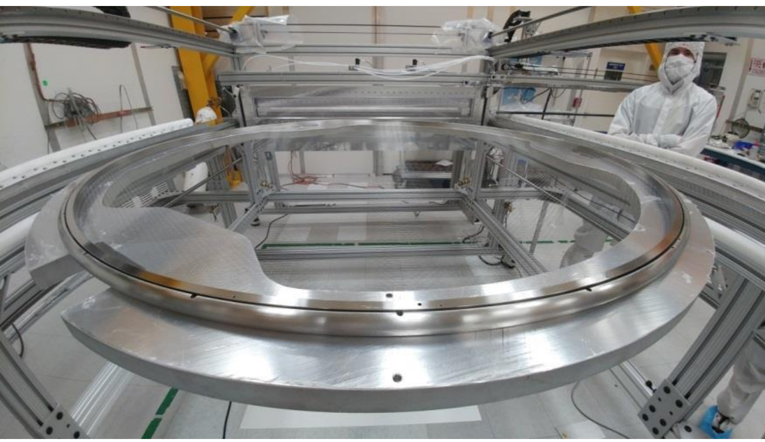
Dark matter searches with LUX-ZEPLIN (LZ)



Alfredo Tomás

Imperial College London

on behalf of the LZ collaboration

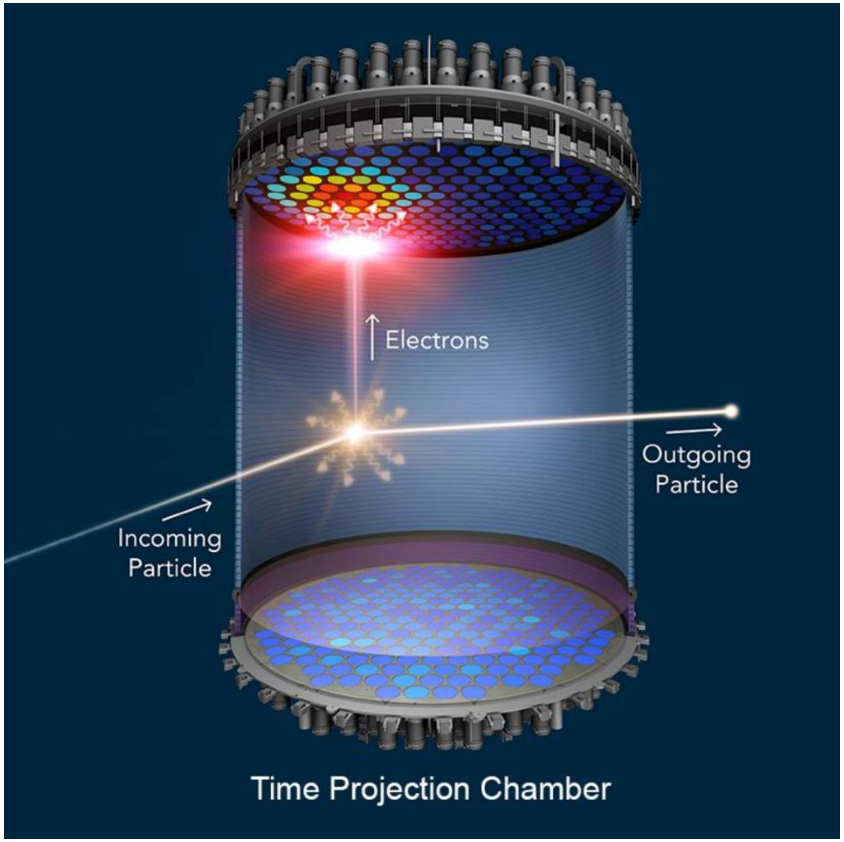
LZ collaboration

38 institutions; 250 scientists, engineers, and technicians

Brandeis CM, July 2018

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)

