Overview and Status of the EXO-200 experiment

Steven Herrin
PhD Student
SLAC National Accelerator Laboratory

On behalf of the EXO Collaboration

APS April Meeting
May 2, 2009

Outline

- EXO Concept
  - Double Beta Decay
  - Xenon
- EXO-200 Prototype
  - Time Projection Chamber
  - Vessel and Cryostat
  - WIPP Site
- Status
  - Time Projection Chamber
  - At WIPP

Concept: Double Beta Decay

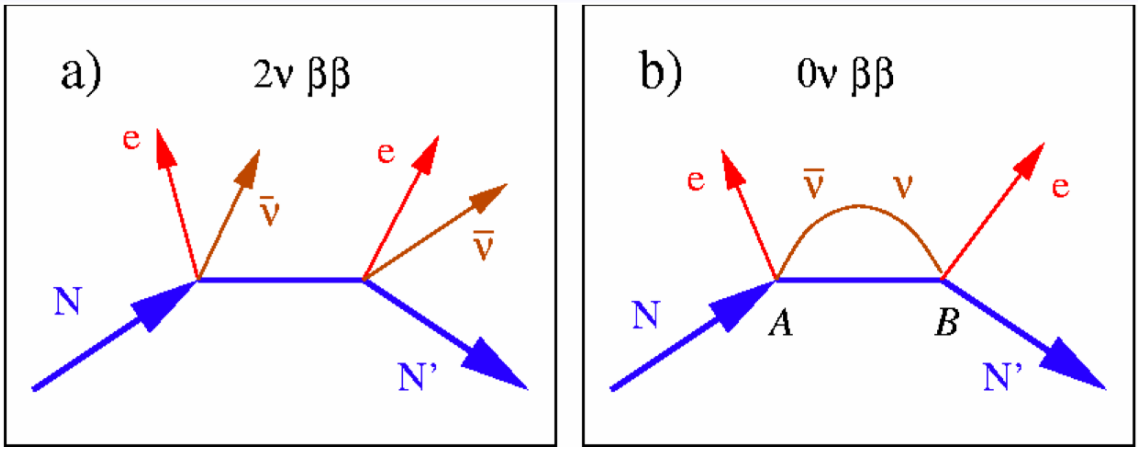
- Occurs in ^{48}Ca, ^{76}Ge, ^{82}Se, ^{130}Te, ^{136}Xe (theorized), ...
- Neutrinoless mode
  - Lepton number not conserved
  - $\nu = \bar{\nu}$
  - $m_\nu \neq 0$
- Rate tells majorana mass:

$$\langle m_\nu \rangle^2 \propto \left(T_{1/2}^{0\nu\beta\beta} \right)^{-1}$$

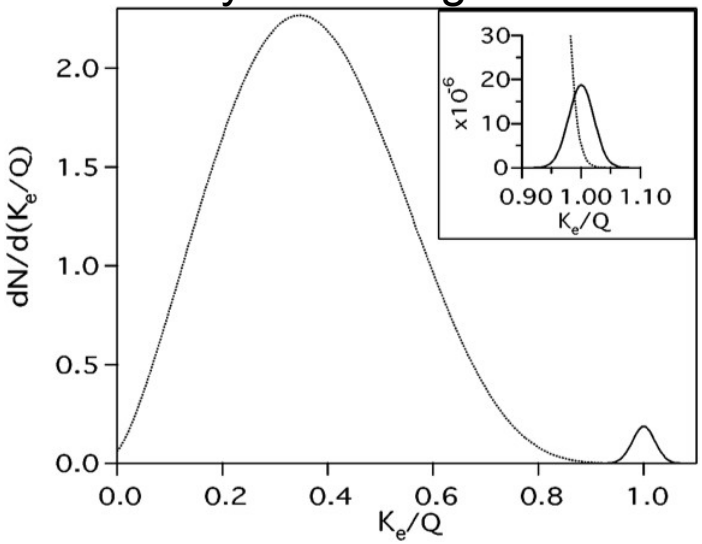
$$\langle m_\nu \rangle = \sum_{i=1}^{3} |U_{e,i}|^2 m_i \epsilon_i$$

