

# 兩岸科研合作十五載：TEXONO-CDEX 團隊於微中子與暗物質物理的研究

- 架構：歷史；團隊；實驗設施；研究計畫
- 內涵：低能區之微中子物理、暗物質找尋、探測器

Henry T. Wong / 王子敬  
Academia Sinica / 中央研究院

May 2012 @



**2012年兩岸核子物理与宇宙学研讨会**

会议时间：2012年5月7-12日  
地点：武警会议中心

主办单位：中国科学院理论物理研究所  
承办单位：重庆邮电大学数理学院  
赞助单位：中国科学院港澳台办公室  
国家自然科学基金委

# TEXONO-CDEX Collaboration

🏆 研究主軸：低能區微中子與暗物質物理

TEXONO

*Taiwan EXperiment On Neutrino* [since 1997]

◎ 台灣國聖核電廠微中子實驗室(KSNL)

➤ 台灣 (中研院, 清大, 核能所, 核二廠)

➤ 土耳其 (METU, KTU)

➤ 印度 (Banaras Hindu U)



CDEX

*China Dark Matter EXperiment* [birth 2009]

◎ 中國錦屏地下實驗室(CJPL)

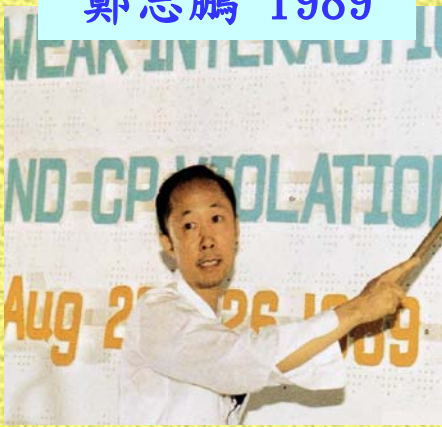
➤ 中國 (清大, 原子能院, 南開大, 川大, 二灘水利)



# 歷史與里程

- ~1990: 台灣中研院高能組(李世昌)與北京高能所(鄭志鵬)啟動交流、互訪
- 1996/4: 探討合作策略架構 *[Who, Where, What]* (張仲濤、李世昌、鄭志鵬、李金)
- 1997/1: 王子敬加入、與李金共同推動、內容與細節 *[How's]* 定案、組織兩岸團隊
- 2009: 中國團隊、由清大領導、組織CDEX合作團、全力開展CJPL計畫 (物理-岳騫)

鄭志鵬 1989



李金 1990's



張仲濤 2010



李世昌 2010



## 創新精神 (時、空、人、事):

- 🏆 國聖實驗(KSNL): 首次於台灣本土執行的大型粒子物理實驗
- 🏆 錦屏地下實驗室(CJPL): 中國首個、世界最深的地下實驗室
- 🏆 TEXONO-CDEX 團隊: 台灣與中國大陸重點科研單位首次合作

16 MAY 2003 VOL 300 SCIENCE [www.sciencemag.org](http://www.sciencemag.org)



## Taiwan-China Collaboration



### A Bridge Over Troubled Waters

Researchers from Taiwan and the mainland have hit scientific pay dirt with the first—and so far the only—collaboration between two institutions across the Taiwan Strait

**TOKYO**—A hot campaign issue in Taiwan's presidential election in March 1996 was whether the island should drop its long-held objective of reuniting with the mainland and formally declare its independence. As a

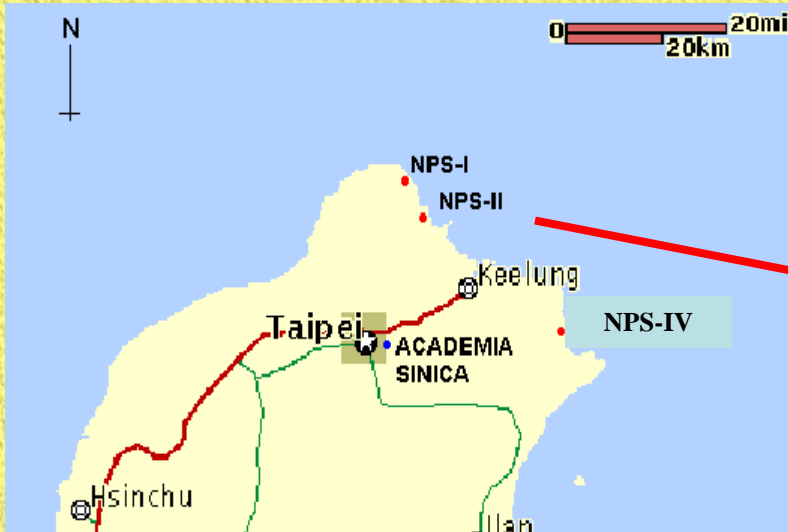
the mainland but is now a U.S. citizen. It was his idea to get Taiwanese scientists together with researchers at the Chinese Academy of Sciences' Institute of High Energy Physics (IHEP). That month, the two

