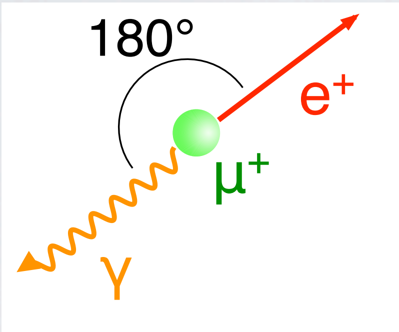
MEG実験 液体キセノンガンマ線検出器の性能改善

OUTLINE

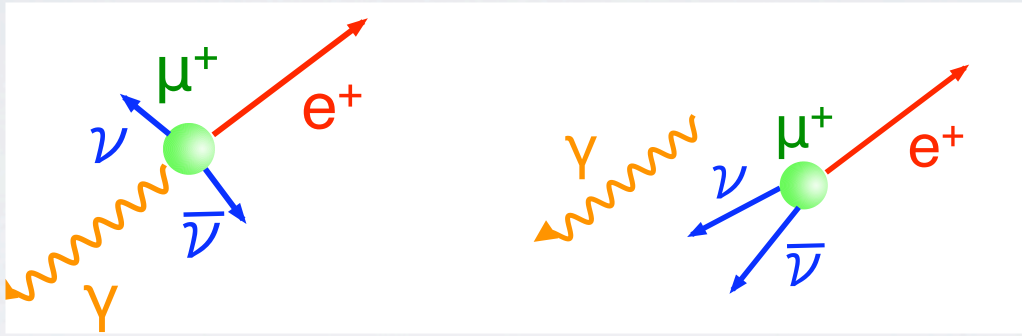
- Introduction
- New developments
  - face factor optimization
  - dead channel recovery
  - non-uniformity correction
  - alternative energy reconstruction

