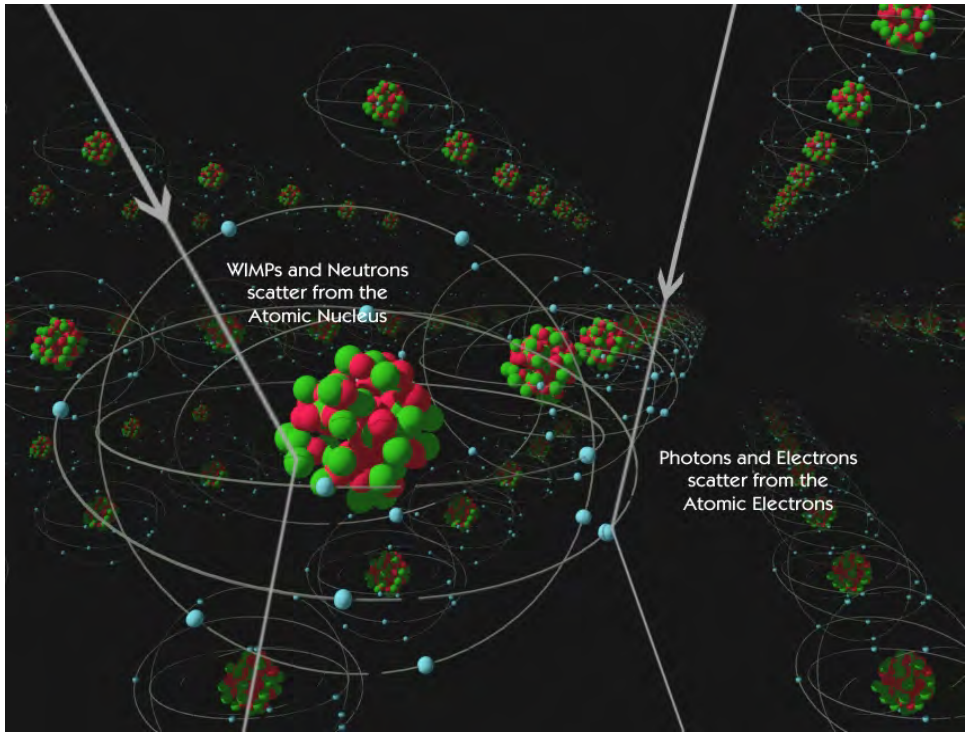
Status of the LUX-ZEPLIN Dark Matter Experiment

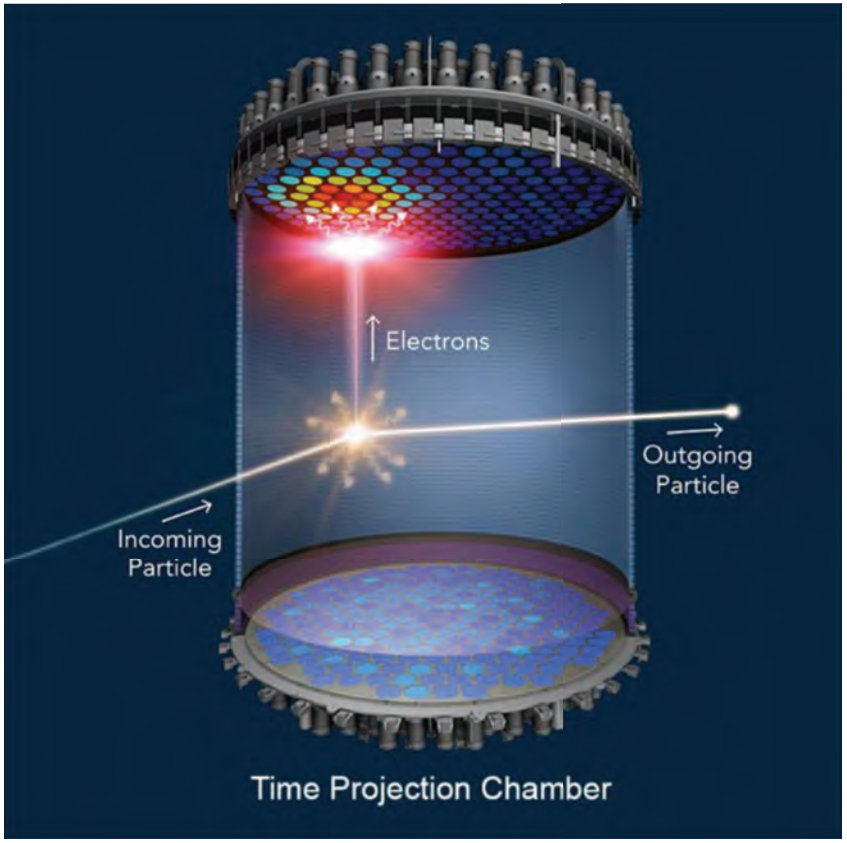
Carter Hall, University of Maryland, *for the LZ collaboration*

July 24, 2018

IDM 2018, Brown University, Providence, RI

A WIMP search with 10 tonnes of Liquid Xenon





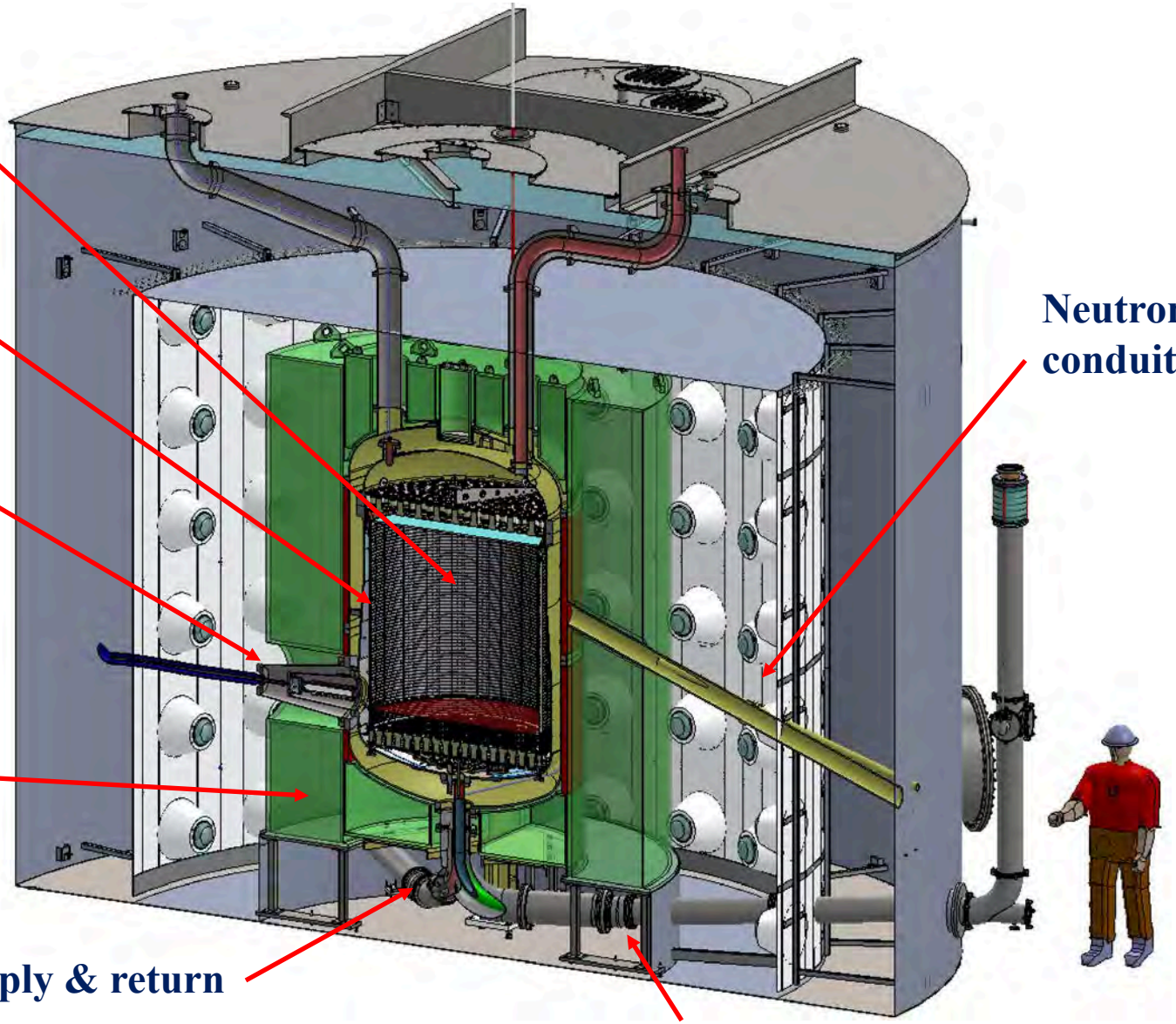
Search for anomalous low-energy nuclear recoils

