The XENONnT experiment: Recent status and updates

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XENON

NAGOYA UNIVERSITY

ISEE
Institute for Space-Earth Environmental Research

DMNet

The XENON collaboration

12 Countries, 27 institutions, ~160 scientists

Columbia
KIT
Nikhef
Muenster
Stockholm
Mainz
MPIK, Heidelberg
Freiburg
Zurich
Chicago
Tsinghua
UCSD
Tokyo
Rice
Nagoya
Purdue
Kobe
Subatech
Coimbra
LPNHE
Torino
Bologna
L'Aquila
LNGS
Napoli
Weizmann
NYUAD

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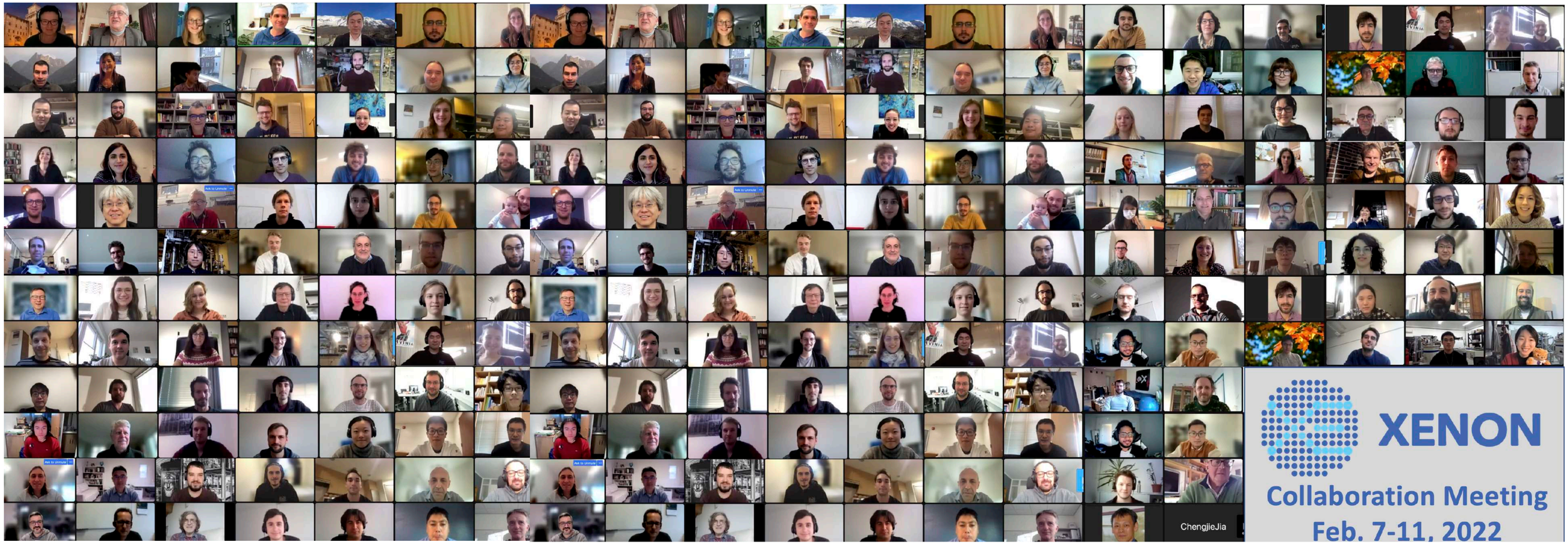
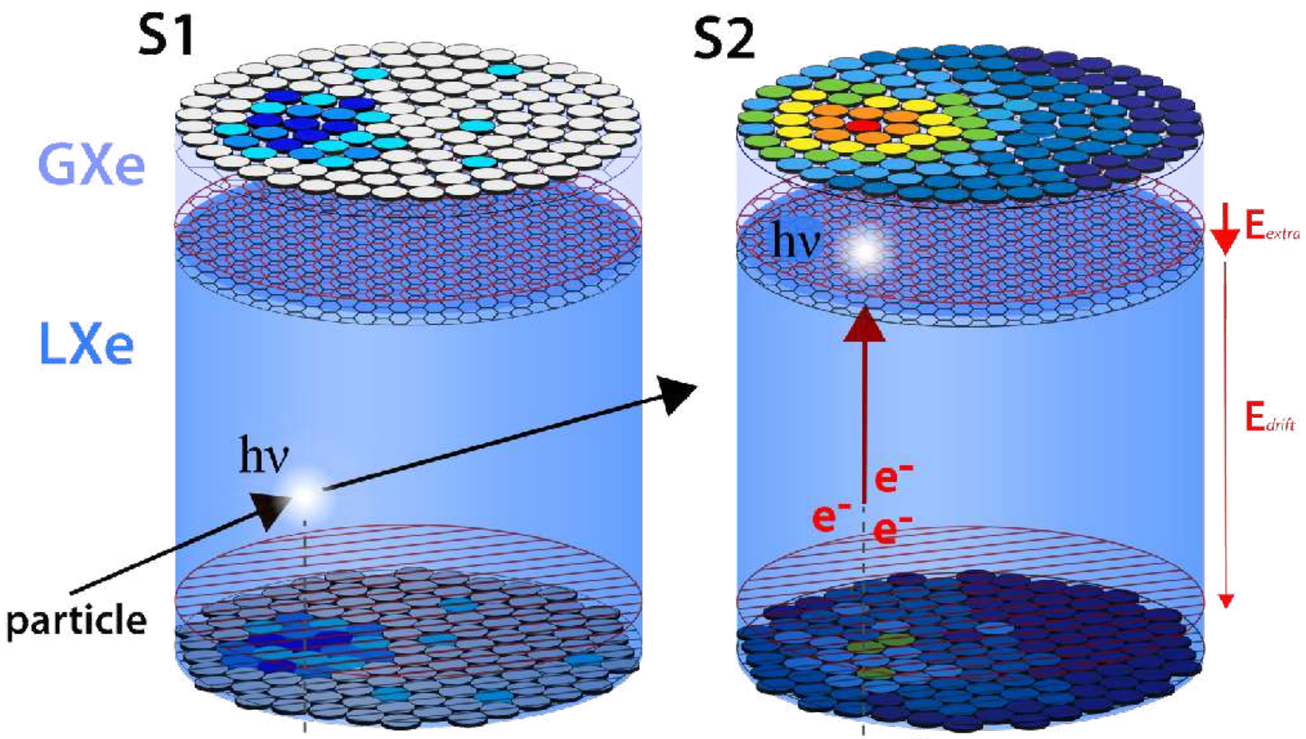


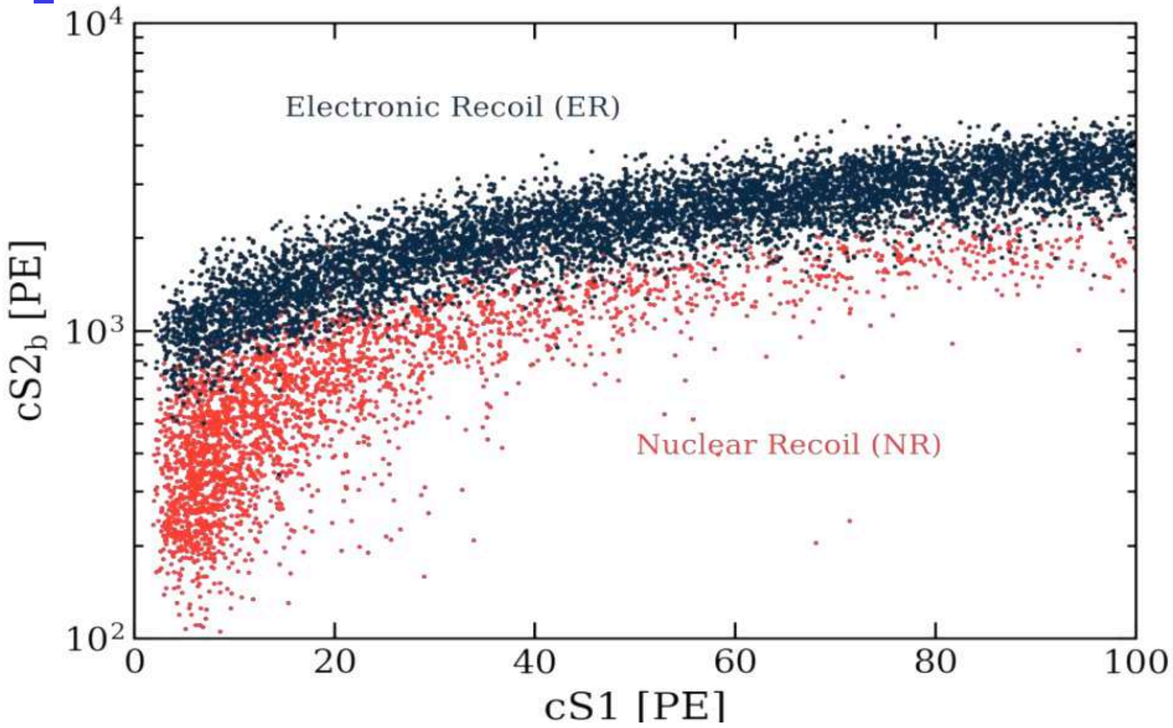
XENON experiments

- The (main) target of XENON project: **Direct detection of dark matter**
  - **WIMPs**, ALPs, …
- Other physics targets: Solar axions, neutrino physics, …

Years	2005 - 2007	2008 - 2016	2012 - 2018	2019 - now
Total Xe mass	25 kg	161 kg	3200 kg	8600 kg
WIMPs sensitivity	~10^{-43} cm^2	~10^{-45} cm^2	~10^{-47} cm^2	~10^{-48} cm^2