MEG EXPERIMENT

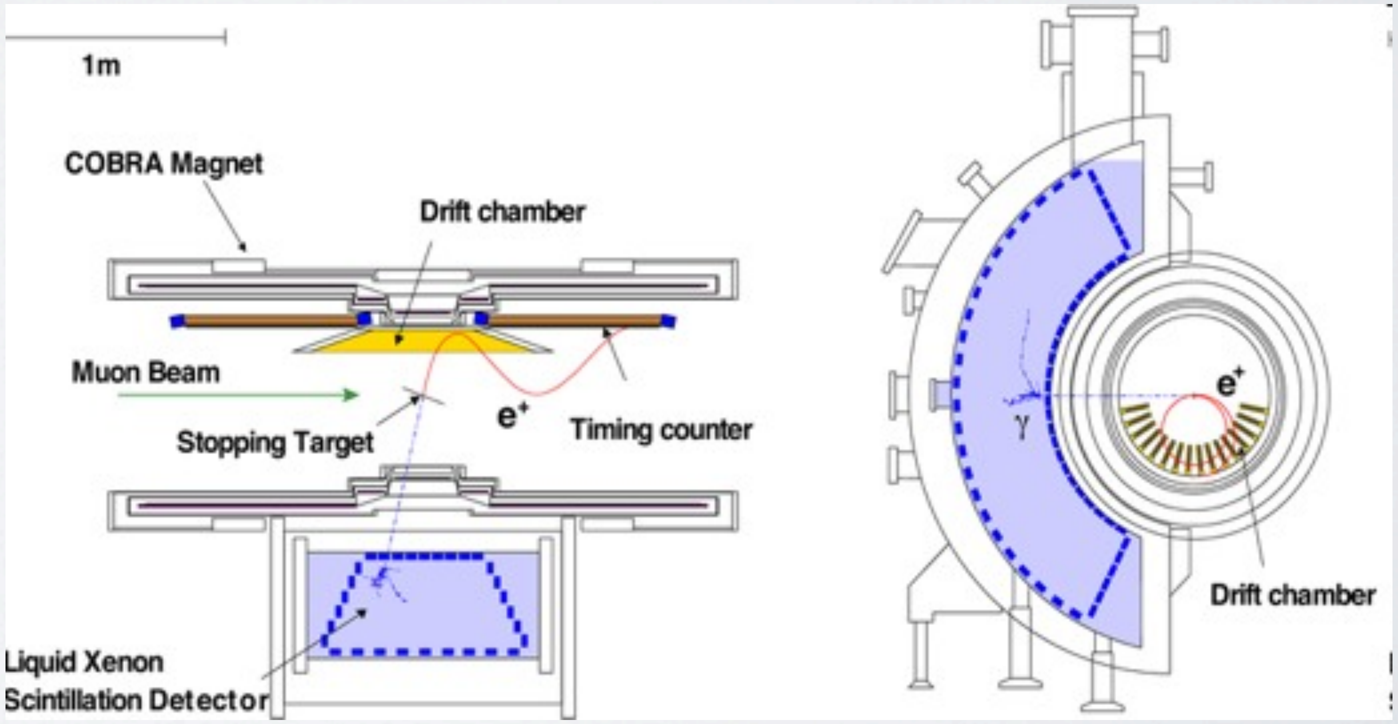
signal



backgrounds

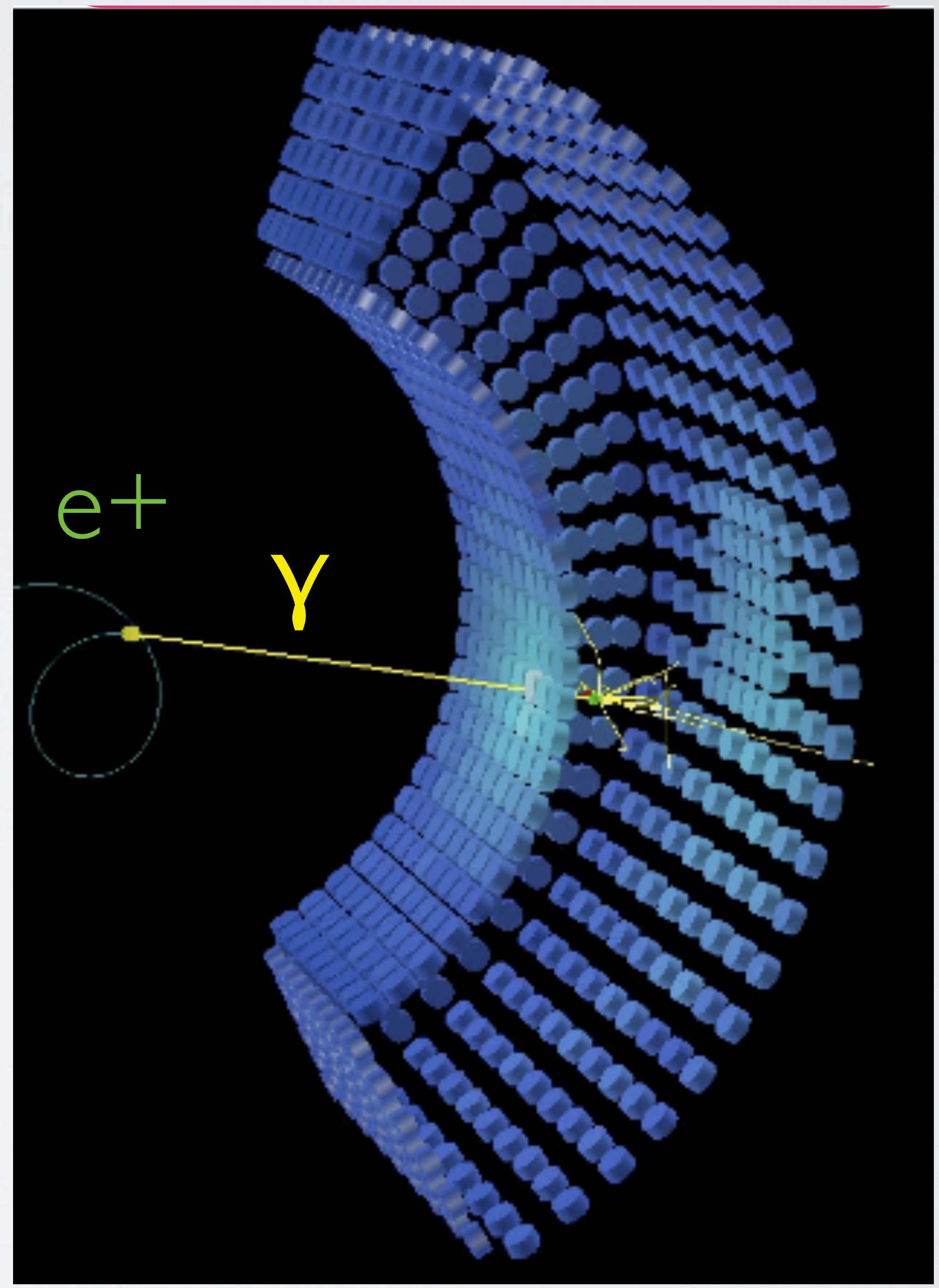


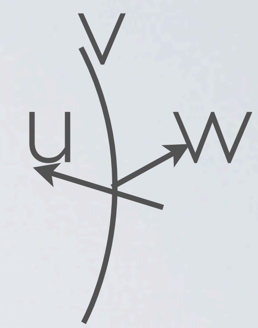
- **Target sensitivity : Br($\mu \rightarrow e\gamma$)~10^{-13}**



LIQUID XENON DETECTOR

- 900L liquid xenon
- 846 PMTs
-



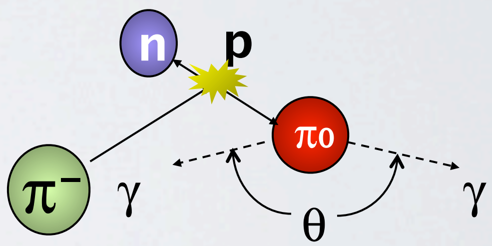


ENERGY RESOLUTION

- energy resolution key to sensitivity

$$R_{acc} \propto (R_{\mu})^2 * (\Delta\theta)^2 * (\Delta E_{\gamma})^2 * \Delta T * \Delta E_e$$

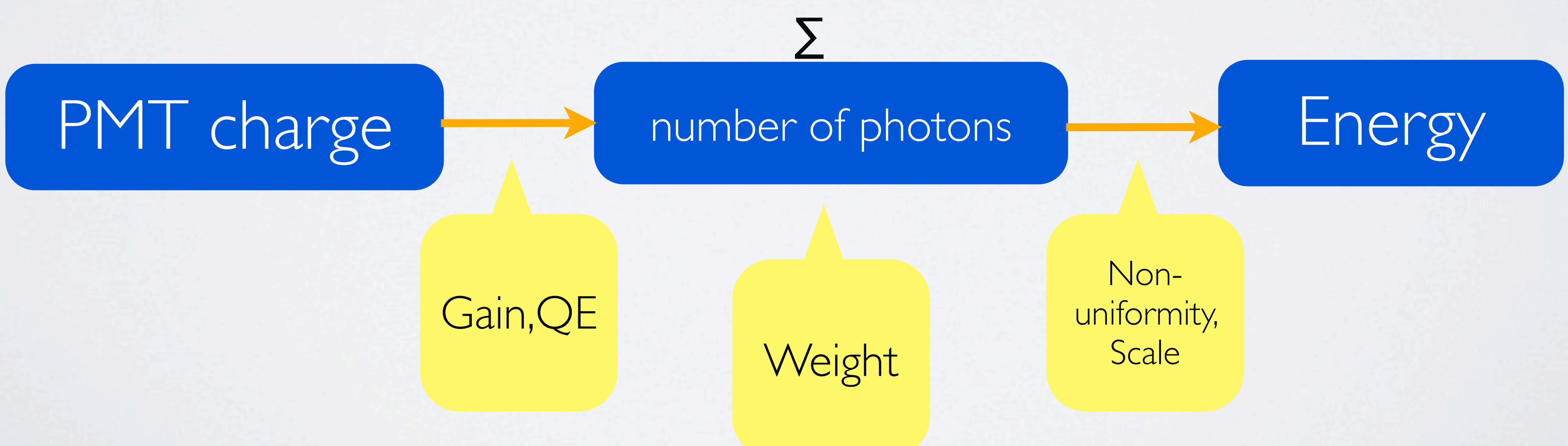
- evaluated with 55MeV γ from π^0 runs ($\pi + p \rightarrow \pi^0 + n$)



