Deep Underground Laboratories in the USA

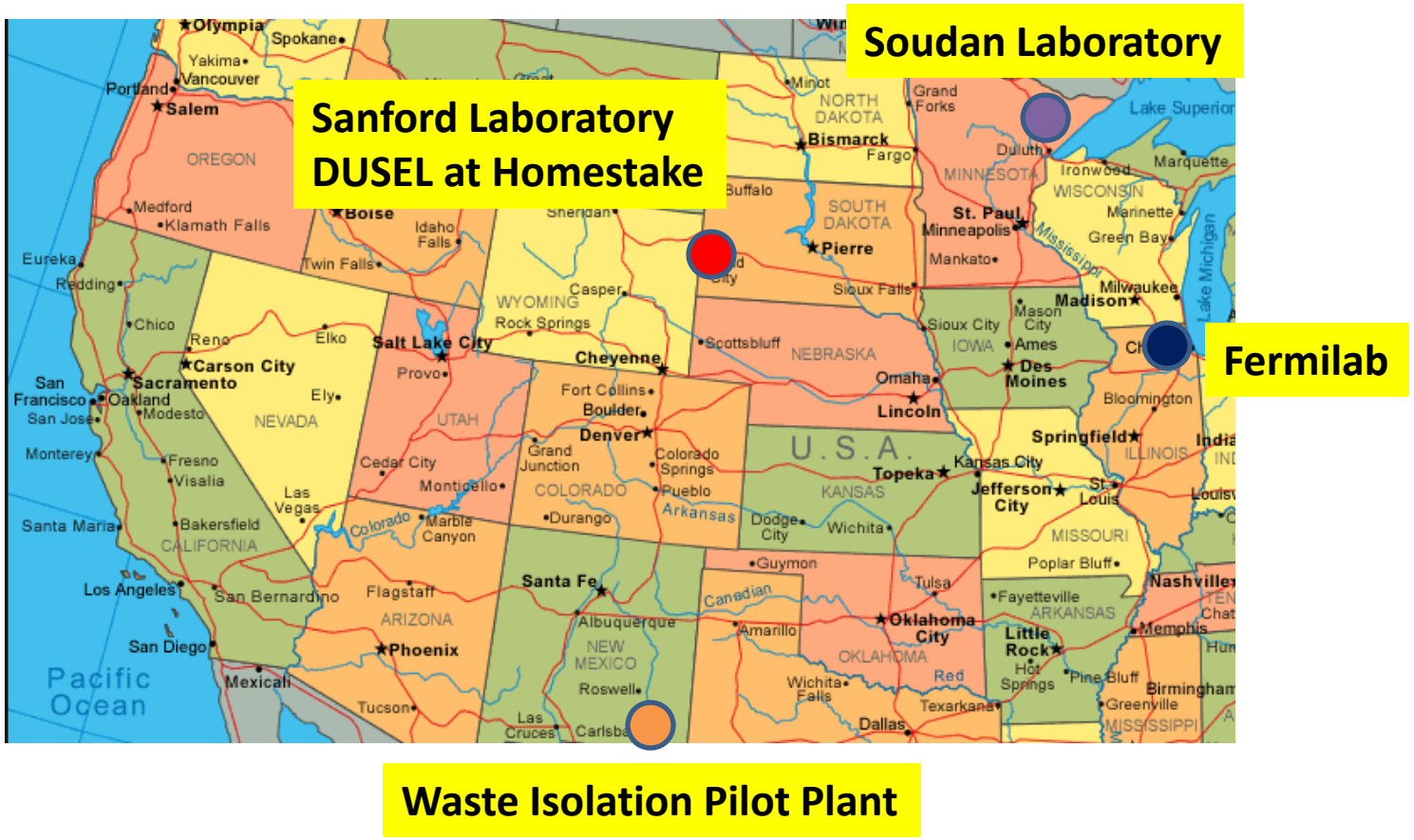
M. G. D. Gilchriese
Lawrence Berkeley National Laboratory
Aspera Workshop
June 30 – July 2, 2011

Overview

- High level view
- Existing laboratories
  - Soudan Underground Laboratory
  - Waste Isolation Pilot Plant
- Under construction
  - Sanford Underground Laboratory at Homestake
- Planning
  - Deep Underground Science and Engineering Laboratory at Homestake
- Outlook

Locations in This Talk

- US sites described in this talk are sites with shaft access*



*Note Kimbalton Underground Research Facility has drive in access – see http://www.physics.unc.edu/research/nuclear/particle_astro/kimballton.php

Connections with Biology and Geosciences

- All of the existing and planned deep underground laboratories in the U.S. have activities related to biology and/or some aspects of geosciences
- Not covered here but very diverse set of experiments underway or planned.

2090 mwe. Operated by the University of Minnesota Located in an iron mine which is now a Minnesota State Park

HPGe Screening *(SOLO)*

Lift from Surface

Visitors' gallery

MINOS

Cu Electroforming

offices

CDMS Exp.

CDMS office

Shielded hall

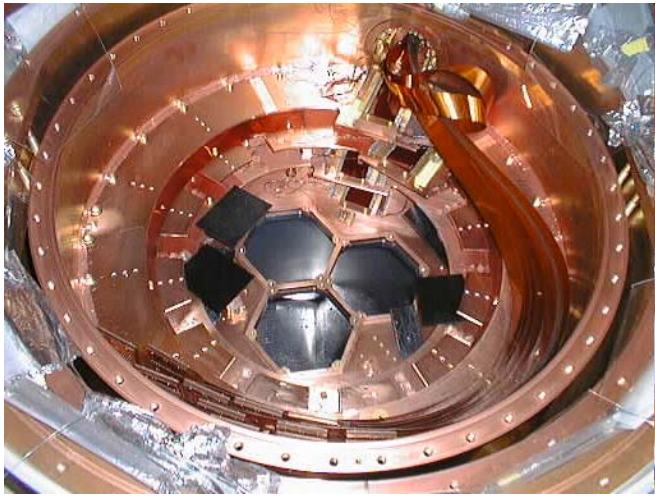
Fully lined with an active muon veto.

CoGeNT,
Medtronics
Cosmo-n Detector
XIA alpha, BetaCage
Gopher HPGe

Historic Mine Tour (rail cars)

Soudan Status(I)

- Operational again after fire in shaft, improvements planned
- The 5,500 ton MINOS Far Detector for long baseline neutrino oscillation studies using Fermilab ν beam operational
  - shutdown starting March 2012 for upgrades for Nova (beam)
  - MINOS+ proposal to run starting 2013 concurrently with Nova.
- The Cryogenic Dark Matter Search (Super CDMS) experiment to search for dark matter – see other talk in this Workshop

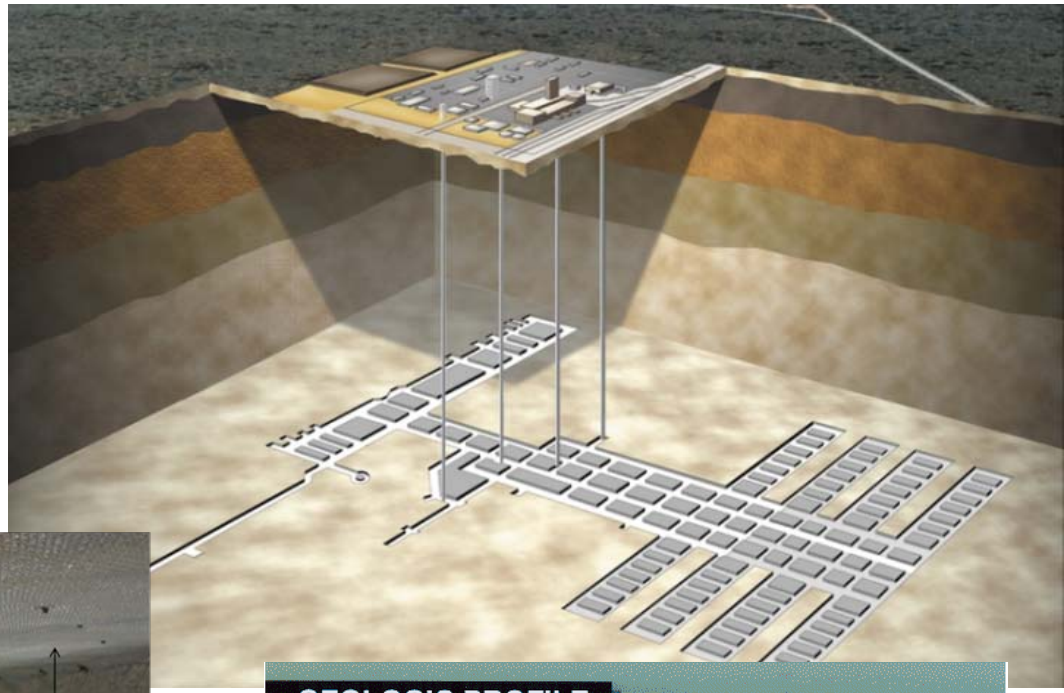


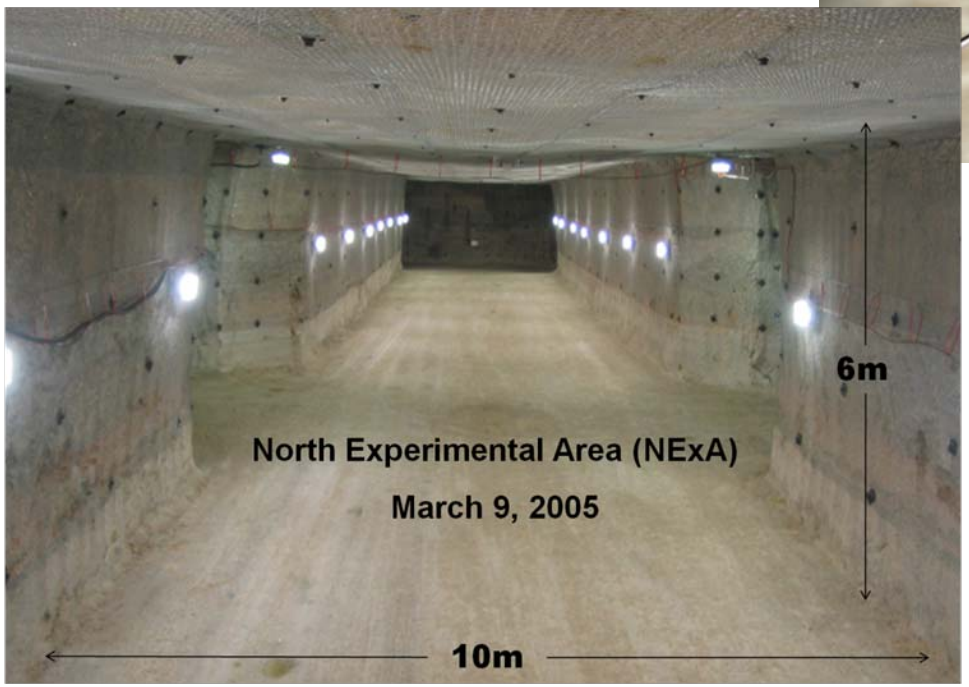
Soudan Status(II)

