The XENONnT

INFN LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

Neutron Veto:
Status and Latest Results

EDSU-Tools 2024

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on behalf of the XENON collaboration
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Île de Noirmoutier, France
Village Les Quatre Vents, L'Épine
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The XENON project

Direct search for dark matter (DM) with **liquid xenon (LXe)** deep underground at the INFN **Laboratori Nazionali del Gran Sasso** (LNGS) in Italy

XENON10	XENON100	XENON1T	XENONnT
25 kg	161 kg	3.2 t	8.5 t
2005	2008	2016	2020

SEE ELENA APRILE'S TALK

About 200 scientists

from 28 institutions

in 12 countries

1.4 km rock

10^6 μ reduction factor

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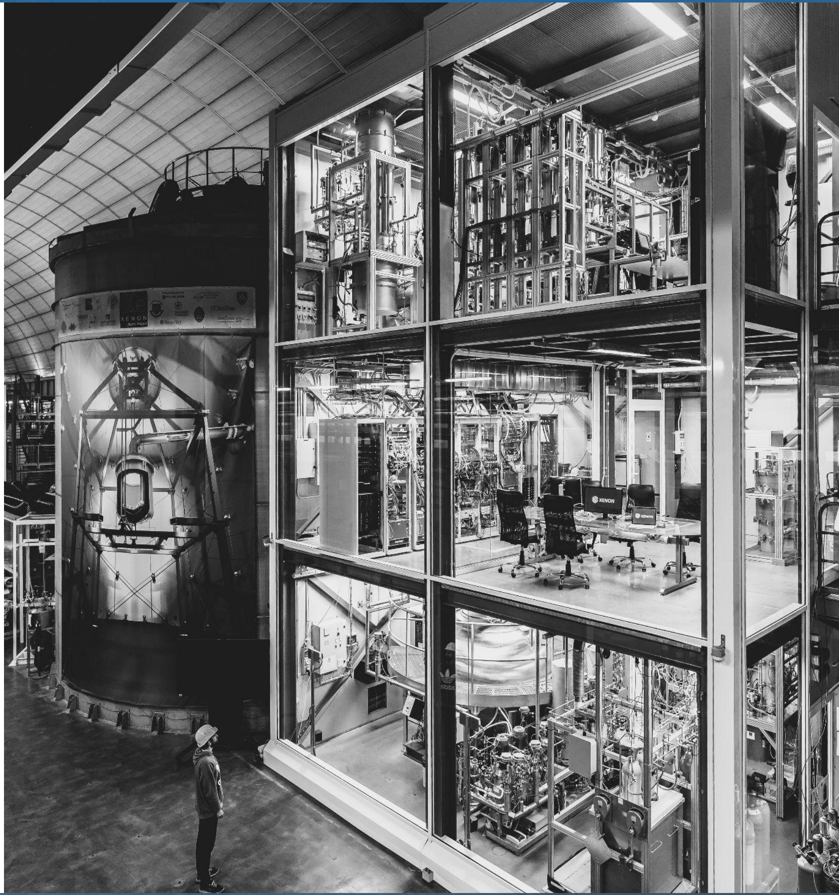
The XENONnT experiment



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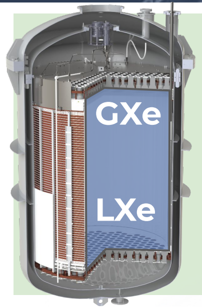

Dual phase Xe Time Projection Chamber

5.9 t active target mass, **8.5 t total** mass

1.5 m drift length, **1.3 m** diameter

494 Hamamatsu 3'' **PMTs**

TPC

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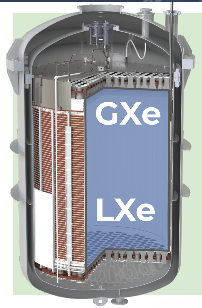

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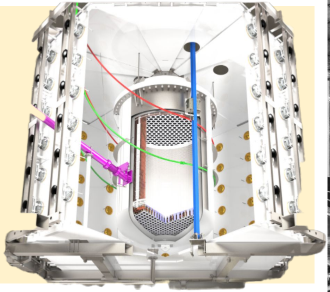
(Gd-)Water Cherenkov Neutron Veto

33 m^3 volume around cryostat

120 8" high QE **PMTs**

High reflectivity expanded **PTFE**



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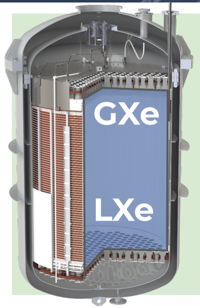

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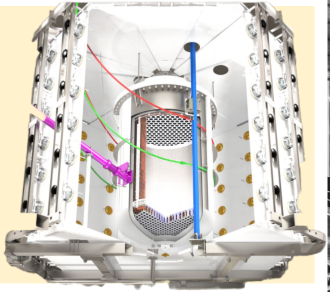
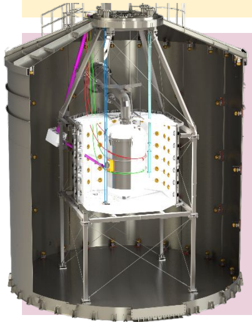




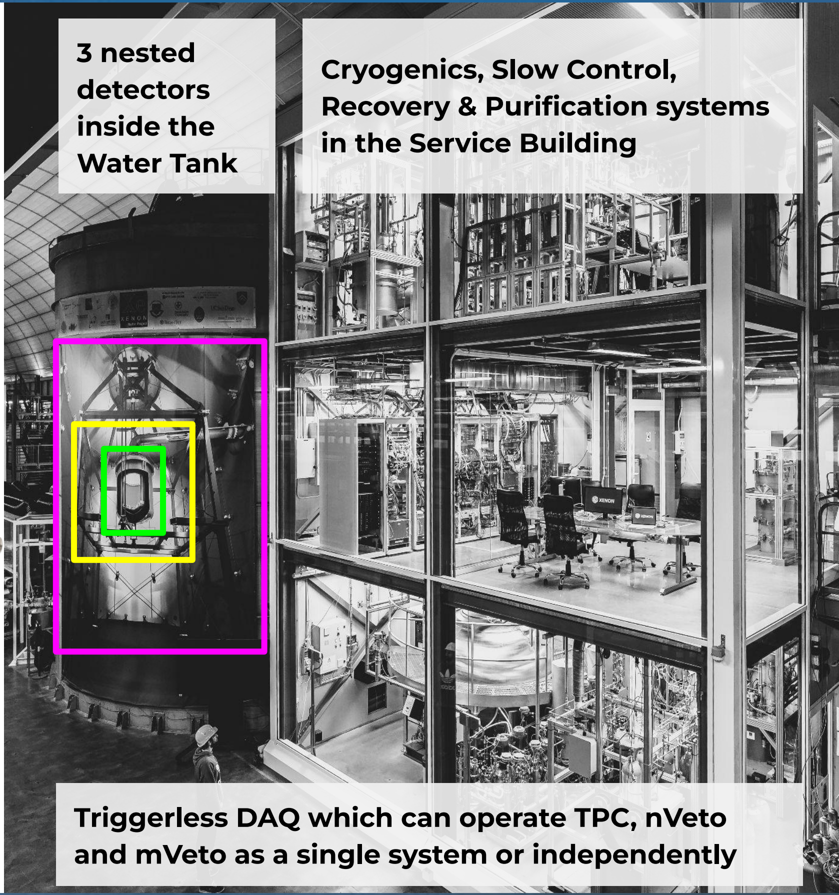
(Gd-)Water Cherenkov Muon Veto

mVeto

700 t water, **84** 8" high QE **PMTs**

Active veto against **muon**-induced **neutrons** (n)

Passive veto against **γ** and **n** from **natural radioactivity**



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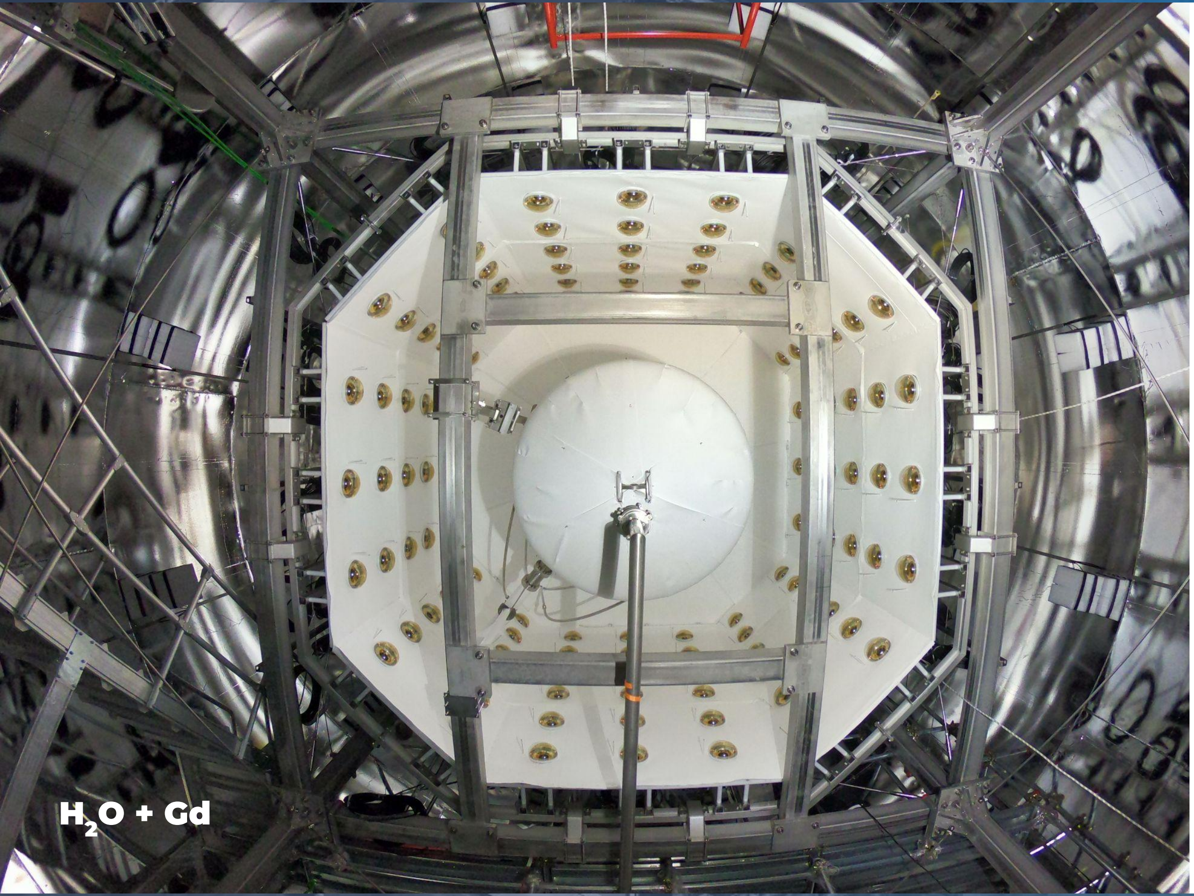
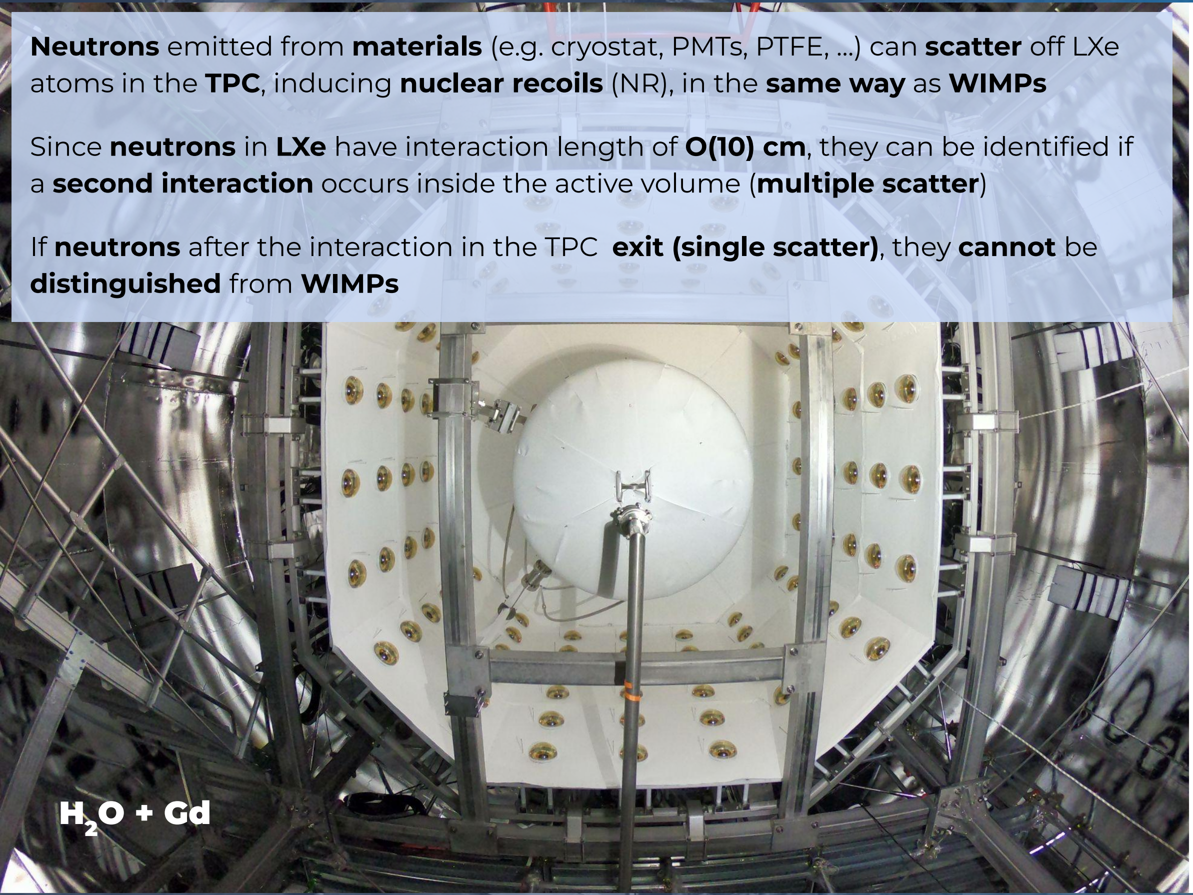


The XENONnT Neutron Veto

Neutrons emitted from **materials** (e.g. cryostat, PMTs, PTFE, ...) can **scatter** off LXe atoms in the **TPC**, inducing **nuclear recoils** (NR), in the **same way** as **WIMPs**

Since **neutrons** in **LXe** have interaction length of **O(10) cm**, they can be identified if a **second interaction** occurs inside the active volume (**multiple scatter**)

If **neutrons** after the interaction in the TPC **exit (single scatter)**, they **cannot** be **distinguished** from **WIMPs**



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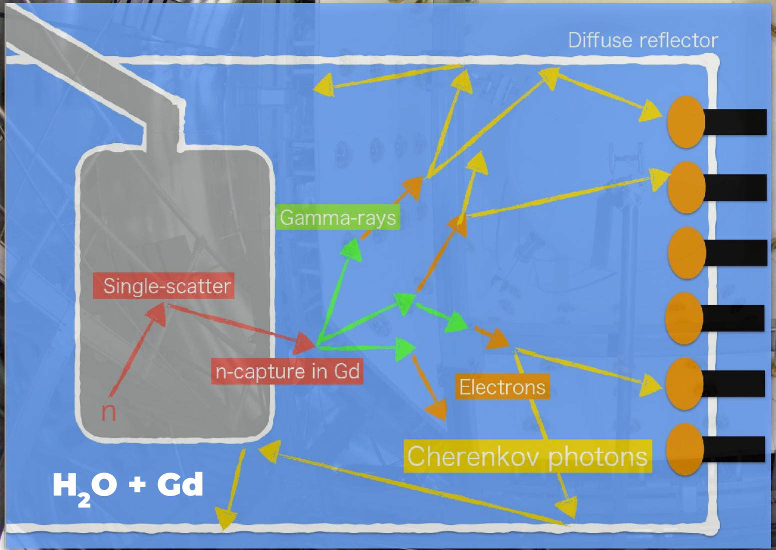

