



**Pietro DI GANGI**  
per il gruppo XENON Bologna



# XENON

Assemblea di Sezione INFN Bologna  
**28.03.2022**

# The XENON Collaboration

180 SCIENTISTS 27 INSTITUTIONS 11 COUNTRIES



Pietro Di Gangi | 28.03.2022

# XENON Bologna

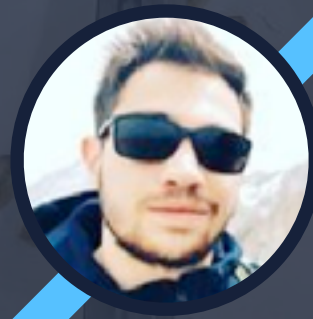


Gabriella  
**SARTORELLI**

PI of XENON Bologna group  
Responsible for construction of Neutron Veto



Andrea  
**MANCUSO**



Marco  
**SELVI**

National INFN responsible  
Neutron Veto WG coordinator  
Editorial board and PR member



Pietro  
**DI GANGI**

MC Simulations WG coordinator



Lorenzo  
**BELLAGAMBA**



Stefania  
**VECCHI**  
\* UniFe



Franco  
**SEMERIA**



Federica  
**AGOSTINI**

\*Former member  
(now at CNAF)

Guido  
**ZAVATTINI**  
\* UniFe



# Direct Dark Matter Search



# Direct Dark Matter Search



EARTH-BASED  
EXPERIMENT

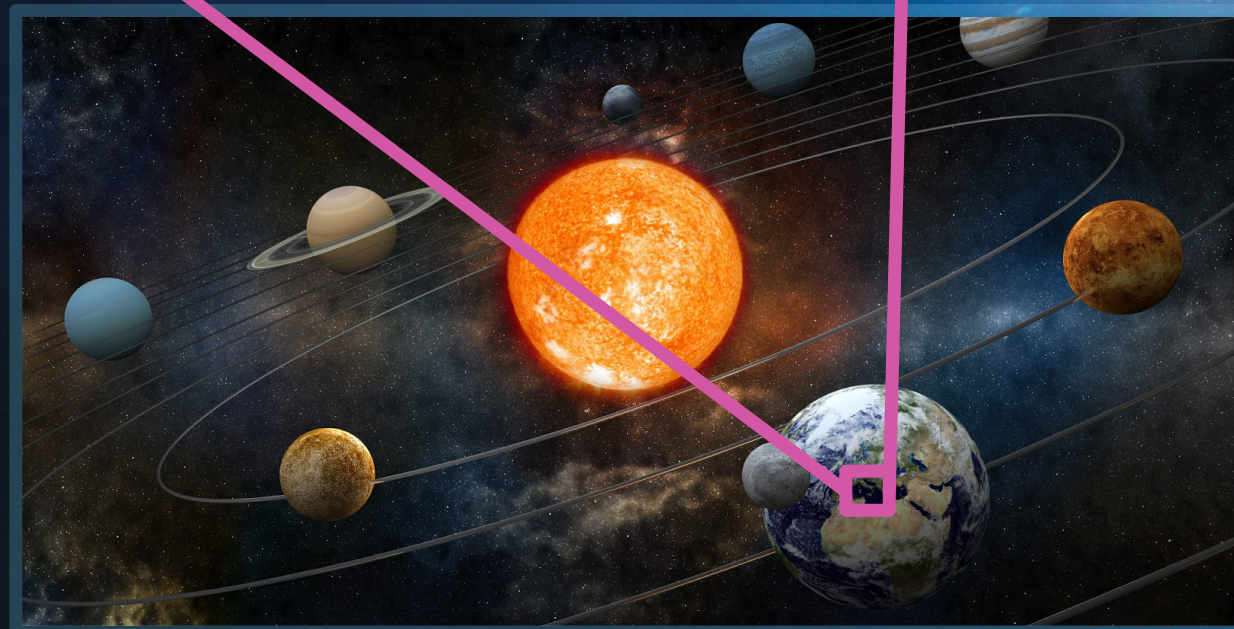
# Direct Dark Matter Search



UNDERGROUND @ LNGS  
3600 m.w.e. ROCK SHIELD



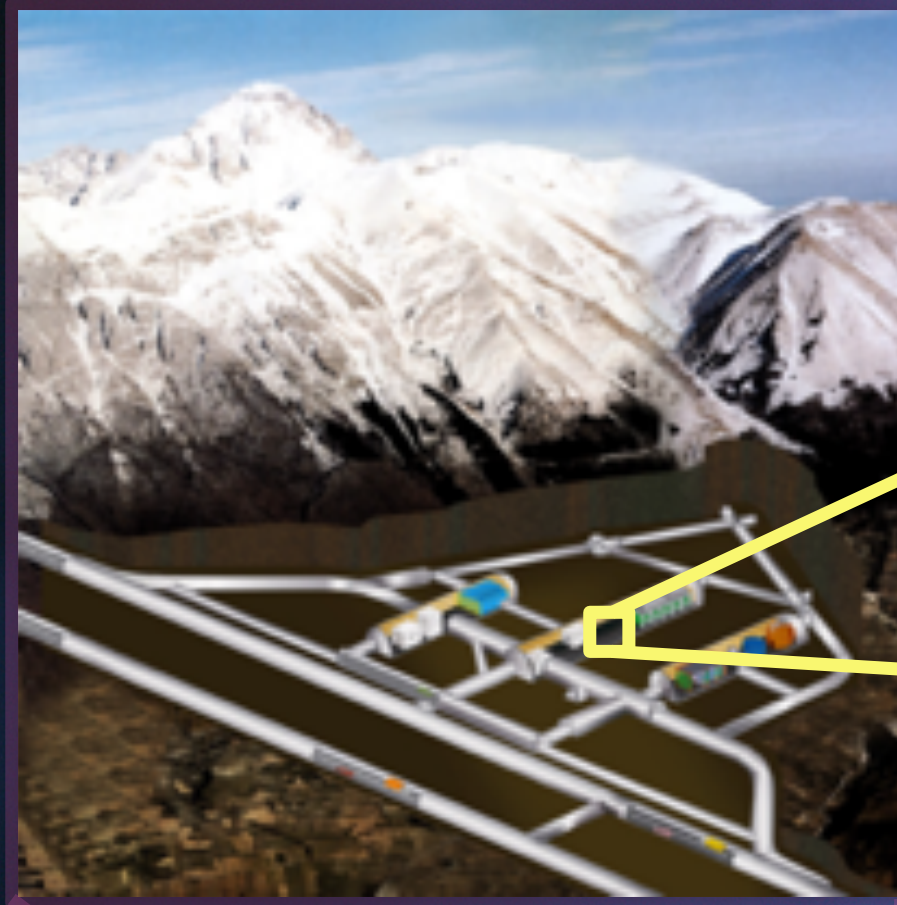
EARTH-BASED  
EXPERIMENT



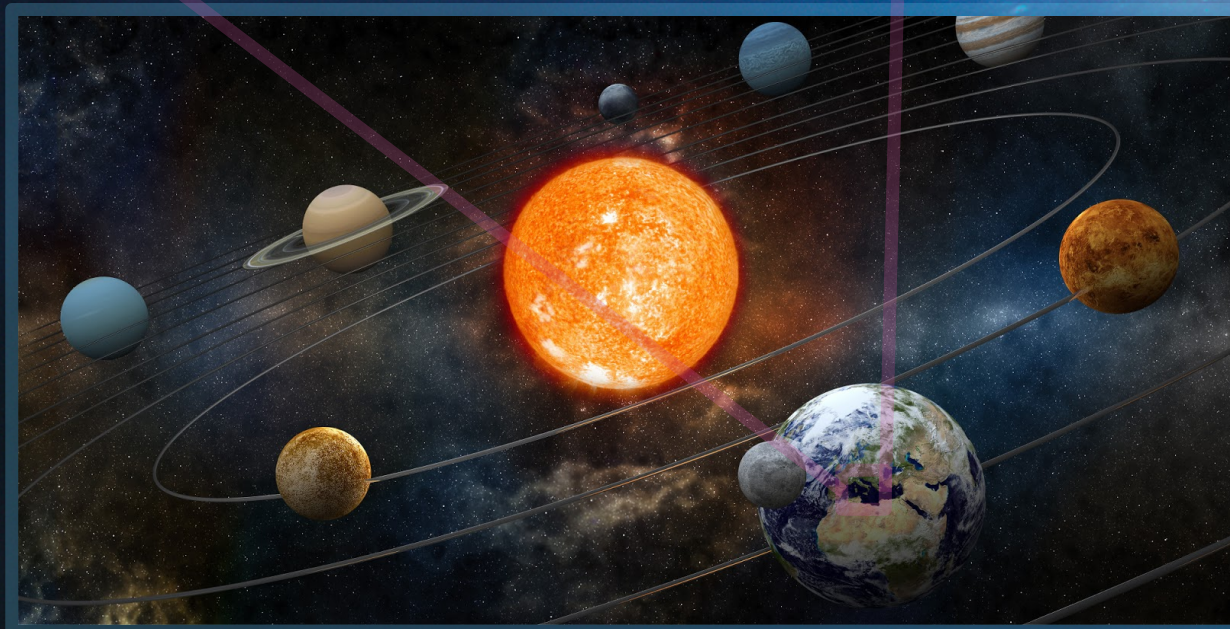
# Direct Dark Matter Search



UNDERGROUND @ LNGS  
3600 m.w.e. ROCK SHIELD



EARTH-BASED  
EXPERIMENT

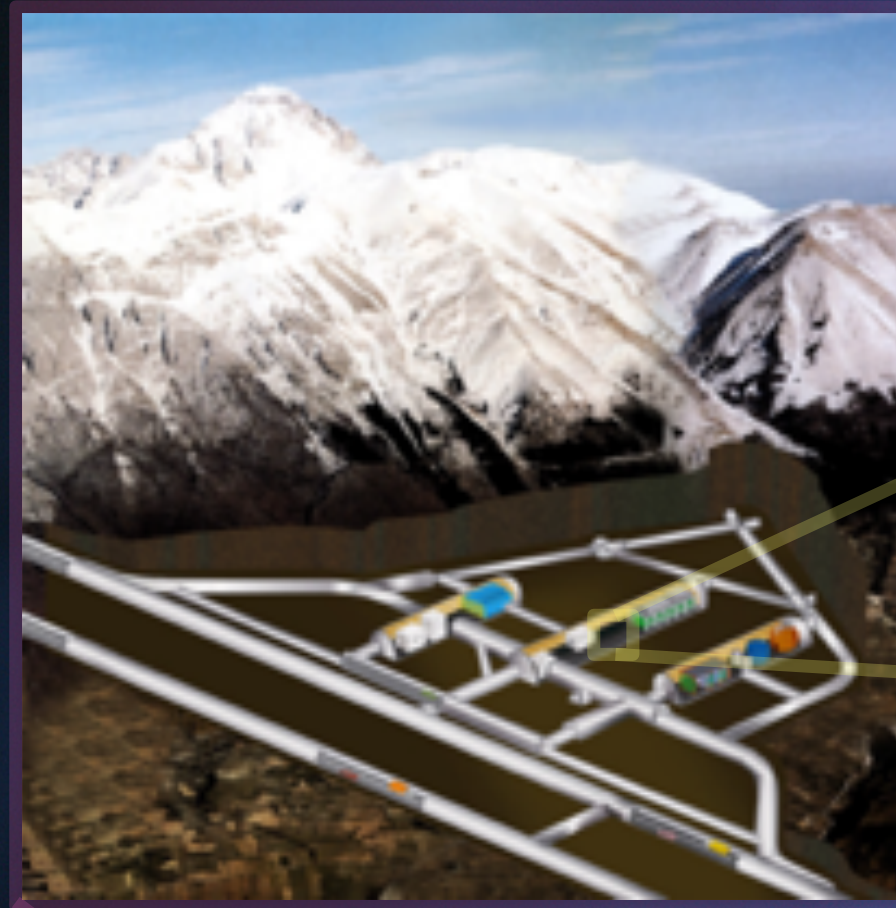


MUON VETO  
700 t WATER TANK

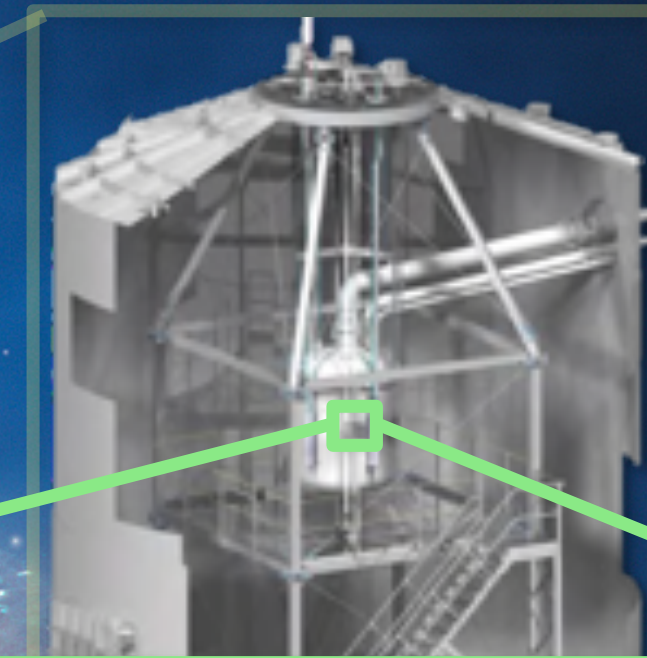
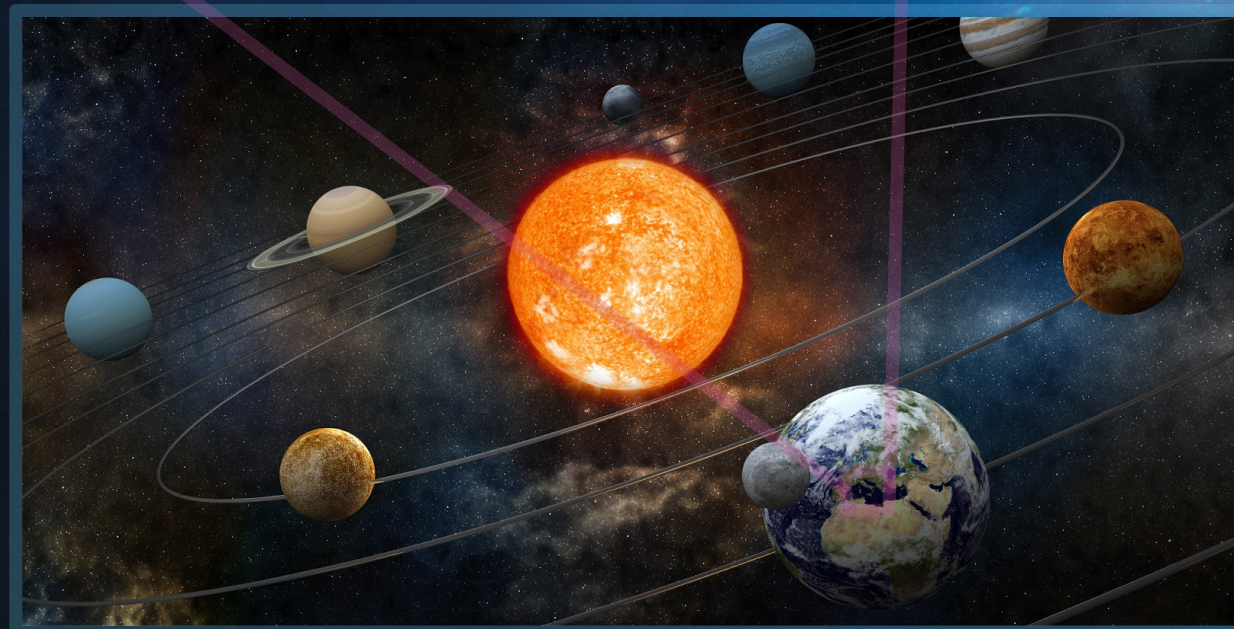
# Direct Dark Matter Search



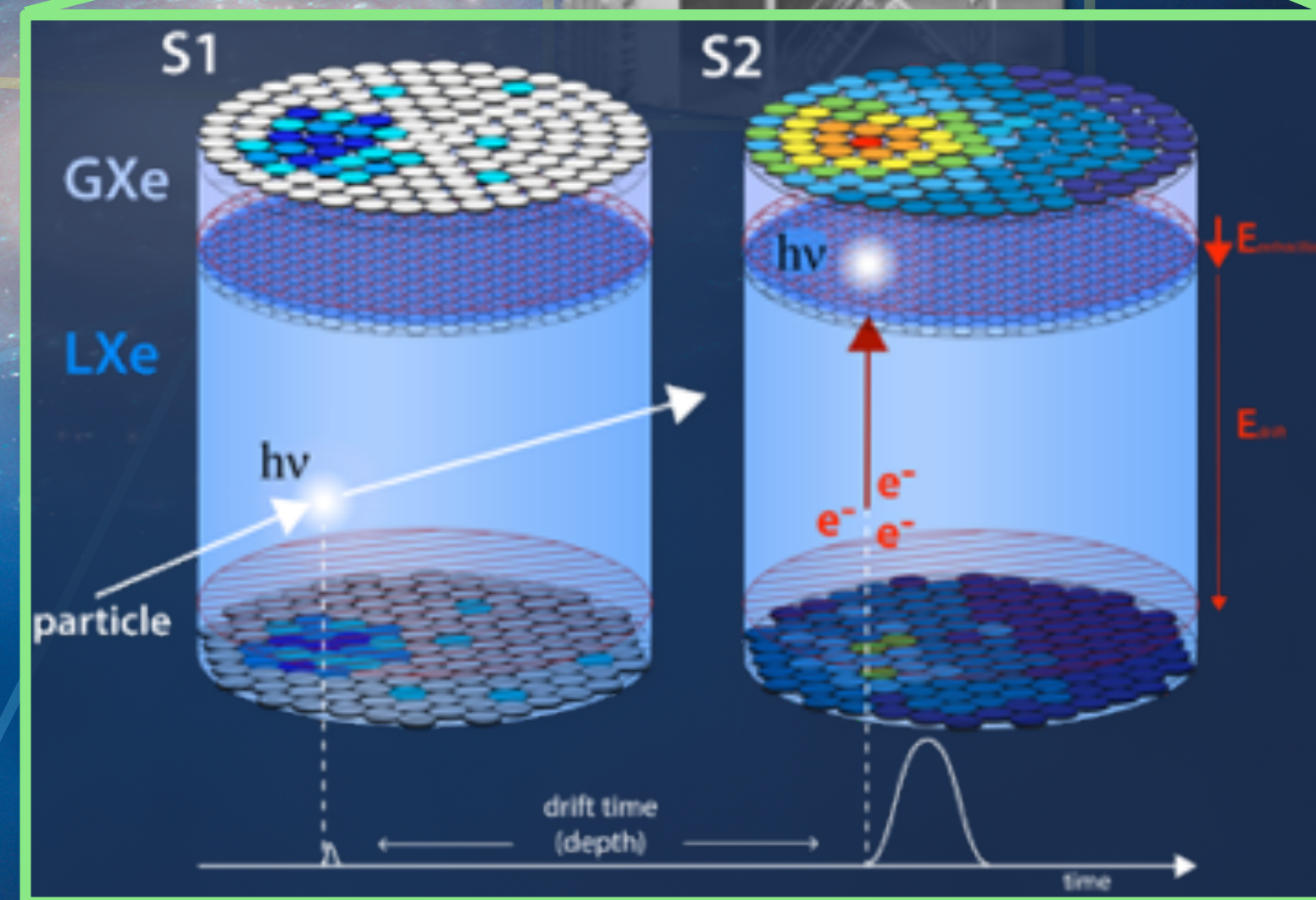
UNDERGROUND @ LNGS  
3600 m.w.e. ROCK SHIELD



