CDEX and other Germanium/Xenon based dark matter searches

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On behalf of CDEX Collaboration
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CJPL 中国锦屏地下实验室 China Jinping Underground Laboratory

Symposium of the Sino-German GDT cooperation, Tubingen, German. April 8-12, 2013

Outline：

- CDEX Collaboration
- Recent status of CDEX
- China Jinping Underground Laboratory(CJPL)
- Summary

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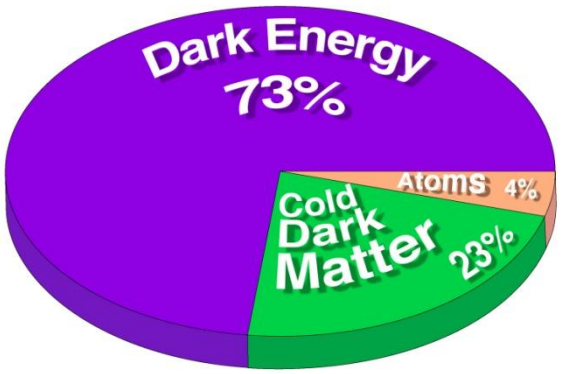
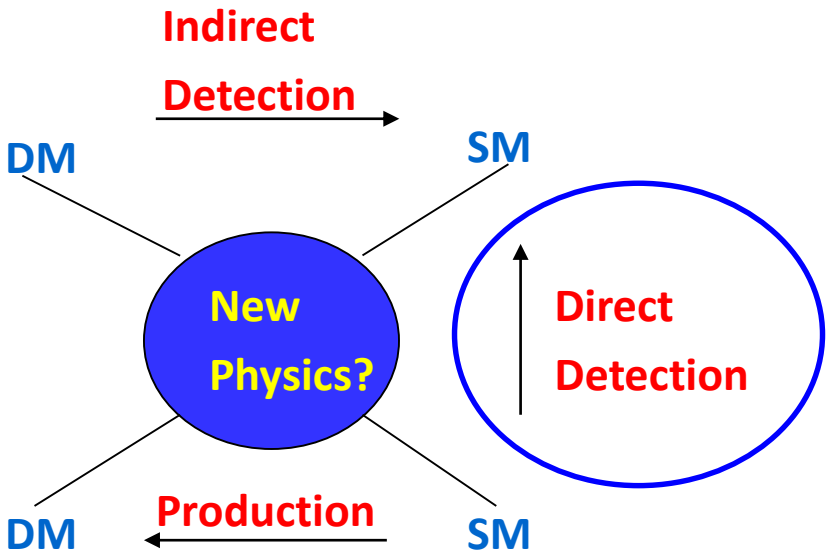
China Dark matter Experiment （CDEX）





CDEX Target：

Direct detection of cold dark matter with Ton-scale Point-Contact Germanium (PCGe) array detectors with ultra-low energy threshold(<300eV).

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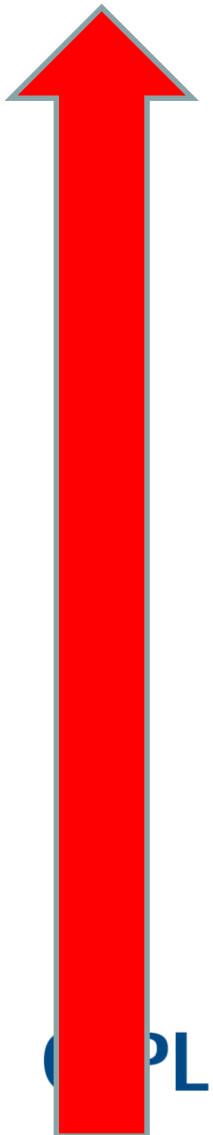
China Darkmatter EXperiment (CDEX) Established in 2009

- Tsinghua University, THU
- Sichuan University, SCU
- Nankai Univeristy, NKU
- China Institute of Atomic Energy, CIAE
- Ertan Hydropower Company, EHDC
- Collaborate with TEXONO and KIMS group.

Before and after CDEX born



2015: Design of CDEX-1T (based on new CJPL space)

2014: CDEX-10 10kg Ge array + LAr shielding

2013: CDEX-1 preliminary result(without B/S and ACV)

2011: CDEX-1 Detector test and data taking

2010: CJPL run; CDEX-1 20g Array +1kg PPCGe

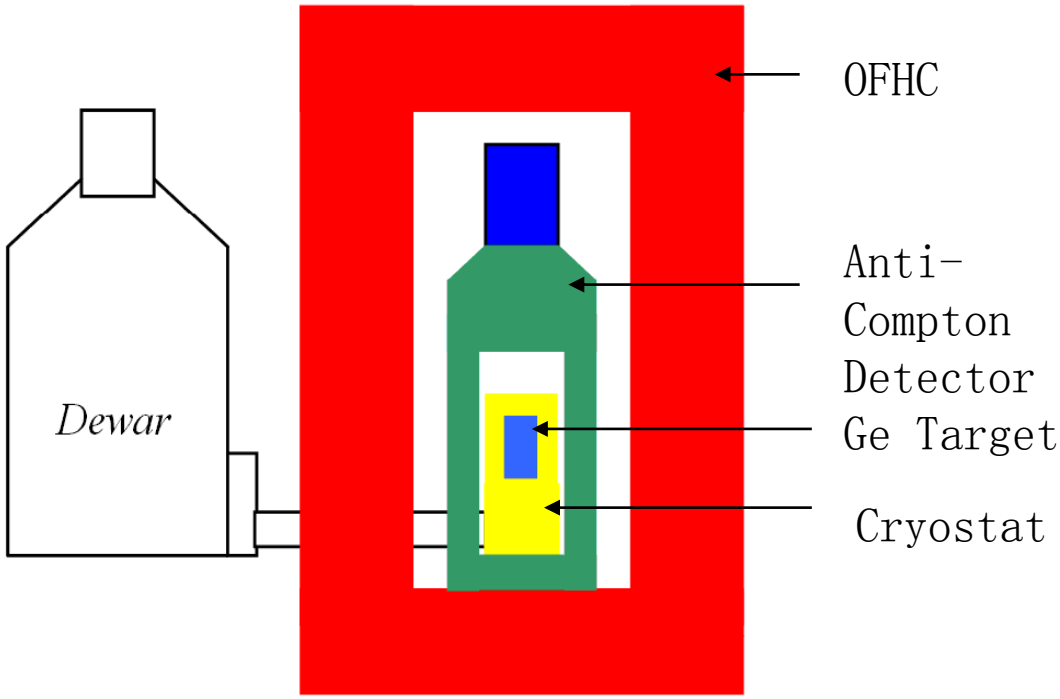
2009: CJPL planed; CDEX was born

2005: 5g Ge det. run in Y2L, S. Korea

2003: A group led by THU, joined by members from TEXONO and KIMS

CDEX-1kg @ CJPL

- ✓ Point-contact Ge array detector with ultra-low energy threshold (~300eV or less).
- ✓ Mass of Ge target: 20g, 1000g.
- ✓ Further ultra-pure crystal serve as active shielding and anti-compton detector.



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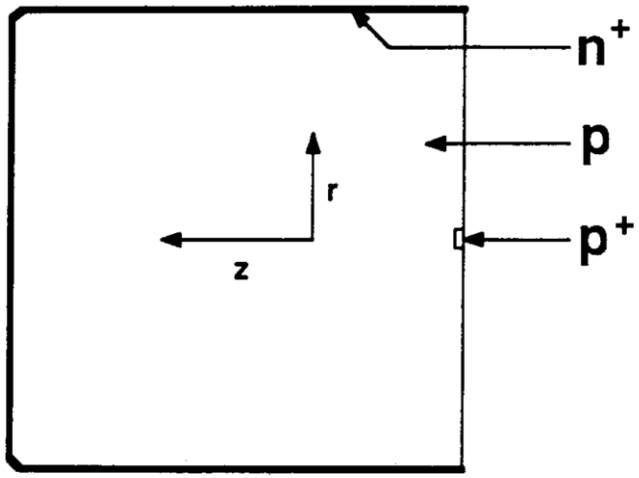
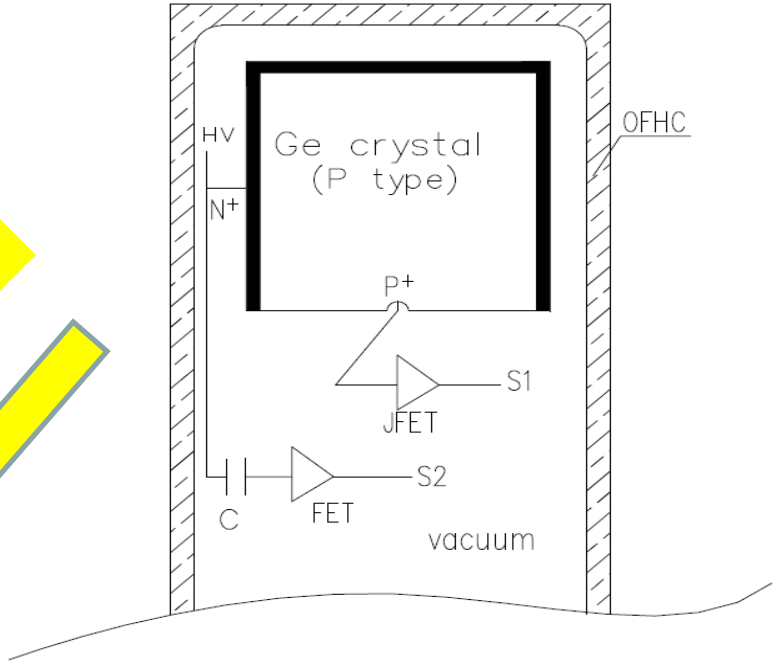
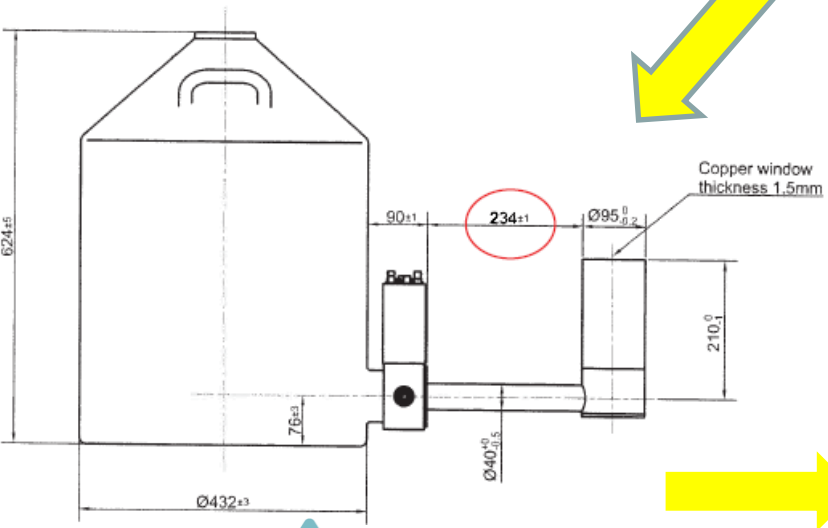
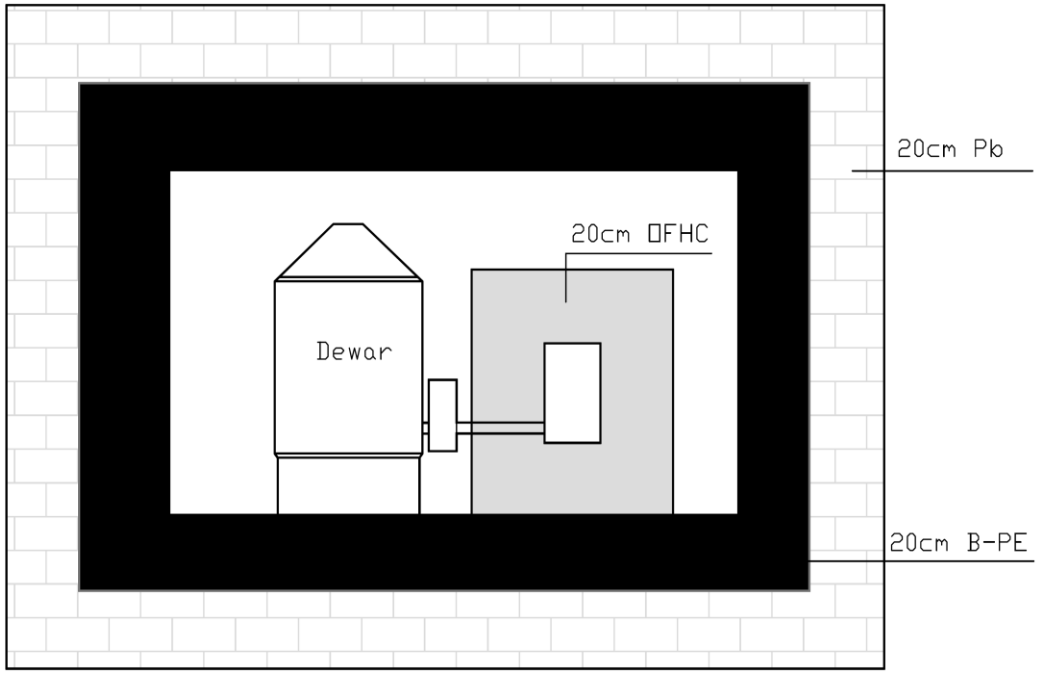


1kg PPCGe Crystal







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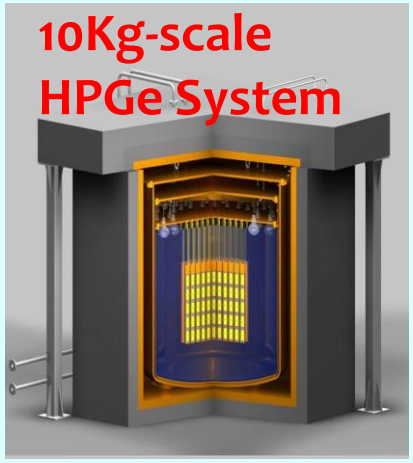
CDEX-1 Shielding System

PE shielding room



CDEX-1 Shielding system

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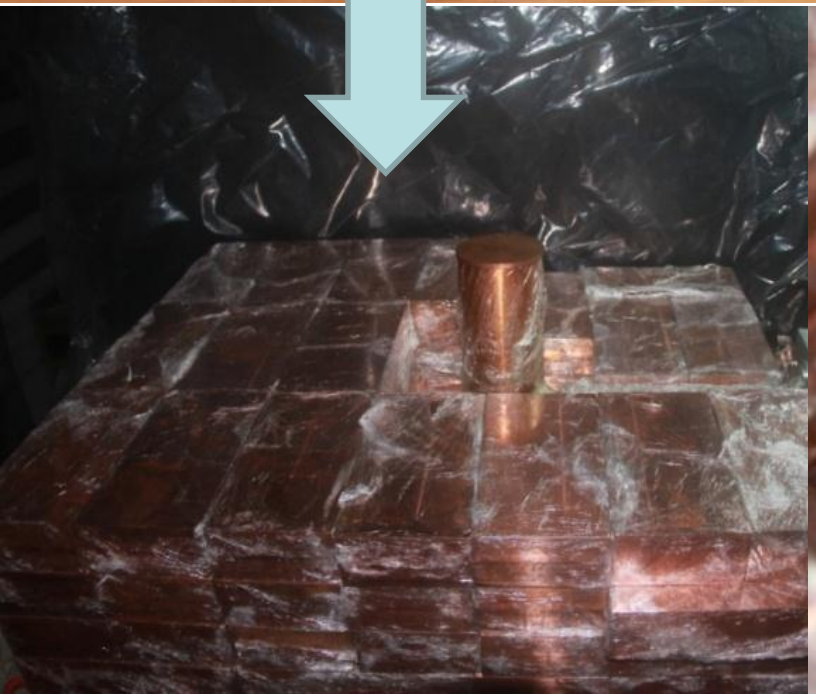
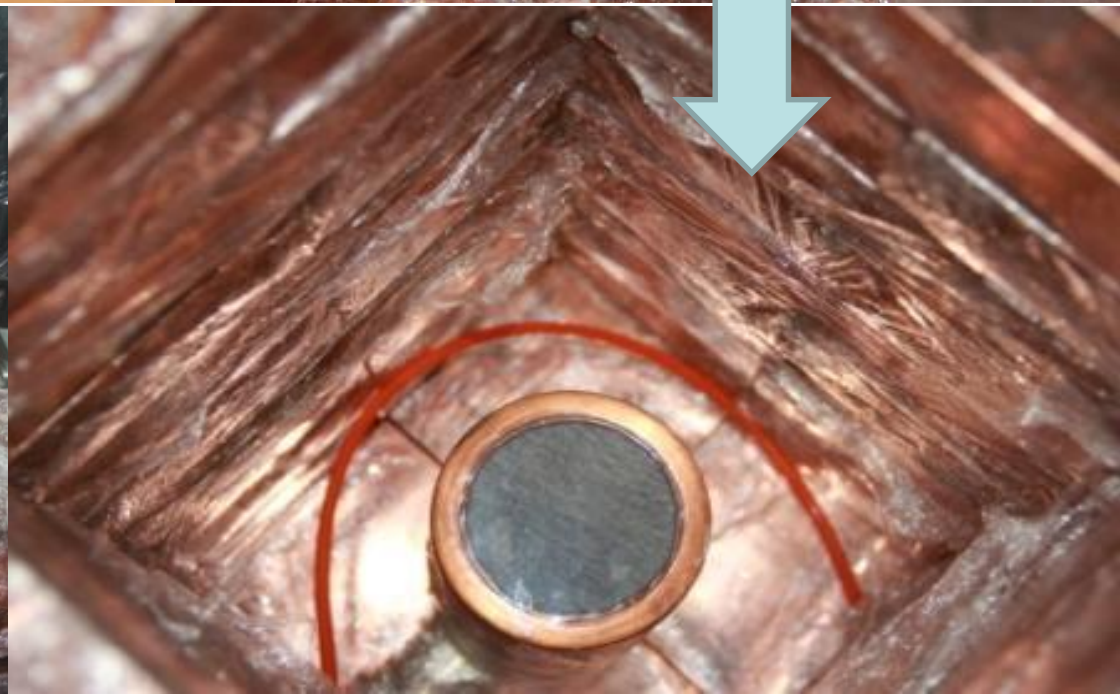
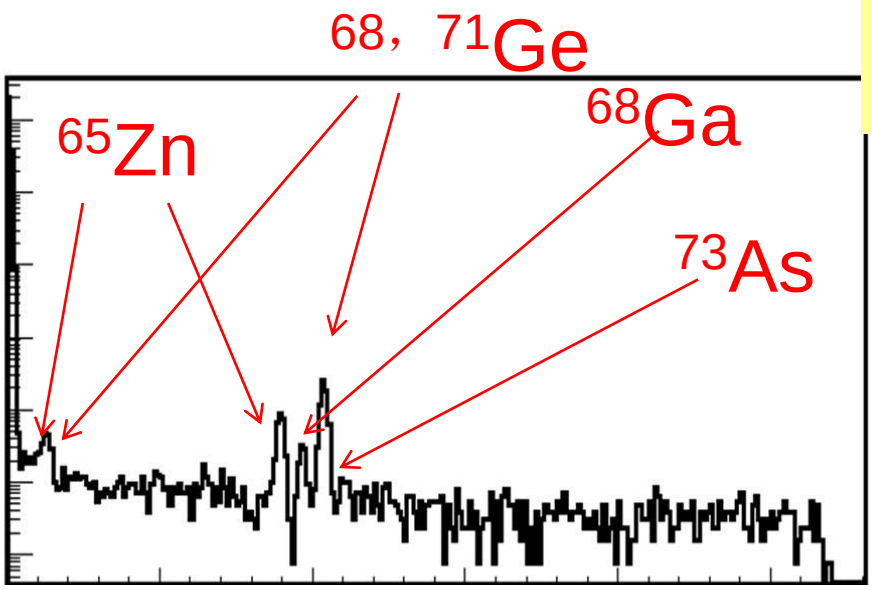
CDEX-1 实验
1kg ULEGe
20g PCGe
20cm OFHC Copper
+20cm Lead

