The XENON Dark Matter Project

Current Status and Future Prospects

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For the XENON Collaboration

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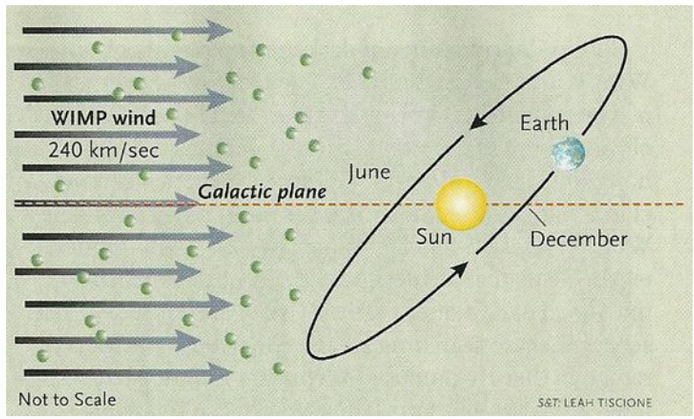
Astroparticle Physics in Germany 18.09.2018

WIMP Detection Strategies

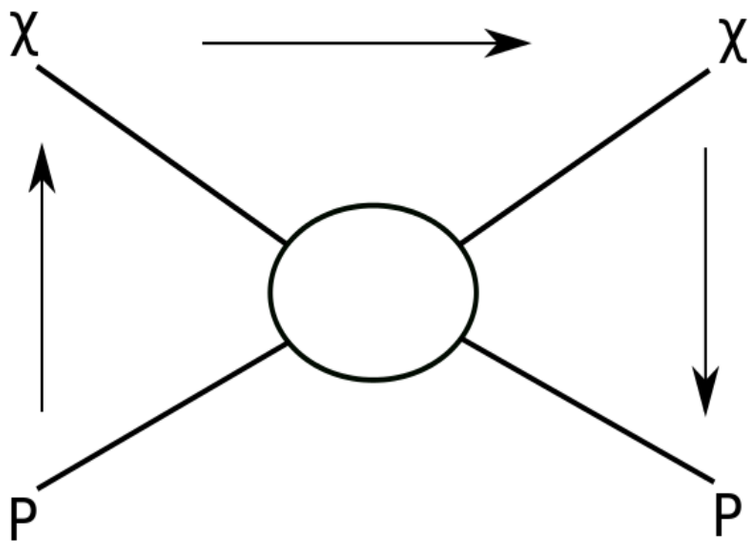


XENON, LUX, DEAP, CDMS, PICO, DAMA ...

ATLAS, CMS, ...

Direct Detection

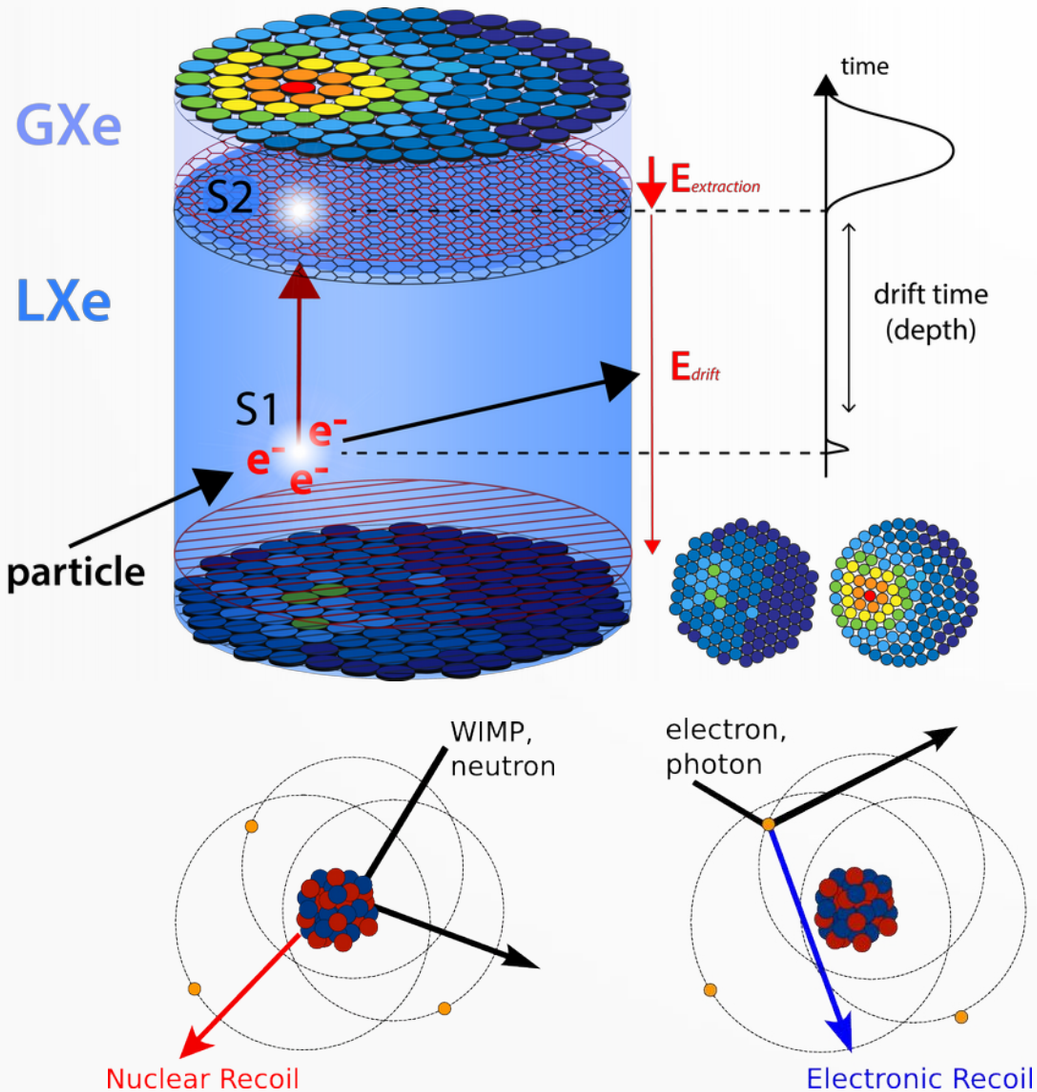
Production at Colliders



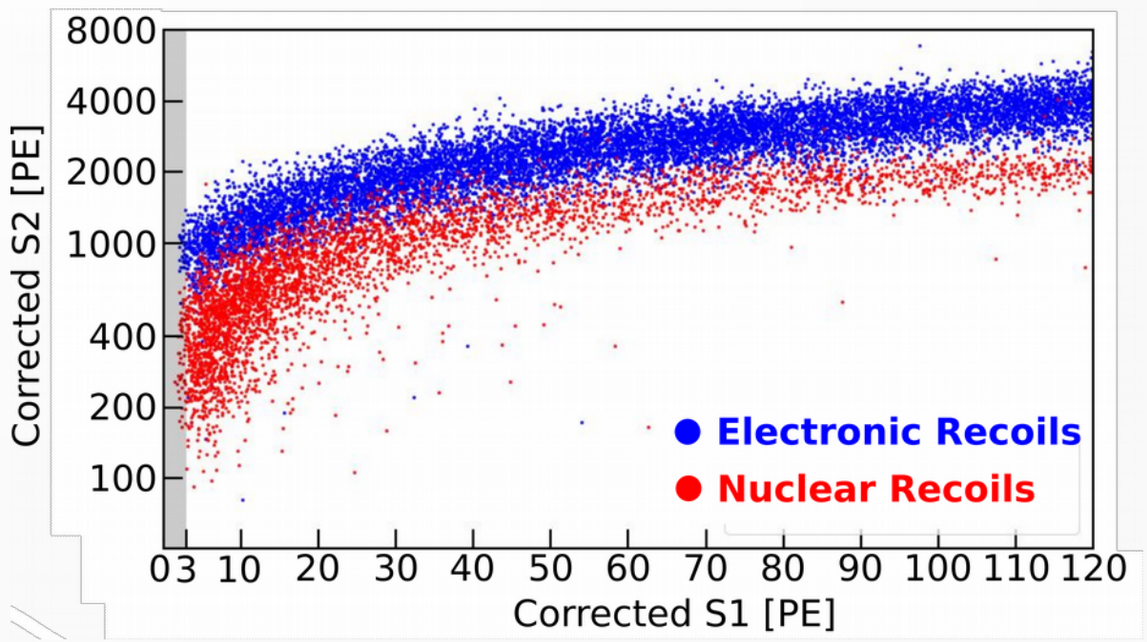
Indirect Detection

Fermi, Ice Cube, AMS,...

