Status of CJPL and DURF

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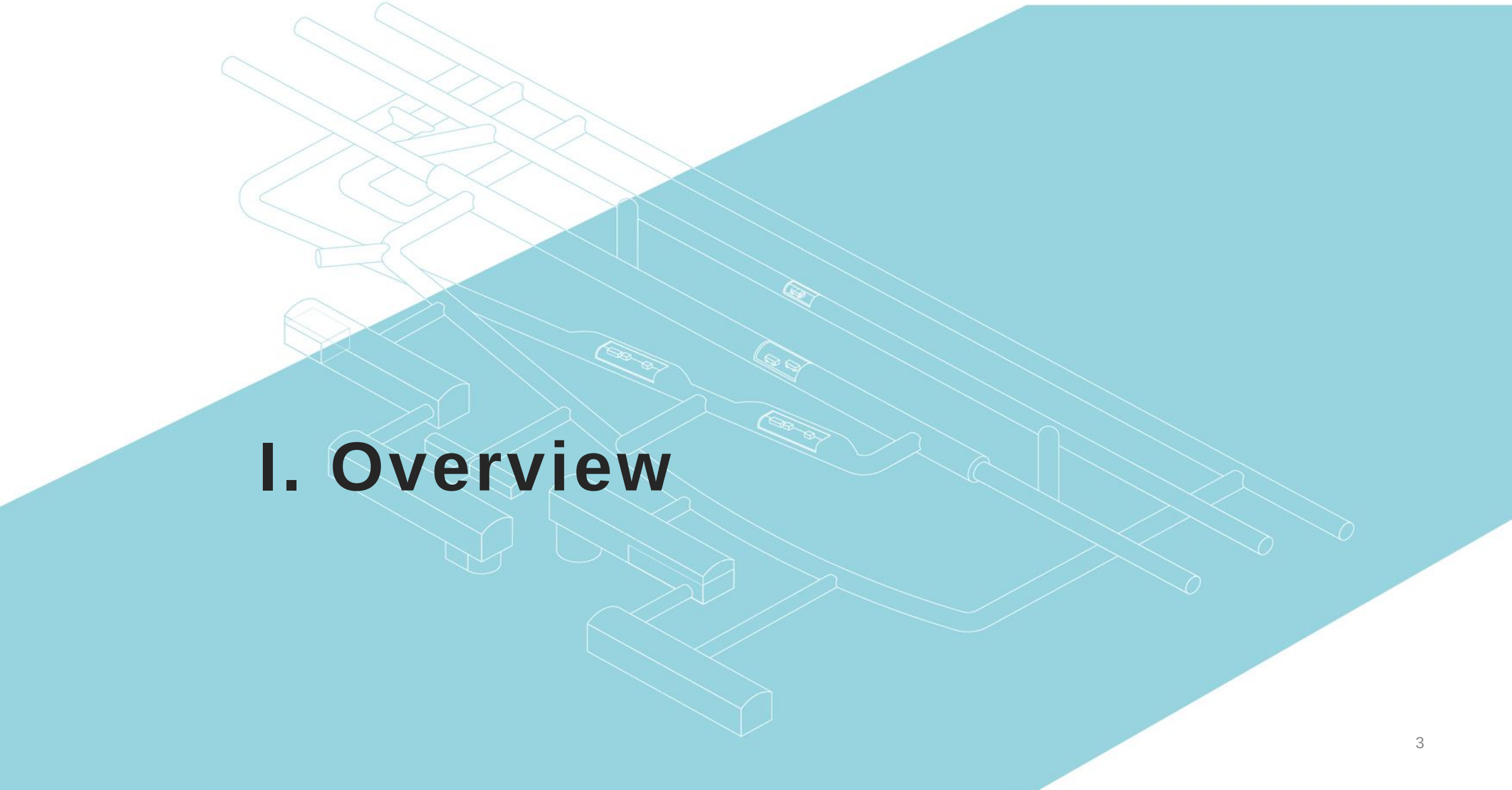
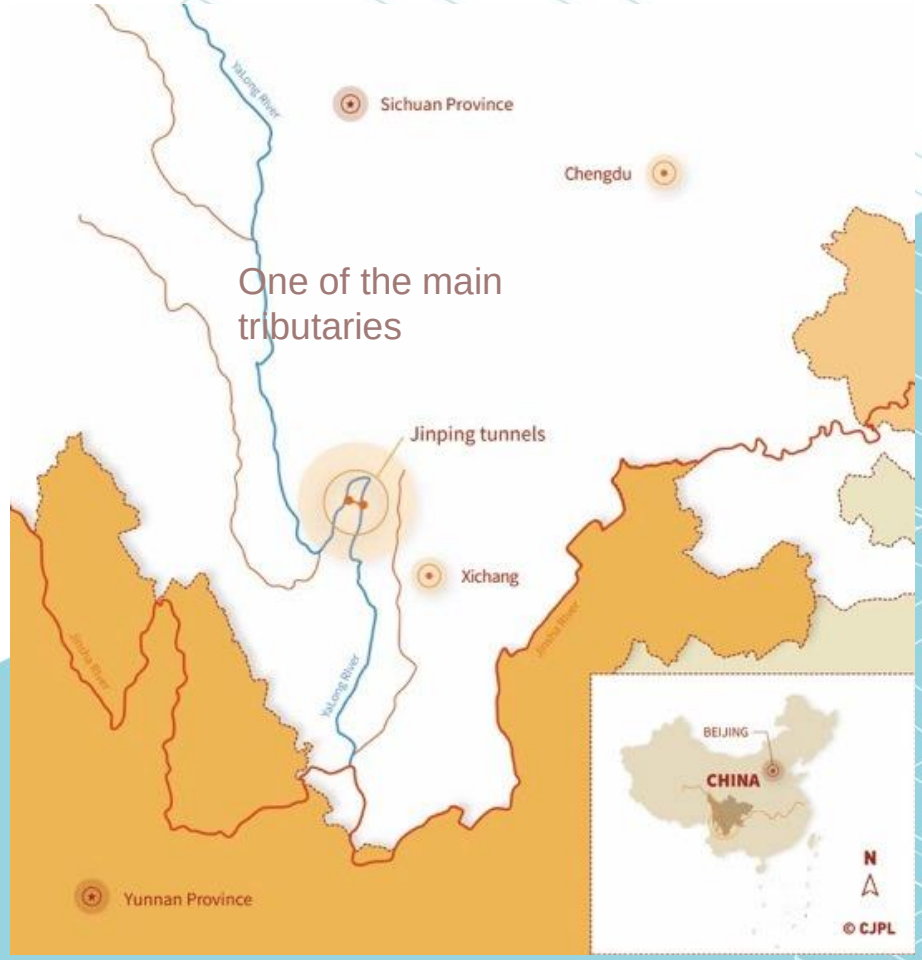
Oct. 30, 2023
Chengdu, China

Contents



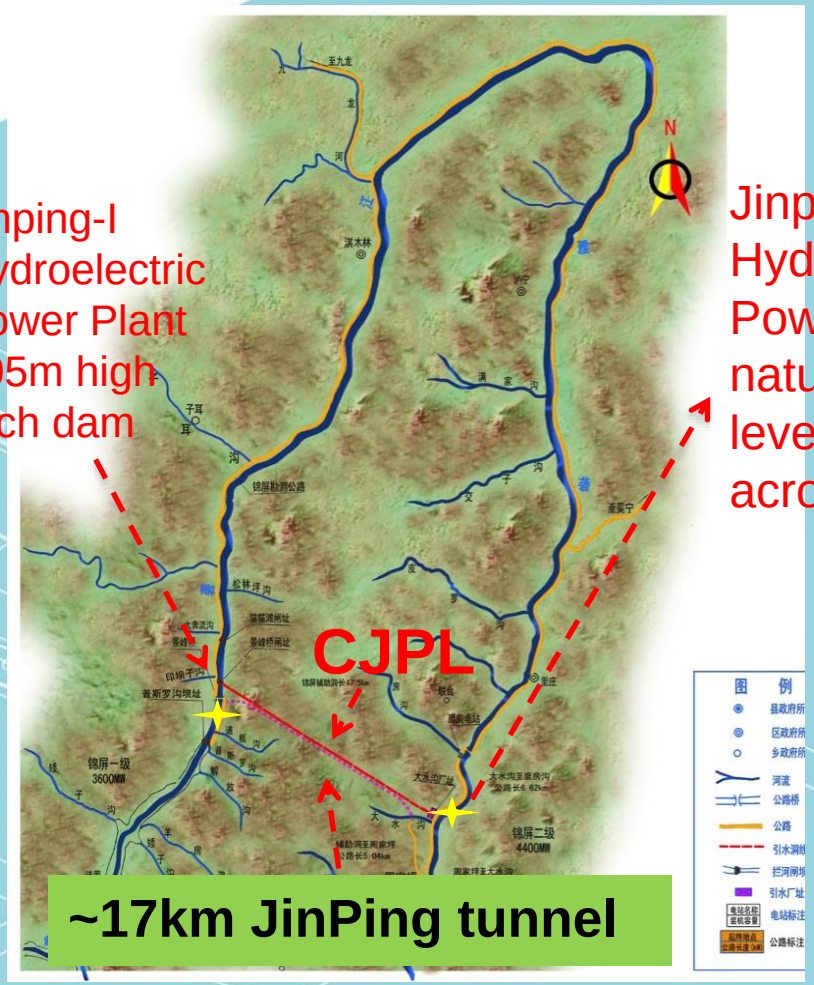
I. Overview

Jinping Hydroelectric Power Plants



Yalong river meets Jinping Mountain:

- The largest tributary of Jinsha River
- Jinping river bend：150km long



Jinping traffic tunnel

- 17.5km long x 2
- **Overburden**: max. 2400m, 73% of length >1500m.
- Finished on Aug. 8, 2008

Tunnel Layout inside Jinping Mountain

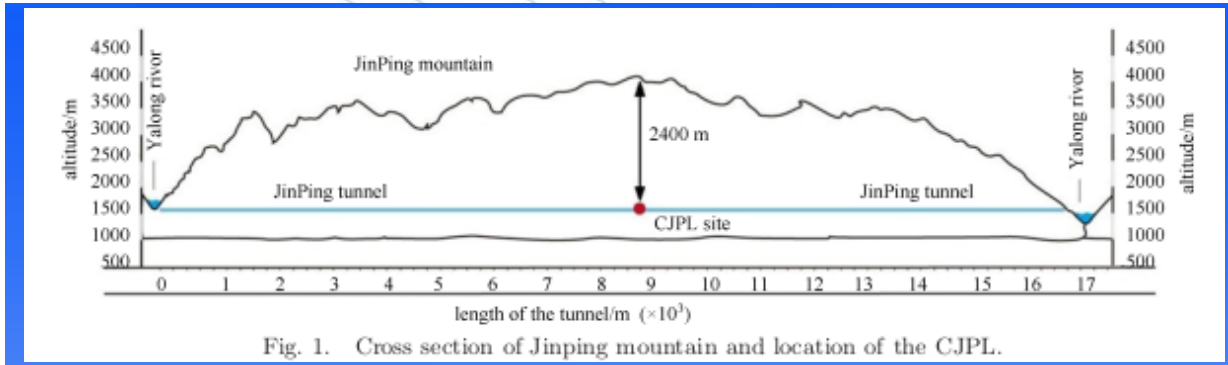


Fig. 1. Cross section of Jinping mountain and location of the CJPL.

West inlet

CJPL-II

CJPL-I

2 traffic tunnels (Jinping Tunnel)

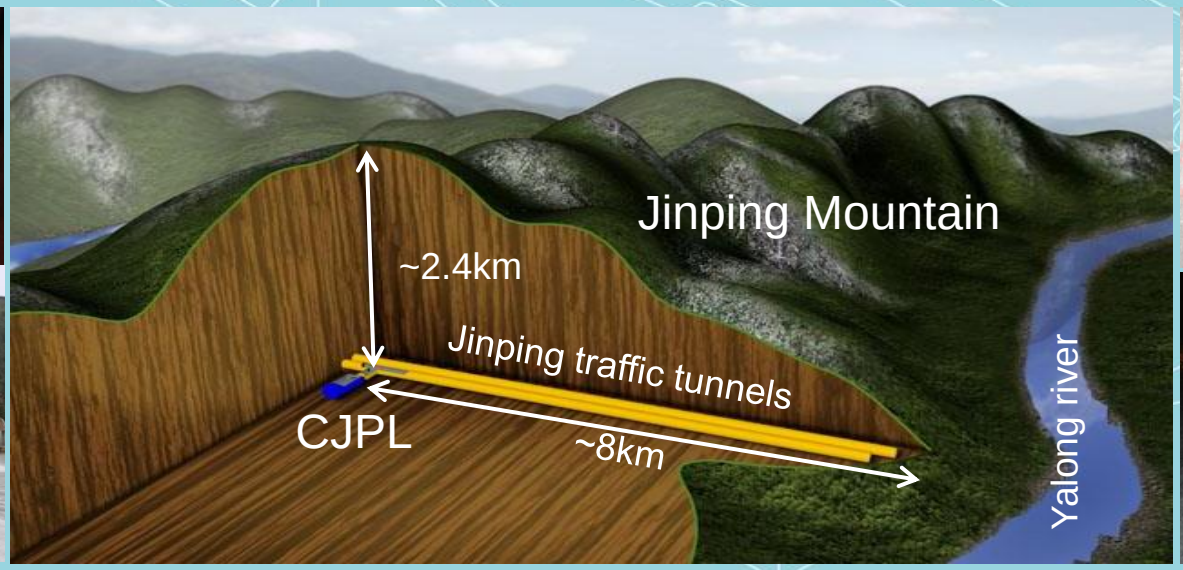
Drain tunnel

power generator

4 hydraulic tunnels for electric power generator

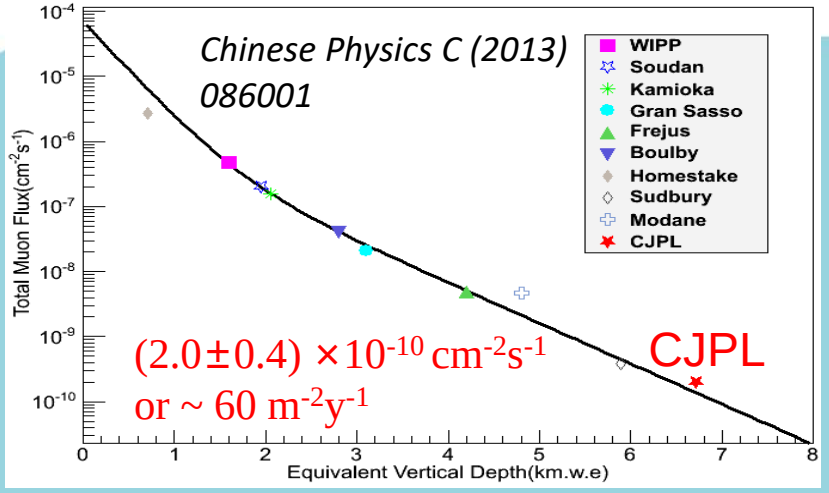
China JinPing Underground Laboratory(CJPL)

