Introduction

M. Gilchriese

July 30, 2013

Outline of Session

Working group organization and goals
Brief overview and non – U.S. summary

Talks are short

Emphasis on summary and conclusions

This is only session on underground facilities at Snowmass

Feedback during meeting, and offline

Very short summary on Aug. 6

U.S underground capabilities and organization
Summary of key conclusions

Tuesday July 30, 2013

08:30 - 12:30 Frontier Capabilities: Underground Facilities 1
Convener: Murdock Gilchriese (Lawrence Berkeley National Laboratory)
Location: Blegen 105
08:30 Overview of existing and planned underground capabilities 15'
Speaker: Murdock Gilchriese (Lawrence Berkeley National Laboratory)
08:45 Connection to dark matter experiments 15'
Speaker: Michael Witherell (UCSB)
09:00 Connection to neutrinoless double beta decay and other nuclear physics experiments 15'
Speaker: Josh Klein (University of Pennsylvania)
09:15 Discussion 30'
9:45 Frontier Capabilities: Underground Facilities 1: [Coffee Break] 30'
10:15 Reactor Experiments and underground capabilities 15'
Speaker: Karsten Heeger (University of Wisconsin)
10:30 Non-proliferation Detectors and Underground Capabilities 10'
Speaker: Adam Bernstein (LLNL)
10:40 Supernova and Atmospheric Neutrinos and Underground Capabilities 15'
Speaker: Kate Scholberg (Duke University)
10:55 Long baseline neutrinos, proton decay and underground capabilities 15'
Speaker: Prof. Henry Sobel Sobel (University of California)
11:10 Discussion 20'
11:30 Underground capabilities and Detector R&D 15'
Speaker: Prof. Priscilla Cushman (University of Minnesota)
11:45 Organiziation of US Underground Capabilities and Wrap Up 15'
Speaker: Murdock Gilchriese (Lawrence Berkeley National Laboratory)
12:00 Discussion 30'

Why Underground Facilities Working Group?

- Underground facilities and capabilities essential to support experiments that are central to the world-wide and U.S. scientific program
  - Direct dark matter
  - Neutrinoless double-beta decay ($0\nu\beta\beta$)
  - Neutrino properties, mixing parameters and CP violation
  - Connections to astrophysics and nuclear science
- Critical decisions soon for U.S. program involve underground facilities
  - LBNE underground?
  - Breadth and evolution of U.S. role in direct dark matter and $0\nu\beta\beta$ experiments?

Underground Capabilities - General Charge

1. Assess the status and potential plans for underground facilities worldwide, with particular attention to the current and planned role of U.S. scientists;
2. Answer the following question in conjunction with the relevant Cosmic Frontier, Intensity Frontier and Instrumentation Frontier working groups – how will the existing or planned underground facilities meet the needs of US scientists and their scientific goals over the next 10 – 15 years (to about 2025)?
3. Address future U.S. organizational aspects for underground facilities

Underground Capabilities - Working Groups

- NAF1 – on underground facilities to support very large detectors for neutrino physics, proton decay and other science requiring detectors of the multi-kiloton scale.
  - NAF1 conveners: K. Heeger (Wisconsin), K. Scholberg (Duke), H. Sobel (Irvine)
- NAF2 – on underground facilities for dark matter experiments, neutrinoless double beta decay experiments, underground accelerators for nuclear astrophysics or other physics, low background assay of materials and related topics.
  - NAF2 conveners: P. Cushman (Minnesota), J. Klein (Pennsylvania), M. Witherell (Santa Barbara)
- Underground facilities in support of instrumentation development in both working groups
  - Conveners, contact with Instrumentation: P. Cushman (Minnesota), M. Gilchriese (LBNL)
- Neutrinos and society
  - Convener is A. Bernstein (LLNL), potential connections with underground capabilities. Primarily detectors for non-proliferation monitoring.

