Status and prospects of CJPL and CDEX dark matter experiment

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(on behalf of CDEX collaboration)

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

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Outline：

- 1.Introduction of CJPL-I
- 2.Construction progress of CJPL-II
- 3.CDEX and Future Plan
  - CDEX-1 and CDEX-10
  - CDEX-10X
  - CDEX future plan @ CJPL
- 4.Summary

1. Introductions of CJPL-I

- History and characteristics of CJPL-I
- Research activities at CJPL-I

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Jinping hydropower station

- **Yalong river meets Jinping Mountain**
  - –Jinping river bend:150km long
  - –1st power plant: 305m high arch dam
  - –2nd power plant: natural 310m level difference from west to east
- **Jinping traffic tunnel**
  - –17.5km long x 2
  - –Overburden max. 2400m, 73% of length >1500m.
  - –Finished on Aug. 8, 2008

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Jinping traffic tunnel

Jinping Mountain

~2400m

Half length~8km

Yalong river

Jinping traffic tunnel

Ideal site
for an underground laboratory!

East entrance to tunnel

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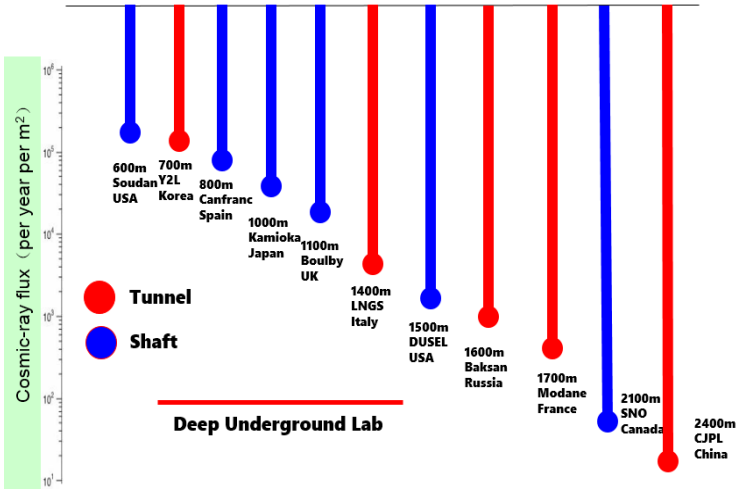
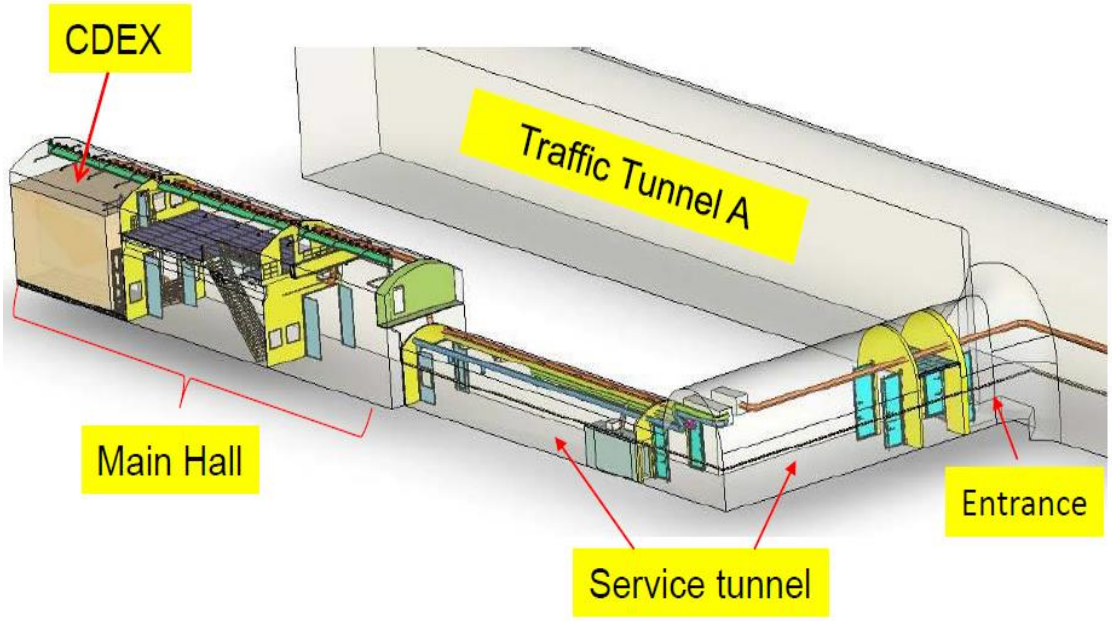
China Jinping Underground Laboratory

- ✓ Agreement between THU and EHDC reached in May 2009
- ✓ Site selection of CJPL-I completed in Aug. 2009
- ✓ CJPL-I opened in Dec. 12, 2010



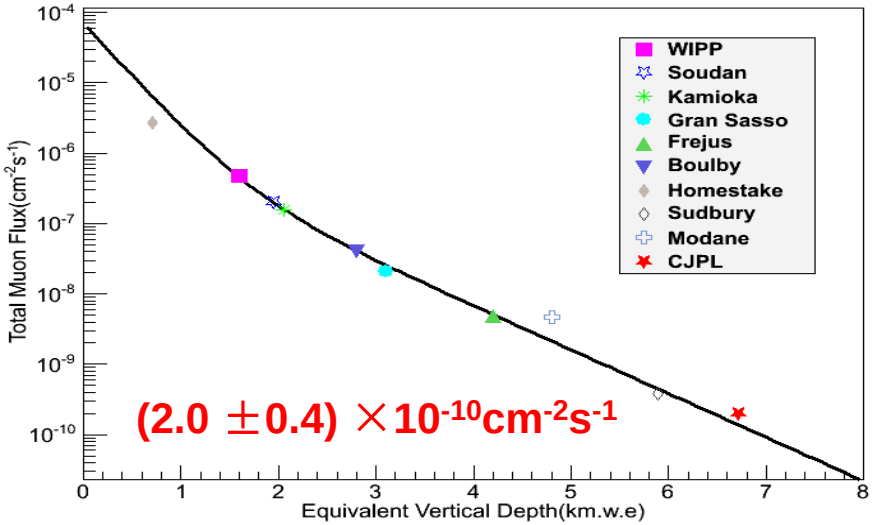


- Total space: ~4000 m^3
- Main Hall: 6.5m(W) x 6.5m(H) x 42m(L)

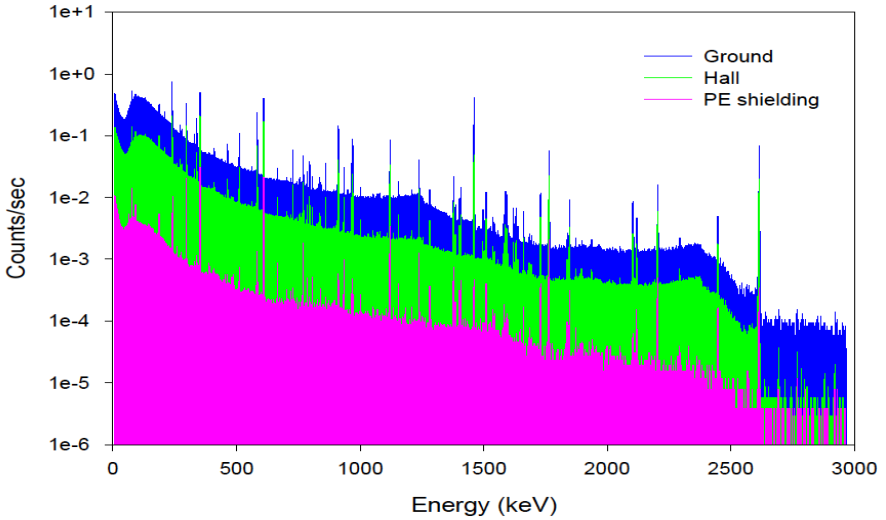
Background Measurement of CJPL-I

Ref: Chinese Physics C 37, 8 (2013) 086001

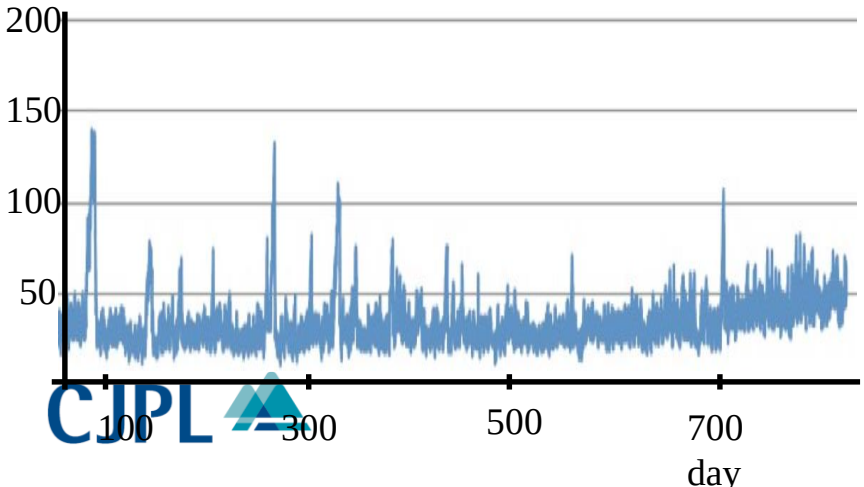
Muon flux ~ 60 muons/year/m^2



Gamma ray background



Radon concentration (Bq/m^3)



