Research Program towards Observation of $\bar{\nu}_e N$ Coherent Scattering

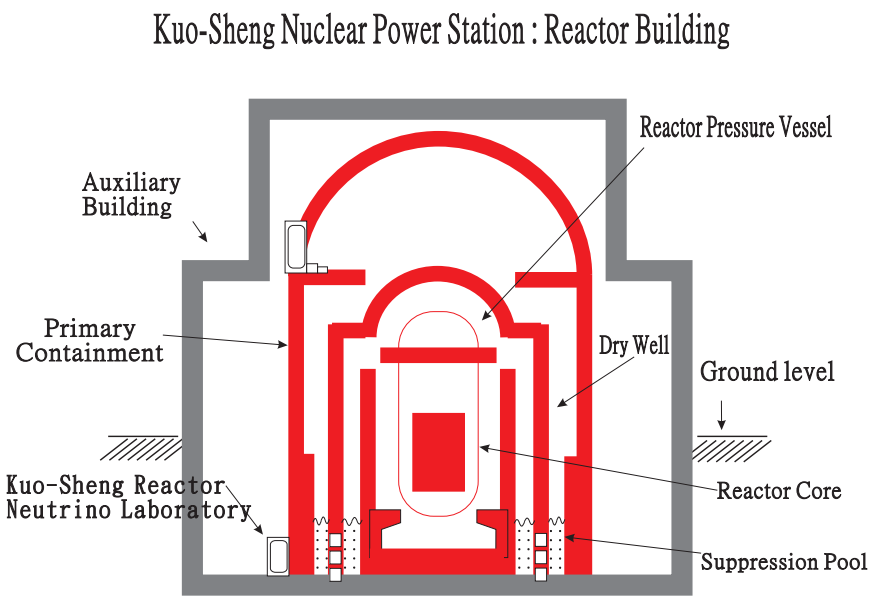
- TEXONO Collaboration & Magnetic Moment Search
- $\bar{\nu}_e N$ Coherent Scattering
- LEGe Detector Prototype
- Plans & Summary

H. B. Li 李浩斌 Academia Sinica, Taipei 中央研究院
Moscow, Russia
2006 July 29

Institute of Physics
Academia Sinica

TEXONO Collaboration

- Collaboration : Taiwan(**AS**, **INER**, **KSNPS**, **NTU**),
  China(**IHEP**, **CIAE**, **THU**, **NJU**),
  Turkey(**METU**), USA(**UMD**), India(**BHU**)
- Program : Low Energy Neutrino & Astroparticle Physics

