World Underground Labs: Status and Plans

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ICFA Seminar
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Acknowledgements

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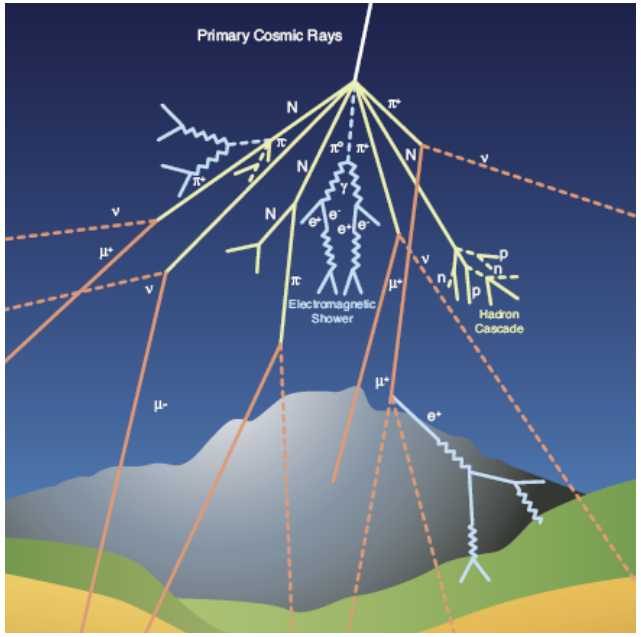
- citations for material used and consulted
  - A. Bettini, B. Cabrera, J. Kotcher, J. Peltoniemi

Apologies

- have time to talk only about larger labs that have undergone recent changes and/or have larger-scale plans

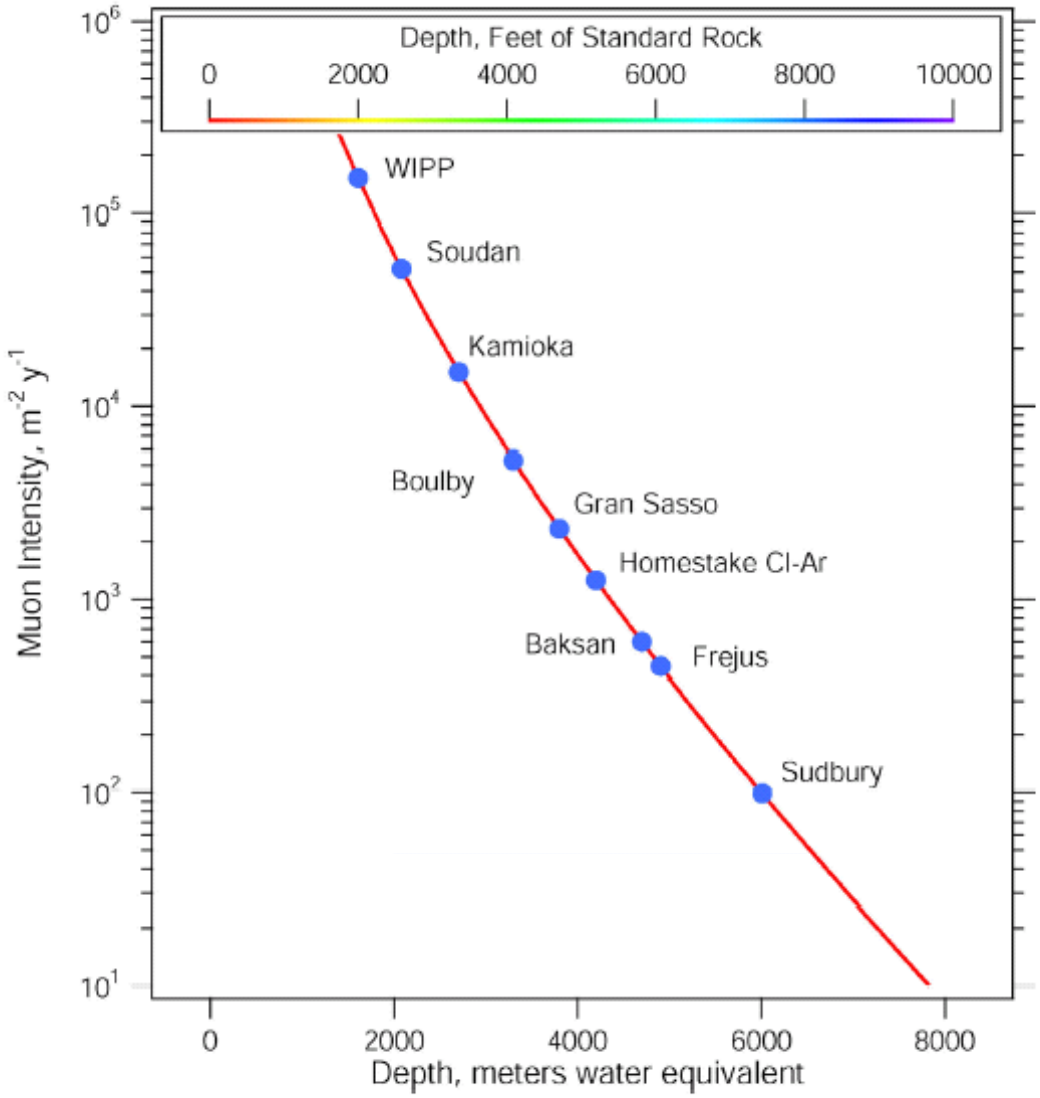
Physics and Astrophysics Underground

- searching for rare processes
  - neutrinoless double beta decay
  - proton decay
- detecting very weakly-interacting particles
  - neutrinos
  - dark matter particles (e.g. WIMP)
- requires ultra-low backgrounds
  - underground (cosmic rays)
  - shielding (neutrons and gamma rays)
  - low radioactivity detector materials



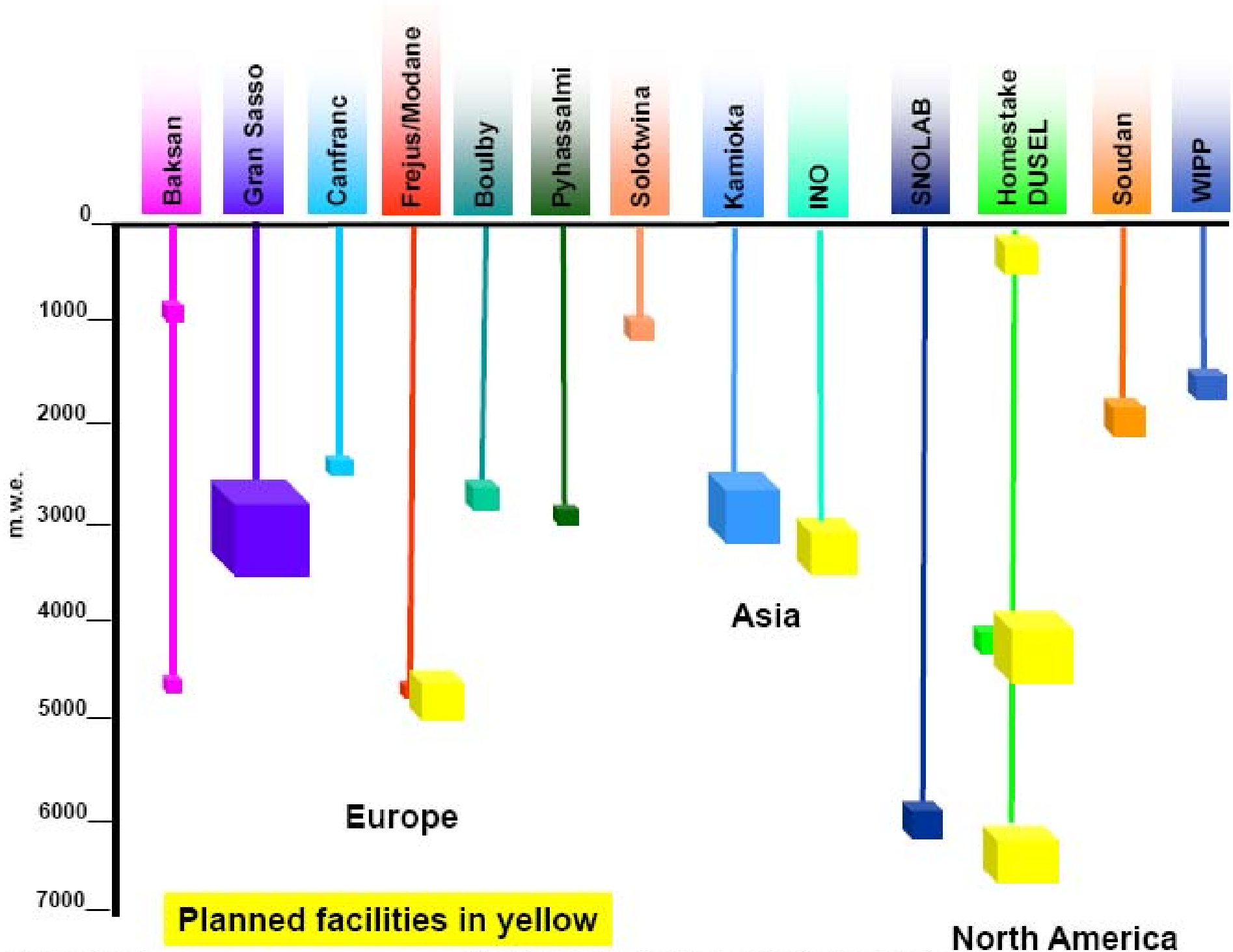
Muon Background versus Depth

- muons produce neutrons and radioactive isotopes in spallation, showering and capture reactions
- these are important backgrounds in most experiments; they are reduced with depth underground



Physics in Underground Labs

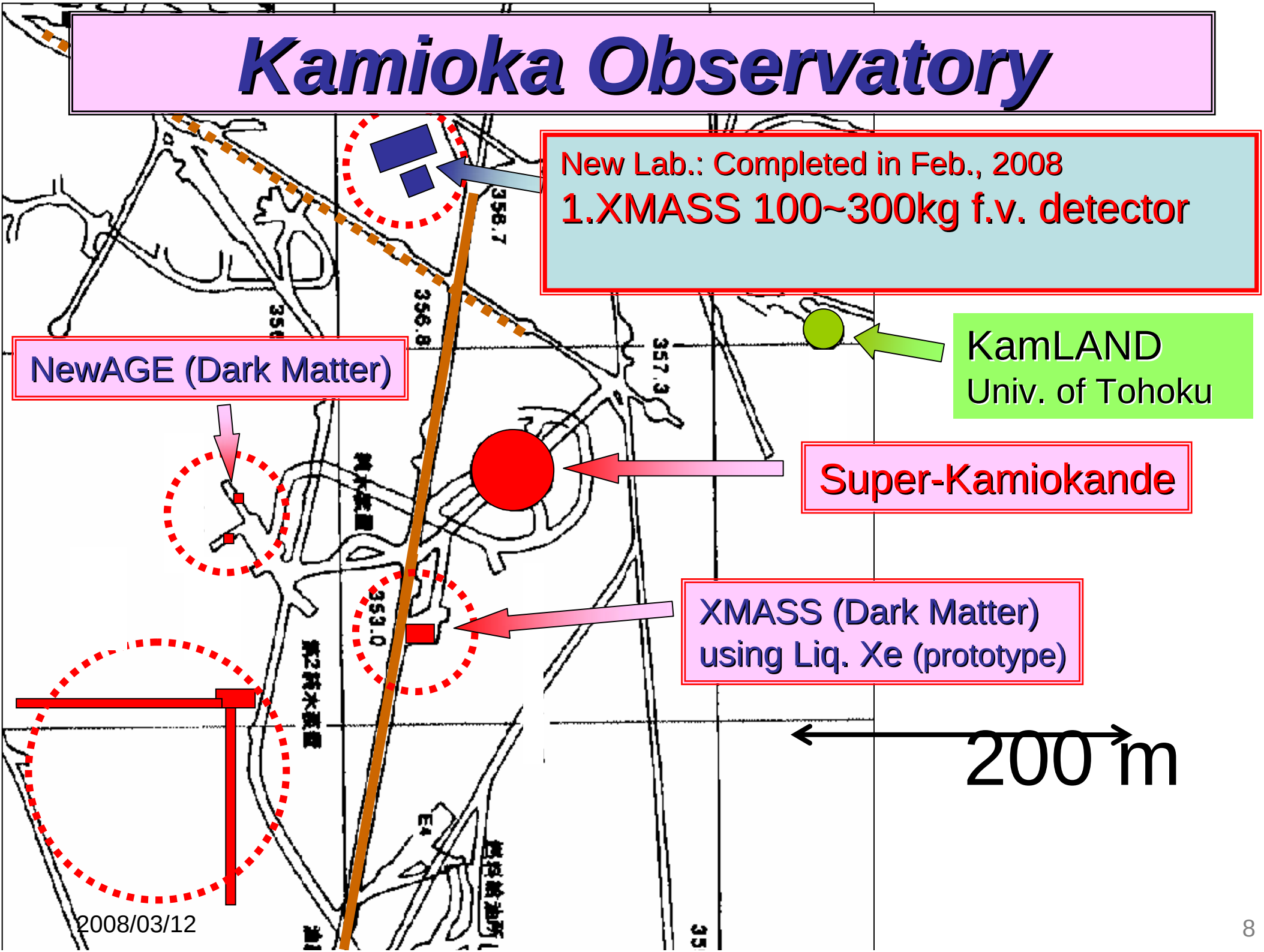
- neutrino physics (to study neutrino properties and the nature of the neutrino sources)
  - solar neutrinos
  - atmospheric neutrinos
  - reactor neutrinos
  - geo neutrinos
  - supernova neutrinos
- double beta decay
- proton decay
- dark matter
- nuclear astrophysics
- detectors for long-baseline neutrino beams
- gravitational waves
- cosmic rays


Baksan
Gran Sasso
Canfranc
Frejus/Modane
Boulby
Pyhassalmi
Solotwina
Kamioka
INO
SNOLAB
Homestake DUSEL
Soudan
WIPP
0
1000
2000
3000
4000
5000
6000
7000
m.w.e.
Europe
Asia
North America
Planned facilities in yellow

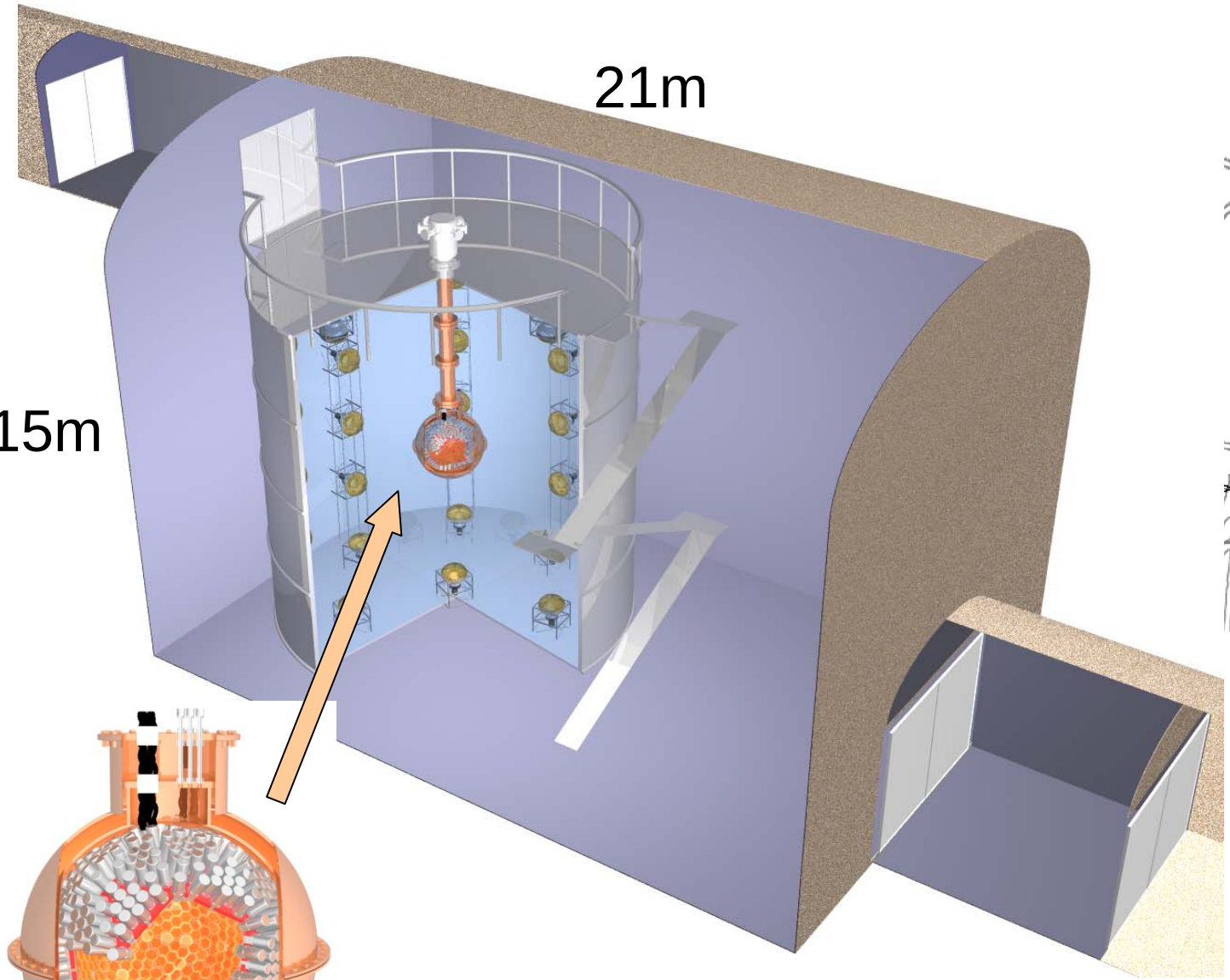
Underground Labs: Asia

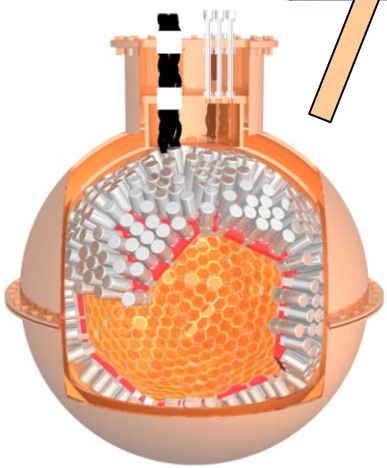
- Kamioka [Japan] beam
- Y2L [Korea] small 100 m^2
- INO [India] approved wants beam
- sites in China being explored