Neutron Veto (NV) designed for **otherwise irreducible background**

Designed to operate with **Gd-loaded water**

Neutron **capture** on **H** or **Gd** nuclei, with emission of **~ MeV gammas**

Gammas make **Compton scattering** off **electrons**, which emit **Cherenkov** light

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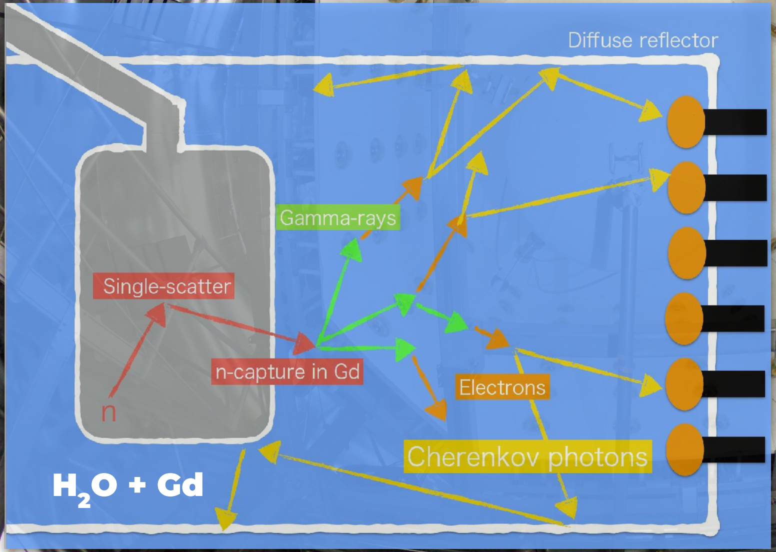

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SR0
NV cut applied

	Nominal	Best fit	
	ROI		Signal-like
ER	134	135^{+12}_{-11}	0.92 ± 0.08
Neutrons	$1.1^{+0.6}_{-0.5}$	1.1 ± 0.4	0.42 ± 0.16
CEνNS	0.23 ± 0.06	0.23 ± 0.06	0.022 ± 0.006
AC	4.3 ± 0.9	$4.4^{+0.9}_{-0.8}$	0.32 ± 0.06
Surface	14 ± 3	12 ± 2	0.35 ± 0.07
Total background	154	152 ± 12	$2.03^{+0.17}_{-0.15}$
WIMP	…	2.6	1.3
Observed	…	152	3

Phys. Rev. Lett. 131, 041003, 2023

Thanks to new **background reduction** techniques, **electronic recoils** now **comparable** to radiogenic **neutrons** in **signal-like** region

First Science Run **(SR0)** performed with **demineralized water** in **Water Tank (WT)**

Large light collection **efficiency** with **high-reflectivity ePTFE** panels

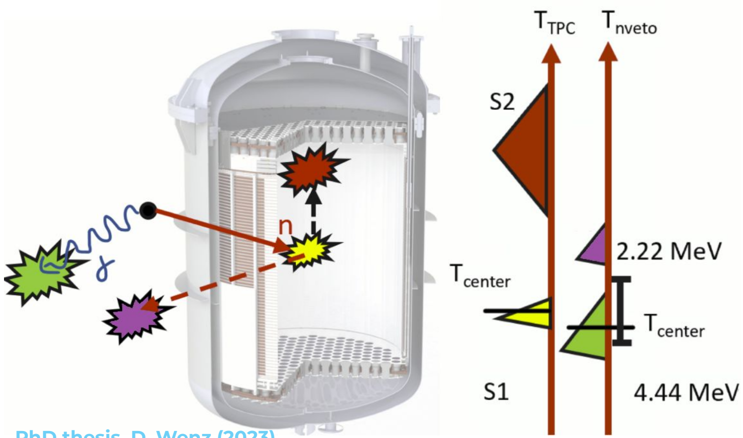
LED calibration for **PMT Gain** and **Laser** calibration for **transparency** monitor

Neutron calibration with AmBe

AmBe calibration source placed close to cryostat (**same signature** of radiogenic **neutrons** from **detector materials**)

4.4 MeV gamma (γ) **emission** with **neutron** in about **50%** of cases

First **4.4 MeV** γ detected in **NV**, then coincidence requirement for **nuclear recoil** in **TPC**, hence search for **signals** from **neutron capture** in **NV**



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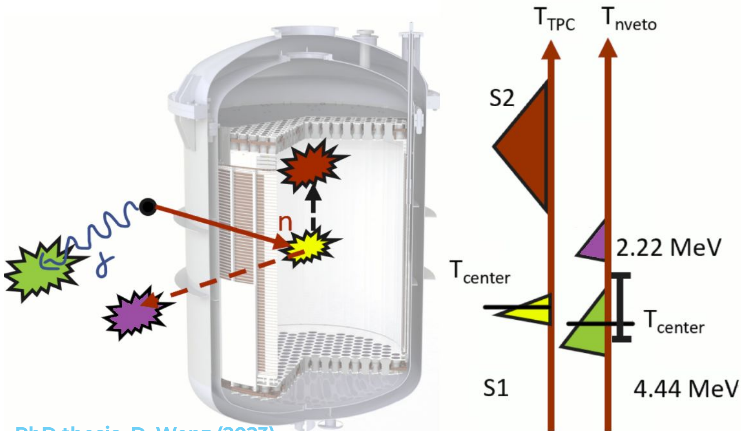

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Direct measurement of **neutron tagging efficiency**

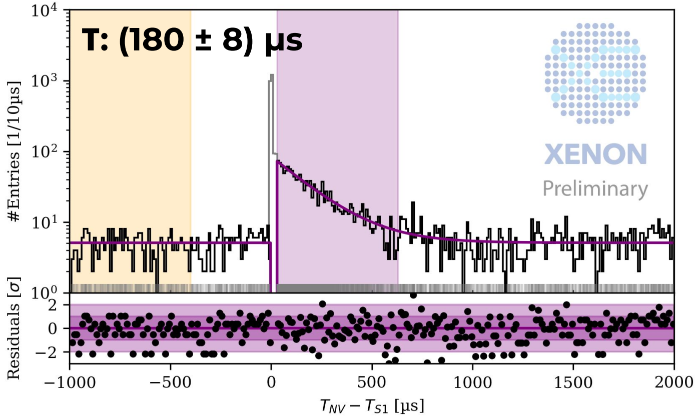
After background subtraction, at **5-fold** coincidence, **5 PE** threshold, **600 μs** time windows: **(68 ± 3) %**

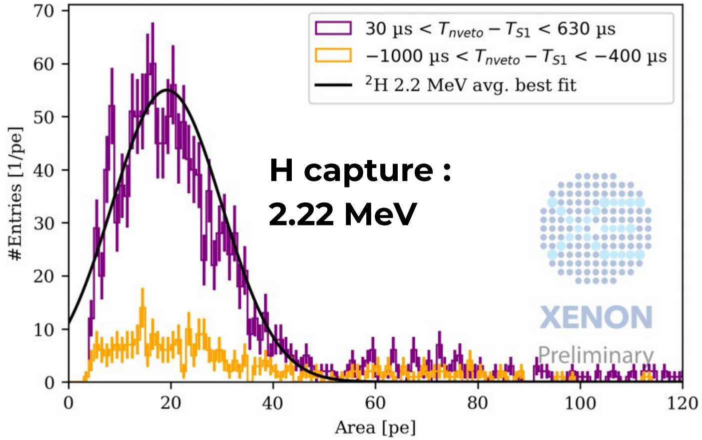
Average **capture time** in **demi-water** of about **180 μs**

Highest neutron **detection efficiency ever measured** in a **water Cherenkov** detector

In Science Run 0, **time window** shortened to **250 μs** to **reduce** induced **dead time**

Then, neutron **tagging** efficiency is **(53 ± 3) %** with **1.6% livetime loss**

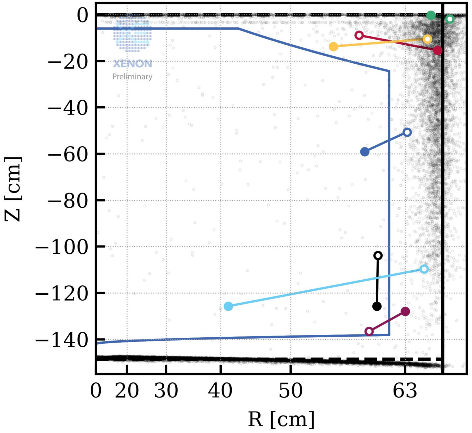


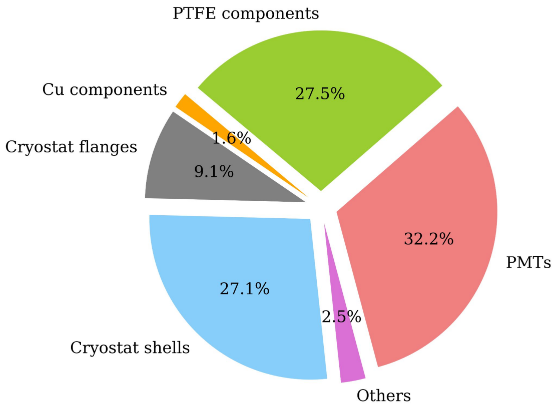


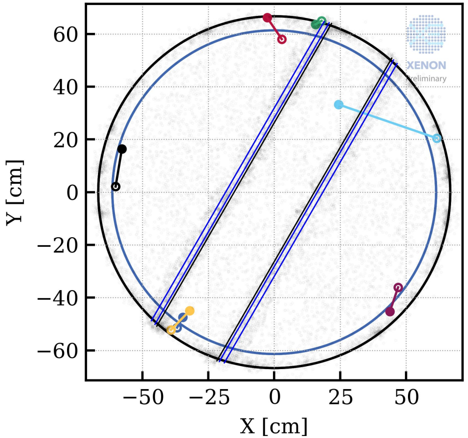
Neutron Veto in XENONnT Science Run 0

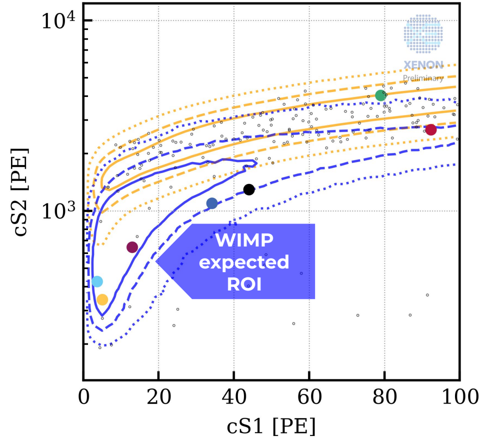
Neutron background originated mostly from **PMTs**, **cryostat** and **PTFE** components

Signals in **TPC** can be attributed to **neutrons** from detector materials if, **differently** from **WIMPs**, **multiple-site** energy deposit occurred (**multiple scatter**)









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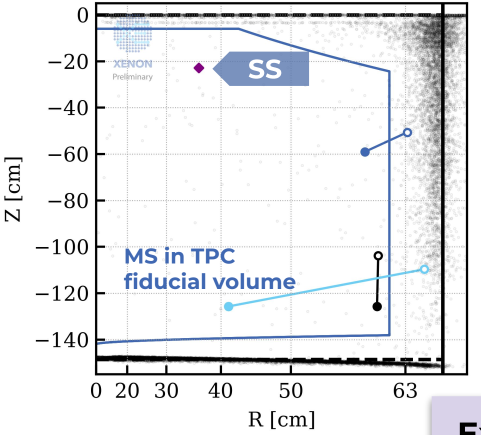
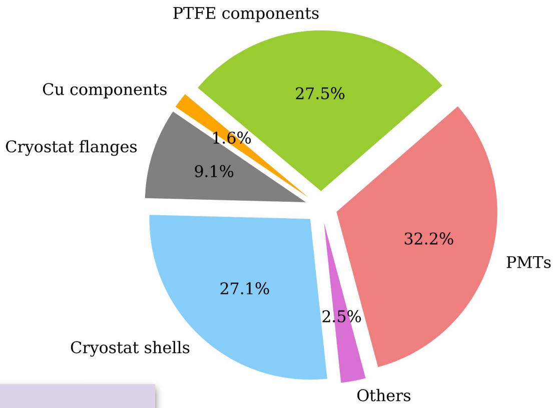
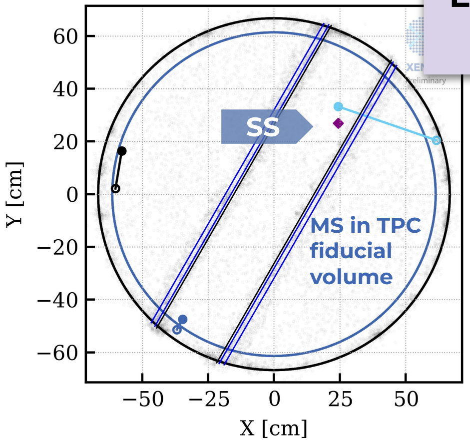
4 events in the **WIMP blinded** region tagged by **NV** and excluded: **3 multiple scatter (MS)** + **1 single scatter (SS)**

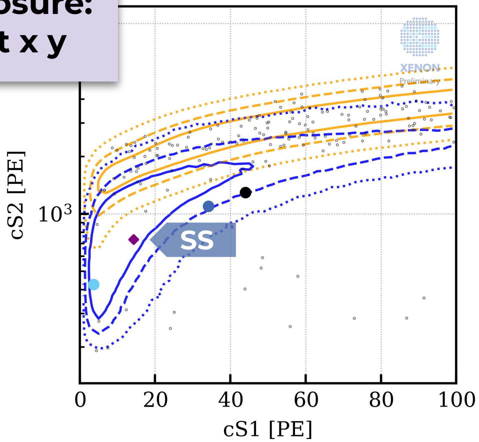
In **agreement** with **MS/SS** ratio of about **2.5** obtained from MC and AmBe calibration data





Exposure:
1.1 t x y





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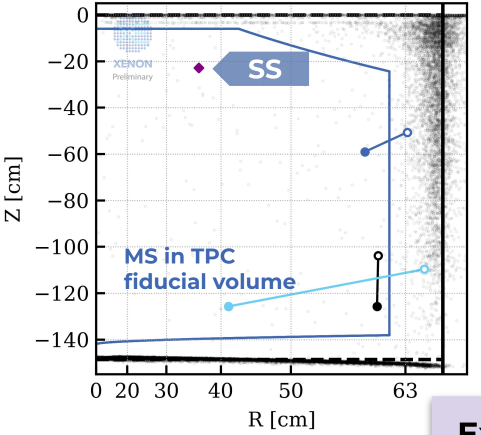
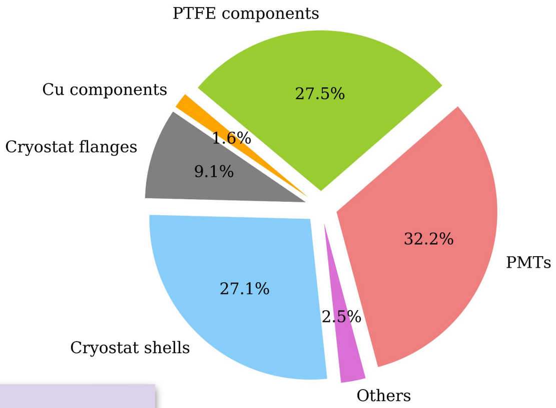
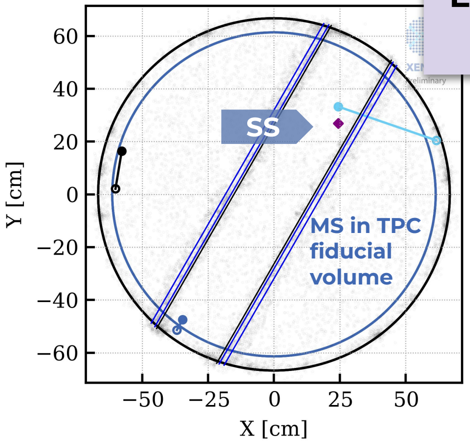
Considering **NV tagging efficiency** of **53%**, the **total neutron expectation** is **$1.1^{+0.6}_{-0.5}$** events

