Karlsruhe Institute of Technology

XENON

Status Update & Results from the XENONnT Project

Alexey Elykov

on behalf of the XENON Collaboration

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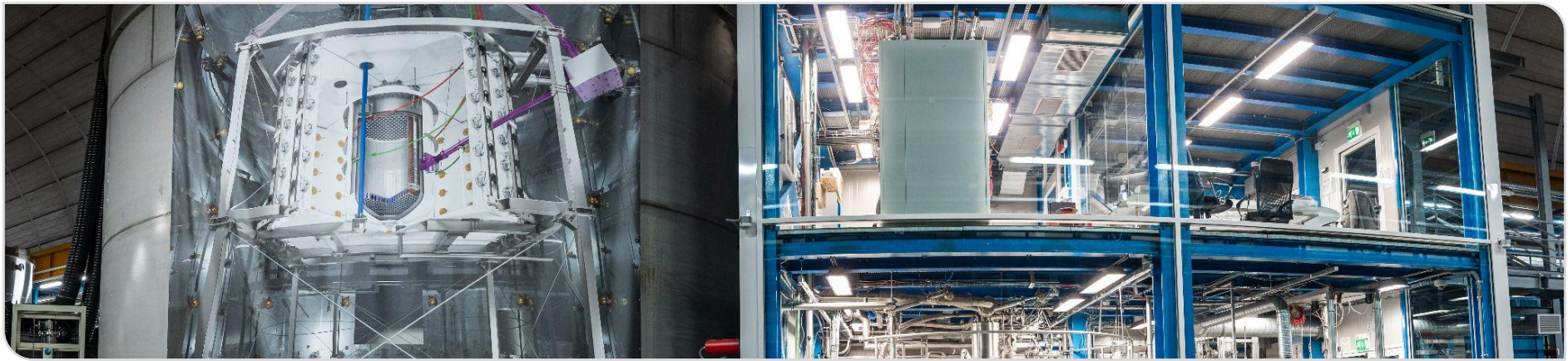


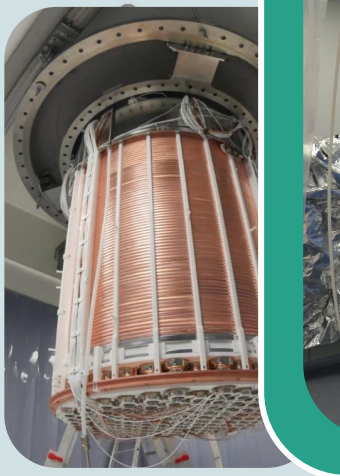
The XENON Collaboration

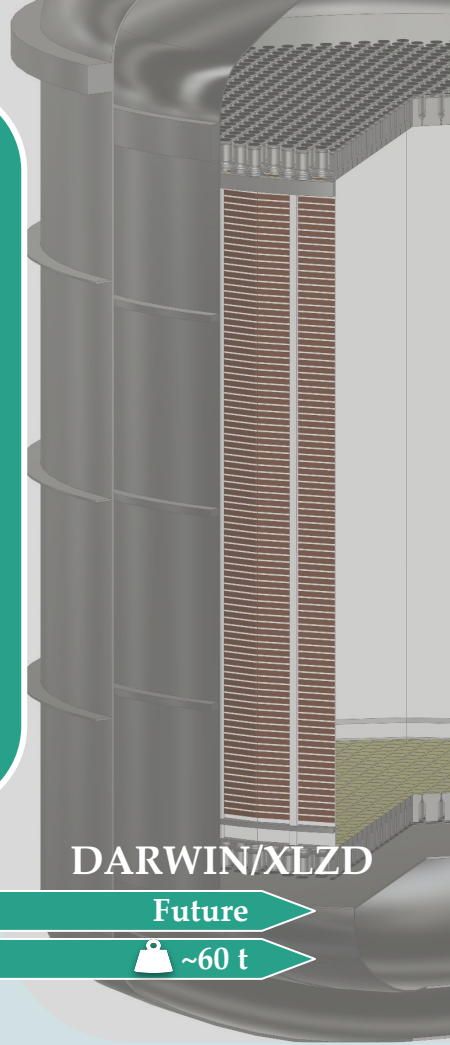
XENON dark matter direct detection experiments at Laboratori Nazionali del Gran Sasso (LNGS)

12 countries
27 institutions
170+ scientists

XENON Experiments

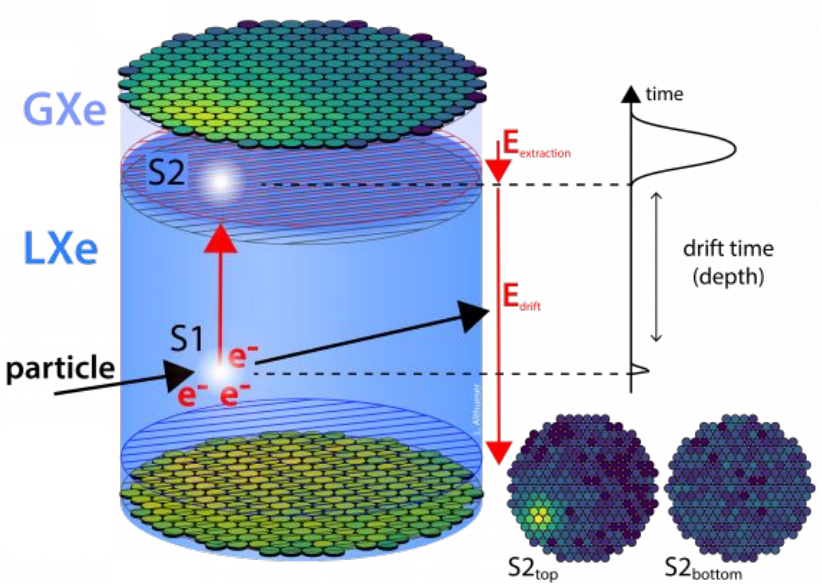
XENON dark matter direct detection experiments
at Laboratori Nazionali del Gran Sasso (LNGS)



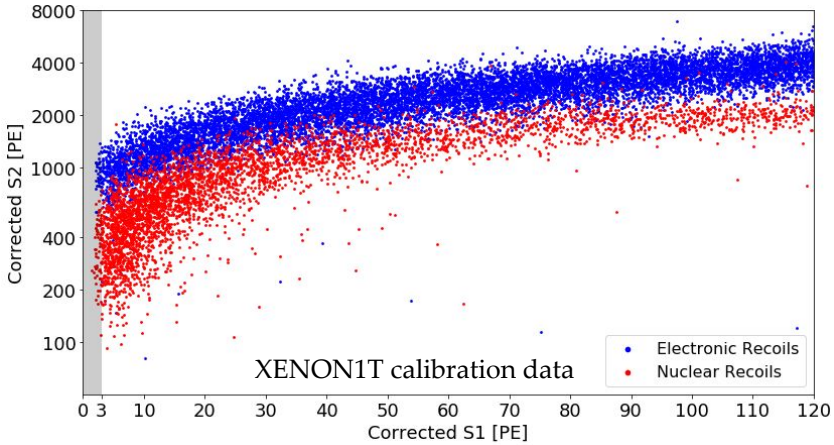


XENON10	XENON100	XENON1T	XENONnT	DARWIN/XLZD
2005 - 2007	2008 - 2016	2016 - 2019	2020 - Now	Future
15 kg	161 kg	3.2 t	8.5 t	~60 t

Dual-phase Time Projection Chamber (TPC)