Summary of Process

- Interactions with scientific working groups: cosmic frontier(dark matter direct detection, facilities), intensity frontier (double beta decay, accelerator and non-accelerator neutrinos)
- Working group members “embedded” in scientific working groups
- Requested “1 pagers” from U.S. labs, Antarctica and Snolab, phone meetings with each of these lab heads
- Phone meetings with presentations for Kamioka, CJPL, LNGS
- Our focus has been
  - Future capabilities – where going, not so much where we are or past
  - Key U.S. issues that might be of interest to P5
- Or focus has not been
  - Summarizing enormously diverse underground experimental program or why important – a number of recent Academy of Science studies do this well + numerous review articles
  - Or current facilities – again, current situation well documented e.g. EJPL dedicated issue

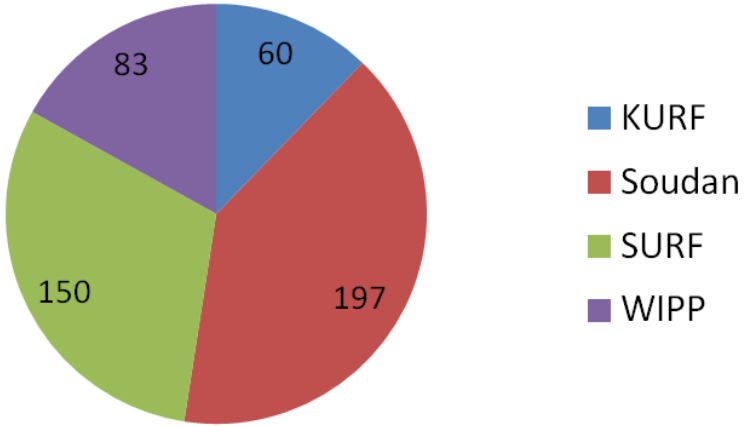
Our Underground Facilities Scope

- Underground includes under ice – South Pole
- We have included Daya Bay/RENO in our definition of “underground”
  - Some overlap of experimental aspects with other underground experiments
  - Evolution of these experiments(JUNO, RENO50) will be deep enough to have even more overlap with traditional underground experiments
- We have not include shallow sites e.g. Nova
- We have not included underwater experiments/facilities
- Welcome any input on this.

