

Recent Status And Prospects of CDEX

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On behalf of **CDEX Collaboration**

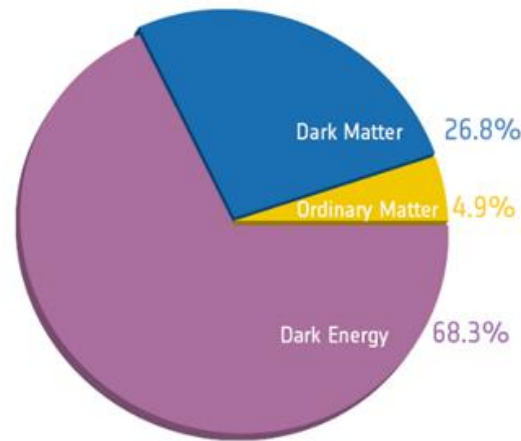
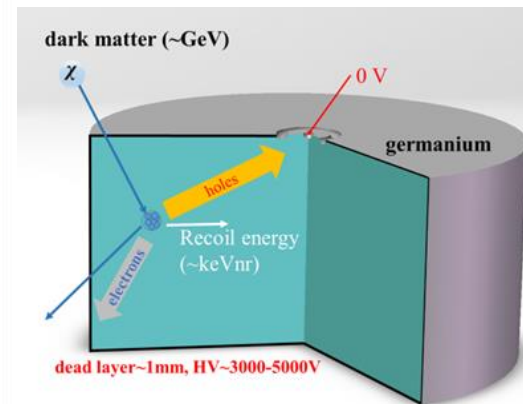
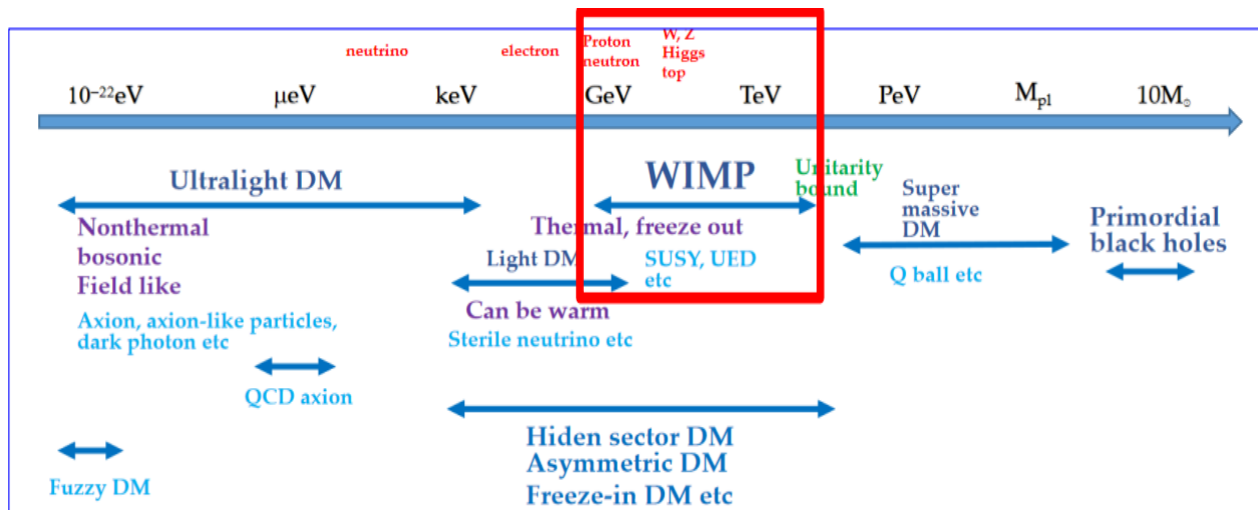
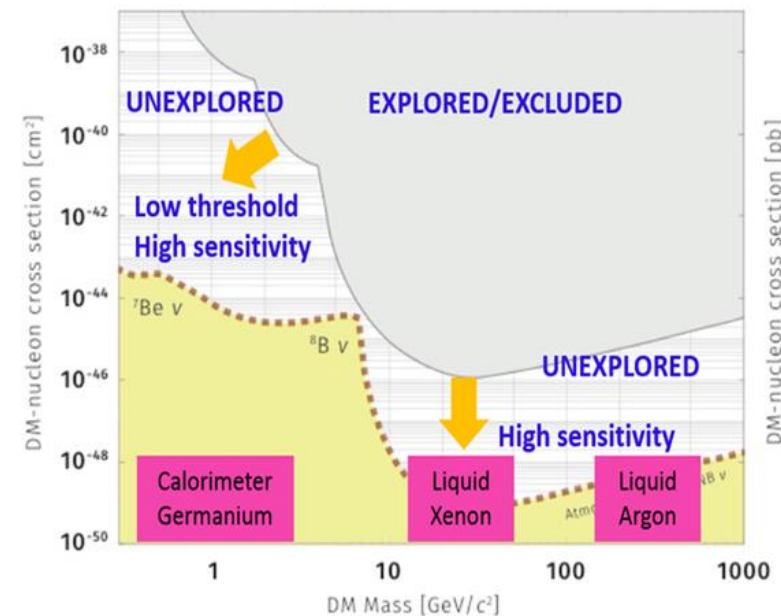
2026/10/29

OUTLINE

- **Introduction**
- **Physics Results of CDEX-1&CDEX-10**
- **Overview of CDEX-50 and CDEX-300 ν**
- **Summary**

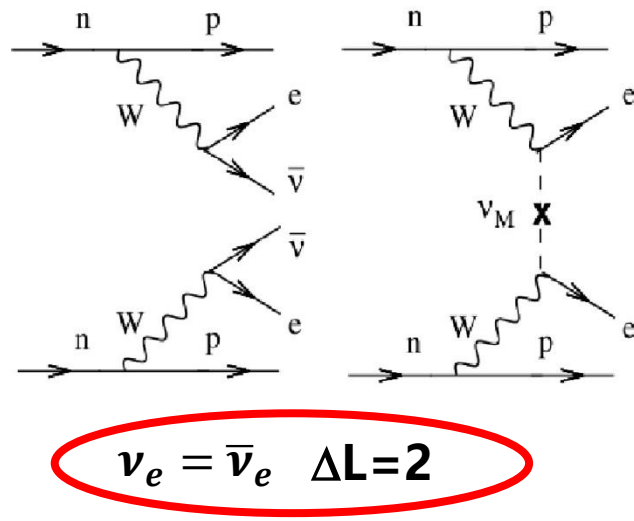
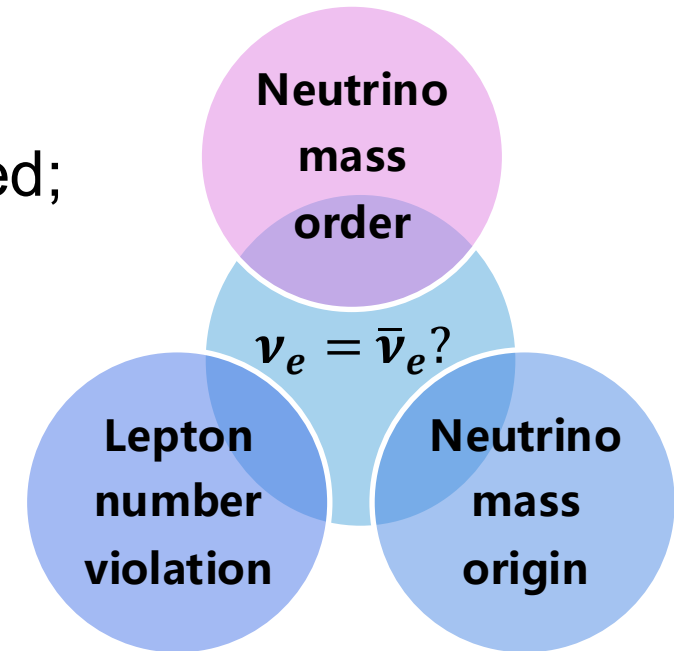
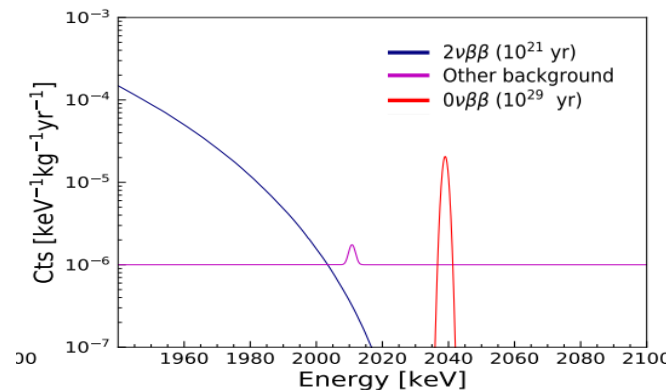
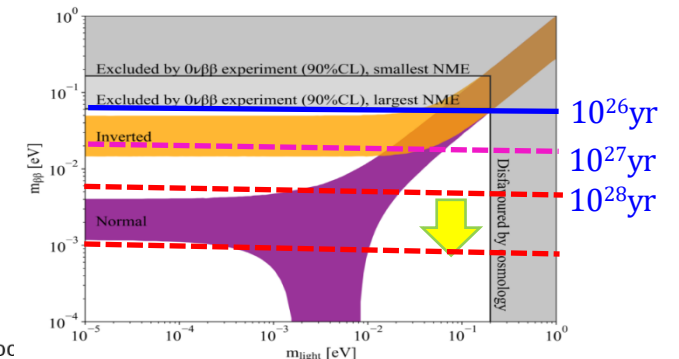
Dark Matter

- **26.8%** of the Universe consists of DM;
- **WIMP** is the most popular candidate, while many other models are proposed;
- Direct detection develops towards **lower threshold & higher sensitivity**;



Neutrinoless double-beta decay

- $0\nu\beta\beta$ is key fundamental topic in particle physics;
- ^{76}Ge , ^{136}Xe , ^{130}Te , ^{100}Mo , ^{82}Se etc. $0\nu\beta\beta$ being detected;
- $0\nu\beta\beta$ half-life towards **10^{27} year**;



China Dark matter EXperiment



<http://cdex.ep.tsinghua.edu.cn/>

- Established in 2009, 11 institutions and over 100 researchers now;
- **DM & $0\nu\beta\beta$ direct detection** by High Purity Germanium detectors (**HPGe**);

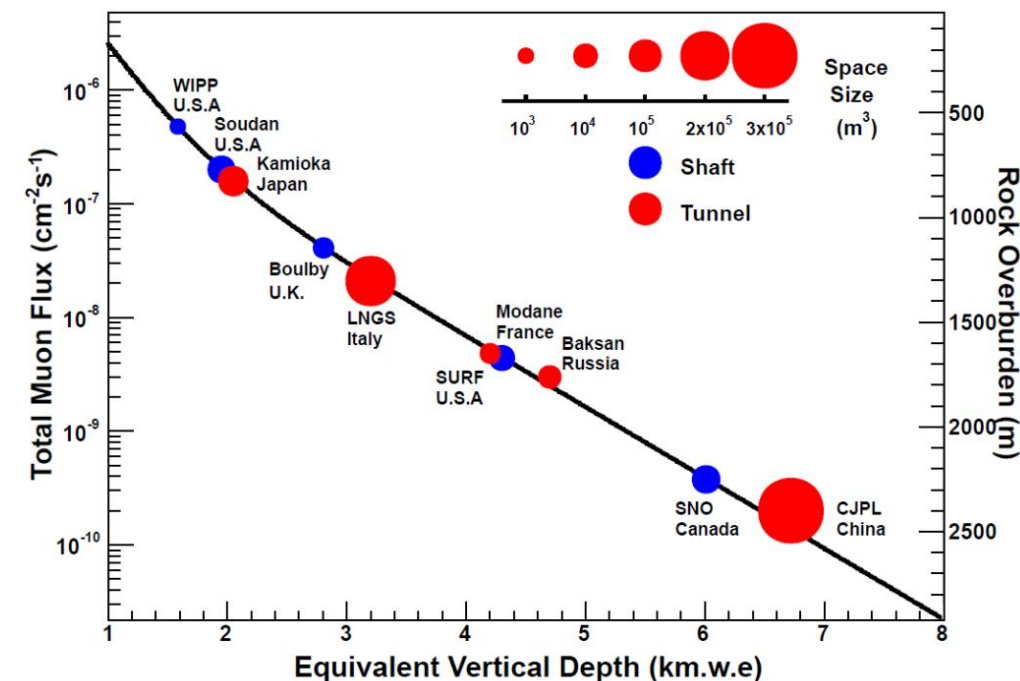


China JinPing underground Laboratory

World's **deepest & largest** underground lab, CJPL

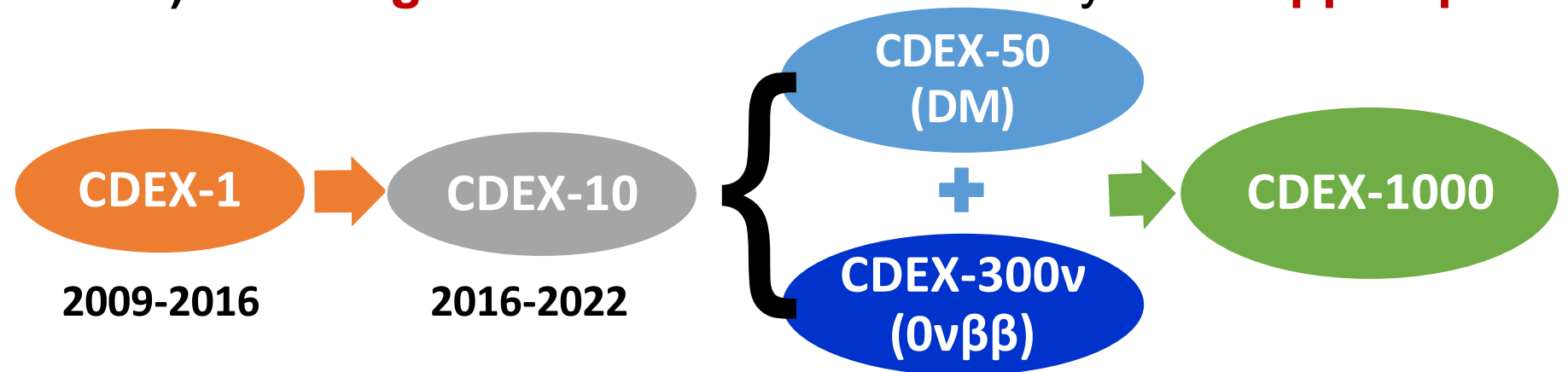
<https://cjpl.tsinghua.edu.cn>

- CJPL-I constructed by Tsinghua U. and Yalong Hydropower Company in **2009-2010**
- Extension project, CJPL-II is completed and begin scientific operation from **2024**
- CJPL-II **2400 m in depth**, over **$3 \times 10^5 \text{ m}^3$ space**, 8 experimental halls;

