The China Jin-Ping Underground Laboratory (CJPL) and the TEXONO-CDEX Dark Matter Experiment

- **CJPL – History, Status & Prospects**
- **TEXONO-CDEX Experiment**
- **Interface with Theorists**

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Academia Sinica / 中央研究院

March 2011

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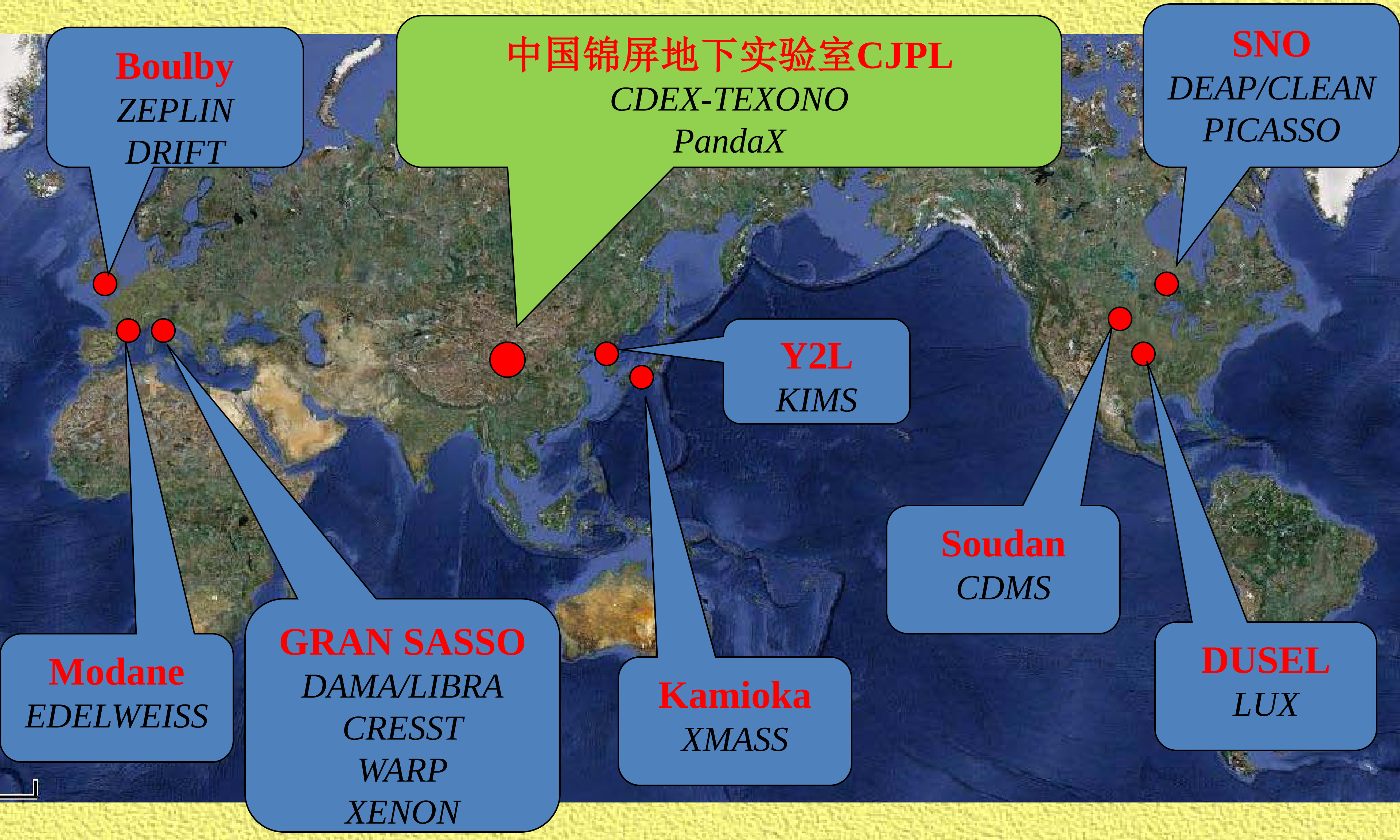
Underground Laboratory Worldwide
[& Dark Matter Experiments]



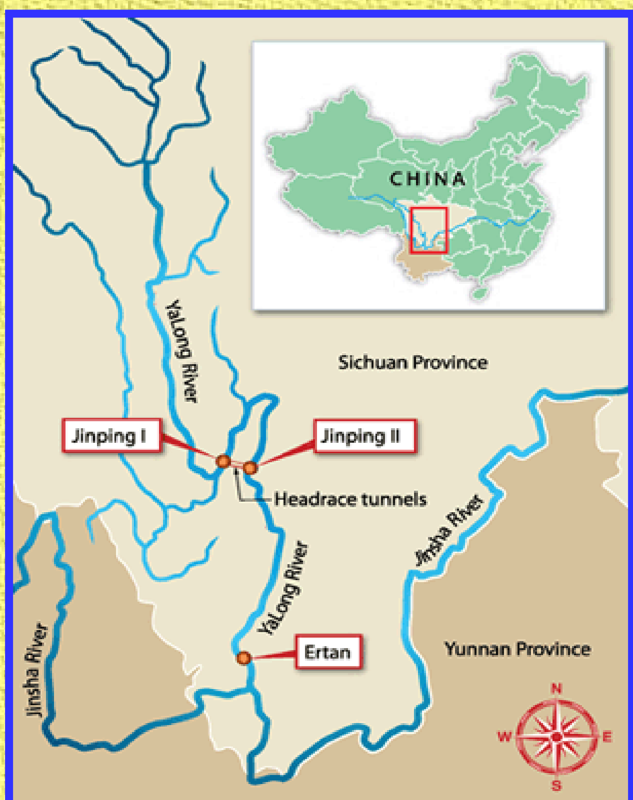
Once Upon A Time [How the Story Begins]

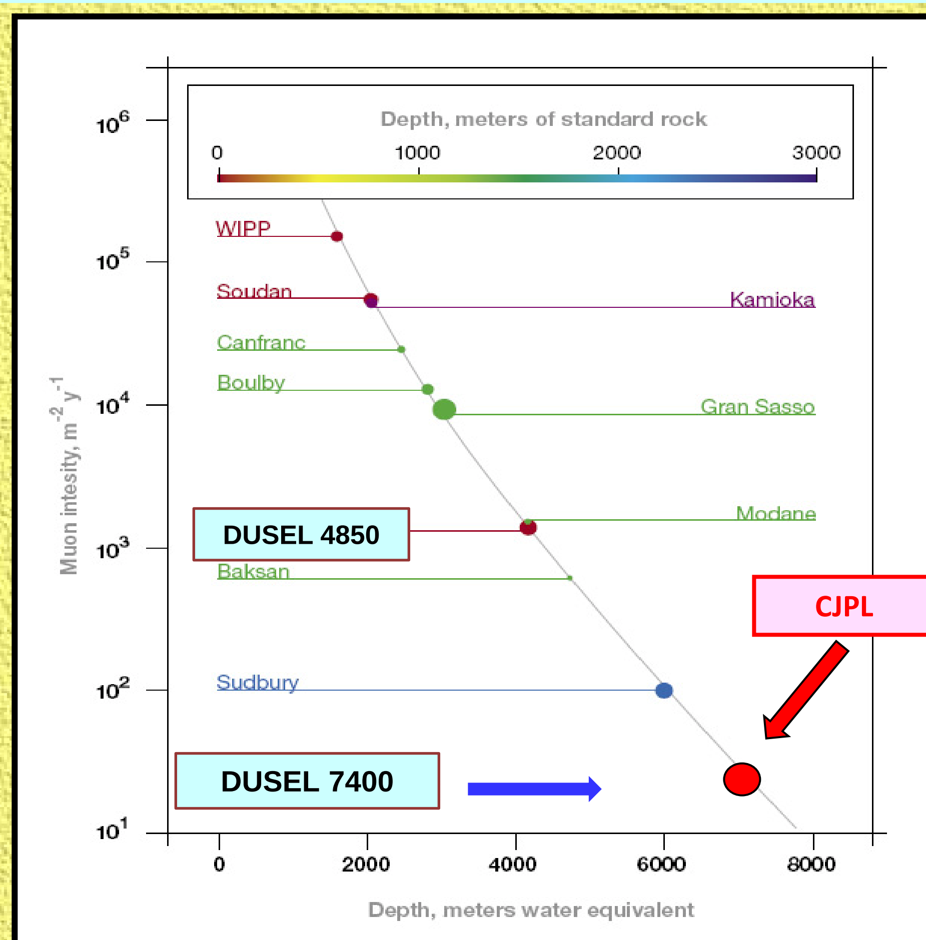
- **1996/97 : TEXONO Program on Reactor Neutrino Physics established ; based in Taiwan (PI: Henry Wong, AS) with collaborating institutes from China (PI: Li Jin, IHEP) as first Taiwan-China Scientific Collaboration ; Facilities at Kuo-Sheng Neutrino Laboratory (KSNL) built.**
- **2002 : Beijing Tsinghua U (THU) – Engineering Physics joined TEXONO program ; Li Jin & Yue Qian (TEXONO PhD) joined THU as faculties ; spearheaded dark matter physics at Y2L in South Korea.**
- **2008 : Researchers learned (from TV news) of the completion of road tunnels under Jin-Ping mountains in Sichuan as part of massive hydro-electric projects**
- **2009/5 : MoU signed between THU & site owner, Ertan Hydroelectric Development Company ; site excavation begins ; Chinese groups expanded to form CDEX Program**
- **2010/6 : Site excavation completed ; CDEX-TEXONO experiment installation and commissioning starts.**
- **2010/12 : Official Opening Ceremony of China Jin-Ping Underground Laboratory (CJPL)**

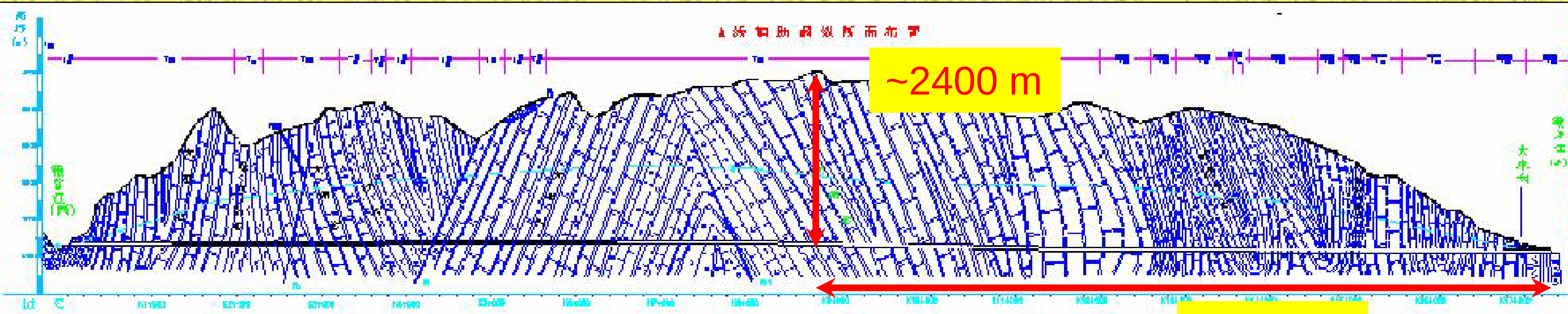
The Rest Will be History …….

