



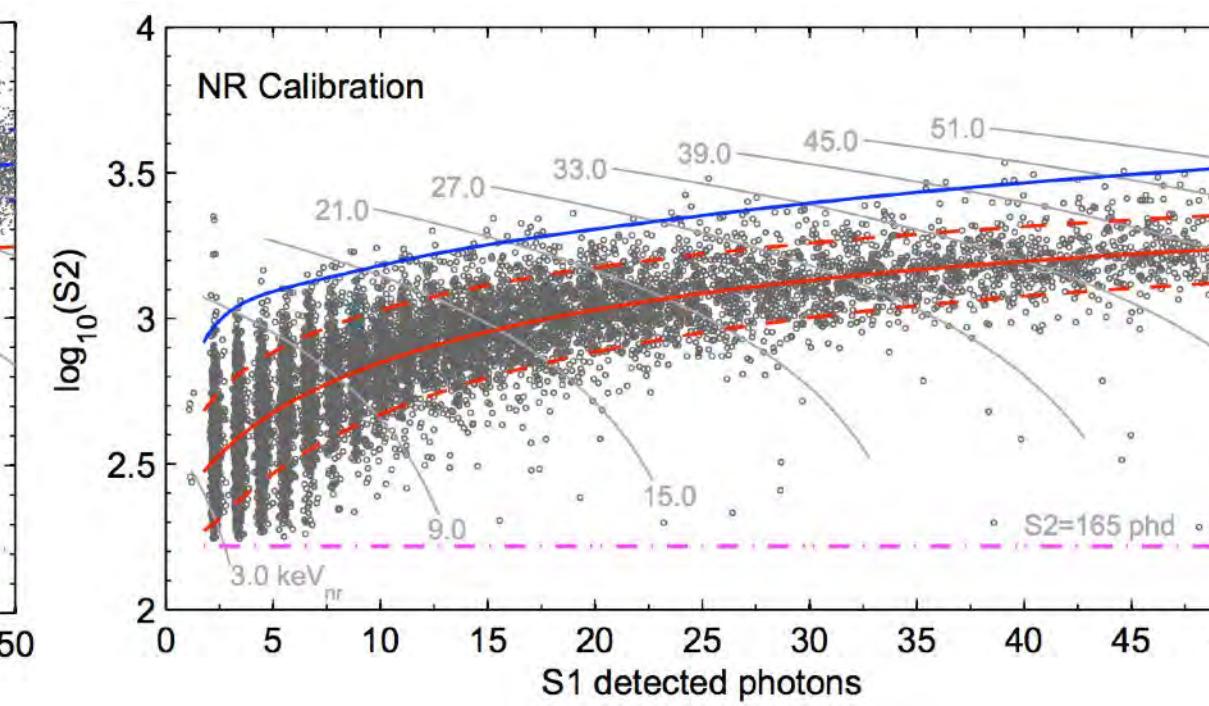
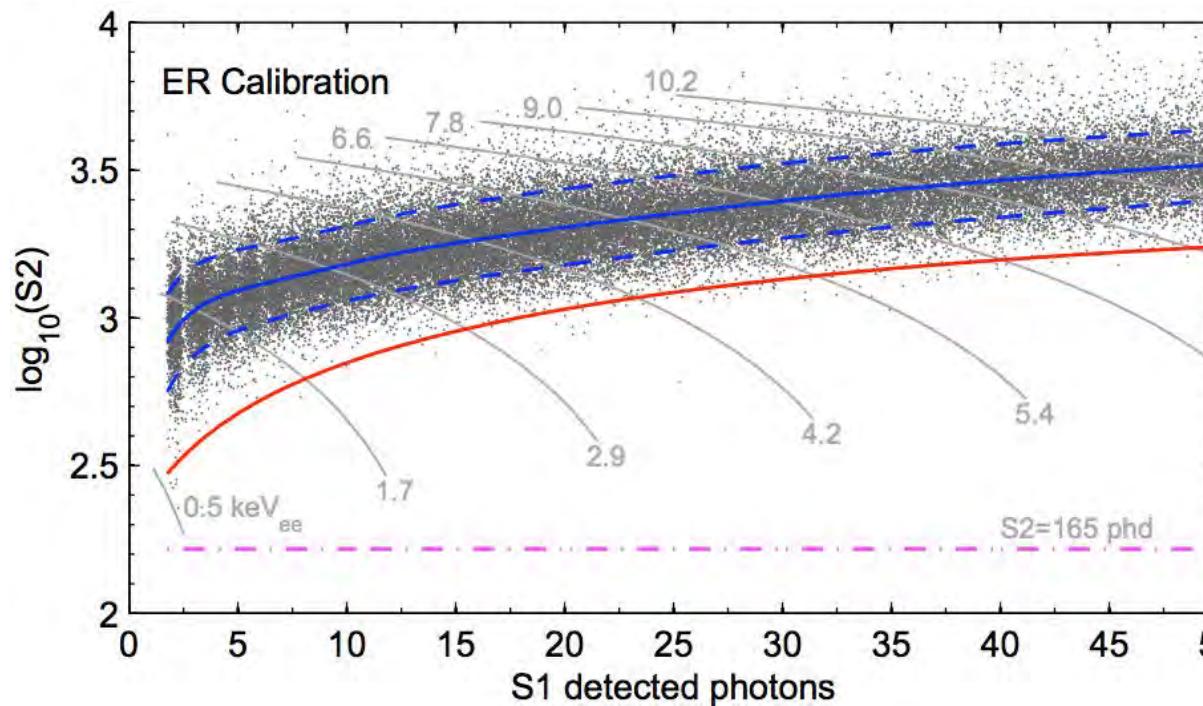
# Status of the LZ Dark Matter Experiment



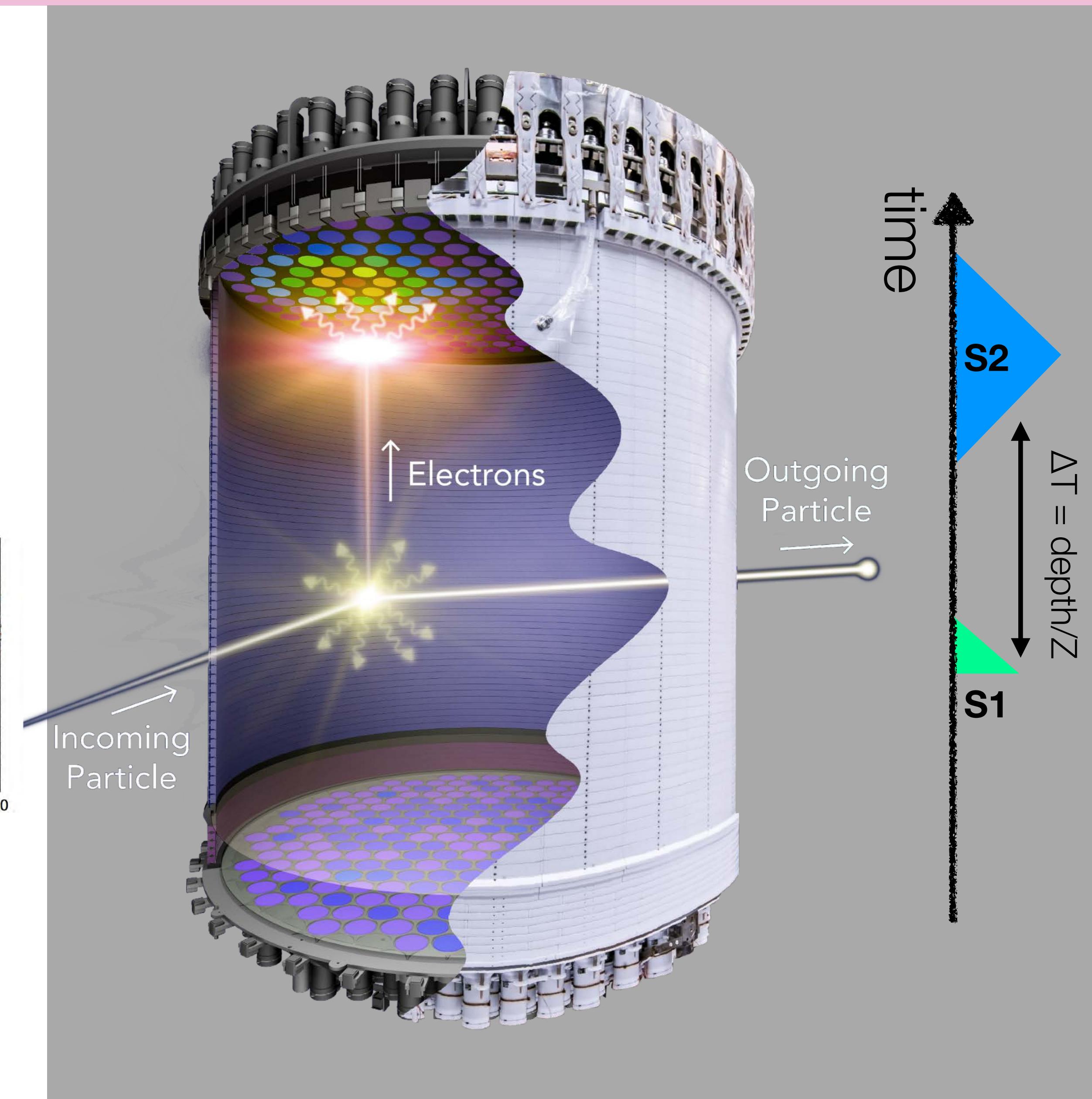


# Direct Detection with Dual-Phase LXe TPCs

- Primary signal is **nuclear recoil** of a xenon atom. Most backgrounds are electron recoils.
- Two signals: scintillation (S1) in LXe and ionisation (S2) in GXe
  - ER/NR **discrimination** from ratio of S1 and S2 signals



- 3D position reconstruction - XY from PMT array, Z from  $\Delta t$  between S1 and S2





# The LZ Collaboration

- 1) Center for Underground Physics (South Korea)
- 2) LIP Coimbra (Portugal)
- 3) MEPhI (Russia)
- 4) Imperial College London (UK)
- 5) Royal Holloway University of London (UK)
- 6) STFC Rutherford Appleton Lab (UK)
- 7) University College London (UK)
- 8) University of Bristol (UK)
- 9) University of Edinburgh (UK)
- 10) University of Liverpool (UK)
- 11) University of Oxford (UK)
- 12) University of Sheffield (UK)
- 13) Black Hill State University (US)
- 14) Brandeis University (US)
- 15) Brookhaven National Lab (US)
- 16) Brown University (US)
- 17) Fermi National Accelerator Lab (US)
- 18) Lawrence Berkeley National Lab (US)
- 19) Lawrence Livermore National Lab (US)
- 20) Northwestern University (US)
- 21) Pennsylvania State University (US)
- 22) SLAC National Accelerator Lab (US)
- 23) South Dakota School of Mines and Technology (US)
- 24) South Dakota Science and Technology Authority (US)
- 25) Texas A&M University (US)
- 26) University at Albany (US)
- 27) University of Alabama (US)
- 28) University of California, Berkeley (US)
- 29) University of California, Davis (US)
- 30) University of California, Santa Barbara (US)
- 31) University of Maryland (US)
- 32) University of Massachusetts (US)
- 33) University of Michigan (US)
- 34) University of Rochester (US)
- 35) University of South Dakota (US)
- 36) University of Wisconsin – Madison (US)
- 37) Washington University in St. Louis (US)
- 38) Yale University (US)