A WIMP search with 10 tonnes of Liquid Xenon

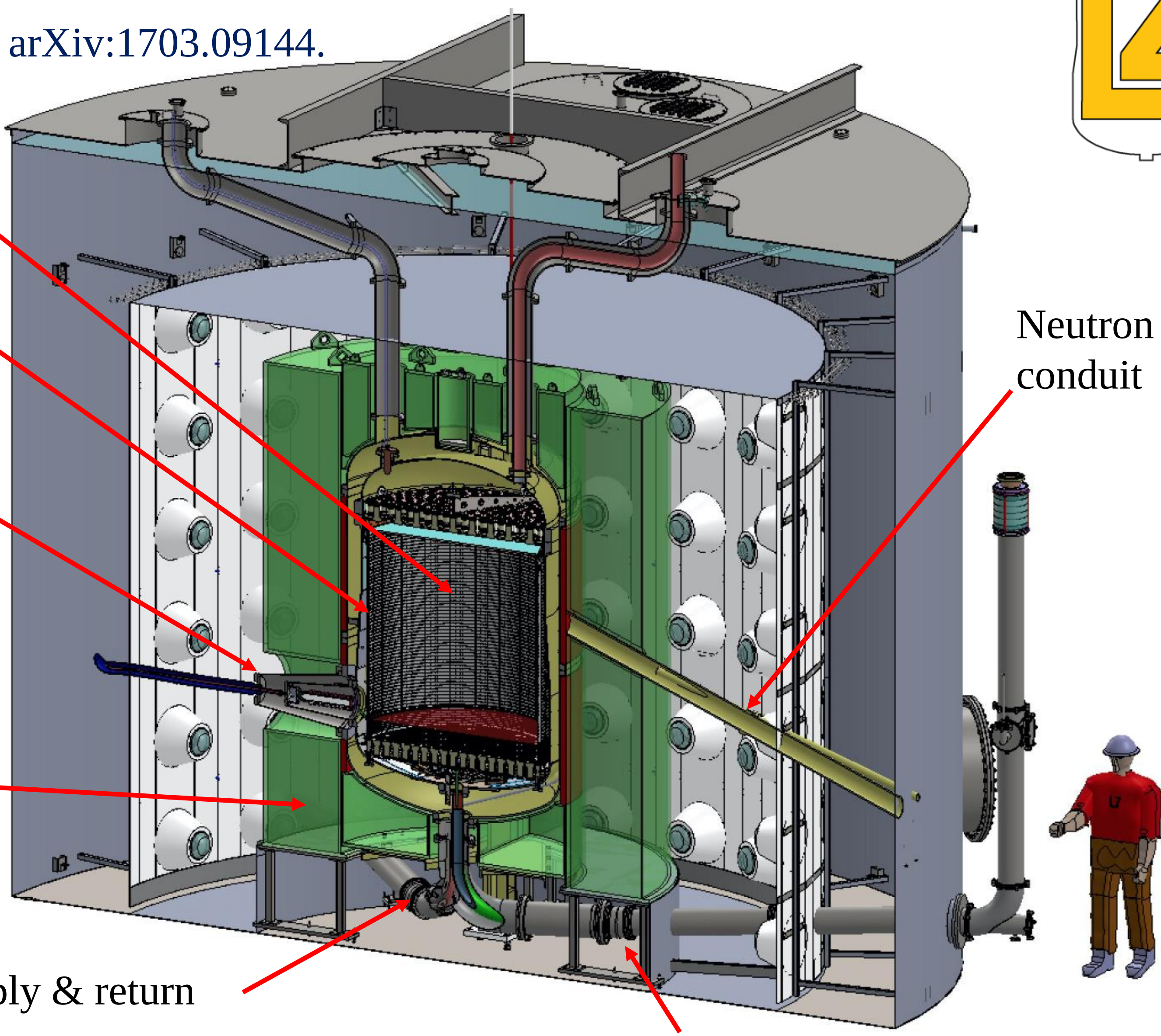


Aims and challenges with respect to ZEPLIN & LUX:

- Near two orders of magnitude increase on target mass
- Maintain TPC performance (and get over LUX limitations: High Voltage and PTFE-charging)
- Much more aggressive background control