±1 if CP conserved

neutrino mixing matrix



Feynman diagrams



Double beta decay spectrum for 5% energy resolution

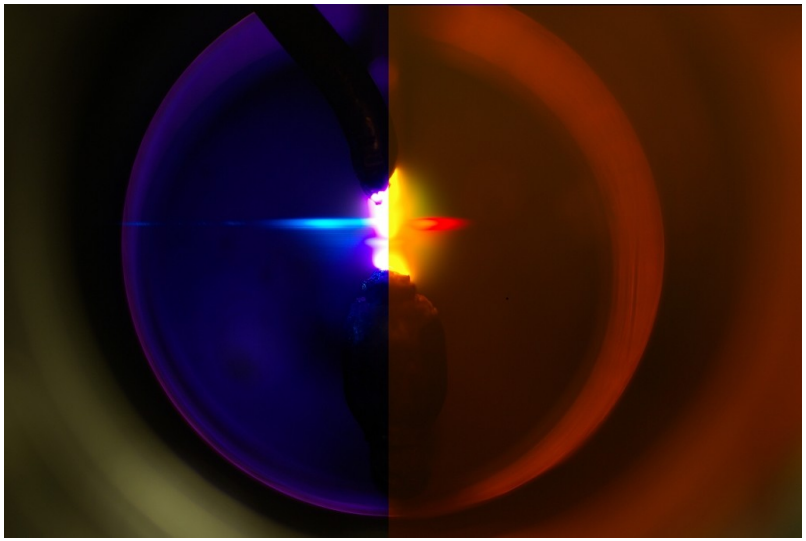
from Elliott and Vogel, Ann.Rev.Nucl.Part.Sci. **52** *(2002) 115*

Enriched Xenon Observatory EXO for double beta decay

SLAC NATIONAL ACCELERATOR LABORATORY

Concept: Xenon

- Advantages:
  - High Q (2.48 MeV)
  - Easily enriched (gas centrifuge)
  - Reusable
  - No long-lived, cosmically activated isotopes
  - Can be used as its own detector
  - Tag barium daughter nucleus to minimize backgrounds
  - Purify *in situ*
- Disadvantages:
  - Comparatively poor energy resolution (~ 1%) vs. solid state (~ 0.1 %)



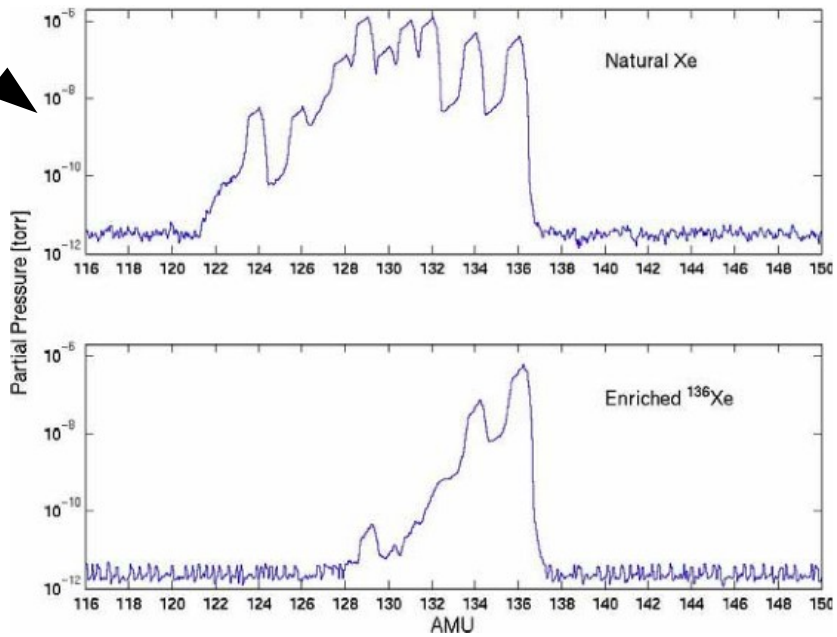
Barium ions fluorescing in a trap

Enriched Xenon Observatory EXO for double beta decay

SLAC NATIONAL ACCELERATOR LABORATORY

EXO-200: Sketch

- Prototype using 200 kg of xenon enriched in isotope 136
- Time projection chamber using liquid xenon
  - Detect ionization and scintillation due in order to improve energy resolution with anticorrelation
- Expected energy resolution ~ 1.6 % @ $Q_{\beta\beta}$ [1]
- No barium tagging



