

# Status and prospects of CDEX the China Dark Matter Experiment

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(on behalf Qian Yue, Tsinghua U. & CDEX collaboration)

## OUTLINE

- Dark Matter and CDEX Introduction
- CDEX-1 and CDEX-10
- CDEX next-stage plan
- Summary

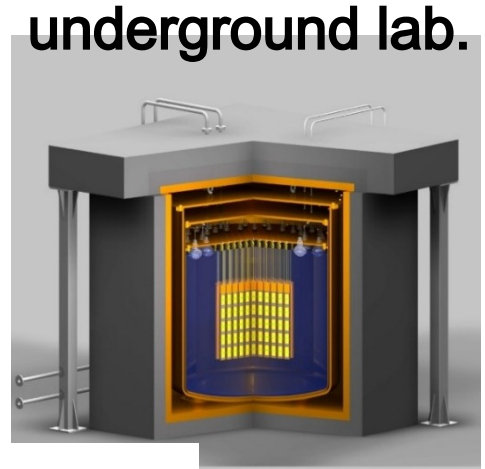
CJPL 

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



ICHEP2018 SEUL  
XXXIX INTERNATIONAL CONFERENCE  
ON *high Energy* PHYSICS  
2018.7.7(Sat)

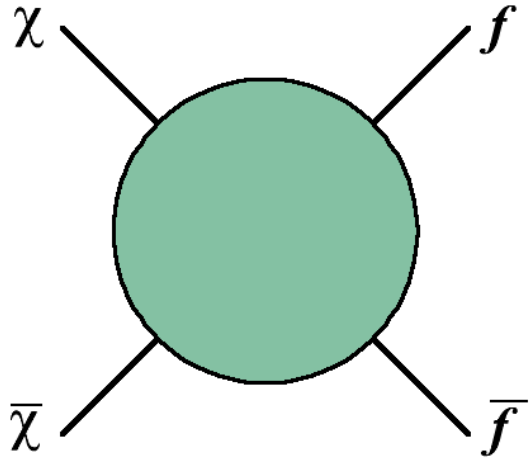
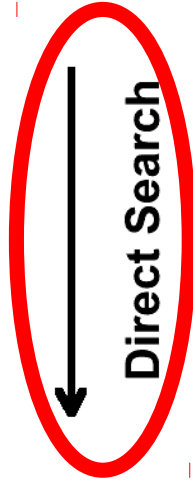
# Dark Matter detection



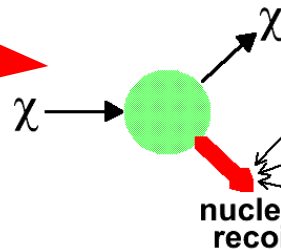
Indirect Search



Direct Search



Colliders

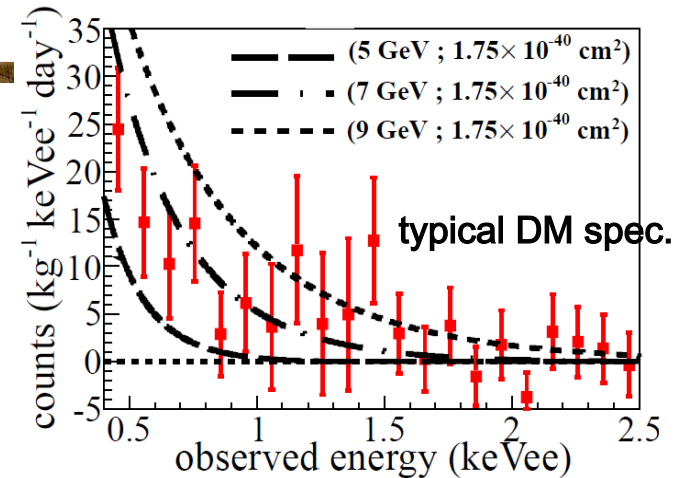
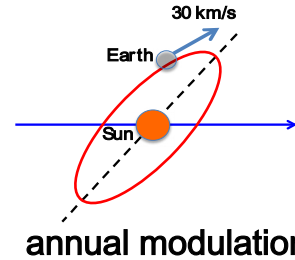


Ionization:  
Ge, Si

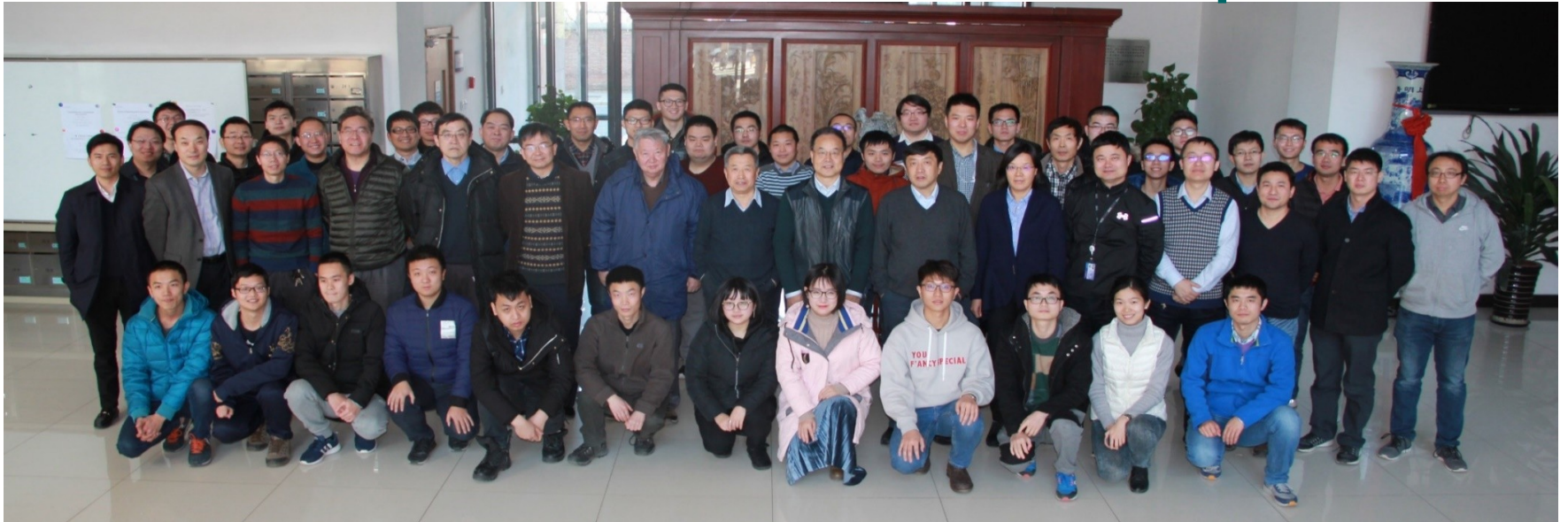
Bolometer:  
TeO<sub>2</sub>, Ge, CaWO<sub>4</sub> ...

Scintillation:  
NaI(Tl), LXe ...

nucleus recoil



# CDEX: China Dark matter EXperiment



## Established in 2009

- Tsinghua University (THU)
- Sichuan University (SCU)
- Nankai University (NKU)
- China Institute of Atomic Energy (CIAE)
- Beijing Normal University (BNU)
- Yalong River Company

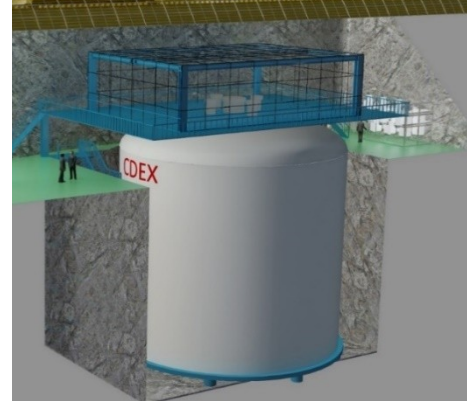
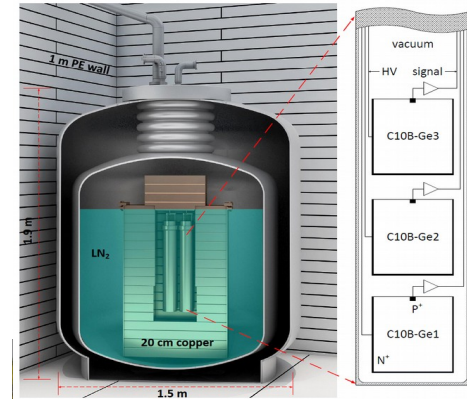
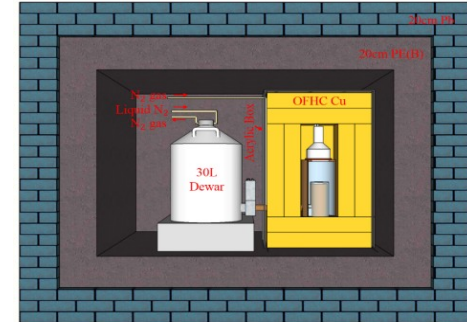
+