EARTH-BASED  
EXPERIMENT



MUON VETO  
700 t WATER TANK

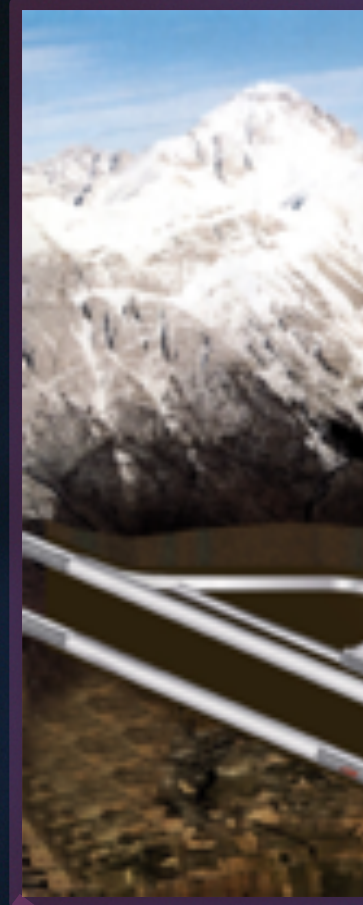




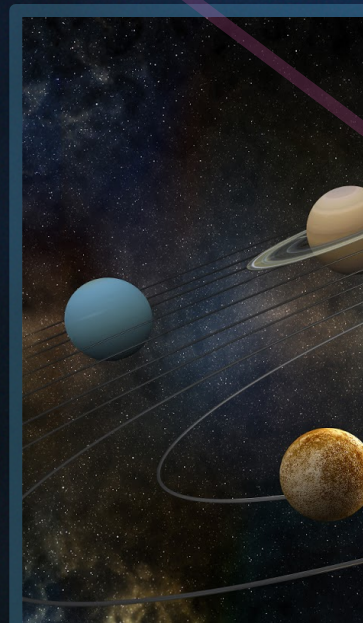
# Direct Dark Matter Search



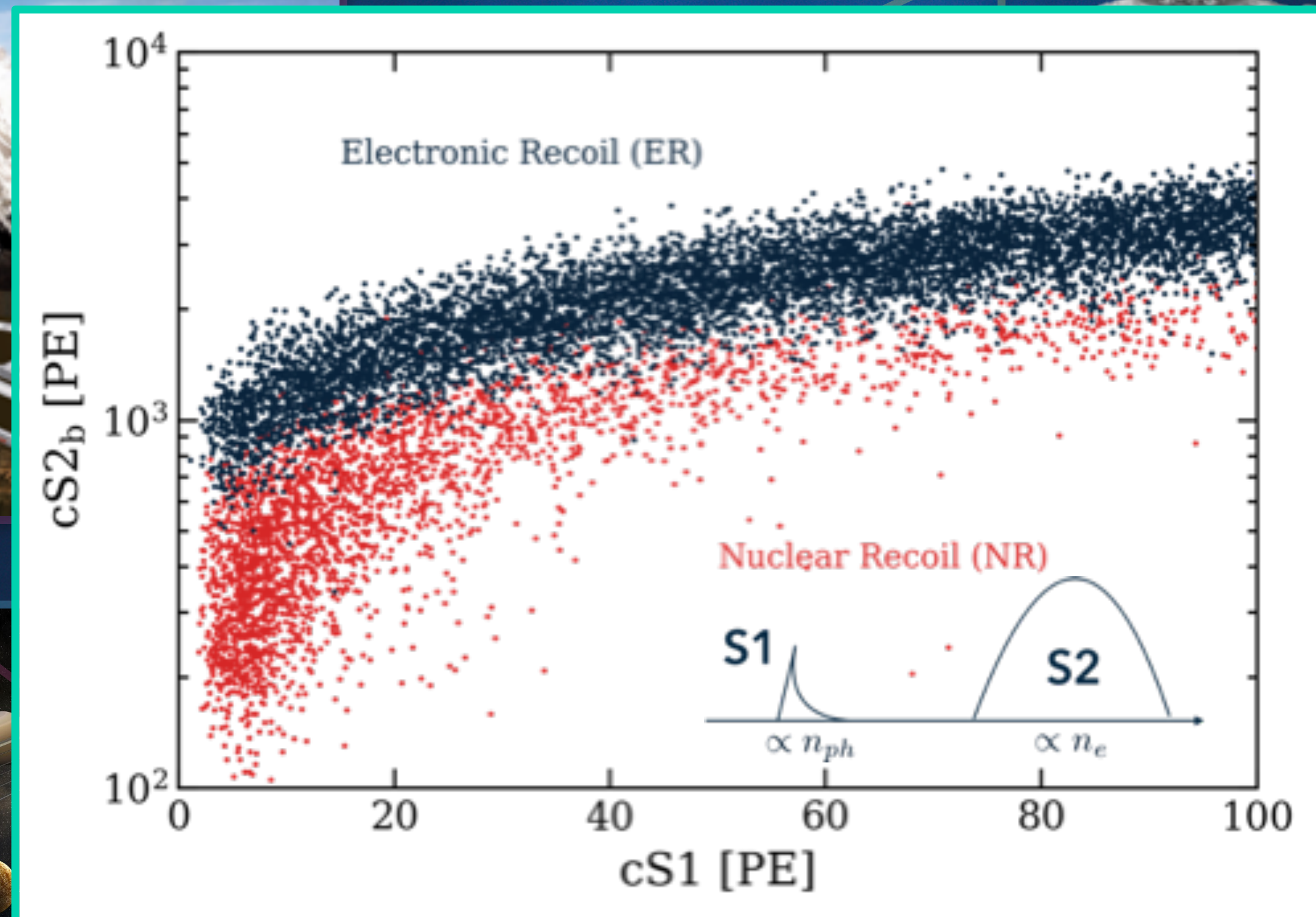
UNDERGROUND @ LNGS  
3600 m.w.e. ROCK SHIELD



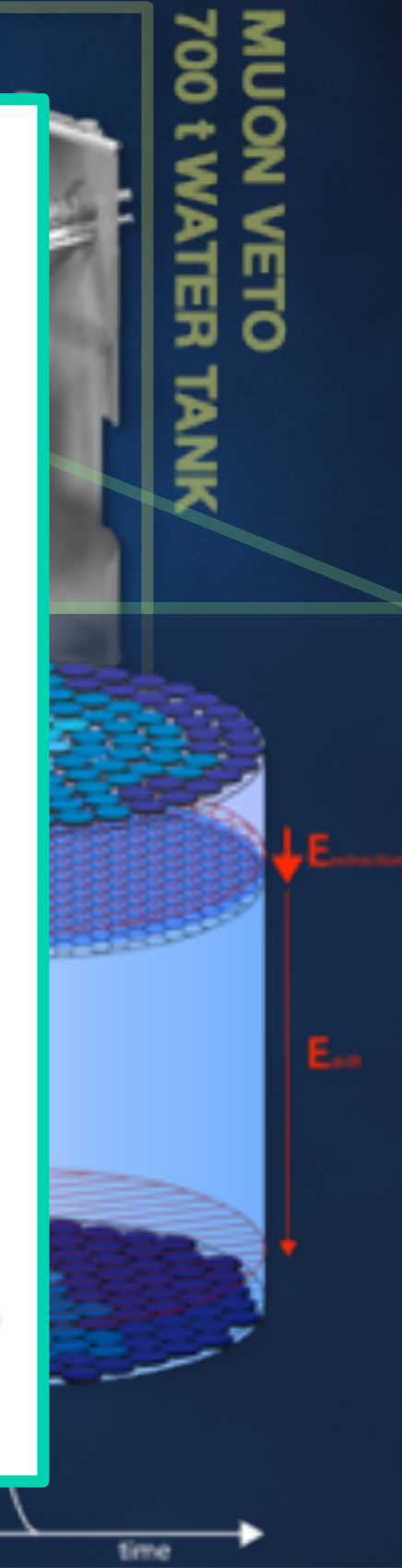
EARTH-BASED  
EXPERIMENT



ER vs NR DISCRIMINATION



MUON VETO  
700 t WATER TANK

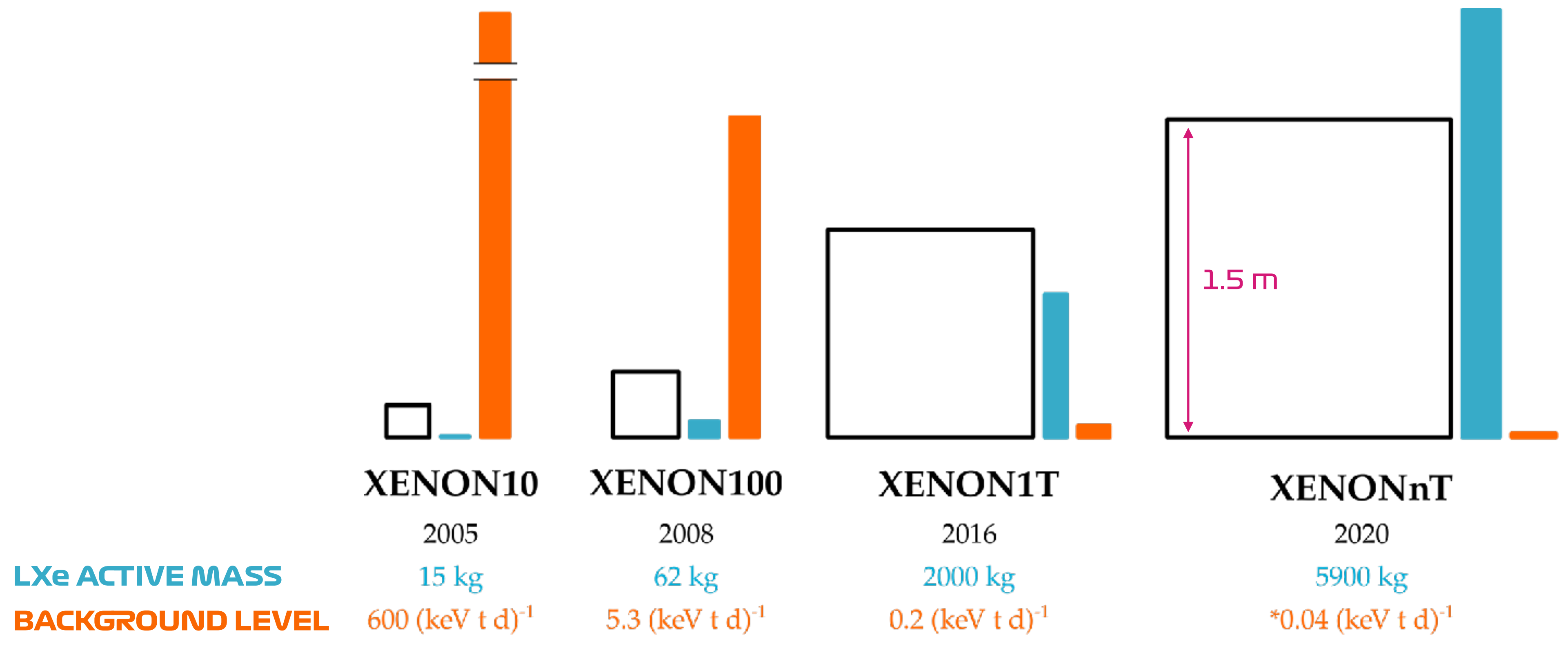


DUAL PHASE XENON TPC

# XENON TPCs



P. Di Gangi, *The Xenon Road to Direct Detection of Dark Matter at LNGS: The XENON Project*, *Universe* 2021, 7(8), 313

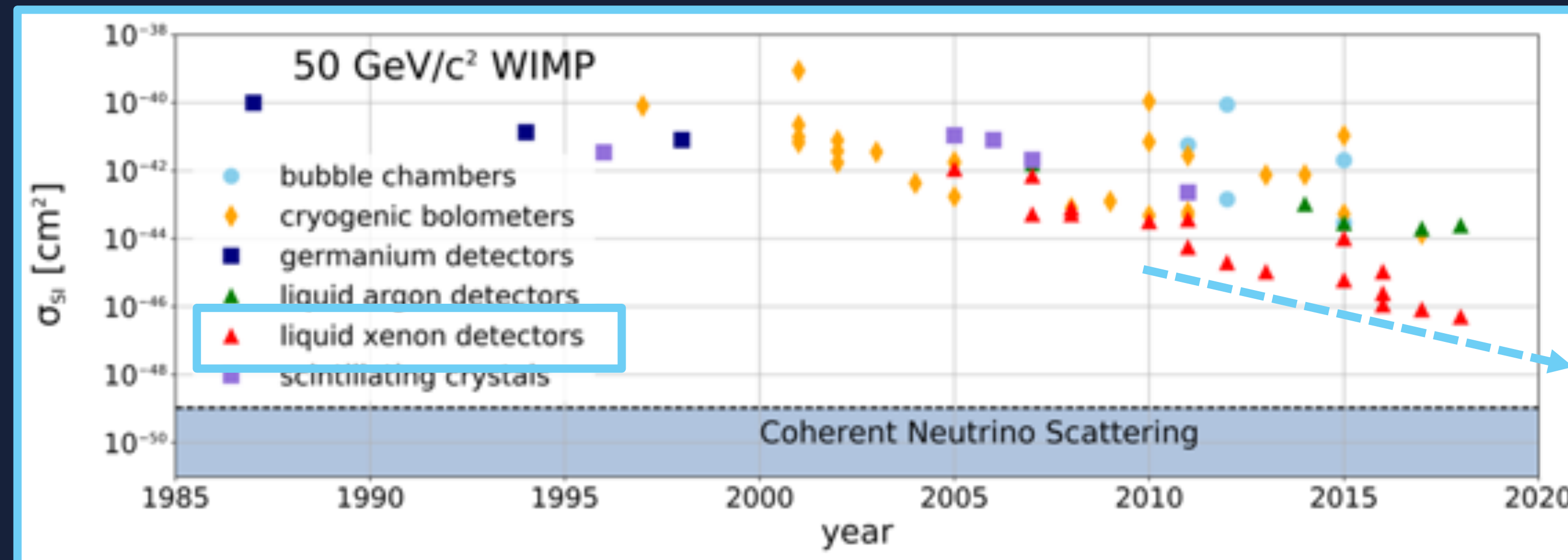


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# LXe TPCs evolution

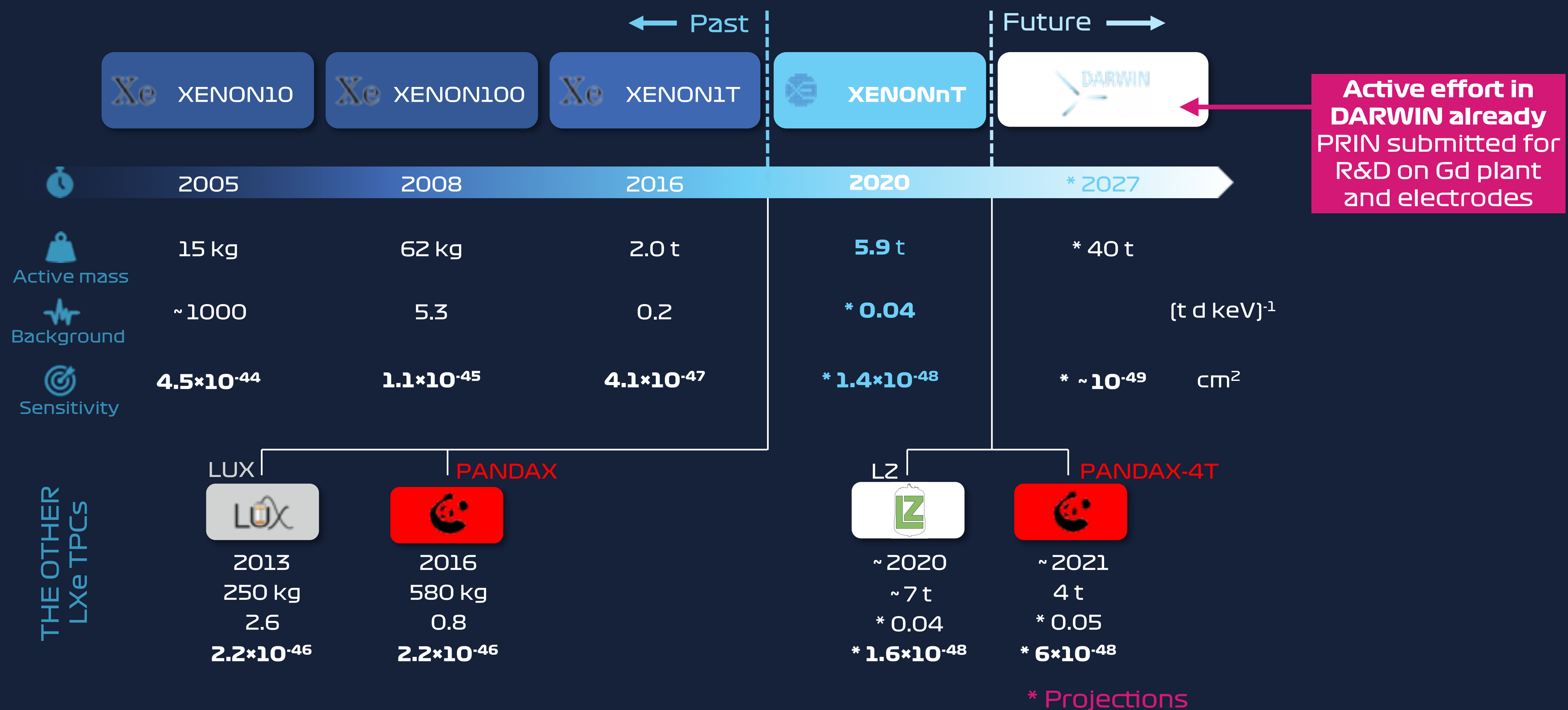


## MOST SENSITIVE detectors to WIMPs



Sensitivity improved by more than 3 orders of magnitude in last 10 years!

