Underground Facilities & Infrastructure Summary

Co-Conveners
Laura Baudis (U. Zurich), **Jeter Hall** (SNOLAB),
Kevin Lesko (LBNL), **John Orrell** (PNNL)

Outline

- Reminder of UF organization
- “Going off script”
- Key underground programs
- 2013 Snowmass & 2014 P5 underground conclusions/recommendations
  - Progress assessment
- Status of facilities
- UF as a supporting Frontier
- Draft UF observations & conclusions
- Toward UF completion

Underground Facilities & Infrastructure
Co-Conveners & Topical Conveners

Group	Topic	Conveners	Liaisons
UF1	Underground Facilities for Neutrinos	Tim Bolton (KSU) Patrick Decowski (Nikhef & U Amsterdam) Danielle Speller (Johns Hopkins)	Neutrinos Albert de Roeck (CERN) Astronomical ν Gabriel Orebi Gann (Berkeley)
UF2	Underground Facilities for Cosmic Frontier	Scott Hertel (UMass Amherst) Kaixuan Ni (UCSD) Emilija Pantic (UC Davis)	Particle DM Hugh Lippincott (UCSB) Jodi Cooley (SNOLAB) Instrumentation Eric Dahl (Northwestern)
UF4	Supporting Capabilities	Richard Schnee (SDSMT) Alvine Kamaha (UCLA) Brianna Mount (BHSU)	
UF5*	Synergistic Research	Daniel Robertson (Notre Dame)	*Many external contributors*
UF6	Integrated Strategy for Underground Facilities and Infrastructure	Laura Baudis (U. Zurich) Jeter Hall (SNOLAB) Kevin Lesko (LBNL) John Orrell (PNNL)	

* UF3 – Underground Detectors – was absorbed into UF5

UF Co-Conveners


Laura Baudis (U. Zurich)


Jeter Hall (SNOLAB)


Kevin Lesko (LBNL)


John Orrell (PNNL)

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- Steve Ritz commented on DUSEL in context programmatic changes
  - DUSEL = Deep Underground Science and Engineering Laboratory
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PHYSICS TODAY

