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XENONnT The First WIMP Results

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XENON Collaboration

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The XENON Collaboration:
27 Institutions
12 Countries
~180 Scientists

XENONnT: A Two-phase Time Projection Chamber

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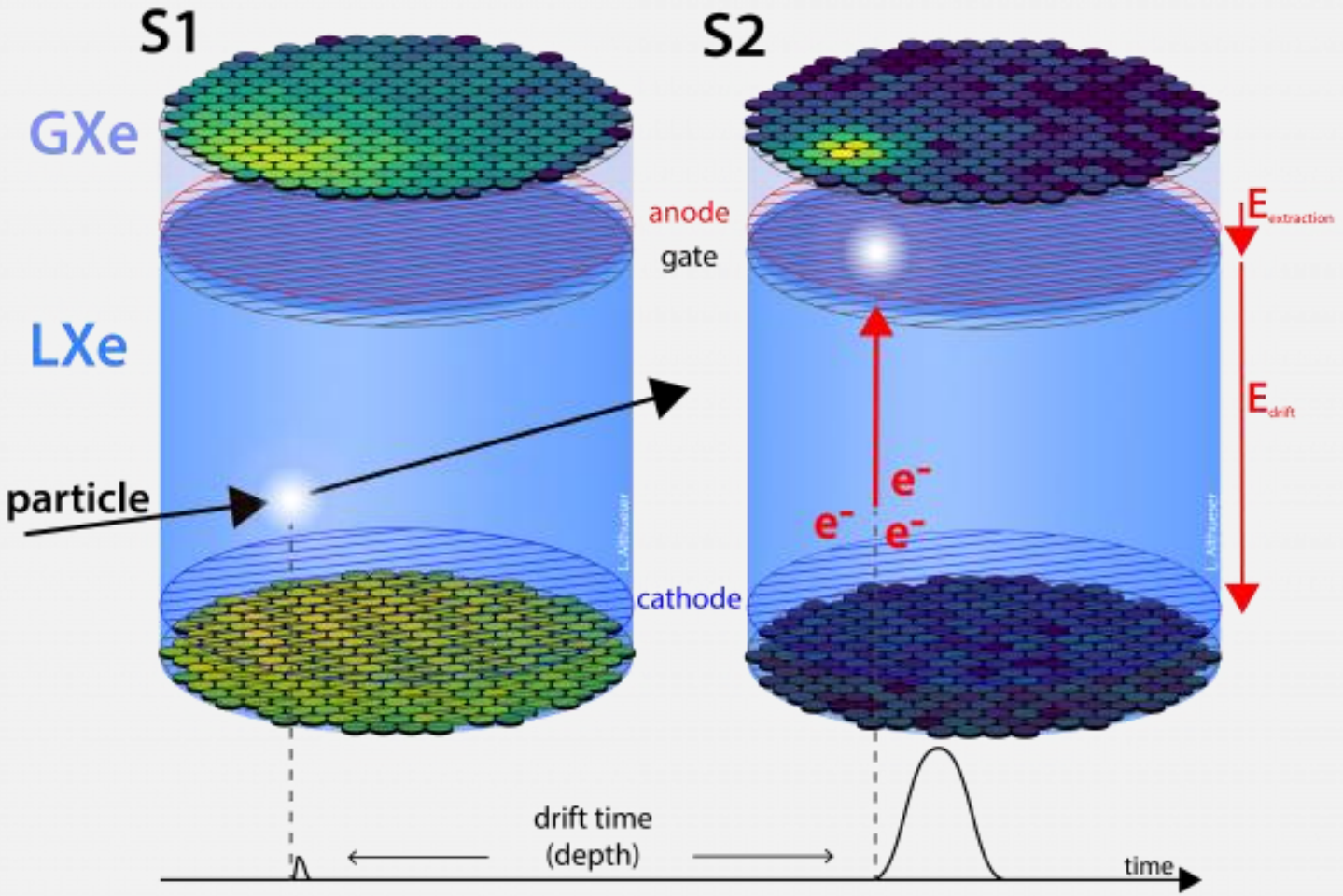


Signal detection after particle interaction

- Prompt scintillation light (**S1**)
- Delayed signal from charge extracted into gas phase (**S2**)