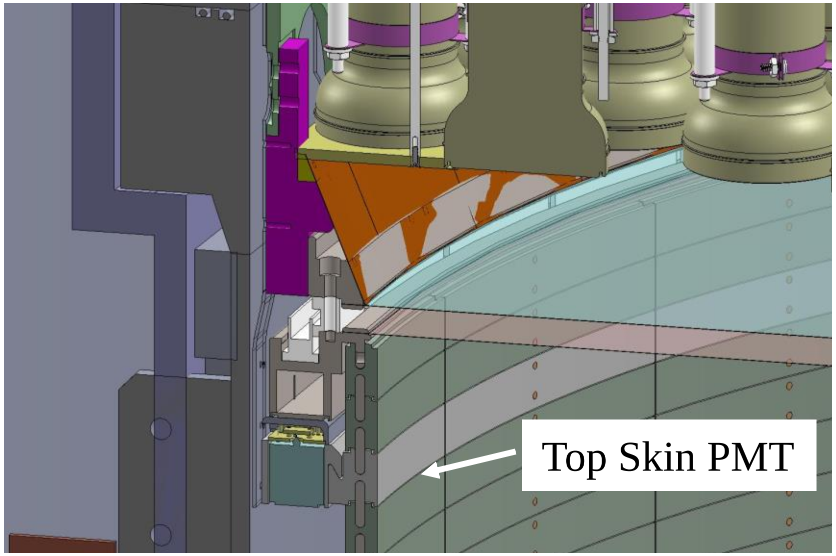
LUX-ZEPLIN (LZ) detector

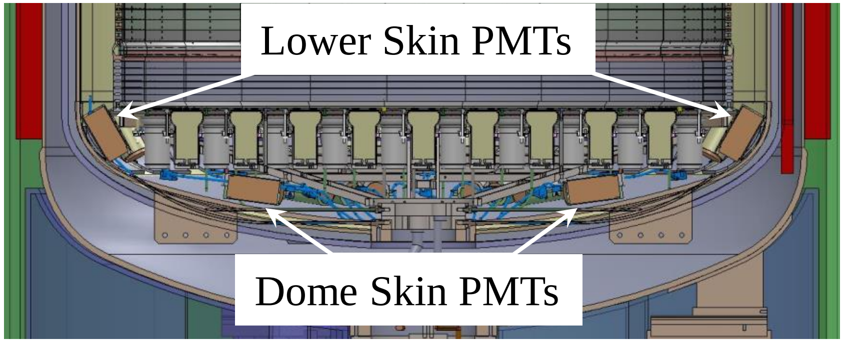
Technical Design Report, arXiv:1703.09144.



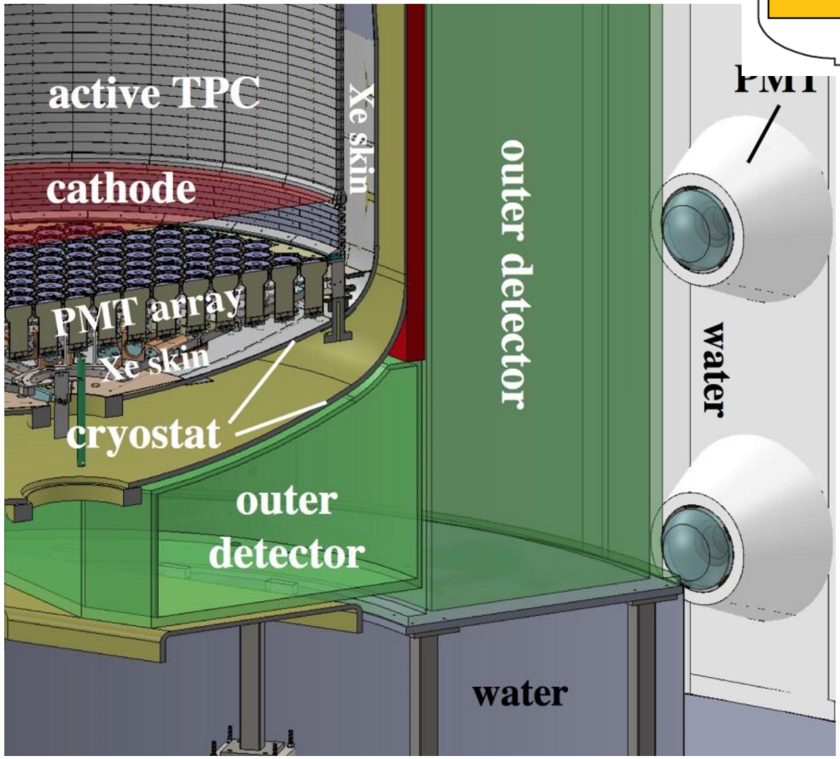
Two veto systems: Xe skin PMTs & Outer Detector

