Nigel Smith
SNOLAB
with thanks to A. Bettini, G. Gerbier, K Lesko, S.Paling, F. Picuemal, B. Sadoulet, Y. Suzuki, Q. Yue
...and others

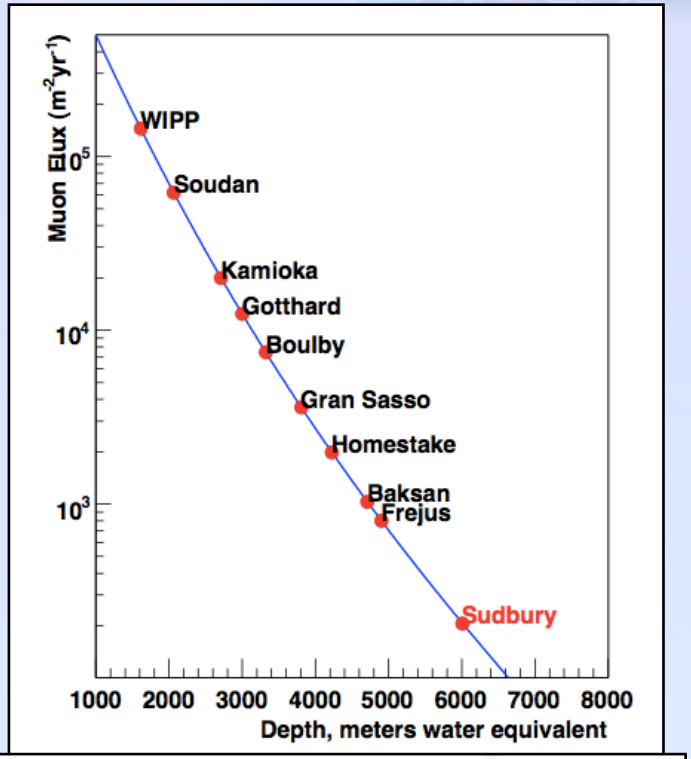
Status update on deep underground facilities

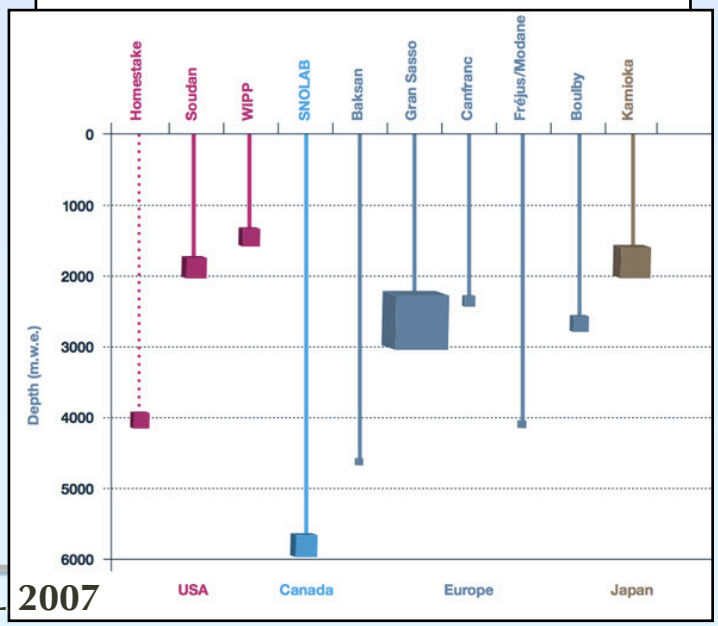
Outline

- Scope of talk:
  - Focus from the facilities perspective
  - Detailed reviews of experiments and techniques in following talks this week....
  - New/planned expansions to facilities
- Why go underground?
  - What other considerations relate to experiment deployment at underground facilities?
  - Background suppression
- Status update on underground facilities
  - Europe
  - Asia
  - North America

Why go underground?

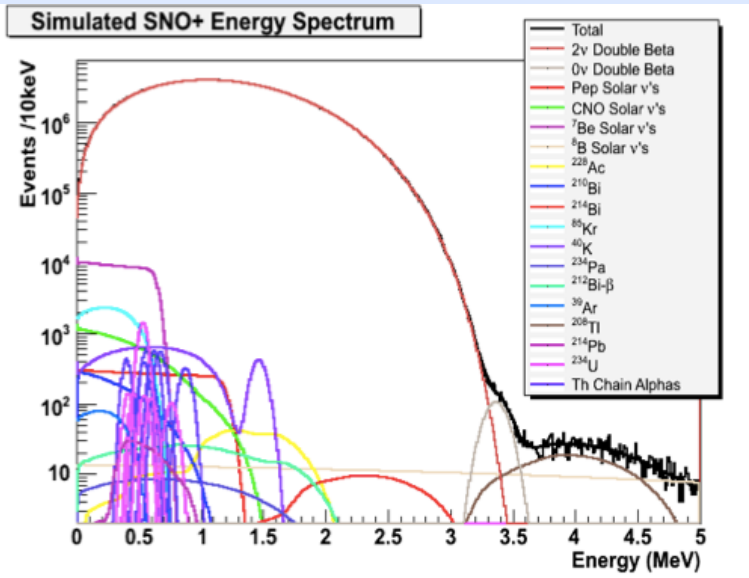
- Studies for rare events, either decays (eg proton or 0νββ) or weak interactions (dark matter, natural or generated neutrino), require very radio-quiet environments to undertake searches
- Deep underground facilities provide significant rock overburden and commensurate reduction in c.r. flux, and c.r.-spallation induced neutrons
  - Additional science programmes possible with such infrastructure - nuclear astrophysics, extreme biosystems, geology, geophysics, ...



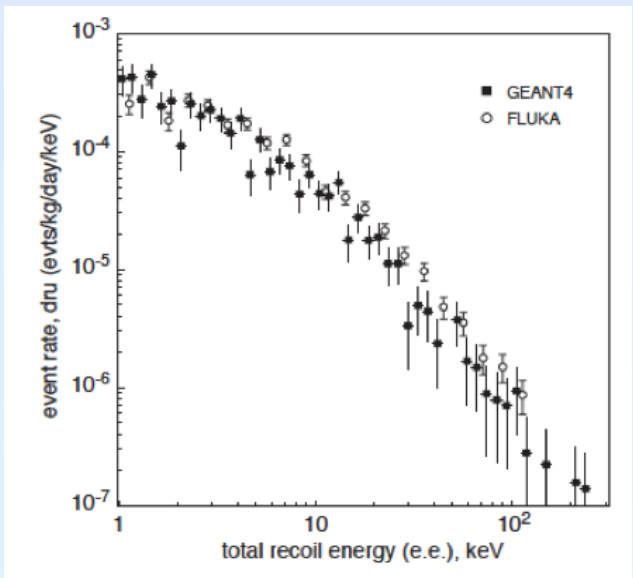


Backgrounds

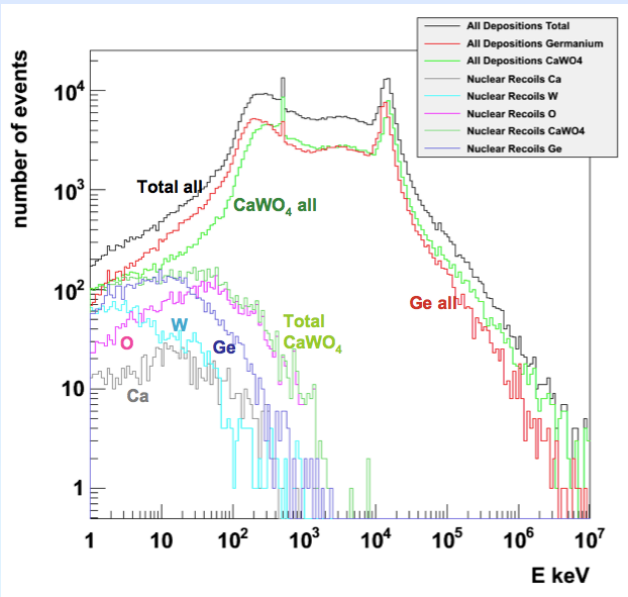
- Background suppression
  - c.r. μ spallation (depth, μ veto, self veto)
  - γ,β (traditional gamma shielding or gamma blind)
  - radon (clean room operations, atmospheric and material selection and radon suppression)
  - U/Th (α,n) in rock and detector materials (shield, veto)
  - Cosmogenics (underground fabrication)



SNO+ @ SNOLAB



LXe @ Boulby (Ajaujo)

