

# Status and prospects of CDEX the China Dark Matter Experiment

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

## OUTLINE

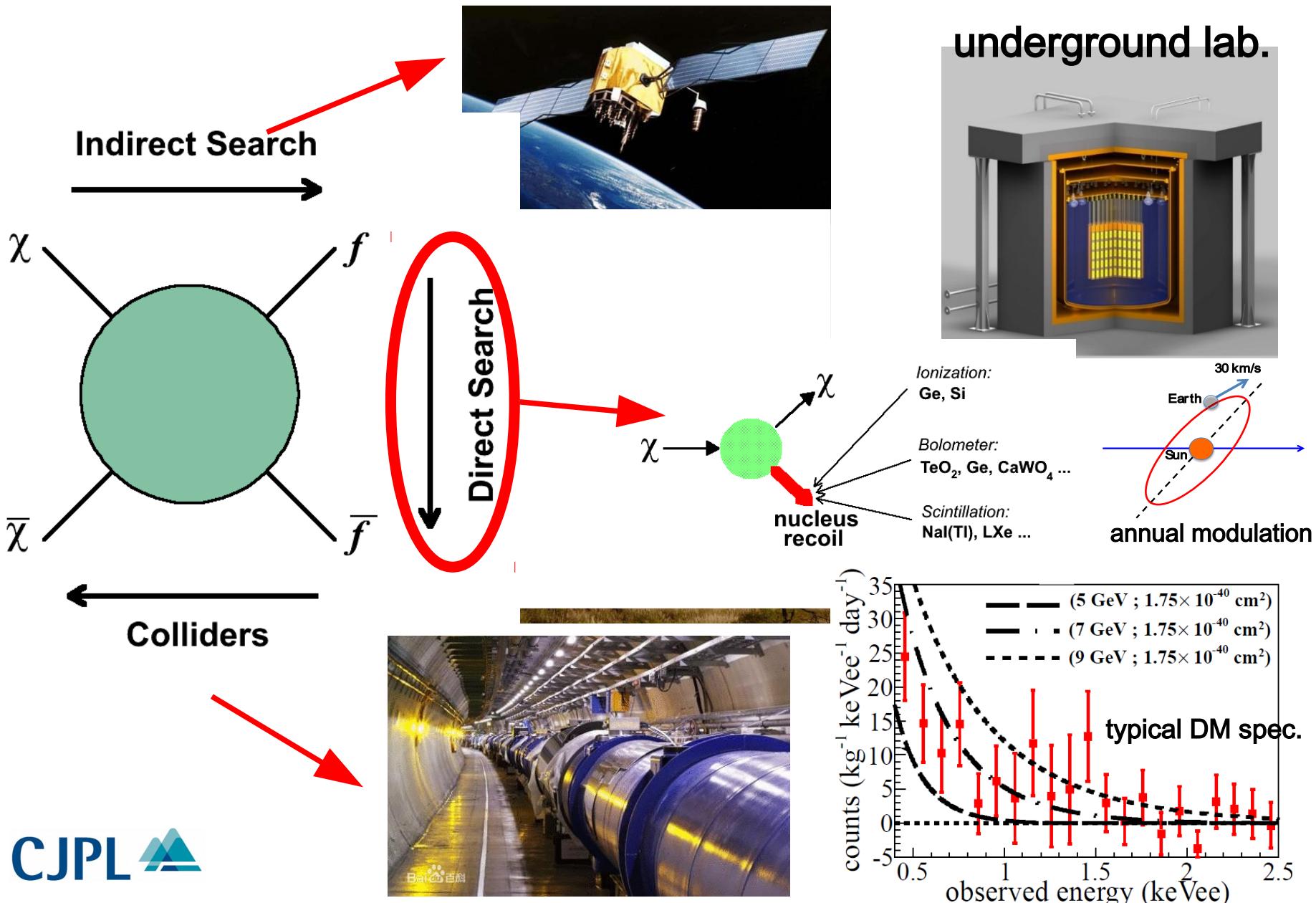
- Dark Matter and CDEX Introduction
- CDEX-1 and CDEX-10
- CDEX next-stage plan
- Summary



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



# Dark Matter detection



# CDEX: China Dark matter EXperiment



## Established in 2009

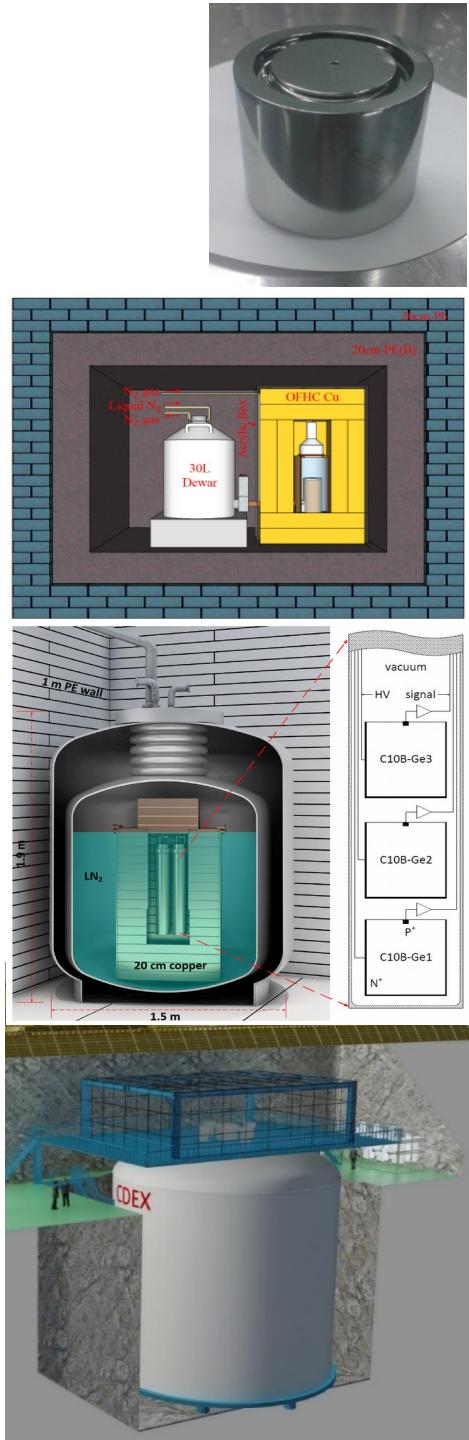
- Tsinghua University (THU)
- Sichuan University (SCU)
- Nankai University (NKU)
- China Institute of Atomic Energy (CIAE)
- Beijing Normal University (BNU)
- Yalong River Company

