Enriched Xenon Observatory
for double beta decay

EXO-200 Progress

Liang Yang

Research Associate

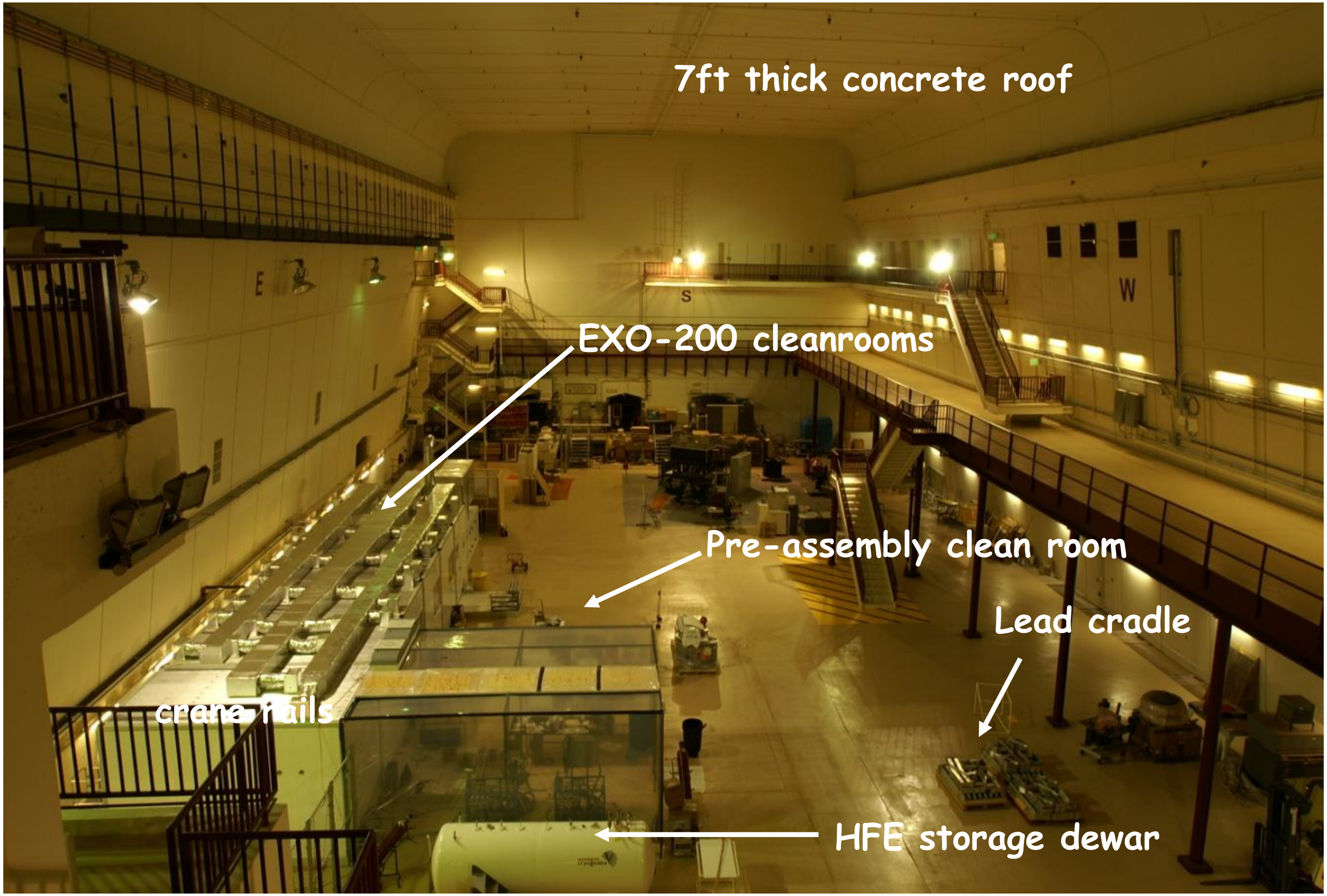
Introduction

- EXO collaboration aims to observe and measure the double beta decay mode of Xe^{136}. In particular, the measurement of the $0\nu\beta\beta$ mode of decay can tell us about the nature and mass of neutrino.
- The main effort in the EXO collaboration at present is the construction of a prototype experiment of significant scale: EXO200.
- EXO200 is a ultra-low background detector, operated underground. This prototype will use the 200 kg of 80% enriched Xe^{136}, and will *not* employ barium ion tagging.

In the past year, two majors efforts were underway in parallel :

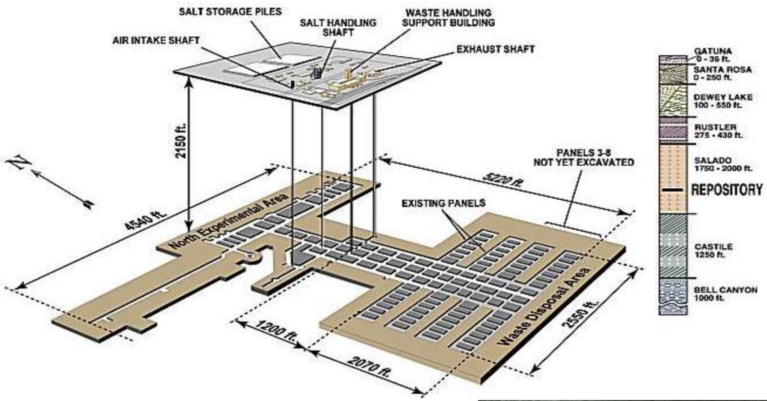
- Transport the Cleanrooms from Stanford to WIPP, a salt mine in New Mexico. Build a clean underground laboratory and its support facilities. SLAC provided substantial manpower (30%) and critical engineering support.
- Build and test low background detector at Stanford and SLAC. The design of the TPC, electronics and slow control system are all done at SLAC.