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DOI:10.1063/PT.5.024918

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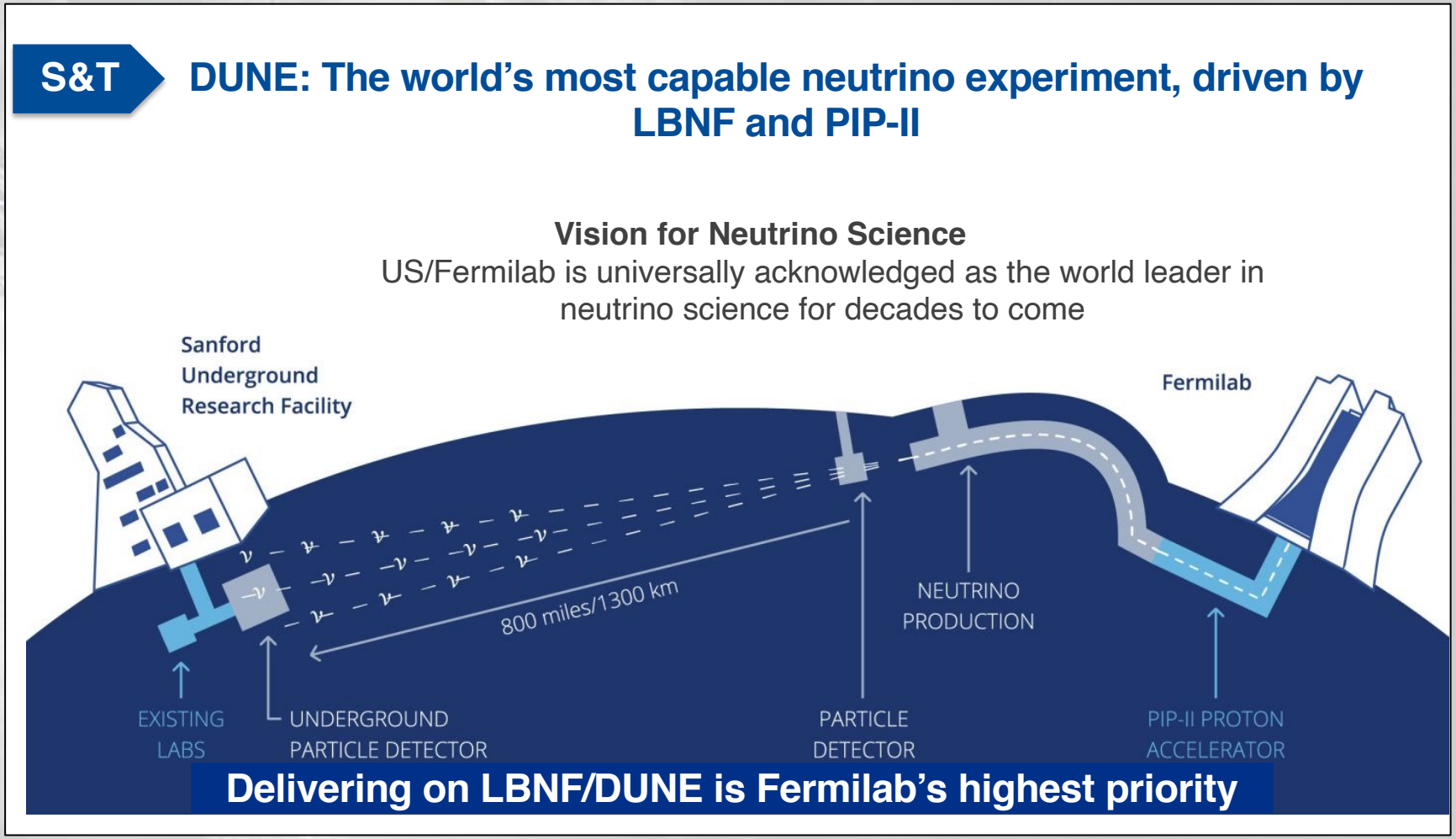
  - This was a community development activity ~2010 – pre-Snowmass 2013
- Headlined not withstanding…
  A decade on, we *are* doing great science underground
  - Conversation today is not about a dearth of underground labs