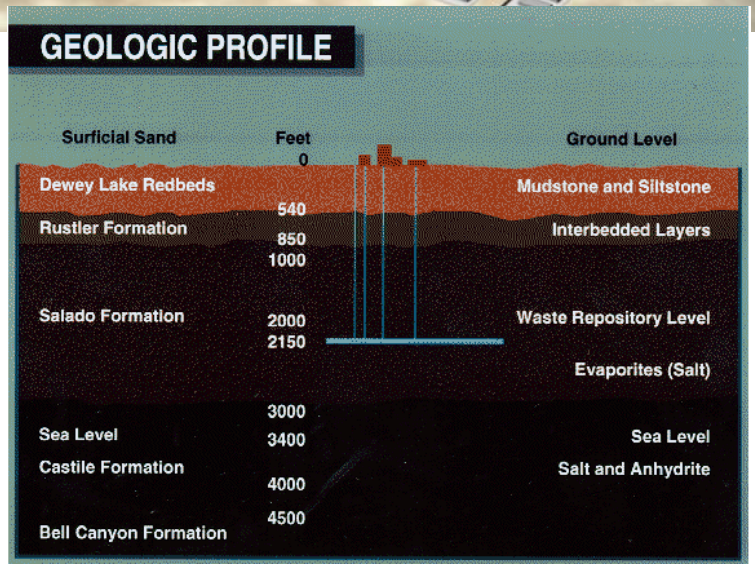
- LBCF—Low Background Counting Facility. The LBCF is an a volume of approximately 15 m by 15 m by 25 m in length, surrounded by a proportional tube active shield and housing user facilities including:
  - A Neutron Multiplicity Meter (NMM) operated by University of California, Santa Barbara
  - The CoGeNT P-type Germanium Dark Matter Detector
  - GOPHER, a high purity germanium detector for materials screening
  - XIA, a commercially designed proportional alpha counter
- Other activities related to screening or low background materials.

Waste Isolation Pilot Plant (WIPP)

- **Primary mission is rad-waste storage**
- **About same depth as Soudan**
- **Very low background radiation**
- **Existing infrastructure**
- **Longevity (>35 years)**
- **Big hoists**
- **Dry but salt creeps**

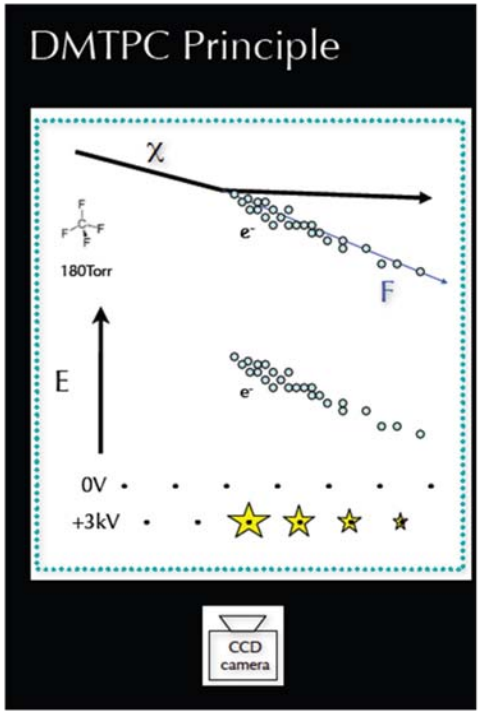




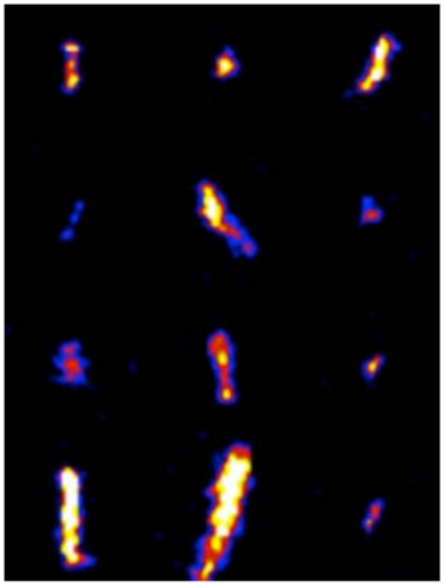


Recent Science at WIPP

- 2004: The MAJORANA Project's Segmented Enriched Germanium Assembly (SEGA) and Multiple Element Germanium Array (MEGA) experiments began in the WIPP underground.
- 2006: An Argonne counting chamber is refurbished and placed in the WIPP underground.
- 2007: The first two clean room modules for the Enriched Xenon Observatory (EXO) project were successfully placed in the WIPP site.
- 2008: In examining fluid inclusions in the salt and solid halite crystals of the WIPP underground, scientists found abundant cellulose microfibers, estimated to be 250 million years old.
- 2009: Researchers begin an experiment in the WIPP underground designed to examine the effects of low background radiation on bacteria.
- 2010: The detector for the EXO project, called the Time Projection Chamber (TPC), is installed in January. The experiment itself begins in the fall of 2010.
- 2010: The Dark Matter Time Projection Chamber (DMTPC) is installed in the WIPP underground.

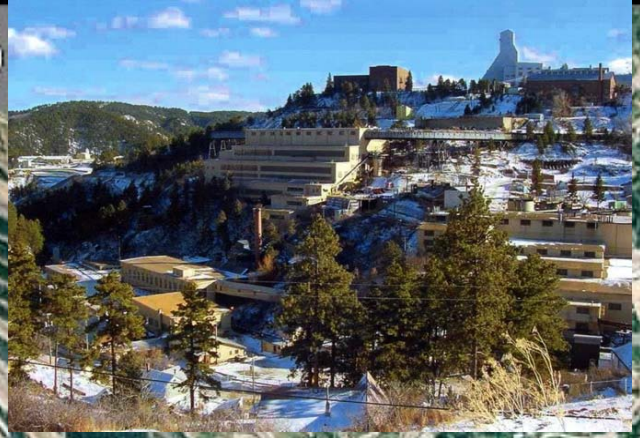


C, F Recoils (40 to 100 keV) from Cf-252 neutrons



Soudan and WIPP Plans

- Soudan
  - SuperCDMS through 2015
  - MINOS+, if approved, into ~ 2016
  - COGENT 4
  - Low background and R&D activities, studies for underground accelerator
  - Upgrades to access under consideration
- WIPP
  - EXO and DMTPC for next few years, R&D and low background measurements
  - Open to new ideas
- Future of underground physics at Soudan and WIPP coupled to future of new deep underground lab at Homestake in US



Waste Water Treatment

Open Cut

Yates Complex

Town of Lead

~1km

Sanford Underground Laboratory
And proposed site for Deep Underground Science and Engineering Laboratory (DUSEL) at Homestake

