MEG実験2008 光電子増倍管量子効率測定の改良

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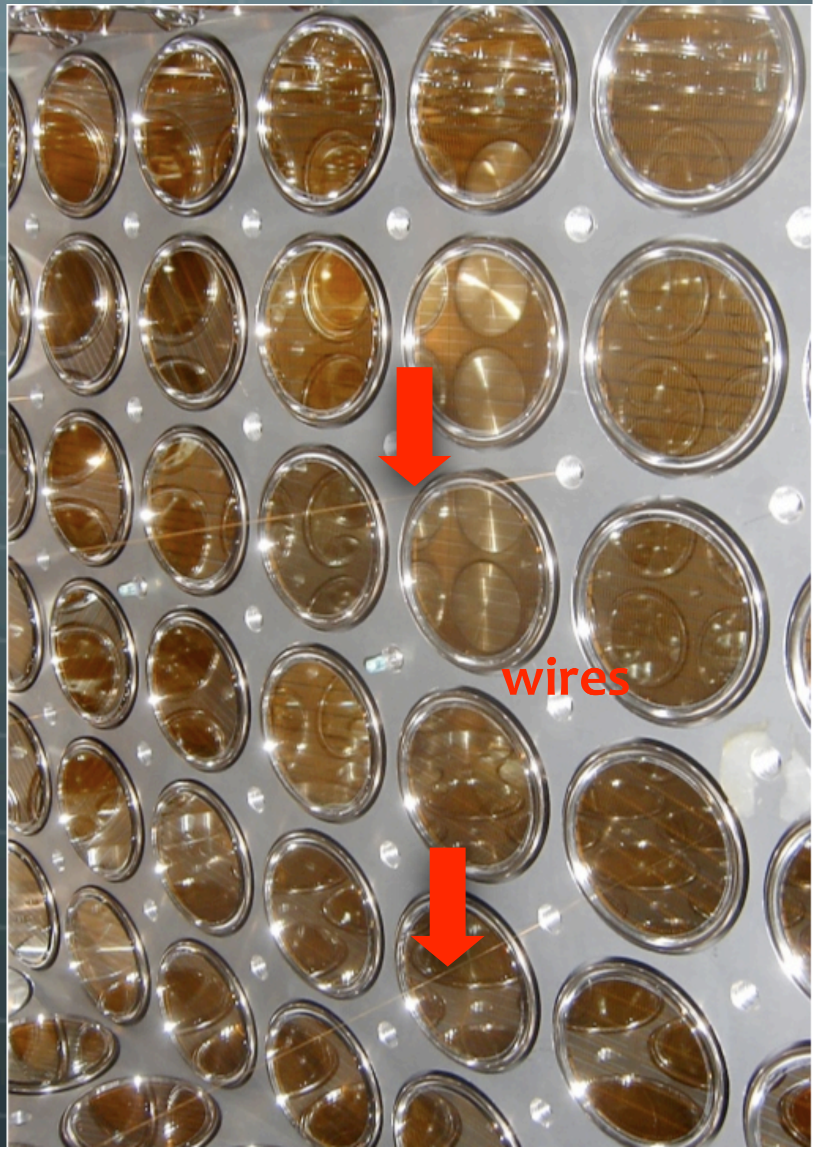
Contents

