International Underground science: Status and Prospects

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and
CENBG (CNRS/IN2P3 and Bordeaux I university)

IoP meeting

April,29-31 UCL

Thanks to: E. Coccia, N. Spooner, A. Bettini, N. Smith, G. Gerbier, K. Lesko, Y. Suzuky

Underground Physics

- **Physics beyond the standard Model, search for rare events or decays**

- **Proton decay** **GeV**

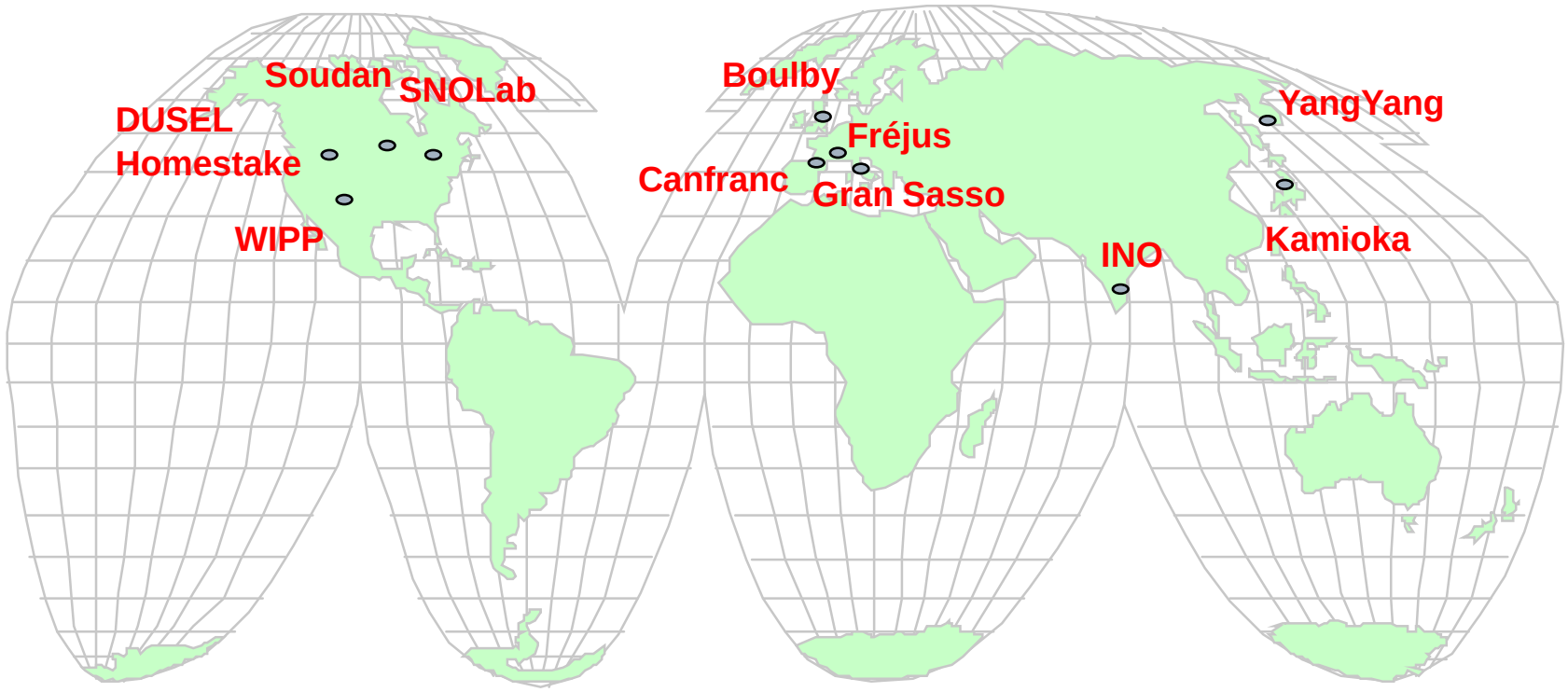
  Origin of the creation of deep underground labs
  - **SUSY**

- **Neutrino oscillations and astronomy** **Mev - GeV**
  - **Solar neutrinos**
  - **Atmospheric**
  - **Accelerators**
  - **SuperNovae**

- **Neutrino properties** **MeV**
  - **Double beta decay** **Nature of neutrino and mass**

- **Dark matter** **keV**
  - **Universe content**

Deep Underground Laboratories



Underground Laboratories

Underground labs are characterized by:

Depth :muons flux

Rock density: meter water equivalent

Cavity size : surface and volume

Access: horizontal (tunnel) or vertical (mine)

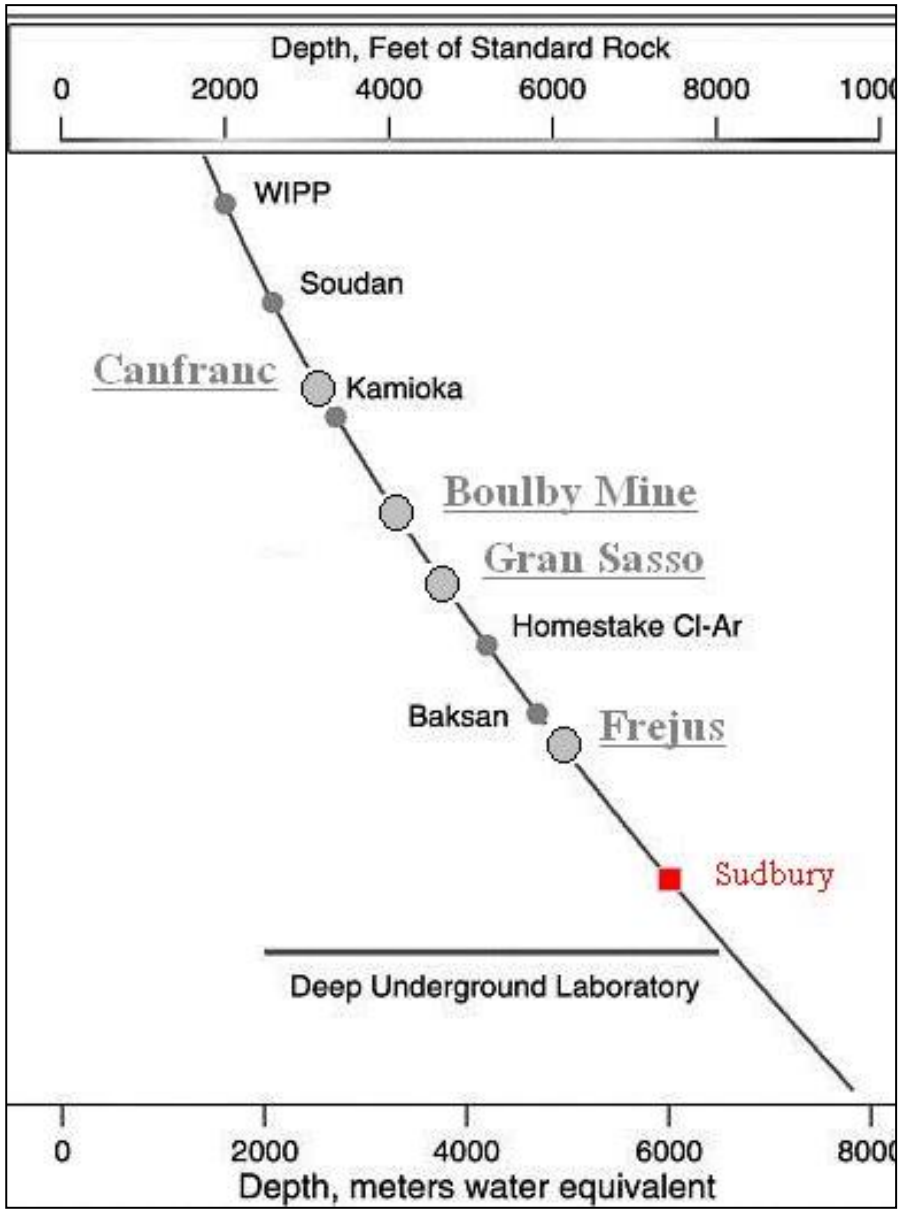
Neutron flux: rock radioactivity (fission (α,n) reactions) spallation from muons

Gamma-rays flux: rock radioactivity γ up to 2.6 MeV Muons bremstrahlung Radon

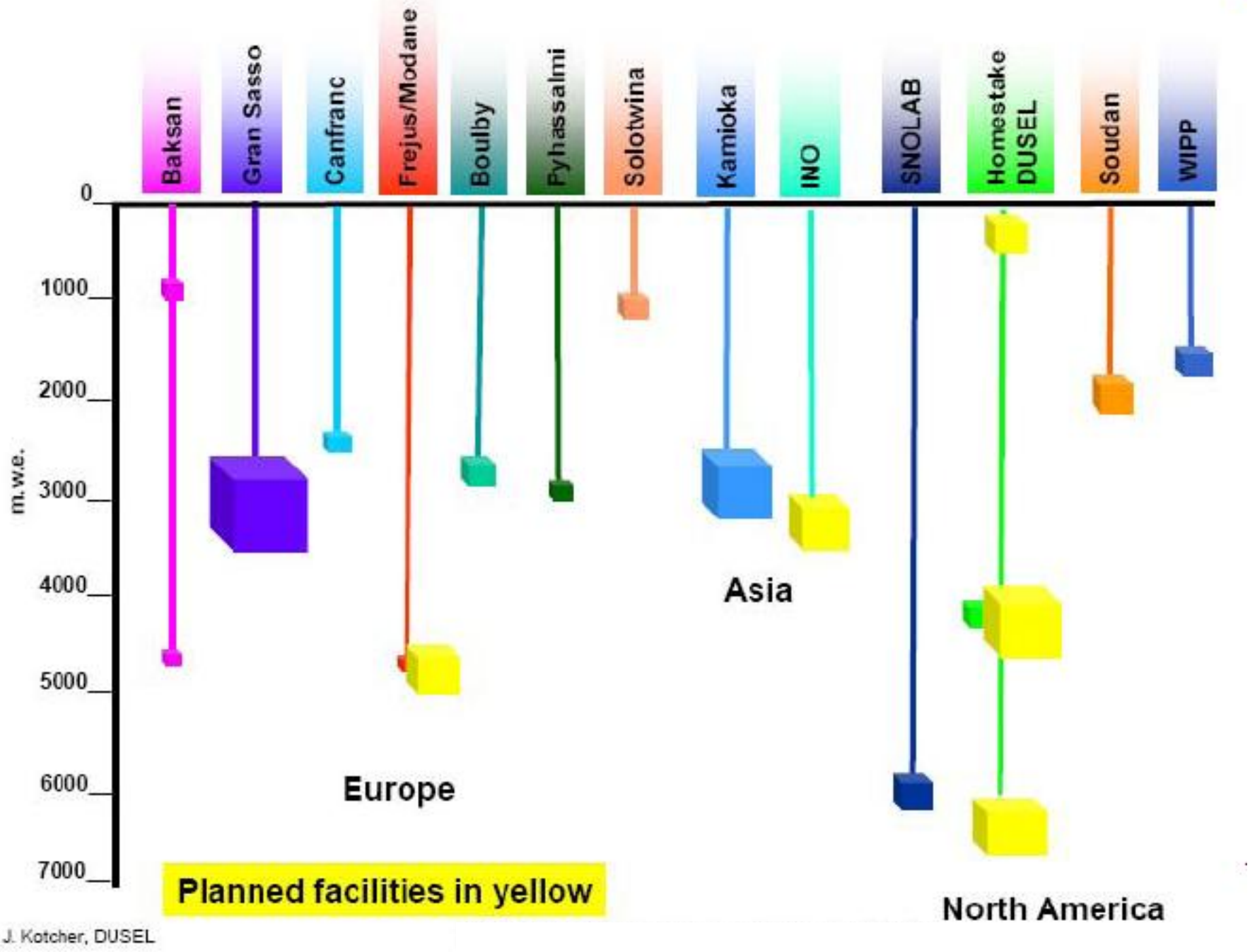
renewal of air in the lab : radon

Access : horizontal (tunnel) or vertical (mine)

