The XVIII International Conference on Topics in Astroparticle and Underground Physics (TAUP2023)

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

The status and prospects for China Jinping Underground Lab(CJPL)

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Aug. 28, 2023 , Vienna

清華大學 Tsinghua University

国投 SDIC | 雅砻江水电 YALONG HYDRO

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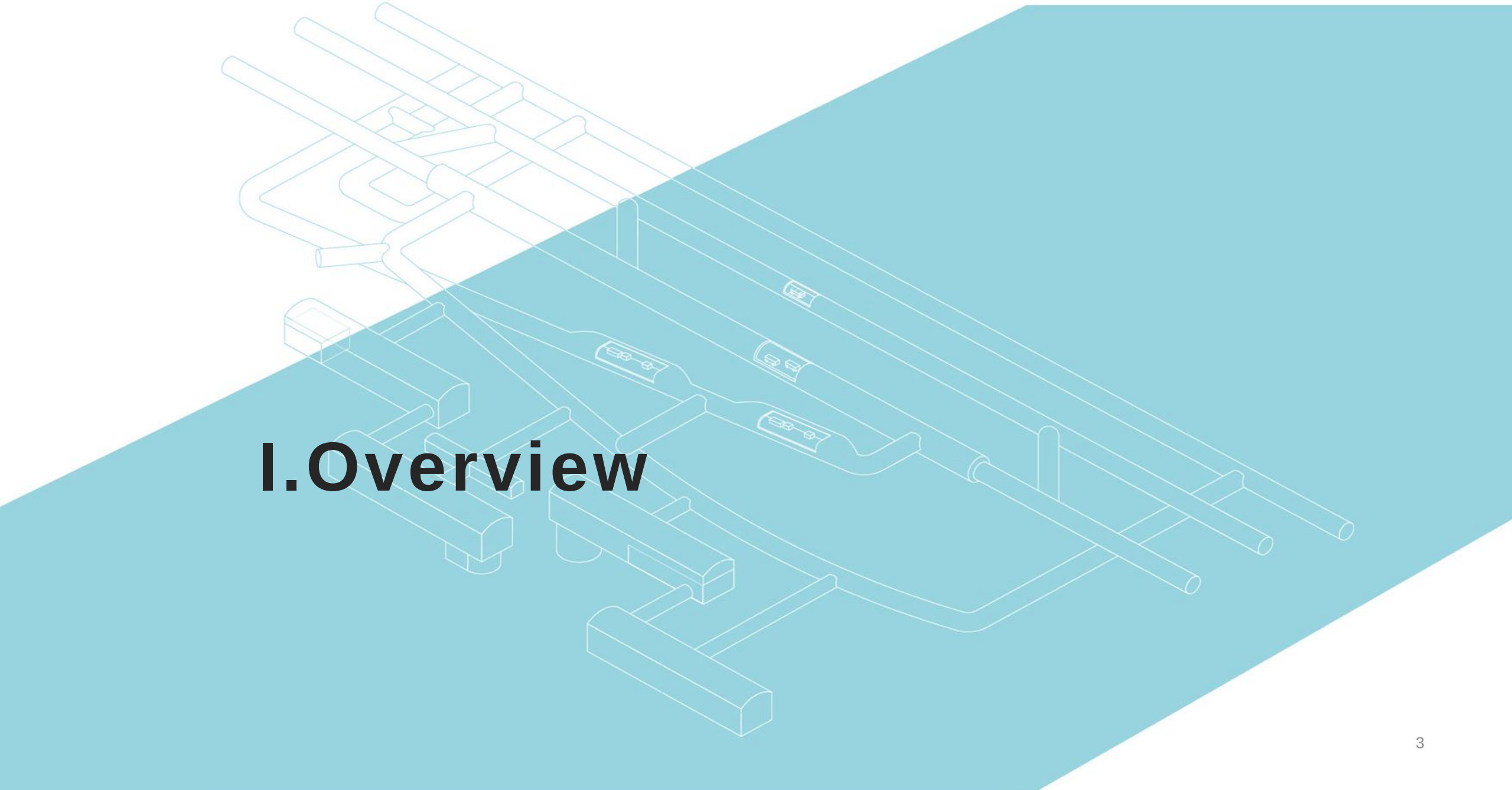
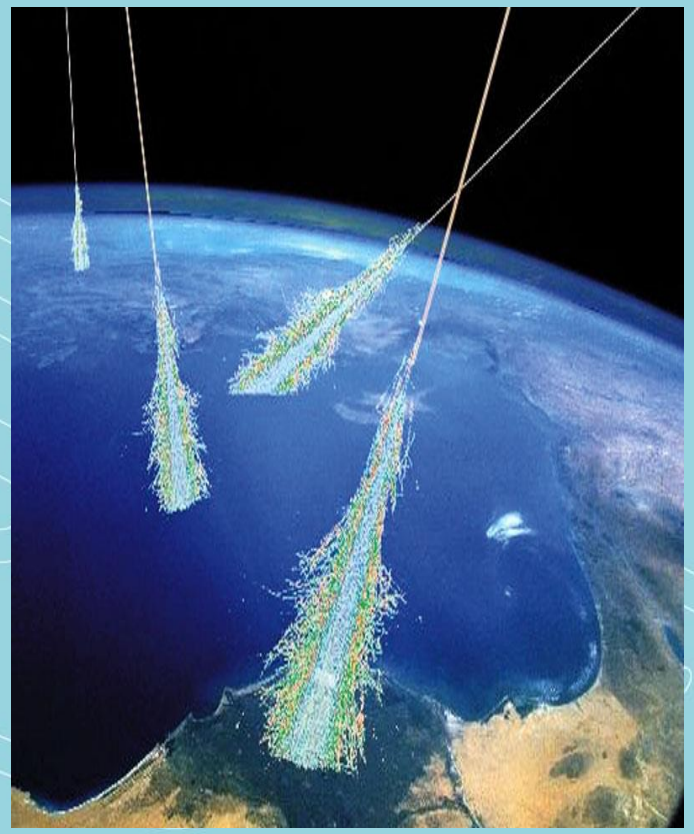


I.Overview

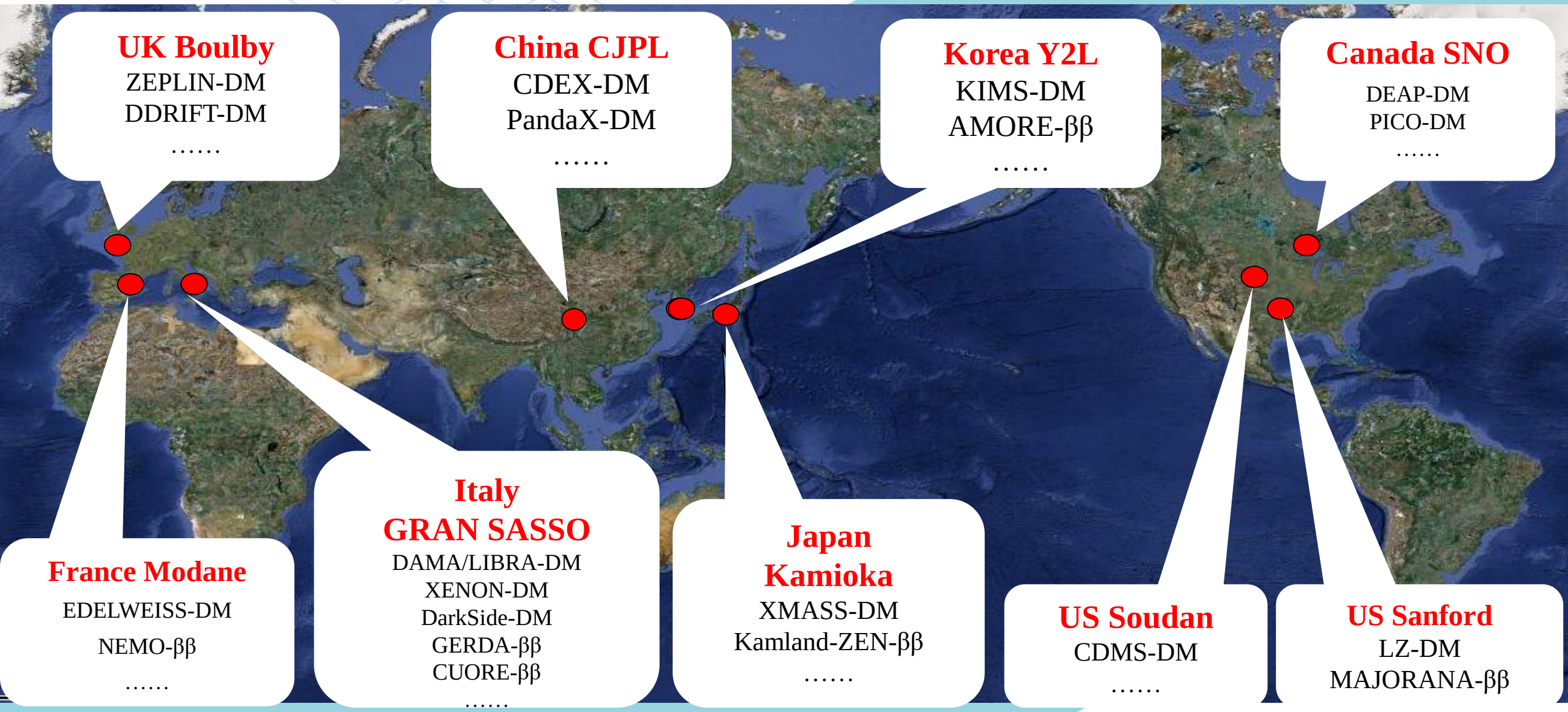
Go underground for frontier sciences

- Dark matter
- Neutrino
- Nuclear astrophysics
- Proton decay
- Biology
- Seismology
- Rock mechanics
- ……

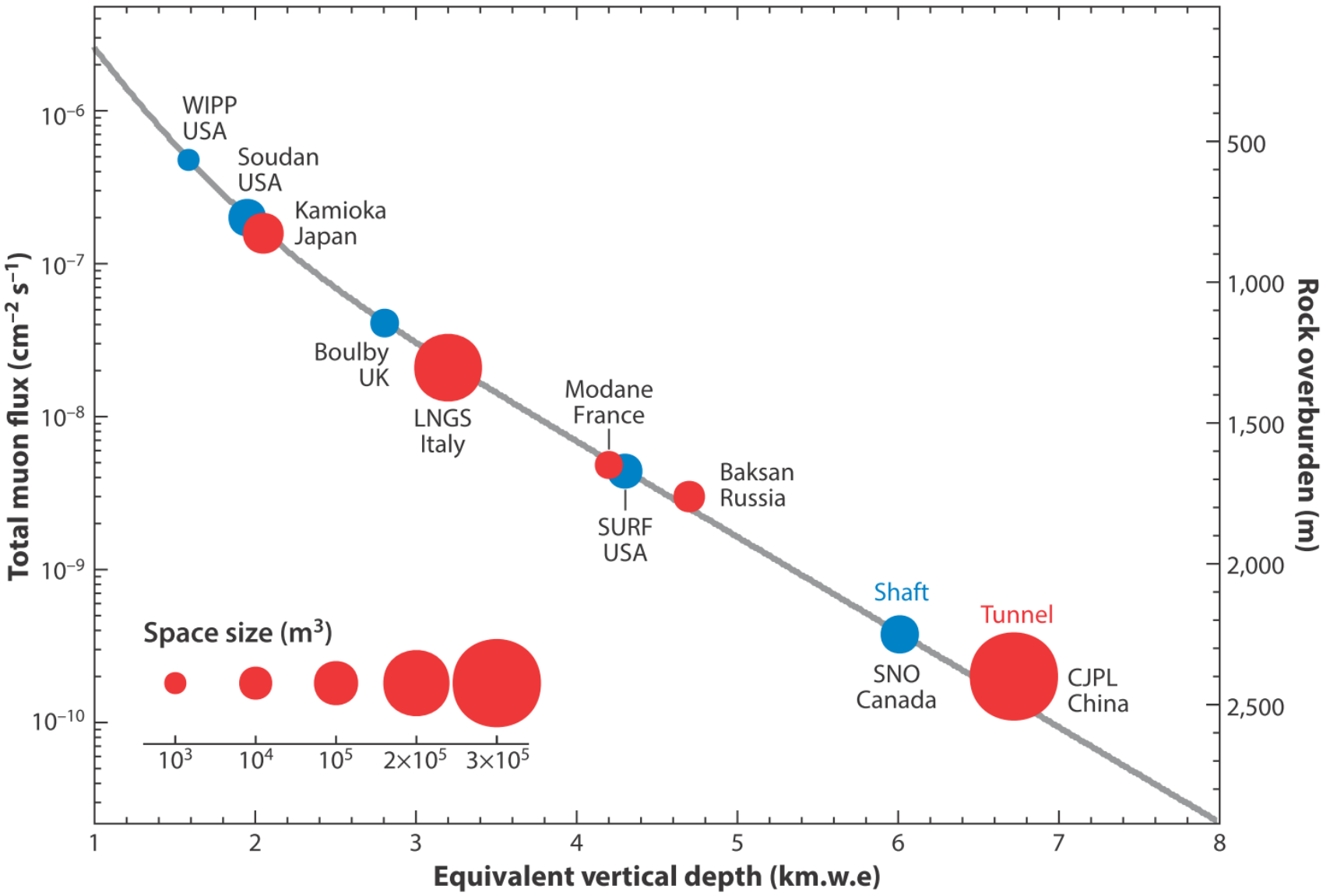


Shielding Cosmic rays

Main underground laboratories in the world



Main underground laboratories in the world



Jinping Hydroelectirc Power Plants Project

Yalong river meets Jinping Mountain:

- The largest tributary of Yangzi 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

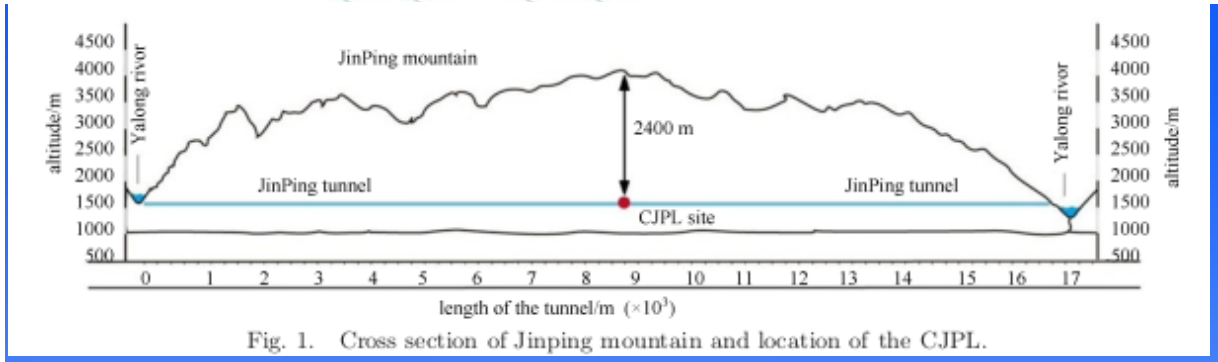


Fig. 1. Cross section of Jinping mountain and location of the CJPL.

