

# New Development of the Underground Facilities

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November 1-3, 2018

The 19th International Workshop on Next Generation Nucleon Decay and  
Neutrino Detectors (NNN18)

UBC Robson Square, Vancouver

# Preface

- The majority of the NNN (Next-generation Nucleon decay and Neutrino) detectors are to be constructed deep under the ground
- This talk is to review **new development** of the **deep underground facilities** for present and future (mainly neutrino) experiments
  - Ocean/ice-based projects are beyond the scope of this talk
  - Focusing on facilities, will mention experiments themselves only little
- Much more should be taking place than what can be covered in 15 minutes
  - Omission from this talk does not mean less importance

# Kamioka underground facilities

Access by tramcar  
(until Kamiokande era)



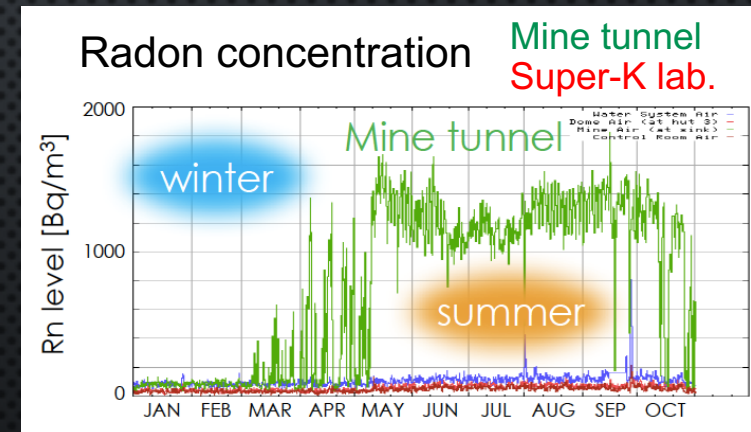
Easy access by car  
(since Super-K construction)



Entrance of the 2km horizontal tunnel



Kamioka, Hida-City  
Gifu Prefecture



Rn level of the buffer air in the SK tank is much lower ( $\sim 30\text{mBq/m}^3$ ) thanks to the Rn-free air purification system

# Kamioka underground facilities (central part)

**KamLAND(-Zen)**  
1000t LS(+Xe) detector

**Super-Kamiokande**  
50000t water Cherenkov detector

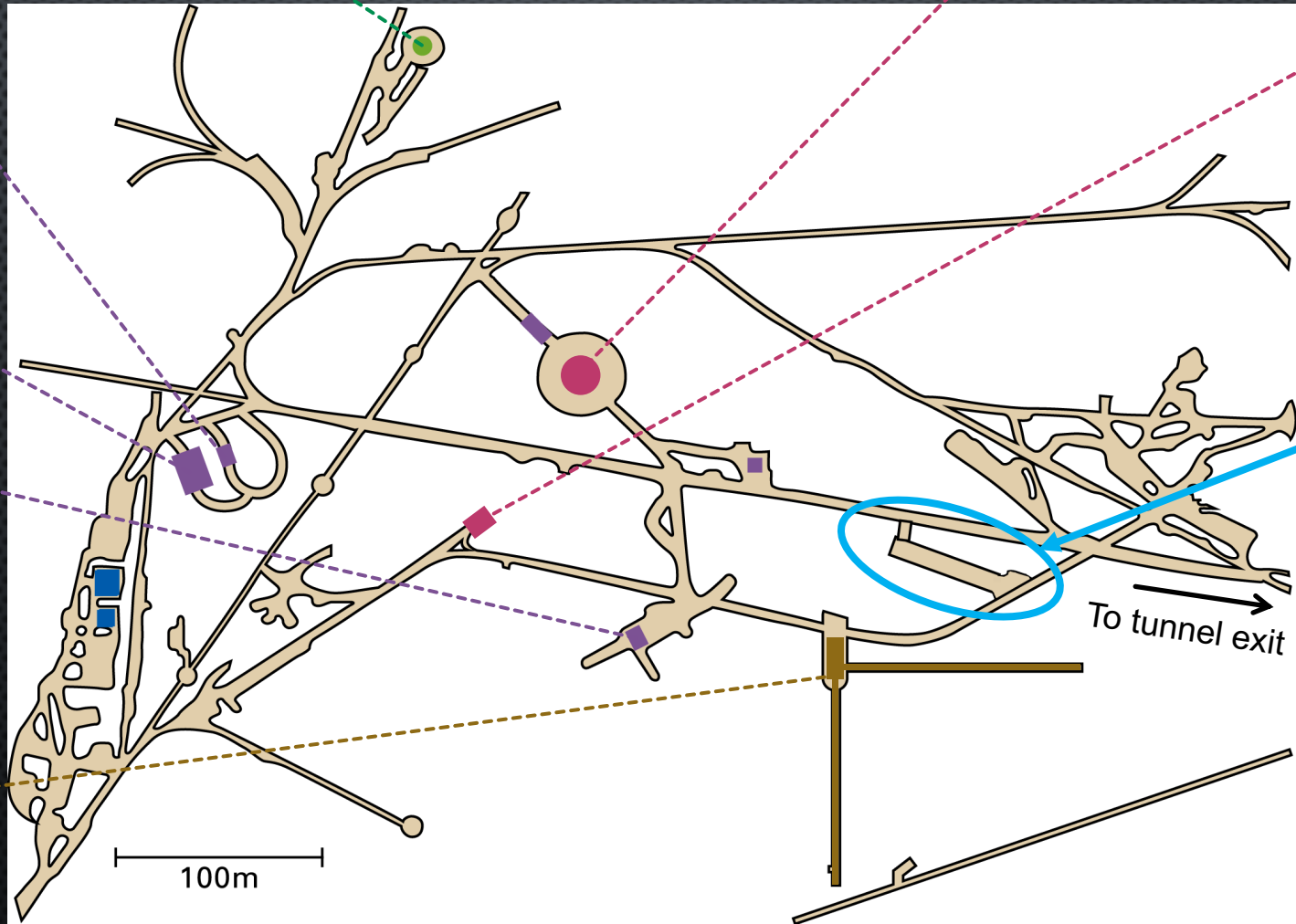
**EGADS**  
200t water tank  
for Gd-loading test

