U.S. Underground Capabilities and Conclusions

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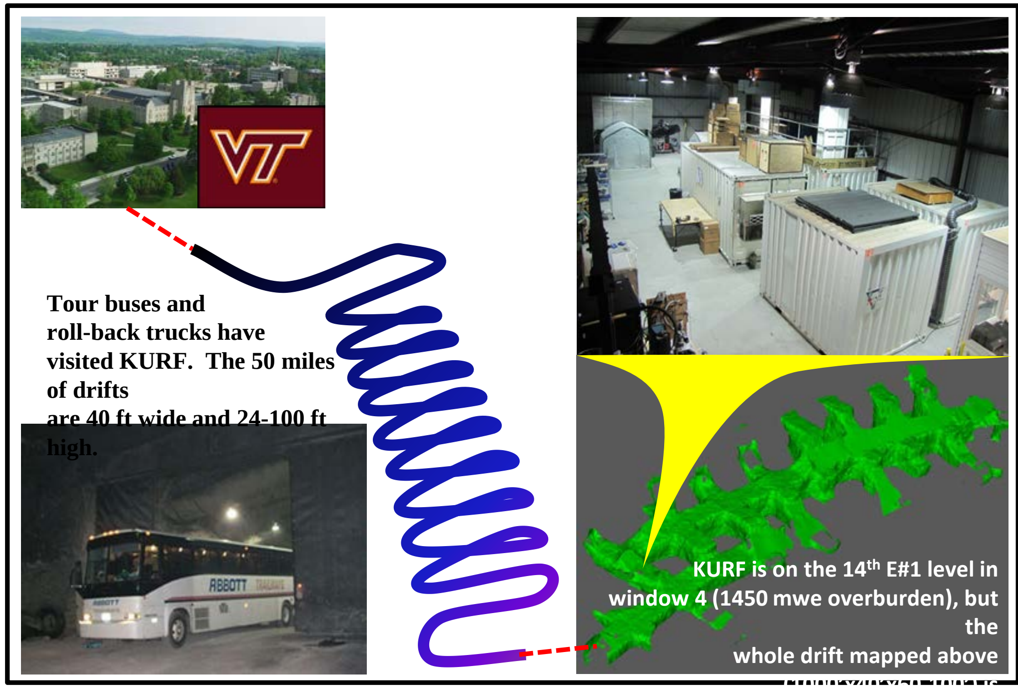
U.S. Underground Capabilities - Introduction

- Brief overview here and next few pages
- See "one-pagers" attached to agenda
- Organizational aspects
  - All U.S. - located sites rely on non – HEP support
  - Made/makes existence/operation possible
  - There is no explicit coordination of underground facilities in the U.S. – needed?
  - Organizational aspects have been discussed in meetings of the Deep Underground Research Association (DURA), and raised by our working group in phone meetings with U.S. lab heads – come back to this in the discussion session following this talk.
- South Pole facility, U.S. led, is unique.

	Non – HEP Support
KURF	Mining
Soudan	State of Minnesota
SURF	South Dakota, private
WIPP	Other part of DOE

