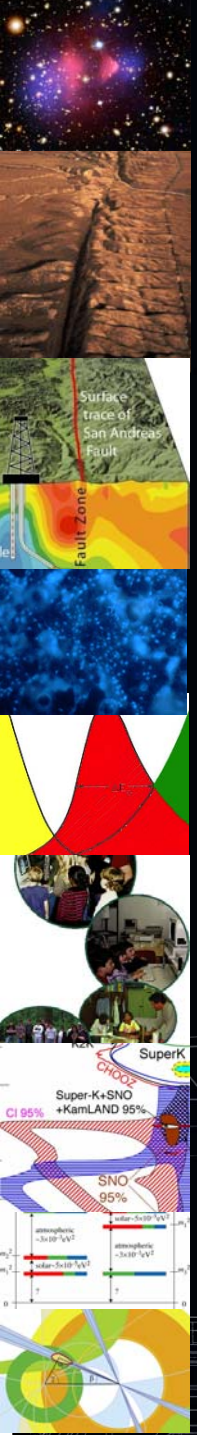
Homestake DUSEL
Large Cavity Detectors

Richard W. Kadel,

Physics Division, LBNL

FNAL, July 13, 2009



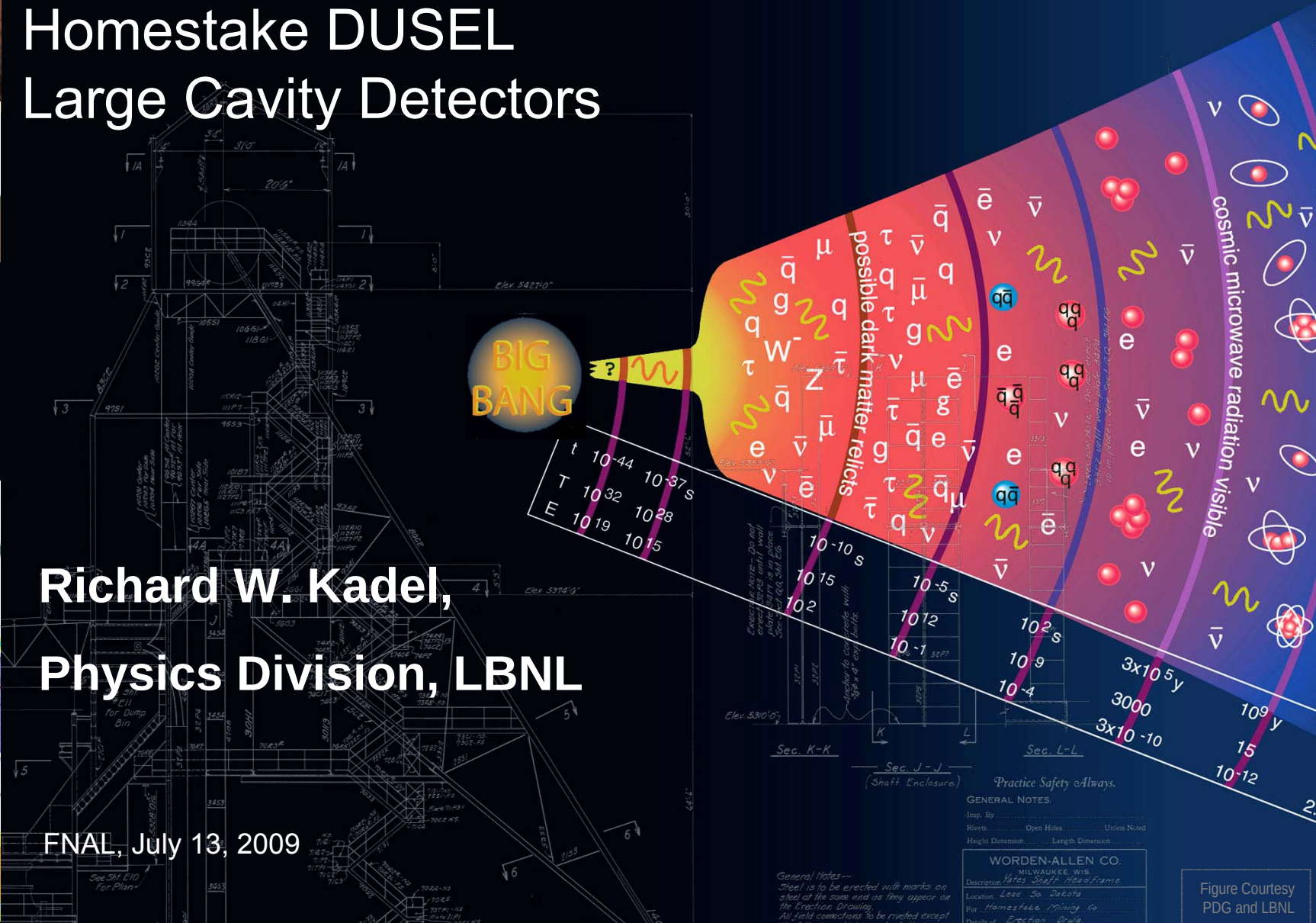
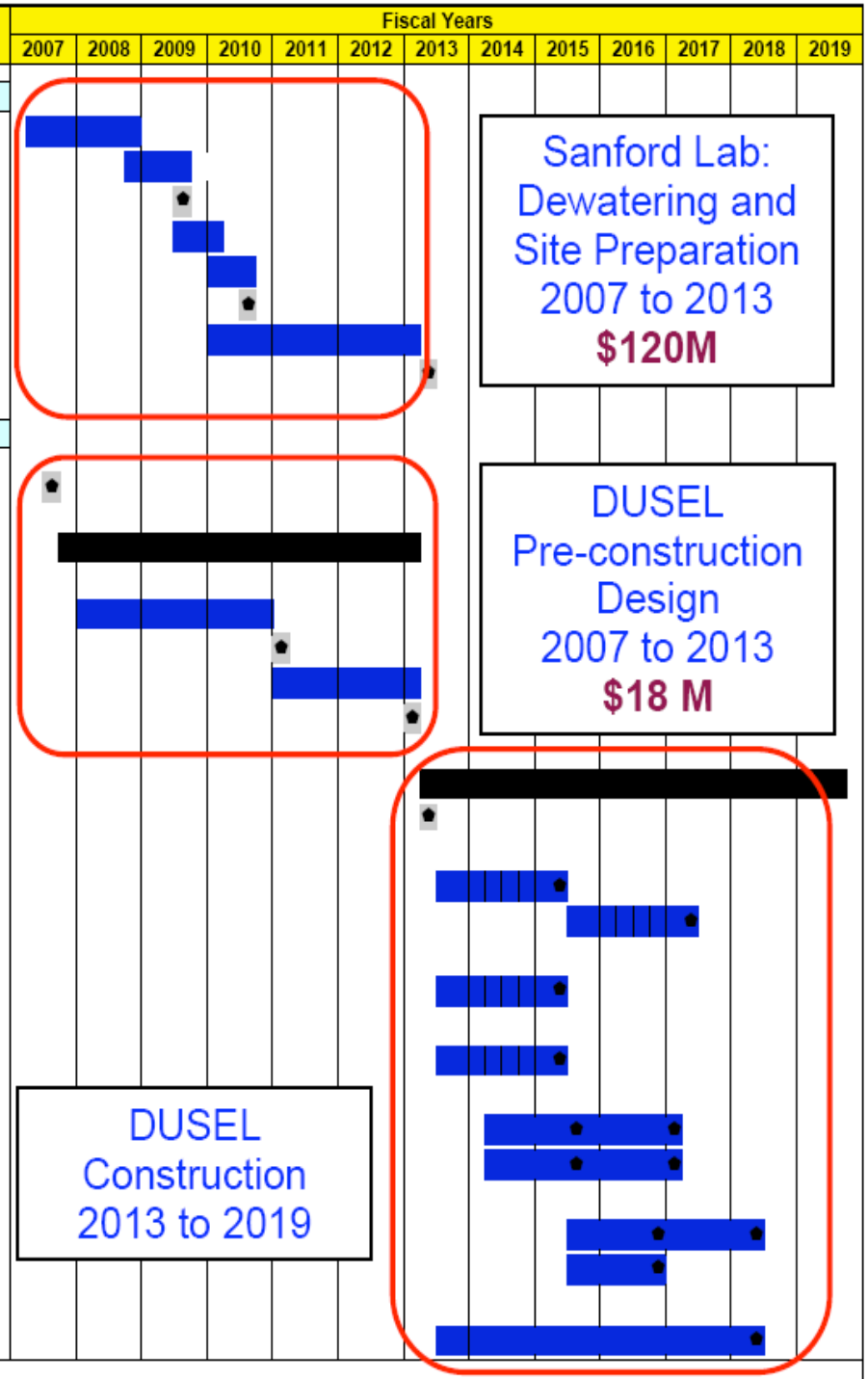


Figure Courtesy PDG and LBNL

Outline

- DUSEL Schedule
- Major Milestones and Contracts
- Dewatering progress
- Initial Cavern Specification for Water Cherenkov
- Isometric Drawings of Cavern
- LCAB meeting
- Conclusions