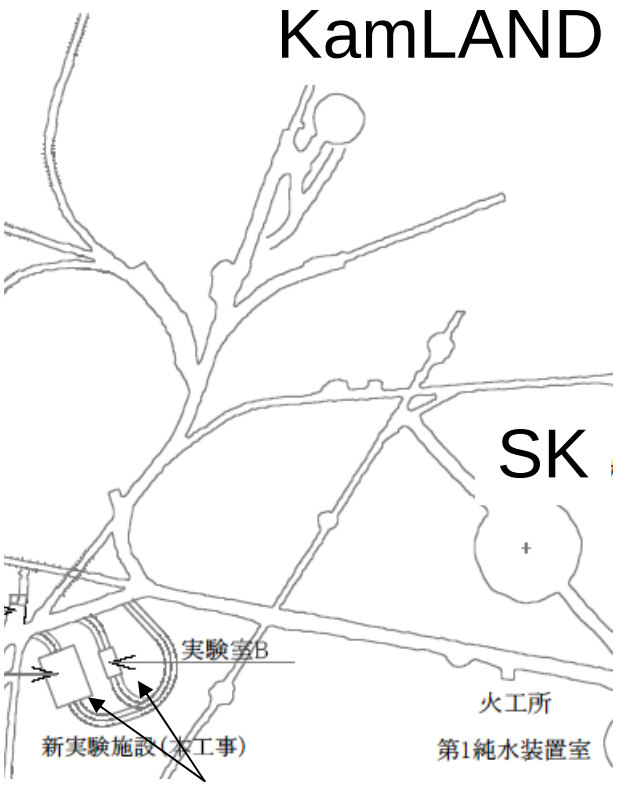
Kamioka Observatory



XMASS experimental hall

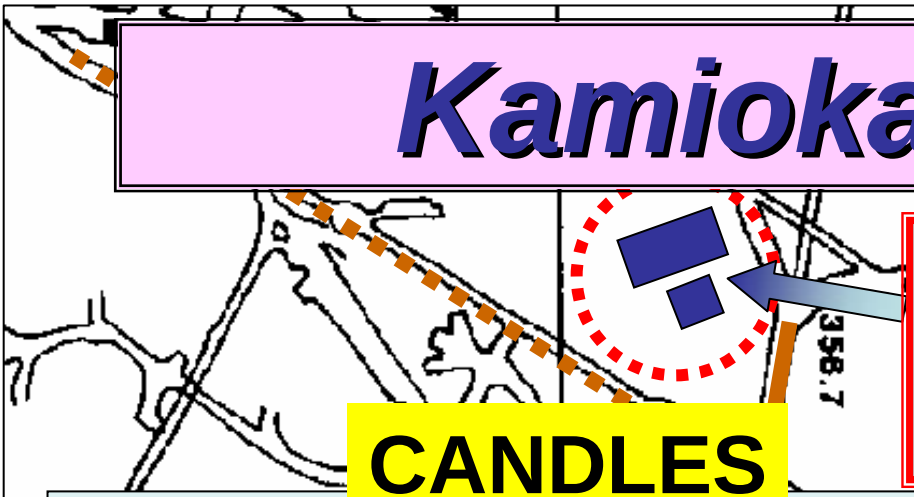






Cavity is completed last month.

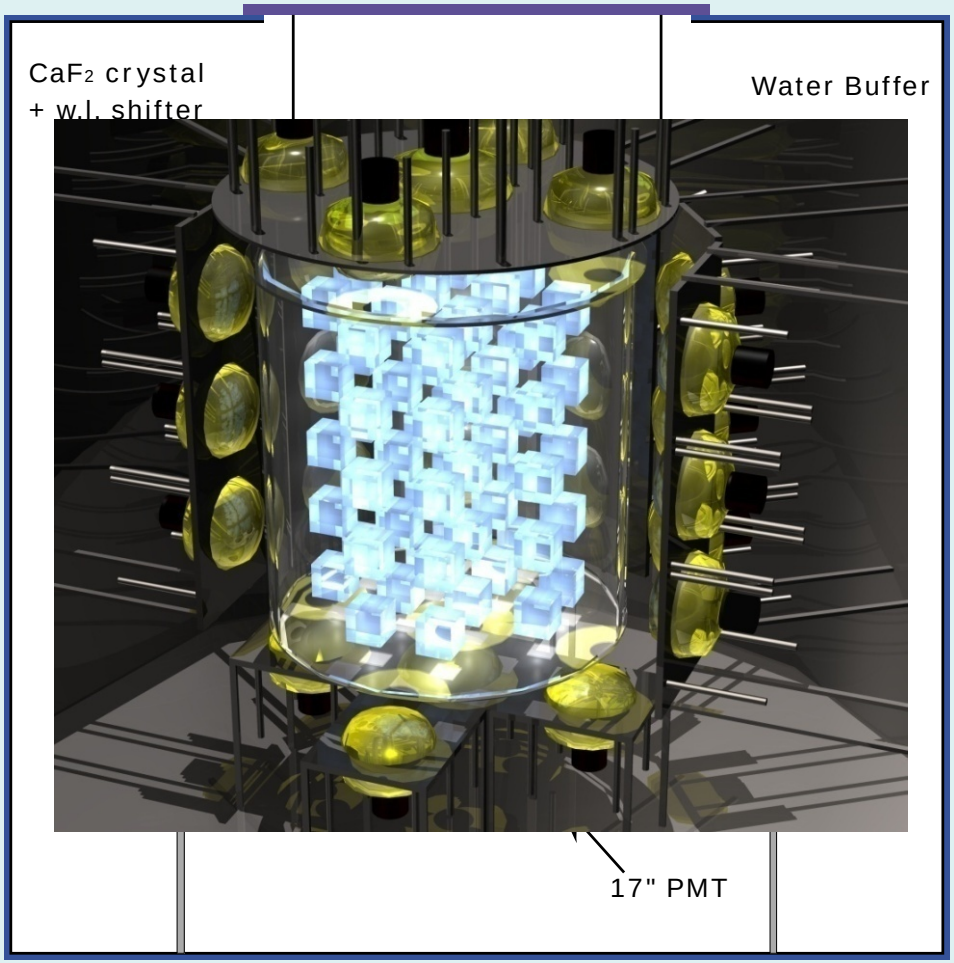
Kamioka Observatory



New Lab.: Completed in Feb., 2008

1. XMASS 100~300kg f.v. detector
2. $0\nu\beta\beta$ detector (^{48}Ca) (Osaka U.)

CANDLES



- undoped **CaF_2** (CaF_2(pure))
  - **^{48}Ca (0.187%) Q=4.27 MeV**
  - 305 kg (III-chika) 10^3cmx96

    ⇩

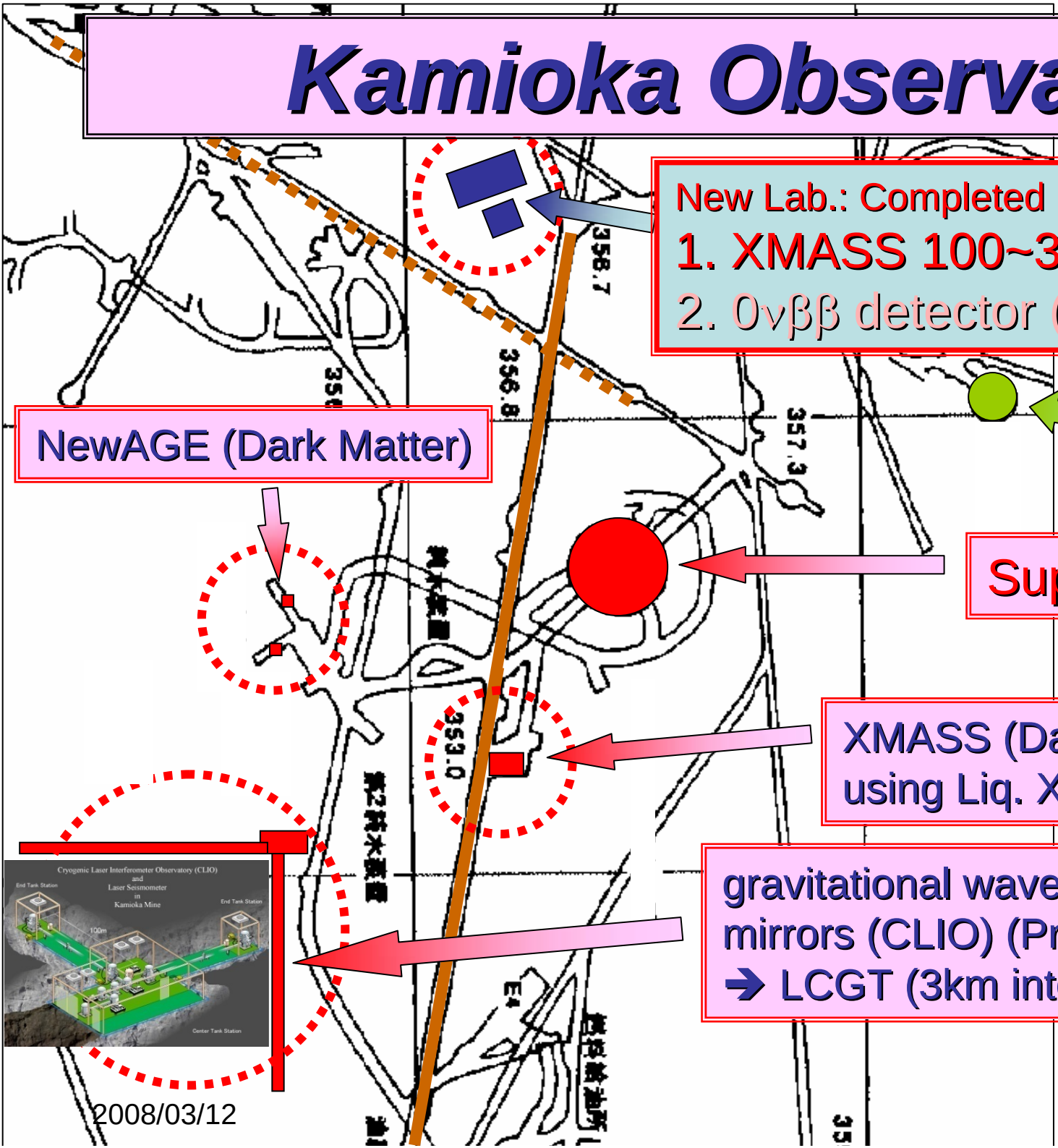
    3.4 t (IV) ~0.1 eV

    ⇩

    30 t, 2% enriched (V)

    ~30 meV (best NME)
- Liquid Scintillator (LS)
  - 4π active shield
- Photomultiplier
  - large photo-coverage
- Water buffer→Passive shield

Kamioka Observatory



New Lab.: Completed in Feb., 2008

1. XMASS 100~300kg f.v. detector
2. $0\nu\beta\beta$ detector (^{48}Ca) (prototype)

KamLAND
Univ. of Tohoku

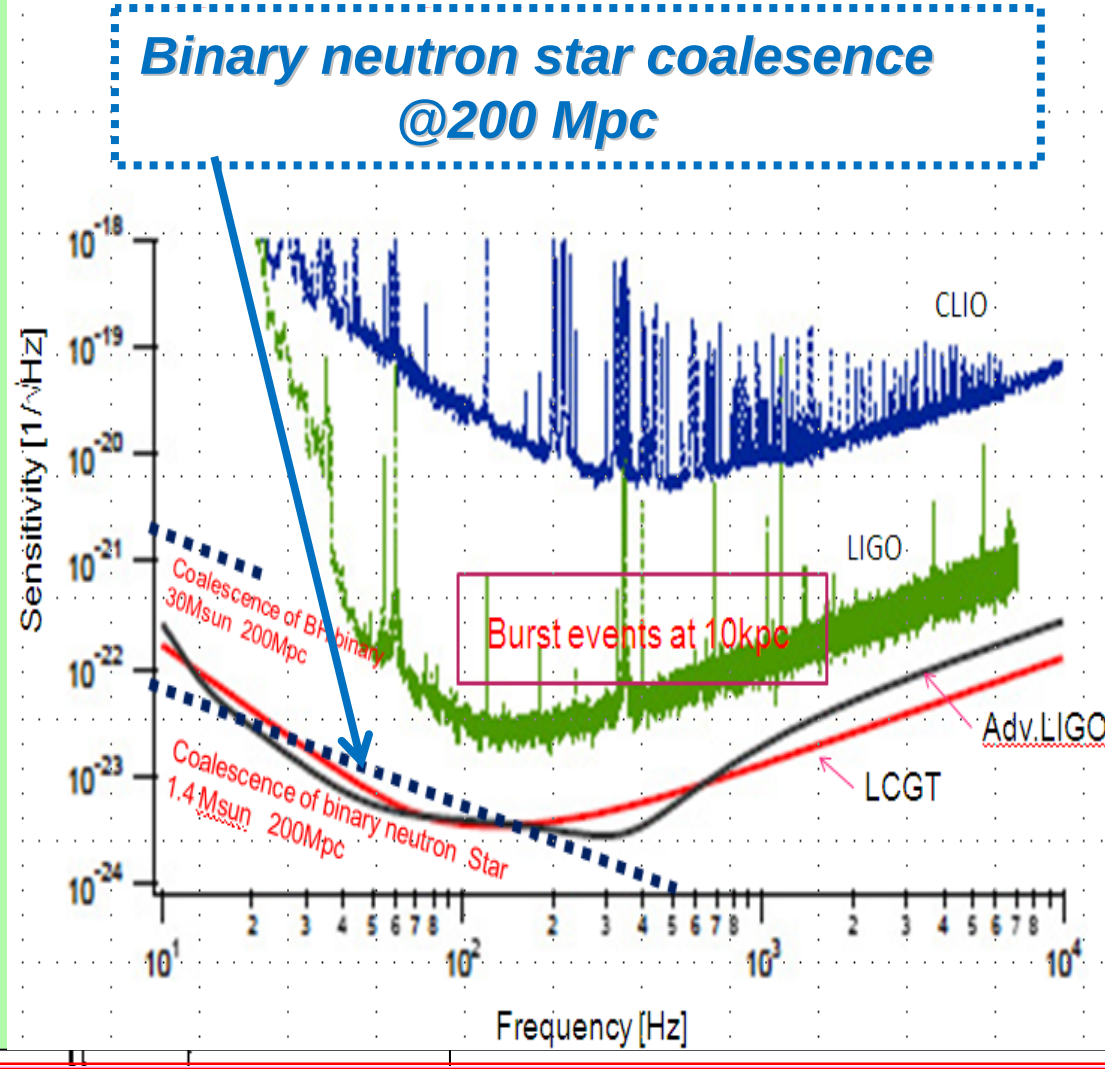
NewAGE (Dark Matter)

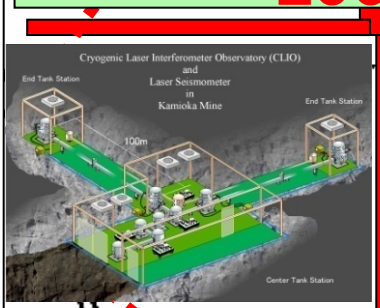
Super-Kamiokande

XMASS (Dark Matter)
using Liq. Xe (prototype)

gravitational wave antenna w/ cryogenic mirrors (CLIO) (Prototype)
➔ LCGT (3km interferomer) ~ Adv. LIGO

- **Large Cryogenic Gravitational Wave Telescope (LCGT)**
  - **Baseline ~ 3km**
  - **150W laser**
  - **Underground**
    - **➔ Small Seismic Noise**
  - **Cryogenic mirror**
    - **➔ 30kg Sapphire mirrors**
    - **➔ Reduce thermal Noise**
  - **Budget request**
  - **Prototype CLIO**
    - **100m interferometer**