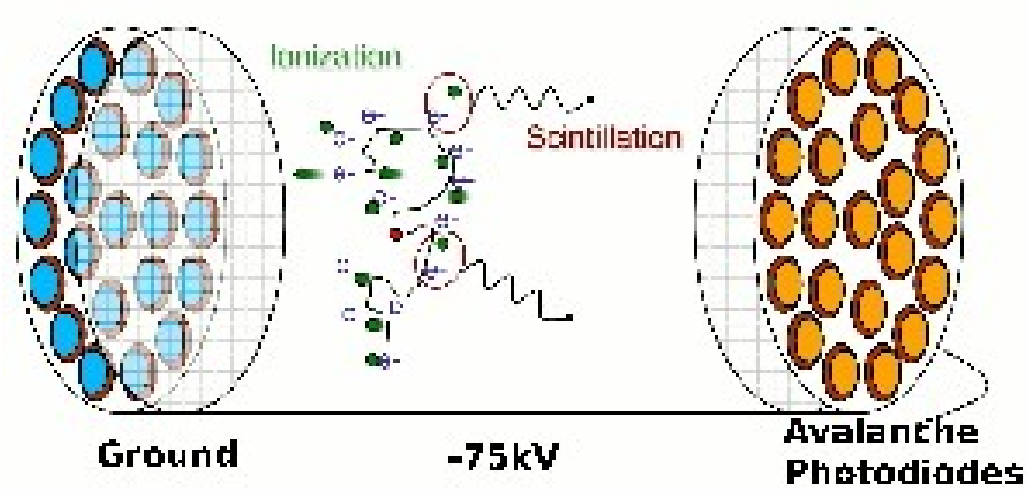
RGA scan showing enrichment

[1]E. Conti, *et. al.*, Phys. Rev. B: **68** (2003) 054201
[2]Rodin, *et. al.*, Nucl. Phys. A **793** (2007) 213-215
[3]Caurier, *et. al.*, Phys. Rev. Lett. **100** (2008) 052503

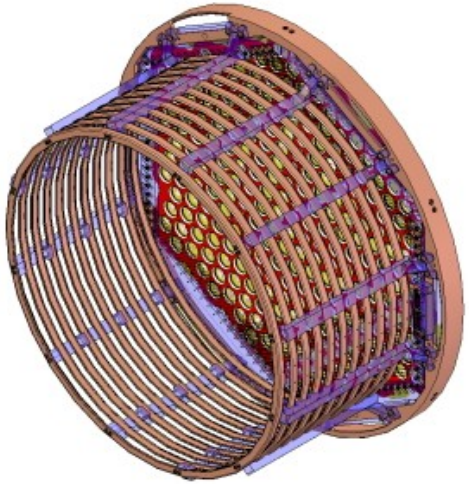
Case	Mass (ton)	Eff. (%)	Run Time (yr)	σ_E/E @ 2.5MeV (%)	Radioactive Background (events)	$T_{1/2}^{0\nu}$ (yr, 90%CL)	Majorana mass (meV) QRPA	(NSM)
Prototype	0.2	70	2	1.6*	40	$6.4*10^{25}$	133[2]	(186)[3]

EXO-200: Time Projection Chamber

- Monolithic: liquid xenon is both detector and medium
- Wire grid gives 2D location for event
- Solid state Avalanche PhotoDiodes (APDs) detect scintillation light, allowing 3D reconstruction
- Connects to outside world through thin (~ 50 µm) flex cables
- Copper, phosphor bronze, acrylic, teflon construction



