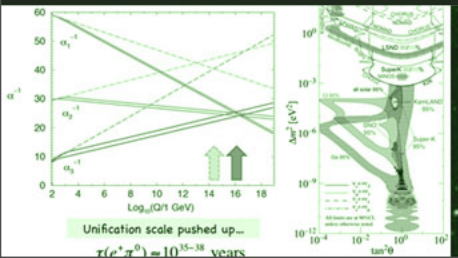
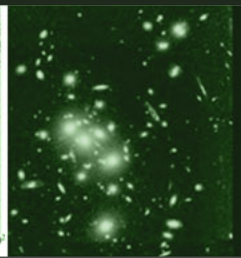
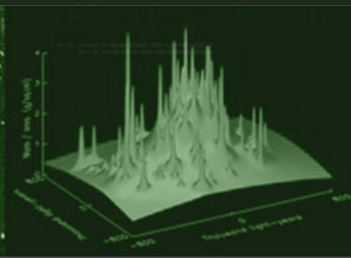
10 – 11 August 2012

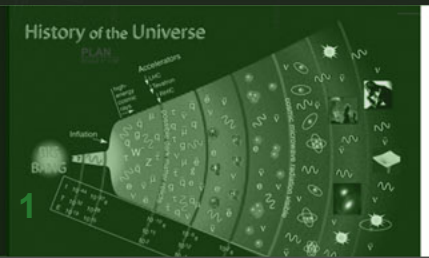
The Sanford Underground Research Facility at Homestake
&
Underground US Nuclear Physics Experiments

Kevin T. Lesko
UC Berkeley and LBNL









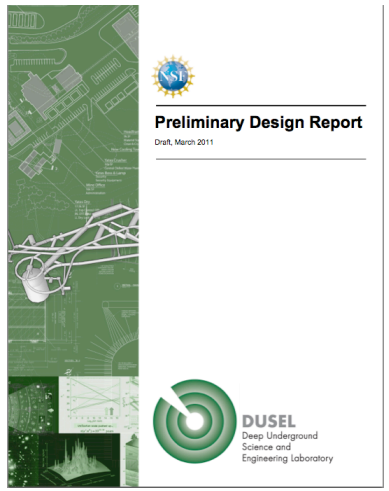
Sanford Underground Research Facility
SURF

Outline of SURF Overview

- Transition of the US Underground Research Facilities from NSF to DOE stewardship: DUSEL ⇒ SURF
- Overview of the Sanford Underground Research Facility
  - What major scientific discoveries have occurred in your research area since the 2007 LRP was drafted?
  - What major and unique science is to be done in the next 5 years?
  - What science would you expect to pursue in the program in 2020 and beyond?
  - What is the international context, and how does it affect [y]our vision?

Transitioning From NSF's Deep Underground Science and Engineering Laboratory to DOE's Sanford Underground Research Facility

- Since 2000 the NSF sought to develop a deep underground laboratory to host a multidisciplinary experimental program (Physics, Earth Science, & Biology)
- 2001 - 2003: NUSL led by University of Washington
- 2005 - 2012: DUSEL led by University of California, Berkeley
  - Comprehensive site selection of 8 alternative sites, development of CDRs, PDR, Environmental work, 106 consultation plans, etc.
- In December 2010 (FY11), the National Science Board halted funding to develop the NSF-led facility, DUSEL
- The plans for DUSEL advanced to a preliminary design report (~ CD2) and the project was baselined in July 2011, the National Academy completed it evaluation of the scientific program in July 2011



The Road to an Underground Laboratory

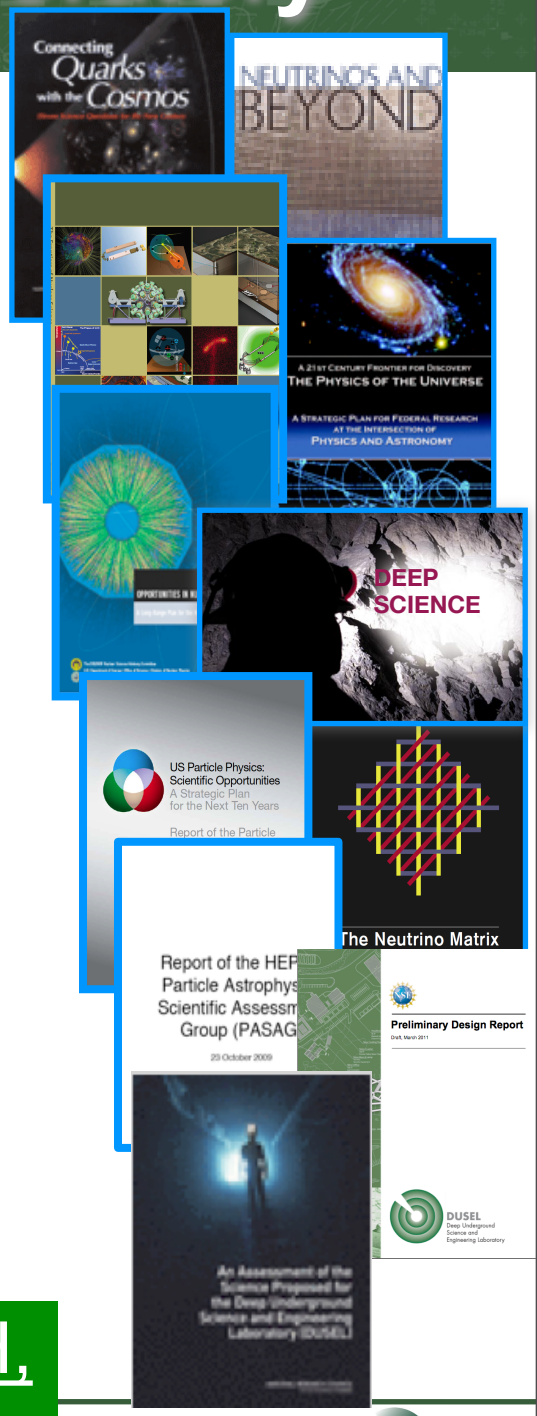
- NUSL 2000
  - DNP Neutrino Pre-Town meeting
  - Bahcall Committee Report
  - NESS
  - Neutrinos and Beyond
  - Quarks to the Cosmos
  - NP LRP, DOE Facilities Report
  - HEPAP LRP 2003
- DUSEL 2004 - Underground Lab reorganization
  - S-1, S-2, S-3, S-4
  - Homestake CDR, DMSAG, NuSAG
  - P5 Report, Quantum Universe, Neutrino Matrix
  - PASAG
  - *NSB Decision*
  - Homestake PDR
  - National Academy DUSEL Science Report
  - Marx/Reichanadter Report
- SURF 2012