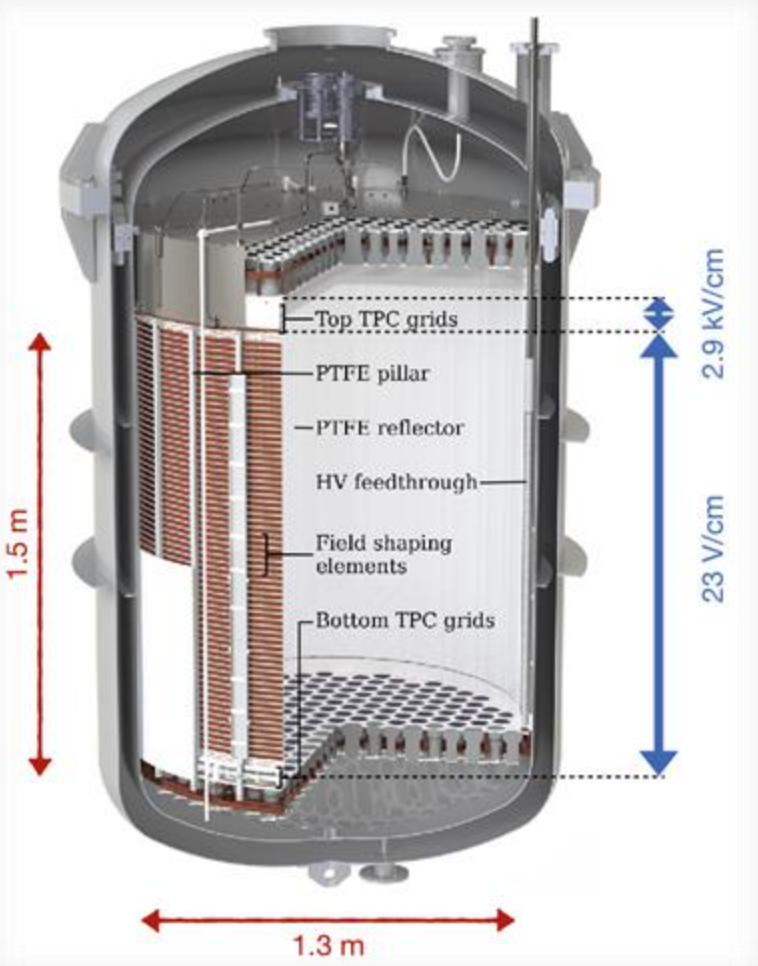
Full 3D position reconstruction

- x-y from PMT response to S2
- Depth (z) from S1-S2 delay

Particle discrimination through S1/S2 signal ratio

- Neutrons, WIMPs: **Nuclear Recoil**
- Gammas, Betas: **Electronic Recoil**

The XENONnT TPC in its First Science Run



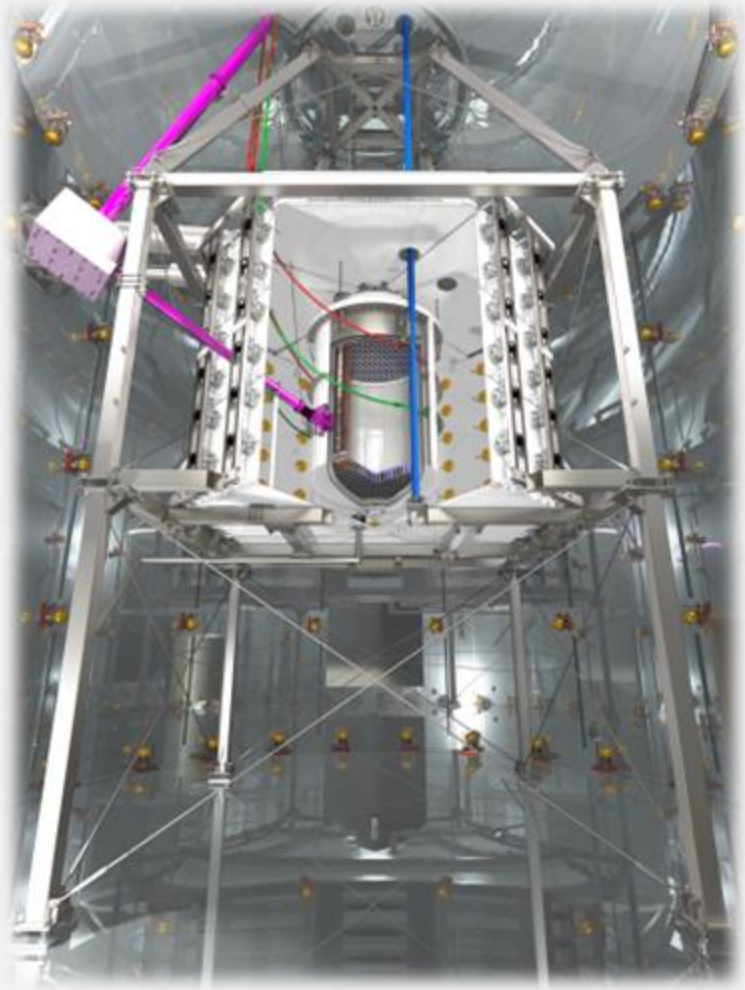
TPC Design

- 8.5 tonnes of Liquid Xenon (LXe) total
- 5.9 tonnes LXe inside TPC

First Science Run (SR0) Configuration

- Drift field 23 V/cm
- 477 out of 494 PMTs operational
- Extraction field of 2.9 kV/cm (in Liquid)
  ~50% Extraction efficiency

Important new Subsystems



Neutron Veto

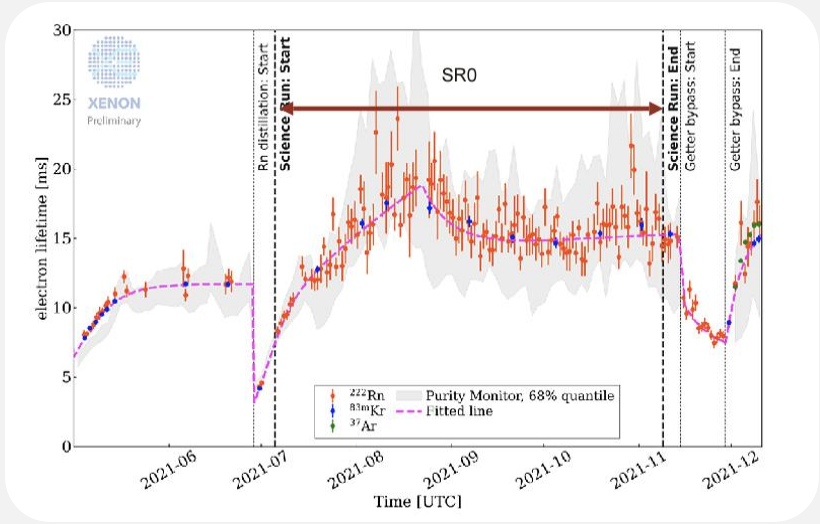
- Built inside muon veto (700 tonne water tank)
- 120 PMTs optically separated from muon veto by PTFE panels
- Tagging efficieny for neutrons of 53.3% (lifetime loss of 1.6%)

Radon Distillation Column

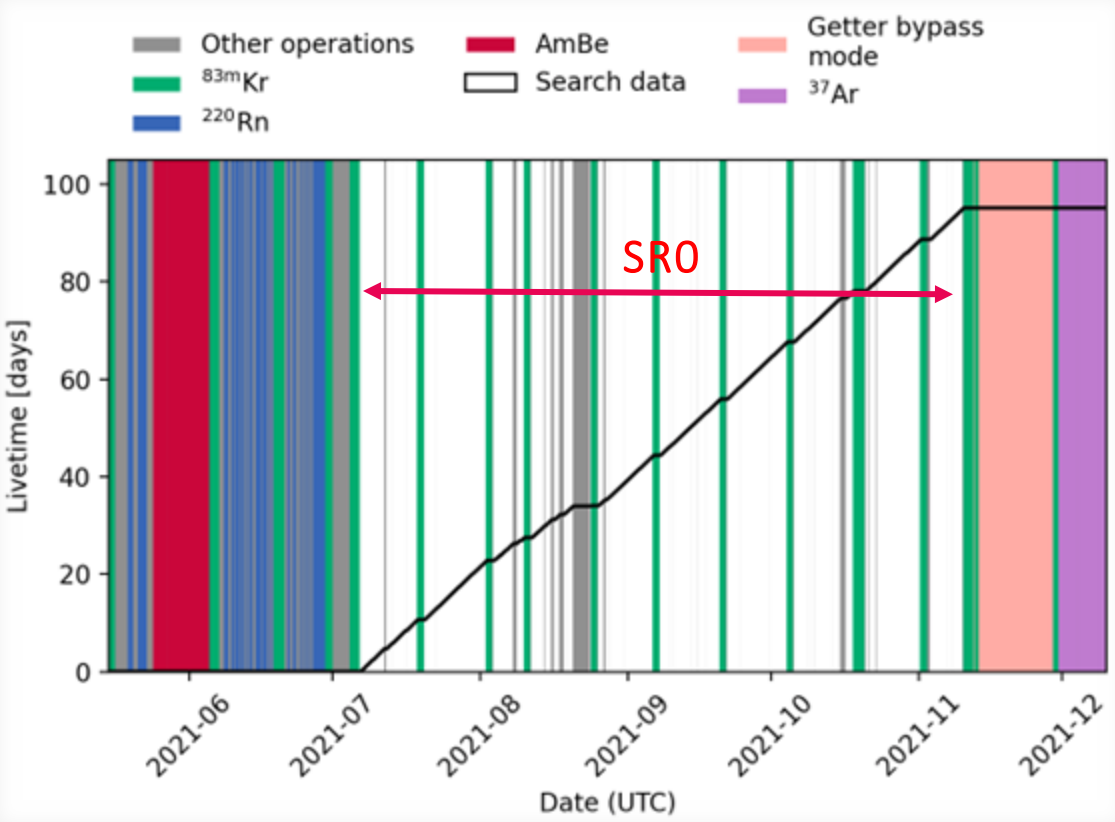
- Allows for continuous Rn removal via cryogenic distillation
- Rn activity reduced to <2 μBq/kg
- Electronic recoil background 1/5 of XENON1T

