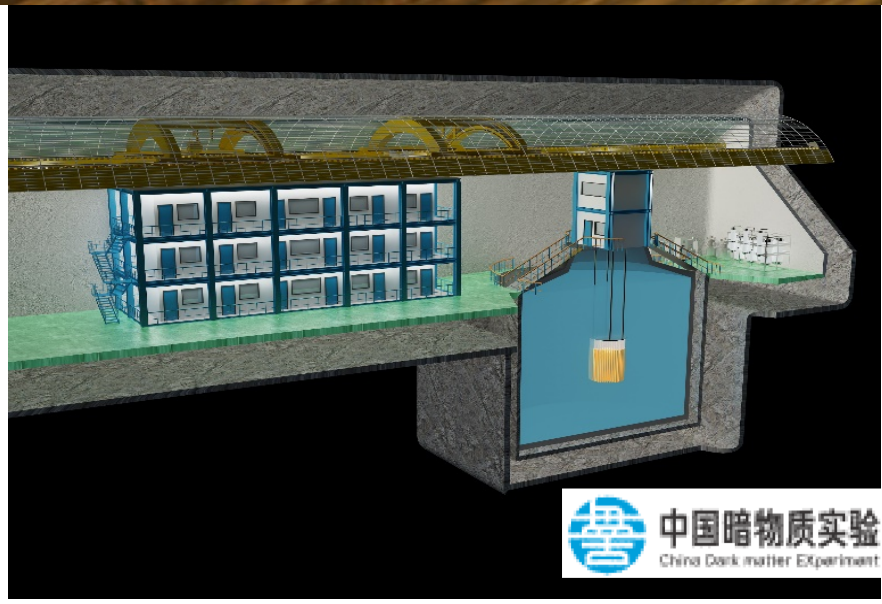
Dark matter program of the CDEX collaboration at China Jinping Underground Laboratory

Shin Ted Lin / Sichuan University
On behalf of CDEX Collaboration
@MG16 virtual meeting 9th July 2021



CJPL

OUTLINE

- ✓ CDEX (Collaboration : Programs)
- ✓ Results from CDEX-1/10 (WIMPs, AM-WIMPs, solar axions, ALP DM, vector Bosonic DM, dark photon EFT-involved interactions & $0\nu\beta\beta$)
- ✓ CDEX-50dm at CJPL-II
- ✓ R&D on the key Ge technologies & background controls
- ✓ Summary & Prospects

China Dark matter EXperiment (CDEX) - 2009

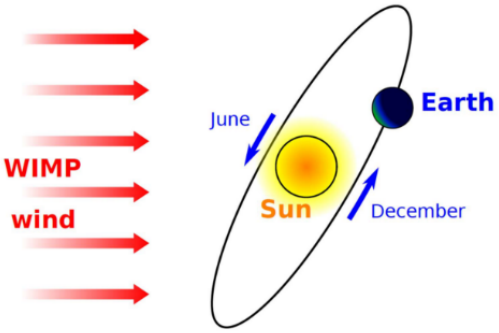
中国暗物质实验
China Dark matter EXperiment

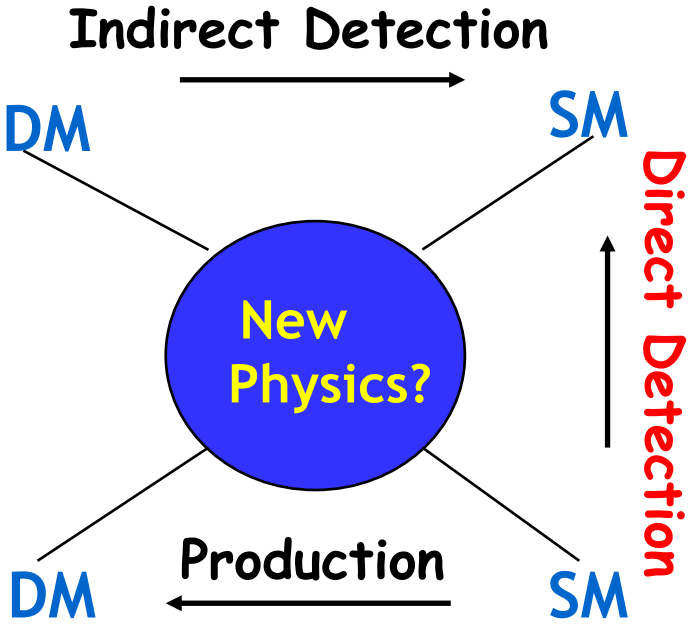
- Tsinghua University
- Sichuan University
- Bejing Normal U
- Nankai University
- China Institute of Atomic Energy, CIAE
- Yalong River company

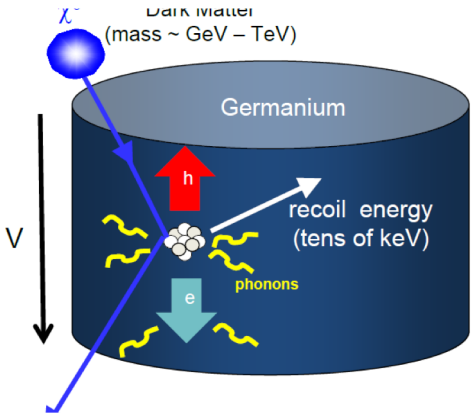
- *Intensively collaborate with TEXONO group.*

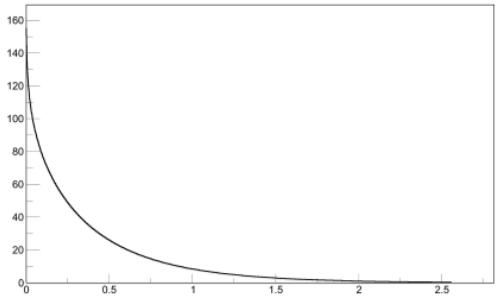
China Dark matter EXperiment (CDEX)

中国暗物质实验
China Dark matter EXperiment





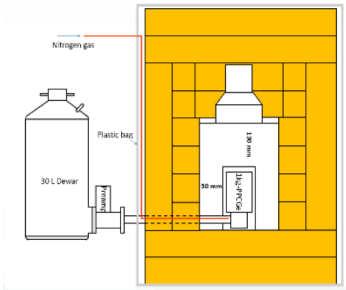


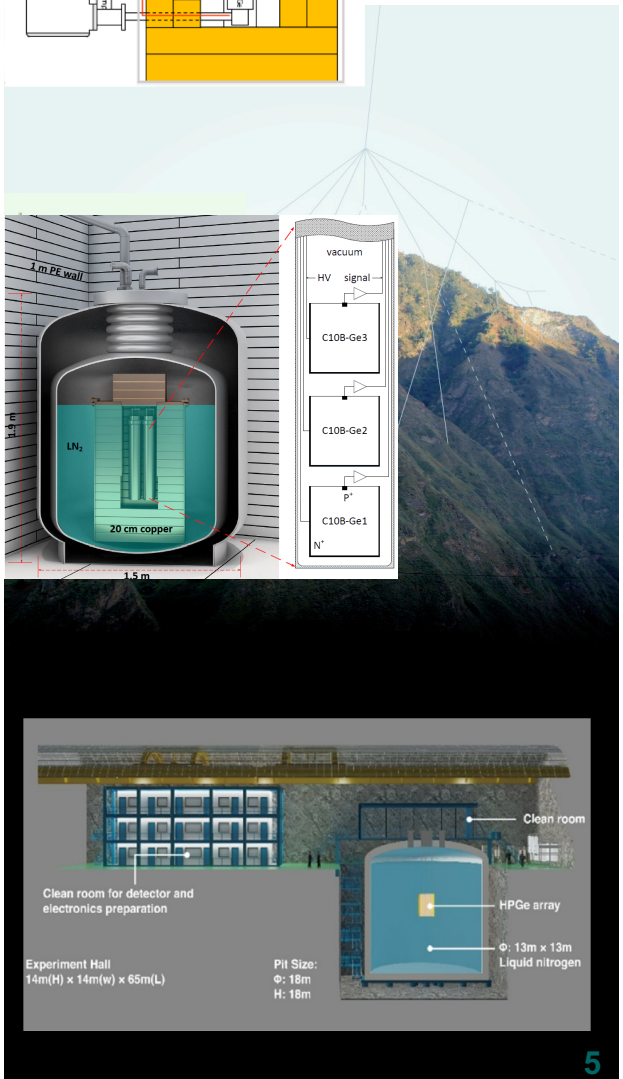


CDEX target:
Direct detection of light WIMPs with a point-contact Germanium detector array!