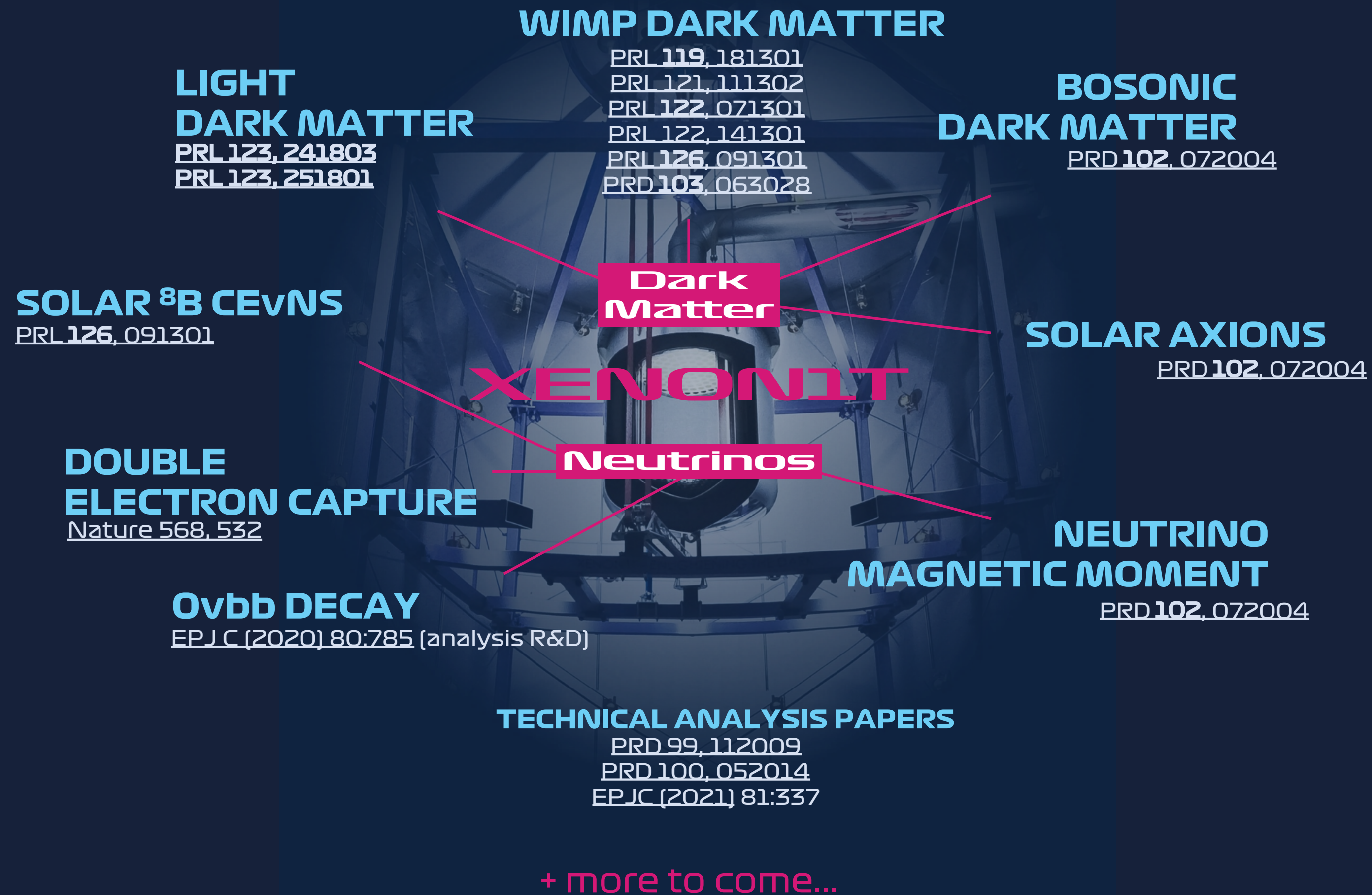
# LXe TPCs evolution



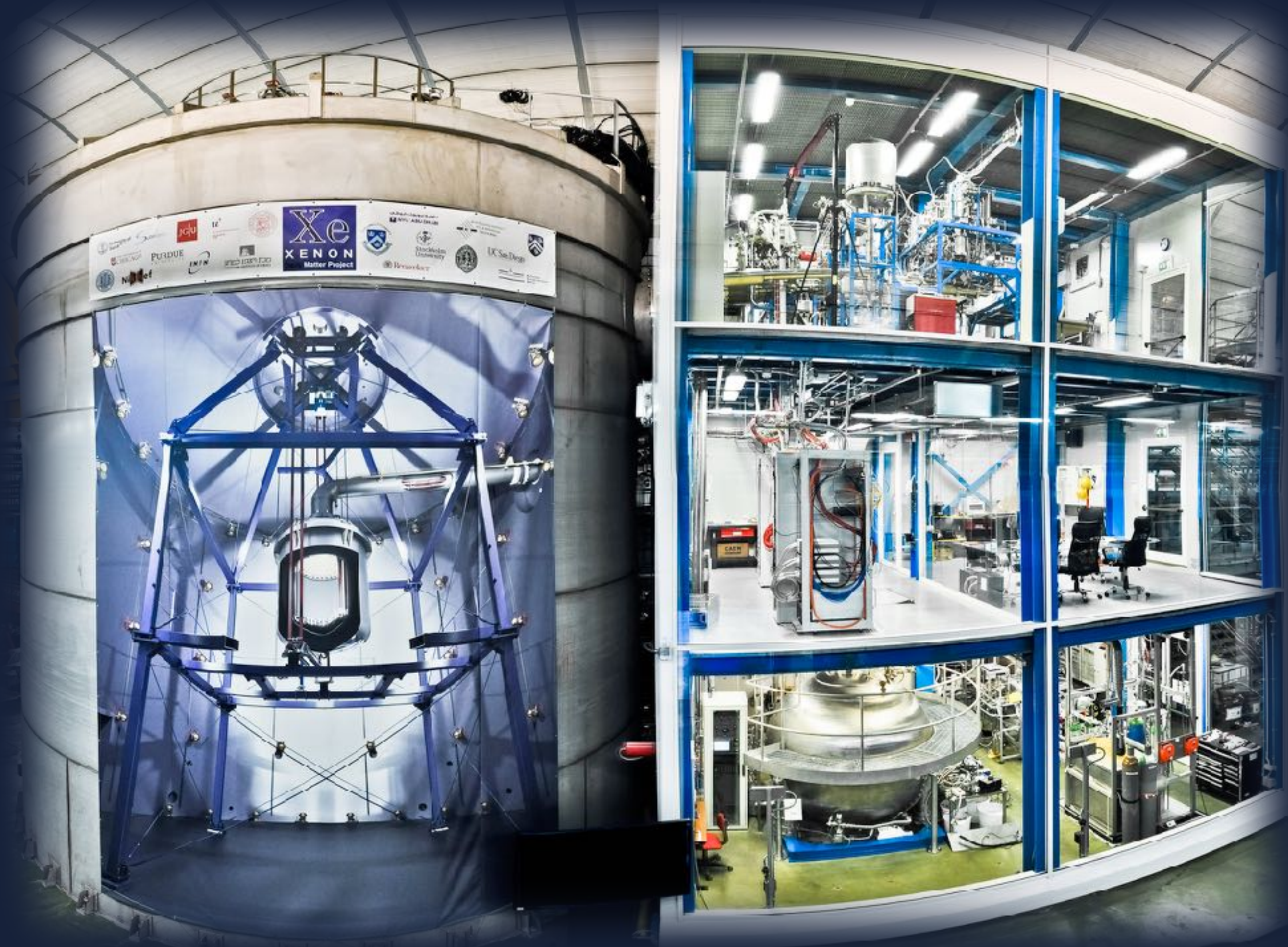
Active effort in DARWIN already PRIN submitted for R&D on Gd plant and electrodes

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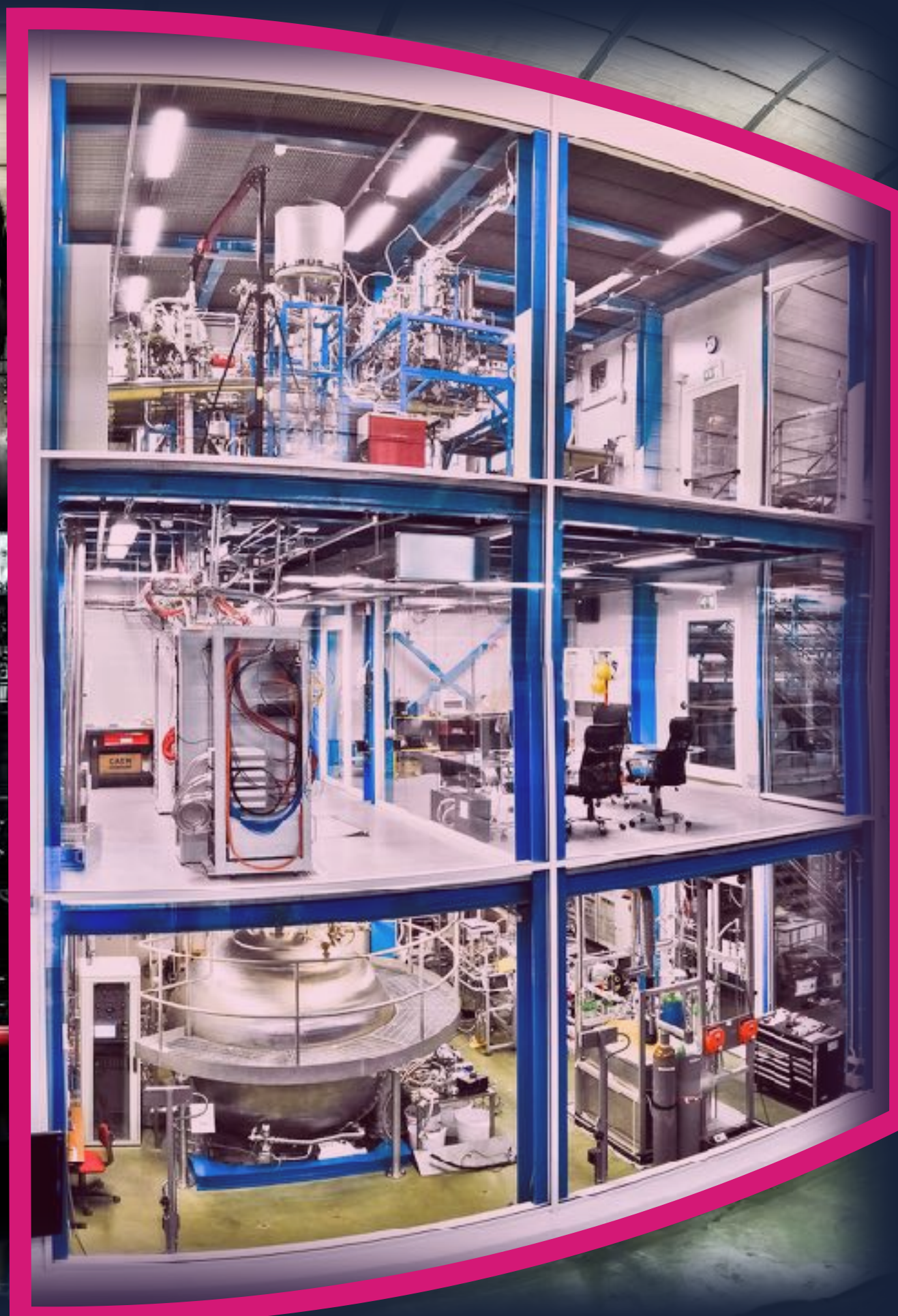
# Not just WIMPs to discover



# XENONnT at LNGS



# XENONnT at LNGS



## SERVICE BUILDING

- CRYOGENICS
- GXe PURIFICATION
- LXe STORAGE
- Kr DISTILLATION COLUMN
- DAQ
- SLOW CONTROL

# XENONnT at LNGS



## MUON VETO

- 700 t WATER CHERENKOV
- 84 PMTs



## SERVICE BUILDING

- CRYOGENICS
- GXe PURIFICATION
- LXe STORAGE
- Kr DISTILLATION COLUMN
- DAQ
- SLOW CONTROL



# XENONnT at LNGS

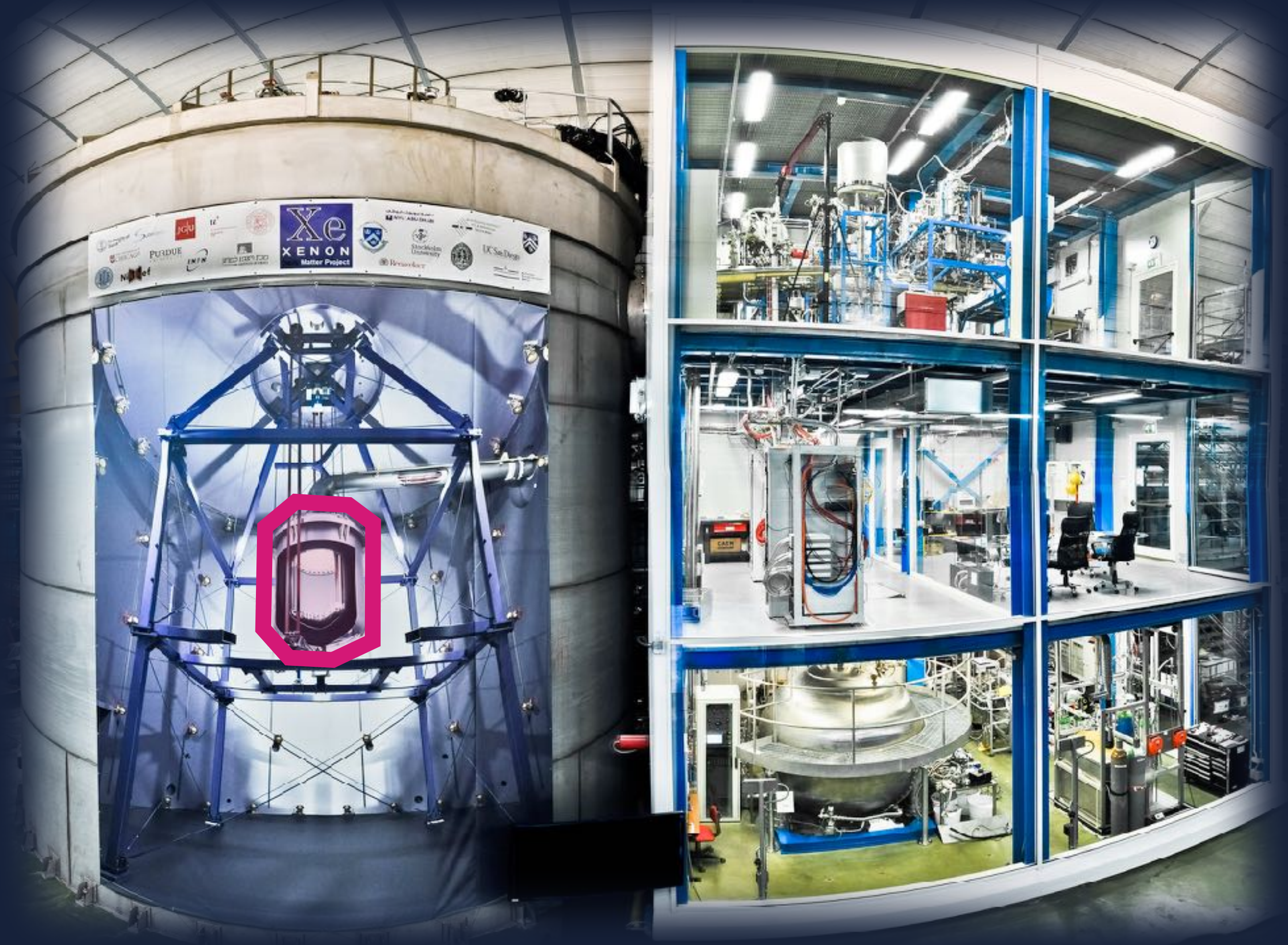


## MUON VETO

- 700 t WATER CHERENKOV
- 84 PMTs

## TPC

- 2.0 t LXe TARGET
- 248 PMTs



## SERVICE BUILDING

- CRYOGENICS
- GXe PURIFICATION
- LXe STORAGE
- Kr DISTILLATION COLUMN
- DAQ
- SLOW CONTROL

# XENONnT at LNGS



## MUON VETO

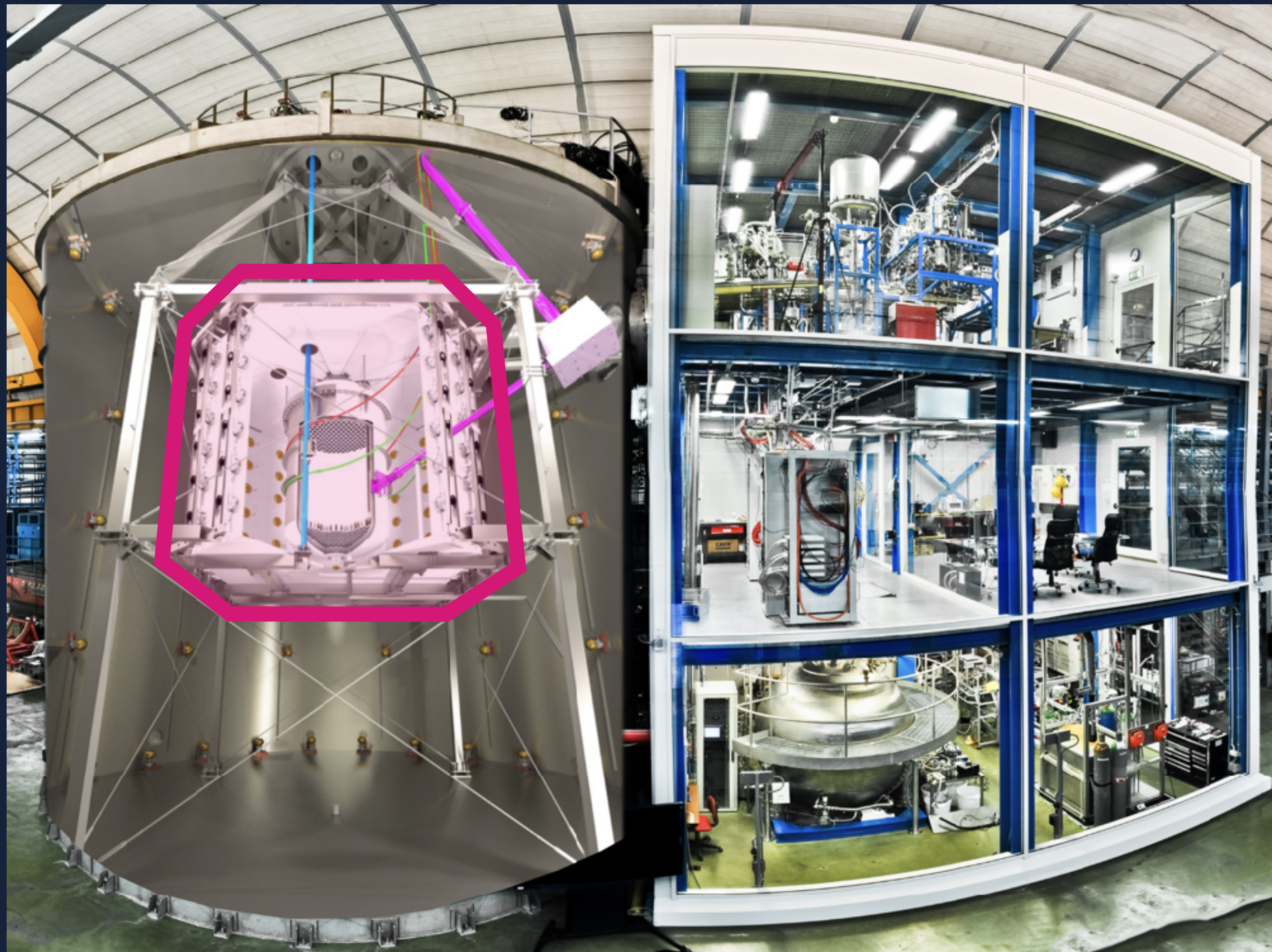
- 700 t Gd-DOPED WATER CHERENKOV
- 84 PMTs