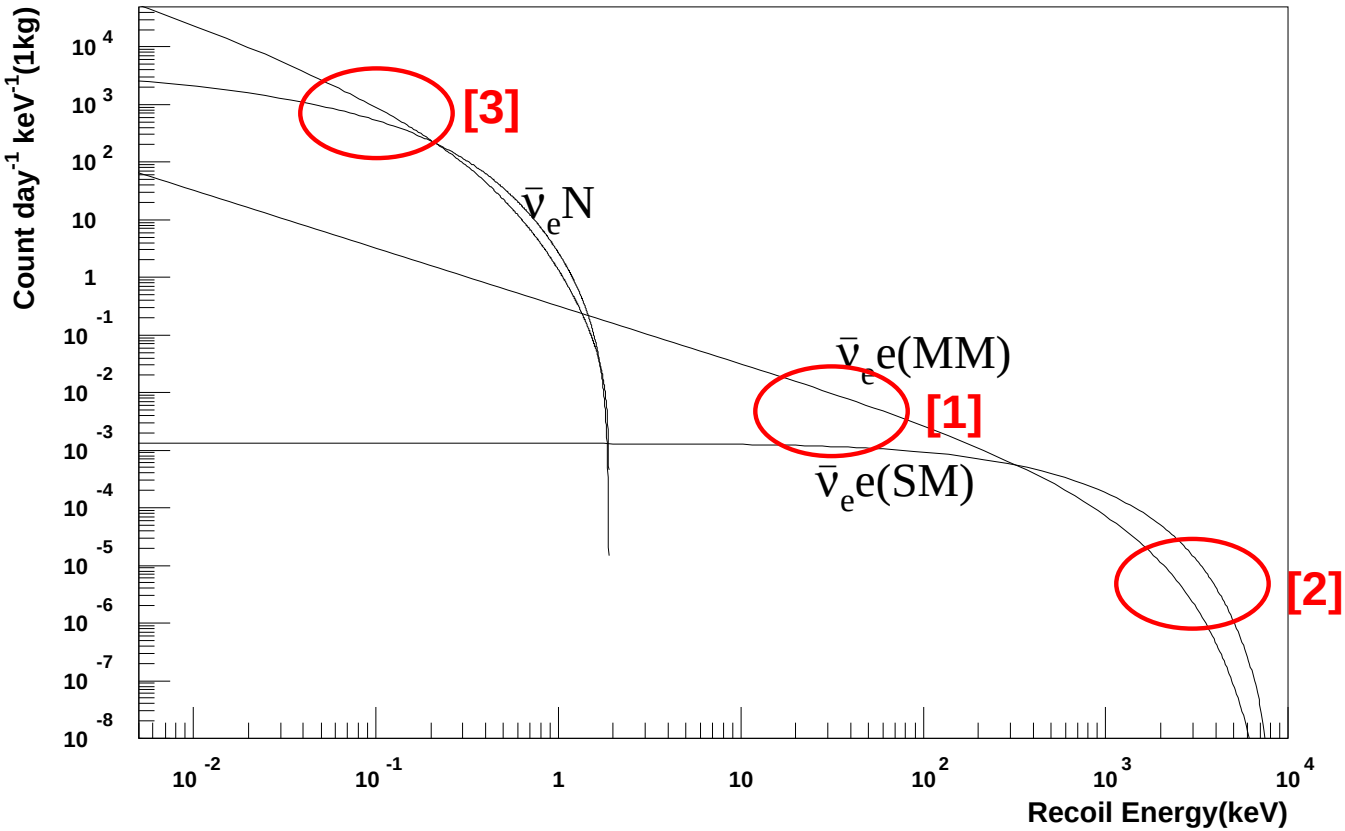


28 m from Reactor core

Kuo-Sheng Reactor Neutrino Laboratory

Institute of Physics
Academia Sinica

Physics Programs

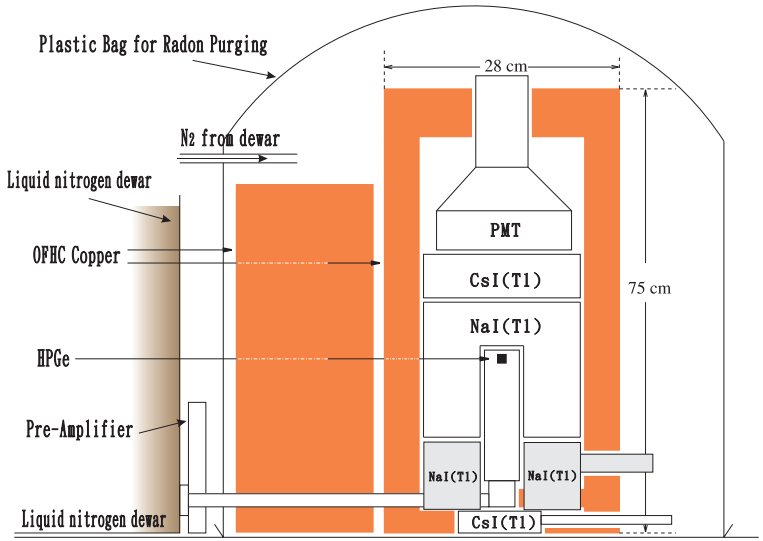


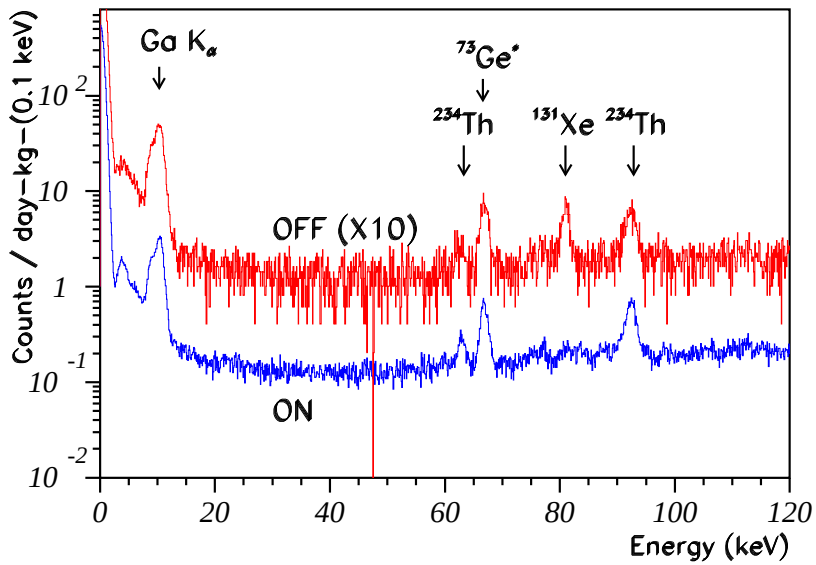
[1] Magnetic Moment search at $\sim$ 10 keV range $\rightarrow$ Results published.

[2] $sin^2\theta_W$ measument at $\sim$ MeV range $\rightarrow$ Analysis under way.

