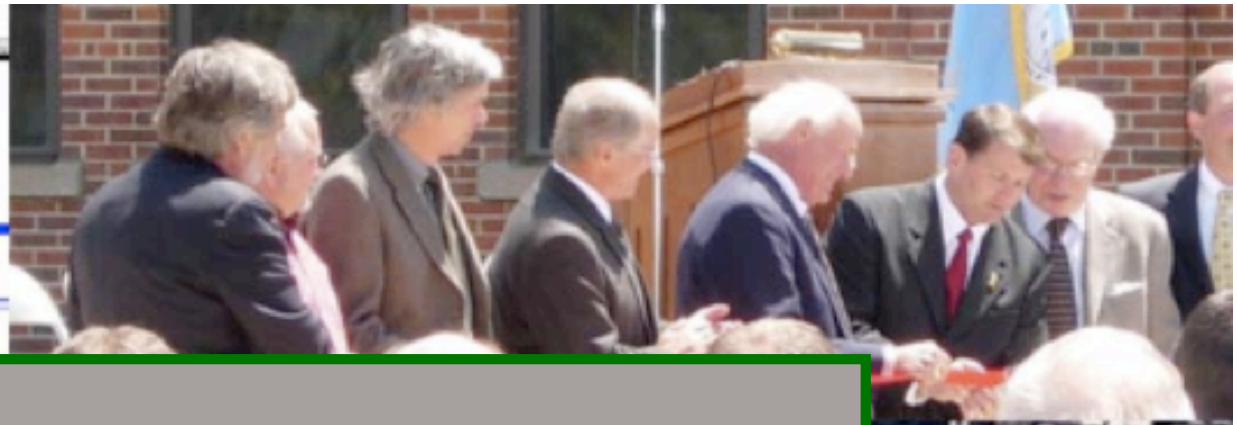


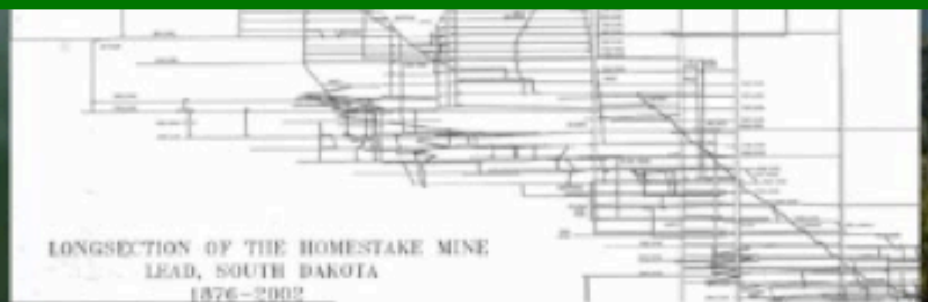
The Homestake Deep Underground Science and Engineering Laboratory

Kevin T. Lesko
UC Berkeley
May 2008

South Dakota
Science and Technol
Authority

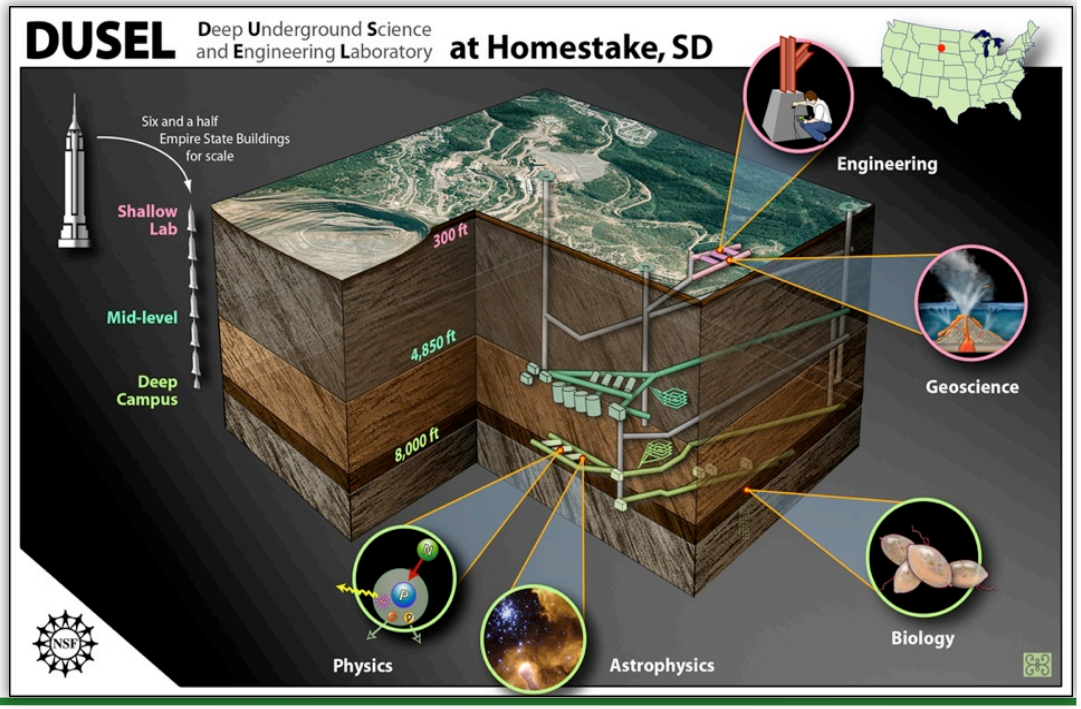
Homestake Mining
Company

Administration Building
630 East Summit Street



Homestake DUSEL Proposal

- NSF's Major Research Equipment and Facility Construction Effort
  - Facility
  - Initial Suite of Experiments
- Multidisciplinary
  - Physics
  - Geology
  - Biology
  - Engineering
  - Education



***See Jose Alonso's Sanford Lab poster

Process and Progress

- DUSEL Three-Step Process
  - S-1: Assess the Science -- Deep Science ✓
  - S-2: Produce Site-specific Conceptual Designs ✓
  - S-3: Select a site -- Homestake ✓
    - $15M - 3 year planning grant with UCB, **funded**
- DUSEL Proposal
  - Recommendation to Advance to ***Readiness***
    - Producing Preliminary Design
    - Define & Integrate Initial Suite of Experiments
  - Construction estimated at ~$500 - 600M
  - 6 - 8 year construction phase

