Status and Results from CDEX Collaboration at China Jinping Underground Laboratory

- ✓ CDEX Collaboration : (People, Program, Facility)
- ✓ Results from CDEX : (Dark matter & Axions)
- ✓ CJPL-II construction and its science program
- ✓ R&D on low radioactivity, low threshold techniques
- ✓ Outlook & Prospects

Shin Ted Lin / Sichuan University
for the CDEX Collaboration
Dark2016@NCTS, HsinChu. Taiwan. December 29-31 2016

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

China Dark matter EXperiment (CDEX) - EST in 2009

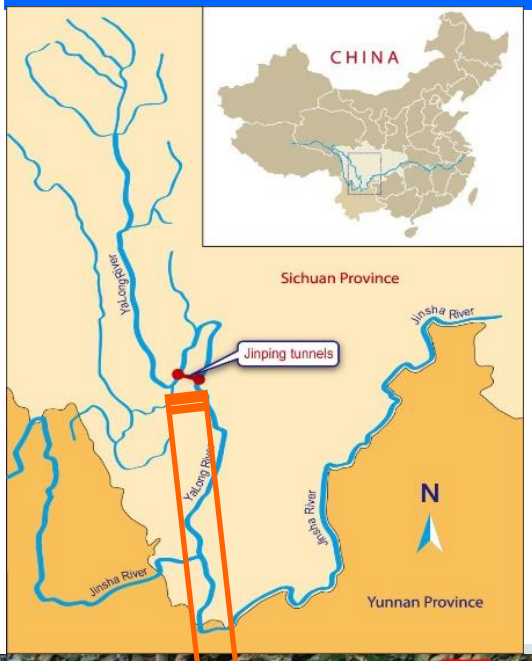
- Tsinghua University
- Sichuan University
- Nankai University
- China Institute of Atomic Energy, CIAE
- Yalong River company (former:EHDC)

- *Intensively collaborate with TEXONO group.*

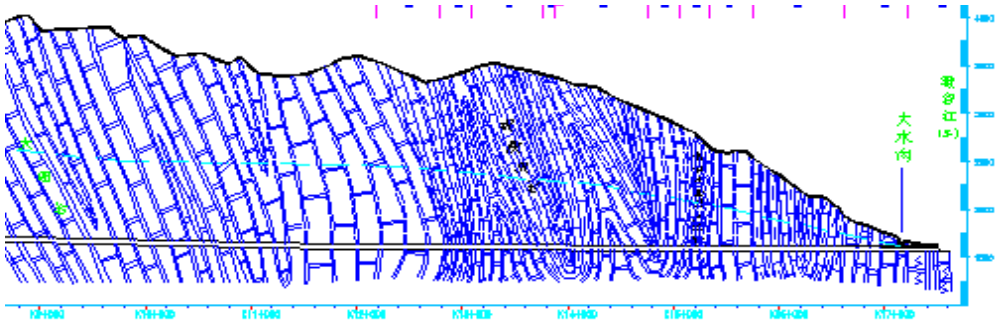
🏆 **Detection of dark matter with a point-contact germanium(PCGe) array**

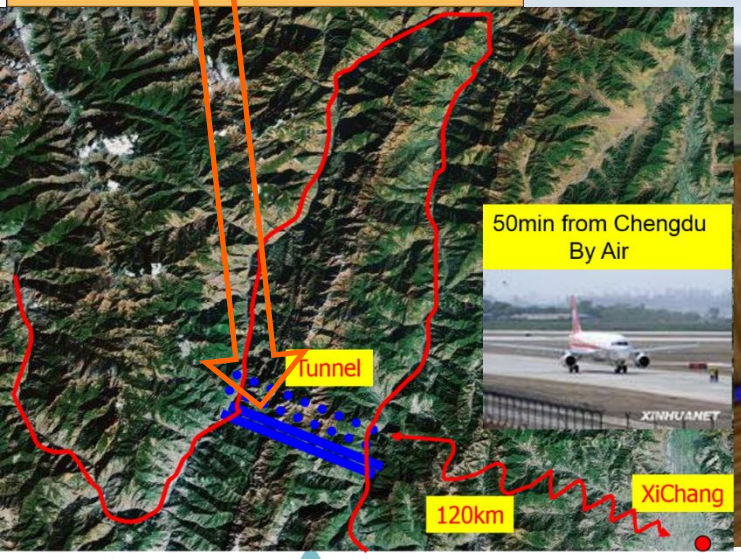
CJPL

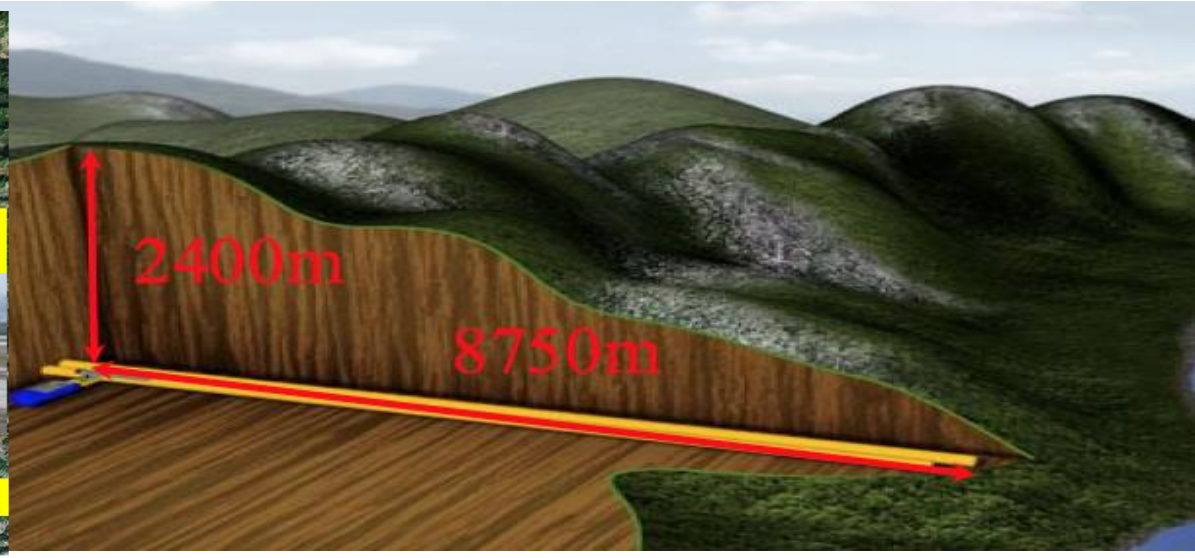
CDEX at China JinPing Underground Laboratory



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



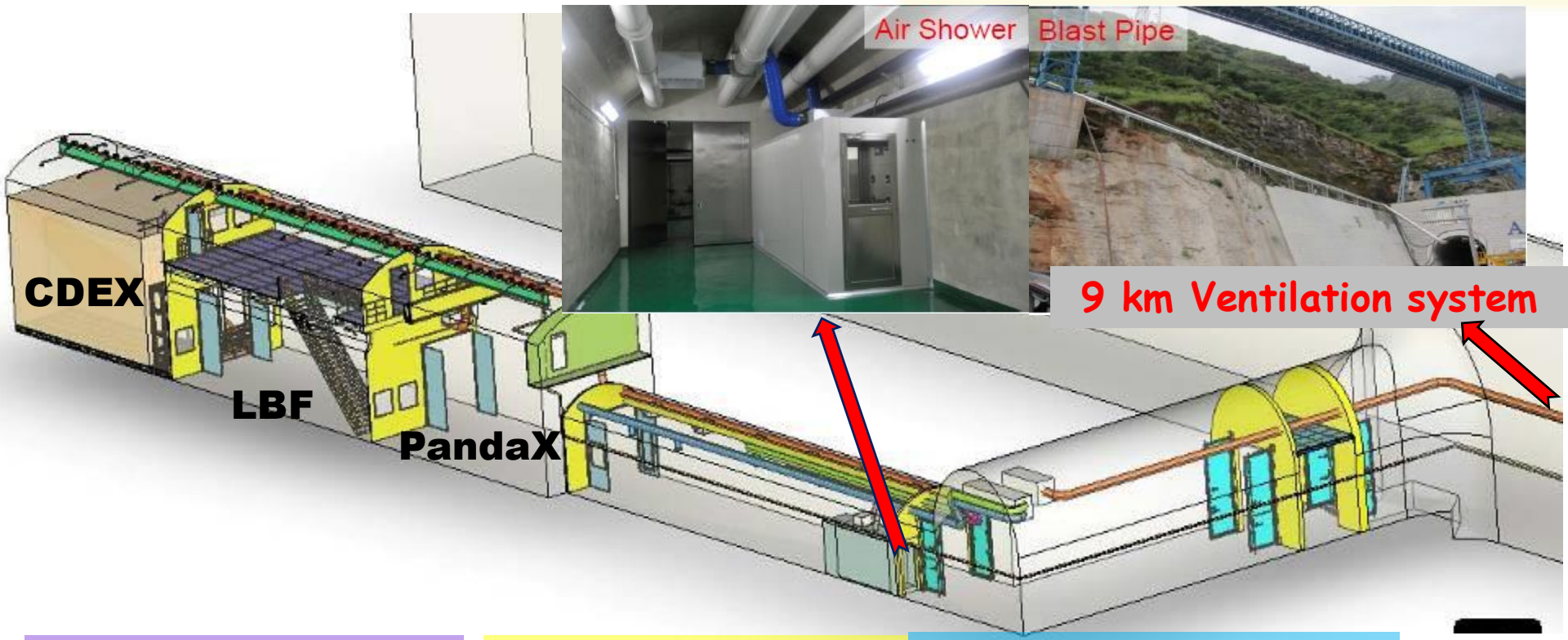




CJPL

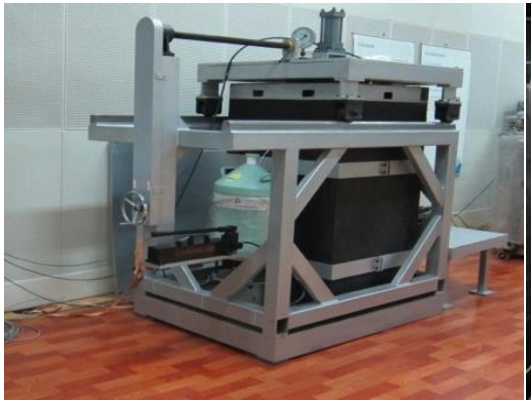
The space allocation of CJPL-I

- Total space: 4000 m^3
- Lab Space: 6.5m(W) x6.5m(H) x 42m(L)



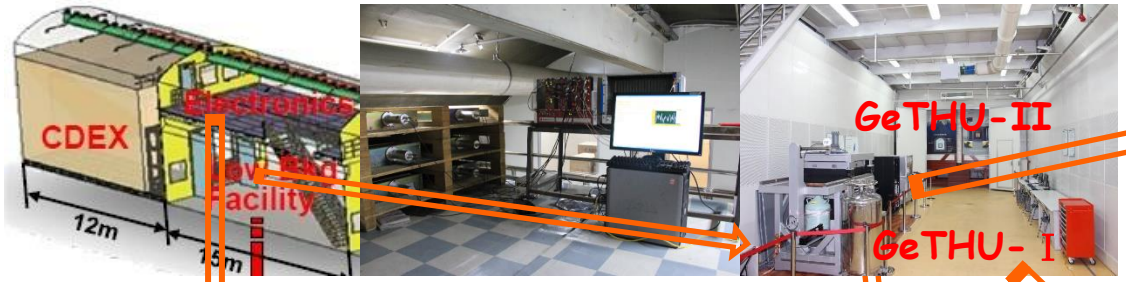
✓ CDEX

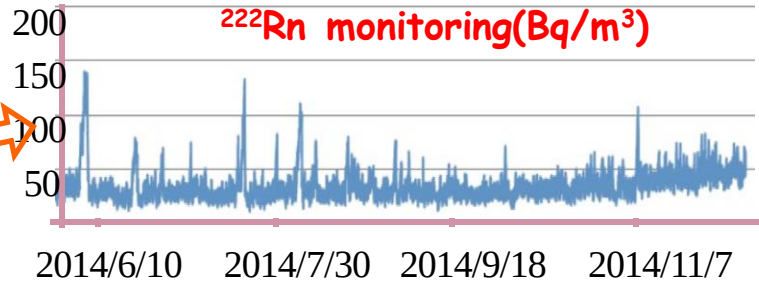
✓ CJPL-LBF

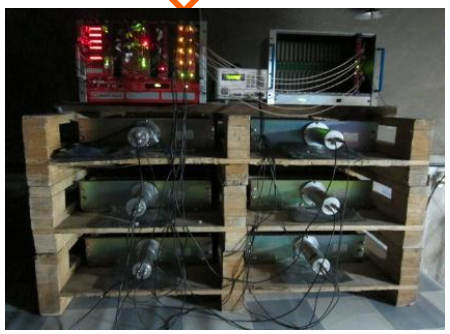


✓ PandaX

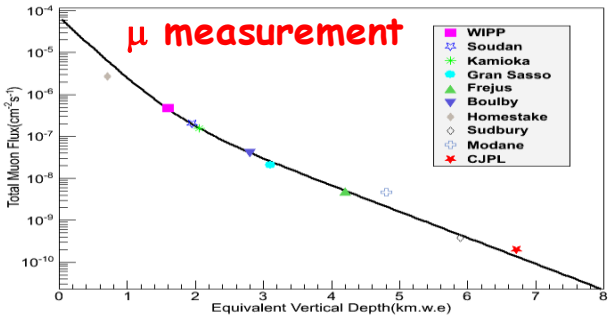
Low-background Counting facilities at CJPL-I





