
XENONnT

Status and First Science Results

IBER 2023, Coimbra

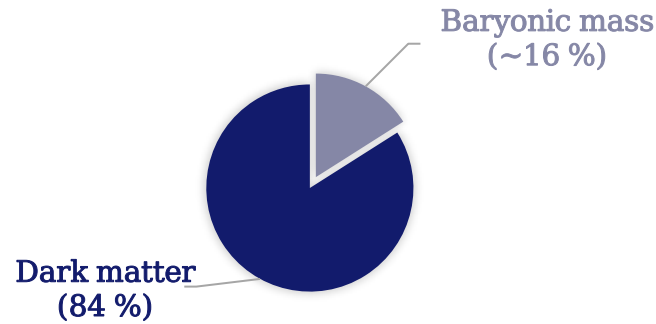
08.09.2023

Ricardo Peres
on behalf of the XENON
Collaboration

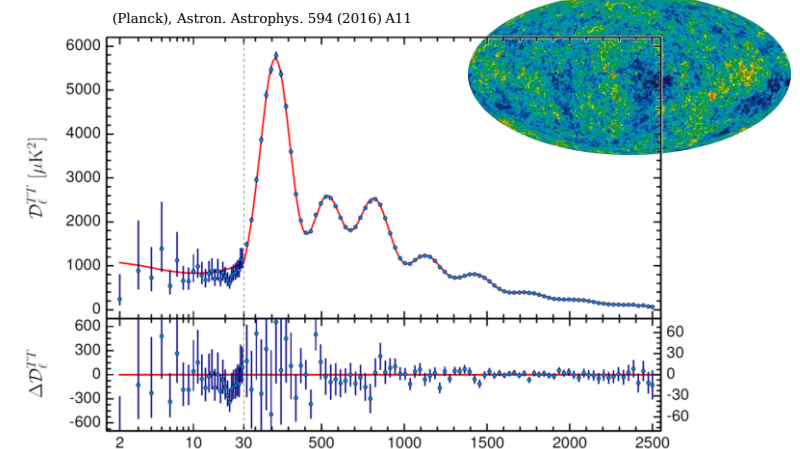
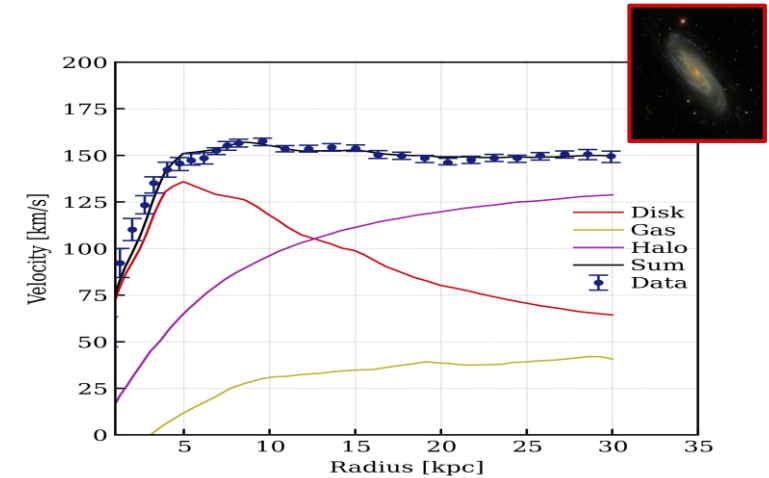
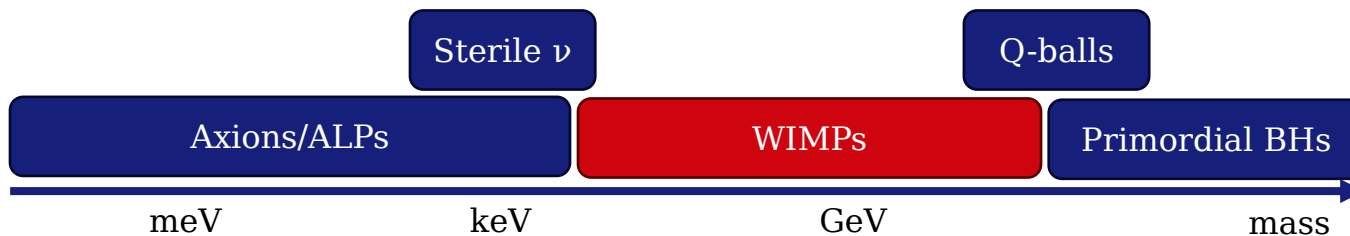
rperes@physik.uzh.ch

The search for dark matter

- Many evidence point to the existence of dark matter

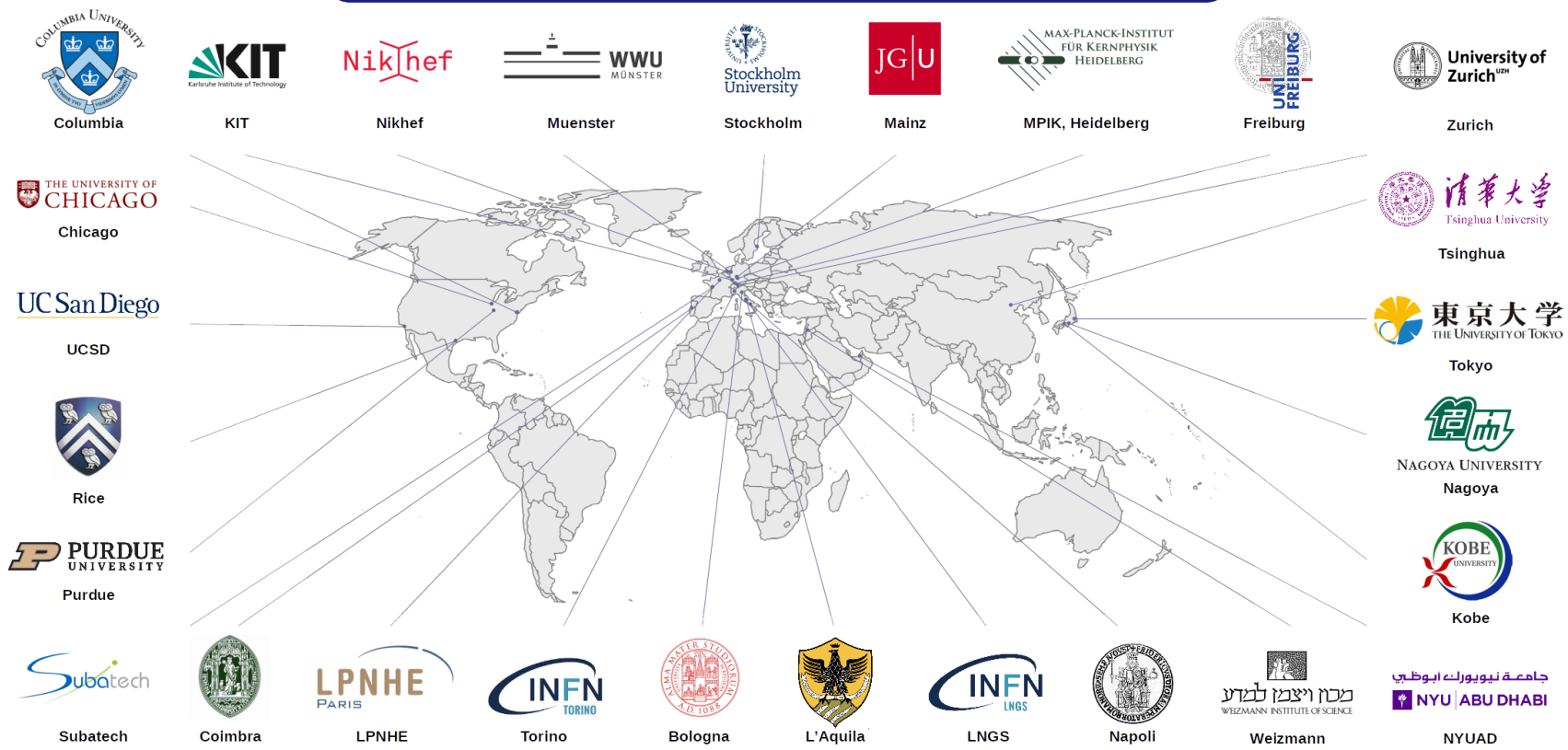


- Dark matter particles expected to be:
 - Massive
 - Neutral
 - Stable (lifetime longer than the Universe age)
 - Weakly-interactive