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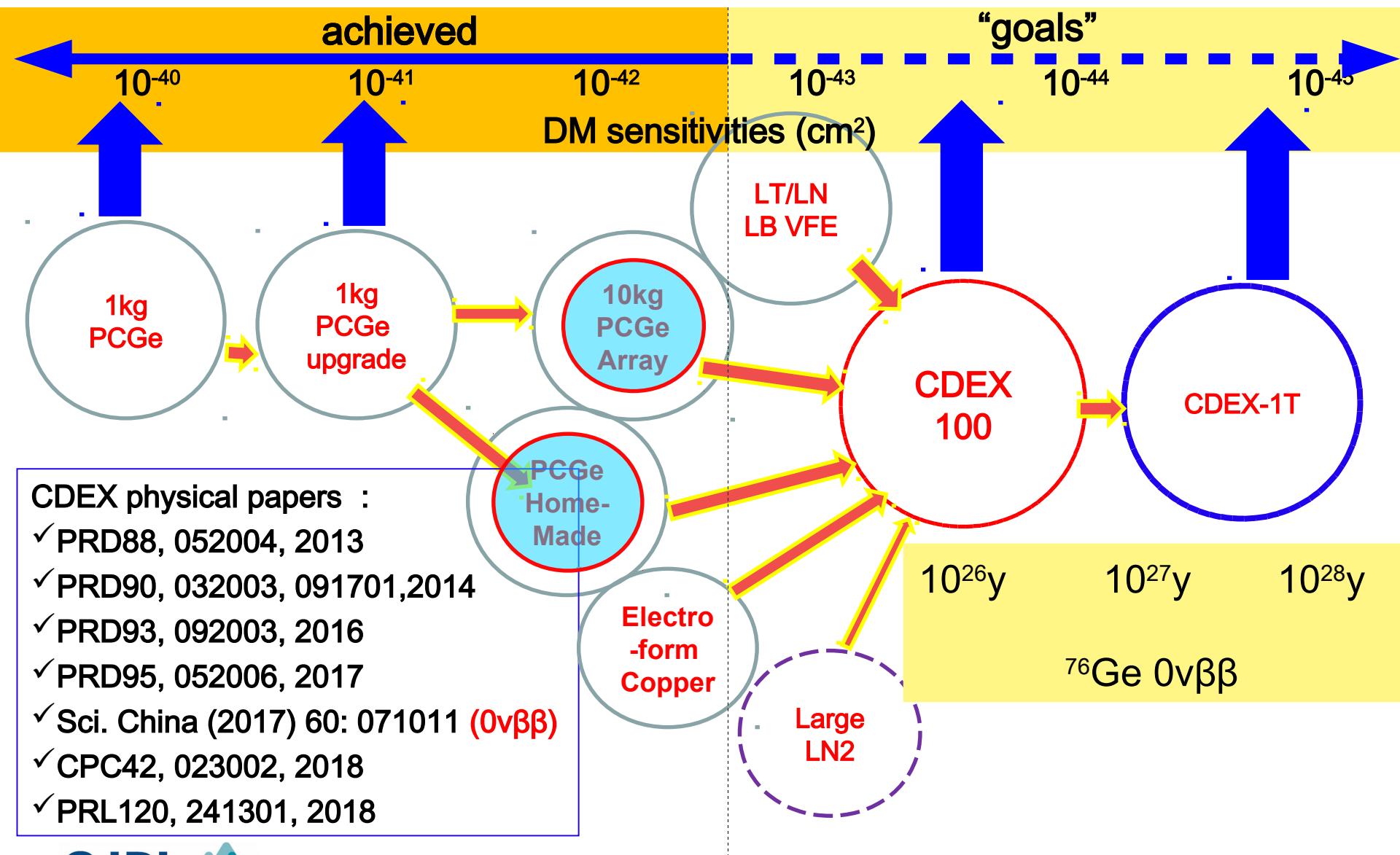
- Academia Sinica, Taiwan
  - Banaras Hindu University, India
  - Dokuz Eylül University, Turkey
- (as members of TEXONO collaboration)

# CDEX stages

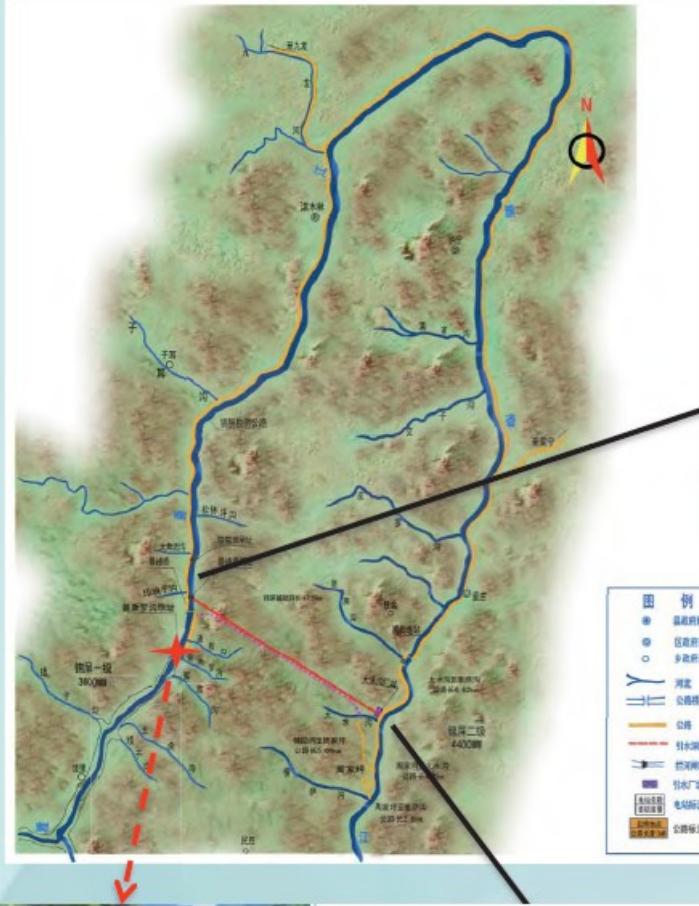
- Light WIMP mass searches with pGe
- CDEX-1: Development of pPC-HPGe detector, its background understanding, results published.
- CDEX-10: Performances of HPGe array detector system, results published.
- CDEX-10X: Fabrication of HPGe and Ge crystal growth by CDEX.
- CDEX-100: Ultra-low cosmogenic background and large  $\text{LN}_2$  cooling and shielding system.
- CDEX-1T: Multi-purpose experiment for dark matter and double beta decay.



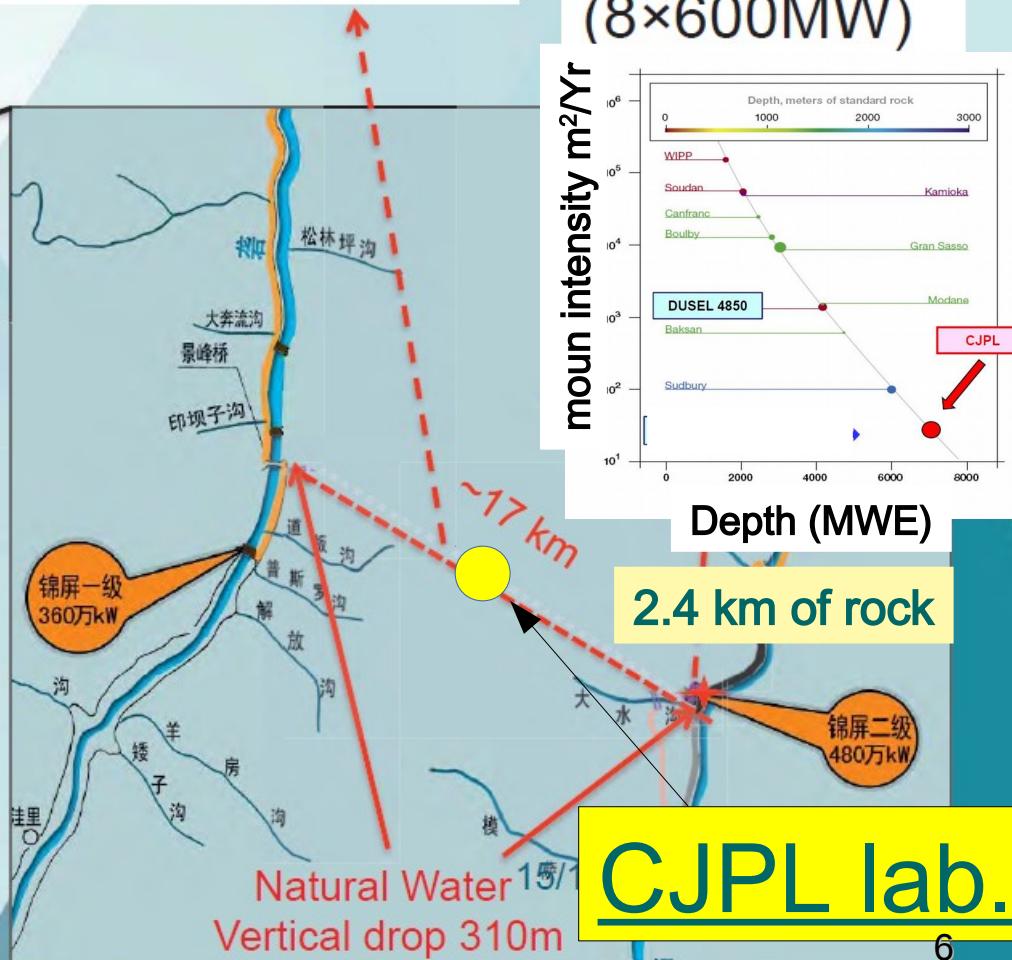
# CDEX plan for DM & $0\nu\beta\beta$



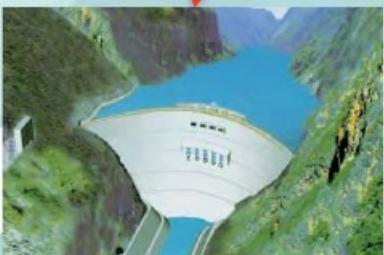
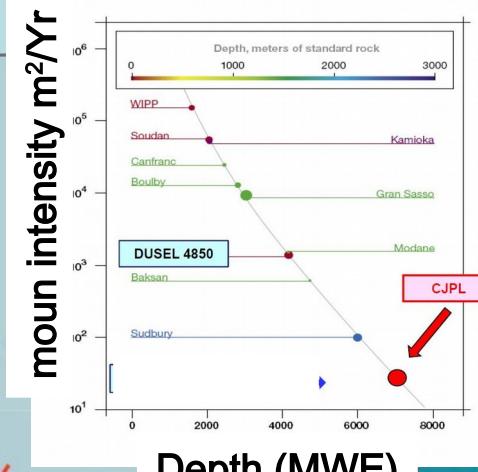
# Jinping Hydroelectric Power Plants