**CANDLES**  
CaF<sub>2</sub> scintillation detector  
for <sup>48</sup>Ca 0νDBD search

**XMASS**  
Direct DM search

**NEWAGE**  
Direct DM search

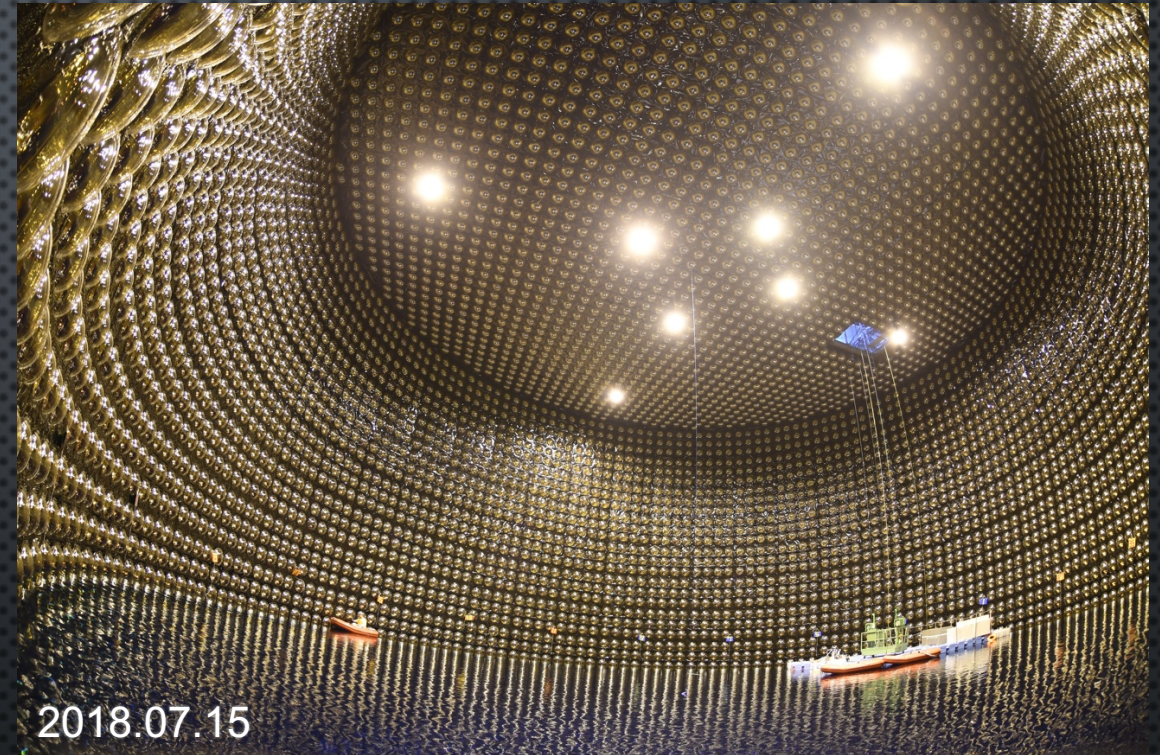
**CLIO**  
100m prototype  
GW detector



**New facility**  
will mention later

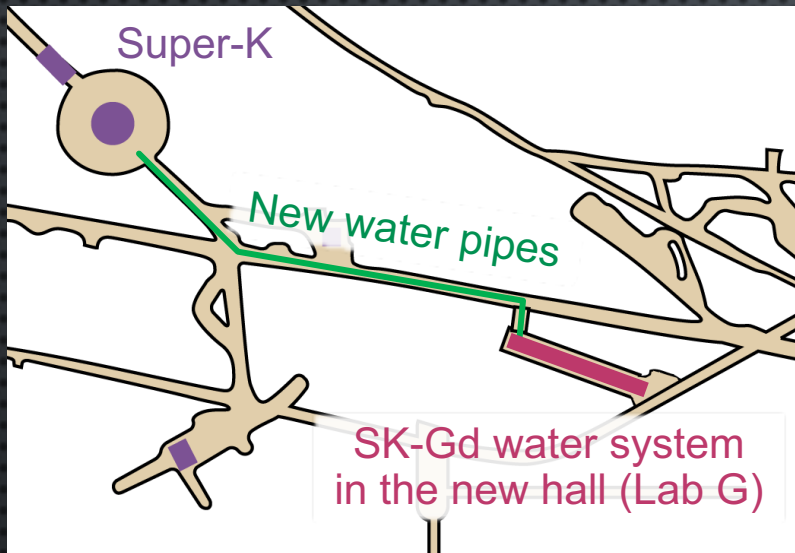
# Super-Kamiokande refurbishment

- Super-K detector has been refurbished in this summer to prepare for the gadolinium loading
  - Motivation of the Gd loading :  
Enhance neutron tagging efficiency for supernova relic  $\nu$  detection, proton decay BG reduction, etc.
  - The Super-K tank opened in May 2018 after the 12 years of SK-III and SK-IV operations
  - The refurbishment work includes
    - Fixing water leakage from the tank
    - Replacing failure PMTs with spare/new ones
    - Improvement of the water plumbing
- Started filling the tank with pure water in this month
  - Tank to be full in early 2019

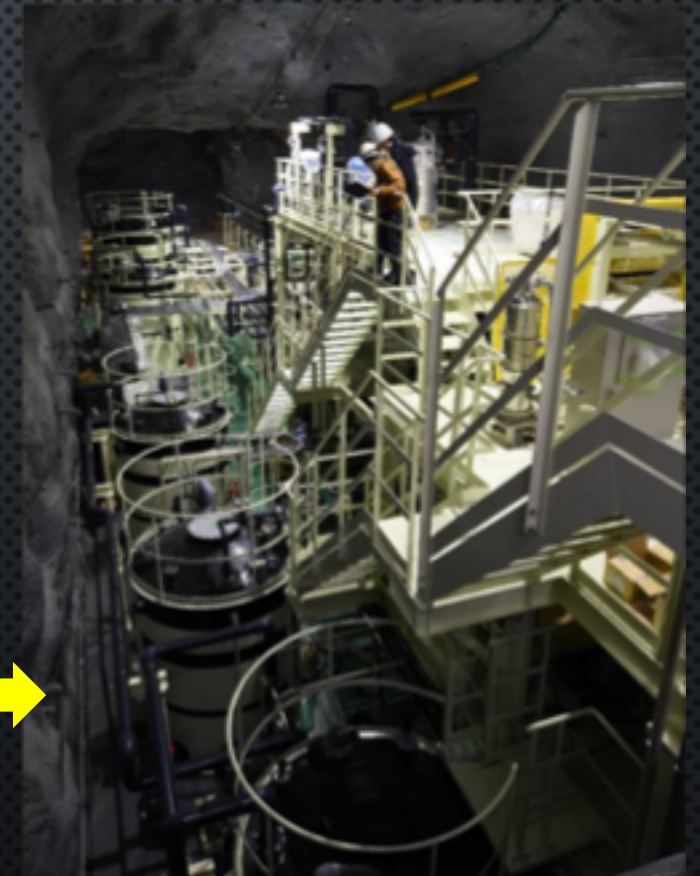


For more details about SK-Gd,  
M. Smy (UCI) talk on Nov 2nd

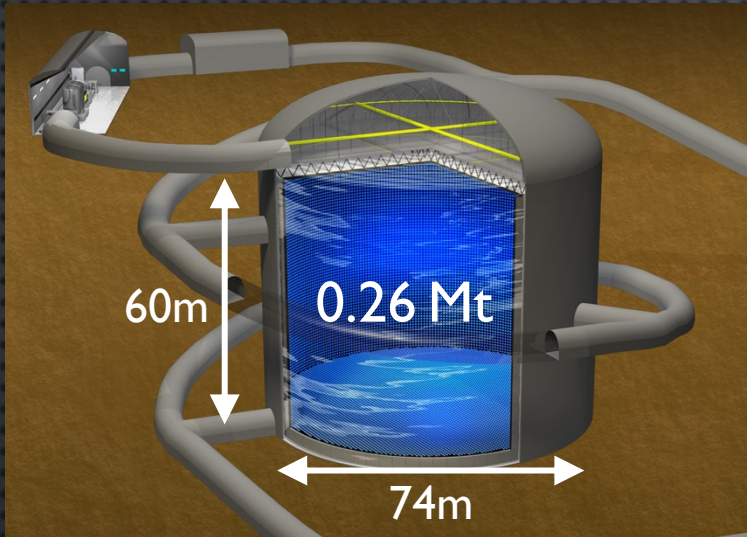
# SK-Gd water purification system in a new hall



