Low Energy Neutrino Physics at the Kuo-Sheng Reactor Neutrino Laboratory in Taiwan

- **Overview : Experimental Particle Physicsin Taiwan & TEXONO Collaboration**
- **Kuo-Sheng(國聖) Reactor Neutrino Laboratory**
  - ※ **Facilities** TEXONO
  - ※ **Research Topics**
- **R&D Program (omitted)**
- **Summary & Outlook**

*Taiwan EXperiement On NeutrinO

http://hepmail.phys.sinica.edu.tw/~texono/

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5th Rencontres du Vietnam
Hanoi 2004

Experimental Particle Physics in Taiwan

…… started late 80's , with existing nuclear physics/engineering programs

Academia Sinica (中央研究院) :

- **CDF@Tevatron@Fermilab (opto-electronics ….)**
- **AMS@Space Shuttle & Station (space electronics ….)**
- **TEXONO Program on Neutrino Physics *in* Taiwan *[LOCALLY based and led]***
- **LEPS@SPring8 (fast electronics, analysis ….)**
- **ATLAS@LHC@CERN (GRID computing, opto-electronics …….)**

National Taiwan University (台灣大學) :

- **Belle@KEKB@KEK (EFCalo, analysis …)**
- **CMS@LHC@CERN**

National Central University (中央大學) :

- **L3@LEP@CERN**
- **PHOBOS@RHIC@BNL (Si-detectors …..)**
- **CMS@LHC@CERN (Si-detectors…..)**

⊕ Satellite Institutes

⊕ *closely-connected* Theory, Astronomy , Space Program, Sync. Rad. … communities

TEXONO* Collaboration

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Co-Prinicipal Investigators

Ph.D. Students

HISTORY

- Initiate : Chang Chung-Yung 1996
- First Collab. Meeting/Official Start : October 1997
- First Paper : October 1998
- KS Reactor Experiment Installation : June 2000
- First Ph.D. : Liu Yan , July 2000
- First Physics Data Taking : June 2001.
- First Physics Results: Dec 2002.

TEXONO Overview

Program:

- **Kuo-Sheng Reactor Neutrino Laboratory**
  - ※ **oscillation expts. ⇒ $m_\nu \neq 0$ ⇒ anomalous ν properties & interactions**
  - ※ **ν physics full of surprises , need intense ν-source**
  - ※ **reactor : high flux of low energy electron anti-neutrinos**

  ∴ **study/constraint new regime wherever experimentally accessible**

  ∴ **explore possible new detection channels**

- **R&D Projects**

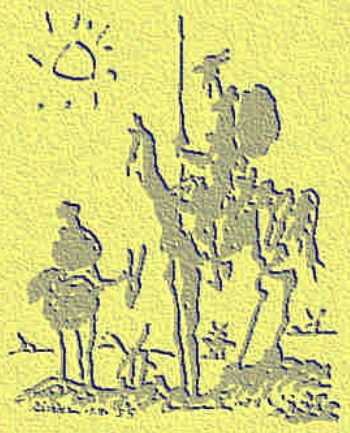
Poineering Efforts : *"Zero-Background Experiment" !*

🏆 **KS Expt: 1st large-scale particle physics experiment *in* Taiwan**

🏆 **TEXONO Coll. : 1st big research Coll. % Taiwan & China**

[feature report in Science, Vol. 300, 1074 (2003)]

16 MAY 2003 VOL 300 SCIENCE 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

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Researchers make headway in neutrino study

By Myra Lu

After six years of painstaking work, researchers on the TEXONO project, or Taiwan Experiment on Neutrinos, have

more than 20 fundamental particles that make up the universe. Scientists around the world have conducted numerous experiments to learn more about this particle, which remains one of the least understood. Neutrinos are produced in the Earth's atmosphere, the sun, particle accelerators and nuclear power reactors.

Physicists believe that neutrino studies will help shed light on questions about the particle's

The Kuo-Sheng Nuclear Power Station, which produces electricity used by millions of households in northern Taiwan, also houses the research facilities of the TEXONO project.

Wong said. The results of international collaborations such as the Super-Kamiokande in Japan and Sudbury Neutrino Observatory in Canada gave the Taiwan project what Wong described as a "positive impact."

