LXe PHOTON DETECTOR - CRYOGENICS

KEK

Tom HARUYAMA

1. Cryogenic operation of 120 L large-proto detector
2. Pulse tube refrigerator development
3. Purification scheme
4. Final photon detector system

LXe is heavier than Aluminum!
CRYOGENIC OPERATION FOR LARGE-PROTO DETECTOR

- LXe 120 L
- PMT 250

First operation--March, 2001
8 runs up to now
Refrigeration only mode
Safety operation
## LARGE-PROTO DETECTOR
### Operation history

<table>
<thead>
<tr>
<th>RUN</th>
<th>DATE(DAYS)</th>
<th>LXe</th>
<th>TEST</th>
<th>REFRIG. OPERATION</th>
<th>SITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3/1-3/5, 2001(5)</td>
<td>10 L</td>
<td>INITIAL</td>
<td>2.5 days</td>
<td>KEK</td>
</tr>
<tr>
<td>2</td>
<td>4/27-5/9, 2001(13)</td>
<td>96 L</td>
<td>INITIAL</td>
<td>2.5 days</td>
<td>KEK</td>
</tr>
<tr>
<td>3</td>
<td>6/8-6/19, 2001(12)</td>
<td>106 L</td>
<td>γ-beam</td>
<td>3 days</td>
<td>AIST</td>
</tr>
<tr>
<td>4</td>
<td>8/16-9/9, 2001(25)</td>
<td>96 L</td>
<td>Cosmic ray</td>
<td>18 days</td>
<td>KEK</td>
</tr>
<tr>
<td>5</td>
<td>11/5-12/2, 2001(28)</td>
<td>120 L</td>
<td>Cosmic ray</td>
<td>16 days</td>
<td>KEK</td>
</tr>
<tr>
<td>6</td>
<td>2/15-3/7, 2002(17)</td>
<td>120 L</td>
<td>γ-beam</td>
<td>7 days</td>
<td>AIST</td>
</tr>
<tr>
<td>7</td>
<td>5/8-7/10, 2002(63)</td>
<td>120 L</td>
<td>Cosmic ray</td>
<td>(50 days)</td>
<td>KEK</td>
</tr>
</tbody>
</table>

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LARGE PHOTODETECTOR
-System flow diagram (without circulation purification)-

- ROTARY VALVE
- COMPRESSOR
- LN2
- Pulse tube refrigerator
- Xe bottle for 120L
- GXe BOTTLE 250L
- PURIFIER (Getter+Oxisorb)
- LXe
- HEATER
- PMT

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CRYOGENIC OPERATION FOR LARGE-PROTO DETECTOR
-Operation Overview-

2002.7.15-17 PSI Meeting
# LARGE-PROTO DETECTOR

- Typical operation mode for 120 L of LXe-

<table>
<thead>
<tr>
<th>Operation mode</th>
<th>Time (days)</th>
<th>Liq/rec. rate</th>
<th>LN2* (Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-cooling</td>
<td>24-36 H (1-1.5)</td>
<td>--</td>
<td>15-20 L/H (400-700 L)</td>
</tr>
<tr>
<td>Liquefy</td>
<td>48-72 H (2-3)</td>
<td>2.2-2.5 L/H</td>
<td>15 L/H (800-1000 L)</td>
</tr>
<tr>
<td>Steady</td>
<td>-</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>Recovery</td>
<td>36 H (1.5)</td>
<td>2.5-2.9 L/H</td>
<td>~30 L/H (1000 L)</td>
</tr>
<tr>
<td>Warm-up</td>
<td>72 H (3)</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

*~15m long foam-insulated cooling pipe

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CRYOGENIC OPERATION FOR LARGE-PROTO DETECTOR
-Heat Load-

<table>
<thead>
<tr>
<th>Phase</th>
<th>LXe (L)</th>
<th>PMT</th>
<th>Heat Load W@165K</th>
<th>Total (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.Proto</td>
<td>120</td>
<td>250</td>
<td>24</td>
<td>50</td>
</tr>
<tr>
<td>Final</td>
<td>800</td>
<td>800</td>
<td>20</td>
<td>122</td>
</tr>
</tbody>
</table>

*Static heat load depends on manufacturers design
*PMT power dissipation 65mW/PMT
*Due to number and length of cables

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PULSE TUBE REFRIGERATOR DEVELOPMENT
-KEK in-house pulse tube refrigerator-

Features of pulse tube refrigerator
- No vibration
- Effective direct re-condensing
- Possibly long life
- Easy maintenance
- Eco-friendly

Achieved Cooling Power
- 70 W @165K
- 2.2 kW compressor
- 2.2 Hz operation
- Coefficient Of Performance ~3%
PULSE TUBE REFRIGERATOR DEVELOPMENT
-Stable temperature control -

- Very quiet environment is achieved!
- No ON-OFF, no excess cooling
Heat Load for Final Detector

