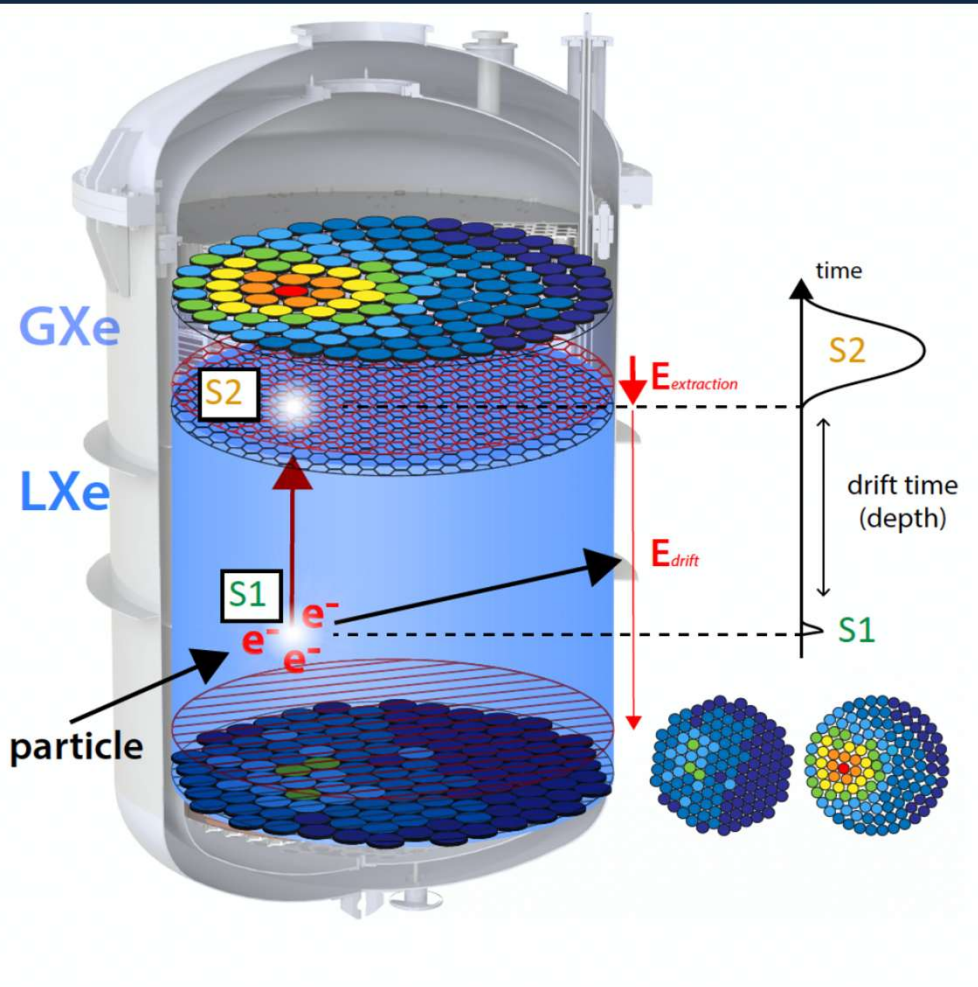
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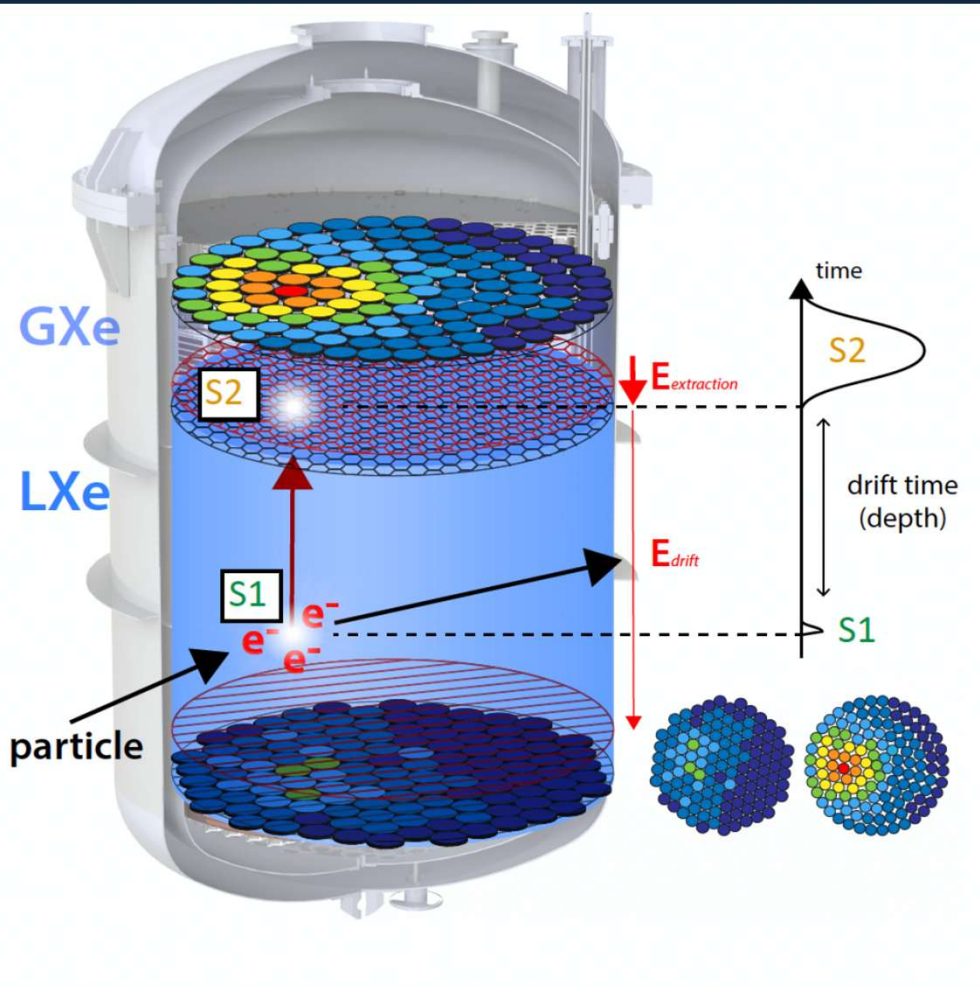
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LXe TPC DETECTION PRINCIPLE

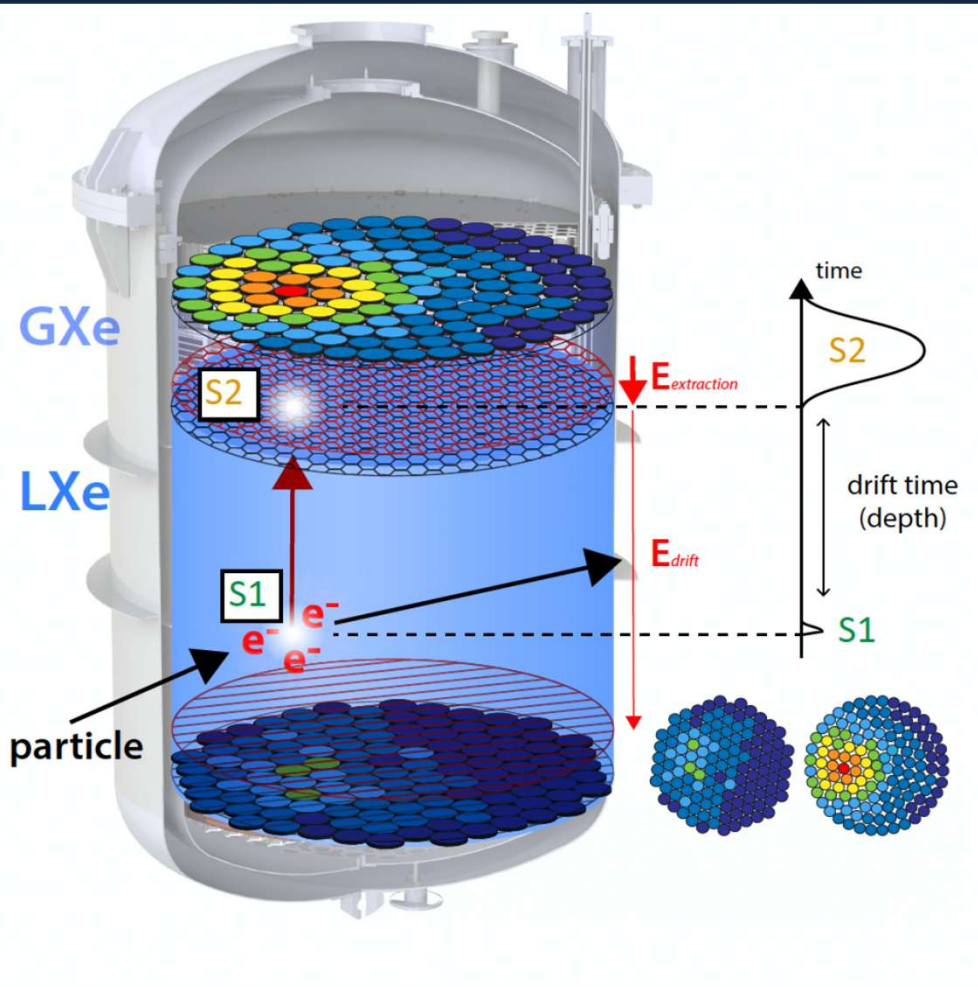


LXe TPC DETECTION PRINCIPLE



- READOUT of SCINTILLATION AND IONIZATION signals
S1: prompt scintillation signal in LXe (LIGHT)
S2: secondary light from drifted e⁻ in GXe (CHARGE)

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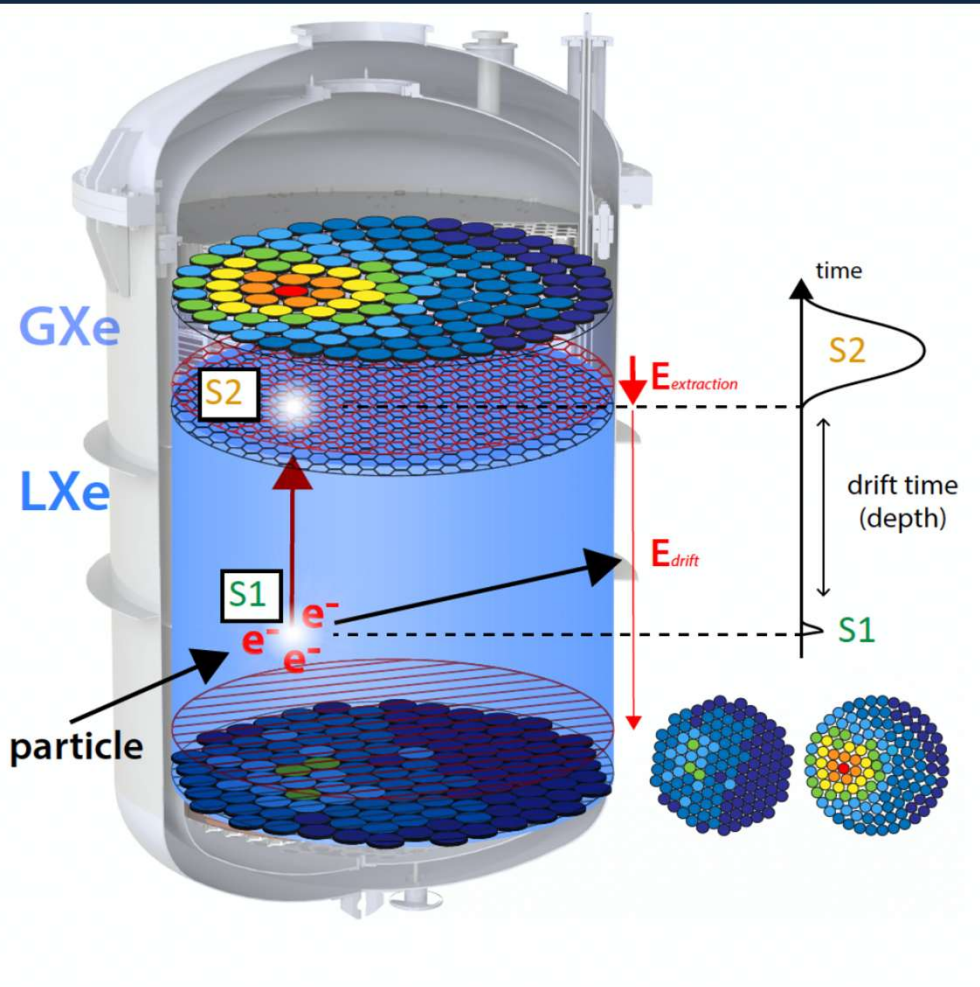


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3D POSITION: x-y (PMTs light pattern)
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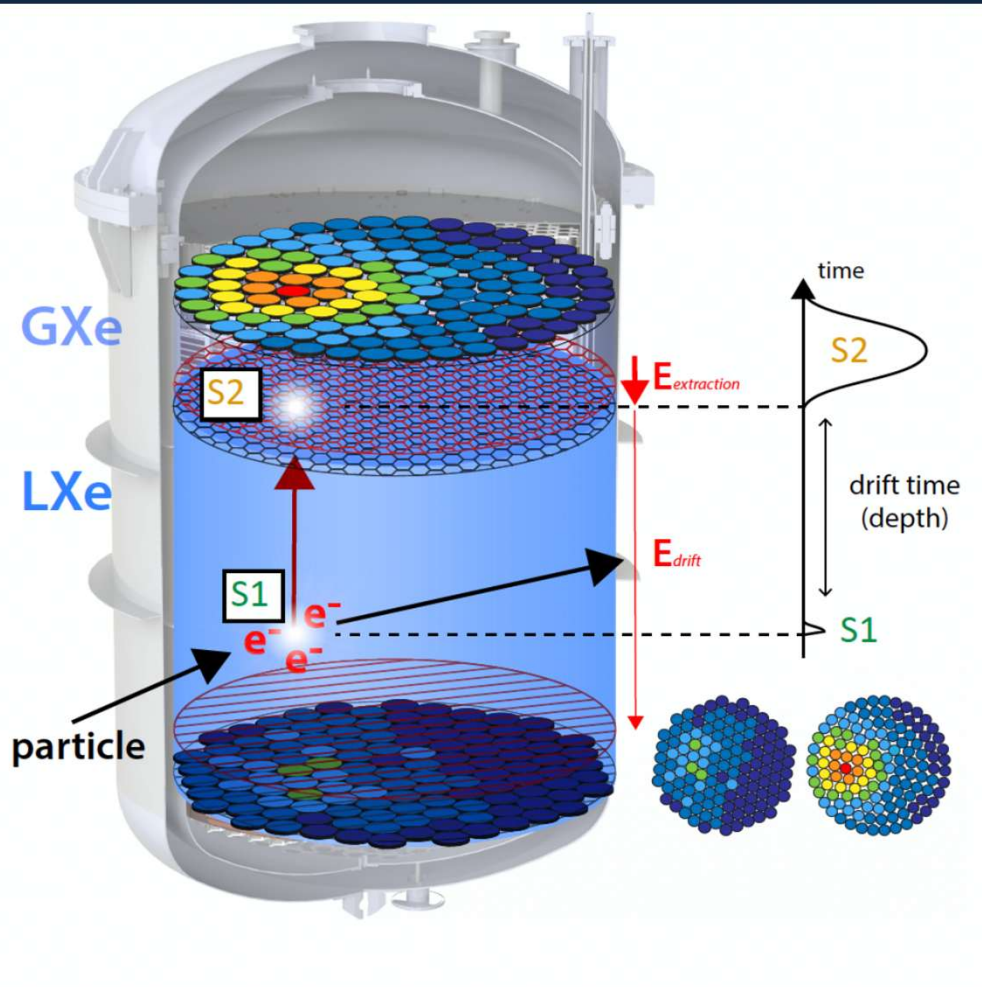
ENERGY: $E_{dep} = \frac{W(n_\gamma + n_e)}{L}$ $W = \text{average energy to produce a quanta}$
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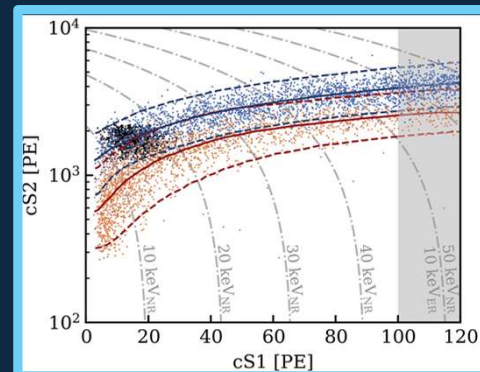