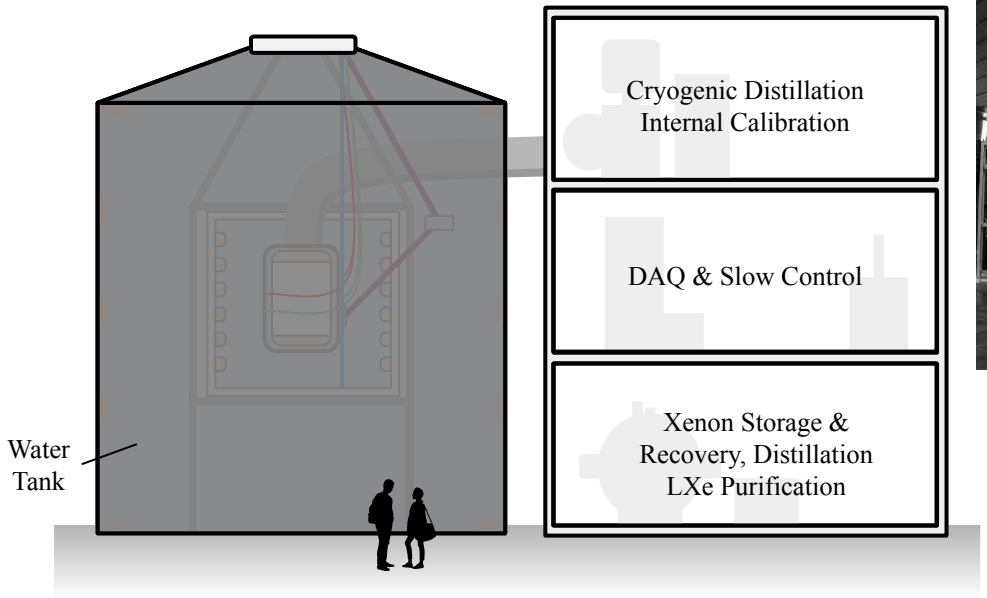


- Initial scintillation light: S1
- Proportional scintillation signal: S2
- Energy: S1 area, S2 area
- Position: X-Y (S2 signal), Z (drift time)
- Interaction type: S2/S1 ratio (**ER**/**NR**)



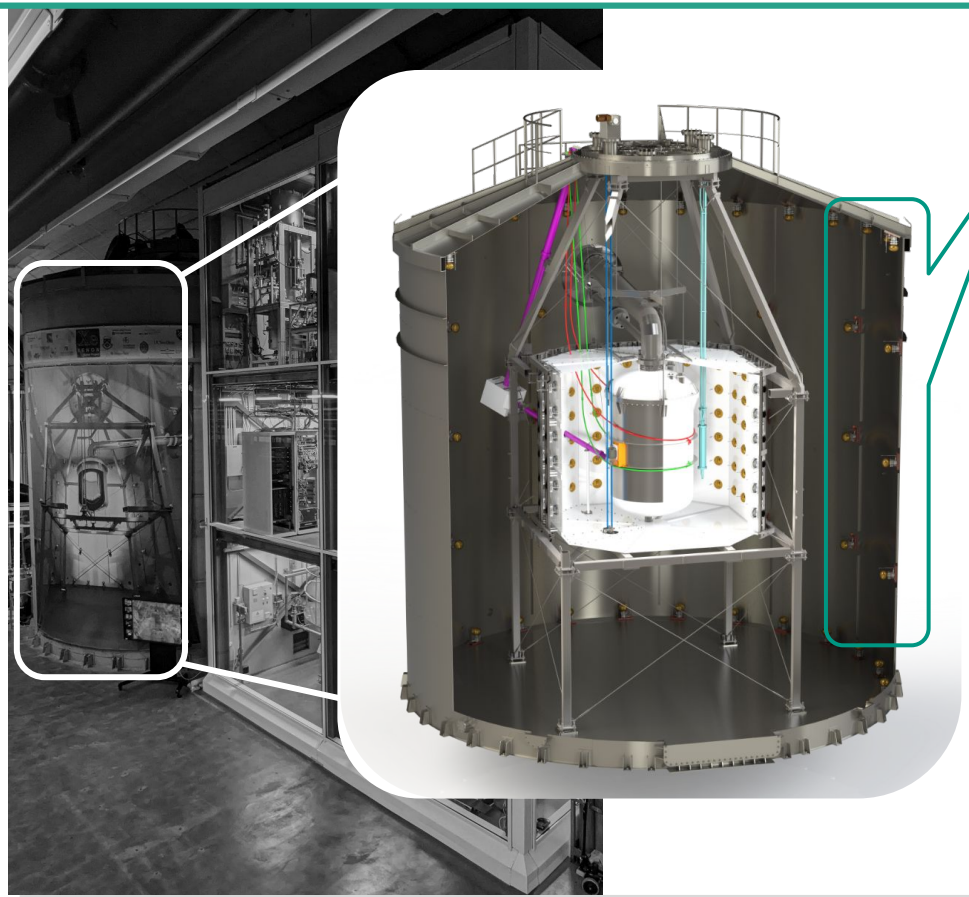
From XENON1T to XENONnT

Located at Laboratori Nazionali del Gran Sasso, Italy
~1500 m rock overburden (3600 m.w.e.)



Reused XENON1T infrastructure

From XENON1T to XENONnT



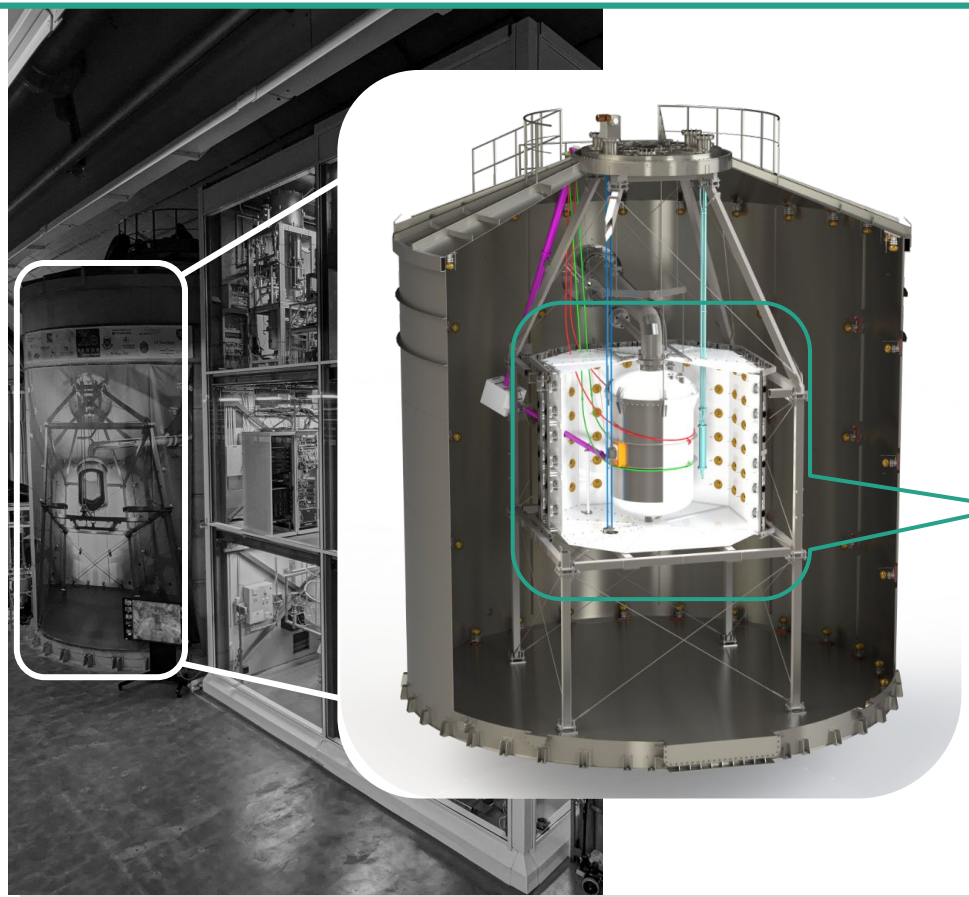
Water Cherenkov Muon Veto (Same as XENON1T)

- Tank (10.2 × 9.6 m) filled with 700 t of pure water
- 84 × 8″ PMTs
- Active muon veto
- Passive γ and neutron shield

Neutron Veto

- Optically separated inner region
- 33 m³ volume
- 120 × 8″ PMTs, high reflectivity ePTFE
- Neutron tagging efficiency of 53%
- **SOON:** Gd loaded - 87% neutron tagging efficiency