  - π^0 decay provides 55-83MeV γ ray
  - Monochromatic γ obtained by selecting back-to-back opening angle

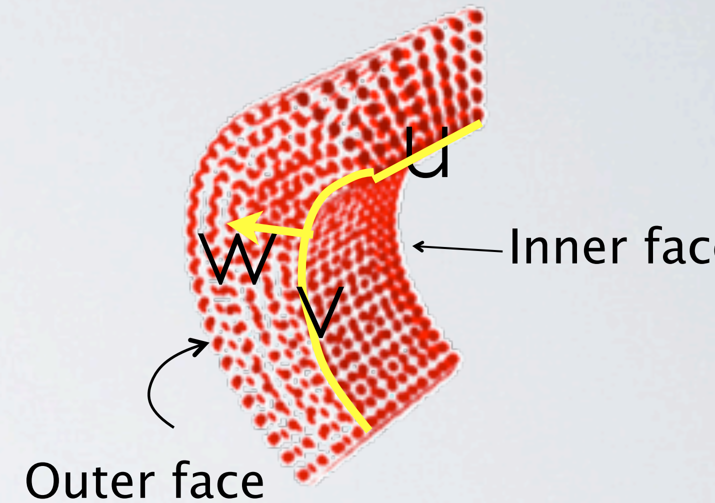
ENERGY RECONSTRUCTION

- weighted sum of scintillation photons $N = \sum Q_i / g_i / qe_i \times w_i$
- Energy scale determined at 55MeV in π^0 run
- correction in position (non-uniformity) and change in light yield



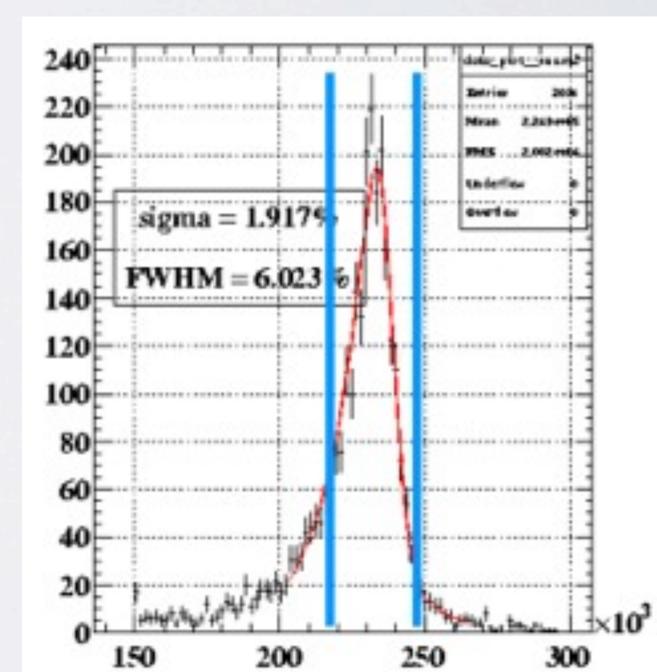
FACE FACTOR OPTIMIZATION

- Optimize weight factor of each face for each position

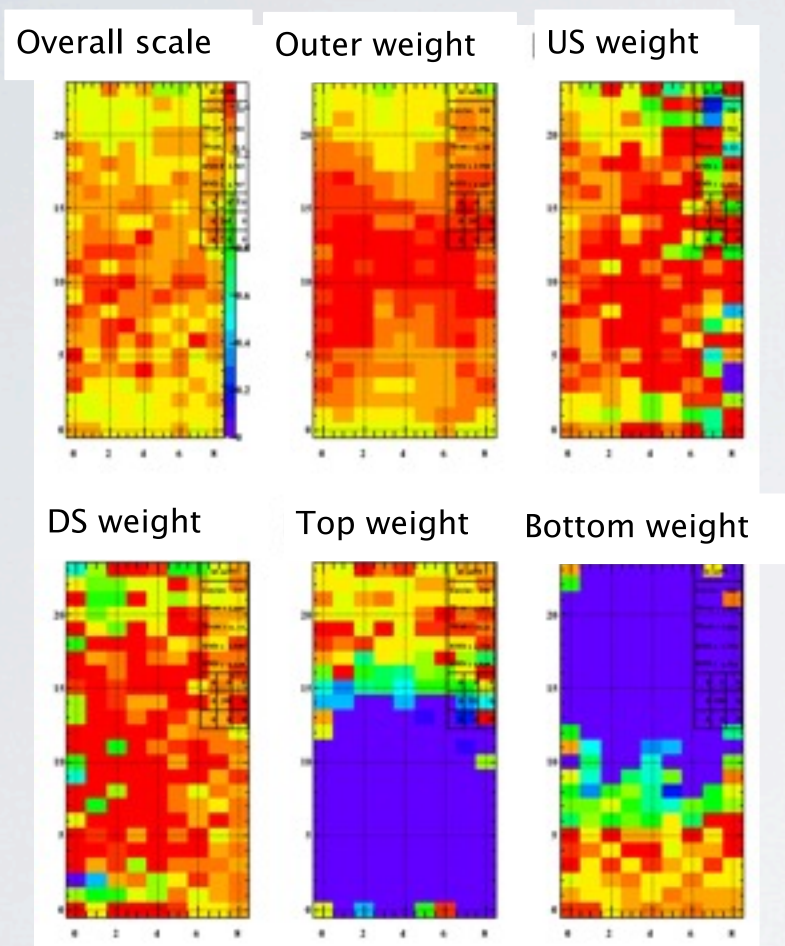


- Energy is reconstructed as a linear combination of each faces ($\sum w_i \times nface[i]$)

