DUSEL plans

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UCLA Dark Matter Meeting 2/22/2008

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Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN
NATIONAL LABORATORY

Outline

- No personal viewpoints here
- First, few slides from Jon Kotcher from the SLAC p5 meeting.
- Second, few slides from Kevin Lesko from the same meeting.
- Discussion of the next steps.

http://www-group.slac.stanford.edu/ppa/Reviews/p5/

DUSEL Overview

- Joint initiative within NSF between Physics (lead), Engineering, and Geosciences
  - Biology currently serving in advisory capacity
- Science and engineering program driven by physics, being designed to accommodate a broad, evolving multidisciplinary program
- New opportunity for growth, diversity, inter-disciplinary research
- Addresses worldwide need for dedicated, extensive space at depth, for all programs, over multiple decades
- Intrinsically strong program for education, outreach
- Will enable new, long-term partnerships among disciplines, organizations: public, private, international
- Transformative, high-risk/high-reward, visionary facility & program
- #1 priority for new project start in Physics Division

Solicitation 4

- Solicitation 4 (S4, in clearance): call for proposals to develop project plans for potential candidates for the ISE
- Design funds to address: what do you need to execute the experiment you propose?
  - Will include opportunity for limited, targeted R&D
- Open to all disciplines
- Up to $15M total from Physics/MPS, over 3 years
  - Primarily for physics experiments
  - Additional $0.5-1.0M from engineering
  - Approach to BIO, GEO being determined; will depend on proposals received
  - Independent of '08 DUSEL R&D *(more later)*
- Expect publication in spring '08.

Solicitation 5

- S4 provides design & development funds for experiments that might be included in ISE
- Solicitation 5 (S5): will call for proposals from which final selection of ISE will be made
- Must allow sufficient time to review, develop final MREFC package
  - Facility + experiments, interfaces
- Current plan has publication in winter ’09
- Funding recommendations for both S4 & S5 will be obtained via peer review through NSF panels

DUSEL Status in MREFC Process

- S3 site selection review played dual role as Conceptual Design Review for facility.
- DUSEL passed this requirement.
- Recommendation to enter Project Readiness phase being considered by MPS Advisory Committee (Witherell, Chair).
- Preparations being made for final discussion at April 2008 MPS AC meeting.
- Will then be considered by MREFC Panel (OD, ADs)

Working Model of DUSEL Timeline

- Spring 08: S4 published
- Summer 08: Peer review of S4 proposals
- October 08: S4 funds released (requires 09 funds)
- December 08: NSF Review of DUSEL
  - Facility + experiments
- Winter 09: S5 published, proposals for initial suite
- Spring 09: Peer review & selection of initial suite
- December 09: NSF Preliminary Design Review of DUSEL
- Spring 10: Presentation of DUSEL package to NSB
- FY12: earliest construction funding start

DUSEL Facility & Program Planning

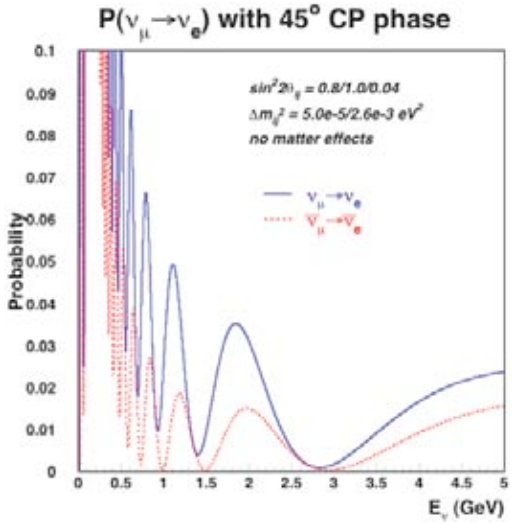
- Planning assumes facility costs would be borne by NSF
- Partnerships with DOE & others will be sought & encouraged for ISE
- At this early stage, Physics Division uses following rough planning targets:
  - $500M for initial phase MREFC, split evenly between facility and experiments
    - Not etched in stone – will be responsive to project plan, compelling nature of case, etc.
  - 7-8 year construction period, experiments interleaved as they are ready
  - Preliminary Design Review end CY09
  - Earliest construction start FY12

Long Baseline Application in ISE

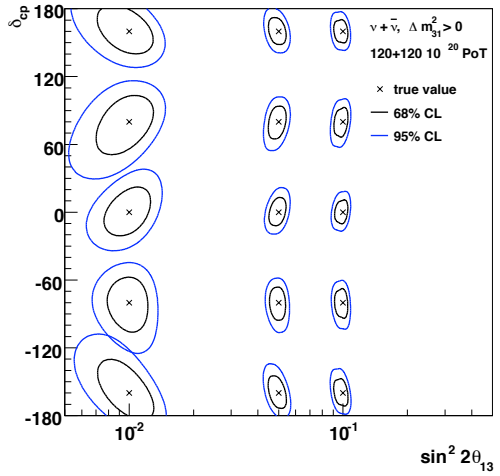
- Responding to the community, a mega-module (50 kton or more) is being planned for inclusion as part of the initial suite
  - Includes excavation, instrumented detector
- Would establish a flagship, world-class program as part of initial research plan
- Costs will have to be carefully examined, vetted in context of rest of ISE.
- As with rest of DUSEL, partnerships matter greatly here
- As does the community voice

Long Baseline ν, Nucleon Decay, and Ancillary Programs

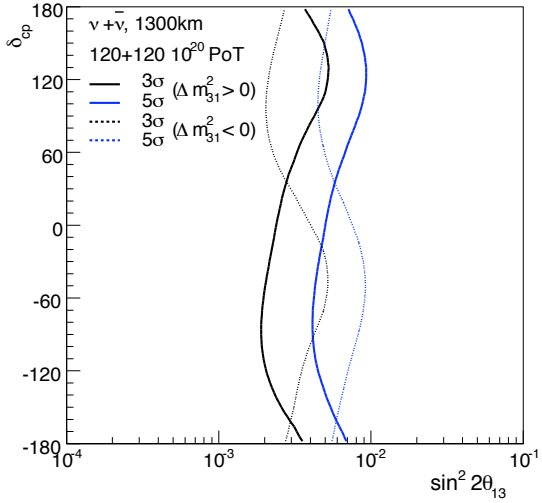
- Long Baseline Neutrinos and Nucleon Decay
  - Same detectors
- Discovery
  - Neutrino mass hierarchy
  - θ_{13}
  - CP violation
  - Nucleon decay
- Diverse Program
  - Full MNSP matrix
  - Atmospheric and solar neutrinos
  - Supernovae neutrinos
- World-class Program