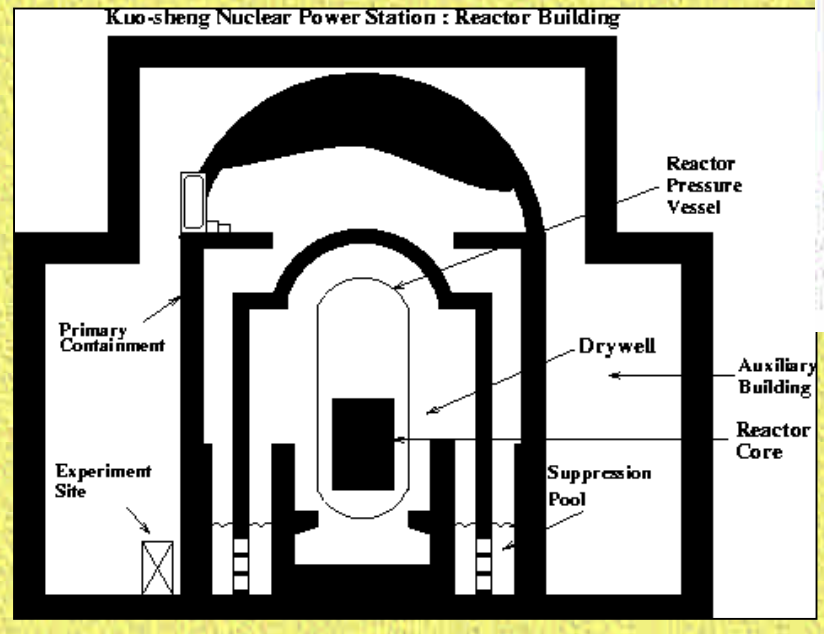
This is because these earlier experiments have confirmed that the neutrino does have mass and that neutrino oscillation does take place. The latter refers to a phenomenon where neutrinos change from one type to another while traveling great distances. Such oscillation would not occur if neutrinos were entirely without mass, which scientists used to believe to be the case.

"These experiments use much larger instruments to explore different aspects of the neutrino properties from those pursued by the TEXONO experiment. However, given their findings, we know there is a grander picture behind and which direction to go," Wong noted.

Kuo-Sheng Nuclear Power Plant

KS NPS-II : 2 cores × 2.9 GW

KS ν Lab: 28 m from core#1



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

Kuo Sheng Reactor Neutrino Laboratory

Front Gate

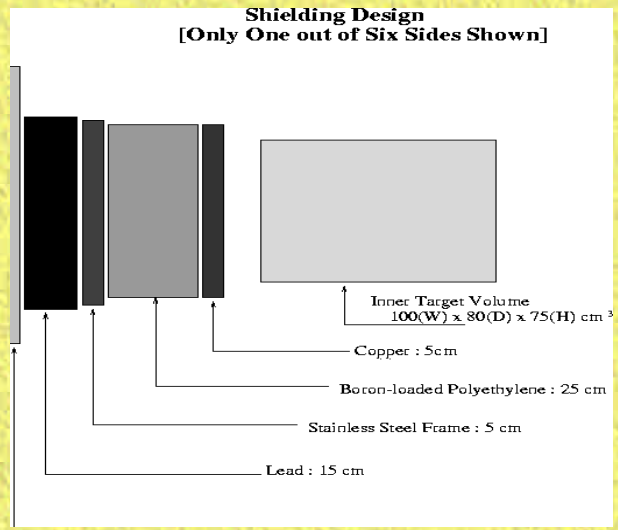
Front View *(cosmic vetos, shieldings, control room …..)*