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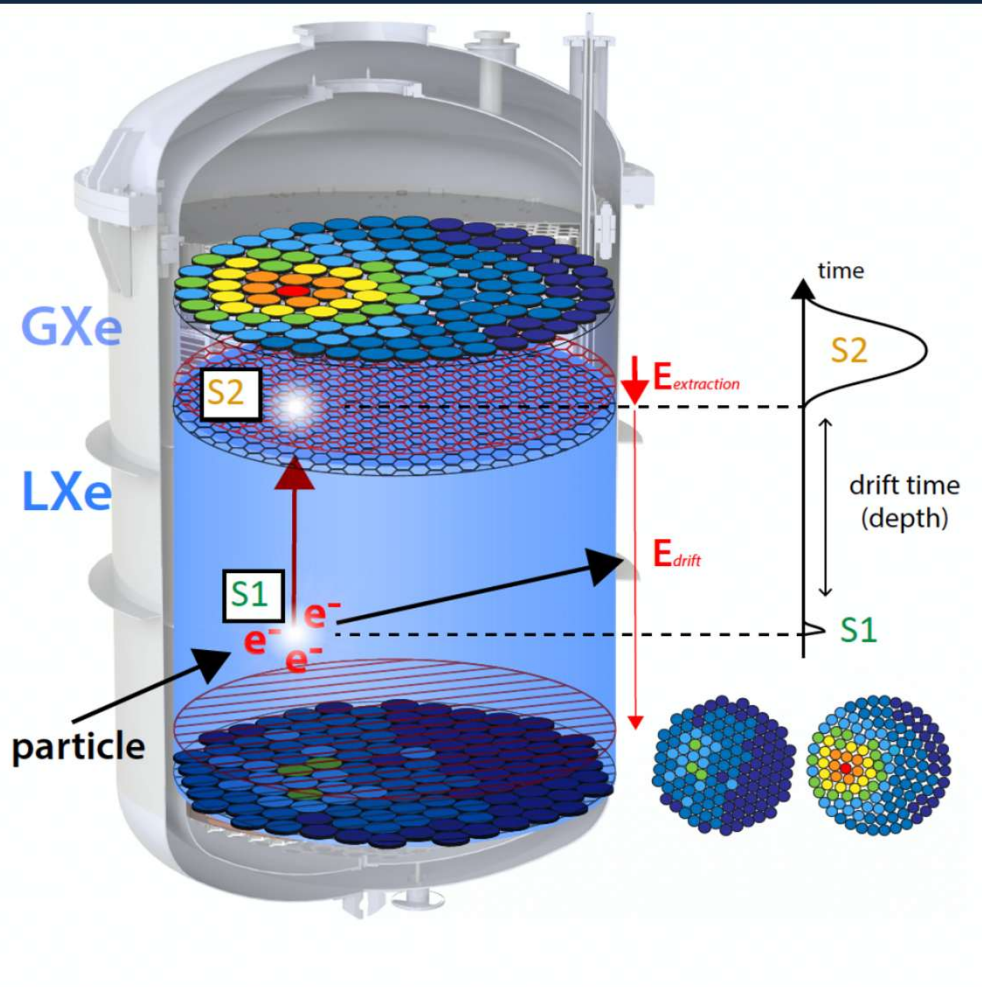
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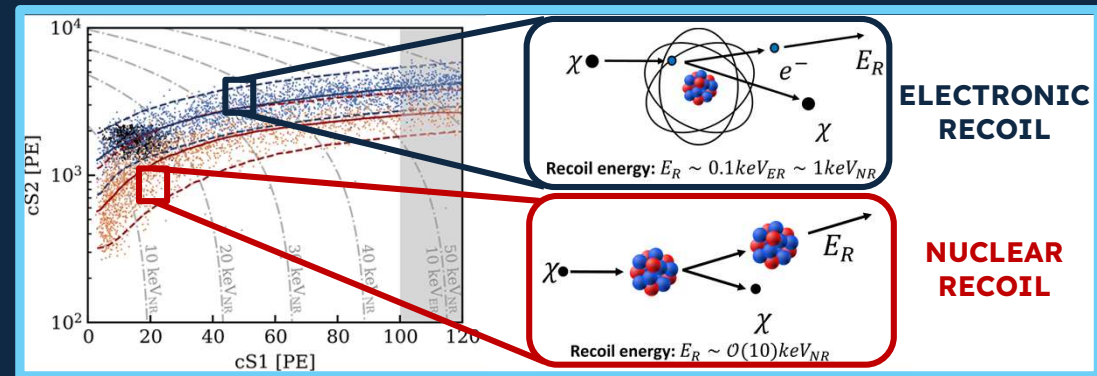
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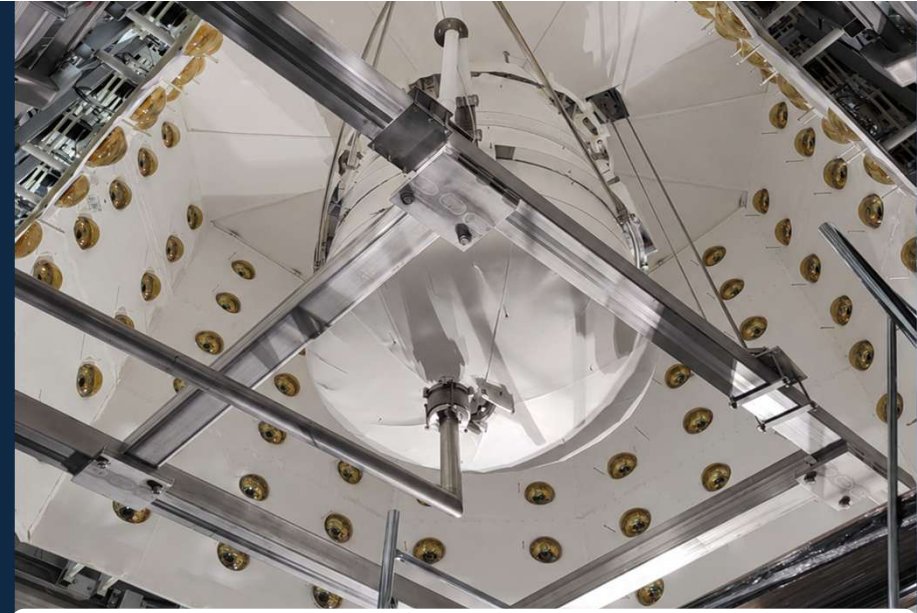
XENON_nT NEUTRON VETO

MAIN GOAL

TAGGING RADIOGENIC NEUTRONS that induce single scatter **NUCLEAR RECOILS (NR)** in TPC (like **WIMPs**)

DETECTOR DESIGN

- **Gd-loaded water Cherenkov detector**
- **120 PMTs** at 1 m from cryostat
- Optically separated from the MV with highly reflective ePTFE panels ($V=33 \text{ m}^3$)
- **LED** and **LASER** systems for PMT gain and optical properties monitor



NV design, construction and run coordinated by INFN groups 

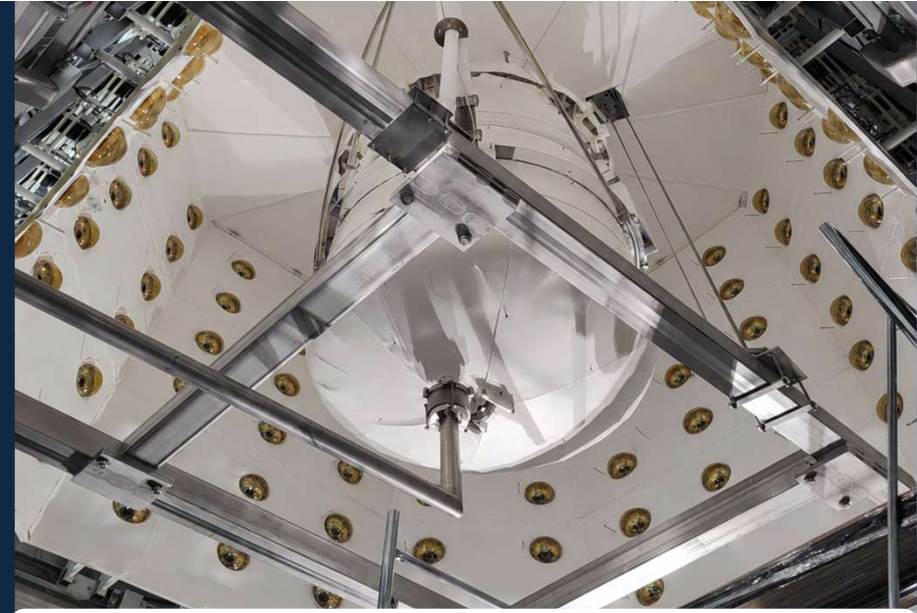
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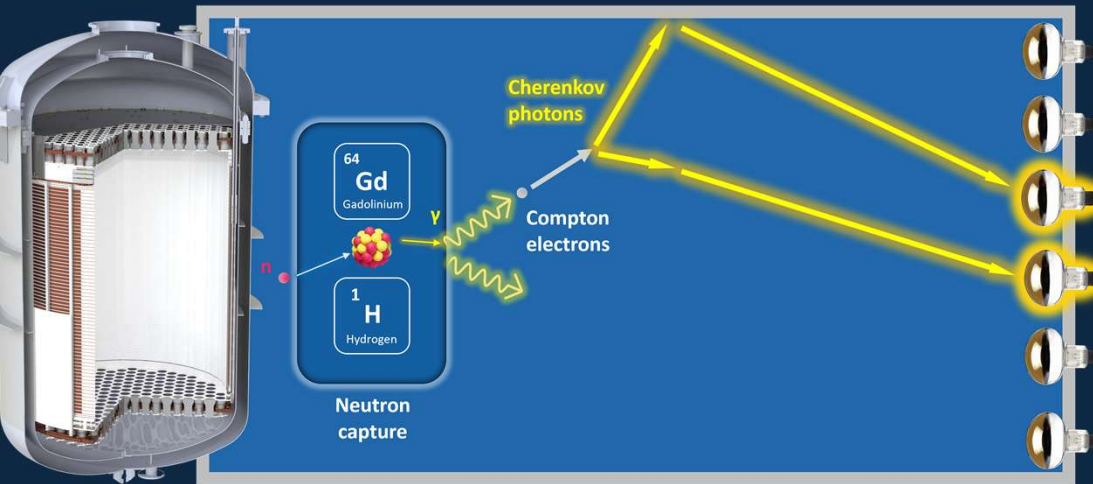
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It operates **thermalizing and capturing bkg n_s** : when a n is captured, it releases γ_s that produce Cherenkov radiation which is then detected by NV PMTs.

	Neutron capture cross section	Gamma Energy	Mean capture time
H	0.33 b	Single, 2.2 MeV	200 us
Gd	49000 b	3-4 gammas, 8 MeV in total	75 us

WORKING PRINCIPLE

XENONnT NEUTRON VETO

The **neutron tagging efficiency** quantifies the **fraction of dangerous neutron signals in the TPC** that are **tagged by the NV**.

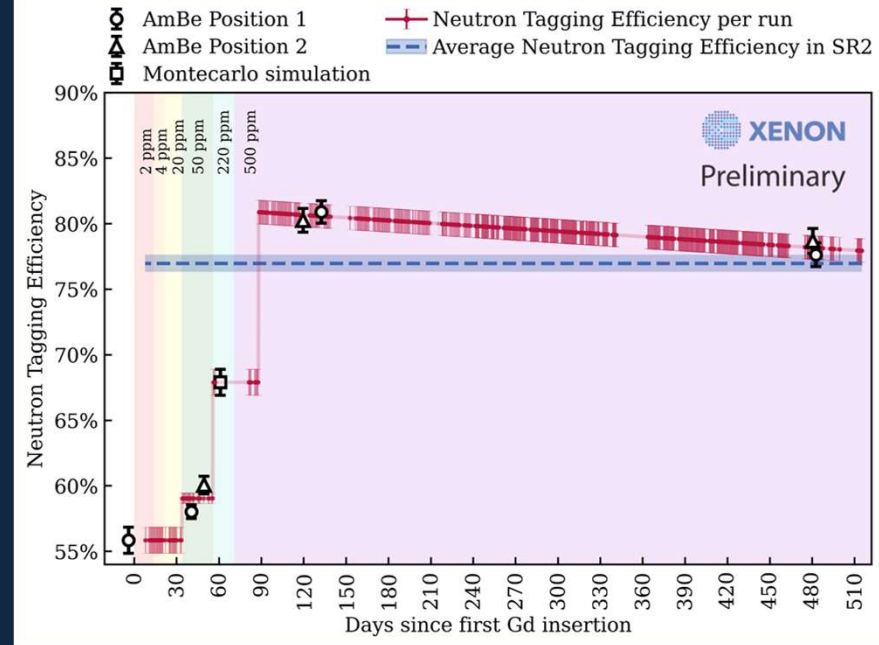
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Gadolinium Sulfate Octahydrate ($Gd_2(SO_4)_3 \cdot 8H_2O$, GdSO) injected into WT at beginning of SR2 (Oct-Dec 2023). Reached **0.02% uniform Gd mass concentration** with 350 kg of GdSO (500 ppm Gd-sulfate) in Jan 2024.

**n-TAGGING
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SR1	50 ppm	500 ppm (early SR2)	500 ppm (late SR2)
55%	59%	81%	78%



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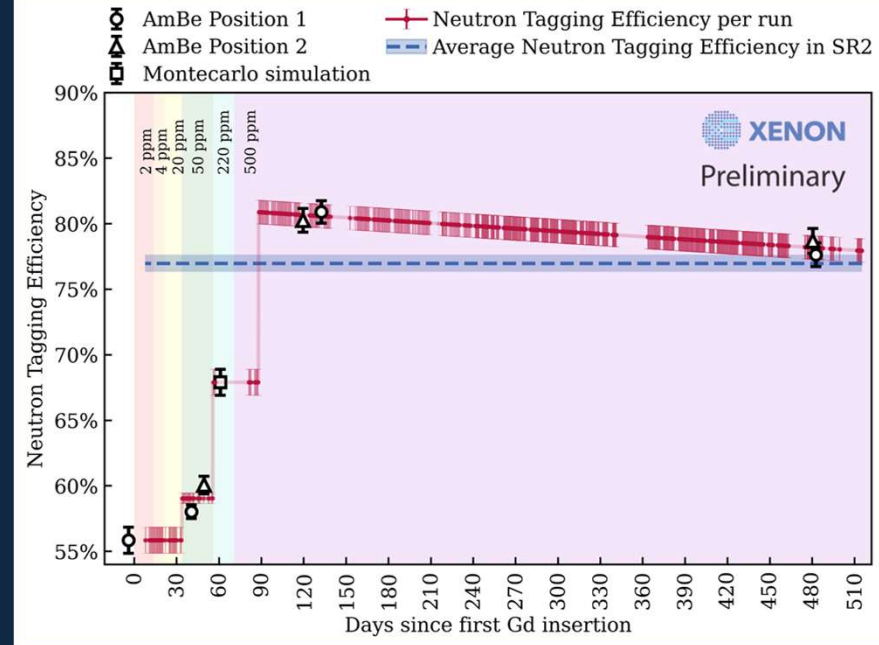
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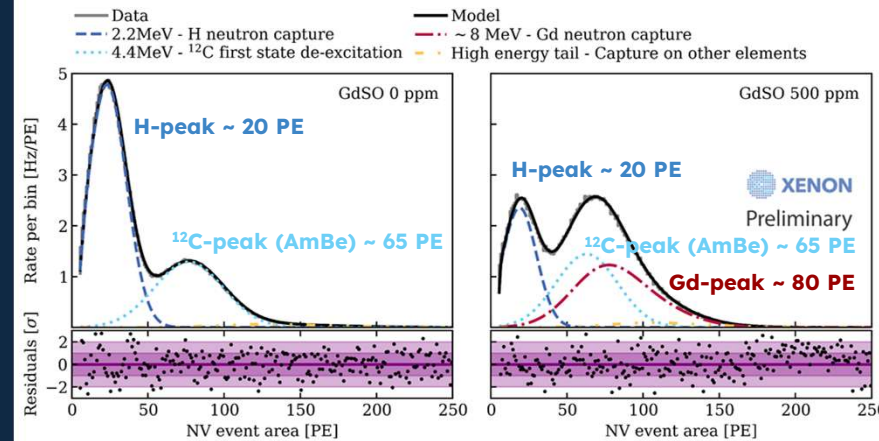
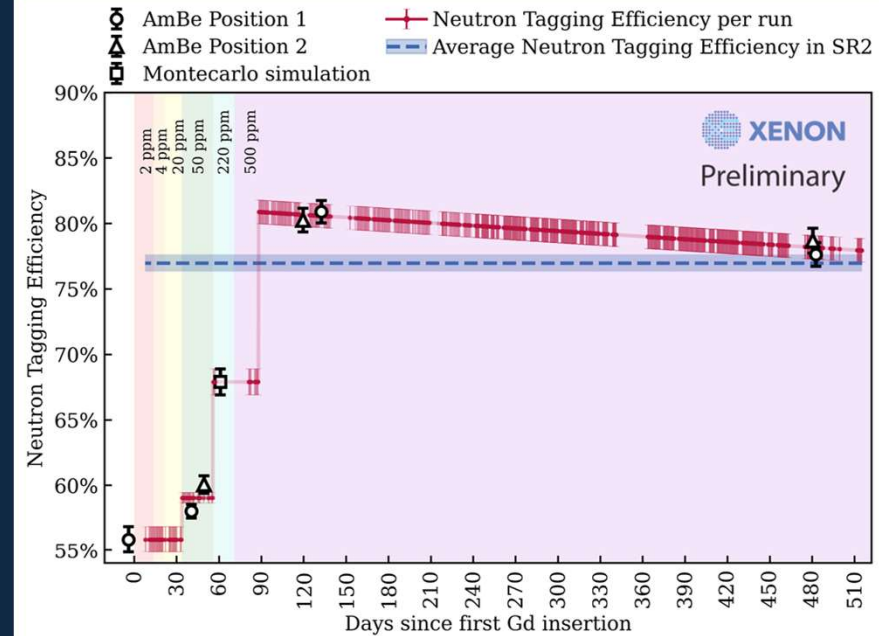
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With **NV EVENT AREA ≥ 5 PE** and **TIME WINDOW = 250 μ s**, the **n-tagging efficiency** sensibly **increases** and the **neutron background** is **reduced by a factor 2.**



XENONnT REGION OF INTEREST

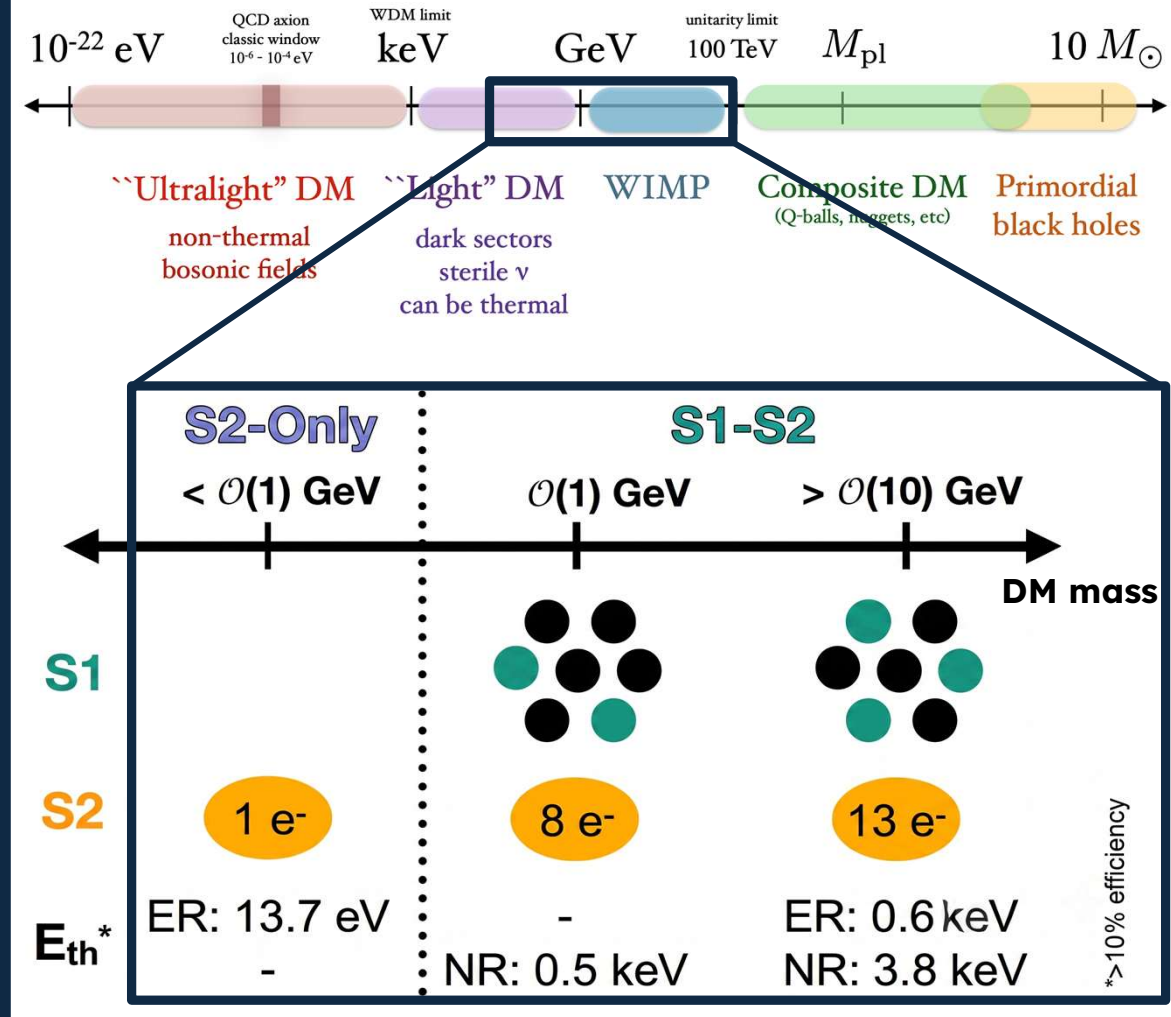
DM SEARCH

3-FOLD S1-S2 Standard WIMP search:
stay tuned for upcoming results!