CDEX dark matter stages

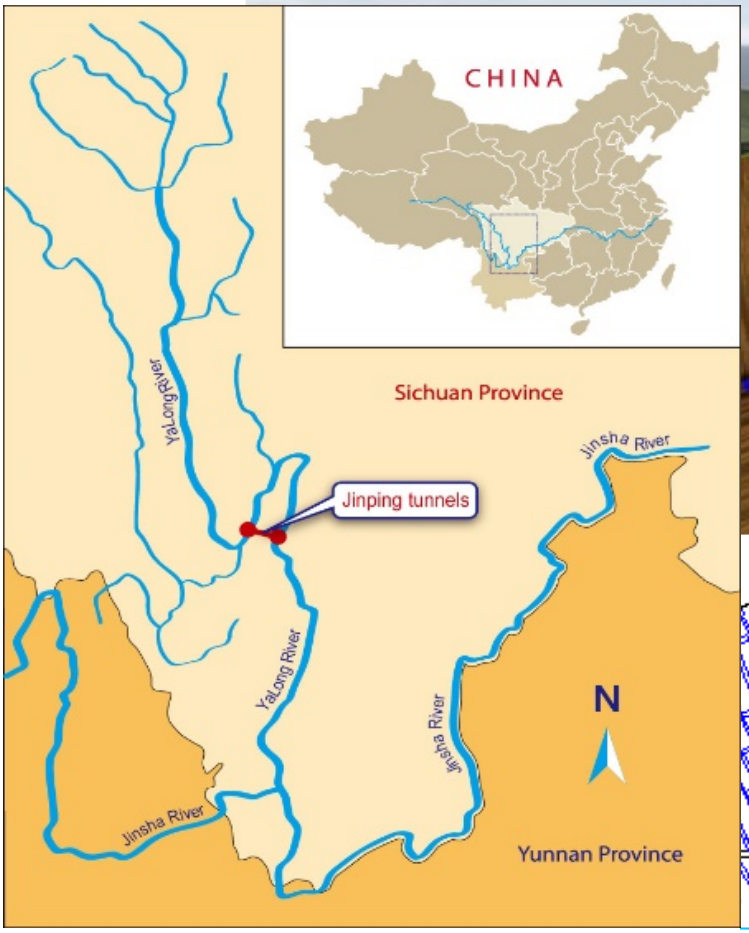
- CDEX-1: Develop a large-mass PCGe detector prototype, data analysis methods, and its background understanding and suppression; since 2011.
- CDEX-10: Performances of a HPGe array detector system and its passive/ active shielding systems; since 2015.
- CDEX-10X: Fabrication of HPGe, Ge crystal growth, VFE and ULB-Cu; since 2016
- CDEX-50dm: Combine the bare Ge detectors immersed in LN_2/LAr technology and low radioactivity techniques to lower the threshold & reduce the background. since 2021.

