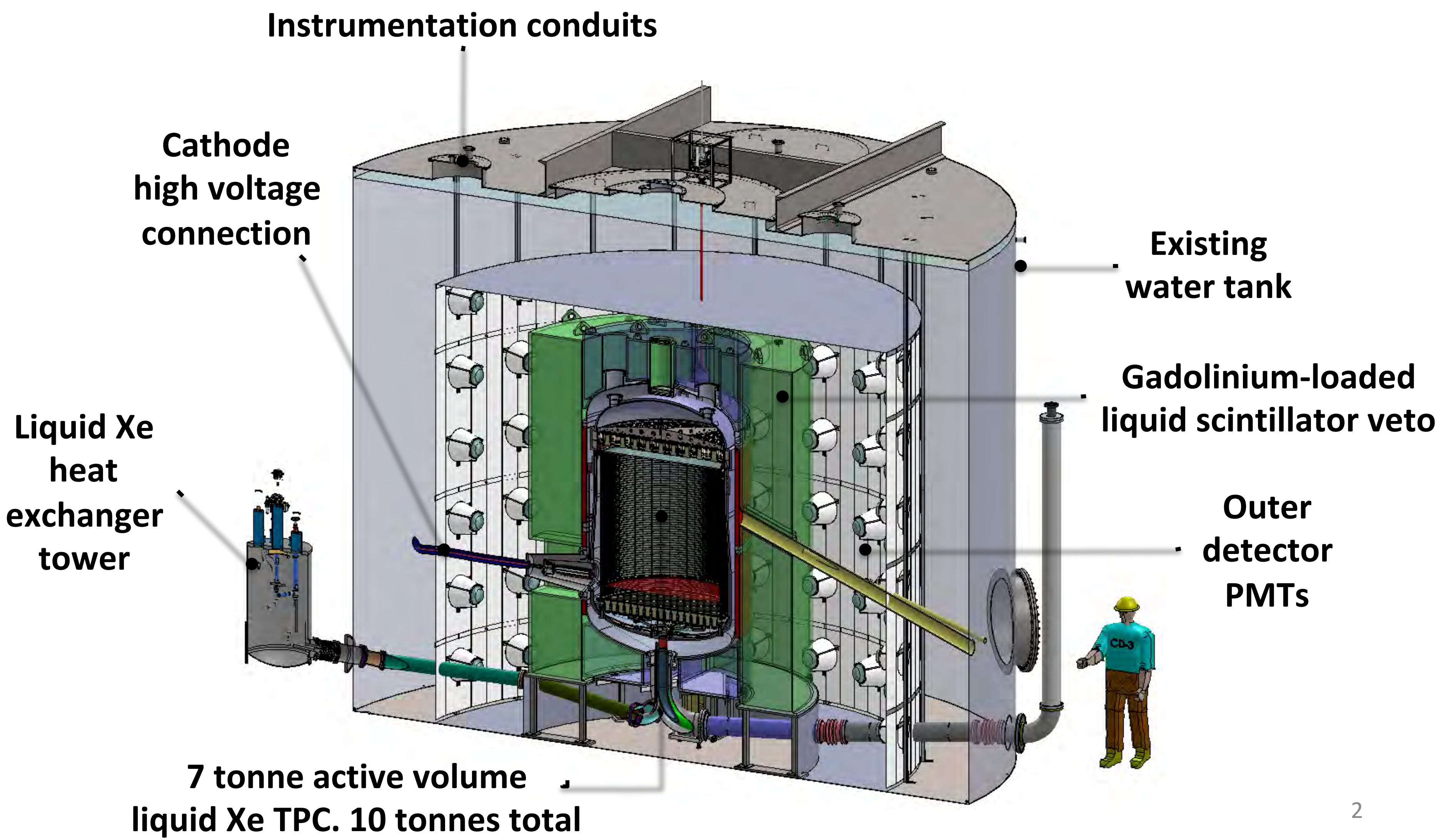
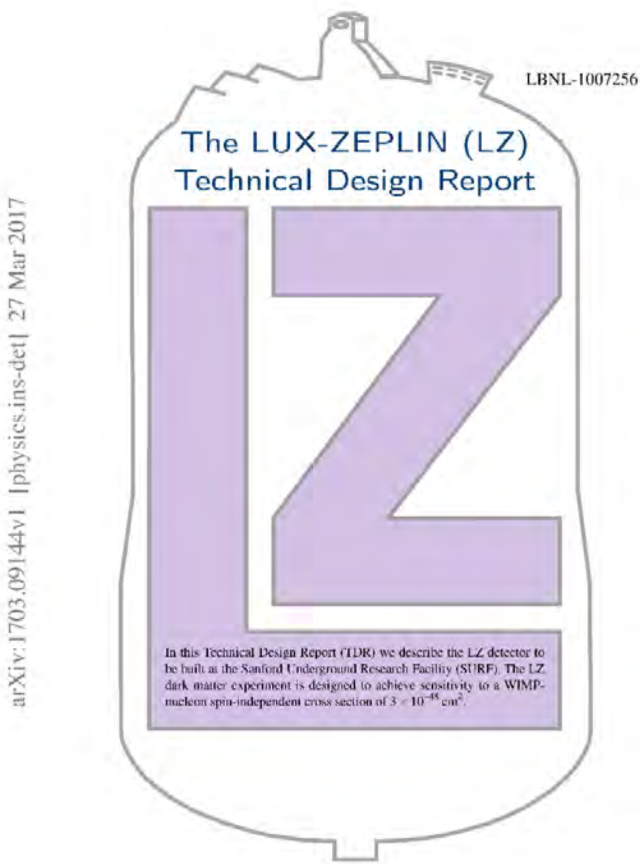
Status of the LZ Project