Requirements: large target mass + low energy threshold + background control.

This talk is about the current status of the LZ construction project.

See also the following talk by Maria Elena Monzani on the LZ WIMP sensitivity; and parallel talks by Luke Korley, Vitaly Kudryavtsev, and Rachel Mannino.

LUX-ZEPLIN (LZ) detector



Technical Design Report, arXiv:1703.09144.

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

arXiv:1802.06039

See also the talks by M. E. Monzani on the LZ WIMP sensitivity (next) and V. Kudryavtsev on LZ simulations (Tues. pm).

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Mostly neutrons

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Radon dominates ER backgrounds

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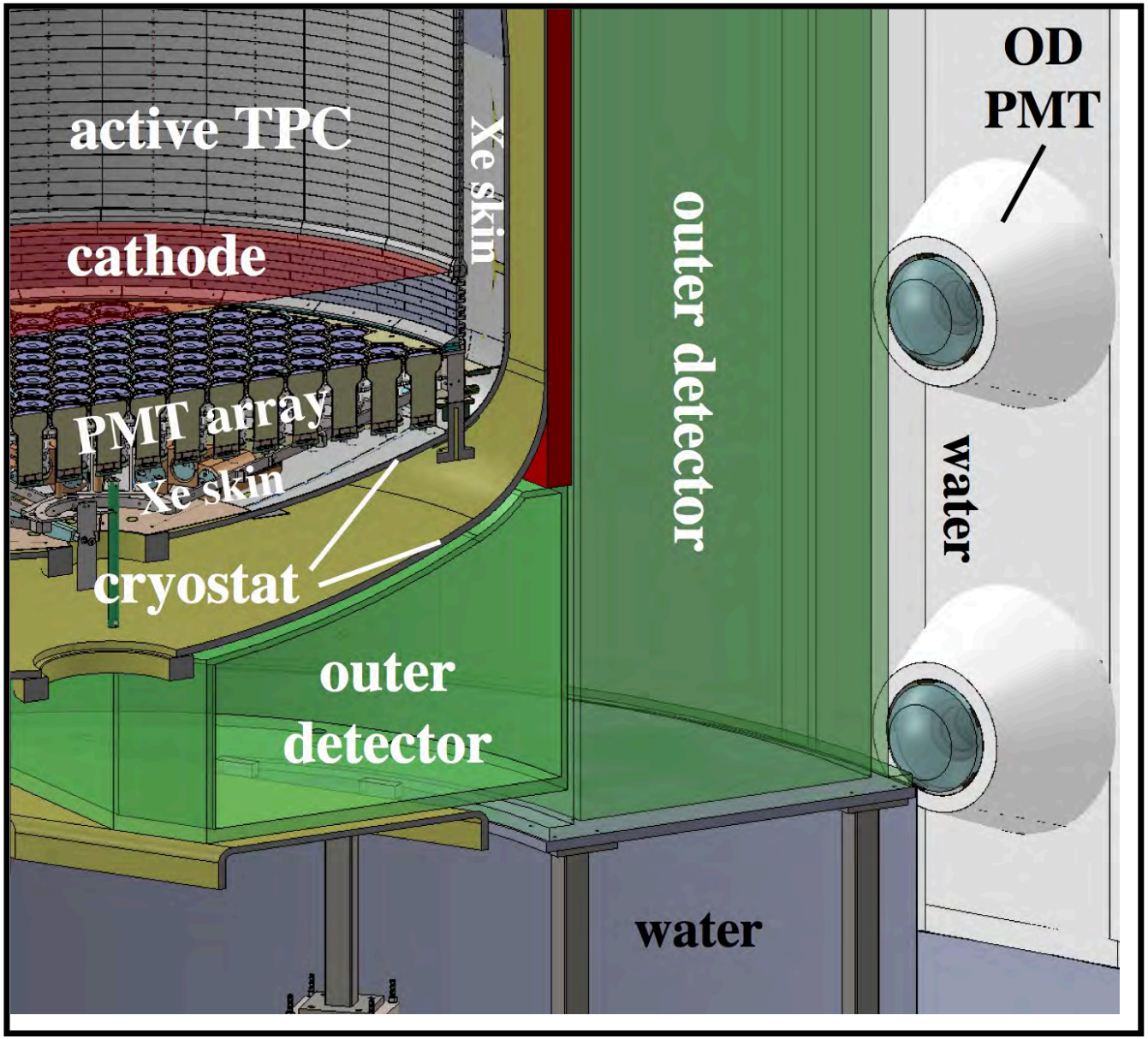
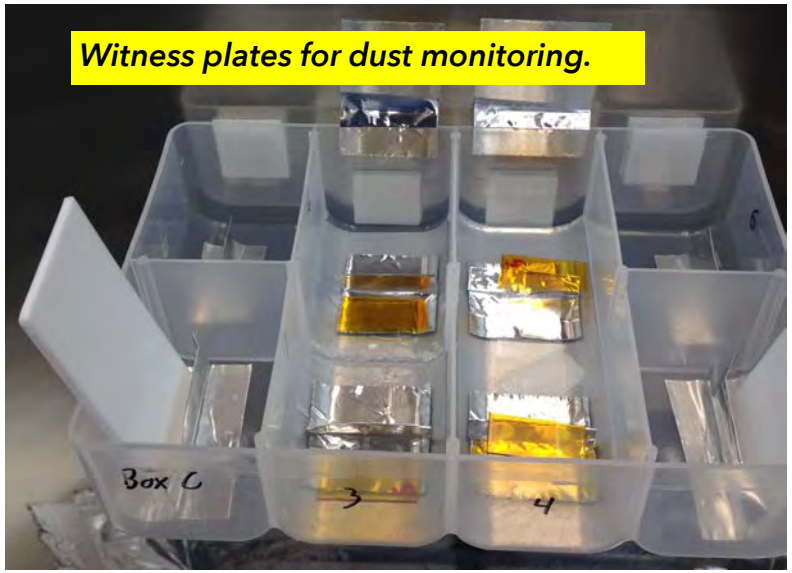
Two veto systems: Xe skin PMTs & Outer Detector



