MEG実験2008
液体キセノン検出器II

東京大学　素粒子物理国際研究センター

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他 MEGコラボレーション

Performance of liquid xenon detector

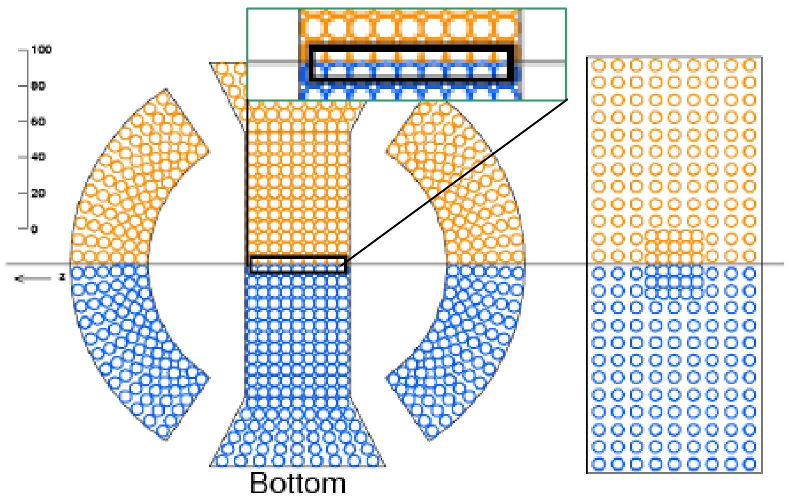
- Timing resolution
  - intrinsic timing resolution
  - absolute timing resolution
- Position resolution
  - compared with MC simulation

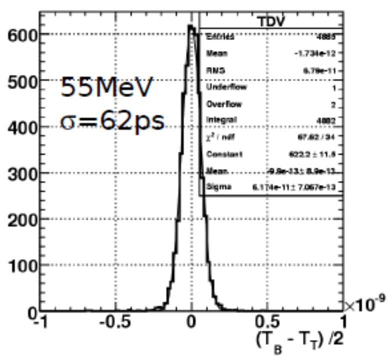
- Energy scale calibration
  - peak dependence and correction
- Energy resolution
  - resolution map on front face
  - resolution by position in a PMT lattice
  - resolution along depth
- Linearity and detection efficiency
- Summary in 2008

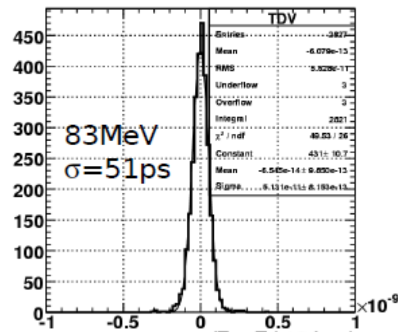
Intrinsic timing resolution

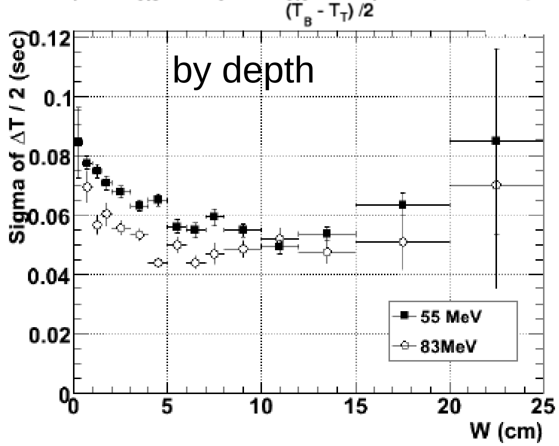
- PMTs are divided to 2 groups
  - top and bottom part around centre
  - and checked by some divisions
- The timing difference of 2groups
  - σ = 50 ~ 60 ps @ 52.8MeV signal

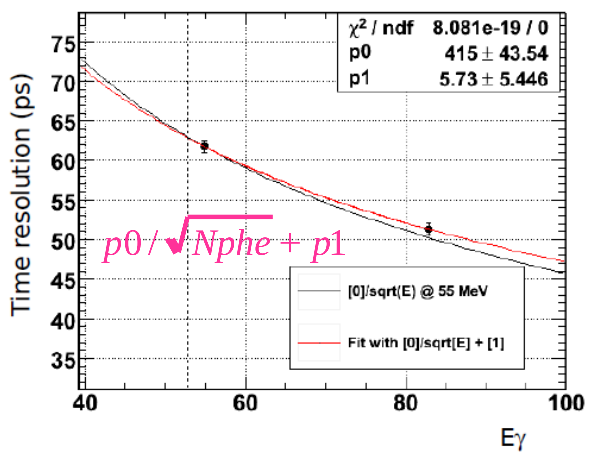
PMTs on surface of liquid xenon detector





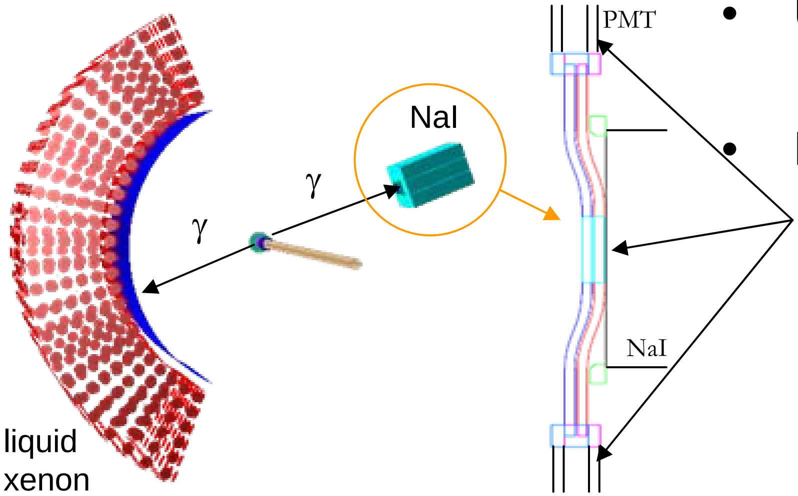






Timing resolution depends on the number of photo electron, but the light yield is increasing.