Liquid Xenon Purification

- Electronegative impurities removed from liquid phase
- 2 liters of LXe/min (Entire inventory in 18h)
- Achieved electron lifetime ~ 15 ms



Data Taking for SR0



Calibration before/after dark matter search

- Nuclear Recoil Response: **AmBe**
- Electronic Recoil Response: **Rn**
- Light yield and Corrections: **Kr** and **Ar**

SR0

- July – November (97.1 real live days)
- **95.1** live days after corrections
- **(4.18±0.13) tonnes** Fiducial Volume
- Total exposure of **1.1 tonne.year**

Calibration of the Detector Response

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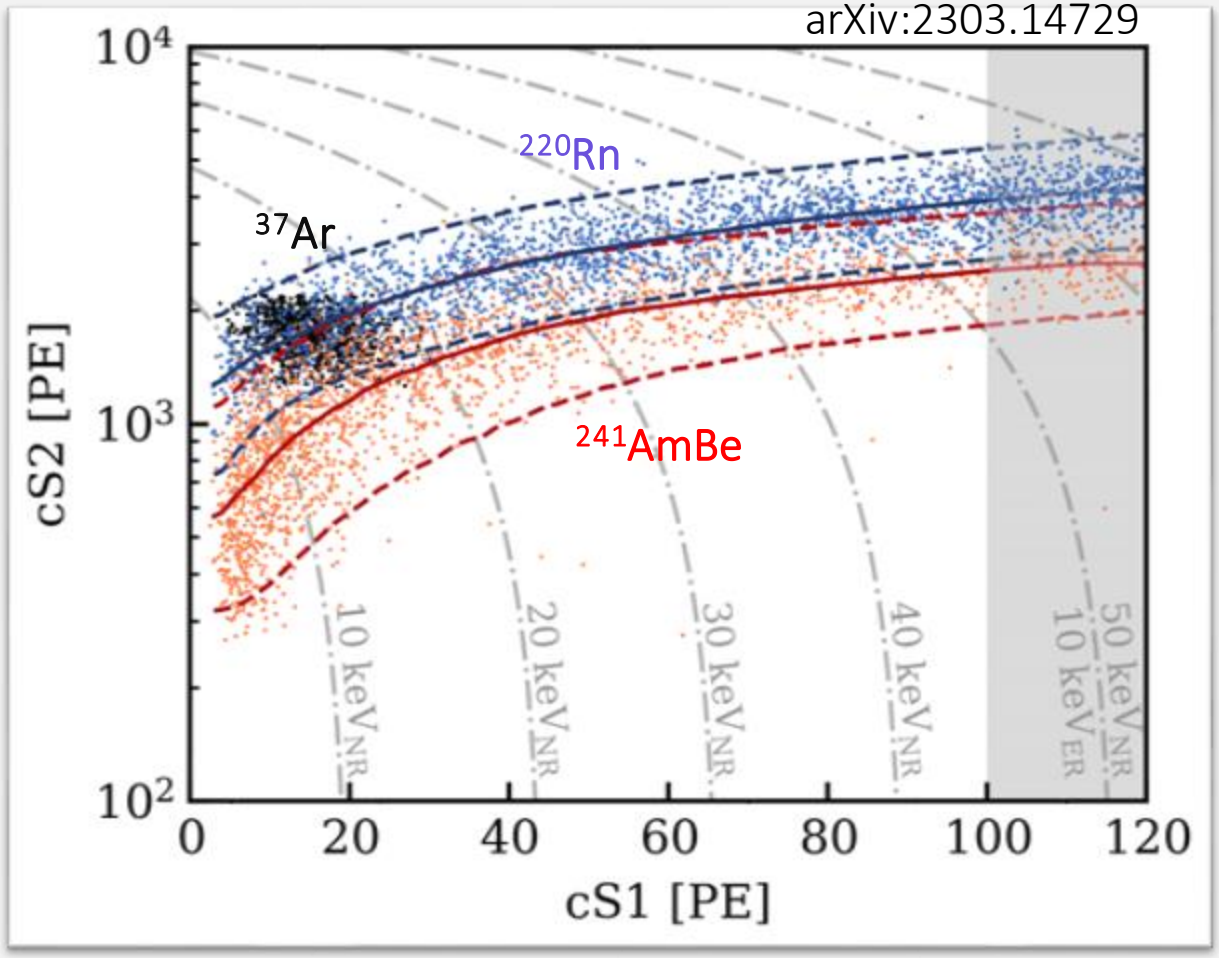

Nuclear Recoil

- Neutrons from external ^{241}AmBe source
- Selected via coincident 4.4 MeV gamma in NV

Electronic Recoil

- ^{220}Rn has flat energy spectrum in region of interest
- Validates cut acceptances

Low energy

- ^{37}Ar has monoenergetic signal at 2.8 keV$_{ER}$
- Validate response at lowest energies

Detector response model

- LXe NR response derived from fit to ^{241}AmBe
- Combined fit to ^{37}Ar and ^{220}Rn data to derive ER response model