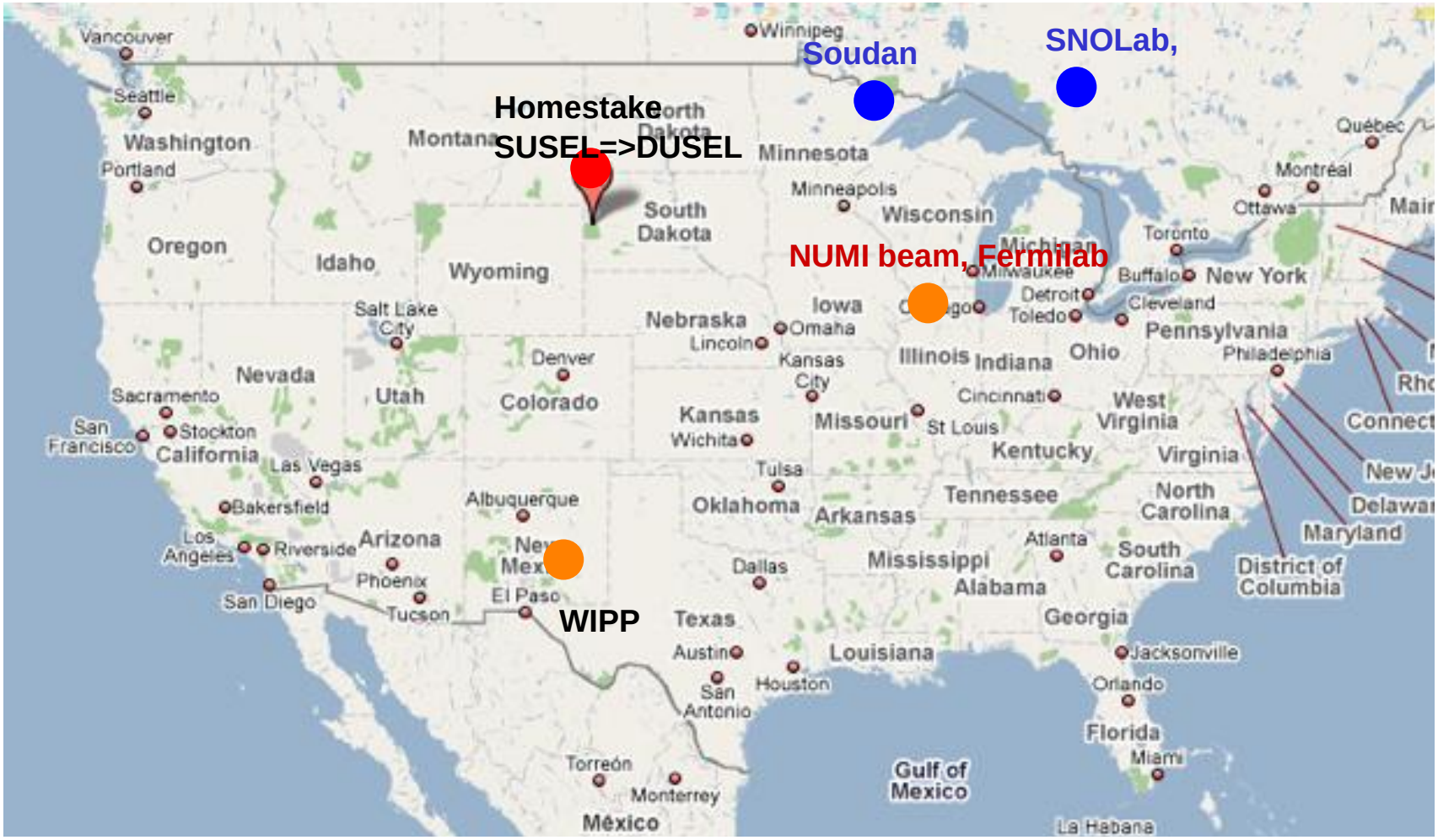
Distance to a beam



Underground Laboratories



North American Laboratories



SNOLAB (Canada)

SNOLAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

Depth: 6000 m.w.e.

Surface: 3000 m2

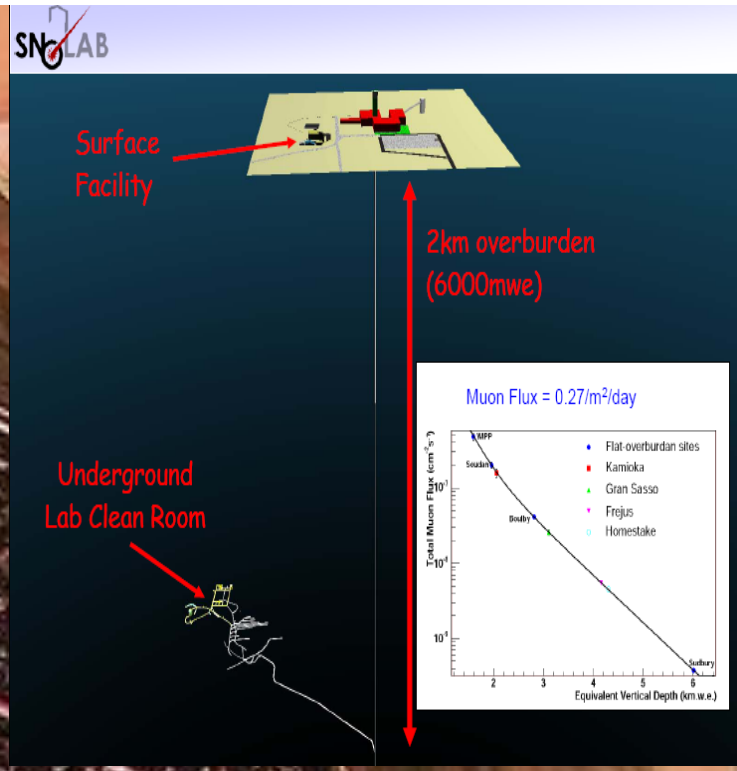
Volume : 30000 m^3
clean room, class 2000, 37 000m^3

Muon flux: 3 10-6 $\mu.m^{-2}.s^{-1}$

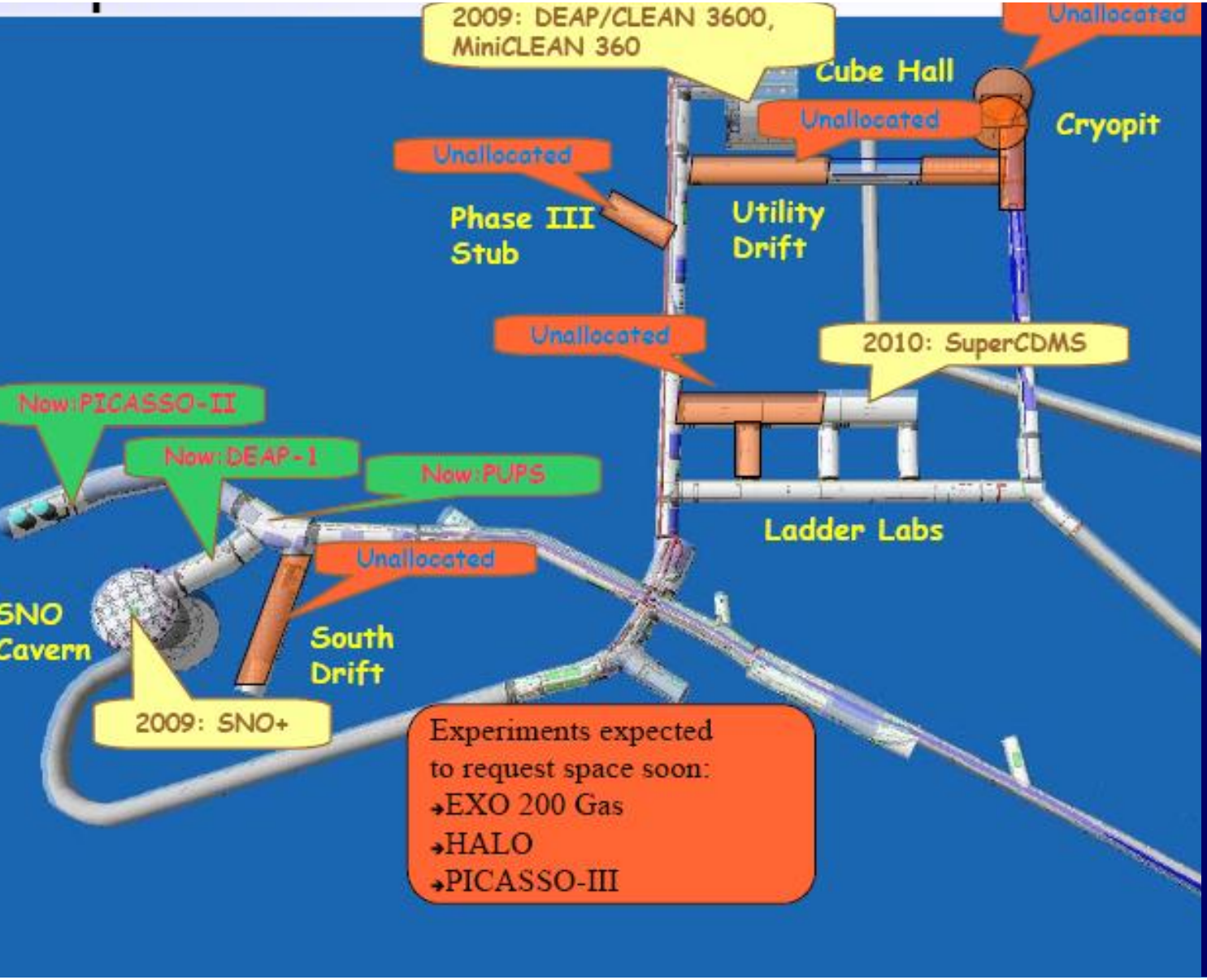
Neutrons:
Fast flux: 4.7 10^{-2} $n.m^{-2}.s^{-1}$
Thermal flux: 4.7 10^{-2} $n.m^{-2}.s^{-1}$