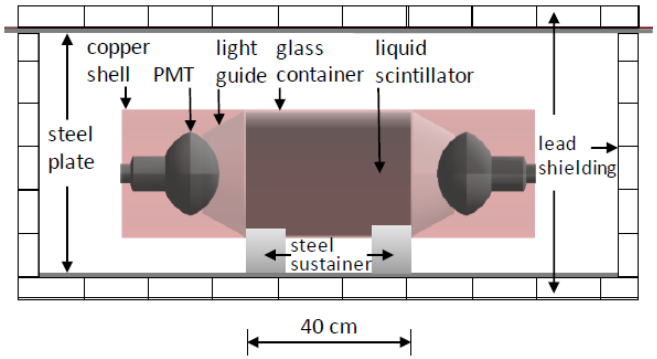


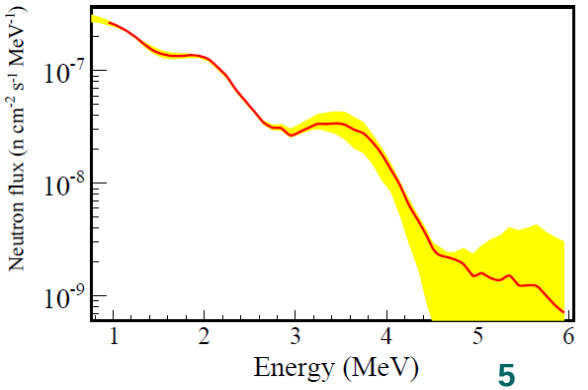
(Unit : Bq/kg)	K-40	Ra-226 (609keV)	Th-232 (911keV)
Rock Sample	< 1.1	1.8±0.2	< 0.27
Ground Level (Beijing)	~600	~25	~50



- μ flux ~ 60 /year/m²

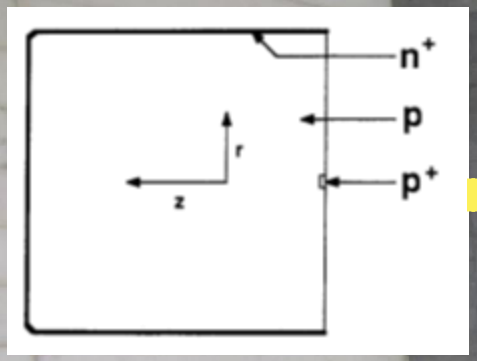
Ref: Chinese Physics C 37, 8 (2013) 086001

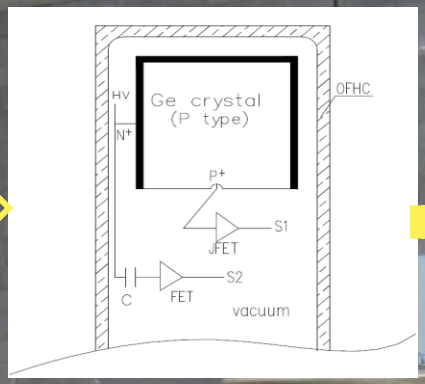


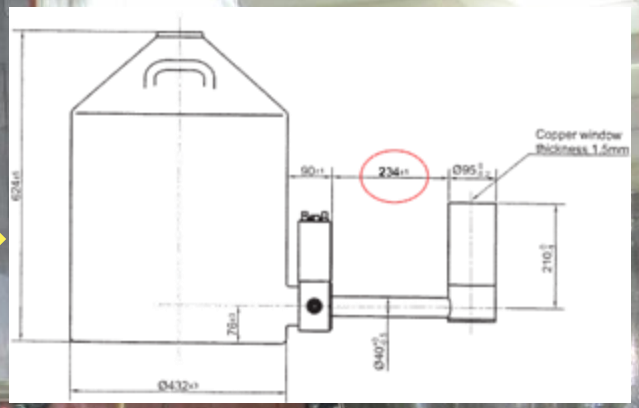


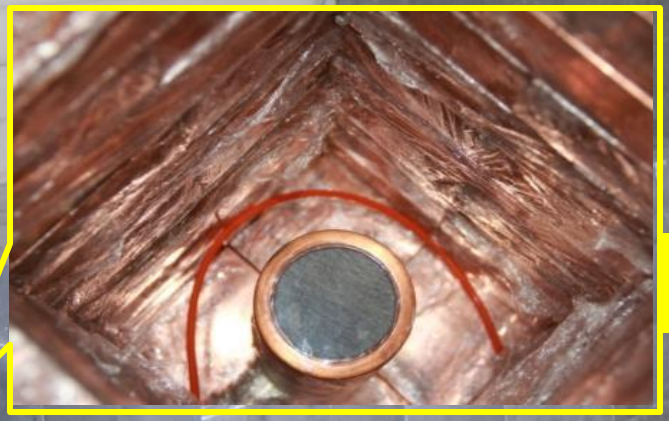
CJPL

Detectors in CDEX -0/1





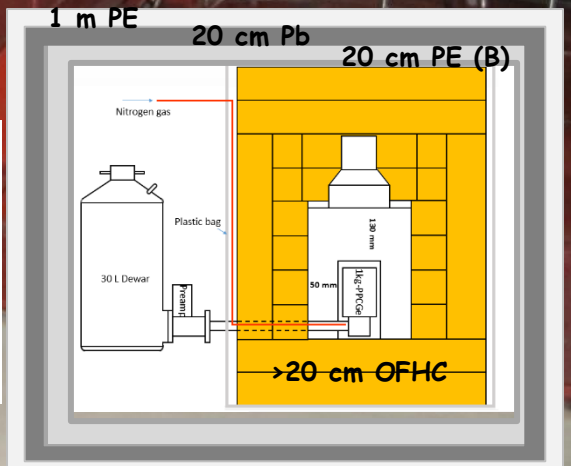




1kg pPCGe

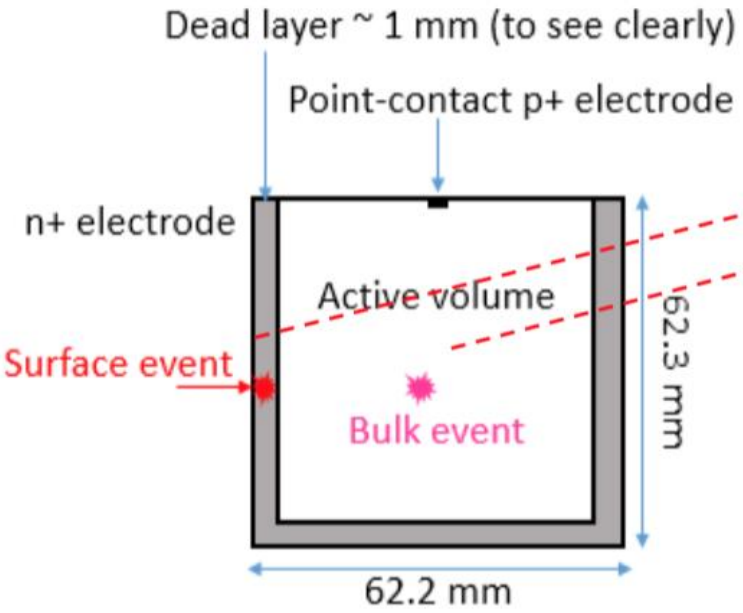
4*5g ULEGe

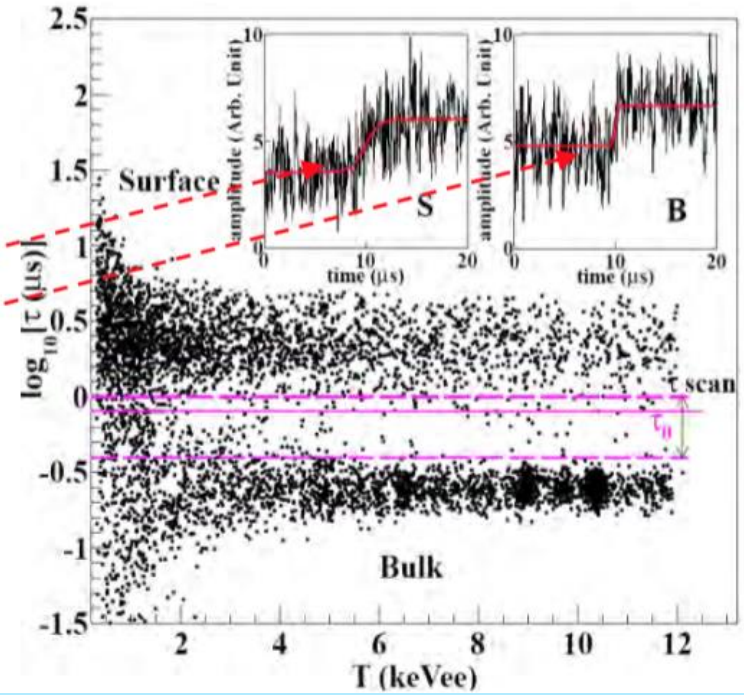
- ✓ 1 kg-scale pPCGe : low energy threshold & good energy resolution.
- ✓ NaI, enclosed the cryostat of Ge, served as anti-Compton detector.



Event Selection & Efficiencies

✓ n+ "inactive layer" is not totally dead; signals finite but slower rise time





1kg pPCGe @ CJPL

$$B' = \epsilon_{BS} \cdot B + (1 - \lambda_{BS}) \cdot S$$
$$S' = (1 - \epsilon_{BS}) \cdot B + \lambda_{BS} \cdot S$$

✓ **Algorithm**

Measure energy-dependent signal-retaining (ε_{BS}) & background-suppressing (λ_{BS}) efficiencies through at least two calibration data & solving the coupled equations.

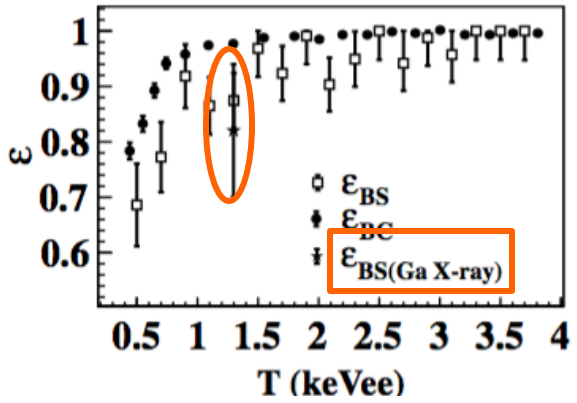
CJPL

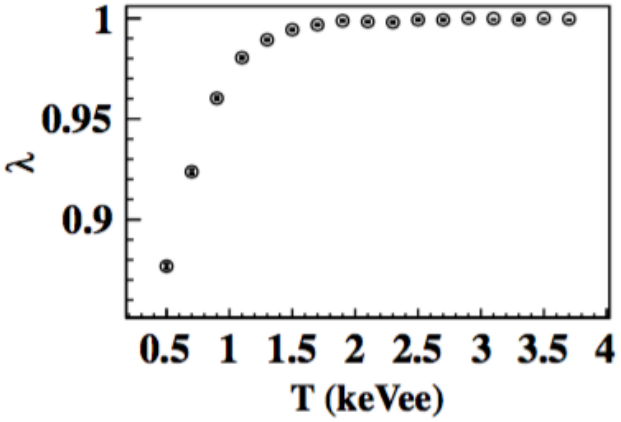
✓ The analysis details are established together with TEXONO group.