Community Activities

www.deepscience.org

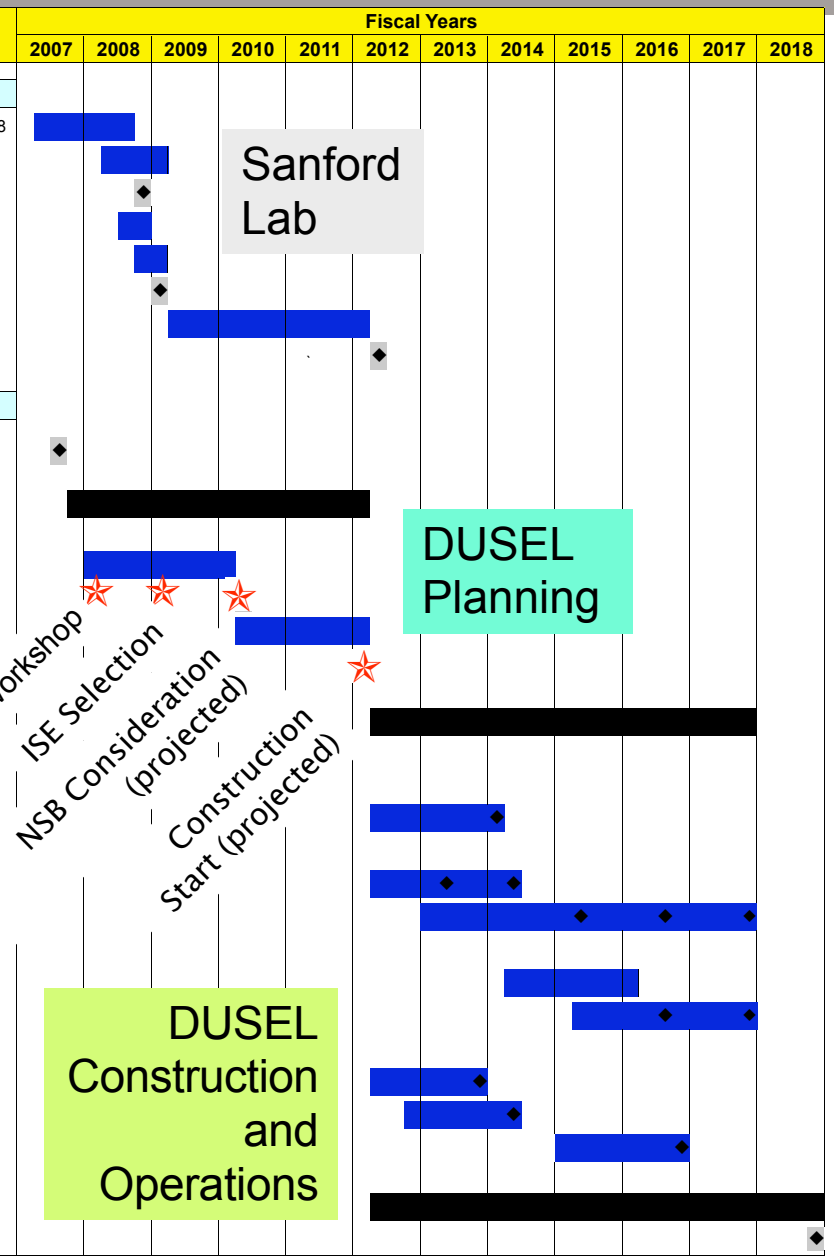
- S-1: culminated in Deep Science
  - November 2007 Town Meetings
- DUSEL Experiment Development Committee (DEDC) Follows on from S-1
  - Steve Elliott (LANL) Phys
  - Derek Elsworth (Penn State) Geo/Eng
  - Daniela Leitner (LBNL) Phys
  - Larry Murdoch (Clemson) Geo/Eng
  - T.C. Onstott (Princeton) Geo/Bio
  - Hank Sobel (UCI) Phys

The Next Round of NSF Solicitations

- S-4: Develop Superset of Experiments
  - Provide $15M over 3 years to develop experimental plans (preliminary designs)
  - To be announced soon, funding in Oct 2008
  - Open to all disciplines
- April Homestake Workshops began defining Initial Suite Experiments Proposals
- S-5: Select Initial Suite of Experiments
  - S-4 is neither necessary nor sufficient
  - There are additional “on ramps” for experiments other than NSF “S-x” solicitations

Milestone Schedule

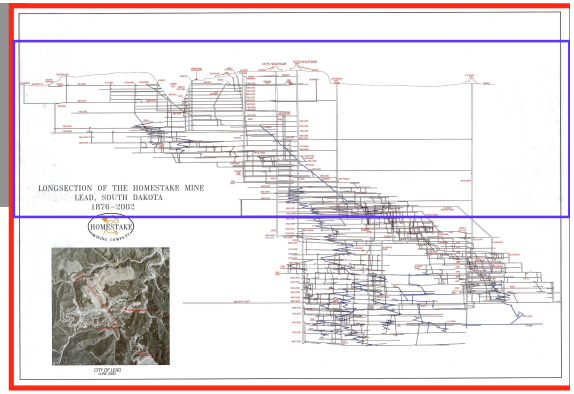
Proposed Timeline for Sanford Laboratory and DUSEL	Start	Finish
Sanford Laboratory at Homestake		
Ross Shaft Rehab and Pumping Column Commissioning	Jan-07	May-08
Yates Shaft Rehab.	Mar-08	Dec-08
Gain safe access to 4850L for EIP construction start, and hold water level at 5000L		Jun-08
Install facility infrastructure for Davis Lab early experiments	May-08	Sep-08
Install and commission research instrumentation in Davis Lab	Jul-08	Dec-08
Early experiments in Davis Lab ready for operation		Dec-08
Continued rehabilitation and infrastructure upgrades for Sanford Lab		Dec-11
Transition from Sanford Lab to DUSEL Operations		Jan-12
NSF Deep Underground Science and Engineering Laboratory at Homestake		
Homestake site selection announcement		Jul-07
DUSEL Preconstruction Planning and Development (R&RA)	**Oct-07**	**Dec-11**
Preliminary Design Phase to develop Baseline Cost and Schedule	Oct-07	Dec-09
Preliminary Design Review and National Science Board Recommendation		Mar-10
Final Design Phase	Mar-10	Dec-11
Final Design Review and Authorization for Construction Start		Dec-1
DUSEL Facility - Construction and Commissioning (MREFC)	**Jan-12**	
Construction Start		-12
Near-Surface Campus Construction at 300L		
300L Laboratories and Education and Outreach Facilities	Jan-12	Dec-13
Mid-Level Campus Construction at 4850 Level		
4850L Common Facilities and Lab Module #1 (Excavation & Lab Build-out)	Jan-12	
4850L Lab Modules #2, #3 and #4	Oct-12	
Deep-Level Campus Construction at 7400 Level		
7400L Common Facilities and Lab Module #1 (Excavation & Lab Build-out)	Jan-14	Dec-15
7400L Lab Modules #2 and #3	Jun-15	Jul-17
Surface Campus Construction		
Infrastructure to support Underground Construction and Operations	Jan-12	Sep-13
Phase 1 Offices and Laboratories	Jul-12	Mar-13
Phase 2 Offices and Laboratories	Oct-14	Sep-16
DUSEL Initial Suite of Experiments - Construction and Commissioning	**Jan-12**	**Sep-18**
MREFC Construction Finish		Sep-18