Ross Complex

Kirk Canyon Adit

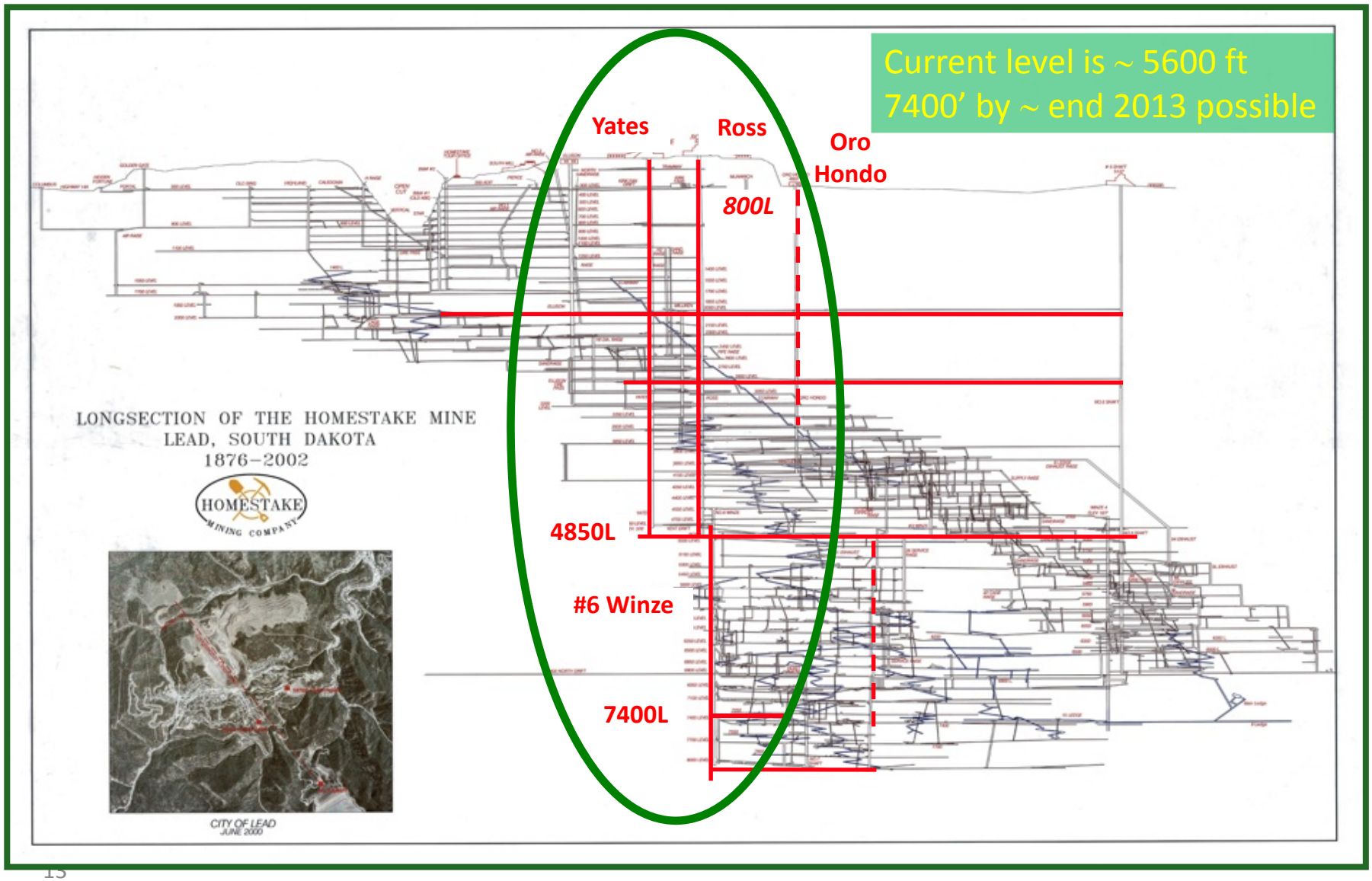
Homestake Site

History

2000	Mine closure announced
	DUSEL concept
2002	Barrick Gold buys Homestake
	Davis Nobel Prize
2003	Pumps off, water starts to rise
2004	South Dakota Science and Technology Authority (SDSTA) formed, funded by State
	Multiple DUSEL sites in US proposed
2005	Homestake one of two sites
	Agree to develop 4850' level by South Dakota
	Solicit LoIs for experiments
2006	Barrick donates site to SDSTA
	DUSEL Conceptual Design done
2007	National Science Foundation selects Homestake
2008	Water pumping starts in March

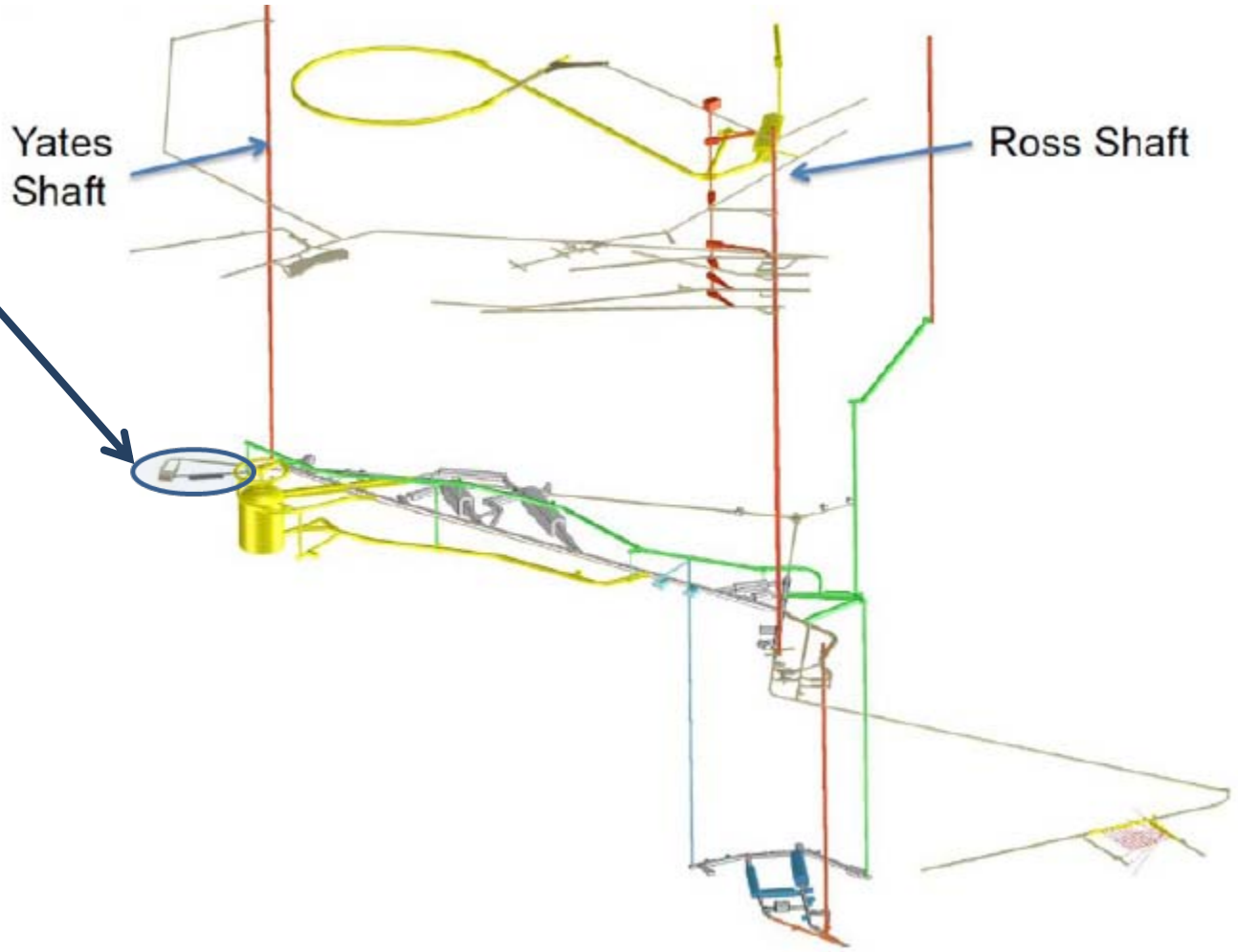
- Since 2008, two principal activities have been underway
- Create Sanford Underground Laboratory
  - Large Underground Xenon(LUX) dark matter experiment
  - MAJORANA DEMONSTRATOR $0\nu\beta\beta$
  - Low background counting
  - R&D areas
- DUSEL design
  - Preliminary Design Report, now completed.

Homestake Cross Section

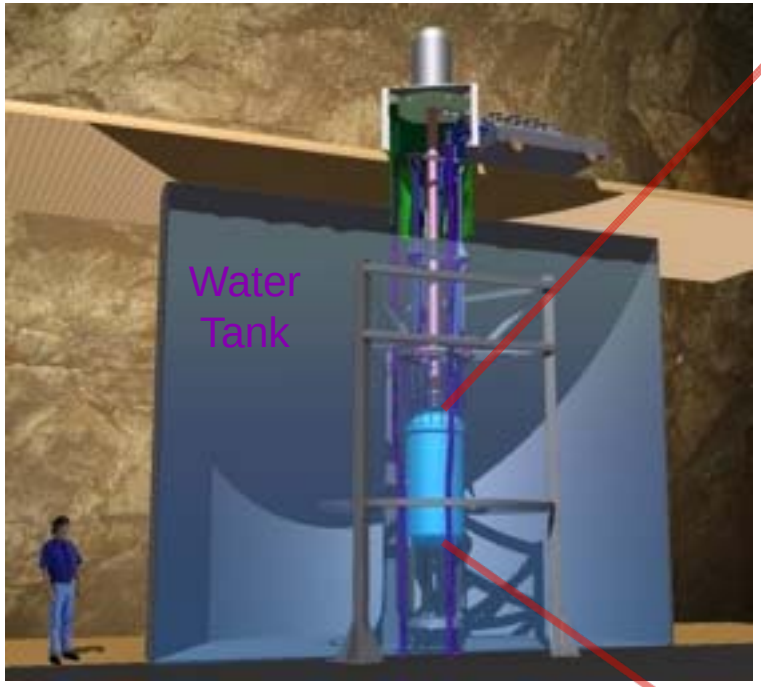


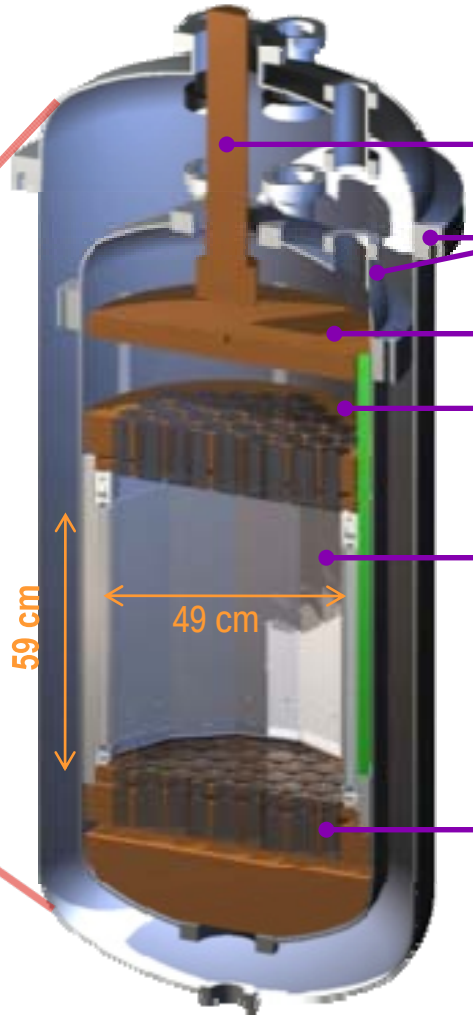
Sanford Lab/DUSEL at Homestake

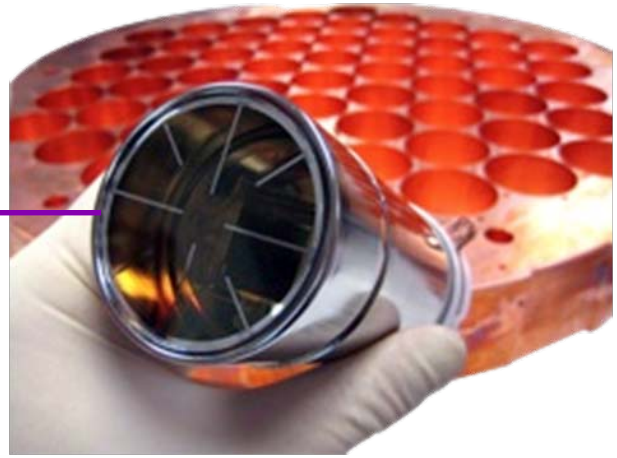
1. Sanford Lab construction and status
2. DUSEL preliminary design report
3. Alternatives under study
4. Status