The dual-phase TPC Technology



- Light from prompt scintillation (S1) and ionization (S2)
- 3D position reconstruction
- Background discrimination

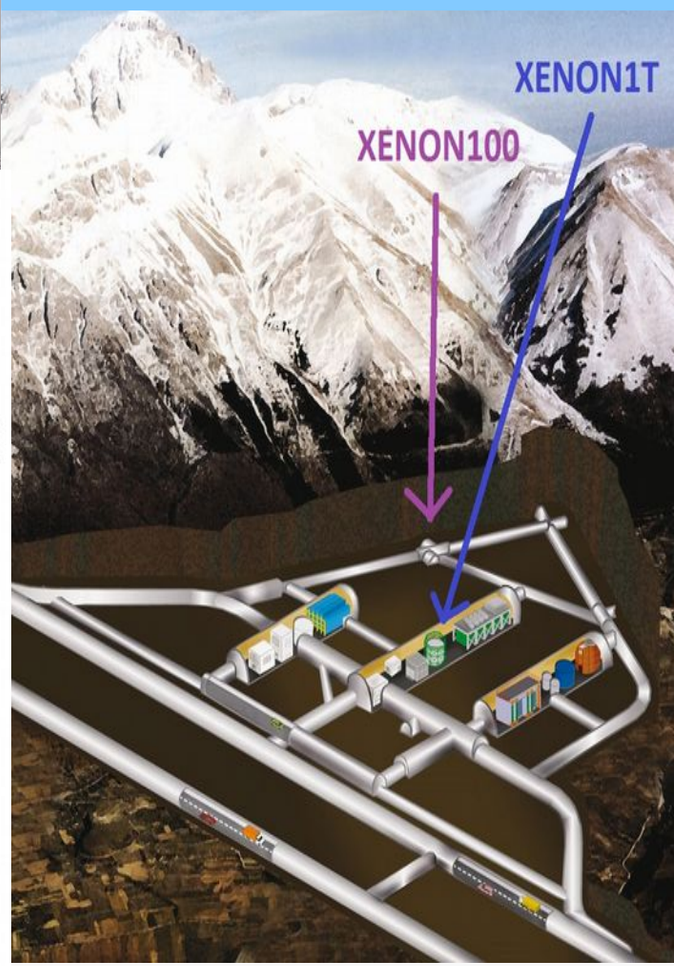


The XENON Collaboration

~170 scientists from 27 institutions

Columbia · RPI · Nikhef · Muenster · Stockholm · Mainz · MPIK, Heidelberg · Freiburg · Zurich · Chicago · UCLA · UCSD · Rice · Tokyo · Nagoya · Kobe · Purdue · Coimbra · Subatech · LPNHE · LAL · Bologna · LNGS · Torino · Napoli · Weizmann · NYUAD

Laboratoi Nazonali del Gran Sasso (LNGS), Italy



The XENON Story

XENON10

2005-2007
Total: 25 kg
Target: 14 kg
Limit: 8.8 x 10^{-44} cm^{-2}

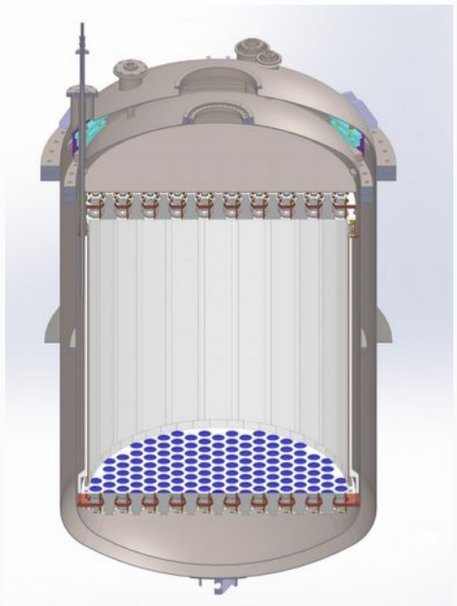
XENON100

2008-2016
Total: 162 kg
Target: 62 kg
Limit: 1.1 x 10^{-45} cm^{-2}

XENON1T

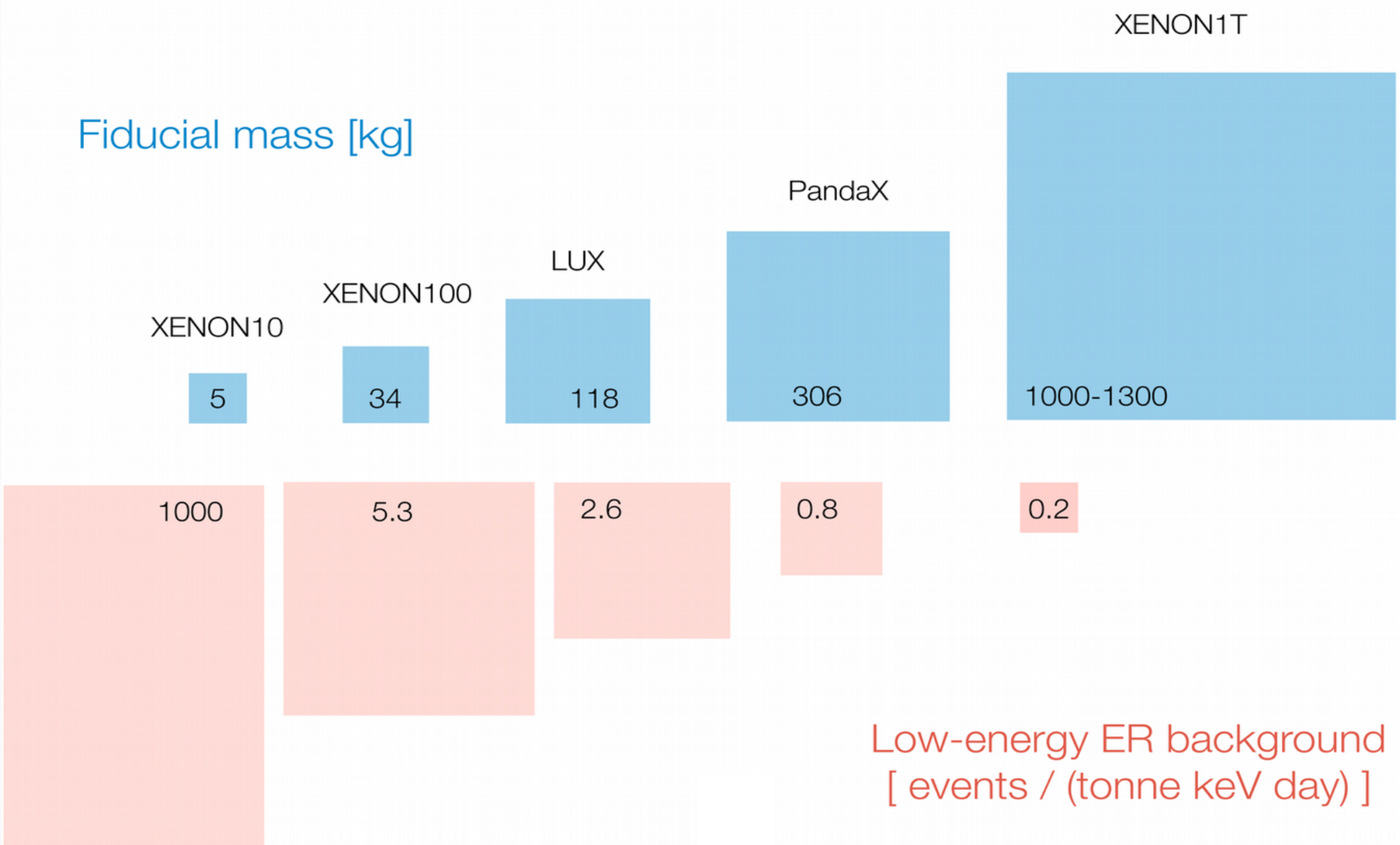
2016-2018
Total: 3200 kg
Target: 2000 kg
Limit: 4.1 x 10^{-47} cm^{-2}