Absolute timing resolution



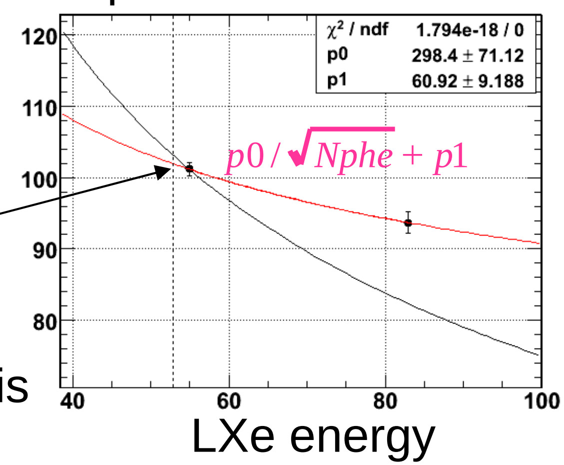
- Use the time difference of 2γ from π^0 decay
- Reference counter opposite liquid xenon detector
  - difference of 2PMTs in the same plates and weighted average of time at 2 plastic scintillators
  - $\sigma_{Tcounter}$ = 93ps

- 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
  - $\sigma_{(Txec\ -\ Tcounter)}$ = 150ps
    - contains the spread of decay point in target ~60ps and the effect of reference counter ~ 93ps

$$\sigma_t \sim 150 \ominus (93 \oplus 60) \sim \underline{100\ \text{ps}}$$

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

timing resolution of liquid xenon detector

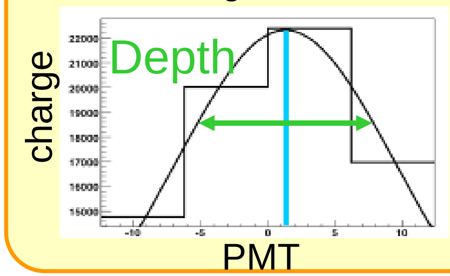


Position reconstruction

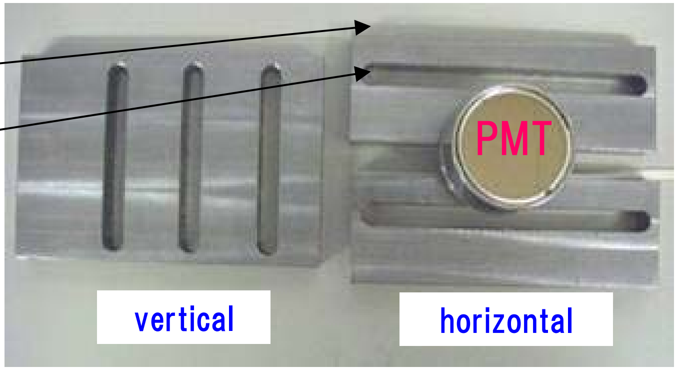
- use lead collimator in π^0 run
  to estimate position resolution
  - in 55~83MeV range
  - collimator slit : 1cm thickness : 1.8cm
  - The effect of target size is not considered.
    - σ_{xy} ~ 8mm x 8mm
- position resolution along vertical direction
  - edge : ~0.52cm (~0.51cm in MC simulation)
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

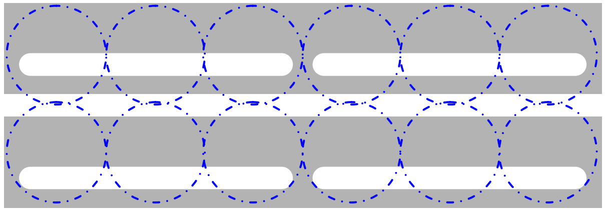
position reconstruction

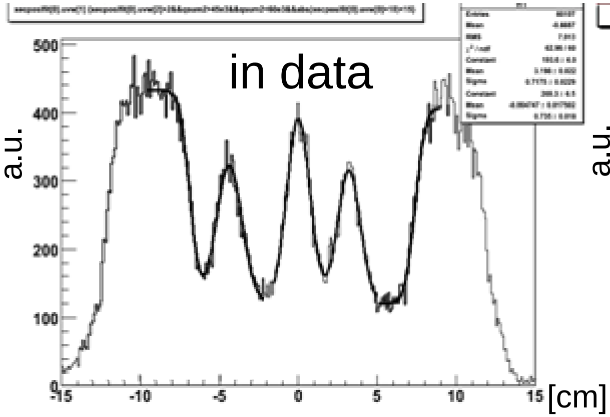
PMT charge distribution (1bin = 1PMT)

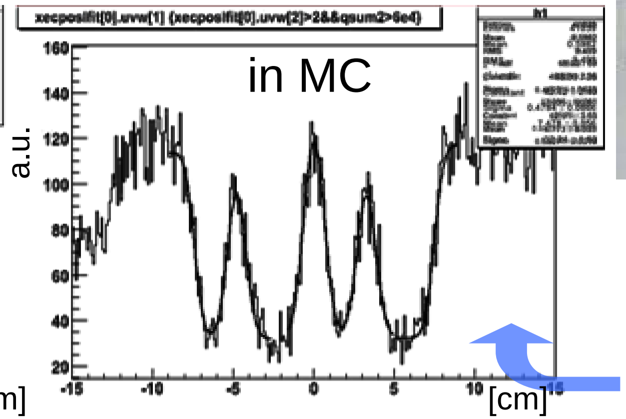


mean
– **position**
width
– **depth**









- 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 σ ~ **0.52cm**

Calibration of energy scale

- Energy is estimated by the number of scintillation photons
  - Energy = Σ (weight x PMT charge / gain / Q.E.)
    x energy scale x correction factor
  - currently using fixed weight determined by the detector geometry
  - the improvement of energy reconstruction is in progress

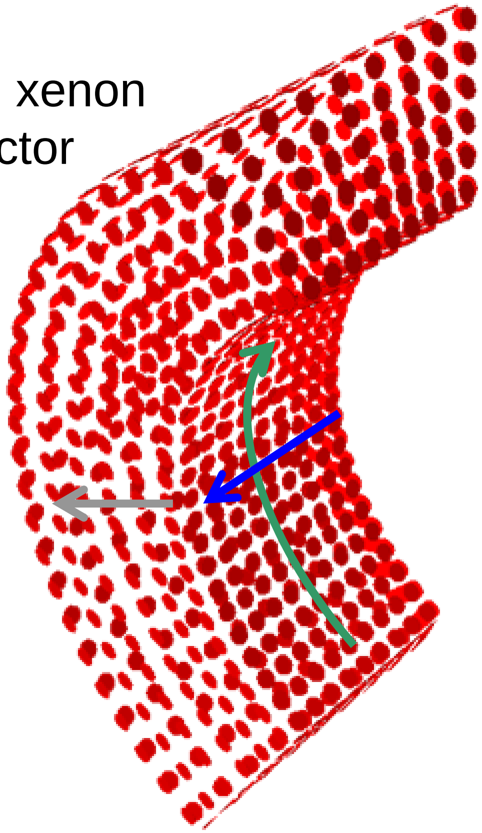
- Energy scale
  - energy scale is determined by 55MeV gamma ray in π^0 run