Sample(Marble) measurement by gamma ray spectrometry

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

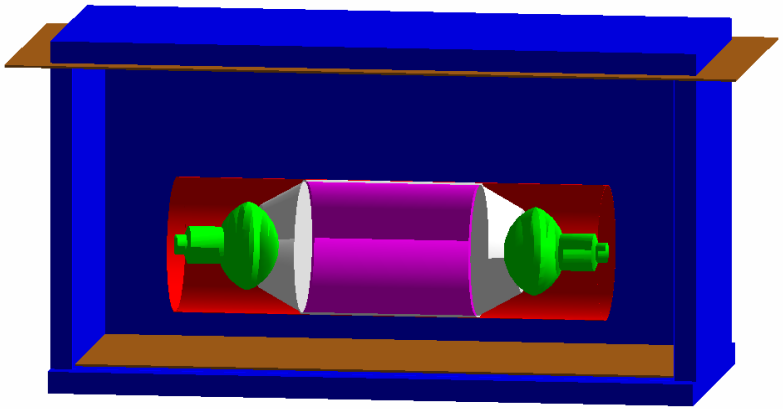
Neutron flux Measurement of CJPL-I

Fast neutron measurement by liquid scintillation detector

0.15 x10^{-6} n/cm^2/s (1-10MeV)

Fast neutron flux compare with other UL

Underground laboratory	Fast neutron flux n/cm^2/s	Energy range	Depth (m)
YangYang	4.17×10^{-6}	1-10MeV	700
Canfranc	0.41×10^{-6}	1-10MeV	800
Gran Sasso	0.42×10^{-6}	1-10MeV	1400
Boulby	1.72×10^{-6}	>0.5MeV	1100
Modane	0.40×10^{-6}	2-6MeV	1780
CJPL Hall	0.15×10^{-6}	1-10MeV	2400
CJPL PE-room	4.27×10^{-9}	1-10MeV	2400

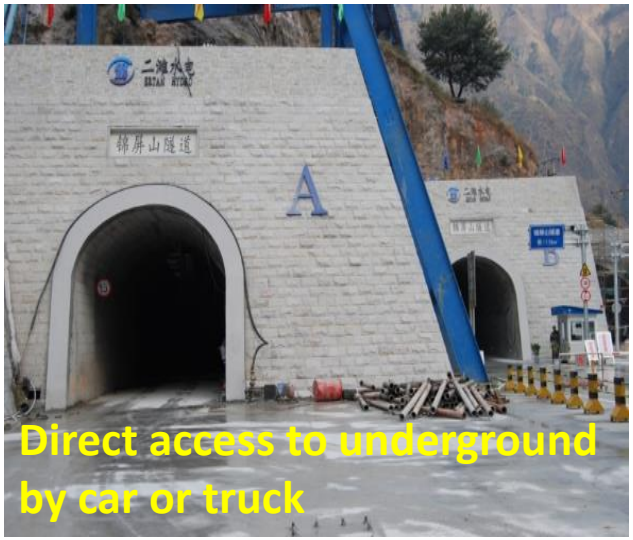


Fast neutron detector (simulation)

Thermal neutron measurement by He-3 tube

Thermal neutron flux@hall: < **4.4 x10^{-6} n/cm^2/s**

Logistics of CJPL



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Convenient & Comfortable

2. Construction progress of CJPL-II

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Researches activities @ CJPL-I

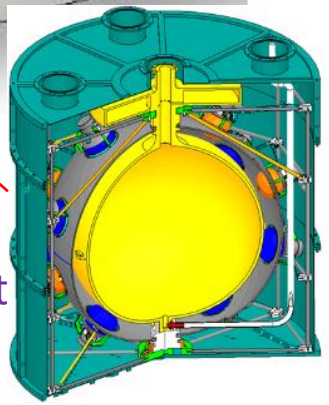
CDEX

CDEX

LBF

PandaX

Prototype of Jinping neutrino experiment



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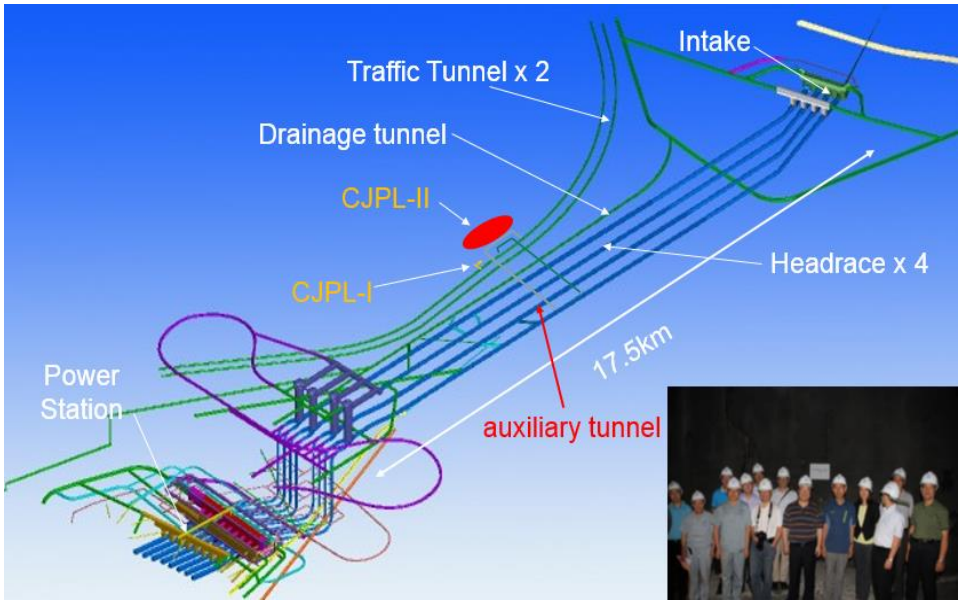
CJPL-II project

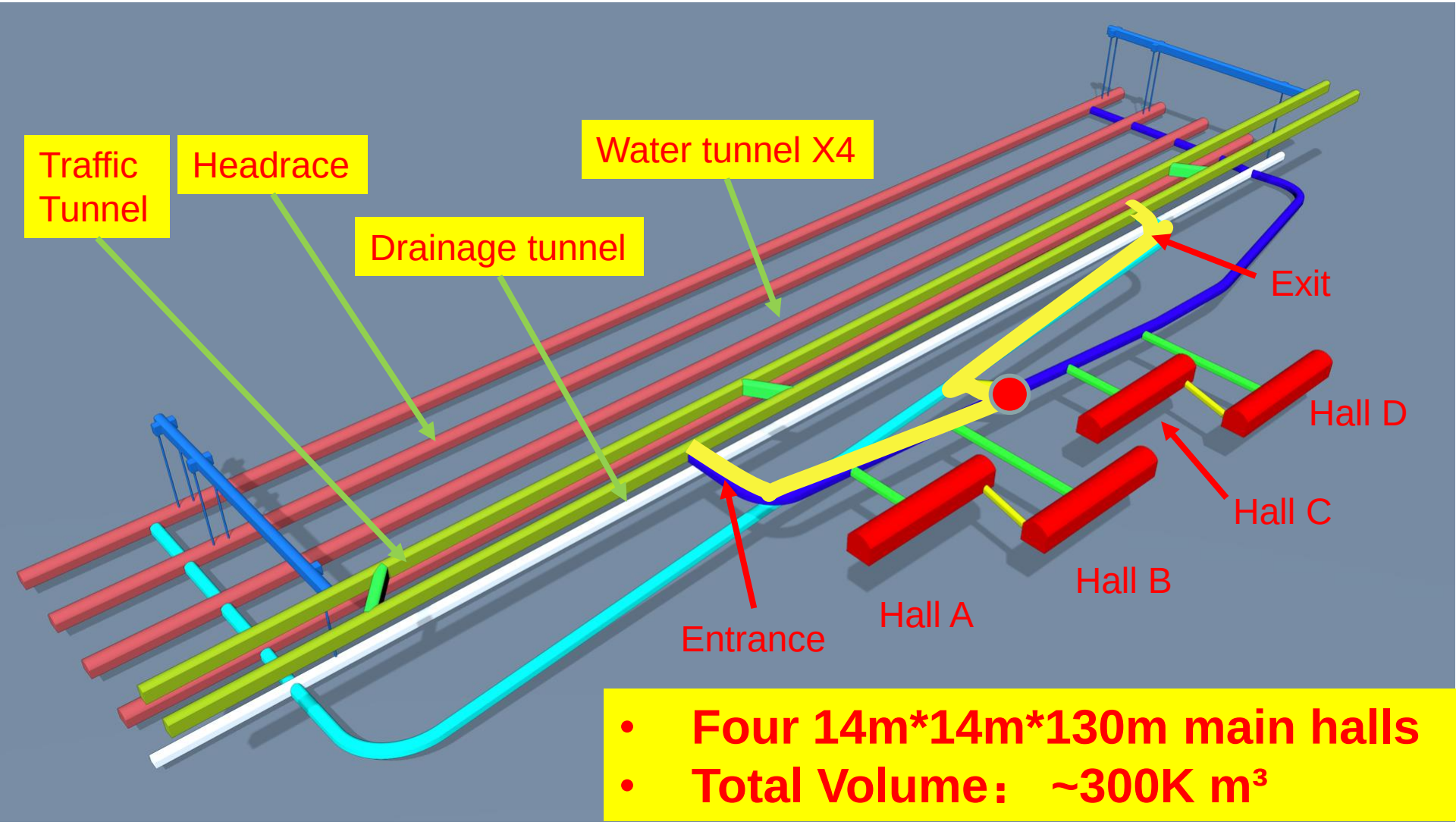
- ✓ CJPL-I is almost full Vs. more requirements
- ✓ Agreement on extension of CJPL reached in Aug. 2014!
- ✓ CJPL-II was born.