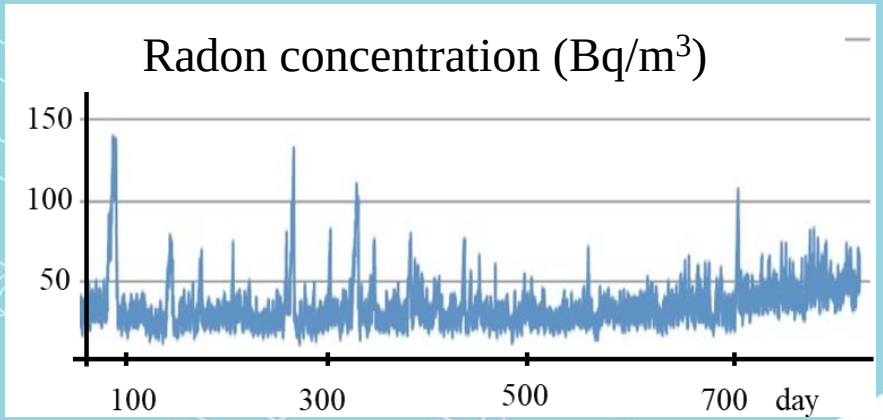
- THU-EHDC cooperation on a new underground lab started in May 2009
- CJPL-I site selected in Aug. 2009
- Rock sampling and in-situ measurement to study environmental radioactivity
- An ideal site for an underground laboratory

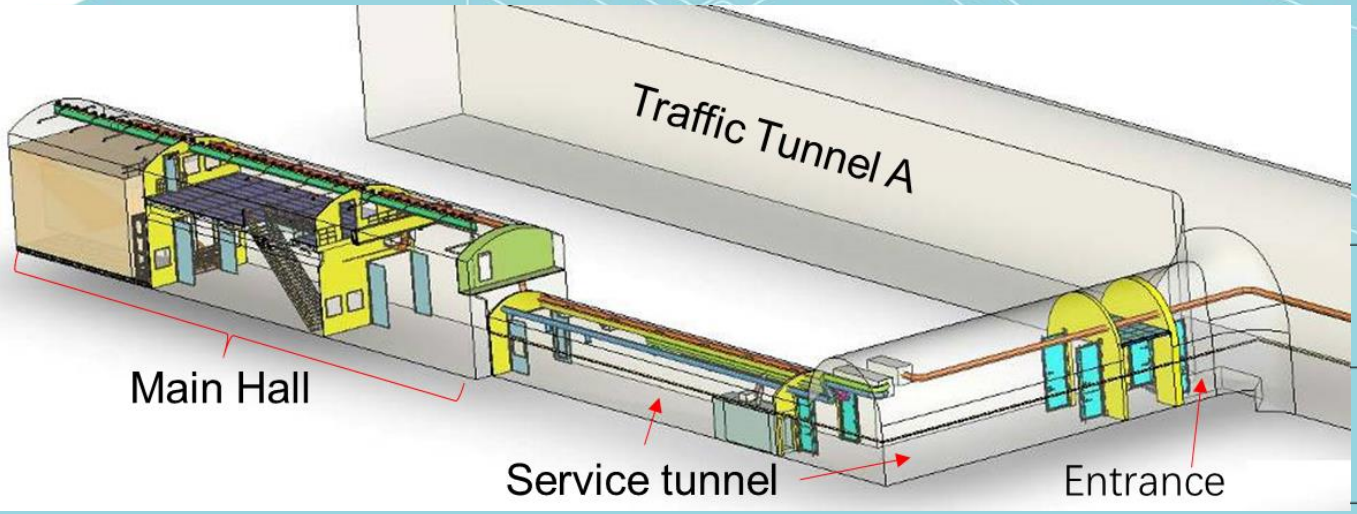


CJPL Features

- Deepest underground lab with 2400m rock overburden
- Opened on Dec. 12, 2010
- Total space: ~4000 m^3
- Main Hall: 6.5m(W) × 6.5m(H) × 42m(L)
- Low muon flux and environmental background





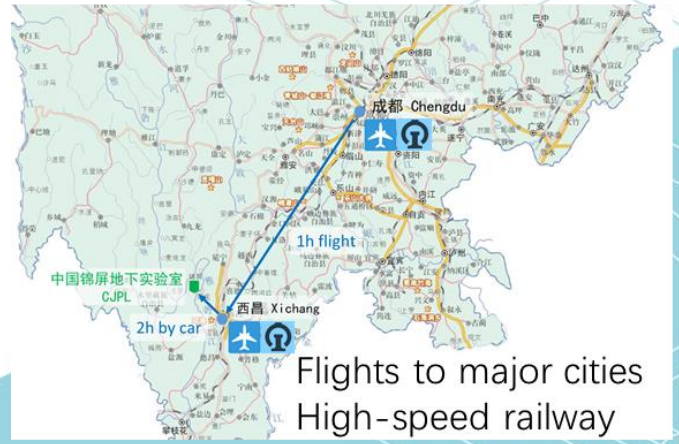


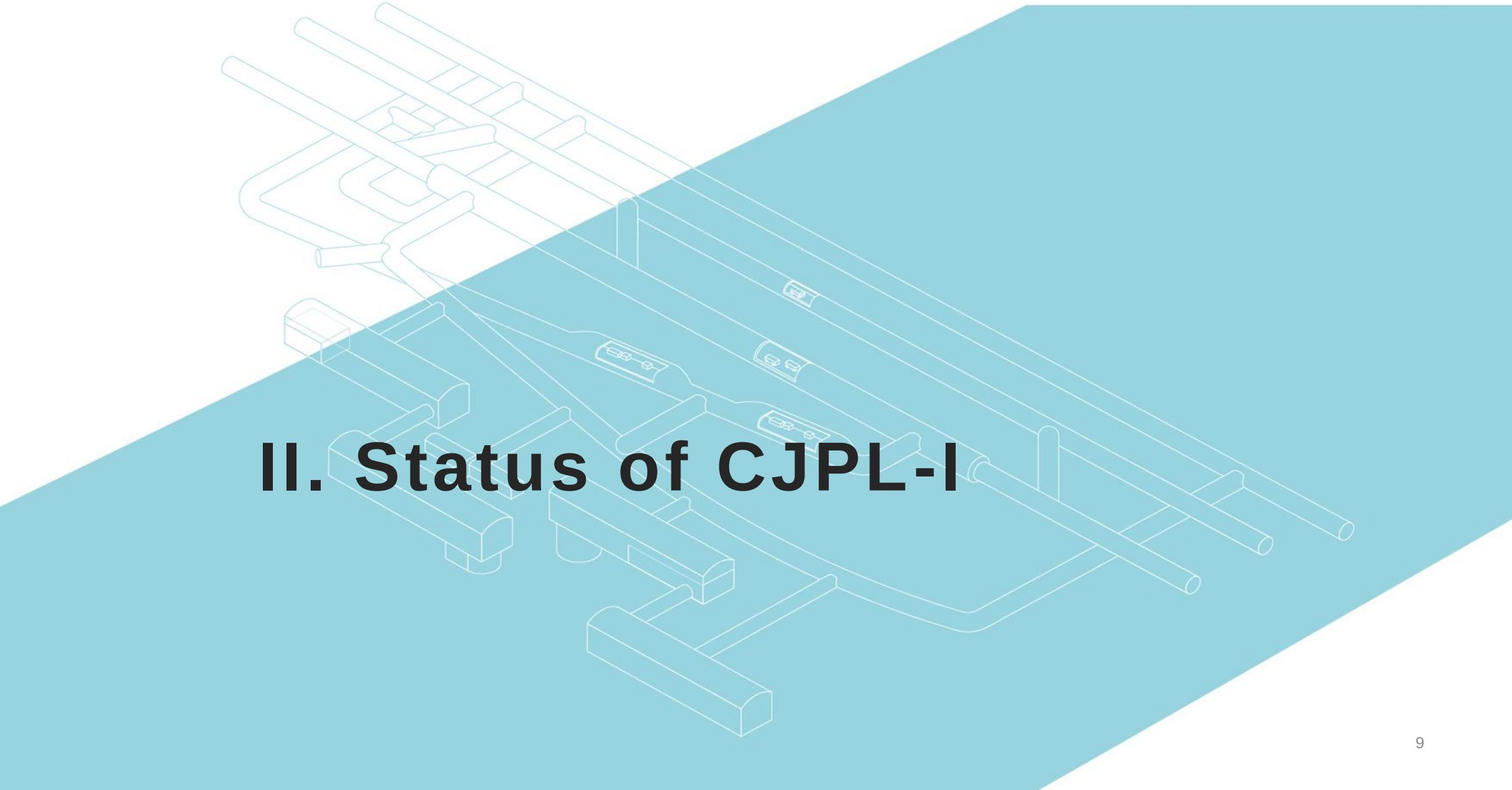
Rock sample(Marble) measured by Ge detector

(Unit : Bq/kg)	K-40	Ra-226 (609keV)	Th-232 (911keV)
Rock Sample	< 1.1	1.8±0.2	< 0.27
Ground Level(Beijing)	~600	~25	~50

Logistics of CJPL

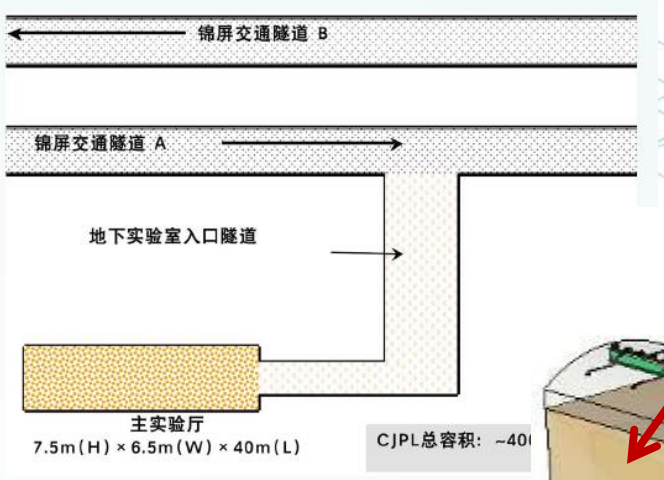
- Comprehensively supported by Yalong river company
- Convenient & Comfortable for researchers

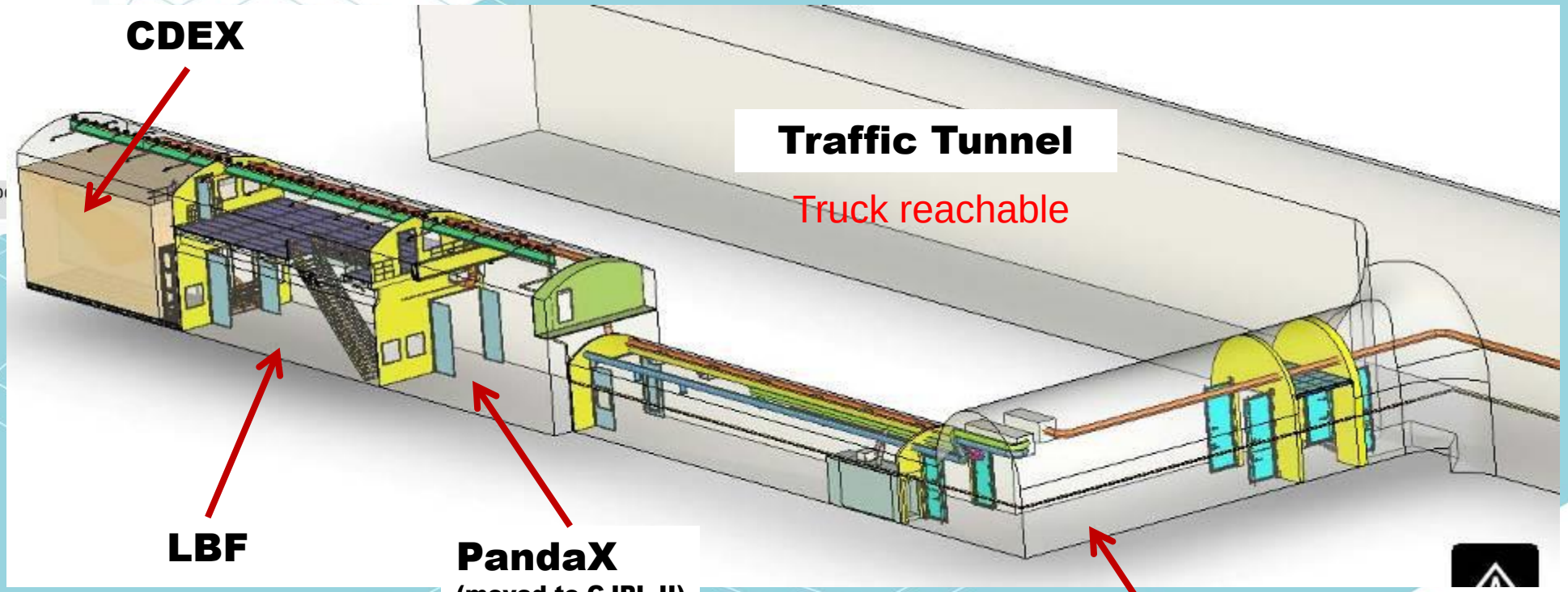




II. Status of CJPL-I

Layout of CJPL-I





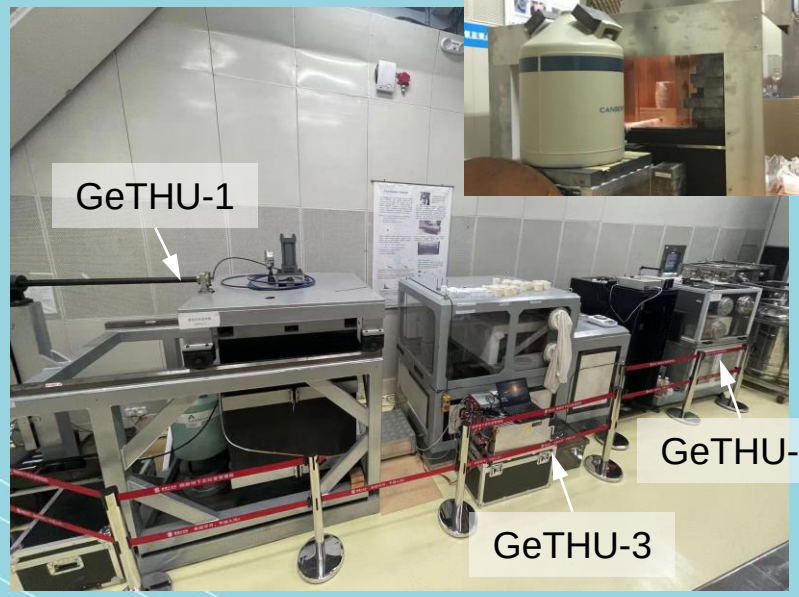
- Total space: 4000 m^3
- Main Lab Space: 6.5(W) x 6.5(H) x 42(L)

