

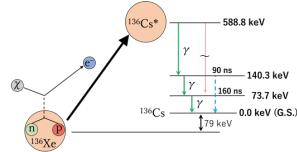
192 A New Method for Detecting Charged-Current Neutrino Interactions on ^{136}Xe in KamLAND-Zen: Implications for Solar Neutrino Measurements and Fermionic Dark Matter Searches

Koga Tachibana and Takahiko Hachiya for the KamLAND-Zen collaboration
 RCNS, Tohoku Univ., GP-PU
 E-mail: tachibana@awa.tohoku.ac.jp



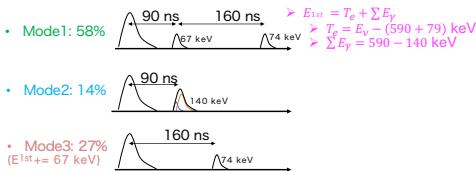
1. ^{136}Xe charged current interaction

- $\nu_e (\text{or DM: } \chi) + ^{136}\text{Xe} \rightarrow ^{136}\text{Cs}^* + e^-$
- Transition to g.s. (5^+) is highly suppressed
- Mostly goes to the excited states [1]
 - (1^+ 590 keV and 840 keV)
- Energy threshold: $79 + 590 = 670$ keV



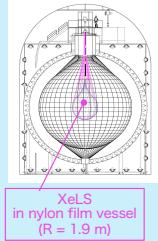
BG free tagging possibility

- Low-lying isomeric states with $O(100)$ ns lifetime observed recently [2,3]
- Double (or triple) coincidence



KamLAND-Zen 800

- Xe gas dissolved organic liquid scintillator (XeLS): 25 ton
 - ^{136}Xe : 680 kg
 - Livetime > 4 yr
- Photons detected by 1879 PMTs
 - 240 p.e./MeV
 - $\Delta E/E = 7\%/\sqrt{E}$ [MeV]
 - $\Delta x = 15 \text{ cm}/\sqrt{E}$ [MeV]
- Scint. decay time: ~6 ns
- Dark hits: 0.04 p.e./ns



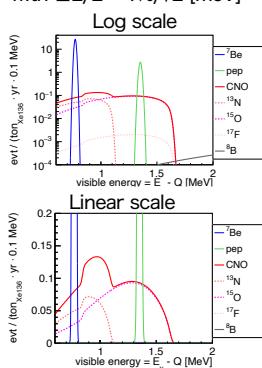
2. Physics targets

Solar Neutrino

- 1:1 energy reconstruction by detecting all γ -rays and e^-
- Robust measurement of CNO- ν 's
- Possible separate measurements of ^{13}N & ^{15}O

| | Events/(yr * ton ^{136}Xe) |
|---|--------------------------------------|
| ^7Be | 5.9 |
| pep | 0.79 |
| CNO | 0.92 |
| CNO (avoiding ^7Be and pep, $\Delta E/E = 1\%/\sqrt{E}$ [MeV]) | 0.80 (87% efficiency) |

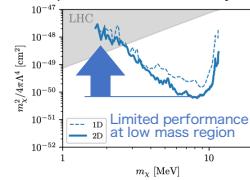
Solar neutrino event rates with $\Delta E/E = 1\%/\sqrt{E}$ [MeV]



Fermionic dark matter (FDM)

- Absorption of fermionic dark matter [6,7]
- EXO-200 collab. performed the search without applying the tagging method [8]
 - Sensitivity is limited at low mass region due to ^{136}Xe $2\nu\beta\beta$ decay BGs
 - The tagging method can drastically improve the sensitivity

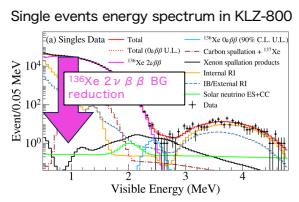
Absorption cross section U.L. by EXO-200



$$R = \frac{\rho_\chi}{2m_\chi} \sum_j N_{T,j} (A_j - Z_j) \frac{|\vec{p}_e| f(Z_j + 1, E_e)}{2\pi\Lambda^4(m_\chi - m_{\text{th},j})}$$

$$|\vec{p}_e|^2 = (m_{\text{th},j}^\beta - m_\chi)(m_{\text{th},j}^\beta - m_\chi - 2m_e)$$

R: rate [s^{-1}]
 ρ_χ : local DM mass [MeV/cm^3]
 f : Fermi function
 Λ : effective energy scale
 $m_{\text{th},j}$: 79 keV + 590 keV + m_e
 $T_e = m_e \cdot m_\chi^\beta$



3. Case for KamLAND-Zen 800

Goal

- Proof of concept by ^7Be solar ν detection
 - KL-Z800 exposure: 4 yr * 0.68 ton
 - Expected # of events: 16 (before considering efficiencies)
- Higher sensitivity search of FDM at low mass region

Data acquisition

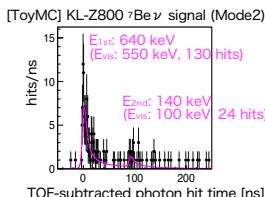
- Trigger threshold: ~0.3 MeV
- Only 1st pulse can be triggered
- 2nd, 3rd pulses can be detected if in the event window of the 1st pulse (~200 ns)

Single vs Multi pulse discrimination

- Double (or triple) pulse fitting
- $(2\nu\beta\beta)$ rate > $10^5 \times (^7\text{Be}\nu)$
 - mis-id of single required to be < 10^5

Correlated BG: ^{212}Bi — ^{212}Po (nylon film)

- ^{212}Po α Visible Energy (E_{vis}) in LS: ~0.8 MeV
 - Film events are continuum (< 0.8 MeV)
- $R < 1.4$ m cut for double-pulse search
- Possible mitigation by triple-pulse search



TOF-subtracted photon hit time [ns]

hits/ns

$E_{\text{1st}}: 640 \text{ keV}$ ($E_{\text{vis}}: 550 \text{ keV}$, 130 hits)

$E_{\text{2nd}}: 140 \text{ keV}$ ($E_{\text{vis}}: 100 \text{ keV}$, 24 hits)

$\approx n1(n2)$: number of hit by 1st(2nd) pulse

dt [ns]

dt threshold [ns]

Mode2 eff [%]

0.67 0.86 1.3 1.9 2.2 2.5

1.2 1.4 1.8 2.4 2.7 3.0

66 70 97 106 125 140

45.3 35.1 23.2 19.9 14.1 10.3

dt threshold [ns]

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