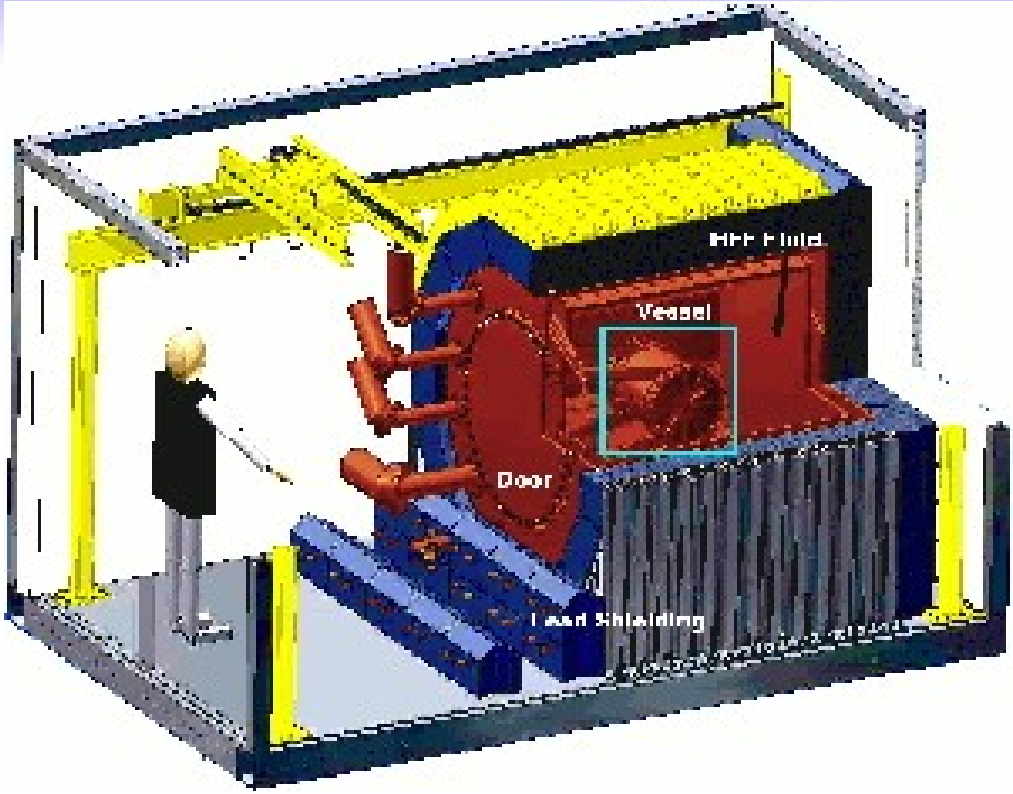
Conceptual illustration of TPC



Inside of TPC

EXO-200: Vessel and Cryostat

- Cryostat and vessel constructed of ultra pure copper
- Inner cryostat filled with HFE-7000
  - Refrigerant and shielding
- Real-time control system keeps xenon pressure inside vessel within 15 torr of HFE pressure
  - Thin walls minimize radioactivity
- Long arms support vessel and connect TPC to readout electronics



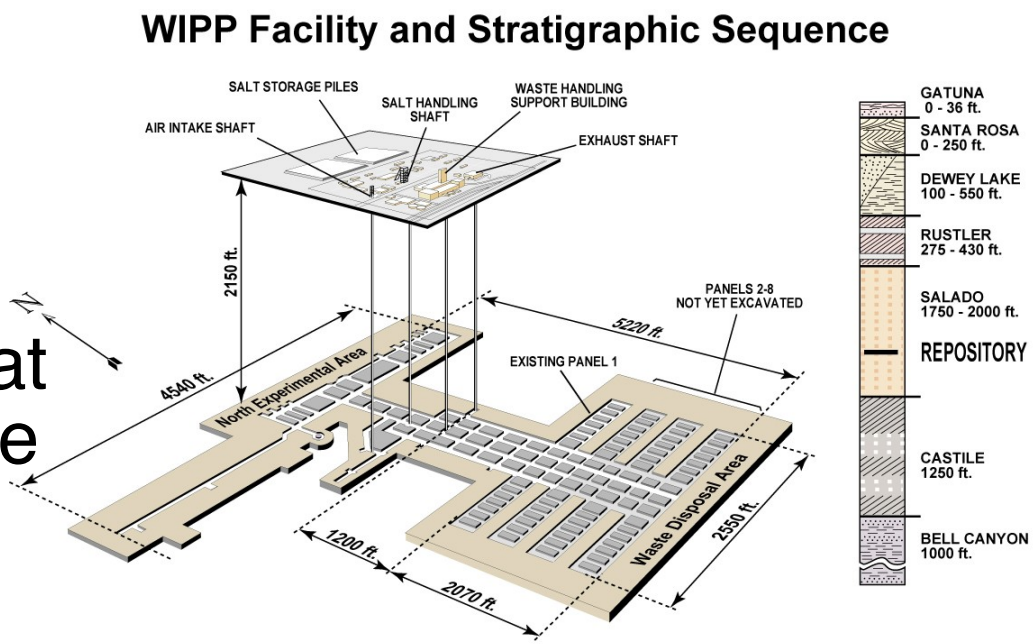
View of cryostat and vessel in clean room

