Status of the LZ experiment

Alden Fan for the LZ collaboration

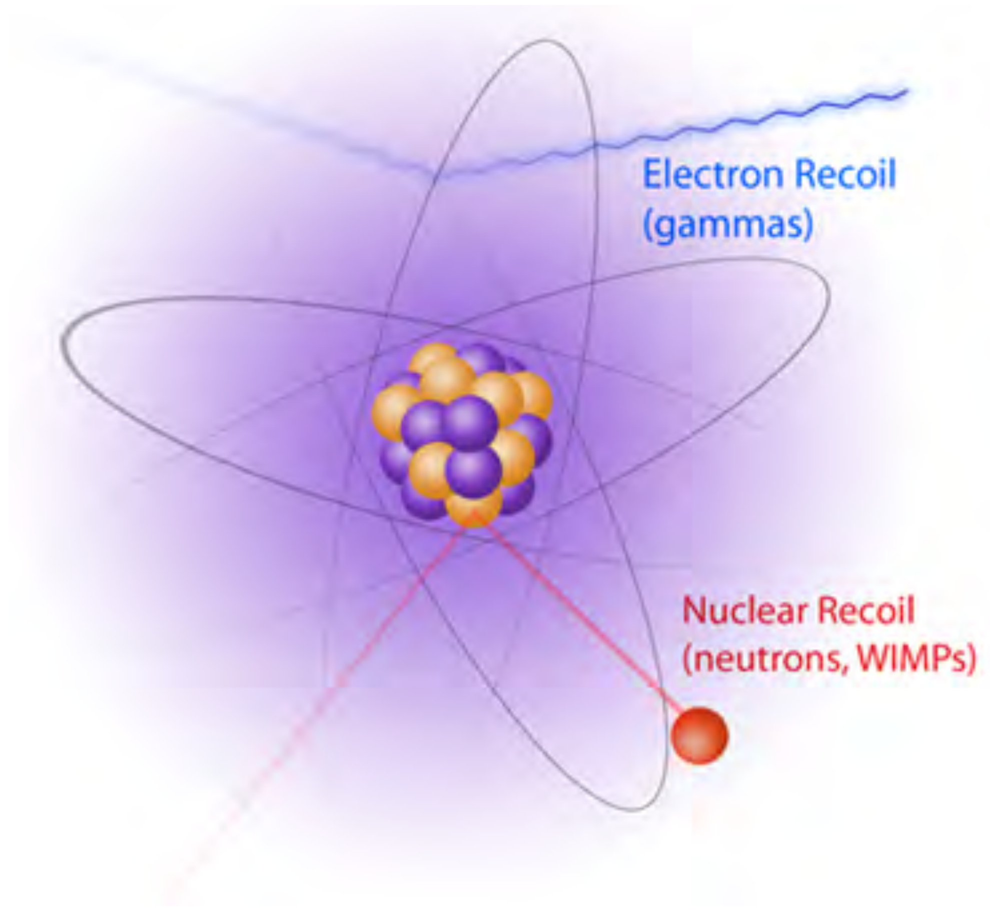
(Stanford/KIPAC/SLAC)

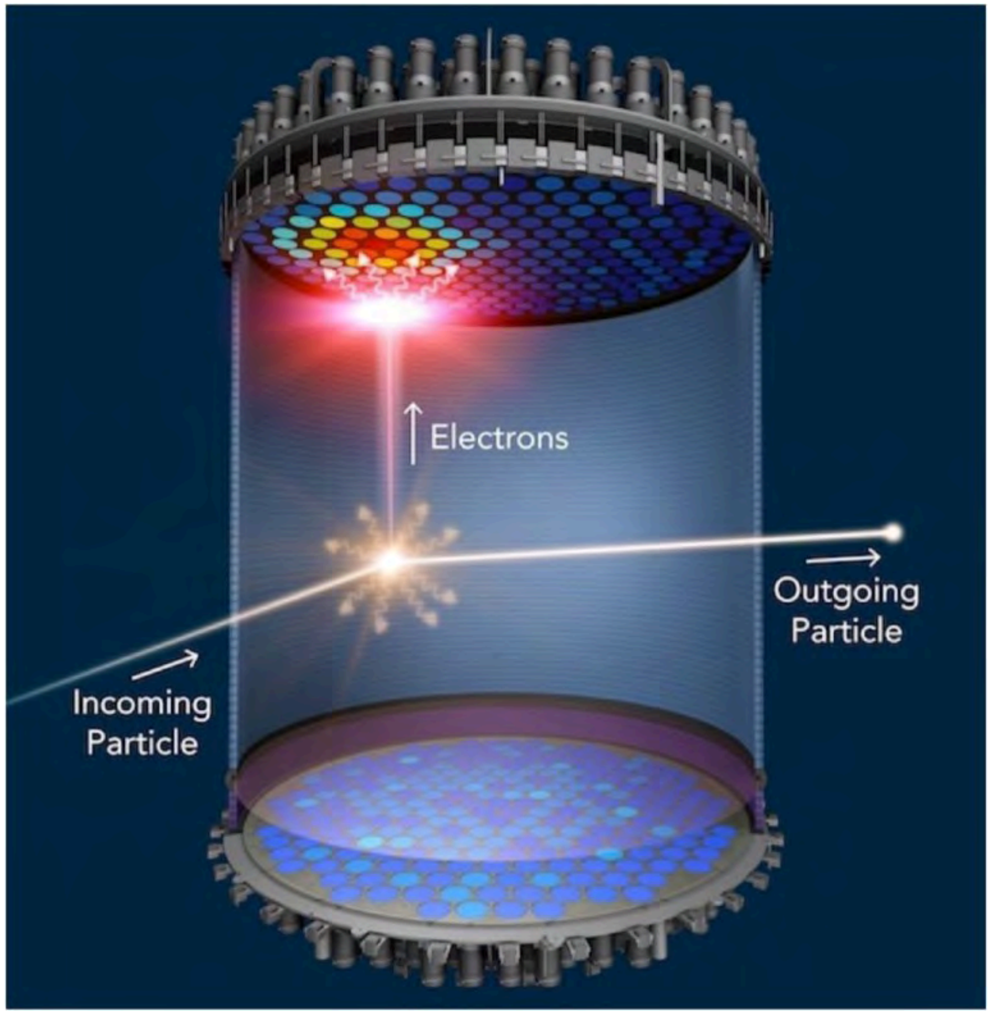
9th Symposium on Large TPCs for Low-energy Rare Event Detection