KURF

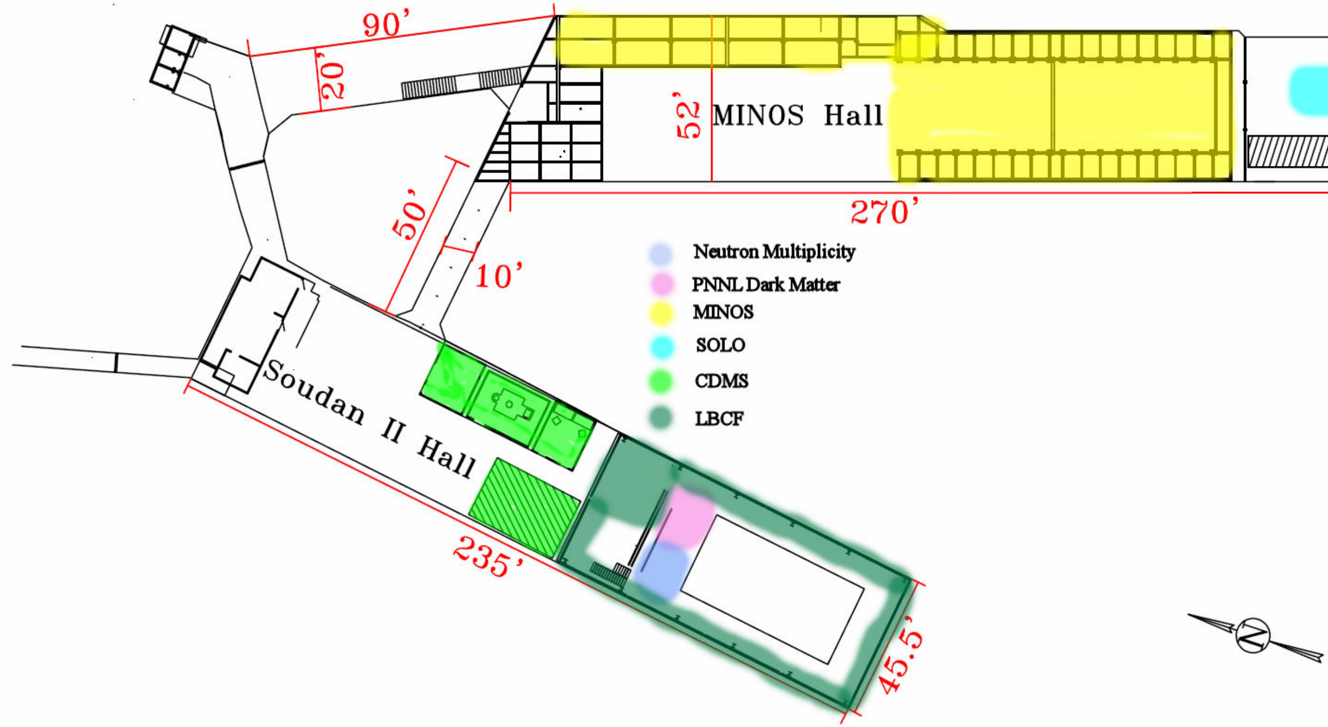
- Large, shallow to mid-depth, drive in access
- The Lhoist Group owns and operates the host limestone mine, providing unlimited researcher access 6am-11pm five days a week (7am-3pm on Saturdays) with very little interference.
- Virginia Tech and Lhoist have a 30 year agreement in place for KURF
- Currently over sixty researchers are trained to use KURF
- Future
  - No G2 DM or large-scale $0\nu\beta\beta$ proposed for KURF
  - No neutrino beam or other major ν experiment proposed
  - Was backup site for DIANA underground accelerator. Since large-scale DIANA rejected, future of this is uncertain
  - Continue as R&D and support site

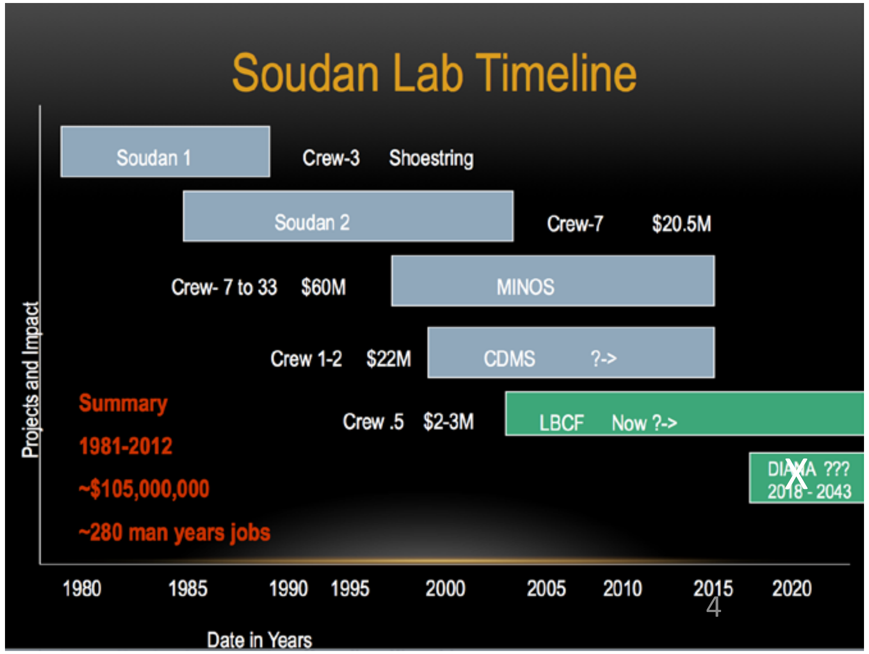


- **mini-LENS (Low Energy Neutrino Spectroscopy) (NSF: Virginia Tech, Louisiana State University, BNL, UNC, NCCU, HBNI)**
- **Neutron Spectrometer (NSF: University of Maryland, NIST)**
- **$\beta\beta$ Decay to Excited States (DOE: Duke University)**
- **HPGe Low-Bkgd Screening (NSF: North Carolina State University, University of North Carolina, Virginia Tech)**
- **MALBEK (Majorana $0\nu\beta\beta$) (DOE: University of North Carolina)**
- **^{39}Ar Depleted Argon (NSF: Princeton University)**
- **Watchman (Watchboy) (DOE: LLNL – located on the second level)**