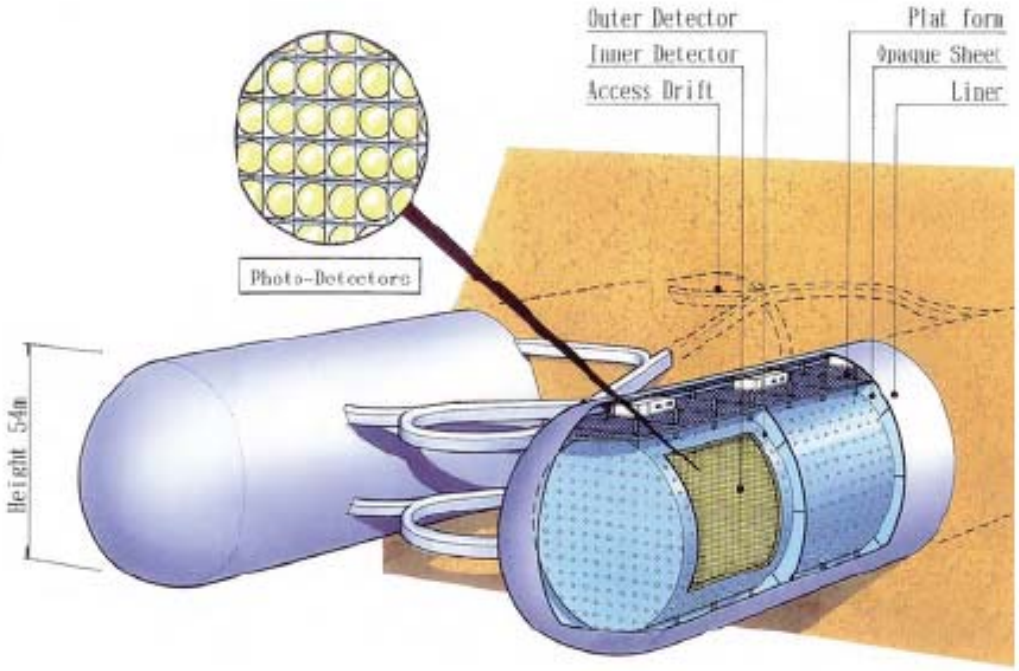


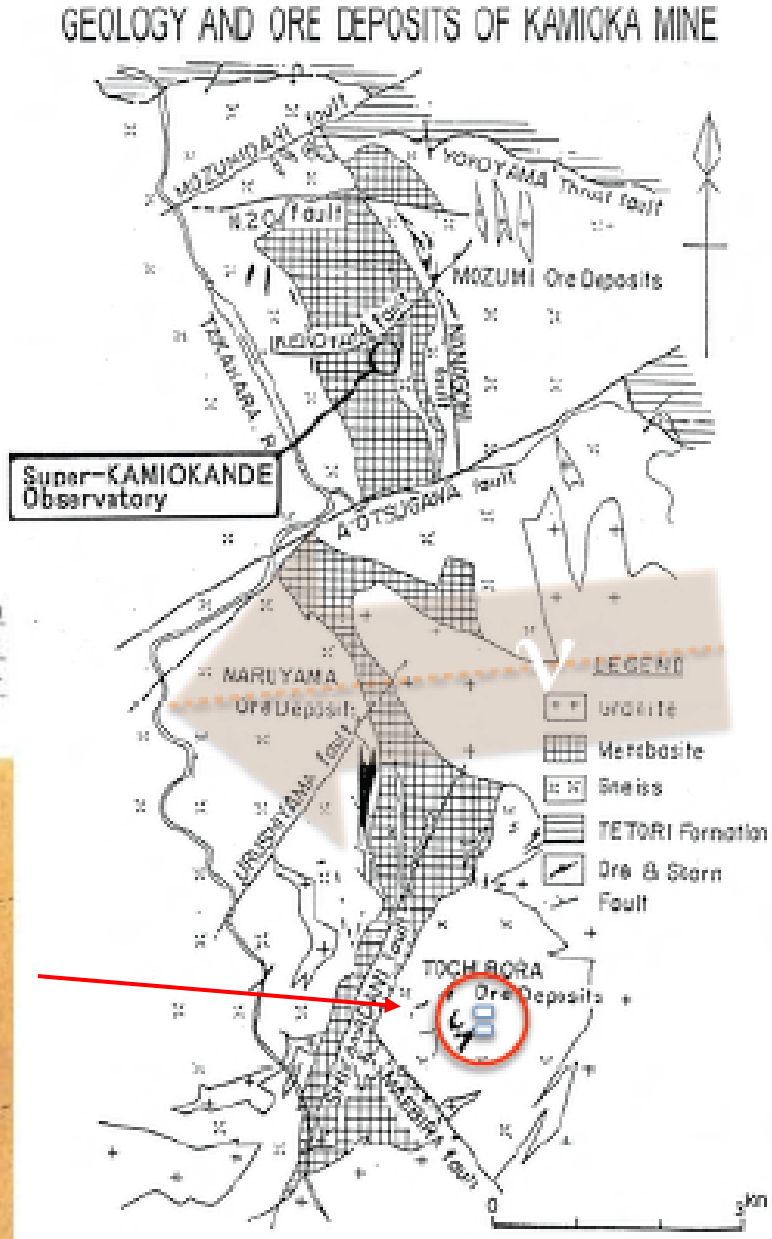


gravitational wave antenna w/ cryogenic mirrors (CLIO) (Prototype)
➔ LCGT (3km interferomer) ~ Adv. LIGO

Hyper-Kamiokande

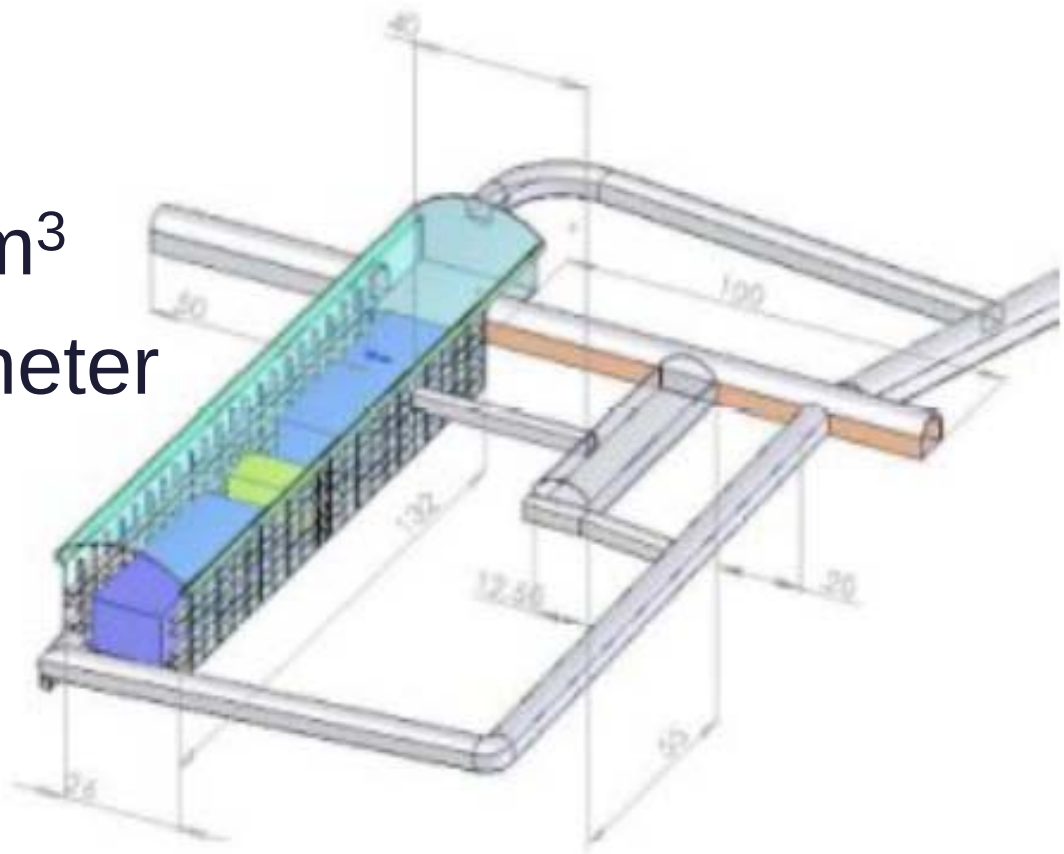
- prelim studies of possible location in the mine
  - other side of the beam
  - less overburden





India Neutrino Observatory (Approved)

- 3500 mwe overburden
- horizontal access
- new hall: 26x25(h)x135 m^3
- ICAL 50 kton iron calorimeter
  - magnetized
  - atmospheric ν
  - cosmic rays
  - possible long-baseline
- data taking in ~5 yr from t = 0

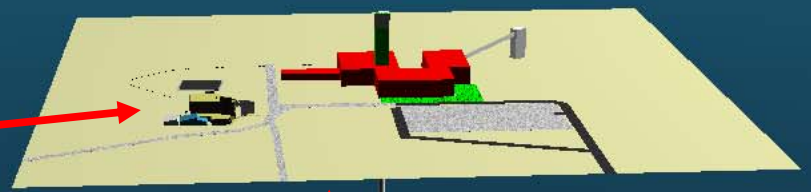


Underground Labs: North America

- SNOLAB [Canada]
- DUSEL [USA] wants beam
- Soudan [USA] beam
- WIPP [USA]

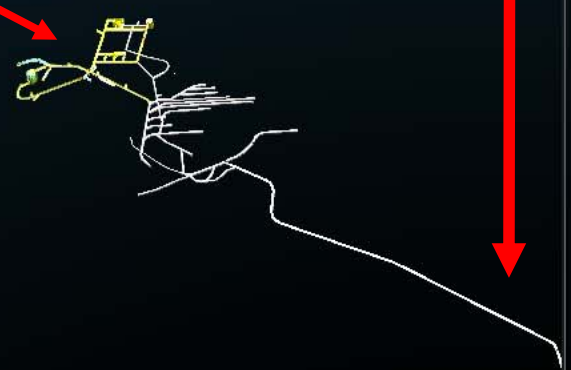
SNOLAB

Surface Facility

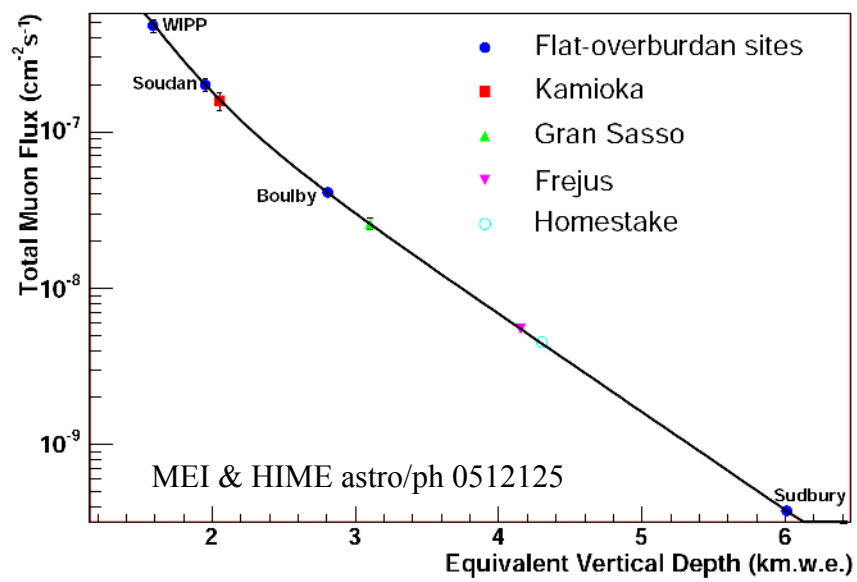


2km overburden (6000 mwe)

Underground Laboratory



Muon Flux = 0.27/m^2/day

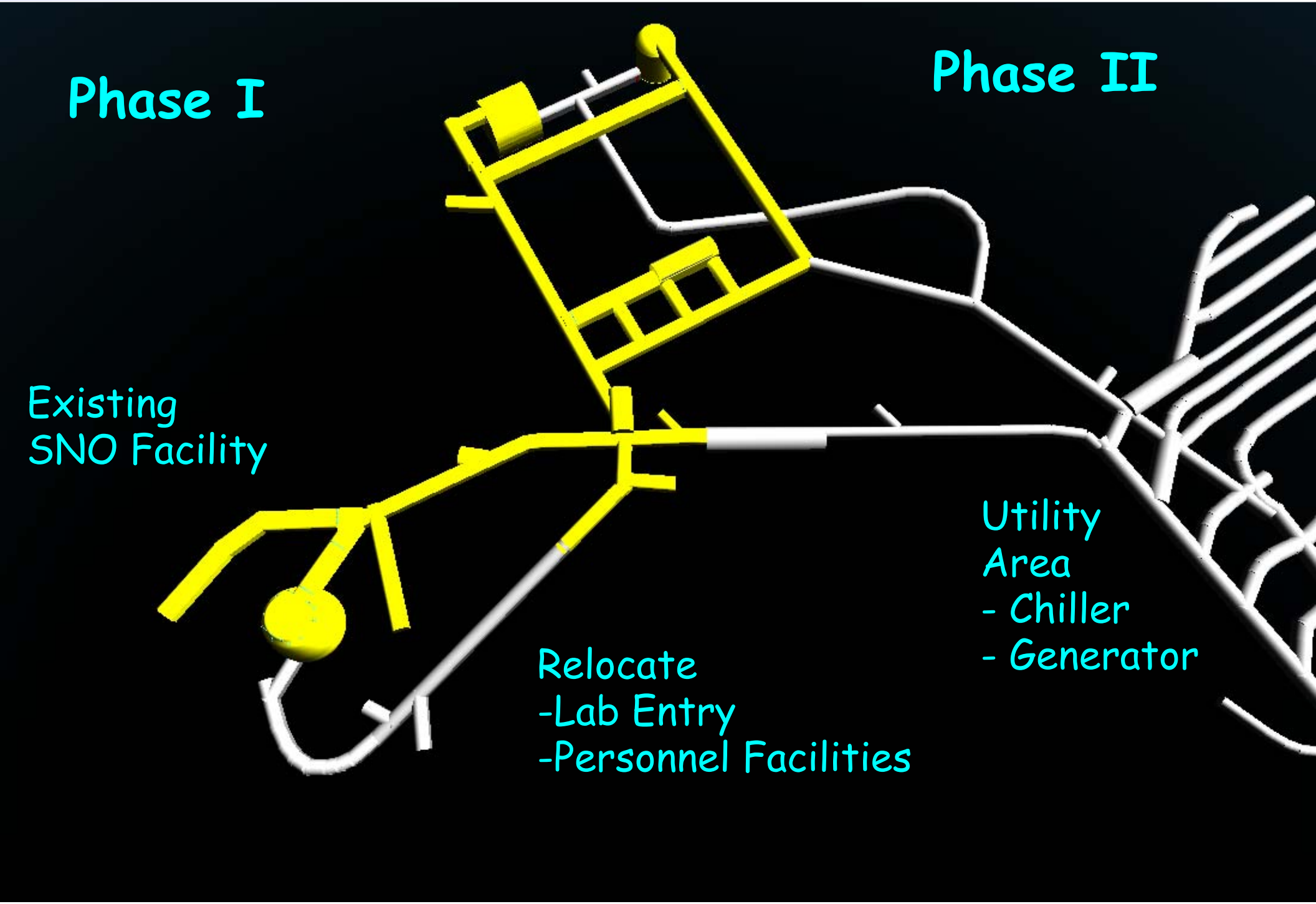


SNOLAB

SNOLAB

Phase I

SNOLAB


Phase I
Phase II
Existing
SNO Facility
Utility
Area
- Chiller
- Generator
Relocate
-Lab Entry
-Personnel Facilities