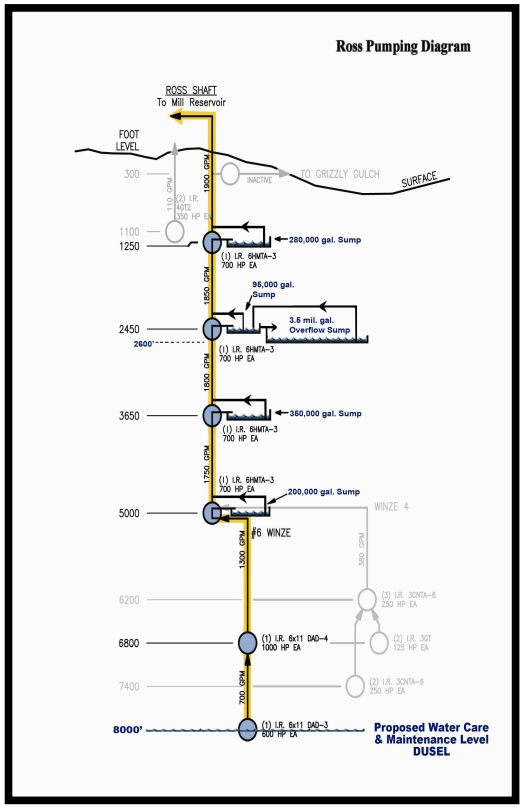


Progress at the Sanford Lab

- ☑ October 2005, State Legislature approves additional $20M funding for Homestake, total of $46M
- ☑ Property Donation Agreement Completed 14 April 2006, Property transfered May 2006,
- ☑ June 2006 $70M Sanford Gift, $15M gifted '07
- ☑ January 2007 Rehab initiated, $60M in hand
- ☑ October 2007 SDSTA Hires Jose Alonso, Lab Director, additional Key Staff, SDSTA hiring staff to oversee and operate Homestake: ~30 for rehab, ~ 25 to 30 staff
- ☐ Early Implementation Program at Homestake 2008 - 2012 "The Sanford Laboratory"

Progress at the Sanford Lab

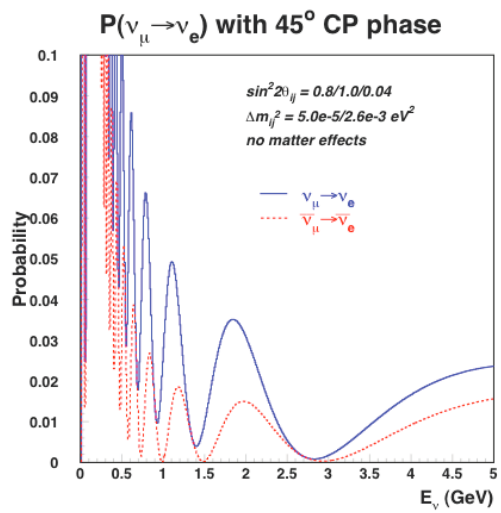




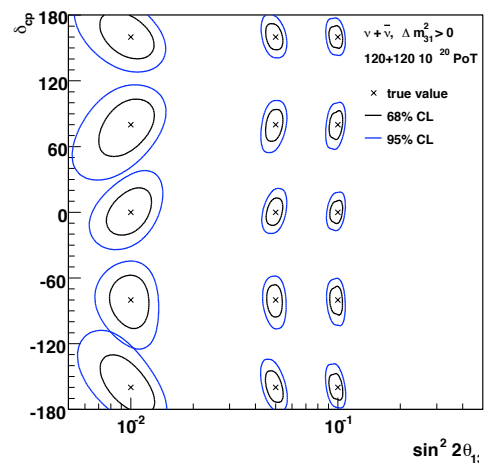
- Focusing on re-gaining access and stabilizing facility
- Pumped ~4M Gal in May
- Routine pumping in June
- Access to 4850L by Sept
- Upper Level Experimental Program Initiated
  - Geology, Seismology, Geochemistry, Geomicrobiology
- Science at 4850L by Dec
  - Dark Matter, 0νββ, low seismic R&D…

Long Baseline ν, Nucleon Decay, and Associated Programs

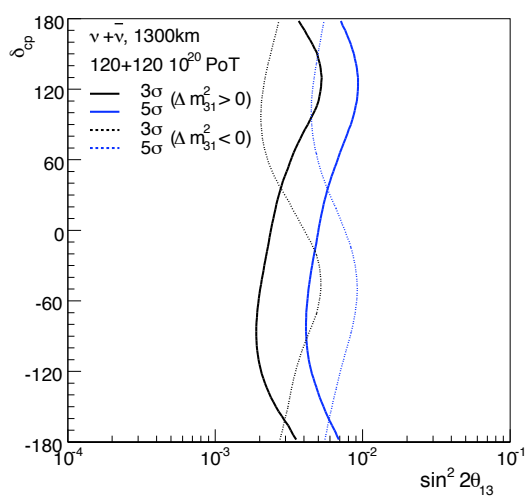
- Long Baseline Neutrinos
- Nucleon Decay
  - Same detectors
- Discovery Potential
  - Neutrino mass hierarchy
  - θ_{13}
  - CP violation
  - Nucleon decay
- Diverse Program
  - Full MNSP matrix
  - Atmospheric and solar neutrinos
  - Supernovae neutrinos