Soudan

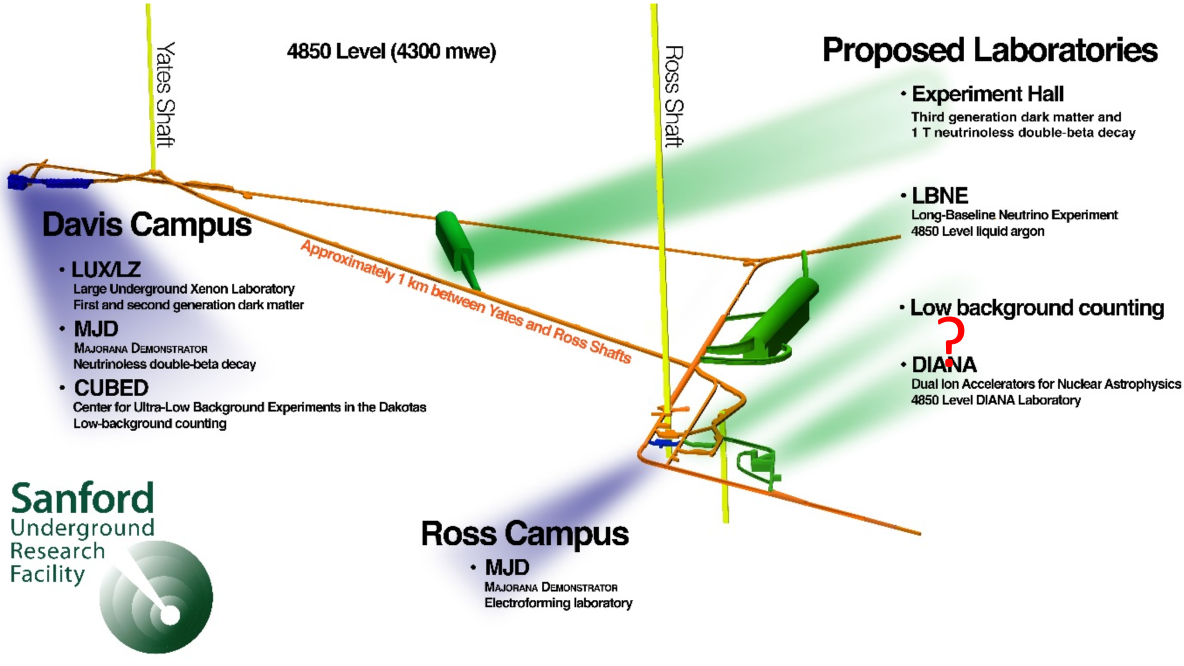
- Mid-depth, shaft access
- Substantial current program
  - MINOS(+), NUMI beam
  - Multiple dark matter experiments
  - Active low background
  - And R&D
- Future
  - No G2 DM or large-scale $0\nu\beta\beta$ proposed for Soudan
  - Future of NUMI beam beyond MINOS+?
  - No other major ν experiment currently proposed
  - Not a DIANA site
  - Major low-background and R&D site
  - Small experiments (CoGeNT C4, neutron benchmarking, muon tracking) can continue
  - Will be maintained by DNR and University for geology, microbiology, and hydrology studies