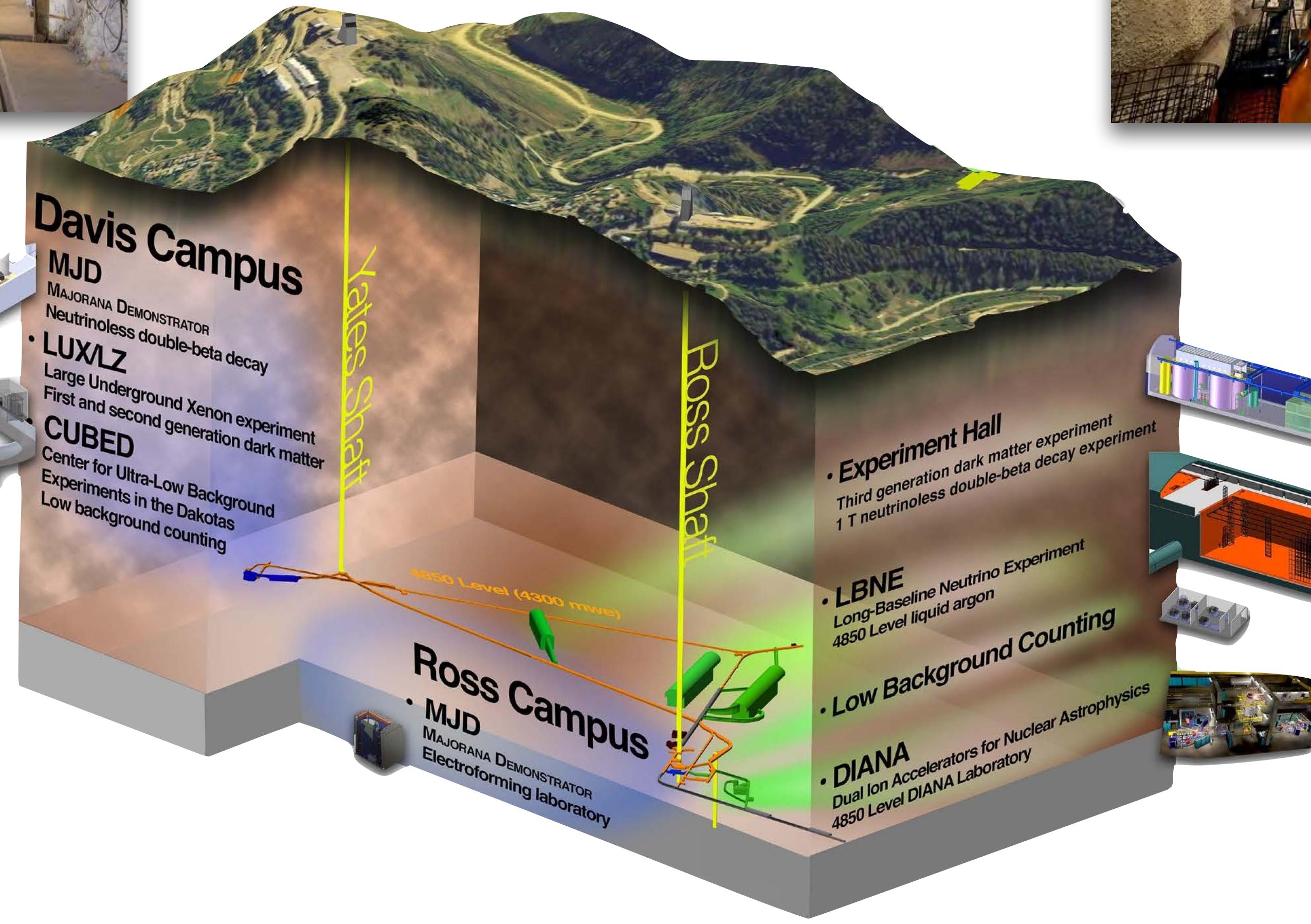


**38 institutions across the US, UK, Portugal and South Korea**

**250 scientists, engineers, and technicians**

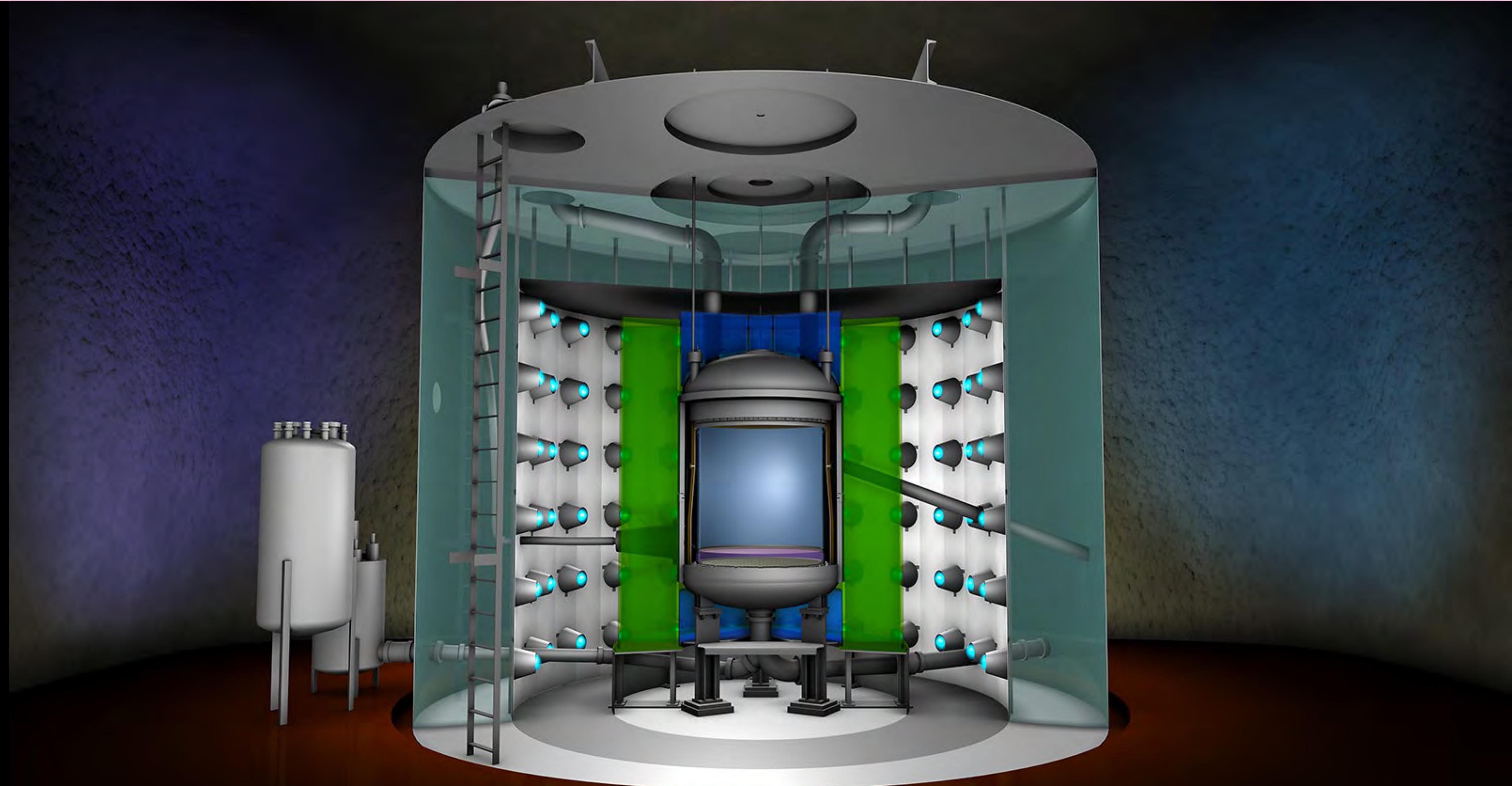


# The Sanford Underground Research Facility



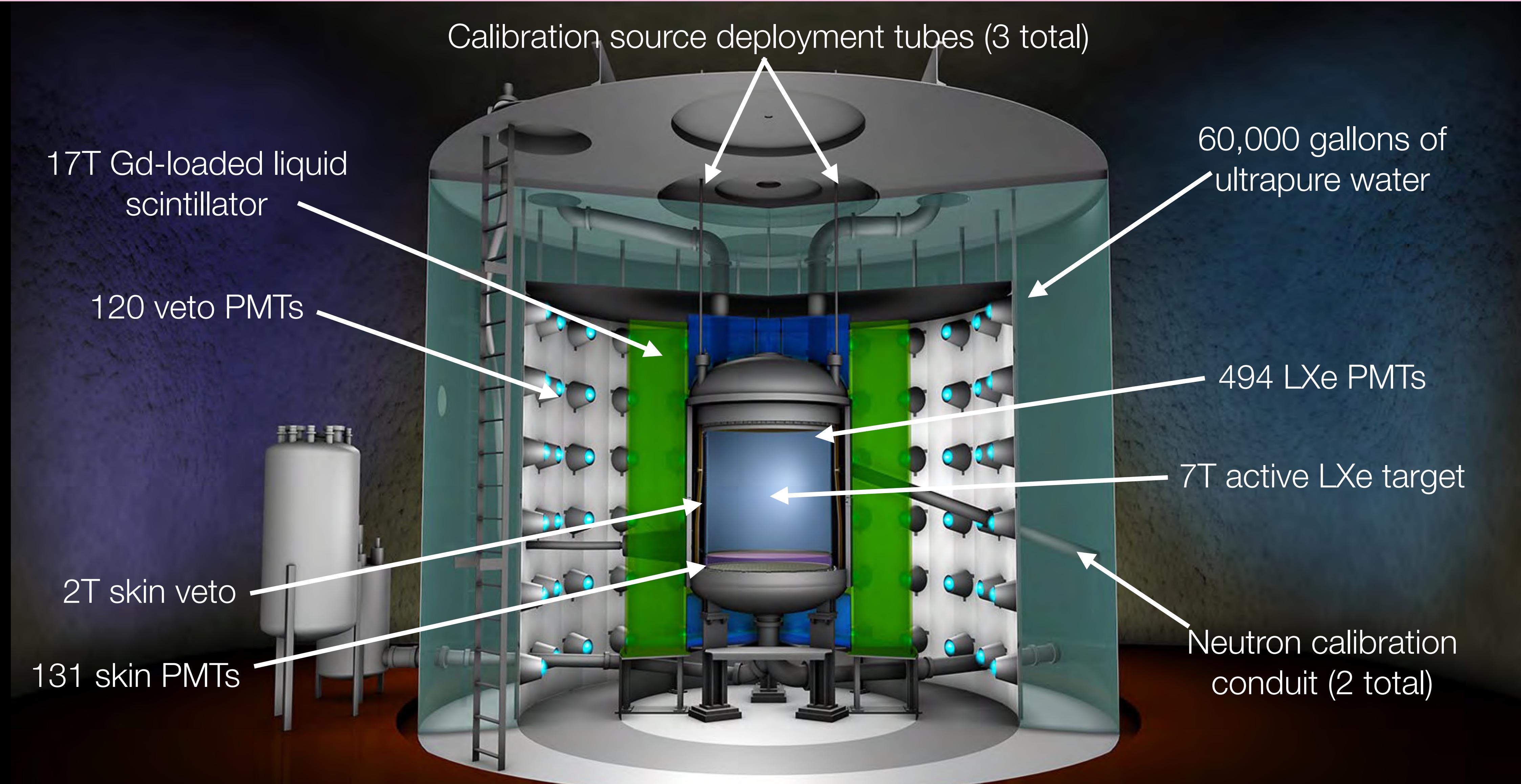


# The LZ Detector





# The LZ Detector





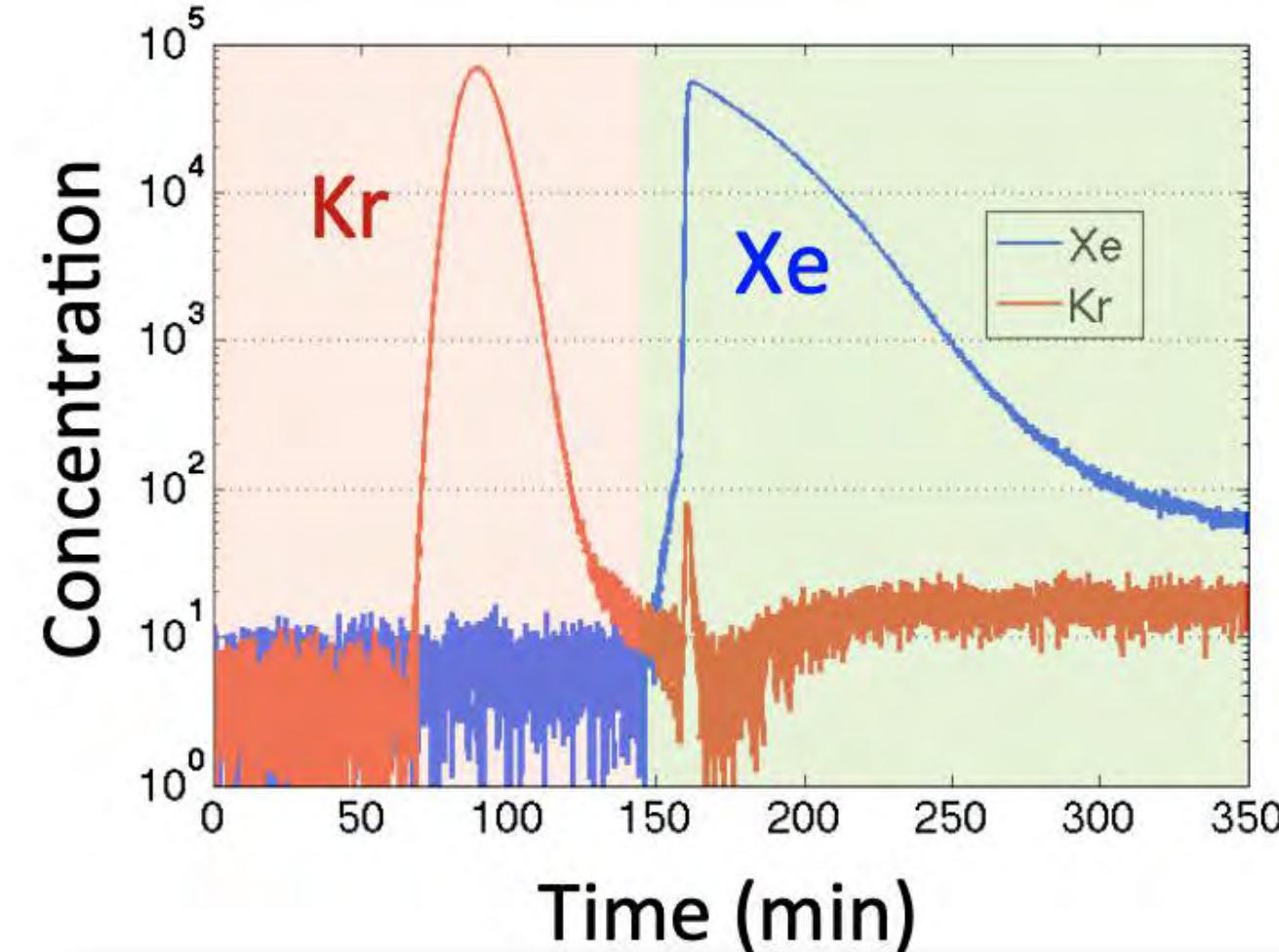
# Xenon

10T total Xenon, undergoes:

- Krypton removal at SLAC\*
  - **Gas charcoal chromatography**
  - Goal: < 300 ppg  $^{nat}\text{Kr}/\text{Xe}$
- Online purification of GXe
  - **Hot zirconium getter** removes electronegative impurities
  - Full 10T purified every 2.4 days
- Radon removal
  - Inline radon removal system uses **activated carbon trap**, 10x reduction of radon in 1 pass