CDEX-1 实验

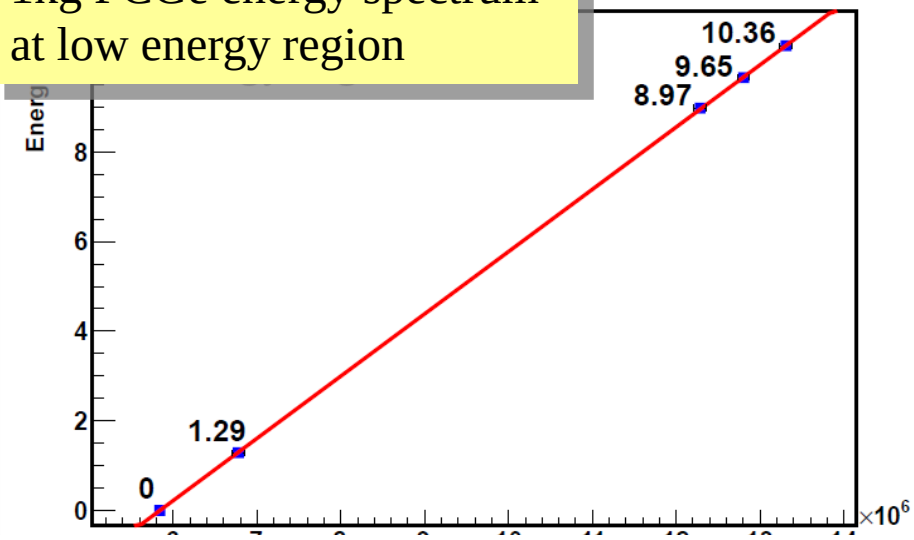


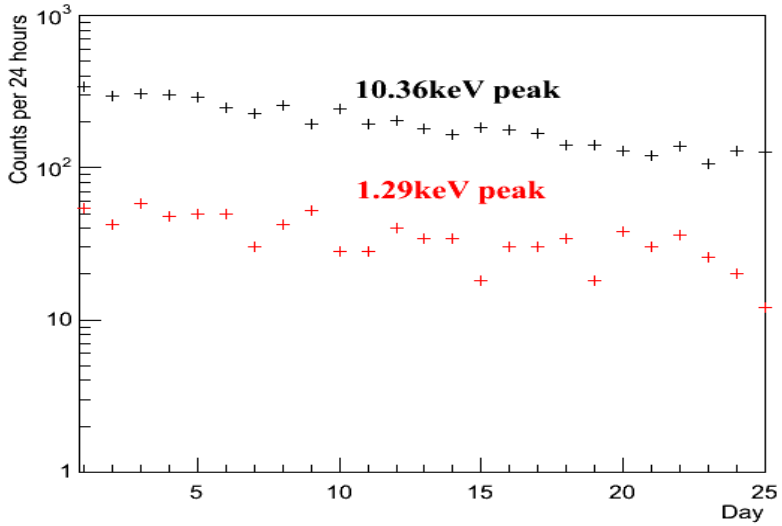


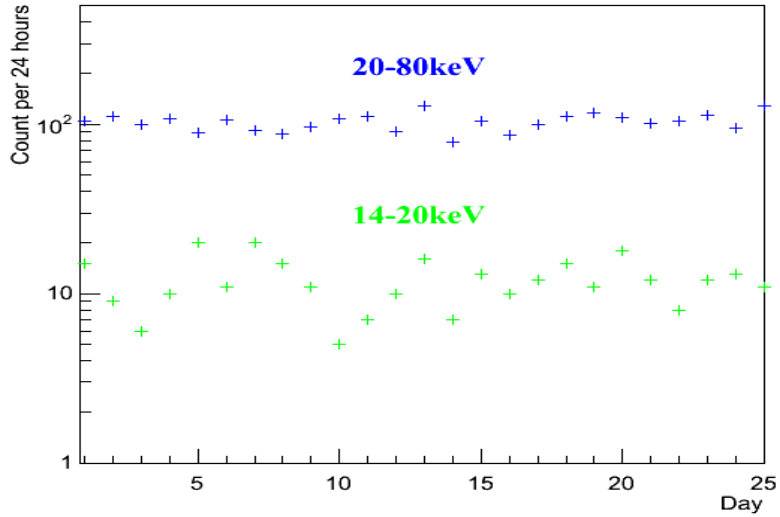
Background understand of PCGe detector



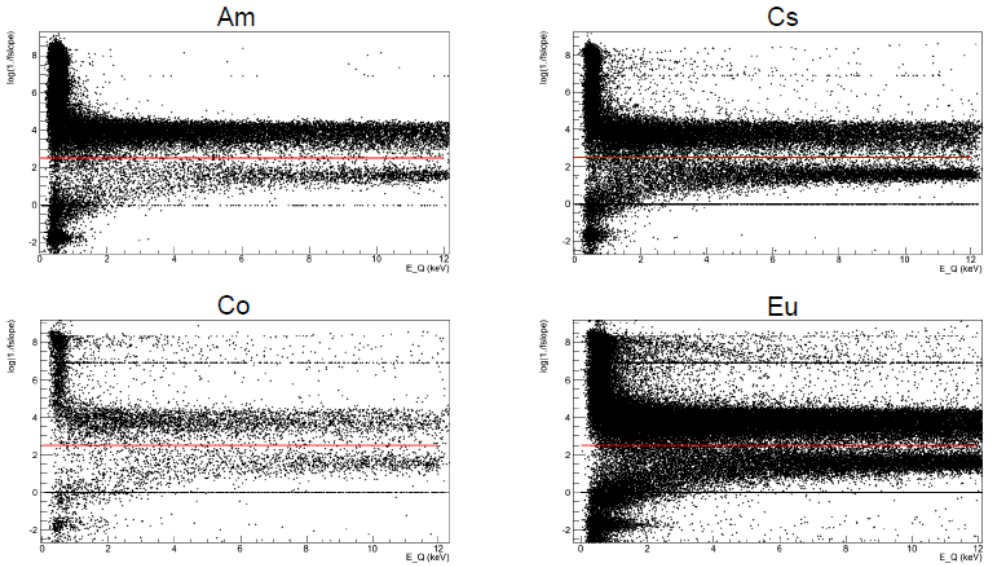
1kg PCGe energy spectrum at low energy region







Bulk/surface discrimination



d_{side}

d=0.5 mm， m=955g
d=0.78mm， m=933g
d=1.16mm， m=904g

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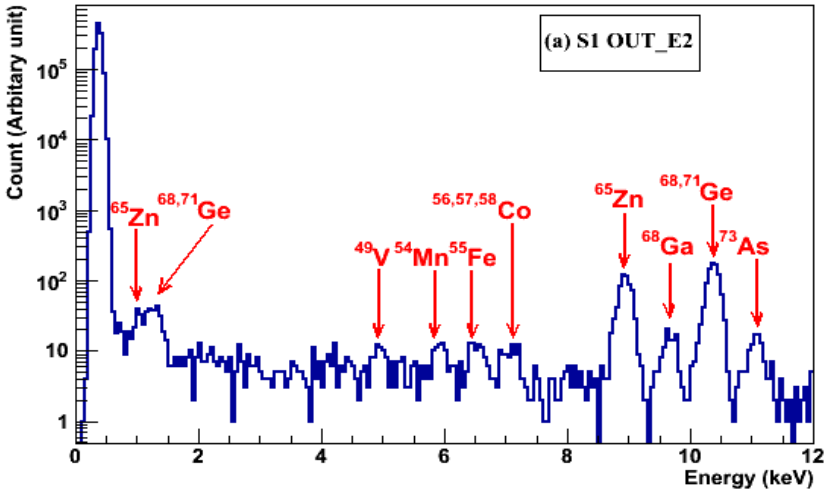
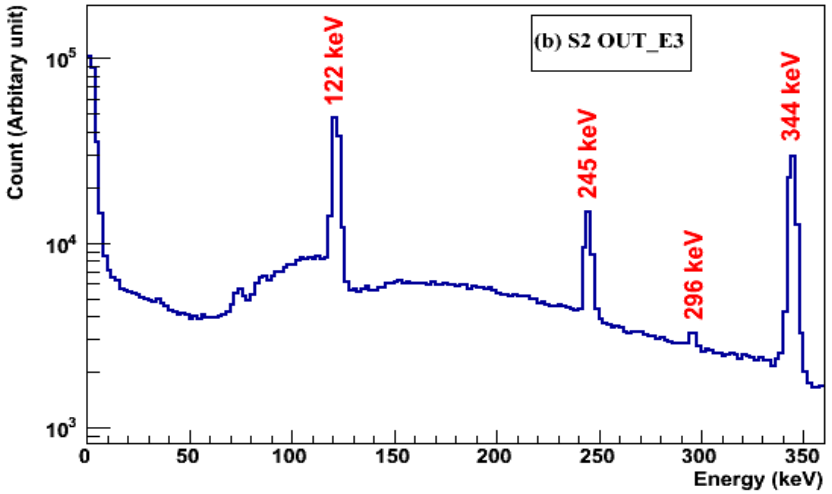
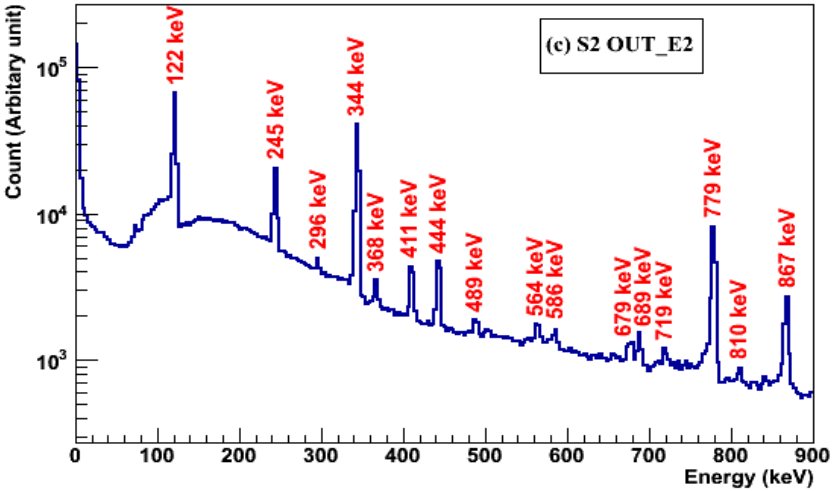
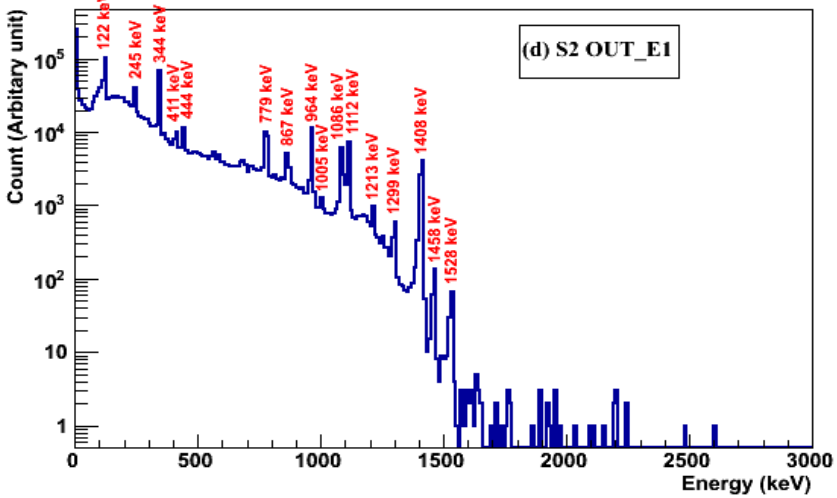
Background spectrum

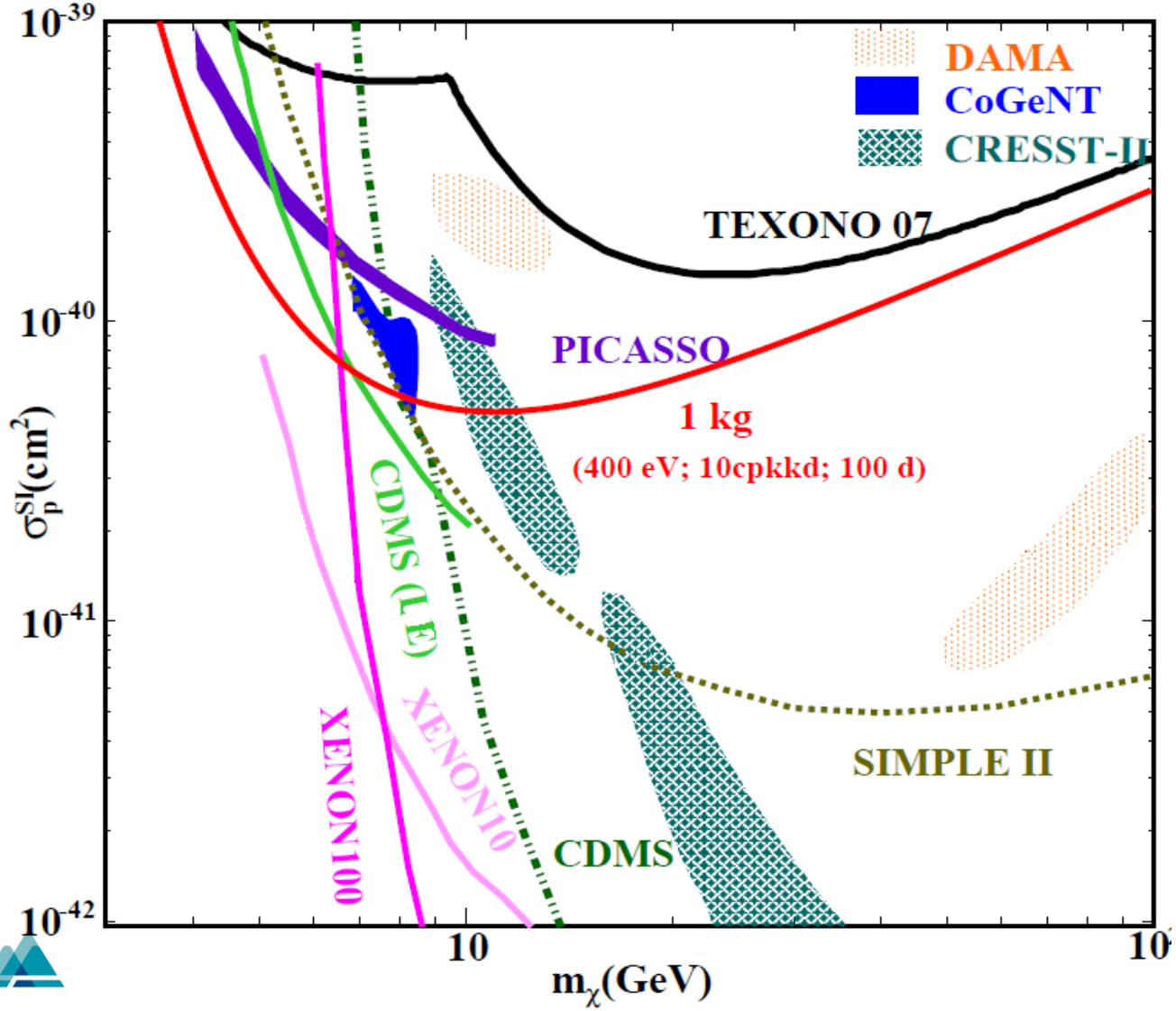








CDEX-1 predicted result



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High energy region backgrounds understand for Ge detector

- Background from Structure materials;
- Background from cosmogenic nuclei;

PCGe and BEGe detector will be used to do these studies in CJPL.