West inlet

CJPL-II

CJPL-I

2 traffic tunnels (Jinping Tunnel)

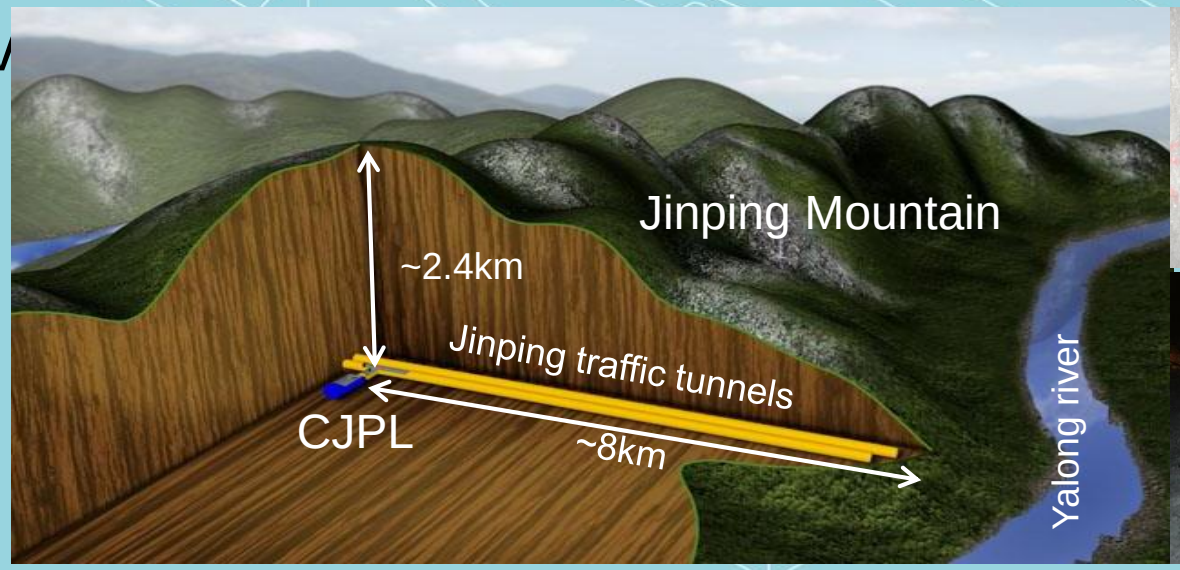
Drain tunnel

power generator

4 hydraulic tunnels for electric power generator

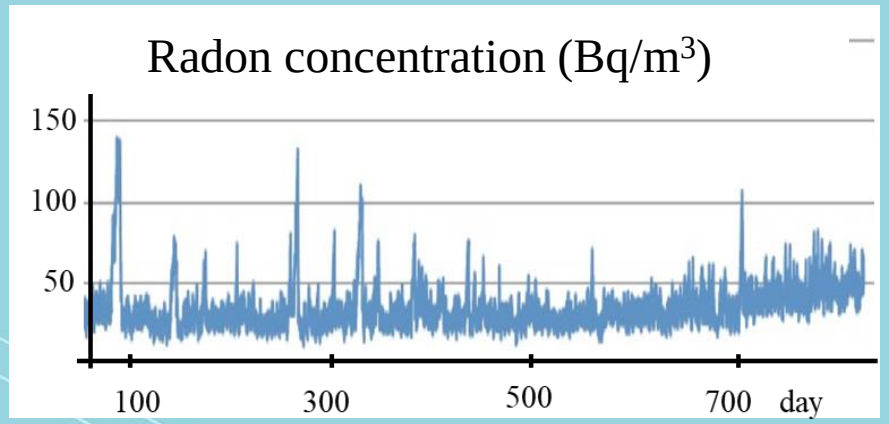
China JinPing Underground Laboratory(CJPL)

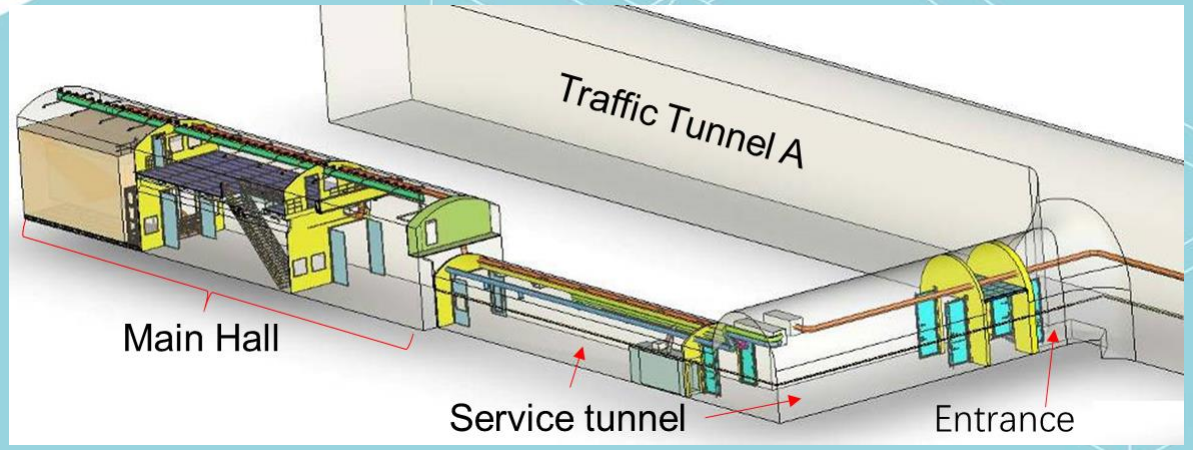
- An ideal site for an underground laboratory!
- THU-YHPC cooperation on a new underground lab started in May 2009.
- CJPL-I site selected in Aug. 2009.
- Rock sampling and in-situ measurement to study environmental



CJPL Features

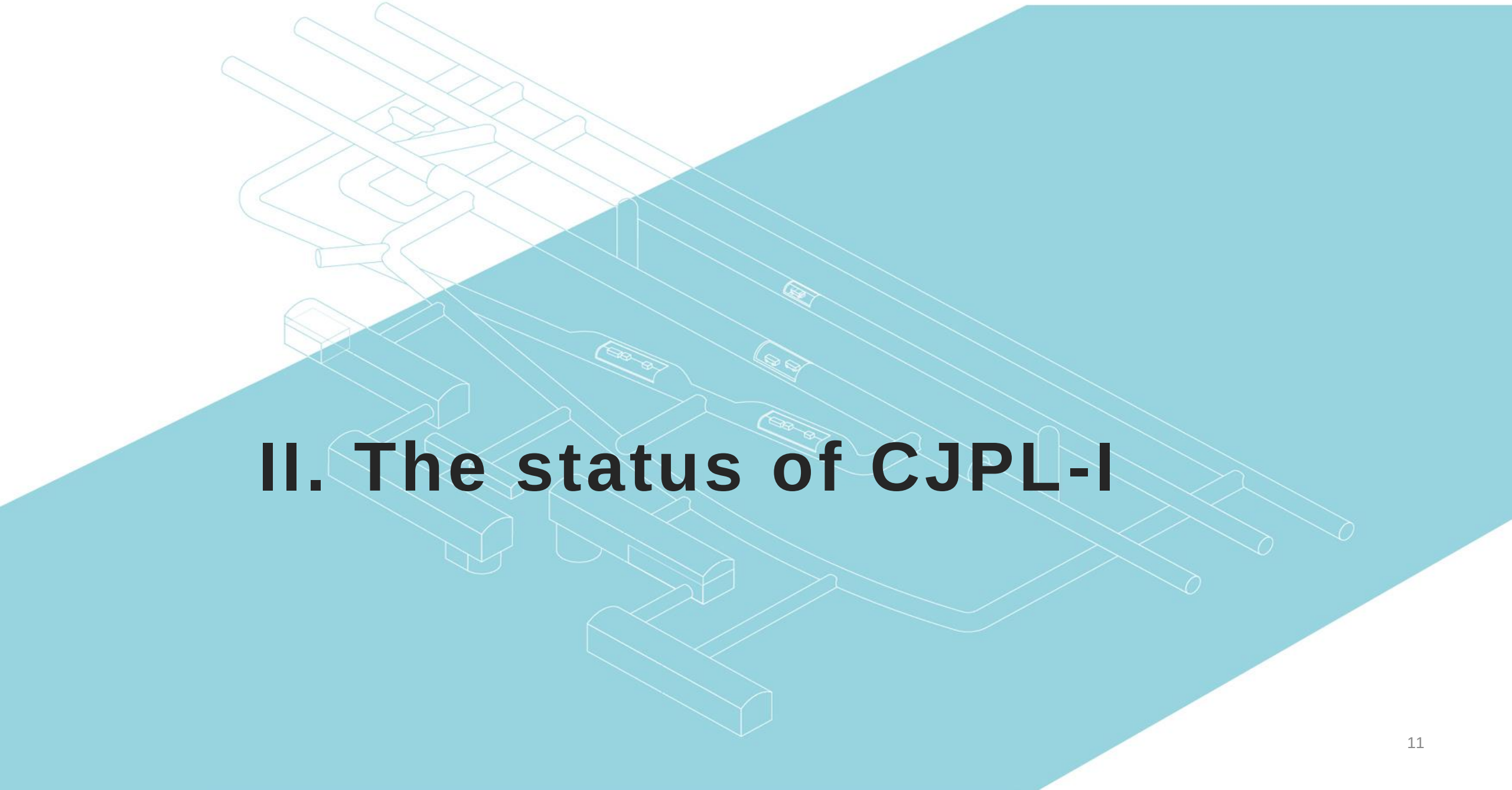
- Open on Dec. 12, 2010.
- Total space: ~4000 m³.
- Main Hall: 6.5m(W) × 6.5m(H) × 42m(L).
- Deepest underground laboratory with a rock overburden of 2400m.
- Low Muon flux and low environmental background.





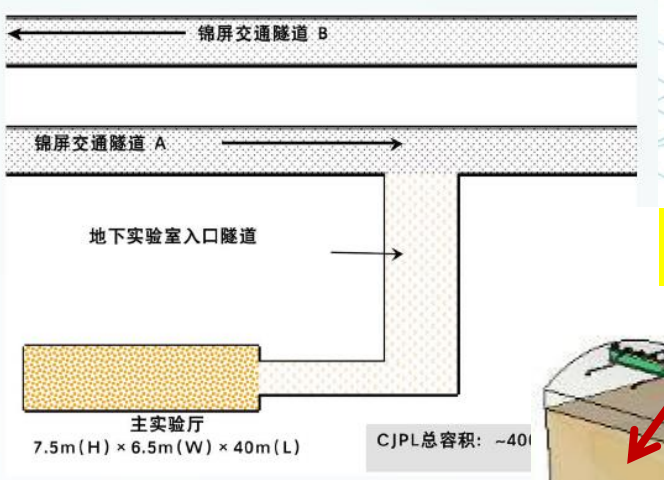
Rock sample(Marble) measurement by Germanium

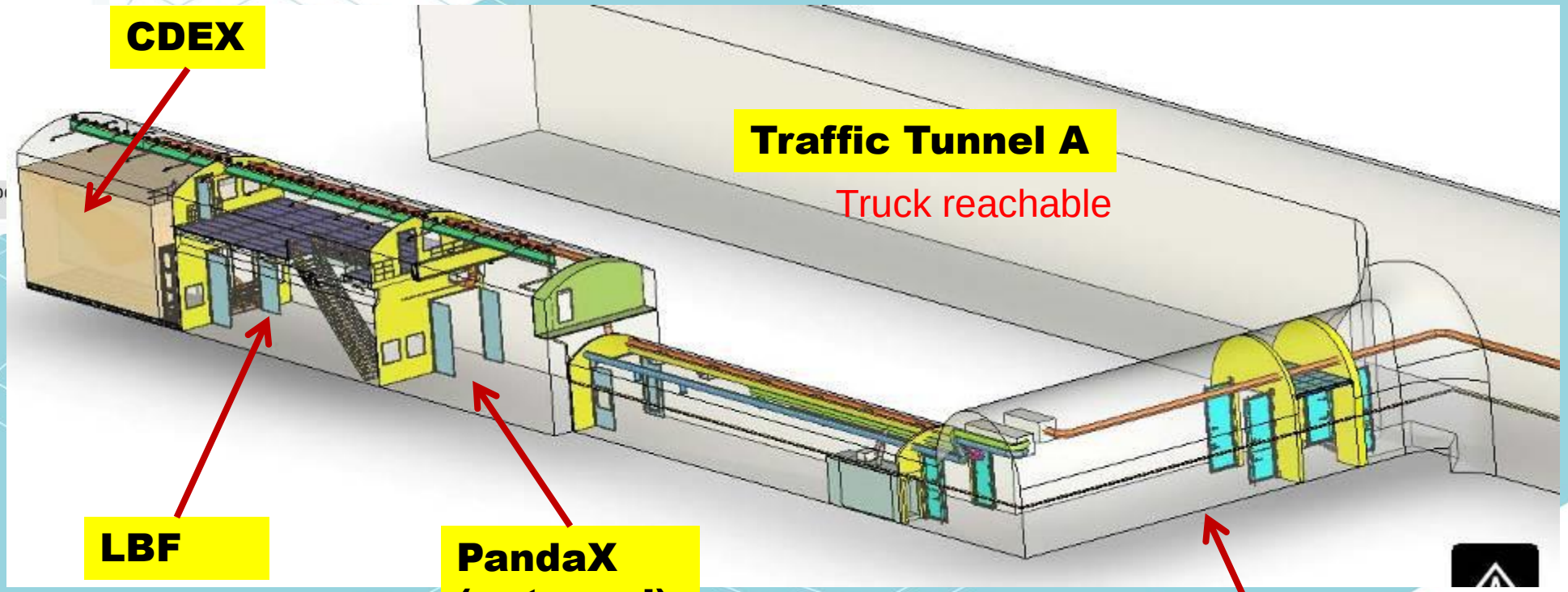
(Unit : Bq/kg)	K-40	Ra-226 (609keV)	Th-232 (911keV)
Rock Sample	< 1.1	1.8±0.2	< 0.27
Ground Level(Beijing)	~600	~25	~50