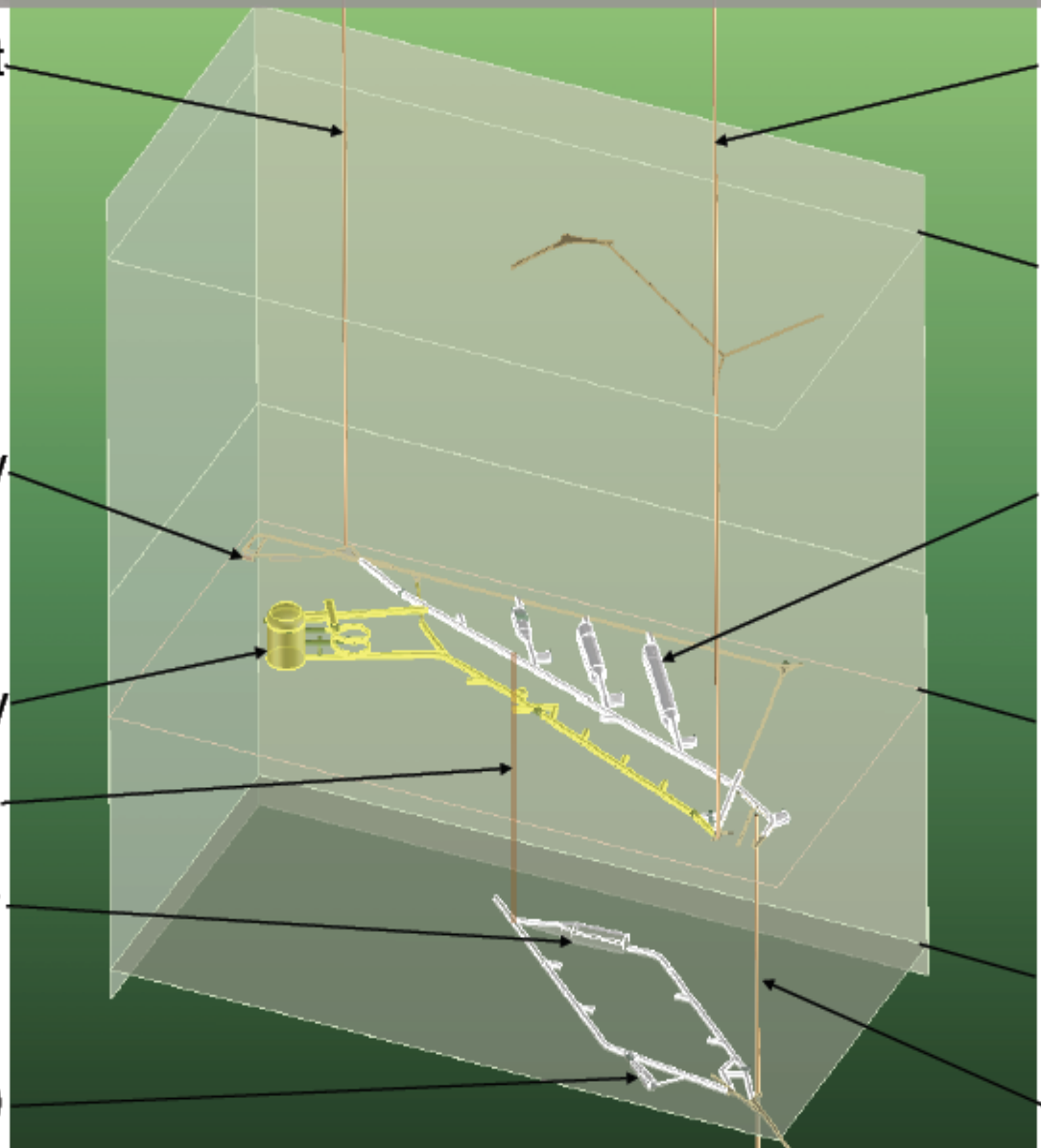
Proposed Timeline for Sanford Laboratory and DUSEL Facility Development	Start	Finish
Sanford Laboratory at Homestake		
Ross Shaft Rehab and Pumping Column Commissioning	Jan-07	Sep-08
Yates Shaft Rehab.	Aug-08	Aug-09
Gain safe access to 4850L for EIP construction start, and hold water level at 5000L		Jun-10
Install facility infrastructure for Davis Lab early experiments	Jun-10	Dec-10
Install and commission research instrumentation in Davis Lab	Sep-09	Jun-10
Early experiments in Davis Lab ready for operation		Jun-10
Continued rehabilitation and infrastructure upgrades for Sanford Lab		Dec-12
Transition from Sanford Lab to DUSEL Operations		Jan-13
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-12**
Preliminary Design Phase to develop Baseline Cost and Schedule	Oct-08	Dec-10
Preliminary Baseline Design Review and National Science Board Recommendation		Mar-11
Final Design Phase	Jan-11	Dec-12
Final Design Review and Authorization for Construction Start		Dec-12
DUSEL Facility - Construction and Commissioning (MREFC)	**Jan-13**	**Sep-19**
Proposed Construction Start		Jan-13
Surface Campus Construction		
Phase 1 Offices and Laboratories, Education and Outreach	Apr-13	Mar-15
Phase 2 Offices and Laboratories	Apr-15	Mar-17
Near-Surface Campus Construction at 300L		
300L Labs and Education and Outreach Facilities	Apr-13	Mar-15
Infrastructure Development to support underground construction		
Mid-Level and Deep-Level Campuses	Apr-13	Mar-15
Mid-Level Campus Construction at 4850 Level		
4850L Common Facilities and Lab Module #1 (Excavation & Lab Build-out)	Jan-14	Dec-17
4850L Davis lab Alterations and Lab Module #2 (Excavation & Lab Build-out)	Jan-14	Dec-17
Deep-Level Campus Construction at 7400 Level		
7400L Common Facilities and Lab Module #1 (Excavation & Lab Build-out)	Apr-15	Mar-18
7400L Lab Module #2 (Excavation Only)	Apr-15	Sep-16
Large Cavitiy Excavation and Facility Infrastructure		
Infrastructure Development and Excavation	Apr-13	Mar-18



Major Milestones

- Large Cavity Design Supplement May 2009
- Proposal to Prepare Preliminary Facility Design & Integrate the Suite of Experiments: submitted 15 May 2009
- NSF Solicitation to Develop Experiments (S-4) Results: anticipated ~ July 2009
- S-4 Work Shop in South Dakota: 1-5 Oct 2009
- Preliminary Design Complete: fall 2010
- Presentation to NSB: spring 2011
- Construction Start: 2nd Quarter 2013

DUSEL Preliminary Underground Campus Development, MREFC Scope



Infrastructure, Facility, and Geotechnical Design/Site Assessment

- the Project is relying on three major design contracts for initial assessments
  - Surface Facility Assessment and Design - HDR
  - Underground Infrastructure Assessment and Design - ARUP
  - Geotechnical Site Assessments for Large Cavities and Lab Modules (4850L) - RESPEC
- All are on site
- Contract expansions and new contracts established as funds are available

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- Geotech Site Investigations
  - 3D geological model developed
  - laser mapping of the 300L completed
  - 4100 to 4850L preliminary geological/structural mapping developed (addition work initiated)
  - coring and testings to initiate work on the 4850L in July
    - Lab Modules
      - preliminary siting & orientation
    - Large Cavity
      - Initial sites begin developed
      - geotechnical investigation campaign initiated

RESPEC Start of work on 4850L on July 11 (Monday)

Mapping drifts

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- Surface Facility
  - building assessments, documentation
  - infrastructure
    - power
    - sewers
    - water
    - IT
    - roads
    - security
    - ...
  - preliminary assessment being followed by preliminary design for upgrade and estimate

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- Underground Infrastructure Assessment
  - hoists & motors
  - shafts
  - ventilation
  - ground conditions
  - utilities
  - life and fire-safety plans
  - level inspections and documentation
    - ground conditions
    - hazard assessments
    - mitigation plans drafted

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- Following initial geotechnical siting and infrastructure assessments this summer
  - excavation design
    - lab modules 4850 (extrap
    - large cavity
  - lab module and large cavity design ut
    - using current (initial) requirements
- Extensions to existing contracts and additional contracts being negotiated/ developed
- Education and Outreach Design integrated into Surface and Underground efforts

RFP's for Excavation design and Lab buildout now being advertised

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- Safety Codes and Plans
  - documentation developing
  - OSHA requirements and codes established
  - safety program in place
    - no lost-time injuries in 2009
    - significant increase in activity on the site
  - Emergency Response and Life Safety Programs in place, additional development for DUSEL required

Infrastructure, Facility, and Geotechnical Design/Site Assessment

- Environmental Impact Statement work initiated
  - ANL (environmental division) lead with NSF
    - draft schedule
      - NOI Summer 2009
      - Scoping meetings Summer 2009
      - Draft EIS Fall 2010
      - ROD Late 2011
    - first meetings occurred in Berkeley and Lead
  - Significant Cultural Outreach efforts continuing

NOI = Notice of Intent
ROD = Record of Decision

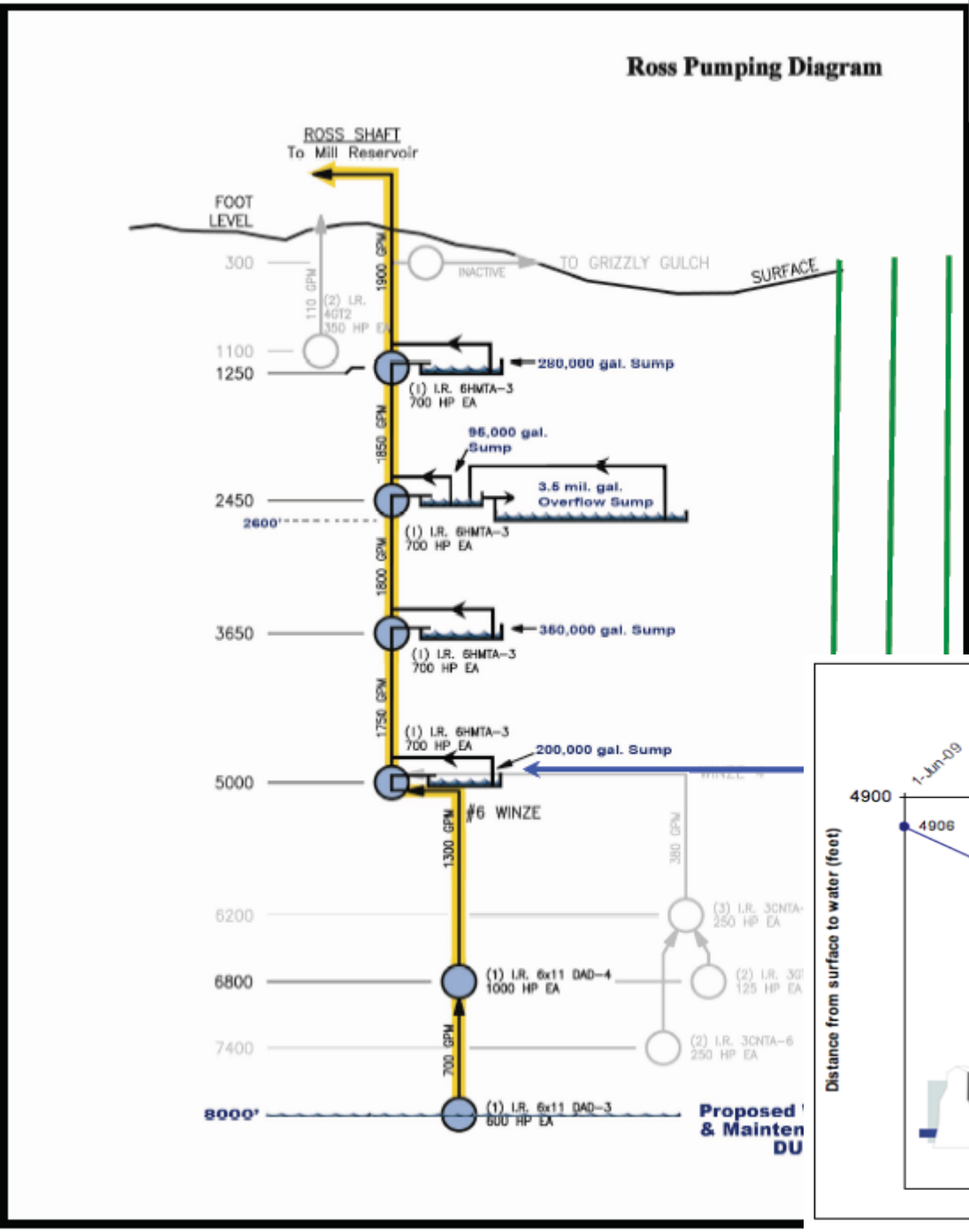
SDSTA Recent Progress

REHABILITATION OF SHAFTS & HOISTS

- Ross Shaft rehabilitated to water level. ($9.2 million)
- Ross Hoist re-certified and operating.
- Yates Shaft rehabilitation in process. ($9 million bid awarded)

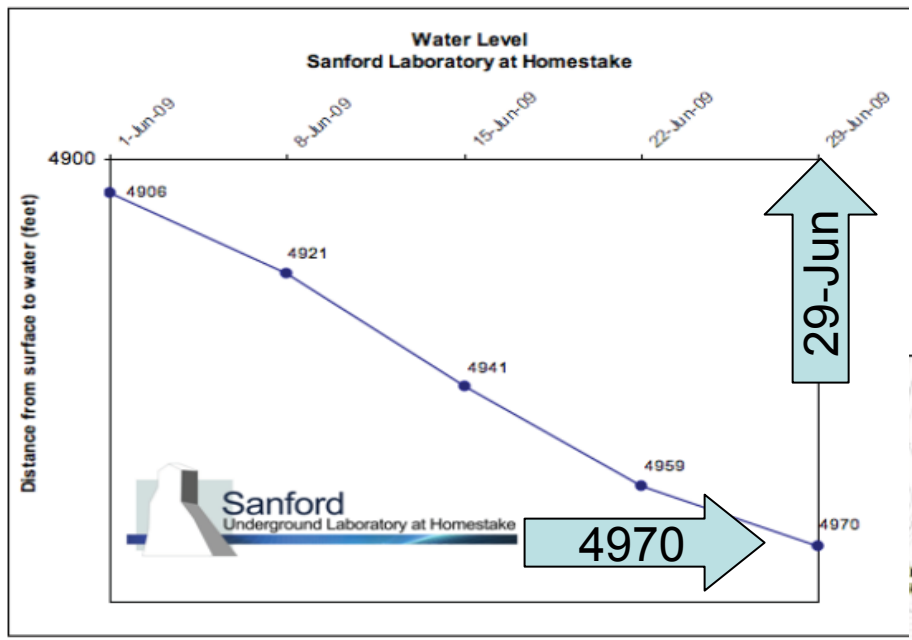
Yates Hoist is re-certified and operating.