- Cooling power @2.2kW comp.
- Design point for L.P
- Cooling power @4.8kW comp.
PULSE TUBE REFRIGERATOR DEVELOPMENT
-KEK in-house U-shape pulse tube refrigerator-

Cold head
Regenerator
1000 SUS mesh inside
Pulse tube
41mm φ

-U-shape: expected higher cooling power
PULSE TUBE REFRIGERATOR DEVELOPMENT
-KEK in-house U-shape pulse tube refrigerator-

- COP~3%
- Remaking regenerator better performance

Cooling power comparison—Coaxial and U-shape

Coaxial type @ 2.2kW

U-shape type @ 1.6kW
Effective purification method is found…
PURIFICATION SCHEME

→ good result, but…

Additional Heat Load
-5L/min Xe gas(300K) → 50-60W@165K
-25L/min → 250-300W@165K!
-Heavy load for refrigerator
-LN consumption increase~10-40L/hour
↓

Can be solved by: Cold heat exchanger
Possible circulating purification scheme...

Purification Scheme

- Purifier (getter)
- LN2
- LXe
- Diaphragm Pump (>25L/min.)
- Cold Heat Exchanger
DESIGN STUDY FOR FINAL CALORIMETER CRYOSTAT
- General view -

2002.7.16 PSI

2800mm
1080i.d
2300o.d
1400mm
DESIGN STUDY FOR FINAL CALORIMETER CRYOSTAT -Layout-

Xe gas storage tanks

LN2 dewars

Transporting solenid

LXe detector
<table>
<thead>
<tr>
<th>DAY</th>
<th>STEP</th>
<th>MAN/AUTO</th>
<th>ACTION</th>
<th>EMERGENCY</th>
</tr>
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<tbody>
<tr>
<td>-</td>
<td>PUMPING/GAS CHARGE</td>
<td>MAN</td>
<td>-OUTER VACUUM PUMPING</td>
<td>POWER SHUT</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-INNER VESSEL PUMPING</td>
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<tr>
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<td></td>
<td>-COLD TRAP ACTIVE</td>
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<tr>
<td>3</td>
<td>BAKING</td>
<td>MAN</td>
<td>-HOT GAS TEMP. CONTROL</td>
<td>POWER SHUT</td>
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<tr>
<td>4</td>
<td>PRECOOL</td>
<td>AUTO</td>
<td>-VESSEL PRESSURE CONTROL (LN2)</td>
<td>POWER SHUT</td>
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<td>-TANK VALVE CHANGE CONTROL</td>
<td>LN2 EMPTY</td>
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<td></td>
<td>-PURIFIER ACTIVE</td>
<td>VACUUM</td>
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<tr>
<td>7</td>
<td>LIQUEFY</td>
<td>AUTO</td>
<td>-PURIFICATION BY LIQUID PUMP OUT</td>
<td>POWER SHUT</td>
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<td>-TANK VALVE CHANGE CONTROL</td>
<td>LN2 EMPTY</td>
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<tr>
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<td>-PURIFIER ACTIVE</td>
<td>VACUUM</td>
</tr>
<tr>
<td>7</td>
<td>STEADY</td>
<td>AUTO</td>
<td>-VESSEL PRESSURE CONTROL (REFRIG.+LN2 BACK-UP)</td>
<td>POWER SHUT</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LN2 EMPTY</td>
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<tr>
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<td>VACUUM</td>
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<tr>
<td>7</td>
<td>RECOVERY</td>
<td>SEMI</td>
<td>-TANK UNIT COOLING</td>
<td>POWER SHUT</td>
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<td>-LN2 LEVEL CONTROL</td>
<td>REF. SHUT</td>
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<td>-XE FLOW CONTROL TO TANKS</td>
<td>LN2 EMPTY</td>
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<tr>
<td>5</td>
<td>WARM UP</td>
<td>SEMI</td>
<td>-HEATER CONTROL</td>
<td>VACUUM</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-VACUUM BREAK</td>
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</table>
SUMMARY
of photon detector cryogenics

1. Cryogenic operation mode is understood through large-proto detector experiments
2. Pulse tube refrigerator development is on-going for the final detector
3. Effective purification scheme can be established
4. Final photon detector is now under detailed designing
Design study for final calorimeter cryostat
Gas for effective bake-out

- large heat capacity
- good thermal conductivity

<table>
<thead>
<tr>
<th>Gas</th>
<th>$N_2$</th>
<th>Xe</th>
<th>Ar</th>
<th>Ne</th>
<th>$H_2$</th>
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</thead>
<tbody>
<tr>
<td>$C_p$(kJ/kgK)</td>
<td>1.04</td>
<td>0.16</td>
<td>0.52</td>
<td>1.03</td>
<td>14.2</td>
</tr>
<tr>
<td>$\lambda$(W/cmK)</td>
<td>2.4</td>
<td>0.3</td>
<td>1.6</td>
<td>4.6</td>
<td>16.8</td>
</tr>
</tbody>
</table>

@300K, 0.1 MPa