This result is **6x higher** than **predictions** from **material screening** (ongoing **checks** to understand the discrepancy)

In SR0, NV had relevant role in **constraining** this specific **background** in a **data-driven** way







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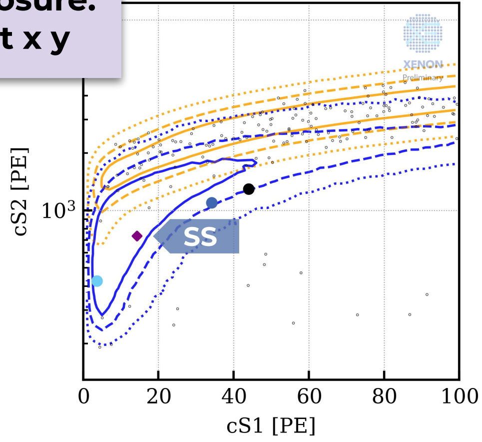


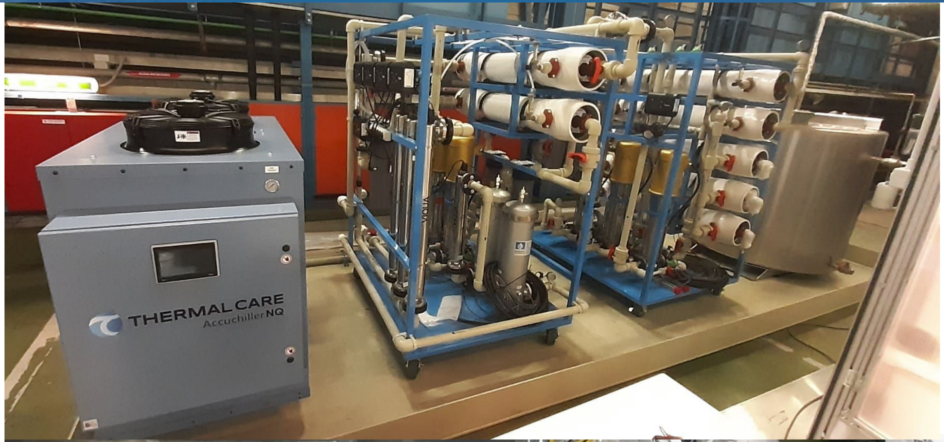
Neutron Veto with Gd-loaded water

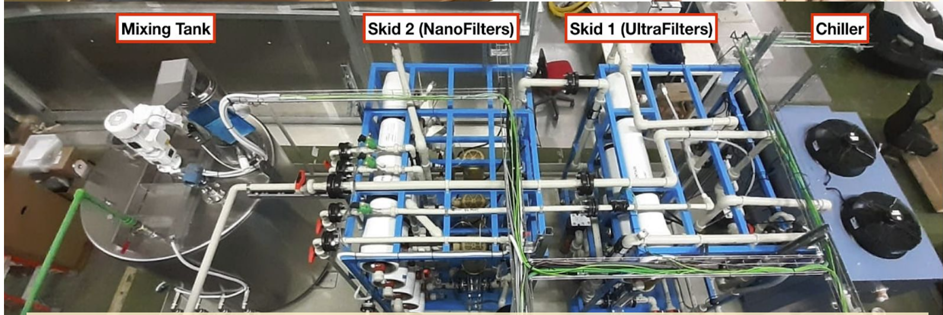
	Neutron capture cross-section	γ energy	Mean capture time
H	0.33 b	Single γ, 2.2 MeV	200 us
Gd	49000 b	3-4 γ, 8 MeV in total	30 us*

Neutron Veto designed to tag **neutrons** following their **capture** on **Hydrogen** or **Gadolinium** nuclei after **thermalization** in water

In the **first** Science Runs, **Gadolinium not yet** present in WT

Novel **Gd-Water Purification System (GdWPS)** has been **commissioned** and **procedure** for **insertion** and **dissolution** of **Gd-sulfate (GdSO)** has been **tested**





The **Gd-Water Purification System**, developed with **technology** from **EGADS** project, is needed to keep good water conditions.
L. Marti et al., NIMA 959, 163549 (2020)

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Gadolinium Sulfate Octahydrate ($Gd_2(SO_4)_3 \cdot 8H_2O$) **injected** into **WT** through GdWPS in various steps

Reached **0.02 % Gd mass concentration** which corresponds to **350 kg** of GdSO (**500 ppm GdSO**)

With Gd, **expected** neutron **tagging efficiency** of about **77%**

*** for a 0.2% Gd mass concentration**

GdSO is transported underground in a **sealed** container, and **transferred** in the **mixing tank** with a **pneumatic tool**

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Neutron Veto response after Gd insertion

AmBe calibration **source far** from **cryostat** (**50 cm**) to characterize NV **response** along time: **area spectrum** can be **modeled** with:

- **2.2 MeV peak** (**H** capture) → **1 Gaussian** with threshold
- **4.4 MeV** peak (**^{12}C de-excitation**) → **1 Gaussian** with threshold
- About **8 MeV** peak (**Gd** capture) → **2 Gaussians** with threshold
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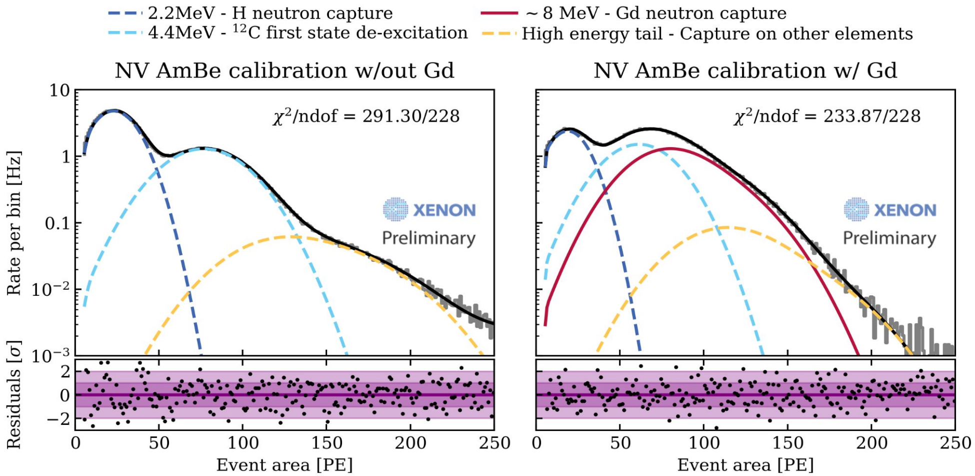
Mean area and **amplitude** correspond to **mean collected light** (that depends on NV **optical properties**) and **neutron captures**



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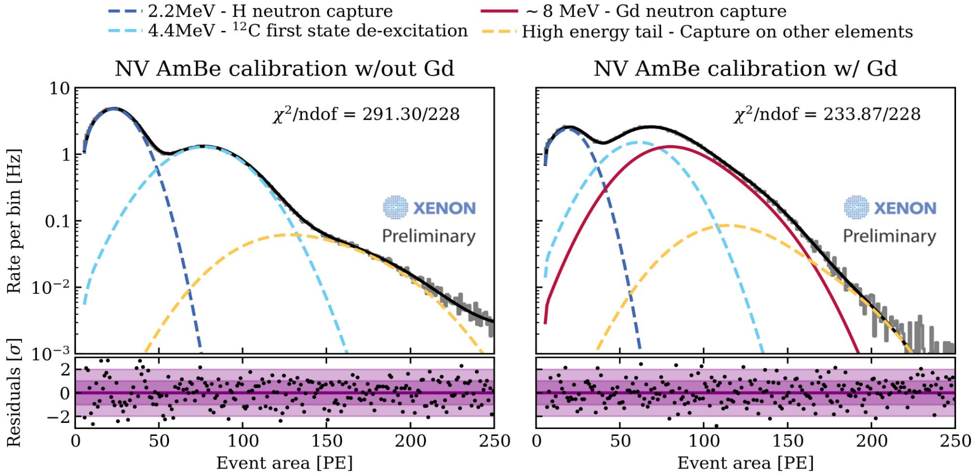

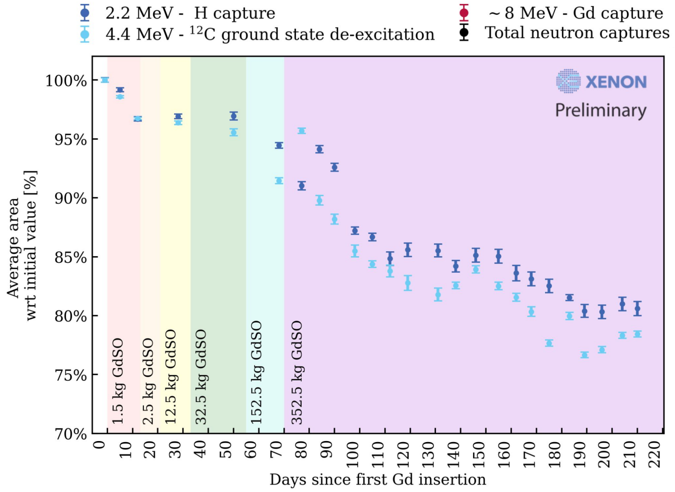

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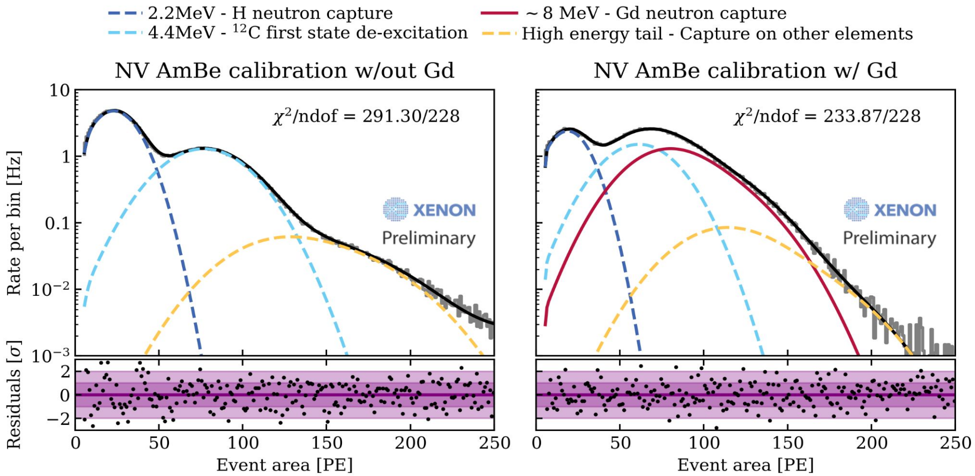

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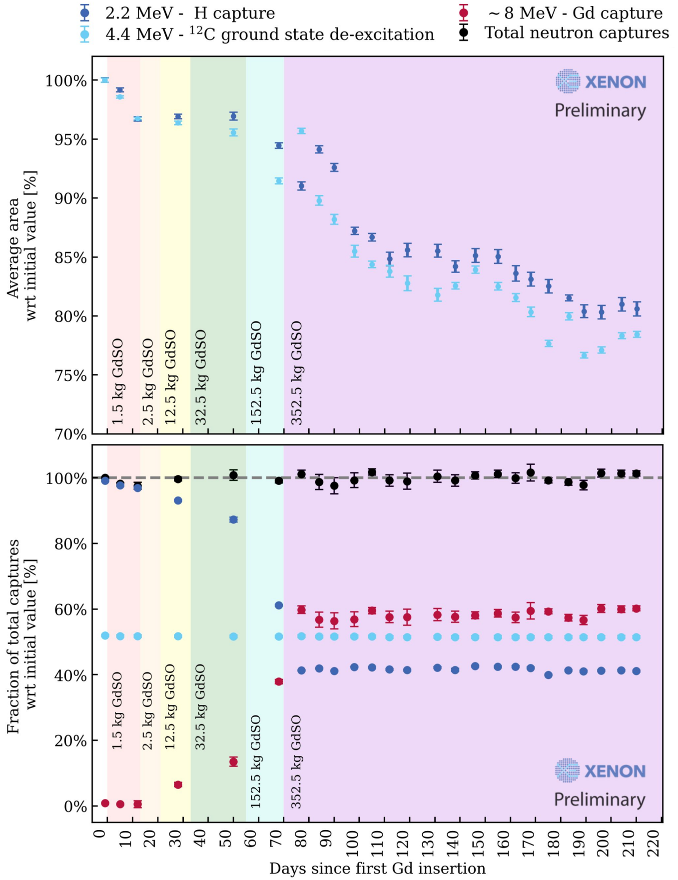
About **60%** of captures occurs **on Gd.** Given the **large** water buffer in this source position, **total number** of **n-capture** does **not change** with Gd



Neutron tagging efficiency with Gd

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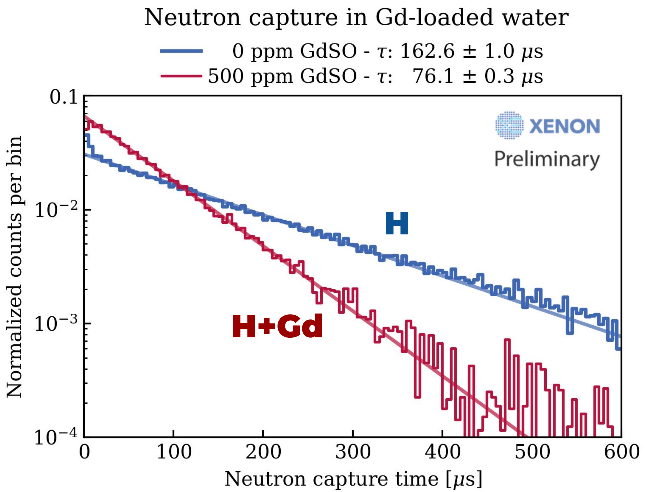
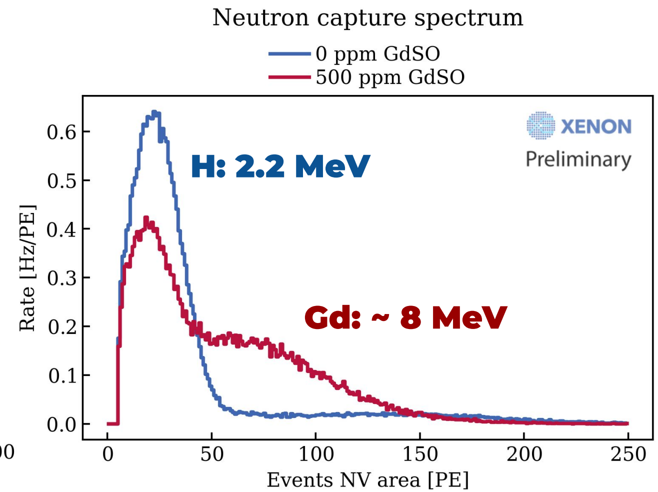
At 500 ppm GdSO, **average** neutron **capture time** around **76 μs** (2x **shorter** than in **demi-water**) and **larger** average **area**, with a **10% increase** in neutron **captures.**