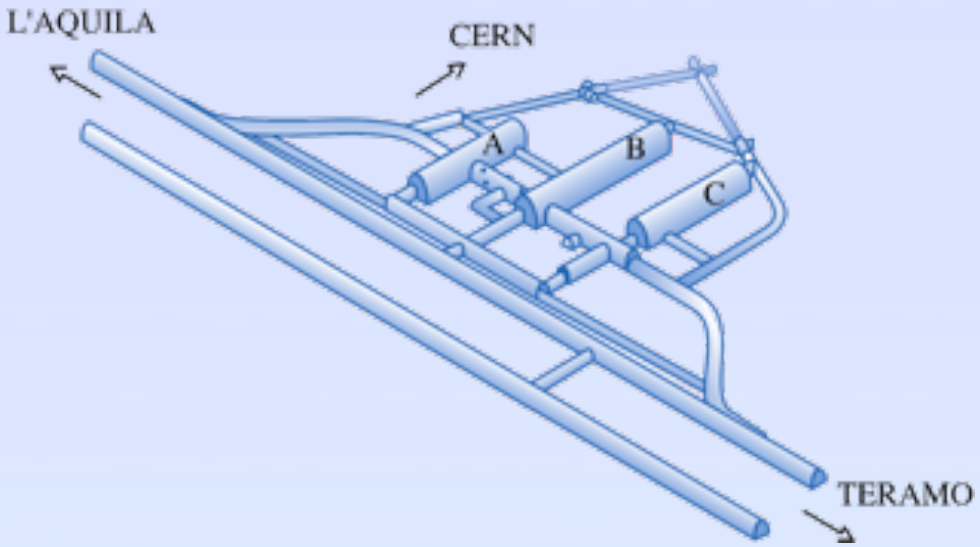


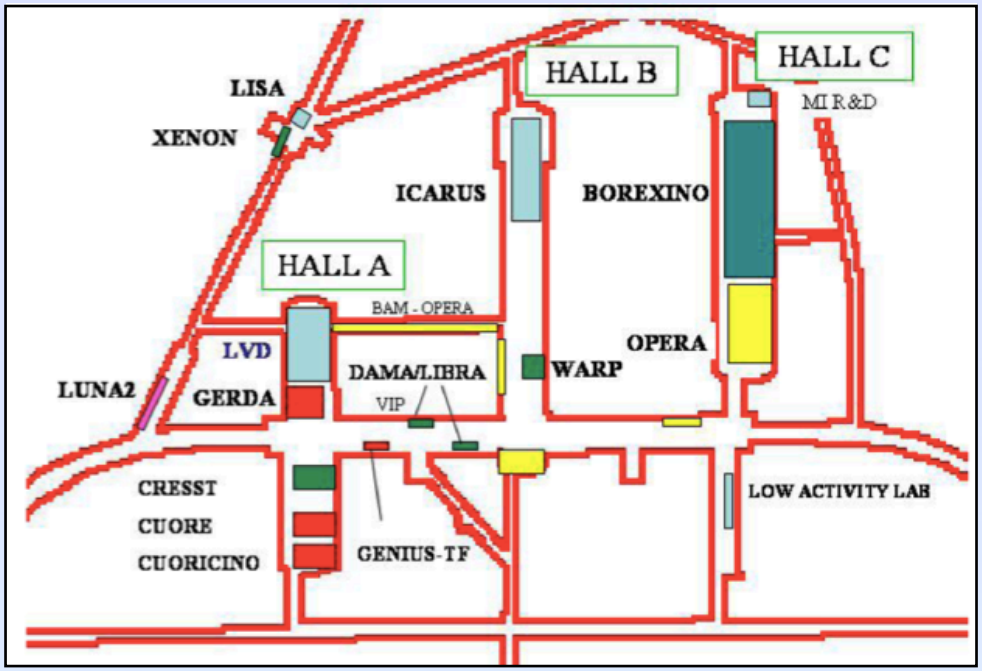
EURECA @ LSM (Kudryavtsev)

European Facilities

- *LNGS (Italy)*
  - *ICARUS, OPERA, BOREXINO, CUORICINO, CUORE, GERDA* operational or under construction
- Pyhäsalmi (Finland)
  - LAGUNA potential site
- Slanic-Prahova (Romania)
  - LAGUNA potential site
- Polkowice-Sieroszowice (Poland)
  - LAGUNA potential site
- Boulby (U.K.)
  - LAGUNA potential site
- Canfranc (Spain)
  - LAGUNA potential site
- LSM (France)
  - NEMO-III operational
  - SuperNEMO planned
  - LAGUNA potential site

LNGS





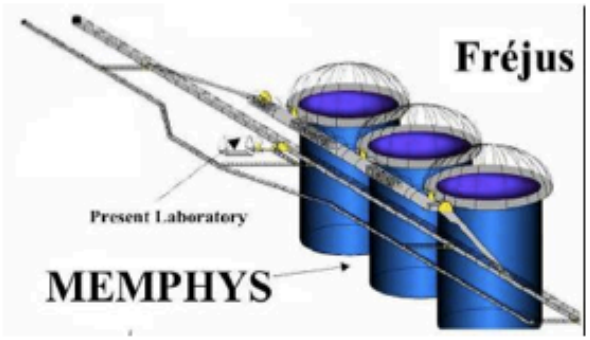
1400 m rock overburden (3.2 km w.e.)
Flat cross-section
Neutron flux = 3.8±0.3 10^{-2} $m^{-2}s^{-1}$
μ flux = 3 x 10^{-4} $m^{-2}s^{-1}$ (angular depend. measured)
γ flux= 1 10^{4} $m^{-2}s^{-1}$
Volume 180 000 m^3, area 17 300 m^2
Ventilation: 1 lab volume/3.5 h
Radon in air 50-120 Bq/m^3 (less @ experiments)
Support facilities on the surface
Drive in to the experiments
The largest international scientific community
Permanent staff = 80 permanent +23

Broad neutrino programme:
ν beam from CERN: ICARUS, OPERA,
Solar νs: BOREXINO,
SuperNOVA νs: LVD,
$0\nu\beta\beta$: CUORICINO, CUORE, GERDA

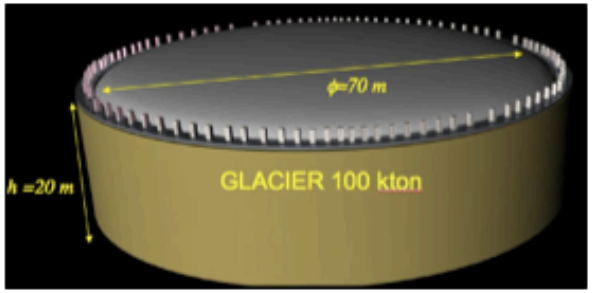
LAGUNA Physics

- Proton decay: improve sensitivity by > factor 10 and test a new class of Supersymmetry models
- Galactic Supernova: 104- 105 events Incredibly detailed information on the early SN phase
- Diffuse flux from past SN: probe cosmological star formation rate
- Solar neutrinos:details of the Standard Solar Model determined with percent accuracy
- Atmospheric neutrinos: high statistics would improve knowledge of neutrino mixing and provide unique information on the neutrino mass hierarchy
- Geo-neutrinos: improve understanding of the Earth interior
- Indirect WIMP search
- Neutrino accelerators over a long baseline (also with dedicated smaller detectors): neutrino properties

LAGUNA detector concepts



- MEMPHYS - MEgaton Mass PHYSics
  - tanks of 60 m heigth $\times$65 m $\varnothing$
  - $\sim$440 kt water Cherenkov detector



- GLACIER - Giant Liquid Argon Charge Imaging ExpeRiment
  - 20 m heigth $\times$70 m $\varnothing$
  - $\sim$ 100 kt liquid Ar TPC

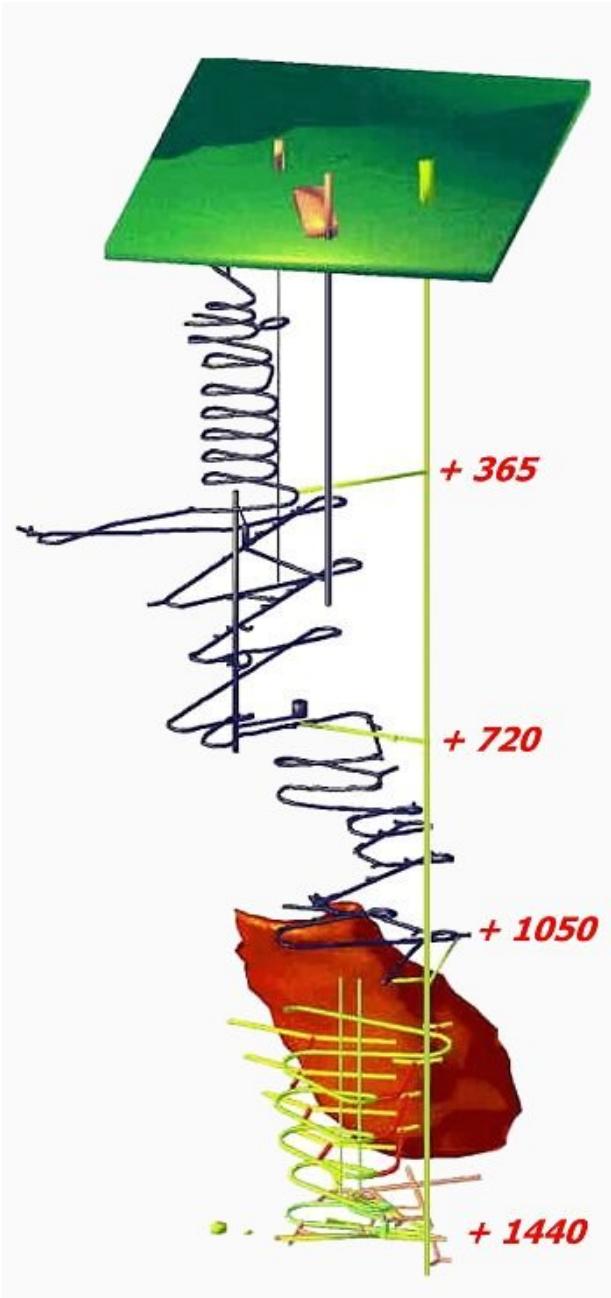
- LENA - Low Energy Neutrino Astronomy
  - 100 m long $\times$ 30 m $\varnothing$
  - $\sim$ 50 kt liquid scintillator

Centre for Underground Physics in Pyhäsalmi CUPP. Finland

Old mine - Operational 1962-2001
Cavities available at several levels from 95 m to 980 m
Lab facilities may be excavated @ 1440 m, 4 km w.e.

Neutron flux being measured
Personnel: 3 on site + 3 @ Oulu
Offices, labs and guest rooms on surface
Access via lifts or inclined road tunnel

EMMA experiment at 75m depth
Composition of atmospheric μ @ knee
Drift chamber and plastic scintillators



Romanian underground laboratory in Unirea salt mine,

Slanic Prahova-ROMANIA

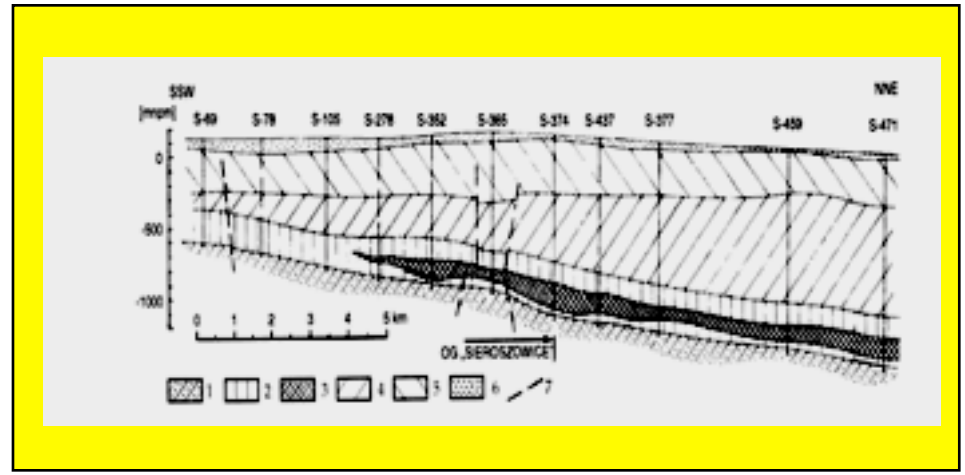
View of underground laboratory

view from Unirea salt mine

The Underground Laboratory for Measurement in Ultra-low Radiation Background is situated in Unirea salt mine, in Slanic Prahova town, in Prahova County, Romania.
Slanic town, Prahova County is situated in sub-Carpathians hills, about 100 km N from Bucharest and 150 km SE from Brasov. The town is placed in Slanic River valley, tributary of Varbilau River.
In this environment, we have constructed the Low Background Radiation Laboratory situated at a depth of 208 m beneath the surface at water equivalent thickness of ~600 m.
This mine consists of a hivelike structure composed of more galleries 32 or 36 meters wide, 52 to 57 m height and hundreds of meter long. Also it must be pointed out the remarkable stability of the microenvironment
characterized by a constant temperature all over the years of 12^0 C and relative humidity of 60 to 65 %.

