Status and prospects of the China Dark Matter Experiment

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Outline：

- Introduction to dark matter experiments
- CDEX Introduction
- CDEX-1 and CDEX-10
- CDEX nex-stage plan
- Summary

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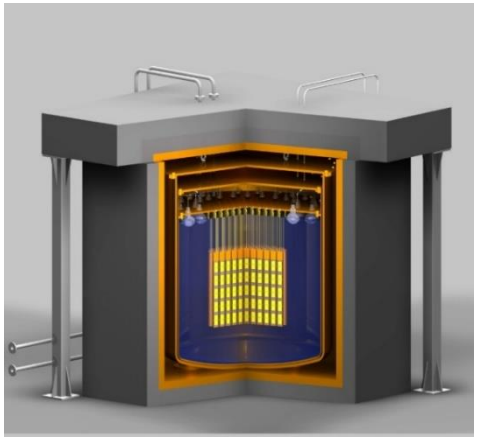
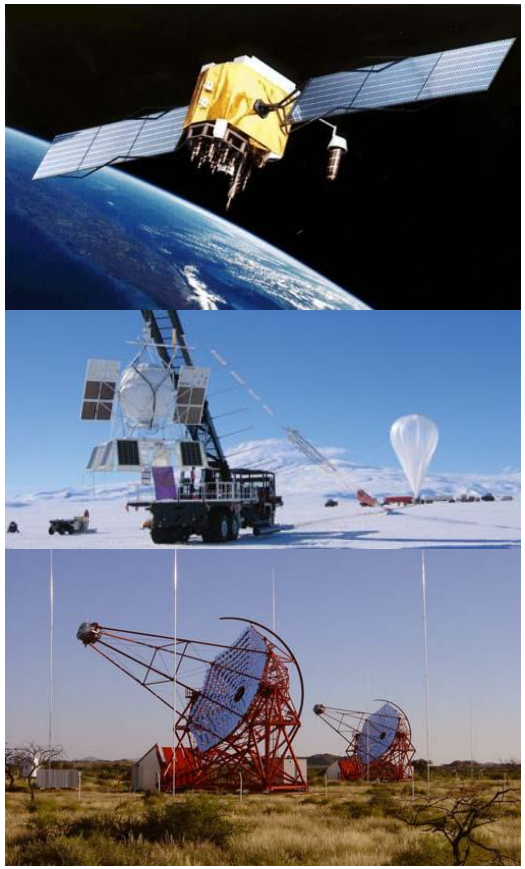
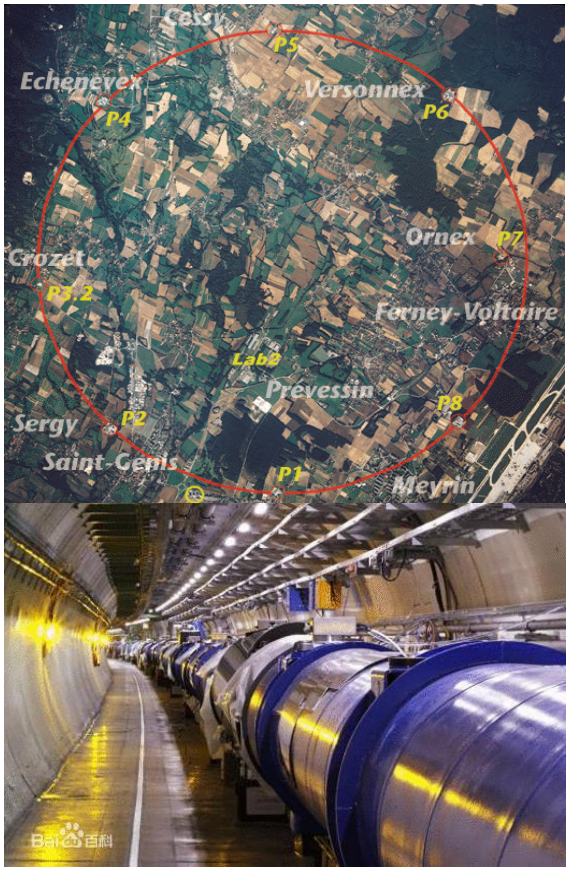
Dark matter detection methods

- Direct Detection (Underground)
- Indirect Detection (Space)
- Accelerator (Man-made)

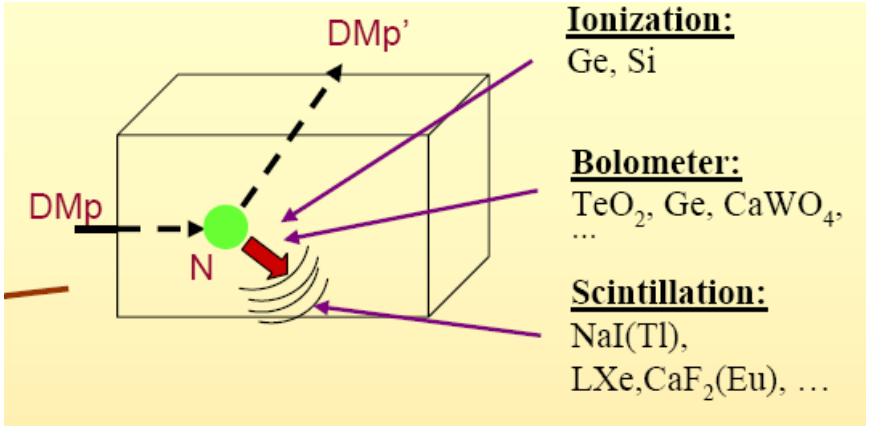


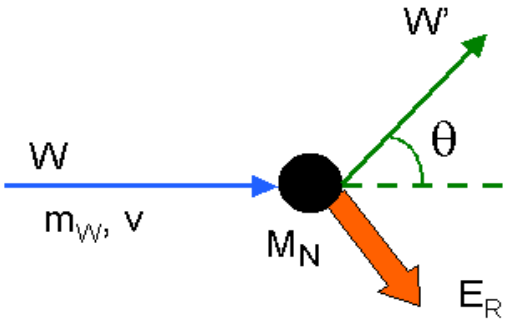


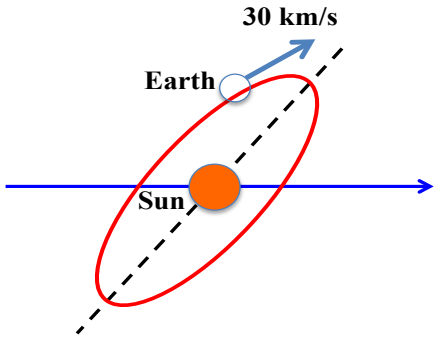


No dark matter particles detected till now!

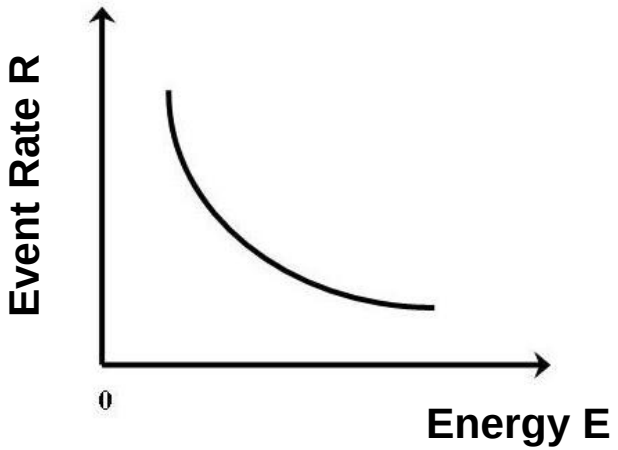
Direct Detection Principle and Characteristics







- Event rate quite small, and the deposited energy quite small;
- Event rate exponentially decreases with recoiled energy；
- <1cpkkd @1keV for 10GeV DM.