  - Conversation today is about…
    - Effectively performing *all the planned physics* within the facilities where we are investing

Key underground physics programs

Lia Merminga, 17 July 2022

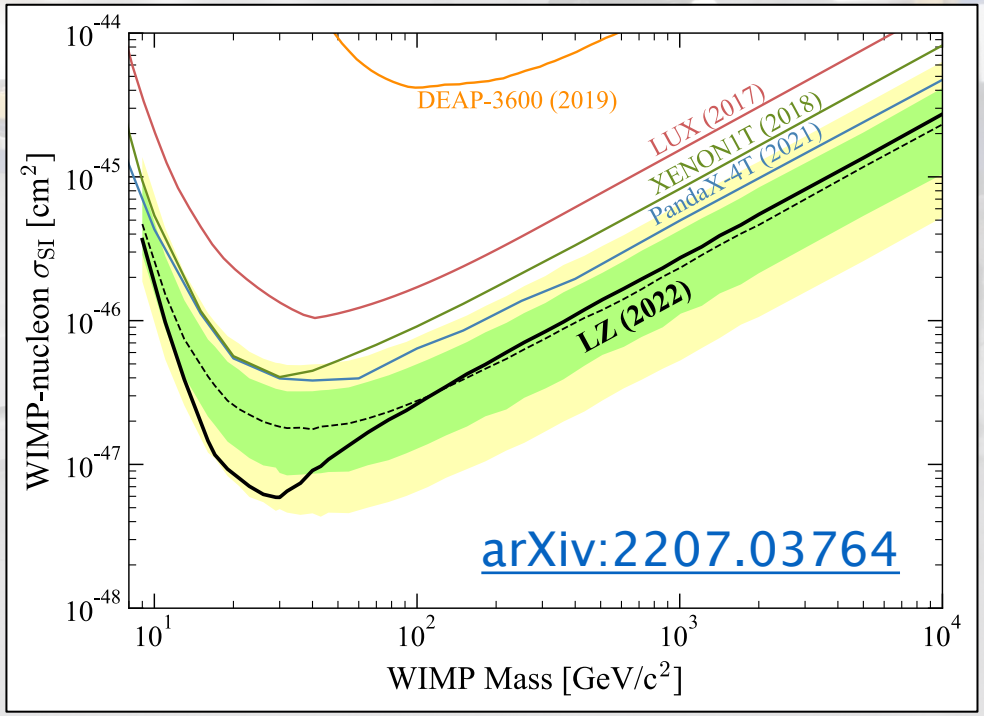
- Flagship HEP neutrino science from the 2014 P5
- Science captured in the Neutrino Frontier
- Underground Facilities & Infrastructure crucial for success