The Polkowice-Sieroszowice mine in Poland

- one of the sites proposed for LAGUNA and ArDM



Geological cutoff – layers of anhydrite, dolomite and salt rocks at depths from 600 till >1400 m below the surface

Near Wrocław, south-west of Poland - easily accessible from the Wroclaw airport and from the A4 motor-way, 950 km from CERN

The Sieroszowice mine (178 km^2 of underground excavation area), belongs to the KGHM holding of copper mines and metallurgic plants - 6th position in the world's copper production and 2nd position for silver.

Boulby Science Facility

- Boulby is **a working potash mine** in the North East of England. Operated by Cleveland Potash Ltd – a major local employer.
- **1100m deep** (2805 mwe giving ~10^6 reduction in CR muons).
- Surrounding **rock-salt = low activity** giving low gamma and radon backgrounds.

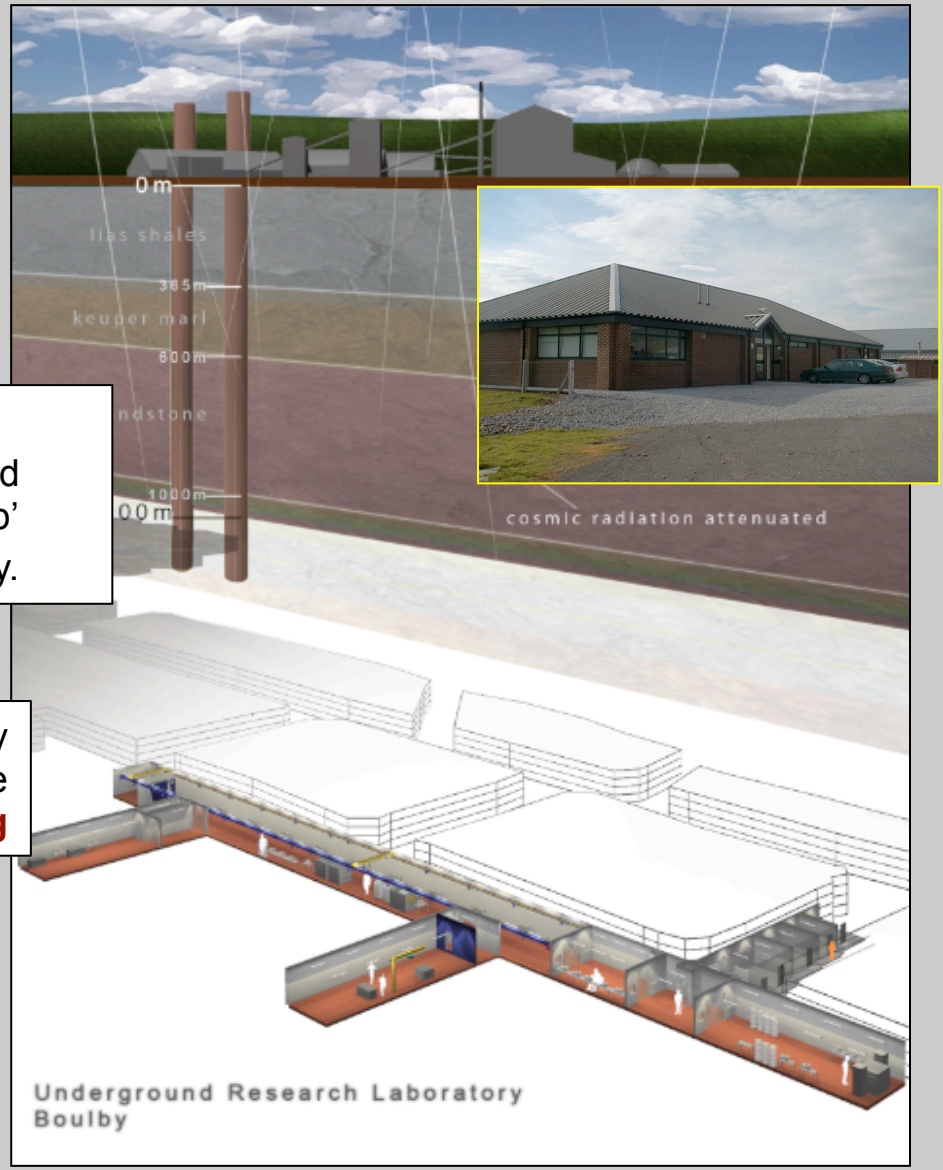
Boulby Mine

JIF facilities - 2003 .

> 1000 m^2, fully equipped underground 'Palmer lab'

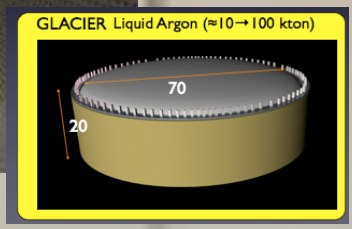
> Surface support facility.

June 2009: New facility manager & science coordinator **Sean Paling**



Boulby Update & Future

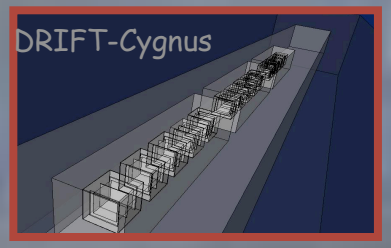
Latest Boulby News:
- June 2009: New facility manager and science coordinator – Sean Paling
- Boulby mine and the Underground facility awarded ISO18001 national H&S management award.



ELENA

ILIAS-next

Future Science Aims / Plans
- Continued hosting / supporting **Dark Matter** searches (DRIFT, ZEPLIN-III and beyond)
- Development of UK centre of excellence for ultra sensitive **low activity material screening**
- Development of **geoscience studies** – (RDA funding already secured for geology/geophysics studies.)
- Continued involvement with 'ILIAS-type' **EU underground lab networking.**
- Pursual of possible future small and large projects – **e.g LAGUNA, ELENA**



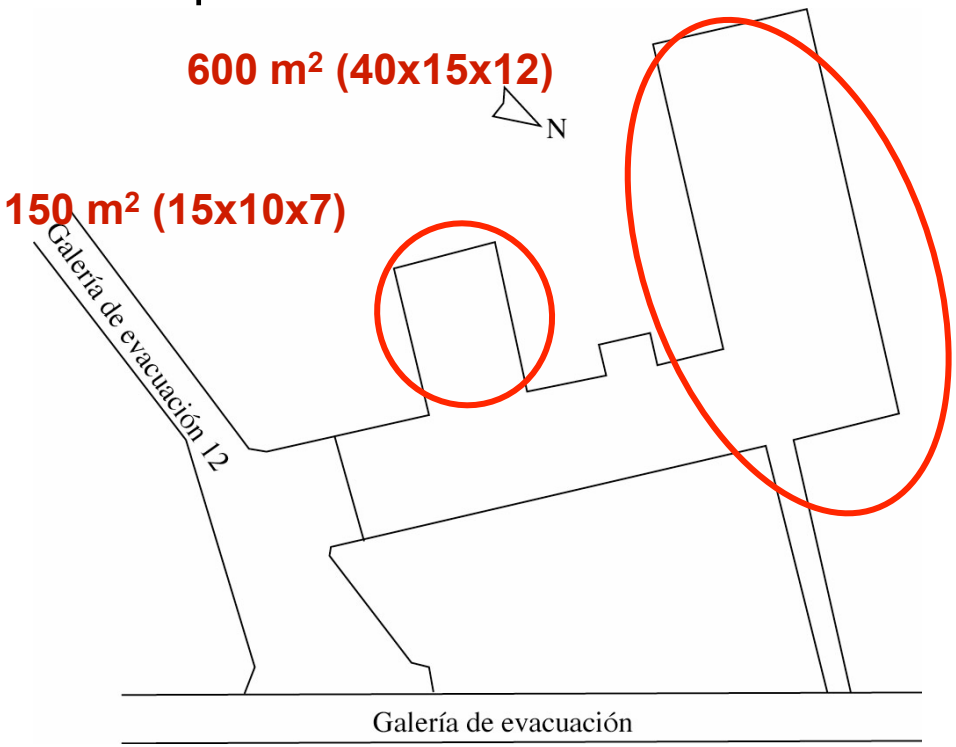
Future expansion?
- Plenty of space and low cost for future excavations @ Boulby
- Proven track record for operations
- Ongoing strong local support

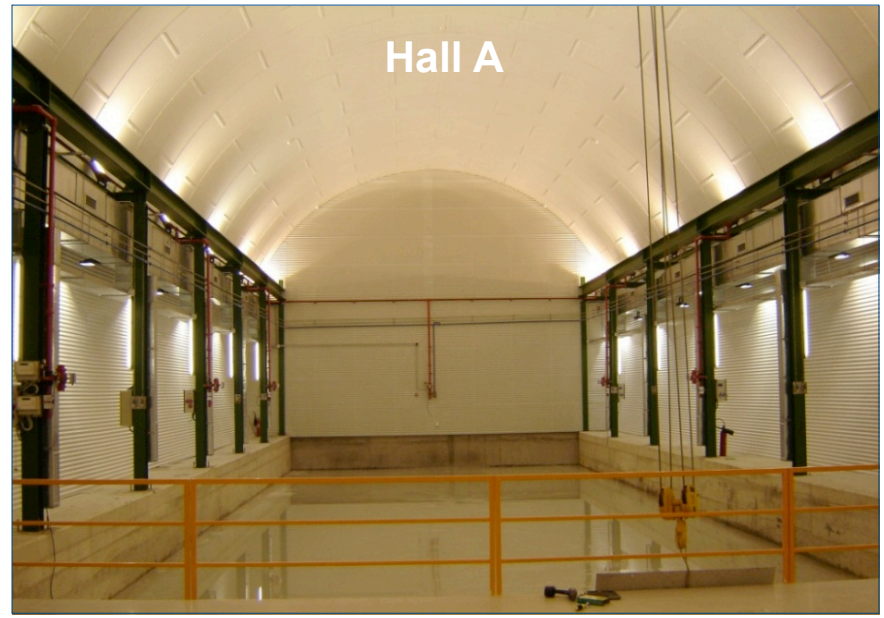
The Canfranc Underground Laboratory (LSC) and Dark Matter