- Academia Sinica, Taiwan
- Banaras Hindu University, India
- Dokuz Eylül University, Turkey

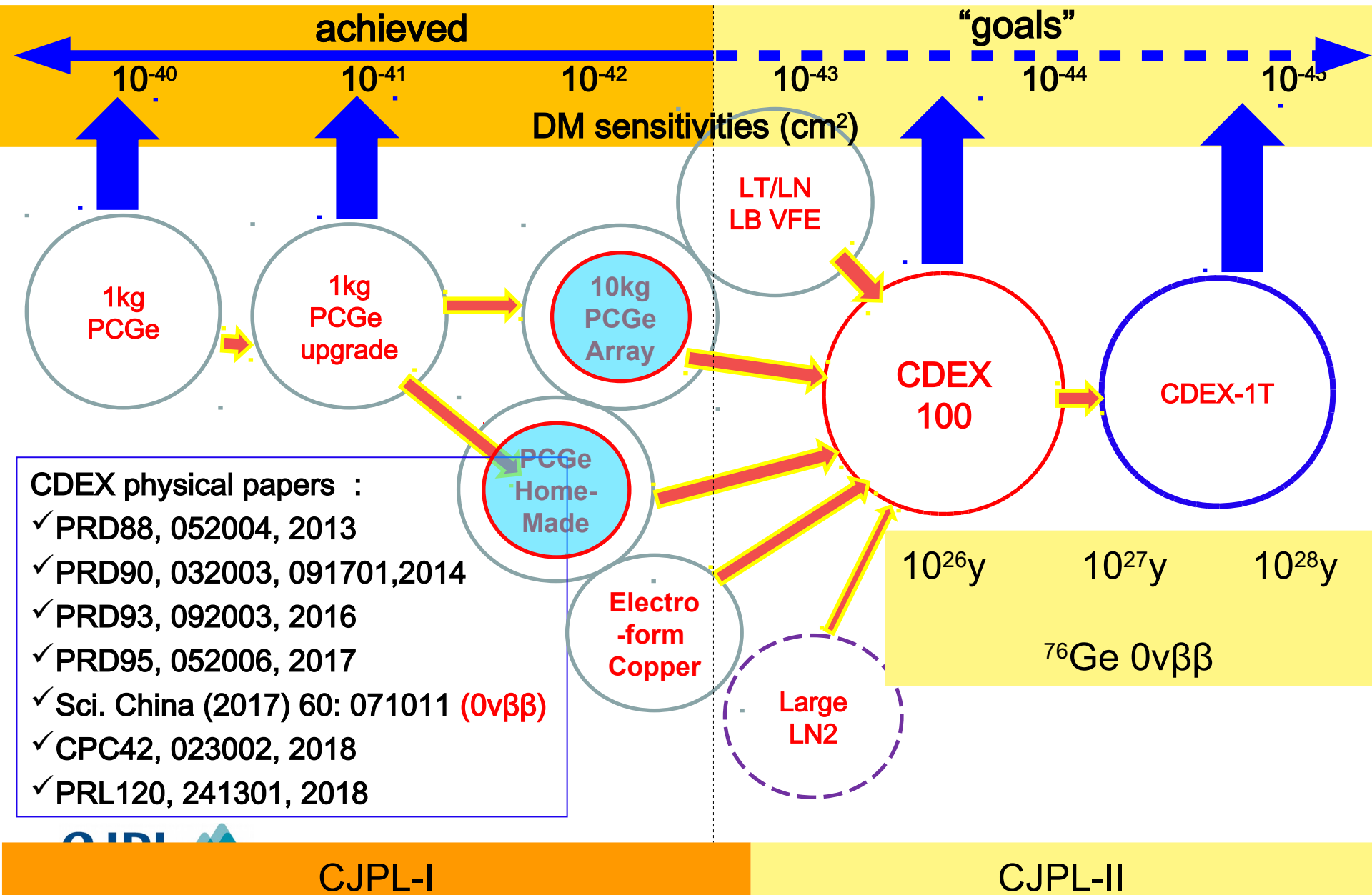
(as members of TEXONO collaboration)

# CDEX stages

- Light WIMP mass searches with pGe
- CDEX-1: Development of pPC-HPGe detector, its background understanding, results published.
- CDEX-10: Performances of HPGe array detector system, results published.
- CDEX-10X: Fabrication of HPGe and Ge crystal growth by CDEX.
- CDEX-100: Ultra-low cosmogenic background and large LN<sub>2</sub> cooling and shielding system.
- CDEX-1T: Multi-purpose experiment for dark matter and double beta decay.



# CDEX plan for DM & $0\nu\beta\beta$



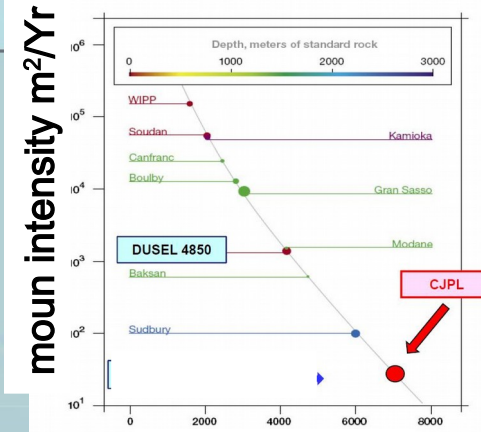
## CDEX physical papers :

- ✓ PRD88, 052004, 2013
- ✓ PRD90, 032003, 091701, 2014
- ✓ PRD93, 092003, 2016
- ✓ PRD95, 052006, 2017
- ✓ Sci. China (2017) 60: 071011 ( $0\nu\beta\beta$ )
- ✓ CPC42, 023002, 2018
- ✓ PRL120, 241301, 2018

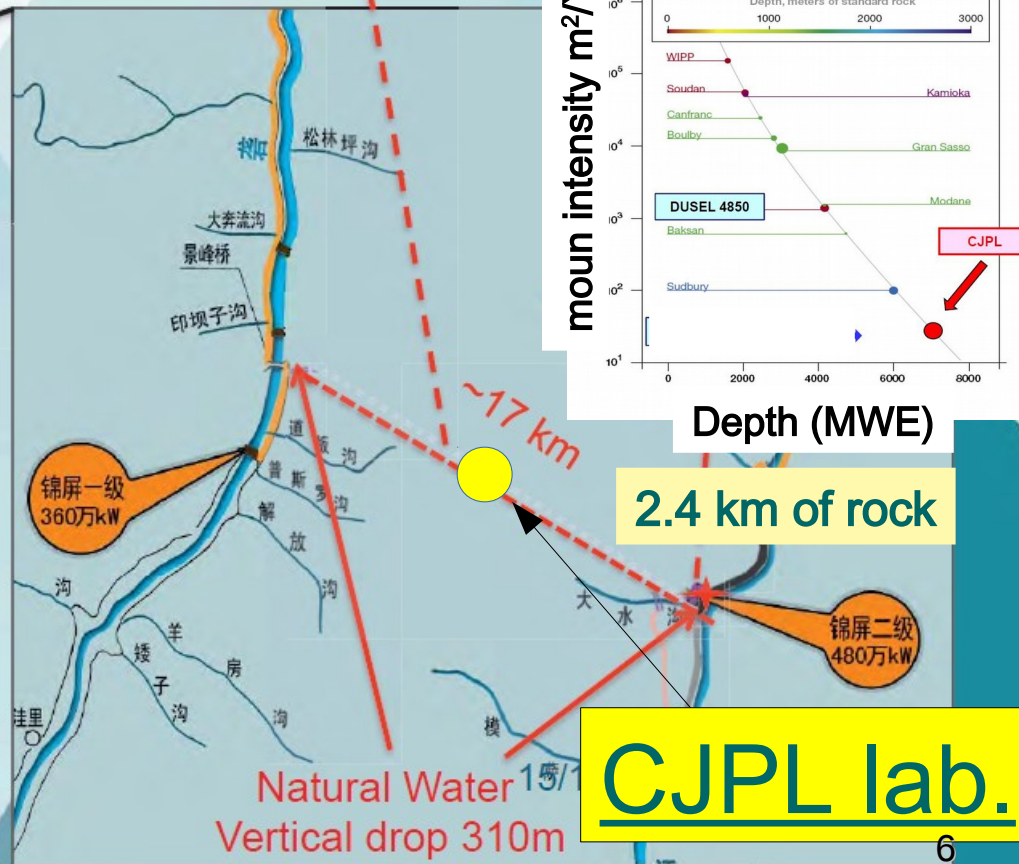
# Jinping Hydroelectric Power Plants

4 hydraulic tunnels  
 $\Phi 13\text{m} \times 16.6\text{km}$

Jinping-II  
 Power Plant  
 4800MW  
 (8×600MW)

