Status and prospects of CDEX the China Dark Matter Experiment

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(on bahalf CDEX collaboration)

OUTLINE

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

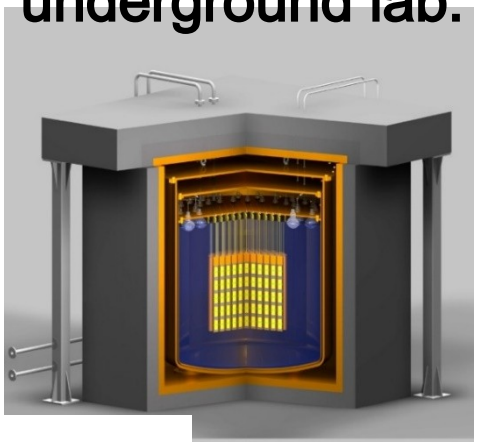
CJPL 中国锦屏地下实验室 China Jinping Underground Laboratory

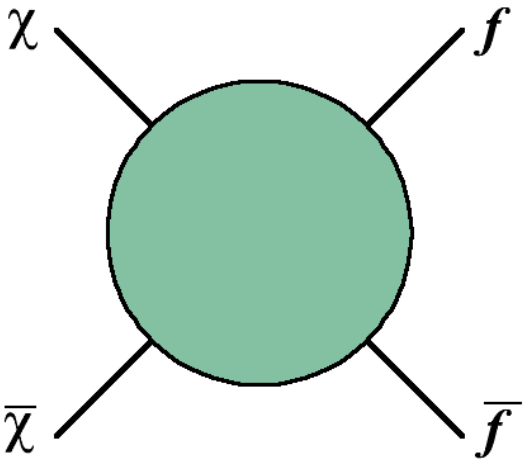
NDM 2018
6th Symposium on Neutrinos and Dark Matter in Nuclear Physics 2018
2018.6.30(Sat)

Dark Matter detection

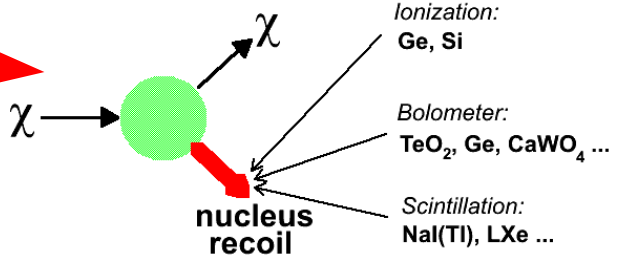
Indirect Search

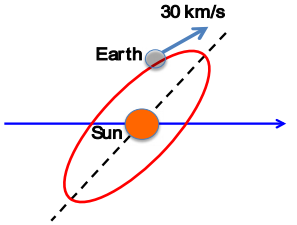
underground lab.





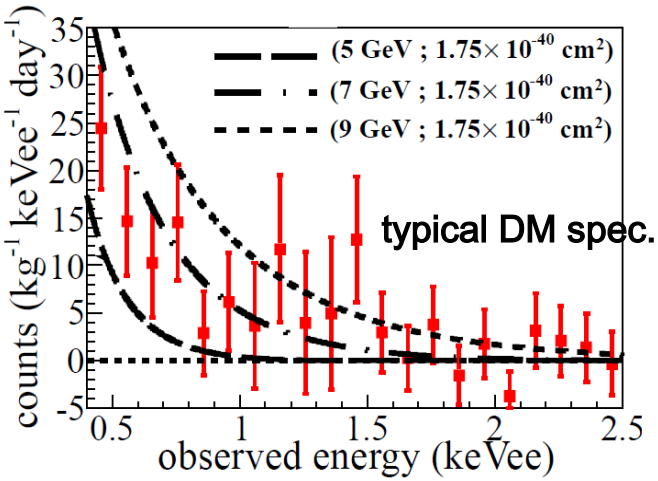
Direct Search





annual modulation

Colliders



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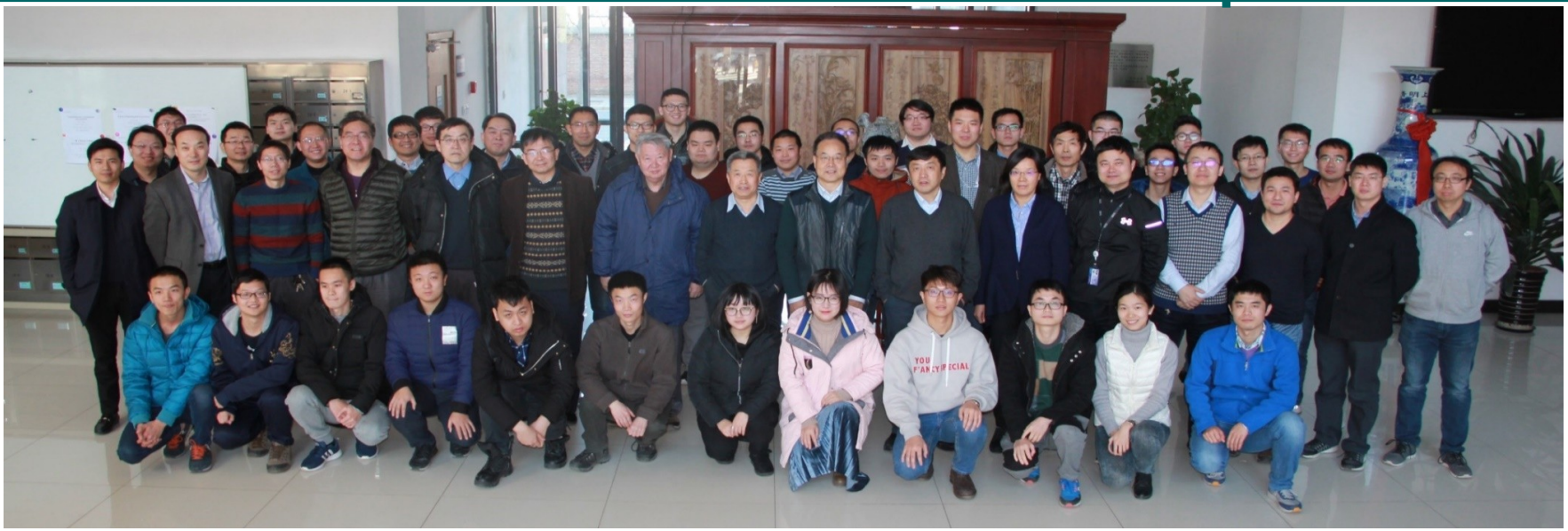
CDEX: China Dark matter EXperiment



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)

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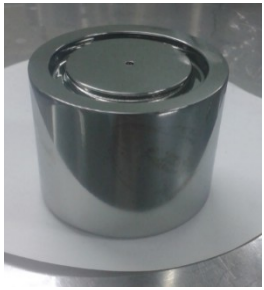
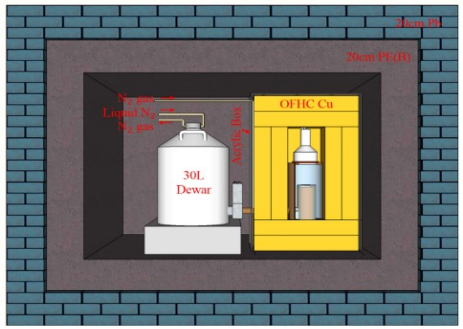
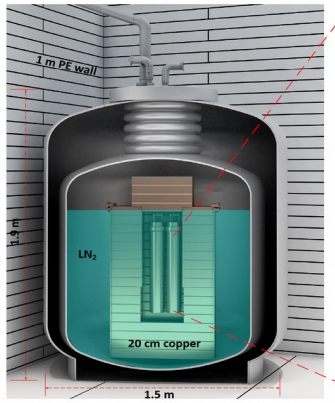
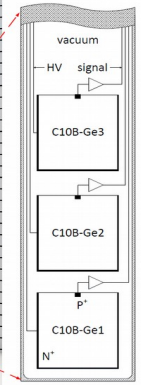
CDEX stages

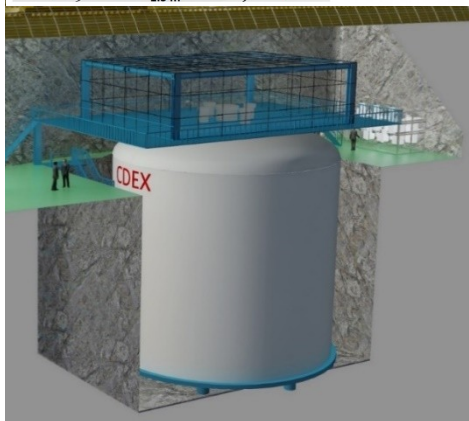


- Light WIMP mass searches on Ge
- CDEX-1: Development of pPC-HPGe detector, its background understanding, results published.
- CDEX-10: Performances of HPGe array detector system, results published.
- CDEX-10X: Fabrication of HPGe and Ge crystal growth by CDEX.
- CDEX-100: Ultra-low cosmogenic background and large LN_2 cooling and shielding system.
- CDEX-1T: Multi-purpose experiment for dark matter and double beta decay.