XENONnT

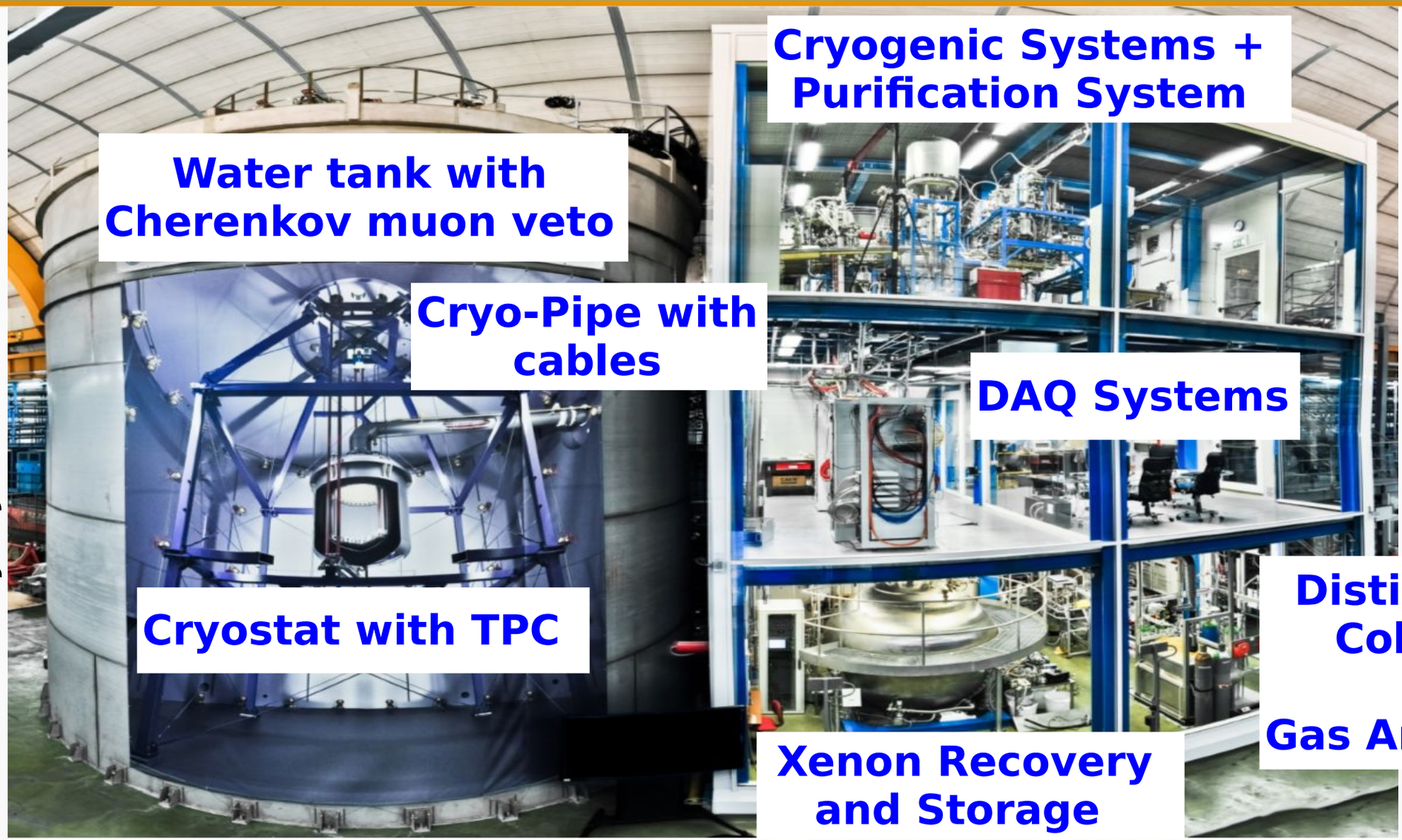


From 2019
Total: ~8000 kg
Target: ~5900 kg
Sensitivity: 10^{-48} cm^{-2}

Scaling up the Fiducial Mass



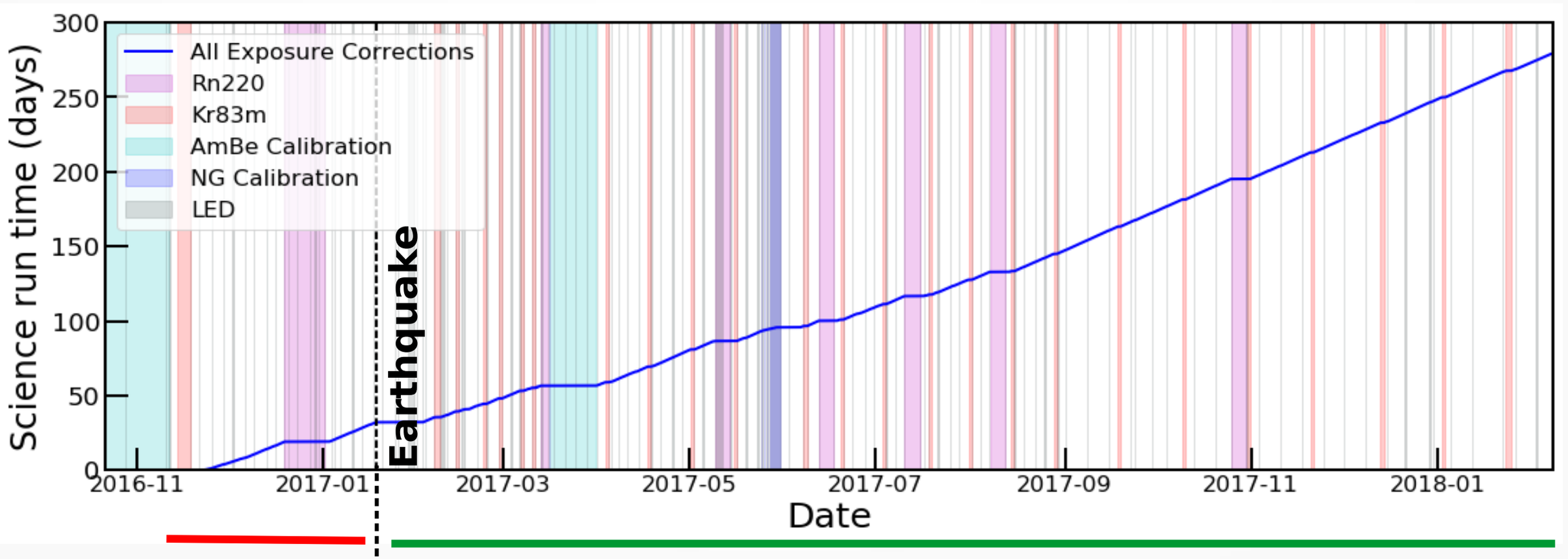
The XENON1T Infrastructure



Eur. Phys. J. C 77, 881 (2017)