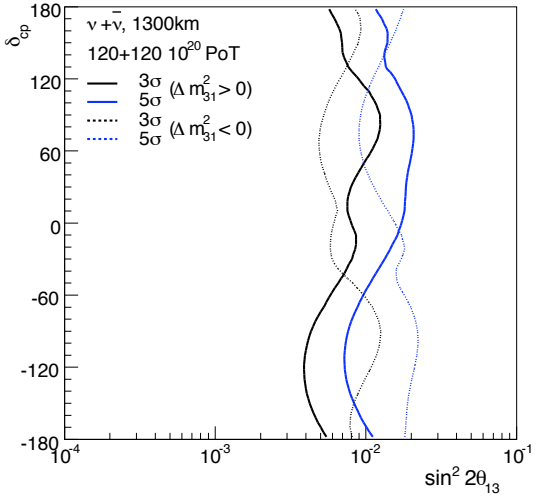
CP Violation



Reach in θ_{13}

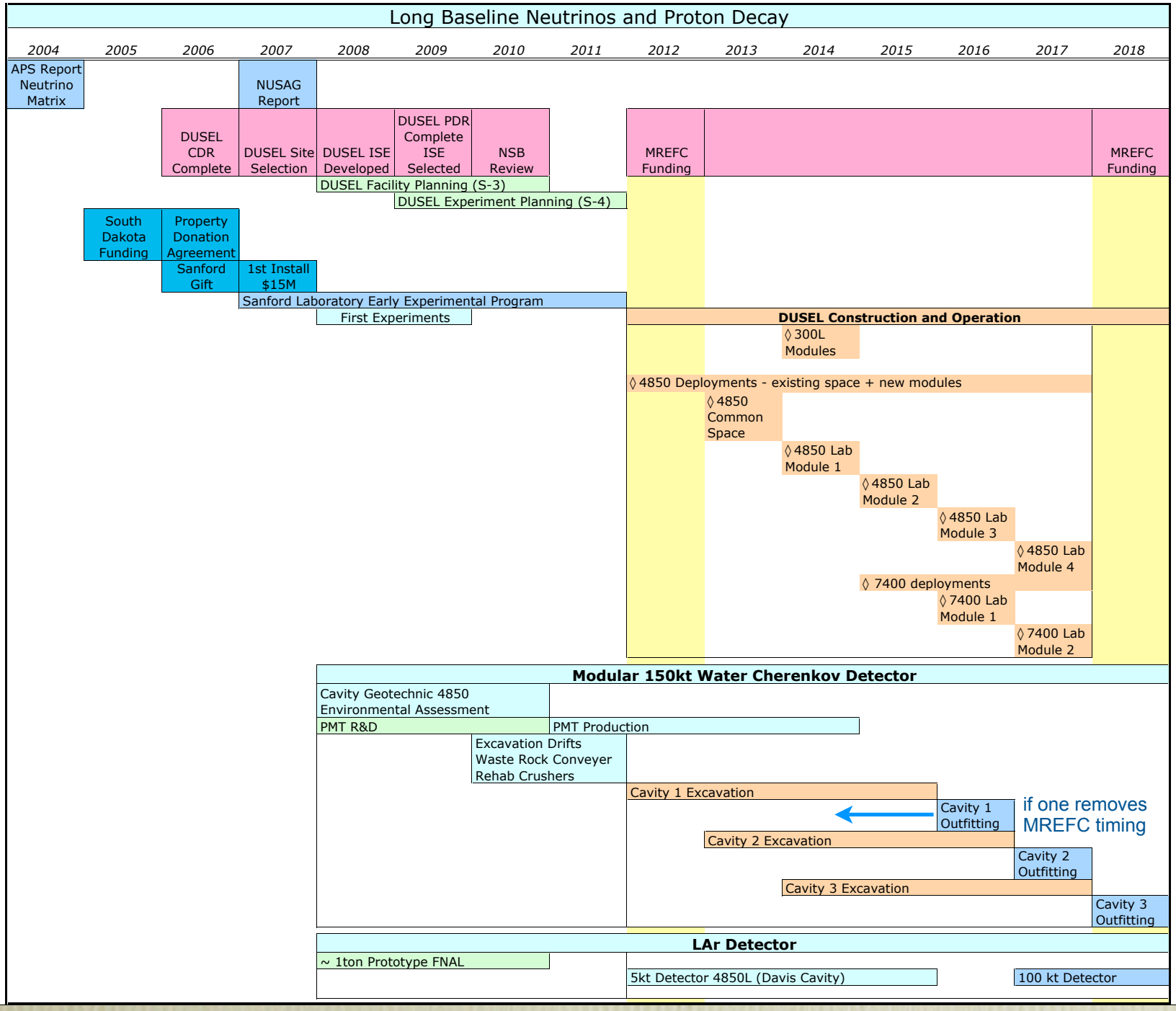


Reach in Mass Hierarchy



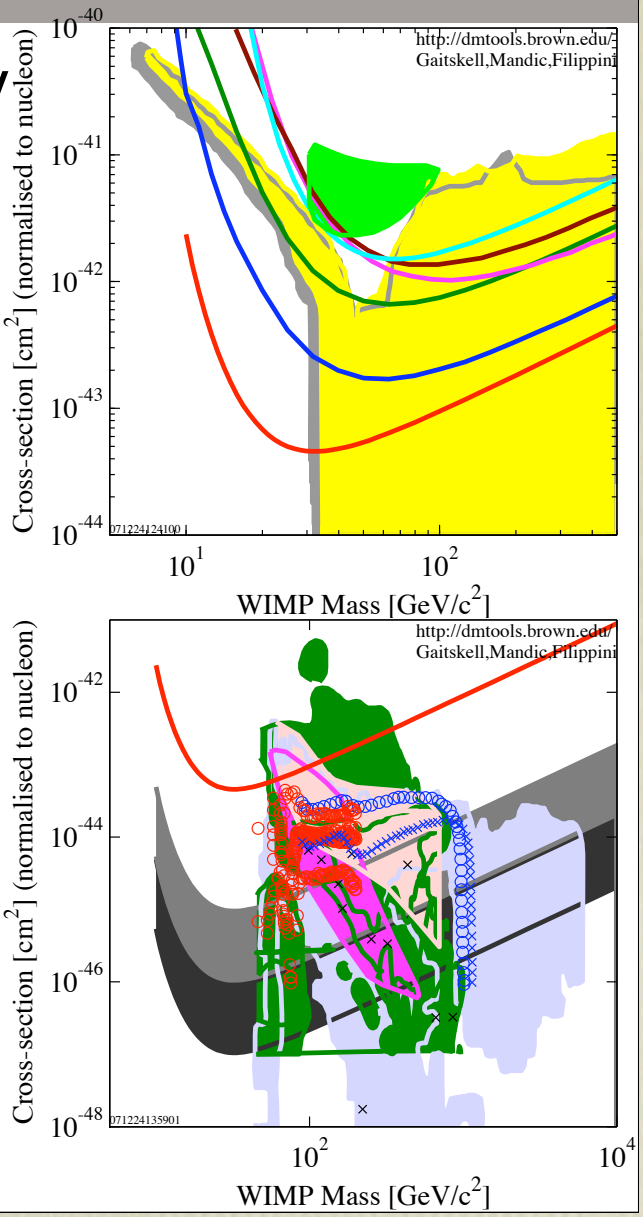
Lesko

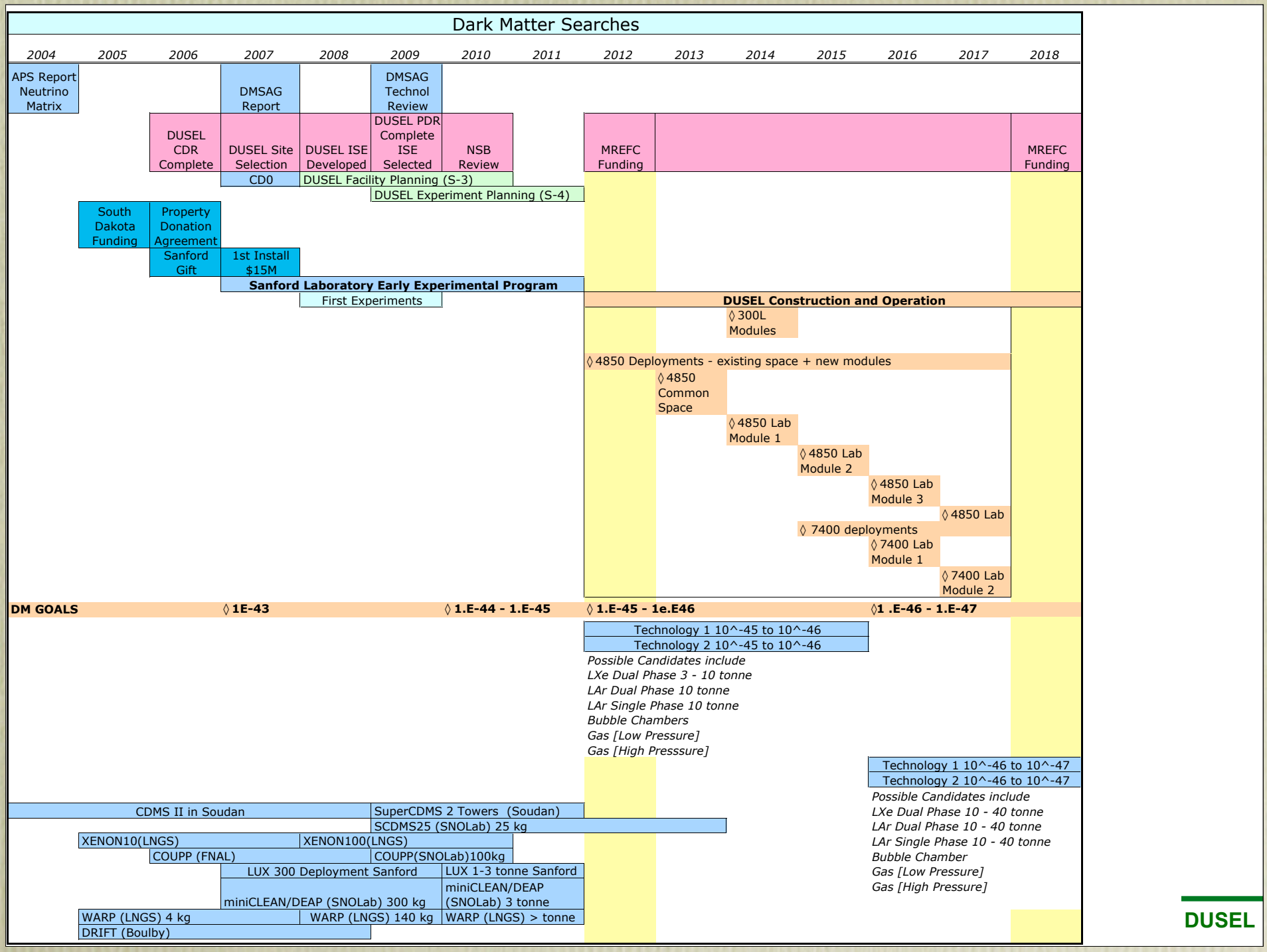
- Homestake anticipates beginning with a ~150-kt Detector (cavity + instrumentation) in Initial Suite of Experiments:
  - Water Cherenkov Detector ≈ 4 to 5 SuperKs
  - Using existing beam or near-term upgrades
  - Build towards ~ 500-kt or more in modules and enhanced beams ~ 2 MW BP
  - Parallel LAr efforts, including deployments of prototype detectors in the near term
- R&D to begin in Sanford Lab
  - Geotechnical assessment and excavation plans
  - EA and waste rock disposal
  - Access/support improvements and customization


Long Baseline Neutrinos and Proton Decay
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
APS Report Neutrino Matrix
NUSAG Report
DUSEL CDR Complete
DUSEL Site Selection