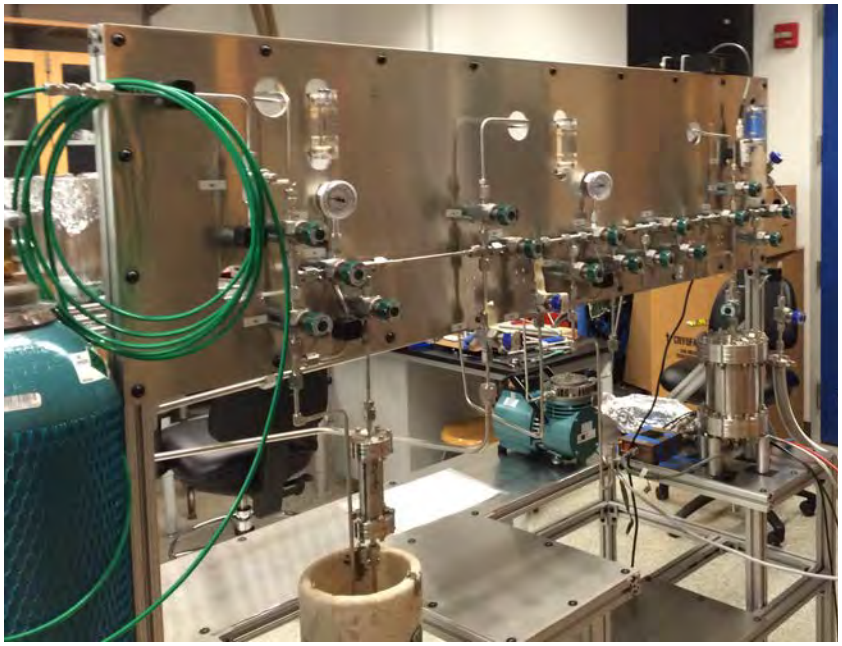
LZ Technical Design Report, arXiv:1703.09144

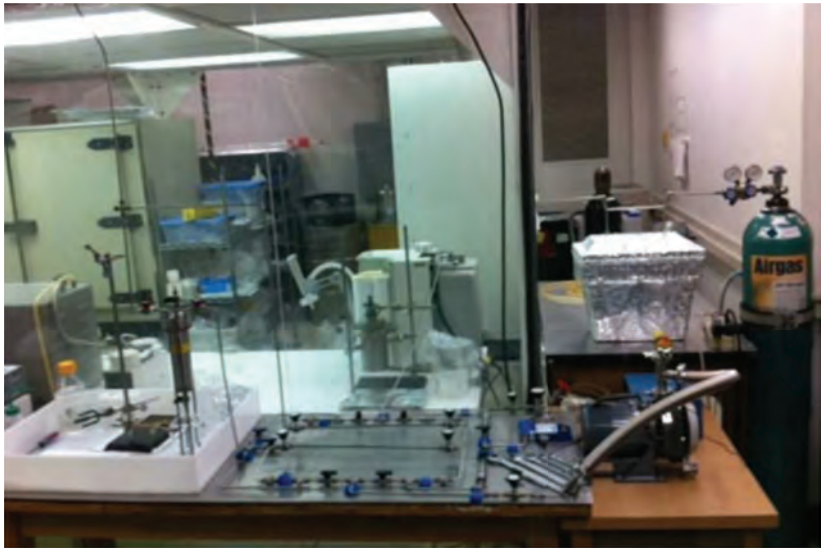
Surface Assembly Lab @ SURF for TPC integration

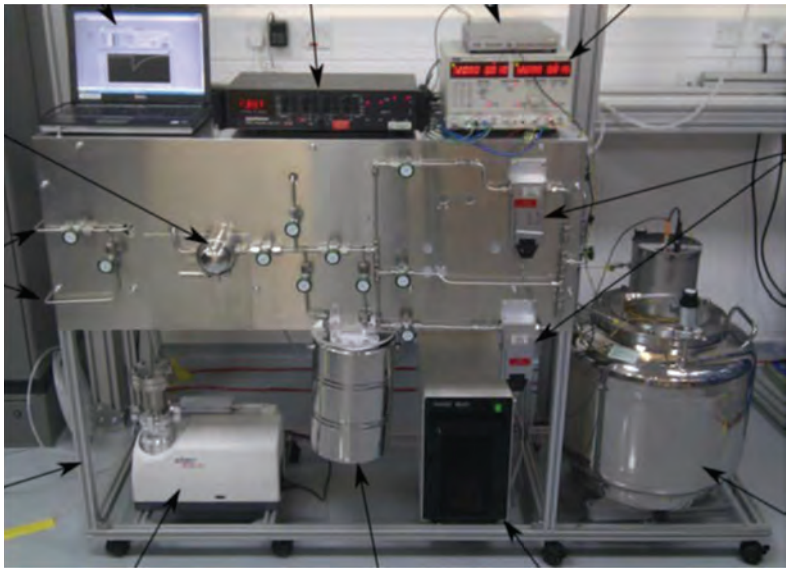
- **Dust Requirement:** < 500 ng/cm^2 on all LXe wetted surfaces
  - Class 100 – 1000 Clean room
  - Dust monitoring via particle counters & witness plates.
- **Radon Plate-out Requirement:** TPC walls < 0.5 mBq/m^2
  - Ateko Radon Reduction System supplies radon-reduced air to cleanroom.



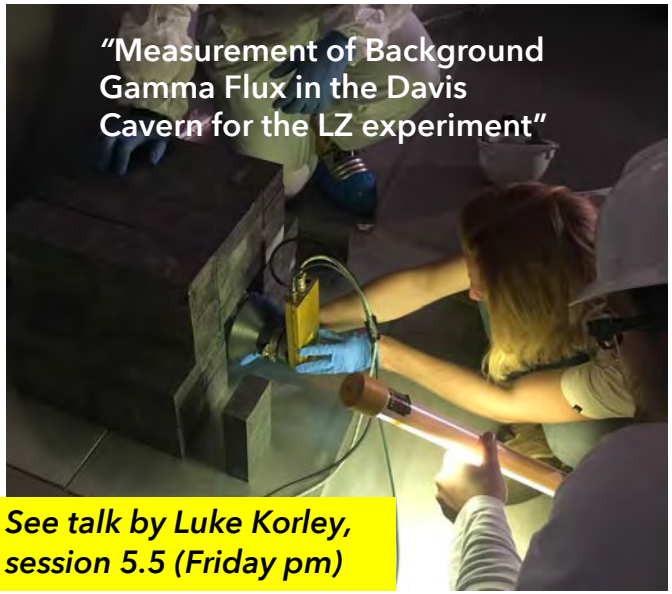
Four radon emanation screening sites







- Water tank modifications nearly complete.
- LZ Occupancy in August ‘18.



