

The Homestake Deep Underground Science and Engineering Laboratory

Kevin T. Lesko
UC Berkeley
June 2008



South Dakota
Science and Technol
Authority

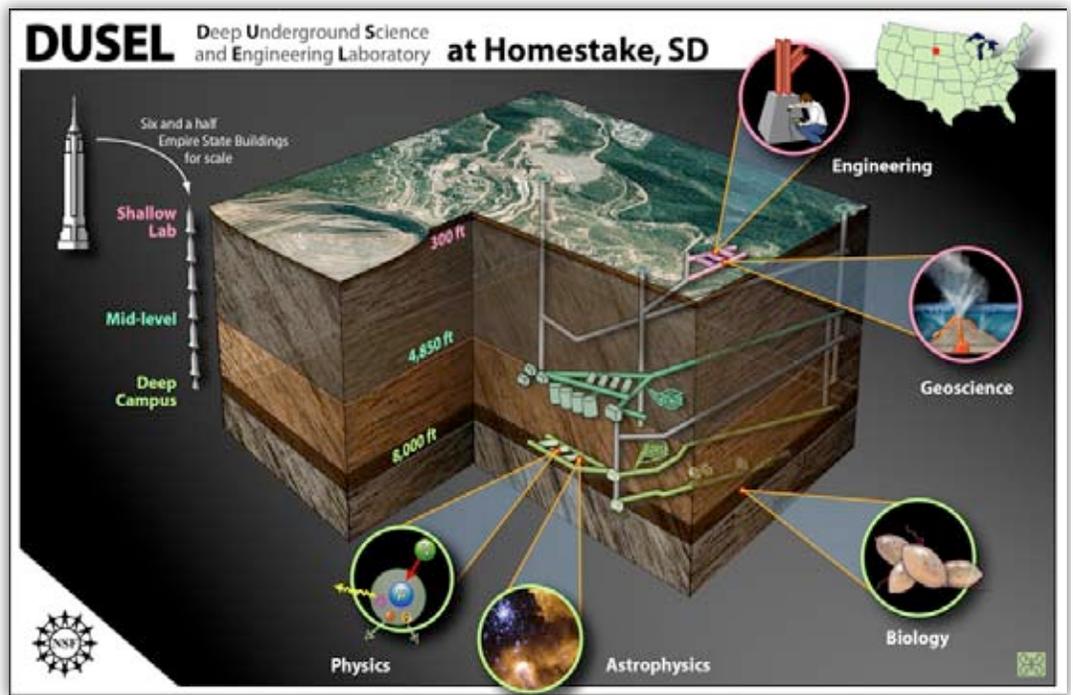
Homestake Mining
Company

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



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

- 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



www.deepscience.org



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 Workshop 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: R&D, DOE, etc.

S-4, DEDC, April Workshops, WGs

- Long Baseline & Neutrino Decay Working Group
 - Bob Svoboda, University of California at Davis, GL
 - S-4 Proposal
 - Suggests a single proposal uniting Water Č and LAr design efforts
 - Is this the right approach for S-5?
 - How do we integrate in other funding sources?
 - How do we handle the different time scales to physics?
 - How do we integrate and coordinate the beam-line efforts?
- Facility team is preparing for a large cavity during initial construction phase
 - In light of the P5 report the need for DOE/NSF cooperation is highlighted

Homestake HE Neutrino Physics S-4 Proposal

- Will describe a Coherent Program in Neutrino Physics encompassing FNAL beam, Proton Decay, Diffuse Relic Supernova measurement, Supernova physics.
- Will focus on 100 kT water Cerenkov detector and 5+25 kT LAr detector as baseline plan.
- S-4 will call for a three year program of cavern and facility engineering studies plus detector characterization and optimization.
- S-4 is NSF part of joint program that will require DOE support and help from {Sanford Lab}.
- S-4 will be the vehicle for organization of a Homestake Large Neutrino Detector Collaboration
- S-5 Milestone – to be defined

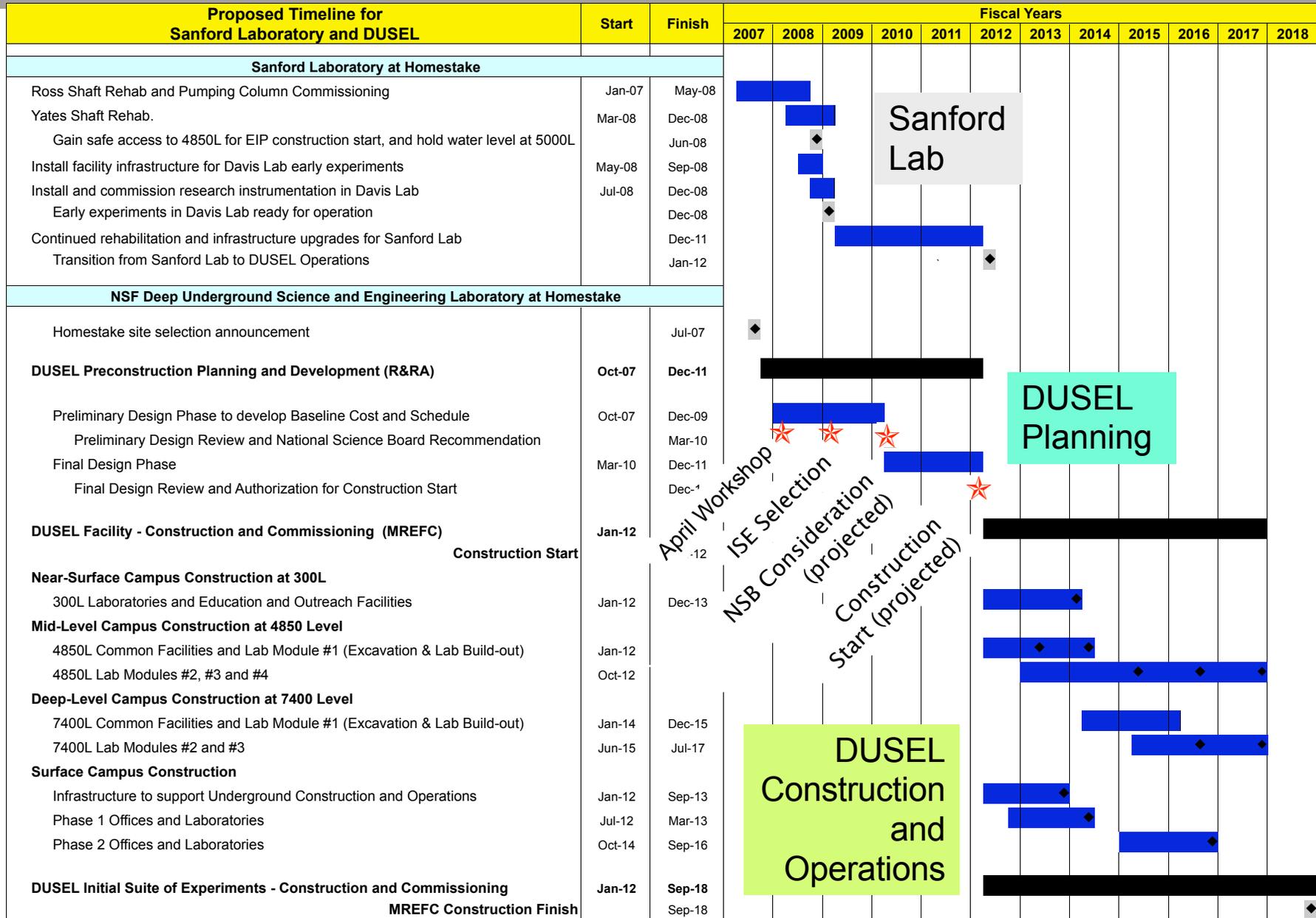
R. Svoboda

- The group strongly recommends that the pending DUSEL R&D proposal for rock coring studies be pursued with high priority and extended to include LAr site.
- There will be a first meeting at FNAL: **JUNE 20th 2008** to form an S-4 Collaboration, extend the size of the group, and set up working groups.
- Collaboration Naming contest is underway

Significant Milestone for Initial Suite of Experiments

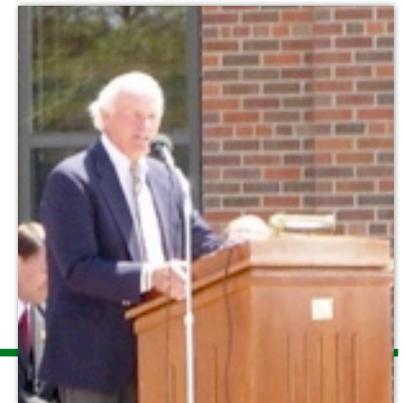
- November 2007 Town Meeting
- ★ ● April 2008 Lead Workshops
- Late Spring S-4 Solicitation Announcement
- July 2008 Internal Review of DUSEL
- Fall 2008 S-4 Funds for Experiment PDRs
- December 2008 NSF Review of DUSEL
- ★ ● Summer 2009 Review of ISE by NSF Panel
- Summer/Fall 2009 Integration ISE and Facility
- Fall 2009 Completion of DUSEL PDR & Review
- ★ ● Winter 2009-10 Presentation to and Review by NSF
- March 2010 Presentation to NSB
- ★ ● FY2012 MREFC funding (projected)