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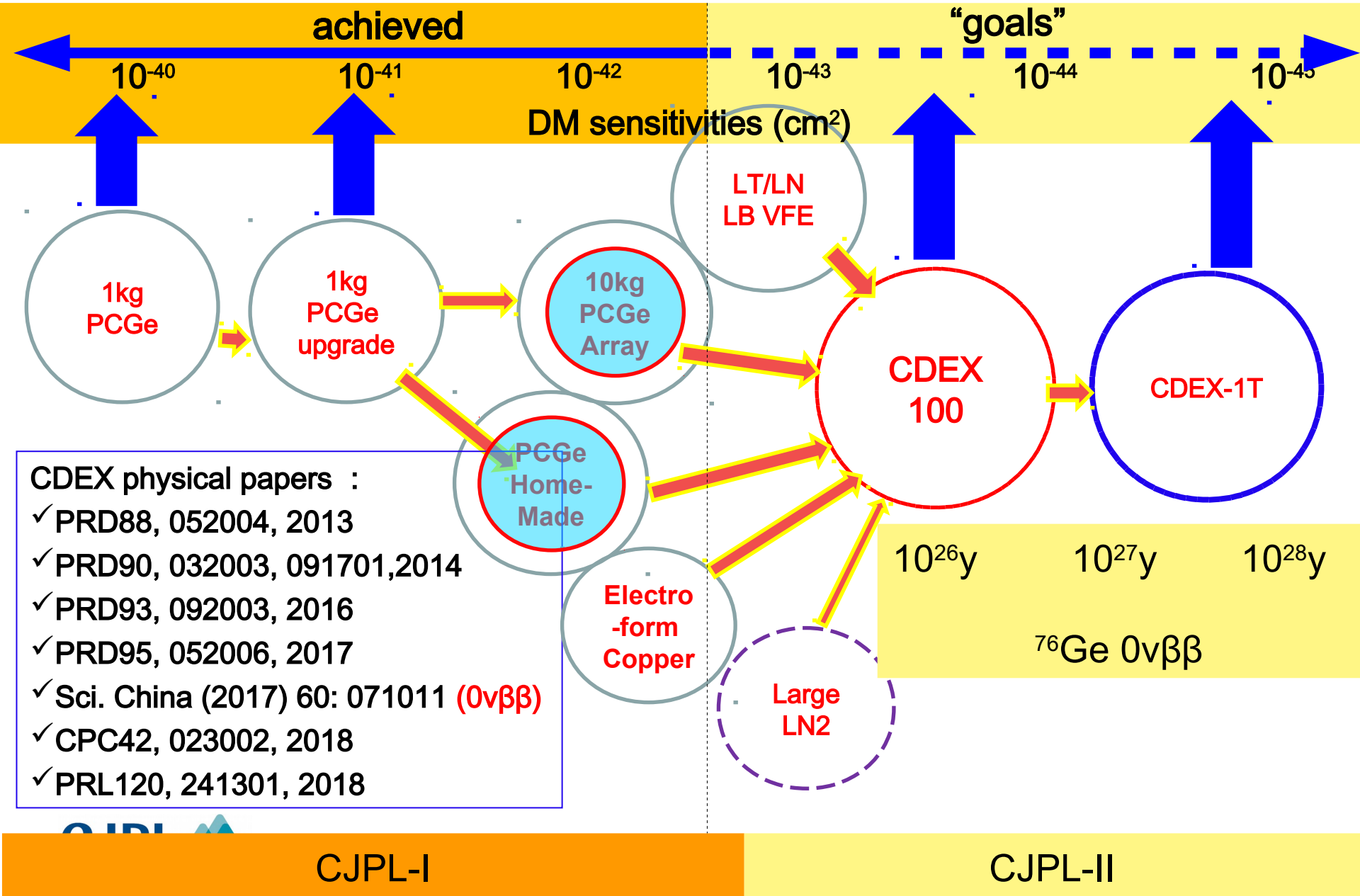
CDEX plan for DM & 0νββ



CDEX physical papers :