XENON1T Science Data

More than one calendar year of stable data taking and still ongoing

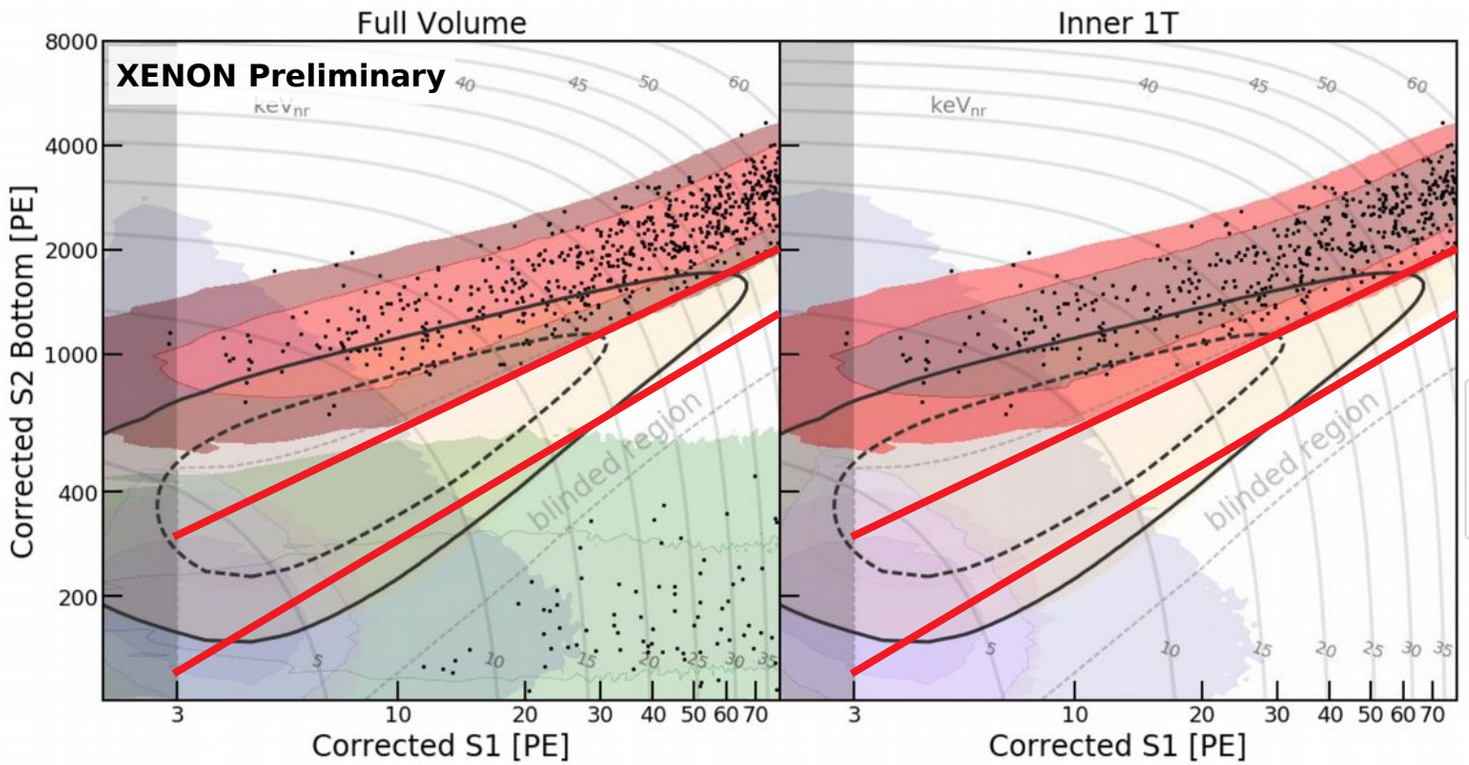


SR0 – 34 live days

SR1 – 247 live days

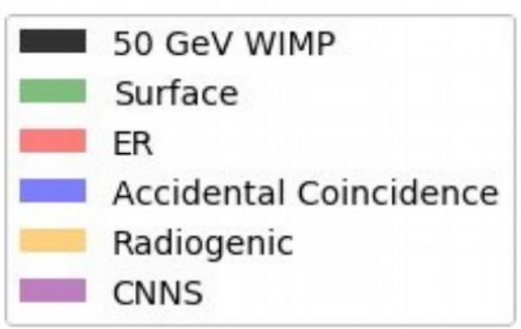
Background Composition

- Electronic recoils
  (68% in reference region)
- Nuclear recoils
  (23% in reference region)
- PTFE Surface events
  (4% in reference region)
- Accidental coincidences
  (5% in reference region)



Reference region:

(NR median, -2σ)



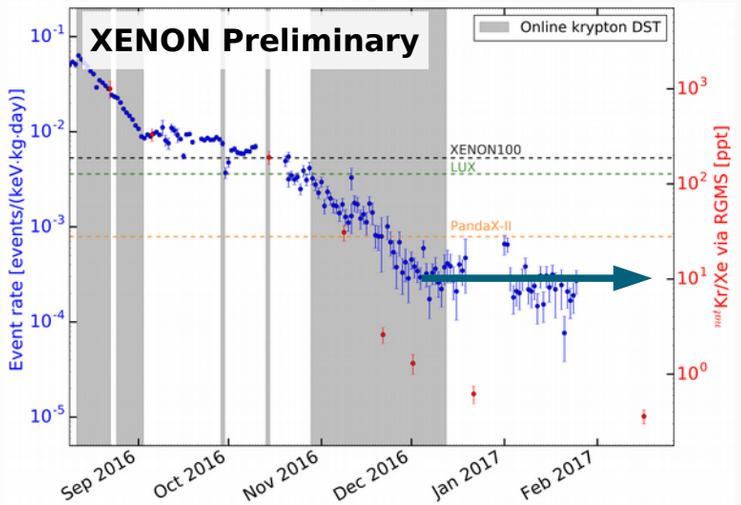
Electronic Recoil Background

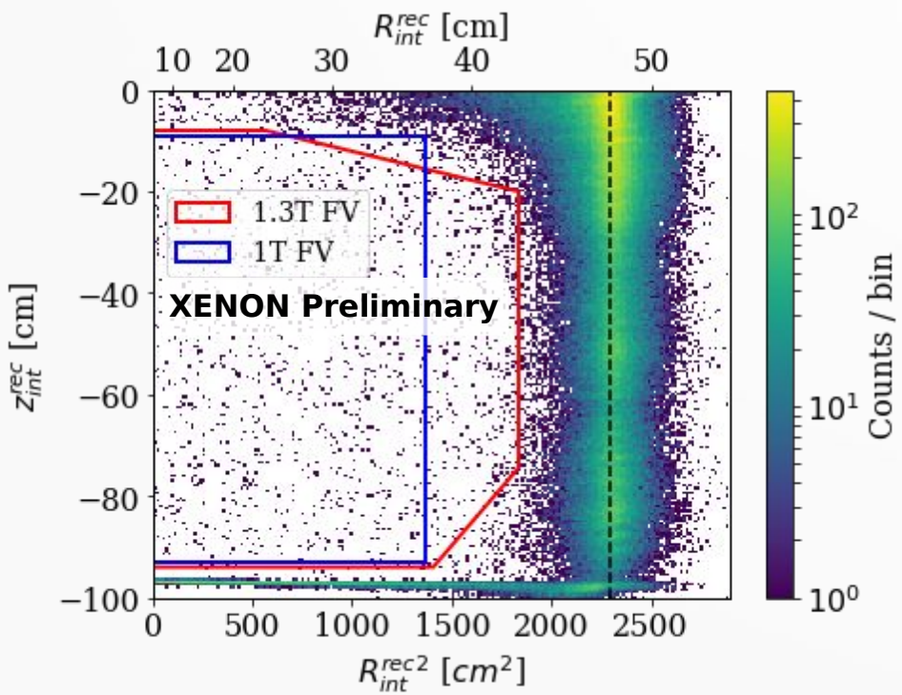
Controlled by:

- Screening of materials during detector construction
- ^{222}Rn emanation measurements of materials
- Cryogenic distillation of Krypton
- Fiducial volume selection

~80 evts/(t·y·keV)