Hugh Lippincott
Fermilab
February 23, 2018
UCLA Dark Matter 2018

LZ Detector Overview



LZ Technical Design Report
arXiv:1703.09144, March 27, 2017



LBNL-1007256

arXiv:1703.09144v1 [physics.ins-det] 27 Mar 2017

The LUX-ZEPLIN (LZ) Technical Design Report

In this Technical Design Report (TDR) we describe the LZ detector to be built at the Sanford Underground Research Facility (SURF). The LZ dark matter experiment is designed to achieve sensitivity to a WIMP-nucleon spin-independent cross section of 3×10^{-48} cm^2.

2 Scientific Performance chap:SIP LZ Technical Design Report

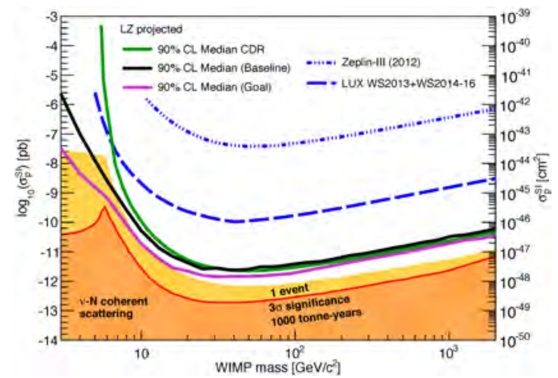


Figure 2.1.2: LZ sensitivity projections. The baseline LZ assumptions described in this Technical Design Report give the solid black curve. LUX and ZEPLIN results are shown in broken blue lines. If LZ achieves the design goals listed in Table **??**, the sensitivity would improve, resulting in the pink sensitivity curve. The gray line shows the projected sensitivity in the LZ Conceptual Design Report (CDR) [10] (see text for details of the changes from the CDR to this report). The shaded regions show regions where background NRs from cosmic neutrinos emerge [13]. `SIPf:LZSISens`

ical neutrinos. In particular, solar neutrinos have been considered as both an interesting signal and as an irreducible background to a WIMP search.

LZ will observe the pp fusion chain of our sun in real time via elastic $ve \rightarrow ve$ scattering, in a lower energy regime than the only other real-time measurement to date, and will most likely detect neutrinos from ^{8}B via coherent nuclear scattering. The coherent neutrino signal from a nearby supernova would be a unique, flavor-independent probe of the neutrino flux.

We have also estimated the potential of LZ to observe neutrinoless double-beta decay ($0\nu\beta\beta$) from ^{136}Xe, and considered the impact on the reactor/source neutrino anomaly and on searches for a neutrino magnetic moment of a prolonged exposure of LZ to a nearby ^{51}Cr neutrino source.

2.2.1 Solar and Atmospheric Neutrinos `SIPSs:SAN`

2.2.1.1 Elastic Scattering of Solar Neutrinos `SIPSss:PP`

A prominent background for WIMP dark matter searches in LZ will come from the elastic scattering of solar neutrinos from the pp fusion chain [14] with the atomic electrons in xenon. Our calculations of the rate of these scatters agree with those of [15] under the same assumptions. The calculations in this report, however,

4

LZ: 256 authors, 36 institutions (25 US), 396 pages.