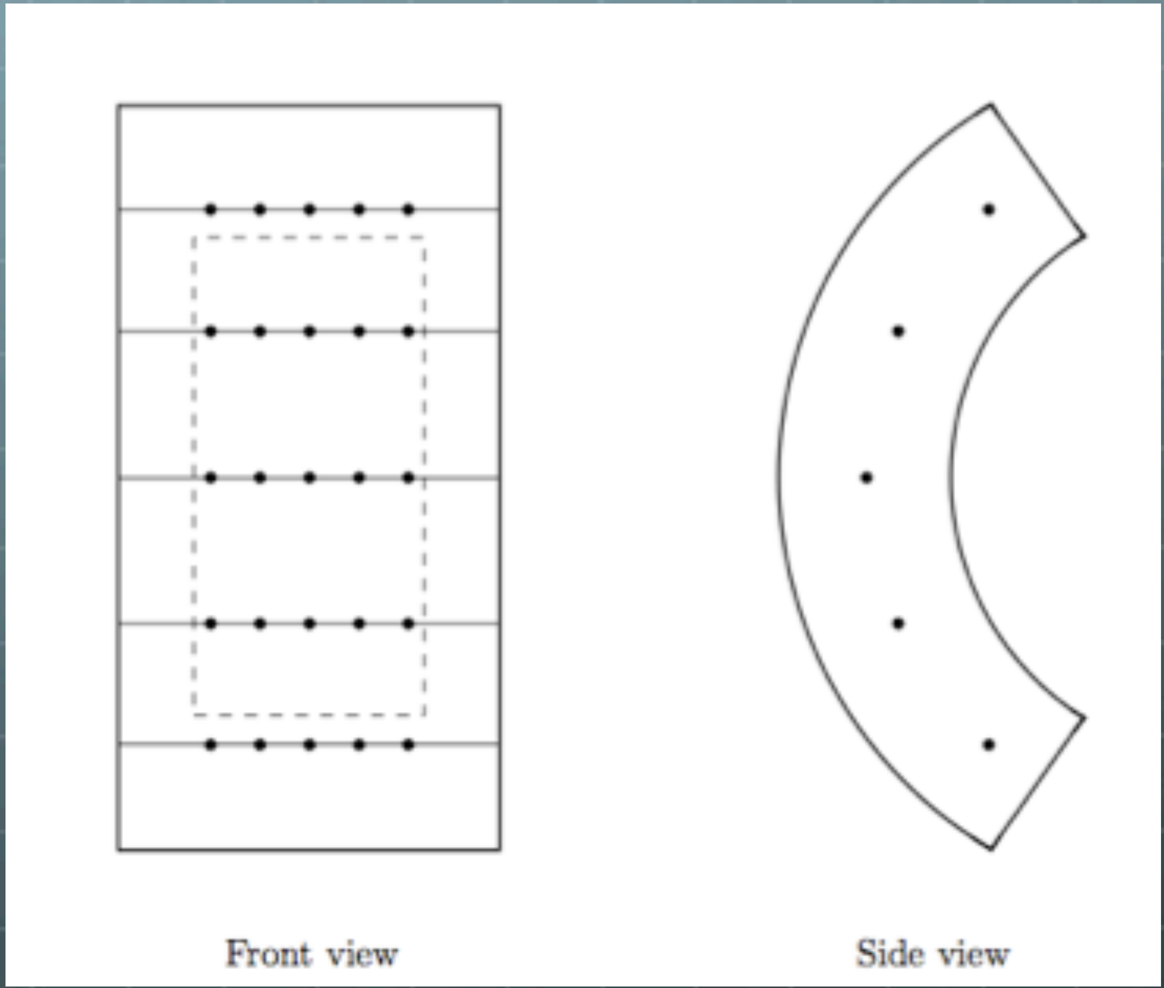
- Introduction
- Application of Q.E. correction
- Method of Calculating Q.E.
- Study on improving accuracy of QE measurement
- Summary

QE Measurement

- Alpha (241Am) is used as light source for QE measurement
- Alpha sources are put on wires, each of the size 1mm
- Diameter of a wire is 100μm