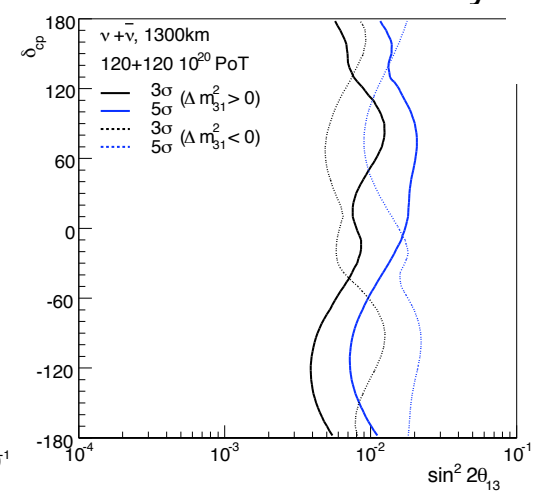
CP Violation



θ_{13}



Mass Hierarchy

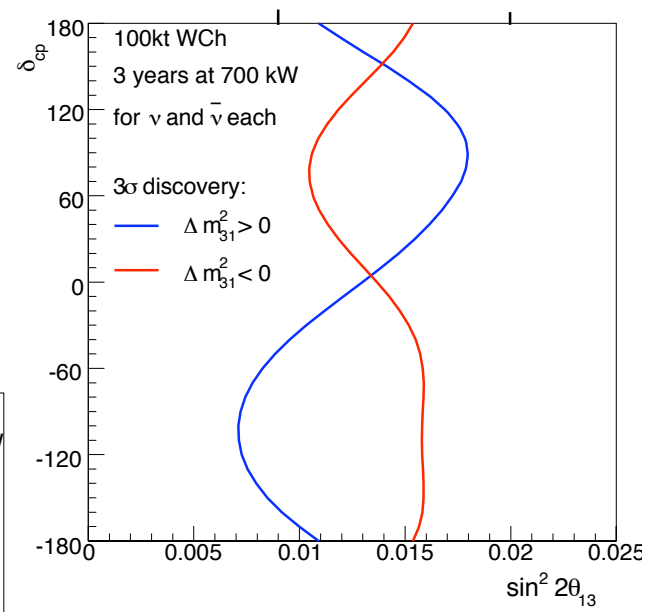


Beginning with 100-kt Water Cherenkov Detector & 700kW FNAL Beams@120 GeV 3 years each $\nu+\bar{\nu}$

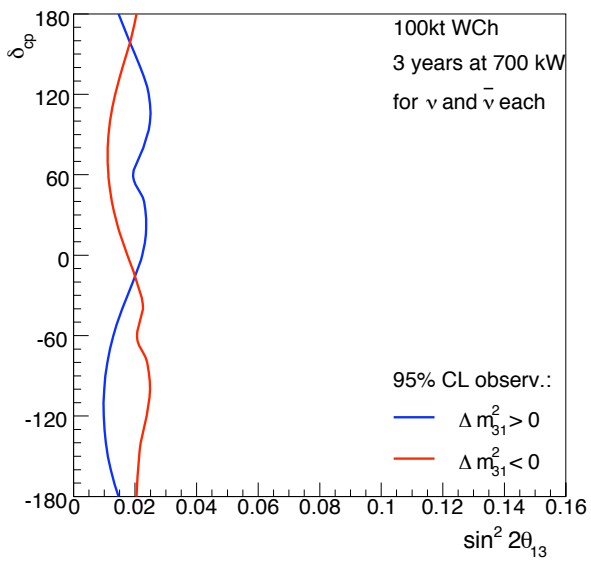
1kt LAr ≈ 3kt H_2O

18×10^{20} POT each

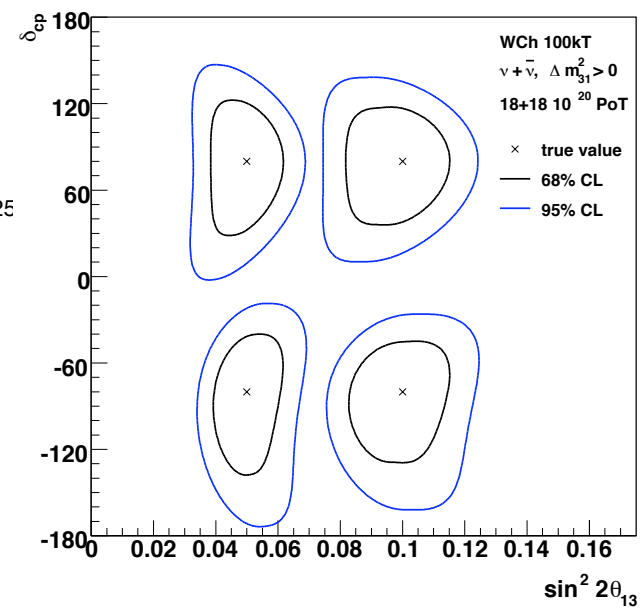
Θ_{13}



Mass Hierarchy



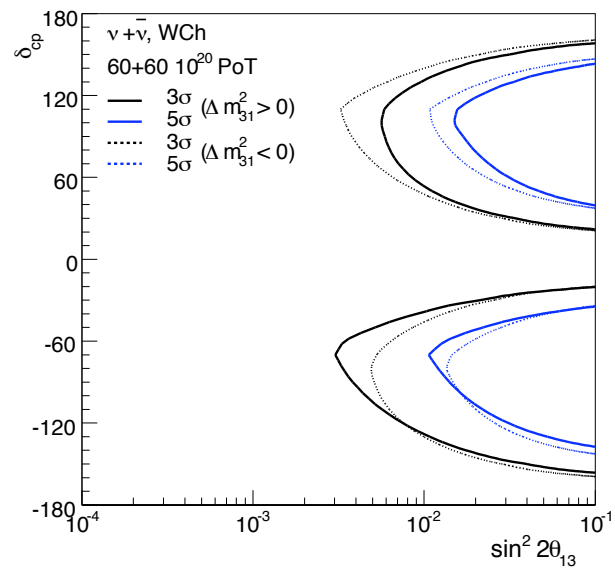
Determination of CP Phase



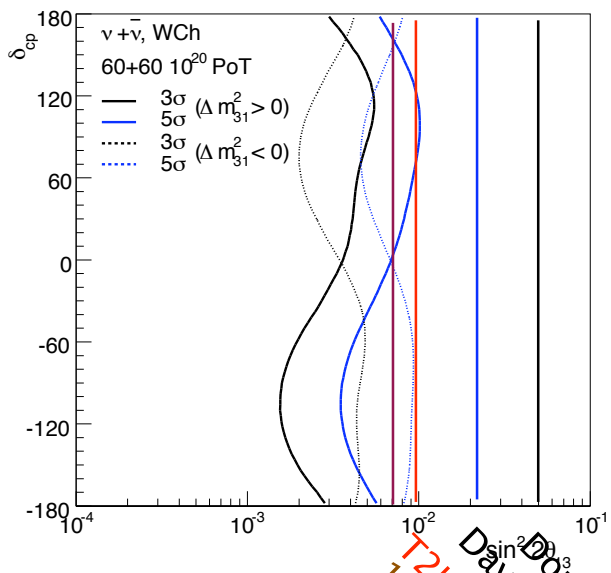
from Mark Dierckxsens
Milind Diwan
Mary Bishal