Lowest ER background rate ever achieved in a DM detector



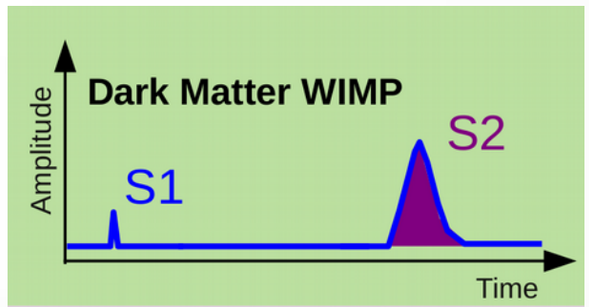


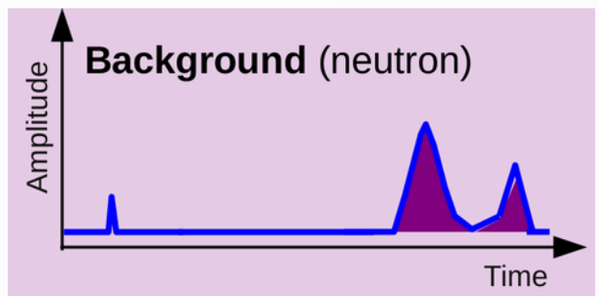
Source	Fraction of ER_{tot} [%] in 1T FV, (1-12)keV
^{222}Rn	85.4
^{85}Kr	4.3
Solar Neutrinos	4.9
Materials	4.1
^{136}Xe	1.4

Nuclear Recoil Background

Controlled by:

- 3600 m.w.e rock overburden
- Water Cherenkov Muon Veto
- Screening of materials during detector construction
- Fiducial volume selection
- Single scatter requirement
- **Total expected rate (NR_{tot}): ~ 0.6 evts/(t·y)**

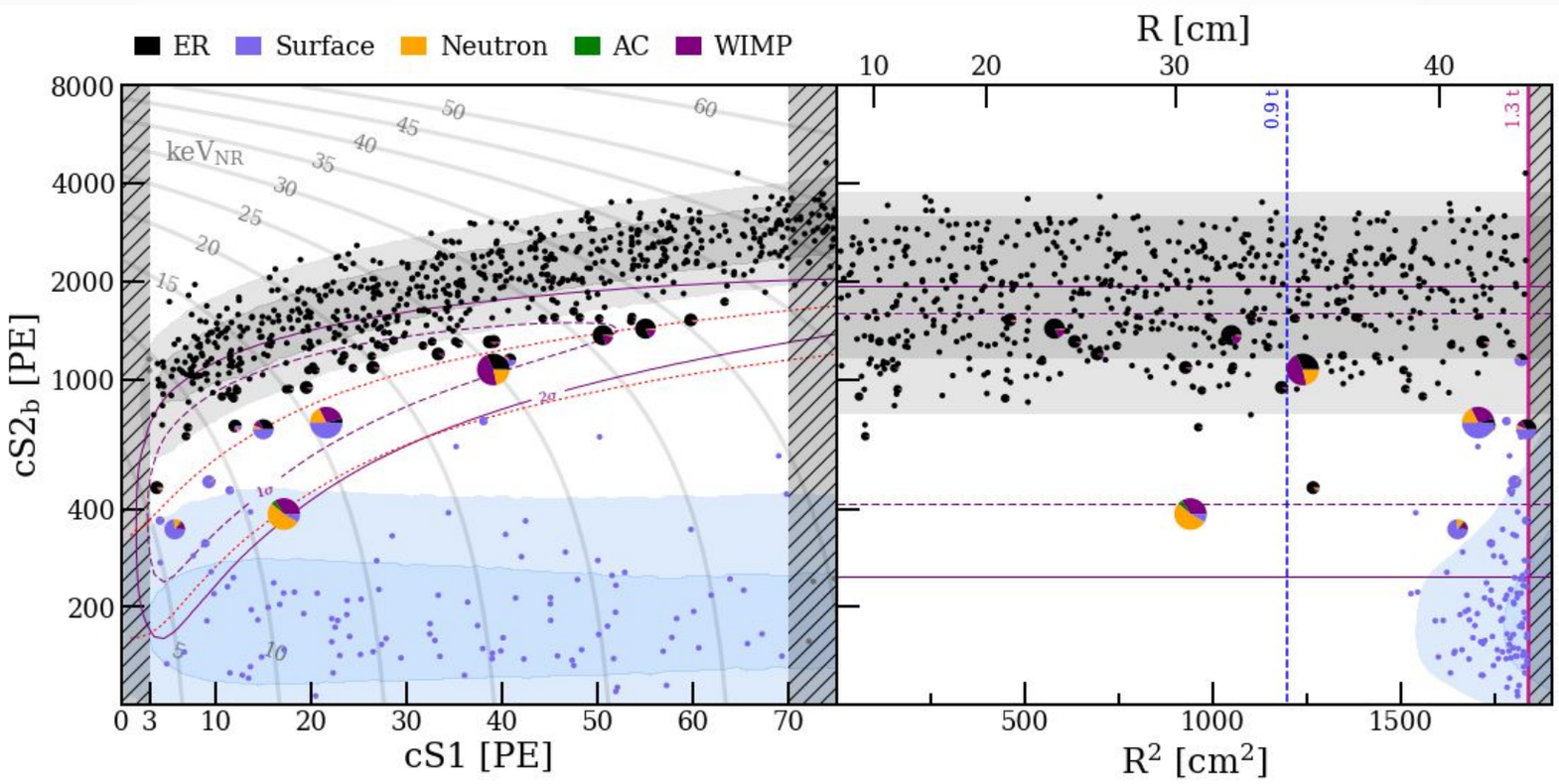




Source	Fraction of NR_{tot} [%] in 1T FV, (4-40)keV
Radiogenic neutrons	96.5
CEνNS	2.0
Muon-induced neutrons	< 2.0

