Rencontres de Blois

Exploring the Dark Universe

XENON

STATUS AND LATEST NEWS FROM XENONnT

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LPNHE | Sorbonne Université

OUTLOOK

XENON PROJECT

- XENON Collaboration
- XENON Detectors
- Dual Phase Xe TPC
- Scientific Goals

DETECTOR UPGRADES

- TPC
- Purification System
- Neutron Veto
- Data-Taking

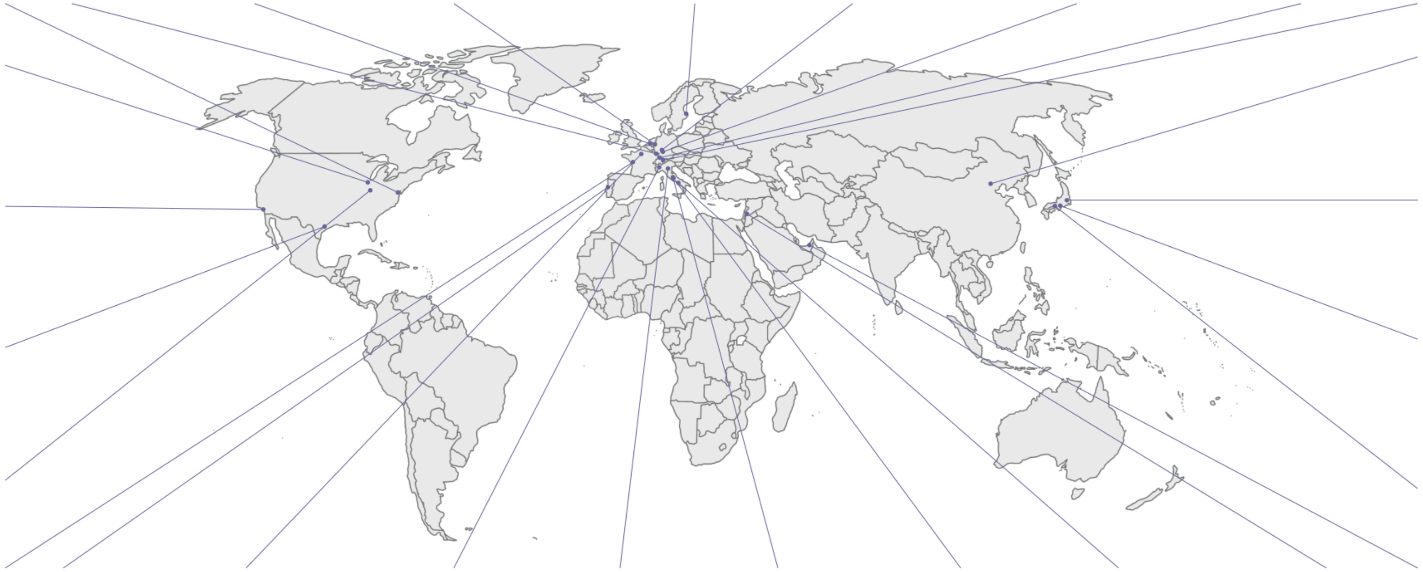
PRESENT & FUTURE

- First Science Run
- Expected Sensitivity
- About the Low-ER Exces?
- Summary and Outlook

THE XENON COLLABORATION

180 SCIENTISTS | 27 INSTITUTIONS | 11 COUNTRIES | 9 TIME ZONES

Columbia
KIT
Nikhef
Muenster
Stockholm
Mainz
MPIK, Heidelberg
Freiburg
Zurich
Chicago
UCSD
Rice
Purdue
Tsinghua
Tokyo
Nagoya
Kobe



Subatech
Coimbra
LPNHE
Torino
Bologna
L'Aquila
LNGS
Napoli
Weizmann
NYUAD

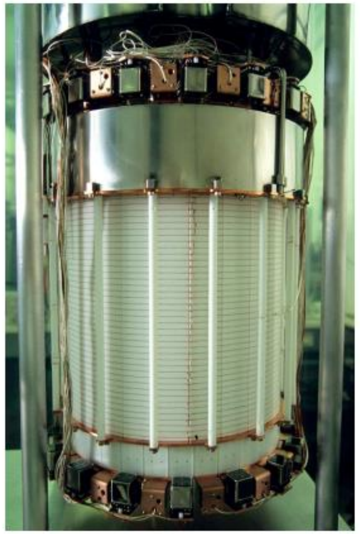
XENON PROJECT
DETECTOR UPGRADES
PRESENT & FUTURE

XENON DETECTORS

THE XENON PROGRAM

XENON10
2005–2007

25 kg LXe
15 cm drift length
$\sigma_{SI} \sim 9 \times 10^{-44}$ cm^2
at 100 GeV/c^2 (2007)