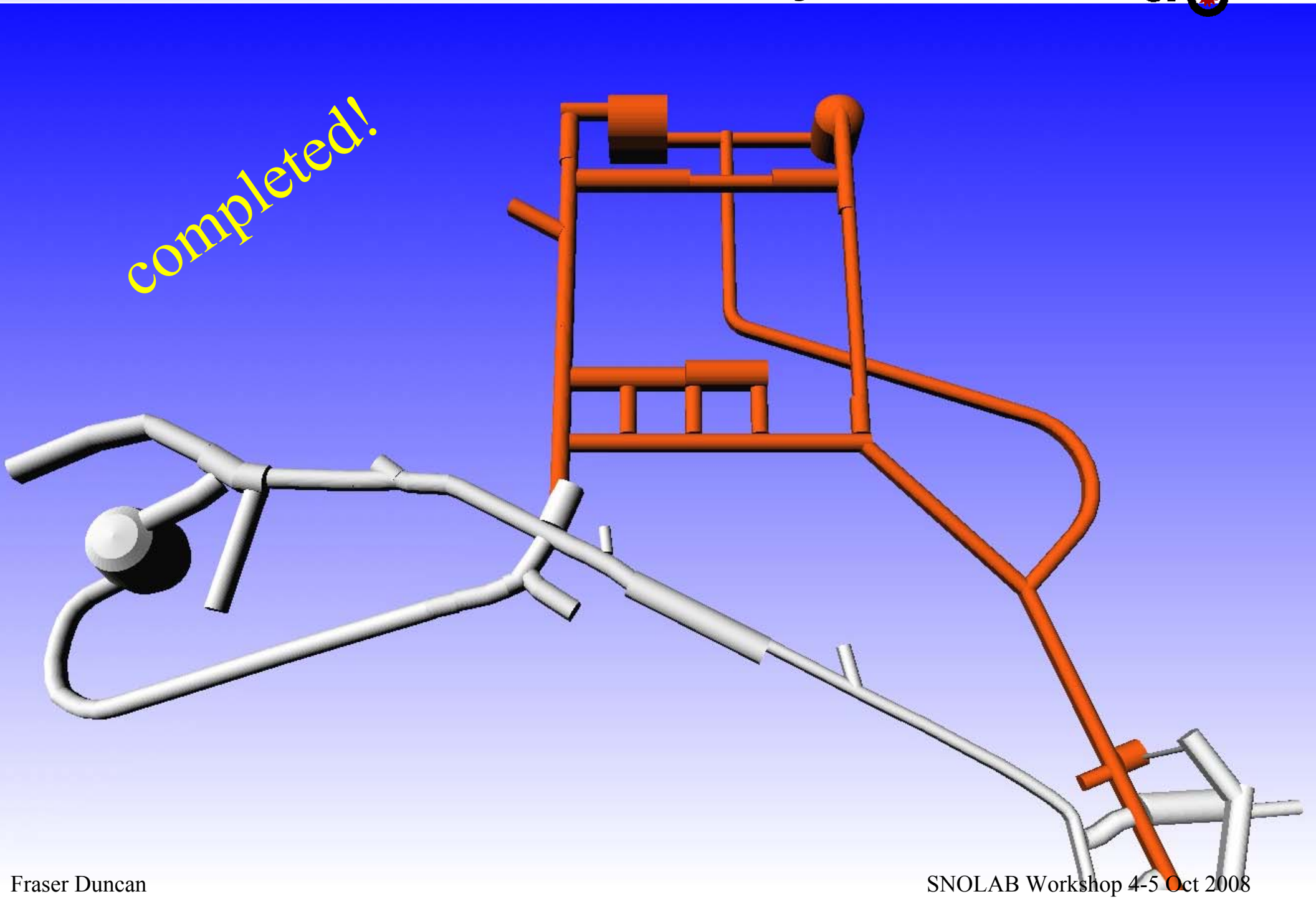
Laboratory Space

	Excavation		Clean Rm		Laboratory	
	Area	Volume	Area	Volume	Area	Volume
Existing	20,049 ft^2	582,993 ft^3	12,196 ft^2	470,360 ft^3	8,095 ft^2	412,390 ft^3
	1,863 m^2	16,511 m^3	1,133 m^2	13,321 m^3	752 m^2	11,679 m^3
Existing	65,340 ft^2	1,367,488 ft^3	41,955 ft^2	1,049,393 ft^3	26,117 ft^2	837,604 ft^3
+ Phase I	6,072 m^2	38,728 m^3	3,899 m^2	29,719 m^3	2,427 m^2	23,721 m^3
Existing	77,636 ft^2	1,647,134 ft^3	53,180 ft^2	1,314,973 ft^3	32,877 ft^2	1,043,579 ft^3
+ Phase I&II	7,215 m^2	46,648 m^3	4,942 m^2	37,241 m^3	3,055 m^2	29,555 m^3

Construction (Underground)

- Excavation:
  - Phase I: Began Nov 2004, completed May 2007
  - Phase II: Began Jun 2007, completed Jun 2008
  - Total excavation 6000 m^2 / 39,000 m^3.
- Outfitting:
  - Began Jun 2007
  - Done: Refuge station, Lab entrance
  - To Do: Completion of Utility Area (chillers, stp, fire water system); Ventilation in Ladder Labs, Cube Hall and Cryopit

Excavation Status: Today




Lab Entry
SNO
LAB
AAF
FEATHERLITE


Lab Entry


Lab Entry
FEATHERLITE


Lab Entry

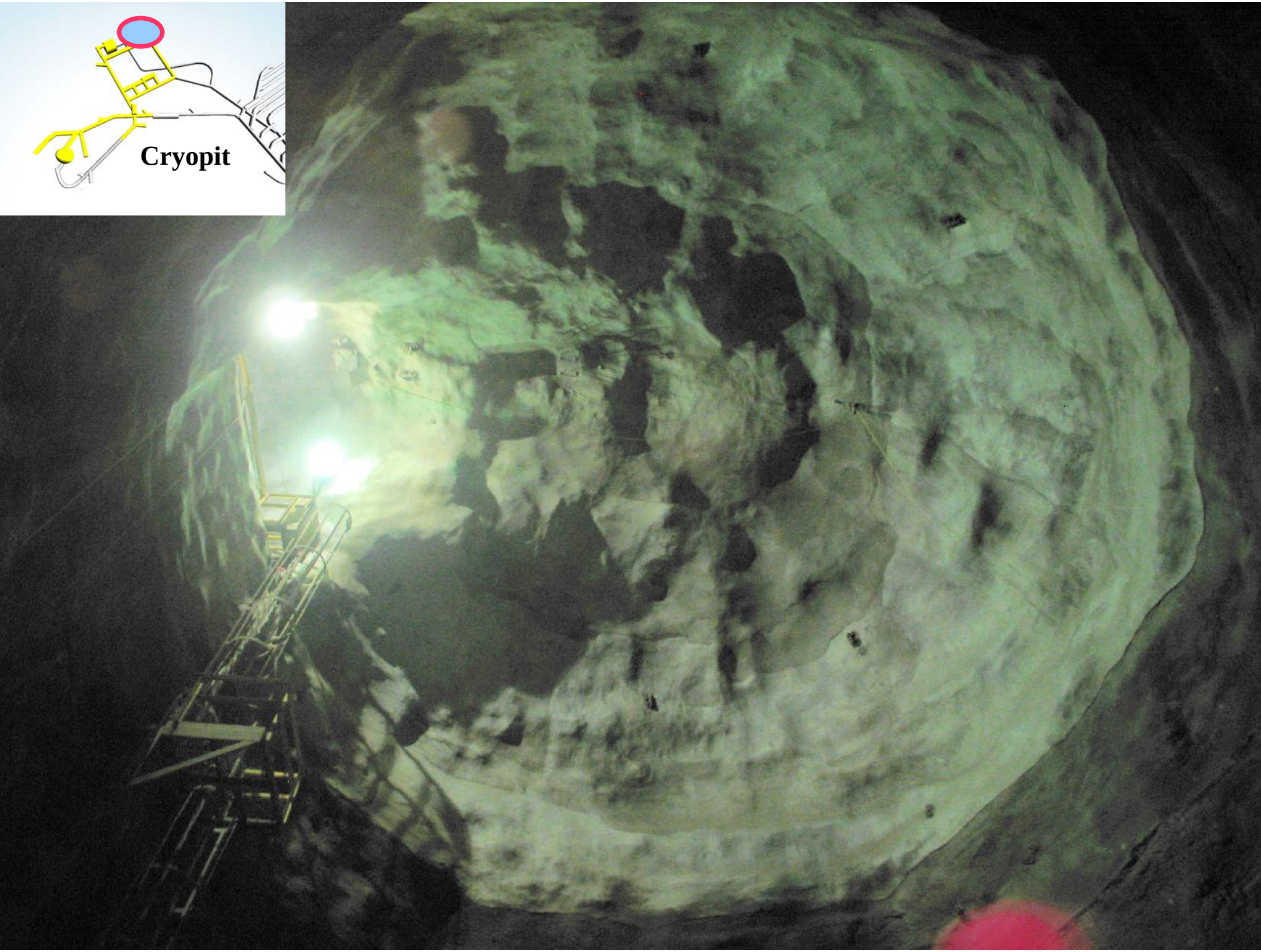

Personnel
Area


Ladder
Labs


Cube Hall


Cube Hall


Cryopit


Cryopit


Cryopit


Hall Bottom
Access

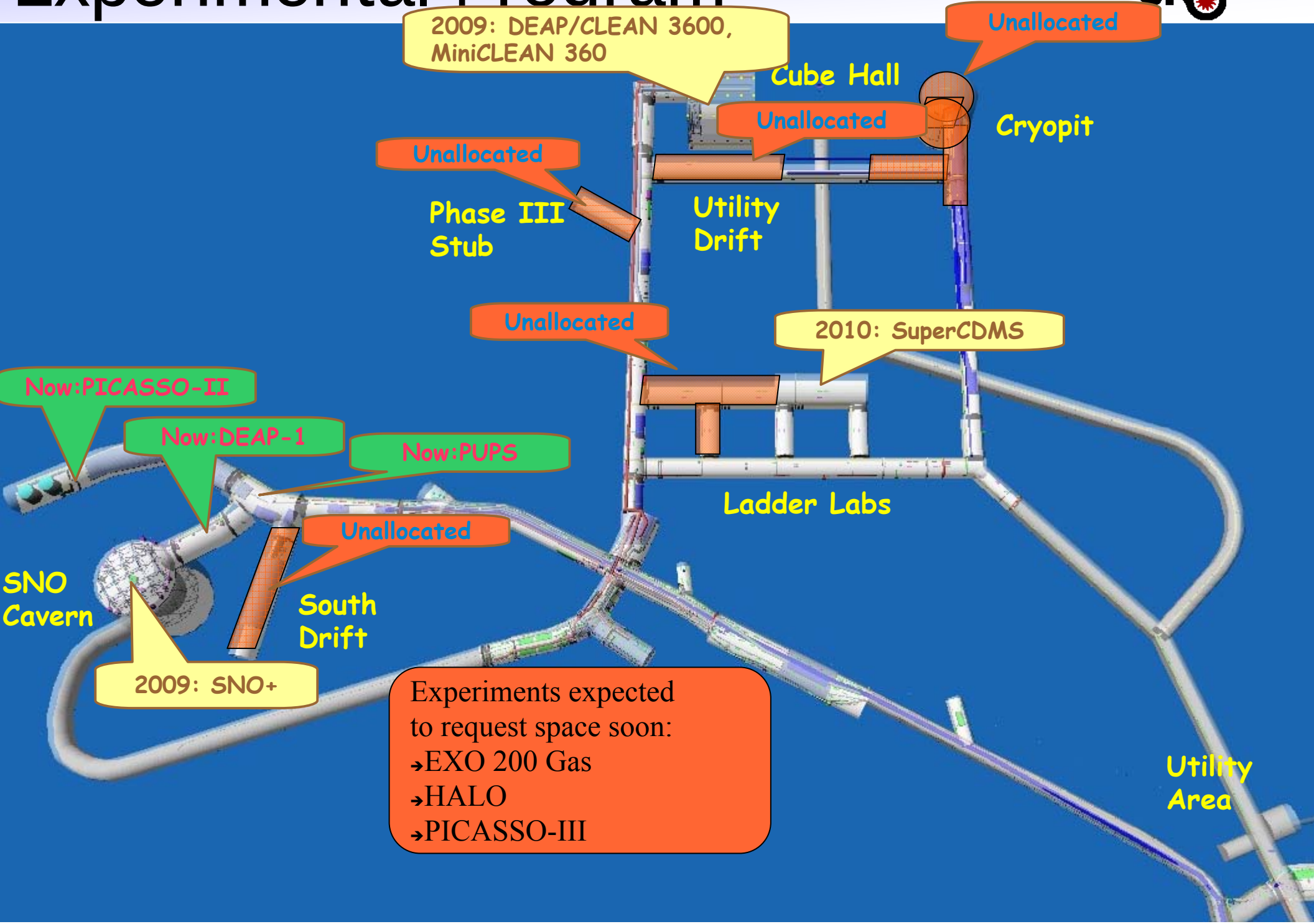

Chiller
Rm


Access
Drift

Day 1 Infrastructure

- **Other Services**
  - Industrial water, fire water, forced drain, compressed air.
  - Ultrapure water from the SNO water purification plant.
  - LN_2 supplied by transport dewar from surface.
- **Low Background Counting**
  - 1 existing HPGe Gamma Counter. requesting funds for 2 additional counters.
  - Rn/Ra Emanation (electrostatic counters, radon emanation).

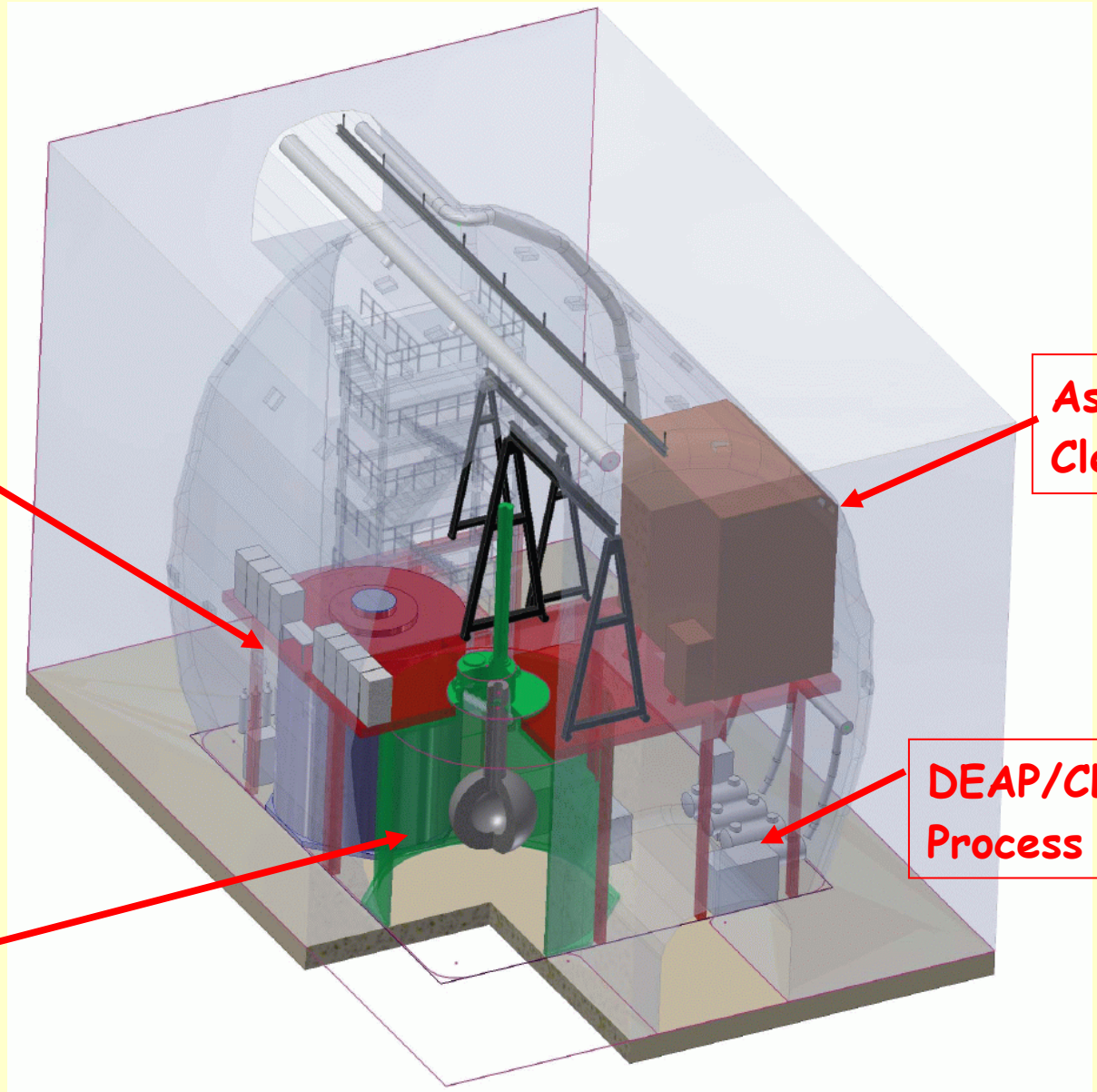
Experimental Program



Experiments expected to request space soon:

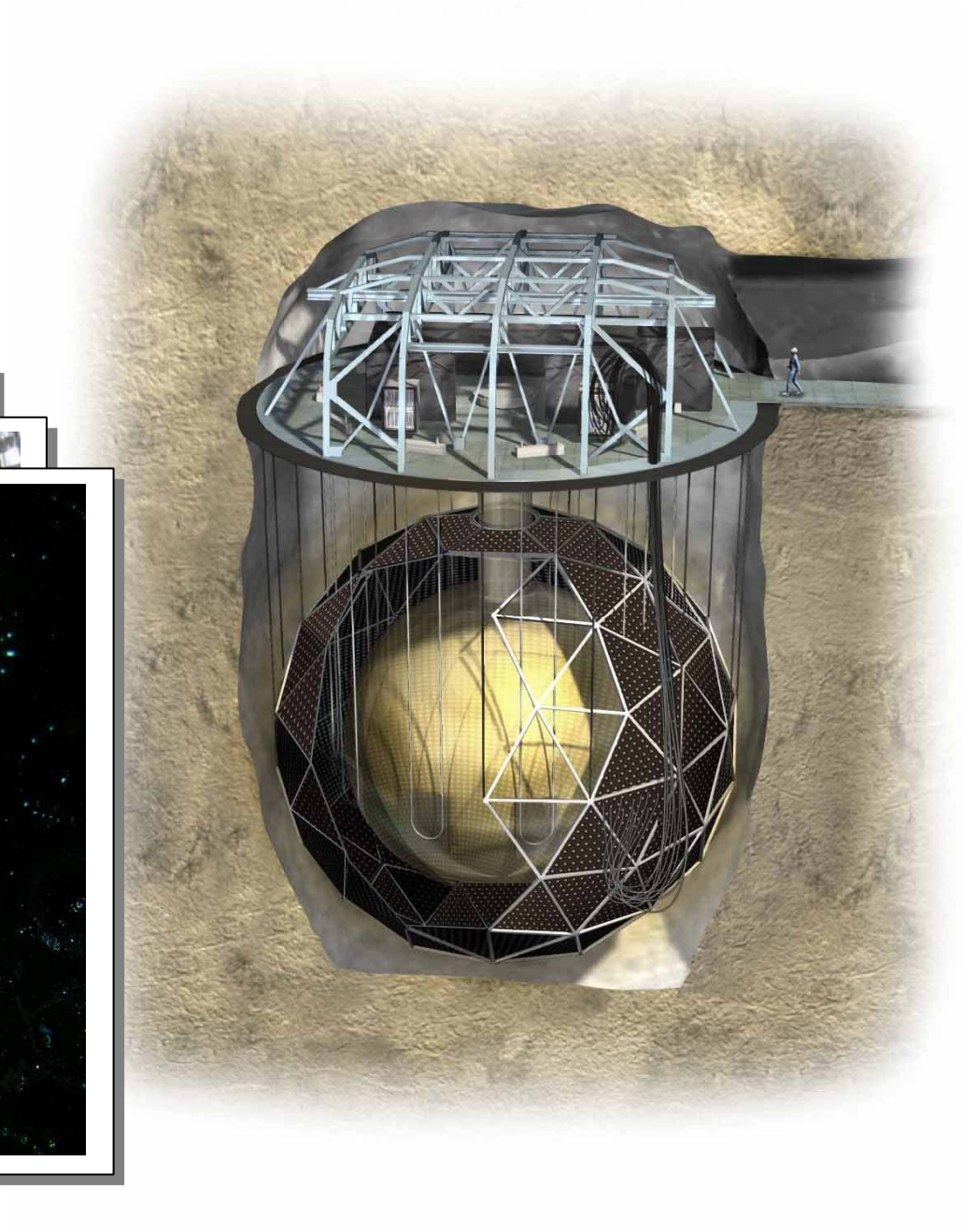
- EXO 200 Gas
- HALO
- PICASSO-III

Cube Hall

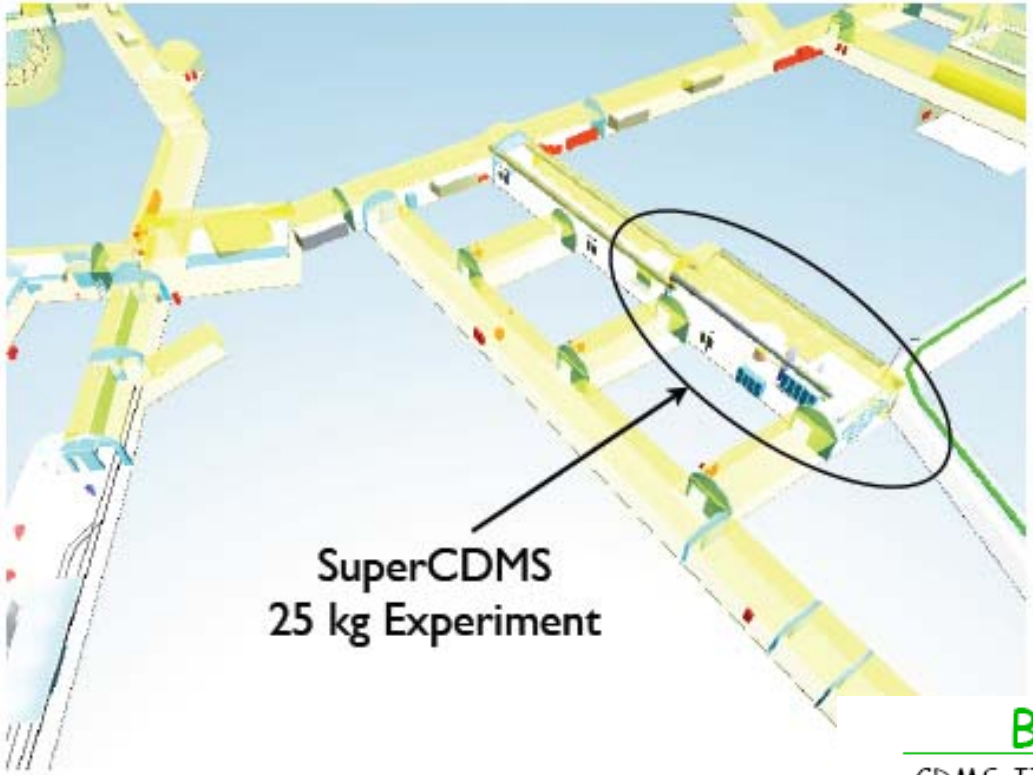

MiniCLEAN
360 kg
2009
Assembly
Clean Room
DEAP/CLEAN
Process Systems
DEAP/CLEAN
3.6 tonne
2010

SNO → SNO+

- ended data taking 28 Nov 2006
- heavy water returned June 2007
- transition from SNO to SNO+ 2008



SuperCDMS at SNOLAB



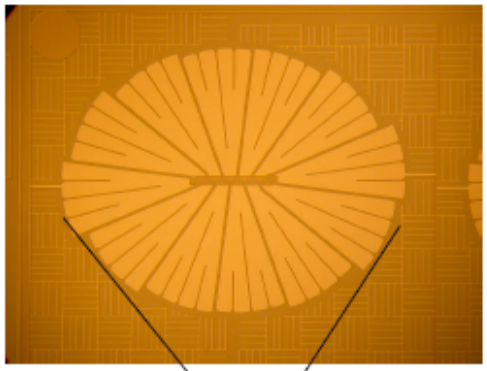
Baseline detector for SuperCDMS

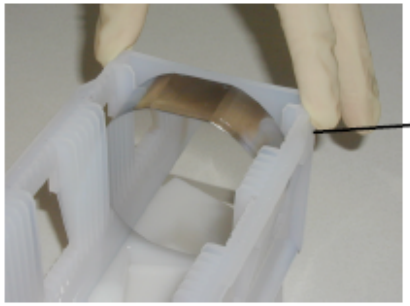
CDMS-II ZIPs:
3" dia x 1 cm => 0.25 kg of Ge

Existing ZIPs

SuperCDMS ZIPs:
3" dia x 1" => 0.64 kg of Ge

ZIPs for SuperCDMS





SNOLAB Summary

- Construction is almost complete
- Ready to begin the installation of the Day 1 experiments. Civil work can being any time in the new laboratory areas.
  - e.g. install steel in the Cube Hall at the beginning of 2009.
- Some space has been allocated for experiments but there is still significant room available.
- SNOLAB is open for business.

Underground Labs: Europe

- Gran Sasso [Italy] beam
- Modane [France] wants beam
- Canfranc [Spain]
- Baksan [Russia]
- Boulby [UK]
- Pyhäsalmi [Finland] wants beam
- Solotvina [Ukraine]

INFN Istituto Nazionale di Fisica Nucleare

Laboratori Nazionali del Gran Sasso

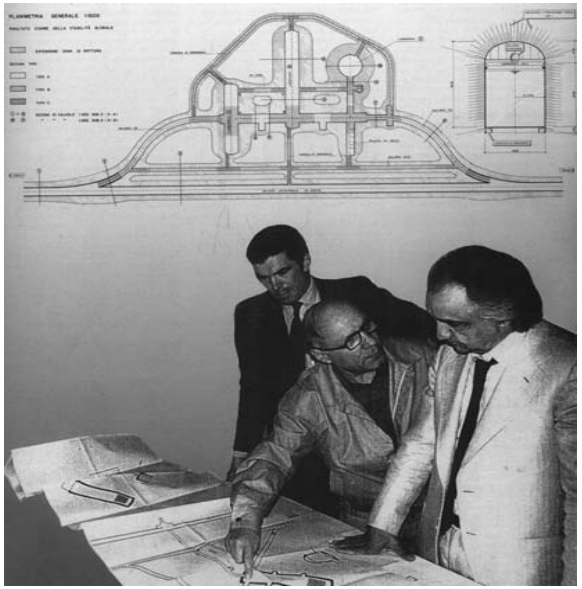
LNGS

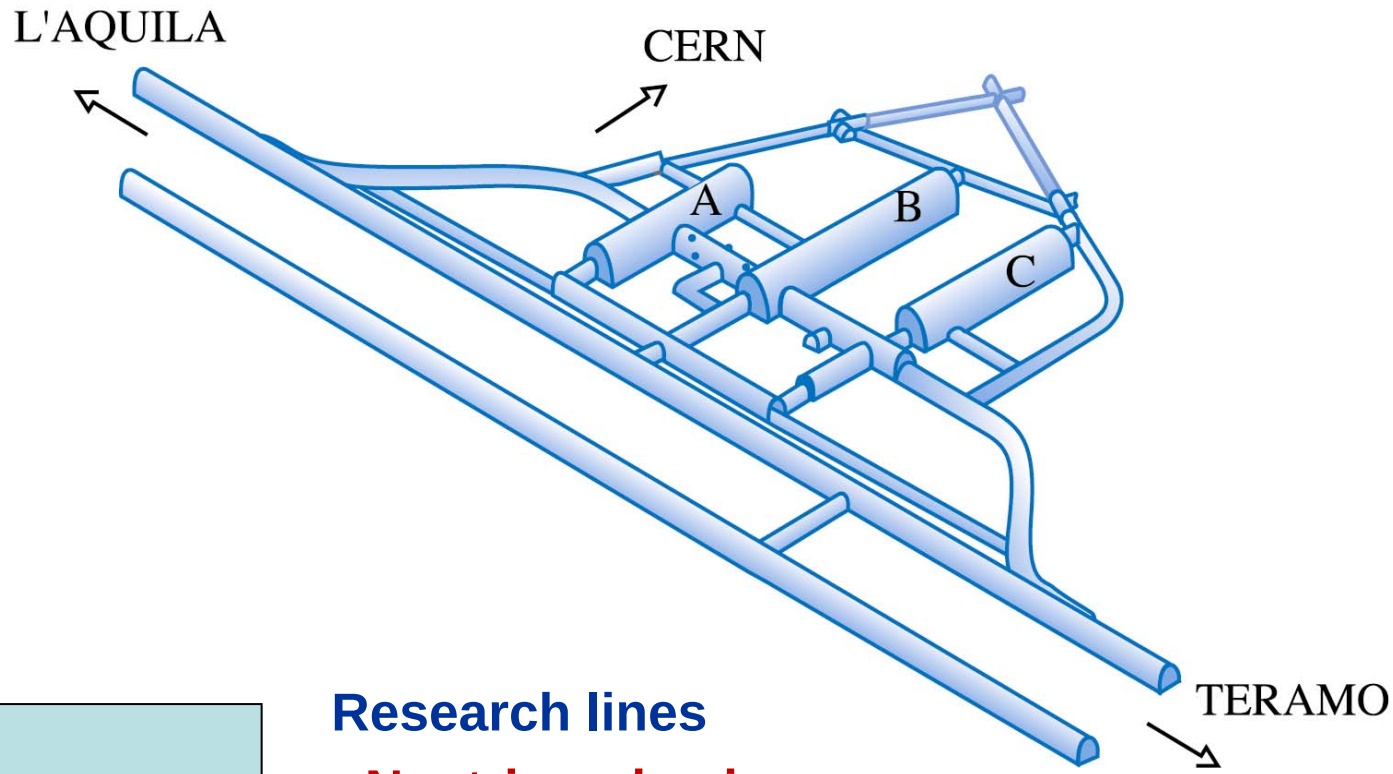
Eugenio Coccia
coccia@lngs.infn.it

october 6 2008

LABORATORI NAZIONALI DEL GRAN SASSO - INFN

Largest underground laboratory for astroparticle physics





1400 m rock coverage
cosmic μ reduction= 10^{-6} (1 /m^2 h)
underground area: 18 000 m^2
external facilities
easy access
756 scientists from 24 countries
Permanent staff = 70 positions

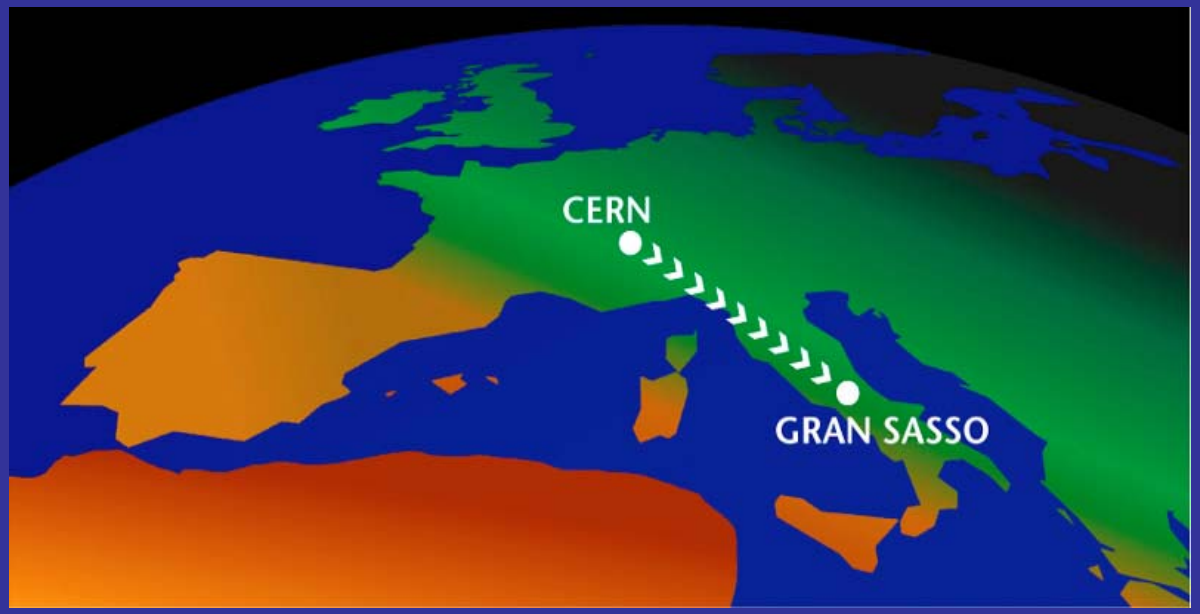
Research lines

- **Neutrino physics**
  (mass, oscillations, stellar physics)
- **Dark matter**
- **Nuclear reactions of astrophysics interest**
- **Geophysics**
- **Biology**

ν beam from CERN:

OPERA

ICARUS



ββ decay and rare events

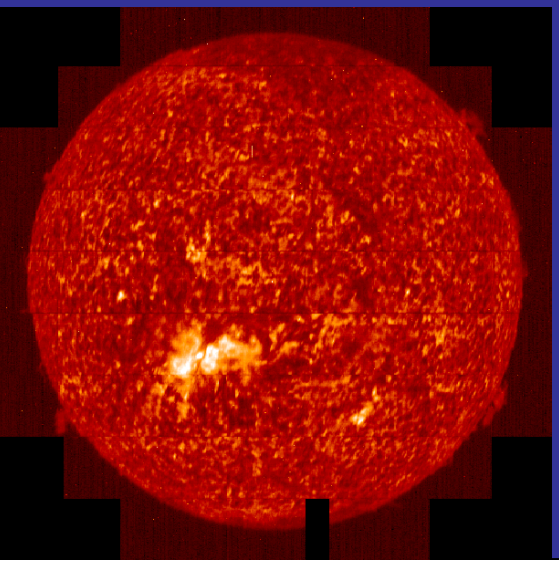
Cuoricino

CUORE; GERDA

Dark Matter

DAMA/LIBRA; CRESST

WARP; Xenon



Solar ν

Borexino

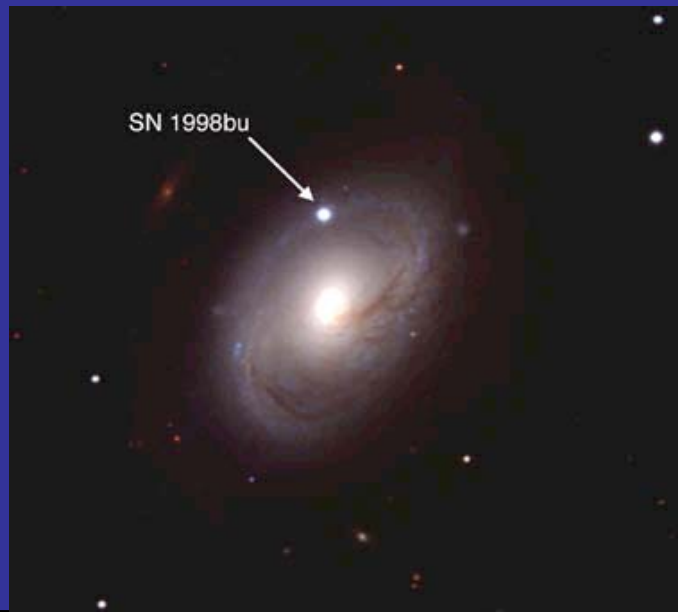
LUNA

ν from Supernovae

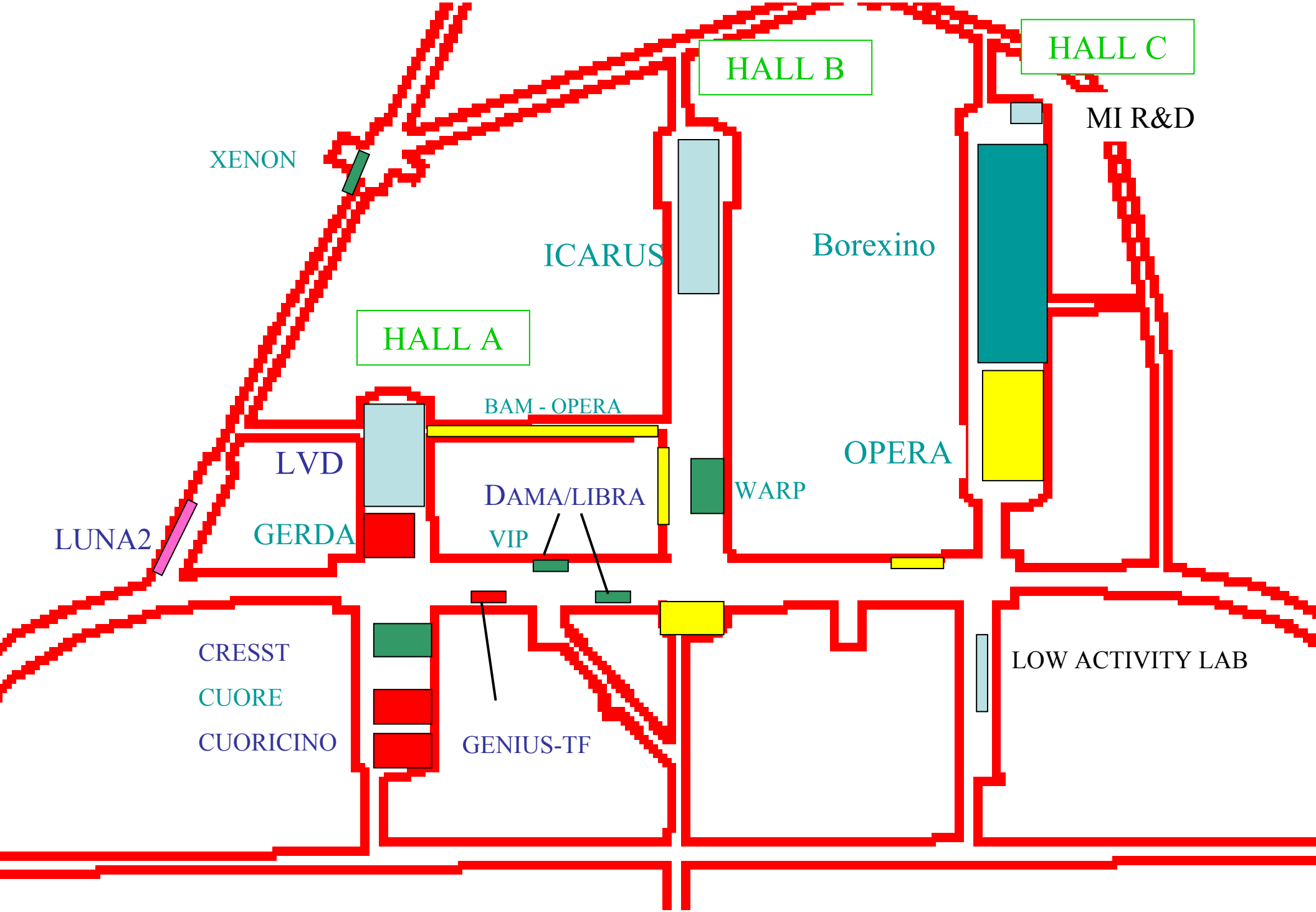
LVD

Borexino

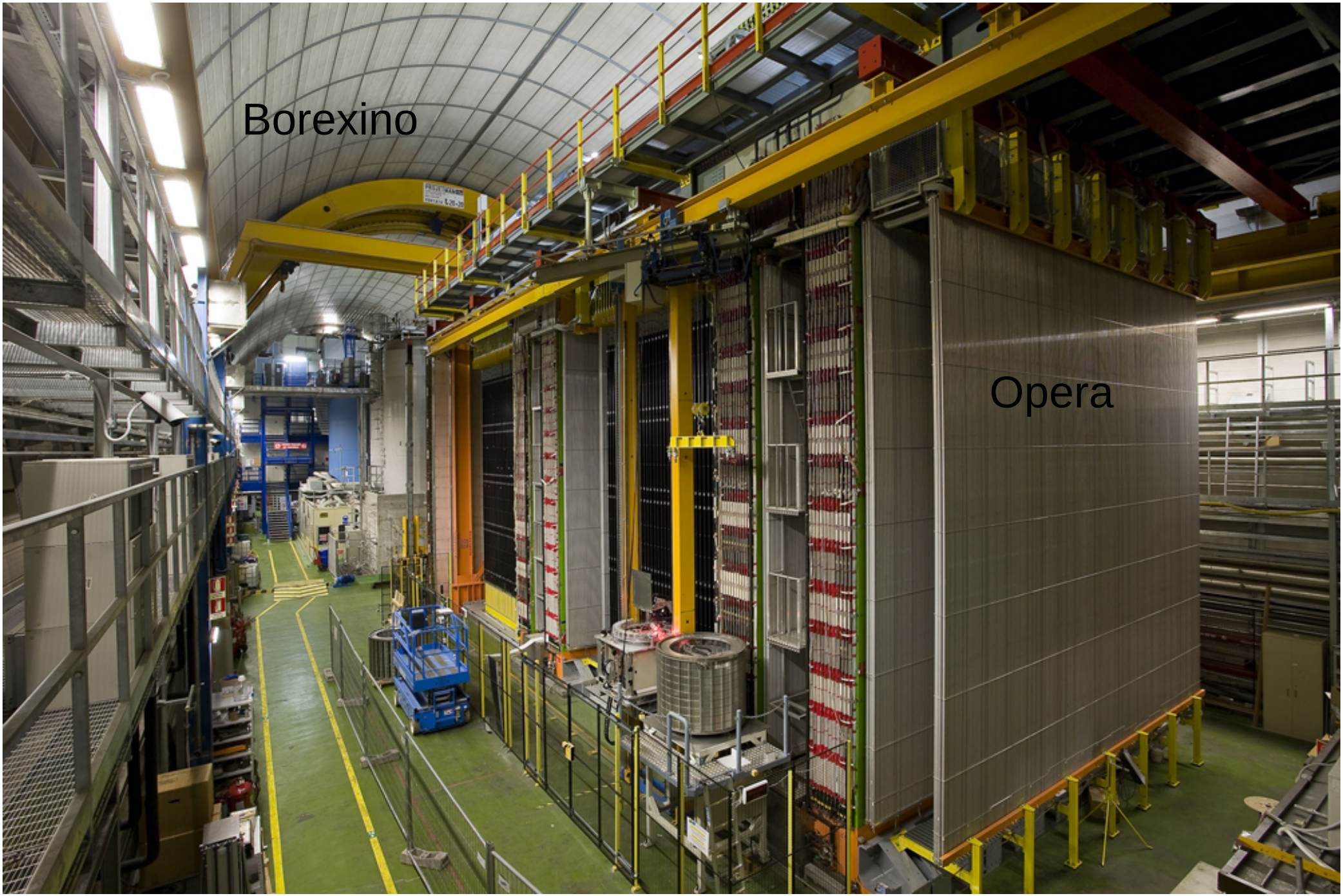
ICARUS



Occupancy


HALL B
HALL C
MI R&D
XENON
ICARUS
Borexino
HALL A
BAM - OPERA
LVD
OPERA
DAMA/LIBRA
WARP
LUNA2
GERDA
VIP
CRESST
CUORE
CUORICINO
GENIUS-TF
LOW ACTIVITY LAB

HALL C

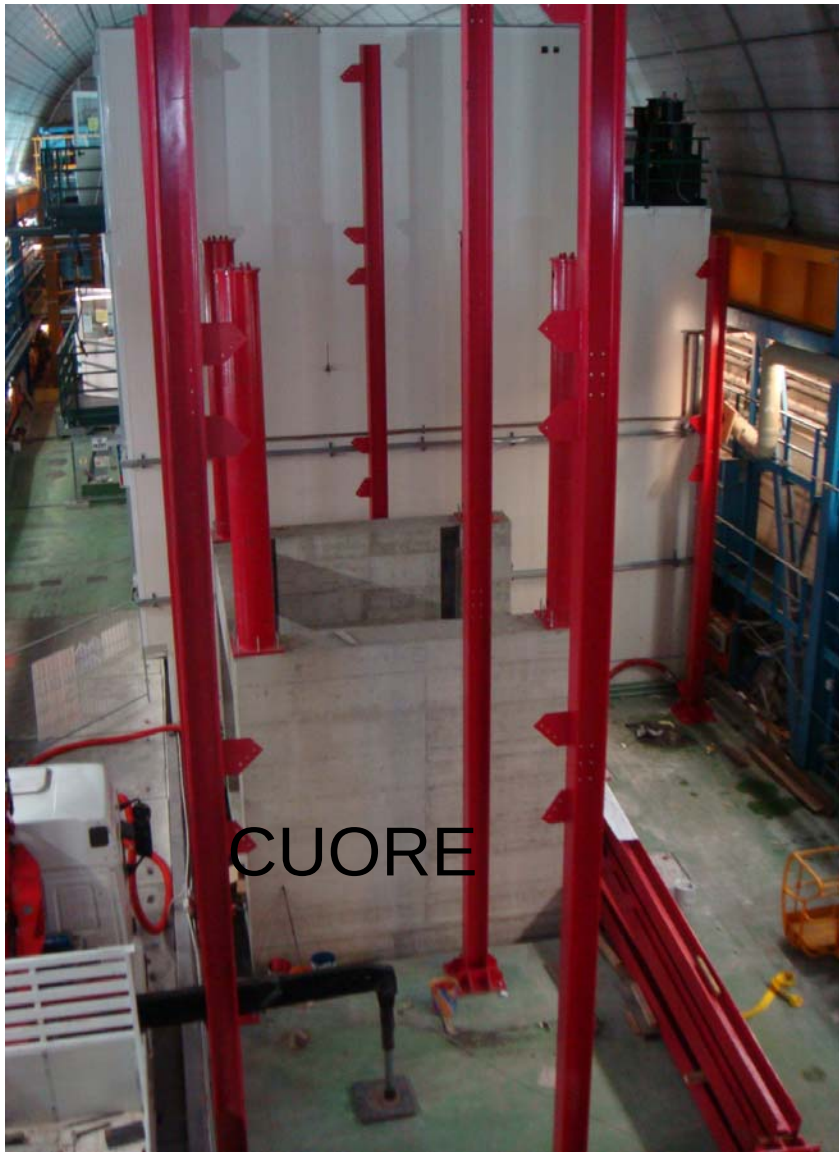


HALL B

Icarus

Warp

HALL A



The future

- Large $\beta\beta$ experiment (1-10 ton)

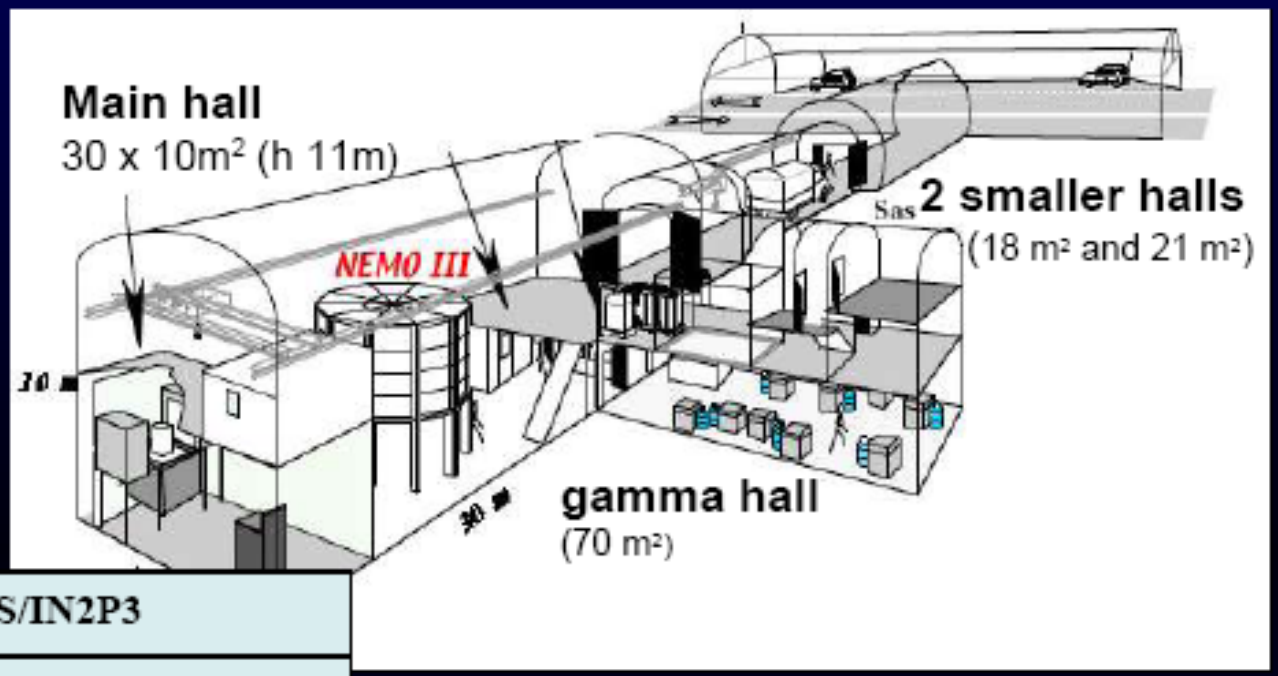
- Large Dark Matter experiment (1-10 ton)

-A new large infrastructure for a LAr detector 10^5 ton scale ?

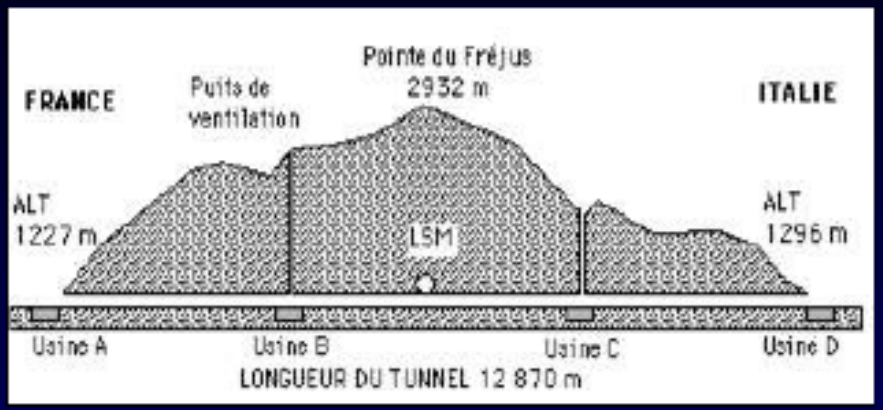
Physics: proton decay, on low-energy neutrinos from astrophysical origin and possible detection of future accelerator neutrino beams

A new laboratory, shallow depth, at 10 km from LNGS, possible target for an upgraded CNGS beam, is being considered.