The XENON Collaboration

27 institutions; ~170 scientists





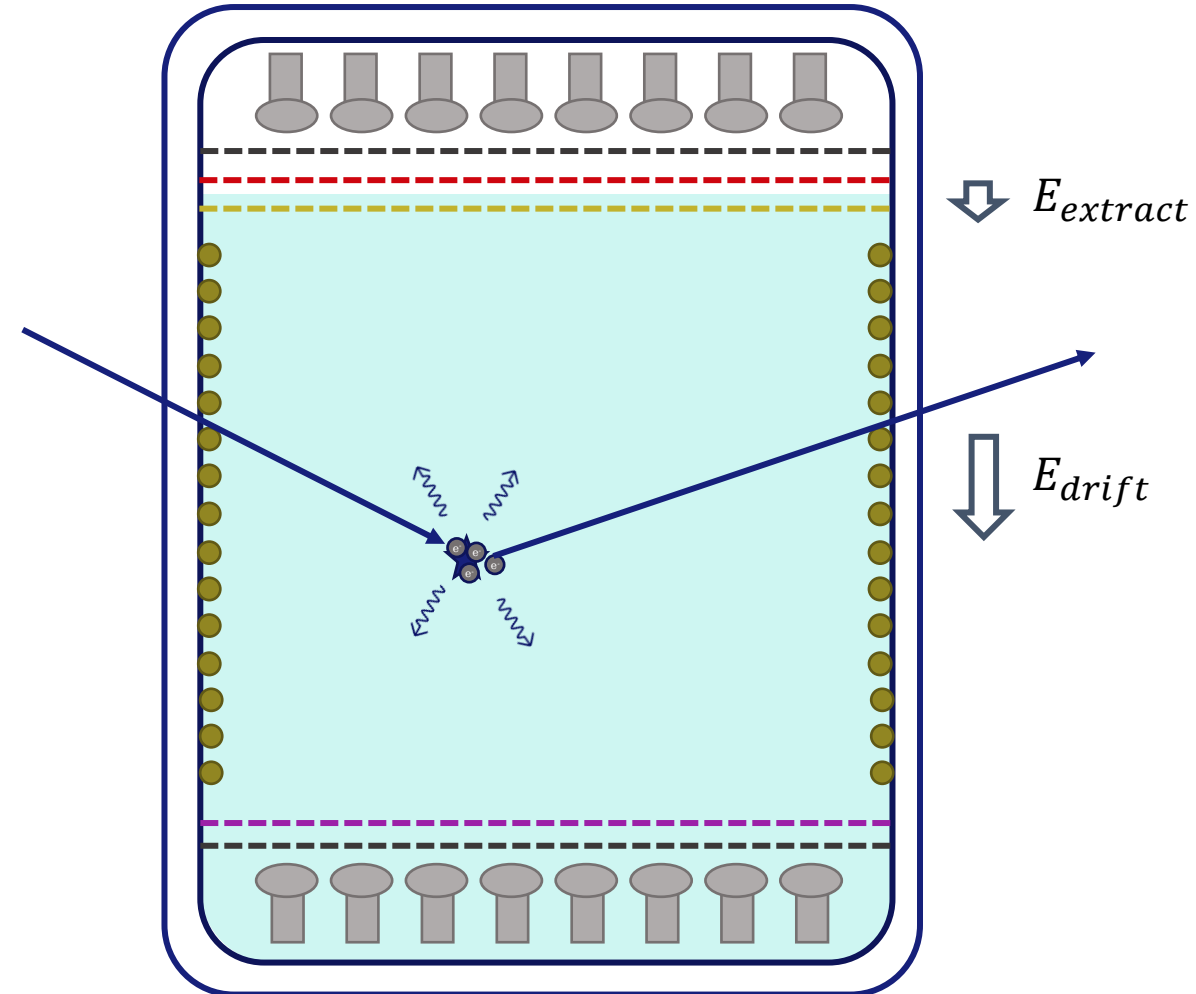
The XENON Collaboration

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The dual-phase TPC

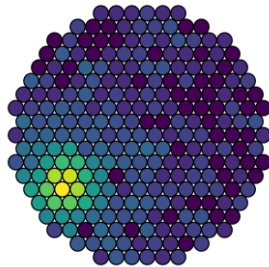
- Sensitive to both **light (S1)** and **charges (S2)**.



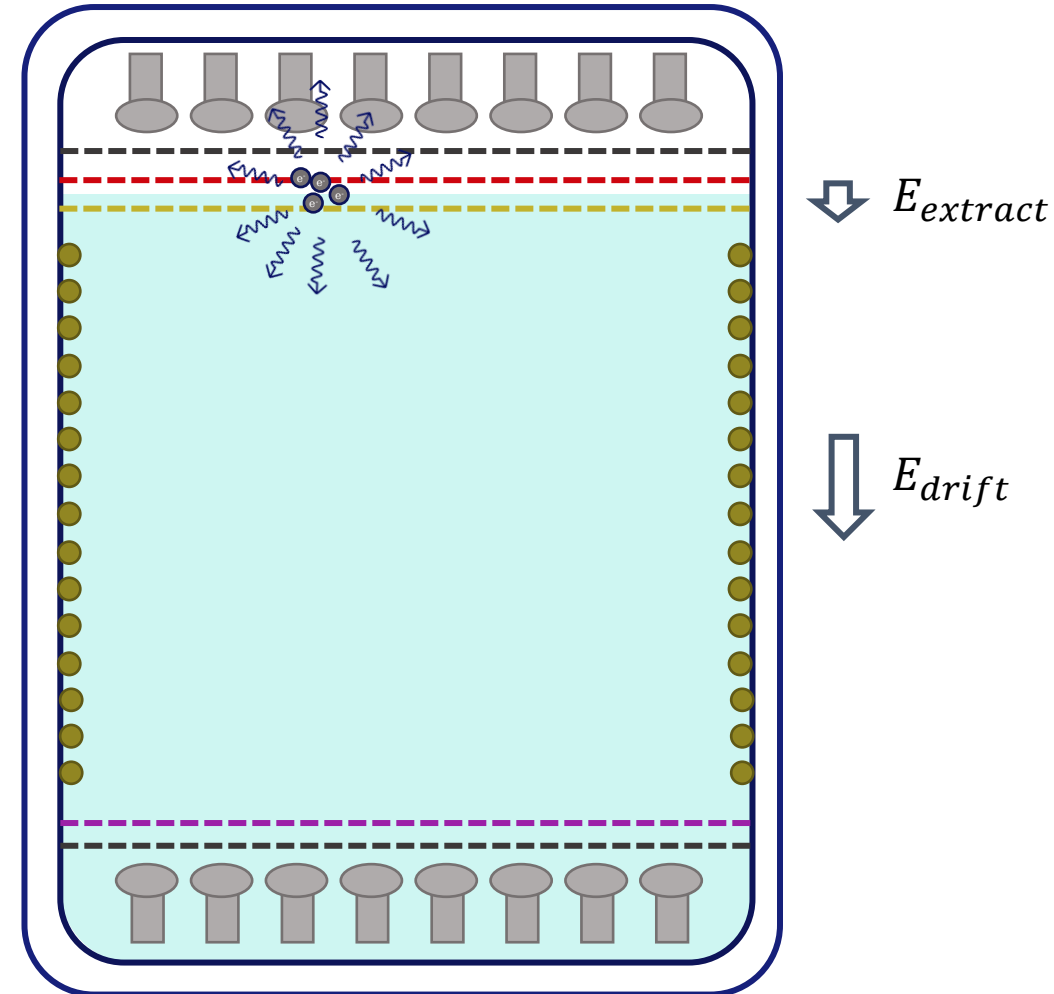
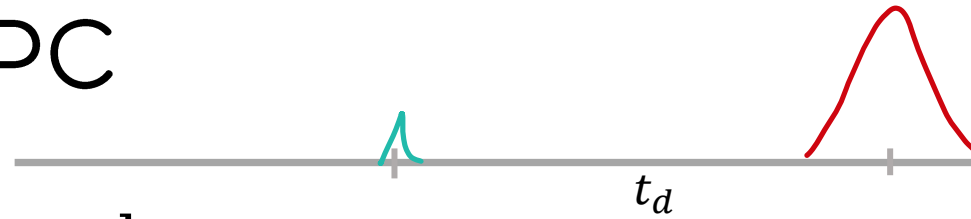
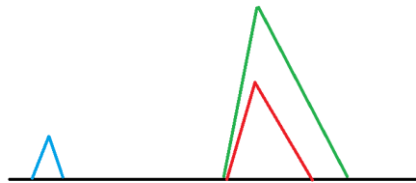
The dual-phase TPC