Radon: 120 Bq/m^3

Access : Mine



SNOLAB



Neutrinos:
SNO+ (solar)
HALO Supernovae

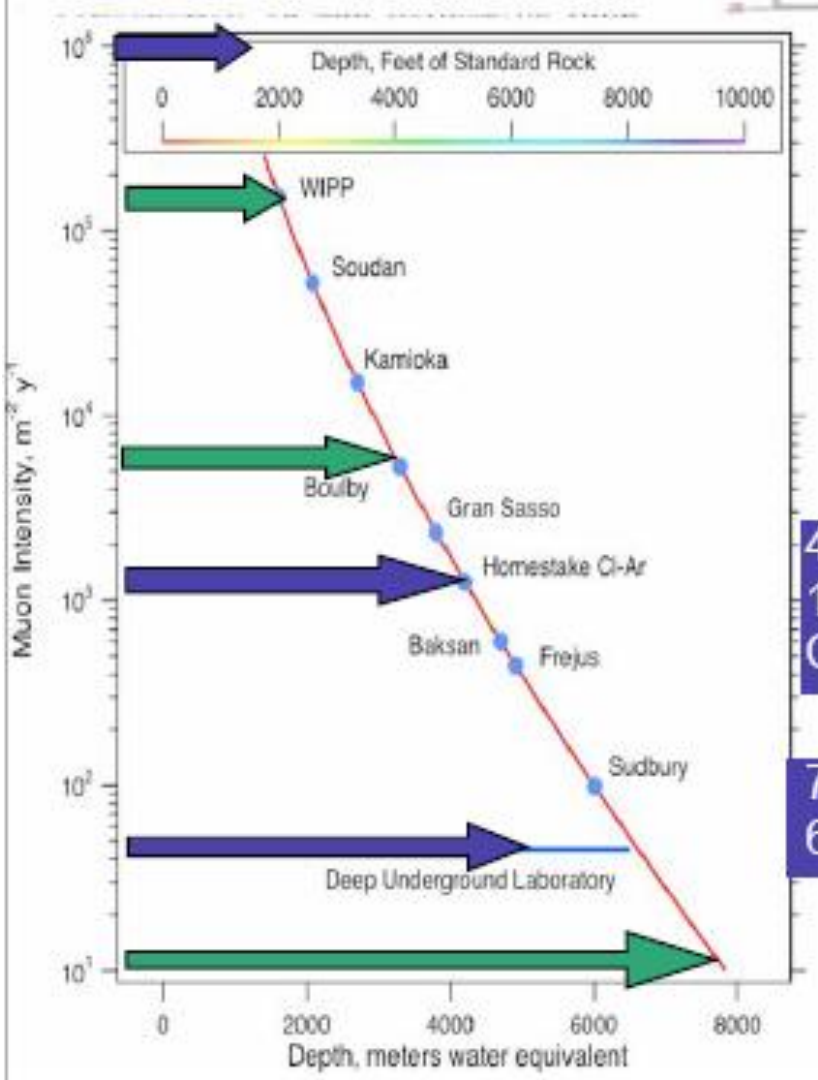
Dark matter:
SuperCDMS
PICASSO
DEAP
CLEAN

Double beta decay:
EXO-200
SNO++

Seismic signal PUPS

DUSEL (USA)

Plans for Research Campuses Optimized for Science



300L R&D E&O 10k ft²

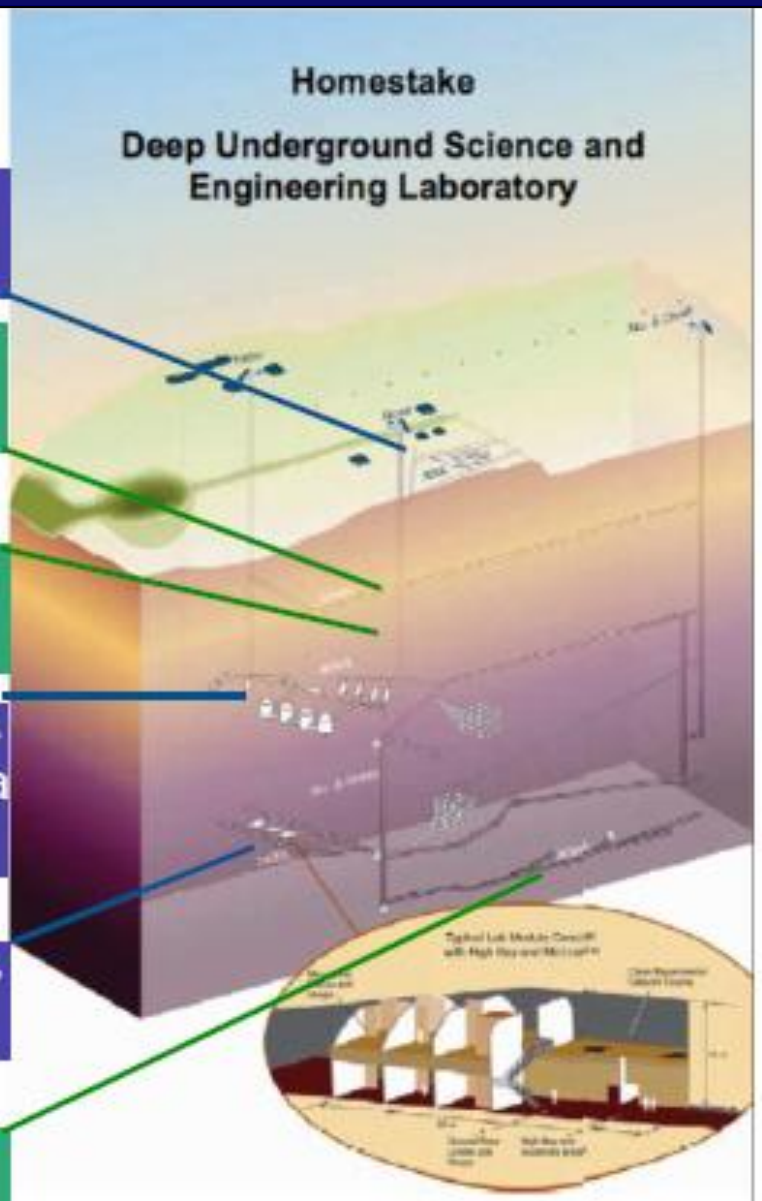
2000L BGE Level

3800L BGE Level

4850L Campus 100k ft² + Mega Cavities

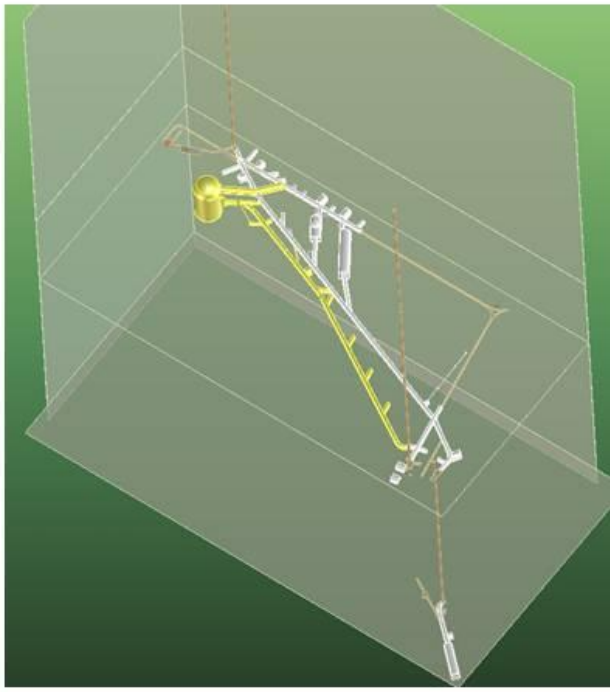
7400L Campus 65k ft²

8000L BGE Lab



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

Asian Laboratories

Kamioka (Japan)

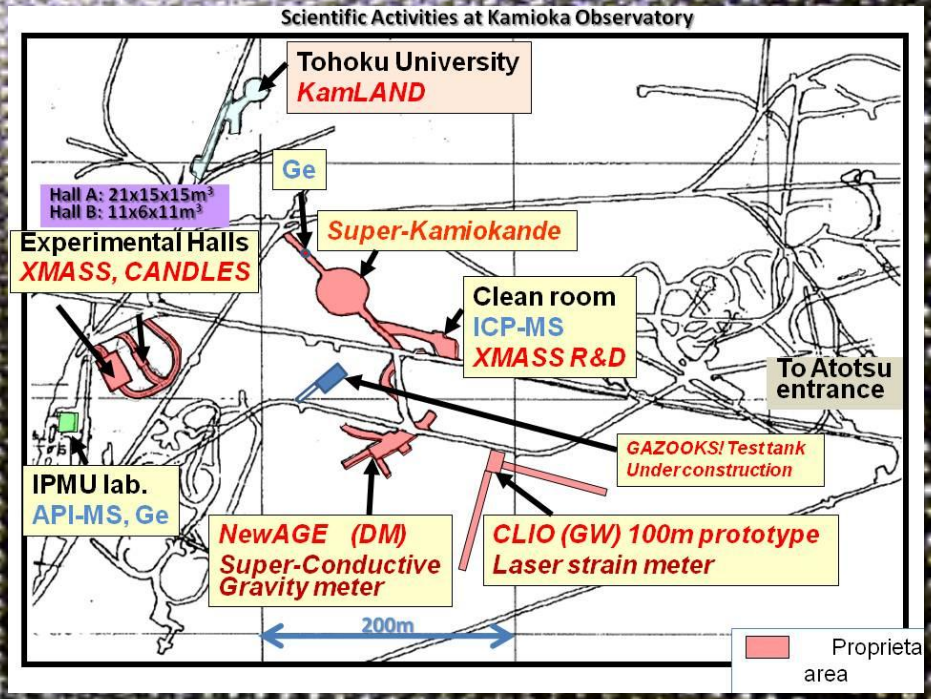
Depth: 2700 m.w.e.

