



Status of the LZ experiment

Alden Fan for the LZ collaboration

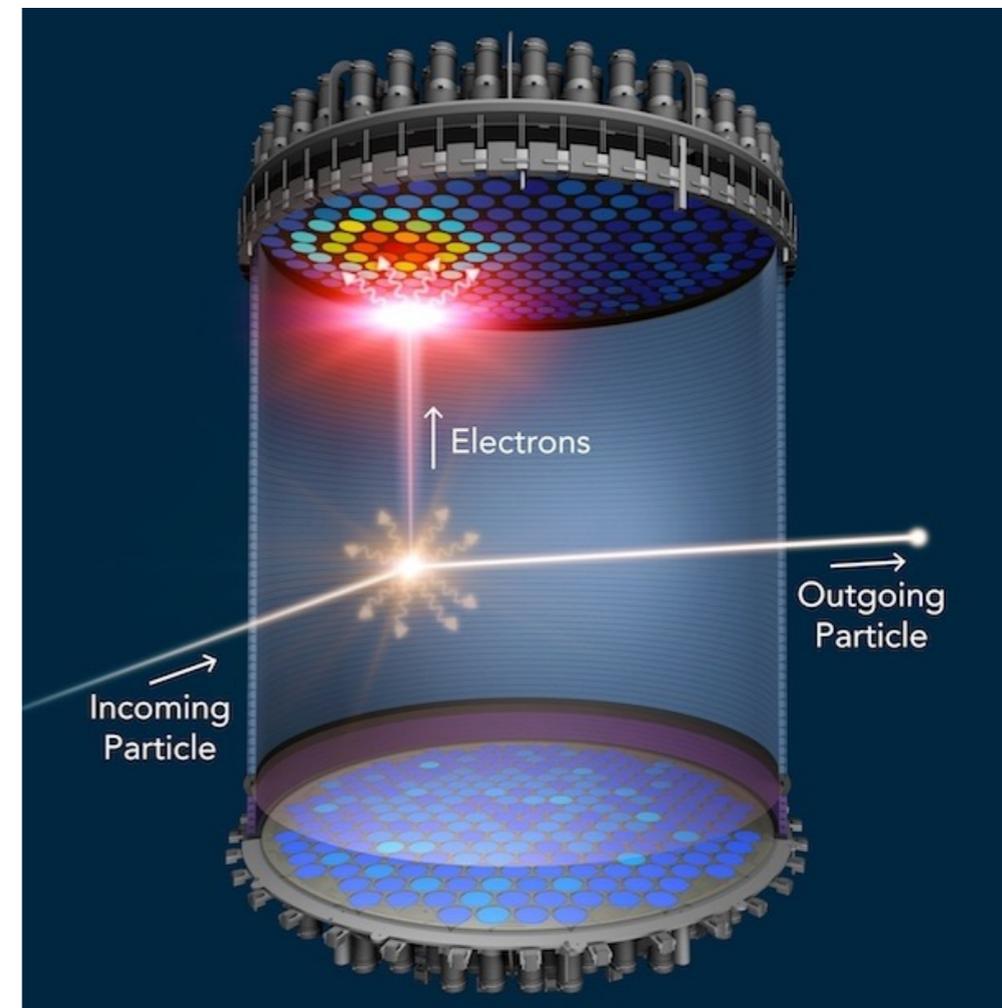
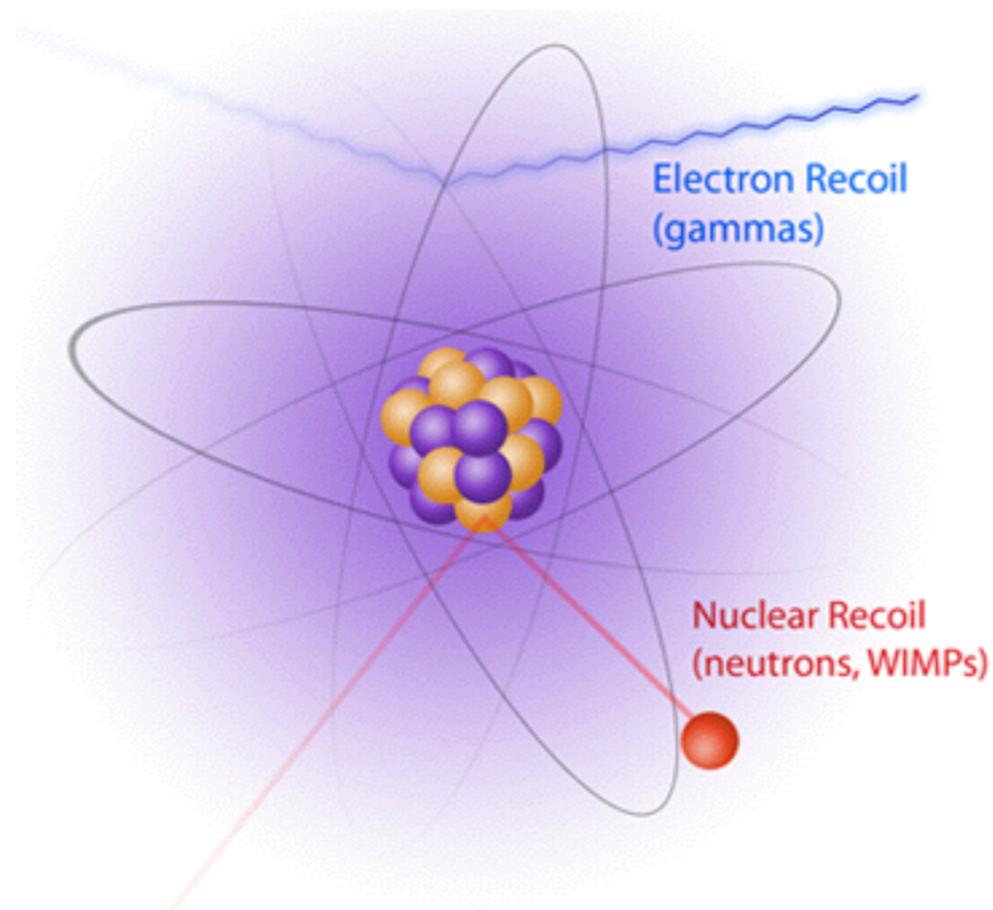
(Stanford/KIPAC/SLAC)

9th Symposium on Large TPCs for Low-energy Rare Event Detection

December 13, 2018

Dark matter search with a dual-phase Xe TPC

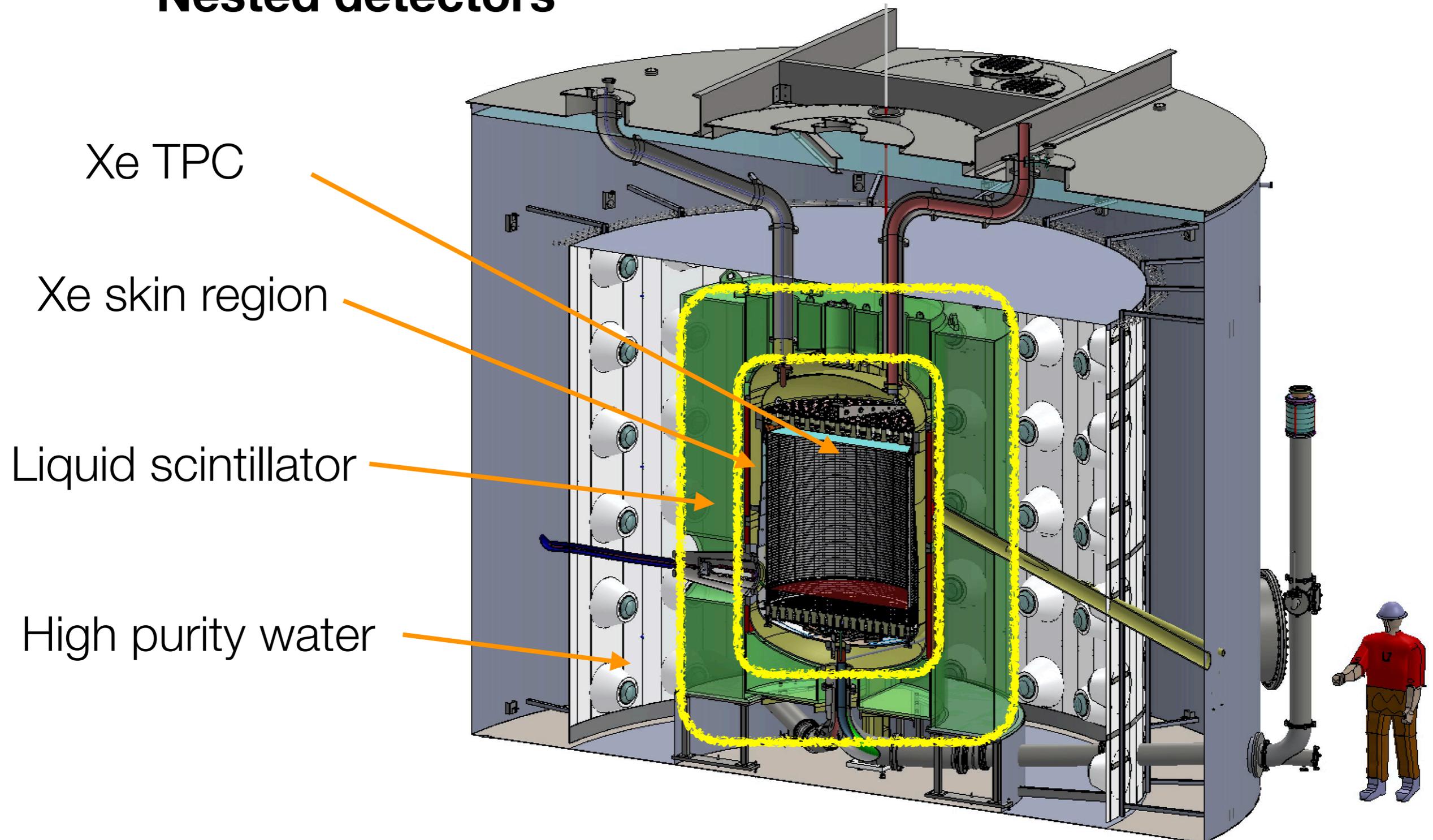
- Primary: search for rare nuclear recoils from WIMP dark matter
- Also sensitive to low energy recoils from other exotica