DUSEL ISE Developed
DUSEL PDR Complete ISE Selected
NSB Review
MREFC Funding
MREFC Funding
DUSEL Facility Planning (S-3)
DUSEL Experiment Planning (S-4)
South Dakota Funding
Property Donation Agreement
Sanford Gift
1st Install $15M
Sanford Laboratory Early Experimental Program
First Experiments
DUSEL Construction and Operation
◊ 300L Modules
◊ 4850 Deployments - existing space + new modules
◊ 4850 Common Space
◊ 4850 Lab Module 1
◊ 4850 Lab Module 2
◊ 4850 Lab Module 3
◊ 4850 Lab Module 4
◊ 7400 deployments
◊ 7400 Lab Module 1
◊ 7400 Lab Module 2
Modular 150kt Water Cherenkov Detector
Cavity Geotechnic 4850 Environmental Assessment
PMT R&D
PMT Production
Excavation Drifts
Waste Rock Conveyer
Rehab Crushers
Cavity 1 Excavation
Cavity 1 Outfitting
if one removes MREFC timing
Cavity 2 Excavation
Cavity 2 Outfitting
Cavity 3 Excavation
Cavity 3 Outfitting
LAr Detector
~ 1ton Prototype FNAL
5kt Detector 4850L (Davis Cavity)
100 kt Detector