Muon flux 3 10^{-3} $\mu.m^{-2}.s^{-1}$

Neutrons: 8.25 10^{-2} $n.m^{-2}.s^{-1}$

Radon: 40 - 1000 Bq/m^3
2mBq/m^3 for SK

Access: horizontal



Neutrino: Atmospheric, long baseline, reactor,solar SK (T2K,K2K), KamLAND

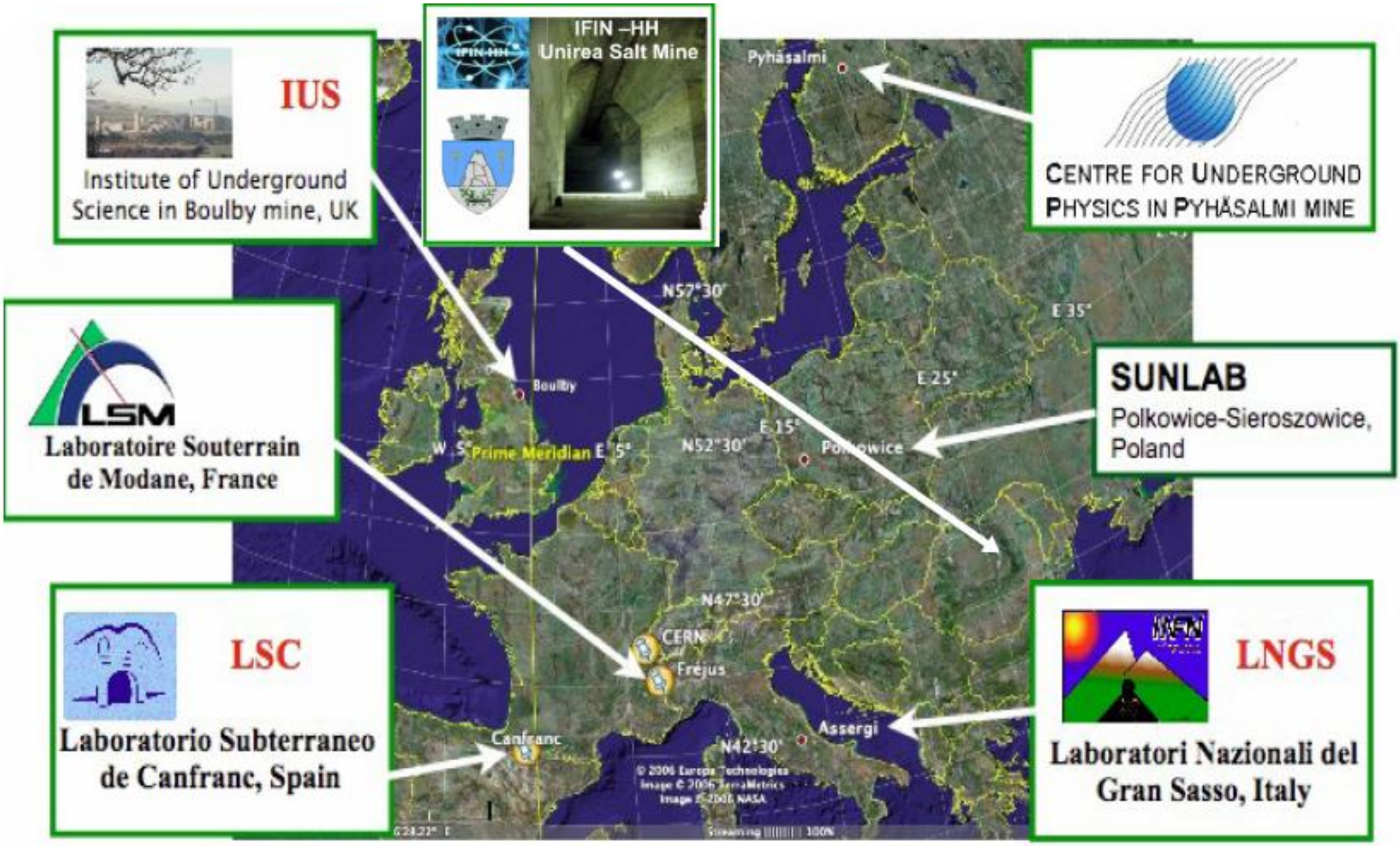
Double beta decay: CANDLE

Proton decay SK

Dark matter: XMASS, NEWAGE

GW antenna: CLIO

DEEP Underground Labs and projects in Europe



DUL in Europe and ILIAS

Integrated **L**arge **I**nfrastructures for **A**stroparticle **S**cience

Aim: to help establish long term integration of Astroparticle Physics in Europe

European Union supported program of 5 years 2004_2009

EU contribution: €7.5 M Participants: ~1500 scientists, 140 institutes, 23 countries

3 prime areas: gravitational waves, dark matter, double beta decay

3 types of activity:

Networking Activities

(N2) Deep Underground science laboratories

(N3) Direct dark matter detection

(N4) Search on double beta decay

(N5) Gravitational wave research

(N6) Theoretical astroparticle physics

Joint Research Activities (R&D Projects)

(JRA1) Low background techniques underground

(JRA2) Double beta decay European observatory

(JRA3) Study of noise in gravitational wave detectors

Transnational Access Activities

(TA1) Access to the EU Deep Laboratories

Coordination of European deep underground labs

CoMAG: board of DUL director

ILIAS-Next proposal → focused on underground science

Gran Sasso (Italy)

Depth: 3200 m.w.e.