- Dual-phase time projection chamber with Xe gives precise 3D position, energy, electron/nuclear recoil discrimination

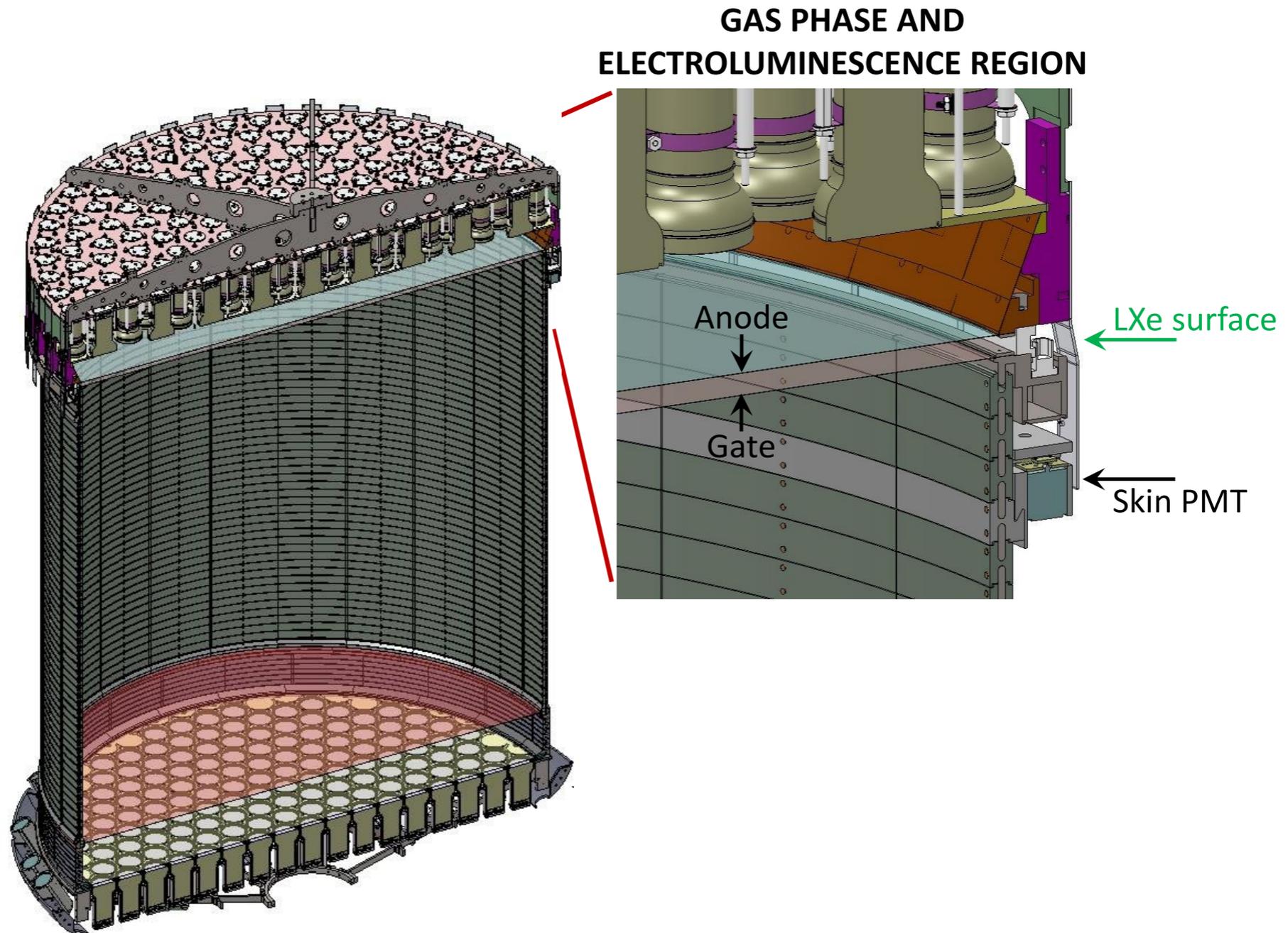
LUX-ZEPLIN

Nested detectors



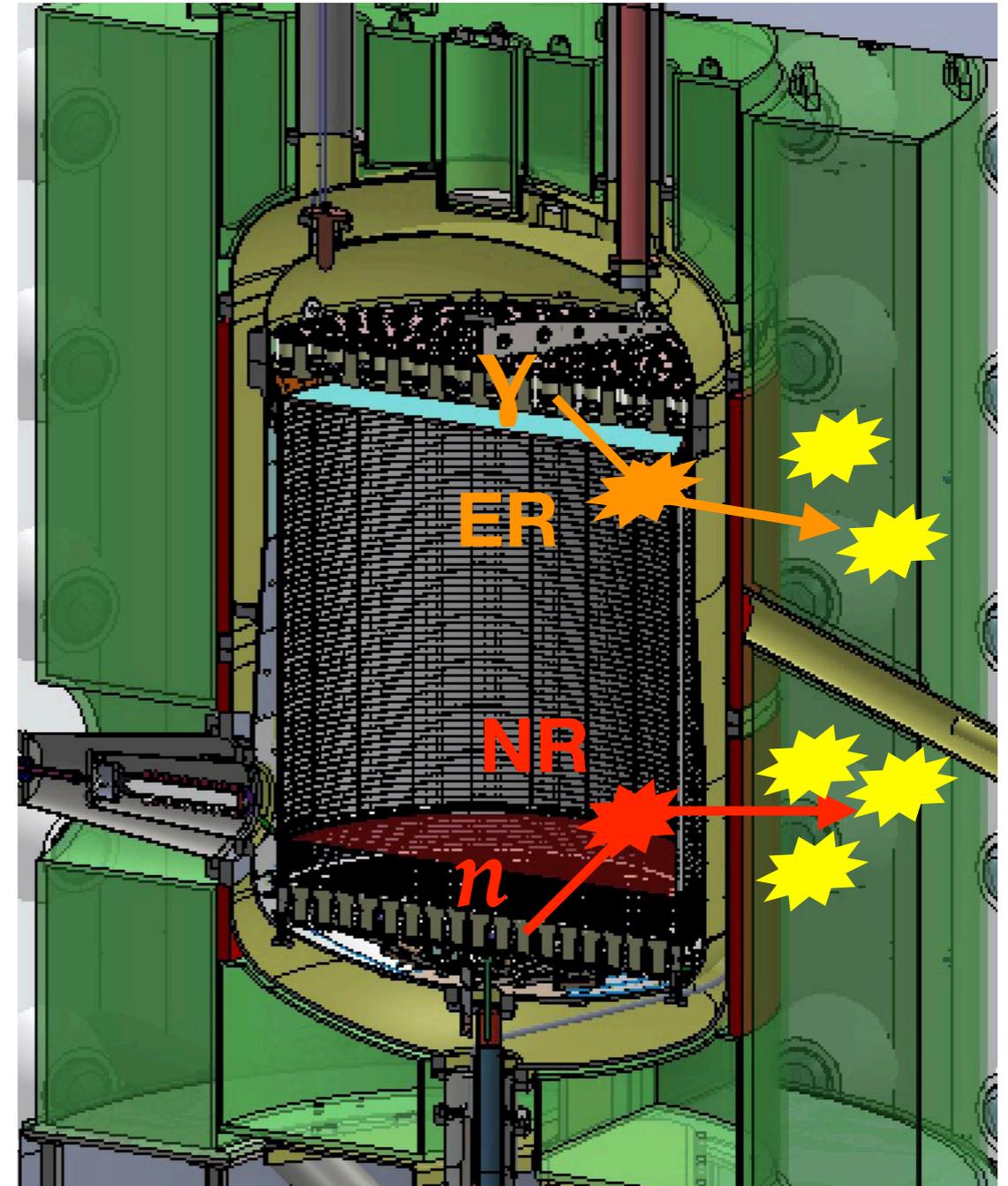
Xenon TPC

- 1.5 m diameter x 1.5 m height
- 7t active LXe (5.6t fiducial)
- 50 kV cathode HV
- 494x 3" PMTs
- Gas circulation @ 500 slpm (turnover full mass in 2.5 days)
- Instrumented Xe skin region, outside the field cage