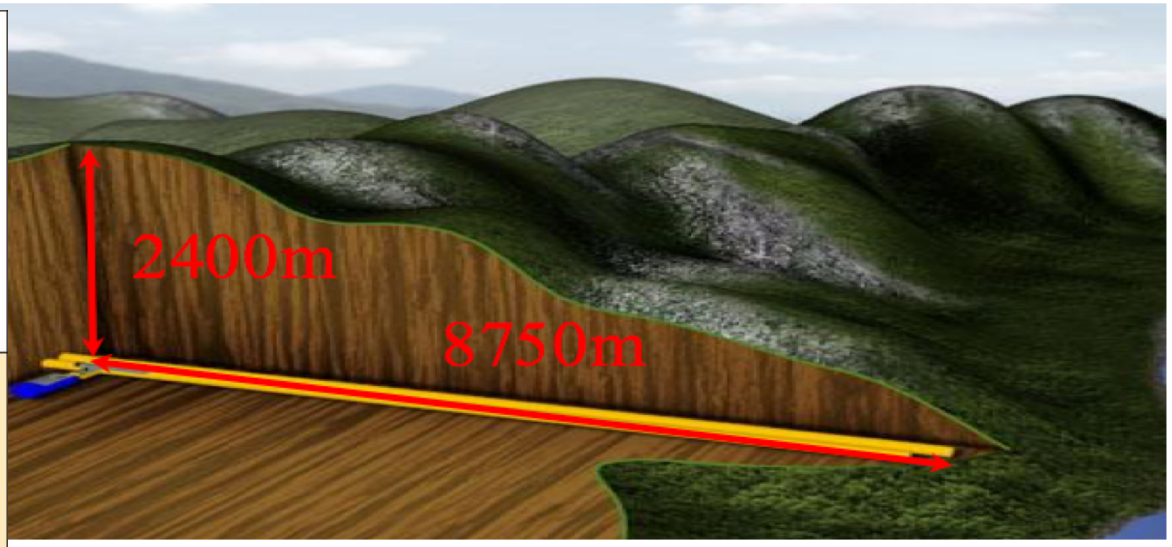


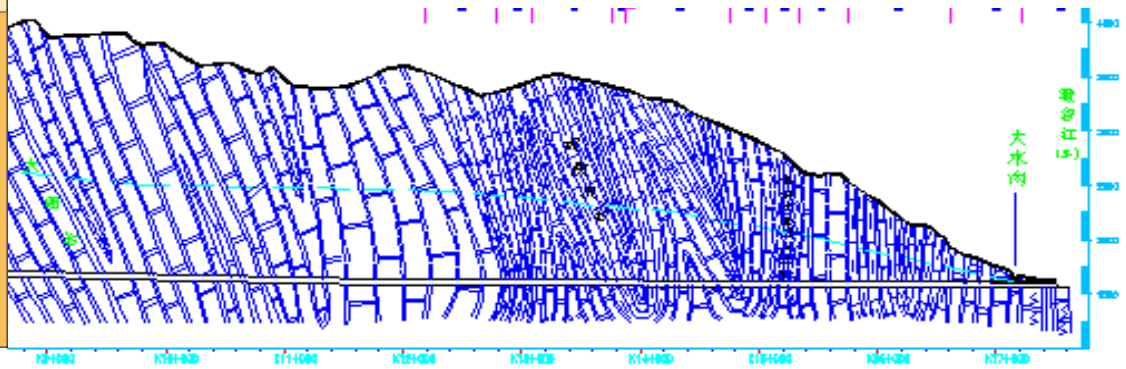


CDEX at China JinPing Underground Laboratory

中国暗物质实验
China Dark matter Experiment





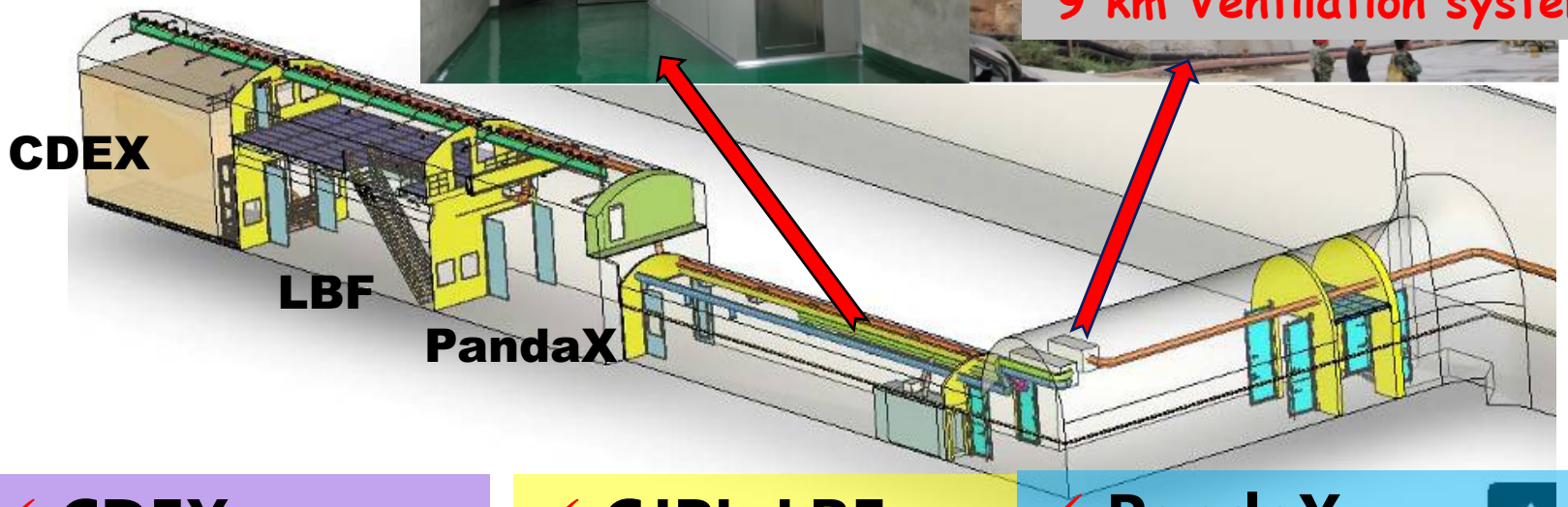


✓ CJPL: The deepest operation Underground Laboratory, located in Sichuan, China.