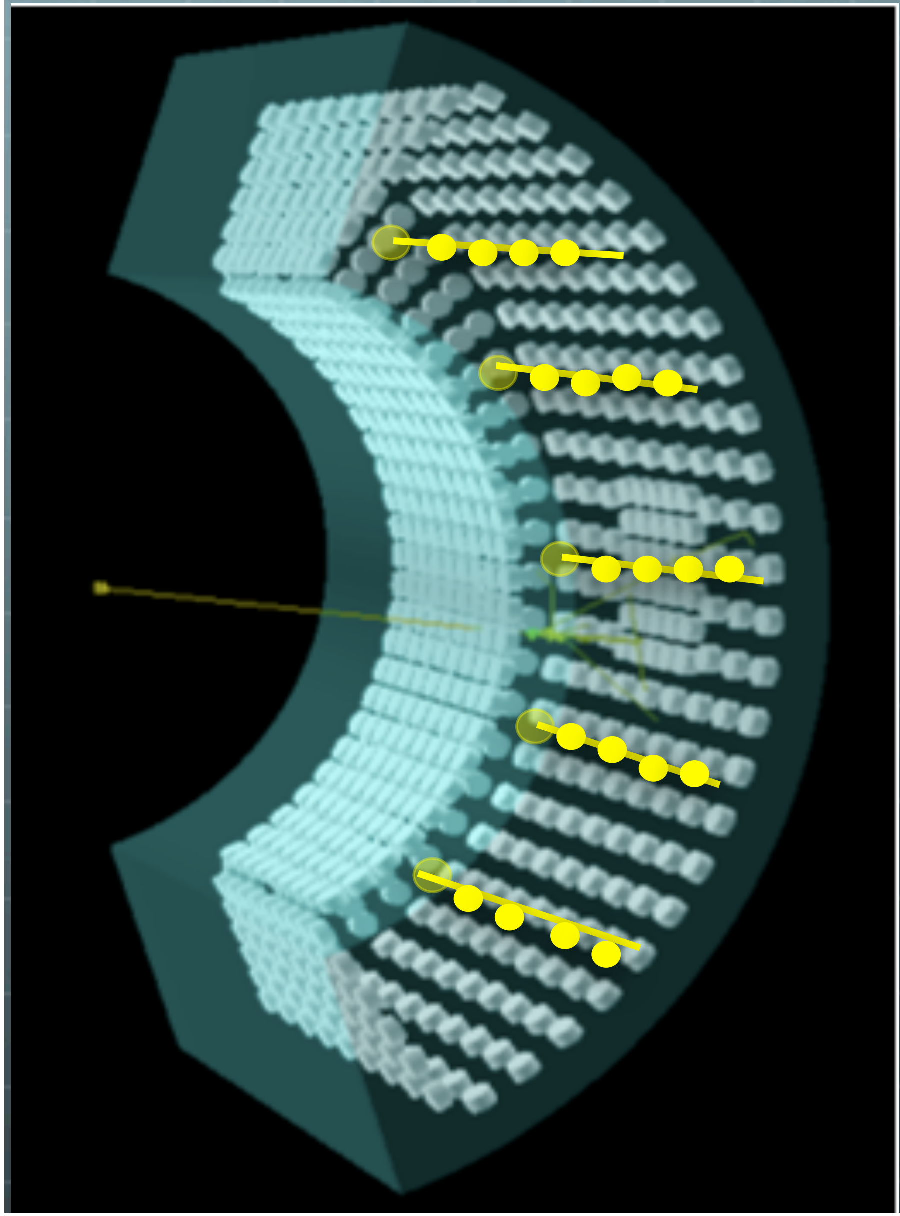


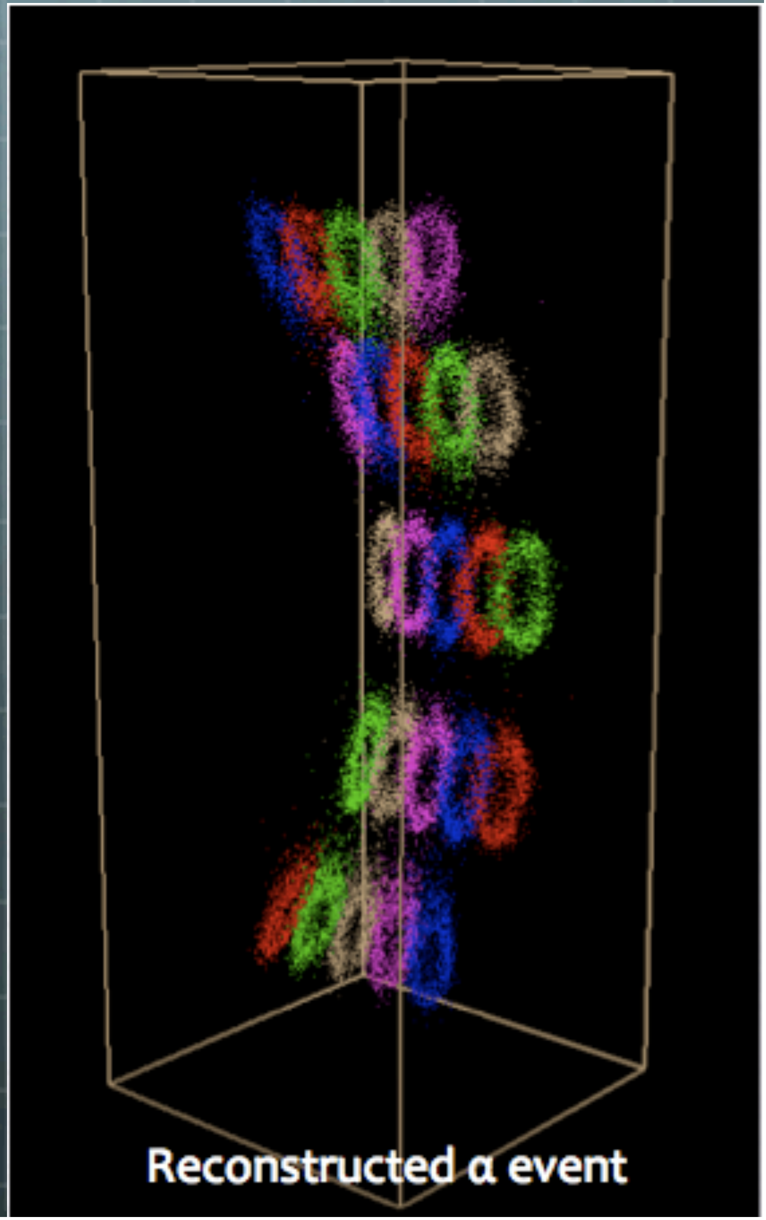
- A total of 25 sources are installed