Gd-loaded outer detector

- **Capabilities:**
 - Tag individual neutrons
 - Characterize LZ radiation environment
- 17.3 tonnes Gd-loaded liquid scintillator
- Neutrons thermalize & capture
 - $n + \text{Gd} \rightarrow \text{Gd} + (4-5x) \gamma \ (\sim 8.5 \text{ MeV})$
 - $^{\text{nat}}\text{Gd}$ thermal n-capture $\sigma \rightarrow 40 \text{ kbarn}$
 - Capture time: $30 \mu\text{s}$ w/ 0.1% Gd loading
- 200 keV threshold



Background sources and mitigation

- **Detector materials**

- Radio-assay campaign with gamma-screening, ICPMS, NAA

- **Rn emanation**

- Four Rn emanation screening sites
- Target Rn activity: 2 $\mu\text{Bq/kg}$

- **Rn daughters and dust on surfaces**

- TPC assembly in Rn-reduced cleanroom
- Dust $<500 \text{ ng/cm}^3$ on all LXe wetted surfaces
- Rn-daughter plate-out on TPC walls $<0.5 \text{ mBq/m}^2$

- **Xenon contaminants — ^{85}Kr , ^{39}Ar**

- Charcoal chromatography @ SLAC
- Final $^{\text{nat}}\text{Kr/Xe}$ 0.015 ppt

- **Cosmogenics and externals**

- 4300 m.w.e. underground at Sanford Underground Research Facility in Lead, SD
- Instrumented Xe skin region
- Gd-LS outer detector
- High purity water shield

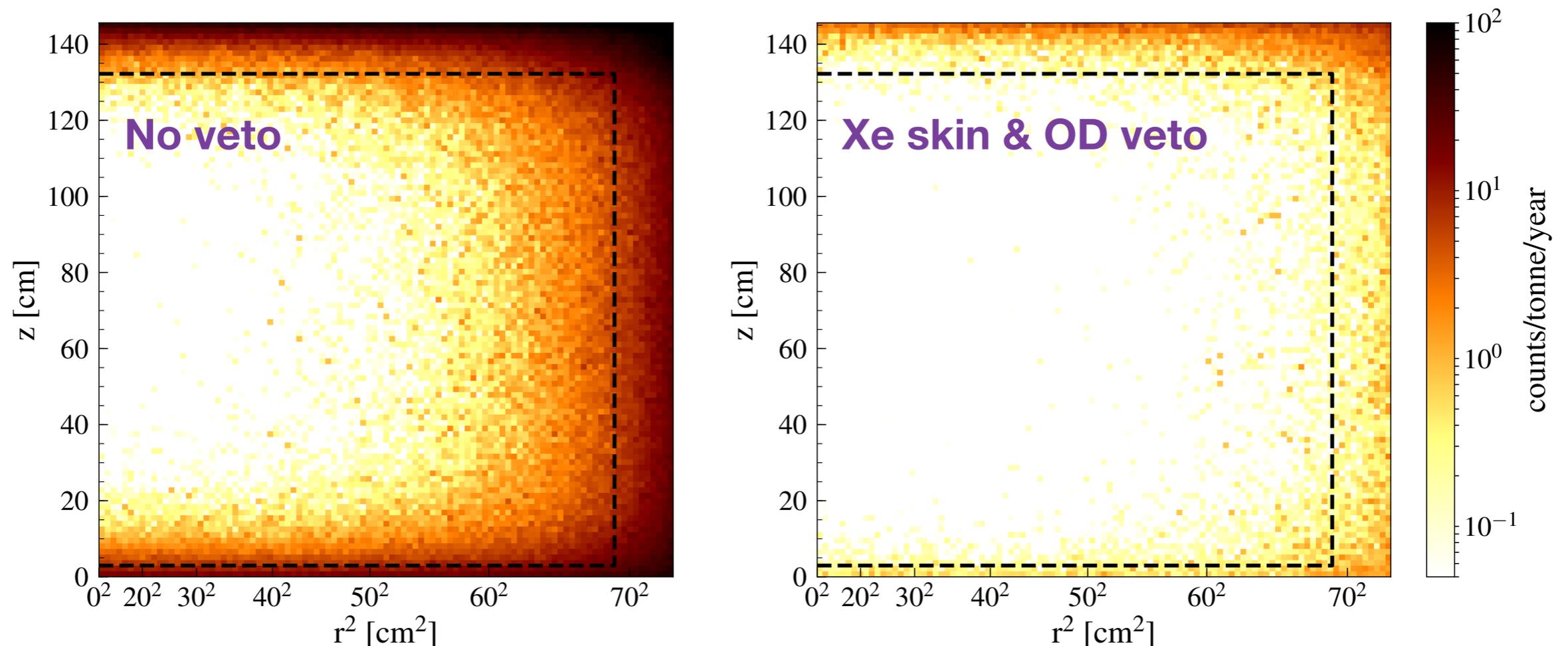
Many sources of BG
Many methods for BG mitigation

Background suppression

Expected BG NR cts / 1000 days in 5.6t FV in 6-30 keV_{nr} :

Without vetoing: 10.43

With skin and OD vetoes: 1.03



NR BG equivalent fiducial volume:

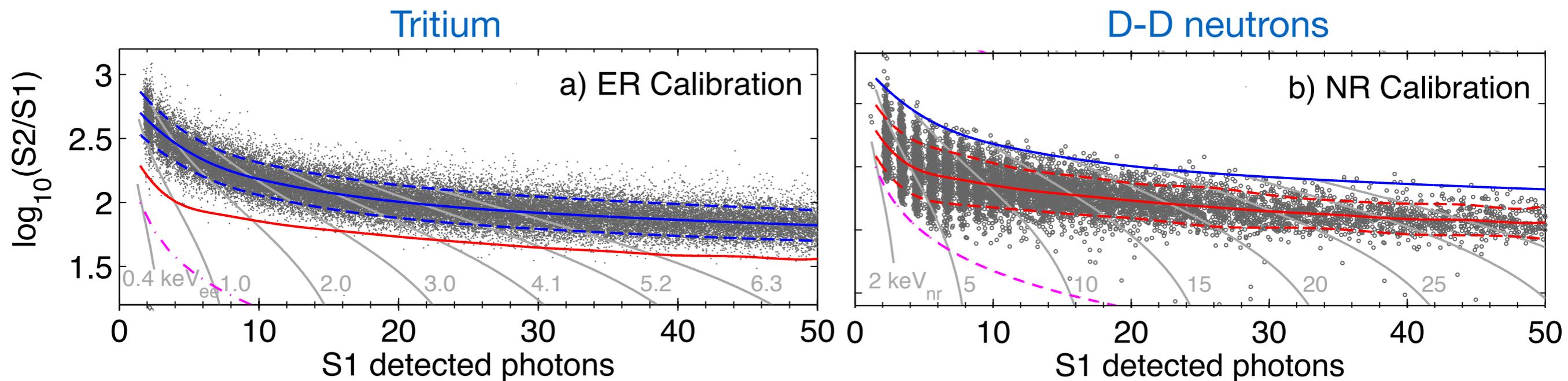
Without vetoing: 3.2t

With skin and OD vetoes: 5.6t

Discrimination

- Light vs. charge distribution varies for ERs vs. NRs → discrimination
- Build on exquisite high statistics calibrations in LUX
- Model with NEST for sensitivity projection
- Extensive calibrations planned for LZ to map bands *in situ*