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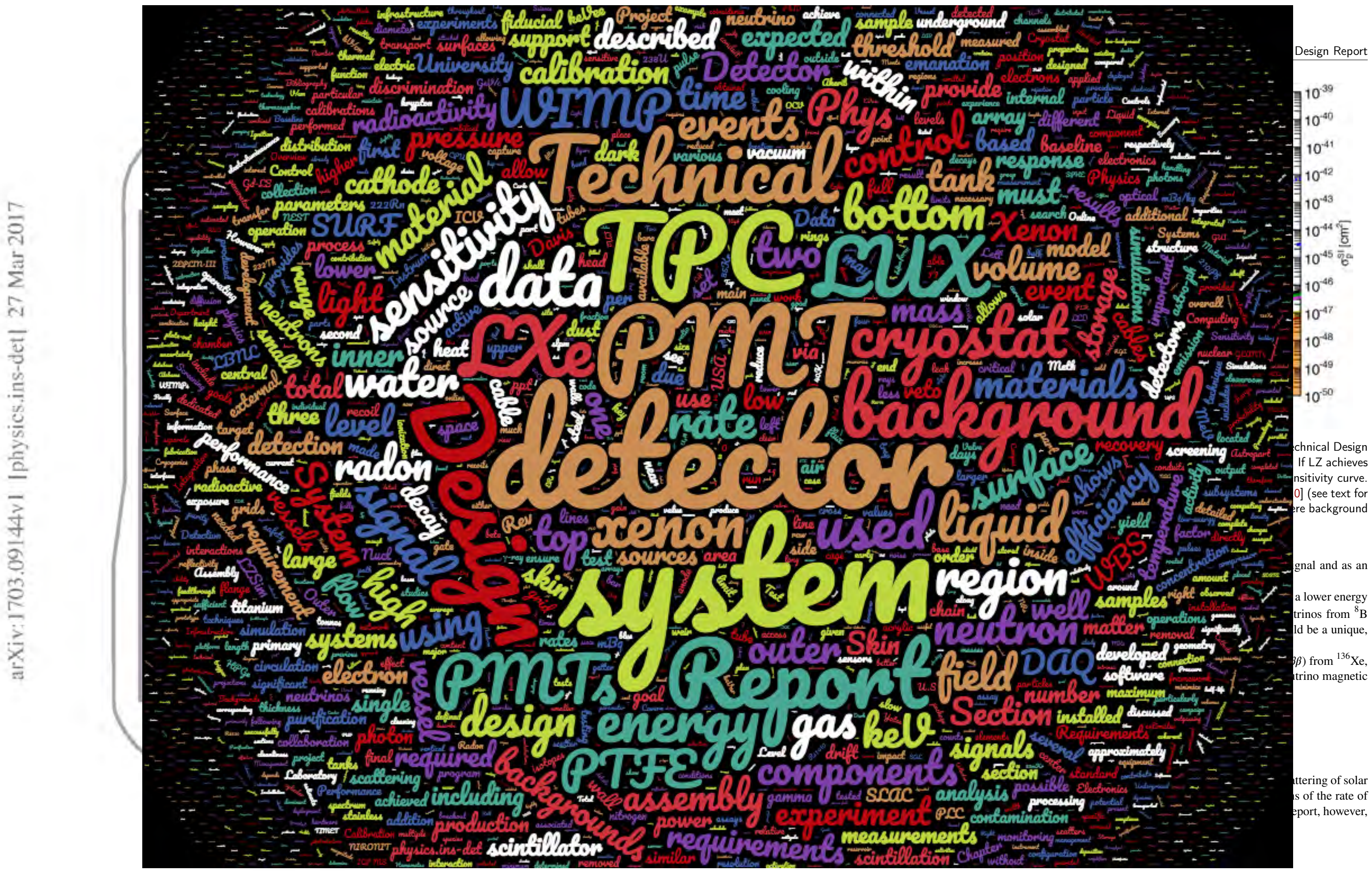

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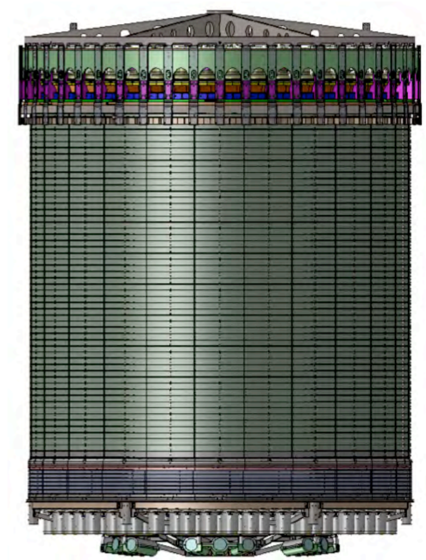
Schedule

- CD1 Review – March 2015
- CD2 Review – April 2016
- CD3 Review – February 2017 - construction can start in earnest
- Cryostat fabrication just completed
- PMT array assembly begins in March
- Xenon handling installation and commissioning starts Fall 2018
- TPC installation Spring-Summer 2019
- Cooldown starts Winter 2019
- First physics data – Spring 2020

Design notes

- Lots of mass – 7 tonnes in TPC, 5.6 tonnes fiducial
  - 494 3” PMTs in TPC
  - 58 drift field sections covered by PTFE segments
- 50 kV cathode HV
  - Significant R&D and prototyping at SLAC
- 2-component veto system
  - LXe skin – 93 1” PMTs, 38 2” PMTs
  - Outer detector – 120 8” PMTs (see S. Shaw, next)
- Gas circulation/purification system
  - 500 slpm, turns over inner volume every ~2.5 days
- Calibrations
  - Extensive internal and external sources, including DD generator and photoneutron sources