Direct Searches for of Dark Matter

- Strong science motivation for discovery
  - Convergence of particle and astrophysics theory/experiment
- Significant recent advancements in sensitivity
  - US is current world leader in field
- Direct searches testing physics complementarity to accelerator work
  - Also indirect/astro signal searches
- Flagship science at DUSEL
  - DUSEL will ensure continued leadership




Dark Matter Searches
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
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DMSAG Report
DMSAG Technol Review
DUSEL CDR Complete
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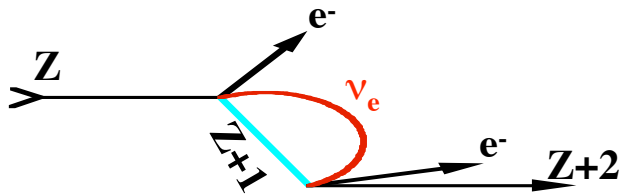
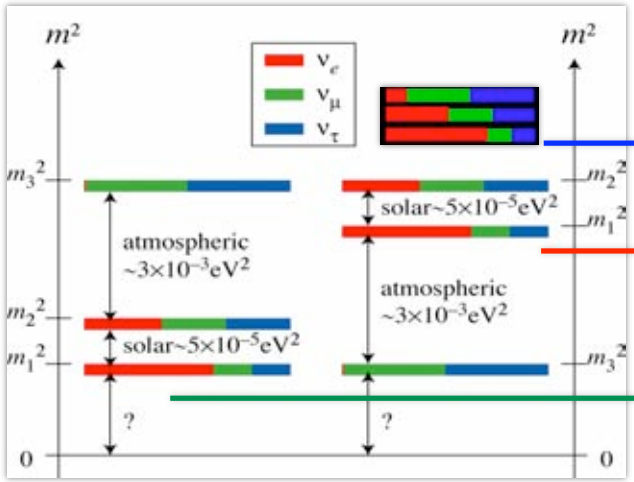
◊ 4850 Lab
◊ 7400 deployments
◊ 7400 Lab Module 1
◊ 7400 Lab Module 2
DM GOALS
◊ 1E-43
◊ 1.E-44 - 1.E-45
◊ 1.E-45 - 1e.E46
◊1 .E-46 - 1.E-47
Technology 1 10^-45 to 10^-46
Technology 2 10^-45 to 10^-46
Possible Candidates include
LXe Dual Phase 3 - 10 tonne
LAr Dual Phase 10 tonne
LAr Single Phase 10 tonne
Bubble Chambers
Gas [Low Pressure]
Gas [High Presssure]
Technology 1 10^-46 to 10^-47
Technology 2 10^-46 to 10^-47
Possible Candidates include
LXe Dual Phase 10 - 40 tonne
LAr Dual Phase 10 - 40 tonne
LAr Single Phase 10 tonne
Bubble Chamber
Gas [Low Pressure]
Gas [High Pressure]
CDMS II in Soudan
SuperCDMS 2 Towers (Soudan)
SCDMS25 (SNOLab) 25 kg
XENON10(LNGS)
XENON100(LNGS)
COUPP (FNAL)
COUPP(SNOLab)100kg
LUX 300 Deployment Sanford
LUX 1-3 tonne Sanford
miniCLEAN/DEAP (SNOLab) 300 kg
miniCLEAN/DEAP (SNOLab) 3 tonne
WARP (LNGS) 4 kg
WARP (LNGS) 140 kg
WARP (LNGS) > tonne
DRIFT (Boulby)
DUSEL

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



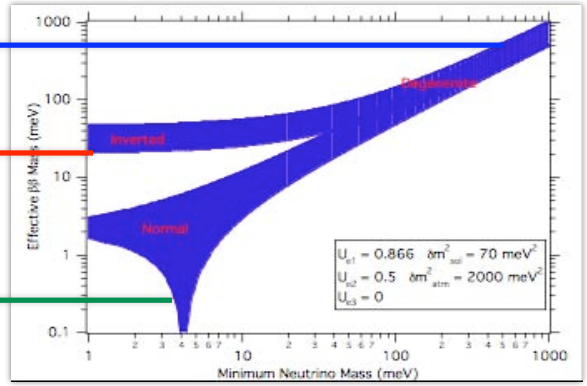
$$n \Rightarrow p + e^- + \bar{\nu}_e \quad (\text{RH } \bar{\nu}_e) \quad (\text{LH } \nu_e) \quad \nu_e + n \Rightarrow p + e^-$$