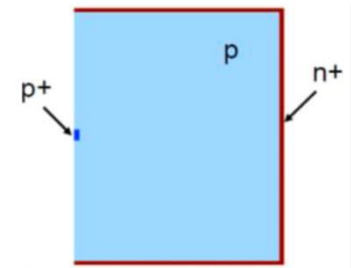
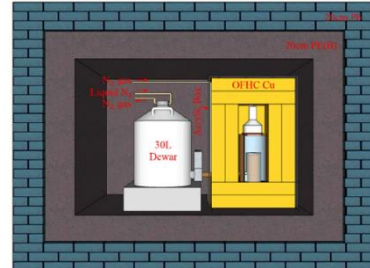


CDEX Roadmap

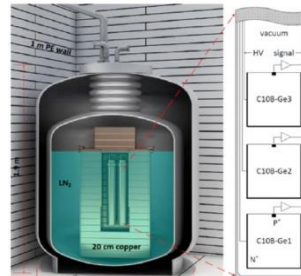
- CDEX-1 (2009-2016): Development of **PPC Ge detector**, bkg understanding
- CDEX-10 (2016-2022): Performances of **Ge array detector immersed in LN₂**
- CDEX-50 (2021-202X): **~50 kg Ge** detector arrays for **DM searches**
- CDEX-300v (2021-202X): **~225 kg enriched Ge** detector arrays for **0νββ Exp.**



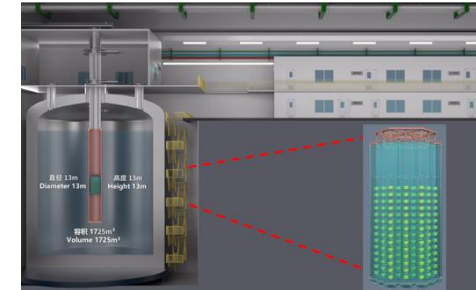
P-type Point-Contact(PPC)
Germanium detector



CDEX-1A&B: 1kg PPC Ge×2

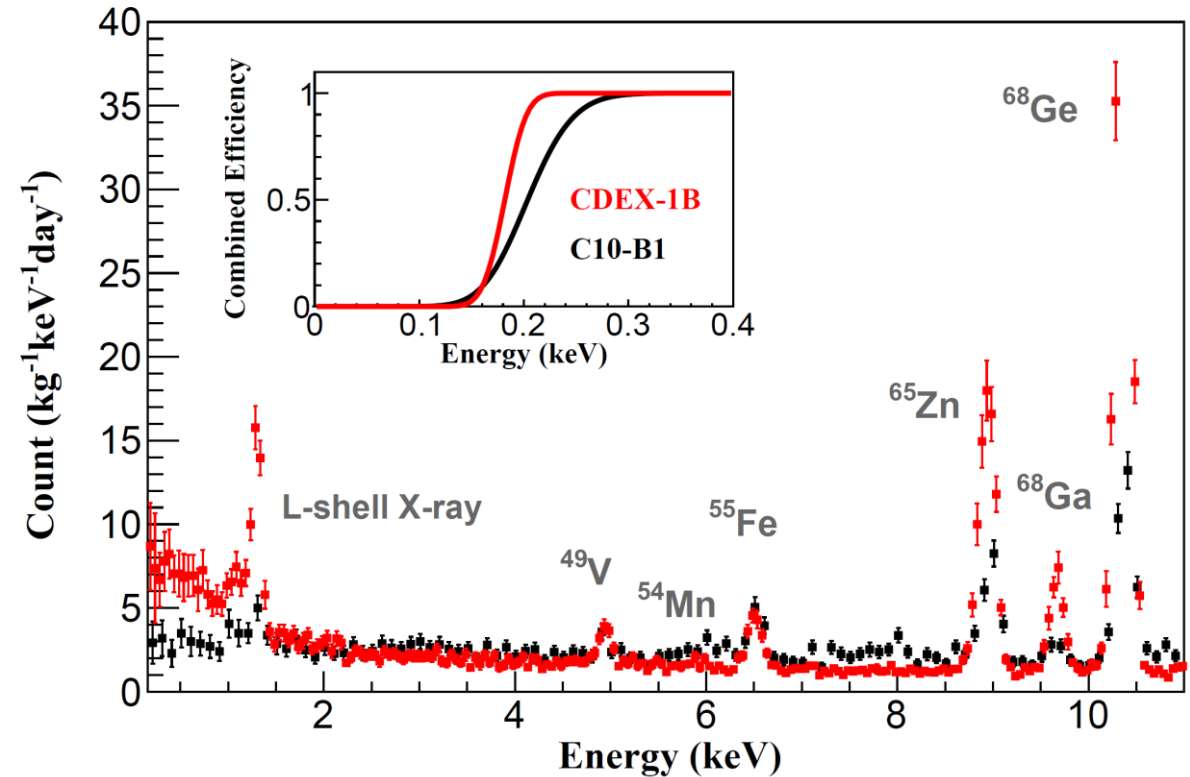


CDEX-10: ~10kg PPC Ge array



Dataset of CDEX-1B&10B

- **Threshold:**
 - ✓ **160 eV_{ee}** (electron equivalent energy)
- **Background level:**
 - ✓ **2.5 cpkkd@2-4 keV_{ee}** (cts/(keV·kg·day))
- **Exposure:**
 - ✓ CDEX-1B: **1107.5 kg·day**
 - ✓ C10-B1: **205.4 kg·day**



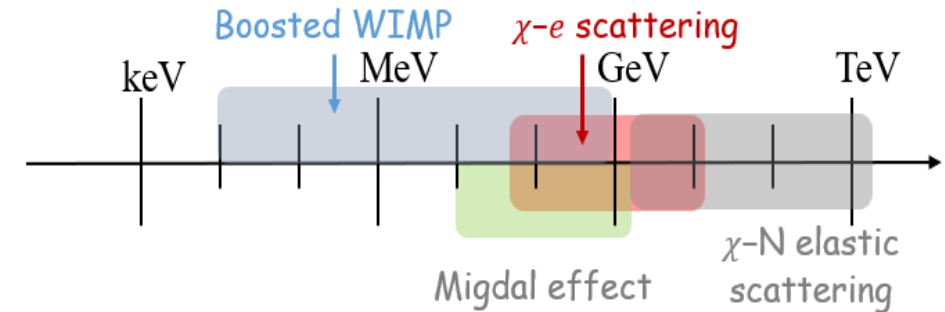
Measured C1B(red) and C10B1 spectrum.
The combined efficiency is shown in the inset.

Chin. Phys. C 42, 023002 (2018); *Phys. Rev. Lett.* 120, 241301 (2018)

CDEX-1 & CDEX-10 DM Results

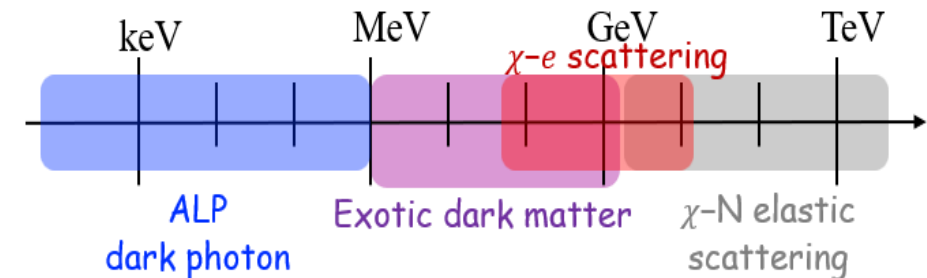
• WIMP search

- ☐ $\chi - N$ elastic scattering *PRL 120, 241301 (2018)*
- ☐ $\chi - N$ inelastic scattering *PRD 112, 112025 (2025)*
- ✓ Annual modulation *PRL 123, 221301 (2019)*
- ✓ Migdal effect *PRL 123, 161301 (2019)*
- ✓ Boosted WIMP: down to $\mathcal{O}(10 \text{ keV})$ *PRD 106, 052008 (2022); PRD 108, 052006 (2023); PRD 112, 092011 (2025)*
- ☐ $\chi - e$ scattering down to $\mathcal{O}(10 \text{ MeV})$ *PRL 129, 221301 (2022); PRL 132, 171001 (2024)*



• New physics beyond the WIMP

- ✓ Axion like particle: down to $\mathcal{O}(100 \text{ eV})$ *PRD 101, 052003 (2020); PRD 95, 052006 (2017)*
- ✓ Dark photon: down to $\mathcal{O}(100 \text{ eV})$ *PRL 124, 111301 (2020)*
- ✓ Exotic DM: down to $\mathcal{O}(1 \text{ MeV})$ *PRL 129, 221802 (2022)*
- ✓ Fermionic DM absorption *PRD 113, 032011 (2026)*
- ✓ Ultra-heavy DM *PRD 113, 052011 (2026)*



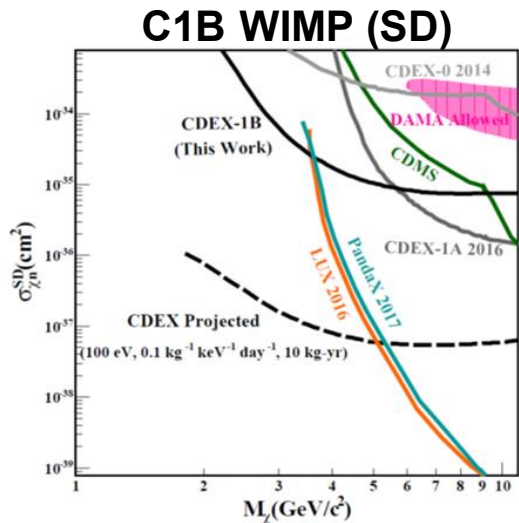
χ -N elastic scattering results

- **CDEX-1B:**

- ✓ First extended the **mass to 2 GeV** among Ge experiments.
- ✓ The most sensitive result on **SD χ -N elastic scattering below 4 GeV.**
- ✓ The best result on the **WIMP annual modulation below 6 GeV.**

- **CDEX-10:**

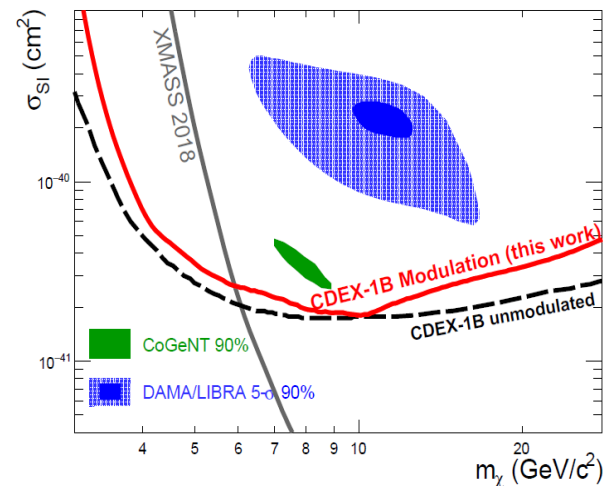
- ✓ The most sensitive result on **SI χ -N elastic scattering at 4-5 GeV.**



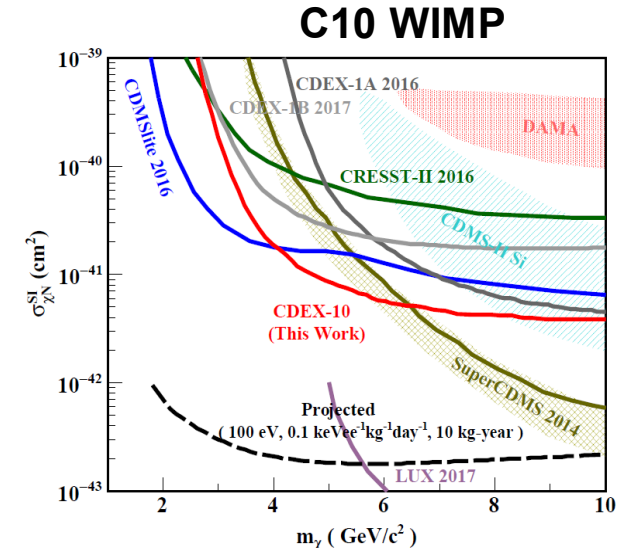
Chin. Phys. C 42, 023002 (2018)