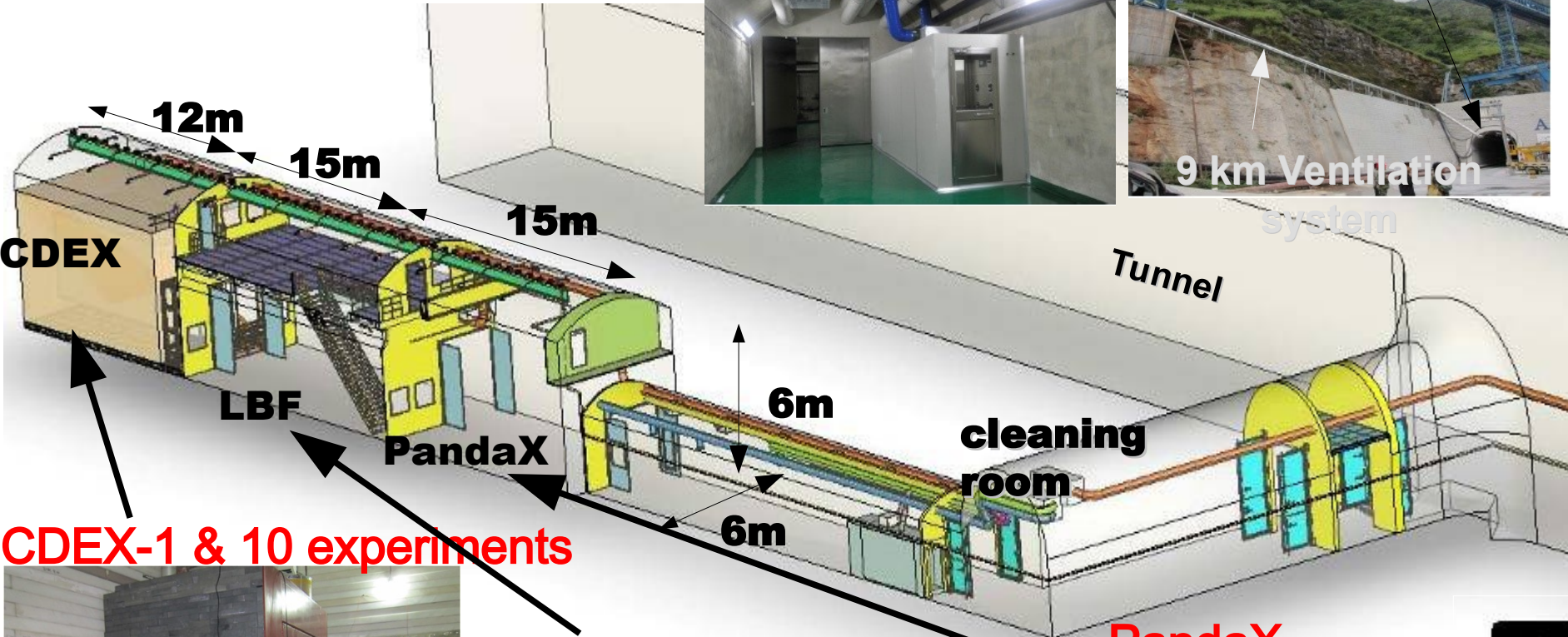


Jinping-I  
 Power Plant  
 3600MW  
 (6×600MW)



# CDEX at CJPL-I

tunnel entrance



CDEX-1 & 10 experiments

Low background facility

PandaX

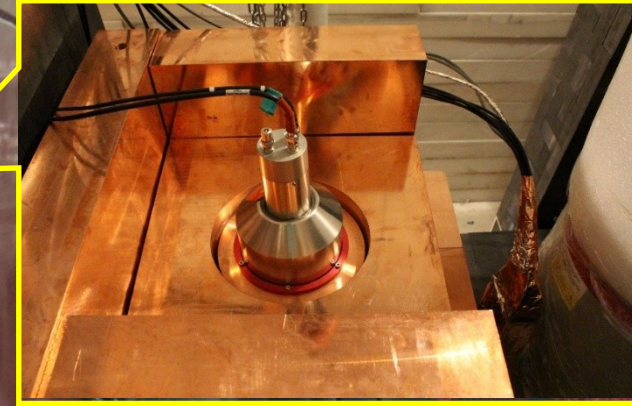


# CDEX-1 experiments

CDEX-1A 1kg PCGe



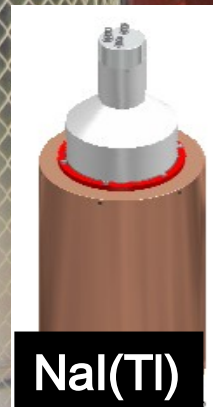
CDEX-1B 1kg PCGe



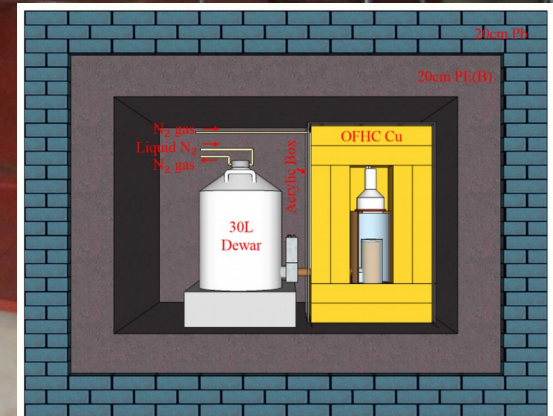
20cm OFHC Copper  
+20cm Lead



1kg-PPCGe



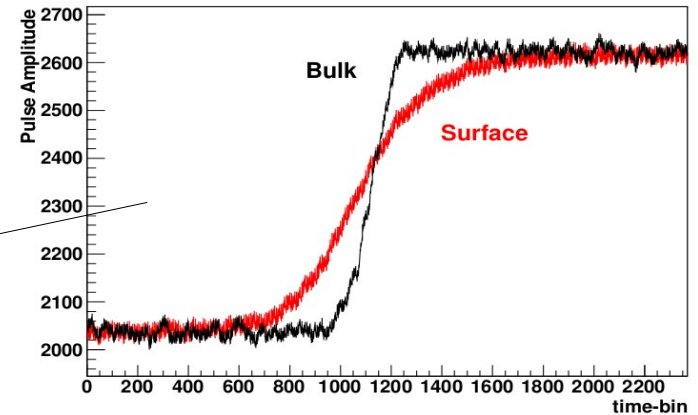
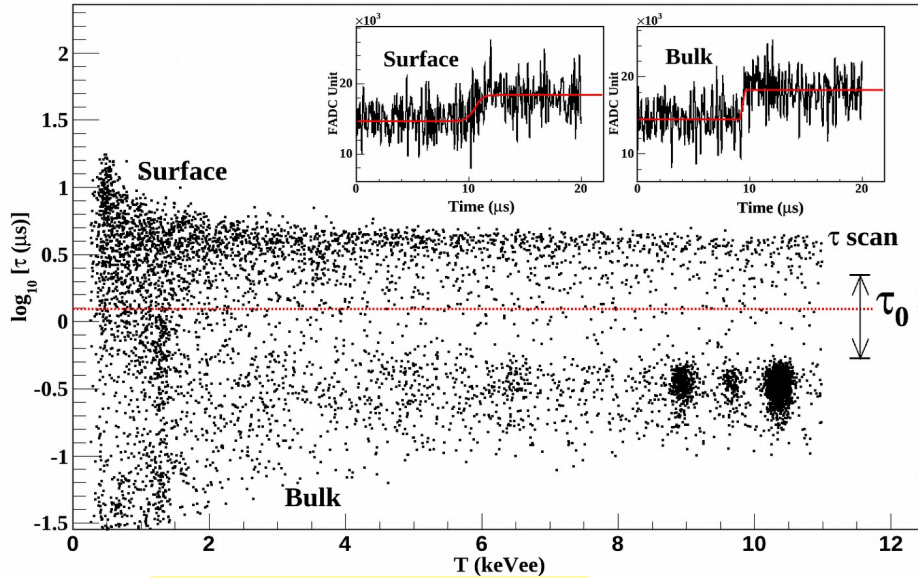
NaI(Tl)





# pPCGe: bulk/surface

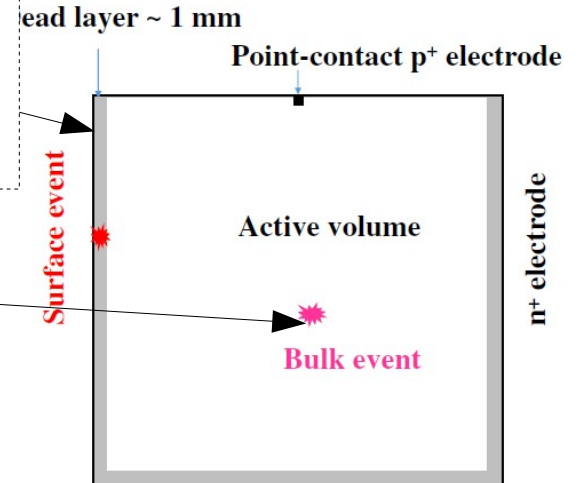
surface events : contamination, largest sources of uncertainties at low energy.