XENON experiments: liquid xenon TPC



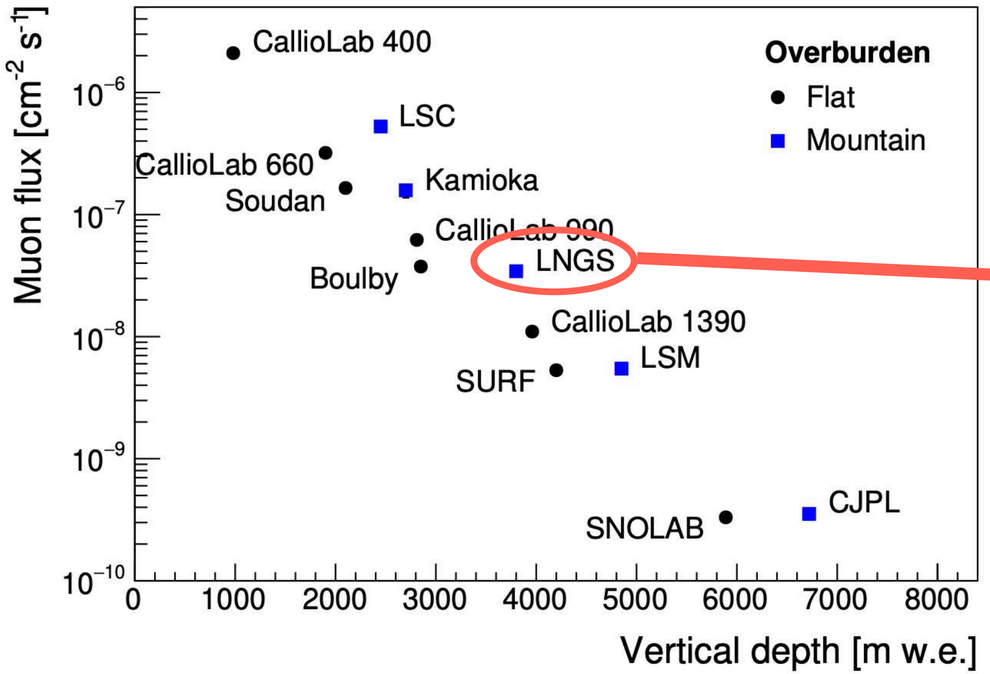


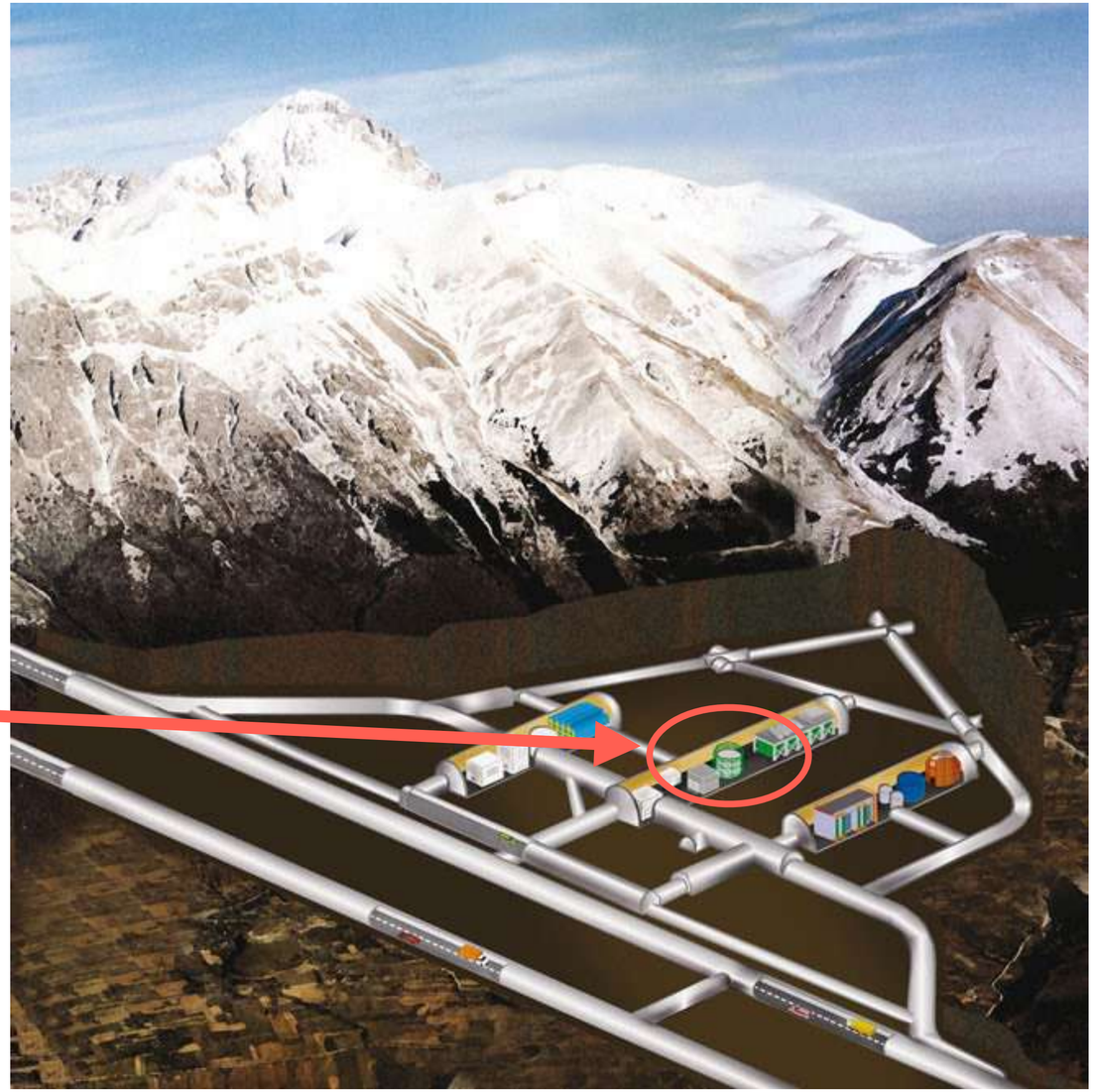
- DM and BG particles generate signal in LXe:
  - S1: Scintillation photons
  - S2: Ionization electrons

- S2/S1 depends on the type of interaction
  - Electronic recoils: Gamma, Beta, Axion…
  - Nuclear recoils: Neutron, WIMPs…
- ER has larger S2 than NR events: BG rejection
- Very high sensitivity for WIMPs

The XENONnT

- Detector located at Gran Sasso Laboratories, Italy
- Underground space to suppress muons
  - 1500 m of rock ~ 3600 m.w.e.
  - ~10^{-6} of surface muon flux