Surface: 17 300m2

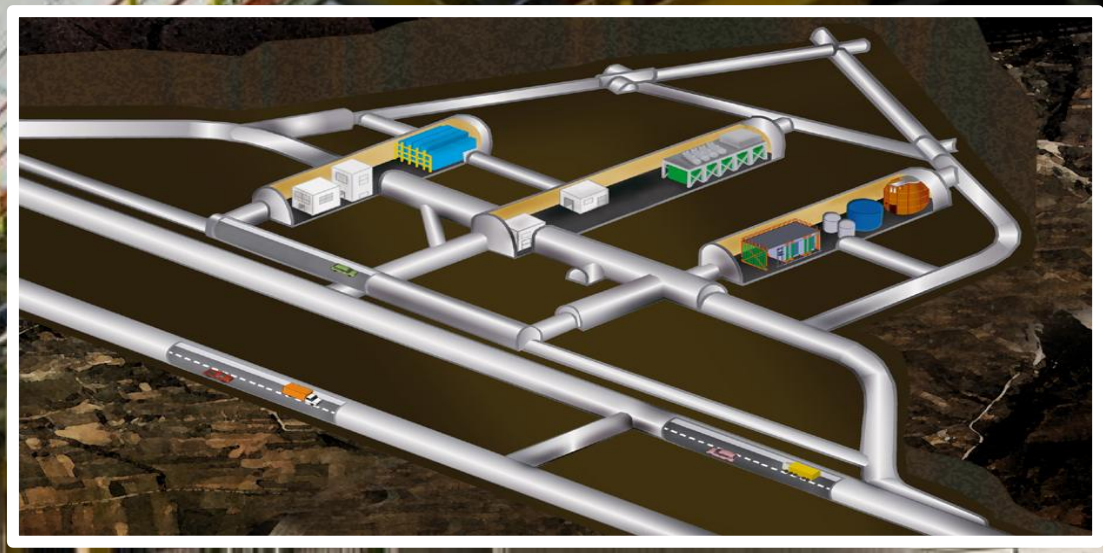
Volume : 180000 m^3

Muon flux: 3 10^{-4} $\mu.m^{-2}.s^{-1}$

Neutrons: 3.8 10^{-2} $n.m^{-2}.s^{-1}$

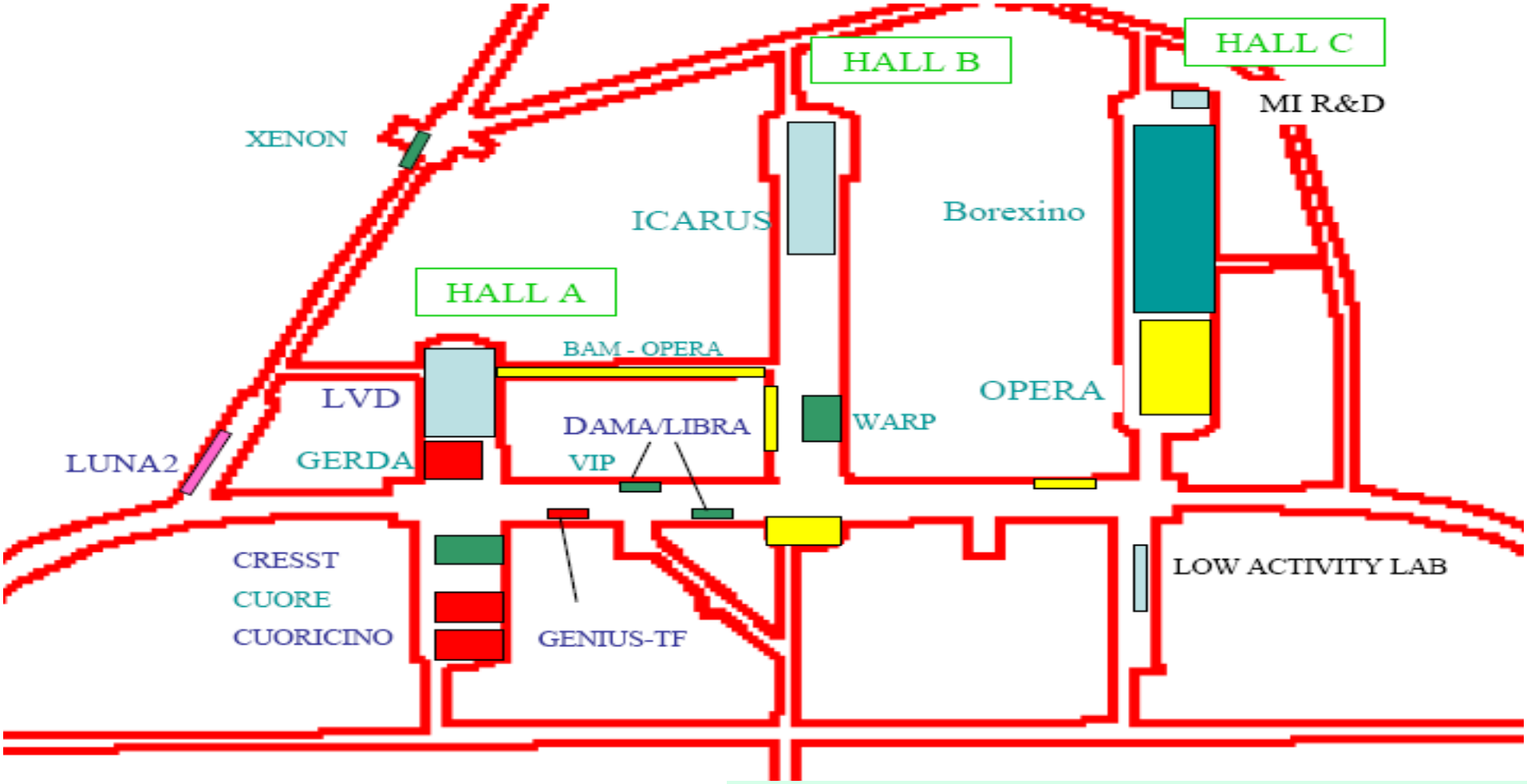
Radon: 50 - 120 Bq/m^3

Access: horizontal



Gran Sasso

Occupancy

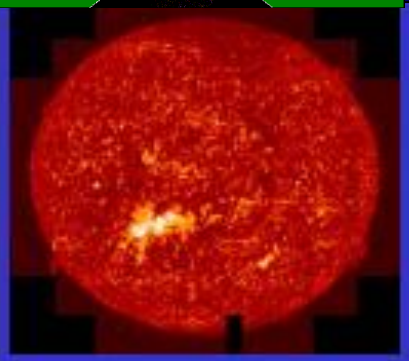


MODULAr perspective

- LAr TPC - ICARUS @ 20 kt scale
- new facility at shallow depth (1.2 km w.e.)
- 10 km off axis the CNGS beam line
- new neutrino source at CERN 1.6 MW beam power

Also Low radioactivity measurements, Geosciences

Gran Sasso



Solar ν

Borexino

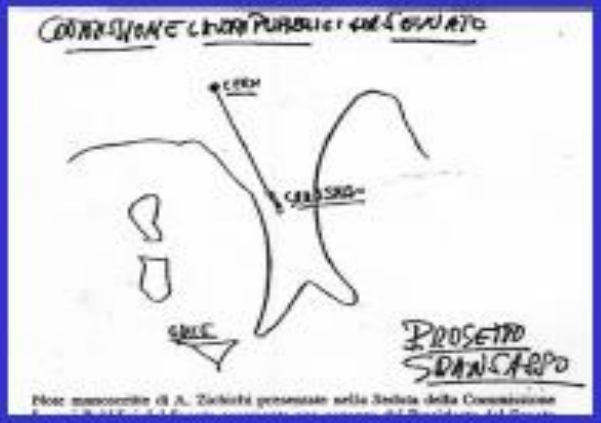
ν from Supernovae

LVD

ν beam from CERN:

OPERA

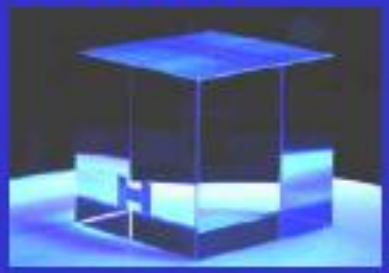
ICARUS



ββ decay and rare events

Cuoricino

CUORE; GERDA



Dark Matter

DAMA/LIBRA; CRESST

WARP; XENON

Nuclear astrophysics

LUNA

Boulby

Boulby (UK)

Depth: 2800 m.w.e.

Surface: 1500m^2

Volume : section limited to 5x10 m^2

Muon flux: 4 10^{-4} µ.m^{-2}.s^{-1}

Neutrons: 1.7 10^{-2} n.m^{-2}.s^{-1}

Radon: 3 Bq/m^3

Access: Mine

Canfranc (Spain)

Depth: 2400 m.w.e.

Surface: 1000m2

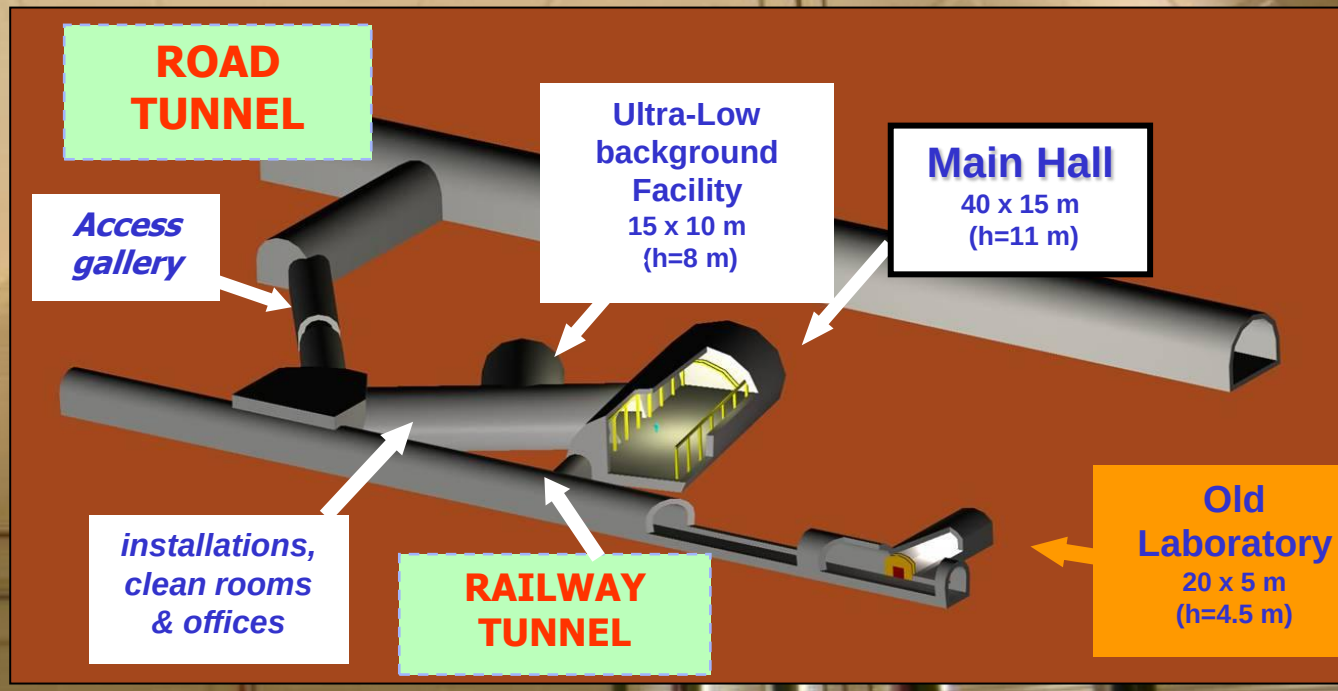
Volume : m^3

Muon flux: $2.4\ 10^{-3}\ \mu.m^{-2}.s^{-1}$

Neutrons: $2\ 10^{-2}\ n.m^{-2}.s^{-1}$

Radon: 50 - 80 Bq/m^3

Access: horizontal



End of civil work: June, 2010

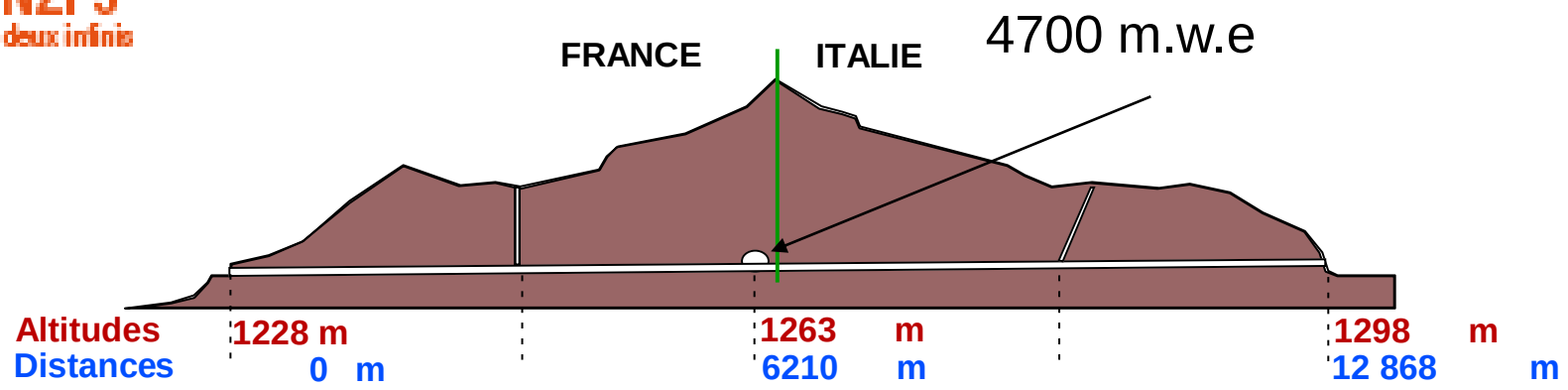
Canfranc (Spain)

Scientific Program

- ✓ EXP-01-2008 (**ANAIS**) Dark Matter (NaI, Annual modulation)
  Direct check of DAMA/LIBRA result
- ✓ EXP-02-2008 (**ROSEBUD**) Dark Matter (Scintillating bolometers)
  Integrated in the European EURECA project
- ✓ EXP-03-2008 (**BiPo**) $0\nu2\beta$ decay (extra-low surface background meas.)
  Ancillary to Super-NEMO
- ✓ EXP-04-2008 (**ULTIMA**) Super-fluid ^{3}He physics
  To be screened by muon background
- ✓ EXP-05-2008 (**NEXT**) $0\nu2\beta$ decay (Enriched ^{136}Xe TPC))
  Majorana vs Dirac neutrinos
  CUP Consolider
- ✓EoI-02-2005 (**ArDM**) EoI on Dark Matter (Liquid Argon TPC)
  In risk analysis phase

CUNA project: Accelerator (~ 3 MeV)

Laboratoire Souterrain de Modane



Built for τaup experiment (proton decay) in 1981-1982

Laboratoire Souterrain de Modane

Depth: 4800 m.w.e.