# 國聖微中子實驗室

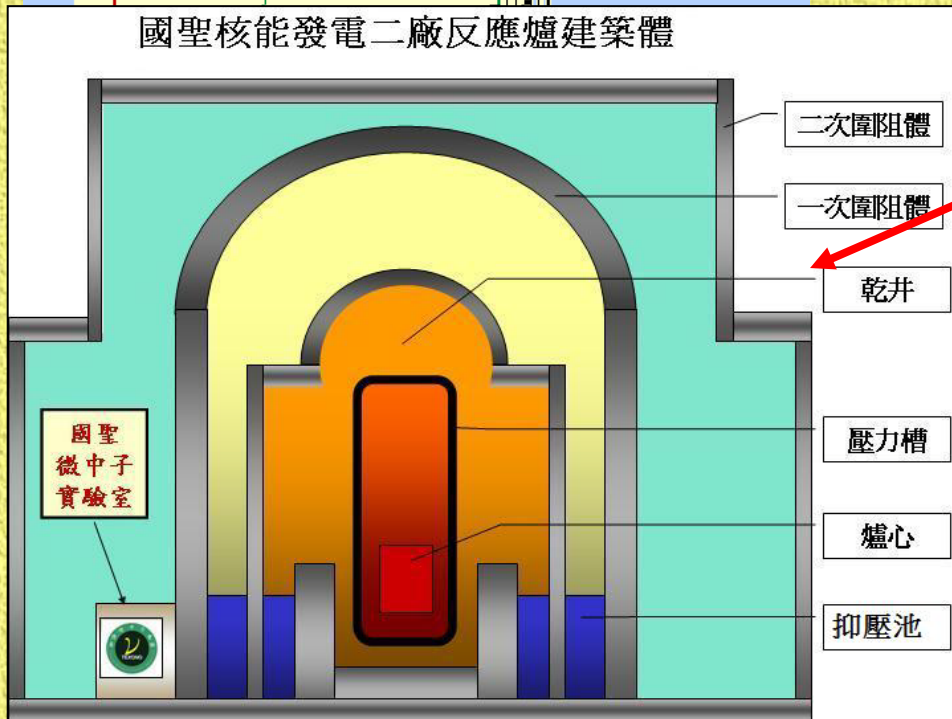
Science Magazine 2003年 專文報導



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



國聖核能發電二廠反應爐建築體



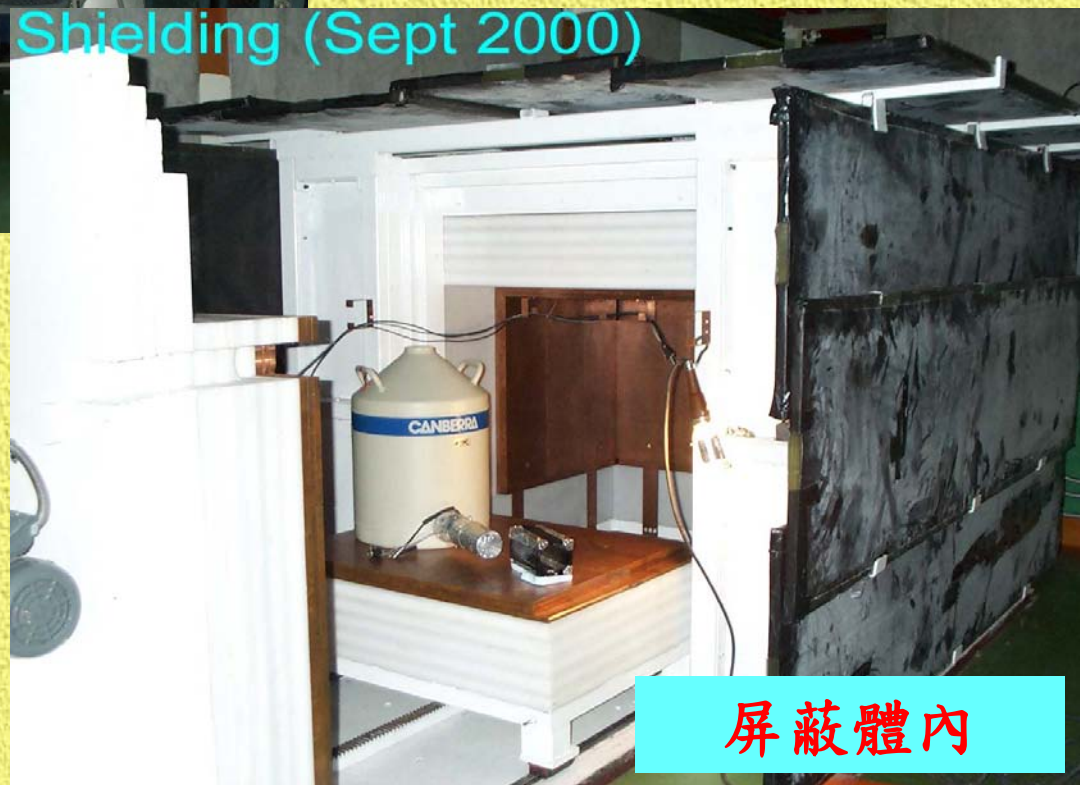
\* 距離爐心 28 m

\* 微中子通量  $\sim 10^{13} \text{ cm}^{-2} \text{ s}^{-1}$   
(比太陽微中子高)



Shielding (Sept 2000)

實驗室外觀 (宇宙線探測器、  
屏蔽體、控制室...)



屏蔽體內

# KS Laboratory : Detectors

ULB-HPGe [1 kg]



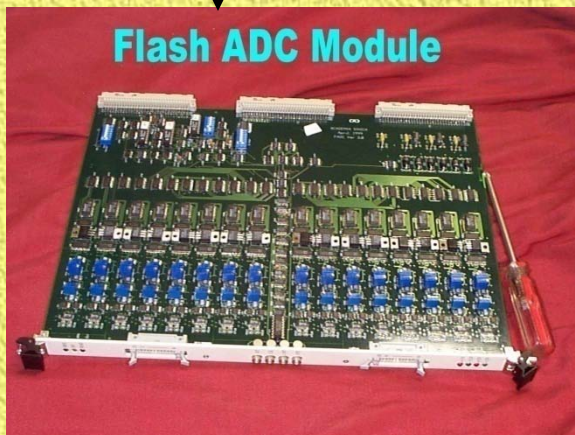
CsI(Tl) [200 kg]



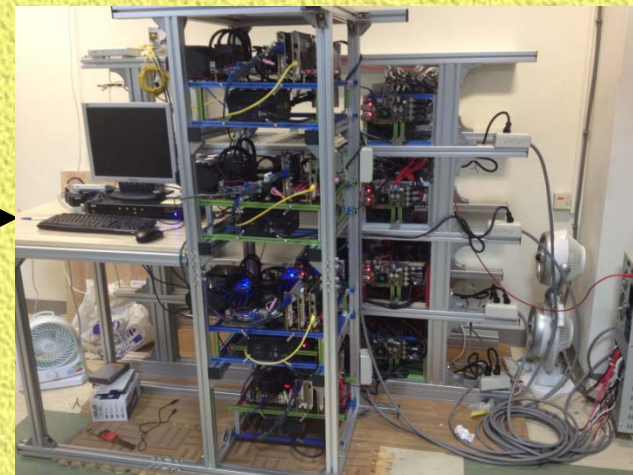
ULE-ULB-HPGe  
Prototype [20 g]