Inner Target Volume

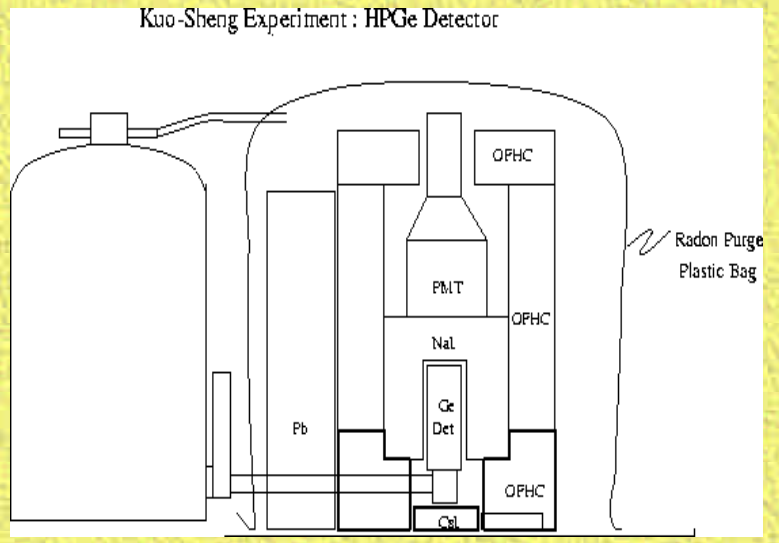
Configuration: **Modest yet Unique**

Flexible Design: **Allows different detectors conf. for different physics**

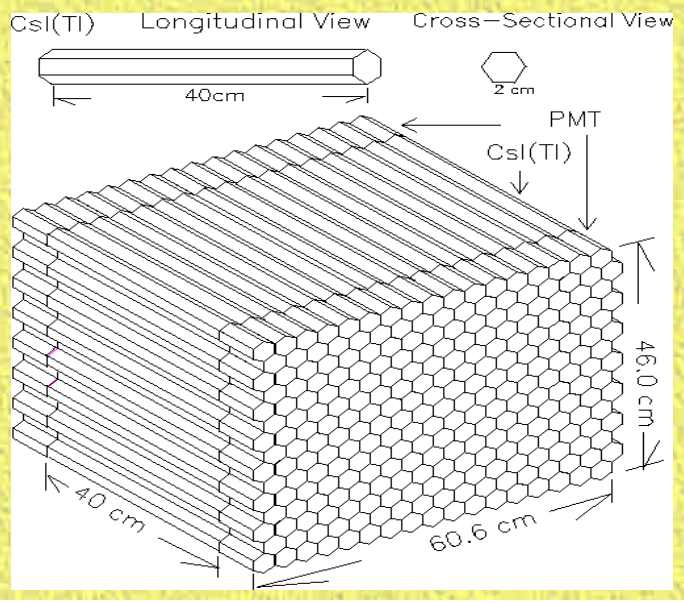
KS Expt. : Period I-III Configuration



Shielding & Veto [one side]



ULB-HPGe + Anti-Comptons

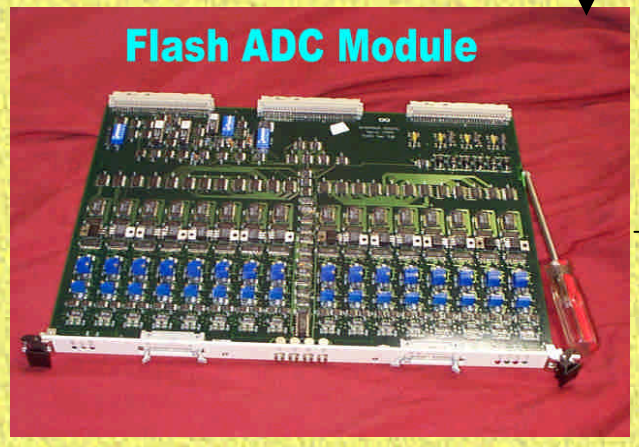


CsI(Tl) Array (200 kg)

KS Expt: Period I,II,III Detectors

ULB-HPGe [1 kg]

CsI(Tl) [196 kg]



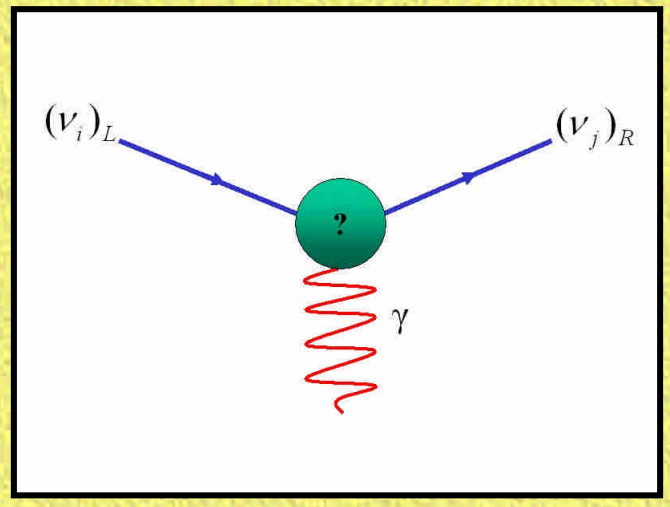
FADC Readout

[16 ch., 20 MHz, 8 bit]