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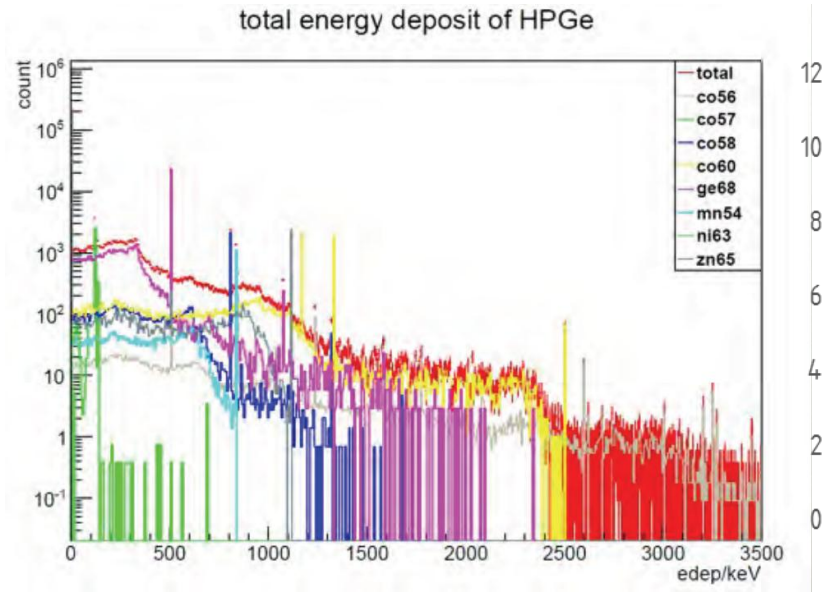
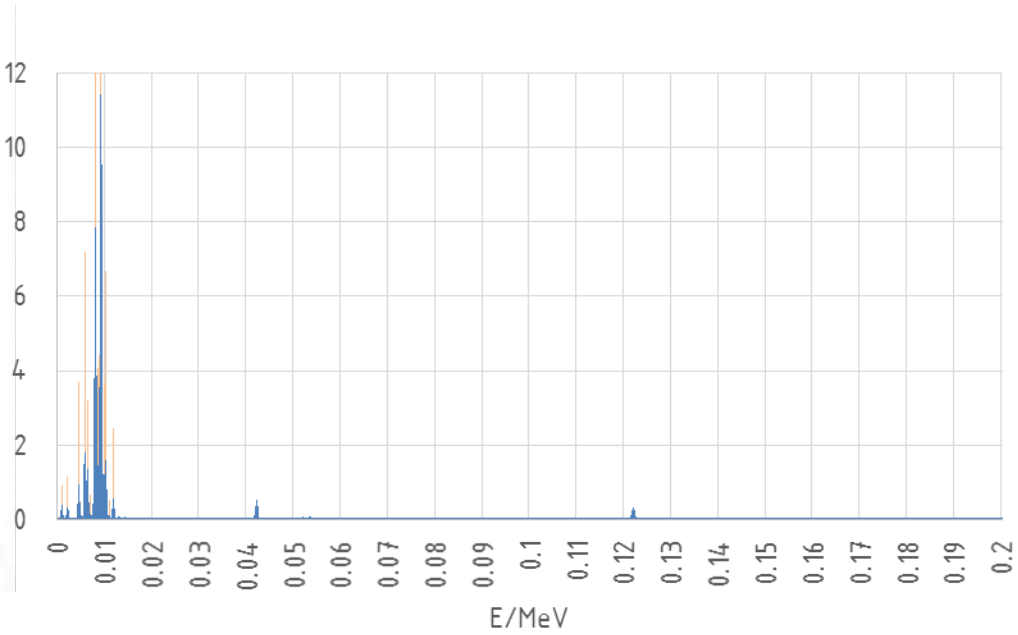
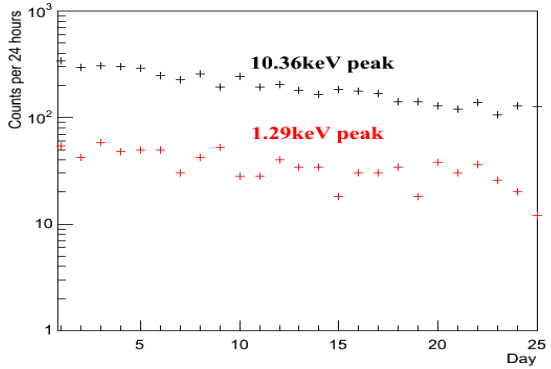
Cosmogenic nuclei in Ge detector

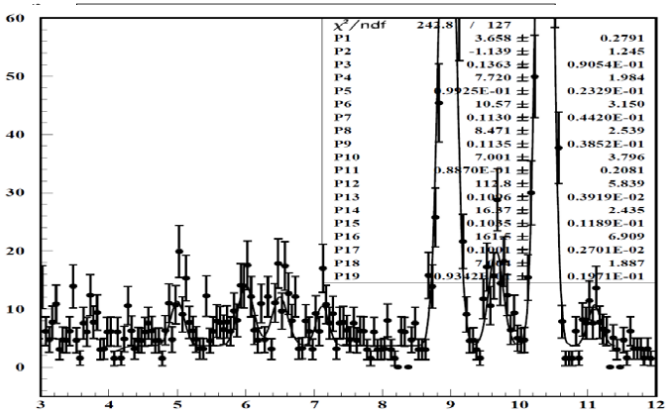
Isotope	Half life	Decay mode	gamma		β	
			Peak(keV)	Prob.	E(keV)	Prob.
Ge68	270.95d	EC				
Ga68	1.1285h	EC, β+	1077.35 1883.19 …...	3.22 0.137 ……	243.2 821.7 1899.1	0.00026 1.2 87.94
Co60	5.27a	β-	1173.24 1332.508 ……	99.85 99.9988 …..	317.32 664.46 1490.56	99.88 0.002 0.12
Zn65	244.01d	EC, β+	344.95 770.64 1115.55	0.00256 0.00269 50.23	329.9	1.421
Mn54	312.13d	EC, ,β+	834.845	99.9997	355.1	0.00000057
Co57	271.8d	EC	14.41 122.06 136.47 230.27	87.69 87.53 12.3 0.0004		
Co58	70.83d	EC, β+	810.765 863.958 1674.75	99.48 0.69 0.52	474.6 1285.4	15 0.00082
Fe55	2.747a	EC	125.949	0.00000013		
Ni63	98.7a	β-			66.980	100
Co56	77.236d	EC, β+	846.77 1037.84 1771.36 2598.5 ……	99.97 14.03 15.45 16.969 …….	421.1 1458.9 2697.2 ….	1.04 18.29 0.25

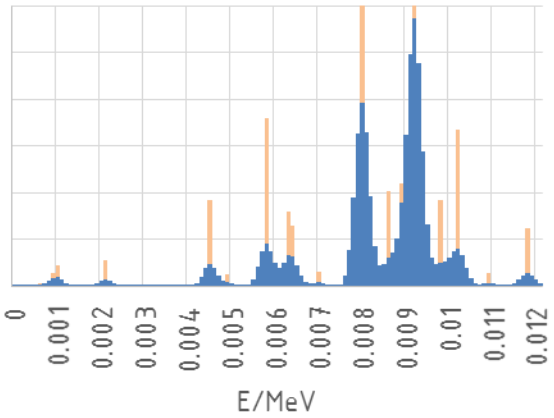
The cosmogenic background from simulation and experiment











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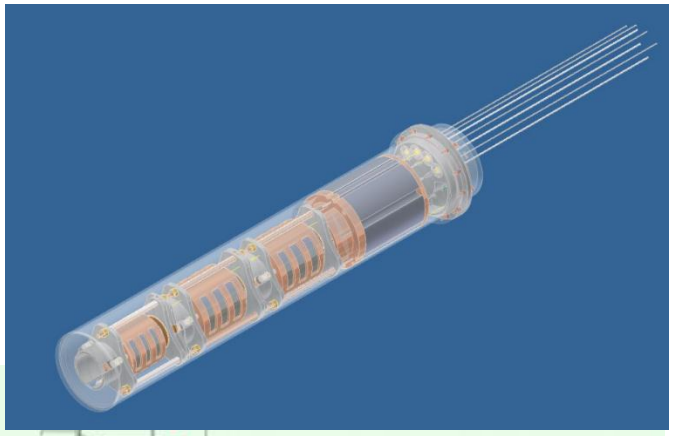
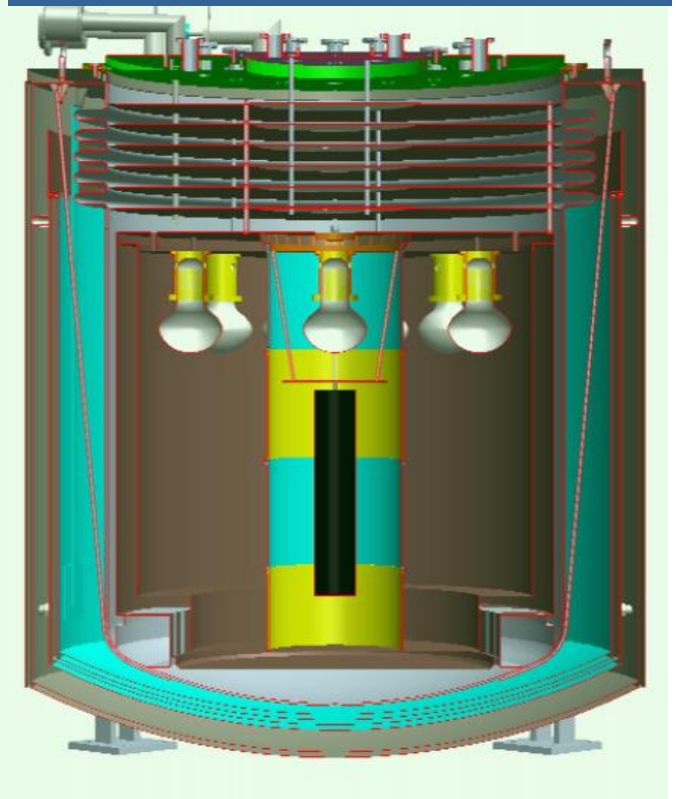
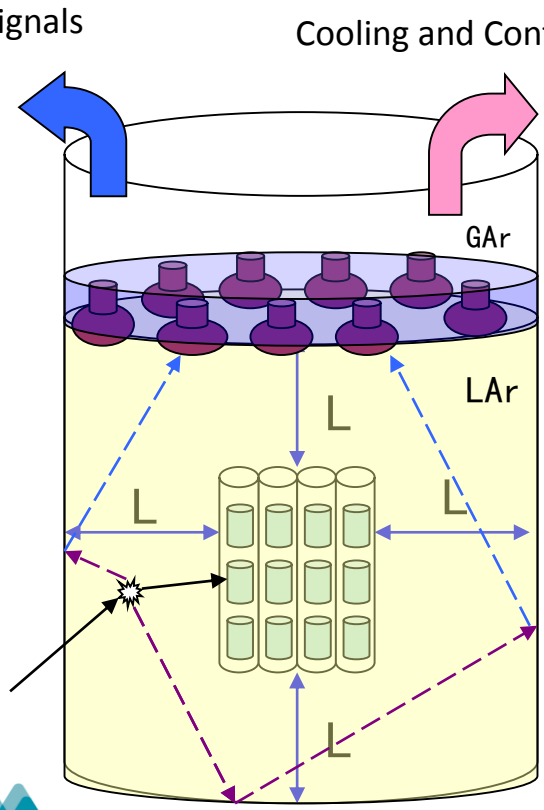
CDEX-10kg Experiment

LAr: Passive shielding +Active shielding.
Ge: Encapsuled into copper vacuum tube.
WLS: Transfering 128nm light to~420nm light.







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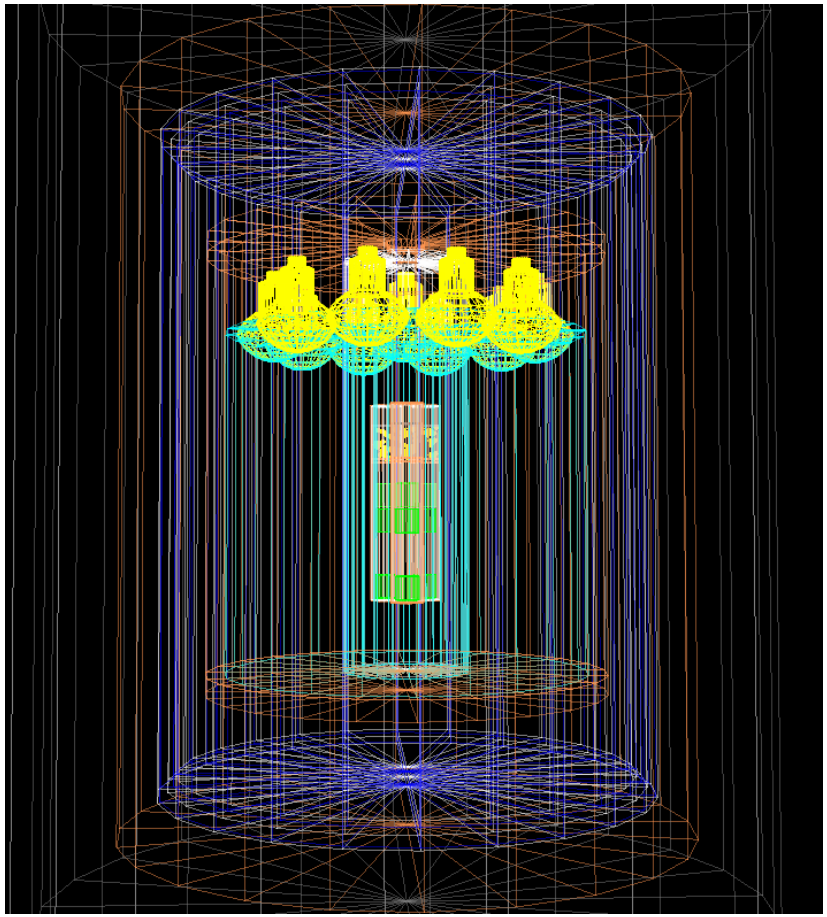
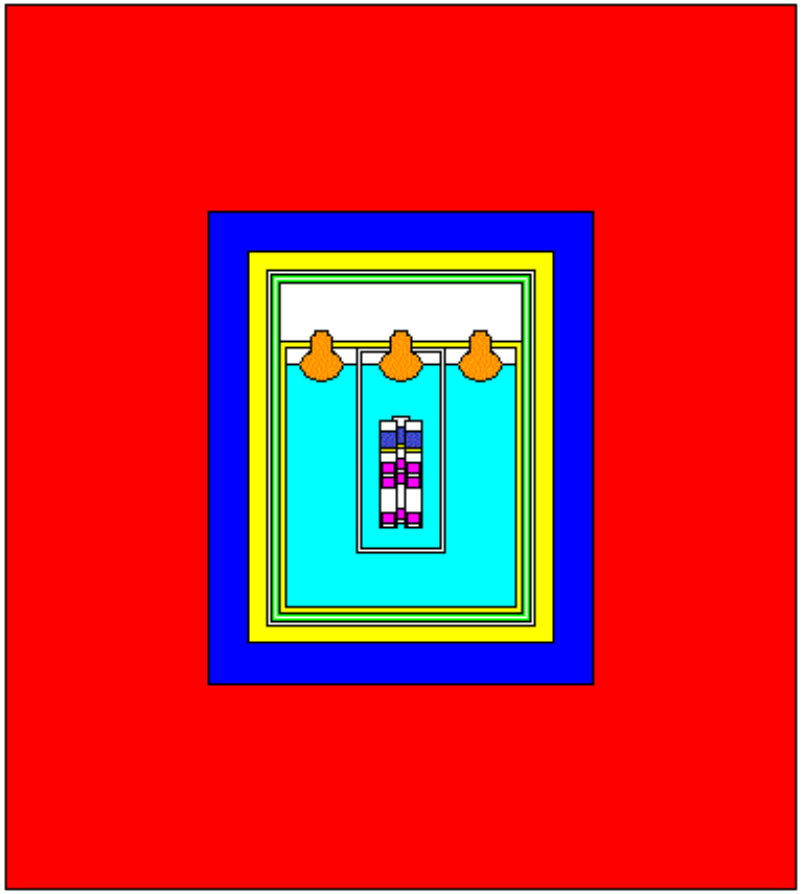
CDEX-10 simulation