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

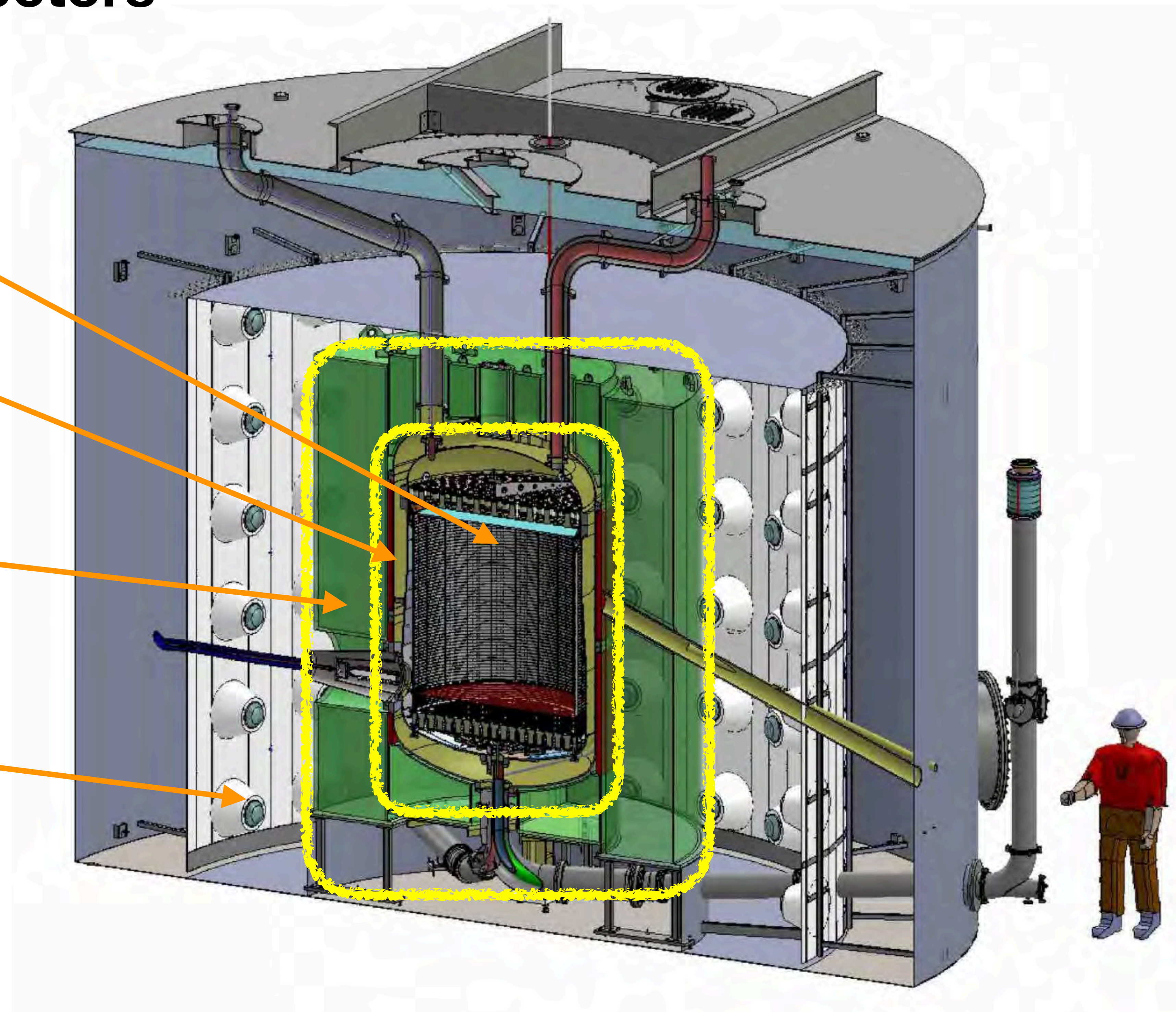




- Dual-phase time projection chamber with Xe gives precise 3D position, energy, electron/nuclear recoil discrimination