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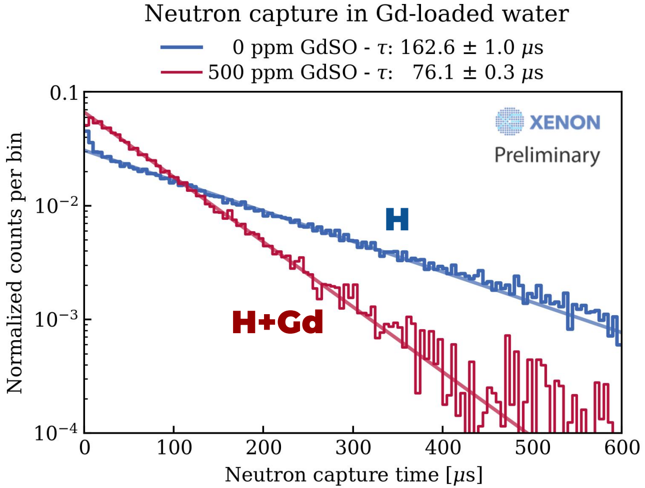
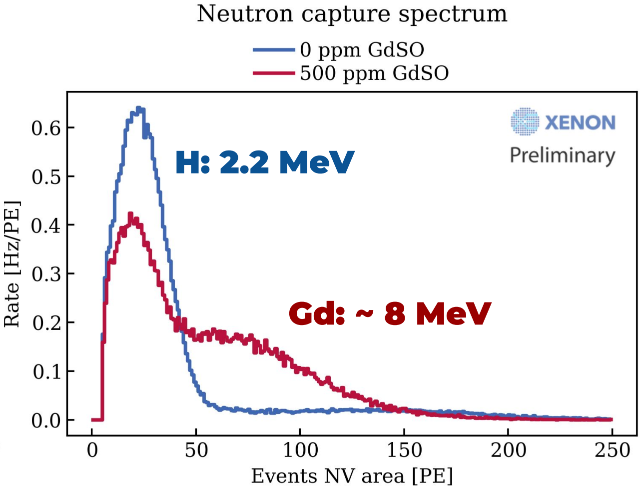
AmBe calibration with **source close** to **cryostat** (**~ 1 cm**) → events with **same** characteristics of **neutron** emitted from **detector materials**

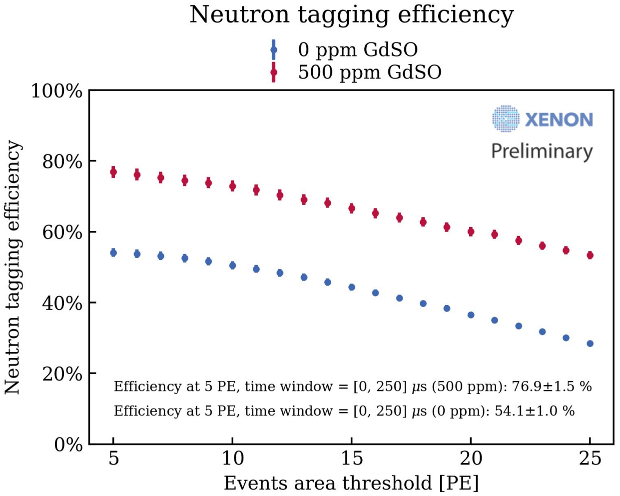
Neutron **capture time** and **area spectrum** can be **estimated** by using **NV** only (**self-trigger**), by looking for NV events **following 4.4 MeV** signals from AmBe source in NV

At 500 ppm GdSO, **average** neutron **capture time** around **76 μs** (2x **shorter** than in **demi-water**) and **larger** average **area**, with a **10% increase** in neutron **captures.**

Tagging efficiency is estimated by **requiring coincidence** with **nuclear recoils** detected in the **TPC**
Neutron tagging efficiency with **500 ppm** of GdSO, in a **250 us** time-window, is about **77%** (about **53%** in SR0):
→ a **factor 2** neutron **background reduction** wrt SR0 with demi-water







Conclusions and future perspective

IN A NUTSHELL

Radiogenic **neutron** background now **relevant** for DM direct search

XENONnT **nVeto** with **demi-water** reached **53% neutron tagging efficiency** in **250** μs time window (68 % in 600 μs)

Currently, **nVeto** is doped with **500 ppm** GdSO (**0.02% Gd mass** concentration), neutron **tagging efficiency** increased up to **77%**, with neutron **background reduction** by **factor 2** wrt to SR0

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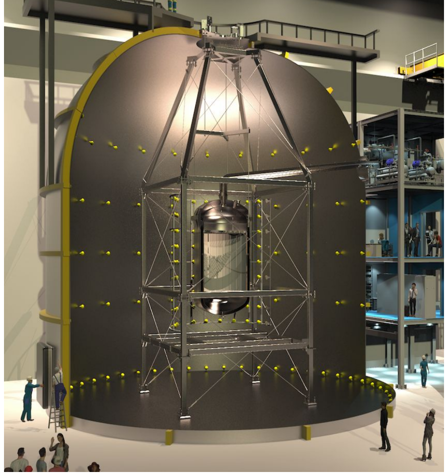
WHAT'S NEXT

Planned **XENONnT** nVeto with **3.5 t** of **GdSO** (0.5% of GdSO, **0.2 % Gd mass concentration**), with **tagging efficiency** of **87%**

Neutron background will be **further reduced** by **factor 3** wrt to SR0

Gd-loaded water technology can be effectively **employed** for **next-generation** LXe detector

Planning the future DARWIN/XLZD observatory, T. Pollman, TAUP 2023



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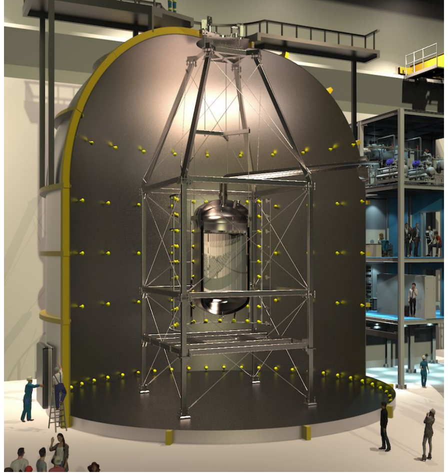
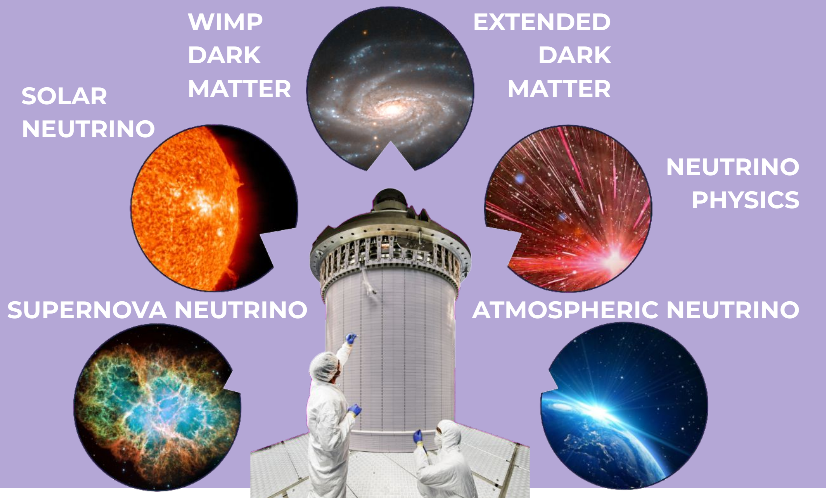


NEXT-GENERATION LXe EXPERIMENT

Dual-phase Xe TPC with **~60** t of active **LXe**, from the **joint** efforts of **XENON**, **LZ** and **DARWIN** collaboration into the **XLZD consortium**

Multi-purpose observatory for **dark matter, neutrino** and **rare events**, probing **WIMPs** down to **neutrino floor**



J. Phys. G: Nucl. Part. Phys. 50 013001

INFN LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

EDSU-Tools 2024

XENON

Merci pour votre attention!

XENON OFFICIAL WEBSITE
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facebook.com/XENONexperiment/

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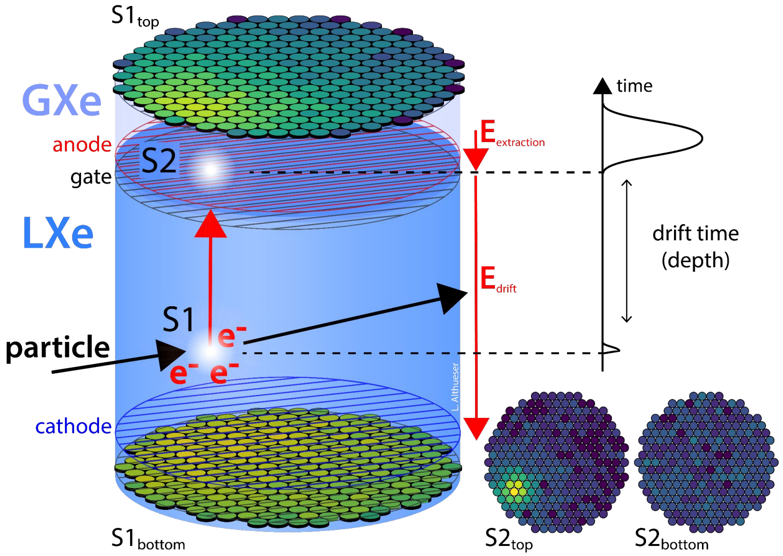
twitter.com/xenonexperiment

Questions?

BACKUP

Dual-phase Time Projection Chamber



ENERGY RECONSTRUCTION
from **combining S1** and **S2** signals

3D POSITION RECONSTRUCTION
x-y from PMTs **light pattern**, **z** from **drift time**

RECOIL TYPE IDENTIFICATION
S2/S1 different for **Electronic Recoils** (**ER**) and **Nuclear Recoils** (**NR**), resulting in two bands

In **dual-phase** Time Projection Chamber (**TPC**) **scintillation** and **ionization** signals:

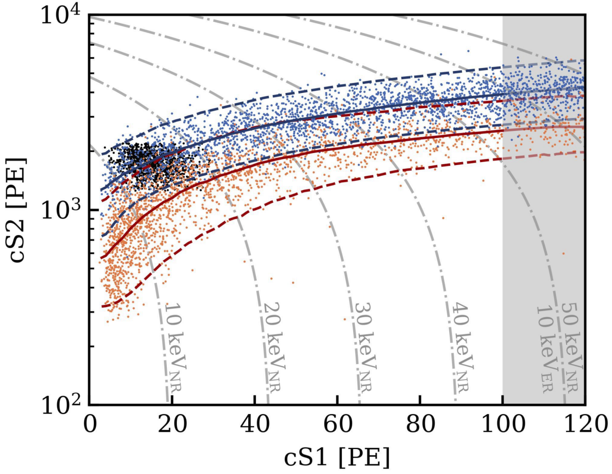
- **Prompt scintillation** light → **S1**
- **Secondary scintillation** proportional to **drifted electrons** → **S2**

Electronic Recoils

Electrons, photons, neutrinos, (axions ...)

Nuclear Recoils

Neutrons, neutrinos via coherent scattering, (WIMPs ...)



Phys. Rev. Lett. 131, 041003, 2023

Upgrades in XENONnT

- **3x** larger **active** mass and **4x** larger **fiducial mass** with **lower material background**
- **2x PMTs** and **better light collection** efficiency
- **Triggerless** Data Acquisition: all data above threshold stored long term
- Additional **LXe purification**: **e-lifetime 0.65 ms → 15 ms**
- **Radon Distillation: ^{222}Rn** suppressed to **~1.8 μBq/kg**

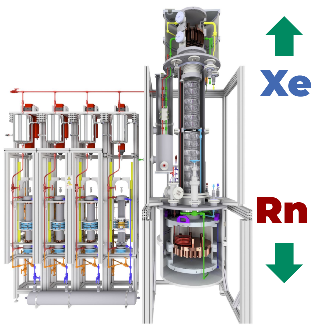
Radon Removal System

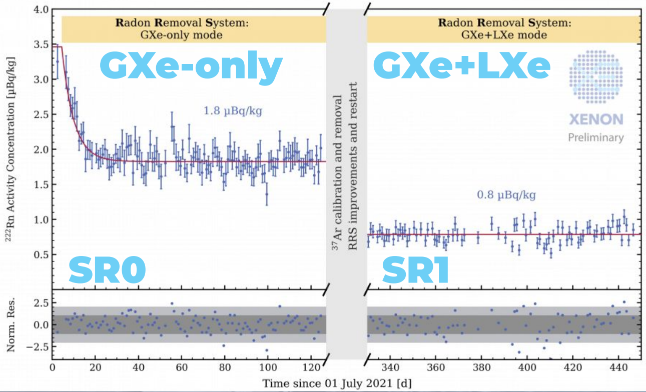
- ^{222}Rn (major ER background) mostly from pipes, cables and cryogenic system
- Continuous distillation at ~70kg/h
- 4.3 μBq/kg → 1.8 μBq/kg in SR0 & 0.8 μBq/kg in SR1

LXe purification

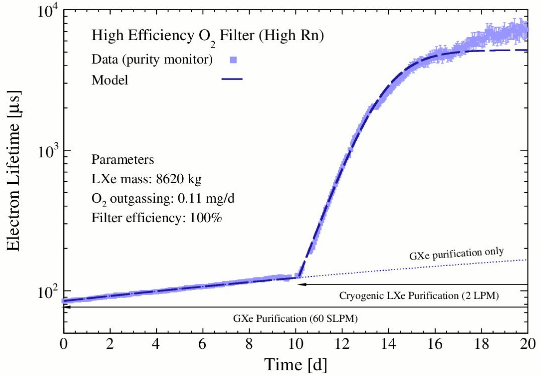
- Removing electronegative impurities (H_2O and O_2)
- Only ~14% charge loss for a full drift length 1.5m
- Purification up to 16 tonne/day

Radon Removal System





LXe purification



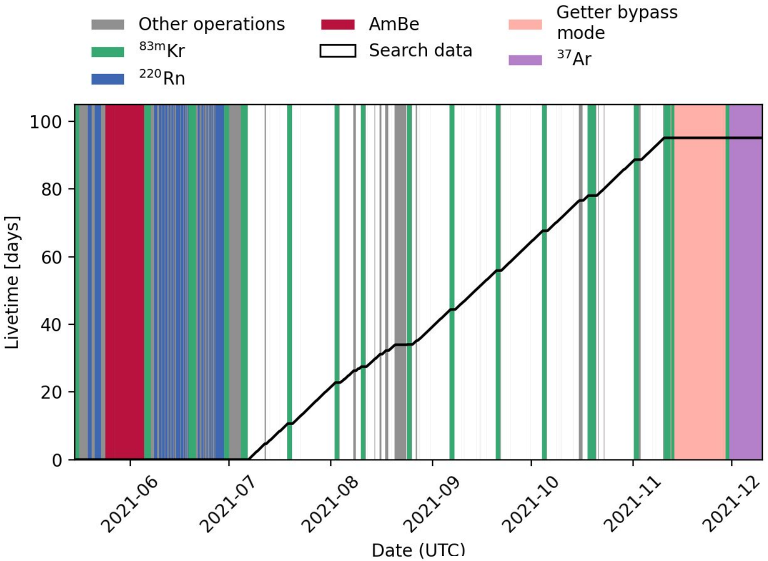
XENONnT Science Run 0

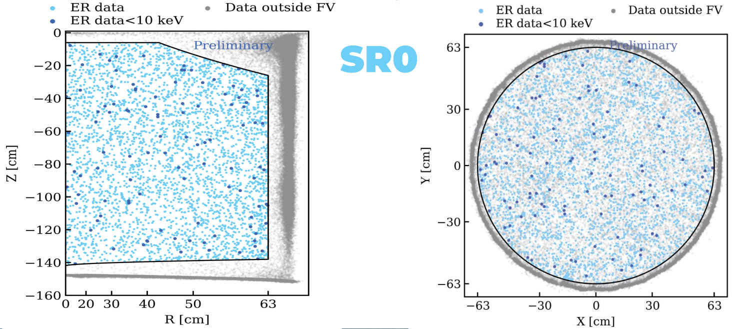
Science Run 0 (SR0)

- **Electronic** and **Nuclear** Recoils **search** data
- **97.1 days** of **exposure** from July 6th - Nov 11th 2021 (**95.1 days** lifetime corrected)
- Duration optimized to **investigate** XENON1T **Low-E ER excess**
- **Fiducial Volume**: **4.18 ± 0.13** tonne for **NR** and **4.37 ± 0.14** tonne for **ER** search
- **Exposure**: about **1.1 tonne-year**
- **Blind** analysis in FV and low energy region for both NR and ER