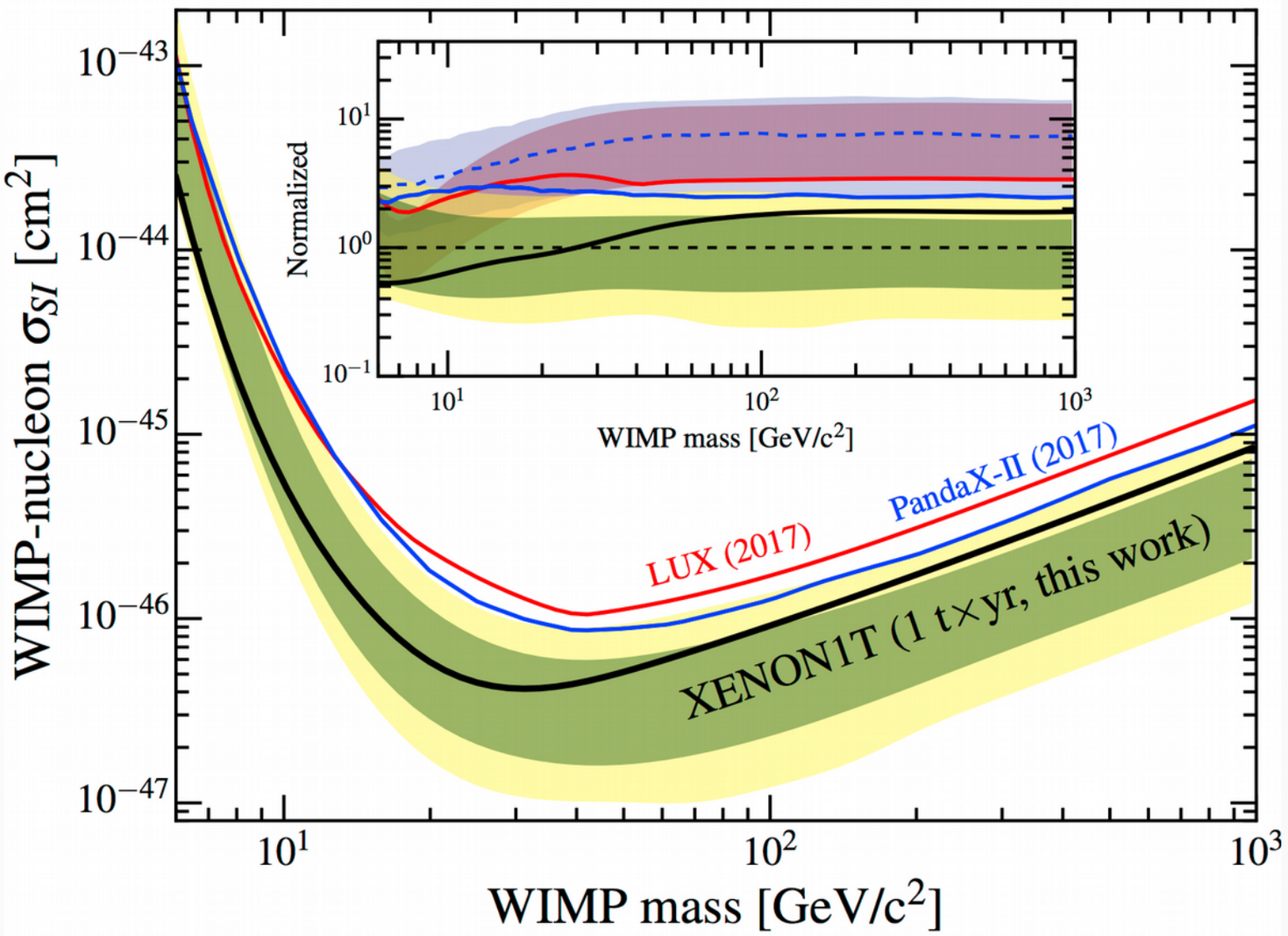
Event Distribution/Interpretation

- SR0 data re-analysis (32.13 d) + SR1 data (246.74 d): **278 live days**
- Blind analysis
- Results interpreted with unbinned profile likelihood analysis in (S1,S2,R) space + segmentation of Z space into two bins
- Piecharts indicate the relative PDF from the best-fit of a 200 GeV/c^2 WIMP with cross-section of 4.4×10^{-47} cm^2

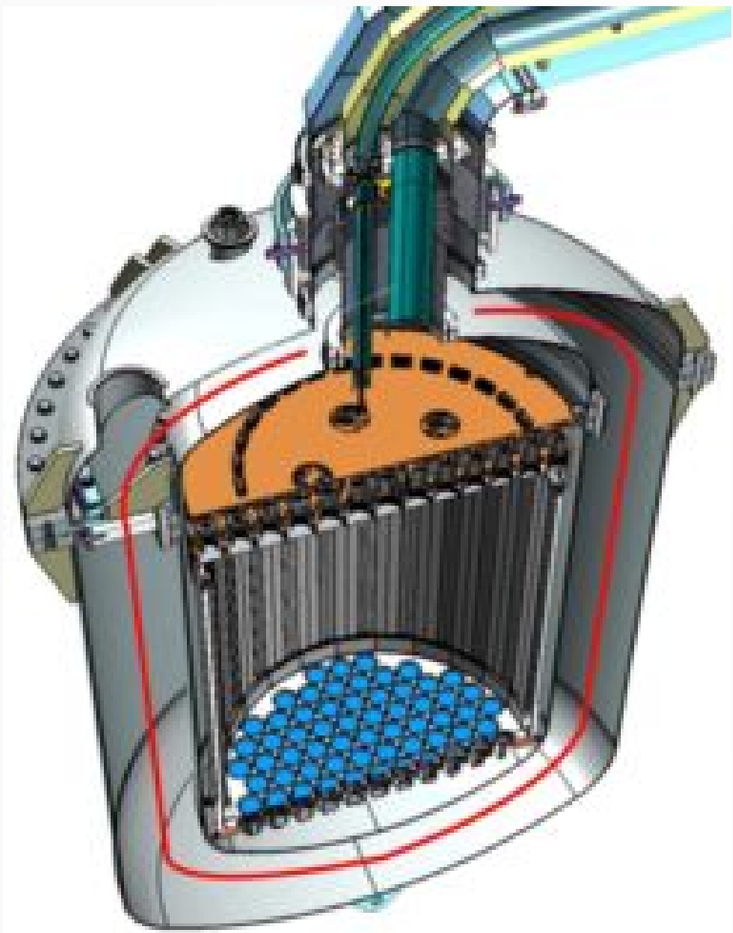


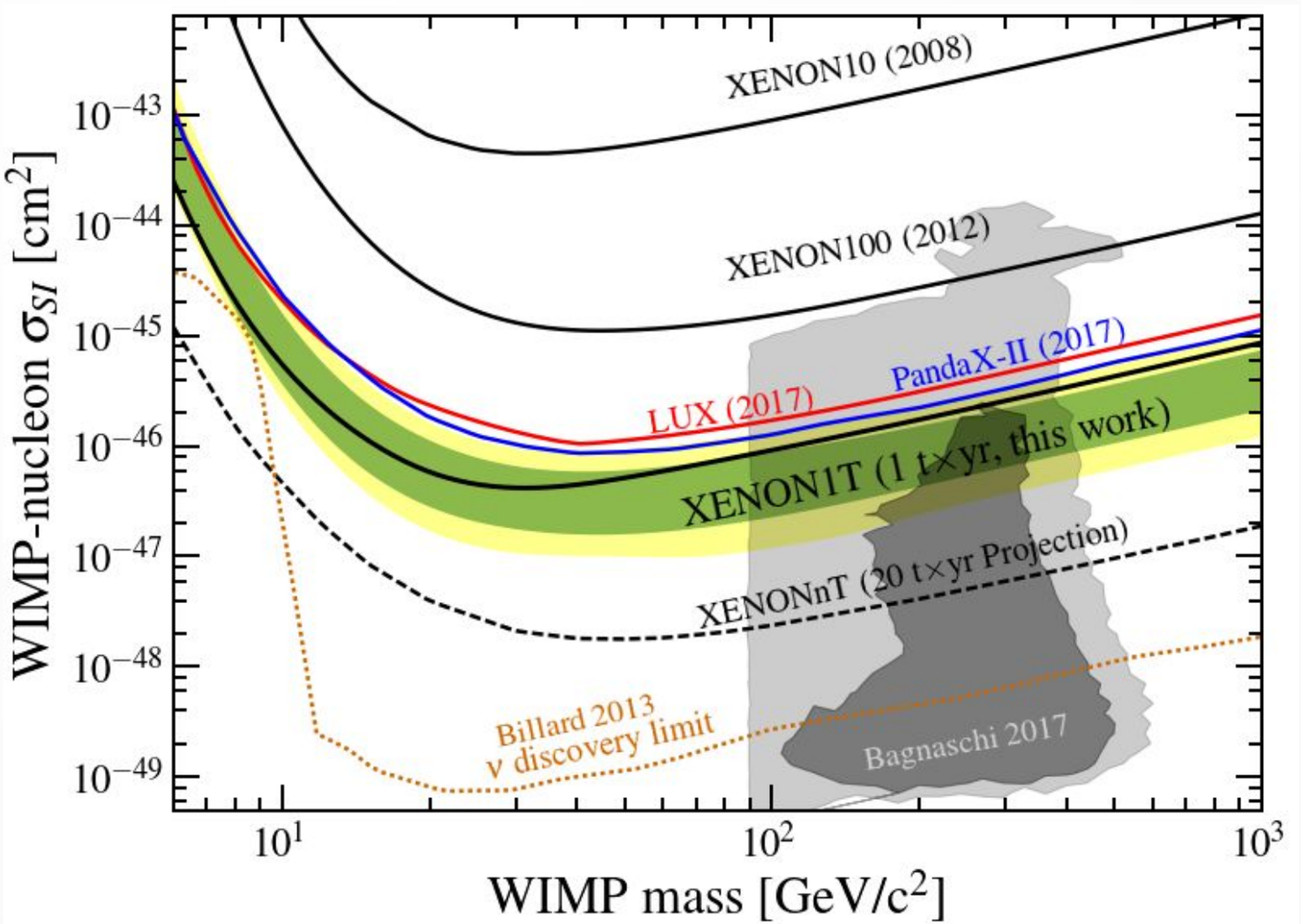
XENON1T Dark Matter Search Result

- Most stringent limit on SI WIMP-nucleon interactions with $m_\chi > 6$ GeV
- Minimum: 4.1×10^{-47} cm² for a WIMP of 30 GeV/c²
- Factor 7 better sensitivity compared to other LXe TPCs
- *Phys. Rev. Lett. 121, 111302 (2018)* → Editors Suggestion