SuperK

SNO

KamLAND

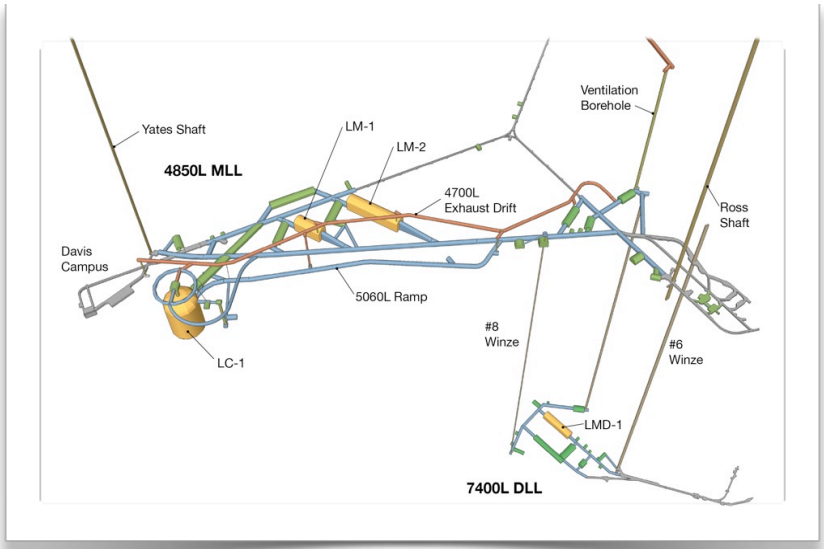
Daya Bay



CPV, 0υββ, υ Osc, υ MH, υ mass, DM, PDK, NA

Transitioning From NSF's Deep Underground Science and Engineering Laboratory to DOE's Sanford Underground Research Facility

NSF MREFC Scope	Targets including Contingency
DUSEL Project Office	$575M
Surface Campus (+ $5M from Sanford)	
Underground Infrastructure and Laboratories (+ $7.5M from Sanford)	
Science Contribution	$300M
Total MREFC	$875M



Science Goal	Total Estimated Experimental Cost Range* ($M)	Proposed MREFC Contribution ($M)	Number of Deploy-ments
Dark Matter	80 - 100	175	≥1
0νββ	240 - 330		1
Bio/Geo/Eng	60 - 180		multiple
Nuclear Astrophysics	30 - 45		1
Advanced low bckgrd & assay	2 - 15		1
Long Baseline Neutrinos & Proton Decay	785 - 1065	125	200 kt WCE

* per experiment, not CD estimates

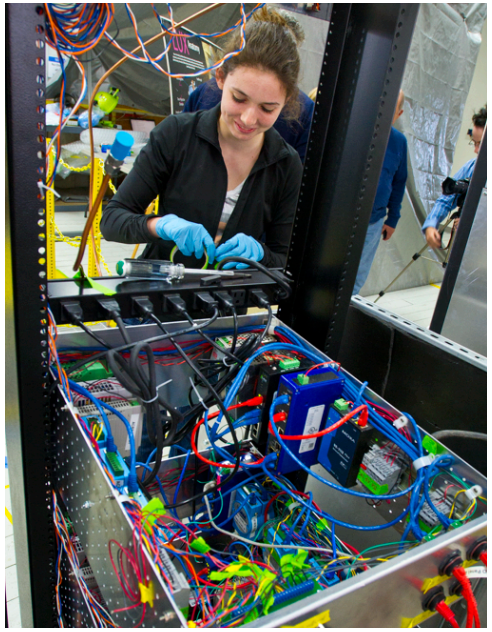
Sanford Underground Research Facility SURF

Transitioning From NSF's Deep Underground Science and Engineering Laboratory to DOE's Sanford Underground Research Facility

- DOE was relying on NSF's DUSEL to host major experiments
- Office of Science responded expeditiously to this challenge
  - Convened Marx/Reichanadter Committee to review options and risks
  - Funded operations in FY12 to preserve the site while it evaluates options
    - Long Baseline Neutrinos
    - Dark Matter Searches
    - Neutrinoless Double-Beta Decay Searches
- As a major element of the DUSEL program, began facility rehabilitation and the development the 4850 Laboratory primarily with South Dakota funds. This continued in FY12 with installation of experiments:
  - Large Underground Xenon Dark Matter Experiment (LUX)
  - MAJORANA DEMONSTRATOR Neutrinoless Double Beta Decay (MJD)
  - SD's Center for Ultralow Background Experiments at DUSEL (CUBED)
  - a number of small Bio/Geo/Eng efforts

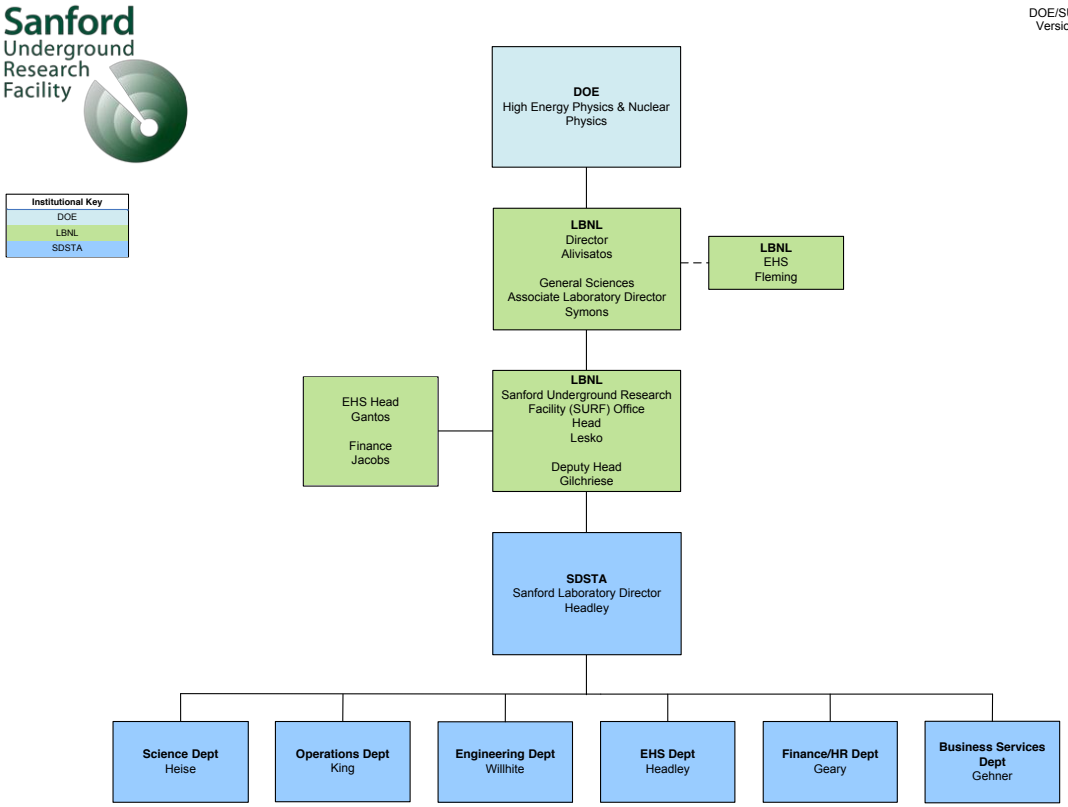
What is the current status of SURF?

- FY 2012
  - Facility
    - Facility Dewatered below the 6000 foot level Complete
    - Yates promoted to primary access Complete
    - Davis Laboratory Outfitting Complete
    - Ross Shaft Rehab - design complete and reviewed, rehabilitation Initiated (still provides secondary egress)
  - Science
    - LUX Dark Matter, MAJORANA DEMONSTRATOR Neutrinoless Double Beta Decay, & CUBED - Installing
    - LBNE 10kt on surface - CD1 review scheduled October 2012
    - Proposals for DIANA, LZ, LBCF submitted and under review
- FY 2013 - 15
  - Facility
    - Ross Shaft Rehab continues
  - Science
    - LUX and MJD taking data
    - LBNE advancing towards CD2 Review
    - Support for additional funded activities



DOE-funded SURF Organization

LBNL provides management and oversight for DOE for SURF Operations, established Operations office: support in FY12 from HEP and NP. For FY13 HEP has indicated desire to express stewardship of SURF.

