KOREAN EFFORTS ON REACTOR ANTINEUTRINO PHYSICS

Yeongduk Kim Sejong University For HANARO-SBL collaboration.

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Reactor Neutrino Anomaly



4th, Sterile Neutrinos ?



All combined



 $\Delta m^2 \square 2.4 eV^2$, $\sin^2 2\theta_{ee} \square 0.15$

ILL Experiment

Old, Shortest Baseline Reactor neutrino experiment, yet it indicates some oscillational pattern !!



Experiment @ a research reactor



RENO : 15Ton, <10>GWth @1km \rightarrow 150 events/day HANARO : 0.5Ton, 0.03GWth @ 5m \rightarrow 600 events/day

Short Baseline Experiment @ HANARO

Strategies :

- Locate at shortest baseline from reactor core.
- **Utilize PSD (Pulse Shape Discrimination) power.**
- **D** Measure γ , neutron backgrounds on site when Reactor ON.
- Test a prototype detector (50L) with full shielding @ overground Lab. first, and confirm the background rates.
- Move the prototype detector on site, and measure neutrino event rates.
 - •Sejong University : YDKIM, EJJEON, KJMA, JYLEE, JYKIM
 - •KyungPook National University : HJKIM, JYLEE
 - Chonnam National University : KKJOO
 - Seokyung University : KSPARK
 - •HANARO : CHLEE, +.....

HANARO research reactor



- Located 2 hour driving from Seoul.
- 30MW thermal power
- Open Tank in Pool type
- Multi-purpose Research Reactor
- 19.75% U-235
- Core Size
 - (20cmX40cmX60cm)
- Overburden Roof only.
- HANARO has a compact core, and it is a critical issue for short baseline oscillation search. It is still sensitive over 10 eV² mass difference.
- 0.5Ton, 30MW, @ L=5m \rightarrow 600 neutrino nts/day

Simulations





Ratio in energy spectra between two distances





Data at two distances can be compared.

Core Size dependences





Sensitivity

T is # of event with osc parameters, O is event # when theta_new=0

$N_{i,k}$ # of events of bin i, detector k

$$\chi^{2} = \sum_{i=1}^{N_{b}} \sum_{k=1}^{N_{D}} \left[\frac{(T_{i}^{k} - O_{i}^{k} - e_{k}B_{i}^{k})^{2}}{O_{i}^{k} + (\sigma_{b2b}O_{i}^{k})^{2} + B_{i}^{k} + (\sigma_{bkg}B_{i}^{k})^{2}} + \left(\frac{b_{k}}{\sigma_{rel}}\right)^{2} + \left(\frac{e_{k}}{\sigma_{bkg}}\right)^{2} \right] + \left(\frac{a}{\sigma_{abs}}\right)^{2} + \sum_{i=1}^{N_{b}} \left(\frac{c_{i}}{\sigma_{shp}}\right)^{2}$$

Estimated errors

Minimize χ^2 w.r.t. all the parameters

References : Fogli et al., PRD 66, 053010

 $T_{i}^{k} = (1 + a + b_{k} + c_{i})N_{ik}$

 $\sigma_{abs} = 0.025$ (absolute normalization) $\sigma_{shp} = 0.05$ (shape bin by bin error) $\sigma_{rel} = 0.006$ (bin by bin relative error) $\sigma_{bkg} = 0.3$ (Background error) $\sigma_{b2b} = 0.02$ (Li9 error) B_i^k = Backgrounds

Signal/Background dependence

1Ton, 6month Data, 4% normalization Error, various backgrounds



Research reactor vs Commercial reactor



Locations - nearest





Background Measurements



0.7L neutron detector

3" Nal detector

20L neutron detector

- Since the neutrino energy spectrum would be obtained by subtracting Reactor-Off data from Reactor-ON data, we must have little Reactor related background events.
- Single backgrounds rate can be compared between Reactor On/Off

Gamma background with 3" NaI(TI) : Reactor Off



E>1 MeV ; 10.6 Hz

Gamma background with 3" NaI(TI) : Reactor ON

20



Rate for E>1 MeV : 100 Hz (x10 bg) – higher energy gammas from reactor.
The shielding container seem to have leakage.

Neutron background : On/Off comparison



- Neutron rate for E_visible >1 MeV : On/Off ~ 40
 - ✓ : Off 20/hour
 - ✓ : ON 800/hour
- We must construct shielding for gammas & neutrons to make reactor related background events.

Detector Design, R&D



Prototype detector(~50L) with 6PMTs



1811(W) x 1009(H) x 1706(D)

1811(W) x 1009(H) x 962(D)

• total weight \sim 5.6 ton

⁶Li or Gd ?



γ-α coincidence can effectively reject backgrounds;
 two neutron capture background (γ-γ)
 single fast neutron background (n-γ)
 → may work as overground neutrino detector

Safer liquid scintillator for reactor experiment



Scintillation of Li Loaded LSC

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- Ultima-Gold AB(UG-AB) (DIN based) by Perkin-Elmer for LSC is used.
- 0.16% Li loaded with LiCl. 0.08% of Li for LiBr.
- Light output degrades little with metal loading.



Various LS tested w/ alpha source





Put ²²⁶Ra with water

Ra226 alphas :

Rn222(4.878 MeV) Po218(5.590 MeV) Pb214(6.115 MeV) Po210 (7.833 MeV)



PSD of Safer Scintillator





(qtot_psd[0]+qtot_psd[1])

Sterile neutrinos at RENO





Summary

- □ It is necessary to confirm the claims about sterile neutrinos.
- □ At HANARO research reactor, neutrino detection can be done as close as 5~6m.
- At present, reactor related n, gamma backgrounds should be reduced by shielding the leakage.
- With full power of PSD for ⁶Li loaded liquid scintillator, the background reduction may be better than 3:1 (S/B).
- Background reduction should be studied overground laboratory with a prototype detector.

Sterile-active neutrino oscillation - Gouvea

Sterile neutrinos – right-handed neutrinos

- Sterile neutrinos maybe Warm Dark Matter
- \square Nothing is known about the masses. Maybe very light (m_v<<1MeV) or very heavy (m_v>>10^{10}GeV)