- Purification of the Gd-loaded water needs special care because Gd should not be removed from the water while other impurities should be removed
- Dedicated new underground hall (W:8m x H:7m x L:50m) was constructed
- Completed Gd-water system including new pipe lines to Super-K (~150m)



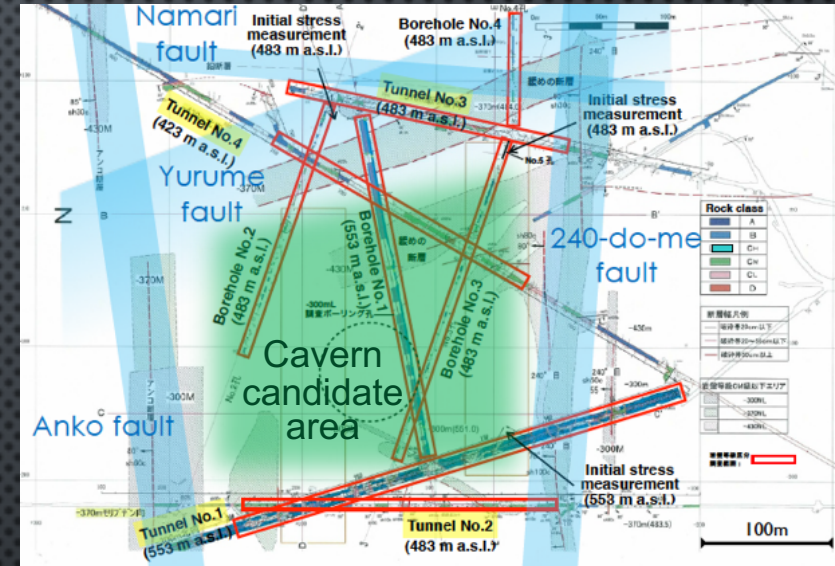
# Facilities for Hyper-Kamiokande



- Hyper-Kamiokande
  - A gigantic water Cherenkov detector for neutrino science and proton decay studies
  - BIG NEWS : The University of Tokyo announced that **the Hyper-K construction is to begin in April 2020**
    - Observation expected to start in 2027
  - For more details, A. Pritchard (Liverpool) talk on Nov 2<sup>nd</sup>
- Preparation for surface facility constructions is progressing
  - Completed a topographical survey and a boring geological survey at the access tunnel entrance site
  - Designing the power line to the entrance site as consulting a electric power company and local governments
  - Completed natural environmental surveys around the rock disposal site → No showstopper found

# Geological surveys at the cavern site for Hyper-K

- The underground cavern is the biggest facility for Hyper-K
- Geological information at the cavern site has been obtained by tunnel and boring surveys
- A seismic prospecting was carried out using existing mine tunnels to obtain information over the entire candidate area (3D)