2-FOLD S1-S2 Light WIMP & ^8B CE ν NS

To probe lower DM mass need to lower E_{thr} \rightarrow charge signal only

S2-only Light WIMP & Sub-GeV DM



XENONnT SCIENCE DATA

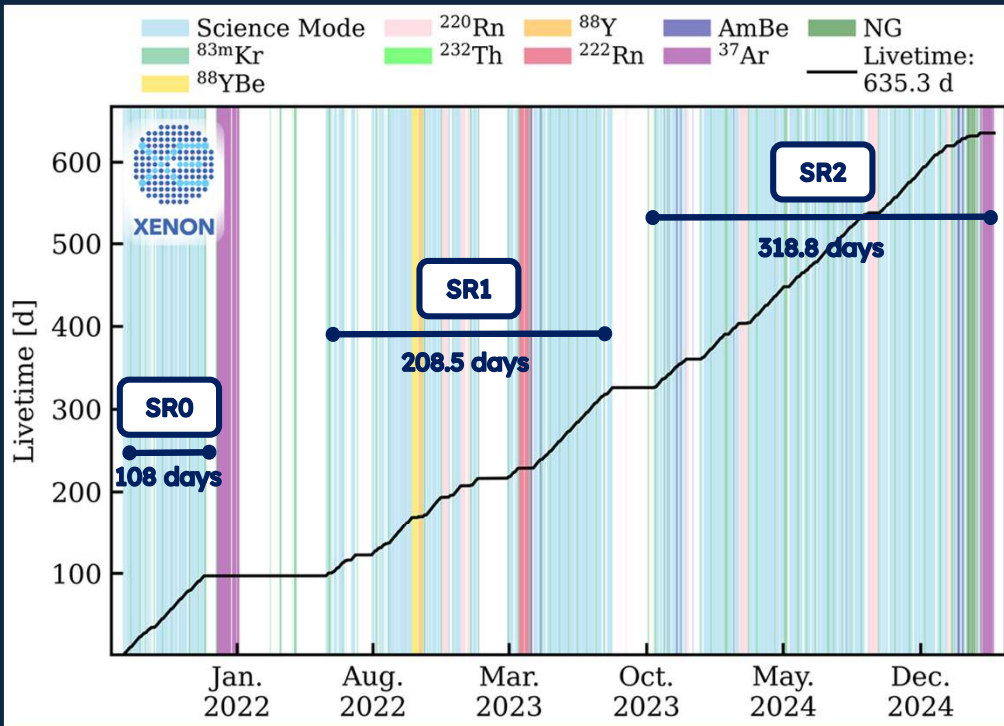
FIDUCIAL MASS:
≈4 tonnes

EXPOSURE:
≈7 tonnes × year

FROM SR0 TO SR1:
ONLINE Rn DISTILLATION
 ^{222}Rn : 1.9 → 0.9 uBq/kg

[Phys. Rev. X 15, 031079](#)

Reached **SOLAR pp ν**
bkg level (ER)



FROM SR1 TO SR2:

Gd-LOADED NV
n-tag eff: 55% → 81%

REDUCED n-bkg (NR)
compared to previous
science runs

FROM SR2 TO SR3:

**UPGRADED TPC with NEW
ELECTRODES:**
COMMISSIONING NOW !

Improved **ER/NR
DISCRIMINATION**
with higher drift field

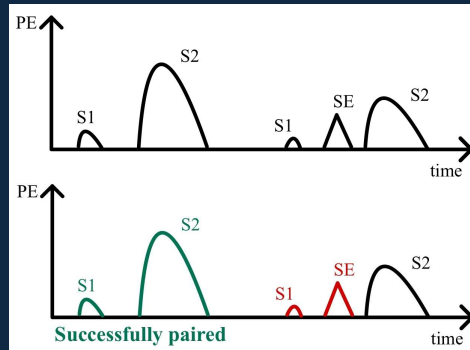
WIMP SEARCH: RECONSTRUCTION

PEAK RECONSTRUCTION

Dominated by 3-fold requirement for S1

EVENT BUILDING & SELECTION

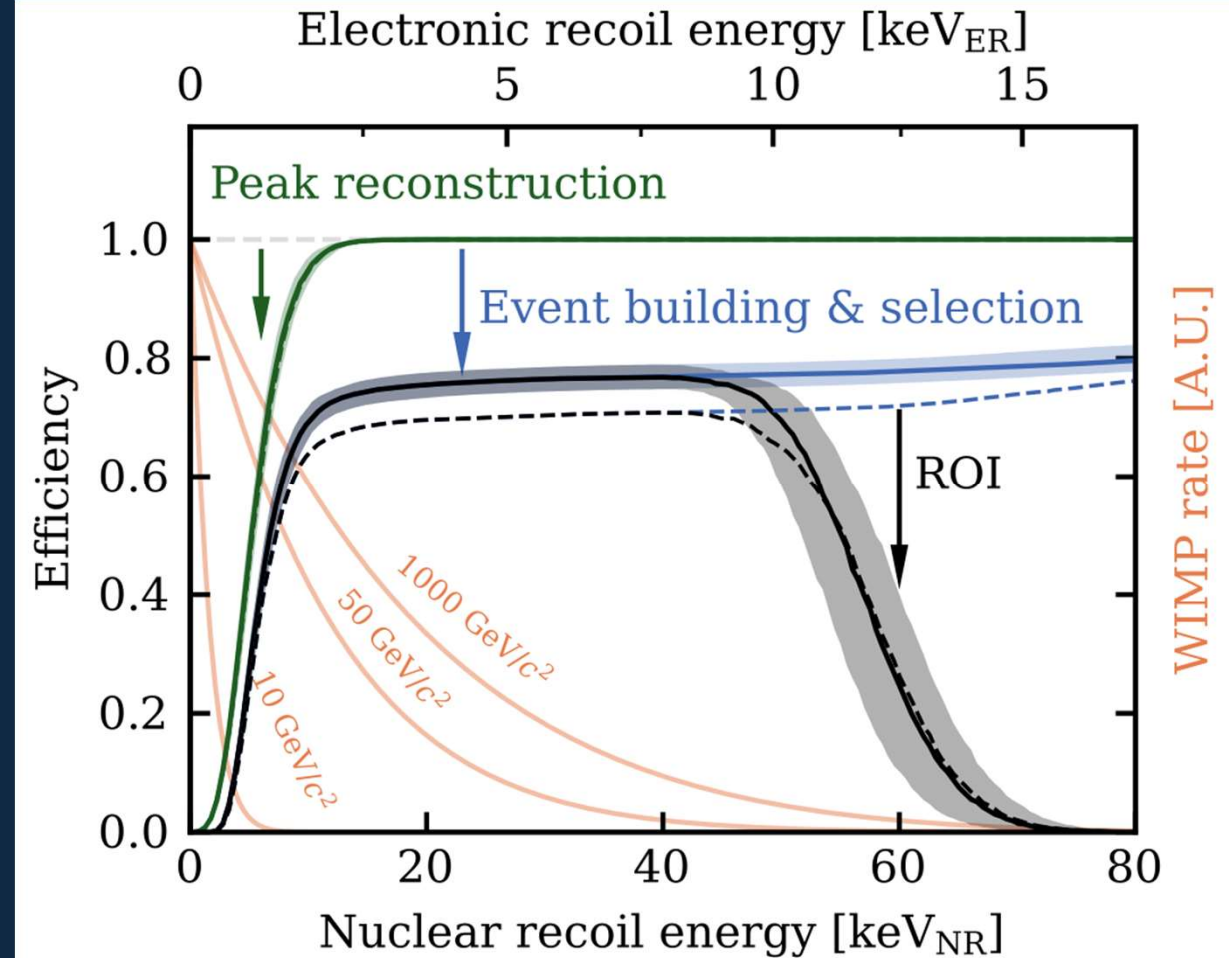
- Cuts (quality, selection, etc)
- Is the event successfully reconstructed



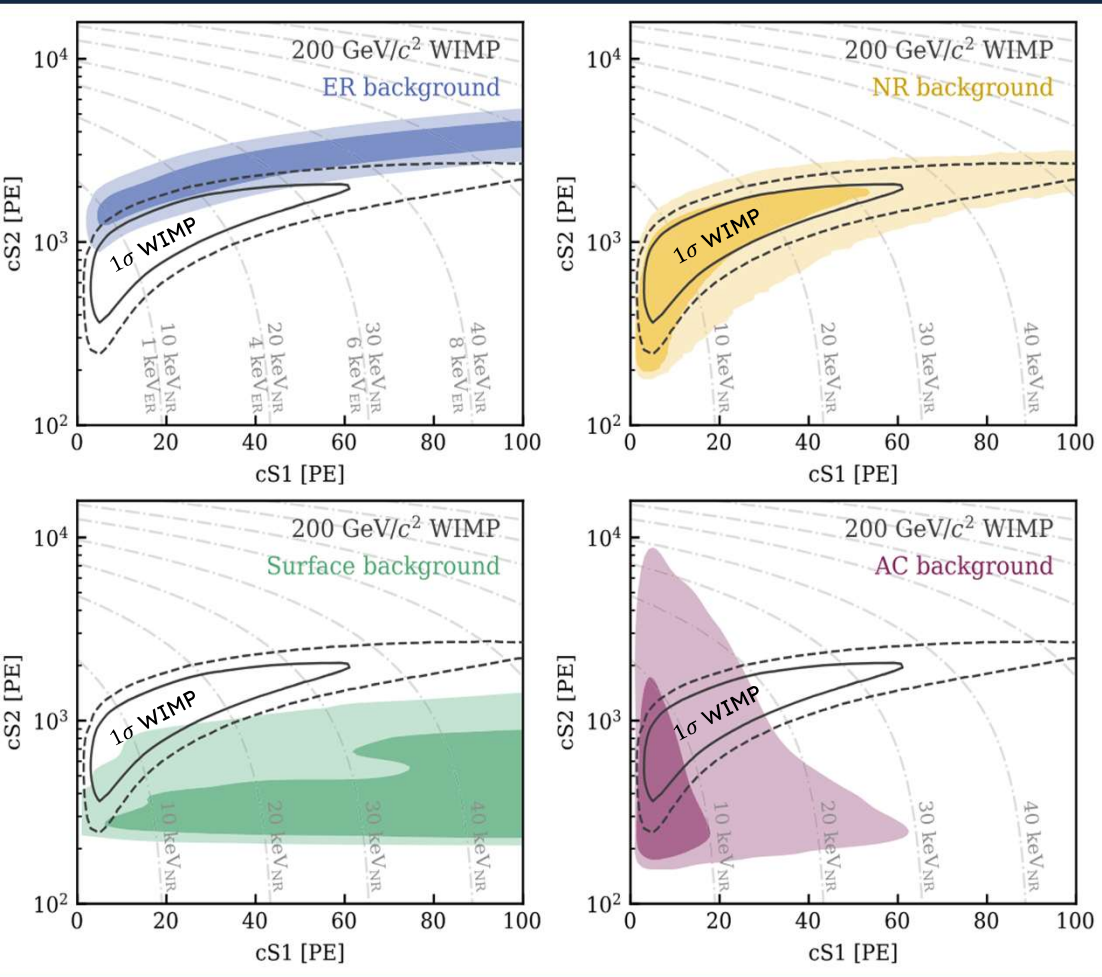
ROI

$cS1 \in [0, 100]$ PE and $cS2 \in [10^{2.1}, 10^{4.1}]$ PE

*($cS1/cS2 =$ corrected $S1/S2$)

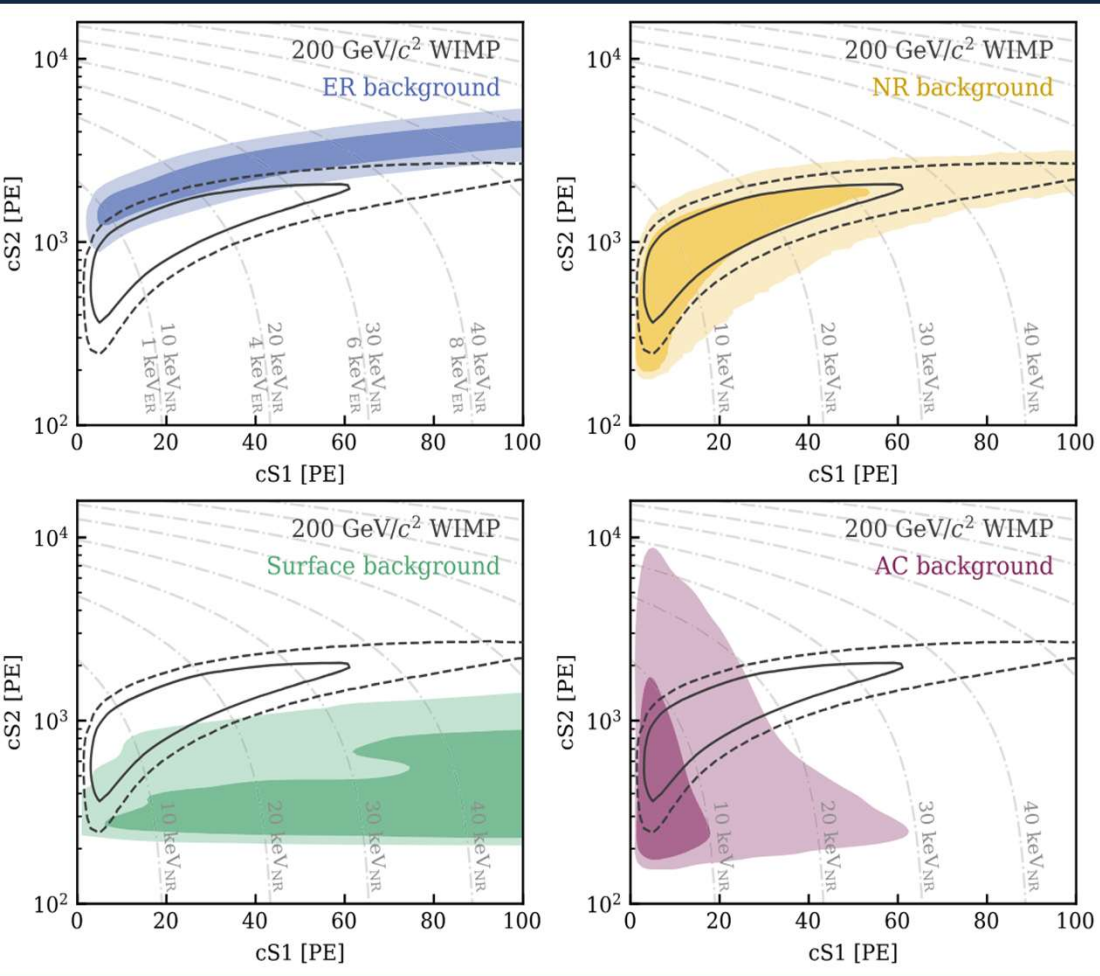


WIMP SEARCH: BACKGROUNDS



[Phys.Rev.D 111 \(2025\) 6, 062006](#)