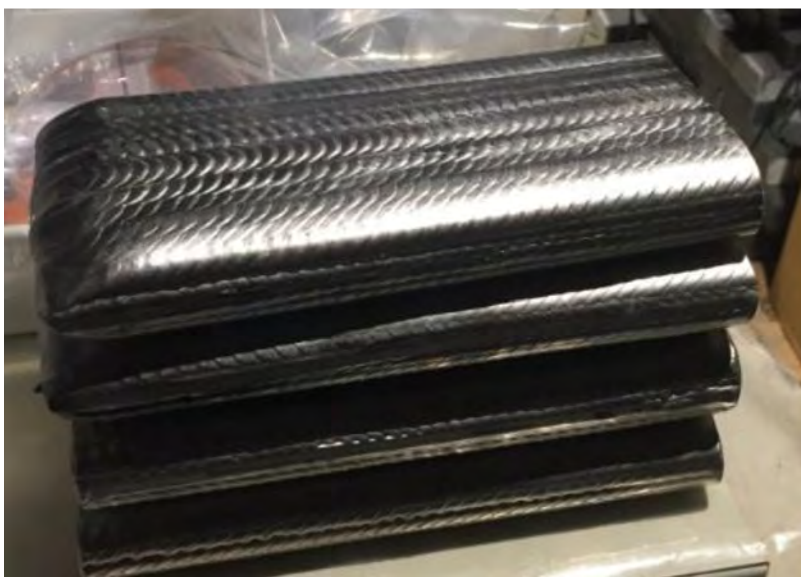


Radiopurity

- Nothing goes into the detector without being screened
  - ~2000 planned assays, roughly 50% complete
    - 13 HPGe detectors, Neutron Activation Analysis, GDMS, two ICPMS setups, four radon emanation chambers, two XIA alpha counters, etc.
  - Extensive searches for low radioactivity components
    - Titanium for cryostat and other internal structures
      - ”Identification of Radiopure Titanium for the LZ Dark Matter Experiment and Future Rare Event Searches”, arXiv:1702.02646, Astroparticle Physics 96 (2017) 1–10
    - All PMT materials screened before fabrication by Hamamatsu, finished PMTs assays 95% complete
    - All PMT base components and completed bases (100%)
    - PTFE source material (in fabrication now)
    - Bolts, nuts, peek fasteners, cable ties, cables, instrumentation, etc., etc., etc.
  - Internal detector components contribute less than 10 total events before discrimination! (See J. Dobson on sensitivity)

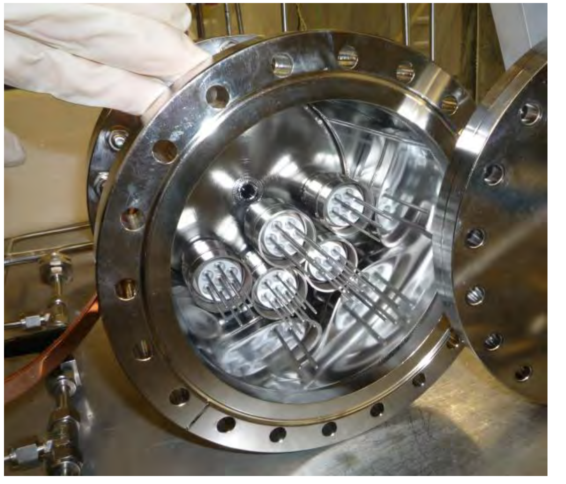
Radiopurity

- Backed up by extensive quality control
  - E.g. Cryostat fabrication – weld coupons made early on were hotter than stock Ti
  - Fabrication stopped, massive screening investigation launched
  - Wrong welding tips were being used - color code on one provided by a supplier was missing, and trace Th was being introduced into the welds
  - Caught in time, fabrication restarted



Central part (1) Weld (2) Weld (3)

Radon and Dust

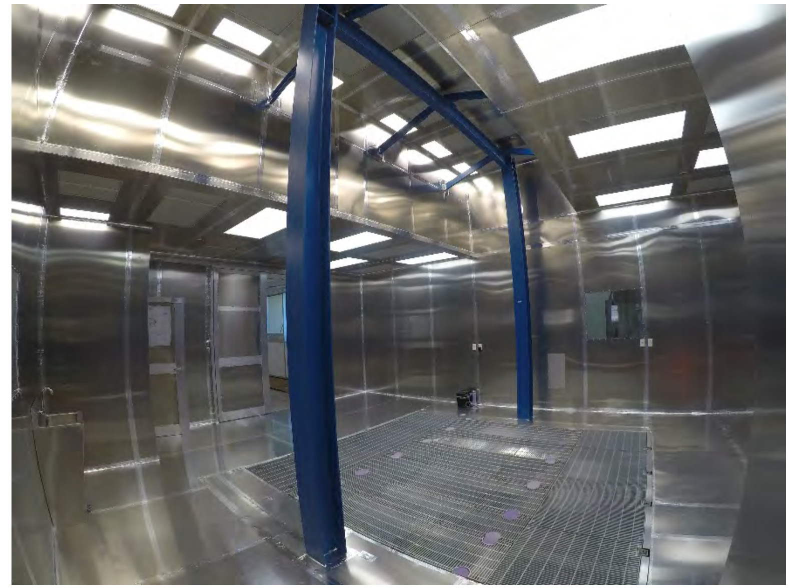


- Radon (naked Pb beta decay) is biggest expected background (see J. Dobson)
- Extensive radon assay campaign underway
  - Cables, getter, heat exchanger
  - Some credit taken for cold components
- Radon mitigation system for portion of warm plumbing
- Dust another large component
  - 500 ng/cm^2 of dust allowed
- All parts fabricated in well-understood clean rooms with witness plates and travelers to ensure quality control
- Commercial vendor cleaning most TPC parts