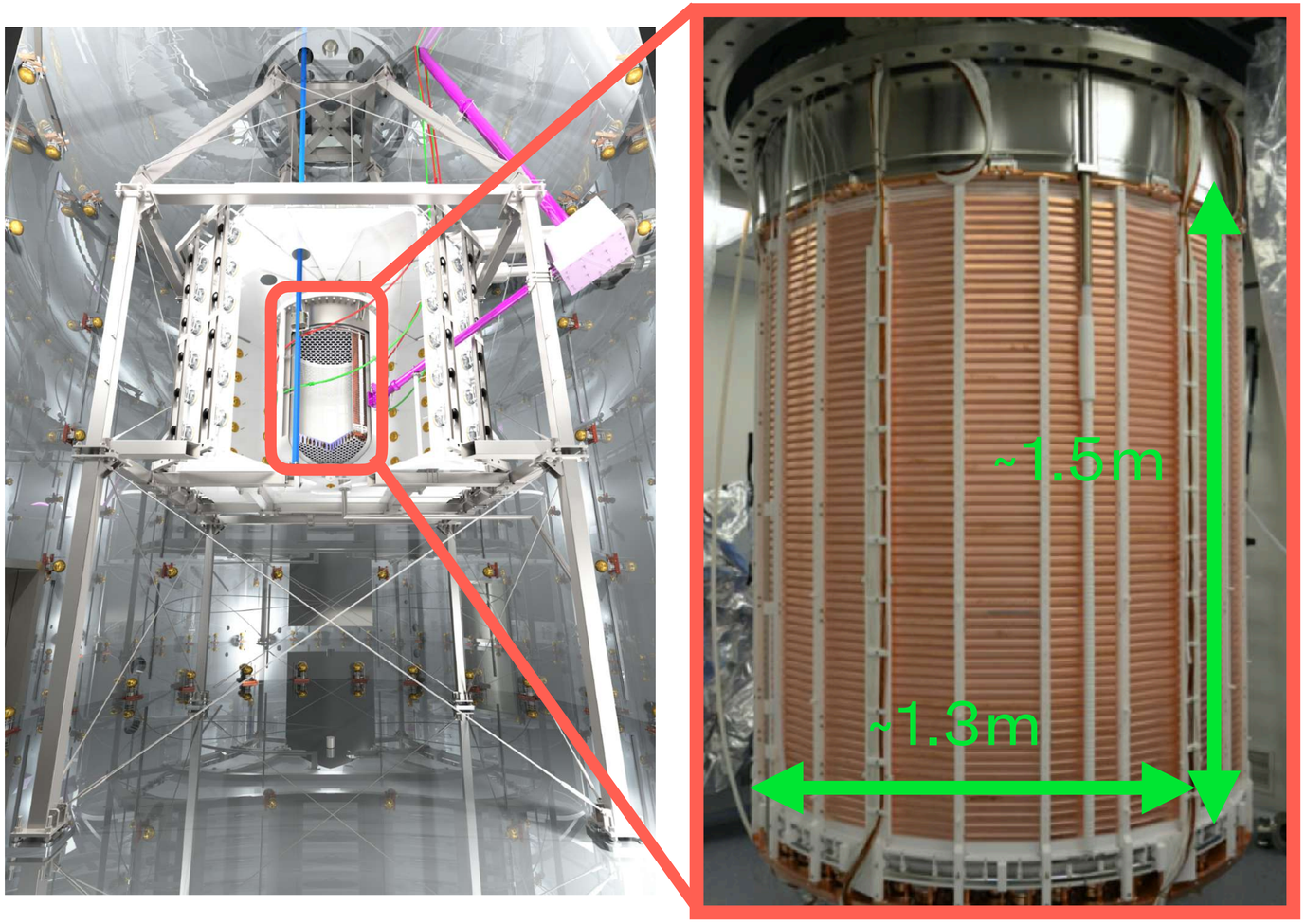


The XENONnT

The XENONnT

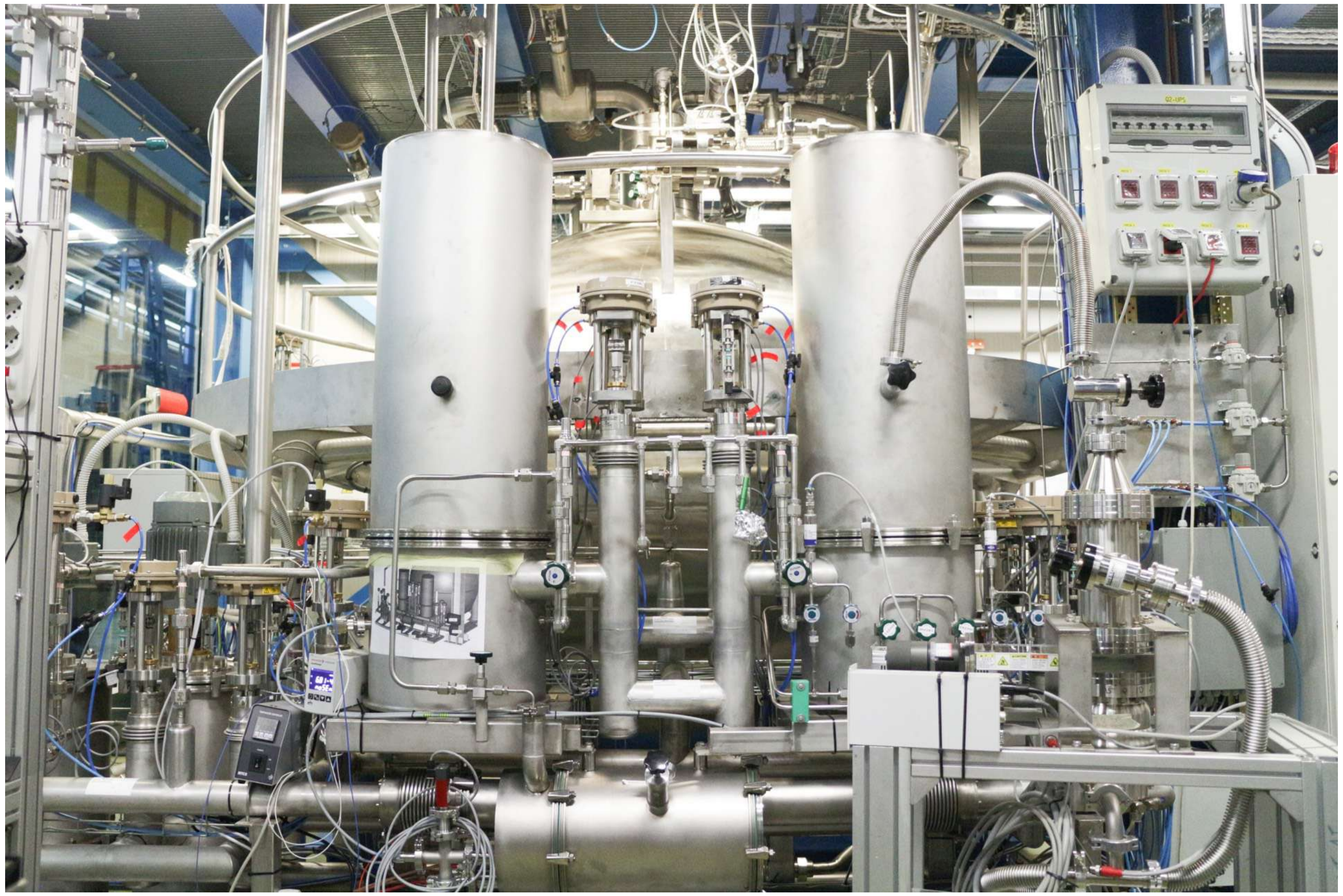
: New systems

XENONnT TPC



- XENONnT TPC
  - Diameter=1.3m, Height=1.5m
  - Full/Active: 8.6 / 5.9t
    - ~x3 larger than XENON1T
- Low energy ER BG: 1/6 of XENON1T
  - Target: ^{222}Rn 1uBq/kg

Xenon purification system



- Direct liquid circulation with cryogenic pump
- Online purity measurement by purity monitor
- Multiple filters works very well
  - High eff / high Rn (for intense purification)
  - Mid eff / low Rn (for DM data taking)
  - Arxiv:2205.07336 for more detail
- Achieved x10 better purity than XENON1T (> 10ms)

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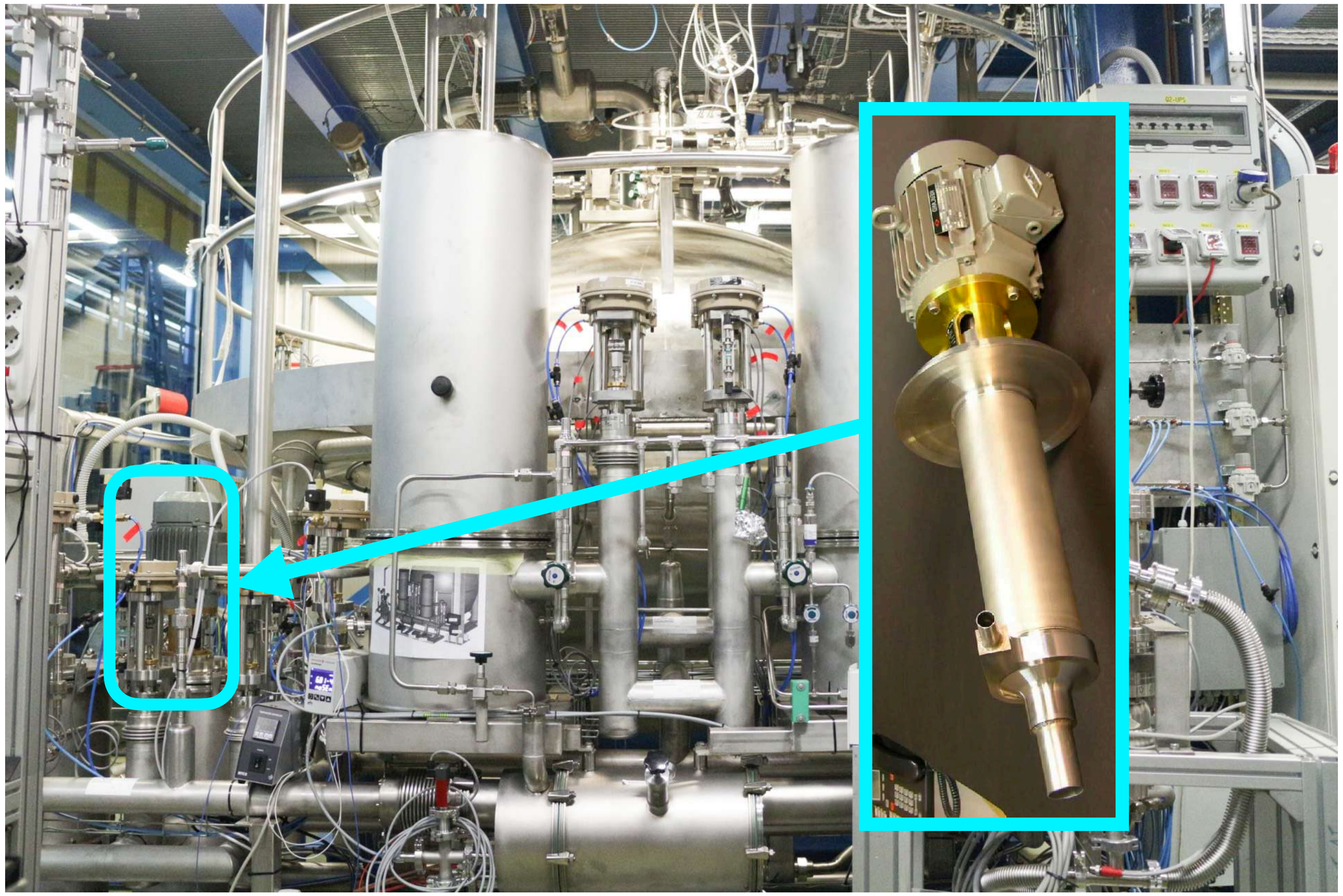