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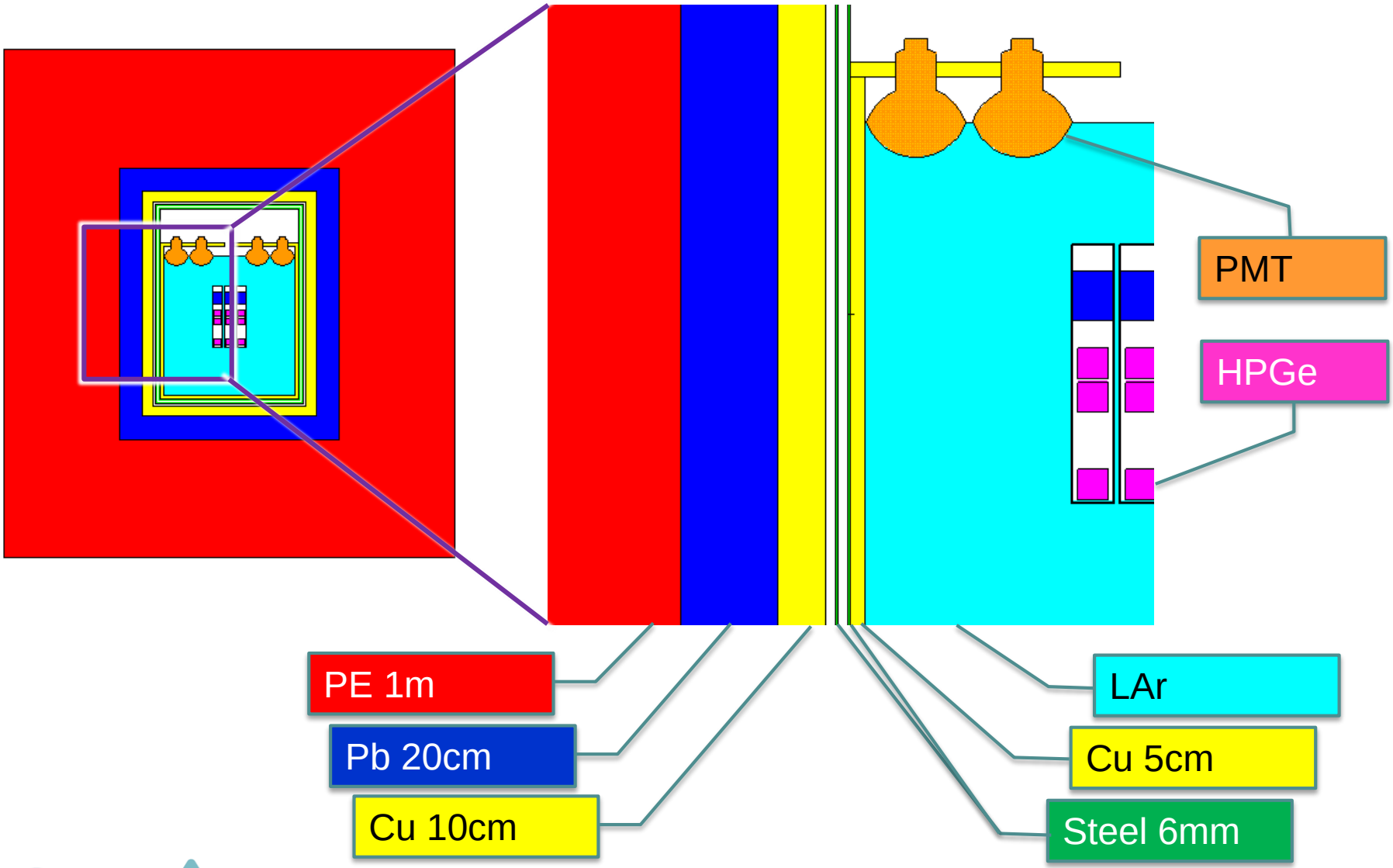
CDEX shielding system



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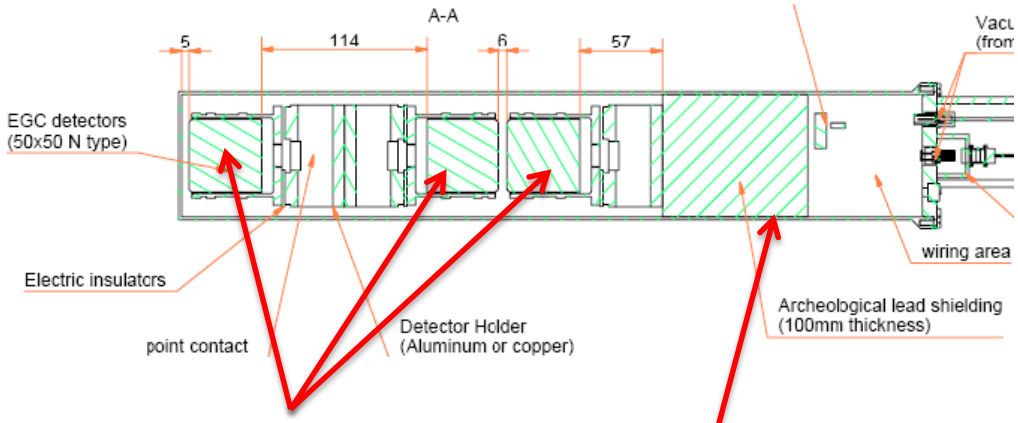
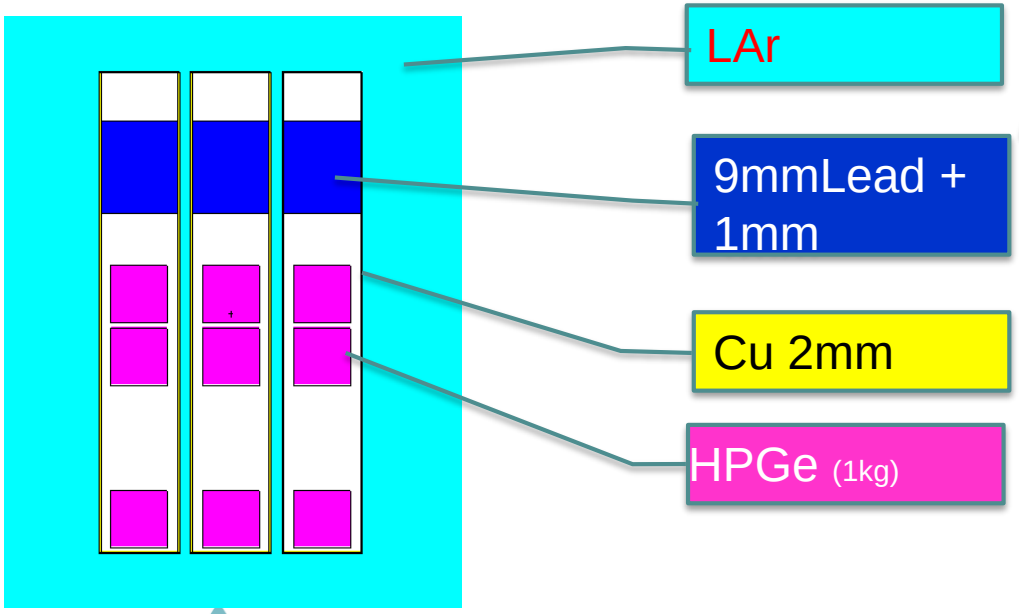
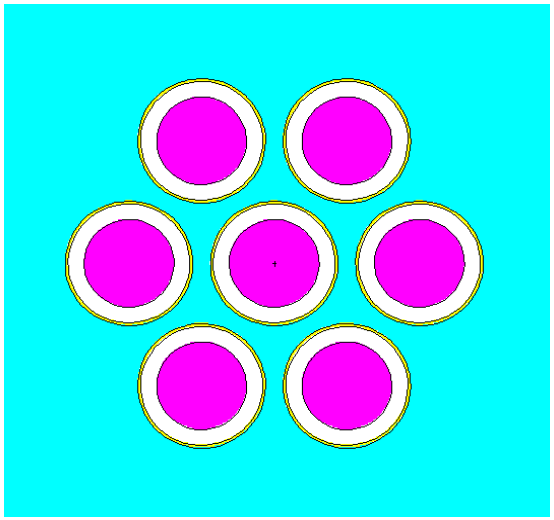
PCGe detector



HPGe crystal





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Materials and its background

- Pb*:

$C_U = (29 \pm 12) \cdot 10^{-12}$ g/g
$C_{Th} < 39 \cdot 10^{-12}$ g/g
$C_K = (65 \pm 25) \cdot 10^{-9}$ g/g

- Cu**:

Material	Measured by	Method	^{238}U (ppb)	^{232}Th (ppb)	^{40}K (ppm)	Comments
Cu, electroformed (Waveform)	Charles Evans/Cascade Scientific	GDMS	< 0.012	< 0.011	< 0.0056	Lu < 0.6 ppb, Rb < 0.26 ppb (no K!)

- PMT***:

		9357UKB borosilicate
K	(ppm)	60
Th	(ppb)	30
U	(ppb)	30

❖Steel****:

U-238	< 0.0012
Th-232	0.006 ± 0.002
K-40	0.013 ± 0.004
Co-60	< 0.002

（Bq/kg）

- LAr*****:

Isotope	Activity (Bq/kg)
^{39}Ar	10^{-6}
^{42}Ar	$(0.1–7.0) \times 10^{-6}$

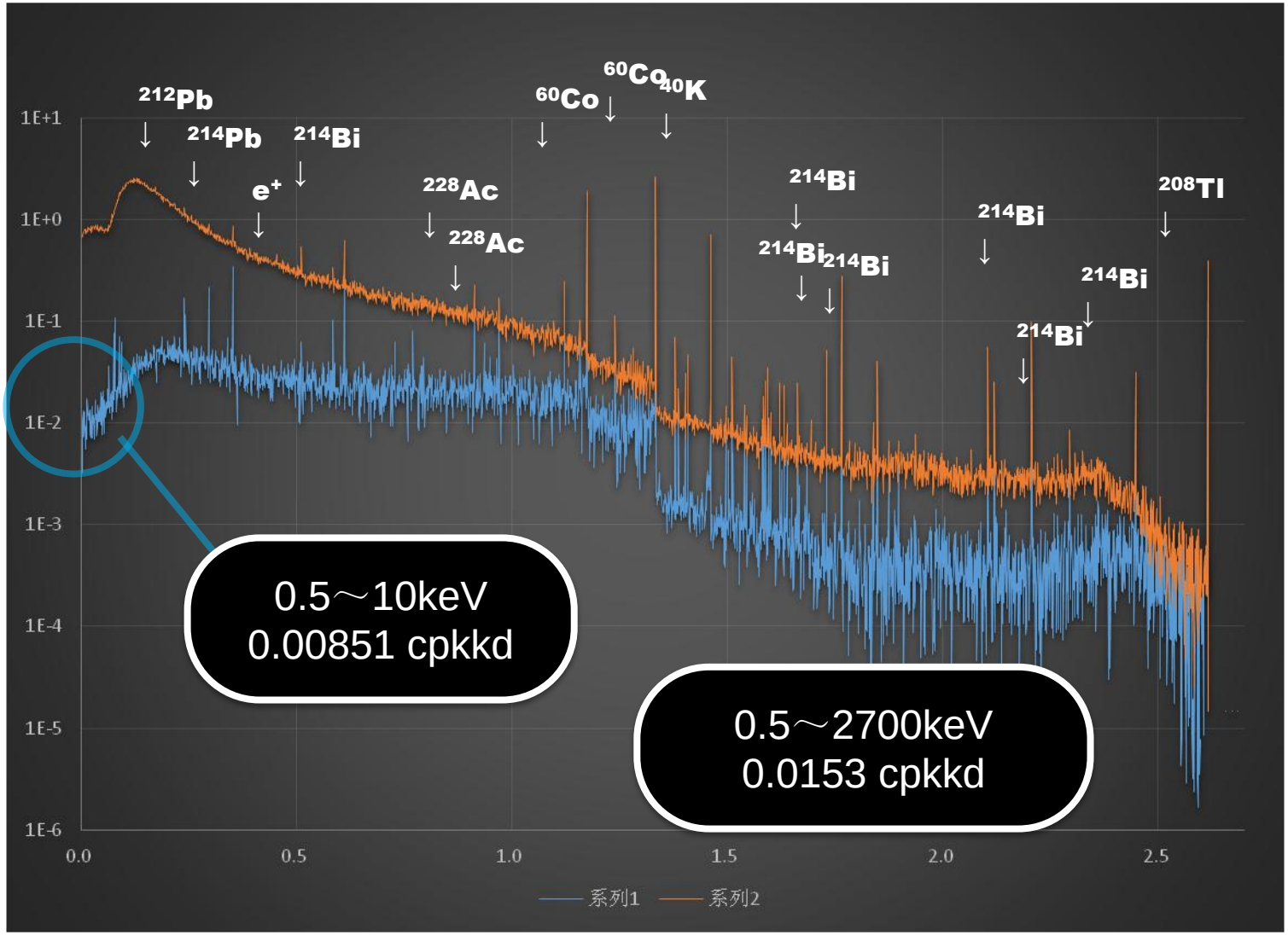
*数据来源 **http://www.plombum.republika.pl/Plombum2011_pliki/Page383.htm**

数据来源 **http://radiopurity.in2p3.fr/search.php?Material=copper

***数据来源 **200mm (8”) photomultiplier 9357KB series data sheet** （**ET**公司）

****数据来源 **LBNL**对大亚湾**SS**的测定结果

*****数据来源 **J. A. Formaggio and C. J. Martoff. Backgrounds to sensitive experiments underground. Ann. Rev. Nucl. Part. Sci., 54 (2004), 361–412**


212Pb
214Pb
214Bi
e+
228Ac
228Ac
60Co
60Co
40K
214Bi
214Bi
214Bi
214Bi
214Bi
214Bi
208Tl
1E+1
1E+0
1E-1
1E-2
1E-3
1E-4
1E-5
1E-6
0.0
0.5
1.0
1.5
2.0
2.5
0.5～10keV
0.00851 cpkkd
0.5～2700keV
0.0153 cpkkd
系列1
系列2

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LAr AC detector

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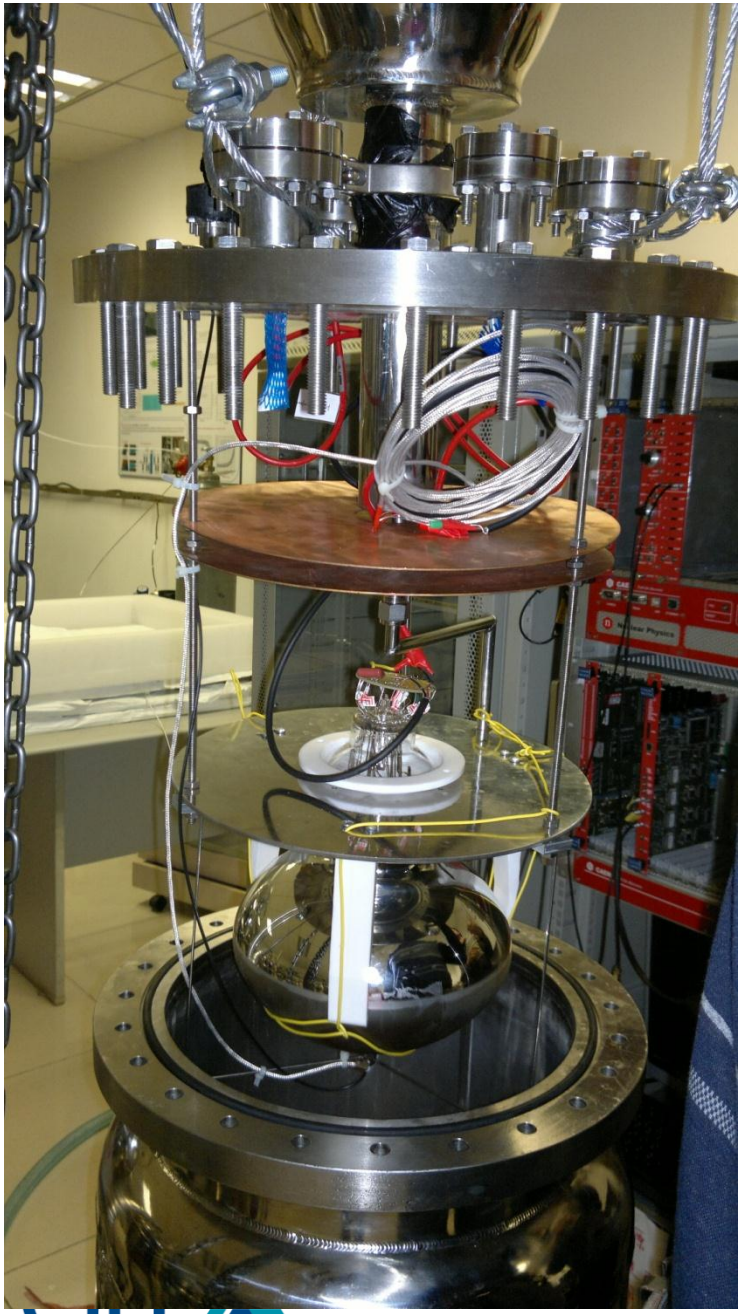
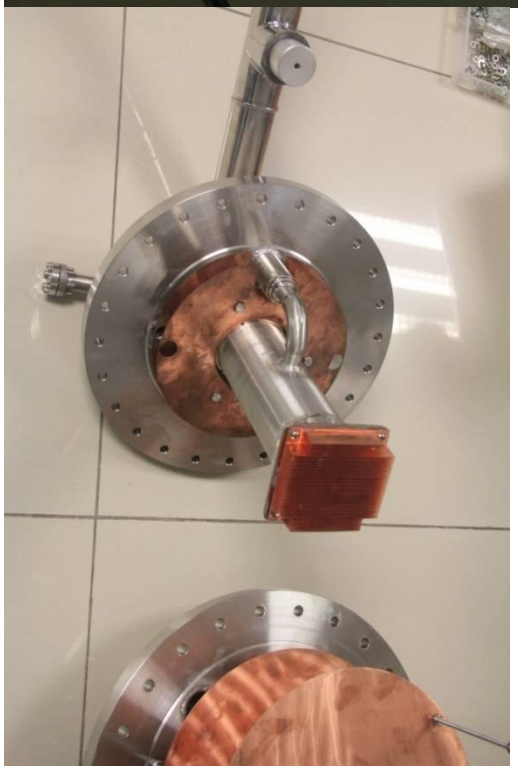
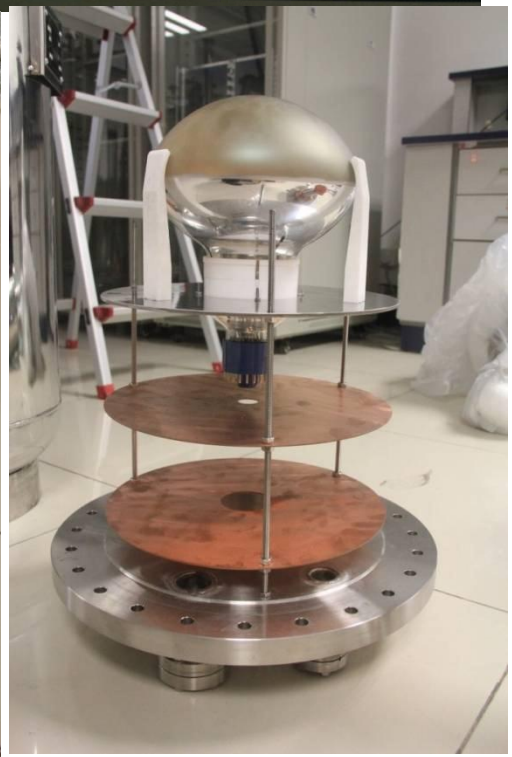