4 hydraulic  
tunnels  
 $\Phi 13m \times 16.6km$

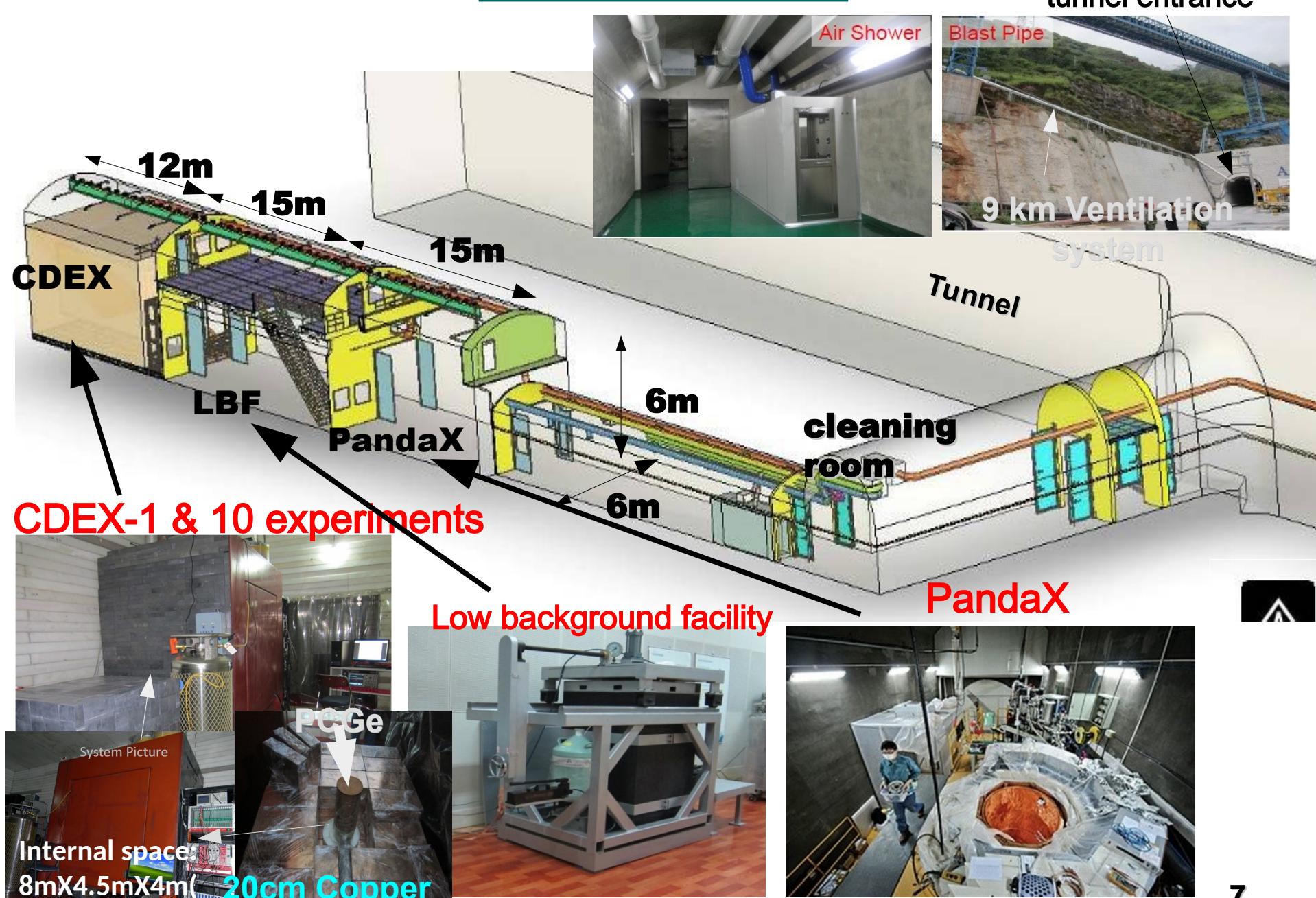


Jinping-II  
Power Plant  
4800MW  
(8×600MW)