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

CJPL-I

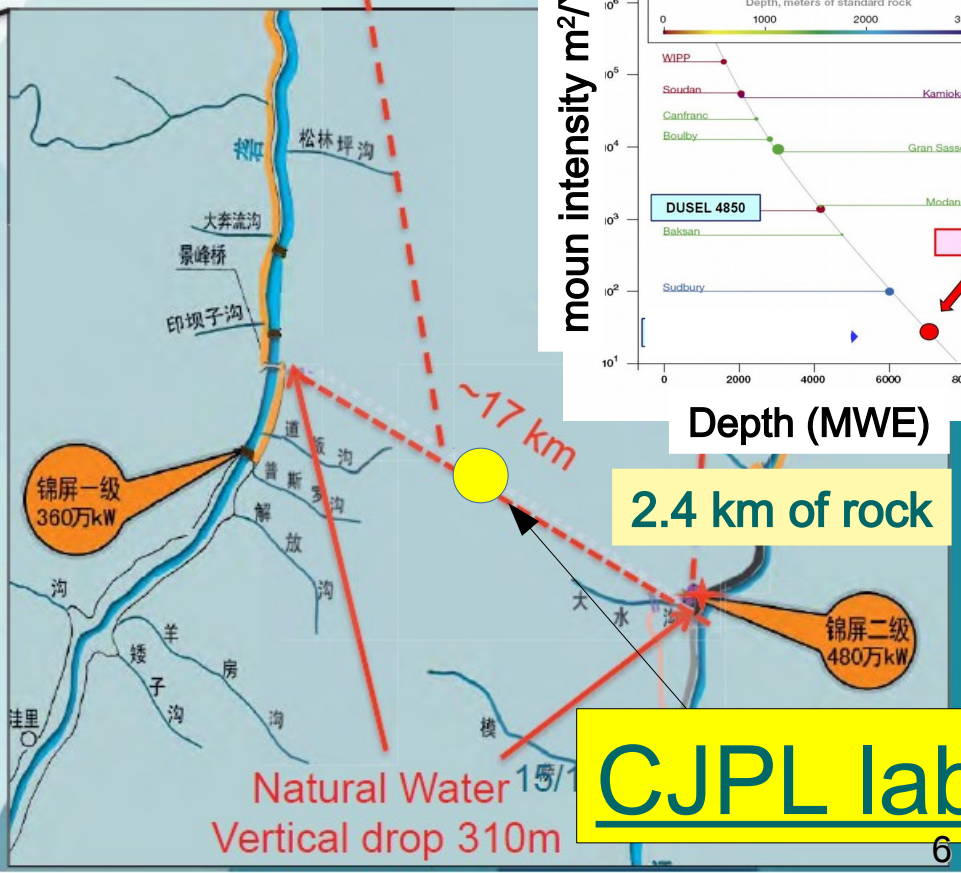
CJPL-II

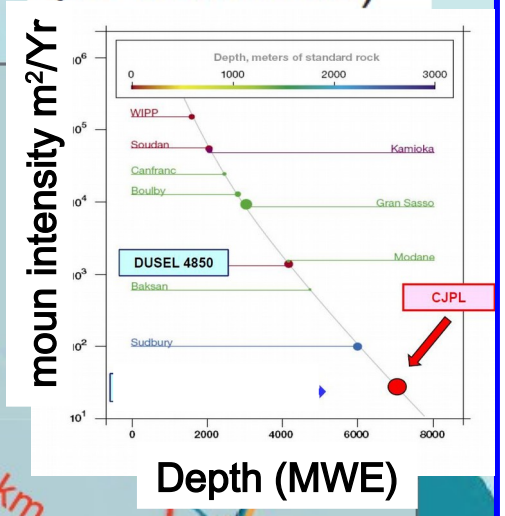
Jinping Hydroelectric Power Plants

4 hydraulic tunnels
Φ13m×16.6km

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

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





2.4 km of rock

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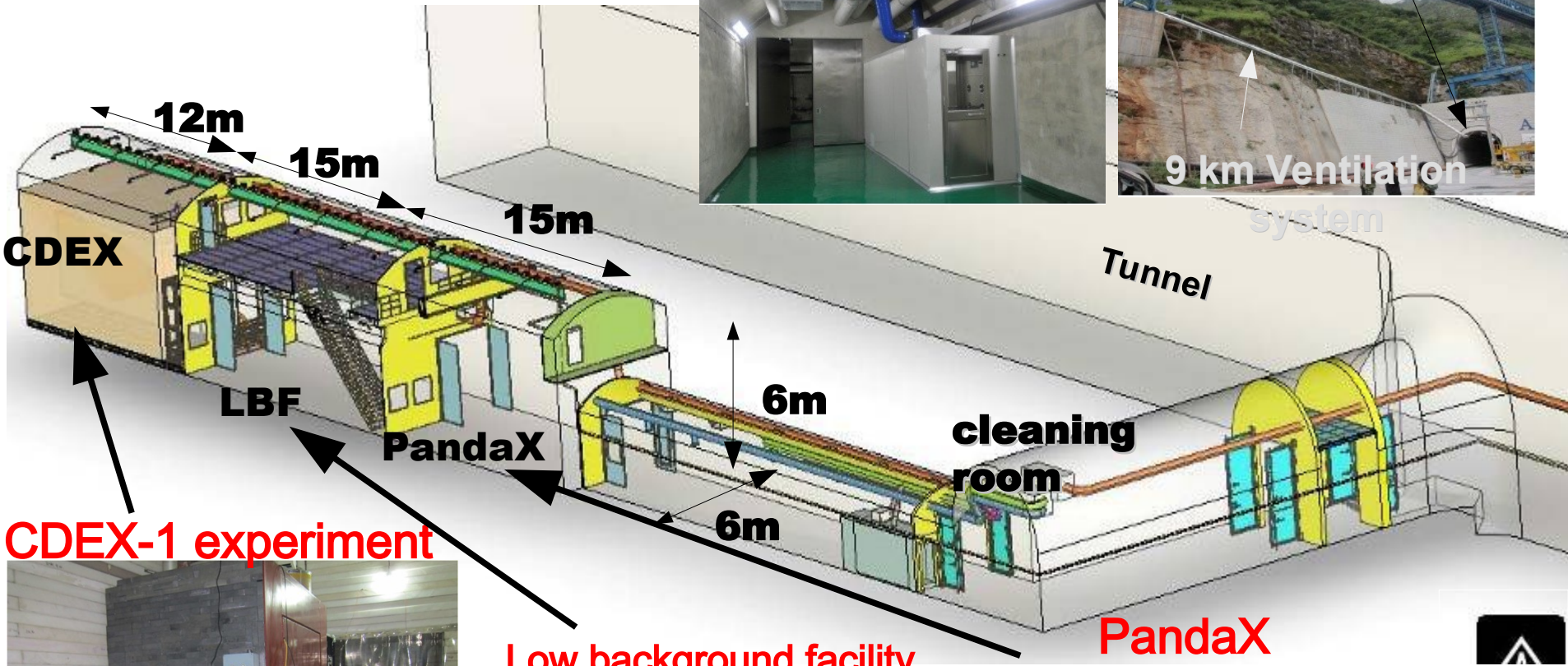
CDEX at CJPL-I

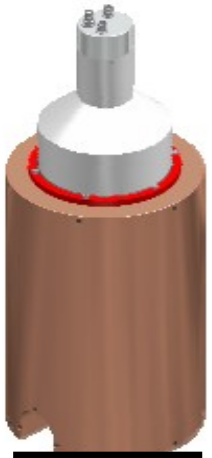


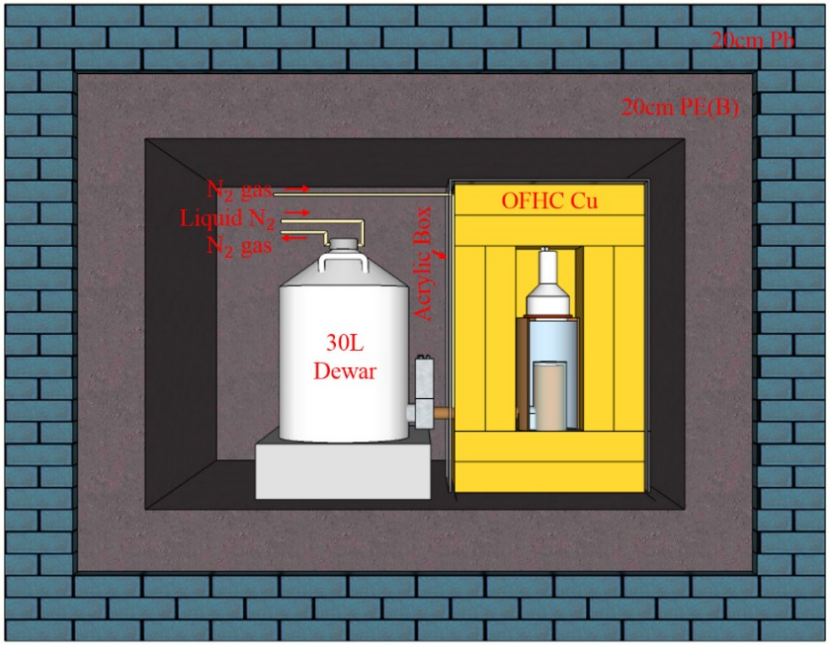
Low background facility

CDEX-1 experiment

1. HPGe technology
   - ✓ Designed the first one single module 1kg-scale p-type point-contact Ge detector (1kg-PPCGe) "prototype" CDEX-1A
   - ✓ Improved 1kg-PPCGe CDEX-1B
2. Active shielding technology: NaI(Tl) used as anti-Compton detector
   - ✓ CDEX-1A 1kg-PPCGe run
   - ✓ CDEX-1A 1kg-PPCGe + NaI(Tl) run
   - ✓ CDEX-1B 1kg-PPCGe + NaI(Tl) run

1kg-PPCGe


NaI(Tl)



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CDEX-1

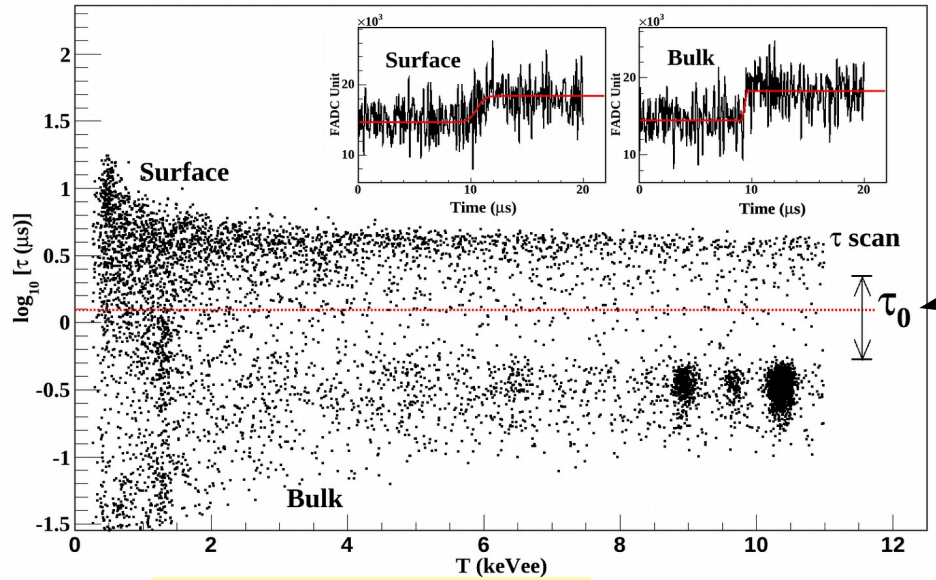
CDEX-1A 1kg PCGe

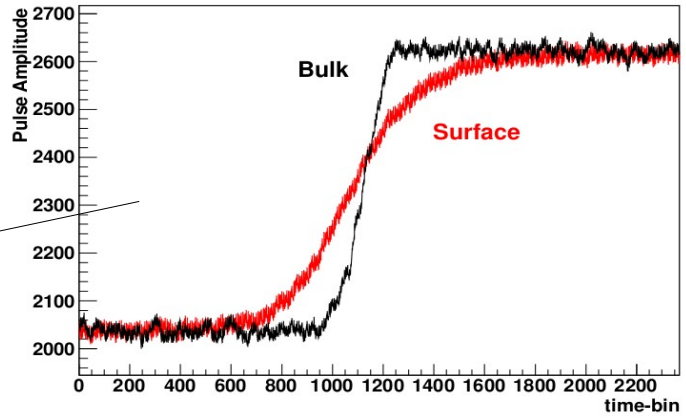
CDEX-1B 1kg PCGe

20cm OFHC Copper
+20cm Lead

pPCGe: bulk/surface

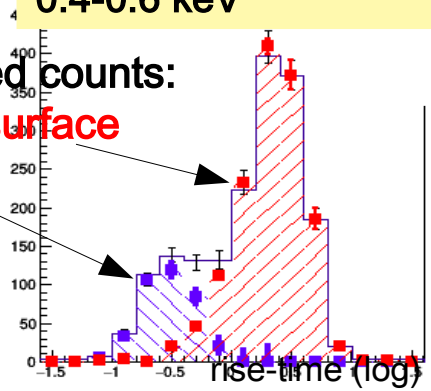
surface events : contamination, largest sources of uncertainties at low energy.