EXO200 cleanrooms – in End Station III at HEPL (Stanford) 5/07



E-300 Drift at Waste Isolation Pilot Plant (WIPP), 5/07

WIPP Facility and Stratigraphic Sequence

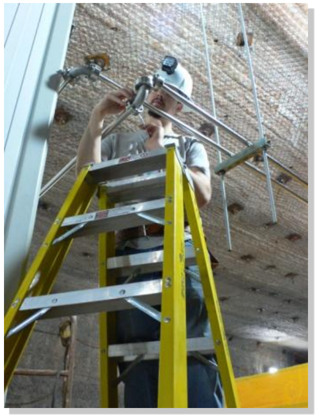


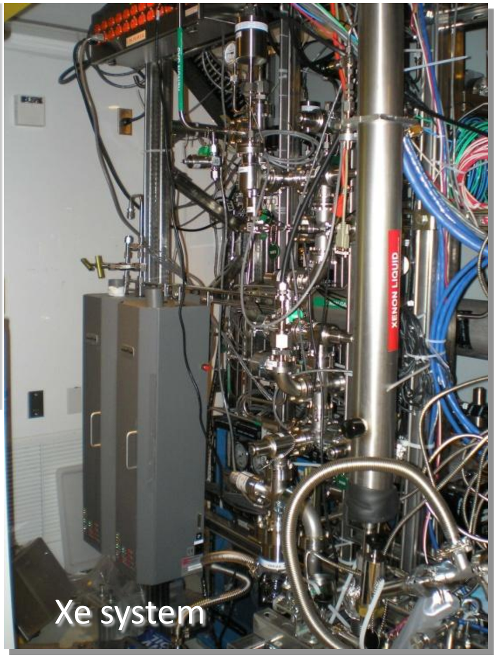
Packing up at Stanford, 6/07

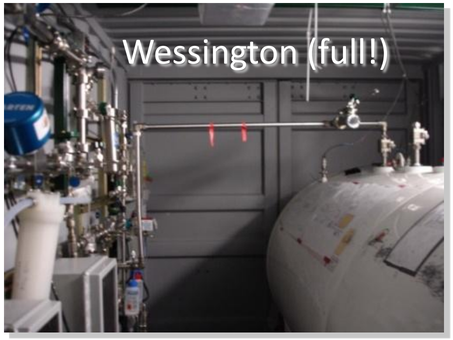
Module Arrival at WIPP , 6/07-8/07

Underground Module Coupling 8/07-9/07

Building EXO-200 at WIPP, 10/07-7/08



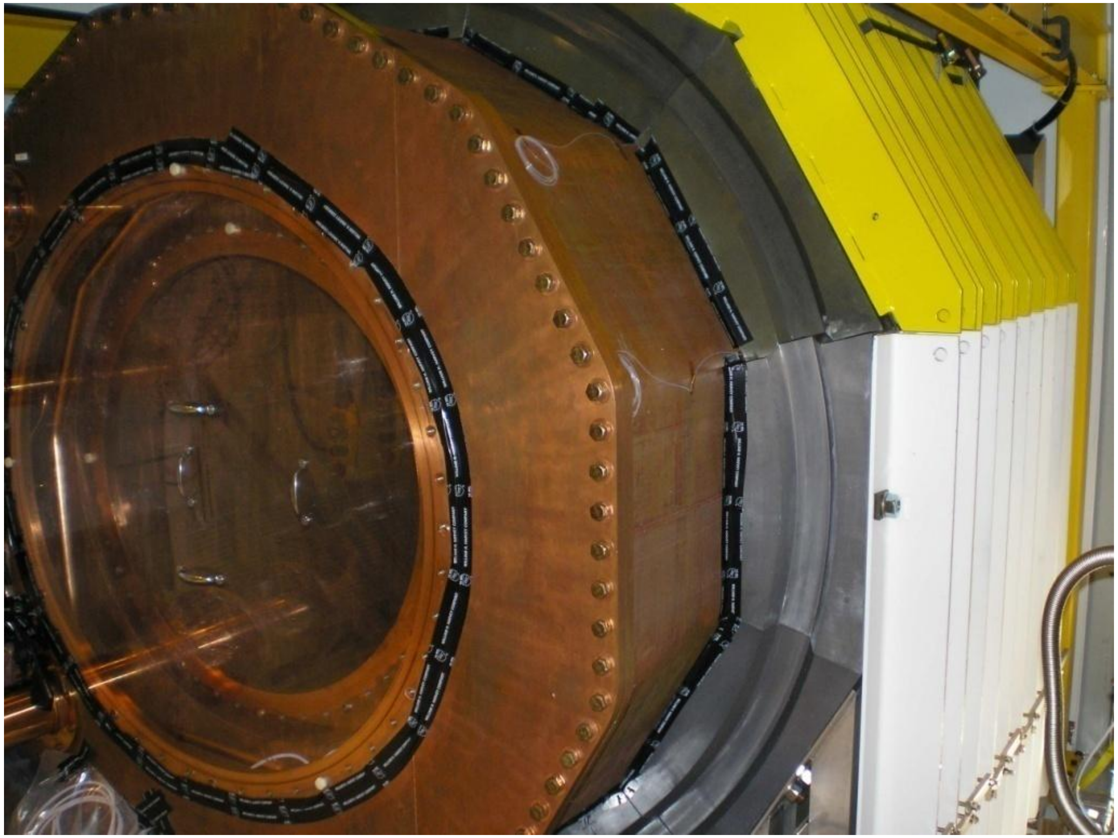




Lead Shielding Installation (3/08 – 6/08)