The space allocation of CJPL-I

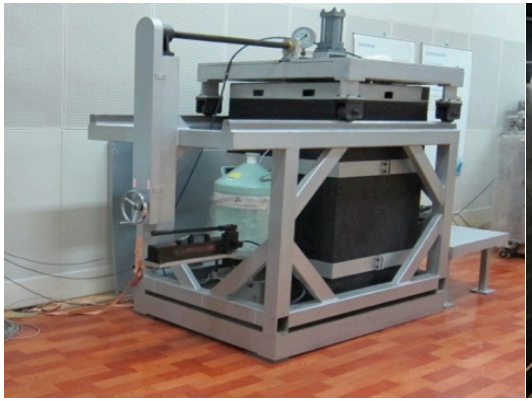
中国暗物质实验
China Dark matter Experiment

9 km Ventilation system



✓ CDEX

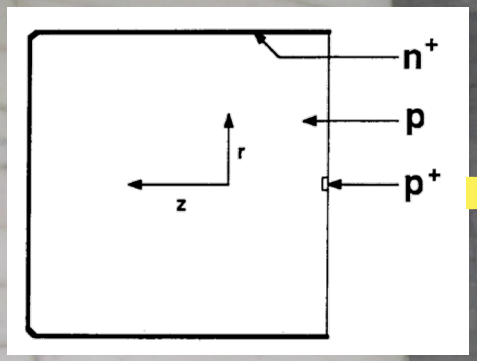
✓ CJPL-LBF

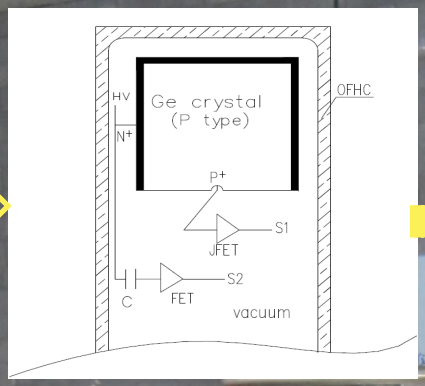


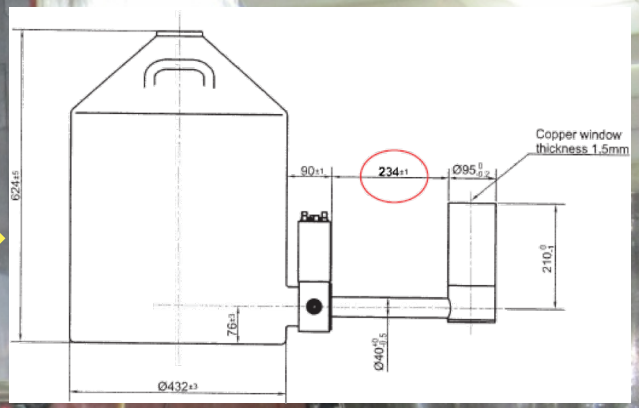
✓ PandaX

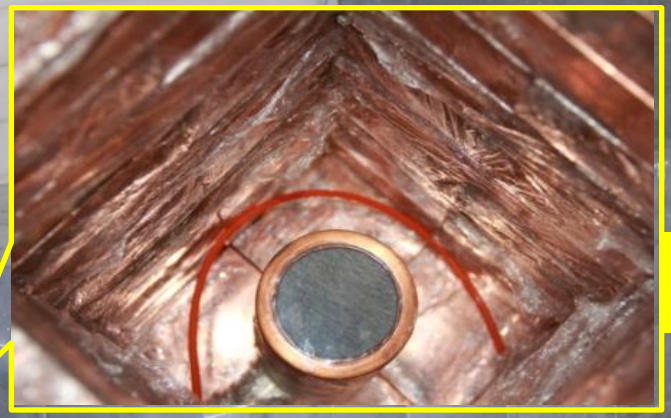
CDEX-1 at CJPL-I

中国暗物质实验
China Dark matter Experiment



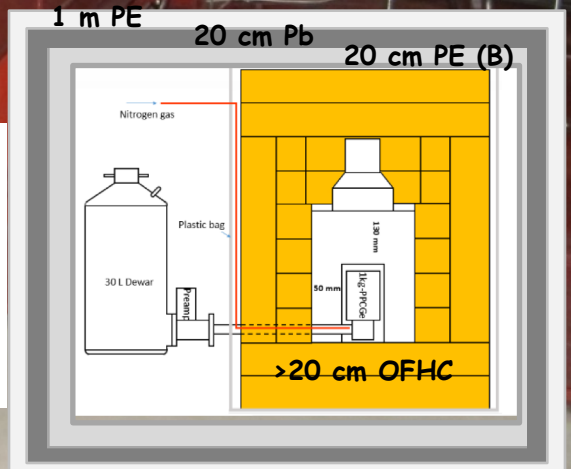






1kg pPCGe

4*5g ULEGe

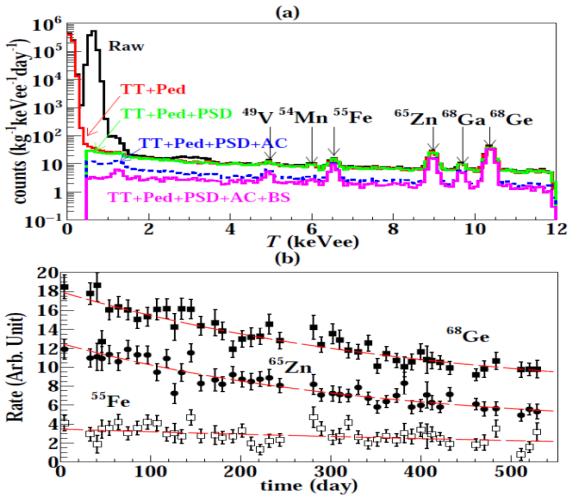


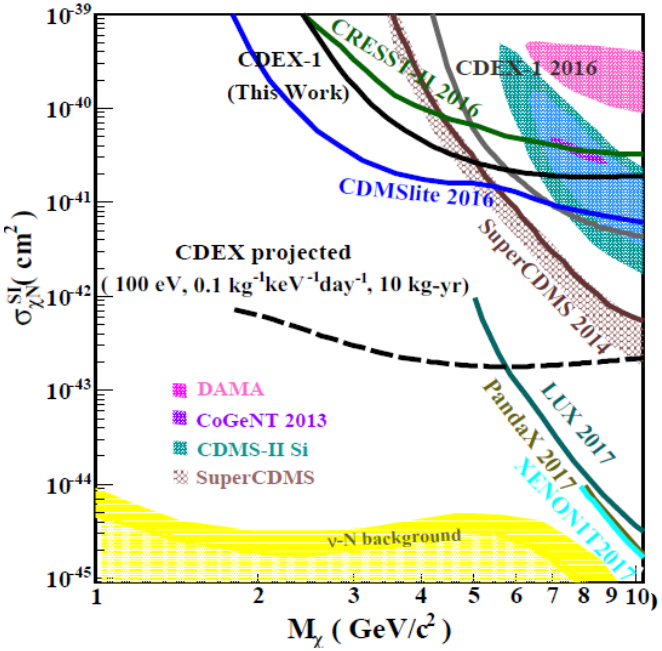
- ✓ 1 kg-scale pPCGe : low energy threshold & good energy resolution.
- ✓ NaI, enclosed the cryostat of Ge, served as anti-Compton detector.

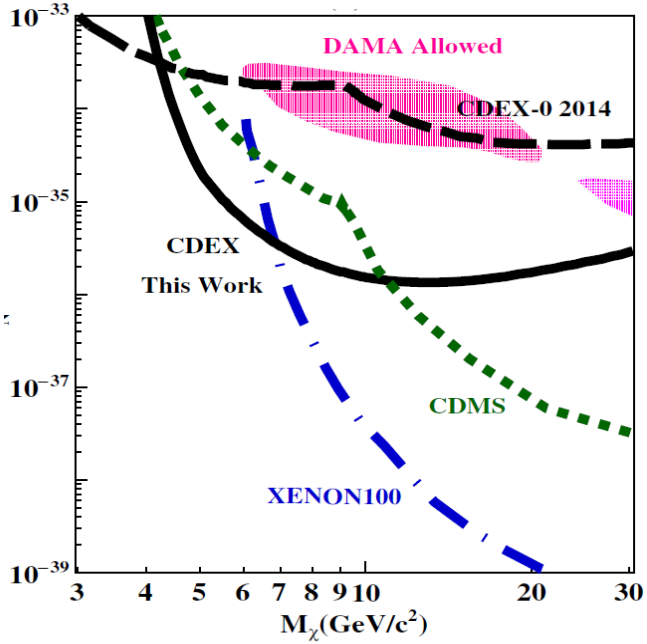
CDEX-1 results on light WIMP searches

中国暗物质实验 China Dark matter Experiment

CDEX-1A



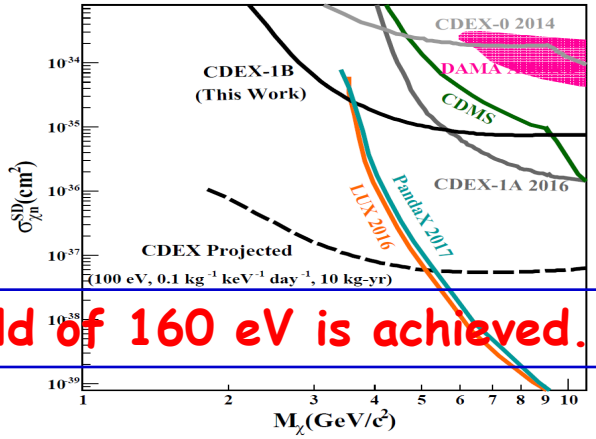




CDEX-1B

Configurations:

- Baseline design with NaI(Tl)
- Fiducial mass : ~ 1kg
- Analysis above : 475 eV(1A) 160 eV(1B)
- Q.F. adopted by TRIM software with 10% systematic uncertainty

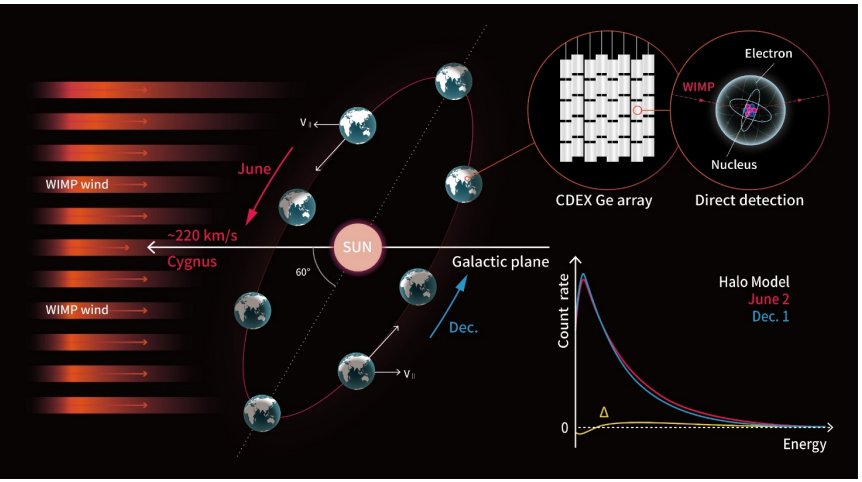


✓ Threshold of 160 eV is achieved.

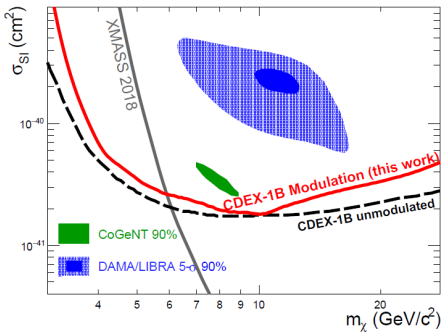
Reference: PRD 93 092003 (2016) ; CPC 42, 023002, 2018

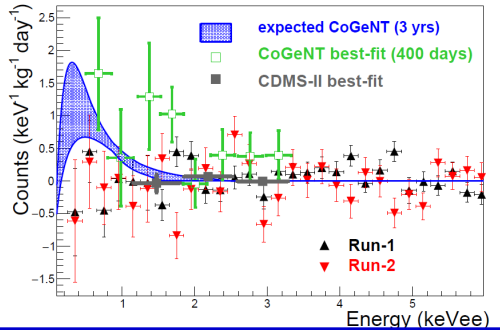
AM results & Migdal effect analysis from CDEX-1B