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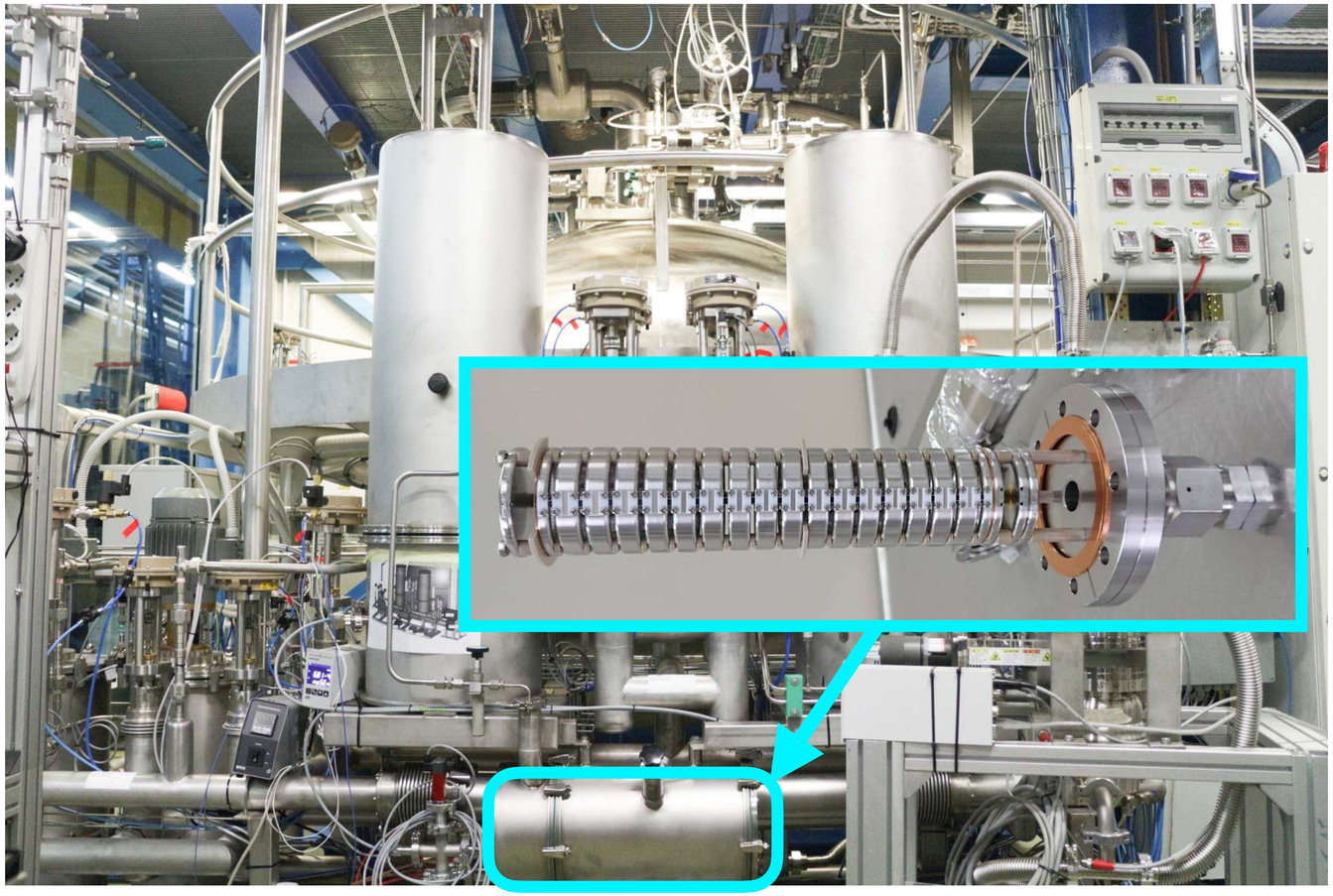

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Xenon purification system

Copper power on ceramic ball

Non evaporable getter

From: SAES Getters https: //www.saesgetters.com/sites/default/files/St%20707%20Pills%20%26%20Pieces_0.pdf (2012)

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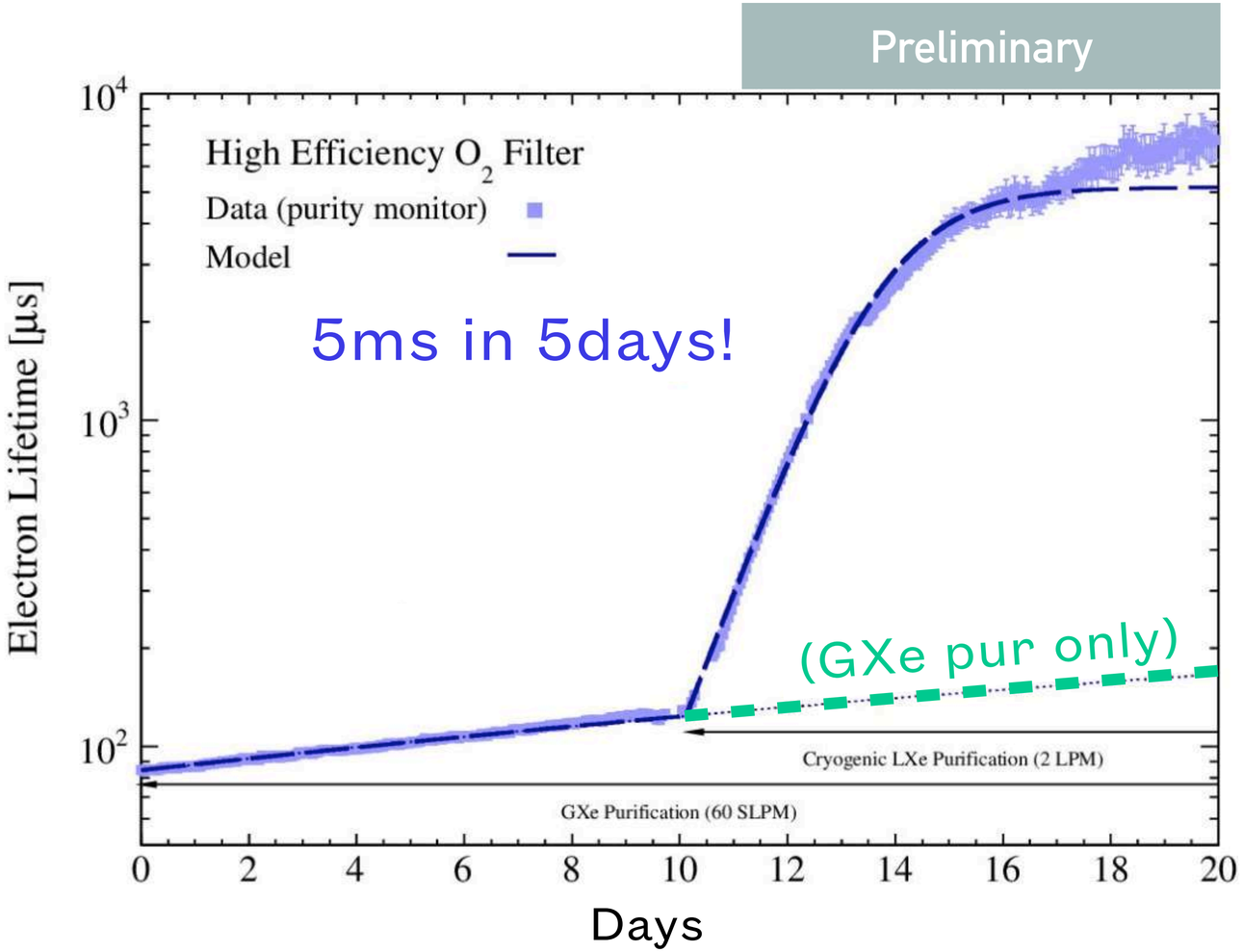

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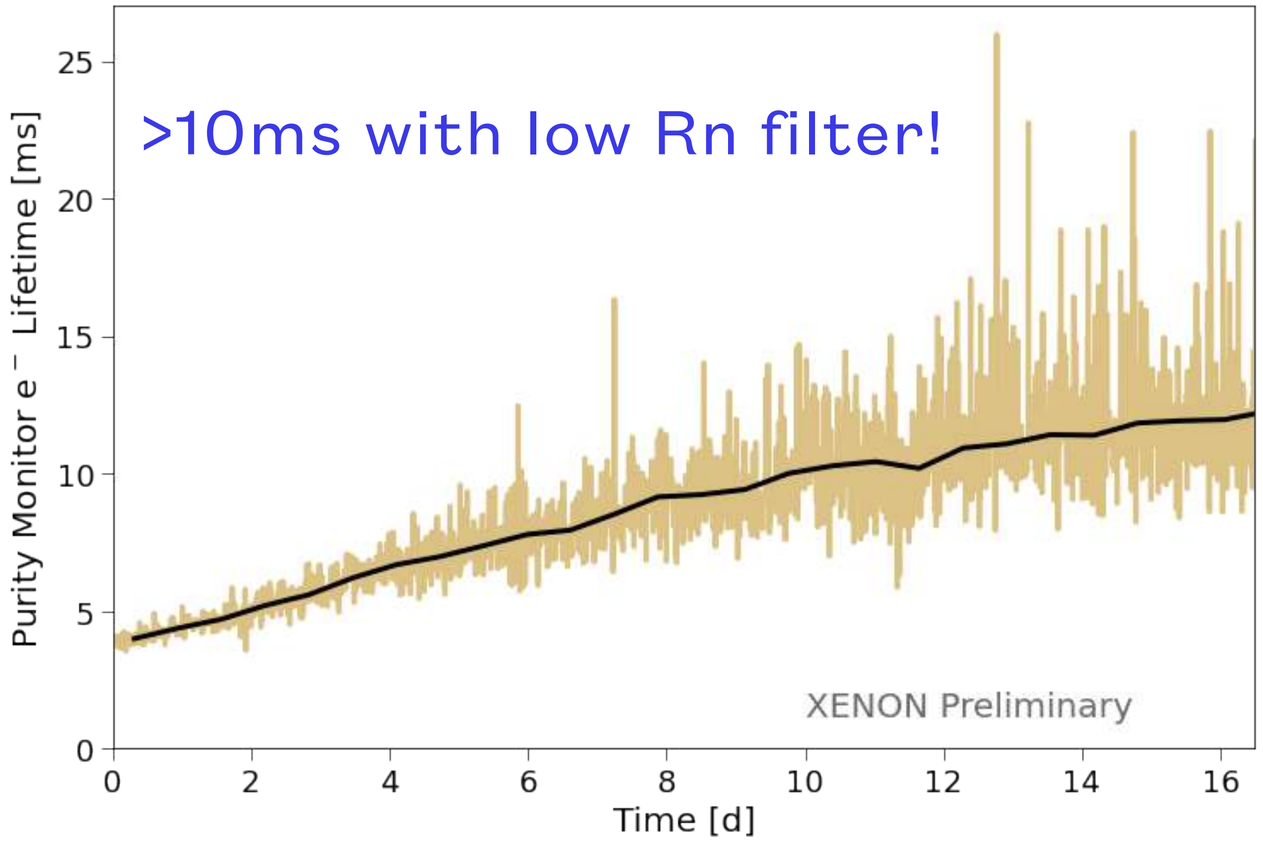