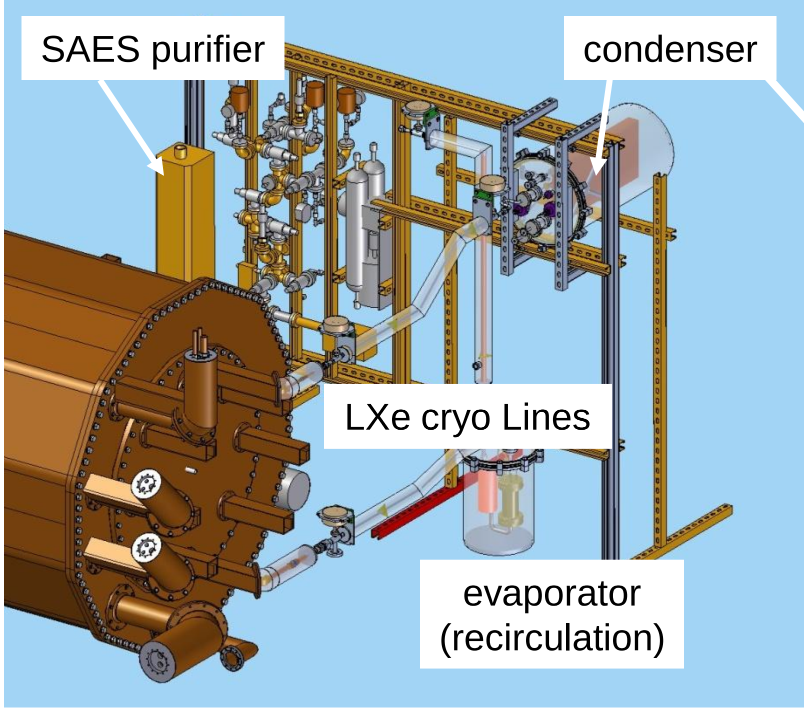
Rear Pb wall assembly

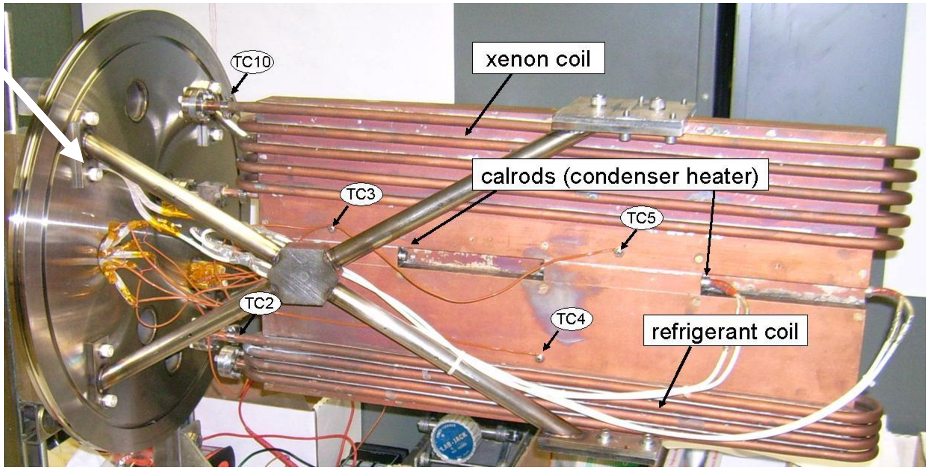
Pb arch installation



Pb shielding close to completion

Cryogenic Commissioning at WIPP

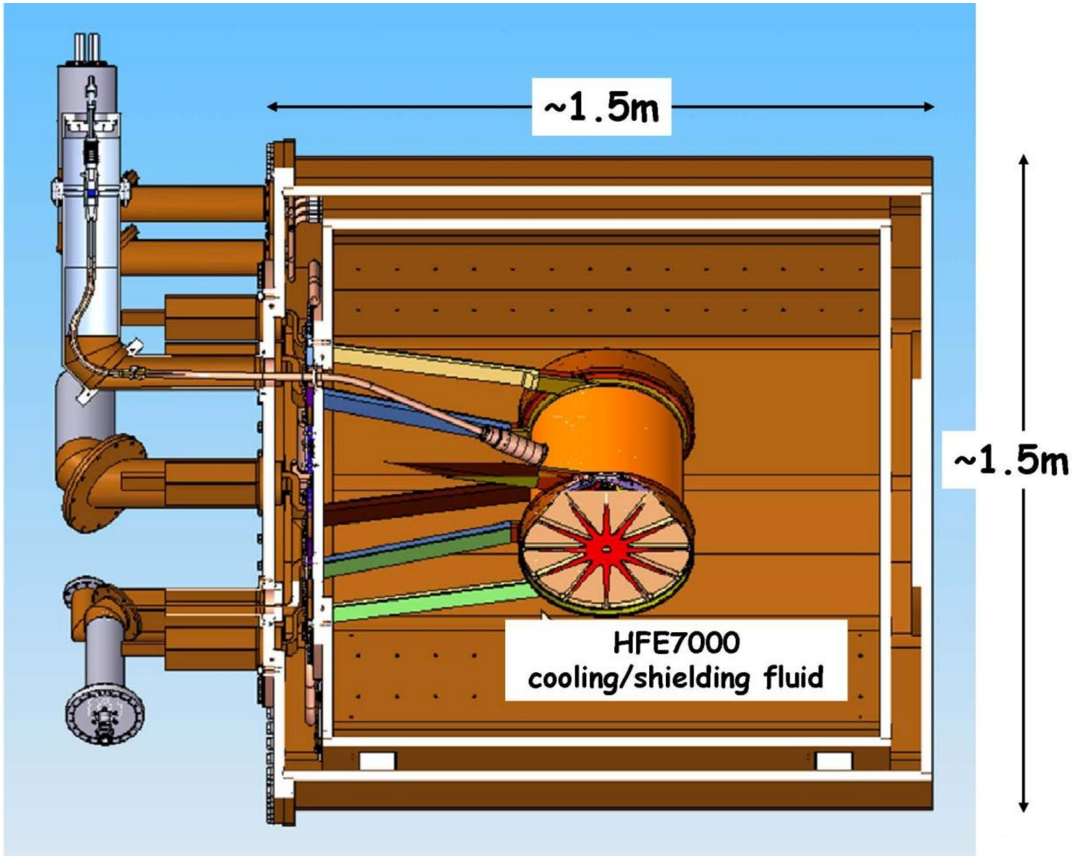




condenser (inside vac.can)

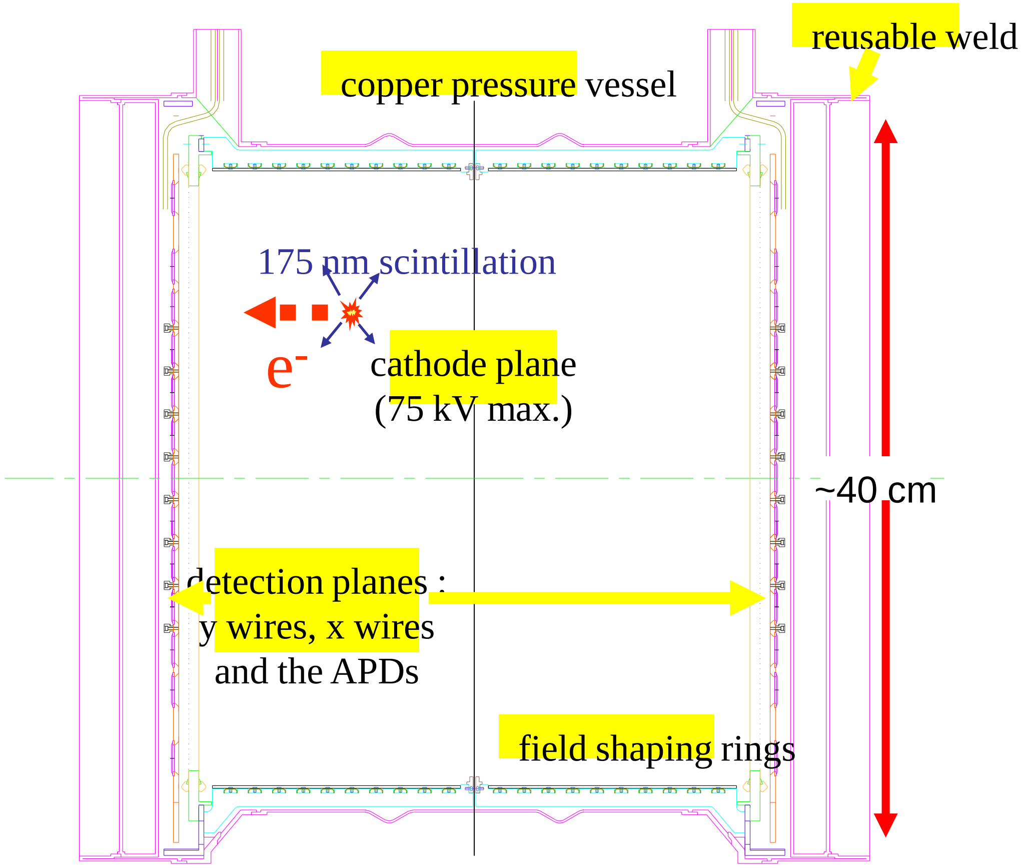
- SLAC postdoc and physicist (Wodin, Rowson) are currently leading the effort to commission the cryogenic system.
- Liquid Xenon circulation and purification systems are designed and built by SLAC physicists and engineers.
- The new vacuum insulated liquid xenon lines built by cryo group should solve the heat leak issue in previous test.