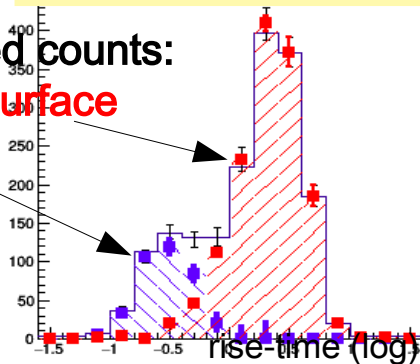
DM candidate events:  
0.4-0.6 keV

surface  
partial energy deposit  
diffuse and drift  $\rightarrow$  slow

bulk  
full energy deposit  
drift  $\rightarrow$  fast



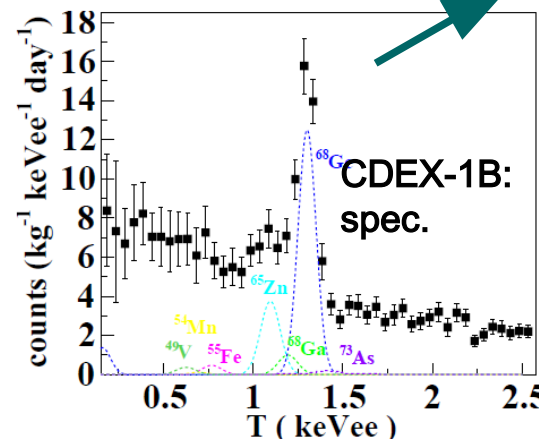
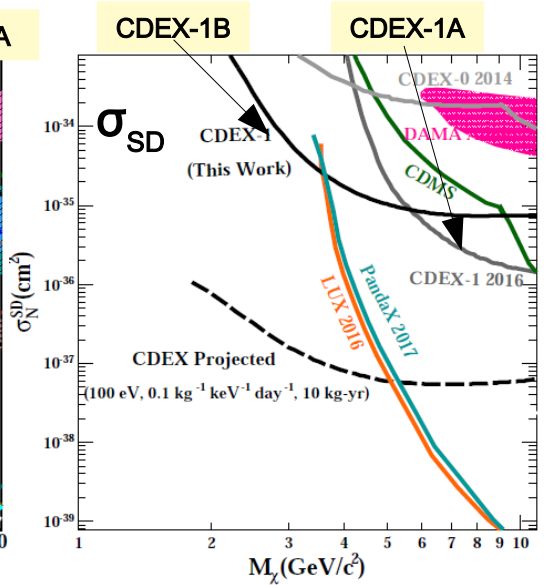
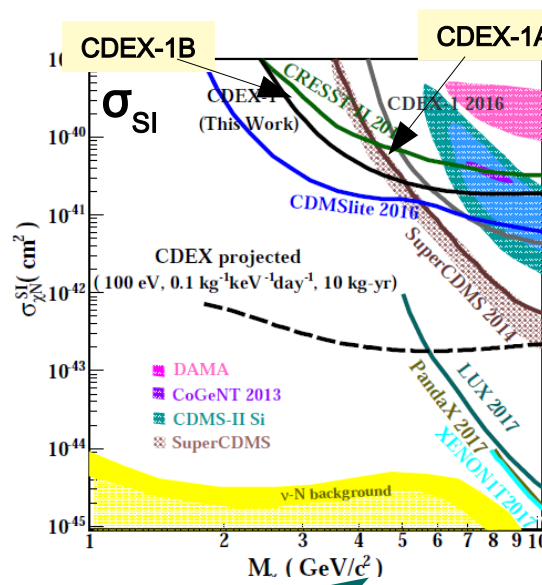
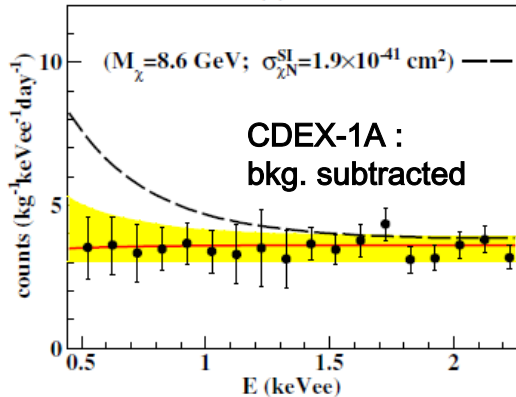
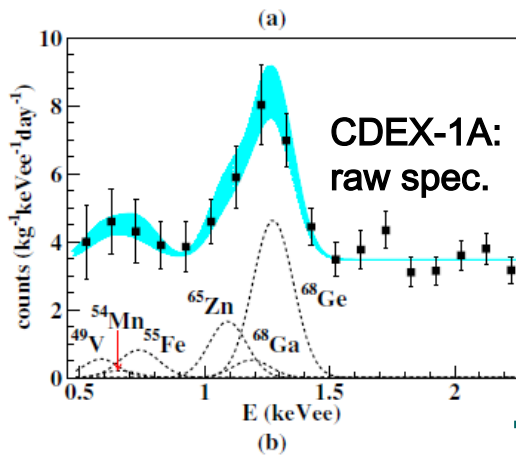
constructed counts:  
bulk and surface



# CDEX-1 results

Data set: CDEX-1A: ~500 kg-day; CDEX-1B: ~1000 kg-day

- Competitive SI/SD sensitivities pPCGe PRD93, 092003, 2016 , CPC42, 023002, 2018
- Competitive galactical Axion sensitivity below 1 keV PRD95, 052006, 2017
- threshold: CDEX-1A: 475 eV, CDEX-1B: 160 eV.



CDEX-1B:  
threshold=160eV, ~2 yrs,  
annual modulation  
analysis undergoing

# CDEX-1 axion results

M1 transition from  $^{57}\text{Fe}$  from Sun:  $^{57}\text{Fe}^* \rightarrow ^{57}\text{Fe} + a$  [ $g_{\text{AN}}$ ]

PRD95, 052006, 2017

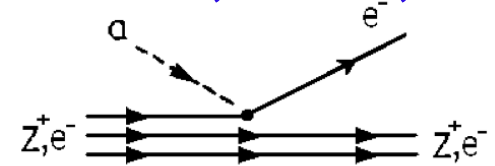
axion(a) from sun [ $g_{\text{Ae}}$ ]

Compton(C):  $\gamma + e \rightarrow e + a$

bremsstrahlung(B):  $e + Q \rightarrow e + Q + a$

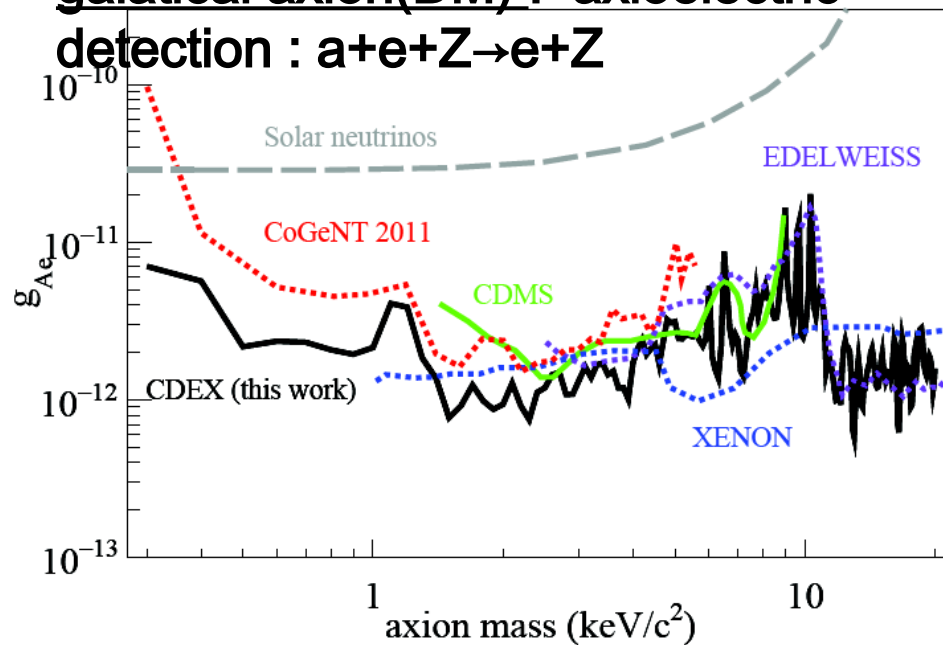
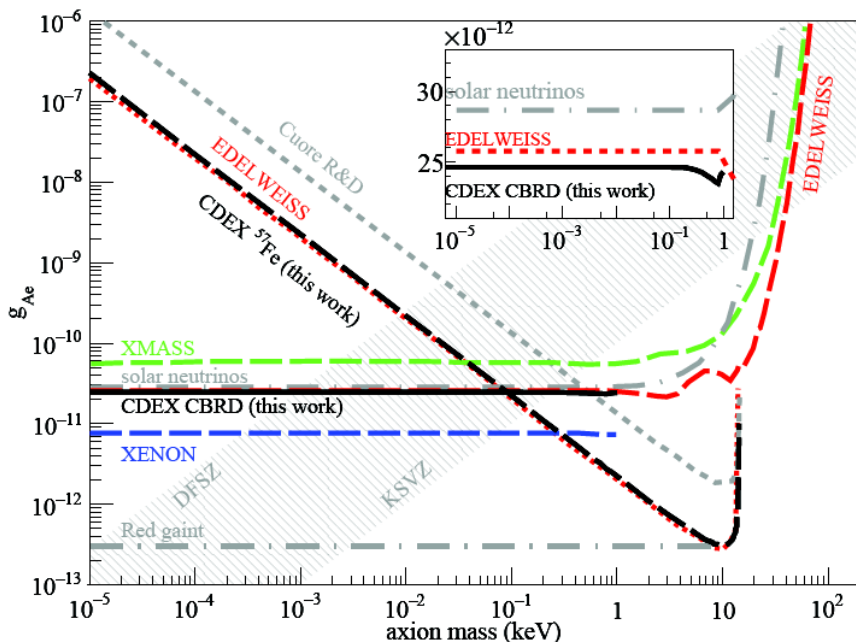
recombination(R):  $e + I \rightarrow I + a$