Flash ADC Module



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



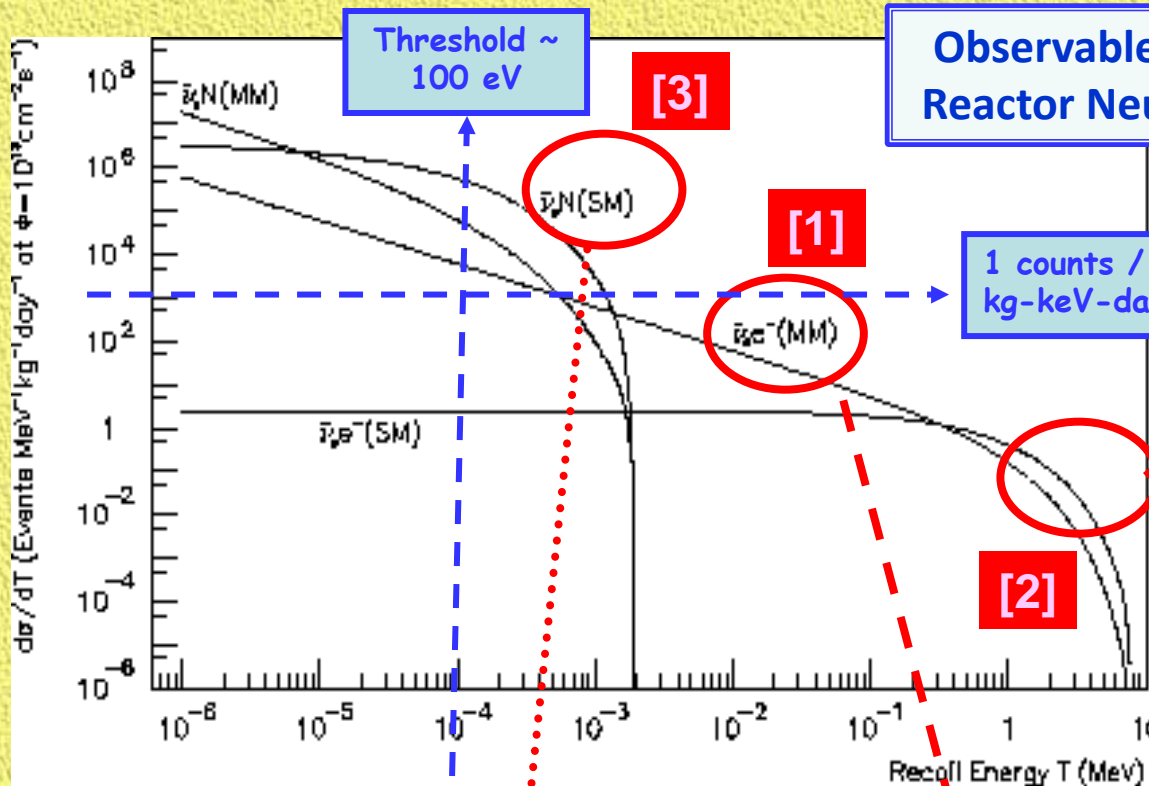
Multi-Disks Array [~300 Tb]

# Neutrino Properties & Interactions at Reactor

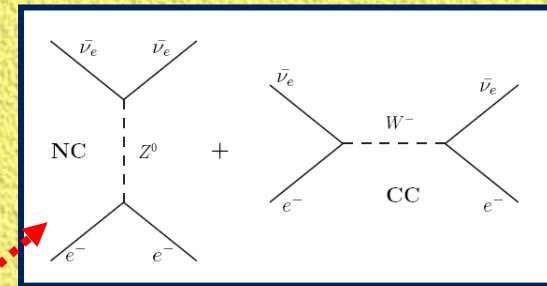
quality

Detector requirements

mass



Observable Spectra with Reactor Neutrino "Beam"

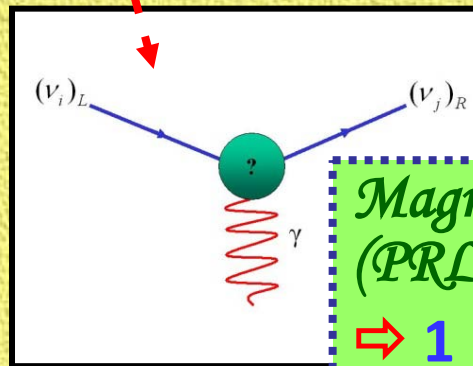


Standard Model & NSI  $\nu e$  Scattering (2  $\otimes$  PRD10, PRD12)  
 ⇒ 200 kg CsI(Tl)

$\nu N$  Coherent Scattering

⇒ Dark Matter Searches (PRD-RC09)

⇒ sub-keV O(kg) ULEGe / PCGe



Magnetic Moments (PRL03, PRD05, PRD07)

⇒ 1 kg HPGe



# 重點研究成果：於低能區開啟觀察視窗



## 微中子與光子可能交互作用的研究

[*Phys. Rev. Lett.* 2003 ; *Phys. Rev. D* 2005, 2007]