TPC Top Skin Upper Corner: 93 1” PMTs





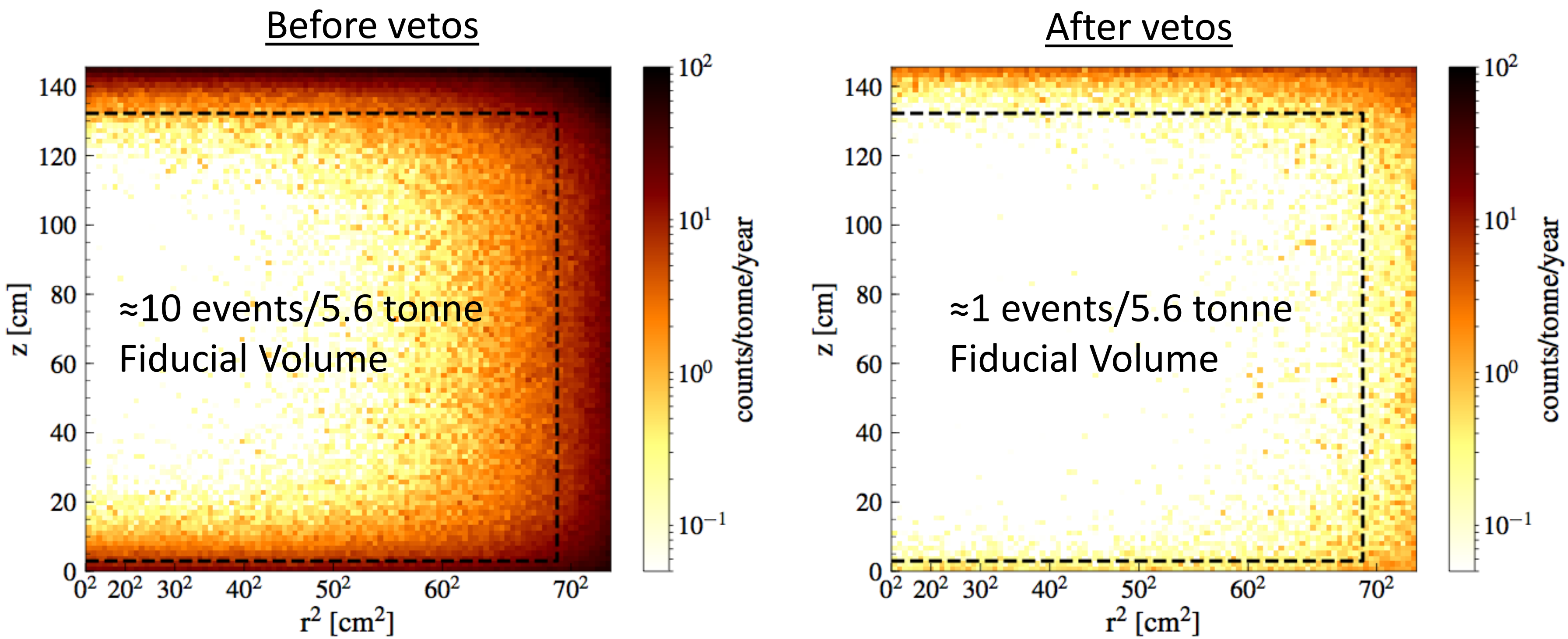
TPC Bottom Skin and Lower Dome:
38 2” PMTs