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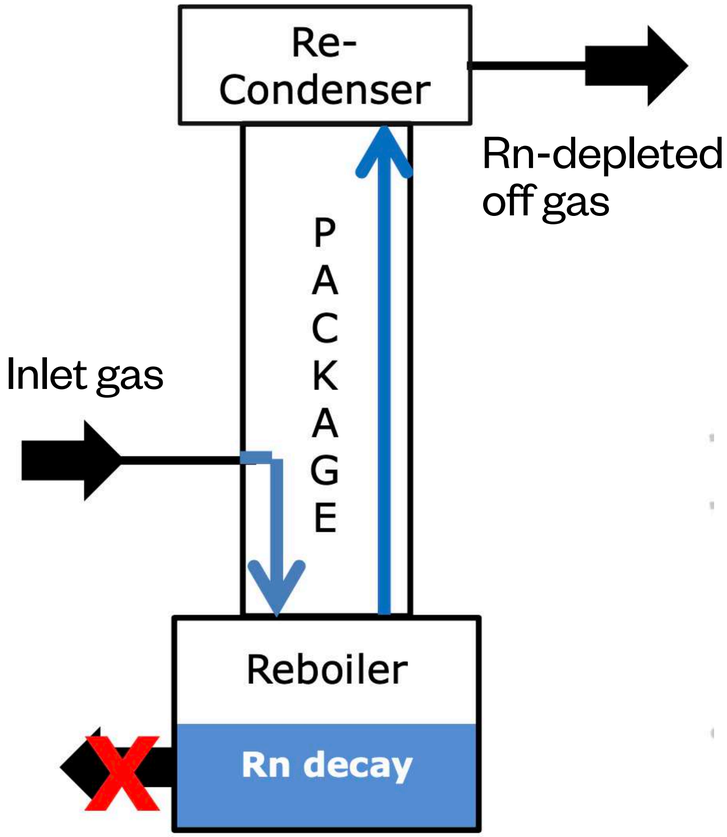
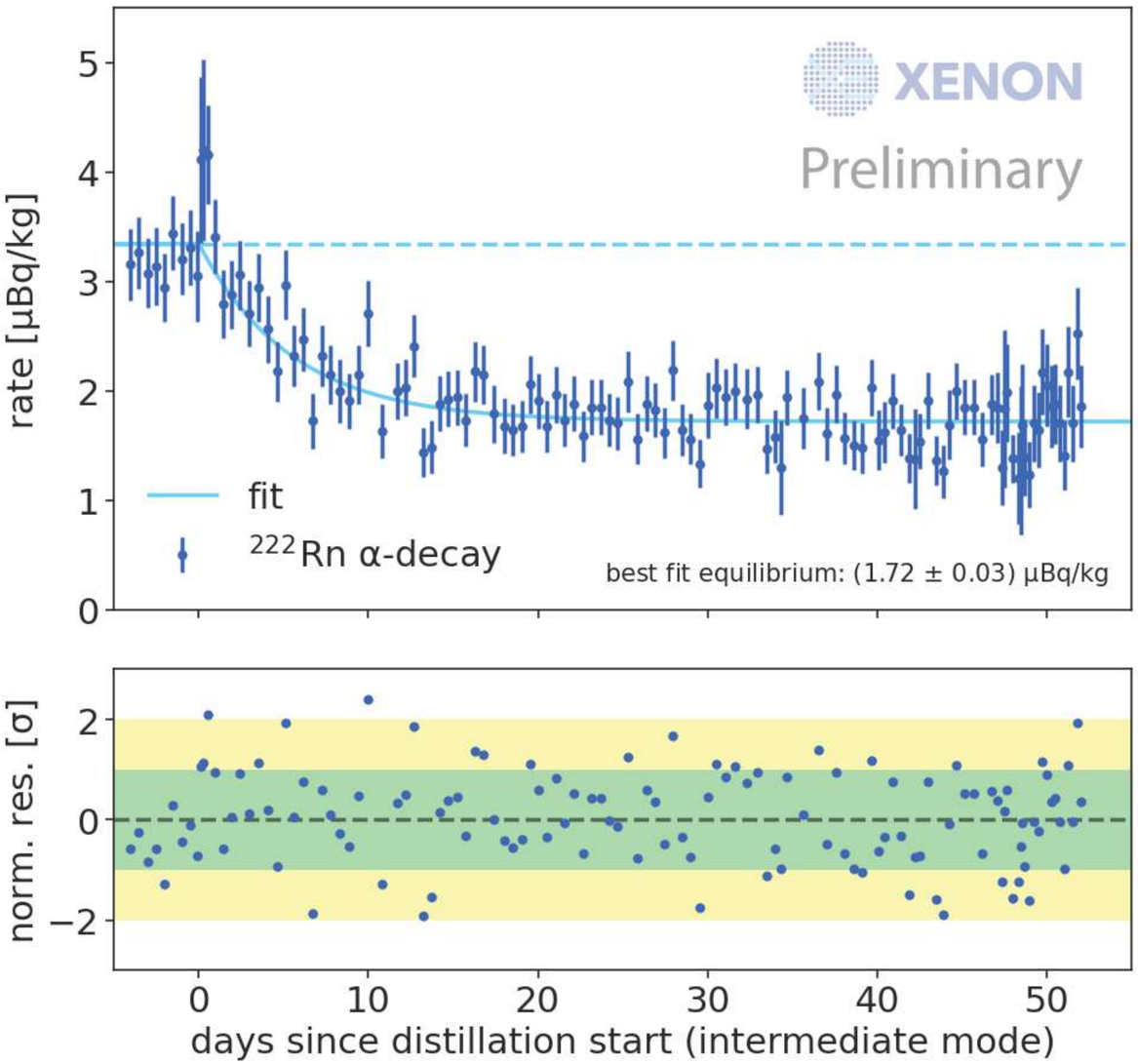
Rn distillation system



- Rn atom accumulates more into LXe than GXe
  - Rn distillation: pure off-gas
- Rn atoms are kept in the column and decay
- Already tested in XENON100, XENON1T
  - Eur. Phys. J. C (2017) 77: 358
- New Rn column built for XENONnT: 200SLPM speed

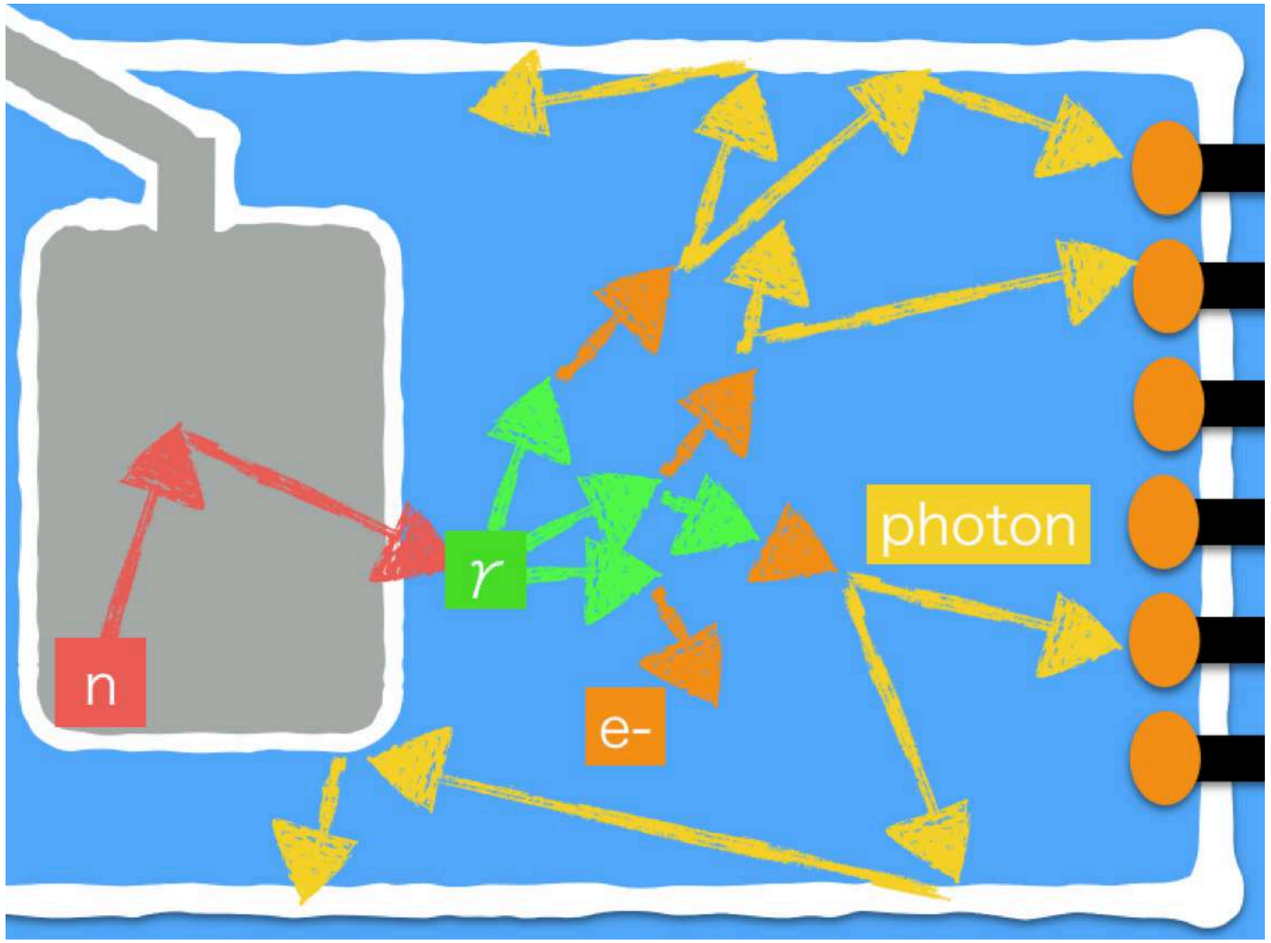
Rn distillation system



- Two operation modes: GXe + LXe
- GXe mode:
  - Remove Rn from GXe, before entering to LXe
  - Ex: signal cables, cryogenic pipe, …
- LXe mode:
  - Remove Rn from LXe
  - Ex: TPC body, PMT, …

- 1.7uBq/kg achieved with GXe-only mode
  - Further x2 reduction expected with GXe+LXe mode: 1 uBq/kg or less