- Sensitive to both **light (S1)** and **charges (S2)**.
- Event reconstruction
 - Energy
 - 3D position
 - Particle discrimination (**ER/NR**)

$$E = W \left(\frac{cS1}{g_1} + \frac{cS2}{g_2} \right)$$



$$z = v \cdot t_d$$



The XENON detectors

XENON10
2006 – 2007
25 kg



XENON100
2008 – 2016
160 kg



XENON1T
2015 – 2018
3200 kg



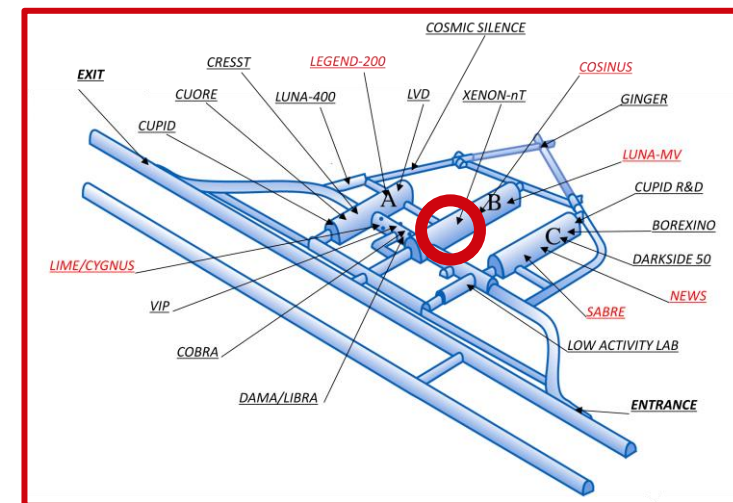
XENONnT
2020 – (2026)
8500 kg



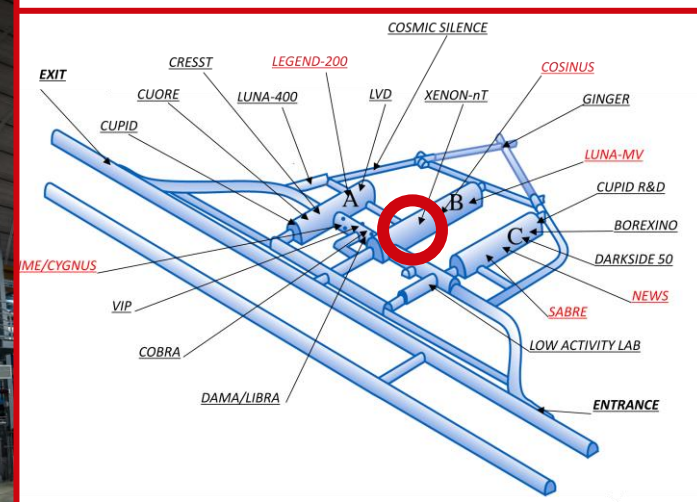
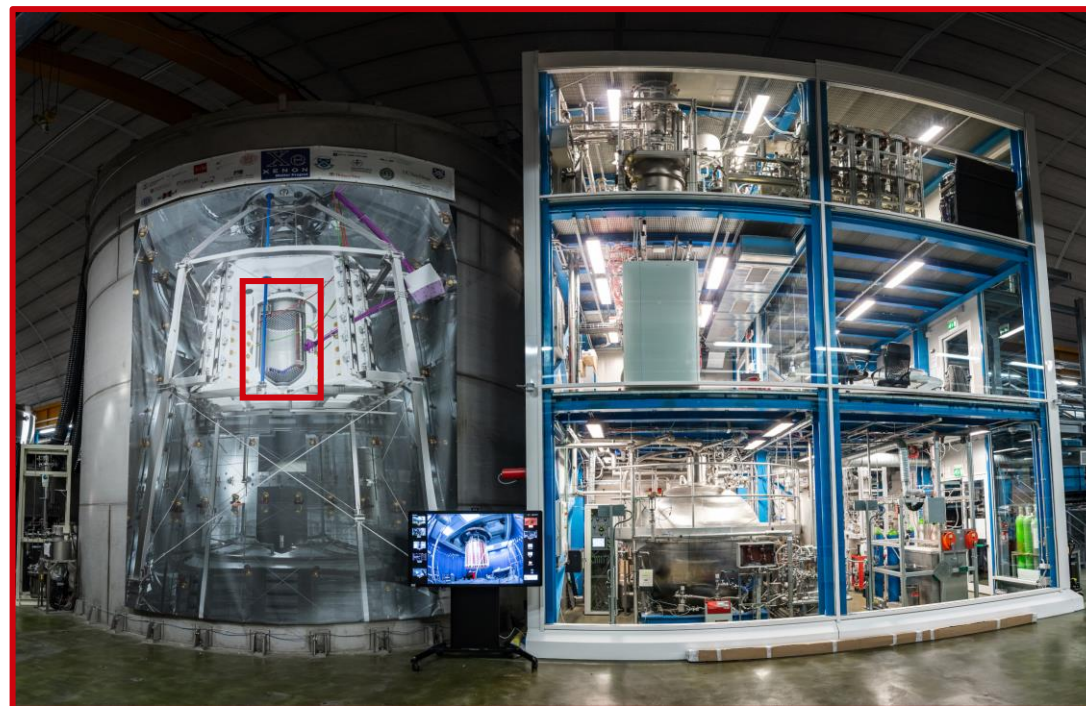
DARWIN
(2026)
50 t



The XENONnT detector @LNGS

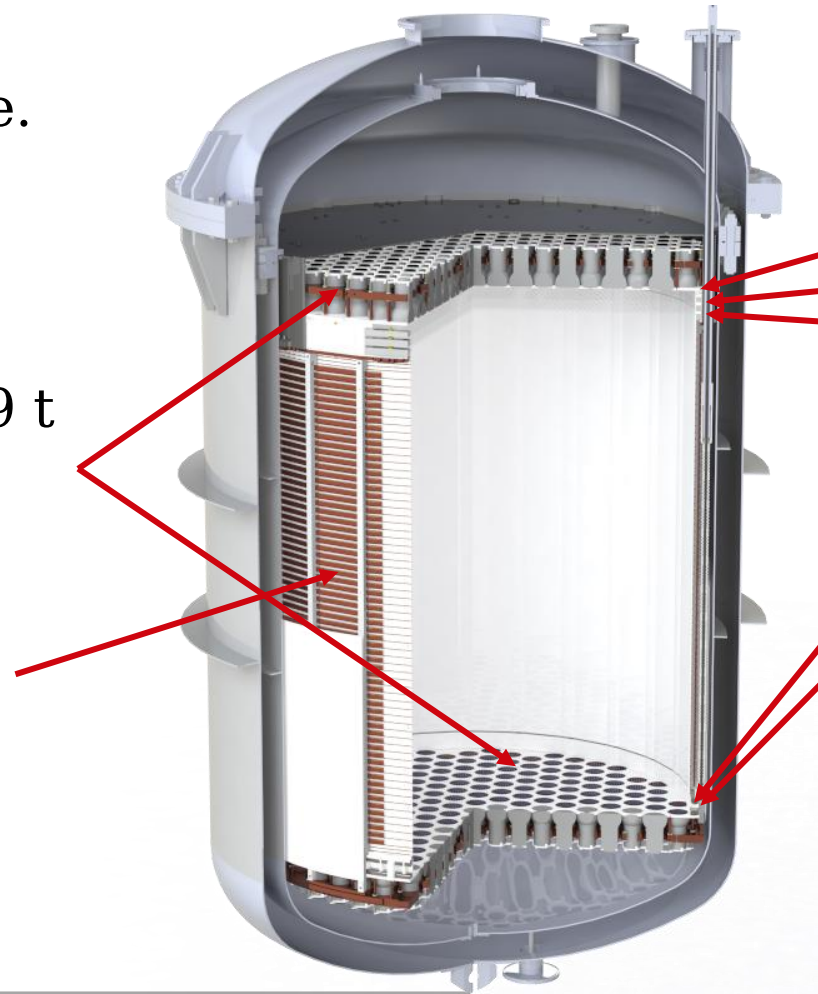


The XENONnT detector @LNGS



The XENONnT TPC

- Under 3600 meter w. e.
- ~1.5 m height
- ~1.3 m diameter
- Total active region: 5.9 t
- 494 PMTs
- Two concentric field cage elements