MREFC Milestone Schedule



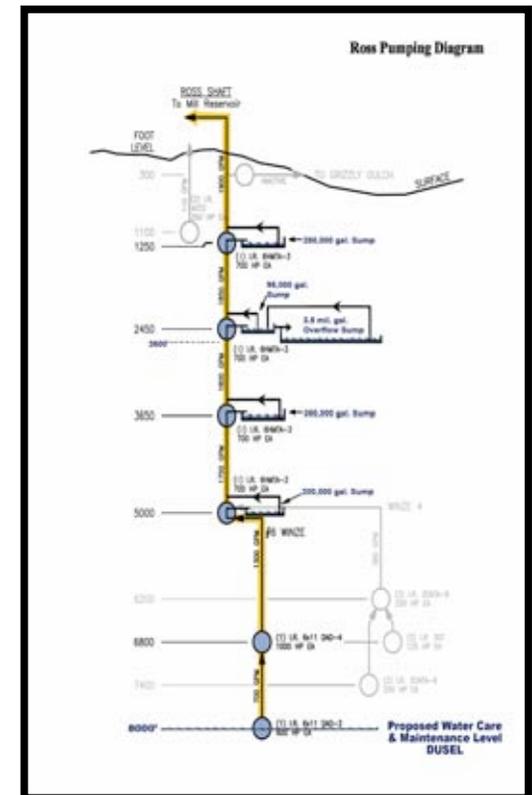
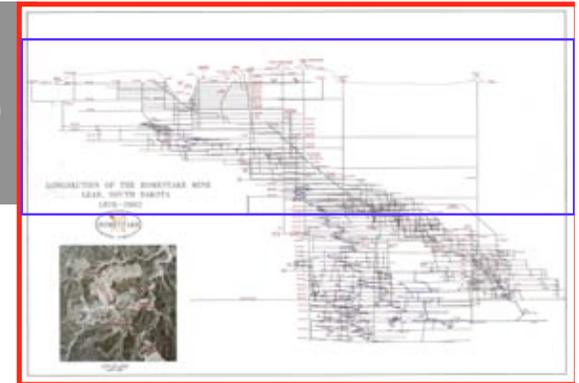
Progress at the Sanford Lab

- ☑ October 2005, State Legislature approves additional \$20M funding for Homestake, total of \$46M
- ☑ Property Donation Agreement Completed
14 April 2006, Property transferred 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”



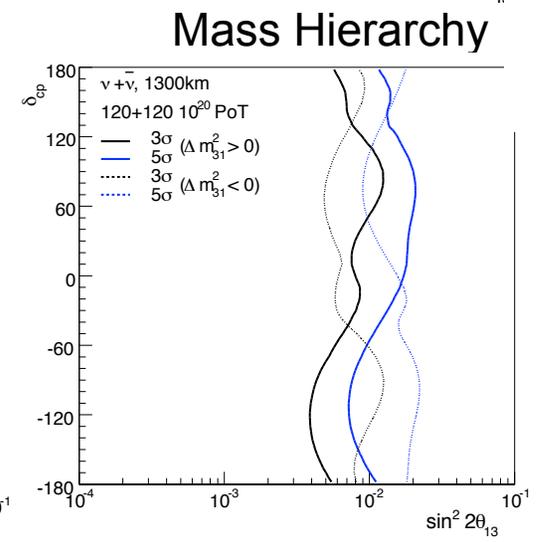
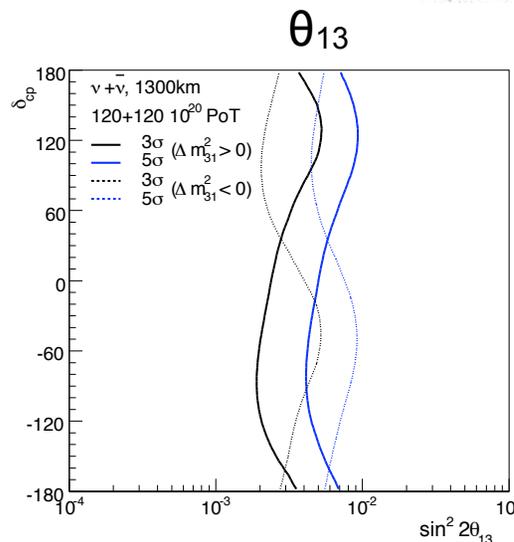
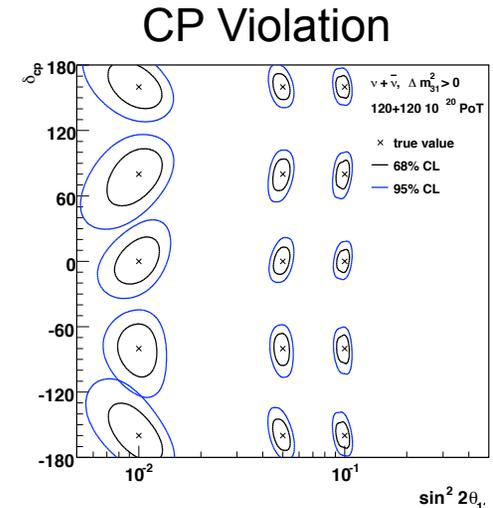
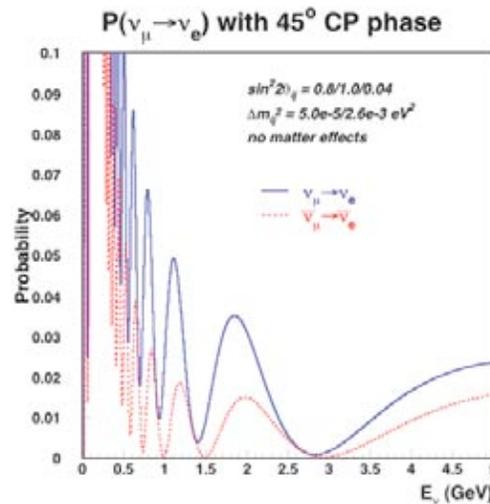
Progress at the Sanford Lab

- Focusing on re-gaining access and stabilizing facility
- Pumped ~4M Gal in May
- Routine pumping in June
- Access to 4850L by September
- Upper Level Experimental Program Initiated
 - Geology, Seismology, Geochemistry, Geomicrobiology
- Science at 4850L by Dec
 - Dark Matter, $0\nu\beta\beta$, 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 vs
 - Supernovae neutrinos
 - Relic SN vs
 - Exotics, Unexpected

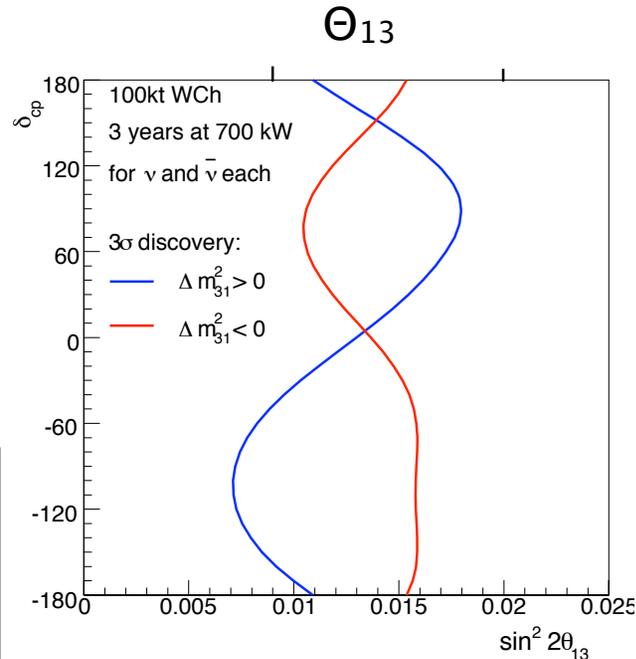
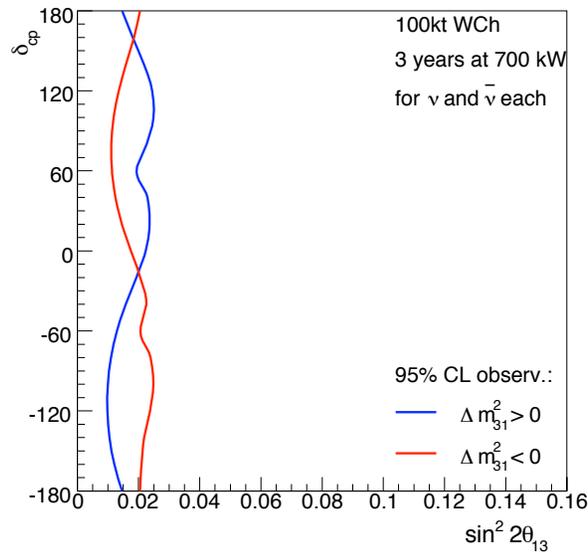