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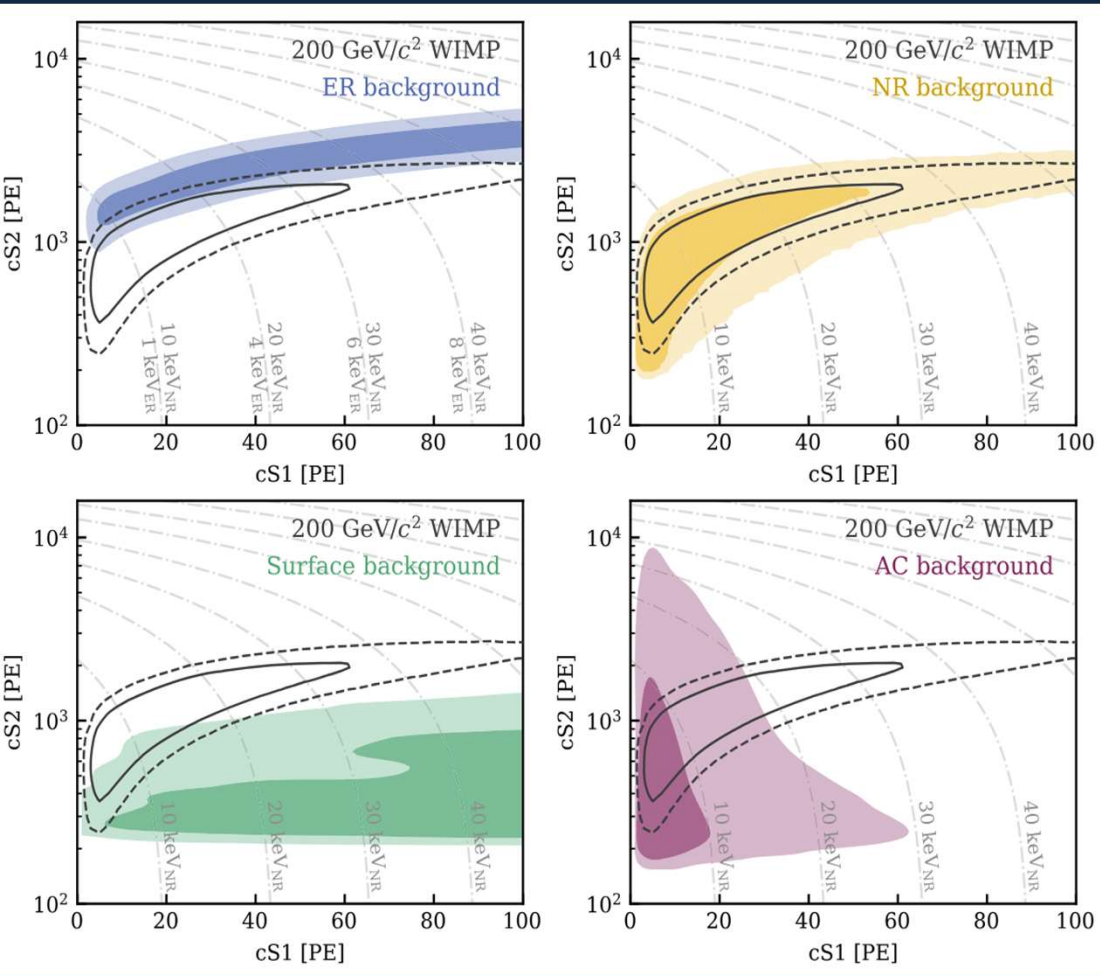
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ELECTRONIC RECOILS

- ^{214}Pb from ^{222}Rn
- ^{85}Kr β -decays
- ^{124}Xe Double Electron Captures (DEC)
- solar-pp $\nu - e$ elastic scattering

CALIBRATION: ^{220}Rn in [20, 140] keV_{ER}

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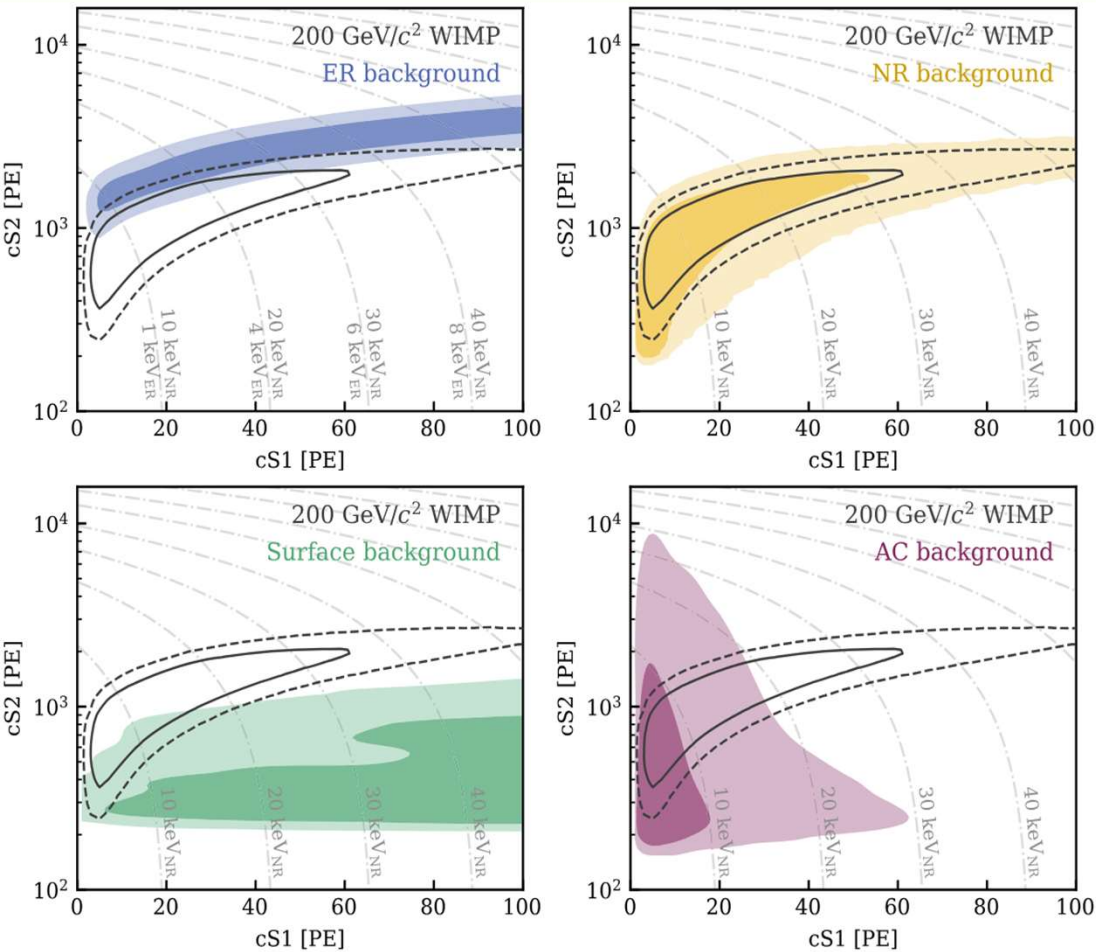
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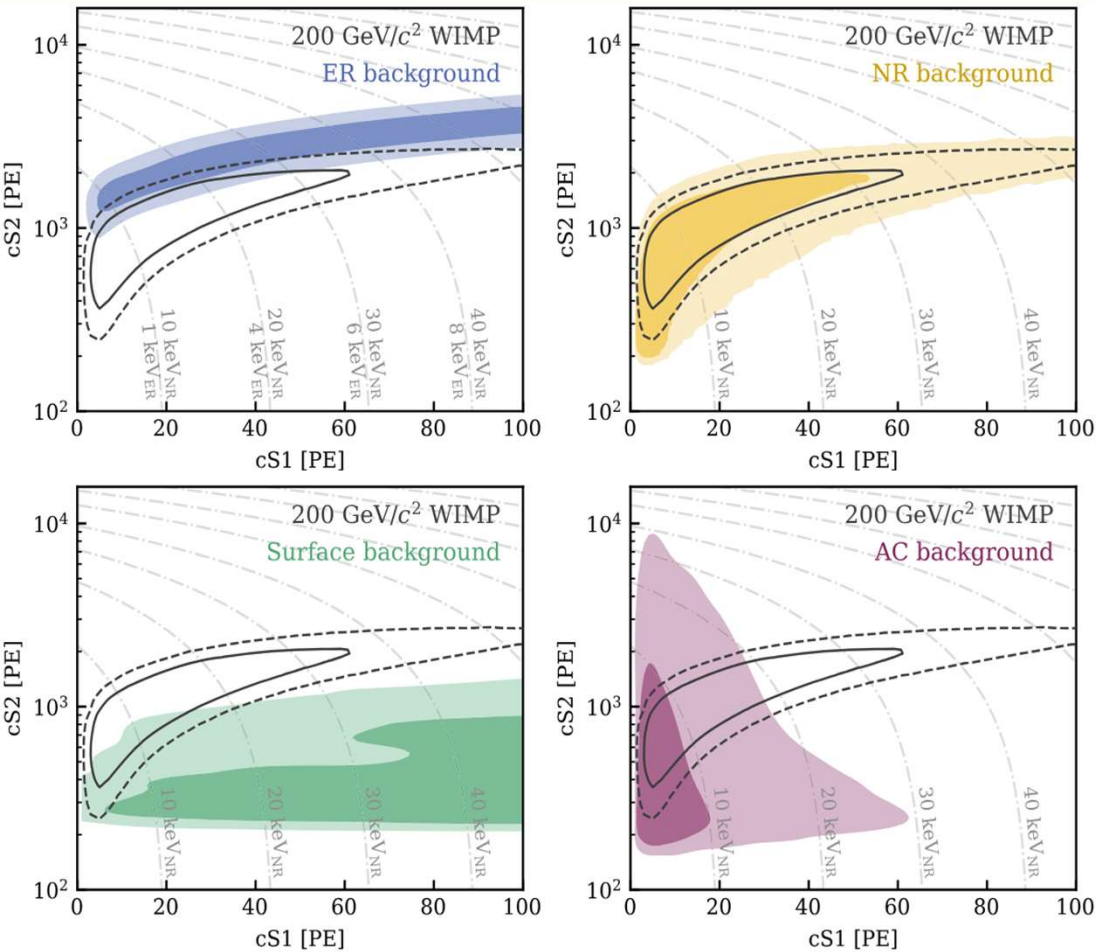
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SURFACE

- ^{210}Pb (^{226}Ra chain) from plate-out effect from PTFE walls

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ACs

- Accidental pairing of isolated S1-S2

Removed by dedicated machine-learning based cuts

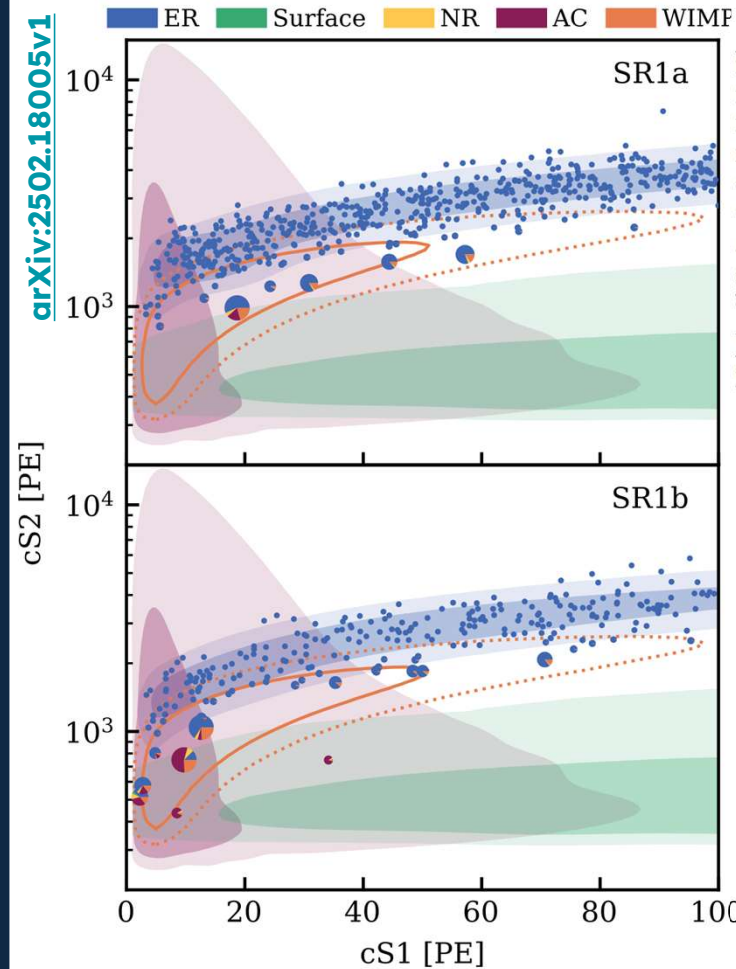
WIMP SEARCH: SR0+SR1 RESULTS

ANALYSIS

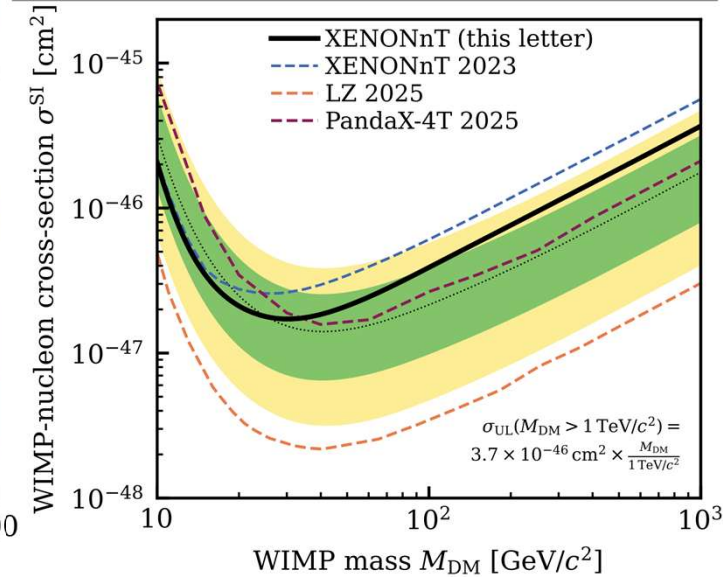
SR0: updated n-bkg model

SR1: blinded analysis

- SR1a: Higher ER rate from ^{85}Kr , ^{37}Ar , ^3H
- SR1b: Low ^{85}Kr , ^{37}Ar after cryogenic distillation BUT ^3H still present



	SR0		SR1a		SR1b	
	Nominal	Best fit	Nominal	Best fit	Nominal	Best fit
ER (flat)	134	136 ± 12	430 ± 30	450 ± 20	151 ± 11	154 ± 10
ER (^3H -like)	-	-	62	40 ± 30	101	80 $^{+18}_{-17}$
ER (^{37}Ar)	-	-	58 ± 6	55 ± 5	-	-
Neutron	0.7 ± 0.3	0.6 ± 0.3	0.47 ± 0.19	0.45 ± 0.19	0.7 ± 0.3	0.7 ± 0.3
CEνNS (solar)	0.16 ± 0.05	0.16 ± 0.05	0.010 ± 0.003	0.010 ± 0.003	0.019 ± 0.006	0.019 ± 0.006
CEνNS (atm.+DSNB)	0.04 ± 0.02	0.04 ± 0.02	0.024 ± 0.012	0.024 ± 0.012	0.05 ± 0.02	0.05 ± 0.02
AC	4.3 ± 0.9	4.4 $^{+0.9}_{-0.8}$	2.12 ± 0.18	2.10 ± 0.18	3.8 ± 0.3	3.8 ± 0.3
Surface	13 ± 3	11 ± 2	0.43 ± 0.05	0.42 ± 0.05	0.77 ± 0.09	0.76 ± 0.09
Total background	152	152 ± 12	553	550 ± 20	257	239 ± 15
WIMP (200 GeV/c ²)	-	1.8	-	1.1	-	2.1
Observed	152		560		245	



WIMP SEARCH: SR0+SR1 RESULTS

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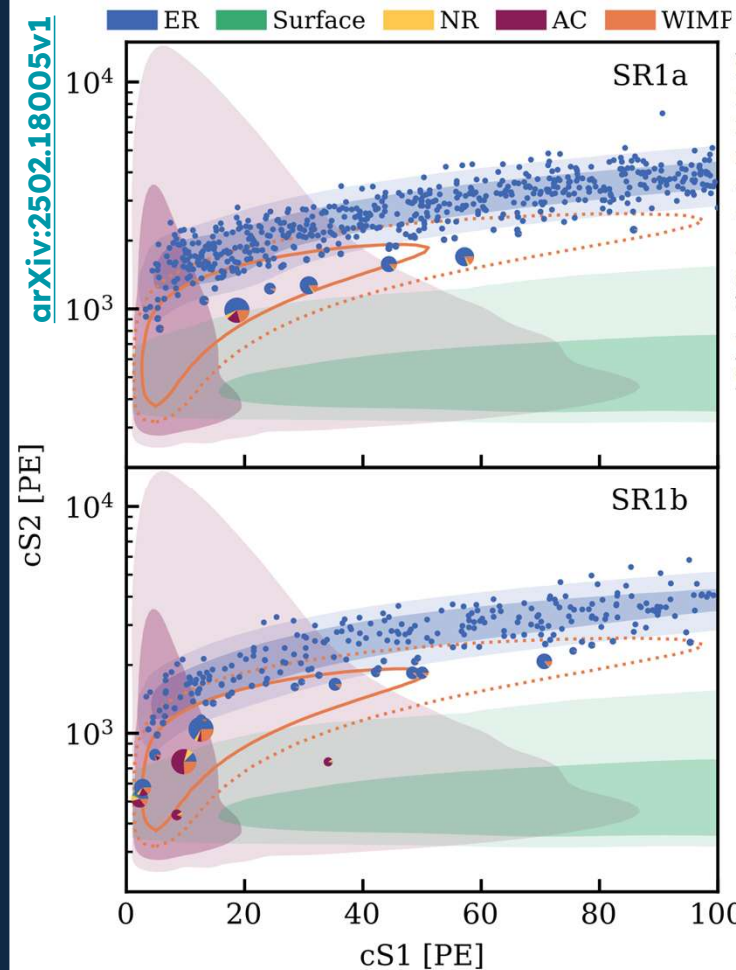
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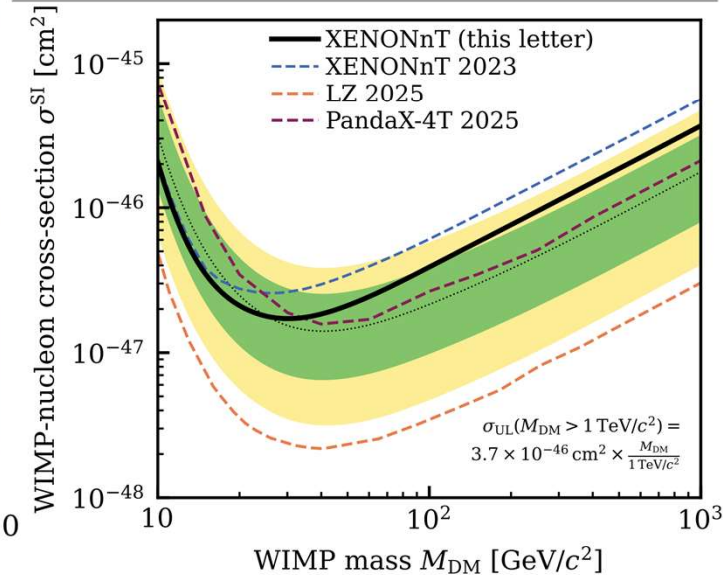
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RESULTS