II. The status of CJPL-I

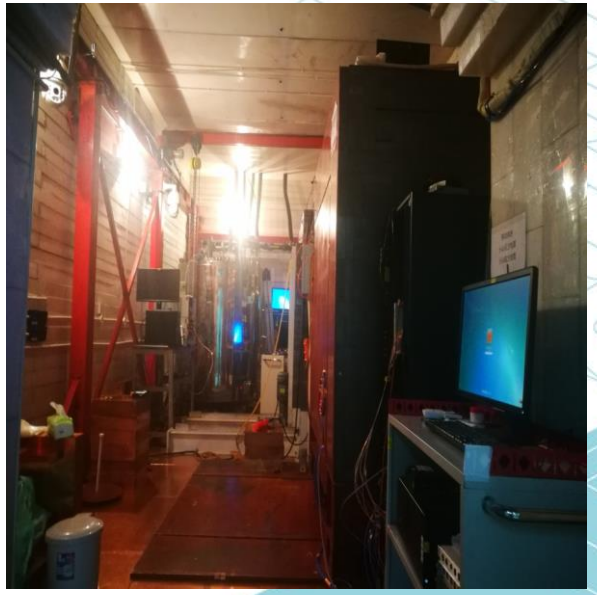
Layout of CJPL-I





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

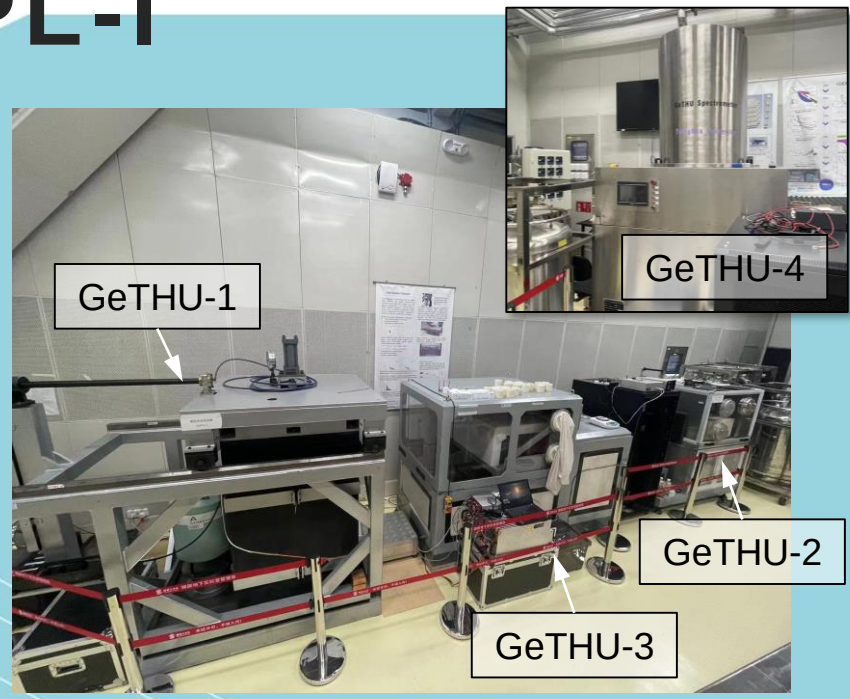
Experiments in CJPL-I



CDEX experiment

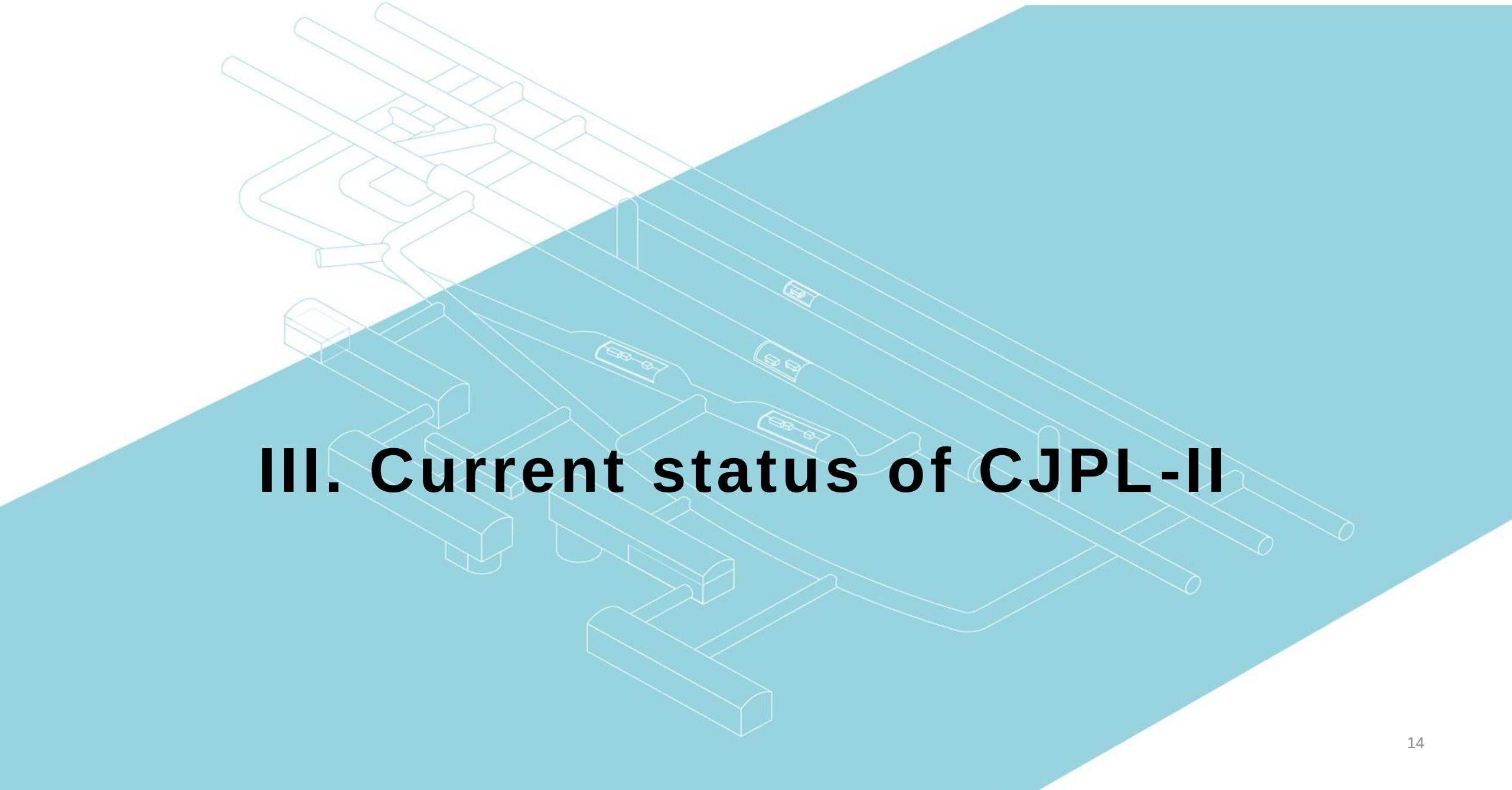
PandaX(removed)

Jinping neutrino



Low-background γ spectrometers

- Physics experiments:
  - 2 dark matter experiments: CDEX, PandaX (now to CJPL-II)
  - 1 neutrino experiment: Jinping Neutrino experiment
- Low background counting facilities:
  - 4 low-background gamma spectrometers: GeTHU1, 2, 3,4



III. Current status of CJPL-II

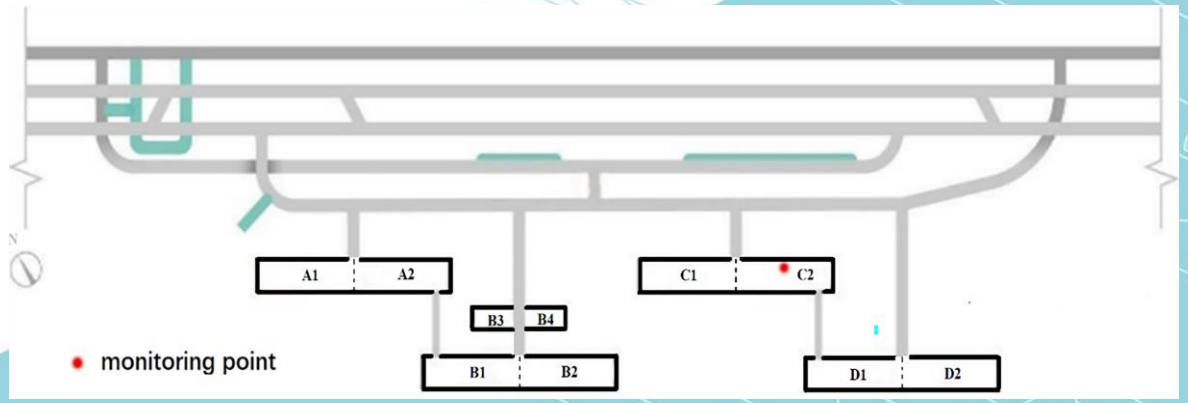
Deep Underground and ultra-low Radiation background Facility for frontier physics experiments(DURF) in CJPL-II

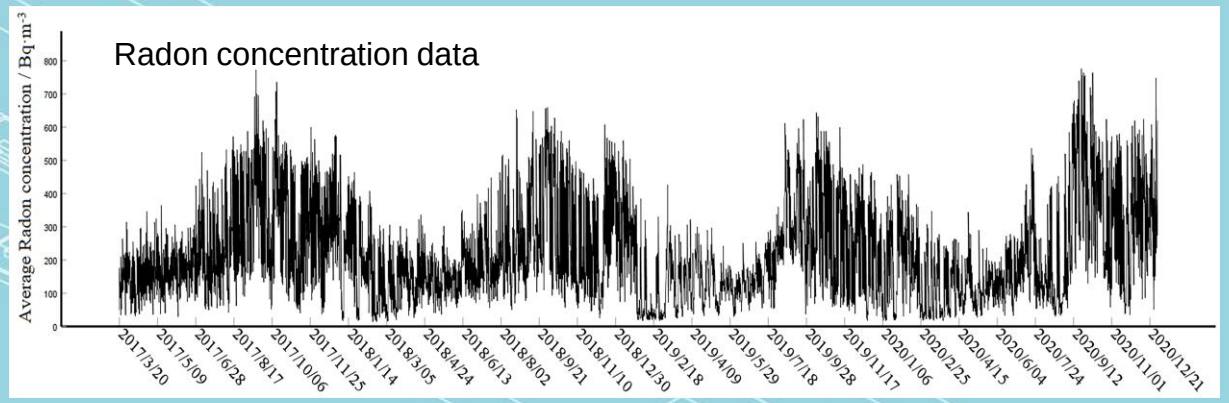
- Internal Construction started at 2020/12
- Civil engineering will be finished in Oct. 2023
- All constructions will be completed at 2024
- 4 experiment halls (A-D), total space of >300,000 m^3
- Will be the deepest and largest underground lab worldwide

Key Project: water-resistant and radon suppression

☐ Monitoring Rn-222 in Hall-C2 in bare cavern state

- Rn-222 concentration in 14~776 Bq/m^3 (average 201 Bq/m^3)
- Data fitting demonstrates a Rn-222 change cycle of 12.7 month



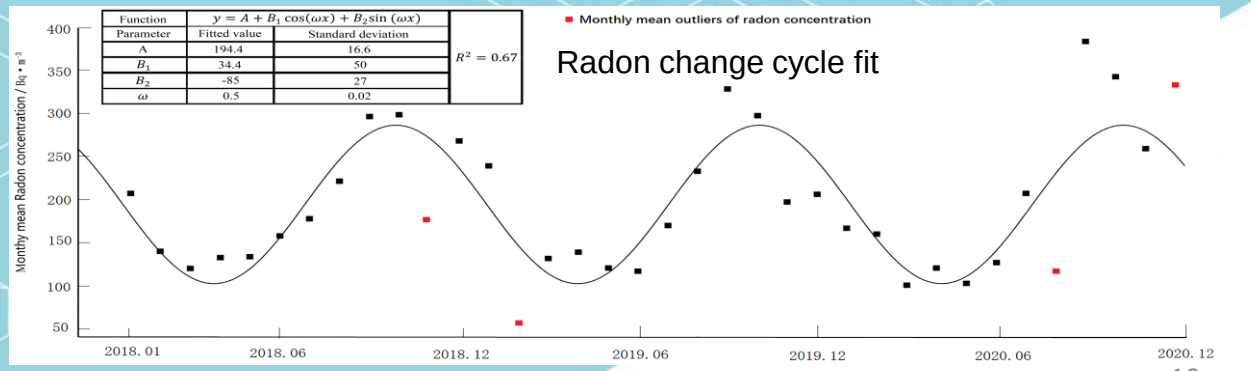


Det: Alpha-GUARD PQ2000

Loc: CJPL-II hall-C2

Date: 2017.3-2020.12

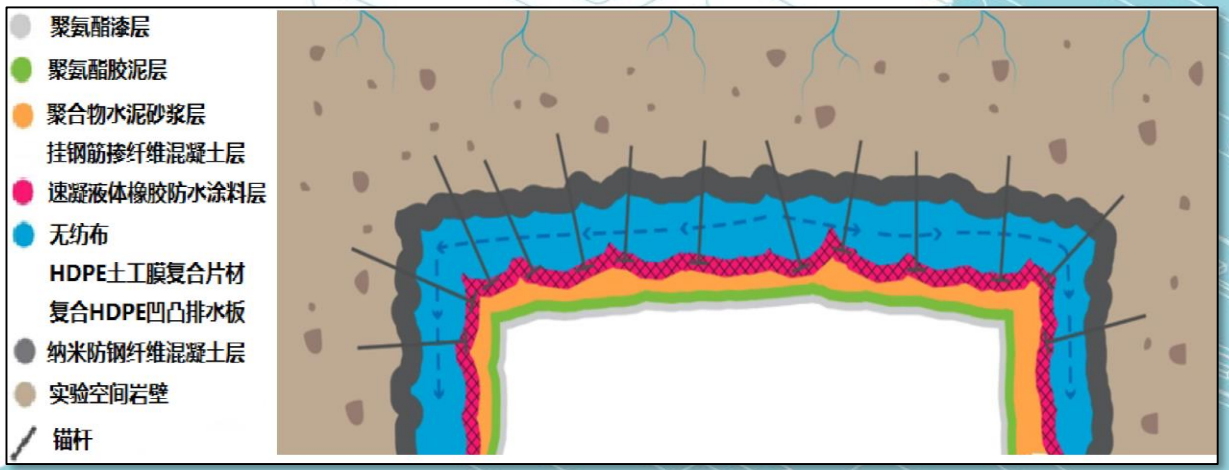
Mea-time: 60 min/point



Key Project: water-resistant and radon suppression

☐ Water-Resistant and Radon Suppression (WRRS) layer

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

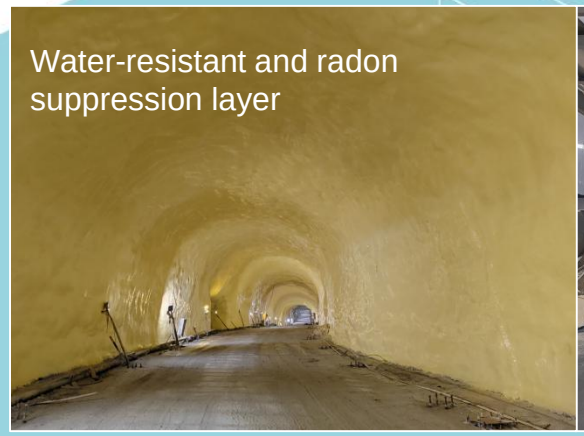


Features of WRRS layer:

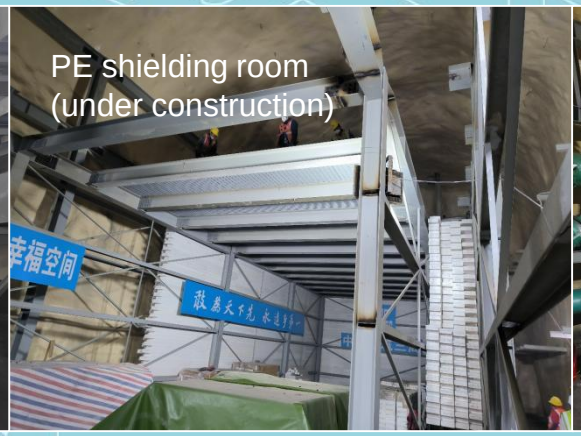
- ➢ Preventing water and radon permeating from the rock into lab space simultaneously
- ➢ Covering the full-space of each experiment hall (wall and floor)
- ➢ Using low-background materials in WRRS
- ➢ 7 layers, 9 processing, dozens of materials

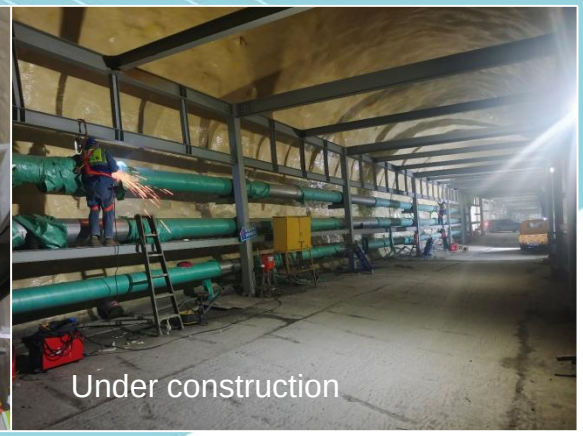
Civil engineering of CJPL-II

- **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: 1427 m^3 PE blocks entered, and 40% completion for construction**
- **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 (under construction)

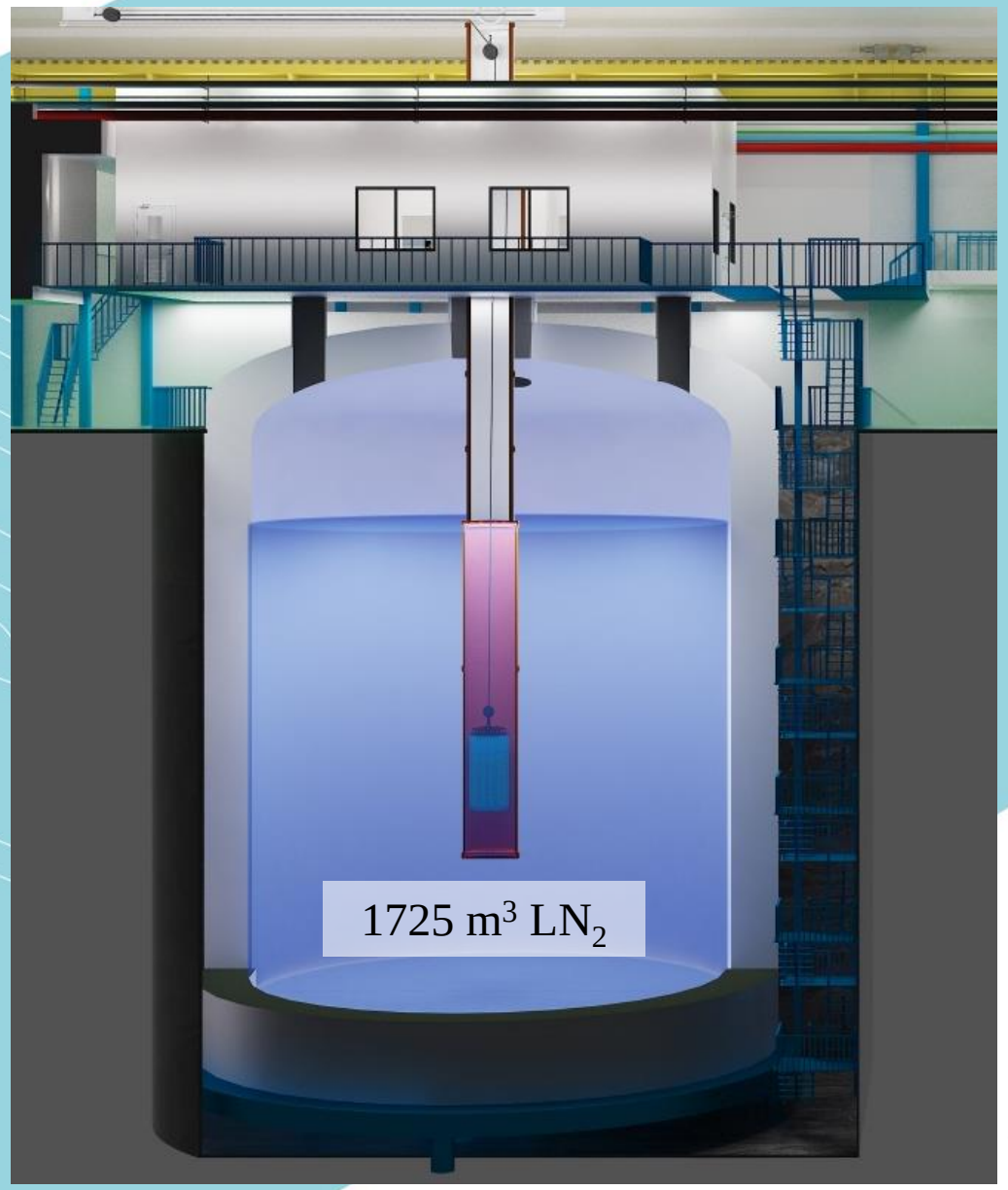

Under construction

Key Project: Large Nitrogen vessel shielding

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

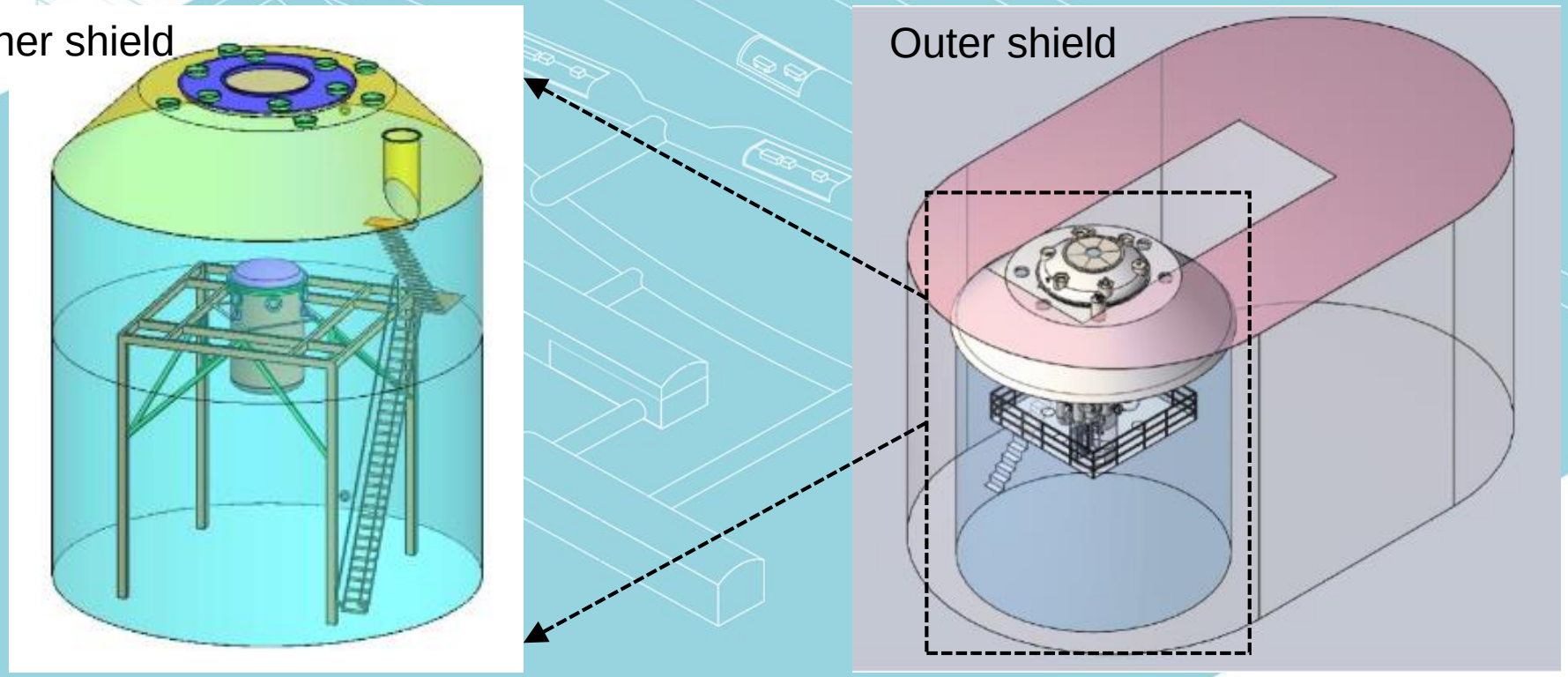

Pit in Hall C1


1725 m^3 LN_2 tank in Hall C1



Key Project: Large pure water tank shielding

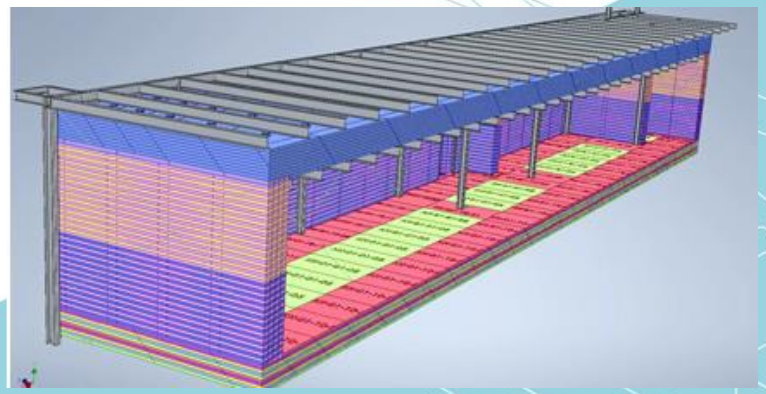
- **Located in Hall-B2:**
  - Outer shield (4500 m^3 water) and inner shield (1000 m^3 water)
  - 12 L low-level radon measure device completed
  - Water-radon system pressure test completed



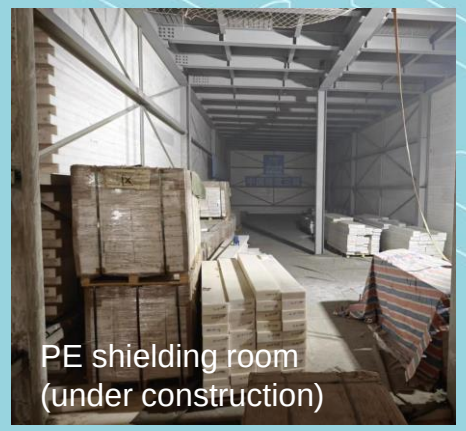
Key Project: Assemble combine shielding

☐ Multi-purpose PE, Copper, and Lead shield

- PE room under construction, 40% completion
- Inner copper and lead combined shielding module under preparation



PE shielding room
(under construction)

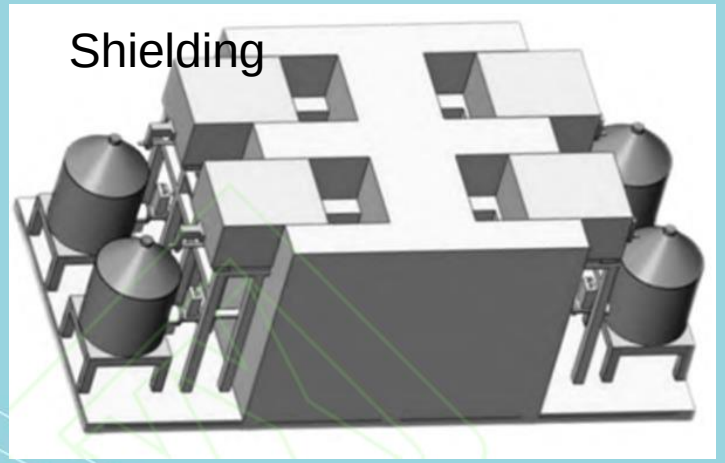


PE shielding room
(under construction)

Key Project: Ultra-low-background γ spectrometers

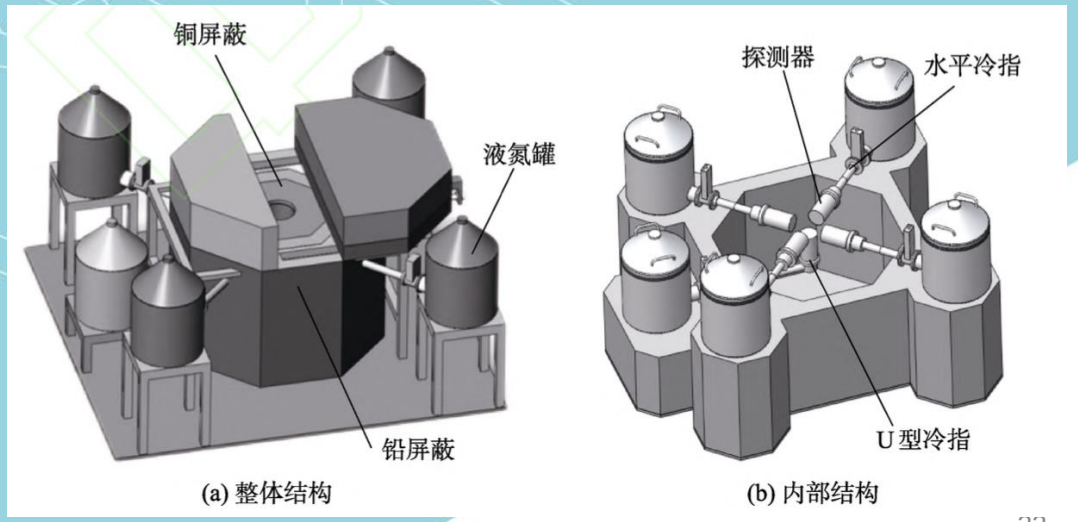
☐ mBq/kg spectrometers (GeTHU)

- 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 scale
- 5 commercial HPGe detectors
- Low-background shielding



Key Project: Cavern safety monitor system

☐ Detectors:

- Multi-detectors to monitor the rock vibration and displacement.