See talk by Luke Korley, session 5.5 (Friday pm)

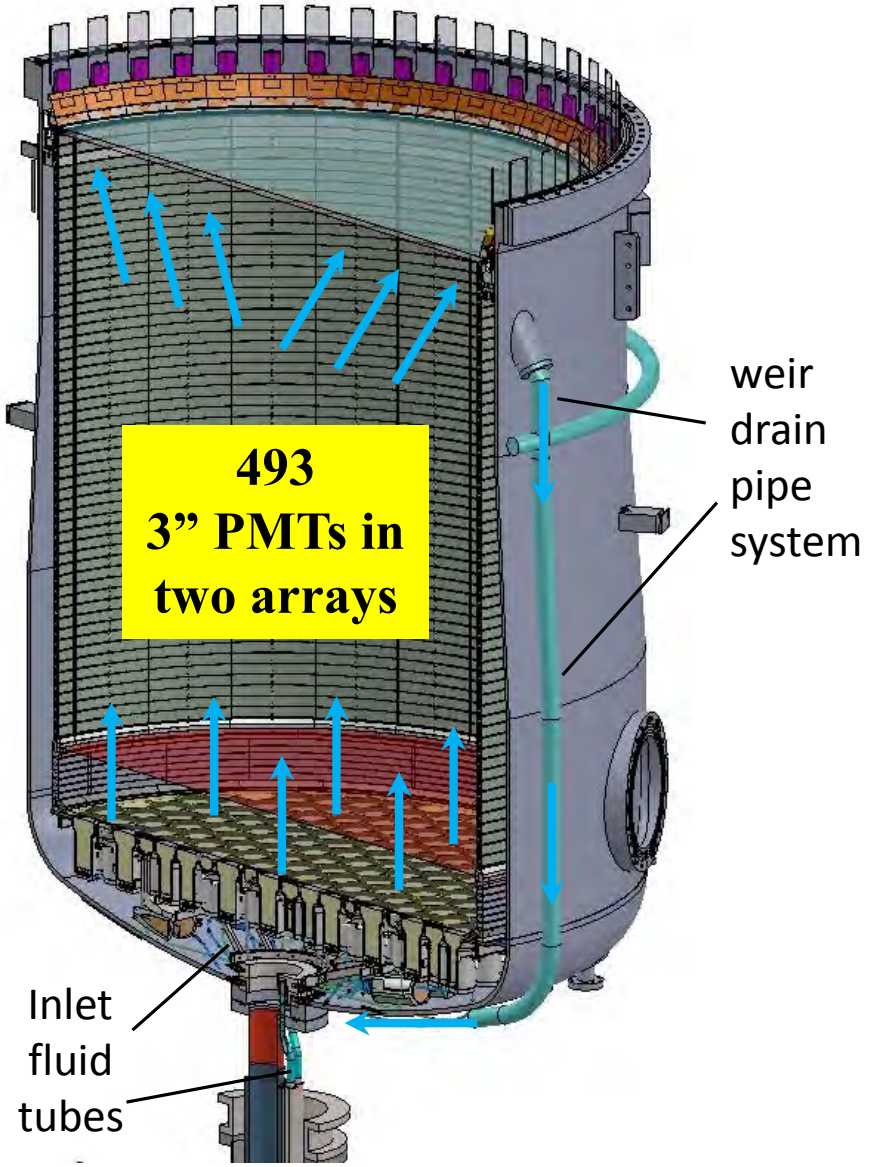
Titanium Cryostat

- UK deliverable to LZ.
- Intensive R&D program identified low activity titanium material (arXiv:1702.02646)
- Arrived at SURF May 14, 2018.
- Outer vessel acceptance testing complete; inner vessel in progress.