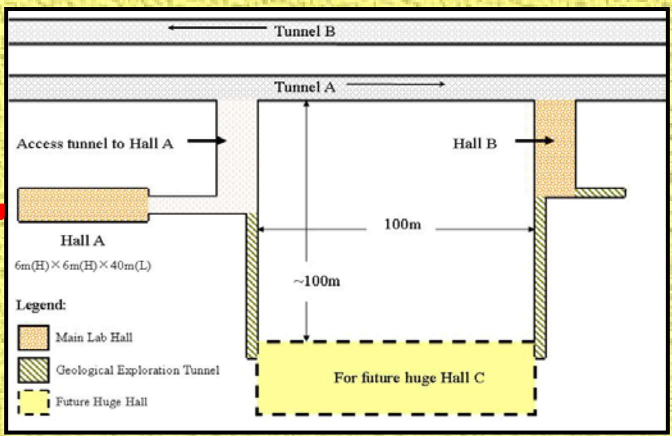
CJPL 中国锦屏地下实验室 China Jinping Underground Laboratory

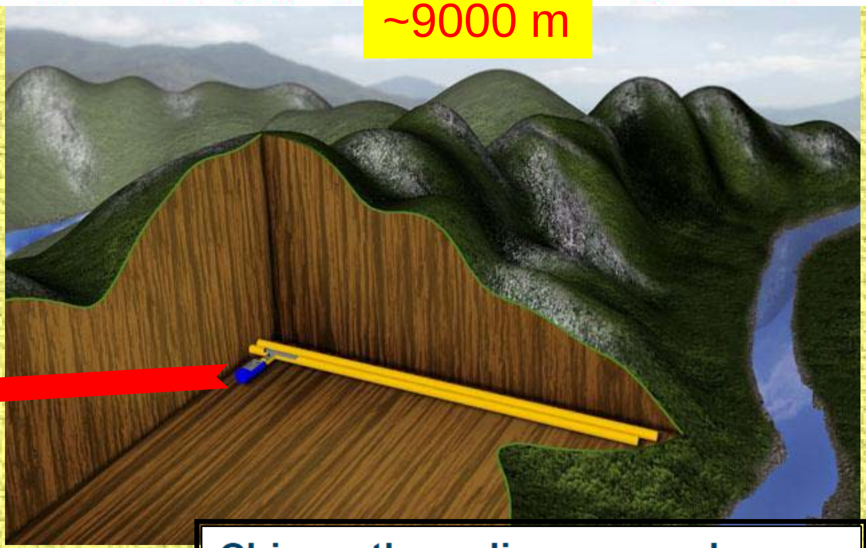
- **Merits:** 2500+ m rock overburden ; drive-in road tunnel access ; superb supporting infrastructures
- 6X6X40 m cavern construction completed *[THU & EHDC]*

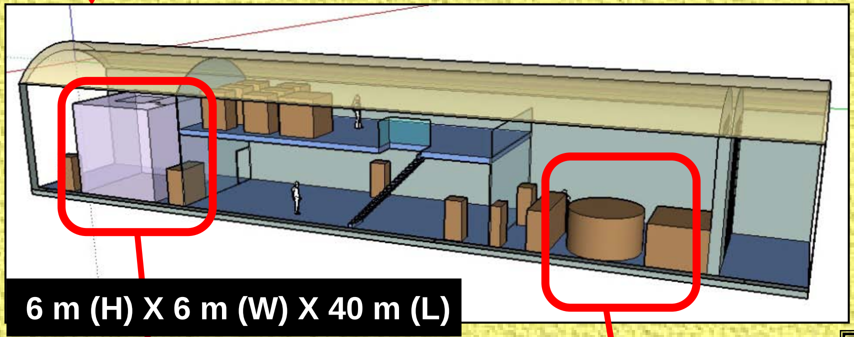












CDEX-TEXONO

PandaX

China, others dig more and deeper underground labs

From tiny to gargantuan, experiments are in the works to exploit the shielding from cosmic rays that being deep underground offers.

Physics Today September 2010

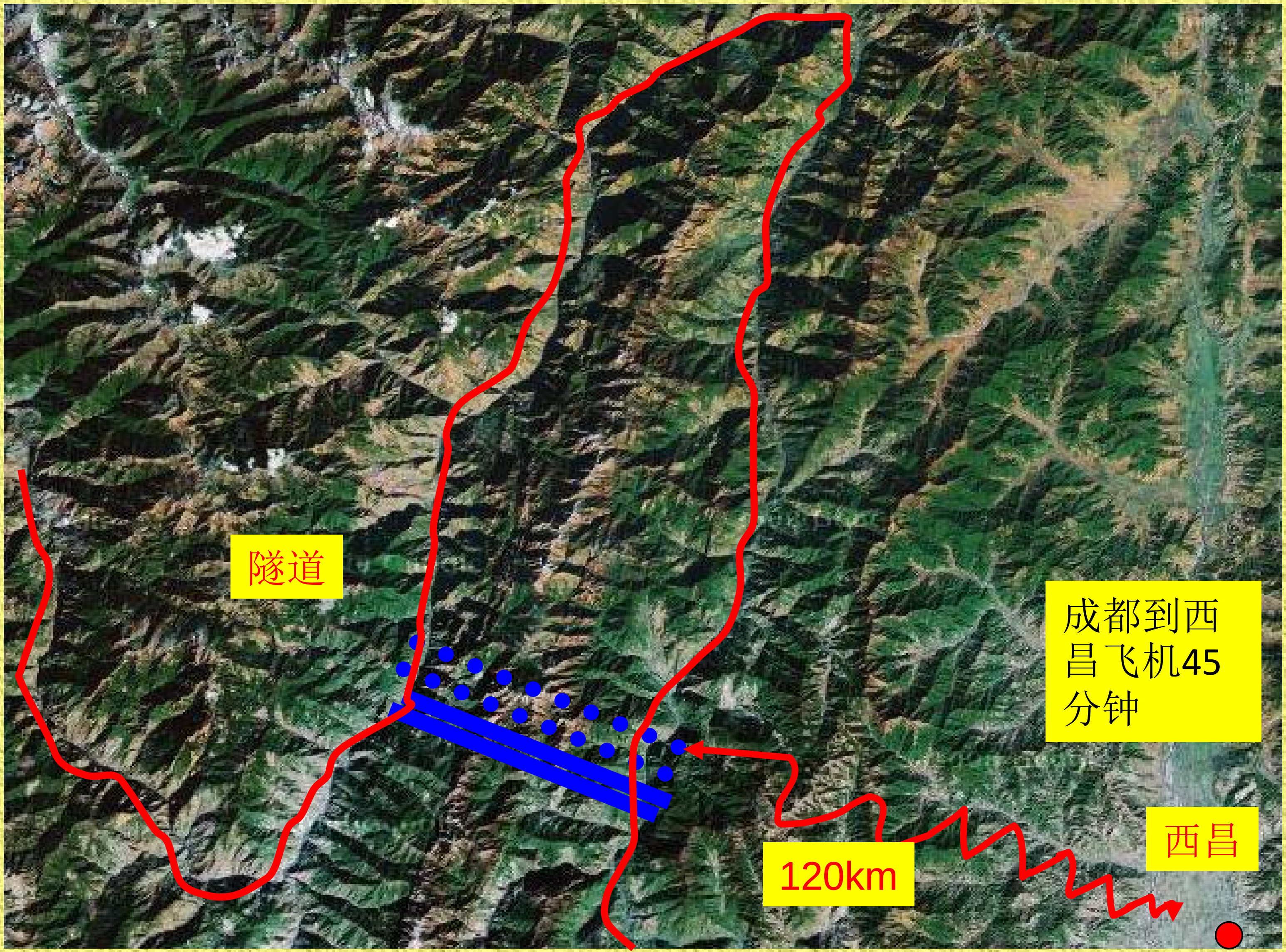
PARTICLE PHYSICS:

Chinese Scientists Hope to Make Deepest, Darkest Dreams Come True

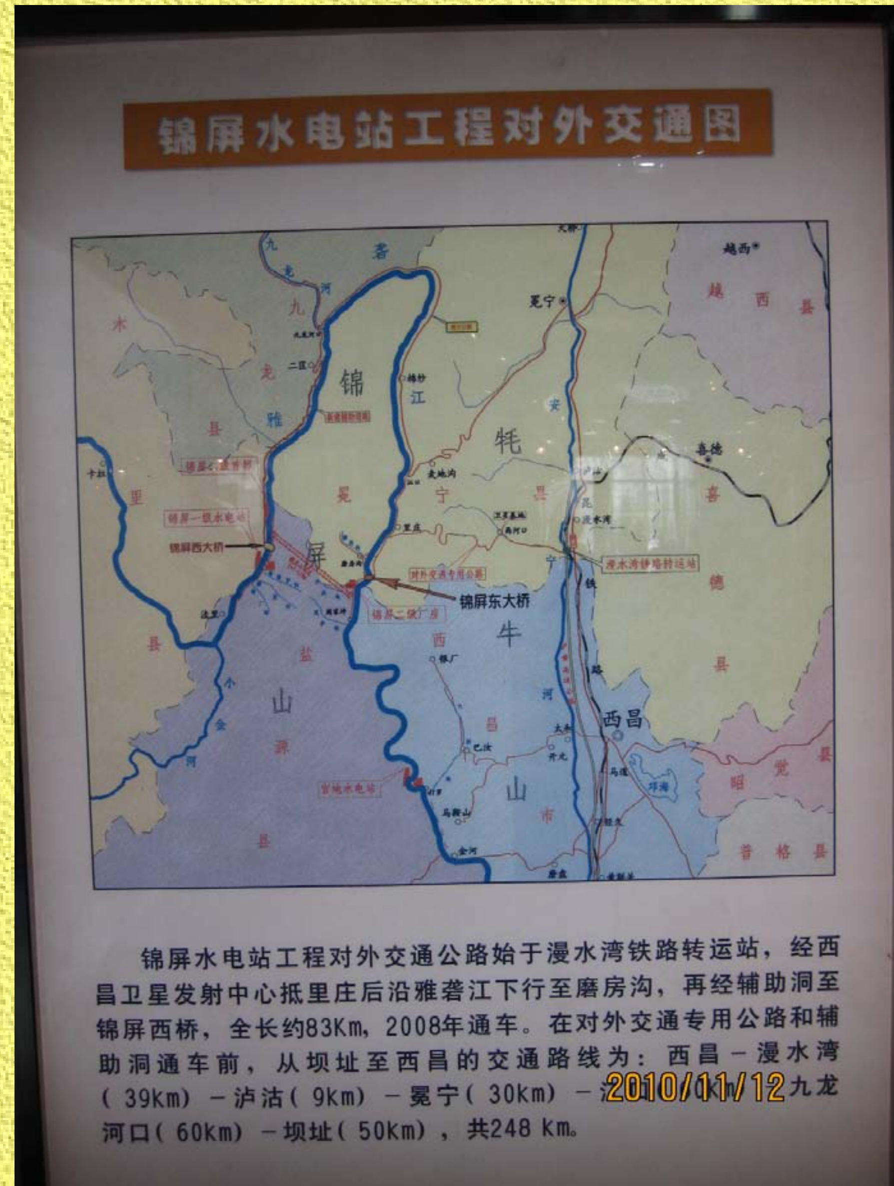
Dennis Normile

Science 5 June 2009:
Vol. 324. no. 5932, pp. 1246 - 1247
DOI: 10.1126/science.324_1246