## TPC

- 5.9 t LXe TARGET
- 494 PMTs

## NEUTRON VETO

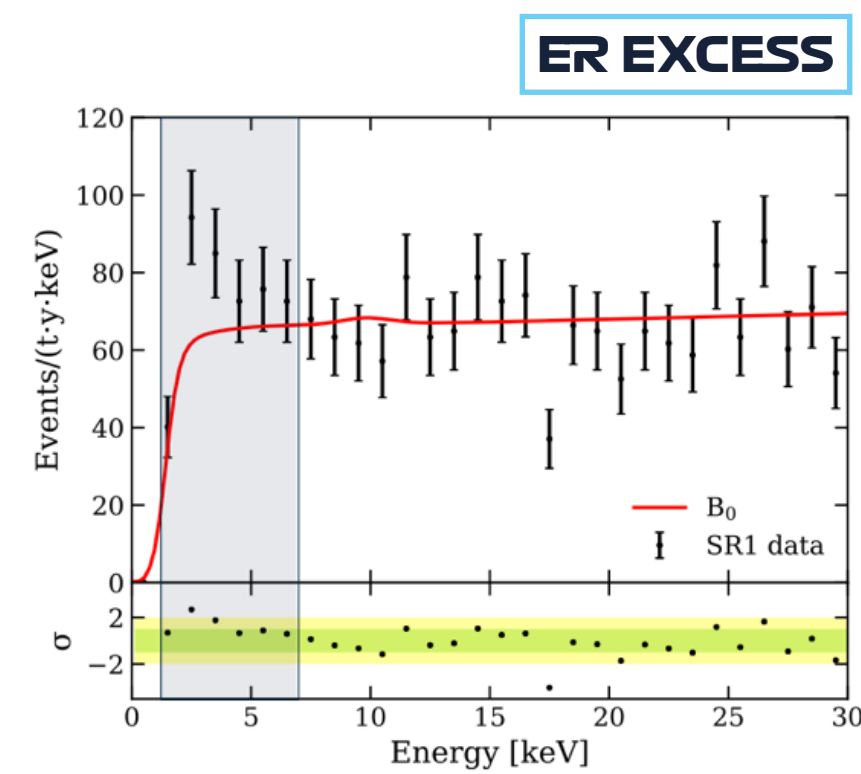
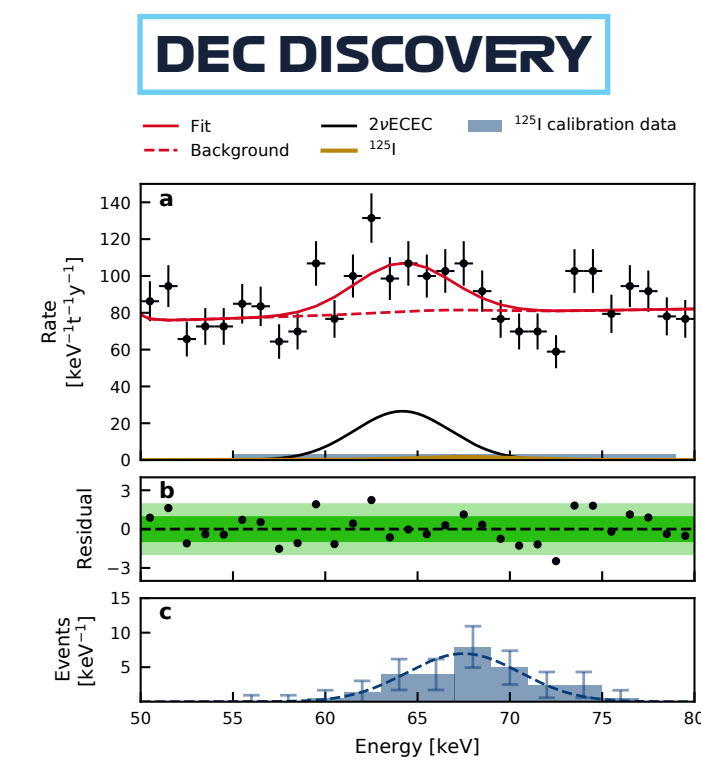
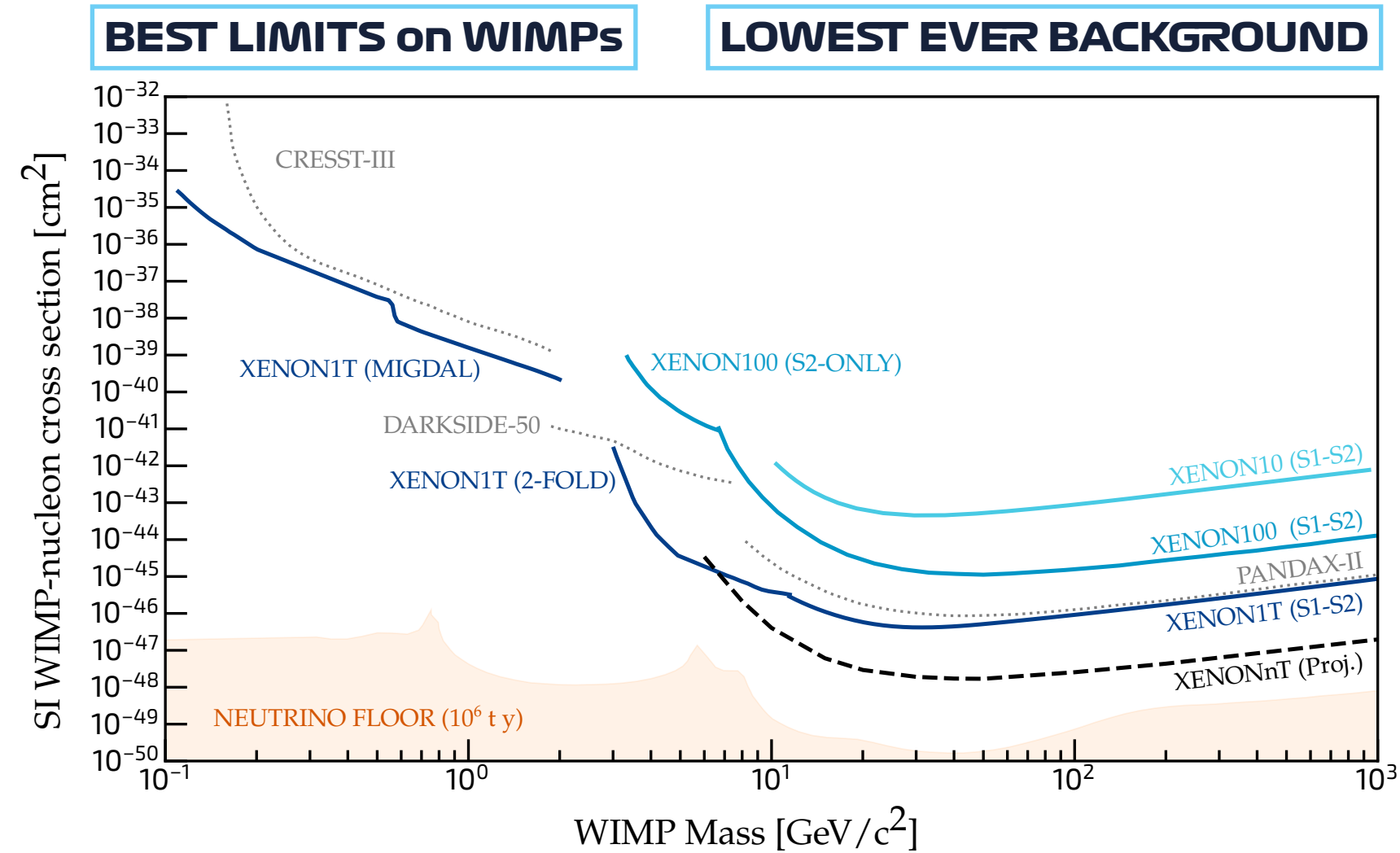
- Gd-DOPED WATER CHERENKOV
- >99% REFLECTIVE
- 120 PMTs



## SERVICE BUILDING

- CRYOGENICS
- GXe PURIFICATION
- LXe PURIFICATION
- LXe STORAGE
- Kr DISTILLATION COLUMN
- Rn DISTILLATION COLUMN
- DAQ
- SLOW CONTROL

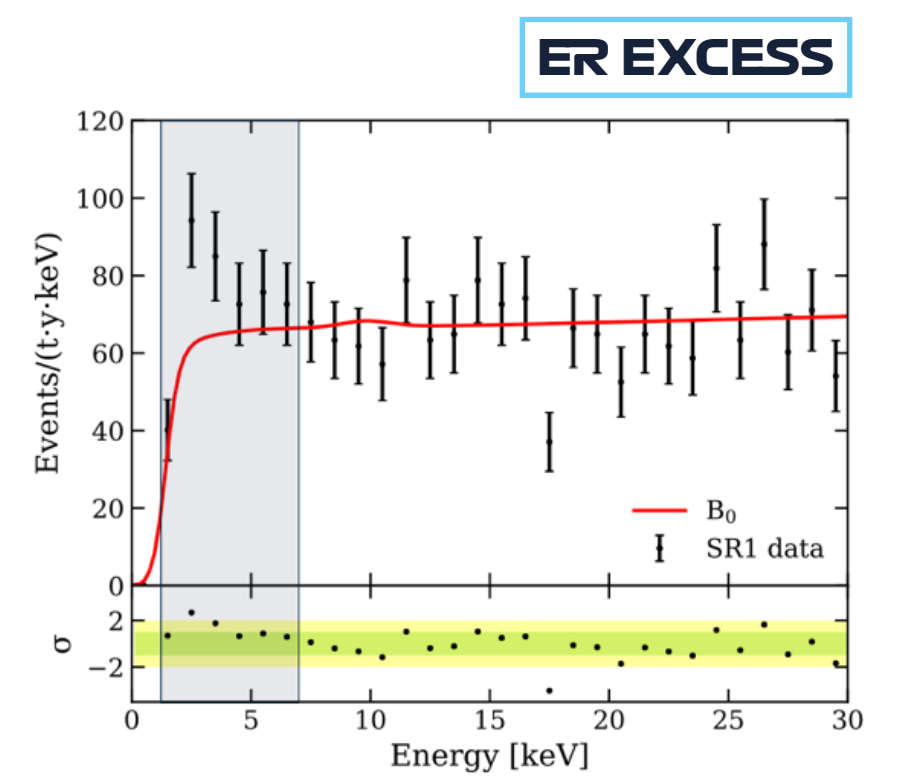
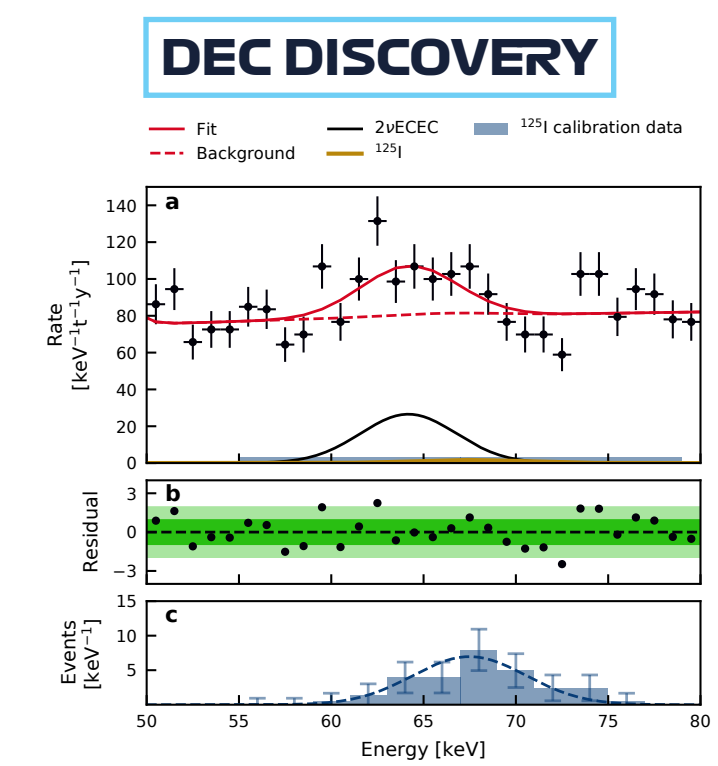
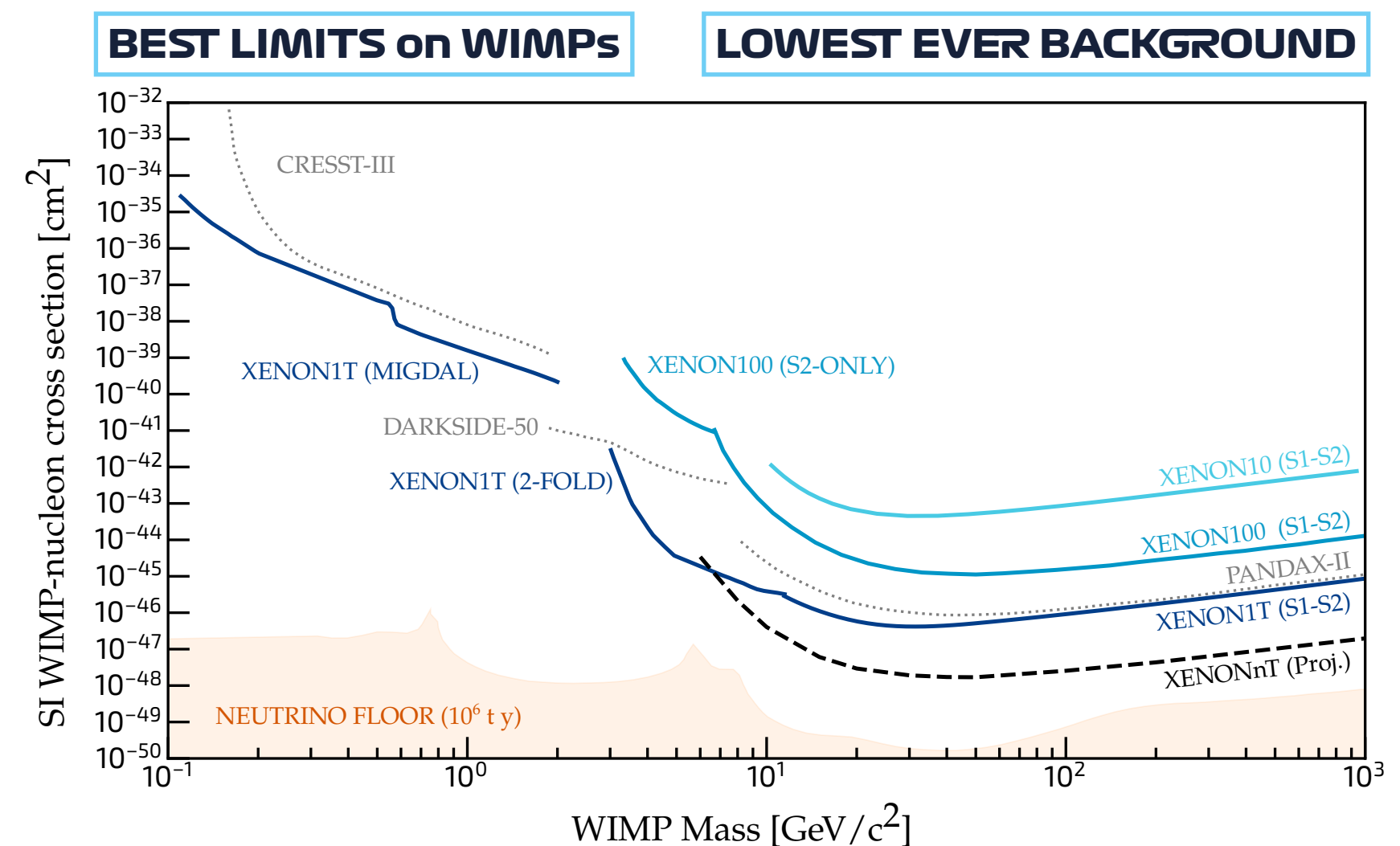
# Highlights from XENON1T