2026/10/29

C1B WIMP Annual Modulation



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

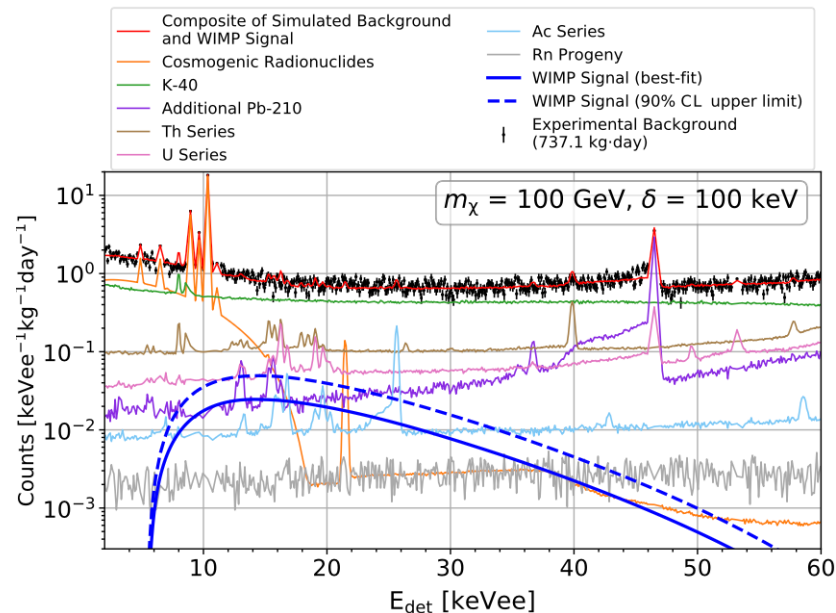
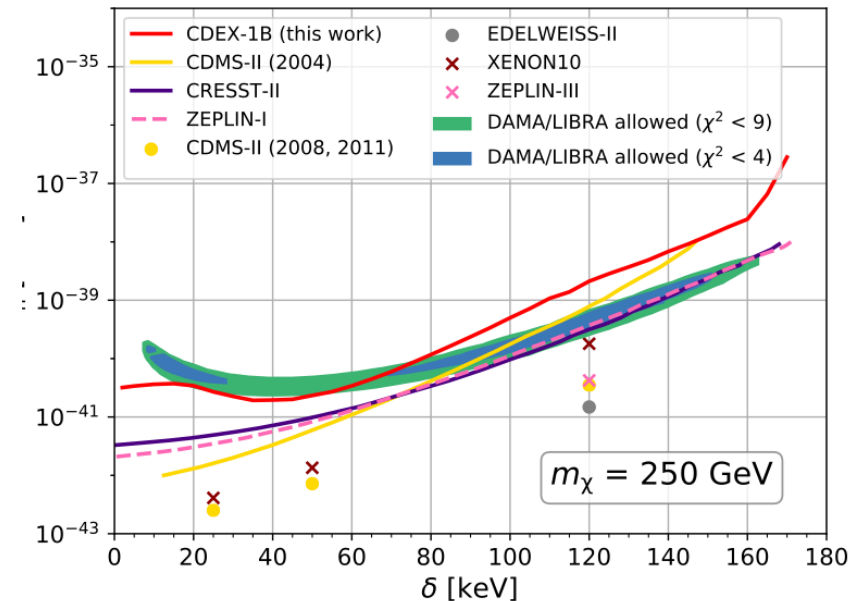


Phys. Rev. Lett. 120, 241301 (2018)

χ -N inelastic scattering results

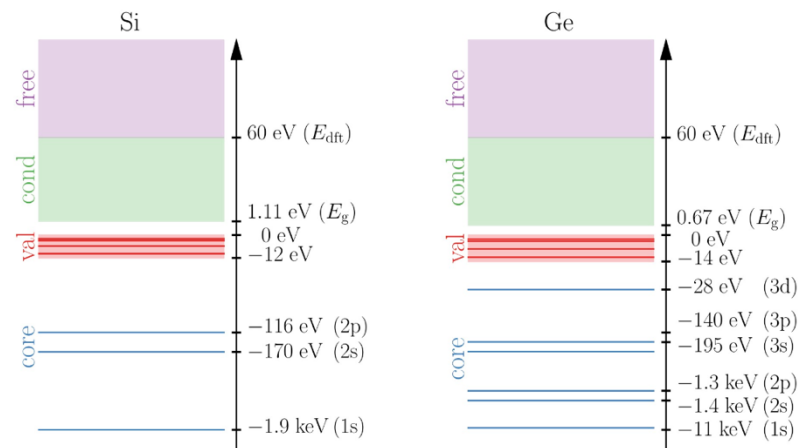
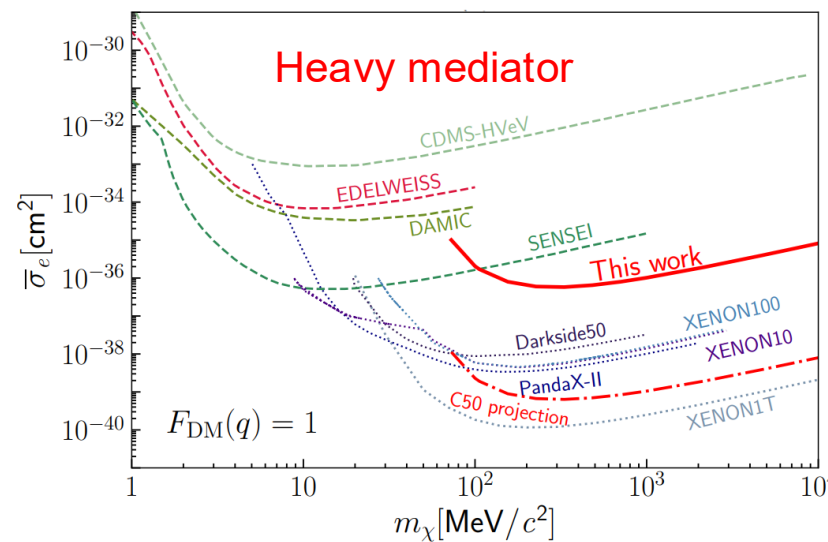
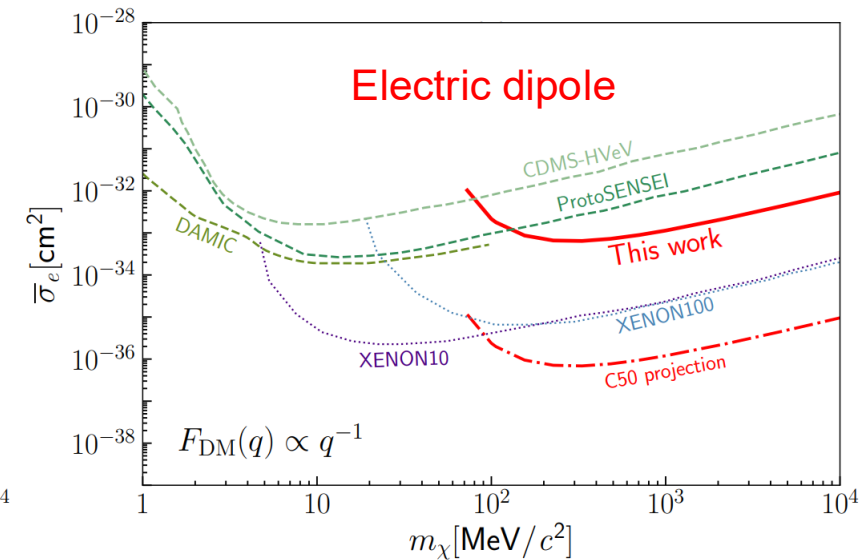
- Use CDEX-1B 737.1 kg day dataset
- Study **WIMP inelastic scattering** for different splitting energy δ
- Construct **accurate background model** of CDEX-1B
- Exclude several DAMA/LIBRA allowed regions

Phy. Rev. D 112, 112025 (2025)



χ -e scattering in Ge detectors

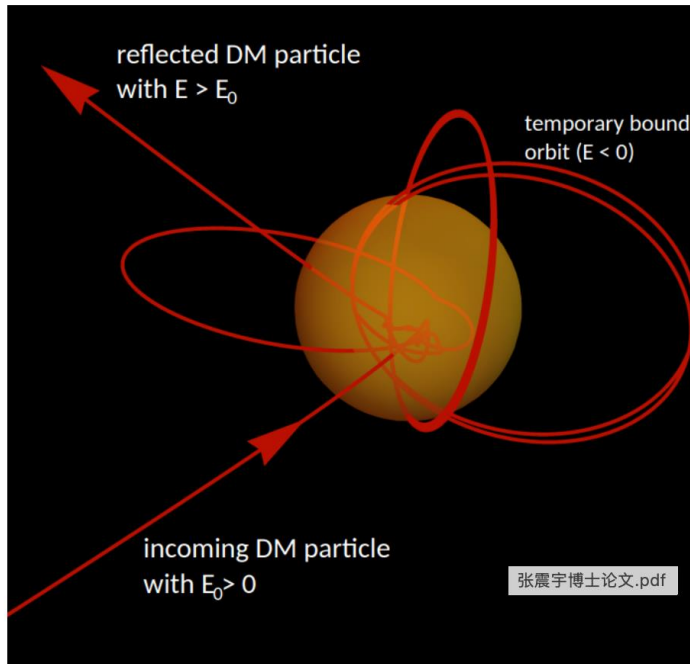
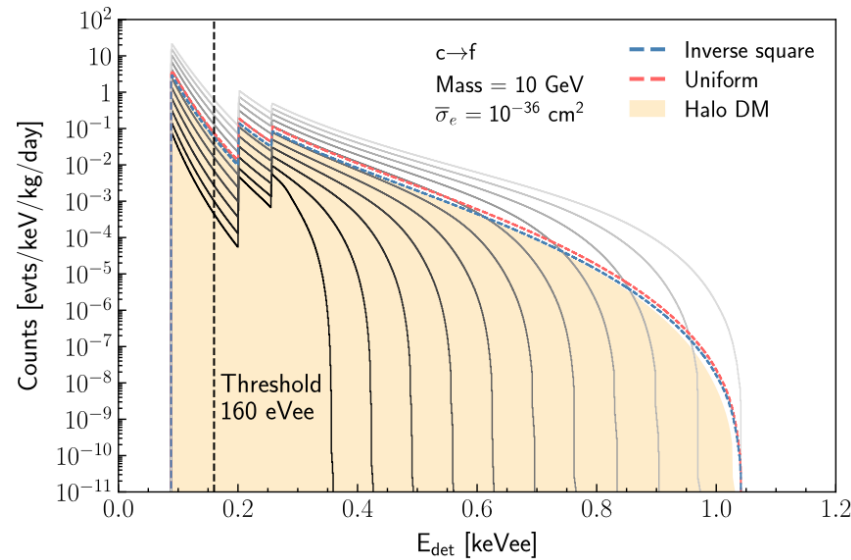
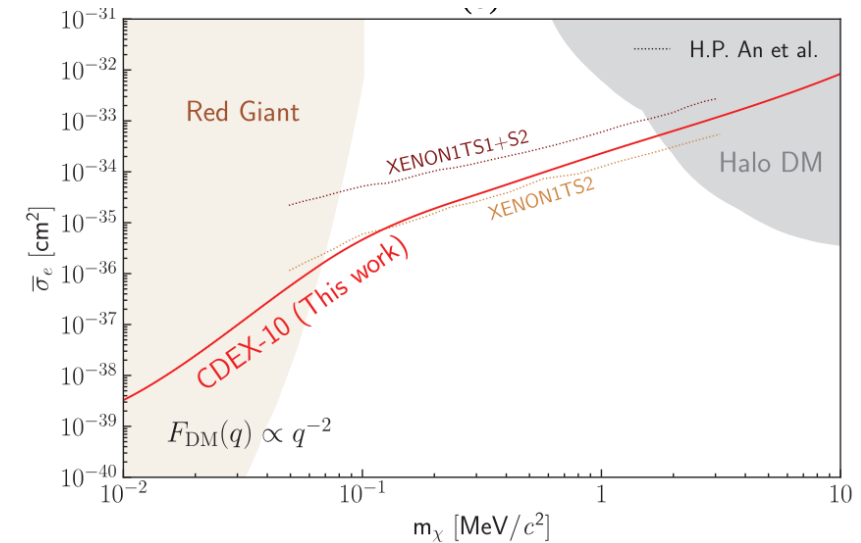
- $\chi - e$ scattering in semiconductor difficult to compute due to electron state;
- Using **EXCEED-DM** package combine DFT & semi-analytical method to evaluate $\chi - e$ scattering in Ge;
- Leading results for the **heavy mediator /electric dipole** coupling scenario among solid detector experiments;



Phys. Rev. Lett. 129, 221301 (2022)