XENON100
2009–2016

161 kg LXe
30 cm drift length
$\sigma_{SI} \sim 10^{-45}$ cm^2
at 50 GeV/c^2 (2016)

XENON1T
2016–2018

3.2 t LXe
1 m drift length
$\sigma_{SI} \sim 4 \times 10^{-47}$ cm^2
at 30 GeV/c^2 (2018)

XENONnT
2020–2025

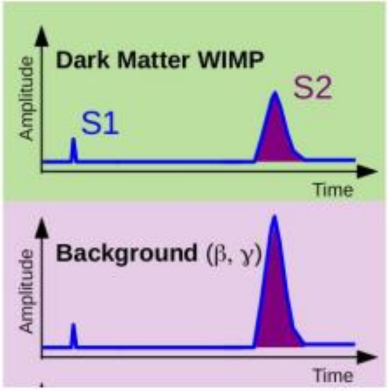
NOW

8.4 t LXe
1.5 m drift length
$\sigma_{SI} \sim 1.4 \times 10^{-48}$ cm^2
at 50 GeV/c^2 (20 t × yr)

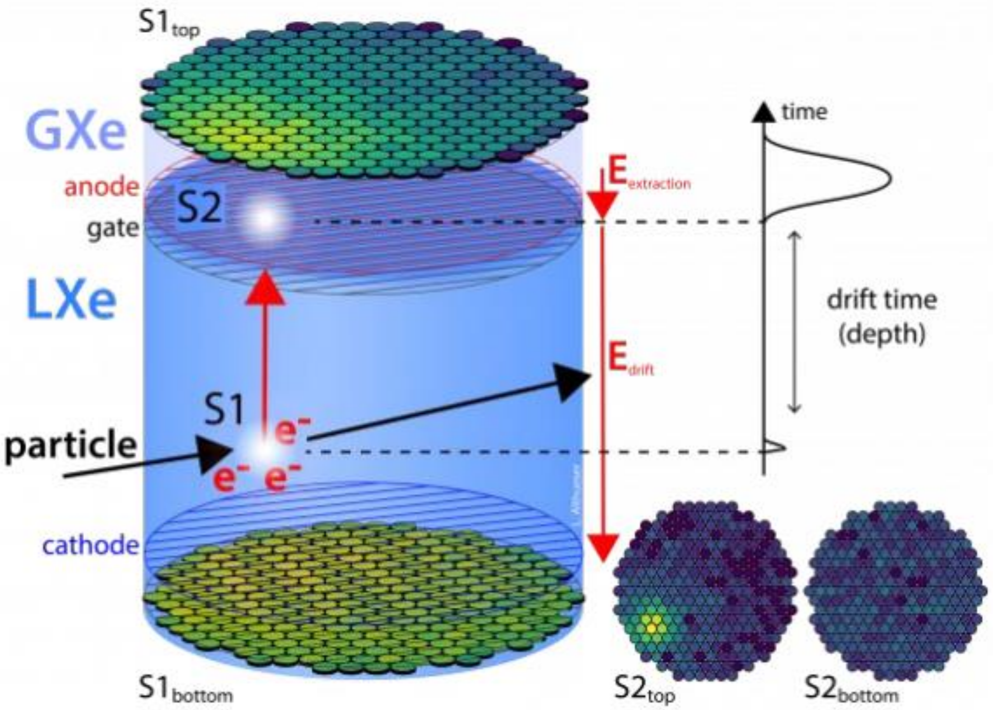
XENON DETECTORS

XENON DUAL PHASE TPC

- dual-phase Xenon (**LXe** + **GXe**)
- **prompt scintillation light S1** generated in LXe
- **secondary-light signal S2** created by proportional scintillation in GXe
- **electrodes** to establish electric fields
- **3D event reconstruction**



S2/S1 ratio used to differentiate between electronic recoil (ER) and nuclear recoil (NR) interactions



$$E = W\left(\frac{S_1}{g_1} + \frac{S_2}{g_2}\right)$$

SCIENTIFIC GOALS

WIMP Dark Matter

Spin Independent (SI), Spin Dependent (SD) interactions

best limits for WIMP masses above 6 GeV/c^2
PRL 121, 111302 (2018)

Light Dark Matter

Sub GeV, Dark Photons, Axion-Like Particles

best limits from 0.1 to 6 GeV/c^2 (except 2-3 GeV/c^2)
PRL 123, 241803 (2019) ,PRL 123, 251801 (2019)

Solar ^{8}B Coherent Elastic neutrino-nucleon scattering

Background reduction in Dark Matter search

Unprecedented sensitivity in LXe
PRL 126, 091301 (2021)

Double Electron Capture in ^{124}Xe

Rarest process ever OBSERVED
Half-life: 1.8×10^{22} years

direct observation in ^{124}Xe
Nature 568, 532-535 (2019)
arXiv:2205.04158 (2022)