LUX-ZEPLIN

Nested detectors



Xe TPC

Xe skin region

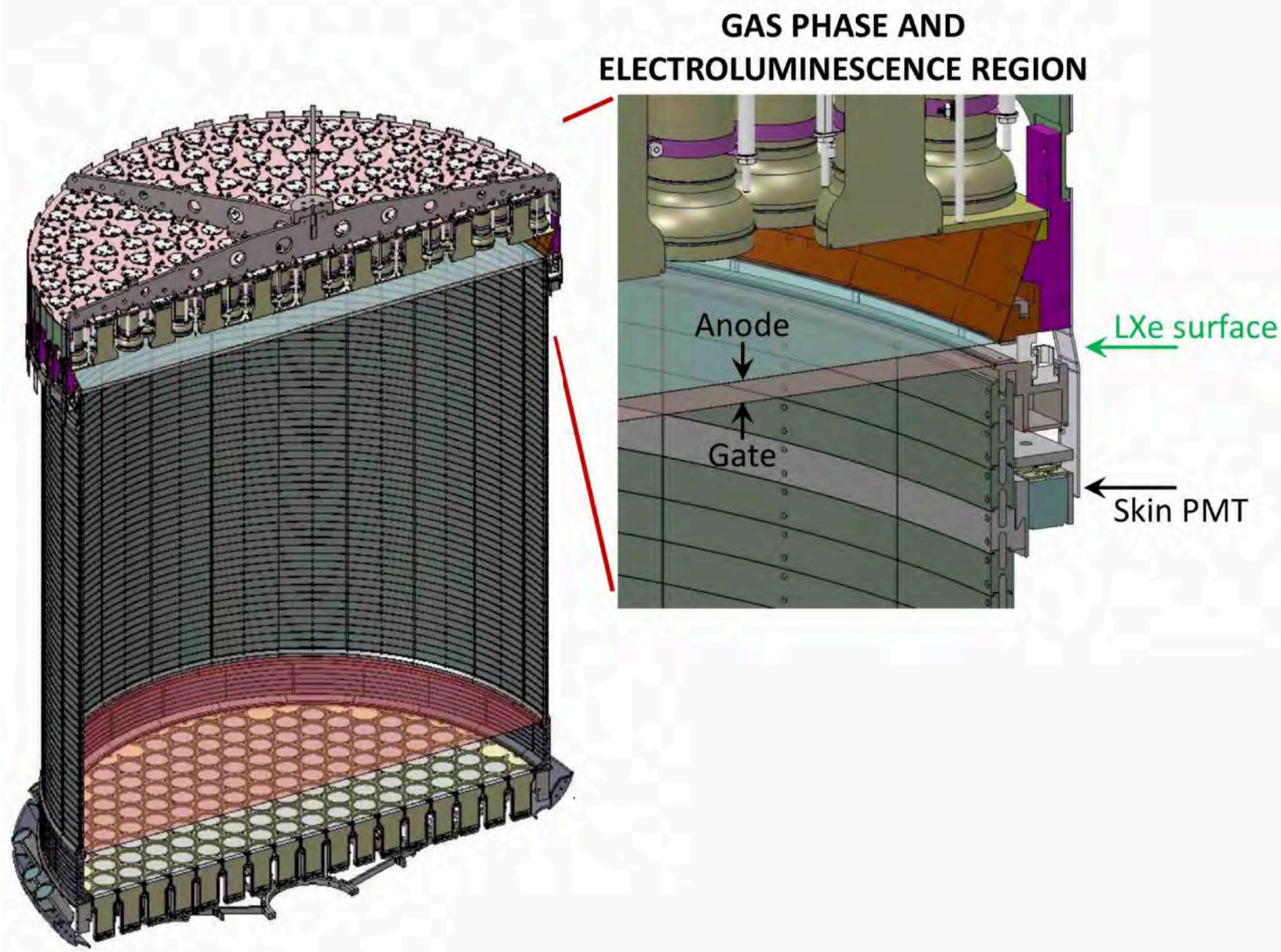
Liquid scintillator

High purity water

LZ TDR arXiv:1703.09144

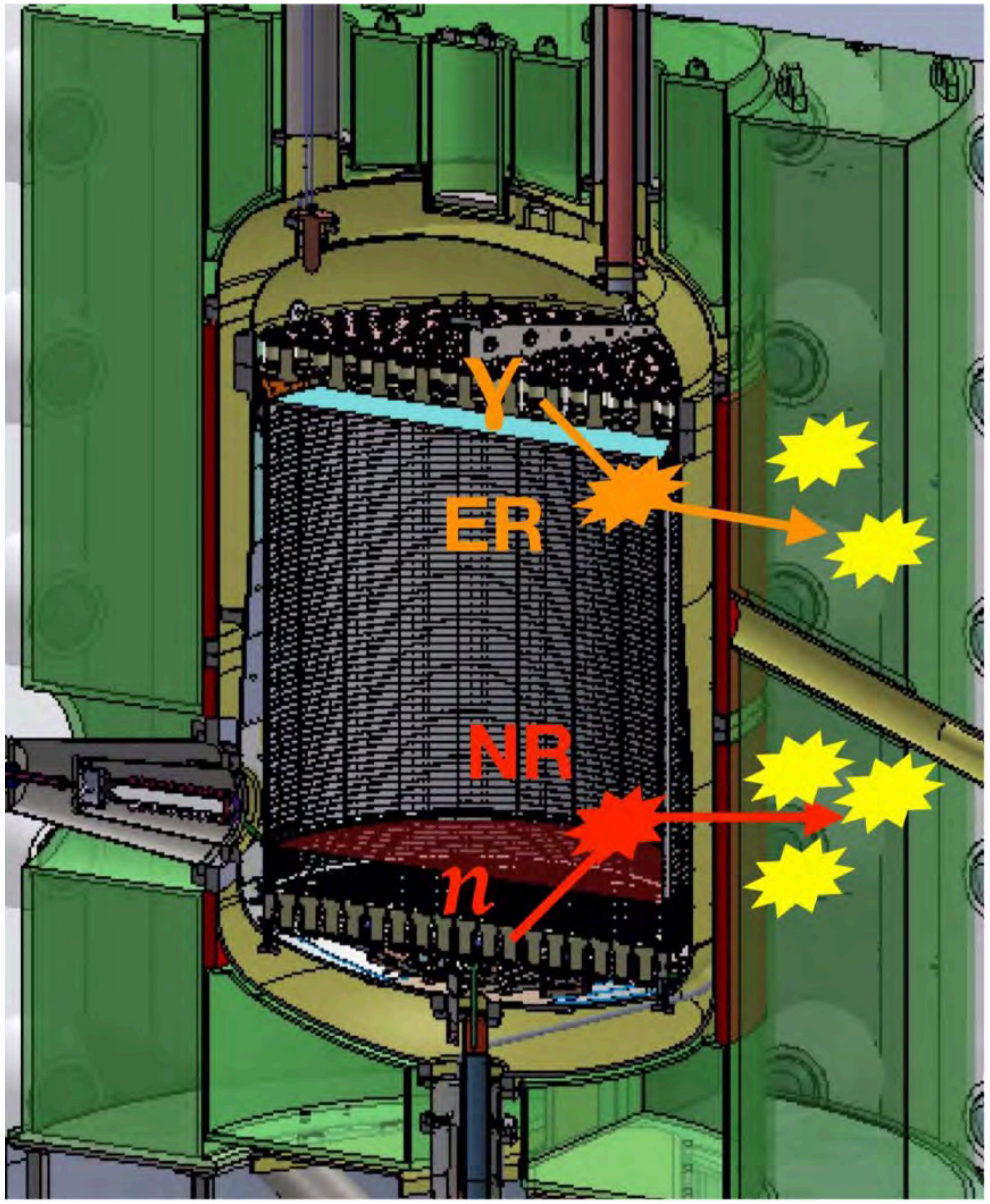
Xenon TPC

- 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+Gd → Gd + (4-5x) γ (~8.5 MeV)
  - ^{nat}Gd thermal n-capture σ → 40 kbarn
  - Capture time: 30 μs 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 µBq/kg
- **Rn daughters and dust on surfaces**
  - TPC assembly in Rn-reduced cleanroom
  - Dust <500 ng/cm^3 on all LXe wetted surfaces
  - Rn-daughter plate-out on TPC walls <0.5 mBq/m^2
- **Xenon contaminants — ^{85}Kr, ^{39}Ar**
  - Charcoal chromatography @ SLAC
  - Final ^{nat}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

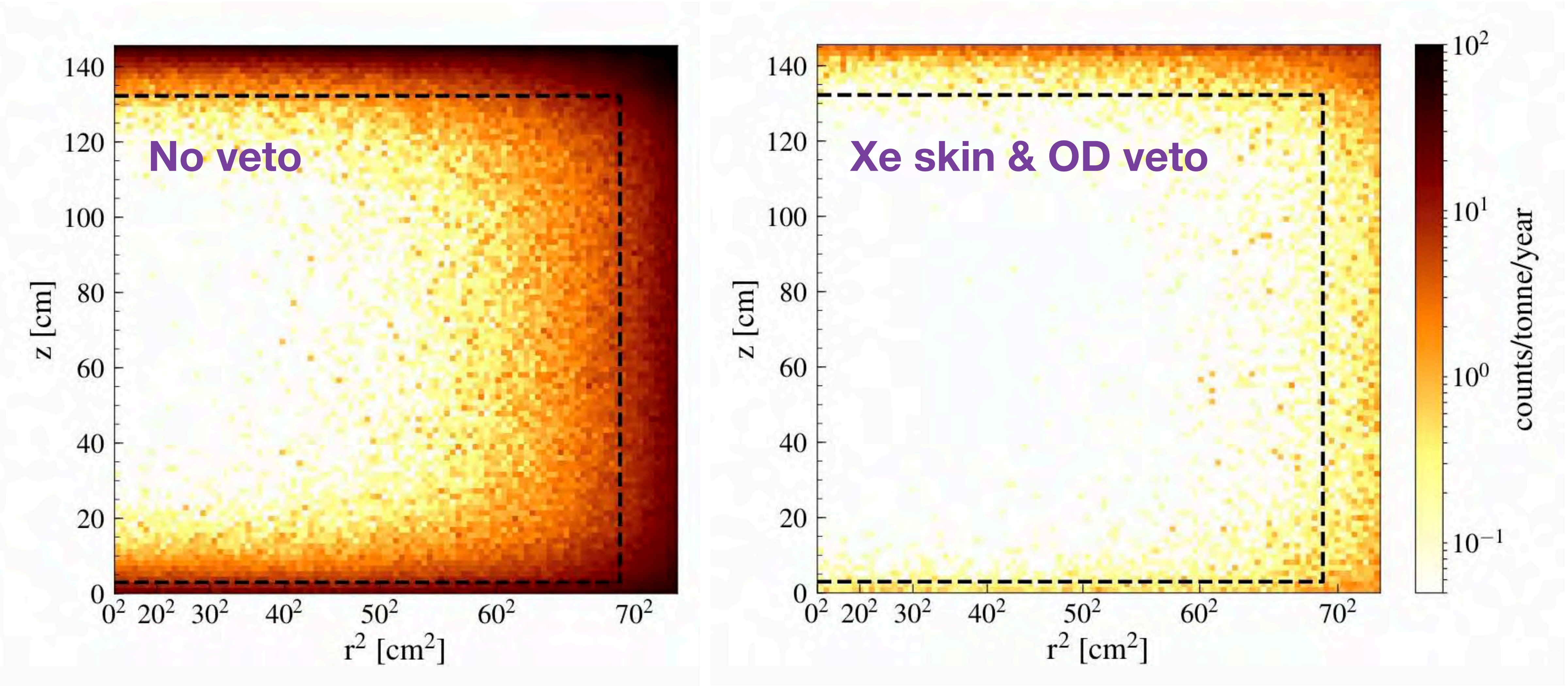
Many sources of BG
Many methods for BG mitigation

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:

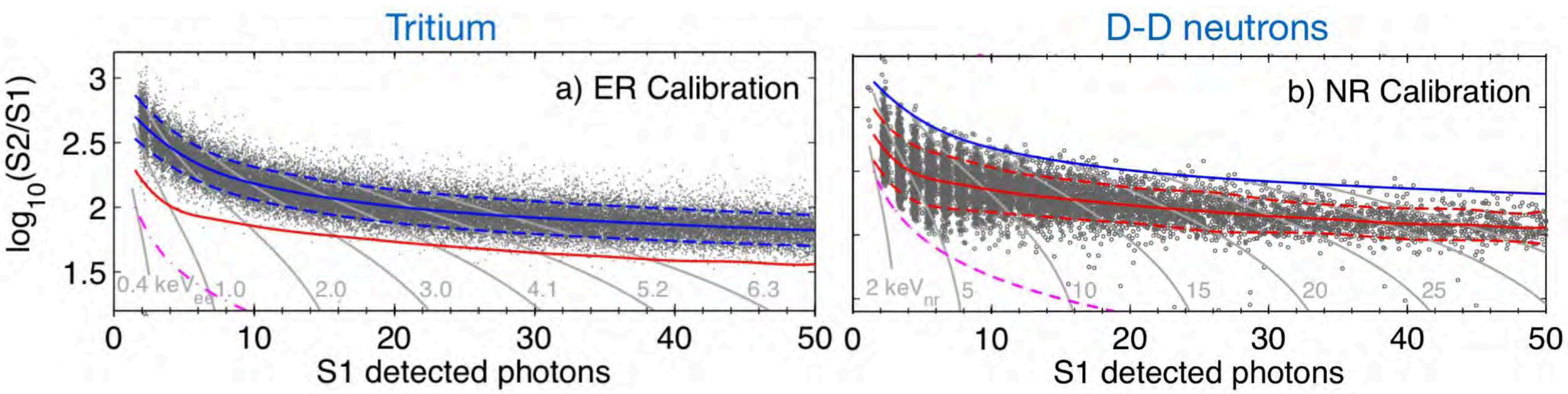
Without vetoing: 3.2t

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



D.S. Akerib et al (LUX collaboration) 2018 Phys. Rev. D 97, 102008

Expected backgrounds

5.6 ton fiducial, 1000 live-days

1.5-6.5 keV_{ee} (6-30 keV_{nr})