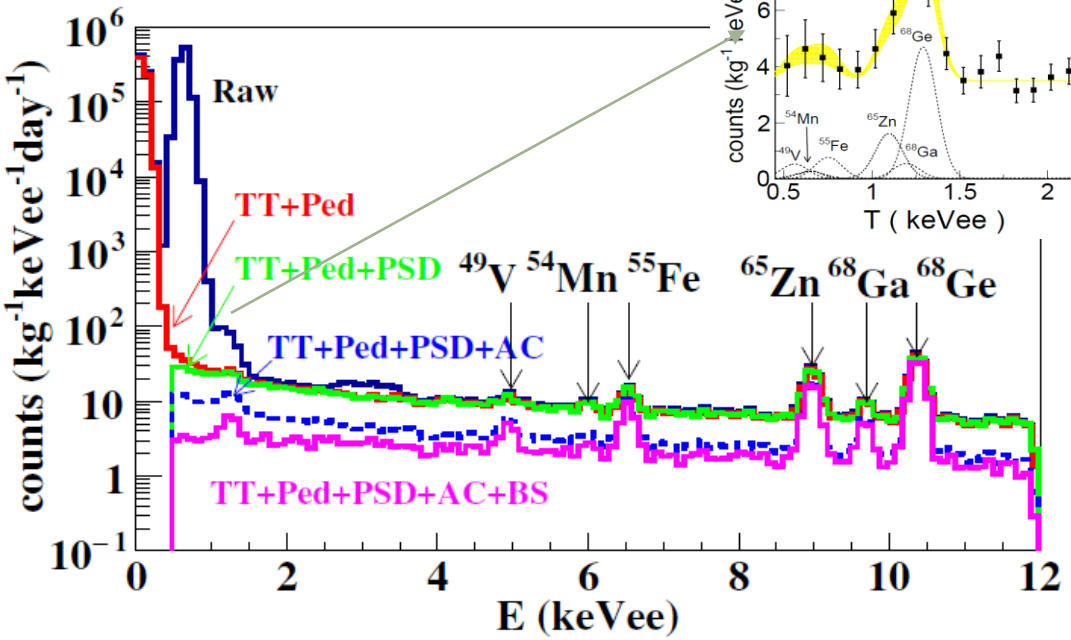
Recoil Spectrum for pPGe at CJPL

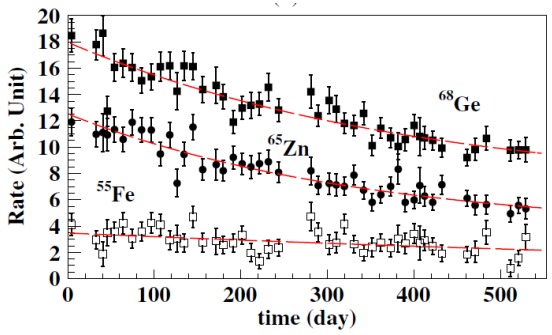
$$B_0 = \frac{\lambda_{BS}}{\varepsilon_{BS}+\lambda_{BS}-1}\cdot B - \frac{1-\lambda_{BS}}{\varepsilon_{BS}+\lambda_{BS}-1}\cdot S$$

$$S_0 = \frac{\varepsilon_{BS}}{\varepsilon_{BS}+\lambda_{BS}-1}\cdot S - \frac{1-\varepsilon_{BS}}{\varepsilon_{BS}+\lambda_{BS}-1}\cdot B$$

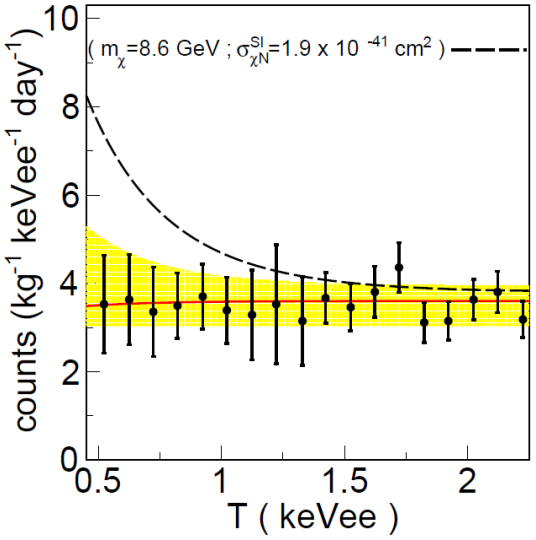






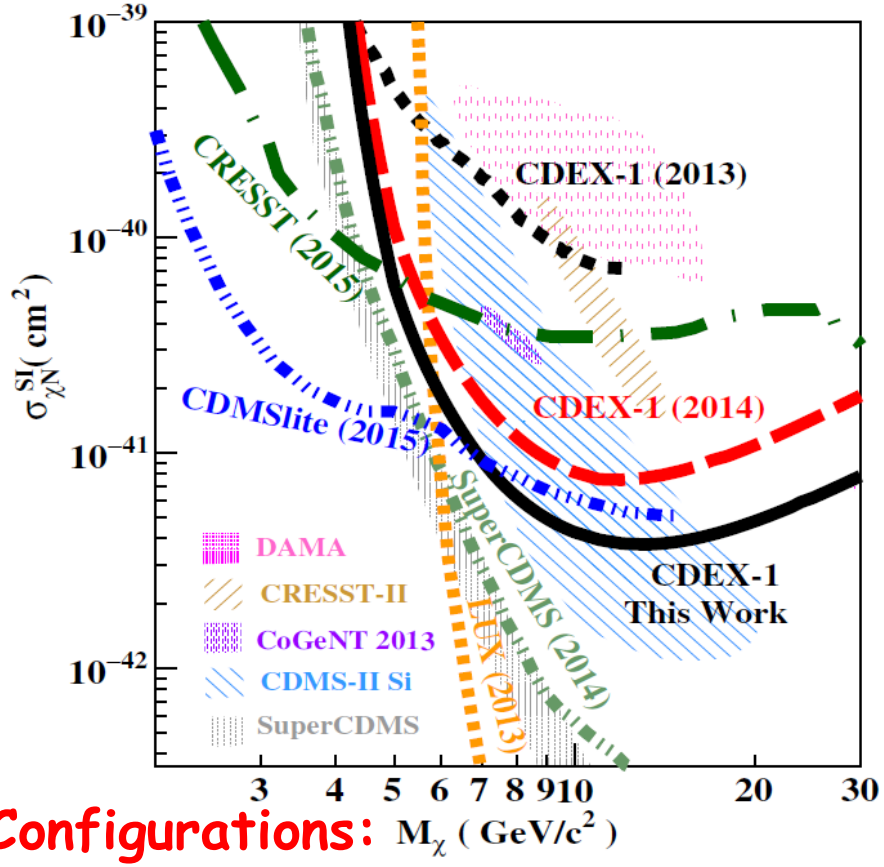


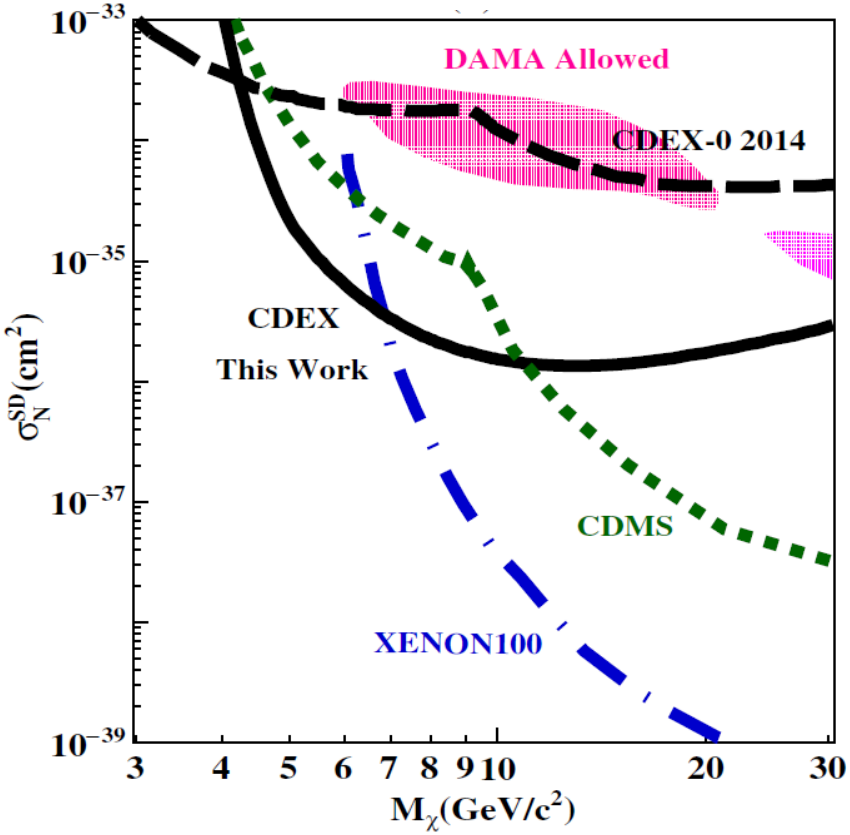
- **Time evolution of Cosmogenic peaks**



CJPL

Results of Light WIMPs Searches from CDEX





Configurations:

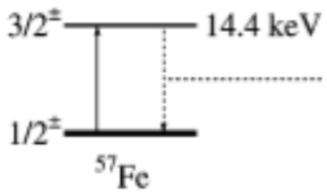
- 335 kg-days of data @ CJPL (2016)
- Baseline design with NaI(Tl)
- Fiducial mass : 915 g
- Analysis above : 475 eV
- Q.F. adopted by TRIM software with 10% systematic uncertainty

Reference: *PRD 93 092003 (2016) ; PRD(R) 90 091701(2014); PRD 90 032003 (2014); PRD 88 052004 (2013)*

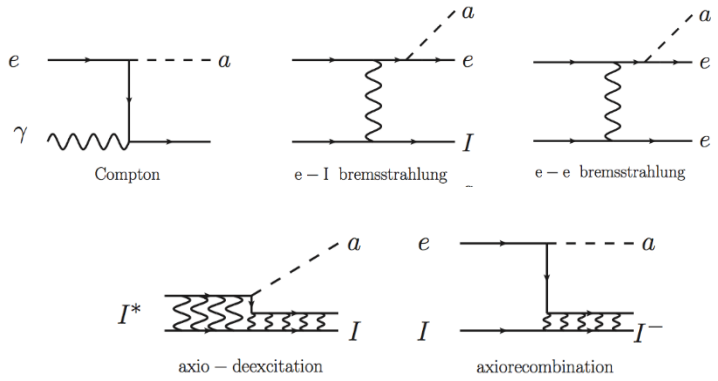
CJPL

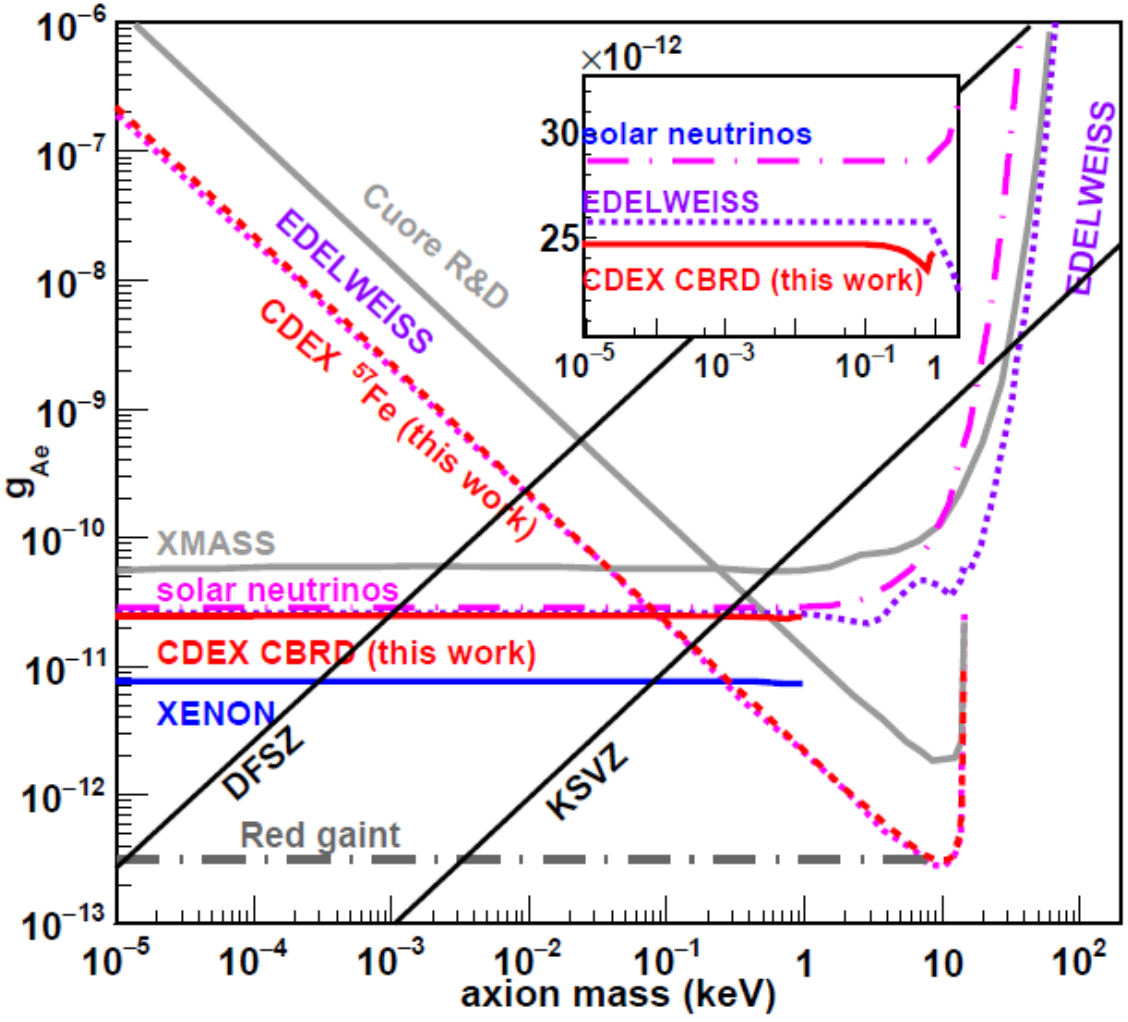
Preliminary Results of axion searches at CJPL