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

# CDEX at CJPL-I

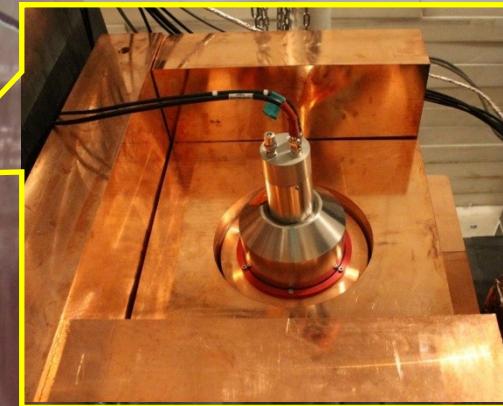


## CDEX-1 experiments

CDEX-1A 1kg PCGe



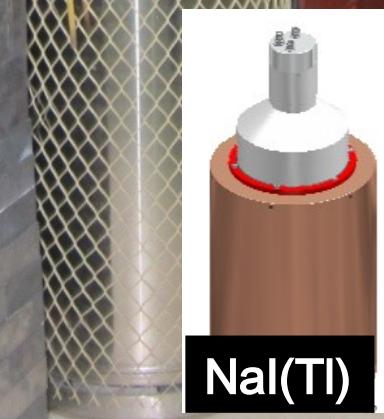
CDEX-1B 1kg PCGe



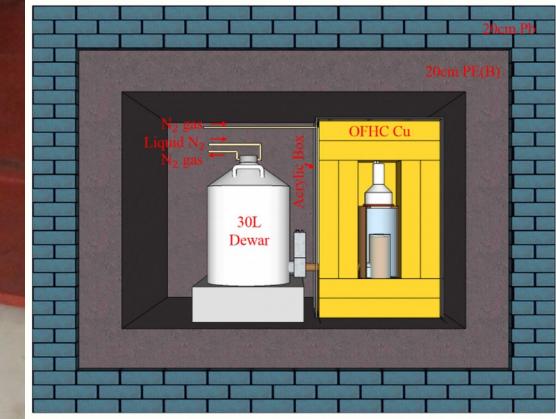
20cm OFHC Copper  
+20cm Lead



1kg-PPCGe

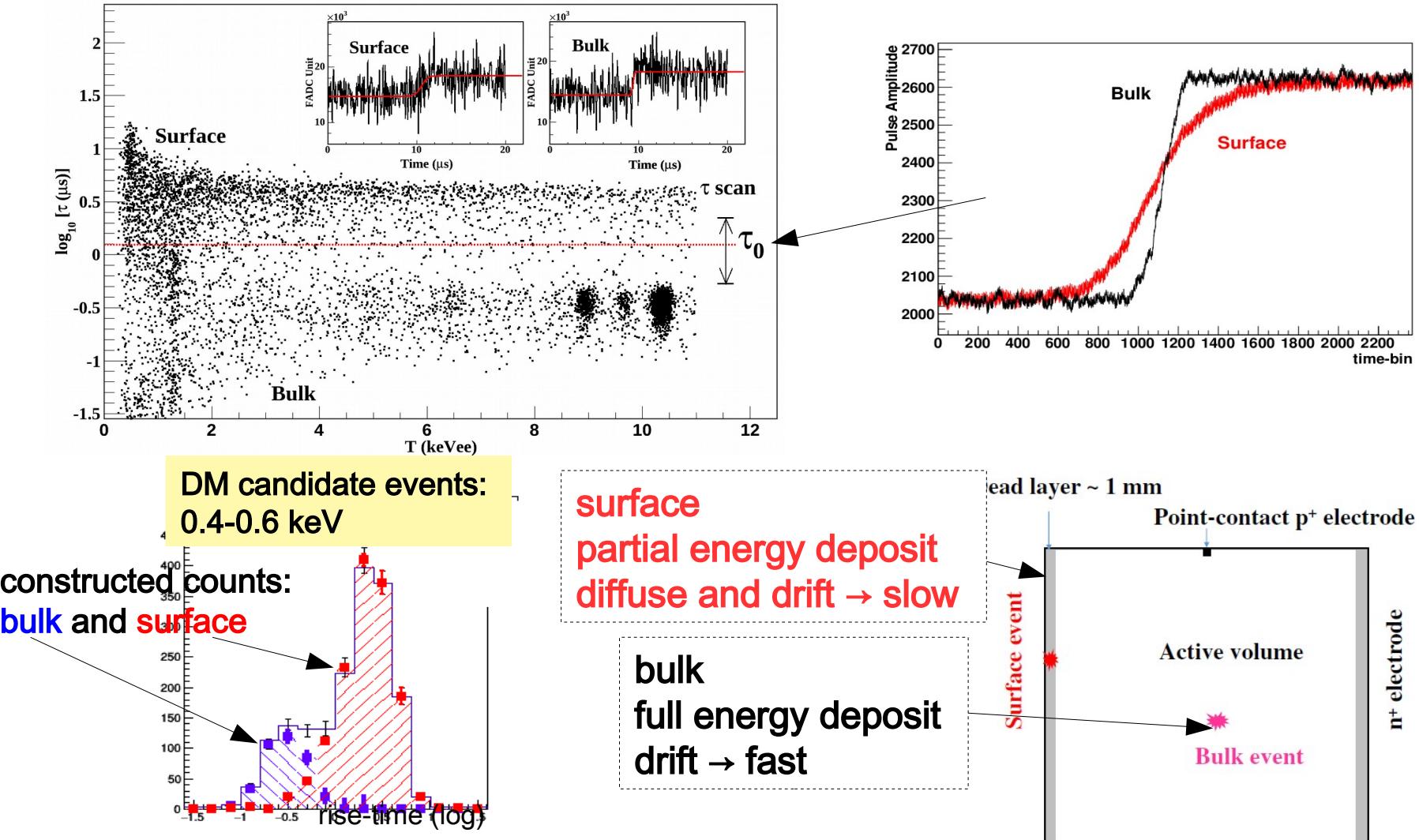


NaI(Tl)



# pPCGe: bulk/surface

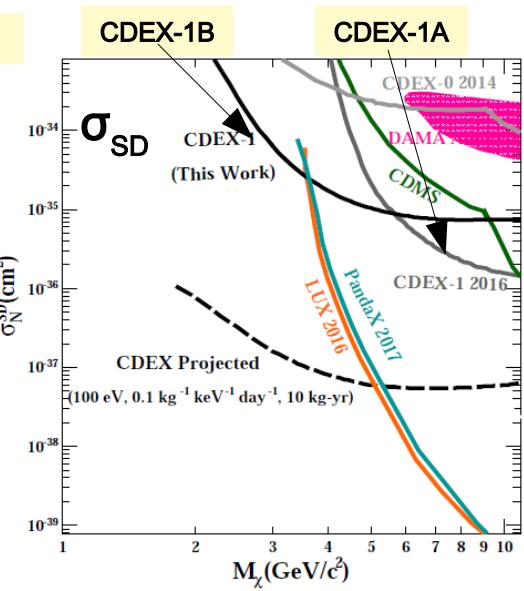
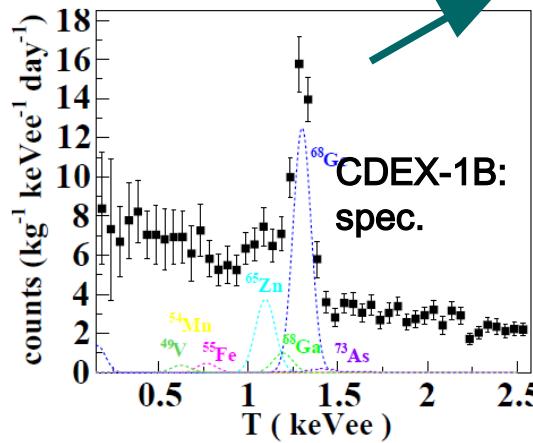
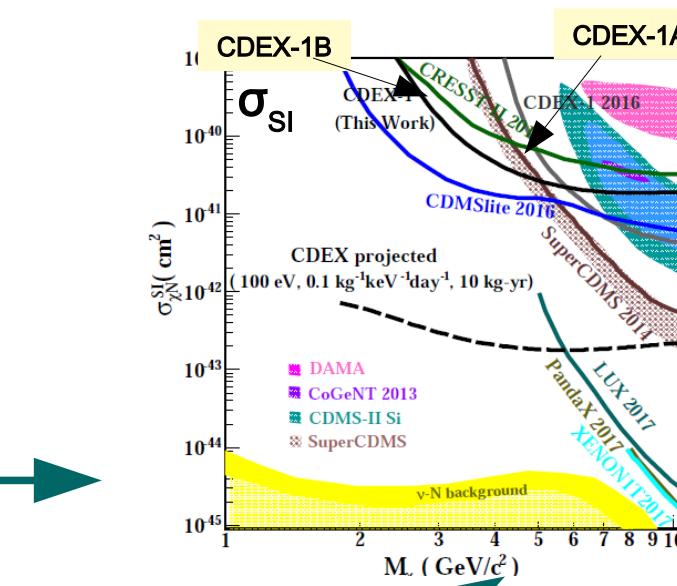
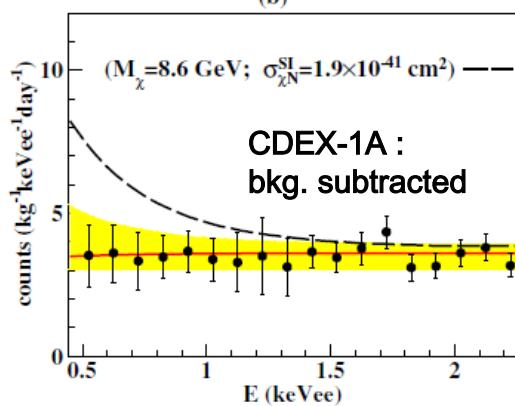
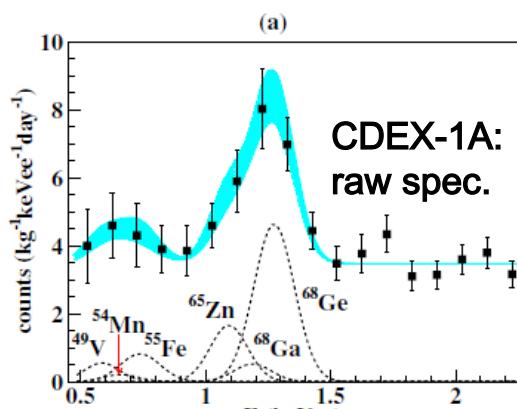
surface events : contamination, largest sources of uncertainties at low energy.