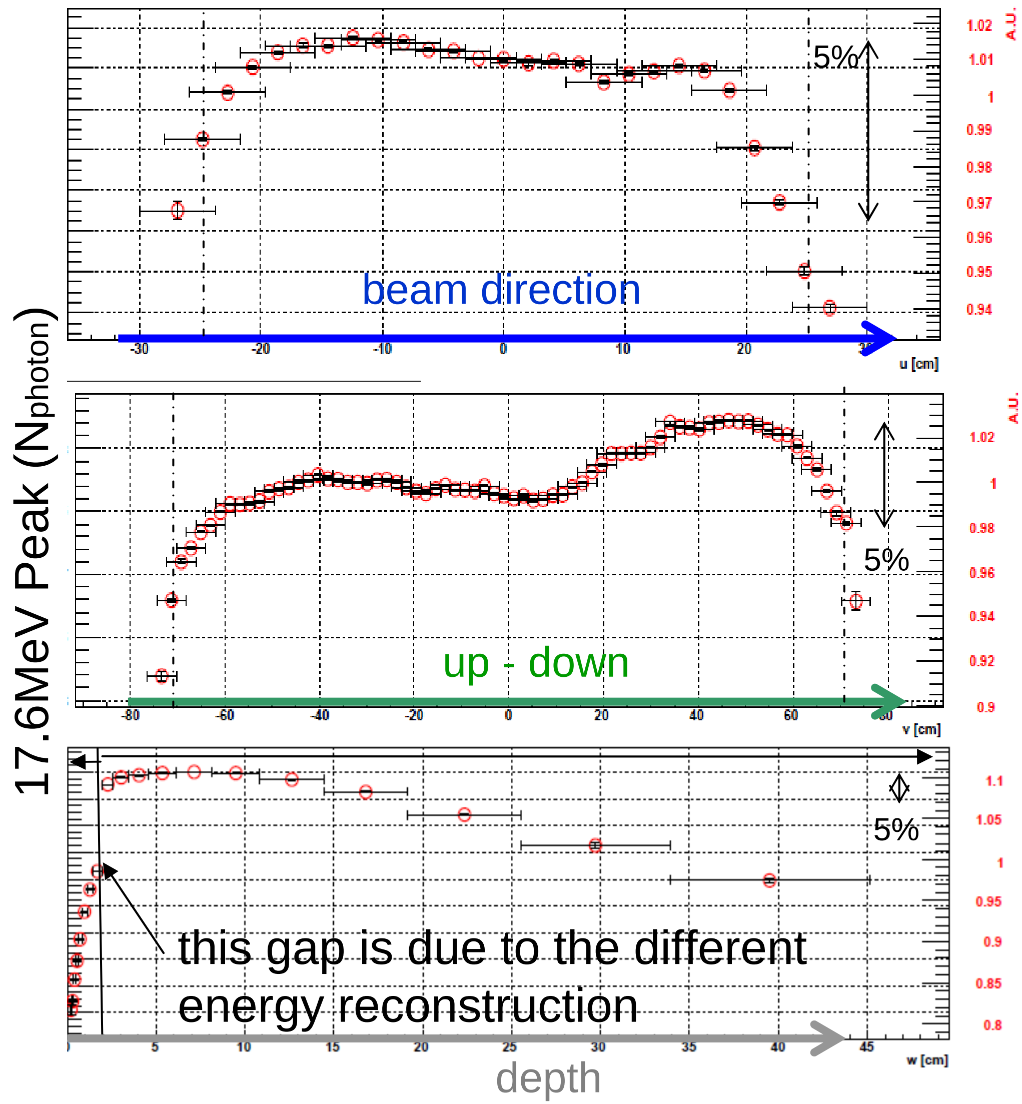
- Correction by time, position, etc.
  - chase the change of the light yield of liquid xenon by various calibration for all the run
  - compensate the dependence by position

Non-uniformity

- Position dependence of 17.6MeV peak by Li

Liquid xenon detector

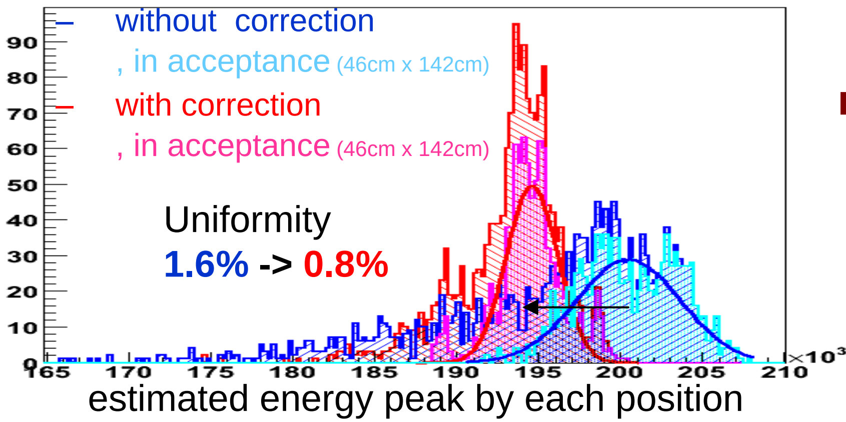




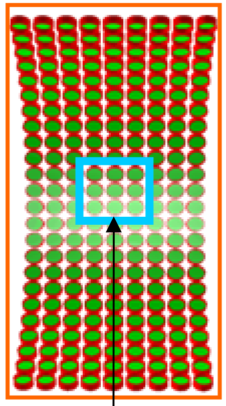
- Wrong Q.E. estimation may worse uniformity.