de-excitation(D):  $I^* \rightarrow I + a$



Axioelectric  
or Photoelectric-like

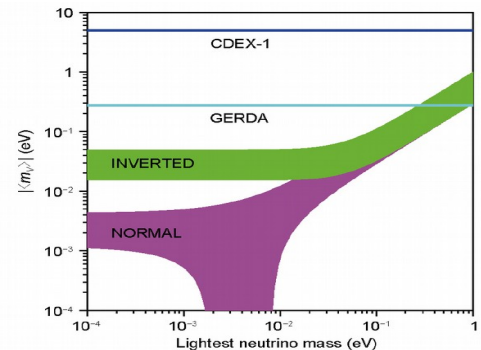
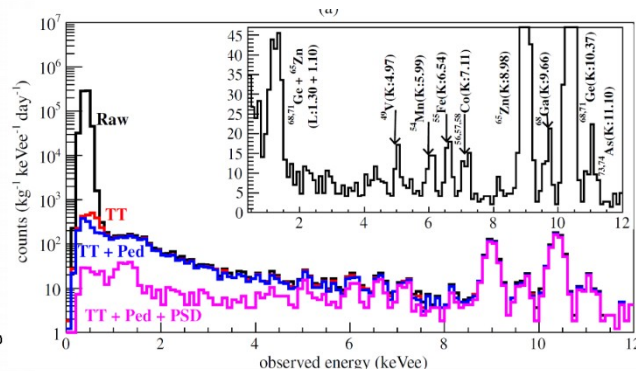
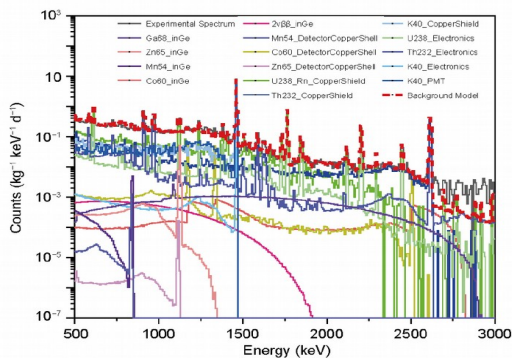
galactical axion(DM) : axioelectric  
detection :  $a + e + Z \rightarrow e + Z$



**Competitive results for DM axion  
below the axion mass of 1 keV.**

# CDEX-1 $0\nu\beta\beta$ result

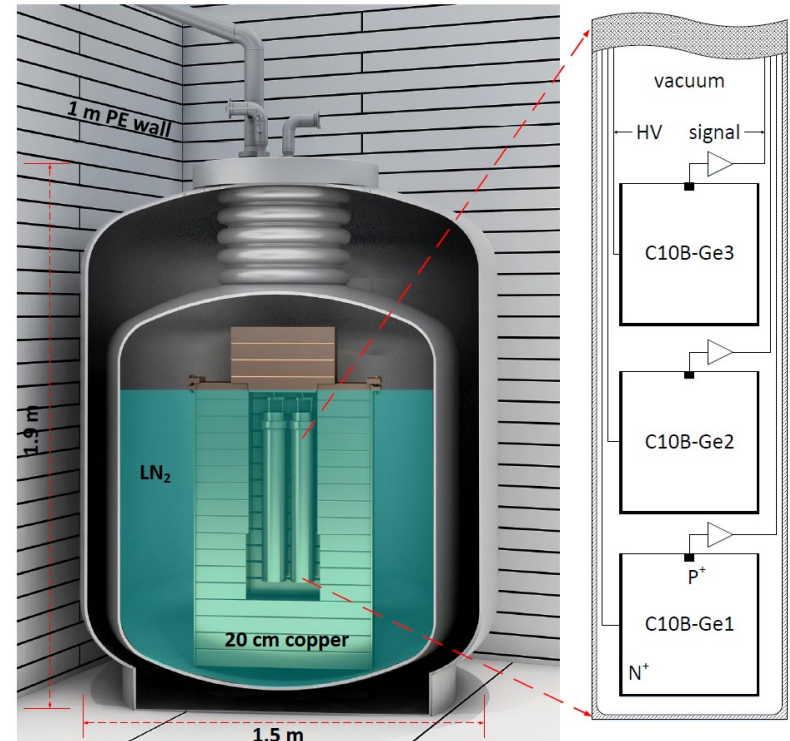
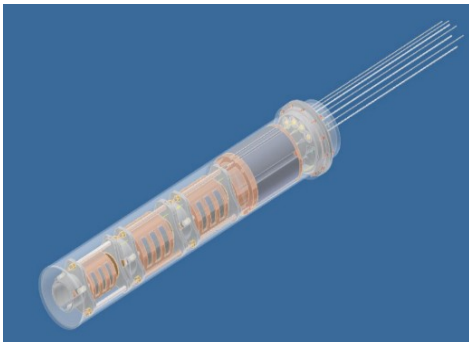
- Published  $^{76}\text{Ge}$   $0\nu\beta\beta$  result based on CDEX-1A (natural Ge).
- Calculation of the level of cosmogenic events @ 2 MeV based on cosmogenic characteristic X-ray peaks  $<10\text{keV}$ .
- $\tau_{1/2} > 6.4 \times 10^{22} \text{yrs}$