# 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<sub>AN</sub>]

PRD95, 052006, 2017

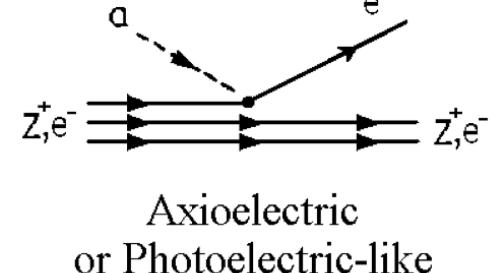
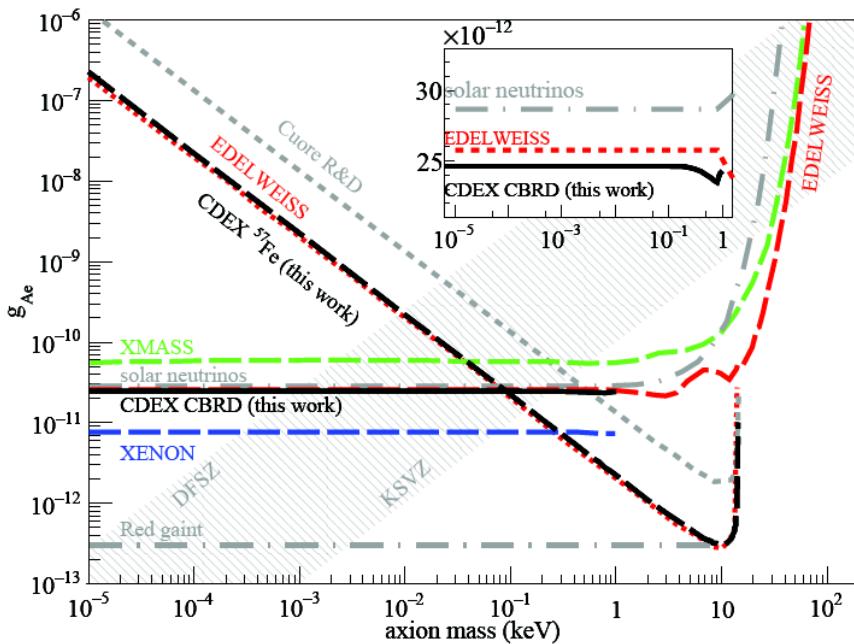
axion(a) from sun [g<sub>Ae</sub>]

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

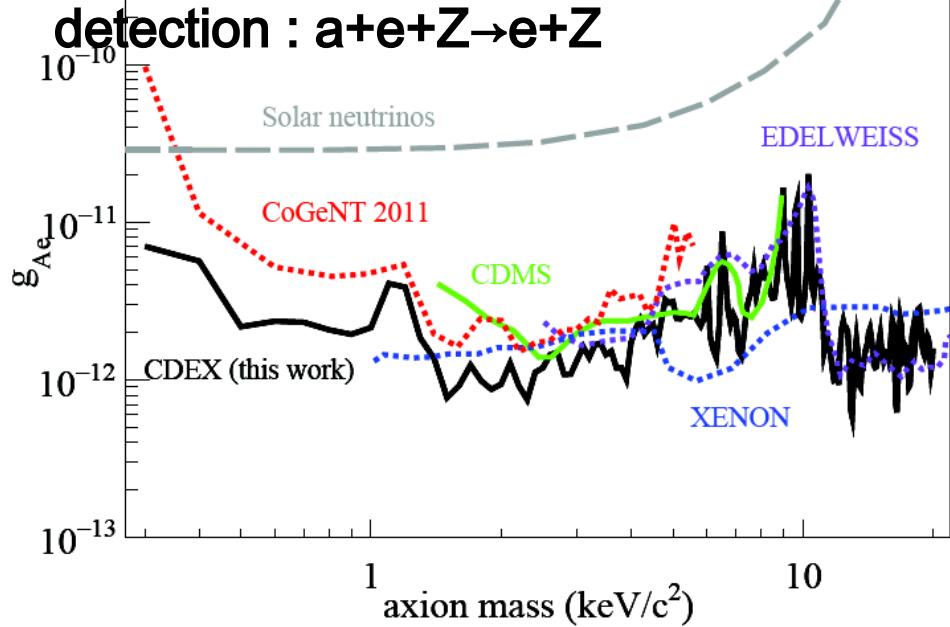
bremsstrahlung(B):  $e + Q \rightarrow e + Q + a$

recombination(R):  $e + l \rightarrow l^- + a$

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



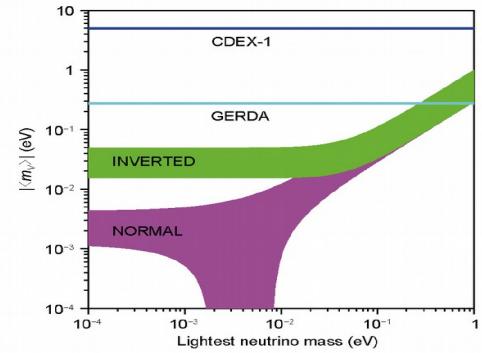
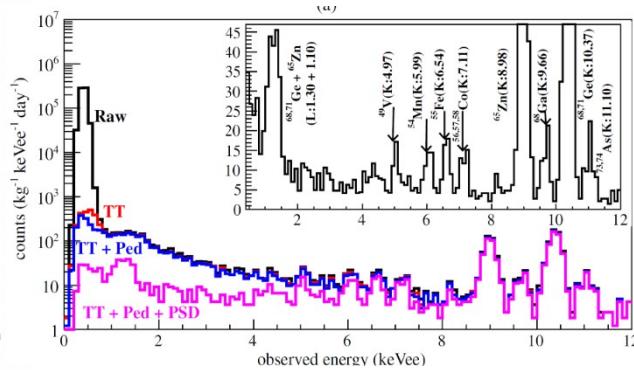
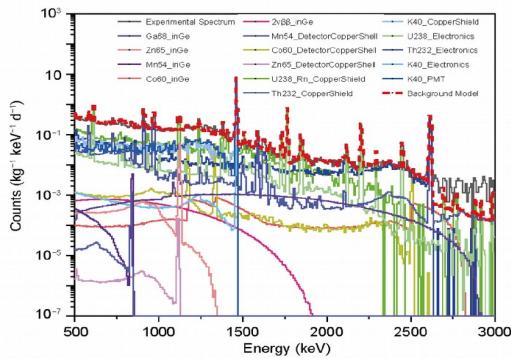
galactical axion(DM) : axioelectric detection :  $a + e + Z \rightarrow e + Z$



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

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

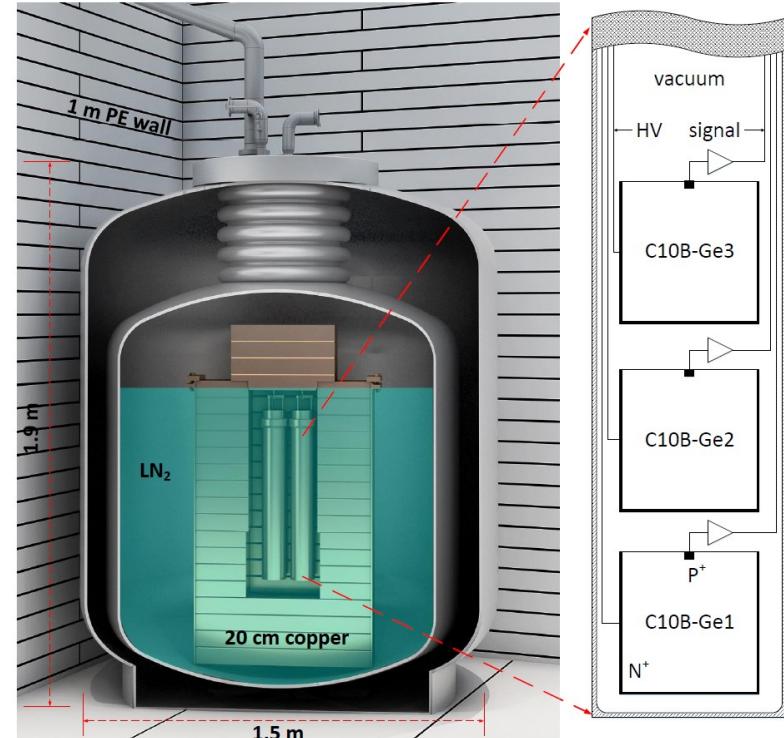
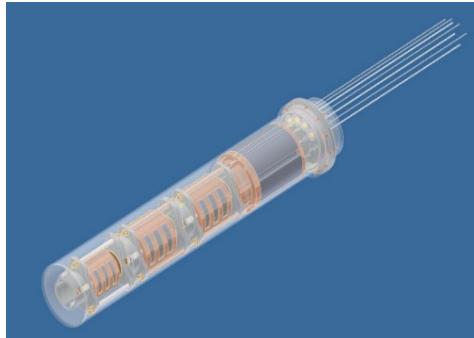
- Published  ${}^{76}\text{Ge}$  0v $\beta\beta$  result based on CDEX-1A (natural Ge).
  - Calculation of the level of cosmogenic events @ 2 MeV based on cosmogenic characteristic X-ray peaks <10keV.
  - $T_{1/2} > 6.4 \times 10^{22} \text{ yrs}$



Sci. China (2017) 60: 071011

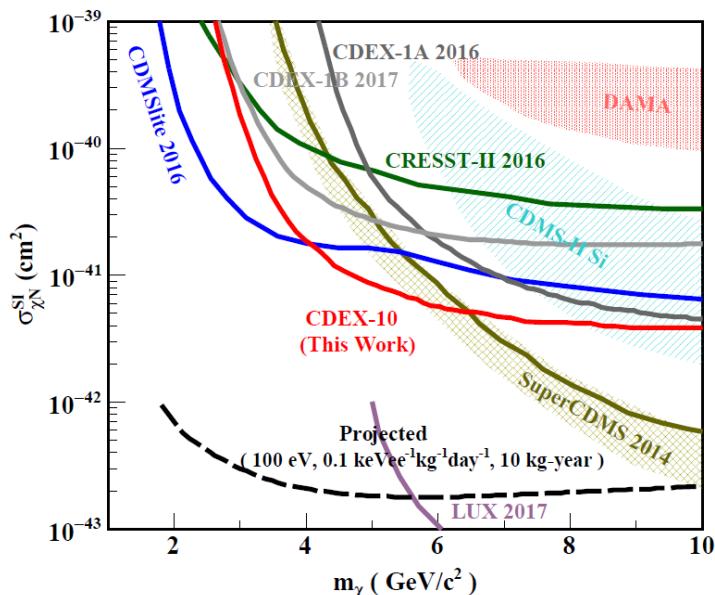
# CDEX-10 experiment

- 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.