Beginning with 100-kt Water Cherenkov Detector & 700kW FNAL Beams@120 GeV 3 years each $\nu+\bar{\nu}$

1kt LAr \approx 3kt H₂O

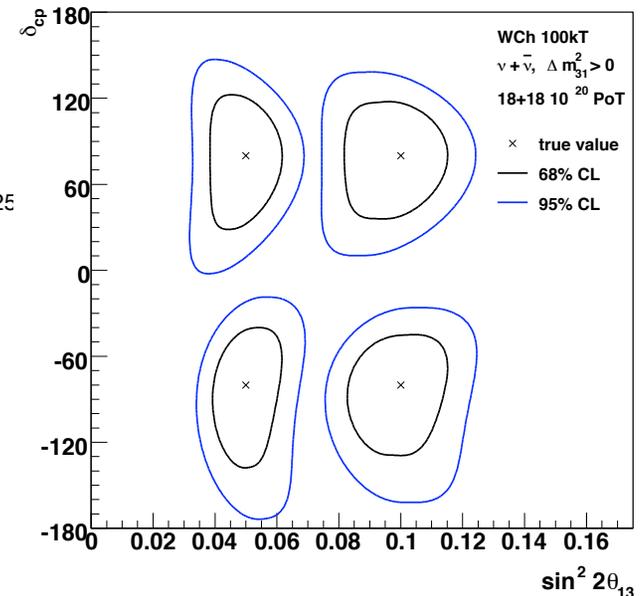
18x10²⁰ POT each

Mass Hierarchy



from Mark Dierckxsens
Milind Diwan
Mary Bishal

Determination of CP Phase

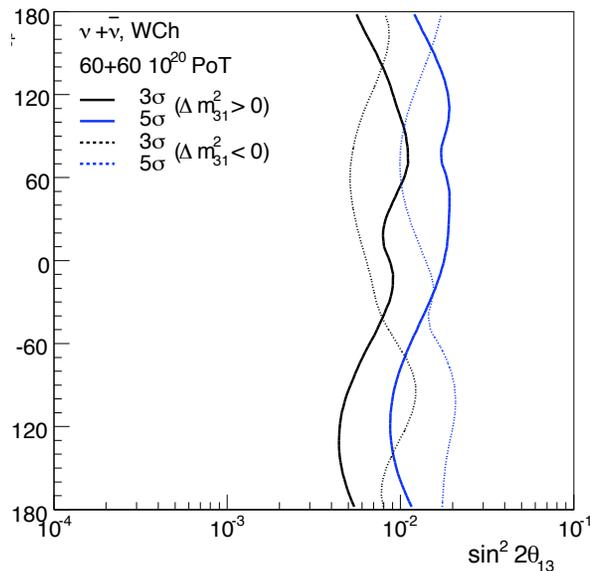


Physics with 300-kt Water Cherenkov Detector & 2 MW Beams @ 120 GeV 3 years each $\nu+\bar{\nu}$

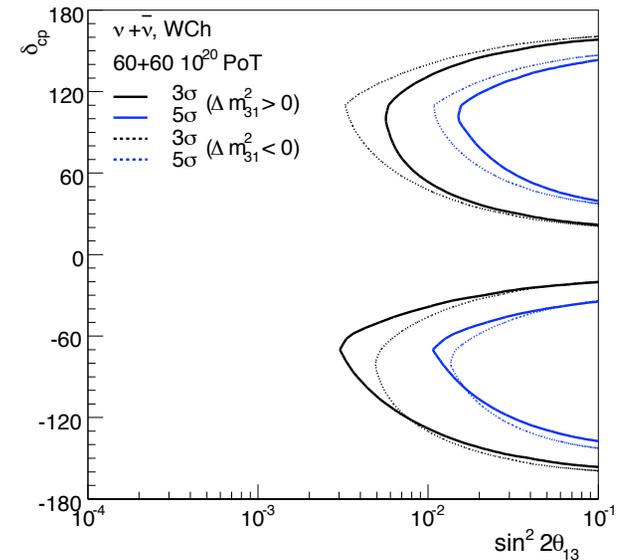
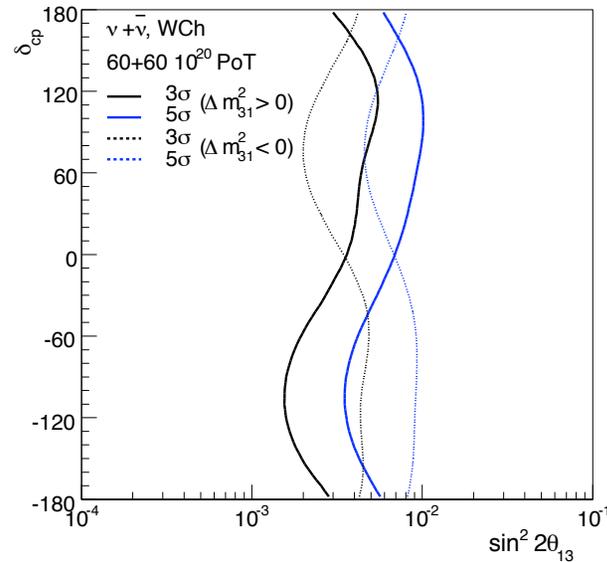
LONGSECTION OF THE HOMESTAKE MINE

Exclusion of CP Violation

Mass Hierarchy



Θ_{13}



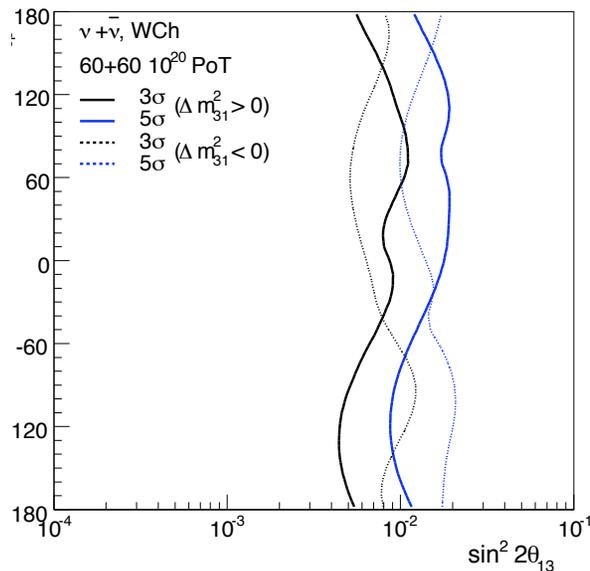
60x10²⁰ POT each

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

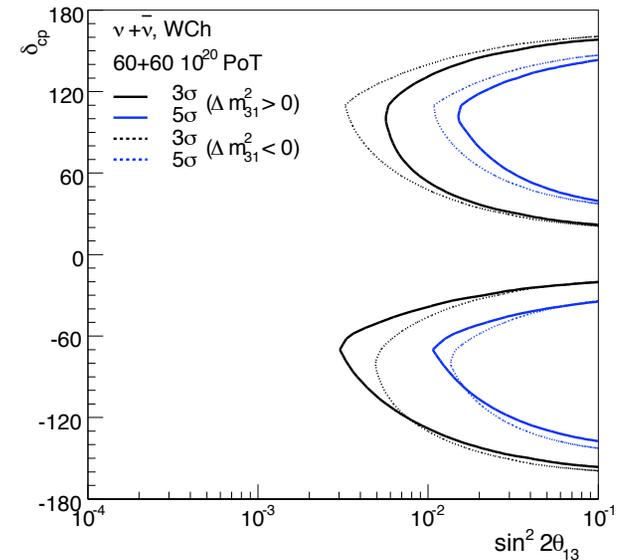
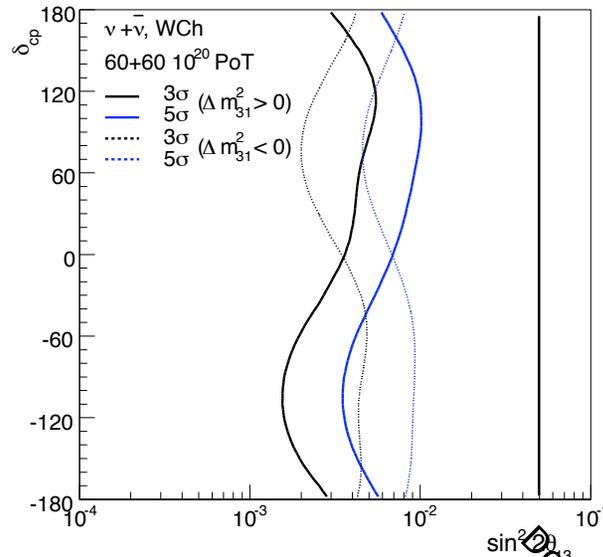
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Exclusion of CP Violation