Extensive care to measure and minimize radioactivity for all materials used

D. S. Leonard, *et. al.*, N.I.M. A, **531** (2008) 490

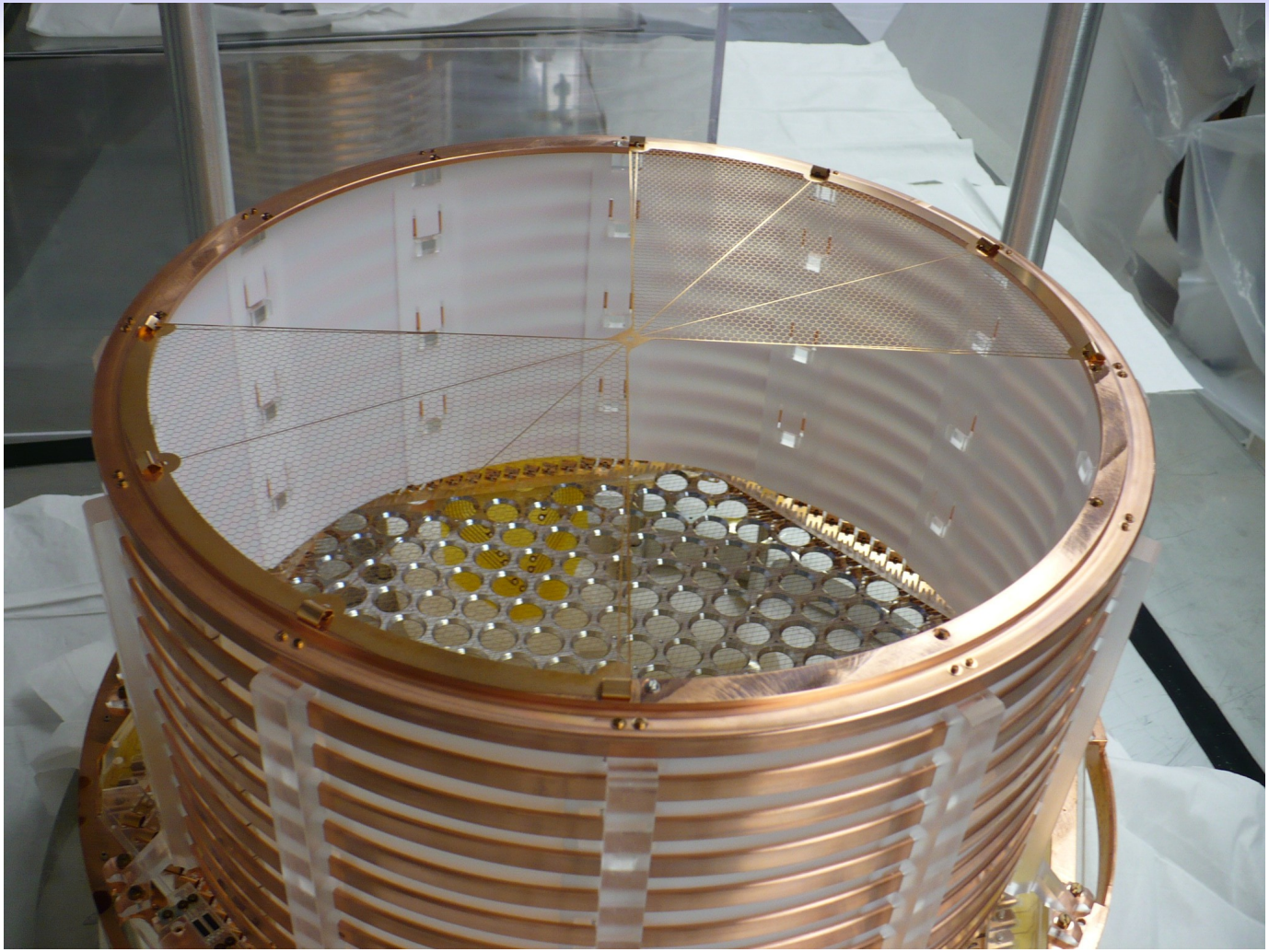
EXO-200: WIPP

- The Waste Isolation Pilot Plant is a DoE facility located near Carlsbad, NM
- Mission is to safely and permanently dispose of US nuclear waste
- Salt mine
- Also holds our experiment at the opposite end from waste
- 2000 mwe protects from cosmic rays



Map of WIPP underground. Roughly 2000 ft underground.

Status: TPC 1



Half chamber with field rings, cathode, teflon reflectors installed. Wire grid and APD plane (no APDs) at bottom.

Enriched Xenon Observatory EXO for double beta decay

SLAC NATIONAL ACCELERATOR LABORATORY

Status: TPC 2

Cables being potted into their flanges. A very delicate operation.