Improvement by non-uniformity

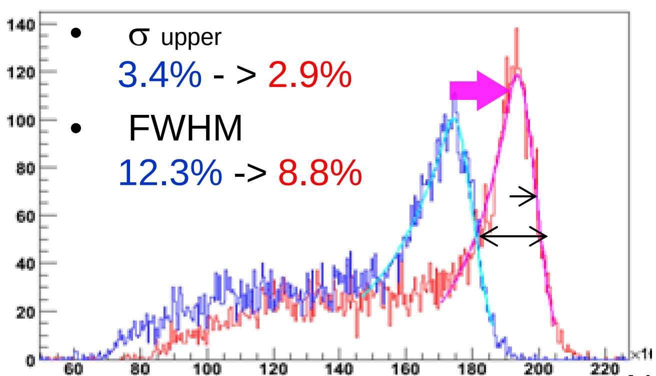
- checked **55MeV peak from π^0 decay after correction with 17.6MeV Li peak**
- Peak distribution estimated by 1PMT region for all front face

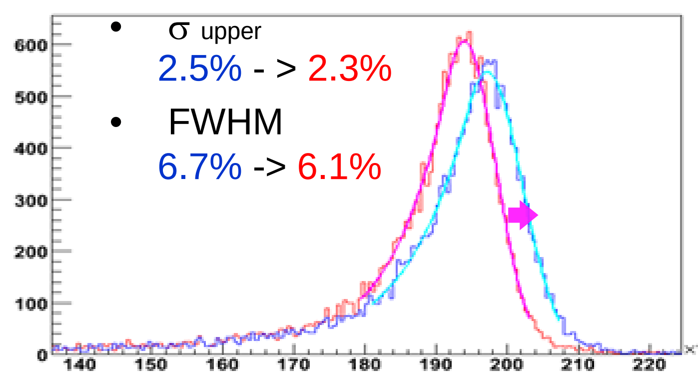


→ still contains the change of light yield, gain aging effect



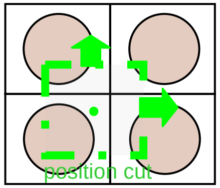
- Energy resolution before and after position correction in the light blue region
  - Depth < 2cm
  - Depth > 2cm





Energy resolution map @ 55MeV

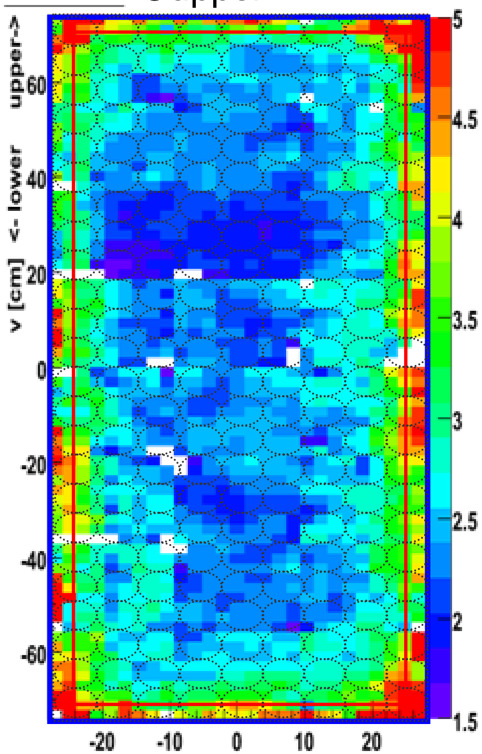
- corrections
  - Gain shift correction
  - Light yield correction
  - No gain aging correction
  - No position correction
- Energy resolution around 55MeV (over 2cm depth)



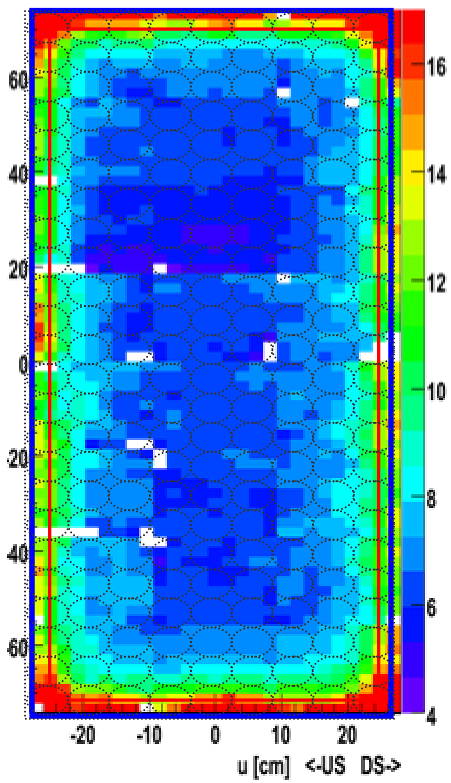
Energy resolution by 1PMT size window

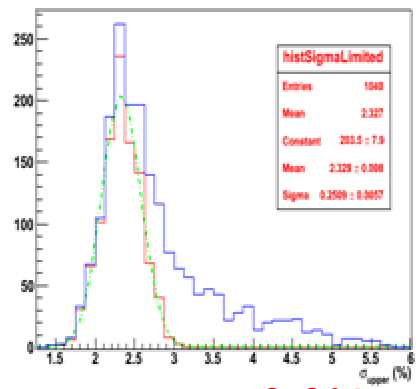
- blue : all region
- red : in acceptance (46cm x 142cm)

