XENON NT EXPERIMENT

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TABLE OF CONTENT

INTRODUCTION

INTRODUCTION: THE XENON PROJECT

~ 170 scientists ◆ 26 institutions ◆ 11 countries

Columbia | RPI | Nikhef | Muenster | KIT | Stockholm | Mainz | MPIK, Heidelberg | Freiburg

Chicago

UCSD

Rice

Purdue

Zurich

Tokyo

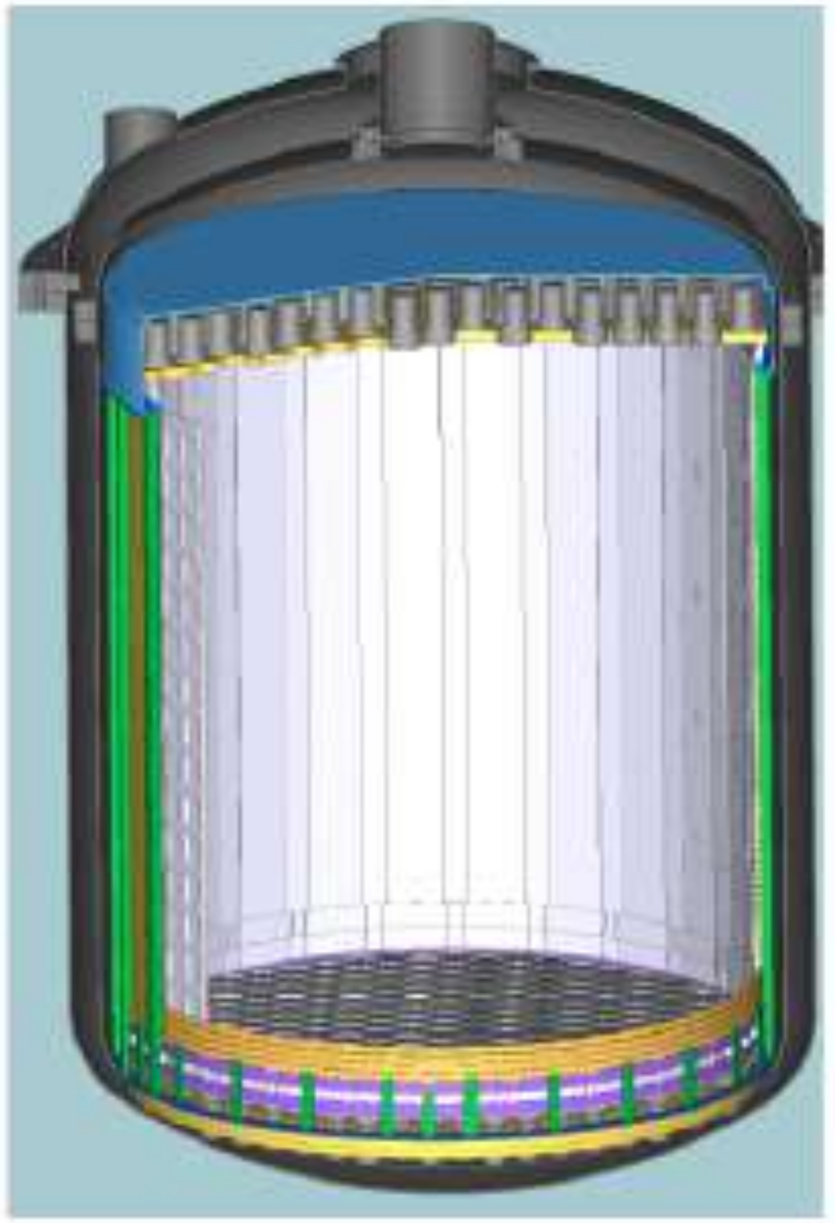
Nagoya

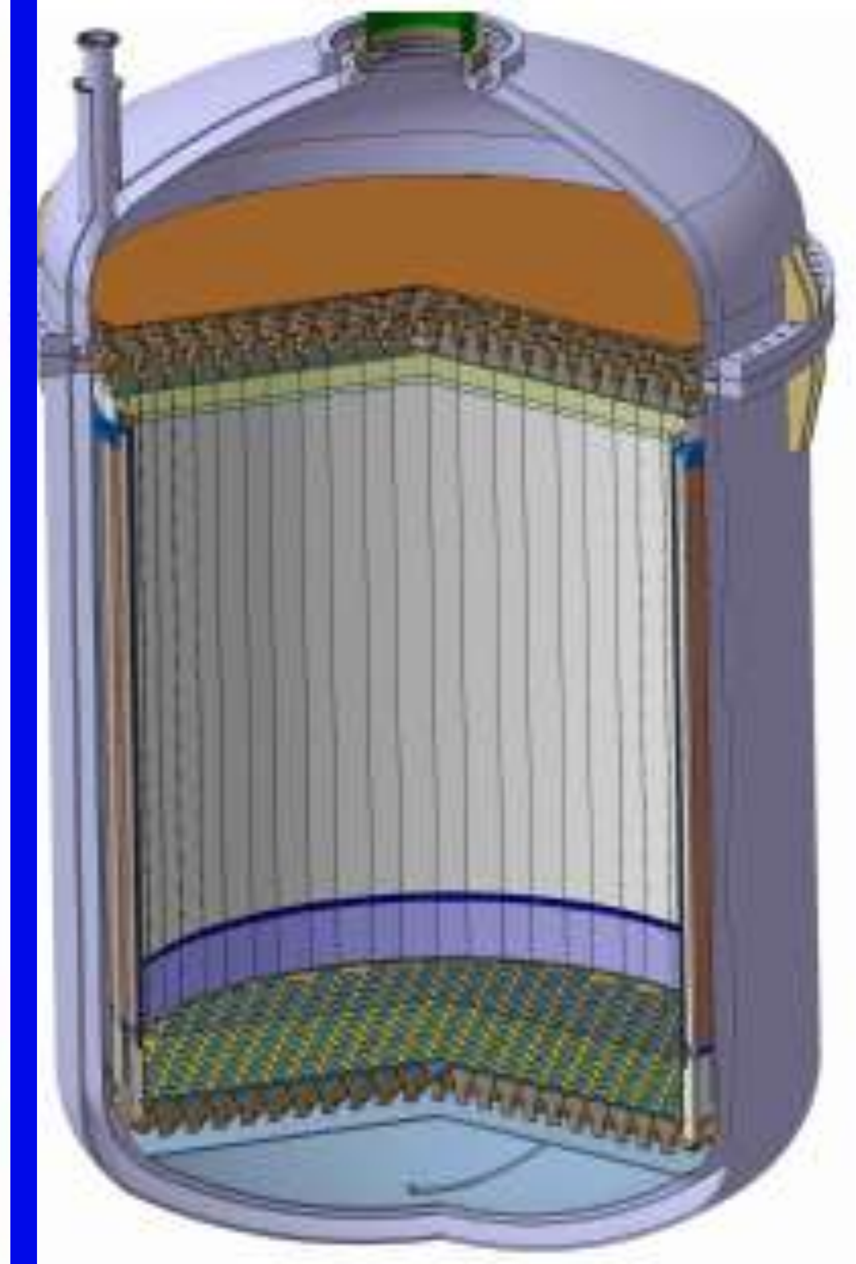
Coimbra | Subatech | LPNHE | IJCLab | L'Aquila | Bologna | LNGS | Torino | Napoli | Weizmann | NYUAD | Kobe

INTRODUCTION: THE XENON PROJECT

Technical meeting @May 2020

INTRODUCTION: THE XENON PROJECT (AND DARWIN)





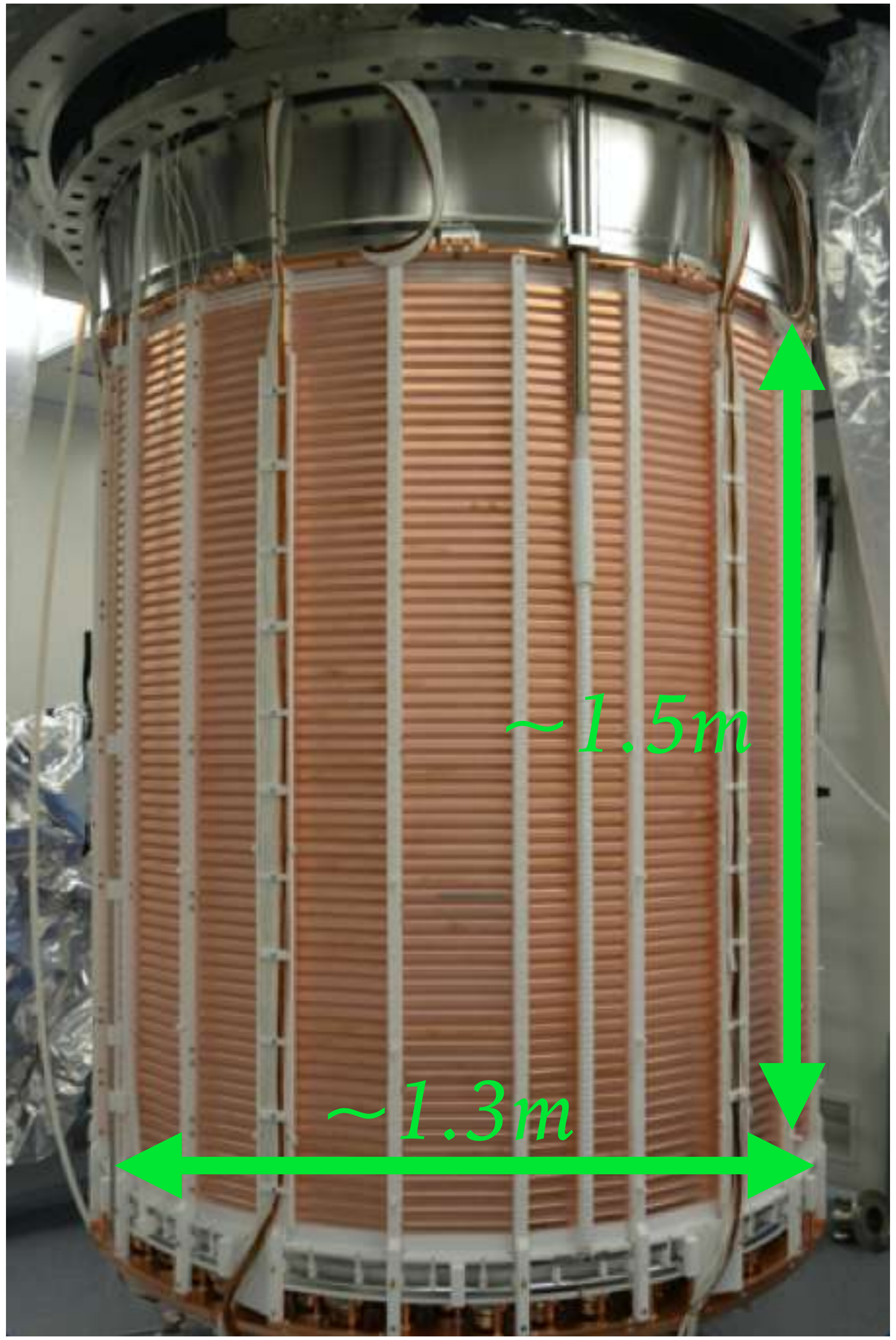
XENON10	XENON100	XENON1T	XENONnT	DARWIN
2005-2007	2008-2016	2012-2018	2019-2023	2020+
15 kg	161 kg	3200 kg	8200 kg	50 tonnes
~10^{-43} cm^2	~10^{-45} cm^2	~10^{-47} cm^2	~10^{-48} cm^2	~10^{-49} cm^2

INTRODUCTION: THE XENON PROJECT

- Located at Laboratori Nazionali del Gran Sasso (LNGS), Italy
- XENON1T water tank + building
  - Top: Cryogenics/Purification
  - Middle: DAQ/Slow Control
  - Bottom: Storage/Distillation
- Being upgraded for XENONnT

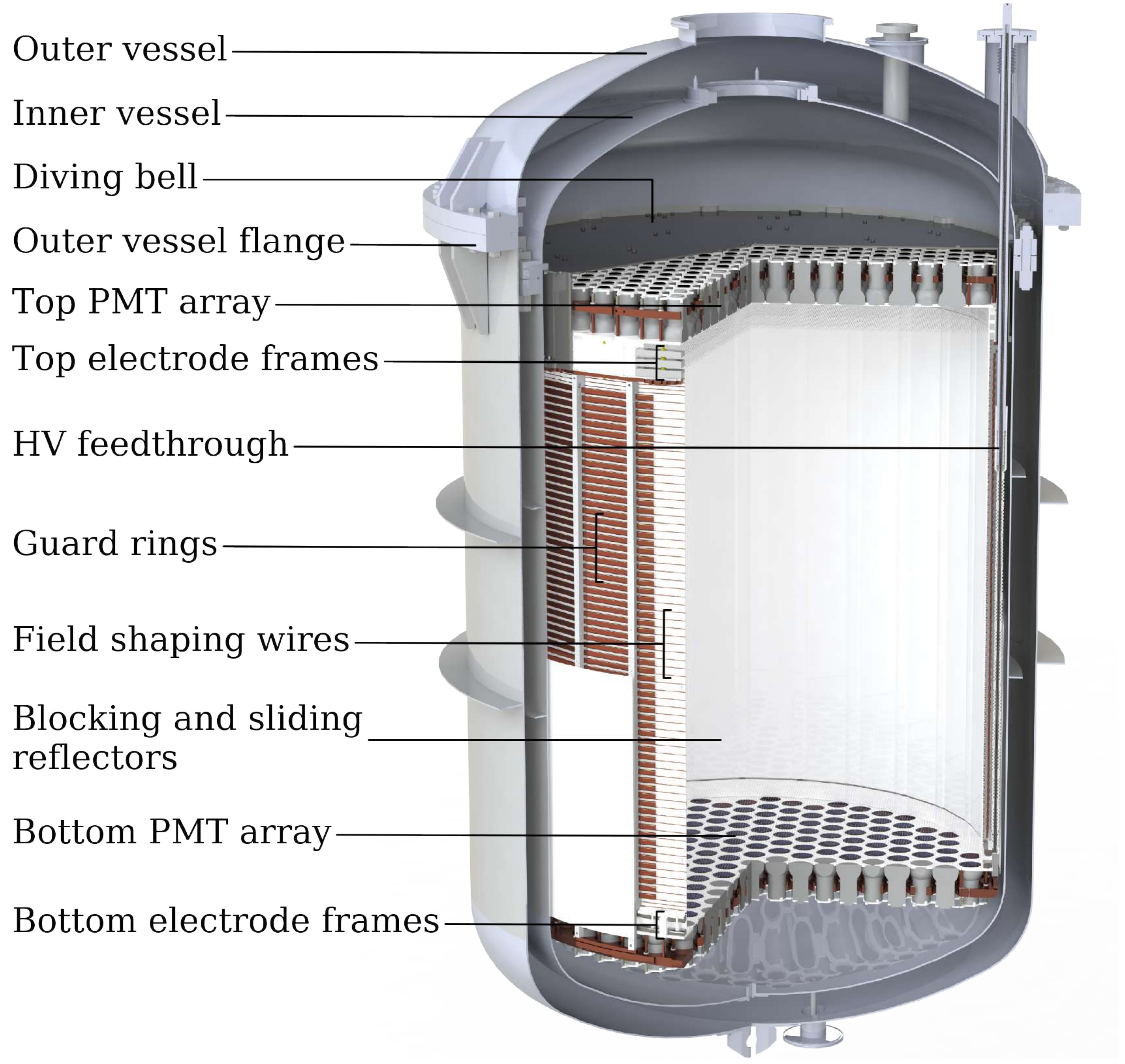
XENON NT EXPERIMENT:
WHAT'S NEW FROM XENON1T?