From XENON1T to XENONnT



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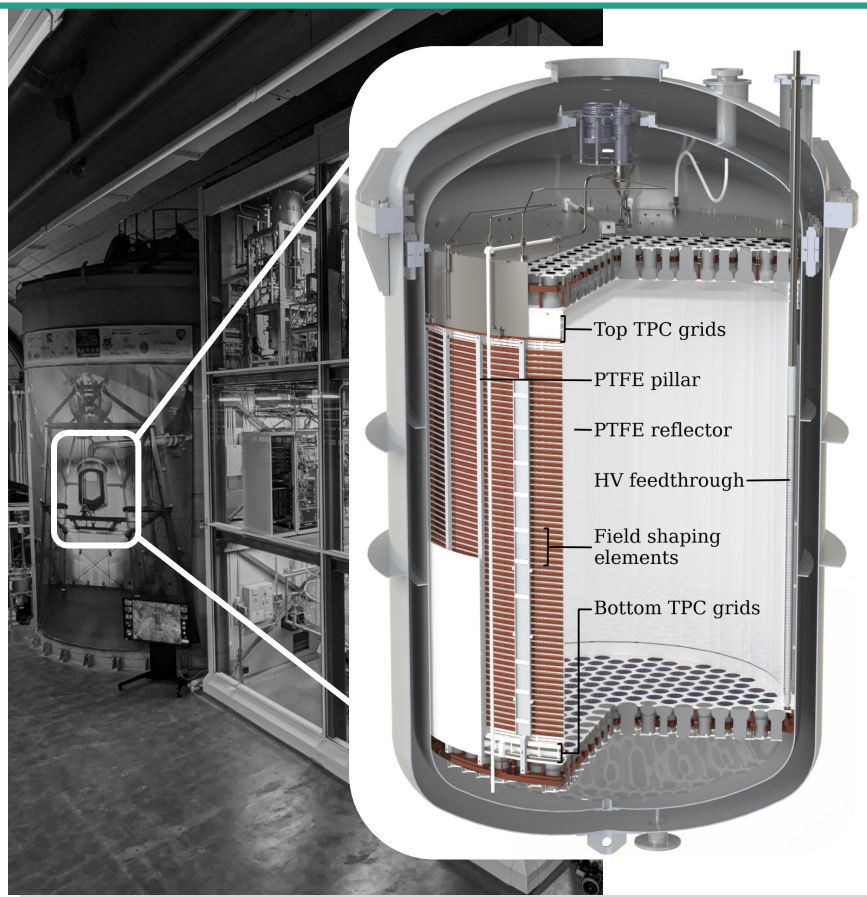
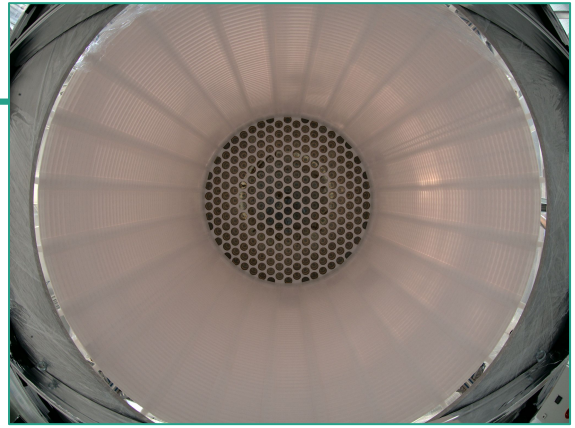
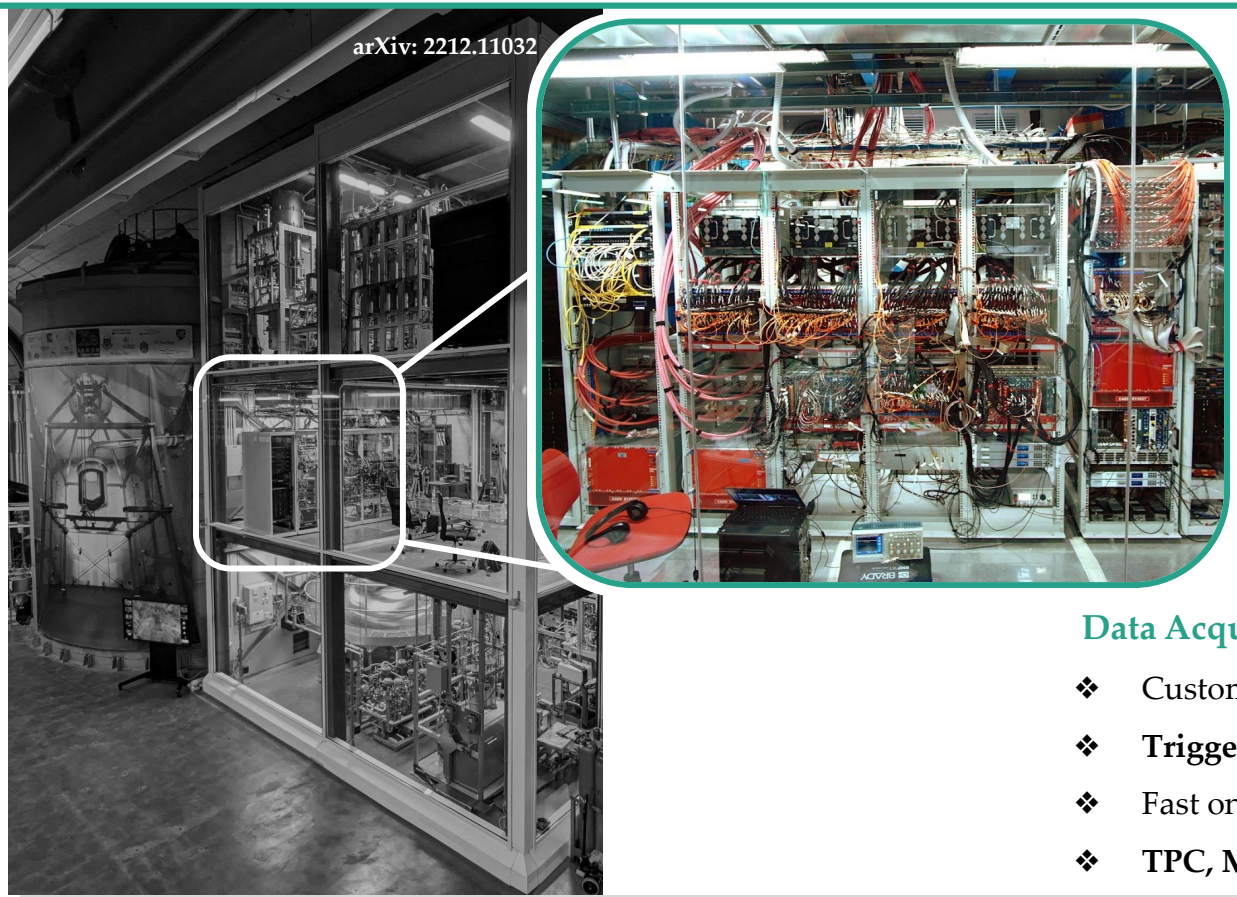




Time Projection Chamber

- 8.5 t of LXe, 5.9 t in active target
- 1.5 m long, 1.3 m in diameter
- 494 × 3″ PMTs (253 top, 241 bottom)
- SS wire electrodes