Detection and Selection Efficiencies

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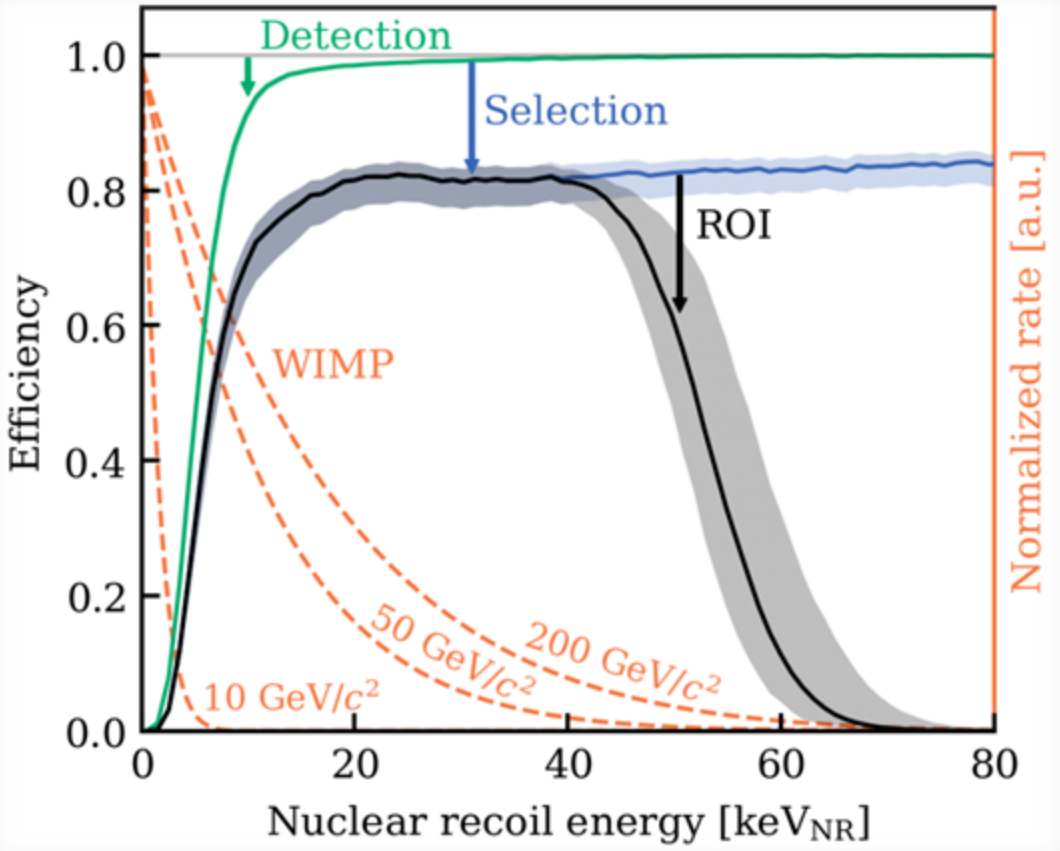
arXiv:2303.14729



Detection Efficiency

- Dominated by 3-fold PMT coincidence for S1s
- Derived from waveform simulation, verified by data driven approach

Selection Efficiency

- Removal of unphysical and multi-site events
- Plateaus at 80%

Region of Interest

- Corrected S1 (cS1) range: 0-100 PE
- Corrected S2 (cS2) range: $10^{2.1}$ - $10^{4.1}$ PE
- Covers recoil energies of ~GeV WIMPs

Backgrounds in WIMP ROI

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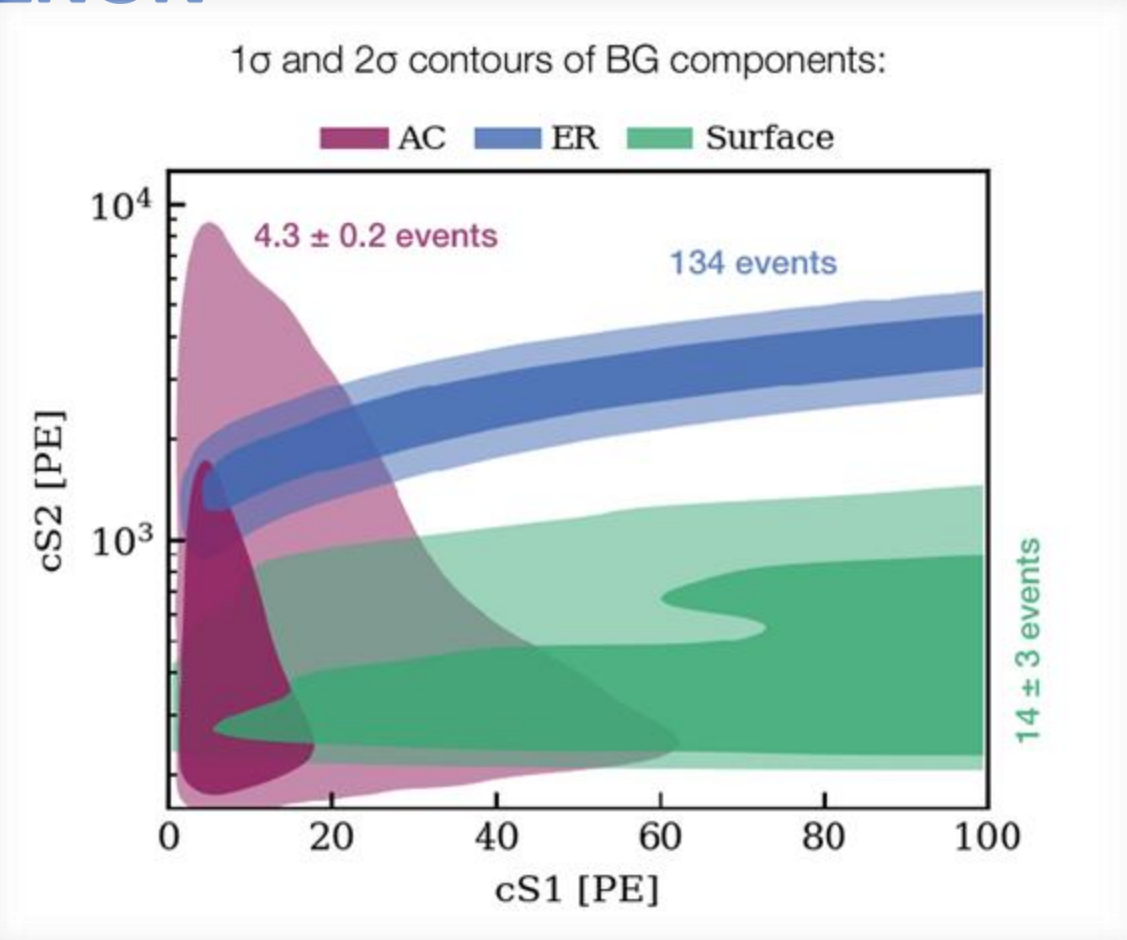