http://www.lsc-canfranc.es/

Experimental halls A, B and C

Completion of the reinstallation of the infrastructure. June 2010





Depth: 800 m

Muons: 0.47 μ x 10^{-2} m m^{-2} s^{-1}

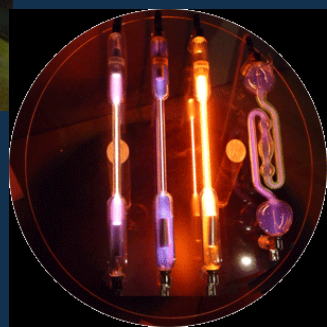
Ventilation: 11.000 m^3/h

Operative budget: ≈1600 k€/yr

External building

Opened in June 2009

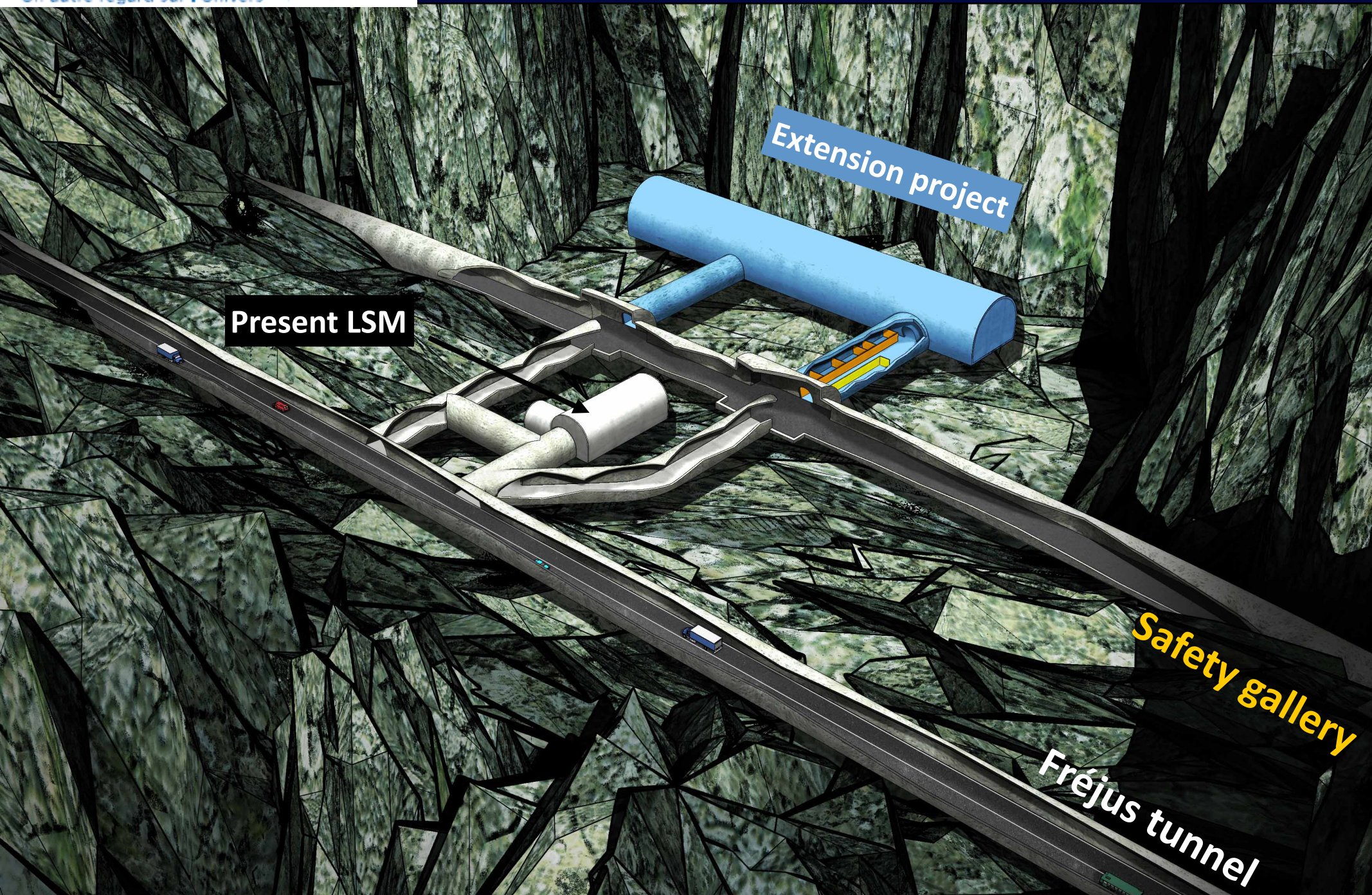
Permanent exhibition



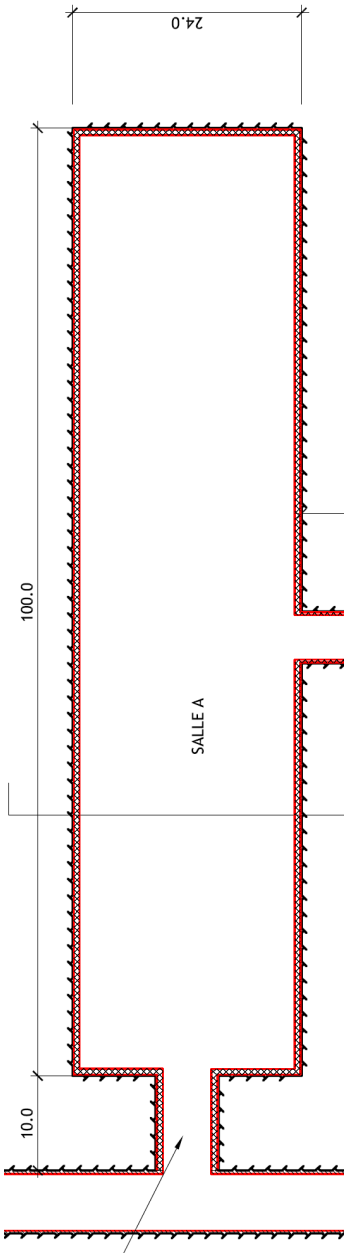
1 000 visitors in 1 year

LSM UL | SSE
Un autre regard sur l'Univers

LSM Extension project



ULISSE Project

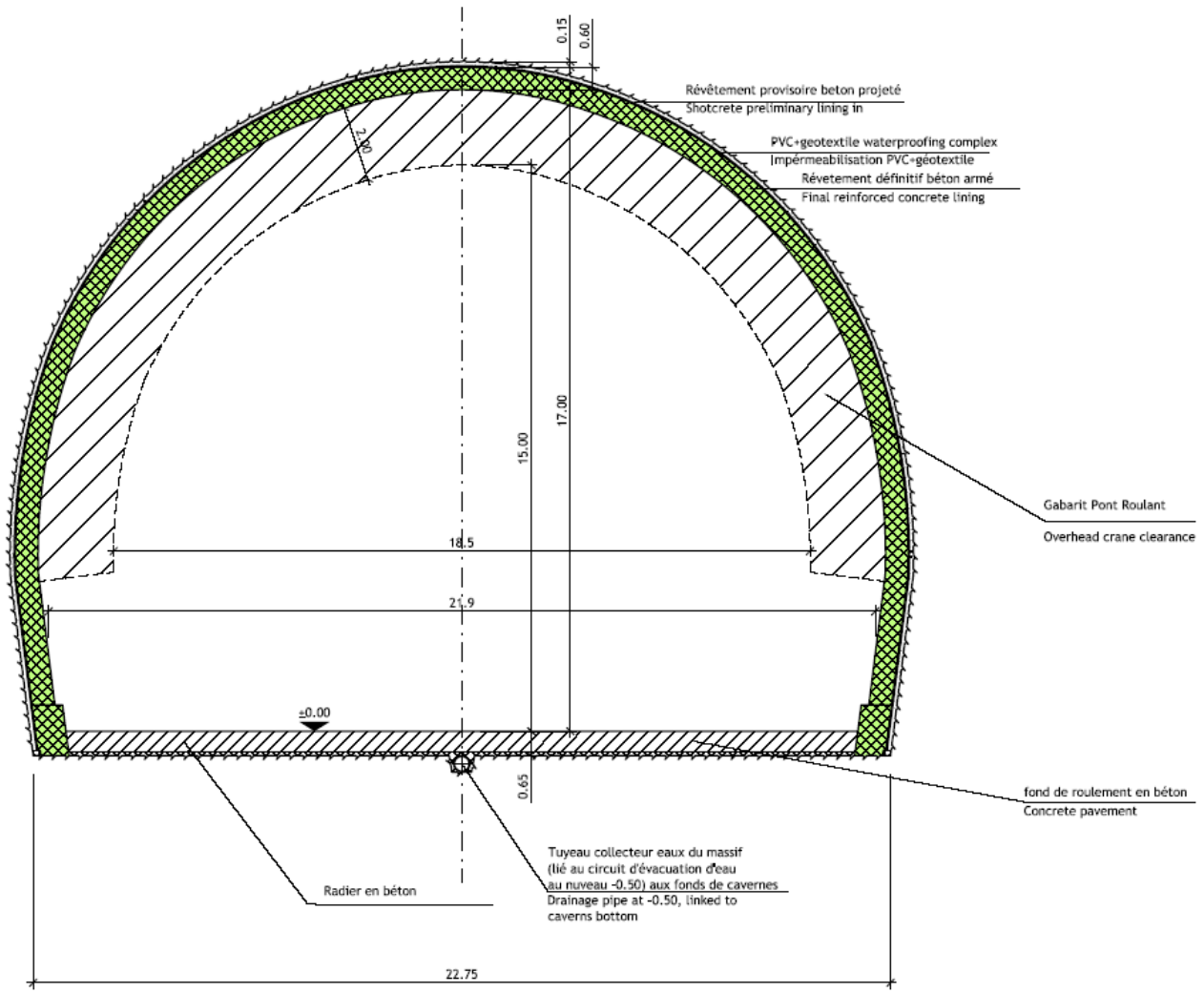


COUPE TYPE SALLE A

SECTION EXCAVEÉ 375 m²
SECTION UTILE 320 m²
1:100

CAVERN A CROSS SECTION

EXCAVATED AREA 375 m²
INTERNAL CLEARANCE 320 m²
1:100



ULISSE Project

Budget estimation:

Cavity (45 000 m^3) 12 M€

Equipments (cooling, electrical power, ventilation,…) 3 M€

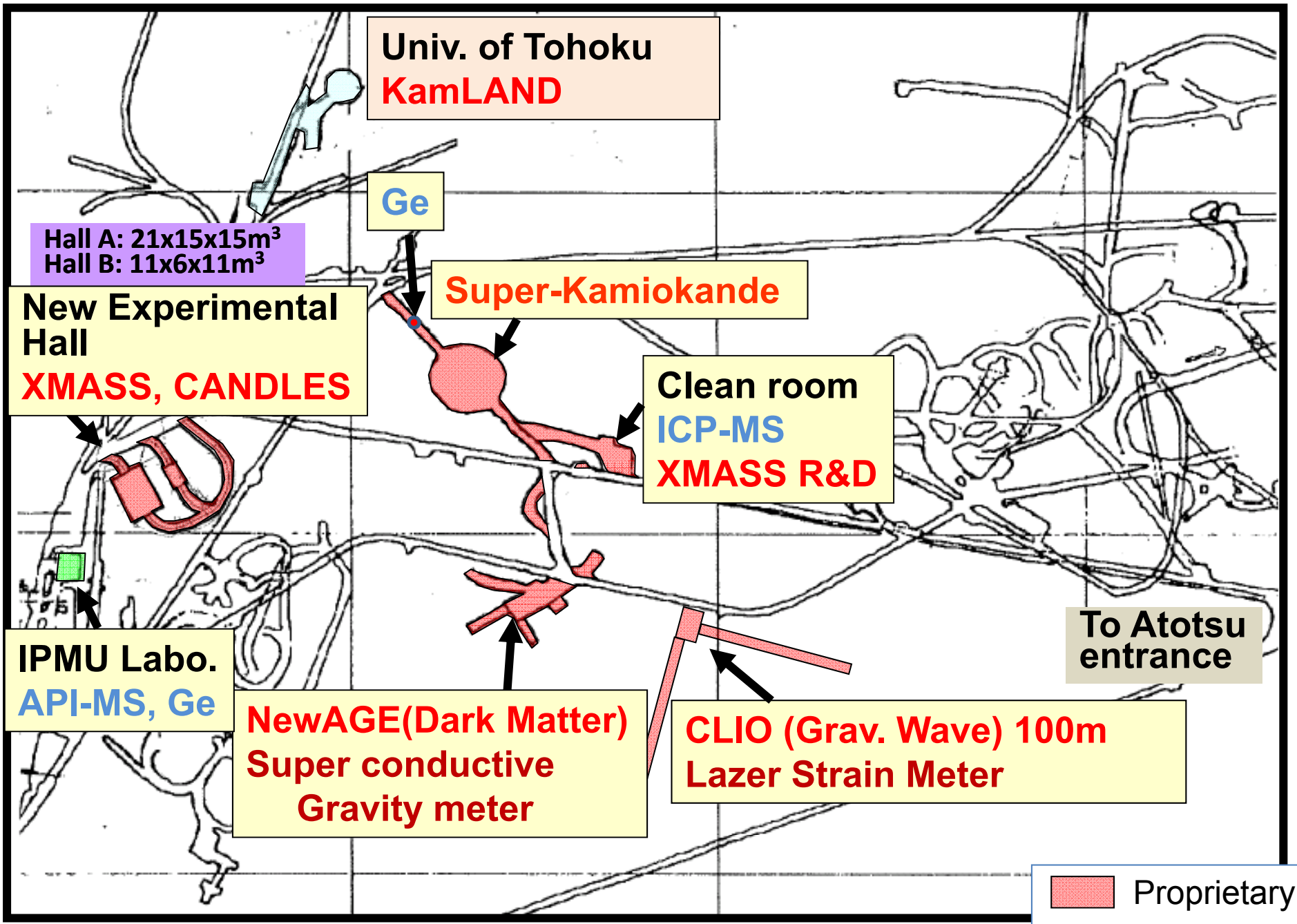
Schedule:

- Safety gallery work has started in September 2009
- TBM at the level of present lab end 2011 → digging of new lab beginning 2012
- 1 year to dig and equip new the laboratory

Decision for funding expected Autumn 2010

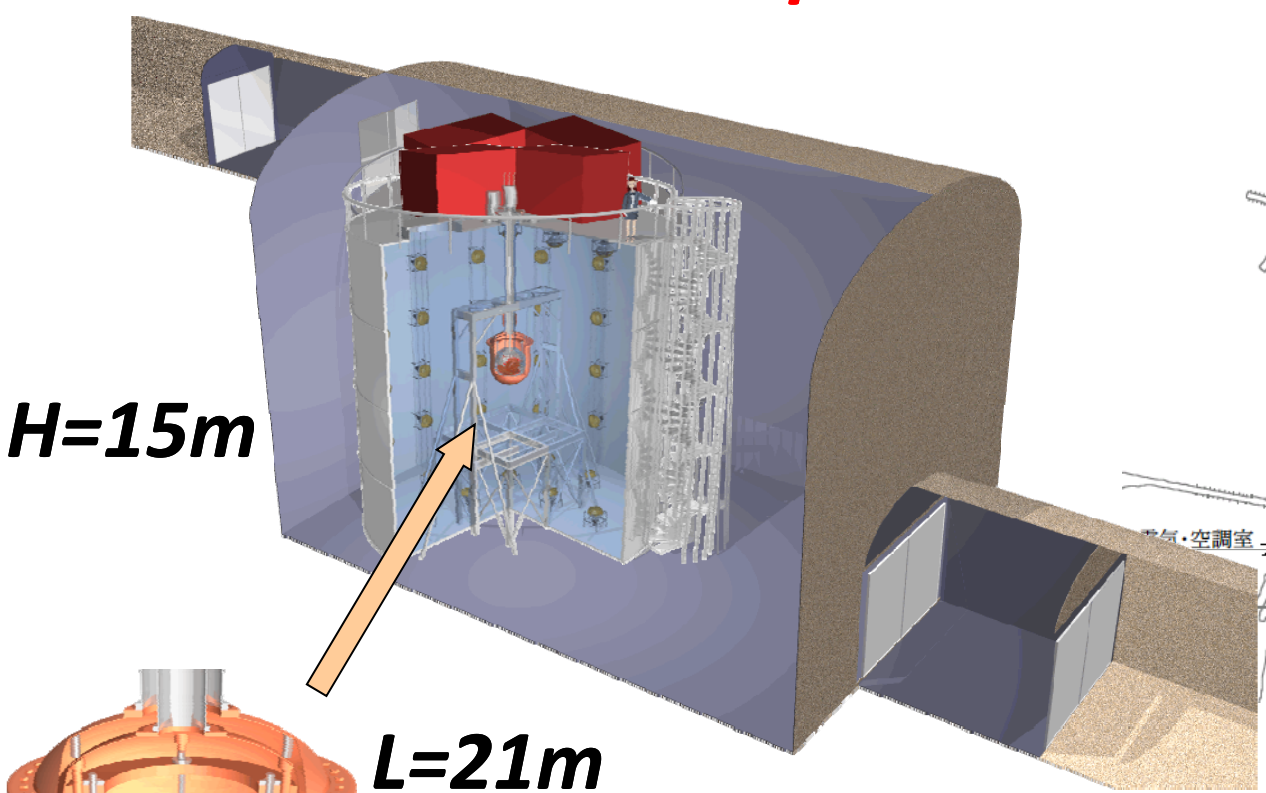
Asian Facilities

- Kamioke (Japan)
  - XMASS in construction
- Yangyang (Korea)
  - KIMS operational
- CJPL (China)
  - CDEX planned
- INO (India) planned


Univ. of Tohoku
KamLAND
Ge
Hall A: 21x15x15m3
Hall B: 11x6x11m3
Super-Kamiokande
New Experimental Hall
XMASS, CANDLES
Clean room
ICP-MS
XMASS R&D
IPMU Labo.
API-MS, Ge
To Atotsu entrance
NewAGE(Dark Matter)
Super conductive
Gravity meter
CLIO (Grav. Wave) 100m
Lazer Strain Meter
Proprietary area

New experimental Hall

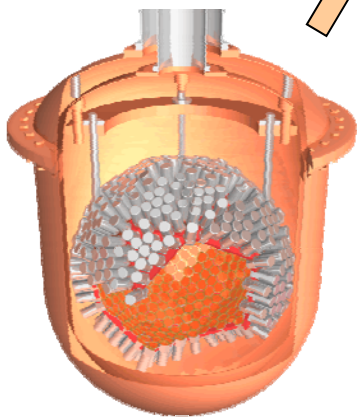
Completed in 2008

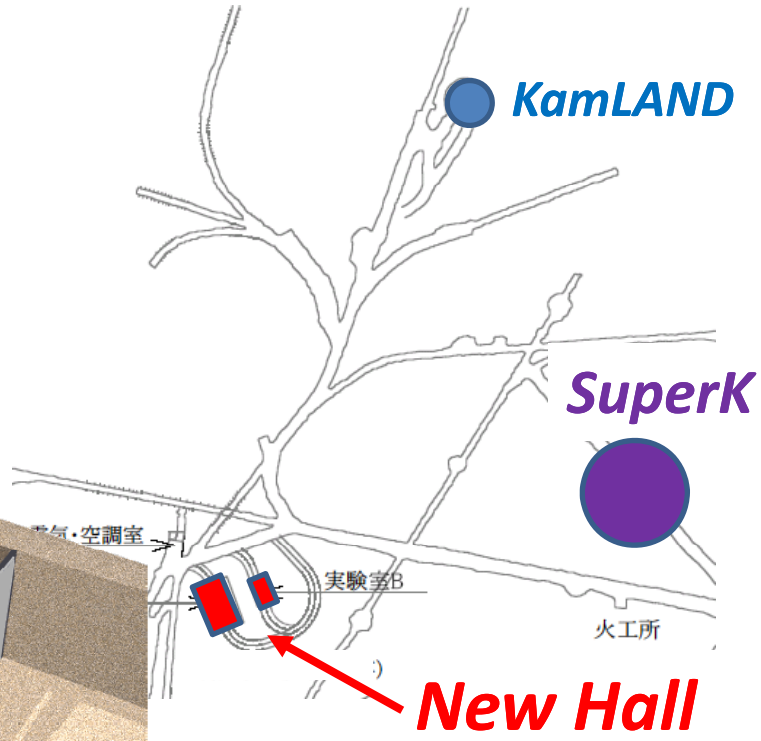


H=15m

L=21m

W=15m





Water tank is completed in 2009

Yangyang Underground Laboratory

Korea Middleland Power Co.