The LUX Detector





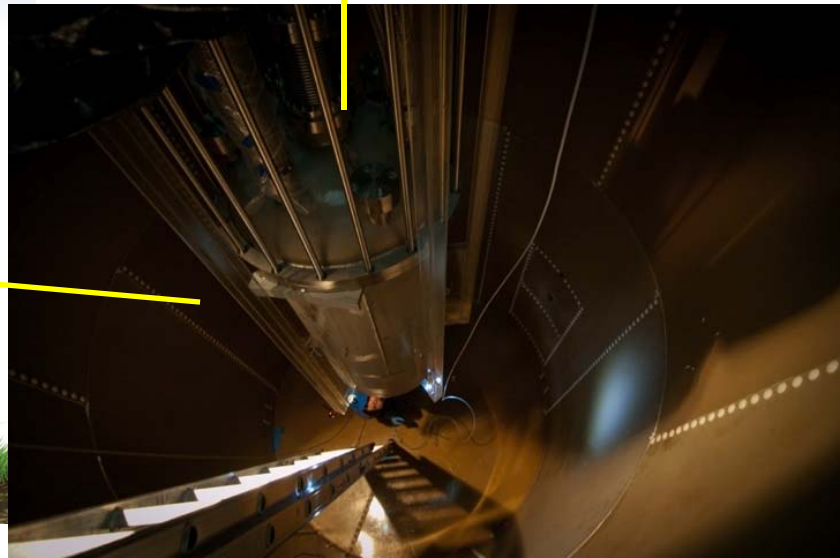


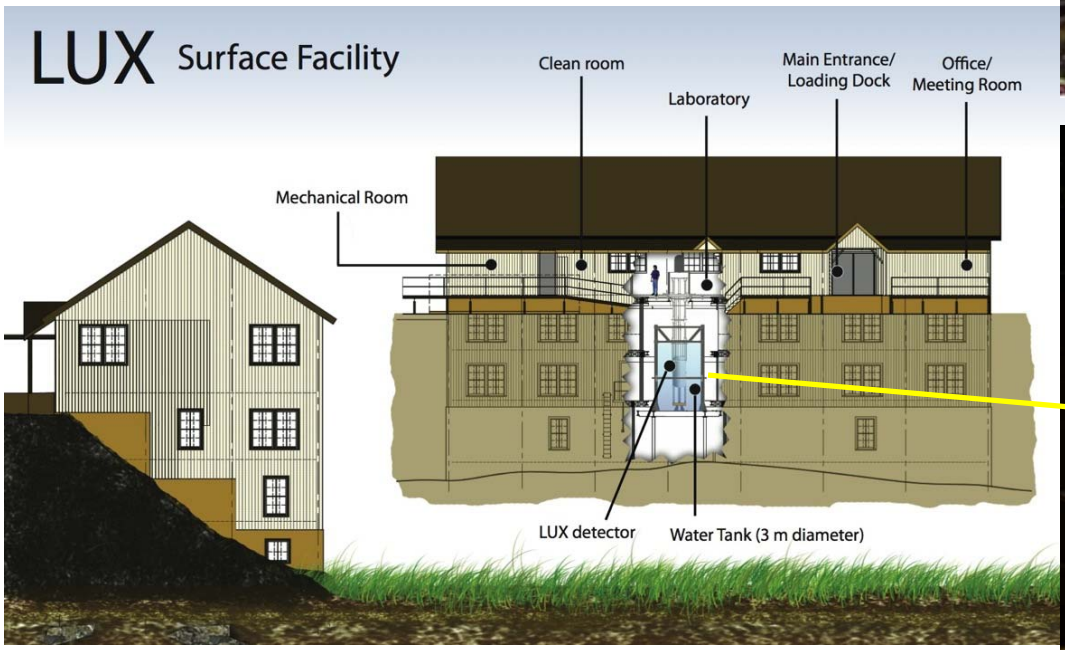
2” Hamamatsu R8778
Photomultiplier Tubes (PMTs)

- 350 kg LXe detector
- 122 PMTs (2” round)
- Low-background Ti cryostat
- PTFE reflector cage
- Thermosyphon used for cooling (>1 kW)

LUX at Sanford Lab

- Assembly and operation in surface building at Sanford Lab.
- Operate prior to underground installation.

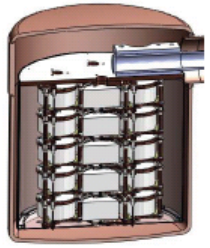


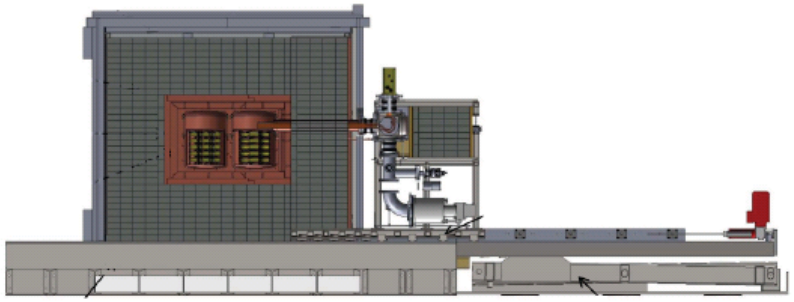


MAJORANA DEMONSTRATOR (MJD)

Goals: Demonstrate backgrounds low enough to justify building a tonne scale Ge experiment.
Establish feasibility to construct & field modular arrays of Ge detectors.

- Located underground 4850' Sanford Lab
- Background Goal in the 0νββ peak region of interest (4 keV at 2039 keV)
  4 counts/ROI/t/y (after analysis cuts)
  scales to 1 count/ROI/t/y for a 1-tonne experiment
- 40-kg of Ge detectors
  - Baseline is 20-kg of 86% enriched ^{76}Ge crystals and 20-kg of ^{nat}Ge
  - Up to 30-kg of 86% enriched ^{76}Ge crystals and 10-kg of ^{nat}Ge
  - Detector Technology: P-type, point-contact.
- 2 independent cryostats
  - ultra-clean, electroformed Cu
  - 20 kg of detectors per cryostat
  - naturally scalable
- Compact Shield
  - low-background passive Cu and Pb shield with active muon veto

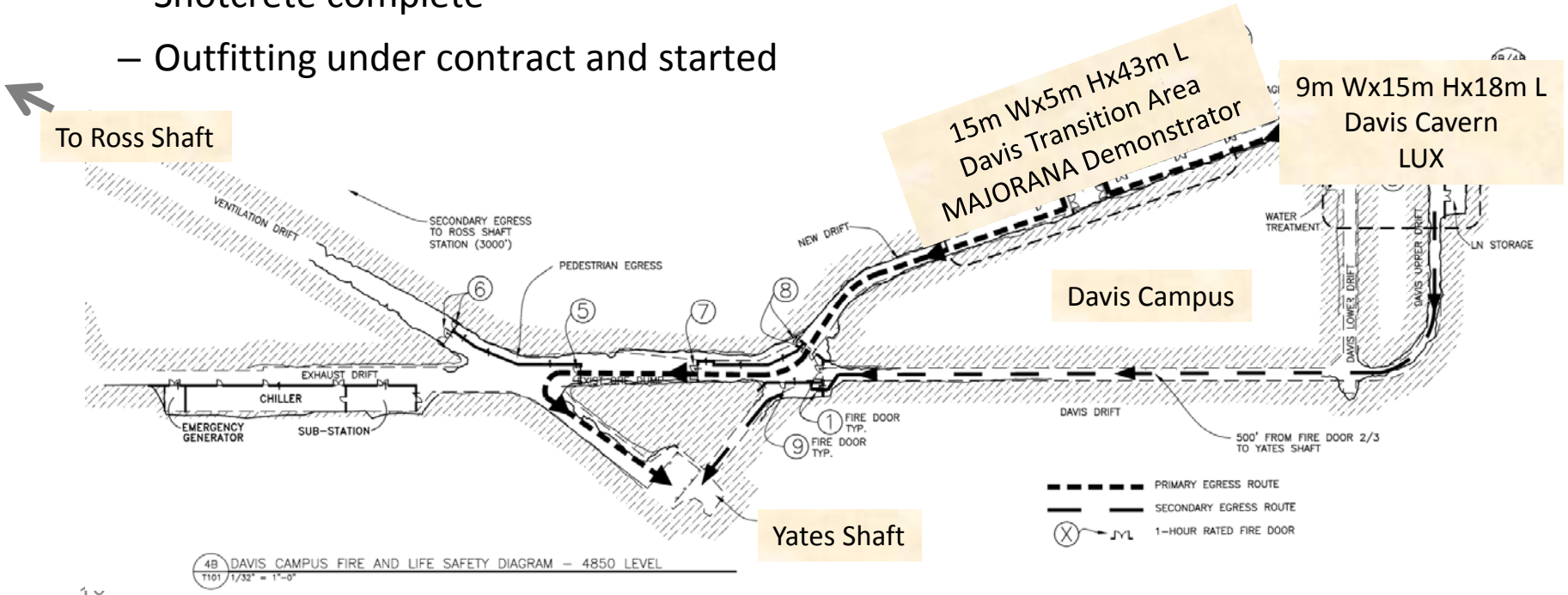




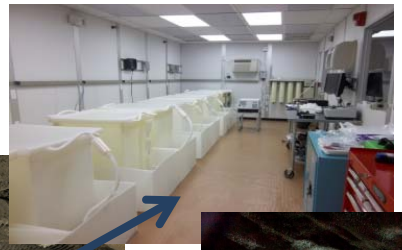
Sanford Lab Support of LUX and MJD

- LUX surface assembly
  - Underway
  - 1st cooldown complete
- Davis campus
  - Excavation complete
  - Shotcrete complete
  - Outfitting under contract and started