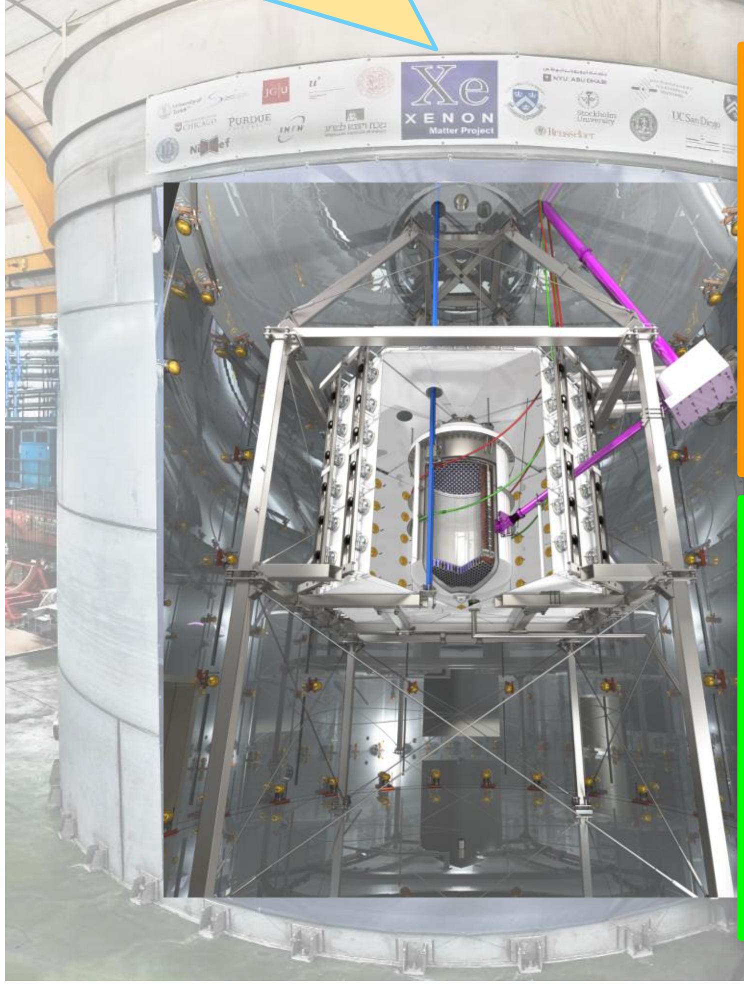
Neutrinoless Double Beta Decay in ^{136}Xe

Majorana neutrino and lepton number violation

probed new search method EPJ C 80:785 (2020)

XENONnT

FAST UPGRADE FROM XENON1T
RE-USE MOST OF SUBSYSTEMS



NEW LARGER TPC

3 TIMES LARGER VOLUME

2.0 t ➞ 5.9 t active mass LXe

1 m ➞ 1.5 m drift length

248 ➞ 494 PMTs and larger light detection efficiency

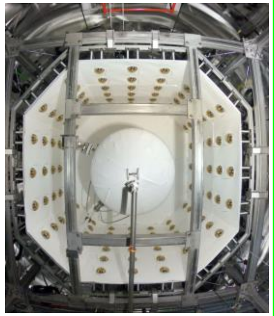
NEW NEUTRON VETO

NEUTRON BACKGROUND FROM TPC

Water cherenkov detector (120 PMTs)

Gadolinium to increase capture in future

Expected 87% neutron tagging efficiency (around 65% with pure water)



PURIFICATION SUSTEM

NEW RADON DISTILLATION COLUMN

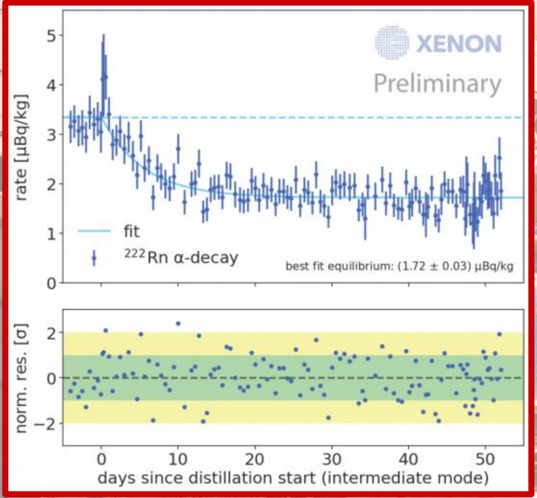
ELECTRONIC RECOILS BACKGROUND

Radon intrinsic background from materials

Dedicated system in addition to Kr column

Lowest level in LXeTPC (<2 µBq/kg ^{222}Rn)