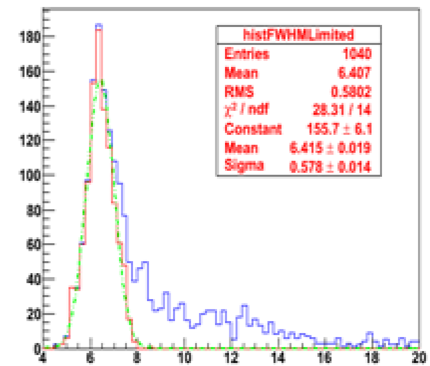
σupper



FWHM

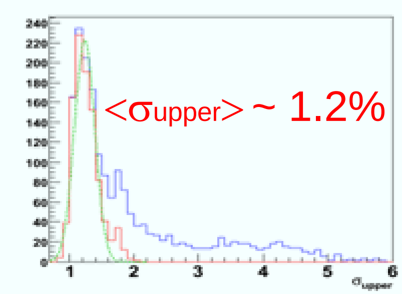


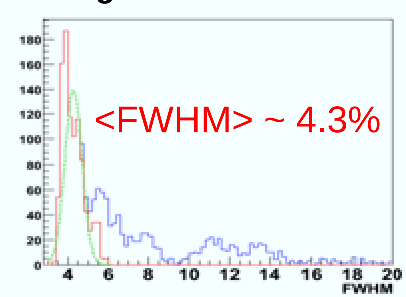




<σupper> ~ 2.3% <FWHM> ~ 6.4%

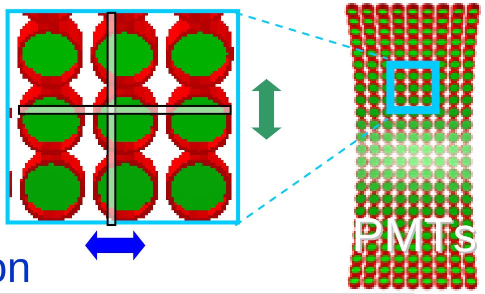
Monte carlo simulation of 53MeV signal



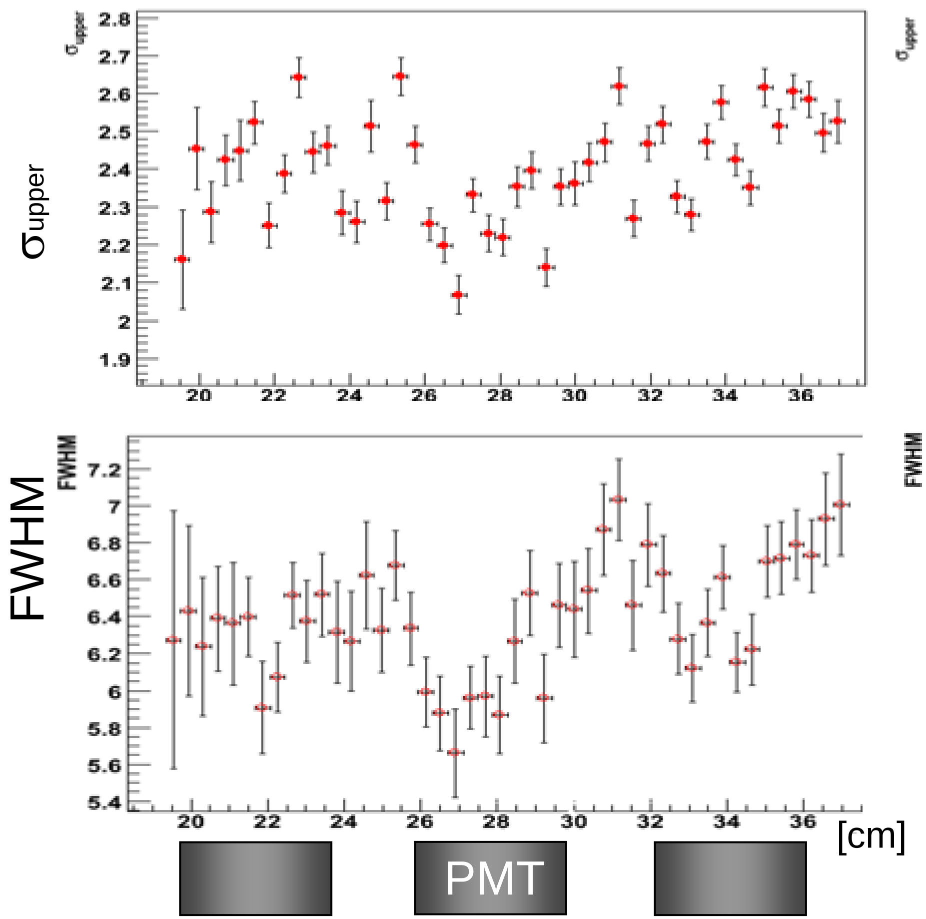


Dependence on PMT positions

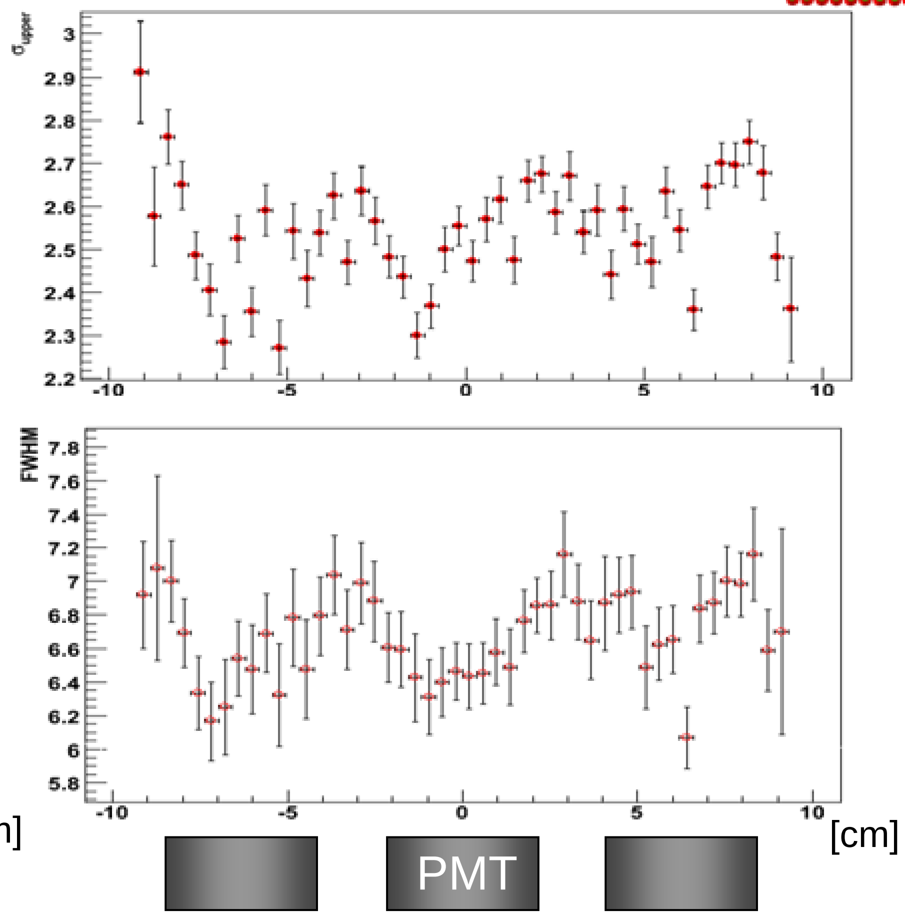
- cut by narrow window to see the effect of PMT position
  - over 2cm depth, 55MeV peak in π^0 run
- The peak is almost independent from the PMT position, but energy resolution is influenced by that.