ER and NR band calibrations from LUX



Expected backgrounds

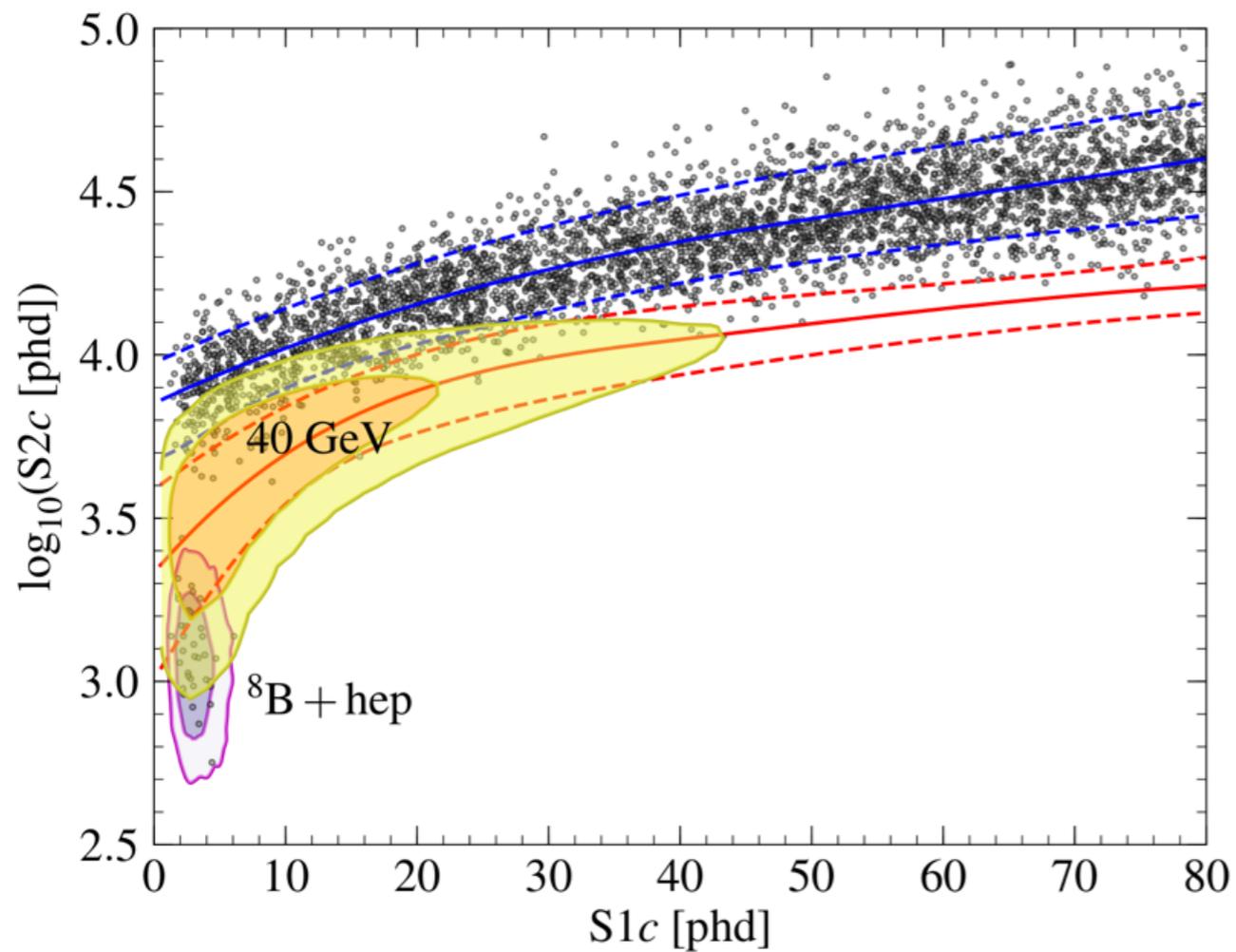
5.6 ton fiducial, 1000 live-days
1.5-6.5 keV_{ee} (6-30 keV_{nr})
single scatters, anti-coincidence with vetoes

Background Source	ER [cts]	NR [cts]
Detector components	9	0.07
Dispersed Radionuclides — Rn, Kr, Ar	819	—
Laboratory and Cosmogenics	5	0.06
Surface Contamination and Dust	40	0.39
Physics Backgrounds — 2β decay, neutrinos*	322	0.51
Total	1195	1.03
After 99.5% ER discrimination, 50% NR efficiency	5.97	0.51

* not including ^8B and HEP

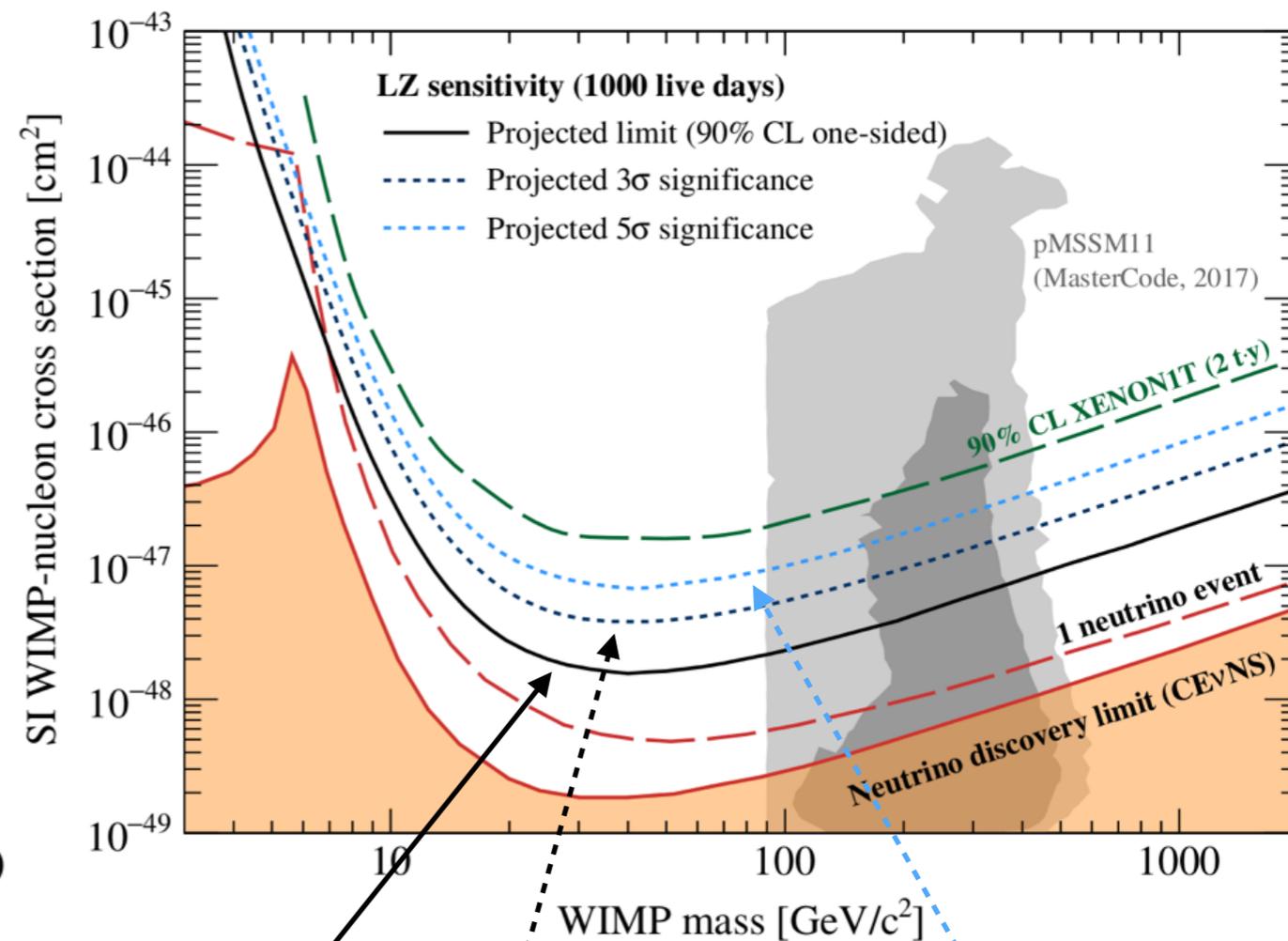
Sensitivity

Simulation of a 1000 day run of LZ



Projected:

Projected detection and exclusion curves



90% CL limit

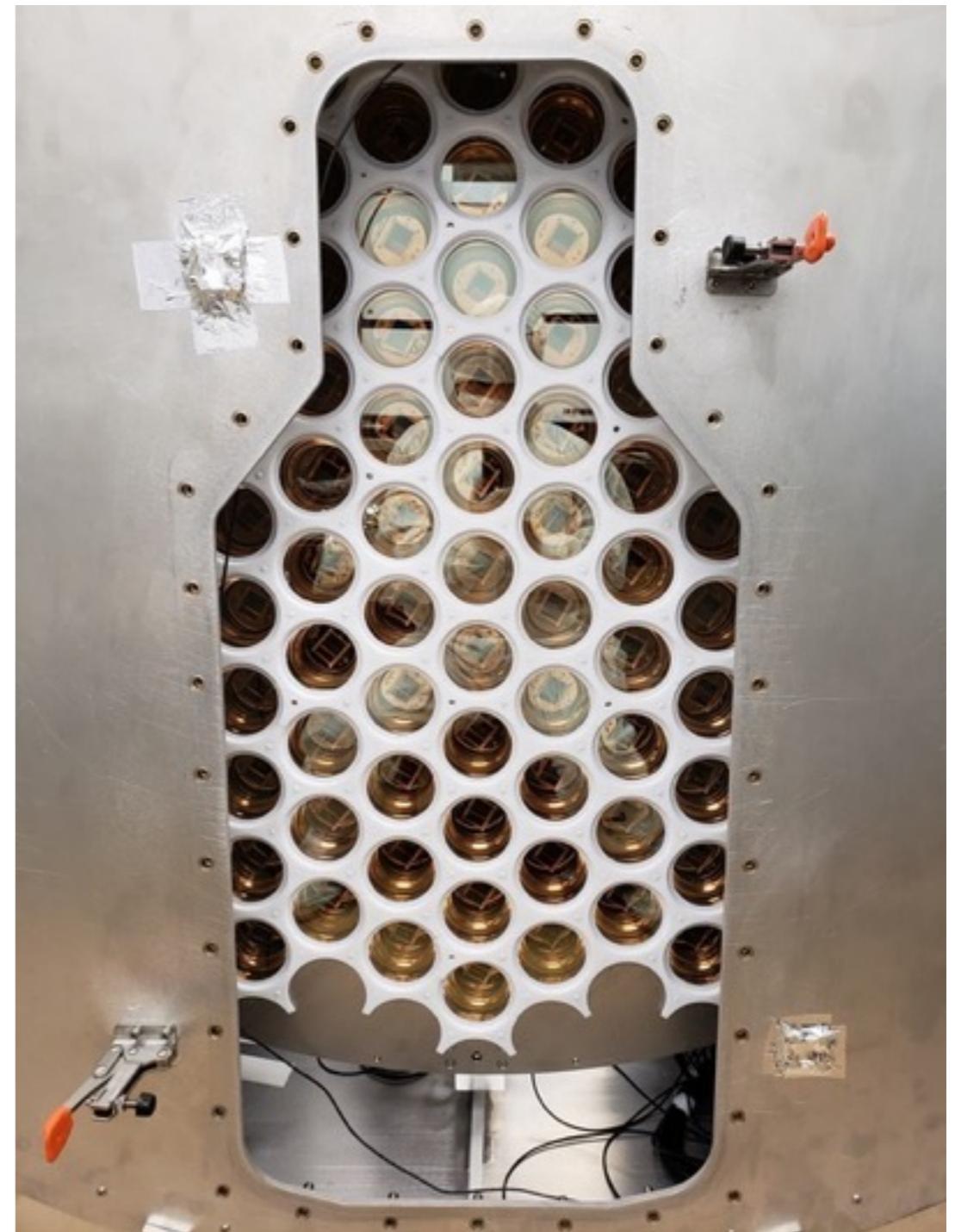
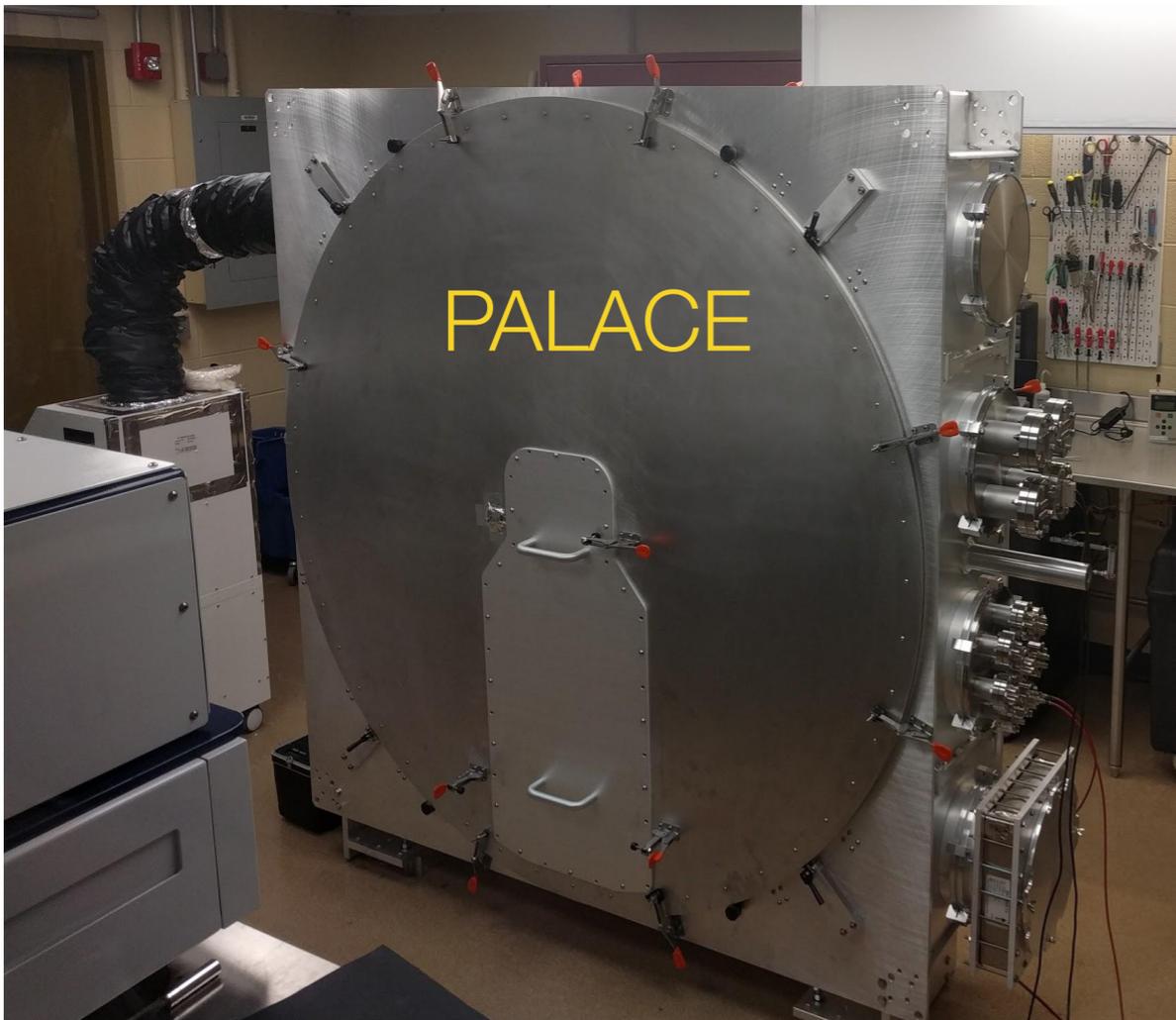
3σ

5σ

90% CL minimum of $1.6 \times 10^{-48} \text{ cm}^2$ at $40 \text{ GeV}/c^2$

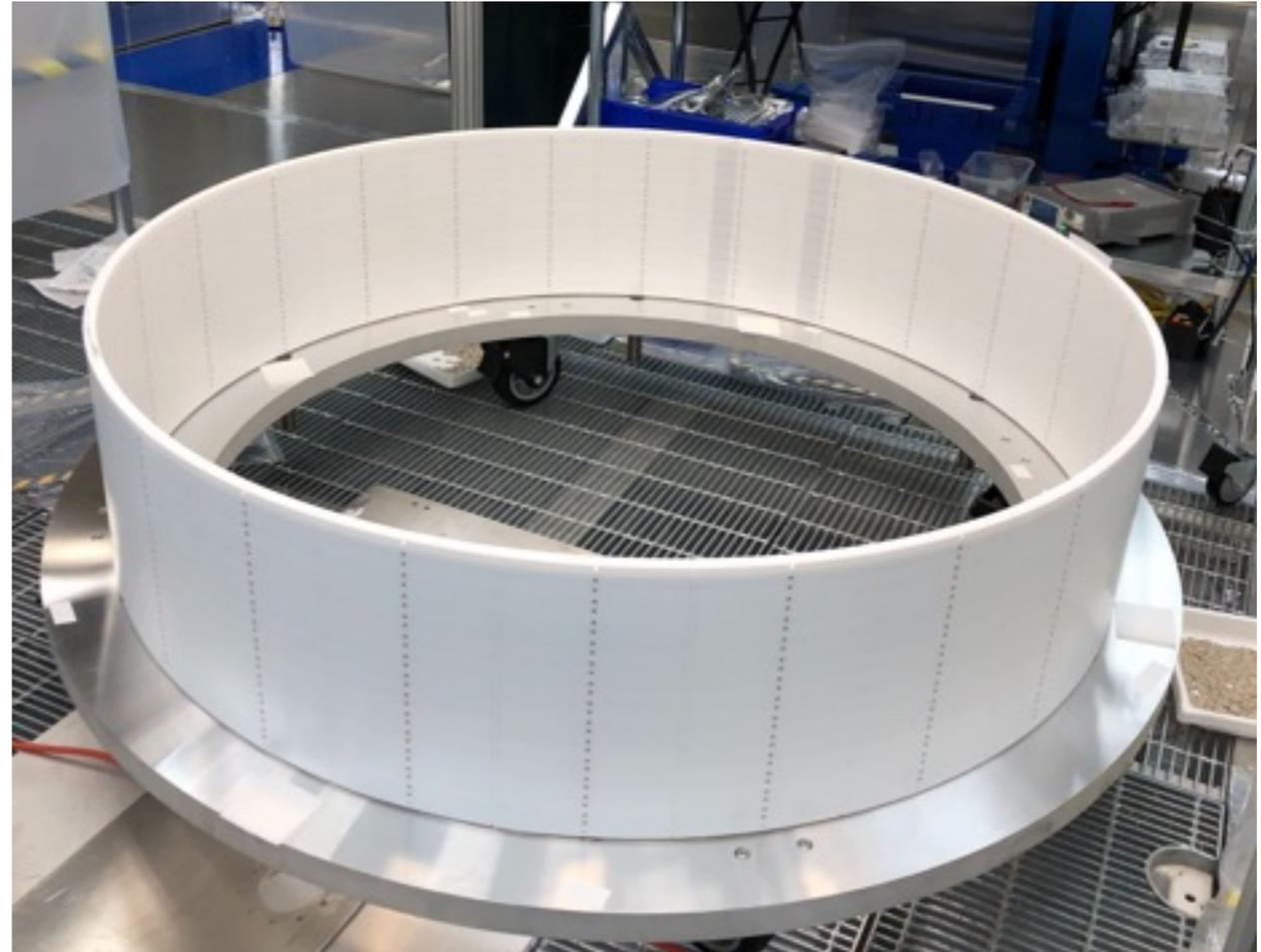
TPC: PMTs

- PMT arrays assembled in PALACE
 - PMT dark electrical testing
 - Shipping housing
 - Dust control with HEPA filtered air
- Low airborne Rn, 2-4 Bq/m³
- Witness plates for dust surveillance



