MEG実験2008
液体キセノン検出器II
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Performance of liquid xenon detector

- Timing resolution
  - intrinsic timing resolution
  - absolute timing resolution
- Position resolution
  - compared with MC simulation
- Energy scale calibration
  - peak dependence and correction
- Energy resolution
  - resolution map on front face
  - resolution by position in a PMT lattice
  - resolution along depth
- Linearity and detection efficiency
- Summary in 2008
Intrinsic timing resolution

- PMTs are divided to 2 groups
  - top and bottom part around centre
  - and checked by some divisions
- The timing difference of 2 groups
  - $\sigma = 50 \sim 60$ ps @ 52.8MeV signal

Timing resolution depends on the number of photo electron, but the light yield is increasing.
**Absolute timing resolution**

- Use the time difference of $2\gamma$ from $\pi^0$ decay

- Reference counter opposite liquid xenon detector
  - difference of 2PMTs in the same plates and weighted average of time at 2 plastic scintillators
  - $\sigma_{\text{counter}} = 93\text{ps}$

- Timing in liquid xenon detector referred by reference counter
  - corrected by the charge of reference counter, sum charge of PMTs by each faces, time of flight, propagation time
  - $\sigma_{(T_{\text{exec}} - T_{\text{counter}})} = 150\text{ps}$
  - contains the spread of decay point in target $\sim 60\text{ps}$ and the effect of reference counter $\sim 93\text{ps}$

  $\sigma_t \sim 150 \Theta (93 \Theta 60) \sim 100\text{ ps}$

- Bad resolution of clock signal included but will be improved.
- The timing resolution between gamma ray and positron is estimated by radiative decay.

<table>
<thead>
<tr>
<th>$\chi^2$</th>
<th>NDF</th>
<th>Width [MeV]</th>
<th>p0</th>
<th>Width [MeV]</th>
<th>p1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.794e-18</td>
<td>0</td>
<td>298.4 ± 71.12</td>
<td>60.92 ± 9.188</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Position reconstruction

• use lead collimator in $\pi^0$ run to estimate position resolution
  – in 55~83MeV range
  – collimator slit: 1cm thickness: 1.8cm
  – The effect of target size is not considered.
    • $\sigma_{xy} \sim 8$mm x 8mm
• position resolution along vertical direction
  – edge: $\sim 0.52$cm ($\sim 0.51$cm in MC simulation)
  – slit: $\sim 0.75$cm ($\sim 0.70$cm in MC simulation)

In MC the worse resolution of slits is due to the spread of true incidence point. Actual resolution excluded this spread of slit and edge is the same level.
  – position resolution along vertical $\sigma \sim 0.52$cm
Calibration of energy scale

• Energy is estimated by the number of scintillation photons
  – Energy = \( \sum (\text{weight} \times \frac{\text{PMT charge}}{\text{gain} / \text{Q.E.}}) \times \text{energy scale} \times \text{correction factor} \)
  – currently using fixed weight determined by the detector geometry
  – the improvement of energy reconstruction is in progress

• Energy scale
  – energy scale is determined by 55MeV gamma ray in \( \pi^0 \) run

• Correction by time, position, etc.
  – chase the change of the light yield of liquid xenon by various calibration for all the run
  – compensate the dependence by position
Non-uniformity

- Position dependence of 17.6MeV peak by Li

- Wrong Q.E. estimation may worse uniformity.

Liquid xenon detector

- This gap is due to the different energy reconstruction.
Improvement by non-uniformity

- checked 55MeV peak from $\pi^0$ decay after correction with 17.6MeV Li peak

- Peak distribution estimated by 1PMT region for all front face

- Energy resolution before and after position correction in the light blue region
  - Depth < 2cm
    - $\sigma$ upper 3.4% -> 2.9%
    - FWHM 12.3% -> 8.8%
  - Depth > 2cm
    - $\sigma$ upper 2.5% -> 2.3%
    - FWHM 6.7% -> 6.1%

Uniformity 1.6% -> 0.8%

still contains the change of light yield, gain aging effect
Energy resolution map @ 55MeV

- **corrections**
  - Gain shift correction
  - Light yield correction
  - No gain aging correction
  - No position correction

- **Energy resolution around 55MeV (over 2cm depth)**

  - $\sigma_{\text{upper}}$
  - FWHM

  \[ \text{<FWHM>} \sim 6.4\% \\ \text{<}\sigma_{\text{upper}}\text{>} \sim 2.3\% \]

  - Energy resolution by 1PMT size window

  - blue : all region
  - red : in acceptance (46cm x 142cm)

  - Monte carlo simulation of 53MeV signal

  \[ \text{<FWHM>} \sim 4.3\% \\ \text{<}\sigma_{\text{upper}}\text{>} \sim 1.2\% \]
Dependence on PMT positions

- cut by narrow window to see the effect of PMT position
  - over 2cm depth, 55MeV peak in \( \pi^0 \) run
- The peak is almost independent from the PMT position, but energy resolution is influenced by that.

- vertical direction

- horizontal direction
Depth dependence

- Without correction by depth
- Energy resolution depends on the reconstructed depth
  - 55MeV peak in $\pi^0$ run

- Energy resolution can be obtained by each position
  - by the position on front face, depth
Linearity / Efficiency

- Possible estimation of detection efficiency
  - 1. Monte Carlo simulation
  - 2. $2\gamma$ from $\pi^0$ decay
    - Tagged by opposite NaI detector
      - select events around 83MeV in NaI and count hits in Liquid xenon
  - Linearity check by C.W. and $\pi^0$ decay
    - Small non linearity was observed.
      - Using high pass filter for waveform
      - without depth correction
      - correction of saturation may be wrong
      - shower by different energy scale
    - No problem about non-linearity
      - calibrate signal region (53MeV) by 55MeV $\gamma$ from $\pi^0$
Summary of detector performance in 2008

- Timing resolution ~ 100 ps
  - ~ 55 ps (intrinsic)
- Position resolution ~ 0.52cm
- Energy resolution @ 55MeV
  - mean: $\sigma_{\text{upper}} = 2.3\%$, FWHM = 6.4%
  - energy resolution is acquired by the incident position
- Current energy reconstruction has non-uniformity
  - make a flat by calibration such as
    - 17.6MeV LiF peak
    - 55MeV peak from $\pi^0$ decay
- Linearity and detection efficiency can be estimated
  - under study
- All analysis is in progress and will improve.
53MeV peak

- Energy calibration for MC will be ready
  - used 53 MeV signal about 2.2M events

- MC peak by position is different from actual position dependence.
- Energy calibration is possible by signal peak.
MC energy resolution sliced along u, v, w

- without position correction
Combined light yield history