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

**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 Organization 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)

*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

<table>
<thead>
<tr>
<th>Facility</th>
<th>Canada</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>Non-proliferation</th>
<th>Proton decay</th>
<th>Long baseline ν</th>
<th>Supernova ν</th>
<th>Atmospheric ν</th>
<th>Reactor ν</th>
<th>Geoneutrino ν</th>
<th>Astrophysical ν</th>
<th>Solar ν</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNO+</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JUNO</td>
<td>China</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CUPP</td>
<td>Finland</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INO</td>
<td>India</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamland</td>
<td>Japan</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SuperK/T2K</td>
<td>Japan</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HyperK</td>
<td>Japan</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RENO50</td>
<td>Korea</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antarctica(various)</td>
<td>South Pole</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LBNE(underground)</td>
<td>USA</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soudan(MINOS+, etc)</td>
<td>USA</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WATCHMAN</td>
<td>USA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
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 m³
  • 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 0νββ
  • 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
  • 65,000m³
  • 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