Sci. China (2017) 60: 071011

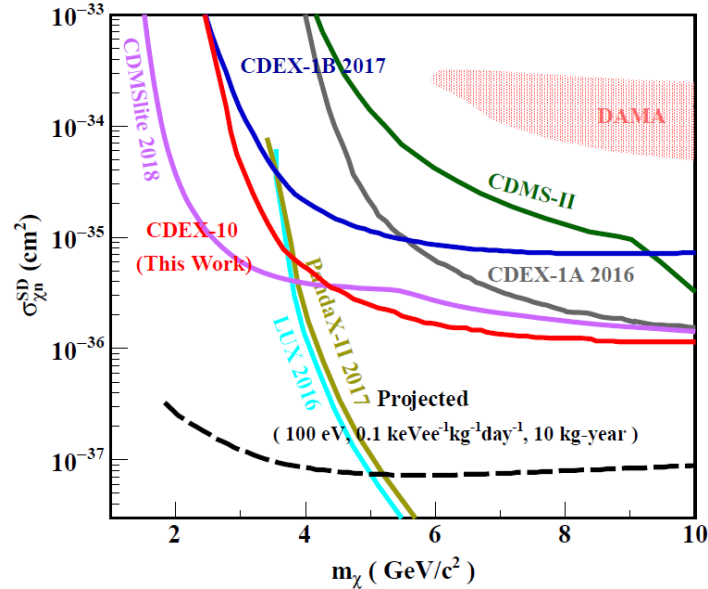
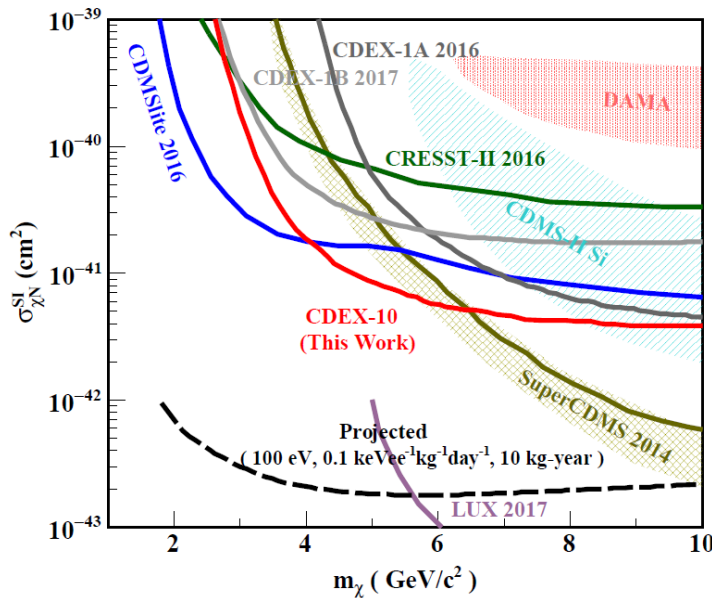
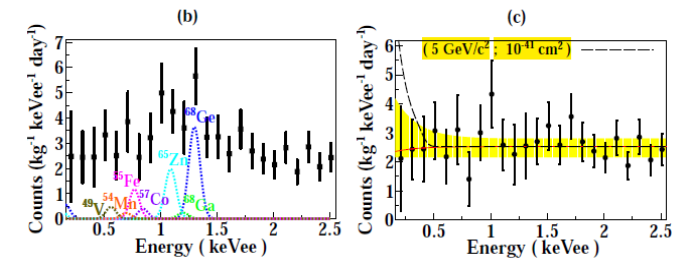
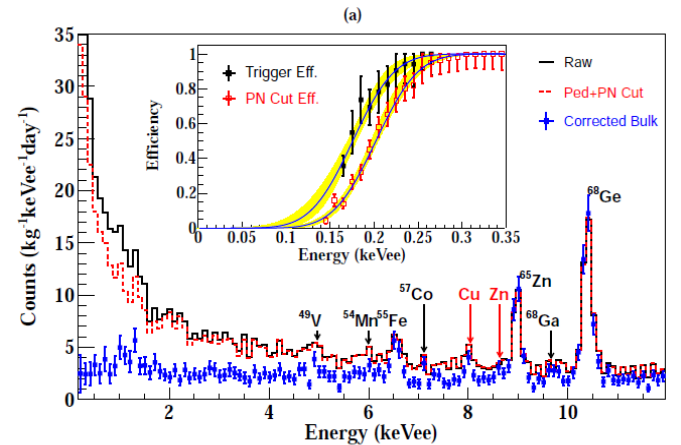
# CDEX-10 experiment

- The important stage towards large-scale Ge experiment.
- Directly immersed into liquid nitrogen for cooling: operate at few K lower than “cold-finger” configuration.
- Dataset: 102.8 kg-day.



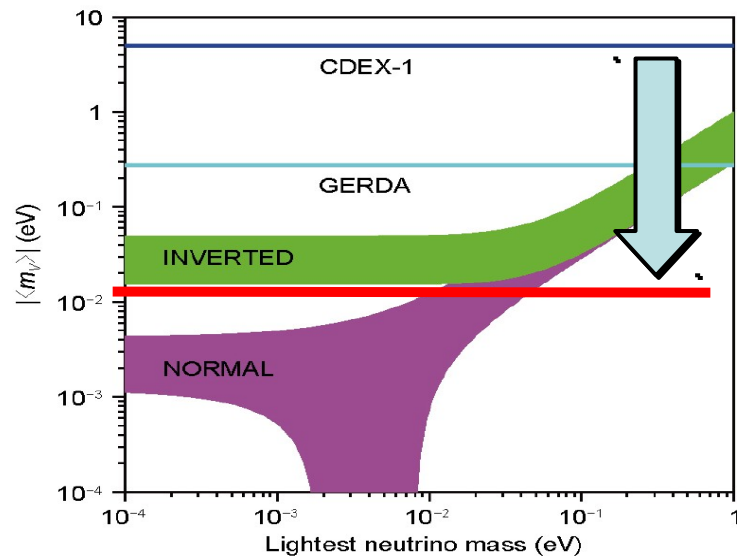
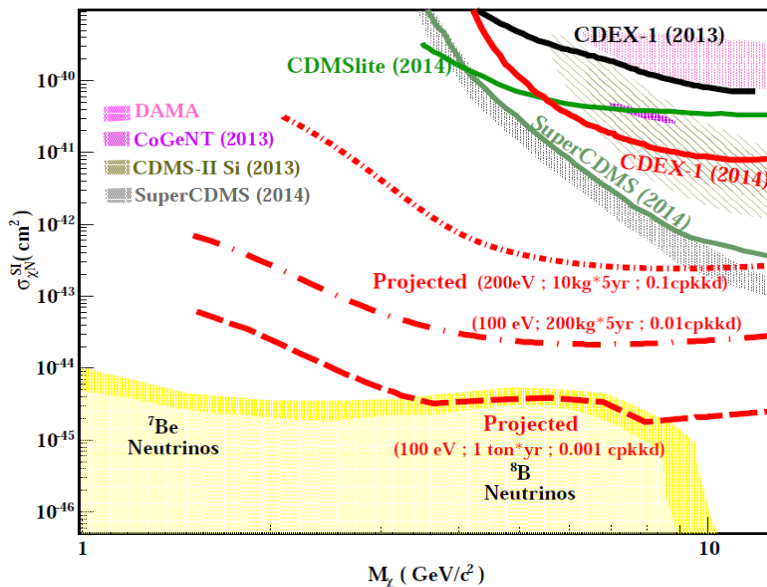
# CDEX-10 results

- ✓ threshold: 160eV
- ✓ The competitive SI/SD results at light WIMP mass



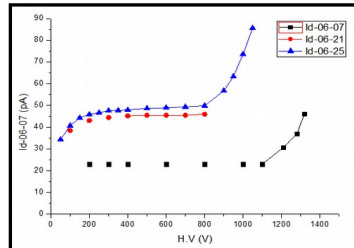
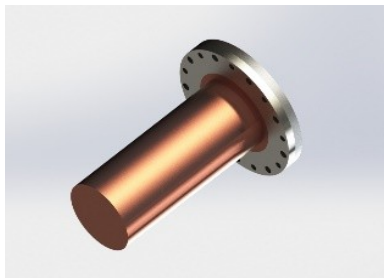
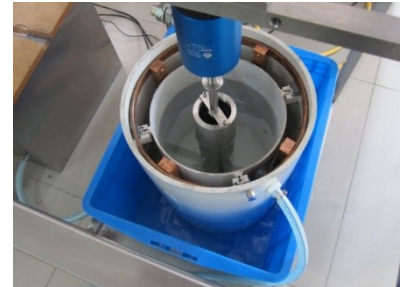
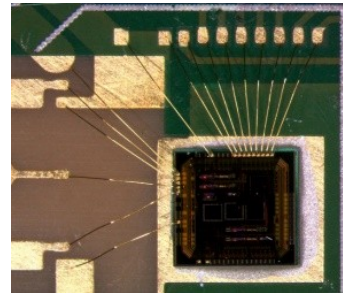
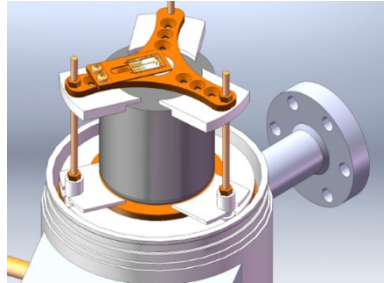
# Toward CDEX-1T@CJPL-II

- 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
- (Some CDEX members are part of LEGEND programs)