From XENON1T to XENONnT

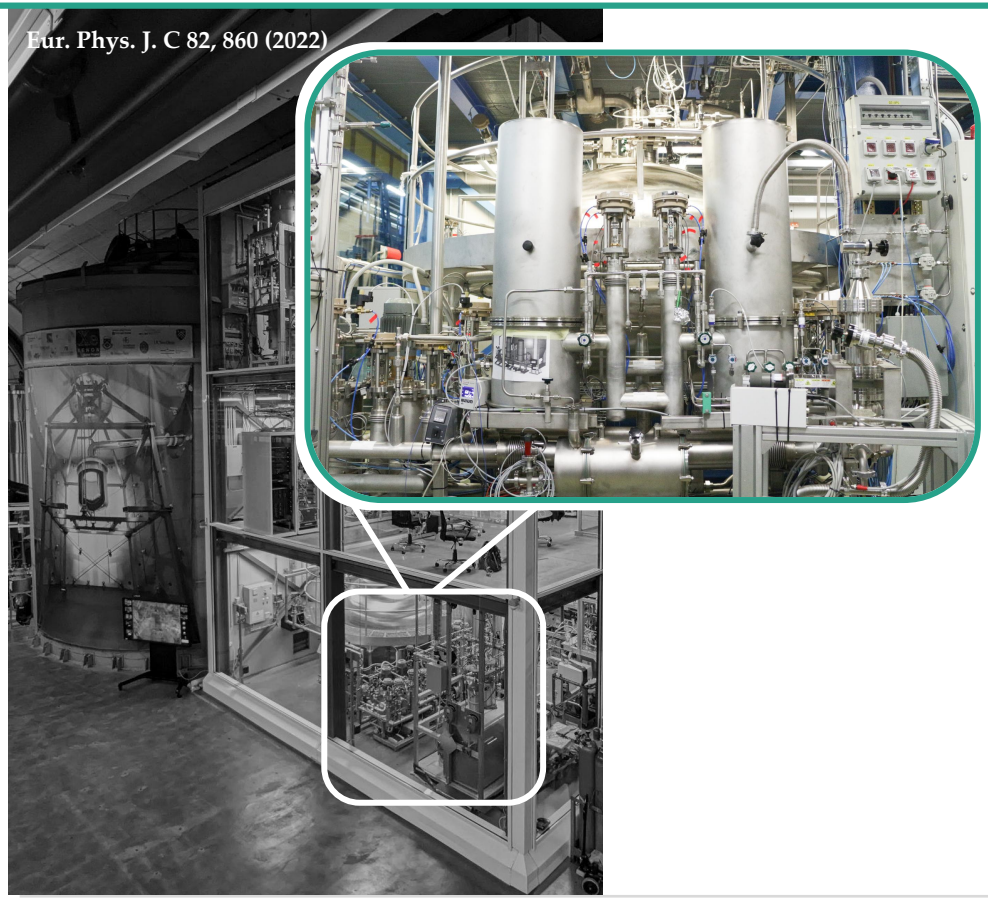


Data Acquisition System

- Custom software with commercial hardware
- **Triggerless data acquisition** (TPC, Neutron Veto)
- Fast online processing & live data monitoring
- **TPC, Muon Veto, Neutron Veto** - fully synchronized

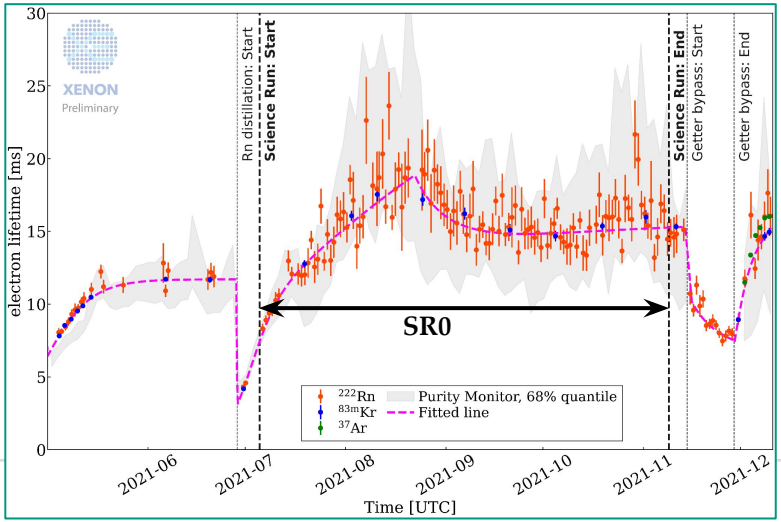
From XENON1T to XENONnT

Eur. Phys. J. C 82, 860 (2022)

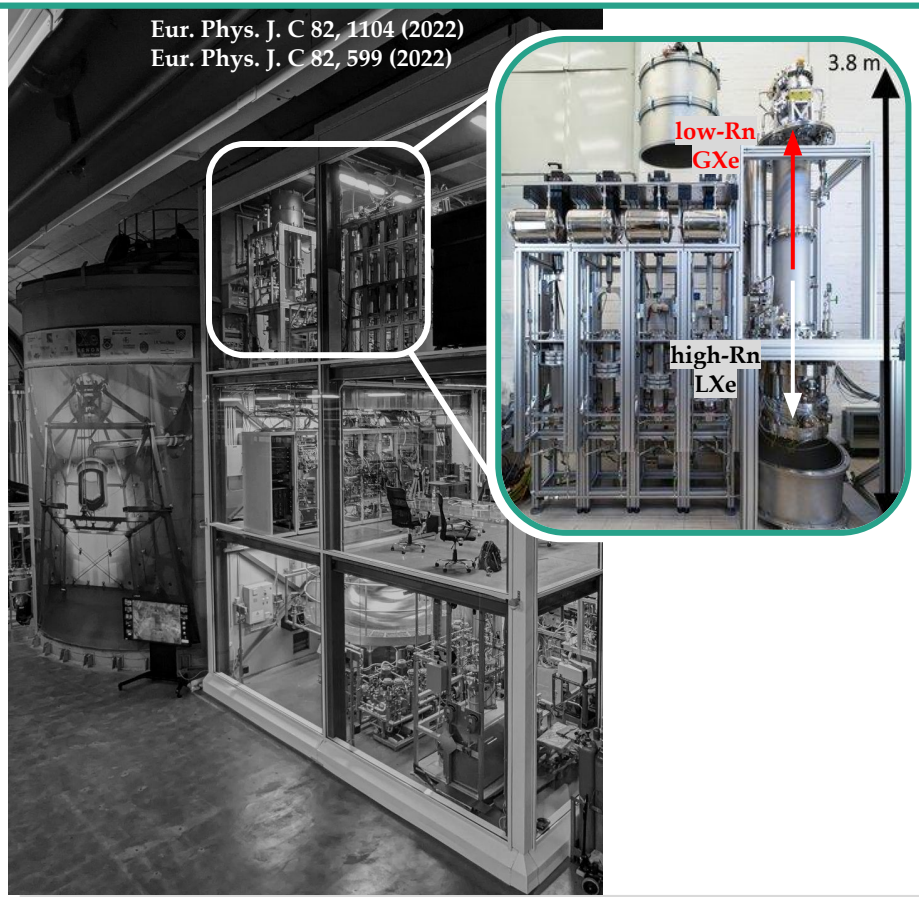


Liquid Xenon Purification

- Average electron lifetime > 10 ms
- High LXe flow of 2 liters/min
  (18 h to exchange the entire volume)

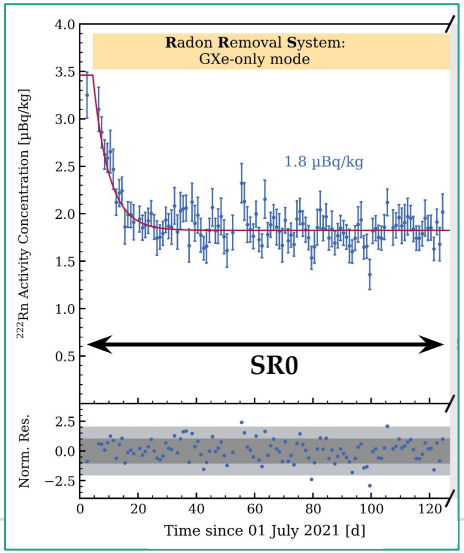


From XENON1T to XENONnT



Radon Removal

- ^{222}Rn mitigation - material selection & screening
- Radon removal via online cryogenic distillation
- Radon activity < 2 μBq/kg
- Low-energy ER background: (15.8 ± 1.3) events /(keV × t × yr)