Solar electron boosted DM analysis

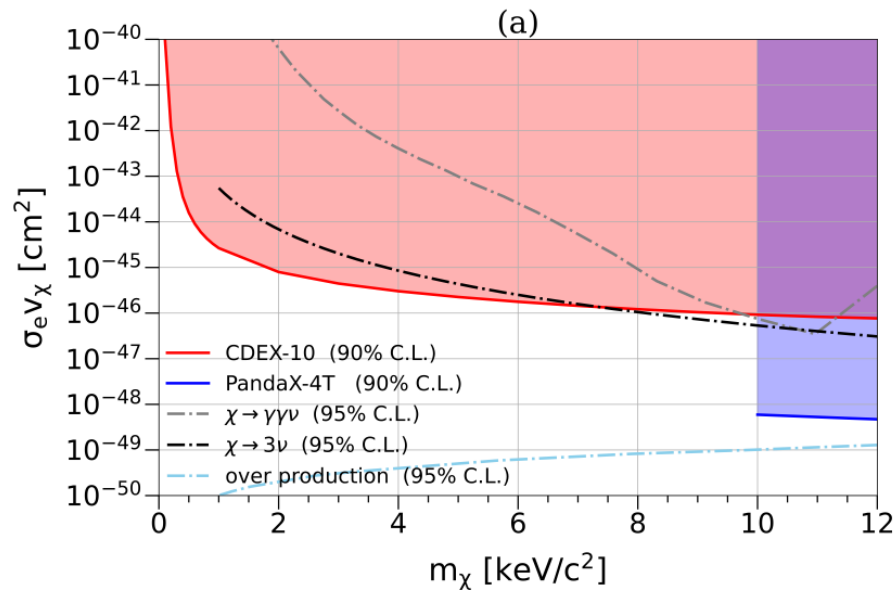
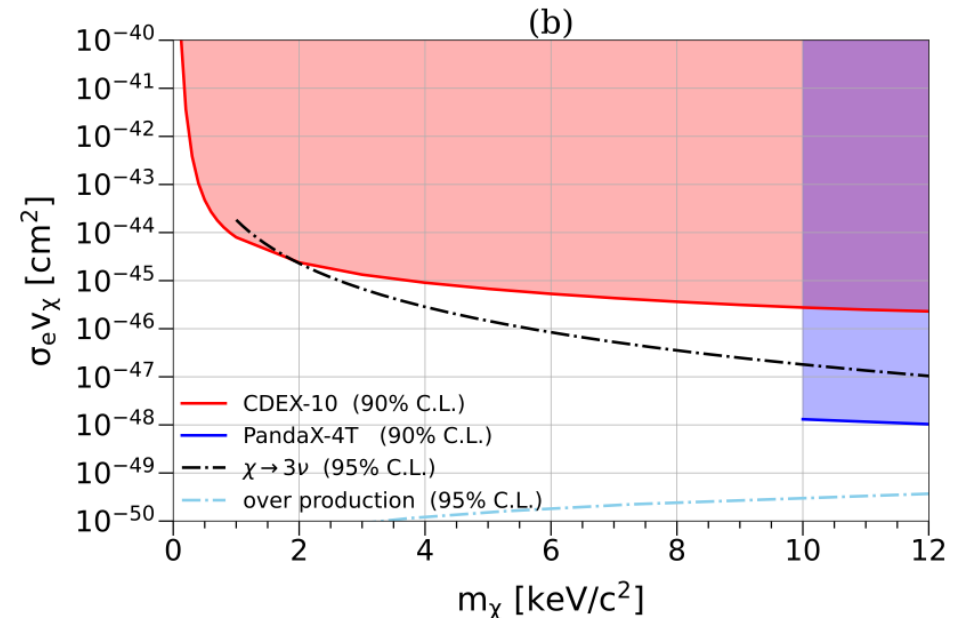
- Consider the DM **boosted by electrons in the Sun**;
- Develop novel velocity component analysis (VCA) method for **swift boosted DM-e scattering calculation** in Ge detectors
- **Best sensitivity under DM mass 0.1 MeV** in light mediator scenario



Phys. Rev. Lett. 132, 171001 (2024)

Fermionic DM electrons absorption

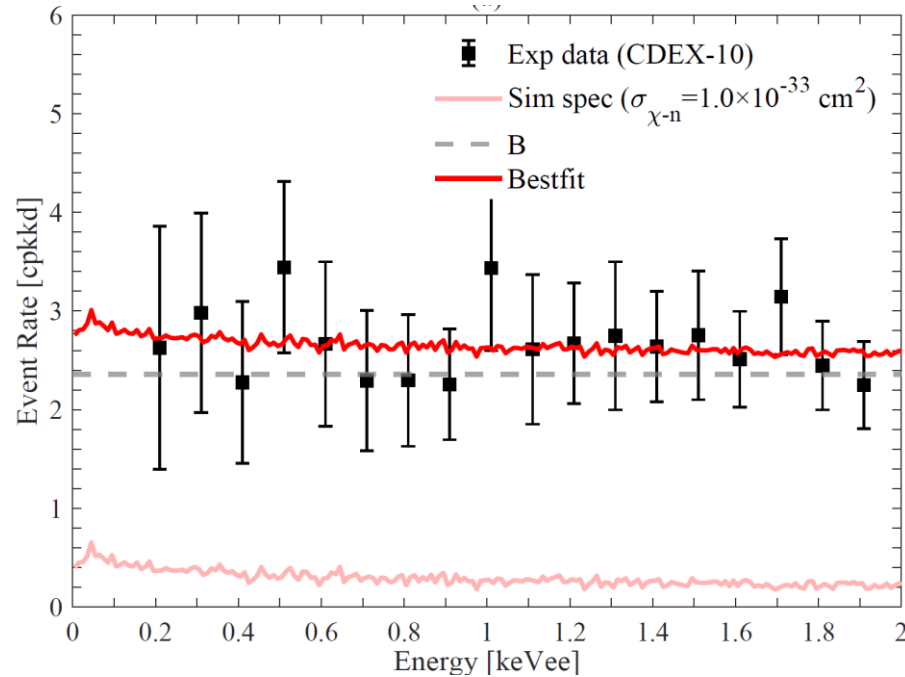
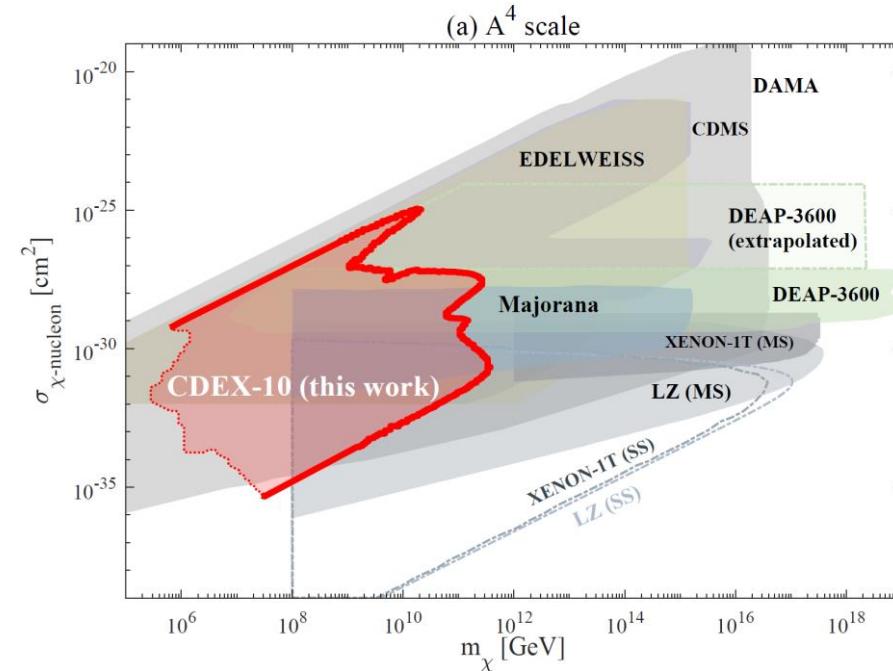
- The fermionic dark matter absorbed by electrons: $\chi + e^- \rightarrow \nu + e^-$
- Novel constraints for DM mass 0.1-10 keV is set using CDEX-10 data.



Phy. Rev. D 113, 032011 (2026)

Ultra-heavy DM study

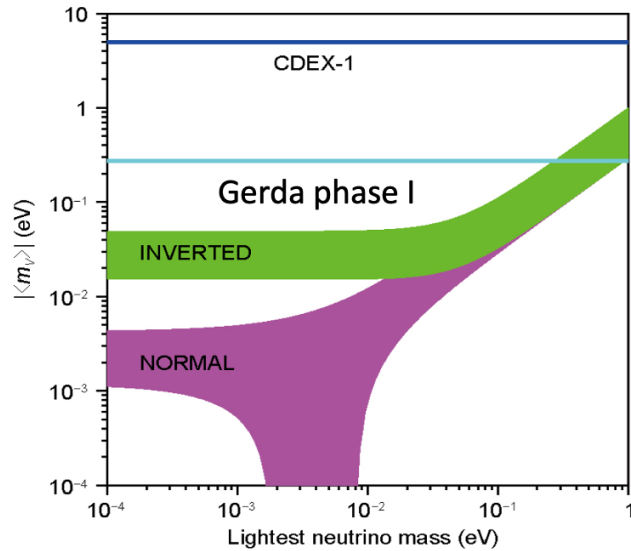
- Explore UHDM model covering DM mass range **10^6 - 10^{11} GeV**
- MC Simulation of whole UHDM scattering process, in mountains & detectors
- Best constraints with solid-state detectors below **10^8 GeV**



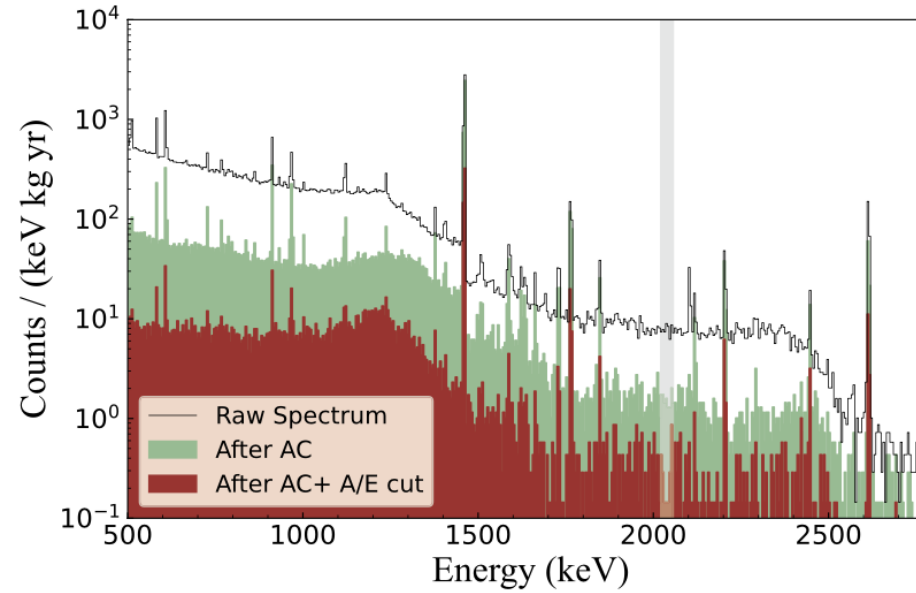
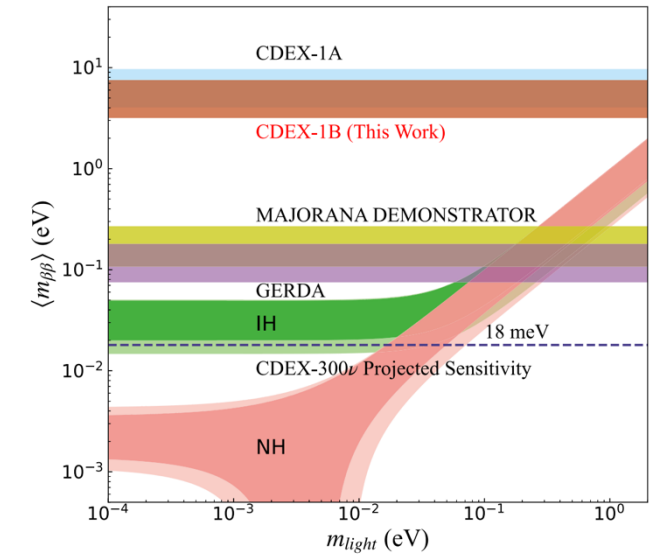
Phy. Rev. D 113, 052011 (2026)

CDEX $0\nu\beta\beta$ results

- **First ^{76}Ge $0\nu\beta\beta$ result in China in 2017:** $T_{1/2}^{0\nu} \geq 6.4 \times 10^{22} \text{ yr @90\% C.L.}$
- Apply **PSD and NaI AC-veto, 23 times bkg reduction** in ROI, achieve best CDEX $0\nu\beta\beta$ C.L.