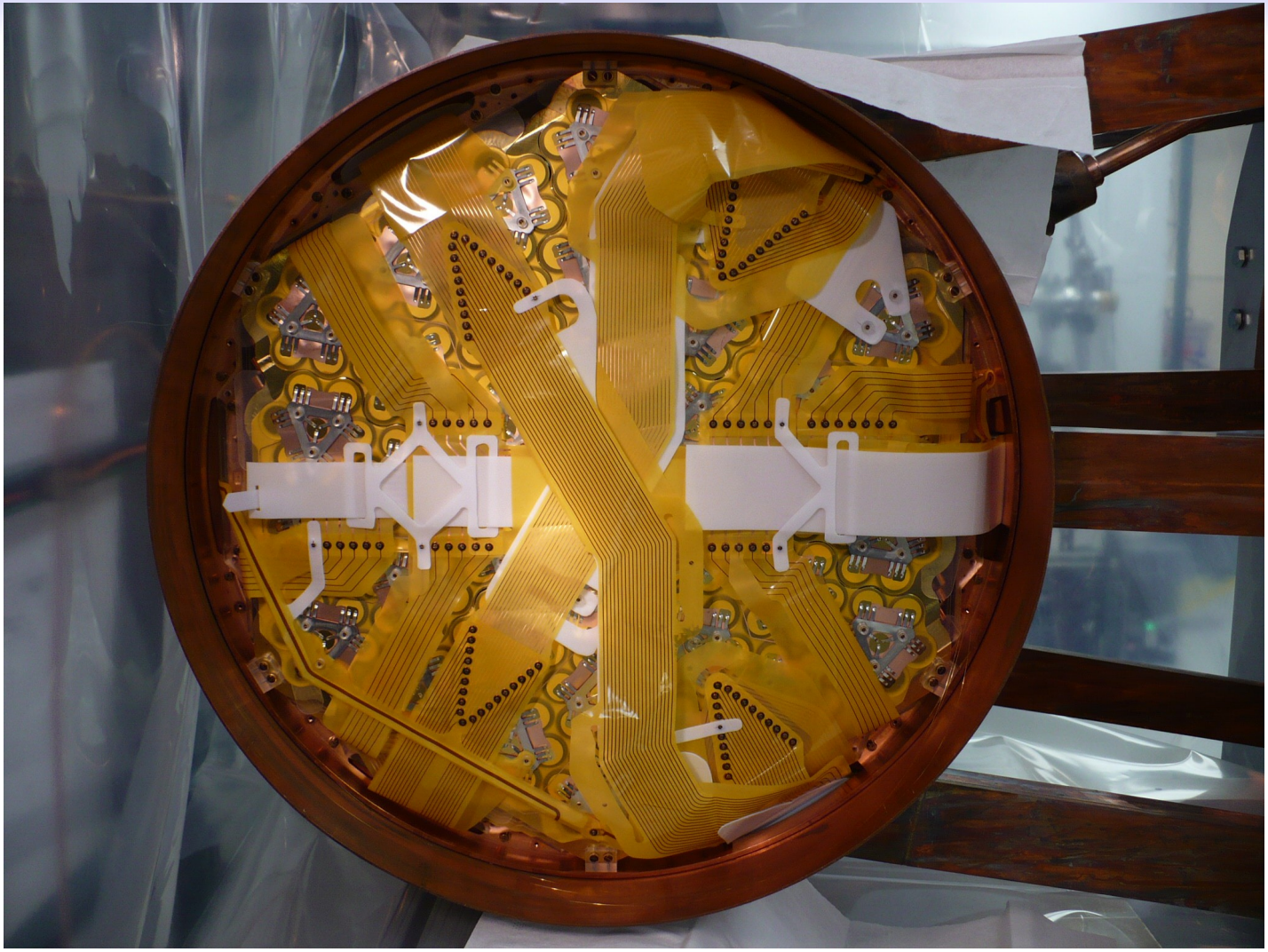
Enriched Xenon Observatory EXO for double beta decay

SLAC NATIONAL ACCELERATOR LABORATORY

Status: TPC 3

Inserting the APDs

Status: TPC 4



TPC wired and inserted into vessel.

Enriched Xenon Observatory EXO for double beta decay

SLAC NATIONAL ACCELERATOR LABORATORY

Status: TPC 5

- TPC undergoing final electrical testing prior to transport to WIPP
- Probably will reach WIPP in June or July