- ✓ M1 transition from ^{57}Fe from Sun [axion-nucleons]



- ✓ Compton, bremsstrahlung and axio-RD (recombination & de-excitaion) [axion-electron]

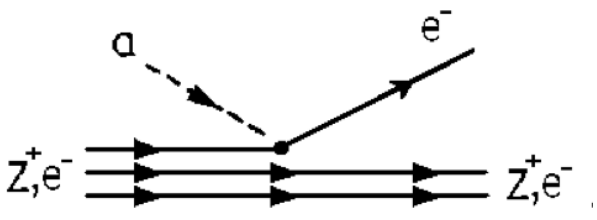




CJPL

Preliminary Results of ALPs as Dark Matter Candidate

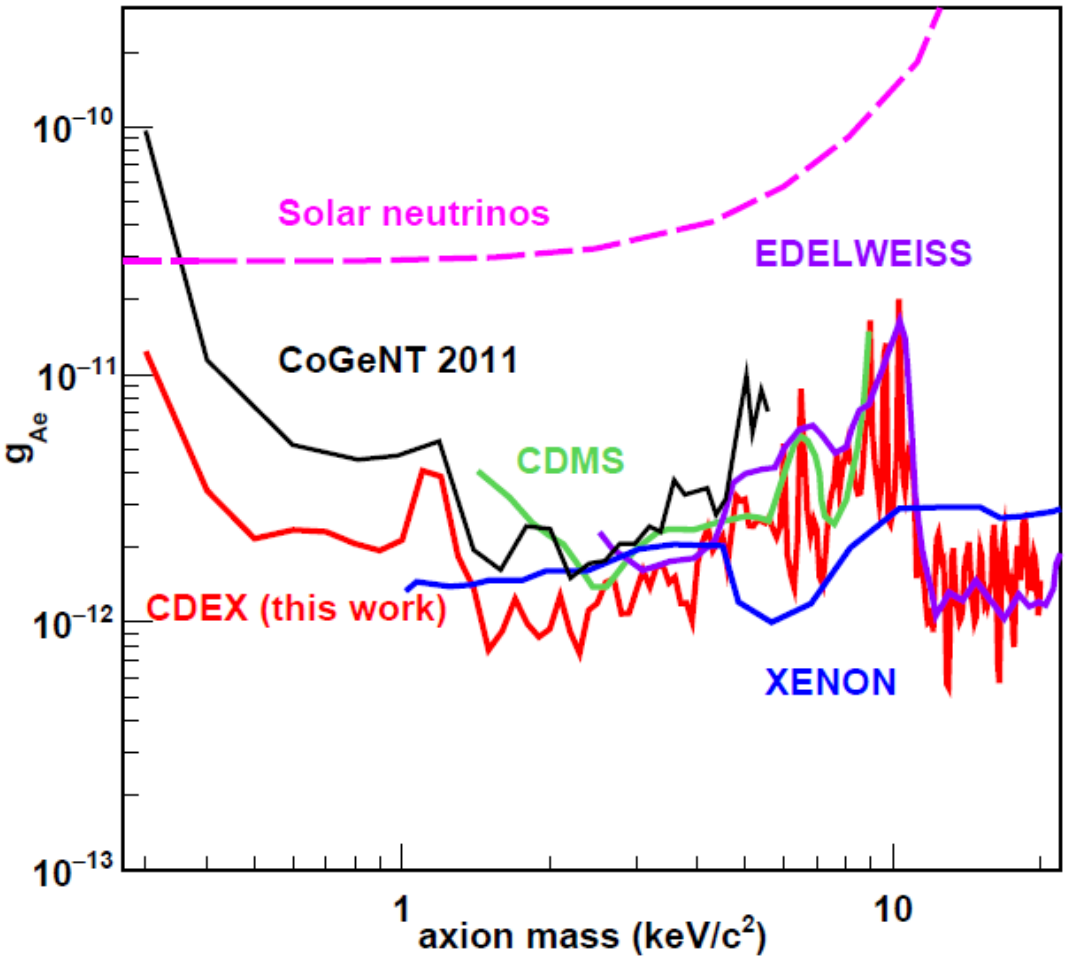
$$R = \frac{1.2 \times 10^{19}}{A}\, g_{aee}^2\, \frac{m_a}{\mathrm{keV}}\, \frac{\sigma_{pe}}{\mathrm{barns/atom}}\, \frac{1}{\mathrm{kg}}\, \frac{1}{\mathrm{day}}$$



Axioelectric
or Photoelectric-like

Reference: Pospelov et al. PRD 78, 115012 (2008)

- ✓ **Competitive results below the axion mass of 1 keV.**



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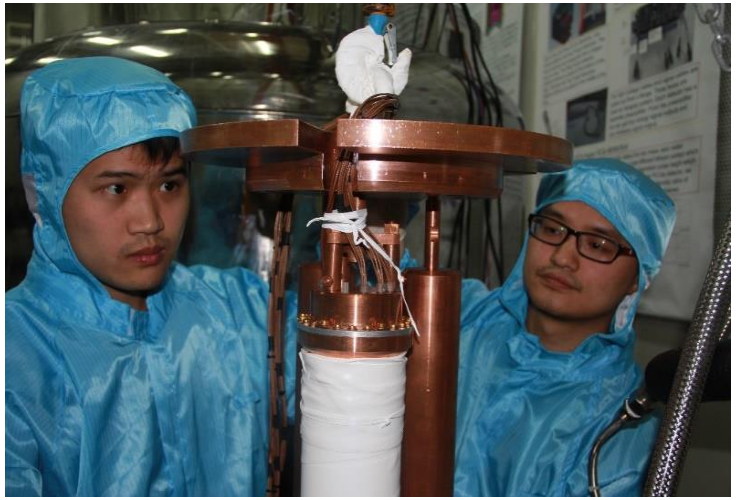
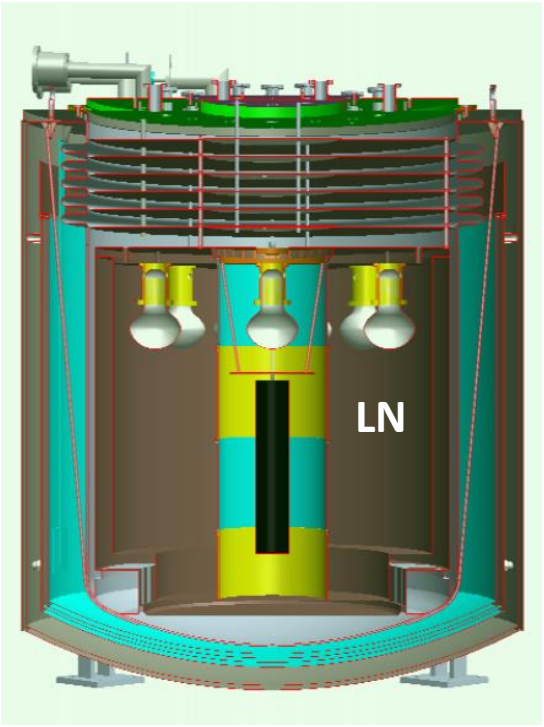
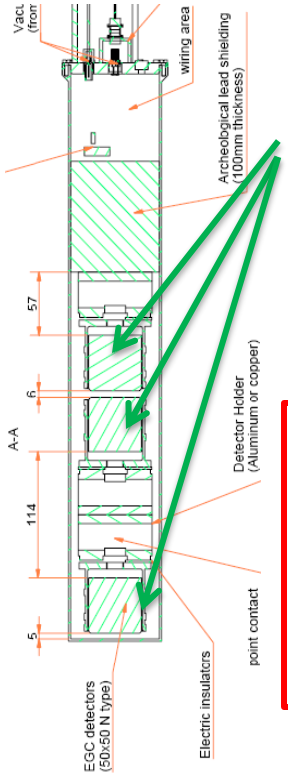
CDEX-10 experiment