Dewatering Homestake: Current Water Levels



Re-entry Efforts, begun July '07

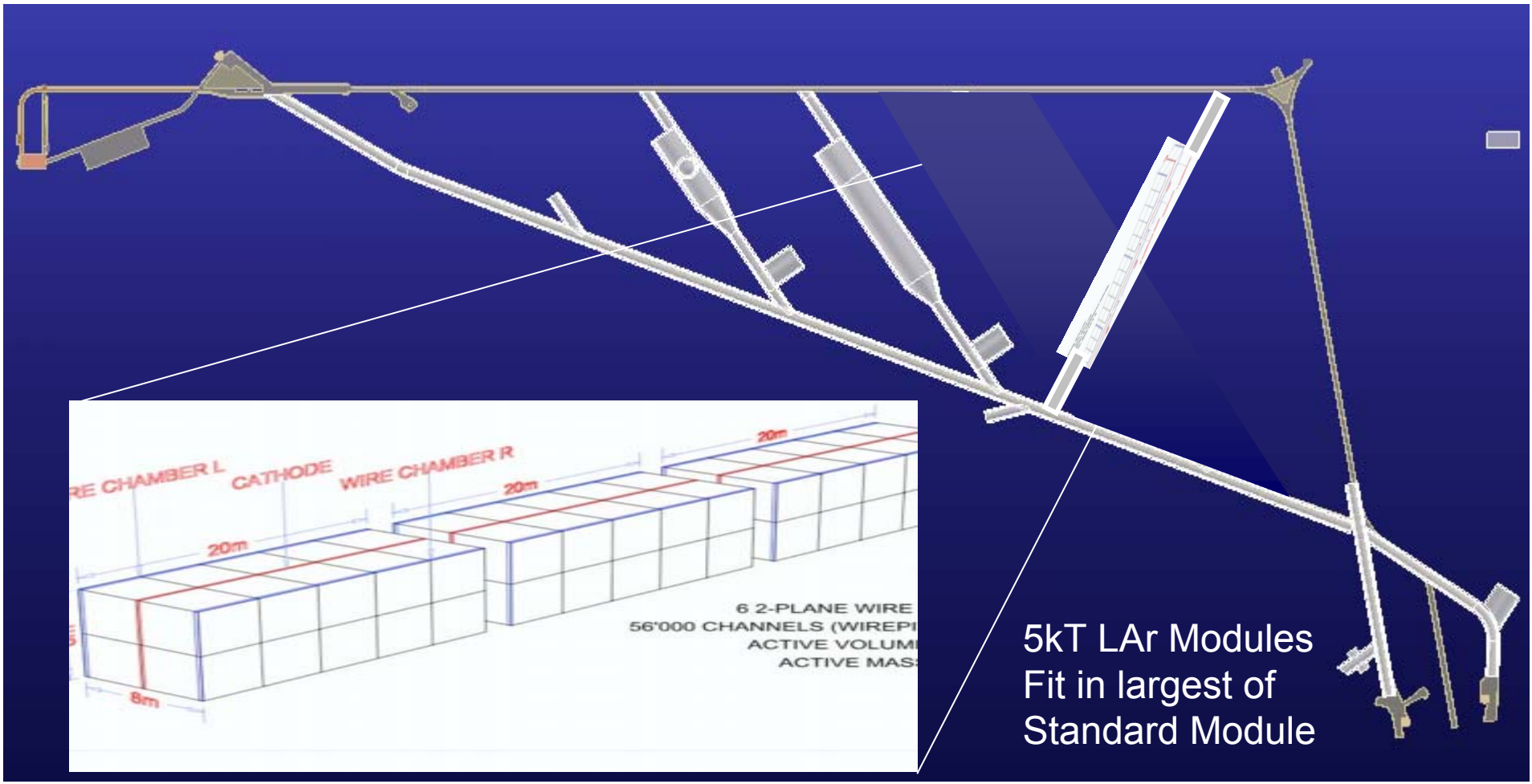
- Ventilation reestablished
- Ross Shaft hoists rehabbed
- Inspected levels and Ross shaft down to ~ 4850
- 4850L achieved May 2009



Cavern Specs

- Assume that 5kT LAr S4 proposal can fit in standard lab module at 4850.
- Have drafted “physics” specification for 100kT F.V. Water Cherenkov
- Shape of cavity will ultimately depend on
  - Geology
  - Constructability
  - Cost

Liquid Argon S4 Proposal : 5kT



LAr Action Item

For 5kT S4 detector, document efficiency as a function of the angle between the detector and the beam from FNAL.

H_20 Cavern Spec Document

DUSEL

Long Base Line Neutrino Experiment
(LBNE)
Cavern Size Requirements

R. W. Kadel
LBNL
11-June- 2009

DUSEL Note # 73

Abstract: This note describes the excavation necessary for a 100kT fiducial volume water Cherenkov detector. The necessary volume is a right cylinder, with a free diameter of 55 m and a free depth of 58 m deep below the 4850L.

Definitions

Cavern spec summarized from physics perspective in DUSEL note 73.

Free Diameter: Unobstructed diameter of finished cavern with ground support installed.

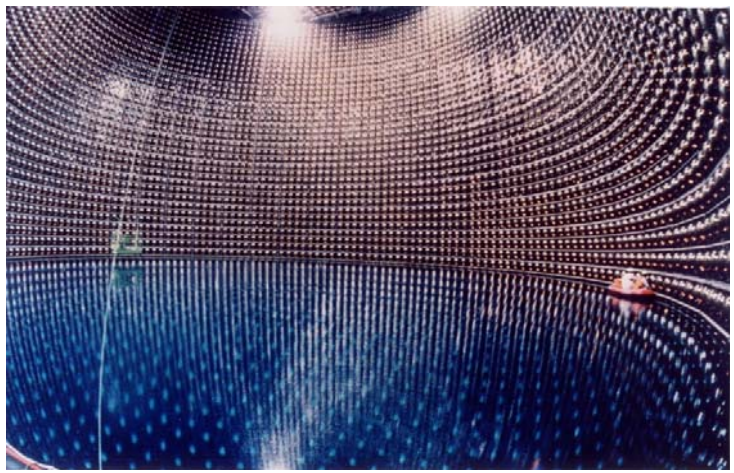
Free Height: Unobstructed distance from the top of the detector to a [possibly virtural] flat floor of the cavern.

Free board: distance between the top of the water and the next thing higher it should not touch.

Fiducial Volume: The allowance in meters, either radially or axially, between the maximum extent of photocathode and the volume of water used for physics analysis (see following pictures).

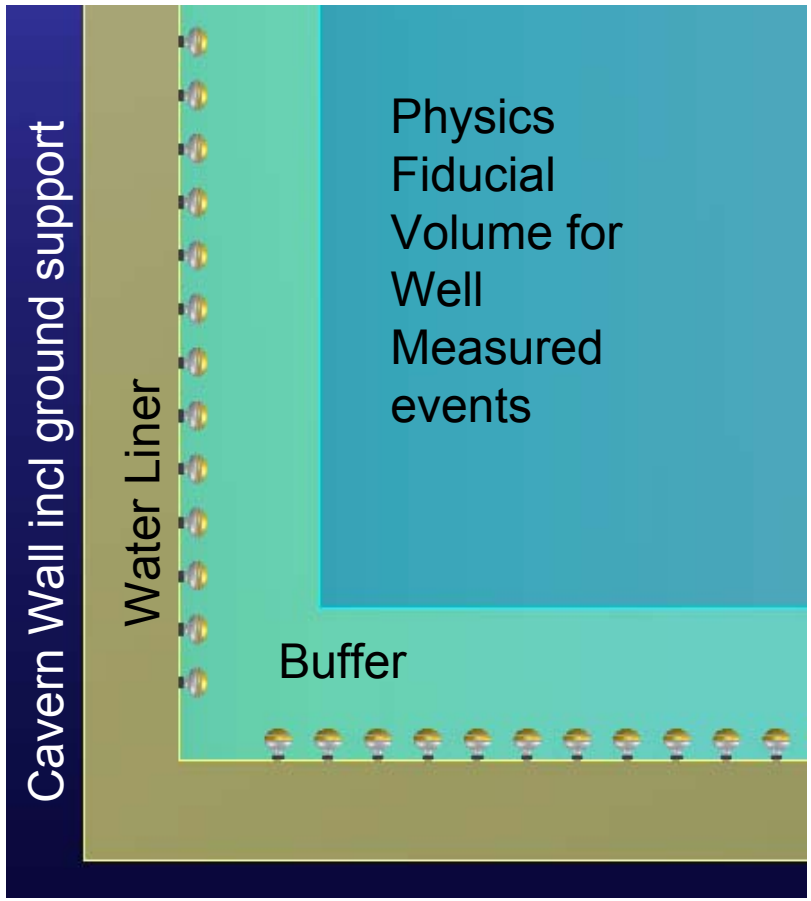
Buffer volume: volume of water immediately around PMTs including the volume need for their support and any fiducial volume cut

Cross section at lower Corner of Cavity



Super-Kamiokande
22 kT F.V., 50kT total.

"Virtual" dividing line
Not a physical boundary



Courtesy D. Plate, S. DeVries

Requirements and Constraints

Item	Value	Reason
Total Volume of WCh detector	≥300kT	Neutrino Oscillation parameter measurement, Proton Decay,
Minimum fiducial Volume per Cavity	≥100kT	Scientific Competiveness
Maximum distance between cavities	5 km perpendicular to neutrino beam	Neutrino beam opening angle
Maximum Depth of Water above lowest PMT	60 m	PMT collapse under water pressure
Depth of Cavity below Surface	4850L	Cosmogenic background to proton decay
Maximum Distance between PMTs	80 m	Water attenuation length at peak PMT wavelength sensitivity when convoluted with Cherenkov light spectrum
Cavity Lifetime	≥30 years	Proton Decay, Neutrino Oscillation parameter measurement
Egress	Dual Egress from drifts and cavities during all phases of construction and operation	Personnel Safety
Water management	Inherently protect the remainder of the DUSEL facility from catastrophic failure of the water containment	Personnel, Equipment or facility safety
Code requirements	TBD	Personnel, Equipment or facility safety

Assumptions

Assumption	Value
Fiducial Volume	100kT
Shape	Right Cylinder
Minimum Diameter of Water (incl buffer)	53 m
Fiducial Volume cut	1 m
Buffer size (radially and axially)	1.5 m
Allowance for drainage and liner (sides and bottom)	1 m
Allowance for freeboard and deck (top only)	3 m combined
Top of deck	Level with 4850L

Specification

Item	Specification
Shape	An unobstructed right cylindrical volume free of rock outcroppings or ground support *
Free Diameter	55 m*
Top of right cylindrical	level with the 4850L
Free Height from [possibly virtual] flat floor to 4850L	58 m*
Lifetime	≥30 years

*This value follows from assumptions

Discussion

- Freeboard: The spec allows 3m vertical height between the top of the water and the 4850L (assumed level of deck)
- Crane access over full detector volume possible only at top of cylindrical volume, otherwise interference with dome.
- Full crane access may not be necessary for excavation.
- A 55 m span Deck may need support from above, either by cables, truss system, etc
- Support cables or truss for deck may interfere with crane for detector construction. A series of jib cranes around perimeter of the cavern may be adequate for the experiment.
- Final water temperature ≤ 15 degC (supress biologicals)

Temperature

- Final water temperature ≤ 15 degC (suppress biological activity)
- Estimate 70kW from rock.

