MEG実験用液体キセノン検出器プロトタイプの新型PMT導入による分解能の向上

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π⁻ beam test was performed to estimate resolution in signal and higher energy region. (55 MeV and 83 MeV)

Updates and comparison of π⁻ beam test in 2003 and 2004.

- π⁻ beam test
- Updates from previous beam test
- Analysis
- Energy resolution
- Time resolution
- Summary
$\pi$ beam test

**LXe detector**

$\pi^p \rightarrow \pi^0 n$

$\pi^0(28\text{MeV/c}) \rightarrow \gamma \gamma$

54.9 MeV $< E(\gamma) < 82.9$ MeV

- Requiring $\theta > 170^\circ$
  - FWHM = 1.3 MeV
- Requiring $\theta > 175^\circ$
  - FWHM = 0.3 MeV

**NaI+ LYSO**

**LH2 target**

$\gamma$ photon energy

- $54.9$ MeV $< E(\gamma) < 82.9$ MeV

- $55$ MeV

- $83$ MeV
Updates from previous test

- Result of beam test 2003
  - Energy 1.6% (right $\sigma$)
  - Time 102 psec

Updates from previous beam test

- Improvement of PMT
- Newly installed calibration source
- Filled space in beam window to reduce inefficiency.
- High power refrigerator (189W@165K)
- Waveform digitizer
- New analysis softwares (ROME)

24aWJ T, Haruyama
24aWJ Y, Uchiyama
Improvement of PMT

1st generation R6041Q
Rb-Cs-Sb
Mn layer
QE~4-6%
reduction of output in very high BG

2nd generation R9288TB
K-Cs-Sb
Al strip
Higher QE ~15-17%
Still slight reduction of output in very high BG

3rd generation R9288ZA
K-Cs-Sb
Al strip density is doubled.
Higher QE~15-17%
Much better performance in very high BG

24pWJ  H,Natori’s talk
Newly installed α source

- 4 tungsten wires plated with Au (50 micron φ)
- Po attached on the wires, 2 active points per wire
- Active points are coated with Au (200-400Å)
- Fixed on the wall with spring.
Analysis of alpha

Wire (50 μm φ)

40 μm

Alpha

Alpha source are used for
- Q.E. estimation
- purity monitor
- optimization of MC

Output of a PMT

Q.E. of PMTs

with θ selection

1st generation

2nd generation
Energy Resolution

- Sum of photons taking into account Q.E.
- Depth selection. (22%)
- Depth dependence correction.

![Graphs showing energy resolution for different energies and depths.](attachment:graph.png)

- **55 MeV**
  - Number of photons: 3018
  - Mean: 9.183e+05
  - RMS: 3.221e+05
  - \(\chi^2/\text{ndf}\): 708.6/169
  - Peak: 1.142e+06 ± 1703
  - Transition: -3723 ± 623.8
  - Height: 123.5 ± 5.0
  - Sigma: 1.408e+04 ± 1051
  - FWHM = 4.8
  - \(\sigma = 1.23\%\)

- **83 MeV**
  - Number of photons: 4260
  - Mean: 1.228e+06
  - RMS: 5.29e+05
  - \(\chi^2/\text{ndf}\): 89.47/43
  - Peak: 1.726e+06 ± 2413
  - Transition: -2990 ± 519.4
  - Height: 102.3 ± 4.1
  - Sigma: 1.723e+04 ± 1360
  - FWHM = 5.2
  - \(\sigma = 1.00\%\)
Intrinsic Time Resolution

\[ \Delta (T_R - T_L) / 2 \]

L-R Analysis to get rid of affection from conversion depth reconstruction.

Gain

<table>
<thead>
<tr>
<th></th>
<th>normal</th>
<th>high</th>
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</thead>
<tbody>
<tr>
<td>1G PMT</td>
<td>0.5 E-6</td>
<td>1.0 E-6</td>
</tr>
<tr>
<td>2G PMT</td>
<td>1.0 E-6</td>
<td>5.0 E-6</td>
</tr>
</tbody>
</table>
Absolute Time Resolution

\[ \Delta(T_{\text{xenon}} - T_{\text{LYSO}}) \]

The standard deviation \(\sigma_t(\text{Xe-LYSO})\) contains:

- resolution of LYSO > 61 psec
- effect from beam spot and target size. 60 psec

![Graph showing time resolution comparison between xenon and LYSO.]
Practical Time Resolution

Practical timing resolution of Xe

LYSO target

Normal gain

\[ 110 \oplus 64 \oplus 61 = 65 \]

Intrinsic depth

\[ = 56 \oplus 33 \text{ psec} \]

High gain

\[ 103 \oplus 64 \oplus 61 = 53 \]

\[ = 43 \oplus 31 \text{ psec} \]
## Comparison 2003 & 2004

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
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<tbody>
<tr>
<td><strong>Energy resolution [%]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 MeV</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>83 MeV</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Time resolution [psec]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 MeV (normal gain)</td>
<td>&lt; 65</td>
<td></td>
</tr>
<tr>
<td>55 MeV (high gain)</td>
<td>102</td>
<td>&lt;53</td>
</tr>
</tbody>
</table>
Summary of π beam test

Many updates from previous test
- PMT, calibration source, refrigerator, reduction of material, waveform, software ...

Energy resolution for 55 MeV gamma rays were improved from 1.6% to 1.2%.

Time resolution for 55 MeV gamma rays were improved from ~100 psec to ~50 psec.
Summary of prototype tests

Prototype test is completed.

- Energy & position resolution for 10, 20, 40 MeV gammas @ TERAS
- Energy & time resolution for 55, 83 MeV gammas @ π-beam test
- Liquefaction and keep LXe only with refrigerator
- Attenuation length measurement and purification technique (pre-print physics/0407033)
- PMT development and test
- Calibration and reconstruction algorithms
- High speed purification with liquid pump (<100 l/hrs).

**Final detector is under construction.**

<table>
<thead>
<tr>
<th>Energy</th>
<th>1.3 %</th>
</tr>
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<tbody>
<tr>
<td>Time</td>
<td>60 psec</td>
</tr>
<tr>
<td>Position</td>
<td>4 mm</td>
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</table>
Liquid phase (high speed) purification was successfully done.