Total Expectation: 154 Events

Accidental Coincidence (AC)

- Random pairing of lone S2s and S1s
- Use GBDT cut, applied to S2 features to suppress

Electronic Recoils (ER)

- Major contribution from beta decay of ^{214}Pb
- Sub dominant contribution from ^{85}Kr

Surface Background

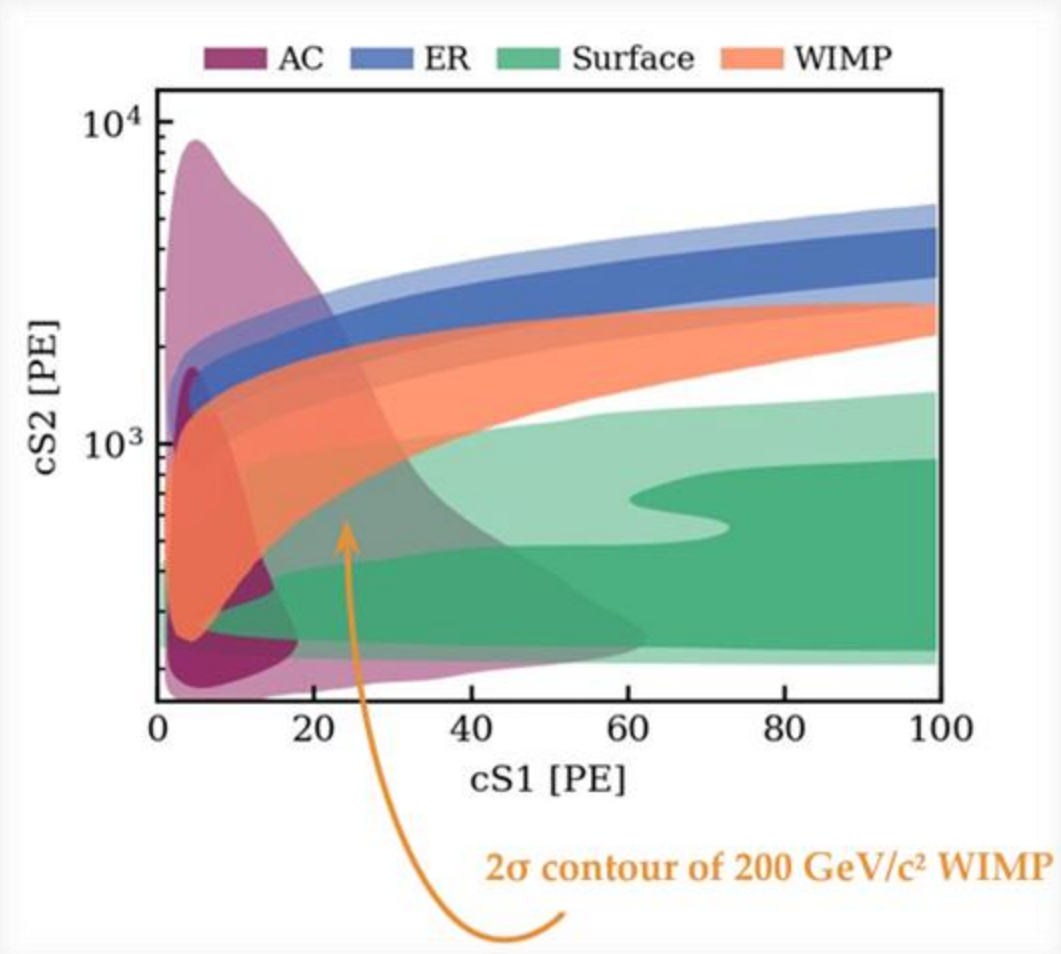
- ^{210}Pb is known to plate out on PTFE walls
- Decays at walls result in charge loss before S2 is observed
- Suppressed by FV cut

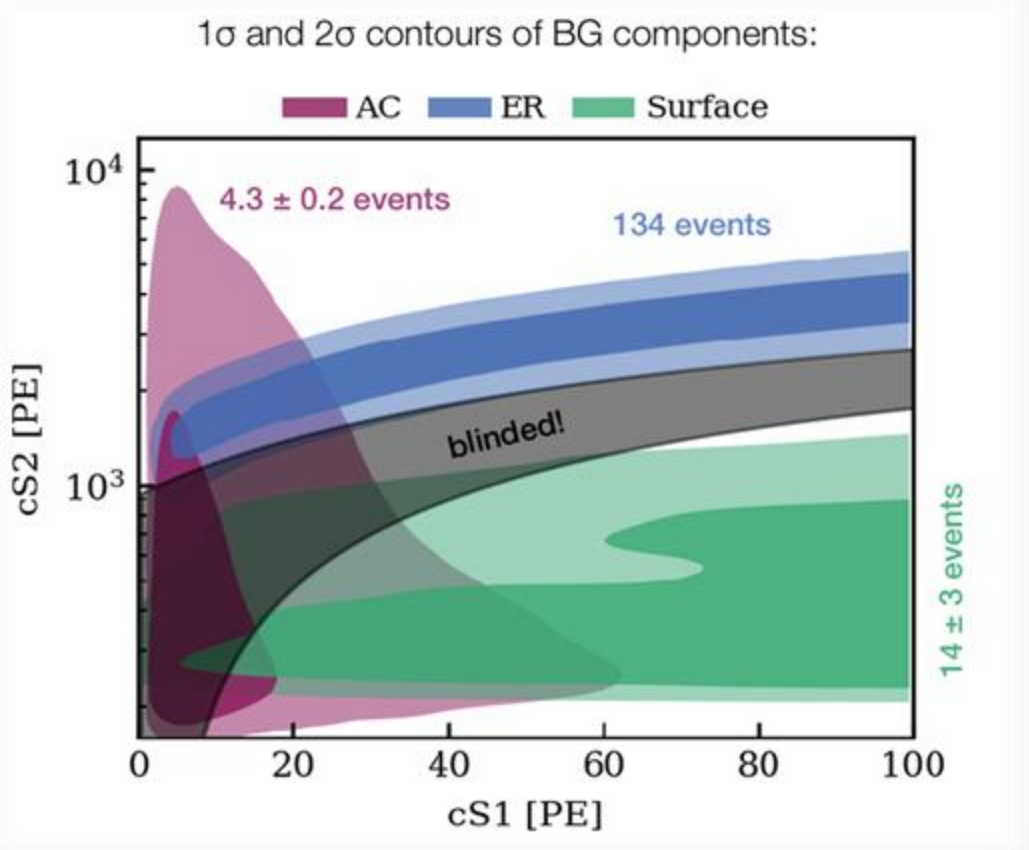
Nuclear Recoil backgrounds

- Radiogenic neutrons constrained by NV tagging (~1.1 events)
- CEvNS expectation of 0.2 events