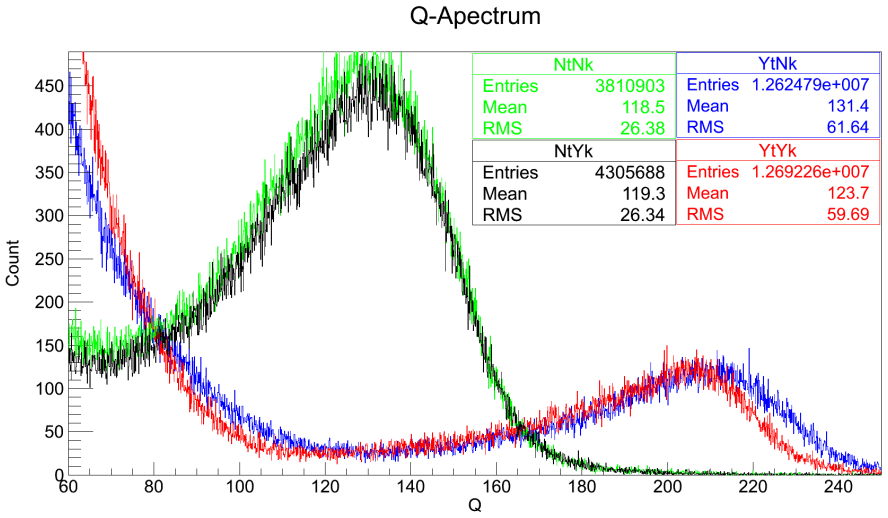

XMZ604
智能显示仪
J1
J2
COM
197.9
SET



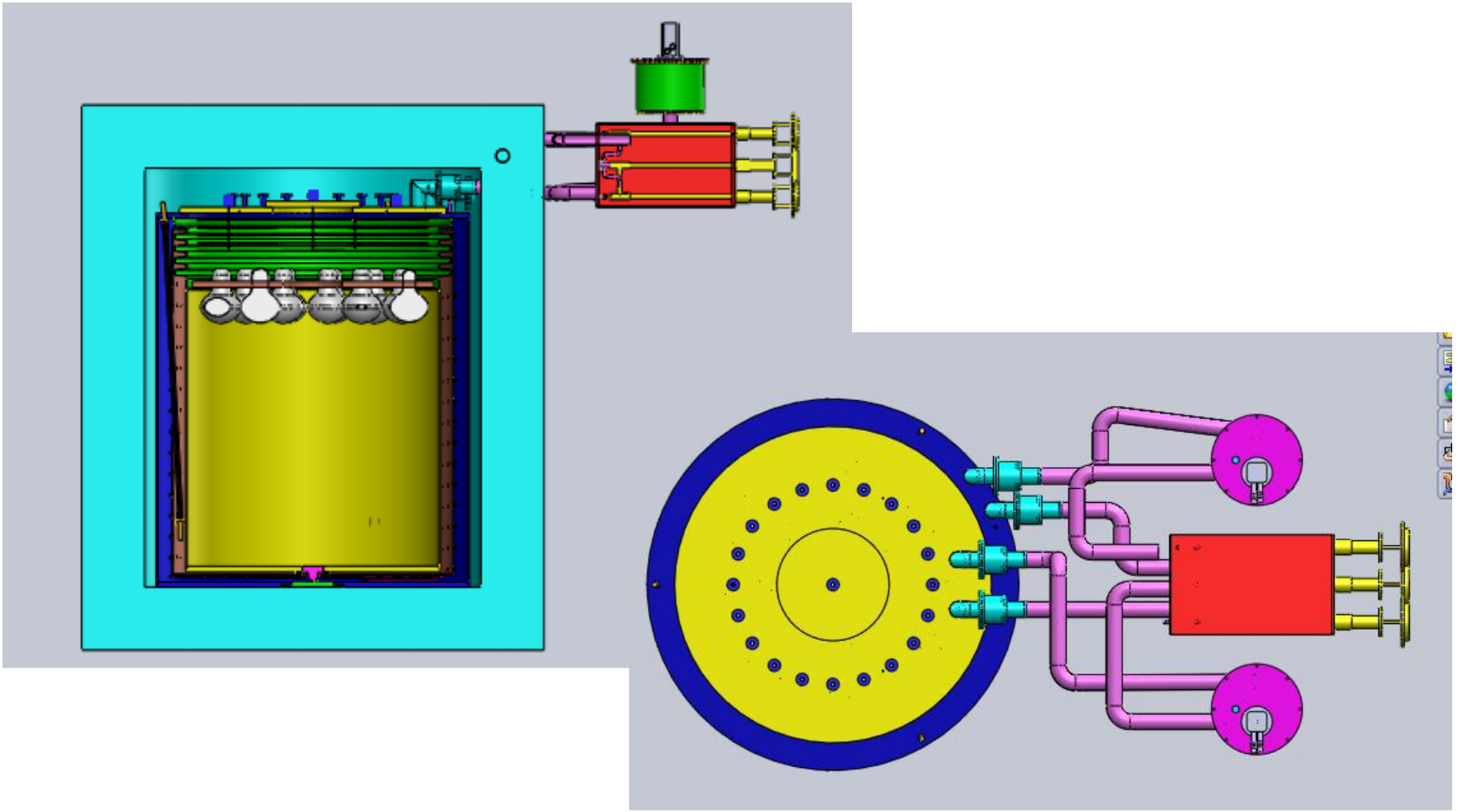


WLS Test


XMZ604
智能显示仪
485.7
SET


Q-Apectrum
NtNk
Entries 3810903
Mean 118.5
RMS 26.38
YtNk
Entries 1.262479e+007
Mean 131.4
RMS 61.64
NtYk
Entries 4305688
Mean 119.3
RMS 26.34
YtYk
Entries 1.269226e+007
Mean 123.7
RMS 59.69
Count
Q
0
50
100
150
200
250
300
350
400
450
60
80
100
120
140
160
180
200
220
240

CDEX-10 LAr AC system



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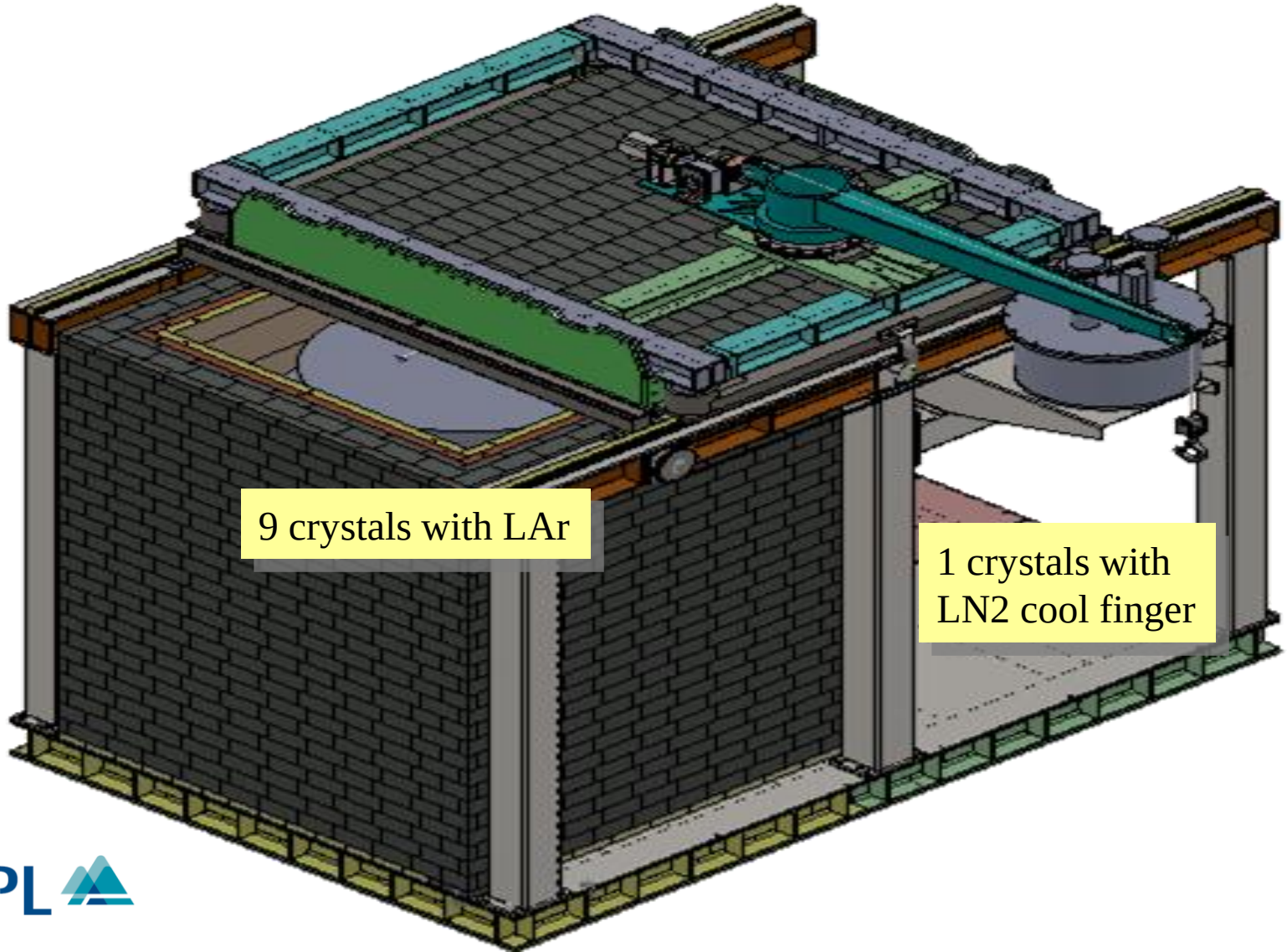
CDEX-10 Layout
Ground testing at SCU this May



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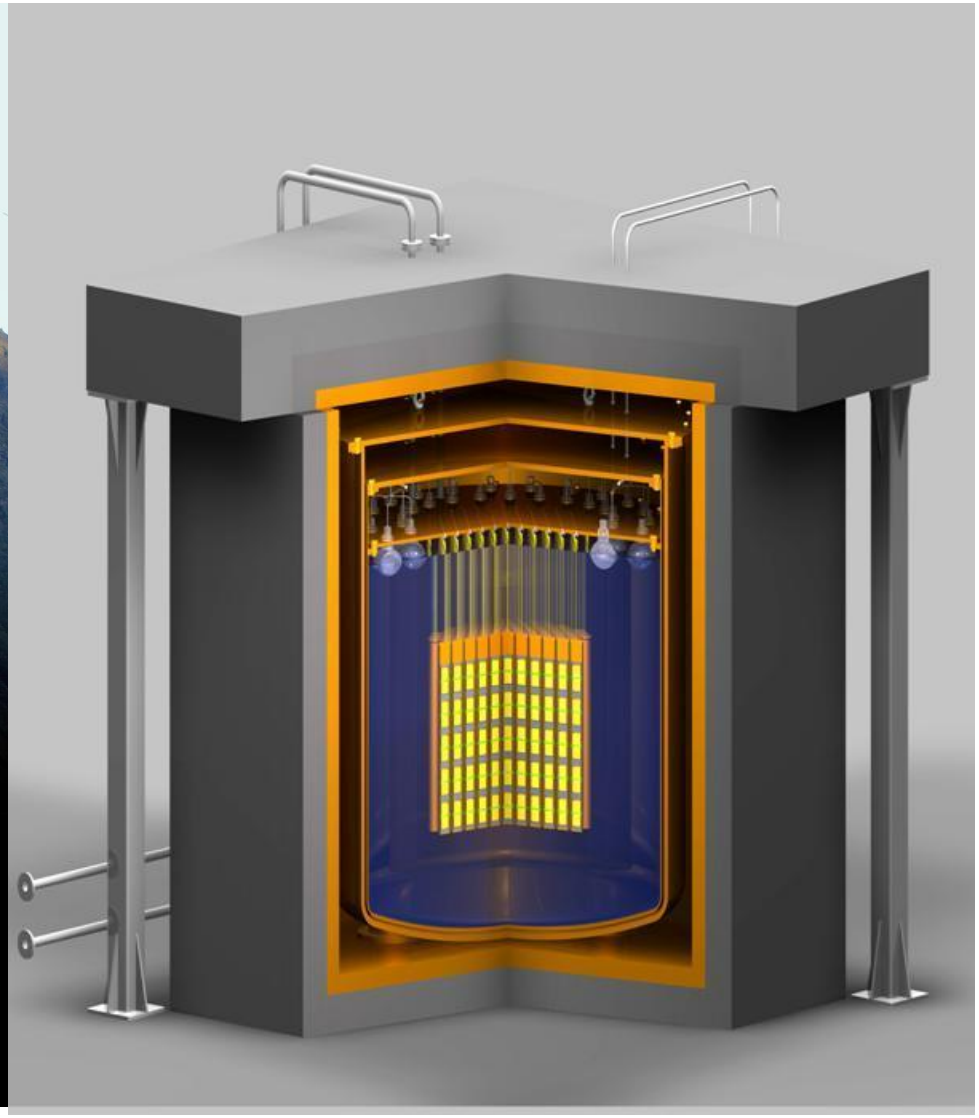
CDEX-1T plan



CJPL

Towards 1 tonne-scale experiment

- Detector technologies;
- Background sources and control;
- Low-background Ge crystal growth;
- Larger UL;
- Electronics;
- Team and collaboration;
- Funding;

CDEX structure and activities

- CDEX-1 and CDEX-10 studies;
- Ge detector development;
- Ge crystal growth;
- Electronics;
- Ultra-low background facilities;
- Larger underground laboratory;

We know we are in the very beginning, but we will try our best to make a strong basis for the possible ton-scale Ge experiment to cover low energy DM and possible higher energy DBD experiment.