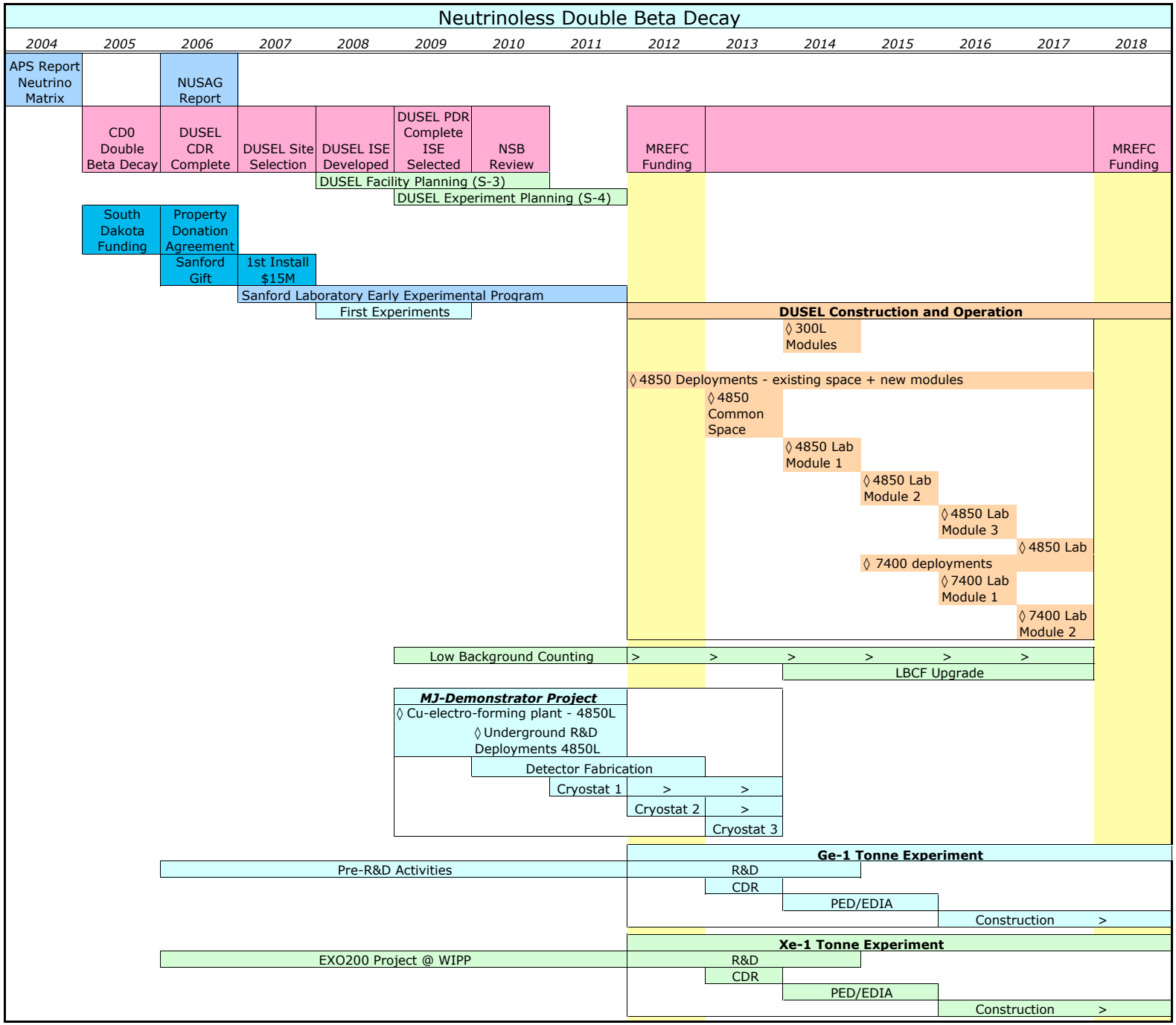
Degenerate

Inverted

Normal



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



Homestake DUSEL

DUSEL Initial Suite of Experiments (ISE)[1]	Experimental Cavity Size (m^2)[2a]	Required U/G Support Space (m^2)[2b]	Minimum Depth (mwe)[3]	Approximate Construction Start Date for "Generations" or Experiments[4]
Dark Matter (WIMPS)				
Generation 0 (PreDUSEL) Sensitivity 10^-44 - 10^-45				
Noble Liquid (2 phase)	100	250	4100	LUX 300 proposal for Sanford Lab (2008) (Xe)
Low Temperature Solid State	100	250	2000	CDMS Experiment in Soudan (running) (Ge + Si)
Low Temperature Solid State	100	250	4100	SuperCDMS Proposal to SNOLab (2009) (Ge + Si)
Noble Liquid (1 phase)	*N/A*	N/A	N/A	miniClean Proposal to SNOLab (2008) (Ar)
Noble Liquid (2 phase)	*N/A*	N/A	N/A	WARP Experiment to Gran Sasso (running) (Ar)
Noble Liquid (2 phase)	*N/A*	N/A	N/A	Xenon10 Experiment to Gran Sasso (completed) (Xe)
Noble Liquid (2 phase)	*N/A*	N/A	N/A	Xenon100 Proposal to Gran Sasso (2008) (Xe)
Generation 1 (DUSEL ISE) Sensitivity 10^-45 - 10^-46				~ 2011 - 2013
Technology 1 TBD	100	250	4100	detector construction to commence earlier on the surface
Technology 2 TBD	100	250	4100	detector construction to commence earlier on the surface
Generation 2 (DUSEL ISE) Sensitivity 10^-46 - 10^-47				~ 2015
Technology 1 TBD	200	500	6400	detector construction to commence earlier on the surface
Technology 2 TBD	200	500	6400	detector construction to commence earlier on the surface
Neutrinoless Double Beta Decay				
Generation 0 (PreDUSEL) Degenerate Mass Scale Sensitivity				
Solid State (Ge)	100	200	4100	R&D for demonstator prior to MREFC at Sanford Lab (2009)
Noble Liquid (Xe)	150	200	2000	EXO200 running at WIPP
Bolometric (Te European)	N/A	N/A	3200	Cuoricino running, Cuore being built at Gran Sasso (2010)
Generation 1 (DUSEL ISE) Atmospheric Mass Scale Sensitivity				~ 2015
Solid State (Ge)	250	500	6400	
Noble Liquid/Gas (Xe)	500	200	6400	

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

Dark Matter

Sanford Lab

4850L

7400L

Neutrinoless ββ Decay

Sanford Lab

7400L

(see handout)

DUSEL Initial Suite of Experiments (ISE)[1]	Experimental Cavity Size (m^2)[2a]	Required U/G Support Space (m^2)[2b]	Minimum Depth (mwe)[3]	Approximate Construction Start Date for "Generations" or Experiments[4]
Long Baseline Neutrinos and Nucleon Decay				
Large Cavity R&D (~ 100kt first cavity)	2400	250	4100	
Site Investigations, coring, geotech work				~ 2008 - 2009
Continued geotech work, and Initial mobilization, instrumentation, access drifts 1-time equipment costs				~ 2011
Excavation ~ 55m cavity				~ 2012
Instrumentation				~ 2015 (PMT production to start earlier)
1 Ton Liquid Argon Module at 300 Level	500	200	230	~2013
Nuclear Astrophysics				
Low Energy Accelerator	800	200	4100	~ 2013
Heavy Ion Medium Energy Accelerator				~ 2015
Geoneutrino (multipurpose)				
1 kt liquid Scintillator Detector	250	250	4100	~ 2015
Low Energy Solar Neutrinos				
Generation 0 (PreDUSEL) (7Be, CNO?, pep?)				
Borexino	1000		3700	Borexino running at Gran Sasso
KamLAND	300	200	2000	Kamland Solar being developed in Kamioka
miniLENS	100	100	4100	miniLENS stage II proposal for Sanford Lab (2009)
Generation 1 (DUSEL) (pep, pp)				
Charged Current (CC)	250	200	4100	~ 2013
1 kt liquid Scintillator Detector (ES)	250	250	4100	~ 2015
3000kg Noble Gas (ES)	500	200	6400	~ 2015
Characterization of Low Vibration Studies for Future Gravity Wave Experiments				
Low vibration and microseismic studies	20000		1690	~ 2013

