The XENON Dark Matter Project

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Xe
XENON
Dark Matter Project

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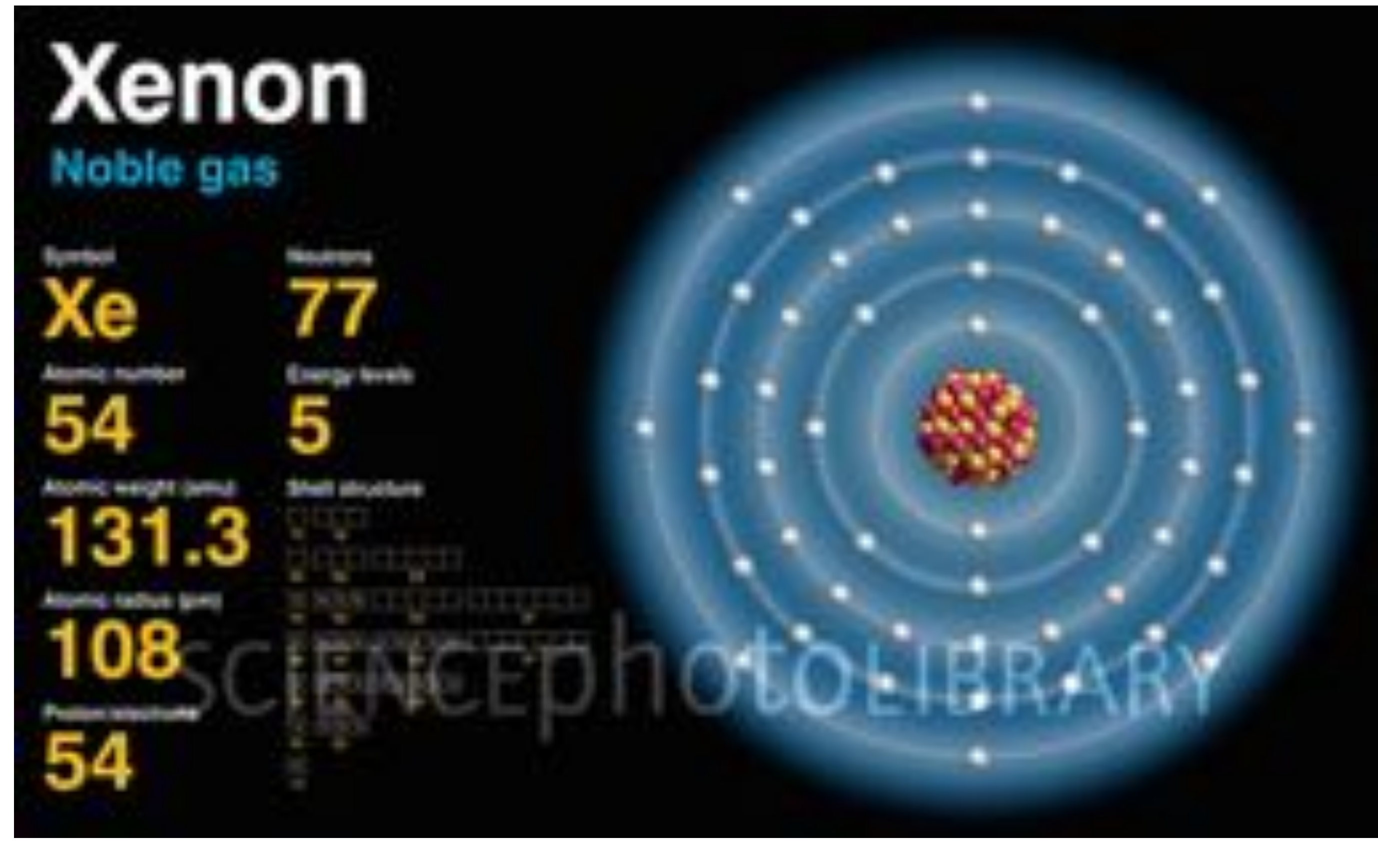
Why Liquid Xenon for a Dark Matter Detector?

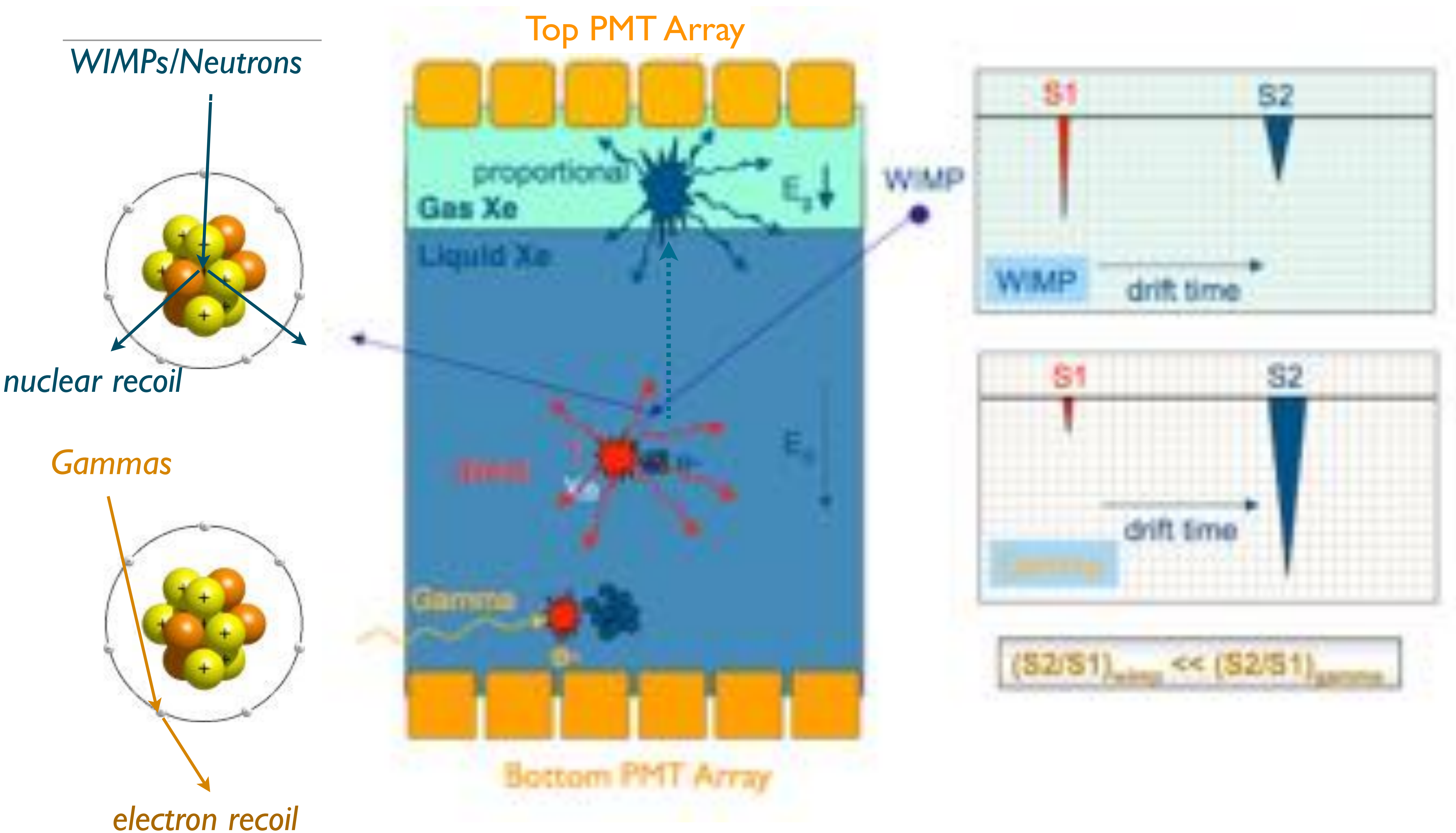
Selected Properties of Xe

Property	Value
Atomic Number (Z)	54
Atomic Weight (A)	131.30
Number of Electrons per Energy Level	2,8,18,18,8
Density (STP)	5.894 g/L
Boiling Point	−108.1 °C
Melting Point	−111.8 °C
Volume Ratio	519
Concentration in Air	0.0000087 % by volume



- ✦ *dense liquid for a massive WIMP target at reasonable cost (~1000$/kg)*
- ✦ *large nucleus and presence of isotopes with nuclear spin allow to probe SI and SD interactions with one target*
- ✦ *we have improved technologies to keep it cold and clean over long time*
- ✦ *no intrinsic radioactivity other than Kr85 which we know how to remove*
- ✦ *two signals (ionization and scintillation) in response to radiation*