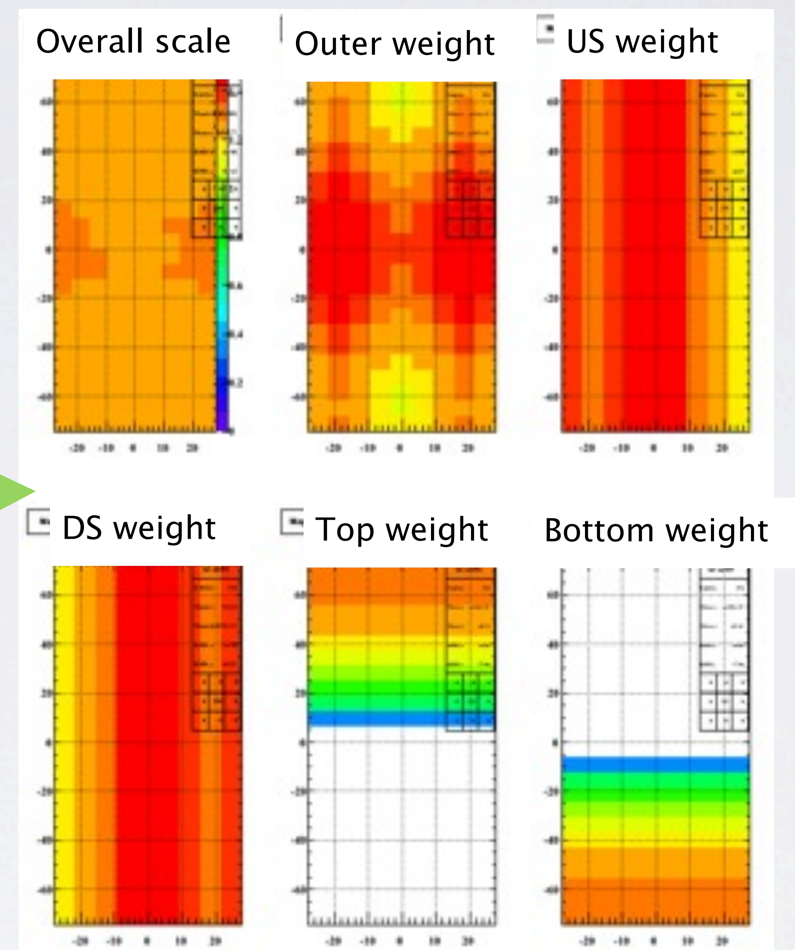
- Optimize by minimizing the variance in π^0 peak