Yalong River (雅龍江) & Jinping Mountain (錦屏山)



Massive Hydro Power Projects @ SW Sichuan

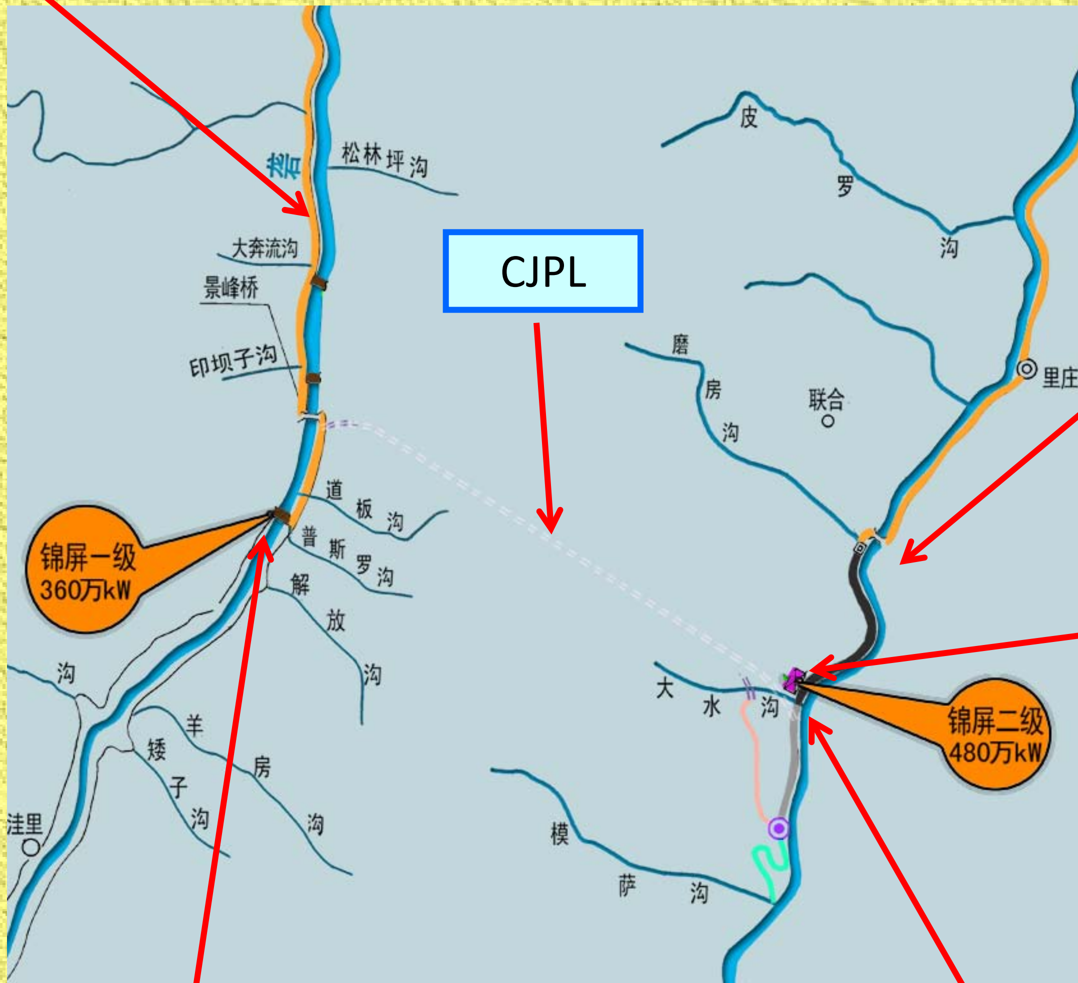


Campsite #1

CJPL

Campsite #2

Jin-Ping Hydro #2
4.8 GW



Jin-Ping Hydro #1
3.6 GW

Surface Labs., Control Room, Offices, Dorms.

Good Supporting Infrastructures


Road from Xichang (西昌)

Tunnel Entrance

Campsite #1


Campsite #2

ASIDE: View of Satellite Launch Site at Xichang

Facilities at Campsite #1
(a la Resort)

EHDC Staff Villas

Fresh Air & Stunning Scenery

Guest House & Restaurant

EHDC Office

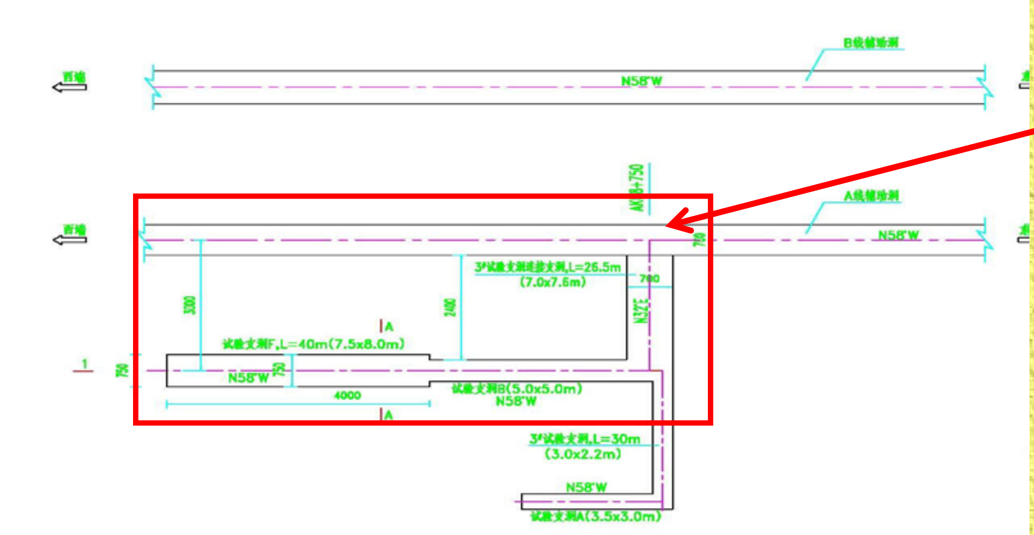
Sports Facilities

First Site Visit 2009/3

CDEX Science PI
(岳骞)

THU-EHDC MoU 2009/5/8

CJPL Excavation Started
July 2009



CJPL平面图

主实验厅：约240平米的面积

CJPL Excavation 2010/1-2

CJPL April 2010

6月20日土建工程建成并通过验收

主实验厅

CJPL Hall A: Excavation Completed June 20, 2010.

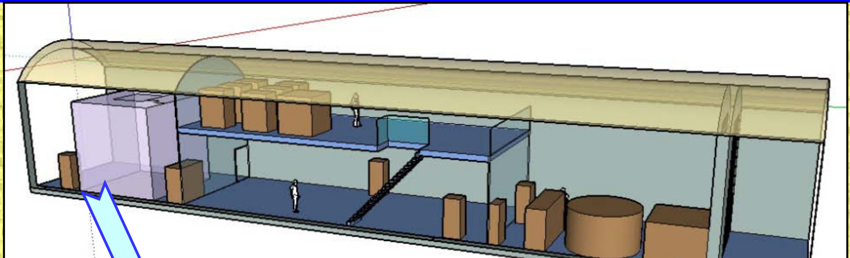
CDEX-TEXONO Shielding Construction

2010年8月
顾秉林校长、康克军副校长、程建平副校长视察地下实验室

CJPL Dir. JP Cheng
(程建平)

CDEX PI KJ Kang
(康克軍)

CJPL Hall A:
Basic Infrastructures Completed & Research Started Sept 27, 2010.



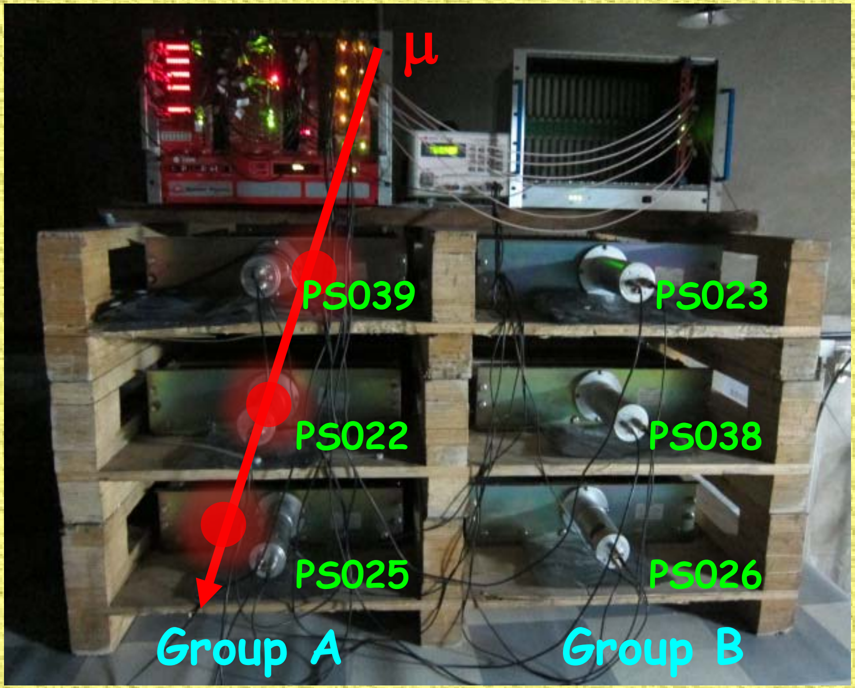
6 m (H) X 6 m (W) X 40 m (L)