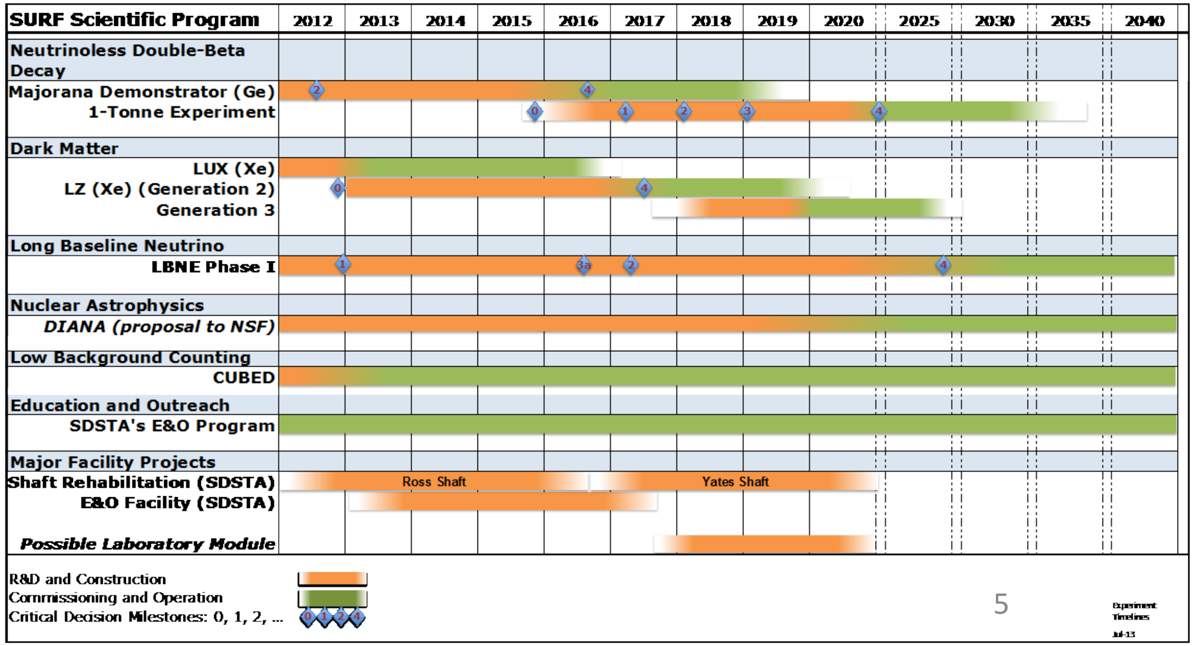




SURF

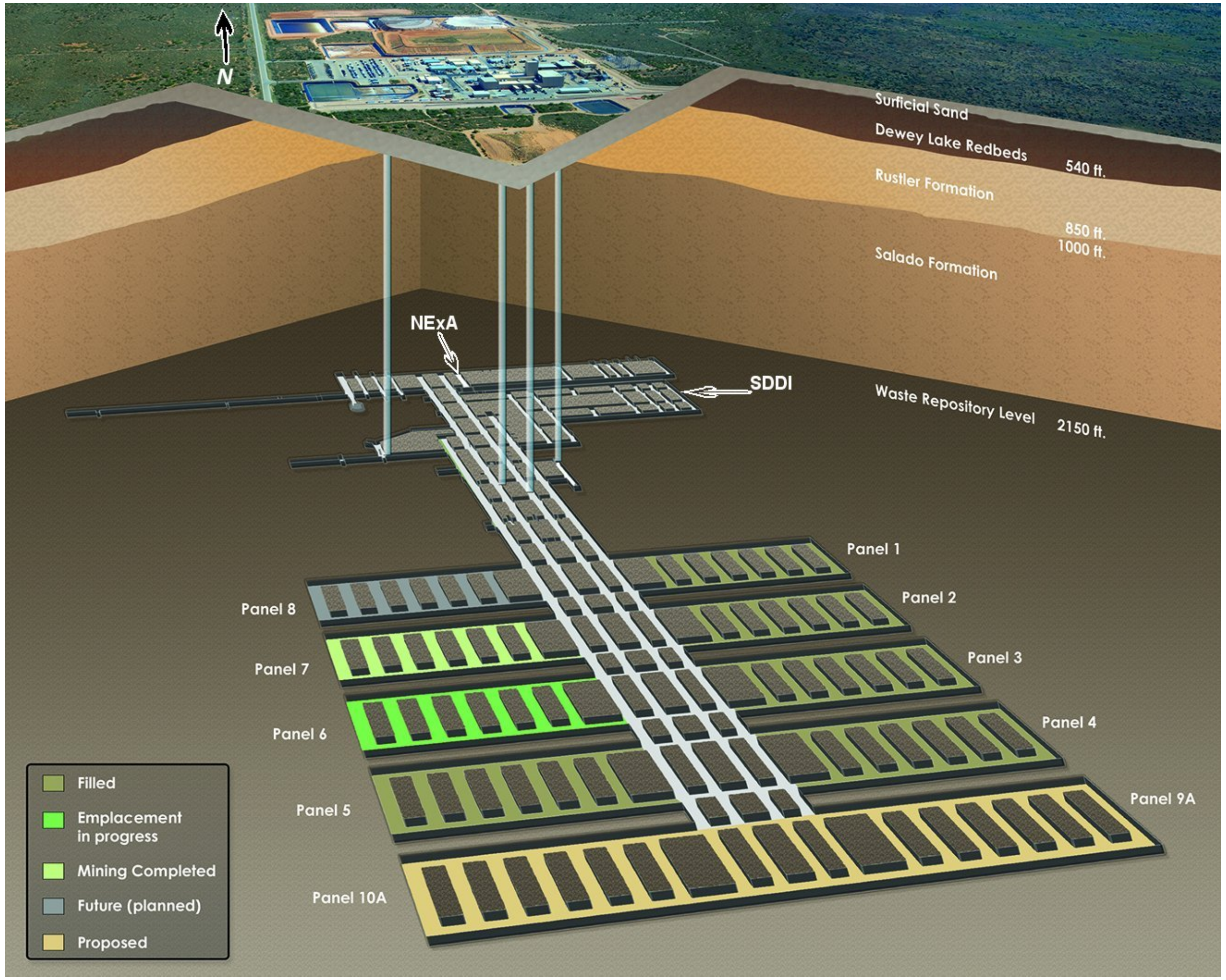
- Deep site, shaft access
- Currently
  - DM(LUX) operating
  - $0\nu\beta\beta$(MJD) assembling, operations soon
  - Low-bkgnd counting and R&D
  - “DIANA-lite” feasibility underway
  - Shaft upgrades, LBNE undergnd. geotech
- Future
  - DM(G2 proposal), decision next year
  - MJD for next ~ 5 years
  - DIANA evolution, not clear
  - Low-background expansion, R&D
  - LBNE underground?
  - New hall(s)?