閾10 keV、靈敏度世界水平前沿

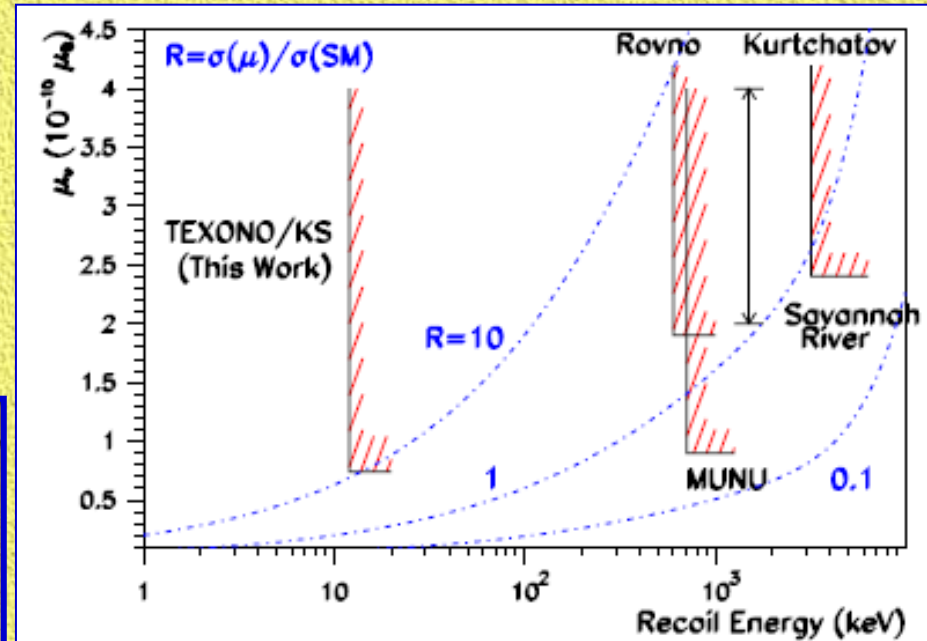
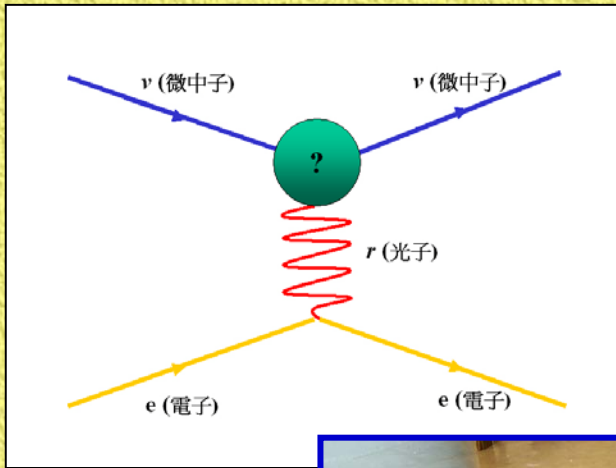


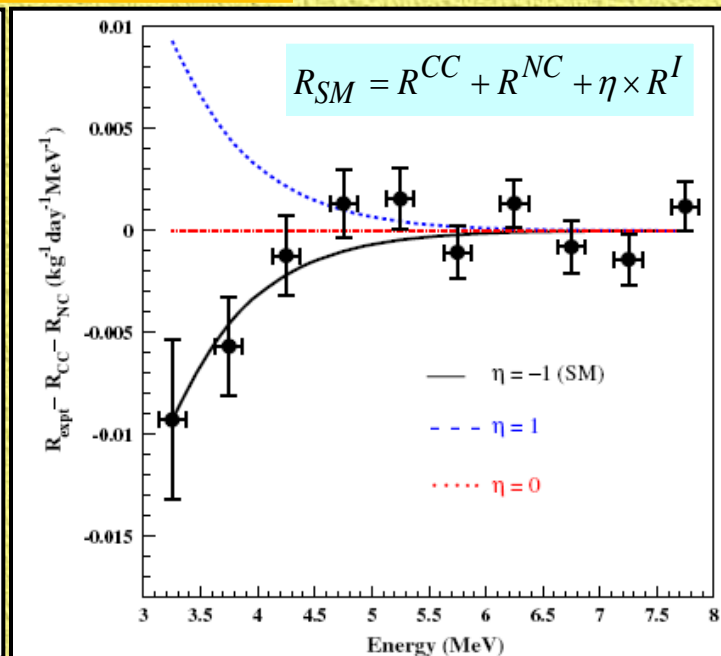
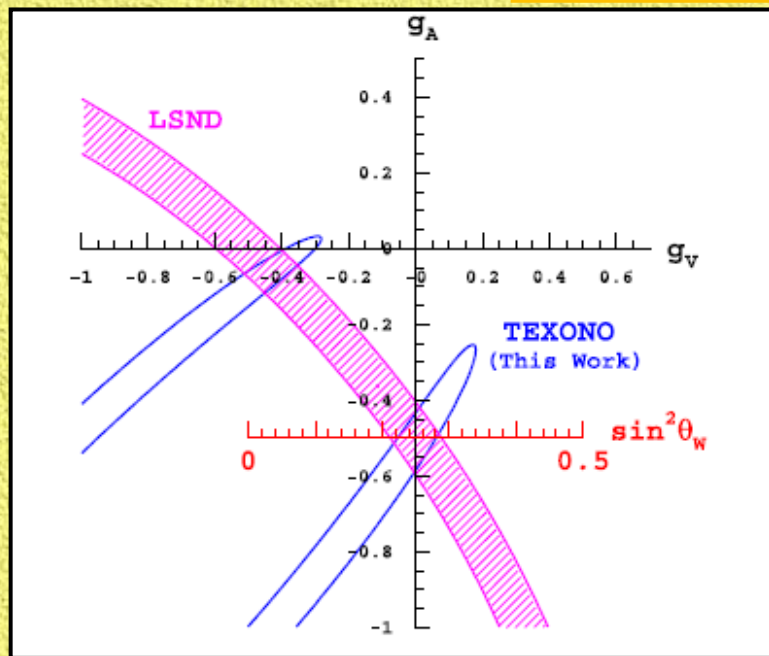
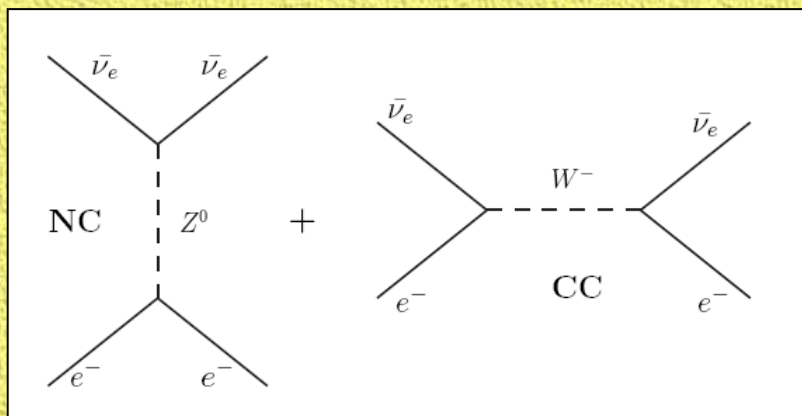
FIG. 14 (color online). Summary of the results in the searches of neutrino magnetic moments with reactor neutrinos. Both the limits and the detection thresholds of the various experiments are shown.