XENON NT EXPERIMENT: XENONNT TPC



- XENONnT TPC
  - Diameter=1.3m, Height=1.5m
  - LXe mass:
    - Full: 8.2 ton
    - Active: 5.9ton
    - Fiducial: 4 ton
      - 3 times larger than XENON1T
  - Top/bottom PMTs : 253/241

XENON NT EXPERIMENT: XENONNT TPC



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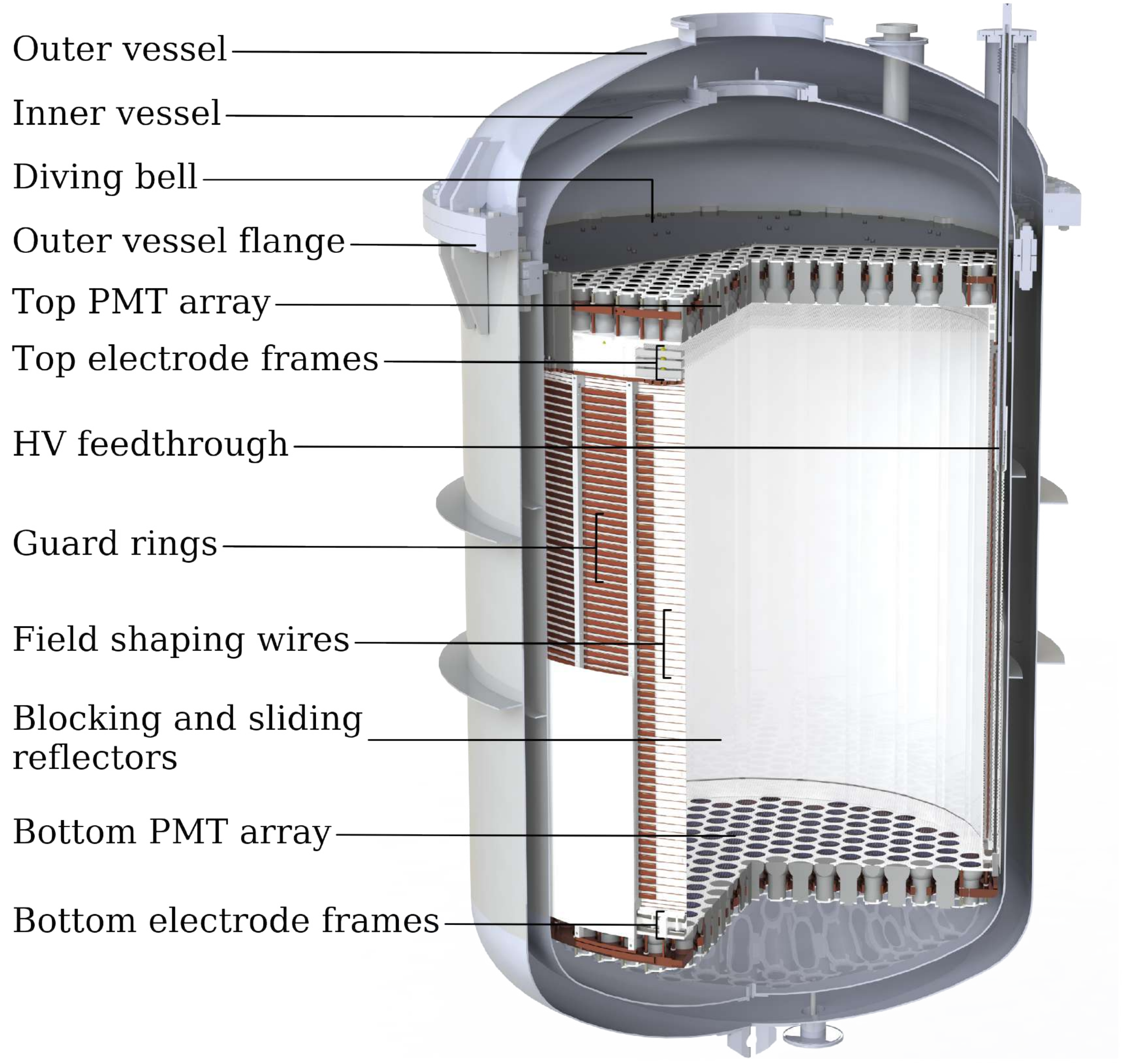

- Low energy ER Background: 1/6 from XENON1T
  - Reduction of Rn222 : 1uBq/kg
- Expected event rate
  - ~0.035 event/day/keV/ton
    - ~0.2 in XENON1T

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

Purification

Rn distillation

Neutron veto

Xenon Storage

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XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

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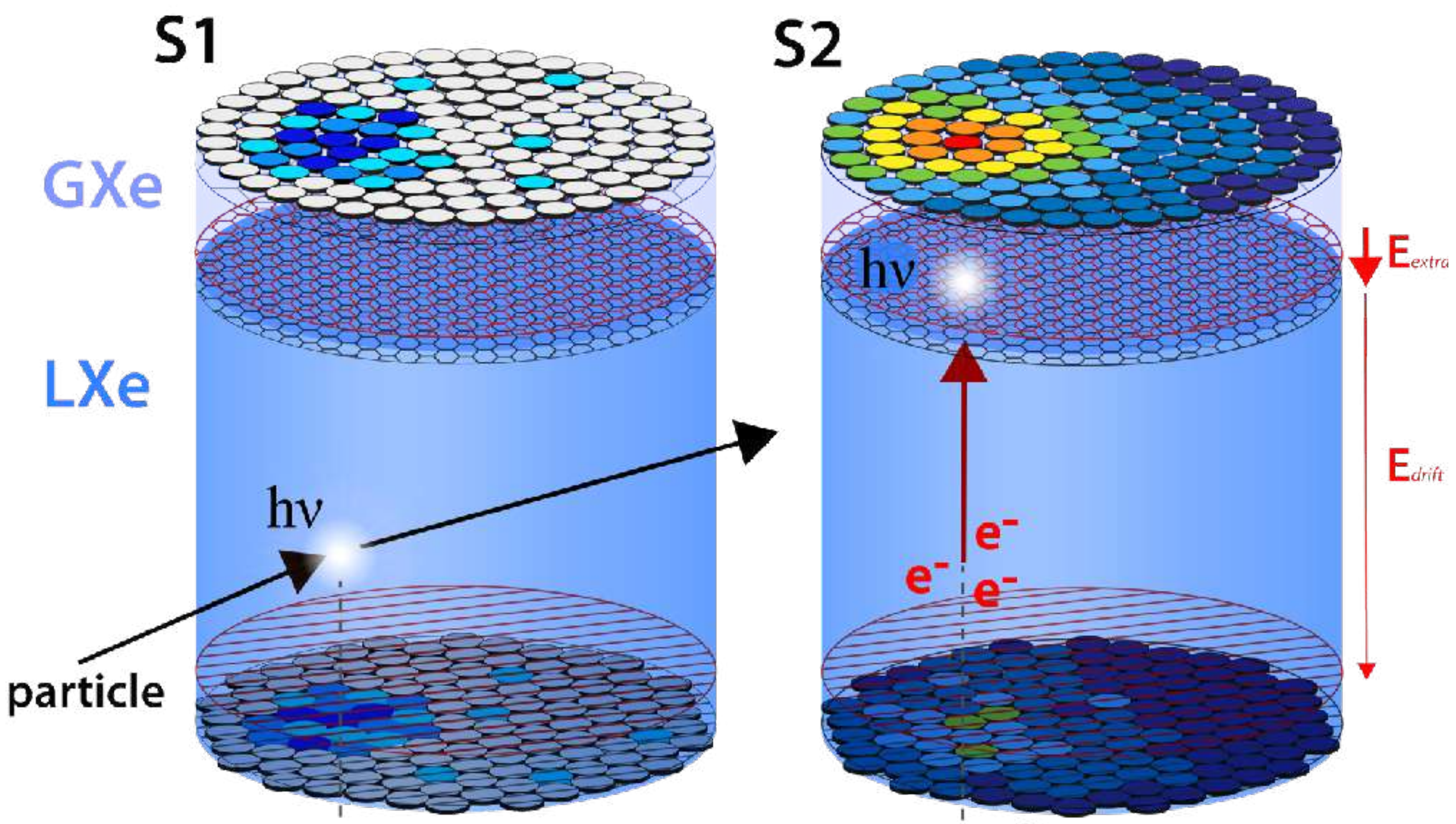
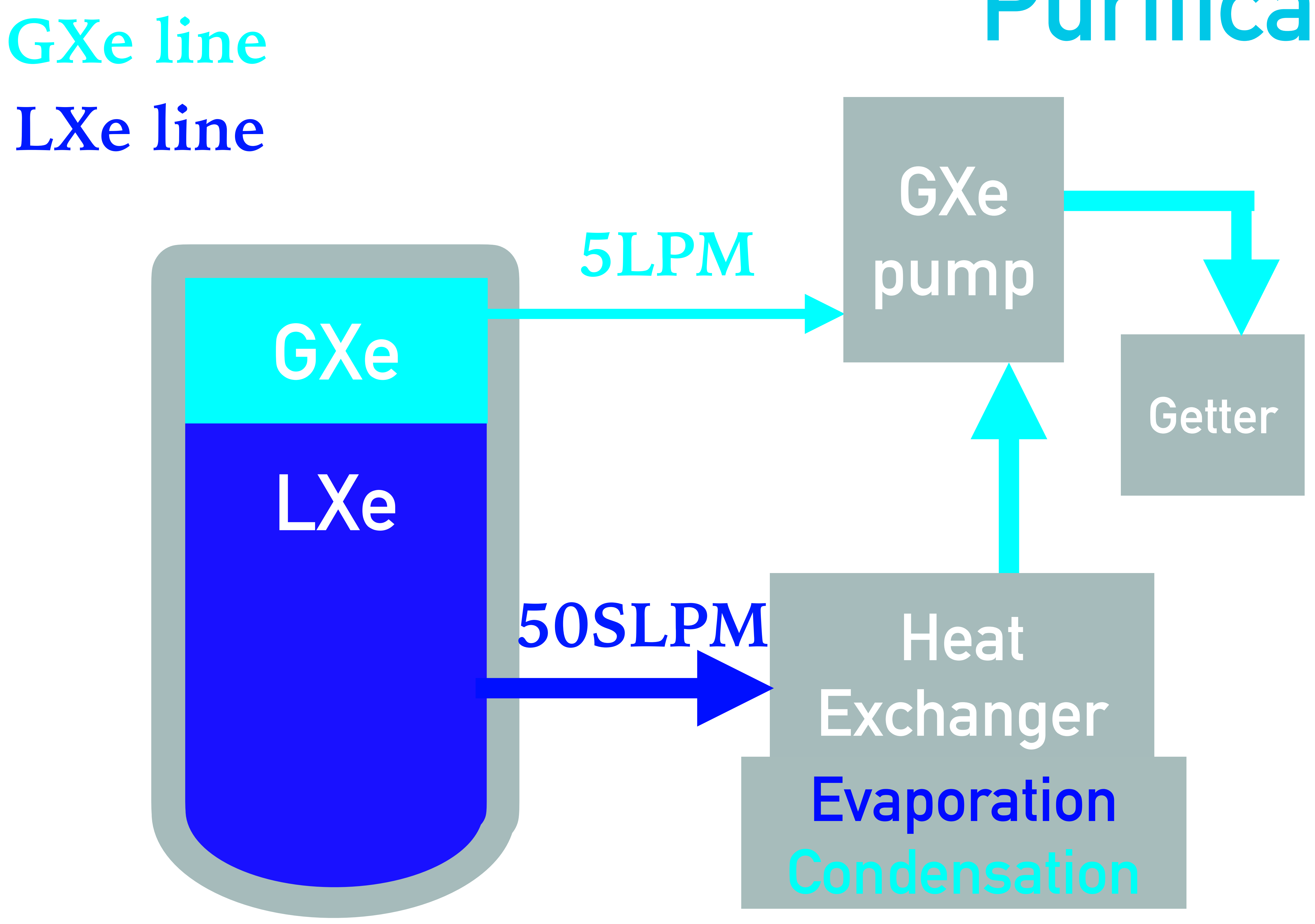


- Signal generation in LXe:
  - S1: Scintillation photons
  - S2: Ionization electrons
- Impurities in Xe (ex: H2O, O2)
  - H2O: Reduce attenuation length
  - O2: Absorb electron and reduce S2

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

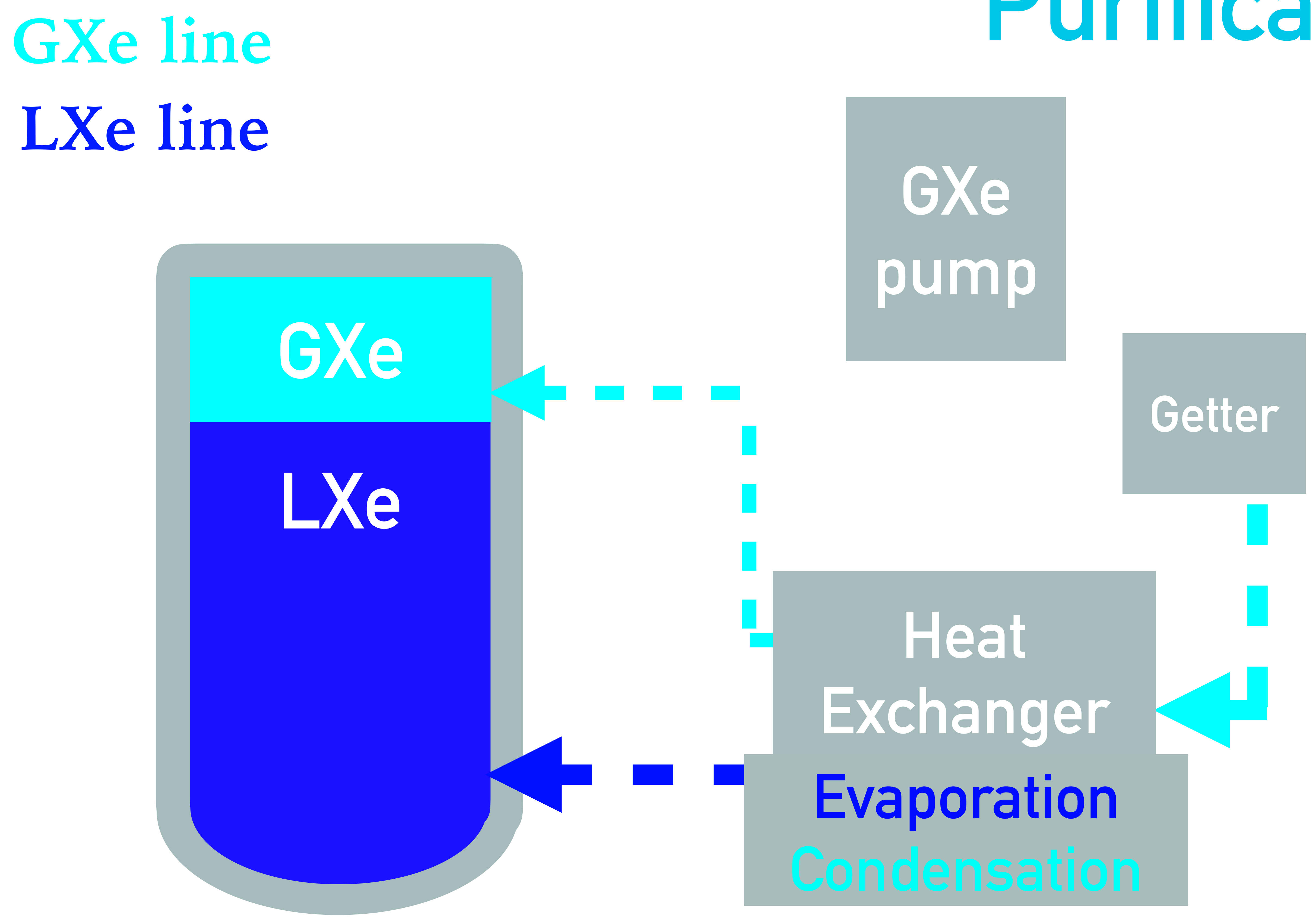
Purification



- Xenon1T purification system
  - Evaporate LXe and purify with Zr-Fe-V (+HRU) getter
  - Upgrade: Magnetic GXe pump
    - Low Rn emanation
      - Rn level reduced ~45% with test in 1T
    - Speed: ~100 SLPM