\* see talk by D. Ames, Friday at 11am

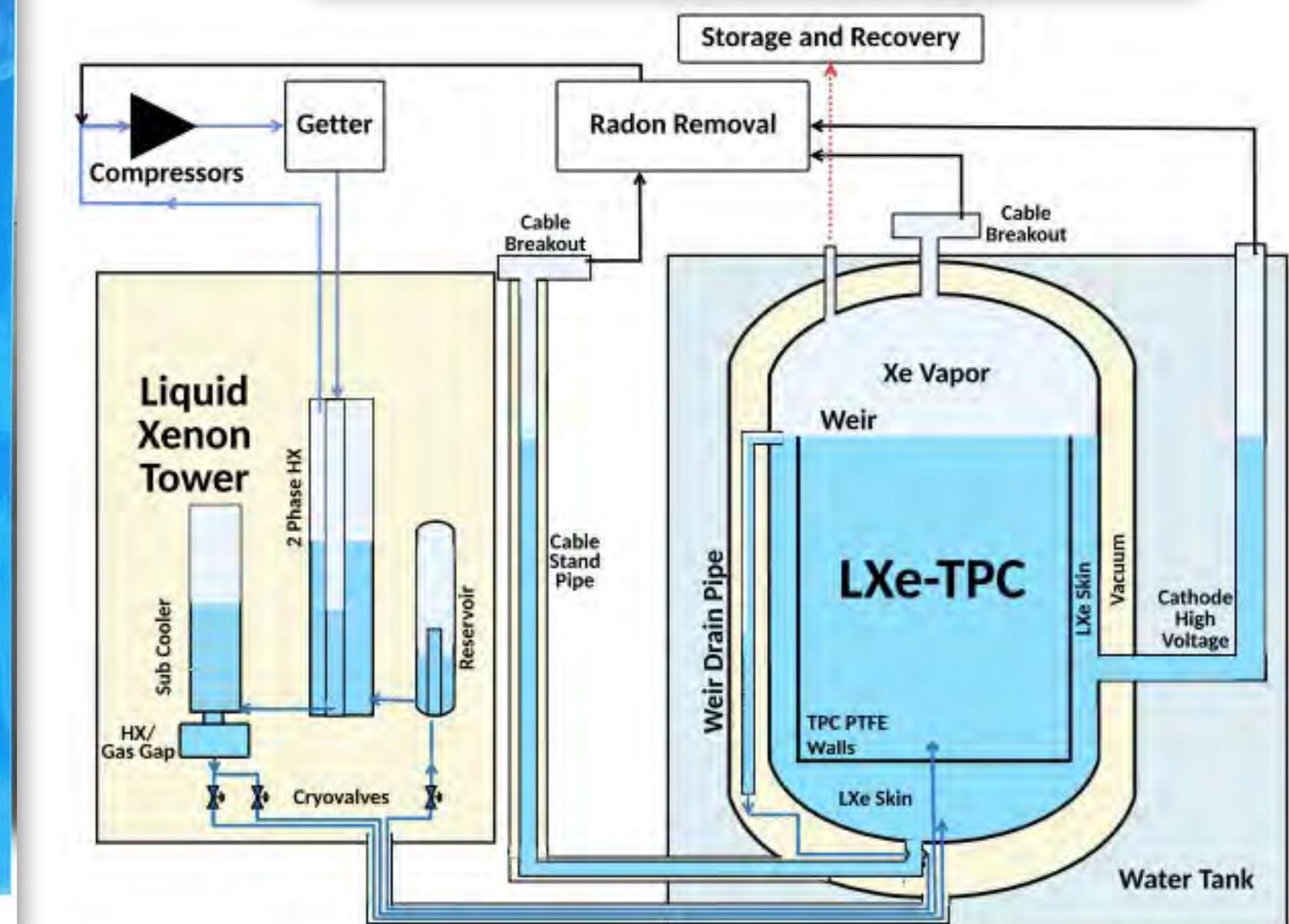
The LZ Krypton Removal Chromatography System



Radon reduction system at SURF



Krypton removal system at SLAC

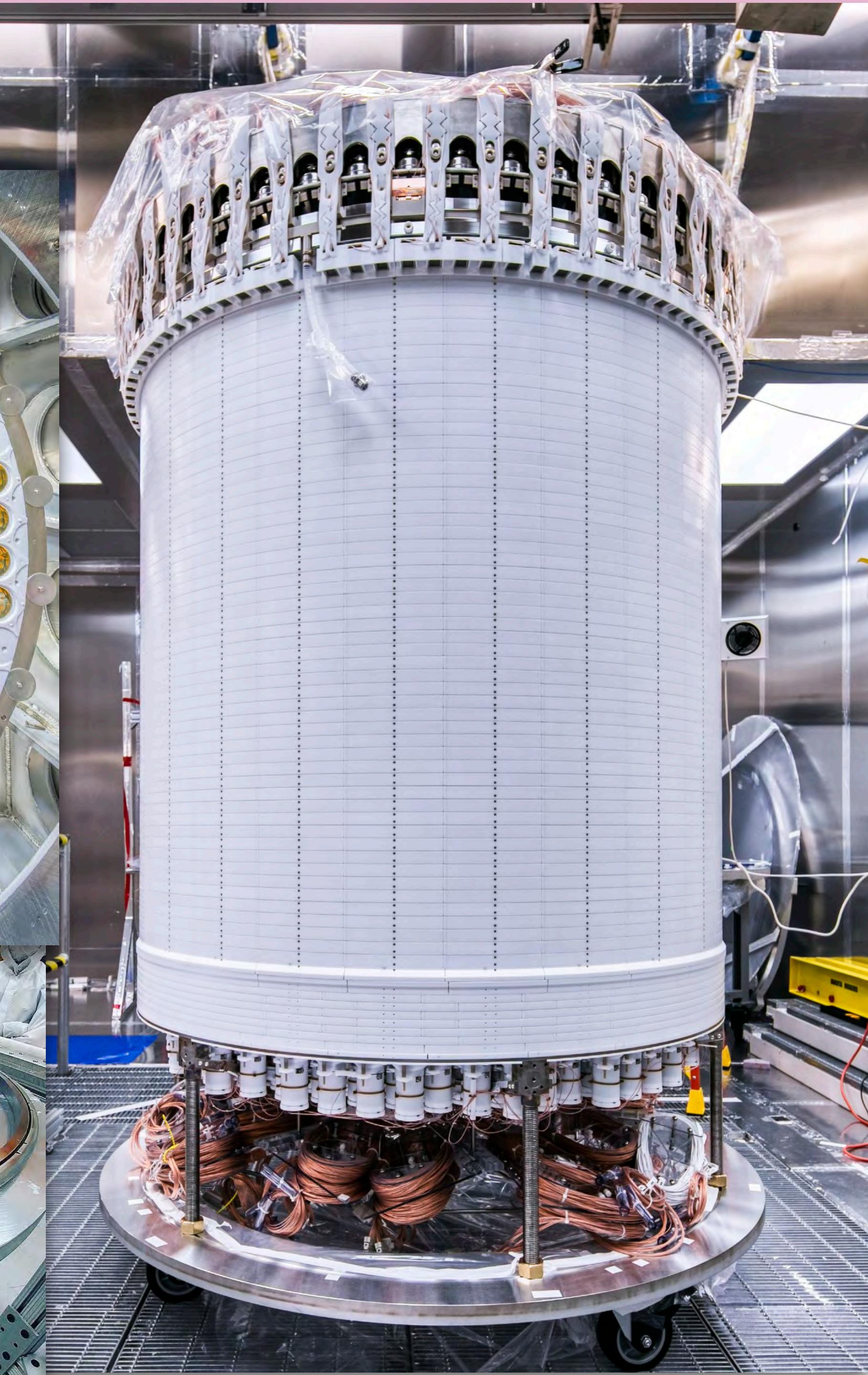
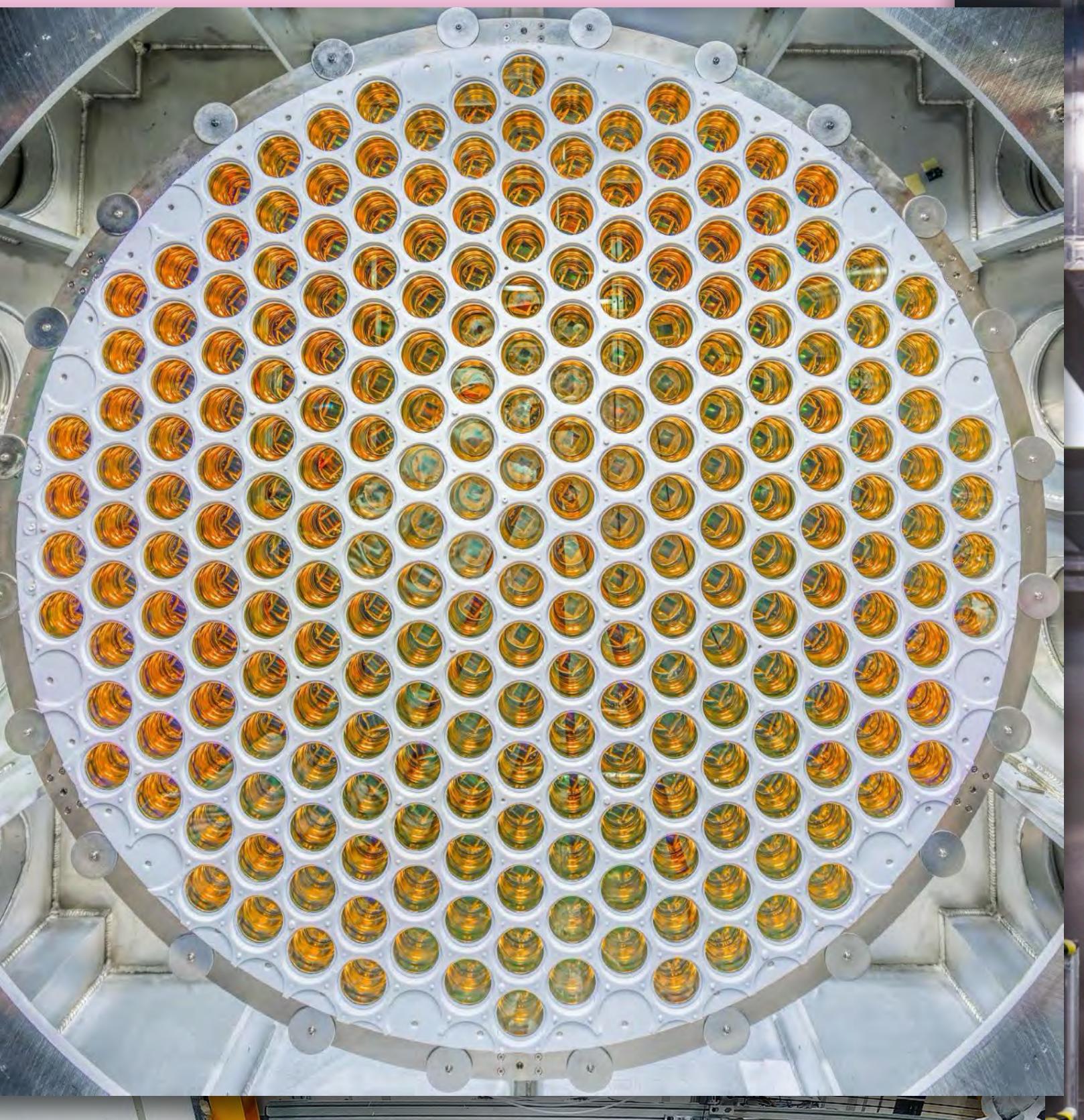




# Time Projection Chamber

- 2 PMT arrays of Hamamatsu R11410-20 PMTs (494 total)
- 4 electrodes/grids woven on specialized looms and **passivated** to reduce e- emission\*
- 57 field rings embedded in reflective PTFE → **310V/cm drift field**
- TPC completed August 2019
- Inserted into ICV at surface assembly lab