Experiments in CJPL-I

CDEX

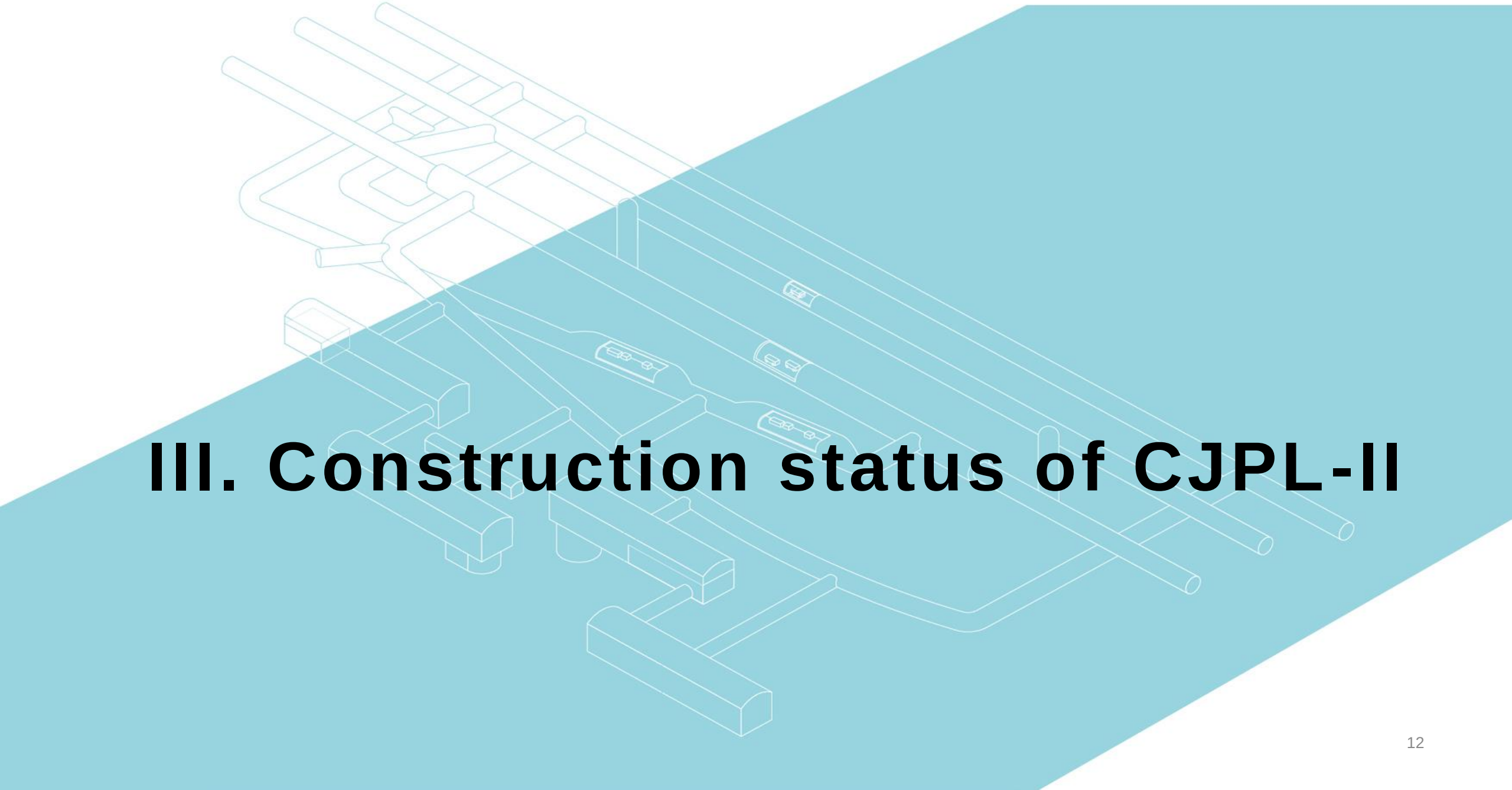
PandaX(removed)

Jinping neutrino Exp.



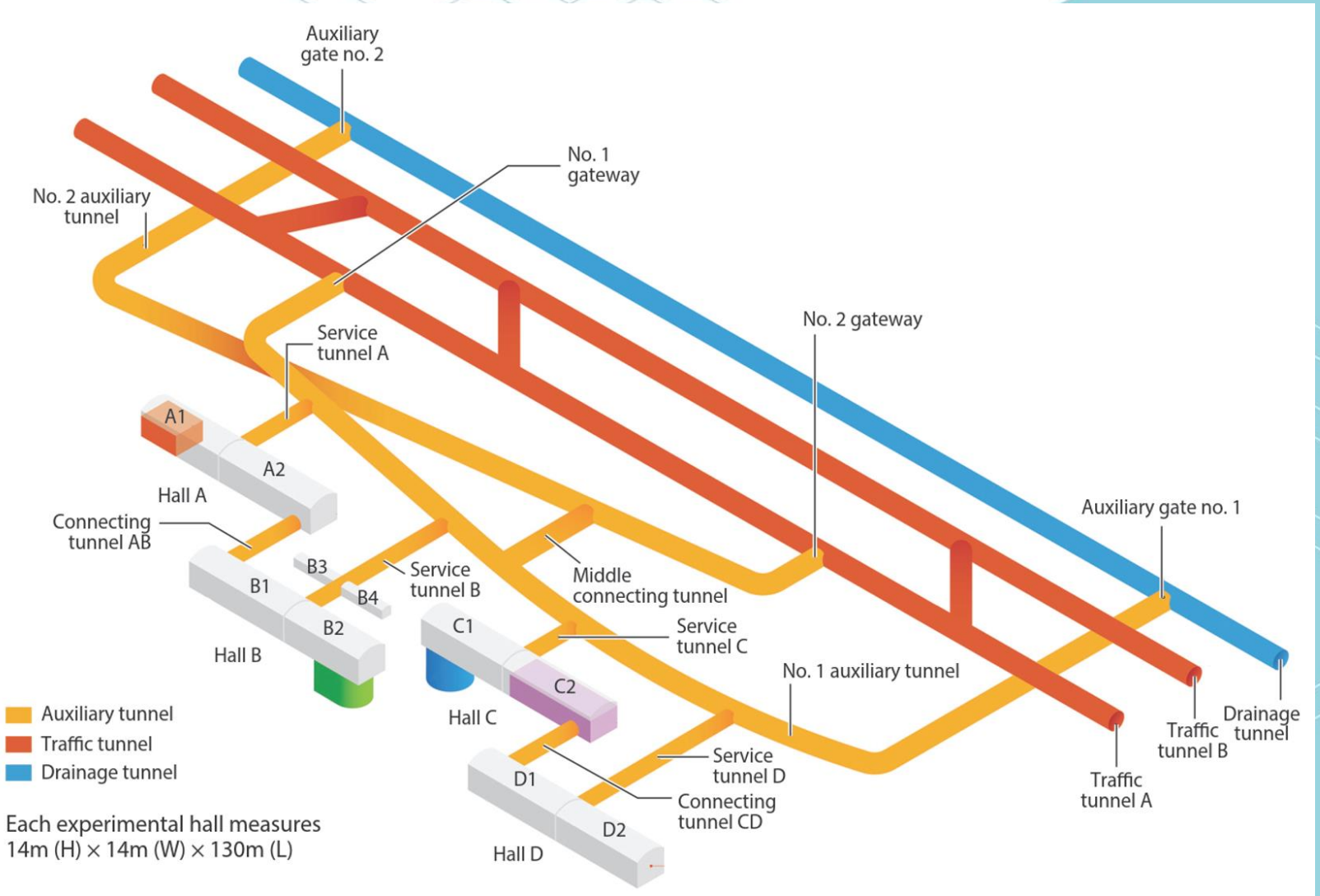
Low-background γ spectrometers

- Physics experiments
  - 2 dark matter experiments: CDEX, PandaX (now to CJPL-II)
  - 1 neutrino experiment: Jinping Neutrino Exp.
- Low background counting facility
  - 4 low-background γ-ray spectrometers: GeTHU1-4



III. Construction status of CJPL-II

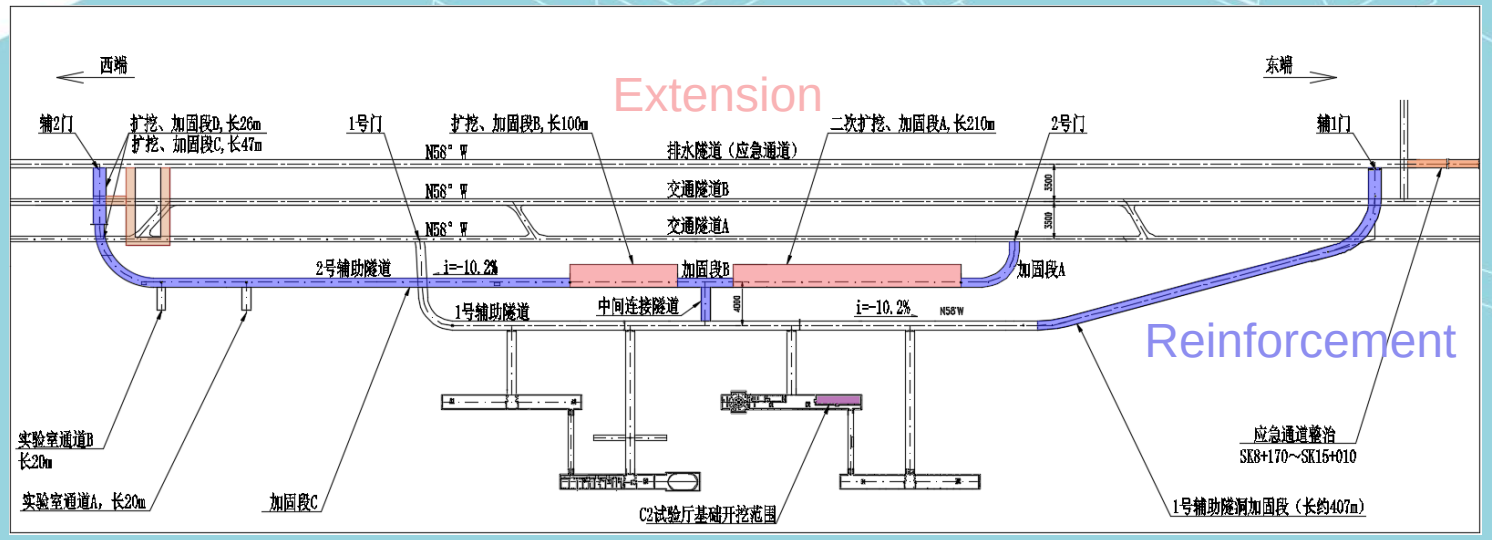
Deep Underground and ultra-low Radiation background Facility for frontier physics experiments(DURF) in CJPL-II



- Proposal approved in 2019
- Construction started in Dec. 2020
- Civil engineering to be finished late 2023
- To be completed late 2024
- 4 experiment halls (A-D), total space of >300,000 m^3
- To be the deepest and largest underground lab worldwide

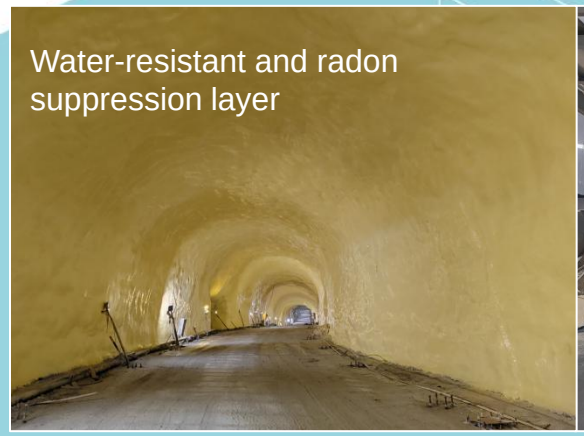
Civil engineering of CJPL-II

- Cavern extension and reinforcement
  - Completed at Jan. 2020

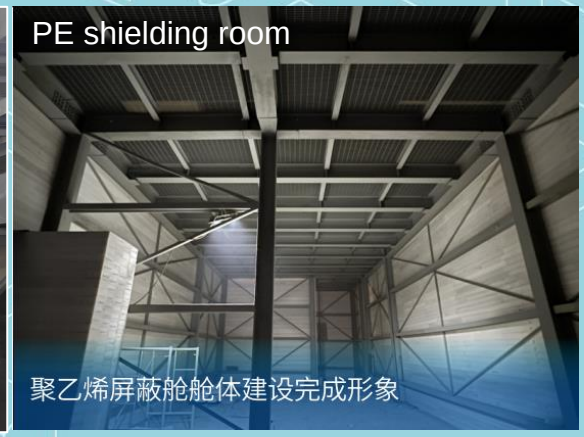


Civil engineering of CJPL-II

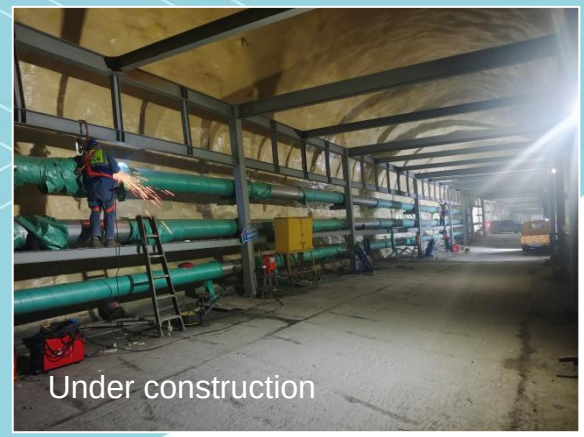
- **Water-resistant and radon suppression: construction on wall is completed except for B2 hall, and processing on floor is ongoing**
- **Steel structure: Completed for A/B halls, and 70% completion for the rest**
- **PE shielding room: completed**
- **Mechanical and electrical installation: 60% completion for hall-A and 15% for 1/2 auxiliary tunnels**