Key underground physics programs

- Direct detection of dark matter
  - Searches for particle-like dark matter from MeV to TeV masses
  - Broad program of experimental approaches located in underground laboratories
- Science captured in the Cosmic Frontier (Topical group CF1)
- Underground Facilities & Infrastructure crucial for success

- Result from the LUX-ZEPLIN (LZ) direct detection dark matter experiment

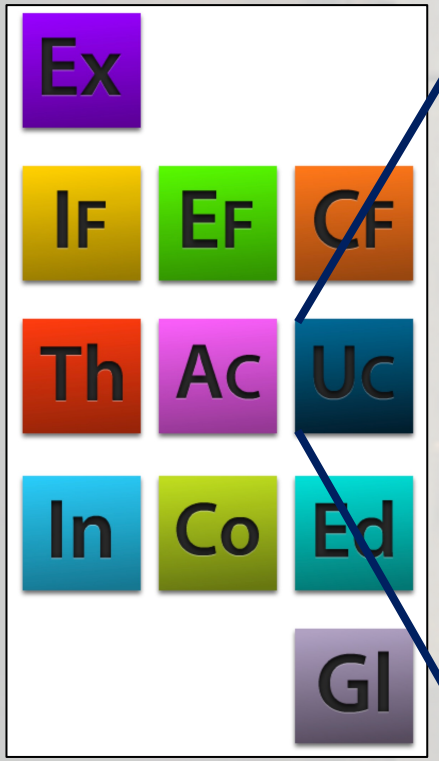


Key underground physics programs ++

- Neutrinoless double beta decay:
  - Nuclear Physics research program
  - Ton-scale program will be active into the 2030s
  - Research expertise and infrastructure requirements *have significant overlap* with direct detection dark matter
- Other research programs sharing underground laboratory space:
  - Quantum information science
  - Accelerator-based nuclear astrophysics
  - Experiments in fundamental symmetries
  - Gravitational wave detection
  - Geology and geophysics
  - *and more…*

Looking back at Snowmass 2013…

- The Underground Laboratory Capabilities evaluation reported…



Our conclusions related to the upcoming U.S. planning process are:

1. Locate LBNE underground to realize its full science potential. This step would also provide a natural base for additional domestic underground capabilities at SURF in the future.
2. The U.S. has leading roles in many of the future dark matter, neutrinoless double beta decay and neutrino experiments.
3. More coordination and planning of underground facilities (overseas and domestic) is required to maintain this leading role, including use of existing U.S. infrastructure and closer coordination with SNOLAB as the deepest North American Lab.
4. Maintaining an underground facility that can be expanded to house the largest dark matter and neutrinoless double beta decay experiments would guarantee the ability of the U.S. to continue its strong role in the worldwide program of underground physics.