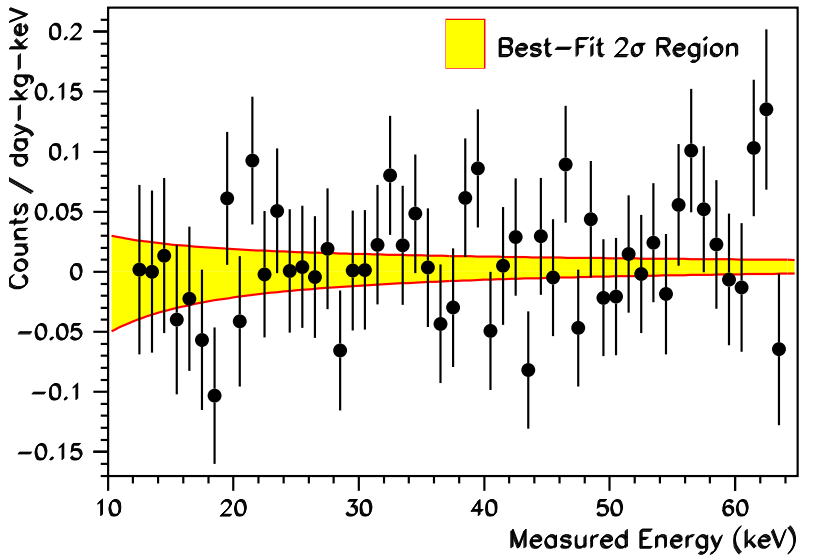
[3] $\bar{\nu_e}N$ Coherent Scattering at sub keV range $\rightarrow$ Future goal.

$\bar{\nu}_e$ Magnetic Moment Search





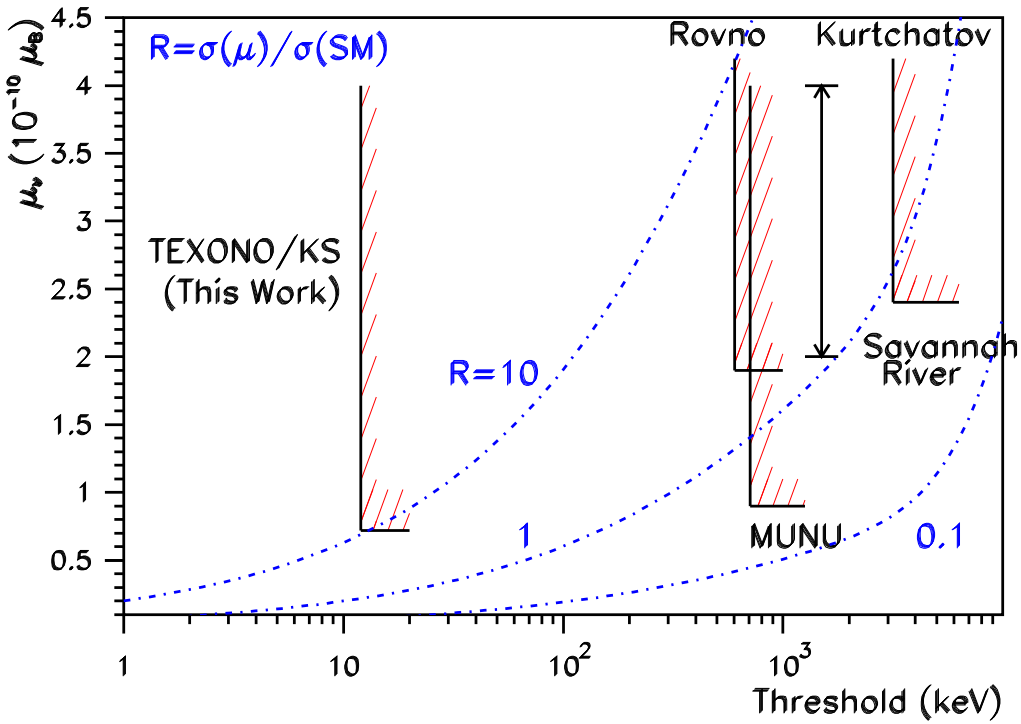
- 1 kg HPGe detector at reactor 571/128 days ON/OFF data.
- Background level $\sim$ 1 cpd
- $\mu_\nu < 7.2 \times 10^{-11} \mu_B$ 90% C. L.
- Low threshold ($\sim$500 eV) detector
  $\Rightarrow \mu_\nu \rightarrow 2 \times 10^{-11} \mu_B$