- ✓ 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

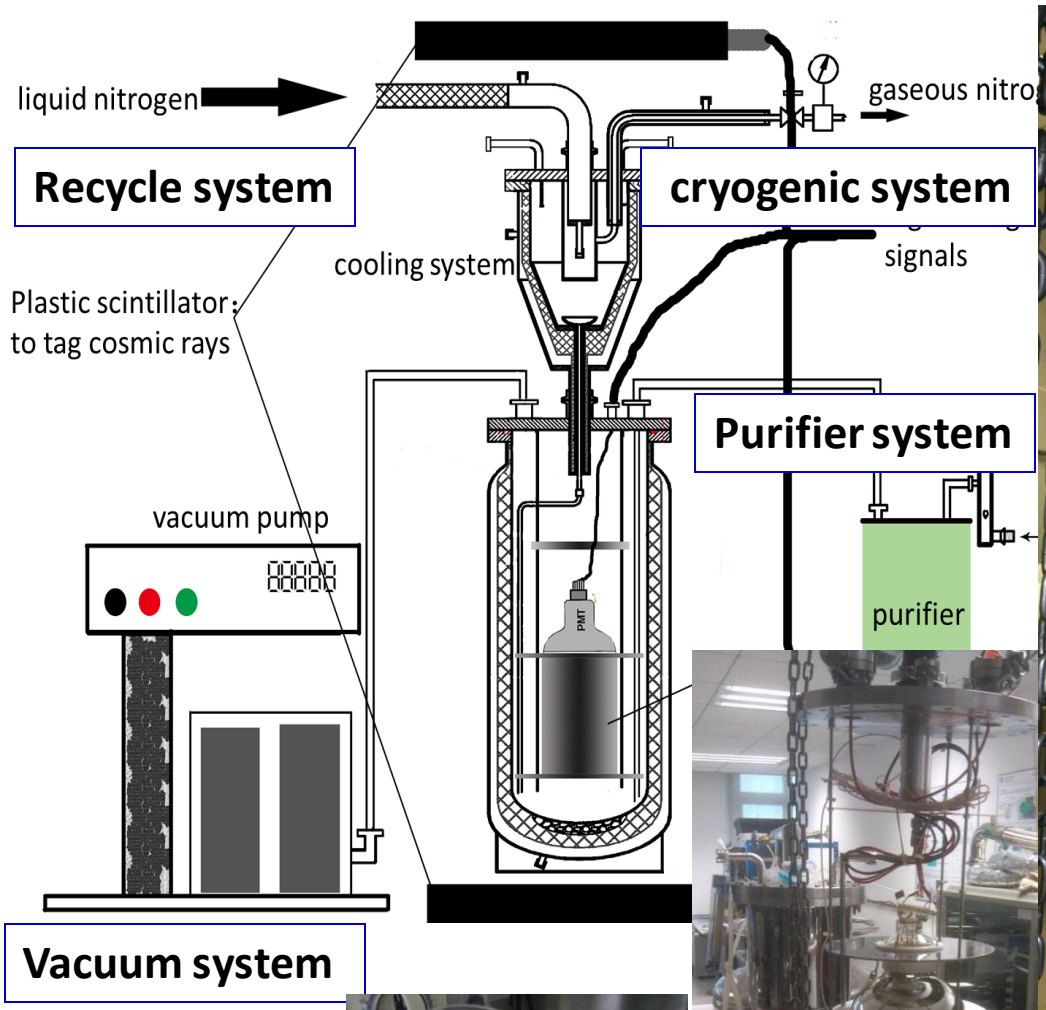
~9 Kg of PCGe

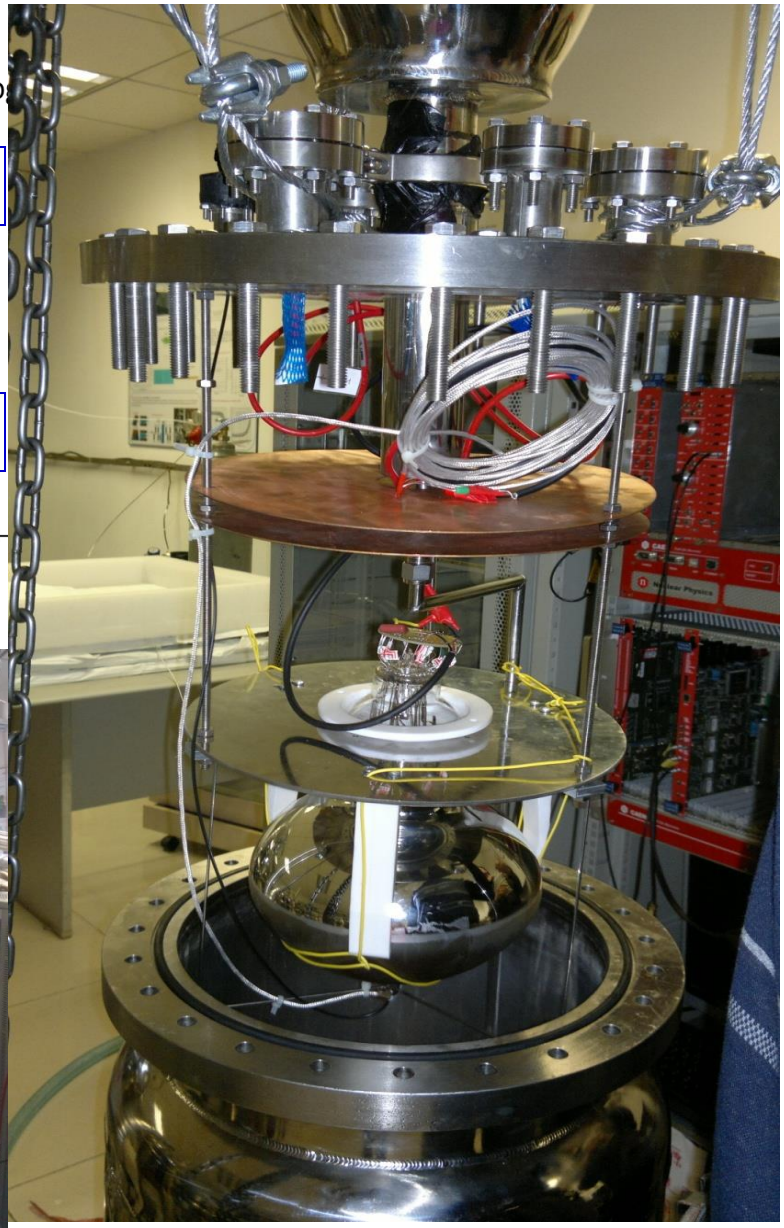
⊕

1.5 Ton of LN/LAr

CJPL

Prototype of LAr anti-Compton detector





CJPL

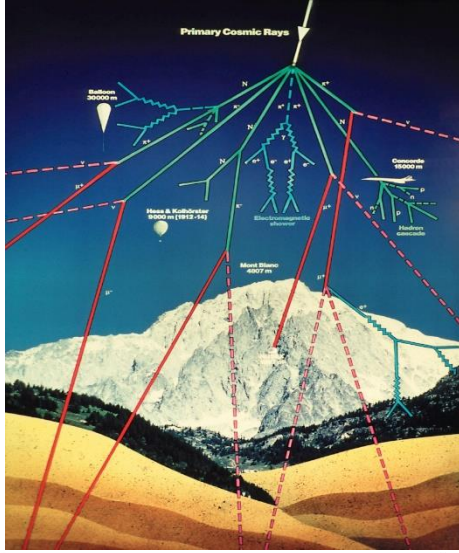
Why go deep underground

- ✓ Reduction of cosmic ray and cosmic ray spallation induced neutron.
- ✓ Highly suppression on cosmogenic radioactive isotopes of the material.

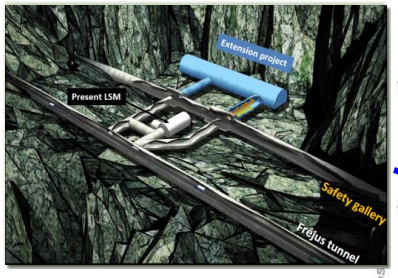
Underground Science

- Particle and astroparticle physics : Dark matter search, $0\nu\beta\beta$, proton decay as well as rare-event phenomena…
- Beyond physics: rock mechanics, subsurface Microbiology, geothermal