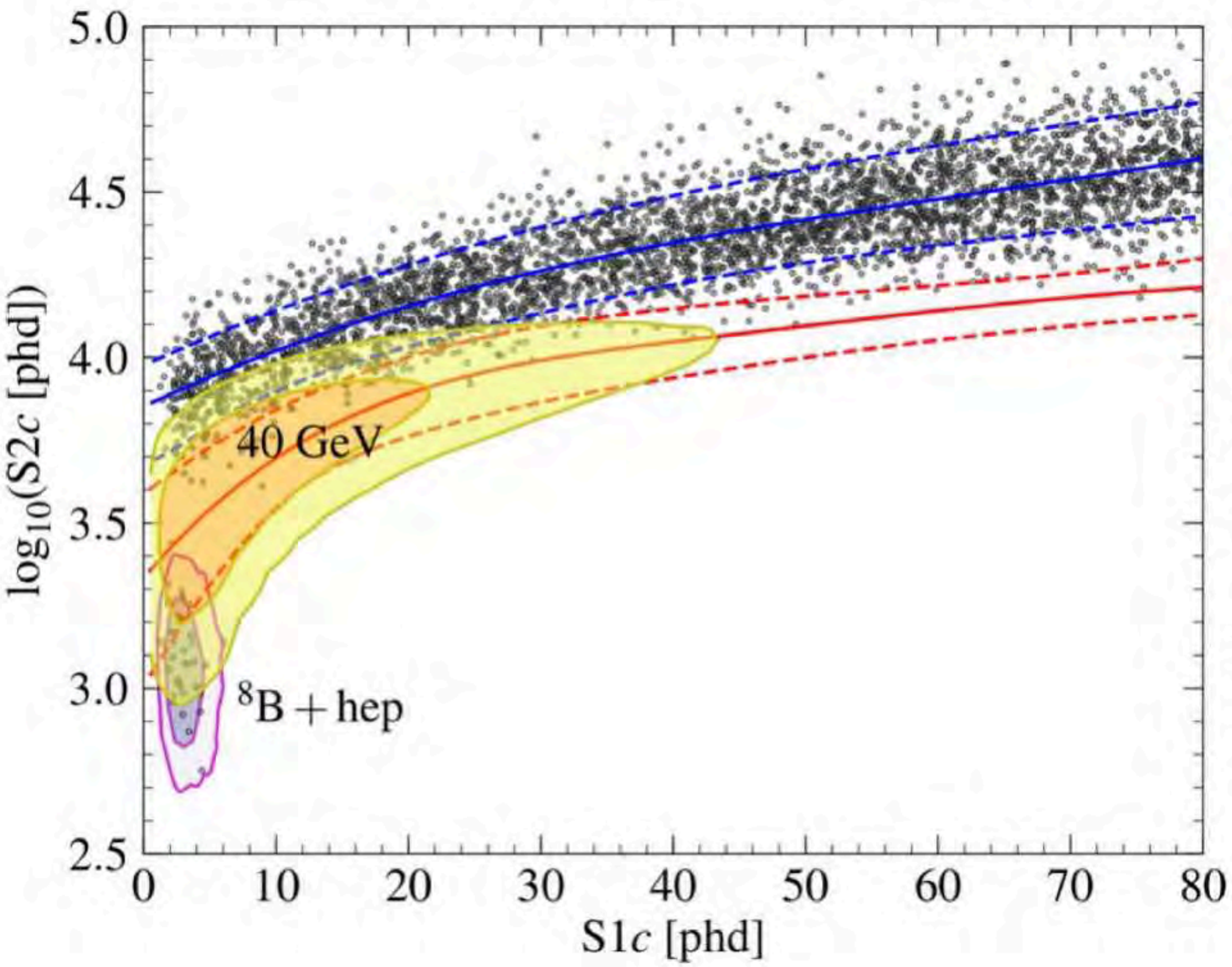
single scatters, anti-coincidence with vetoes