LZ Project

- Ready for the picture round

On Site Facilities

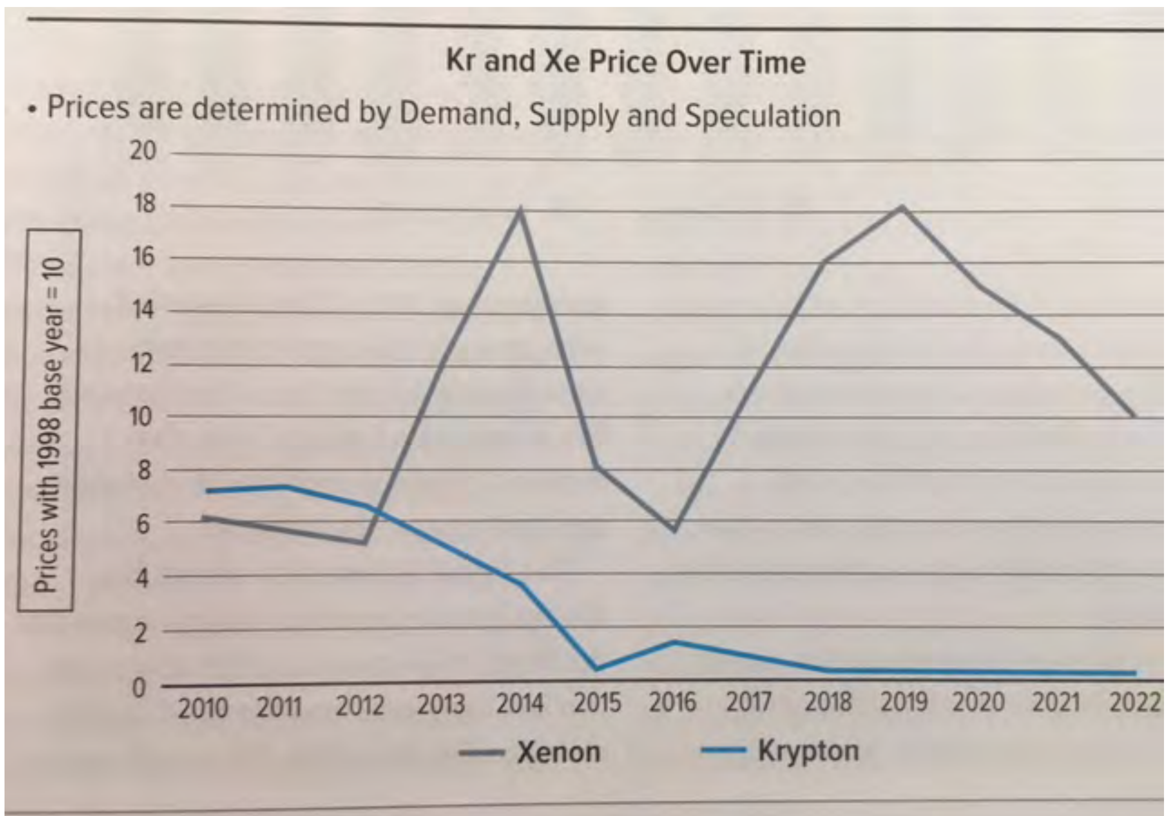


- Low radon, class 100-1000 cleanroom ready at SURF for first parts
- Radon reduction system installed
- Underground improvements started, to finish by May

Xenon

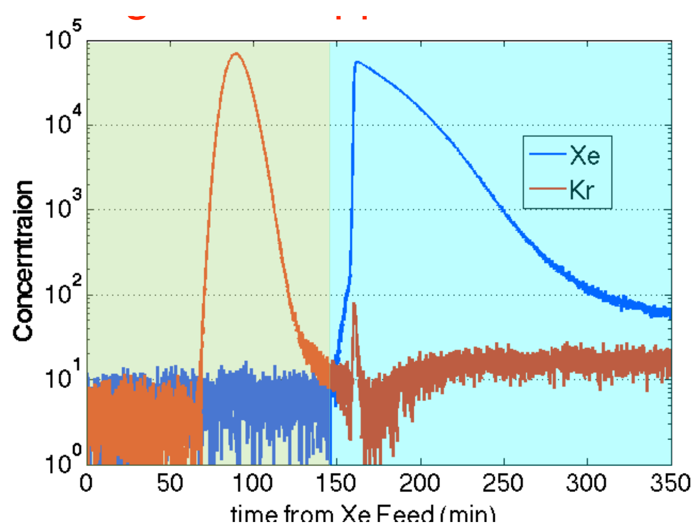
- 10.7 tonnes xenon under contract (most in 2016)
- 6.5 tonnes in hand, with final delivery middle of 2019