Neutron Veto



- Neutron: ultimate BG for WIMPs search
- Neutron Veto system
  - Gd-Water Cherenkov detector
- Neutrons are captured by Gd, then produce 8MeV γ
- Covering entire Cryostat with ePTFE structure
- Tagging efficiency: ~80-90% expected from simulation
  - At 0.5% $Gd_2(SO_4)_3 \cdot 8H_2O$

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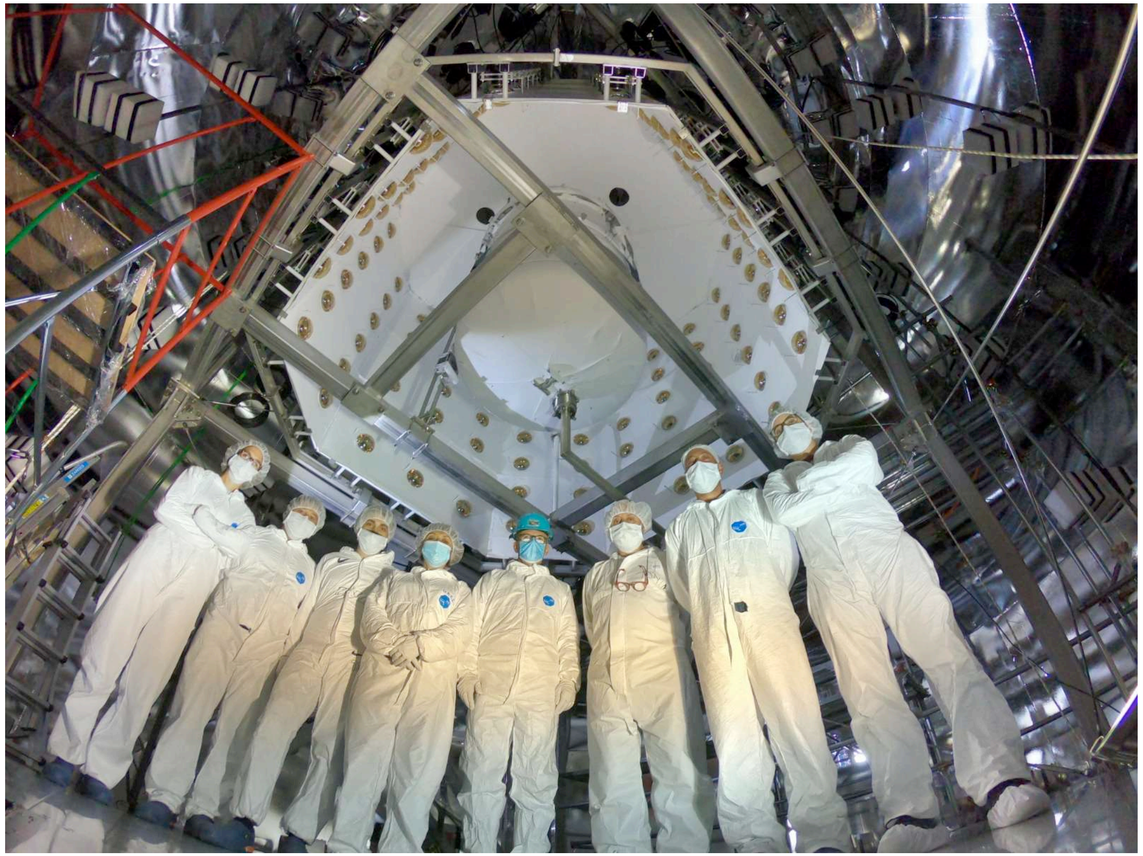

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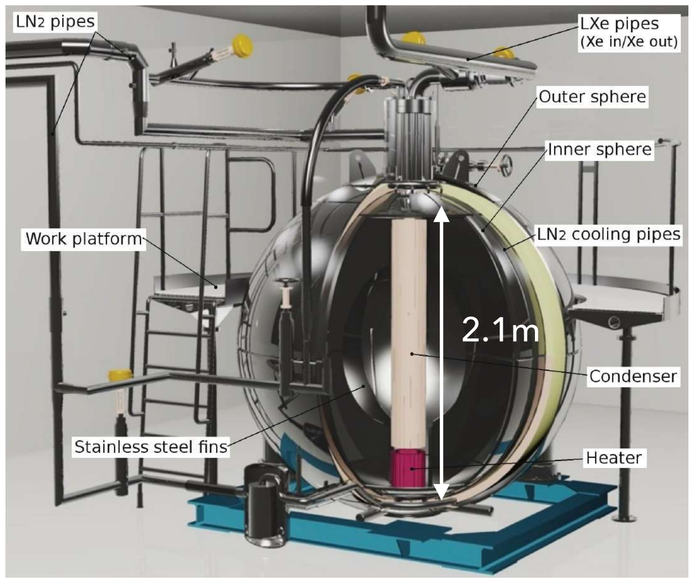
Xenon storage

RestoX1

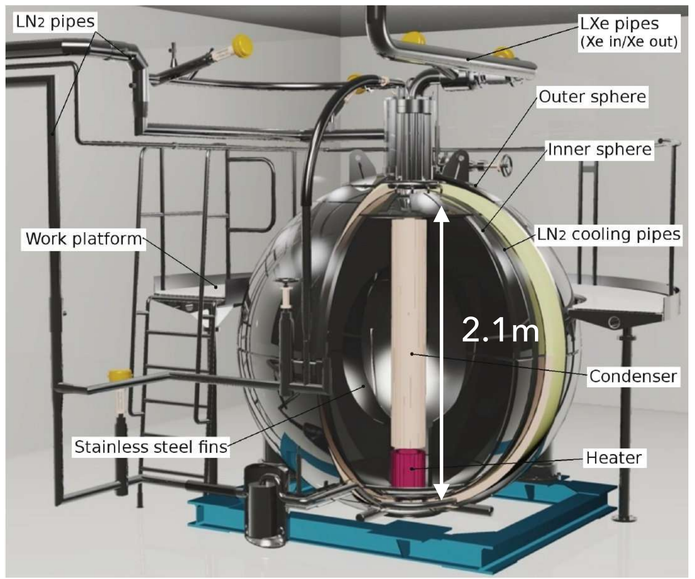


RestoX2

- Total amount of Xenon for the detector:
  - XENON1T: ~3.2 t
  - XENONnT: ~8.6 t
- Xenon Strage + Emergency recuperation
  - ReStoX1: GXe + LXe, 7.5 t
  - ReStoX2: GXe + SXe, 9 t