Water-resistant and radon suppression layer

Steel structure

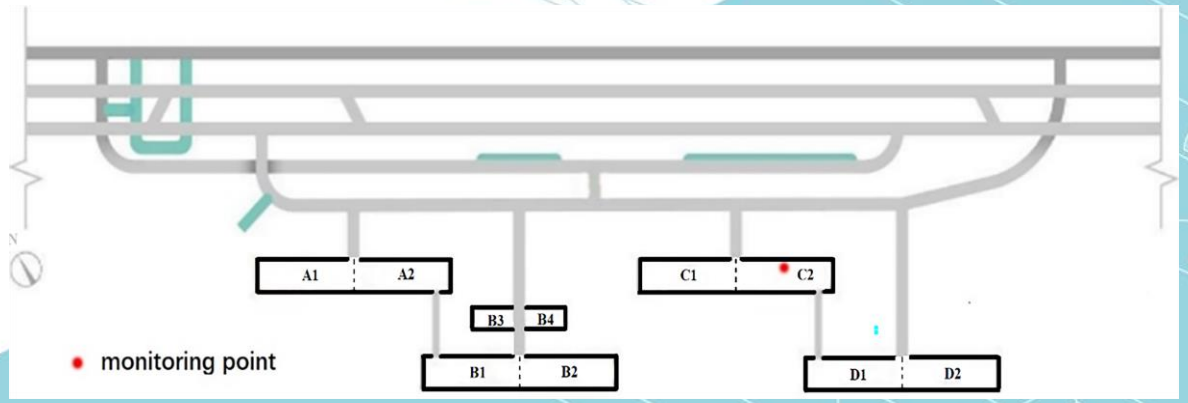

PE shielding room

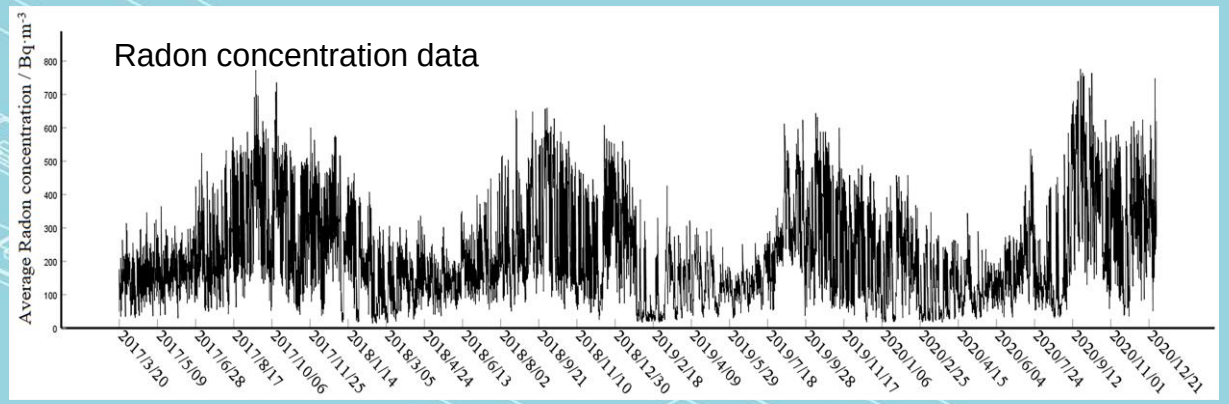
聚乙烯屏蔽舱舱体建设完成形象


Under construction

Key Project: water-resistant and radon suppression

- Monitoring Rn-222 in Hall-C2 in bare caverns
  - Rn-222 concentration in 14~776 Bq/m^3 (average 201 Bq/m^3)
  - Data fitting demonstrates a Rn-222 variation cycle of 12.7 month



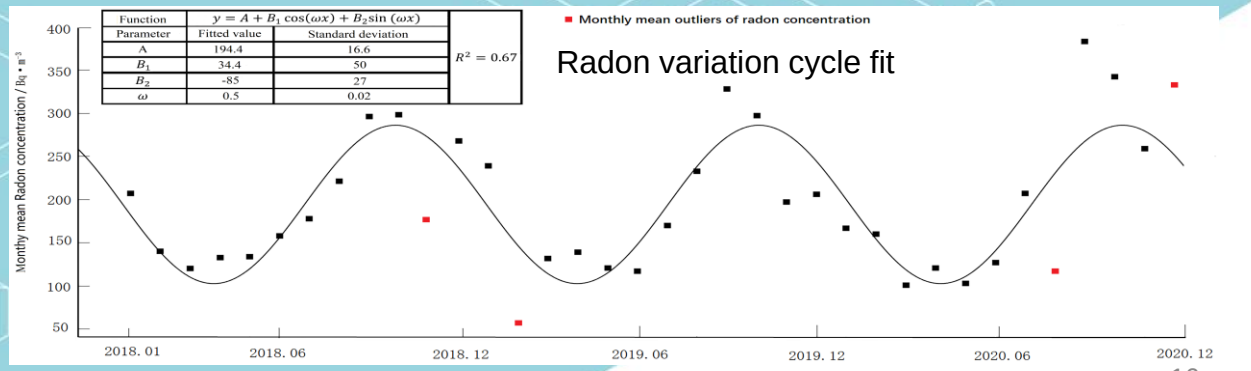


Det: Alpha-GUARD PQ2000

Loc: CJPL-II hall-C2

Date: 2017.3-2021.1

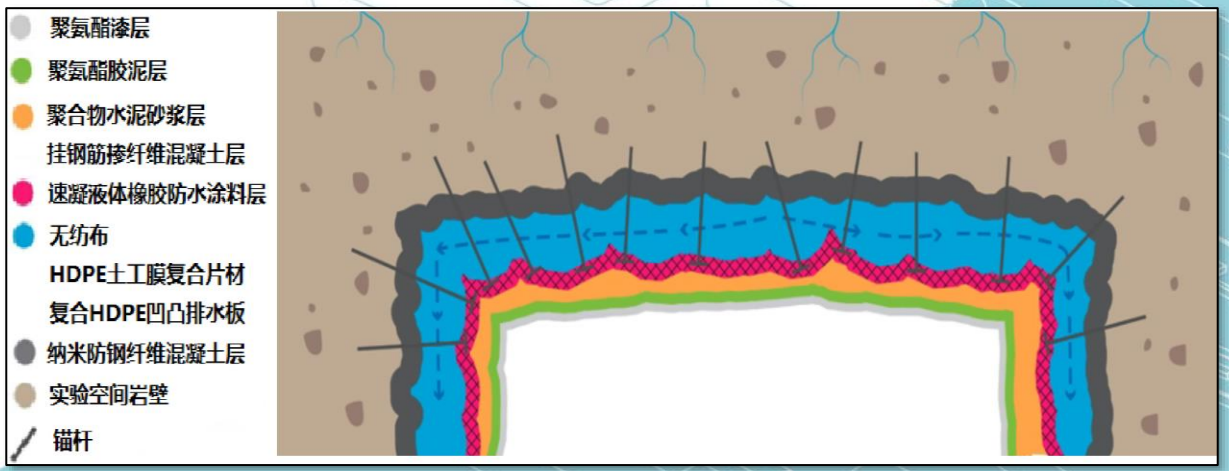
Mea-time: 60 min/point



Key Project: water-resistant and radon suppression

◘ Water-Resistant and Radon Suppression (WRRS) layer

- A dedicated engineering using multi-layer protection against water and radon

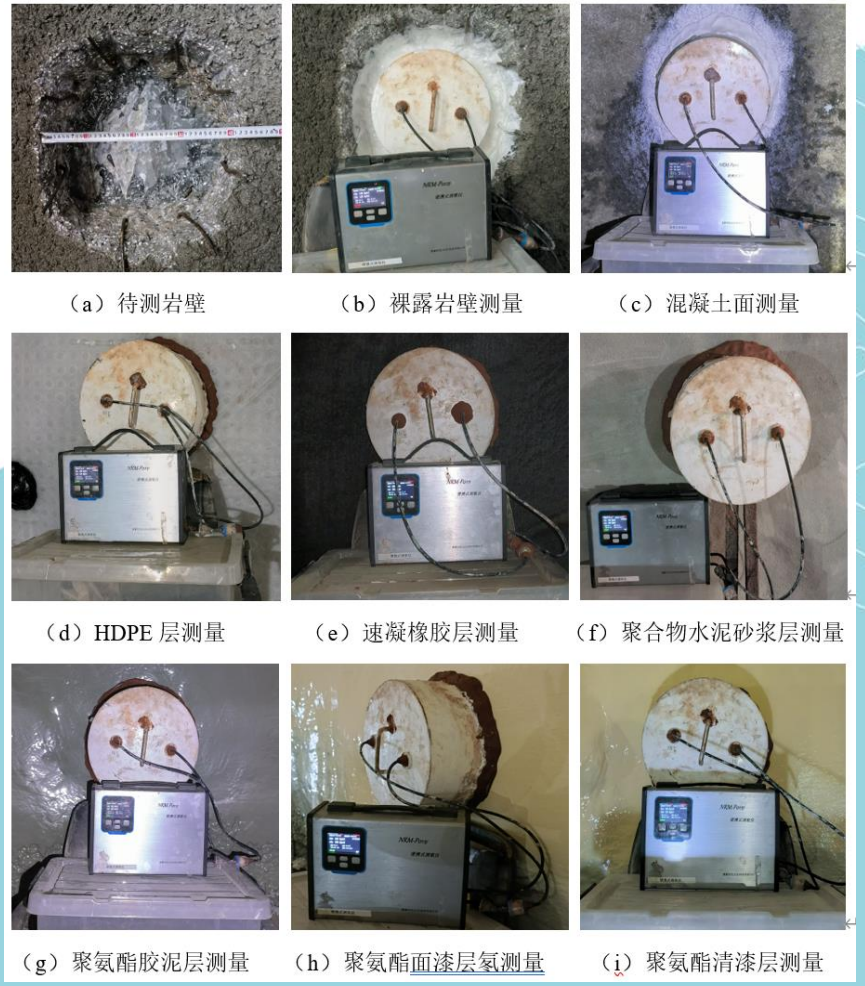


Features of WRRS layer:

- ➢ Preventing water and radon permeating from the rock simultaneously
- ➢ Covering the full-space of each experiment hall (wall and floor)
- ➢ Using low-background materials in WRRS
- ➢ 7 layers, 9 processing, dozens of materials

Key Project: water-resistant and radon suppression

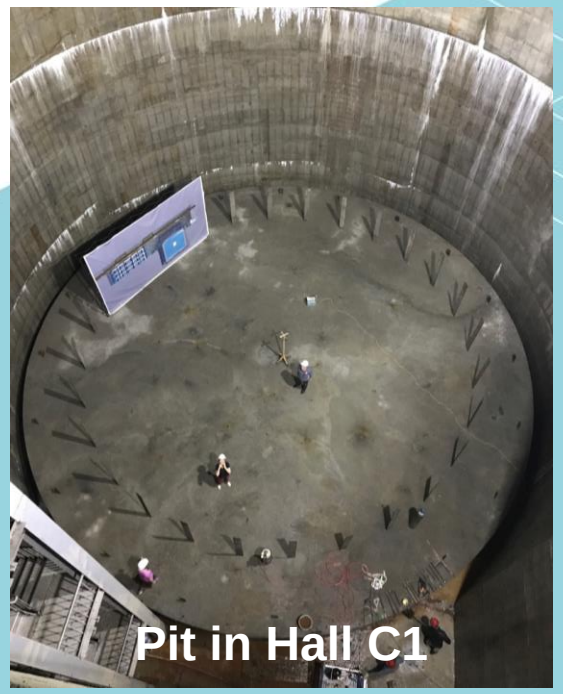
- Radon suppression power of the WRRS layers < 0.1 mBq/m²/s
  - After WRRS, radon exhalation reduced to less than 1% of its initial value



WRRS layers	Radon exhalation rate ($mBq•m^{-2}•s^{-1}$)		
	Value	Error	Detection limit
Rock (before WRRS)	6.99	0.331	0.239
Concrete	3.23	0.171	0.058
HDPE	0.09	0.057	0.075
Accelerated rubber layer	-	-	0.075
Concrete-polymer-cement	0.14	0.092	0.087
Polyurethane cement	-	-	0.080
Polyurethane top-coat	-	-	0.077
Polyurethane varnish	-	-	0.072