Inside with shielding structure

CJPL Opening Ceremony (2010/12/12)

CCTV Report
Dec 2010

Cosmic Ray Telescope



First Triple Coincidence Event

Date: 2010/12/02

Time: 04:49:19

First Data Taking :

- 6 events in 33 days in 1 m^2
  (c.f. ~100 Hz / m^2 at sea-level)
- Consistent with expectations

+ Measurements of ambient radioactivity (γ's, neutrons, radon) underway

TEXONO-CDEX Collaboration

TEXONO

Taiwan EXperiment On NeutrinO *[since 1997]* :

- **Neutrino Physics at Kuo-Sheng Reactor Neutrino Laboratory (KSNL)**
  - **Taiwan (AS, NTHU, INER, KSNPS)**
  - **Turkey (METU)**
  - **India (BHU)**

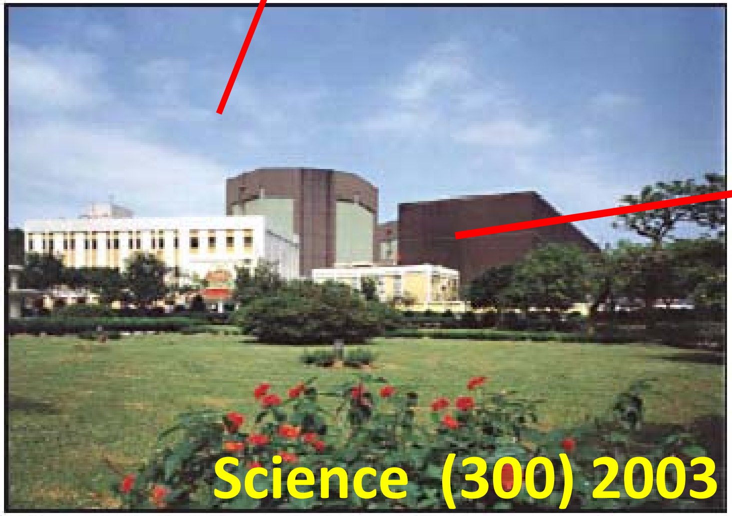
CDEX

China Dark Matter EXperiment *[birth 2009]* :

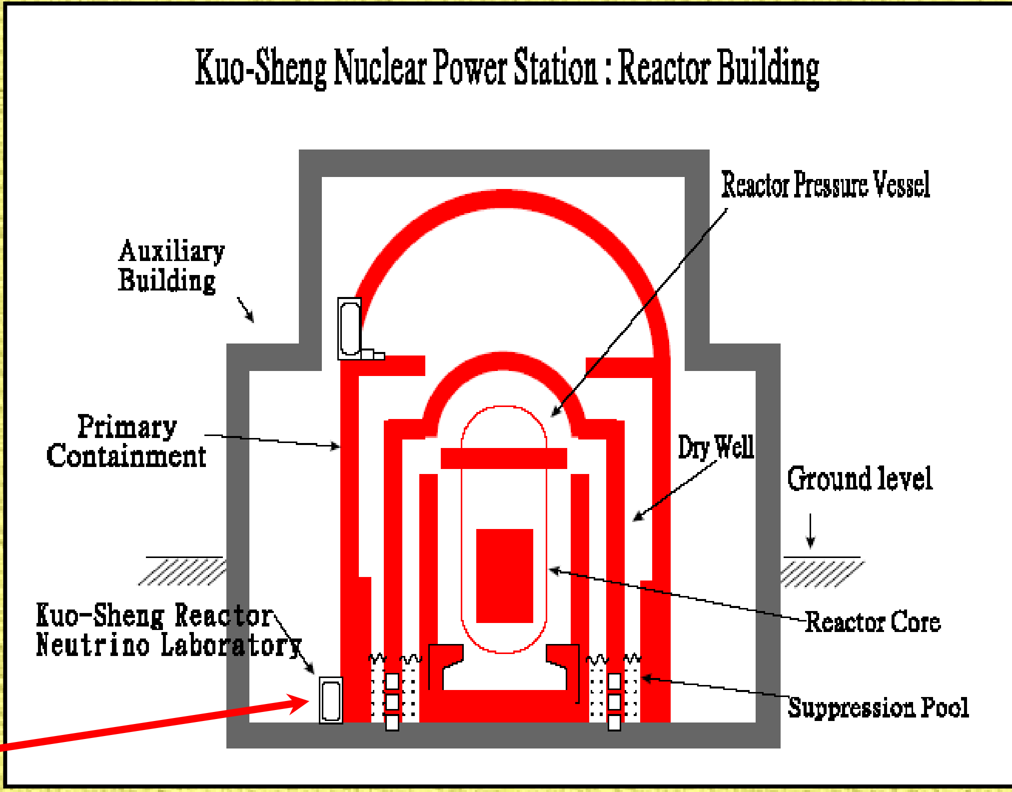
- **Dark Matter Searches at China Jin-Ping Underground Laboratory (CJPL)**
  - **China (THU, CIAE, NKU, SCU,EHDC)**

Research Program: Low Energy Neutrino and Dark Matter Physics

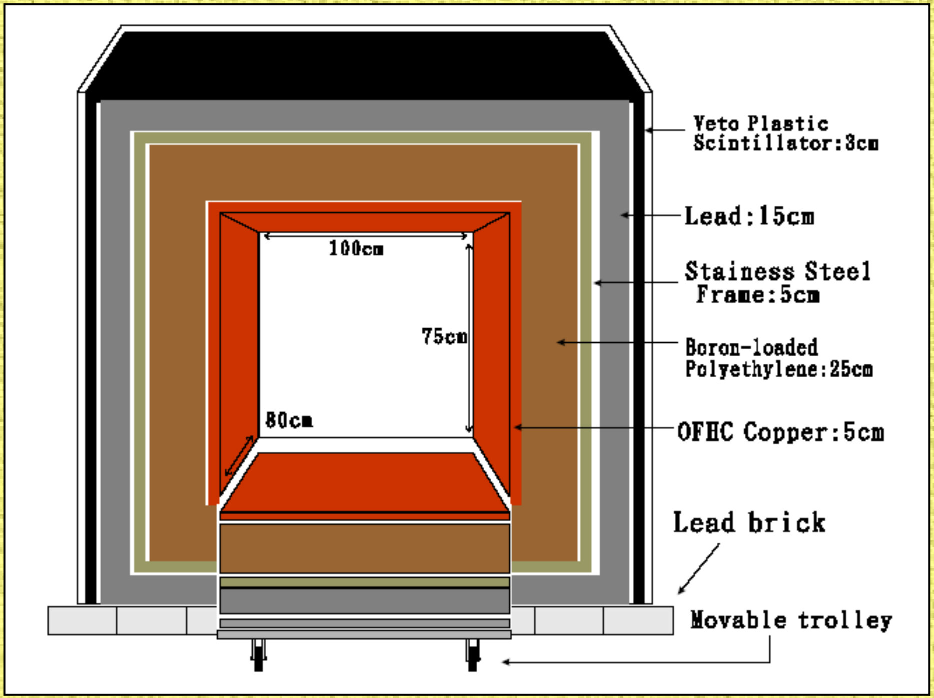
Kuo Sheng Reactor Neutrino Laboratory :



Powerful collaboration. Scientists from Taiwan and mainland China are studying neutrino emissions from this nuclear power plant outside Taipei.



- **28 m from core#1 @ 2.9 GW**
- **Shallow site : ~30 *mwe* overburden**
- **~10 m below ground level**



Front View *(cosmic vetos, shieldings, control room …..)*

Inner Target Volume

Configuration: Modest yet Unique

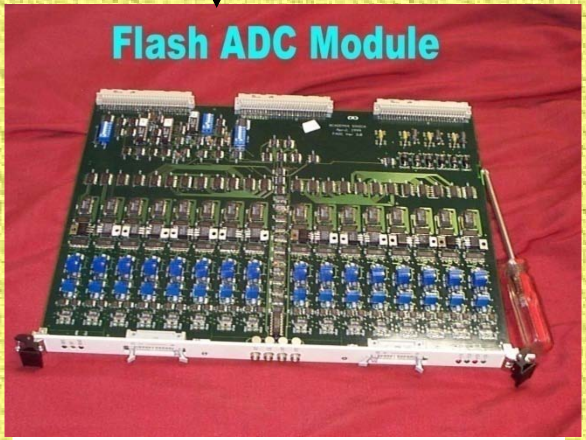
Flexible Design: Allows different detectors conf. for different physics

KS Laboratory : Detectors

ULB-HPGe [1 kg]

CsI(Tl) [200 kg]

ULE-ULB-HPGe
Prototype [20 g]

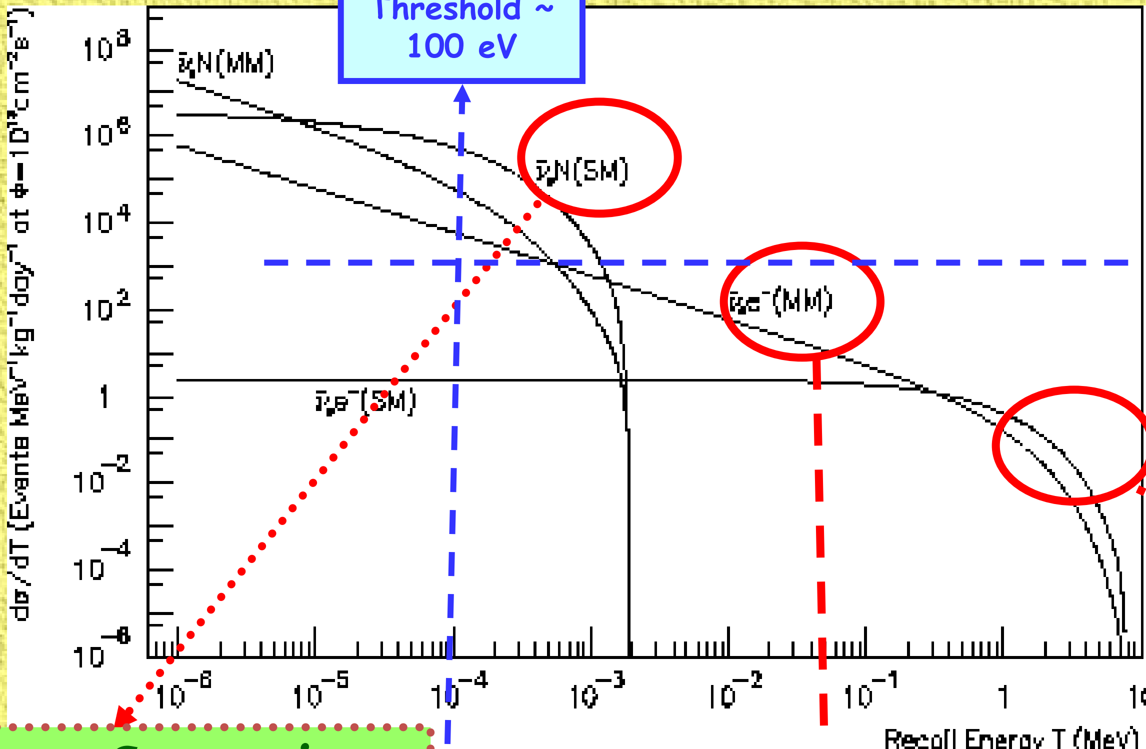


FADC Readout
[16 ch., 20 MHz, 8 bit]