Multi-Disks Array [600 Gb]

Neutrino Magnetic Moments

μ_ν



Γ_ν

- **fundamental neutrino properties & interactions ; a channel to differentiate Dirac/Majorana neutrinos (ν_D/ν_M)**
- **look for surprises and/or constrain parameter space with future precision oscillation data**
- **study 1/T spectral shape in ν-e scattering,**

  T is electron recoil energy
- **Related to neutrino radiative decays**

$$\frac{d\sigma}{dT}(\nu e)_\mu = \frac{\pi\alpha^2}{m_e^2}\left[\frac{1}{T} - \frac{1}{E_\nu}\right]\mu_\nu{}^2$$

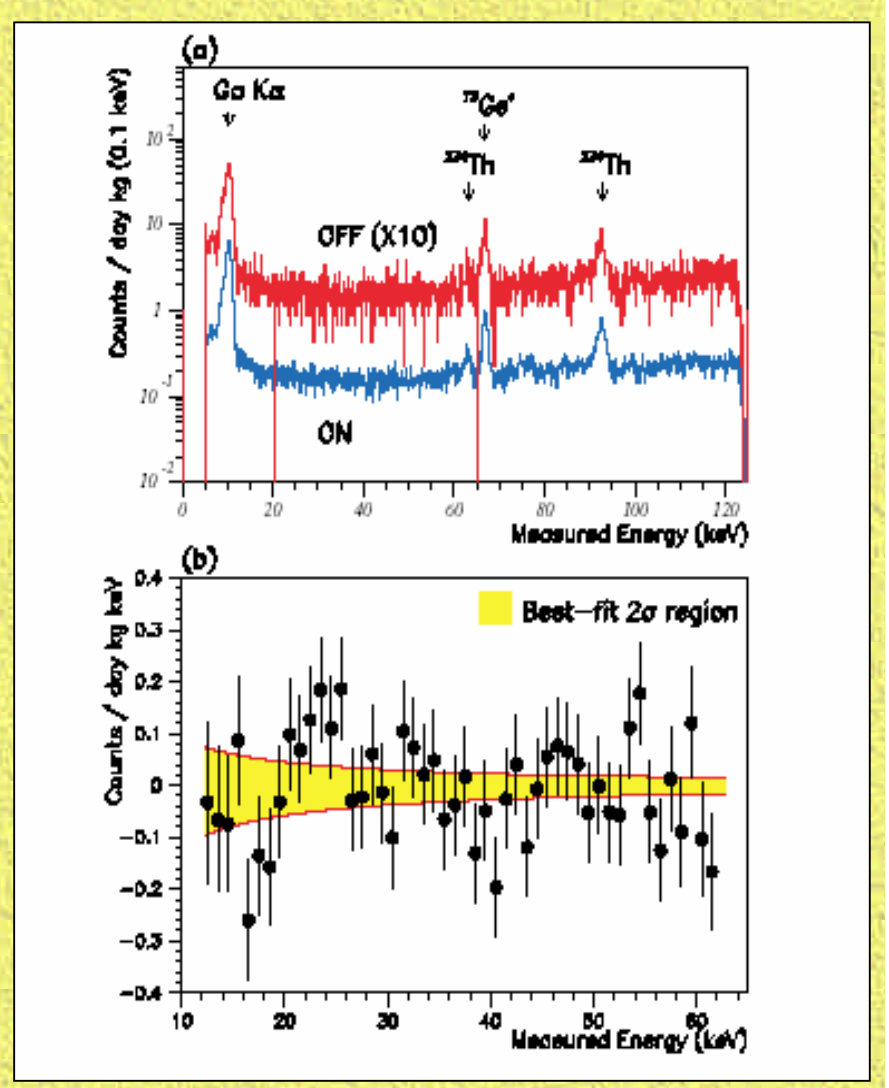
$$\Gamma(\nu_i \to \nu_j \gamma) = \frac{1}{8\pi}\frac{(\Delta m_{ij}{}^2)^3}{m_i{}^3}\mu_\nu^2$$