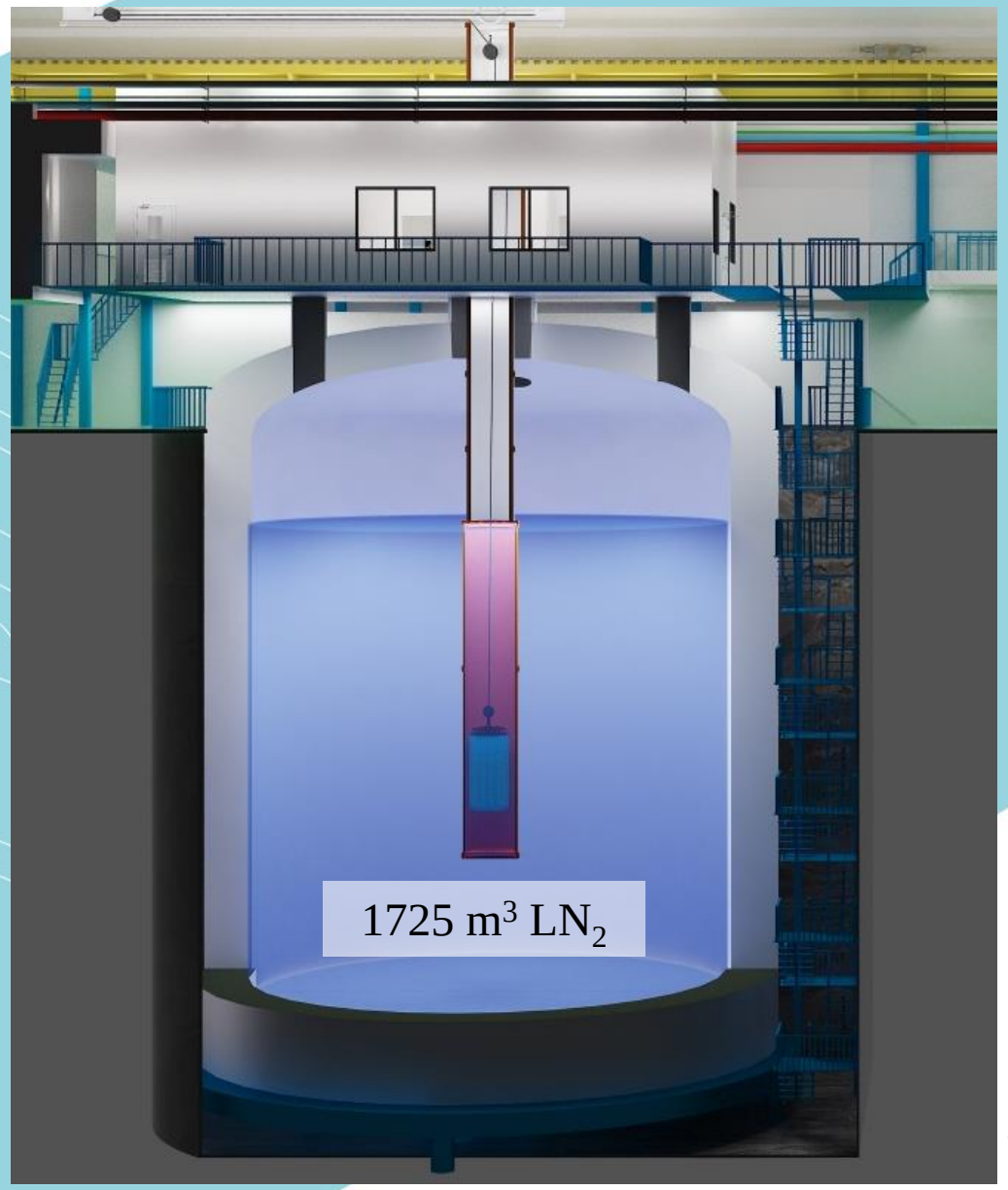
Key Project: Large Nitrogen vessel shielding

- Large LN tank completed
- Clean room under construction
- LN volume: Φ13m×H13m, ~1725 m^3
- LN filling planned in 2024



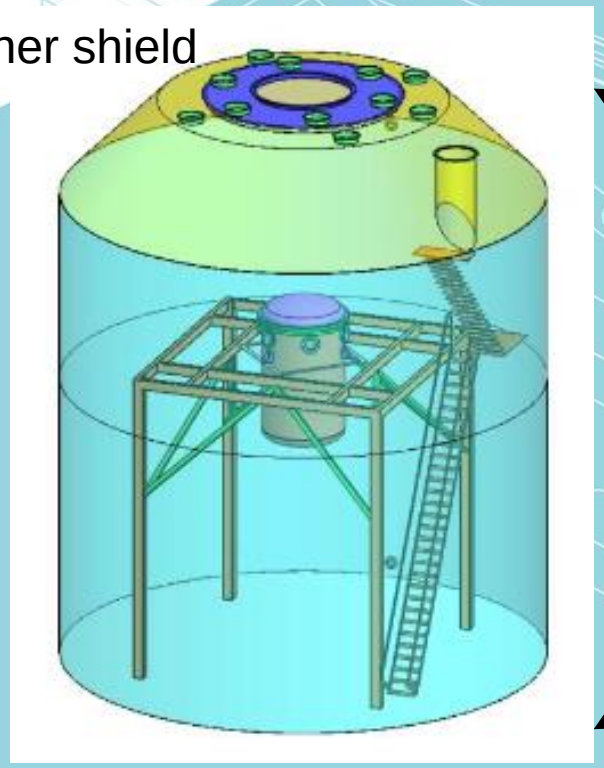
Pit in Hall C1

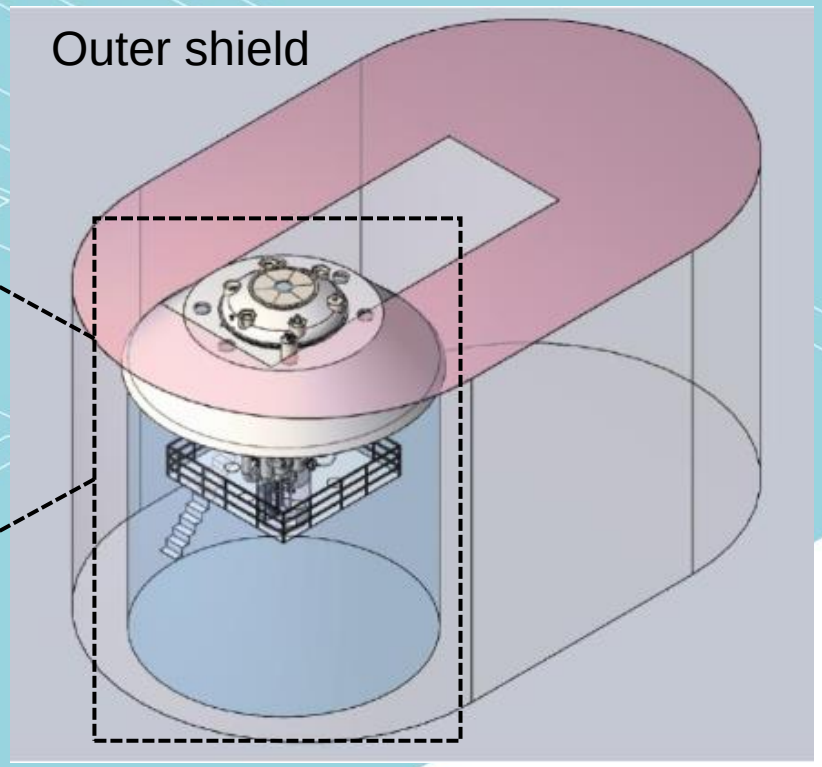
1725 m^3 LN tank in Hall C1



Key Project: Large pure water tank shielding

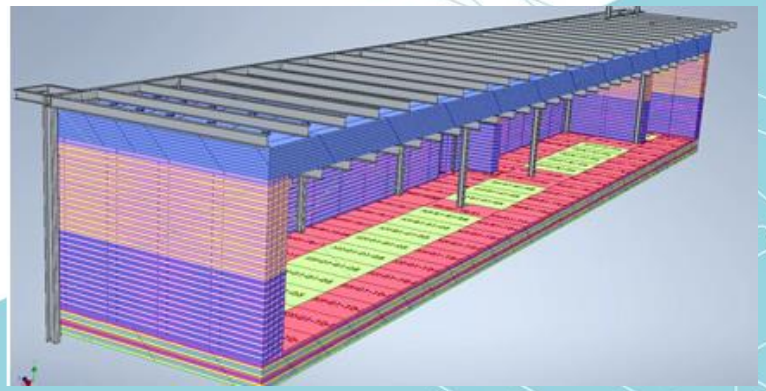
- Located in Hall-B2
- Outer shield (4500 m^3 water) and inner shield (1000 m^3 water)
- 12 L low-level radon measurement device completed

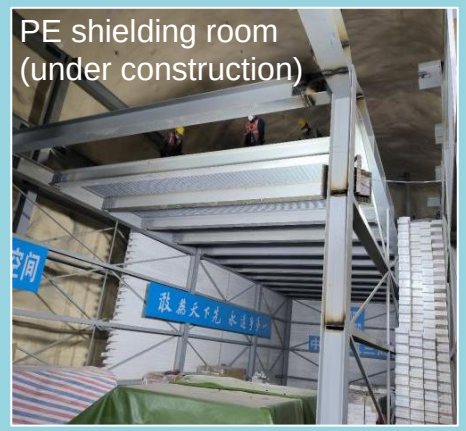




Key Project: Combined shielding module

- Multi-purpose shielding combined by PE, Copper, and Lead
  - PE room completed
  - Inner copper and lead combined shielding module under production

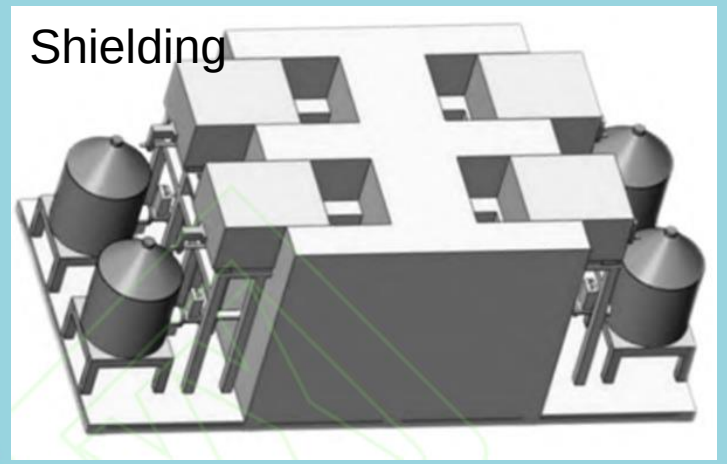


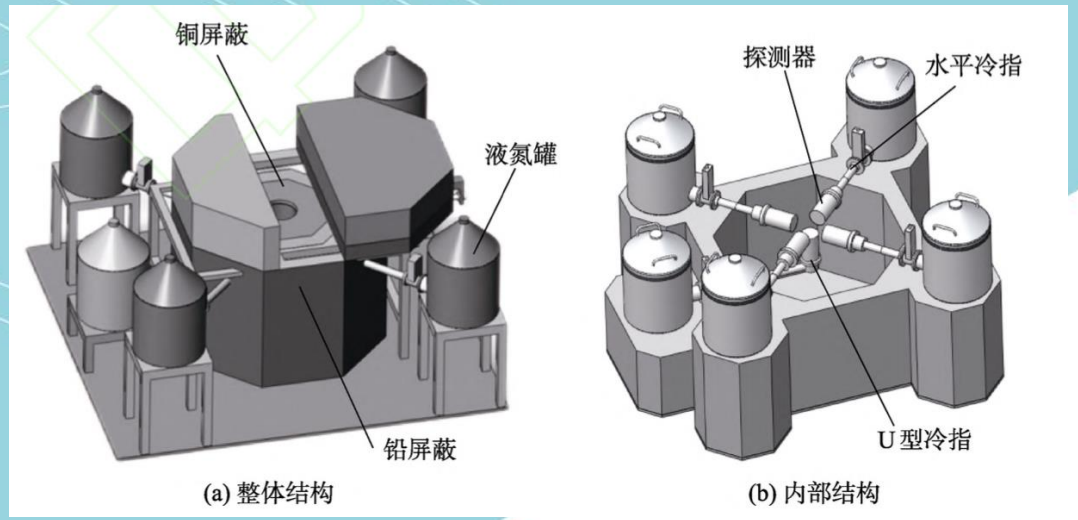


Key Project: Ultra-low-background γ spectrometers

- mBq/kg spectrometers (GeTHU)
  - Extension of current GeTHU-1/2/3/4
  - Detection limit: ~ mBq/kg scale
  - Total 15 HPGe γ spectrometers
  - Commercial HPGe detectors

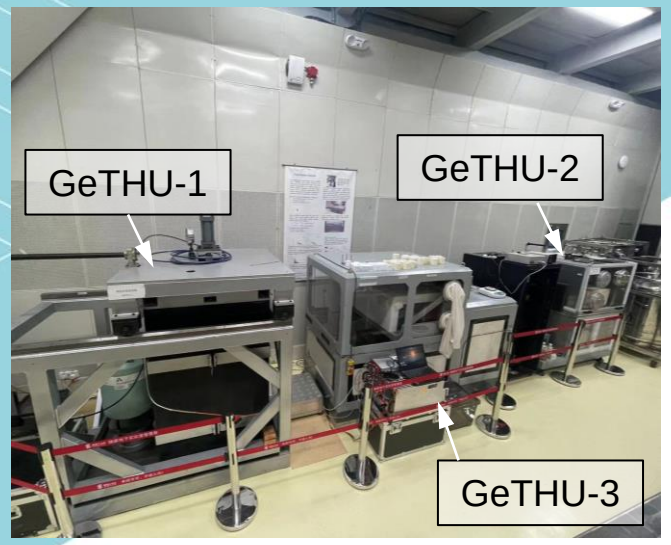
- μBq/kg spectrometers (ARGUS)
  - Detection limit: ~ μBq/kg
  - 5 commercial HPGe detectors
  - Low-background shielding





Key Project: Low-background material selection

- Measurement and selection of construction materials
  - Samples are randomly selected at the construction site and measured at GeTHU gamma-spectrometers
  - 2703 samples, 24359 h in total until Sept. 30, 2023
  - Work with manufacturers to get low-background cement