Surface: 400 m2

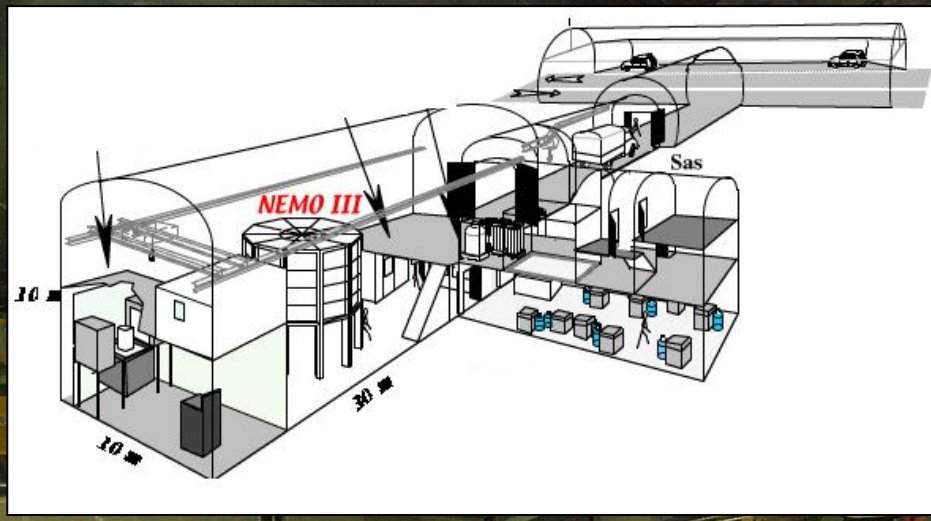
Volume : 3500 m^3

Muon flux: 4 10^{-5} $\mu.m^{-2}.s^{-1}$

Neutrons:
Fast flux: 4 10^{-2} $n.m^{-2}.s^{-1}$
Thermal flux: 1.6 10^{-2} $n.m^{-2}.s^{-1}$

Radon: 15 Bq/m^3

Access : horizontal



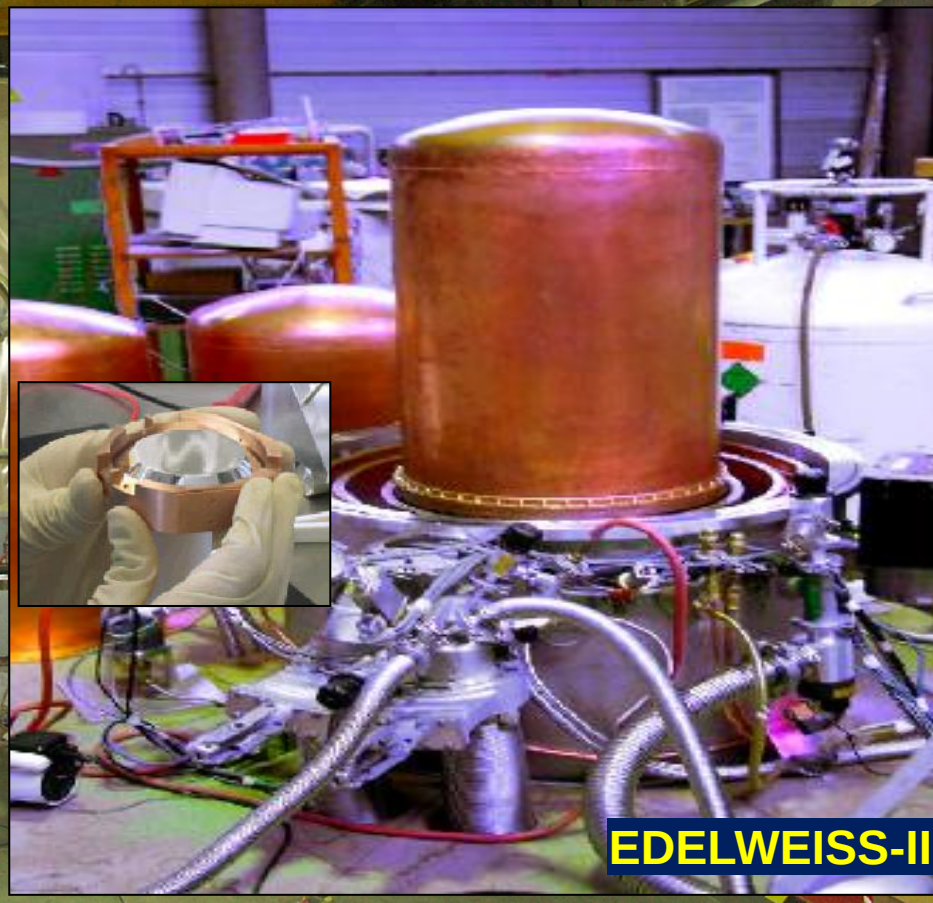
New External building

New infrastructure for offices, workshop, outreach space

The LSM today

Double beta decay **NEMO-III (tracking + calorimeter - ^{100}Mo 7 kg)**

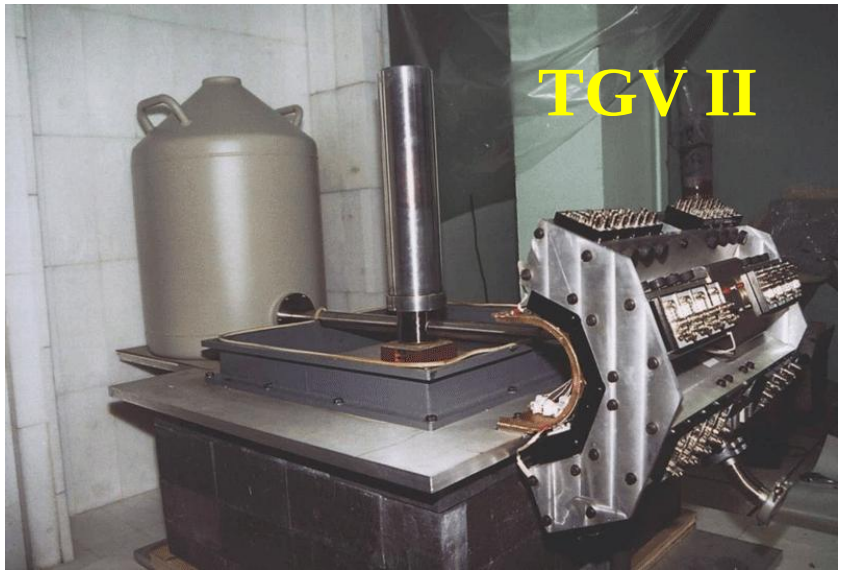
Dark Matter **EDELWEISS-II (10 to 35 kg Ge heat+ion)**



The LSM today

Double EC TGV-II (Ge with sheets of Double EC candidates)

Heavy elements SHIN *(*super heavy elements in nature, Z=108, A=280)



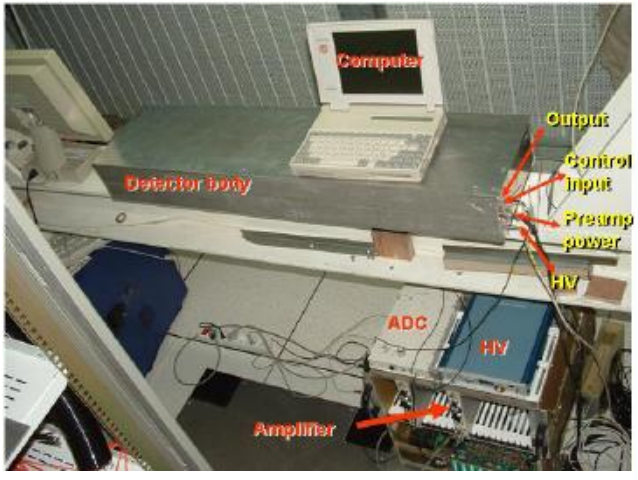
SHIN

BiPo (related to SuperNEMO)

Radon detectors Saga University (Japan) and Dubna (Russsie))