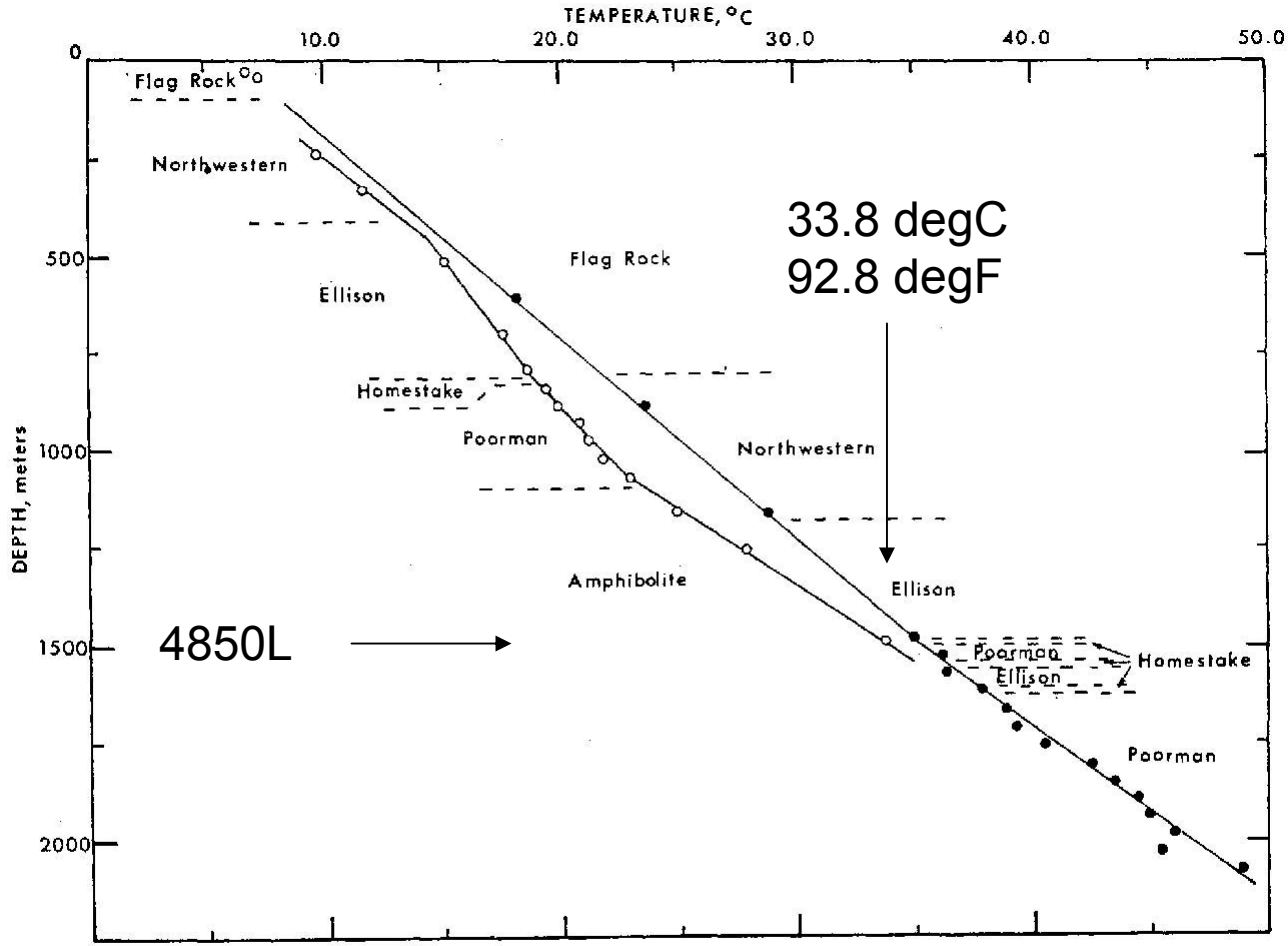


Fig. 2. Temperature-depth curves and rock units in Yates (open circles) and No. 4 and No. 5 (solid circles) Shafts, Homestake Mine, Lead, South Dakota.

D. Blackwell, PhD Thesis, Harvard 1967

Thermal Conductivity

Table 2. Thermal Conductivity, Gradient and Heat Flow
Homestake Mine, Lead, South Dakota

		Number of samples	Number of temperatures*	Average thermal conductivity**	Average gradient	Average heat flow
Flag Rock Formation	Yates	2	2	9.1	***	--
	#4	--	1	--	--	--
Northwestern Formation	Yates	1	2	10.9	20.4	(2.2)
	#4	--	2	--	--	--
Ellison Formation	Yates	3	3	16.4	12.8	2.10
	#4	3	--	11.2	--	--
Homestake Formation	Yates	--	--	--	****	--
	#4	4	--	7.9	--	--
Poorman Formation	Yates	8	7	10.8 ± 1.1	17.2 ± 3.4	1.86 ± .37
	#4	7	11	7.5 ± .5	24.4 ± 2.1	1.83 ± .28
Amphibolite	Yates	6	3	6.9 ± 1.1	26.4	1.82
		4		7.3 ± 2.0	26.4	1.93
	#4	--	--			

*The number of temperatures is the number of points within each unit.

**The average conductivity has been calculated for dip of 65°.

***No gradient calculated as both points are at less than 50 m. depth.

****The Homestake Formation is too thin and highly contorted to calculate a gradient

Watt/m/degC

H_20 Cherenkov Action Item:

Document
requirement for
water temperature
≤ 15 degC

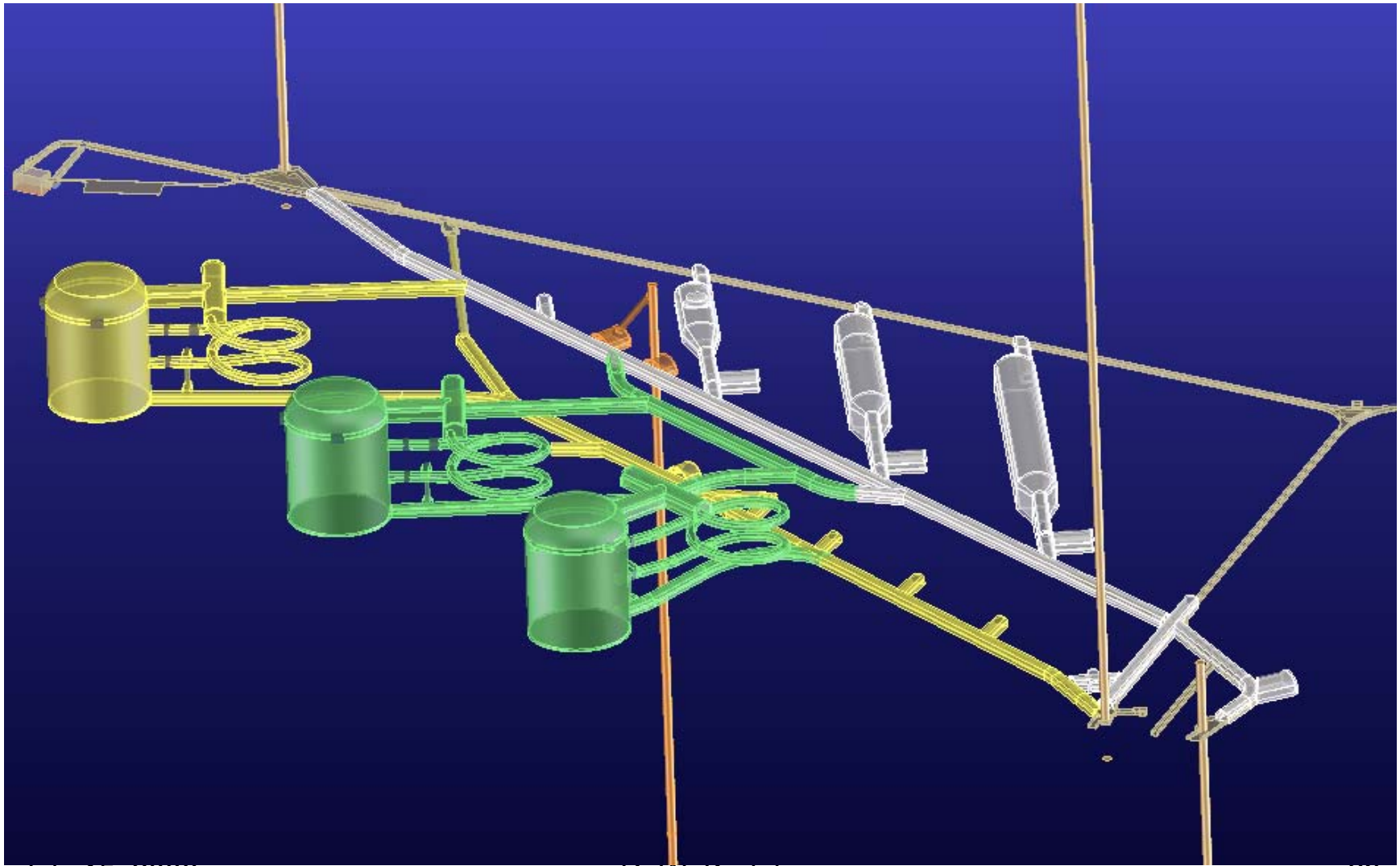
100 kT fiducial Volume Liners

	Unit	1 Steel self supporting	2 Concrete blocks	3 Unitary post-stressed concrete vessel self supporting	4 Liner on shotcrete	5 Cast concrete against rock	6 Pressure balanced wall
Fiducail Radius	m	25	25	25	25	25	25
Fiducial volume cut	m	1	1	1	1	1	1
PMT module thickness	m	0.5	0.5	0.5	1	1	1
Gap between PMT module and tank wall	m	0	0	0	0.2	0	0.2
Buffer size	m	1.5	1.5	1.5	2.2	2	2.2
Sealing/coating layer thickness	m	0.005	0.005	0.005	0.005	0.005	0.01
Tank water radius	m	26.51	26.51	26.51	27.21	27.01	27.21
Tank wall thickness top	m	0.05	0.5	1	0.1	1	0.01
Tank wall thickness bottom	m	0.12	0.5	1.0	0.1	1	0.0
Tank wall thickness average	m	0.09	0.50	1.00	0.10	1.00	0.01
Tank outer radius	m	26.63	27.01	27.51	27.31	28.01	27.22
Access/drainage/balance gap	m	2	0.2	3	0	0	0.5
Rock wall raidus	m	28.63	27.21	30.51	27.31	28.01	27.72
Tank wall mass	tonne	5989	11453	23331	2316	23755	231
Fiducial volume	cu m	100000	100000	100000	100000	100000	100000
Fiducial height	m	51	51	51	51	51	51
Tank water height	m	54	54	54	54	54	54
Tank floor thickness	m	2	2	2	2	2	2
Excavation height	m	56	56	56	56	56	56
Excavation volume (without upper part)	cu m	144155	130207	163712	131168	137978	135184
Normalized		1.04	0.94	1.19	0.95	1.00	1.00