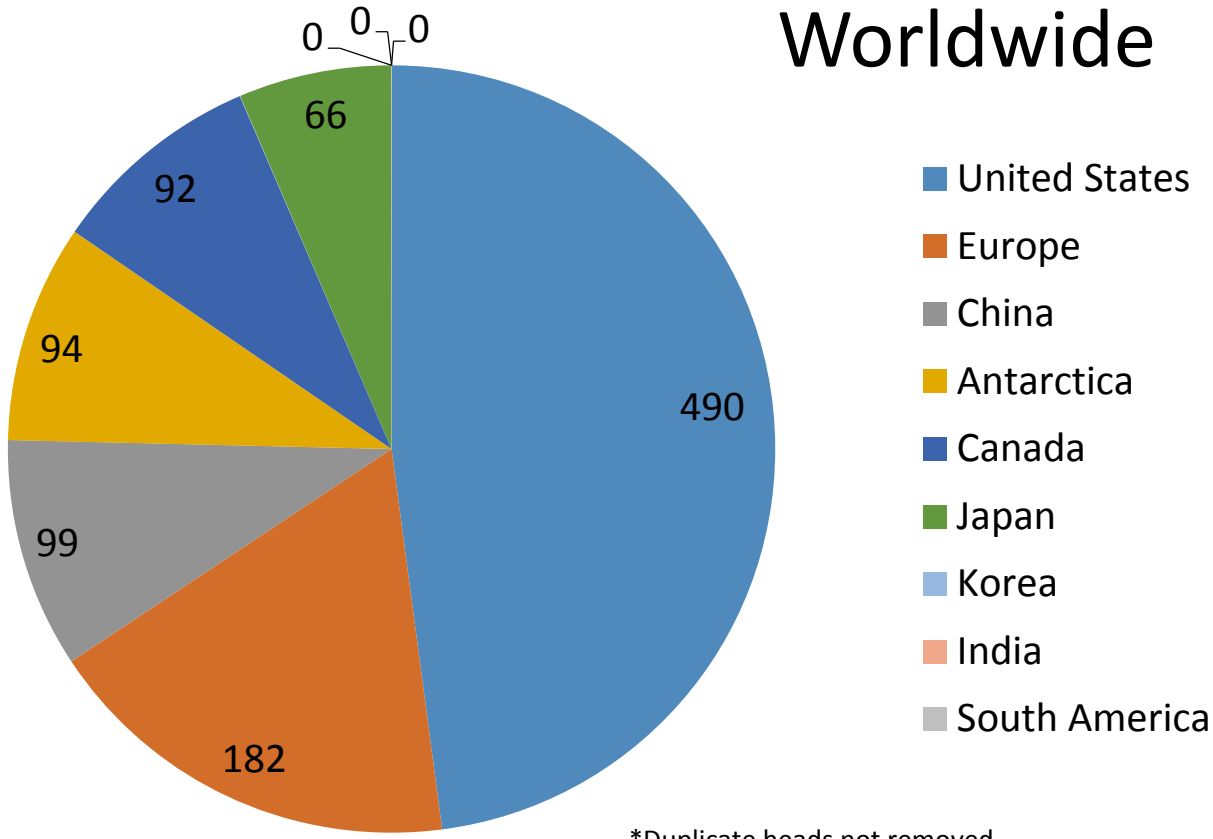
U.S. Scientists Underground

- Count of current U.S. heads (only)* at underground facilities, including Antarctica. Roughly 1,000 U.S. heads.
- Future: 30-50% growth(no hard estimate)