The TPC team pose after finally getting it assembled

Enriched Xenon Observatory EXO for double beta decay

SLAC NATIONAL ACCELERATOR LABORATORY

Status: WIPP 1

Clean rooms, gas tent, and dewar container (for HFE), viewed facing north

Clean rooms and HVAC system, viewed facing south

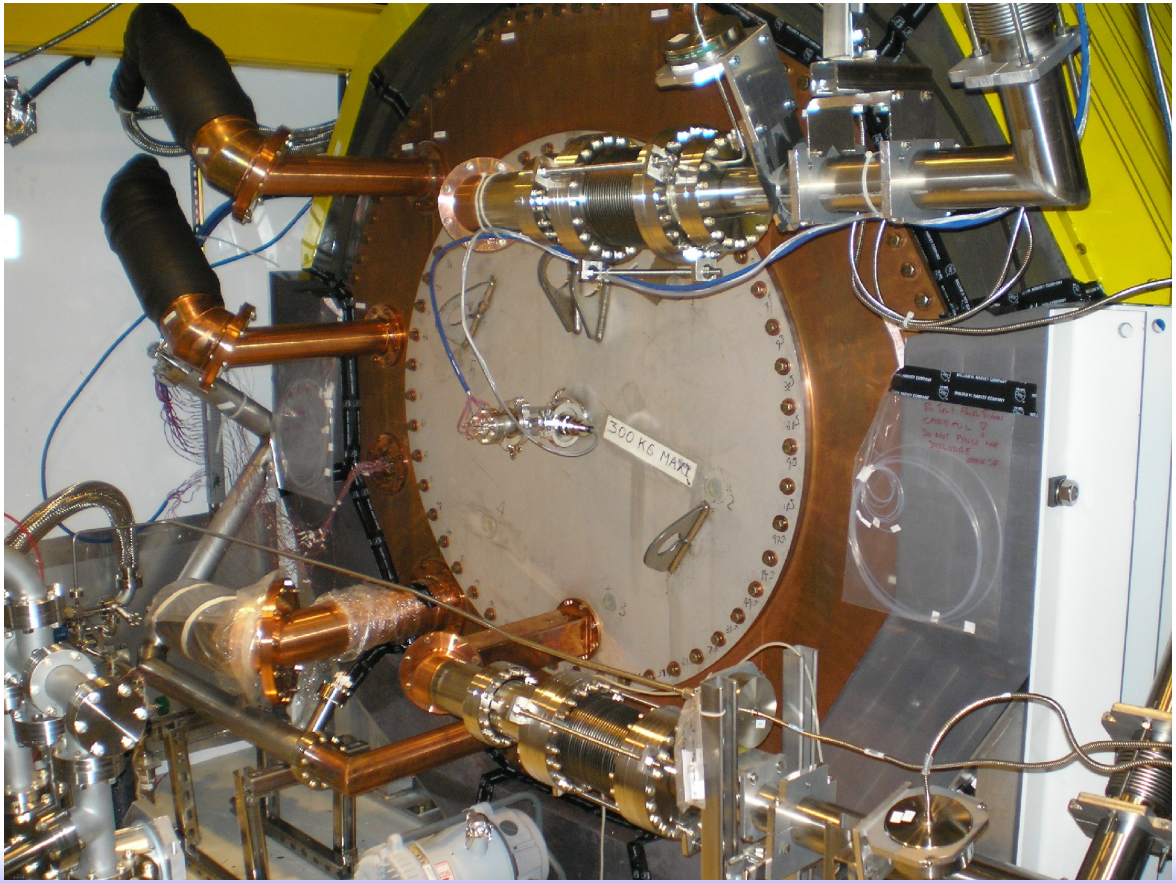
Enriched Xenon Observatory EXO for double beta decay