Key Project: Cavern safety monitoring system

- Multi-detectors to monitor the earth/rock movements

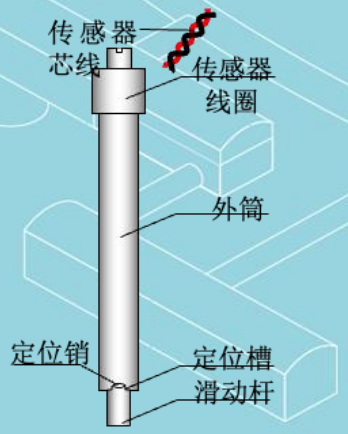
microseismic monitoring system

gravity meter

seismograph

osmometer

Disturbed Stress monitor



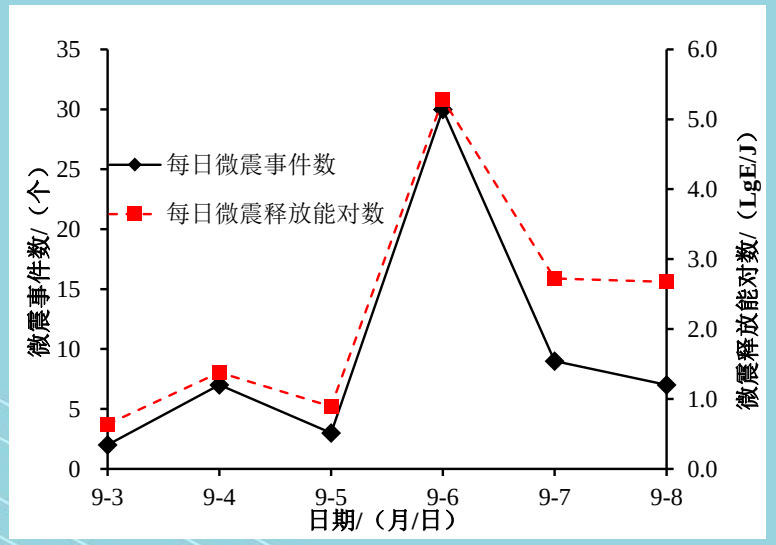
displacement sensor

Surface deformation monitor

rock cracking monitor

Key Project: Cavern safety monitor system

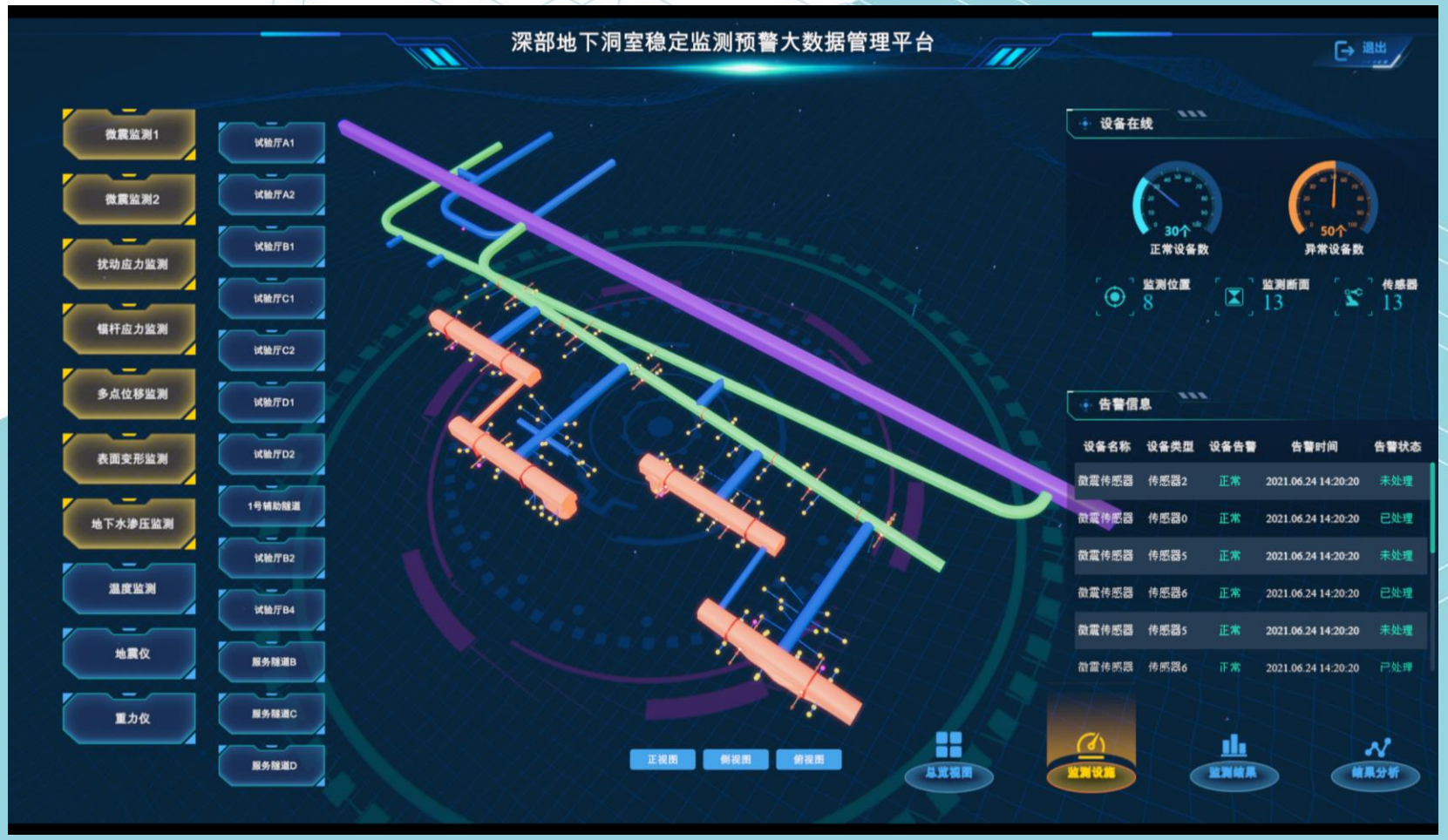
- Monitoring rock-burst for construction
  - Continuous monitoring with real-time data processing for rock-burst early warning
  - Total 27 rock-burst predicted in 120 days, including a B0+7~0+10 level rock-burst at 2021/9/7

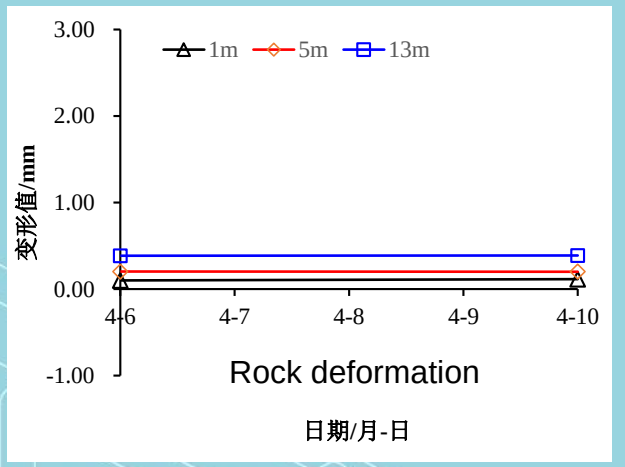


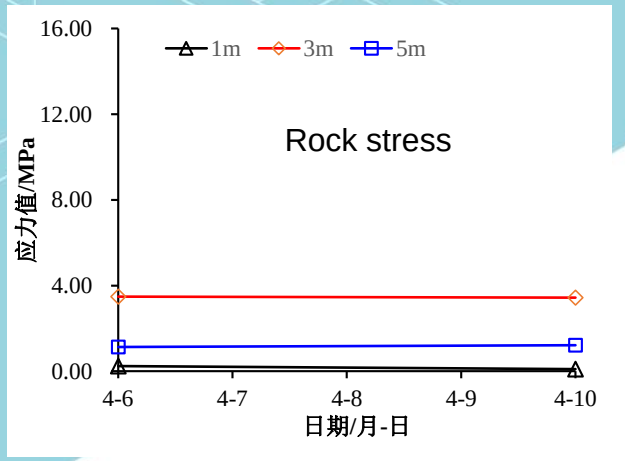
- Monitoring construction effects on science experiment
  - Continuous rock movement monitoring during construction
  - Monitor data help adjust and optimize blast design to control blasting vibration velocity within 0.5 cm/s

Key Project: Cavern safety monitor system

☐ User Interface of monitoring system







Ground laboratory in Xichang

Experimental hall

Clean room

Experimental building

Office building(5/6F)

Located in between Xichang airport and downtown

Labs for sample treatment

ICP-MS room

Ventilator room

Basement storage room

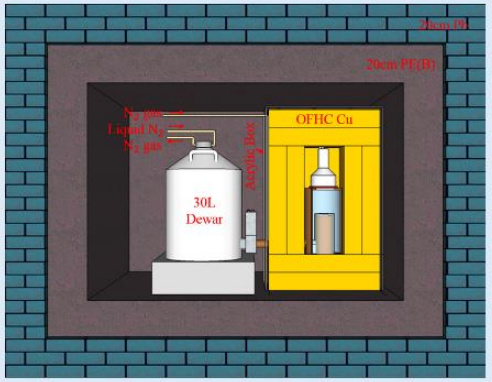
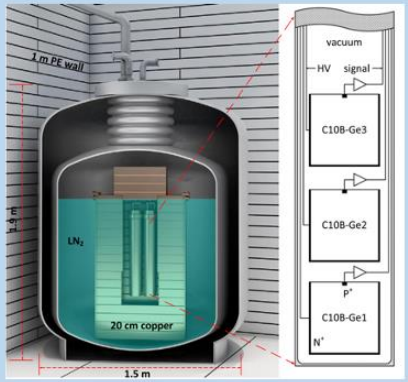
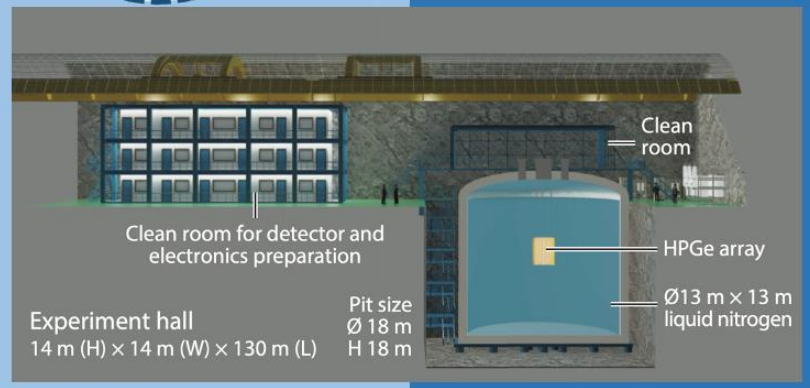
IV. Experiment proposals of CJPL-II

- CDEX、PandaX
- JUNA
- Jinping Neutrino Program
- CUPID-China、NvDEX
- GeoDEX、 IC SER Exp.

➢ Process for Approving and Supporting Proposed New Experiments

CDEX

- Founded in 2009, 11 institutions, more than 100 people now
- Focused on Dark Matter detection and Ge-76 0νββ search using HPGe technology

2009-2016	2016-2020	2021-	Planed
CDEX-1 **CDEX-1A** • DM: χ-N (SI/SD) • Axion & Axion-like DM • CDEX first ovββ result **CDEX-1B** • DM: χ-N (SI/SD) • DM: χ-N (Migdal Effect) • DM: χ-N (AM) • Axion & Axion-like DM	**CDEX-10** • DM: χ-N (SI/SD) • DM: χ-N (EFT) • Solar dark photon • Dark photon DM • DM: CR boosted DM • DM: Exotic DM • DM: χ-e • DM: Evaporating PBHs	CDEX-50 (DM) CDEX-300 (0νββ)	CDEX-1T (0νββ, DM…)
			
CJPL-I		CJPL-II	

PandaX

- Started in 2009, consists of dozens of Universities and research Institutions
- Increasing LXe detector mass for DM and neutrino studies

PandaX

Phase-I
120 kg

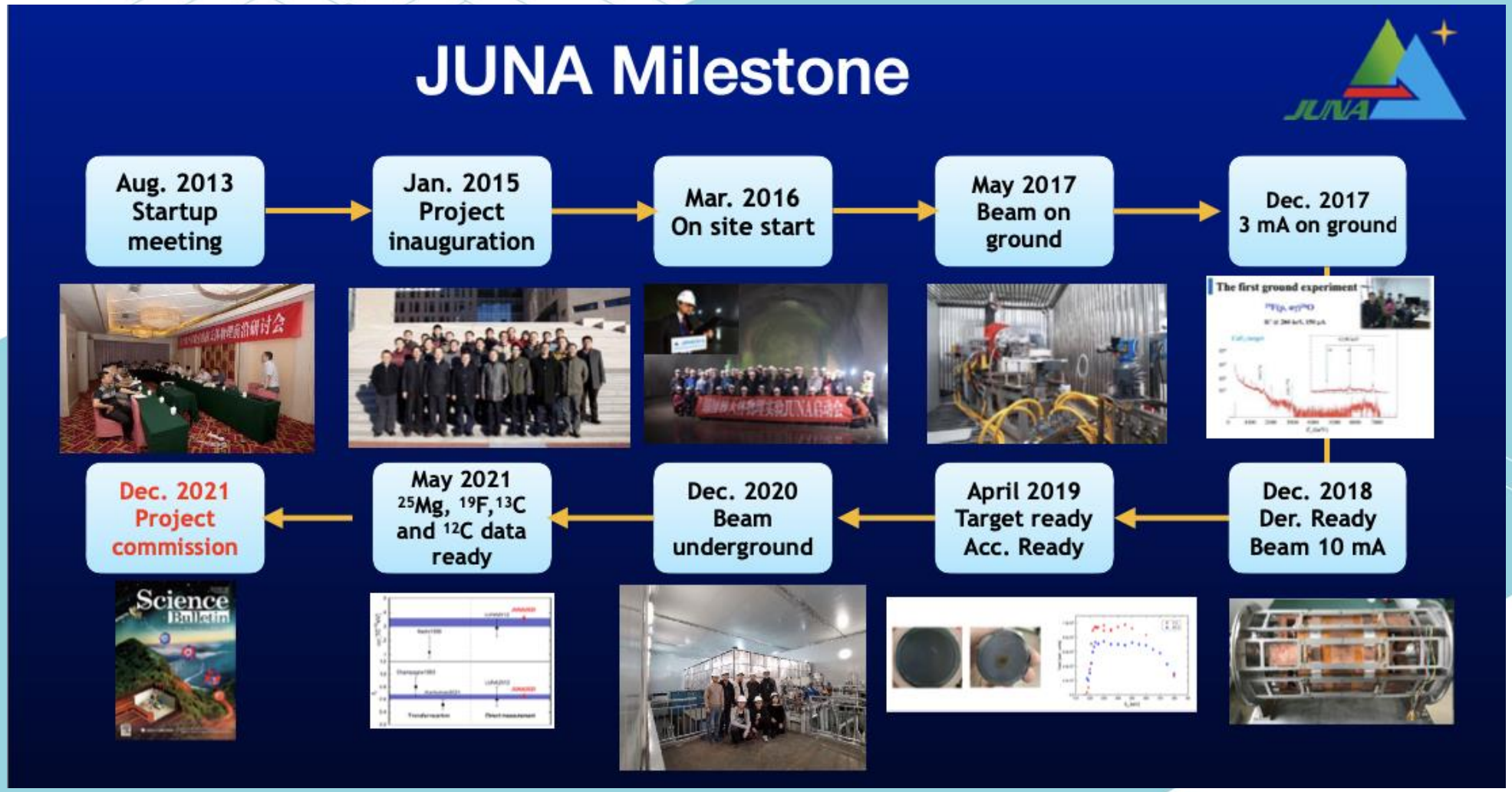
Phase-II
580 kg

PandaX-4T
3.7 ton

2009 | **2010-2014** | **2015-2019** | **2020-**

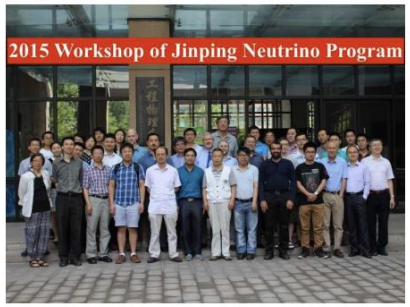
JUNA

- Started in 2013, 7 Universities and research Institutions
- Goals: Nuclear astrophysics study using underground accelerator

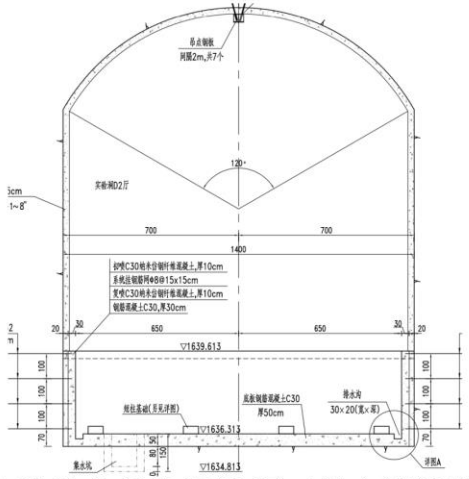


Jinping Neutrino Program

- Ever growing interest from the community.
- Active working group.
- Starting CDR draft: Welcome to join!