# How to improve the best ever DM detector (so far)?

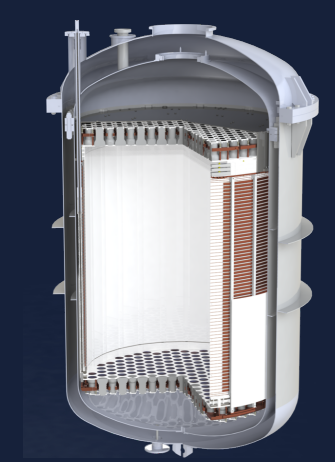


## XENONnT's LEGACY



## LARGER AND MORE PURE TARGET

3x LARGER TPC



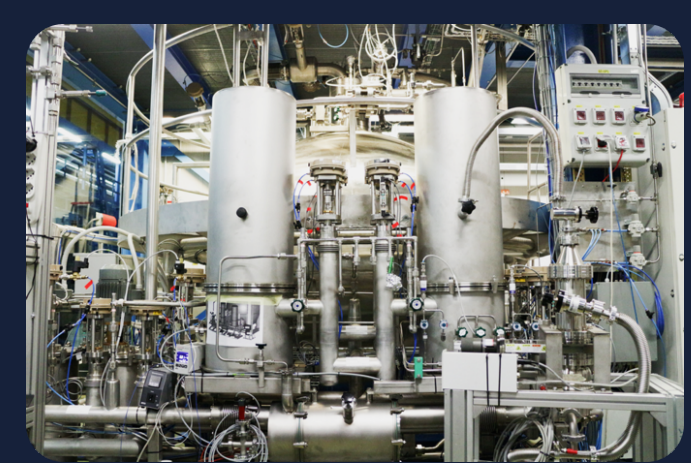
NOVEL LIQUID Xe PURIFICATION SYSTEM



## SUPPRESS KEY BACKGROUNDS

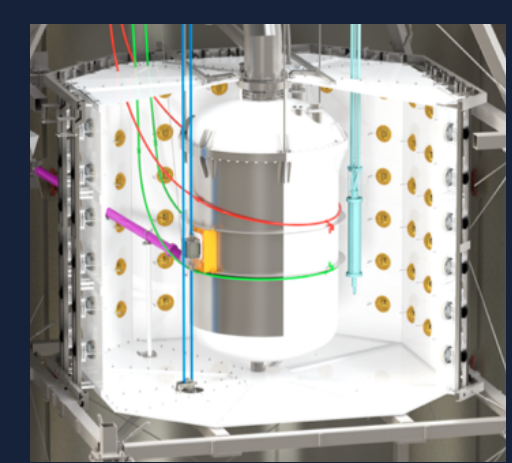
ER Background  $^{222}\text{Rn}$

NOVEL Rn REMOVAL SYSTEM



NR Background Radiogenic neutrons

NEUTRON VETO



# XENONnT Timeline



Spring  
2020



TPC Installation

Summer  
2020



Neutron Veto  
Installation

December  
2020



Water Tank filled

Early  
2021



Test of all the  
subsystems and TPC  
commissioning

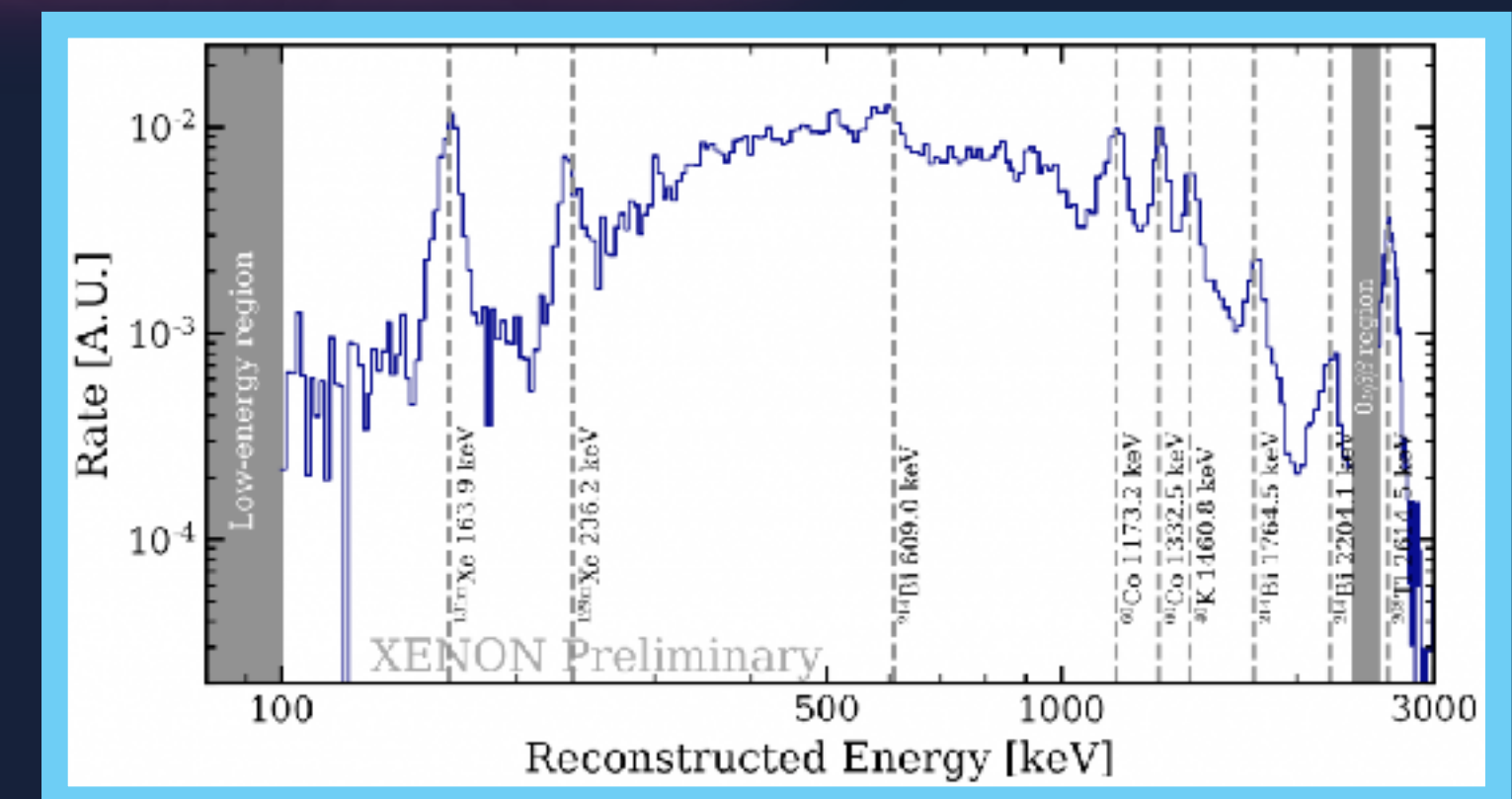
Now



Science Run



Background spectrum  
(4.2 days)



# XENONnT Upgrades



**TPC**

- Fiducial mass: 1 → 4 t
- Tunable field shaping rings chain
- Materials selection based on intense screening campaign



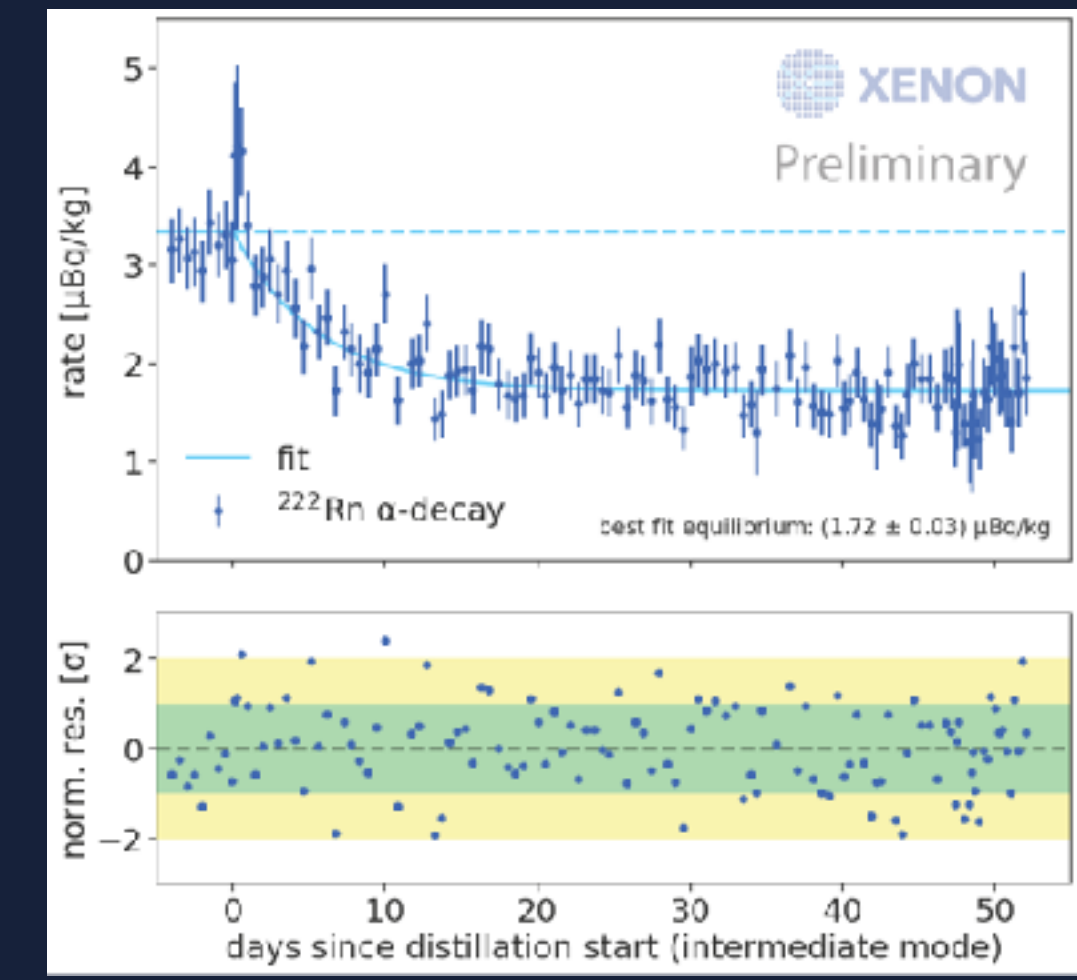
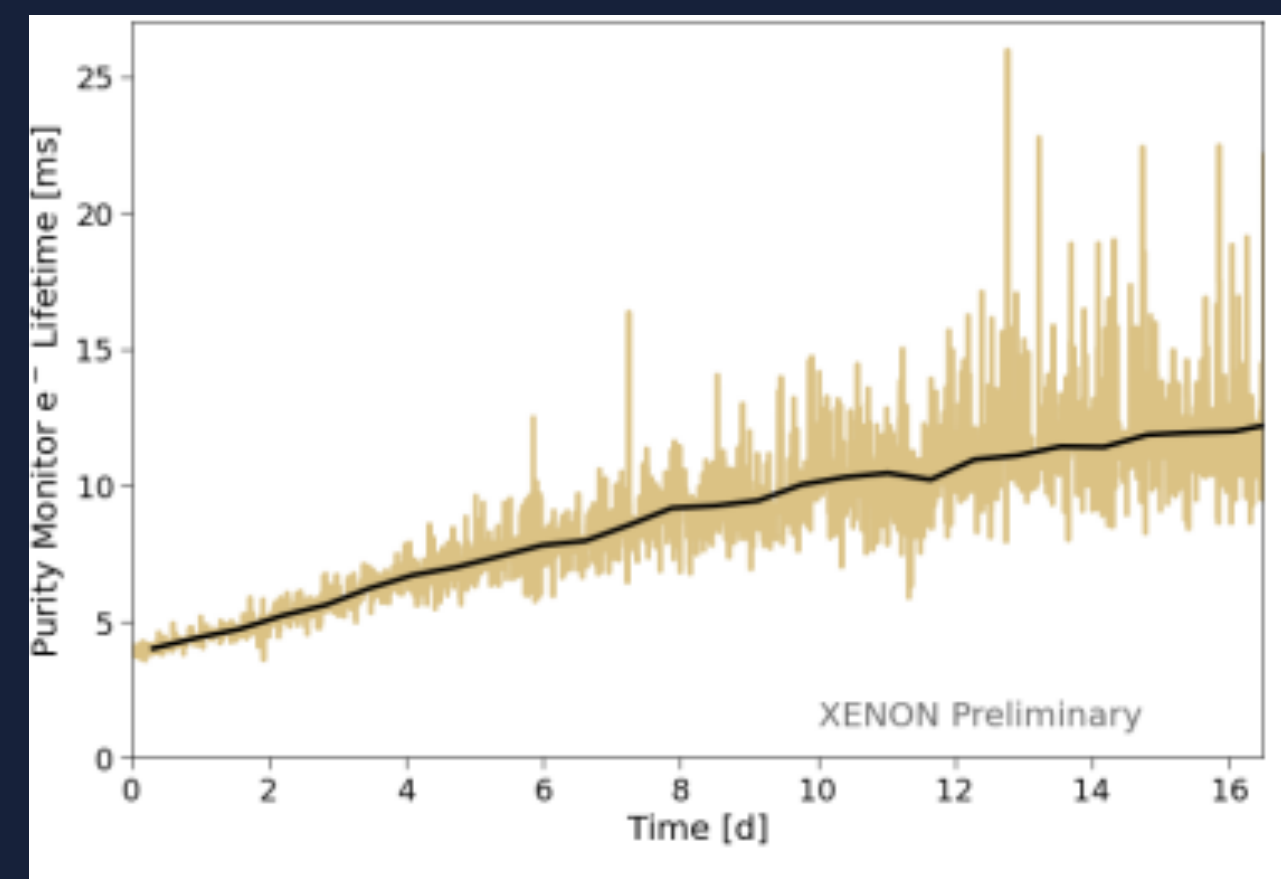
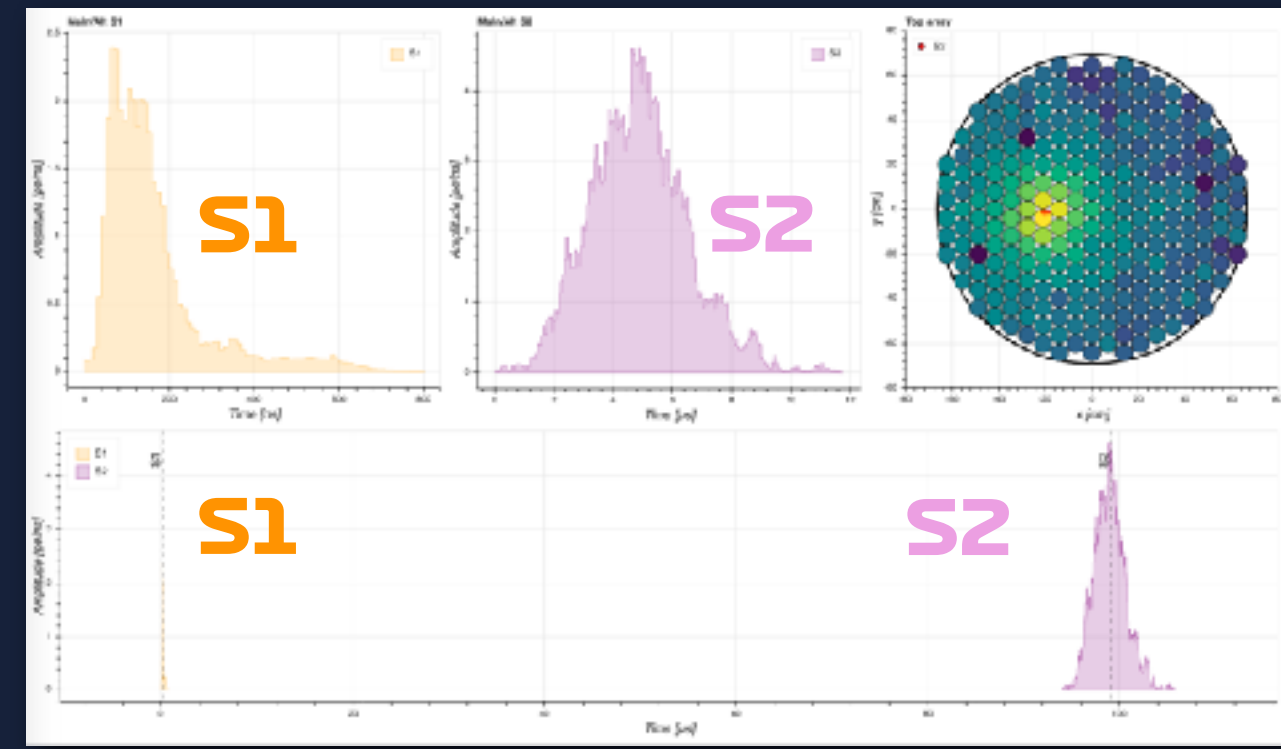
**LXe PUR**