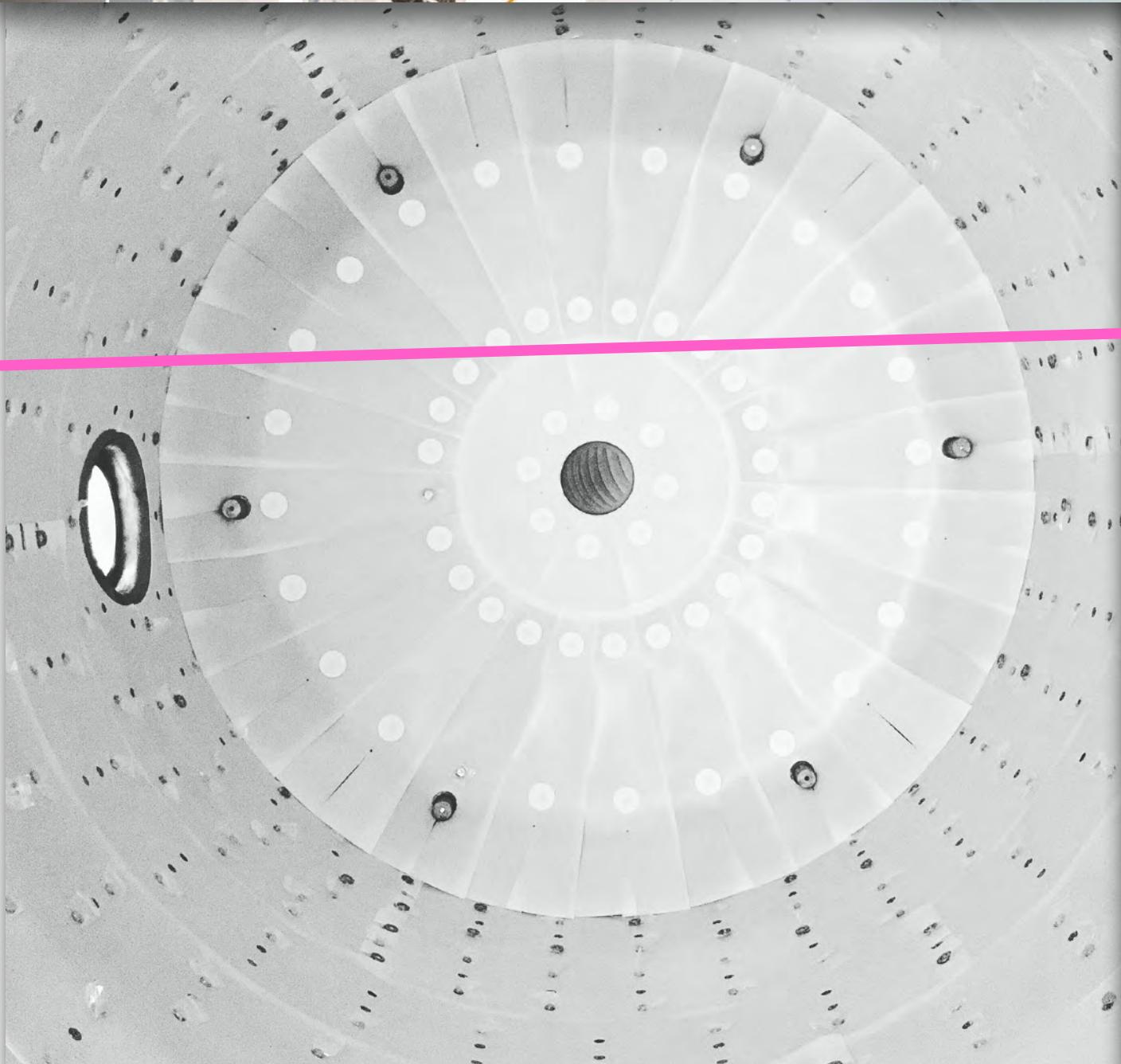
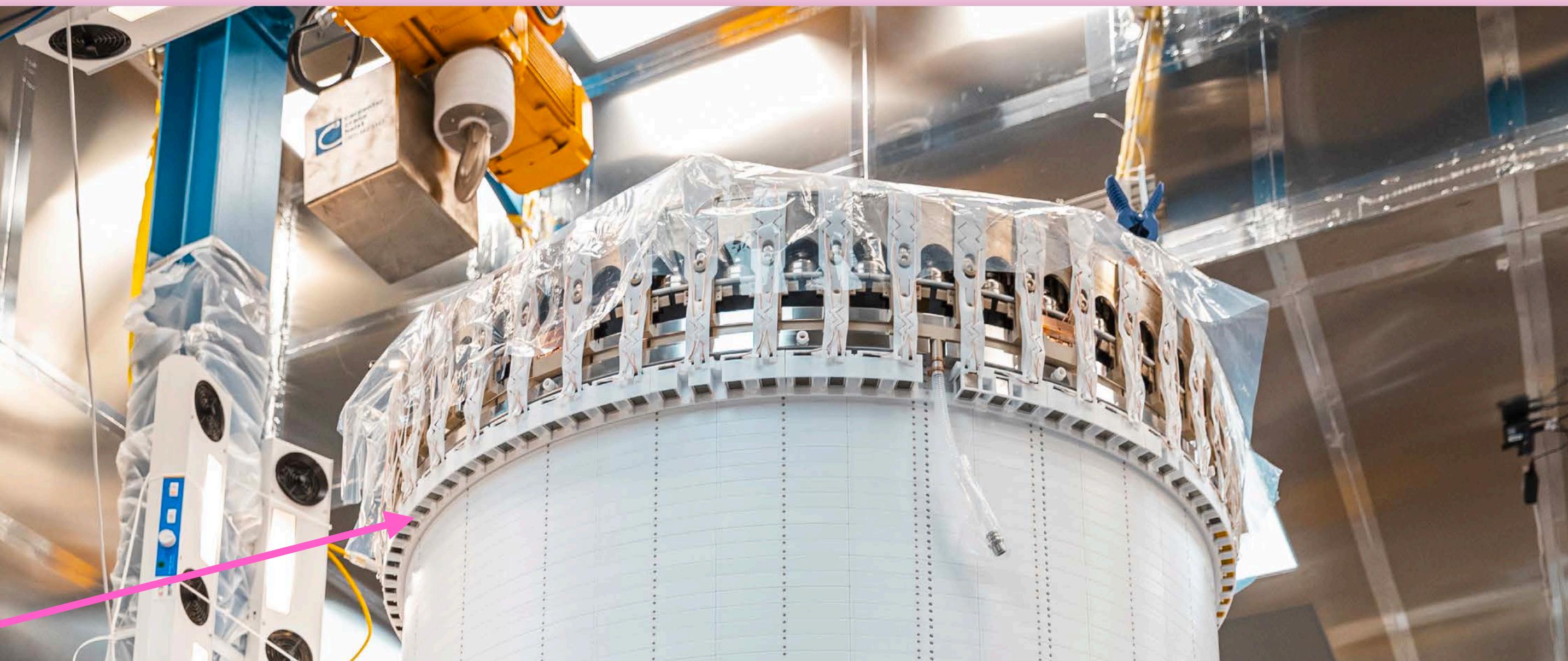
\* see talk by R. Linehan, Thurs at 8am  
*Understanding the impact of high voltage electrodes on low-energy dark matter searches with the LZ dual phase xenon TPC*





# Liquid Xenon Skin Detector

- 2T of active xenon between the ICV and the TPC field cage
  - Optically isolated from TPC
  - 93 1" R8520 PMTs in ice cube trays at the top
  - 20 side + 18 dome 2" R11410 PMTs at the bottom
- Expected to be **>95% efficient** at tagging  $\gamma$ -rays





# Titanium Vessels



ICV at the Surface Assembly Lab

Inner vessel installed in the water tank  
December 2019



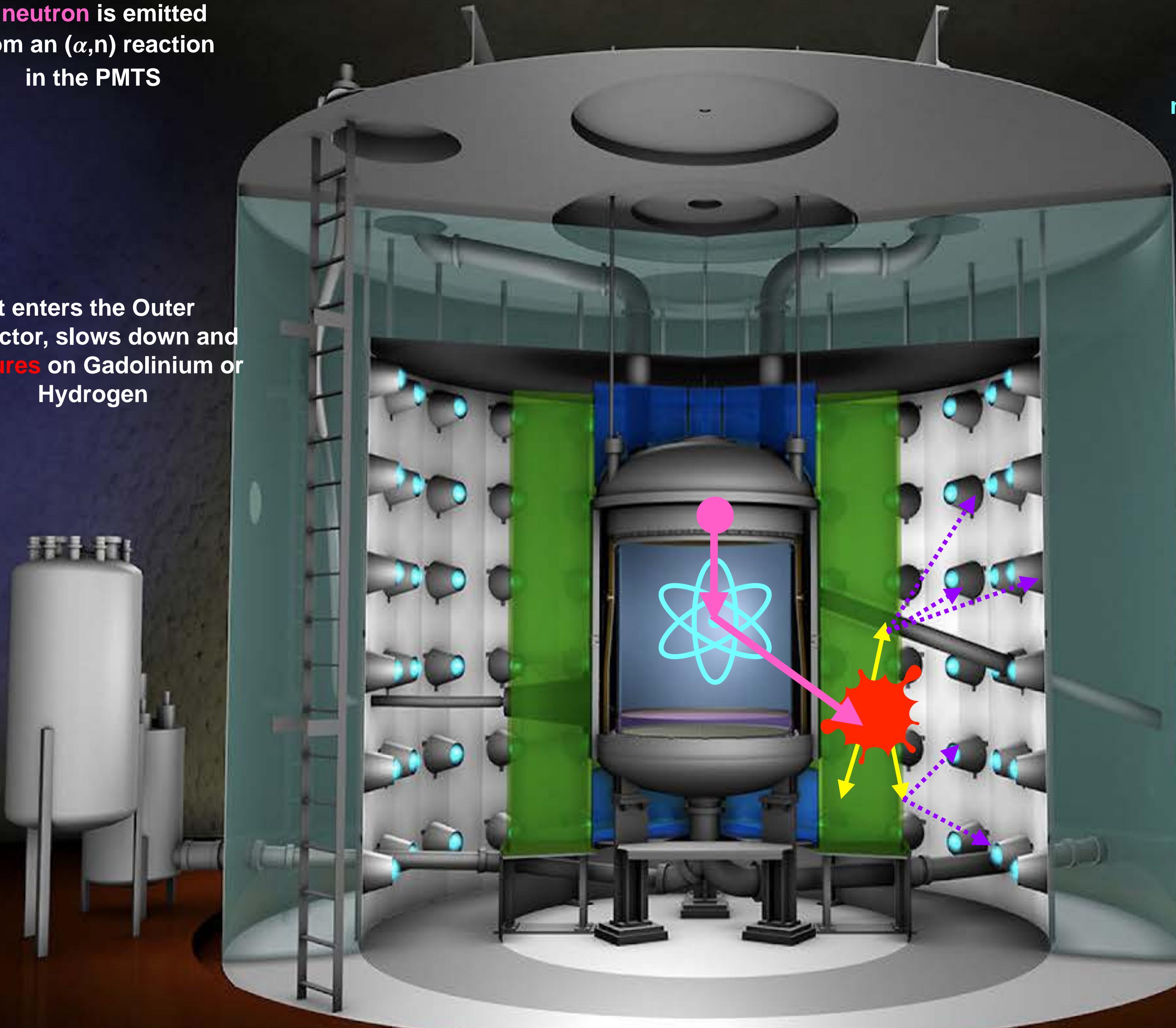
ICV being lowered into OCV



ICV and OCV in place in water tank

A neutron is emitted from an  $(\alpha,n)$  reaction in the PMTS

It enters the Outer Detector, slows down and captures on Gadolinium or Hydrogen



It scatters from a Xe nucleus, causing a nuclear recoil inside the LXe detector

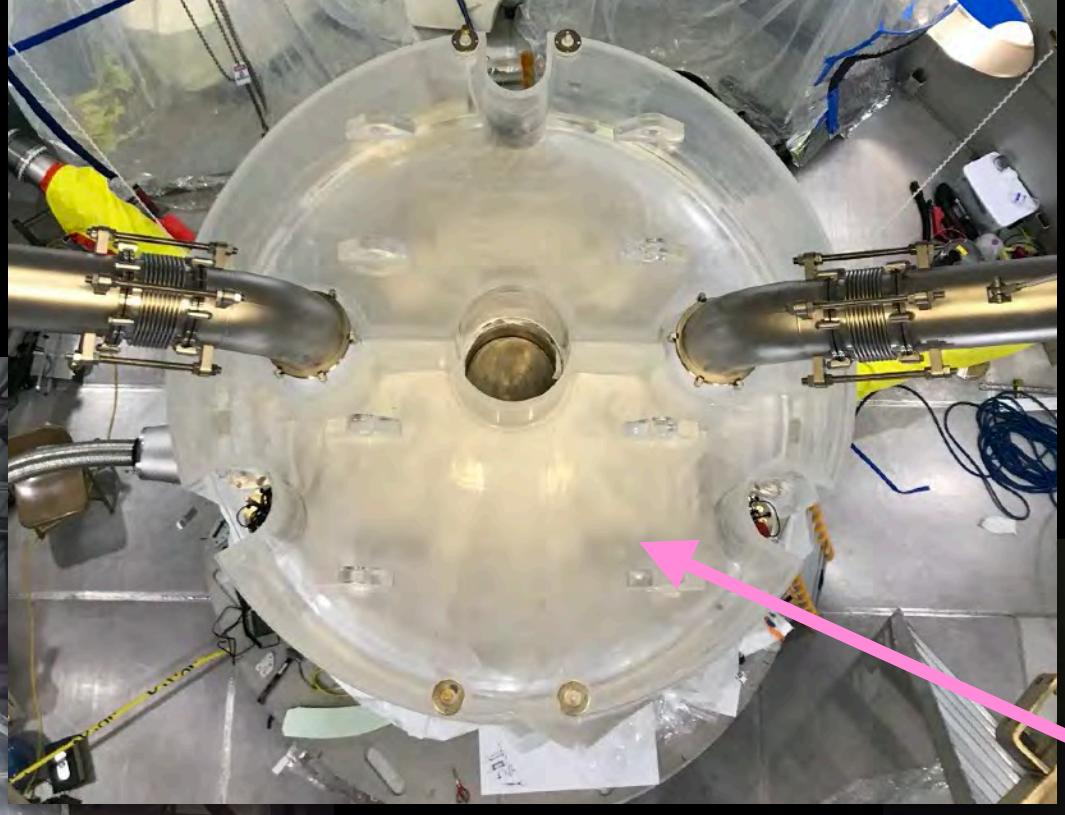
$\gamma$ -rays are emitted from the post-capture nucleus

$\gamma$ 's interact in the liquid scintillator, producing photons, which are detected by PMTs