LZ Technical Design Report, arXiv:1703.09144

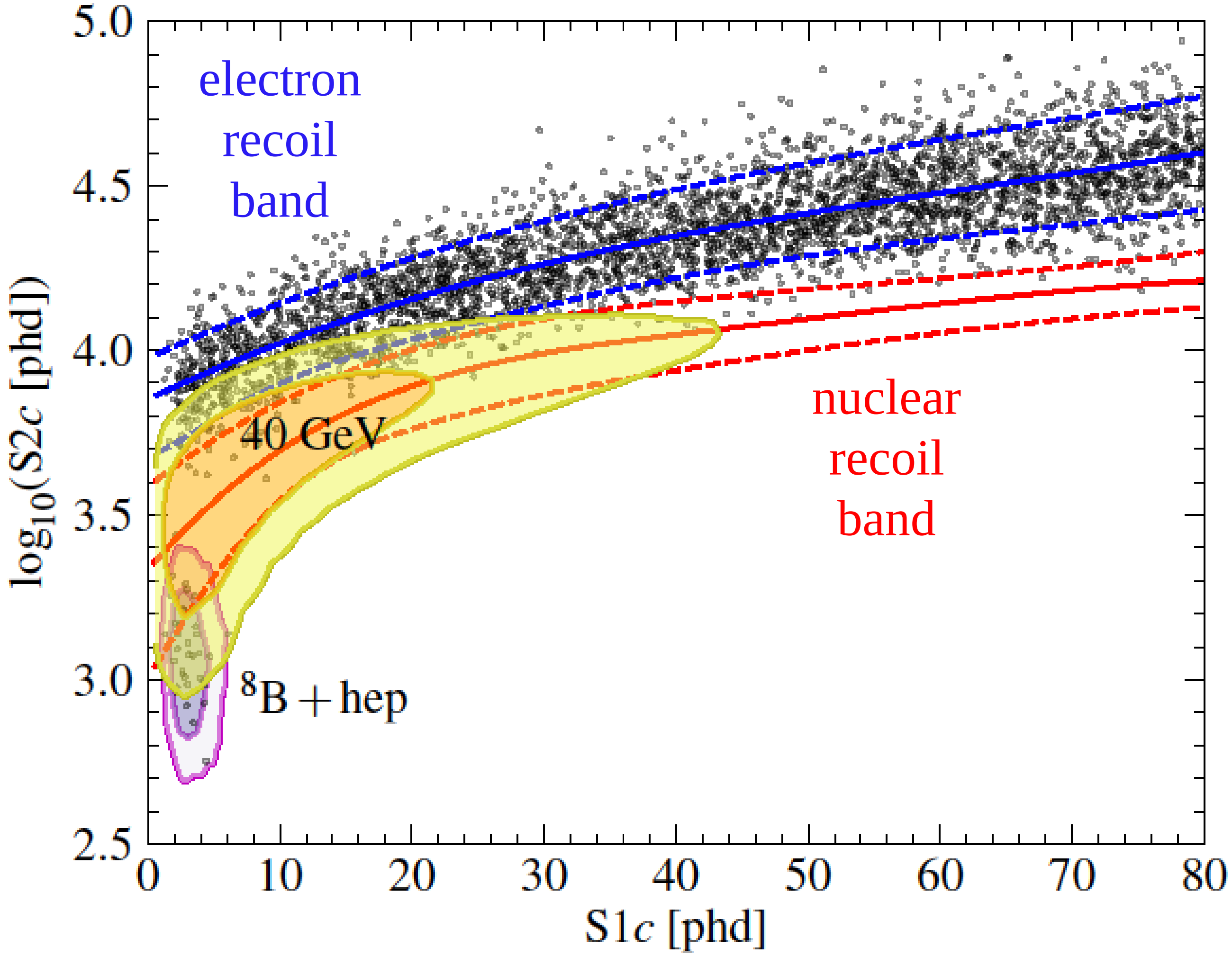
Veto System Performance

WIMP-like nuclear recoil backgrounds in 6-30 keV region of interest

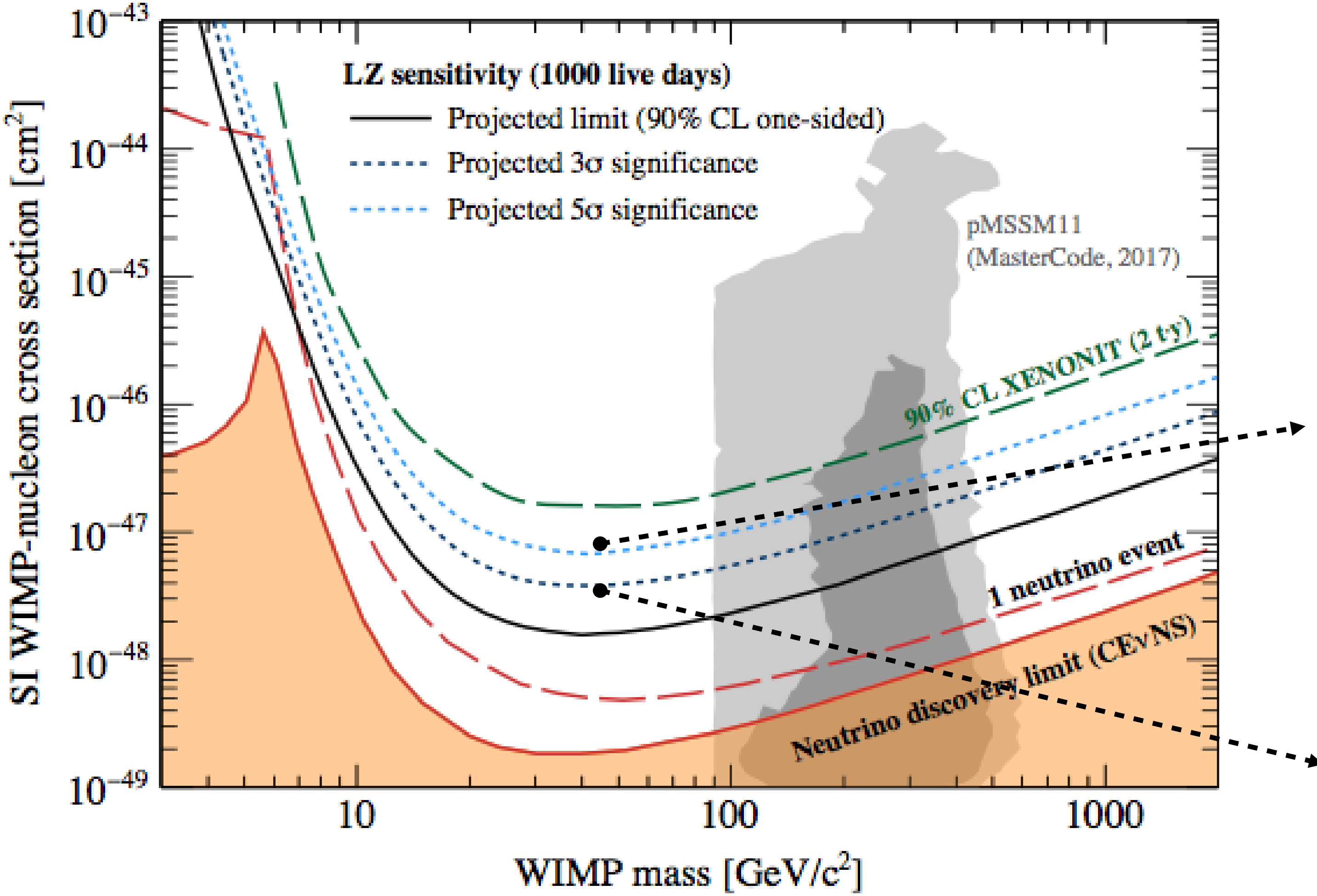


Fiducial would be reduced from 5.6 to 3.2 tonnes
w/o Outer Detector & Xe skin vetoes.

Simulated LZ full exposure with 40 GeV/c² WIMP 1000 days, 5.6 Tons



WIMP Discovery Potential
3σ and 5σ



5σ:
6.7×10^{-48} cm^2

3σ:
3.8×10^{-48} cm^2

arXiv:1802.06039

WIMP backgrounds summary

5.6 tonnes x 1000 days; ~1.5 to ~6.5 keV

Background Source	ER (cts)	NR (cts)
Detector Components	**9**	**0.07**
Surface Contamination	**40**	**0.39**
Laboratory and Cosmogenics	**5**	**0.06**
Xenon Contaminants	**819**	**0**
222Rn	681	0
220Rn	111	0
natKr (0.015 ppt g/g)	24	0
natAr (0.45 ppb g/g)	3	0
Physics	**322**	**0.51**
136Xe 2νββ	67	0
Solar neutrinos (pp+7Be+13N)	255	0
Diffuse supernova neutrinos	0	0.05
Atmospheric neutrinos	0	0.46
Total	1195	1.03
with 99.5% ER discrim., 50% NR eff.	**5.97**	**0.51**

Neutrons, mostly from alpha-n on PTFE

Radon dominates ER backgrounds

νe scattering of *pp* solar νs; (atomic electron recoils)