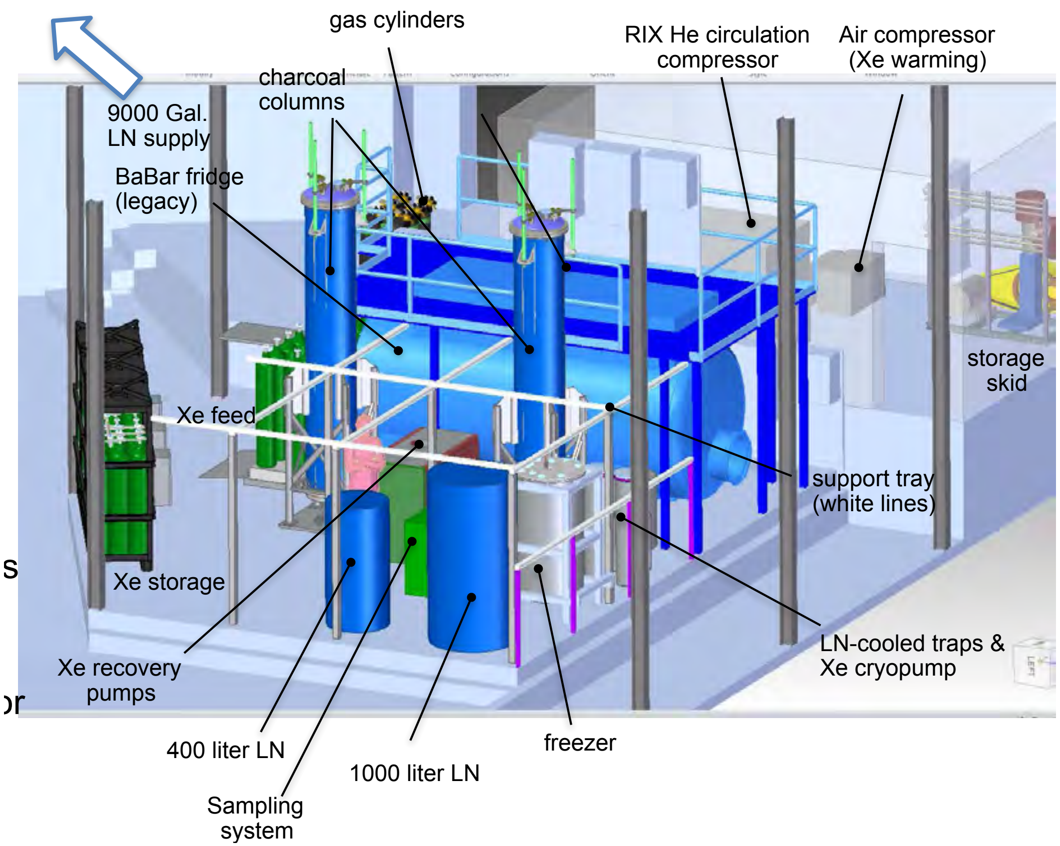
Approximately $/gas liter



Xenon and Krypton

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





- On track for production second half of 2019

Xenon Circulation

- Full circulation test planned underground starting end of 2018
- Commission all parts of circulation system with a dummy cryostat

Circulation Compressors under construction (2 of 4)

Xenon storage pack (1 of 12)

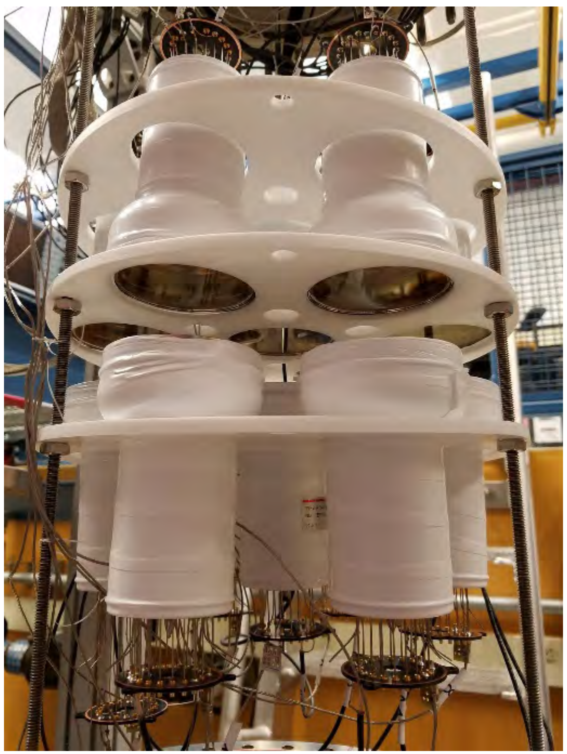
Heat exchanger

Cryostat

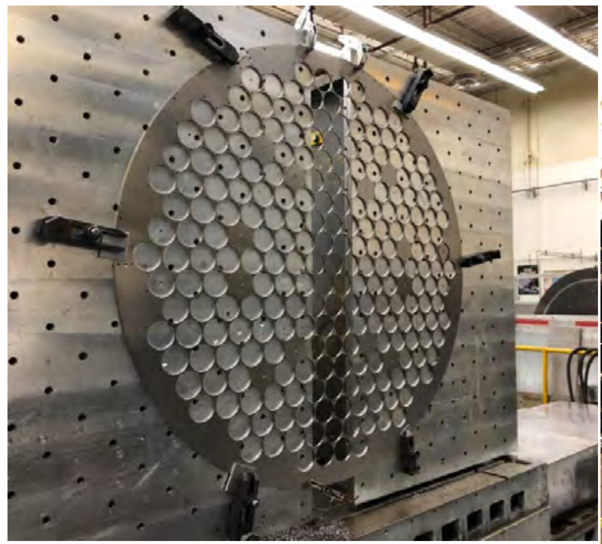
- Fabrication complete at Loterios in Italy - about to ship to US

PMTs

- 3" PMT delivery complete except for small number of replacements (96% yield)
- Main array assembly construction launching at Brown in March, practice assembly now underway