Mass Hierarchy



θ_{13}



Double Chooz 2012

60x10²⁰ POT each

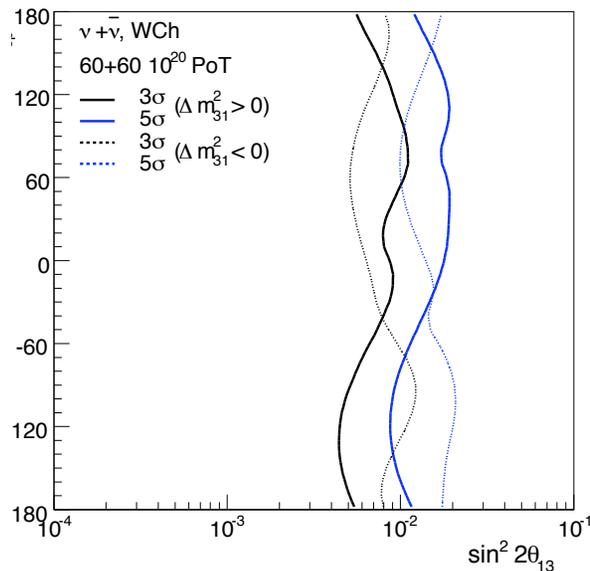
Homestake DUSEL

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

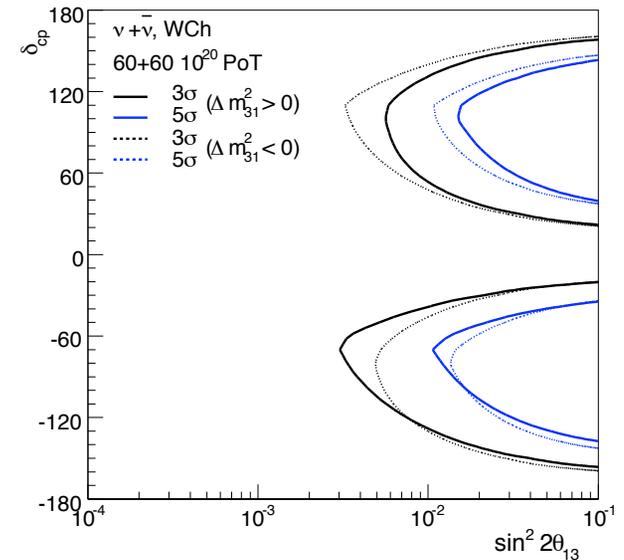
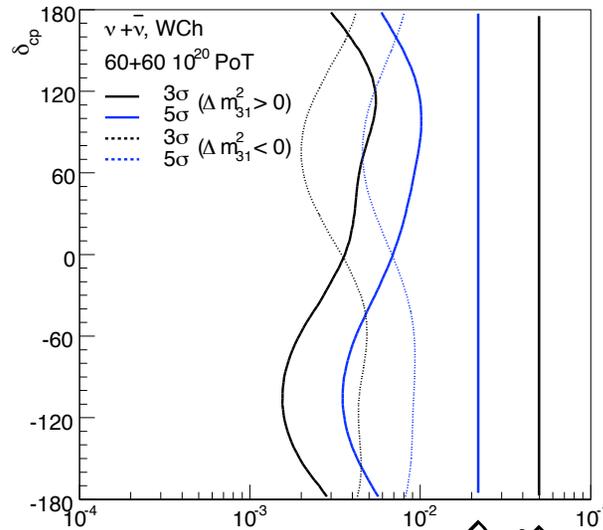
LONGSECTION OF THE HOMESTAKE MINE

Exclusion of CP Violation

Mass Hierarchy



Θ_{13}



sin²θ₁₃
 Double Chooz 2012
 Daya Bay 2013

60x10²⁰ POT each

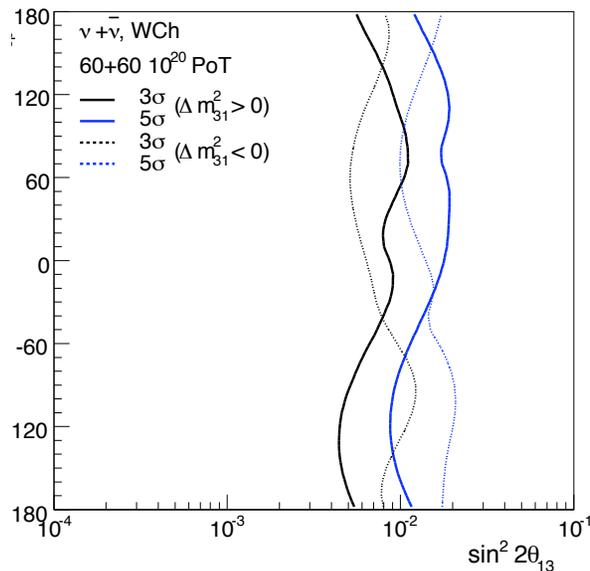
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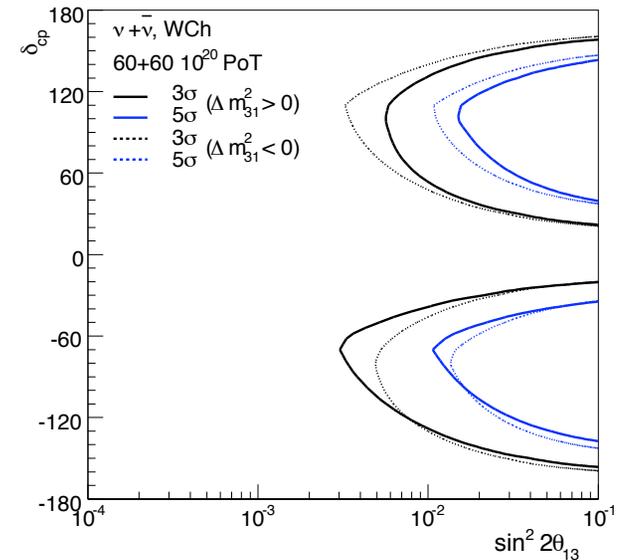
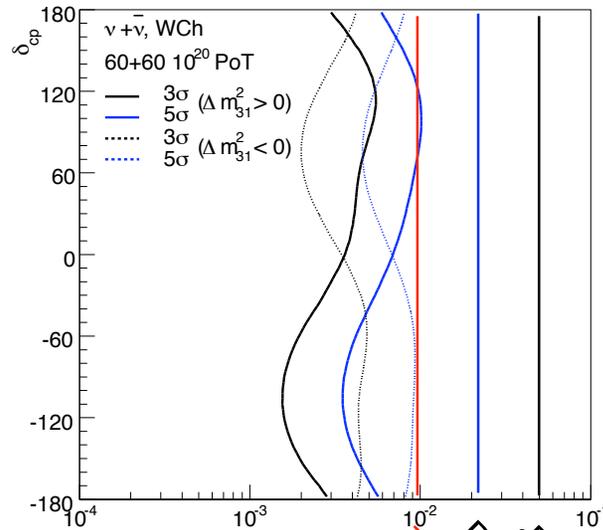
LONGSECTION OF THE HOMESTAKE MINE

Exclusion of CP Violation

Mass Hierarchy



Θ_{13}



$\sin^2 \theta_{13}$
T2K 2012
Daya Bay 2013
Double Chooz 2012

60x10²⁰ POT each

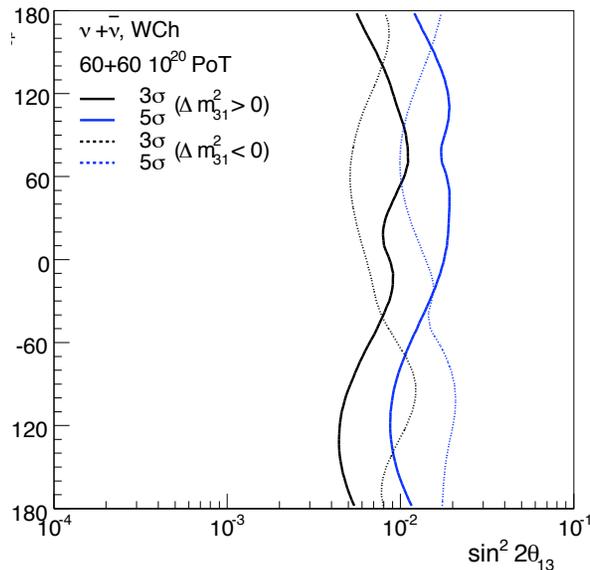
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Physics with 300-kt Water Cherenkov Detector & 2 MW Beams @ 120 GeV 3 years each $\nu+\bar{\nu}$