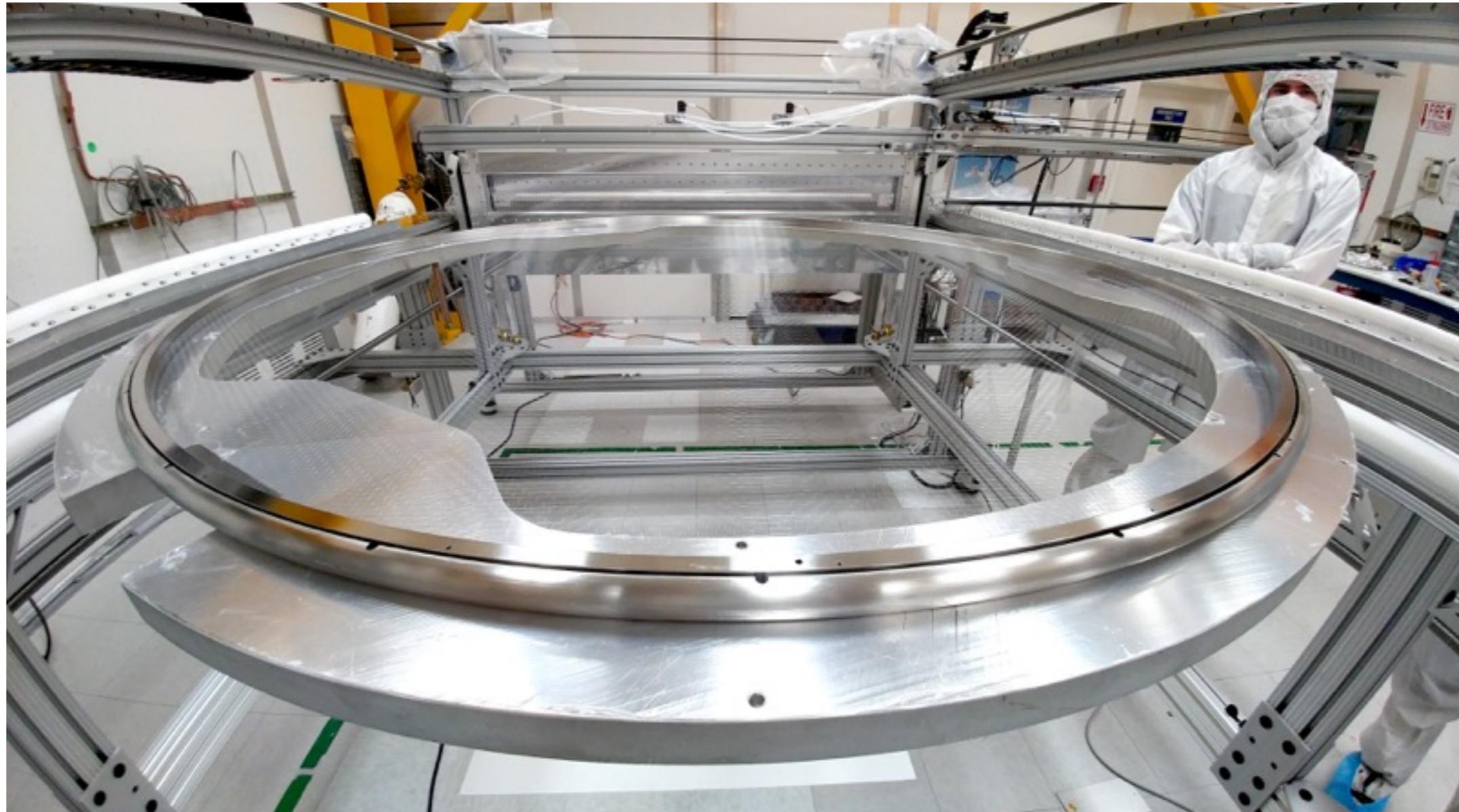
TPC: field cage

Assembling
now



TPC: grids

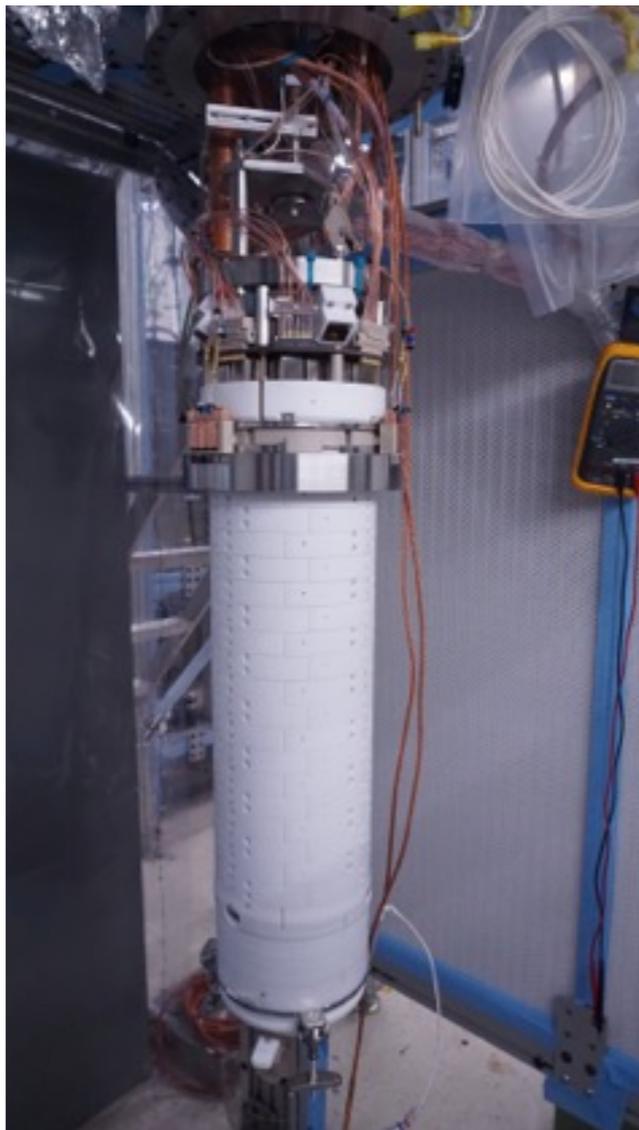
- (Semi-)automated loom for weaving SS wire meshes
- Video of the weaving process: <https://www.youtube.com/watch?v=yNycDcMQkss>
- Final LZ grids in production



