JSNS$^2$ Detector Construction

Jungsic Park
High Energy Accelerator Research Organization (KEK) with JSNS$^2$ Collaboration

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- Concept of the JSNS\textsuperscript{2} Detector
  - Target / Catcher / Veto
  - Optical separator
- PMT Installation scheme
- Production of Gd-LS / LS
  - DayaBay / RENO
- Filling / extracting scheme
- Calibration / Monitoring
- Summary
Concept of the JSNS² Detector

- **Target** (Gd-LS)
- **Veto** (LS)
- **Catcher** (LS)

- **Optical separator**
- **Anti Oil-Leak Tank**

Dimensions:
- 80 cm height
- 42 cm inner diameter
- 3.2 m outer diameter
- 2.5 m inner diameter
- 3.5 m height
- 6.6 m width
- 4.6 m length

Volume: V~19 m³
**Concept of JSNS² Detector**

<table>
<thead>
<tr>
<th></th>
<th>Radius [m]</th>
<th>Height [m]</th>
<th>Filled with</th>
<th>Volume [m³]</th>
<th>Material</th>
</tr>
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<tbody>
<tr>
<td>Target</td>
<td>1.6</td>
<td>2.5</td>
<td>Gd-LS</td>
<td>19.3</td>
<td>Acrylic</td>
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<tr>
<td>Catcher</td>
<td>1.85</td>
<td>3.0</td>
<td>LS</td>
<td>35 in total</td>
<td>**</td>
</tr>
<tr>
<td>Veto</td>
<td>2.3</td>
<td>3.5</td>
<td>LS</td>
<td></td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Anti oil-leak tank</td>
<td>3.3</td>
<td>2.7</td>
<td>air</td>
<td>84</td>
<td>Stainless steel</td>
</tr>
</tbody>
</table>

- Target + Catcher 193, 8 inch PMTs
  (Barrel : 24 × 5, Top / Bottom : 36 with 3 rings)
- Veto 48, 5 inch PMTs

Optically separated with PMT structures
→ LS can passing through between “Catcher” and “Veto” region

**
Status of Preparation of Detector vessels

Acrylic vessel
- Under preparation of detailed design / bidding documents

Stainless steel
- Finished the bidding procedure
- Morimatsu win the bid (http://www.morimatsu.jp)
### Construction schedule of Veto vessel + Anti-oil leak Tank

<table>
<thead>
<tr>
<th></th>
<th>Oct-17</th>
<th>Nov-17</th>
<th>Dec-17</th>
<th>Jan-18</th>
<th>Feb-18</th>
<th>Mar-18</th>
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<td></td>
</tr>
<tr>
<td>base</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>side wall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tank</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bottom</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>side wall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>top</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>small parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>welding</td>
<td></td>
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<tr>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
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<td></td>
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</table>

- Detailed schedule was made by company.
- ➡️ Construction will be finished until Mar, 2018.
Optical separator with PMT Support Structures

Barrel
- 5 PMTs in one column
- Frame is made by L-angle

Top / Bottom
- Three ring shape
  (6, 12, 18 PMTs)
- Frame is made by L-angle

3mm thickness
PMT positions

- Drew with MC

Side view

Top view
Assemble Covers to PMTs

Three different layers to cover individual PMTs

- **Black PET**: Avoid flashing from PMT
- **FINEMET**: Shielding of magnetic field
- **RuireMirror**: Increase reflectivity to increase light collection efficiency of Veto

Inner to Outer
Attach PMT to L-angle

L-angle
U-shape supporter
Support ring
Installation test of Barrel / Bottom pieces
Magnetic field strength measurement (For Decision of FINEMET)

Usual magnetic field strength ➔ around 1000 mG
- Measurement was performed with magnetometer.
- Fluxmaster, up to 2000mG.
- Reproducibility was measured ~10 mG at each direction.