Laboratoire Souterrain de Modane

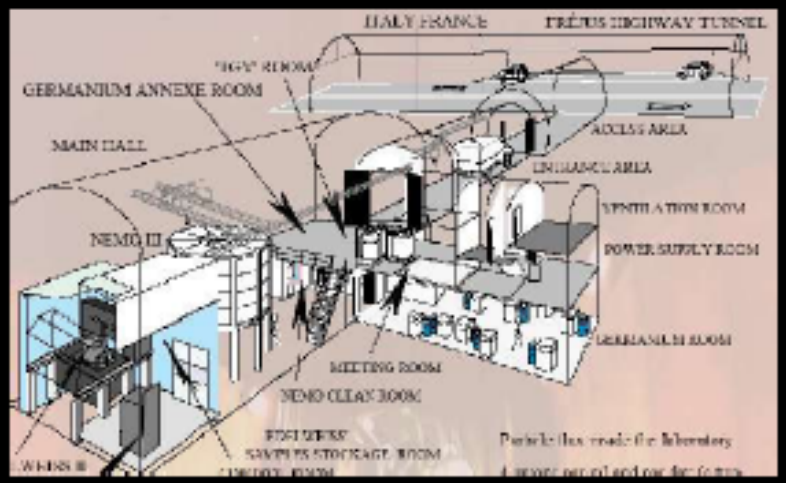


Operators	**CEA/DSM & CNRS/IN2P3**
Location	**Fréjus Tunnel (Italian-French border)**
Excavation	**1983**
Underground area	**1 main hall (30m x 10m x 11m) + gamma spectroscopy hall (70 m²) + 2 secondary halls of 18 m² and 21 m²**
Depth	**1700 m (4800 mwe)**
Surface	**> 400 m²**
Permanent staff	**8**
Scientists users	**100**



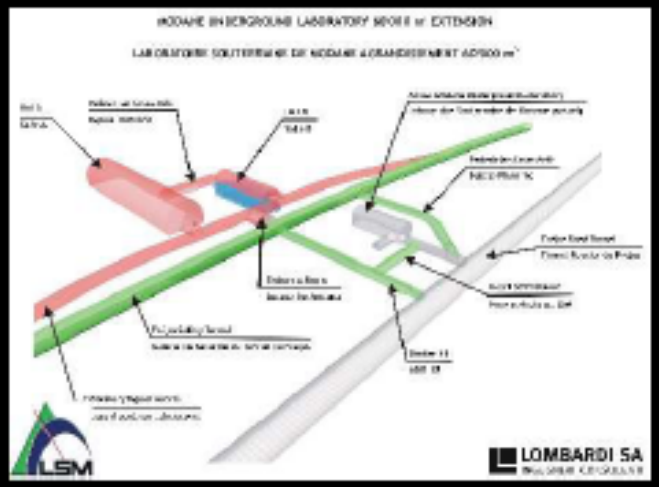
LSM and future projects

IN2P3 (CNRS) and DAPNIA (CEA) run the Modane Underground Laboratory (LSM)
The Lab Facilities are composed by:

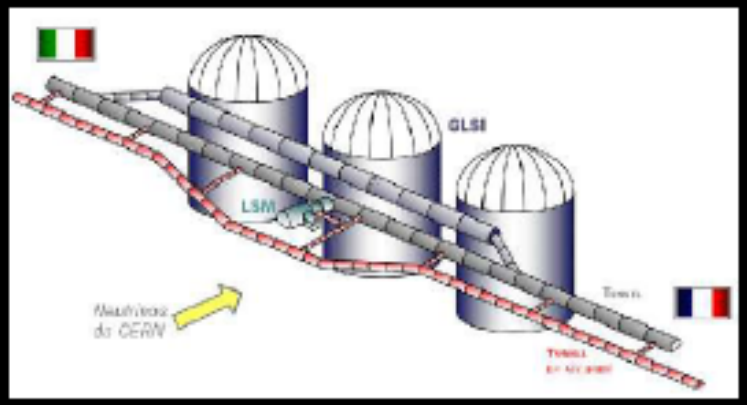


A cavity of about 3'500 m3 at middle of Fréjus Road Tunnel in French Territory

External LSM buildings (construction 2008)



LSM Project for a 60'000 m3 extension to be constructed according to on-going projects (safety tunnel)

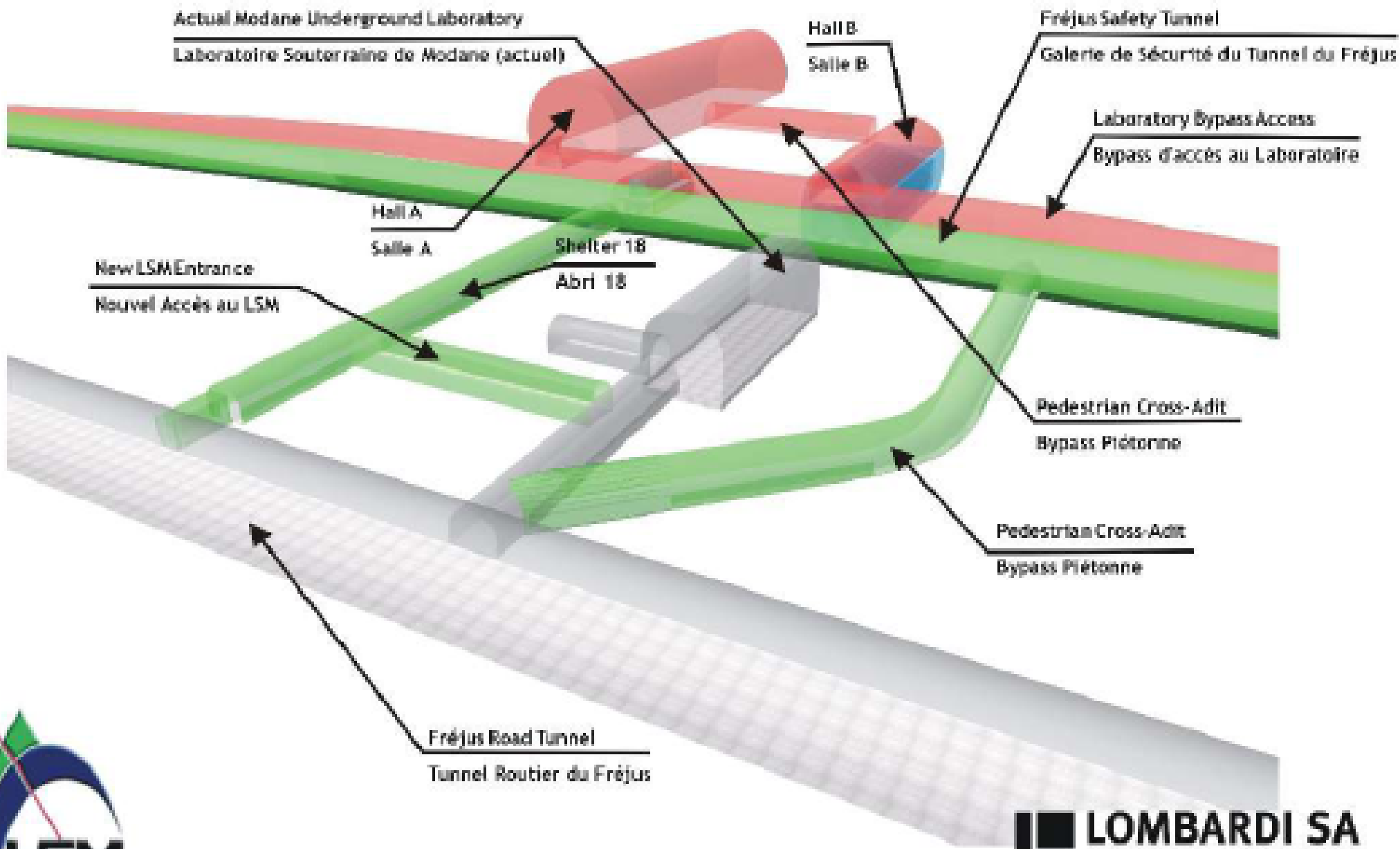


Project for Large scale underground laboratory (1'000'000 m3)