The LSM today

Neutron detectors at LSM



^{3}He counters

Sphere TPC

Gd loaded liquid scintillator

Support from ILIAS TARI for the 3 detectors

Logical test Failure

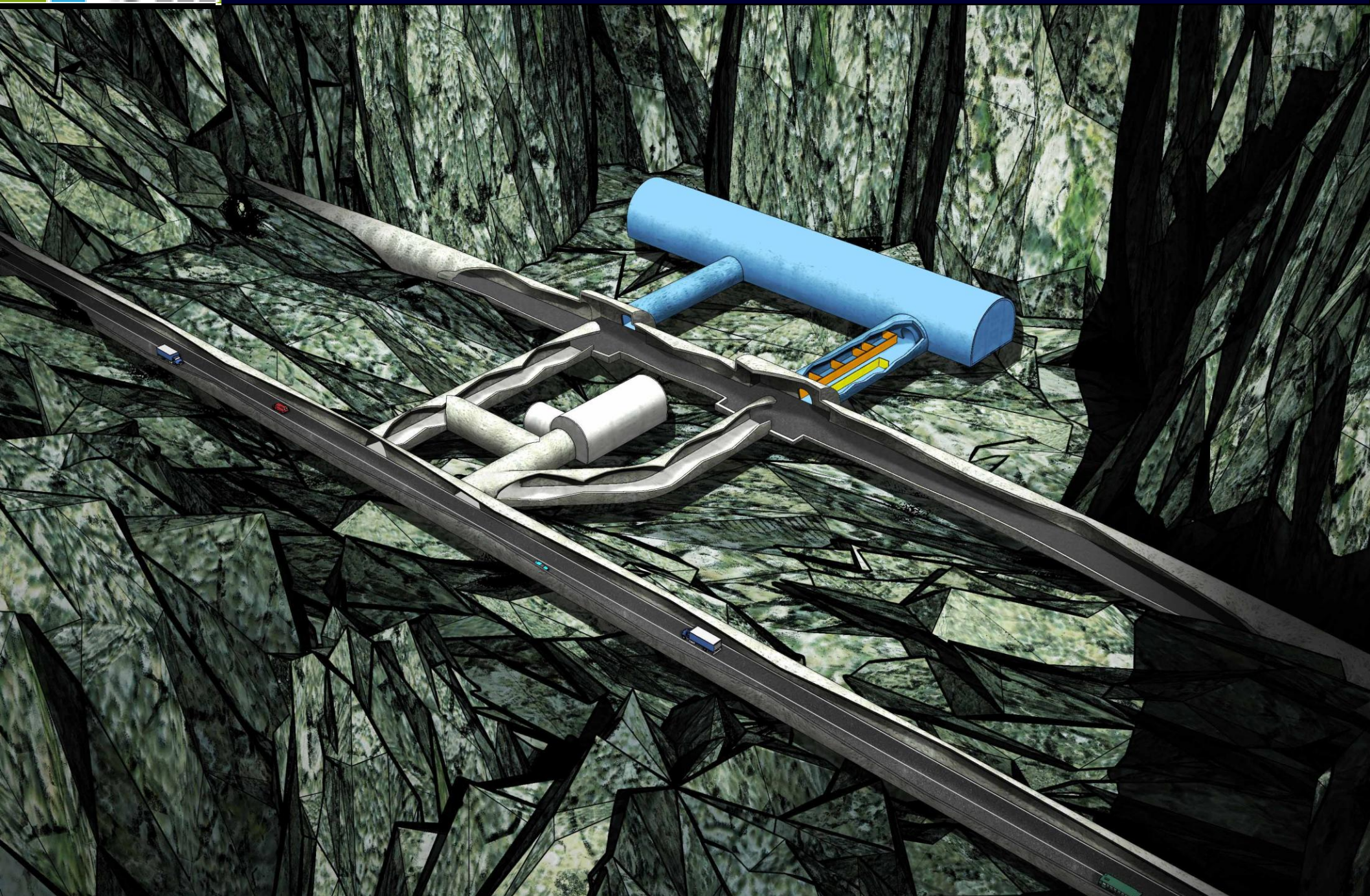
LSM is reference lab for JEDEC norm

Laboratoire Souterrain de Modane

13 HPGe from 6 different laboratories of CNRS and CEA are available at LSM

- Material selection for astroparticle physics,
- Environnemental research (oceanography, climat, retro-observation,….)
- Environmental survey
- Applications (wine datation, salt origin,…)
- Developements of Ge detector (ILIAS)

Extension LSM



ULISSE Project

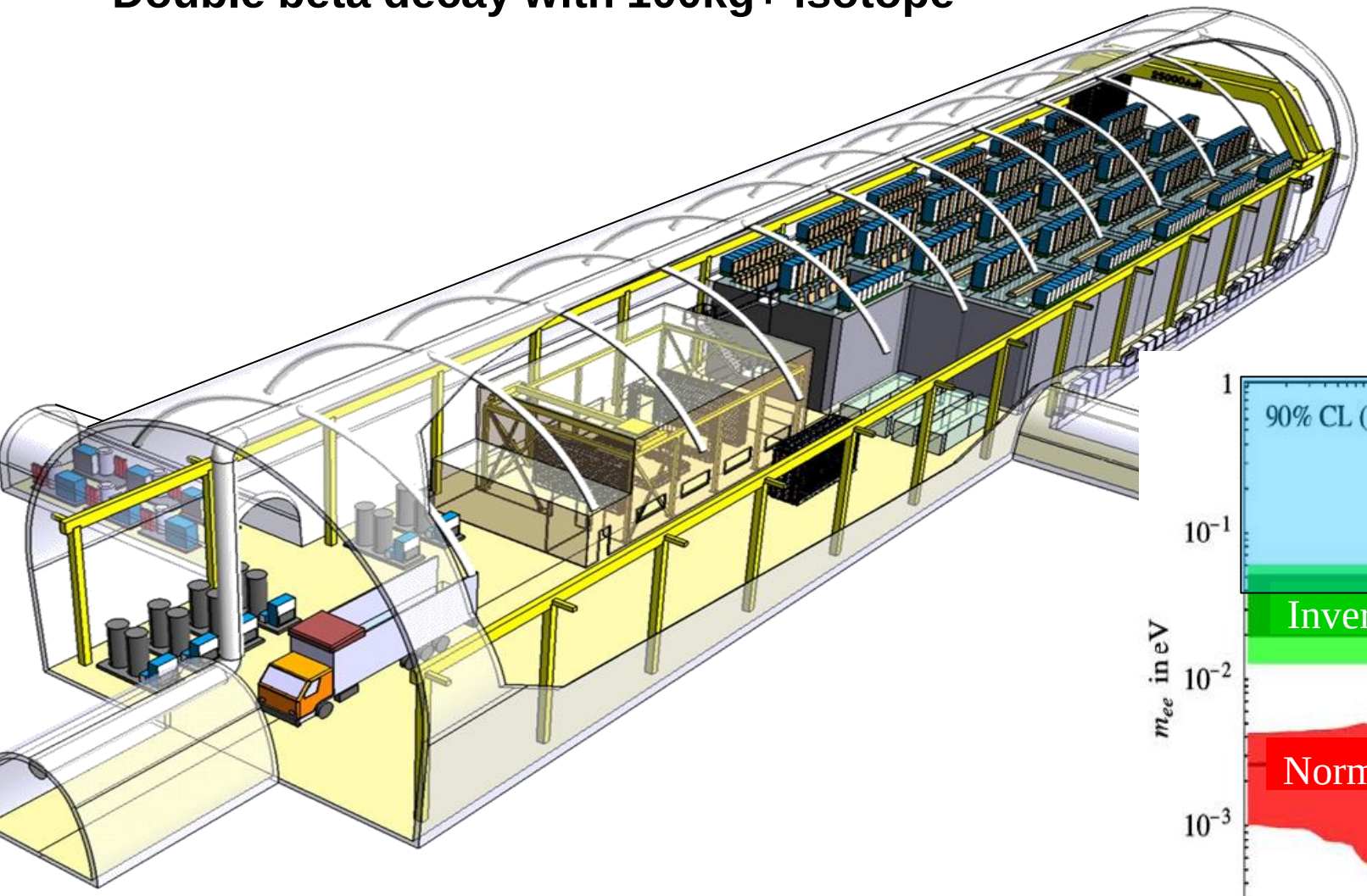
An unique opportunity

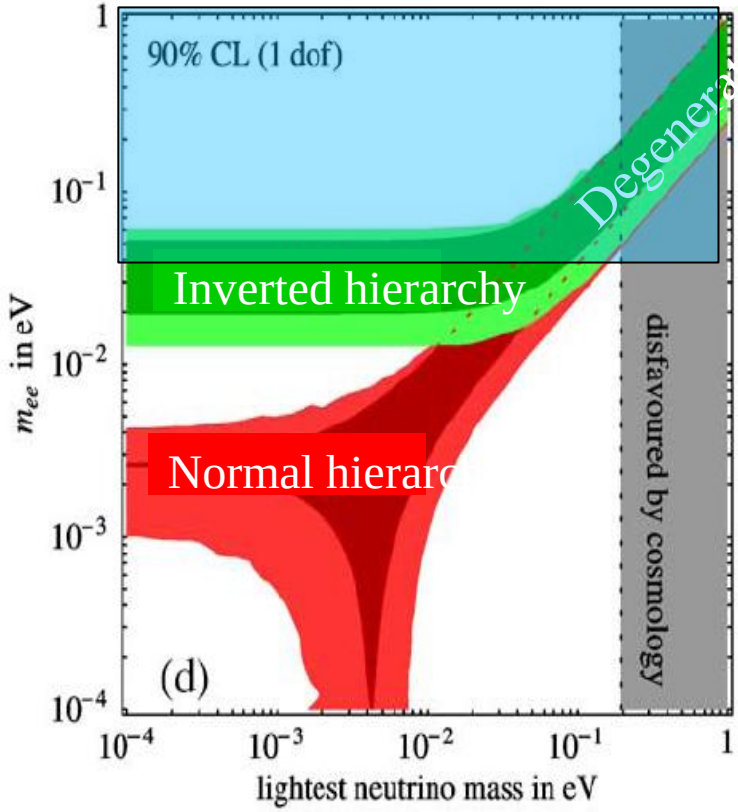
- **Deepest site in Europe (4800 mwe)** (Deepest in Pyhasalmi mine is deeper)
- **Known and « good » site (low convergence, dry, stiff rock)**
- **Central location in Europe, easy access (plane, train car)**
- **23 years experience in running such platform**
- **Independent, convenient, safe, horizontal access**
- **European Roadmap (SuperNemo,EURECA,XENON,COBRA …)**
- **Safety gallery work started**
- **Integration of project to tunnel company planning and constraints**
- **Performed pre study : moderate cost**