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

Purification



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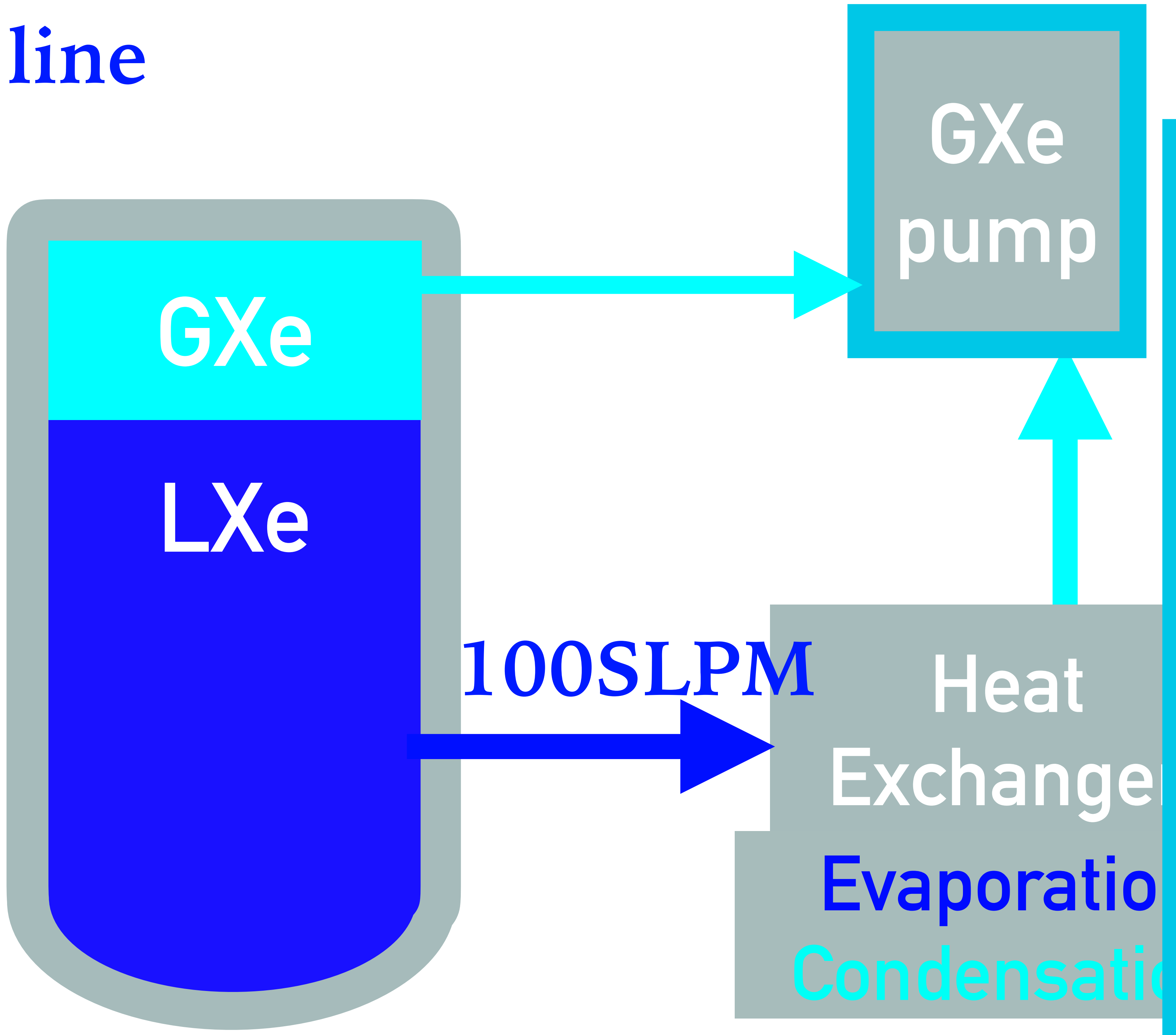
XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

Purification

GXe line

LXe line



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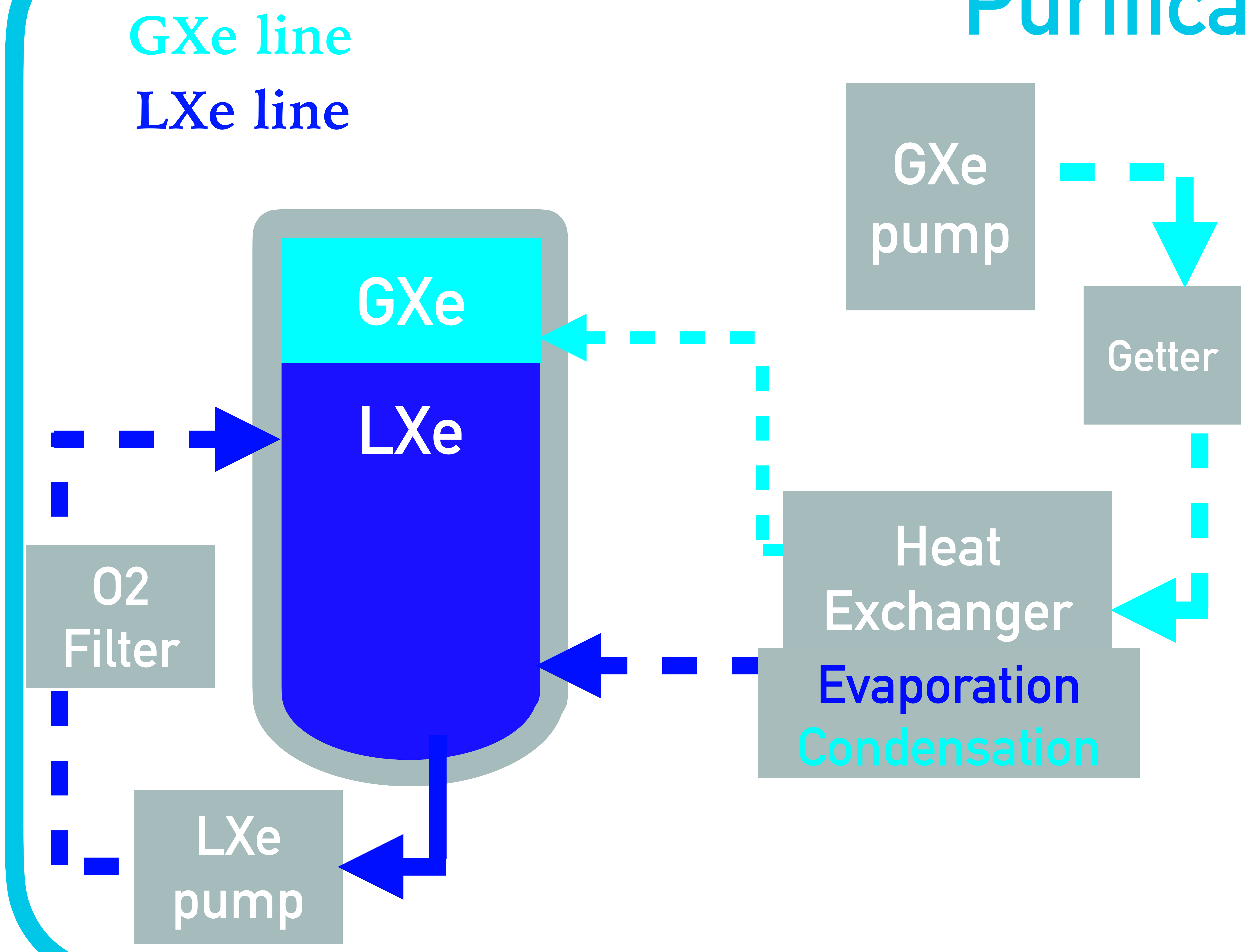
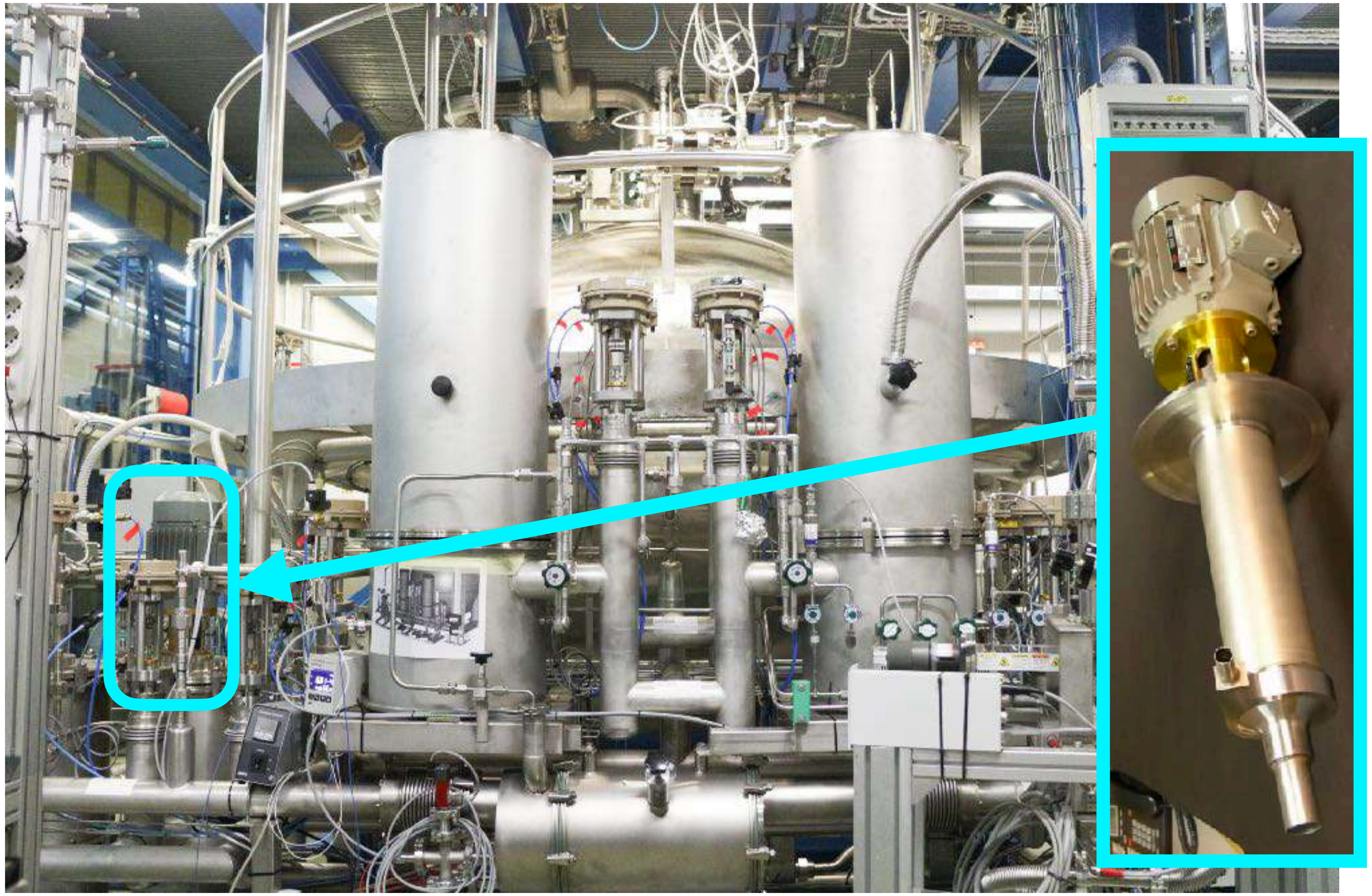


- Xenon1T purification system
  - Speed: ~100 SLPM
  - Not enough for XENONnT…
- New system for XENONnT
  - LXe purification circuit
    - ~3 LPM= 1500 SLPM

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

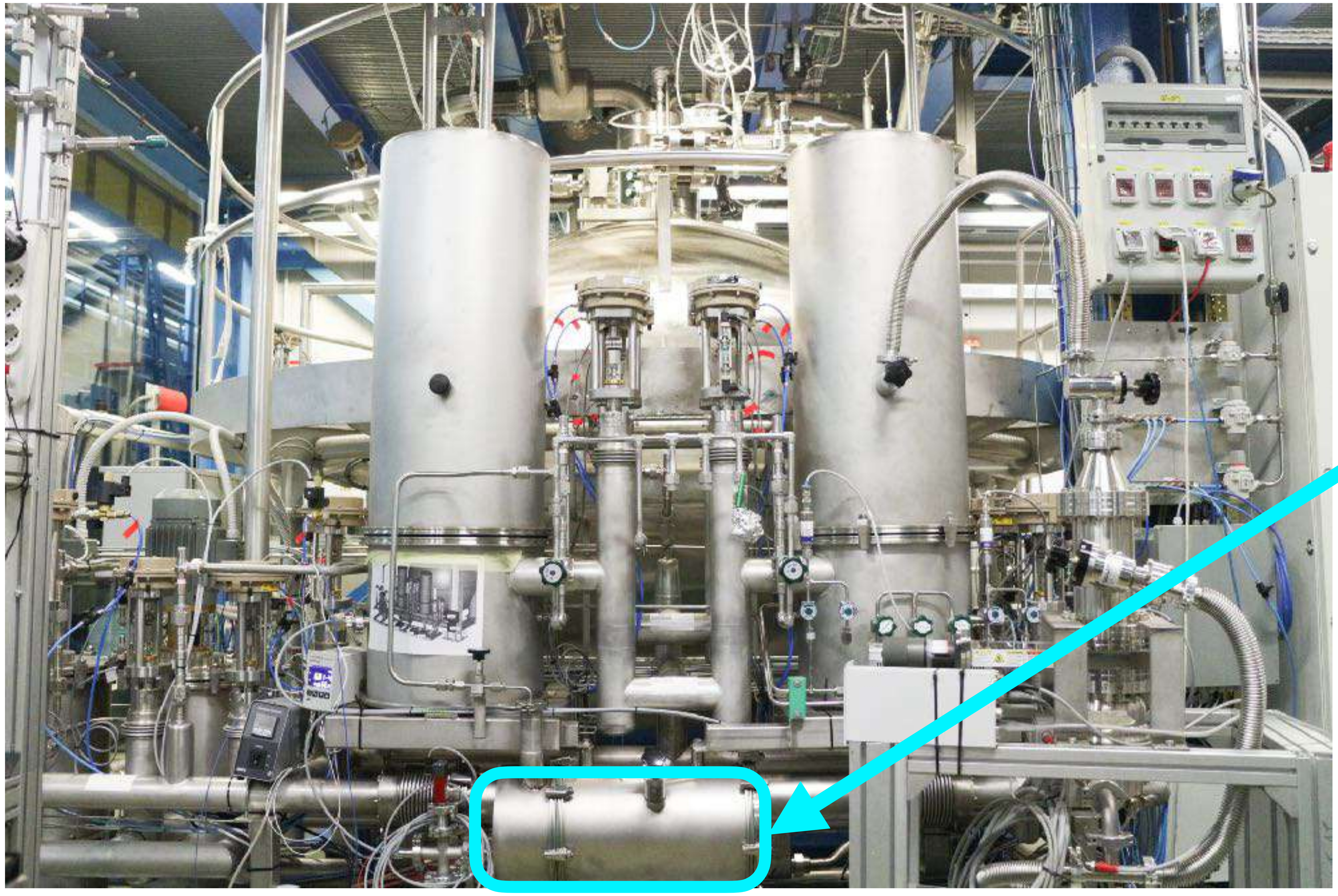
Purification



- Direct liquid circulation
  - Barber-Nicols cryogenic pump
  - Besed on LAr technology (ICARUS experiment)
- Oxigen removal
  - Remove O2 by chemical reaction of Pure-Cu
- Purity measurement by purity monitor