Ge detector fabrication

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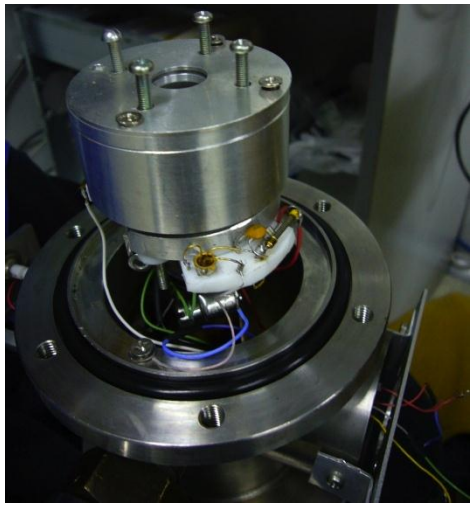
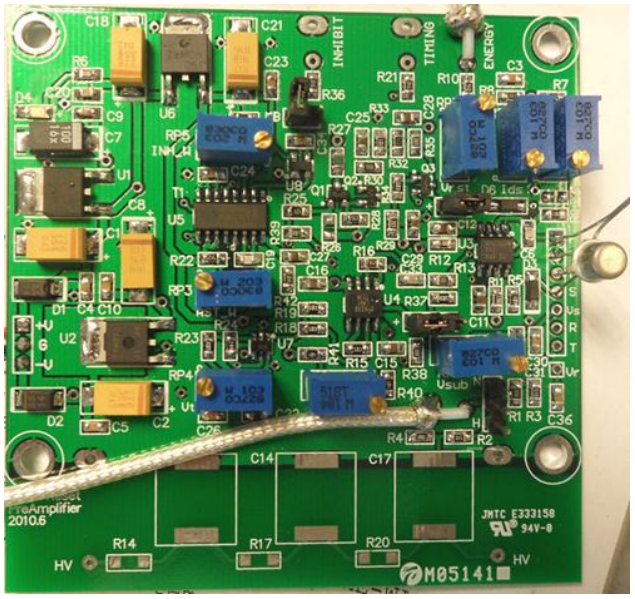
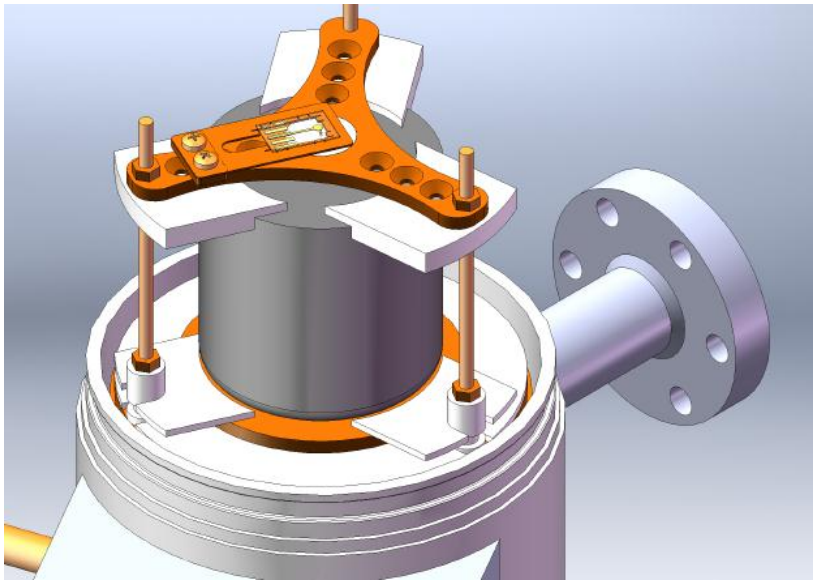
HPGe detector study and manufacture







Laboratory Set-up

- Clean room

Vacuum Coating Machine

Magnetron Sputtering Device

- Wet Lab

- Machine-shop

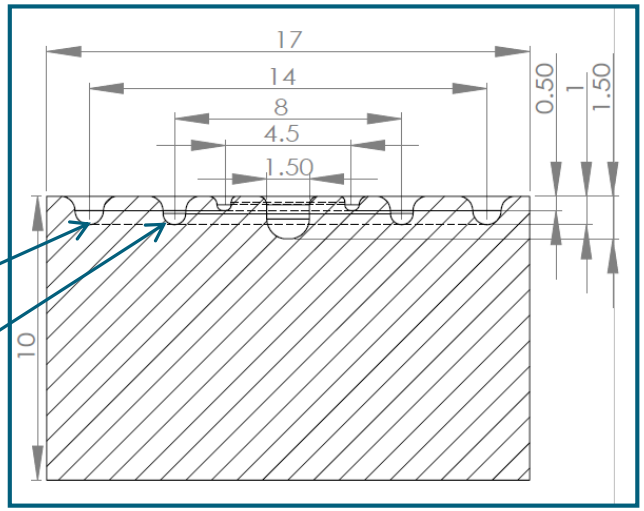
CJPL

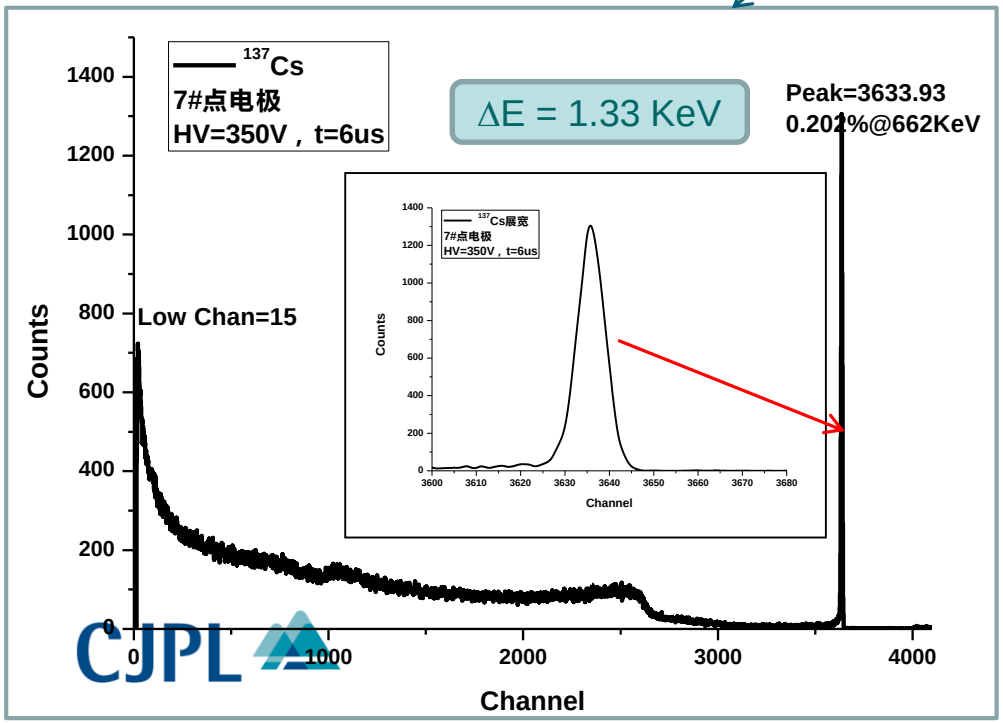
Detector Performance

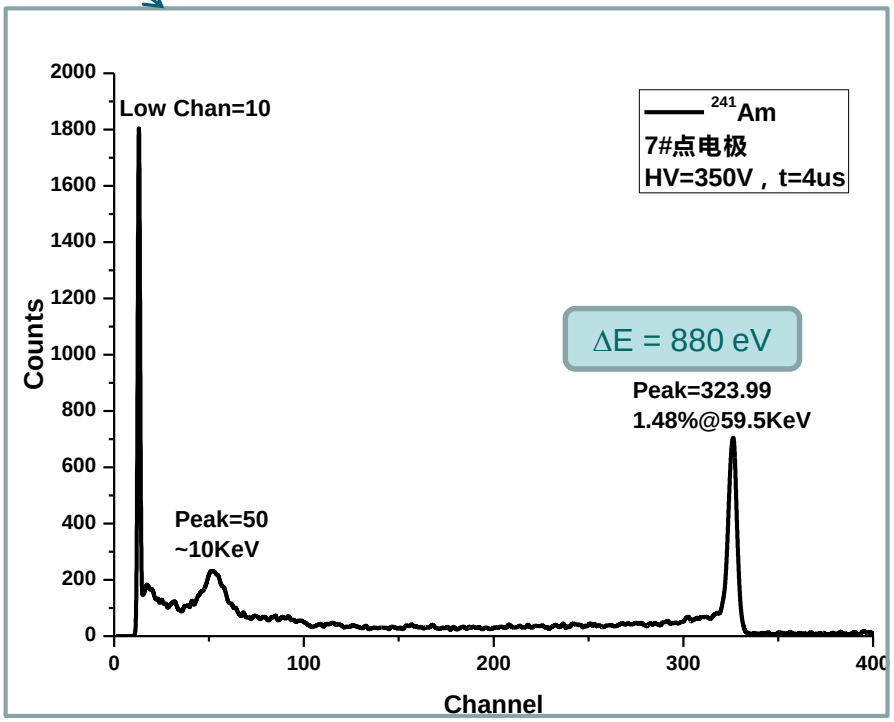
- Point-contact Configuration

Recycled crystal
~10 g

Test Result with
2-outer grooves

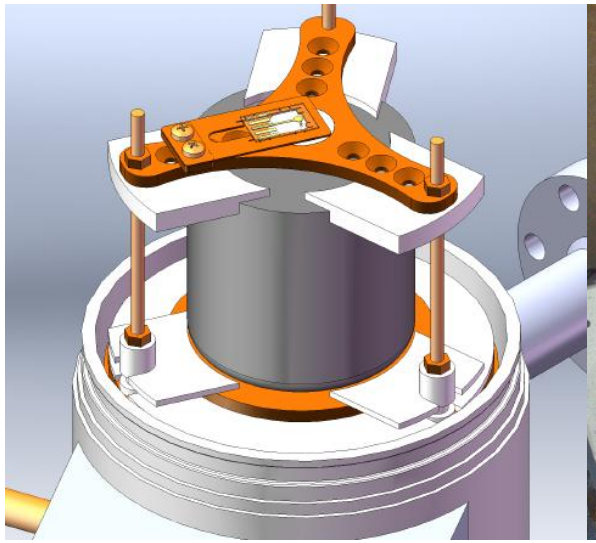


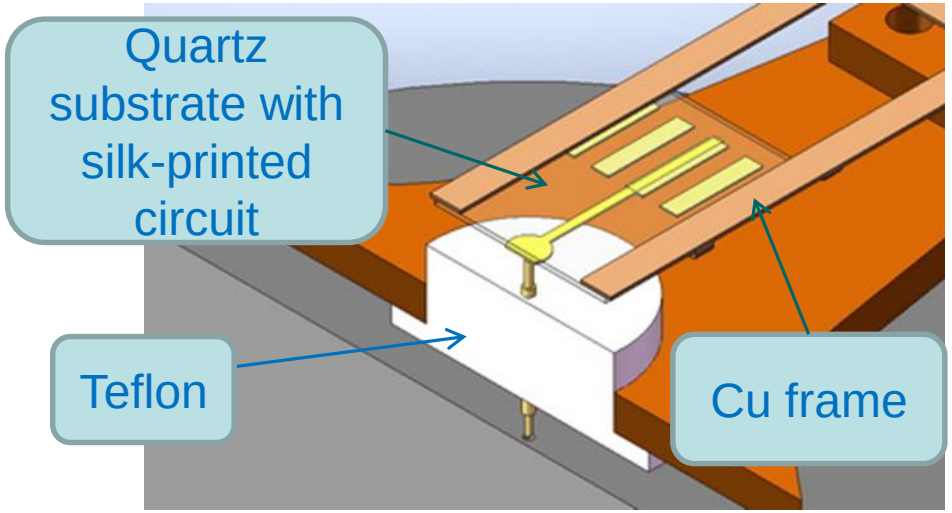




Cryostat Design

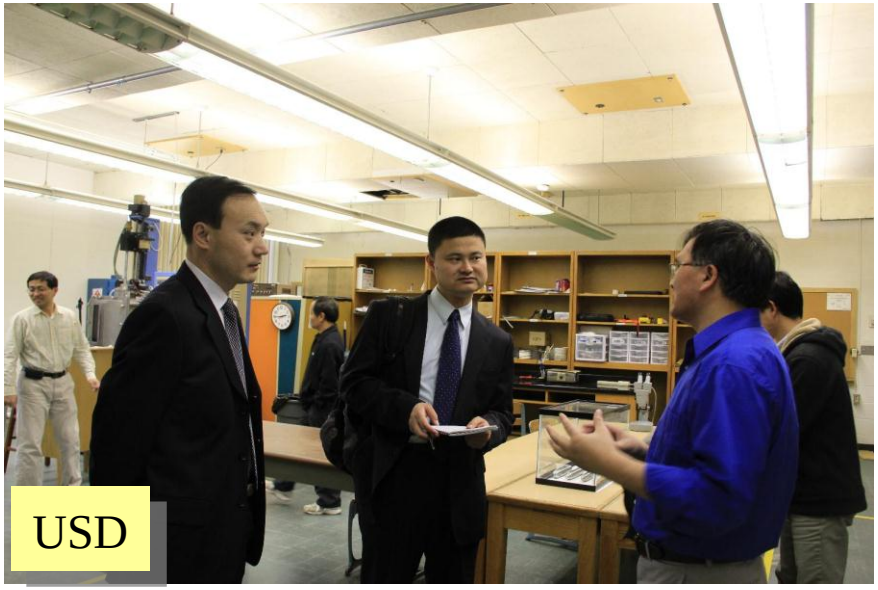
- Traditional design:
  - not optimized for point-contact configuration
- New design:
  - Point-contact probe
  - Scalable for different sizes of crystal
  - Low background material:
    - Quartz substrate for J-FET bonding





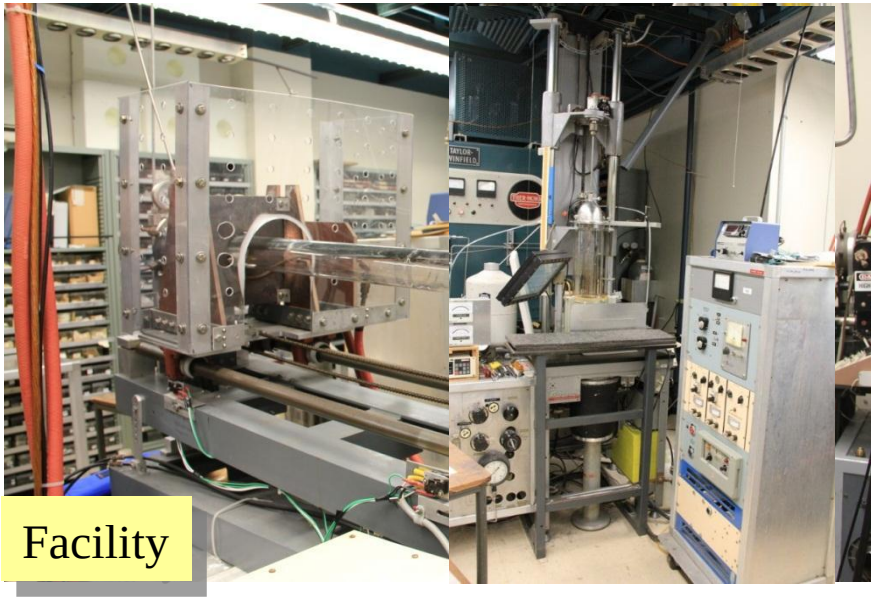
Ge crystal growth

LBNL



USD

Berlin



Facility

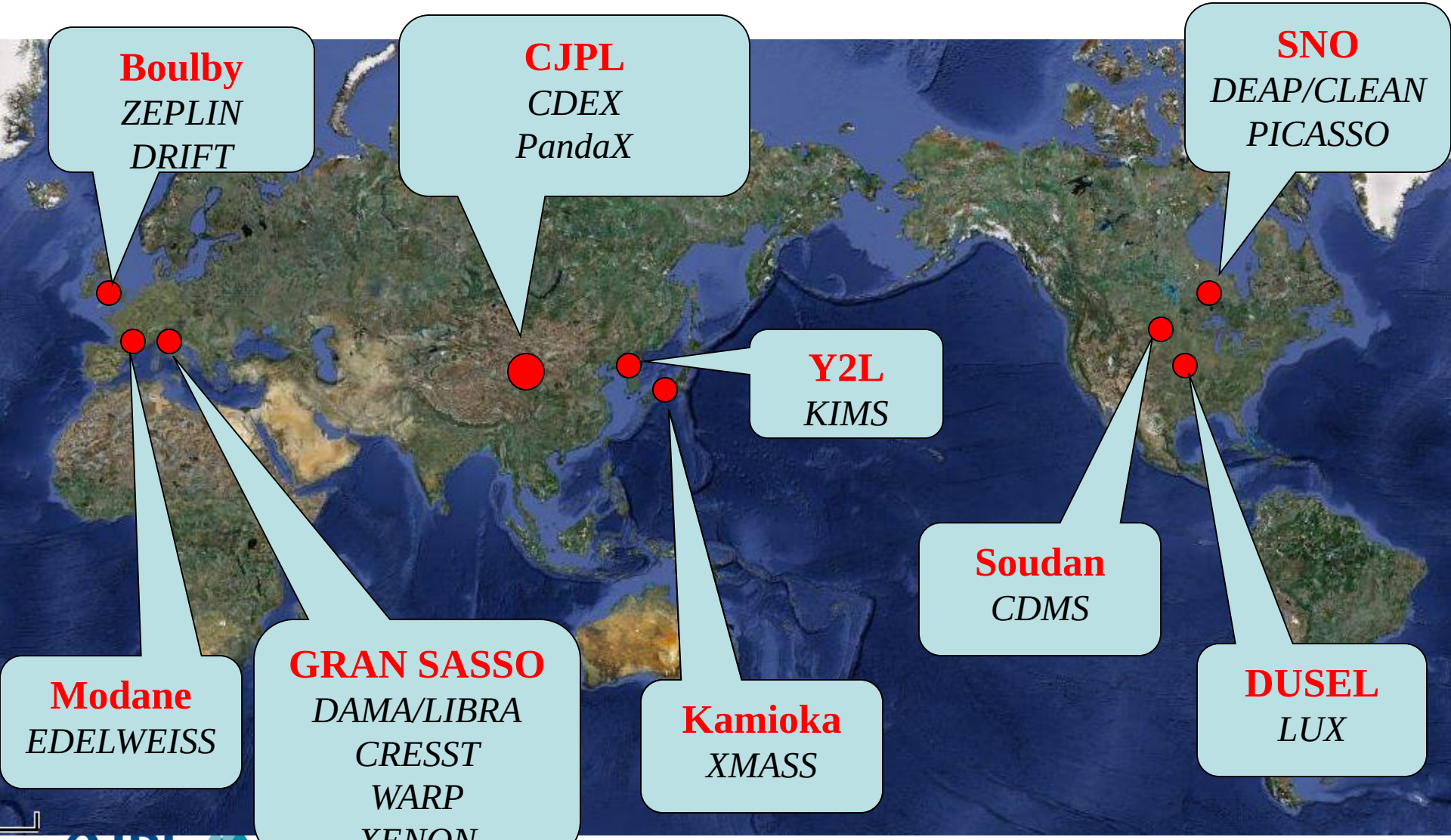
China Jinping Underground Laboratory (CJPL)

- Tsinghua University, have collaborated with Yalong River company to construct and run CJPL.