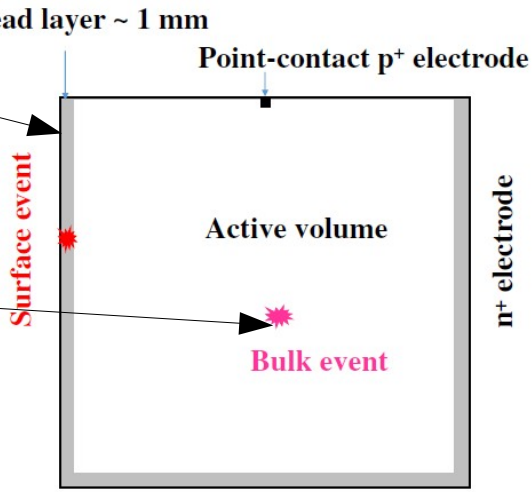
DM candidate events:
0.4-0.6 keV

constructed counts:
bulk and surface



surface
partial energy deposit
diffuse and drift → slow

bulk
full energy deposit
drift → fast



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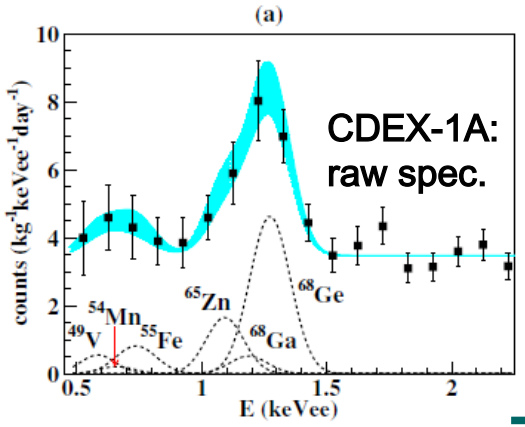
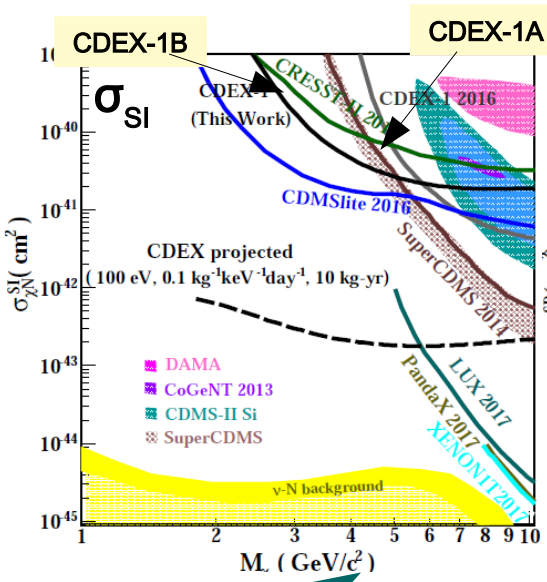
Astropart. Phys. 56, 2014, NIMA 886, 2018

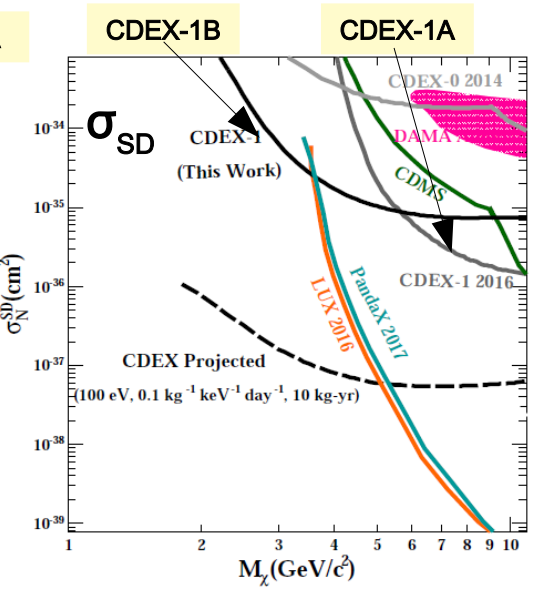
CDEX-1 results

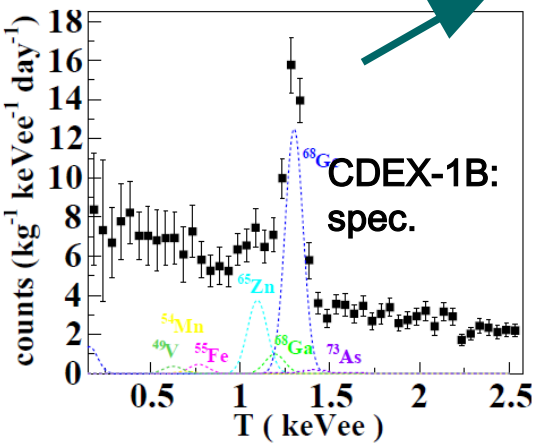
Data set: CDEX-1A: ~500 kg-day; CDEX-1B: ~1000 kg-day

- Competitive SI/SD sensitivities pPCGe PRD93, 092003, 2016 , CPC42, 023002, 2018
- Competitive galatical 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 results soon

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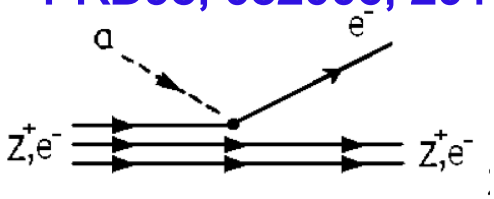
CDEX-1 axion results

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

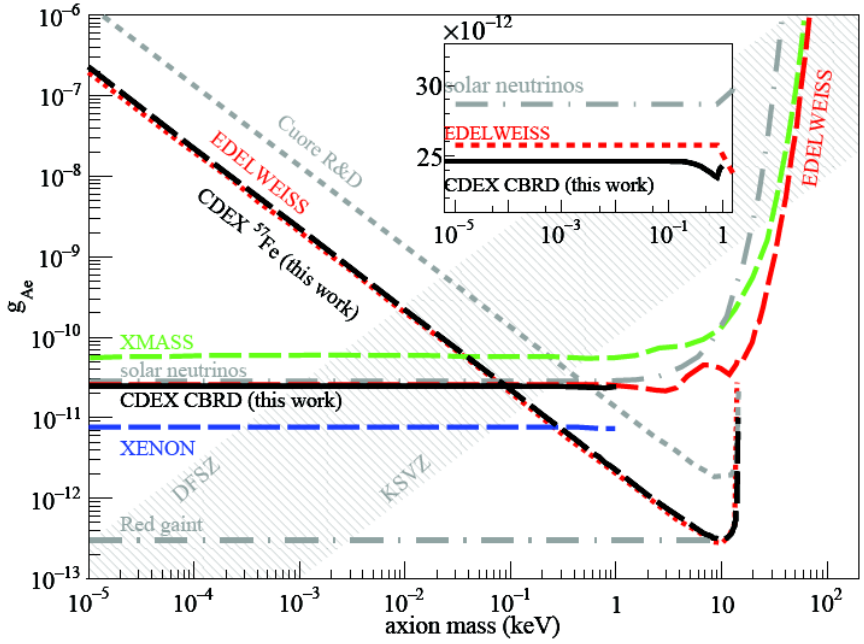
PRD95, 052006, 2017



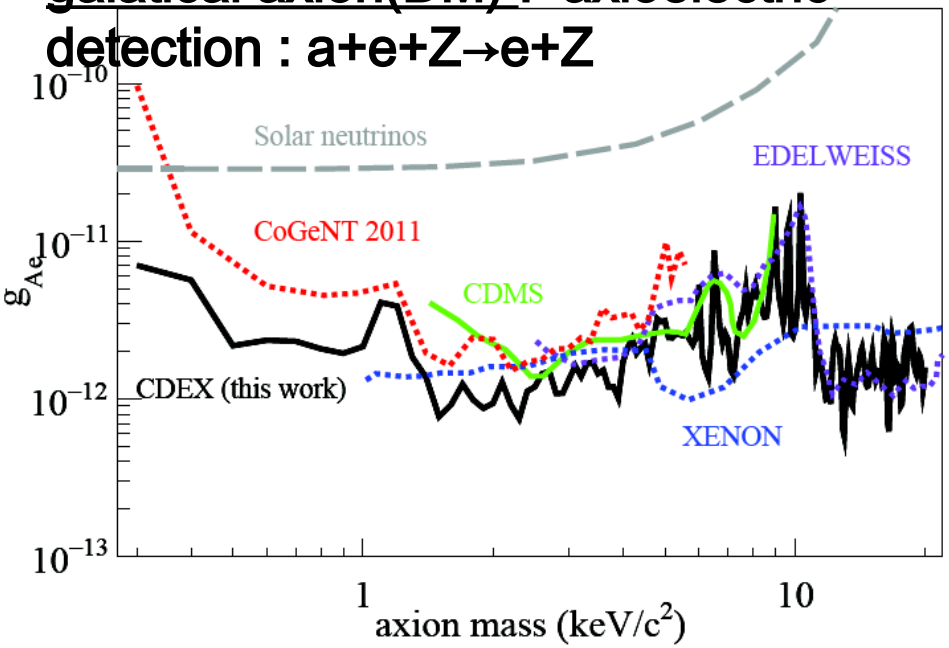
Axioelectric
or Photoelectric-like

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

Compton(C): γ+e→e+a
bremsstrahlung(B): e+Q→e+Q+a
recombination(R): e+I→I⁻+a
de-excitaion(D): I*→I+a



galatical axion(DM) : axioelectric detection : a+e+Z→e+Z



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

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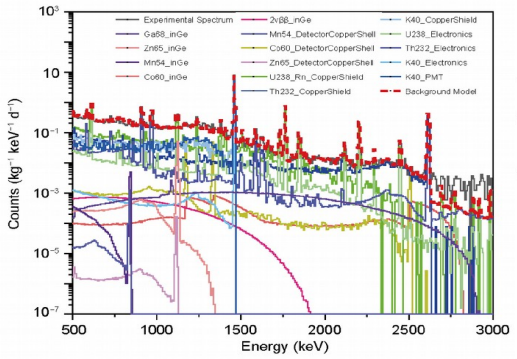
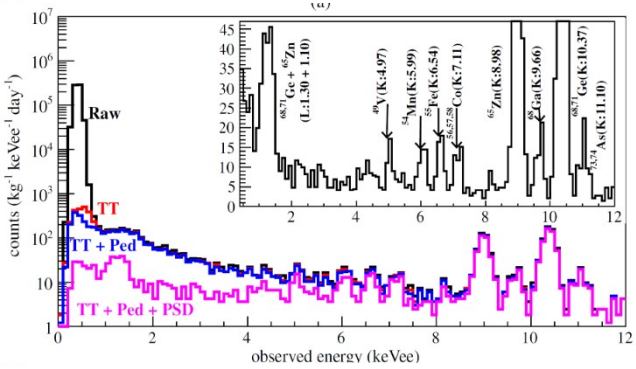
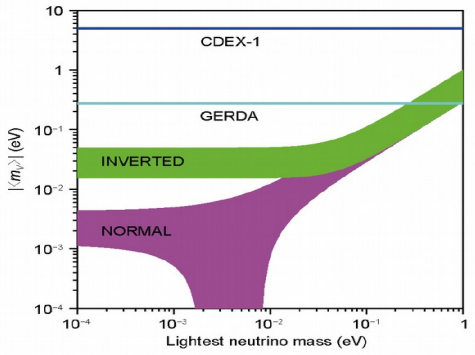
CDEX-1 0νββ result