- **NO WIMP EXCESS** over bkg
- New limits on WIMP-nucleon cross section: $1.7 \times 10^{-47} \text{ cm}^2$ @ **30 GeV/c²** (1.8x improvement wrt SR0)



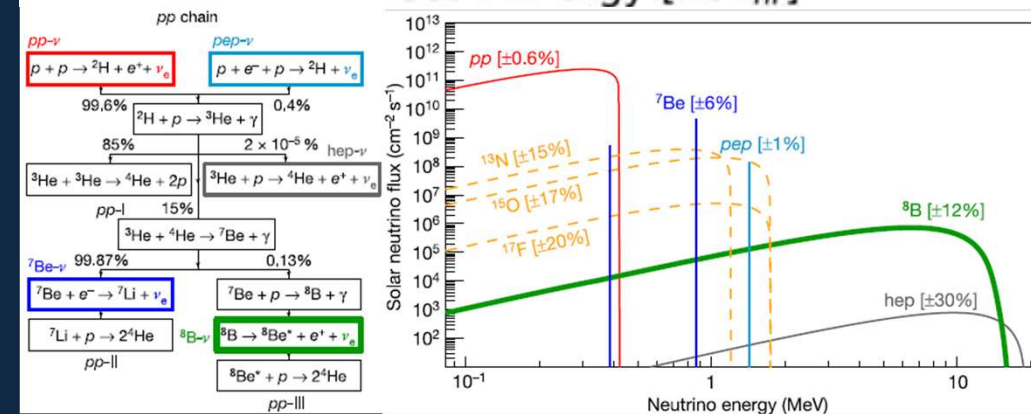
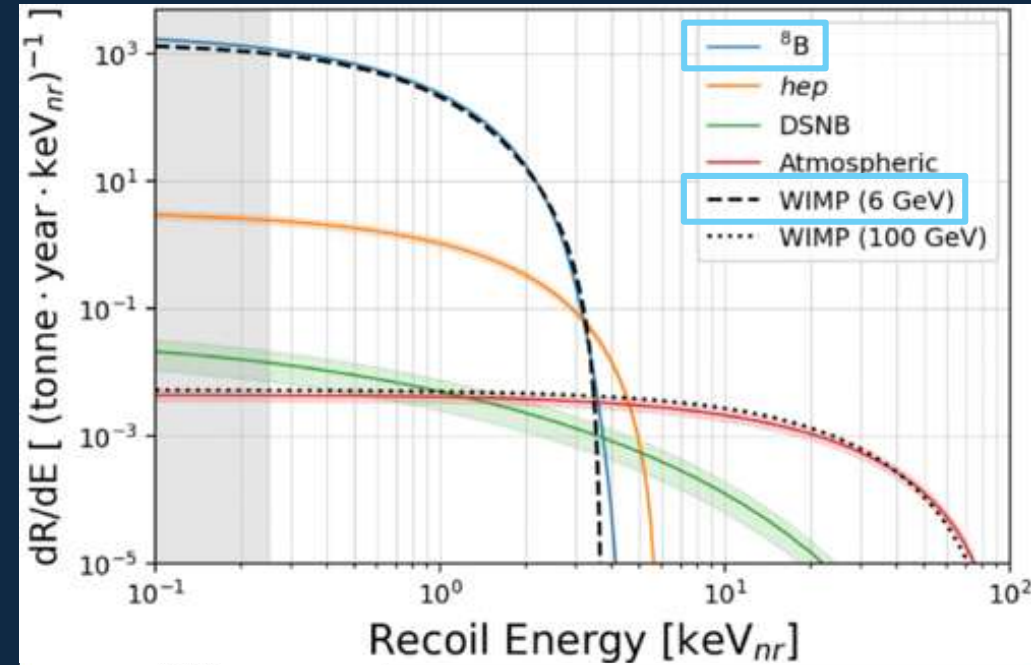
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Neutron	0.7 ± 0.3	0.6 ± 0.3	0.47 ± 0.19	0.45 ± 0.19	0.7 ± 0.3	0.7 ± 0.3
CEνNS (solar)	0.16 ± 0.05	0.16 ± 0.05	0.010 ± 0.003	0.010 ± 0.003	0.019 ± 0.006	0.019 ± 0.006
CEνNS (atm.+DSNB)	0.04 ± 0.02	0.04 ± 0.02	0.024 ± 0.012	0.024 ± 0.012	0.05 ± 0.02	0.05 ± 0.02
AC	4.3 ± 0.9	4.4 $^{+0.9}_{-0.8}$	2.12 ± 0.18	2.10 ± 0.18	3.8 ± 0.3	3.8 ± 0.3
Surface	13 ± 3	11 ± 2	0.43 ± 0.05	0.42 ± 0.05	0.77 ± 0.09	0.76 ± 0.09
Total background	152	152 ± 12	553	550 ± 20	257	239 ± 15
WIMP (200 GeV/c ²)	-	1.8	-	1.1	-	2.1
Observed	152		560		245	



^8B SEARCH: SPECTRA

The ^8B spectrum is (almost) identical to the one of 6 GeV/ c^2 WIMPs.

Phys.Rev.D 108 (2023) 2, 022007, [2304.06142]



^8B SEARCH: SPECTRA

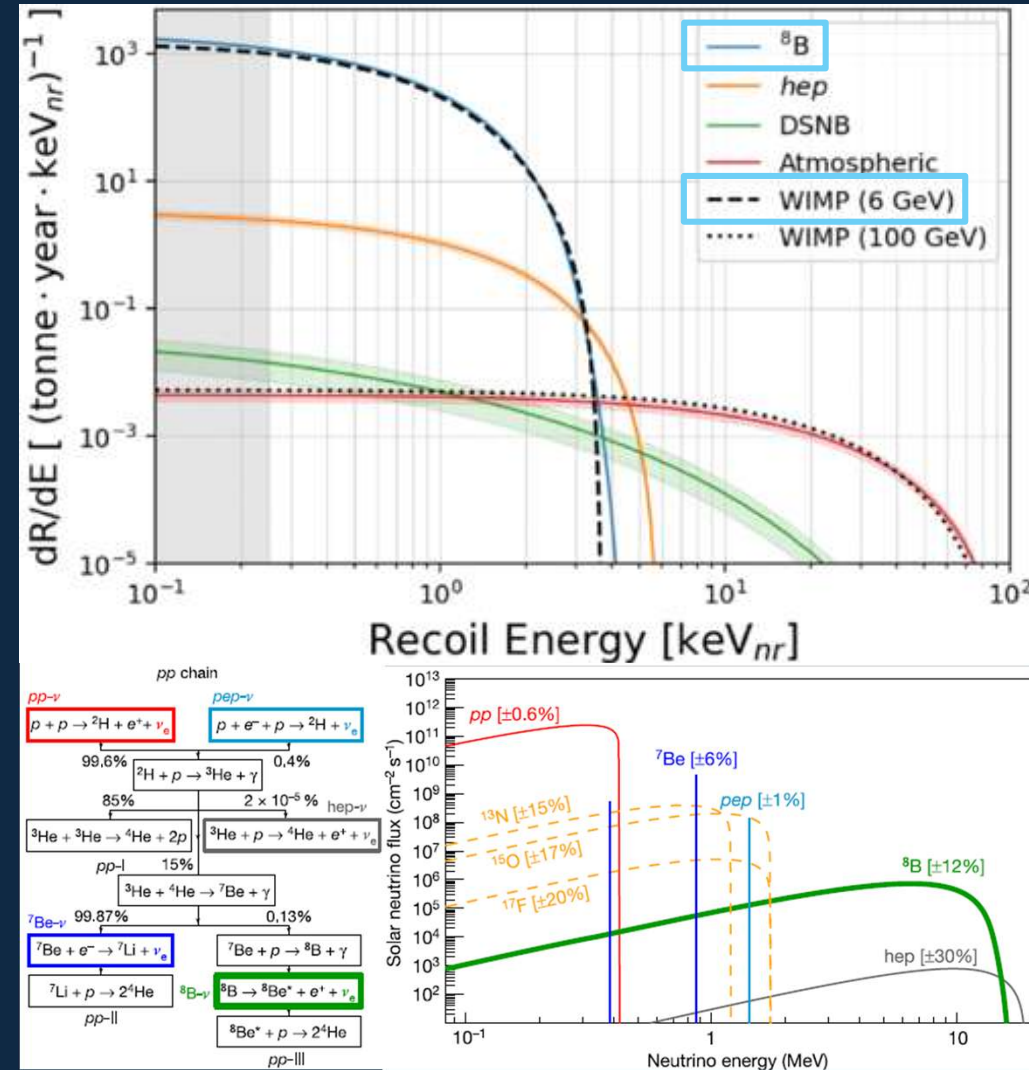
The ^8B spectrum is (almost) identical to the one of 6 GeV/ c^2 WIMPs.

ANALYSIS

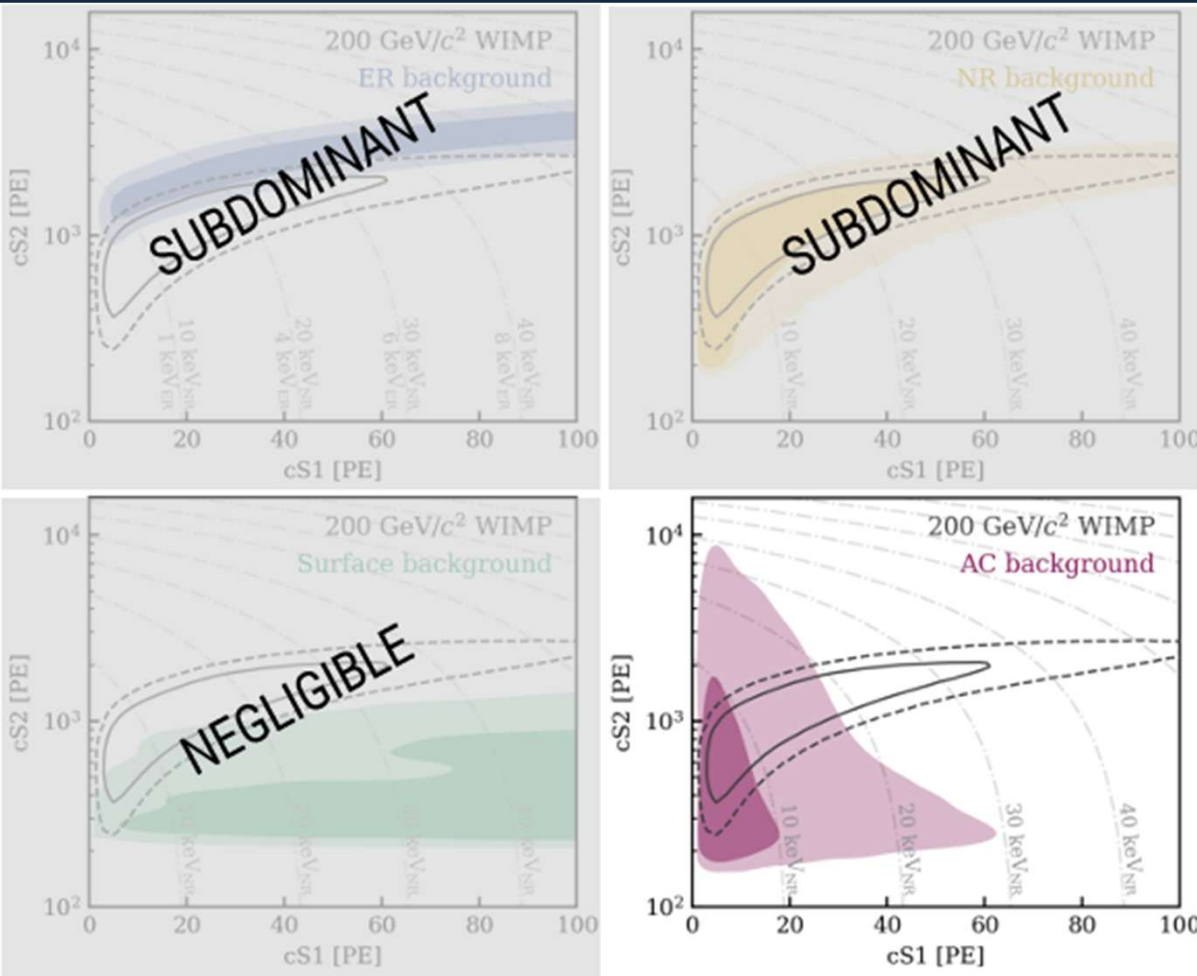
- ROI: $\text{NR} \in [0.75, 2.25]$ keV ($E_\nu \in [9.2, 13.8]$ MeV)
- **Low momentum transfer**
PRO: large cross section $\sigma \propto N_n^2$ ($\propto 6400$ for Xe)
CONTRO: near detector thr
 \rightarrow **2-fold S1** (x17 higher CEvNS rate wrt 3-fold) & 152 keV n_s from an external ^{88}YBe source

COST: most **dominant bkg** = AC_s ($\approx \text{O}(400)$ events per day)

Phys.Rev.D 108 (2023) 2, 022007, [2304.06142]

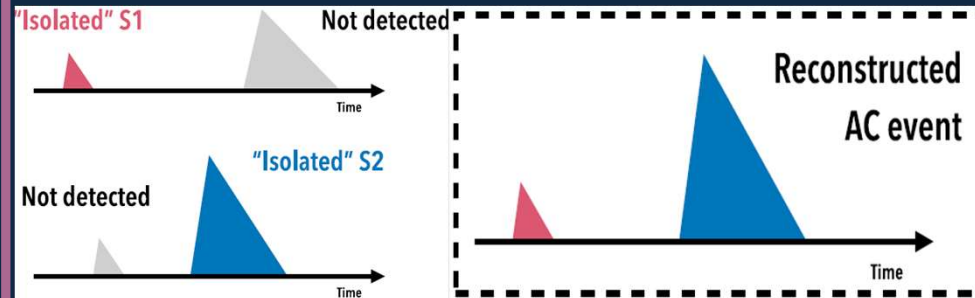


^8B SEARCH: BACKGROUNDS

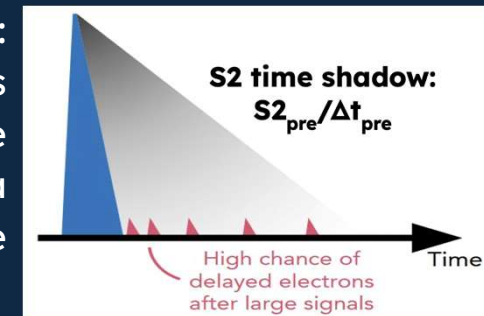


ACs

DEF: accidental pairing of isolated S1-S2



MITIGATION STRATEGY:
S1 and S2 BDT, cuts based on time and space info of peaks following a high energy one ("shadow")



EXPECTED ACs (after mitigation): SR0: 7.5 ± 0.7 , SR1: 17.8 ± 1.0 events

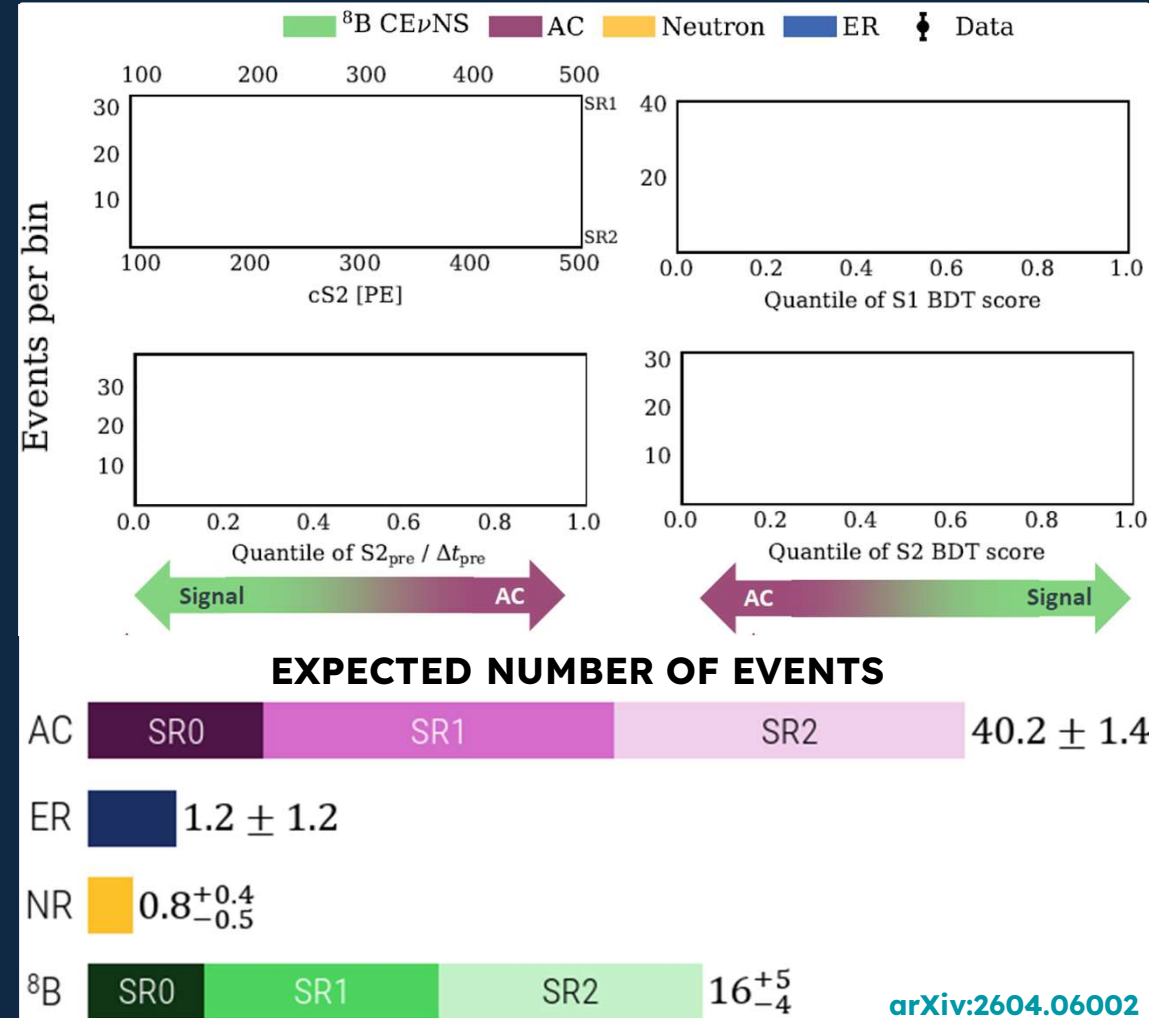
^8B SEARCH: RESULTS

MODEL

- ^8B ν spectrum from Standard Solar Model
- $\sigma_{\text{CE}\nu\text{NS}}$ from Standard Model
- Xe natural isotopic abundances