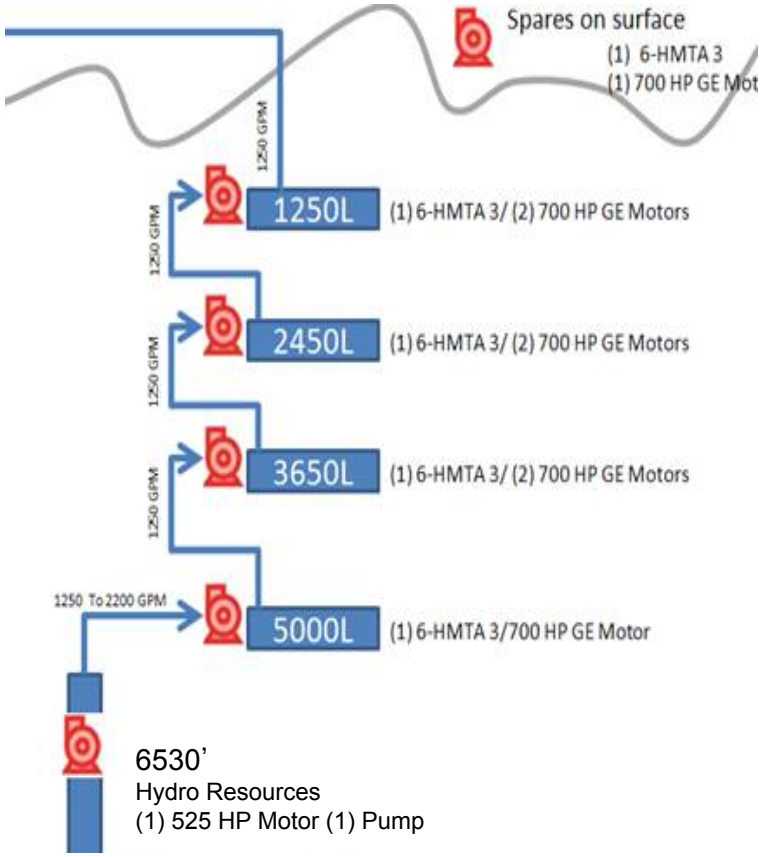


This maintains facility operations, engineering, science, & EH&S functions. Key staff transferred from NSF to DOE at LBNL/UCB and SDSTA

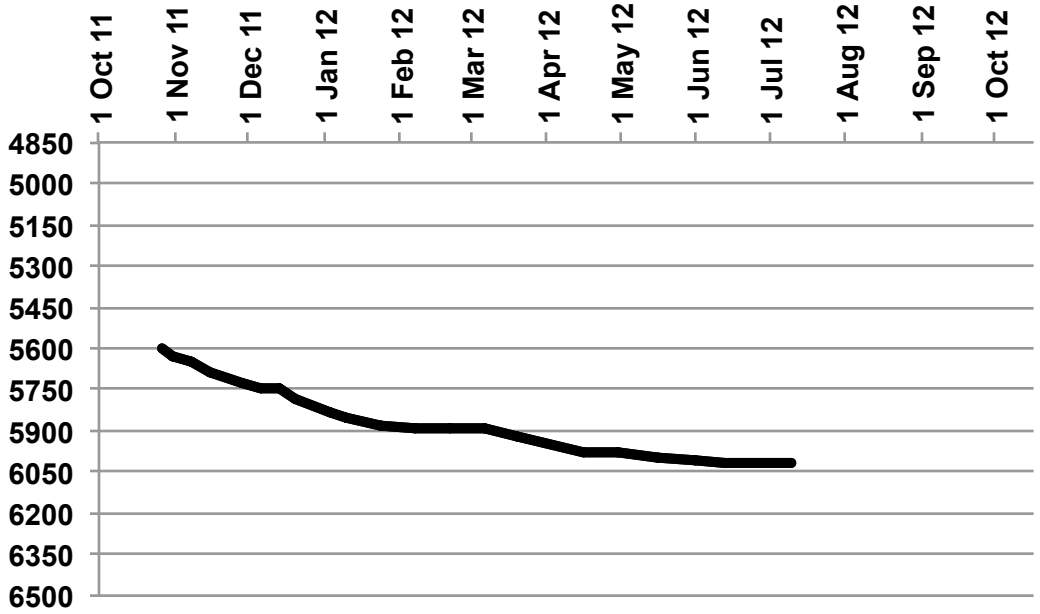
FY12 Activities - World-class Science not just Pumping (Iron-laden) Water

- Preservation of essential infrastructure (buildings, shafts, & drifts) and provide safe access to the underground including ventilation, redundant egress, EH&S, ground support
- Support of the 4850L Science Program (LUX and MJD) but also new proposals
- Dewatering (pumping, treating, disposal)
- Management and Oversight for DOE by LBNL
- *Facility Upgrades and Rehabilitation (primarily with South Dakota funds)*

Dewatering the Underground Facility

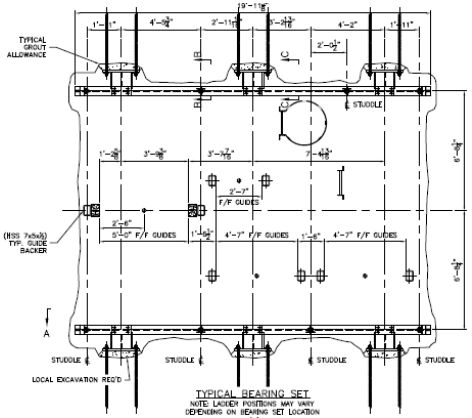


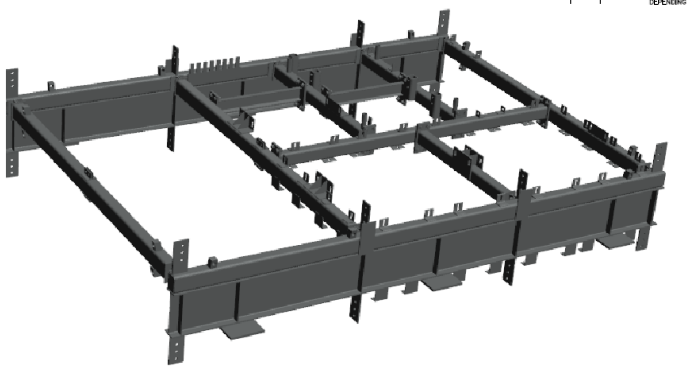
- Dewatered facility from a highpoint of 4300 down to 6000 feet below ground
- holding water at this level
- ~ 1 year of freeboard if all pumps should fail