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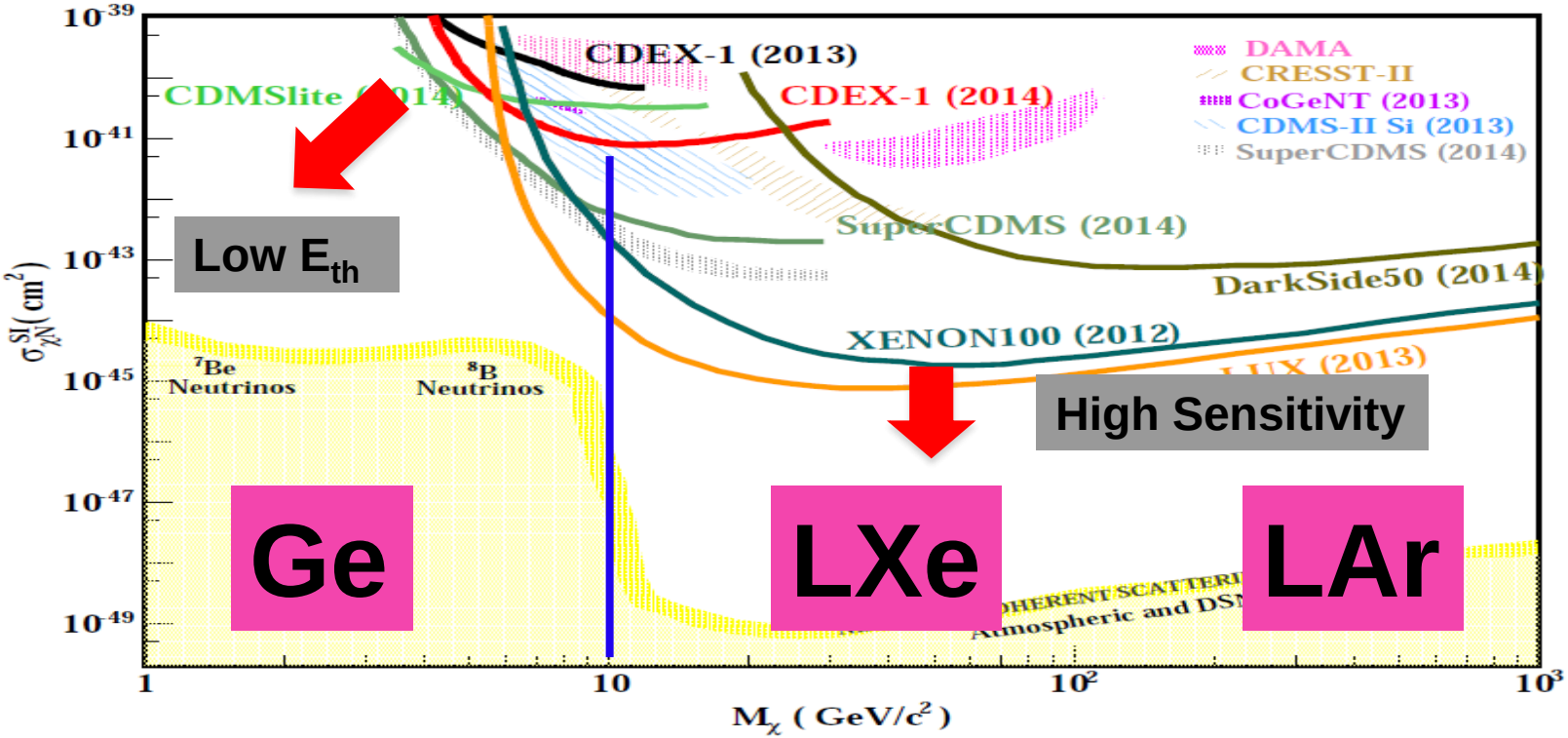
The trends for dark matter direct detection

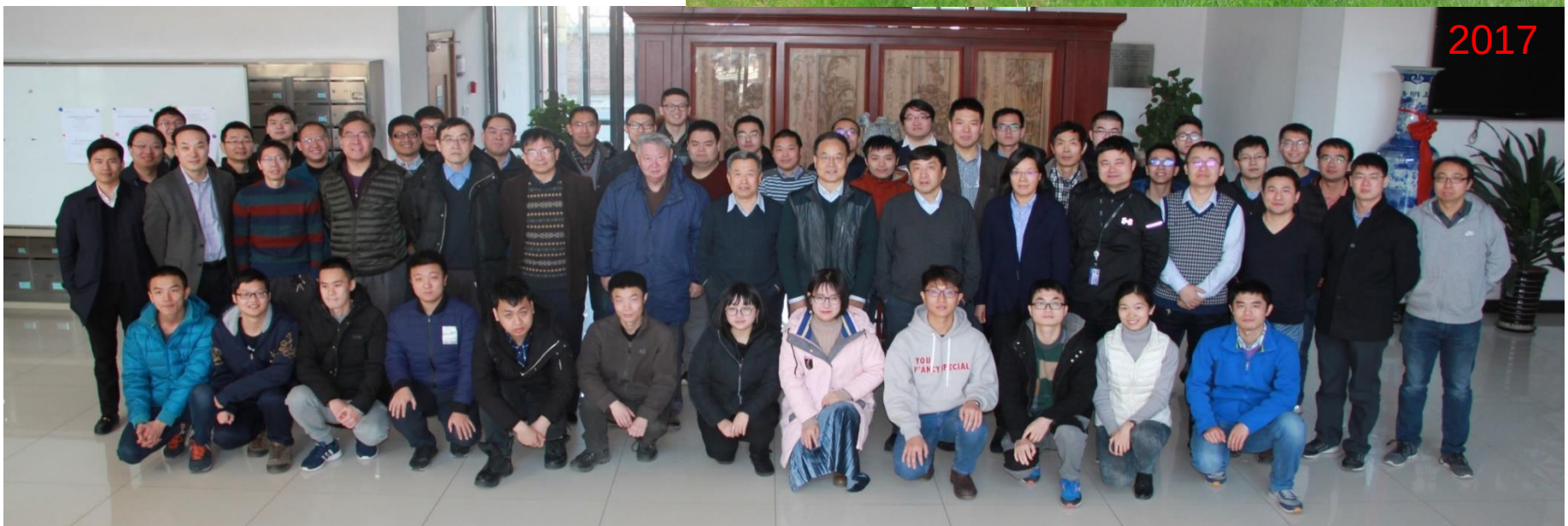
- The sensitivities several order improved in last years ;
- Lower background level and larger target mass needed for high mass DM search experiment;
- Lower energy threshold, low background level and larger mass target needed for light DM particle search.



CDEX: China Dark matter EXperiment

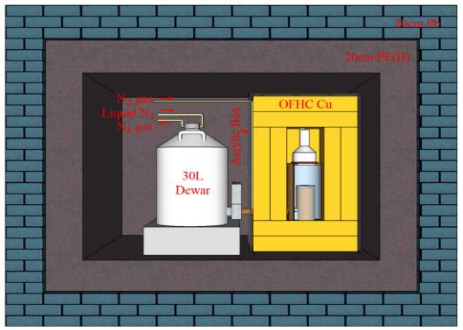
Established in 2009.