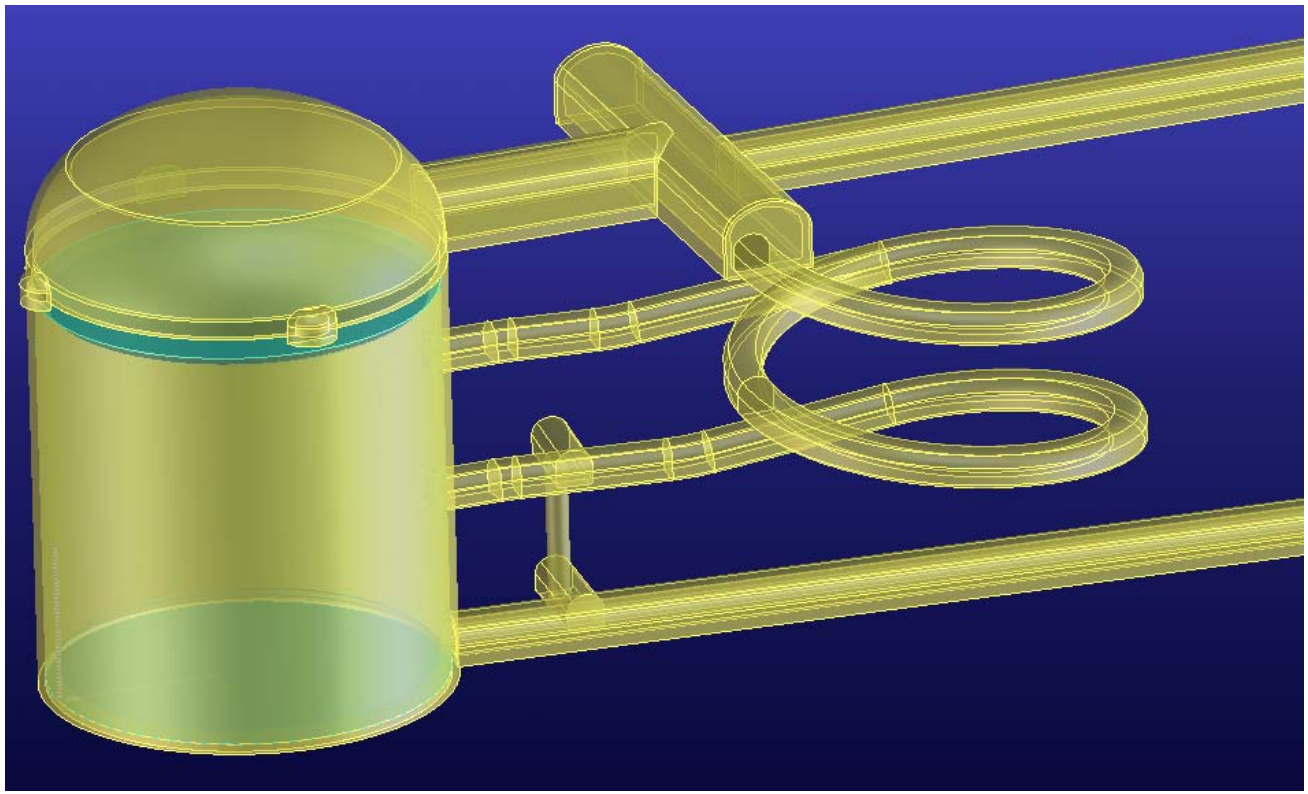
55m < Free Cavity Diameter < 61m

130,000 m^3 < Excavated Volume < 164,000 m^3

Cavity layout as of July 1

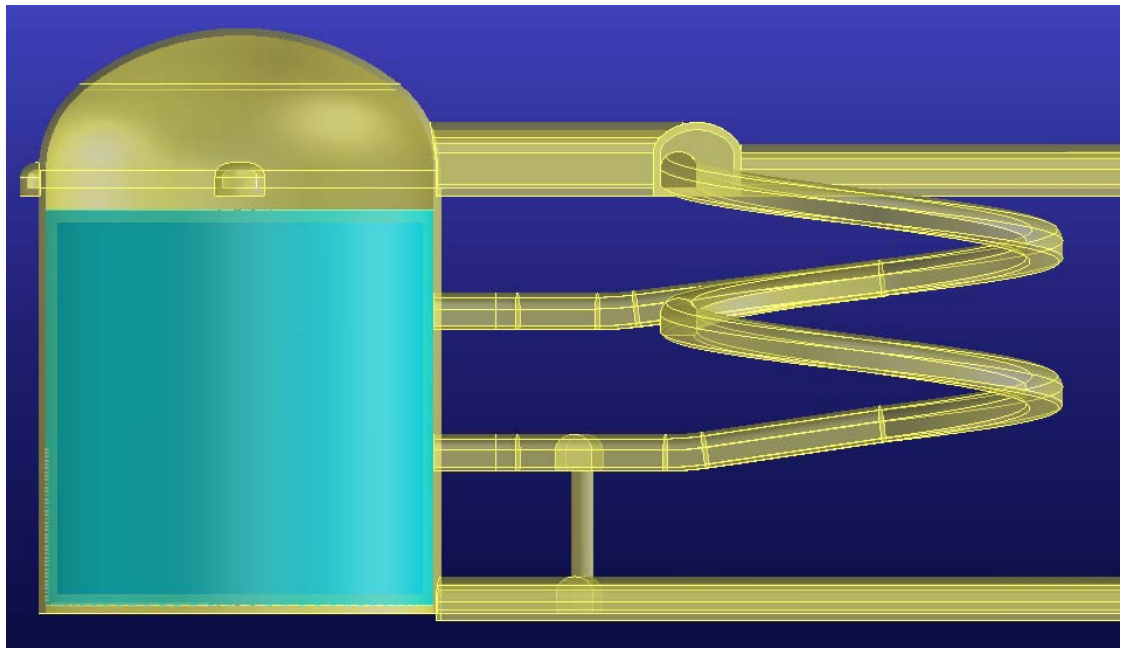


Isotropic view of Cavern, auxiliary spaces and excavation ramps



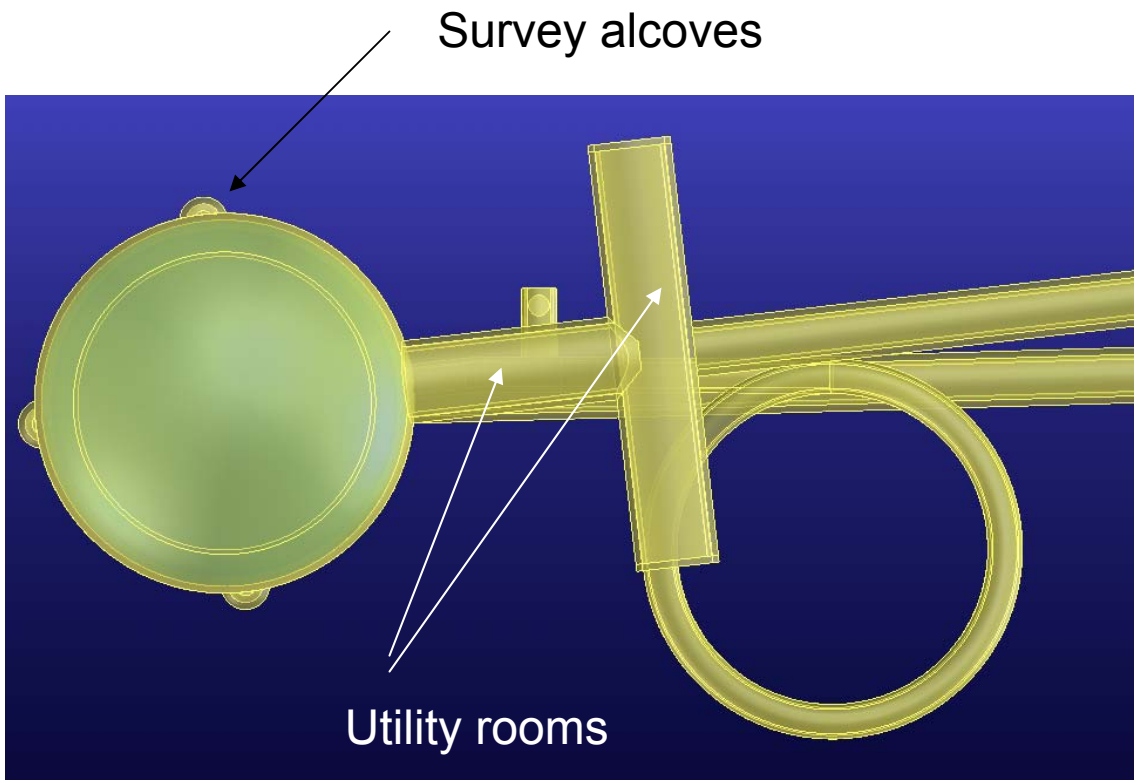
Courtesy D. Plate, S. DeVries

Side View of Cavern



Courtesy D. Plate, S. DeVries

Top View



Courtesy D. Plate, S. DeVries

LCAB meeting July 6-10, 2009 Lead, SD

- 2nd Meeting of the LCAB
- Agenda
  - Monday: Underground tour (20 people)
    - 4850L Triangle incl. Davis cavity (drained) & Ross shops
    - 4100L (Access to higher layer in Yates Anticline)
    - 2050L (VCR* stope in Poorman > 100ft dia)
  - Tuesday: Geology Reports
    - 2 core samples
  - Wednesday:
    - Physics Cavern Spec
    - 2nd mine tour (5 people)
    - Discussion of mine tour results
  - Thrusday: LCAB & Sanford Reports to NSF
  - Friday: Report writing & departure.

LCAB
(L-R) Ed Cording,
Evert Hoek,
John MacDonald,
Derek Martin

(*Vertical Crater Retreat)

Conclusions

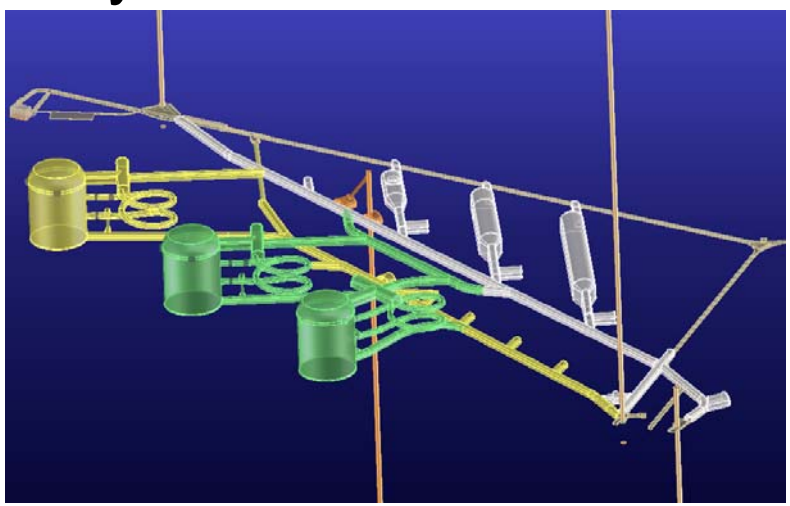
- DUSEL is moving quickly to establish contracts for underground and surface facilities design
- Early Physics program at Sanford Lab underway, excavation plans for LUX and Majorana demonstrator ~complete.
- Physics specification for cavity well received by LCAB. Continue to consider 60m dia cavities
- Geotech investigations at 4850L starting this week to determine best location and size of large cavities
- Size and shape of cavity will be determined by
  - Geology
  - Constructability
  - Cost