U.S. Labs



Worldwide



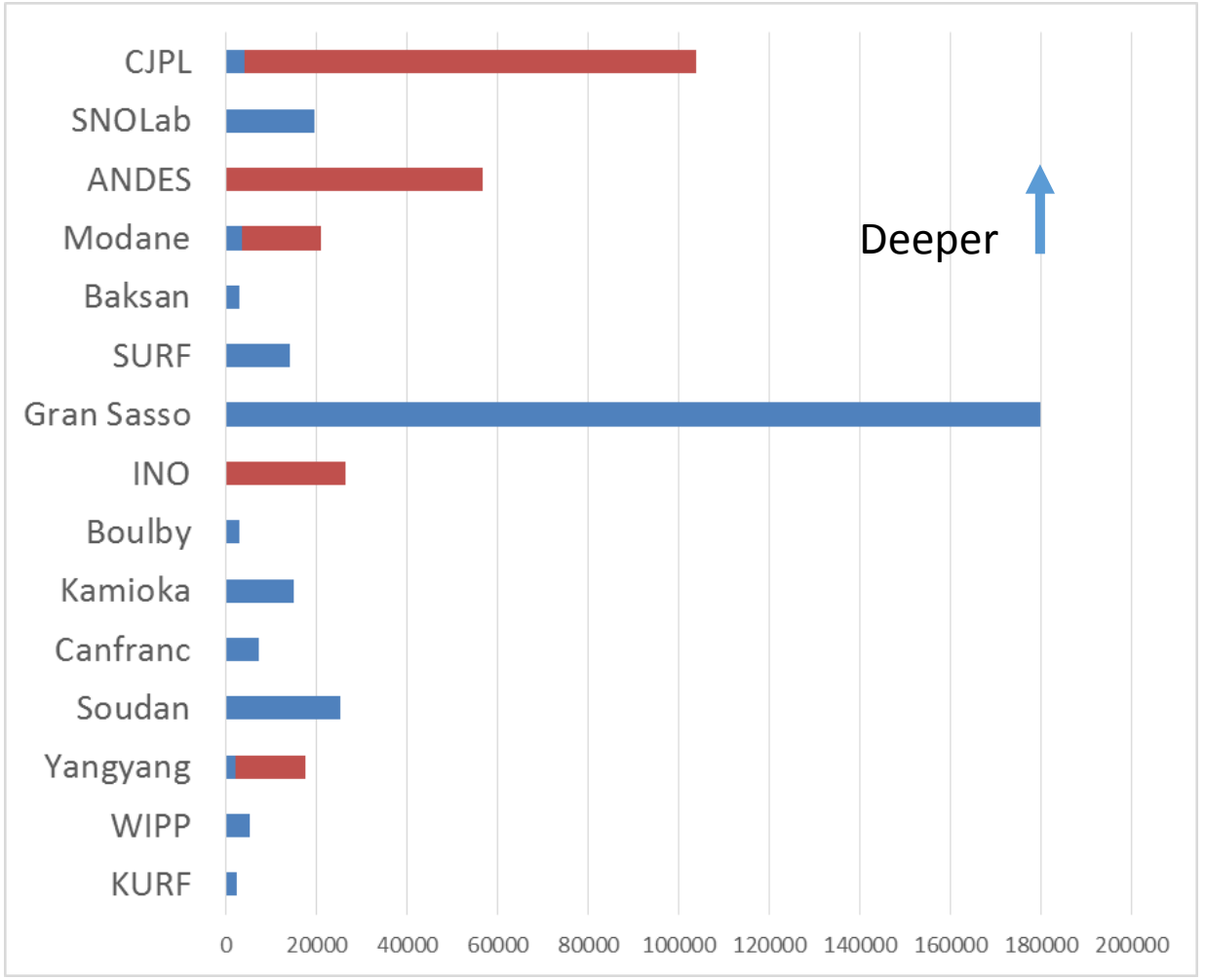
*Duplicate heads not removed

Recent Expansion in Non – U.S. Underground Facilities

- Within the last ~ 3 years there has been a significant expansion in non – U.S. underground facilities. Will discuss U.S. at end of session.
- Canfranc (Spain) – medium deep lab, still in process of implementing dark matter and $0\nu\beta\beta$ experiments. Small U.S. involvement.
- CJPL(China) – very deep lab, tunnel access, initial dark matter experiments (CDEX, PANDA-X) installed, starting to operate. Small U.S. involvement.
- Snolab(Canada) – very deep lab, shaft access, broad and diverse program now initiated. Substantial U.S. involvement.
- This trend – expansion of underground facilities outside the U.S. – is planned to continue and in fact grow in the remainder of this decade.

Summary Non – U.S. “General Purpose” Underground

- Comparison of current(blue) and future(red) volumes
- Key aspects of non – U.S. expansion covered in this talk
- U.S. in last talk of session, current volumes shown here for reference
- INO and Kamioka do not include space for large neutrino detectors in this plot(see next page)
- If all realized, general purpose underground space worldwide will about double by end of decade.