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

Purification



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XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

Purification

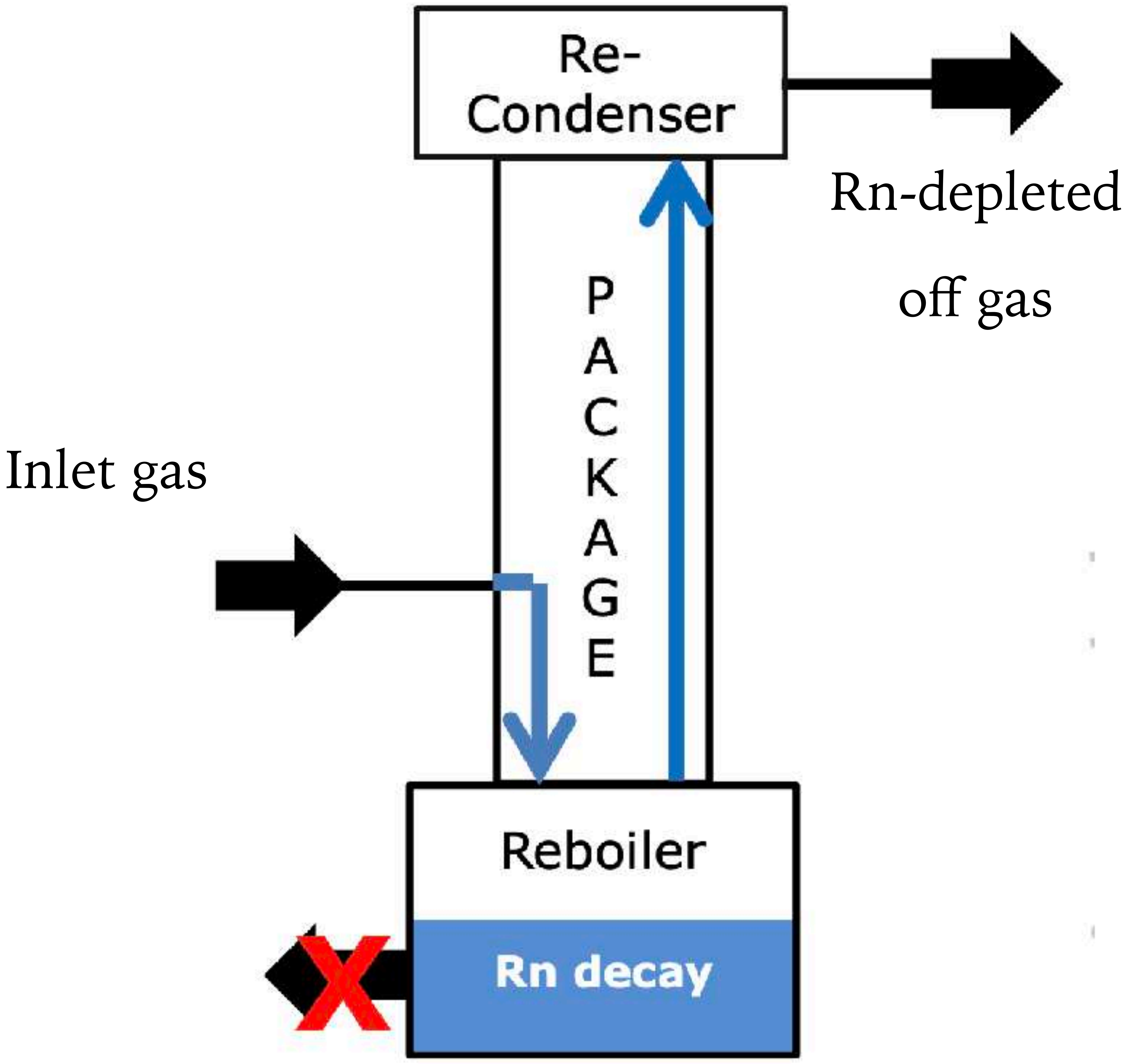
Rn distillation

Neutron veto

Xenon Storage

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

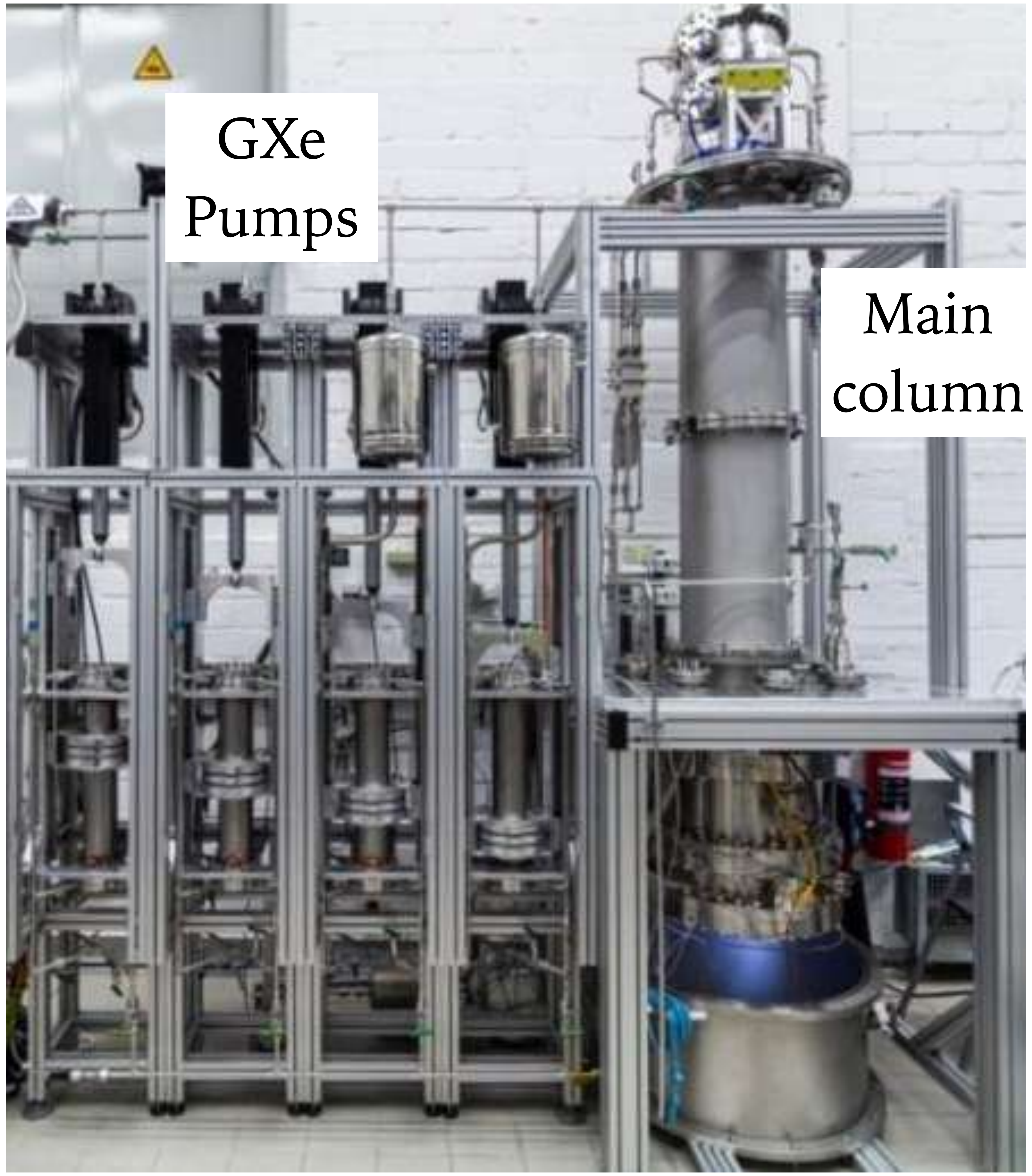
Rn distillation



- "Inverse distillation" of Kr/Ar distillation
- Rn atom accumulates into LXe more than GXe
  - Kr/Ar distillation: **dirty** off-gas
  - Rn distillation: **pure** off-gas
- Rn atoms are kept in the column and decays
- Already tested in XENON100, XENON1T

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

Rn distillation



- Take Xe partially from LXePUR system, and back Rn-free Xe
- One of Rn source in Xenon1T:
  - Cryogenic/purification system
- Active circulation also with external systems
  - Suck Rn-rich Xe from external pipes, then send Rn-free Xe back to TPC
- Expected speed: ~200 SLPM

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

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XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

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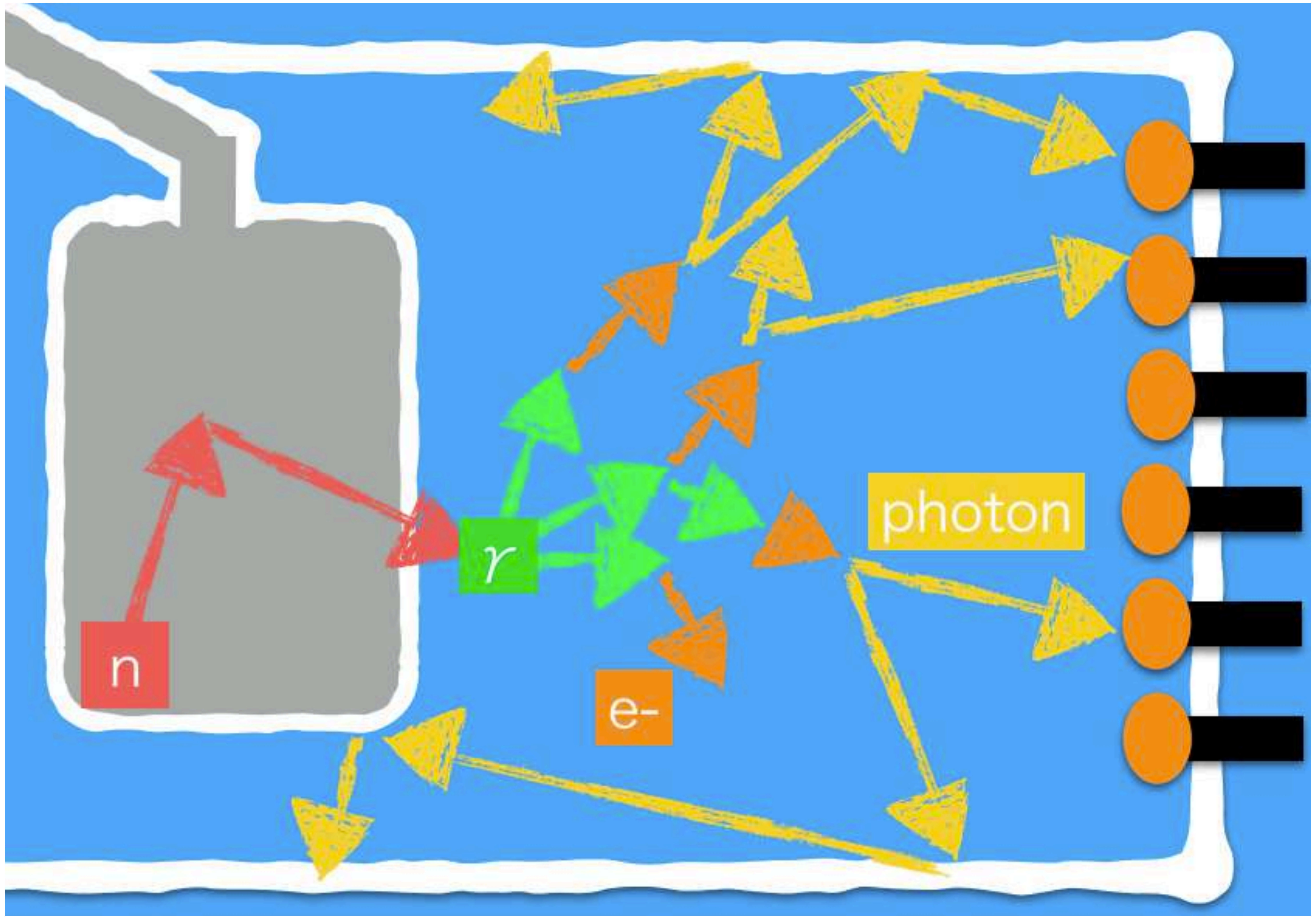
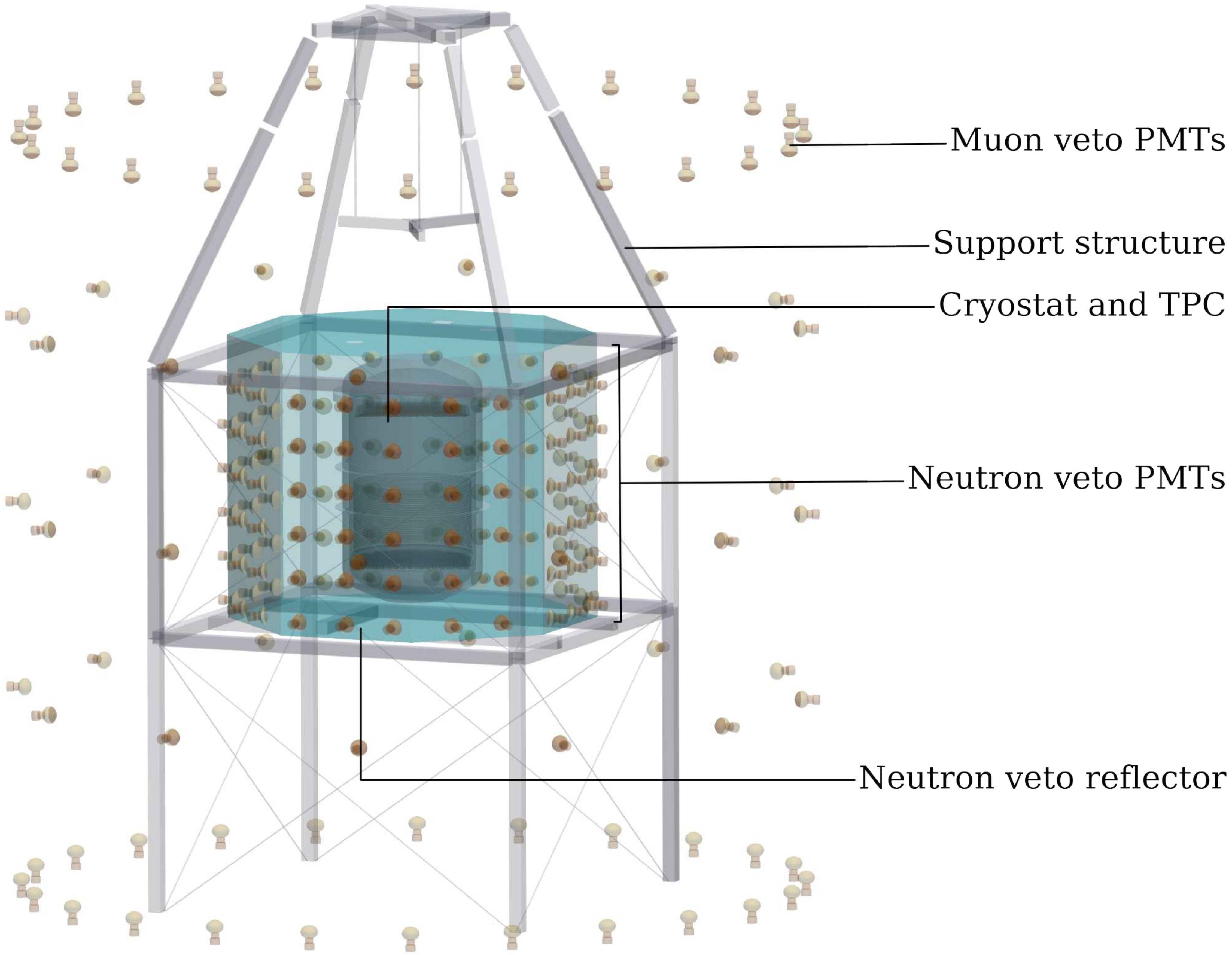