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**

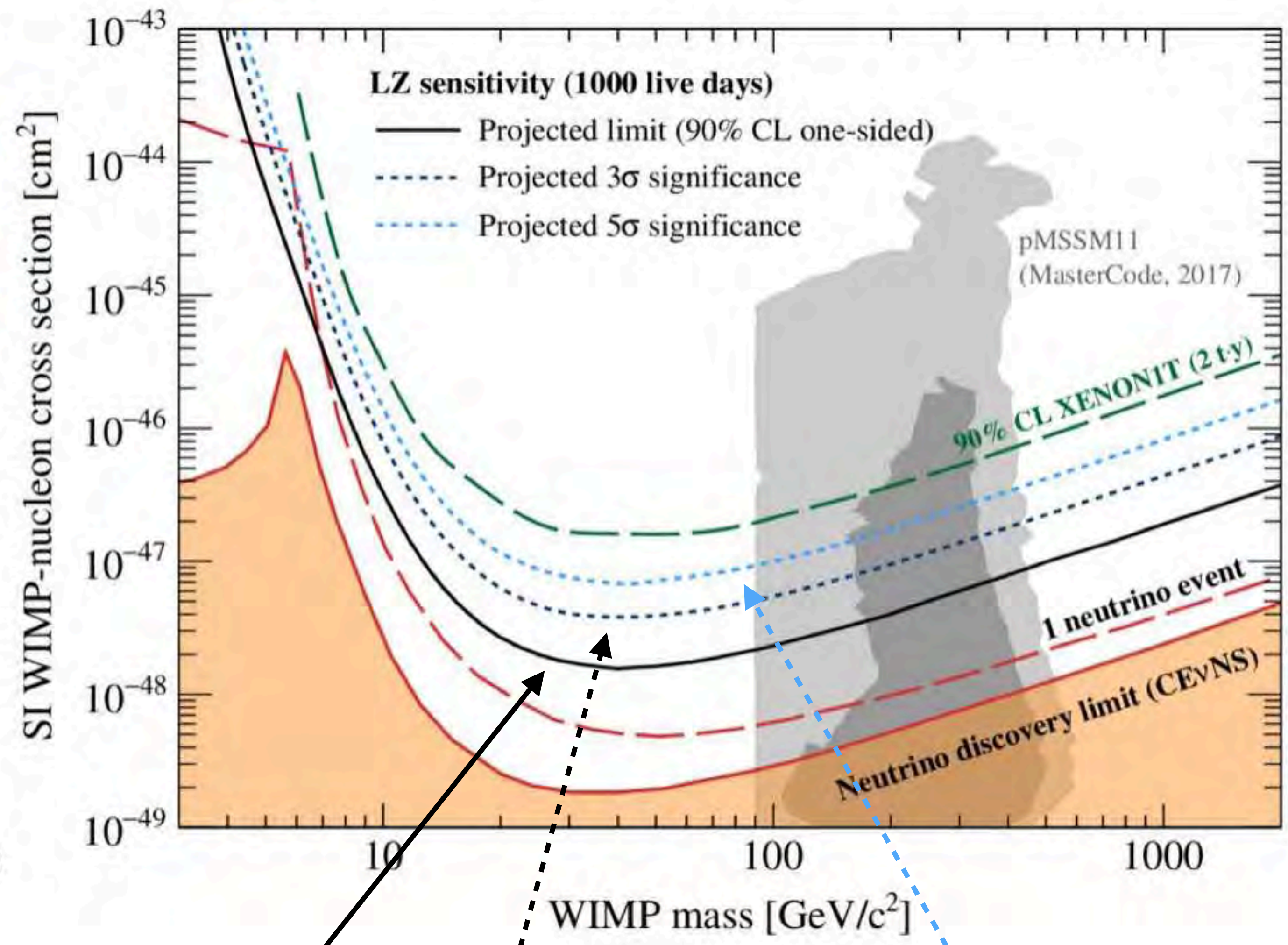
* not including ^{8}B and HEP

Sensitivity

Simulation of a 1000 day run of LZ



Projected detection and exclusion curves

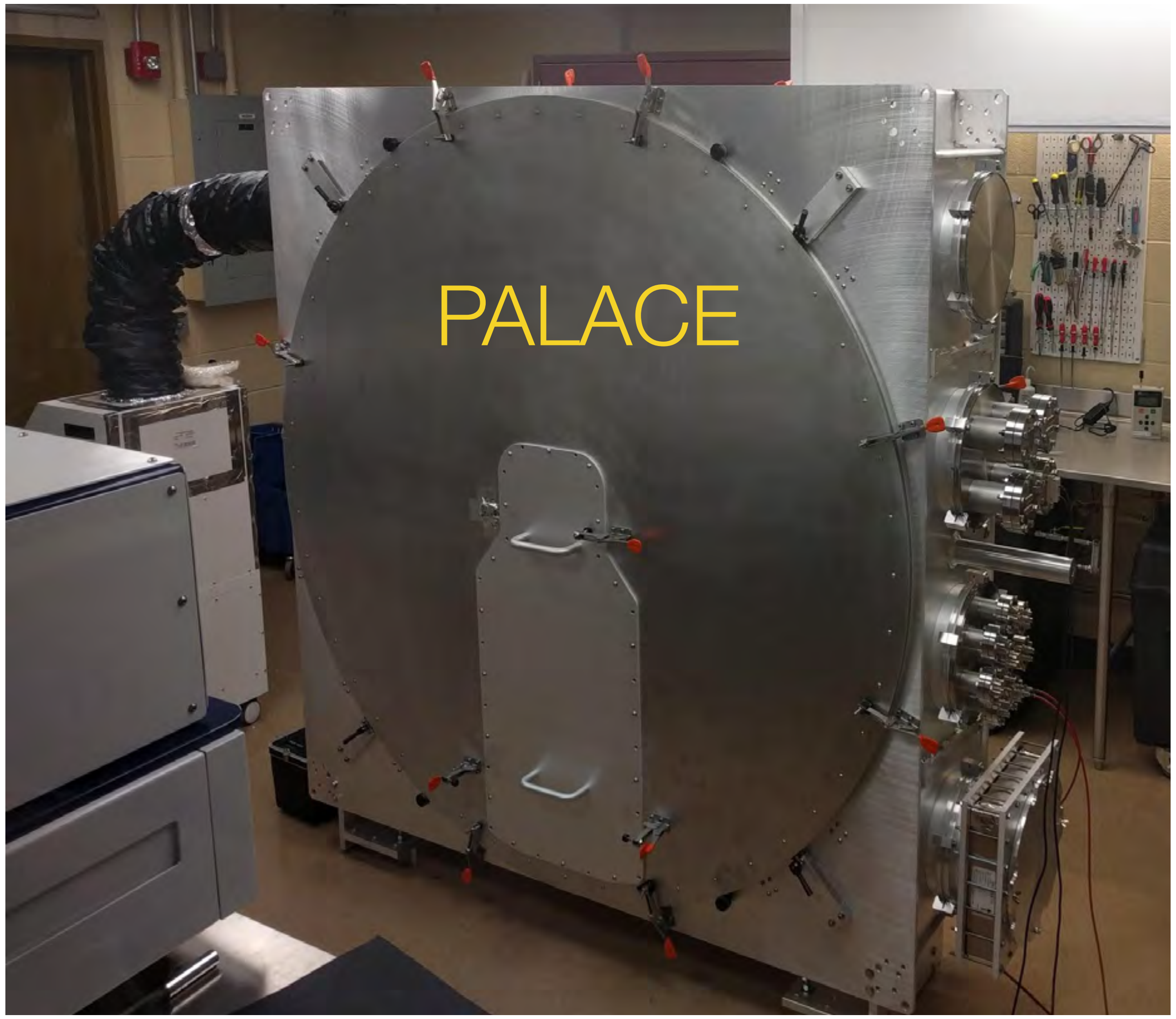


Projected: 90% CL limit 3σ 5σ

90% CL minimum of 1.6 x 10^{-48} cm^2 at 40 GeV/c^2

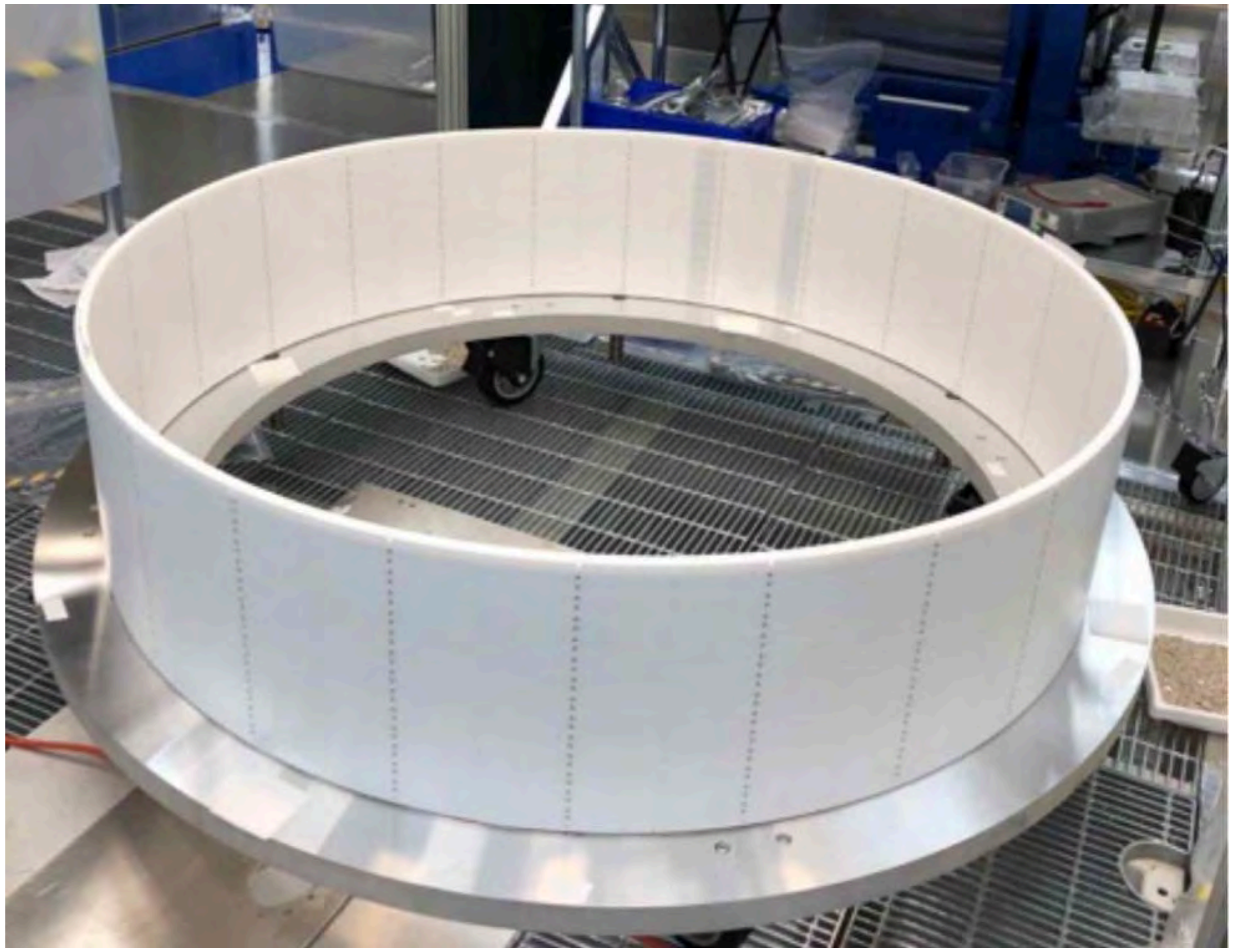
TPC: PMTs

- PMT arrays assembled in PALACE
  - PMT dark electrical testing
  - Shipping housing
  - Dust control with HEPA filtered air
- Low airborne Rn, 2-4 Bq/m^3
- Witness plates for dust surveillance