Physics with 300-kt Water Cherenkov Detector & 2 MW Beams @ 120 GeV 3 years each $\nu+\bar{\nu}$

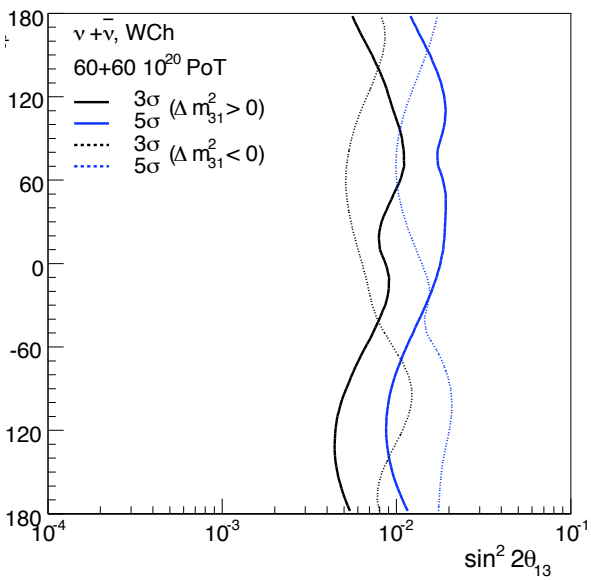
Exclusion of CP Violation



Θ_{13}



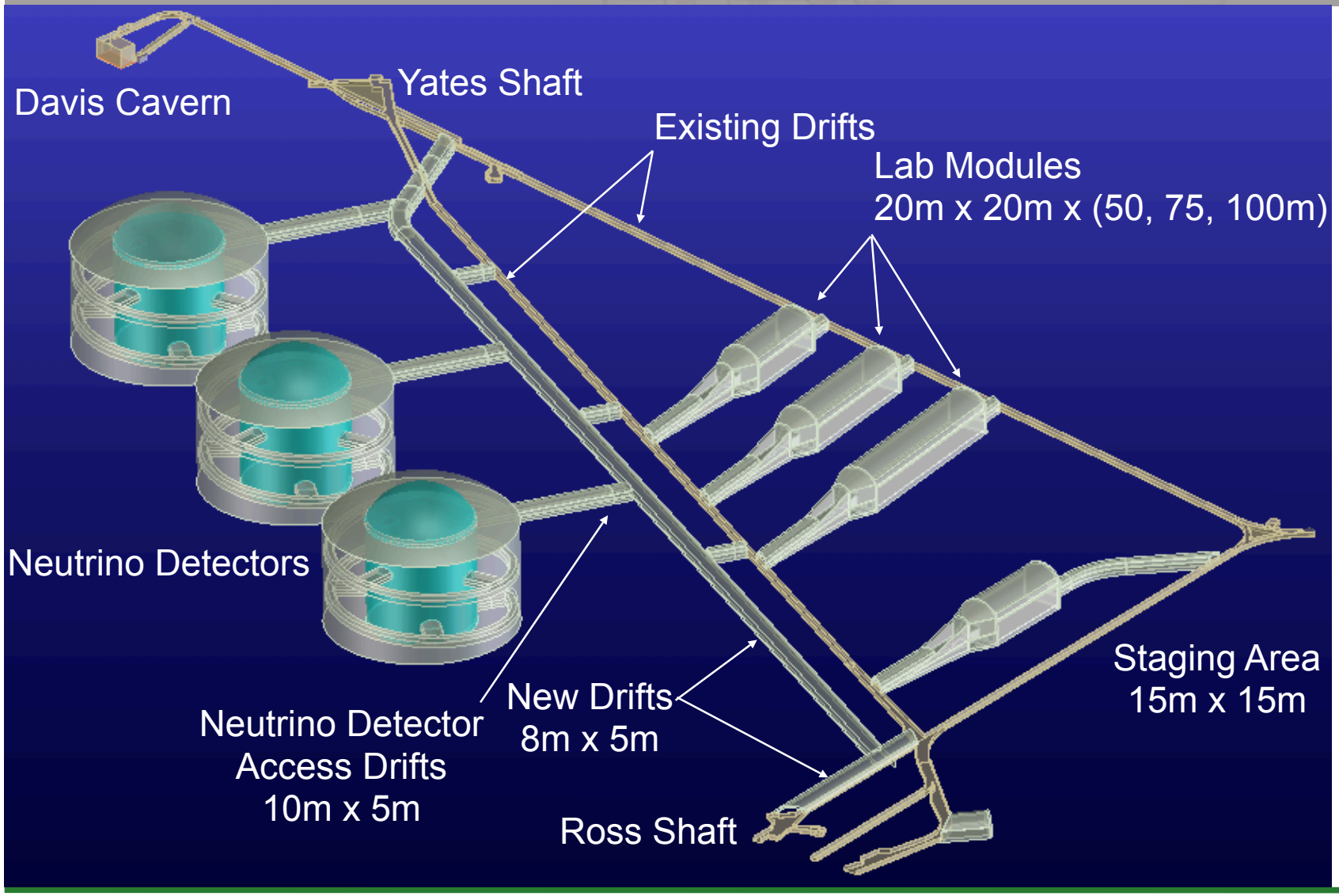
Mass Hierarchy



Double Chooz 2012
Daya Bay 2013
NOvA 201
NOvA 2017
T2K 2012
100kt LAr DUSEL

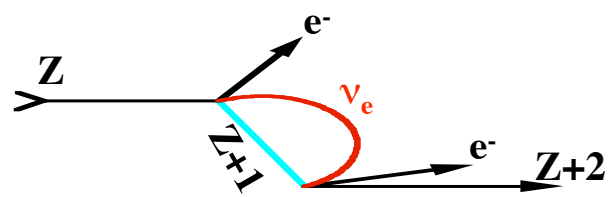
60×10^{20} POT each

4850 Level Conceptual Layout



Neutrinoless Double Beta Decay

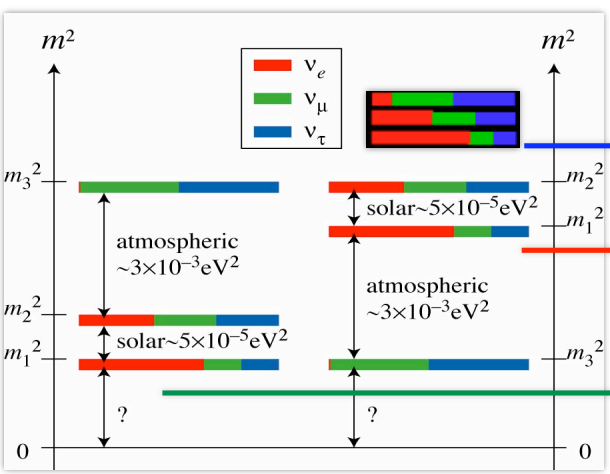
- Well Motivated by ν Oscillation Experiments & Theory
  - Absolute ν mass scale
  - ν Mass hierarchy
  - Dirac or Majorana Nature of ν
  - Even null results are valuable



$$n \Rightarrow p + e^- + \bar{\nu}_e$$

(RH $\bar{\nu}_e$) (LH ν_e)