Yangyang Pumped Storage Power Plant

(Upper Dam)

Construction of Lab. buildings done in 2003

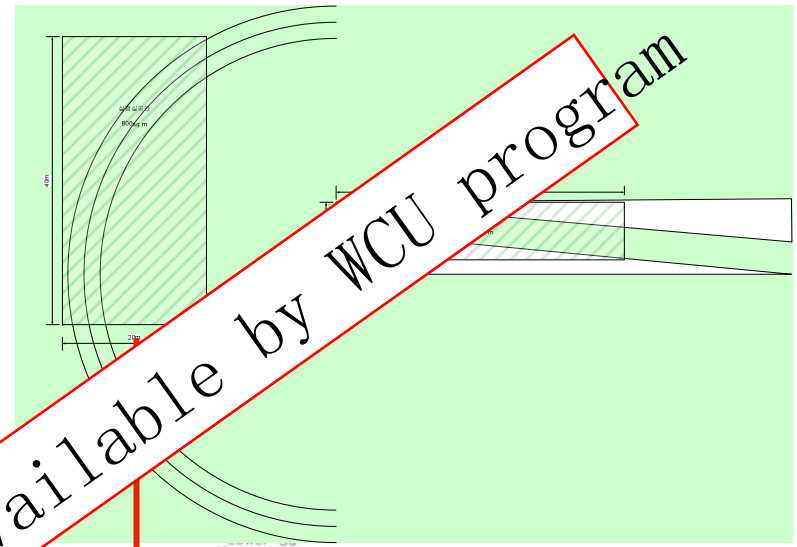
(Power Plant)

(Lower Dam)

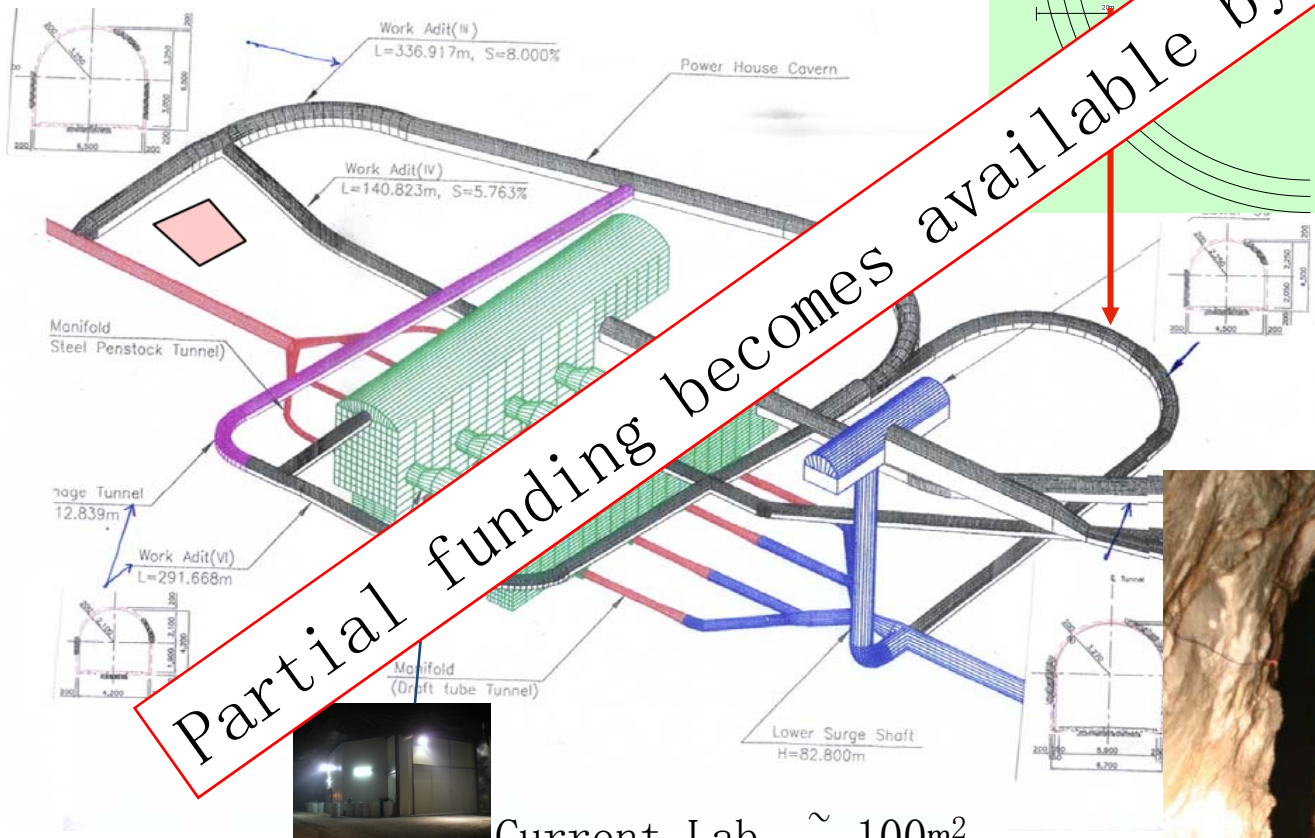
양양양수발전소

Minimum depth : 700 m / Access to the lab by car (~2km)

New Space in Underground Lab. expected.