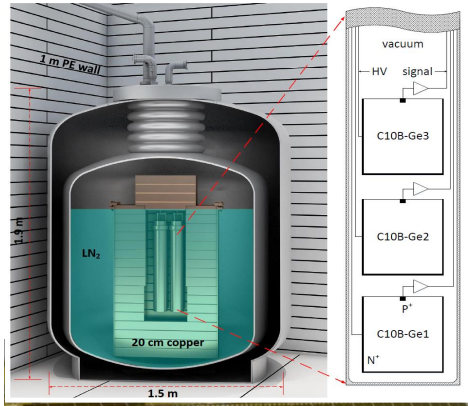
- Tsinghua University (THU)
- Sichuan University (SCU)
- Nankai University (NKU)
- China Institute of Atomic Energy (CIAE)
- Beijing Normal University (BNU)
- Yalong River Company

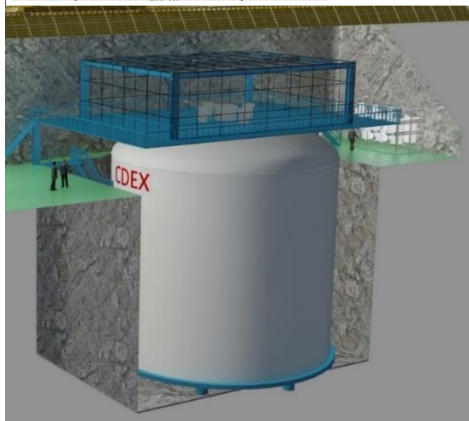


CDEX stages

- CDEX-1: Development of pPC-HPGe detector, its background understanding;
- CDEX-10: Performances of HPGe array detector system;
- 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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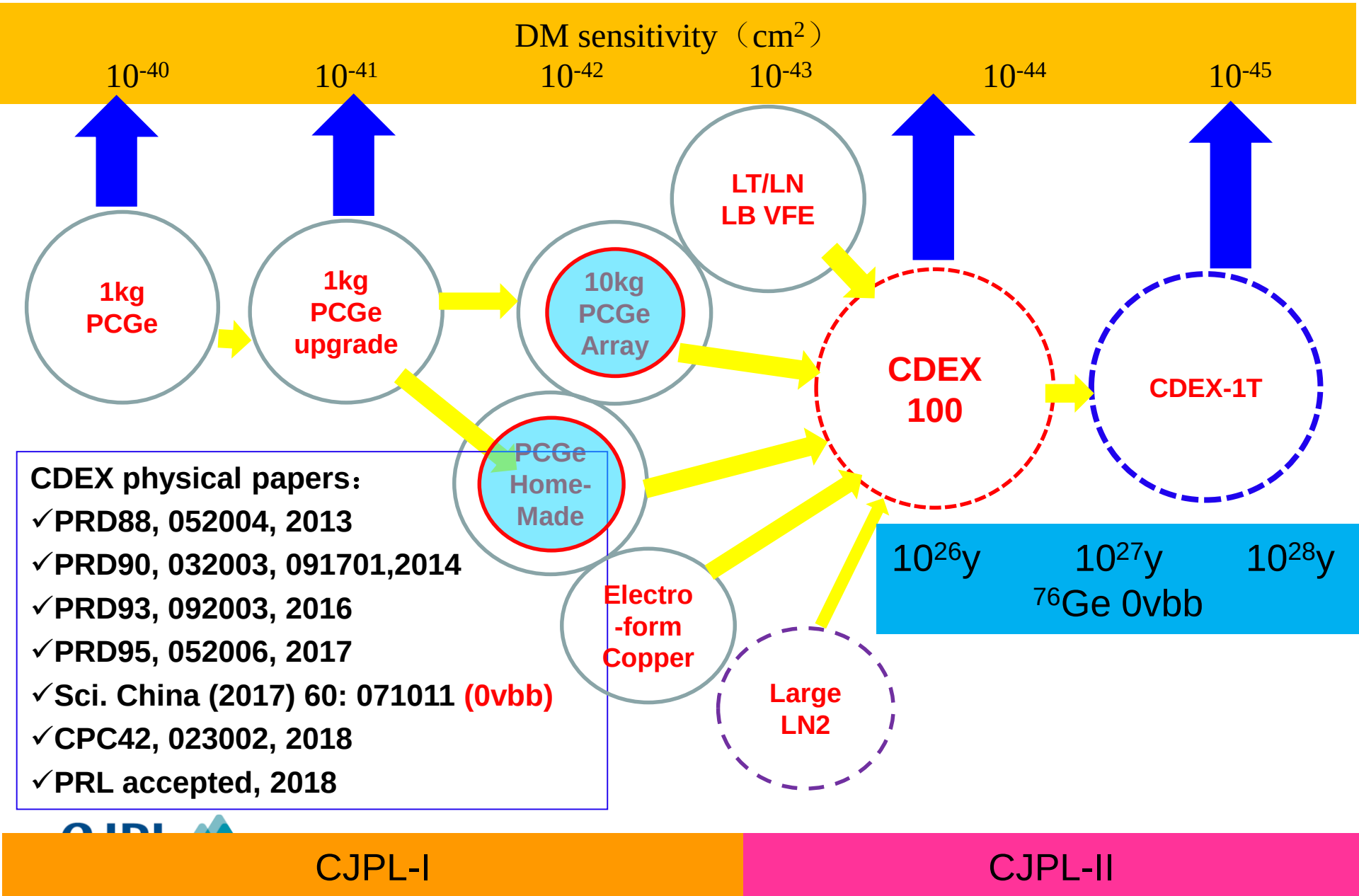
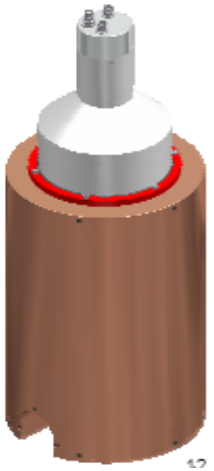
CDEX plan for DM



