The China Jinping Underground Laboratory (CJPL) and Its Science Programs

- CJPL – History, Status
- Highlights of Science at CJPL-I
- CJPL-II and Potential Science
- Summary & Prospects

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July 28, 2017
Taiwan Research Communities welcome Expanding Connections with Vietnamese Colleagues *(short/long-term visits, any ranks; opportunities for students; institute/group-based collaboration .....)*

To confront the most intriguing problems posed by Nature, the “Future Session” would appropriately be about ”exploring New Parameter Space”, from New Techniques to New Facilities to New Infrastructures to New Communities to New Eco-Systems ..... *(Spirits of Recontres du Vietnam & ICISE)*
Once Upon A Time [How the Story Begins]

- **1997**: TEXONO Program on Low Energy Neutrino Physics at Kuo-Sheng Reactor Neutrino Laboratory (KSNL) since 1997.
- **2002**: Beijing Tsinghua U (THU) – Engineering Physics joined TEXONO program; spearheaded Dark Matter experiment with sub-keV Ge detector at Y2L in South Korea.
- **2008**: Chinese researchers learned (from TV news on 2008/08/08) of the completion of road tunnels under Jin-Ping mountains in Sichuan as part of massive hydro-electric projects.
- **2009/5**: MoU signed between THU & site owner, Ertan (now Yalong River) Hydroelectric Development Company; site excavation begins; Chinese groups expanded to lead the CDEX Program.
- **2010/6**: Site excavation completed; CDEX-1 experiment installation and commissioning starts, following KSNL-Baseline Design. First cosmic-ray event 2010/12.
- **2010/12**: Official Inauguration of China Jinping Underground Laboratory (CJPL).
- **2013/9**: First scientific results from CDEX-1 (PRD14).
Merits: 2400+ m rock overburden; drive-in road tunnel access; superb supporting infrastructures

Operated & Managed by THU & YLRHDC

CJPL-I (2010): 6X6X40 m cavern

CJPL-II (2017-18): [ 4X(14X14X130 m) Halls ] + Pits
Yalong River (雅龍江) & Jinping Mountain (錦屏山)
Good Supporting Infrastructures

Road from Xichang (西昌)

Tunnel Entrance

Campsite #1

Campsite #2
In the Neighbourhood ......

Jinping-I Dam
[Tallest Dam in the World, at 305 m]

Satellite Launch Site @ Xichang
Starting with plans & sketches ….

China, others dig more and deeper underground labs

From tiny to gargantuan, experiments are in the works to exploit the shielding from cosmic rays that being deep underground offers.
First Site Visit 2009/3

Excavation Started 2009/7

Hall-A Excavation Completed 2010/6/20

Measurements Started 2010/9/27

Inauguration (2010/12/12)
Most ambient background measured: neutrons, γ-rays, radon.....

\[ 4.8 \pm 0.9 \times 10^{-9} \text{ cm}^{-2} \text{ s}^{-1} \]

First Triple Coincidence (Cosmic-Ray)
Date: 2010/12/02
Time: 04:49:19

\[ \sim 60 / \text{yr-m}^2 \ [ \sim 1 / 6 \text{ day-m}^2 \] 
(c.f. \sim 100 \text{ Hz/m}^2 @ sea-level)

Consistent with expectations

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**Table 2: Summary of the environmental radiation background measurements at the main experiment hall of China Jinping Underground Laboratory, Phase I**

<table>
<thead>
<tr>
<th>Background radioactivity</th>
<th>Detection techniques</th>
<th>Measurement results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmic muon flux (12)</td>
<td>Plastic scintillator telescope</td>
<td>( (2.0 \pm 0.4) \times 10^{-10} \text{ cm}^{-2} \text{ s}^{-1} )</td>
</tr>
<tr>
<td>Radioactivity of bedrock (58)</td>
<td>In situ high-purity germanium detector</td>
<td>3.69 ± 0.21 Bq kg(^{-1})</td>
</tr>
<tr>
<td>232Th series ( ^{40}K )</td>
<td>In situ high-purity germanium detector</td>
<td>4.28 Bq kg(^{-1})</td>
</tr>
<tr>
<td>214Pb ( 214Bi )</td>
<td>Ionization chamber</td>
<td>19.88 Bq kg(^{-1})</td>
</tr>
<tr>
<td>232Th series</td>
<td></td>
<td>16.03 Bq kg(^{-1})</td>
</tr>
<tr>
<td>228Ac</td>
<td></td>
<td>7.38 Bq kg(^{-1})</td>
</tr>
<tr>
<td>212Pb</td>
<td></td>
<td>7.48 Bq kg(^{-1})</td>
</tr>
<tr>
<td>209Tl</td>
<td></td>
<td>8.15 Bq kg(^{-1})</td>
</tr>
<tr>
<td>40K</td>
<td></td>
<td>36.67 Bq kg(^{-1})</td>
</tr>
<tr>
<td>Air absorbed dose rate</td>
<td>Ionization chamber</td>
<td>19.27 nGy h(^{-1})</td>
</tr>
<tr>
<td>Inside polyethylene room</td>
<td>Ionization chamber for α counting</td>
<td>0.43 nGy h(^{-1})</td>
</tr>
<tr>
<td>Air radon concentration December 2010–September 2011 (59)</td>
<td>Ionization chamber</td>
<td>101 ± 14 Bq m(^{-3})</td>
</tr>
<tr>
<td>Ventilated January-December 2015</td>
<td></td>
<td>86 ± 25 Bq m(^{-3})</td>
</tr>
<tr>
<td>Unventilated January-March</td>
<td></td>
<td>108 ± 50 Bq m(^{-3})</td>
</tr>
<tr>
<td>Ventilated April-December</td>
<td></td>
<td>45 ± 28 Bq m(^{-3})</td>
</tr>
</tbody>
</table>