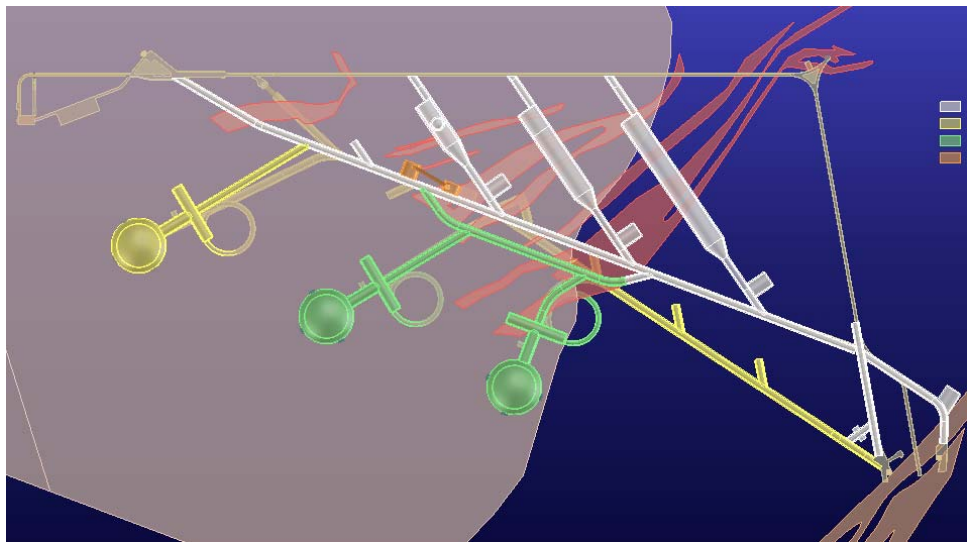
End/Backup

Detector Depth Conclusion

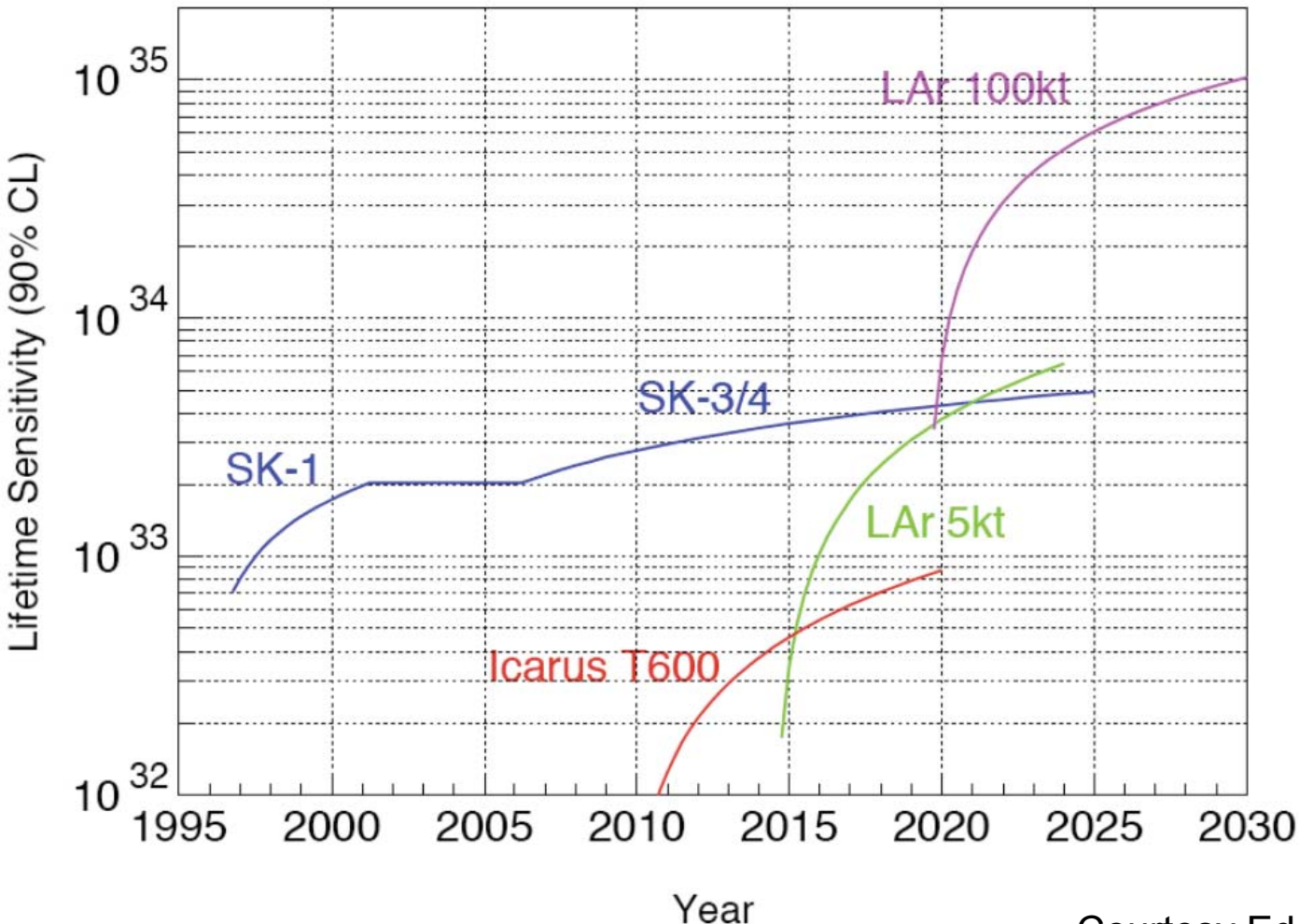
No physics goal requires a depth deeper than the 4850 Level

- Significant burden to go deeper (requires all material, equipment and personal change shafts)
- <u>Conclusion</u>: The depth required by physics goals weighed against the siting criteria suggest that the 4850L is the best location to search for candidate sites suitable for the large cavity detectors.