# Outer Detector

2 top vessels



17T Gd-loaded liquid scintillator



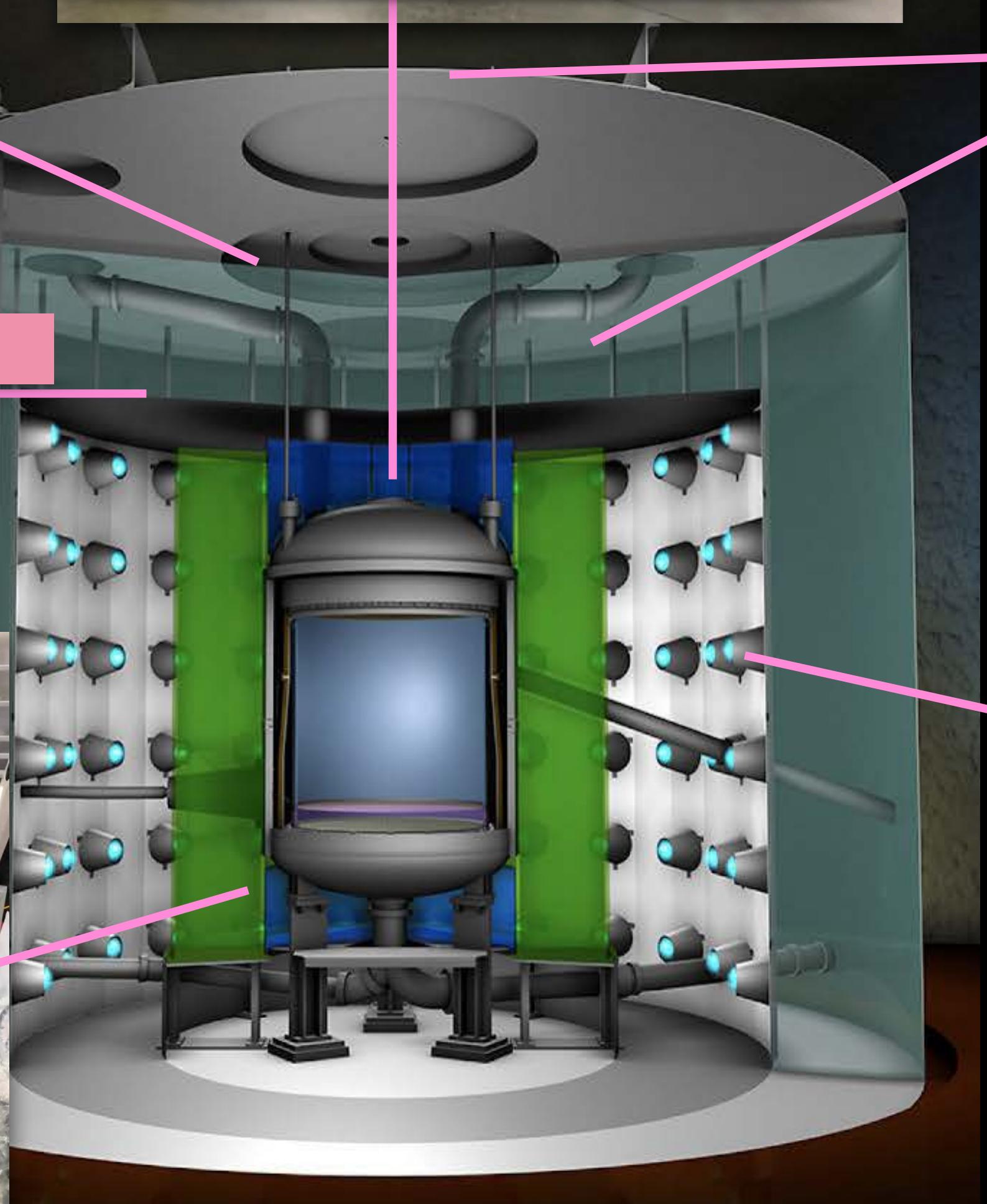
10 segmented acrylic vessels



3 bottom vessels



3 side vessels



120 8" PMTs





# Outer Detector Installation



OD construction completed  
spring 2021



# Cleanliness and Background Mitigation

- **Detector materials**
  - Radio-assay campaign
  - gamma-screening
  - ICPMS
  - NAA
- **Rn emanation**
  - Four Rn emanation screening sites
  - Two portable Rn assay panels
  - Target Rn activity:  $2 \mu\text{Bq}/\text{kg}$
- **Rn daughters and dust on surfaces**
  - TPC assembly in Rn-reduced cleanroom
  - Dust  $< 500 \text{ ng/cm}^3$  on all LXe contact surfaces
  - Rn-daughter plate-out on TPC walls  $< 0.5 \text{ mBq/m}^2$
- **Xenon contaminants**
  - $^{85}\text{Kr}$ ,  $^{39}\text{Ar}$
  - Charcoal chromatography @ SLAC
  - Final natKr/Xe  $< 300 \text{ ppq}$
- **Cosmogenics and externals**
  - 4300 m.w.e. underground
  - Instrumented Xe skin region
  - GdLS outer detector
  - High purity water shield





# Backgrounds

## ER Backgrounds:

- $\gamma$ -rays &  $\beta$ -decays from  $^{238}\text{U}$ ,  $^{232}\text{Th}$  chains
- $^{60}\text{Co}$ ,  $^{40}\text{K}$
- Xenon lines
- $^{222}\text{Rn}$ ,  $^{220}\text{Rn}$  and  $^{85}\text{Kr}$  in the LXe



## NR Backgrounds

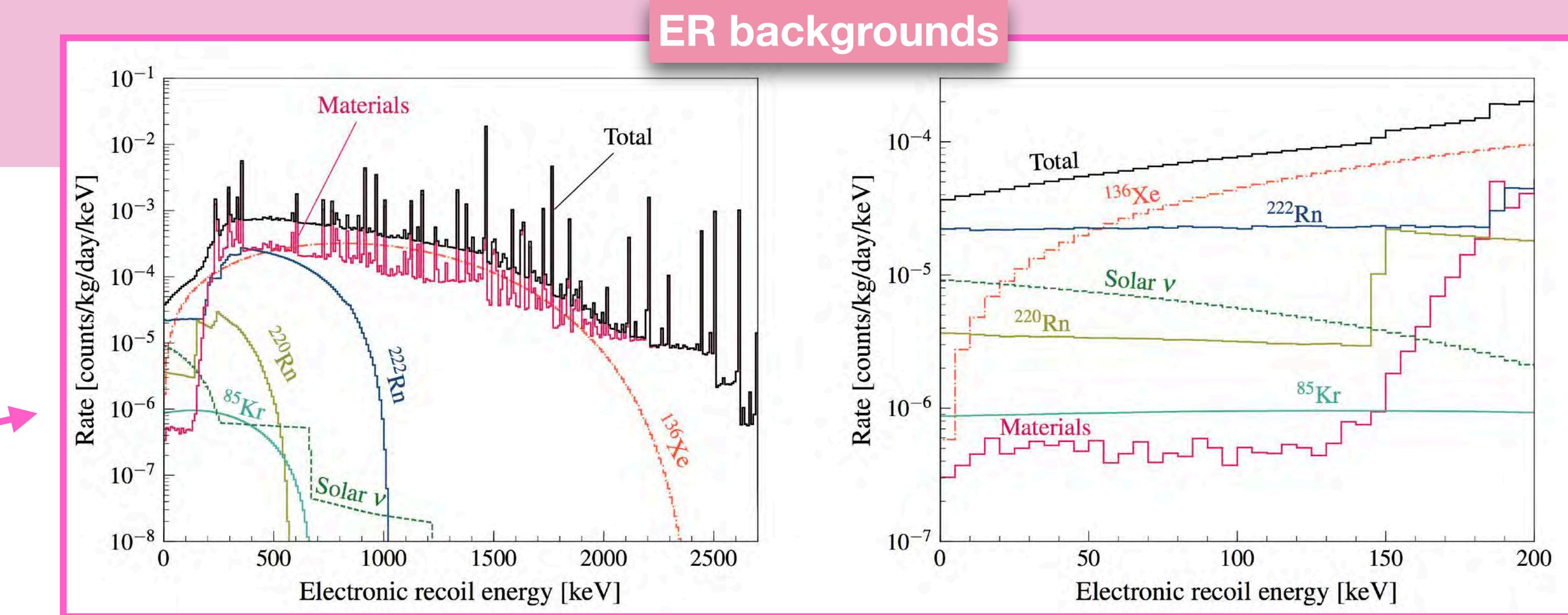
- Neutrons from (a,n) & spontaneous fission in detector components
- $^{8}\text{B}$  solar neutrinos
- Wall background (mis-reconstructed ion recoils)



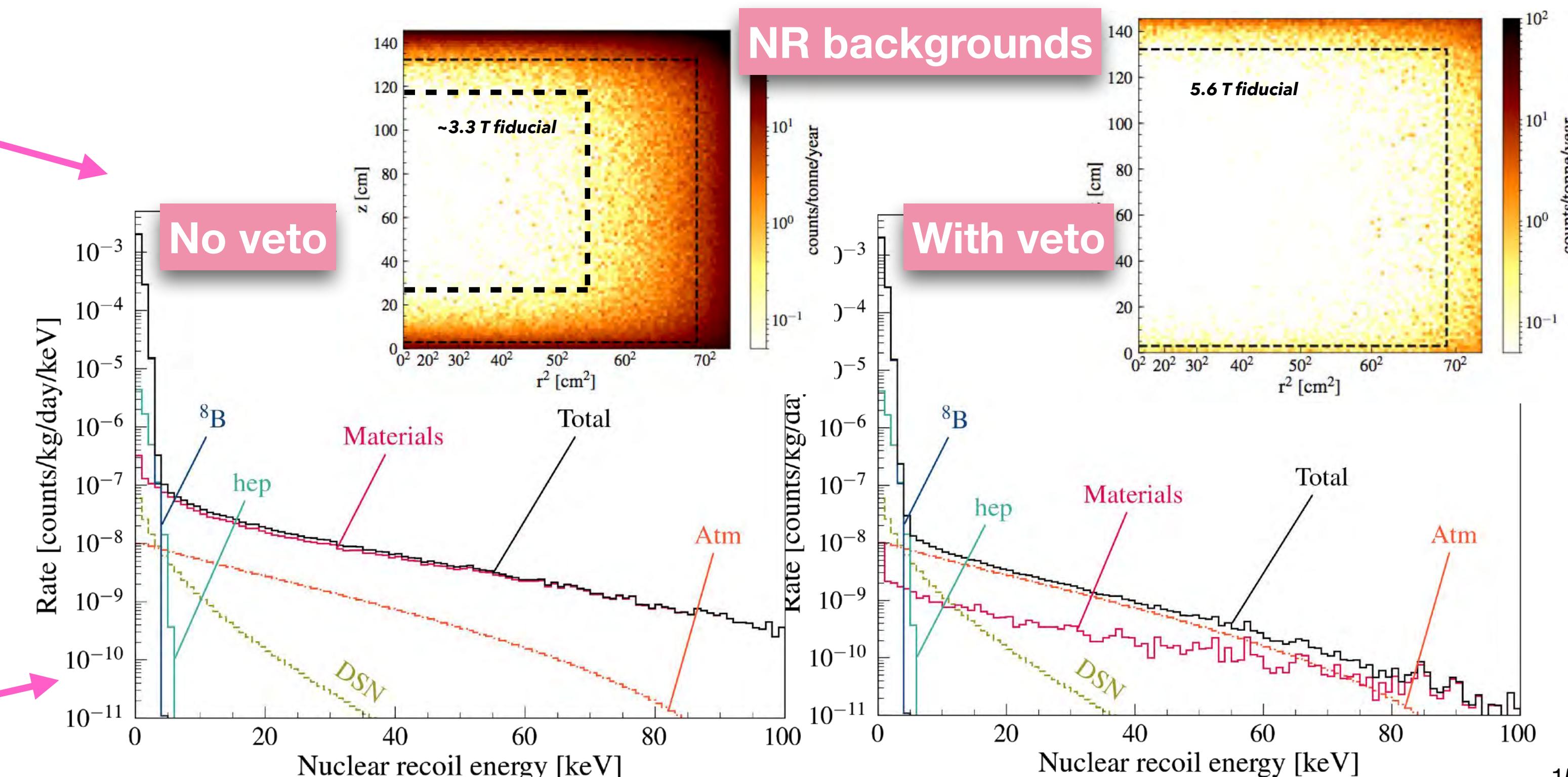
## Key for reducing background:

- Fiducialisation (self-shielding)
- Single scatter cuts
- Energy cuts
- Dual veto system (skin and OD)