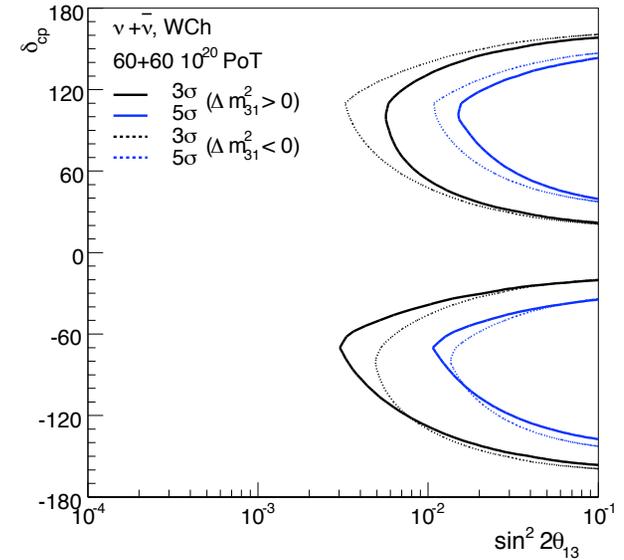
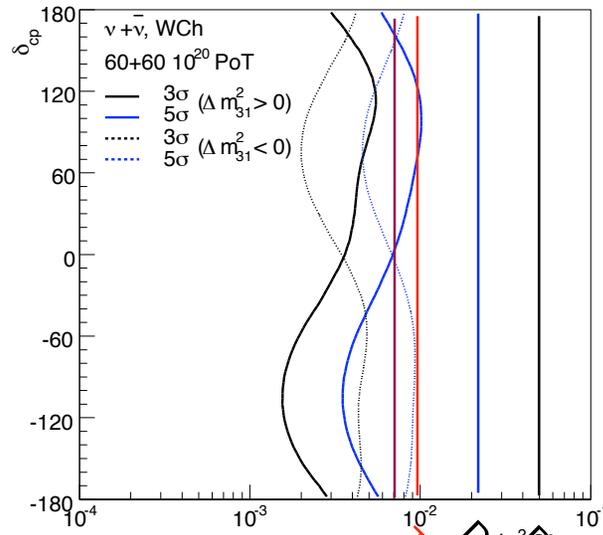
LONGSECTION OF THE HOMESTAKE MINE

Exclusion of CP Violation

Mass Hierarchy



Θ_{13}

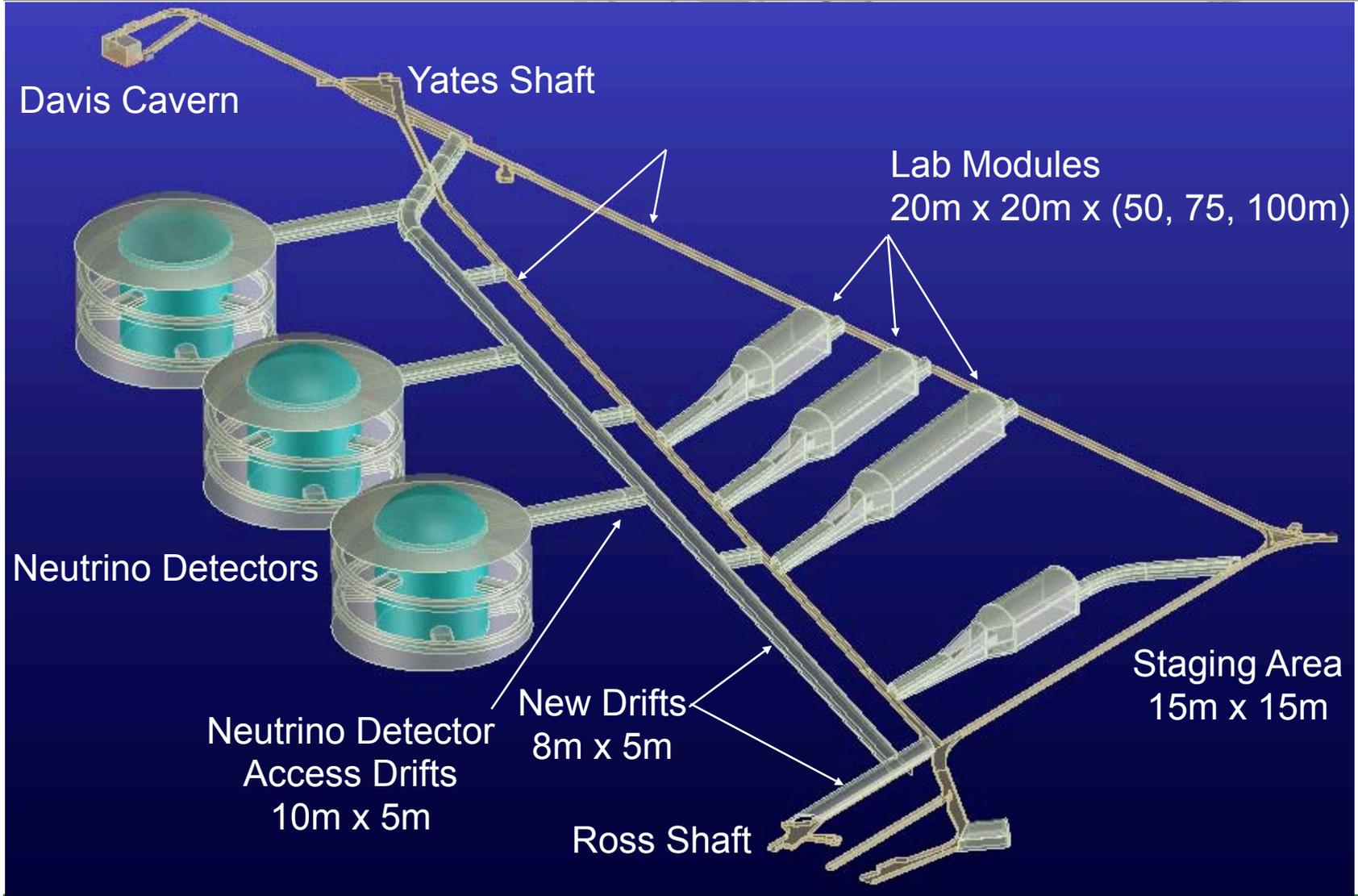


Double Chooz 2012
 Daya Bay 2013
 T2K 2012
 100kt LAr DUSEL

60x10²⁰ POT each

Homestake DUSEL

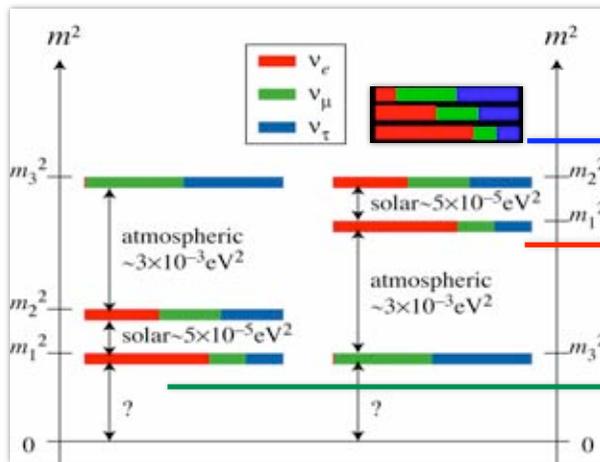
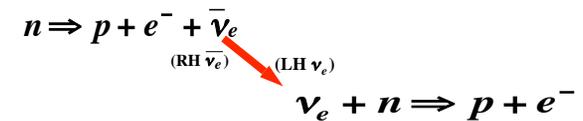
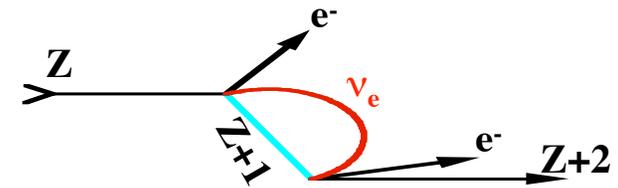
4850 Level Conceptual Layout



Neutrinoless Double Beta Decay

LONGSECTION OF THE HOMESTAKE MINE

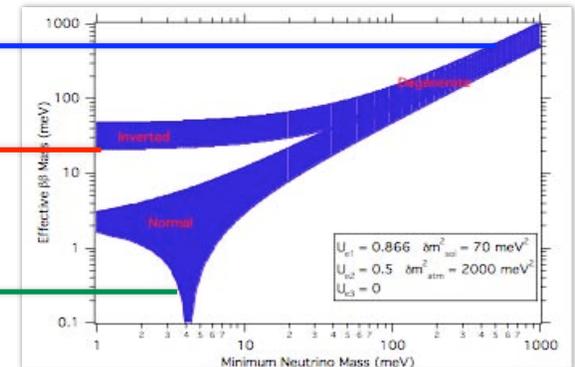
- Well Motivated by ν Oscillation Experiments & Theory
 - Absolute ν mass scale
 - ν Mass hierarchy
 - Dirac or Majorana Nature of ν
 - Even null results are valuable