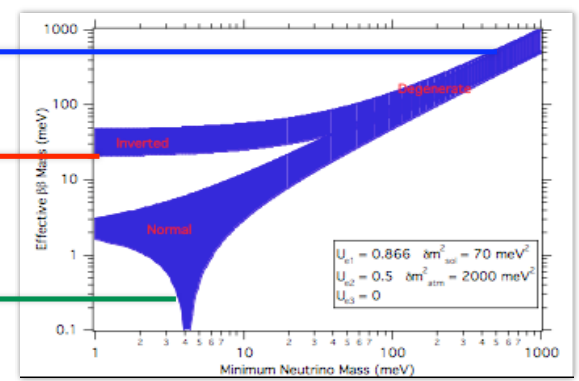
$$\nu_e + n \Rightarrow p + e^-$$



Degenerate

Inverted

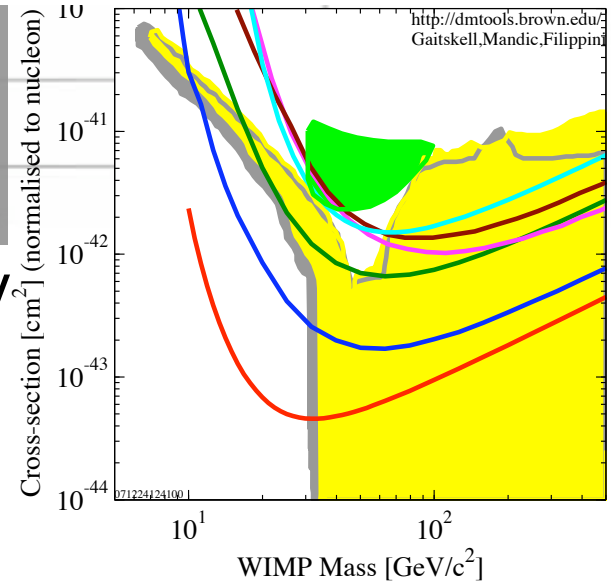
Normal

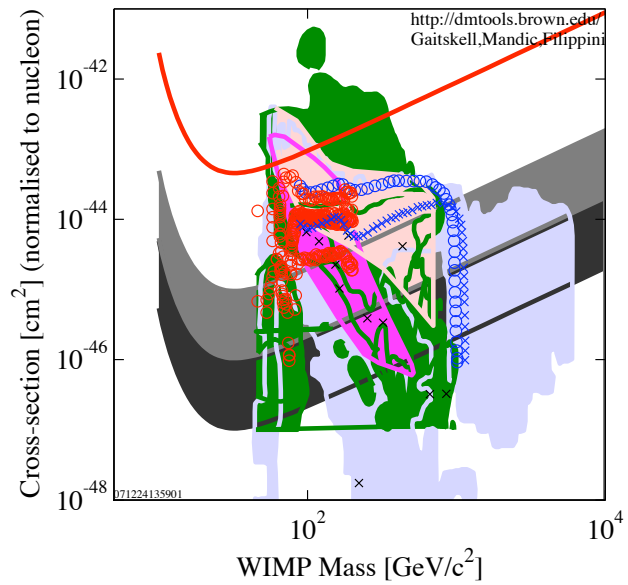


– $[T^{0\nu}_{1/2}]^{-1} = G^{0\nu}(E_0,Z)\,|\langle m_\nu \rangle|^2 \quad |M^{0\nu}_F - (g_A/g_V)^2 M^{0\nu}_{GT}|^2$

Direct Dark Matter Searches

- Strong science motivation for discovery
  - Convergence of particle and astrophysics theory/experiment
- Significant recent advancements in sensitivity
- Direct searches testing physics complementarity to accelerator work
  - Also indirect/astro signal searches
- Flagship science at DUSEL
  - DUSEL will ensure continued progress as experimental program requires reduced backgrounds

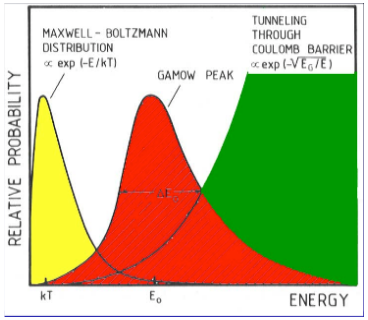


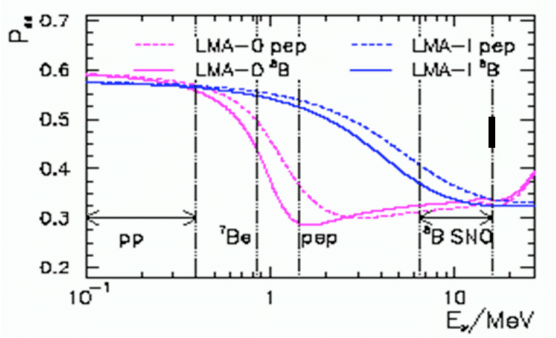


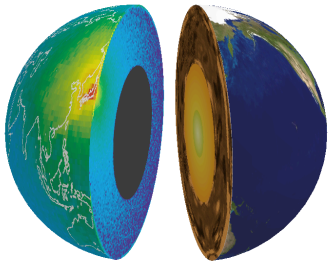
figures from Town Meeting DM working group

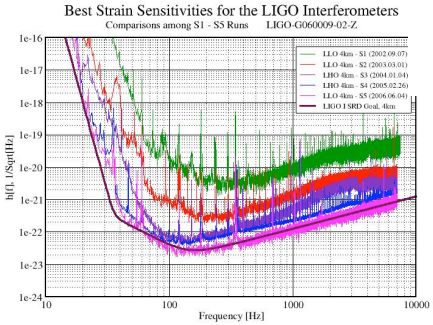
Research in Targeted Fields of Opportunity

- Solar Neutrinos
- Nuclear Astrophysics
- Gravity Waves
- Geoneutrinos
- Atom Interferometry
- Nucleon-oscillations
- ...









$$i\hbar\frac{\partial}{\partial t}\begin{pmatrix} n \\ \bar{n} \end{pmatrix} = \begin{pmatrix} m+V_1 & \delta \\ \delta & m+V_2 \end{pmatrix}\begin{pmatrix} n \\ \bar{n} \end{pmatrix}$$