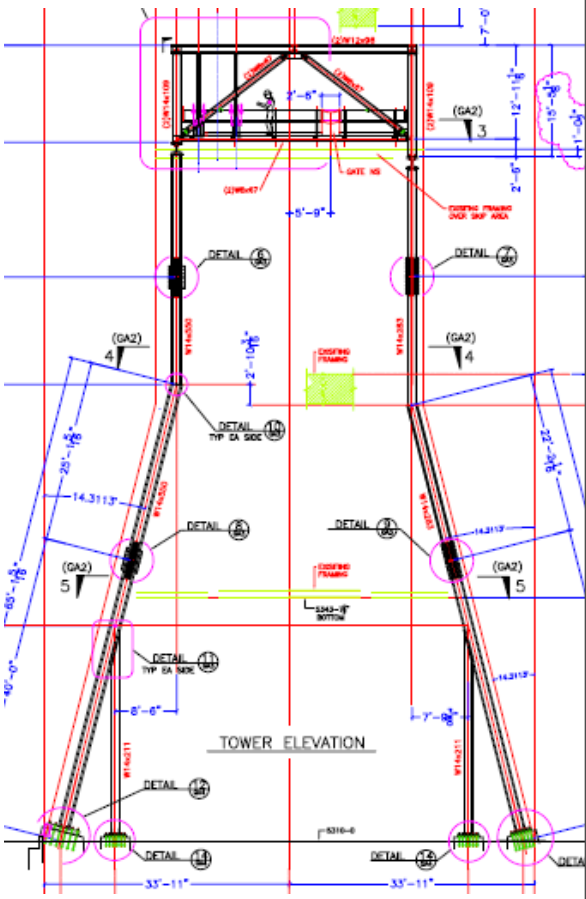


Providing Safe, Redundant Access

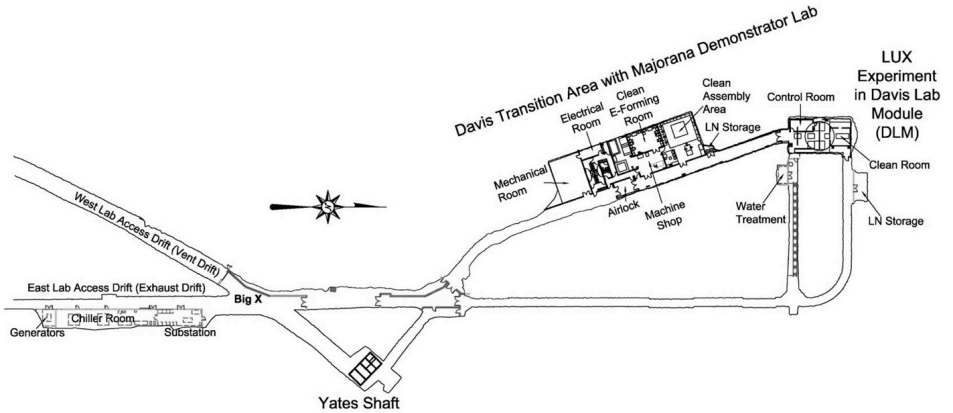
- Yates Shaft Upgraded to primary access
  - Established primary access to support LUX and MJD
- Ross Shaft Rehabilitation Initiated
  - SD financed rehab
    - steel
    - work-decks
    - labor







Davis Campus at the 4850 level



Davis Campus at the 4850 level

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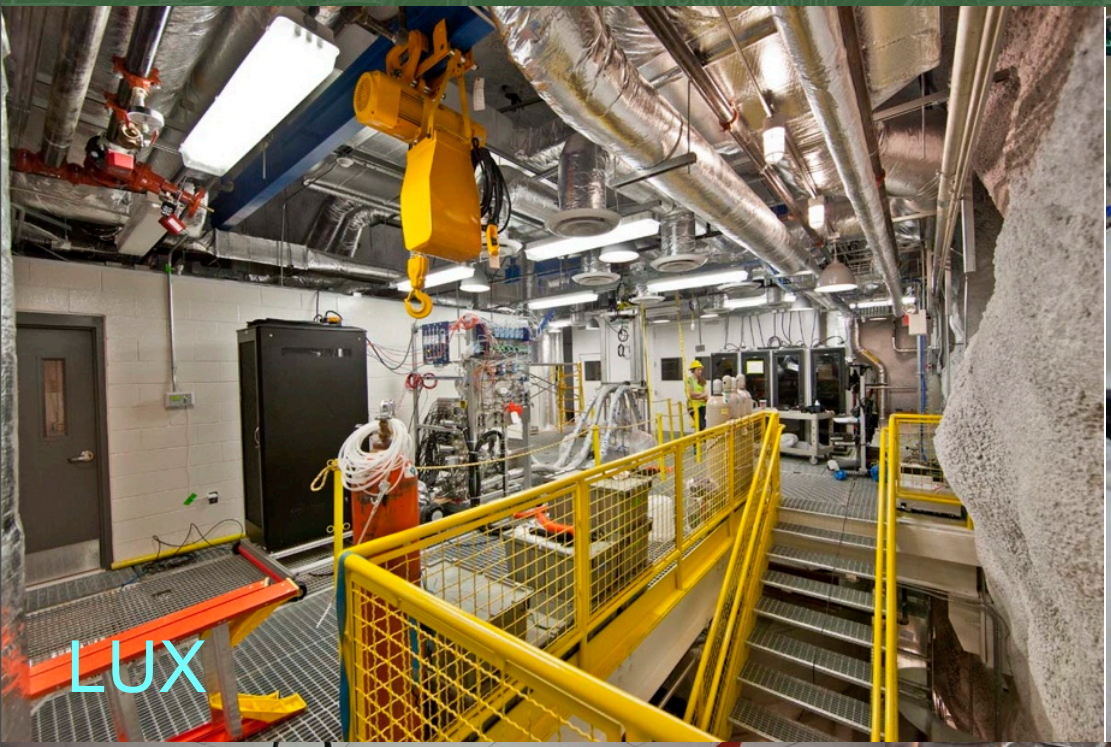


Scientific Assessment of Underground Science

- **Nuclear Physics Long Range Plan (2007)**

  Recommendation III: We recommend a targeted program of experiments to investigate neutrino properties and fundamental symmetries. These experiments aim to discover the nature of the neutrino, yet-unseen violations of time-reversal symmetry, and other key ingredients of the New Standard model of fundamental interactions. Construction of a **Deep Underground Science and Engineering Laboratory is vital to U.S. leadership in core aspects of this initiative**.

- **An Assessment of the Science Proposed for the Deep Underground Science and Engineering Laboratory - National Academy (2011)**

  Conclusion: Three underground experiments to address fundamental questions regarding the nature of dark matter and neutrinos would be of paramount and comparable scientific importance:

  • The direct detection dark matter experiment,

  • The long baseline neutrino oscillation experiment, and

  • The neutrinoless double-beta decay experiment.

  Each of the three experiments addresses at least one crucial unanswered question upon whose answer the tenets of our understanding of the universe depend.

  Conclusion: A small underground accelerator to enable measurements of low-energy nuclear cross-sections would be scientifically important. These measurements are needed to elucidate fundamental astrophysical processes such as thermonuclear reactions and the production of heavy elements in the sun and the stars.