- Ross area for MJD
  - Temporary clean room for Cu electroforming complete. Underway.
- Beneficial occupancy March 2012
- <u>Experiments begin operation in 2012</u>

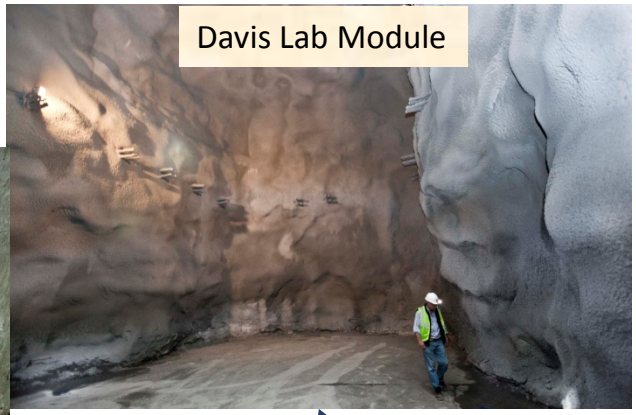


Davis Campus and Ross Clean Room



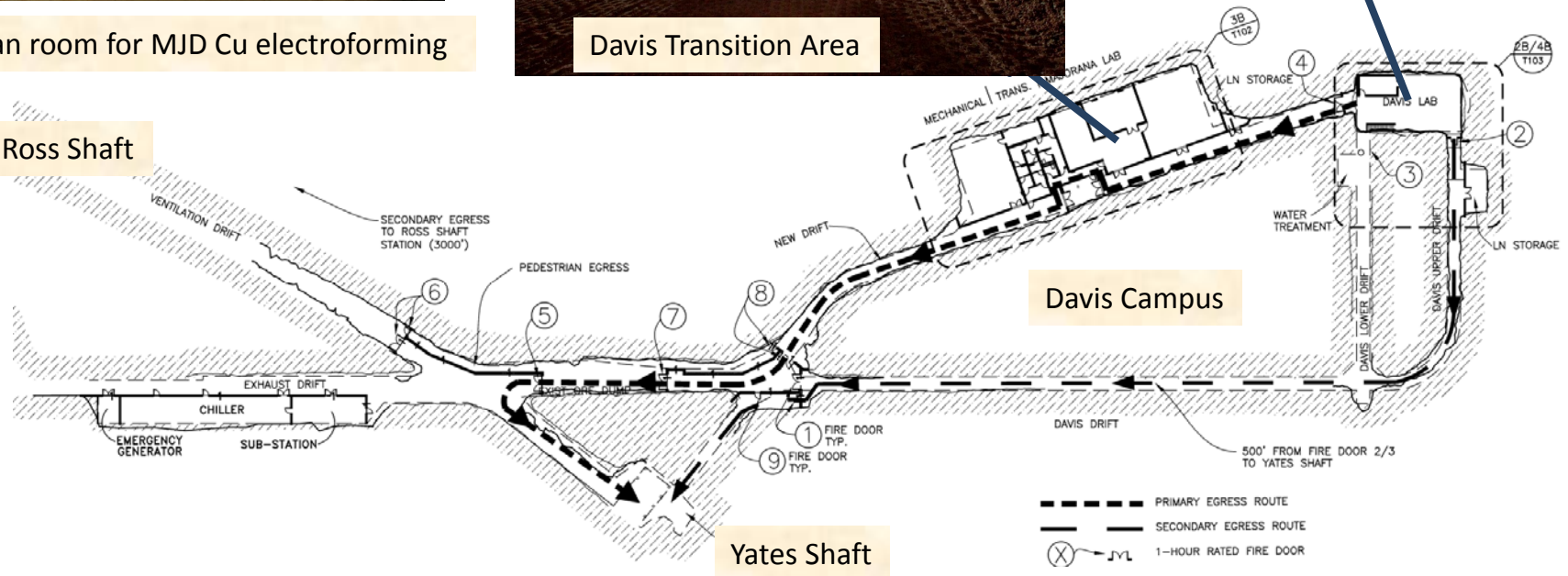
Ross clean room for MJD Cu electroforming

Davis Transition Area



Davis Lab Module

To Ross Shaft



Davis Campus

Yates Shaft

Sanford Lab Planning

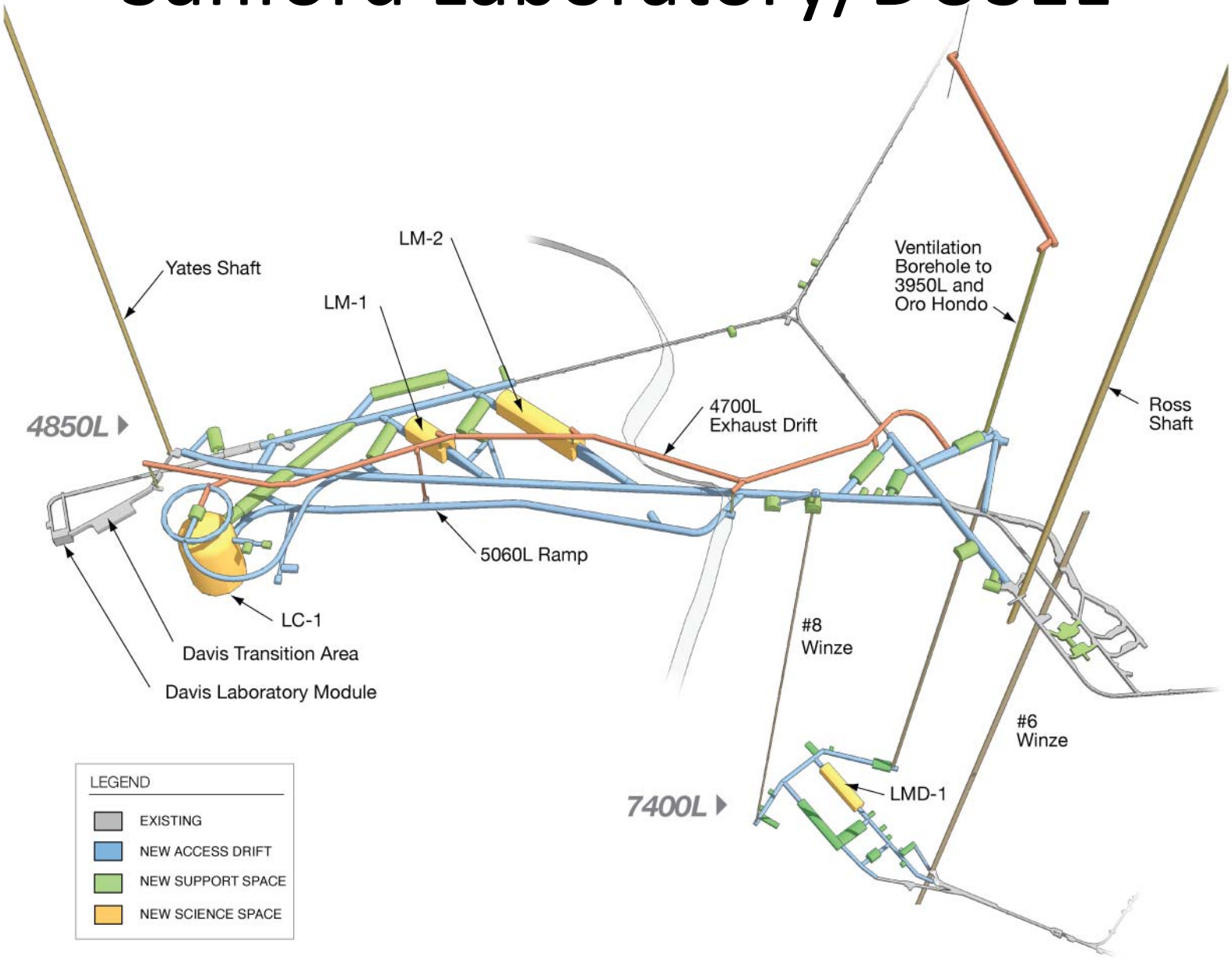
- Complete outfitting of Davis Lab Module(DLM) and Davis Transition Area(DTA) by March 2012
- Install LUX in 2012 and operate until ~2014
- Start installation of MAJORANA Demonstrator in 2012, followed by phased detector installation and operate until ~ 2017+
- Plan: Initiate process for G2 dark matter experiment in DLM by ~ 2012, install ~ 2015 and operate until ~ 2018+. Utilize water tank in place.
- Depends on future Homestake development