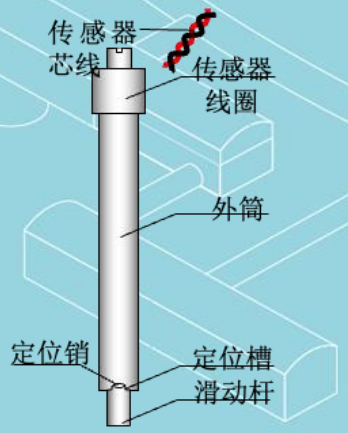
microseismic monitoring system

gravity meter

seismograph

osmometer

Disturbed Stress monitor



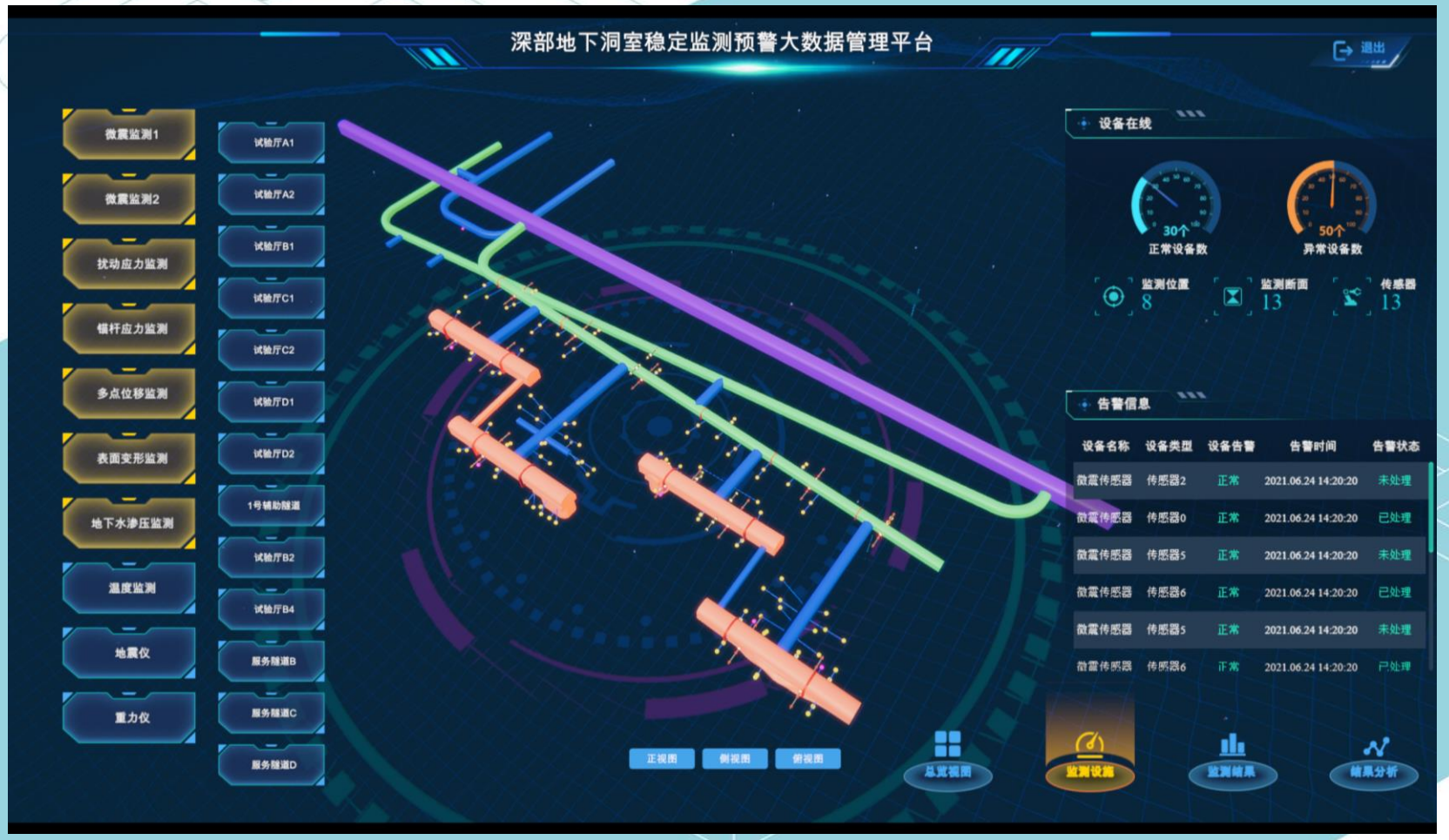
displacement sensor

Surface deformation monitor

rock cracking monitor

Key Project: Cavern safety monitor system

- **User Interface:**



IV. Experiments in CJPL-II

- CDEX (DM+0νββ)
- PandaX (DM+0νββ)
- JUNA (Nuclear Astroparticle)
- Jinping Neutrino Program (Solar and Geoneutrino)
- SER (integrated circuit Soft Error Research)
- GeoDEX (Deep underground geologic experiment)
- CUPID-CJPL (0νββ)
- NvDEx (0νββ)
- More coming……

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

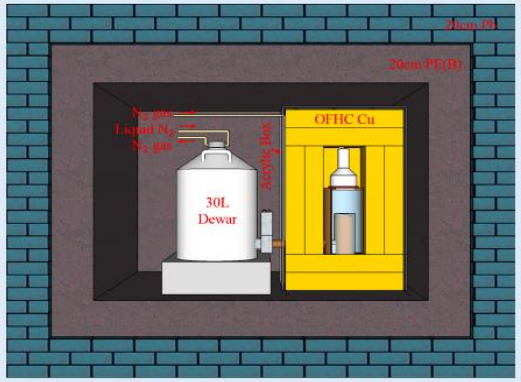
CDEX-1

CDEX-1A

- DM: χ-N (SI/SD)
- Axion & Axion-like DM
- CDEX first ovββ result

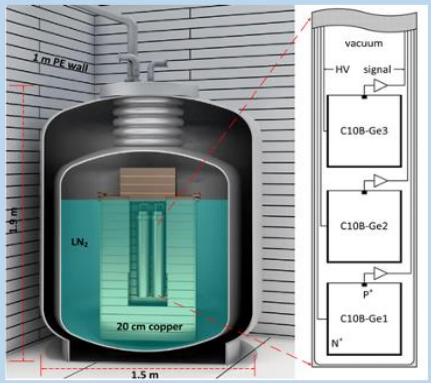
CDEX-1B

- 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



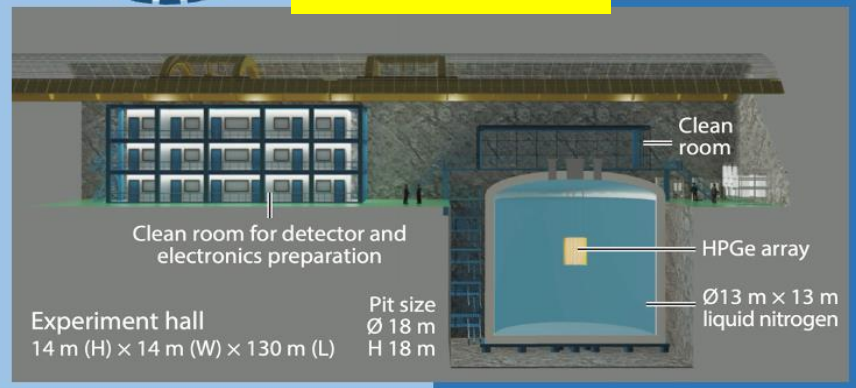
CDEX-50 (DM)

Litao Yang's Talk

CDEX-300 (0νββ)

CDEX-1T (0νββ, DM...)

Hao Ma's Talk

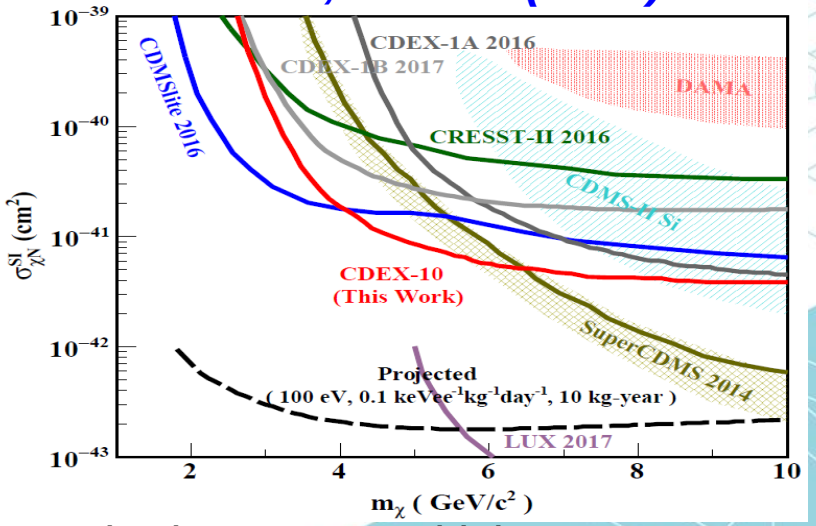


CJPL-I

CJPL-II

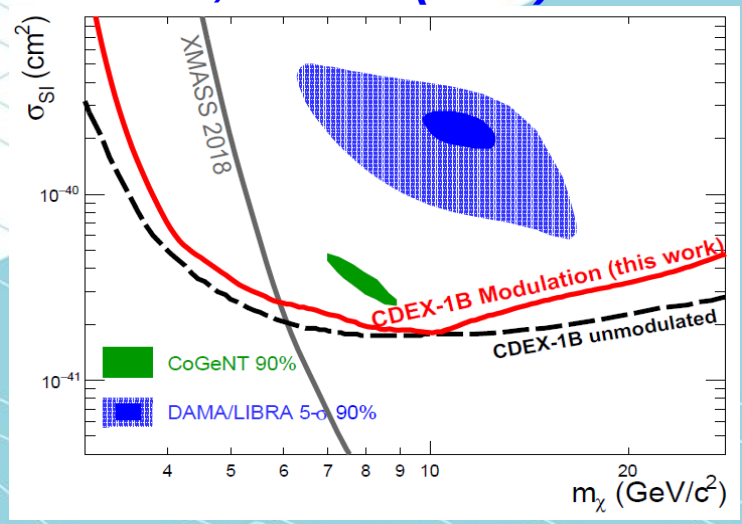
CDEX

PRL ***120, 241301 (2018)***



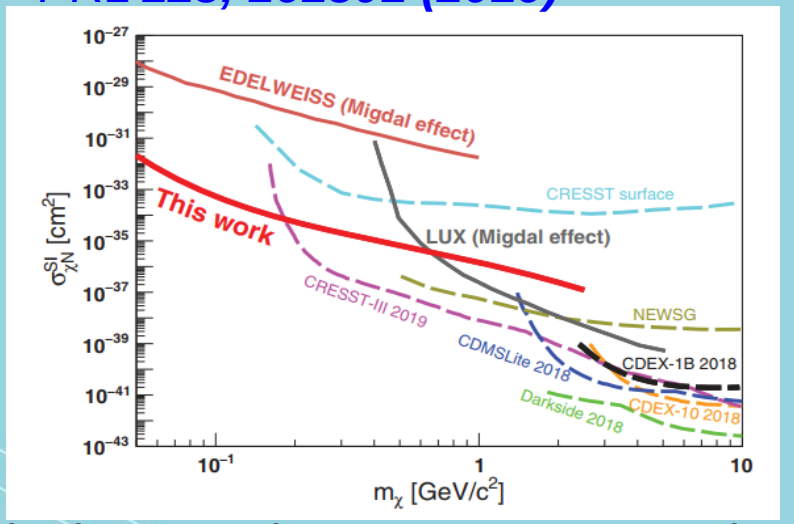
The best SI sensitivity at 4-5GeV energy region from CDEX in 2018