- Electron lifetime: 0.6 → >10 ms
- Ultra low Rn emanation



**Rn DST**

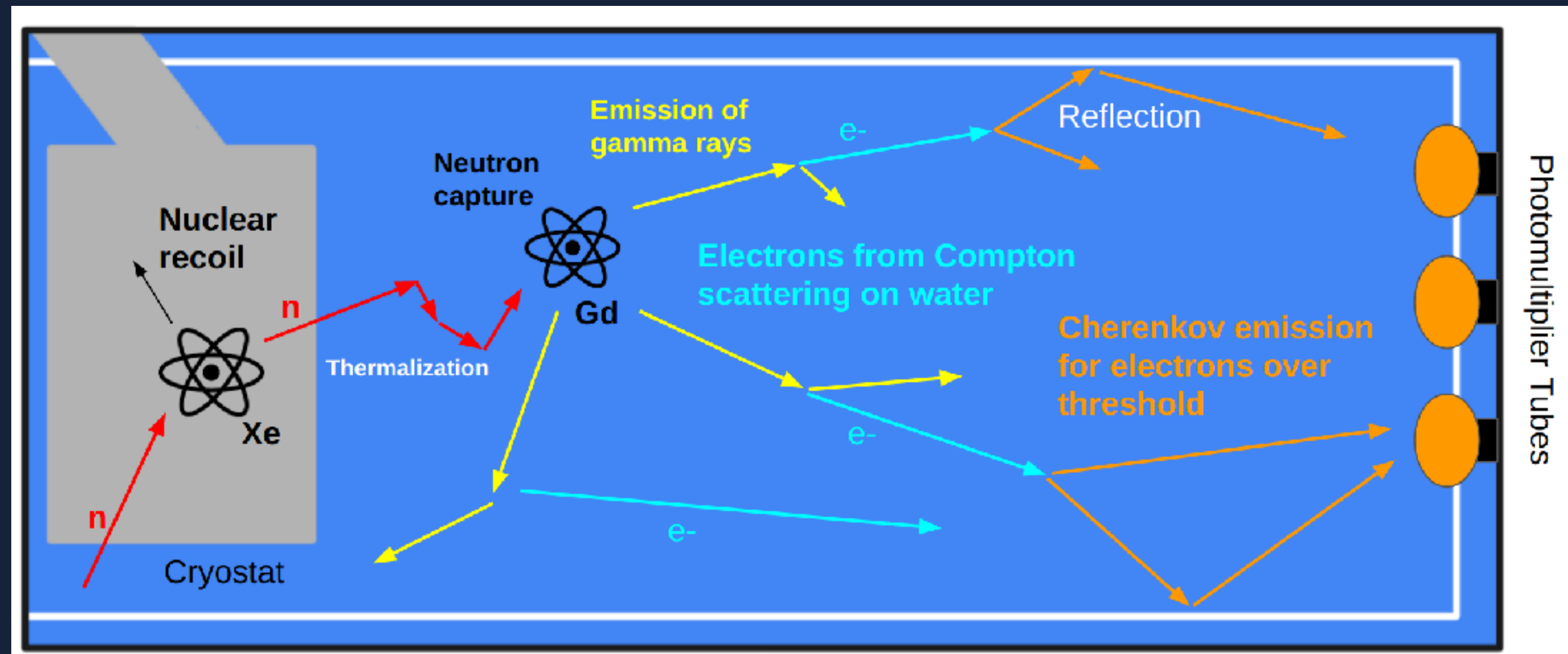
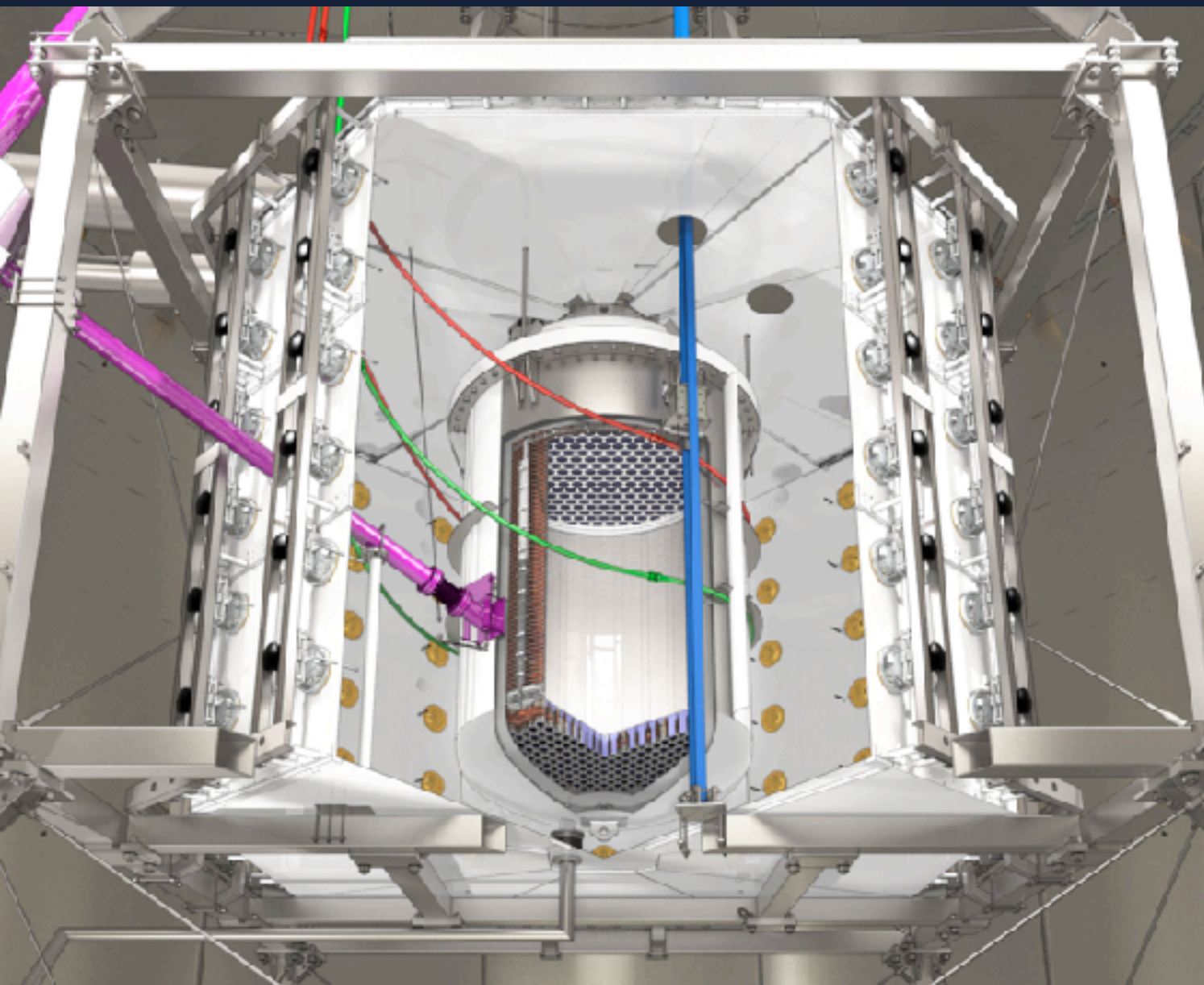
- Rn concentration: 13 → < 2 μBq/kg
- Goal 1 μBq/kg achievable



# Neutron Veto

## WORKING PRINCIPLE

- ⊗ Radiogenic neutrons scatter in the TPC (potential NR background event) and escape into the Neutron Veto
- ⊗ Neutrons captured in water by H ( $\sim 200 \mu\text{s}$ )  $\rightarrow$  2.2 MeV gamma emitted  $\rightarrow$  Cherenkov light



High light collection efficiency required:

- ⊗ 8" **high-QE** low-radioactivity PMTs
- ⊗ ePTFE coating **>99% reflectivity**
- ⊗ High water **transparency**

# Neutron Veto

[Bologna leads the Neutron Veto WG, responsible: Marco Selvi]

Novel system designed, built and managed under the responsibility of INFN groups and Bologna in particular.

Responsible of the construction and installation onsite:  
**Gabriella Sartorelli**

Crucial contribution by **INFN Bologna**:

- **STG** (special thanks to A. Chiarini)
- **Progettazione** (Ing. Guerzoni and R. Michinelli)
- **Officina Meccanica** (A. Margotti, G. Pancaldi)
- **Amministrazione** (M. Allegro and the whole staff)
- **Direzione**

Realized in a delicate situation under COVID-19 emergency [Summer 2020]



**XENON**

## THE MAKING OF NEUTRON VETO

Constant presence onsite @ LNGS for XENON to work on Neutron Veto and Gd Plant (XENON has the highest number of INFN missions over the last 2 years of COVID emergency)





# Neutron Veto

Gd PLANT

- **CURRENT CONFIGURATION:** Tank filled with demi-water
- **IN PREPARATION:** novel upgrade doping water with Gadolinium sulphate with 0.5% mass concentration
- Gd-water purification plant under commissioning at LNGS



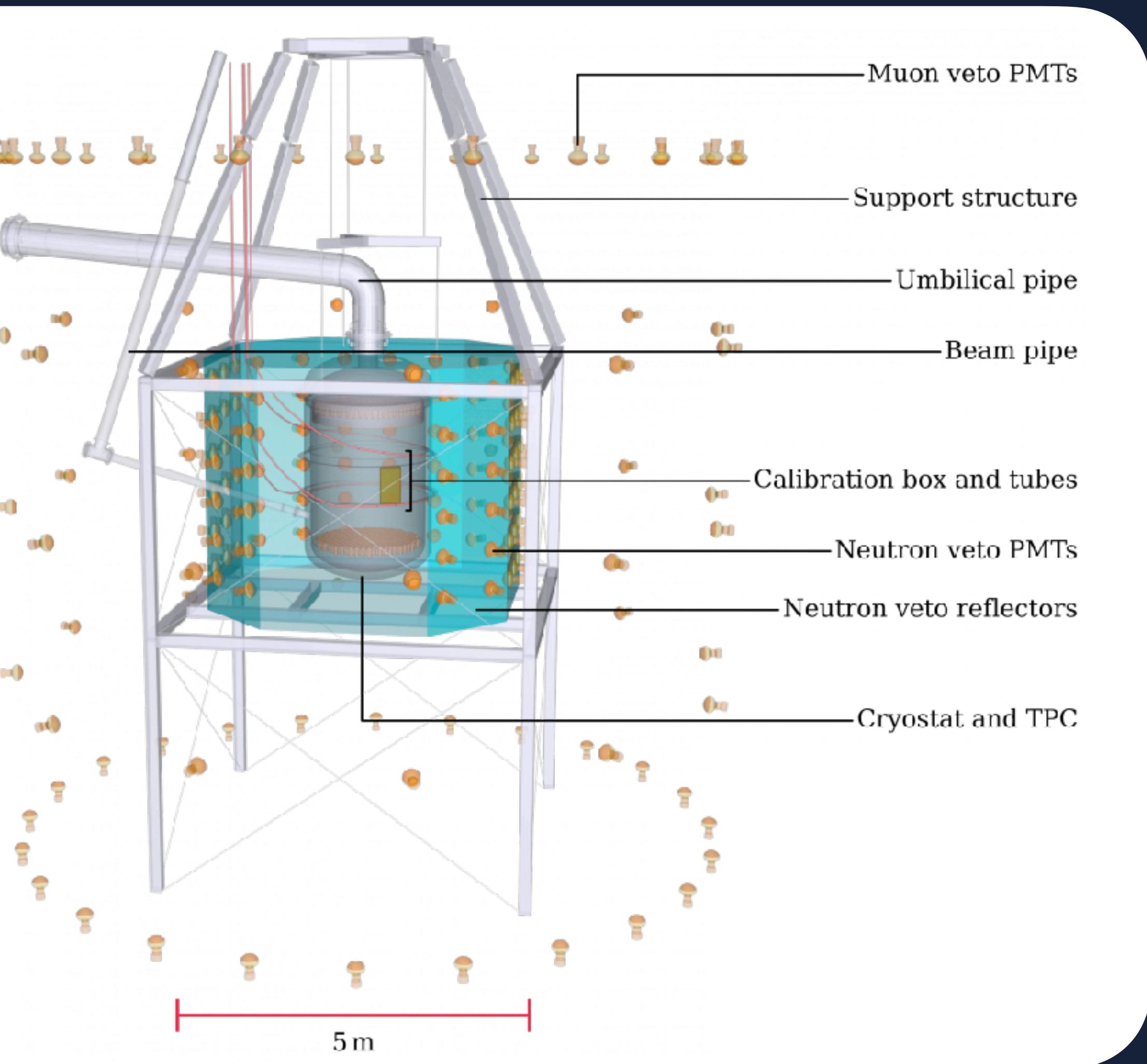
90% of neutron captures on Gd  
→ emitted a gamma cascade of ~8 MeV  
→ Higher detection efficiency



Pietro Di Gangi | 28.03.2022

# Neutron Veto

MC SIMULATIONS (Bologna leads the XENON MC WG, responsible: Pietro Di Gangi)



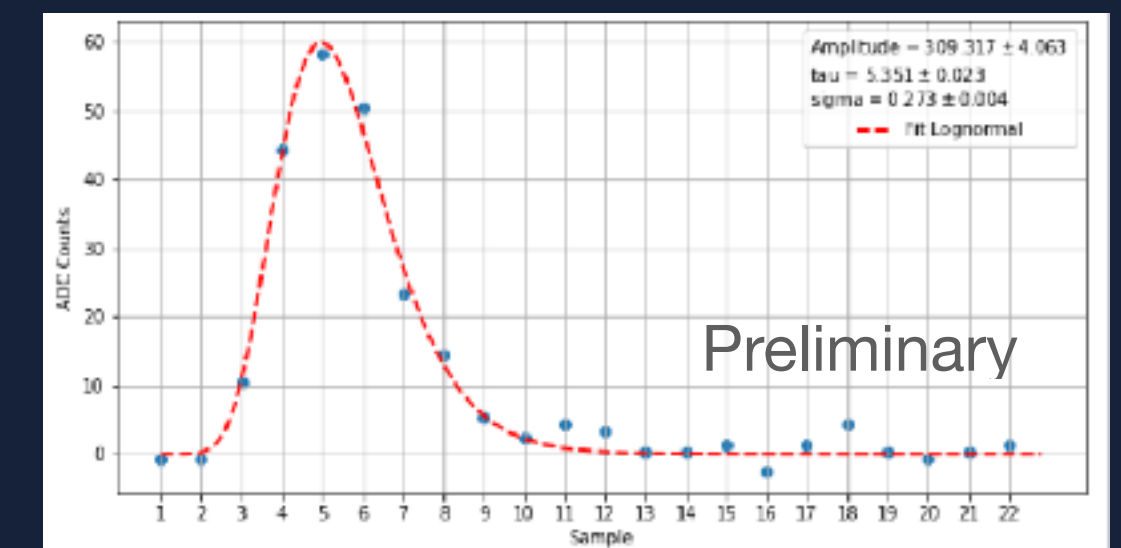
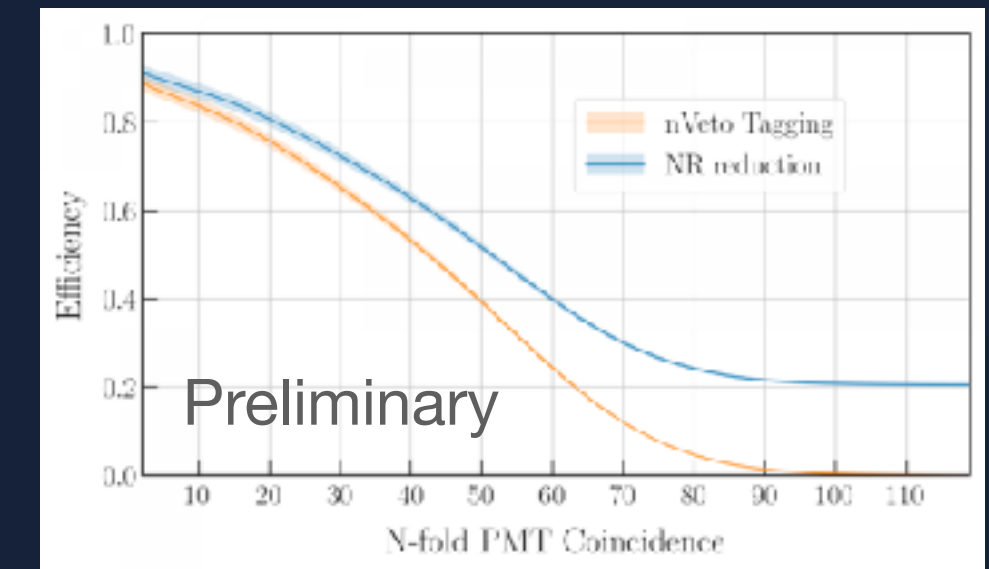
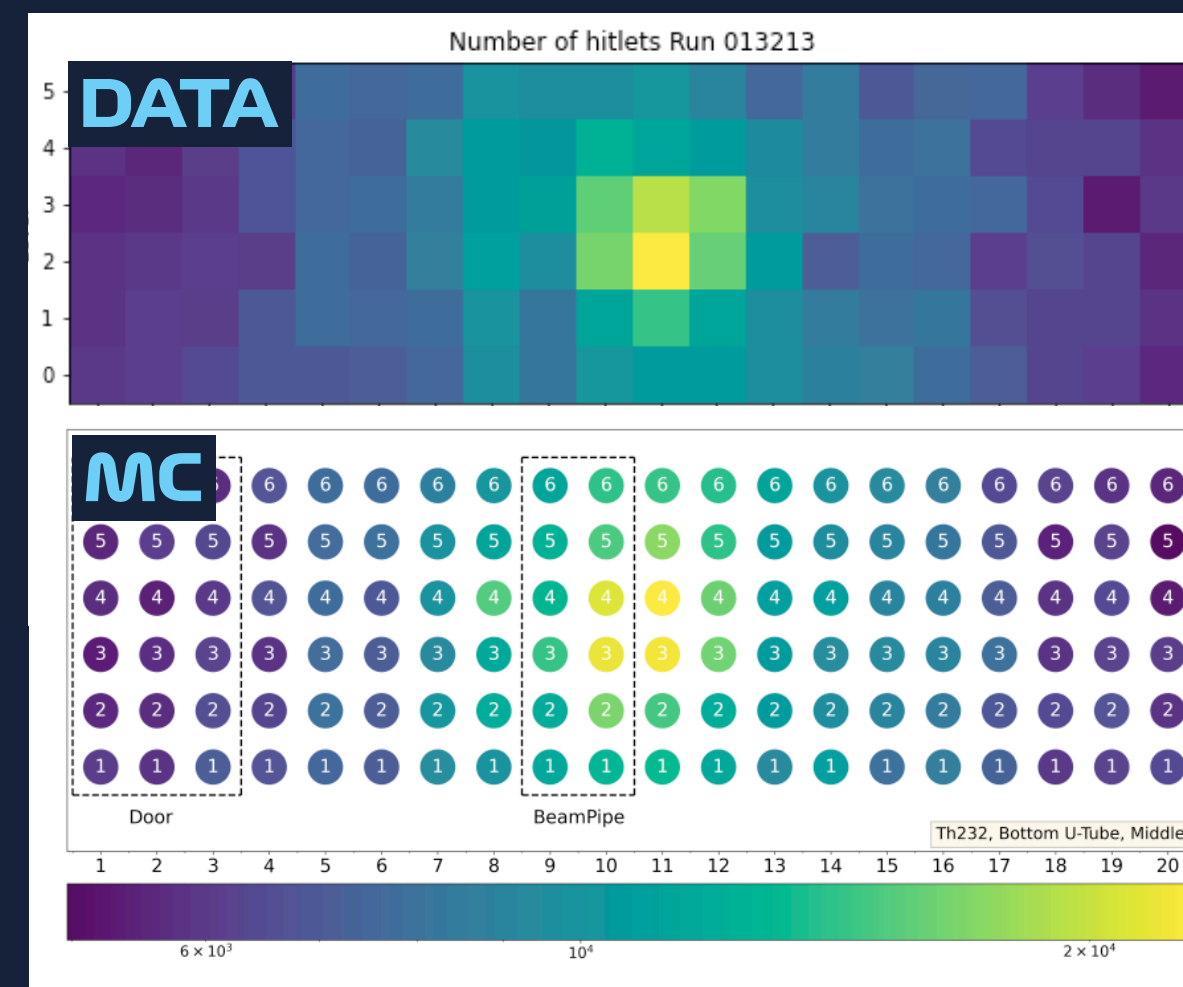
Neutron Veto fully reproduced with Geant4 for design, background and performance studies