A Time Projection Chamber to detect these two signals



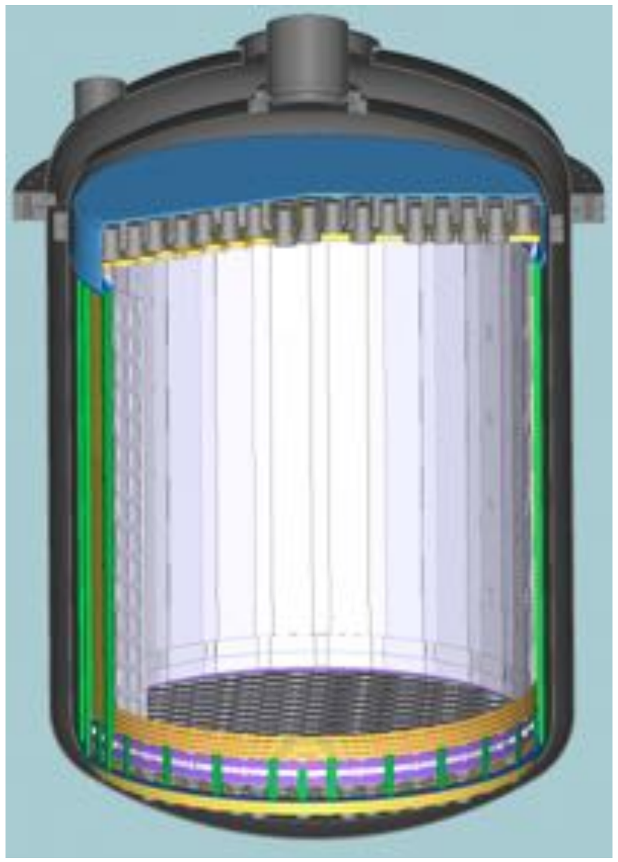
The TPCs of the XENON Program

XENON10

XENON100

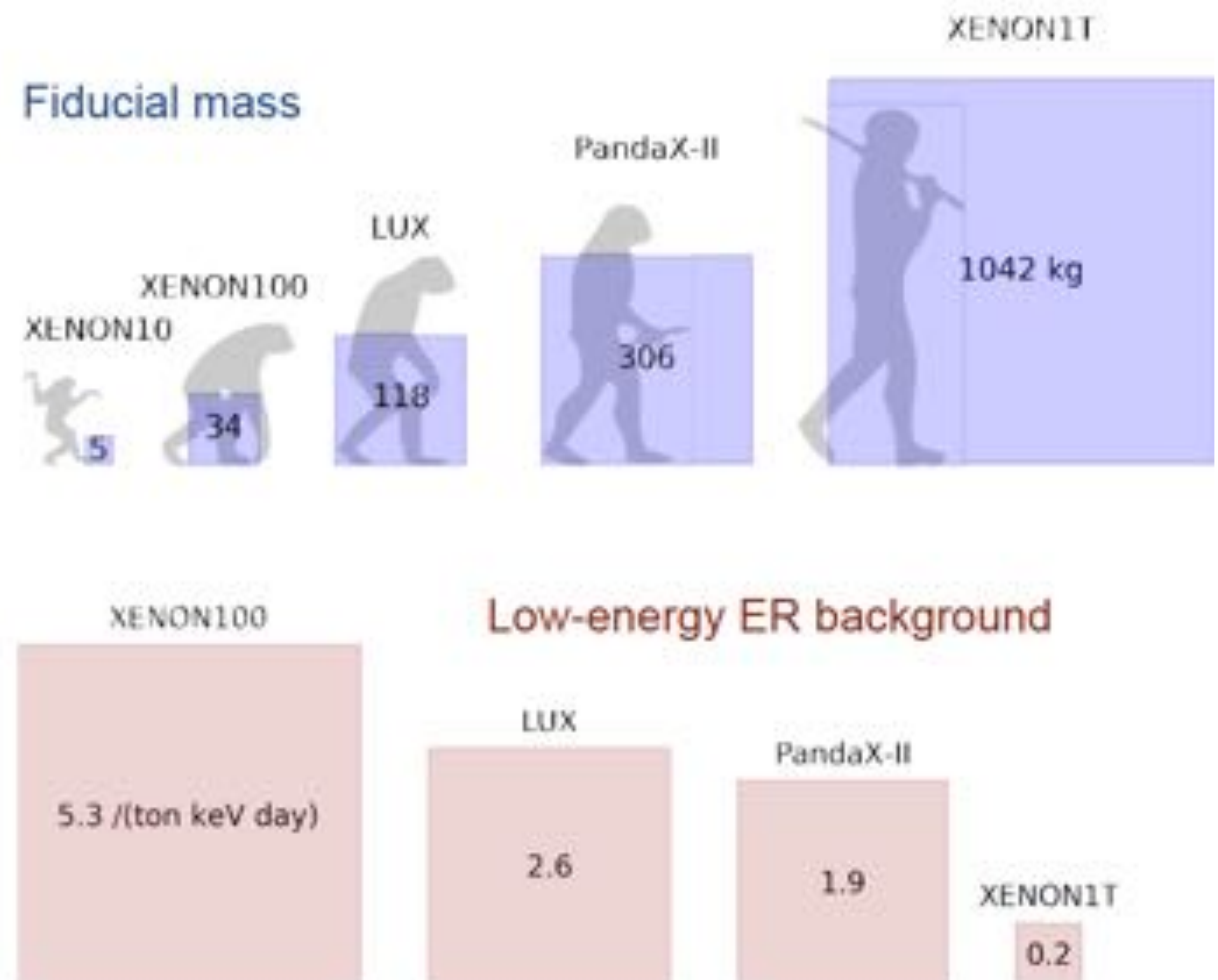
XENON1T

XENONnT



2005-2007	2008-2016	2012-2018	2019-2023
25 kg- 15cm drift	161 kg- 30 cm drift	3200 kg- 100 cm	8000 kg-150 cm
~10^{-43} cm^2	~10^{-45} cm^2	~10^{-47} cm^2	~10^{-48} cm^2

XENON1T: the next step in evolution



from Jelle Aalbers

The XENON collaboration

140 scientists

22 institutions

10 countries














The XENON1T Experiment
www.xenon1t.org

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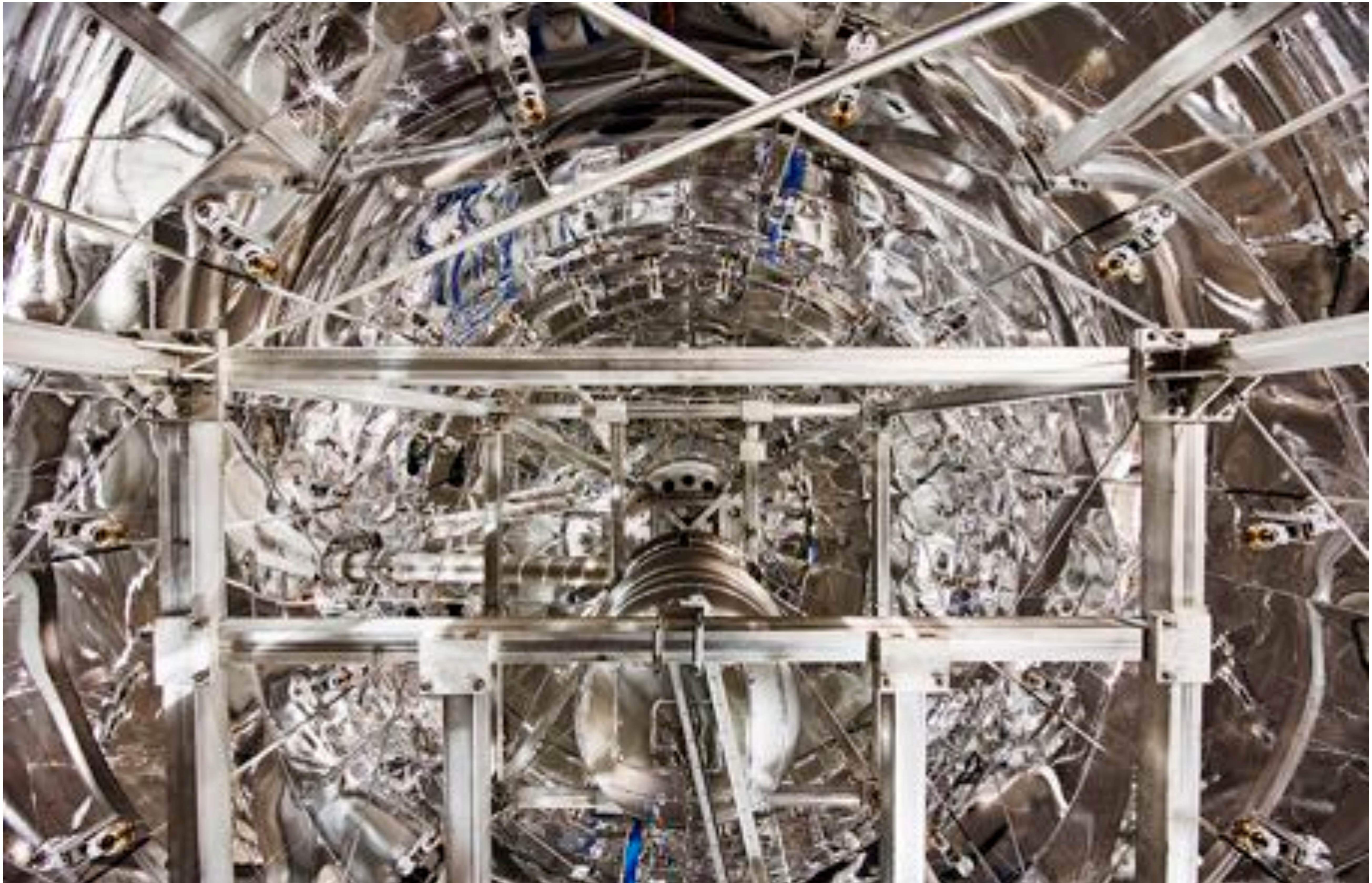
www.xenon1t.org