Location
- 24m baseline
- 5 points
- 2 different height (floor, 1.3 m height)

Three perpendicular direction

Beam Direction

\[X \quad Z \quad Y\]
### Magnetic field strength ➞ 300 to 500 mG without FINEMET

<table>
<thead>
<tr>
<th>24 m Floor</th>
<th>X (mG)</th>
<th>Y (mG)</th>
<th>Z (mG)</th>
<th>Total (mG)</th>
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<tbody>
<tr>
<td>1</td>
<td>- 309</td>
<td>- 3</td>
<td>- 233</td>
<td>387</td>
</tr>
<tr>
<td>2</td>
<td>- 317</td>
<td>- 20</td>
<td>- 186</td>
<td>368</td>
</tr>
<tr>
<td>3</td>
<td>- 292</td>
<td>- 22</td>
<td>- 159</td>
<td>333</td>
</tr>
<tr>
<td>4</td>
<td>- 336</td>
<td>18</td>
<td>- 140</td>
<td>364</td>
</tr>
<tr>
<td>5</td>
<td>- 378</td>
<td>- 5</td>
<td>- 92</td>
<td>389</td>
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<table>
<thead>
<tr>
<th>24 m 1.3m height</th>
<th>X (mG)</th>
<th>Y (mG)</th>
<th>Z (mG)</th>
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<td>1</td>
<td>- 227</td>
<td>15</td>
<td>- 233</td>
<td>326</td>
</tr>
<tr>
<td>2</td>
<td>- 291</td>
<td>- 97</td>
<td>- 82</td>
<td>318</td>
</tr>
<tr>
<td>3</td>
<td>- 71</td>
<td>- 36</td>
<td>- 465</td>
<td>472</td>
</tr>
<tr>
<td>4</td>
<td>- 353</td>
<td>- 24</td>
<td>225</td>
<td>419</td>
</tr>
<tr>
<td>5</td>
<td>- 478</td>
<td>10</td>
<td>- 40</td>
<td>480</td>
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</table>
Effect of FINEMET: prevent effect from magnetic field

Measured magnetic field at on-site: 30 – 50 μT

- Prepared 2 layers of FINEMET

Measured magnetic field before / after cover with FINEMET.
- One component of direction

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
<th>Before</th>
<th>After</th>
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</thead>
<tbody>
<tr>
<td>387</td>
<td>111</td>
<td>-360</td>
<td>-170</td>
</tr>
<tr>
<td>-486</td>
<td>-49</td>
<td>471</td>
<td>284</td>
</tr>
</tbody>
</table>

cf) We put outer layer to inside only for demonstration purpose.
Effect of FINEMET to PMT gain

- Data taking with FADC
- 2 layers of FINEMET
- Used Blue LED with NIM module to match single photon electron

LED On (No signal case)

LED On (Signal case)
Effect of FINEMET to PMT gain

Typical signal shape

30 ns integration window

Single gauss fitting
SPE peak : 19.5 ➔ 22.2 (14 % increase)
Production of Gd-LS / LS

Produce at RENO site after refurbishing the production facility.
Production of LS

Production scheme at RENO site

- LAB (10 ton)
- Filter
- Ultra pure water
- LS master
- LS (2000 L)
- ISO tank (~25 ton)
- N₂
Production of Gd-LS

Or, there is possibility of Donation from **DayaBay**.
- Got positive response from Spokes person of Daya Bay at Jul, 2017.
- Letter of donation is under discussion.
Filling and extracting of Gd-LS / LS

- If emergency is happen at mercury target, detector is required to be moved within one week.
  ➔ Filling or extracting should be finished within few days.

- Flow path of Gd-LS should be not any metallic material.
  ➔ MEGA 960 from TREBOR company. (DC also used it)
    Flow path is made by PFA / PTFE
    Max 95 LPM (5.7 ton / hour), 5.5 m suction lift.

- Liquid height of target, gamma-catcher, veto should be similar.
  ➔ Need to install flow meter, and distance measurement sensor.

- Chimney part needs special care for safety.
  ➔ Filling will be done into expansion tank, and reverse-siphon pipe
    will deliver Gd-LS into chimney.

- Filter will be used to prevent dust.
Filling stage (Image)

- Iso Tank

- LS

- Gd-LS

- Filling pipe
- Reverse-siphon
- Expansion tank

- pump
- flow meter
- filter

- Veto
- Target
Filling stage

- We assumed that even with optically separation, liquid can go through between gamma-catcher and veto.