# Key technologies towards CDEX-1T

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





# CDEX-1T Ge crystal growth



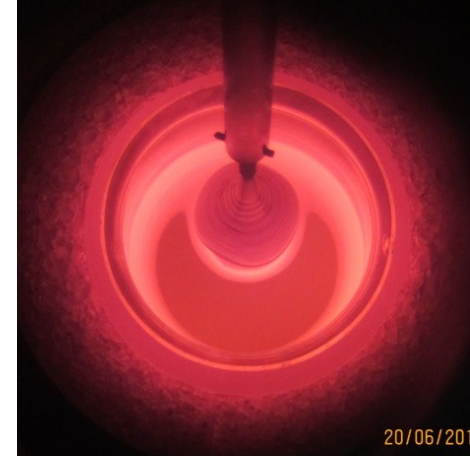
**Zone refining  
machine**



**Czochralski  
machine**



**Cutting &  
Polishing**



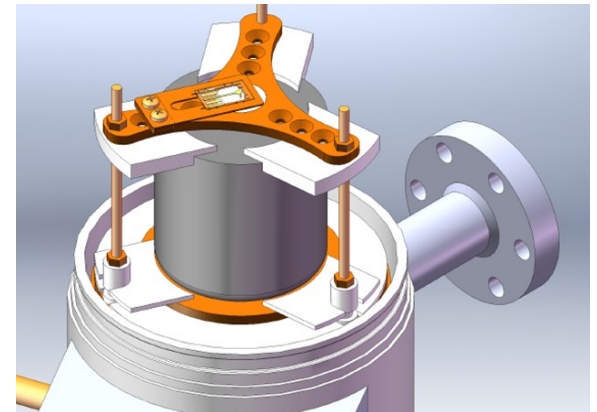
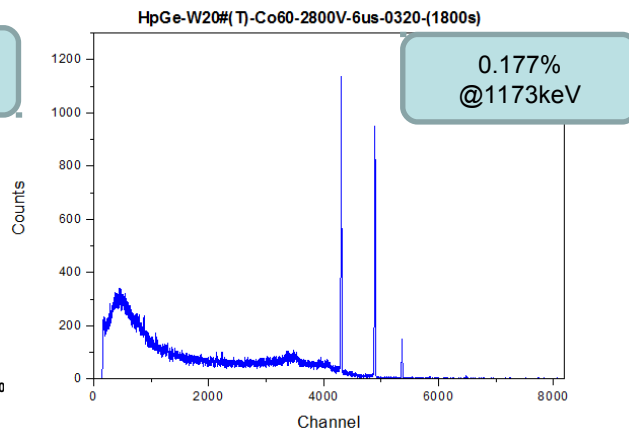
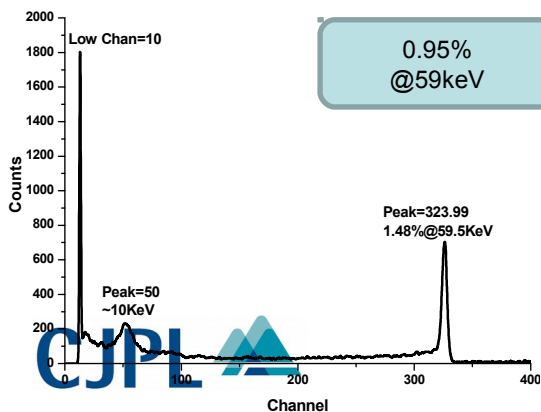
**Crystal growth**



- ✓ The requirement for making P-type Ge detector
  - ✓ Impurity density:  $\sim 10^{10} \text{ cm}^{-3}$
  - ✓ Dislocation:  $< 5000 \text{ cm}^{-2}$
- ✓ CDEX are working on this two points.

# HPGe detector fabrication

- First 500g home-made pPCGe+ASIC finished testing, energy resolution and energy threshold compared with commercial one.



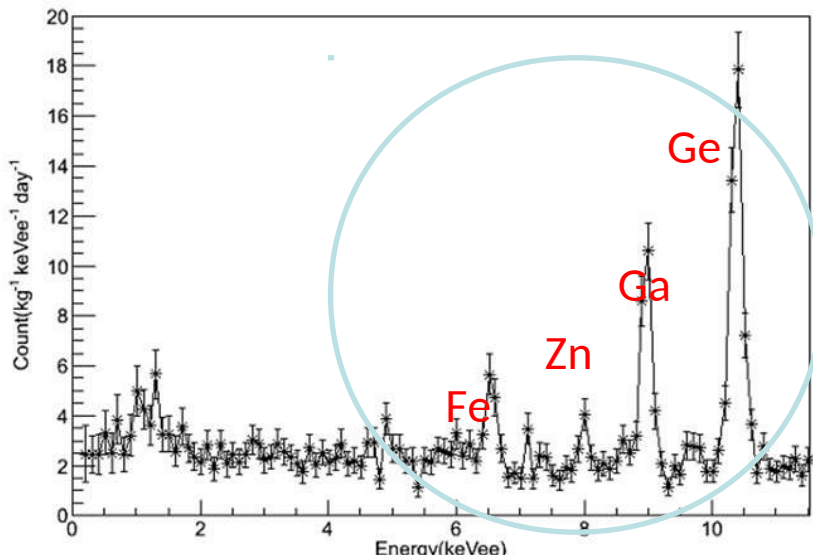
# CDEX ULB-Cu @ CJPL

- Setting up the facilities for ULB-Cu production;
- CDEX copper goal will be the Majorana EFCu purification:  
 $Th < 0.06 \mu\text{Bq/kg}$  、  $U < 0.17 \mu\text{Bq/kg}$ .
- Shielded by LN2, Structure materials used as little as possible in order to lower the background contribution.

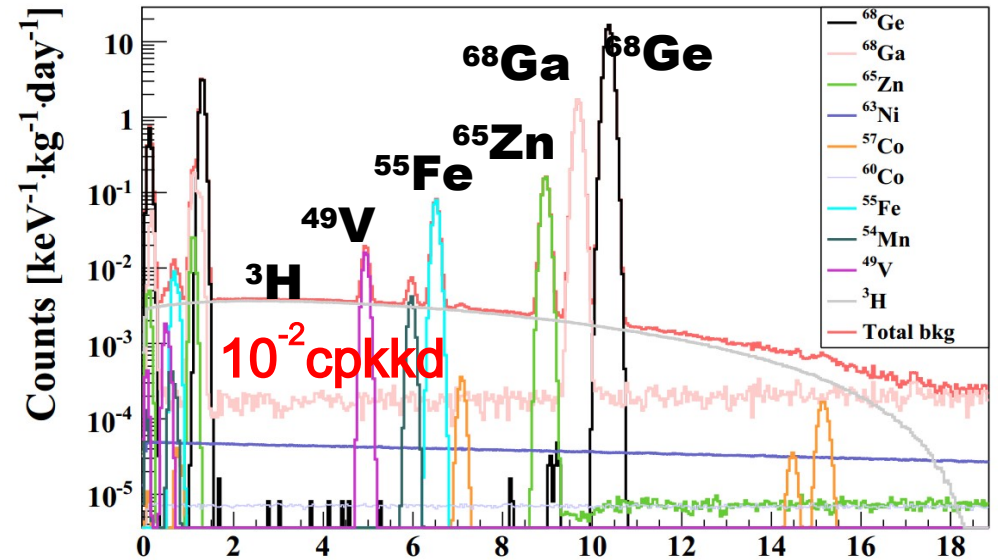


# Cosmogenic Background of Ge detector

- Long-time ground preparation of detector induces high cosmogenic background level ( $\sim 2 \text{cpkkd}$  @2-4keV);
- Based on simulation, **2 months ground fabrication and transportation** could decrease the  $^3\text{H}$  continuous background level to  **$\sim 10^{-2} \text{cpkkd}$**  @ 2-4 keV.



CDEX-10 background spectrum

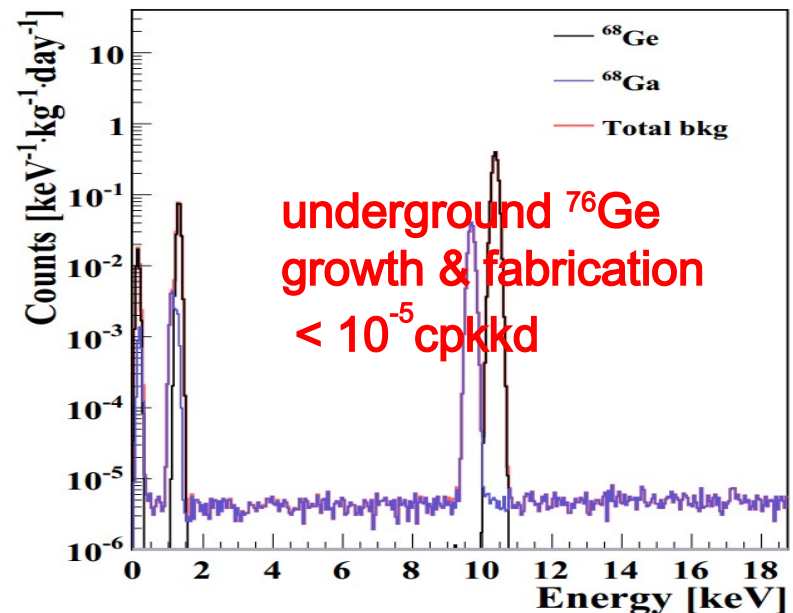
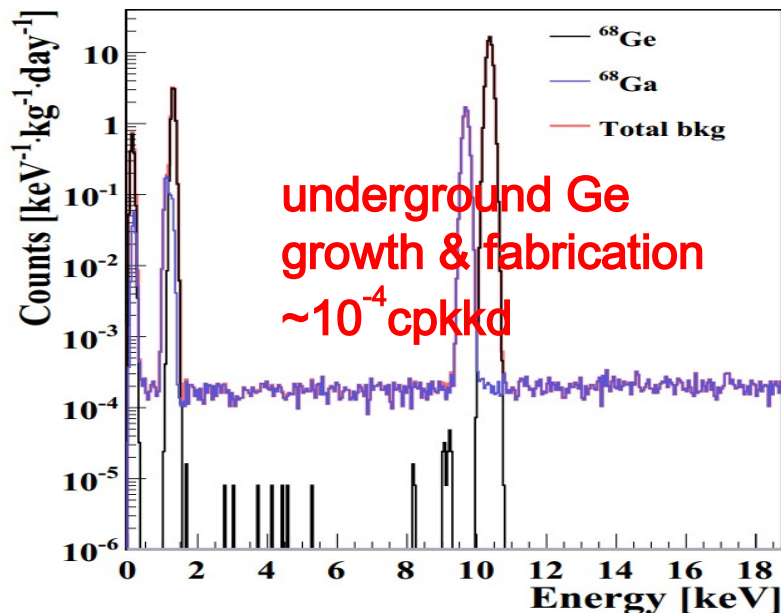


Simulation spectrum

Energy [keV]

# Cosmogenic Background of U-Ge detector

- Underground germanium crystal growth and detector fabrication could dramatically decrease the cosmogenic backgrounds from non-Ge isotopes, such as  $^3\text{He}$ ,  $^{65}\text{Zn}$ ;
- $^{76}\text{Ge}$  Enriched germanium material could help to decrease  $^{68}\text{Ge}$ ( $^{68}\text{Ga}$ ) cosmogenic backgrounds too.