- **TEXONO data (4712/1250 hours ON/OFF) [PRL 90, 2003]**
- **comparable bkg level to underground CDM experiment at 10-20 keV :**

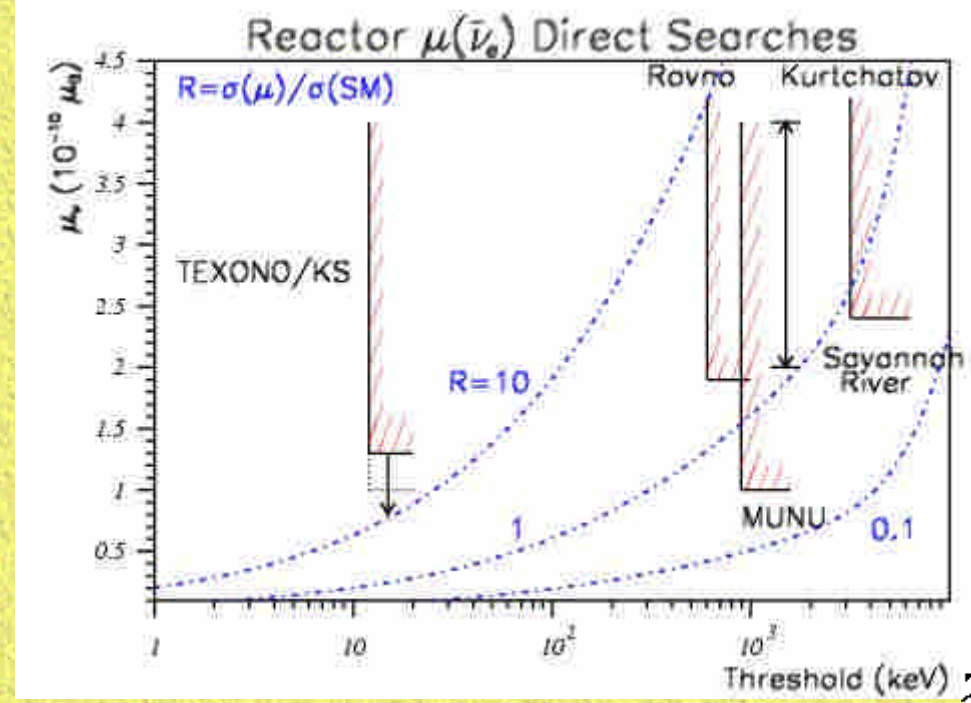
  ~ 1 day^{-1}keV^{-1}kg^{-1} (cpd)
- **analysis threshold 12 keV**
- ***No excess* of counts ON/OFF comparison**
- **Limit:**

  $\mu_\nu(\nu_e) < 1.3 \times 10^{-10}\ \mu_B$ **(90% CL)**
- **more data/improvement to get to sensitivity range**