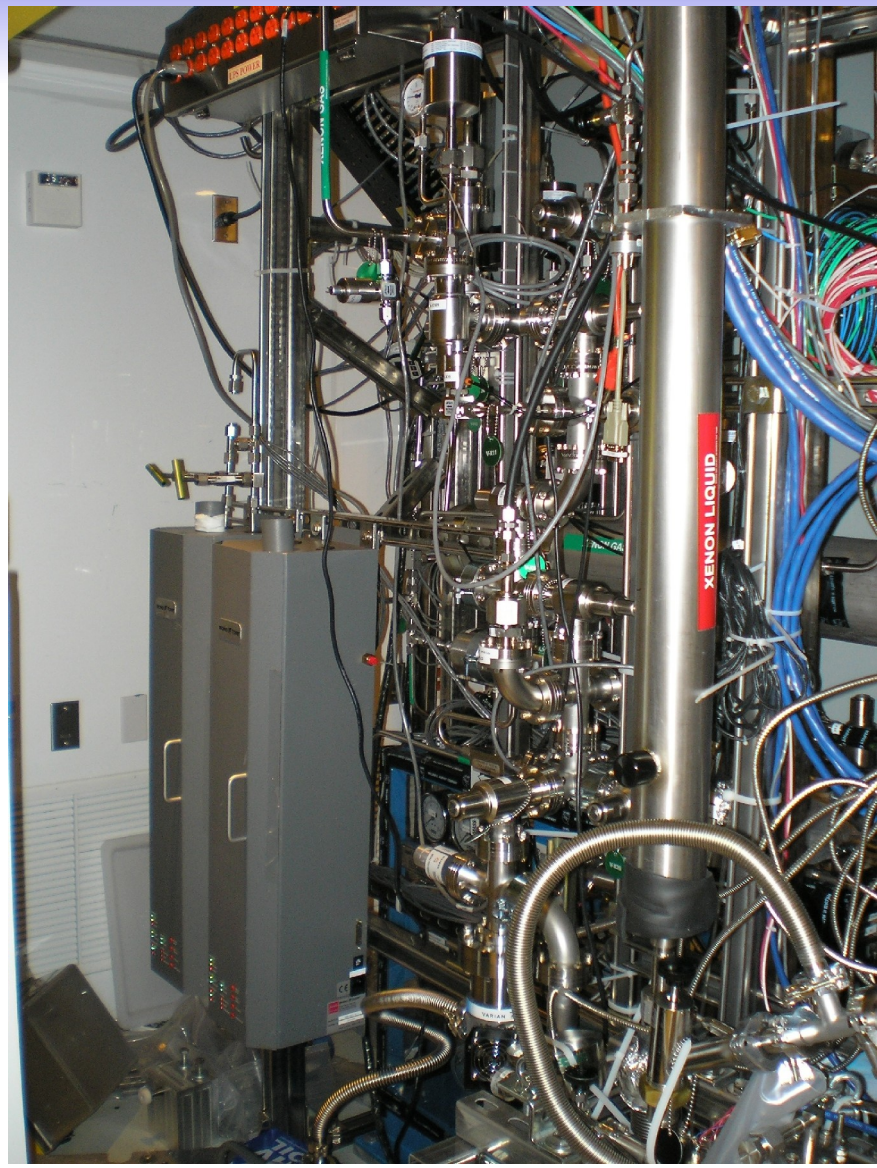
SLAC NATIONAL ACCELERATOR LABORATORY

Status: WIPP 2

Xenon plumbing

Cryostat with temporary door





Enriched Xenon Observatory EXO for double beta decay

SLAC NATIONAL ACCELERATOR LABORATORY

Status: WIPP 3

- Currently tweaking systems and preparing for chamber arrival
- Veto panel installation "soon"
- Technical run with natural xenon in late summer or fall 2009
- Begin data taking before end of 2009

Ribbon cutting ceremony at WIPP

Enriched Xenon Observatory EXO for double beta decay

SLAC NATIONAL ACCELERATOR LABORATORY

EXO Collaboration

K.Barry, E.Niner, A.Piepke
Physics Dept., U. of Alabama, Tuscaloosa AL, USA
P.Vogel Physics Dept., Caltech, Pasadena CA, USA
A.Bellerive, M.Bowcock, M.Dixit, K.Graham, 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 U., Fort Collins CO, USA
M.Moe Physics Dept., UC Irvine, Irvine CA, USA
D.Akimov, I.Alexandrov, A.Burenkov, M.Danilov, A.Dolgolenko, A.Karelin, A.Kovalenko, A.Kuchenkov, V.Stekhanov, O.Zeldovich
ITEP Moscow, Russia
B.Aharmin, K.Donato, J.Farine, D.Hallman, U.Wichoski
Laurentian U., Canada
H.Breuer, C.Hall, L.Kaufman, D.Leonard, S.Slutsky, Y-R.Yen
U. of Maryland, College Park MD, USA
K.Kumar, A.Pocar U. of Massachusetts, Amherst, Amherst MA, USA
M.Auger, G.Giroux, R.Gornea, F.Juget, G.Lutter, J-L.Vuilleumier
Laboratory for High Energy Physics, Bern, Switzerland
N.Ackerman, M.Breidenbach, R.Conley, W.Craddock, S.Herrin, J.Hodgson, D.Mackay, A.Odian, C.Prescott, P.Rowson, K.Skarpaas, J.Wodin, L.Yang, S.Zalog
SLAC, Menlo Park CA, USA
L.Bartoszek, R.Cooper, R.DeVoe, M.Dolinski, B.Flatt, G.Gratta, M.Green, F.LePort, M.Montero-Diez, R.Neilson, A.Reimer-Muller, A.Rivas, K.O'Sullivan, K.Twelker
Physics Dept., Stanford University, Stanford CA USA

Enriched Xenon Observatory EXO for double beta decay

SLAC NATIONAL ACCELERATOR LABORATORY