EXO-200 Cryostat and Detector



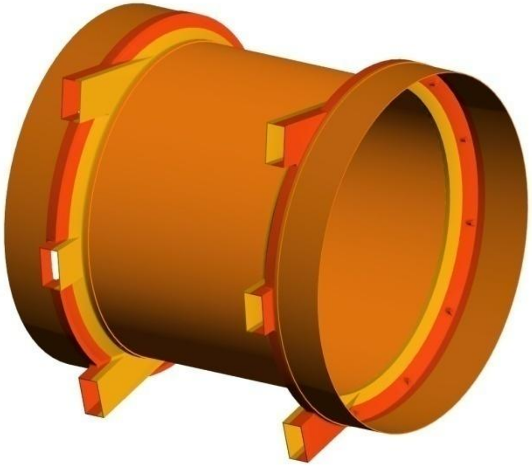
- The detector is being built at Stanford and SLAC.
- SLAC designed all parts inside the detector, field cages, grid wires, high voltage feedthrough and signal cables.
- SLAC is also responsible for electronics and slow control systems.

EXO-200 Detection Scheme



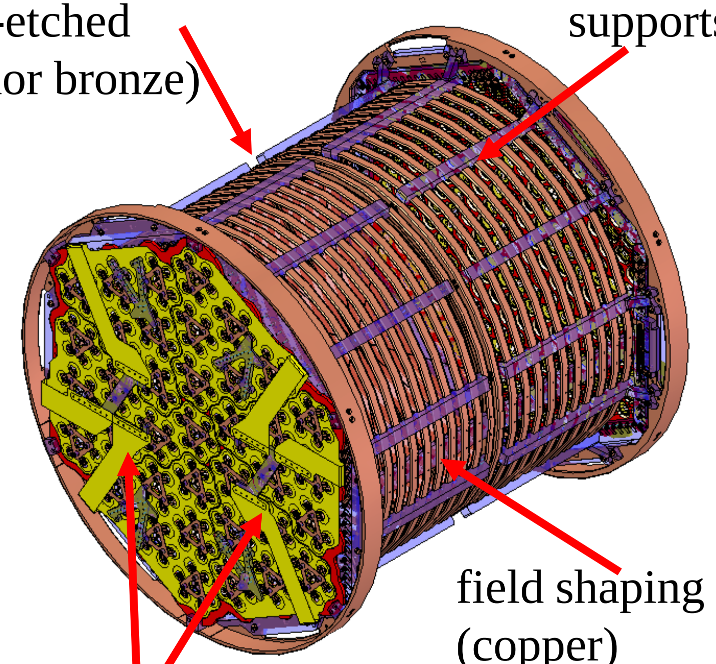
- Detect both scintillation light and ionization charges from a decay event.
- Scintillation light collected by APDs for timing and to enhance energy resolution.
- x wires collects drifted electrons, on y wires uses induced signal for transverse localization .

Ultra-low Activity Cu Vessel



- Very light (wall thickness 1.5 mm, total weight 15 kg), to minimize material.
- All parts machined under 7 ft of concrete shielding to reduce activation by cosmic rays.
- Different parts are e-beam welded together at Applied Fusion. Construction of the vessel with 55 welds has been completed.
- End caps will be TIG welded.