Dropping weight



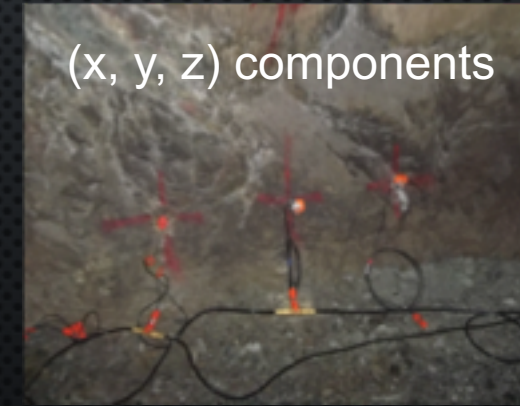
Wooden maul



Seismic waves

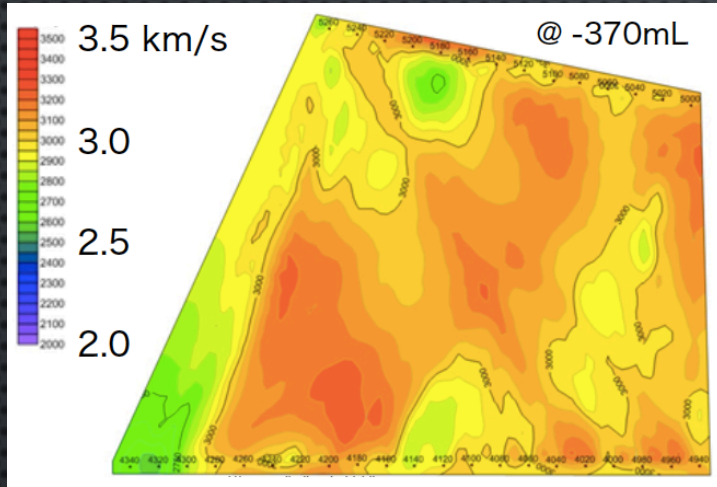


Geophones



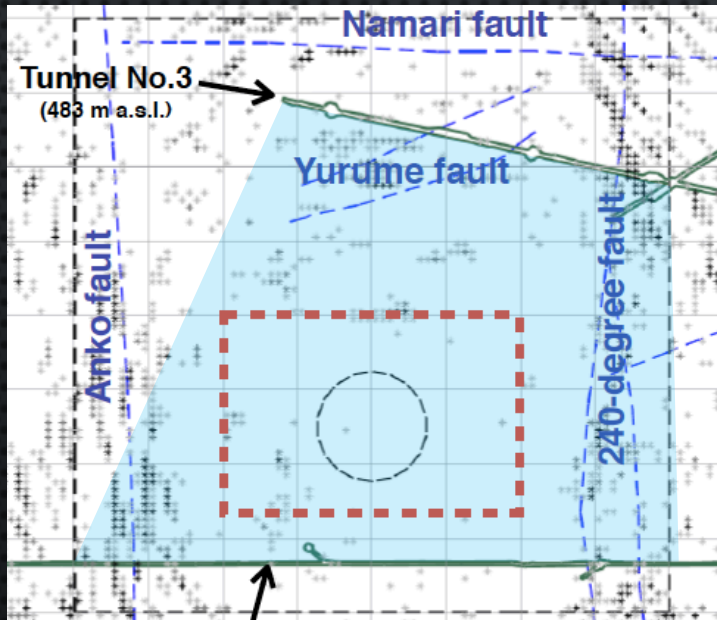


# Seismic prospecting at the cavern site for Hyper-K



## Tomography (S-wave)

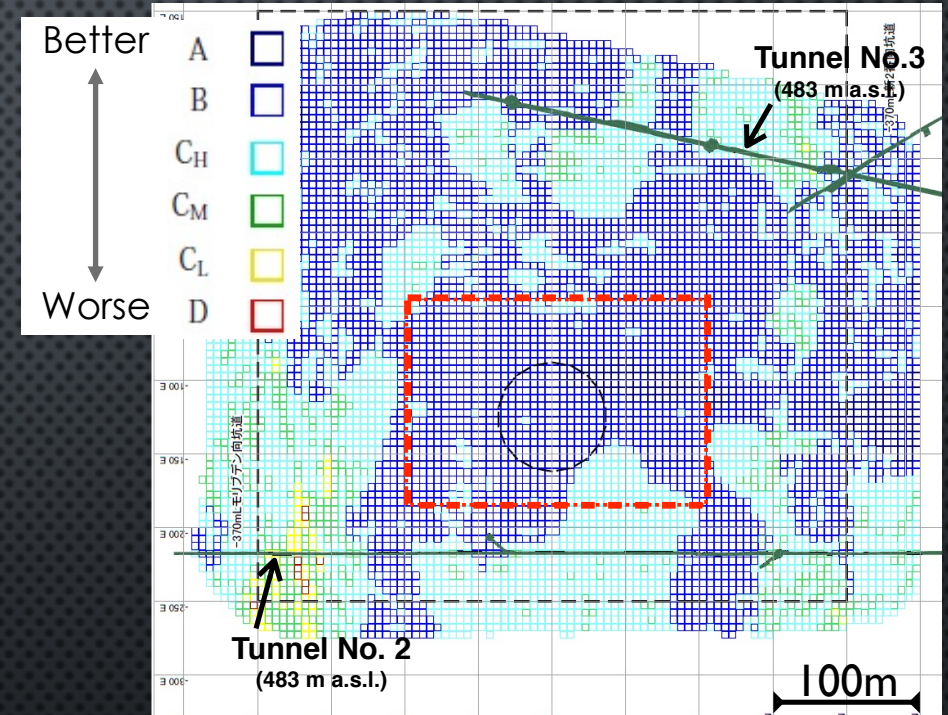
- The location where shows lower velocity is consistent with the location of known faults/fracture zones



## Reflection imaging

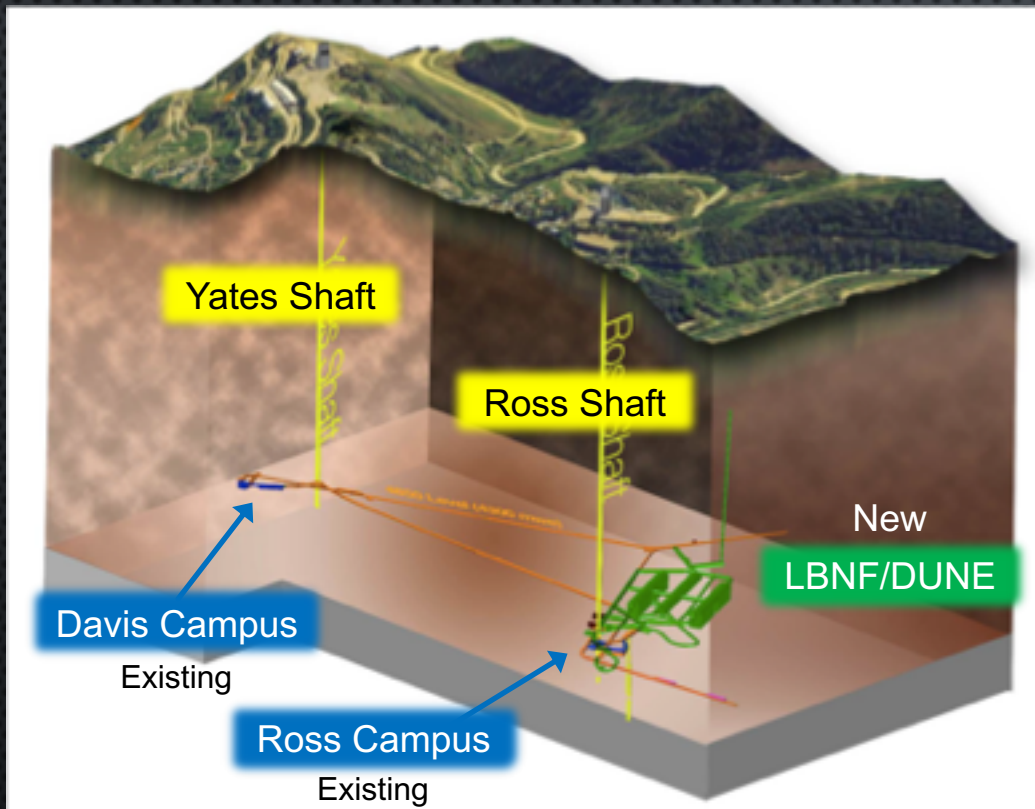
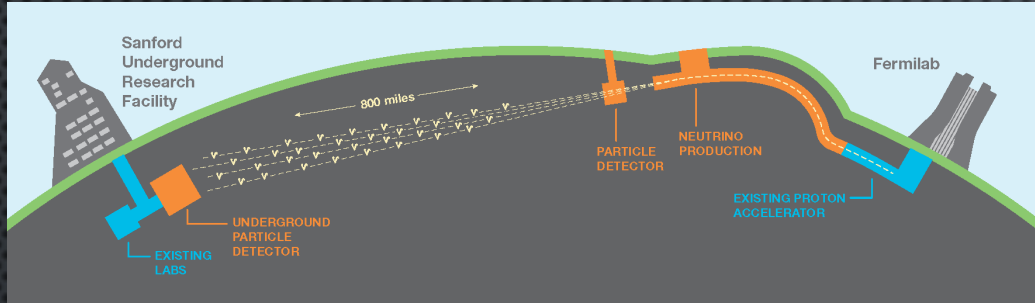
- \* = reflection points
- Known faults identified by reflection imaging
- Identified a location where there is no major cluster of reflections (red rectangle)

## Estimated rock class distribution



- Converted S-wave velocity to rock class. Reflection imaging also used for correction
- The best candidate region where has good rock quality and no fault/fracture zone is identified

# LBNF at the Sanford Underground Research Facility

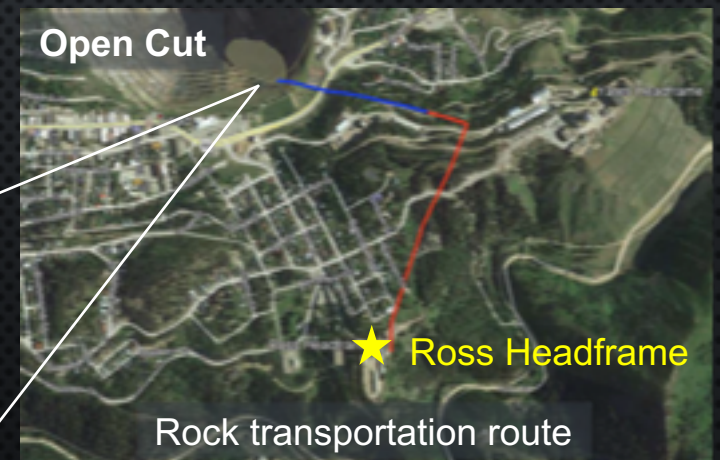
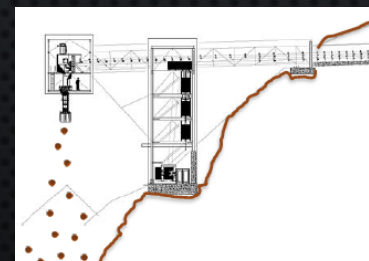


- The DUNE far detector
  - Four 17,000-ton liquid argon TPCs
  - Will be installed in large caverns at the Sanford Underground Research Facility, South Dakota
    - 1475 m (4850 feet) underground
- LBNF at SURF : Phases of work
  1. Sanford lab reliability projects (FY16-19)
    - Ross Shaft rehabilitation, Hoist motor rebuilds, ..
  2. Pre-excavation construction (FY17-20)
    - Rock disposal systems, Ross headframe upgrade, ..
  3. Excavation and surface construction (FY21-24)
  4. Cryostats/Cryogenic systems (FY22-26)