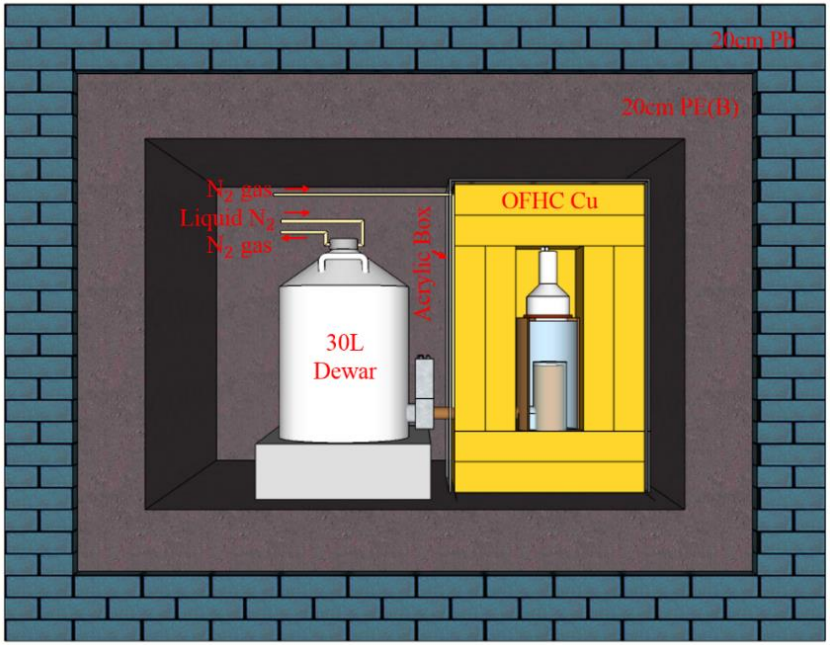
CDEX-1 experiment

1. HPGe technology
   - ✓ Designed the first one single module 1kg-scale p-type point-contact Ge detector (1kg-PPCGe) "prototype" C1A
   - ✓ Improved the second 1kg-PPCGe C1B
2. Active shielding technology: NaI(Tl) used as anti-Compton detector
   - ✓ C1A 1kg-PPCGe run
   - ✓ C1 20g Ge + NaI(Tl) run
   - ✓ C1A 1kg-PPCGe + NaI(Tl) run

1kg-PPCGe



NaI(Tl)



CDEX-1

CDEX-1A 1kg PCGe

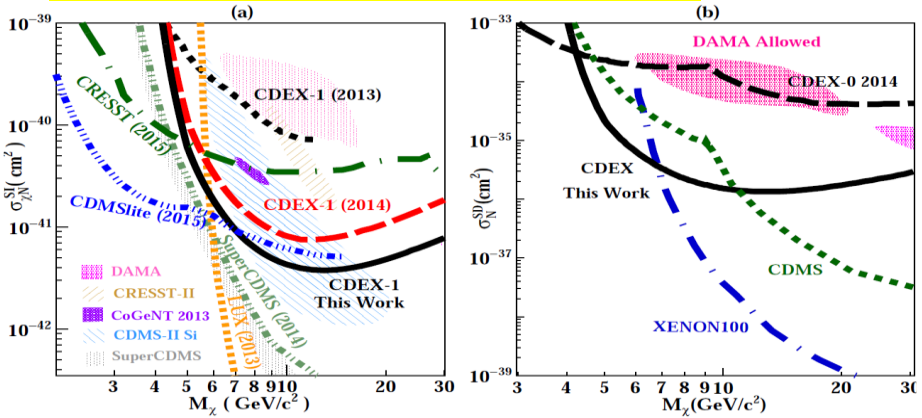
CDEX-1B 1kg PCGe

20cm OFHC Copper
+20cm Lead

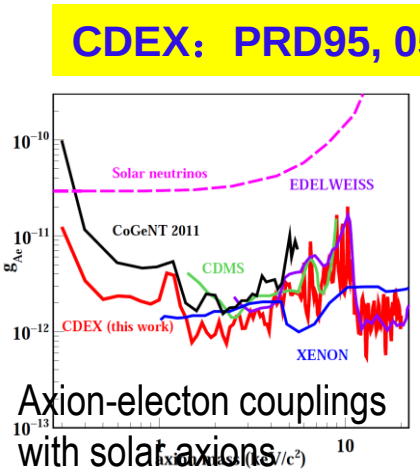
CDEX-1A&B physical results

- Data set: >500 kg·day by **C1A** and >1000 kg·day by **C1B**:
  - Best SI/SD sensitivities achieved with pPCGe;
  - Best Axion sensitivity achieved below 1 keV;
  - E_{th} improved from 475 eV → 160 eV;
  - AM result under preparation.

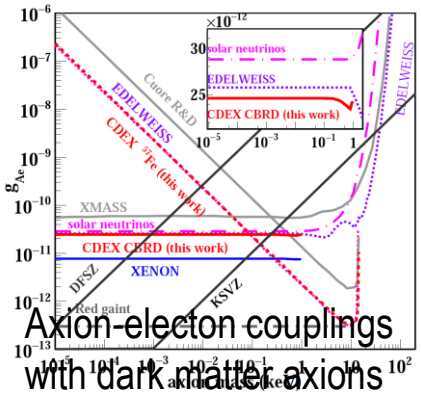
CDEX：PRD93, 092003, 2016



CDEX：PRD95, 052006, 2017



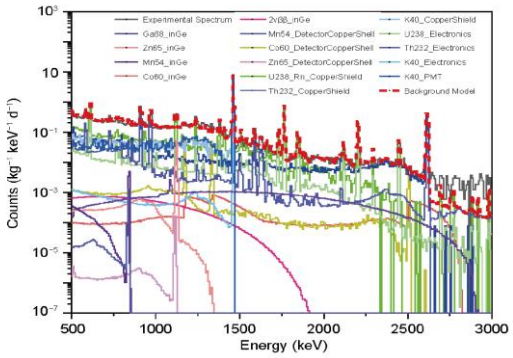
Axion-electon couplings with solar axions

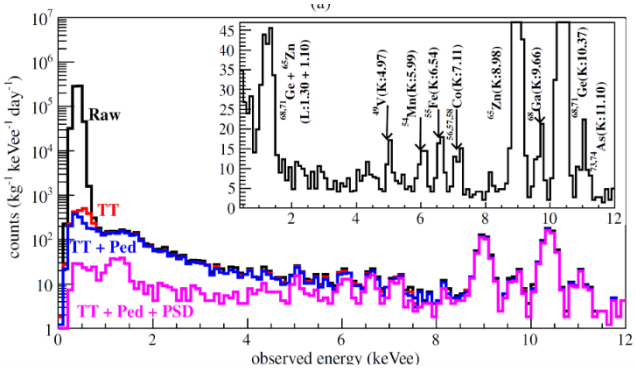


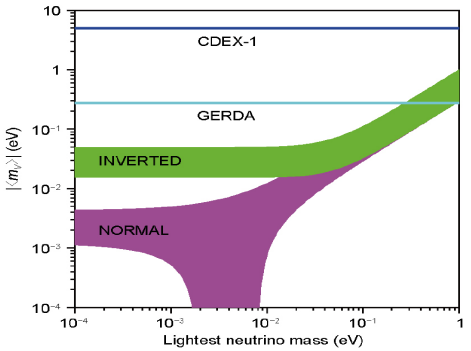
Axion-electon couplings with dark matter axions

CDEX-1 0vbb result

- Published ^{76}Ge 0vbb result based on CDEX-1 PCGe data;
- Calculation of the level of cosmogenic events @ 2MeV based on cosmogenic characteristic X-ray peaks <10keV;