ref : [PRL 90 2003], hep-ex/0605006

Institute of Physics
Academia Sinica

$\bar{\nu}_e$ at Low Energy



- $(\frac{d\sigma}{dt})_{MM} = \frac{\pi\alpha^2\mu_\nu^2}{m_e^2}(\frac{1}{T} - \frac{1}{E_\nu})$
- Low Energy $\rightarrow (d\sigma/dT)_{MM} >> (d\sigma/dT)_{SM}$ decouple bkg & unknown sources
- For $T << E_\nu \rightarrow d\sigma/dT$ depends on total flux $\phi\nu$ NOT shape of $\phi\nu(E_\nu)$

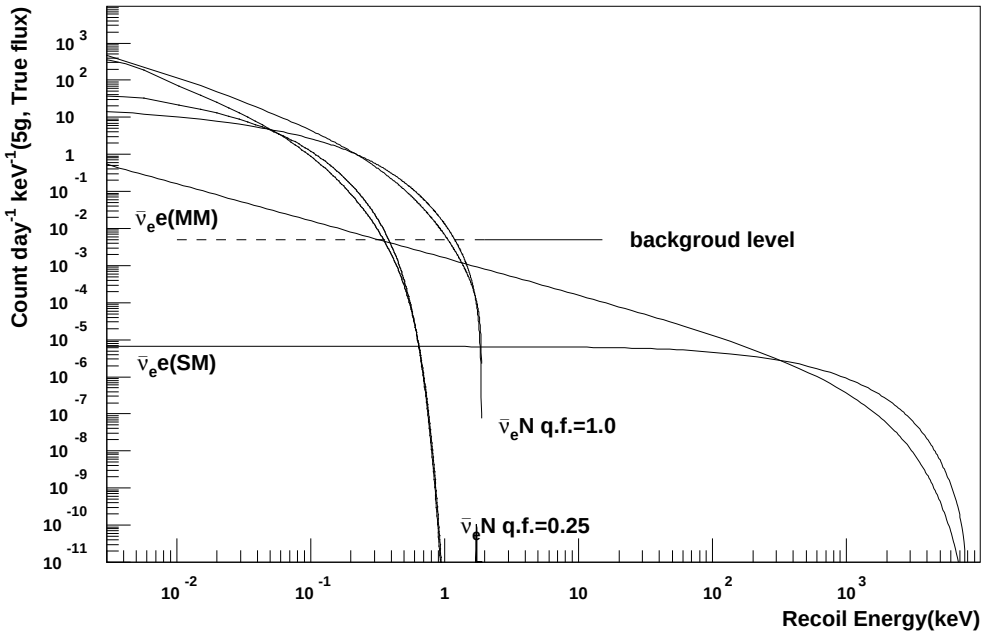
$\bar{\nu}_e N$ Coherent Scattering

- $\nu + N \rightarrow \nu + N$
  - $(\frac{d\sigma}{dt})_{SM} = \frac{{G_F}^2 m_N}{4\pi}[Z(1 - 4sin^2\theta_W) - N]^2[1 - \frac{M_N T_N}{2E_\nu^2}]$

    $\rightarrow N^2$ enhancement
  - Low recoil energy : $\sim$ 1.9 keV for $E_\nu = 8$ MeV, Ge
- A fundamental neutrino interaction never been expermentally observed.
- A sensitive test to Standard Model.
- An important interaction/energy loss channel in astrophysics media.
- A promising new detection channel for neutrinos, without strict lower bound on E_ν & the channel for WIMP direct detection.
- Involves new energy range at low energy, many experimental challenges & much room to look for scientific surprises.