# LBNF at SURF

- LBNF/SURF groundbreaking in Jul 2017
- Ross Shaft rehabilitation
  - Completed work to 4850L in Oct 2017. Work below 4850L remaining
- Surface rock conveyor
  - Conveyor ordered in Jun 2017
  - Completed geotechnical field investigation (including open cut lip)
- Pre-excavation work to start in fall 2018 includes :
  - Underground rock handling system, rock crushing system, installing surface rock conveyor to open cut, Ross headframe reinforcement, ..
- Final designing for cavern/drift excavation underway
- Expected to start excavation in 2019

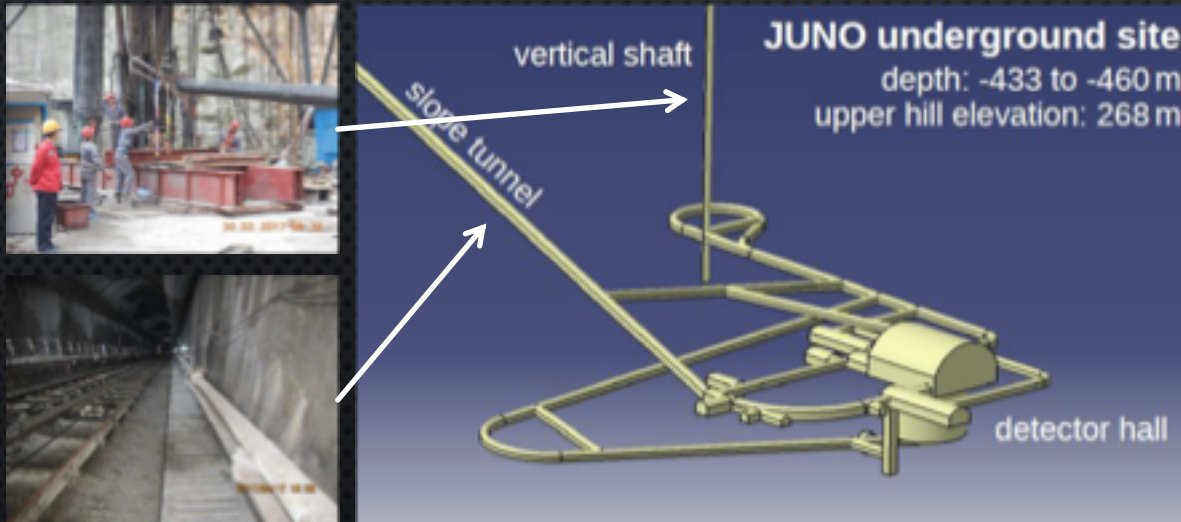
Steady progress to move forward



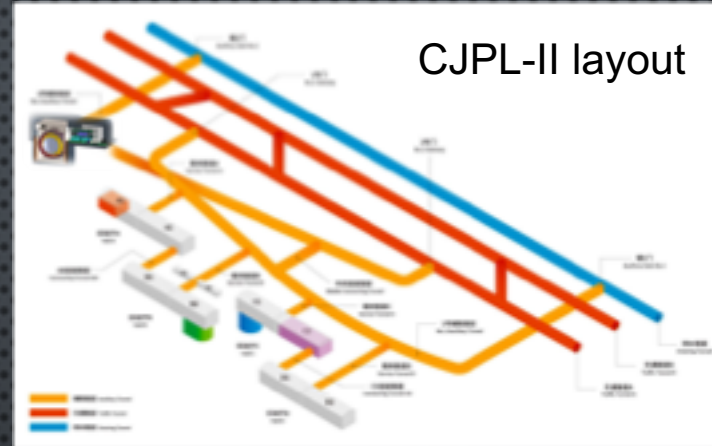
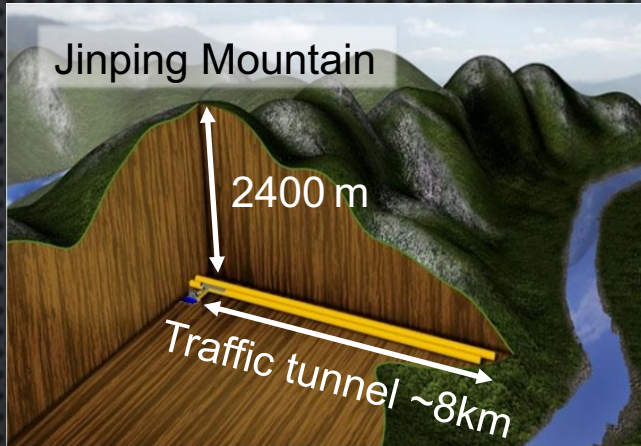
# Jiangmen Underground Neutrino Observatory (JUNO)



- 20 kton liquid scintillator detector
  - Aiming for  $\nu$  mass ordering determination, oscillation parameters precision measurements, supernova/solar/geo- $\nu$  studies, ..
- LS purification test ongoing with a pilot plant at Daya Bay
- Completed the construction of the slope tunnel and vertical shaft
  - Delayed due to unexpectedly large amount of spring water
- Started to excavate the experimental hall → will finish in 2019
- JUNO schedules to start data-taking in 2021