中国暗物质实验 China Dark matter Experiment



A.M. WIMPs searches

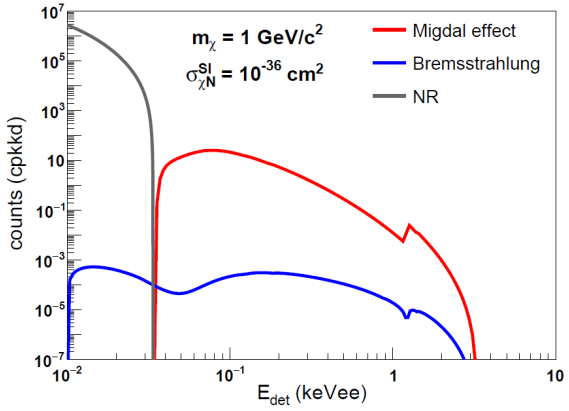


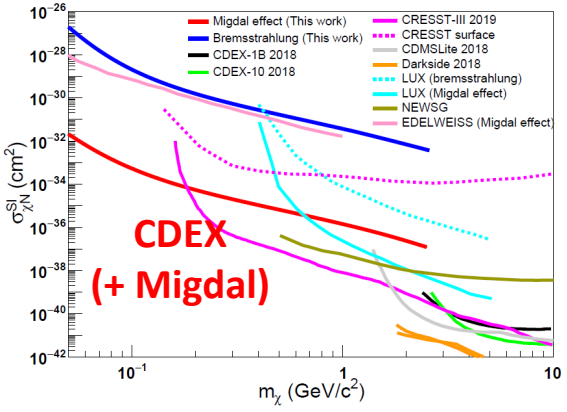


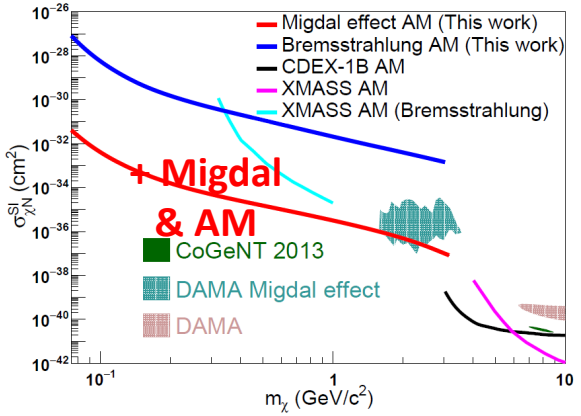
✓ Explore the new AM detection channel below the mass of 6 GeV/c²

Phys. Rev. Lett. 123, 221301 (2019)

sub-GeV WIMPs: Migdal effect





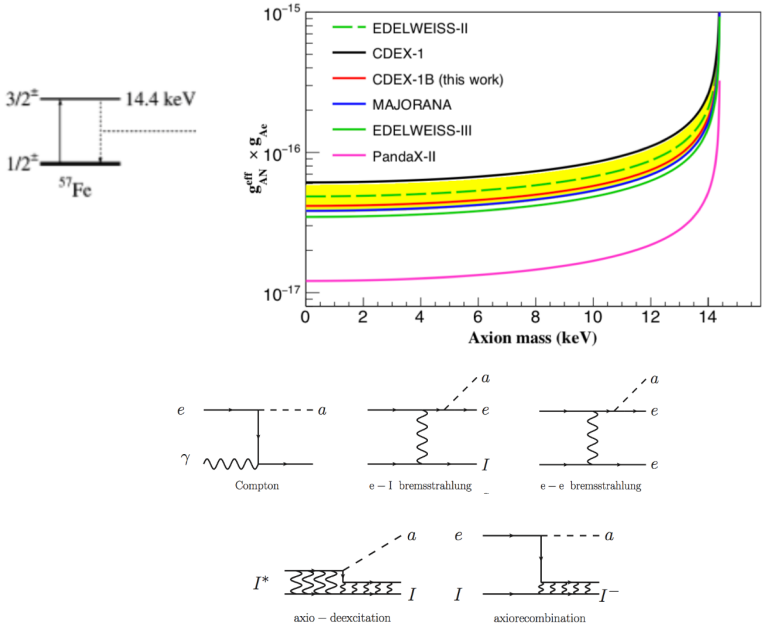


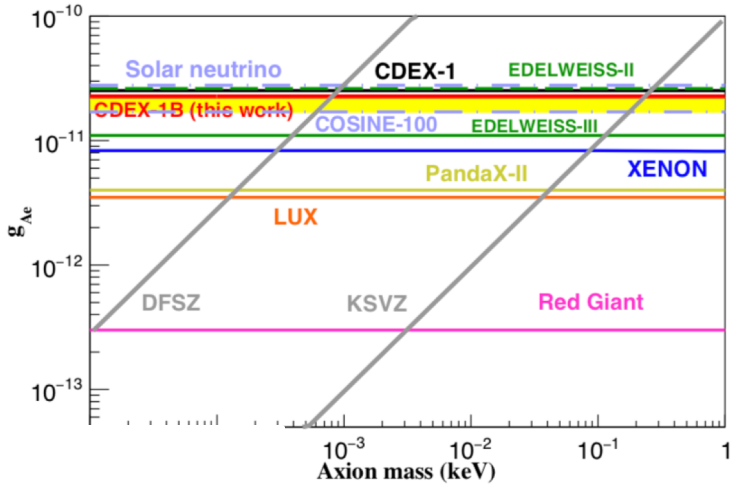
✓ The best sensitivities between 50 MeV/c² to 180 MeV/c² are achieved.

Phys. Rev. Lett. 123, 161301 (2019)