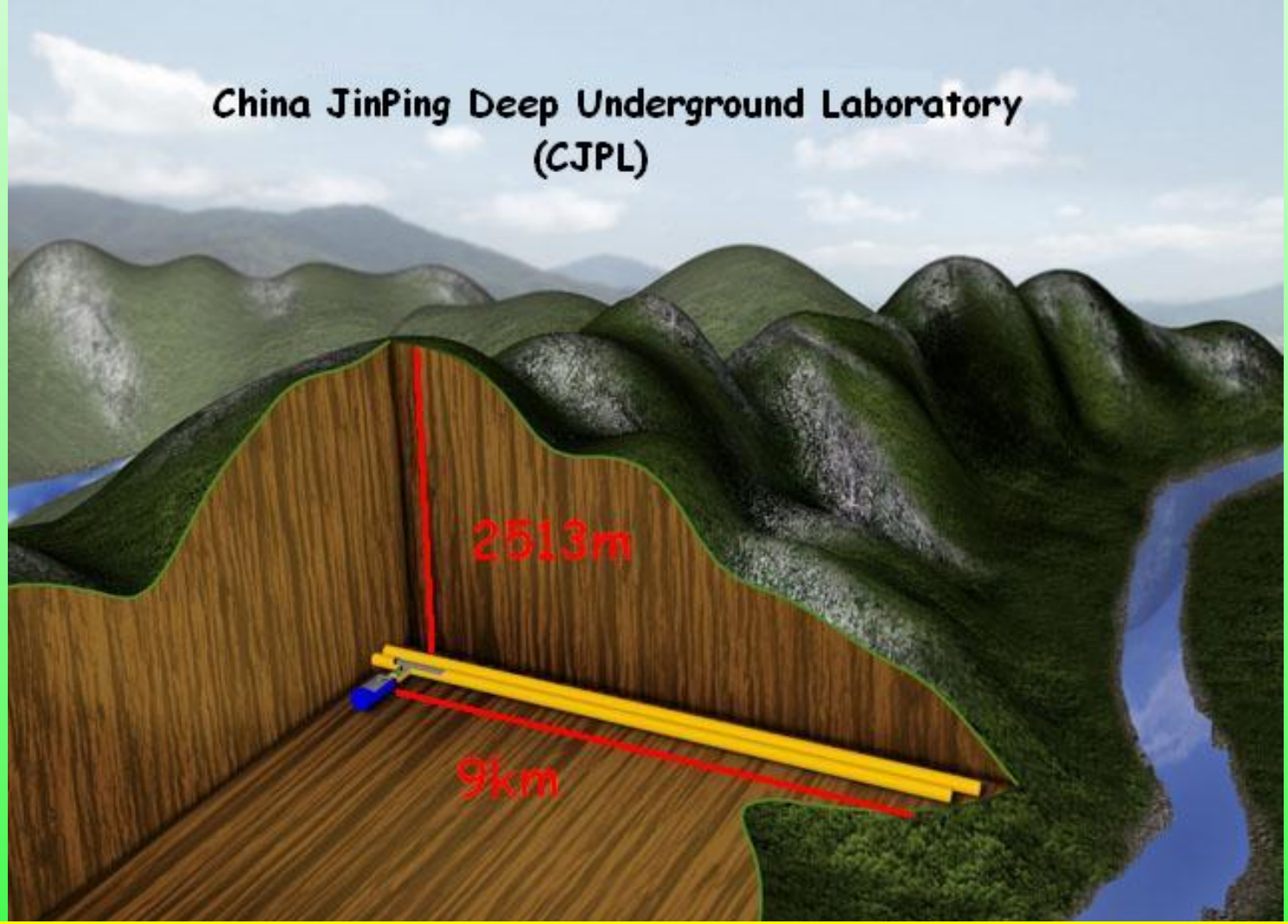


Partial funding becomes available by WCU program

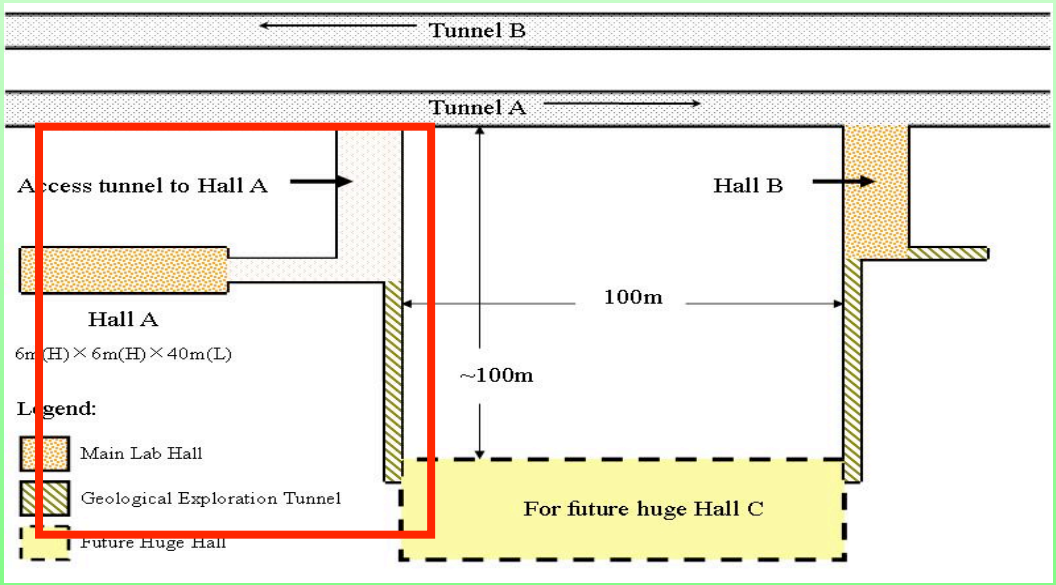


New Lab. space
40 m x 20 m = 800 m^2

Current Lab. ~ 100m^2

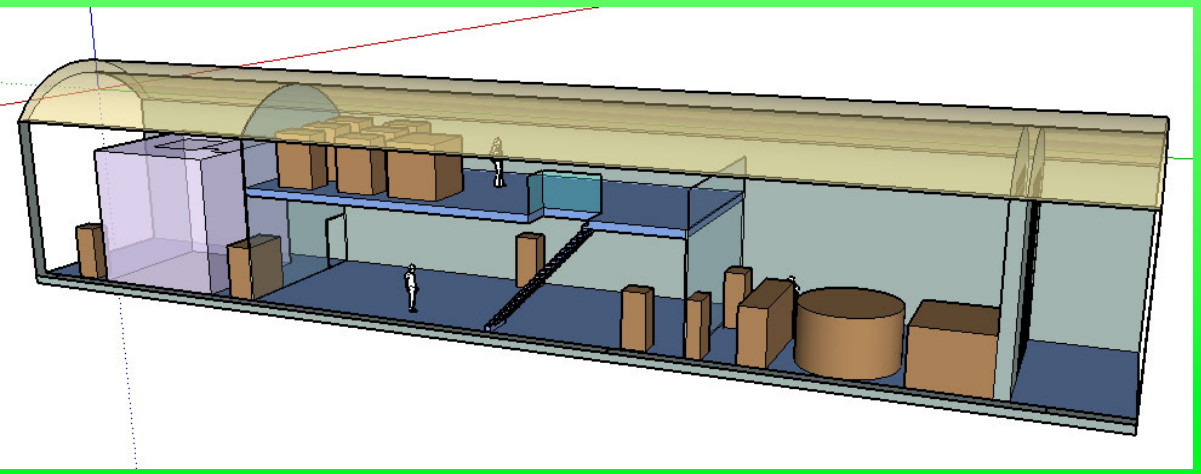


- Jinping Mountain Peak：4193m
- Maximum rock overburden: ~2500m
- Length of Jinping transportation tunnel: 17.5km
- Rock cover larger than 1500m:>70%



Layout of CJPL and
its Phase-I space (red square)

2009, Hall-A cavity OK!



6.5m*6.5m*40m main hall A

- The construction of infrastructure of CJPL Phase-1 will be finished in April,2010.
- The Low background measurement facility will be established in Sept. 2010.

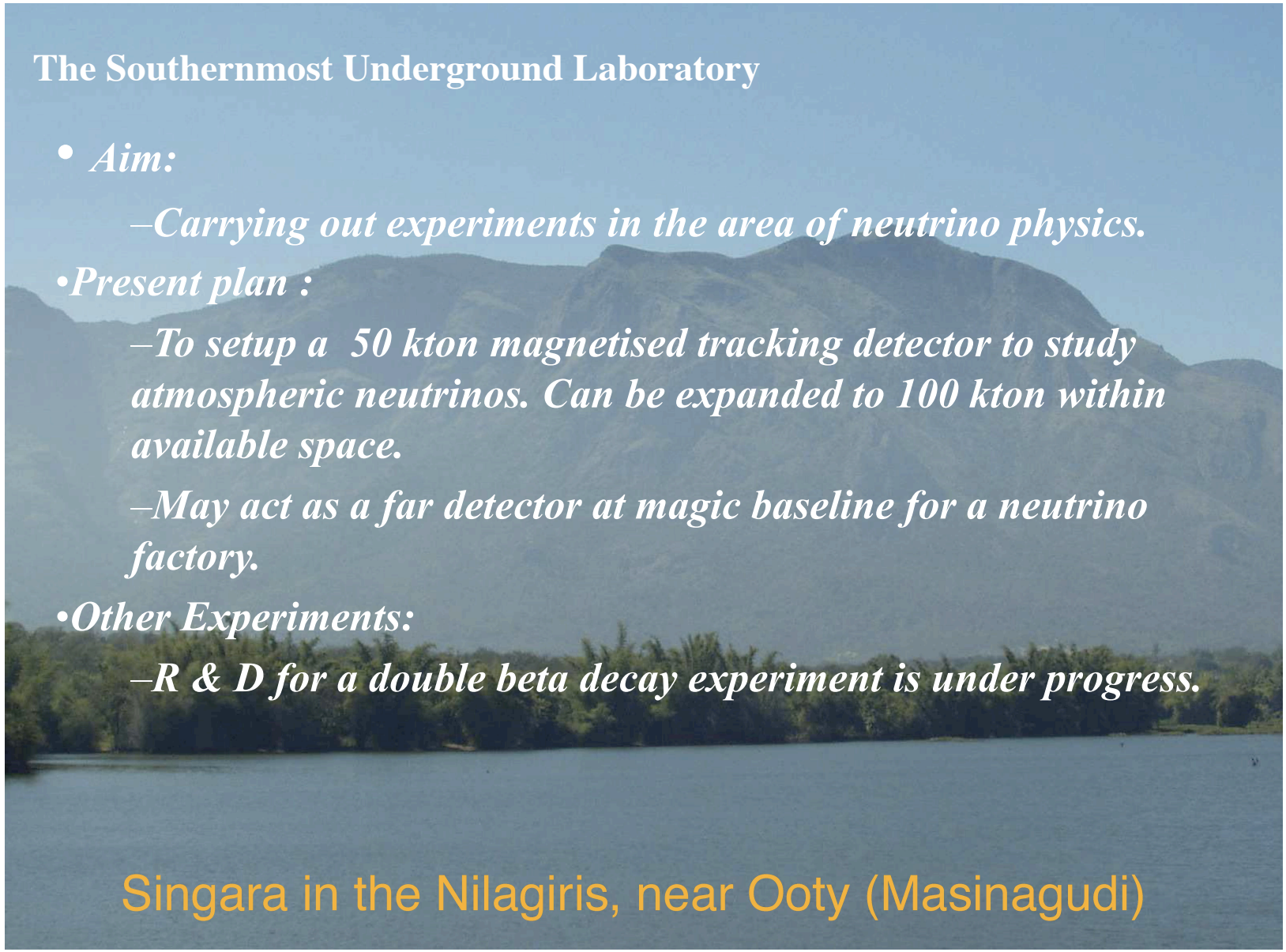
Main hall is ready!

Electronics Layer and Crane

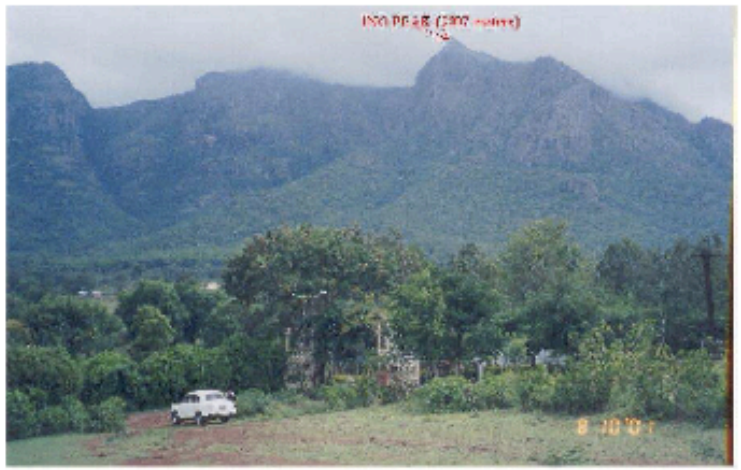
Painting Radon-proof Layer

Tunnnel to main hall

The India Based Neutrino Observatory (INO)



Location of INO site



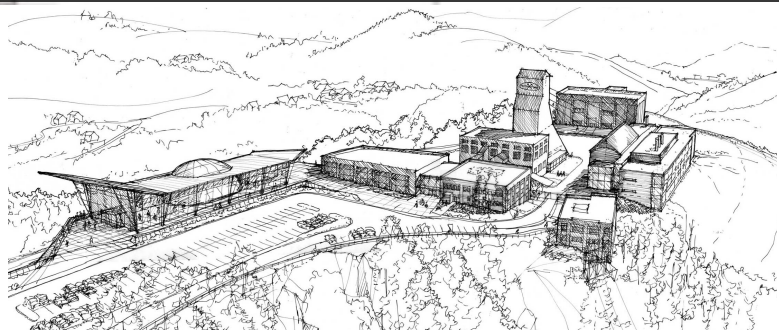
PUSHEP : 11.5°N 76.6°E, 6.5 km from Masinagudi, 96.5 km from Mysore, 5 hrs from Bangalore, Coimbatore, Calicut

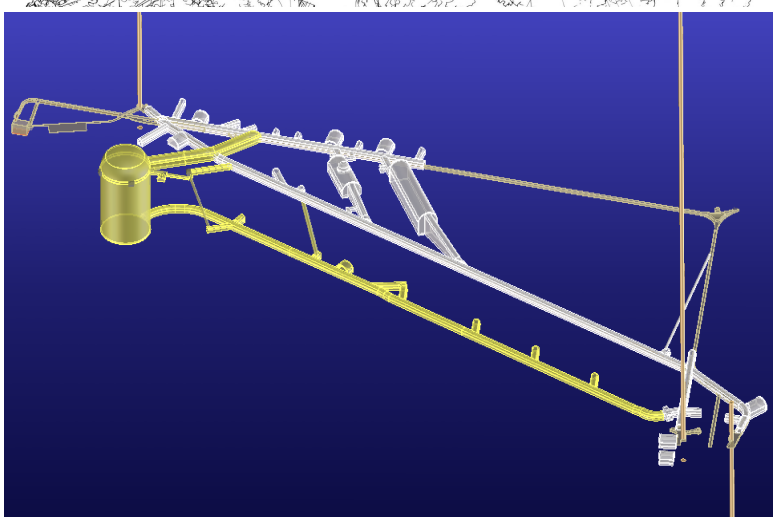
North American Facilities

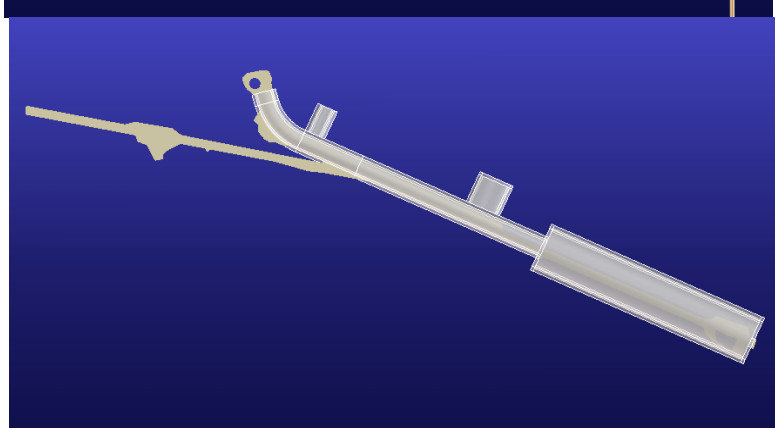
- *Soudan*
  - *MINOS operational*
- *WIPP*
  - *EXO-200 in construction*
- SUSEL/DUSEL
  - Majorana in construction
  - Large future DUSEL neutrino programme planned
- SNOLAB
  - SNO+ in construction
  - HALO in construction
  - EXO R&D *operational*