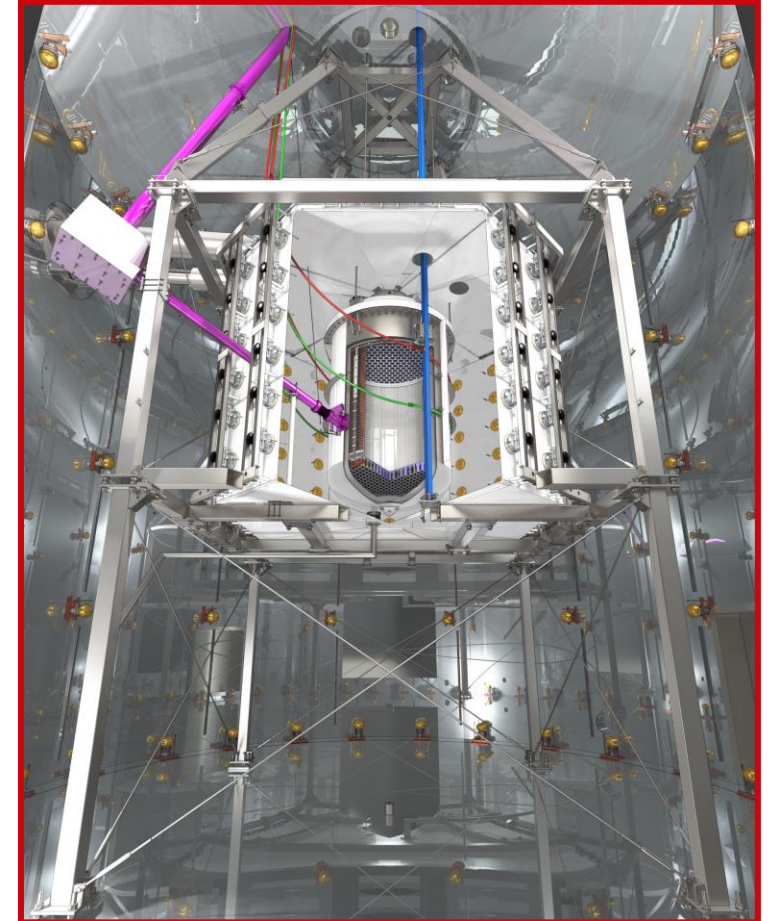
- 5 electrodes
 - Top screening mesh
 - Anode
 - Gate
 - Cathode
 - Bottom screening mesh
- Drift field: ~23 V/cm
- Extraction field: ~2.9 kV/cm

Veto systems

- ~700 t water tank
- Muon veto based on Cherenkov emission in water
 - ~98% of muon tagging
- Neutron veto optically decoupled from MV
 - Neutron ~53 % tagging efficiency in current configuration
 - ~87 % tagging efficiency with Gd-doping
 - Reduction of neutron background to ~0.3 neutrons per t•y



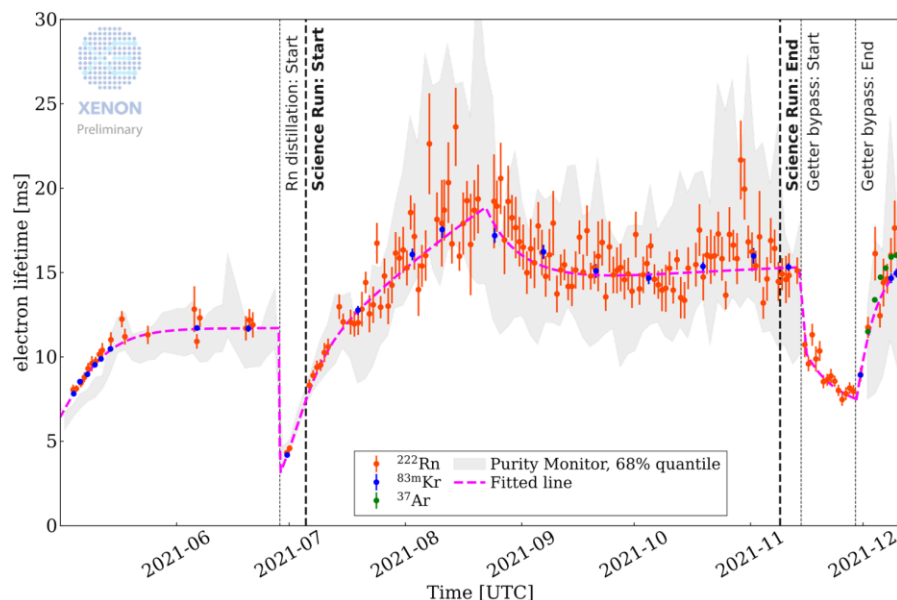
JCAP 11, 031 (2020)



Liquid purification system

- Electronegative impurities
 - attach drifting electrons (reducing the S2 signal)
 - absorb scintillation photons (reducing the S1 signal)
- New liquid Xe purification system
 - Xenon flow up to 2 lpm
 - 18h to exchange the entire volume

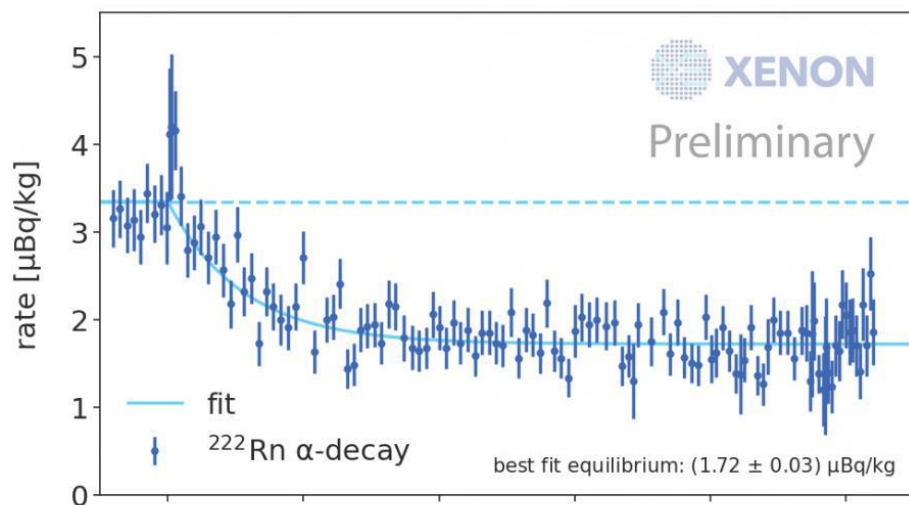
> 10 ms of stable electron lifetime achieved!