- Published ^{76}Ge 0νββ result based on CDEX-1A (natural Ge).
- Calculation of the level of cosmogenic events @ 2 MeV based on cosmogenic characteristic X-ray peaks <10keV.
- $T_{1/2} > 6.4\times10^{22}$yrs







Sci. China (2017) 60: 071011

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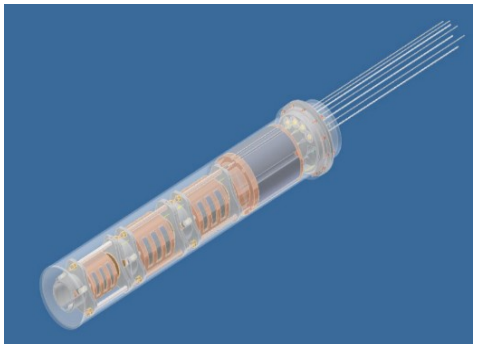
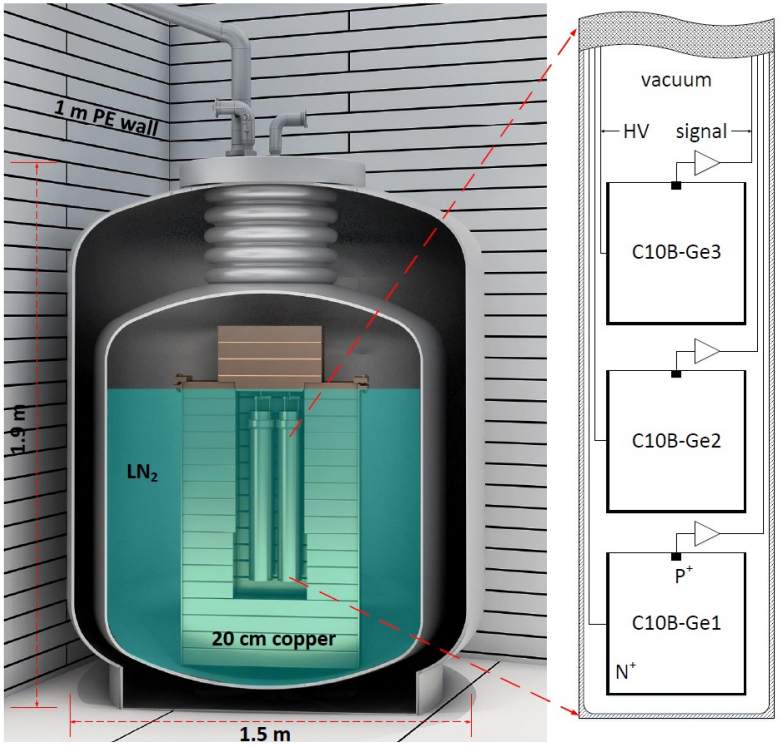
CDEX-10 experiment

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





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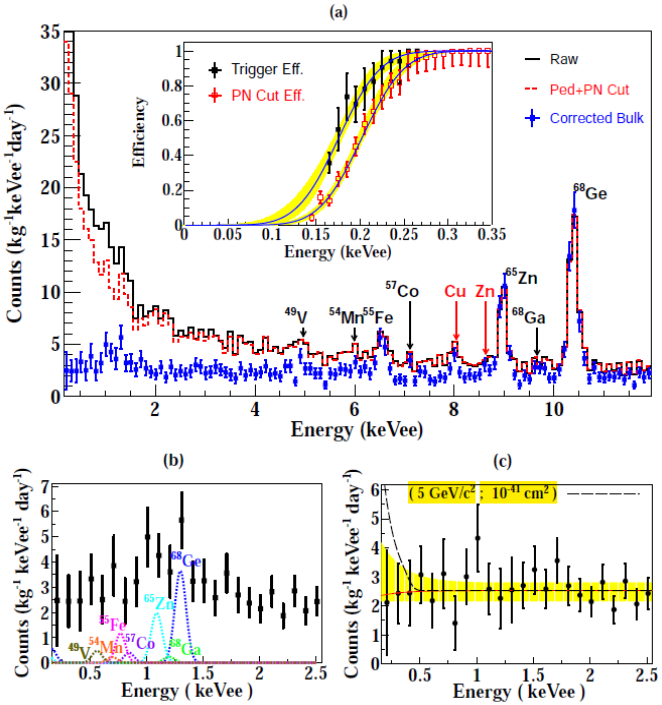
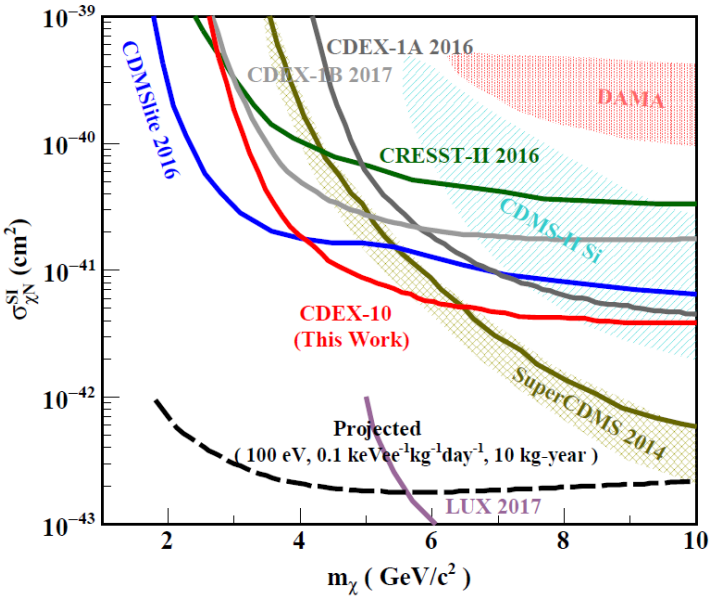
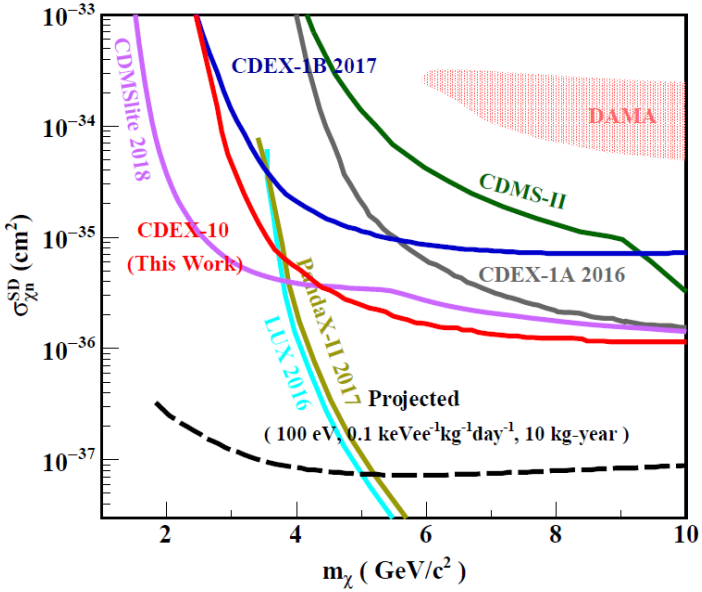
CDEX-10 results