Quenching Factor

Quenching factor $= 0.25$, $\frac{\Delta E}{E} \sim 0.05$



- Take Q. F. $= 0.25$, extrapolate background to eV level
  $\Rightarrow$ signal/noise > 1 at 300 eV
- At threshold $\sim$ 100 eV $\Rightarrow$ 11 count day^{-1} kg^{-1}
  - νN at accelerator $\sim$ 0.1 count day^{-1} kg^{-1}
  - $\bar{\nu_e} P$(water) at KS $\sim$ 1 count day^{-1} kg^{-1}

ULE-HPGe detector

- ULE-HPGe $\rightarrow$ developed for soft X-rays detection
  $\rightarrow$ easy & inexpensive & robust operation
- threshold $\sim$100 eV achievable.
- $\bar{\nu}_e N$ coherent scattering, CDM search, μ_ν search.
- Prototype detectors:
  - 5 g, 4$\times$5 g, 10 g, 20 g segmented.
- Scale-up $\sim$ 1 kg (segmented or multi-array).

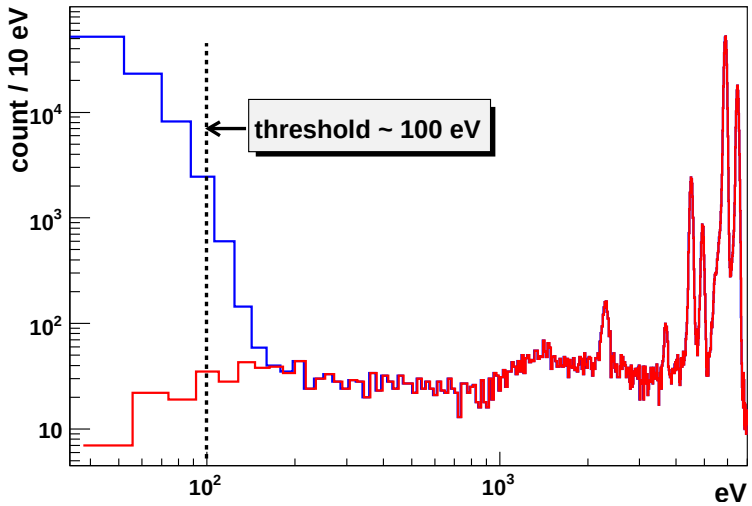
5 g Detector

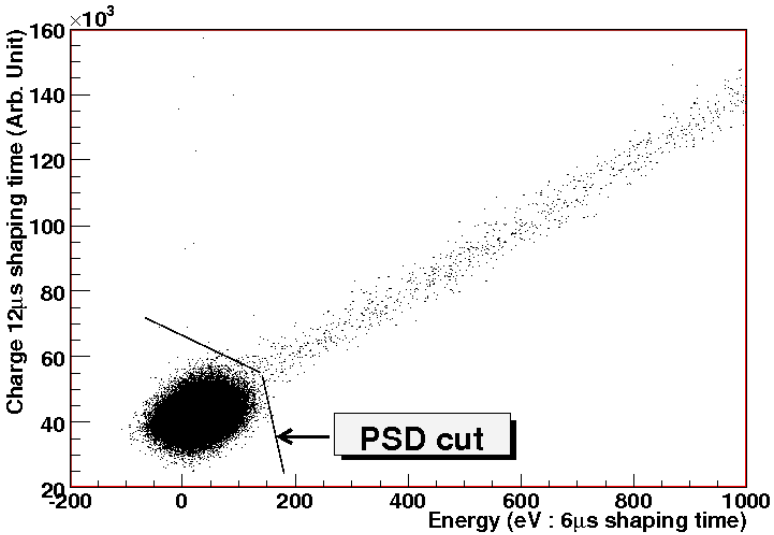
4$\times$5 g Detector

Institute of Physics
Academia Sinica

Calibration & Threshold

Source : $^{55}\mathrm{Fe}$(5.9 keV, 6.49 keV) and Ti(4.51 keV, 4.93 keV) :