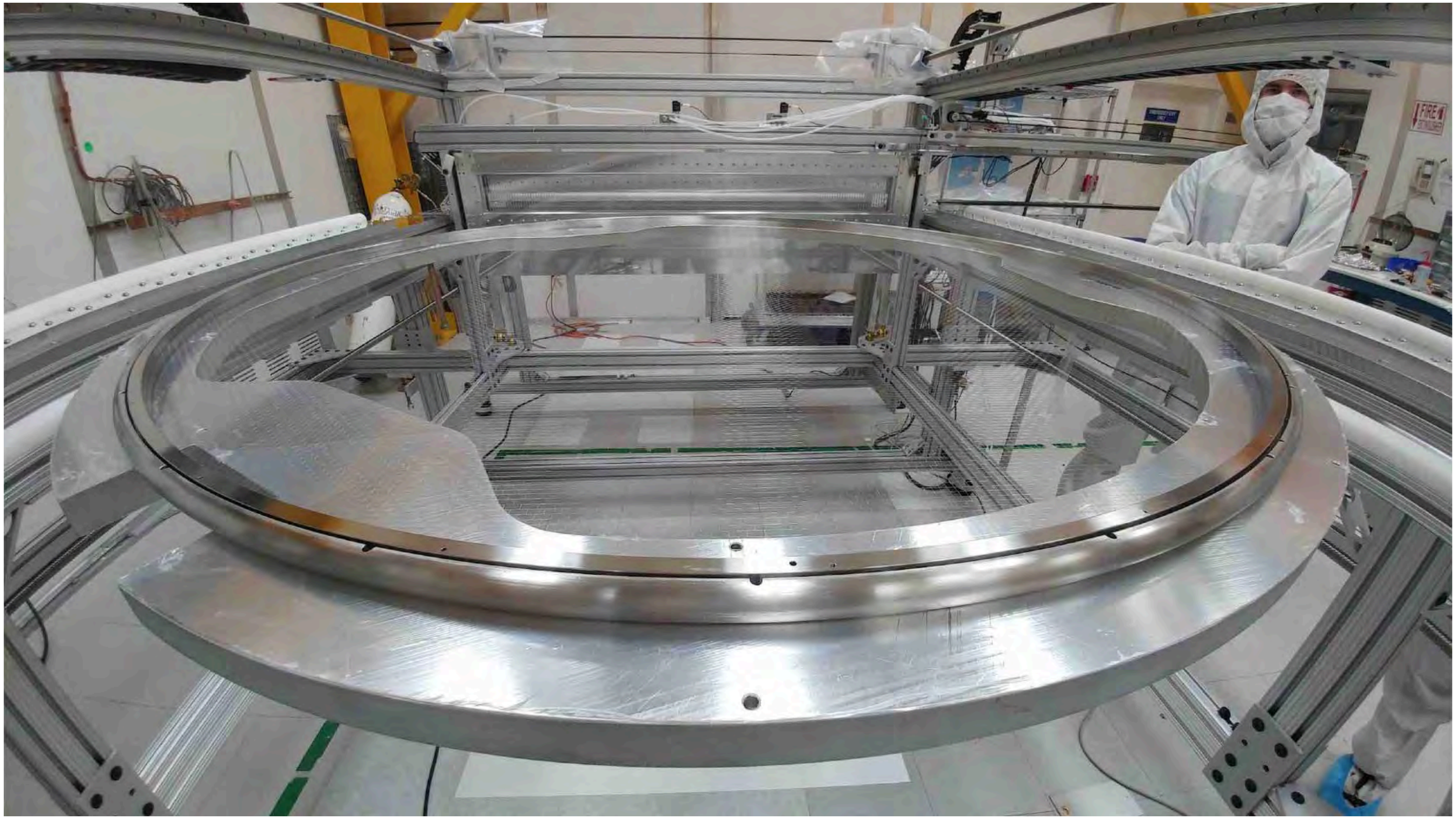
TPC: field cage

Assembling
now



TPC: grids

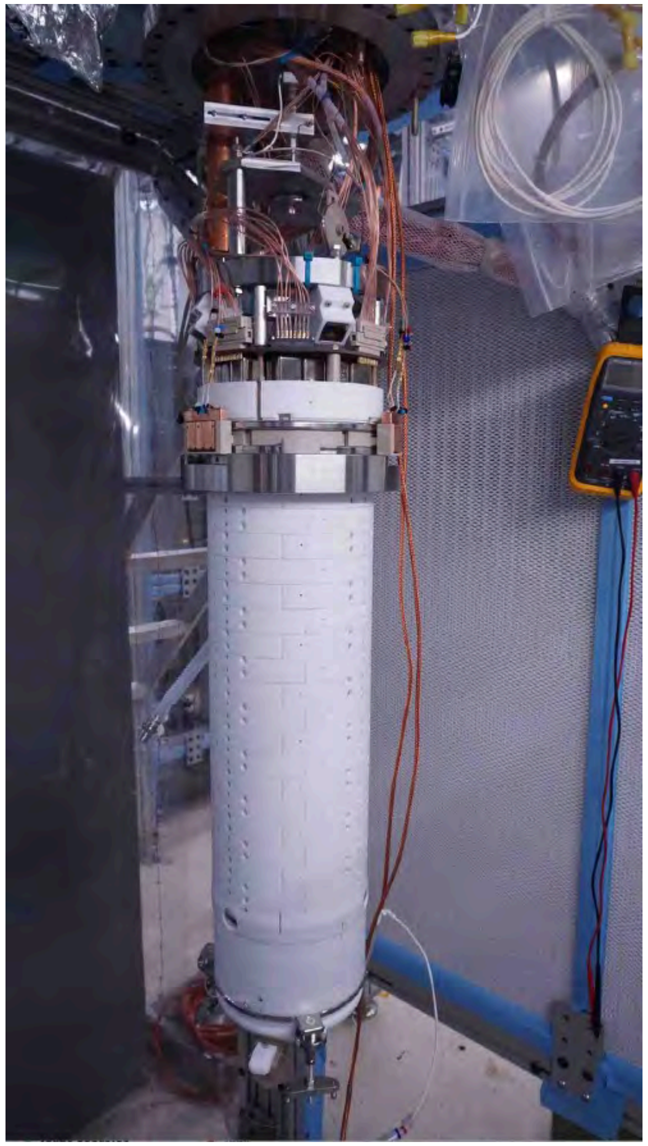
- (Semi-)automated loom for weaving SS wire meshes
- Video of the weaving process: https://www.youtube.com/watch?v=yNycDcMQkss
- Final LZ grids in production