Upgrade XENONnT





XENONnT Strategy

Minimal Upgrade

- Re-use XENON1T infrastructure
- Only exchange TPC

Fiducial LXe Target

- Total LXe: 8 tons
- Fiducial mass: ~4 tons

Background

- Reduce ^{222}Rn induced backgrounds by a factor of ~10

Fast Turnaround

- XENONnT commissioning in 2019

New Features of XENONnT

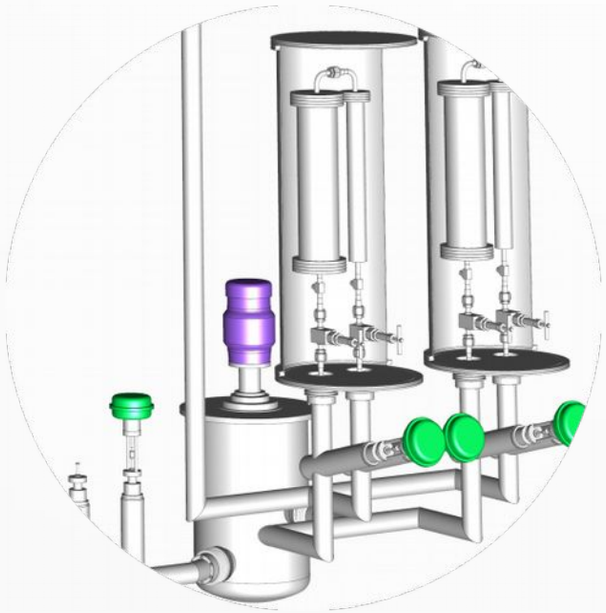
New TPC

- PMT number increased from 248 to 494 → Almost finished testing additional tubes
- Length: ~1.5 m
  Diameter: ~1.3 m

Poster X3

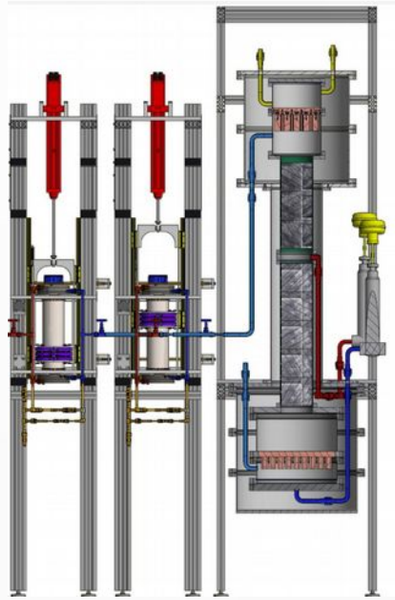
LXe-Purification

- To achieve fast cleaning of the large LXe volume (5L/min LXe, 2500 SLPM)
- GXe purification (120 SLPM)



Radon-Distillation Collumn

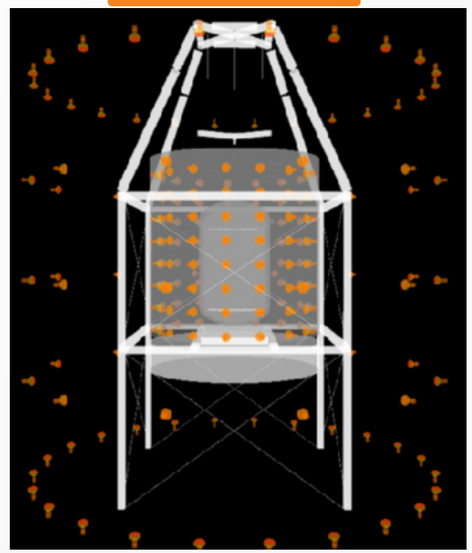
- High throughput of 200 SLPM to extract Rn from TPC and remove from LXe



Neutron Veto

- Gd in the Water tank: 0.5% of $Gd_2(SO_4)_3$
- 120 PMTs 8-inch PMTs (sames as for Muon-Veto)