All PMTs cold tested at Brown



Titanium array plate machining

Base burn in at Imperial

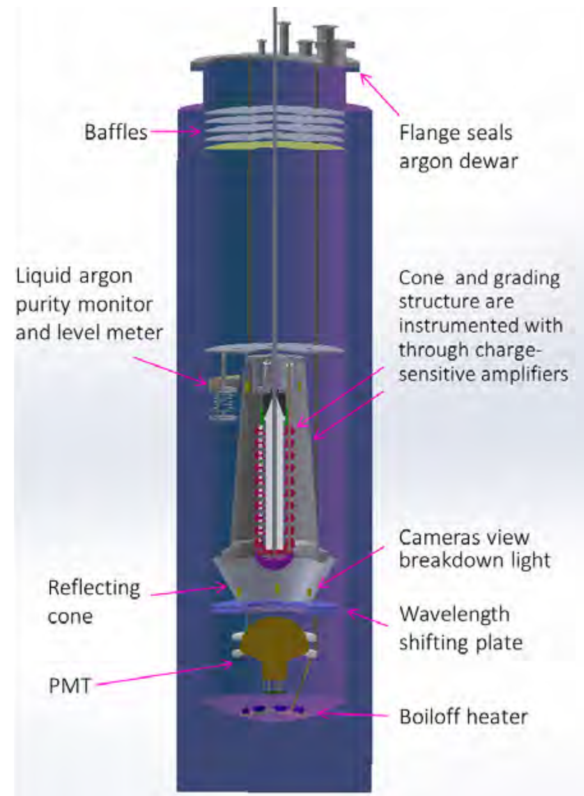
PALACE shipping frame

HV Delivery

- Main cable tested to 120 kV
- Full cathode testing happening now in LAr

Liquid argon testing at LBNL

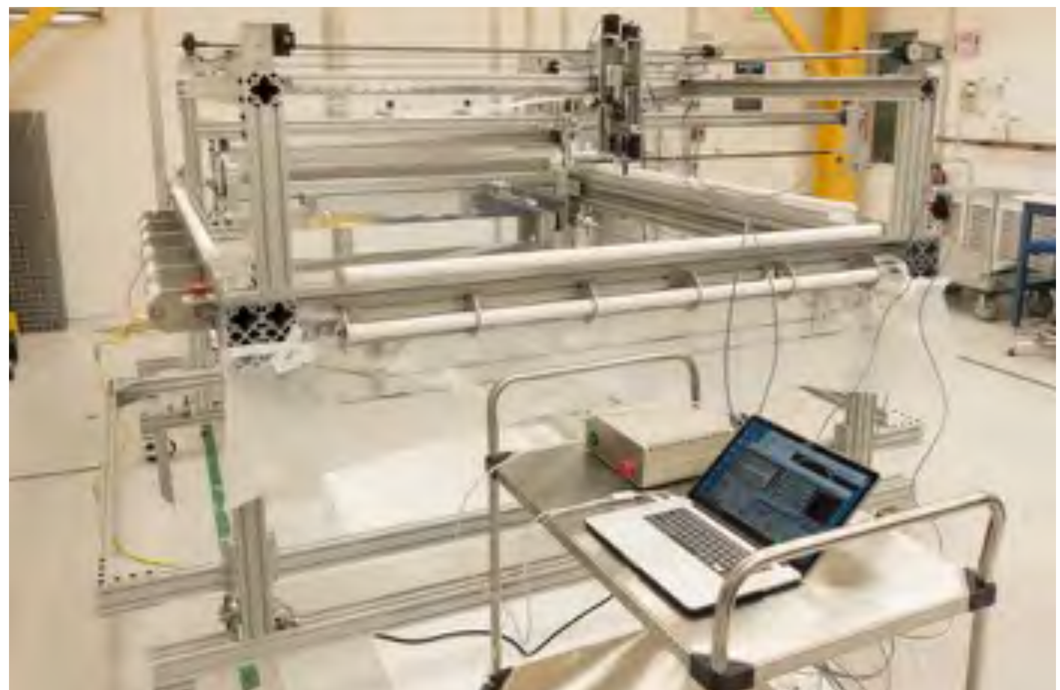
Test Structure
Under Assembly



HV Grids and Rings

- TPC field rings being machined
- Prototype grid rings for bottom and cathode complete, to be tested in SLAC system test
- Machining of production grid rings underway

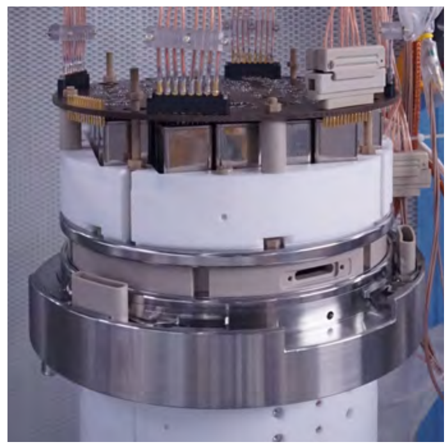
Titanium TPC field ring



Grid weaving loom at SLAC: [Loom in action]

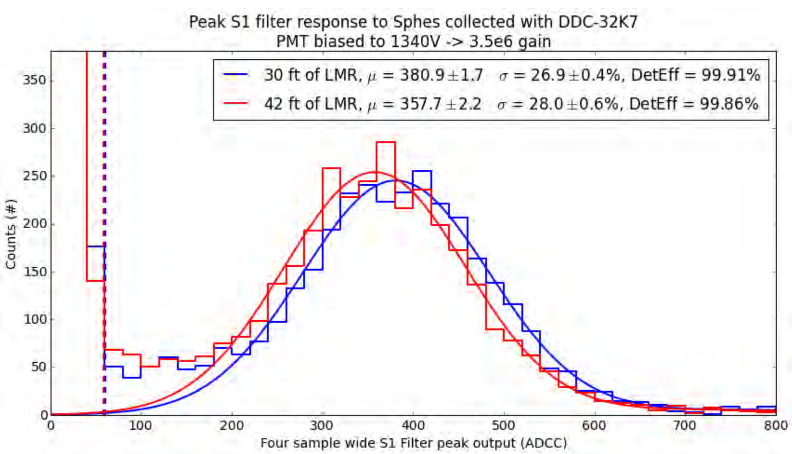
System Test and R&D

- PTFE reflectivity measurements, wire emission, HV design verification, purification, circulation, full scale grid QA, etc, etc, completed or in full swing