Detector **configuration** in SR0:

- Drift field: **23 V/cm**
- Extraction field in LXe: **2.9 kV/cm**
- **477** out of 494 PMTs working
- **Localized** high **single-electron** emission **sporadically**, anode ramped down





WIMP searches NR background

ELECTRONIC RECOILS (ER)

- **Dominated by ^{214}Pb** (from ^{222}Rn)
- Suppressed by **ER/NR separation**

ACCIDENTAL COINCIDENCE (AC)

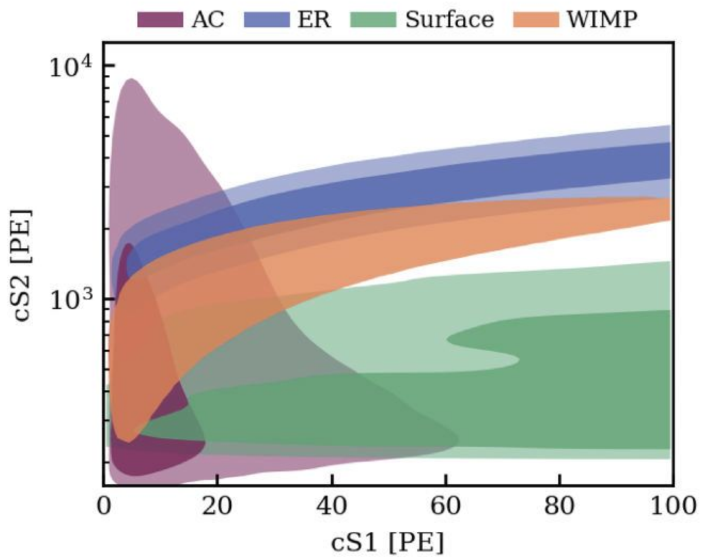
- **Random** pairing of **isolated S1/S2**
- **Suppressed** by analysis **cuts**

SURFACE

- **^{210}Pb** plate-out during **construction**
- **Radial** selection

NUCLEAR RECOILS (NR)

- **Radiogenic** neutrons: fission & (α, n)
- **CEvNS**: Solar & atmospheric **neutrinos**



ER	AC	Surface
134	4.3 ± 0.2	14 ± 3
Neutrons	**CEvNS**	**Total**
$1.1^{+0.6}_{-0.5}$	0.23 ± 0.06	154

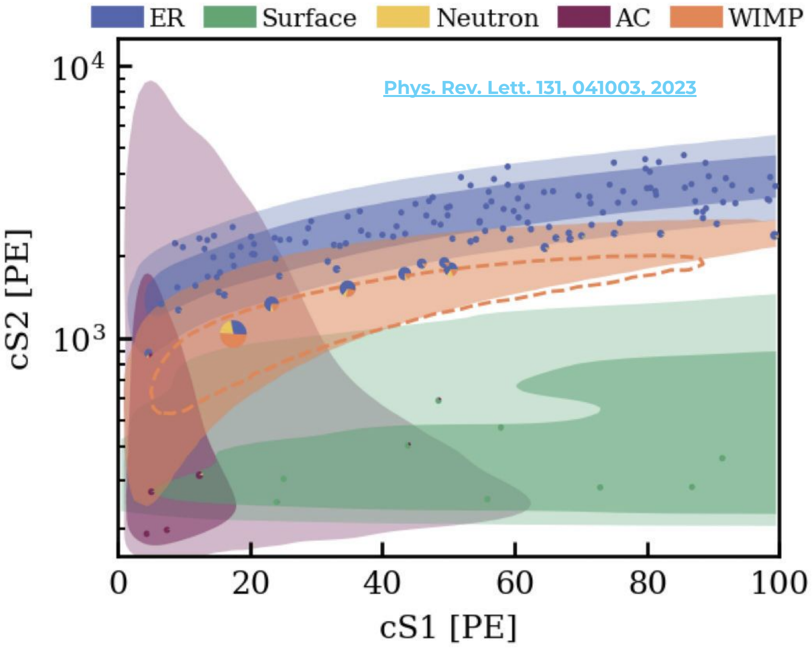
WIMP searches results

- **152 events** in **NR/ER** search region
- **16** in **NR blinded** region
- **No** significant **excess**
- **Best fit** assuming a **200 GeV/c^2 WIMP** and **σ = 2.5 × 10^{-47} cm^2**

	Nominal	Best fit	
	ROI		Signal-like
ER	134	135^{+12}_{-11}	0.92 ± 0.08
Neutrons	$1.1^{+0.6}_{-0.5}$	1.1 ± 0.4	0.42 ± 0.16
CEνNS	0.23 ± 0.06	0.23 ± 0.06	0.022 ± 0.006
AC	4.3 ± 0.9	$4.4^{+0.9}_{-0.8}$	0.32 ± 0.06
Surface	14 ± 3	12 ± 2	0.35 ± 0.07
Total background	154	152 ± 12	$2.03^{+0.17}_{-0.15}$
WIMP	…	2.6	1.3
Observed	…	152	3

4.4 t fiducial volume

1.1 t x y exposure



Pie-chart:
Event showing the **fraction** of the **best-fit PDF** for a **200 GeV** mass **WIMP** (assuming there are WIMPs)

Signal-like region:
containing 50% of a 200 GeV/c^2 WIMP signal with highest signal-to-noise ratio

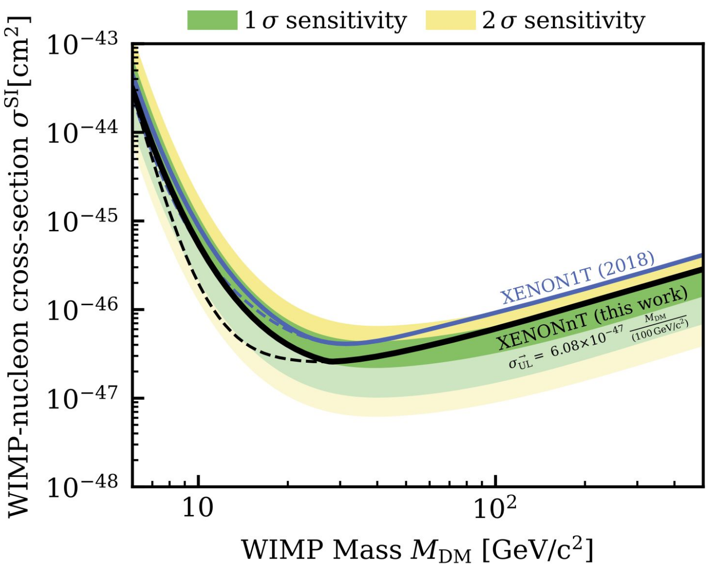
Limits on WIMP interactions with nucleons

Median **upper limit** at **90% confidence** (Feldman-Cousin construction obtained by MC) for Log-Profiled **Likelihood ratio** (PDF in cS1, cS2, R)

WIMP discovery **p-value** indicates no significant excess

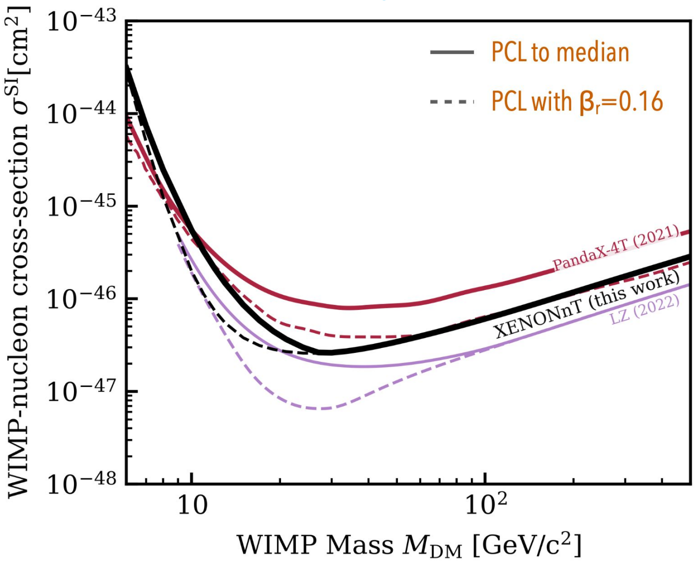
Power constraint limits (PCL) to avoid **problematic** spurious **exclusion** (too low exclusion limits) → Conservative **PCL** to **0.5** (median)

Upper limit for **WIMP** interactions σ, minimum at **2.6 × 10⁻⁴⁷ cm²** at **28 GeV/c²** (spin-independent), **improvement** by **factor 1.7** wrt XENON1T



Comparison to other blinded analysis

Phys. Rev. Lett. 131, 041003, 2023

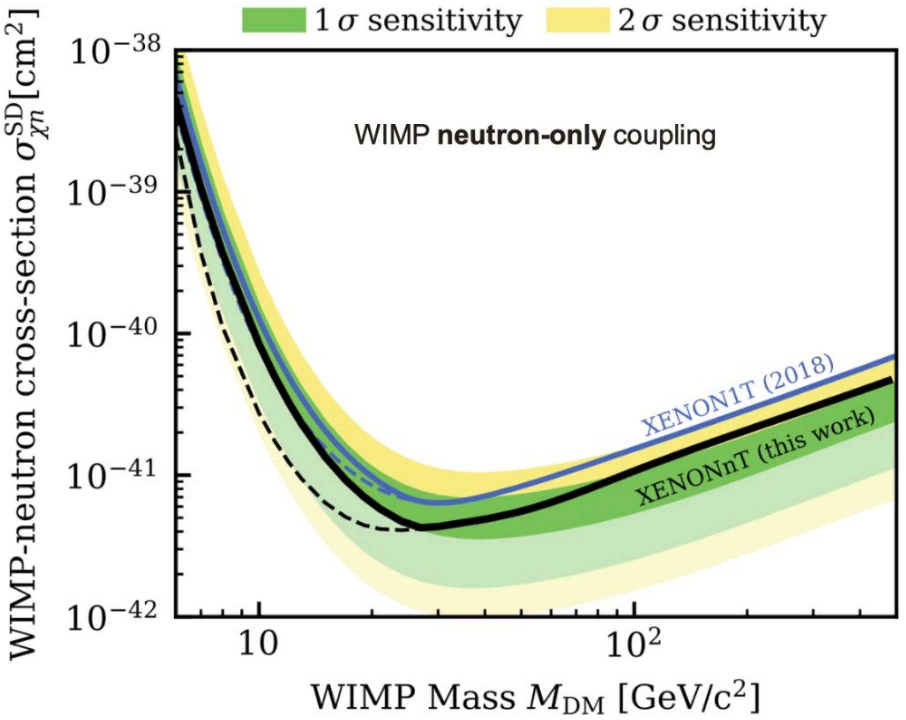


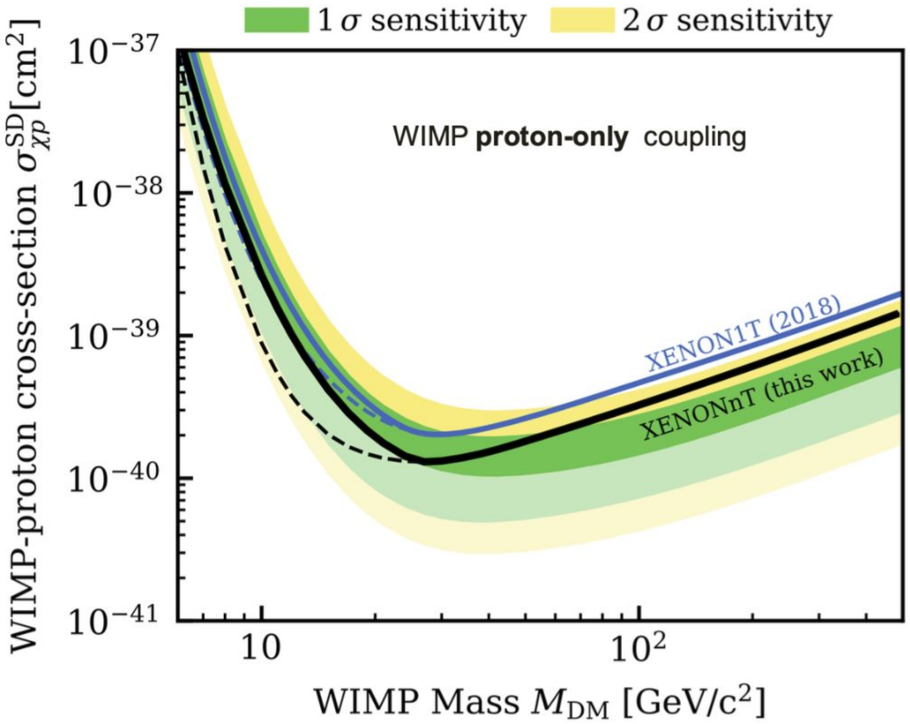
Comparison to other unblinded analysis

These limits are obtained for spin-independent (SI) process, similar results can be obtained also for spin-dependent (SD) interactions with protons or neutron in LXe nuclei

Limits on WIMP interactions with nucleons

Phys. Rev. Lett. 131, 041003, 2023





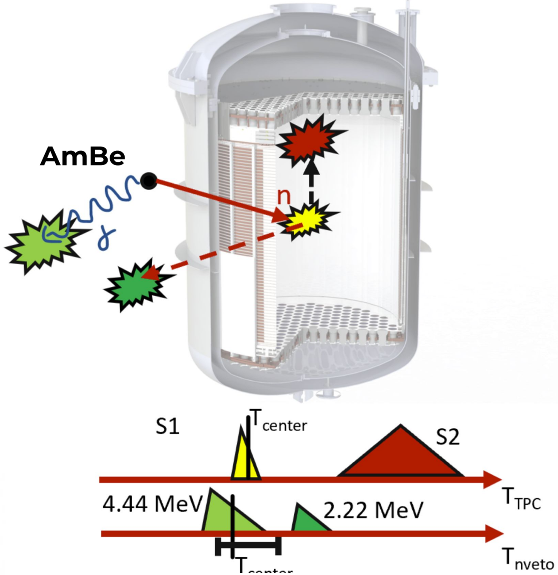
Neutron calibration with AmBe source

Neutron calibration with **AmBe source** placed **close** to the **cryostat**

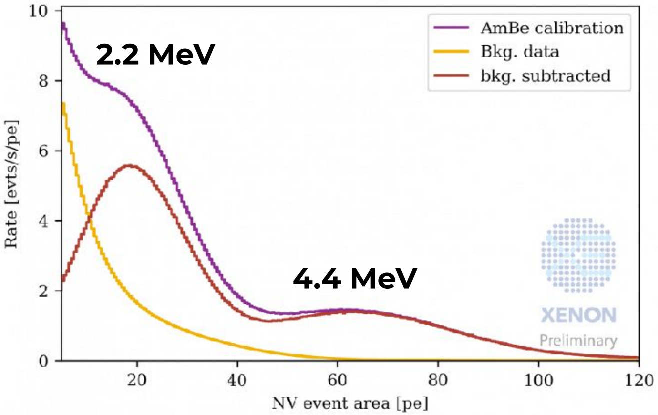
AmBe emits a **4.4 MeV** gamma together with the **neutron** in about **50%** of cases

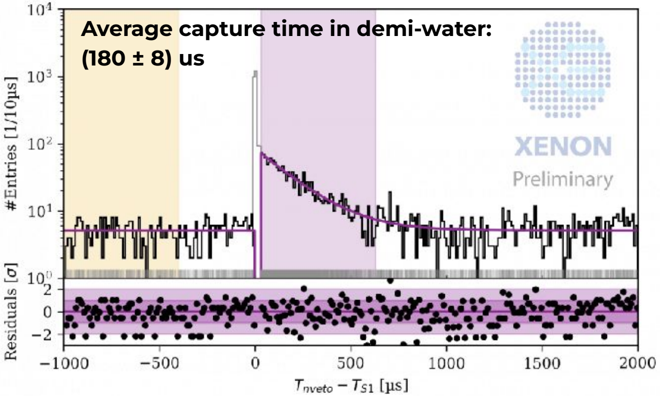
Detect the **4.4 MeV** gamma, require the **coincidence** with a **single-scatter NR** event in the **TPC** and look for the **2.2 MeV** gamma of **neutron capture on H** in the nVeto

Direct measurement of the **neutron tagging efficiency** of the nVeto:
(**68 ± 3**)% at **5-fold** coincidence, **5 PE** threshold and **600 us time window**



Highest neutron detection efficiency ever obtained in a water Cherenkov detector!