Xenon storage

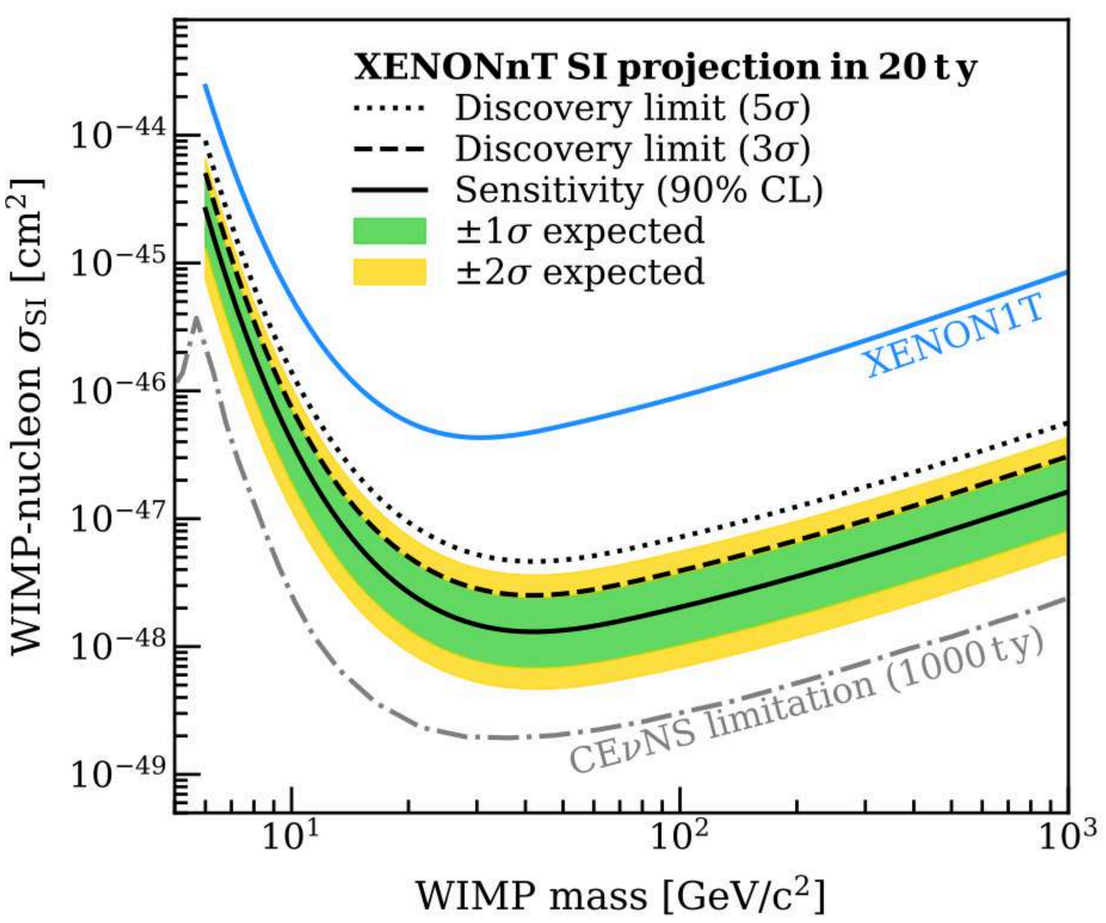
RestoX1

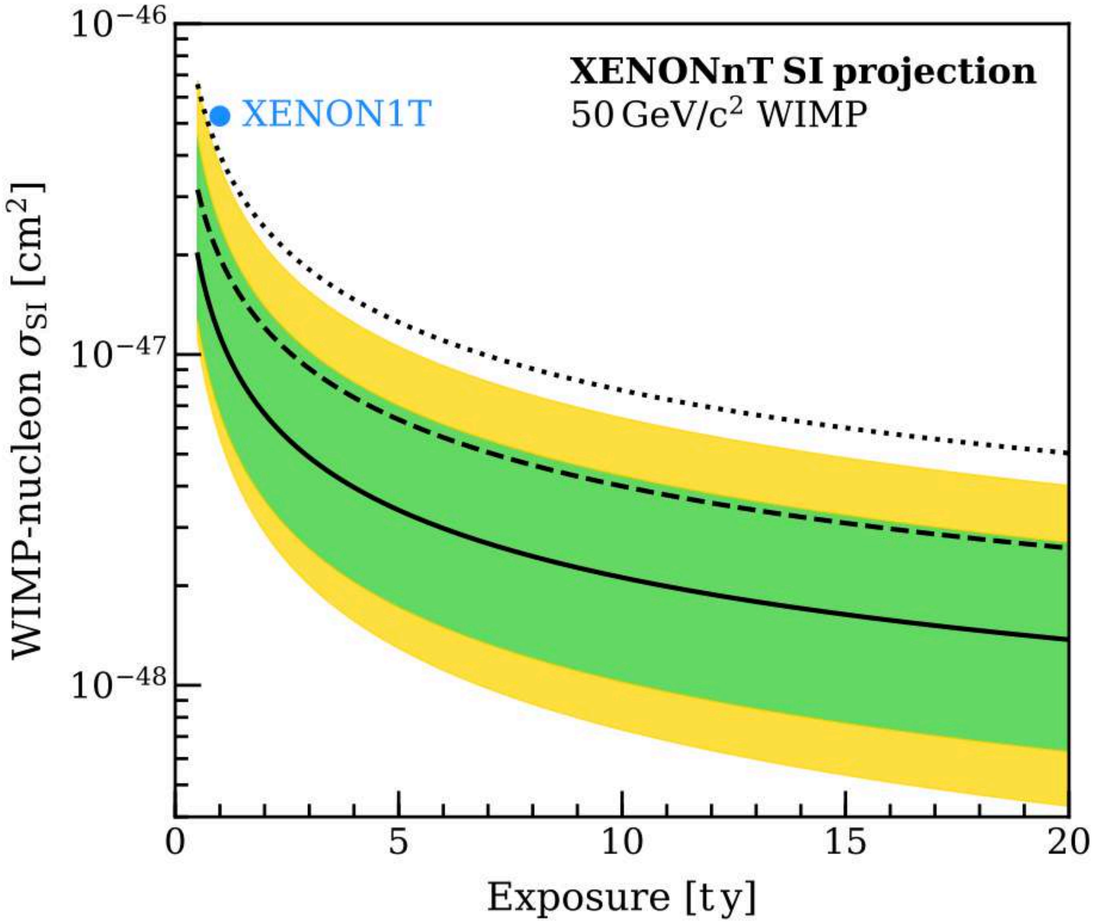


RestoX2

- RSX1: upgrade from 1T
  - Quick LXe recuperation with new line
  - Common liquid line with purification
- RSX2: new system for nT
  - Quick GXe recuperation by freezing Xe gas
  - Capable of holding all xenon in room temperature

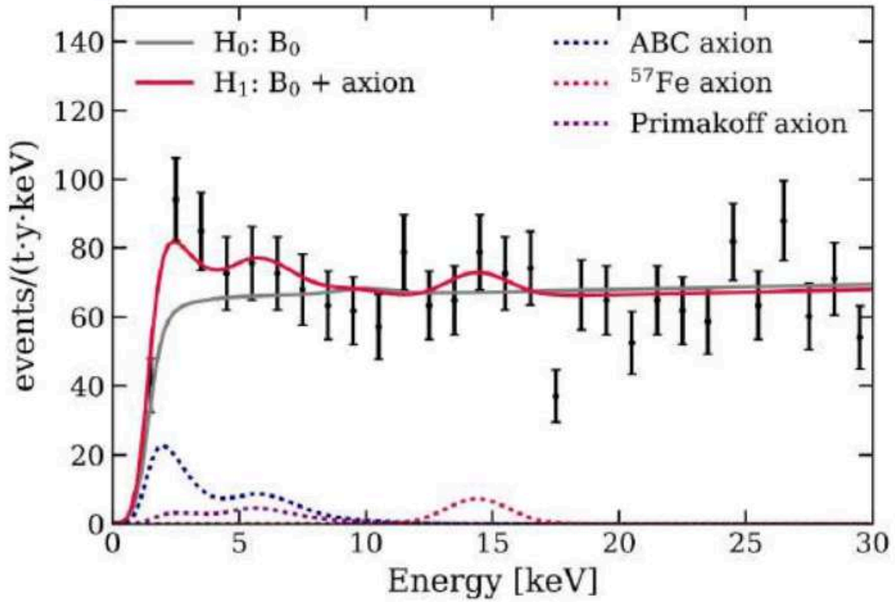
Expected sensitivity (SI WIMP)



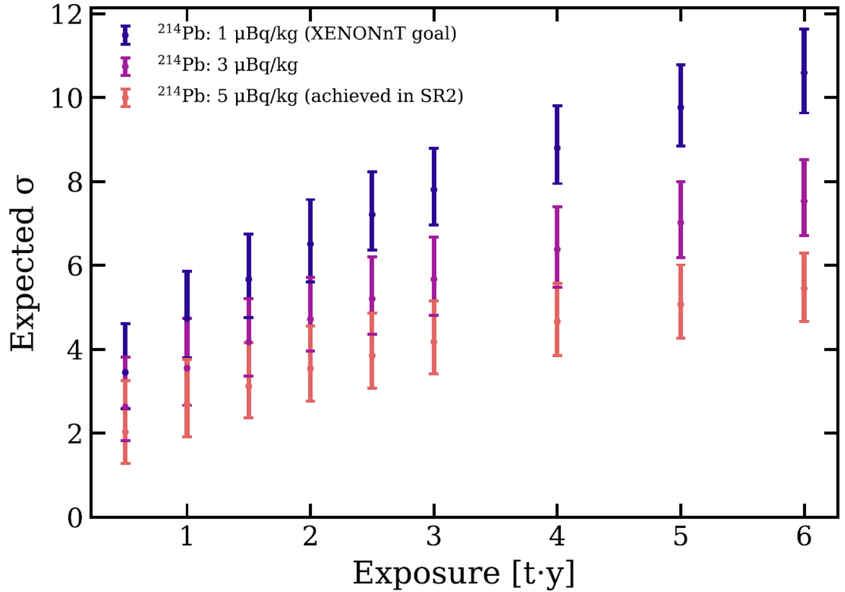


- JCAP 11 (2020) 031 for more detail

Expected sensitivity: Tritium vs Axion ?



- XENON1T LowER excess in 1-7 keV region
  - Phys.Rev.D 102 (2020) 7, 072004
- Significance with Axion spectrum:
  - 3.4 σ without tritium BG assumption
  - 2.0 σ with tritium BG assumption

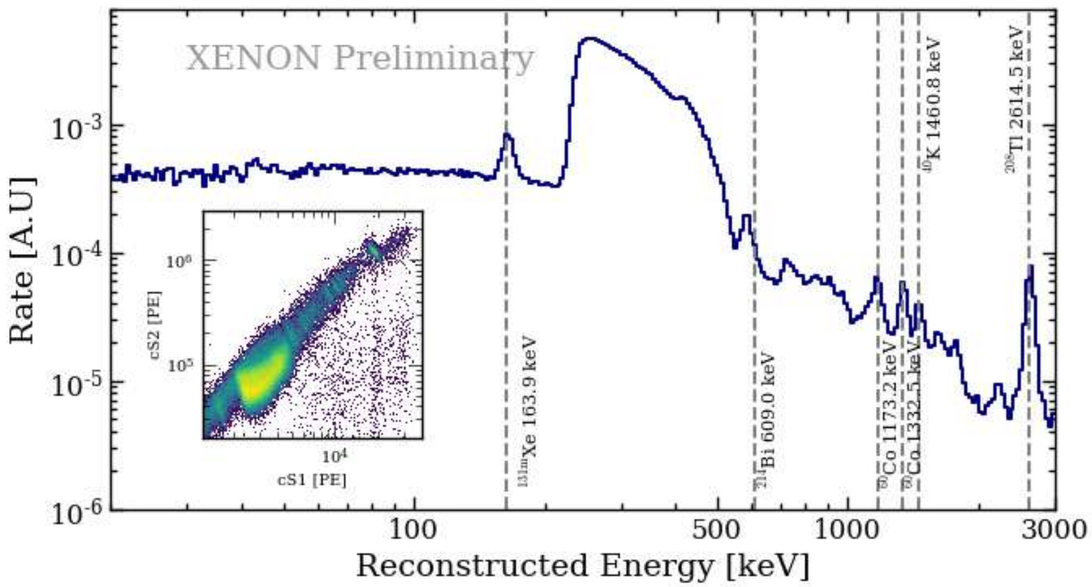


- Discrimination power between axion and tritium
  - With 1T best fit BG
- Axion/tritium can be distinguished even with few month of data (depending on Rn level)
  - XENONnT Rn level from alpha: ~1.7 uBq/kg