Signing ceremony, Aug 2014



Site selection of CJPL-II

Design of CJPL-II



- **Four 14m*14m*130m main halls**
- **Total Volume： ~300K m³**

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Construction progress of CJPL-II

Science, Nov. 30, 2014

- ✓ **Nov. 25, 2014:** Construction of CJPL-II started;
- ✓ **Dec. 2015:** The rock excavations of all halls completed;
- ✓ **May. 2016:** Expansion of two pits finished;
- ✓ **Dec. 2016:** Installation of ventilation system started;

Hall

Pit for CDEX-1T(in front)

Ventilation pipes

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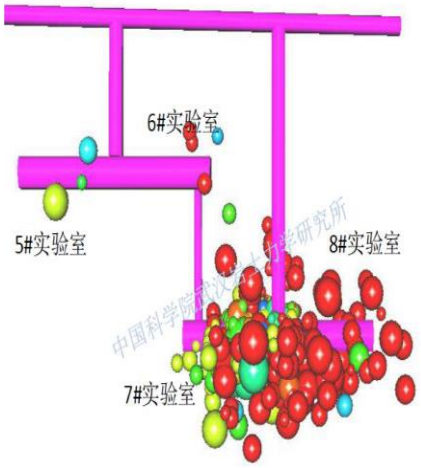
Recent status of CJPL-II

- Ventilation system being installed.
- Environmental parameters measurement
  - ✓ Rock mechanics
  - ✓ Radon concentration
  - ✓ γ, n background, muon flux

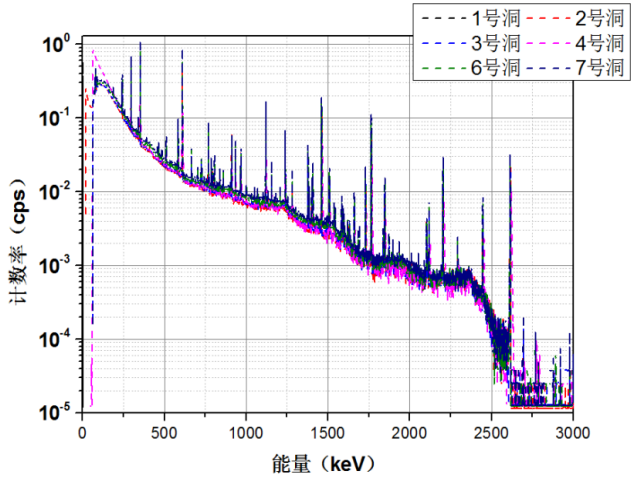
Cosmic ray flux measurement



Microquake monitoring

Ventilation pipes

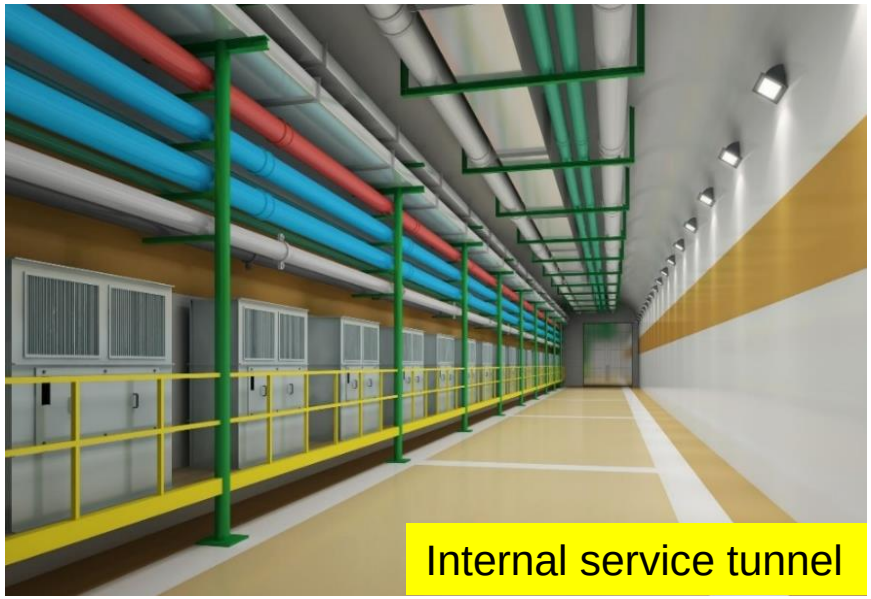
Neutron measurement



In-situ Gamma ray spectrum

CJPL-II plan


Main Hall


Internal service tunnel


Ground Campus

- CJPL was selected to be a candidate project of national major S&T infrastructure of China in 2016.
- Proposal being prepared and possibly approved at the end of 2017.

CJPL-II possible users

- CDEX (Ge DM+DBD Exp.)
- PandaX(Xe DM+DBD Exp.)
- LAr dark matter experiment
- CUPID-China(DBD)
- Nuclear astroparticle physics
- Solar neutrino experiment
- rock mechanics
- SeF6 0vbb experiment
- ……

Service:

–Low background counting

–Ultra pure copper

–popularization of science

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- 3.CDEX and Future Plan
  - CDEX-1 and CDEX-10
  - CDEX-10X
  - CDEX future plan @ CJPL

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China Dark matter EXperiment (CDEX) – EST in 2009

- *Collaborate with TEXONO group.*

- **Tsinghua University**
- **Sichuan University**
- **Nankai University**
- **China Institute of Atomic Energy, CIAE**
- **Yalong River company (former:EHDC)**

Detection of dark matter and 0νββ with a point-contact germanium(PCGe) array

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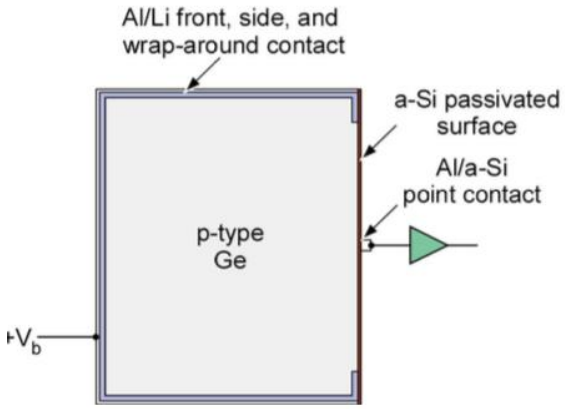
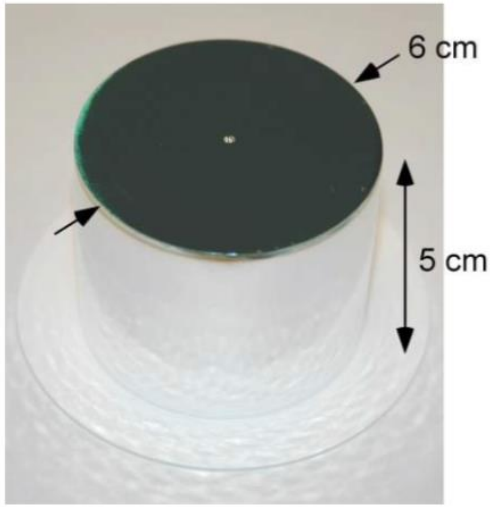
Point Contact Germanium (PCGe) detector





$$C_{PPC} = 2\pi\epsilon r$$

~1 pF possible

- **Good candidate for 0νββ and DM**
  - **Low threshold: ~ 200 eV**
  - **Excellent energy resolution: FWHM ~200 eV @ 10.37 keV, 4.3 keV @ 2039 keV (CDEX1A)**
  - **Long-time stability**
- **Challenges**
  - **Control the material background near PCGe**
  - **Decrease the cosmogenic background**
  - **No particle discrimination**
  - **Large mass**