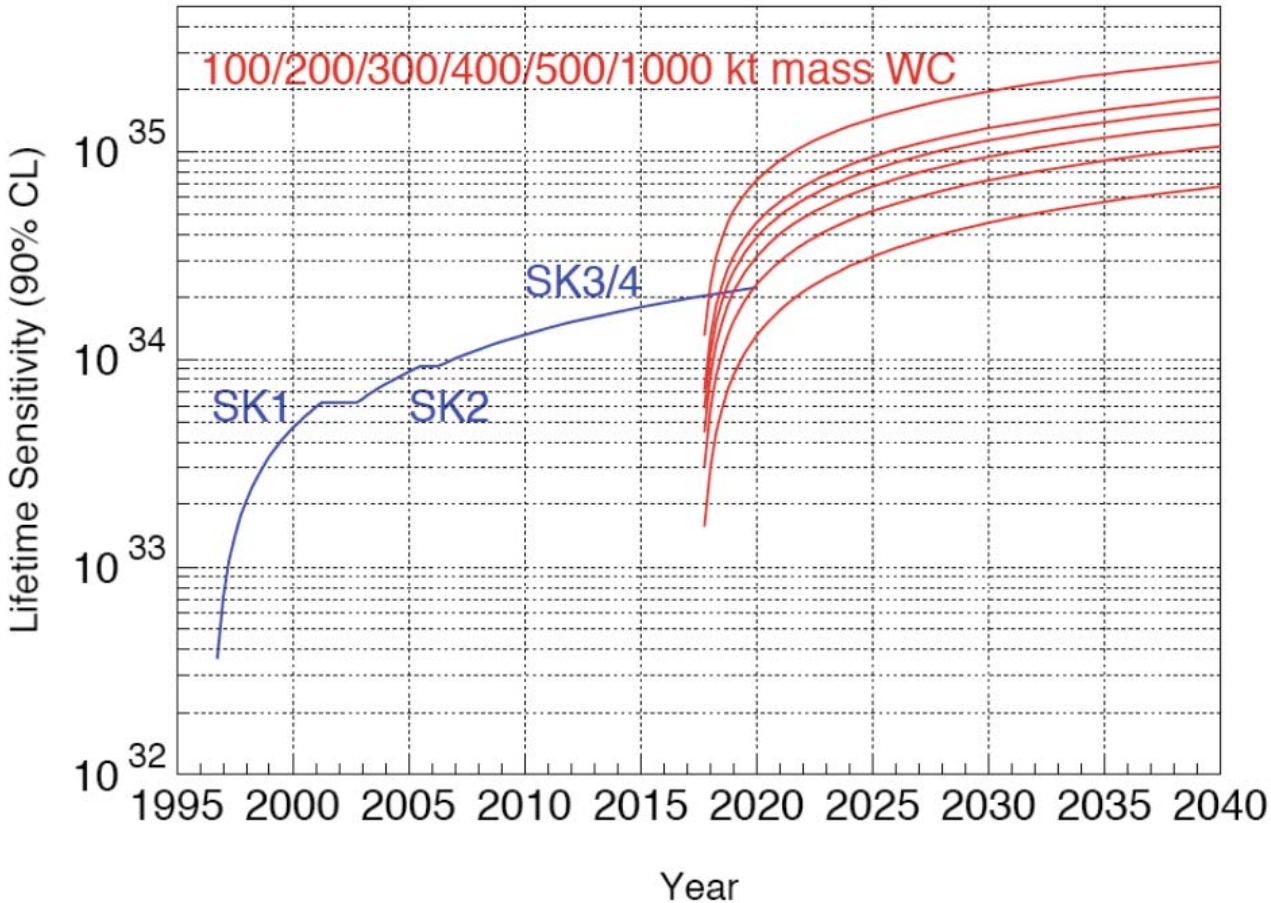


Proton Lifetime Sensitivity, LAr detector



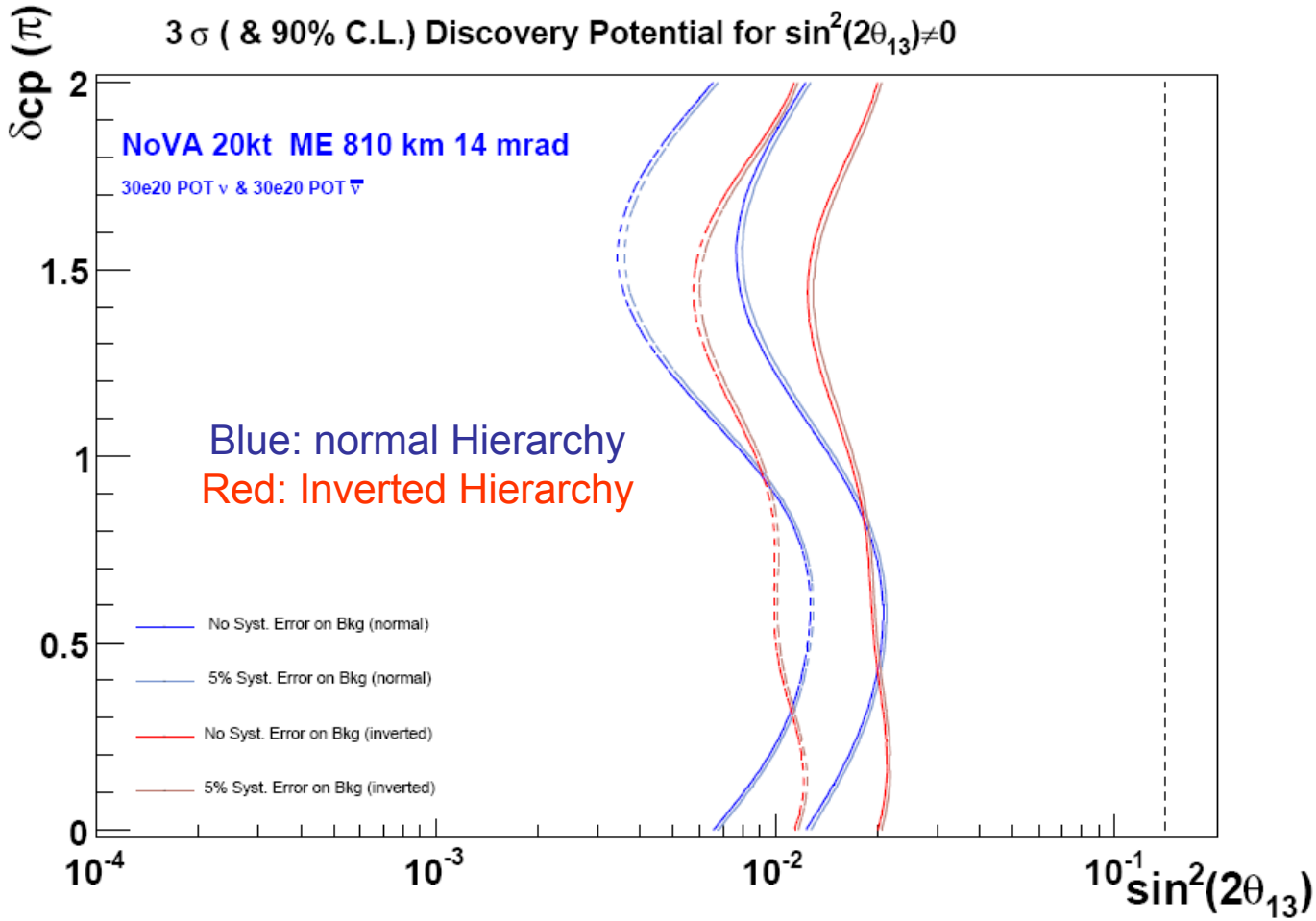
Courtesy Ed Kearns

Proton Life Time Sensitivity, Water Cherenkov



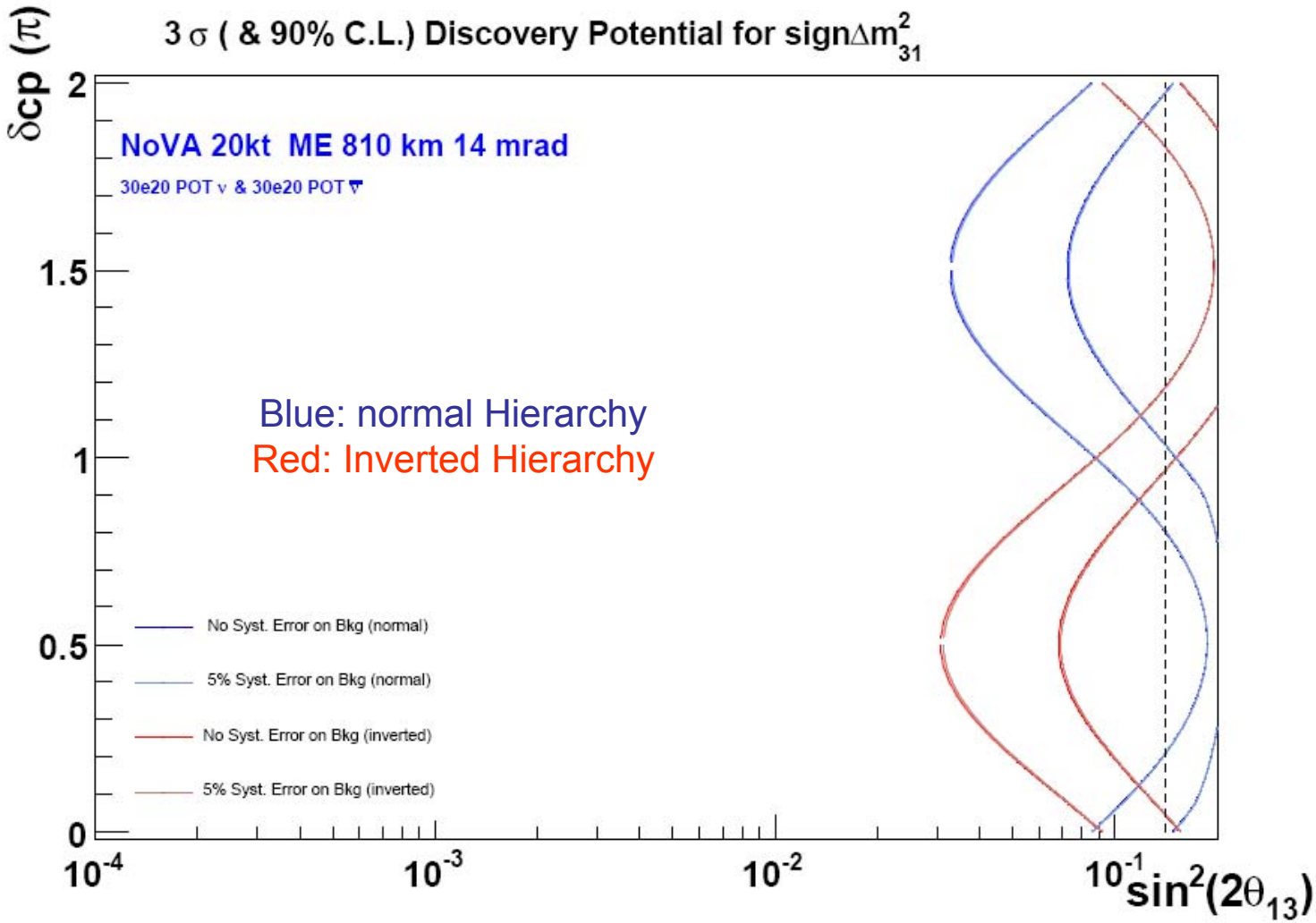
Courtesy Ed Kearns

NOVA, $\sin^2 2\theta_{13} \neq 0$



Report of the US long baseline neutrino experiment study, Fermilab-0801-AD-E

NOVA, Discovery Potential for



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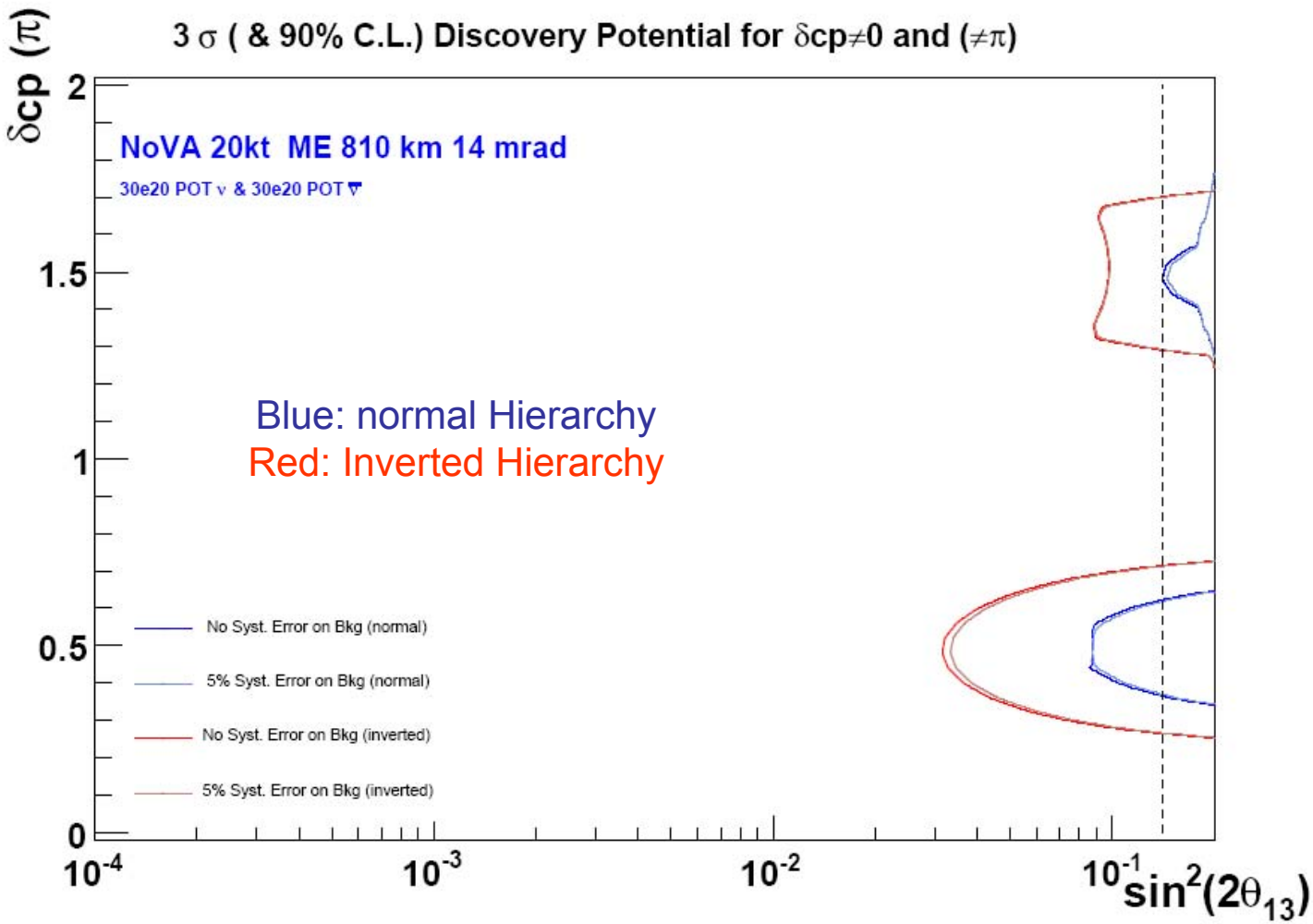
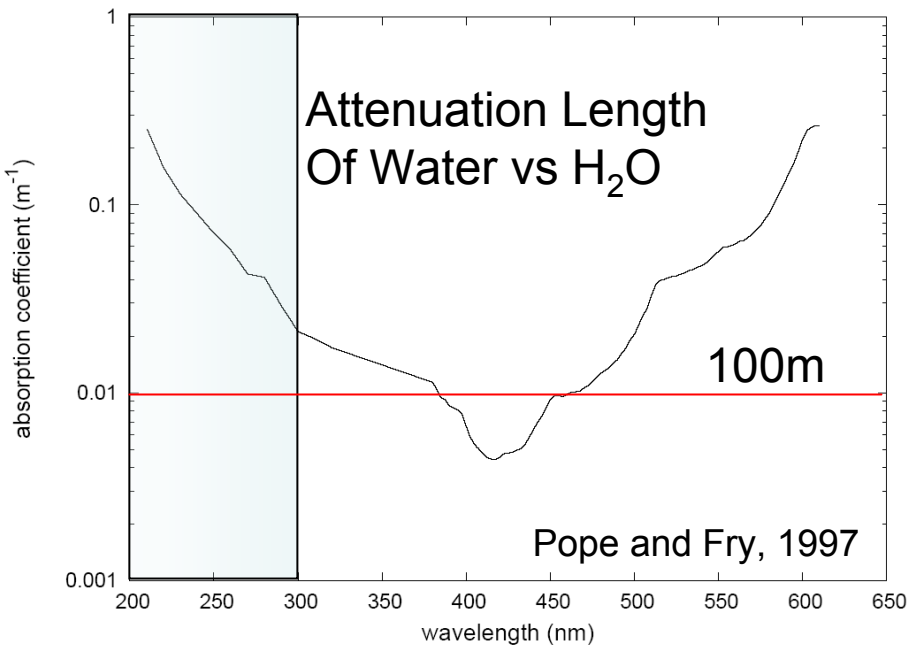
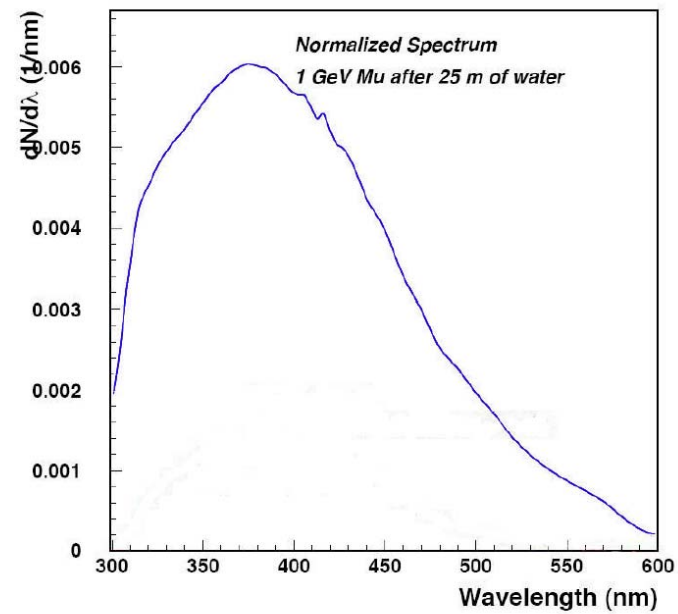
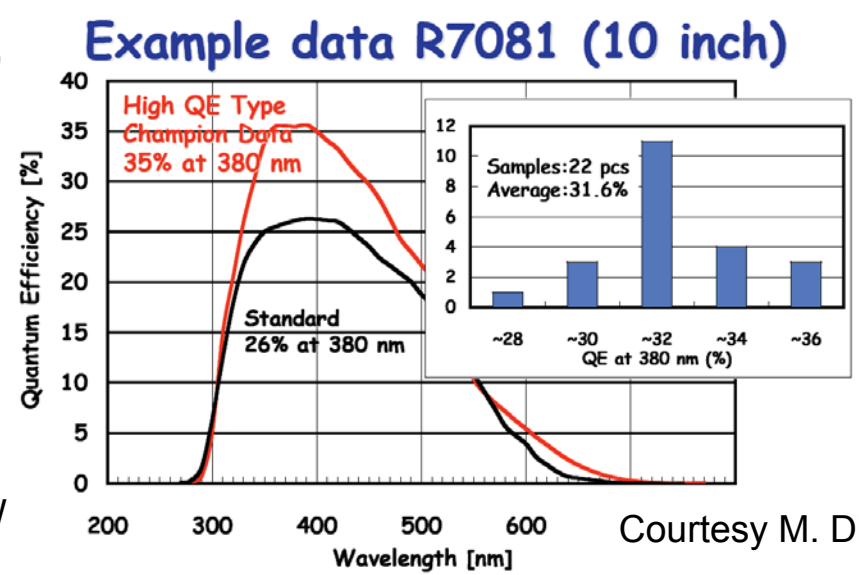