  $\mu_\nu(\nu_e) \rightarrow 1.0 \times 10^{-10}\ \mu_B$



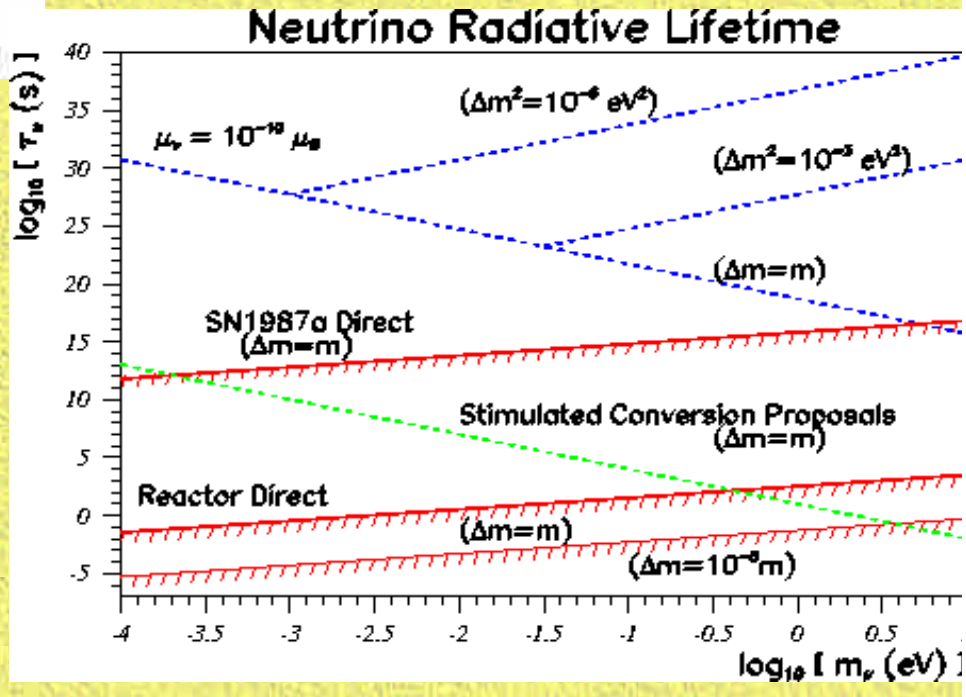
Reactor $\mu_\nu(\nu_e)$ Sensitivities



μ_ν

Γ_ν Sensitivities

Γ_ν



KS Physics Program : Periods I & II & III

HPGe [1 kg] :

- $\mu_\nu + \Gamma_\nu$: **x2 more data from PRL**
  improved background & analysis
- **study ν_e flux from reactor & physics potentials**
- **study possible nuclear transitions**
- **Possible reactor axion search**

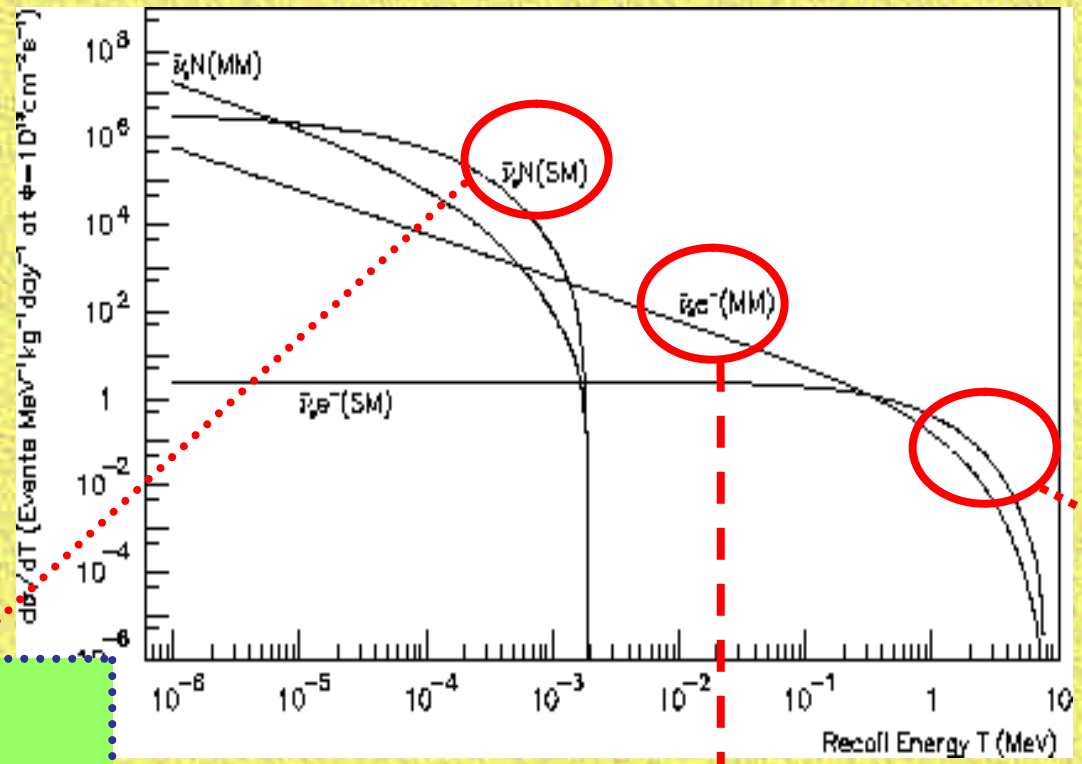
CsI(Tl) [196 kg] :