Multi-Disks Array [600 Gb]

Neutrino Properties & Interactions at Reactor

quality ← **Detector requirements** → **mass**



Threshold ~ 100 eV

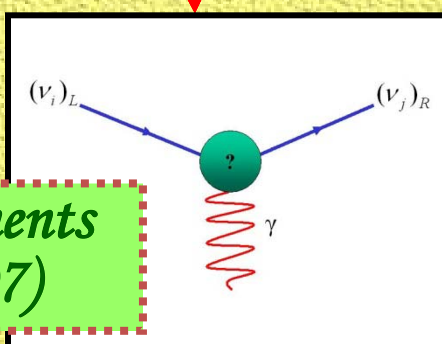
1 counts / kg-keV-day

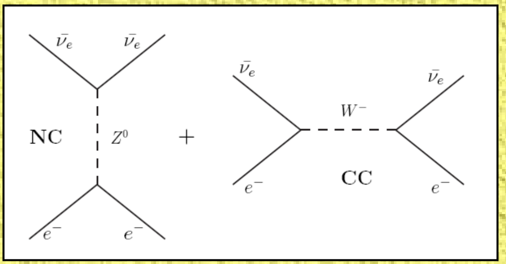
Standard Model νe Scattering (2⊗ PRD10)

νN Coherent Scattering

Dark Matter Searches (PRD-RC09)

Magnetic Moments (PRL03,PRD07)



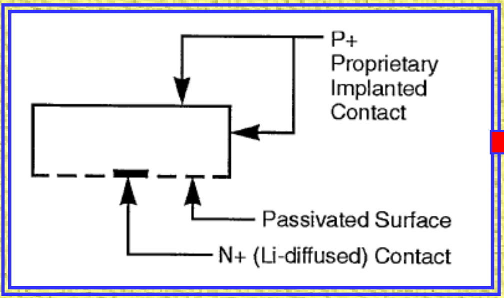


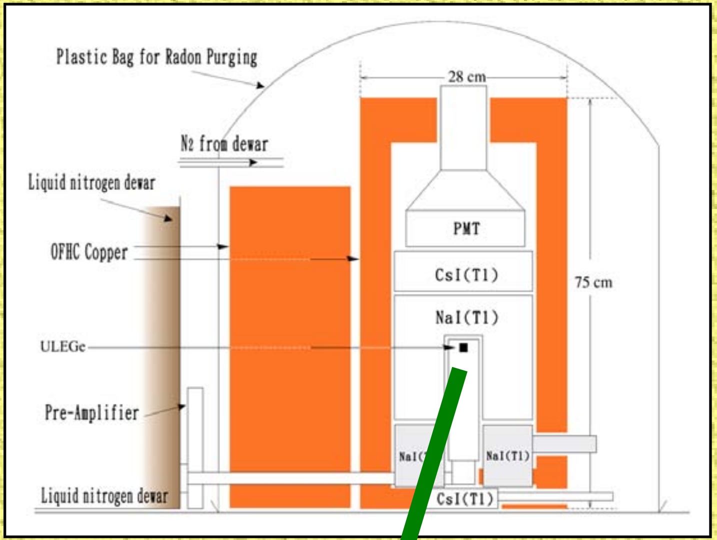
Current Research Theme:

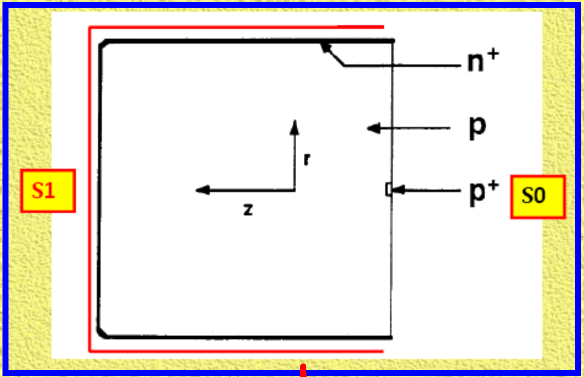
"sub-keV" Ge Detectors

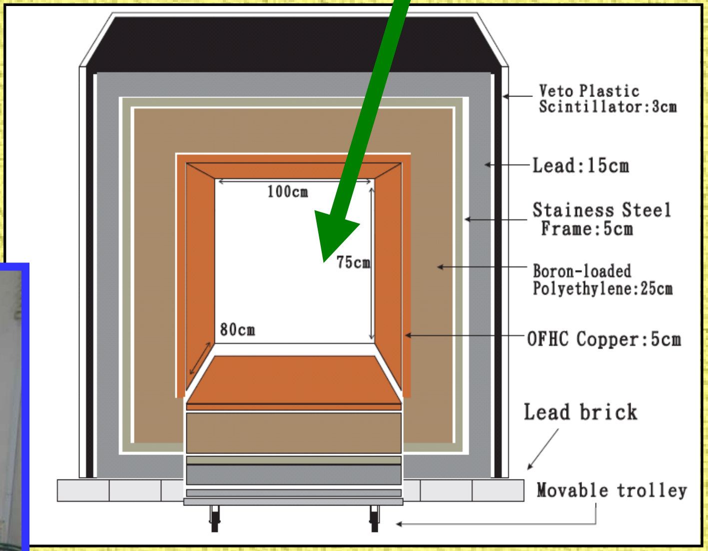
- **Physics Goals for *O[100 eV threhold⊕1 kg mass⊕1 cpkkd] detector* :**
  - **νN coherent scattering**
  - **Low-mass WIMP searches**
  - **Improve sensitivities on neutrino magnetic moments**
  - **Implications on reactor operation monitoring**
  - **Open new detector window & detection channel available for surprises**

TEXONO-CDEX : ULEGe & PCGe @ KSNL & CJPL

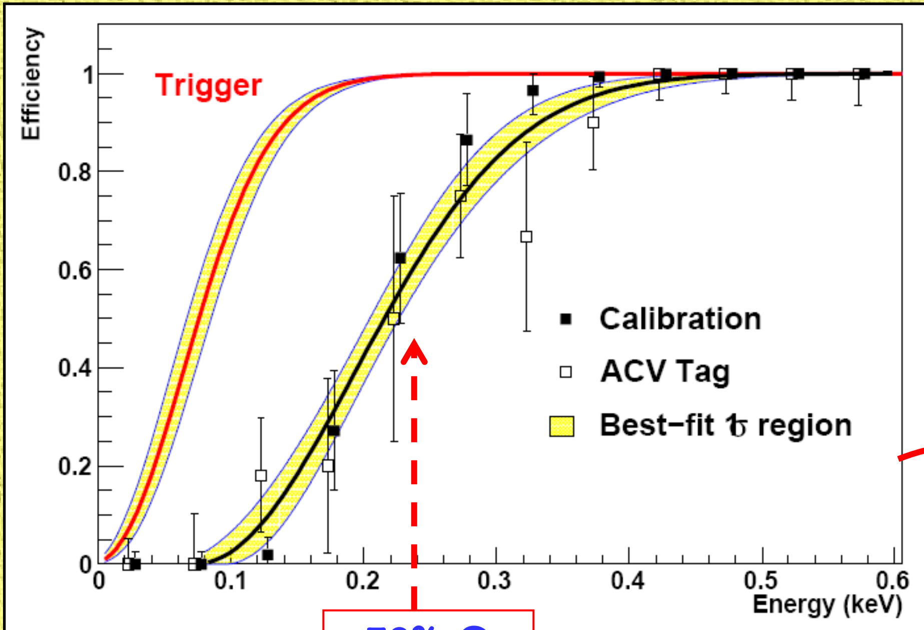






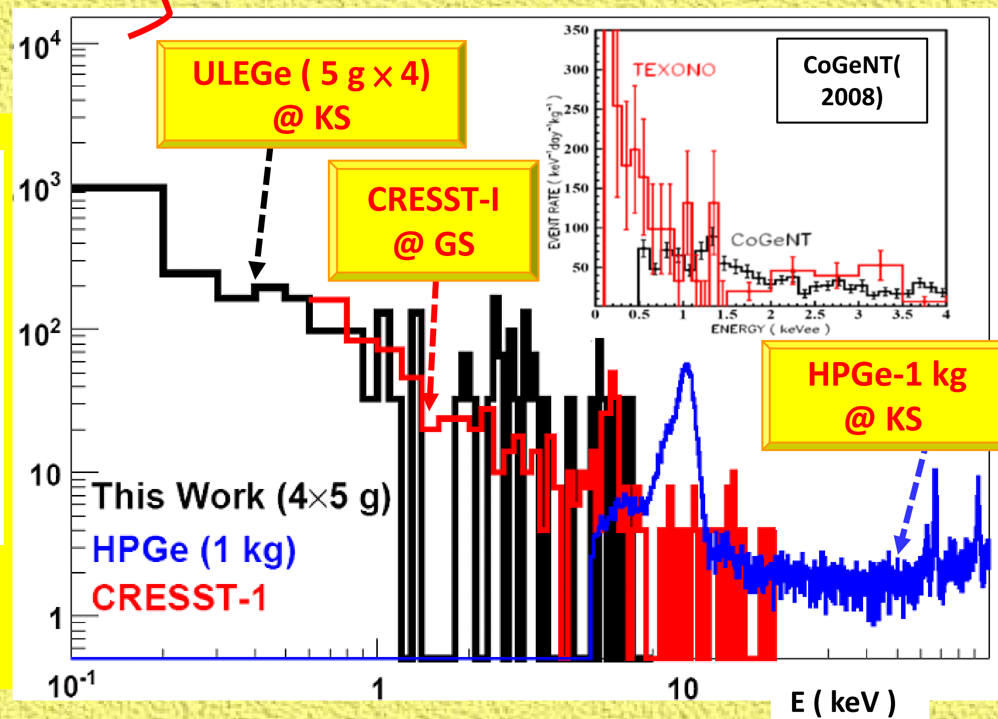


Threshold & Efficiencies & Background for 20g ULEGe @ KSNL (2007)