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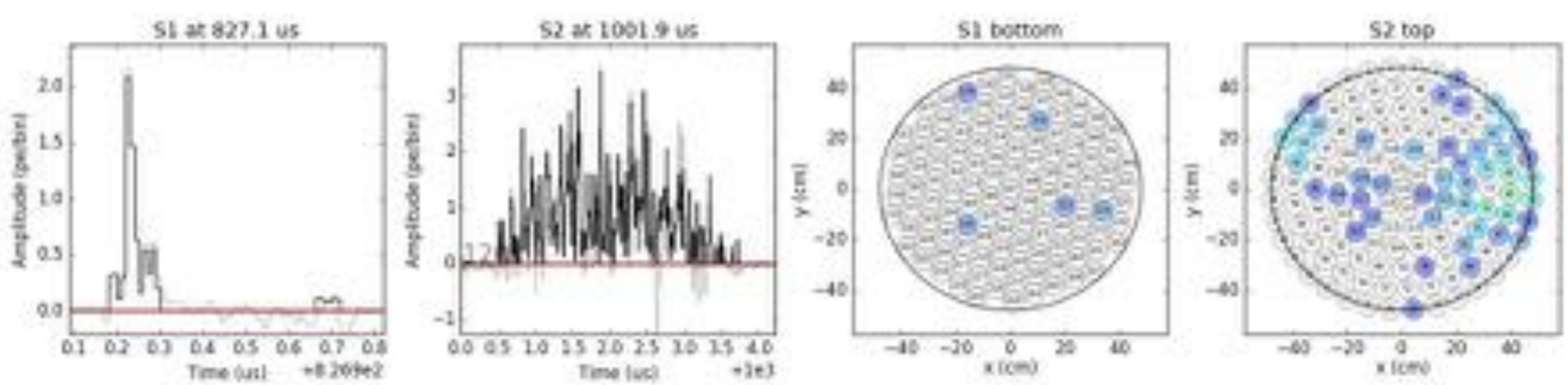
The XENON1T Time Projection Chamber

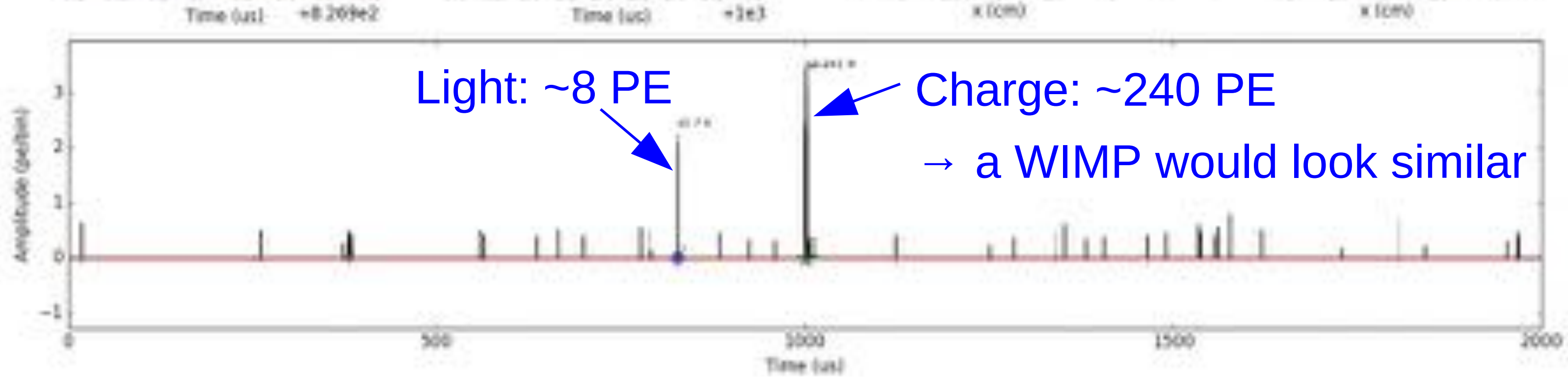
- 248 3-inch, low-radioactivity PMTs arranged in two arrays EPJC 75 (2015) 11, 546