ANALYSIS

- Blinded analysis w/ 6.77 t \times yr exposure
- Extended binned likelihood in 4D parameter space



^8B SEARCH: RESULTS

MODEL

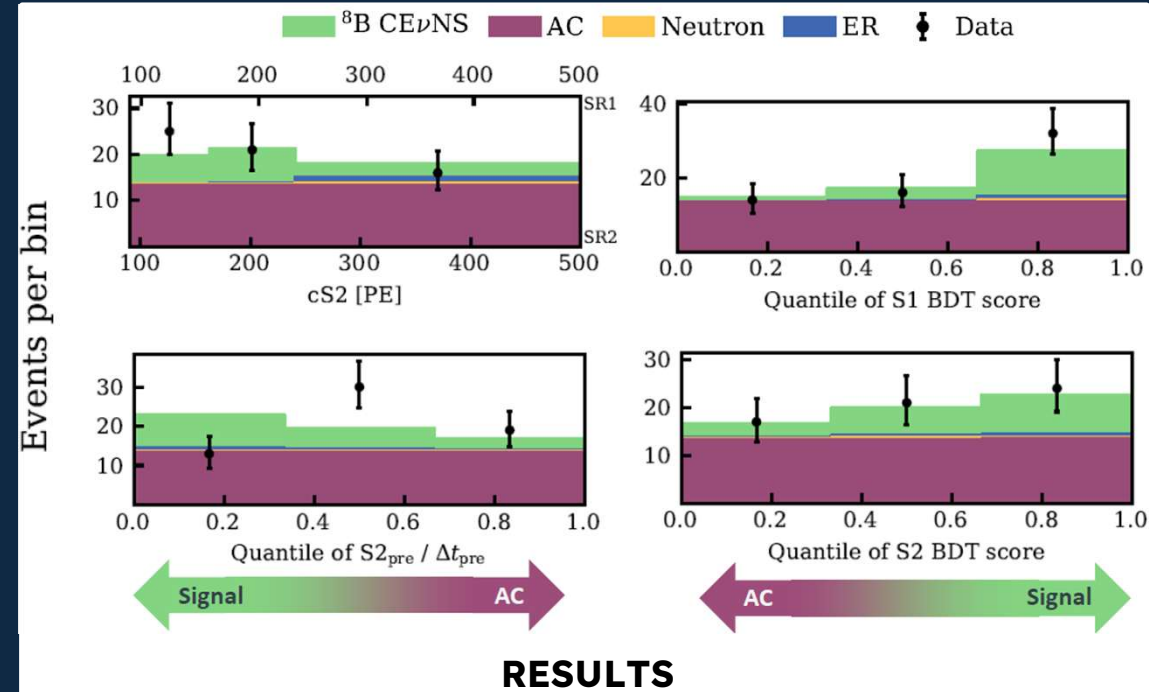
- ^8B ν spectrum from Standard Solar Model
- $\sigma_{\text{CE}\nu\text{NS}}$ from Standard Model
- Xe natural isotopic abundances

ANALYSIS

- Blinded analysis w/ 6.77 t \times yr exposure
- Extended binned likelihood in 4D parameter space

RESULT

Best-fit ^8B signal events: $(17 \pm 5) @ 3.3\sigma$



Component	Expectation	Best-fit
Total background	$42.1^{+1.9}_{-1.7}$	42.4 ± 1.9
Total ^8B	16^{+5}_{-4}	17 ± 5
Total observed	9 (SR0) + 28 (SR1) + 25 (SR2) = 62	

^8B SEARCH: RESULTS

MEASUREMENT ^8B ν flux

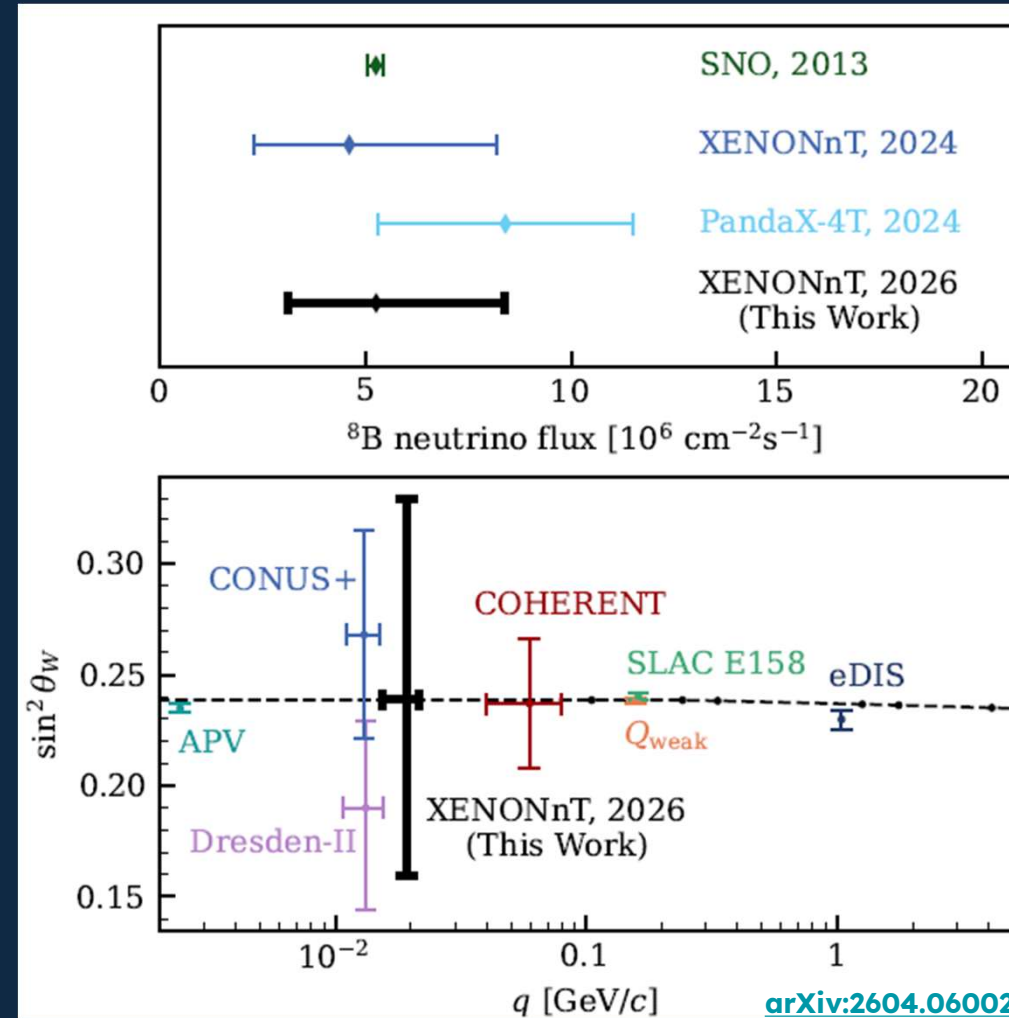
Assuming SM prediction for the CE ν NS cross section:

$$^8\text{B } \nu \text{ flux} = 5_{-2}^{+3} \times 10^6 \text{ cm}^{-2} \text{ s}^{-1} \text{ compatible w/ SNO}$$

MEASUREMENT $\sin^2 \theta_W$

Assuming solar ^8B neutrino flux constrained by SNO:

$$\sin^2 \theta_W \in [0.159, 0.330] \text{ @ } q \sim 0.02 \text{ GeV}/c \text{ } (\pm 1\sigma \text{ interval})$$



[arXiv:2604.06002](https://arxiv.org/abs/2604.06002)

SUMMARY AND CONCLUSIONS



RESULTS

- ⊗ **WIMP**: New limits on WIMP-nucleon cross section $1.7 \times 10^{-47} \text{ cm}^2$ @ 30 GeV/c² (1.8x improvement wrt SR0)
- ⊗ **⁸B**: Best-fit **⁸B signal events** = (17 ± 5) @ 3.3σ (**NO EXCESS** beyond the ⁸B CEvNS and bkg), fixing the cross-section **⁸B ν flux** = $5_{-2}^{+3} \times 10^6 \text{ cm}^{-2} \text{ s}^{-1}$ (compatible w/ SNO), fixing the flux $\sin^2 \theta_W \in [0.159, 0.330]$ @ $q \sim 0.02 \text{ GeV}/c$

OUTLOOK

- ⊗ XENONnT recently underwent a **detector upgrade**: Higher electric fields → Better bkg suppression → Better sensitivity
- ⊗ Ongoing searches: WIMP searches with SR0+1+2, solar-pp neutrinos via e- scattering, Supernova neutrinos, $0\nu\beta\beta$ and much more
- ⊗ **XLZD** collaboration established to build the next generation LXe TPC with up to 60t target mass

Thanks for your attention



www.xenonexperiment.org
xe-pr@lngs.infn.it



facebook.com/XENONexperiment



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twitter.com/xenonexperiment

Photo credit: Luigi Di Carlo for the XENON Collaboration



Dark Matter
Phenomenology
M. Cirelli

Neutrino
Phenomenology
F. Terranova

Axion Theory
and Detection
C. Braggio

Liquid
Scintillators and
Water Cherenkov
Detectors
B. Caccianiga

Noble Liquid
Detectors
E. Aprile

Solid State
Detectors
R. Strauss

Statistics
(+Hands-on)
R. Hammann

Material
Screening
S. Cebrian Guajardo

Speed Talk
and
Poster
sessions

SoUP School on Underground Physics

- Organized by INFN.
- WHEN: 26-30 October 2026
- WHERE: CeUB, Bertinoro (FC), Italy
- Registration is NOW OPEN through the [Indico web site](#).
- Agenda on [Indico](#).
- CONTACTS: soup2026@lists.bo.infn.it

26 - 30 OCTOBER 2026

CeUB · BERTINORO (FC) · ITALY



Early Registration

Fee: 650 €

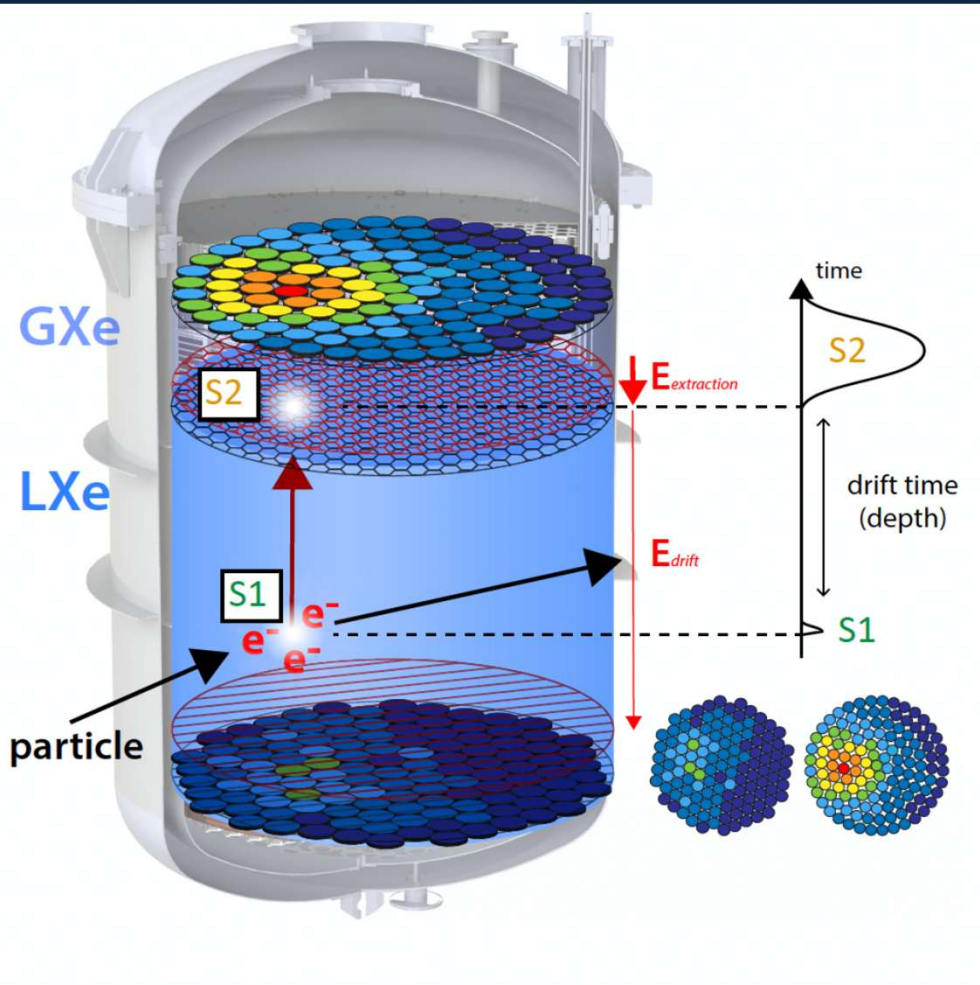
Deadline: 15 June

Hope to see you there!

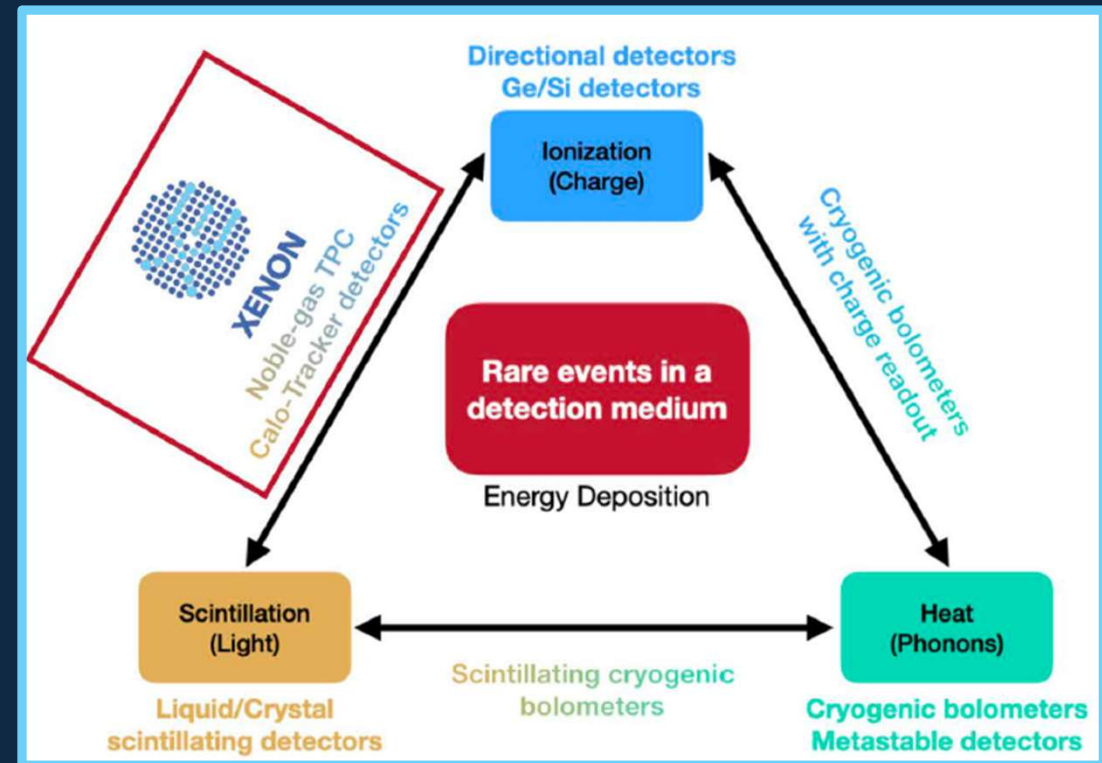


BACKUP
ВУСКІЎ

LXe TPC DETECTION PRINCIPLE

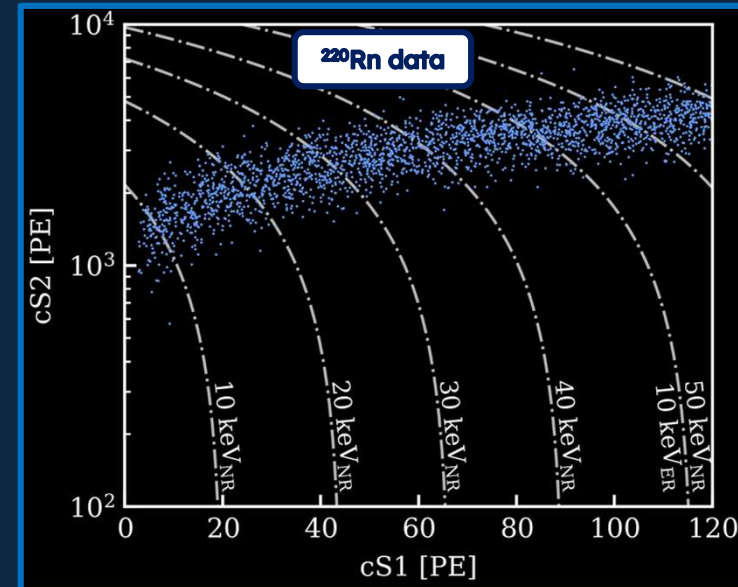
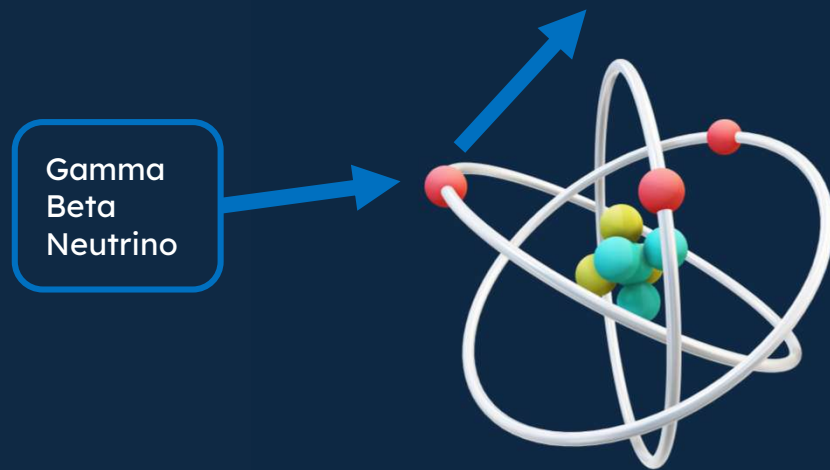