Sea-level $4\times10^{9} m^{-2}y^{-1}$

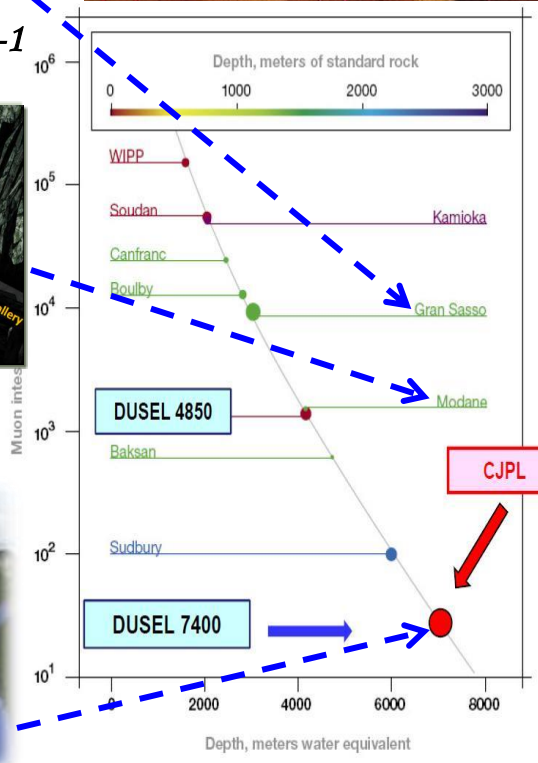


LNGS $1\times10^{4} m^{-2}y^{-1}$

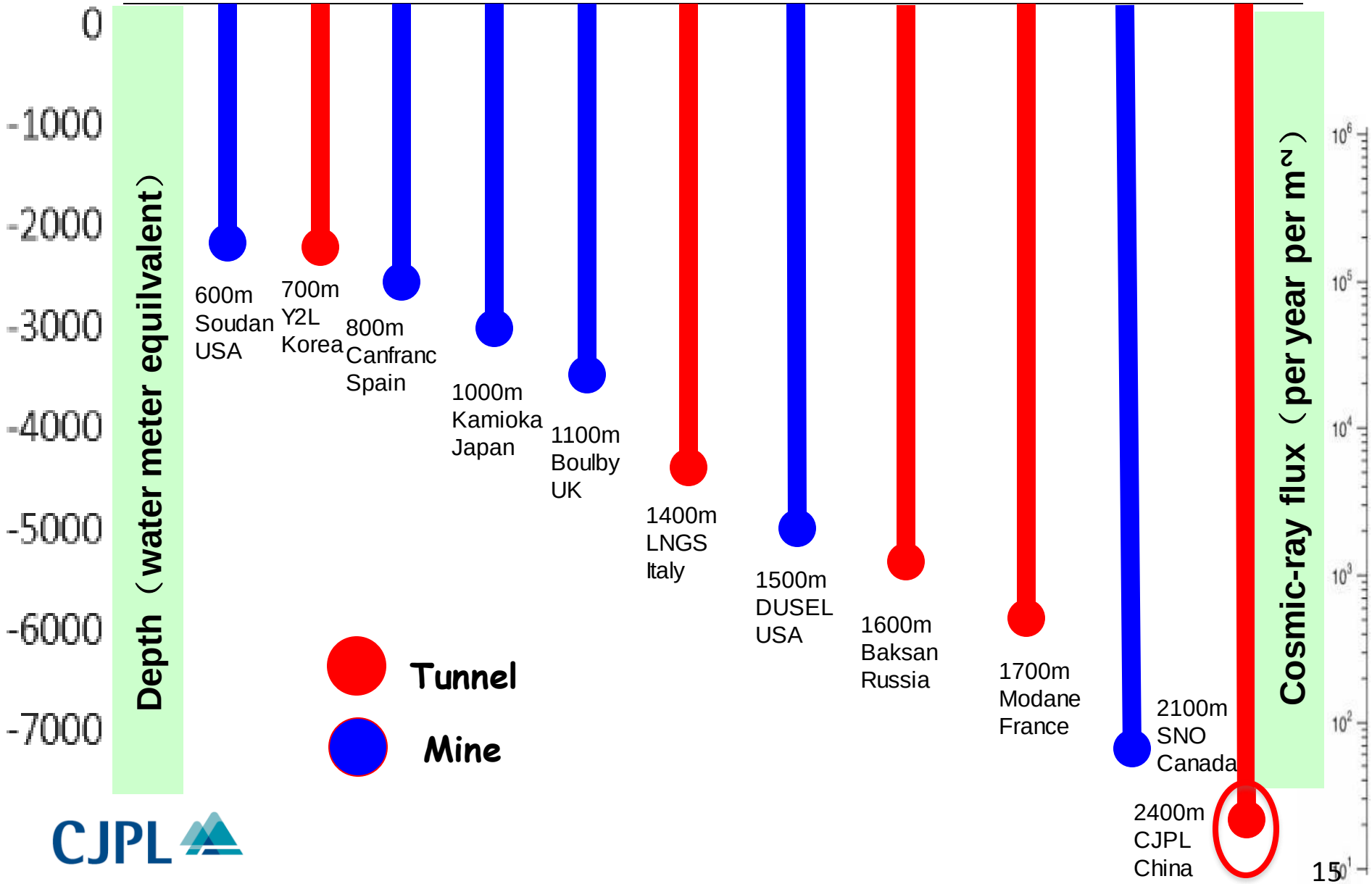


LSM $1\times10^{3} m^{-2}y^{-1}$

CJPL $2\times10^{1} m^{-2}y^{-1}$

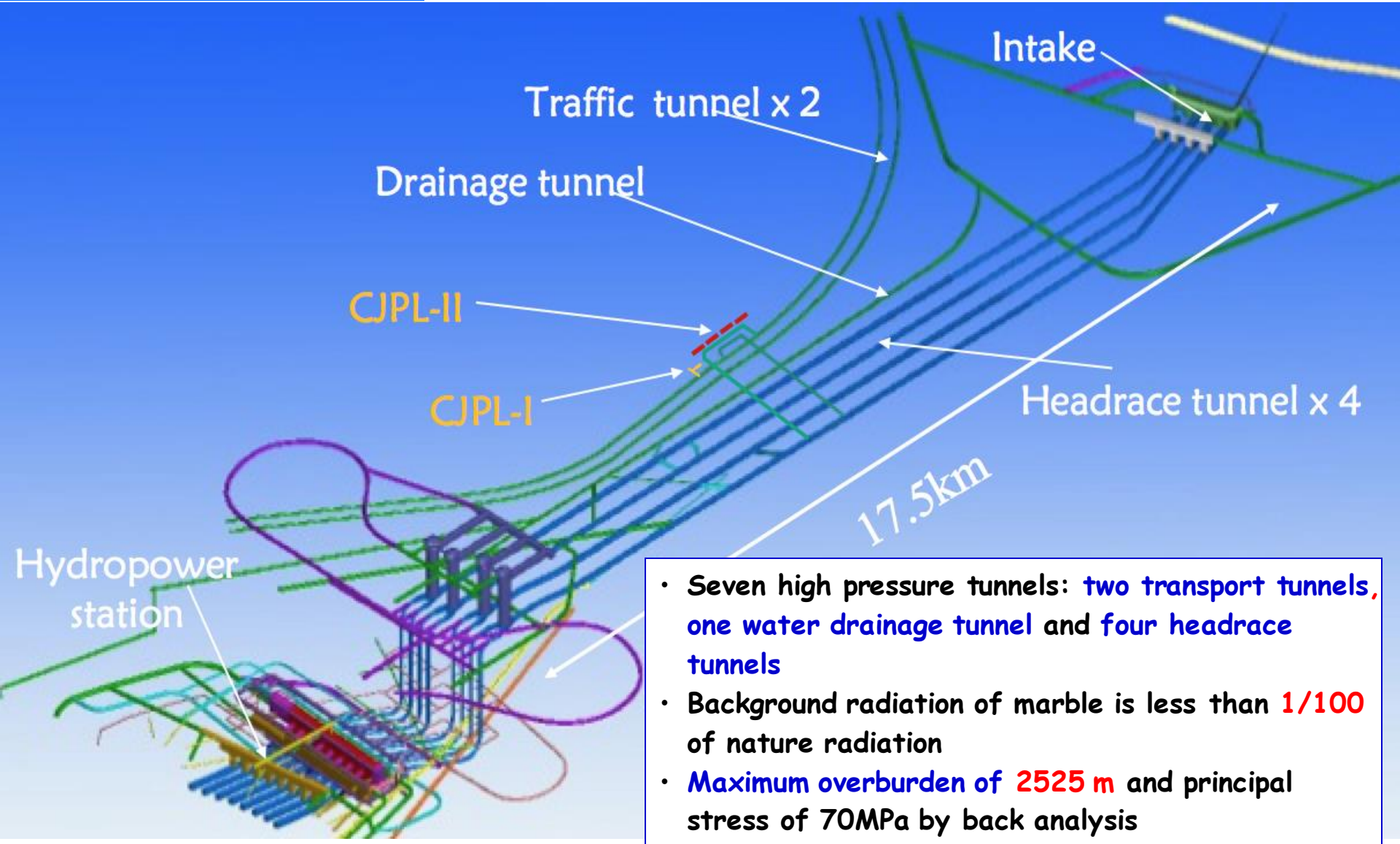


Rock overburden distribution of the UL



CJPL

CJPL-II layout

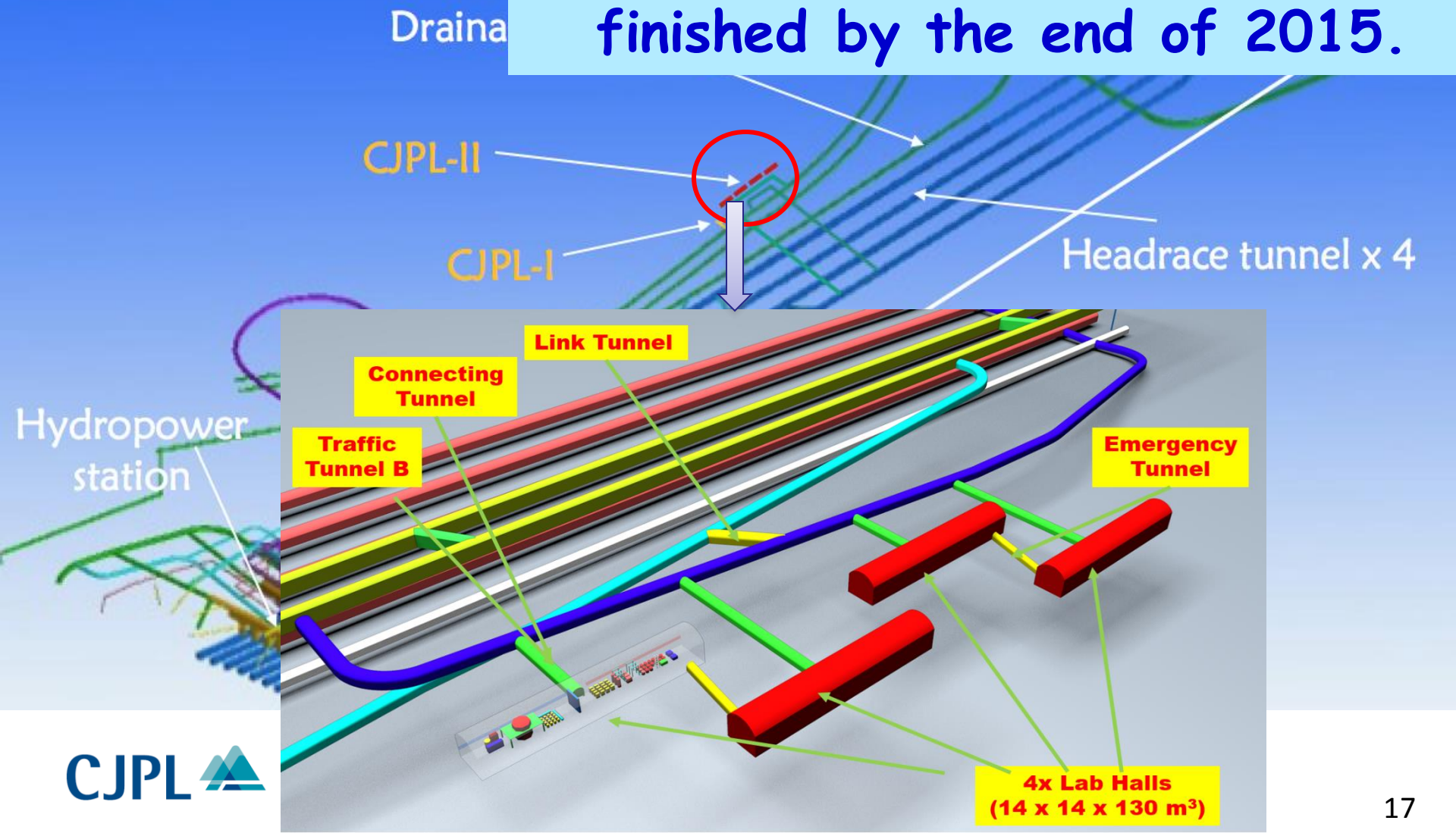


- Seven high pressure tunnels: two transport tunnels, one water drainage tunnel and four headrace tunnels
- Background radiation of marble is less than 1/100 of nature radiation
- Maximum overburden of 2525 m and principal stress of 70MPa by back analysis
- Average length of 17.7km with two curves in the end, good for comic radiation shielding.

CJPL

CJPL-II layout

- Four 14m*14m*130m tunnel
- Total space:~200,000m³
- Infrastructure has been finished by the end of 2015.



CJPL

CJPL-II layout

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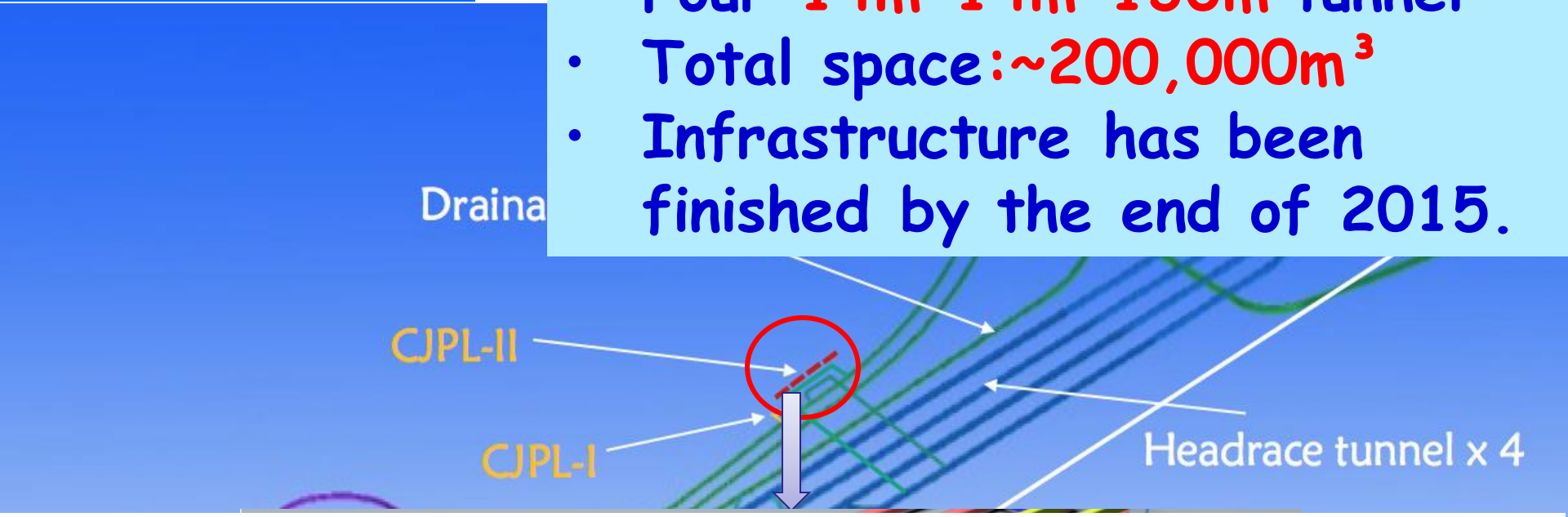


PHYSICS

China supersizes its underground physics lab

Planned expansion could pave way for "ultimate dark matter experiment"

By **Dennis Normile**

The world's deepest physics laboratory is about to become one of its largest. Early next year, workers will start carving four cavernous experiment halls along a tunnel through Jinping Mountain in China's Sichuan province. Once the science at the China Jinping Underground Laboratory (CJPL) is scaled up as well, "it will be a milestone for Chinese

WIMPs exist, they should occasionally travel unmolested through the mountain and collide with a xenon nucleus, producing a flash of light. In the other experimental hall, the China Dark Matter Experiment (CDEX) aims to catch the electrical signal produced if a WIMP bumps into a nucleus within a germanium crystal. "There is complementarity" between the two approaches, says Henry Wong, a physicist at Academia Sinica's Institute of Physics in Taipei and member of the CDEX

other labs indicating that WIMPs are likely to have very little mass.

For an initial effort, the results are "pretty decent," says Wick Haxton, a theorist at the University of California, Berkeley. To boost its chances of sighting WIMPs and determining their mass, CJPL needs a larger volume of xenon, more germanium crystals, and better