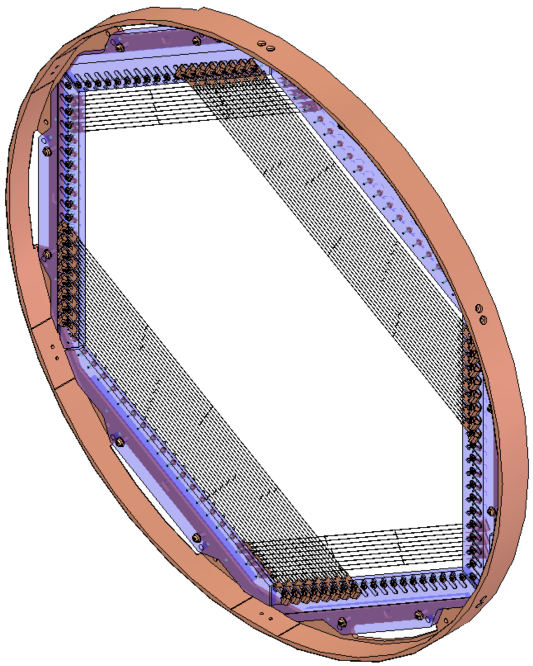
TPC Field Cage and Read out Plane

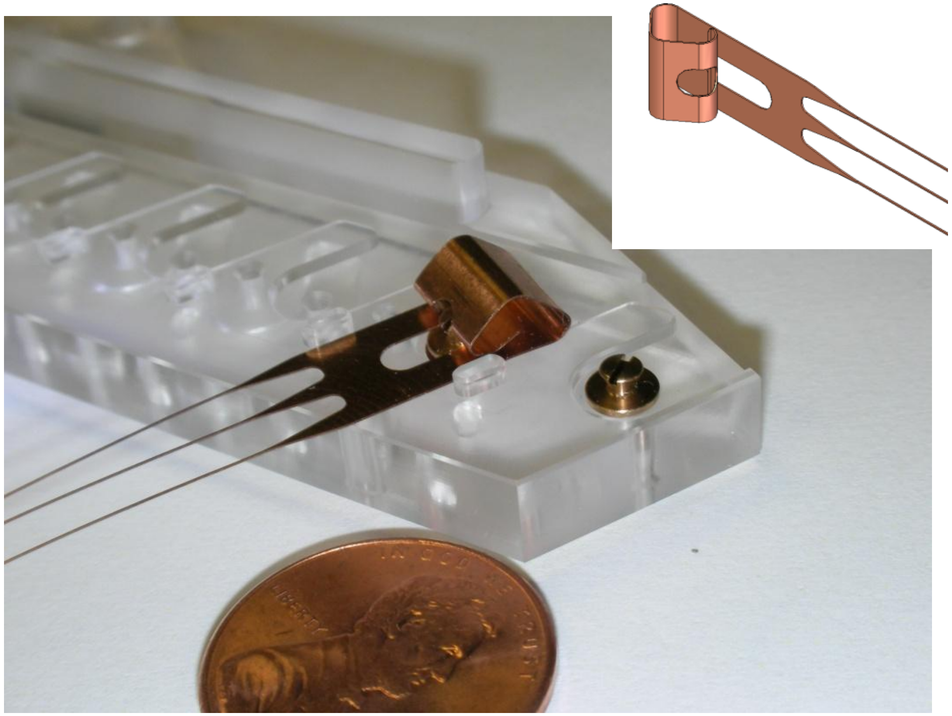


Half chamber mock-up model, parts for the real chamber have almost all been machined, waiting for final assembly

SLAC engineer Skarpaas with support from Campell, Conley, Hodgson and Swift is responsible for the design.

TPC Wire Planes (Ionization Detection)





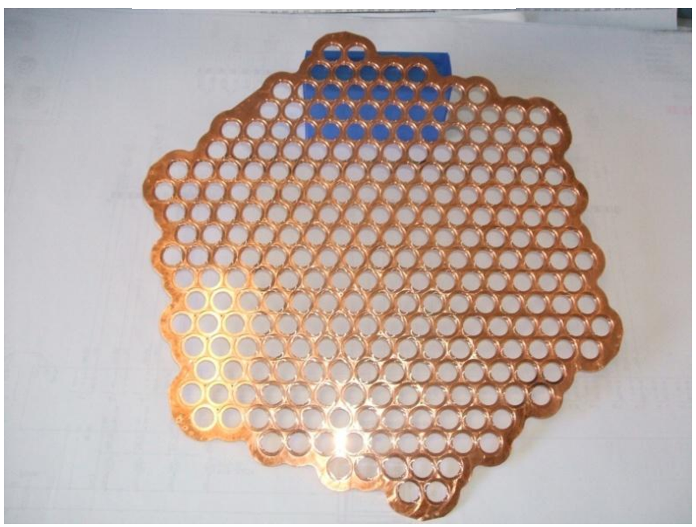
X and Y wire plane with Cu support ring, and acrylic frame.

Most parts have been machined, stored in nitrogen flush box at End Station III

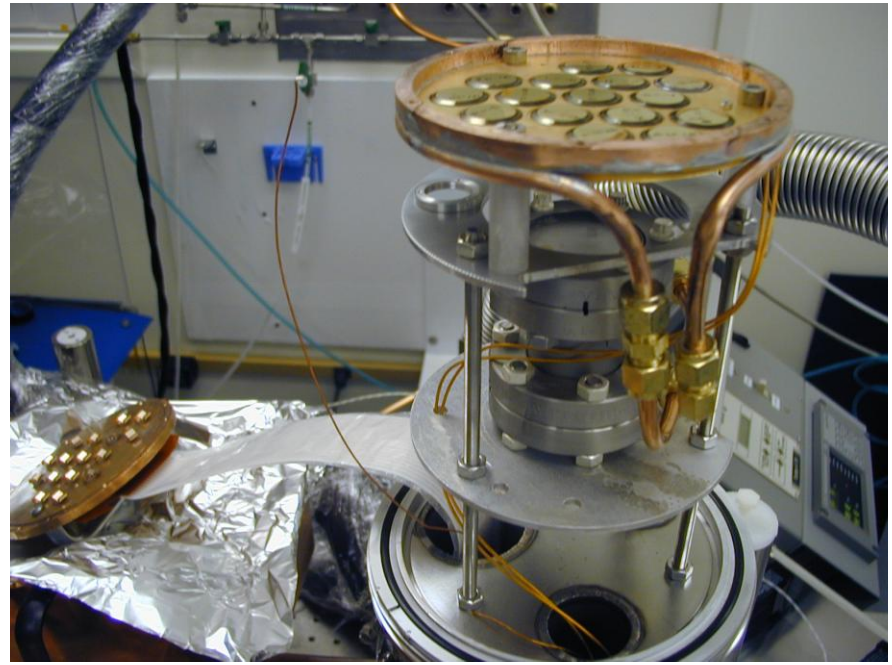
X and Y wires are made from etched phosphor bronze. A novel spring load mechanism accommodates the thermal contraction and minimize extra material Inside the detector region.