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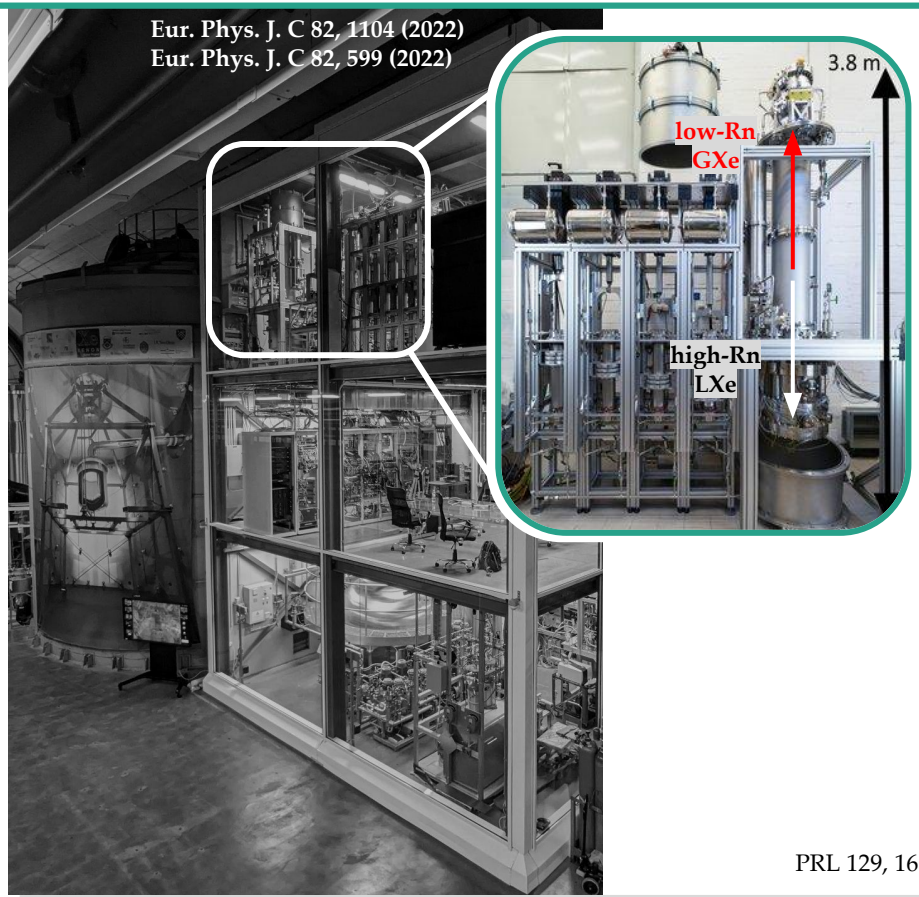

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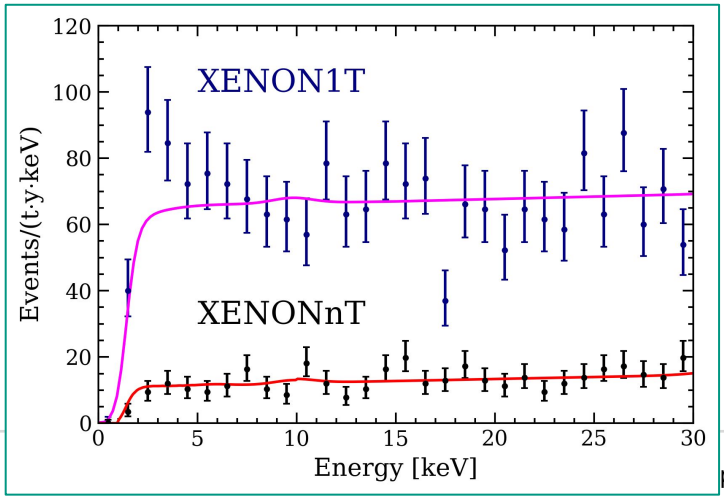
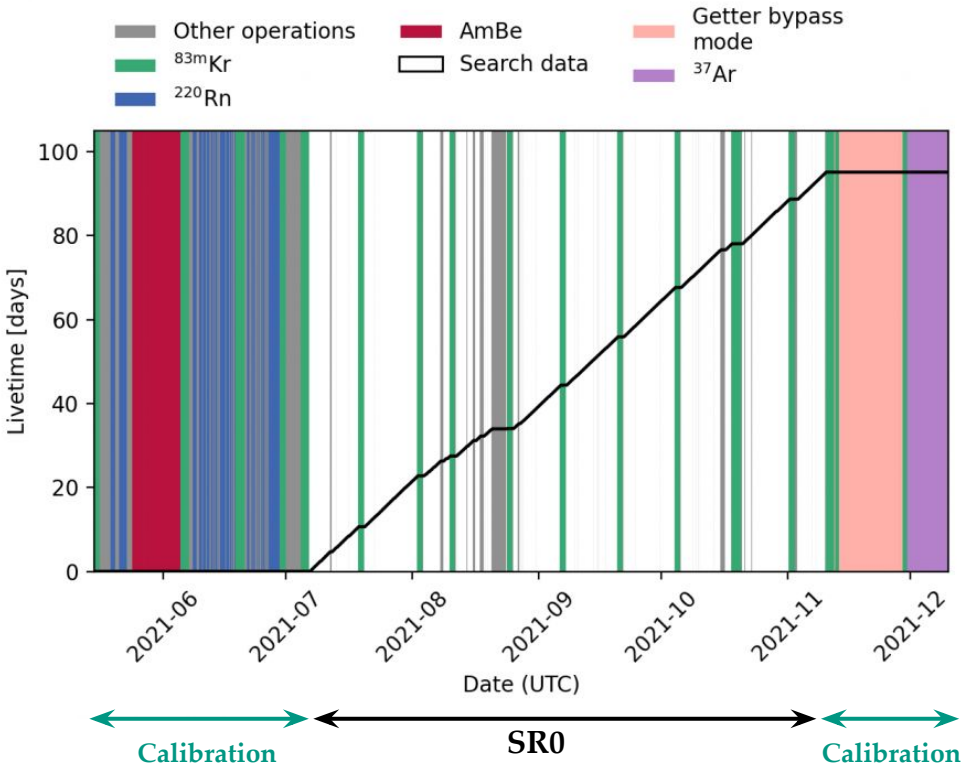
ER Background ~5x smaller than in XENON1T



PRL 129, 161805 (2022)

XENONnT - Science Run 0



Detector Configuration

- 477 out of 494 PMTs working
- **Drift field:** 23 V/cm
- **Extraction field in liquid:** 2.9 kV/cm (~50% EE)
- Light Yield (PE/keV) max variation ~ 1%
- Charge Yield (PE/keV) max variation ~ 1.9%

- July 6 - November 10, 2021
- **Livetime:** 95.1 days (lifetime corrected)
- **Fiducial volume:** 4.18 ± 0.13 t
- **Exposure:** 1.1 t × yr
- Blinded data analysis

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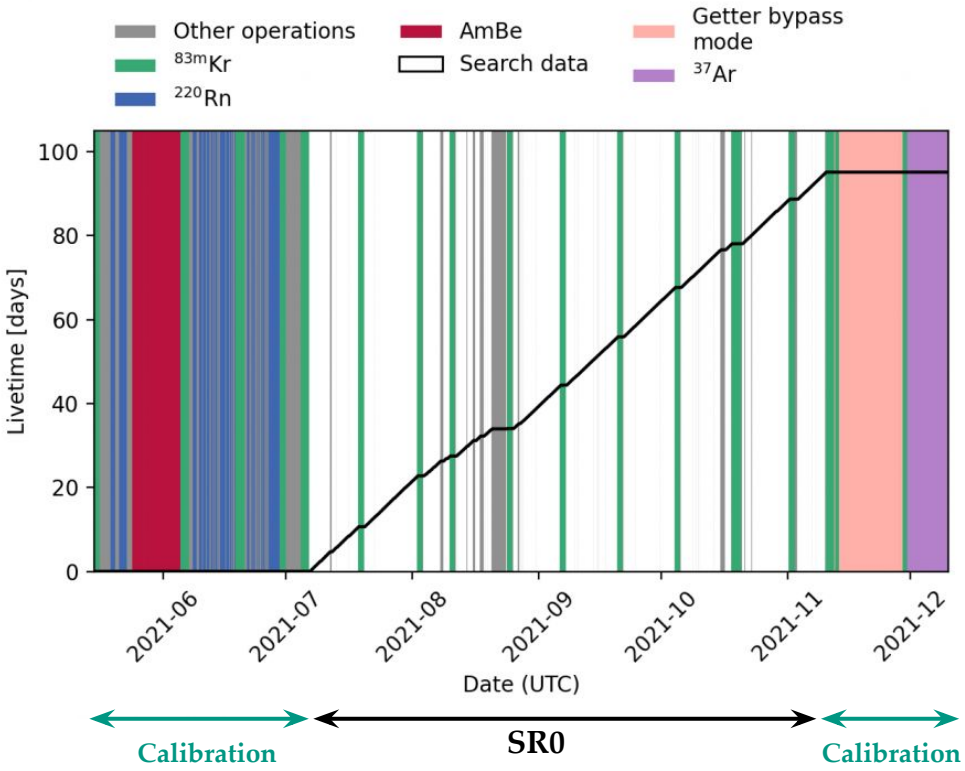