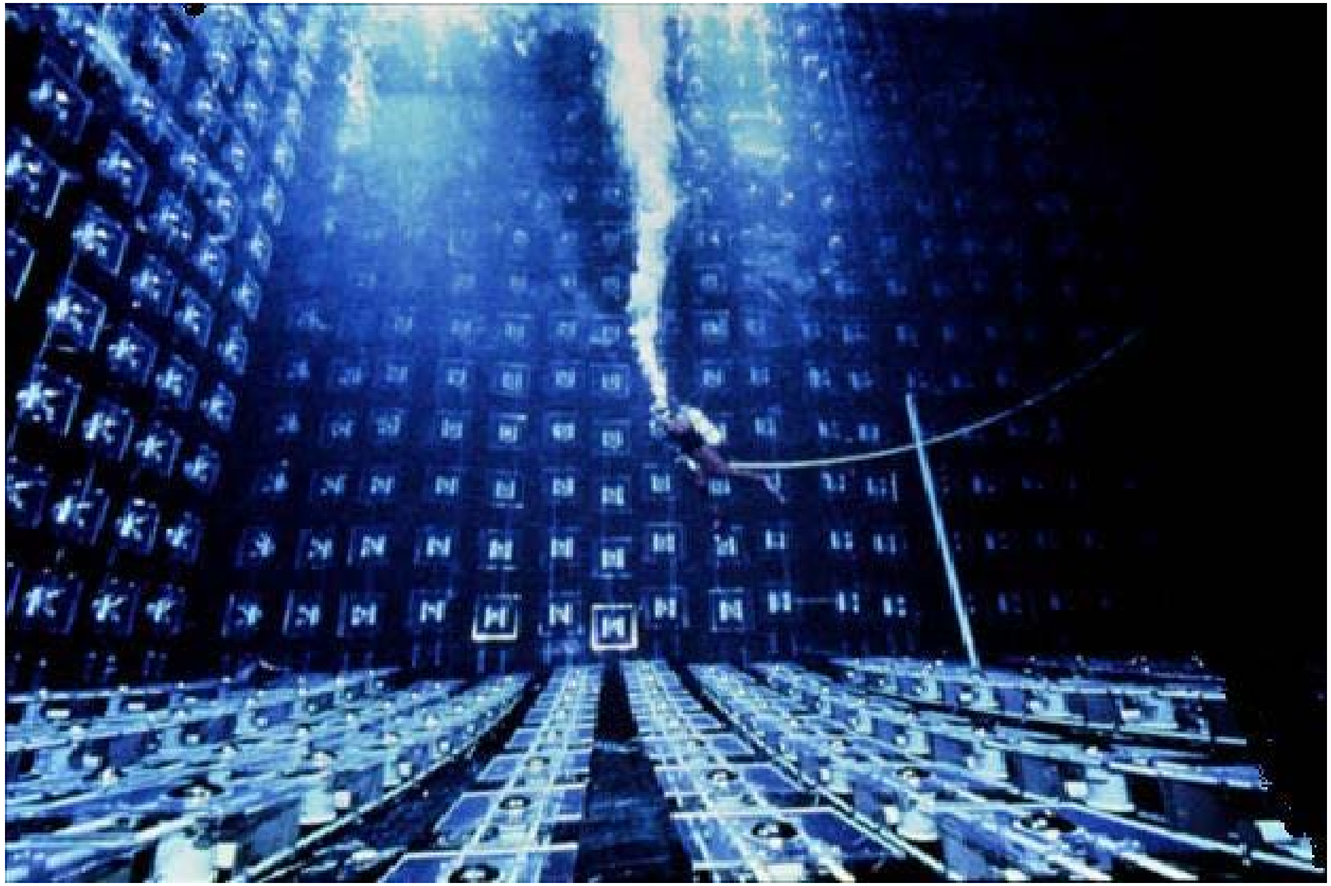
WIPP

- Mid-depth, shaft access
- Currently supports EXO200 and R&D activities(direct dark matter experiment and others)
- Ample space possible
- Long-term operation expected for primary mission
- Future
  - No G2 DM or large-scale $0\nu\beta\beta$ proposed for WIPP. Assumes EXO stops, future activity elsewhere
  - No neutrino beam or other major ν experiment proposed
  - Continue as R&D and support site