- **attempt measurement of Standard Model $\sigma(\nu_e e^-)$**
  - ↳ **$\sin^2\theta_w$ at MeV range**

Prototype ULE-HPGe [5 g] :

- **threshold < 300 eV → ~ 100 eV**
- **explore potentials on νN coherent scattering & CDM**

Reactor Neutrino Interaction Cross-Sections



R&D :

- Coh. (νN)
- T < 1 keV

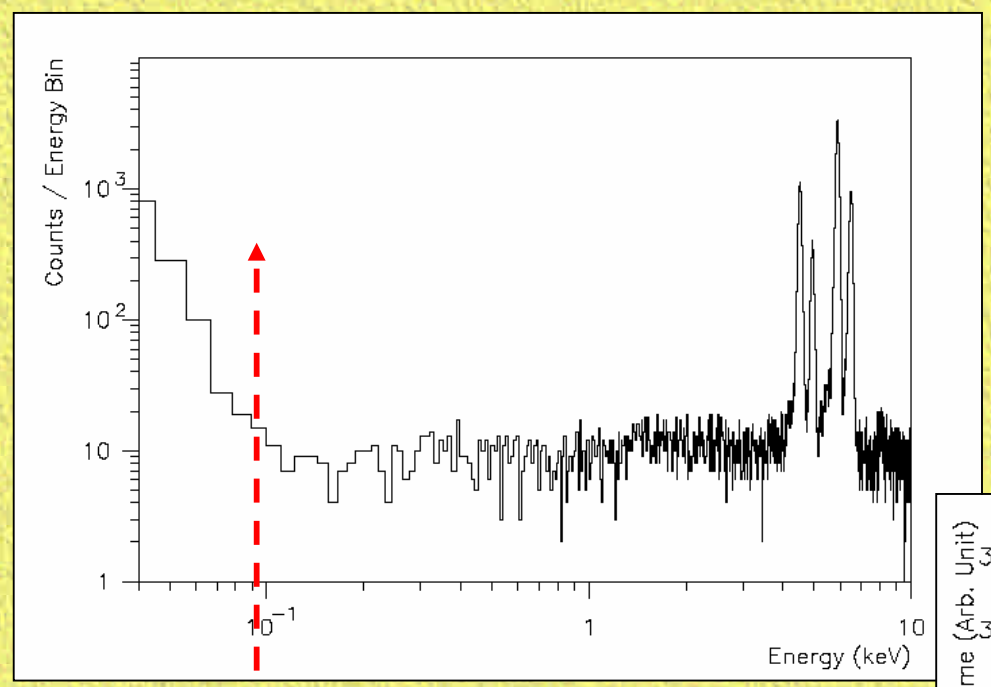
Results & More Data:

- $\mu_\nu(\nu_e)$
- T ~ 1-100 keV

On-Going Data Taking:

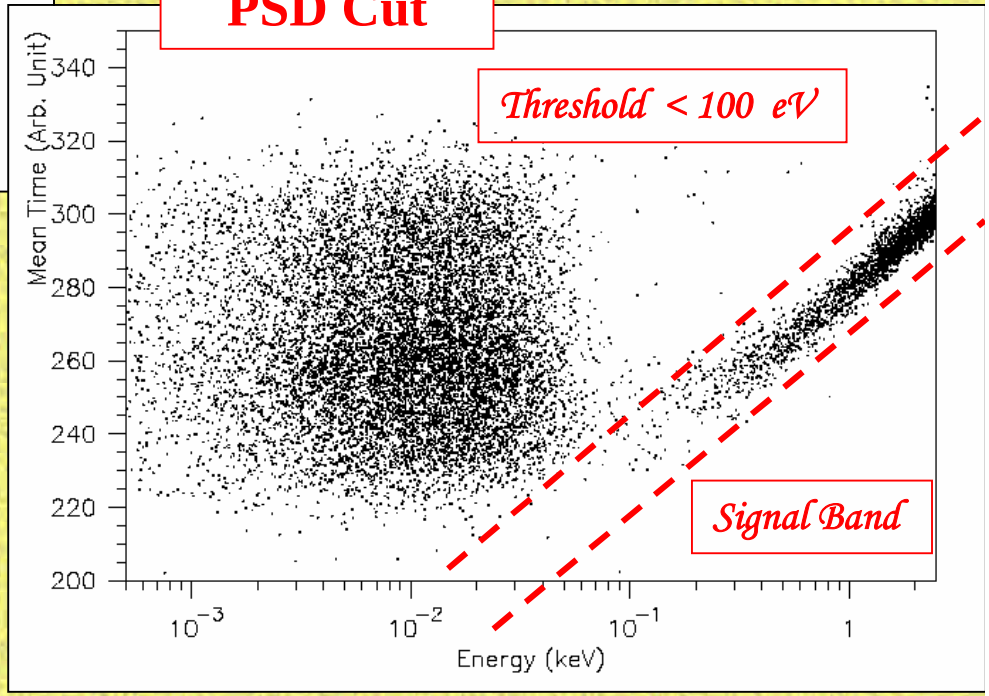
- SM σ(νe)
- T > 2 MeV

ULE-HPGe : 5 g Prototype Results



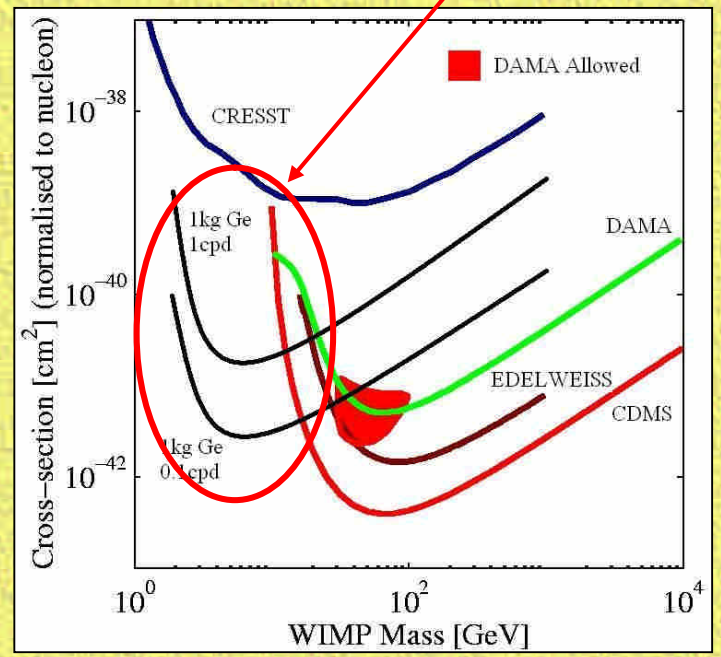
Threshold ~ 100 eV

PSD Cut



CDM Project: TEXONO ⊕ KIMS

- **KIMS: funded Dark Matter program with underground facility @ Y2L in Korea**
- **move ULE-HPGe 5 g prototype → Y2L for measurement 04/05 : sub-keV bkg & CDM searches**
- **may evolve into a full-scale (1 kg) CDM experiment : different sensitivity region**



Yangyang（襄陽）Lab (Y2L)
min. 700 m of rock overburden

Summary & Outlook

- **TEXONO Collaboration: ⇨ Built-Up & Growing**
- **Kuo-Sheng Neutrino Lab.:**
  - ↳ **Established & Operational**
    - ※ **Modular & Flexible Design**
  - ↳ **Physics Data Taking since June 01**
    - ※ **Unique HPGe Low Energy Data**
    - ※ **Bkg Level ~ Underground CDM Expt.**
- **Results published on μ_ν (Γ_ν) ⇨ More DAQ+analyses under way**
- **Diversified R&D Program in parallel**
  - ※ *Current Research Focus at :*

    μ_ν (Γ_ν) & $\sigma(\nu$-*e*$)$ & $\sigma_{coh}(\nu N)$ & *SonoLum.* & *CDM* & *AMS*
- **Reaching Out**
  - ⇨ **Y2L @ Korea / IHEP's Daya Bay θ_{13} Project (?) / Regional (?)**
  - ⇨ **welcome new ideas/collaborators & explore other scenario**

♥ *TEXONO is (a modest) part of the world's neutrino physics community*