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







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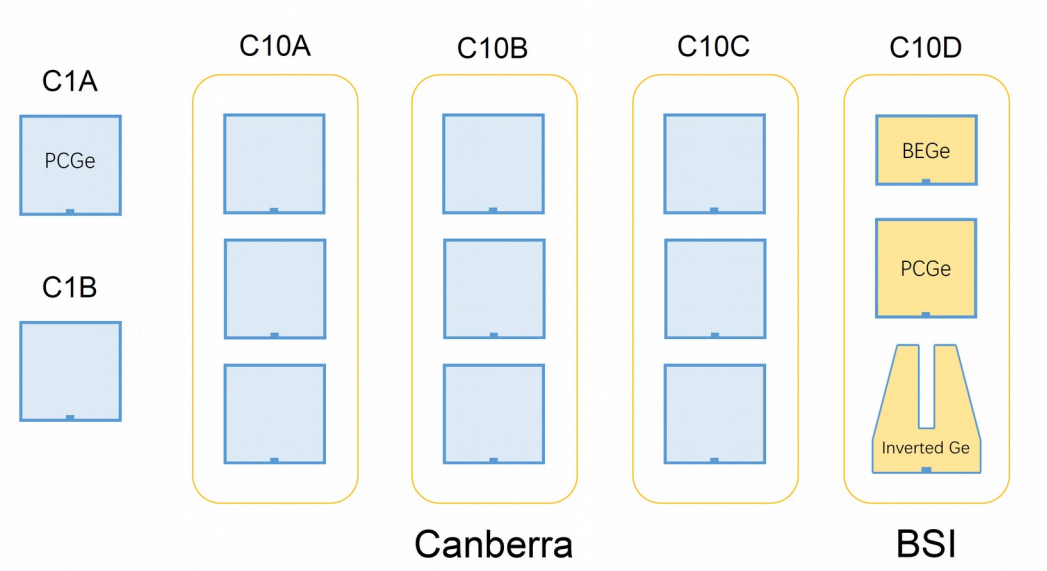
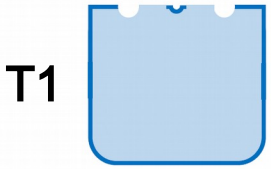
PRL120, 241301, 2018

CDEX-10 pPCGe detectors

- Collaborate with commercial companies, such as Canberra, ORTEC, BSI and so on;
- Home-made pPCGe for the lower cosmogenic backgrounds prepared at CJPL now.





- Commercial Ge crystal;
- Structure machining;
- Li-drift and B-implanted;
- Home-made ULB PreAmp;
- Underground EF-Cu;
- Underground assemble;
- Underground testing…

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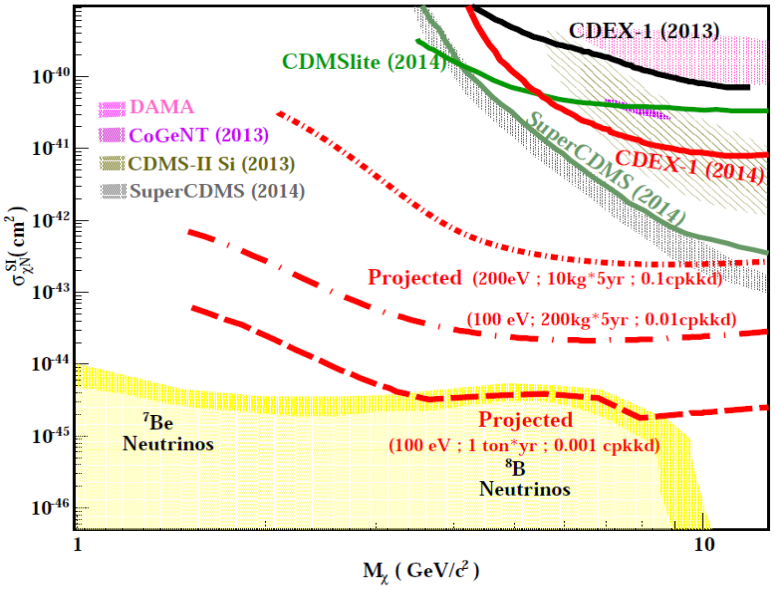
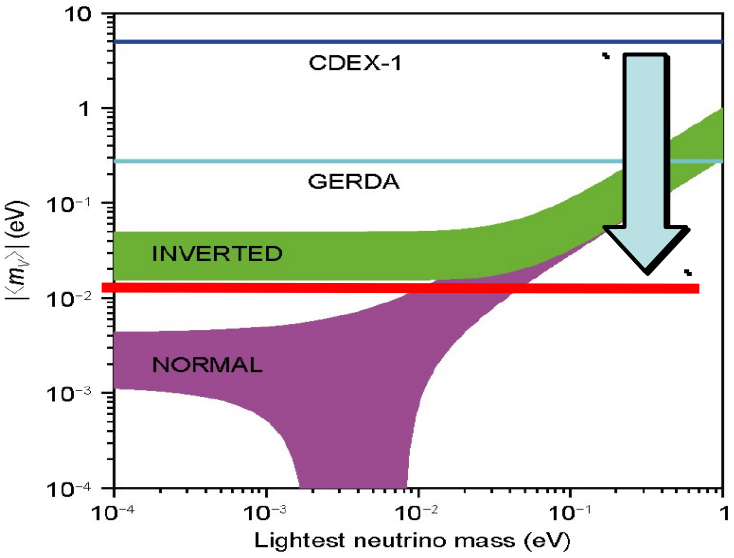
Toward CDEX-1T@CJPL-II

- 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 (CDEX groups are part of LEGEND programs)





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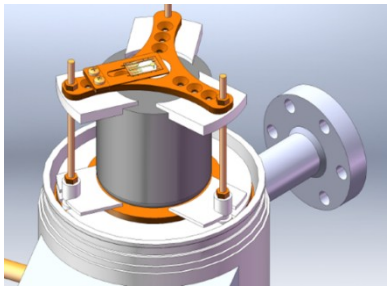
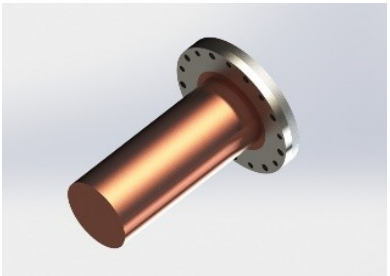
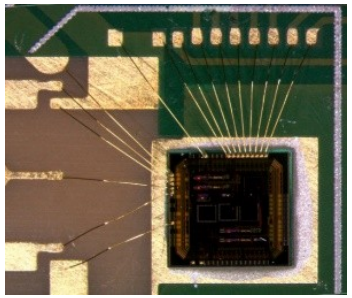
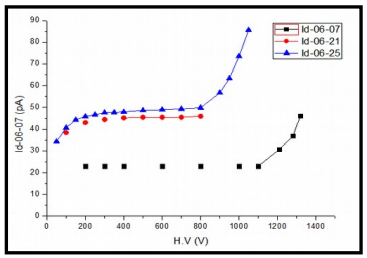
Key technologies towards CDEX-1T

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







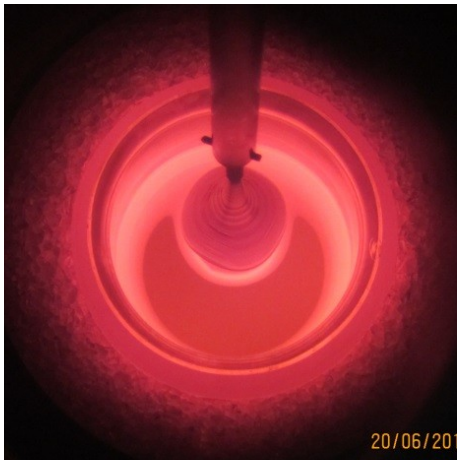


CDEX-1T Ge crystal growth

Zone refining machine

Czochralski machine

Cutting & Polishing



Crystal growth

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

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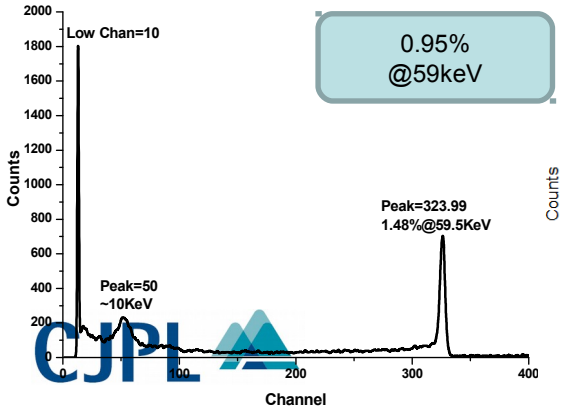
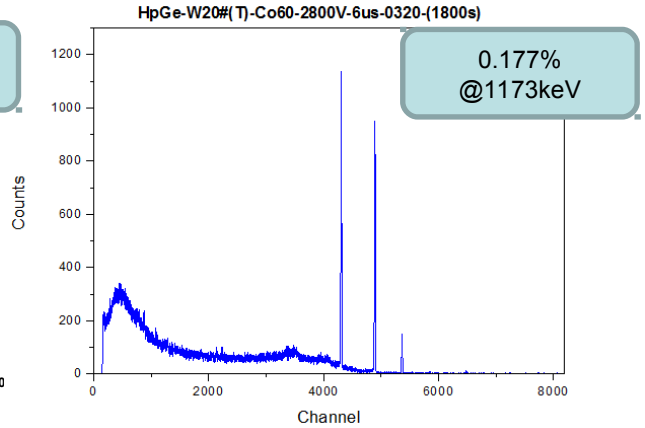
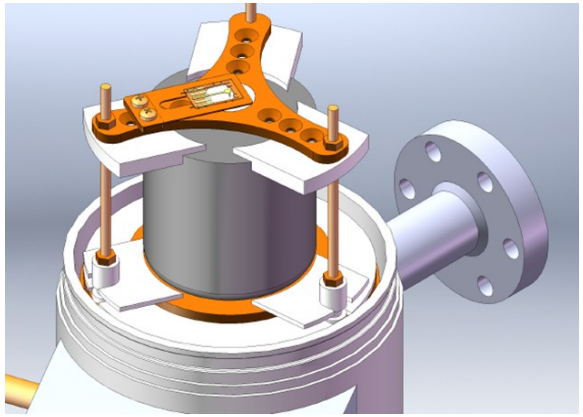
HPGe detector fabrication

- 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 μBq/kg 、 U<0.17 μBq/kg.
- Shielded by LN2, Structure materials used as little as possible in order to lower the background contribution.