Coherent scattering of atmospheric νs on Xe nuclei

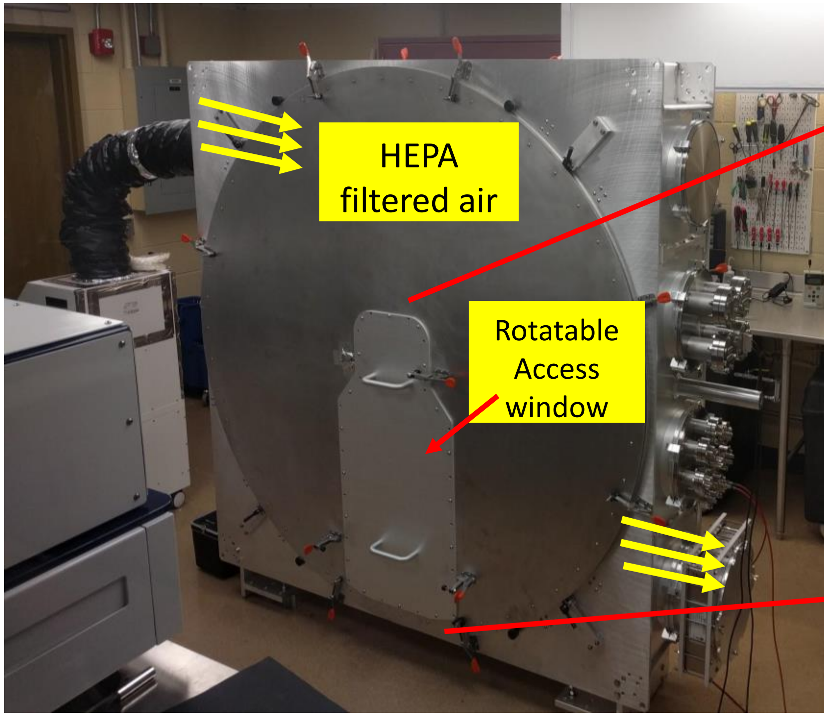
Background control strategy

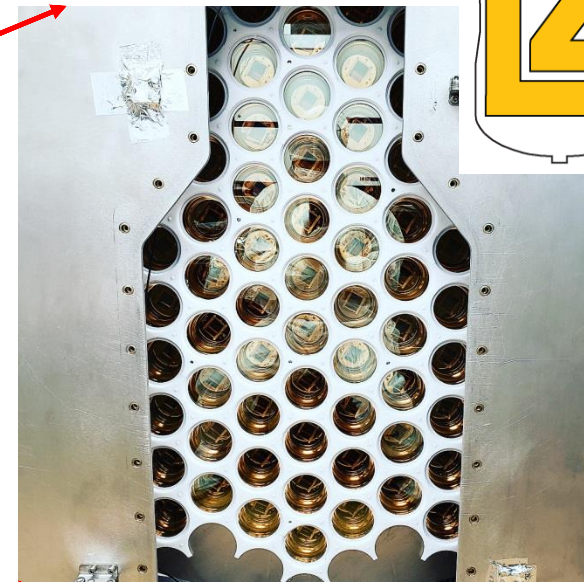
- Radio-assay campaign for detector materials
  - γ-screening, ICP-MS, NAA.
- Charcoal chromatography to remove ^{85}Kr and ^{39}Ar
  - Dedicated facility at SLAC
  - Final ^{nat}Kr/Xe 0.015 ppt (g/g)
- Rn emanation screening campaign
  - Four Rn screening sites
  - Target Rn activity = 2 μBq/kg
- Rn daughters (plate-out)
  - TPC Assembly in Rn-reduced cleanroom to limit daughter recoils on surfaces
  - Screening or Rn daughters on exposed surfaces (coupon program)
  - Rn-daughter plate on TPC walls < 0.5 mBq/m^2
- Dust
  - Cleanliness controls. Microscope screening of dust density (coupon program)
  - Dust < 500 ng/cm^2 on all LXe wetted surfaces

Titanium Cryostat

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

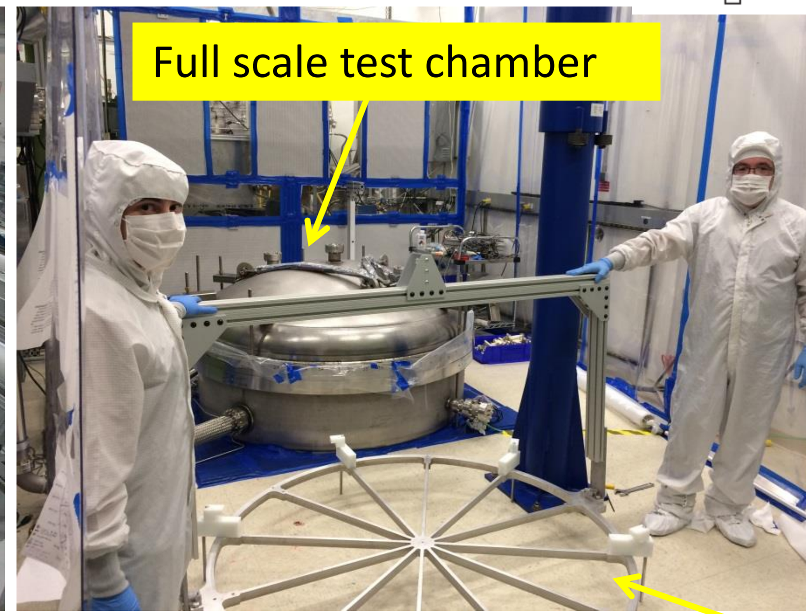
PMT Array Assembly at Brown University





- Above: ‘PALACE’, PMT dark electrical testing, shipping housing for LZ PMT arrays (~2 x 250 PMTs).
- Witness plates for dust surveillance over whole assembly; measured dust levels met the requirement.
- ‘In-house’ manufactured (Imperial College London) low background and clean PMT bases
- LXe temperature calibration of each tube-base pair. Detailed Xe VUV light calibration of 35 tubes (Astropart. Phys. 102 (2018) 56-66:)