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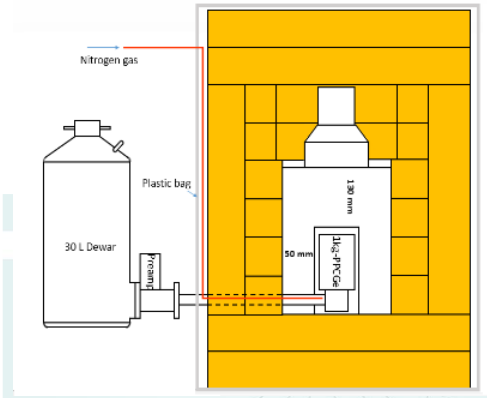
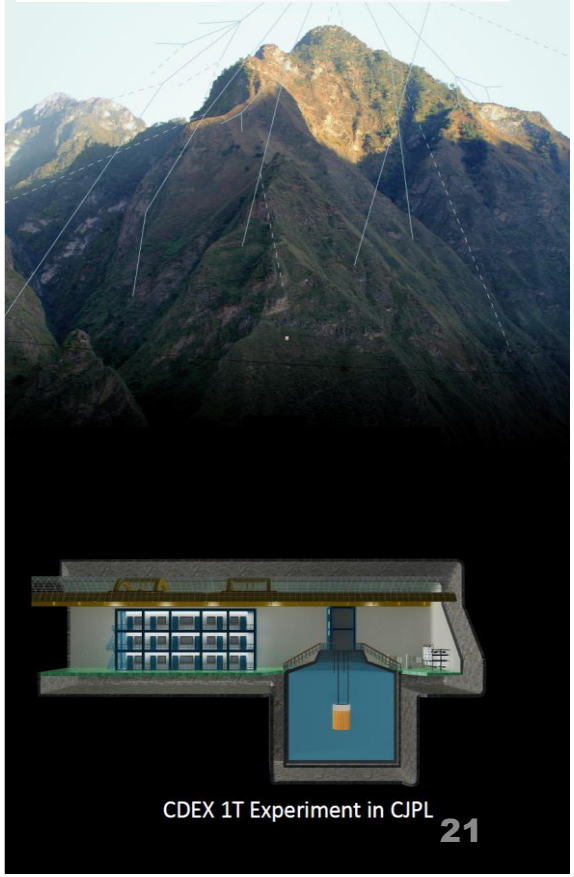
CDEX Stages

- **CDEX-1:** Development of large-mass prototype PCGe detector, data analysis methods, and its background understanding and suppression;
- **CDEX-10:** Performances of HPGe array detector system and its passive/active shielding systems;
- **CDEX-10X:** Fabrication of HPGe, VFE and ULB-Cu, low background techniques, Ge crystal growth;
- ……
- **CDEX-1T:** Multi-purpose experiment for dark matter and double beta decay.





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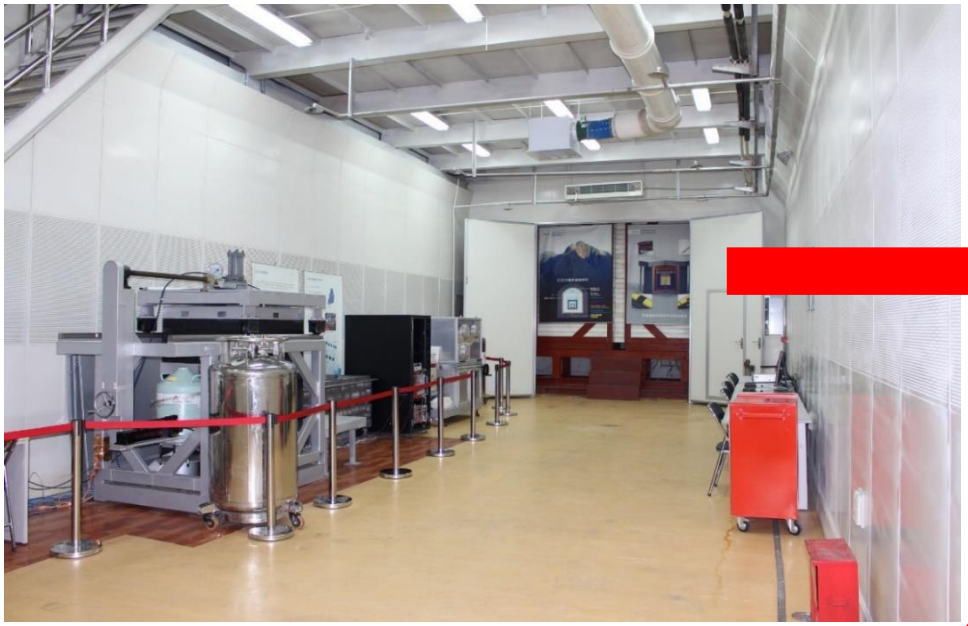
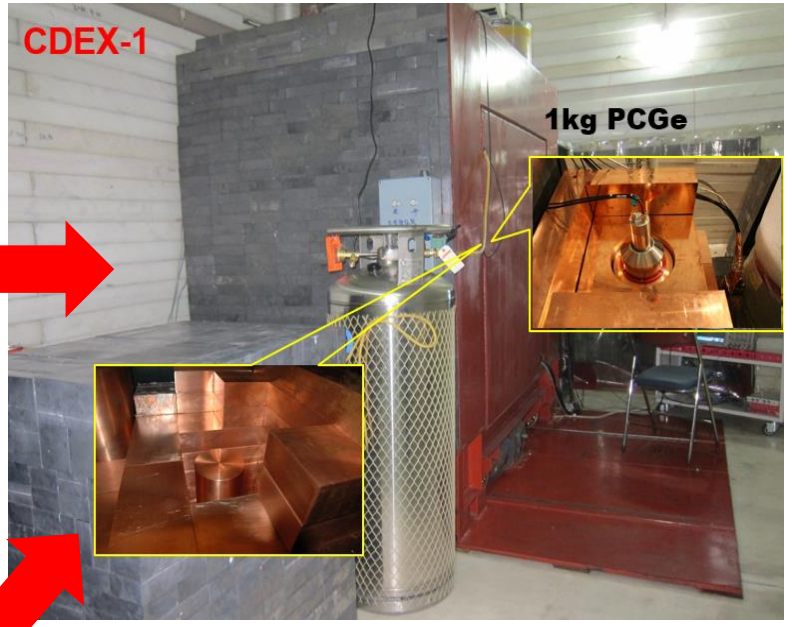
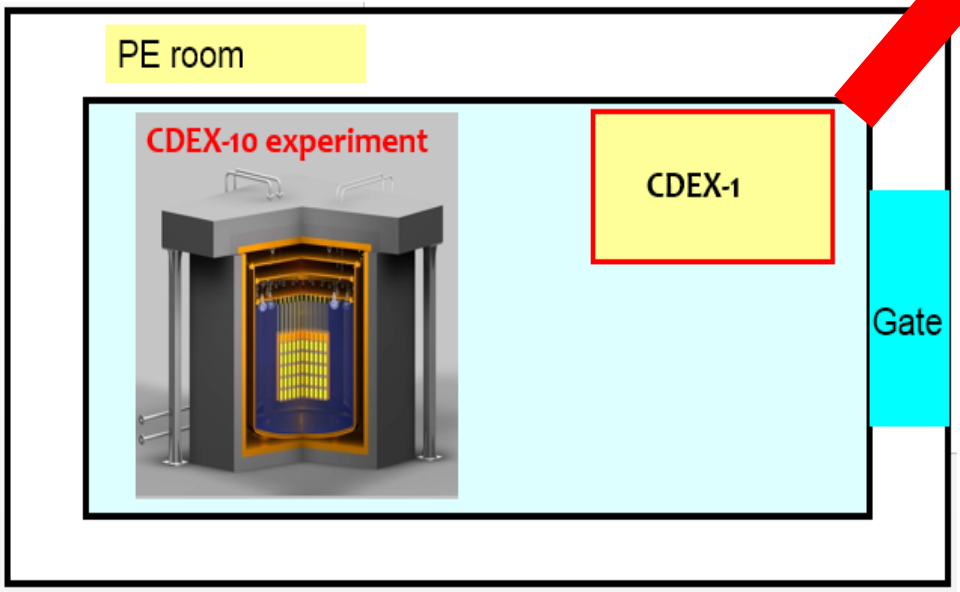
CDEX-1@CJPL-I