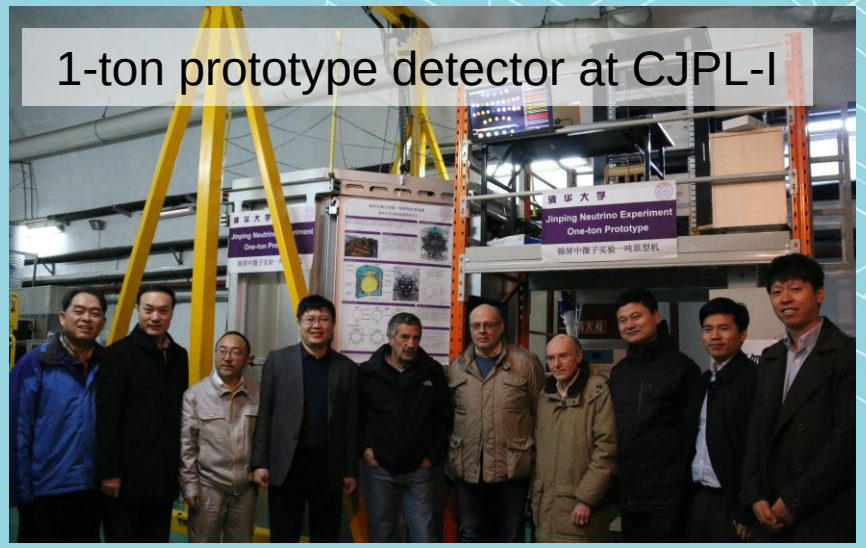
Pit for 500 ton Neutrino Observatory at Hall D2



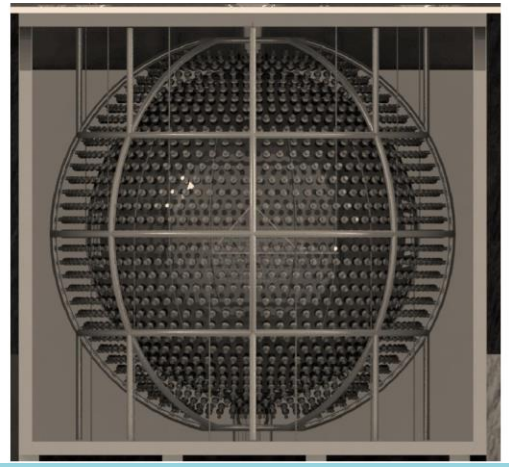
实验设备基坑设计图（华东设计院）

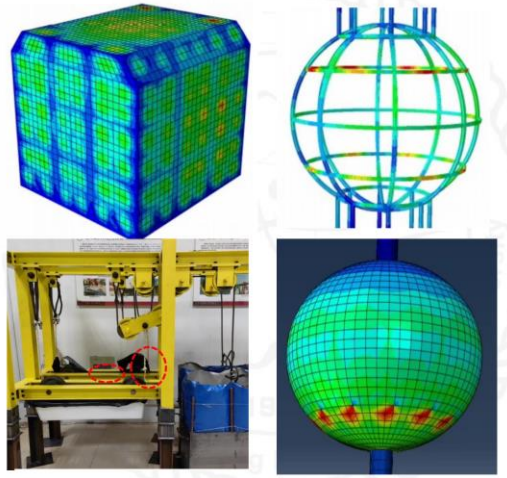
实验设备基坑，长16米，宽14米，深3.8米，开挖工作完成（水电5局）

1-ton prototype detector at CJPL-I



Neutrino detector design





CUPID-CJPL: ^{100}Mo-based bolometric exp. for 0νββ search

Crystal testing
(2021-2022)
6-12 natural crystals

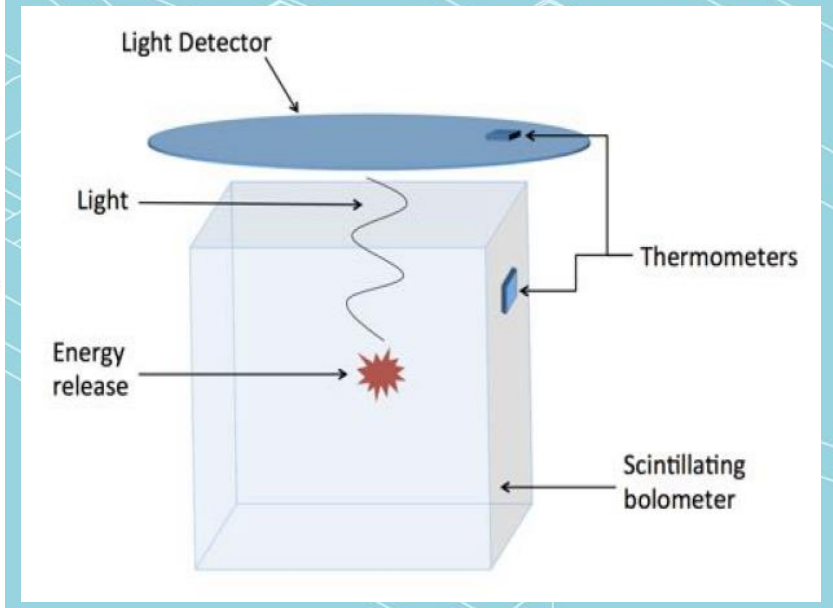
CUPID-CJPL demonstrator
(2022-2024)
10 kg, 36 enriched crystals

CUPID-CJPL-200/1T
(2024+)
>1000 enriched crystals

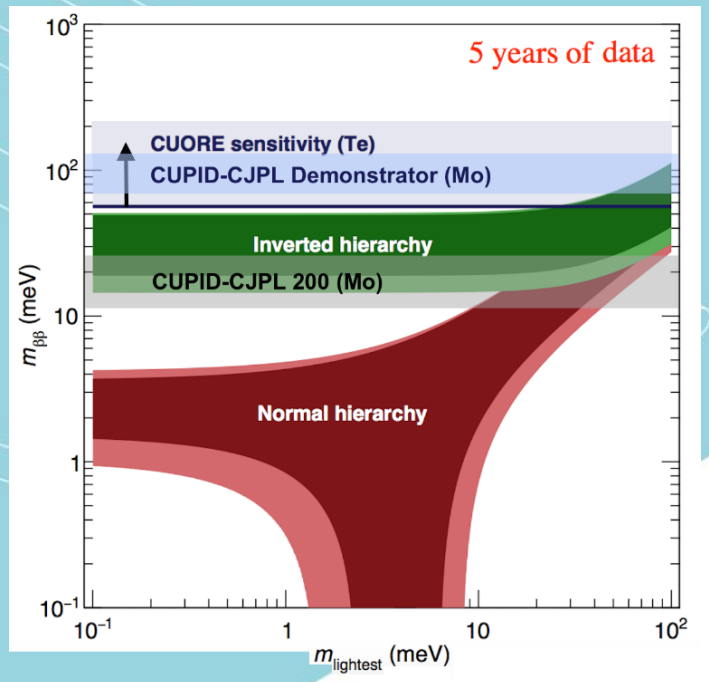
CUPID-China

- Fudan University*
- Beijing Normal University*
- Shanghai Institute of Applied Physics
- Shanghai Institute of Ceramics
- Shanghai JiaoTong University*
- Tsinghua University
- University of Science and Technology of China*
- Ningbo University

*officially joined international CUPID

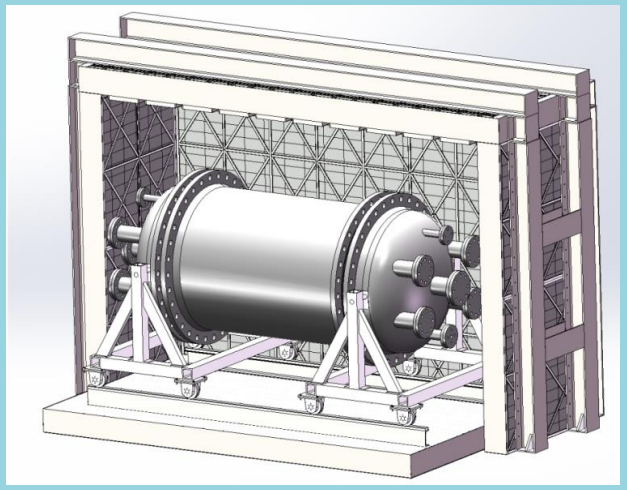


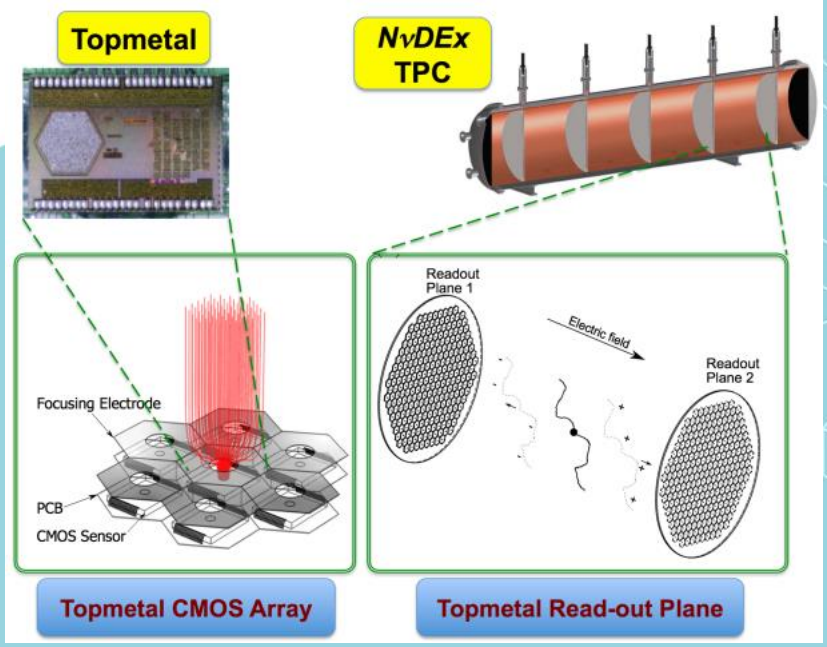
From Long Ma, Fudan U.