Degenerate

Inverted

Normal

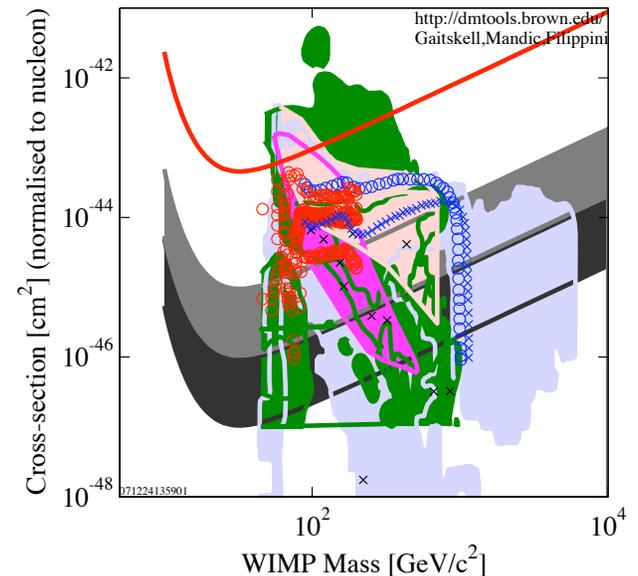
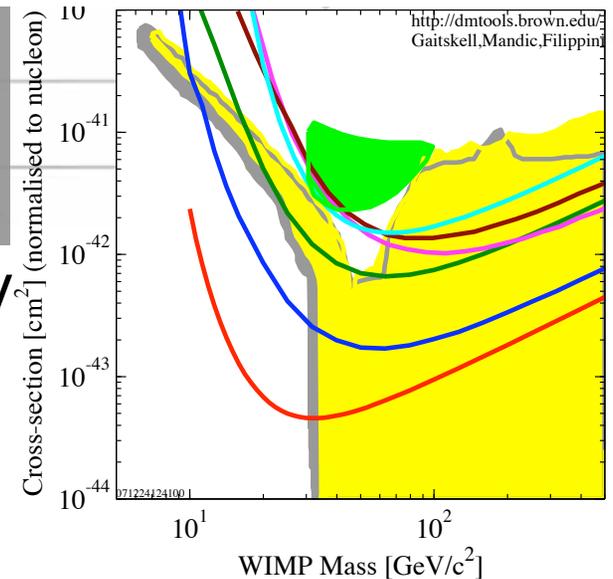


$$[T^{0\nu}_{1/2}]^{-1} = G^{0\nu}(E_0, Z) |\langle m_\nu \rangle|^2 \quad |M^{0\nu}_F - (g_A/g_V)^2 M^{0\nu}_{GT}|^2$$

Homestake DUSEL

Direct Dark Matter Searches

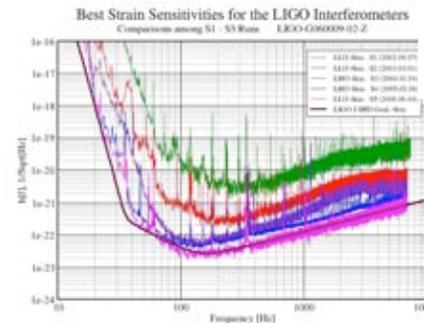
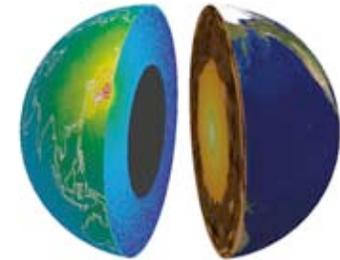
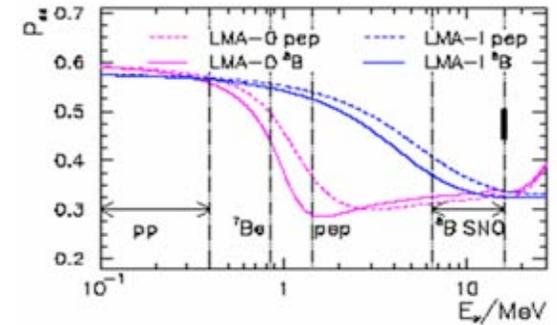
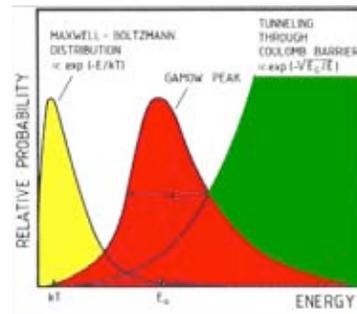
- Strong science motivation for discovery
 - Convergence of particle and astrophysics theory/experiment
- Significant recent advancements in sensitivity
- Direct searches testing physics complementarity to accelerator work
 - Also indirect/astro signal searches
- Flagship science at DUSEL
 - DUSEL will 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
- ...



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

Dark Matter (6-8)