Scientific Assessment of Underground Science

- ***Nuclear Physics: Exploring the Heart of Matter*** **- National Academy Report (2012)**

Recommendation: *The Department of Energy, the National Science Foundation, and, where appropriate, other funding agencies should develop and implement a*

targeted program of underground science*, including*

important experiments on whether neutrinos differ from antineutrinos*, on the*

nature of dark matter*, and on*

nuclear reactions of astrophysical importance*.*

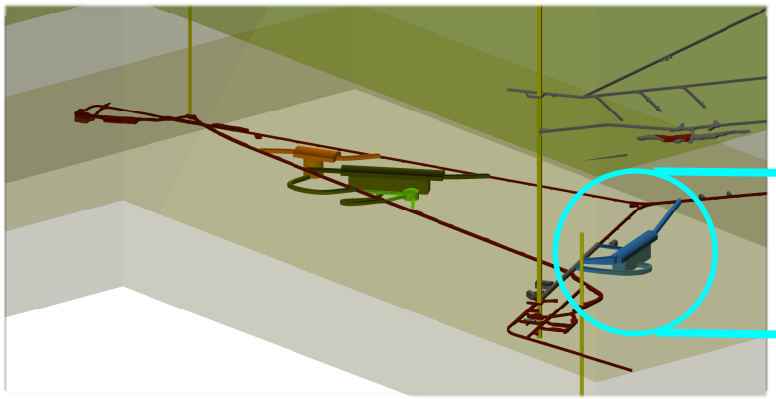
Such a program would be substantially enabled by the realization of a deep underground laboratory in the United States*.*

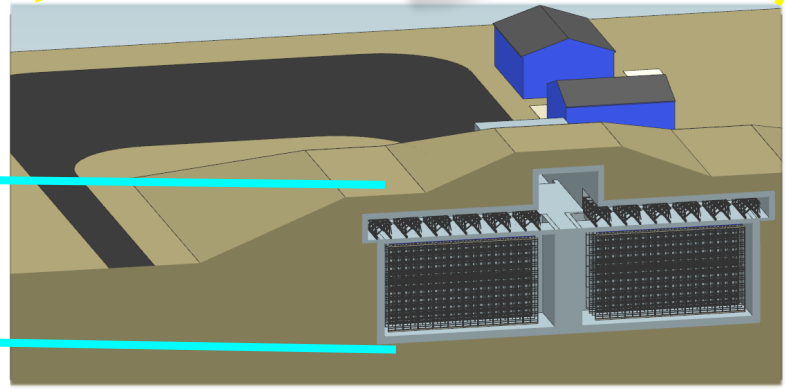
Long-Baseline Neutrino Experiment

- Originally scoped (December 2011) 35 kt Liquid Argon at the Homestake's 4850L
- ~$1.5 to 2 B
- Office of Science asked for a reconfiguration
  - phased program
  - significant physics results at each step
  - first step targeted at $700 to 800M
- Steering committee considered many (~17) options, and advanced three http://www.fnal.gov/directorate/lbne_reconfiguration/index.shtml
  - 30 kt LAr on the surface at Ash River
  - 15 kt LAr underground at Soudan 2350 feet
  - 10 kt on the surface at Homestake - preferred approach, stronger physics, self-reliant physics, upgradable, utilizes uniqueness to establish a world-leading program

Long-Baseline Neutrino Experiment

- Office of Science has accepted the LBNE reconfiguration plan (June 2012)
  - 10 k-ton (fiducial) LAr on the surface, new FNAL beam-line
  - options to go underground with additional funds identified between CD1 and CD2: $130M loaded
  - CD1 review October 2012
    - CDR created, EA work initiated, MOUs drafted
  - CD2 ~ 2014



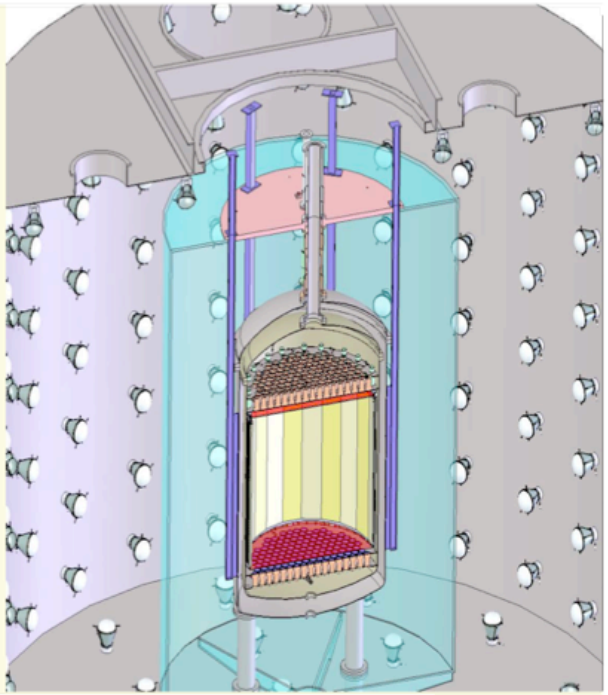


Dark Matter Searches

- Generation-1 Experiment installing now - LUX
- Generation-2 Dark Matter Experiment
  - proposals submitted to NSF and DOE
- LZ builds on LUX experience
- Strong support from SD
- Uses SURF existing infrastructure, no new excavation

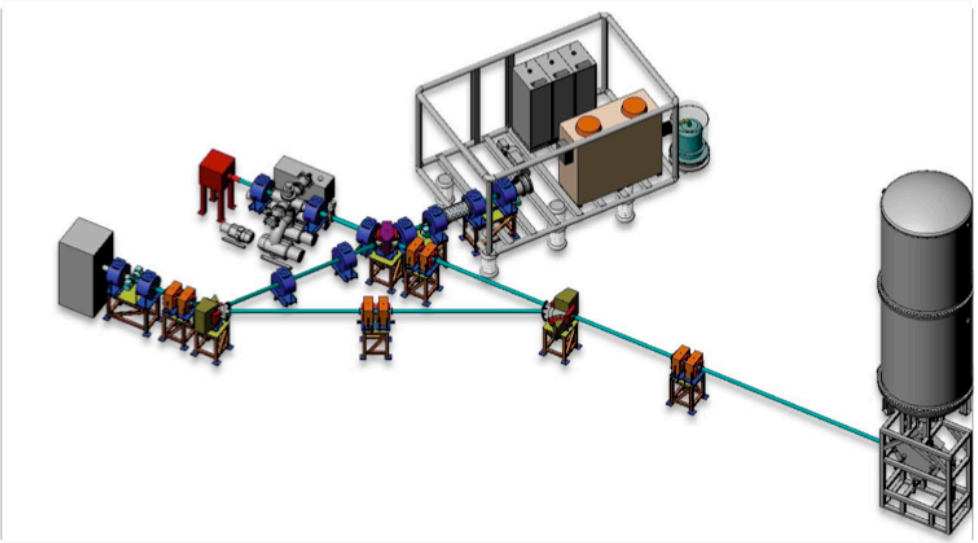
LZ Experiment

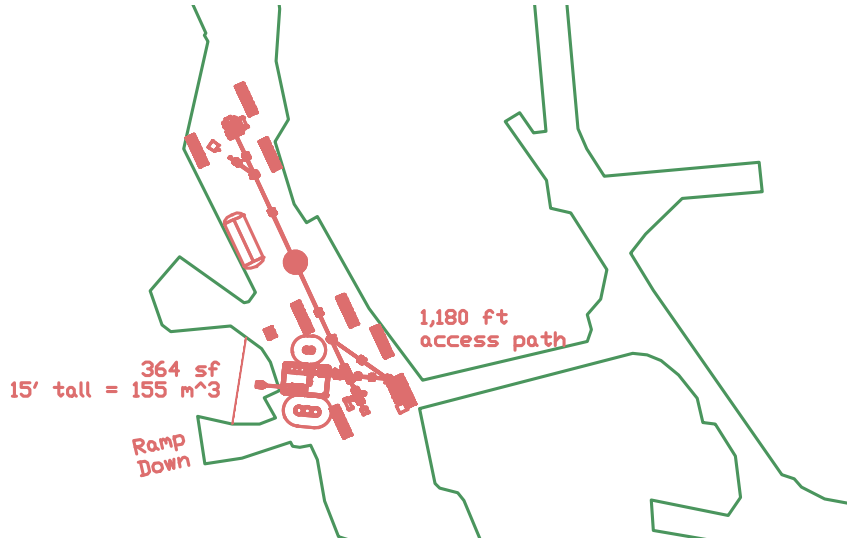
- LUX + ZEPLIN collaborations
- 20-fold scale-up of LUX
- Veto system
  - 0.75 m thick Gd-loaded scintillator shield (Daya bay experience)
  - Instrumented Xe "skin"
  - Effective for neutrons and gammas
- Fits in existing Davis Campus water shield, and complex