PRL ***123, 221301 (2019)***

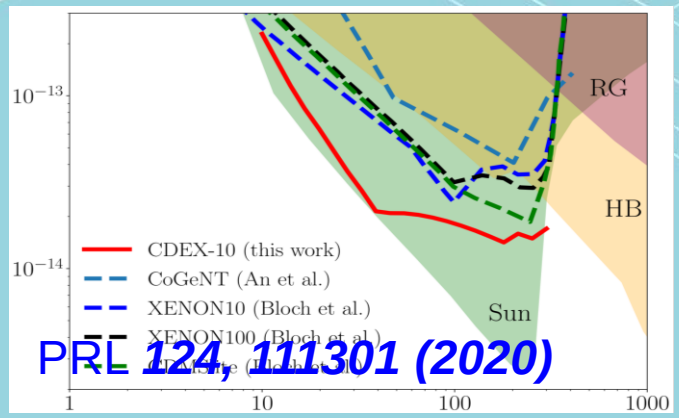


Exclude the possible region favored by CoGeNT and DAMA based on 4yr Data

PRL ***123, 161301 (2019)***

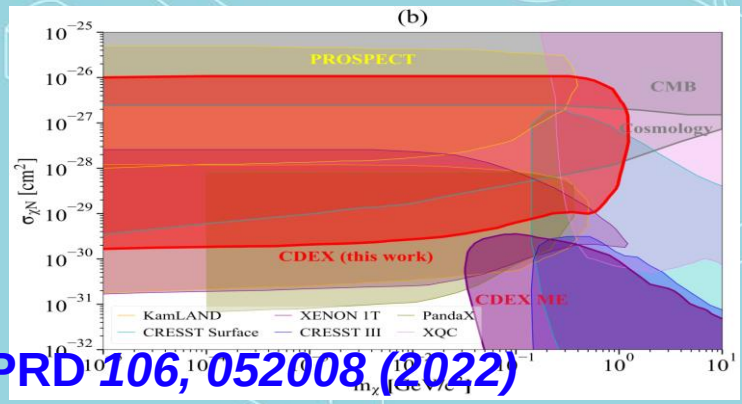


the best results at 50-180 MeV region With Migdal Effect



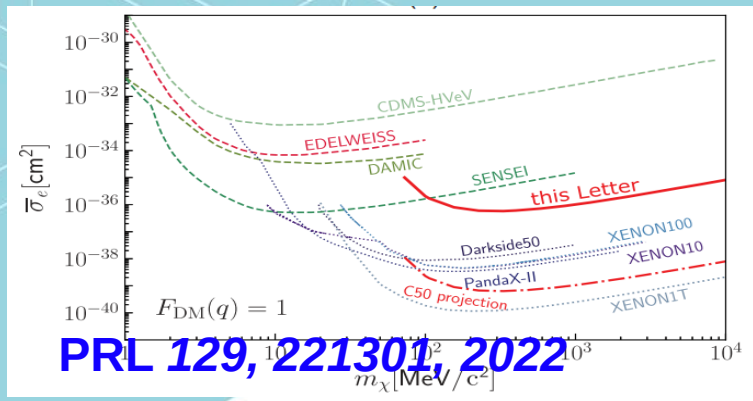
PRL ***124, 111301 (2020)***

Leading sensitivity in m_V ~10-300 eV for solar dark photon



PRD ***106, 052008 (2022)***

Detected CR- accelerated DM and scaned the new light-mass parameter region



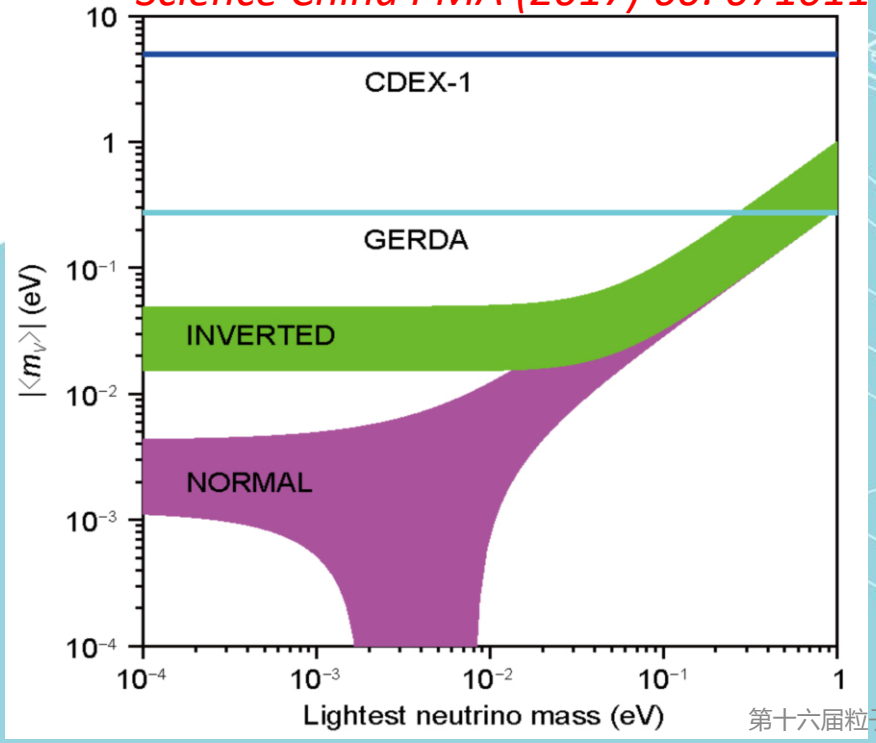
PRL ***129, 221301, 2022***

DM-Electron recoil with HPGe

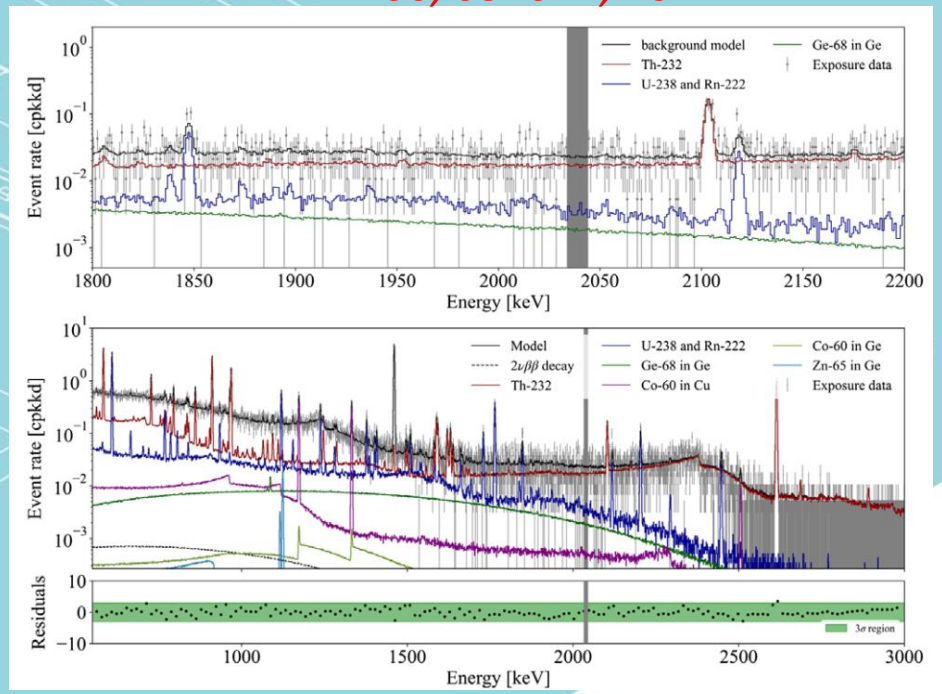
CDEX ^{76}Ge 0νββ results

- Based on the CDEX-1 natural PCGe detector, first ^{76}Ge 0νββ result in 2017.
- $<m_{\beta\beta}>$ sensitivity: one order less than GERDA-I at that time.
- Develop new BEGe detector for CDEX-0vbb experiment。

Science China PMA (2017) 60: 071011



PRD 106, 032012, 2022



PandaX

- Starting in 2009, consists of dozens of universities and research Institutions
- Goals: Increase LXe detector mass for DM and neutrino studies

Jianglai Liu's Talk

PandaX

Phase-I
120 kg

Phase-II
580 kg

PandaX-4T
3.7 ton

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

PandaX

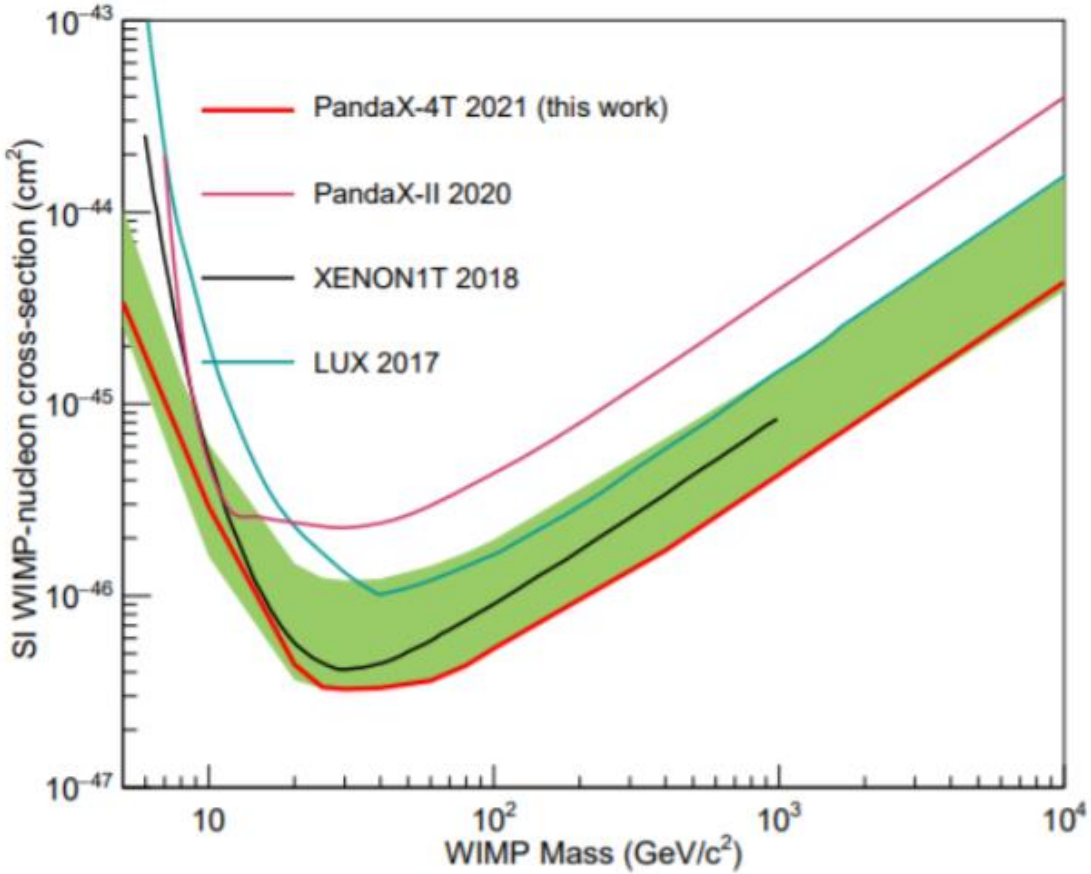
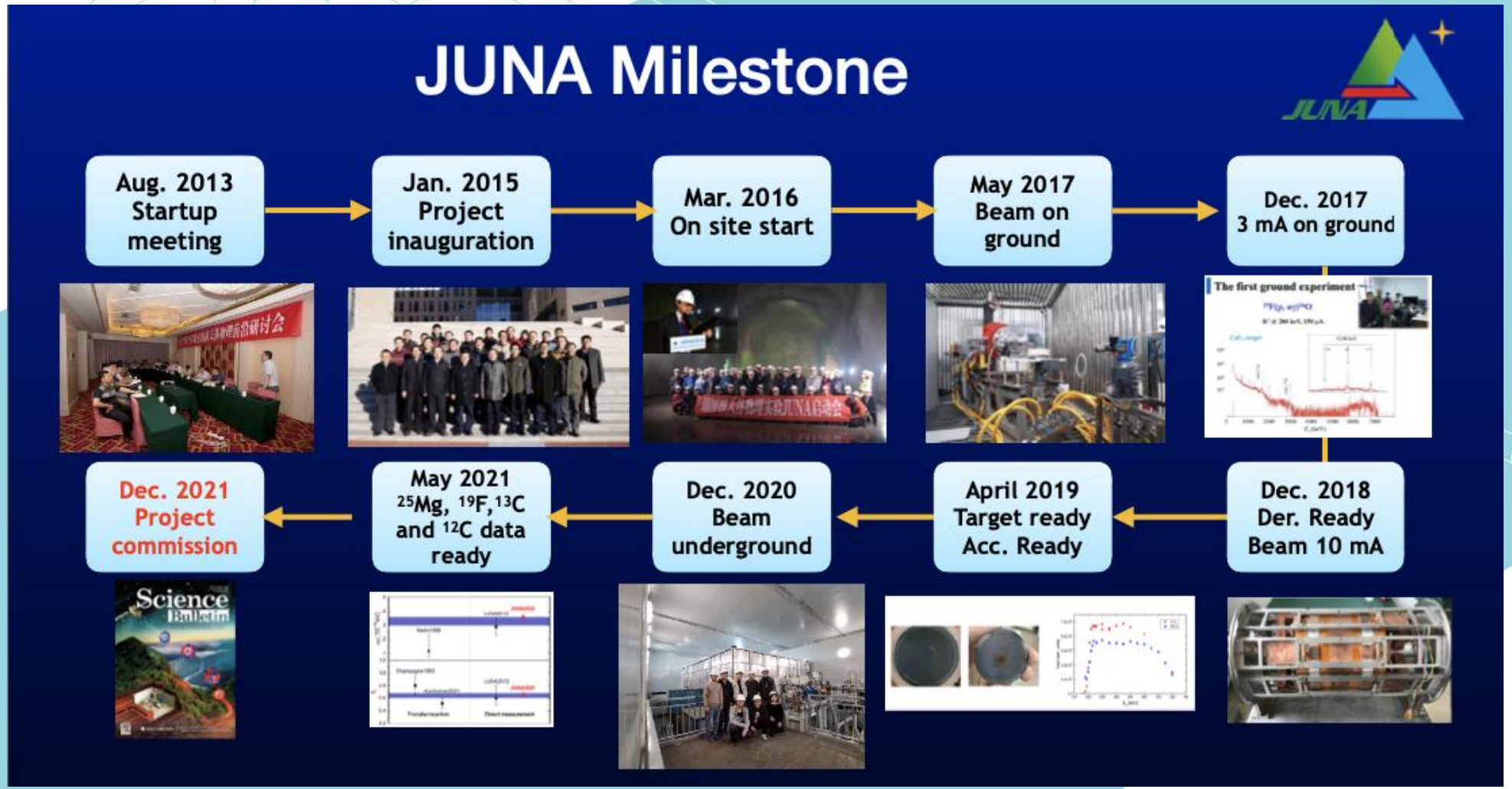


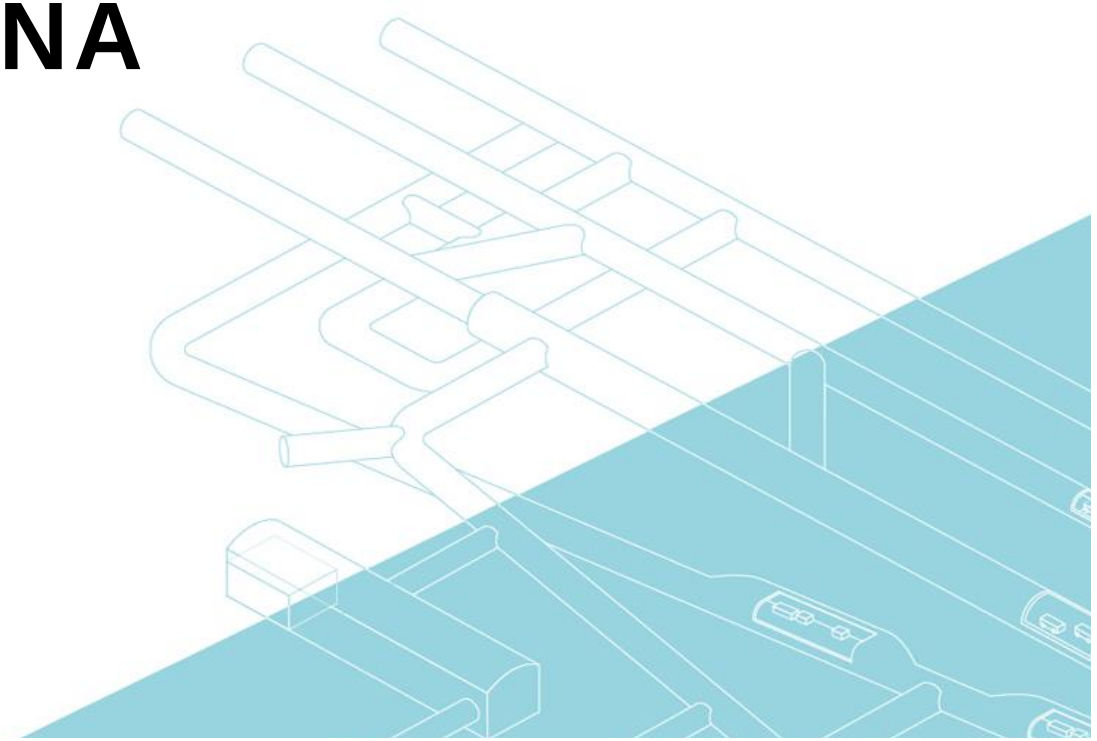
Fig. 9. The 90% C.L. upper limit vs. m_χ for the SI WIMP-nucleon elastic cross section from PandaX-4T commissioning data (red), overlaid with that from LUX 2017,[4] XENON1T 2018[3] and PandaX-II 2020.[5] The green band represents the $\pm 1\sigma$ sensitivity band.