# The layout of CJPL-II

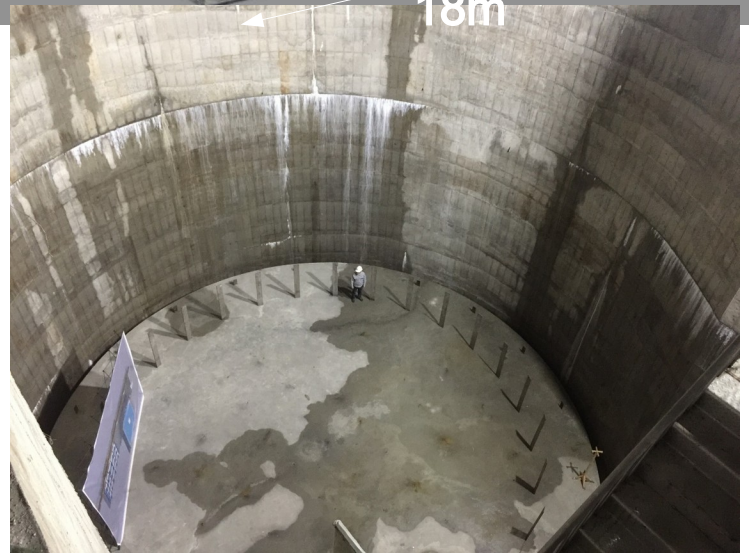
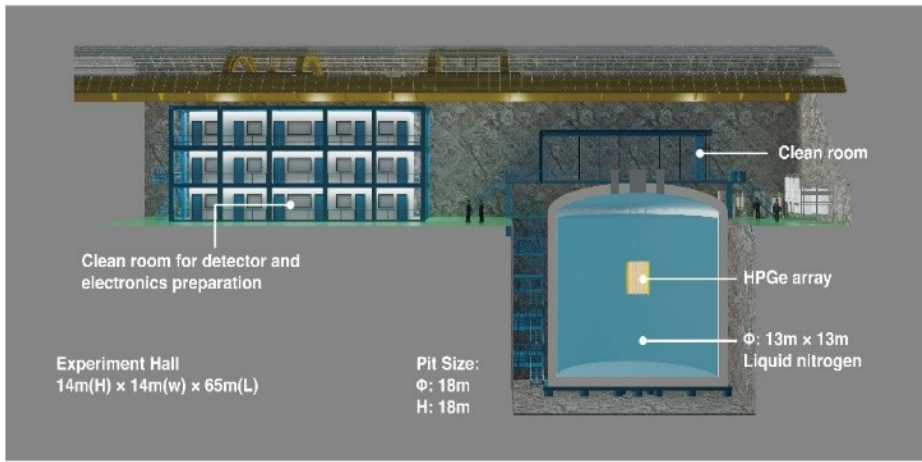
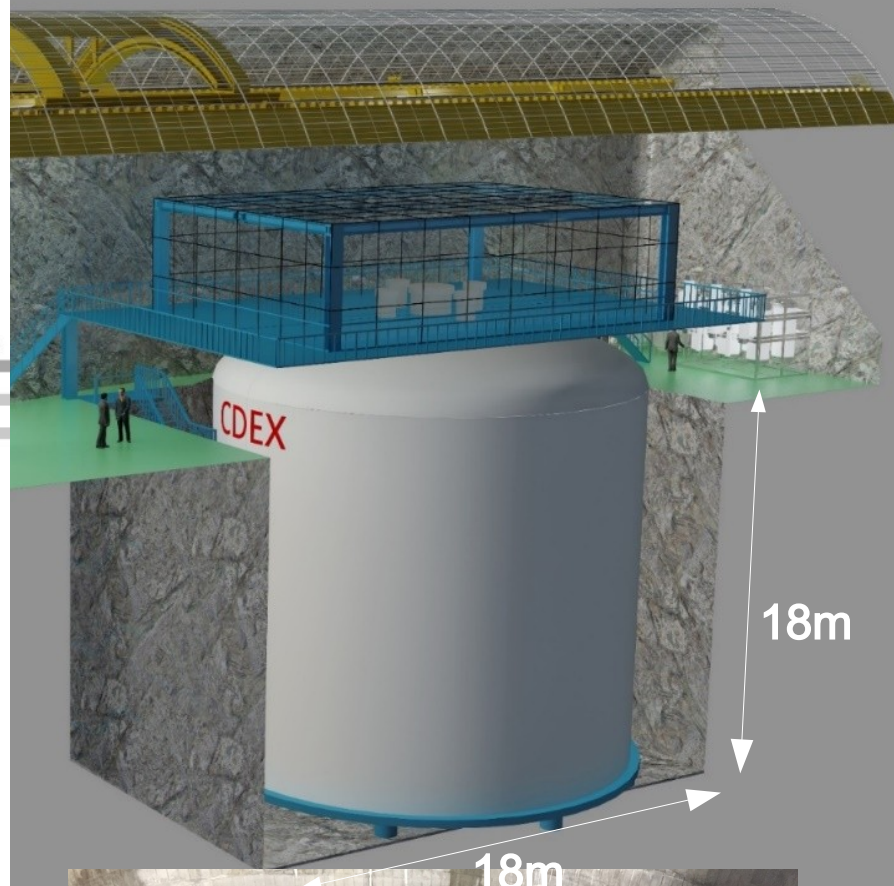
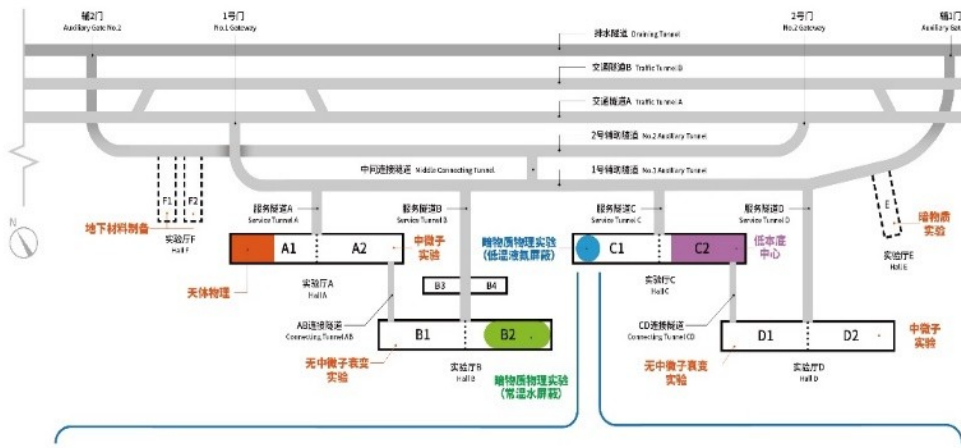
- 4 main halls : 14m(H)×14m(W)×130m(L);
- Total Volume: 300K m<sup>3</sup>;
- Two expanded spaces:

C1-- $\phi 18\text{m} \times 32\text{m(H)}$ →CDEX-1T  
 B2-- $27\text{m(L)} \times 14\text{m(W)} \times 30\text{m(H)}$

	CJPL-I	CJPL-II
Rock Work	4100 m <sup>3</sup>	210000+151000m <sup>3</sup>
Electric Power	70x2 kVA	10x2 MVA
Fresh Air	2400 m <sup>3</sup> /h	15000x3 m <sup>3</sup> /h



# CDEX-1T@CJPL-II



# Summary

- CDEX has achieved competitive DM physical results since 2013
- The first physical results from CDEX-10 published, competitive SI/SD sensitivities at light WIMP mass region.
- CDEX is developing the key technologies of low background Ge detector towards **CDEX-100** → **CDEX-1T** experiment for DM (+DBD+Solar Neutrino).



Thanks for your attention!