Sanford Lab

4850L

7400L

Neutrinoless $\beta\beta$

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

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

Low Background

Assay & Materials

300L

4850L

R&D Efforts

Surface

300L

4850L

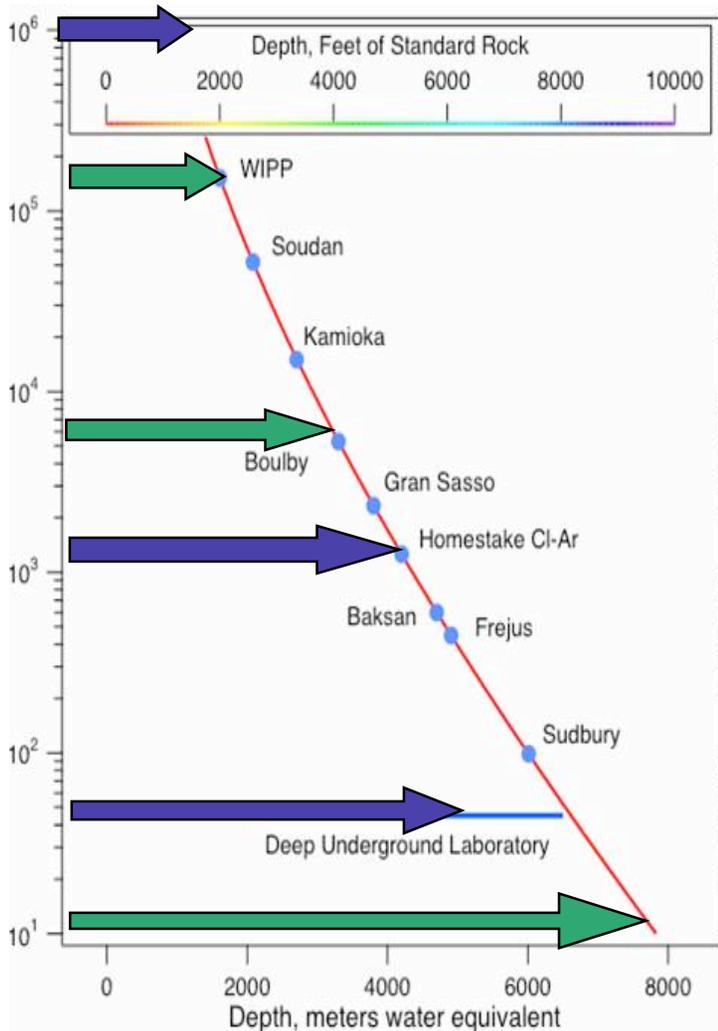
7400L

Education & Outreach

Surface

300L

Homestake Research Campuses



300L R&D, E&O 10k ft²

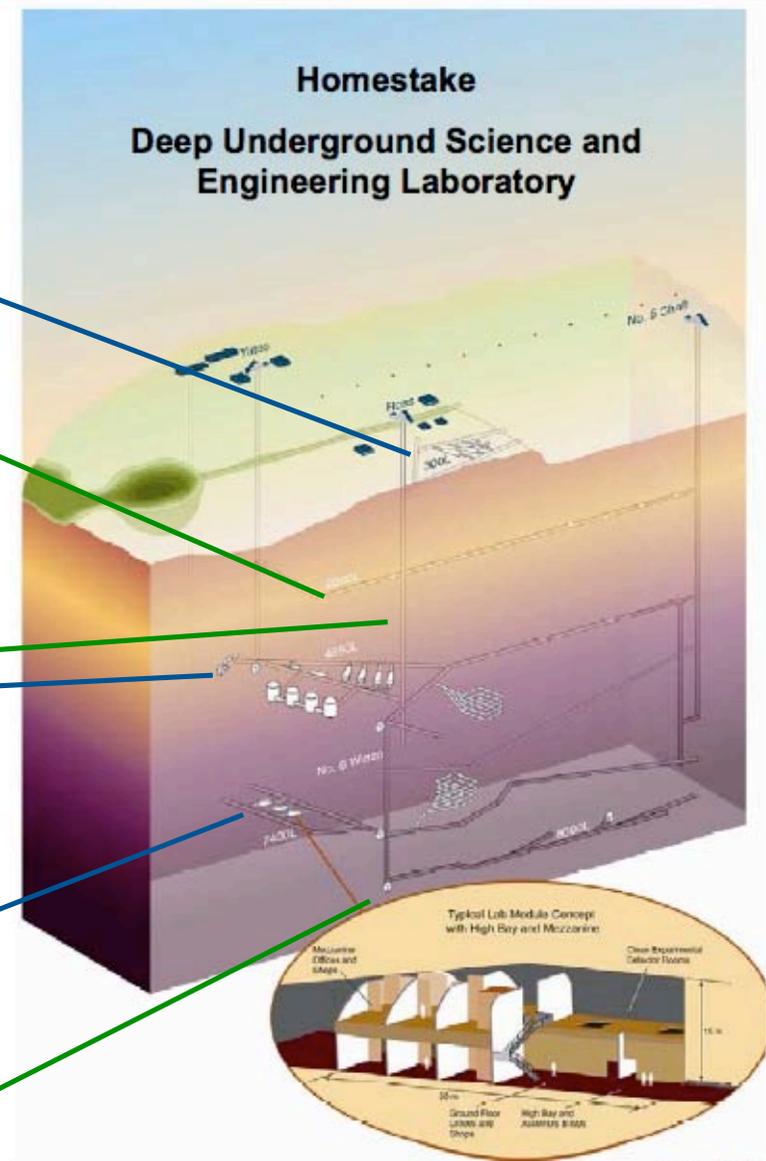
2000L Geo Level

3800L Geo Level

4850L Major Campus 100k ft²

7400L Major Campus 65k ft²

8000L Geo Lab



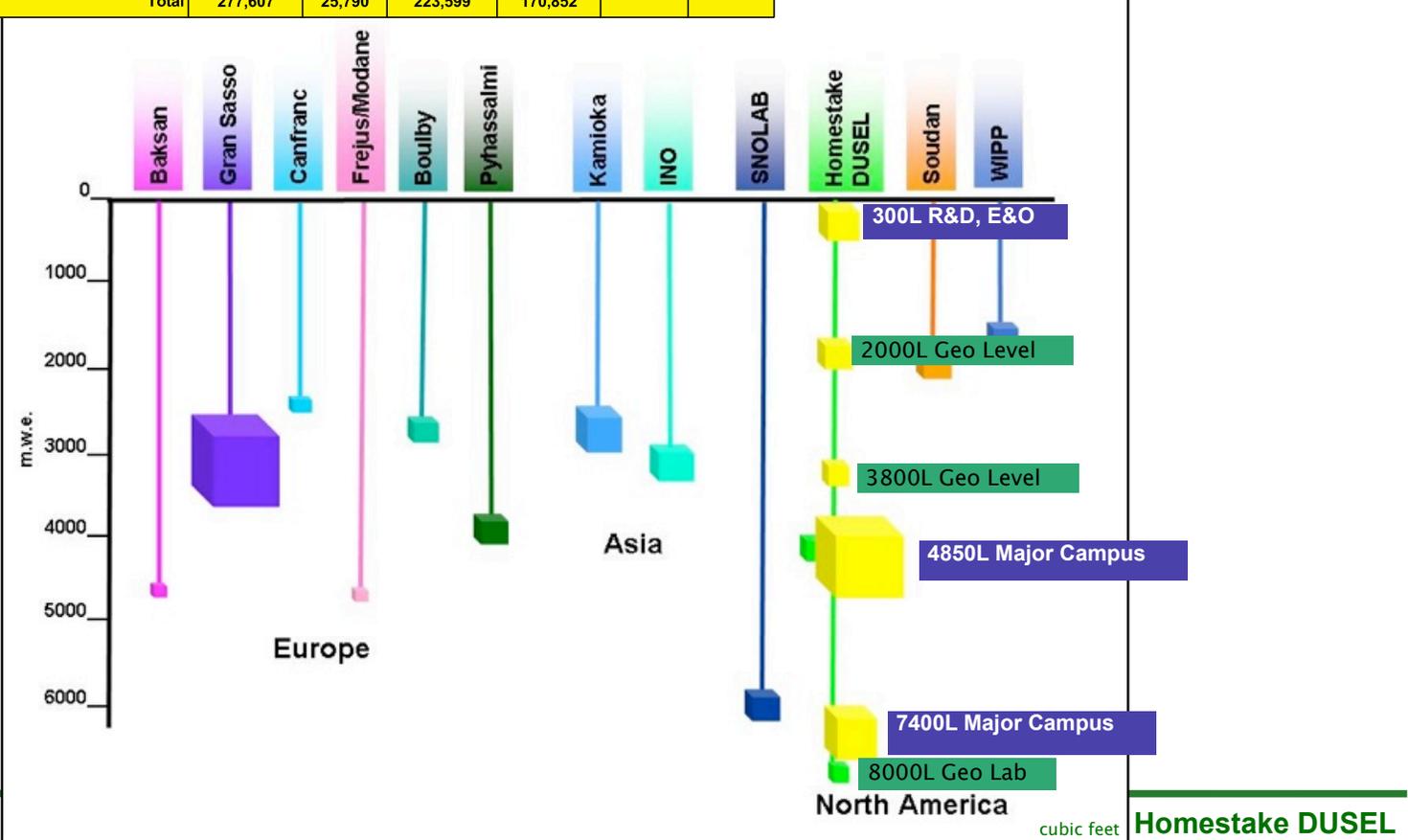
Details of the Conceptual Design at www.lbl.gov/nsd/homestake

Homestake DUSEL

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	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	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	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	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



There is a World-wide Need for Space Underground

Site	Location	Depth (kmwe)	Total Space for Research (m ²)	Total Available Space (m ²)
Europe				
Baksan Neutrino Observatory (BNO)	Russia	0.9	600	0
		4.7	600	0
Boulby	UK	2.8	1,500	0
Center for Underground Physics at Pyhasalmi	Finland	4.0	2,050	2,050
Gran Sasso (LGNS)	Italy	3.2	17,300	0
Canfranc	Spain	2.4	1,000	1,000
Laboratoire Subterrain de Modane	France	4.7	400	0
Solotwina Underground Laboratory (SUL)	Ukraine	1.1	700	500
Total Europe			24,150	3,550
Total Europe below 4.0 kmwe			1,050	50
Asia				
Kamioka	Japan	2.1	10,000	0
OTO-Cosmo Observatory	Japan	1.4	80	0
Y2L	Korea	2.0	100	0
INO	India	3.0	0	0
Total Asia			10,180	0
Total Asia below 4.0 kmwe			0	0
Americas				
SNOLab	Canada	6.0	3,055	500
Soudan Underground Laboratory (SUL)	US	2.0	2,300	0
Waste Isolation Pilot Plant (WIPP)	US	1.6	920	400
Total Americas			6,275	900
Total Americas below 4.0 kmwe			3,055	500
WORLD TOTAL			40,605	4,450
WORLD TOTAL BELOW 4.0 KMWE			4,105	550
DUSEL				
	US	0.3	640	640
		1.7	20,000	20,000
		3.2	1,010	1,010
		4.1	7,200	7,200
		6.4	4,500	4,500
		7.0	100	100
Space required for Initial Suite of Experiments		0.3	2,350	
		1.7	20,000	
		3.2	1,010	
		4.1	12,300	
		6.4	7,900	
		7.0	350	

Assessment and vetting by Homestake Team, S-1 Panel, Town Meeting Group leaders, and community spokespeople

Homestake DUSEL

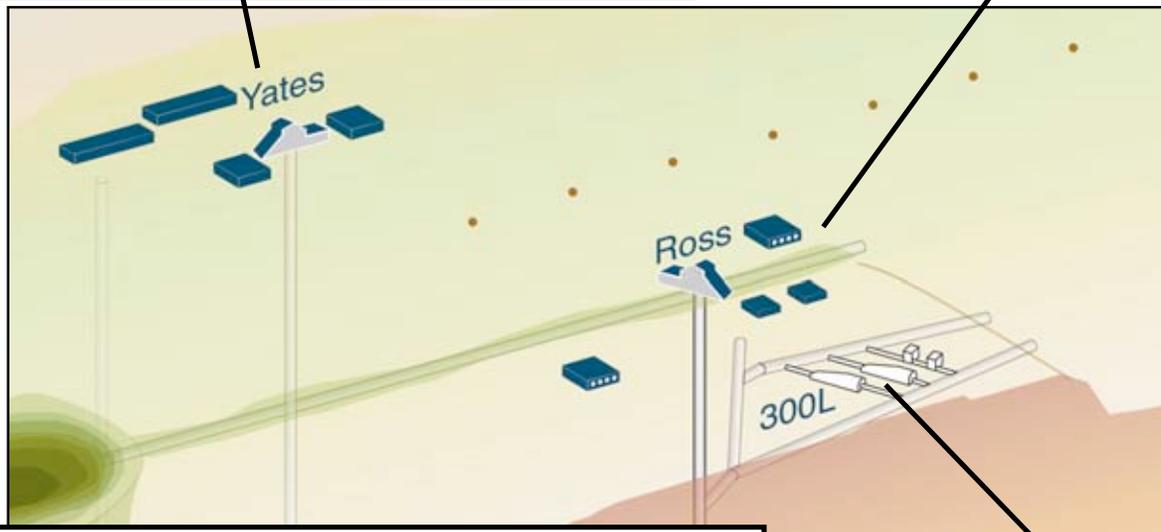
Campus Development Concepts for Surface & 300 Level