- vertical direction

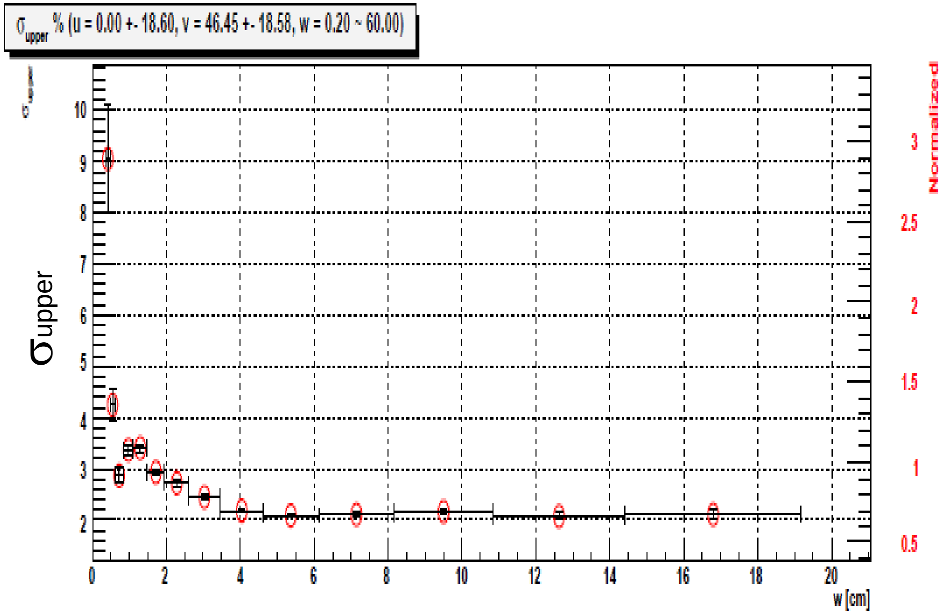


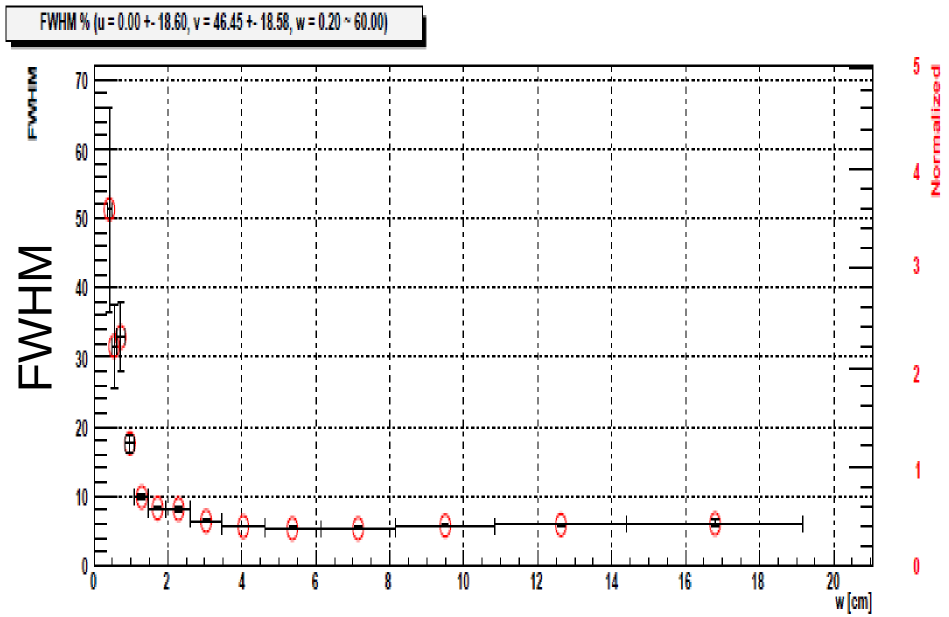
- horizontal direction



Depth dependence

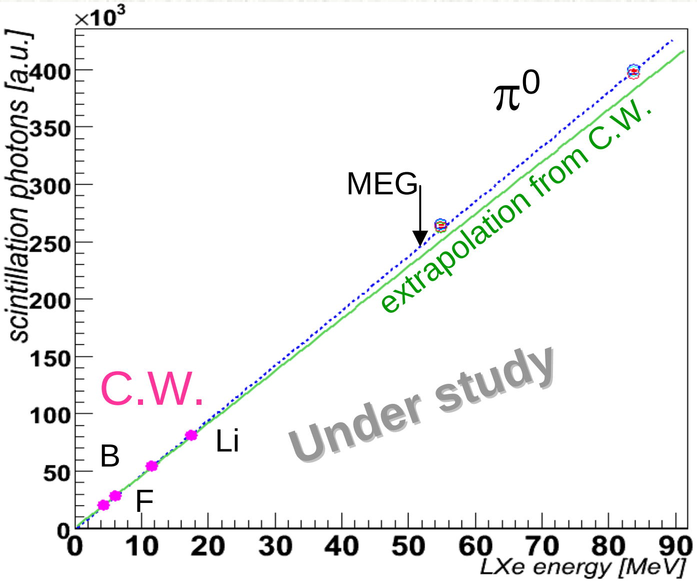
- Without correction by depth
- Energy resolution depends on the reconstructed depth
  - 55MeV peak in π^0 run





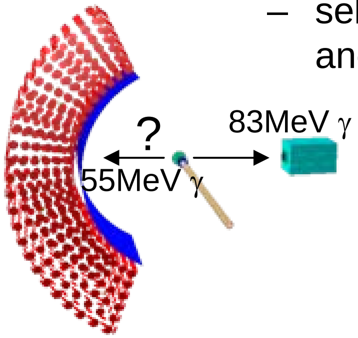
- Energy resolution can be obtained by each position
  - by the position on front face, depth