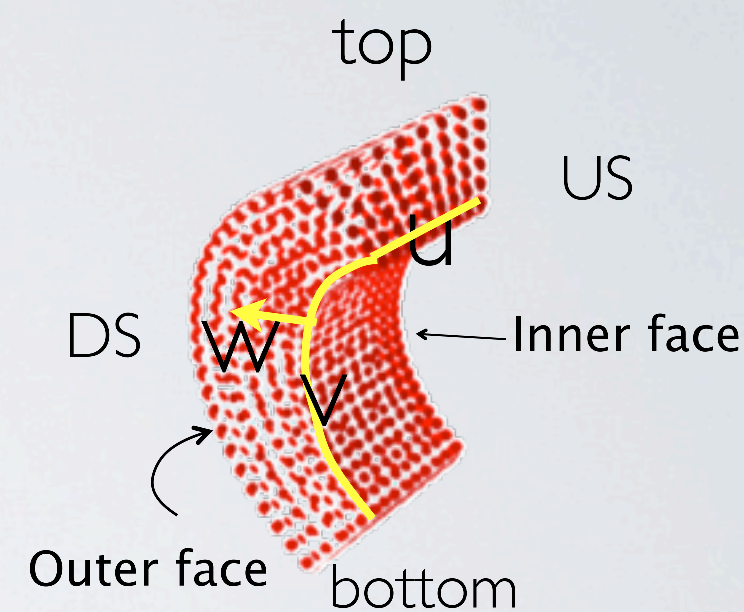
FACE FACTOR OPTIMIZATION



Optimize weights at each position

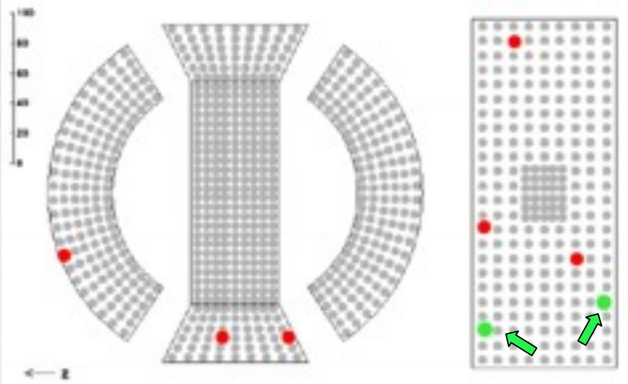


Parameterize weights and optimize at the same time

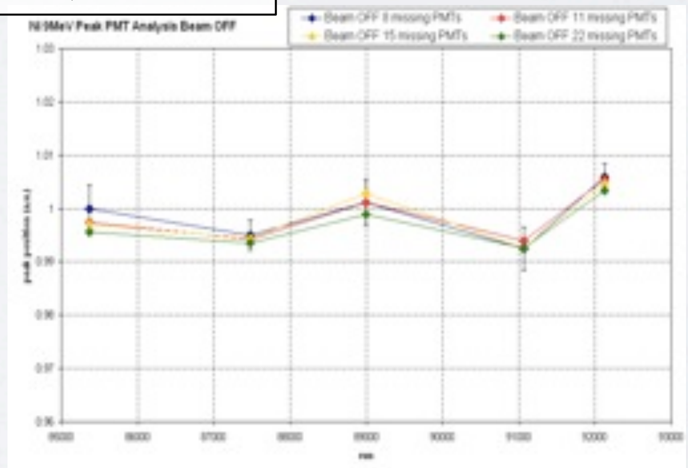


Dead Channel Recovery

- 8 PMTs in 2010
- No dead channels on inner face
- Little effect on resolution
- Apply correction so not to disturb uniformity and energy scale



Dead channel effect study with Ni9MeV
(artificially mask several PMTs)

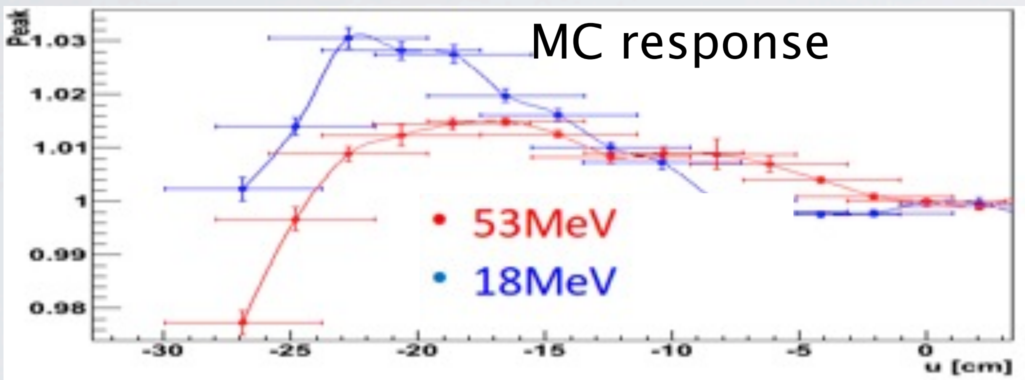


11 missing PMT:
-0.3 %
15 missing PMT:
-0.6 %
22 missing PMT:
-1.3 %

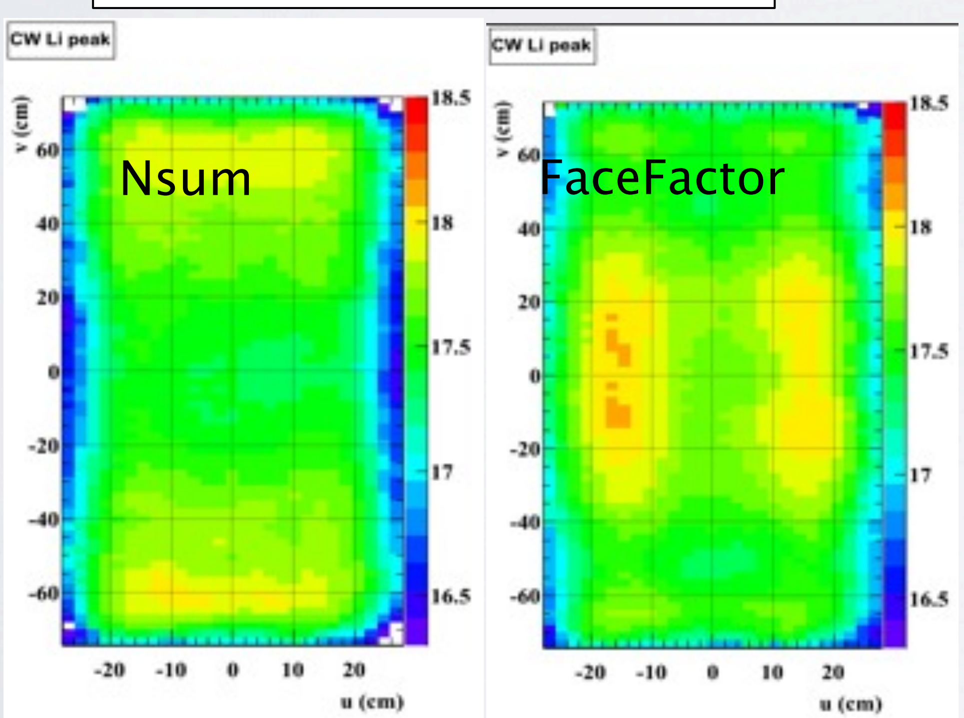
NON UNIFORMITY CORRECTION

- Correct position dependent detector response
- Calibration with CW-Li peak and π^0-55MeV peak
- Depth correction with π^0 peak
- position correction with CW-Li peak
- Included additional position correction with π^0-55MeV peak
- Remaining non-uniformity ~0.2%