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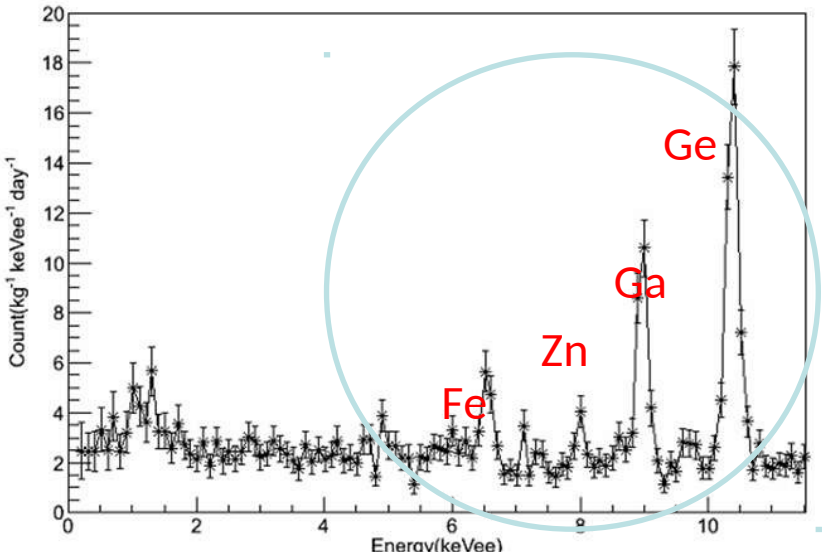
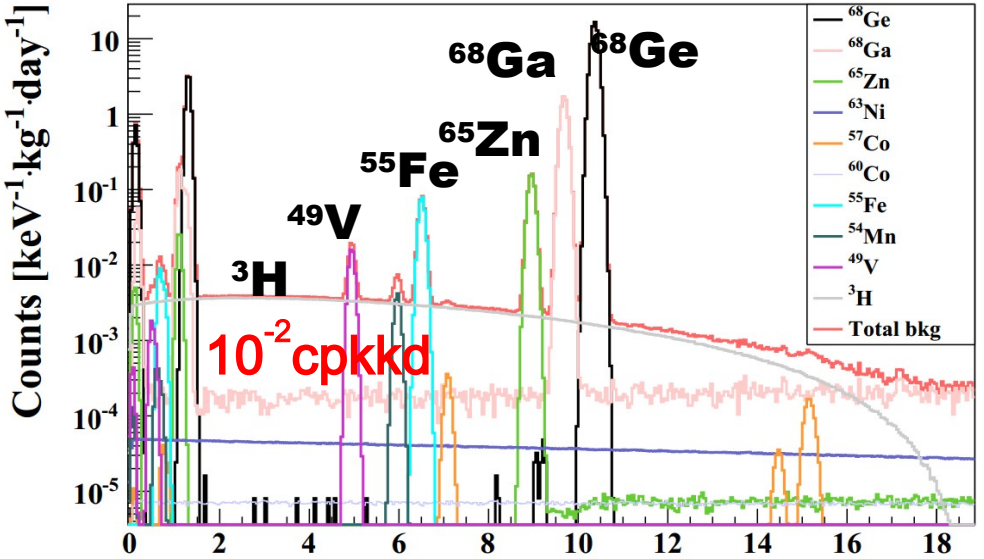
Cosmogenic Background of Ge detector

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



CDEX-10 background spectrum



Simulation spectrum

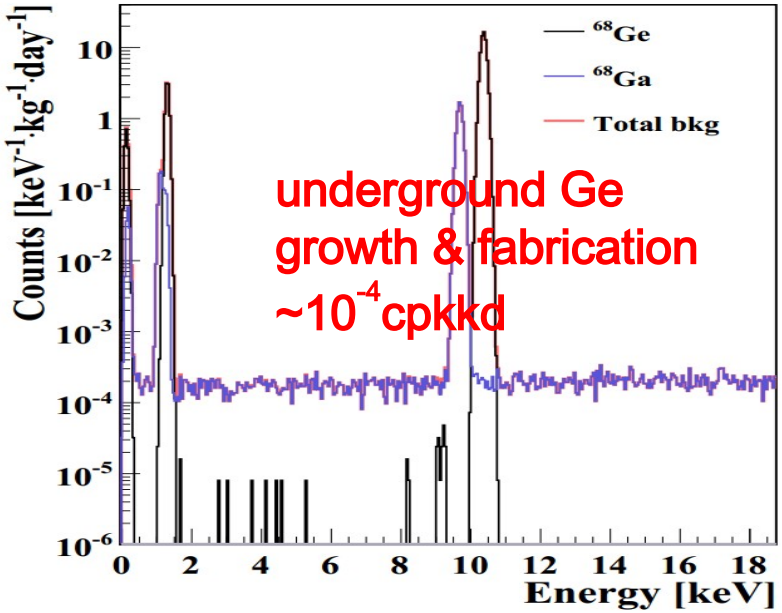
CJPL

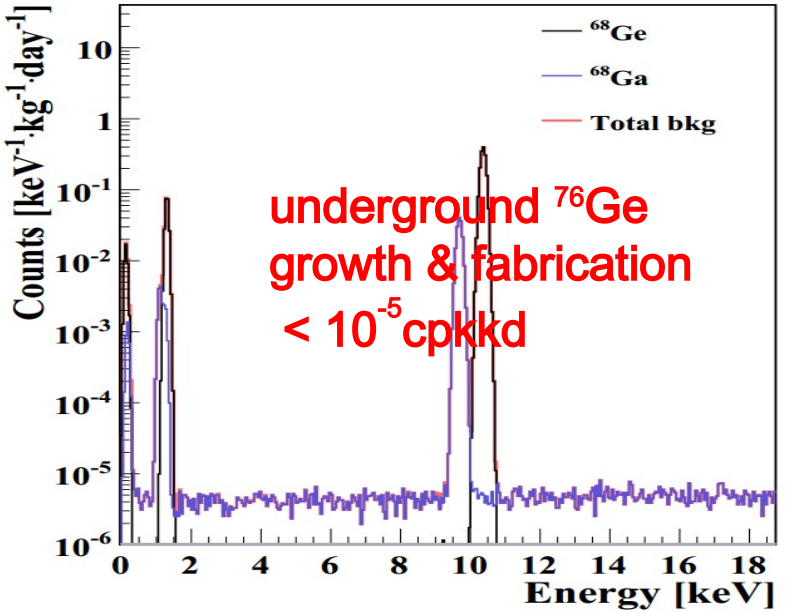
arXiv:1802.09327

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}He, ^{65}Zn;

- ^{76}Ge Enriched germanium material could help to decrease ^{68}Ge(^{68}Ga) cosmogenic backgrounds too.