Nuclear Astrophysics

- Proposal submitted to NSF
- Strong support from South Dakota
- Existing sites identified (3950L) without significant new excavation
- NSF appears favorably inclined towards proposal (builds on S-4 grant)





Science at SURF

- SURF is hosting world-class experiments providing the US with leadership in three primary experimental areas: dark matter searches, neutrinoless double beta decay experiments, and long baseline neutrinos
- The SURF team is critical for integrating the science into the underground environment and operating the facility
- SURF provides a stable, safe, and state-of-the-art, operating, deep domestic facility on which we can continue to develop scientific missions within the time frame of the 2007 LRP

SURF and Global Context

An Assessment of the Science Proposed for the Deep Underground Science and Engineering Laboratory - National Academy (2011)

Conclusion: The three major physics experiments provide an exceptional opportunity to address scientific questions of paramount importance, to have a significant positive impact upon the stewardship of the particle physics and nuclear physics research communities, and to have the United States assume a visible role in the expanding field of underground science. The U.S. particle physics program is especially well positioned to build a world-leading long-baseline neutrino experiment due to the availability of the combination of an intense neutrino beam from Fermilab and a suitably long-baseline from the neutrino source to an appropriate underground site such as the proposed DUSEL. In light of the leading roles played by U.S. scientists in the study of dark matter and double-beta decay, together with the need to build two or more large experiments of each of these two types, **U.S. particle and nuclear physicists are also well positioned to assume leadership roles in the development of one direct detection dark matter experiment of ton- to multi-ton scale and one neutrinoless double-beta decay experiment on the scale of a ton**. While installation of U.S.-developed experiments in an appropriate foreign facility or facilities would significantly benefit scientific progress and the research communities, **there would be substantial advantages to the communities if these two experiments could be installed within the United States at the same site as the long-baseline neutrino experiment.**

Marx/Reichanadter Report April 2011

Given the extent of investment needed to carry out these experiments, the long timescales and the likelihood of follow-on experiments in each of these areas of research, the committee recognizes that there are major advantages to developing a common underground site for these experiments. Advantages include:

Opportunities to share expensive infrastructure and to coordinate design efforts, construction, management and operations.

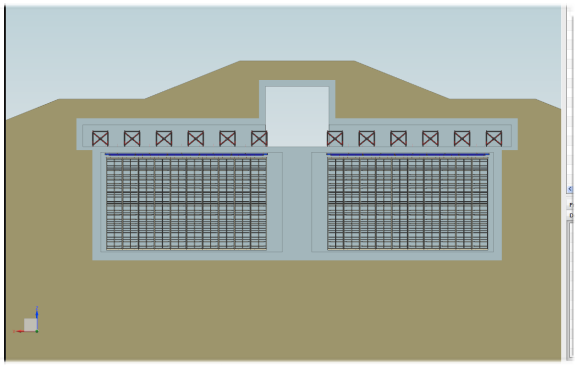
Significant benefits in training the next and subsequent generations of scientists by having a common facility serve as an intellectual center in these fields of research.

This facility should include needed underground support facilities for example, low background counting facility, clean machine shop, electroforming, and material storage.

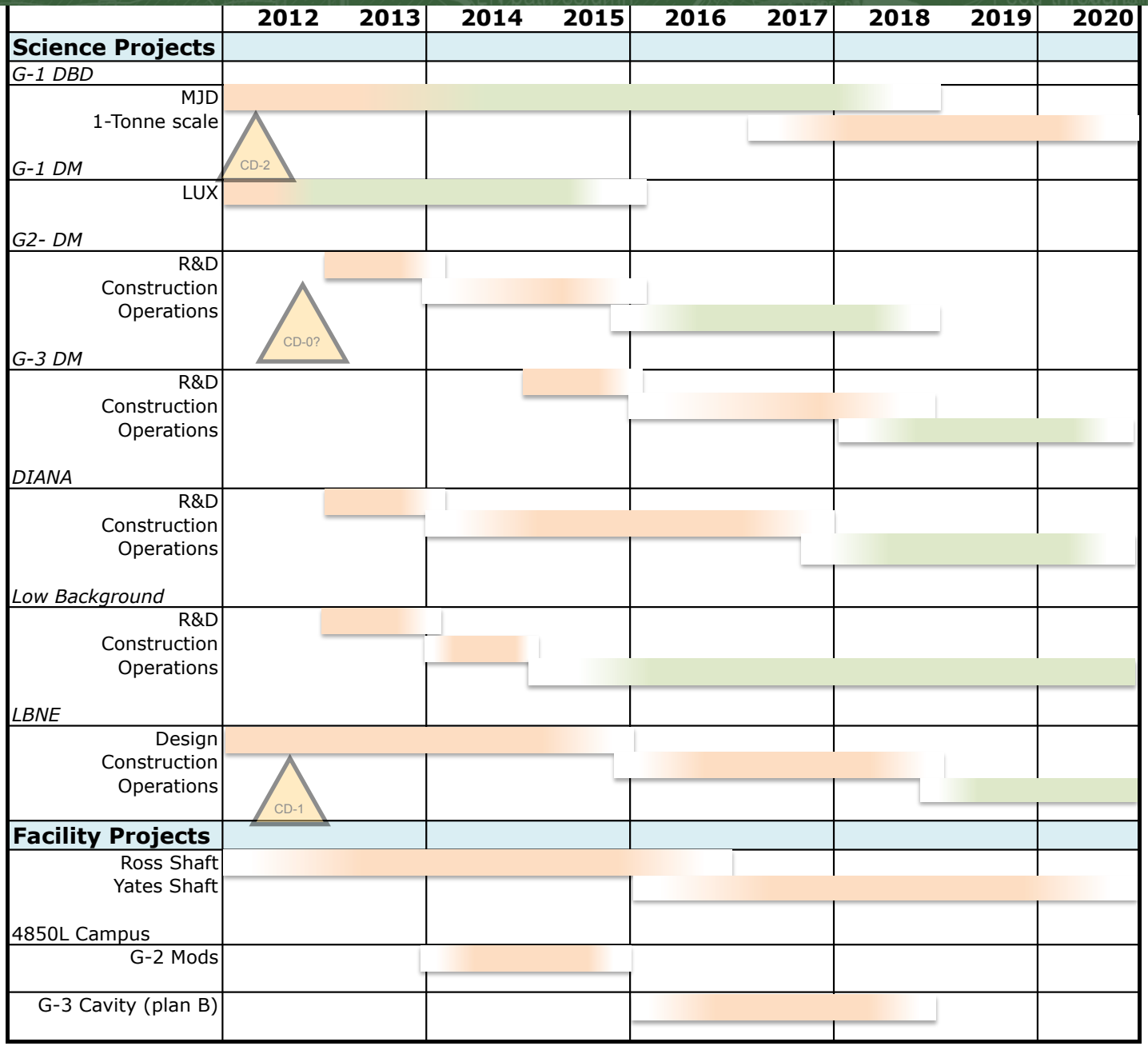
Locating the facility in the U.S. would help to promote U.S. leadership in these fields for the foreseeable future.