Outer cryostat vessel @ SURF

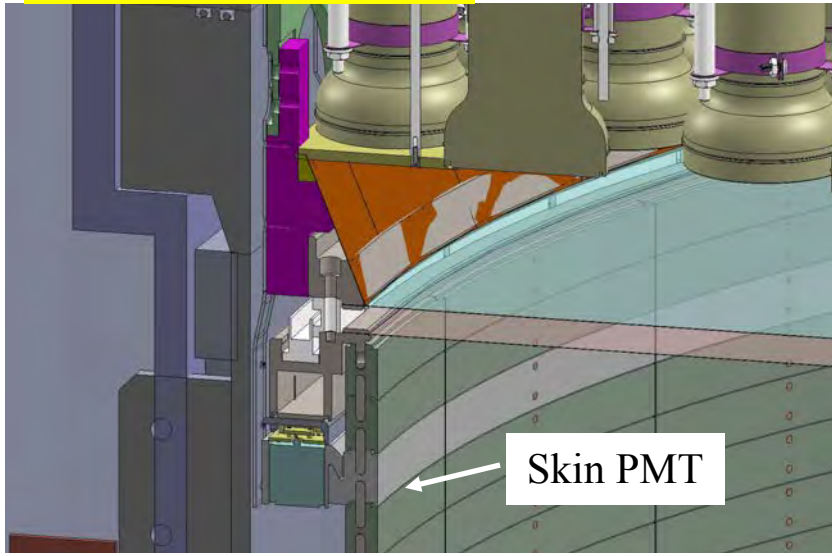

Test fitting

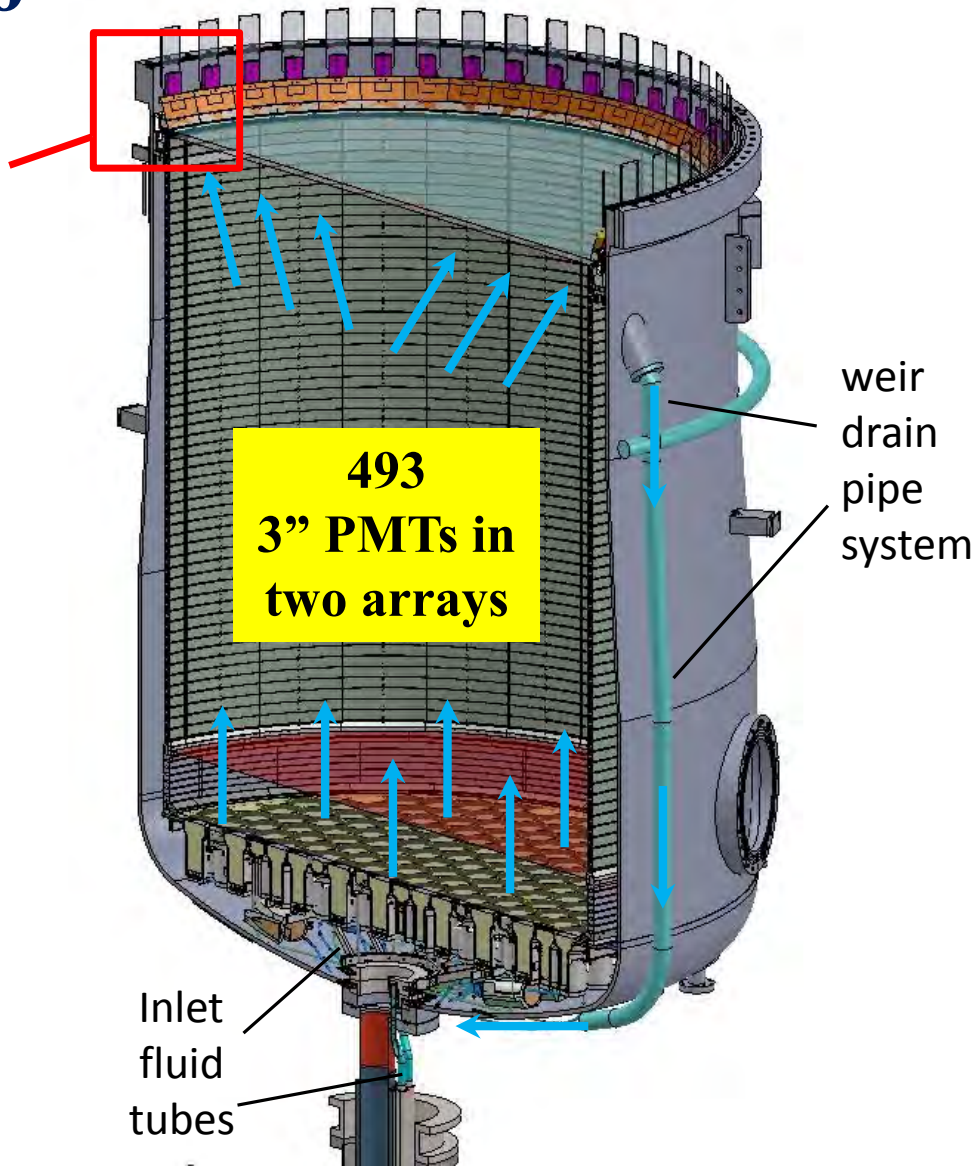
TPC & skin veto



TPC & skin veto

TPC Upper Corner





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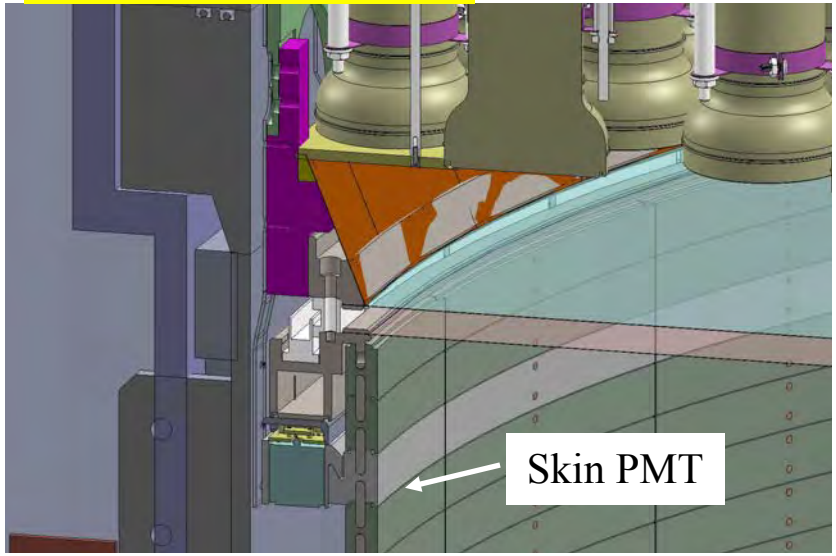
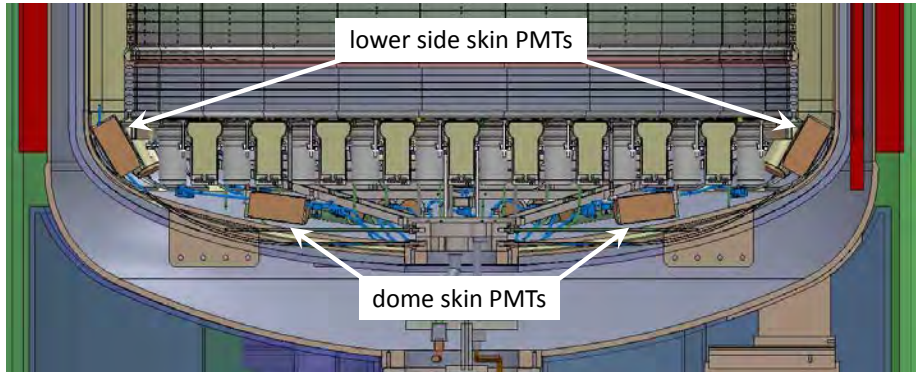
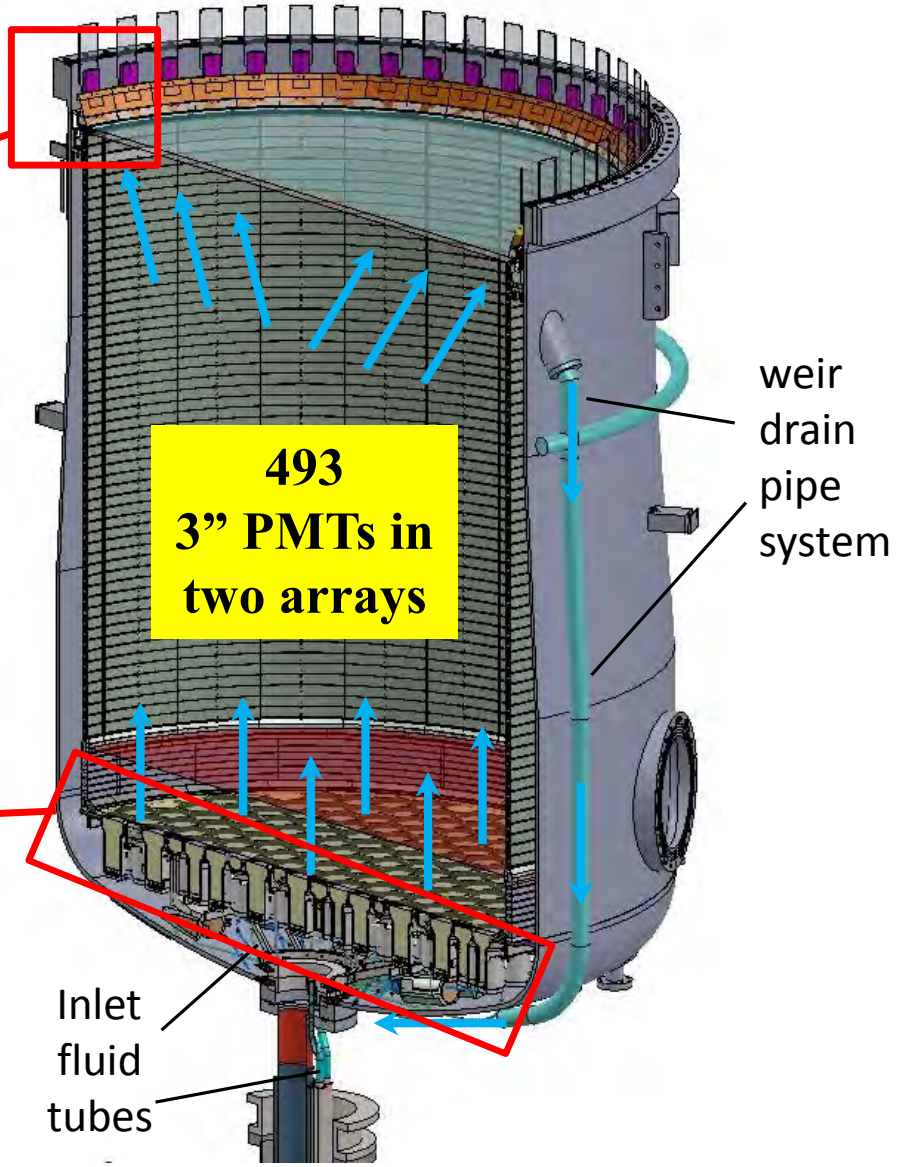
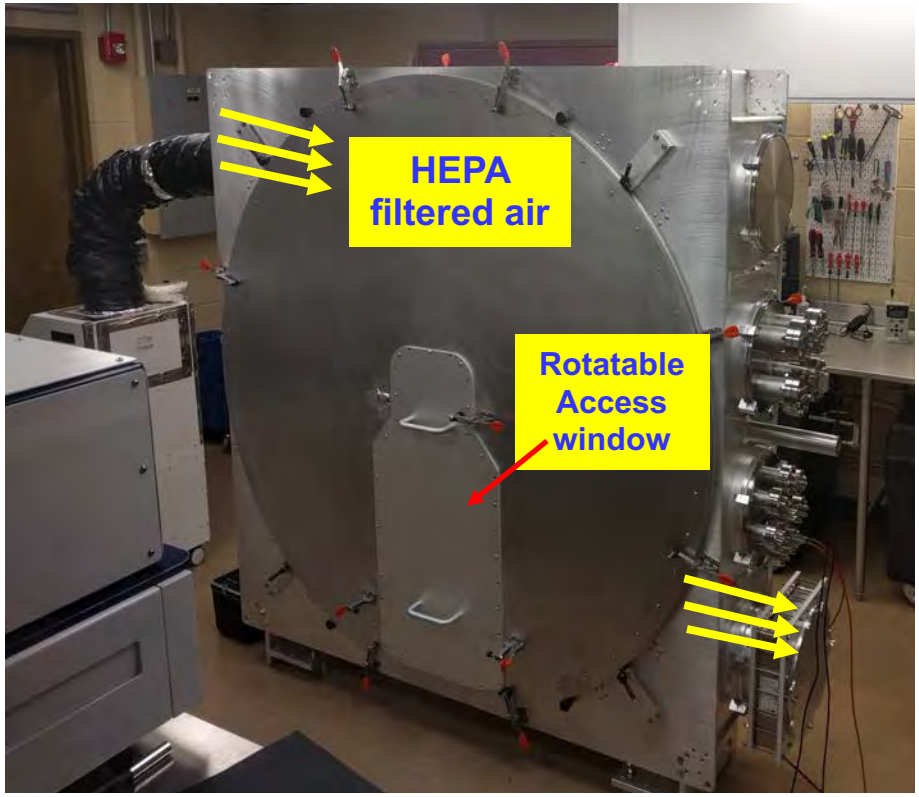