SLAC test platform

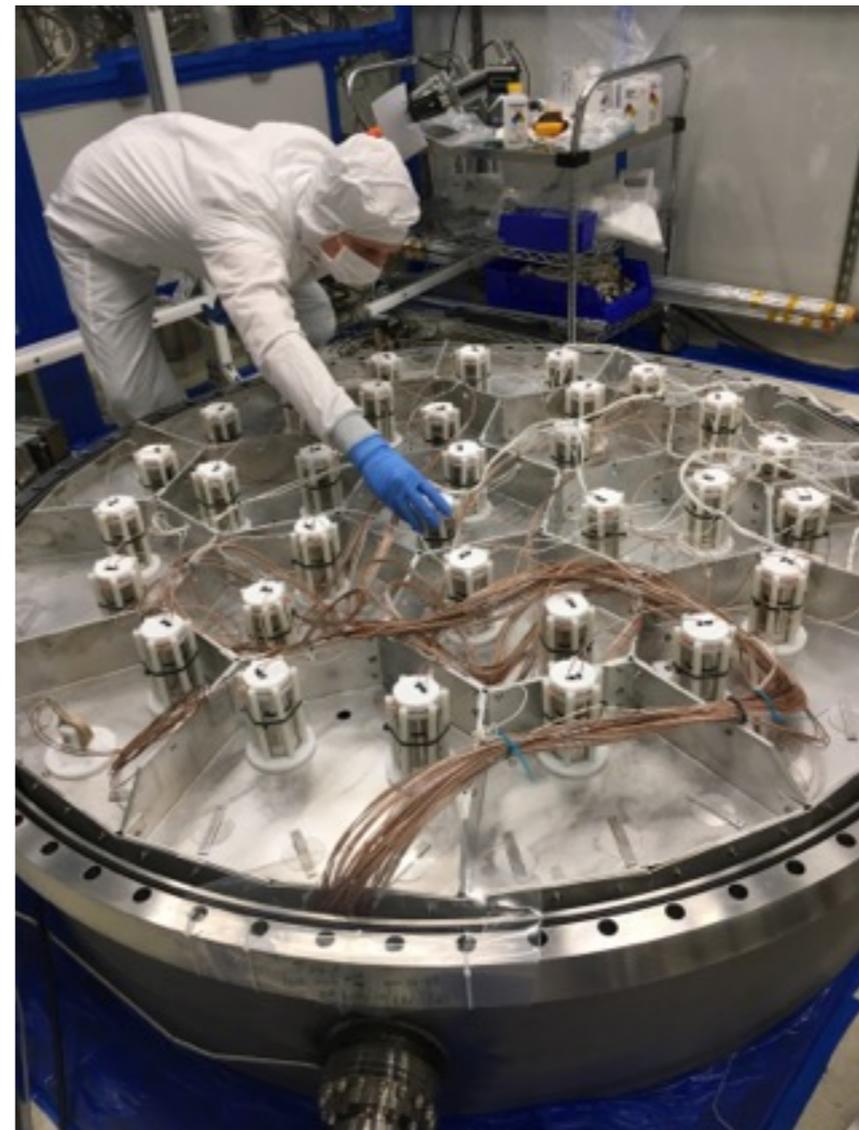
Phase 1

- Field cage and “extraction region” design
- Cryogenics and circulation design
- Instrumentation testbed



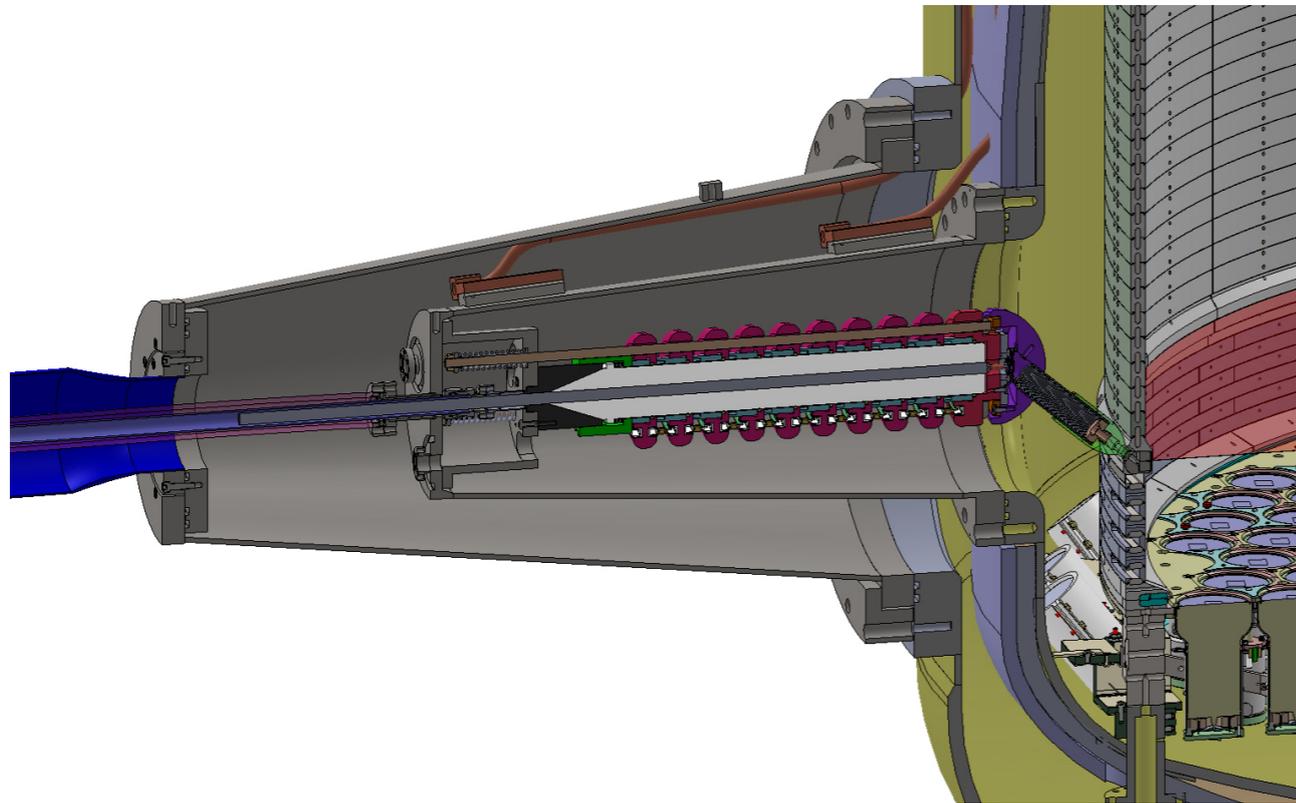
Phase 2

- Validate LZ grids
- Gas Xe
- Single electron sensitivity



Cathode HV

- Extensive prototyping at design field (50 kV/cm)
- Tests of cathode cable grading structure in liquid argon; successfully reaches 120 kV (50 kV required)
- Embedded polyethylene conductive components in HV cable → simple O-ring seal



Titanium cryostat

- Intensive R&D program identified low activity titanium material ([Astropart. Phys. 96 \(2017\) 1-10](#))
- Arrived at SURF May 14, 2018



Outer detector

- Acrylic vessels staged underground in water tank
- Gd-LS production equipment being installed at BNL
- All PMTs in hand, testing at IBS (Korea) is nearly done