Long Baseline ν & Nucleon Decay

300L

4850L

Nuclear Astrophysics

4850L

Geoneutrinos

4850L

Low Energy Solar ν

4850L

7400

Gravity Waves

2000L

DUSEL Initial Suite of Experiments (ISE)[1]	Experimental Cavity Size (m^2)[2a]	Required U/G Support Space (m^2)[2b]	Minimum Depth (mwe)[3]	Approximate Construction Start Date for "Generations" or Experiments[4]
GeoBiology				
Biology Observatory	50	200	6400	~ 2014
Pristine Fracture Zone		300	6400	~ 2016
Intermediate Bio/Geo Drilling	50	300	4100	~ 2011
Deep Bio/Geo Drilling	50	300	7000	~ 2015
Deep Engineering and Excavation Research Facility				
Cavity Engineering	200	100	4100	~ 2011
Excavation Research (TBM)	400	200		
Excavation Research (Drilling)	200	100		
Cavity Engineering	200	100	6400	~ 2016
Excavation Research (TBM)	400	200		
Excavation Research (Drilling)	200	100		
Scale Effects Experiment				
Run-of-Mine Fracture Characterization	50	50	4100	~ 2011
State-of-Stress and Deformation Research	50	50		
Multiphase Fluid Flow Research	50	50		
Run-of-Mine Fracture Characterization	50	50	6400	~ 2016
State-of-Stress and Deformation Research	50	50		
Multiphase Fluid Flow Research	50	50		
Seismic Array - surface	1000		100	~ 2008
Seismic Array - 3800	1000	10	3200	~ 2009
Active Processes Laboratory				
Transparent Earth (Shallow)		200	4100	~ 2011
Transparent Earth (Deep)	200	100		
THMBC (Chemical Migration)	200	100		
THMCB (Multiphase Migration)	200	100		
Fracture Processes Facility	1000	200		
Transparent Earth (Deep)	200	100	6400	~ 2016
THMBC (Chemical Migration)	200	100		
THMCB (Multiphase Migration)	200	100		
Fracture Processes Facility	1000	200		
CO2 Sequestration and Flow	bore holes		Various	~ 2011
Low Background Counting				
Prescreening array, ICPMS & NAA Assay Facility	50	100	230	~ 2011
Gamma, Beta, Alpha, Whole Body Assays and Radon Emanation Measurements	200	100	4100	~ 2011
Materials Storage				
	150		230	~ 2013
	150		4100	~ 2011
	150		6400	~ 2013
Ultralow Background Materials Processing				
Copper Facilities including Ultraclean Machine Shop	350	150	4100	~ 2011
Education and Outreach				
Shallow Lab	250	100	230	~ 2013
Intermediate Depth Lab	100	100	4100	~ 2013
Prototyping and R&D				
	500	500	230	~ 2013
	250	500	4100	~ 2015
	250	500	6400	~ 2017

Geobiology

0 - 16,000

Engineering and Excavation Research

4850L

7400L

Scale Effects

4850L

7400L

Active Processes

4850L

7400L

Low Background Materials

300L

4850L

Education and Outreach

300L

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

Initial Suite of Experiments Estimates

Initial Suite of Experiments*	Experimental Discipline
$520,000k	Physics
$119,000k	Biology, Geology & Engineering
$8,600k	Common Usage (LBCF)
$644,600k	Total Experiment Capital Costs

DM	2 technologies @ 2 generations
DBD	2 ~ 1 tonne experiments
LBL νs PDK	1 150-kt cavity + detector + LAr R&D
Nuclear Astro	LE + HI accelerators
Geo/LE Solar ν	~ 1kT scale

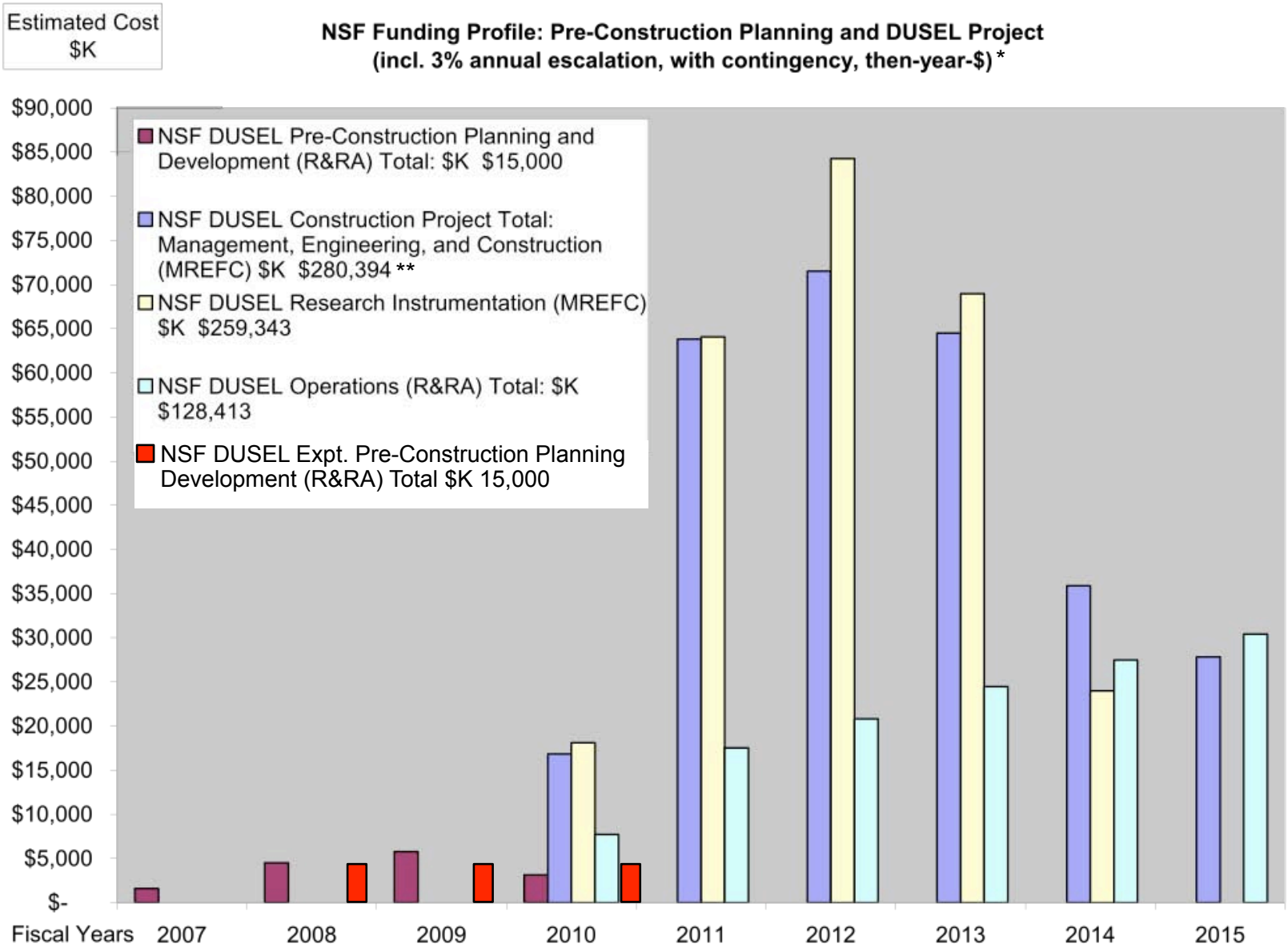
* Estimates obtained from Proposals and CDRs, vetted through the Town Meeting Group Leaders, S-1, Homestake.
For rapidly evolving fields, such as DM, these are clearly estimates for detectors.
Capital Costs only.
S-4 will establish PDR and estimates