3.2 t LXe @180 K
~1 meter drift length
~1 meter diameter

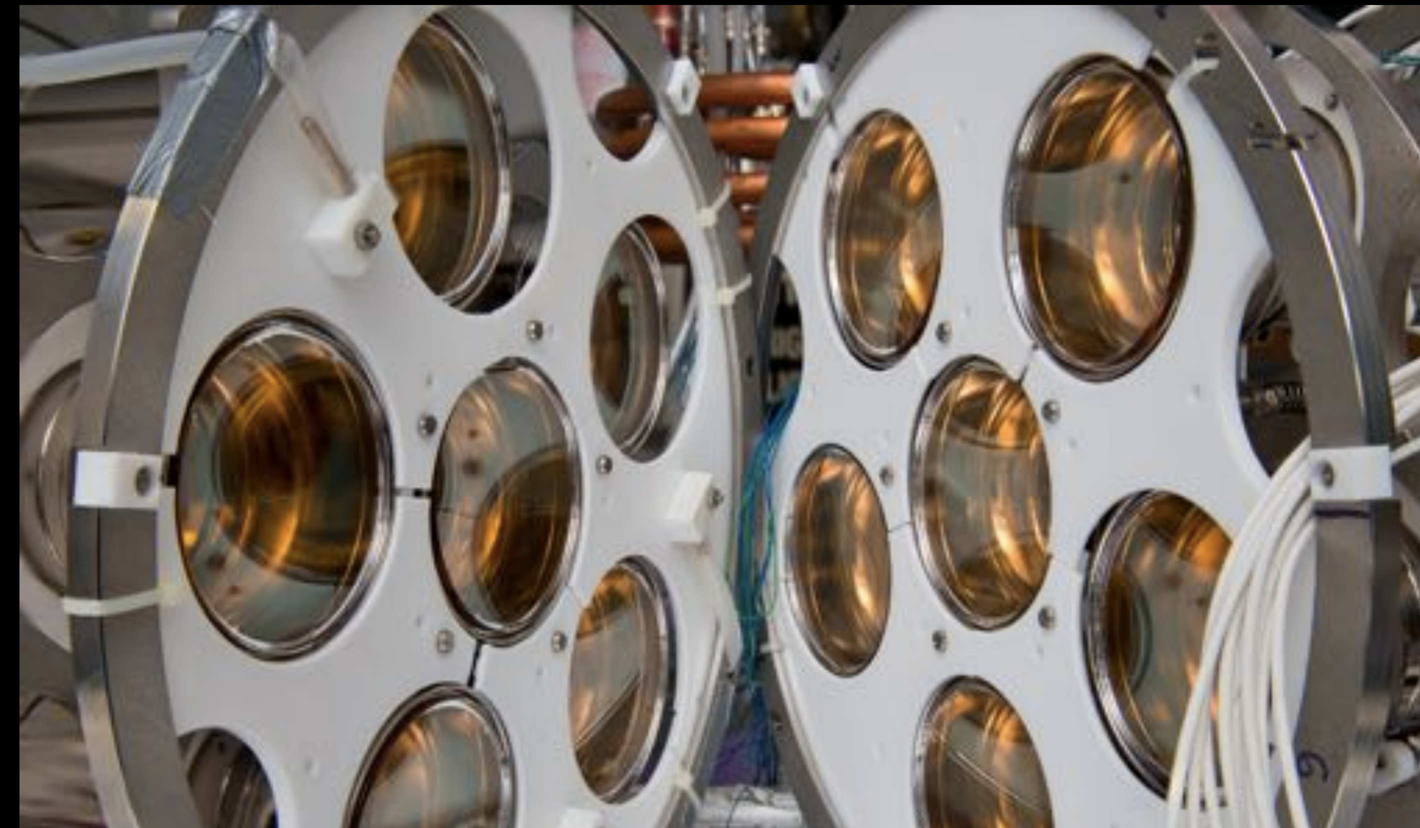
127 PMTs in the top array

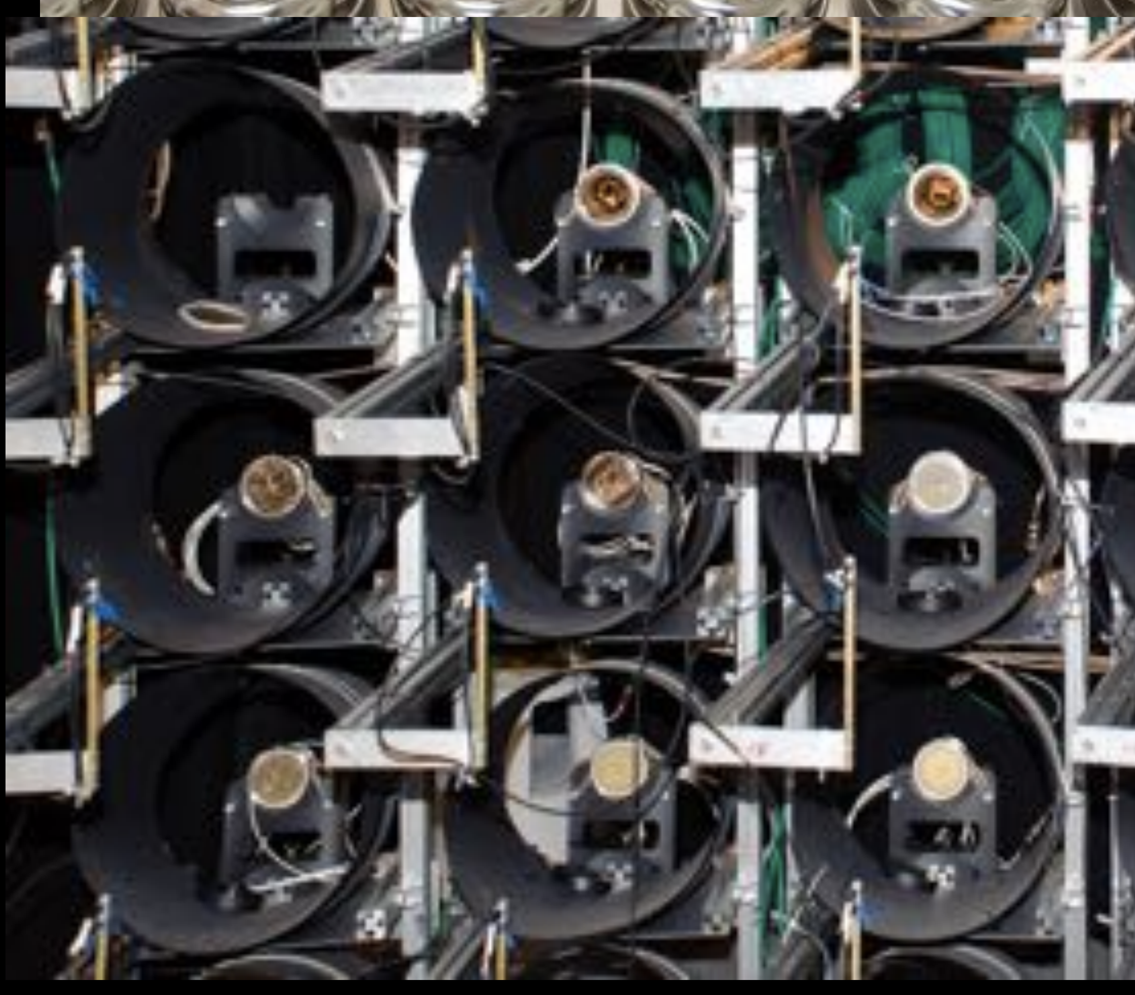
121 PMTs in the bottom array





MPIK: big contribution to the“eyes” of XENON1T



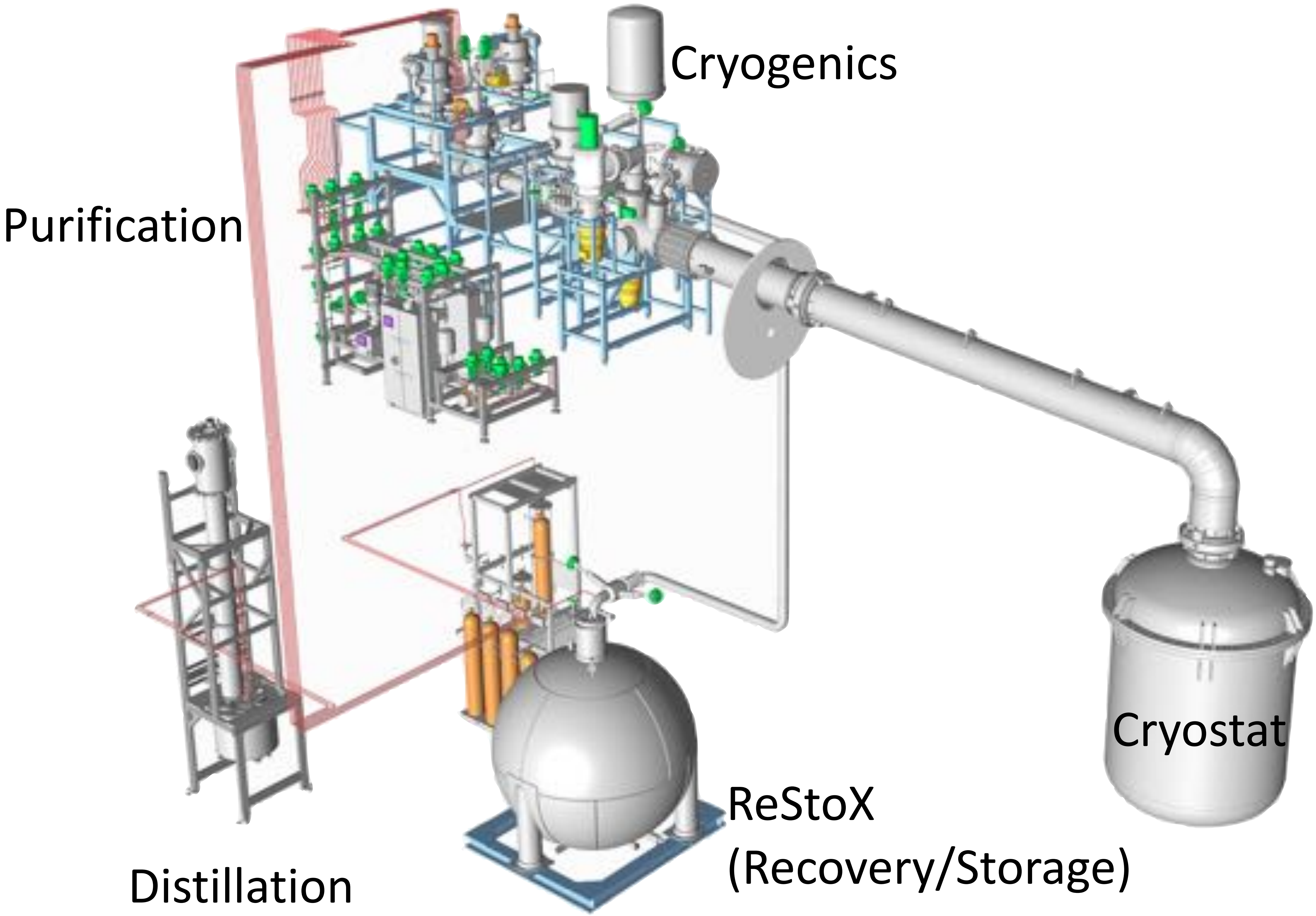


It takes ~600,000 liters of Xe gas to fill the detector with 3500 kg of LXe


Iceblick

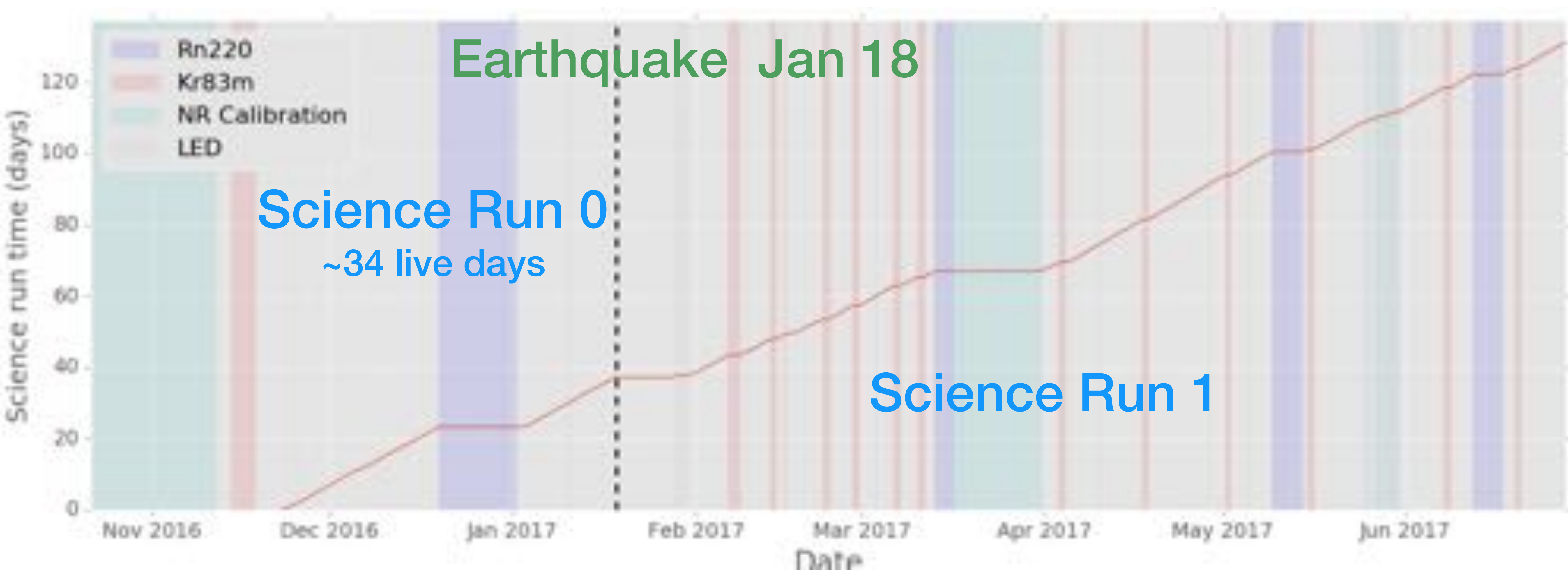
and custom-developed systems to handle/ condense/purify/ keep Xe cold and clean