Report of the US long baseline neutrino experiment study, Fermilab-0801-AD-E

Requirements: Attenuation Length in H_20



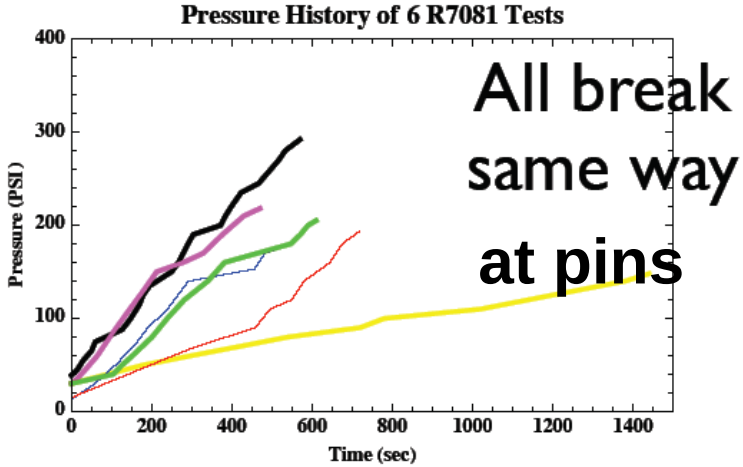


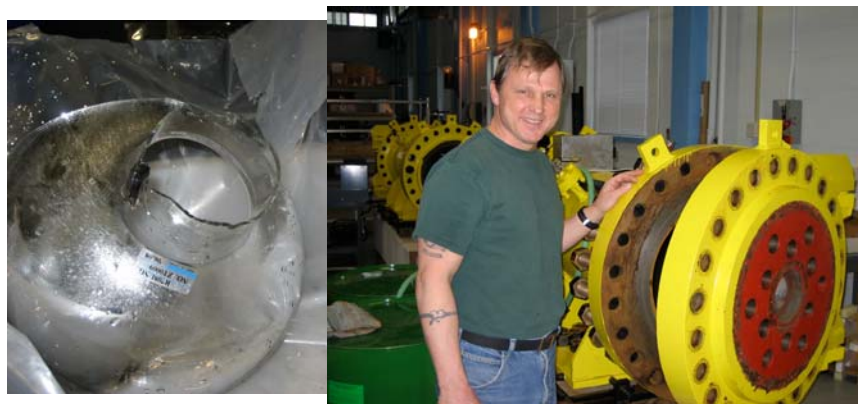


Courtesy M. Diwan

Requirements: PMT collapse Strength

- PMT's
  - collapse strength
  - QE. PMT's with 38% QE for available from Hamamatsu
  - Coverage >25%
- PMT's limit water depth to 60 m.
- PMT redesign or enclosures could improve performance.
- Pressure pulse

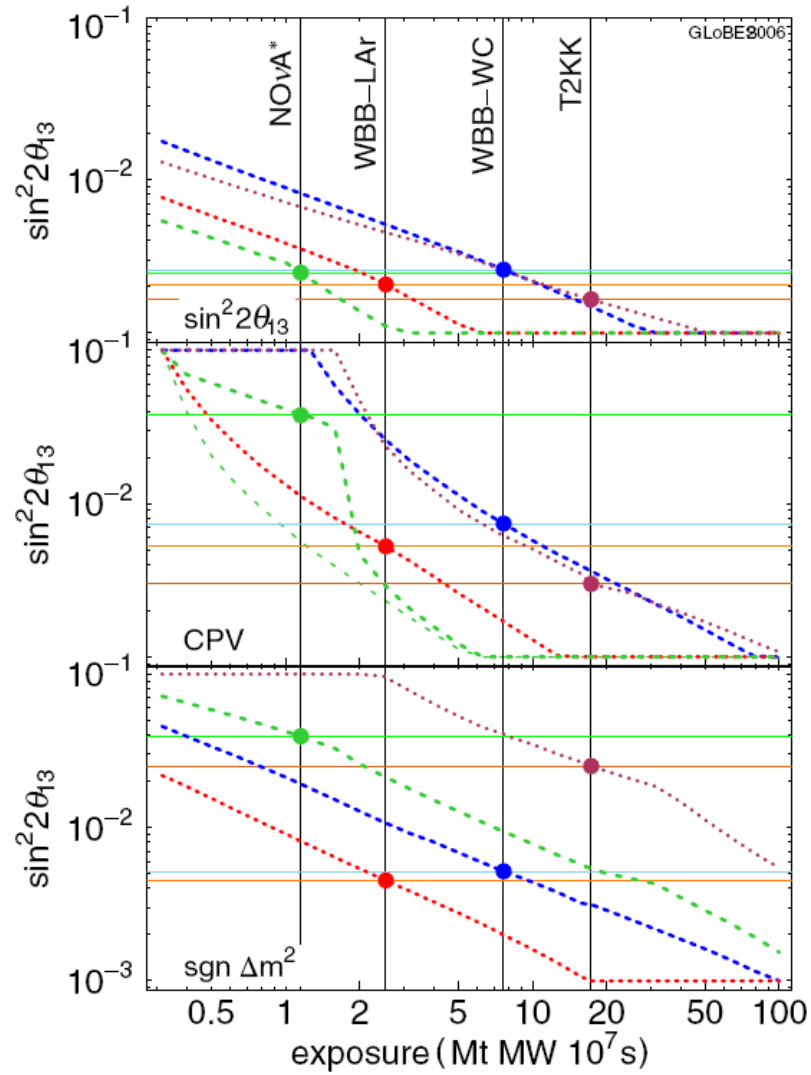




Courtesy M. Diwan

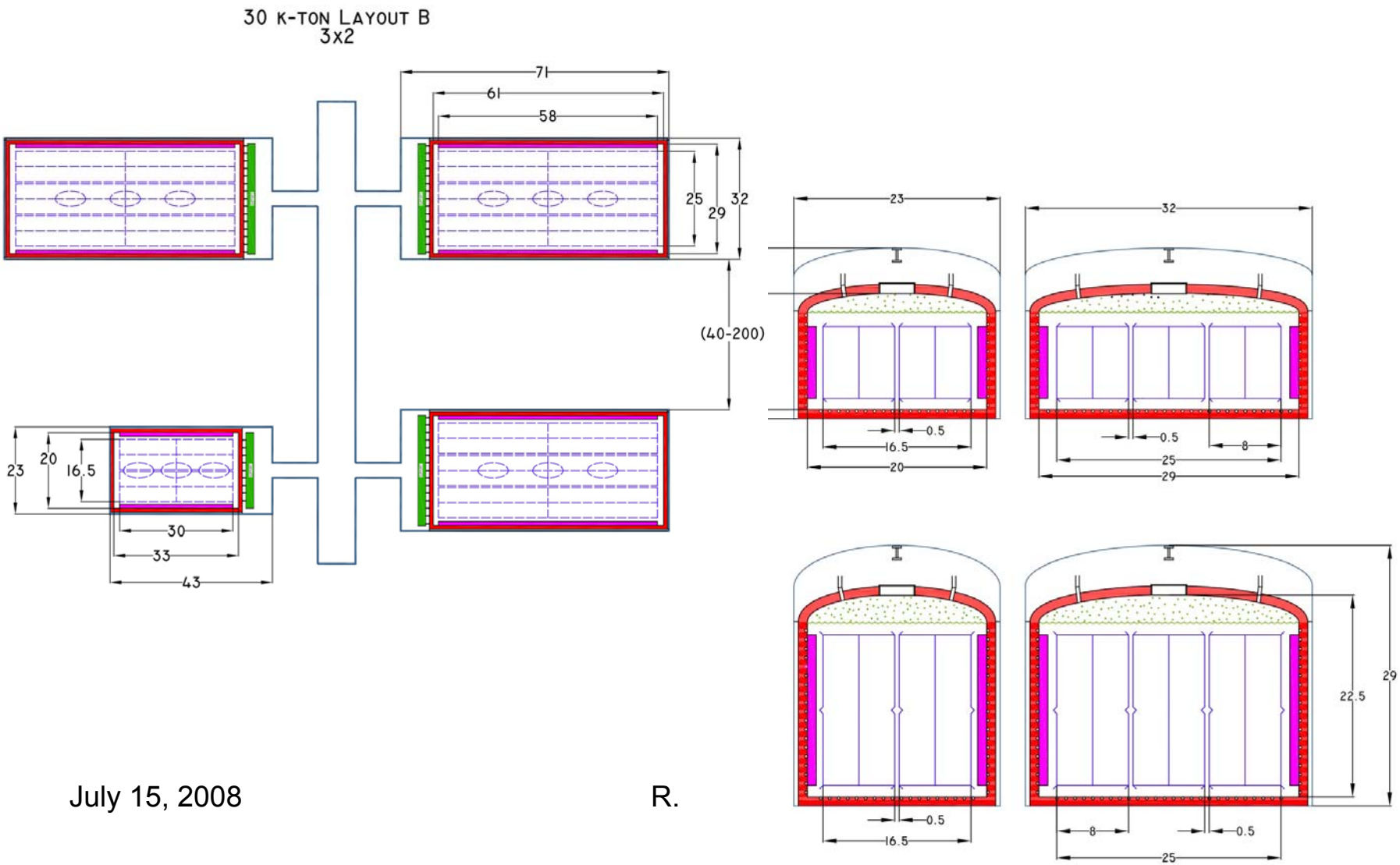
3σ Sensitivity
Future Long Base Line Experiments

Item	NOνA* LAr	WWB WCh	WWB LAr	T2KK WCh
POT/yr x10^{20} (ν)	10	22.5	22.5	52
POT/yr x10^{20} ($\bar{\nu}$)	10	45	45	52
Years ν + $\bar{\nu}$	3+3	5+5	5+5	4+4
Power (MW)	1.13	1 (ν) 2 ($\bar{\nu}$)	1 (ν) 2 ($\bar{\nu}$)	4
Baseline (km)	Ash River	1290	1290	295 + 1050
Mass (kT)	100	300	100	270 + 270
Exposure: (Mt-MW-10^7 sec)	1.15	7.65	2.55	17.85



Barger, et al, PRD 76, 031301 (2007)

Beyond 5kT LAr: Custom Cavities



Liner types

- Self supporting Steel can (PSL)
- Segmented Concrete blocks (Laurenti)
- Self supporting concrete vessel (BNL)
- Slip formed concrete from top or bottom
- No liner (ie water barrier over shotcrete) (LBNL./UCB)
- Pressure balanced wall