- Neutron Veto system
  - Gd-Water Cherenkov detector
- Neutrons from cryostat will be captured by Gd and produce 8MeV gamma
- Entire Cryostat will be surrounded by the ePTFE structure
- Collect photons as much as possible

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

Neutron veto



- Tagging efficiency: ~80-90% based on simulation
  - At 0.5% $Gd_2(SO_4)_3 \cdot 8H_2O$
- Upgrade for Gd-water purification
  - Based on EGADS technology
- Purity/reflectivity measurement systems are installed

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

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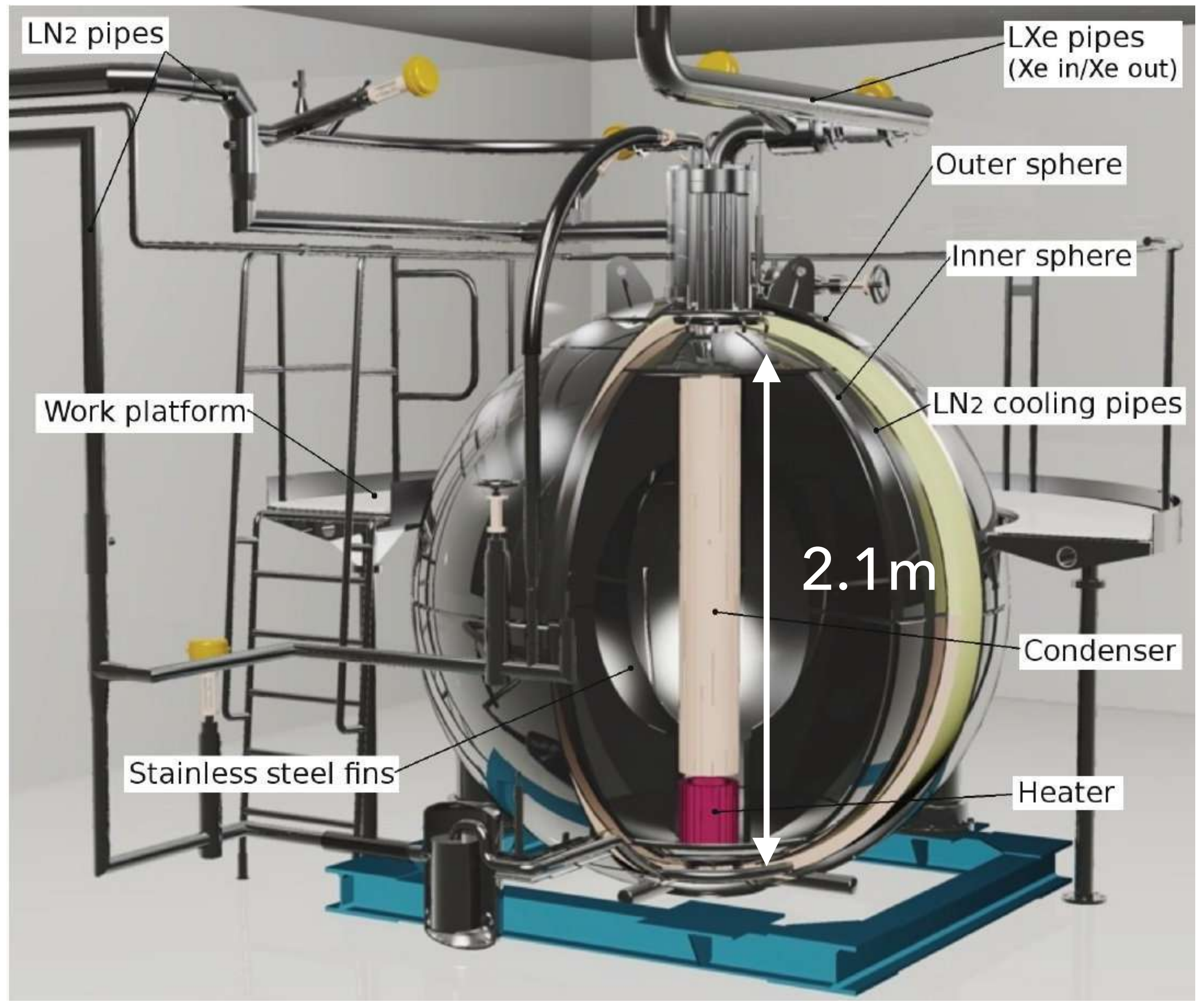
XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

Xenon Storage

RestoX1

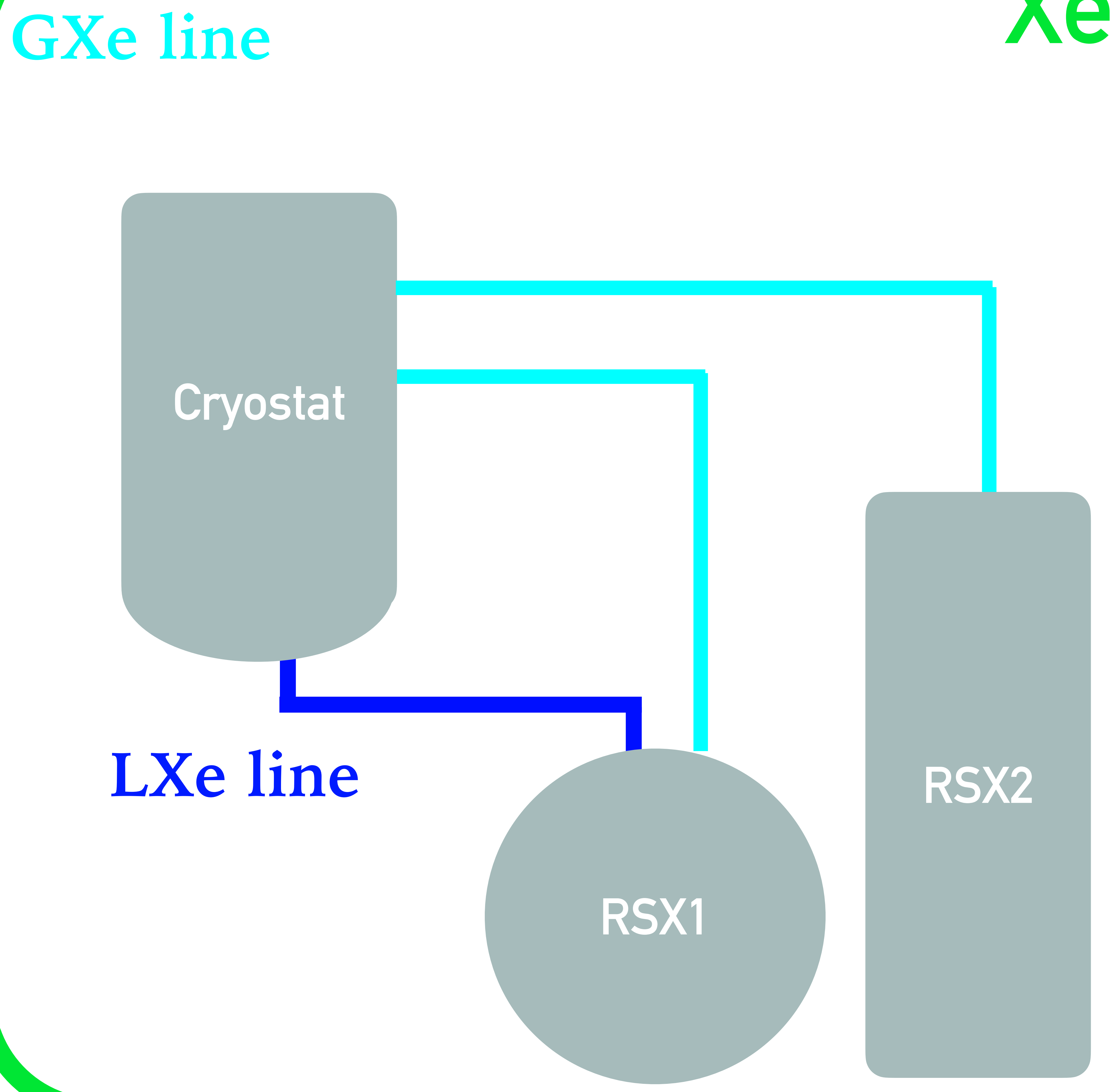


RestoX2

- Total amount of Xenon for the detector:
  - XENON1T: ~3 ton
  - XENONnT: ~8 ton
- Upgrade of Xenon Strage + Emergency recuperation
  - ReStoX1: GXe + LXe, 7.5ton
  - ReStoX2: GXe + SXe, 9ton

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

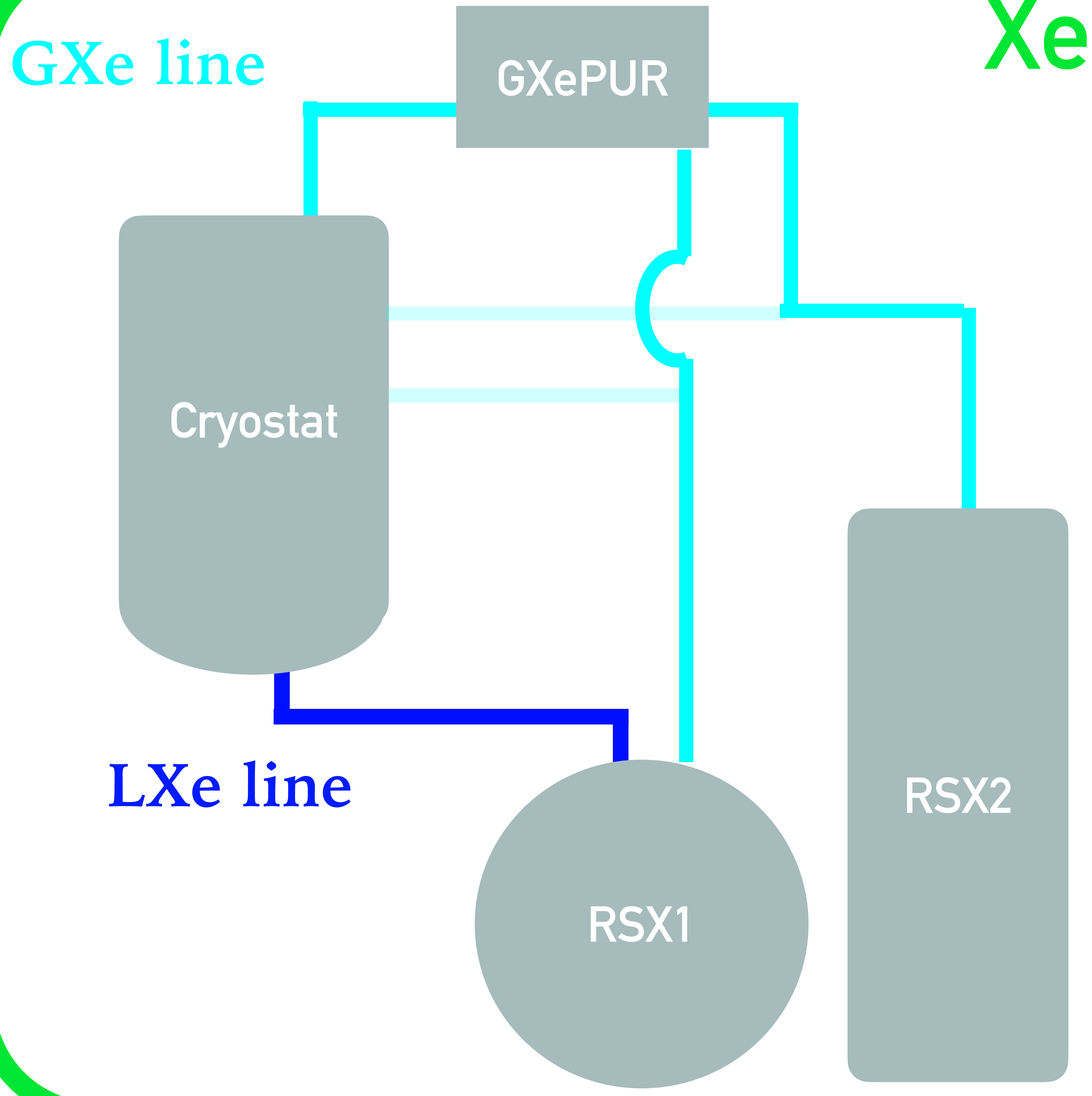
Xenon Storage



- 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
  - Keep all Xe gas in room temperature
- All GXe lines are connected to GXePUR too

