World Underground Labs: Status and Plans

Mark Chen
Queen’s University
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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
Underground Labs: Asia

- Kamioka [Japan] beam
- Y2L [Korea] small 100 m²
- INO [India] approved wants beam
- sites in China being explored
Kamioka Observatory

New Lab.: Completed in Feb., 2008
1. XMASS 100~300kg f.v. detector

NewAGE (Dark Matter)
KamLAND
Univ. of Tohoku
Super-Kamiokande

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

200 m
Cavity is completed last month.
New Lab.: Completed in Feb., 2008

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

- undoped $\text{CaF}_2$ ($\text{CaF}_2$(pure))
  - $^{48}\text{Ca}$ (0.187%) $Q=4.27$ MeV
  - 305 kg (III-chika) $10^3\text{cmx96}$
    - 3.4 t (IV) $\sim0.1$ eV
    - 30 t, 2% enriched (V) $\sim30$ meV (best NME)

- Liquid Scintillator (LS)
  - $4\pi$ active shield

- Photomultiplier
  - large photo-coverage

- Water buffer $\rightarrow$ Passive shield
New Lab.: Completed in Feb., 2008
1. XMASS 100~300kg f.v. detector
2. 0νββ detector (48Ca) (prototype)

KamLAND
Univ. of Tohoku

Super-Kamiokande

NewAGE (Dark Matter)

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

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

Kamioka Observatory
**Binary neutron star coalescence @200 Mpc**

- **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 interferometer) ~ 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 m³
- 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]
Muon Flux = 0.27/m²/day

SNOLAB Workshop 4-5 Oct 2008
Existing SNO Facility
Phase I

Existing SNO Facility

Relocate
- Lab Entry
- Personnel Facilities

Utility Area
- Chiller
- Generator
Phase I

Existing SNO Facility

Phase II

Utility Area
- Chiller
- Generator

Relocate
- Lab Entry
- Personnel Facilities
<table>
<thead>
<tr>
<th></th>
<th>Excavation Area</th>
<th>Volume</th>
<th>Clean Rm Area</th>
<th>Volume</th>
<th>Laboratory Area</th>
<th>Volume</th>
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</thead>
<tbody>
<tr>
<td>Existing</td>
<td>20,049 ft²</td>
<td>582,993 ft³</td>
<td>12,196 ft²</td>
<td>470,360 ft³</td>
<td>8,095 ft²</td>
<td>412,390 ft³</td>
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<td></td>
<td>1,863 m²</td>
<td>16,511 m³</td>
<td>1,133 m²</td>
<td>13,321 m³</td>
<td>752 m²</td>
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<td>Existing + Phase I</td>
<td>65,340 ft²</td>
<td>1,367,488 ft³</td>
<td>41,955 ft²</td>
<td>1,049,393 ft³</td>
<td>26,117 ft²</td>
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<td>6,072 m²</td>
<td>38,728 m³</td>
<td>3,899 m²</td>
<td>29,719 m³</td>
<td>2,427 m²</td>
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<td>Existing + Phase I&amp;II</td>
<td>77,636 ft²</td>
<td>1,647,134 ft³</td>
<td>53,180 ft²</td>
<td>1,314,973 ft³</td>
<td>32,877 ft²</td>
<td>1,043,579 ft³</td>
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<td>7,215 m²</td>
<td>46,648 m³</td>
<td>4,942 m²</td>
<td>37,241 m³</td>
<td>3,055 m²</td>
<td>29,555 m³</td>
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Construction (Underground)

- **Excavation:**
  - Phase I: Began Nov 2004, completed May 2007
  - Phase II: Began Jun 2007, completed Jun 2008
  - Total excavation 6000 m² / 39,000 m³.

- **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

completed!
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).
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]
- Pyhäсалми [Finland] wants beam
- Solotvina [Ukraine]
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 $\mu$ reduction = $10^{-6}$ (1/m² h)
underground area: 18 000 m²
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
$\nu$ beam from CERN:
- OPERA
- ICARUS

$\beta\beta$ decay and rare events
- Cuoricino
- CUORE; GERDA

Dark Matter
- DAMA/LIBRA; CRESST
- WARP; Xenon

Solar $\nu$
- Borexino
- LUNA

$\nu$ from Supernovae
- LVD
- Borexino
- ICARUS

SN 1998bu
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
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)
MODANE UNDERGROUND LABORATORY 60'000 m^3 EXTENSION

LUBORATOIRE SOUTERRAIN DE MODANE AGRANDISSEMENT 60'000 m^3

- Actual Modane Underground Laboratory
  Laboratoire Souterraine de Modane (actuel)
- Hall A
  Salle A
- Hall B
  Salle B
- Fréjus Safety Tunnel
  Galerie de Sécurité du Tunnel du Fréjus
- Laboratory Bypass Access
  Bypass d'accès au Laboratoire
- New LSM Entrance
  Nouvel Accès au LSM
- Shelter 18
  Abri 18
- Pedestrian Cross-Adit
  Bypass Piétonne
- Fréjus Road Tunnel
  Tunnel Routier du Fréjus

ULISSE
e.g. SuperNEMO in Modane Expansion

**LSM hall A**

Vertical cut facing EAST

- **Crane clearance**
- **Moving out a module**

- **Water shield vessel**
  - **25t**
  - **6300 m³**

- **Magnetic cell**
  - **18.5m**

- **10t**

- **4m**

- **15m**
HALL A (SuperNEMO type)

100x24 m²
HALL B: Dark matter (EURECA, liq.Xe,...)
**ULISSE project**

Realistic planning!

### ULISSE timetable

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<td>0.1</td>
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<td>1</td>
<td>6</td>
<td>7</td>
<td>cavity</td>
<td>cavity</td>
<td>1</td>
<td>equip</td>
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</table>
A new very large laboratory in Europe?
MEgaton Mass PHYSics

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

The estimated overall cost is $80 \text{ M€} \times \text{Nb of shafts}$

Current choice: 3 shafts
(1 shaft $\approx 150kT$ 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

<table>
<thead>
<tr>
<th>Feature</th>
<th>Measurement</th>
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<tbody>
<tr>
<td>Depth</td>
<td>900 m (2450 mwe)</td>
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<tr>
<td>Main experimental hall</td>
<td>600 m² (oriented to CERN)</td>
</tr>
<tr>
<td>Low background lab</td>
<td>150 m²</td>
</tr>
<tr>
<td>Clean room</td>
<td>45 m² (100/1000 type)</td>
</tr>
<tr>
<td>General services</td>
<td>135 m²</td>
</tr>
<tr>
<td>Offices</td>
<td>80 m²</td>
</tr>
</tbody>
</table>

- 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 experiments 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?