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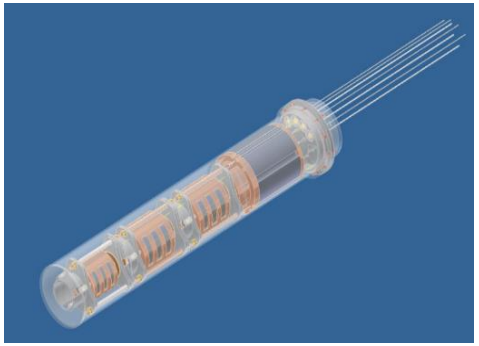
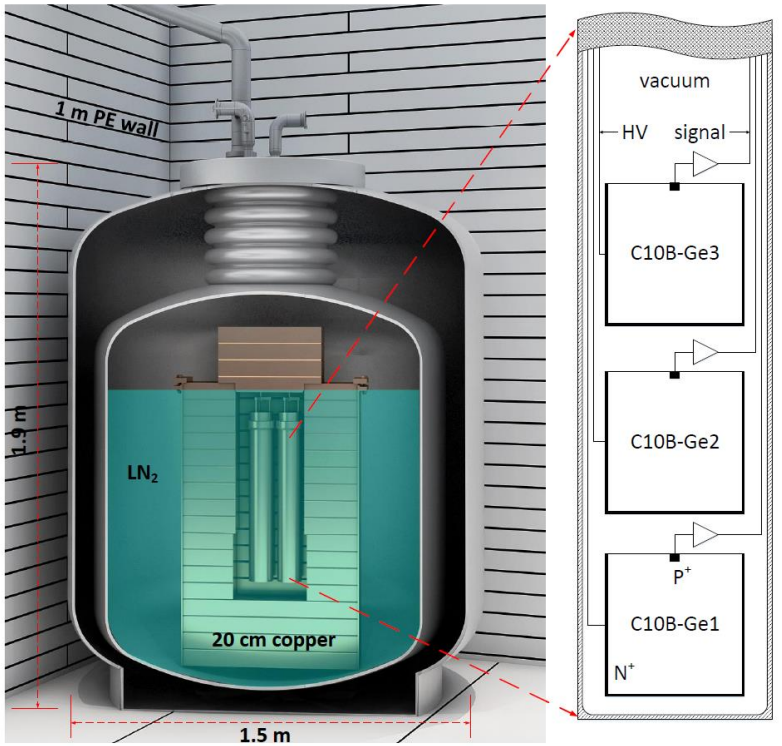
CDEX-10 experiment

- The important stage towards large-scale Ge experiment;
- Directly immersed into liquid nitrogen for cooling;
- Dataset: 102.8kg·d.





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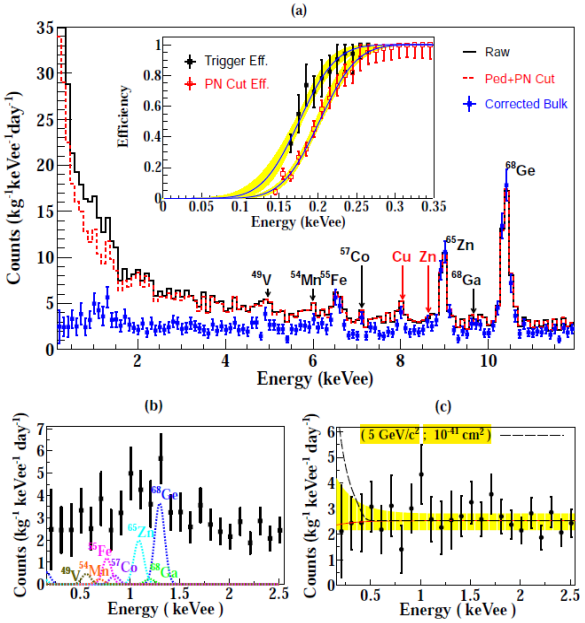
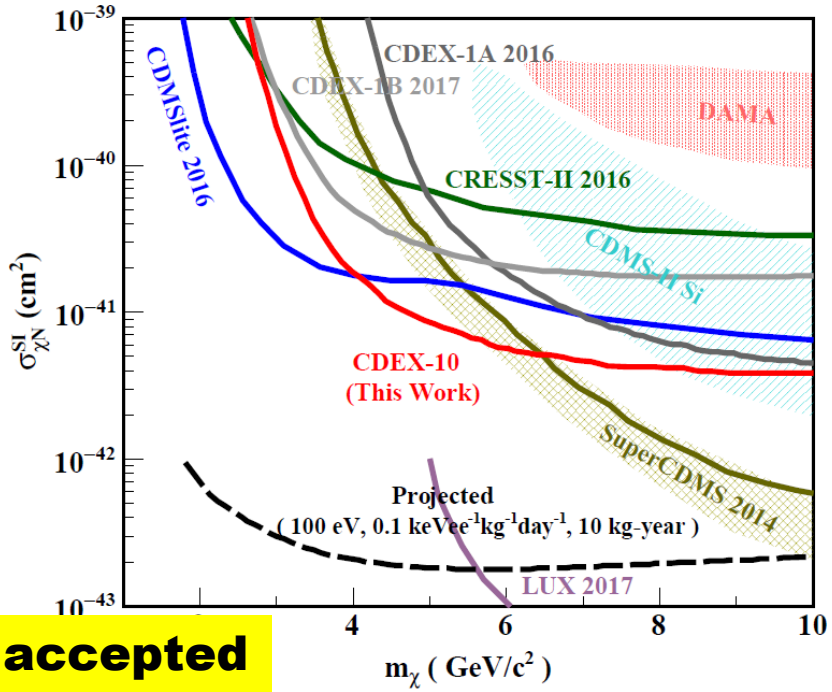
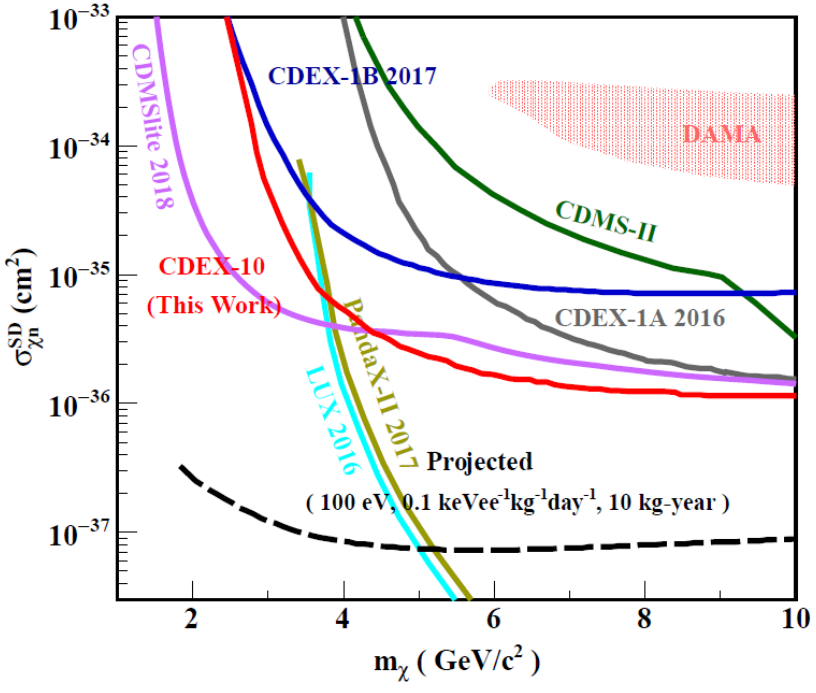
CDEX-10 results

- ✓ E_{th} down to 160eV,
- ✓ The best SI results @ 4-5GeV;
- ✓ The best SD results < 4GeV.