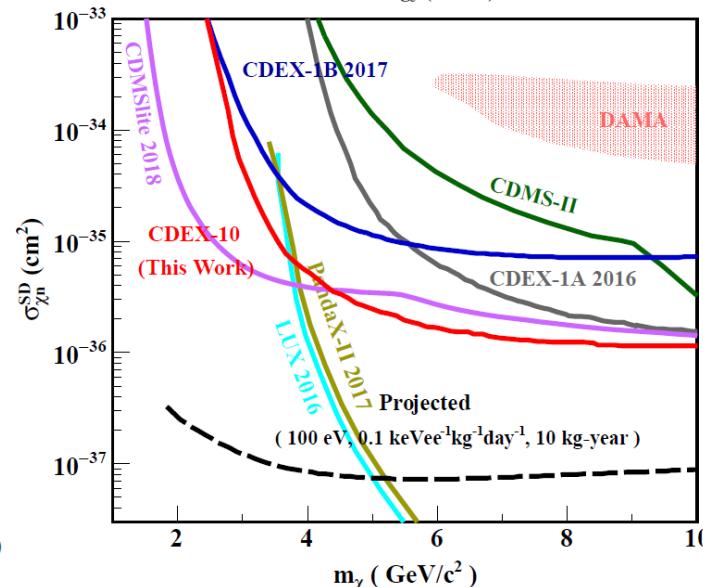
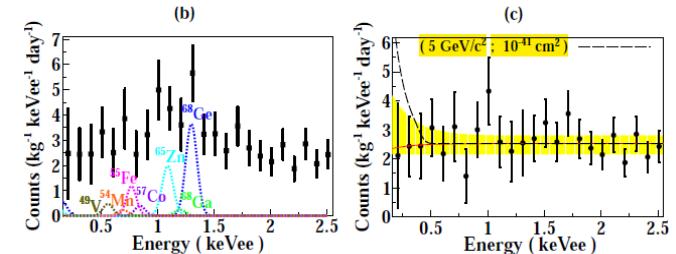
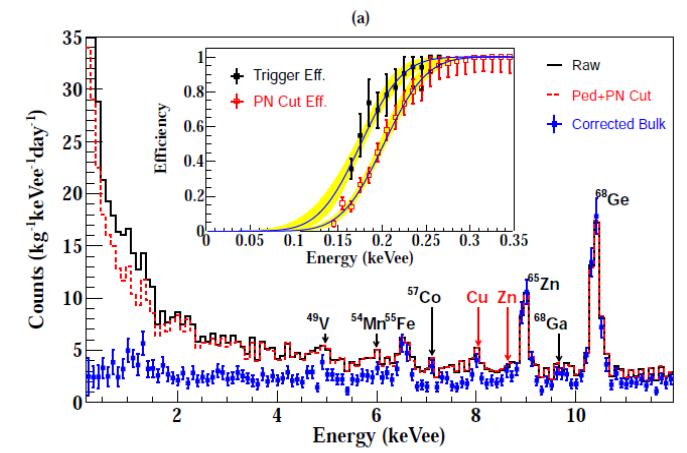


# CDEX-10 results

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

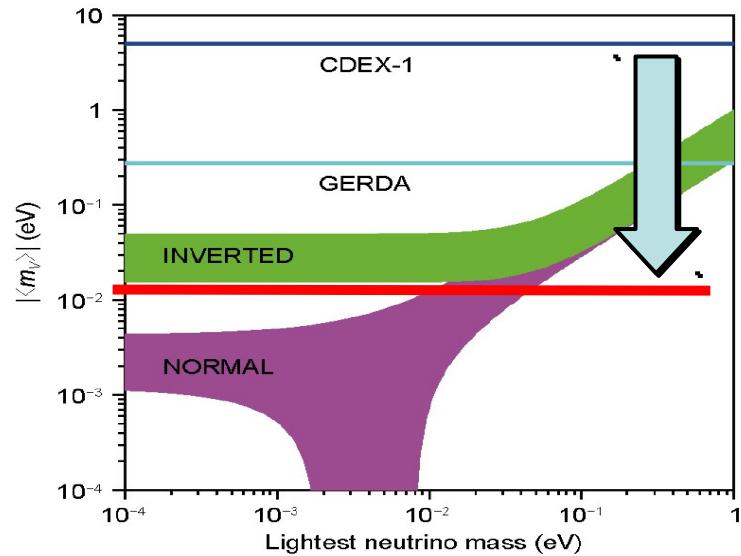
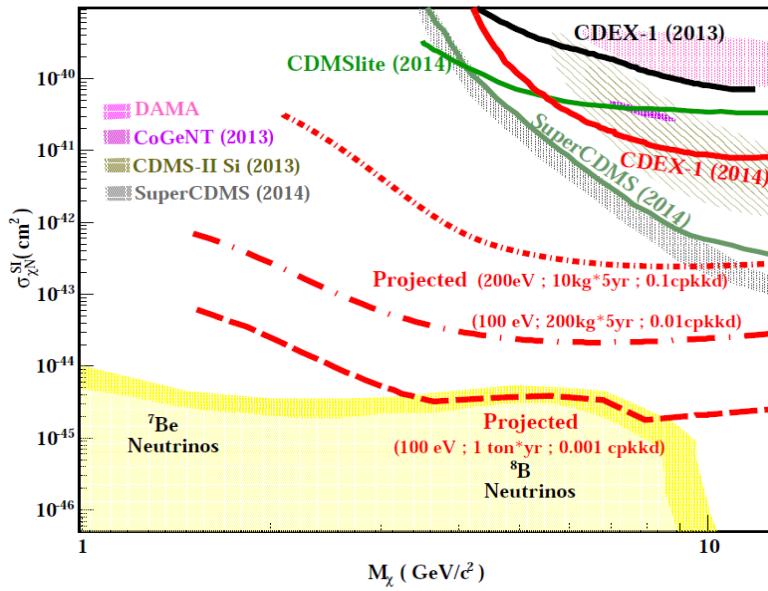


PRL120, 241301, 2018



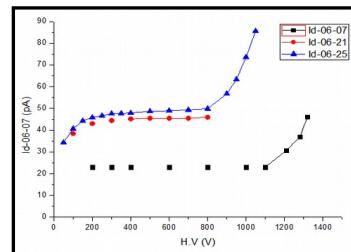
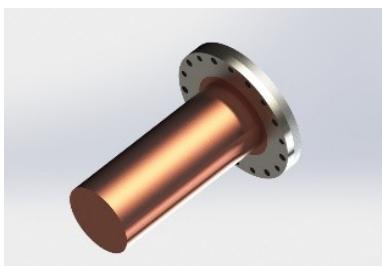
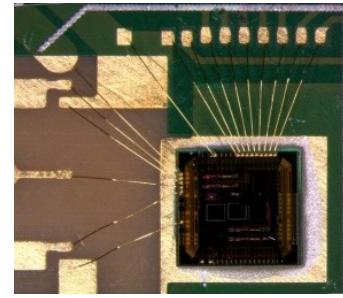
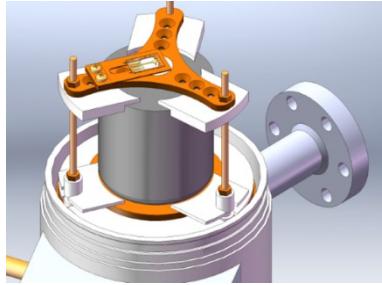
# Toward CDEX-1T@CJPL-II