# 微中子與電子交互作用的研究

[2 ⊗ *Phys. Rev. D* 2010 ; *Phys. Rev. D* 2012]

於新能區證明標準模型有效、限制新物理



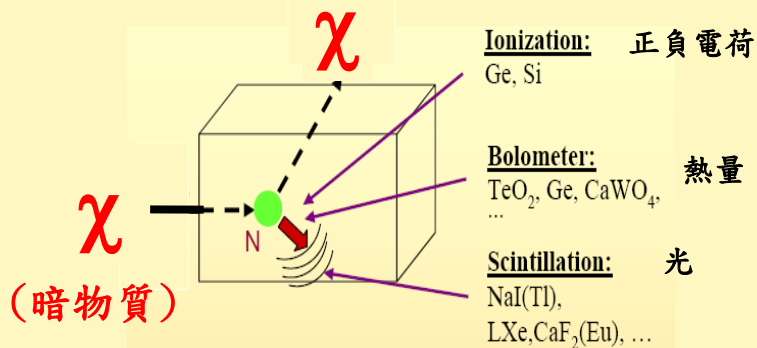
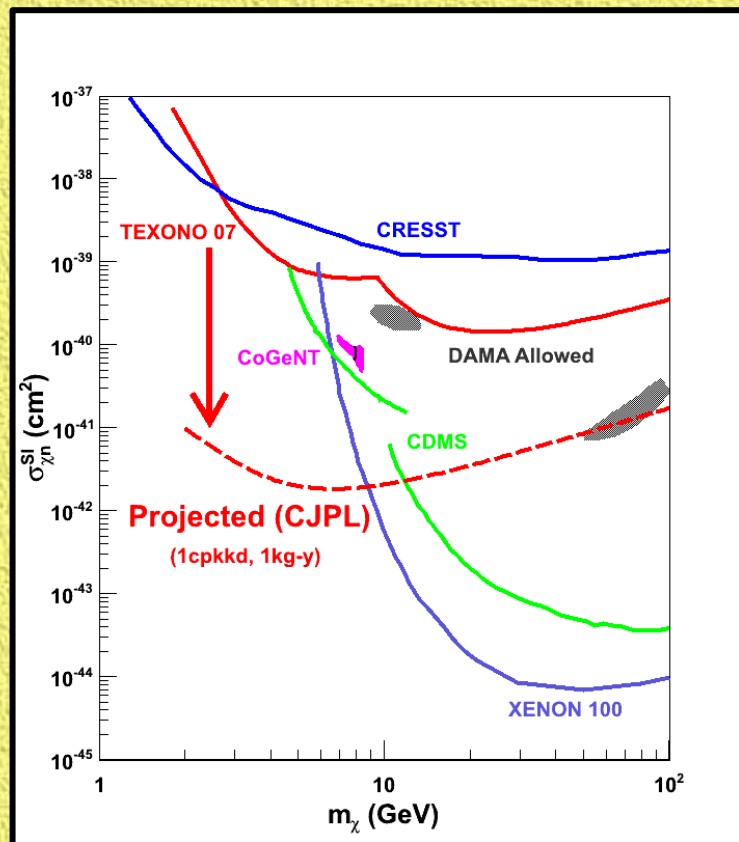
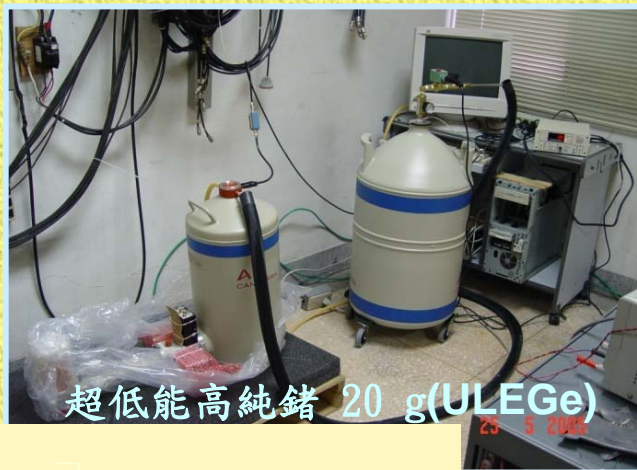
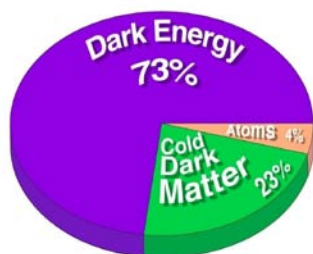
# 🏆 找尋暗物質 [Phys.Rev.D (RC) 2009]