JUNA

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



JUNA



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Editors' Suggestion | Featured in Physics

Direct Measurement of the Astrophysical $^{19}F(p,\alpha\gamma)^{16}O$ Reaction in the Deepest Operational Underground Laboratory

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Article

Measurement of $^{19}F(p, \gamma)^{20}Ne$ reaction suggests CNO breakout in first stars

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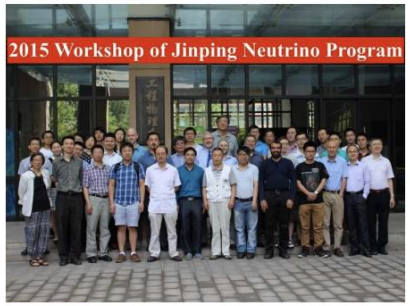
Proposed mechanisms for the production of calcium in the first stars (population III stars)—primordial stars that formed out of the matter of the Big Bang—are at odds with observations[1]. Advanced nuclear burning and supernovae were thought to be the dominant source of the calcium production seen in all stars[2]. Here we suggest a qualitatively different path to calcium production through breakout from the 'warm' carbon–nitrogen–oxygen (CNO) cycle through a direct experimental measurement of the $^{19}F(p, \gamma)^{20}Ne$ breakout reaction down to a very low energy point of 186 kiloelectronvolts, reporting a key resonance at 225 kiloelectronvolts. In the domain of astrophysical interest[2], at around 0.1 gigakelvin, this thermonuclear $^{19}F(p, \gamma)^{20}Ne$ rate is up to a factor of 7.4 larger than the previous recommended rate[3]. Our stellar models show a stronger breakout during stellar hydrogen burning than previously thought[1,4,5], and may reveal the nature of calcium production in population III stars imprinted on the oldest known ultra-iron-poor star, SMSS0313-6708[6]. Our experimental result was obtained in the China JinPing Underground Laboratory[7], which offers an environment with an extremely low cosmic-ray-induced background[8]. Our rate showcases the effect that faint population III star supernovae can have on the nucleosynthesis observed in the oldest known stars and first galaxies, which are key mission targets of the James Webb Space Telescope[9].

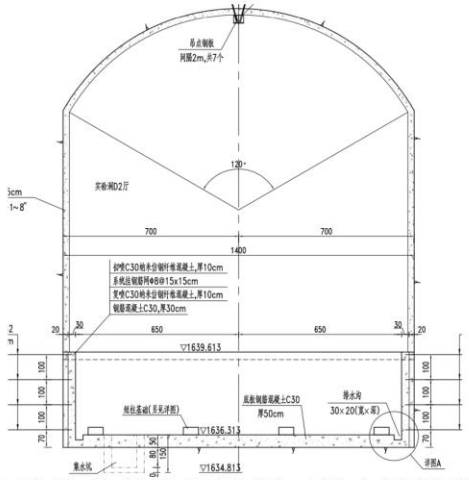
Jinping Neutrino Program

Goal:

- Solar neutrino detection
- Geoneutrino detection
- Supernova neutrino search

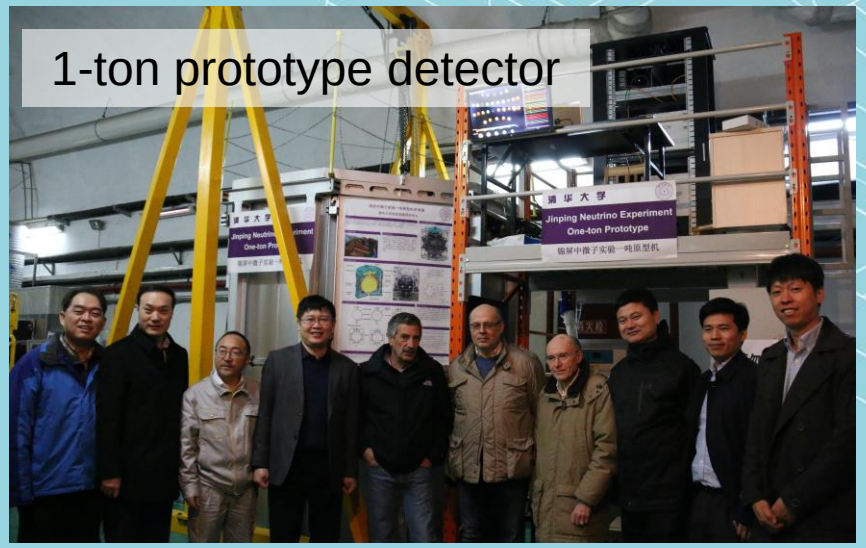


Pit for 500 ton Neutrino Observatory



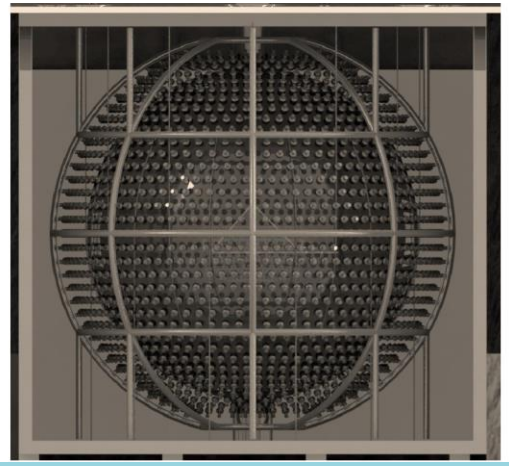
实验设备基坑设计图（华东设计院）

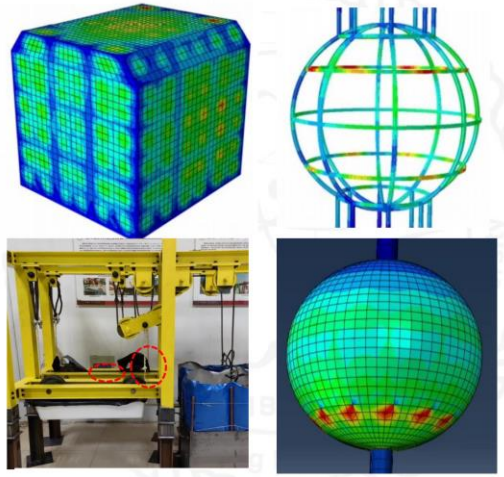
实验设备基坑，长16米，宽14米，深3.8米，开挖工作完成（水电5局）



1-ton prototype detector

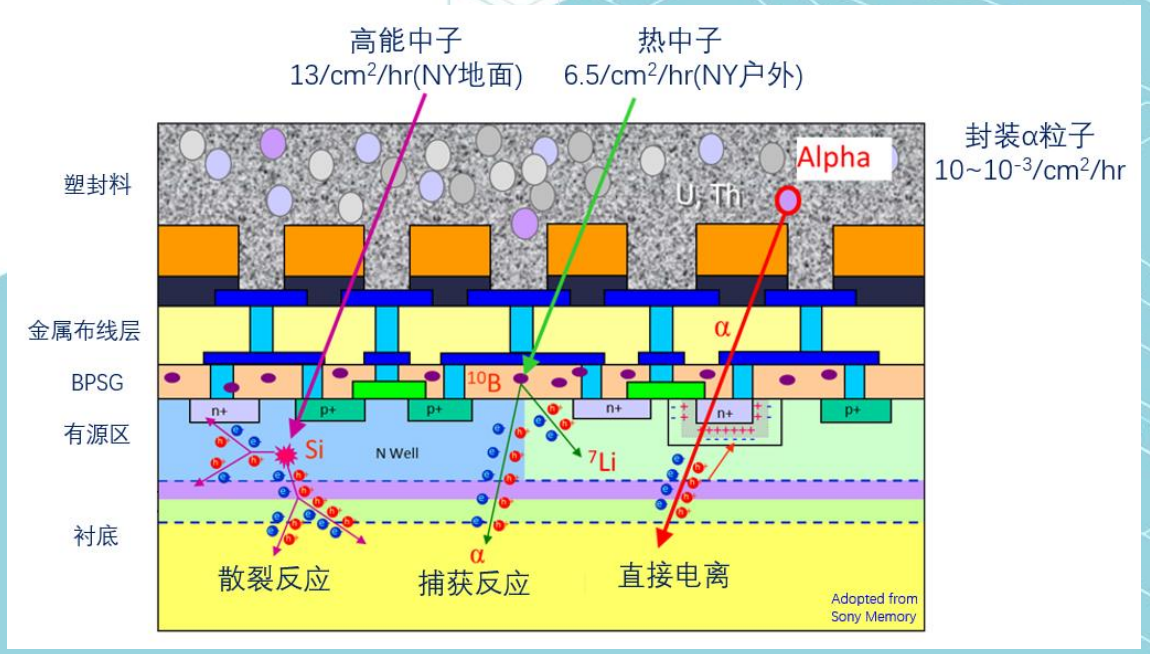
Neutrino detector design





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 atmosphere neutrons
- Compare test data in CJPL and Lasa to acquire “Golden data” for IC SE rate

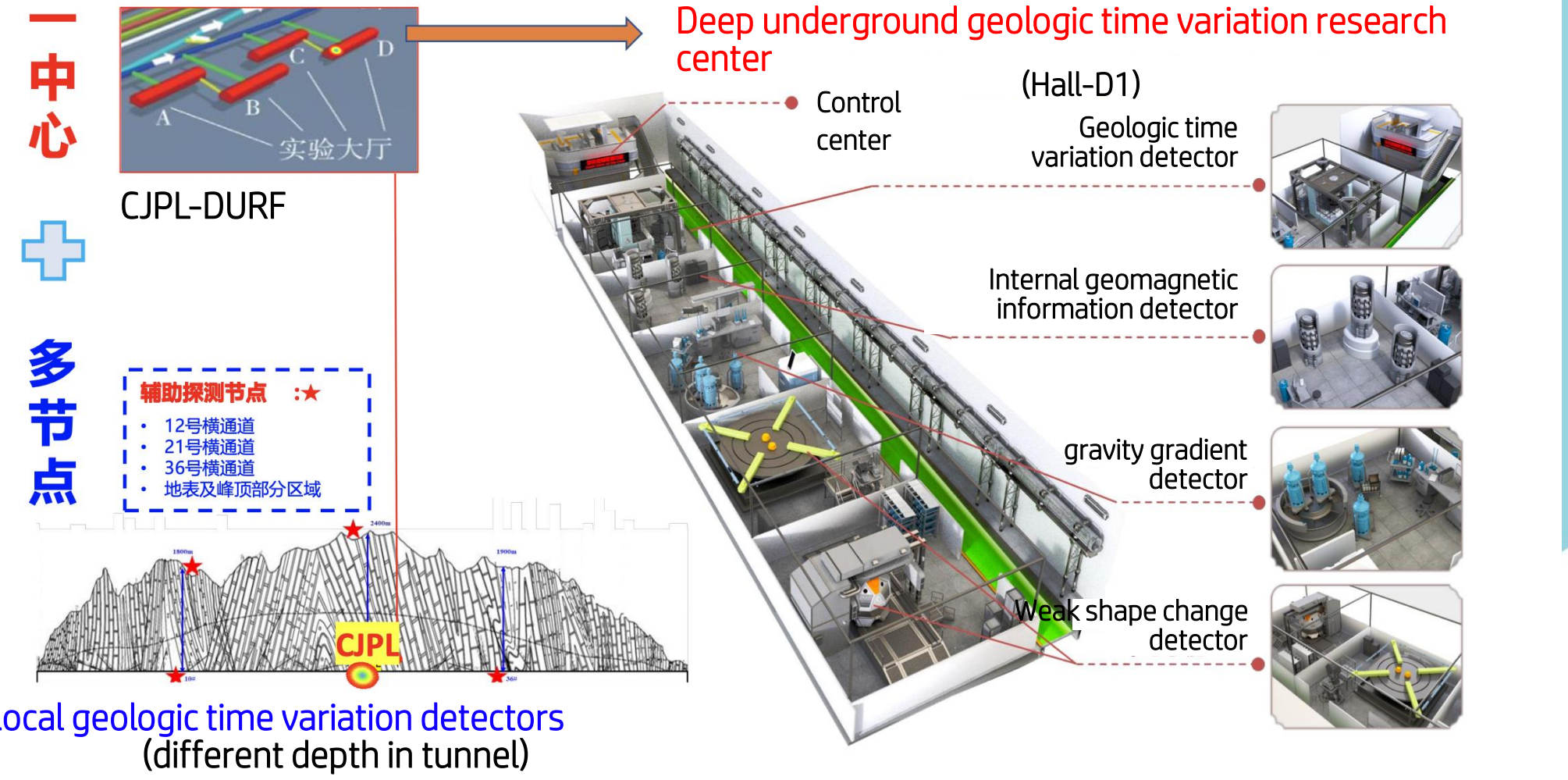


Test at Lasa
- 6651 hr

Test at CJPL
- 6000 hr

GeoDEX

- Deep underground geologic time variation in-situ detector experiment



CUPID-CJPL

- 0νββ experiment based on Mo-100 isotope and LMO crystal calorimeter array.