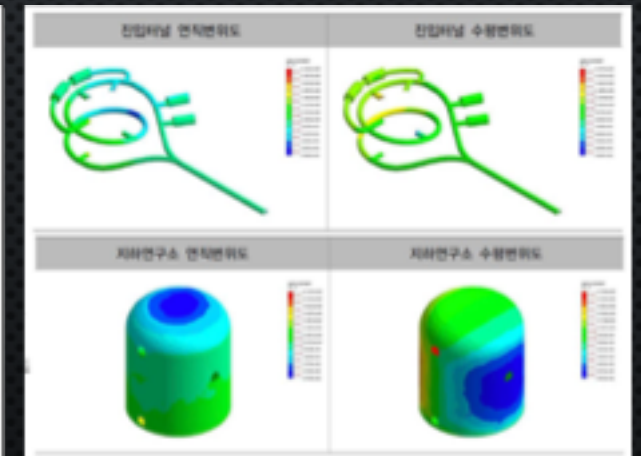
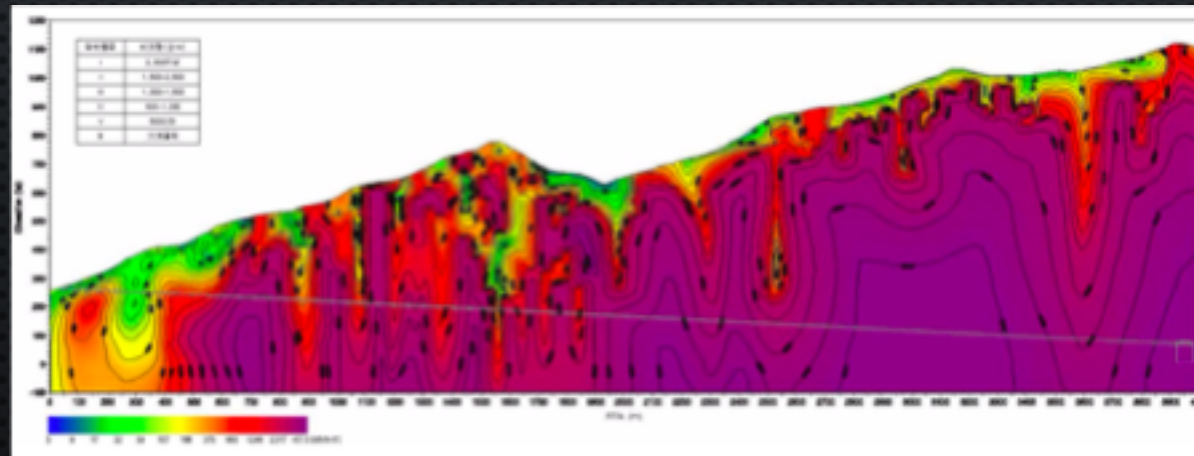
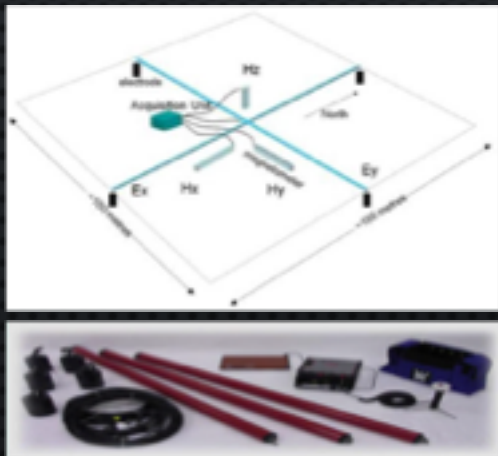
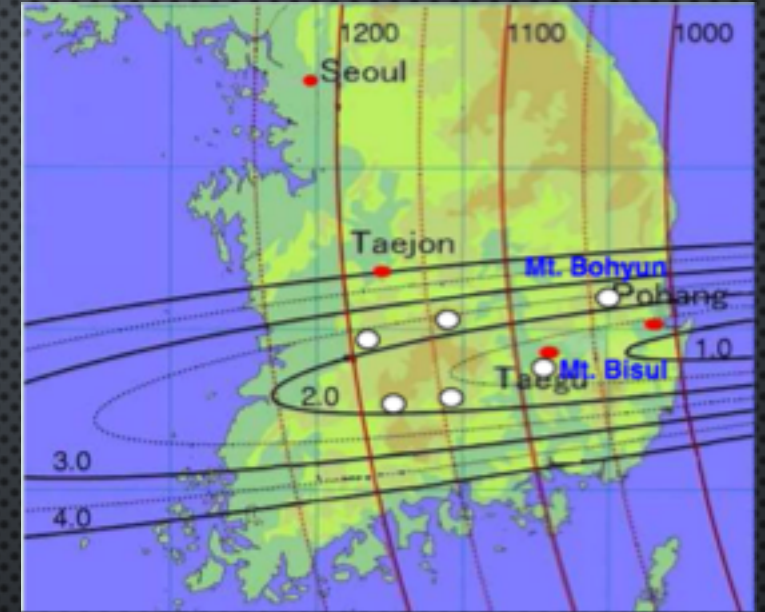
# China Jinping Underground Laboratory II (CJPL-II)



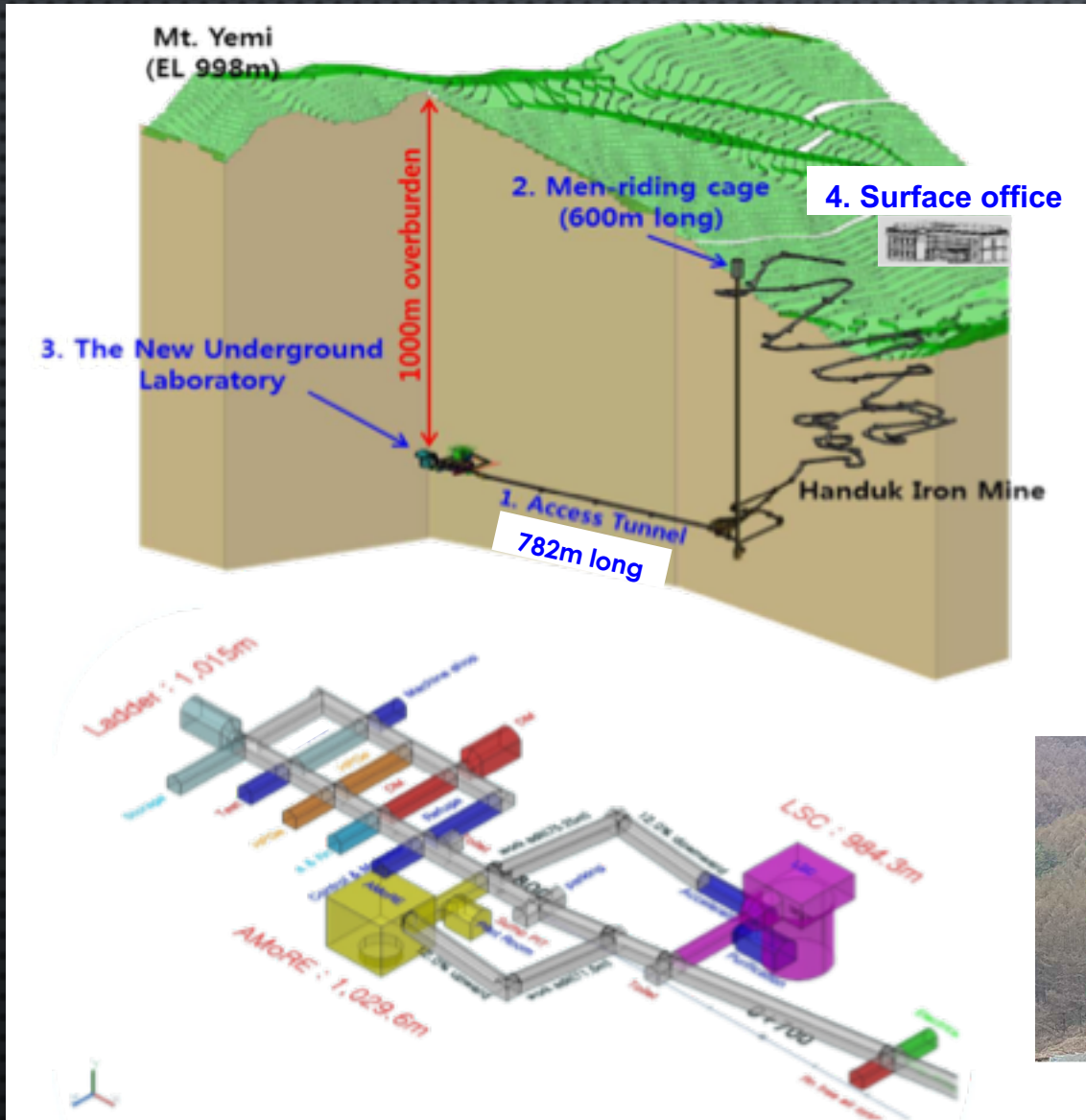
- CJPL-I/II : World-deepest rock-underground lab (~7200 m w.e.)
  - Very low cosmic radiation background
  - Ambient/material radioactive background level also quite low
  - Convenient access by car (Lab located in the middle of traffic tunnels)
- Placing a kilo-ton neutrino detector inside a 30m x 30m cylindrical water tank is now officially under consideration at CJPL
- CJPL-II status
  - Rock excavation completed in 2017 (total volume ~300k m<sup>3</sup>)
  - Ventilation and power supply ready, water system under preparation