Using uncorrelated trigger as energy zero

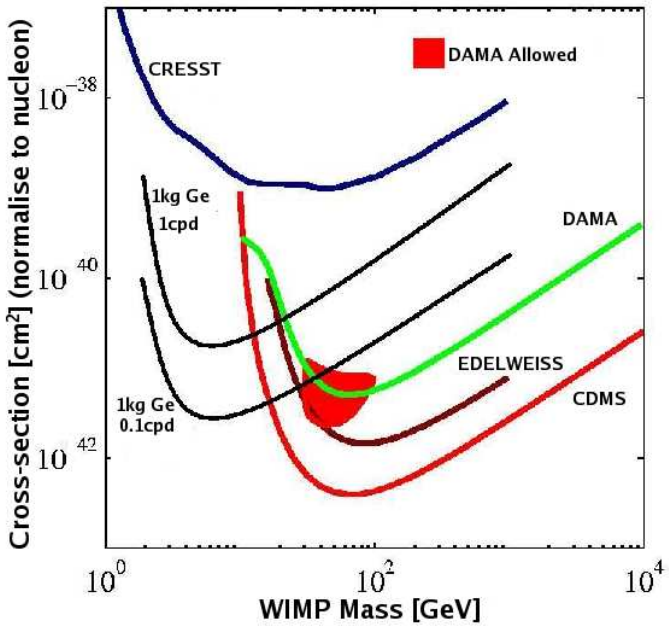
Extrapolate energy calibration to low energy

$\Rightarrow$ threshold $\sim$ 100-200 eV.
Need calibration in low energy to comfirm this!