**OD reduces NR backgrounds and allows maximal fiducial volume**

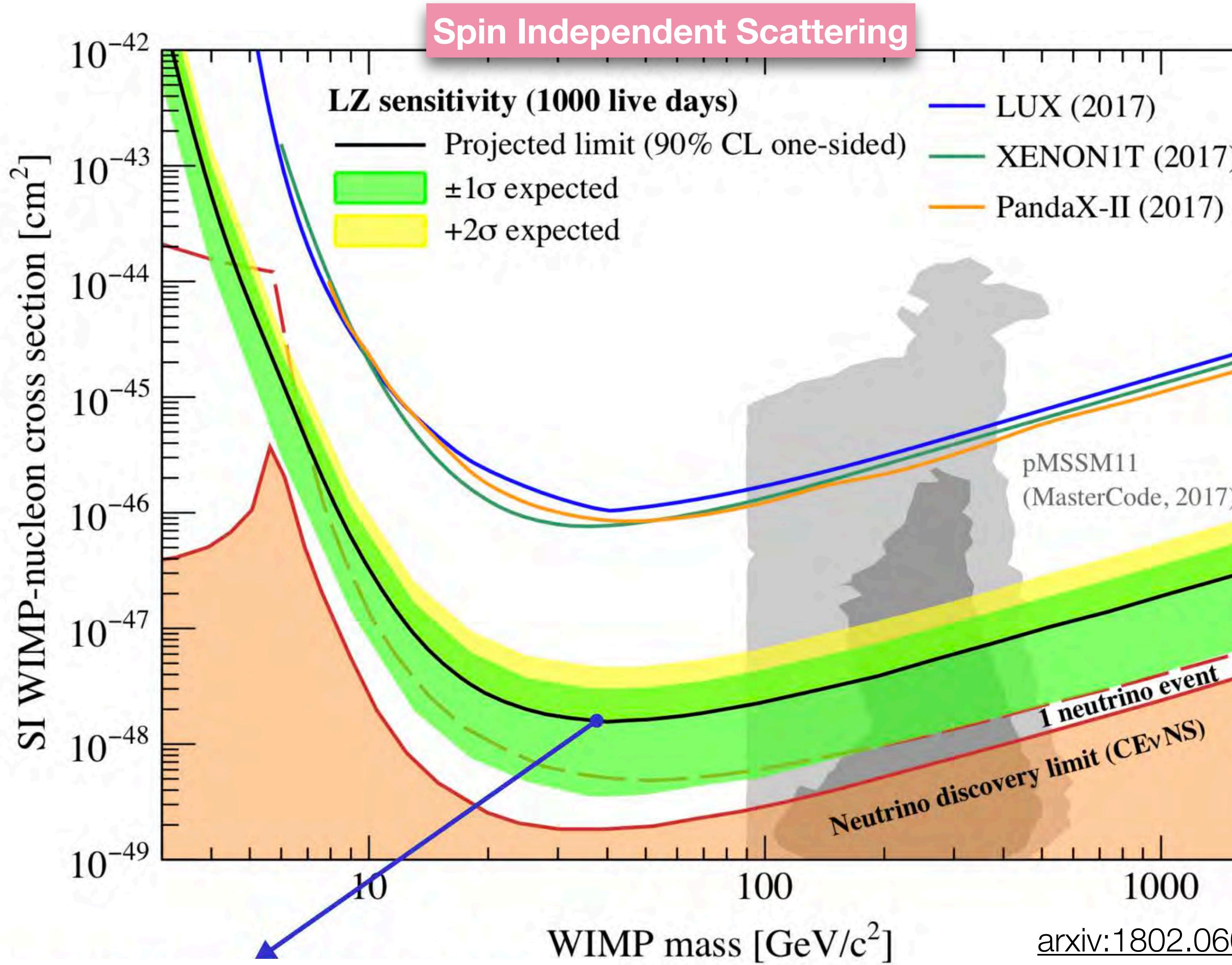


## NR backgrounds

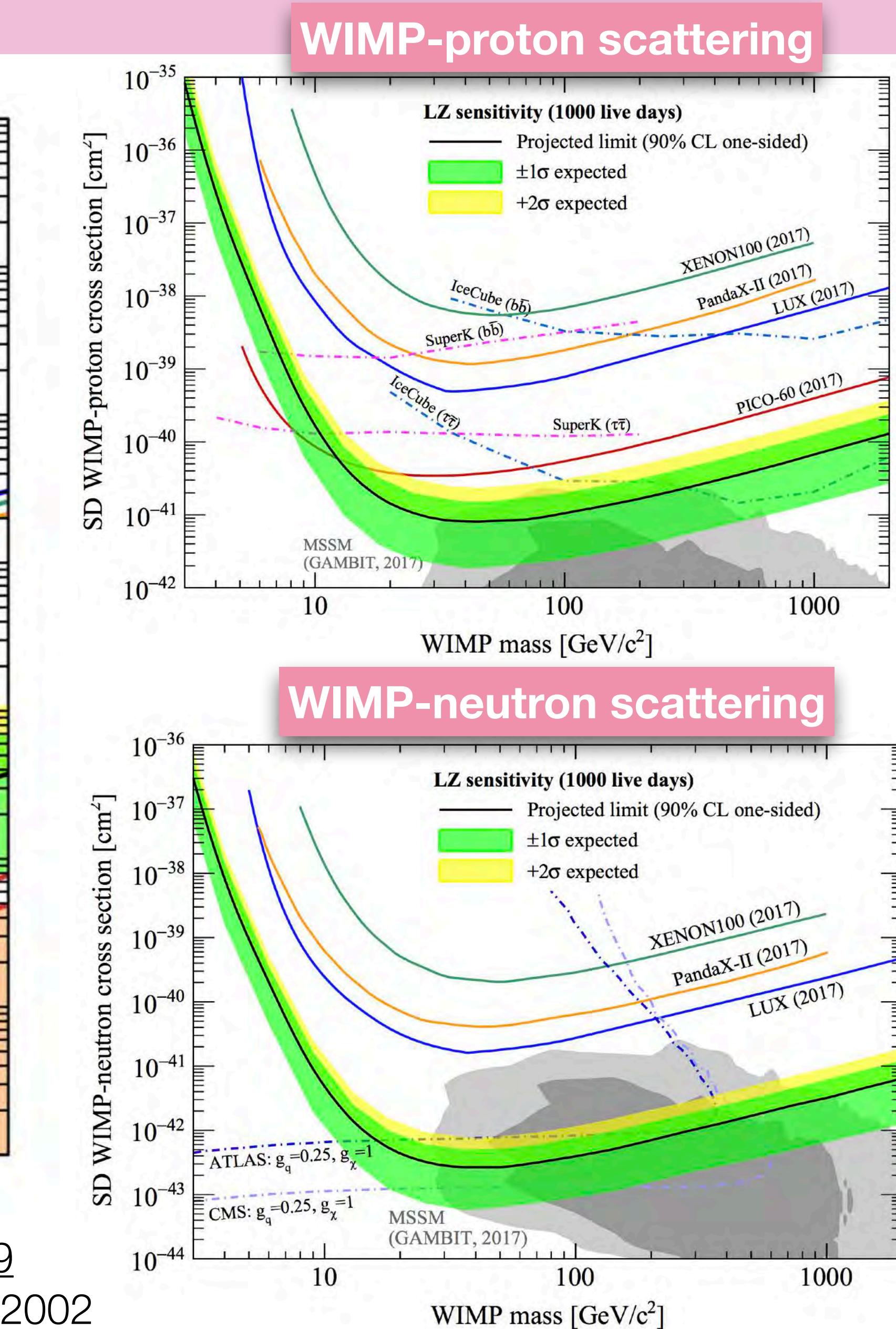




# LZ Sensitivity Projections



arxiv:1802.06039  
Phys. Rev. D **101**, 052002



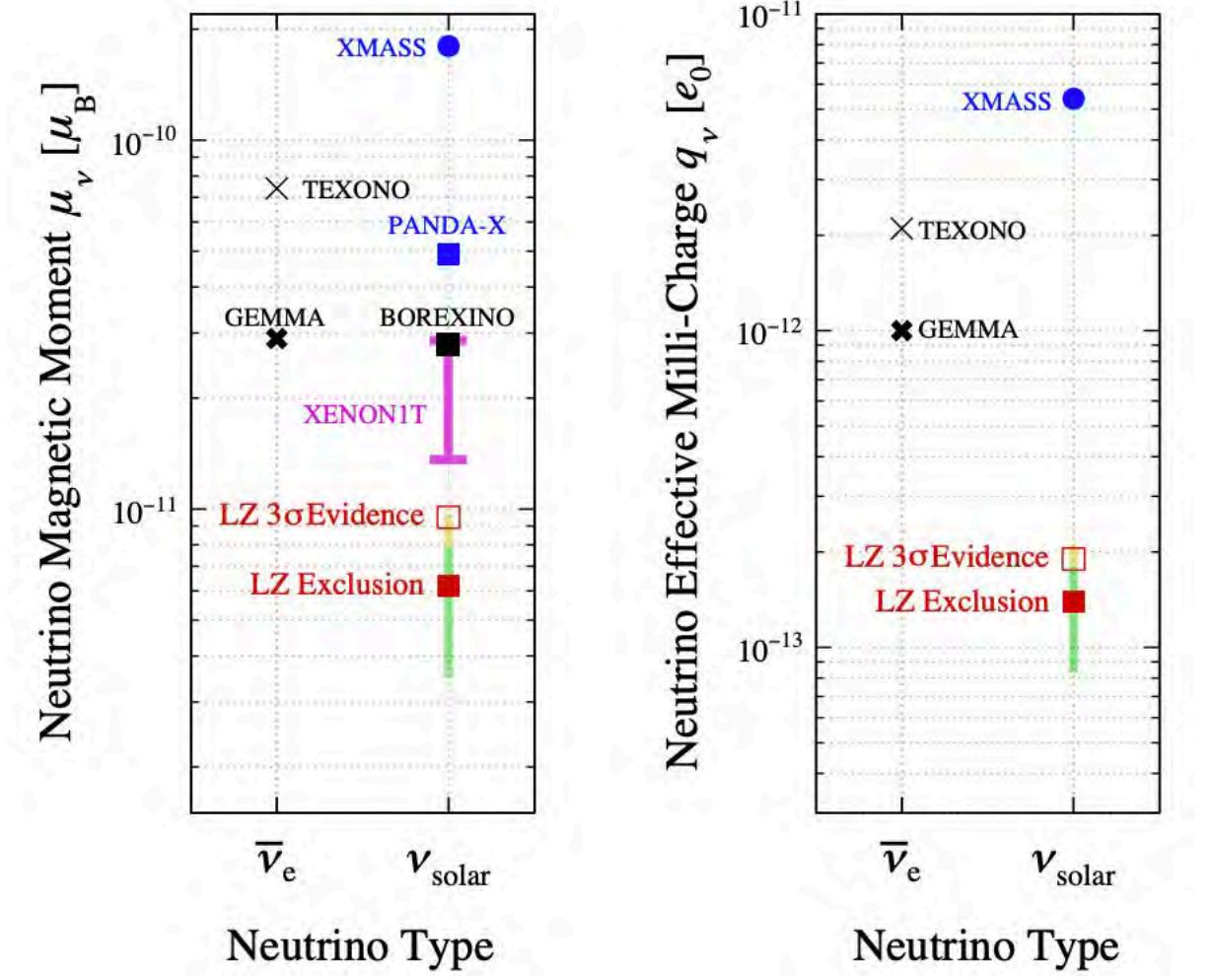


# LZ Physics Reach

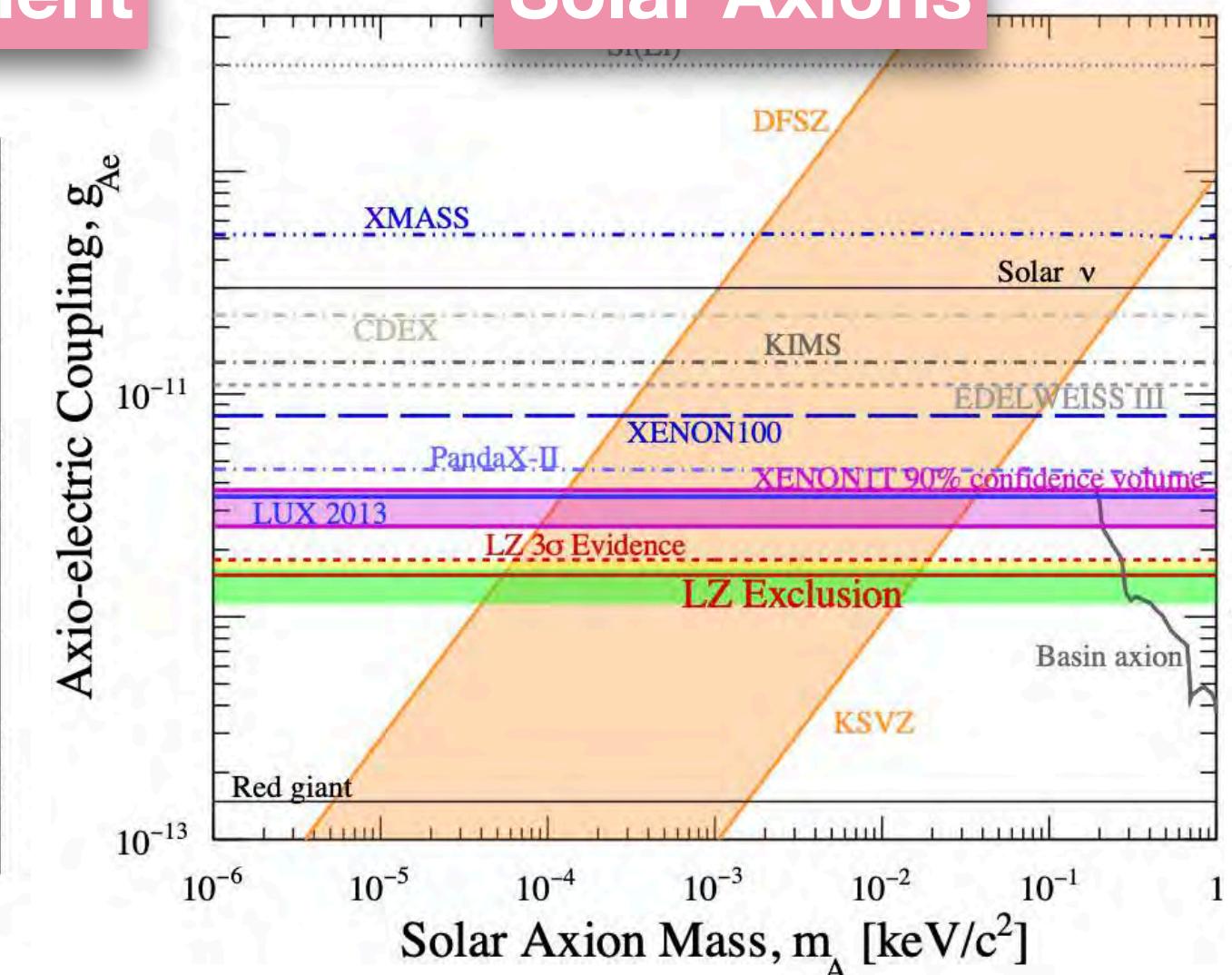
LZ physics reach extends beyond vanilla WIMPs:

- Solar axions
  - Axion-like particles (ALPs)
  - $2\nu\beta\beta$  of  $^{134}\text{Xe}$  with competitive sensitivity to  $0\nu\beta\beta$
  - Enhanced sensitivity to low mass DM through Migdal effect
  - Leptophilic dark matter
  - Neutrino magnetic moment
  - Mirror dark matter
- [arxiv:2102.11740](https://arxiv.org/abs/2102.11740)  
[arxiv:2104.13374](https://arxiv.org/abs/2104.13374)