📖 微中子探測器之開發

⇒ 開啟低質量暗物質視窗

📖 靈敏度世界前沿

📖 迅速有效開展CJPL研究的重要基礎



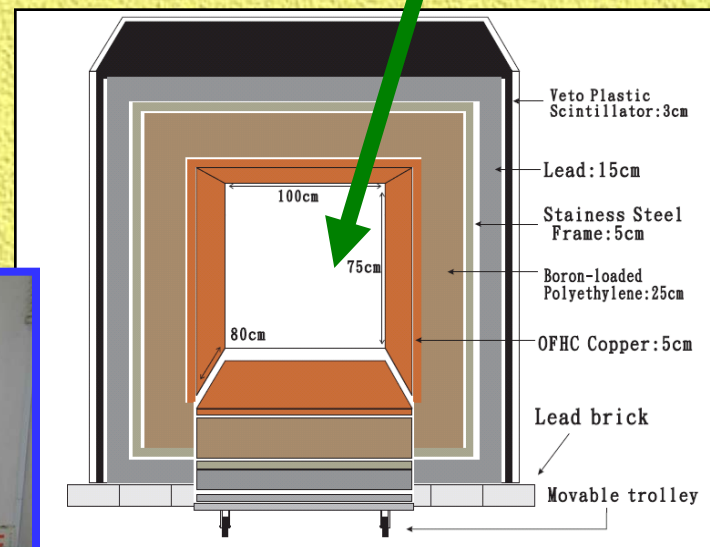
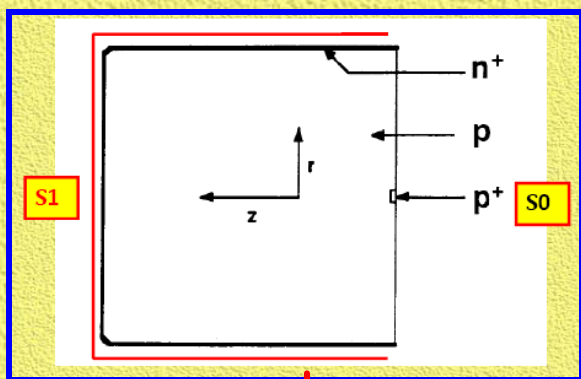
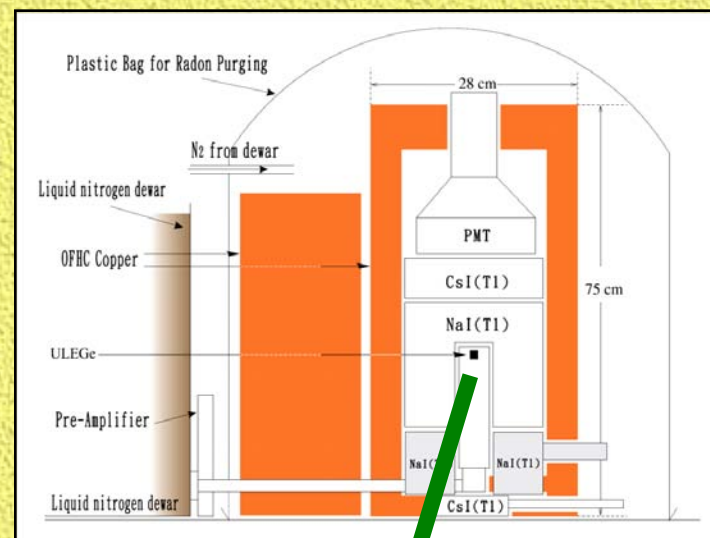
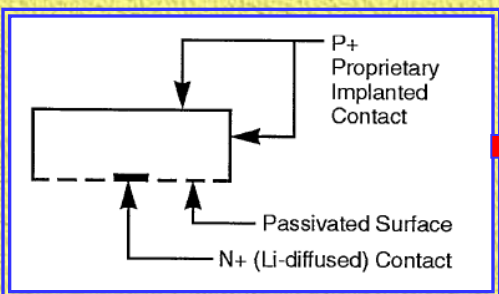
# Current Research Theme:

## "sub-keV" Ge Detectors

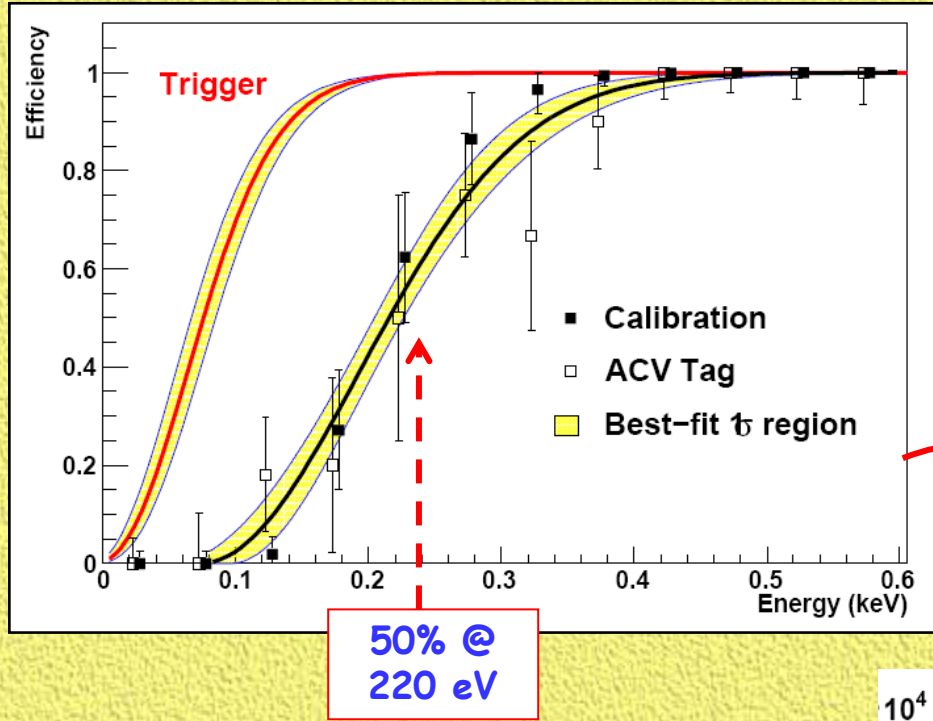
🔦 **Physics Goals for  $O[100 \text{ eV threshold} \oplus 1 \text{ kg mass} \oplus 1 \text{ cpkkd}]$  detector :**