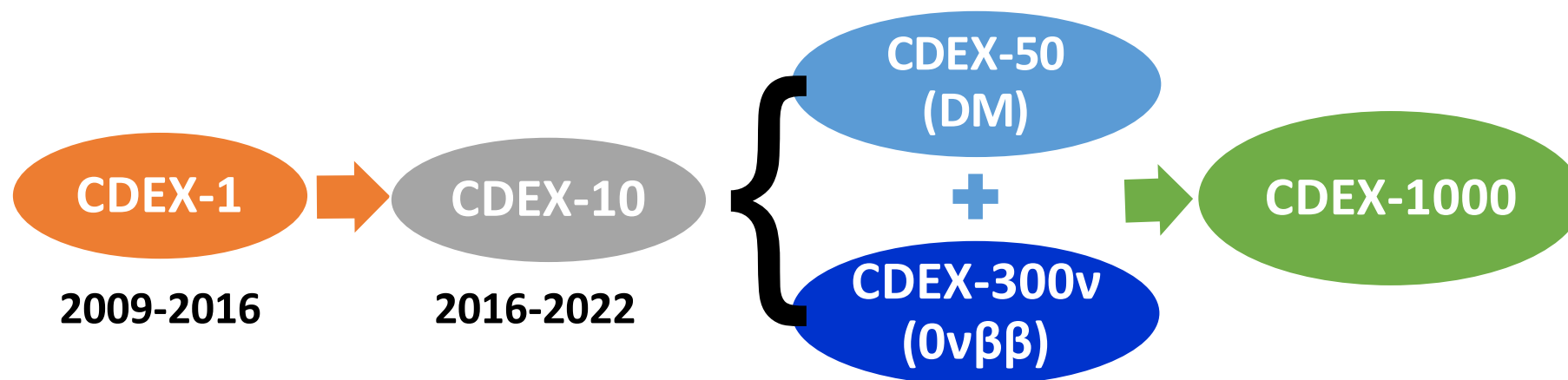
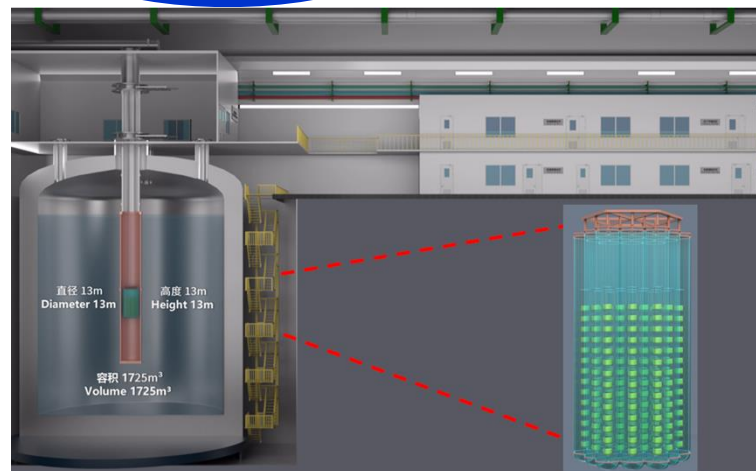
Science China P.M.A.
(2017) 071011



Chinese Physics C. 48, 10, 101001, 2024

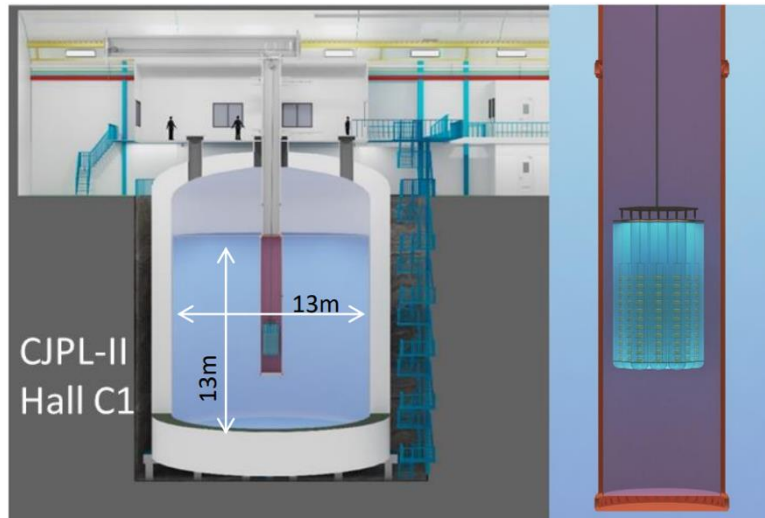
CDEX Roadmap: Next Stage

- CDEX-50 (2021-202X): **~50 kg Ge** detector arrays for **DM searches**
- CDEX-300v (2021-202X): **~225 kg enriched Ge** detector arrays for **$0\nu\beta\beta$ Exp.**



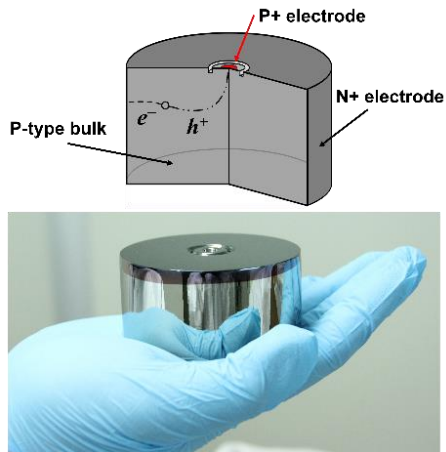
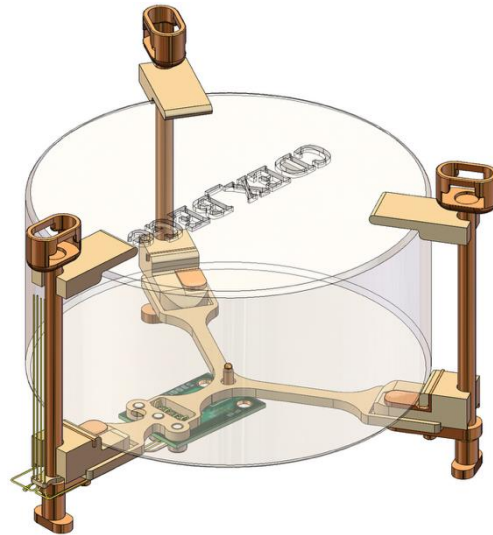
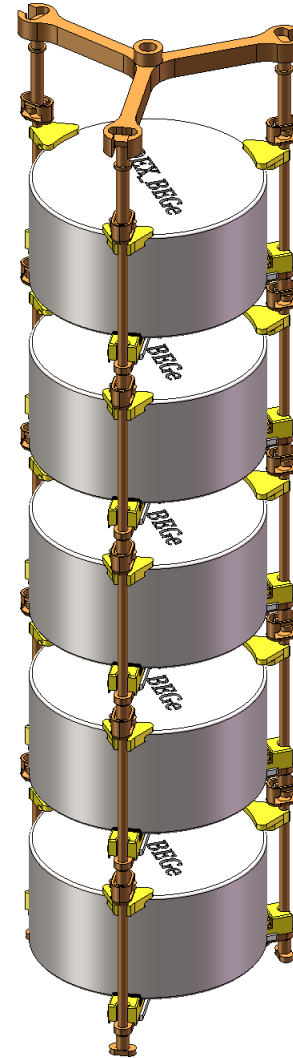
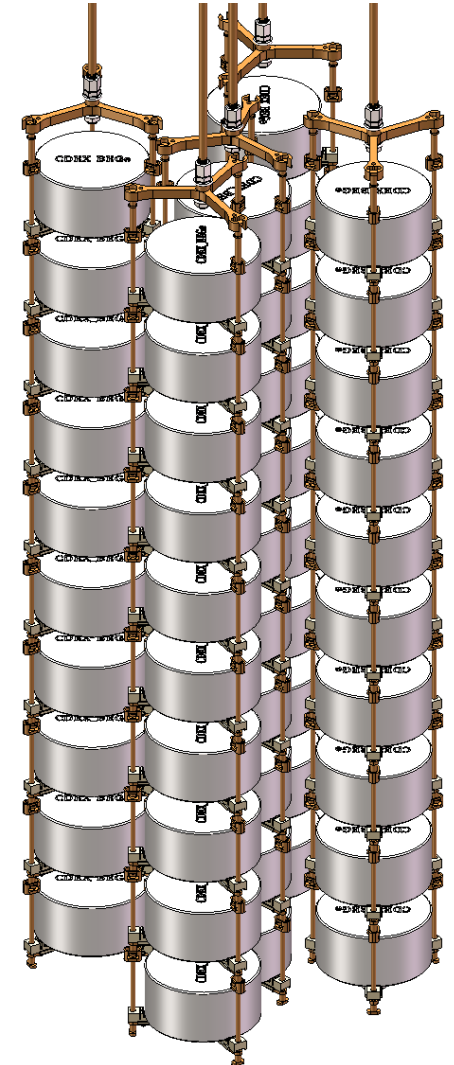
CDEX next stage in Large LN₂ Cryostat

- CDEX has build the **largest underground LN₂ cryostat** in CJPL-II C hall;
- LN₂ volume: **Φ13m×H13m, ~1725 m³**, providing cooling & shielding
- Top 5 flanges for detector deployment: **1×Φ1.5 m, 4×Φ0.75 m**
- **Reentrant copper tube** containing LN₂/LAr submerged in cryostat
- LN₂ filling began in **2024/12**, LN₂ level reaches ~12 m



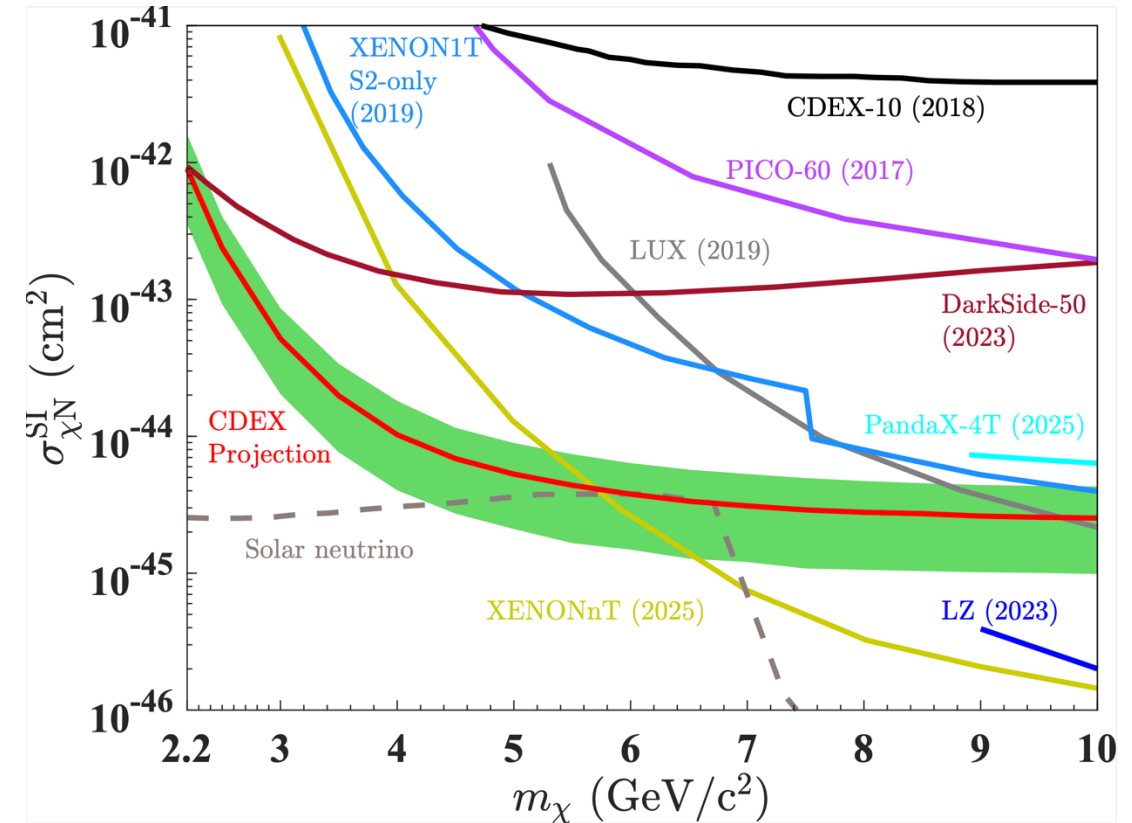
CDEX-50

- Ge detectors array directly immersed in LN_2
- Composed of **5 strings, 10 detectors/string**
- Total mass reaches **~ 50 kg**