- CDEX has done many measurement of its main. These parameters are very important for dark matter experiments.

CJPL

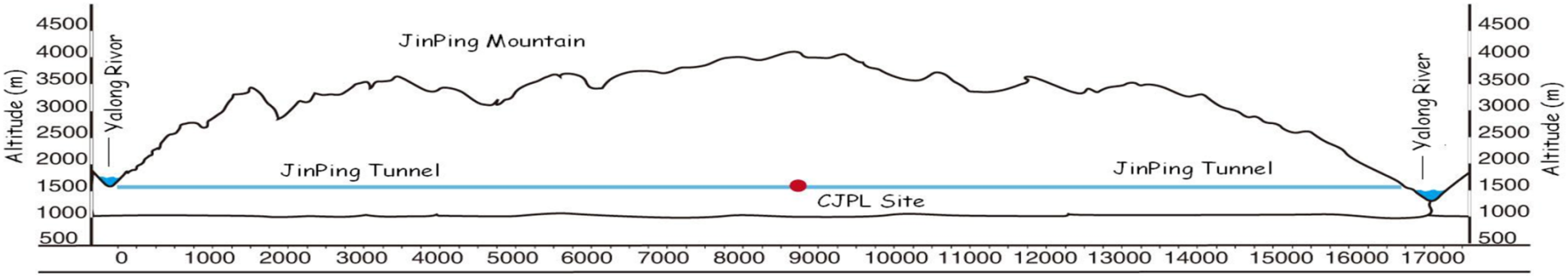
International Main Undergound Laboratories



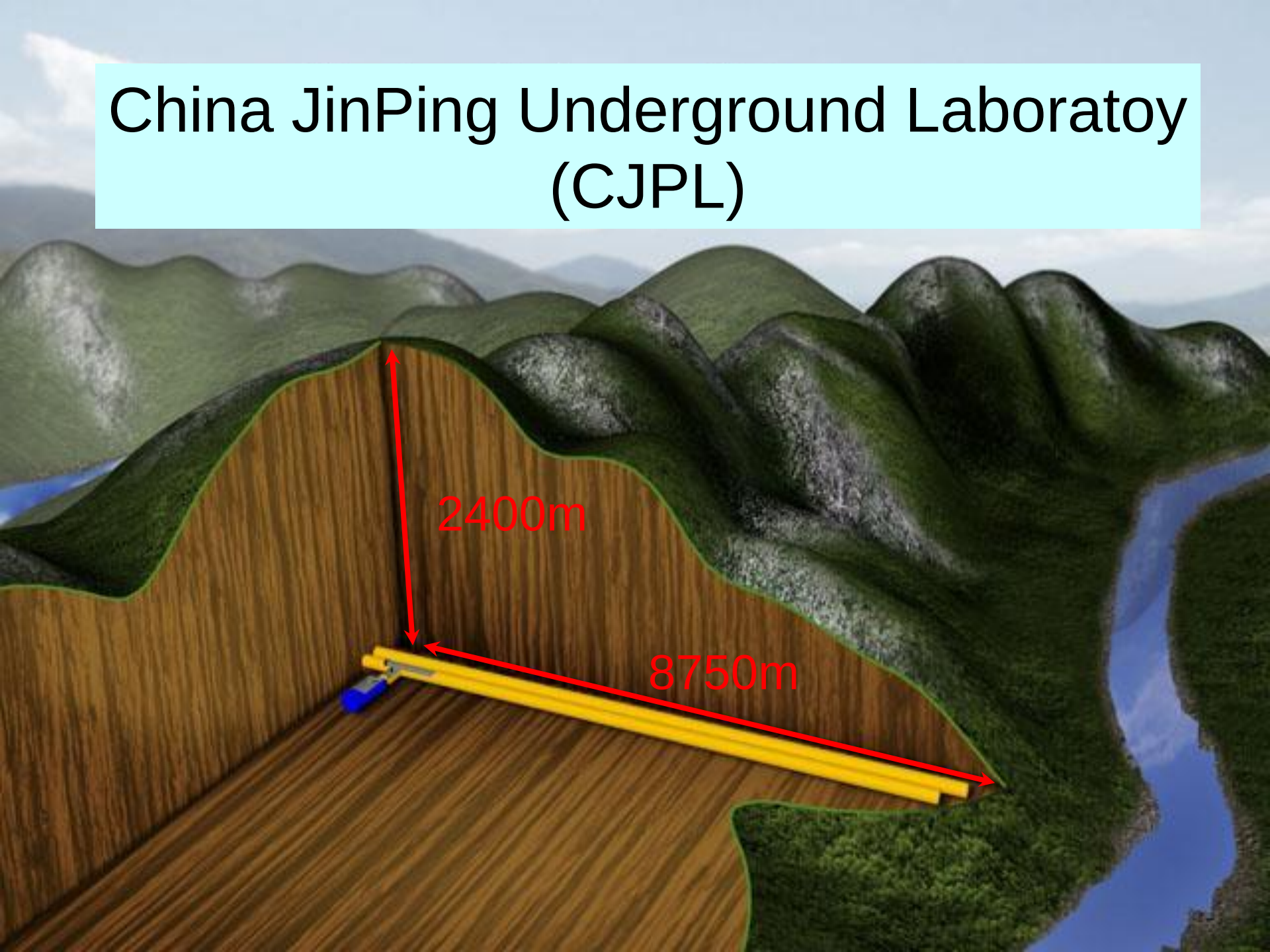
CJPL

CJPL site

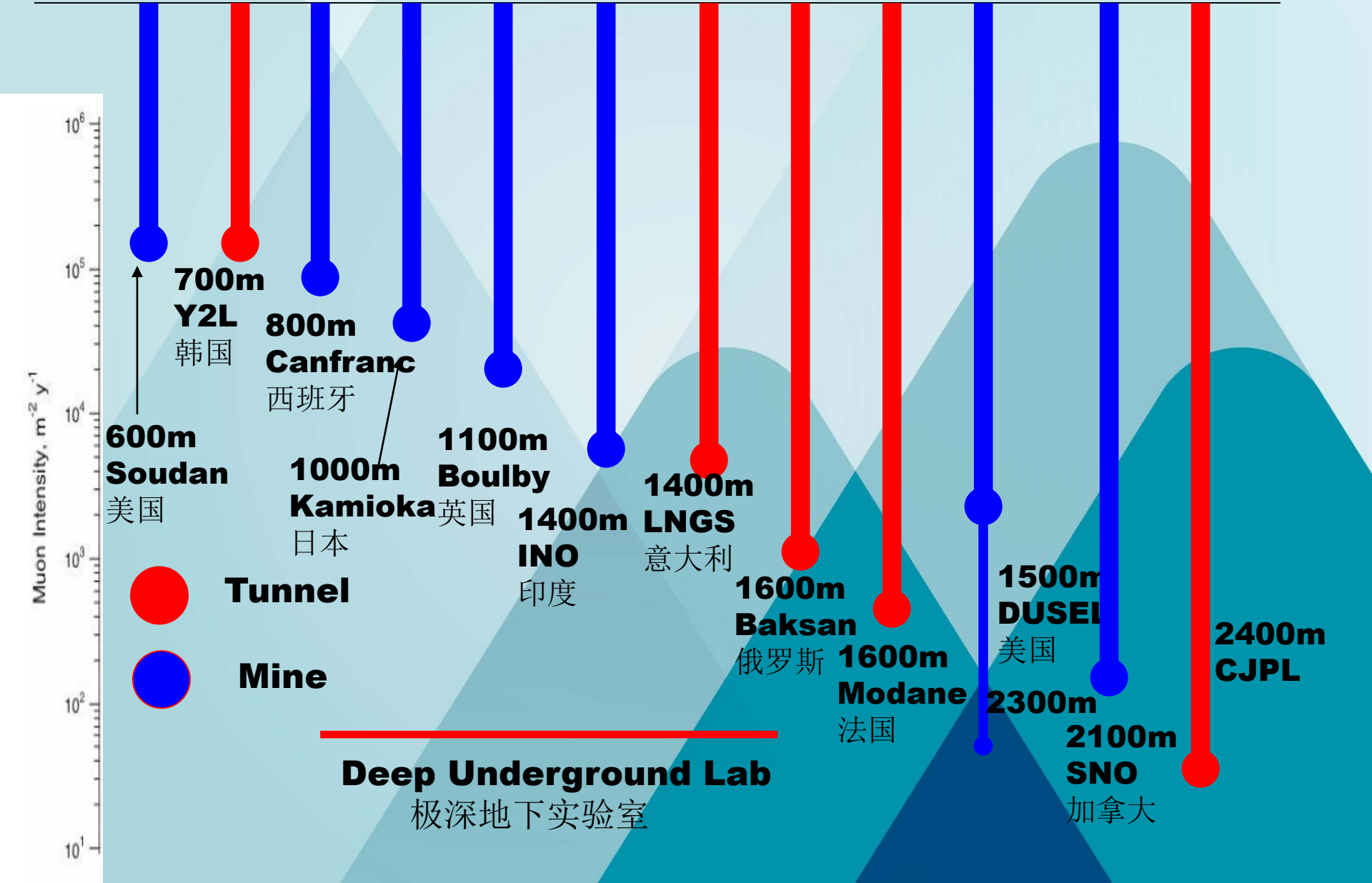

CHINA
Sichuan Province
YaLongRiver
Jinping tunnels
Jinsha River
YaLong River
Jinsha River
Jinsha River
N
Yunnan Province


Altitude (m)
4500
4000
3500
3000
2500
2000
1500
1000
500
Yalong Rivor
JinPing Mountain
JinPing Tunnel
JinPing Tunnel
CJPL Site
Yalong River
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000

China JinPing Underground Laboratoy (CJPL)



UL in the world(rock overburden)

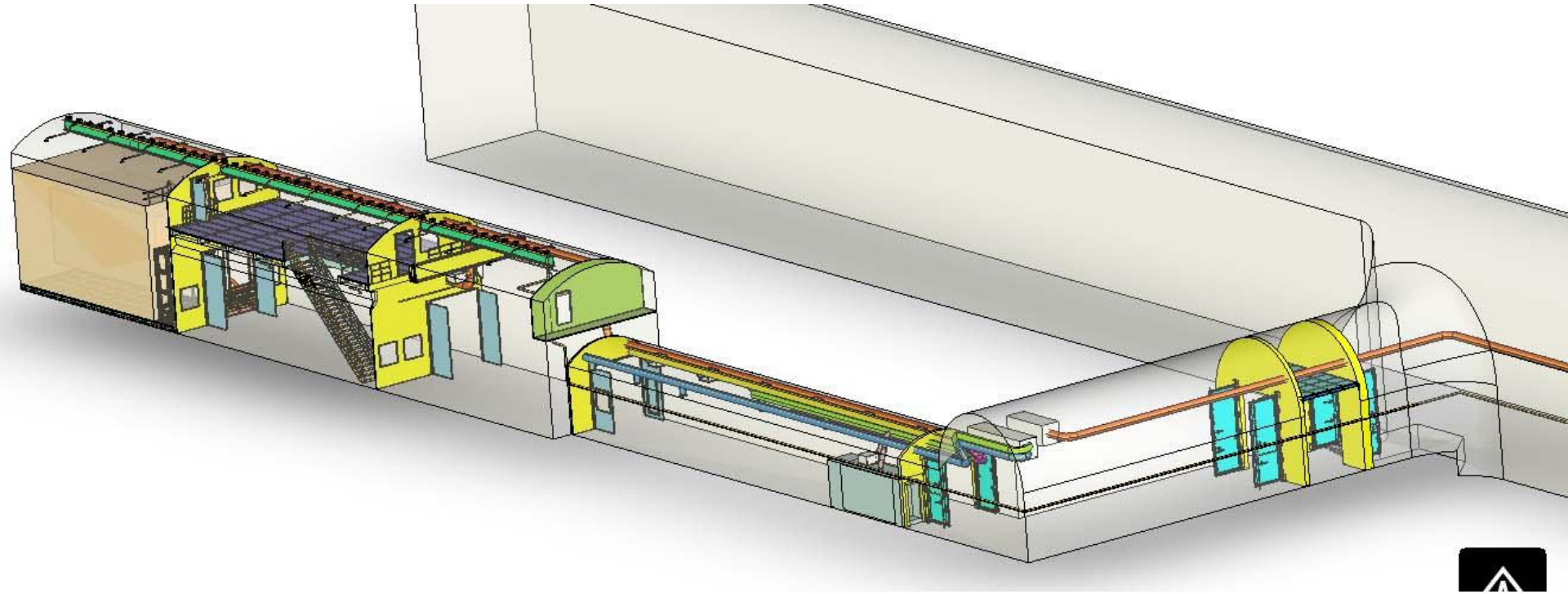


CJPL Rock Background

(Unit： Bq/kg)	**K-40**	**Ra-226 (609keV)**	**Th-232 (911keV)**
CJPL Rock Sample	< 1. 1	1.8±0. 2	< 0. 27
Beijing Normal Ground Level	~600	~25	~50