Dedicated waveform simulator under development

Expected **TAGGING EFFICIENCY**

(@ 10-fold PMT coincidence requirement):

- 65% in pure water
- 87% in Gd-doped water



# Neutron Veto

## SUCCESSFUL COMMISSIONING

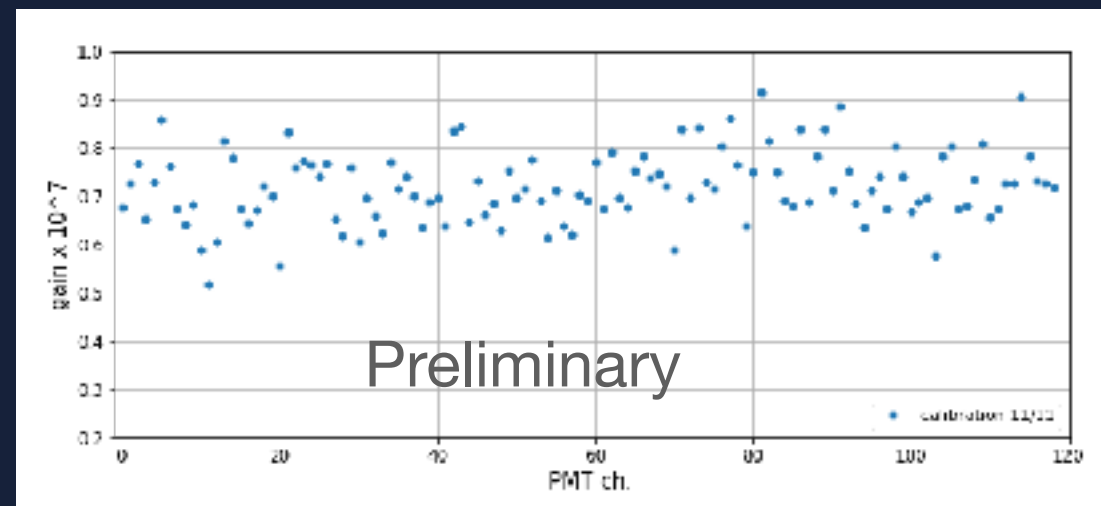
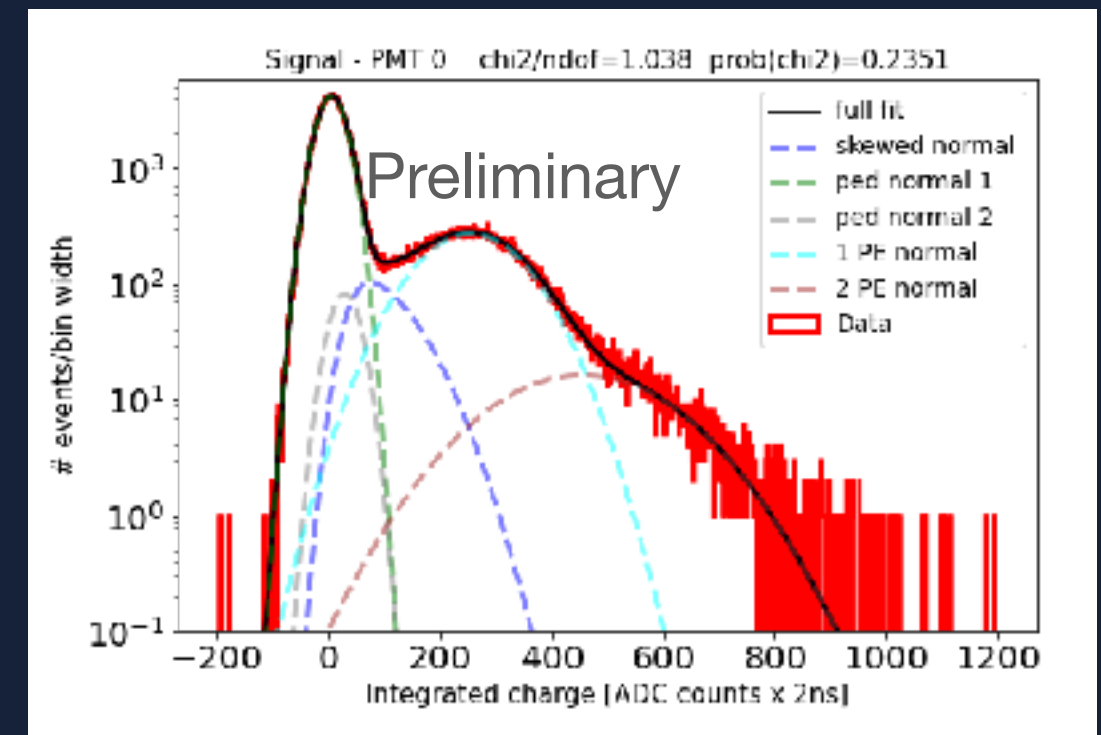


### PMT CALIBRATIONS

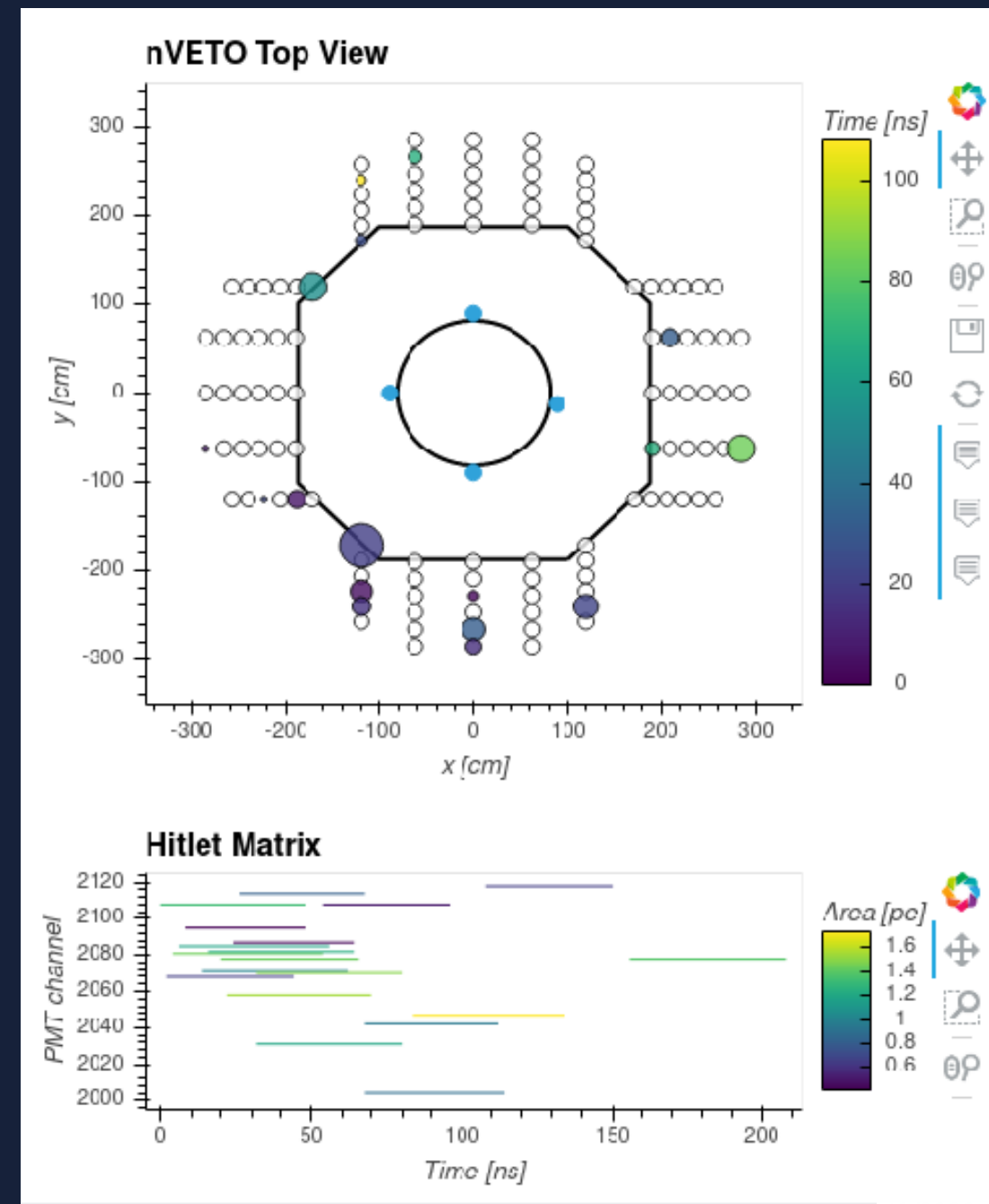
Weekly per-PMT LED calibrations

- Single photoelectron spectrum modelling
- Gain monitoring
- Dark rate:  $\sim 700$  Hz
- High SPE acceptance

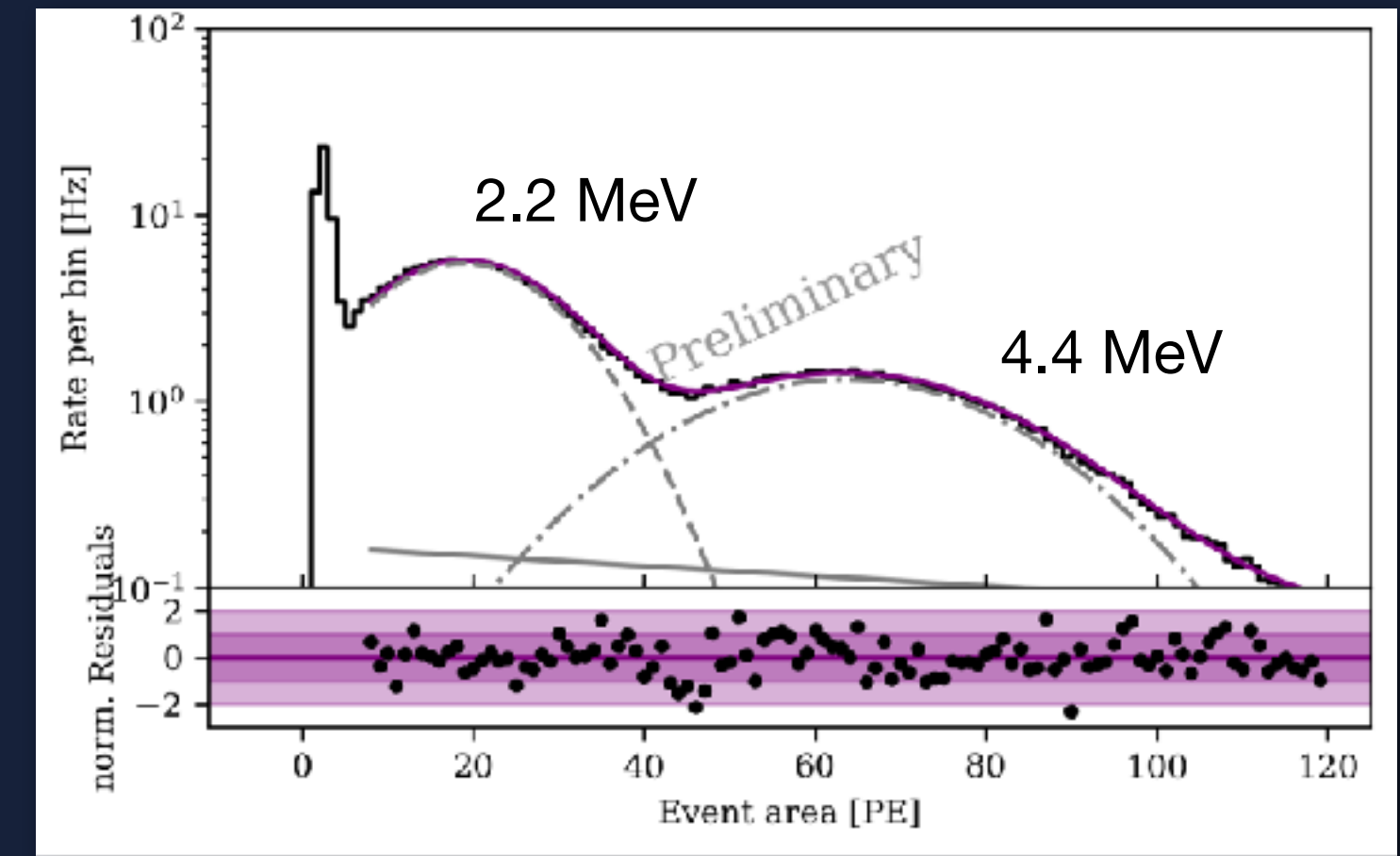
### Excellent PMTs' performance



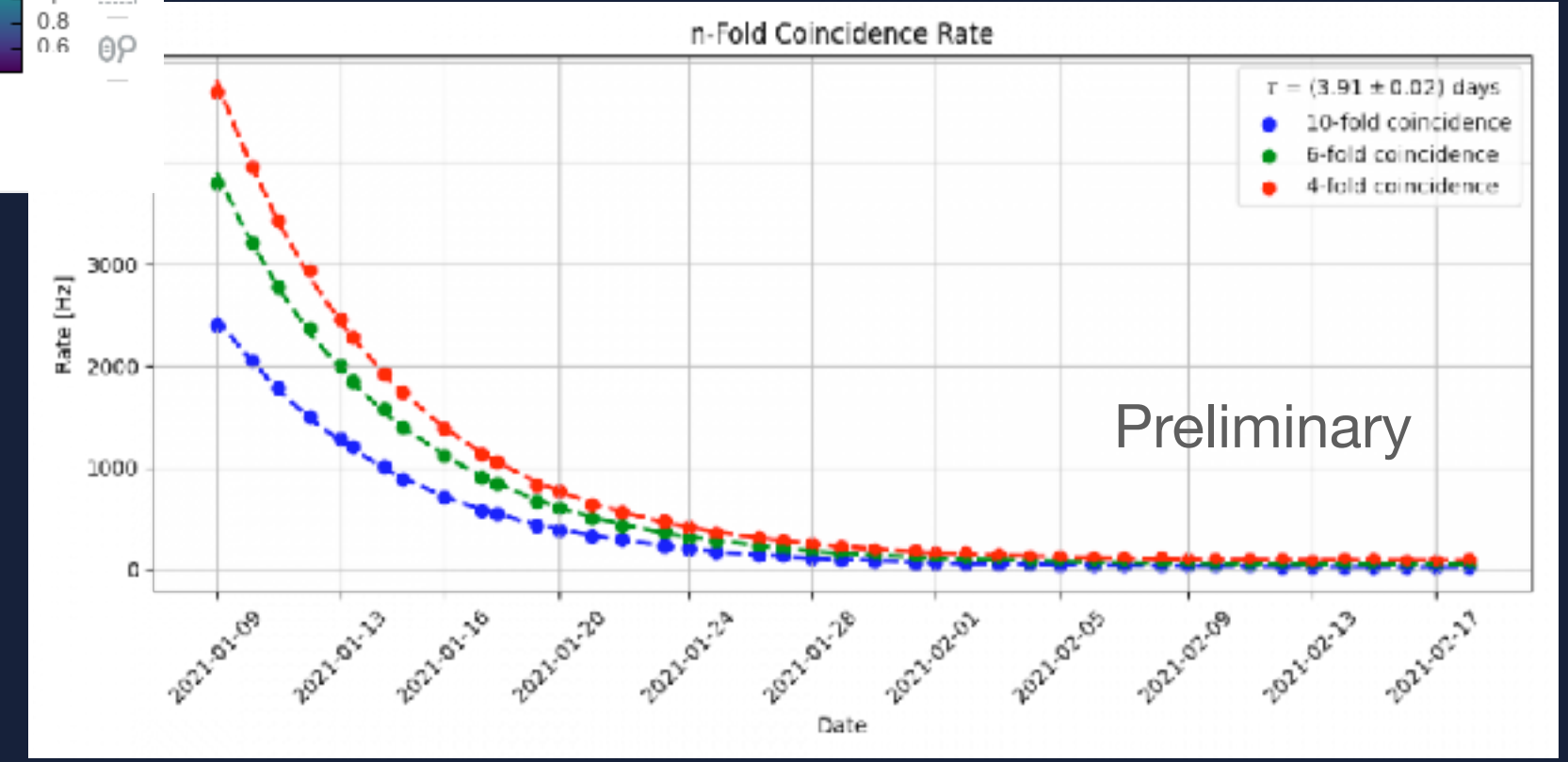
A real event



Energy spectrum:  
 n capture on H  
 gamma from AmBe calibration source



Background rate:  
 $\sim 30$  Hz  
 (Initial decrease due to Rn decay)