Opportunity to create an international infrastructure

LSM extension: SuperNEMO project

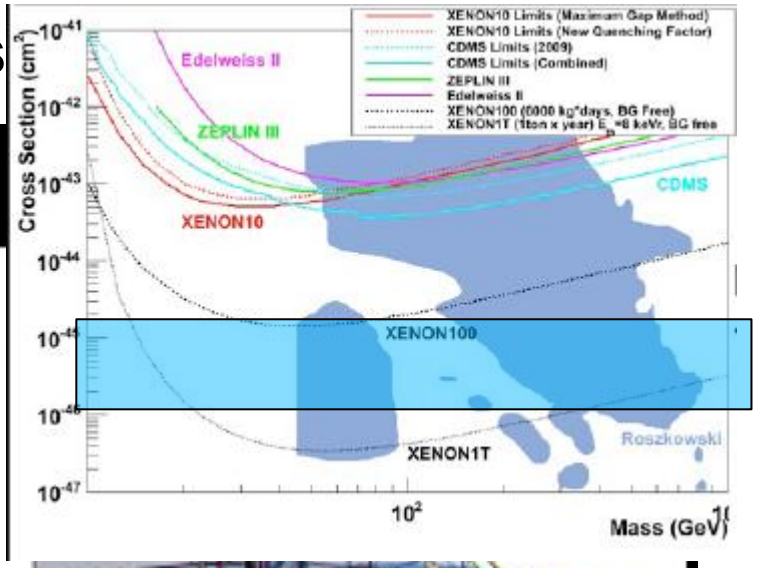
Double beta decay with 100kg+ isotope



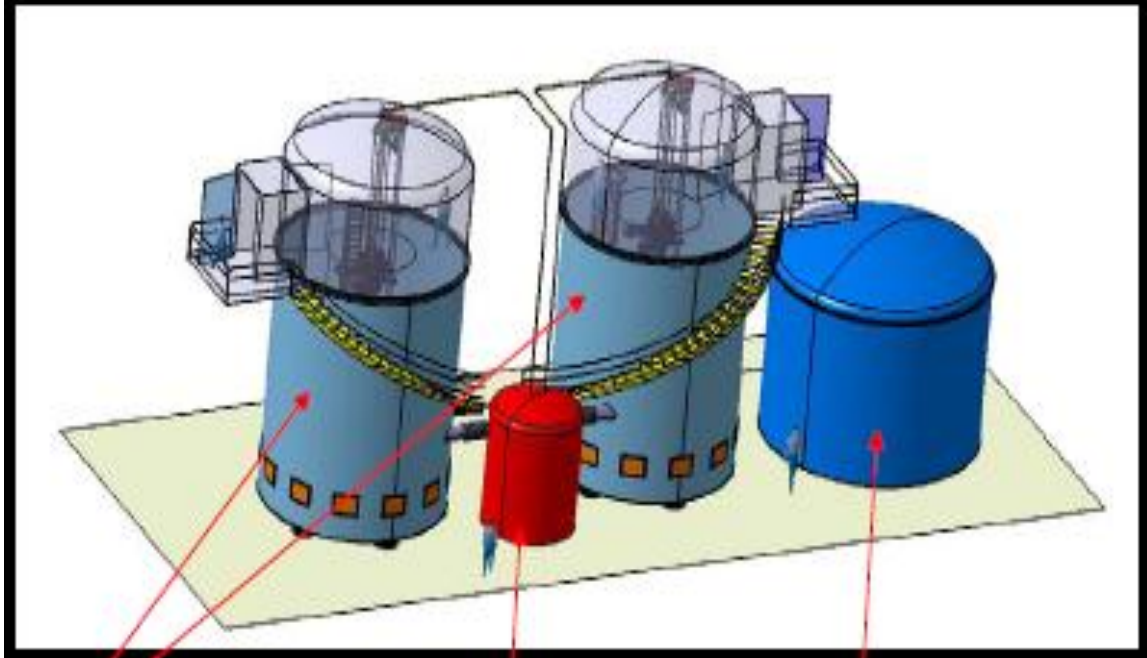


LSM extension: EURECA project

Dark matter search with 1 ton bolometers



Artist's view of EURECA:

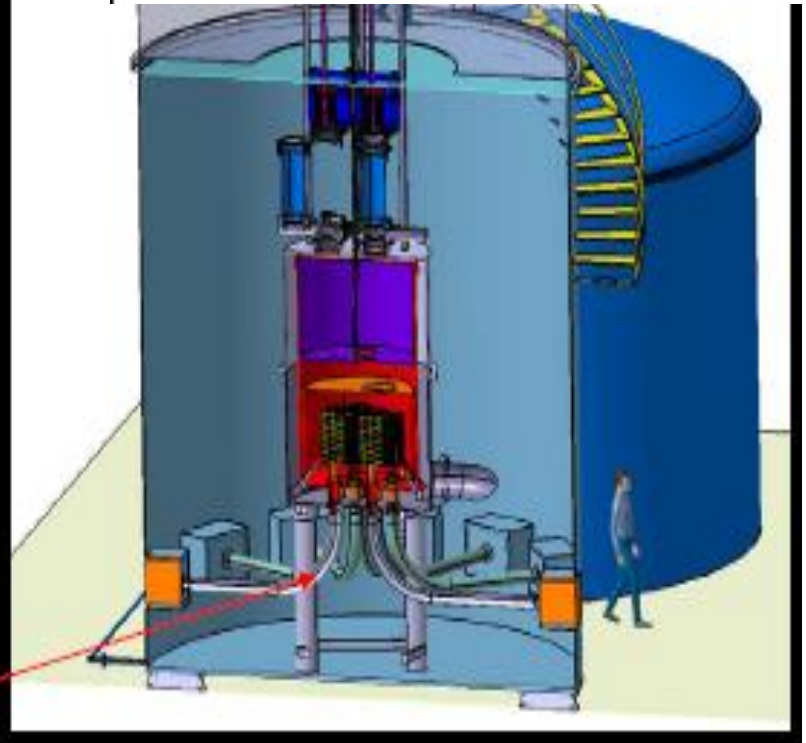


water shieldings

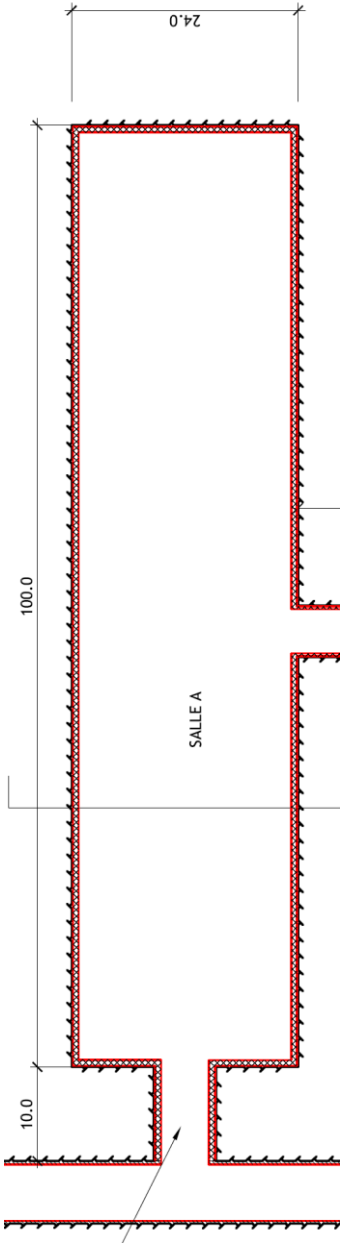
water container

^{3}He/^{4}He dilution unit

„coldfinger" & electronic feedthroughs



LSM extension

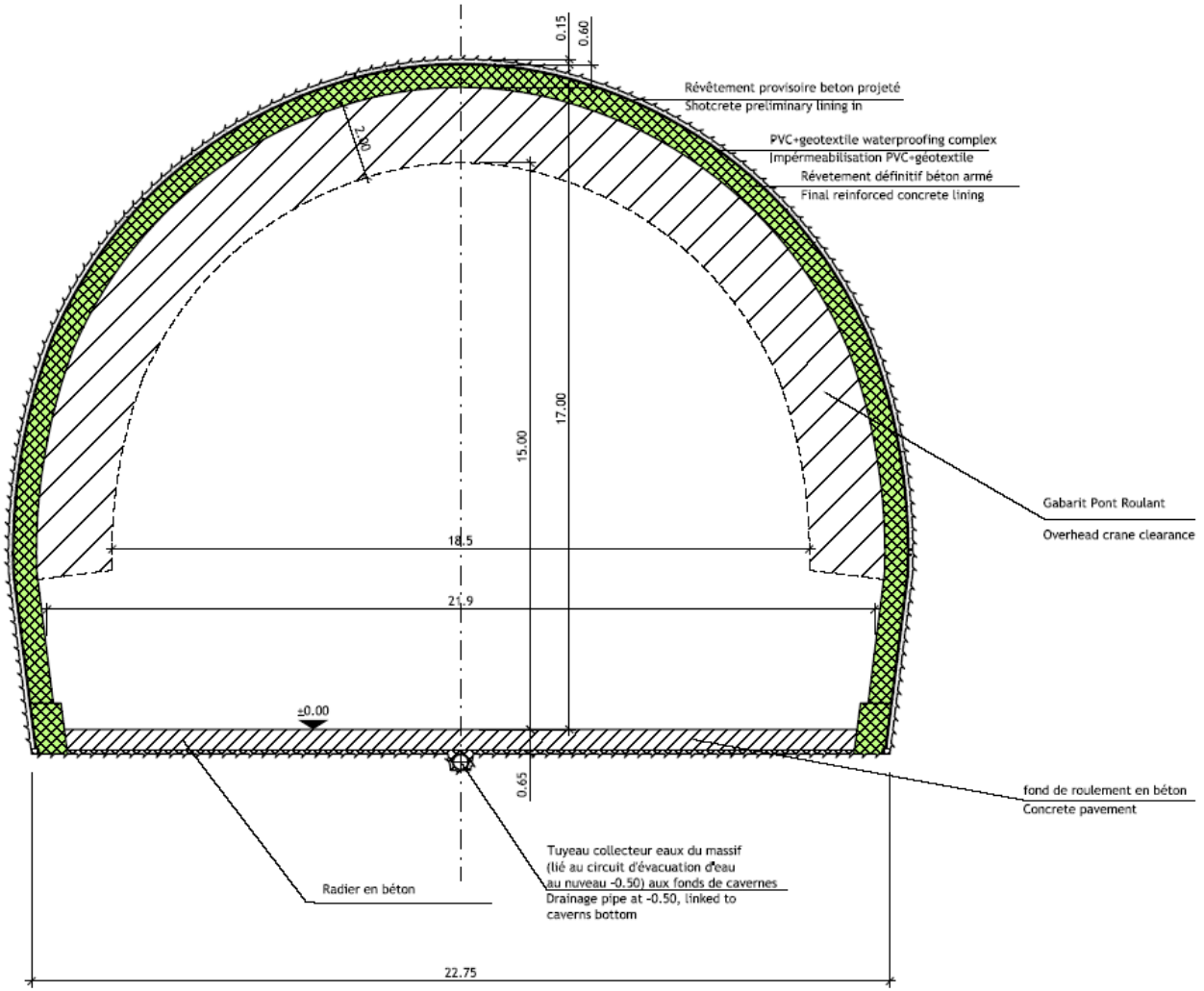


COUPE TYPE SALLE A

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

12 LoI received and one Expression of Interest

Double beta decay:
SuperNEMO (tracko-calo method)
COBRA (solid TPC)

Dark matter:
EURECA (Bolometers)
DARWIN (noble liquid) EoI
MIMAC (TPC)
ULTIMA (Superfluid 3He)

Double EC
TGVIII Double EC (pixellized detector)
Double EC with Ge detectors

R&D for proton decay and neutrino physics

Supernovae neutrinos:
TPC sphere

Logical test failure

Low background techniques

Environmental reasearch

Environmental survey

ULISSE project

- Safety galery work started in September 2009
- Excavation of the extension end 2011.
- In operation in 2013.
- Pre-study funded by LSM and UK in 2006. Preliminary design to host SuperNEMO and EURECA
- Detailed studies funded by Savoie departement and Rhone-Alpes Region
- Review of project and LoI's by an indepeandent Scientific Advisory Committee
- Estimated cost : 10 M€ for civil work
  3 M€ for equipment (ventilation, cooling, electrical power)

Funding in progress

Summary

- 4 deep underground labs are currently in operation in Europe with different specificities and facilities and have complementarities

- Underground faiclities attract new users (environmental sciences, geo-sciences,….)

- ILIAS European program has permitted a cooperation of the European labs on various subjects: science, safety, outreach,...

- The ASPERA/APPEC European roadmap for astroparticule (2009 – 2020) has shown the need of new cavities in Europe

- Projects of new labs and extension around the world.

- For Megaton detector (proton decay, neutrino properties), several sites are studied supported by the LAGUNA European program