DUSEL Preliminary Design Report Completed

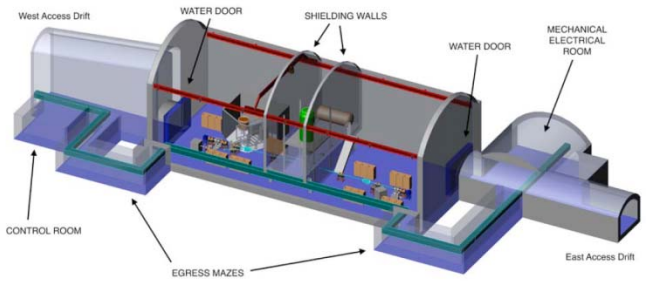
Vol. 0 – Executive Summary
Vol. 1 – Overview
Vol. 2 – Cost, Schedule
Vol. 3 – Science Program and Requirements
Vol. 4 – Education & Outreach
Vol. 5 – Facility Design
Vol. 6 – Safety
Vol. 7 – Project Plan
Vol. 8 – Project Management
Vol. 9 – Systems Engineering
Vol. 10 – Operations
Roughly 800 pages +
Appendices – 86 of them

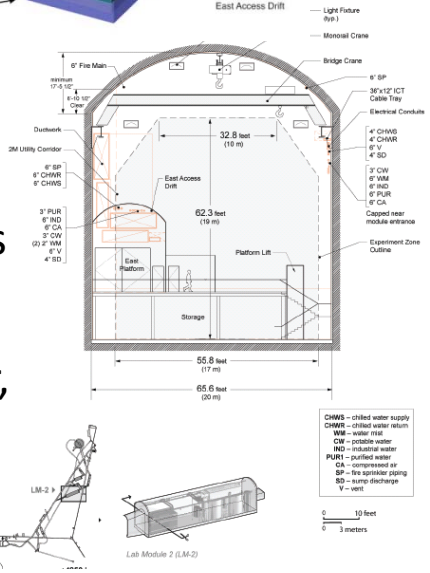
- Primary focus is on design of facility to host broad program of underground physics experiments: dark matter, $0\nu\beta\beta$, long-baseline neutrinos from Fermilab, underground accelerator for low cross-sections, low-background R&D,……
- Cost/schedule, feasibility (geotechnical)
- Extensive design work done by civil construction companies
- Describes facility for decades of research (including future expansion)
- Basis for future U.S. planning, even if all aspects of design not implemented.

Sanford Laboratory/DUSEL

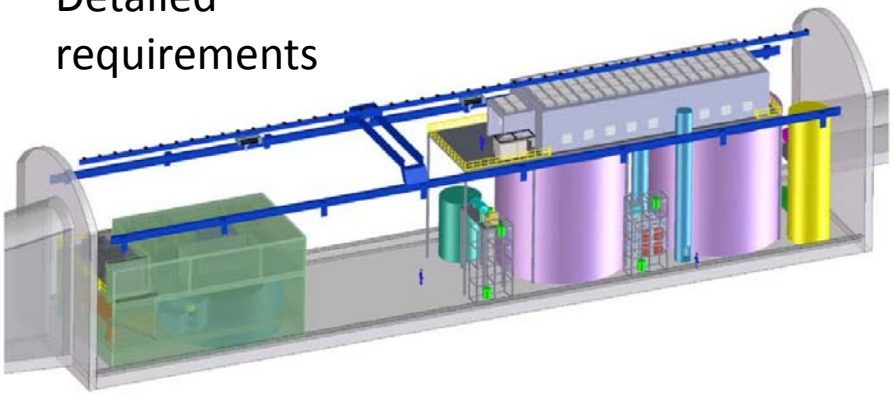


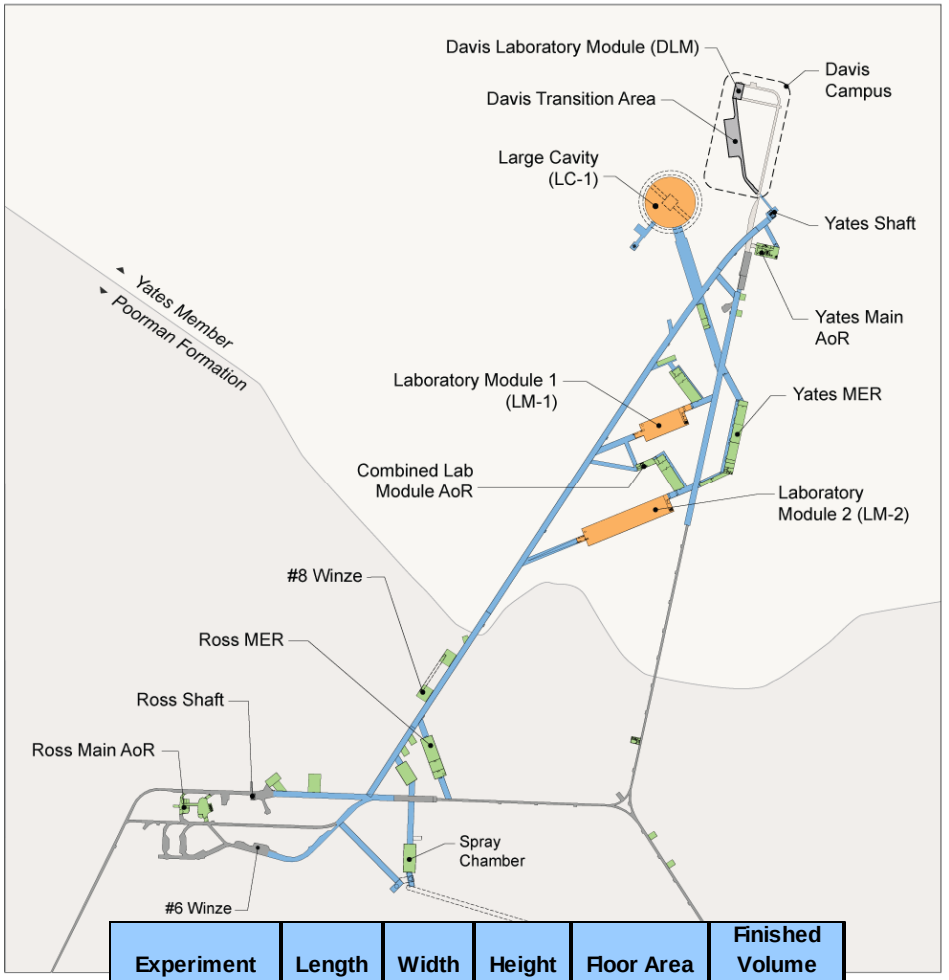
DUSEL 4850L





- Examples
- Generation 3 dark matter experiments
- Potentially $0\nu\beta\beta$
- Nuclear accelerator, isolated (in LM-1)
- Advanced LB R&D
- Detailed requirements