(stage 1, 2 and stage 4, 5 can be combined)

stage 6: LS + chimney

stage 5: LS + chimney

stage 4: LS + chimney + LS
(most dangerous part)

stage 3: LS + Gd-LS + LS

stage 2: LS + LS

stage 1: LS

optically separated
Flow rate

Flow rate is roughly proportional to area.
- Volume of PMT, optically separation, installation part (~ 4000 L) is considered evenly.
- Max flow rate is assumed to 30 LPM in reality.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>stage 6</td>
<td>0.1</td>
<td>1</td>
<td>12</td>
<td>4 + tank</td>
<td>tank’</td>
<td>few</td>
</tr>
<tr>
<td>stage 5</td>
<td>0.1</td>
<td>30</td>
<td>25</td>
<td>8</td>
<td>4000</td>
<td>2.2</td>
</tr>
<tr>
<td>stage 4</td>
<td>0.1</td>
<td>30</td>
<td>25</td>
<td>8</td>
<td>4000</td>
<td>2.2</td>
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<tr>
<td>stage 3</td>
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<td>29.5</td>
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<td>19350</td>
<td>19000</td>
<td>10.8</td>
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<tr>
<td>stage 2</td>
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<td>30</td>
<td>25</td>
<td>0</td>
<td>4000</td>
<td>2.2</td>
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<tr>
<td>stage 1</td>
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<td>30</td>
<td>25</td>
<td>0</td>
<td>4000</td>
<td>2.2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>19370</td>
<td>35000</td>
<td>19.6</td>
</tr>
</tbody>
</table>

Detector Information.
Target : 160 cm (Outer radius), 250 cm (Inner height), chimney (10 cm radius), 30 mm thickness
Catcher : 25 cm, 25 cm (top/bottom, side)
Veto : 25 cm, 45 cm thickness (top/bottom, side)
Extracting stage (Image)

- Exchange position of pump and filter.
- Pump and flow meter should be on the top of detector.

Gd-LS

- ISO Tank
- Filling pipe
- Reverse-siphon
- Expansion tank

Filter
Flow meter
Pump

Veto
Target
Overview of Calibration

Energy conversion function: Number of photoelectrons (PMTs) $\rightarrow$ MeV
- Need to consider non-linearity due to quenching
- Almost constant value at higher energy
- Prompt signal comes from “positron”

$$\text{One of candidate } \Rightarrow \text{p.e. }/ \text{MeV} = P_1 - \frac{P_2}{1 - \exp(-P_3 E - P_4)}$$

Possible Information from
- Radioactive source: $^{137}\text{Cs}$, $^{68}\text{Ge}$, $^{60}\text{Co}$, $^{252}\text{Cf}$, ...
- Neutron captured from data: n-H, n-C, n-Gd, ...
- Continuous spectrum: $^{12}\text{B}$, Michel electron

Possible correction from Monte-Carlo simulation
- Difference between “gamma” and “positron”
- Difference between “single gamma” and “several gammas”
- Difference between “fixed vertex position” and “uniformly distributed at target”

Check of stability according to “time” and “spatial distribution”.

Jungsic Park, KEK

JPS Fall 2017
Study for Calibration

MC: Positron (Prompt signal) at center (10,000 p.e. / MeV)

\[
p.e. / MeV = P1 - \frac{P2}{1 - \exp(-p3^*E - P4)}
\]

Possible radioactive sources

\(^{68}\text{Ge}\): 1.022 MeV
\(^{60}\text{Co}\): 1.17 + 1.33 MeV
\(n\text{-H}\) (from data): 2.2 MeV
\(n\text{-Gd}\) (from data): \(~8\) MeV
\(^{252}\text{Cf}\): neutron

Almost flat
Study for Calibration

MC : Michel electron (10,000 p.e. / MeV)

Applied 225 p.e. / MeV

sharp decrease around 53 MeV as expected
Monitoring sensors
The JSNS$^2$ experiment is preparing to perform sterile neutrino search at J-PARC.

- Direct test of LSND

- Stainless steel vessel will be constructed until Mar, 2018.

- PMT installation scheme is under development with mock-up test.

- Several on-site measurements / preparation works was done.

- LS will be produced from RENO site after refurbishment. (Gd-LS also can be produced from RENO or possible donation from DayaBay)

- Many efforts is on-going to pump / calibration.

- Aim to start experiment at JFY 2018.