Morton Salt Mine in Fairport Ohio

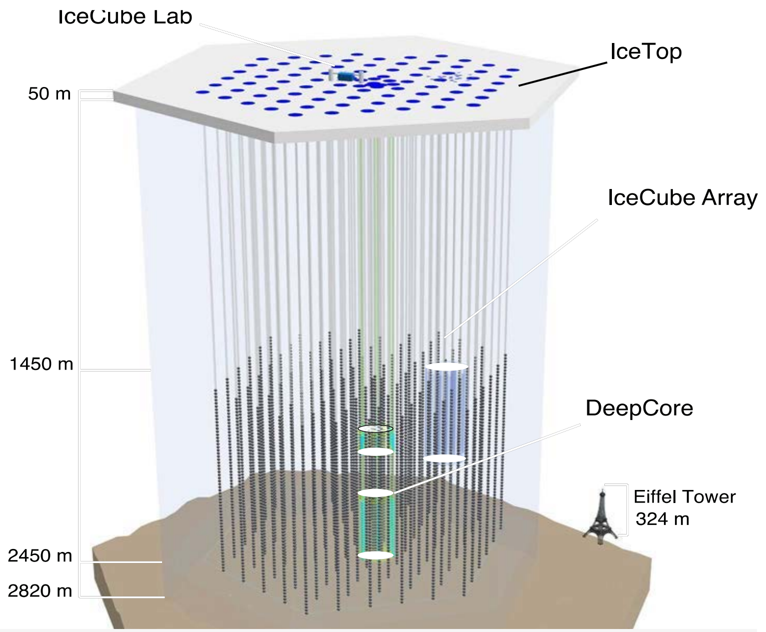
- Operating salt mine 30 minutes from Cleveland Ohio
- 1580 m.w.e., Two shafts
- Old IMB cavern permits deployment of a ~10 kton detector (20 m cube)
- Near future
  - 2016 reactor monitoring demonstration with 1-10 kton Gd-WCD being evaluated by
    US nonproliferation funding agencies
  - Possible deep science synergies – supernova, geo-antineutrinos, limited oscillation sensitivity