Positions of alpha sources in the detector.

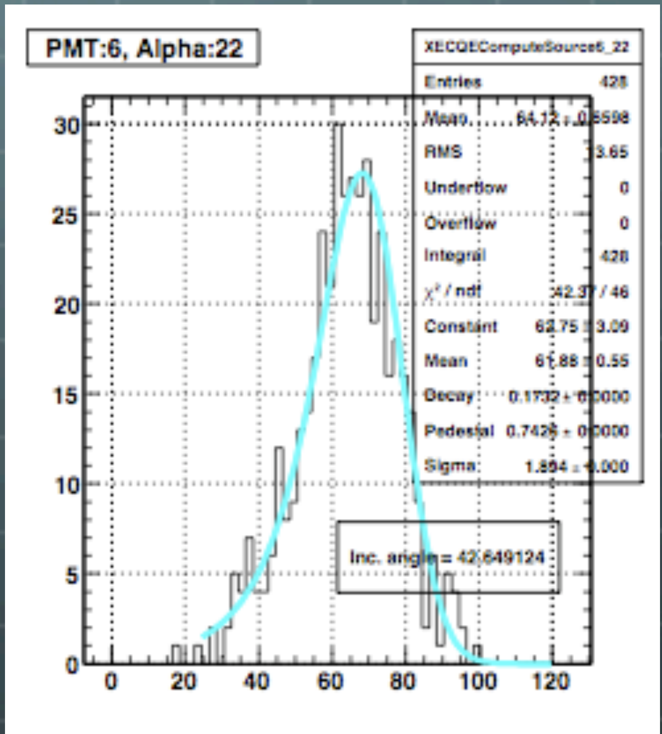
Positions of alpha sources and reconstructed alpha event.