Goal: 1 µBq/Kg, with further improvement



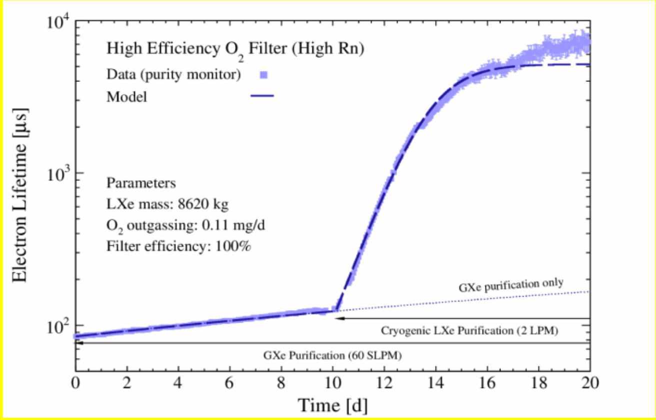
NEW LIQUID Xe PURIFICATION

ELECTRONEGATIVE IMPURITIES

High-flux purification (around 350 kg/h)

High efficiency O_2 filter

Electron lifetime from 100 µs to 5 ms within 5 days (0.65 ms in XENON1T)

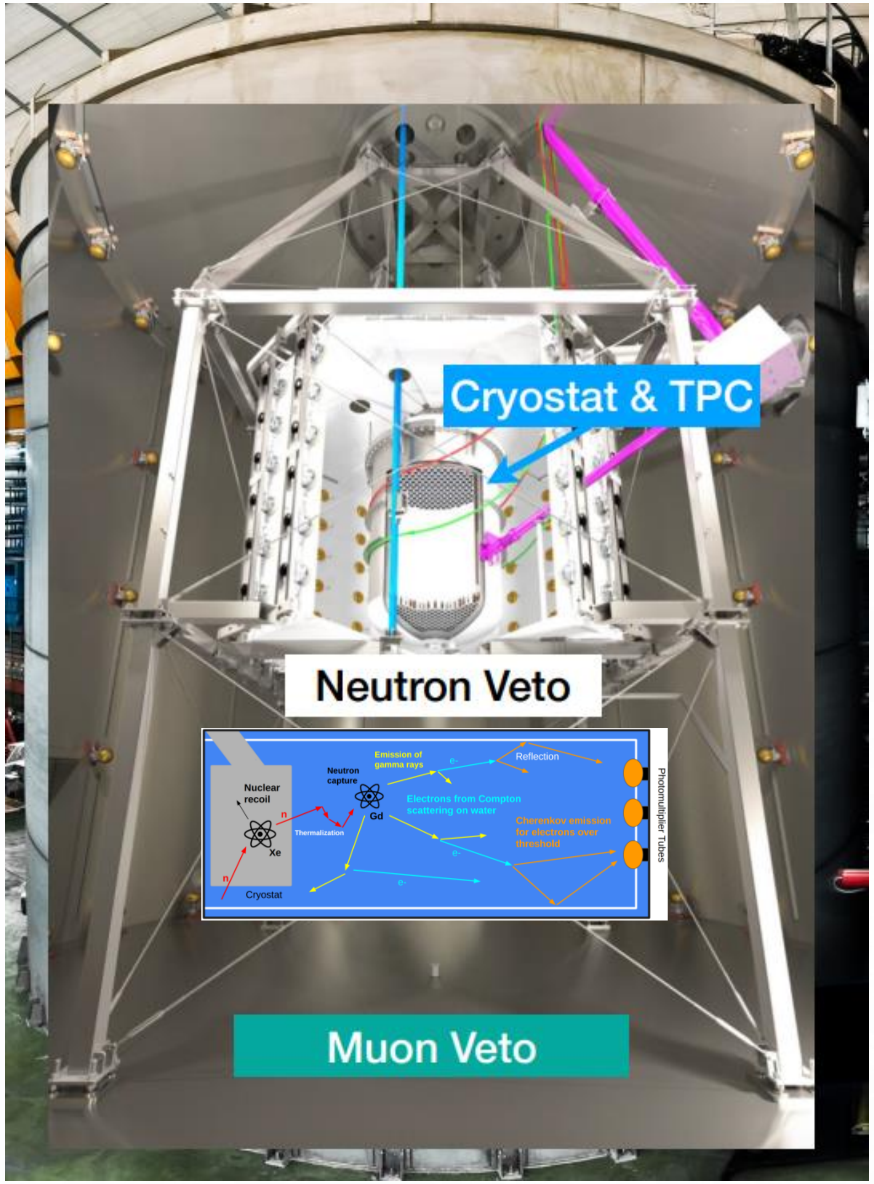


NEUTRON VETO

- A neutron veto, consisting of water Cherenkov detector, was added around the cryostat
- It aims to reduce the background of radiogenic neutrons coming from the detector materials
- In the next phase the water will be doped with 0.5% Gd-sulphate