# Korean Neutrino Observatory as a far detector of the J-PARC beam

- Project to construct a sub-Mton water  $\check{C}$  detector in Korea
  - As the 2<sup>nd</sup> far detector for the J-PARC beam towards Hyper-K
  - L(1000-1200km) at the 2<sup>nd</sup> osc max, larger matter effect
    - Improved sensitivities (MH, CPV, ..) by a combination HK+KNO
- Two nice candidate sites : Mt. Bisul & Mt. Bohyun
  - Geological surface investigation for rock characteristic and fracture
  - Underground electro magnetic survey for rock quality classification
    - Found that rock quality at both sites is excellent
- Stress analysis and reinforcement design made for cost estimate



# New underground laboratory in Handeok mine, Korea



- Astroparticle Research Facility (ARF), a new underground lab in Korea will be placed in Handeok mine
  - To host several DBD/DM experiments like AMoRE-II
- The new 600m-long shaft already constructed. The shaft cage to be ready by the end of 2018.
  - Under rope work for the cage installation and bottom station work
- Tunnel/Lab excavation shall start in Nov 2018
- Excavation expected to be completed by mid-2020



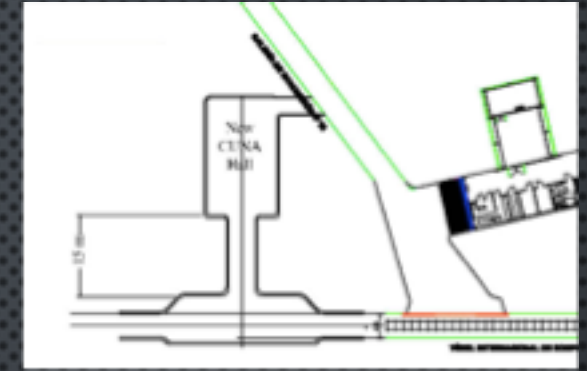
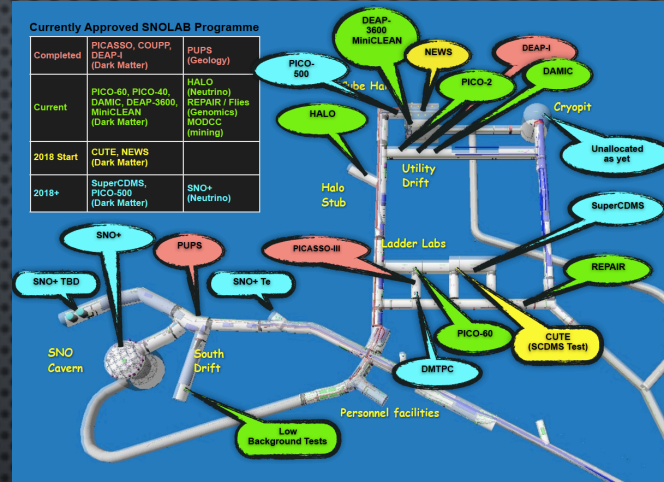
# Lots more ..

Extension plan at Canfranc (Spain/France)

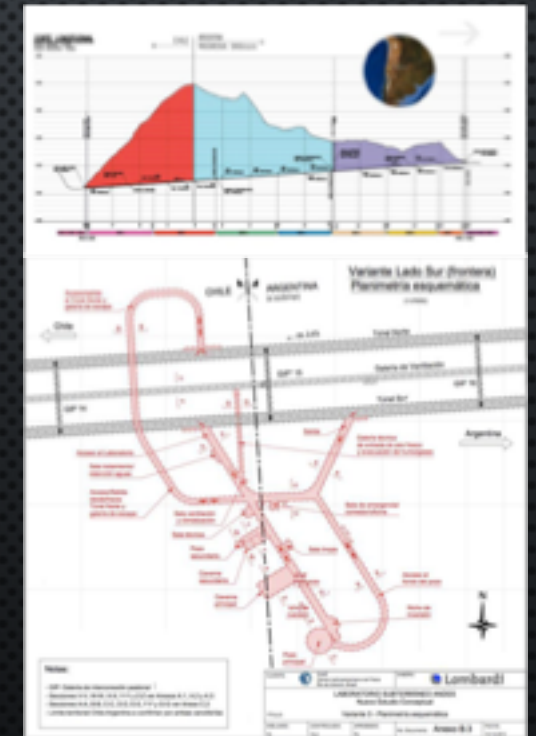
New lab at Boulby (UK)



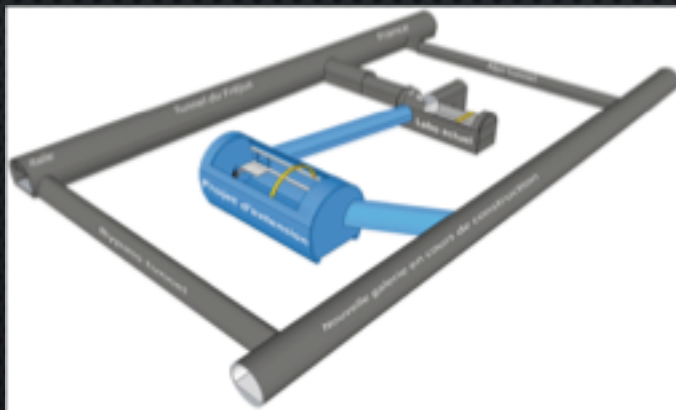
Approved programs at SNOLAB (Canada)



New lab plan at Andes (Argentina/Chile)



Extension plan at Modane (France)



New lab plan at Stawell (Australia)