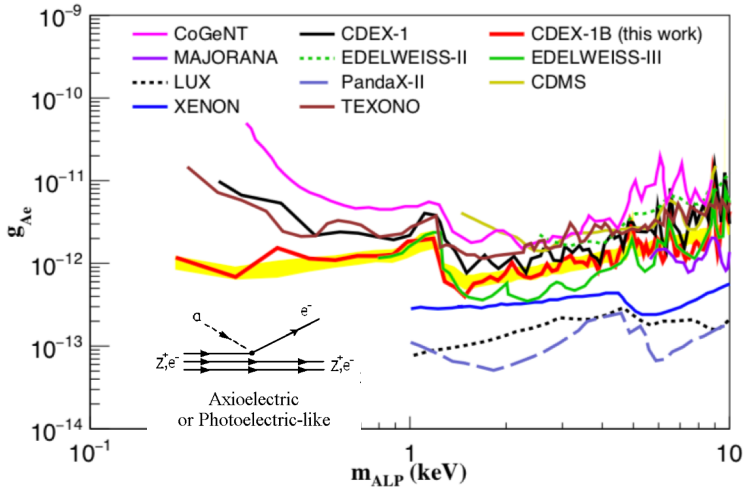
Searches of non-WIMPs via CDEX-1

Solar axion searches

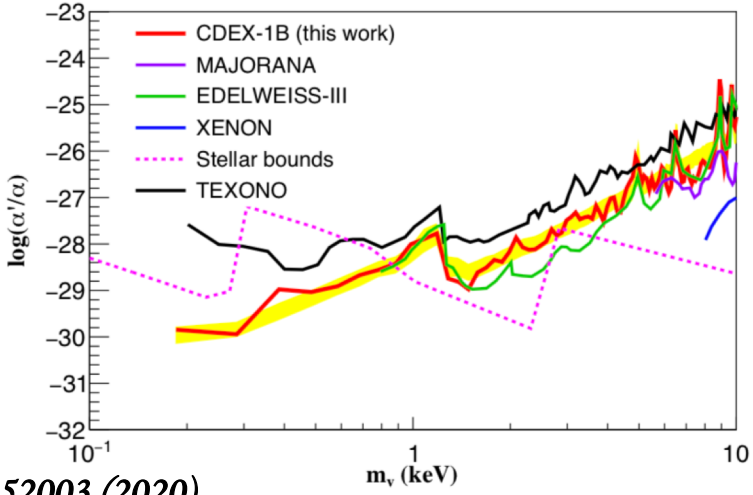




ALP searches



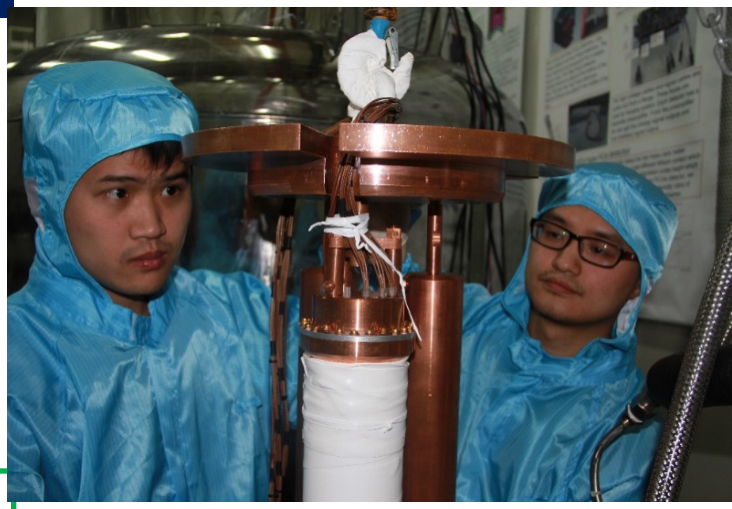
Vector Bosonic dark matter

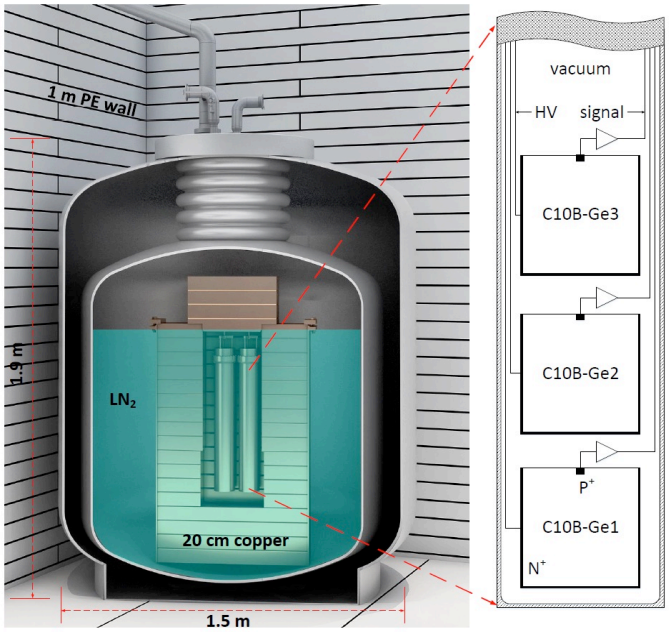


Phys. Rev. D 101, 052003 (2020)

CDEX-10 : An array of PCGe

- ✓ Test of cryogenic system has been done and shipped to CJPL in March 2016.
- ✓ A germanium array with LN in cryogenic system is commissioning.
- ✓ The performance of LAr is under study.





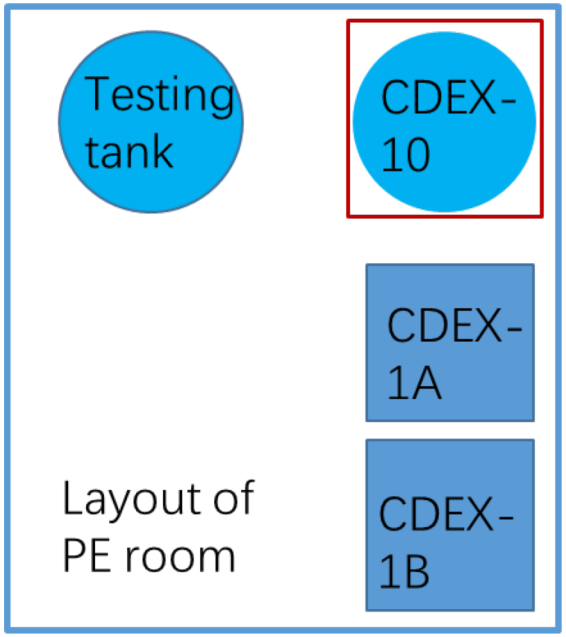
PCGe

Target

~9 Kg of PCGe

⊕

1.5 Ton of LN/LAr



Results of WIMP from CDEX-10

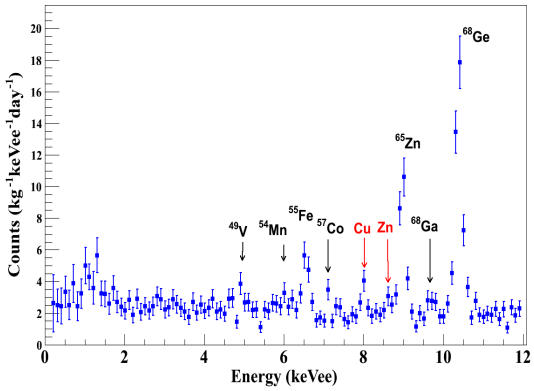
中国暗物质实验 China Dark matter Experiment

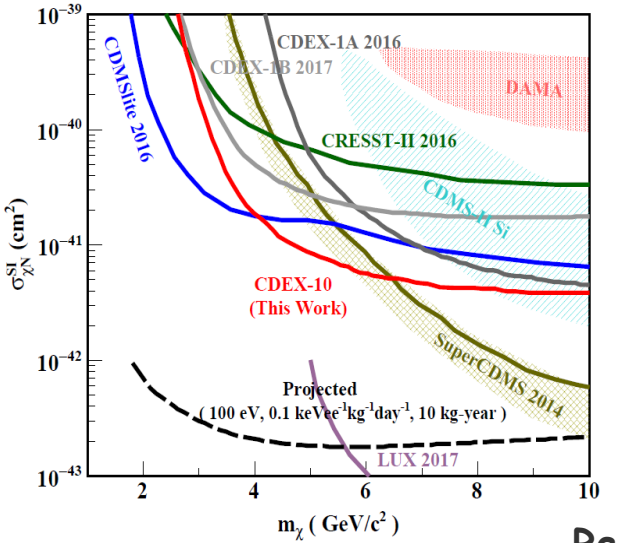
CDEX-10

Configurations:

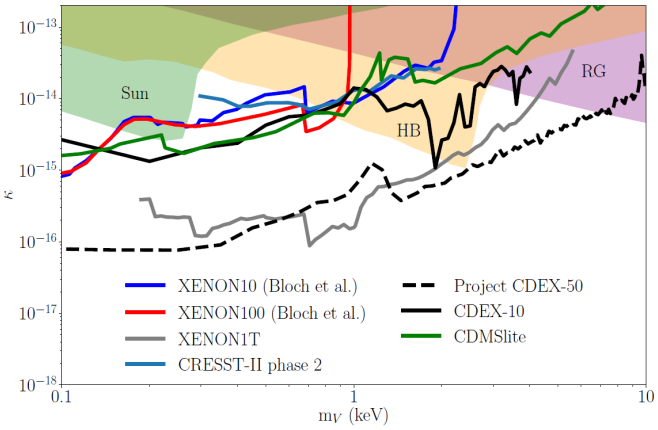
- 102 kg-days of data @ CJPL-I
- Immersed in liquid nitrogen
- Analysis above : 160 eV
- Q.F. adopted by TRIM software with 10% systematic uncertainty