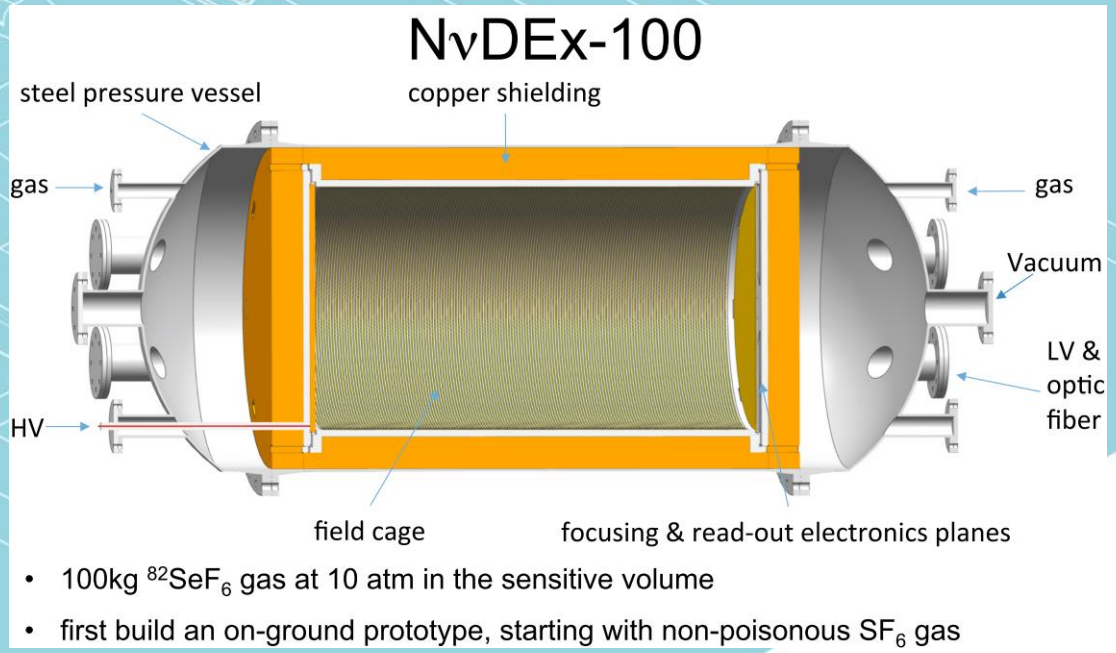


NvDEx for ^{82}Se 0νββ search

- High pressure $^{82}SeF_6$ Gas TPC
- Direct read-out by top-metal CMOS sensors
- Prototype detector being built



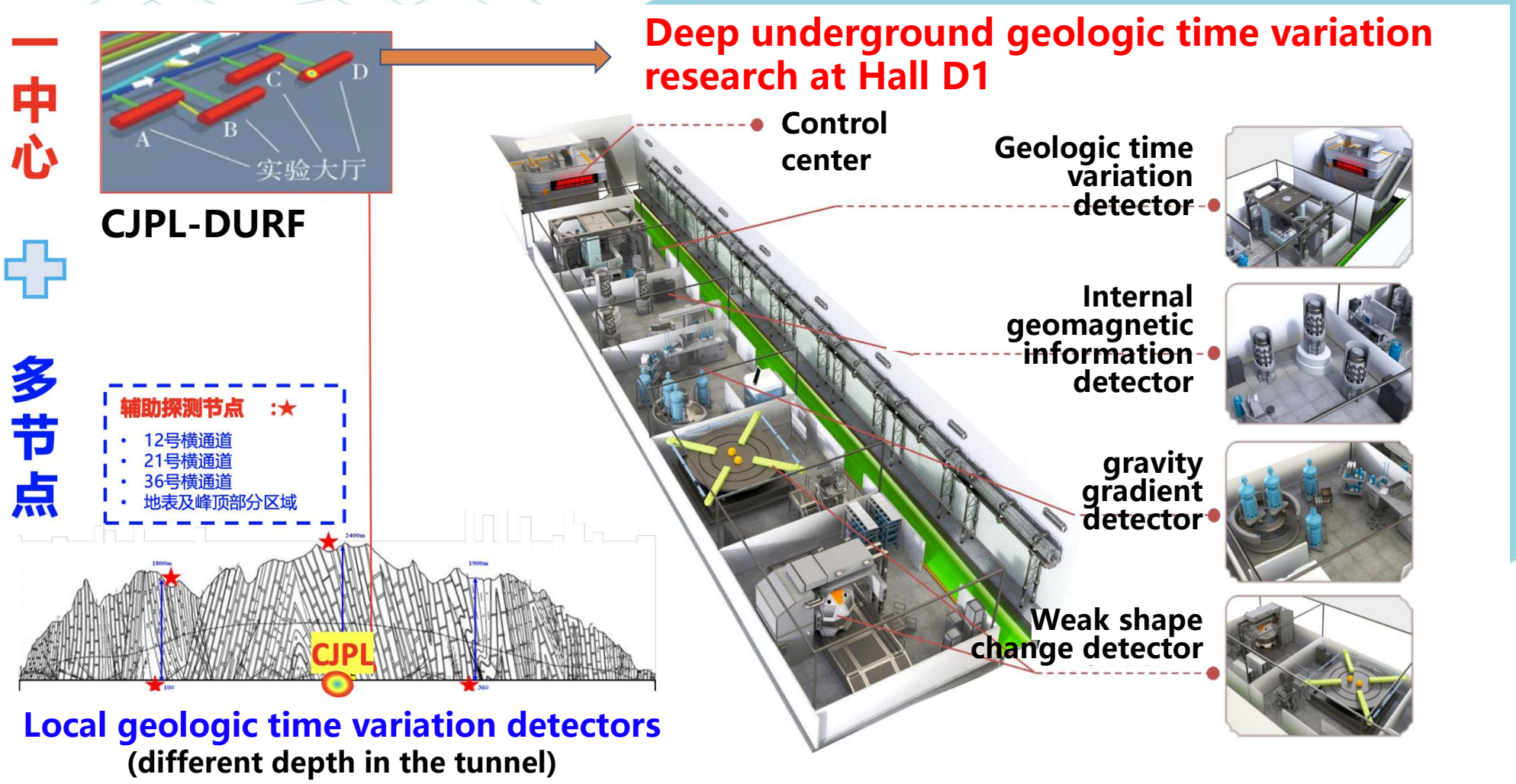




From Hao Qiu, IMP, CAS

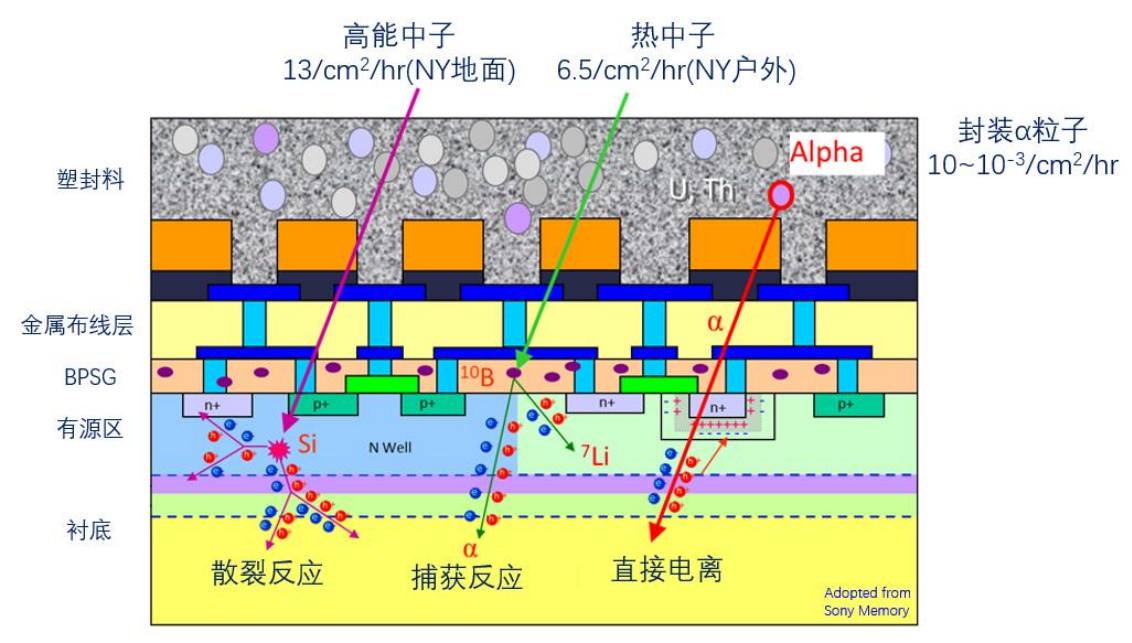
GeoDEX

- Deep underground geologic time variation in-situ detector experiment



IC SER: deep underground Integrated Circuit Soft Error Research

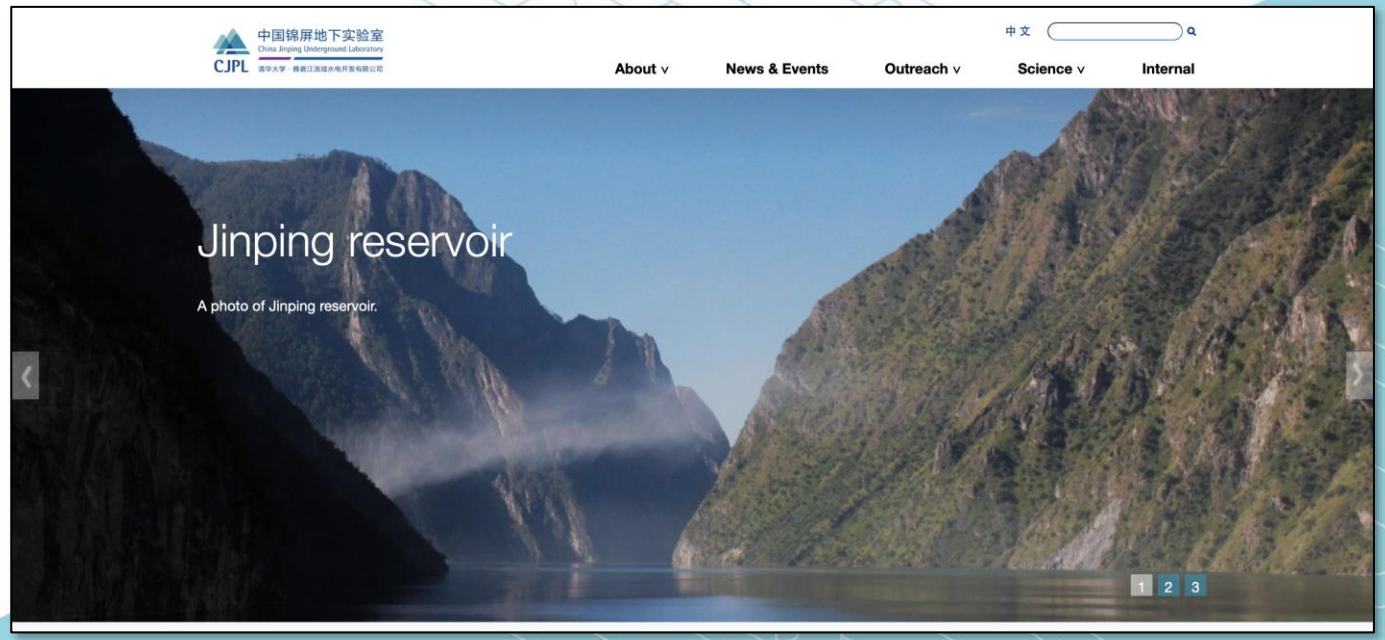
- Radioisotopes in IC could cause soft error (SE) by emitting alpha particles
- Study the SE rate in CJPL to prevent interference from atmospheric neutrons
- Compare test data in CJPL and Lhasa to acquire “Golden data” for IC SE rate



Test at Lhasa
- 6651 hr

Test at CJPL-I
- 6000 hr

Process for Approving and Supporting Proposed New Experiments

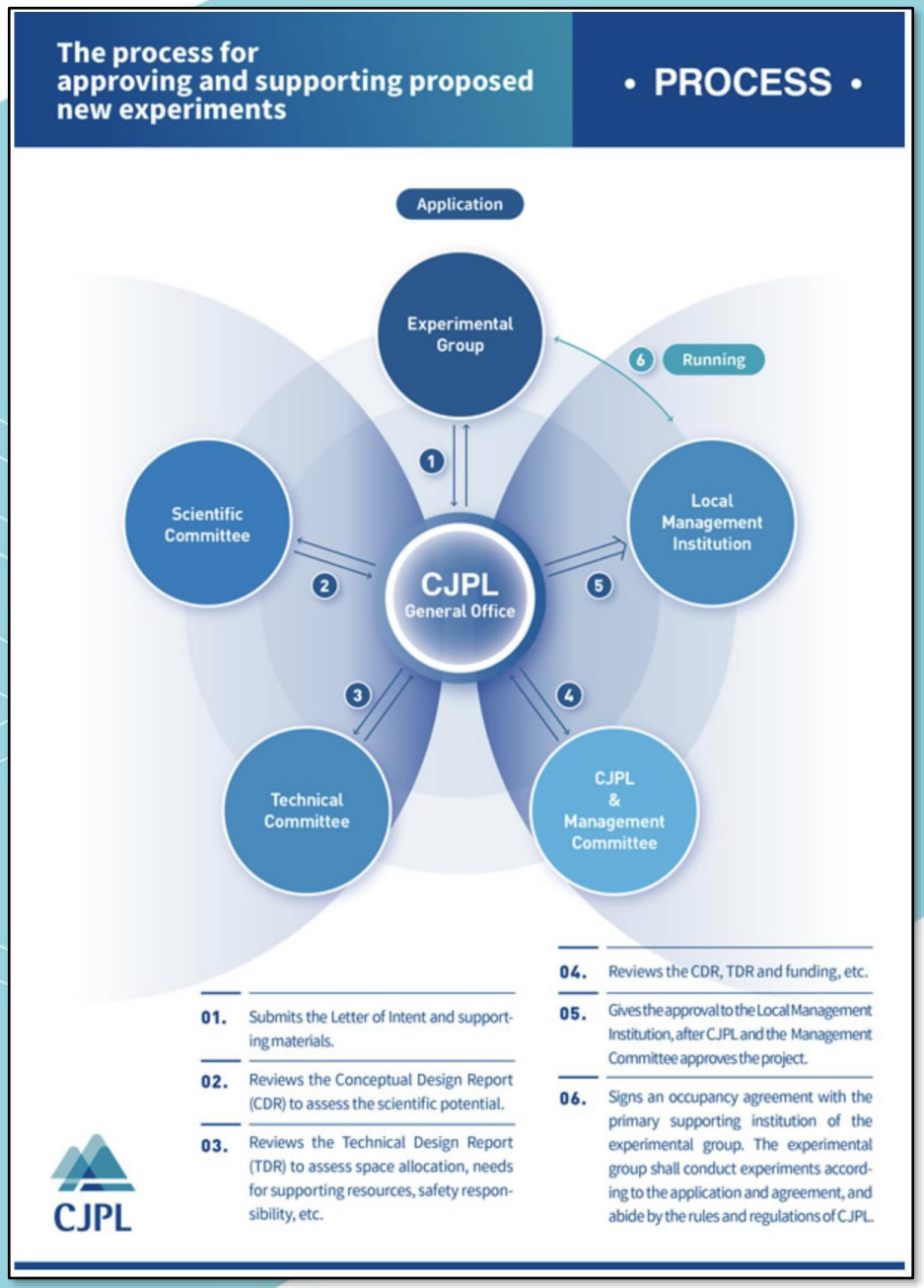


Visit our website for more info:

https://cjpl.tsinghua.edu.cn/

Contact:

cjpl@tsinghua.edu.cn



V. Summary

- CJPL-II will be the deepest (2400m rock) and largest (>300,000 m^3 space) underground Lab worldwide
- Most civil engineering of CJPL-II completed, the remaining will be finished in 2023
- CJPL-II plans to start operation at the end of 2024
- The water-resistant and radon suppression in CJPL-II controls radon exhalation rate to less than 0.1 mBq/m^2/s
- Construction materials are measured and selected to control their background
- Cavern safety monitoring system ensures the safe and smooth operation of CJPL-II

CJPL welcomes experiment proposals worldwide !


CJPL
中国锦屏地下实验室
China Jinping Underground Laboratory
Welcome to CJPL！