XENON1T Cryogenic Plants

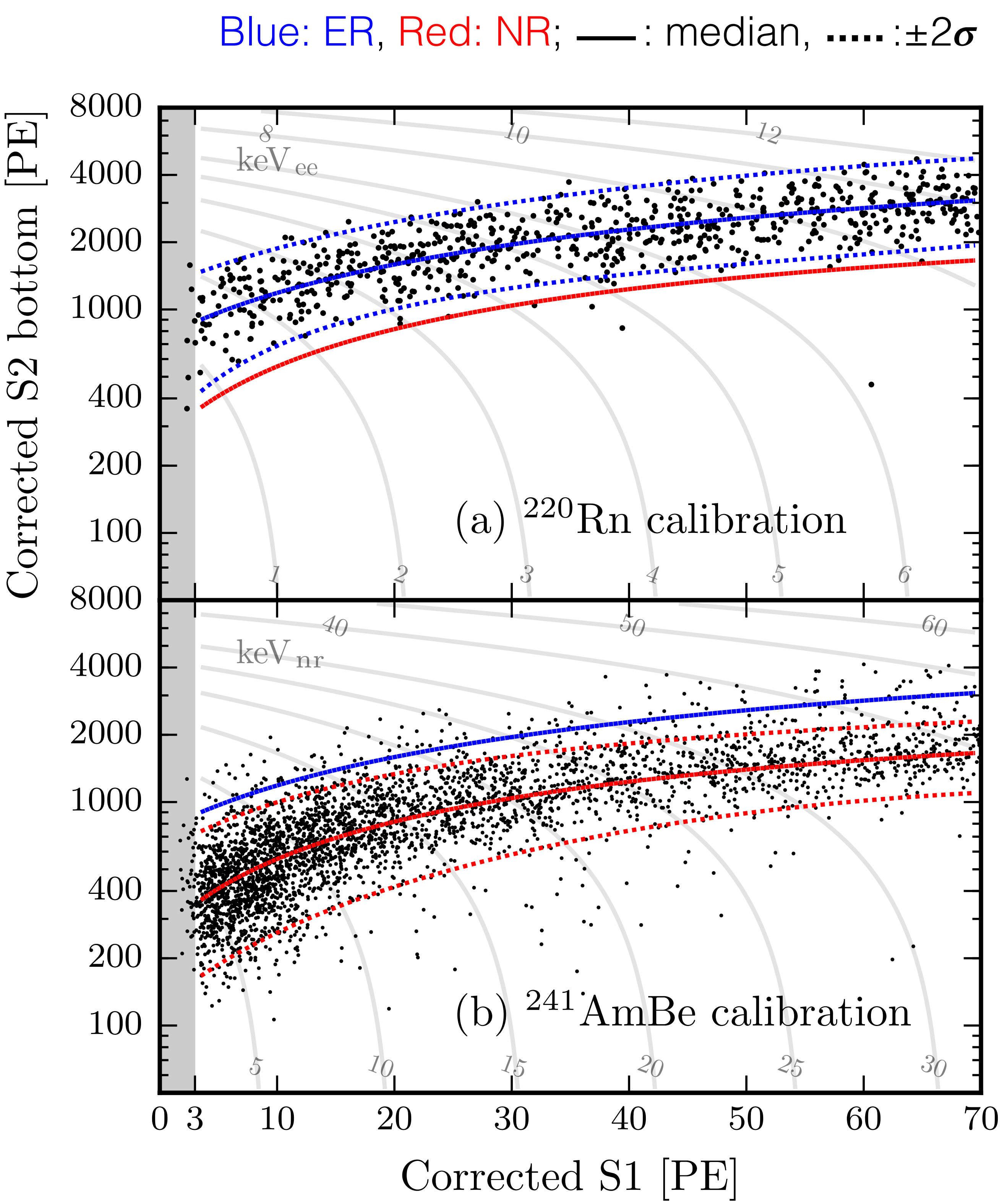


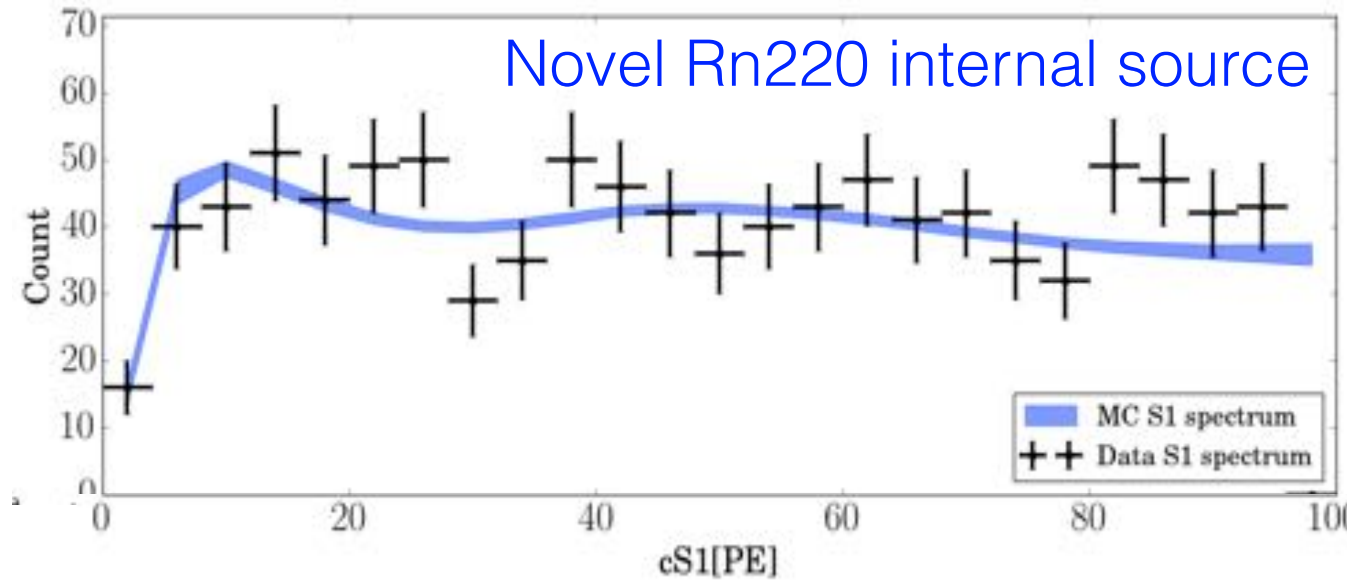
XENON1T Science and calibration data-taking

- First science run: Nov 22, 2016 - Jan 18, 2017 - Blind Analysis completed May ‘17
- Second science run ongoing: >100 days (blinded) on tape - Analysis in progress