Phys.Rev.Lett.120, 241301, (2018)





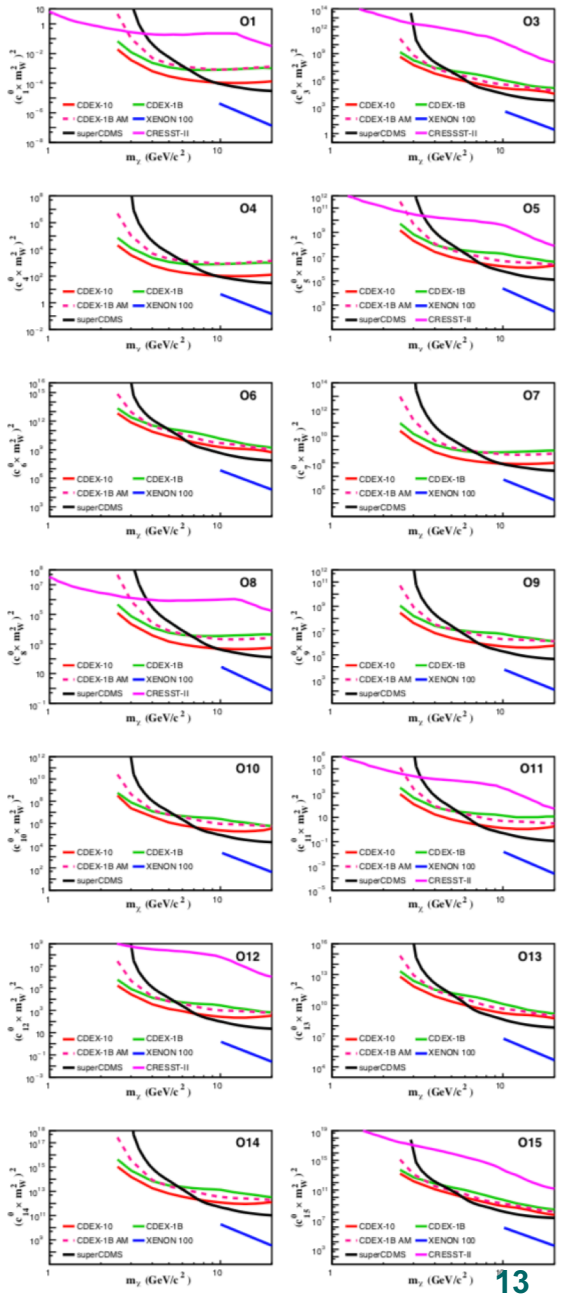
Dark photon searches



Phys. Rev. Lett. 124, 111301 (2020)

Results from different NREFT operators

Sci. China-Phys. Mech. Astron. 64, 281011 (2021)



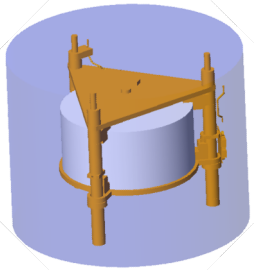
CDEX-50dm experiment @CJPL-II

中国暗物质实验 China Dark matter Experiment

✓Rare Ge detectors immersed in LN_2 or Lar directly.

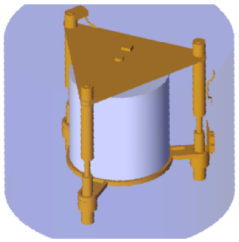
✓ 7 strings consist each 1 BEGE on top and 7 PPCGe detectors, contributing 50 kg.

✓Goal: Background of 0.01 cts/(keV·kg·day) @1 keV & Threshold of 100 eV



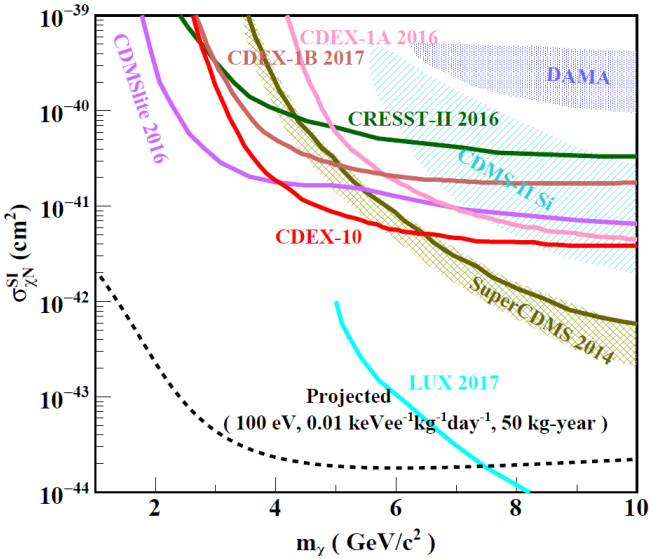
BEGe (Baseline)

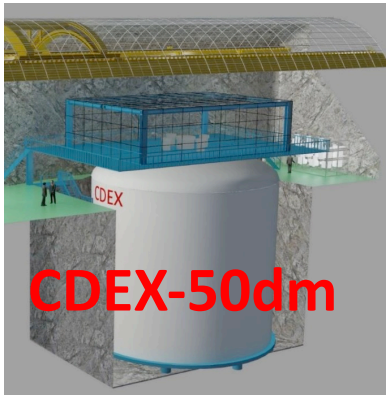
-Mass: 1-1.2 kg;
-Size: φ80mm*40mm;
-Dead layer: 0.6mm;

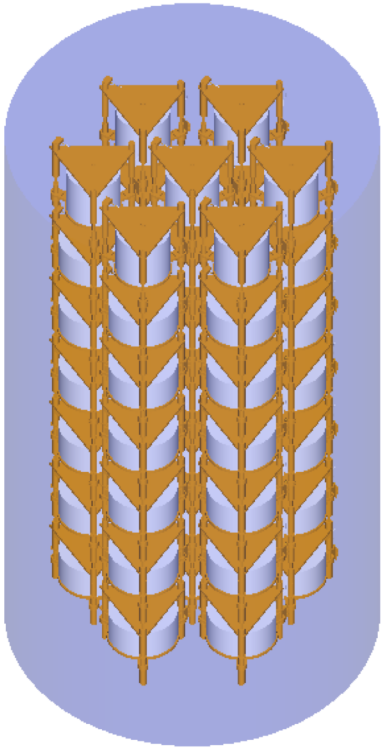


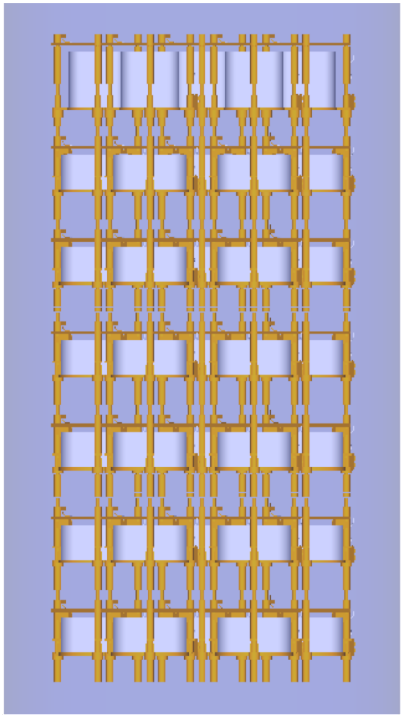
PPCGe

-Mass: ~1 kg;
-Size: φ62mm*62mm;
-Dead layer: 0.8 mm;