DUSEL Experiment Development Committee

- Follows on from S-1 (New Guard)
  - Hank Sobel (UCI) Phy
  - Steve Elliott (LANL) Phy
  - T.C. Onstott (Princeton) Geo/Bio
  - Derek Elsworth (Penn State) Geo/Eng
  - Larry Murdoch (Clemson) Geo/Eng
    - November Town Meeting Workshop Leaders
- Working with Facility Team (S-3)
- To help underground community develop the Initial Suite of Experiments (S-4)

Significant Milestone for Initial Suite of Experiments

- November 2007 Town Meeting
- April 2008 Lead Workshops
- July 2008 Internal Review of DUSEL
- Late Spring S-4 Solicitation Announcement
- 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)

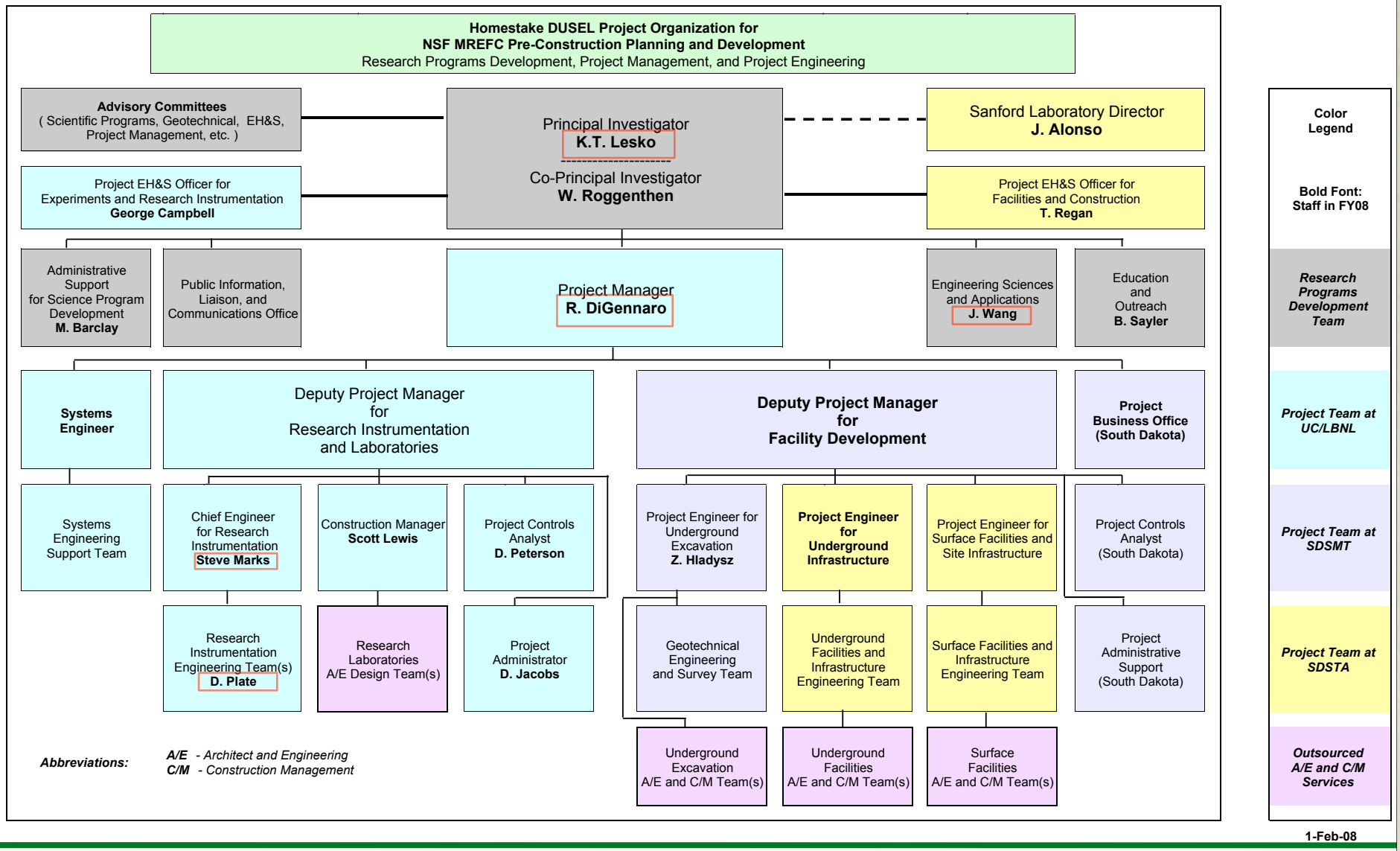


*from CDR - following guidance from solicitation, is being updated to reflect a FY12 start

