Status of XMASS

GLA2011, Department of Physics, University of Jyväskylä, Finland
8th Jun. 2011
A.Takeda for the XMASS collaboration
Kamioka Observatory, ICRR,
University of Tokyo
The XMASS collaborations

- **IPMU, University of Tokyo**: K. Martens, J. Liu
- **Kobe University**: Y. Takeuchi, K. Otsuka, K. Hosokawa, A. Murata
- **Tokai University**: K. Nishijima, D. Motoki, F. Kusaba
- **Gifu University**: S. Tasaka
- **Yokohama National University**: S. Nakamura, I. Murayama, K. Fujii
- **Miyagi University of Education**: Y. Fukuda
- **STEL, Nagoya University**: Y. Itow, K. Masuda, H. Uchida, Y. Nishitani, H. Takiya
- **Sejong University**: Y.D. Kim
- **KRISS**: Y.H. Kim, M.K. Lee, K. B. Lee, J.S. Lee

41 collaborators, 10 institutes
1. XMASS experiment

What’s XMASS

Multi purpose low-background experiment with liquid Xe.

- Xenon MASSive detector for solar neutrino ($^{7}\text{Be}$)
- Xenon neutrino MASS detector ($\beta\beta$ decay)
- Xenon detector for Weakly Interacting MASSive Particles (DM search)

As a 1st phase, an 800kg detector for dark matter search has been constructed.

Y. Suzuki et al., hep-ph/0008296
Why liquid Xe?

- High Atomic mass Xe ($A \sim 131$) good for SI case ($\sigma \propto A^2$).
- Odd isotope ($^{129}$Xe (26.4%), $^{131}$Xe (21.3%)) with large SD enhancement factors.
- High atomic number ($Z=54$) and density ($\rho=\sim 3$g/cc)
  - Effective self-shielding.
  - Compact for large mass detector.
- High photo yield (~46000 UV photons/MeV at zero field)
- Easy to purify for both electro-negative and radioactive impurities.
  - By circulation of Xe with getter for electro-negative.
  - Distillation for $^{85}$Kr removal.
800kg detector

Water tank 11m

Elec. hut

Refrigerator

OFHC copper vessel

Water tank 10m

72 20inch PMTs (veto)

835kg liq. xenon

642 PMTs

~ 1.2m
Structure

Single phase liquid Xenon detector
- 835 kg of liquid xenon, 97 kg in the fiducial volume
- 642 Photo Multiplier Tubes (PMTs): 630 hex +12 round
- Q.E. : 28-39%
- Photo coverage: 62.4%
- 3D event reconstruction
- 5keVee threshold
Background (BG) reduction (1)

BG from detector materials

- 642 PMTs: **Main BG source** although radioactive isotope (RI) level is 1/100 of ordinary PMT.
- OFHC copper: Bring in the mine < 1 month after electrorefining (Mitsubishi Material Co.)
- Other materials: All the components were selected with HPGe and ICP-MS. (>250 samples were measured) The total RI level is much lower than PMT BG.

We developed new ultra low RI PMT (R10789) with Hamamatsu. (1/100 of ordinary one).
### BG estimation from 642 PMTs

<table>
<thead>
<tr>
<th></th>
<th>BG/PMT [mBq]</th>
</tr>
</thead>
<tbody>
<tr>
<td>U chain</td>
<td>0.70 +/- 0.28</td>
</tr>
<tr>
<td>Th chain</td>
<td>1.51 +/- 0.31</td>
</tr>
<tr>
<td>$^{40}$K</td>
<td>&lt; 5.10</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>2.92 +/- 0.16</td>
</tr>
</tbody>
</table>

Counts/day/kg/keV

BG estimation from 642 PMTs

- $^{238}$U BG 75 days
  - all volume
  - 5cm shield
  - 10cm shield
  - 20cm shield

Counts/day/kg/keV

- $< 10^{-4}$ /keV/day/kg (100kg F.V.)
- $n$ contribution $< 1.2 \times 10^{-5}$/keV/d/kg (5-10keV)
**BG reduction (2)**

- γ and neutrons (n) from rock are sufficiently reduced by a 2m thickness pure water tank:
  - $\gamma < \gamma$ from PMT, $n << 10^{-4}$/day/kg
- 10m dia. and 11m height water tank for future extensions.
- 72 20” PMTs for active veto for cosmic-ray $\mu$.