TPC Lower Dome - 93 1” & 38 2” PMTs



PMT Array Assembly here at Brown University



- Above: 'PALACE', PMT dark electrical testing and shipping housing for upper and lower LZ PMT arrays (~250 PMTs per array)
- Low airborne Rn, 2-4 Bq/m^3
- Dust control with HEPA filtered air.
- Witness plates for dust surveillance; measured dust meets the requirement.

TPC grids in production

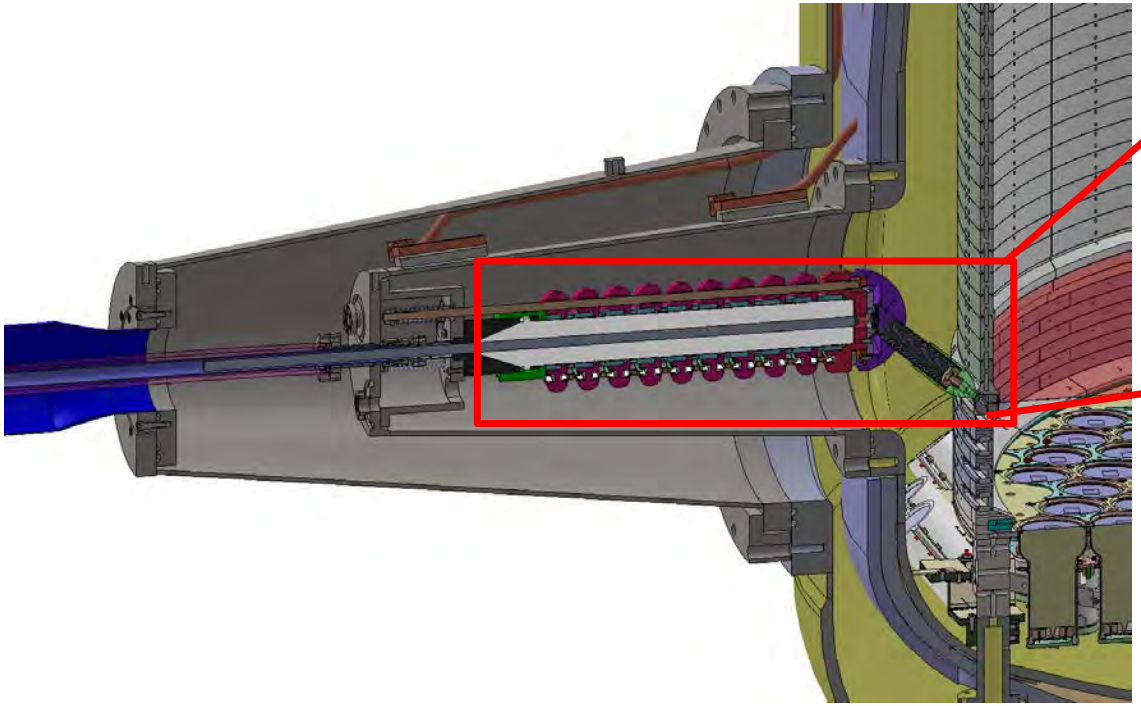
Loom for weaving grids

- Automated loom for weaving SS wire grids.
- 2 Full size (1.5 m diameter) prototype grids complete.
- Production grid rings being fabricated.
- Post-weaving wire treatment to reduce electron emission (arXiv:1801.07231).
- Loom in action: https://www.youtube.com/watch?v=yNycDcMQkss

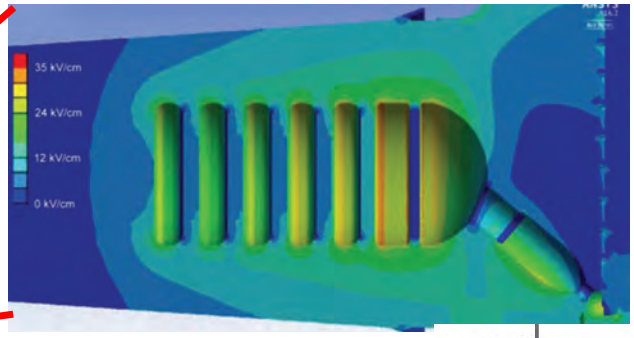
See talk by R. Mannino, 'Production and high voltage testing of the LZ detector grids' session 2.5 (Tues. pm)

