Dark Matter Search Project
PICO-LON

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Planar Inorganic Crystals Observatory for
LOW-background Neutr(ino)ino

Contents
• Introduction
• Merit of segmentation of NaI(Tl)
• Performance of thin NaI(Tl)
• Test measurement at Tokushima
• Summary & Prospects
Collaboration (Welcome !!)

- The University of Tokushima

- Horiba Ltd.
  - K. Imagawa, H. Ito

- Osaka University
  - K.Ichihara, S.Umehara, M.Nomachi, H.Nakamura

- Hiroshima University
  - R.Hazama

- Tohoku University
  - S.Yoshida

- ICU, Spring-8
  - H.Ejiri
Interactions between WIMPs and nucleus

$\sigma \propto A^2$

$\sigma \propto C\lambda^2 J(J+1)$

$\sigma \propto \sqrt{\frac{2J'+1}{2J+1}} \frac{1}{g_M} \langle A|M|A^* \rangle$

We planned to study all the types of interaction!!
Why NaI(Tl)?

- $^{23}\text{Na} \ & ^{127}\text{I}$
  - Sensitive to SD and SI
  - 100% natural abundance of finite spin nuclei
- $^{127}\text{I}$
  - Sensitive to EX
  - Low energy excited state

- Expect: $3.60 \times 10^{-3}$/day/kg (Higgsino)
- Limit: $4.98 \times 10^{-2}$/day/kg (ELE V NaI)

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$\left\vert M_{M1}\right\vert^2 = 0.1$

J. Ellis et al., PLB212(88)375

Signal selection by Spatial and Timing Correlation (SSSTC)

- Signal Selection by Spatial Correlation
  - Signal → 57.6keV $\gamma$ + Low energy recoil
  - Localized event in space and time
  - Background → U, Th chain, $^{40}\text{K}$ etc.
  - Diffused event in space and time

- Signal Selection by Timing Correlation
  - Signal → No following events
  - Background → Time-correlated events by decay chain ($^{210}\text{Pb}$)
Signal Identification by Segmentation

K. Fushimi et al., JPSJ 74(2005)3117
astro-ph/0506329

H. Ejiri, Ch. C. Moustakidis, J. D. Vergados,

\[ \chi \]

\[ \gamma \text{(INELASTIC)} \]
X-ray

\[ \chi \]
RECOIL

\[ \chi \]
S1

\[ \chi \]
S2

\[ \gamma \text{(INELASTIC)} \]
X-ray
Estimation of signal selectivity

- Monte Carlo simulation (GEANT4)
- 57.6keV $\gamma$ ray ($^{127}\text{I}^* \rightarrow ^{127}\text{I}$) from one module
- $\gamma$ is detected the another module
- Next module to the emitter module

The fraction which is detected both sides of emitter
Specification of thin NaI array

- 0.05cmX5cmX5cm NaI(Tl)
- 0.05cmX6cmX0.5cm Acrylic Light Guide
- ESR™ reflector
- 3 plates (PICO-LON-II)
- 16 plates (PICO-LON-III)
- 1024, 2176 (Future)
Estimation of sensitivity

- Radioactive contamination
  - Uniformly contaminated in NaI(Tl) crystal
  - $^{210}$Pb 0.1mBq/kg (1/100 of present value)
  - $^{214}$Pb, $^{214}$Bi 10µBq/kg (present value)

- Monte Carlo Simulation
  - GEANT4
15cm×15cm×0.1cm NaI(Tl) system

Applying JSPS Wakate-S
Development of thin NaI(Tl) PICO-LON-I

- Collaboration with Horiba Ltd.
  - Production of thin NaI plate
  - Selection of reflector ESR™ by 3M
- ~2004/Feb.
  - Design and production method were discussed
- 2004/Apr.
  - First single plate was completed!!
- 2004/May~
  - Performance, stability test.
- 2005/June~
  - 16plates detector and 3plates detector was completed.
PICO-LON-I

Collimator (Pb)

NaI(Tl) crystal (0.5mm)