CDEX-1
1kg PCGe


PE room
CDEX-10 experiment
CDEX-1
Gate

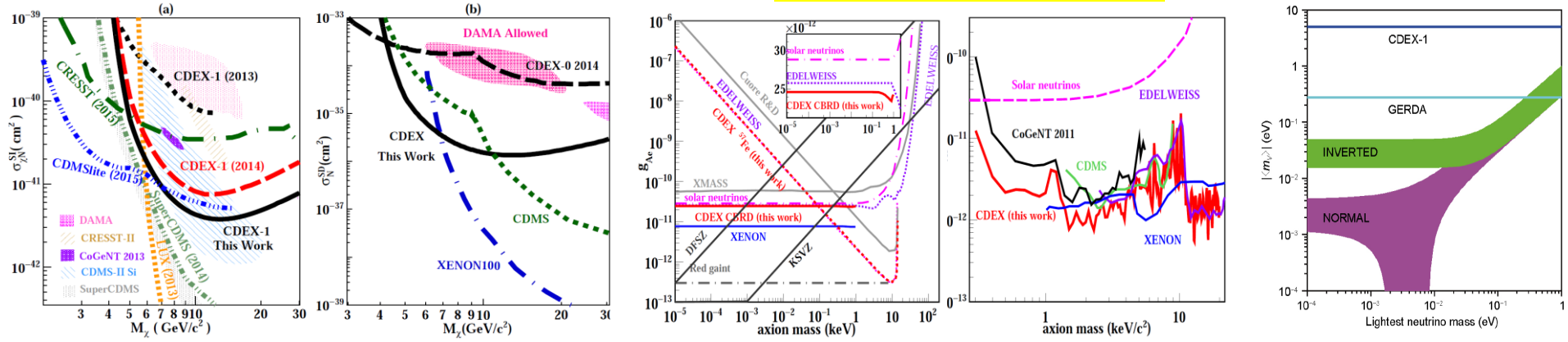

1kg-PPCGe
CANBERRA

CDEX-1 results

- From 2012 on, CDEX-1A (> 700d), CDEX-1B (> 400d);
- Series physical results published:
  - ✓ CoGeNT region excluded definitely with identical technique;
  - ✓ Axion dark matter results published;
  - ✓ AM analysis with >1 year data going on;
  - ✓ 0νββ results distributed based on CDEX-1A data;

PRD93, 092003, 2016

PRD95, 052006, 2017



Spin-independent | Spin-dependent | Solar axions | ALP DM | 0νββ

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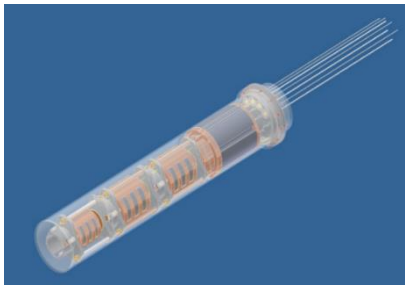
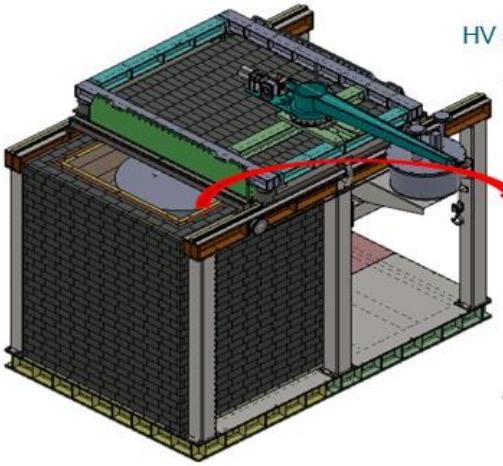
Sci. China-Phys. Mech. Astron. Vol.60 No.7 (2017)

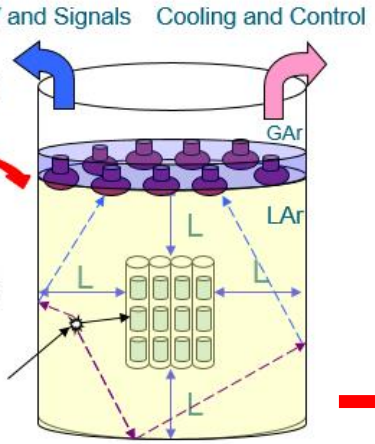
CDEX-10 experiment

- An important stage towards future Ge experiment;
- Design and study of the PCGe array detector;
- PPCGe array detectors under testing and run at CJPL;
  The physical results is under preparation;
- PCGe array with lower energy threshold:
  CDEX-1: 400eV → CDEX-10: <300eV;





CDEX-10 experimental setup



10kg-PCGe + LN2 or LAr

3-PCGe element

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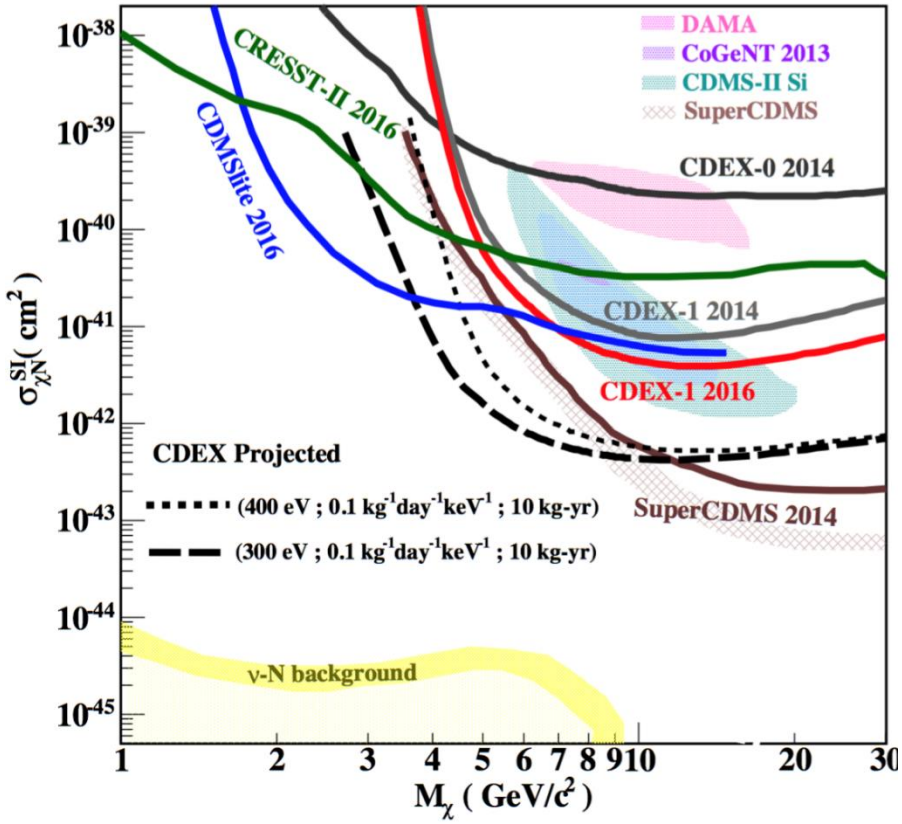
CDEX-10X target

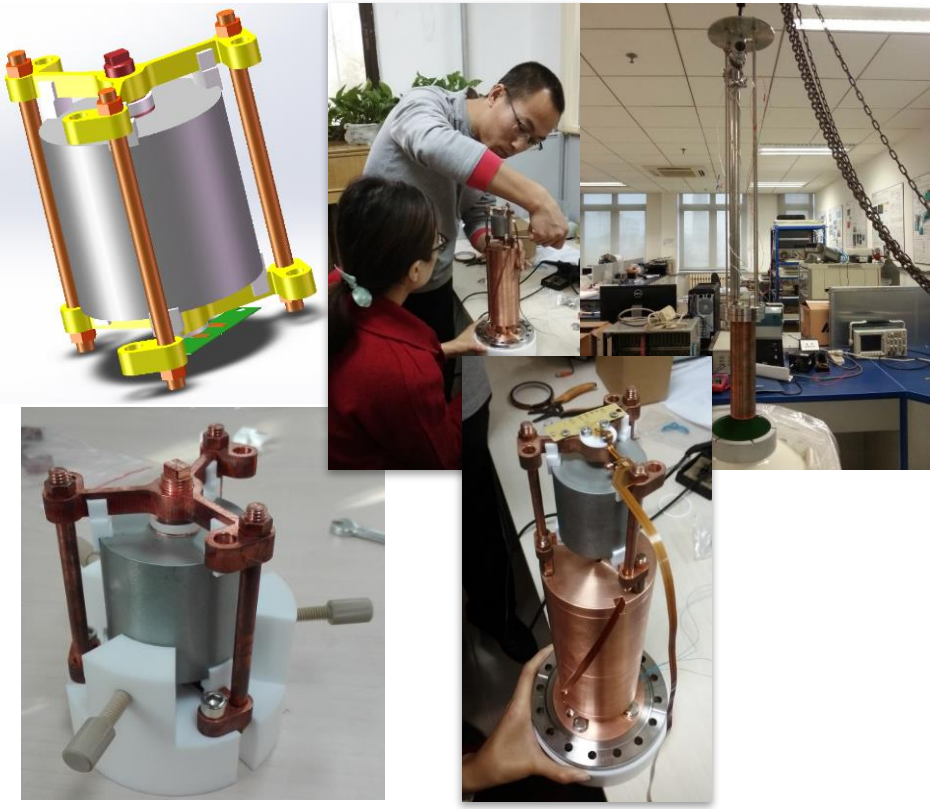
- The target: **reduce the background** <1 cpkkd
- Support by the national key research and development program of China this year
- Master the key technologies toward future Ge experiments:

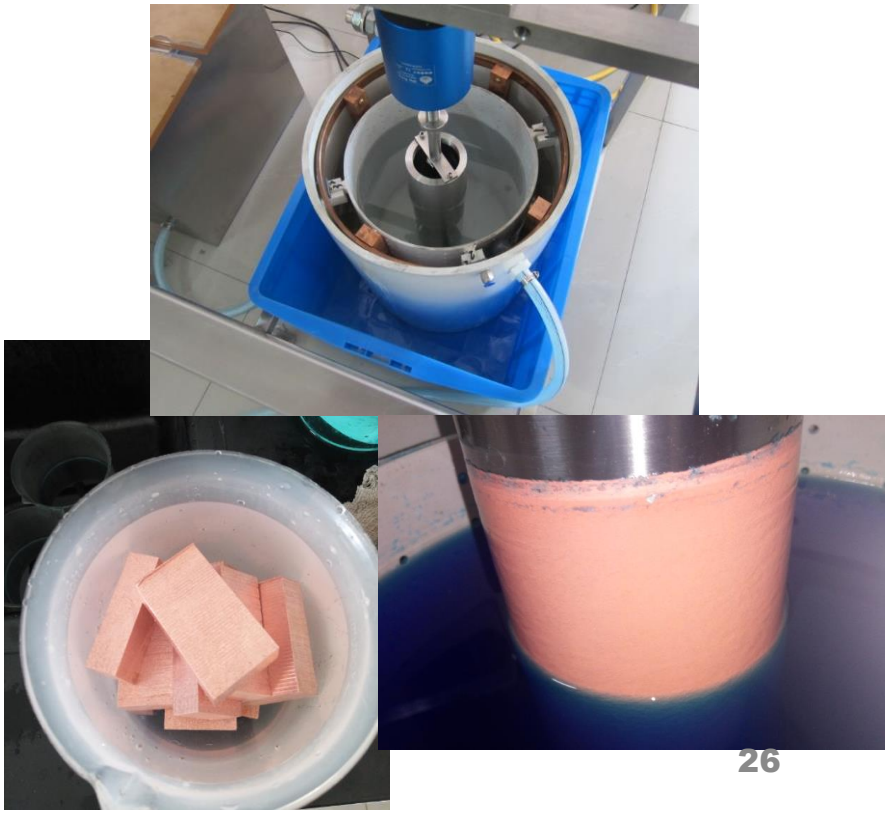


- Ge purification and Ge crystal growth
- HPGe detector fabrication
- Ultra-low background VFE
- Ultra-pure copper for structure and cables
- Large-volume cooling tank
- ……

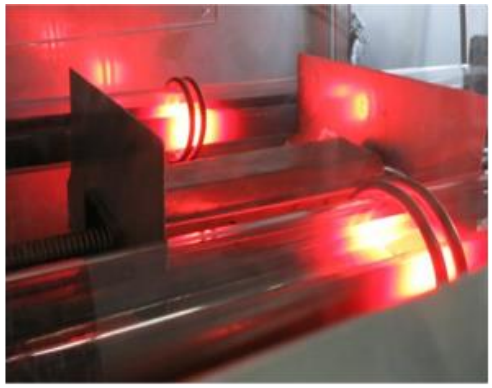
CDEX-10X status

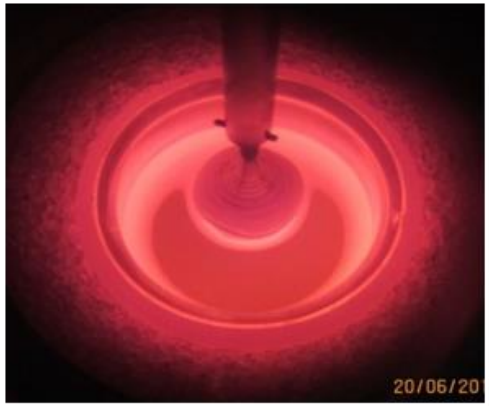
- ✓ Two 0.5kg PCGe with <350eV under preparation first；
- ✓ Totally new design by CDEX and background control with pure cable, VFE substrate and structure materials；
- ✓ Two PreAMP types: JFET and ASIC;





Germanium Crystal growth

- **The requirements**
  - ✓ purity:
    - 13 N Ge
  - ✓ Dislocation: <5000 cm^{-2}

- **Present achievements.**
  - ✓ purity:
    - 11 N Ge
  - ✓ Dislocation : ~15000 cm^{-2}

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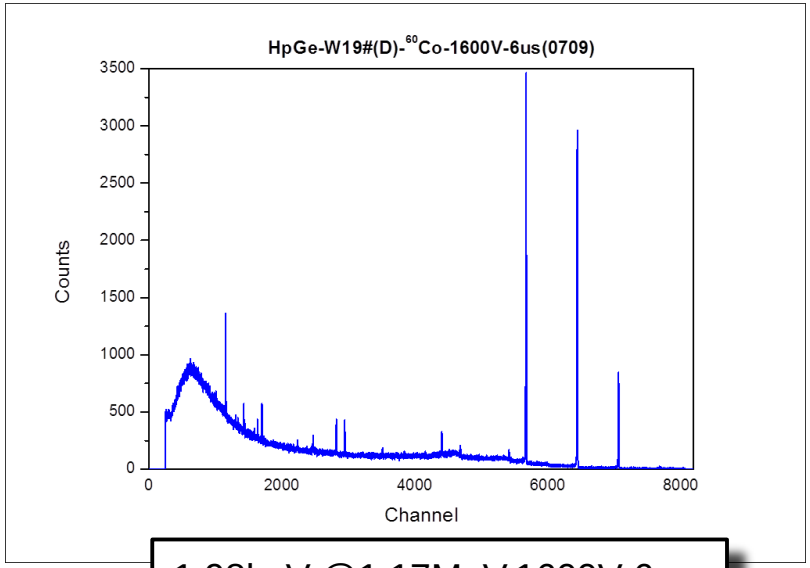
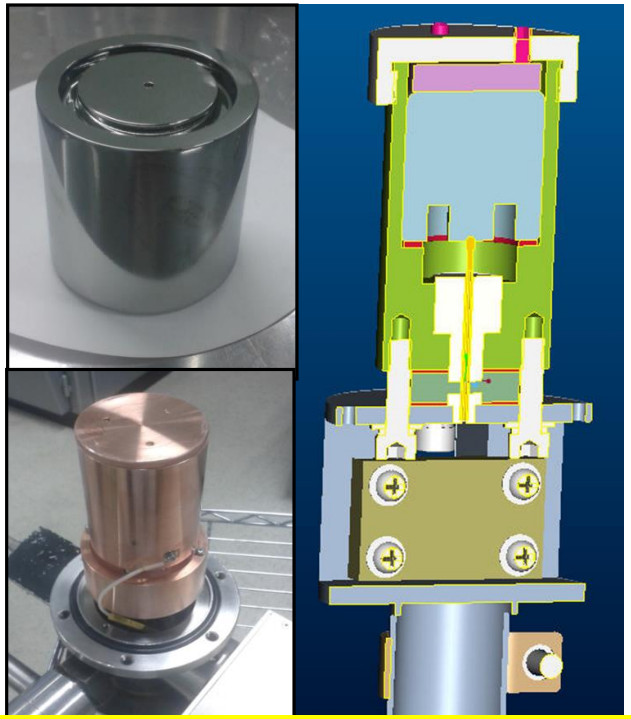
PCGe detector fabrication

- ✓ **Successful on 10 g/500 g Energy resolution (FWHM): 0.95% @ 59.5 keV(10 g) 0.17% @1173 keV(500 g).**
- ✓ **500 g PCGe with home-made fabrication will be studied at CJPL soon.**