CDEX-50 Projected Sensitivities

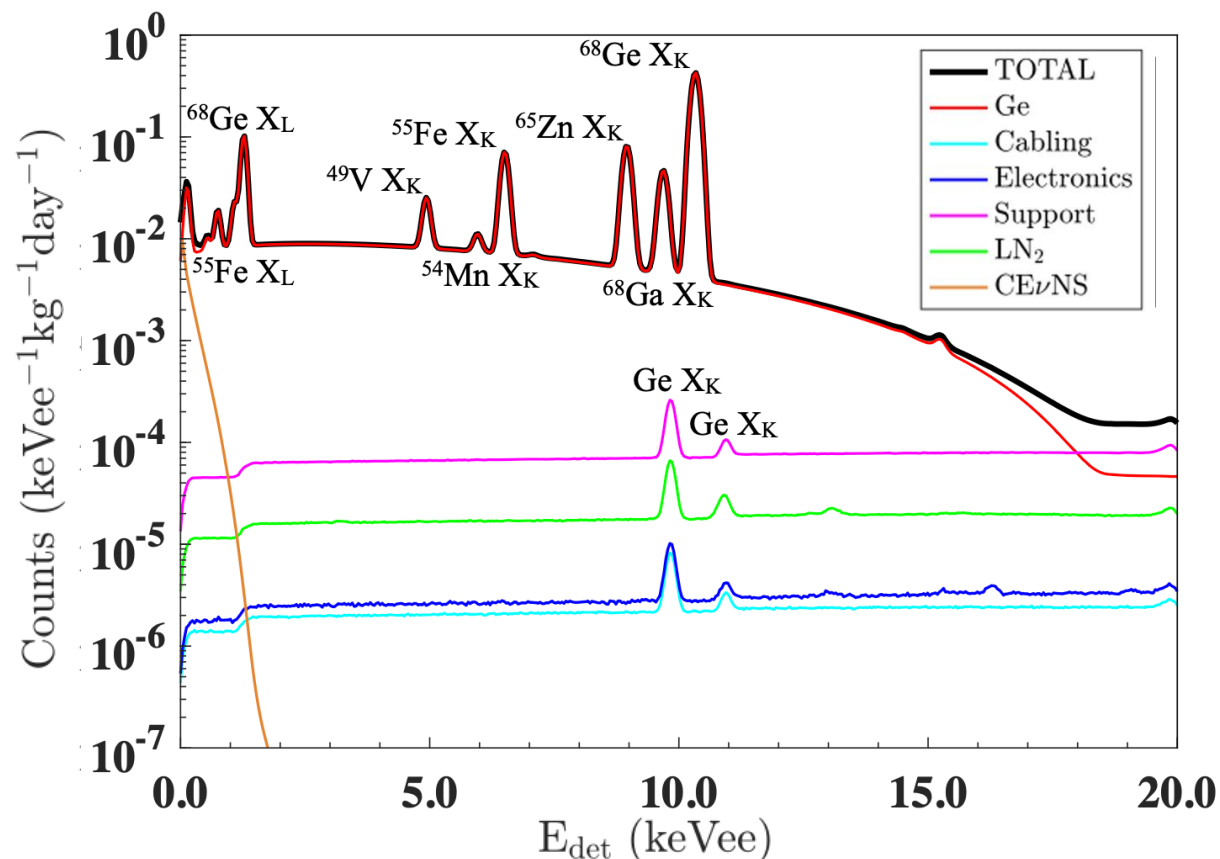
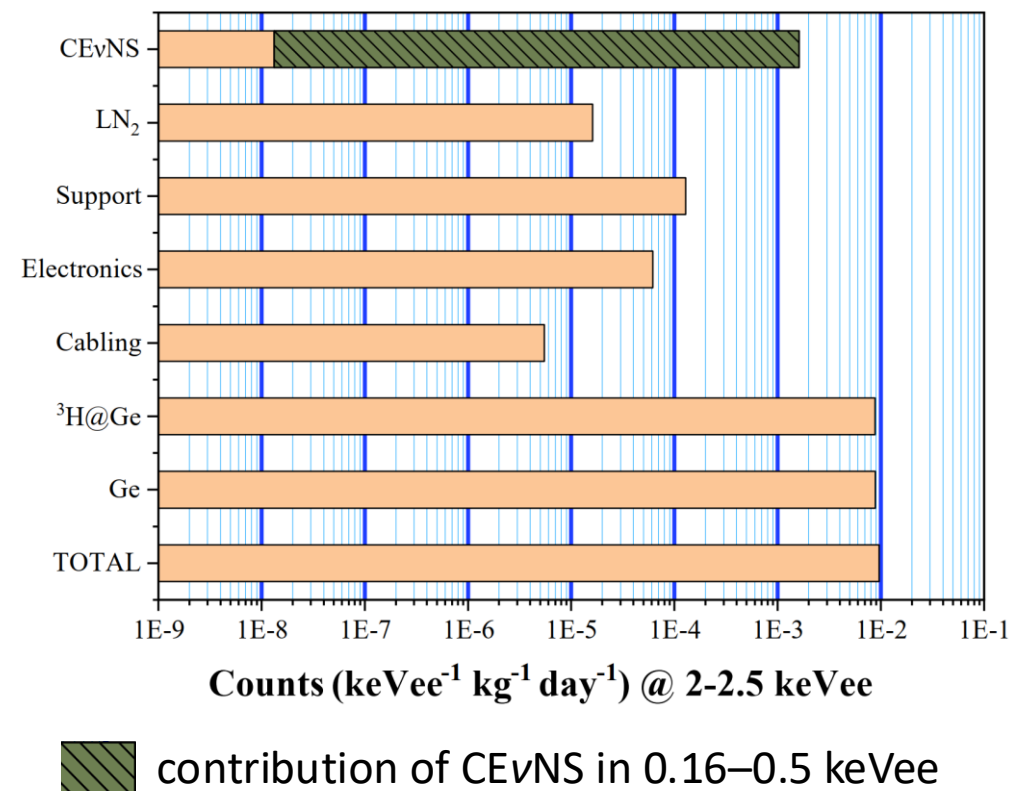
Physics Goal	
WIMP Sensitivity	10^{-44} cm^2
Multi- Physics Channel	Axion, Dark Photon...
Detector Parameter	
Detector mass	50 kg
Background level	1E-2 cpkkd @ 2-4 keV
Analysis threshold	160 eV



JCAP 07 (2024) 009

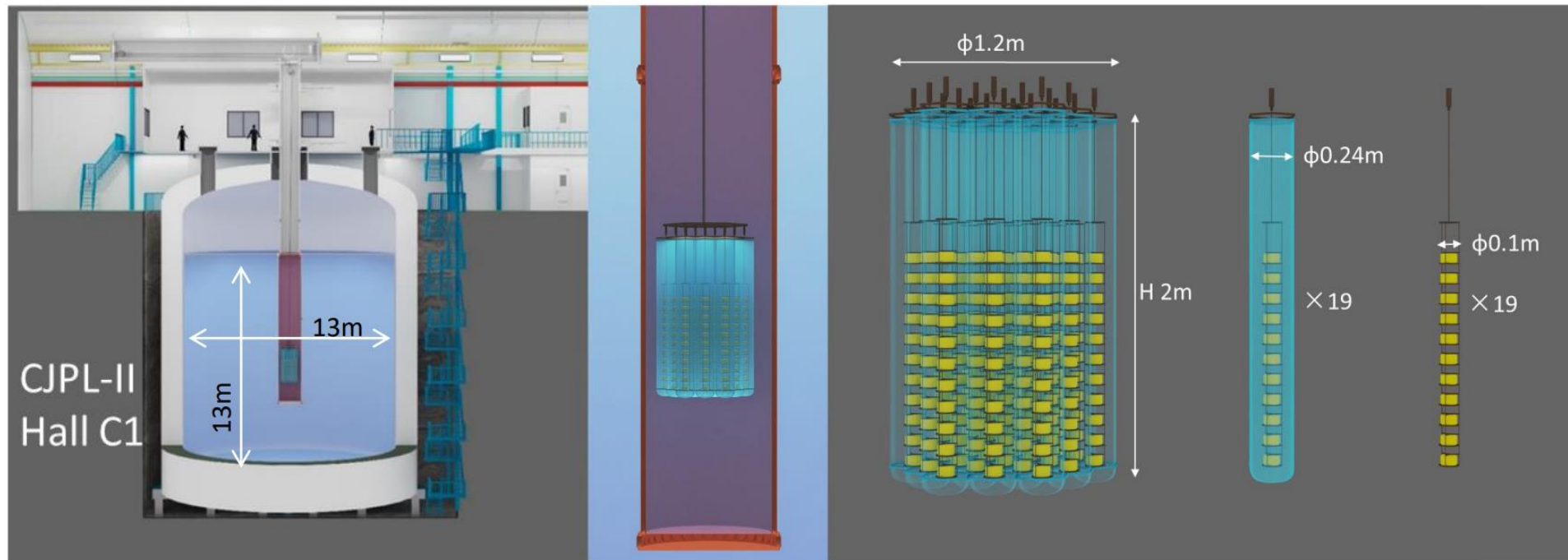
CDEX-50 Bkg Model & Simulation

- Background: **<0.01 cts/(keV·kg·day) @ 2-4 keV**
- Mainly comes from the **^3H and cosmogenic radionuclides** in crystal



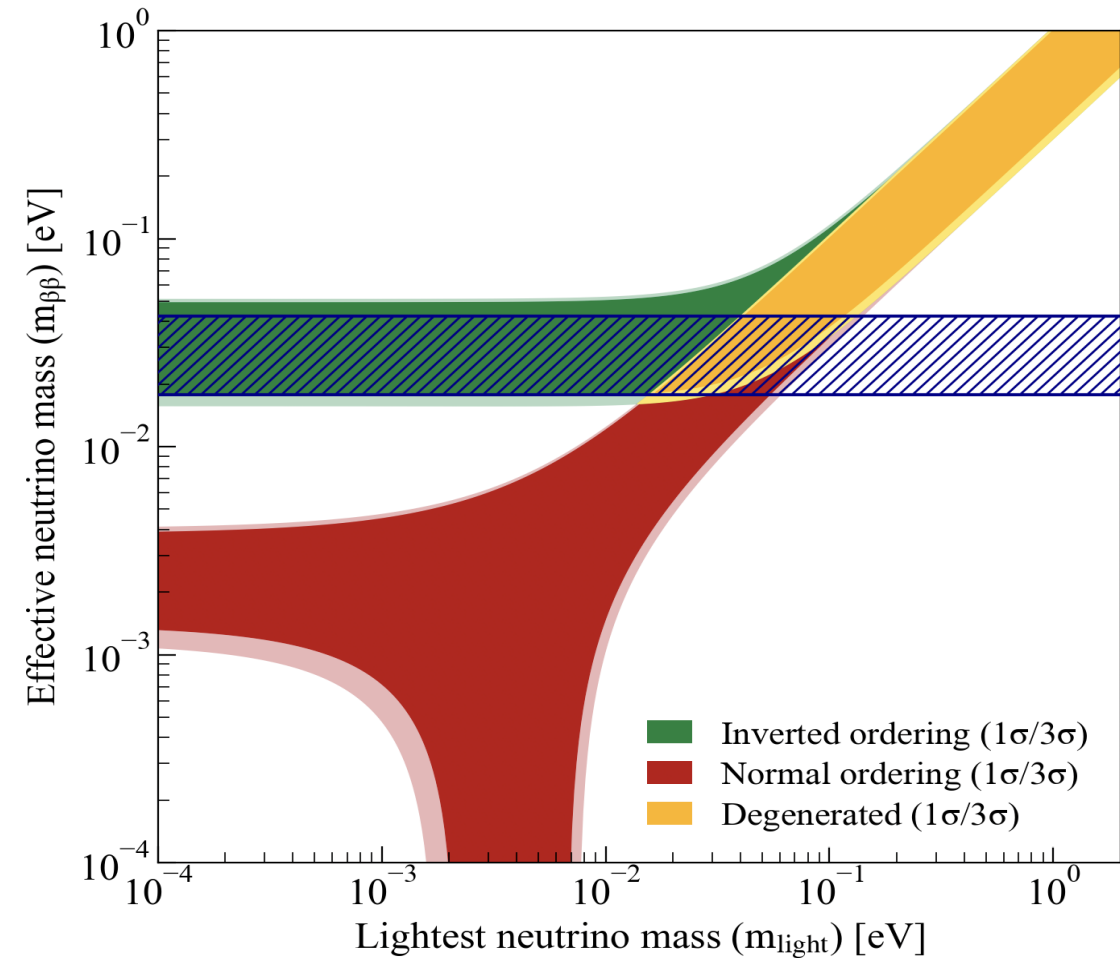
CDEX-300v

- Deployed in reentrant tube containing **~20 ton LAr** submerged in LN₂ cryostat
- Detector array: 19 strings, 10-11 det./string, **~200 det. total mass ~225 kg**
- ⁷⁶Ge enriched detector: **≥ 86%**