Light Guide
Production of thin NaI(Tl) by Horiba Ltd.
Performance of PICO-LON-I

- Dimension of NaI(Tl)
  - 0.05cmX5cmX5cm
- Energy resolution
- Energy threshold
- Photon number/keV
- Position selectivity
- PMT : Hamamatsu R329P
Thin NaI(Tl) scintillator

Collimator
30keV  $R(\text{FWHM})=0.25$
81keV  $R(\text{FWHM})=0.13$
122keV  $R(\text{FWHM})=0.14$

133$^{\text{Ba}}$

57$^{\text{Co}}$
Energy spectrum of low energy $\gamma$ rays

<table>
<thead>
<tr>
<th>Source</th>
<th>Energy</th>
<th>FWHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{133}\text{Ba}$</td>
<td>30keV</td>
<td>0.25</td>
</tr>
<tr>
<td>$^{241}\text{Am}$</td>
<td>60keV</td>
<td>0.18</td>
</tr>
<tr>
<td>$^{133}\text{Ba}$</td>
<td>81keV</td>
<td>0.13</td>
</tr>
<tr>
<td>$^{57}\text{Co}$</td>
<td>122keV</td>
<td>0.14</td>
</tr>
</tbody>
</table>

$\Delta E/E(\text{FWHM})=0.18$

Single P.E. energy = 0.35keV
NaI(Tl) Real Position

$\Delta x, y (FWHM) = 1 \text{cm}$

K. Fushimi et al., JPSJ 75 (2006) 064201
PICO-LON-II (3-layer NaI(Tl))

PICO-LON: Planar Inorganic Crystals Observatory for LOW background Neutr(al)ino
- Energy resolution \((^{241}\text{Am}, ^{133}\text{Ba})\)
- Background reduction
- WIMPs search

H. Kawasuso, K. Yasuda
Background reduction

H. Kawasuso, K. Yasuda
Performance check
Cosmic ray

Energy deposit of cosmic ray
≈ 400 keV
Experiment in Tokushima Univ.

Preliminary!

○: Corrected Spectrum
□: Raw data
◇: Cu 0.5cm+Pb 5cm
×: Cu 0.5cm+Pb 10cm
+: Cu 0.5cm+Pb 10cmXPL
△: Dark current

COUNTS/DAY/keV/kg

ENERGY (keV)
Background reduction

○: Background (No shield)
□: Background (Shielded)

\[
\text{Background (Shielded)} = 0.86
\]

\[
\text{Background (No shield)}
\]
Second layer

Third layer

Background (Shielded) / Background (No shield) = 0.86

Background (Shielded) / Background (No shield) = 0.86
Single Layer Hit

First layer

- ○: Background (No shield)
- □: Background (Single hit)

Background (Single hit) = 0.01
Background (No shield)
Background (No shield)  Background (Single hit) = 0.01
Background (No shield)  Background (Single hit) = 0.01
Future Plan of PICO-LON

- Larger area 15cmX15cm
- No MAPMT
OTO Cosmo Observatory

OTO

- Cosmic ray: $4 \times 10^{-7}$/cm$^2$/sec
- Neutron: $4 \times 10^{-5}$/cm$^2$/sec
- Rn: $\sim 10$Bq/m$^3$

Surface

- Cosmic ray: $1.6 \times 10^{-2}$/cm$^2$/sec
- Neutron: $8 \times 10^{-3}$/cm$^2$/sec
- Rn: $\sim 20$Bq/m$^3$
2nd Laboratory in OTO
Segmentation of NaI(Tl) enhances the sensitivity
  - High selectivity of signal and BG by segmentation
  - 0.05cmX5cmX5cm NaI(Tl) plates was successfully made.

Good performance was obtained
  - 20% FWHM at 60keV
  - $E_{th} \sim 2-3$keV (S.P.E~0.35keV)
  - 3 layers detector (PICO-LON-II) and larger area detector (PICO-LON-III)

Prospect
  - PICO-LON-II will be installed into OTO in July.
  - PICO-LON-III will be installed into OTO in this winter.