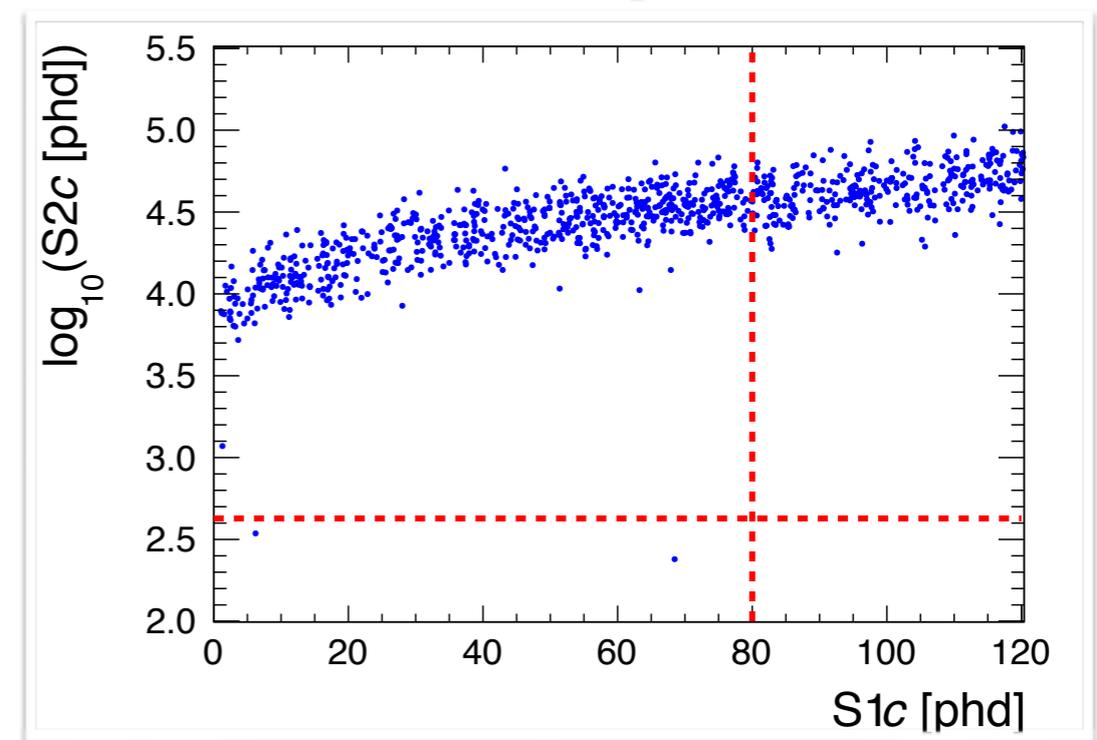
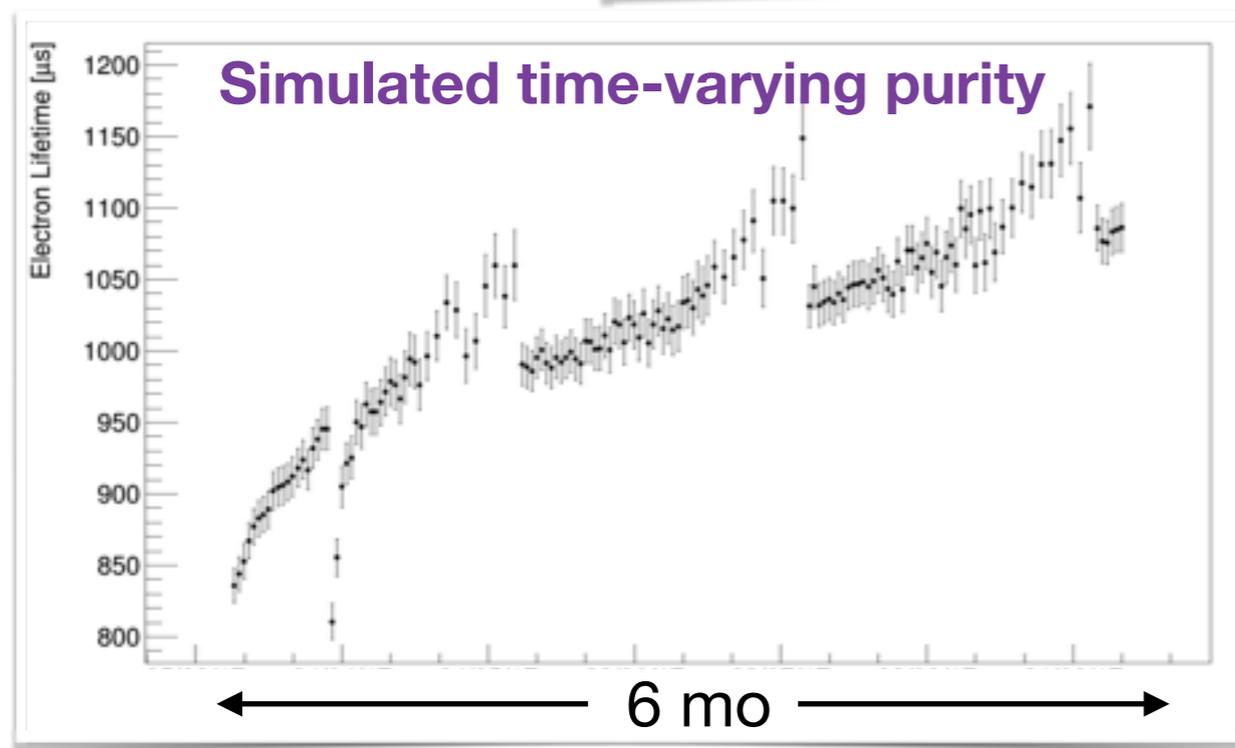
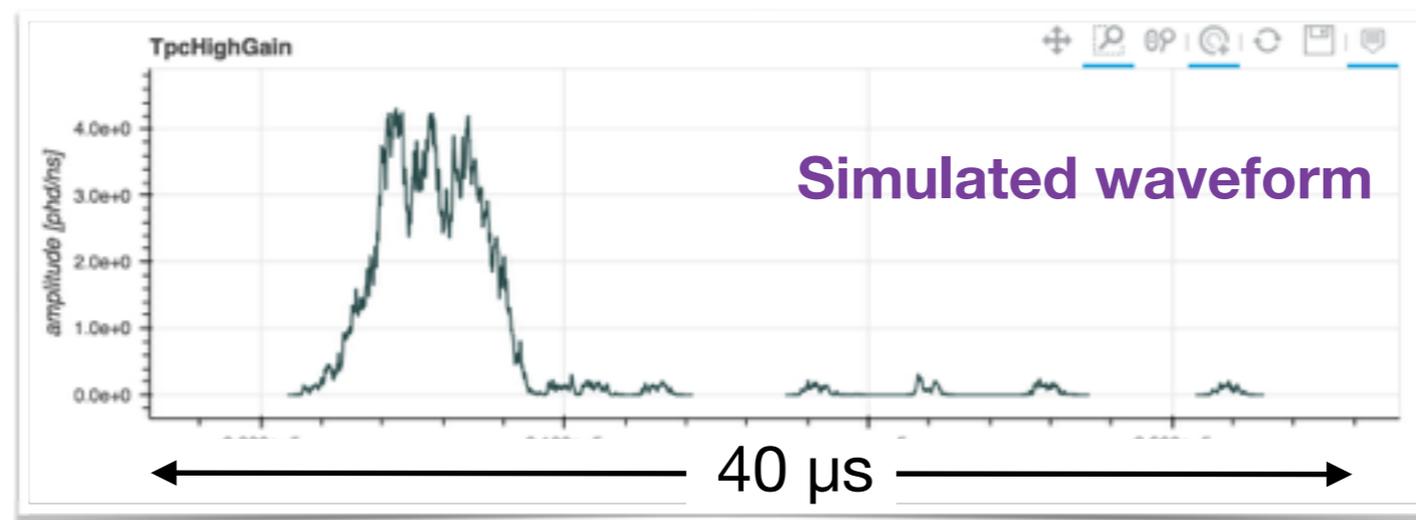
Xe procurement and Kr removal

- 7t Xe in hand
- Chromatography to separate Kr from Xe.
 - Demonstration of 0.06 ppt in R&D at SLAC
 - Production system designed to remove to 0.015 ppt (1/10 solar neutrino BG)
- Kr removal at SLAC on track to start by July 2019 and finish by end 2019.

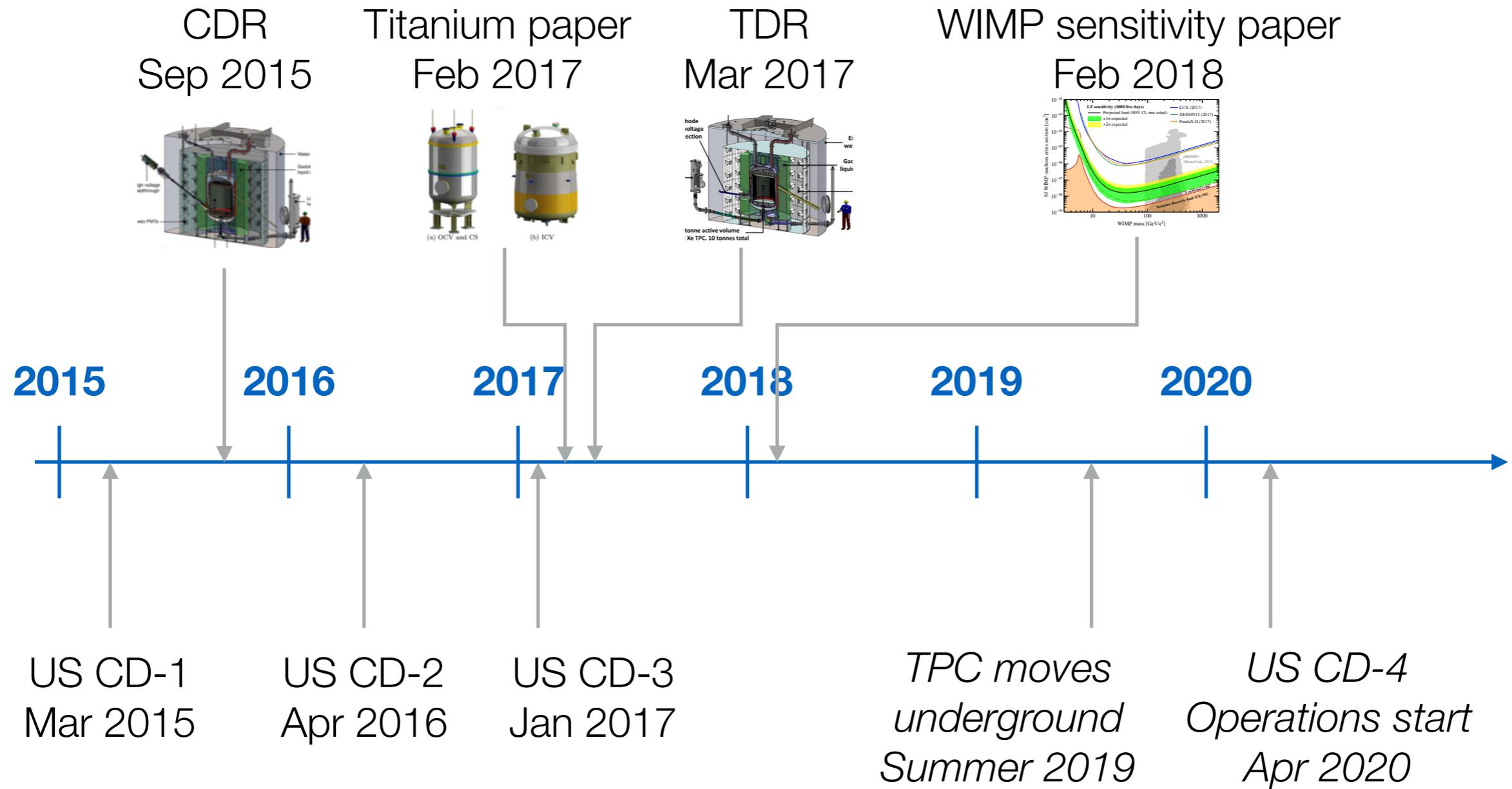


Mock data challenges

- Develop and validate all software before first physics data
- Simulate 6 months of LZ data taking, including detector pathologies, through realistic waveforms
- Analyzers search for injected signal (possibly none!)



Timeline



LZ collaboration

38 institutions, ~250 scientists, engineers, technicians



- 1) IBS-CUP (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)