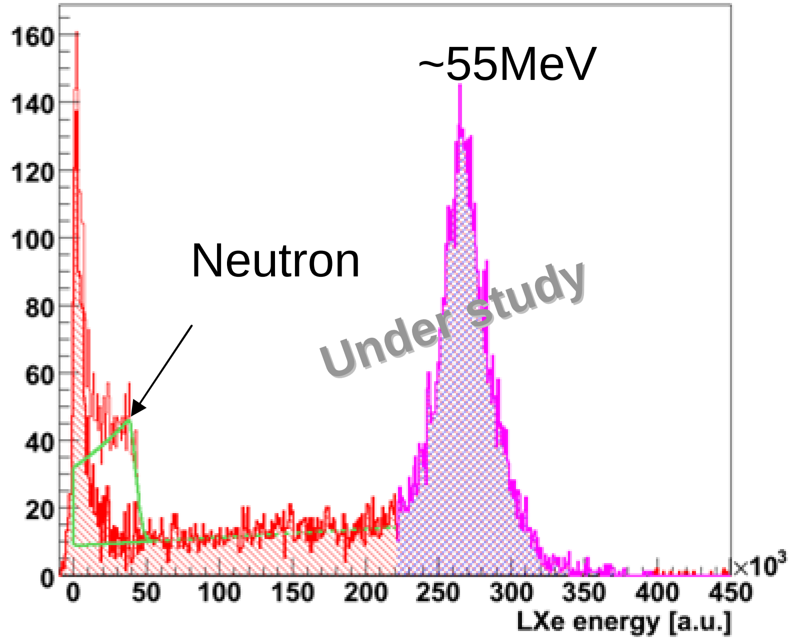
Linearity / Efficiency



- Linearity check by C.W. and π^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 γ from π^0

- Possible estimation of detection efficiency
  - 1. Monte calro simulation
  - 2. 2γ from π^0 decay
    - Tagged by opposite NaI detector
      - select events around 83MeV in NaI and count hits in Liquid xenon



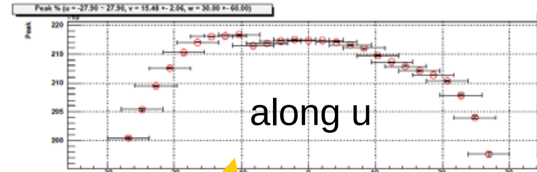


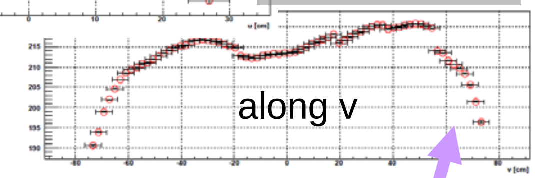
Summary of detector performance in 2008

- Timing resolution ~ 100 ps
  - ~ 55 ps (intrinsic)
- Position resolution ~ 0.52cm
- Energy resolution @ 55MeV
  - mean : σ_{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 π^0 decay
- Linearity and detection efficiency can be estimated
  - under study
- All analysis is in progress and will improve.

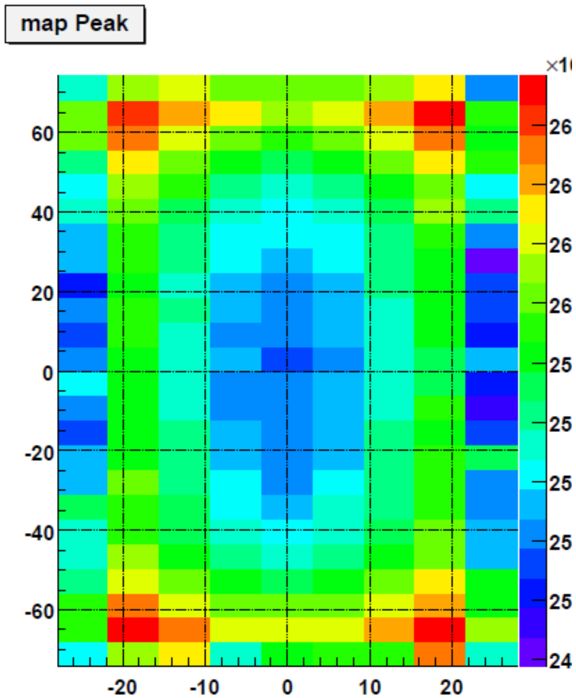
53MeV peak

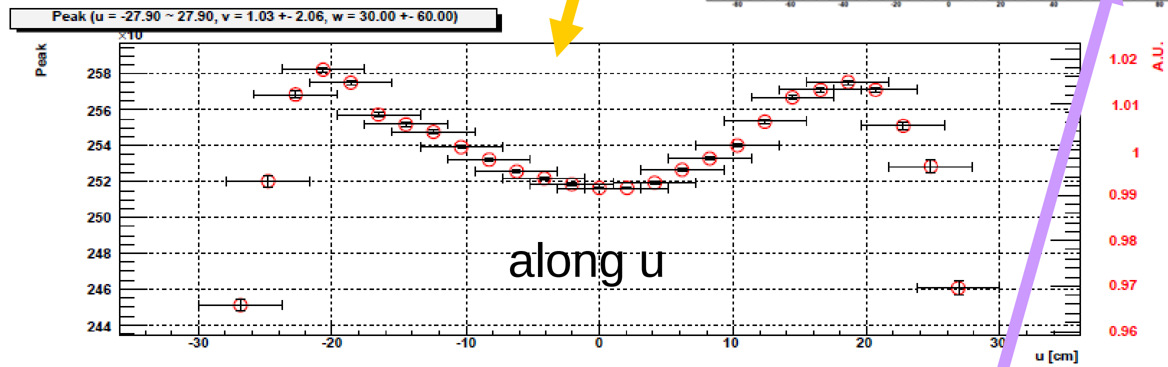
- energy calibration for MC will be ready
  - used 53 MeV signal about 2.2M events