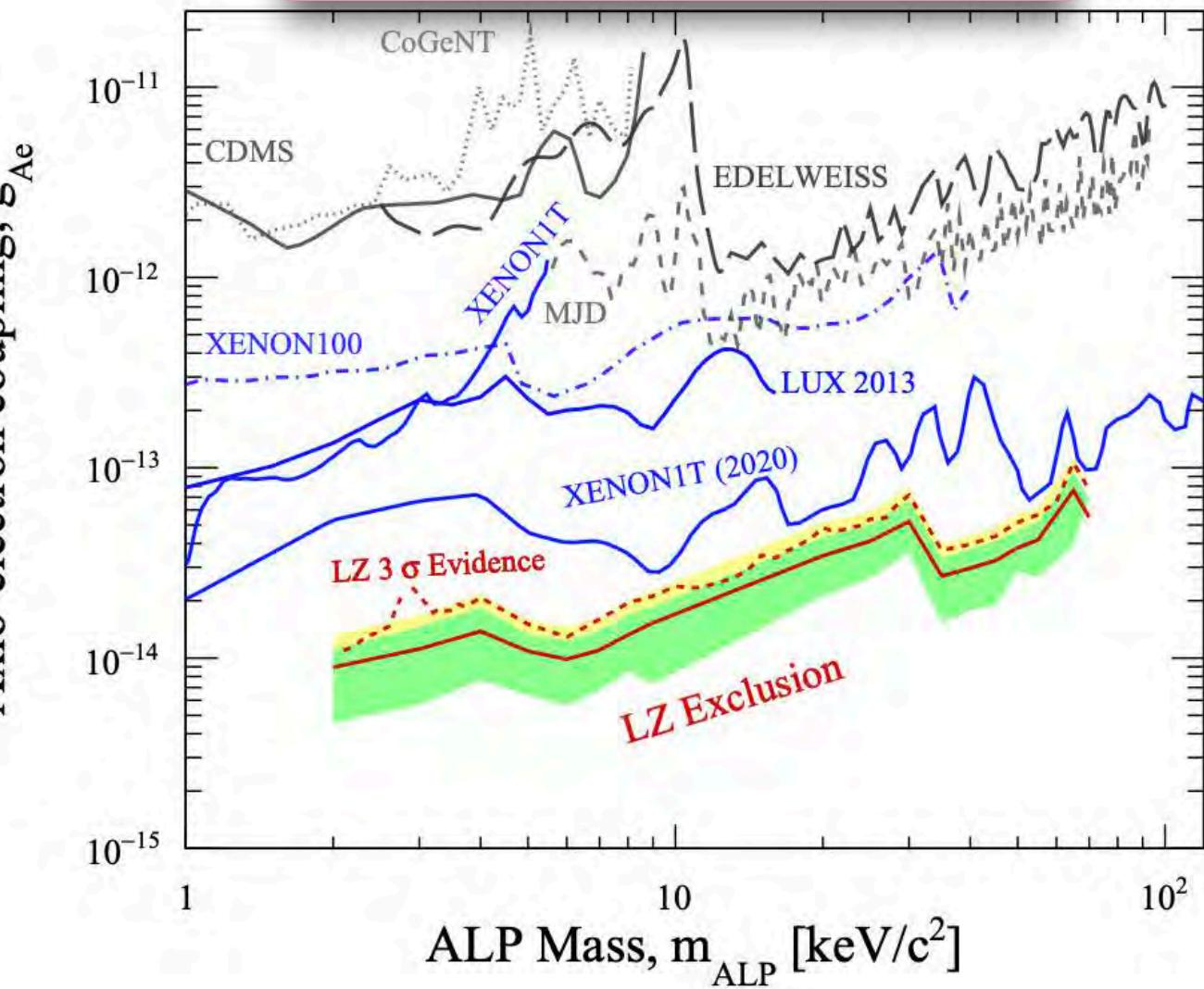
## Neutrino magnetic moment



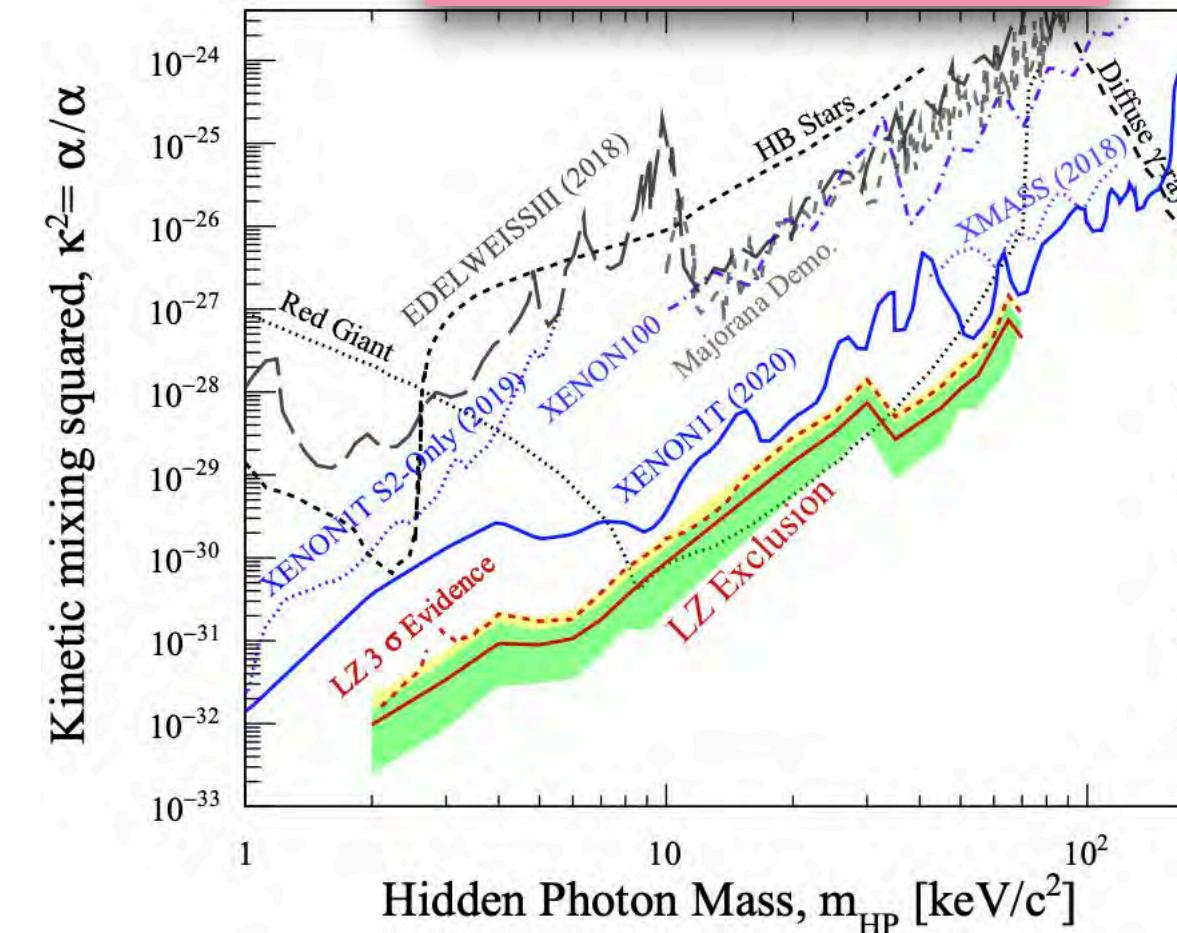
## Solar Axions



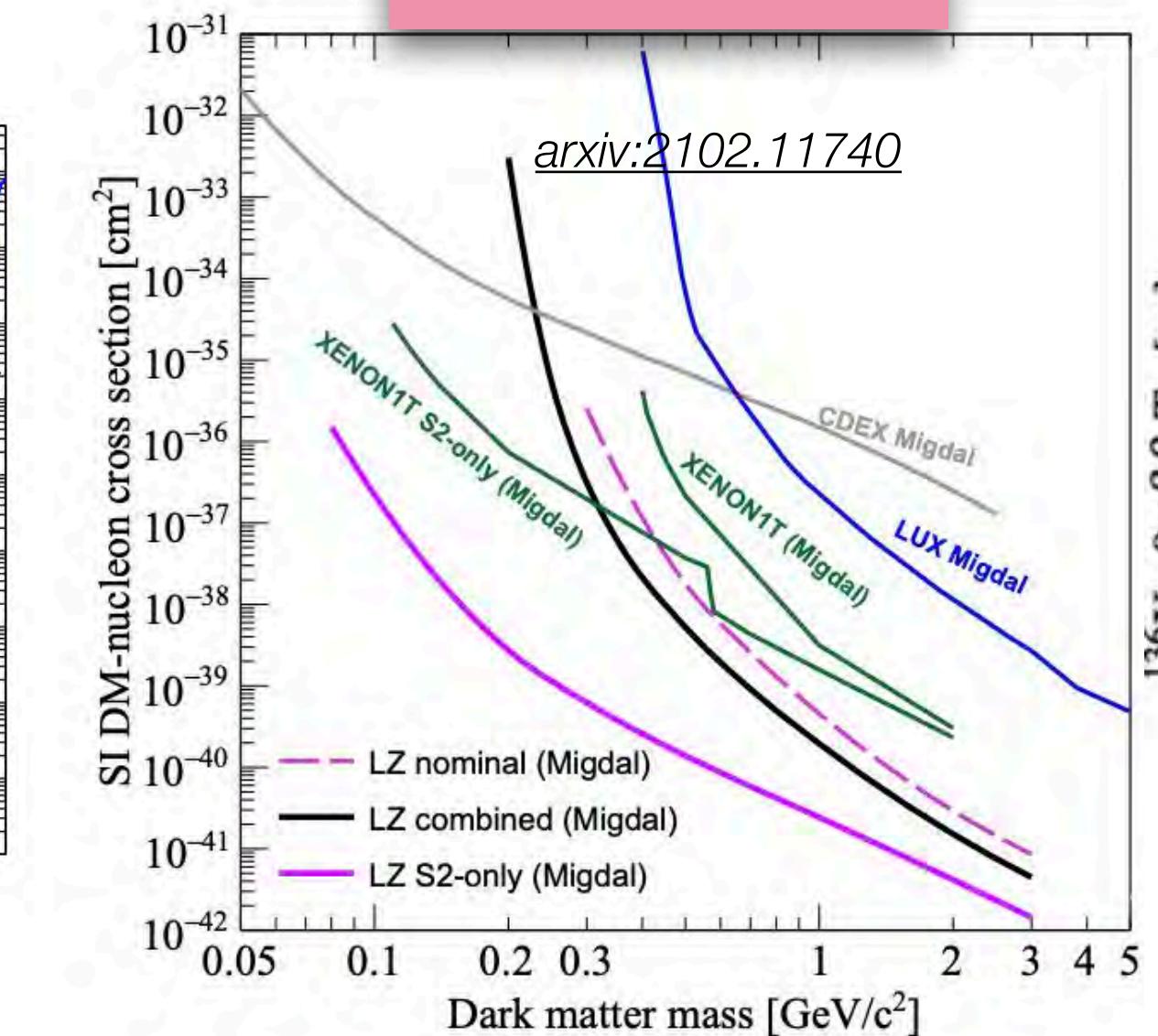
## Axion-Like Particles



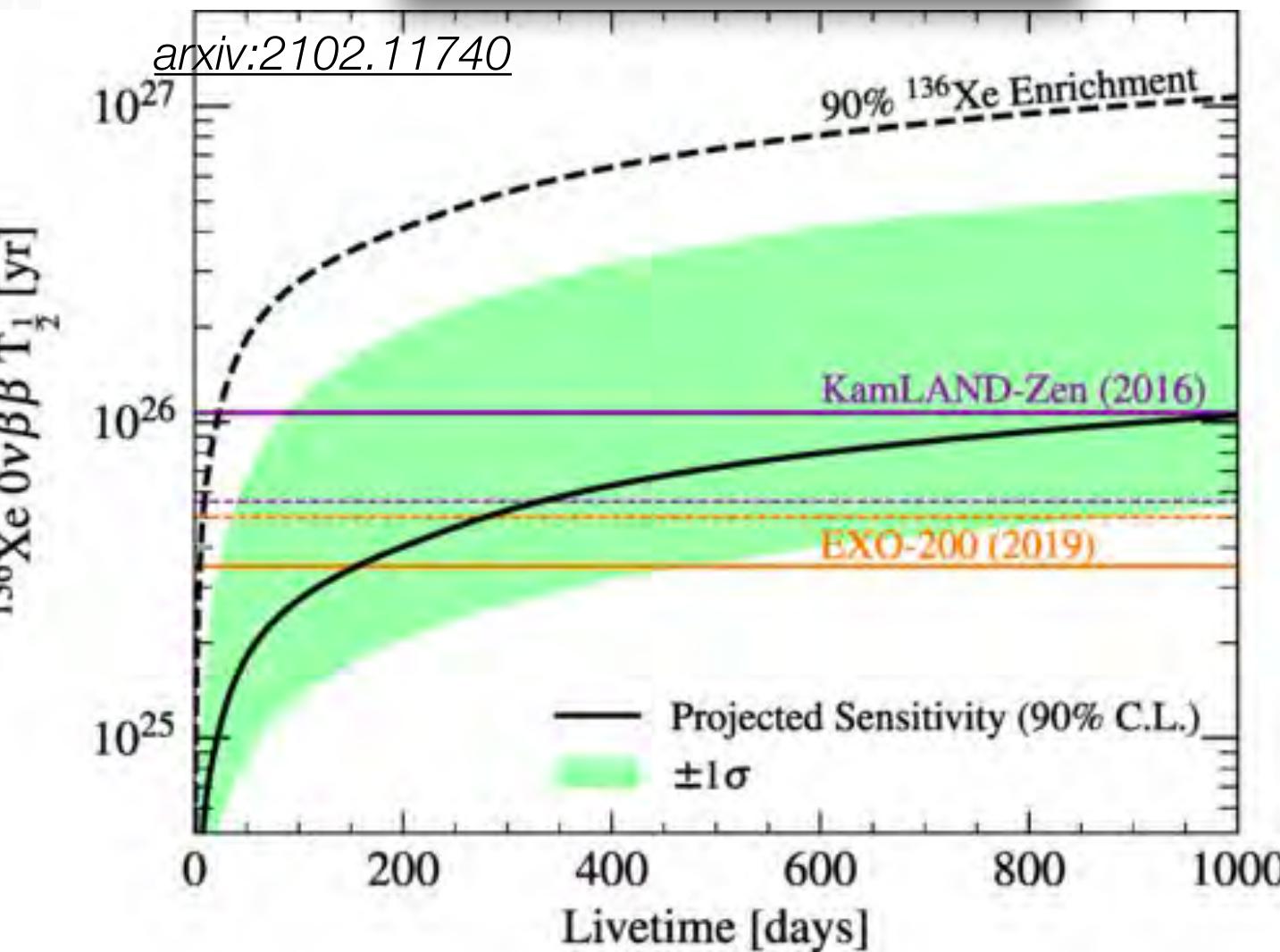
## Hidden Photons



## Low mass DM



## $^{134}\text{Xe} 0\nu\beta\beta$ decay

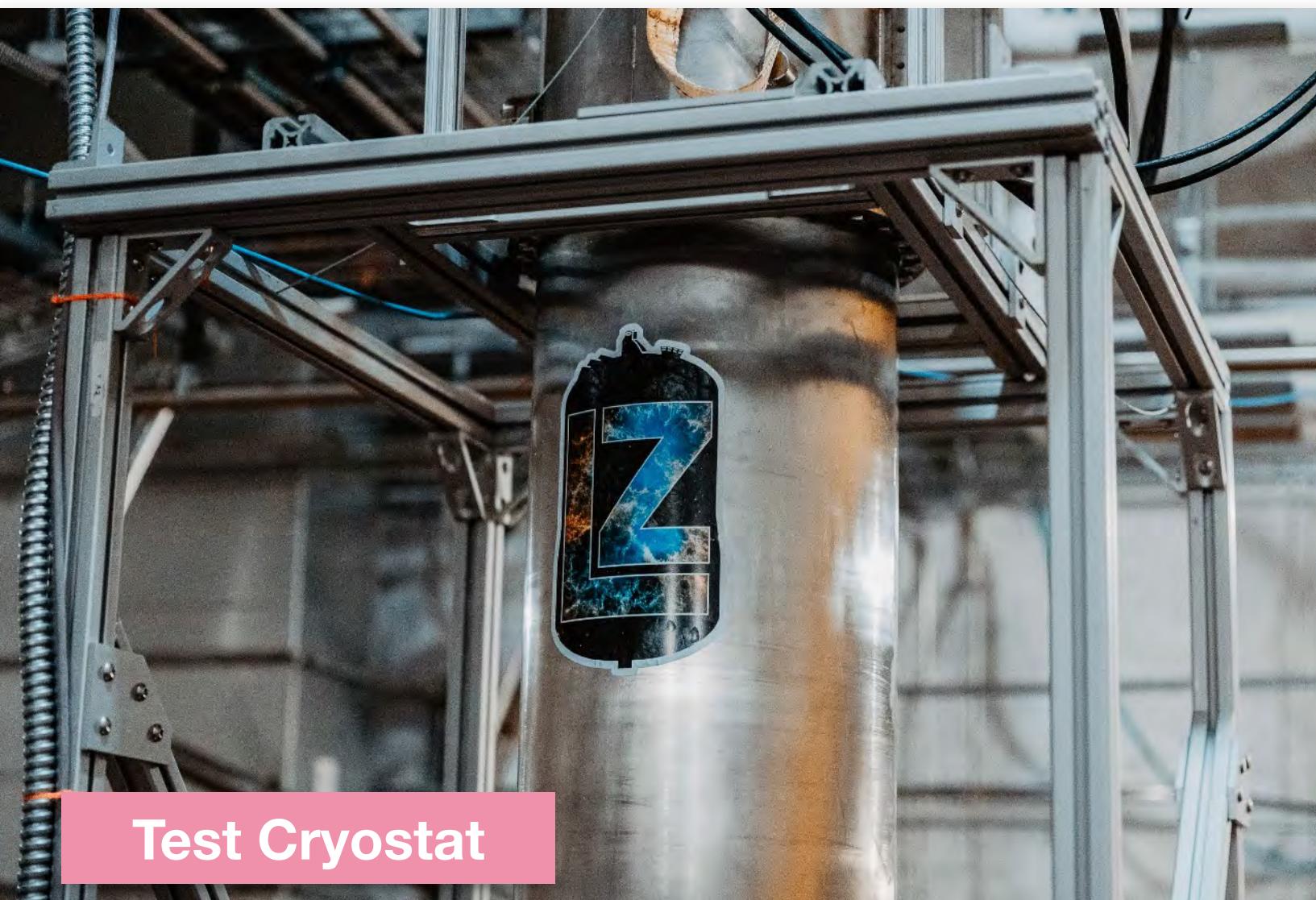




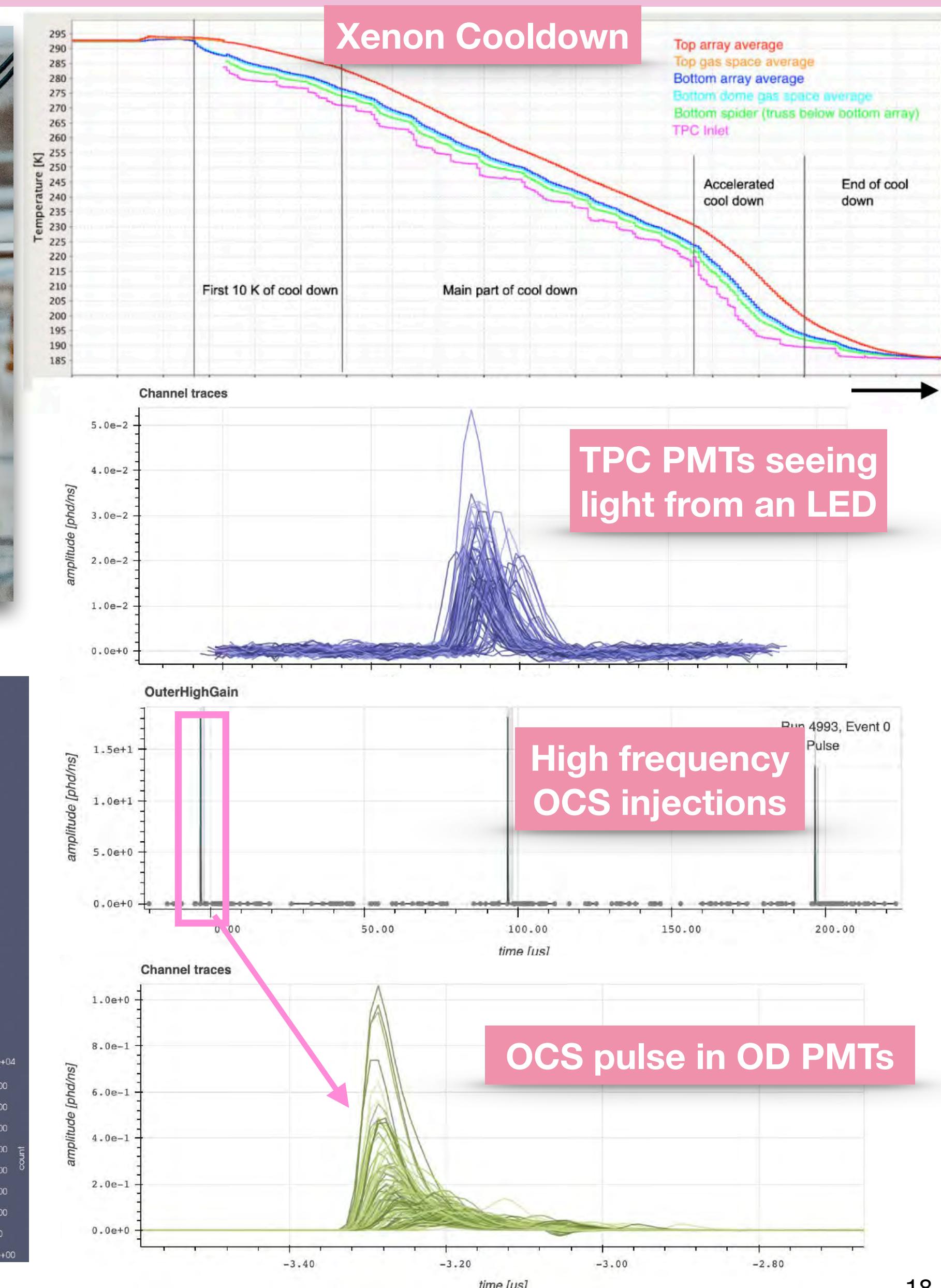
# Commissioning

## Xenon:

- Circulation test completed last year with test cryostat underground
- Achieved designed gas circulation rate of 500 slpm
- TPC has been cooled down to  $\sim 185$  K

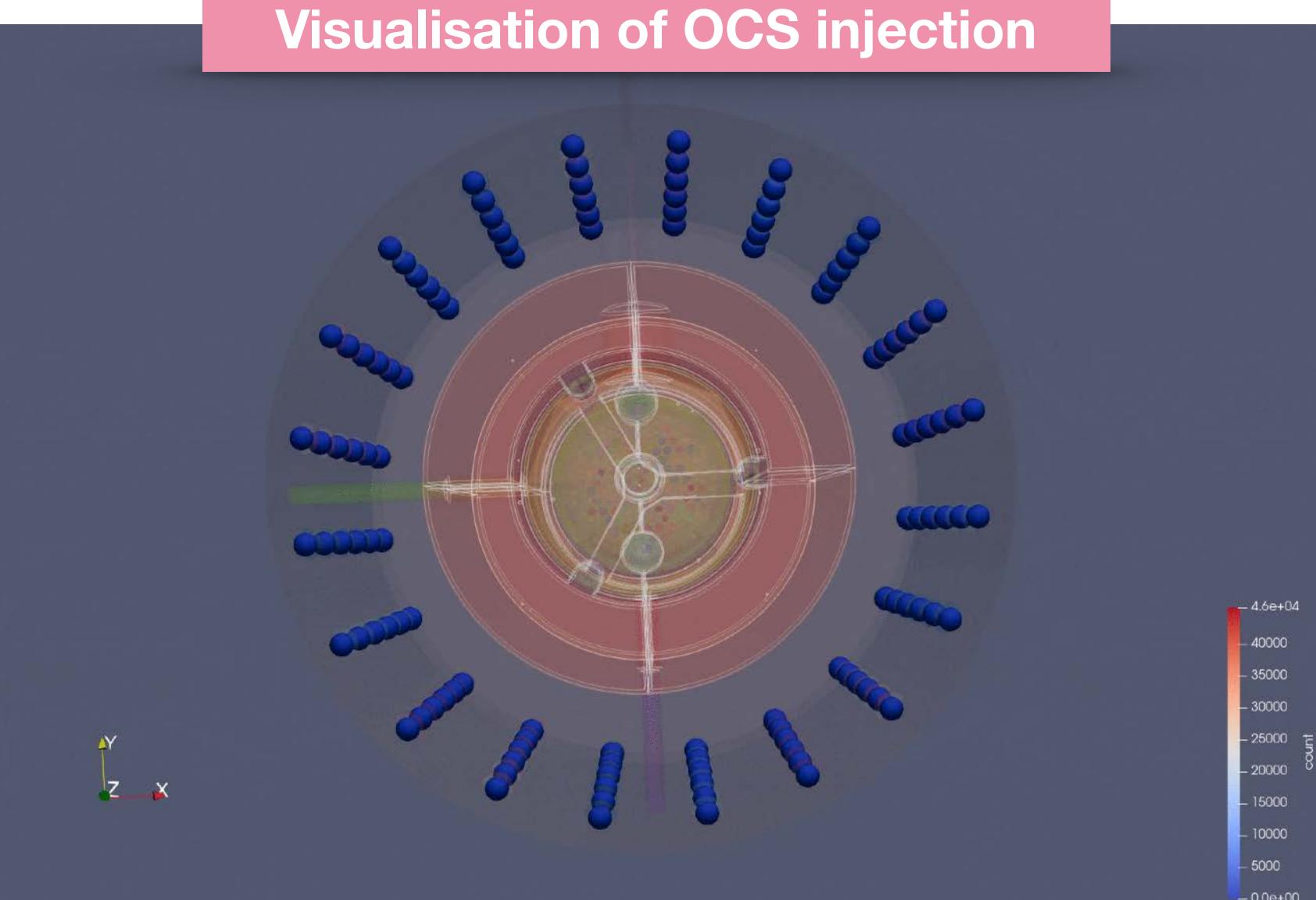


Test Cryostat



## PMTs:

- Fully tested and characterized with LEDs calibration in all three detectors
- OD OCS system fully characterized
  - [arxiv:2102.06281](https://arxiv.org/abs/2102.06281)



## LZ construction is complete!

- We have cold xenon, all PMTs have been tested with LEDs
- Physics data taking this year
- Expected **40x improvement** in sensitivity on current limits, also sensitive to non-WIMP physics
- **2022 will be an exciting year!**

Thanks!



### Other LZ LIDINE talks:

- Salting as a bias mitigation technique in LUX-ZEPLIN (LZ) - Tyler Anderson, Wed 1:45pm
- Understanding the impact of high voltage electrodes on low-energy dark matter searches with the LZ dual phase xenon TPC - Ryan Linehan, Thurs 8am
- The LZ Krypton Removal Chromatography System - Drew Ames, Fri 11 am
- CrystaLiZe: A Solid Future for LZ - Scott Kravitz, Fri 11:15am



# Acknowledgements

- Black Hills State University
- Brandeis University
- Brookhaven National Laboratory
- Brown University
- Center for Underground Physics
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- University of Bristol
- University College London
- University of California Berkeley
- University of California Davis
- University of California Santa Barbara
- University of Liverpool
- University of Maryland
- University of Massachusetts, Amherst
- University of Michigan
- University of Oxford
- University of Rochester
- University of Sheffield
- University of Wisconsin, Madison

US   UK   Portugal   Korea



January 2021 Collaboration Meeting



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