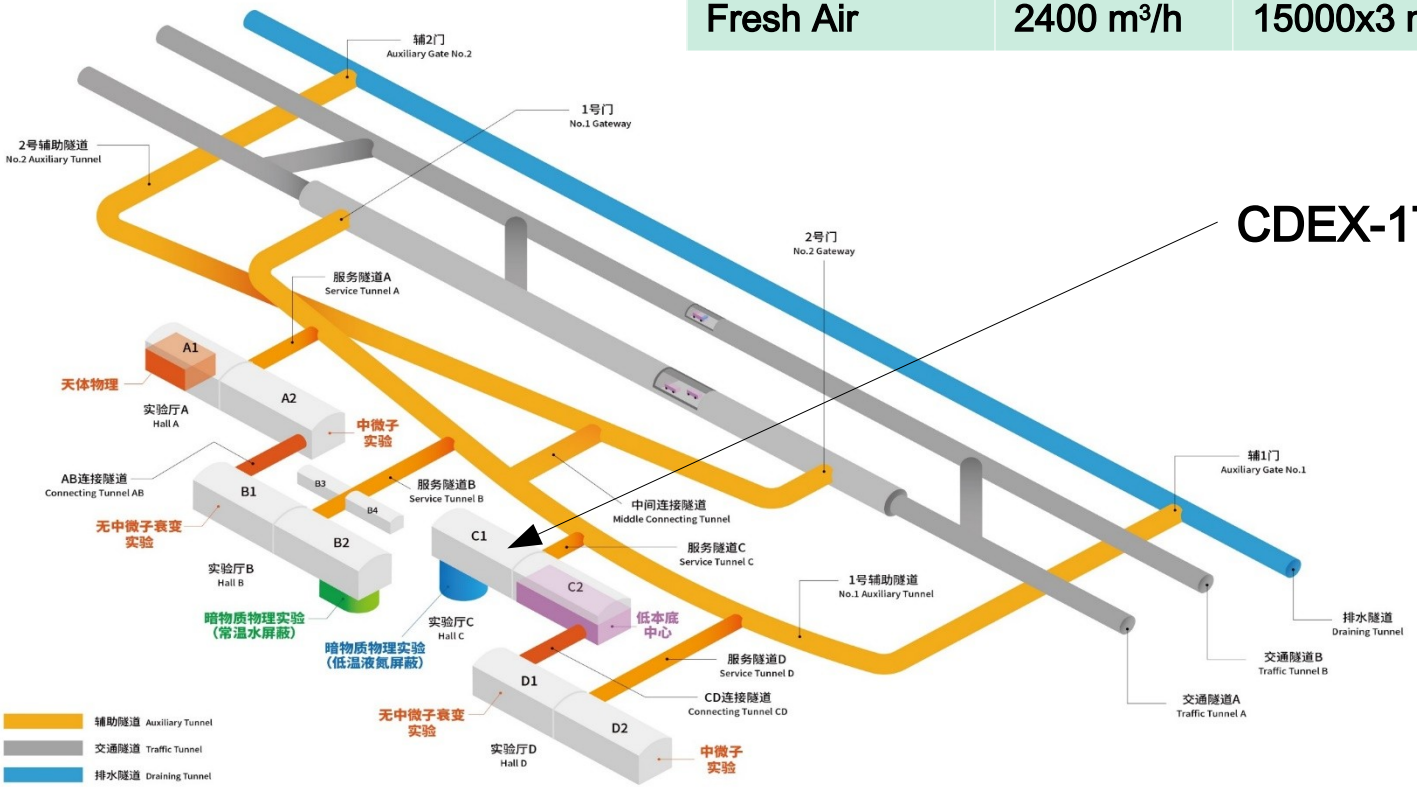
CJPL

arXiv:1802.09327

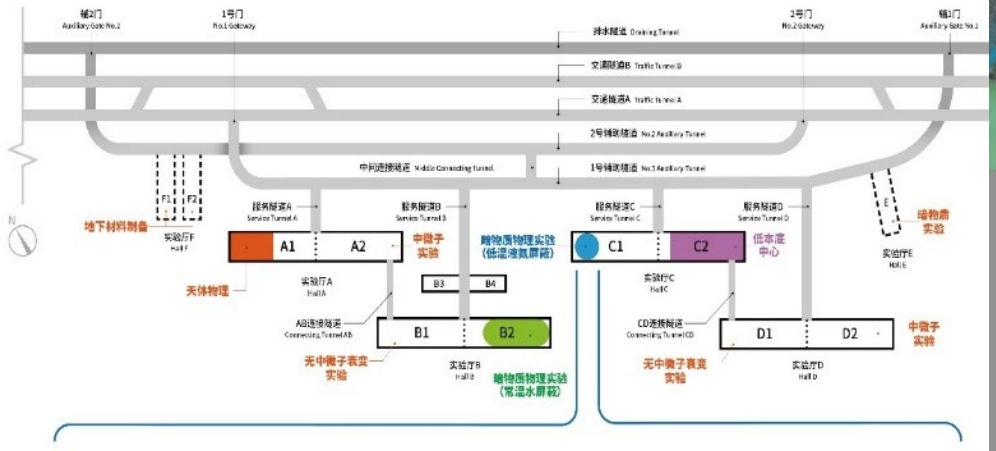
The layout of CJPL-II

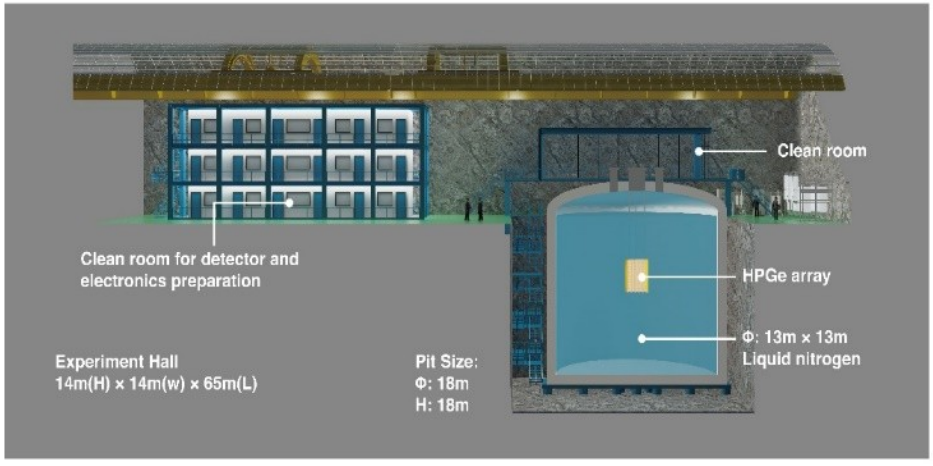
- 4 main halls ： 14m(H)×14m(W)×130m(L);
- Total Volume: 300K m³;
- Two expanded spaces:
  C1--ϕ18m×32m(H)→CDEX-1T
  B2--27m(L)×14m(W)×30m(H)

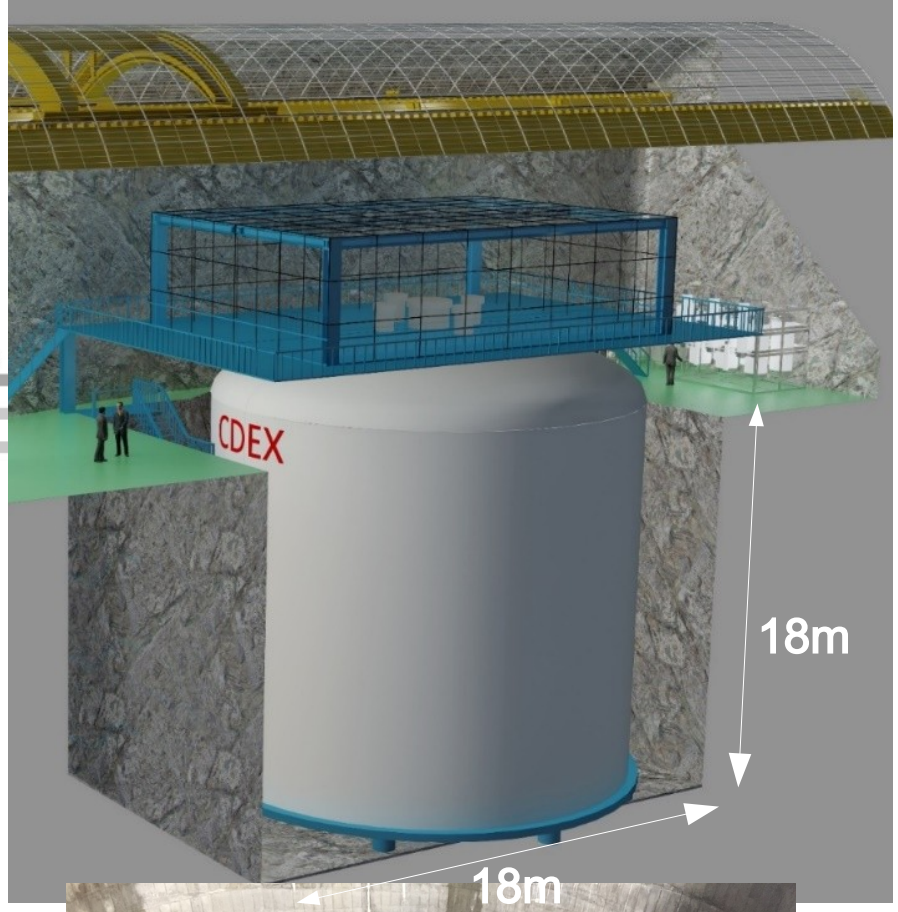
	CJPL-I	CJPL-II
Rock Work	4100 m³	210000+151000m³
Electric Power	70x2 kVA	10x2 MVA
Fresh Air	2400 m³/h	15000x3 m³/h

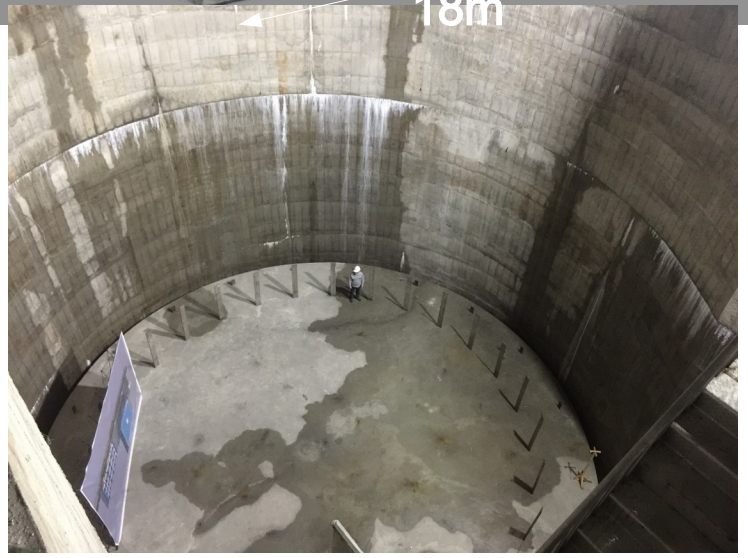


CDEX-1T@CJPL-II









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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).

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