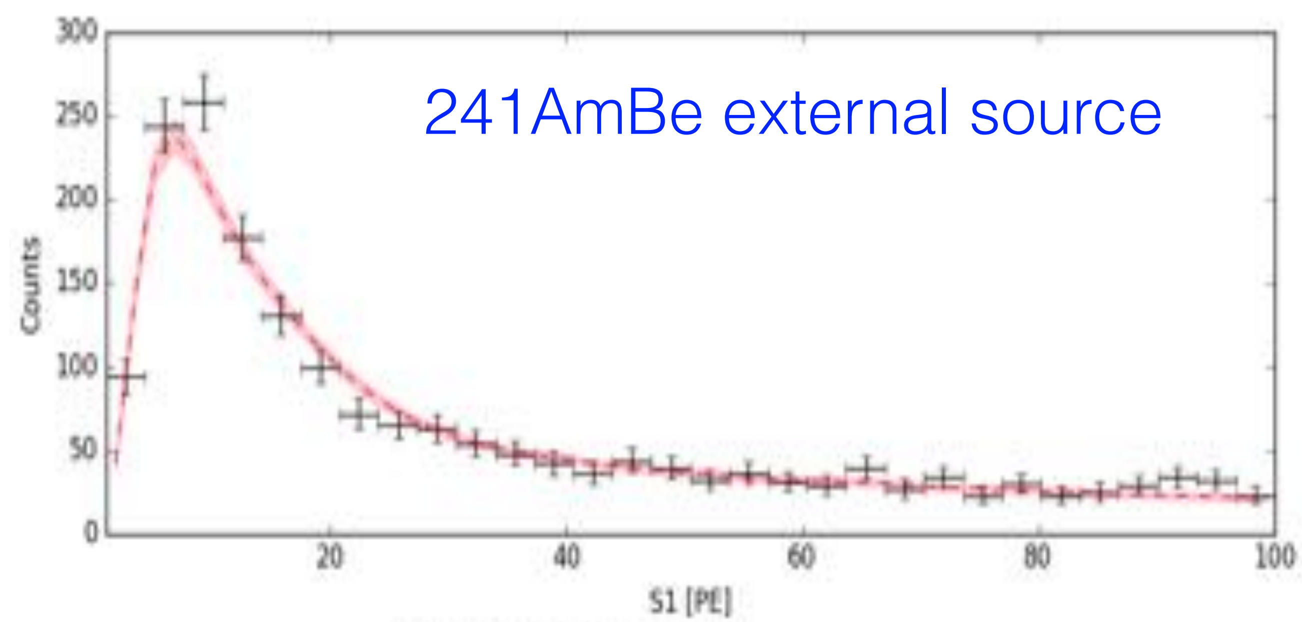


ER and NR Response in SR0



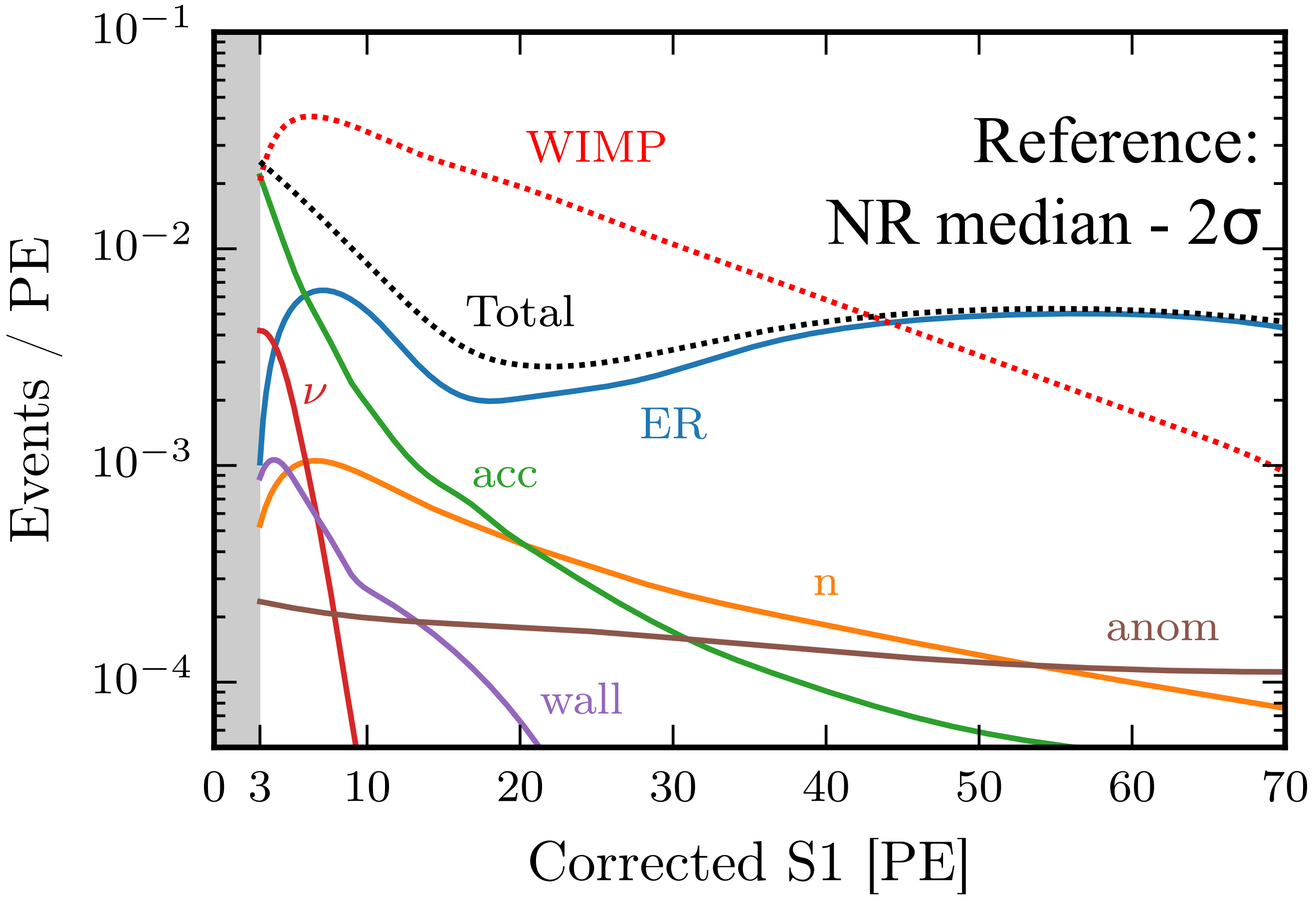


- Full modeling of LXe and detector response in $cS2_b$ vs cS1 space
- All parameters fitted with no significant deviation from priors



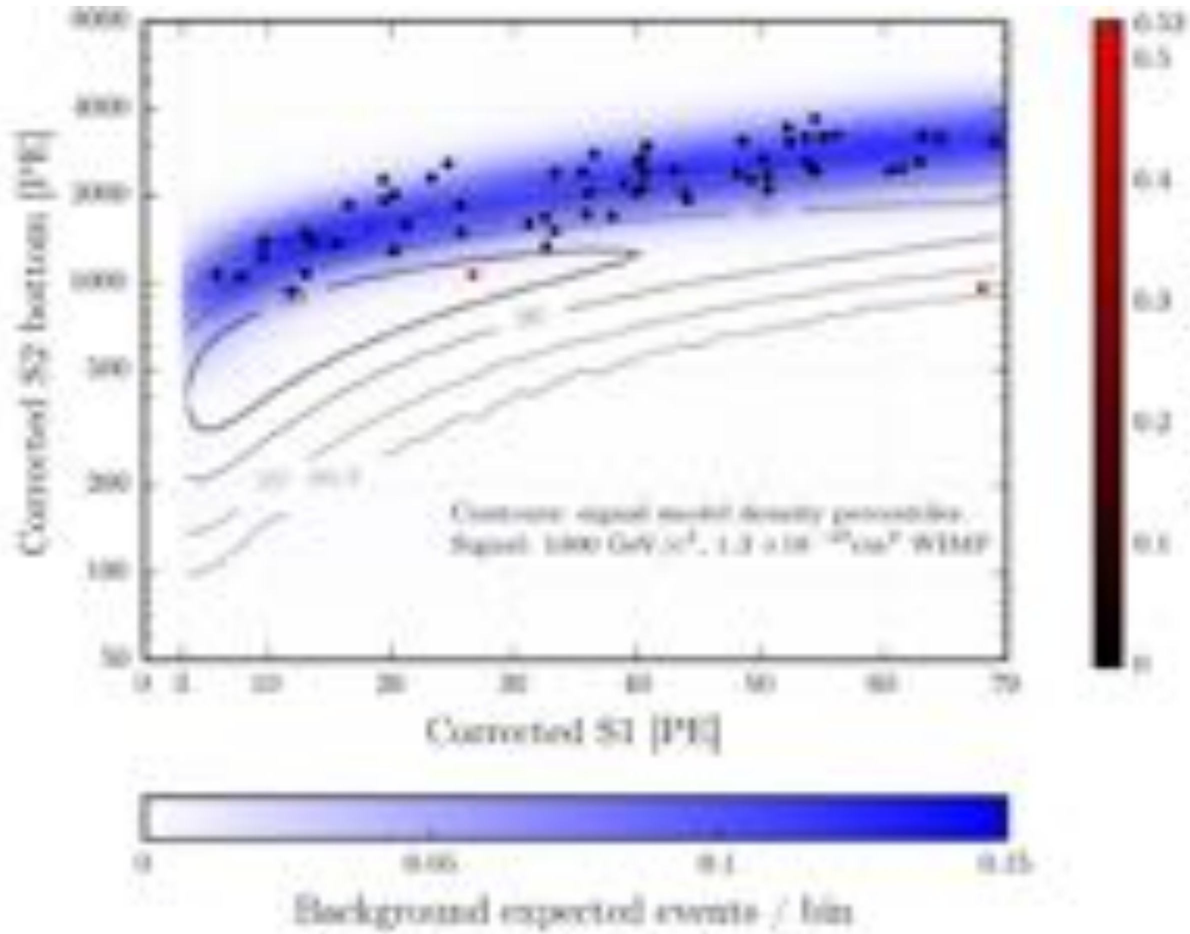
SR0 Background model

- 3-70 PE (5-40 keVnr) in 1042 kg FV
- ER and NR spectral shapes are from models fitted to data.Other background are data-driven
- most significant background (for >10 GeV WIMPs)



Background & Signal Rates	Total	Reference
Electronic recoils *(ER)*	62 ± 8	0.26 (+0.11)(-0.07)
Radiogenic neutrons *(n)*	0.05 ± 0.01	0.02
CNNS (ν)	0.02	0.01
Accidental coincidences (*acc*)	0.22 ± 0.01	0.06
Wall leakage (*wall*)	0.52 ± 0.32	0.01
Anomalous (*anom*)	0.09 (+0.12)(-0.06)	0.01 ± 0.01
Total background	**63 ± 8**	**0.36 (+0.11)(-0.07)**