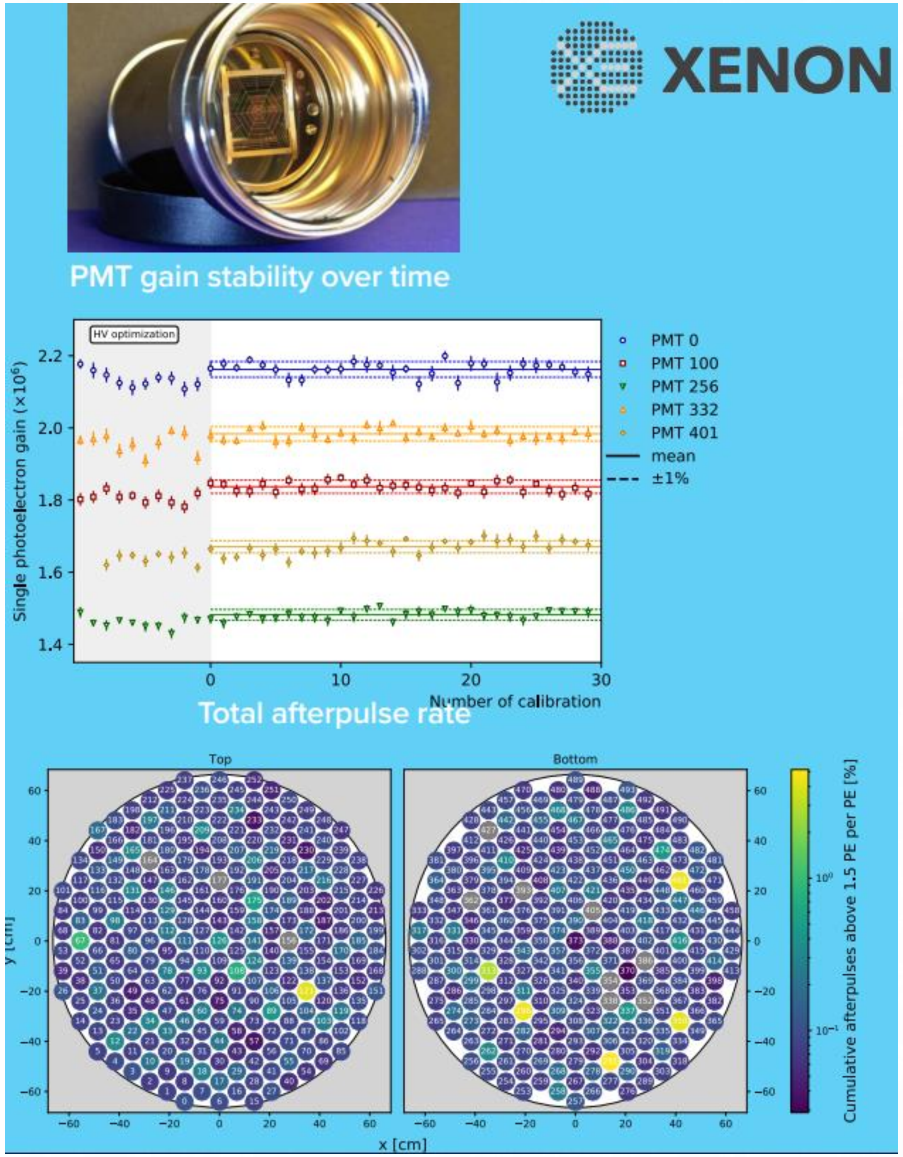
- Neutrons entering the detector are captured by Gd, then produce 8 MeV gammas
- The inner region is optically separated from the muon veto through high-reflectivity ePTFE panels

- The neutron veto is instrumented with 120 low-radioactivity, high-QE PMTs
- The goal is to achieve less than 1 neutron event / (20 tonnes × years) which is an order of magnitude lower than XENON1T.