Blinded WIMP Search in SR0

- WIMP signature is single interaction site nuclear reoil
- Analysis was blinded in lower portion of NR band





Events in search region

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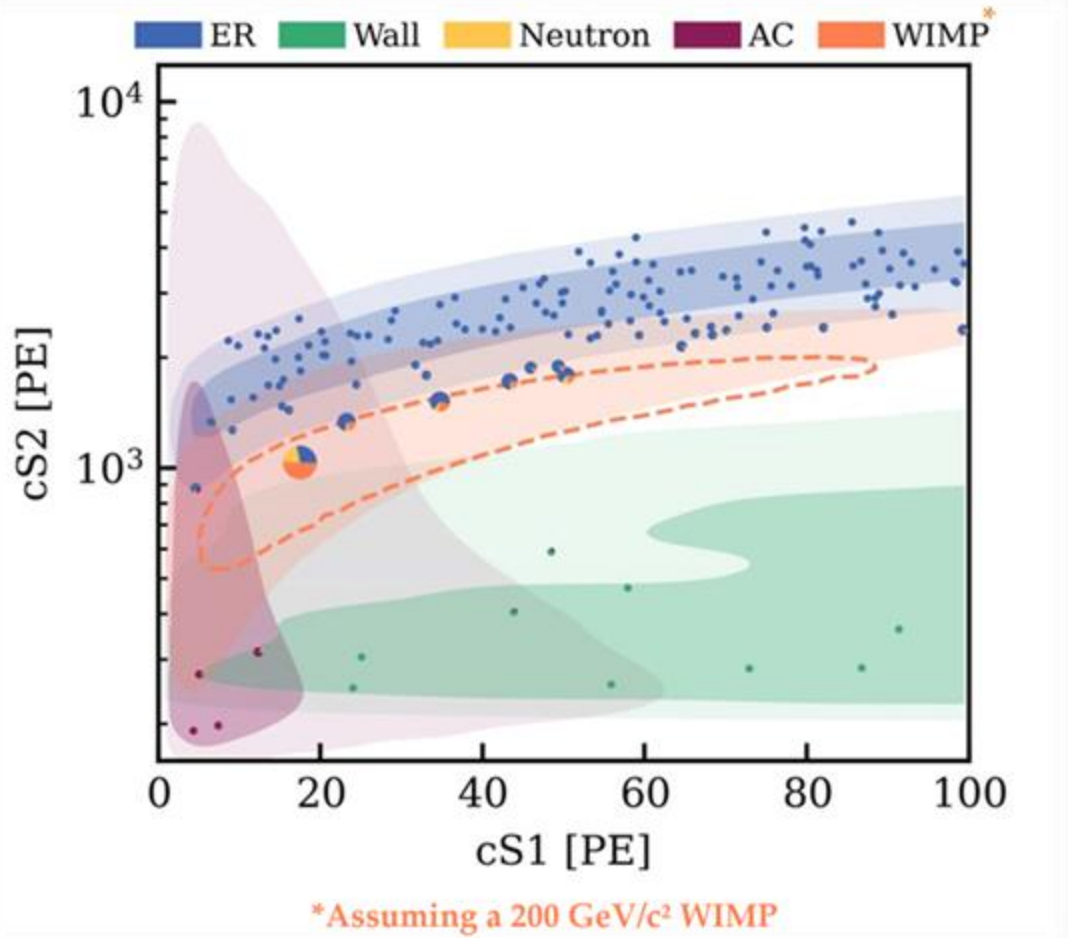
arXiv:2303.14729

	Nominal	Best Fit (200 GeV/c² WIMP)
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)
Background Total	**154**	**152±12**
WIMP	-	2.6
Observed	-	152



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

WIMP Results

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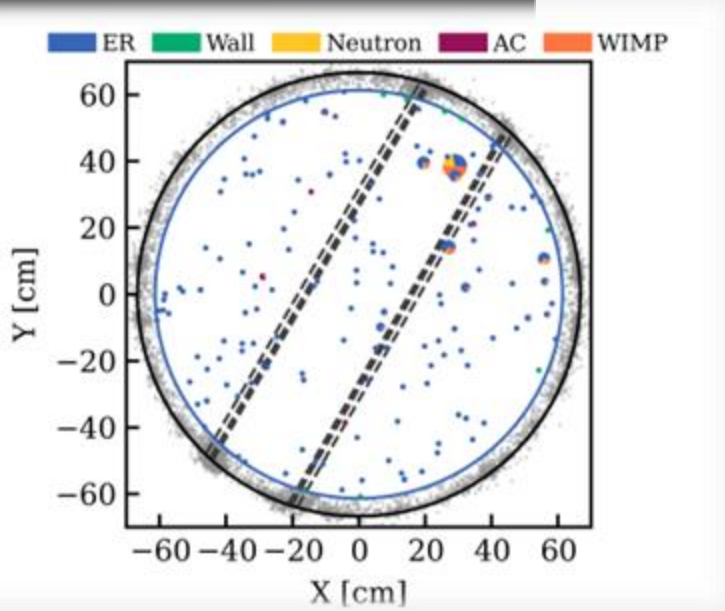
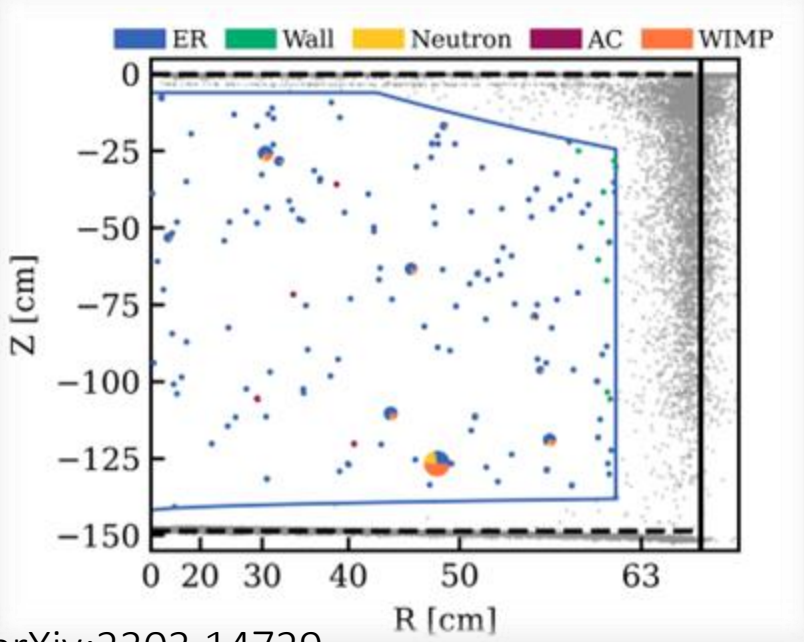
Limit Setting