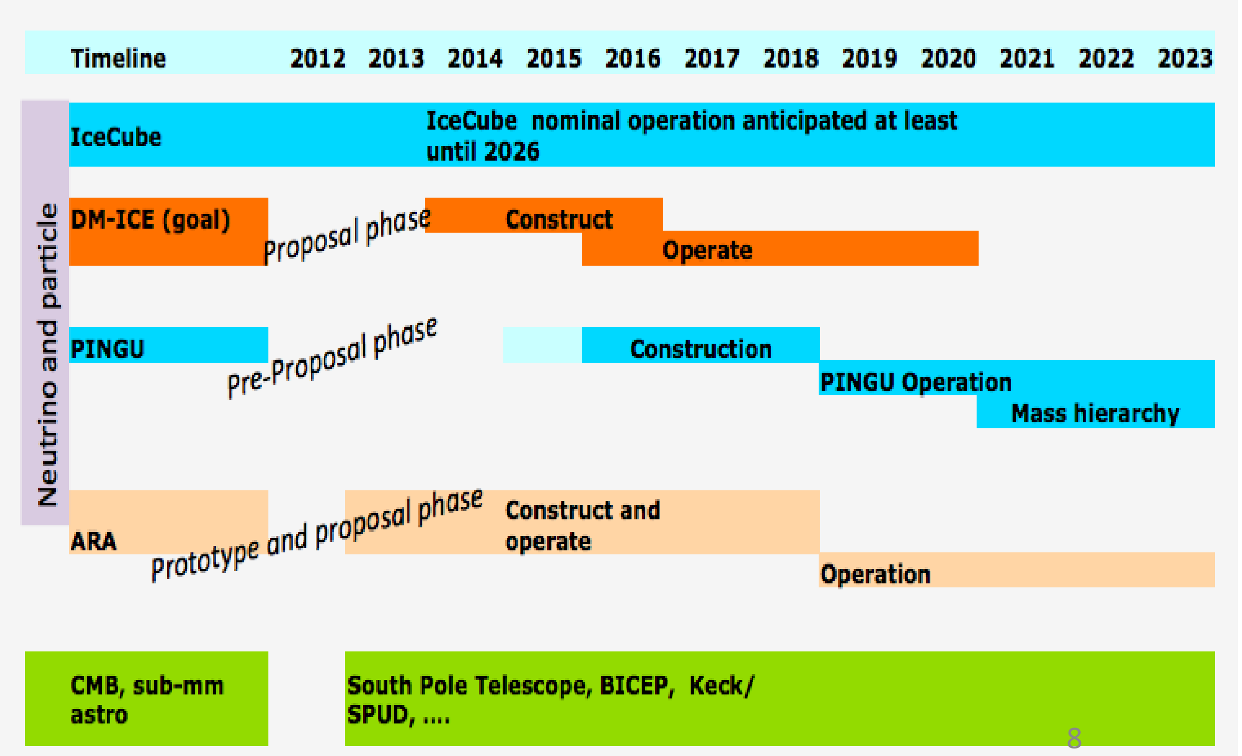


The 10 klloton IMB water Cherenkov detector

Antarctica

- Unique, U.S. led facility
- Synergy with astronomy/cosmology
- Dark matter, neutrino program, including operation and proposals for future experiments
- Future
  - Continue operation of IceCube well into 2020's
  - DM experiment proposed
  - ν experiments proposed
  - Continue to be unique





U.S. Underground Capabilities - Perspective

- Part of our charge is to look ahead ~ 5 years and ~ 10 years (or more)
- Substantial uncertainties in the future of U.S. – based facilities
- Decisions in the next few months (e.g. DOE/NSF G2 DM downselect) to next few years (e.g. LBNE depth) will have substantial impact on the evolution of U.S. – based facilities. Come back to this in conclusions discussion.
- Very short summary of our perspective on next page
- Your detailed feedback is welcome

U.S. Underground Capabilities - Future

	In ~ 5 years	In ~ 10 years
KURF	R&D site, no major DM, $0\nu\beta\beta$ or ν experiments proposed. DIANA uncertain at KURF.	R&D site?
Soudan	Small expt., R&D and low-background counting site, no major DM, $0\nu\beta\beta$ or ν experiments proposed. Assumes termination of NUMI beam program	Low-background counting, R&D site?
SURF	MJD($0\nu\beta\beta$) operation continues Low-background counting and R&D G2 DM experiment? DIANA "lite"?	LBNE(underground?) R&D site(existing labs), low-bkgnd counting? New hall(s)? For DM & $0\nu\beta\beta$? DIANA?
WIPP	R&D site, no major DM, $0\nu\beta\beta$ or ν experiments proposed.	R&D site?
South Pole	Unique facility, DM and ν experiments operational/proposed	Unique facility, multiple experiments?

Next Steps

- Please correct any mistakes we have made.
- <u>We welcome feedback, including additions, deletions and rewording of the conclusions. Please be specific as possible. Contacts on conclusion slides.</u>
- Discussion today and over next few days(informally, no other meetings planned). Suggestions for discussion
  - Conclusions – let's go through them
  - Organization of U.S. facilities – discussion
  - If you had to summarize this session in one slide….message to rest of community
  - Comments on draft executive summary – attached as document to this presentation
- Distillation will occur prior to presentation (15 minutes or so) on August 6.

Conclusions – Dark Matter

- All the next generation (G2) dark matter experiments can be accommodated by existing underground facilities, assuming no reduction in these facilities for the rest of the decade.
- Most G2 experiments are at facilities outside the U.S.
- U.S. scientists are involved in most G2 experiments.
- A G3 experiment is likely to be 5-10x the volume of the G2 experiment of similar technology and mass reach.
- It seems likely that a facility with depth ≥ 3600 mwe (LNGS) will have sufficient depth for a G3 experiment.
- The U.S. does not now have an underground hall large and deep enough to house a large G3 experiment.
- It is premature to develop plans for a facility dedicated to a large directional experiment.

Contact: M. Witherell

Conclusions - $0\nu\beta\beta$/Low E NP

- Several $0\nu\beta\beta$ experiments already under construction at existing underground facilities, all but one outside US. US involvement currently strong in many of these
- Next generation ("tonne scale") $0\nu\beta\beta$ experiments likely to be accommodated by existing and planned facilities, but may face competition for space from G2/G3-scale dark matter experiments
- Likely that there will be at most one next-generation $0\nu\beta\beta$ experiment with large US involvement, may or may not be sited within US
- Depth requirements for tonne-scale $0\nu\beta\beta$ experiments depends on technology choice and are not yet entirely known. New information may be available on 6-month to 2-year timescale.
- Path beyond tonne-scale experiments not well-defined but may require new underground spaces and perhaps facilities
- Broader low-E neutrino/nuclear physics experiments (large-scale solar ν, geoneutrinos, low-E nuclear astrophysics) will require new underground spaces and perhaps facilities