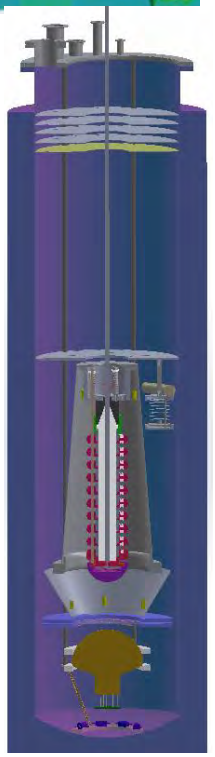
TPC cathode high voltage

50 kV operation, 100 kV design & test



Cathode HV grading

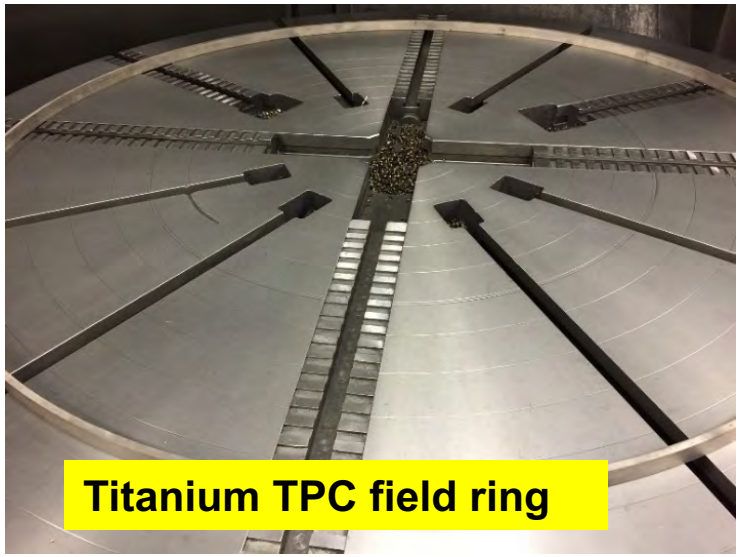




- Extensive prototyping at design field (50 kV/cm) in liquid xenon.
- Tests of cathode cable grading structure in liquid argon; successfully reaches 120 kV (50 kV required)

Liquid argon cathode high voltage test facility

All TPC field cage components are in hand



Titanium TPC field ring

- Trial assembly successful
- Field cage assembly at SURF in fall 2018

Trial assembly of Ti field rings and PTFE field cage elements

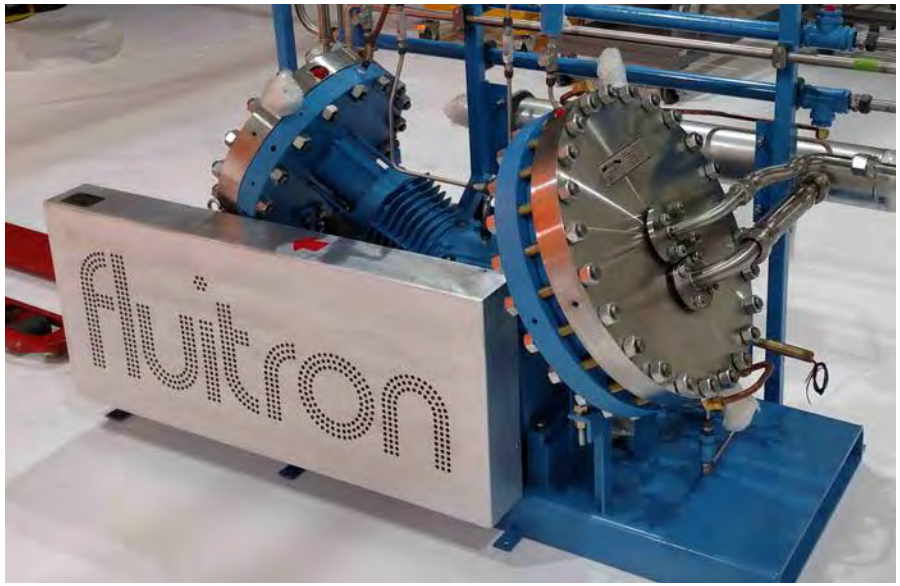
Gd-LS Outer Detector

- Acrylic vessel fabrication underway,
- Gd-LS production equipment being installed at BNL
- All PMTs in hand, testing at IBS is nearly done.

Xe Handling & Purification

- One large getter & efficient two-phase heat exchanger.
- 12 Custom Xe storage packs delivered from Praxair.
- 4 Xe gas compressors under final fabrication or delivered to PSL.
- 500 SLPM Xe gas circulation rate; 2.3 days to purify 10 tonnes.