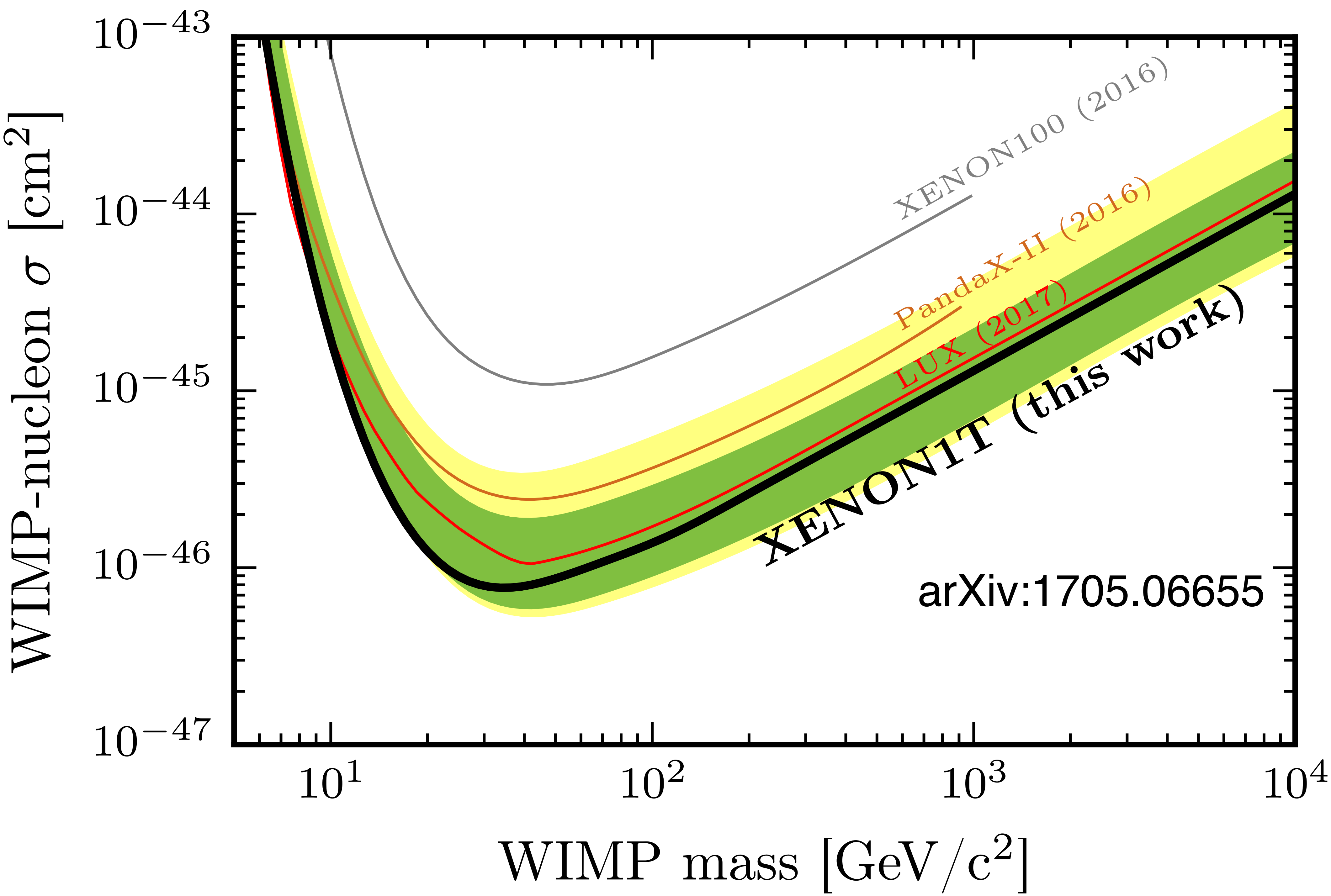
SR0 Data Unblinding



- Extended unbinned profile likelihood analysis
- Most significant ER & NR shape parameters included from cal. fits
- Background-only (no WIMPs) still best fit
- Uncertainties are nuisance parameters:
  - Background component rates
  - ER and NR band shape

Cut	Events remaining
All events (cS1 < 200 PE)	128144
Data quality, selection	48955
Fiducial volume	180
S1 range (3 <cS1< 70 PE)	**63**

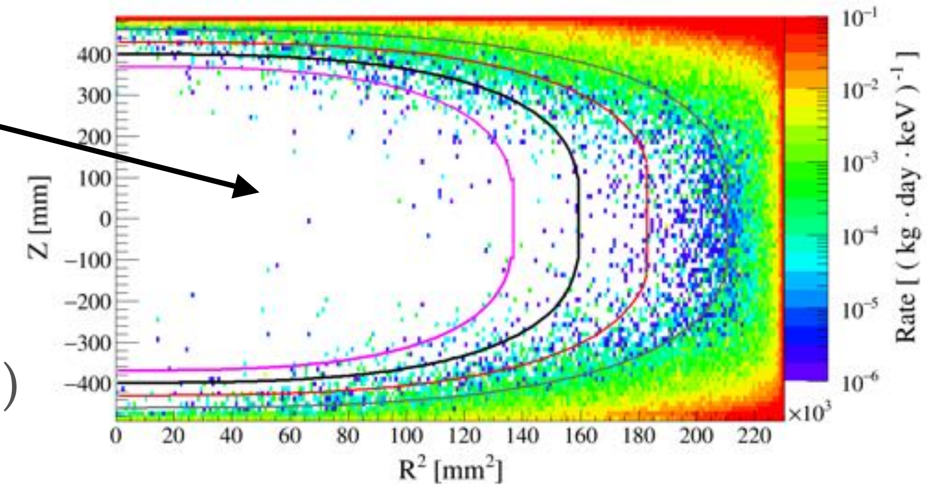
XENON1T First Result



minimum at 7.8 x 10^{-47} cm^2 for 35 GeV

XENON1T ER Background

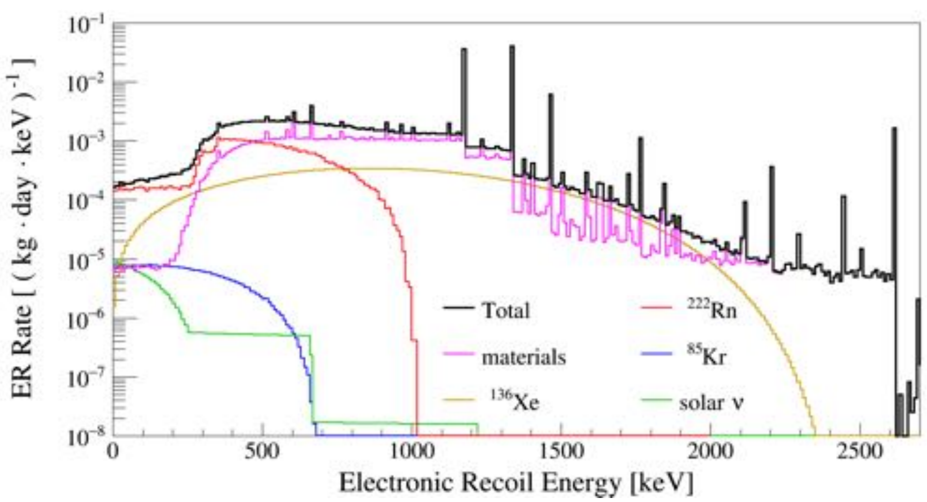
Predictions from MC simulations: ER background from materials is negligible in the 1t FV.

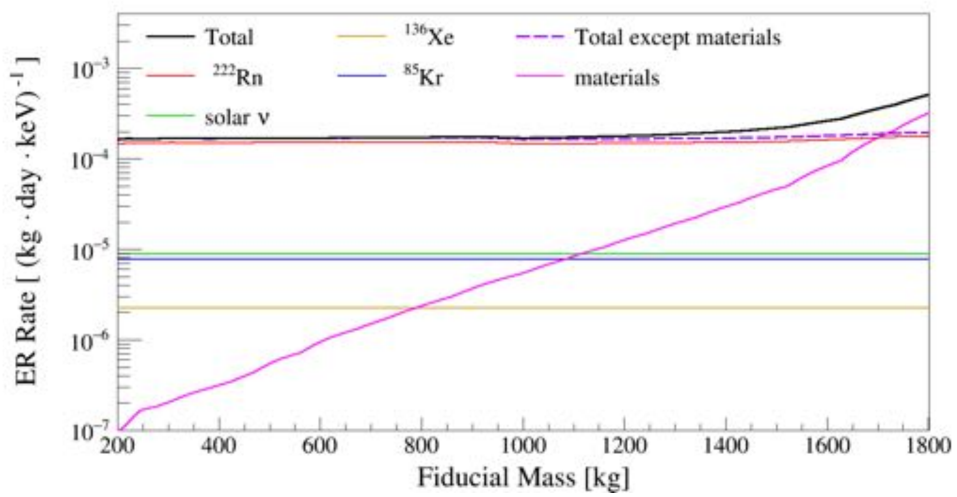


Eur. Phys. J. C77 (2017) no.5, 275 & arXiv:1702.06942

MC assumptions on the intrinsic backgrounds:

- 0.2 ppt of ^{nat}Kr (achieved in XENON1T distillation column tests),
- 10 μBq/kg of ^{222}Rn (estimation based on Rn emanation measurements)