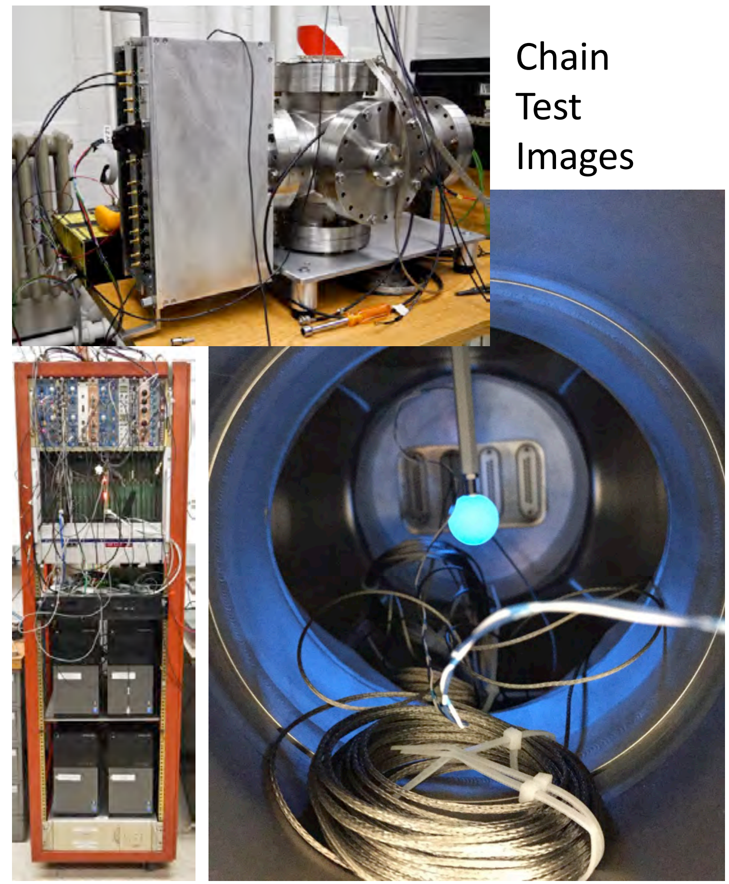
DAQ and Electronics

Pre-production prototype



Excellent results obtained with prototype 1.

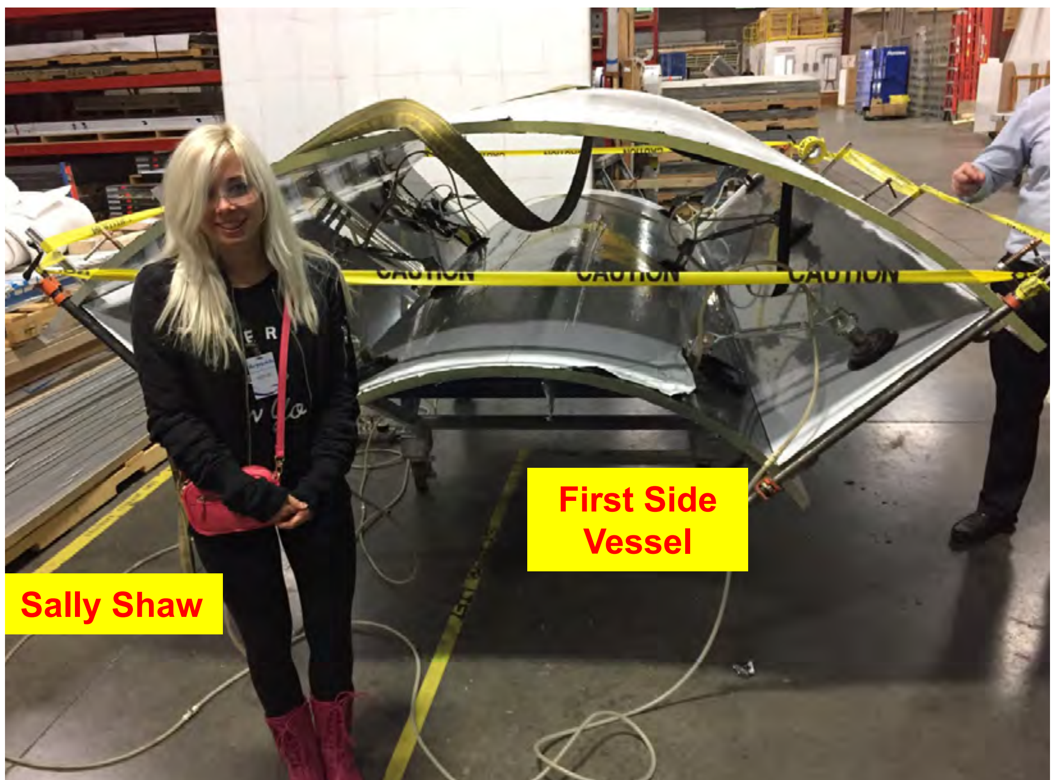
Complete electronics chain test



Chain
Test
Images

Outer Detector

- Final bonding of side tanks this month
- Liquid scintillator production at BNL this summer



Software

- Complete simulation and reconstruction package from events to waveforms to analysis
- Exercised in mock data challenges
  - Second MDC starts in April
- Sensitivity estimates are mature (J. Dobson)
- Will be ready for first data

Summary

- On schedule and on budget
- Good technical progress on all fronts, no showstoppers
- First physics data planned in April 2020