1.98keV @1.17MeV,1600V-6us
2.12keV @1.33MeV,1600V-6us



PCGe Detector-19# (ø50mm)

Bias (V)	800	900	1000	1100	1200
Leakage Current (pA)	1	3	6	7	13
Bias (V)	1300	1400	1500	1600	1700
Leakage Current (pA)	19	39	97	188	922

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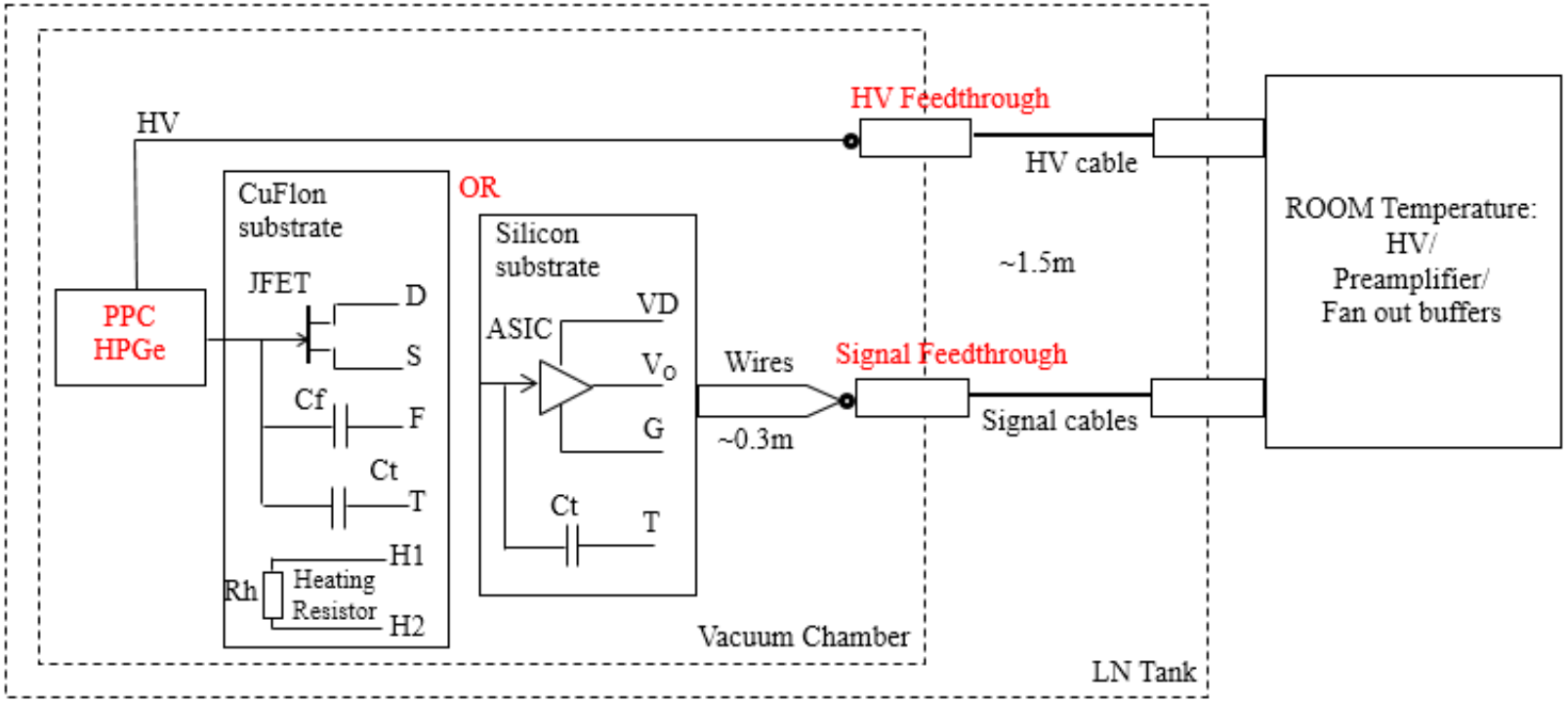
VFE(very front electronics) electronics design



- Develop two types of VFE: JFET and ASIC
- JFET: low 1/f noise, study the most suitable Temp. and low background substrate
- ASIC: basic on CMOS technology, low background substrate (Silicon, small amount of material)

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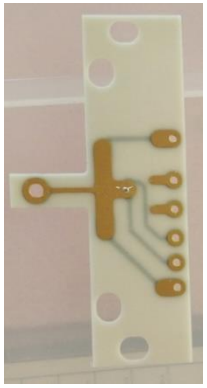
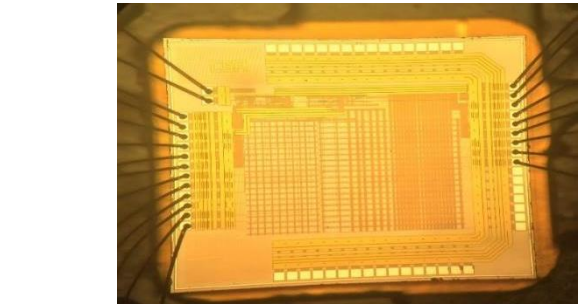
VFE test results

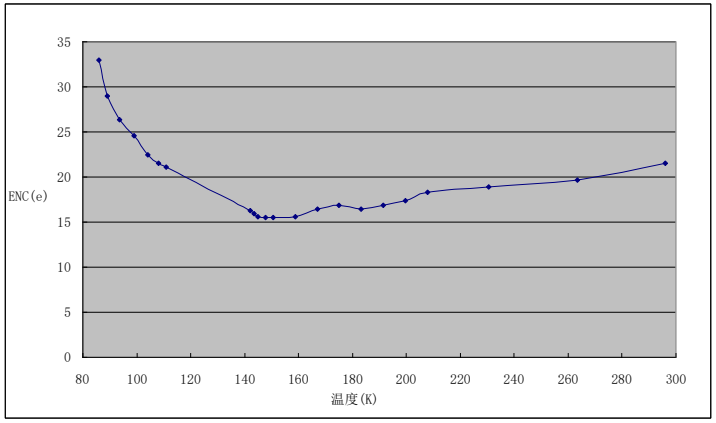
- JFET based readout
- CMOS ASIC based readout



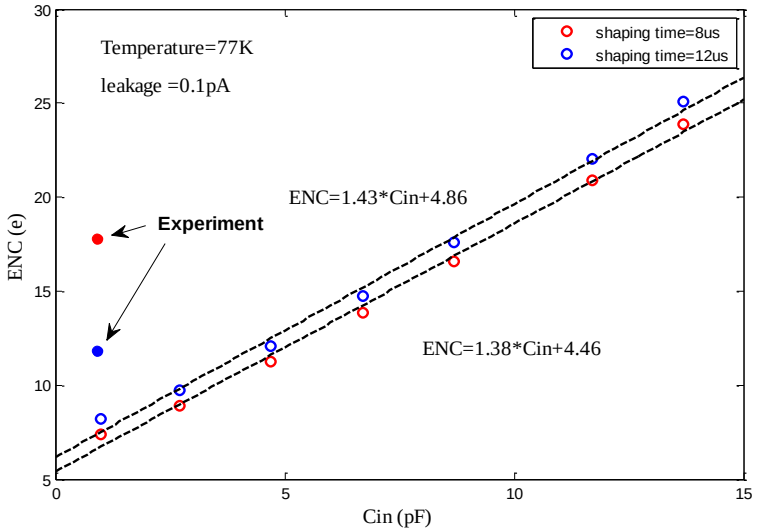
JFET bonded on CuFlon substrate



Preamp ASIC bonded on test PCB



ENC @ Cd=0 vs. Temperature



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Cooperation on Ge detector development

- **LEGEND:** Detector, electronics, simulation, cryogenic system…
- **DHPGDT:** Development of HPGe Detector Techniques for Application in Fundamental Research;
- **PIRE:** A Global consortium for advanced germanium detectors and technology.