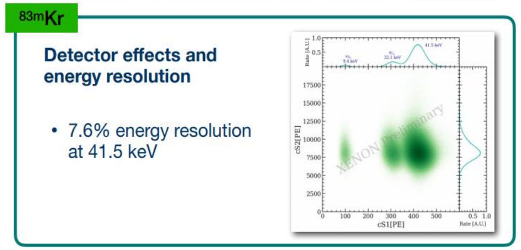


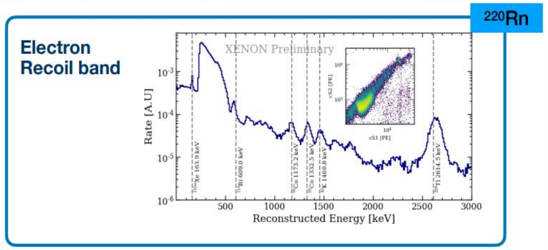
DATA-TAKING STATUS

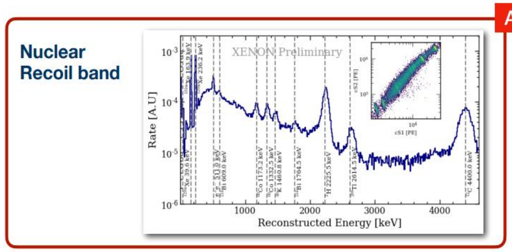
- Detector performance is steady, with the PMTs showing excellent gain stability
- Each PMT was tested in liquid and gas xenon before installation
- Periodic PMT calibrations with LEDs provide single-PE data (low intensity) and after-pulsing (high illumination) to monitor performance
- Only a small number of PMTs exhibit significant afterpulsing