XENON NT EXPERIMENT: NEW EXTERNAL SYSTEM

Xenon Storage



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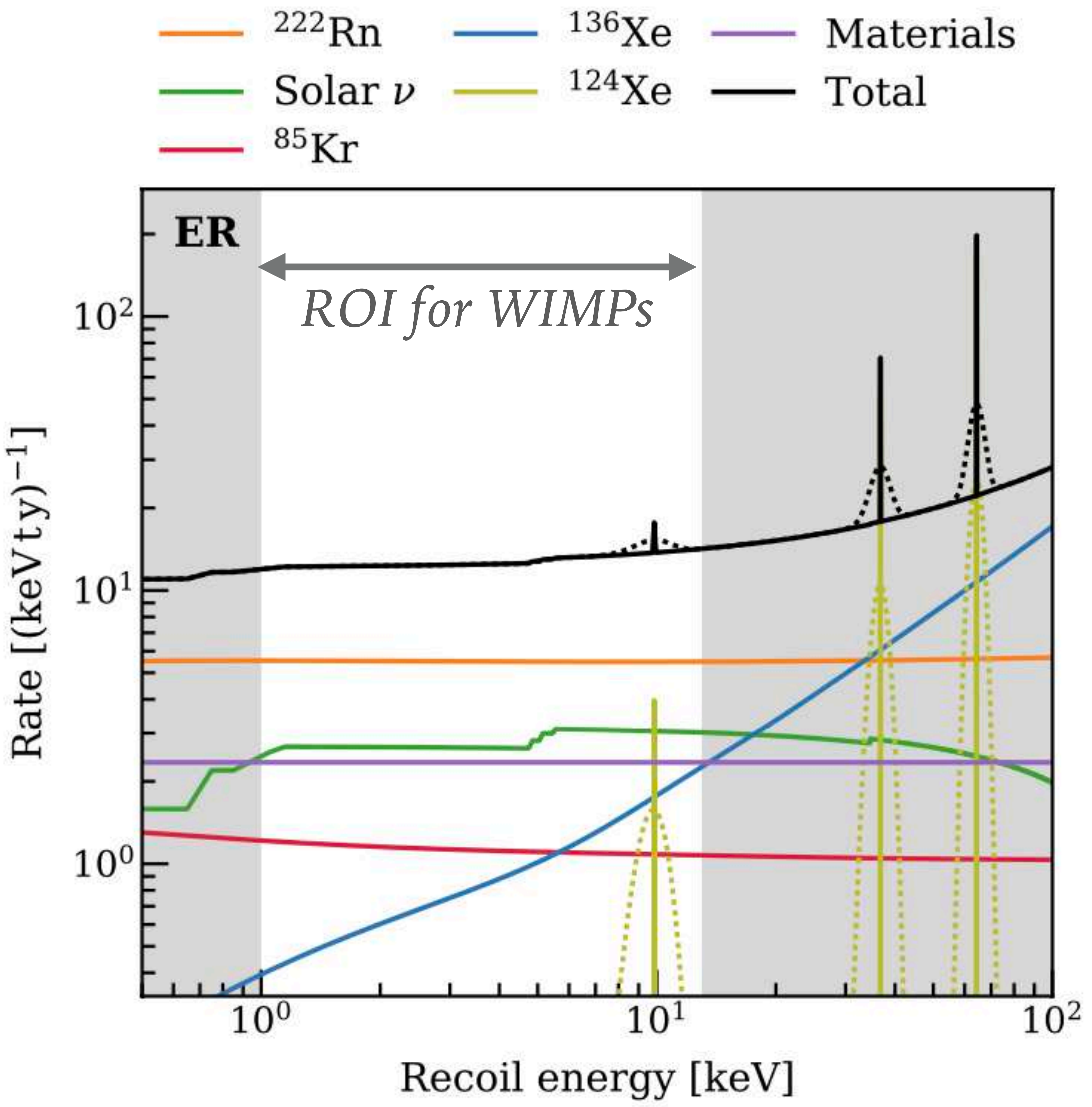
EXPECTED SENSITIVITY

(BASED ON ARXIV:2007.08796)

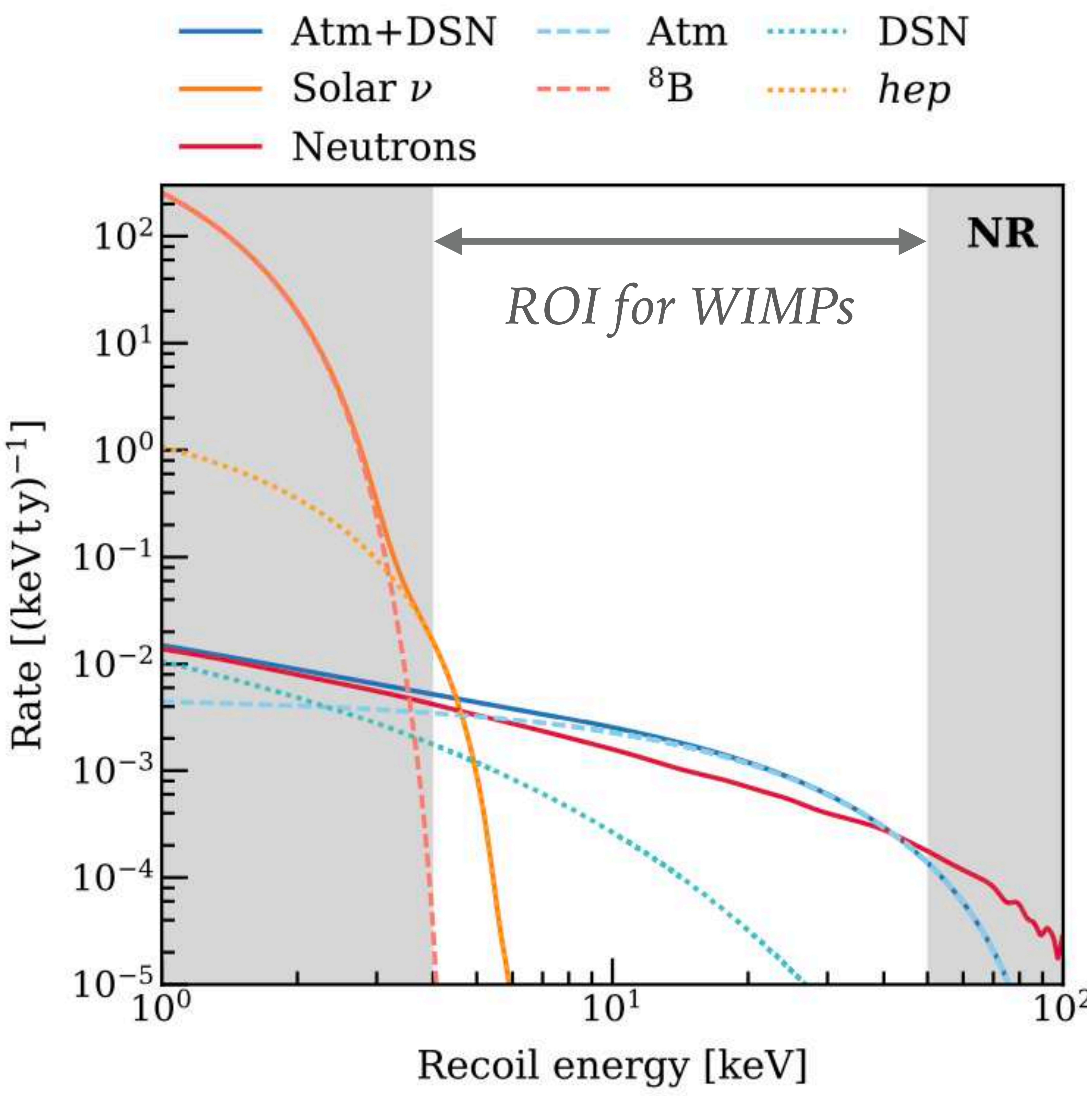
BACKGROUND:ER



Source	Rate $[(\mathrm{t\,y})^{-1}]$
ER background	
Detector radioactivity	25 ± 3
^{222}Rn	66 ± 7
^{85}Kr	13 ± 1
^{136}Xe	16 ± 2
^{124}Xe	4 ± 1
Solar neutrinos	34 ± 1
Total	158 ± 8

- Largest background: from Rn222 and its daughter
  - Here, target value is 1 uBq/kg
- Detector radioactivity: single Compton scattering
  - Gammas from Cryostat and PMTs

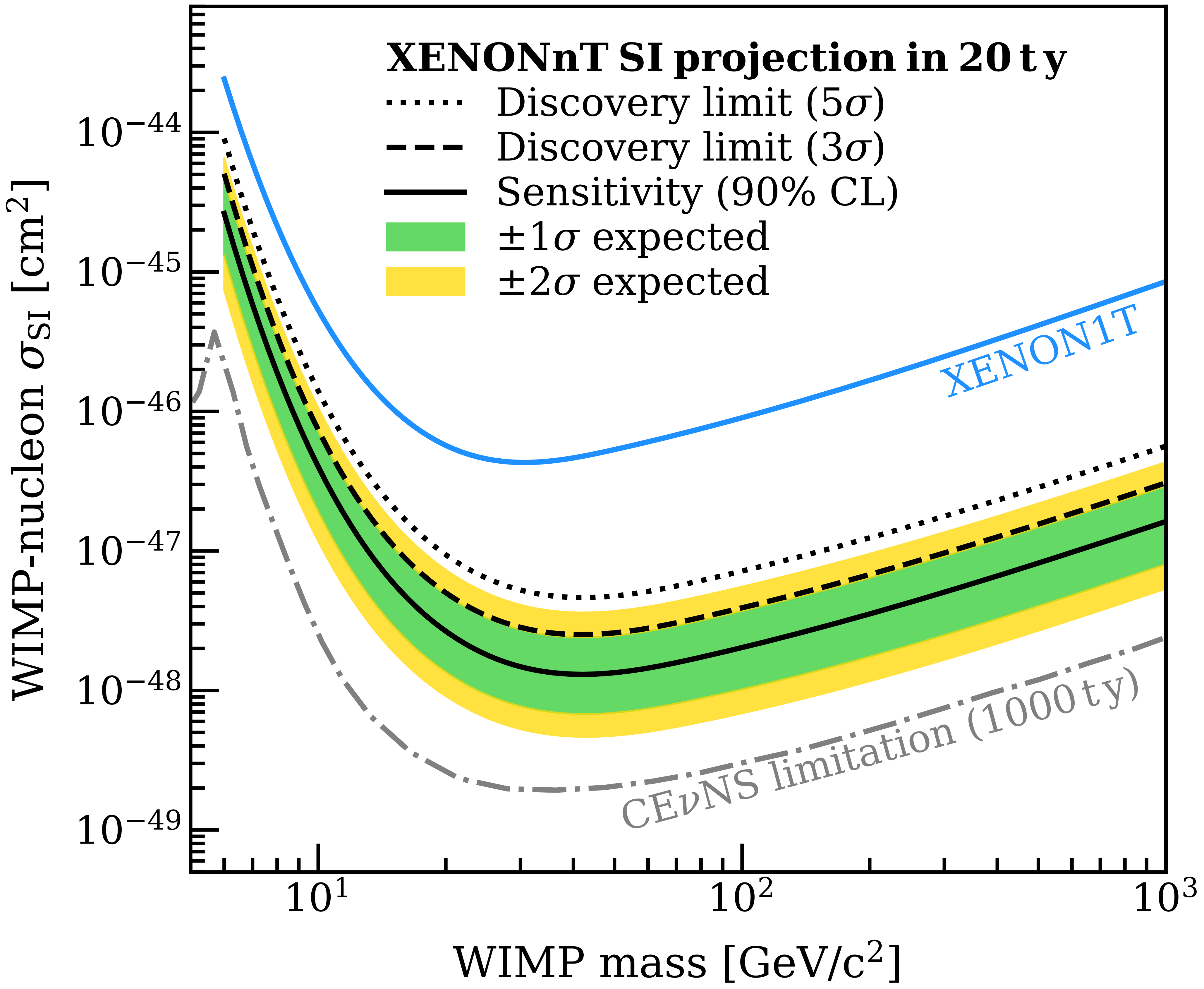
BACKGROUND:NR

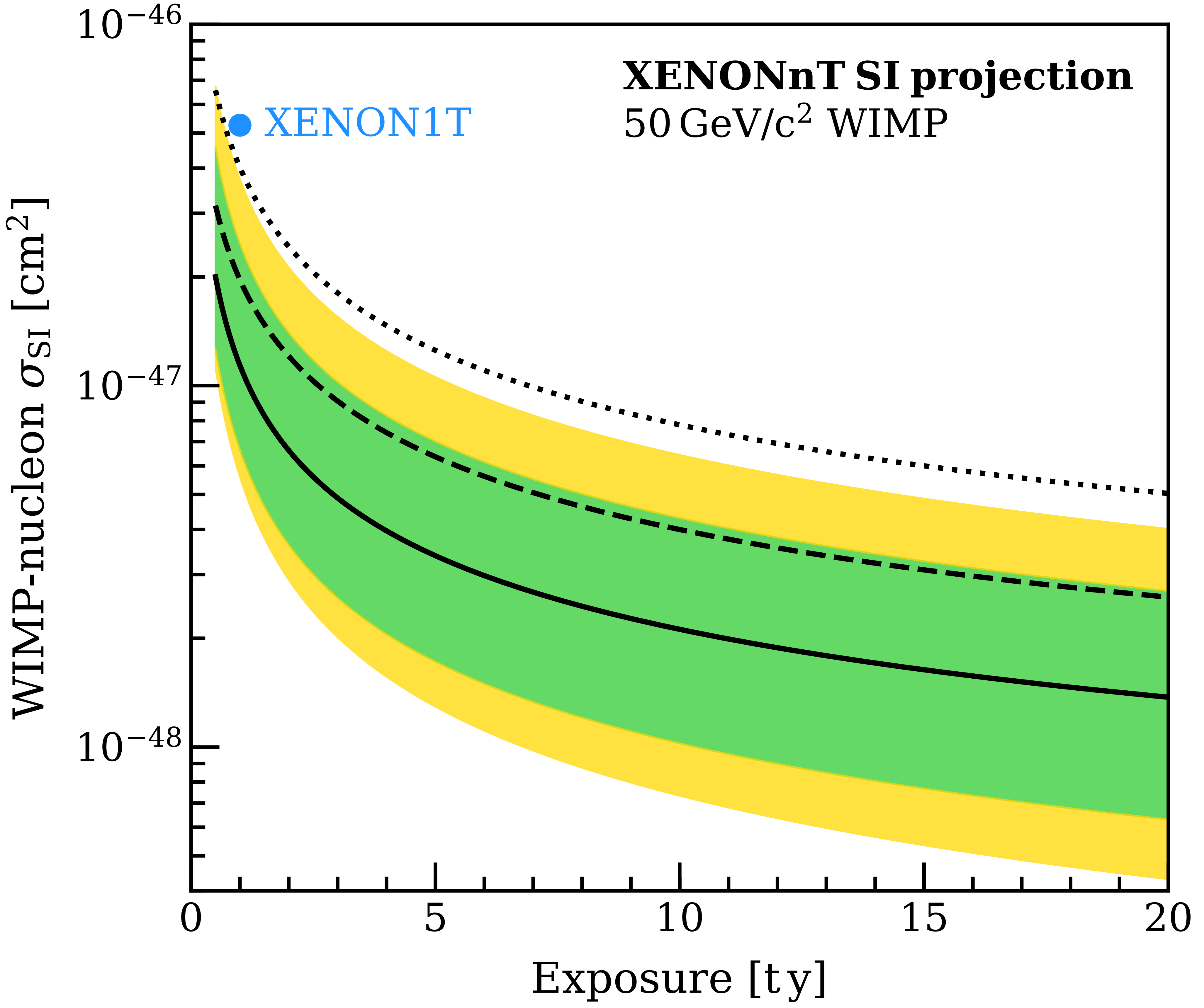


Source	Rate $[(\mathrm{t\,y})^{-1}]$
NR background	
Neutrons	$(4.1 \pm 2.1) \times 10^{-2}$
CEνNS (Solar ν)	$(6.3 \pm 0.3) \times 10^{-3}$
CEνNS (Atm+DSN)	$(5.4 \pm 1.1) \times 10^{-2}$
Total	$(1.0 \pm 0.2) \times 10^{-1}$

- Radiogenic neutron and high energy neutrino would have similar level of BG
  - nVeto efficiency: ~87%
- Main neutron source: Cryostat, PMTs, PTFE