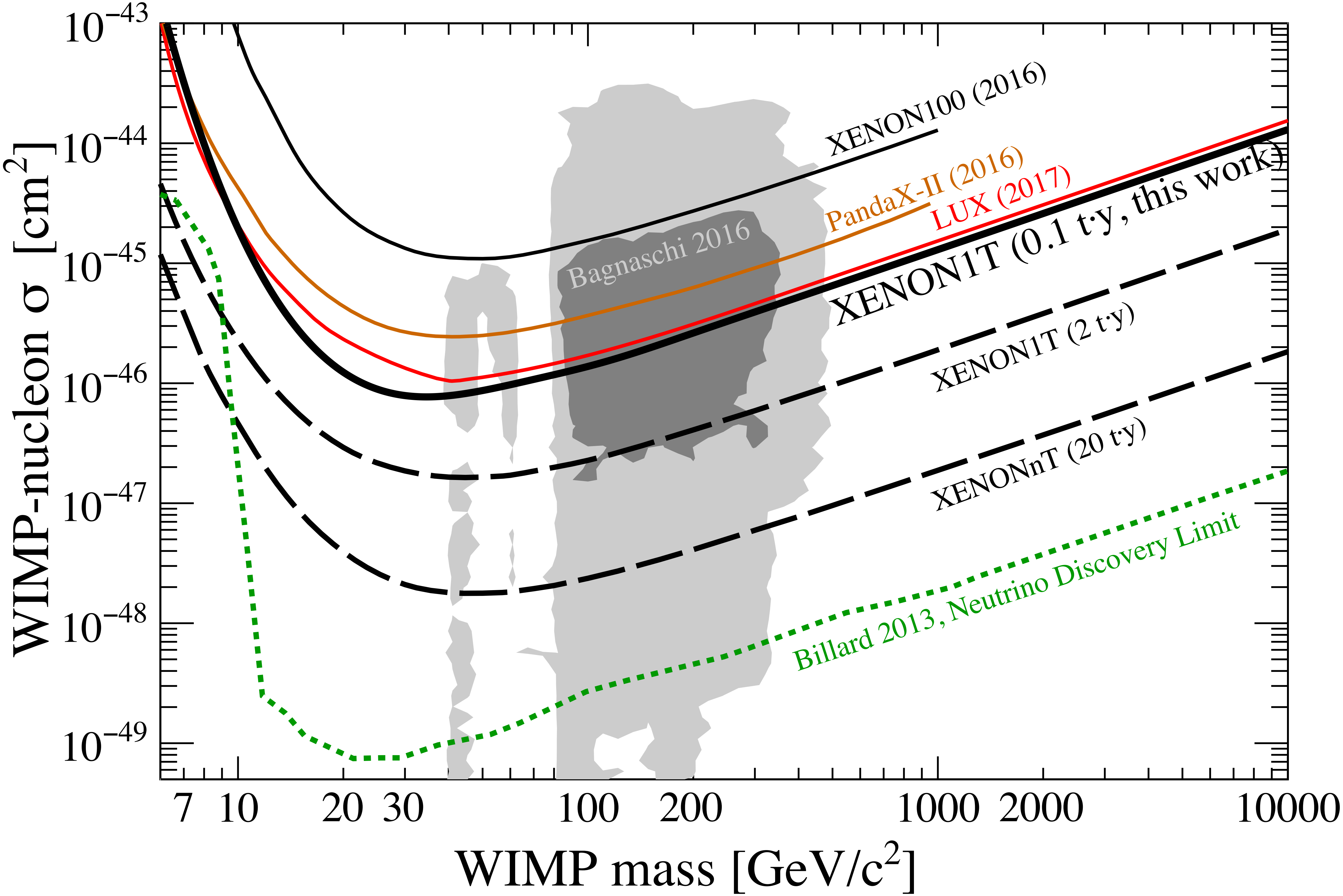


^{222}Rn (mainly from ^{214}Pb β-decay) is the most relevant source of ER background in most of the TPC.

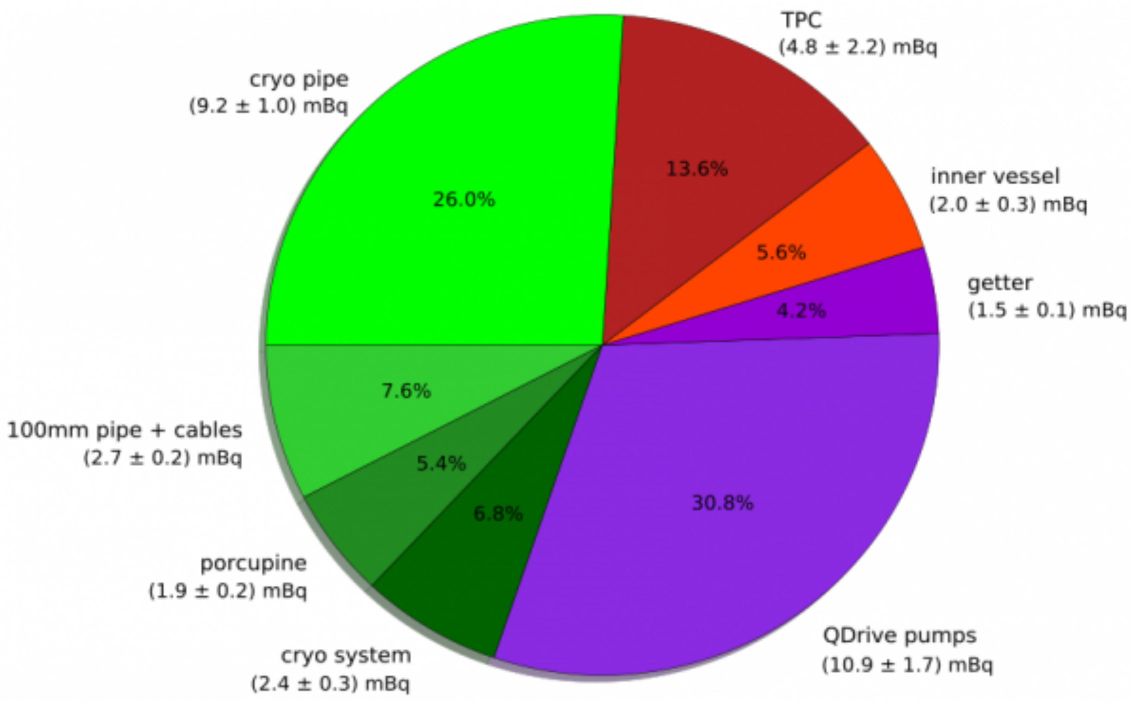
Measured: (1.93 +/- 0.25) 10^{-4} events / (kg day keV) in 1042 kg FV and 5-40 keVnr ROI
Predicted (considering the average 1.5 ppt of Kr in first run): (2.3 +/- 0.2) 10^{-4} events / (kg day keV)

Lowest ER background ever achieved in a DM detector !

Next step: XENONnT to start in 2019

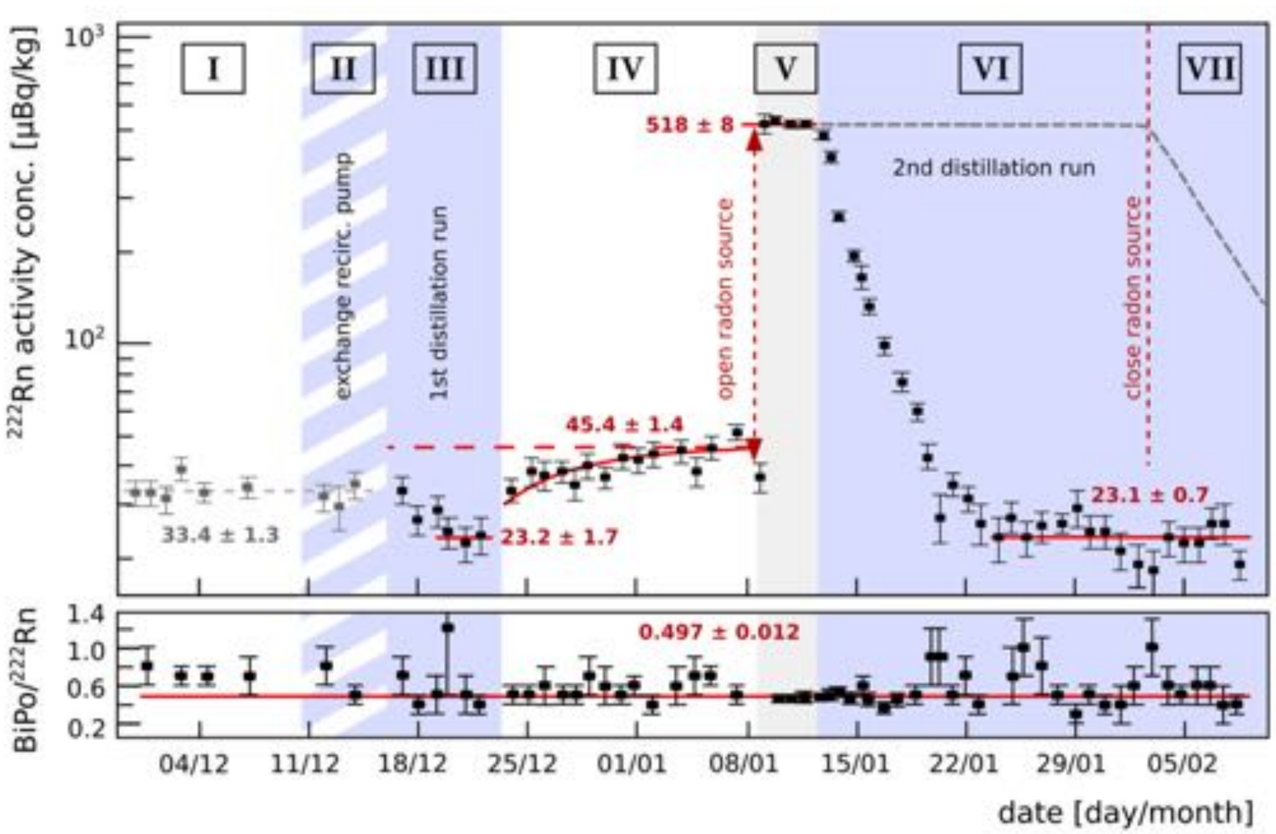


Radon Reduction for XENONnT



Radon source identified in XENON1T

- Material selection with ^{222}Rn screening
  - screening facilities with few atoms/probe sensitivity
- Replace parts with large Rn contribution
- Post-manufacturing surface treatment
- Reduction with high throughput online distillation
- Goal: 1 μBq/kg



Online Rn removal with distillation in XENON100 (Eur. Phys. J. C, 77:358, 2017)

Rn screening facility @ MPIK

Summary

- The WIMP hypothesis is being tested with the first direct detection experiment using a ton-scale Xe target in a detector with the lowest-ever low-energy background of ~2mdru.

- The first results from a short run of XENON1T show the promise of this new experiment. With the additional exposure, still blinded, we will soon probe previously unexplored parameter space.

- With XENON1T and its upgrade to XENONnT, we have the potential to finally discover WIMPs or exclude their existence opening the door to new ideas on DM. At the same time the experience with XENON1T/nT will continue to inform the design of a future experimental effort such as DARWIN to reach the ultimate sensitivity.

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