Concepts for Initial Suite of Experiments - to be revised with community based program

Dark Matter (6-8)
- Sanford Lab
- 4850L
- 7400L

Neutrinoless ββ Decay (2 - 3)
- Sanford Lab
- 7400L

Long Baseline ν & Nucleon Decay (2)
- 300L
- 4850L

Nuclear Astrophysics (2)
- 4850L

Geoneutrinos (1)
- 4850L

LE Solar ν (2)
- 4850L
- 7400

Gravity Waves (1)
- 2000L

Engineering and Excavation Research
- 4850L
- 7400L

Scale Effects
- 4850L
- 7400L

Active Processes
- 4850L
- 7400L

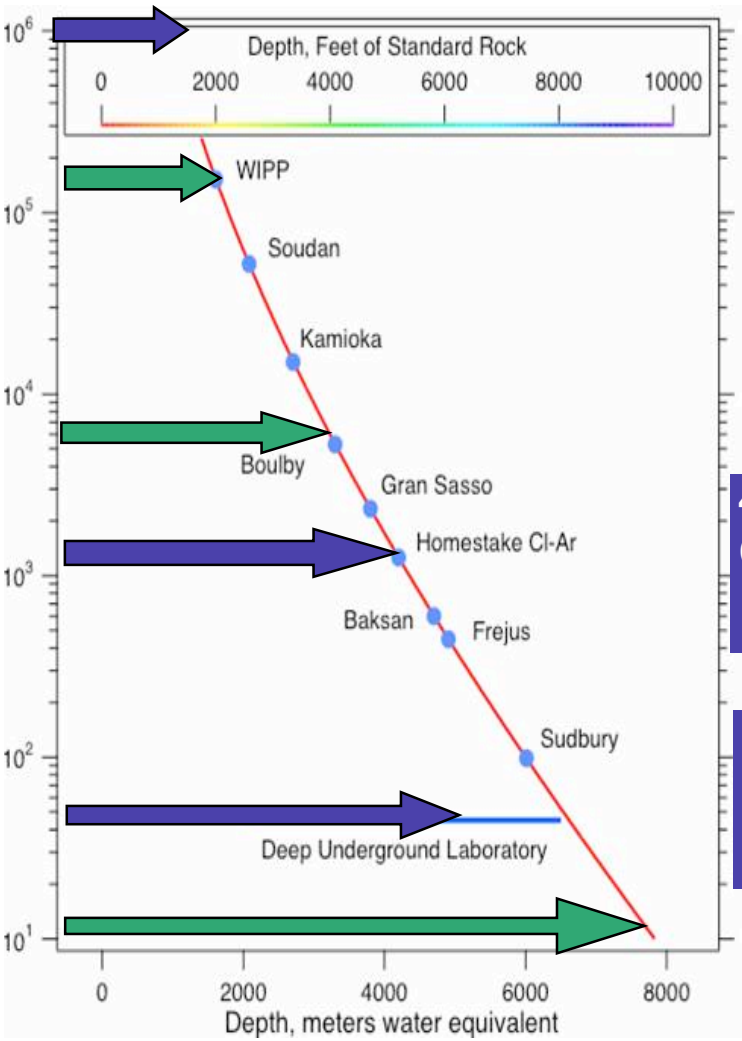
Geobiology
- 0 - 16,000

Low Background Assay & Materials
- 300L
- 4850L

R&D Efforts
- Surface
- 300L
- 4850L
- 7400L

Education & Outreach
- Surface
- 300L

Homestake Research Campuses



300L R&D, E&O 10k ft^2

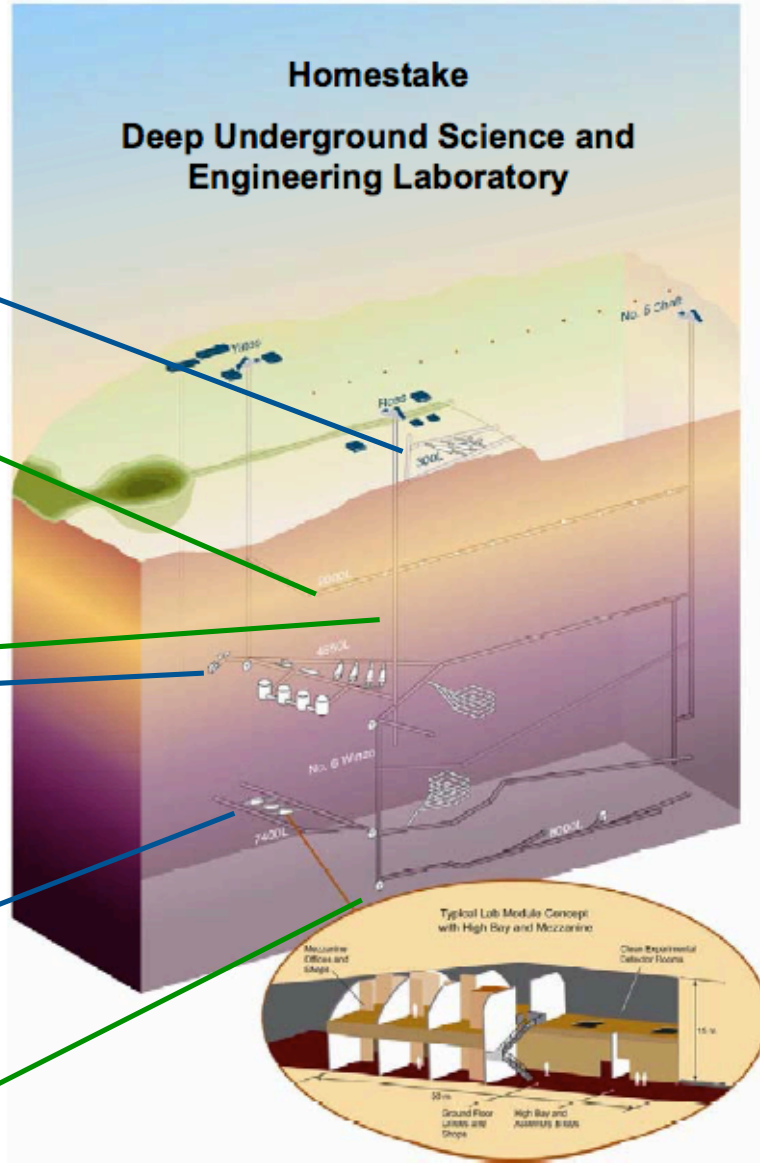
2000L Geo Level

3800L Geo Level

4850L Major Campus 100k ft^2

7400L Major Campus 65k ft^2

8000L Geo Lab

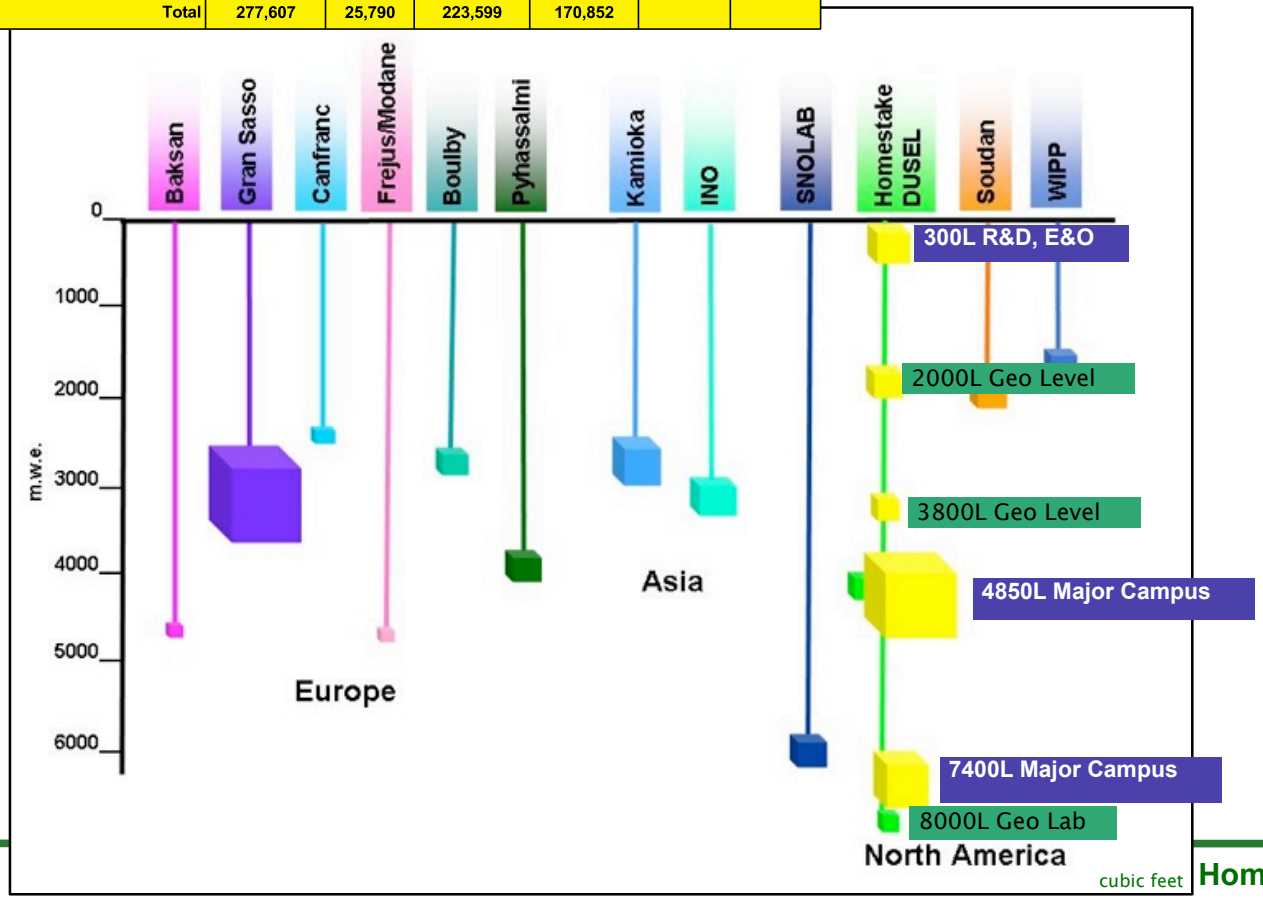


Details of the Conceptual Design at www.lbl.gov/nsd/homestake

Research Campuses

Homestake Interim Lab and DUSEL Summary of Development of Space and Availability (Underground Space Fully Outfitted and Ready for Detector Installation)	Labs, Shops, Offices Usable Floor Area		Excavation Volume (including access drifts)		Construction Schedule	
	sq. ft.	sq. m.	cu. yd.	cu. m.	Start	Finish
4850 Level Subtotal	**107,351**	**9,973**	**111,115**	**84,903**		
Ross Shops for Construction Staging	12,469	1,158	5,738	4,385	Apr-08	Dec-08
Davis Lab, Sanford Lab, and Bio-Geo Lab	15,738	1,462	13,543	10,348	Sep-08	Jul-09