50% @ 220 eV

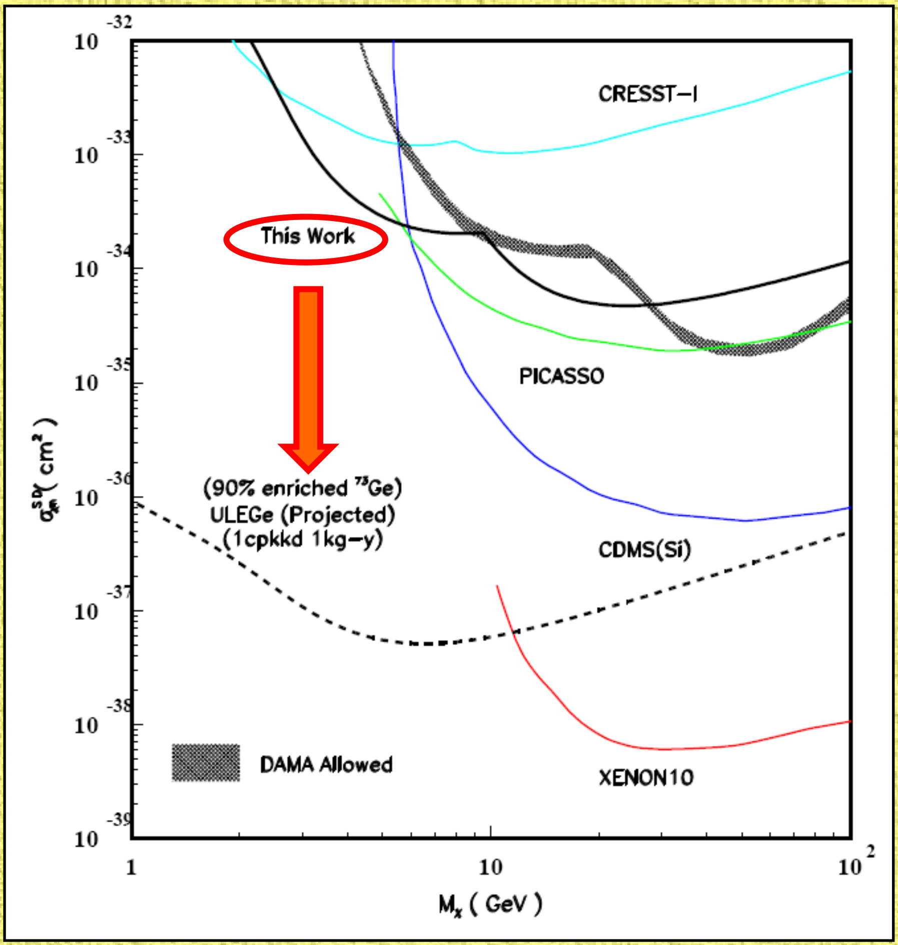
Dark Matter Searches Analysis

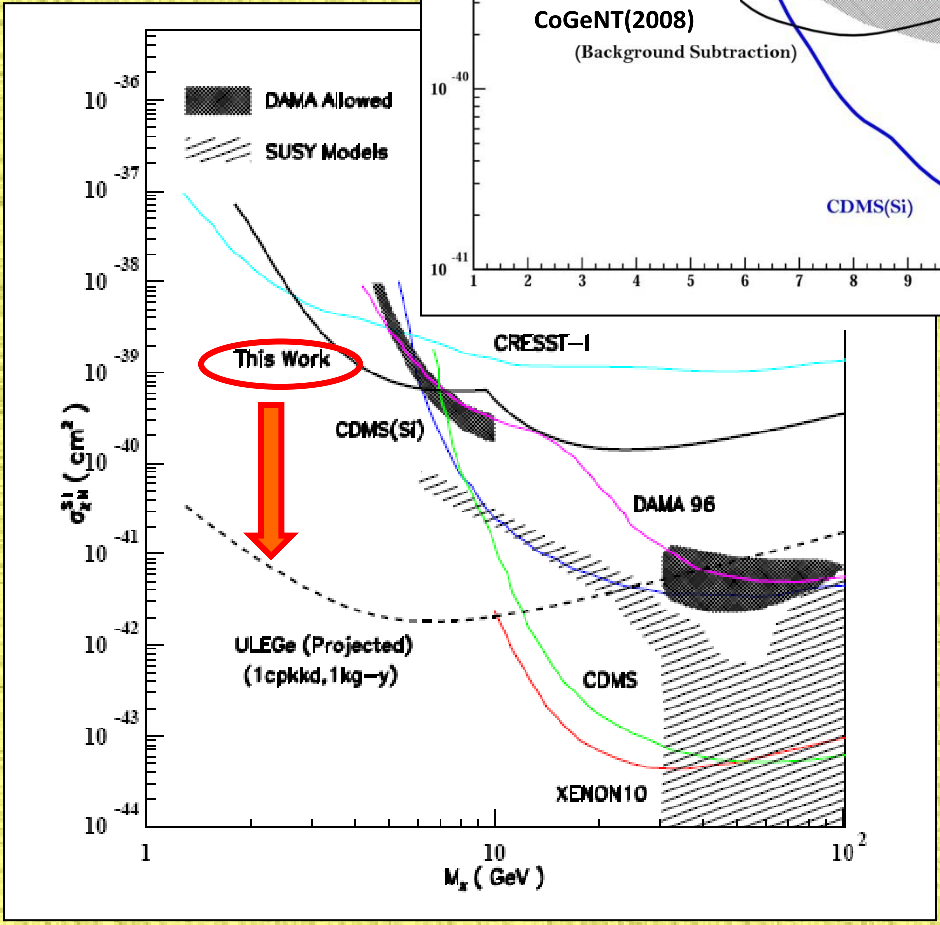


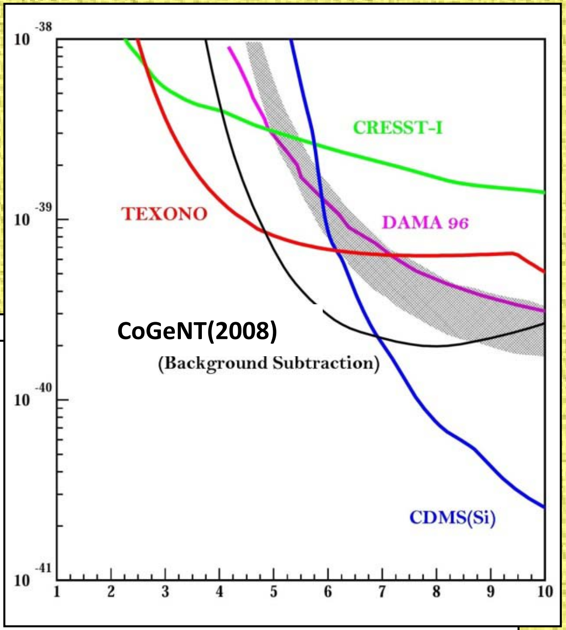
sub-keV Background :

* Not fully explained with conventional background modeling
* Intense work on hardware, software and data taking at new underground site

Limits on Low Mass WIMPs : Spin-Dependent & Independent Couplings (PRDRC09)





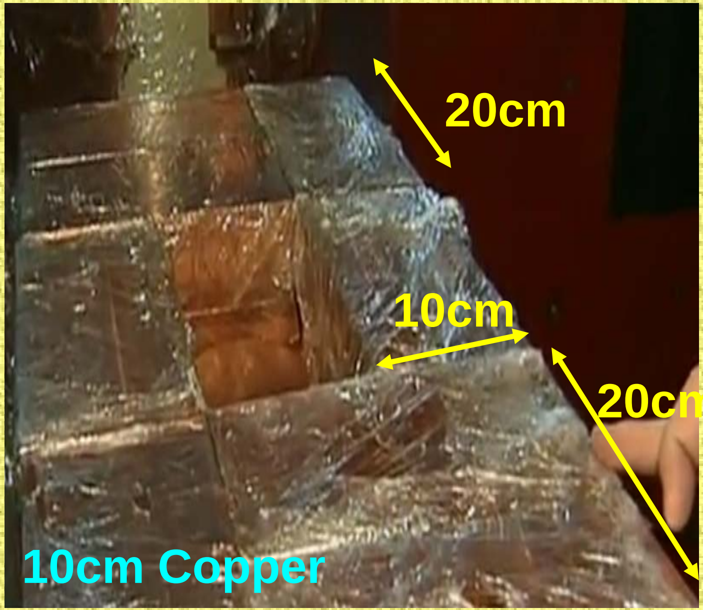


Latest : New CoGeNT 2010 Results (limits & allowed region) ; intense theoretical interest and speculations on low-mass WIMPS