Yates Complex Surface Facilities:

- Laboratory Administration Building and Training
- User Support Services: Clean Room Assembly & Fabrication Shops
- R&D Laboratories, User Offices, Meeting Rooms
- Education and Outreach: Sanford Center for Science Education
- Shipping and Receiving, Storage

Ross Complex Surface Facilities :

- Construction Materials and Equipment Staging
- Construction Superintendents and Contractor Offices
- Maintenance Shops
- Shipping and Receiving, Storage
- Facility Site Services and Operations



Experiments and Facilities at 300 Level:

- Education and Outreach Classroom and Laboratory
- User Support Shops: Assembly, Fabrication and Underground Storage
- Research and Development Laboratories
- Near-surface Experiments
- Low-background Counting and Calibration Facility

300 Level Campus Plan for near-surface, drive-in access



mestake DUSEL

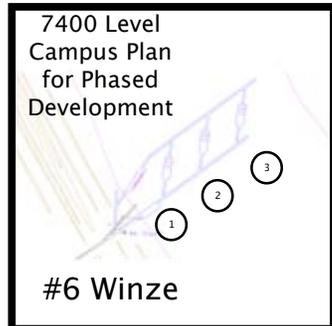
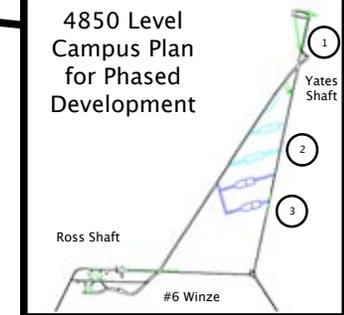
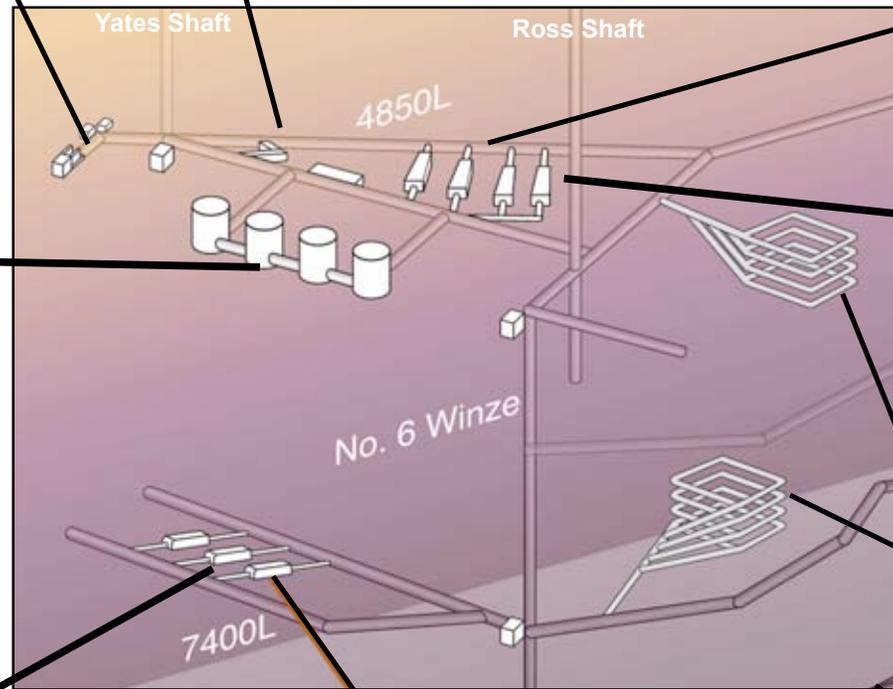
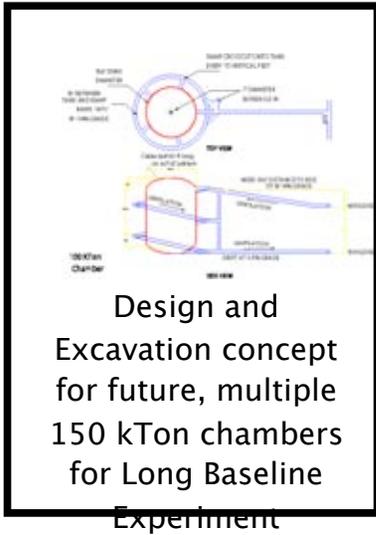
Concepts for Mid- & Deep-level Experiments

Early Implementation Program & Facility Infrastructure Development at 4850L:

- Low-Background Counting Facility
- Earth Sciences and Geo-microbiology Lab
- Neutrinoless Double Beta Decay
- Common Facilities and Clean Room Transition
- Dark Matter
- Utility Services and Refuge Chamber

Initial Suite of Experiments at 4850 Level

- Dark Matter
- Double Beta Decay
- Nuclear Astrophysics
- Solar Neutrinos
- Geoneutrinos



Initial Suite of Experiments at 7400 Level:

- Large Double Beta Decay
- Solar Neutrinos
- Supernovae Detection
- Large Dark Matter

Geosciences:
Large Block Coupled Processes Experiments

Geosciences:
Deep Drill Room at 8000L

Figure 1: Summary of the pre-construction planning and development process for candidate MREFC projects.

	Conceptual Design Stage	Readiness Stage	Board Approved Stage	Construction			
Budget evolution	<p>Concept development – Expend approximately 1/3 of total pre-construction planning budget</p> <p>Develop construction budget based on conceptual design</p> <p>Estimate ops \$</p>	<p>Prelim design over ~1-2 years. Expend approx 1/3 of total pre-construction planning budget</p> <p>Construction estimate based on prelim design</p> <p>Update ops \$ estimate</p>	<p>Final design over ~1 year. Approx 1/3 of total pre-construction planning budget</p> <p>Construction ready budget & contingency estimates</p>	<p>Expenditure of budget and contingency per baseline</p> <p>Refine ops budget</p>			
Funded by R&RA or EHR \$				MREFC \$ 			
Project evolution	<p><u>Conceptual design</u></p> <p>Formulation of science questions</p> <p>Requirements definition, prioritization, and review</p> <p>Identify critical enabling technologies and high risk items</p> <p>Development of conceptual design</p> <p>Top down parametric cost and contingency estimates</p> <p>Formulate initial risk assessment</p> <p>Initial proposal submission to NSF</p> <p>Initial draft of Project Execution Plan</p>	<p><u>Preliminary Design</u></p> <p>Develop site-specific preliminary design, environmental impacts</p> <p>Develop enabling technology</p> <p>Bottoms-up cost and contingency estimates, updated risk analysis</p> <p>Develop preliminary operations cost estimate</p> <p>Develop Project Management Control System</p> <p>Update of Project Execution Plan</p>	<p><u>Final Design</u></p> <p>Development of final construction-ready design and Project Execution Plan</p> <p>Industrialize key technologies</p> <p>Refine bottoms-up cost and contingency estimates</p> <p>Finalize Risk Assessment and Mitigation, and Management Plan</p> <p>Complete recruitment of key staff</p>		<p><u>Construction per baseline</u></p>		
		Proponents development strategy defined in Project Development Plan		Described by Project Execution Plan			
NSF oversight defined in Internal Management Plan, updated by development phase							
Oversight evolution	<p>Merit review, apply 1st and 2nd ranking criteria</p> <p>Forward estimates of Preliminary Design costs and schedules</p> <p>Establishment of interim review schedules and competition milestones</p> <p>Forecast international and interagency participation and constraints</p> <p>Initial consideration of NSF risks and opportunities</p> <p>Conceptual design review</p>	MREFC Panel approves CDR findings	<p>NSF Director approves Internal Management Plan</p> <p>Formulate/approve Project Development Plan & budget; include in NSF Facilities Plan</p> <p>Preliminary design review and integrated baseline review</p> <p>Evaluate ops \$ projections</p> <p>Evaluate forward design costs and schedules</p> <p>Forecast interagency/international decision milestones</p> <p>NSF approves submission to NSB</p>	NSF approves submission to NSB	<p>Apply 3rd ranking criteria</p> <p>NSB prioritization</p> <p>OMB/Congress budget negotiations based on Prelim design budget</p> <p>Semi-annual reassessment of baseline and projected ops budget for projects not started construction</p> <p>Finalization of interagency and international requirements</p>	Congress appropriates funds	<p>Final design review, fix baseline</p> <p>Congress appropriates MREFC funds & NSB approves obligation</p> <p>Periodic external review during construction</p> <p>Review of project reporting</p> <p>Site visit and assessment</p>