APD Planes (Scintillation Detection)

7 APD cluster



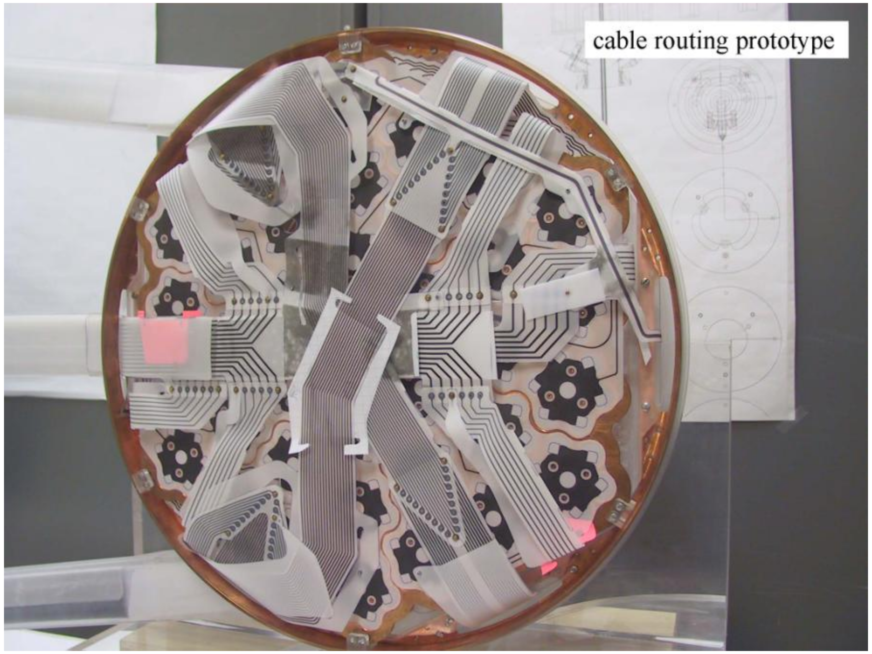
APD Plane holds 259 APDs

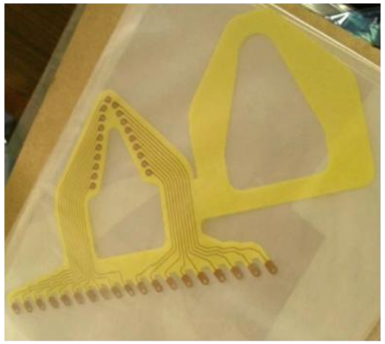


APD Test Setup at ESIII

- APDs are very clean, light weight and sensitive to 175 nm light.
- Gains of APDs are set to 100-150.
- Over 500 APDs have been tested and characterized, enough for the full detector.

Flex Signal Cable





- Signal cables are 18um thick copper on 25um thick Kapton, to minimize material close to the detection region.
- Intricate cable design is the brainchild of SLAC engineer Knut Skarpaas.
- Signal traces are etched and plasma cleaned. Cables are currently in production.