Background Controls for CDEX-50dm

中国暗物质实验 China Dark matter Experiment

1. Construction/supporting material (Material screening)

- ✓ Brass/Aluminum/Lead Holder, cables, electronics
- ✓ Shield material/NaI detector
- ✓ ^{40}K, ^{60}Co, Th and U series

2. Intrinsic contaminations in detectors.
(Ground time exposure control & crystal growing at UL)

- ✓ ^{3}H, beta decay with Q=18.6 keV. (Goal: <0.1 cpkd)
- ✓ Cosmogenic isotopes: $^{73,74}As$, $^{68,71}Ge$, ^{68}Ga, ^{65}Zn, ^{57}Ni, $^{56,57,58,60}Co$, ^{55}Fe, ^{54}Mn, ^{49}V

3.Radon Gas (Screening facility & Surface emanation)

- ✓ Permeability;surface of detector/tank (Radon in liquid nitrogen)

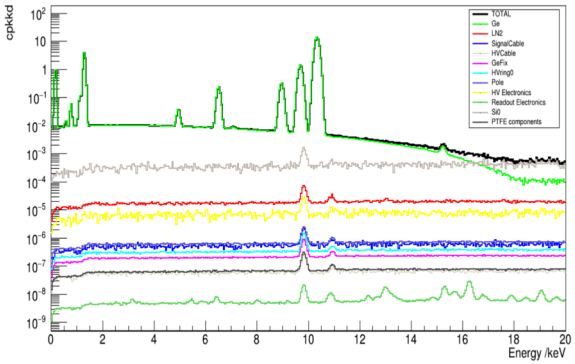
4. On surface of detectors (Detector simulation)

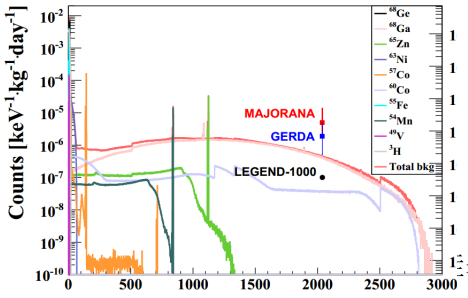
- ✓ α,β-rays to p-type, Bulk/surface differentiation.

Background Modeling for CDEX-50dm

中国暗物质实验 China Dark matter Experiment

Simulation results for the various materials

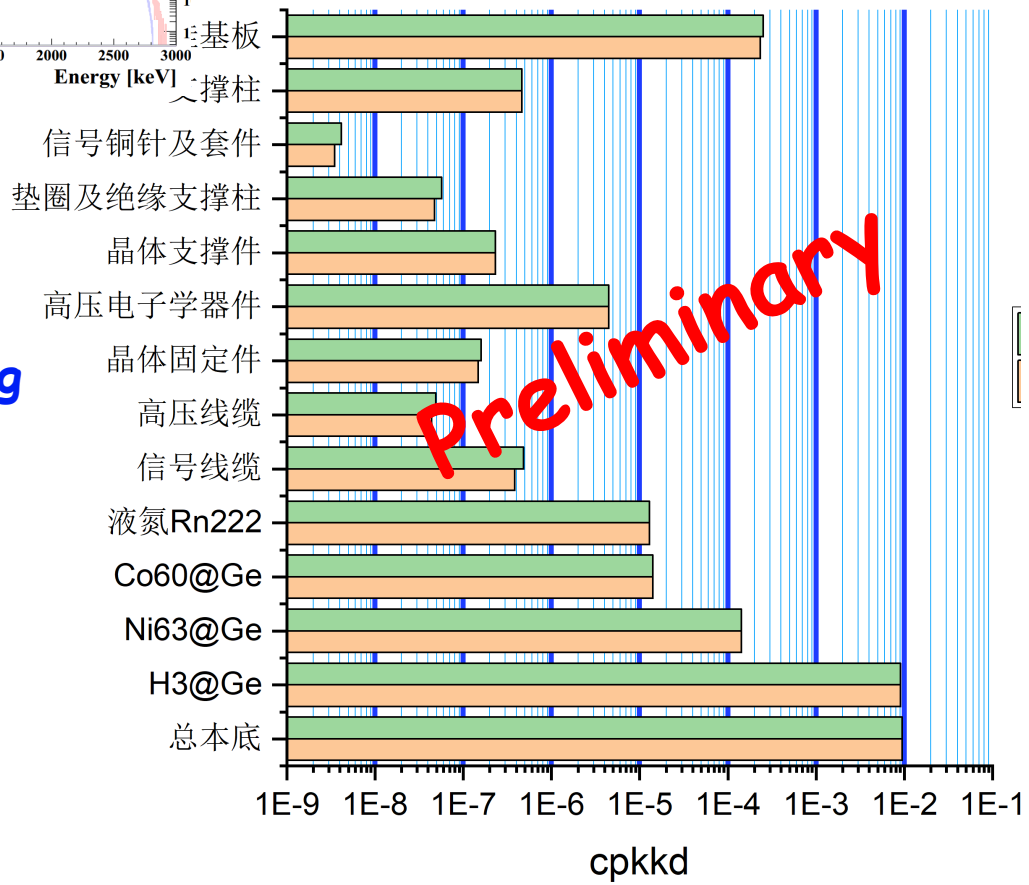




Major background controls

- ✓ >4 m LN_2 surrounded
- ✓ Radon mitigation in LN_2
- ✓ Electroformed copper producing at underground site
- ✓ Material screening
- ✓ Ge crystal ground time control
  - -Detector production
  - -Shipping
  - -Storage

Background budgets @<2keV



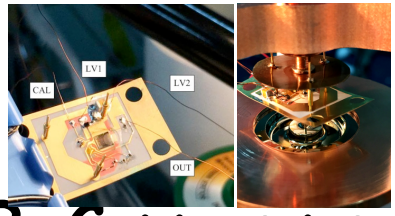
R&D on the Key Ge technologies

中国暗物质实验 China Dark matter Experiment

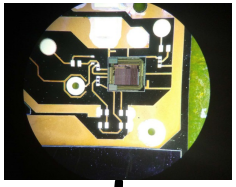
- Ge detector fabrication : Various types, P-type planar/coaxial, P-type point contact/ BEGe ~20 has been successfully done.

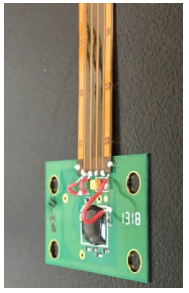
- HPGe crystal growth : on-going project

- ULB-VFE including substrate and cables:

ASIC 

Si substrate 



PTFE 

- ULB-Copper production in underground : Goal: μBq/kg

- ^{76}Ge enrichment: Coupled with $0\nu\beta\beta$

- Bare Ge immersed in LN_2 : Bare BEGe is successful to perform in LN_2

Outlook & Prospects

中国暗物质实验 China Dark matter Experiment

- **Missing Energy Density Problem** is the most intriguing & important one in basic science.
- Results of **light WIMPs** and **physics models** searches from **CDEX-1/10 @CJPL-1** have been carried out.
- **CDEX-50dm @CJPL-II** is proposed. Background model and background reduction is established. R&D on the Key germanium technologies and low radioactivity techniques for **lower background/lower threshold** is intensively on-going. (detector fabrication, crystal growth, upgraded electronics, electroformed copper, radon mitigation)
- The new **Facilities AND Communities** add to the world's arsenal on exciting dark matter & neutrino experiments requiring deep locations. Open to International Community to support/Exploit/Think hard this **Golden Opportunity**