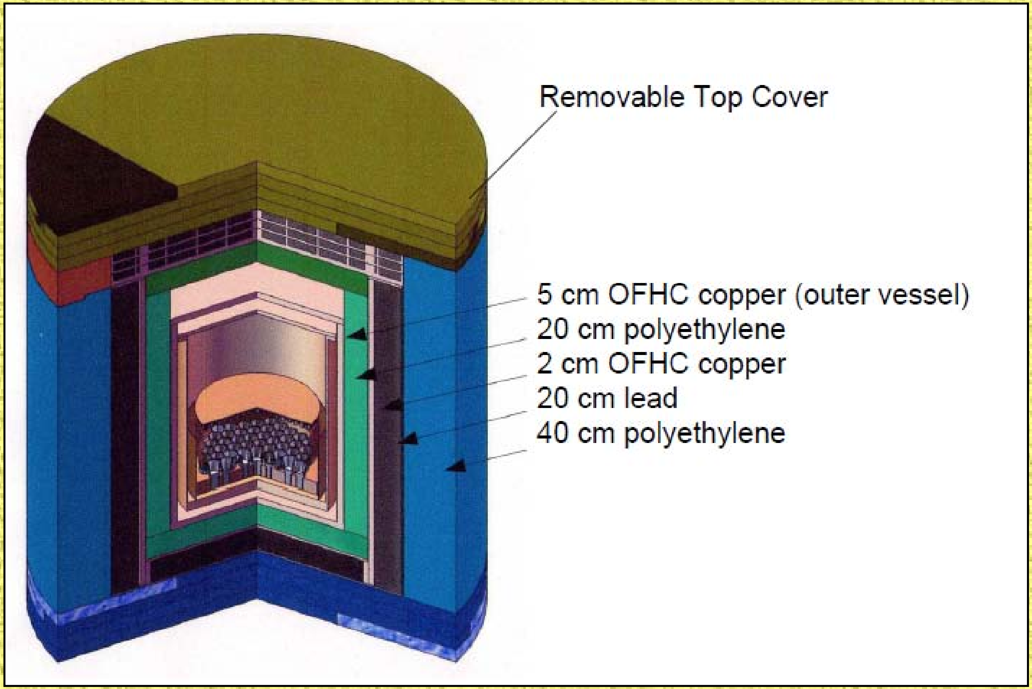
TEXONO-CDEX @ CJPL

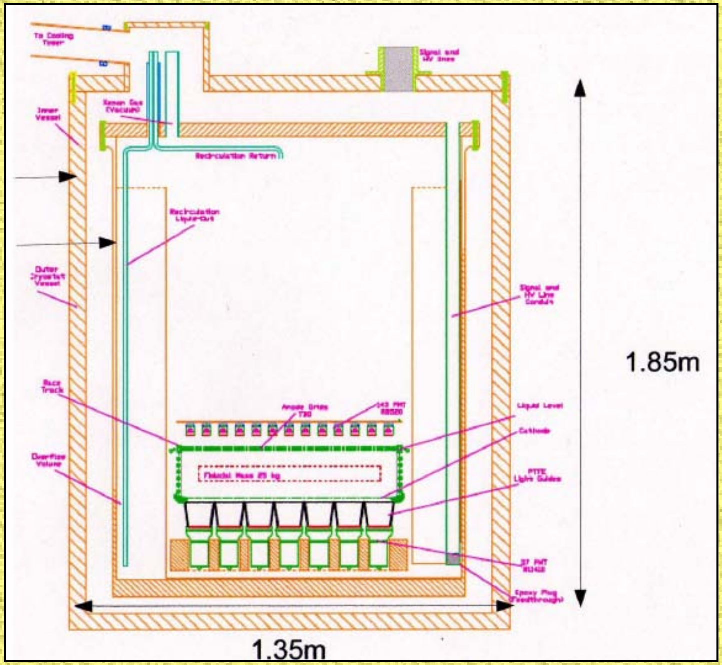
- **2011:** Repeat PRD-09 measurement with 20-g ULEGe
- **2011-12:** 1-kg PCGe
- **2012-14:** 10-kg range PCGe array , with Liquid Argon Anti-Compton
- **2015 & Beyond :** Towards 1-ton scale experiment, include Double Beta Decay to Physics program

Data Taking Configurations in CJPL – Feb 2011



PANDA-X @ CJPL

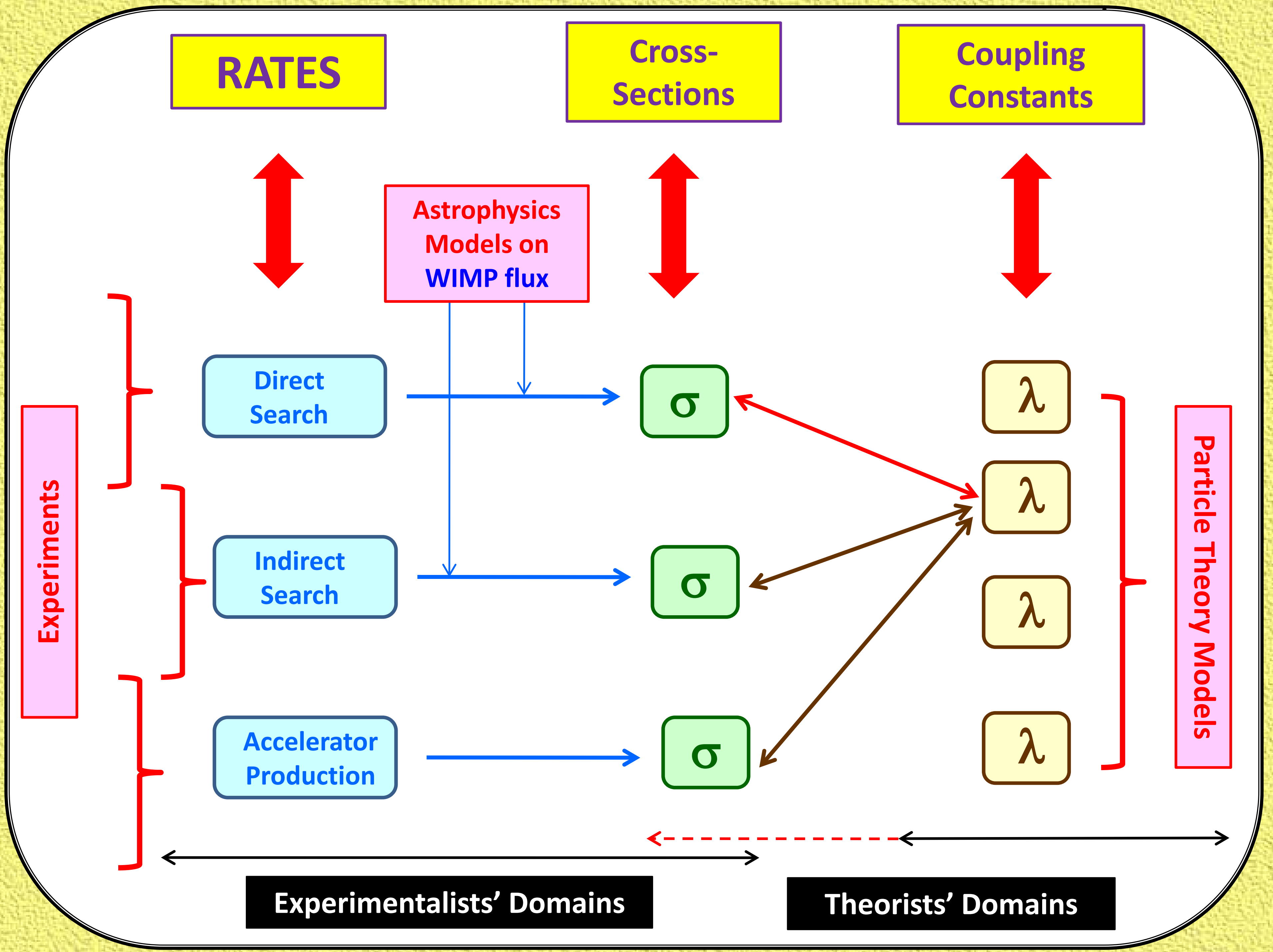




- The second experiment @ CJPL , headed by Shanghai Jiao-Tung U
- Liquid xenon detector, first phase 25-kg fiducial mass
- Installation late 2011 / early 2012

Experiment-Theory Interface

- **Experiments : "Cross-Section (Rate per flux) of Particular Channel Vs WIMP-mass"** e.g. most WIMP results, with SUSY predictions
  - **Merits:** universal , apply to any particle physics models
  - **Drawbacks:** Interaction channel specific ; difficult to compare different approaches (direct, indirect , accelerator searches, astrophysical bounds)
- **Theory : "Coupling Strength of Particular Model Vs CDM-mass"** e.g. Results on Axions Dark Matter Searches
  - **Merits:** the "real" physics information ; can combine and compare different approaches
  - **Drawbacks:** particle physics model specific, needs one plot for every model
- Need "Translation" between two languages – usually are "Theorists' Tasks" to provide the $[\ \sigma \Leftrightarrow \lambda\ ]$ link.
- **Ultimate Answer :** when All Approaches and Experimental data consistently give the same allowed region in $(\lambda\ ,\ m_\chi)$



RATES
Cross-Sections
Coupling Constants
Astrophysics Models on WIMP flux
Direct Search
Indirect Search
Accelerator Production
σ
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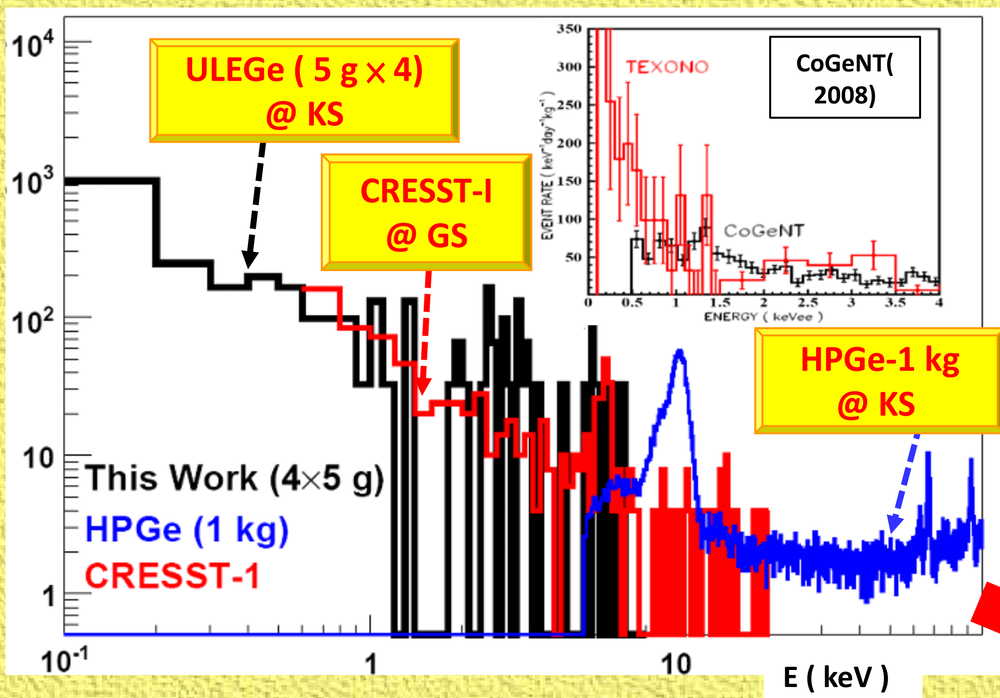
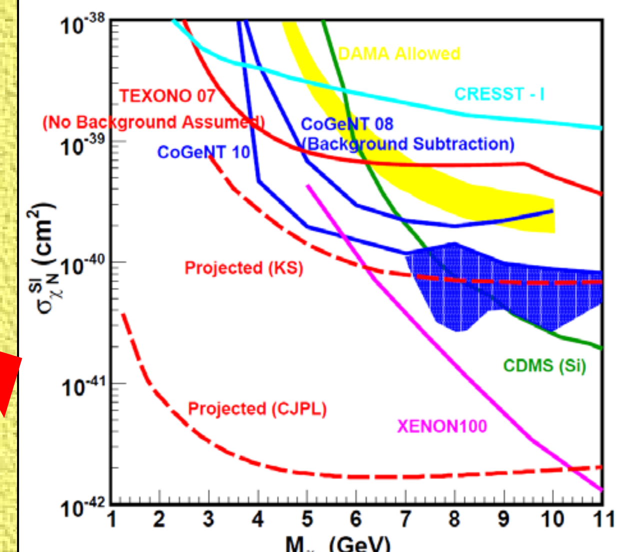
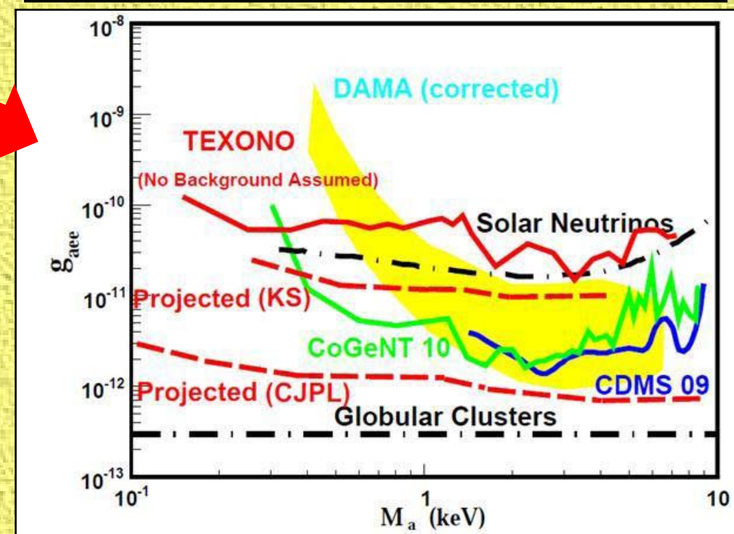
Experiments
Particle Theory Models
Experimentalists' Domains
Theorists' Domains