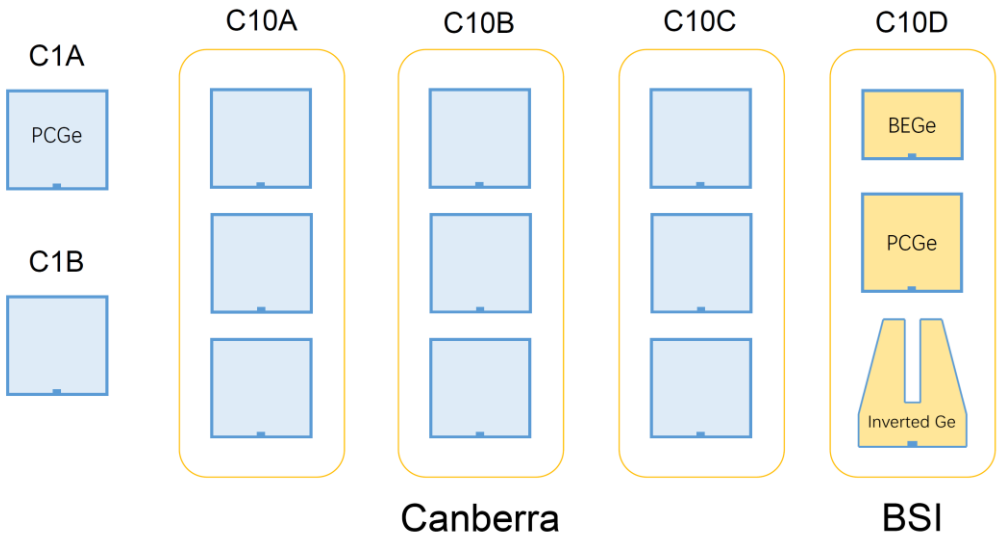




PRL accepted

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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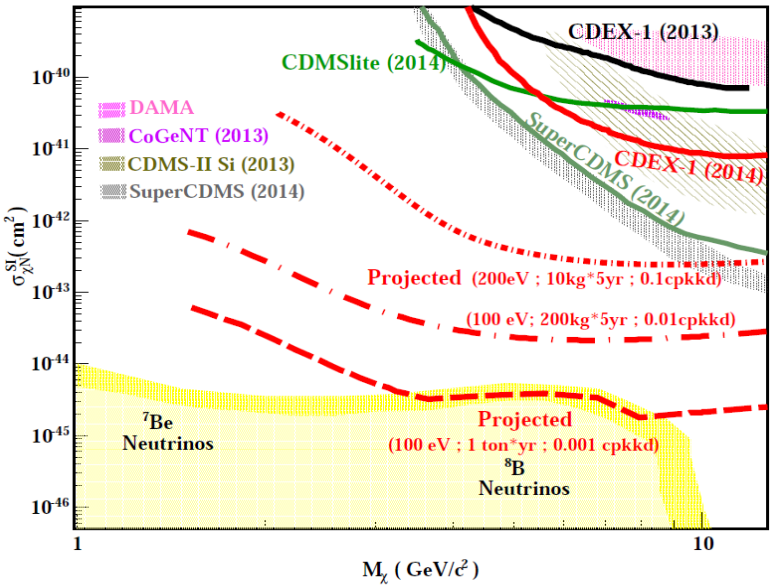
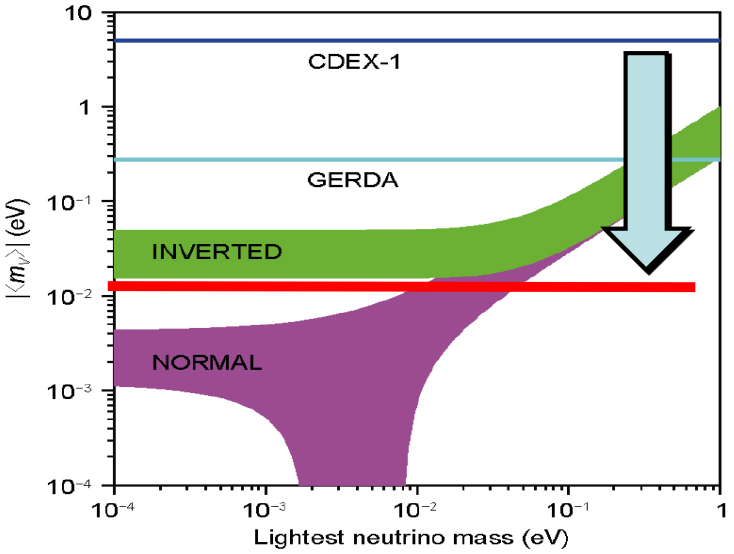
CDEX-1T@CJPL-II

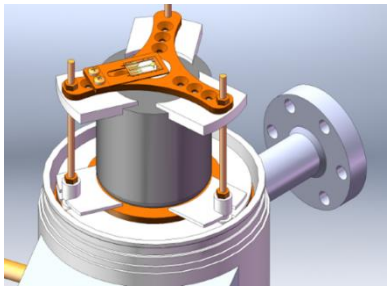
- A future Ge detector composed of the PCGe detector array and LN shielding and cooling system in the CJPL-II
- Both Dark matter and Double Beta Decay