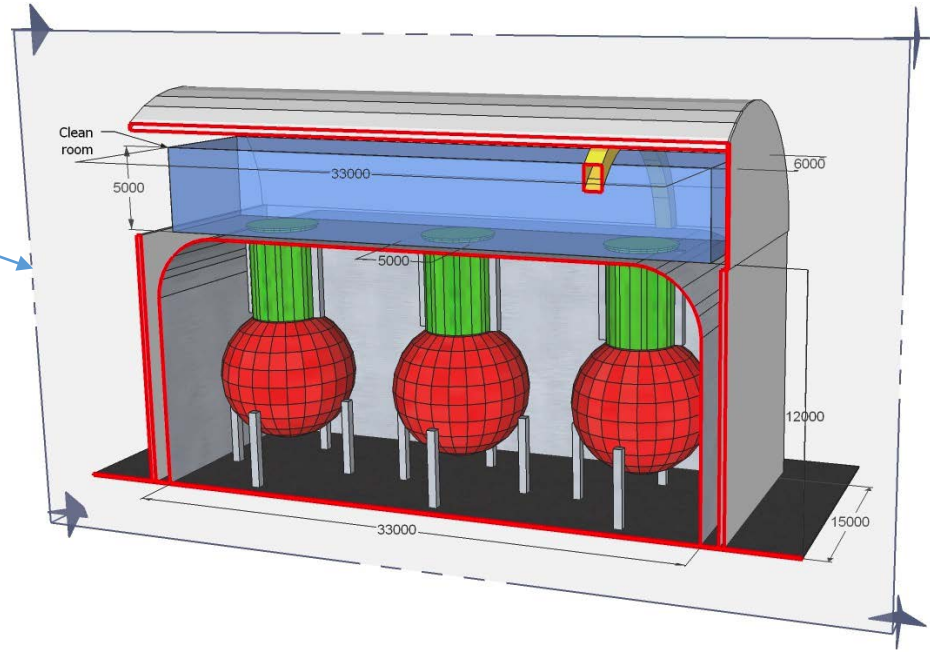
Summary – Mostly Neutrino Underground

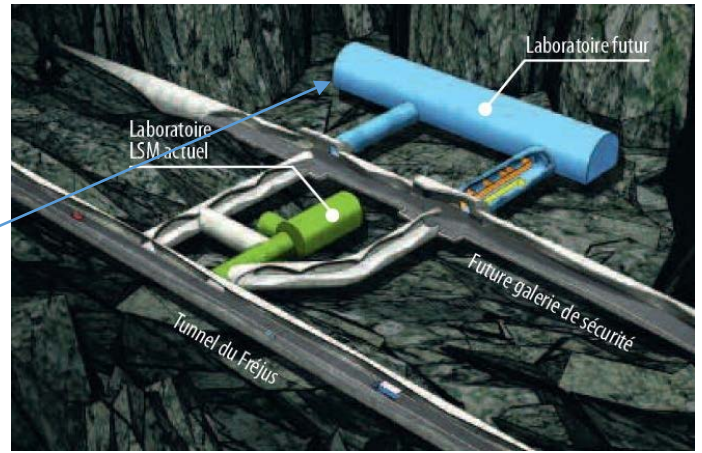
- Hard to separate experiment from facility
- Highlighted are potential new facilities
- Facilities for large neutrino detectors and proton decay covered in subsequent talks

		Proton decay	Long baseline ν	Supernova ν	Atmospheric ν	Reactor ν	Geoneutrino ν	Astrophysical ν	Solar ν	Non-proliferation ν
SNO+	Canada	X		X		X	X			
JUNO	China			X		X	X			
CUPP	Finland	X	X	X	X					
INO	India				X					
Kamland	Japan			X			X			
SuperK/T2K	Japan	X	X	X	X					
HyperK	Japan	X	X	X	X				X	
RENO50	Korea			X		X	X			
Antarctica(various)	South Pole			X	X			X		
LBNE(underground)	USA	X	X	X	X					
Soudan(MINOS+, etc)	USA		X		X					
WATCHMAN	USA			?						X

Future Non – U.S. Underground Facilities(I)

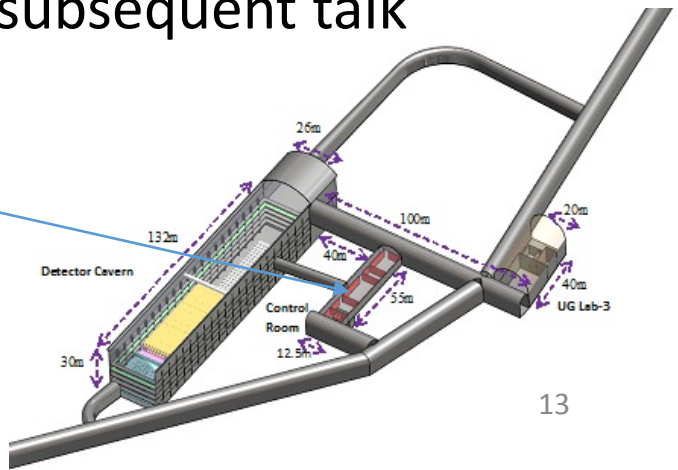
- LNGS(Italy)
  - Termination of neutrinos from CERN will free up space for future dark matter and $0\nu\beta\beta$ experiments
  - Considering implementation of complex, active shielding for multiple experiments (Hall C)
- Snolab(Canada)
  - No plans to expand next ~ 5 years
  - Technically possible, needs to be identified
  - U.S. – Canada arrangement? Needs agency to agency agreement
  - Deeper?
- Modane(France)
  - New, large hall
  - By 2016-2017