Participate in CUPID project: crystal validation and electronics

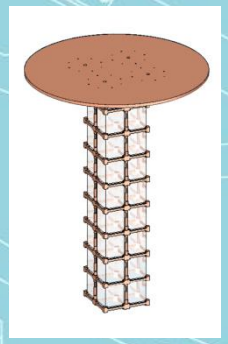
Crystal Testing
(2023-2028)

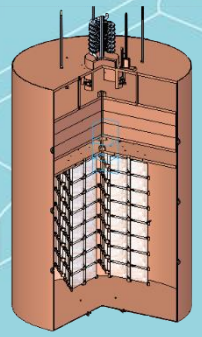
Develop CUPID-reach/1T Technology

CUPID-CJPL Demo
(2026-2028)
10 kg enriched crystals

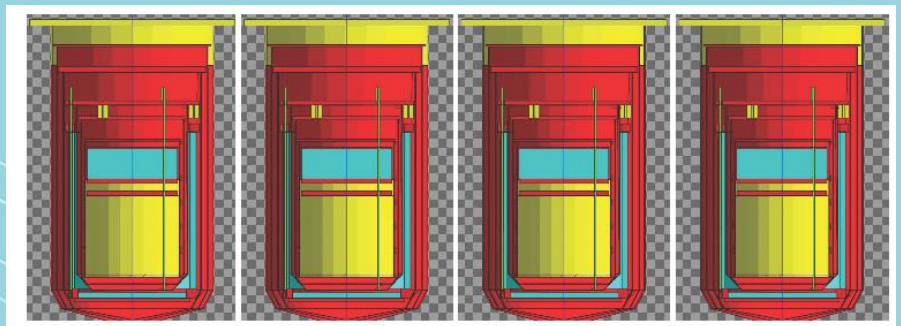
Build CUPID-reach or CUPID-1T at CJPL

CUPID-CJPL-200/1T
(2028+)
> 250 kg enriched crystals





Possible CUPID-1T configuration



- 10 kg experiment
  - low enrichment
  - demonstrate key technologies
- 250 kg+ experiment
  - high enrichment
  - probe $m_{\beta\beta}$ below 10meV

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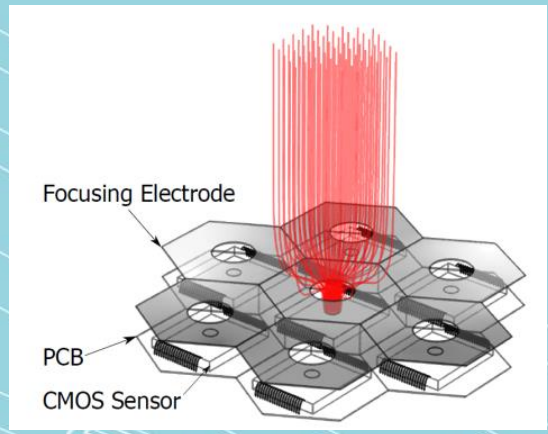
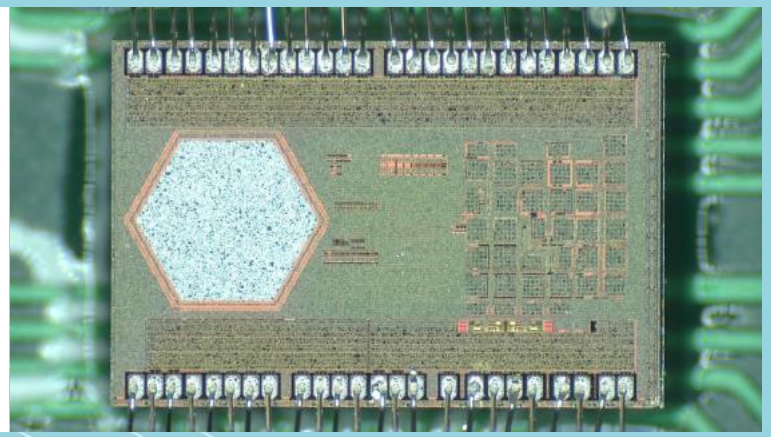
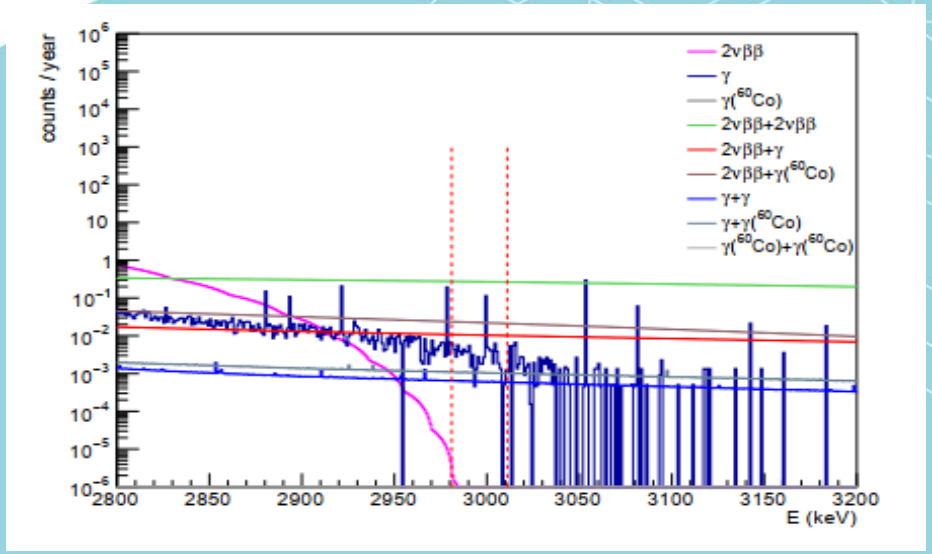
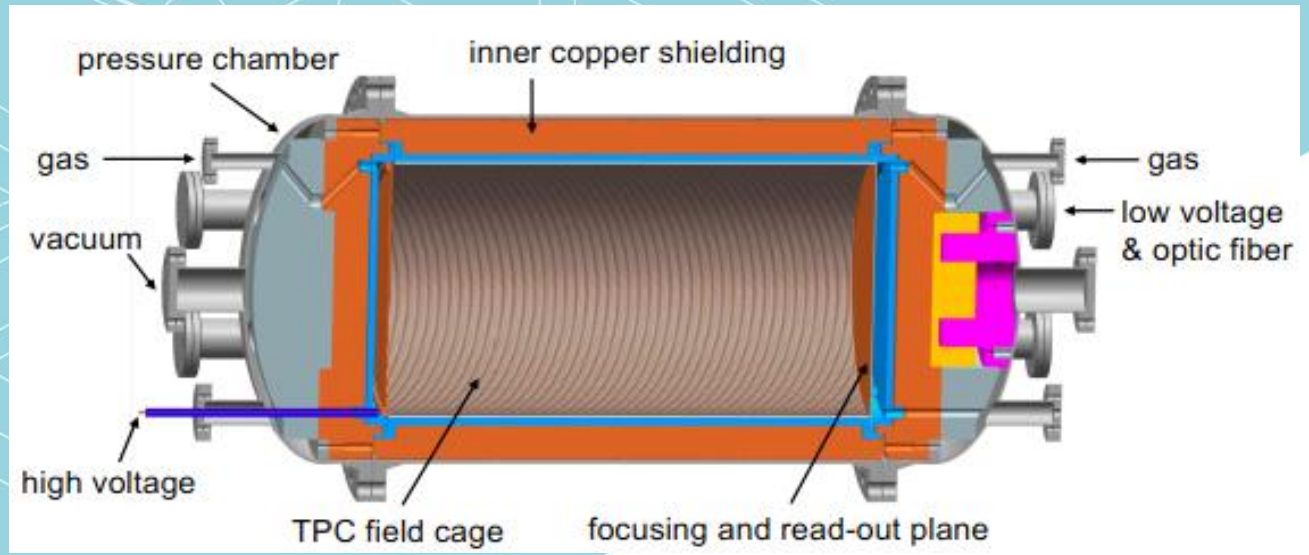
NvDEx

- 0νββ experiment based on Se-82 isotope and High pressure TPC.
- Topmetal technique to readout the ion signal.
- High pressure $^{82}SeF_6$ gas as the source and target.
- 200kg per module * 5

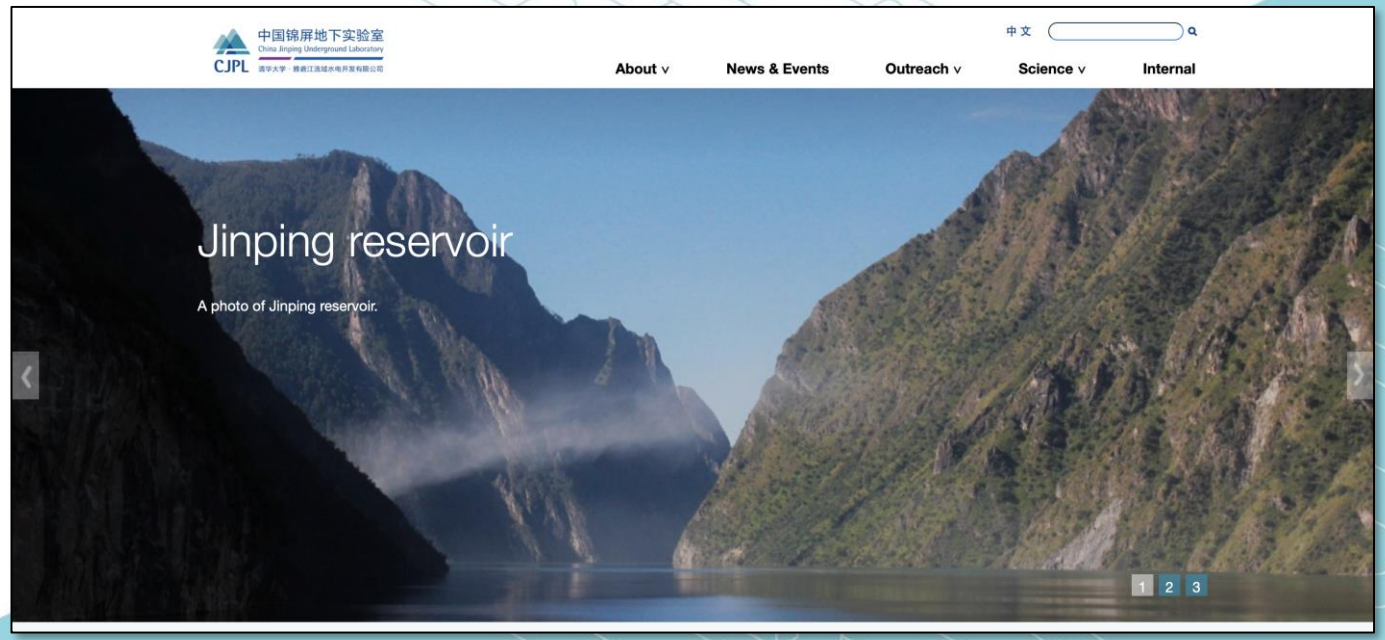








Welcome New Experiments and Collaborations



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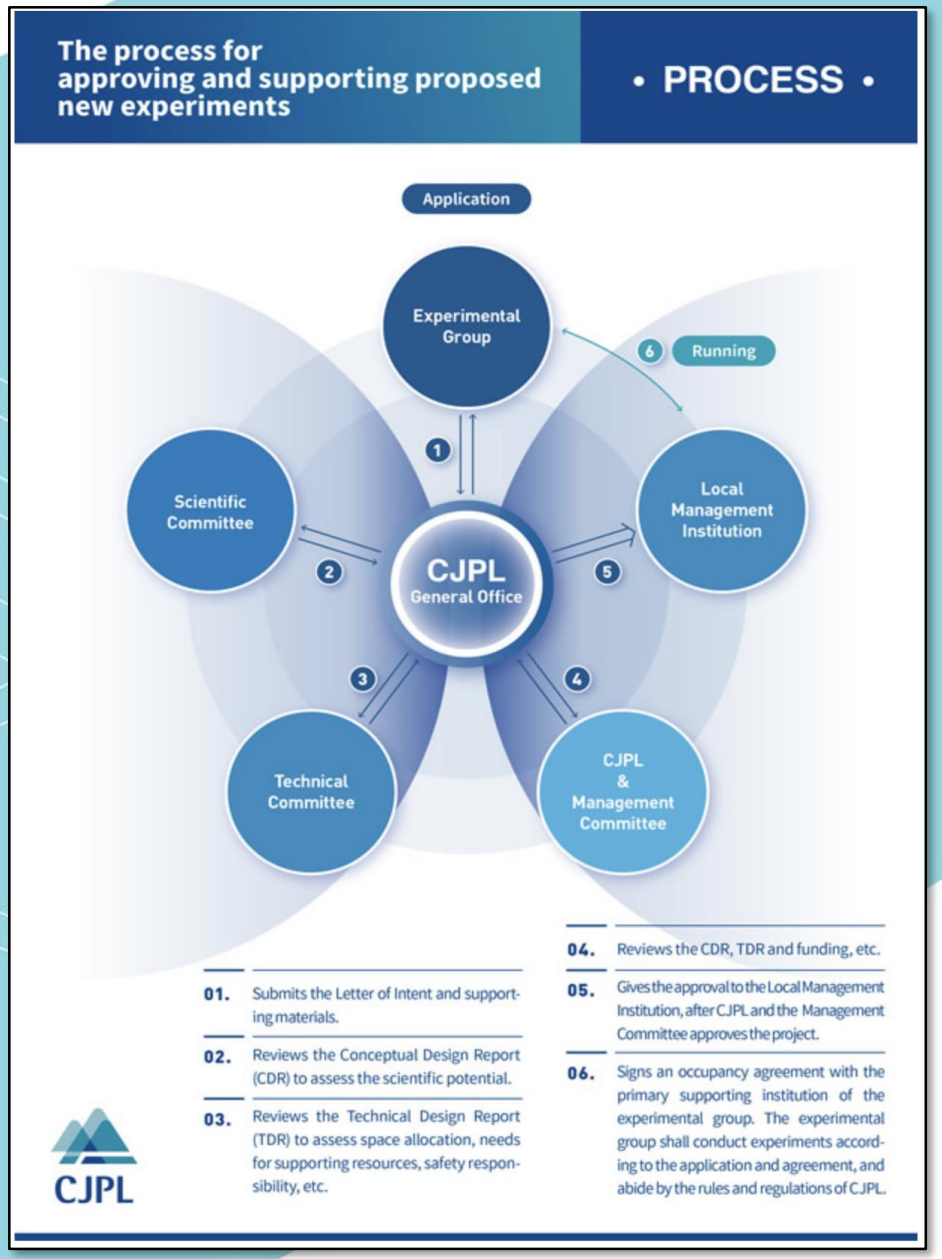
Contact:

cjpl@tsinghua.edu.cn



Summary:

- Series of important physical results on DM, nuclear astroparticle physics has been achieved based on CJPL deep underground platform.
- CJPL-II will be the deepest (2400m rock) and largest (>300,000 m^3 space) underground Lab worldwide;
- CJPL-II plan to start operation in 2024.
- More collaborations have planned to start their experiments in CJPL-II.

CJPL welcomes more projects worldwide to apply for using UL space !

Welcome!