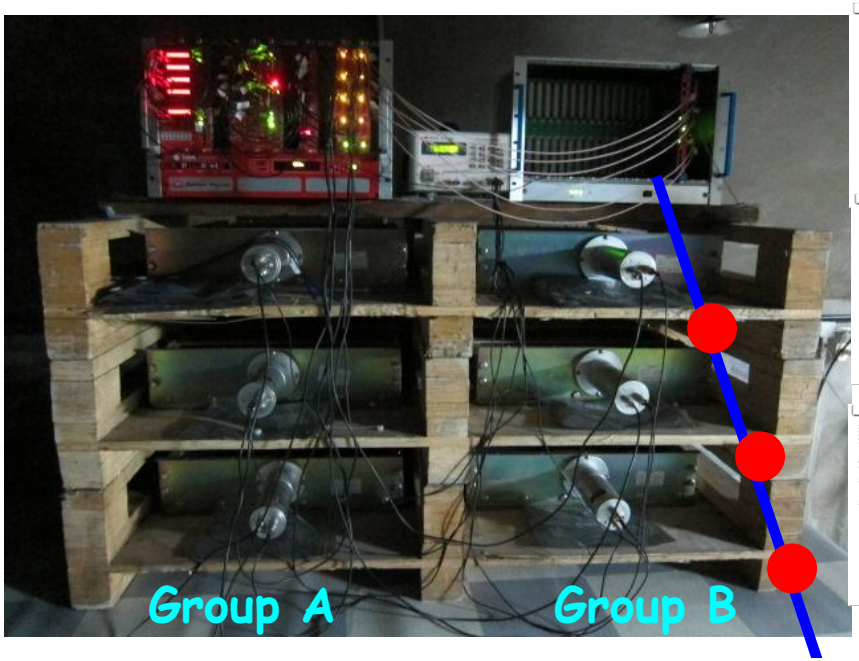
CJPL

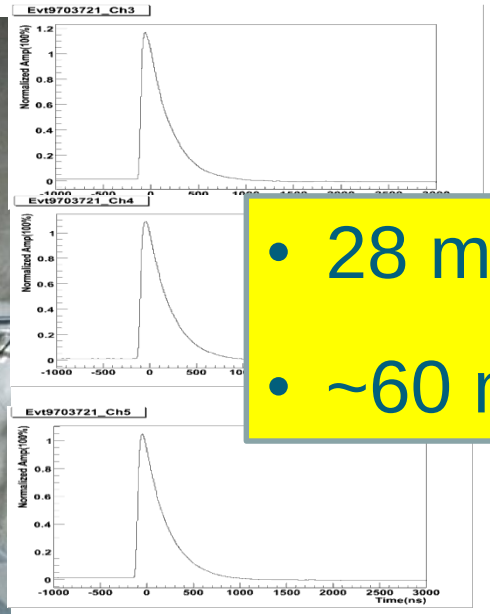
CJPL internal layout



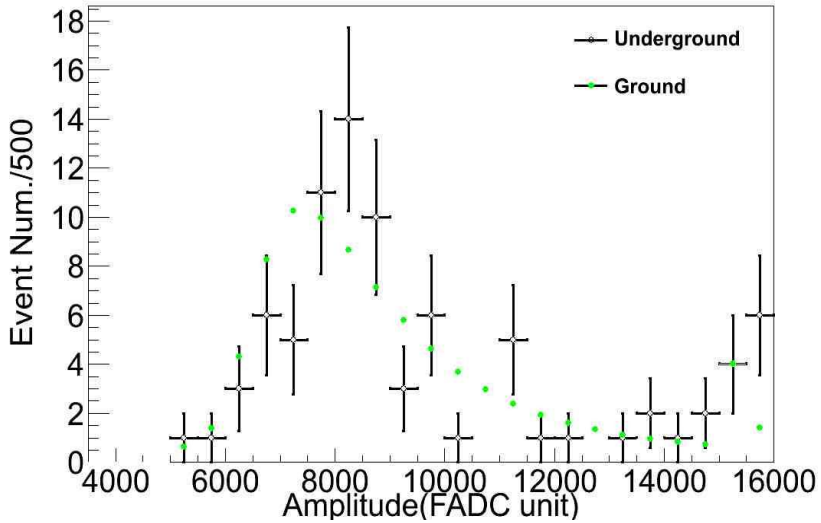
CJPL

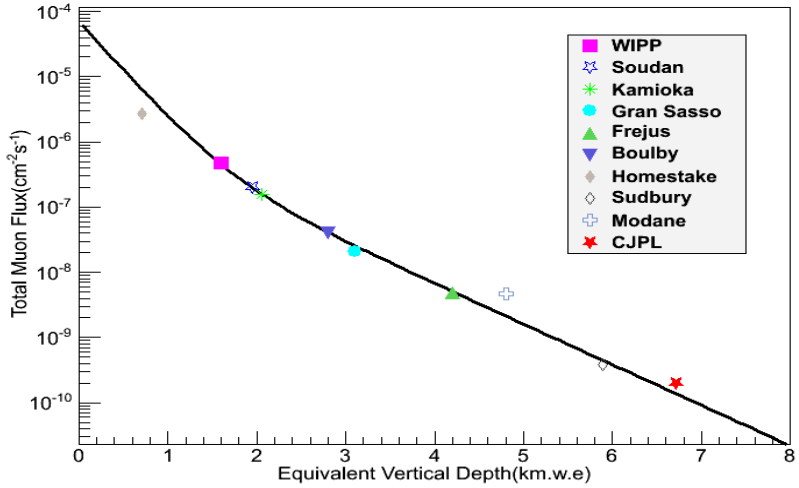
Muon flux @ CJPL



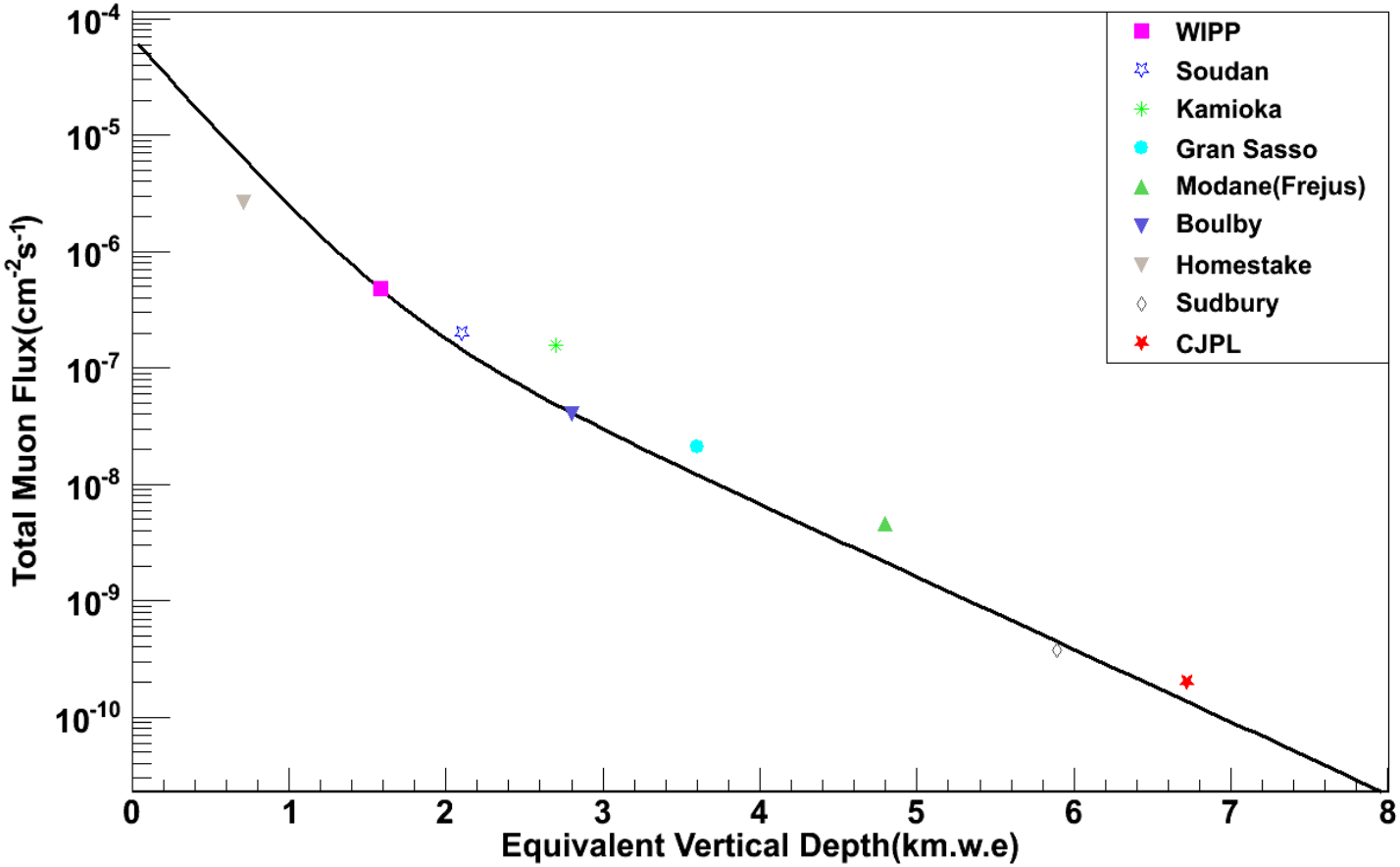


- 28 muons / 171 day;
- ~60 muon/year/m^2;





CJPL muon flux



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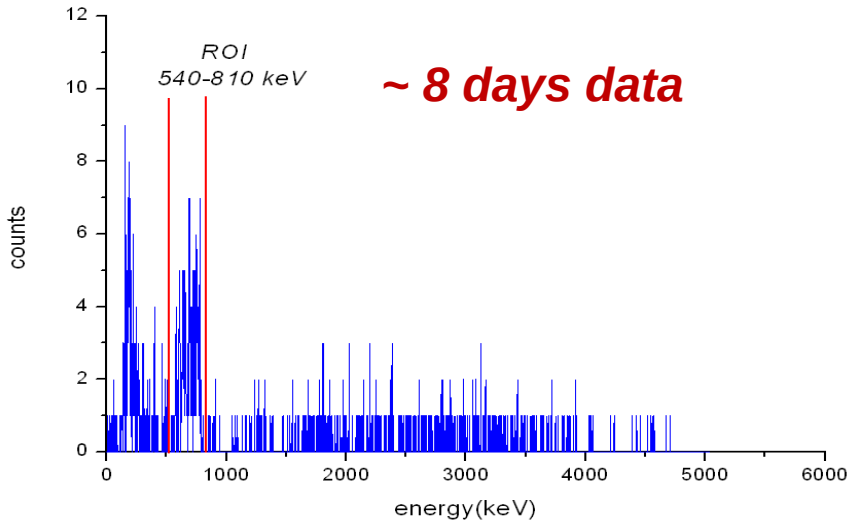
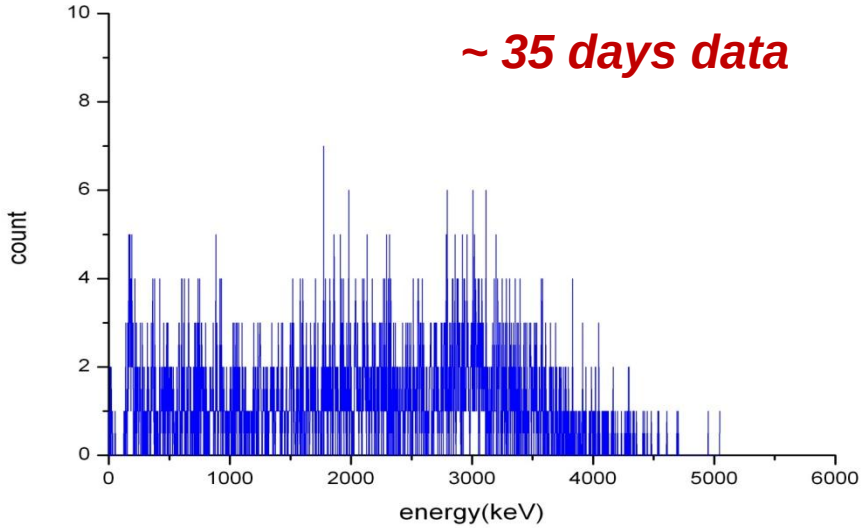
CJPL thermal neutron detection system

CJPL

CJPL thermal neutron flux

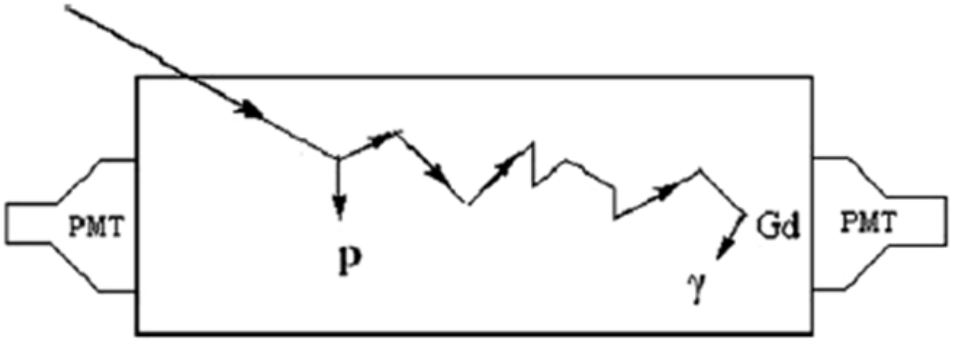


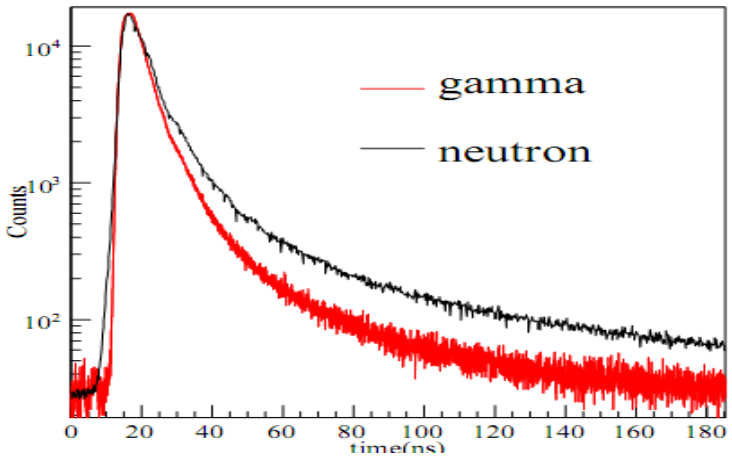


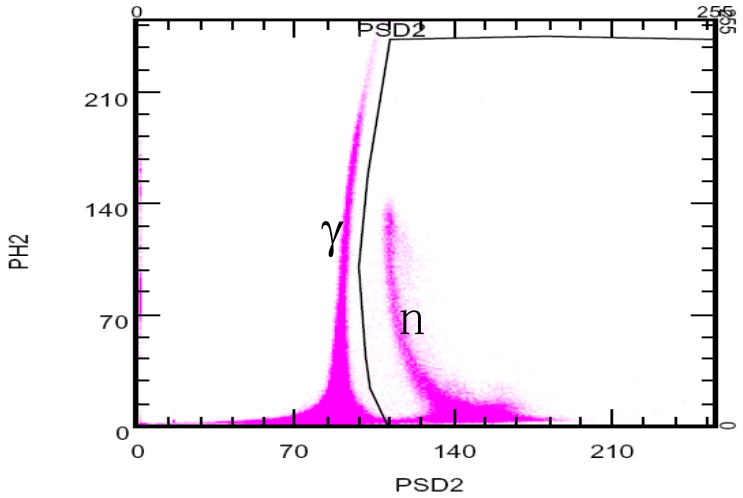
	大厅	屏蔽体内
ROI rate	34.11 cpd	3.71 cpd
α rate in ROI	4 cpd	4.4 cpd
Thermal neutron count	~30 cpd	< 1 cpd
Thermal Neutron flux	4.34 x10^{-6} n/cm^2/s	< 1.45 x10^{-7} n/cm^2/s

CJPL

Fast neutron flux measurement in CJPL (Gd-load LS detector)







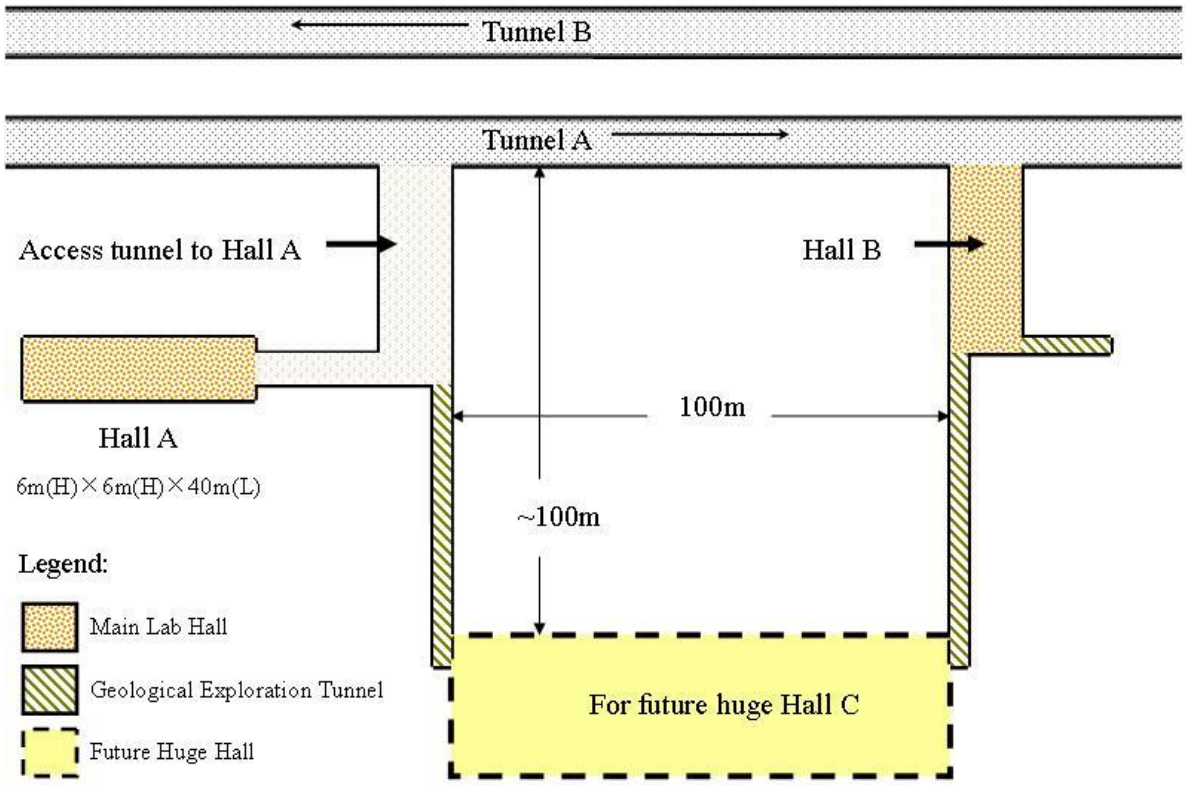
CJPL

Low background facility

CJPL

CJPL Future Plan

- CJPL-II: space 20* CJPL-I;
- Dimension: 12m*12m*50*N;
- Under design now;
- Possible finished 2014.

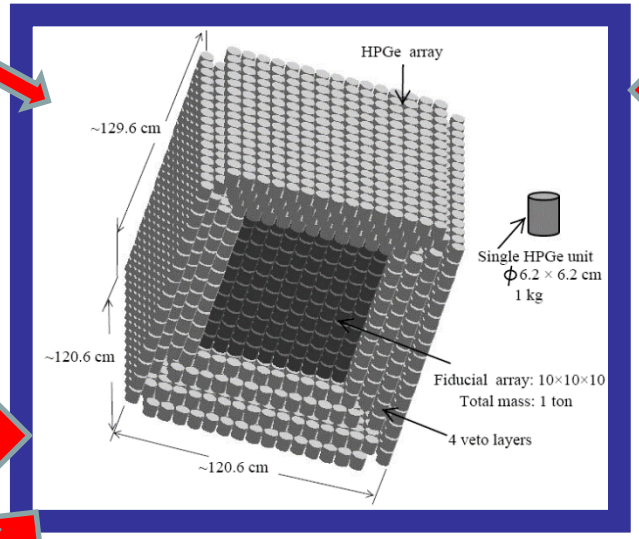


Ton-scale Ge exp. for rare events search

Low energy background:
CDEX, TEXONO, CoGeNT, CDMS, EDELWEISS

High energy background:
Gerda, Majorana, AGATA, CDEX,……

Underground Lab:
CJPL, LNGS, Modane, SNO, Sanford,……



Ge detector fabrication:
Canberra, ORTEC, CDEX, ……

Shielding system:
LAr, LXe, Water, PE, ……

Electronics:
JFET-PreAMP, ASIC, FADC,…

Crystal Growth:
Canberra, Umicore, USD, CDEX, …

CJPL

Summary

- CDEX has started CDEX-1 experiment, and a first physics result will come soon.
- The prototype PCGe and BEGe detectors will also scan the 76Ge DBD energy region to learn the background therein.
- CDEX-10 (PCGe+Lar AC) will start ground testing at SCU from this May on and plan to ship to CJPL from 2014.
- CDEX-1T related technologies has been exploited by CDEX including background understand, detector fabrication, crystal growth, electronics and so on.
- CJPL with deepest rock overburden in the world run now. CJPL-II with 20 times space under design.

CJPL

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

Thank you for your attention!