**Facility Excavation does not include MEGA Detector Cavities

Homestake DUSEL Planning and Engineering funded: $15M over three years:

- Produce Preliminary Design Report for the DUSEL Facility
- Integrate efforts with S-4 and Sanford Lab



1-Feb-08

Progress at 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, SDSTA hiring staff to oversee and operate Homestake: ~30 for rehab, ~ 25 to 30 staff

- June 2007 $70M Sanford Gift, $15M gifted in 2007
- January 2007 Rehab work initiated, $60M in hand
- October 2007 SDSTA Hires Jose Alonso, Lab Director, additional Key Staff

- Early Implementation Program at Homestake 2008 - 2012 "The Sanford Laboratory"

Sanford Lab Science Program: 2007 - 2010

Dark Matter: Gaitskell, Shutt and collaboration

Geo/seismic array: Glaser, Johnson, Roggenthen

Low Background Counting: Mei and collaboration

~~Dark Matter: Hime, McKinsey~~ **Declined**

Dark Matter: Mei and collaboration

Geo/Bio Sampling: Bang, Conrad & collaboration

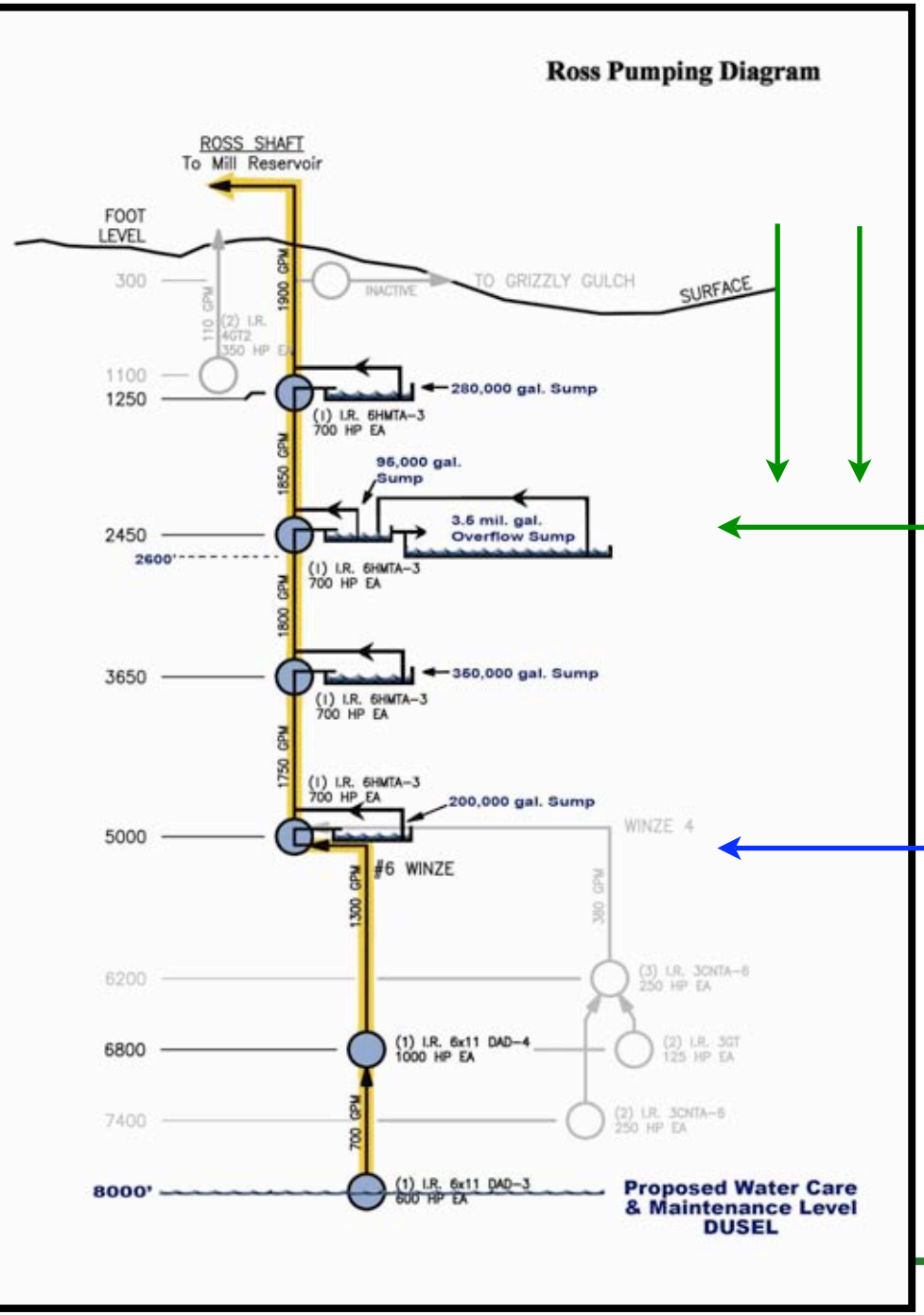
Neutrinoless ββ: Elliott, Wilkerson & collaboration

Large Cavities, LBL νs: Lande, Diwan et al.

Carbon Sequestration: Wang and collaboration

USGS Gravity Line: Anderson and collaboration

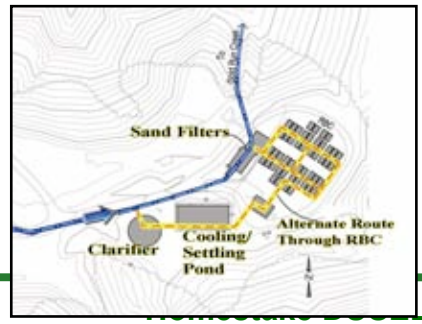
Dewatering Homestake - Current Water Levels



Re-entry Efforts, begun in July, have inspected levels and shafts down to 2100 L

Will focus on turning on pumps at 1250L and 2450L

5000 level tripped July 2007



Summary

- World-class Physics Programs
- Unique capabilities in the world
  - 3 or 4 flag-ship experiments identified
- Efforts underway at Sanford Lab to prepare the site ($126M) independent of and parallel to the DUSEL efforts, with $60M in hand FY08
  - phased program for experiments
- Long-term site
  - tailored access
  - 30 + year horizon
  - no competition