- 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**

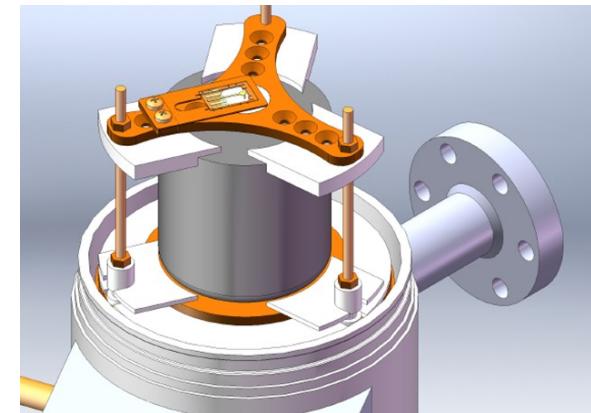
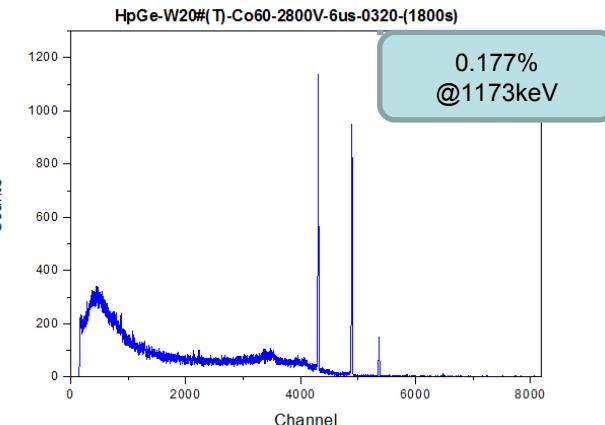
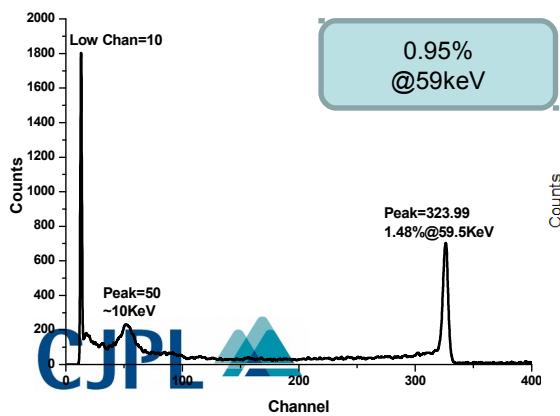
**Crystal growth**



- ✓ 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.



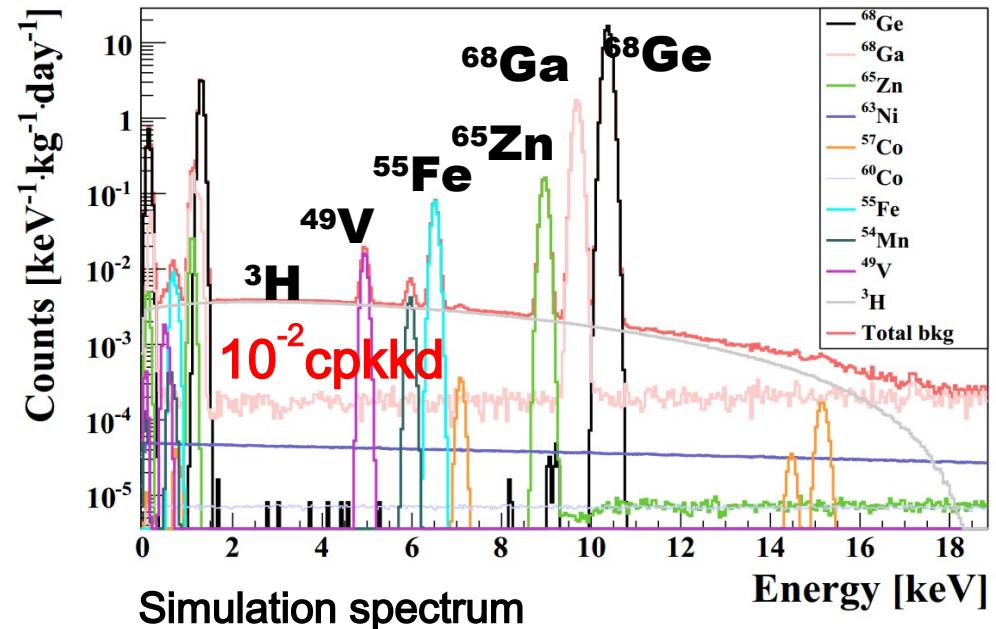
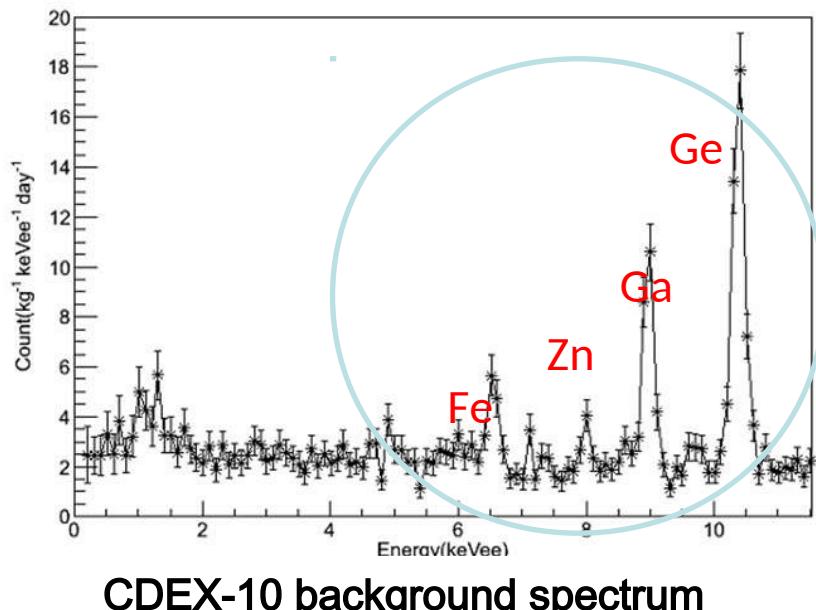
# CDEX ULB-Cu @ CJPL

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



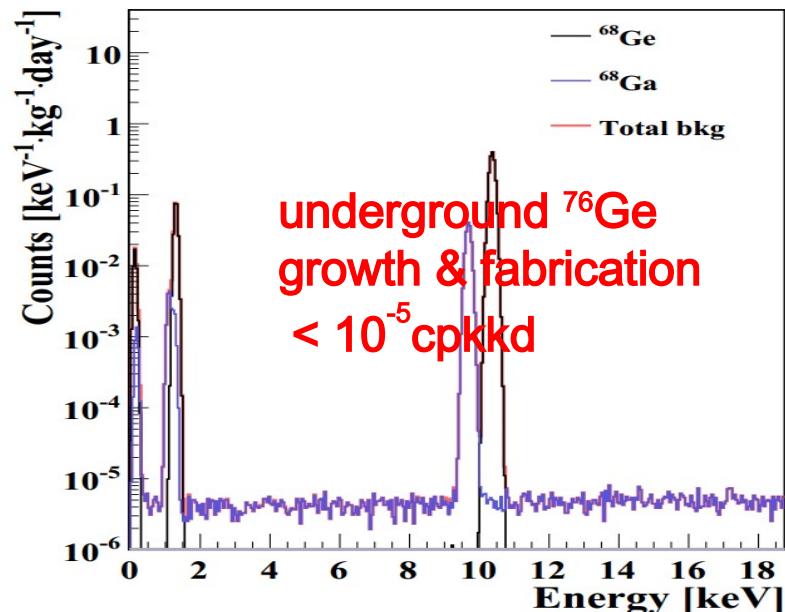
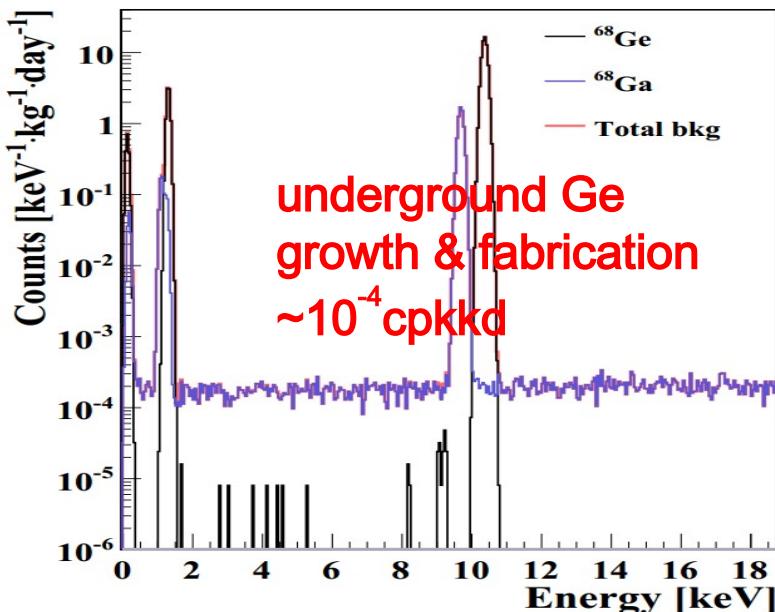
# Cosmogenic Background of Ge detector