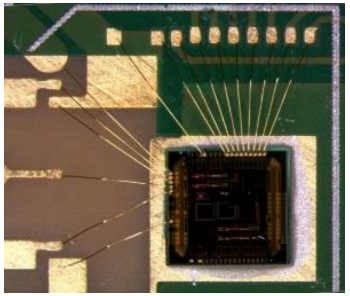


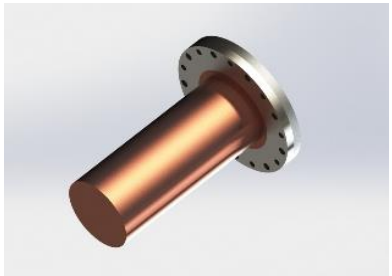


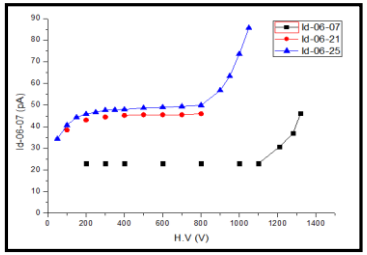
Key technologies towards CDEX-1T

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







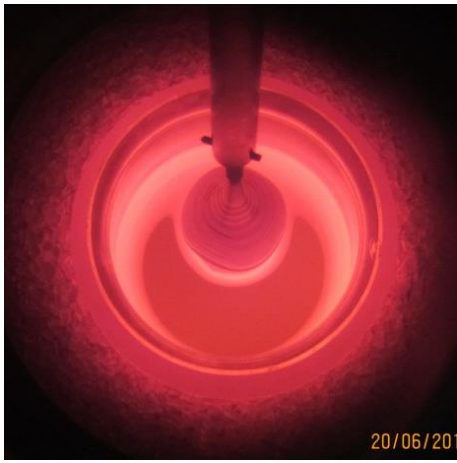


CDEX-1T –Ge crystal growth

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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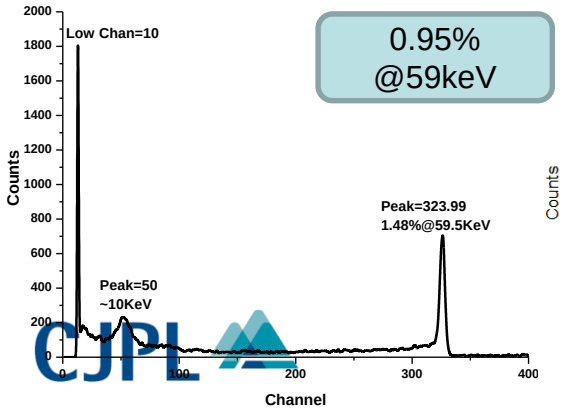
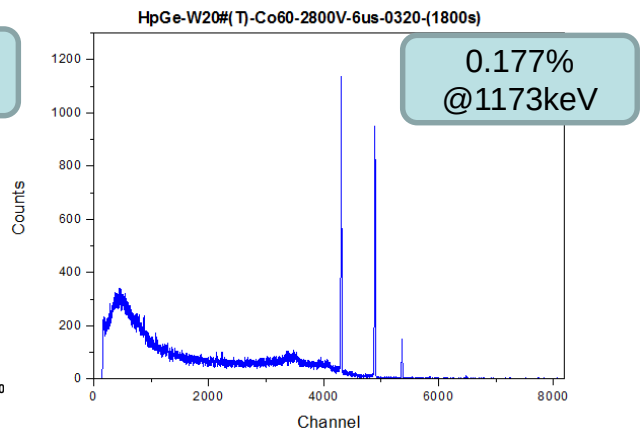
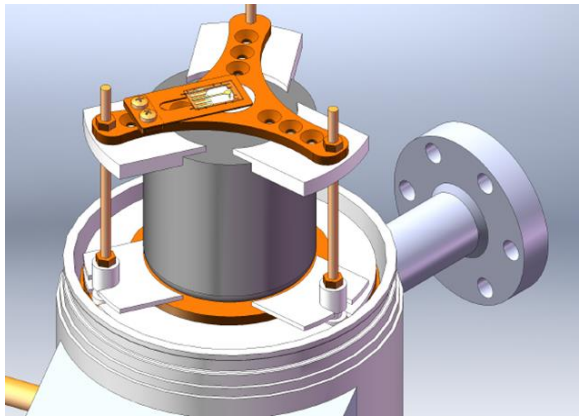
HPGe detector fabrication

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

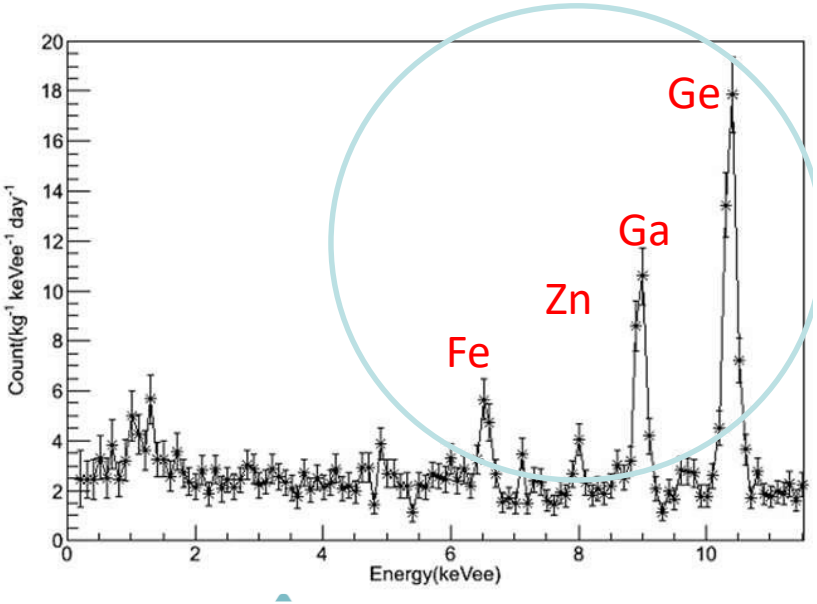




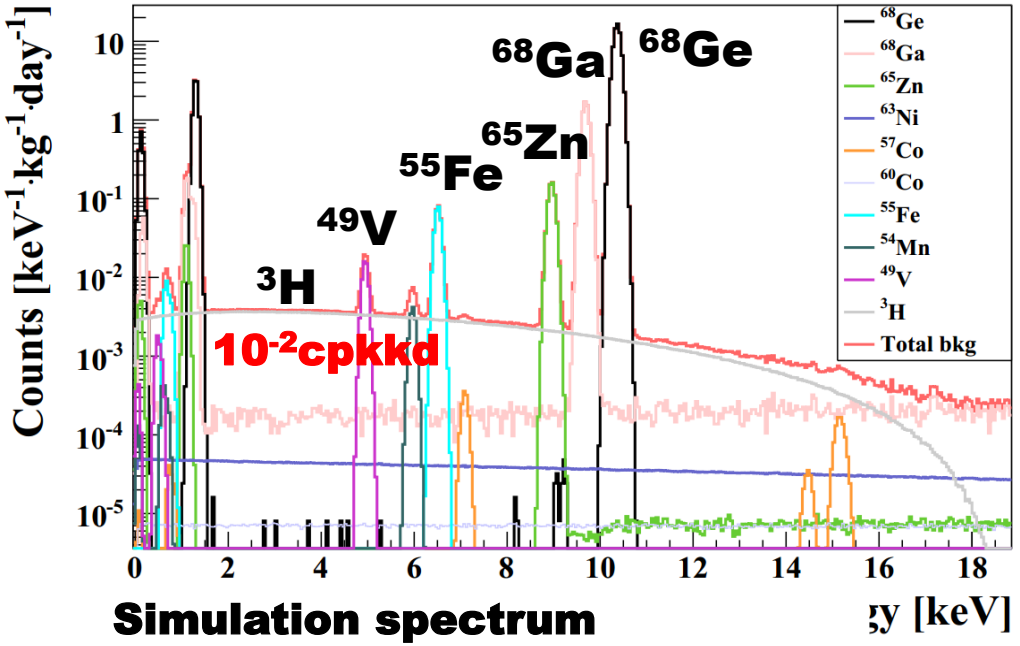


Cosmogenic Background of Ge detector

- 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.