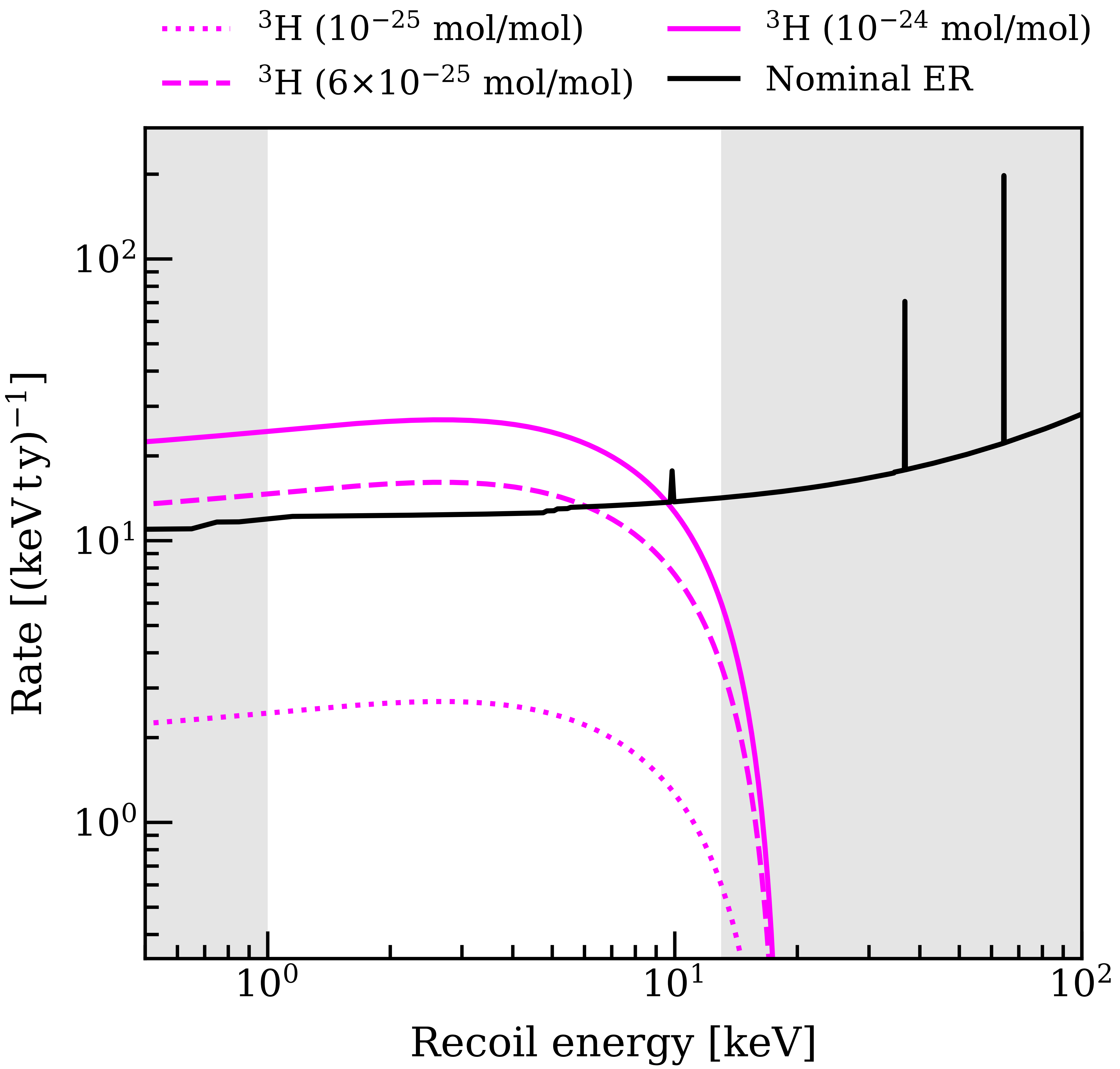
EXPECTED SENSITIVITY (SI WIMP)





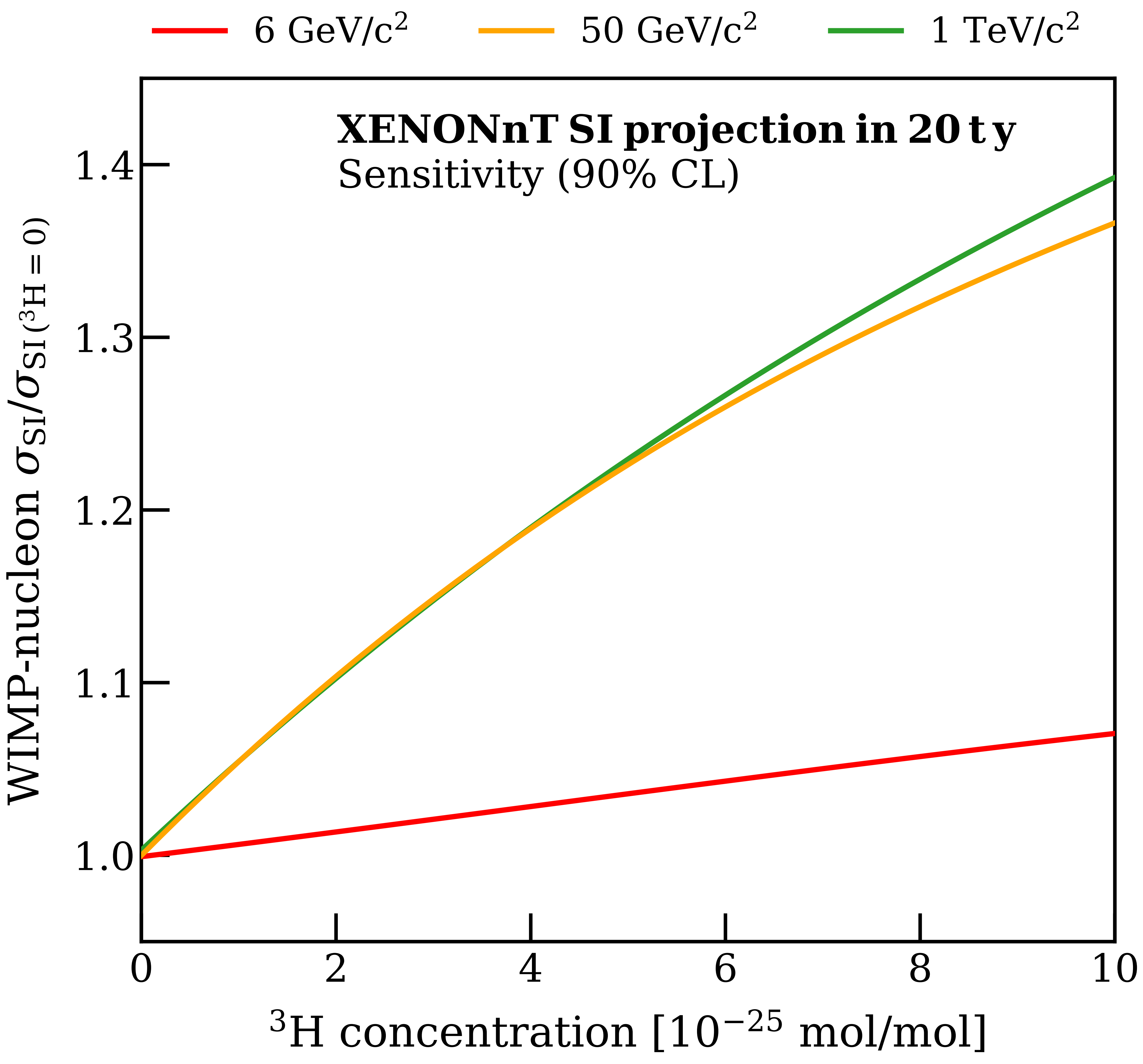
- Expected sensitivity under BGs in previous pages in 20 ty
- At 50GeV, even first few month of data could beat Xenon1T best limit by factor 3-4

SENSITIVITY VS TRITIUM



- ➤ On the other hand, recent study of XENON1T shows excess at low energy ER
- ➤ If the excess is due to the tritium: $6\text{x}10^{-25}$ mol/mol (middle dashed line)
- ➤ If we have more than $7\text{x}10^{-25}$ mol/mol, it will be the same with the summation of all other ER backgrounds
- ➤ Because of the spectrum shape, lighter the WIMPs mass is, smaller the effect is.

SENSITIVITY VS TRITIUM



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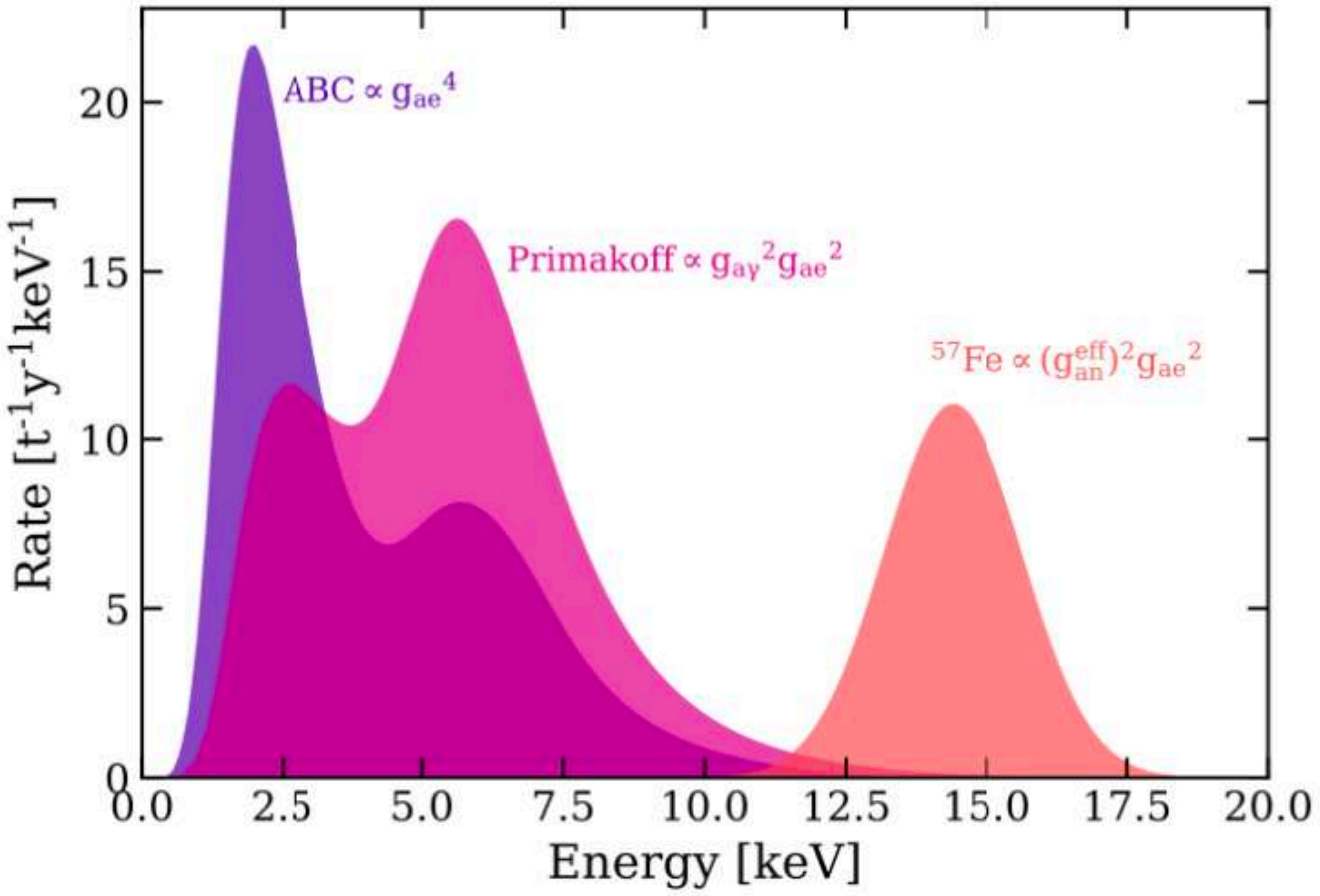
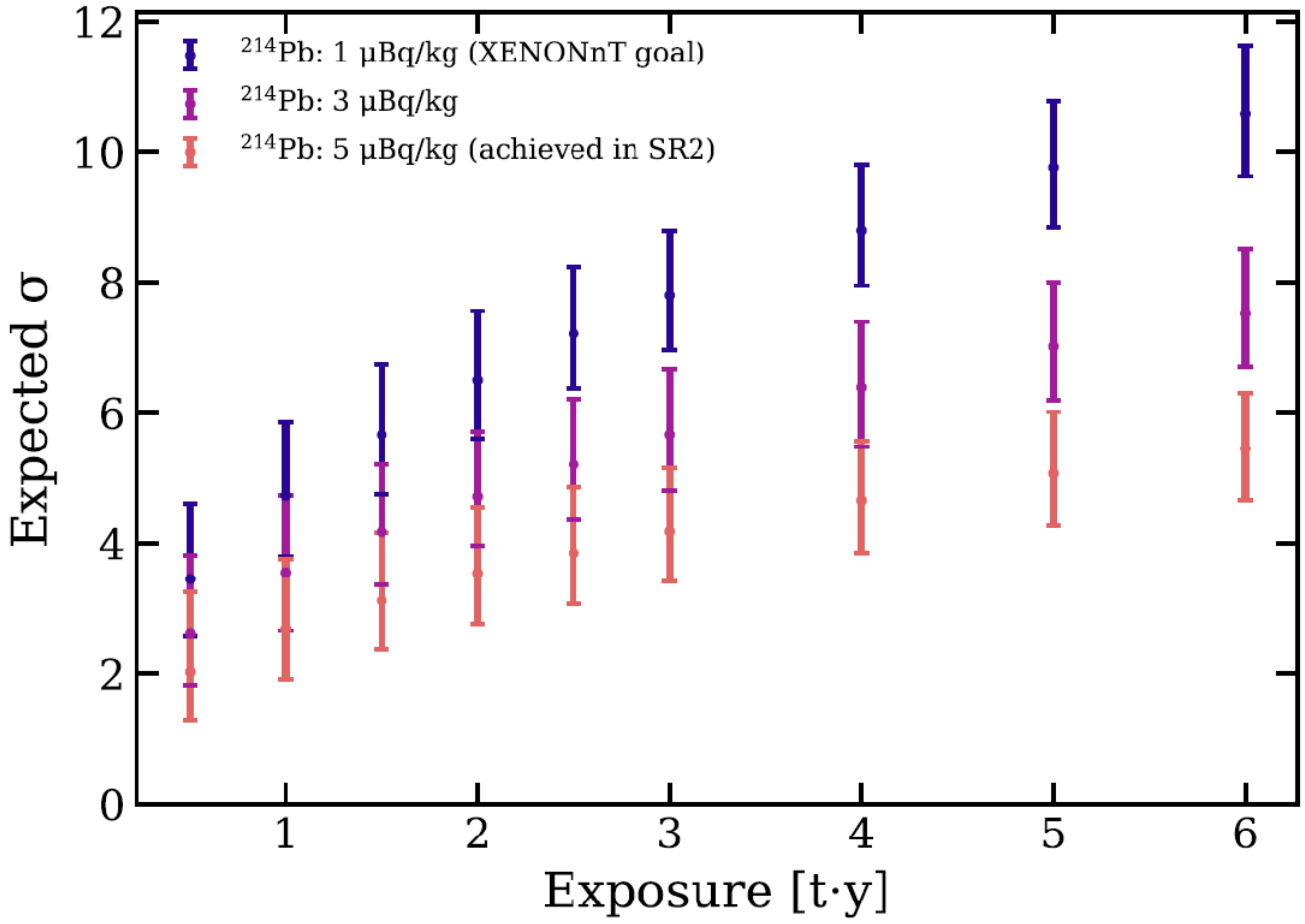
EXPECTED SENSITIVITY: TRITIUM VS ER SIGNAL (AXION) ?



- So far, the sensitivity for WIMPs has been discussed…
- How about the sensitivity for Low energy excess?
- Axion spectrum is continuous, but also have some peak-like shape
- Tritium: smooth beta-decay, Q=18keV
- Distinguish tritium and axion based on the difference of spectrum?