Future Programs & Opportunities

- Long-Baseline Neutrino Experiment (10 kt Surface & advanced options at 4850L)
- Nuclear Astrophysics (DIANA @ 3950L) – NSF
- Generation 2 Dark Matter (LZ @ 4850L Davis Campus) – NSF & DOE
- Low Background Counting (@4850L Ross Campus) – NSF
- Generation 3 Dark Matter (@4850L)



Science Timeline at SURF



- Passed CD2/3 installing @ 4850
- Finished surface run installing @ 4850
- CD0 by the end of summer 2012
- Broad discussions initiated
- Discussions with DIANA advancing
- Awaiting NSF decision
- CD1 review by Nov 2012, CD2 + 24 months

Answers to the central questions from a SURF perspective:

- What major scientific discoveries have occurred in your research area since the 2007 LRP was drafted?
  - Θ_{13} is large and strongly supports LBNE development with 1300km baseline (China)
  - Discovery of the Higgs informs Dark Matter searches and neutrinos mass models (Europe)
- What major and unique science is to be done in the next 5 years?
  - Development and operation of an neutrinoless double-beta decay R&D project (MJD)
  - Operation of Generation-1 Dark Matter (LUX), development and operation of G-2
  - Detector and technology R&D
- What science would you expect to pursue in the program in 2020 and beyond?
  - Ton-scale neutrinoless double-beta decay
  - Generation-3 Dark Matter searches
  - Underground Nuclear Astrophysics
  - LBNE: neutrino properties, CPV, *proton decay, astrophysical neutrinos*
  - Detector and technology R&D
- What is the international context, and how does it affect [y]our vision?
  - SURF provides US with scientific leadership in the 3 or 4 critical experimental areas
  - Provides critical modern, deep facilities with a competent and trained staff
  - Provides opportunities for cross-division and agency cooperation
  - SURF provides the Nuclear Physics with the opportunity to join forces in a near-term critical search - Dark Matter

Summary

- SURF has transitioned from NSF to DOE stewardship
- The facility has completed the transition of preparing for science to hosting and enabling world-class experiments, OHEP stewardship of the facility
- SURF provides the US with a domestic, deep underground research facility to enable US leadership in high energy and nuclear physics
- SURF provides ONP with an opportunity to embrace a new domestic experimental program, using techniques and detectors developed by nuclear physics, to pursue a near-term, discovery-rich field – Dark Matter – as well as maintain leadership in traditional areas of neutrinoless double beta decay and nuclear astrophysics

What does this workshop need to do?

- Endorse underground physics and the continued operation of a deep US laboratory for underground physics to the Tribble Committee
- Support a strong focus of the domestic, experimental underground portfolio at this facility from High Energy and Nuclear Physics
- Endorse the nuclear physics participation in the science that is and will be hosted at SURF:
  - Traditional topics
    - neutrinoless double-beta decay
    - nuclear astrophysics
  - New topics
    - dark matter

Backup slides

- references
  - Homestake - www.dusel.org
  - DUSEL Science NRC report - http://www.nap.edu/catalog.php?record_id=13204
  - DUSEL PDR - arXiv:1108.0959
  - Intensity Frontier Report - arXiv:1205.2671
  - Marx/Reichanadter report - http://science.energy.gov/~/media/np/pdf/review_of_underground_science_report_final.pdf
  - Nuclear Physics NRC report - http://sites.nationalacademies.org/BPA/BPA_055628
  - LBNE matters - http://www.fnal.gov/directorate/lbne_reconfiguration/index.shtml

South Dakota's commitment.

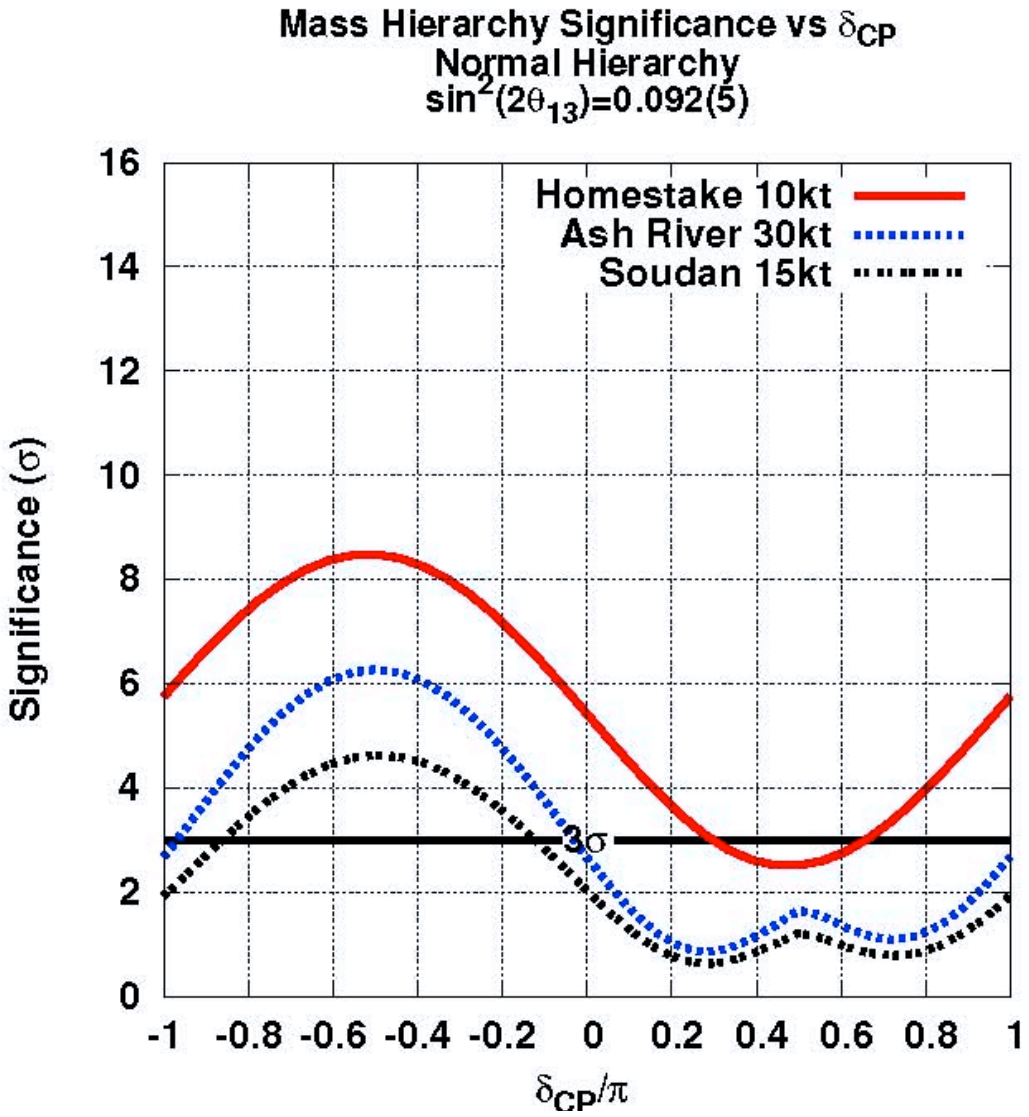
State Funding to date:

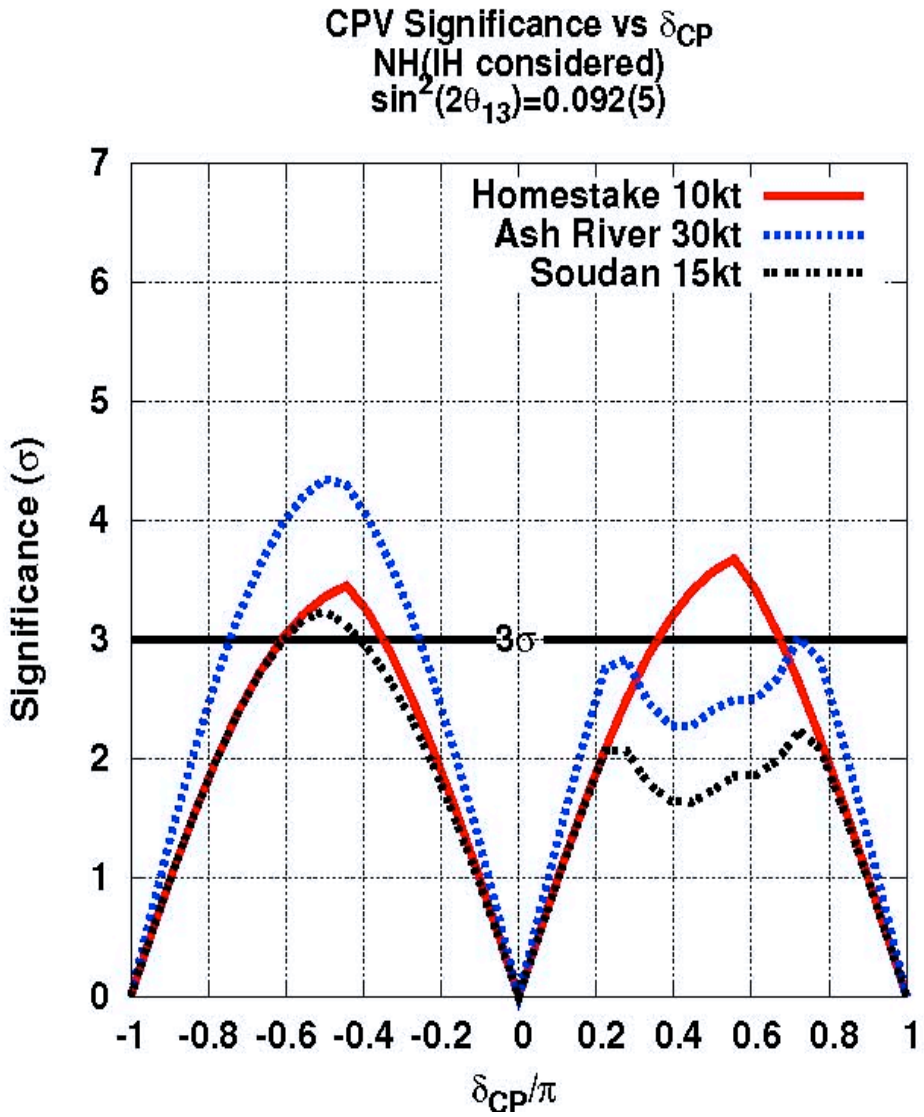
2004	$14.3 million
2005	$19.9 million
2010	$ 5.4 million
2011	$ 0.6 million
T. Denny Sanford	**$70.0 million**
HUD grant	**(Not included)** **$10.0 million**
Earned interest	**$10.5 million**
Total	**$120.7 million**

Future commitments:

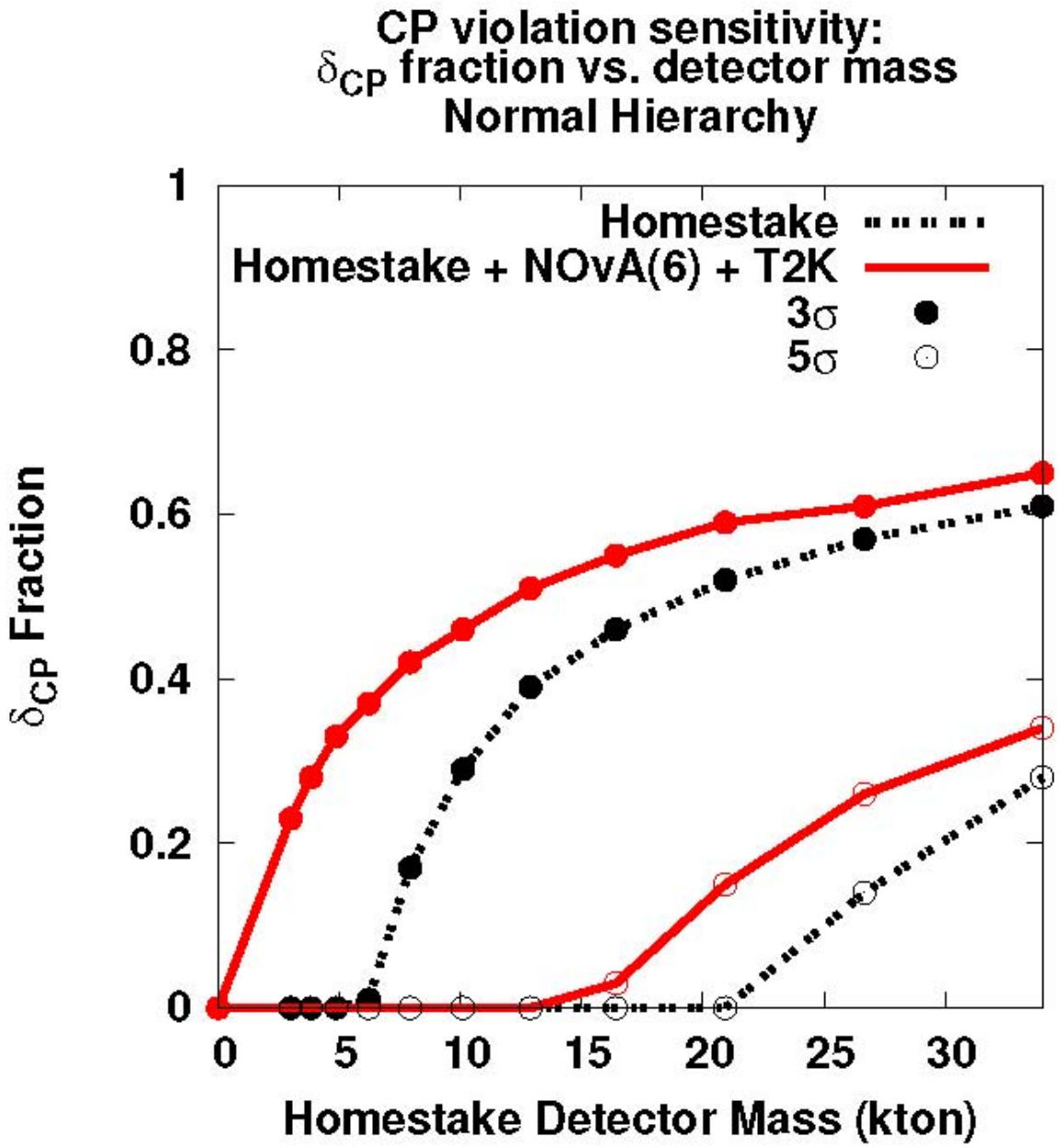
DIANA (provide new space)	$5.0 million
LZ (provide Xenon)	$5.0 million
LBCF (provide new space)	$ .1 million
Ross shaft rehabilitation	$5.0 million
Lab support for LUX & MJD (over future years)	$ .9 million
Total	**$16 million**

LBNE Scientific Reach





LBNE Scientific Reach



Underground Laboratories Worldwide