EPJ. C 78, 604 (2018)
 EPJ. C 82, 860 (2022)
 PRL129, 161805 (2022)

Background removal by distillation

- Two inline distillation columns
- Kr/Ar distillation before the start of the run
- Novel Rn distillation column
- Unprecedented low concentrations achieved



$^{\text{nat}}\text{Kr/Xe}: (56 \pm 36) \text{ ppq}$
 $^{222}\text{Rn}: (1.77 \pm 0.01) \mu\text{Bq/kg}$

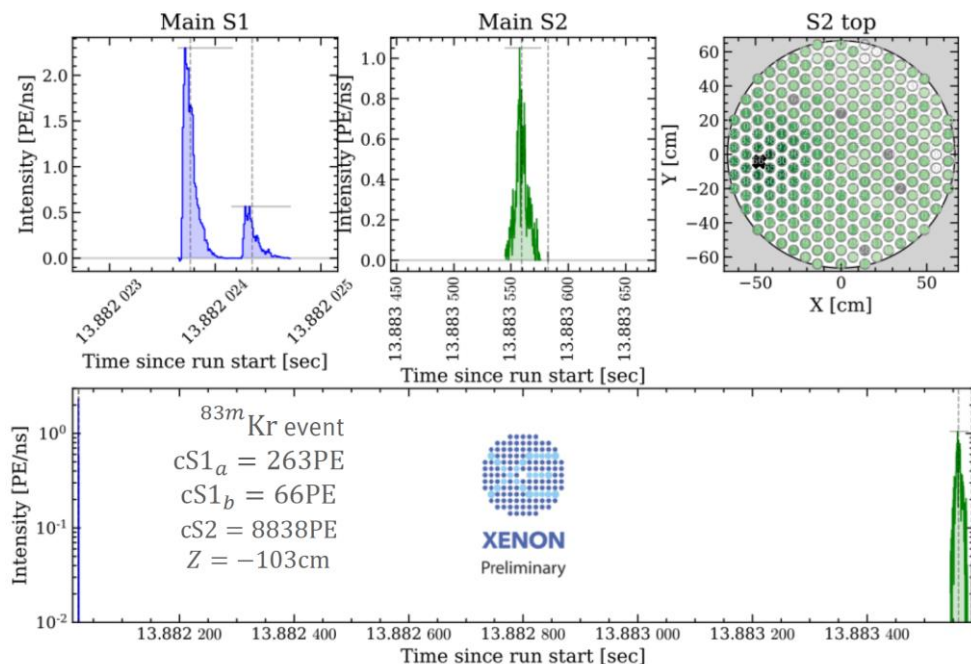


EPJ C 82 (2022)

EPJ C 77 (2017)

A triggerless DAQ

- Triggerless = all photoelectron data recorded
- Full live processing
- Open source processing and simulation software



XENONnT open source software

Strax

Triggerless processor base
github.com/AxFoundation/strax

Straxen

Processing and analysis for XENONnT
github.com/XENONnT/straxen

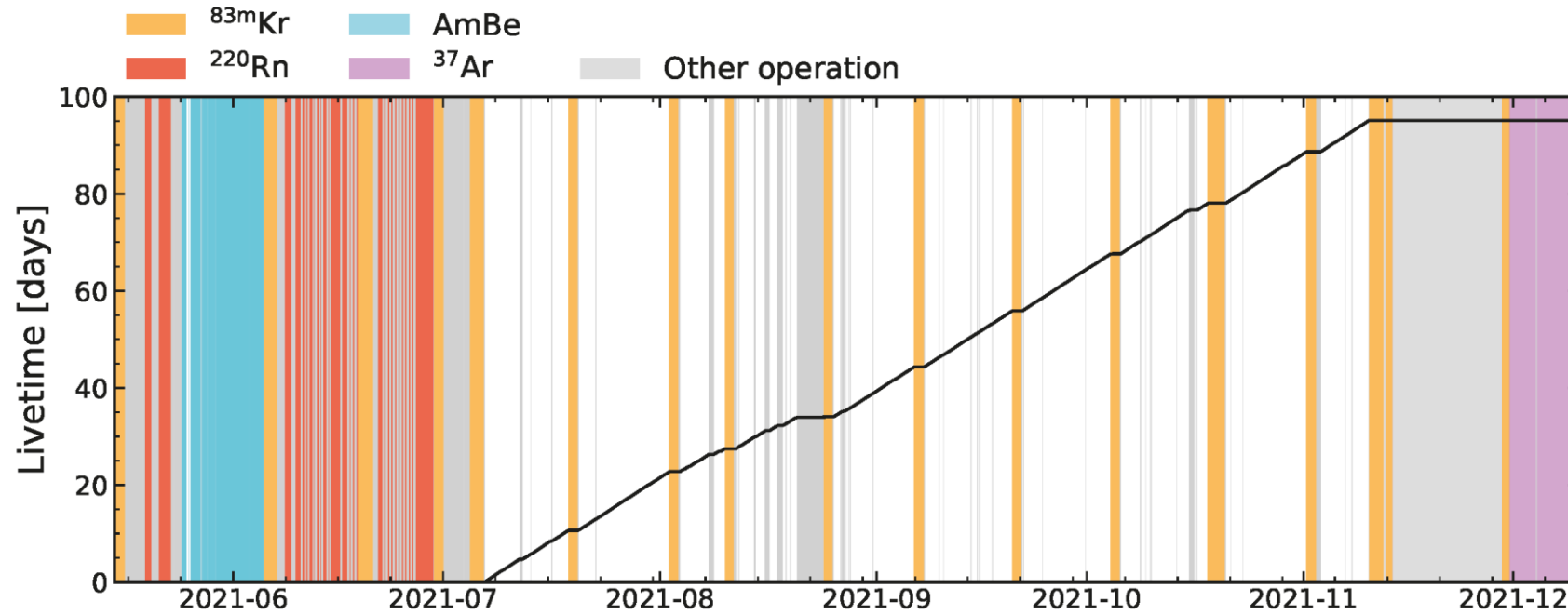
WFSim + epix

Waveform simulator
github.com/XENONnT/wfsim
github.com/XENONnT/epix

XeDocs

Metadata management tool
github.com/XENONnT/xedocs

Science Run 0



Total 1.1 t x yr, blind analysis

97.1 days (Jul. 6th – Nov. 11th 2021) – 95.1 days lifetime corrected

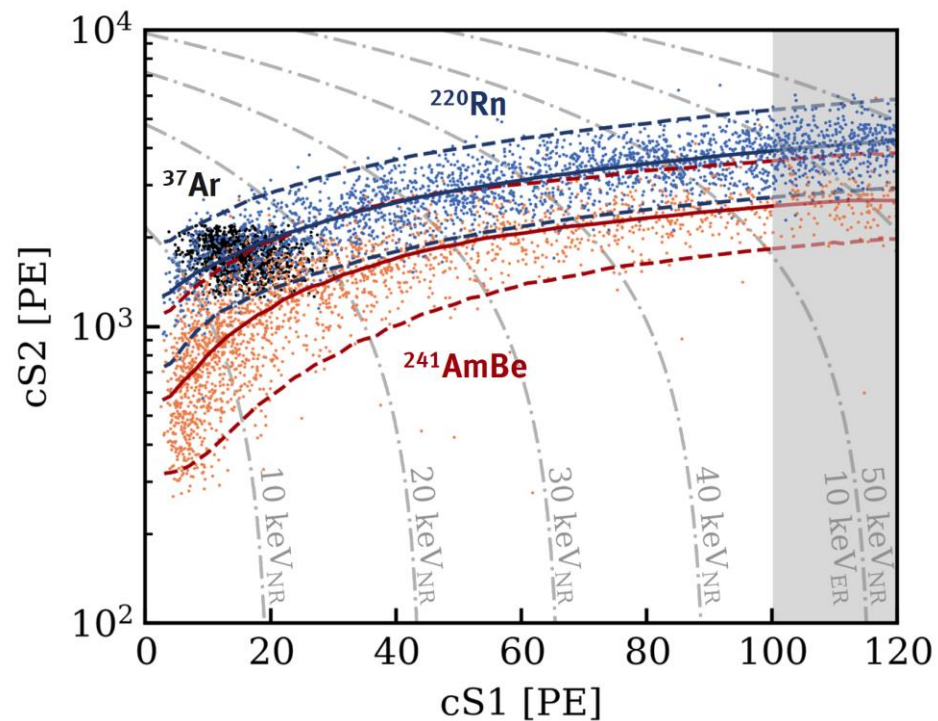
477/494 PMTs working with gain stable up to 3%