---

**Reduction of gamma rays**

- PMT BG level
  - $\Rightarrow$ 2m needed

**Graph**

- $\gamma$: Attraction vs. thickness
- $\gamma$: PMT BG level

**Diagram**

- 10m dia. = ~2m wall thickness
- 5m dia. = 10$^7$ n’s
• Kr ($^{85}$Kr: $Q_\beta$=687keV, $\tau=10.8$y) and Rn can be reduced by:

1. Distillation: Kr has lower (~150K) boiling point than Xe (~175K) 5 orders of magnitude reduction with 4.7kg/hr was achieved for test sample.  


   Distillation of 1ton Xe was finished before filling into the LXe detector.

2. Filtering: by gas and liquid under study.

Charcoal Filter
GXe <30 liter-GXe/m
LXe ~a few liter-LXe/m
Expected sensitivity

Spin Independent

$\sigma_{cp} > 2 \times 10^{-45} \, \text{cm}^2$

for 50-100 GeV WIMP
(90% C.L.)

1 yr exposure, 100kg FV
BG: $1 \times 10^{-4} \, /\text{keV/day/kg}$
Q factor: 0.2

Expected energy spectrum

$\sigma_{\chi p} = 10^{-44} \, \text{cm}^2$

50 GeV WIMP

Black: signal+BG
Red: BG
2. Current status of detector

- 2010 Feb.: PMT installation was finished.
- 2010 Sep.: Detector assembly was finished.
- 2010 Sep.: Distillation and liq. xenon filling.
- 2010 Oct.-: Commissioning run has been started.
  Calibration and internal Rn evaluation.
Calibration

**XMASS Calibration system**
- Introduction of radioactive sources into the detector.
- <1mm accuracy along the z axis.
- Thin wire source for some low energy sources to avoid shadowing effect.
- $^{57}$Co, $^{241}$Am, $^{109}$Cd, $^{55}$Fe, $^{137}$Cs…

Source rod with a dummy source

Stepping motor

Linear and rotary motion feed-through

Gate valve

Top photo tube

$0.21\text{mm}\phi$ for $^{57}$Co source

$4\text{mm}\phi$
57Co source at the center of detector.

The photo electron distribution was reproduced by a simulation well.

High p.e. yield 15.1+/−1.2 p.e./keV was obtained.

Energy resolution for 122 keV γ was ~4%(rms)
Performance of the reconstruction

- Reconstructed vertices for various positioning of the \( ^{57}\text{Co} \) source.
- Position resolution was as expected by a simulation.

\[ z=0\text{cm}: \quad 1.4\text{cm RMS} \]
\[ z=\pm 20\text{cm}: \quad 1\text{cm RMS} \quad (@122\text{keV, } \gamma) \]
Evaluation of internal BG

- External BG ($\gamma$ and n) can be effectively reduced by the water tank and outer part of liq. Xe. On the other hand, Internal BG (radioactive contaminations) need to be reduced by other means.

- Possible internal BG sources are $^{222}$Rn, $^{220}$Rn and $^{85}$Kr.
Tagged by a short time coincidence between $^{214}\text{Bi}$ and $^{214}\text{Po}$ ($t_{1/2}=164\mu s$).

Gain of 321 PMTs (1/2 of all) are reduced to have larger dynamic range.

Result: $8.2\pm0.5\text{mBq}$. (\textlangle \textrangle goal: $1.0\text{mBq}$)

-> would be reduced by a cooled charcoal column in gas phase. (under study)
**220Rn in liq. Xe**

- Tagged by a short time coincidence between two $\alpha$’s ($^{220}$Rn, $^{216}$Po ($t_{1/2}=0.14$ s)).
- Result was consistent with chance coincidence of $\alpha$ of $^{222}$Rn.
- Upper limit < 0.28mBq (90C.L.)

(<- goal: 0.43mBq)

Consistent with chance coincidence and null hypothesis for $^{220}$Rn.
Gas chromatography and API-MS started to work (~10ppt sensitivity). More sensitive measurement (<1ppt) using a cold trap is under preparation.

Data analysis to look for a delayed coincidence event is under study.
3. Summary

- The XMASS 800kg detector with a single phase liq. Xe target aims to detect dark matter with the sensitivity \(2 \times 10^{-45}\) cm\(^2\) (spin independent case).
- Construction of the detector finished last winter.
- Commissioning runs are on going to confirm the detector performance and low BG properties.
  - High p.e. yield was obtained: 15.1+/-1.2 p.e./keV
  - Energy and vertex resolution were as expected: ~1cm (position) and ~4% (energy) for 122keV \(\gamma\).
  - Rn BG are close to the target values and Kr contamination will be evaluated soon.
- Physics run will start after commissioning.
Backup

All the backup slides were removed for publication