SLAC test platform

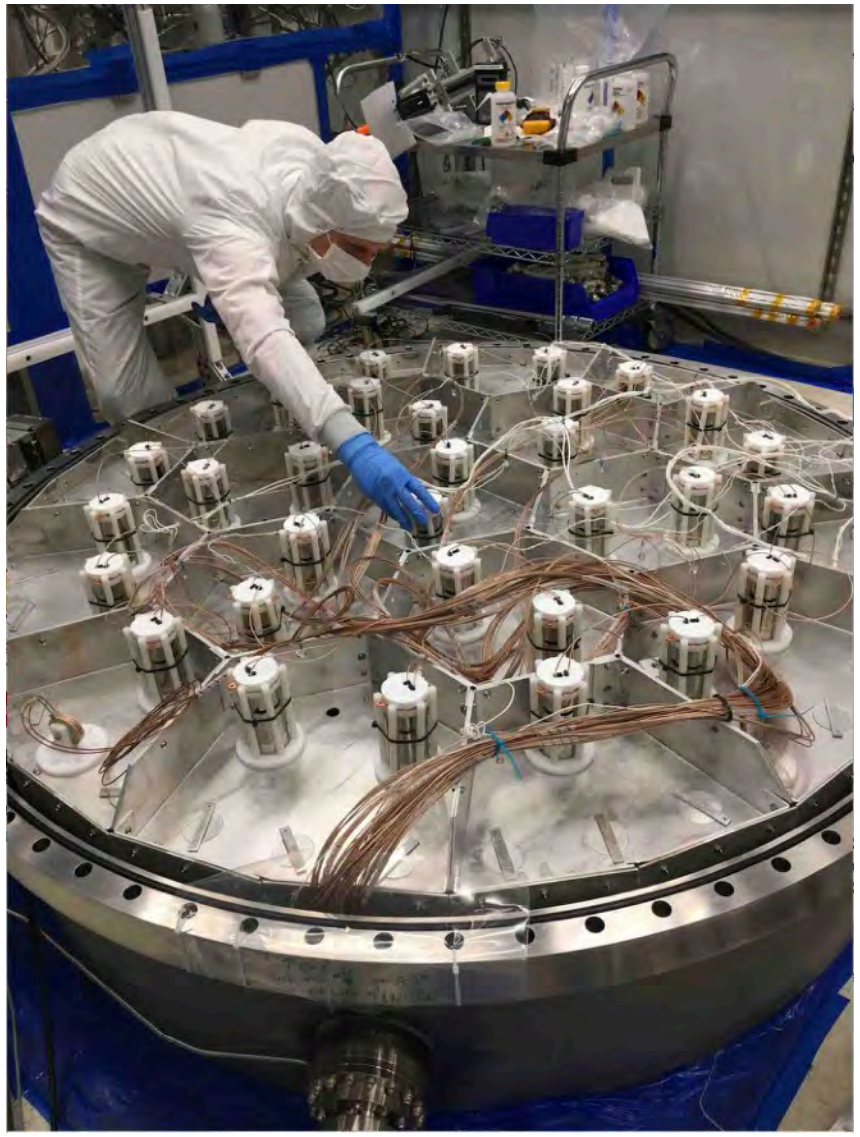
Phase 1

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



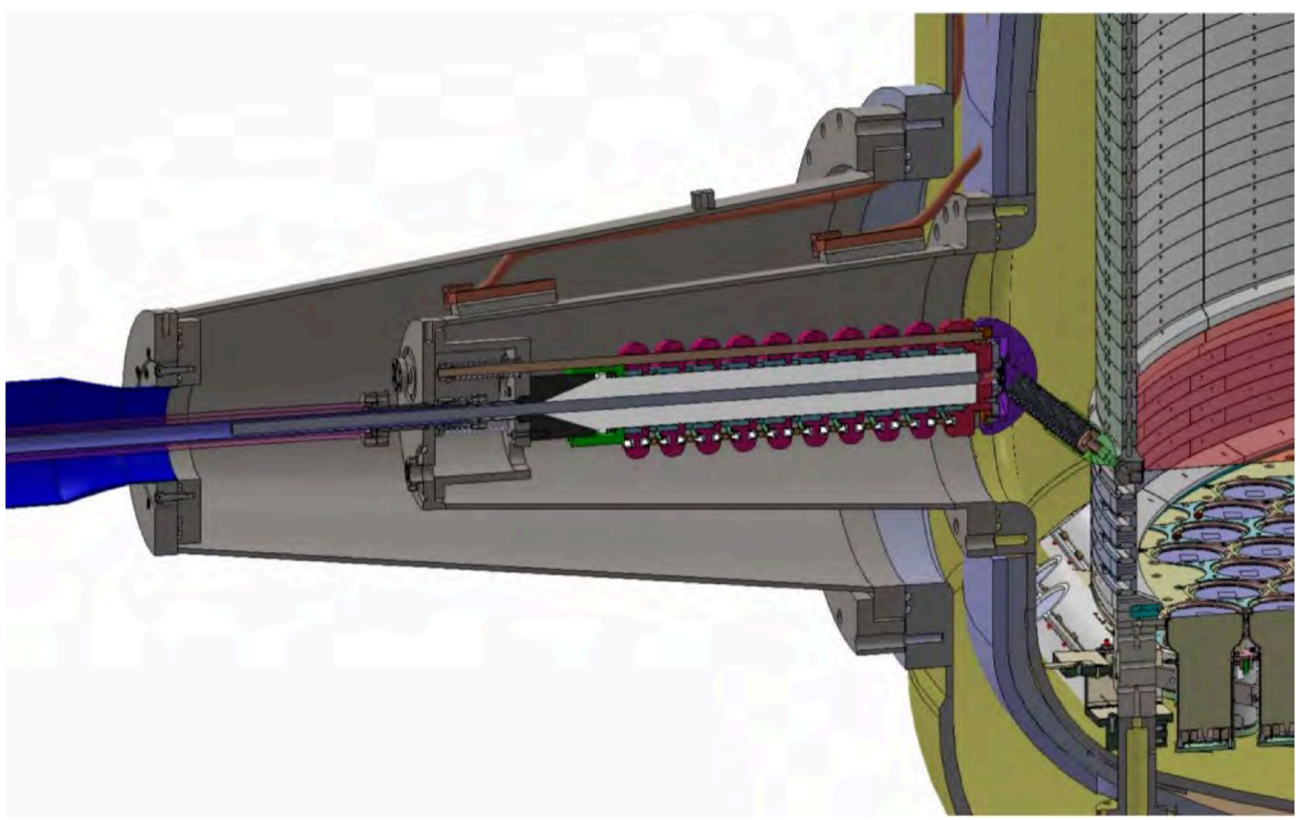
Phase 2

- 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

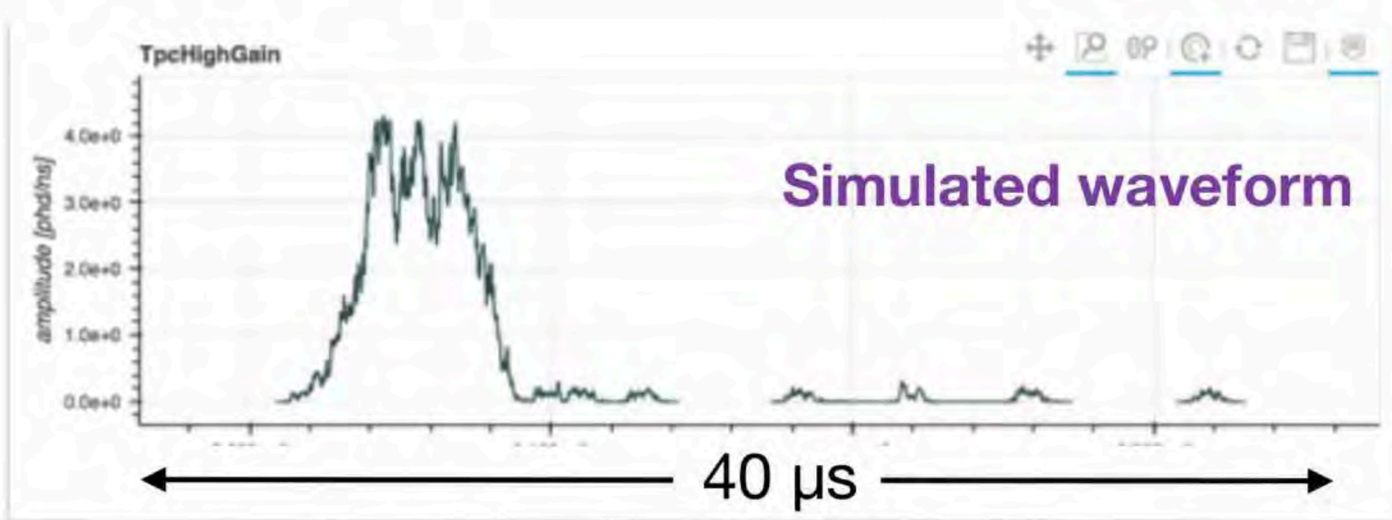
- Acrylic vessels staged underground in water tank
- Gd-LS production equipment being installed at BNL
- All PMTs in hand, testing at IBS (Korea) is nearly done