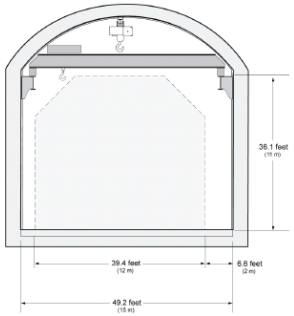


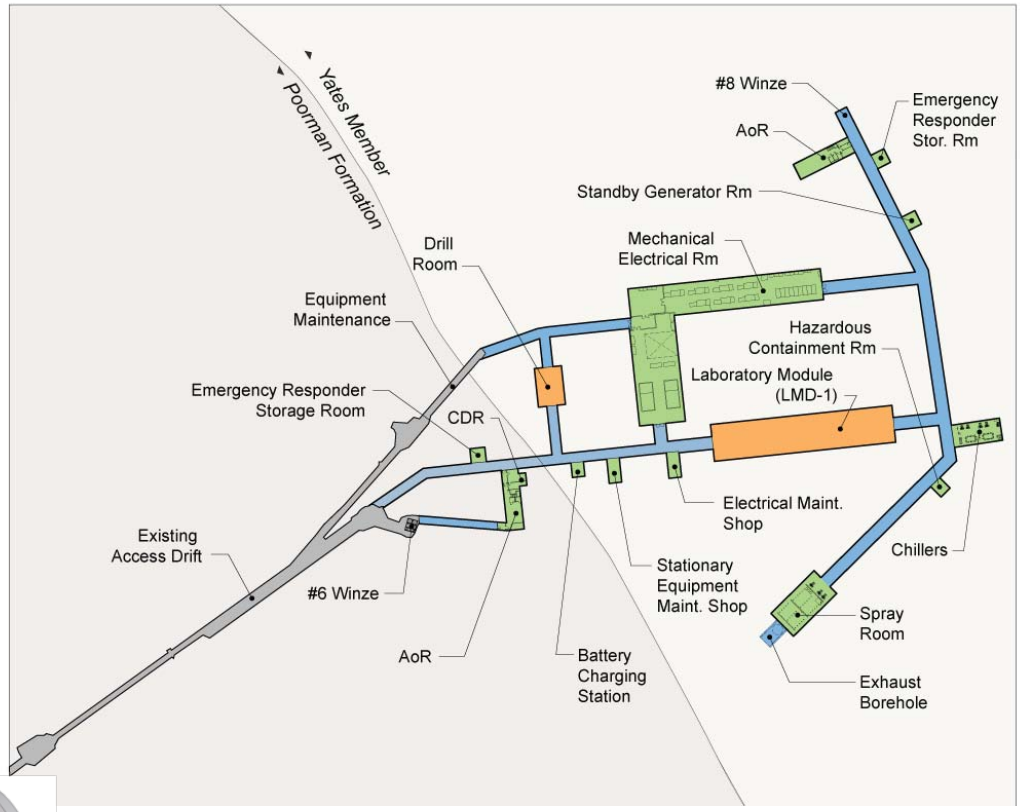


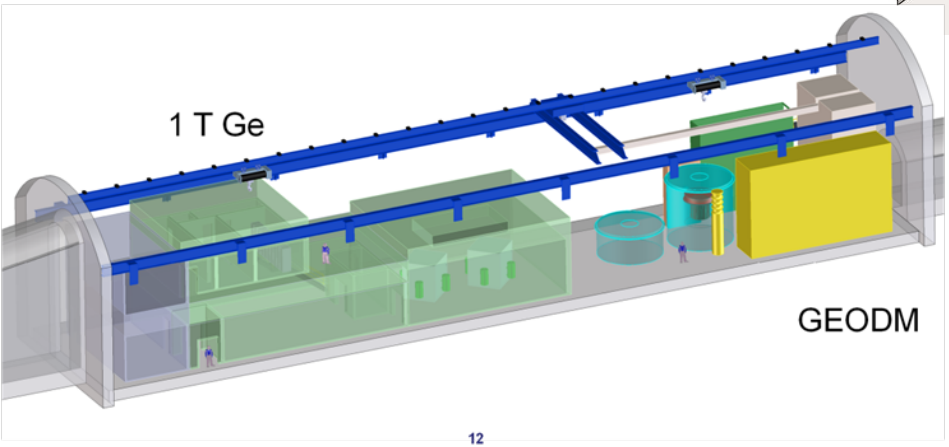
Experiment Space	Length ft (m)	Width ft (m)	Height ft (m)	Floor Area ft^2 (m^2)	Finished Volume yd^3 (m^3)
LM-1	164 (50)	66 (20)	79 (24)	10,764 (1,000)	29,422 (22,495)
LM-2	328 (100)	66 (20)	79 (24)	21,528 (2,000)	58,845 (44,990)
Davis Lab Module (DLM)	60 (18)	30 (9)	50 (15)	1,800 (167)	3,333 (2,548)
Davis Transition Area (DTA)	140 (43)	50 (15)	17.5 (5)	7,000 (650)	4,537 (3,469)
LC-1	180 (55) diameter	-	272 (83)	25,575 (2,376)	243,210 (185,947)
			TOTAL	66,667 (6,194)	

DUSEL 7400L

- Examples shown
- G3 dark matter
- $0\nu\beta\beta$
- Construction follows after 4850L



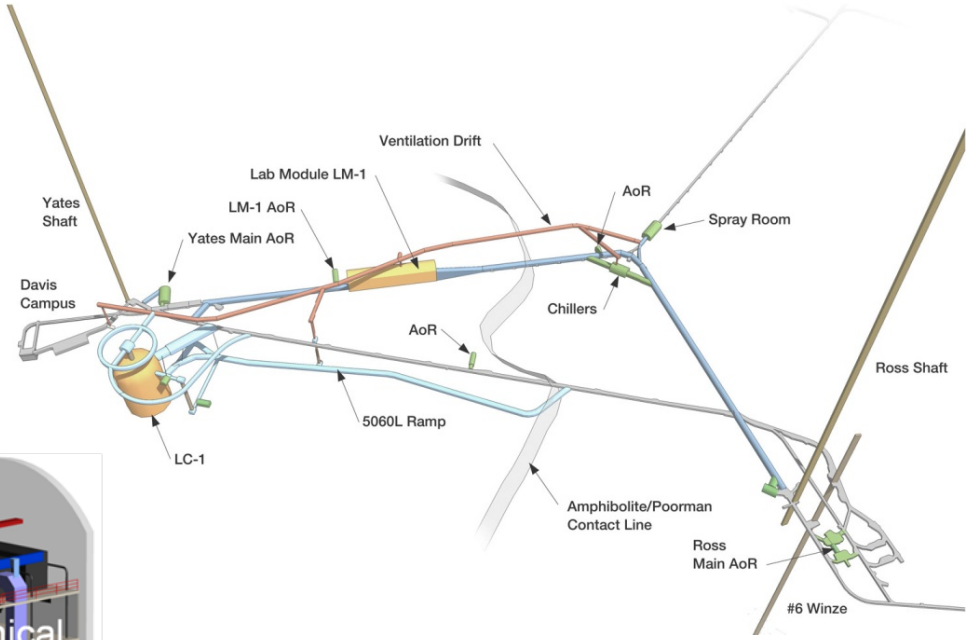


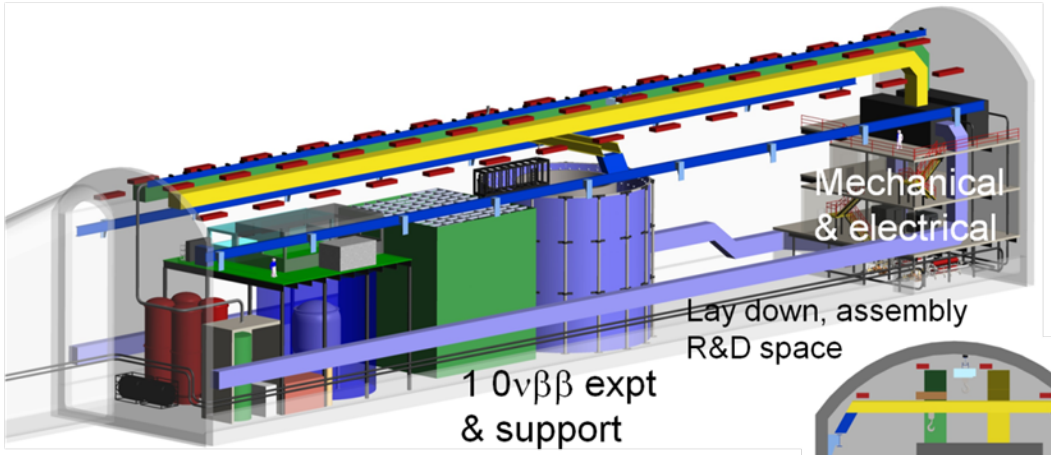


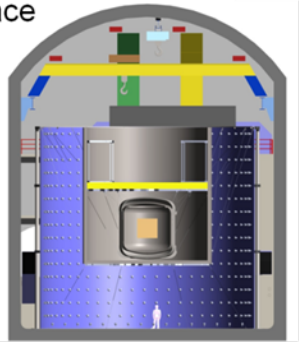
Experiment Space	Length ft (m)	Width ft (m)	Height ft (m)	Floor Area ft^2 (m^2)	Finished Volume yd^3 (m^3)
LMD-1	246 (75)	50 (15)	50 (15)	12,109 (1,125)	18,688 (14,288)
Drill Room	53 (16)	36 (11)	36 (11)	1,894 (176)	2150 (1644)
			TOTAL	14,003 (1,301)	

Alternatives

- Using PDR as basis, studies of less costly alternatives completed.
- Example shown here







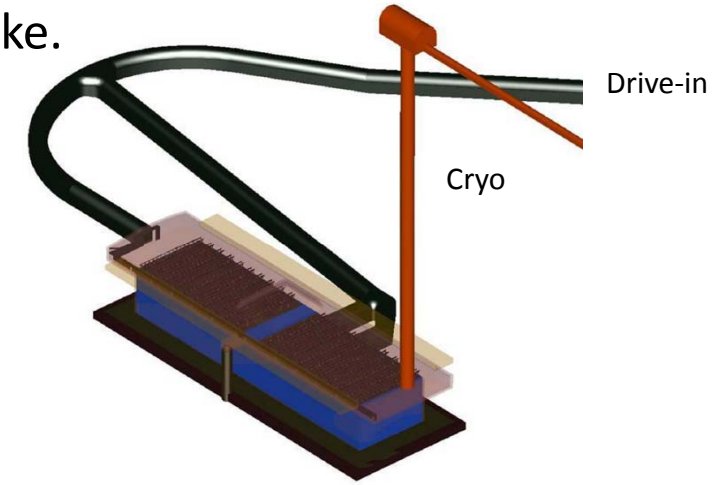
20m W x 24m H x 115m L

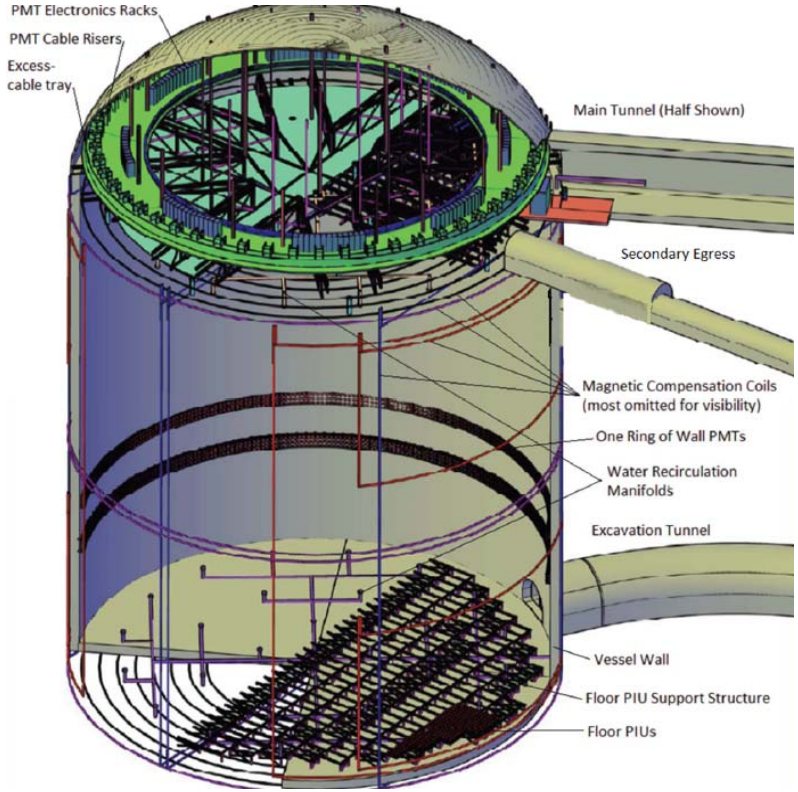
- Phased approach to DUSEL concept
- Support dark matter and other critical science goals.