ULISSE

MODANE UNDERGROUND LABORATORY 60'000 m³ EXTENSION

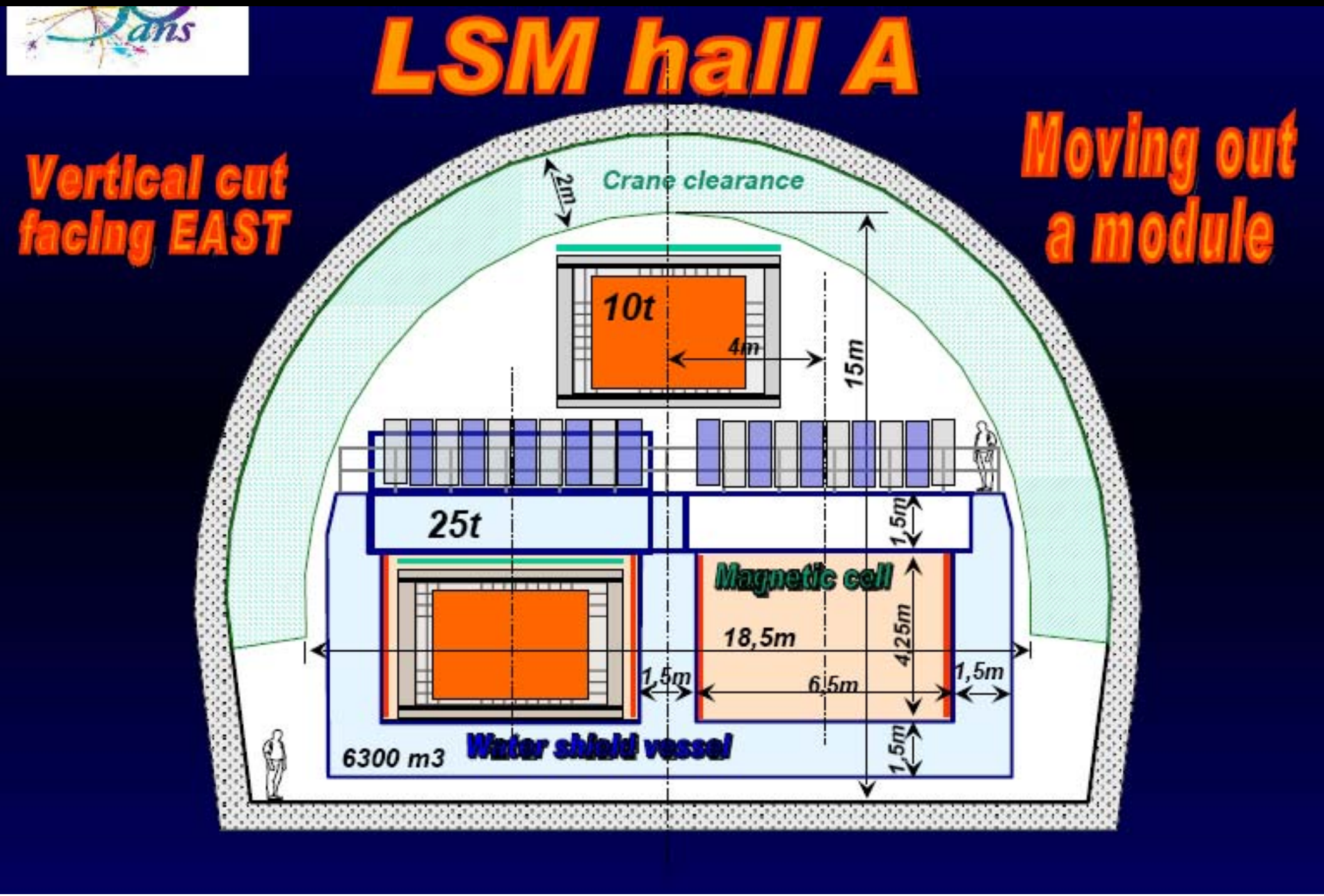
LABORATOIRE SOUTERRAINE DE MODANE AGRANDISSEMENT 60'000 m³



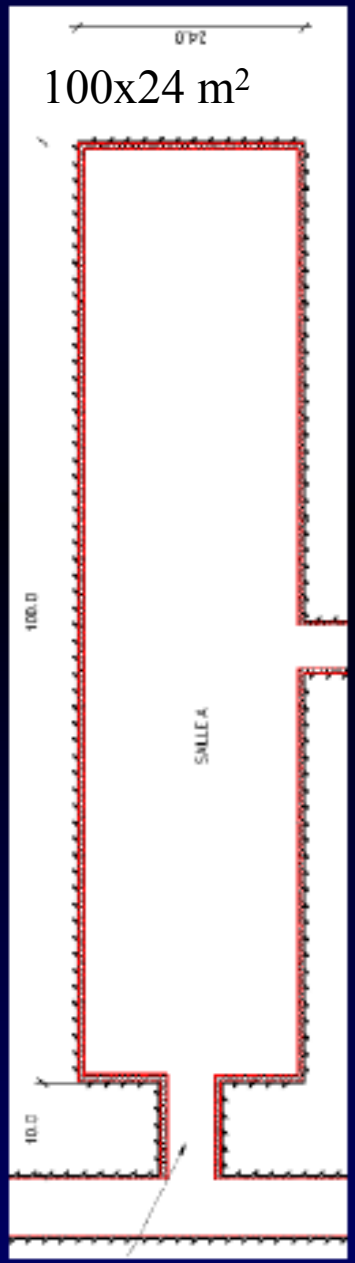
LSM

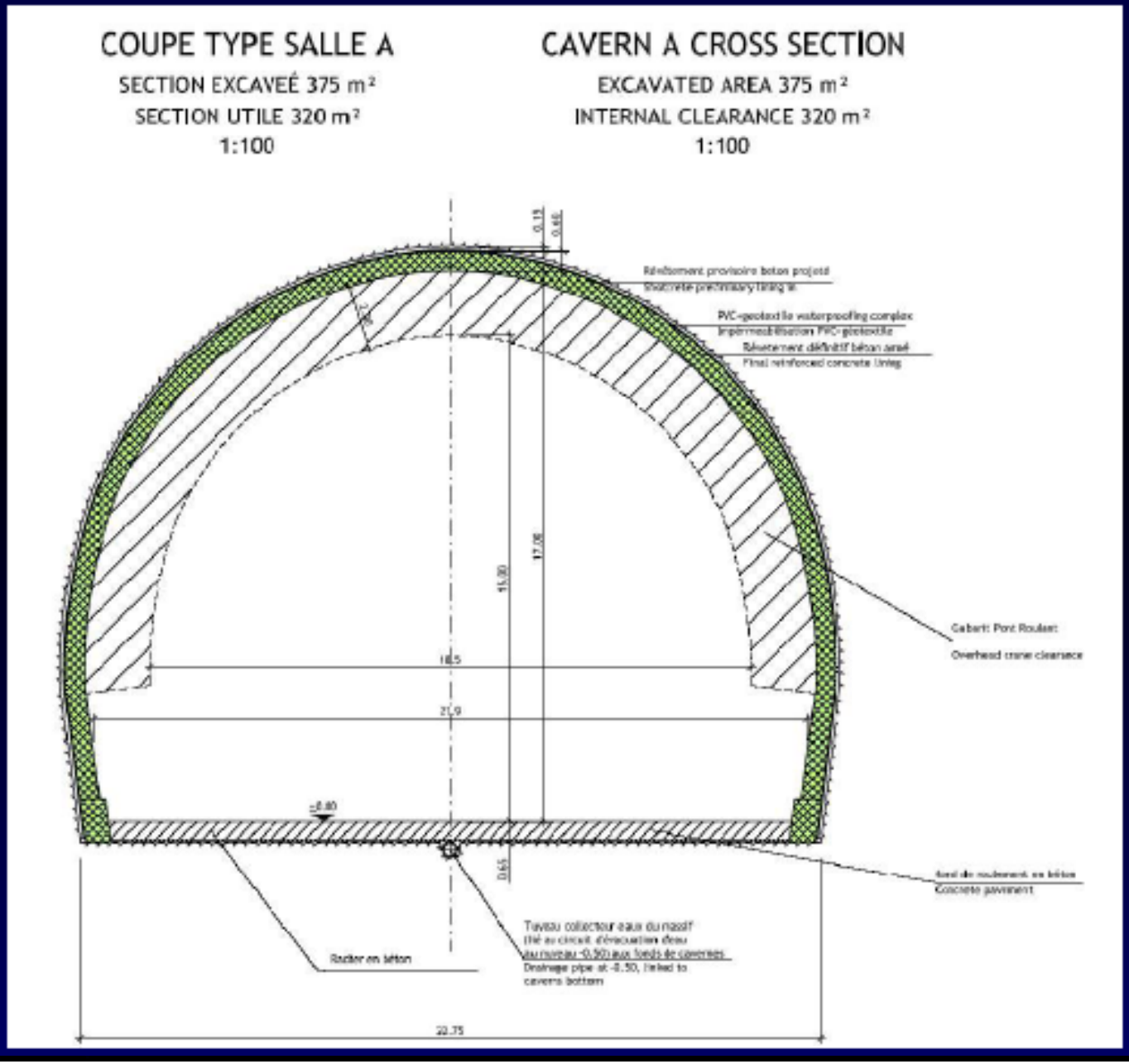
LOMBARDI SA
INGEGNERI CONSULENTI

e.g. SuperNEMO in Modane Expansion

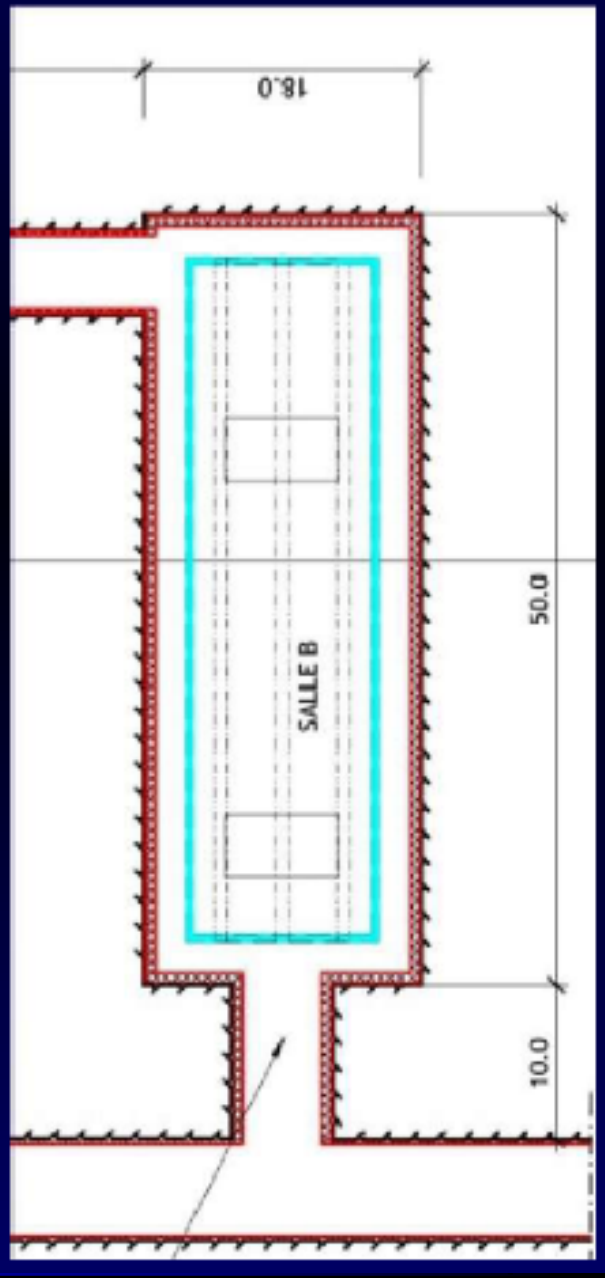


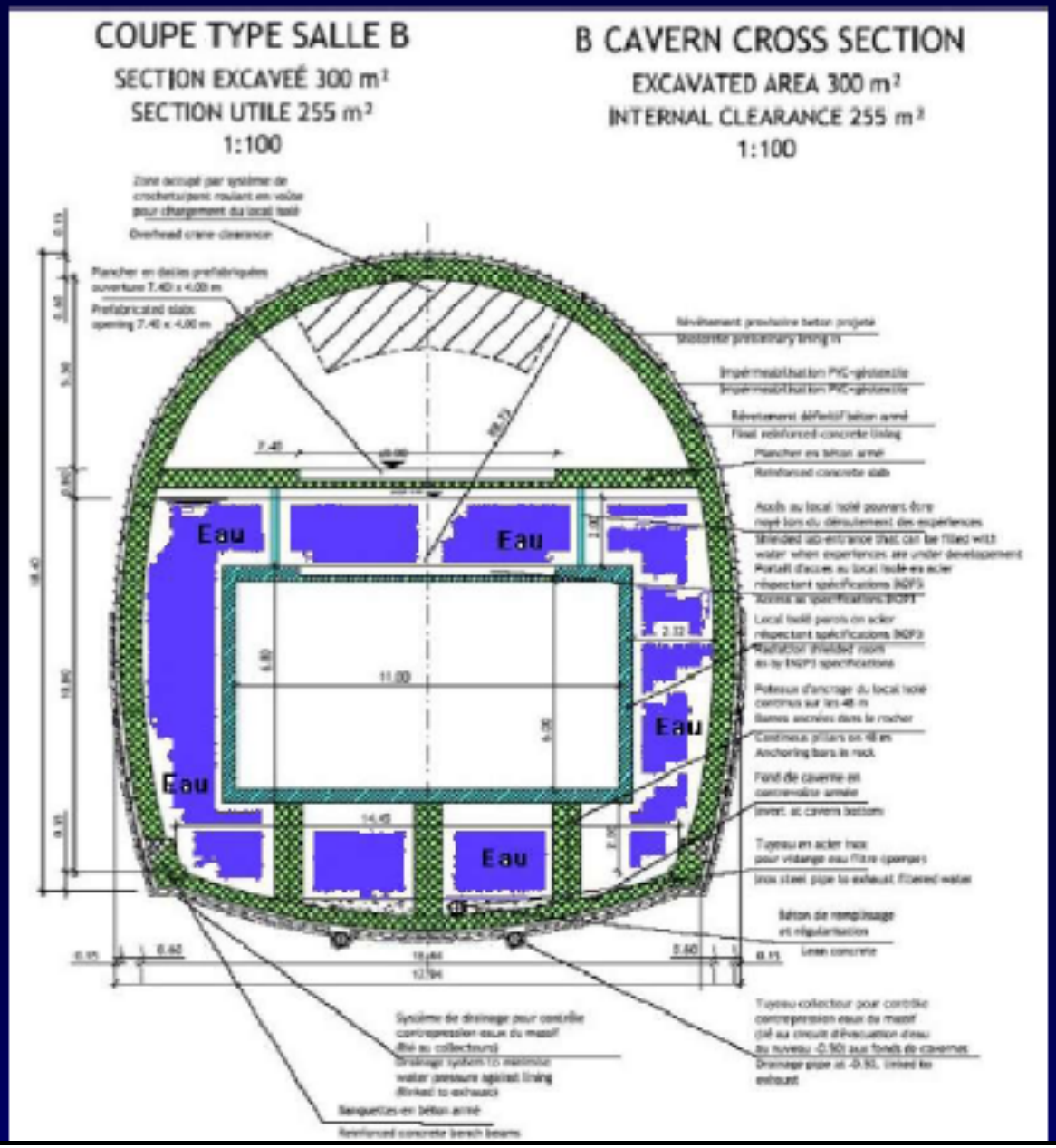
HALL A (SuperNEMO type)





HALL B: Dark matter (EURECA, liq.Xe,…)





ULISSE project

Realistic planning !

ULISSE timetable

	2007	2008	2009	2010	2011	2012	2013	2014	2015
ULISSE		Studies optmis.							
				Order placed					
					Const/equipment				
							Ready to accept expts		
Cost M€	0.1 study			1 equip	6 cavity	7 cavity	1 equip	.8 run cost	.8 run cost

Absolute constraint: Option must be confirm whitin 3 years after Ordering of the safety galery (end of 2008 or beginning of 2009)

Detailed studies must be ready in 2010

Moderate cost compare to the experiments !!!

A new very large laboratory in Europe ?

MEgaton Mass PHYSics

Results of a pre-study conducted by the SETEC Co. (present road tunnel)

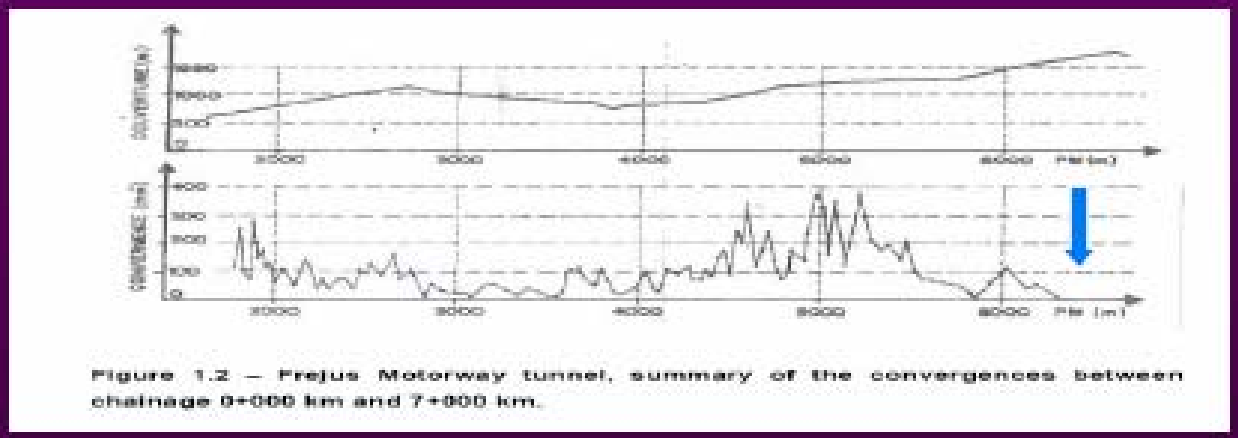
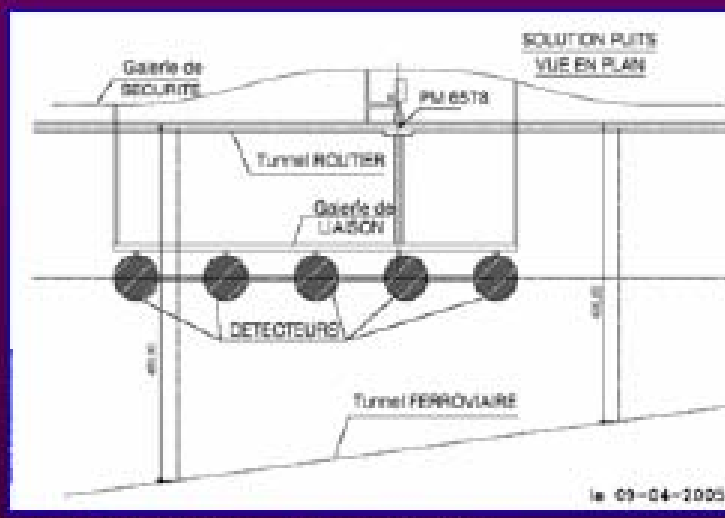
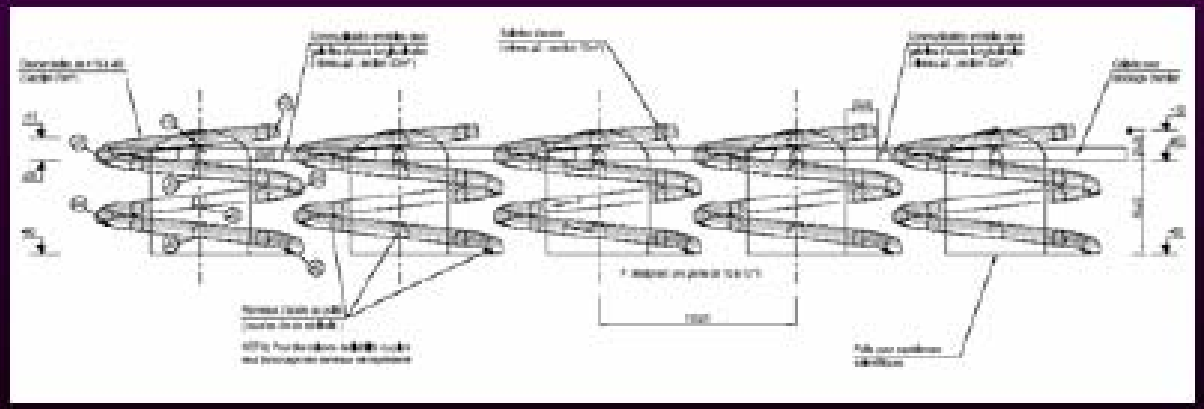


Figure 1.2 – Frejus Motorway tunnel, summary of the convergences between chainage 0+000 km and 7+000 km.



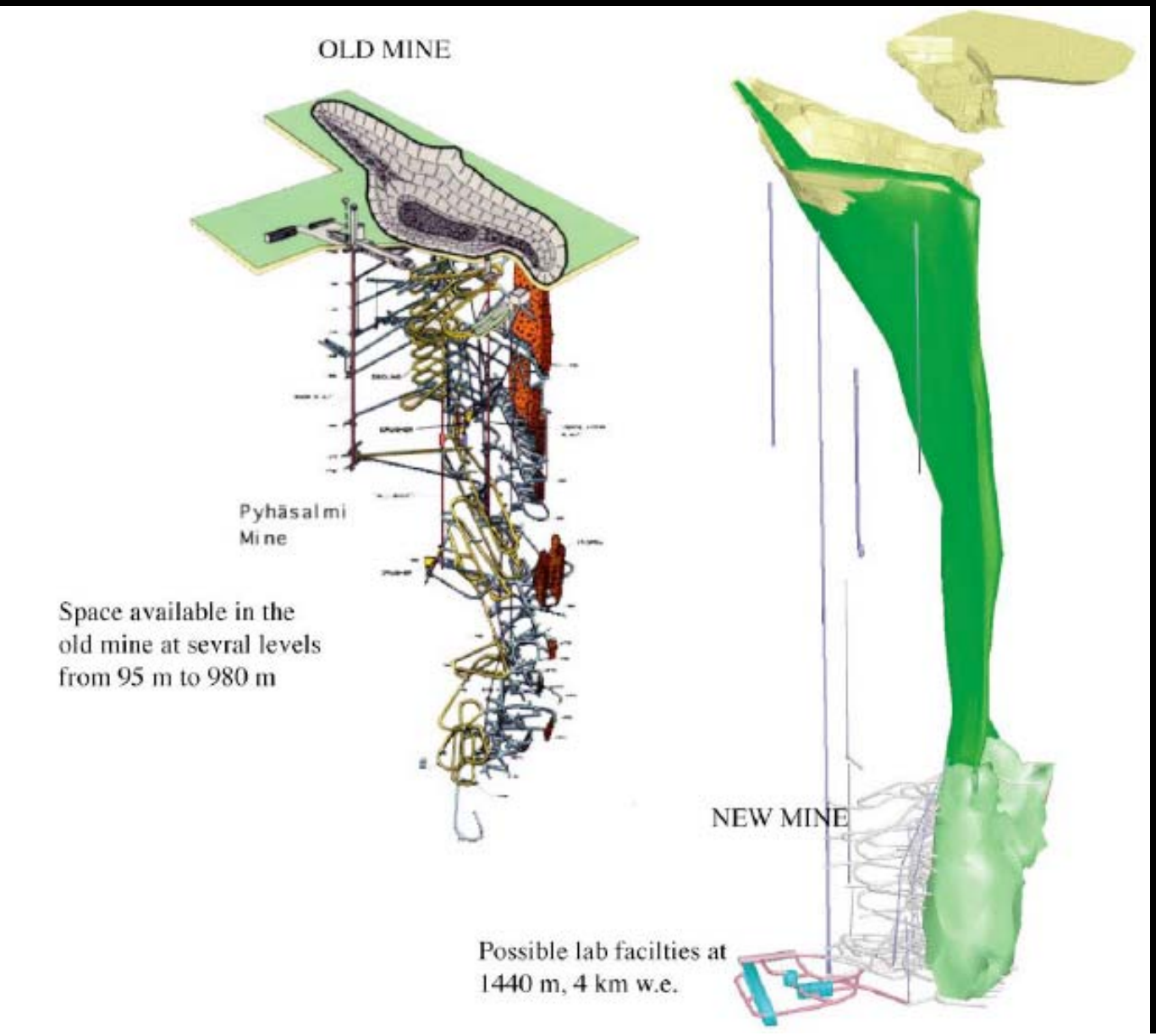
The estimated overall cost is ≈ 80 M€ X Nb of shafts

Current choice=
3 shafts
(1 shaft ≈ 150kT fiducial mass)



A simpler scheme under study of access tunnels

Pyhäsalmi Mine [Finland]



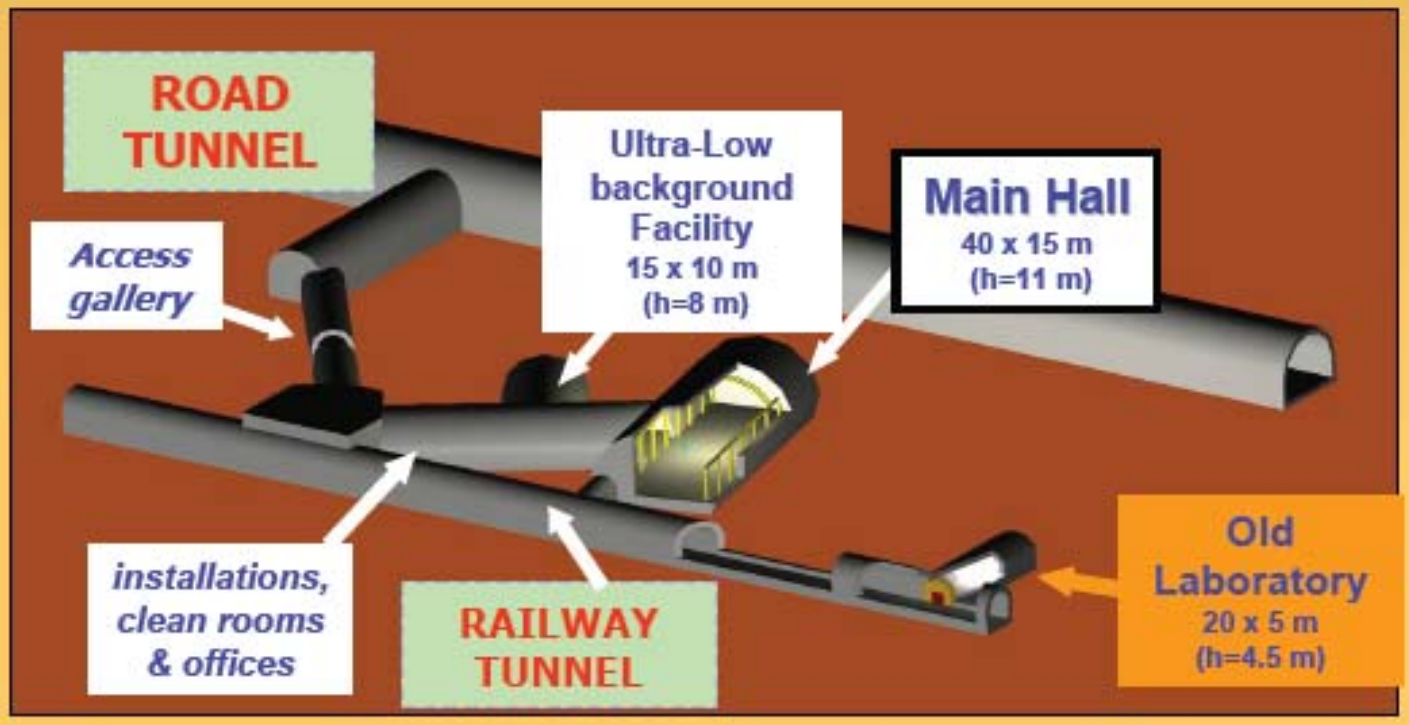
- space not used for mining could be used for small-medium experiments (e.g. EMMA has been taking data as a multi-muon array)
- would require new lab facilities constructed in the new mine for extensive program
- status: not yet approved and no funding yet

LSC Canfranc new lab

The new underground Laboratory is finished in 2005

repairs underway in 2008

Characteristic of the new LSC	
Depth	900 m (2450 mwe)
Main experimental hall	600 m^2 (oriented to CERN)
Low background lab	150 m^2
Clean room	45 m^2 (100/1000 type)
General services	135 m^2
Offices	80 m^2



-BiPo
- SuperNEMO
- ……

Concluding Remarks

- some low background experiments (e.g. dark matter searches) need the greatest depth and best background shielding
- large megaton-scale detectors for long-baseline share the same scale as nucleon decay experiments; obviously these efforts are linked
- excellent physics on the horizon
- interesting prospects for the future
- more coordination between laboratories?