- Performed unbinned maximum likelihood
- Considered range of WIMP masses up to several hundred GeV/c^2
- No significant excess for any WIMP mass

Events in search region

- Represented as pie charts, displaying contribution of each background component in best fit model at event position





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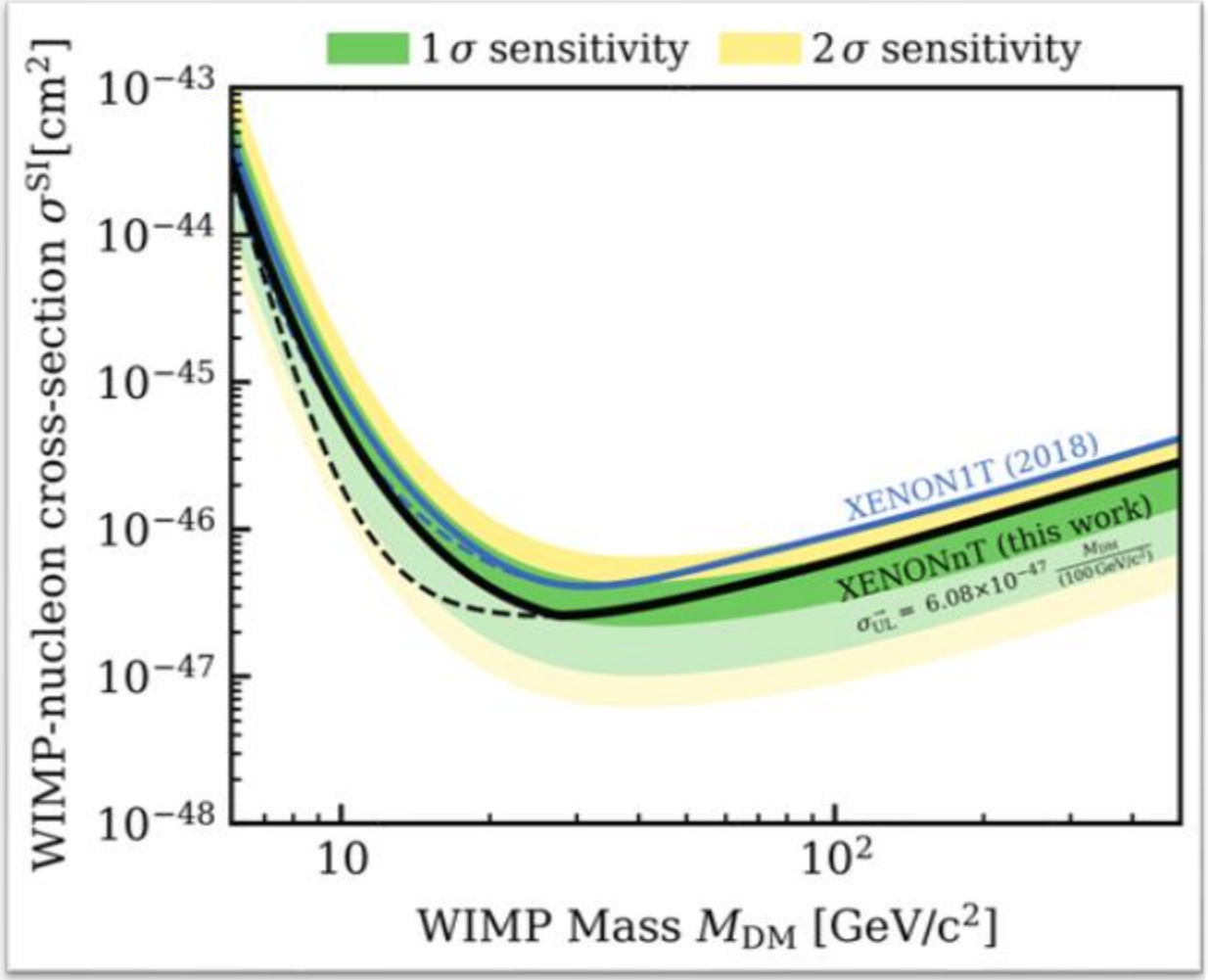
Limit Setting Procedure in XENONnT

- Power constrained limits to avoid spurious exclusion limits
- Minimum rejection power set to 50%
- Limit in effect constrained to median of sensitvity band
- Choice is conservative within community
- Strongest exclusion limit at **28 GeV/c² :**
  2.6 •10^{-47} cm² (90% CL)