Max-Planck-Institut für Physik

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

中德合作研究小组
应用于基础研究的高纯锗探测器技术研发
资助者:中德科学中心 / 中国 北京

Deutsch-Chinesische-Kooperationsgruppe
Development of High Purity Germanium Detector Techniques for Applications in Fundamental Research
Finanziell unterstützt durch: Chinesisch-Deutsches Zentrum für Wissenschaftsförderung Peking, China

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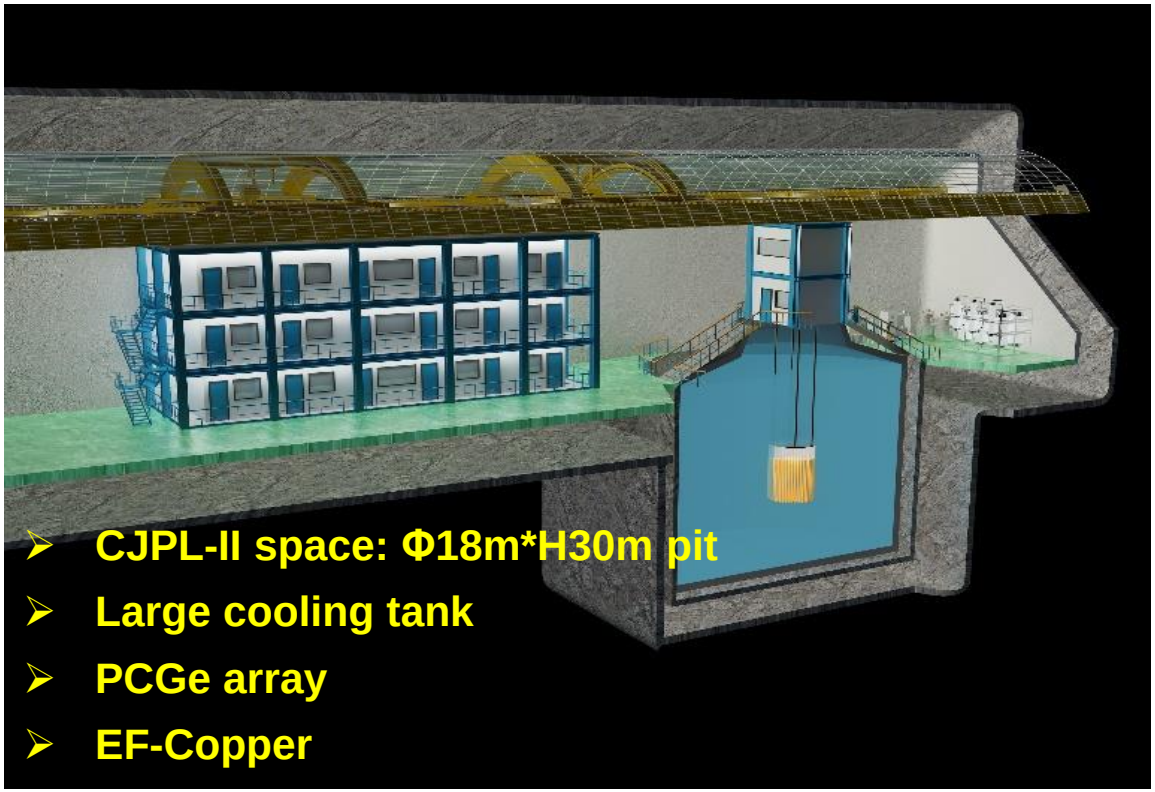
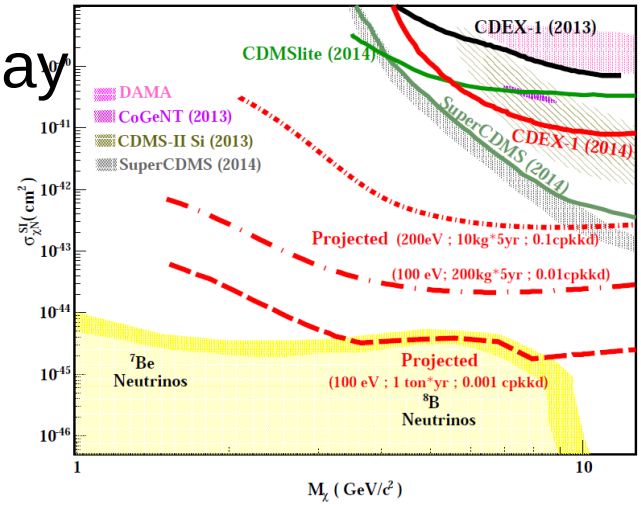
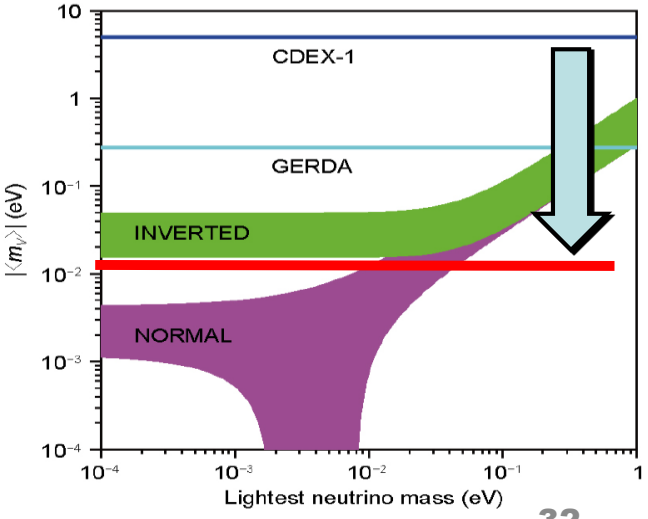
CDEX future projects at CJPL-II

- A future Ge detector composed of the PCGe detector array and LN shielding and cooling system in the CJPL-II
- Both Dark matter and Double Beta Decay

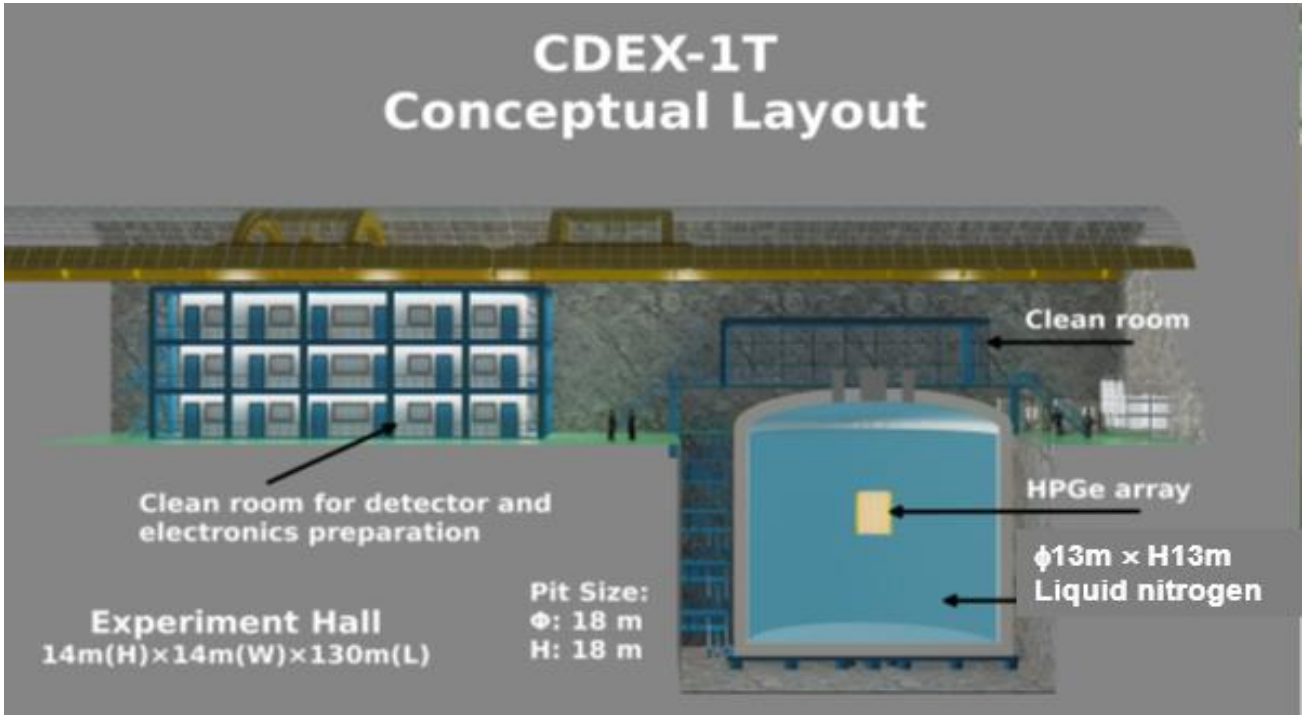






CJPL

CDEX @ CJPL-II



LN2 tank design finished and the installation will start soon.

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Summary

- CJPL with deepest rock overburden in the world run now; Two DM experiments run in and published important physical results.
- CJPL-II with deepest rock overburden, largest space in the world under setup; Several experiments applying CJPL-II space including: DM, DBD, Neutrino, Astroparticle…; Possible users from all over the world are welcome.
- CDEX has achieved competitive DM physical results from 2013 on; CDEX-10 with 10kg array detector testing in CJPL; CDEX DM experiment on track now and lower background level in the next step are pursued.
- The key technologies and infrastructure towards future Ge DM pursued; Joined international collaborations to work together towards NG-Ge experiment.

Thanks for your attention!
Welcome to CJPL!