Contact: J. Klein

Conclusions - Reactor

- Worldwide efforts towards reactor experiments at medium baseline (~50km) and short-baseline (~10m).
- Detectors for reactor experiments at > 100m baseline require medium-depth underground laboratories (several hundred mwe overburden).
- Strong US involvement in recent reactor experiments overseas (KamLAND, Daya Bay, Double Chooz)
- Planning and R&D towards future reactor experiments overseas with funding commitments from host countries (RENO-50, JUNO). May have US involvement.
- Reactor neutrino experiments and associated underground spaces have enabled R&D and development of new neutrino experiments overseas:
    - KamLAND ➔ KamLAND-Zen, CeLAND
    - Daya Bay ➔ JUNO, R&D for dark matter experiments in Daya Bay halls
    - RENO ➔ RENO50
- Future:
    - planned construction of new underground space overseas for medium-baseline reactor experiments
    - multi-purpose use of underground space for neutrino and dark matter R&D in host countries
    - synergies with non-proliferation effort in US (see A. Bernstein's talk)

Contact: K. Heeger

Nonproliferation Overlap with DM/Neutrino Physics Facilities Needs: Conclusions

Remote Reactor Monitoring Facilities

- A new US remote reactor monitoring initiative requires a 500-5000 mwe site to demonstrate sensitivity to reactor antineutrinos using a large Gd-water-Cherenkov detector
- The 1600 mwe Fairport mine near Cleveland Ohio and the 2800 mwe Boulby mine in England are viable options
- A kiloton-scale device will have world-class supernova sensitivity
- Upgrading to LS may enable geo-antineutrino measurements
- The Boulby site with LS would have limited sensitivity to reactor theta-12 oscillations
- The US exercise is intended to pave the way for future very large scale detectors which exclude the existence of small reactors in wide geographical regions

Nuclear Forensics Facilities

- Low background detectors in underground labs is useful, but mostly shallow depth sites – 50-300 mwe
- Nonproliferation sponsors might be persuaded to support operation of deeper sites in order to maintain US expertise

Contact: A. Bernstein

Conclusions – Proton decay, long-baseline and atm. ν

- There is an international effort to search for CP violation in the lepton sector.
- A massive detector in a neutrino beam is required.
- The search for nucleon decay is one of the most important topics in particle physics.
- Atmospheric neutrinos, observable in a large underground detector, are sensitive to all of the currently unknown oscillation parameters.
- The same detector could be used to advance the search for nucleon decay, the study of atmospheric neutrinos and other physics if the detector is located underground.
- This is the plan for Hyper-K and LBNO. It would be a lost opportunity if this condition cannot be satisfied with LBNE.

Contact: H. Sobel

Conclusions – Supernova, Low-E ν

- Tremendous opportunity for physics and astrophysics from supernova neutrino burst.
  - Many existing & planned detectors; SN capability typically comes "for free" if underground
  - Very difficult on the surface
  - Bursts are rare (only every ~30 years): critical to gather as much information as possible
- Other physics opportunities with low-energy neutrinos for underground detectors (solar, DSNB, geo, ...) depending on technology
- This is not "competitive"! The more information, the better, especially for SN burst
  - Diverse detector technologies, at different locations around the globe, enhance physics reach
- Underground location important to avoid loss of once-per-career opportunity

Contact: K. Scholberg

Underground Infrastructure Conclusions

Underground space should be reserved for **materials assay and storage**

Contact: P. Cushman

- Selection of radiopure materials for shielding and detectors is a common need.
- The majority of such tests must be done underground, requiring sensitive detectors, expert personnel, and longterm storage of materials (e.g. Cu) sensitive to cosmogenic activation.
- Surveys of experimental needs worldwide far outstrip current assay capability.
- Operation as a user facility across multiple sites with existing expertise is the most efficient use of resources and personnel, and promotes prompt and open dissemination of results.

Underground space should be reserved for **small protoype testing and generic R&D**

- New technologies need to go underground to validate background performance
- Investment in common use elements (shielding, muon veto, croygenics, radon mitigation) in a reconfigurable user space supports generic R&D and high-risk/high-reward ideas.

There is enough infrastructure space for the future if existing US underground labs are included in the mix. Substantial past agency investment and future leverage of state and university funds make it cost effective and attractive to local users to maintain these sites for smaller experiments, generic R&D, and as elements of a centrally managed materials assay consortium.

Underground Facilities Conclusions - Summary

- Substantial expansion in non – U.S. underground capabilities very likely to occur by end of this decade.
- Critical that U.S. scientists continue to be supported to take full advantage of international and domestic underground facilities.
- Open access policy for all major underground facilities is needed
- Key decisions in next few years will shape the future of the U.S. underground science program
  - G2 dark matter selections and fast start
  - Scope of the U.S. $0\nu\beta\beta$ effort
  - LBNE underground
  - Planning for underground facilities beyond LBNE and G2 DM, including South Pole
  - Coordination of U.S. underground science program
- Will the U.S. have one of the major underground facilities in the future?

Contact: M. Gilchriese

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