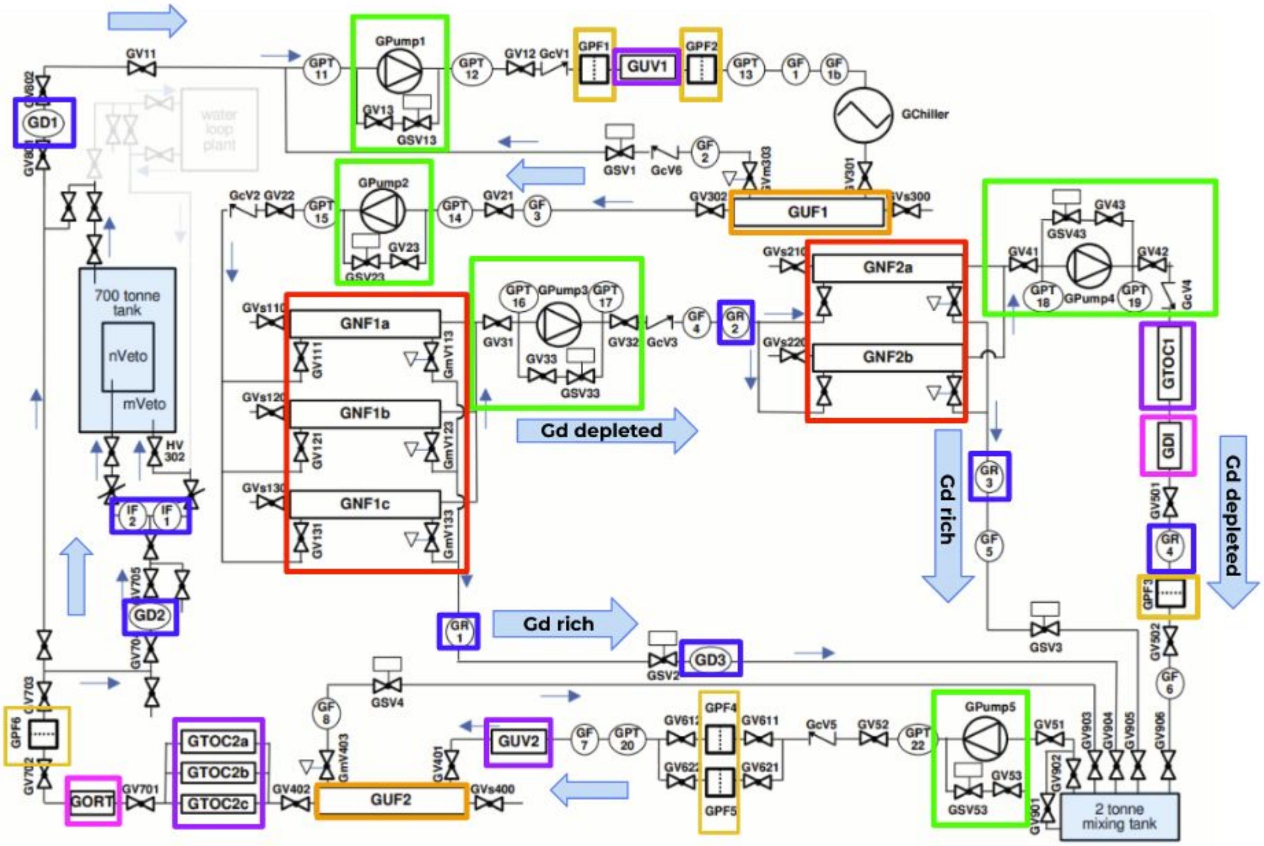




In **Science Run 0**, time **window** reduced to **250 us** to lower the dead time.
The **efficiency** is (**53 ± 3**)%, and **livetime loss** is **1.6%**.

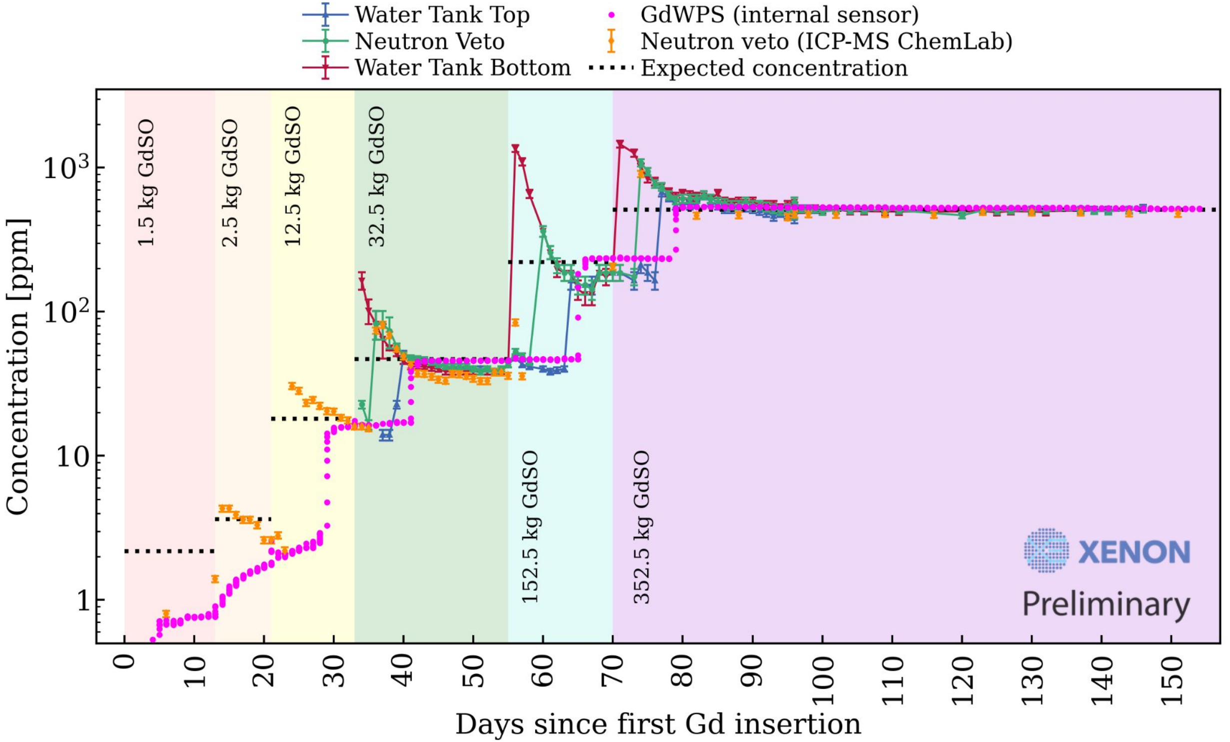
Gd-water Purification System

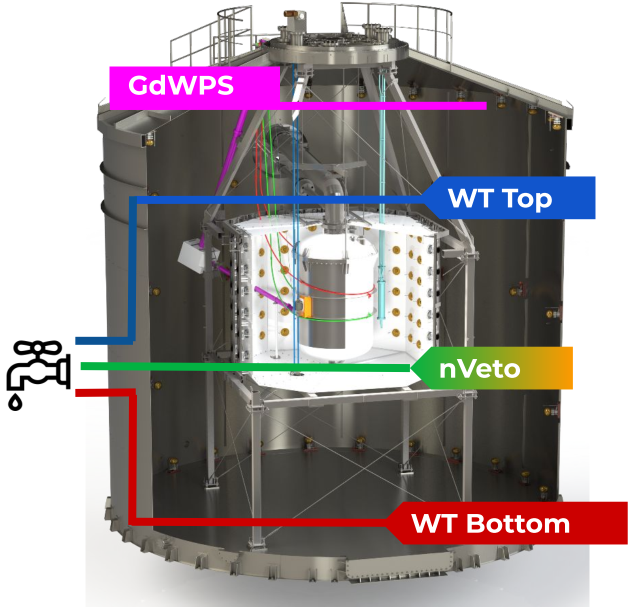
- Preliminary **filtration** and **treatment** of **Gd-water**
- **Separation** via **NanoFiltration** (NF1 and NF2) into a **Gd-rich** part and a **Gd-depleted** part
- **Gd-rich** water sent directly into **Mixing Tank**
- **Gd-depleted** part **purified** via a standard water treatment as **DeIonization**
- **Gd-depleted** then **mixed again** with the other branches
- **Return** to the main 700 t **water tank** of **XENONnT**, after other **treatments**



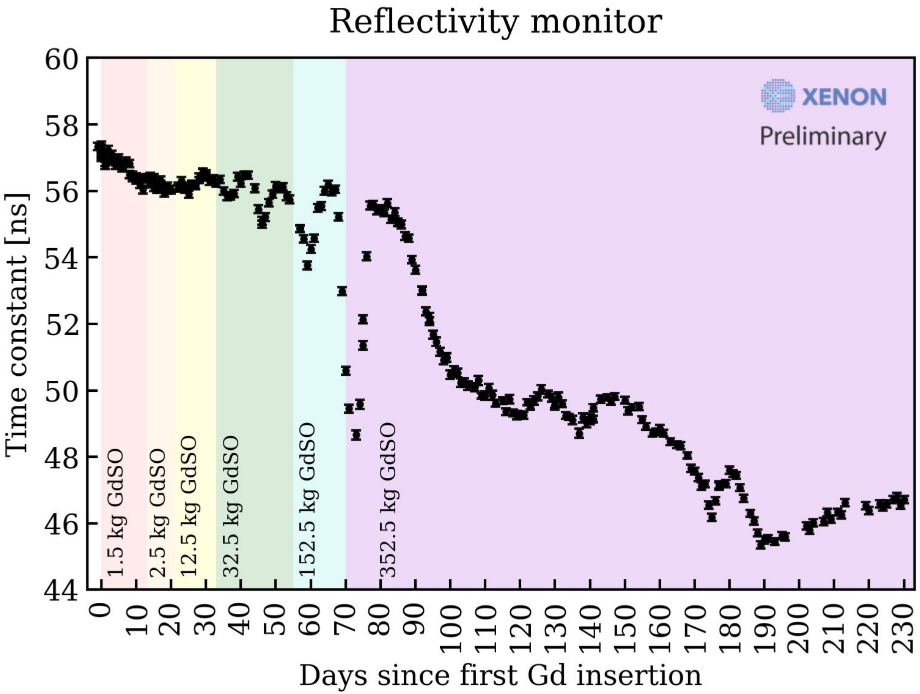
GdSO insertion in the Water tank

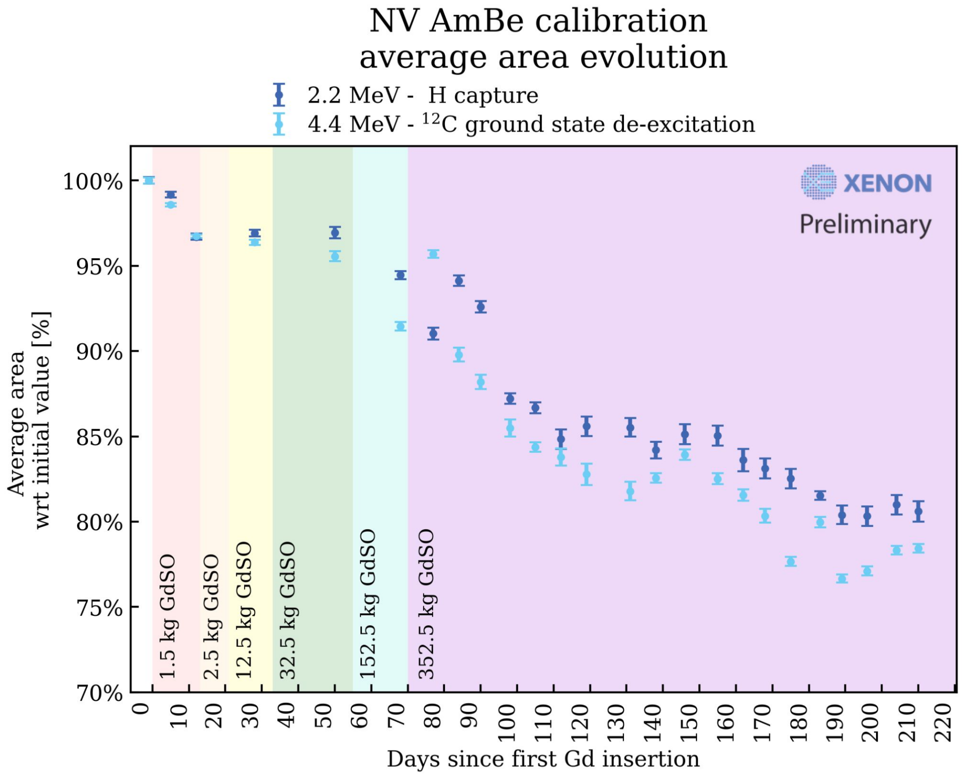
Gd-sulfate **concentration** in the **system** can be estimated with **direct** measurements of **Gd** via mass spectrometry (**ICP-MS** at **LNGS chemistry lab**), **conductivity** of small **samples** from **WT** (performed in situ) **and conductivity** measured by **GdWPS** inner sensor (online)





Neutron Veto optical properties





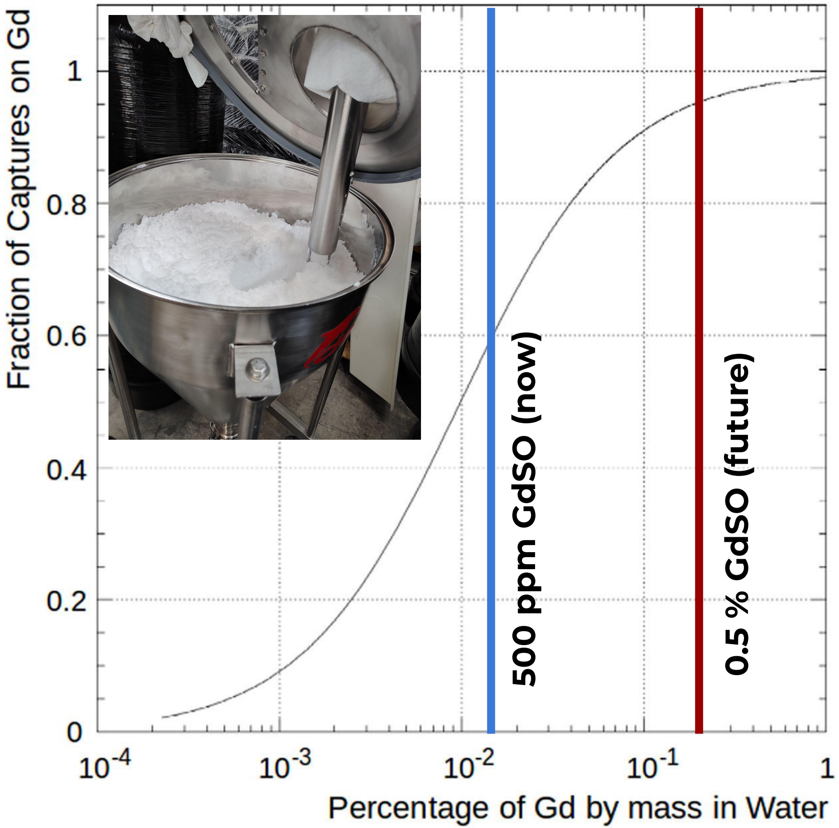
n-captures on Gd as function of concentration

Fraction of **neutrons** captured on **Gd** as a function of its **concentration** in water by **mass**