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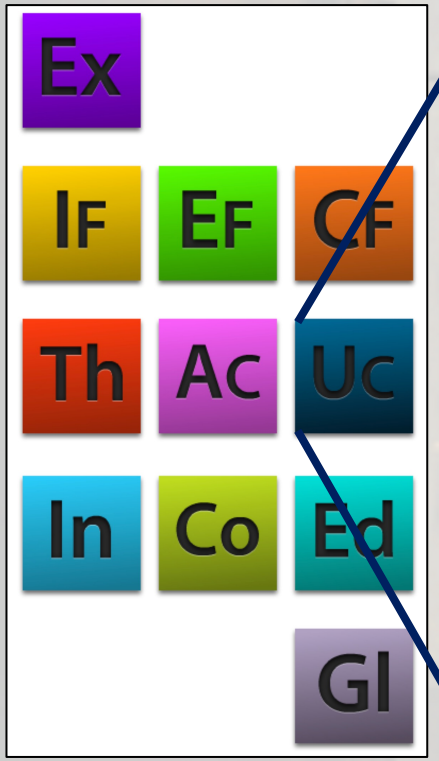

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★4. Maintaining an underground facility that can be expanded to house the largest dark matter and neutrinoless double beta decay experiments would guarantee the ability of the U.S. to continue its strong role in the worldwide program of underground physics.

Review P5 recommendations from 2014…

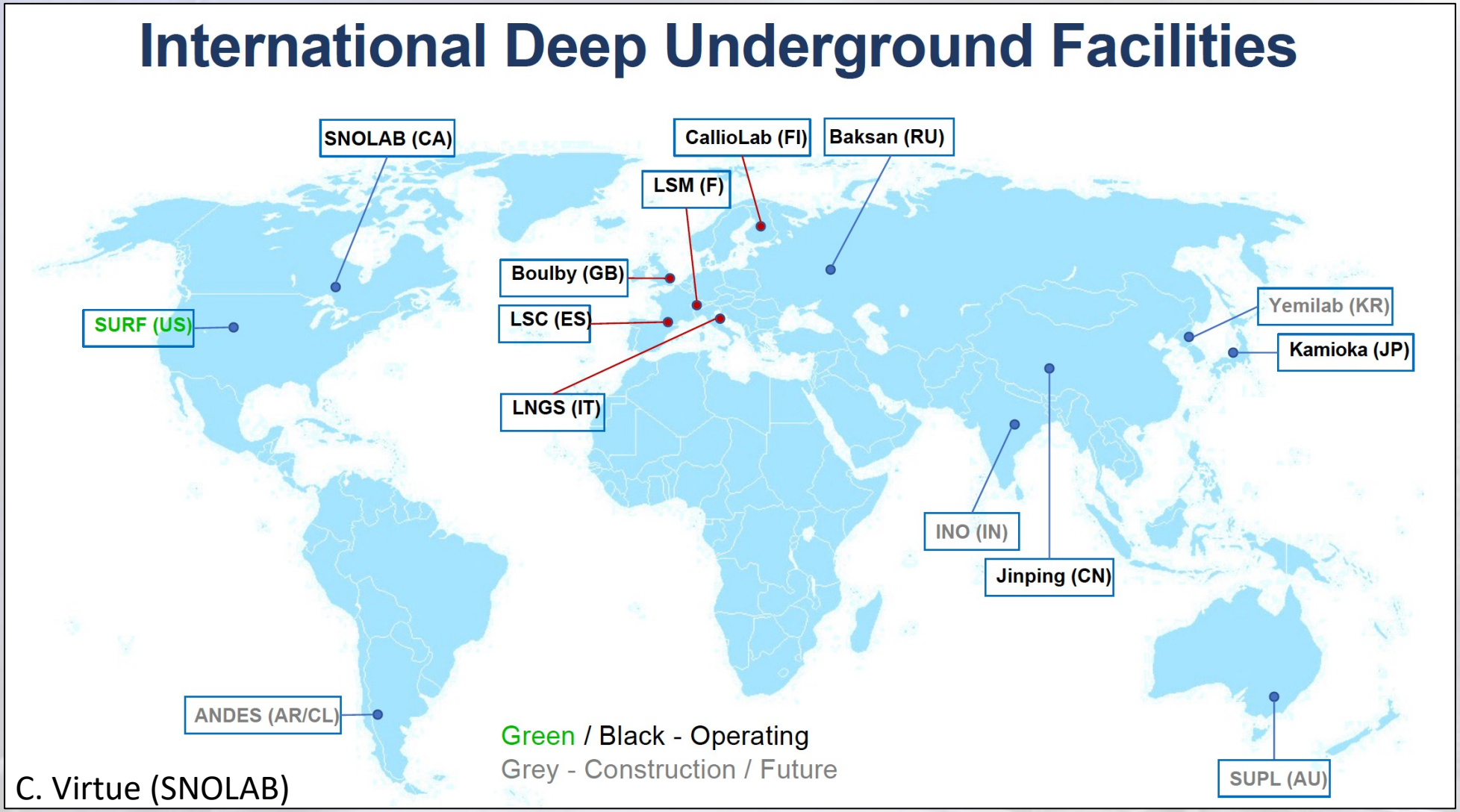
- Focus on those with a connection to underground facilities…
  - One related to the DUNE/LBNF program (R13)
  - Two related to direct detection of dark matter (R19 & R20)