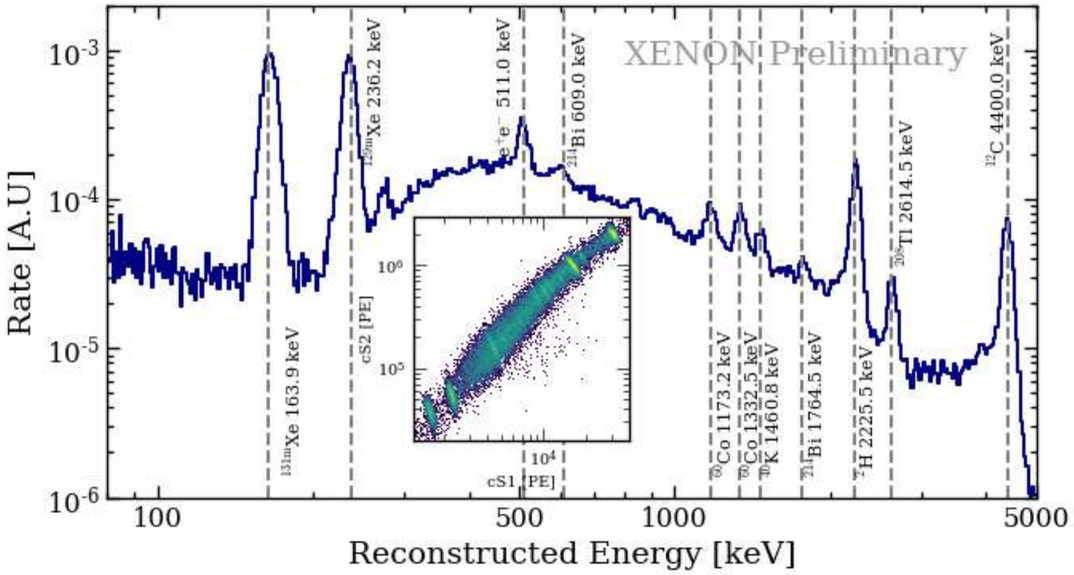
Data taking

- Science data taking stared since mid 2021:
  - Internal calibration: Kr, Rn, Ar
  - External calibration: AmBe
- Energy scale, cut efficiency, simulation…
- DM data taking and analysis ongoing

^{220}Rn calibration spectrum



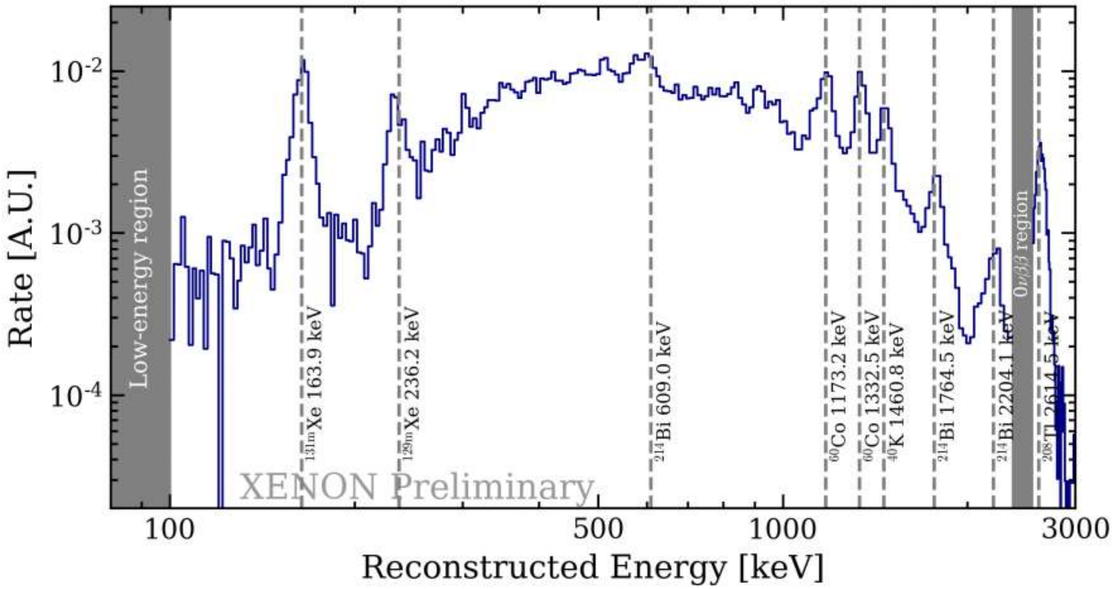
AmBe calibration spectrum



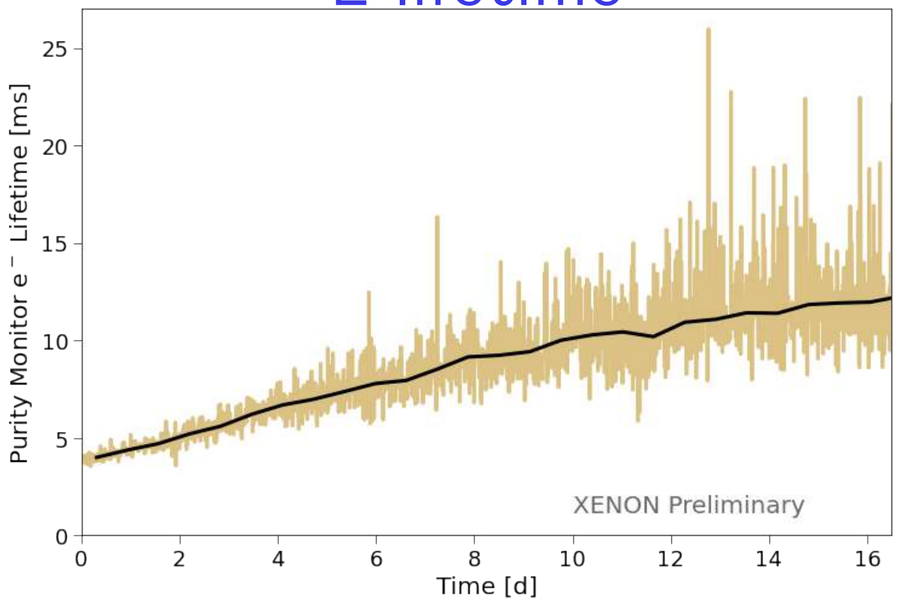
Summary

- The XENONnT finished construction on 2020 and started data taking since mid 2021
- New subsystems works very well
  - High e-lifetime: >10ms
  - Lowest Rn level: 1.7 uBq/kg (and can be further lowered)
- Science data taking and analysis is ongoing: stay tuned!

BG spectrum for early data



E-lifetime



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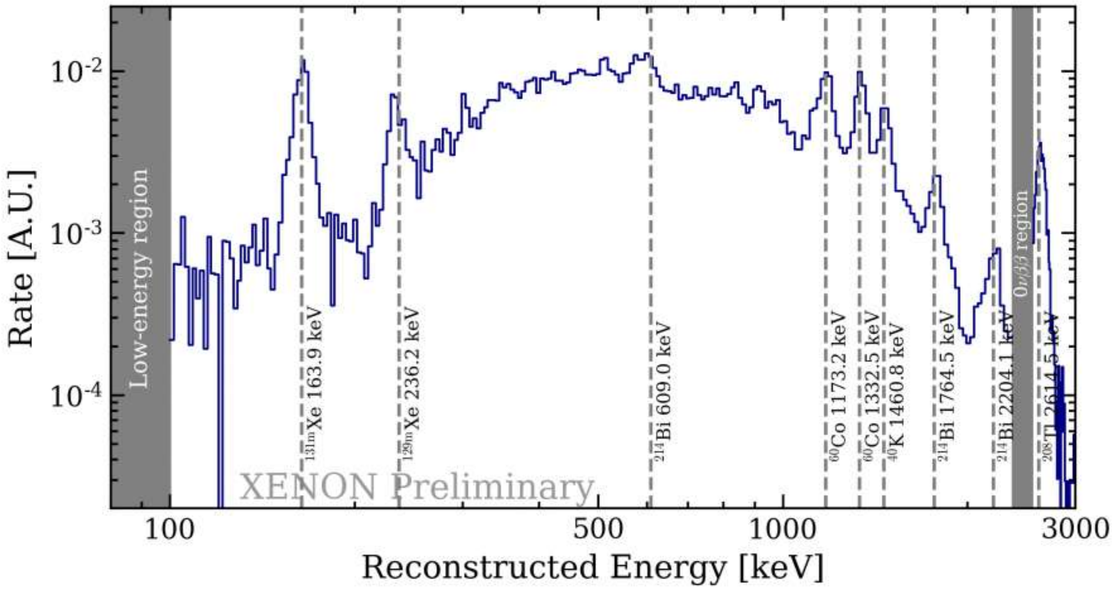
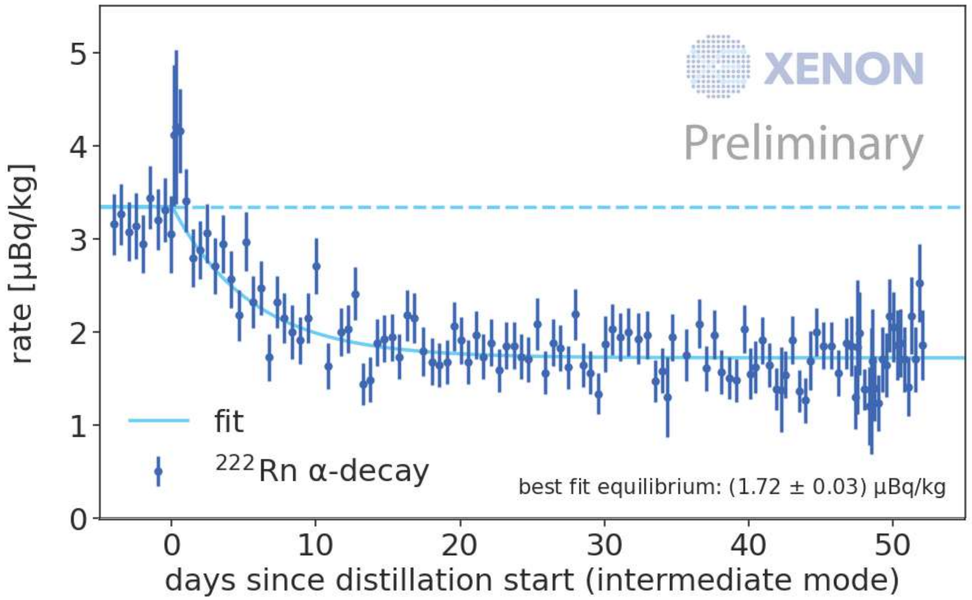


Rn alpha rate



Backup