Science, Nov. 30, 2014

CJPL International Advisory Committee

The visit of CJPL-I in 2014

CJPL IAC meeting, Dec. 2016

The first CJPL IAC meeting, Oct. 2014

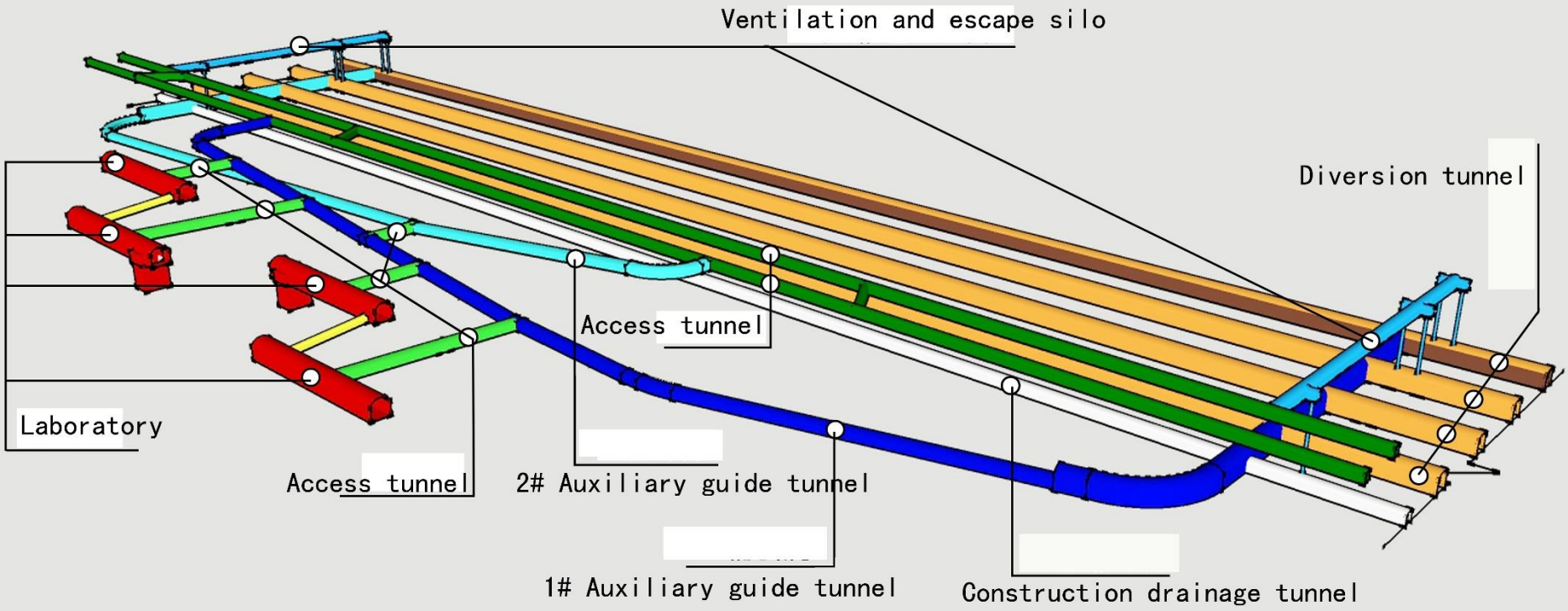
Meeting

CJPL

Status of CJPL-II

CJPL

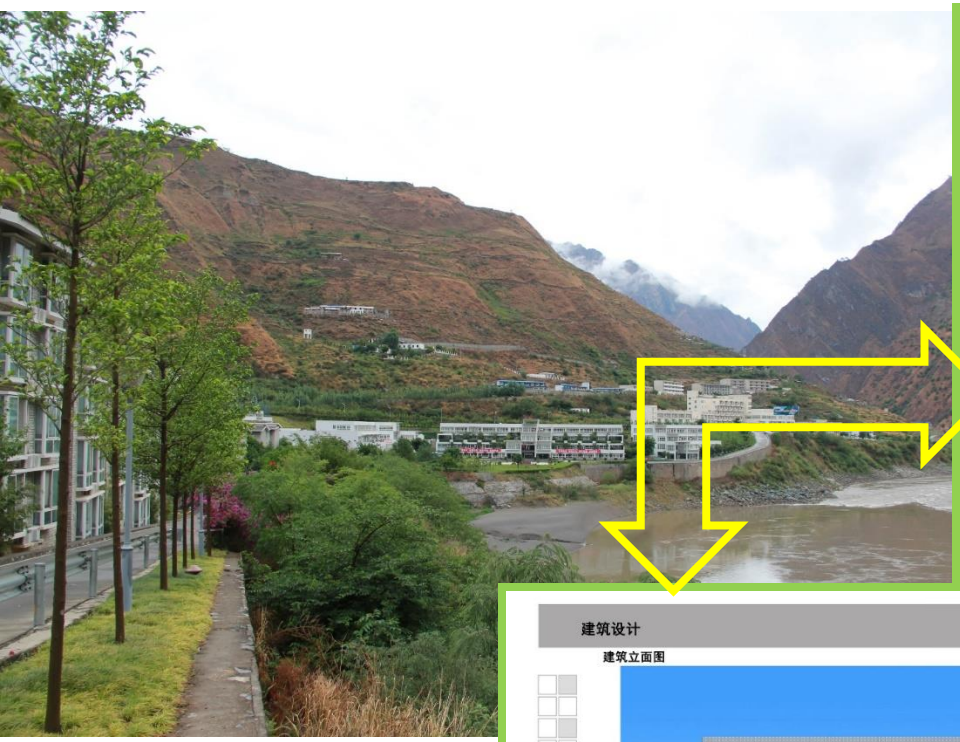
Engineering Design of Laboratory



	CJPL-I	CJPL-
Rock Work	4100 m^3	210000+151000m^3
Electric Power	70x2 kVA	10x2 MVA
Fresh Air	2400 m^3/h	15000x3 m^3/h

CJPL

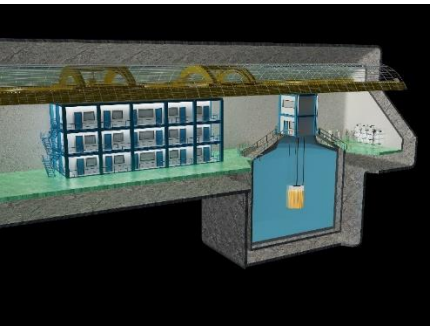
Plan view of ground Laboratory

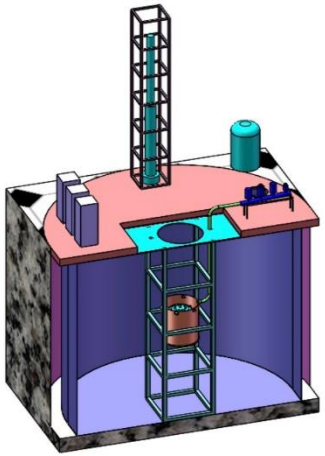
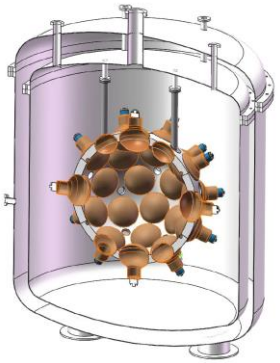
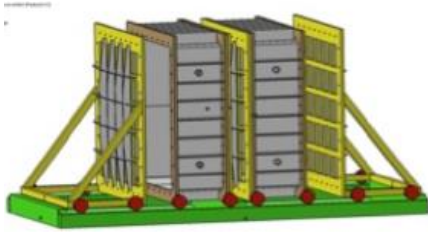


CJPL

Science Programme at CJPL-II

- ✓ CDEX-1T *[Occupied Space]* : Ge DM+0νββ Experiment
- ✓ Jinping Underground laboratory for Nuclear Astrophysics (JUNA) *[Preparing]*
- ✓ PandaX-1T *[Occupied Space]* : Xe DM+0νββ Experiment
- ✓ Ton-scale Ar detector *[Possible user]* : DM Experiment
- ✓ Neutrino Experiment Underground *[Proposal]*
- ✓ MIMAC *[Letter of Interest]* : DM Experiment
- ✓ Rock mechanics, Microbiology…*[Possible users]* Interdisciplinary

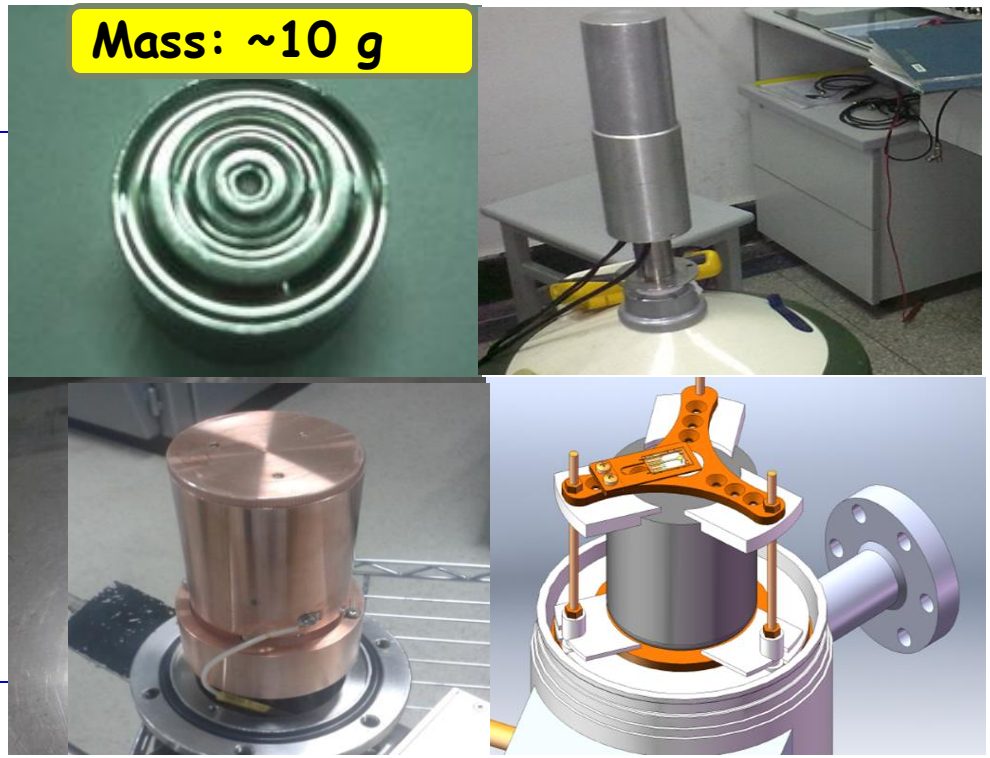


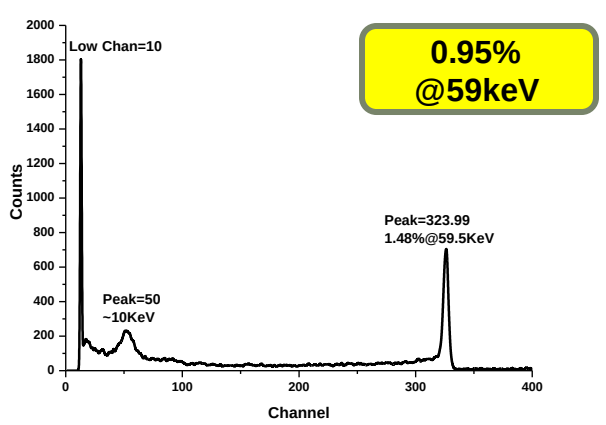




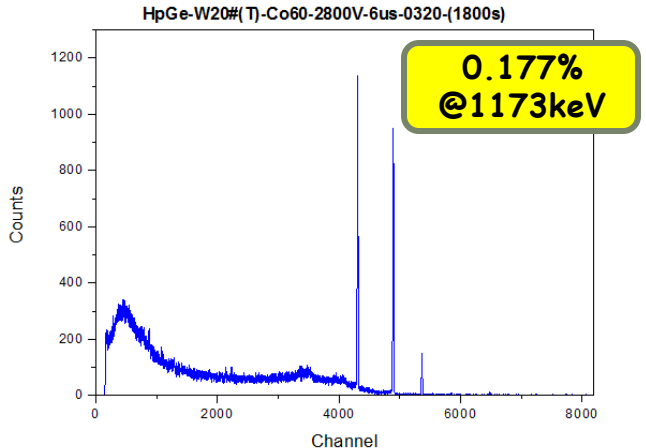
CJPL

Detector Fabrication & Pre-amplifier electronics

- ✓ Successful on 10 g/500 g Energy resolution : 0.95% @ 59.5 keV(10 g) 0.177% @1173 keV(500 g).
- ✓ 2X 500 g PCGe with home-made fabrication will be studied at CJPL in 2017.







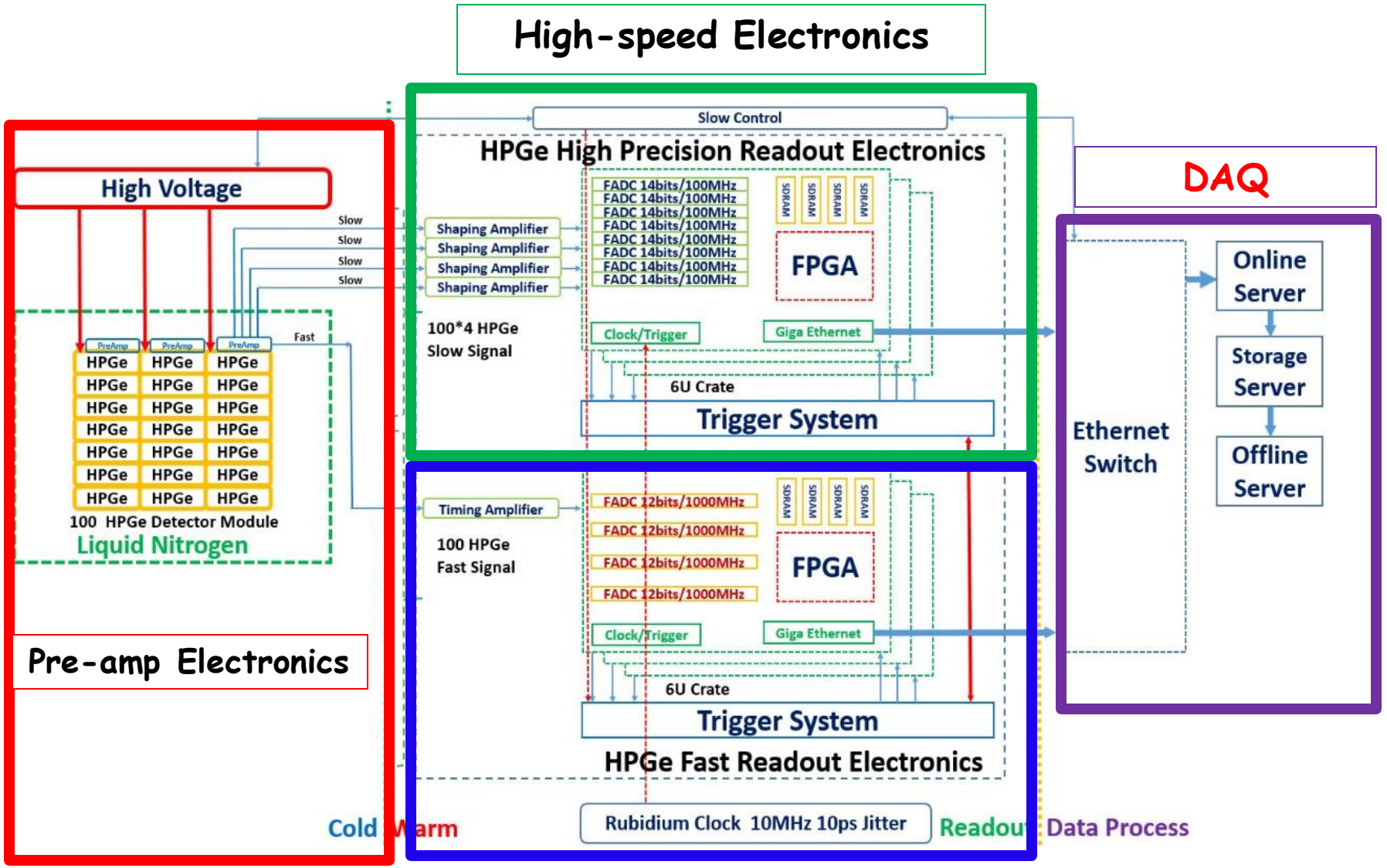
CJPL

Germanium Crystal growth

- **Present achievements.**
  - ✓ Impurity concentration : ~ 5×10^{10} cm^{-3}
  - ✓ Dislocation : ~ 5000 cm^{-2}