- ⊙  $\nu N$  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



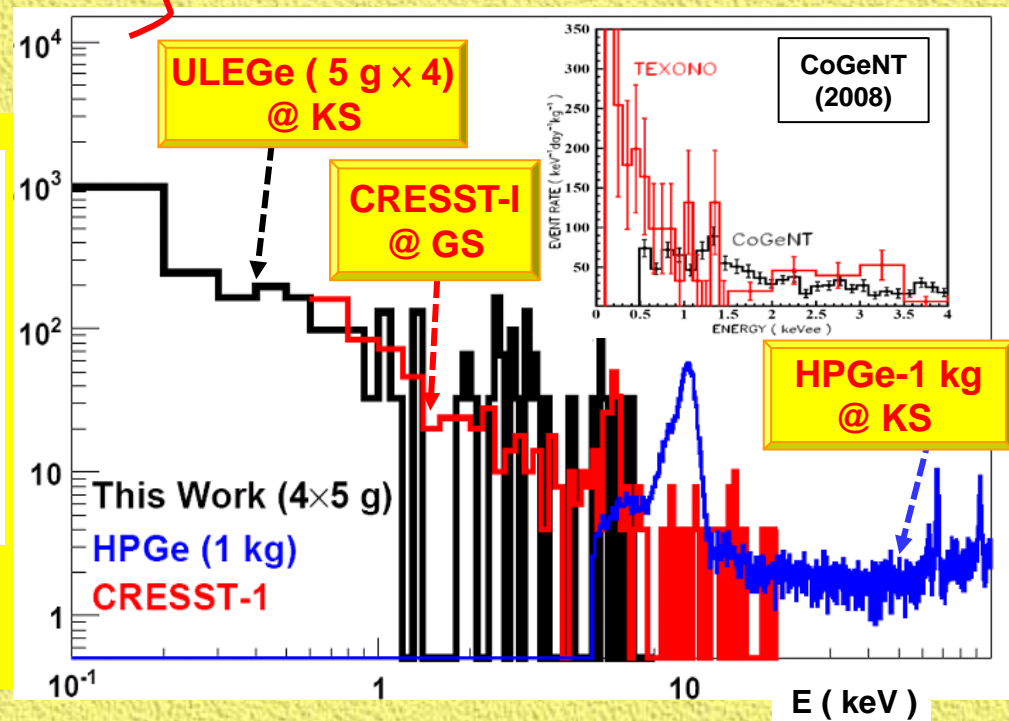
# Threshold & Efficiencies & Background for 20g ULEGe (2007)



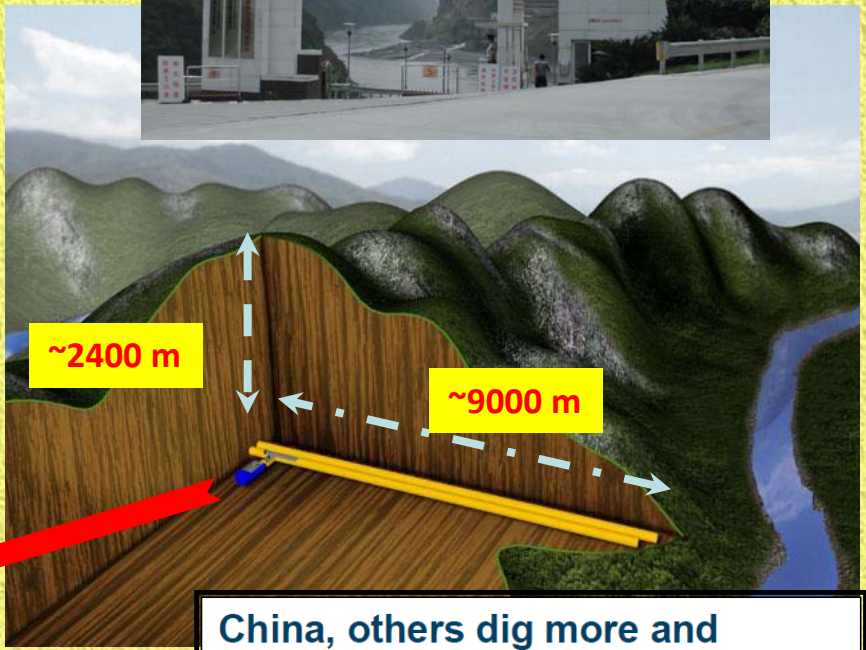
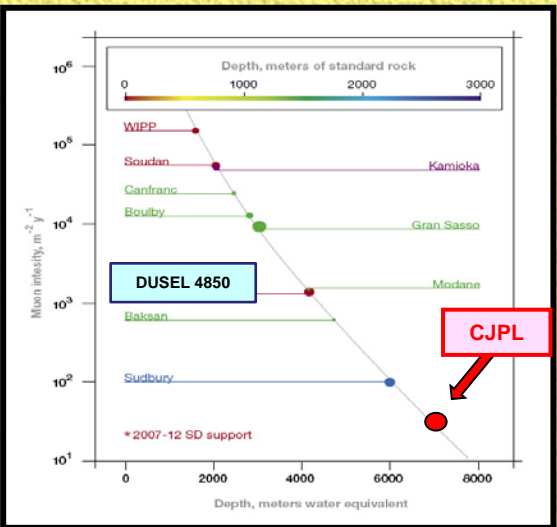
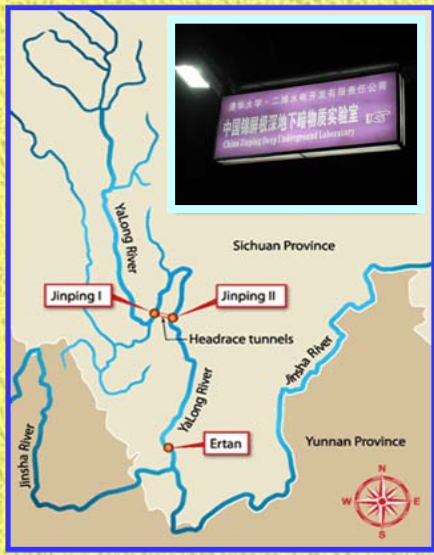
Dark Matter Searches Analysis