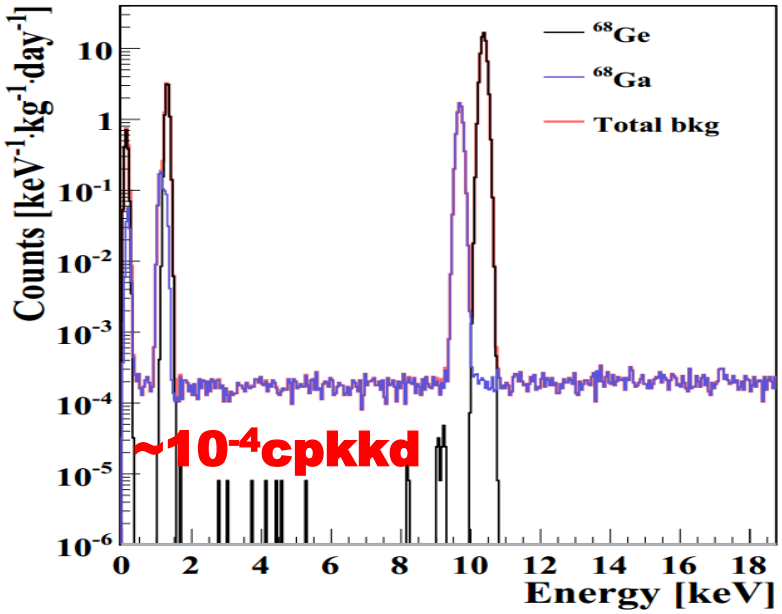
CDEX-10 background spectrum

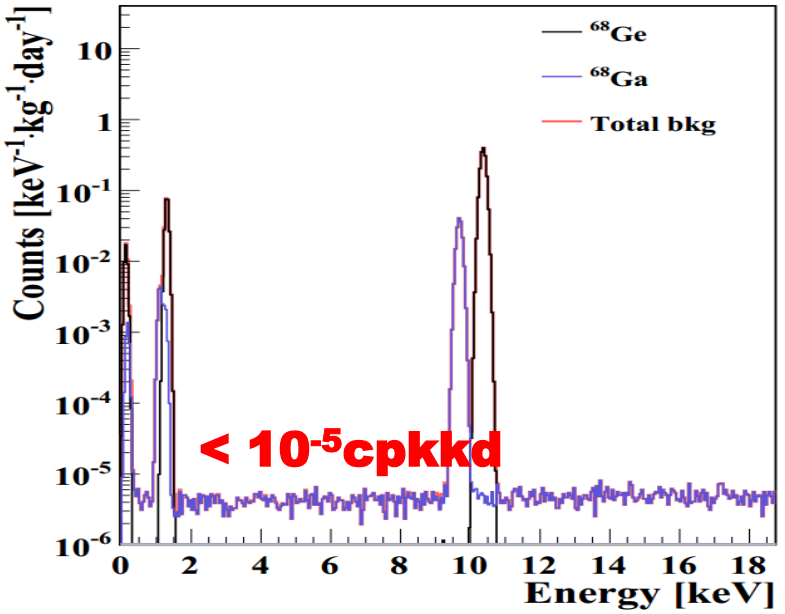


Simulation spectrum

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.





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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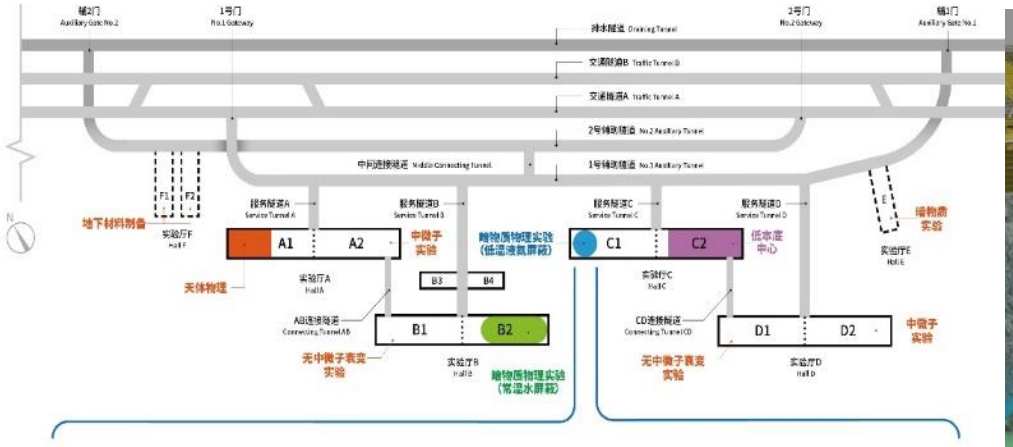
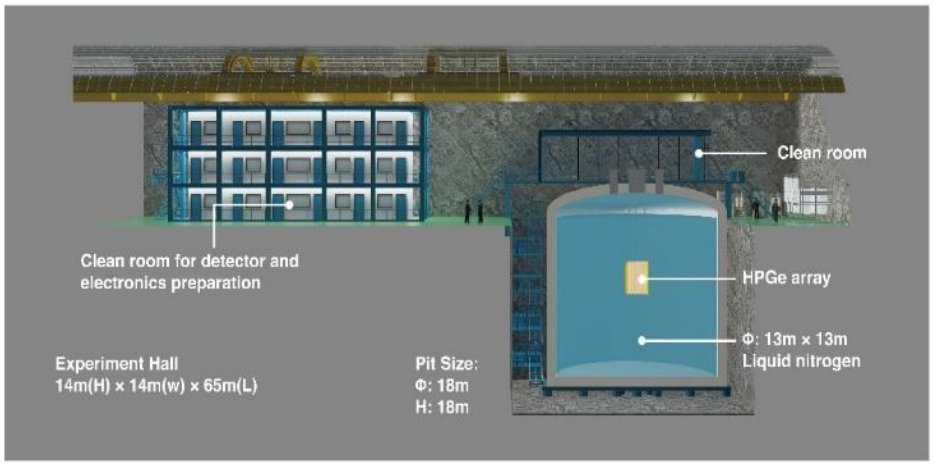
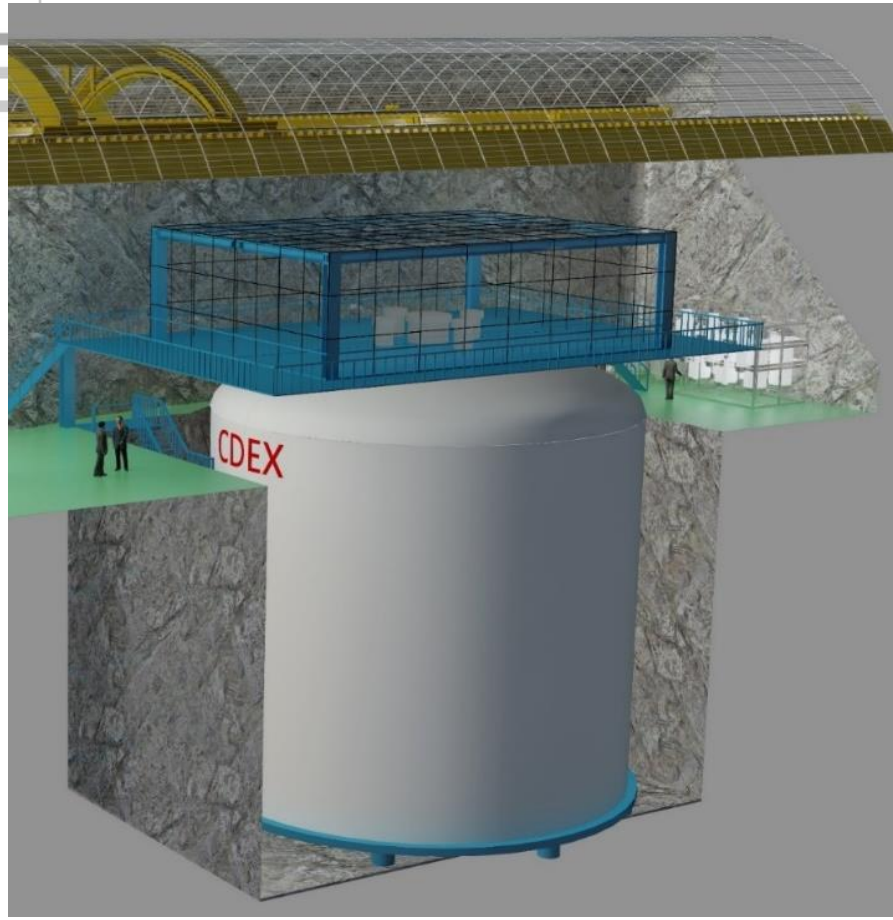
CDEX-1T Plan







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CDEX-1T@CJPL

Summary

- CDEX has achieved competitive DM physical results from 2013 on;
- The first physical results from CDEX-10 will be published by PRL in 2 weeks;
- The best SI sensitivities on 4-5GeV energy region and the best SD sensitivities below 4GeV;
- CDEX is developing the key technologies of low background Ge detector towards a ton-scale Ge experiment for DM (+DBD+Solar Neutrino).

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