Megatorr Getter at SURF



1 of 4 Xe gas compressors – all-metal diaphragms with copper seals

12 Xe storage gas packs

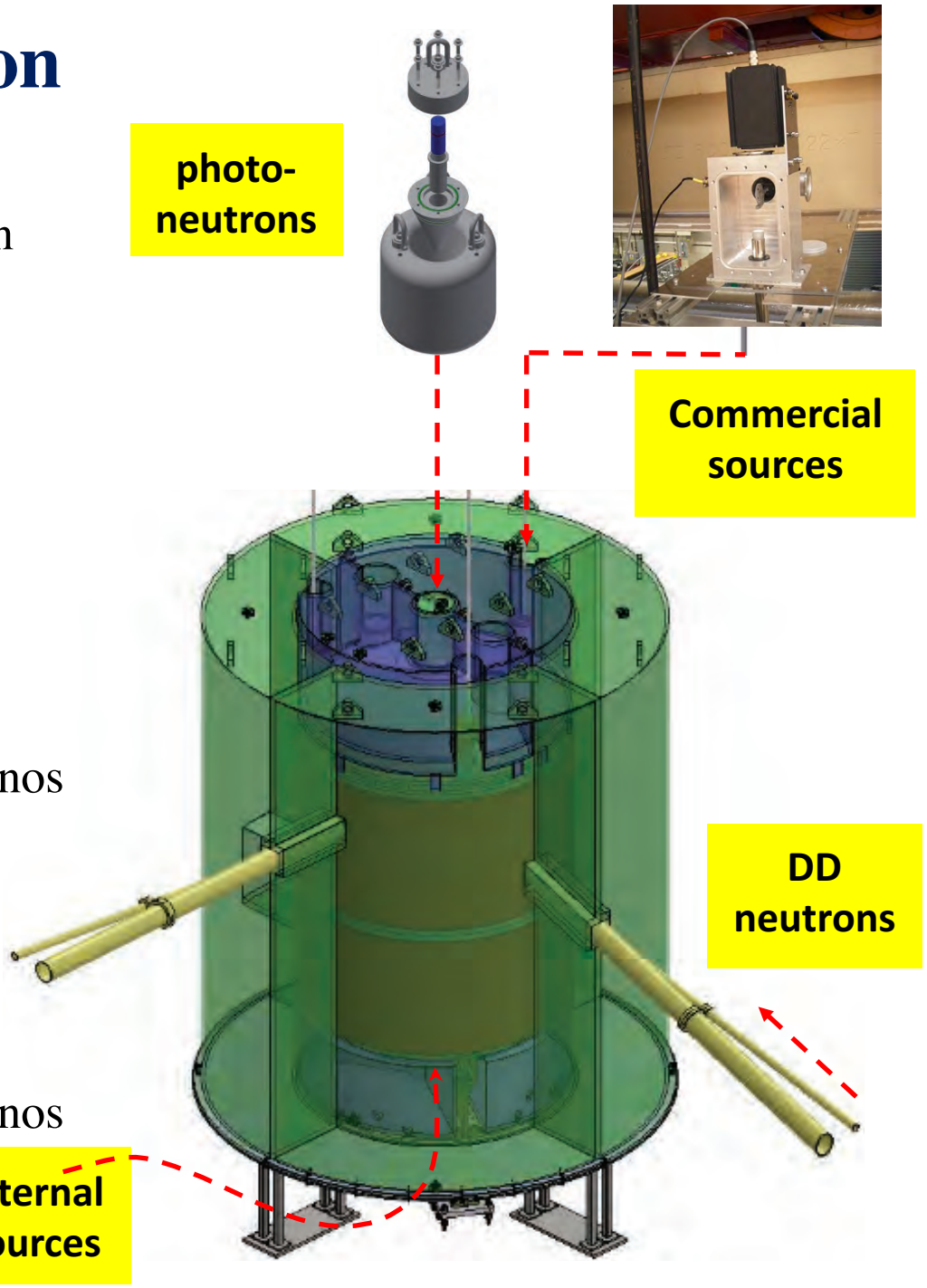
Xe acquisition & Kr removal

- All Xe either in-hand or fixed priced contract.
- Kr removal at SLAC on track to start by July 2019 and finish by end 2019.

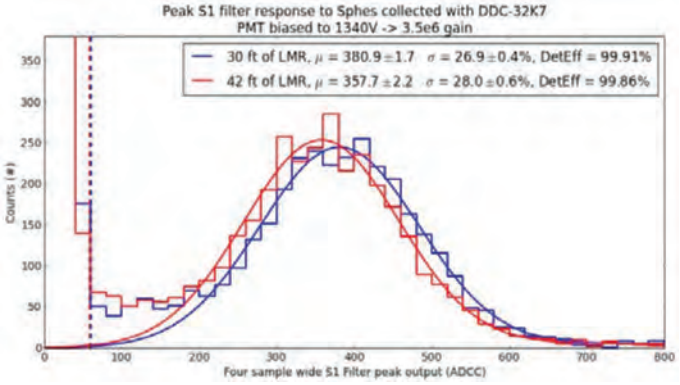
- Chromatography to separate Kr (and ^{85}Kr) from Xe.
- Demonstration of 0.075 ppt (g/g) in R&D at SLAC.
- Production system designed to remove to 0.015 ppt (g/g) (subdominant by >10x to radon).

Source Calibration

- Internal sources:
  - ^{131m}Xe, ^{83m}Kr, tritium, ^{14}C, ^{220}Rn
    - Light and charge collection efficiencies & corrections
    - ER threshold & yields
- Photoneutron sources:
  - YBe: 4.6 keV$_{NR}$ endpoint
  - BiBe: 2.7 keV$_{NR}$ endpoint
    - NR threshold & yields,
    - low mass WIMPs, ^{8}B neutrinos
- Neutrons:
  - D-D neutron generator & D_2 reflector
    - NR threshold & yields,
    - low mass WIMPs, ^{8}B neutrinos



Front End & DAQ

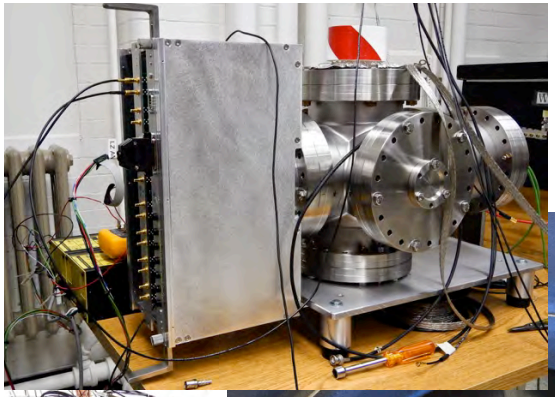


Excellent results obtained with prototype 1.

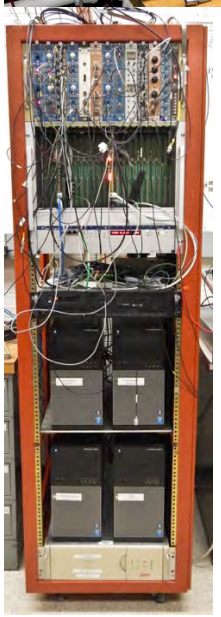
Digitizer prototype

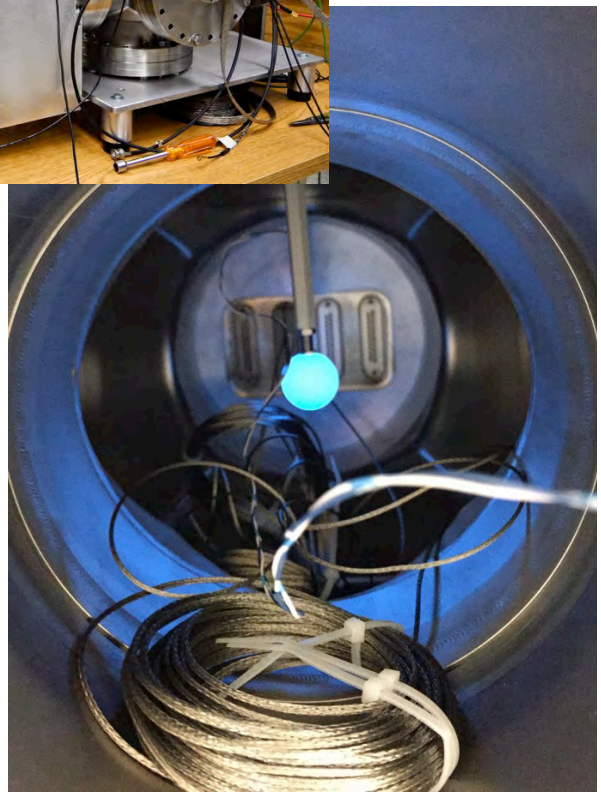
- Single P.E. efficiency is near 99% for the TPC PMTs.
- Pre production 32-channel digitizers and logic boards started.

Complete electronics chain test



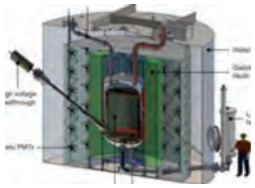
Chain Test Images





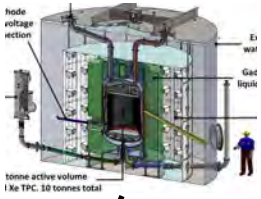
Recent LZ timeline

CDR, Sept 2015

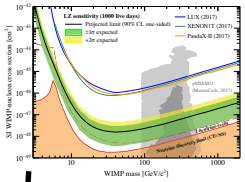


Titanium paper, Feb 2017

TDR, March 2017



WIMP sensitivity paper, Feb 2018



2015 2016 2017 2018 2019 2020

Alabama

US CD-1 March 2015

Coimbra

LLNL

US CD-2 April 2016

Oxford

SLAC

US CD-3 Jan 2017

SURF

FNAL

Coimbra

Brandeis

UK project 97% complete March 2018

TPC moves underground, Summer 2019

US CD-4 and operations start, April 2020

= Collaboration meeting

LZ collaboration

38 institutions; 250 scientists, engineers, and 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)