TPC grids under production at SLAC

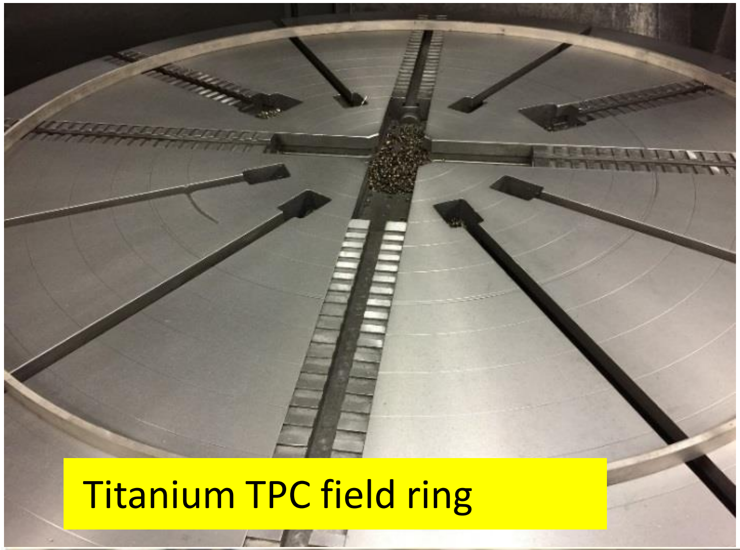


- Automated loom for weaving SS wire grids.
- 2 Full size (1.5 m diameter) prototype grids complete. Final grids under production.
- Post-weaving wire treatment to reduce spurious electron emission

(Astropart.Phys. 103 (2018) 49-61)

  - Benefit confirmed on small-size grid prototype in liquid xenon at SLAC.

TPC field cage

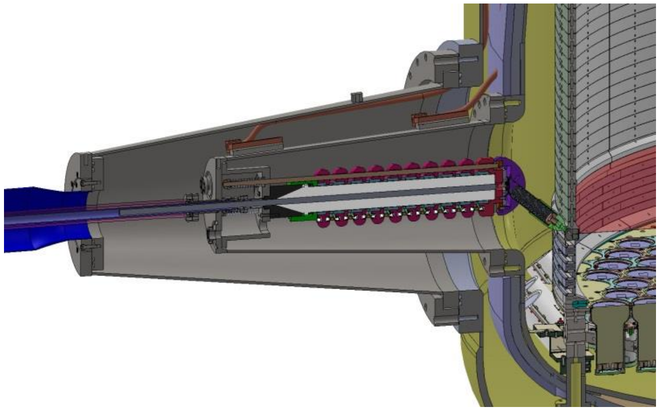


Titanium TPC field ring

- All components are in hand
- Trial assembly successful
- Field cage assembly at SURF in fall 2018

Trial assembly of Ti field rings and PTFE field cage elements

TPC cathode high voltage



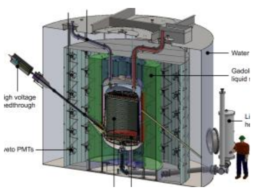
- Tests in liquid argon successfully reached 120 kV(50 kV required).
- Extensive Liquid Xenon prototyping at SLAC.
- High voltage grading structure for cathode assembled at LBL

Model of test structure in liquid argon

Liquid argon cathode high voltage test facility at LBNL

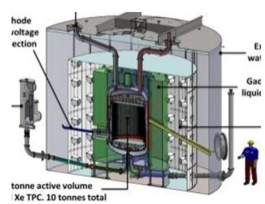
Recent and projected LZ timeline

CDR,
Sept 2015

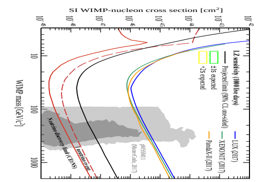


Titanium paper,
Feb 2017

TDR,
March 2017



WIMP sensitivity paper,
Feb 2018



2015 | 2016 | 2017 | 2018 | 2019 | 2020

Collaboration meetings: Alabama, Coimbra, LLNL, Oxford, SLAC, SURF, FNAL, Coimbra, Brandeis

US CD-1
March 2015

US CD-2
April 2016

US CD-3
Jan 2017

UK project
97% complete
March 2018

TPC moves underground, Summer 2019

US CD-4 and operations start, April 2020

= Collaboration meeting