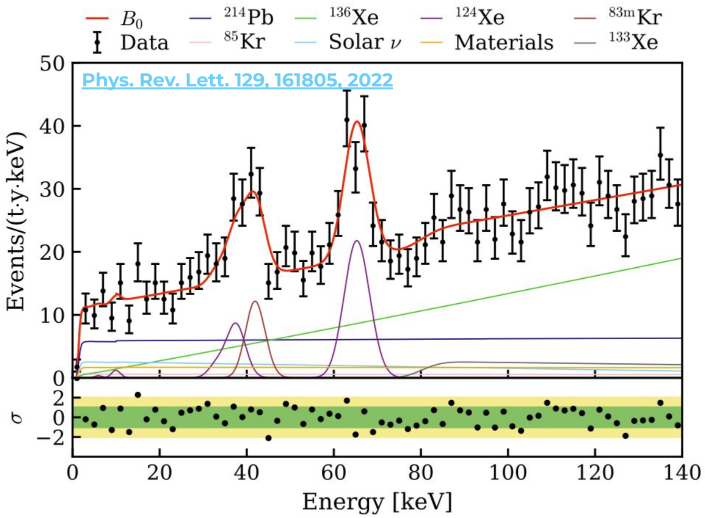
Currently, **nVeto** doped with **500 ppm** GdSO (**0.02% Gd mass** concentration), **tagging efficiency** increased up to **77%**,

Planned **XENONnT** nVeto with **3.5 t** of **GdSO** (0.5% of GdSO, **0.2 % Gd mass concentration**), with **tagging efficiency** of **87%**

L. Marti et al., NIMA 959, 163549 (2020)



Low-energy ER search in XENONnT



Component	Constraint	Fit
^{214}Pb	(570, 1200)	960 ± 120
^{85}Kr	90 ± 60	90 ± 60
Materials	270 ± 50	270 ± 50
^{136}Xe	1560 ± 60	1550 ± 50
Solar neutrino	300 ± 30	300 ± 30
^{124}Xe	···	250 ± 30
AC	0.70 ± 0.04	0.71 ± 0.03
^{133}Xe	···	150 ± 60
^{83m}Kr	···	80 ± 16

Background model including **9 components**

Full **blind analysis** with various stages of unblinding

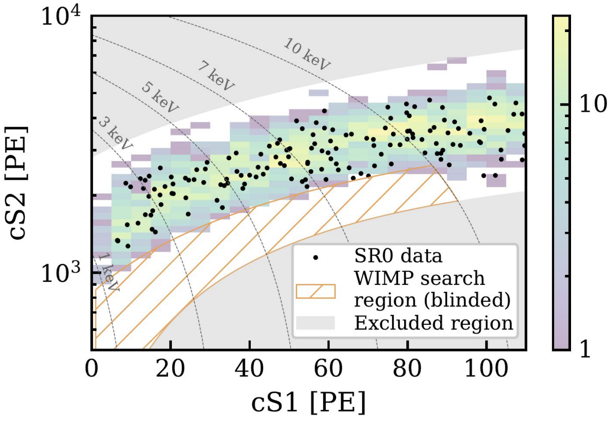
Spectral shape dominated by **second order weak** processes

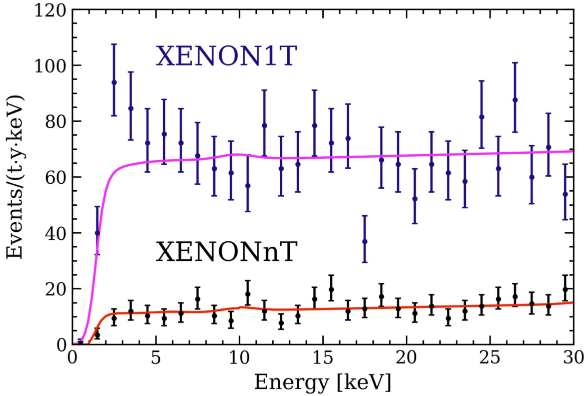
^{124}Xe 2vDEC (half-life ~ **1.8 x 10^{22} yr**, **rarest** process **observed**, first time in **XENON1T**) now used for **energy reconstruction**

^{214}Pb (from ^{222}Rn chain) **dominant** component **below 30 keV** with concentration of about **1.3 μBq/kg** (**1 atom** in **10 mol Xe**)

An **excess** of the **XENON1T** magnitude is **excluded** at **8.6σ**

XENON1T excess was probably due to **^{3}H tritium**

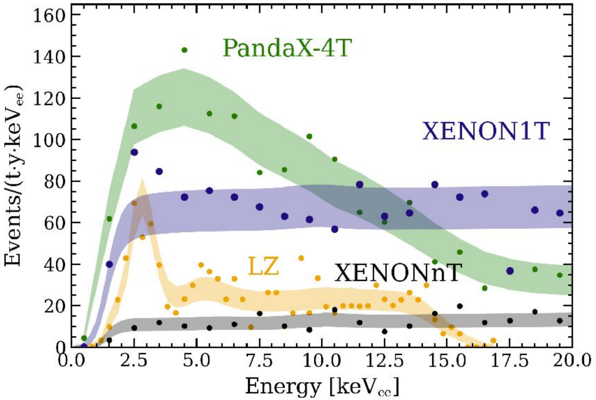




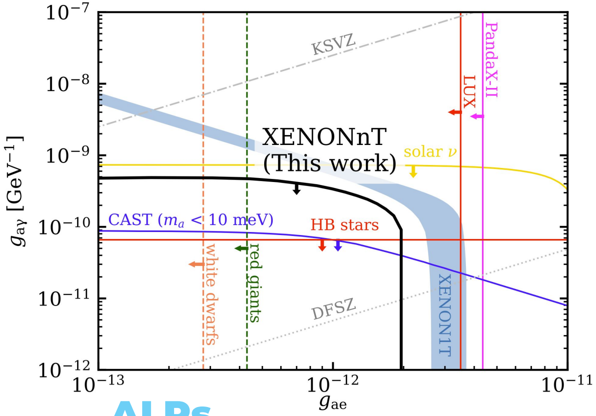
Low-energy ER results

Background ~5x smaller than in XENON1T. **Lowest ER background** ever for a **DM experiment:** (**15.8 ± 1.3**$_{\textbf{stat.}}$)events/(t · y · keV)

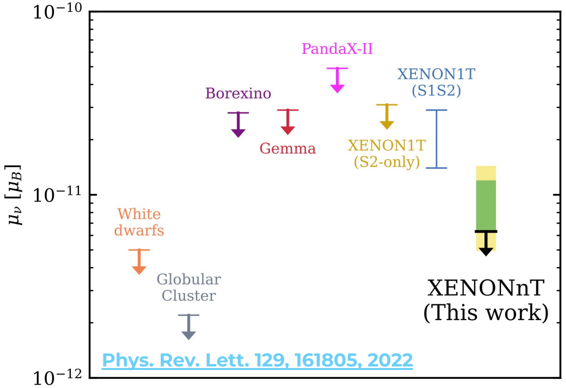
Leading **limits** among **non-astronomical** observation for physics **beyond standard model**



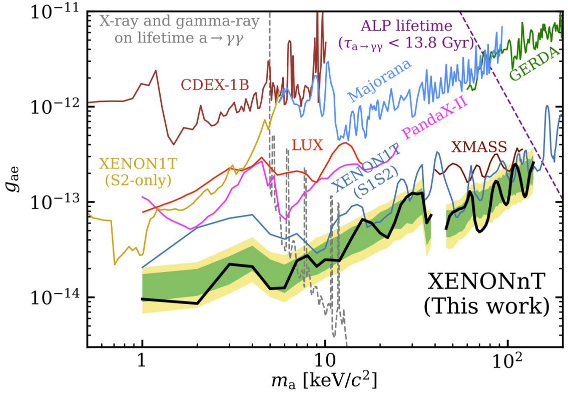
Solar axions



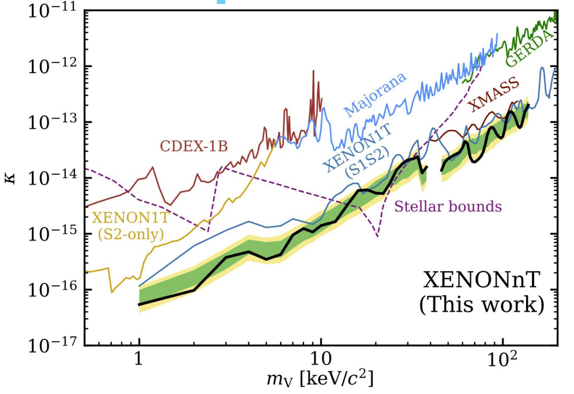
Neutrino magnetic moment



ALPs



Dark photons



Neutrino searches in XENON detectors

After the first **science run** (**SR0** with **~1 t×y**), **another science run** (**SR1**) has **started** to collect data, to obtain the **exposure** needed to perform **these searches** and **improve** obtained **limits**

Search	Recoil	Energy	Physics
Neutrinoless Double β decay ($0\nu\beta\beta$) in ^{136}Xe	ER	2458 keV	Beyond Standard Model
2 Neutrinos Double Electron Capture ($2\nu DEC$) in ^{124}Xe	ER	64.3 keV	Standard Model
Solar pp Neutrinos with Enhanced Magnetic Moment	ER	O(1) keV - O(100) keV	Beyond Standard Model
Solar pp Neutrinos Elastic Scattering	ER	O(1) keV - O(100) keV	Standard Model
Supernova (SN) Neutrinos	NR	< 10 keV	Standard Model
Solar ^{8}B Neutrinos CEvNS	NR	< 3 kev	Standard Model

Nature 568, 532–535, 2019

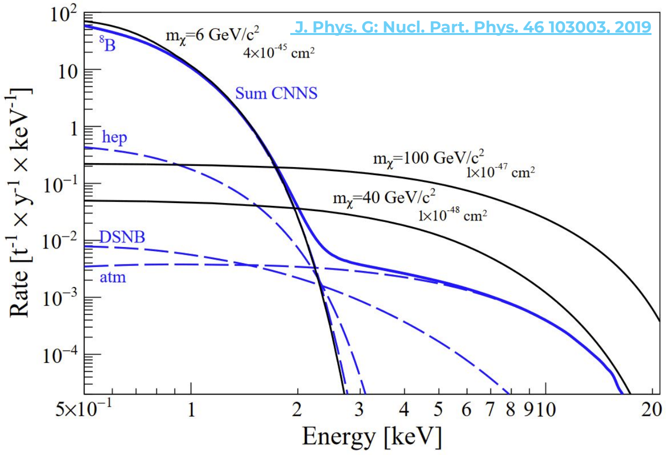
First observed in XENON1T

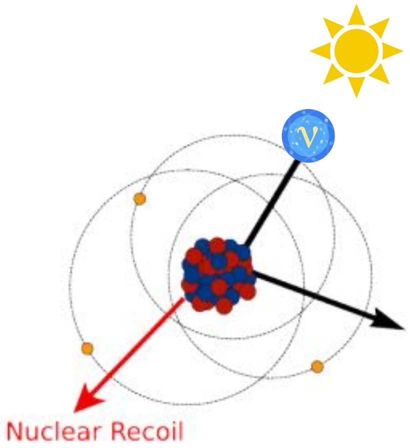
Longest half-life ever measured!

Dark matter and neutrino detection

WIMP dark matter is expected to induce **O(1)-O(10) keV NR scattering** off xenon atoms, as well as neutrons

Coherent elastic neutrino nucleus scattering (**CEvNS**) has the **same** signature of **low mass** spin-independent **WIMP** interaction, producing low-energy **NRs** (via Z-exchange, $\propto (A-Z)^2$)



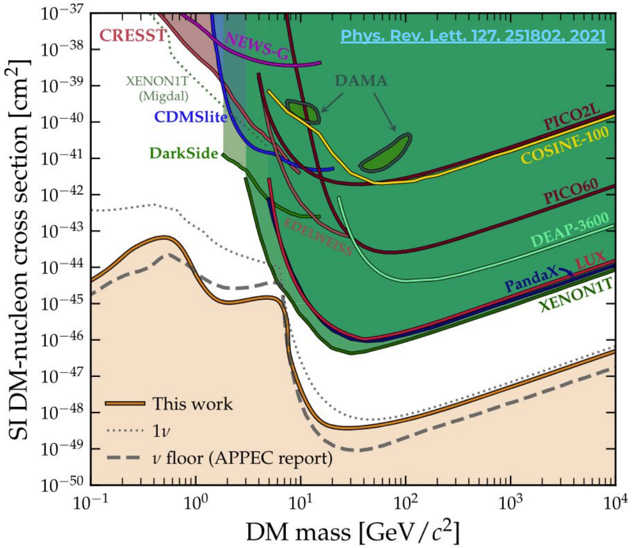


CEvNS process, first measured in **2017** by **COHERENT**, has **never** been observed for **solar neutrinos**

Solar ^{8}B, which is the **main** contributor, can be treated as a **signal** and **detected** in LXe **DM** experiment!

Current detectors are approaching the **neutrino "fog"**, where **distinction** between WIMPs and neutrinos is **challenging**

Neutrino "**floor**", indicated where DM experiment are inevitably limited by **irreducible background** from neutrinos



Solar ^{8}B Neutrinos CEvNS search

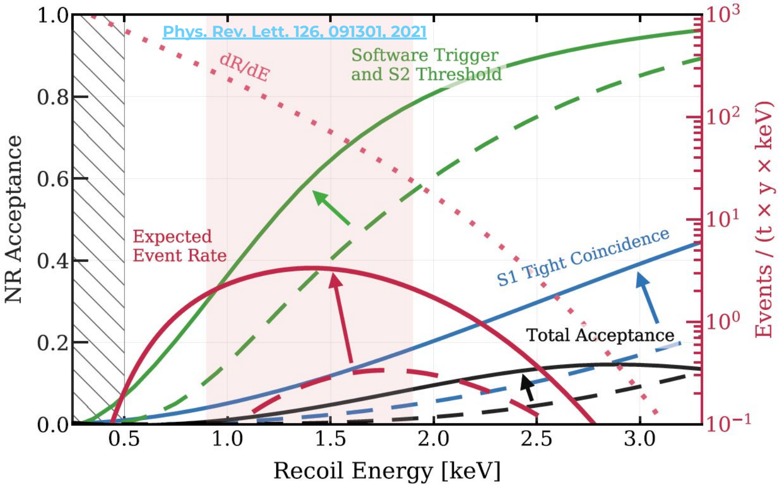
INCREASED DETECTION EFFICIENCY

S1 threshold: 3 → 2 PMTs coincidence

S2 threshold: 200 → 120 PE

Expected **total efficiency** for CEvNS around **1%**

Lower energy **threshold** → **Background rate** increased by **two orders** of magnitude



LOW-ENERGY BACKGROUND REDUCTION

Main background for **CEvNS** given by **Accidental Coincidences** (AC), resulting from random **pairing** of **isolated S1s** and **S2s**.