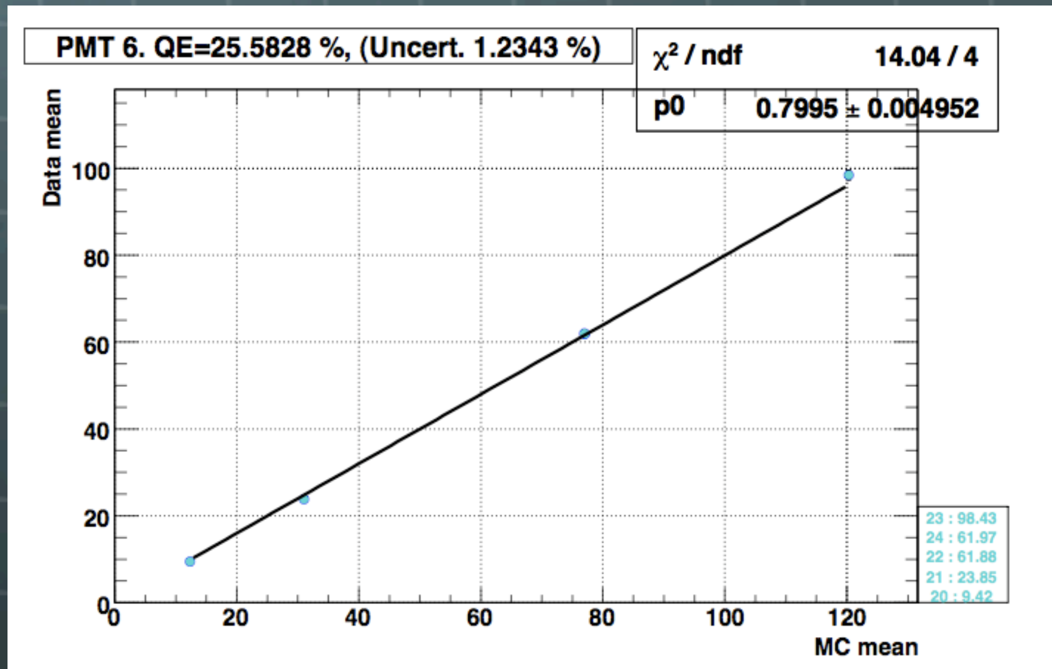




Method of Calculating Q.E.

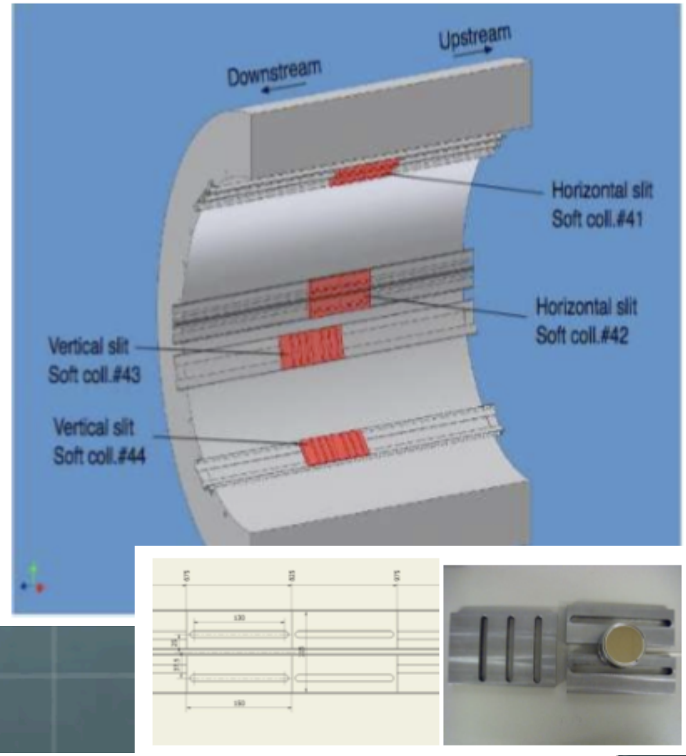
- Q.E. is measured by comparing the charge spectra from a given alpha source with those from simulation
- The outcome of such simulation depends largely on the optical properties of the liquid xenon, such as absorption length, scattering length, refractive index of scintillation light
- To fit the charge spectra from a certain alpha source, an exponential function convoluted with a Gaussian is used
- Q.E. can be calculated in gas xenon and liquid xenon; each method has certain drawbacks