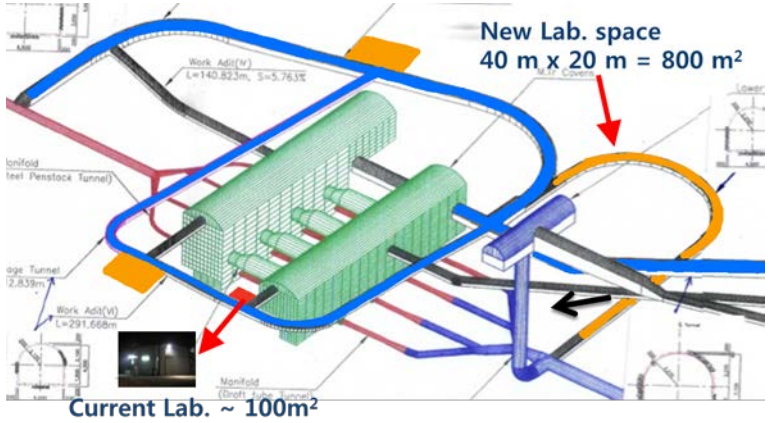


Future Non – U.S. Underground Facilities(II)

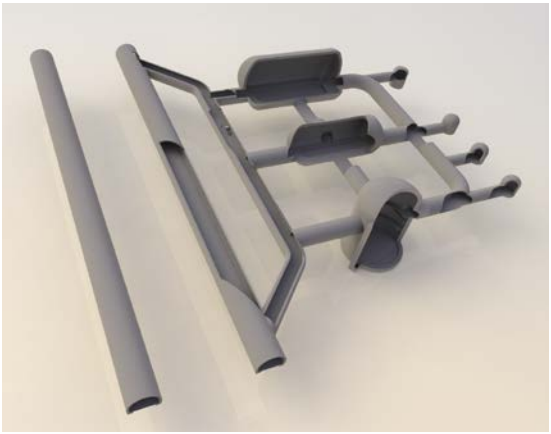
- CJPL(China)
  - Very substantial expansion planned to be completed by ~ 2016
  - Factor 25 expansion: 4,000 -> 100,000 m^3
  - Multiple, connected halls. Eight 12mx12mx60m or four 12mx12mx150m
  - Configuration now under discussion
  - International lab. U.S. workshop Sept. 8 in conjunction with TAUP meeting
- India Neutrino Observatory (INO)
  - Large hall for atmospheric neutrino detector covered in subsequent talk
  - Also halls for dark matter and $0\nu\beta\beta$
  - Timescale uncertain ~ 2018?



Future Non – U.S. Underground Facilities(II)



- Yang-Yang Lab(Korea)
  - Modest depth
  - Approved expansion by factor 8
  - By ~ 2015?
- ANDES(Argentina/Chile)
  - Unique in southern hemisphere(apart from South Pole)
  - High but also deep, significant space proposed
  - 65,000m^3
  - Uncertain. End of decade?



- Kamioka
  - No significant expansion planned(but see HyperK)
  - Could expand if needed.
- Other labs, neutrino facilities covered in talks by Karsten, Hank and Kate

Conclusions

- Large number of U.S. scientists working underground/ice, roughly 1,000 now and may grow to 1300-1500 over this decade
- About ½ currently working at U.S. facilities + South Pole
- Significant expansion of non – U.S. underground facilities in last three years(Canfranc, CJPL, Snolab,…). U.S. scientists benefit (primarily Snolab)
- Expansion will continue outside the U.S. (CJPL, Modane, Y2L, INO,…)
- Facilities for large neutrino experiments, proton decay covered in subsequent talks.
- U.S. situation in last talk of session