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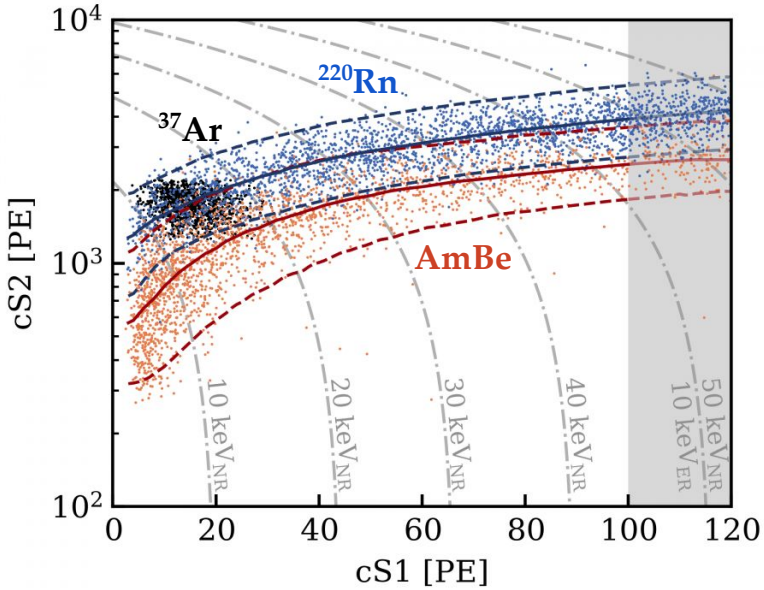
Detector Calibration

ER Calibration

- ^{220}**Rn**
  - ➢ Approximately flat energy spectrum
  - ➢ Used to validate cut acceptance
- ^{37}**Ar** (2.8 keV$_{ER}$ line)
  - ➢ Validate detector performance at low energies
  - ➢ Removed via distillation column
- ER response model based on a combined fit

NR Calibration

- ➢ Neutrons from external ^{241}AmBe source
- ➢ NR selection via coincident 4.4 MeV γ detected in NV
- ➢ Fit LXe NR emission model to determine NR response



XENONnT, arXiv:2303.14729

Detection Efficiency & Data Selection

Detection Efficiency

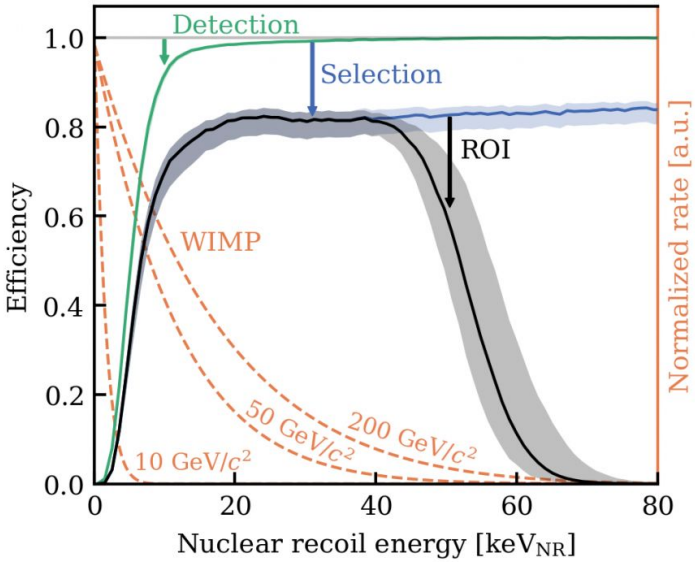
- 3-fold PMT coincidence for S1 (~ 3 photons)
- Full waveform simulation & data-driven methods

Selection Efficiency

- Data quality selection - remove unphysical & multi-site events

Region of Interest (ROI)

- Fully contains WIMP spectra
- cS1: 0 - 100 PE
- cS2: $10^{2.1}$ - $10^{4.1}$ PE

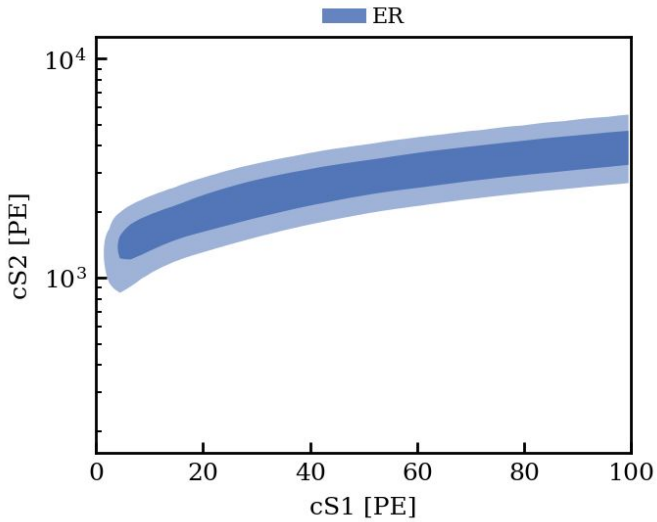


Total efficiency > 10 % from 3.3 keV$_{NR}$ - 60.5 keV$_{NR}$

XENONnT, arXiv:2303.14729

Backgrounds for WIMP Search

- **Electronic Recoil (ER)**:
  - Dominated by beta decay of ^{214}Pb (daughter of ^{222}Rn)
  - ^{85}Kr background sub-dominant



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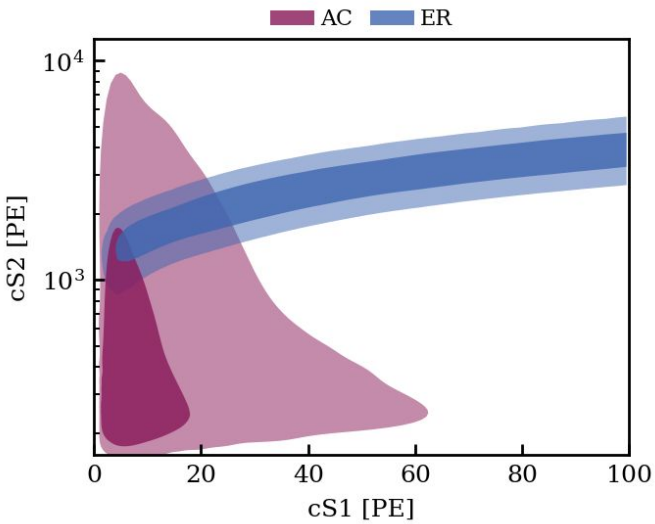

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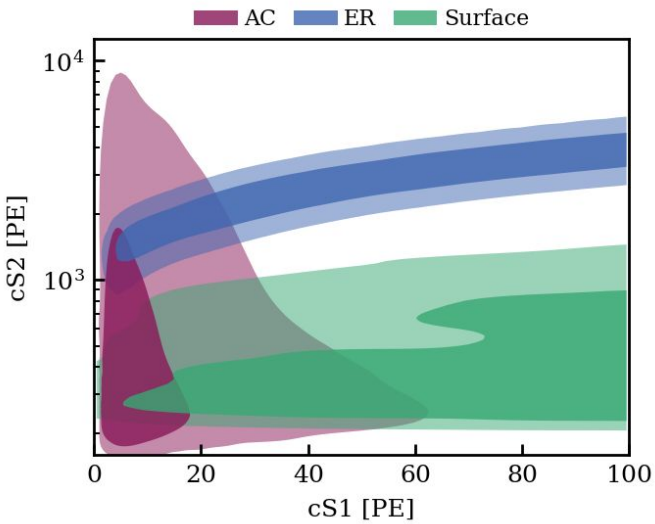
- **Surface:**
  - ^{210}Pb plate-out on PTFE walls of the TPC
  - Suppressed by FV