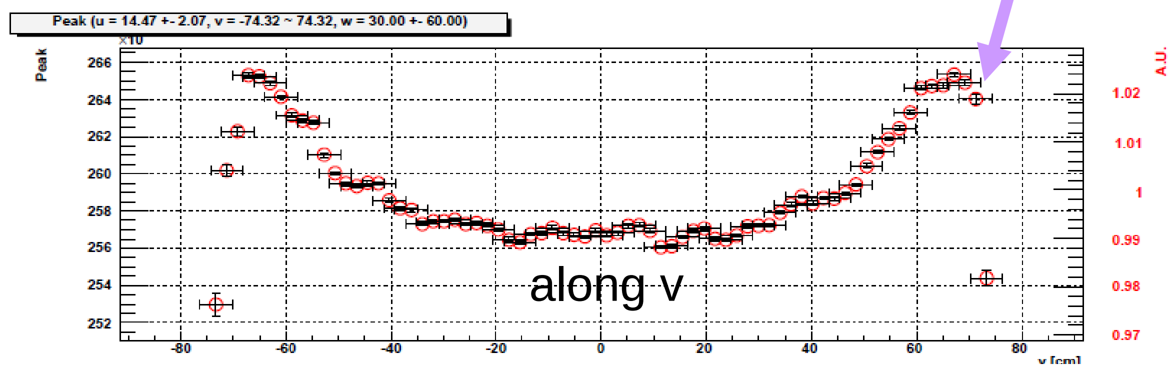




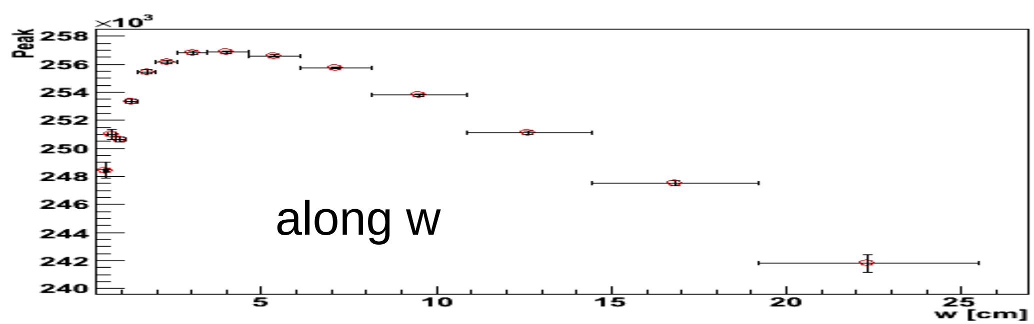
actual CEX peak



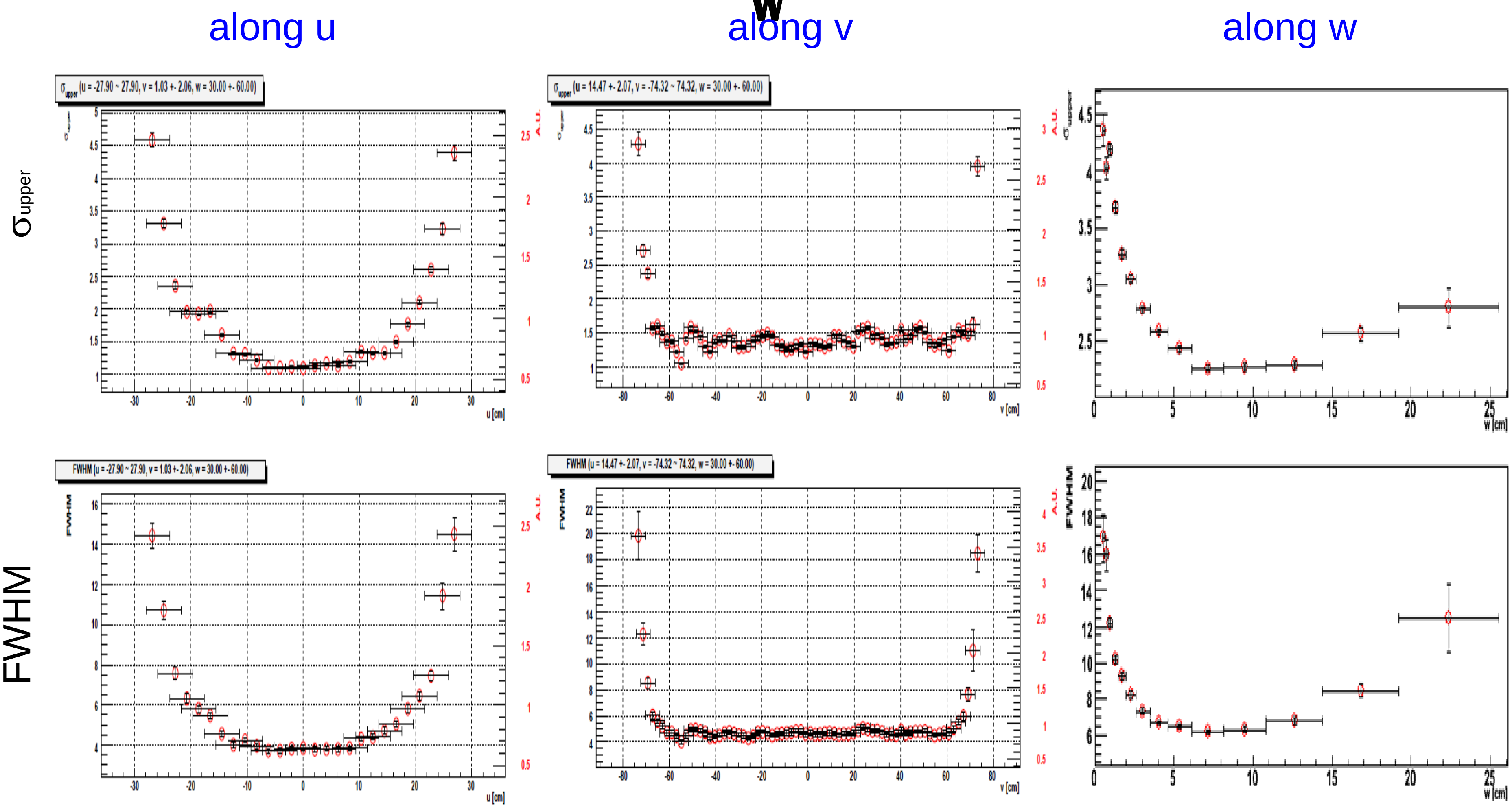




- MC peak by position is different from actual position dependence.
- Energy calibration is possible by signal peak.



MC energy resolution sliced along u, v, w



- without position correction

Combined light yield history