Direct Dark Matter Search with XMASS

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ICHEP 2014, Valencia, Spain
XMASS experiment

- **XMASS**
  - Multi-purpose low-background and low-energy threshold experiment with liquid Xenon
    - *Xenon detector for Weakly Interacting MASSive Particles (dark matter search)*
    - *Xenon MASSive detector for solar neutrino (pp/⁷Be)*
    - *Xenon neutrino MASS detector (ββ decay)*

Purpose of the first phase is the dark matter search.

**history of XMASS**

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
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<tbody>
<tr>
<td>2010</td>
<td>detector construction completed (Sep. 2010)</td>
</tr>
<tr>
<td>2011</td>
<td>commissioning run data taking (Dec. 2010 - May 2012)</td>
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<tr>
<td>2013</td>
<td>resume data taking (Nov. 2013 - )</td>
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<td>2014</td>
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XMASS collaboration

<table>
<thead>
<tr>
<th>Institute</th>
<th>Collaborators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kavli IPMU, University of Tokyo</td>
<td>J. Liu, K. Martens, Y. Suzuki</td>
</tr>
<tr>
<td>Kobe University</td>
<td>R. Fujita, K. Hosokawa, K. Miuchi, Y. Ohnishi, N. Oka, Y. Takeuchi</td>
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<tr>
<td>Tokai University</td>
<td>K. Nishijima</td>
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<tr>
<td>Gifu University</td>
<td>S. Tasaka</td>
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<tr>
<td>Yokohama National University</td>
<td>S. Nakamura</td>
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<tr>
<td>Miyagi University of Education</td>
<td>Y. Fukuda</td>
</tr>
<tr>
<td>STEL, Nagoya University</td>
<td>Y. Itow, R. Kegasa, K. Kobayashi, K. Masuda, H. Takiya</td>
</tr>
<tr>
<td>Sejong University</td>
<td>N.Y. Kim, Y. D. Kim</td>
</tr>
<tr>
<td>KRISS</td>
<td>Y. H. Kim, M. K. Lee, K. B. Lee, J. S. Lee</td>
</tr>
</tbody>
</table>

10 institutes, 39 collaborators
Kamioka mine

To: Atotsu mine entrance

~1000m underneath Mt. Ikenoyama
XMASS detector

- Outer detector (water tank)
  - 72 20-inch PMTs for cosmic-ray muon veto.
  - Water is also passive shield for gamma-ray and neutron from rock/wall.
- Inner detector (Liquid Xe)
  - Liquid Xe surrounded by 642 2-inch PMTs
    - photo coverage: 62%
    - diameter: ~800mm
    - high light yield: 14.7 PE/keV

NIM A716, 78-85, (2013)

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--- result from commissioning run ---

1. Search for light WIMPs

- 6.7 days x 835 kg
- 0.3 keVee threshold

\[ 6.7 \text{ days} \times 835 \text{ kg} \]

\[ 0.3 \text{ keVee threshold} \]

\[ 18\text{GeV} \sigma^{\text{SI}}_{\chi n} = 1.52 \times 10^{-41} \text{cm}^2 \]
\[ 12\text{GeV} \sigma^{\text{SI}}_{\chi n} = 2.84 \times 10^{-41} \text{cm}^2 \]
\[ 7\text{GeV} \sigma^{\text{SI}}_{\chi n} = 4.44 \times 10^{-40} \text{cm}^2 \]


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2. Search for solar axions

- Axions can be produced in the sun by bremsstrahlung and Compton effect, and detected by axio-electric effect in XMASS.
- Used the same data set as the light WIMPs search.

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--- result from commissioning run ---


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--- result from commissioning run ---

3. Search for $^{129}$Xe inelastic scattering by WIMPs

$\chi + ^{129}$Xe $\rightarrow \chi + ^{129}$Xe$^\ast$

$^{129}$Xe$^\ast$ $\rightarrow$ $^{129}$Xe + $\gamma$ (39.6keV)

$\blacktriangleright$ Natural abundance of $^{129}$Xe: 26.4%

Signal MC for 50GeV WIMP  data (165.9 days)

(1)= pre-selection
(2)= (1) & radius cut
(3)= (2) & timing cut
(4)= (3) & band cut

Background level is $\sim$3x10^{-4} count/day/kg/keV.

Red: XMASS (90% C.L. stat. only)
Pink band: XMASS (w/ sys. error)
Black: DAMA LXe 2000 (90% C.L.)

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4. Search for bosonic super-WIMPs

- Candidate for lighter dark matter
- Can be detected by absorption of the particle, which is similar to the photoelectric effect.
- Search for mono-energetic peak at the mass of the particle

arXiv:1406.0502

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Detector refurbishment (RFB)

- We found RIs (210Pb, 238U) in the Aluminum sealing part of PMT (secular equiv. broken).
- Background events at the blind corner of PMT are often misidentified as events in the fiducial volume.
- To reduce this background, new structures to cover this Al seal were installed.

Before RFB

- Blind corner
  - quartz window
  - Al seal

After RFB

- Cu Ring
- Cu Plate
  - High purity Al is vaporized.
  - quartz window
  - Al seal

PMT Al sealing

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Photos of detector surface area

Before RFB

After RFB

detector inner surface

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We resumed data taking in Nov. 2013.

1GS/s flash-ADC was installed to record waveforms of individual PMT.

We have accumulated 126 days data so far.

One order of magnitude reduction above 5 keVee in the entire volume achieved.
Improvement by RFB

- In addition to one order of magnitude reduction in >5keVee, huge background event can be reduced to ~1/10 with simple identification using max PE (maximum PE in one PMT) /total PE.
- Detail analysis is ongoing.

Before RFB

After RFB

Band made by saturation in DAQ

Big improvement
XMASS 1.5 as a next step

- Larger detectors have many advantages. 1t FV (5t total).
  - Target sensitivity is $\sigma_{Si} < 10^{-46}$ cm$^2$ for 100 GeV WIMPs.
- Detector design is ongoing:
  - PMTs
    - We can use U-free Al in hand.
    - New PMTs being developed help to identify surface events.
  - Surface BG must be controlled.
summary

- We have published / are publishing physics results with commissioning data
  - Light WIMPs
  - solar axions
  - $^{129}\text{Xe}$ inelastic scattering by WIMPs
  - Bosonic super-WIMPs
- Detector refurbishment has been completed and we resumed data taking. Results will come in the near future.
- Designing of XMASS-1.5 is ongoing.