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- **Surface:**
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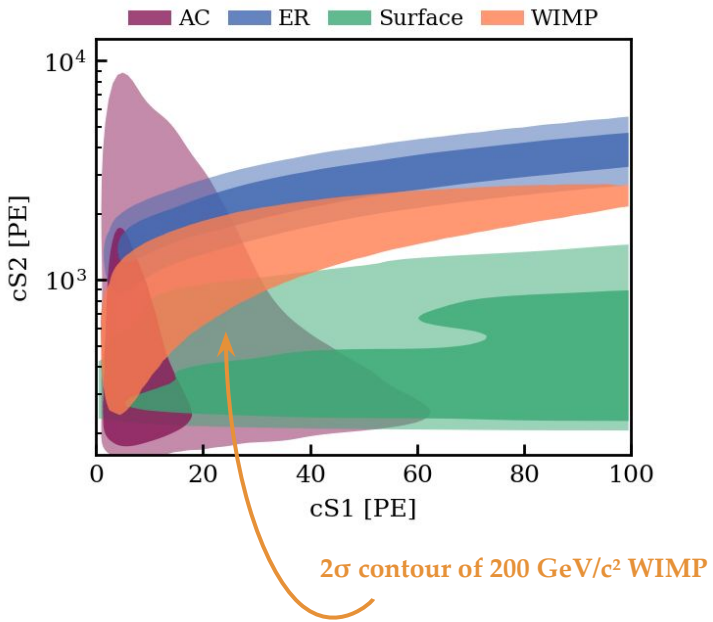
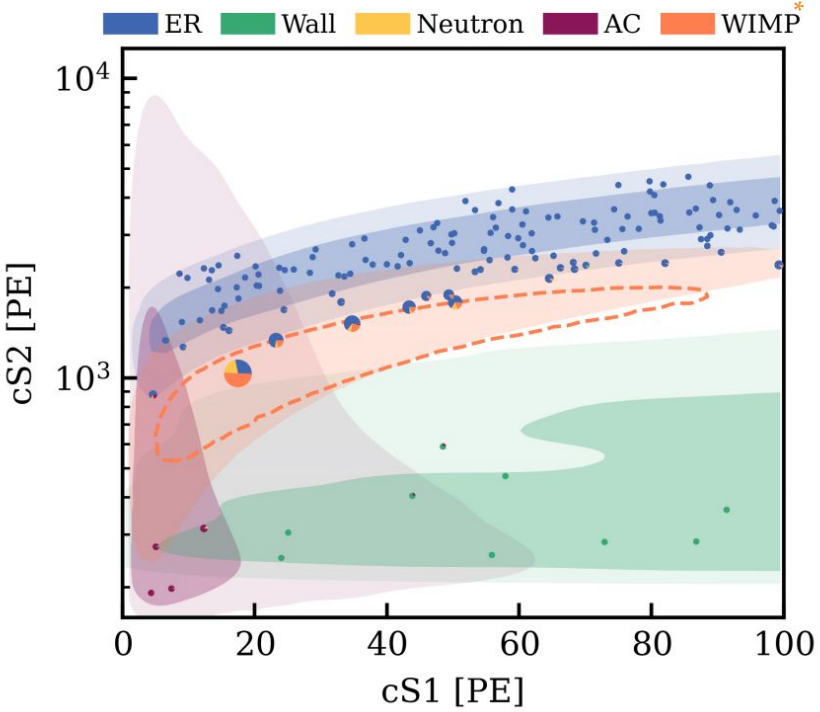
  - Suppressed by FV
- **Nuclear Recoil (NR):**
  - Radiogenic neutrons - spontaneous fission & (α, n)-reactions
  - Radiogenic neutron rate prediction from NV tagging: ~ 1.1 events
  - Cosmogenic - negligible, ^{8}B CEvNS constrained by flux



XENONnT, arXiv:2303.14729

SR0 WIMP Search Results

	Expected	Best Fit
	ROI	
ER	134	135 (+12) (-11)
Neutrons	1.1 (+0.6) (-0.5)	1.1 ± 0.4
CEvNS	0.23 ± 0.06	0.23 ± 0.06
AC	4.3 ± 0.2	4.32 ± 0.15
Surface	14 ± 3	12 (+0) (-4)
Total	**154**	**152 ± 12**
WIMP *	-	2.6
Observed	-	**152**

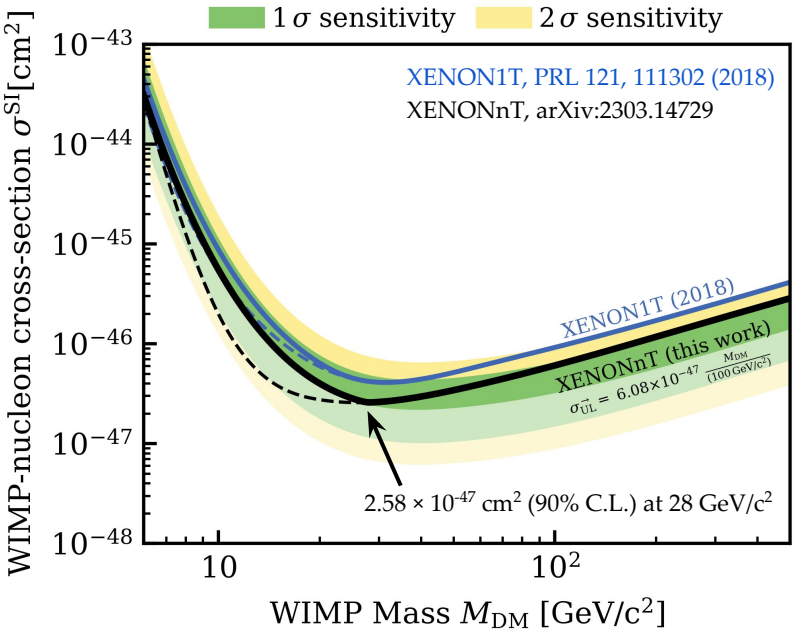


*Assuming a 200 GeV/c² WIMP

- 152 events in ROI, 16 in blinded region
- **No significant excess**

XENONnT, arXiv:2303.14729

WIMP-nucleon Spin-Independent Results



- XENONnT 90% C.L. Power-Constrained Limit (PCL)*
- **Minimum upper limit:** 2.58 × 10^{-47} cm^2 (90% C.L.) at 28 GeV/c^2

* arXiv:1105.3166, arXiv:2105.00599 with 50% [median] rejection power

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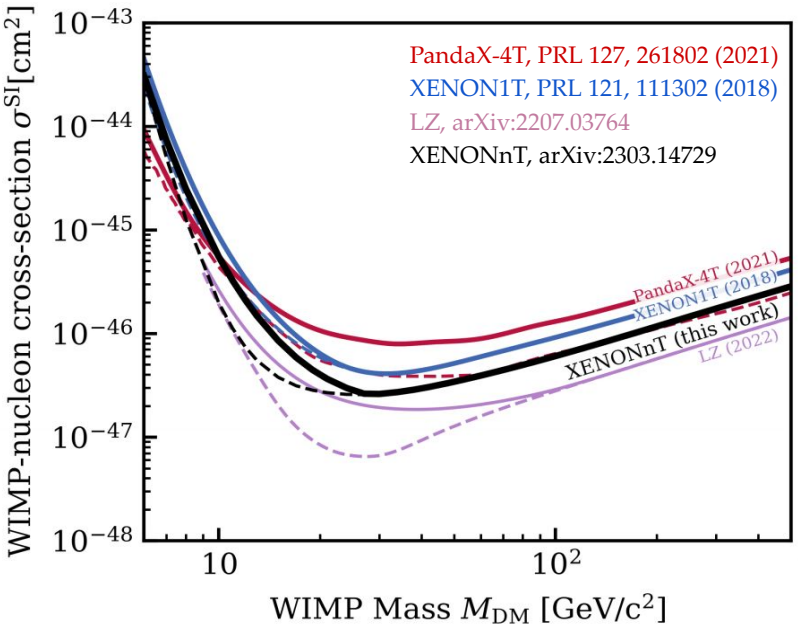