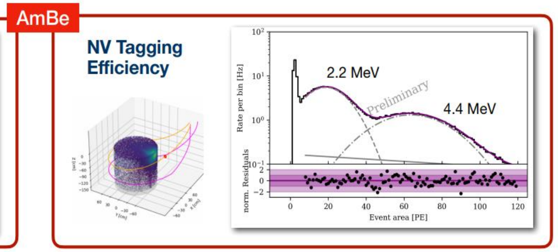


Calibrations









XENON PROJECT
DETECTOR UPGRADES
PRESENT & FUTURE

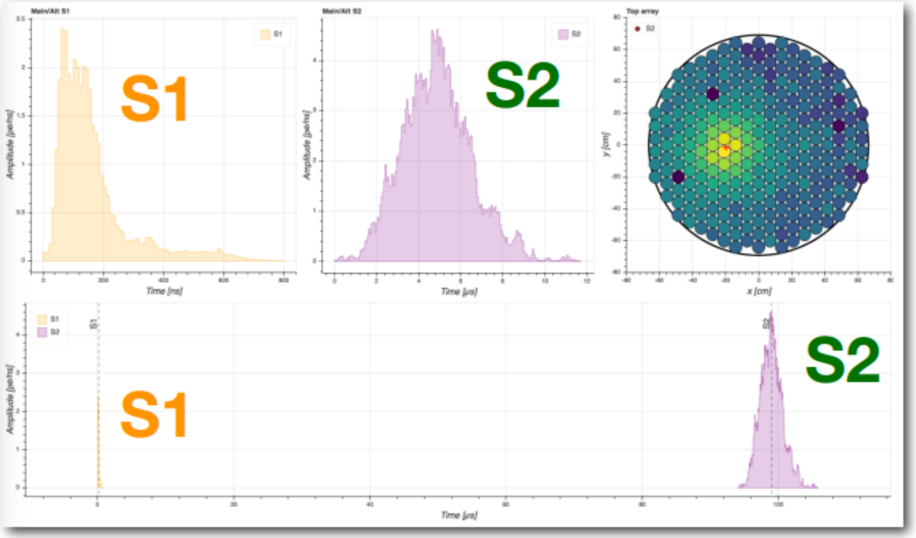
FIRST SCIENCE RUN

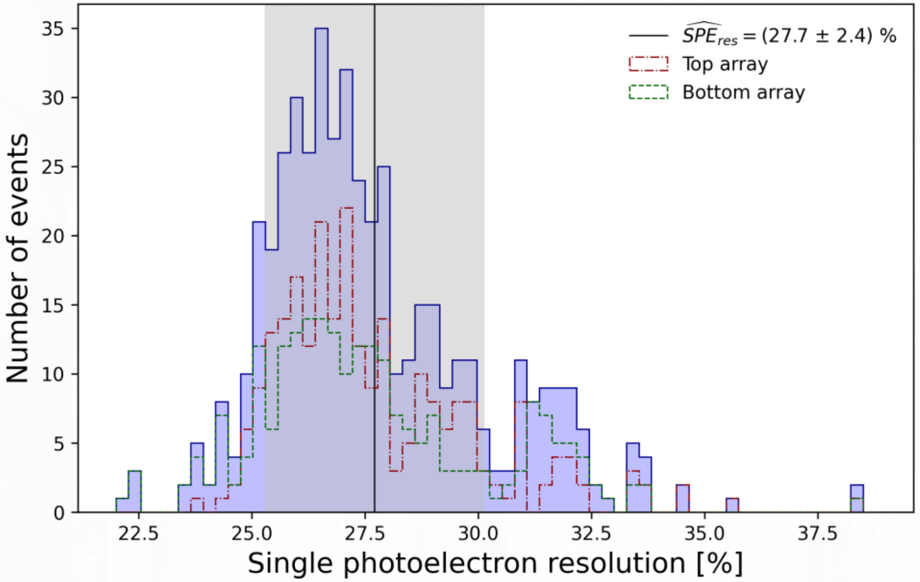
First XENONnT Science Run ongoing

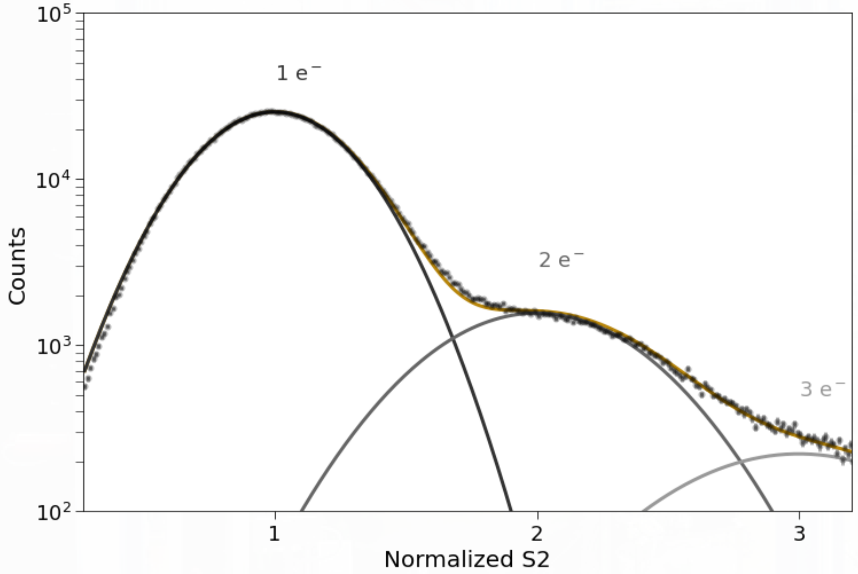
- Focused on WIMP search
- Investigation of the low-energy ER events