High-rate single-electron emission observed spuriously

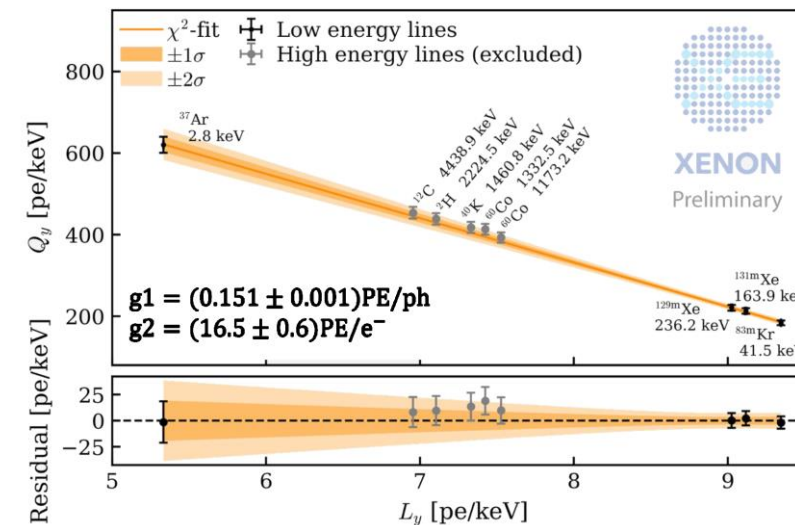
Detector calibration

- ER model
- ^{37}Ar
 - ^{220}Rn

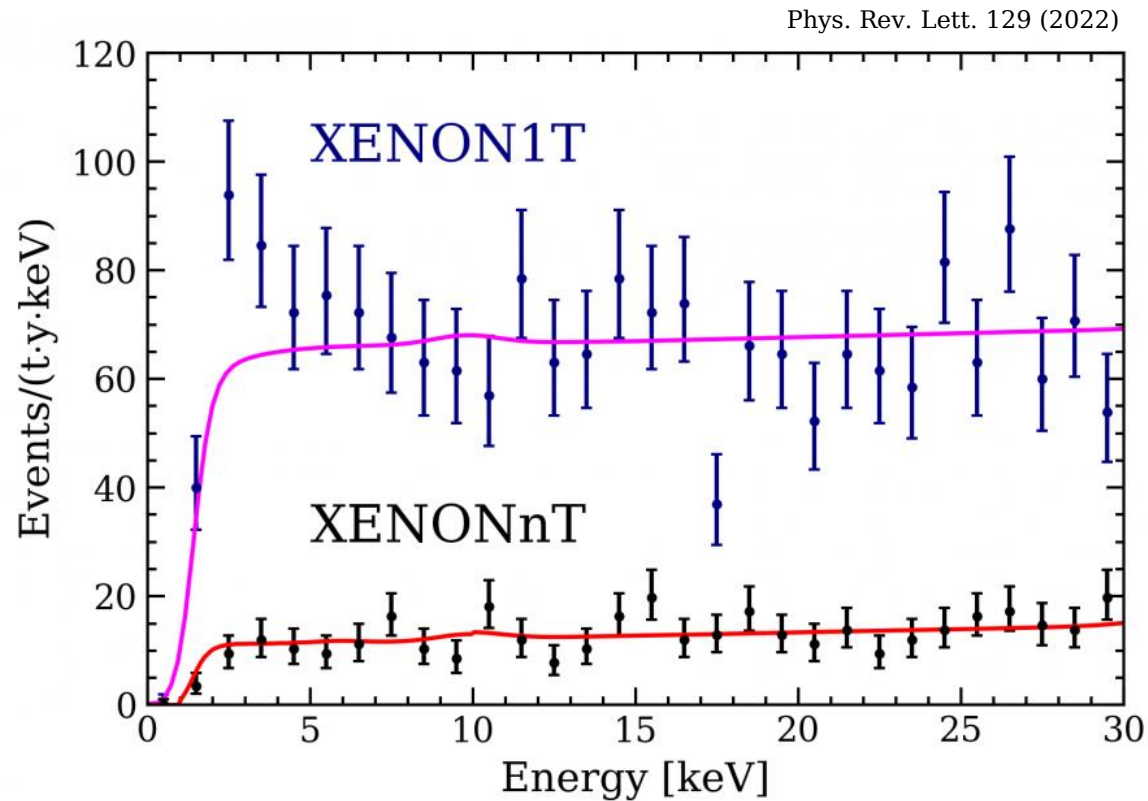
- NR model
- AmBe



- Energy reconstruction
- ^{37}Ar
 - $^{83\text{m}}\text{Kr}$
 - $^{129\text{m}}\text{Xe}$
 - $^{131\text{m}}\text{Xe}$
 - ^{220}Rn



First XENONnT results: low-energy ER



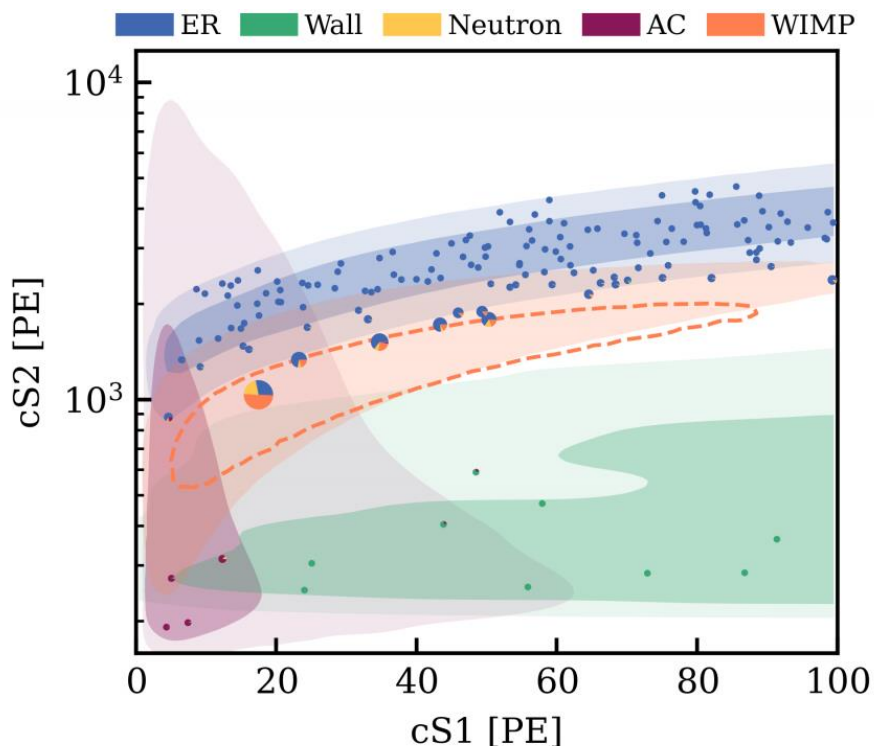
No low-energy ER
excess found

New constraints on:

- Solar axions
- Bosonic DM
- Enhanced ν magnetic moment

Lowest ER background rate in the field
(15.8 ± 1.3) evts/(t yr keV)