**sub-keV Background :**

- \* Not fully explained with conventional background modeling
- \* Intense work on hardware, software and data taking at CJPL



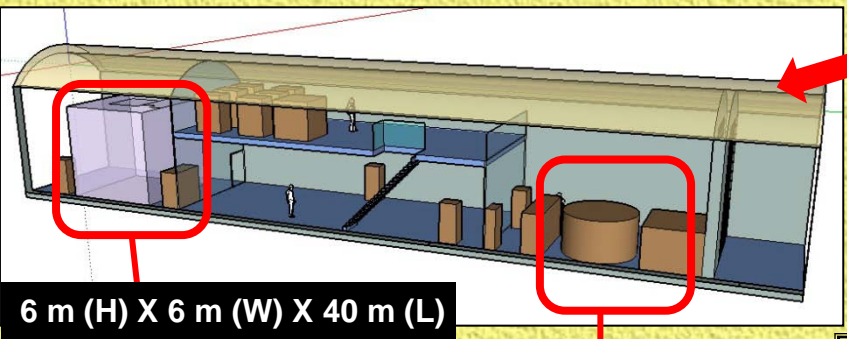
**CJPL**  **中国锦屏地下实验室**  
China Jinping Underground Laboratory



**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



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

**CDEX-TEXONO**

**PandaX**

**PARTICLE PHYSICS:**  
**Chinese Scientists Hope to Make Deepest, Darkest Dreams Come True**  
 Dennis Normile

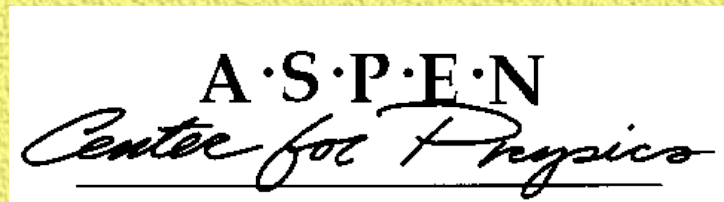
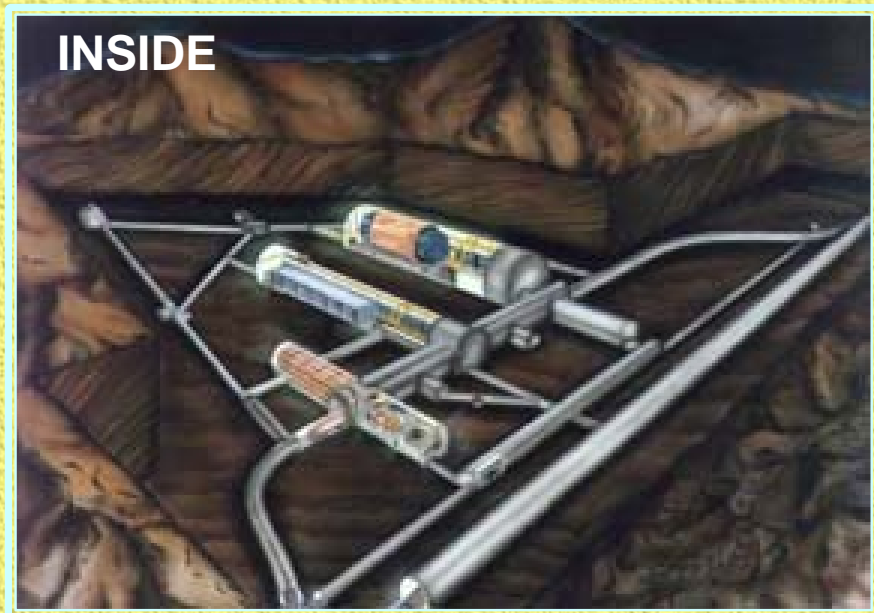
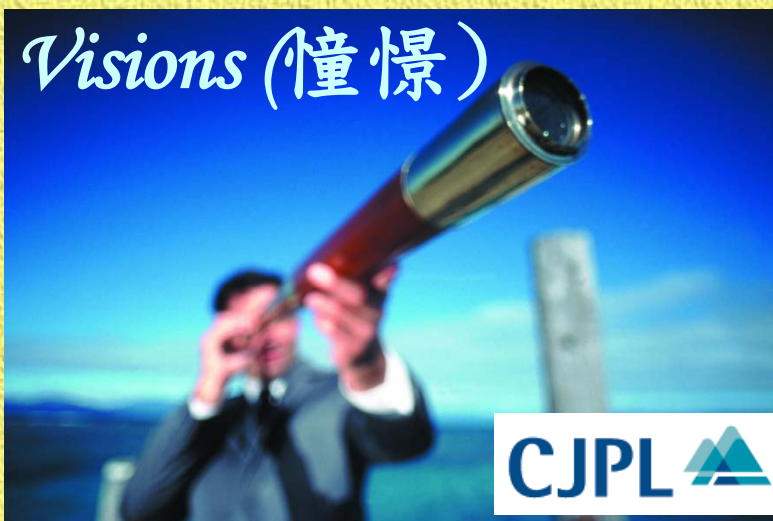
 

Science 5 June 2009:  
 Vol. 324, no. 5932, pp. 1246 - 1247  
 DOI: 10.1126/science.324\_1246

# CDEX-TEXONO @ CJPL

- 📅 **2011-12:** Repeat PRD-09 measurement with 20-g ULEGe
- 📅 **2012-14:** CDEX-1  $\Rightarrow$  1-kg class PCGe's
- 📅 **2012-15:** CDEX-10  $\Rightarrow$  10-kg range PCGe array , with Liquid Argon Anti-Compton
- 📅 **2015 & Beyond :** Towards 1-ton scale experiment, include Double Beta Decay to Physics program





# 願景



## 更上層樓：

- ☞ KSNL 與 CJPL 實驗計畫，繼續全速發展 [繼往、承先]
- ☞ 探討開展微中子/暗物質/地下實驗…等新研究方向 [開來、啟後]