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



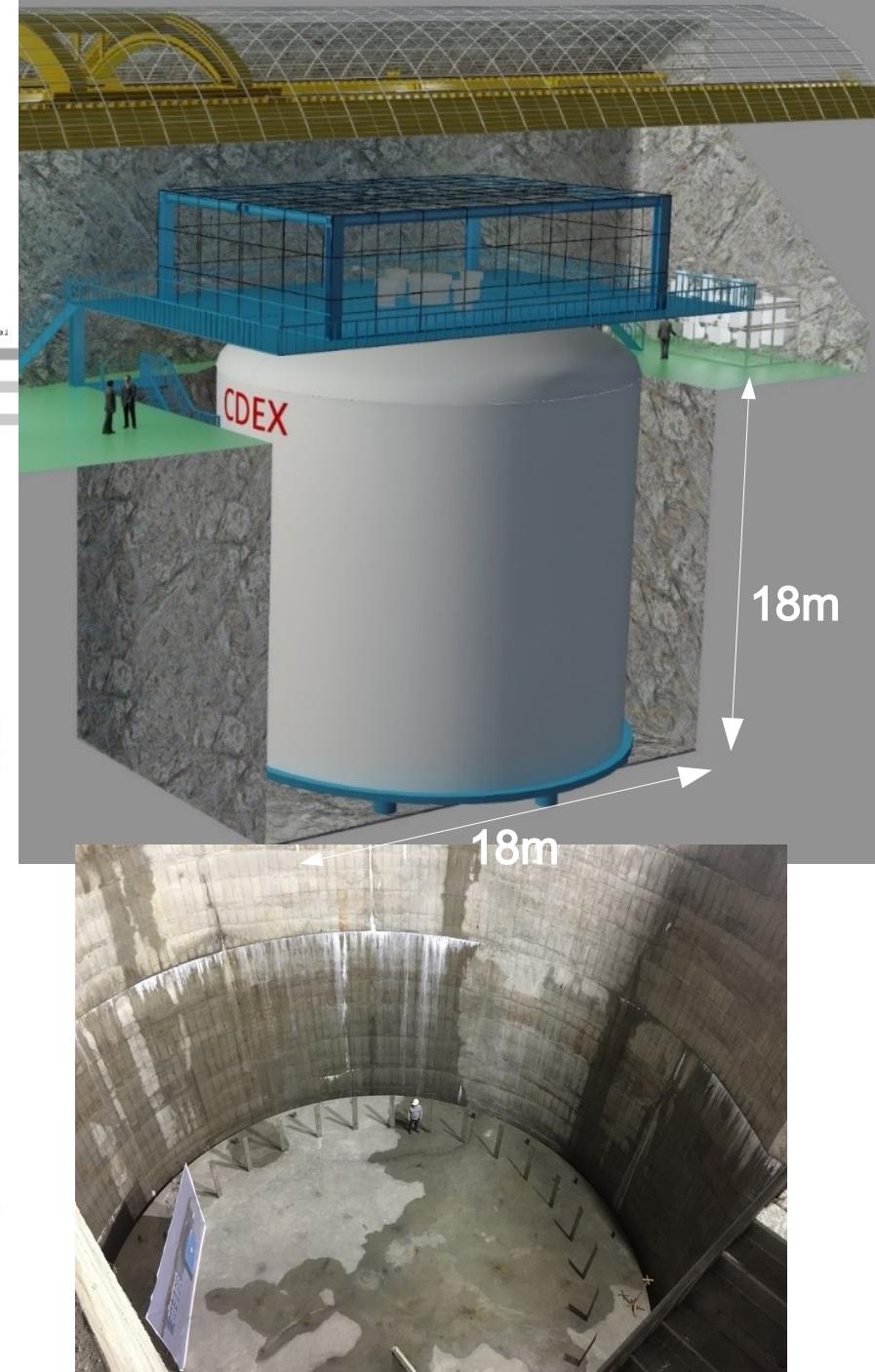
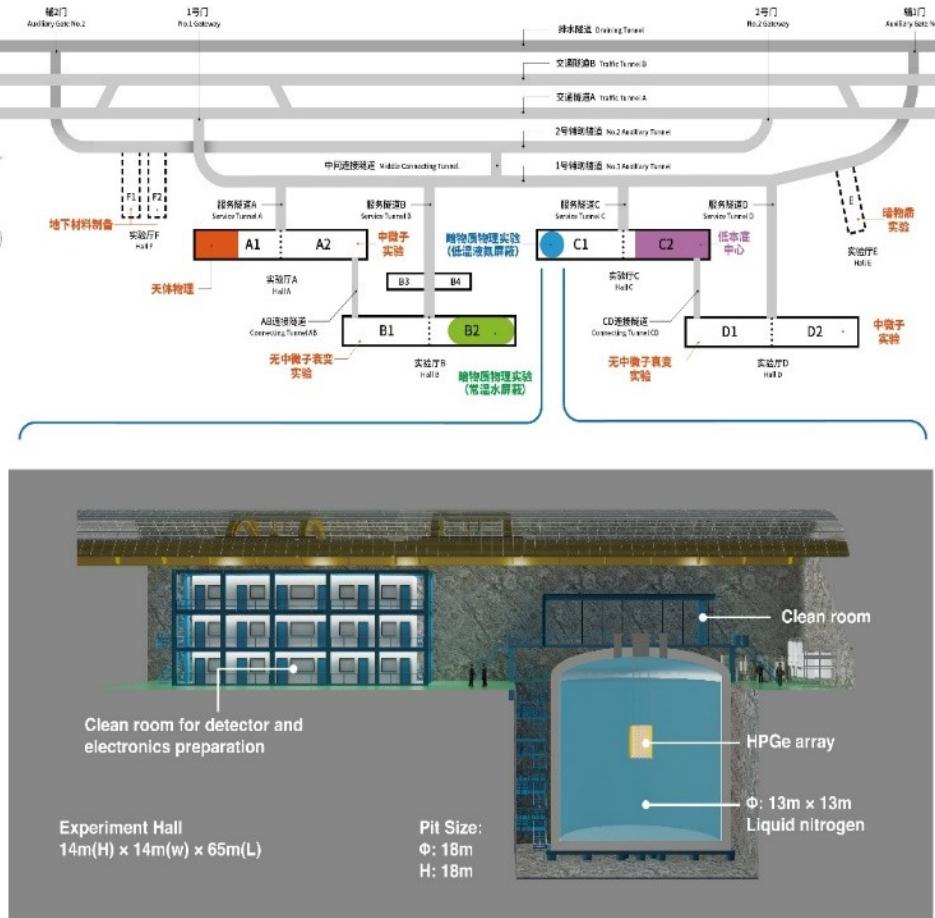
# The layout of CJPL-II

- 4 main halls : 14m(H)×14m(W)×130m(L);
- Total Volume: 300K m<sup>3</sup>;
- Two expanded spaces:  
**C1-- $\phi 18m \times 32m(H) \rightarrow$  CDEX-1T**  
**B2--27m(L)×14m(W)×30m(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!