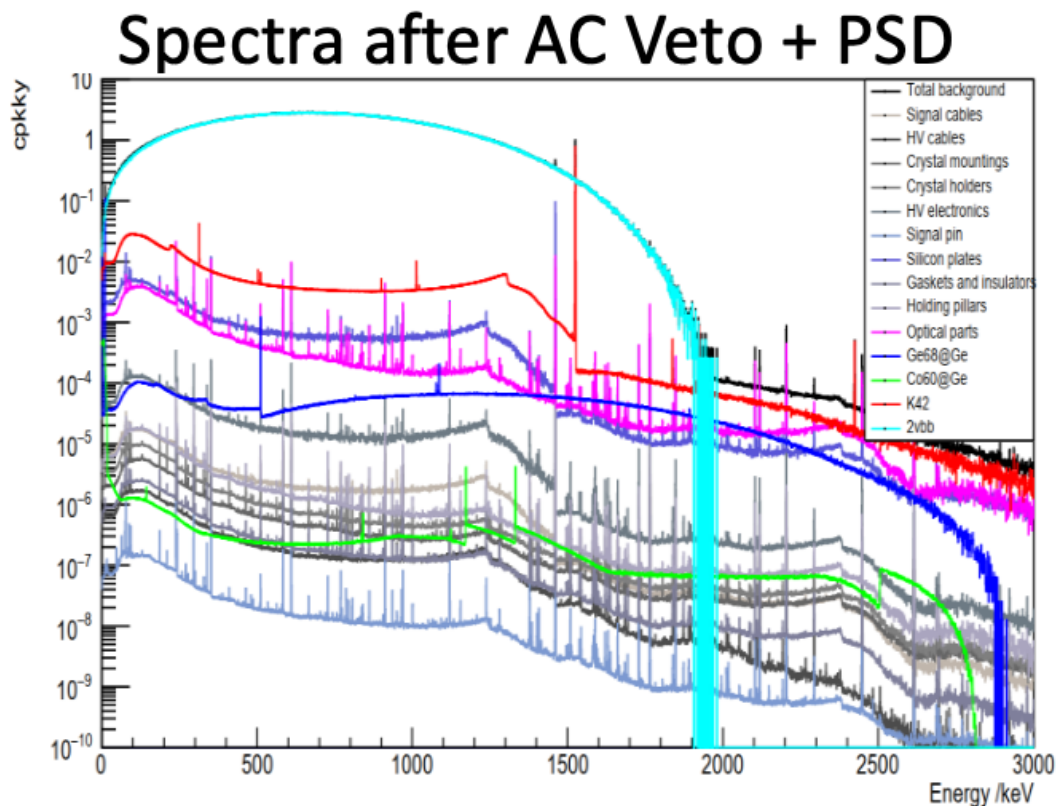
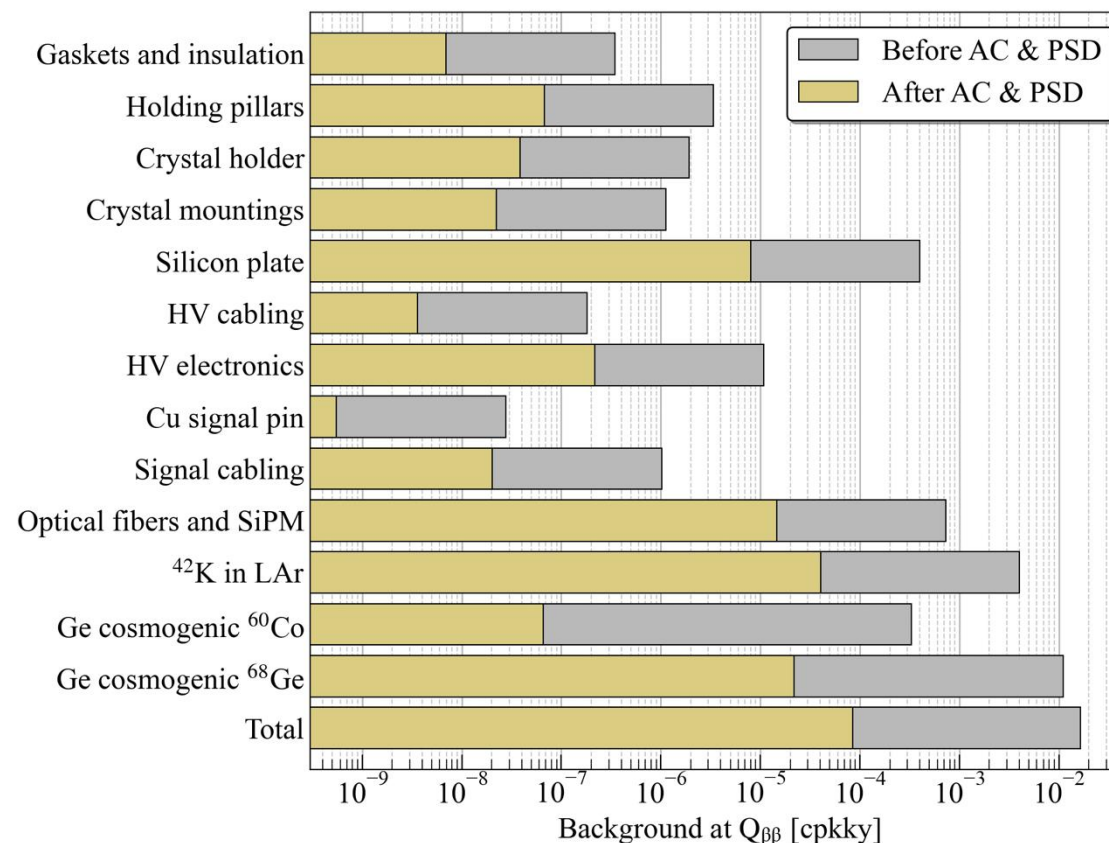
CDEX-300v Physics Goal

Physics Goal	
$0\nu\beta\beta$ half-life	3.06×10^{27} yr (exc) 1.91×10^{27} yr (dis)
Effective mass	$18.5 \sim 44.2$ meV (exc) $23.4 \sim 55.8$ meV (dis)
Detector Parameter	
Detector mass	225 kg
Ge-76 enrichment	$\geq 86\%$
Signal efficiency	76%
Background level	$1\text{E-}4$ cpkky @2 MeV
Energy resolution	2.5 keV FWHM @2 MeV



CDEX-300v Bkg Model & Simulation

- LAr anti-coincidence and Pulse Shape Discrimination can greatly lower the bkg;
- After AC&PSD cut, bkg in ROI **mainly comes from LAr**



Technical R&D Towards Next-stage

- **Large scale** detector array

10 kg $\rightarrow$ 50 kg / 225 kg

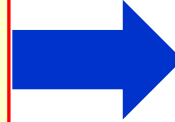
- **Low** background

2 cpkcd $\rightarrow$ 10^{-2} cpkcd @2-4 keV

0.33 cpkky $\rightarrow$ 10^{-4} cpkky @2 MeV

- **Prototype detectors $\rightarrow$ Strings**

- **Strings $\rightarrow$ Arrays**



- **Large shielding and cooling system**

- **Ge detector fabrication**

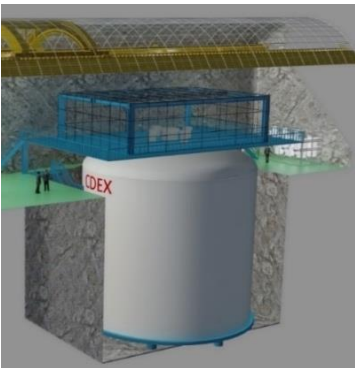
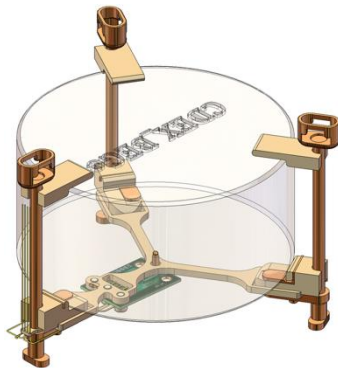
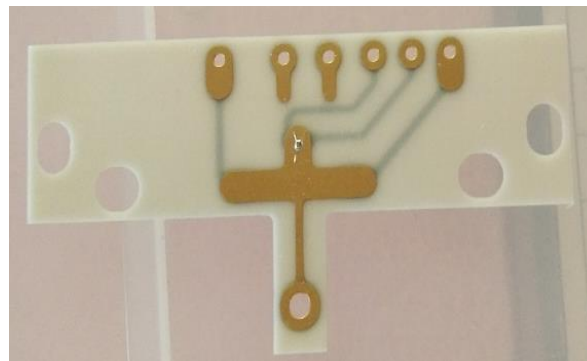
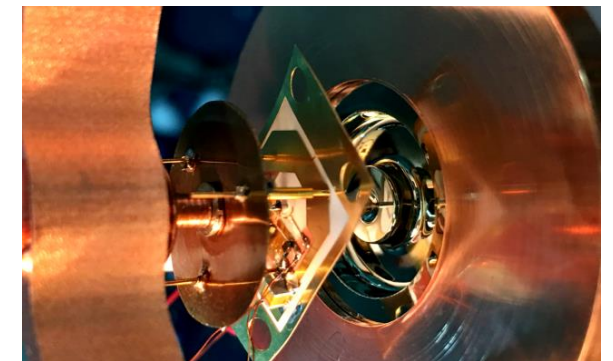
- Low mass detector array design

- Low bkg material

- Low noise ASIC Front-end Electronics

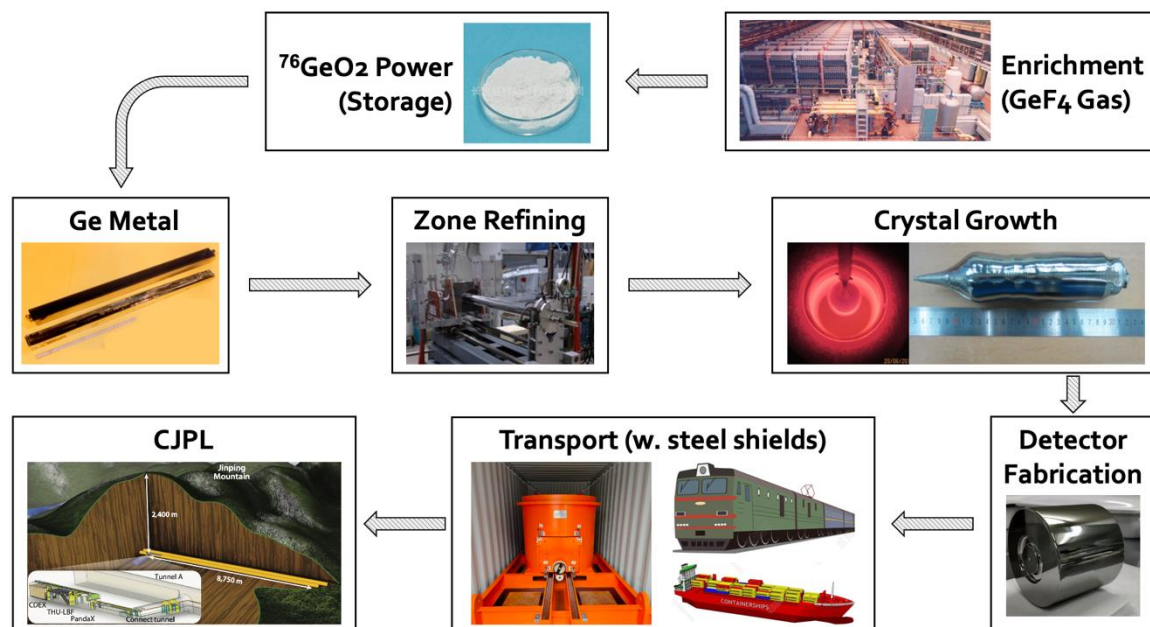
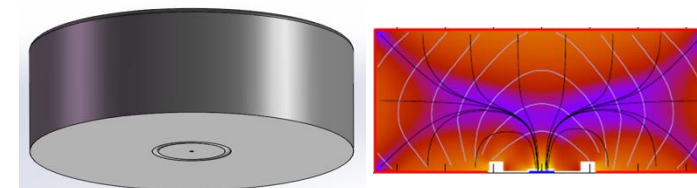
- **Cosmogenic bkg control**

- **High-speed readout electronics**

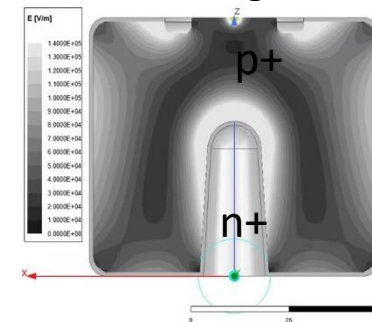


Ge Detector

- Whole technical route of enriched detector fabrication established
- **Cosmogenetic bkg control** during the whole production & transportation process
- BEGe (Baseline) + ICPC (Optional);



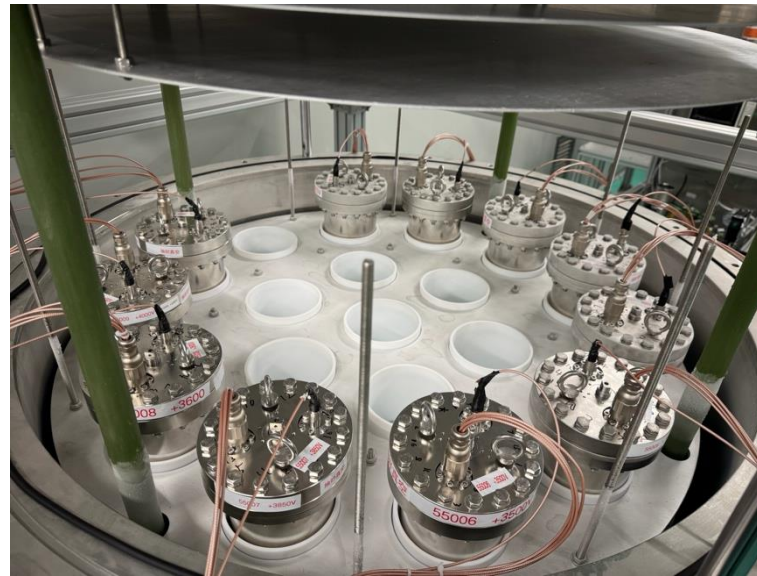
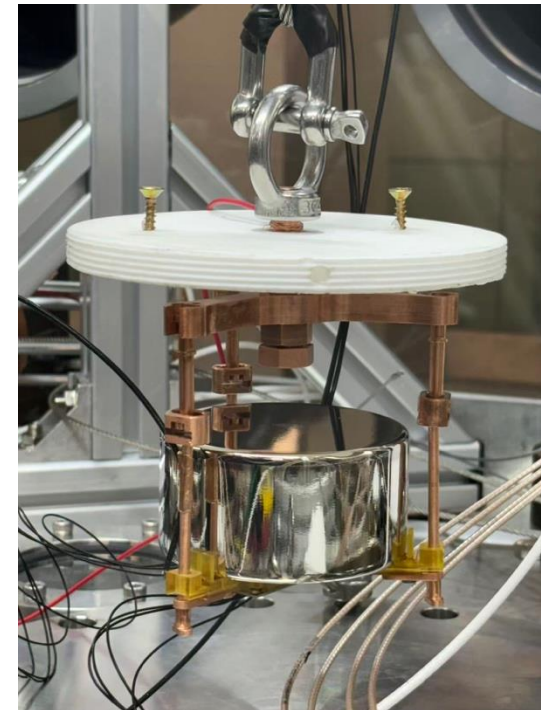
BEGe: Broad Energy Germanium
Φ 80 × 40 mm, mass ~ 1.12 kg