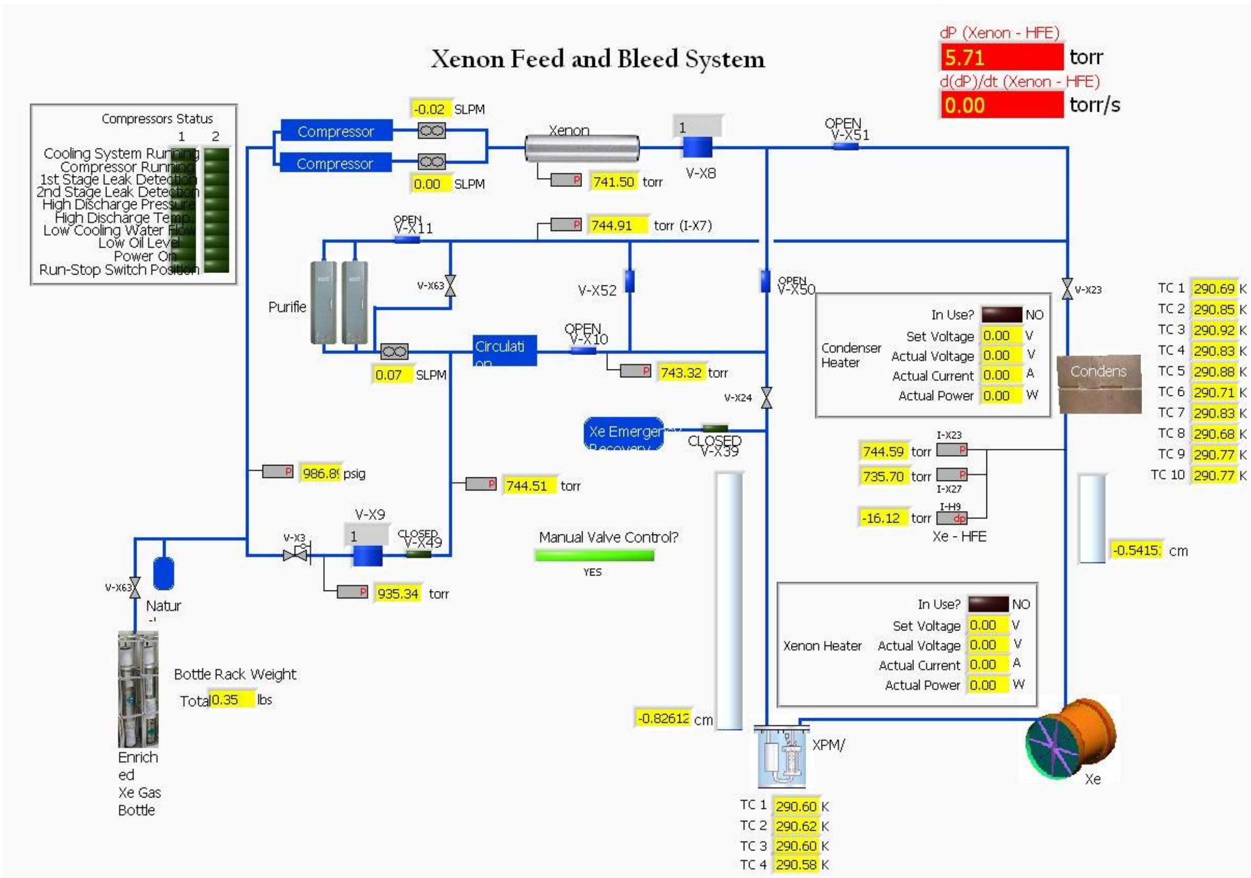
Front End Electronics and DAQ System

EXO Front End Cards

DAQ Test Station at SLAC

- EXO Front end electronics includes 18 front end cards, 226 read out channels total, 2 high voltage boards, 2 distribution boards, one trigger event module and one muon veto module.
- Electronics designed by SLAC engineers Herbst, Freytag and Haller, and built by SLAC technicians Freytag and Salgado.
- The DAQ hardware and software are currently being tested and optimized at SLAC to minimize system noise.

Slow Control System



- EXO slow control system is Labview based and uses NI compact field point system.
- Slow control is critical for the operation of xenon TPC, maintain a minimum pressure across the thin vessel. The software also enables remote monitor and control capability.
- The slow control is entirely developed at SLAC by graduate student Derek MacKay.

EXO200 Schedule

At present, cleanrooms, support facilities (small machine shops, UPS power, clean pre-assembly areas, storage, terminals/communications room) are underground at WIPP.

- Cryo/xenon system/controls tests at WIPP *Aug. & Sept.*
- In ESIII cleanroom (Stanford) : TPC assembly, installation in the Cu xenon vessel, mechanical/electronics testing *July thru October.*
- Detector shipment to WIPP in *late October or late January*.
- Cooldown in early 2009.
- Engineering Run (natural xenon) followed by Physics Runs.

EXO200 Projections

1) $\sigma(E)/E = 1.6\%$

2) Low but finite radioactive background: 20 events/year in the $\pm 2\sigma$ interval centered around the 2.479 MeV endpoint

3) Negligible background from $2\nu\beta\beta$ ($T_{1/2} > 1 \cdot 10^{22}$ yr R.Bernabei et al. measurement)

Case	Mass (ton)	Eff. (%)	Run Time (yr)	σ_E/E @ 2.5MeV (%)	Radioactive Background (events)	$T_{1/2}^{0\nu}$ (yr, 90%CL)	Majorana mass (meV) QRPA	(NSM)
Prototype	0.2	70	2	1.6*	40	6.4×10^{25}	133[1]	(186)[2]

1) Rodin, *et. al.*, Nucl. Phys. A **793** (2007) 213-215

2) Caurier, *et. al.*, arXiv:0709.2137v1

The EXO Collaboration

K.Barry, D.Leonard, E.Niner, A.Piepke *Physics Dept, University of Alabama, Tuscaloosa AL*
P.Vogel *Physics Dept Caltech, Pasadena CA*
A.Bellerive, M.Bowcock, M.Dixit, C.Hargrove, E.Rollin, D.Sinclair, V.Strickland
Carleton University, Ottawa, Canada
C. Benitez-Medina, S.Cook, W.Fairbank Jr., K.Hall, B.Mong *Colorado State University, Fort Collins CO*
M.Moe *Physics Dept UC Irvine, Irvine CA*
D.Akimov, I.Alexandrov, A.Burenkov, M.Danilov, A.Dolgolenko, A.Kovalenko, V.Stekhanov
ITEP Moscow, Russia
J.Farine, D.Hallman, C.Virtue, U.Wichoski *Laurentian University, Canada*
H.Breuer, C.Hall, L.Kaufman, S. Slutsky, Y-R. Yen
University of Maryland, College Park MD
K.Kumar *U. of Massachusetts, Amherst*
M.Auger, R.Gornea, D.Schenker, J-L.Vuilleumier, J-M.Vuilleumier
Physics Dept University of Neuchatel, Switzerland
N.Ackerman, M.Breidenbach, R.Conley, W.Craddock, J.Hodgson, D.McKay, A.Odian, C.Prescott, P.Rowson, K.Skarpaas, J.Wodin, L.Yang, S.Zalog *SLAC, Menlo Park CA*
J.Anthony, L.Bartoszek, R.DeVoe, P.Fierlinger, B.Flatt, G.Gratta, M.Green, S.Kolkowitz, F.LePort, M.Montero-Diez, R.Neilson, M. Noske, K.O'Sullivan, A.Pocar, K.Twilker *Physics Dept Stanford U., Stanford CA*