Initial XENONnT Perfomance

- **Light Collection : ~17%**
- **SPE Resolution : ~27%**







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XENON

Rencontres de Blois | 26 May 2022

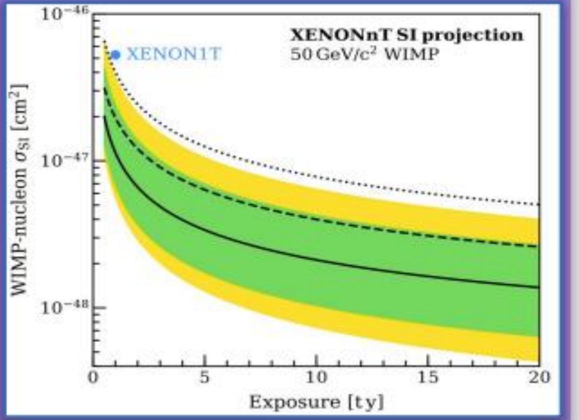
EXPECTED SENSITIVITY

NUCLEAR RECOILS

XENONnT vs XENON1T

x 3 FIDUCIAL VOLUME

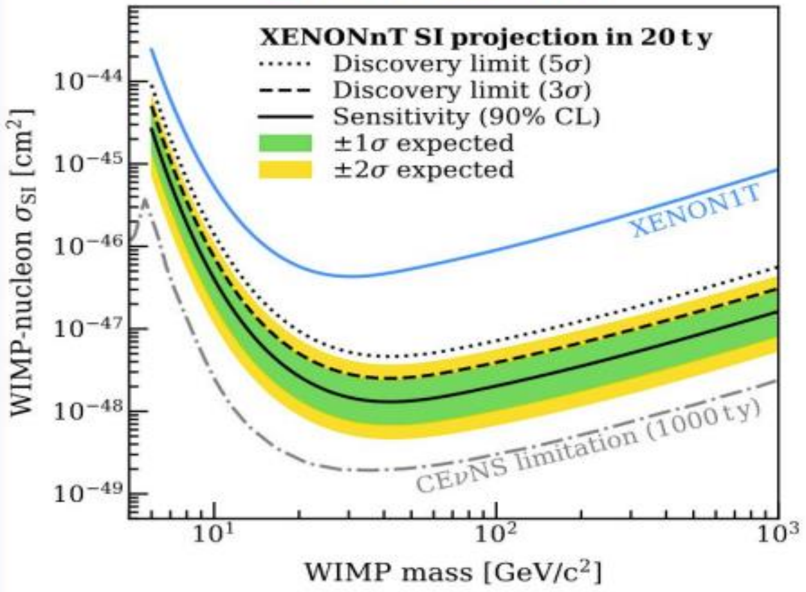
1/6 ER BACKGROUND

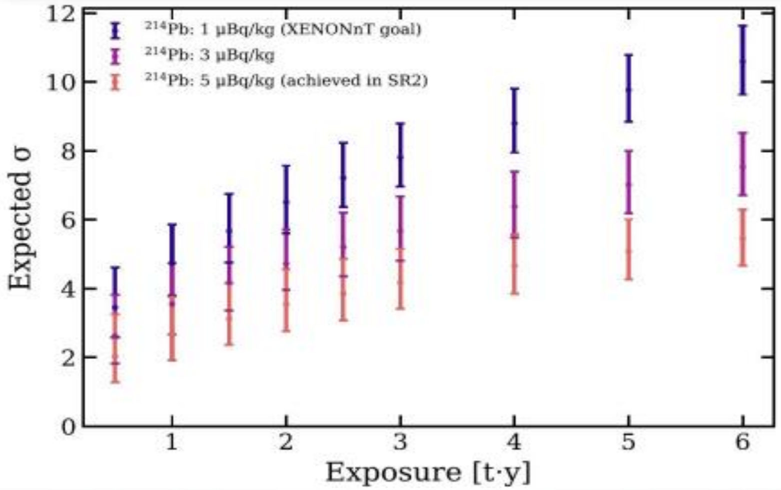


EXPOSURE GOAL:
20 t x yr

WIMP-nucleon
cross section: $\sigma^{SI} \sim 1.4 \times 10^{-48}$ cm² at 50 GeV/c²

JCAP 11 (2020) 031





ELECTRONIC RECOILS

XENONNT WILL INVESTIGATE XENON1T LOW ENERGY EXCESS

Discovery significance depending on background, discrimination in few months

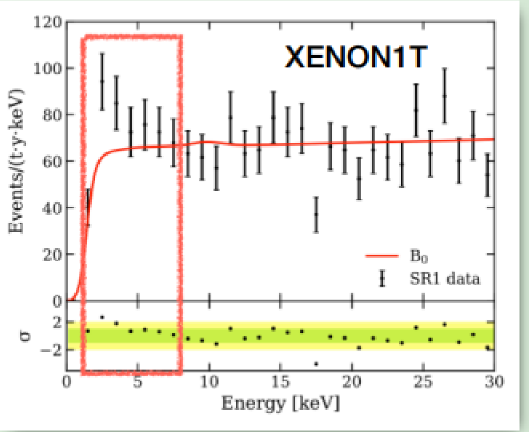
if excess is still there

ABOUT THE EXCESS?

Low-Energy ER excess

- XENON1T observed an excess in the low-ER region
- XENONnT will be able to study this excess:

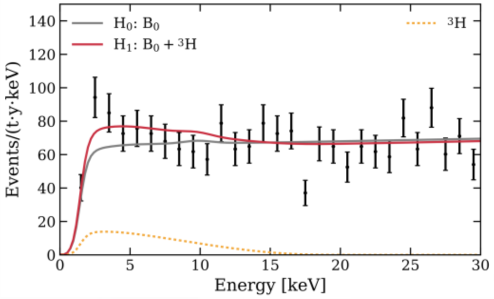
After few months of XENONnT data the various hypothesis to explain this excess can be discriminated at the 5σ level

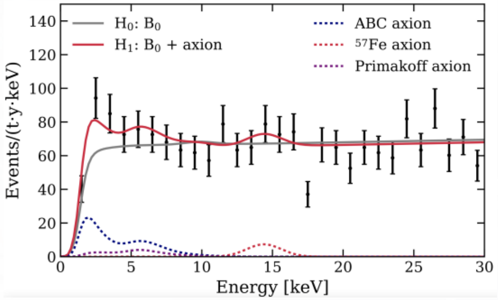


Phys. Rev. D 102, 072004 (2020)

Dedicated Tritium Handling:

- Reduced H2O/H2 outgassing rate from TPC by long-time evacuation
- Regenerated hydrogen removal unit (HRU) as in XENON1T
- Faster removal of H2O/H2 thanks to the faster liquid purification
- Directly measured the water concentration in the LXe





- XENON1T LowER excess in 1-7 keV region
- Significance with Axion spectrum:
  - 3.4 σ without tritium BG assumption
  - 2.0 σ with tritium BG assumption

SUMMARY AND OUTLOOK

- Xe based dual-phase Time Projection Chamber has proven to be the leading technology in the field of direct Dark Matter searches
- Despite challenging times, XENONnT finished construction on 2020 and started data taking since mid 2021
- XENONnT is taking science data as we speak with lowest level of Rd achieved in LXeTPCs, great LXe purity, excellent PMT performance and taking data
- Science data taking and analysis is ongoing: stay tuned for future results!

MERCI DE VOTRE ATTENTION!

XENON

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Photo credit: **Luigi Di Carlo for the XENON Collaboration**