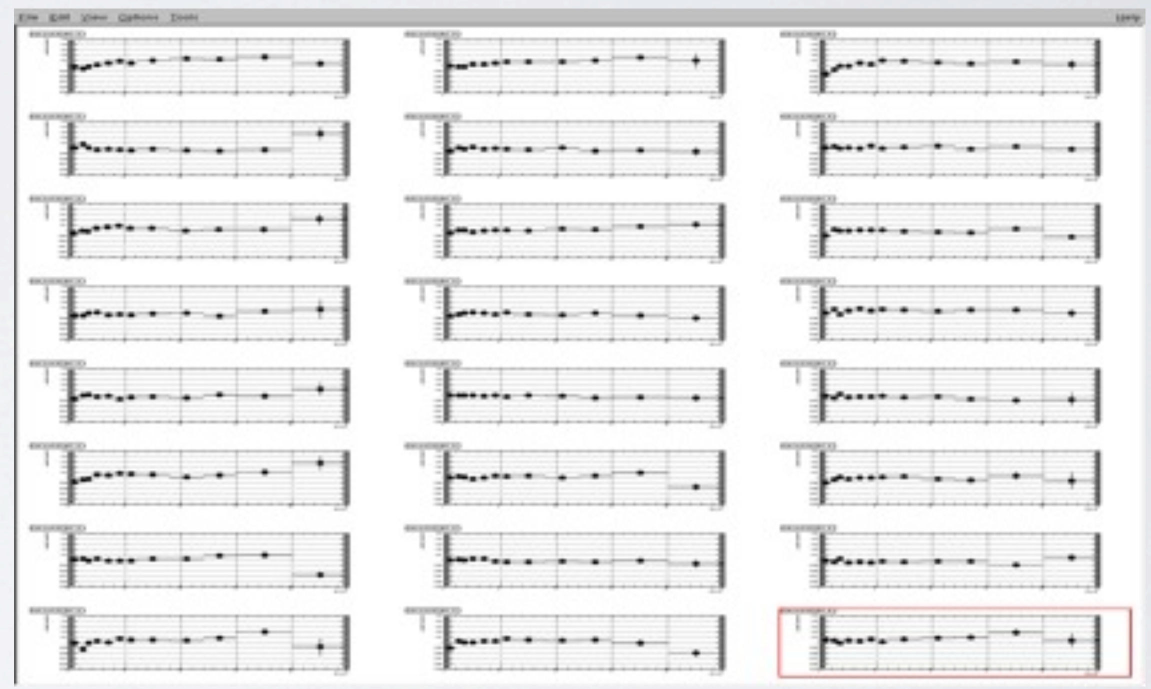
- **Cockcroft–Walton accelerator**
  - Nuclear reaction by protons
  - Li(p, γ)Be 14.6,17.6MeV
  - B(p, γ)C 4.4, 11.7MeV



Response to the CW-Li peak



Depth correction functions for different position



Alternative Energy Reconstruction

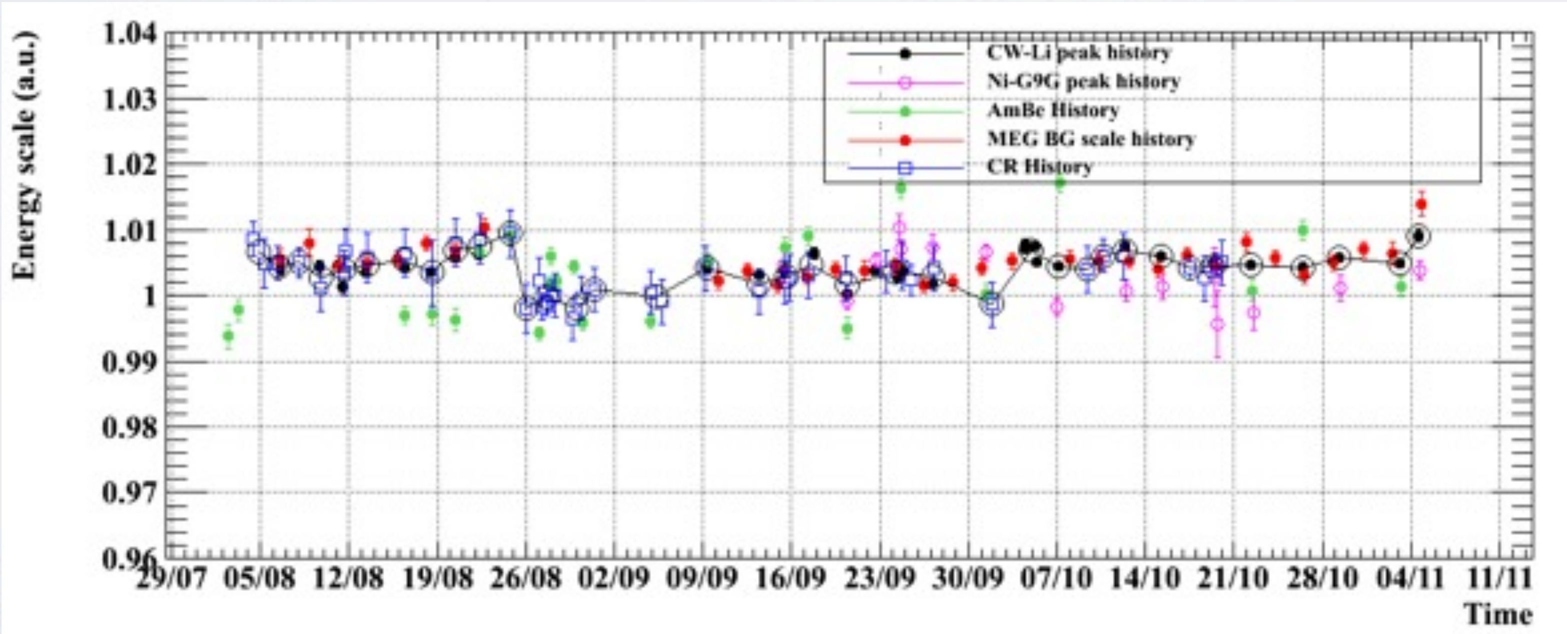
- Treat each PMT as a detector and fit energy for each PMT
- Calculate event energy from tube energies
    - weighted mean energy of truncated distribution
- Correction table for gain×QE is prepared from output of PMT for each event
- Potential advantages:
    - can optimize PMT selection
    - insensitive to vast variations in solid angles subtended by nearby PMTs