First XENONnT results: WIMP search

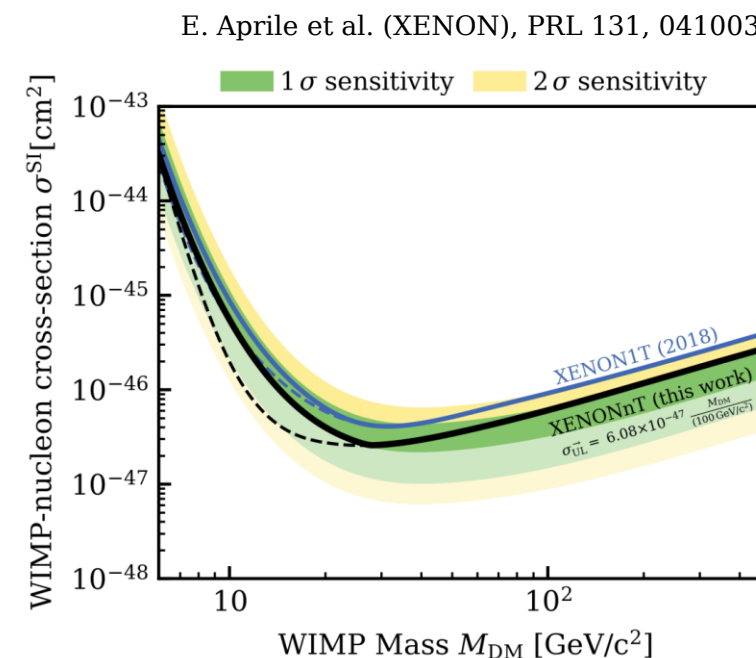


No WIMP excess found above background model

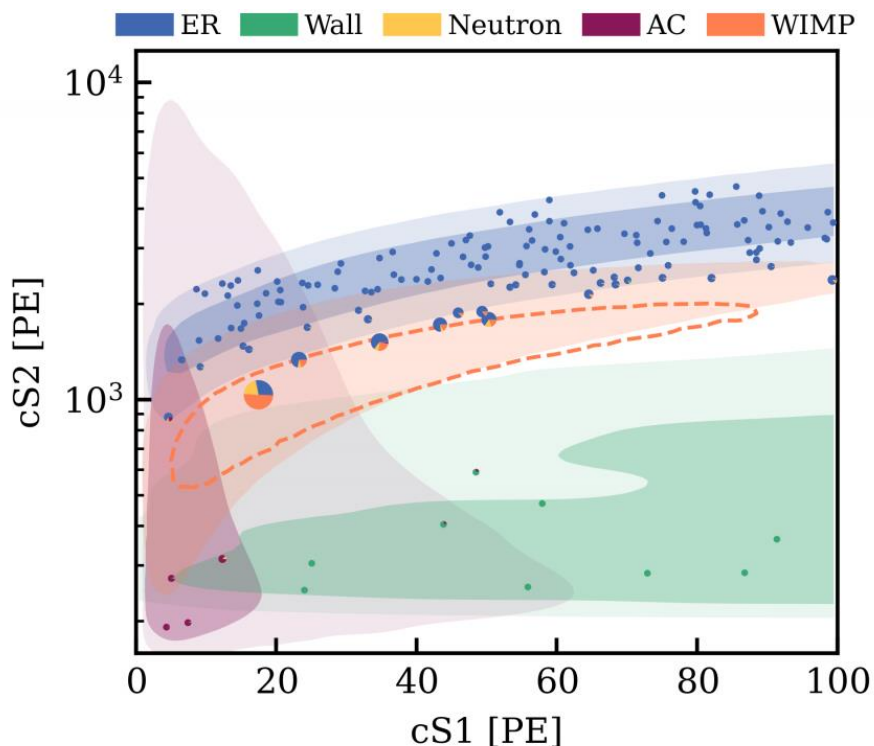
New constraints on SI WIMP-nucleon cross section

$$2.58 \times 10^{-47} \text{ cm}^2 @ 28 \text{ GeV}/c^2$$

Constraints on SD cross section available



First XENONnT results: WIMP search

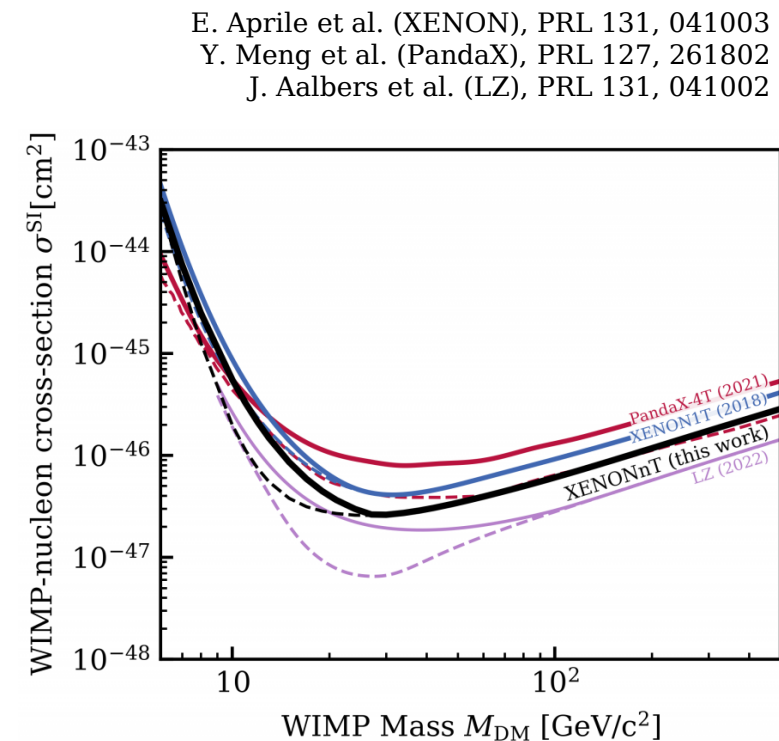


No WIMP excess found above background model

New constraints on SI WIMP-nucleon cross section

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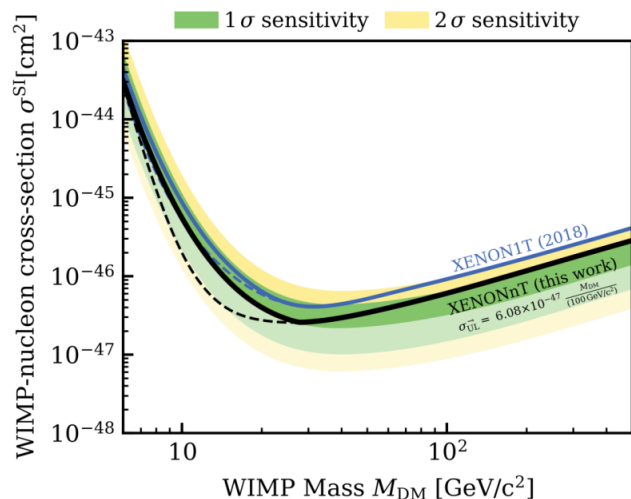
Constraints on SD cross section available



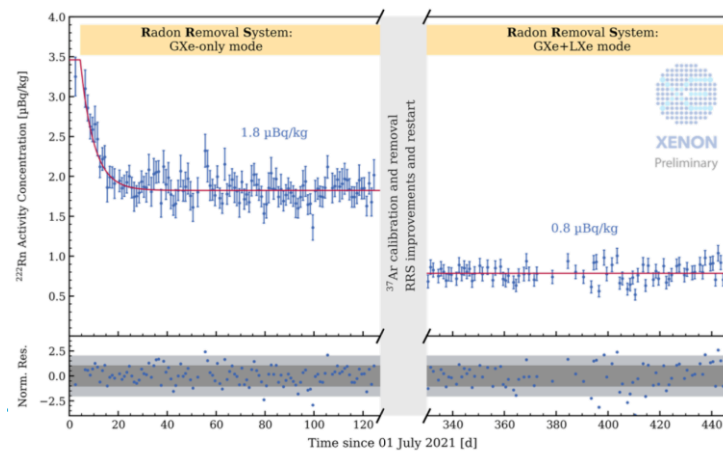
Power constraint limits (PCL) to 50 % minimum rejection power

Summary and Outlook

- Compelling evidence for the existence of DM
- XENONnT achieved the lowest ER background level reported for a LXe TPC
- First science results published



- New science run ongoing!
- Even lower ²²²Rn level: ~ 0.8 $\mu\text{Bq/kg}$
- Improved neutron tagging by Gd-doped neutron veto