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- **Minimum upper limit:** 2.58 × 10^{-47} cm^2 (90% C.L.) at 28 GeV/c^2
- Same PCL applied to results of other recent LXe experiments

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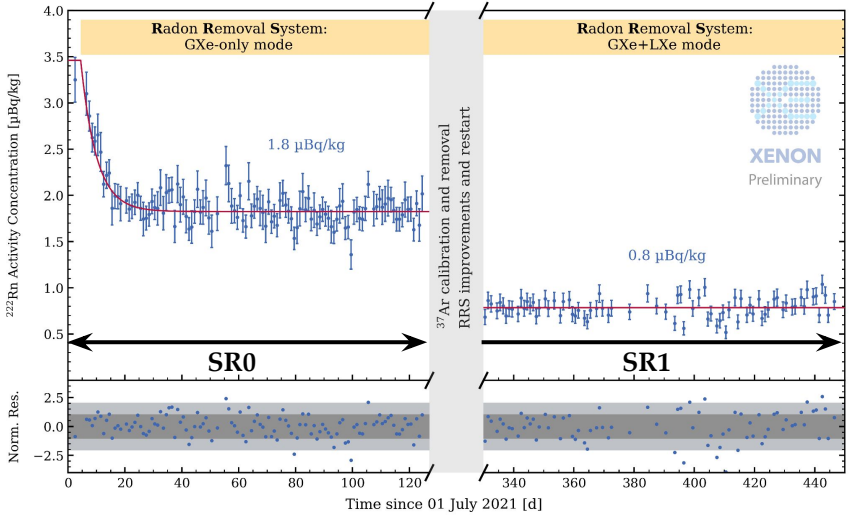
Summary & Outlook

- **SR0** - blinded Dark Matter search with 1.1 t × yr exposure
- **SI limit** of 2.58×10^{-47} cm^2 (90% C.L.) at 28 GeV/c^2
- **Low-energy ER background** of (15.8 ± 1.3) events /(keV × t × yr)

- **SR1** - data taking ongoing, further reduction of ^{222}Rn
- **Gd loading** for NV to increase neutron tagging efficiency

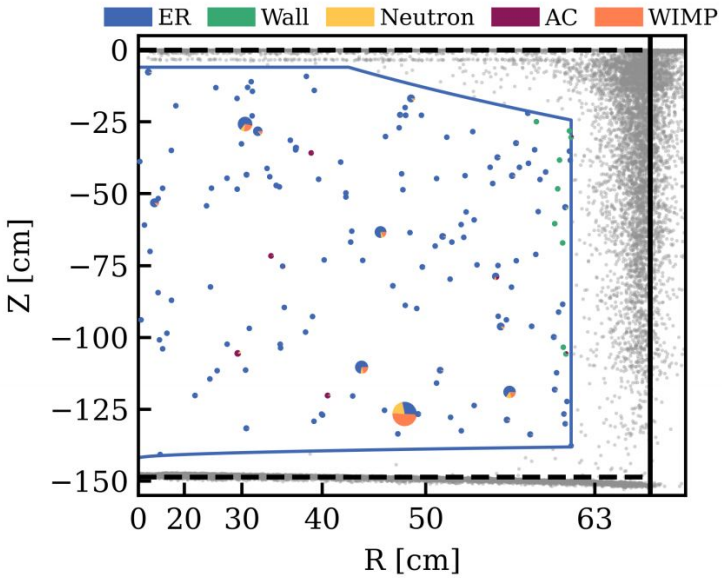
- **Upcoming analyses:**
  - Solar neutrino analyses: pp, ^{8}B CEνNS
  - s2-only studies
  - and more …

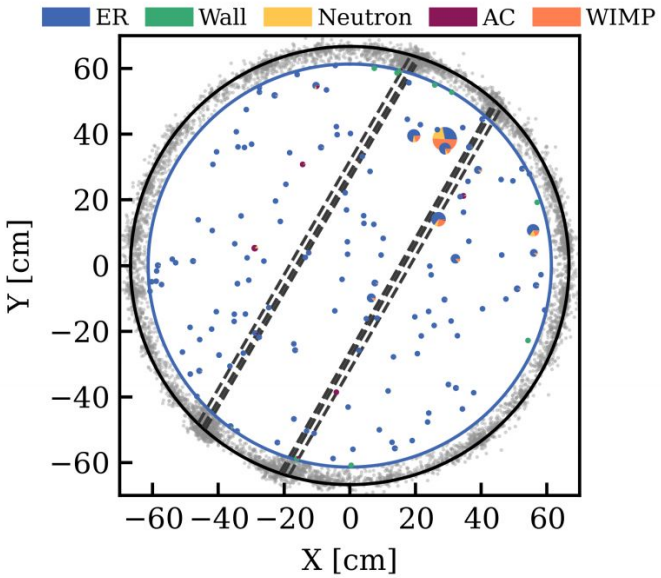


xenonexperiment.org @XENONexperiment @xenonexperiment @xenon_experiment

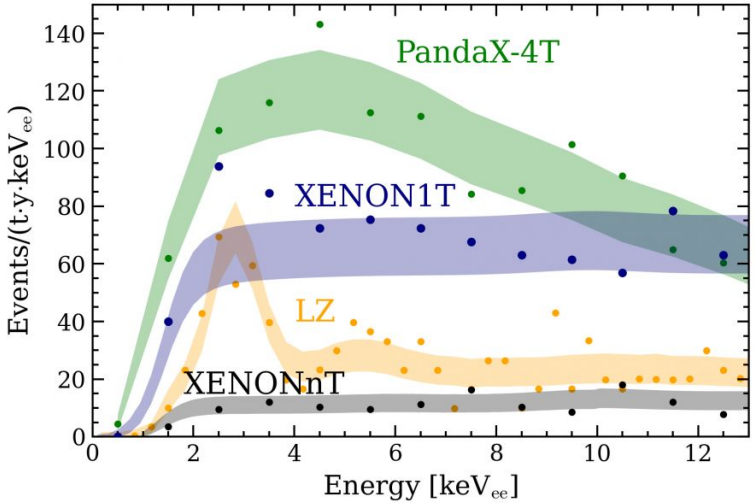
SR0 WIMP Search Data in Spatial Coordinates

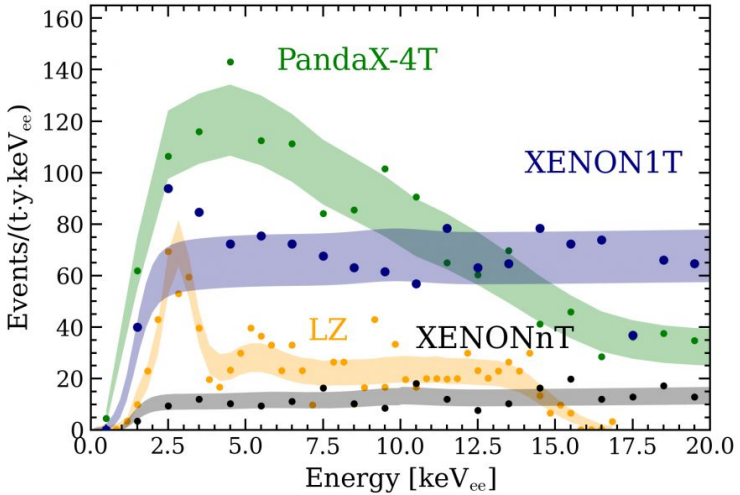
- X-Y asymmetry in unblinded data
- Asymmetry not observed in corrections, quality selection or calibration data





ER Background Comparison





PandaX-4T, PRL 129, 161804 (2022)
XENON1T, PRD 102, 072004 (2020)
LZ, arXiv:2207.03764
XENONnT, PRL 129, 161805 (2022)