ENERGY SCALE TIME VARIANCE

- Light yield monitored with several calibration sources(CW 18MeV γ, Ni 9MeV γ, AmBe 4.4MeV γ, cosmic ray peak)

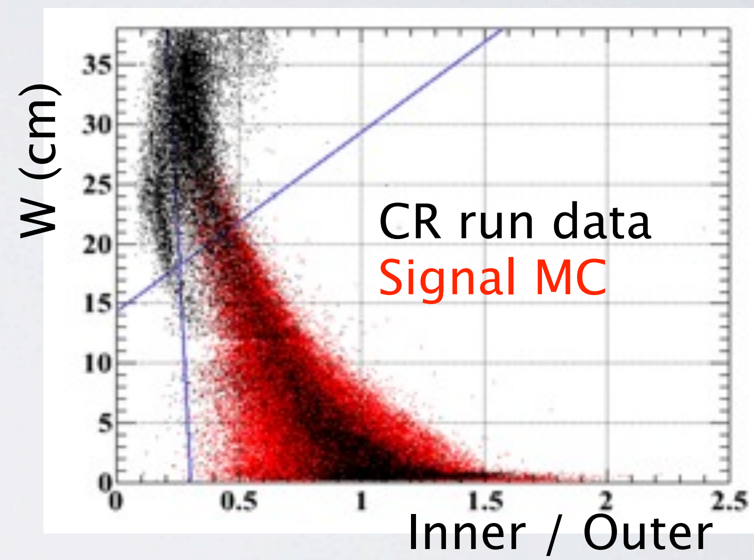
- While each has good stability(0.2%), they show the same trend

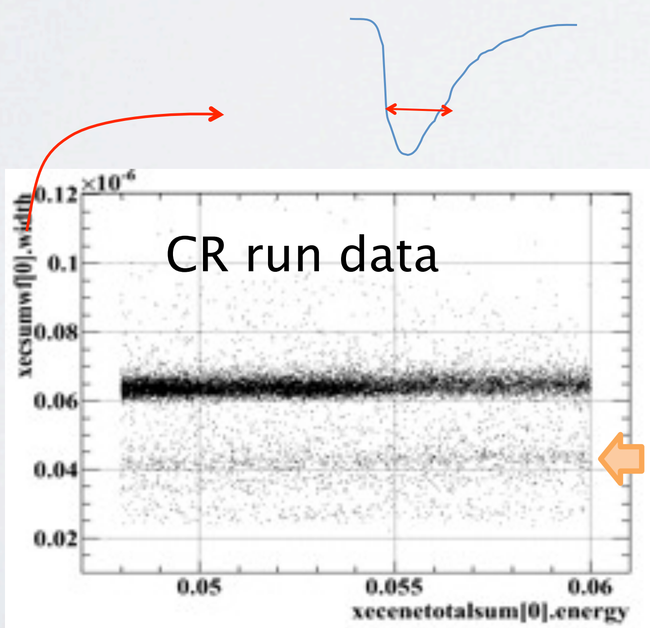
- Time-dependent correction by combination of calibrations

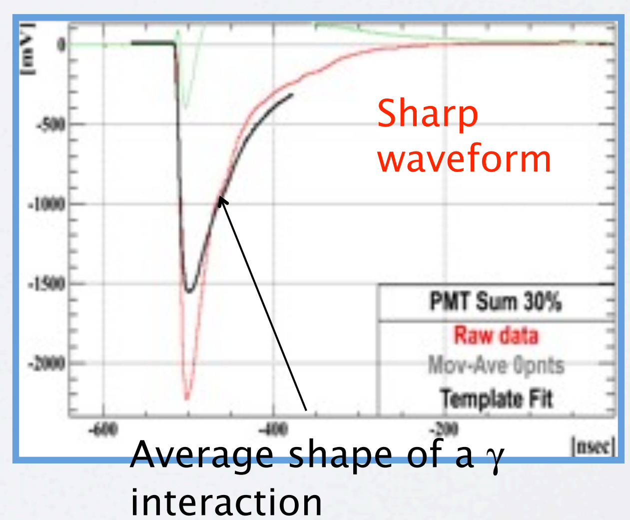


COSMIC RAY REJECTION

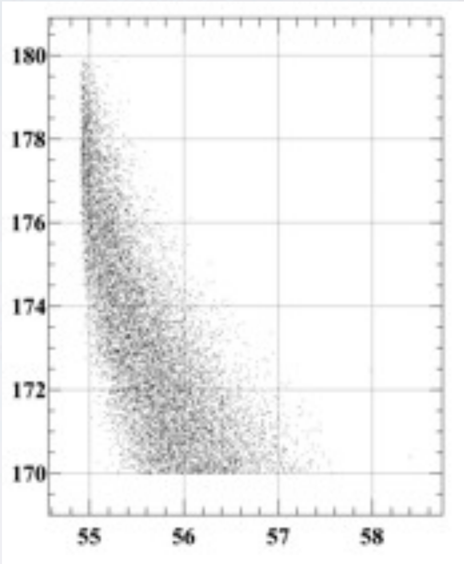
- Cosmic rays that enter from inner face and stop in LXe volume can be accidental background.
- Cut on ratio of inner and outer charge
  - Rejection optimized at 1% inefficiency (from MC signal)
- Introduced additional cut using waveform (inefficiency<0.1%)