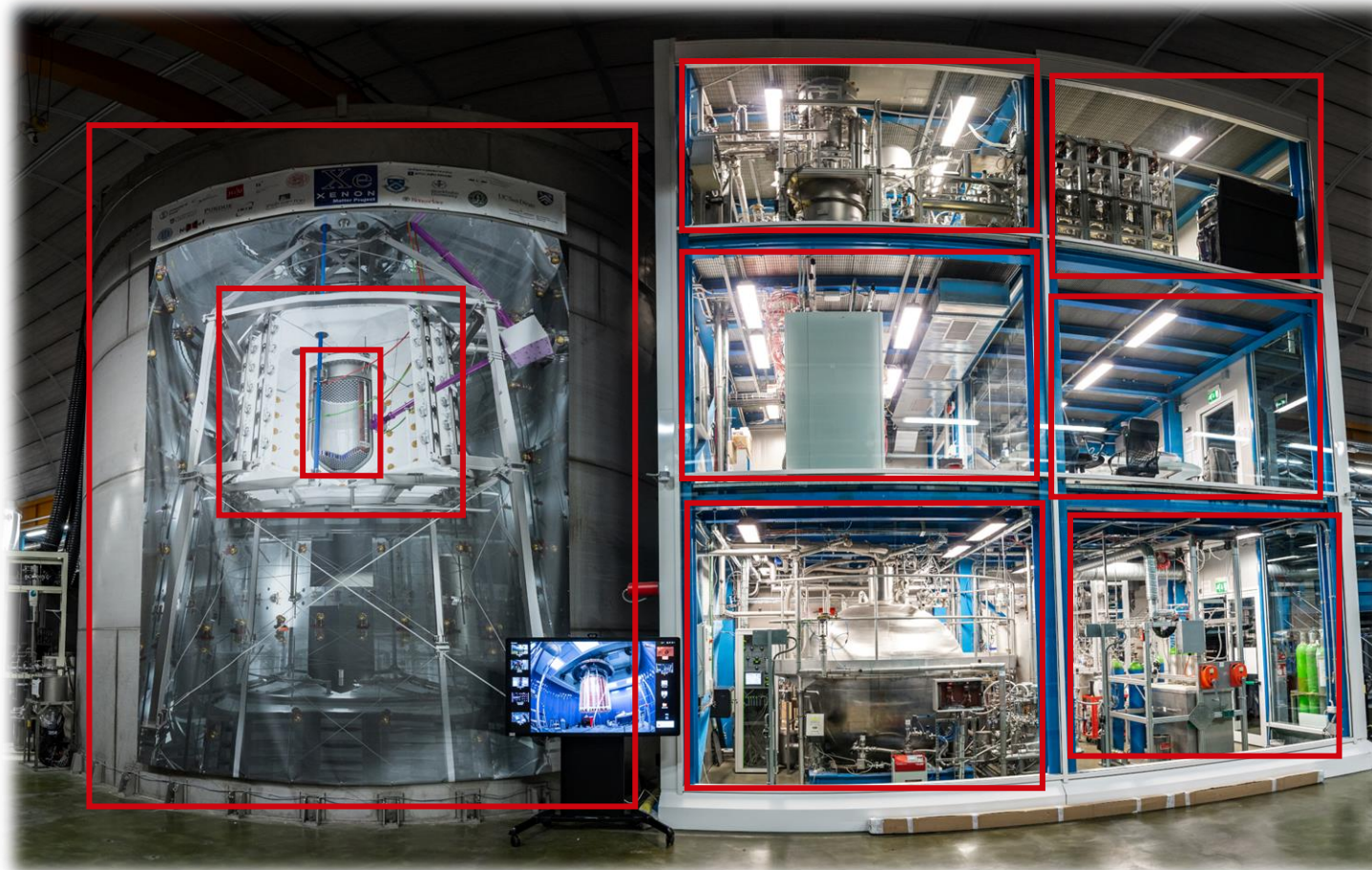
- Consortium merging DARWIN/XENON and LUX-ZEPLIN
- MoU signed July 2021
- Meeting regularly and active internal working groups and structure

Community white paper: *J. Phys. G: Nucl. Part. Phys.* 50 013001 (2023)

Backup slides

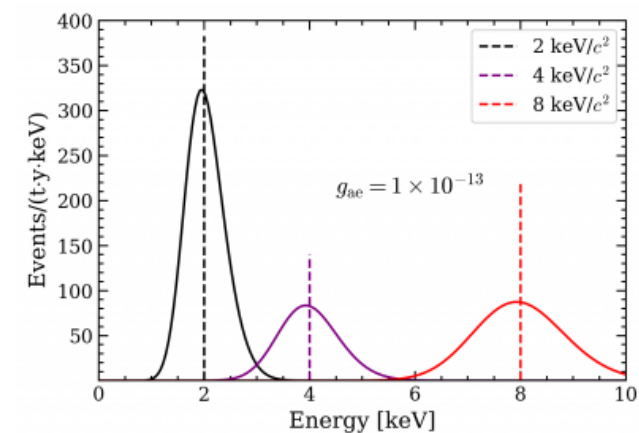
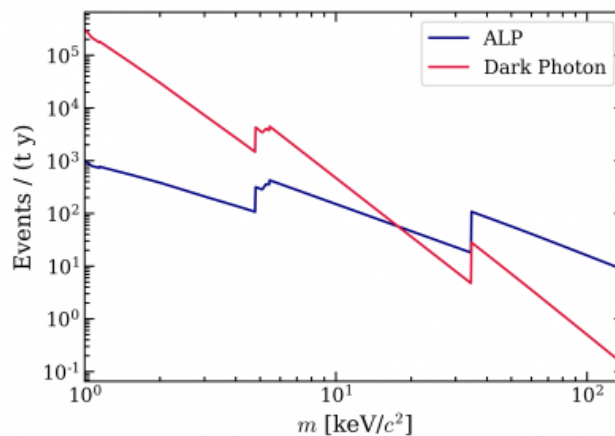
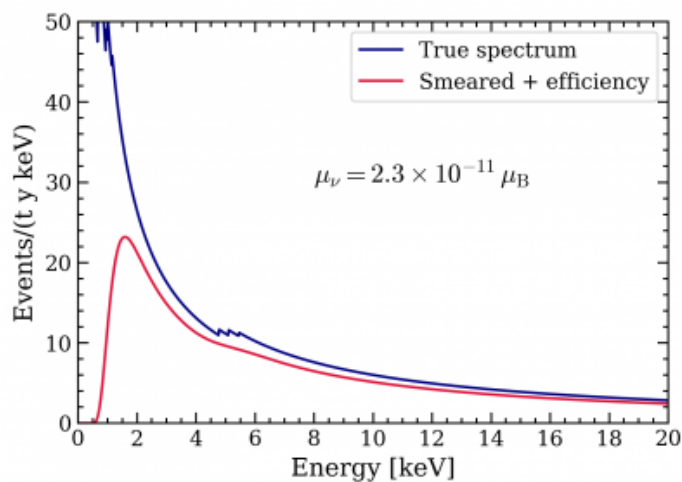
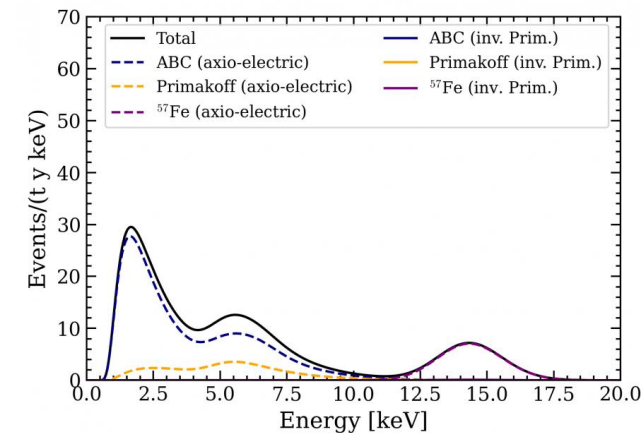
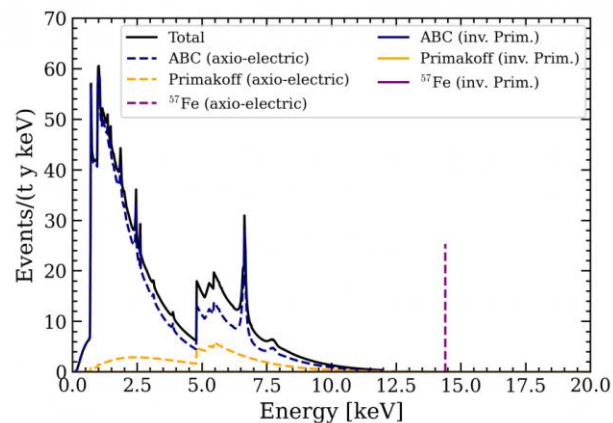
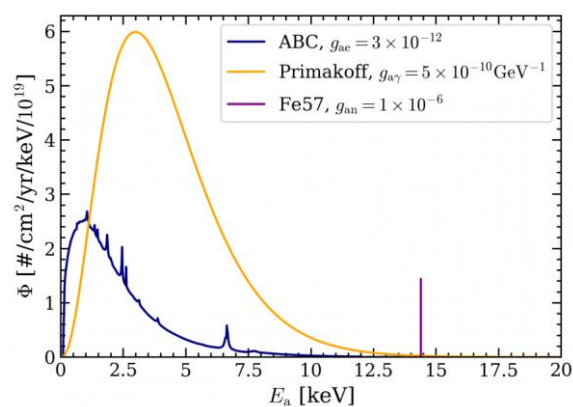
The XENONnT detector @LNGS

- TPC
- Muon veto
- Neutron veto



- Gas and liquid purification
- Cryogenics
- DAQ + processing
- Kr distillation column
- Rn distillation column

ER signals



ER results