✓ **Recommendation 13:** Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S. To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text. LBNF is the highest-priority large project in its timeframe. (p. 12)

✓ **Recommendation 19:** Proceed immediately with a broad second-generation (G2) dark matter direct detection program with capabilities described in the text. Invest in this program at a level significantly above that called for in the 2012 joint agency announcement of opportunity. (p. 14)

★ **Recommendation 20:** Support one or more third-generation (G3) direct detection experiments, guided by the results of the preceding searches. Seek a globally complementary program and increased international partnership in G3 experiments. (p. 14)

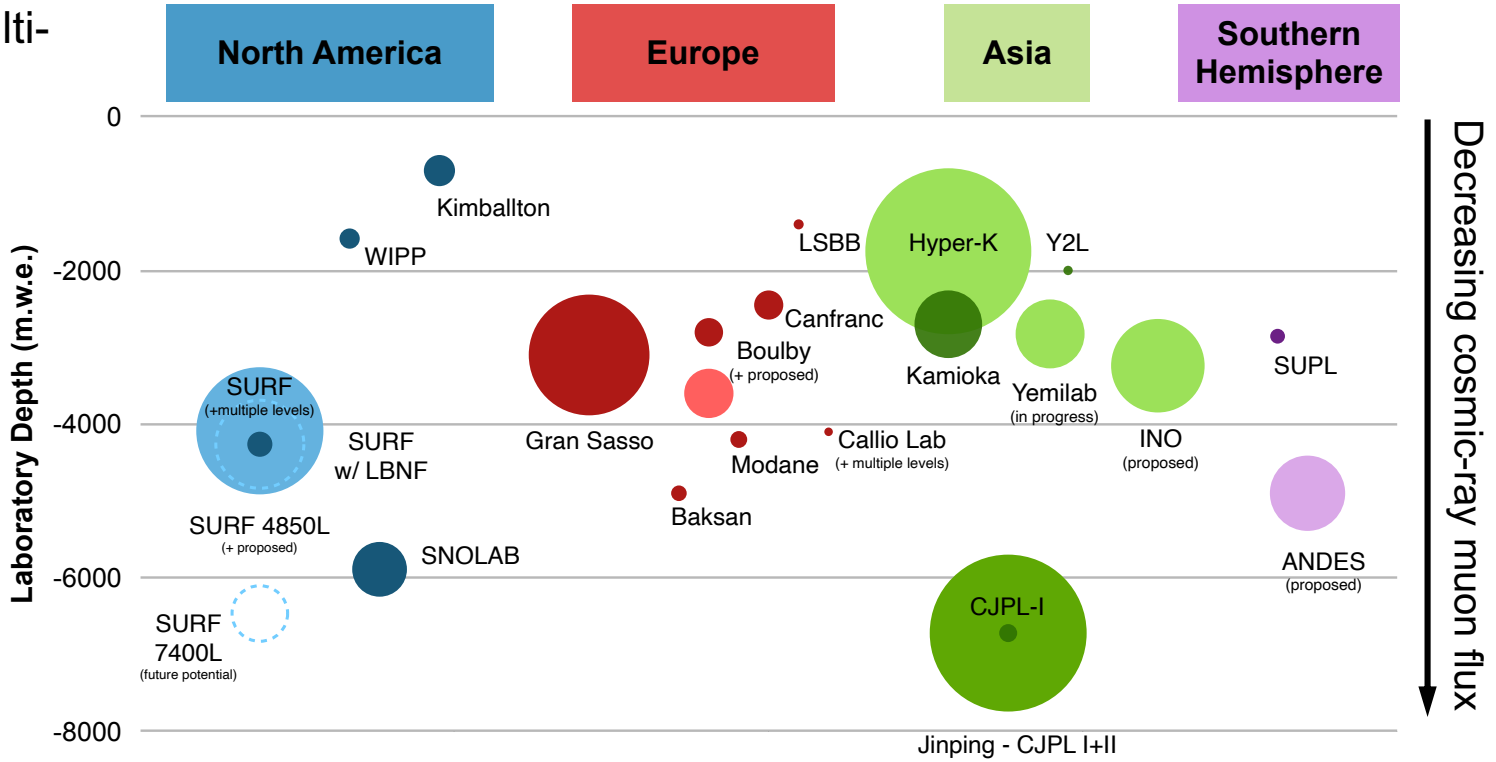
Status of underground facilities



Status of underground facilities

UG Facilities can provide:

- Unique environments for multi-disciplinary research
  - Overburden protection from cosmic-ray muons
- Local radiation shielding
- Assay capabilities
- Material production/ purification
- Environmental control
- Implementation and operations support
- Community catalyst



Note: Circles represent volume of science space

UF as a supporting Frontier

- In a science Frontier, here is where we describe the future program
- UF is a supporting Frontier --- UF supports science priorities in:
  - Neutrino Frontier
  - Cosmic Frontier
  - Rare Processes and Precision Frontier
- UF needs to hear from you!
  - But we'll share what we've heard so far…
  - And we want your feedback on whether we've understood!

Draft underground facilities & infrastructure observations for the U.S. HEP program

- Underground facilities have enabled a leading role for U.S. scientists in the most exciting underground scientific results in the last decade. Many future scientific opportunities require significant underground facilities in the next decade.
- Development of DUNE at SURF is the single largest U.S. investment in underground facilities and infrastructure
- Generally, underground facilities are “fully subscribed” with operating and scheduled next-generation experiments through the 2020s
- The scale of experimental plans for the late 2020s and beyond will out-grow existing underground facilities and infrastructure
- Large-scale underground experiments require substantial preparation of underground facilities prior to experimental construction
- DUNE excavation for the Far Detectors 3 & 4 is a notable underground facility opportunity for beneficial utilization prior to the full DUNE program

Draft conclusions related to underground facilities & infrastructure

- Support U.S. underground facilities to ensure success and completion of DUNE, the flagship HEP neutrino program for the coming decades
- Considering the Cosmic Frontier's priorities requiring underground facilities, and 2014 P5 recommendations, R&D and decision making for a Generation-3 direct detection dark matter program should commence to enable a construction start ~2030
- Ensure the health of scientific programs in underground facilities by supporting the enabling capabilities, technique development, and expertise required for underground experiments
- Through domestic and international interagency engagement seek to ensure both full utilization and necessary expansion planning of underground facilities to support U.S. high energy physics priorities

Toward UF completion

- UF reports are still in draft form
  - Community feedback after Snowmass Seattle is needed
  - Consistency with science Frontier reports is key final step

- UF planned output:
  - Five Topical reports
  - One short Executive summary/Frontier report (~2 page)

- Please work with UF to ensure facility & infrastructure needs for current and future underground research are documented… to provide an up-to-date reference for P5