DUSEL Facility Design Advancing Following Interactions with Agencies and Collaborations

- **World-Class Facility**
  - Research Campuses
    - Surface
    - 4850 (~4200 mwe)
    - 7400 (~7100 mwe)
    - Other Levels and Ramps
  - Dual Access to Research Campuses
  - Best-practices Life Safety Systems and Programs
  - Experimental Support Groups
  - Design Enabling Future Expansion
  - Project Enabling Participation by Other Agencies
- **Suite of Transformational Experiments**
  - Diverse and Compelling Suite
  - Integral Education and Outreach Efforts







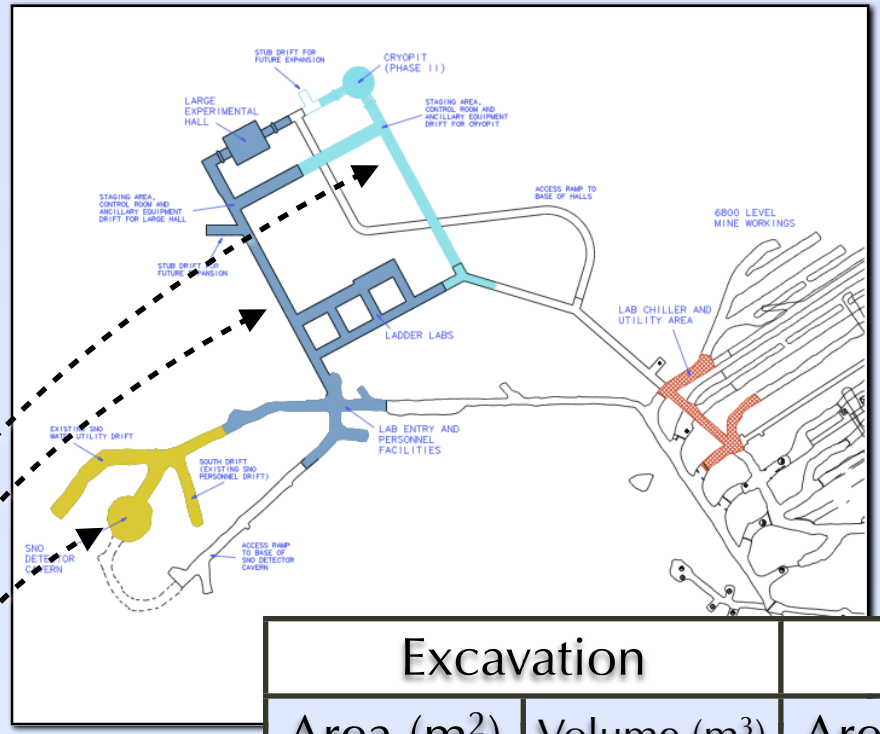
NSF and DOE Cooperation In Creating DUSEL and its Scientific Program

- Initial NSF Guidance - $750M to include:
  - DUSEL Facility (our goal is for FY13 construction start)
  - Diverse and Compelling Suite of Experiments
    - Dark Matter Searches
    - Long Baseline Neutrinos
    - Proton Decay
    - Neutrinoless Double Beta Decay
    - Additional Physics Experiments such as:
      - Nuclear Astrophysics
      - Solar Neutrinos
    - Biology, Geology, Engineering Experiments including topics such as:
      - Geomicrobiology
      - Fault Rupture and geophysics
      - Coupled Processes
- DOE Established CD0 for Long Baseline Neutrinos Experiment January 2010
  - Range established $660 - $940M
  - Joint oversight group (JOG) meeting regularly (DOE OHEP ,DOE ONP, NSF PHY)
- We anticipate maintaining Sanford Lab science program through DUSEL construction
  - LUX dark matter and Majorana Demonstrator neutrinoless double beta decay

SNOLAB Overall Status

- Surface Facility
  - Operational from 2005.
  - Provides offices, conference room, dry, warehousing, IT servers, clean-room labs, detector construction labs, chemical + assay lab
- Underground Construction (Cube Hall, Cryopit, Ladder Labs, Lab Entrance)
  - Excavation complete and outfitting began June 2007.
  - All main infrastructure (Chiller, MPC, HVAC, waste water plant) commissioned
  - General outfitting in Phase I areas almost complete + Cryopit 5T crane/access.
  - Ladder Labs final cleaning complete, first experiment going in
  - First experimental infrastructure installation in Cube Hall, fully clean
- Experimental Programme
  - Continued operation of DEAP-1 and PICASSO.
  - Current allocations to: PICASSO-III, DEAP-I, SNO+, DEAP-3600, MiniCLEAN, SuperCDMS TF, SuperCDMS, COUPP, HALO.
  - Anticipated and under discussion: EXO-gas, DarkSide, low background counters to measure 39Ar, future Cobra upgrade…

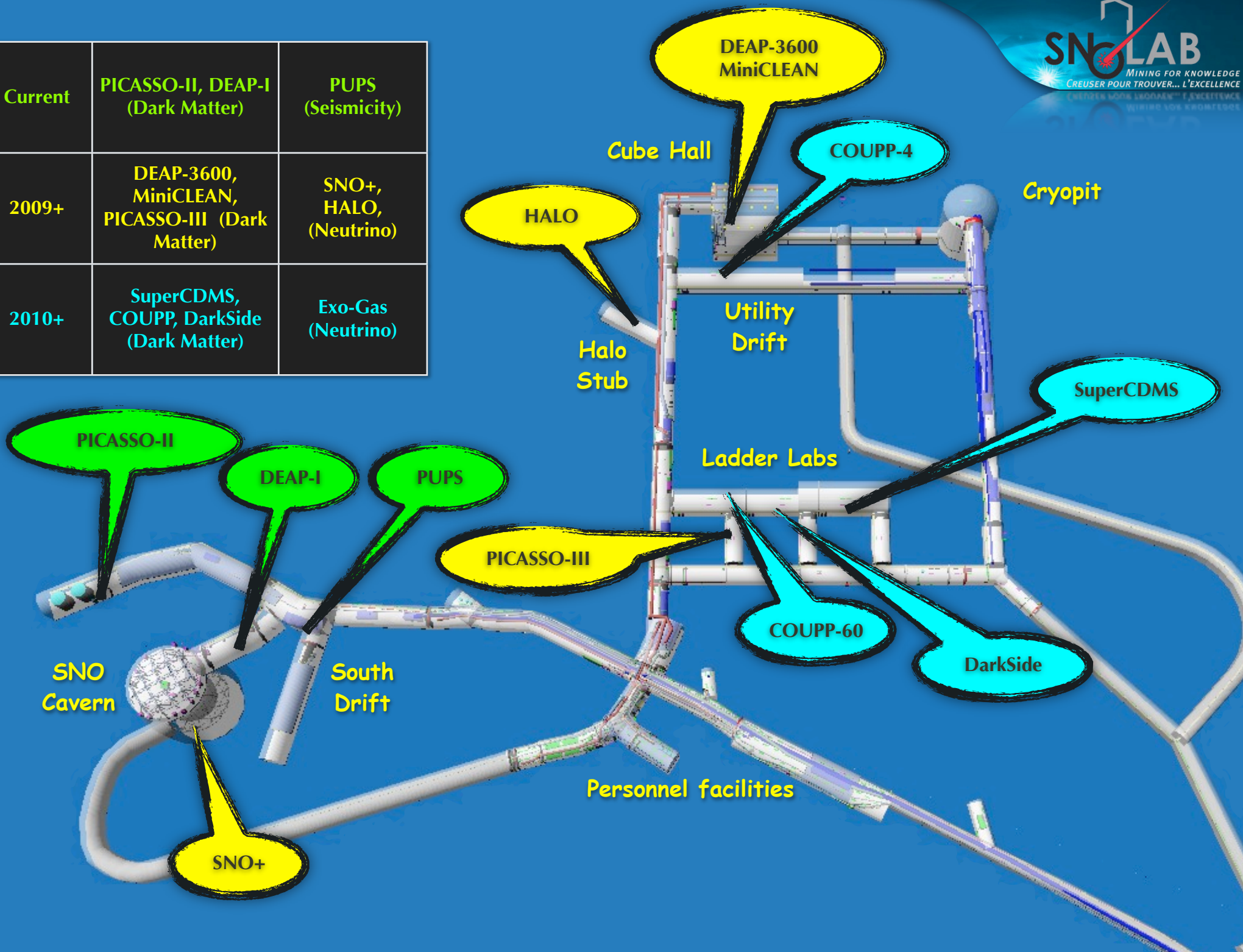
Laboratory Space



All clean spaces will be operated as Class2000 clean rooms (or better).

	Excavation		Clean Room		Laboratory	
	Area (m^2)	Volume (m^3)	Area (m^2)	Volume (m^3)	Area (m^2)	Volume (m^3)
Original SNO Areas	1860	16500	1130	13300	750	11700
Phase I	6070	38750	3900	29750	2430	23700
Phase II	7220	46650	4940	37250	3060	29550

Current	PICASSO-II, DEAP-I (Dark Matter)	PUPS (Seismicity)
2009+	DEAP-3600, MiniCLEAN, PICASSO-III (Dark Matter)	SNO+, HALO, (Neutrino)
2010+	SuperCDMS, COUPP, DarkSide (Dark Matter)	Exo-Gas (Neutrino)



Facility developments

- Several expansions of deep underground facilities completed, in construction or well progressed in planning

Site	Size	Status	Available
Kamioka	+ $5.5 \times 10^3 m^3$	Complete	2008
SNOLAB	$3 \times 10^4 m^3$	Complete	2009
LSC	$8 \times 10^3 m^3$	In Construction	2010
SUSEL	$>3 \times 10^4 m^3$	In Construction	2010
CJPL	$1.7 \times 10^3 m^3$	In Construction	2011
Yangyang	$1.6 \times 10^4 m^3$	In Construction	2011+
LSM	$4 \times 10^4 m^3$	Planned	2013
DUSEL	$>10^5 m^3$	Planned	2015

Outlook

- Deep underground sites provide the required infrastructure for low background DM/0νββ and low energy neutrino programmes
- These physics programmes provide rich fields of study over the next decades
  - Complementary to other search/study techniques
  - Breadth of scale in detectors and infrastructures provides a wide portfolio of projects for physics and training
- Expansion of several deep underground facilities world-wide is completed, underway or well advanced in planning
  - Providing significant additional space world-wide in near to long term
- Exciting discoveries lay ahead!