Long-Baseline Neutrino Experiment

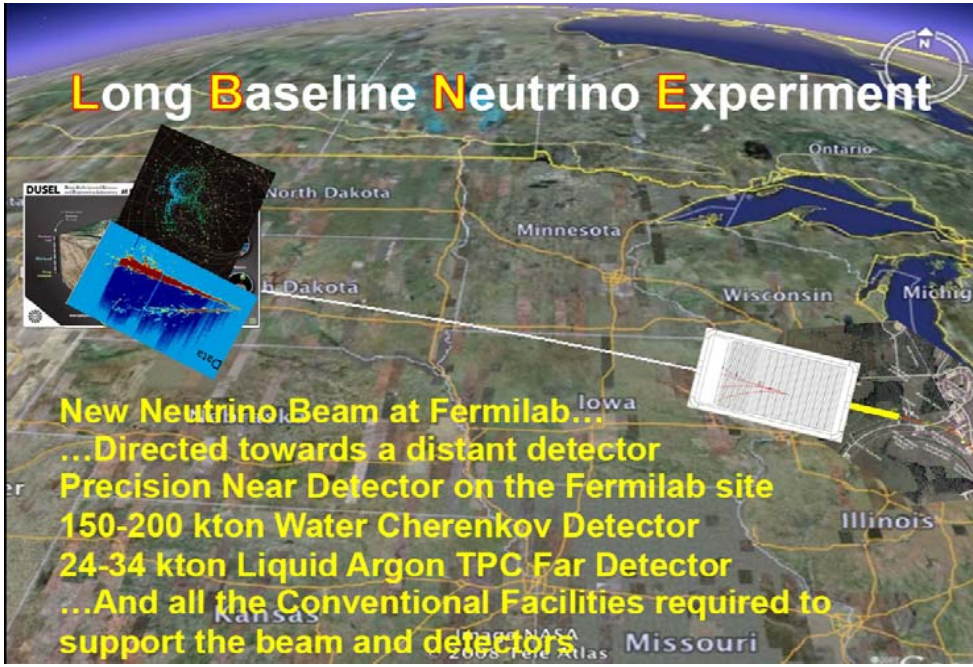
- Technical options for far-detectors at Homestake.
- Water Cherenkov detector (WCD) at 4850L
- Liquid argon(LAr) at 800L or 4850L
- Combination(WCD+LAr), possibly phased

LAr Detector at 800L





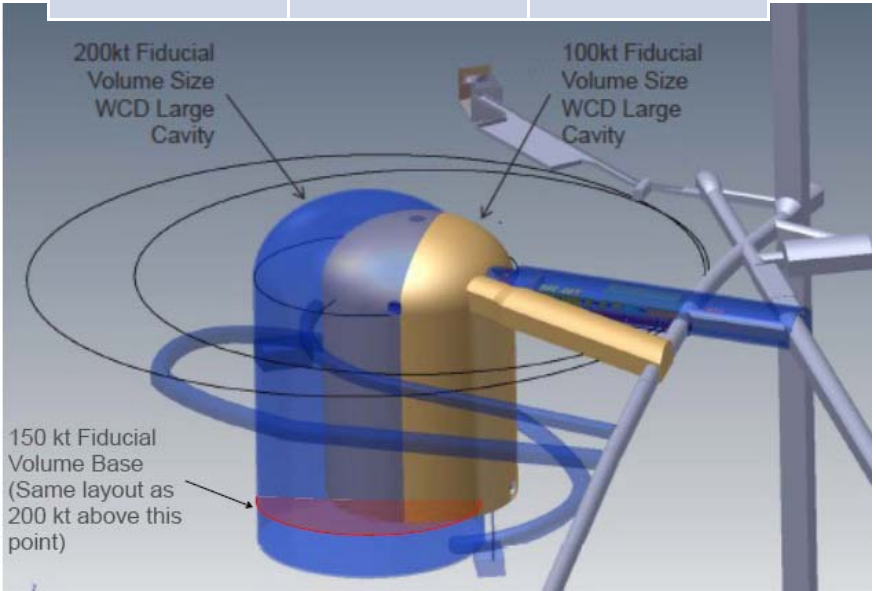
Water Cherenkov Detector at 4850L



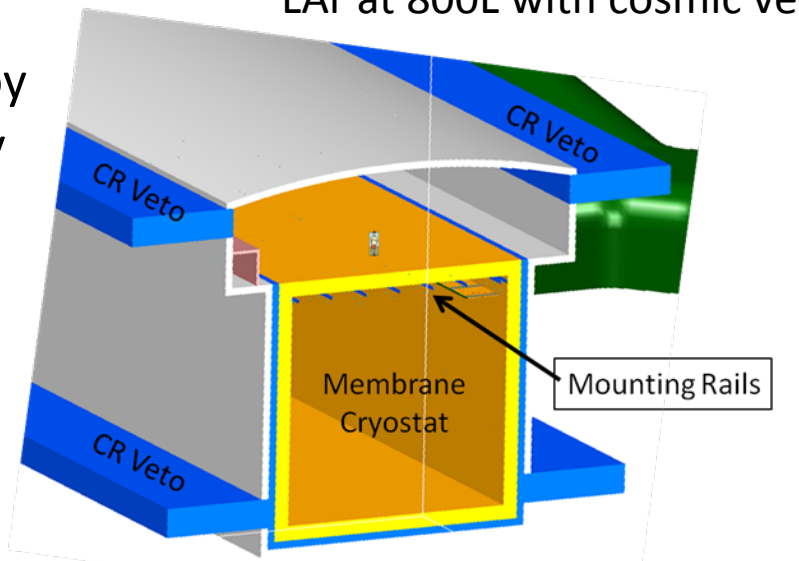
LBNE at Homestake

- PDR contains extensive design for 100 kT WCD, desire to go to 200kT
- Early description of LAr at 800L
- Feasibility of WCD cavern at 200kT validated by expert geotechnical panel (DUSEL Large Cavity Advisory Board)

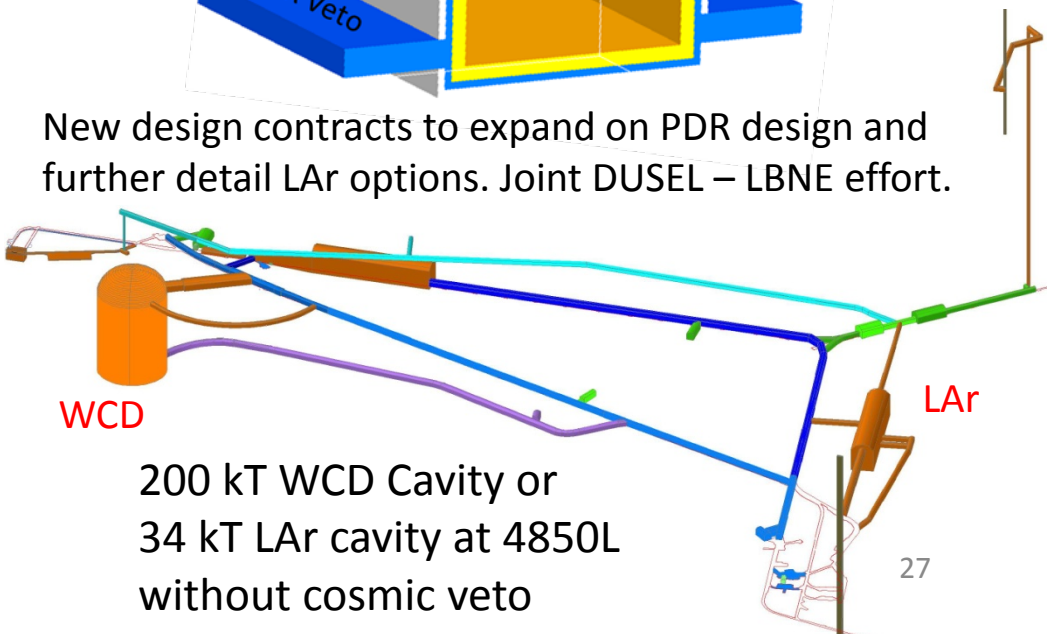
Tonnage(kT)	Diameter(m)	Height(m)
100	55	64
150	66	64
200	66	82



LAr at 800L with cosmic veto



New design contracts to expand on PDR design and further detail LAr options. Joint DUSEL – LBNE effort.



200 kT WCD Cavity or
34 kT LAr cavity at 4850L
without cosmic veto

DUSEL Status

- Preliminary Design Report complete and much of it will become publicly available after US funding agency review in next few months
- National Science Foundation has withdrawn design support funding after this year -> Department of Energy(DOE).
- US National Academy of Sciences panel report shortly.
- Department of Energy process in place to evaluate future at Homestake. Expect funding for 2012 while evaluation underway.
- 1st part of evaluation process just completed.* More to come.
- Homestake future as long-term underground facility strongly coupled to decisions taken regarding LBNE(DOE supported already) at Homestake, and its technology and depth
- LBNE technology choice currently planned by end 2011 and scope/cost/schedule review in March 2012

*DOE assessment panel report: http://science.energy.gov/~/media/hep/hepap/pdf/june-2011/Review_of_Underground_Science_Report_Final.pdf

Outlook

- Ongoing program at deep labs in US
  - Neutrino measurements, dark matter experiments at Soudan
  - Dark matter and $0\nu\beta\beta$ experiments at WIPP
- Near future plans
  - Continue at Soudan and WIPP
  - Complete Sanford Lab for LUX and MJD + possibly future dark matter experiments, R&D
- For next decade, plans but not yet decisions
  - LBNE using Fermilab ν beam at Homestake?
  - Multi-purpose deep facility at Homestake?

Acknowledgements

- Thanks for material and information provided by the Sanford Laboratory staff, DUSEL design team, LBNE collaboration, R. Gaitskell, G. Gratta, J. Wilkerson, J. Nelson, S. Ahlen, M. Marshak, P. Cushman