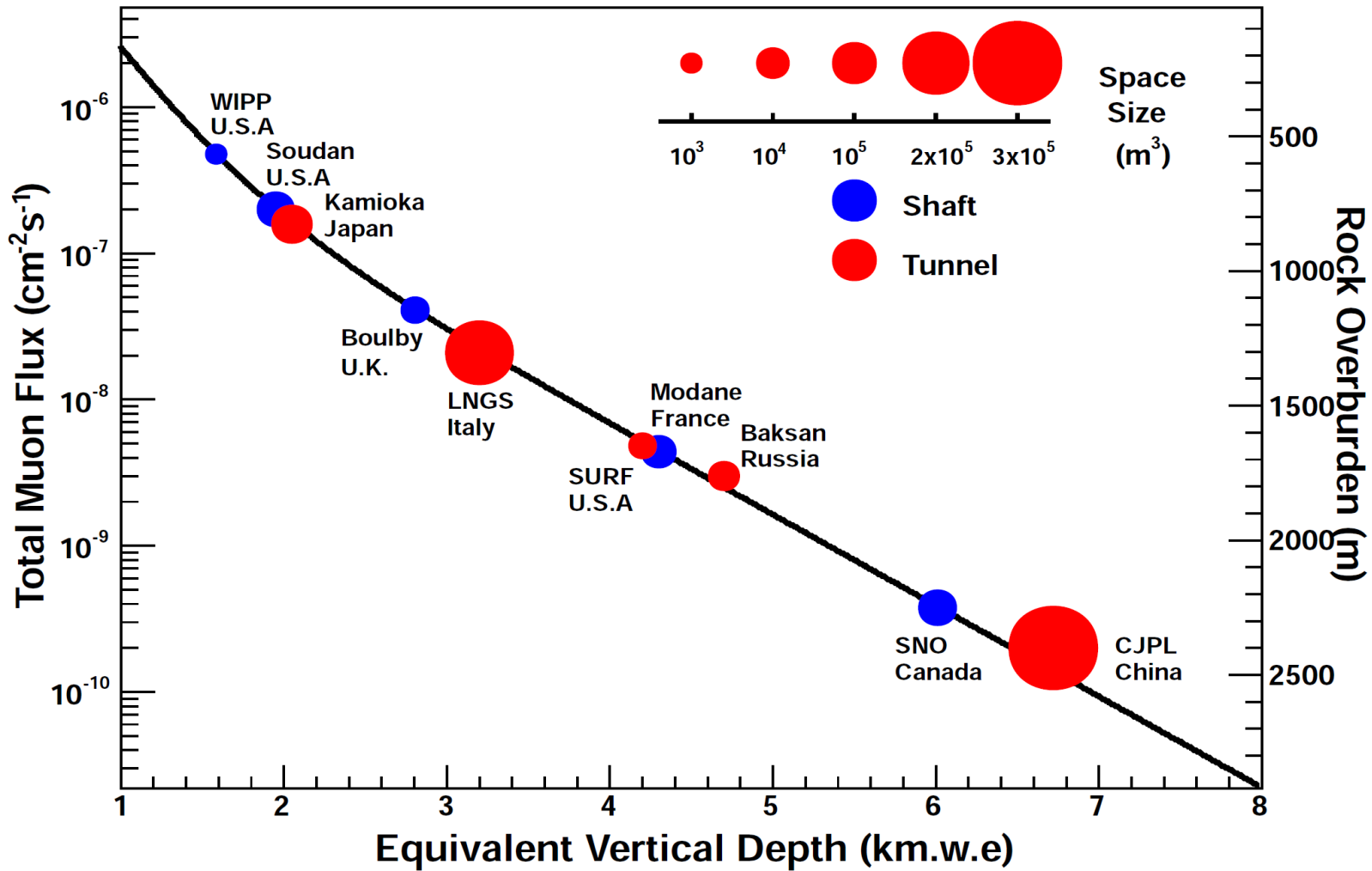




# Conclusion

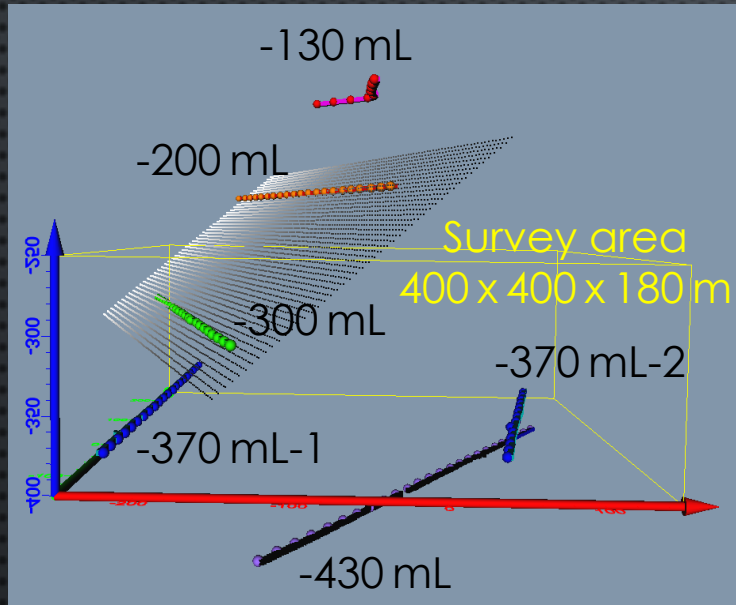
- Developments of the facilities (including preparation work before their constructions) for underground NNN projects are greatly progressing in these years
- Continuous and significant efforts are needed to complete the new facilities and host the NNN projects as scheduled

# Supplement

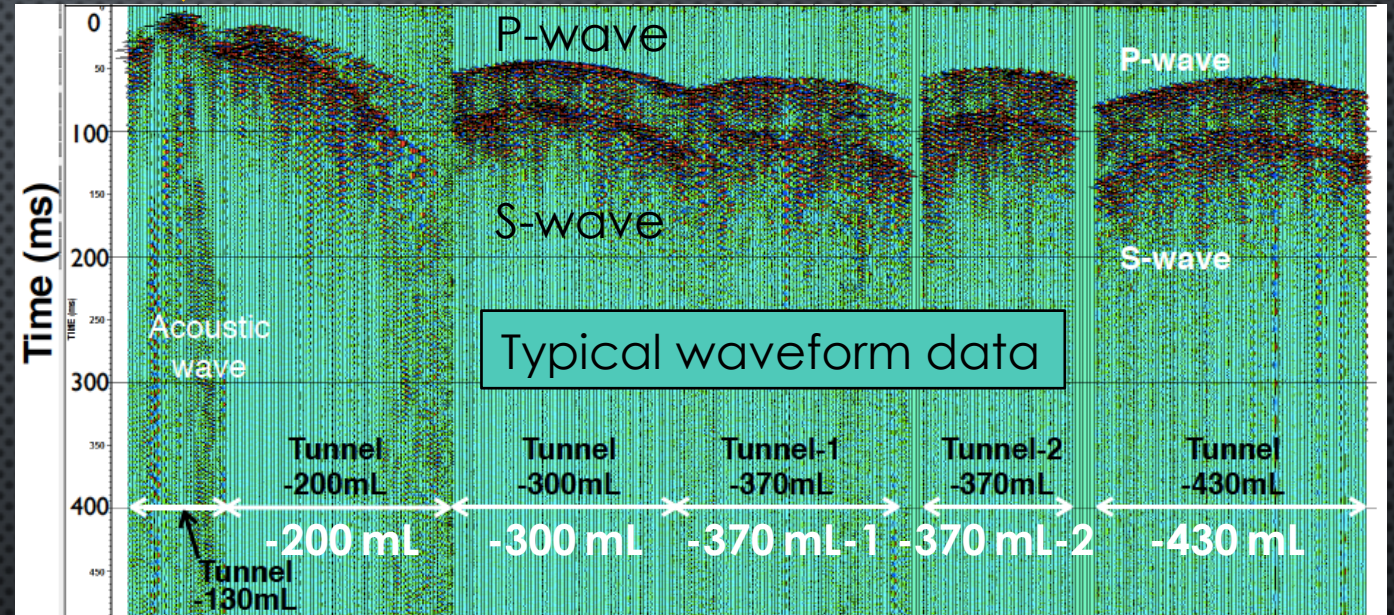


# Seismic prospecting : Data-taking

Layout of tunnels



↓ Generation point in this example



Generation/receiving points set in the 6 mine tunnels at various levels

- Seismic pulses generated at a point are recorded at 111 points (20m spacing)
- Changing generation point one by one : 837 points in total (2.5m spacing)

- Each vertical line : Waveform recorded by a receiver
- Waveforms by all receivers laid along the horizontal axis
- Higher pulse height shown in "black-ish" color

Clearly seen that elastic wave transmitted from the seismic source point (-130 mL) through to -430 mL