- READOUT of SCINTILLATION AND IONIZATION signals
S1: prompt scintillation signal in LXe (LIGHT)
S2: secondary light from drifted e⁻ in GXe (CHARGE)



LXe TPC DETECTION PRINCIPLE

ELECTRONIC RECOIL

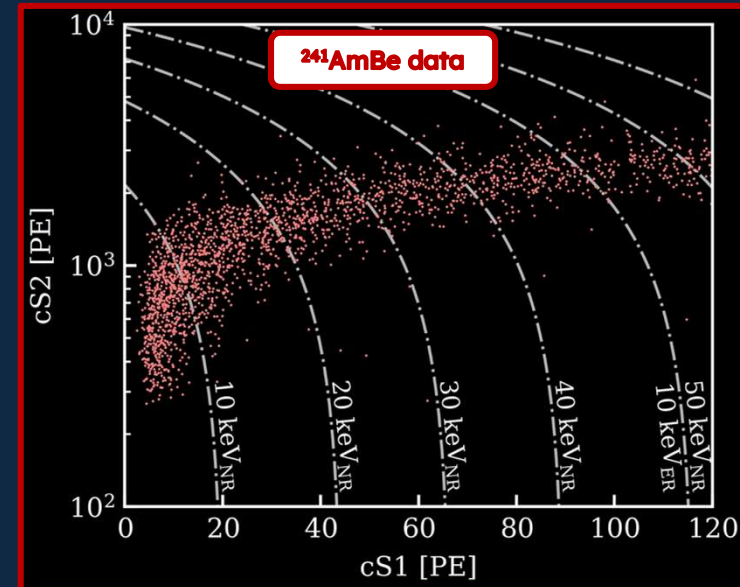
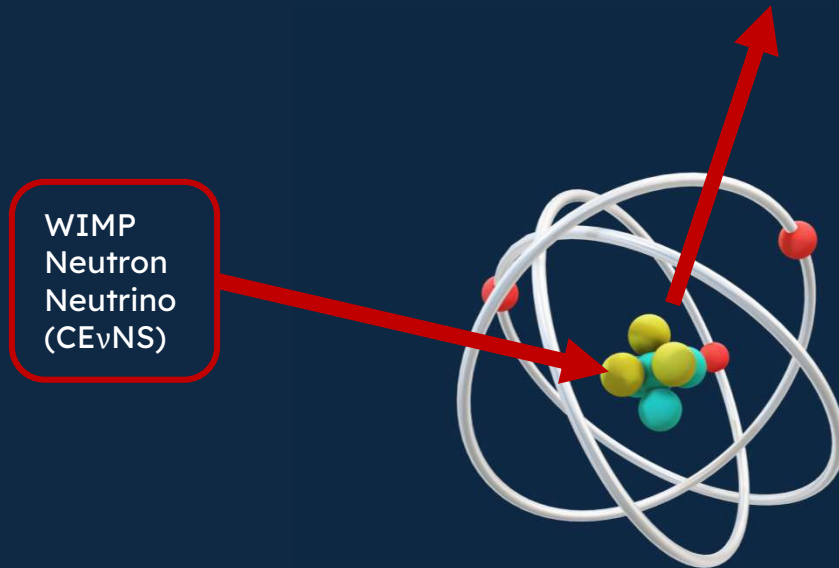


BACKGROUNDS

- **Radon:** Due to its 3.8 d half-life, the emanation of ^{222}Rn from detector materials results in a distribution of ^{222}Rn and its decay products within the whole LXe volume. This is the **largest contribution** in the energy ROI.
- **Krypton:** The xenon target contains natural krypton and therefore traces of the radioactive isotope ^{85}Kr . Its contribution depends on the ^{nat}Kr concentration and is estimated to be a **factor 5 lower than Radon**.
- **Xenon:** Unstable xenon isotopes are distributed uniformly within the target volume.
- **Solar ν_s :** Solar neutrinos can elastically scatter off atomic electrons of the LXe target yielding low-energy ER signals. It is the **second largest source** of ER background in XENONnT

LXe TPC DETECTION PRINCIPLE

NUCLEAR RECOIL



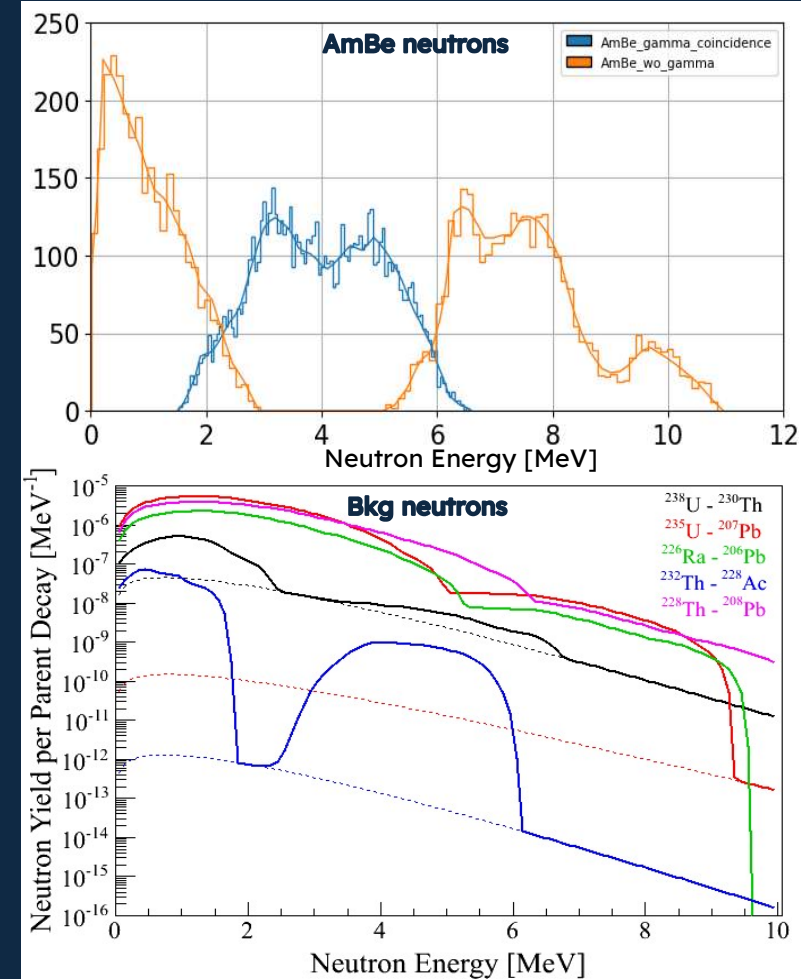
BACKGROUNDS

- **Radiogenic Neutrons:** Radiogenic neutrons are produced through spontaneous fission (SF) or (α, n) reactions in detector materials. **Largest contribution** even after being reduced with a novel Neutron Veto.
- **Cosmogenic Neutrons:** Neutrons induced by cosmic muons interacting in the rock and concrete surrounding the detector can be tagged using the active Muon Veto in the water tank. **Negligible** contribution.
- **CEvNS:** Interactions from solar, atmospheric and diffuse supernova (DSN) ν_s contribute to the NR background through CEvNS. Solar neutrinos limit the sensitivity for \approx few GeV/c^2 mass WIMPs. In contrast, the NR spectra induced by atmospheric and DSN neutrinos affect the sensitivity for heavier WIMPs.

NEUTRON VETO: AmBe CALIBRATION

SOURCE

$^{241}\text{AmBe}$ emits neutrons through α -capture reaction $^9\text{Be}(\alpha, n)^{12}\text{C}$ together with a 4.4 MeV γ in about 50% of cases.



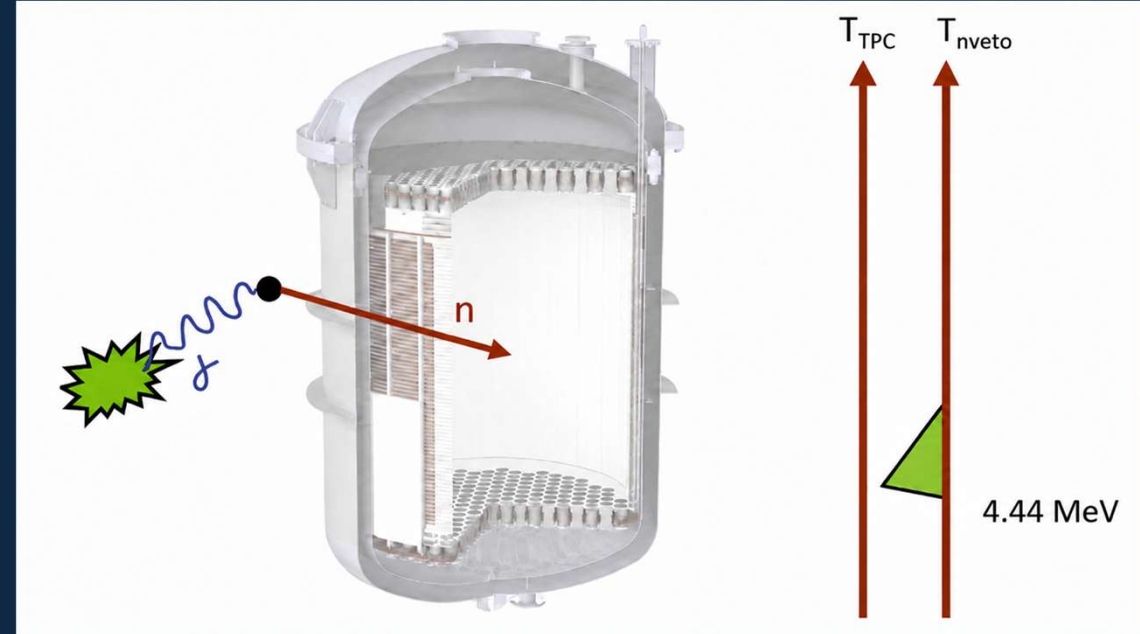
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CALIBRATION PROCESS

1. **PROMPT γ TRIGGER:** 4.4 MeV γ rays emitted in coincidence with neutrons are detected in the NV and provide the event trigger.



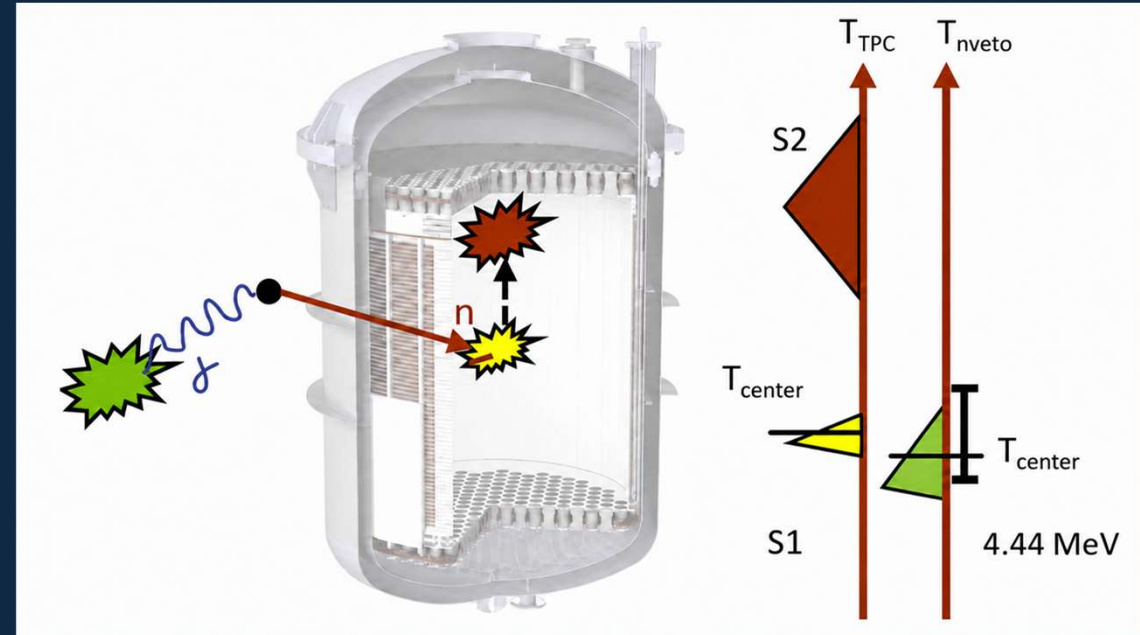
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CALIBRATION PROCESS

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- NR SELECTION:** TPC events occurring within ~ 100 ns of the prompt γ signal are selected.



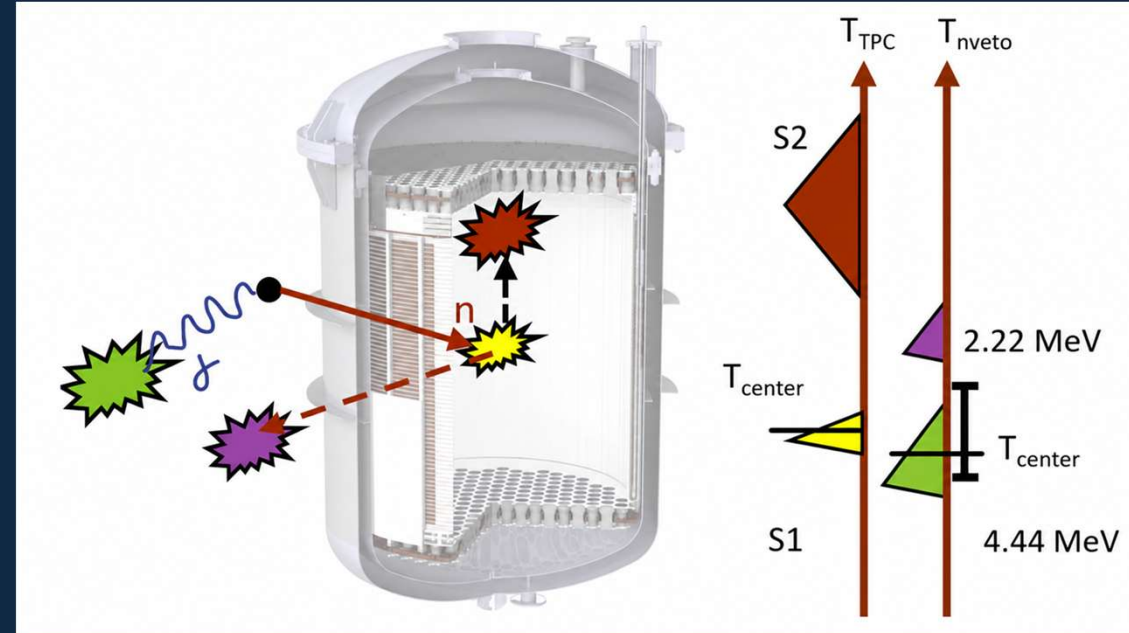
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CALIBRATION PROCESS

- PROMPT γ TRIGGER:** 4.4 MeV γ rays emitted in coincidence with neutrons are detected in the NV and provide the event trigger.
- NR SELECTION:** TPC events occurring within ~ 100 ns of the prompt γ signal are selected.
- NEUTRON CAPTURE DETECTION:** Delayed capture signals are searched for in the NV within $O(1)$ ms after the NR in TPC to evaluate detector performance.