CJPL

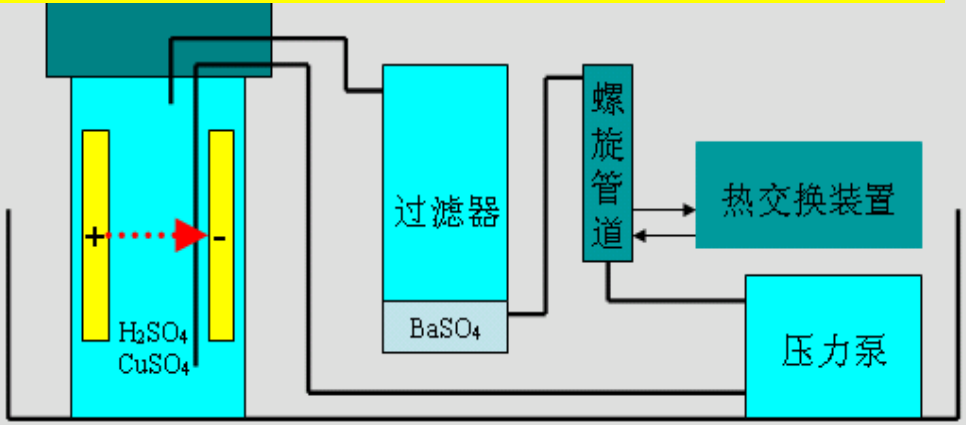
Ungraded Electronics and DAQ



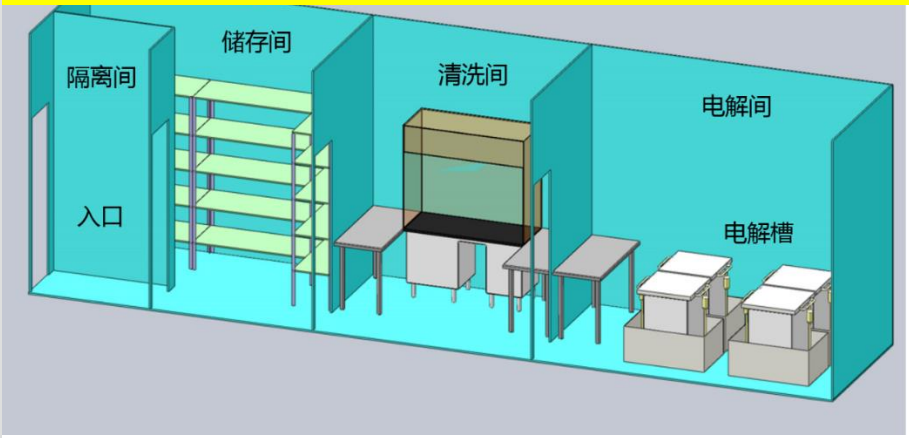
CJPL

Electroformed Cu & Low radioactivity measurement @CJPL

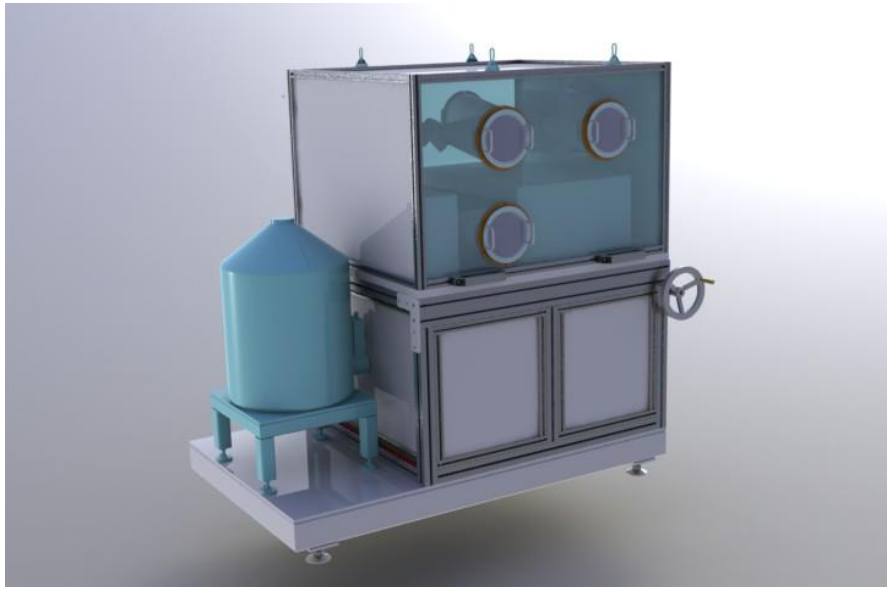
Manufacture process for Electroformed Cu



Schematic diagram for Underground Lab.



- **Plans**
  - ✓ Goal for electroformed Copper: Th<1 μBq/kg ;
    U<5 μBq/kg
  - ✓ Sensitivities of ^{232}Th /^{238}U /^{40}K : <1 μBq/kg



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Close relationship with Germany Scientists on Ge techniques

"Meeting of Germanium Detector techniques" at THU, China 2014

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

SHANGHAI JIAO TONG UNIVERSITY 1896

TSINGHUA UNIVERSITY 1911

EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

中德合作研究小组

应用于基础研究的高纯锗探测器技术研发

资助者:中德科学中心 / 中国 北京

Deutsch-Chinesische-Kooperationsgruppe

Development of High Purity Germanium Detector Techniques
for Applications in Fundamental Research

Finanziell unterstützt durch: Chinesisch-Deutsches Zentrum für Wissenschaftsförderung Peking, China

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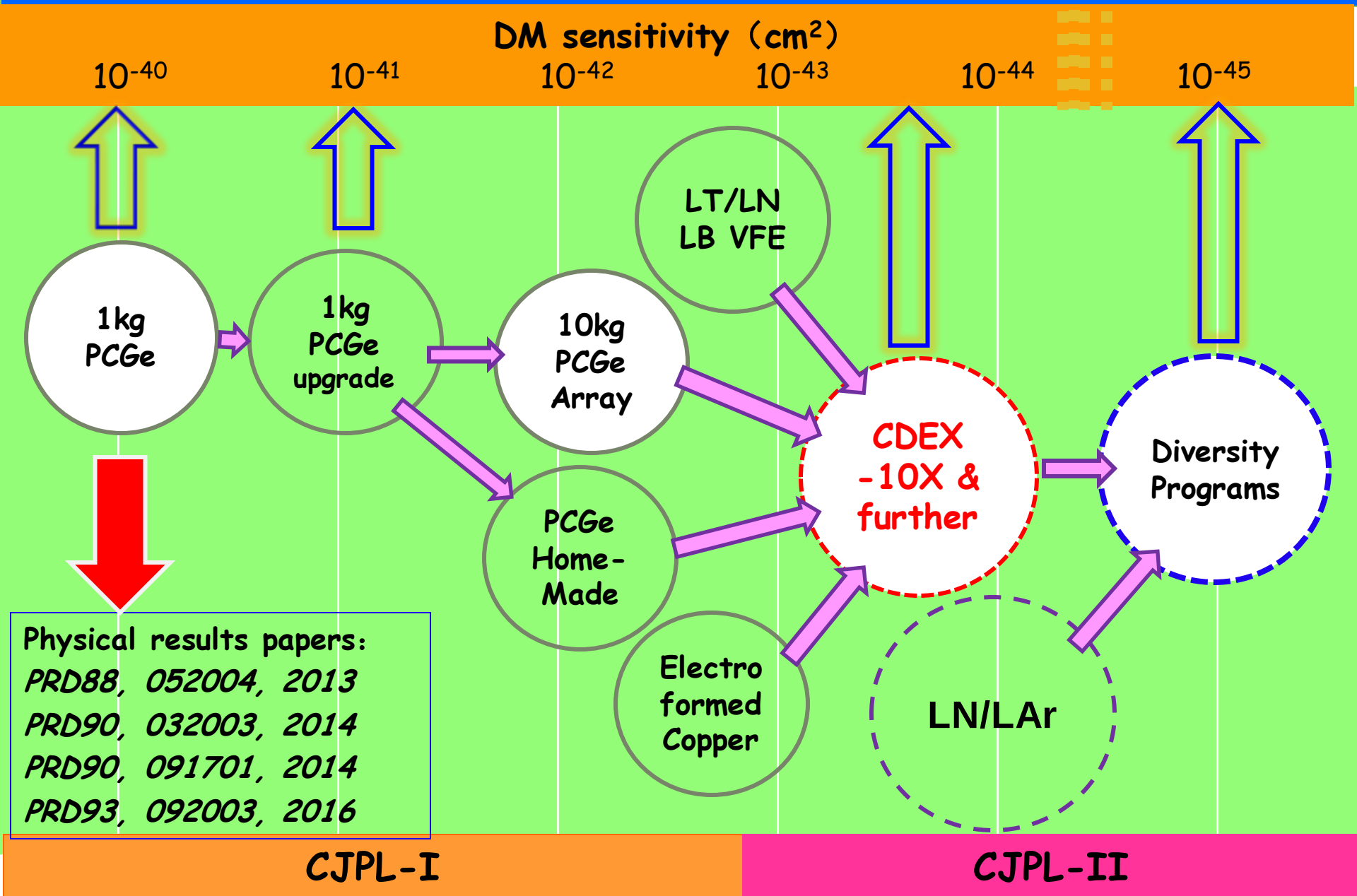
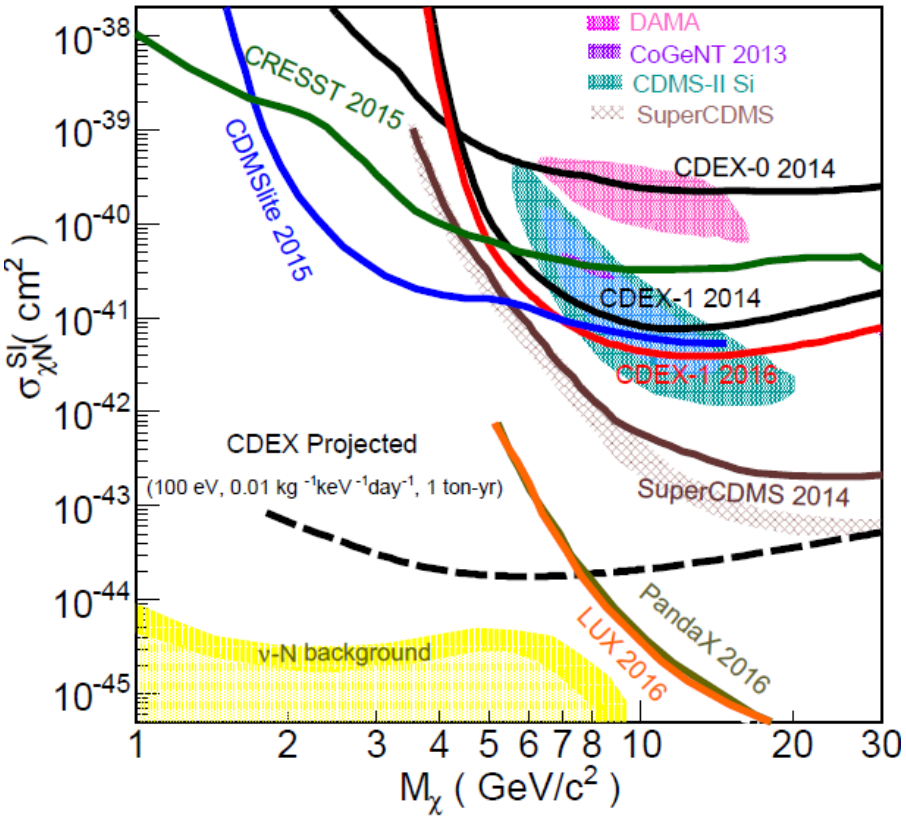
Plans of CDEX



Projected results

- Best sensitive in the range of 10GeV, ~$10^{-44}cm^2$
- ^{76}Ge double beta decay research



CDEX 1T Experiment in CJPL

CJPL

Outlook & Prospects

- CDEX-1@CJPL has been commissioned from 2011.Results of light WIMPs and axion searches from CDEX-0/1 have been achieved. (*PRD-2013, PRD*2-2014,PRD-2016).* Results of annual modulation based on background understanding are coming soon.

- Developed new selections and efficiencies to differentiate the bulk and surface events of pPCGe at low energy region.

- The test of cryogenic system for CDEX-10 has been done and shipped to CJPL in Mar. 2016. Two 3 kg arrays detector(two strings) with LN is intensively studied.

- Key technologies for detector fabrication, crystal growth, upgraded electronics as well as electroformed copper are carried on.

- CJPL-II is well characterized and expansions to accommodate additional science progressing well.

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Welcome to CJPL