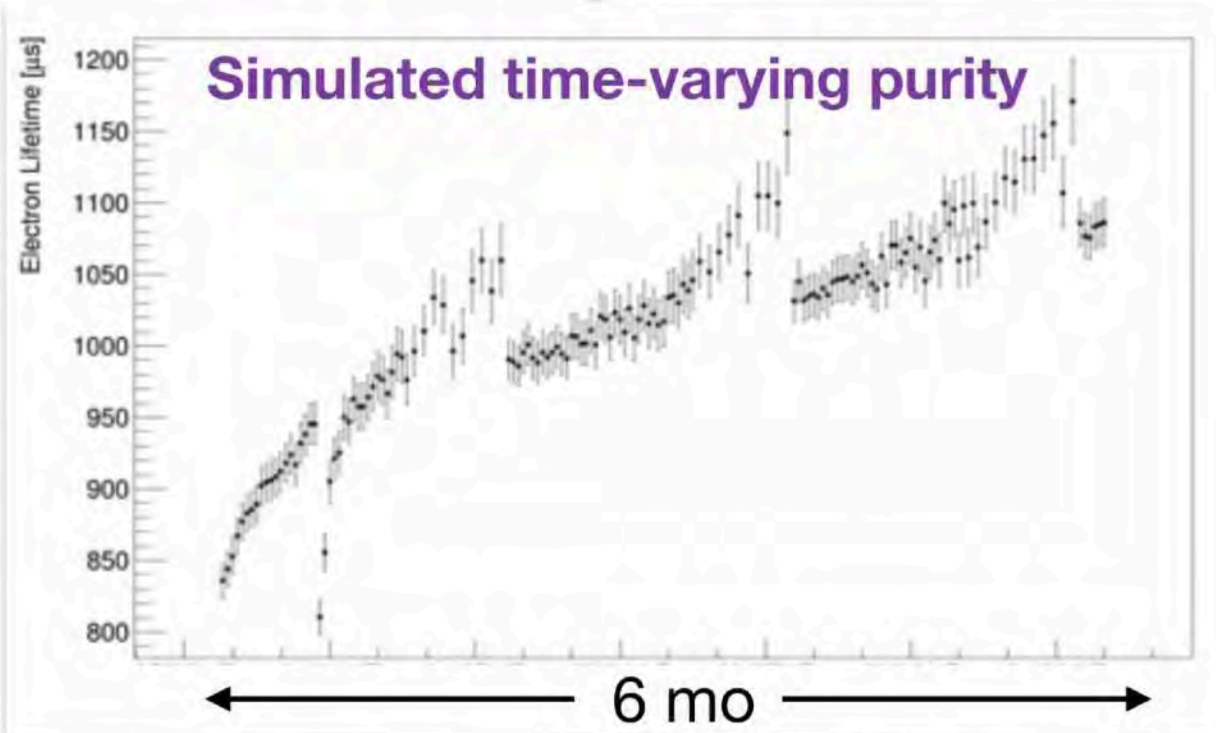
Xe procurement and Kr removal

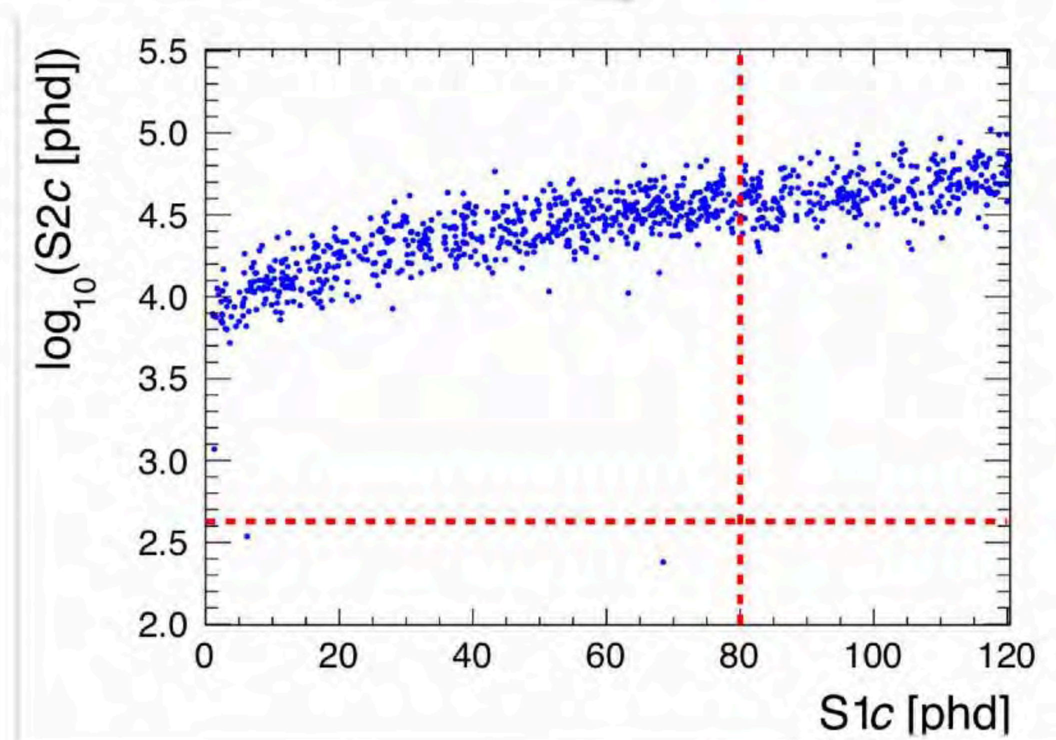
- 7t Xe in hand
- Chromatography to separate Kr from Xe.
  - Demonstration of 0.06 ppt in R&D at SLAC
  - Production system designed to remove to 0.015 ppt (1/10 solar neutrino BG)
- Kr removal at SLAC on track to start by July 2019 and finish by end 2019.

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!)

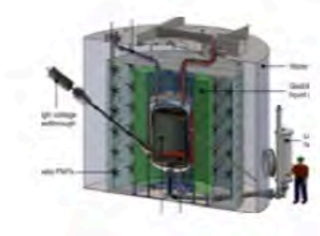






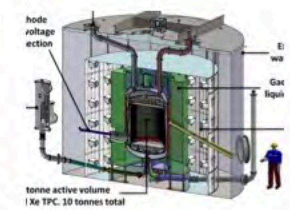
Timeline

CDR
Sep 2015

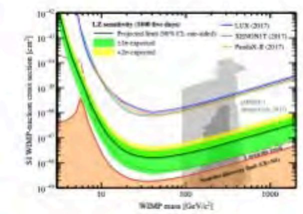


Titanium paper
Feb 2017

TDR
Mar 2017



WIMP sensitivity paper
Feb 2018



2015 2016 2017 2018 2019 2020

US CD-1
Mar 2015

US CD-2
Apr 2016

US CD-3
Jan 2017

TPC moves underground
Summer 2019

US CD-4
Operations start
Apr 2020

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)