**Neutron**

- **Thermal neutron**
  - \(^{3}\)He-proportional tube (60): \( (4.00 \pm 0.08) \times 10^{-8} \text{ cm}^{-2} \text{ s}^{-1} \)
  - Multiple Bonner spheres (61): \( (7.03 \pm 1.81) \times 10^{-6} \text{ cm}^{-2} \text{ s}^{-1} \)
- **Fast neutron**
  - Liquid scintillator: \( (1.50 \pm 0.07) \times 10^{-7} \text{ cm}^{-2} \text{ s}^{-1} \)
  - Multiple Bonner spheres (61): \( (3.63 \pm 0.27) \times 10^{-6} \text{ cm}^{-2} \text{ s}^{-1} \)
- **Total neutron flux**
  - Multiple Bonner spheres (61): \( (2.69 \pm 1.02) \times 10^{-5} \text{ cm}^{-2} \text{ s}^{-1} \)
Threshold (published results): 450 eVee
CDEX-1 Results on $\chi N$ SI/SD ; solar & DM Axions
PandaX @ CJPL-I

PX2 Target Mass: 580 kg

5 cm OFHC copper (outer vessel)
20 cm polyethylene
2 cm OFHC copper
20 cm lead
40 cm polyethylene
PandaX-I/II Results on $\chi N$ SI/SD
CJPL-Phase II

- ~500m west to CJPL-1
- Construction started 2014
- Rock Excavation completed May 2016
- To be Commissioned Soon...

China supersizes its underground physics lab

Planned expansion could pave way for “ultimate dark matter experiment”

<table>
<thead>
<tr>
<th></th>
<th>CJPL-I</th>
<th>CJPL-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock Work</td>
<td>4100 m³</td>
<td>210000+151000 m³</td>
</tr>
<tr>
<td>Electric Power</td>
<td>70x2 kVA</td>
<td>10x2 MVA</td>
</tr>
<tr>
<td>Fresh Air</td>
<td>2400 m³/h</td>
<td>15000x3 m³/h</td>
</tr>
</tbody>
</table>
- Four 14m*14m*130m Main Halls
- Two Pits: (1) 18(φ)X18(H)m ; (2) 27(L)X16(w)X14(D)m
- Total space: ~300K m³

Each Hall: 14m(H) × 14m(W) × 130m(L)
Plan of Ground Laboratory (~2020)
- offices, workshops, meeting venues, accommodation, logistics (~150 people)
**JUNA**

- First approved program for CJPL-II
- Low Count Rate Accelerator Nuclear Astrophysics Facilities
- Installation 2018
PandaX-ⅩT (LiqXe DM) & PandaX-Ⅲ (GasXe 0νββ) Projects

CJPL-II Hall-B Pit (Foreseen)

Liquid Xe
1st Phase: 4 ton

5×200kg High Pressure Xe-136
CDEX-1T (HPGe DM & $0\nu\beta\beta$) Projects

CDEX-1T Conceptual Layout

Experiment Hall
14m(H) × 14m(W) × 130m(L)

Pit Size:
Ø: 18 m
H: 18 m

Clean room for detector and electronics preparation

Clean room

HPGe Array

Ø18m × 18m Liquid nitrogen

CJPL-II Hall-C Pit (Foreseen)
Towards Ton-scale enriched-Ge76 experiment for neutrinoless double beta decay experiment to cover the “Inverted Hierarchy”

Cast: mainly GERDA, Majorana, CDEX groups

CDEX group – build a case of hosting this experiment at CJPL-II

Next-Generation 0νββ Decay

Observed

$\nu = \bar{\nu}$

Not observed

$\nu$ is Dirac*

Oscillation: Hierarchy

Normal

Inverted

$\nu = \bar{\nu}$

$m_1 > 10 \text{ meV}$

$m_1 < 30 \text{ meV}$

Light Neutrino Exchange

76Ge

76Se

Legend: 47 Institutions, 219 Scientists
Other Potential Users at Advanced Stages:

- Jinping Neutrino Experiment
  - 4 kton liquid scintillator for geo- & solar $\nu$’s
- Studies of Deep Rock Mechanics & Seismology Dynamics
Missing Energy Density Problem is the most intriguing & important one in basic science.

Wide spectrum of experimental techniques deployed; Several anomalous results; Strong Potentials for Surprises in both Theory & Experiments.

New Underground Facilities @ CJPL Built with record speed.

The New Facilities AND Communities add to the world’s arsenal on exciting dark matter & neutrino experiments requiring deep locations.

Open to International Community to Support & Think Hard & Exploit this Golden Opportunity.