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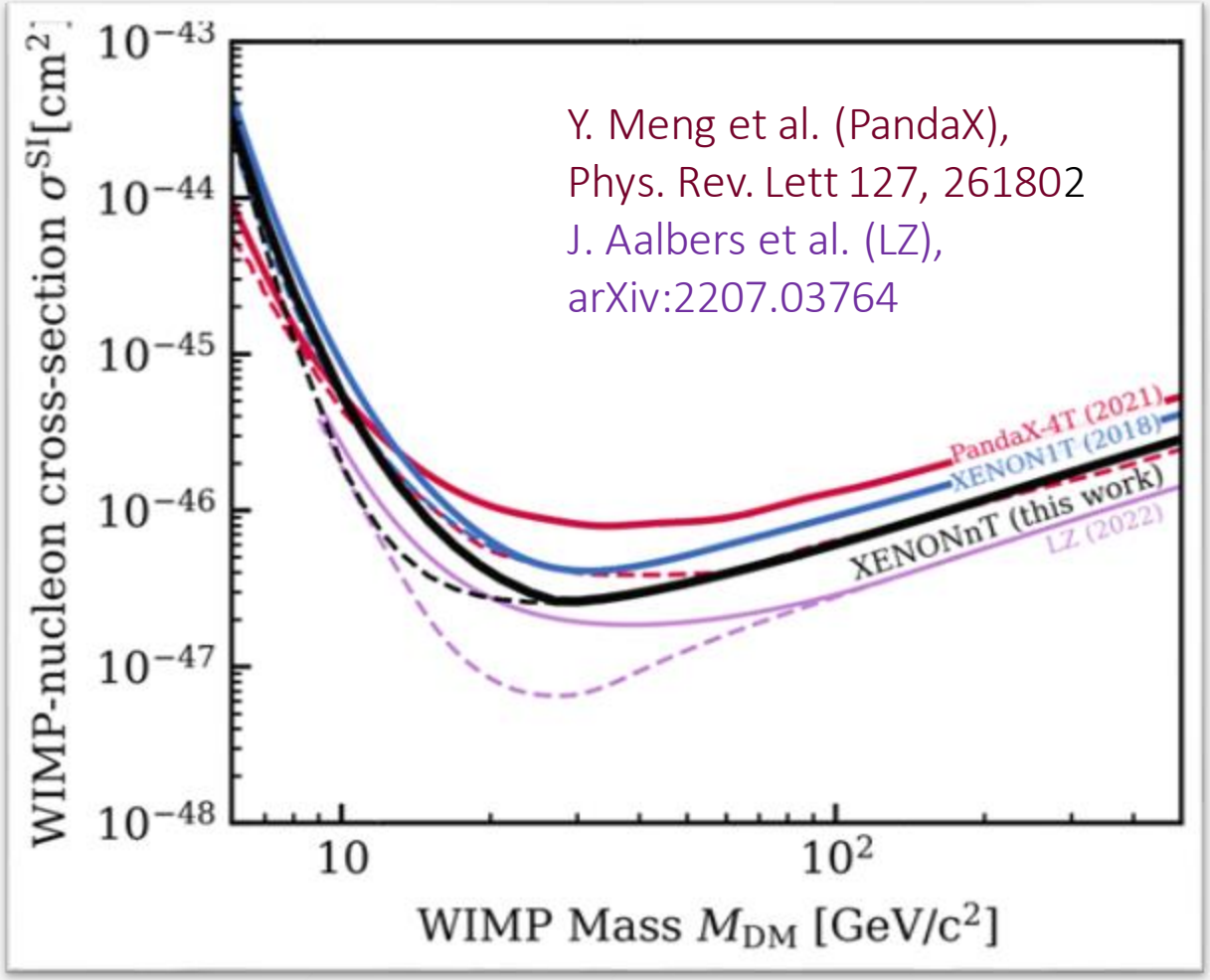
Limits on SI WIMP-nucleon cross section

- Same procedure can be applied to previous limits
- Other Limits shown here are not blinded anlaysis
- XENONnT limit rerpesents factor 1.6 improvement w.r.t XENON1T upper limit
- Data taken in considerably shorter time than XENON1T



Y. Meng et al. (PandaX), Phys. Rev. Lett 127, 261802
J. Aalbers et al. (LZ), arXiv:2207.03764

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Looking into the future!

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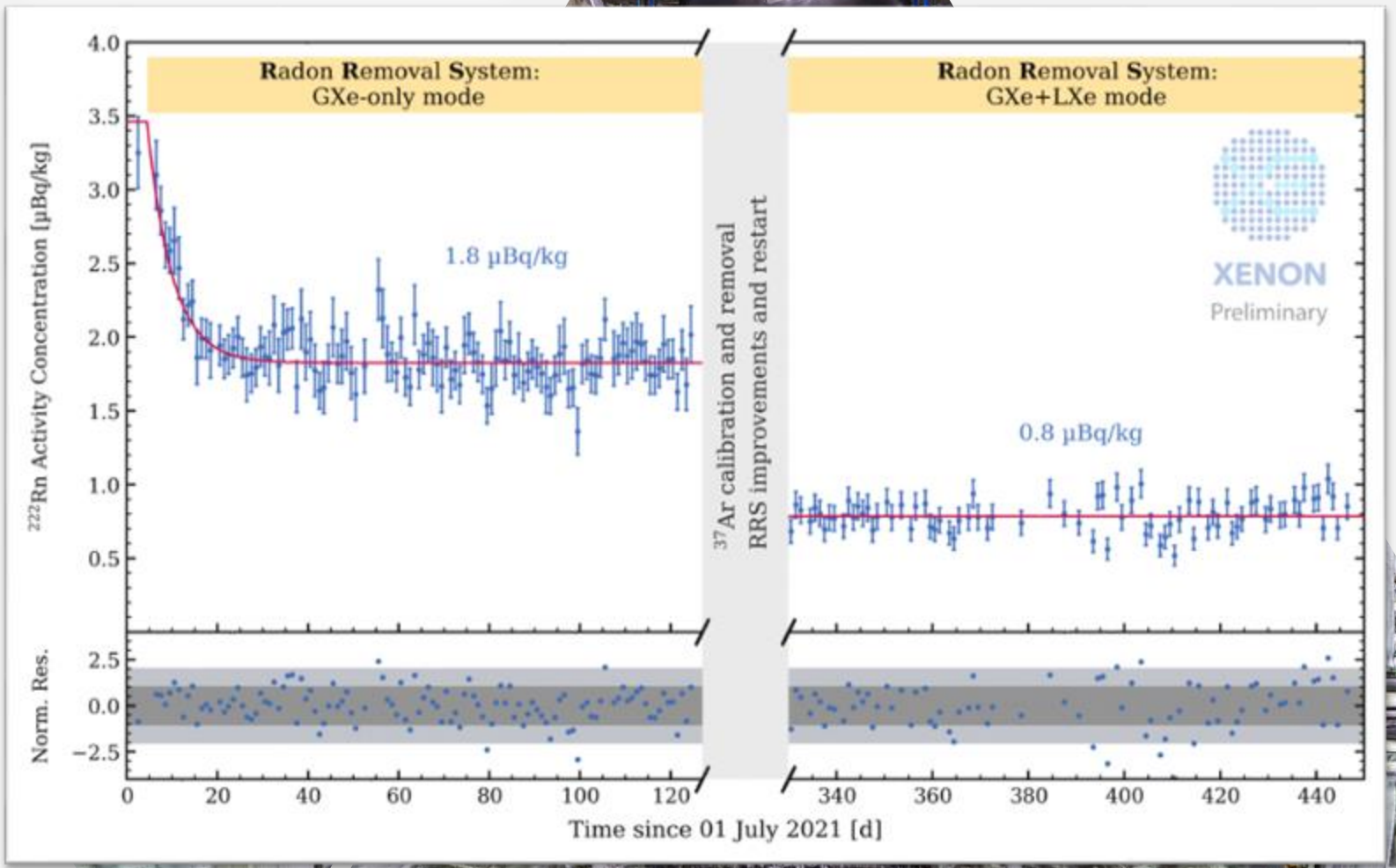

Detector Improvements

- SR1 data taking after further radon reduction
- Gd loading of Neutron Veto

Upcoming analyses

- Solar neutrino analyses
- S2-only studies

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