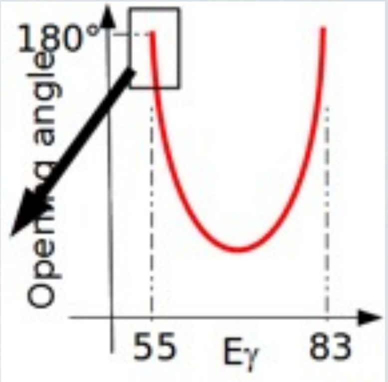






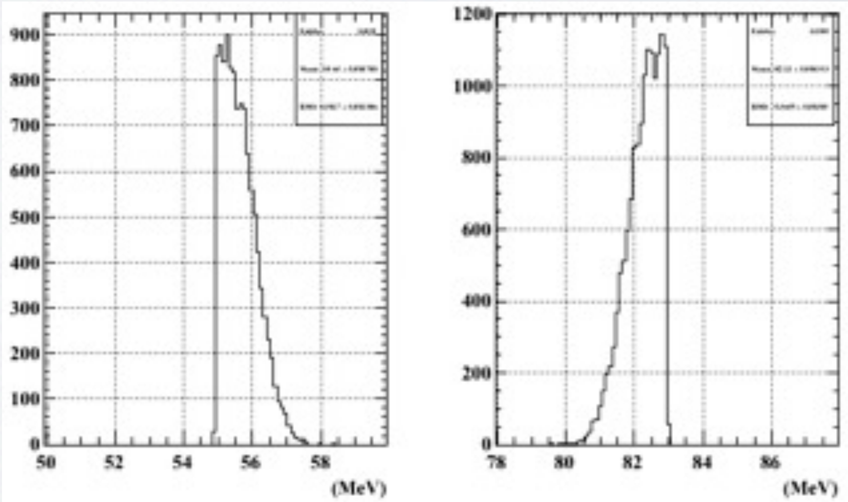
OPENING ANGLE EFFECT





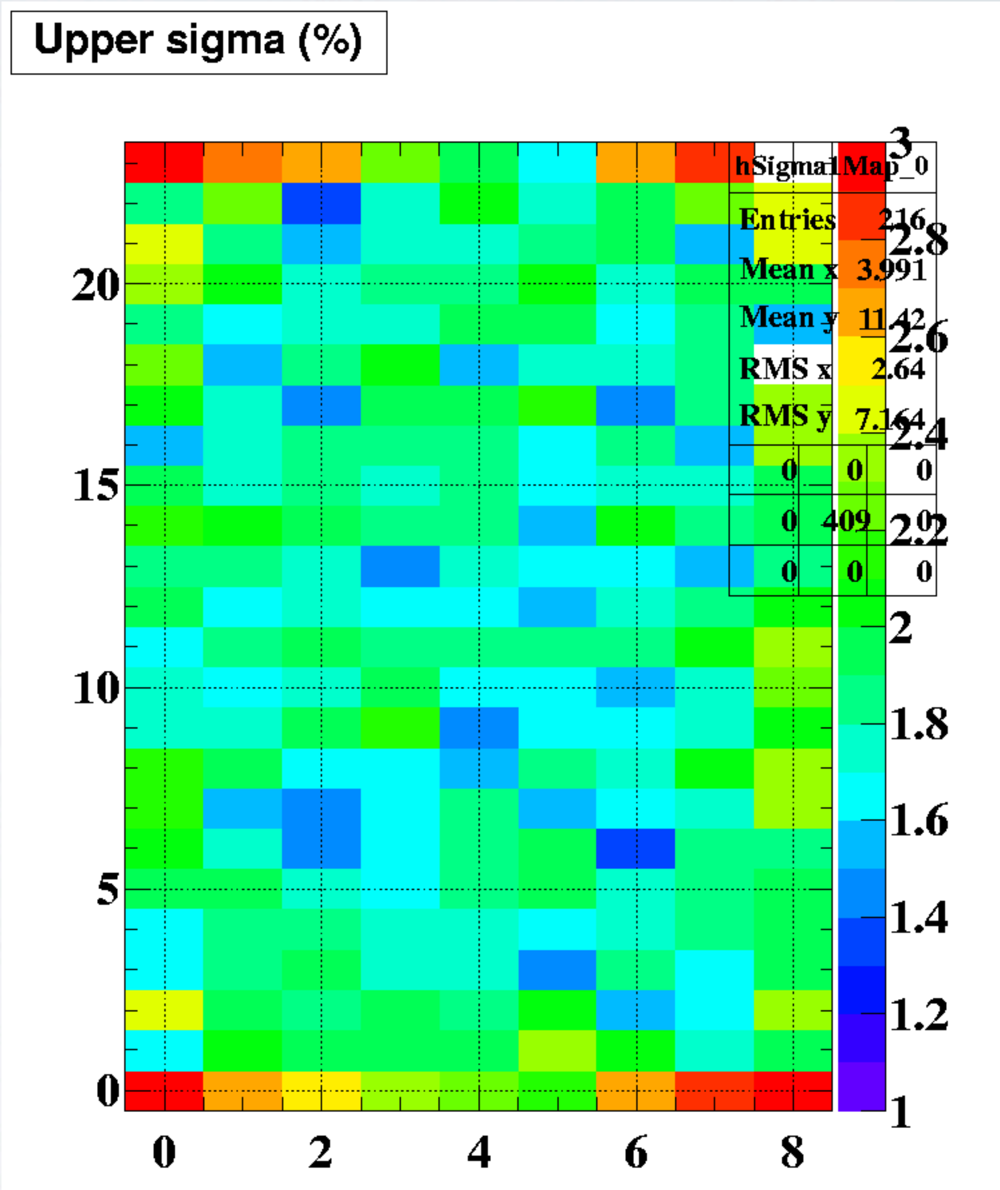
- We choose back to back events in π^0 runs
- Estimate opening-angle effect with data & MC, and unfold the contribution
- Actual resolution is better than the measured by ~0.15%

True Eγ distribution after cut by reconstructed opening angle > 170°



PERFORMANCE

- resolution before: ~2%
- current resolution: 1.9%



SUMMARY

- Energy resolution improved by introducing several new corrections
    - face factor optimization
    - non-uniformity
    - light yield correction
    - CR rejection
    - Opening angle effect
- Alternative energy reconstruction method studied
- Future improvements possible