# Neutron Veto

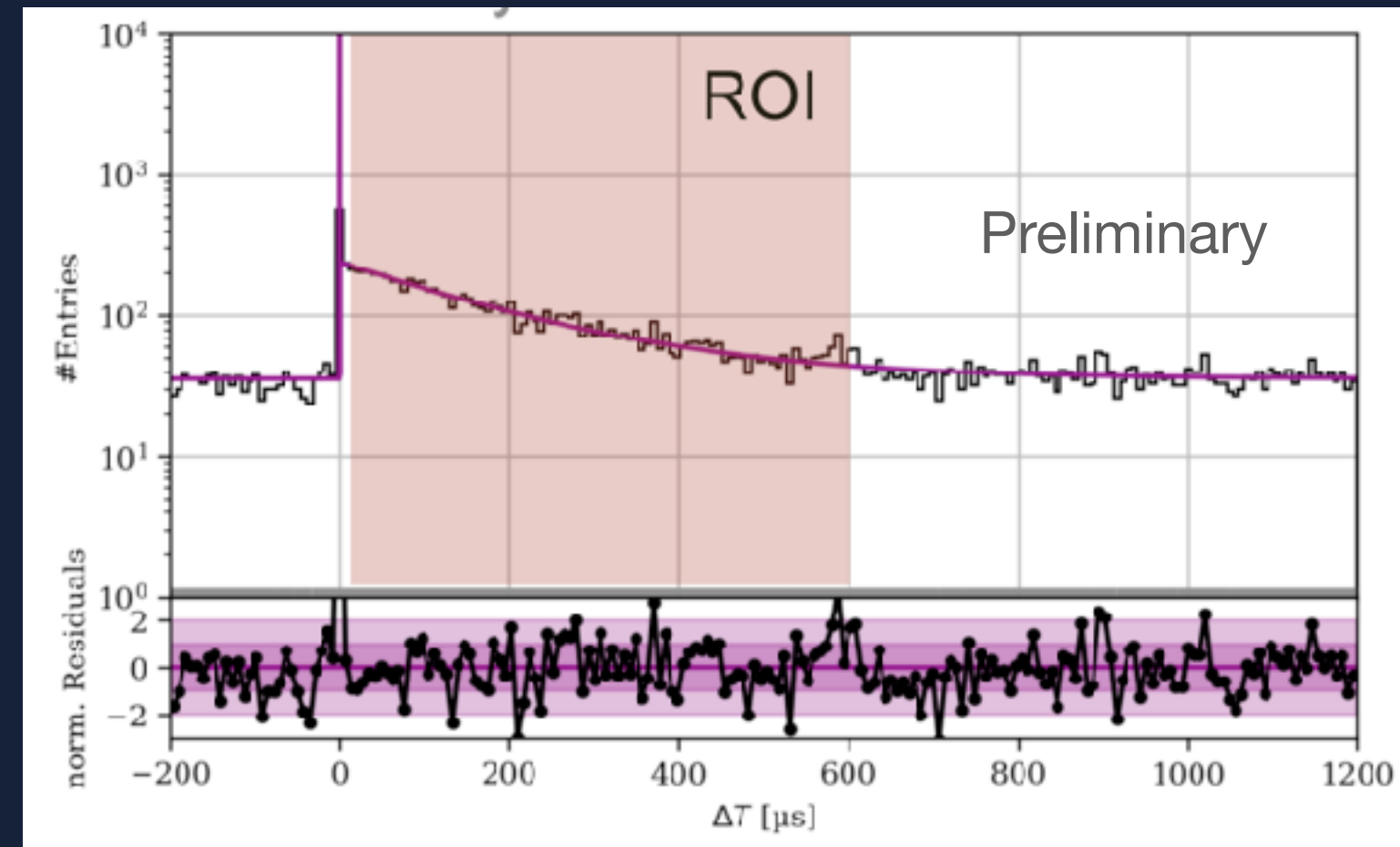
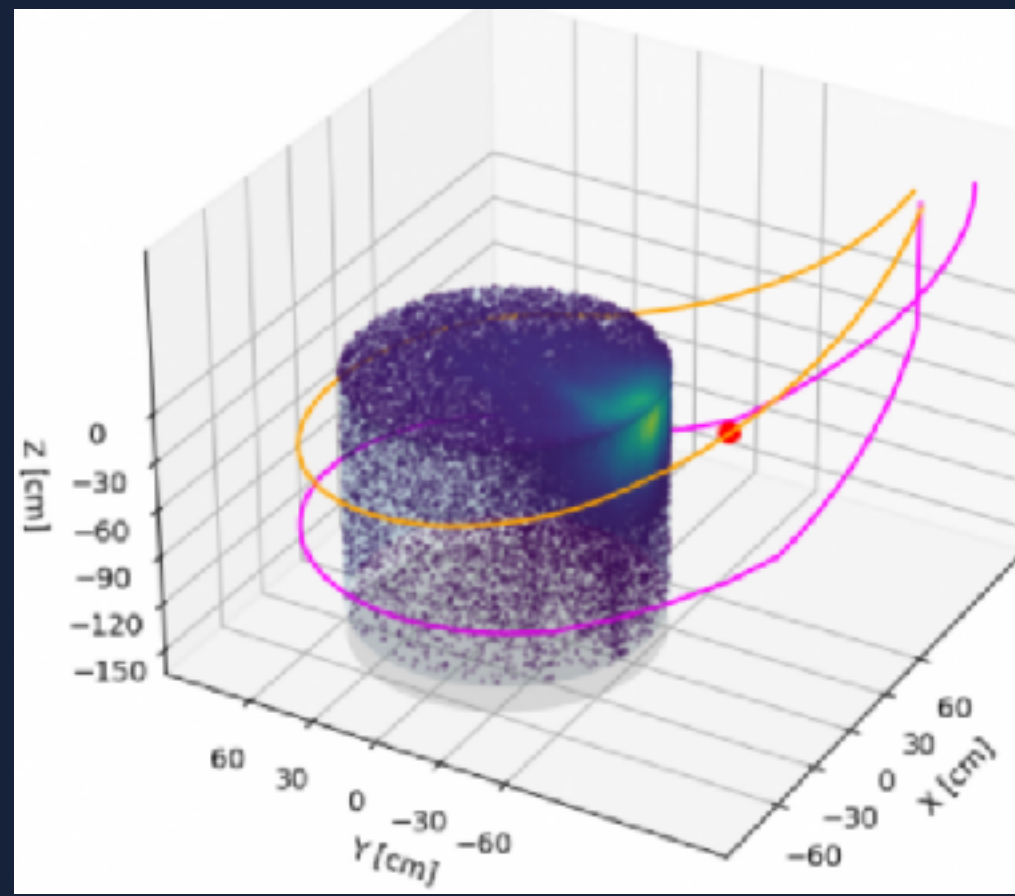
## CALIBRATION



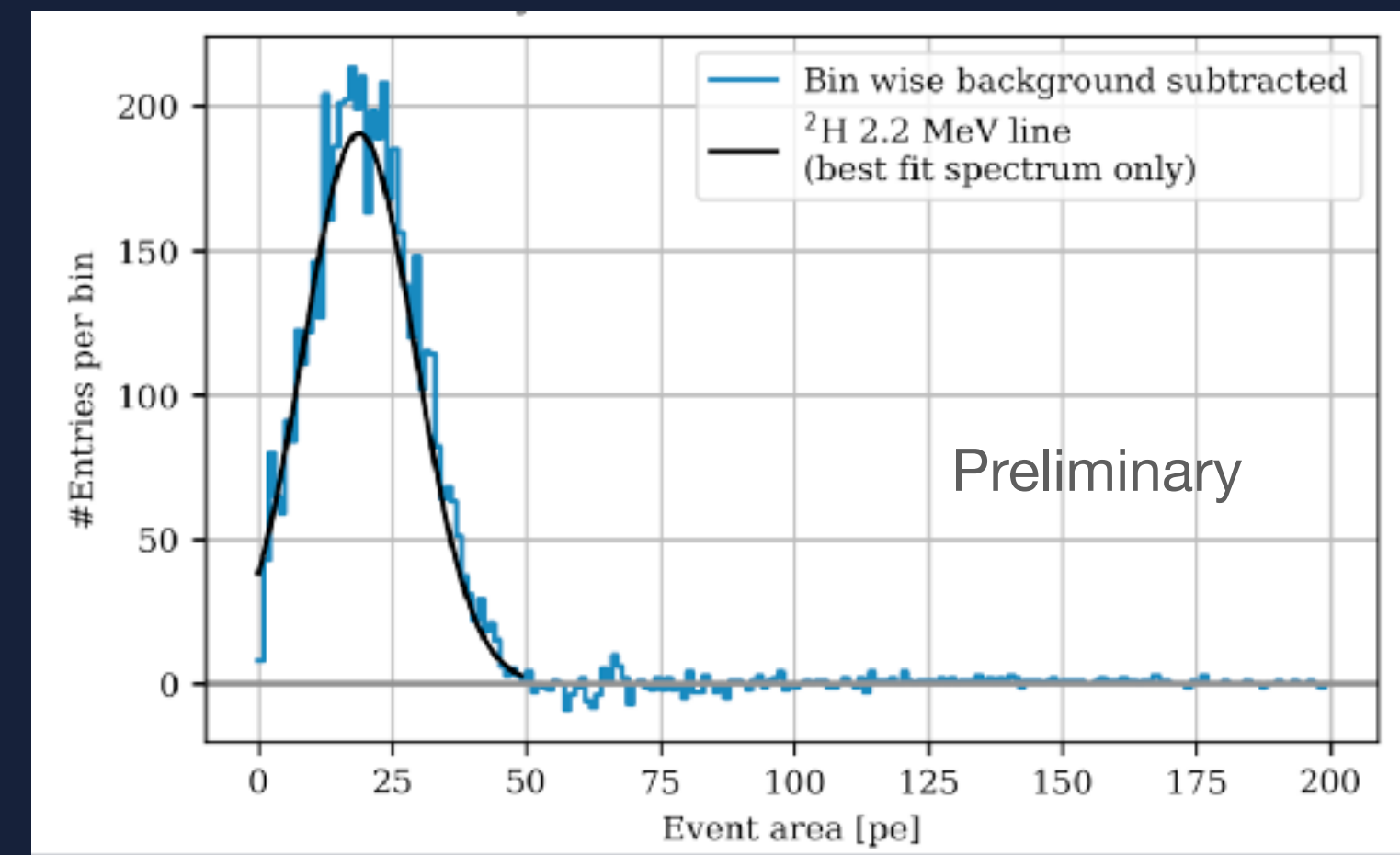
**AmBe** calibration source deployed inside the Neutron Veto through U-tubes

It emits **neutrons + 4.4 MeV gamma** (60% prob.)

Look for neutron capture signals (H line 2.2 MeV) in **coincidence** with the 4.4 MeV gamma detected in the TPC



Delay between TPC and NV:  $190 \mu\text{s}$   
(matching MC prediction)



Neutron capture peak observed by NV



Preliminary

Neutron Veto **efficiency** in detecting emitted neutrons:

**~90%** @ 5 PE threshold

**Highest neutron detection efficiency ever measured by a water Cherenkov detector!**

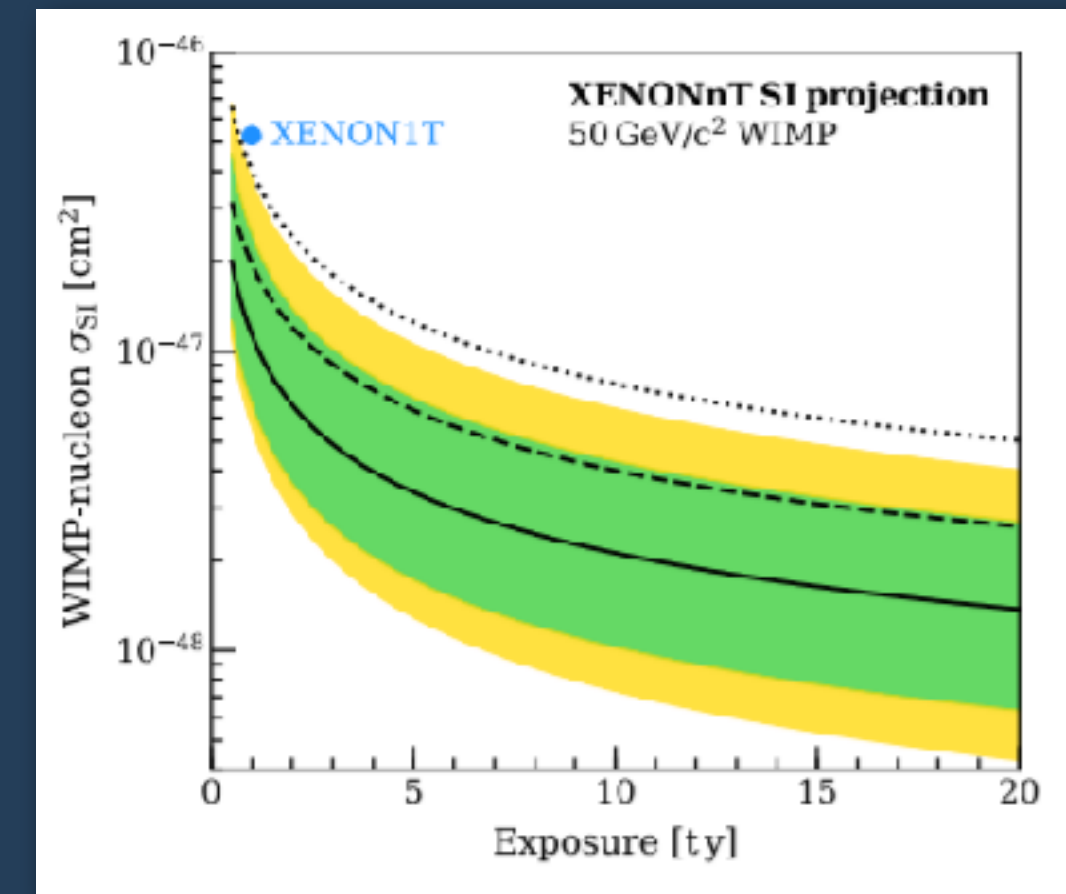
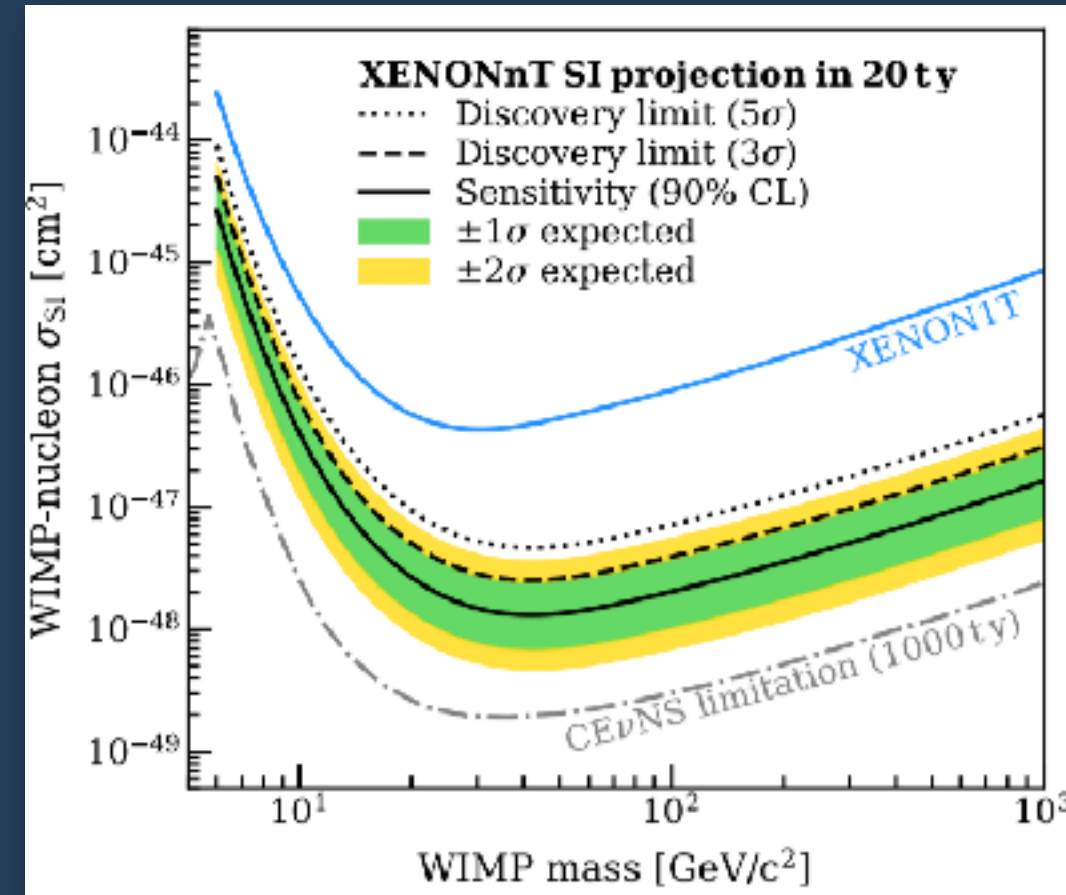
# XENONnT Physics Reach

JCAP 11 (2020) 031 (Bologna's corresponding author: Pietro Di Gangi)



## Expected WIMP-nucleon cross section

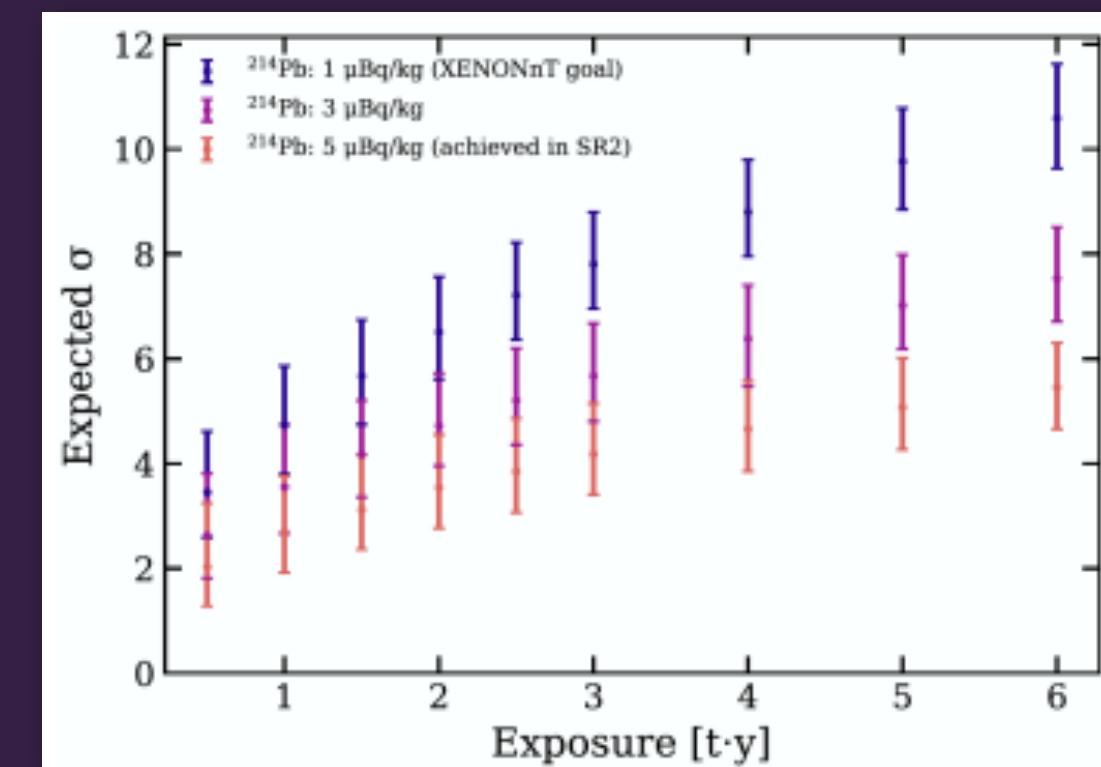
- Exposure Goal : 20 t x y
- $>O(10)$  improvement wrt XENON1T



## 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  $5\sigma$  level



# Data acquisition is ongoing... XENONnT's First Results expected in few months...



[web.bo.infn.it/xenon](http://web.bo.infn.it/xenon)



[www.xenonexperiment.org](http://www.xenonexperiment.org)  
[xe-pr@lngs.infn.it](http://xe-pr@lngs.infn.it)



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