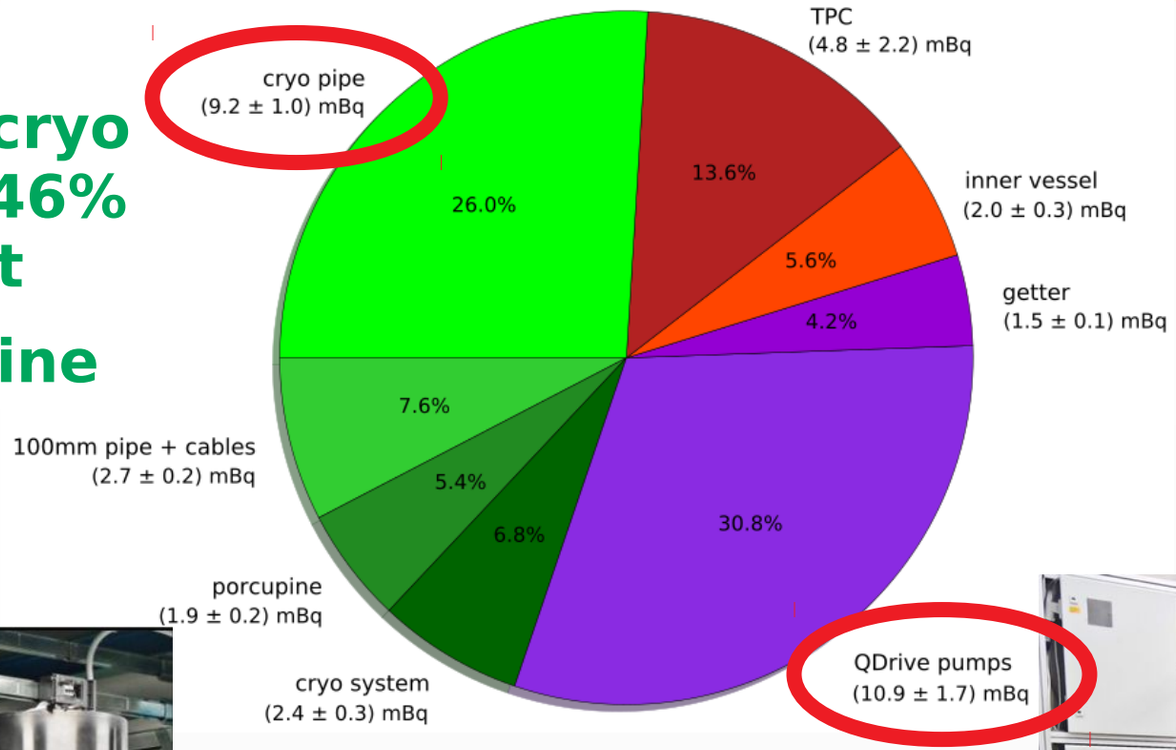
Poster X1



Mitigation of ^{222}Rn Backgrounds

Cryo pipe/cables/cryo system emanate 46% of total Rn budget

→ Reduced by online distillation



Purification system emanates 35% of total Rn budget

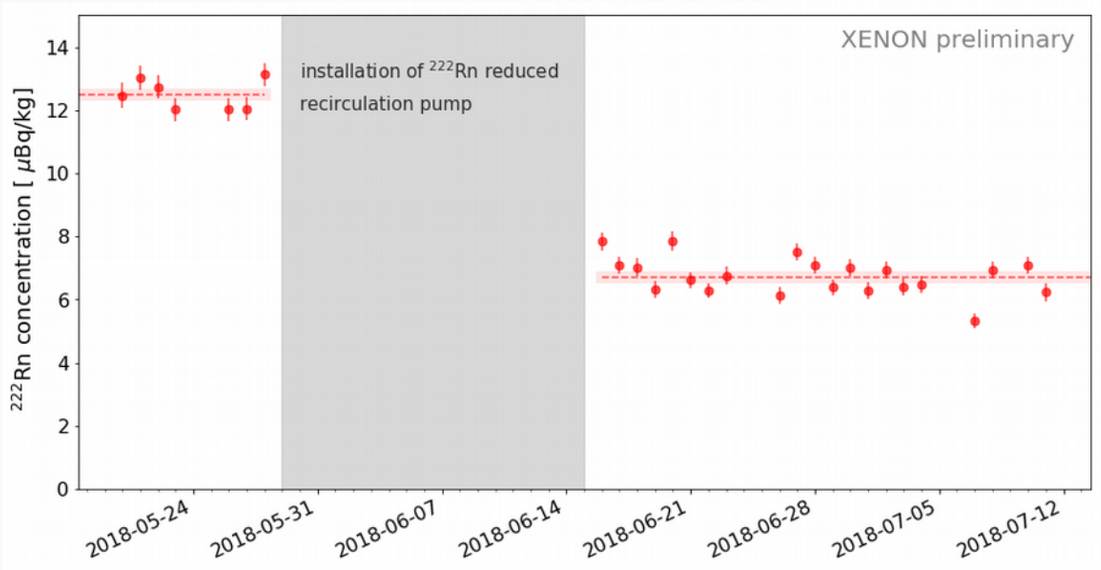
→ Reduced by pump exchange

Achievements towards XENONnT

Radon Reduction:

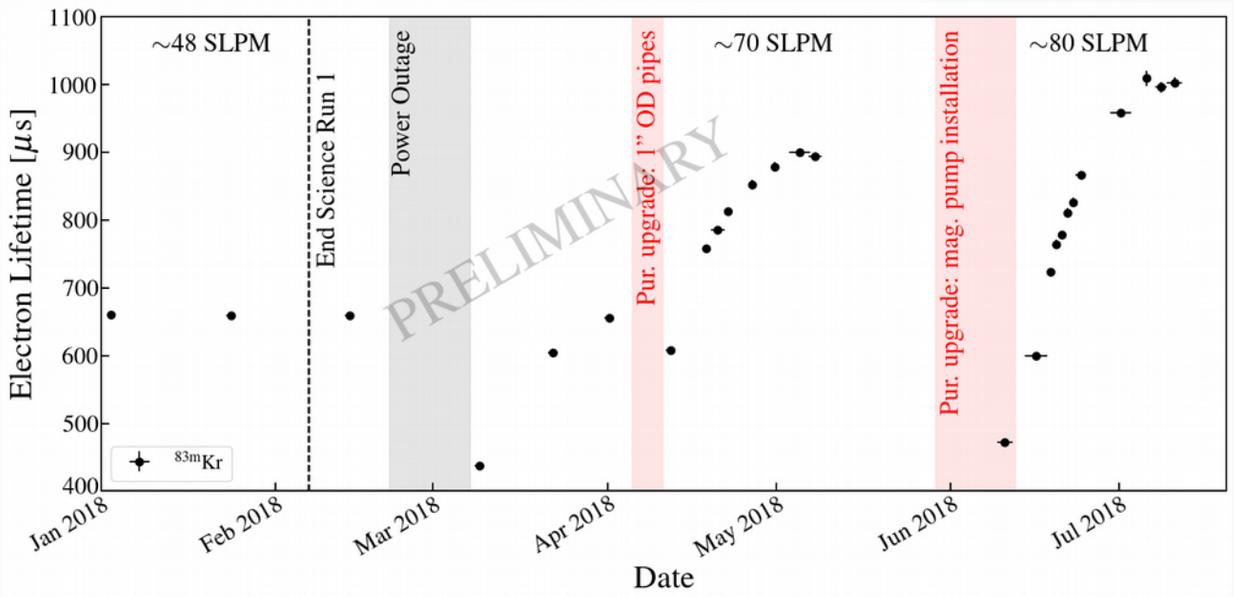
Poster X2

- SR1: (11.8±0.2) µBq/kg
- **New radon-free pump** *(EPJ C 78 (2018) 604)* (6.3±0.1) µBq/kg
- Rn reduction by **45%** w.r.t SR1



Increased purification gas flow

- increased by **39%** w.r.t. Q-drive
- Electron lifetime of **1 ms** reached!

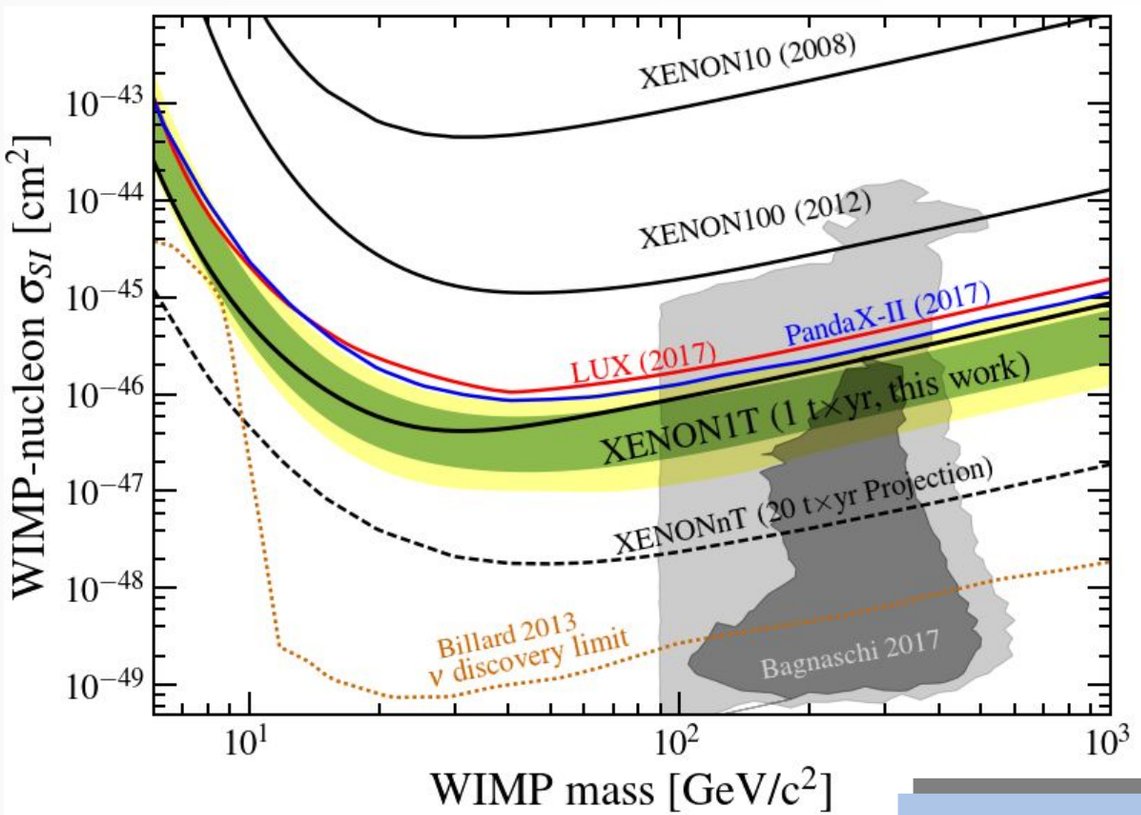


- **Online Radon distillation** allowed another reduction of **~30%** to **~4 µBq/kg**
  → only factor 4 above XENONnT goal

Excellent results with view on XENONnT!

XENONnT is on its Way

XENONnT is on its way! Commissioning in 2019



Ongoing XENON1T Analyses:

- **Spin-dependent** WIMP interactions
- Detection of DM by **annual modulation**
- **Low mass WIMP** searches (investigation of lowering the threshold, S2 only analysis)
- **Double electron capture** of ^{124}Xe and ^{126}Xe → currently most sensitive experiment for this process
- **Neutrinoless double beta decay** of ^{136}Xe

→ Stay Tuned!