ICPC: Inverted Coaxial Point Contact
Φ 80 × 80 mm, mass ~ 2 kg

Ge Detector Test in CJPL

- Cryostat test & bare Ge in LN₂ stability test, **test & storage system** established
- Array mechanical structure & front-end electronic test is underway

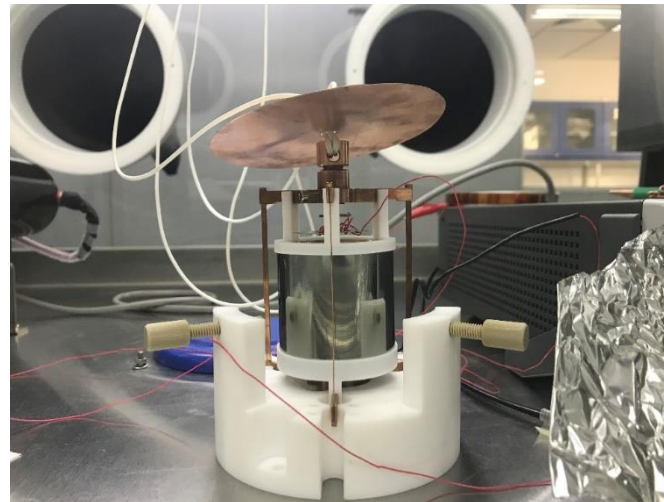


Ge Crystal Growth & Detector Development

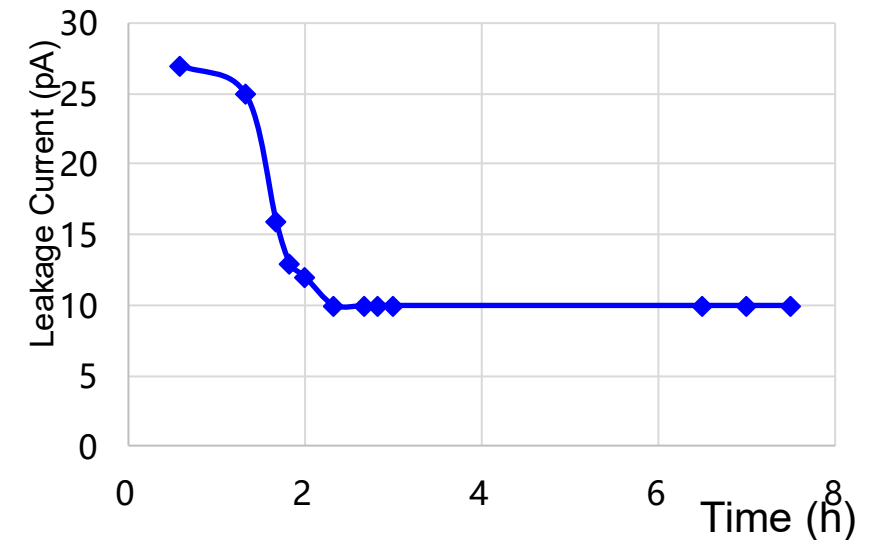
- CDEX are developing the **Ge crystal growth technology**
- CDEX has self-developed HPGe detectors
- Completed bare Ge in LN₂ long stability test



Impurity: $\sim 10^{10} \text{ cm}^{-3}$.
Dislocation: $< 5000 \text{ cm}^{-2}$.



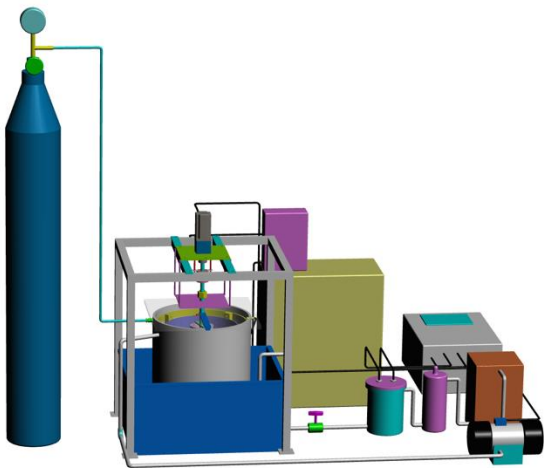
PPC: $\phi 50 \text{ mm} \times 50 \text{ mm}$
Bare Ge in LN₂



Leakage current of bare Ge in LN₂

Underground Production of Material & Detector

- **E-forming copper** production prototype tested, planning to move to CJPL-II C1
- U/Th analysis by ICP-MS, blank sensitivity $\sim 10^{-13}$ g/g
- **Ge crystal growth & detector fabrication** facility is installing in CJPL-II B1



E-forming setup



ICP-MS

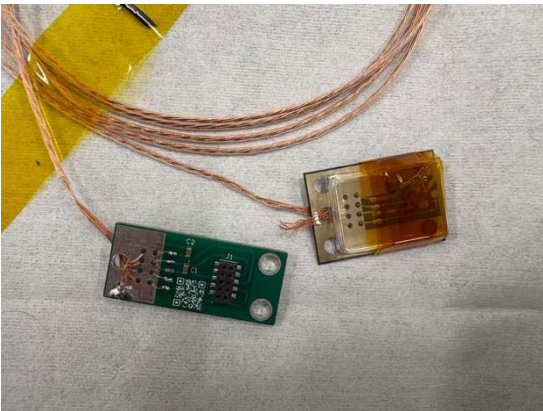


Ge detector fabrication facility



Front-end Electronics

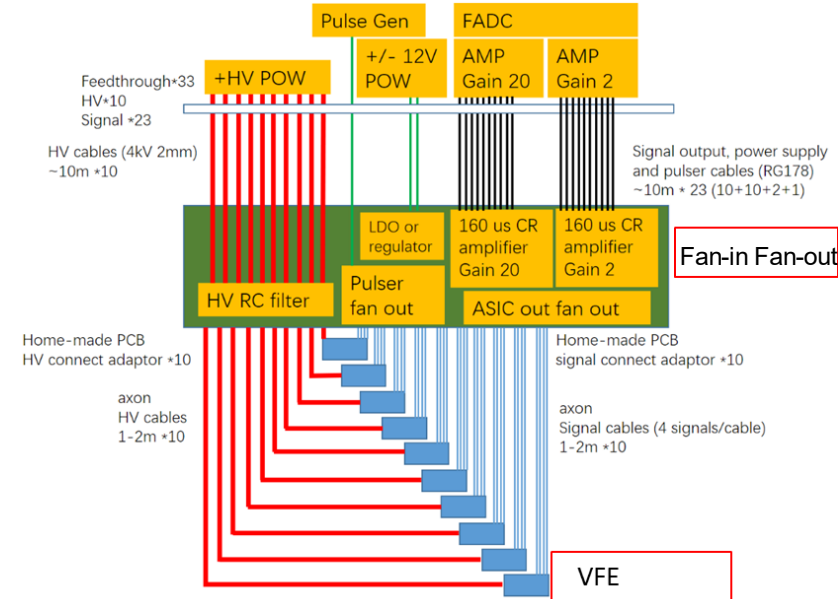
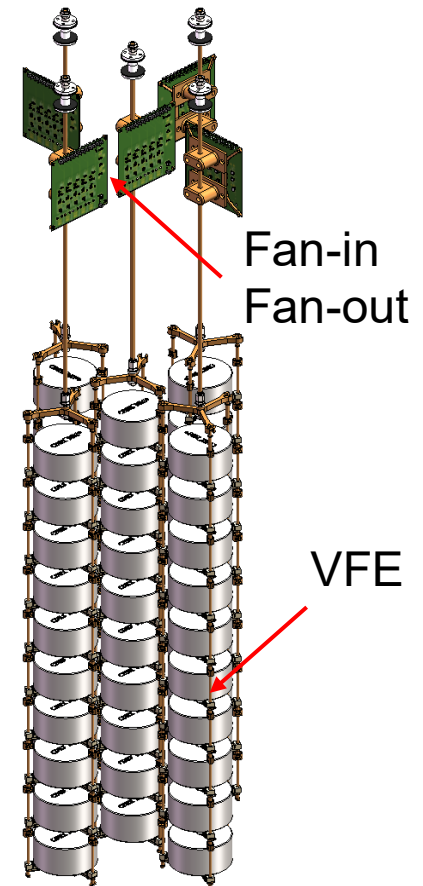
- Light DM search: **low-noise/threshold, low bkg;**
- **VFE** (Very Front-end) ASIC preamplifier + **Fan-in Fan-out** for filter & amplification
- VFE @ 77K:
 - ENC **~ 10 e⁻; silicon substrate;**
- Fan-in Fan-out: HV filter, $\times 2/20$ gain output, fan-in fan-out signal



Silicon substrate ASIC

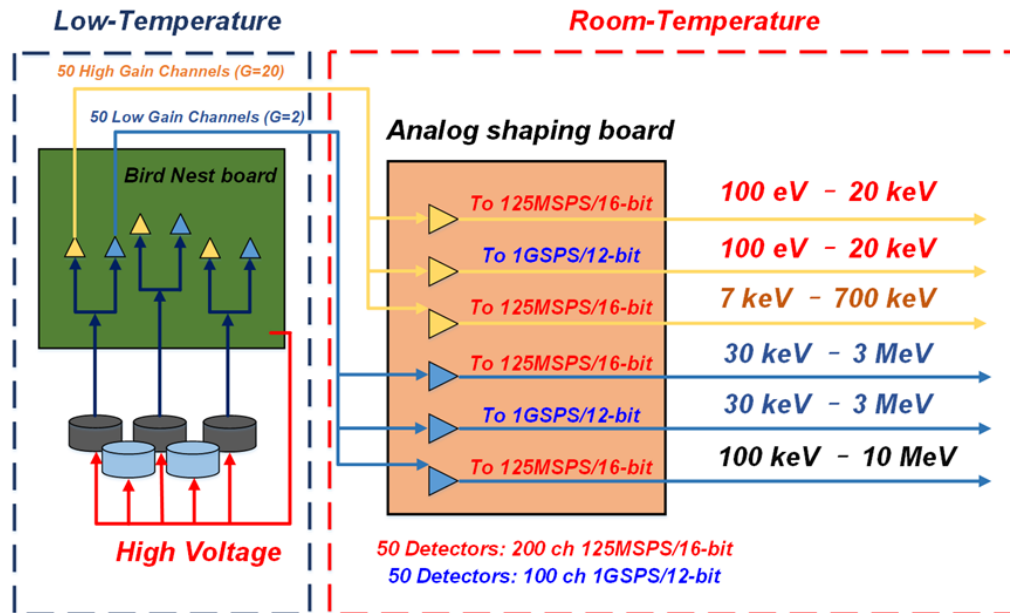
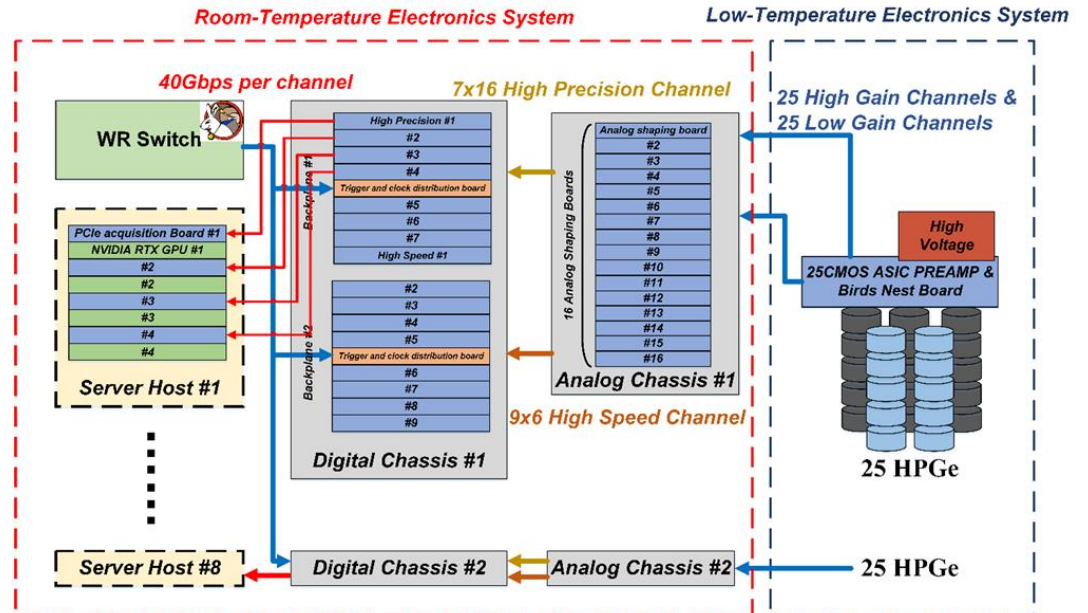


Fan-in Fan-out



Read-out Electronics

- **High-speed high-precision** readout for digitalizing and storage
- Front-end output → 6 channel analog shaping output
- 50 detectors → 200 high-speed ADC channel & 100 high precision ADC channel



Summary

- CDEX: unique advantages of Ge detectors for light DM search and Ge-76 $0\nu\beta\beta$
- CDEX-1&10 accumulate numerous data and achieve many physics results
- CDEX-50 & CDEX-300v construction underway @ CJPL-II C1 Hall
- R&D of key technologies has made considerable progress

Thanks for your attention!



中国暗物质实验
China Dark matter EXperiment

<http://cdex.ep.tsinghua.edu.cn/>



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

<http://cjpl.tsinghua.edu.cn>