EXPECTED SENSITIVITY: TRITIUM VS ER SIGNAL (AXION) ?

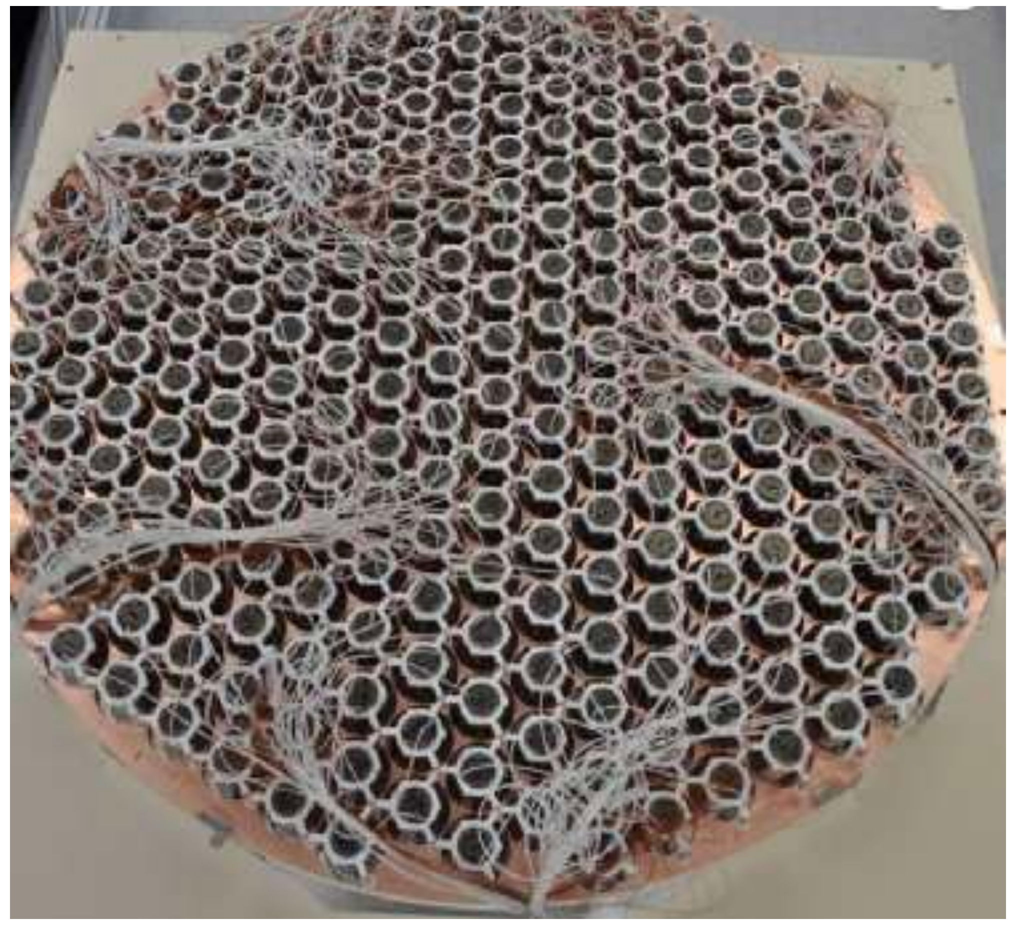


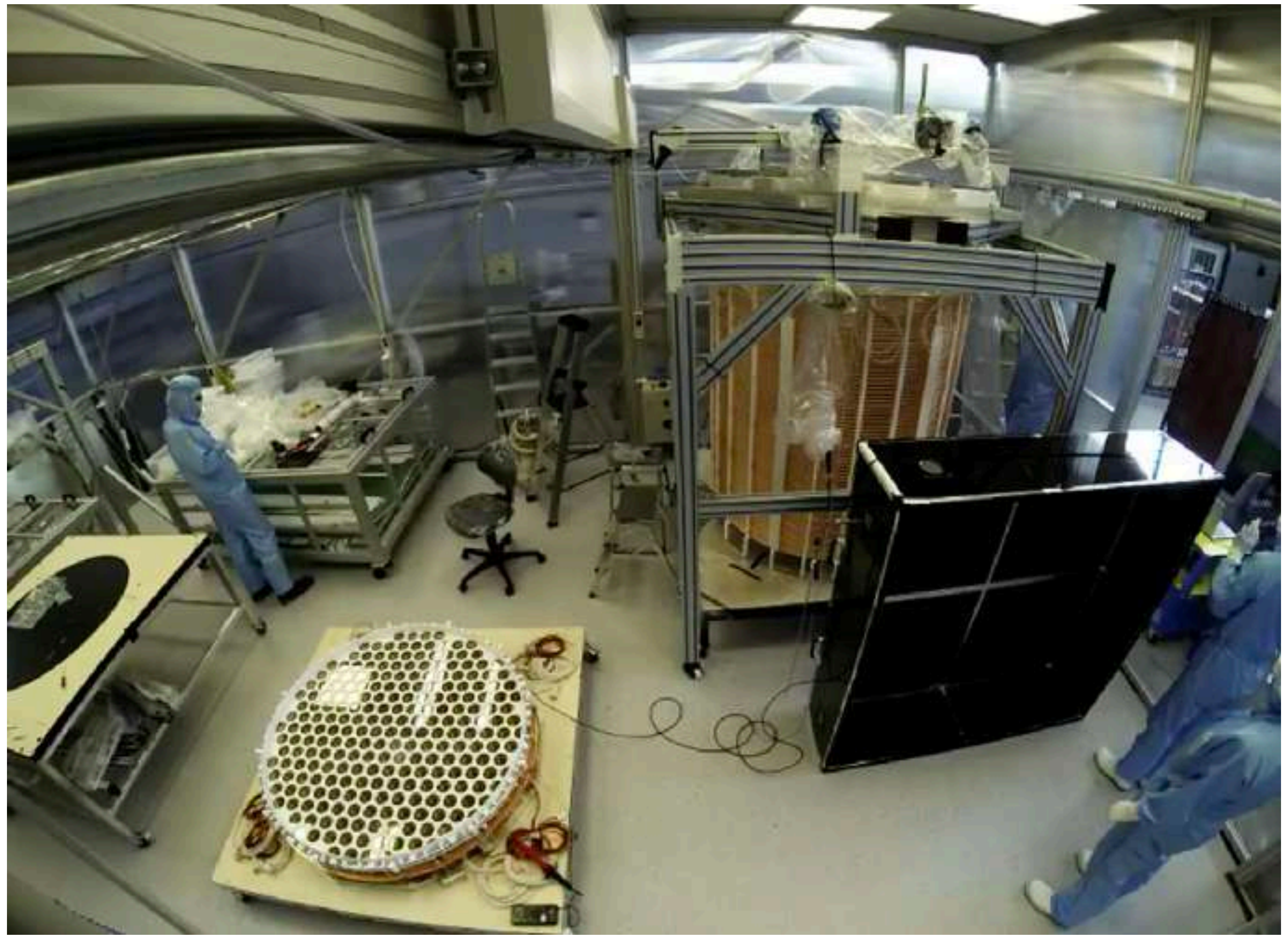
- Discrimination power between axion and tritium
  - Note: BGs are based on 1T best fit
- If Rn BG level is enough low, axion/tritium could be distinguished with few month of data
  - Ex. ~4 sigma with 1-3 uBq/kg

CURRENT STATUS

STATUS OF XENONNT: TPC CONSTRUCTION

- TPC construction: Feb. 2020
    - Constructed in the CR above ground, then brought to UG





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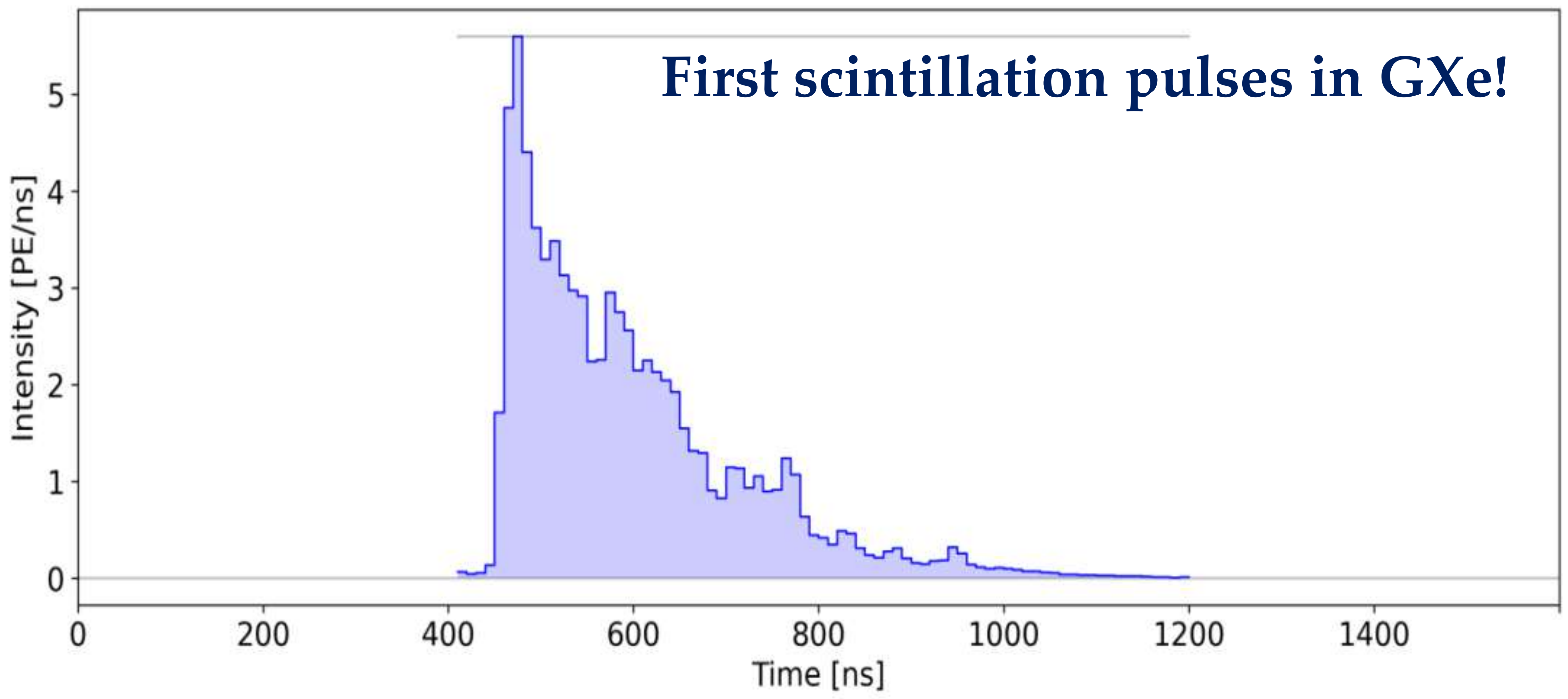
STATUS OF XENONNT: TPC CONSTRUCTION

- TPC construction: Feb. 2020
    - Mounted to the cryostat, and the closed on March 2020



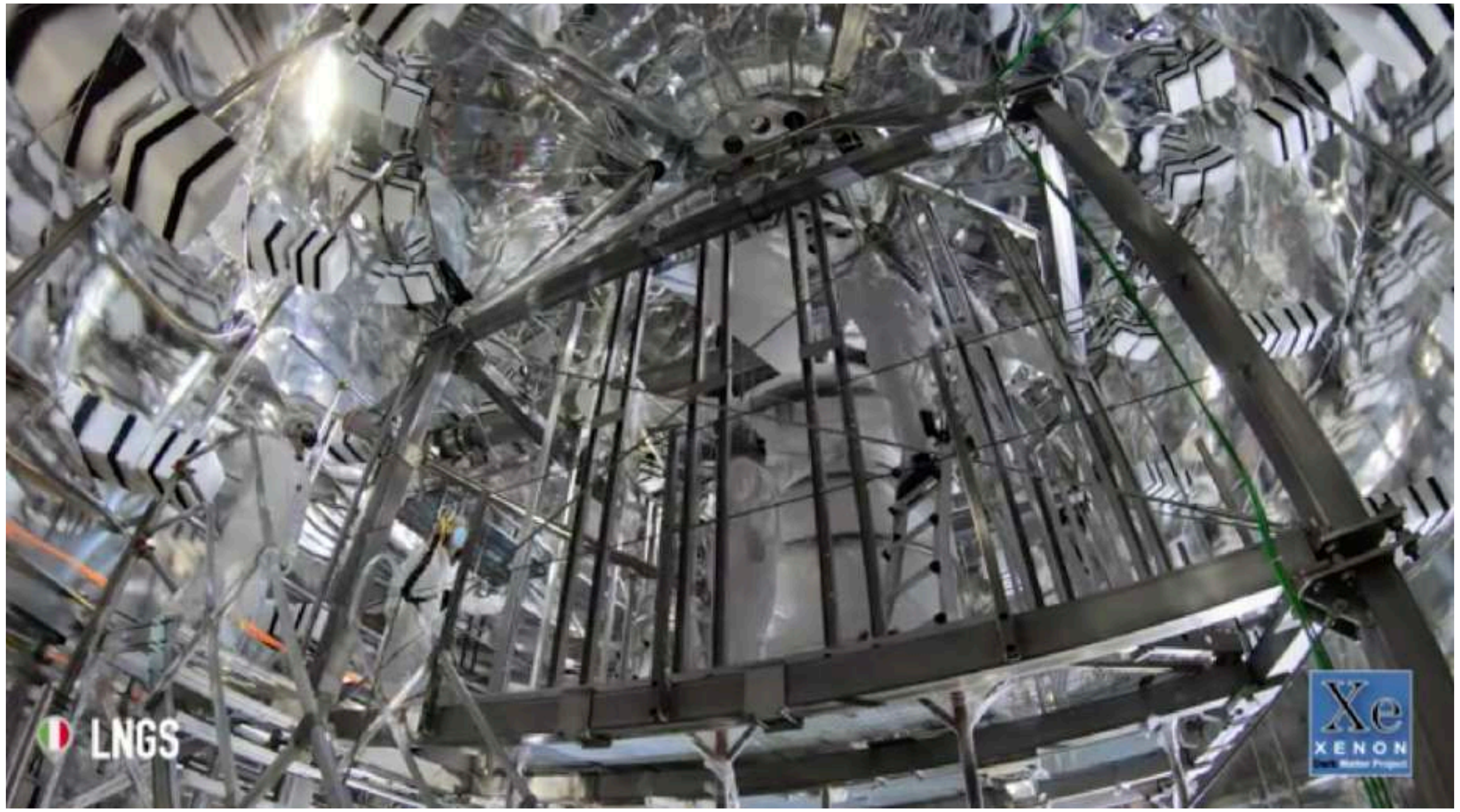
STATUS OF XENONNT: TPC COMMISSIONING

- Because of the corona virus, the activity at LNGS was limited…
  - However: Detector commissioning in vacuum
    - PMT, LED, DAQ, Data analysis tool, etc etc…
- After the lock down: commissioning with GXe
- "First S1 light" in GXe have been observed already



STATUS OF XENONNT: NVETO CONSTRUCTION

➤ Also nVeto construction has already started:



STATUS OF XENONNT: NVETO CONSTRUCTION

- Also nVeto construction has already started:

STATUS OF XENONNT: CRYOSTAT FILLING

- I myself also entered to Italy on July:
  - Cryogenics upgrade
  - Rn column installation
  - GXe purification
  - Cryostat cool down
- Recent news: Cryostat LXe filling started!
- Also a lot of other works are ongoing!

LNGS Cryo-team at the moment of LXe filling