Experiments' RAW DATA



Language I : e.g.
Scalar coherent scattering cross section per nucleon

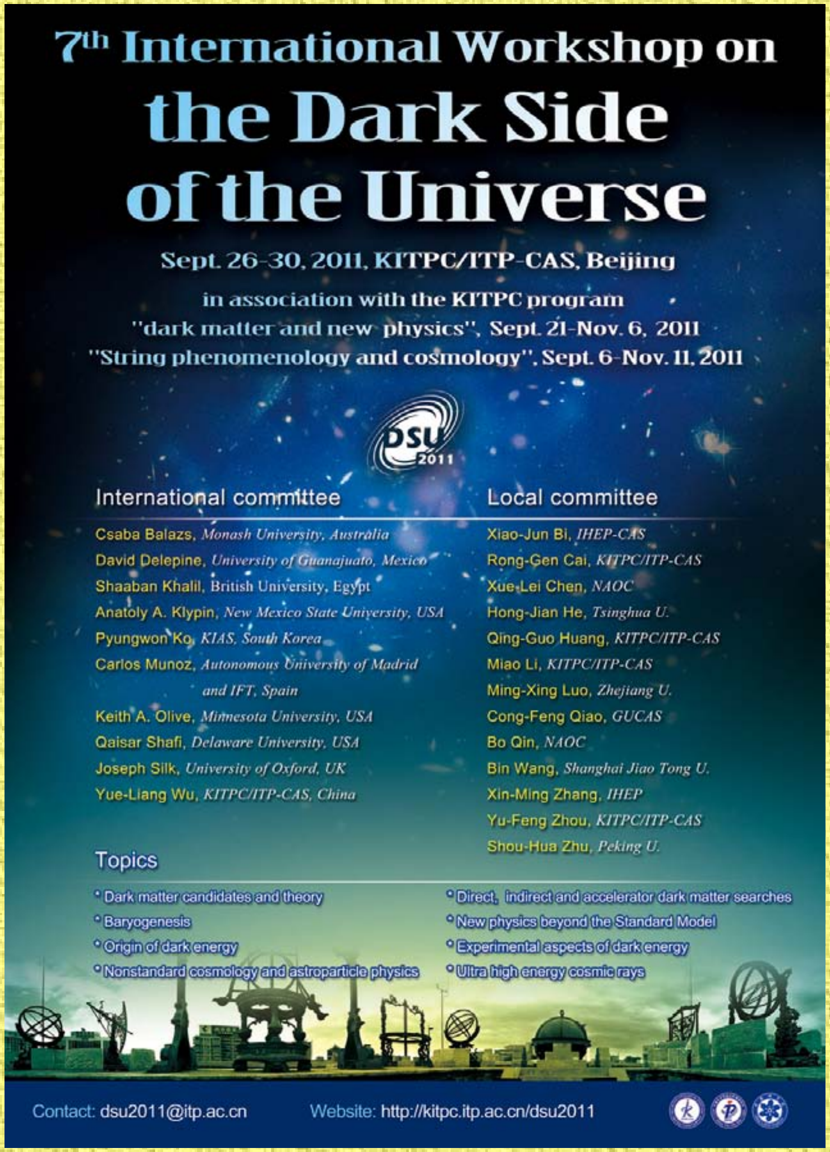


Language II : e.g.
Axion-electron coupling constant

How Theorists Can Support Experimental Program

- CDEX-TEXONO is particularly **unique** in (a) low threshold (to 100 eV) (b) sensitive to electromagnetic final-states (unlike CDMS, XENON)
- **Help to identify** which particle or astrophysics models, which detection channels … etc. in the market which may give us advantages (there exists too many of theory papers for experimentalists to judge and digest !!)
- Provide/identify the **"Punch-Line" Formulae** to translate experimental cross-section to coupling strengths for the various approaches
- Healthy Experimental-Theory **Interactions** : educate and inspire each other ; explore new directions.

Theorist community in China has organized efforts to get into the subject , e.g



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Dark matter and new physics

Date	: From 2011-09-21 To 2011-11-06
International coordinators	: Aprile, Elena (Columbia U., USA) Wang, Tsz-king Henry(IOP,AS) Wefel, John (Louisiana State U., USA) Matsumoto, Shigeki (Toyama U., Japan),Su Shu-Fang (Arizona U. USA) Geng, Chao-Qiang (NCTS), Qaisar Shafi(Chair, University of Delaware),Katherine Freese (Michigan U)
Local coordinators	: Bi, Xiao-Jun (IHEP) Ni, Kai-Xuan (SJTU) Yang, Chang-Geng (IHEP) Yue, Qian (Tsinghua U.) Zhou, Yu-Feng (ITP)

Main | Pictures | Schedules & talks | Sub-Program | Participants | Discussion | **Apply**

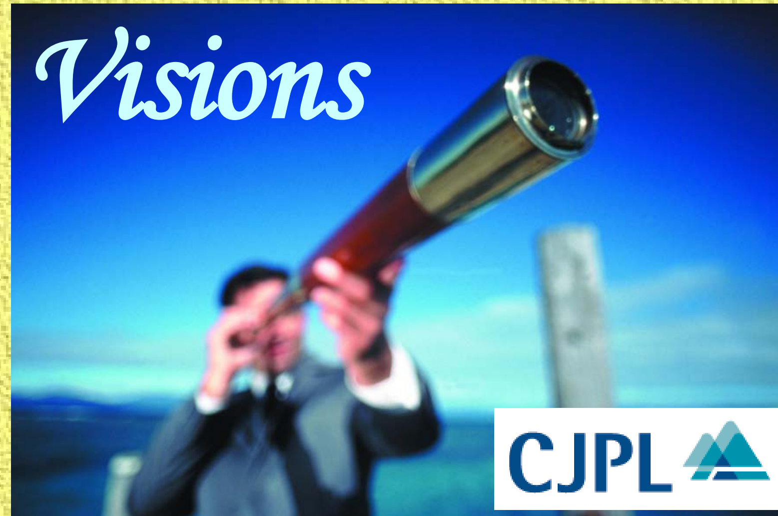
The discovery of dark matter is of fundamental importance to the present-day particle physics and cosmology. Numerous observations such as the rotational curves in galaxies, the gravitational lensing of galactic clusters, the WMAP measurements and the studies of large scale structures of the universe have indicated that nearly 23% of the energy density of our universe is made of non-baryonic cold dark matter, while only 4% is made of ordinary baryonic matter. The origin and the nature of dark matter, however, remains largely unknown, which is a great challenge of our time. From particle physics point of view, it definitely requires new physics beyond the current standard model of particle physics.

Great experimental efforts have been made for detecting and exploring the nature of dark matter. At present there are more than twenty ongoing underground experiments designed for direct detection of signals from dark matter 1 scattering off nuclei such as CDMS, XENON, DAMA, etc.. Different target nuclei and detection methods have been adopted to gain confidences to control systematic uncertainties. Meanwhile, A number of satellite-borne and balloon-borne detecters are also in operation, aiming at detecting the indirect signals such as cosmic positrons, anti-protons and gamma-rays possibly emitted from the dark matter annihilation or decay processes.

With the help of advanced experimental facilities, rapid progresses have been achieved in improving the sensitivity of the dark matter detection in both direct and indirect detections. Recently, the PAMELA experiment indicated a sharp upturn in the positron fraction in the cosmic rays, which is not expected from the standard astro-particle physics. The balloon-borne experiment ATIC-2 reported large excess of the total flux of electrons and positrons in a range of 300-800 GeV with a sharp cut-off at around 600-800 GeV. The latest Fermi-LAT results did not confirm the ATIC results on the excesses, but still indicate a spectrum harder than the expected backgrounds. The underground experiment DAMA/LIBRA has shown indications of an annual modulation of signals consistent with what might be expected from the dark matter nuclei scattering, while other experiments such as CDMS and XENON gave improved upper bounds of the elastic scattering cross section at the order of 10−44cm2. Very recently, the new results from CDMS-II and CoGeNT showed possible dark matter scattering events, which needs to be further examined by future experiments.

In the next few years, new generation of experiments such as AMS02, Ice- Cube, etc. will provide us more accurate information on the cosmic positrons, anti-protons, neutrinos, and gamma-rays, etc. in broader energy ranges. The underground direct detection experiments are going to improve the sensitivity by 1-2 order of magnitudes, which will touch the main bulk of the parameter space of many WIMP models. The running of the Large Hadronic Collider (LHC) will also shed lights on the dark matter detection.

For the aspect of direct detection of dark matter in China, a few domestic universities and institutes such as the Institute for High Energy Physics (IHEP), Purple Moutain Observatory (PMO), TsingHua University (THU) and Shanghai Jiaotong University (SJU) have joined DAMA, ATIC, KIMS, TEXONO and XENON Collaborations to pursue the experimental studies for many years. THU has accumulated rich experiences on technologies includ- 2 ing ultra-pure CsI crystal detector and Ultra-Low-Energy HPGe detector. More theoretical supports are definitely needed for the further development of dark matter experimental search.



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Summary & Outlook

- Missing Energy Density Problem is the most intriguing & important one in basic science.
- Wide spectrum of experimental techniques deployed ; Several anomalous results ; *Strong Potentials for Surprises* in both Theory & Experiments
- TEXONO-CDEX ➡ competitive results in low-mass WIMPs with sub-keV detectors @ KSNL
- New Underground Facilities @ CJPL make realistic for exciting dark matter & neutrino experiments ⇨ Built with Record Speed
- Invite Community to Support & Think Hard & Exploit this Golden Opportunity