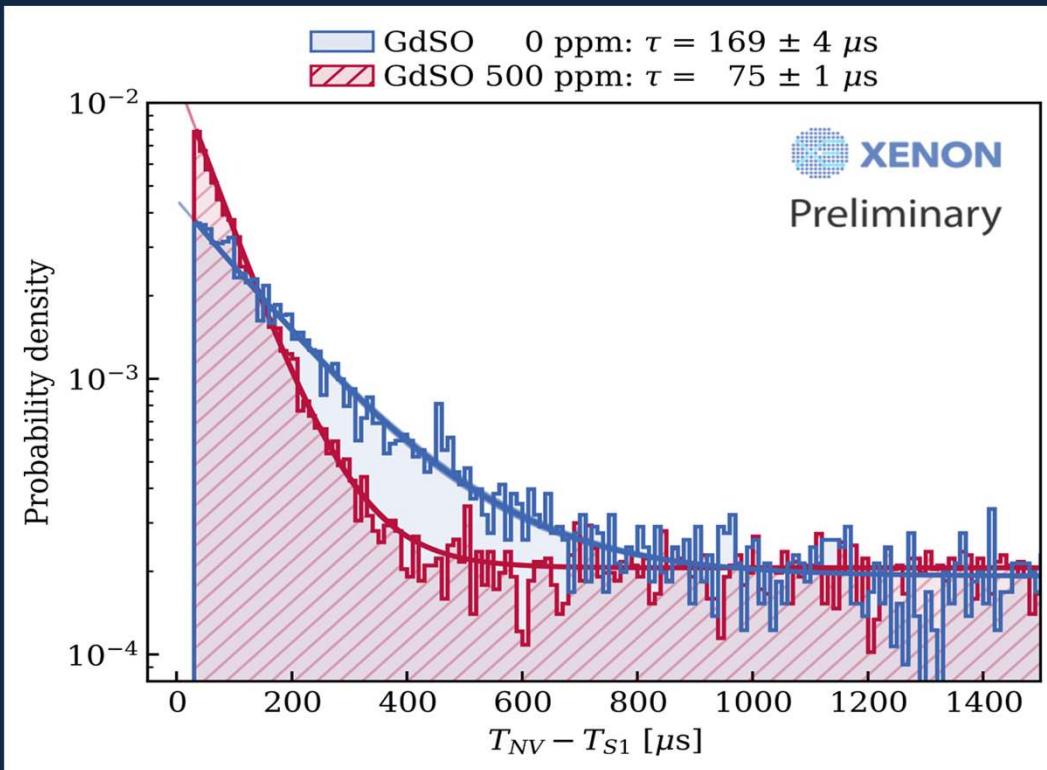


CALIBRATION CAMPAIGNS

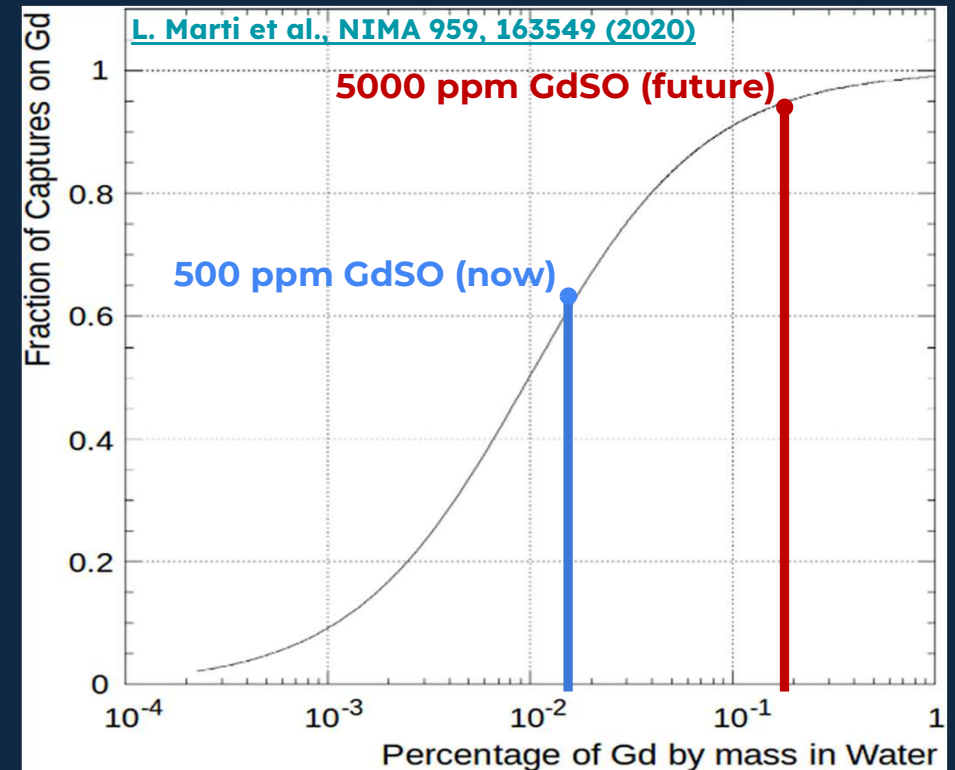
- PRE-SR2: 0 ppm
- INSERTION PHASE: 50 ppm
- EARLY-SR2: 500 ppm
- LATE-SR2: 500 ppm

NEUTRON VETO: n-CAPTURES

The **neutron capture time** is the average time from the neutron emission to its capture. It is obtained by fitting the time distribution of neutron capture events.



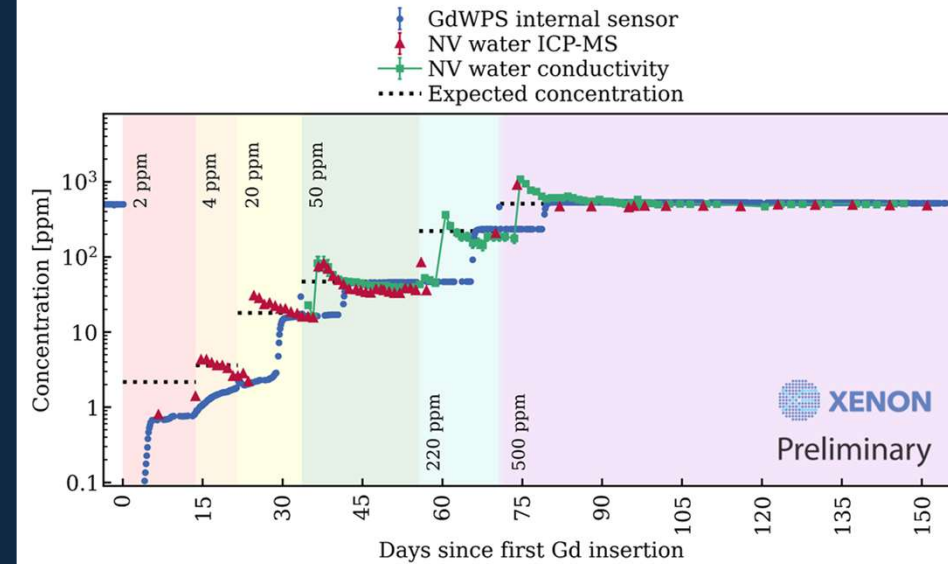
Fraction of **neutrons captured on Gd** as a function of its concentration in water by mass: with 500 ppm about **60%** of captures occur on Gd.



NEUTRON VETO: Gd-INSERTION

Gd CONCENTRATION MONITORING

- **ICP-MS measurements:** Periodic offline determination of Gd-concentration through Inductively Coupled Plasma Mass Spectrometry (ICP-MS) performed at LNGS chemistry laboratory.
- **Water conductivity measurements:** Offline conductivity measurements of water samples collected from the detector system.
- **GdWPS conductivity sensors:** Continuous online monitoring of the gadolinium concentration through conductivity sensors installed in the Gd Water Purification System (GdWPS).



NEUTRON VETO: Gd-INSERTION

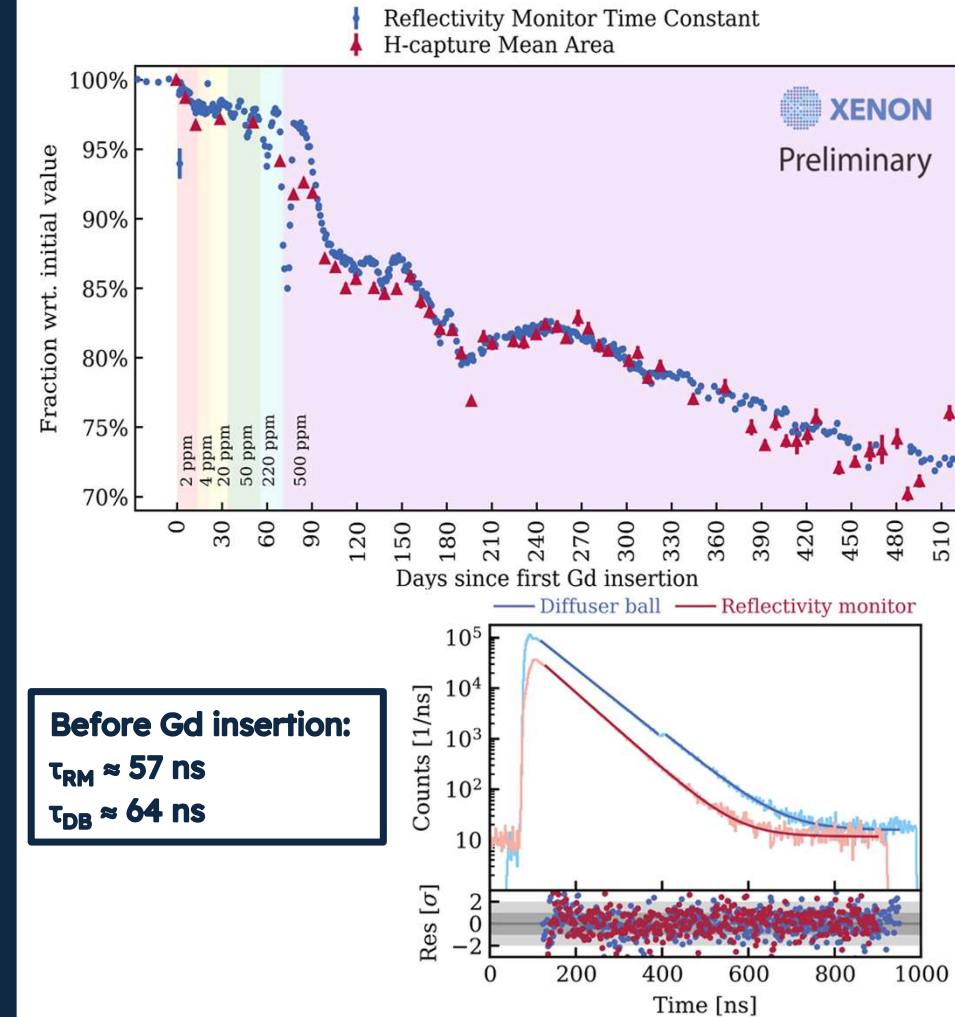
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NV OPTICAL MONITORING

The NV optical performance is monitored through the photon arrival-time distribution:

- **Reflectivity Monitor (RM):** System consisting of four optical fibers oriented upward and downward, illuminated by a 375 nm laser.
- **Diffuser Balls (DB):** Four quartz spheres providing isotropic light emission, illuminated by 448 nm laser pulses to probe detector response.



S2-ONLY SEARCH: BACKGROUNDS

TOP ELECTRODES + GAS REGION

- Radioactivity (electrodes and TPC materials)

ATTENUATION: Negligible after width cut

DELAYED ELECTRONS + ACCIDENTAL ELECTRONS

- Pile-up of electrons trapped in impurities

ATTENUATION: Correlation-based CNF and BDT machine

PTFE WALLS

- Radioactivity (plate-out on the wall)

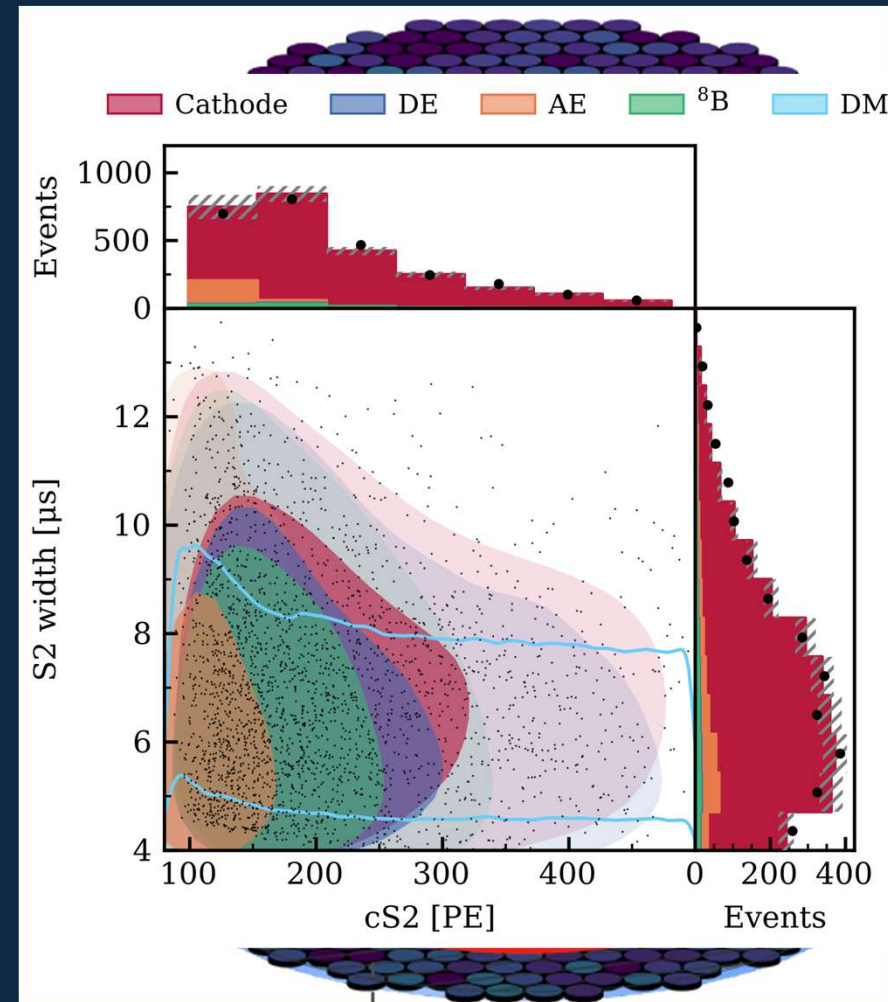
ATTENUATION: Negligible after radial cut

CATHODE ELECTRODES

- Radioactivity (electrodes, ^{210}Pb)

ATTENUATION: Waveform-based BDT machine

Bkg model validated with ^{220}Rn calibration data: cathode bkg dominant while AE primarily contribute to the lowest energy bin.



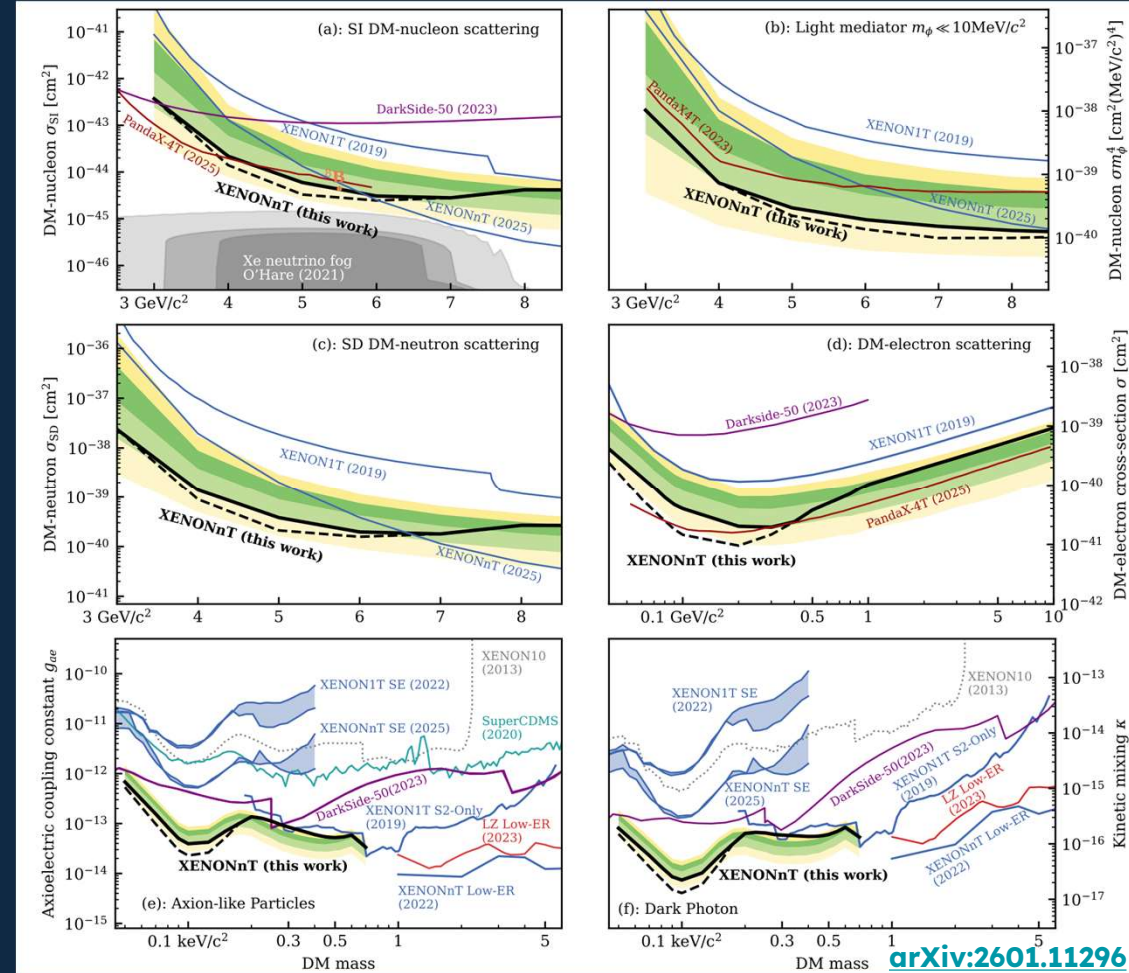
S2-ONLY SEARCH: RESULTS

ANALYSIS

- Blind search w/ 7.83 t×yr exposure
- ROI: $cS2 \in [100, 500] PE \leftrightarrow [3, 16] e^-$ ($= [0.5, 5.0] \text{ keV}_{NR}$ and $[0.04, 0.7] \text{ keV}_{ee}$)
- Profile likelihood test statistic in $cS2$ space

RESULTS

- **Good agreement** between observed events and bkg model
- **NO EXCESS** over bkg observed
- **New limits on Light DM:** most stringent limits on $\sim 5 \text{ GeV}$ light WIMPs and on $[0.04, 0.2] \text{ keV}$ ALPs



arXiv:2601.11296