Lab Module #1 and Common Facilities	26,464	2,459	25,155	19,221	Oct-10	Sep-12
Lab Module #2	17,560	1,631	21,433	16,377	May-11	Apr-13
Lab Module #3	17,560	1,631	23,121	17,667	Sep-13	Jul-15
Lab Module #4 (excavation only, without lab outfitting)	17,560	1,631	22,125	16,906	Aug-14	Jul-15
7400 Level Subtotal	**63,588**	**5,907**	**98,477**	**75,246**		
Lab Module #1 and Common Facilities	28,468	2,645	29,594	22,613	Jan-12	Mar-14
Lab Modules #2 and #3 (excavation only, without lab outfitting)	35,120	3,263	68,883	52,633	Dec-12	Jan-14
300 Level Subtotal	**8,668**	**805**	**14,007**	**10,703**		
Lab #1, Shops, and E&O Rooms	8,668	805	14,007	10,703	Nov-10	Nov-11
Surface Subtotal	**98,000**	**9,104**				
DUSEL Offices and User Support Areas,Phase 1	10,000	929			Dec-10	Jun-12
Sanford Clean Room and Assembly Shop	6,000	557			Dec-10	Jun-12
DUSEL Offices and User Support Areas,Phase 2	32,000	2,973			Jul-11	Jun-13
Sanford Center for Science Education	50,000	4,645			Sep-09	Sep-11
Total	**277,607**	**25,790**	**223,599**	**170,852**		

Estimates exclude Mega Cavities



Summary

- World-class Research Programs
- Unique Capabilities
- Transformational Experiments being Developed
  - Dark Matter
  - Neutrinoless Double Beta Decay
  - Long Baseline Neutrinos + Nucleon Decay
  - Other Topics and Disciplines
- Efforts underway at Sanford Lab to prepare the site ($115M) parallel to DUSEL efforts
  - phased program for experiments
- Long-term, Reduced Risk, Well-known Site
  - tailored access
  - 30+ year horizon, providing critical u/g space
  - no competition from other interests