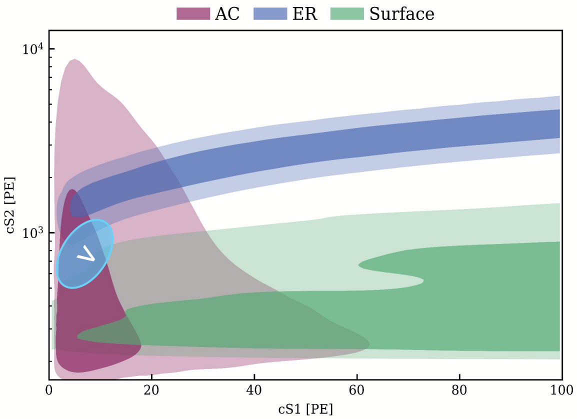
Various **mitigation** strategies: excluded events in **proximity** of **large peaks**, dedicated **selection** in **specific observables**, **machine learning** techniques and AC background modeling

Isolated **S1s**

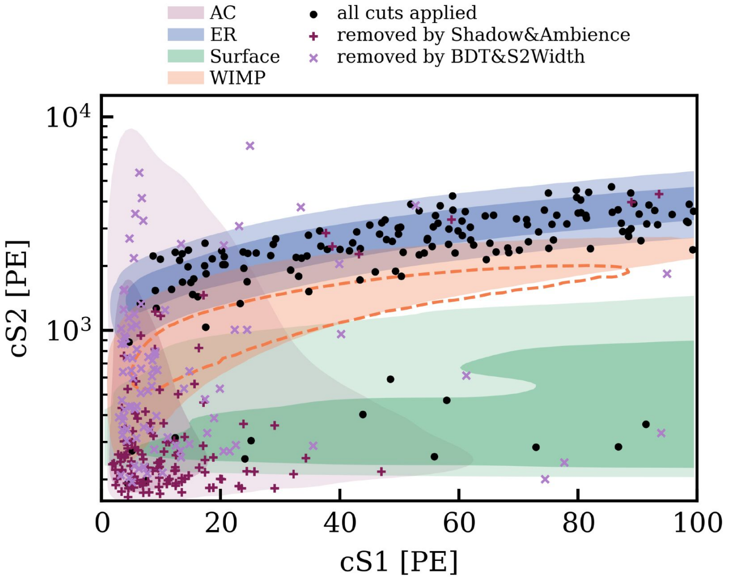
- → PMT **dark counts**
- → Misidentified **single electron**
- → Below-**cathode** and **surface** events

Isolated **S2s**

- → **Single electrons** from **delayed** extraction or **photo-ionization**
- → Misidentified PMT **afterpulses**



Solar ^{8}B Neutrinos CEvNS search



Accidental coincidence background **reduced** and modelling **validated** in the **XENONnT WIMP** analysis (Science Run 0)

Now need to perform a dedicated **low-threshold 2-fold** coincidence analysis!

	Isolated S1	Isolated S2	Drift field	Max drift	Relative AC rate	Exposure
XENON1T	11.2 Hz	1.1 mHz	82 V/cm	730 us	1	0.6 t × y
XENONnT	2.5 Hz	18.5 mHz	23 V/cm	2200 us	11	> 0.6 t × y

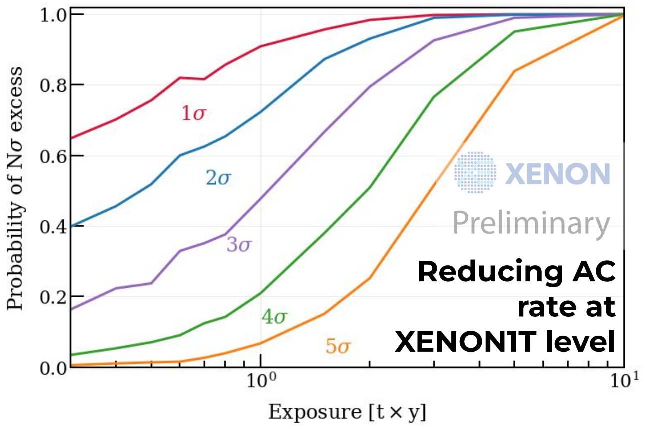
Lower drift **field** results in:

- **larger** isolated **S2** rate
- **longer drift** time
- **worst** NR-ER **discrimination**, but negligible for CEvNS

Higher exposure in XENONnT

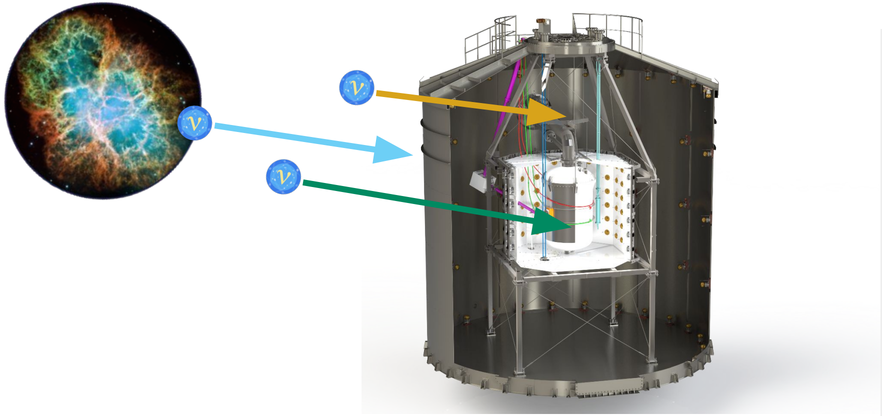
Larger AC rate but improved **AC suppression** with new techniques

Discovery potential in XENONnT should be increased



XENONnT will be more sensitive to solar ^{8}B neutrino and a first observation could be within reach

Supernova neutrino



SUPERNOVA NEUTRINO CHANNELS IN XENONnT

→ **TPC**, **6 t** of LXe

$\nu_{e,\,\mu,\,\tau}$, $\bar{\nu}_{e,\,\mu,\,\tau}$ via **CEvNS** (charged and other neutral current are subdominant)

~ **100 expected** events from supernova at 10 kpc

→ **MUON & NEUTRON VETO**, **700 t** ultra-pure water

$\bar{\nu}_e$ via **inverse beta** decay with H

~ **70 - 200 expected** events from supernova at 10 kpc

PREDICTIONS IN XENONnT

Neutrinos deposit around **O(1) keV** in LXe

Background stable in time, can be reduced with **specific selection** (similar to ^{8}B search)

Possible improvements using **coincident** signals from **vetoes**

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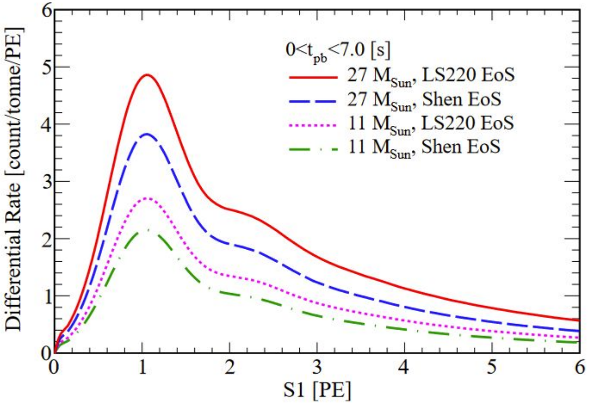
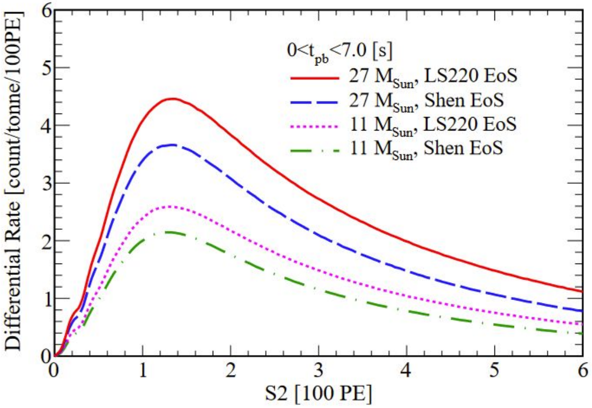




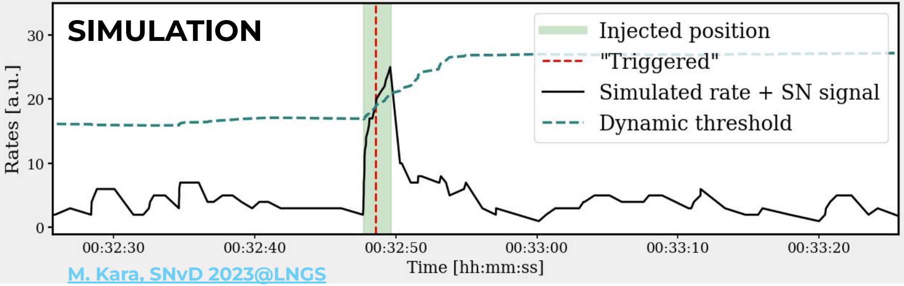
Supernova neutrino

SENSITIVITY PROJECTIONS

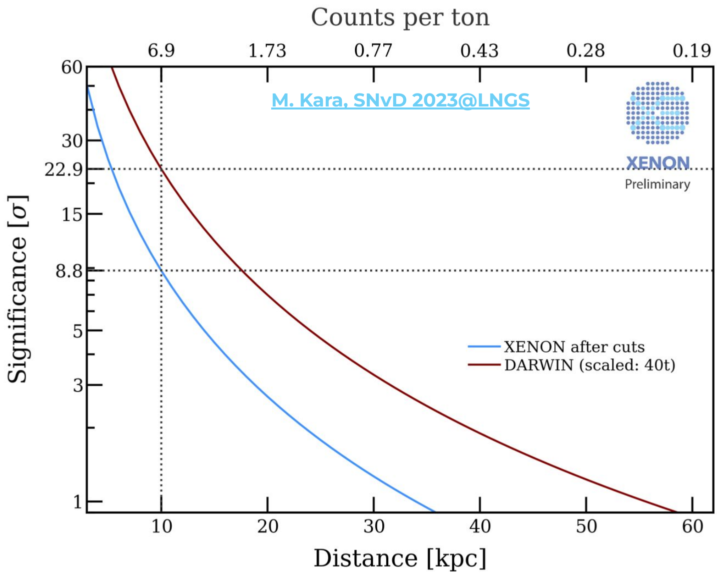
Cuts can **reduce background** down to **~3 Hz**, while **average signal** (SN at **10 kpc**) will results in **~45 events** in **~ 6 s** (~ 18 background events)

Triggerless DAQ allows **continuous** data taking and **increases** in **rate** with respect to a **dynamic threshold** can be monitored online

Considering signal evolution, time **window** can be **optimized**, resulting in ~8σ significance (10 kpc)



M. Kara, SNvD 2023@LNGS



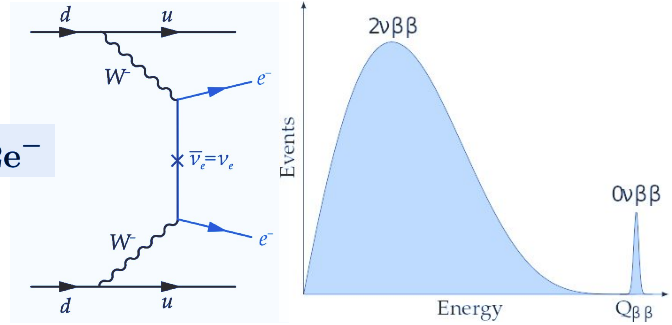
SNEWS INTEGRATION

XENONnT is **ready** to join the **Supernova Early Warning System** (**SNEWS**)

It will **receive** incoming **alerts** to check data and **send** possible **supernova observations**

Neutrinoless double-beta decay in ^{136}Xe

$^{136}Xe \rightarrow ^{136}Ba + 2e^-$



In XENONnT ^{124}**Xe** & ^{136}**Xe (0.1%** and **8.9% abundancy)** are **long-lived** isotope which produce detectable ER signals

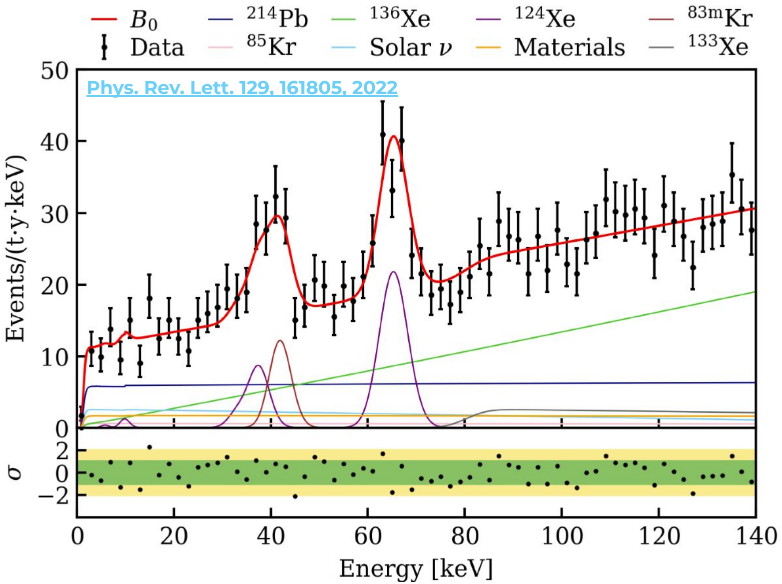
First **observation** of ^{124}**Xe 2νDEC** in **XENON1T** demonstrated **sensitivity** to **extremely rare events** and can be used to constrain **Nuclear Matrix Element (NME)** calculations

2νββ-decaying ^{136}**Xe isotope with** $Q_{\beta\beta}$ = (**2457.83** ± 0.37) **keV** is a good **candidate** for **0νββ**

0νββ would demonstrate the **violation** of **total lepton number** and a **nonzero Majorana component** of neutrino mass

^{124}**Xe** & ^{136}**Xe** produce **single site ER** events due to **LXe high stopping power**

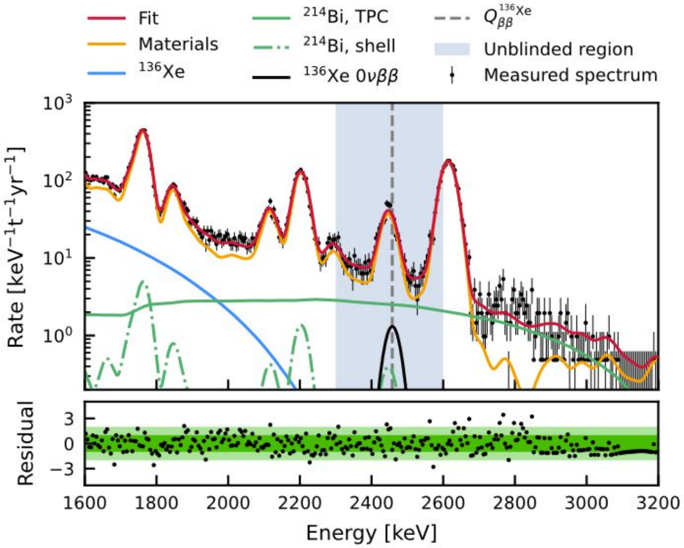
They became a major **background** for **electronic recoil** searches



Neutrinoless double-beta decay in ^{136}Xe

Expected **peak** at **2457.83** keV from **0νββ** on top of **materials** background

Dedicated treatment of signals for **saturation** effects in **digitizers** and **PMTs** at **MeV** energies



XENON1T RESULTS

$T^{0\nu\beta\beta}_{1/2}$ **> 1.2 × 10^{24} yr** with **tonne-scale** fiducial mass, resulting in isotope exposure of **36.16 kg** × yr

Best results for a **non enriched** target detector

NOT COMPETITIVE YET WITH 0νββ EXPERIMENTS

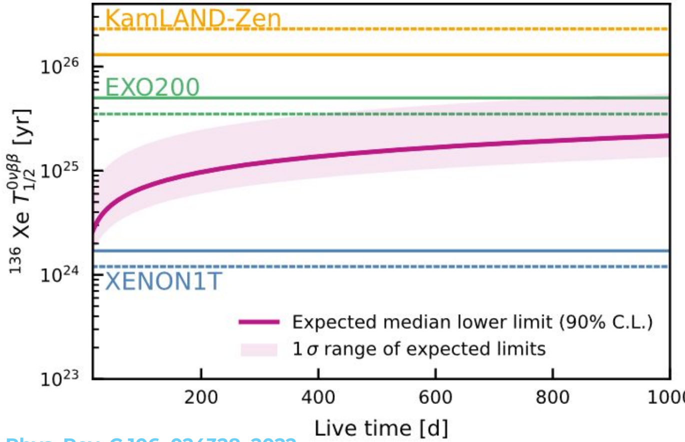
Non-enriched target (dedicated experiments with 90% isotopic abundance)

Materials optimized for **DM search** (stainless steel cryostat)

XENONnT SENSITIVITY PROJECTION

With **275** kg × yr exposure, expected upper limit of $T^{0\nu\beta\beta}_{1/2}$ **> 2.1 × 10^{25} yr**

Future xenon DM detector with **optimized** high-energy **backgrounds** and **larger exposure** can perform also 0νββ searches



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Backup