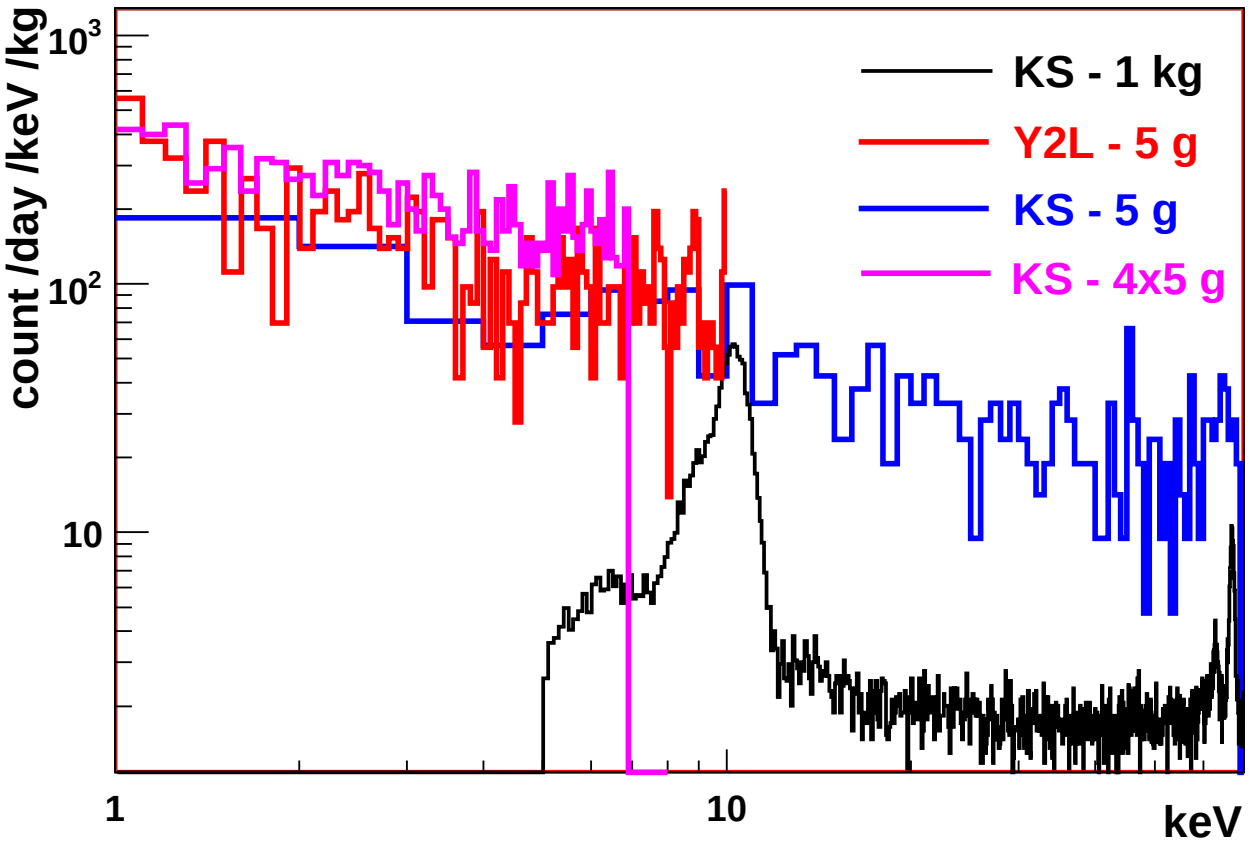
Institute of Physics
Academia Sinica

Yangyang Underground Lab.(Y2L), Korea

- 700 m of rock $\rightarrow$ Cosmic-rays level 5 order less.
- 5 g ULE-HPGe.
- Study background and feasibility for CDM searches.
- may evolve into a full-scale ($\sim$1 kg) CDM experiment.



Background Measurement at KS Lab. & Y2L



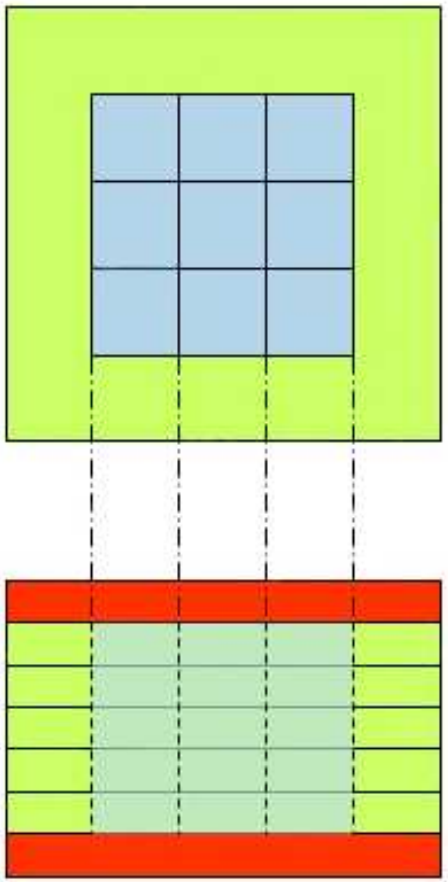
- KS Lab. & Y2L : same background level for 5 g detector.
- Background level different for 1 kg & 5 g detector
  → self-shielding → reproduced in simulations.
- Intensive studies of sub-keV background under way.

R&D Program towards Realistic Size

- O(1 kg) for $\bar{\nu}_e N$ & CDM experiments.
- sub-keV background study at power plant & underground lab.
  - design of active & passive shielding based on this.
- compare performance of various prototypes.
- devise calibration scheme at sub-keV range.
- measure quenching factor of Ge with neutron beam.
- develop advanced PSD techniques to further suppress noise edge
  - reduce threshold
- studying scale-up options ULEGe-detector
  - Discrete elements Vs segmented Ge
  - dual readout channels to suppress electronic noise

A Possible Design

2D Projection



- $3 \times 3 \times 5$ elements, 20 g each (900 g).
- Dual readout per element.
- Outer layer as Veto.
- Gamma background suppress $\sim$ 1/100.

Summary

- Kuo-Sheng Neutrino Lab. :
  - Established & Operational
    - Unique HPGe Low Energy Data
    - Background level $\sim$1 cpd
      $\rightarrow$ comparable to underground Dark Matter experiment.
- Results on μ_ν : Other Program under way.
- Future physics goal : get to $\sim$100 eV threshold.
  - $\bar{\nu_e}N$ coherent scattering experiment.
  - Dark Matter experiment.
  - Improve μ_ν search at threshold $\sim$500 eV.
- R & D Program :
  - Optimise prototype ULE-HPGe.
  - Background study at 100 eV - 1 keV.
  - Study Scale-up options.