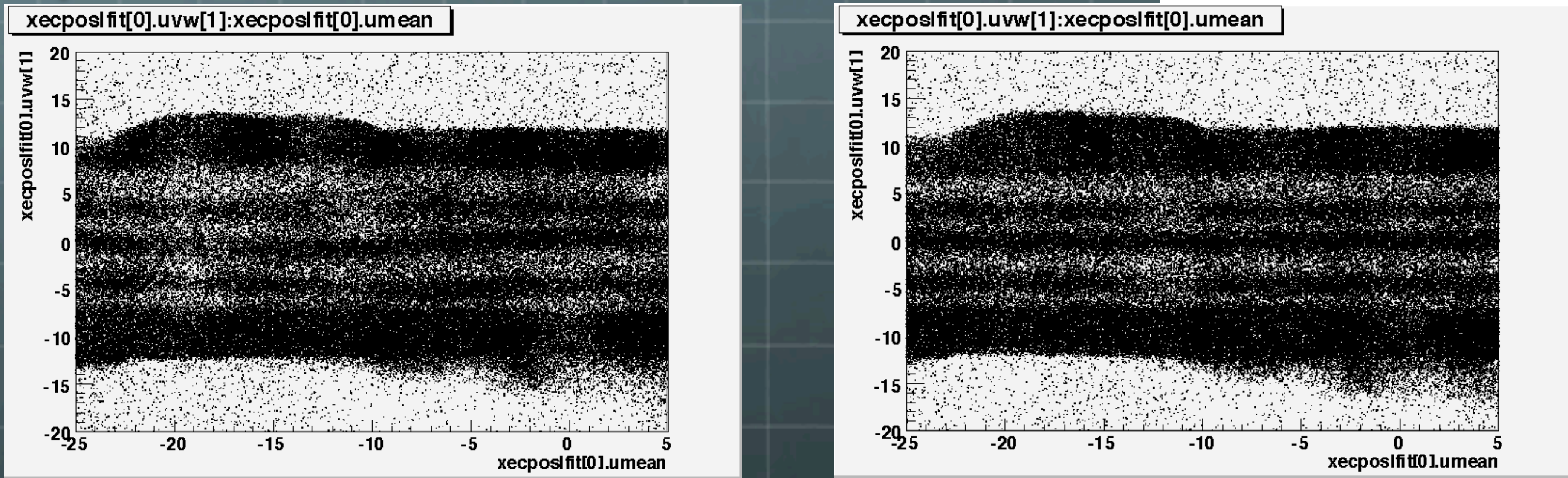




Application of Q.E. correction

- **Position resolution in π0 calibration improves after Q.E. correction.**
- **Gamma rays (55MeV, 83MeV) from π0 decays produced by charge exchange reaction were used to estimate responses of the liquid xenon detector**
- **Pb collimators are prepared for estimation of position reconstruction and resolution.**

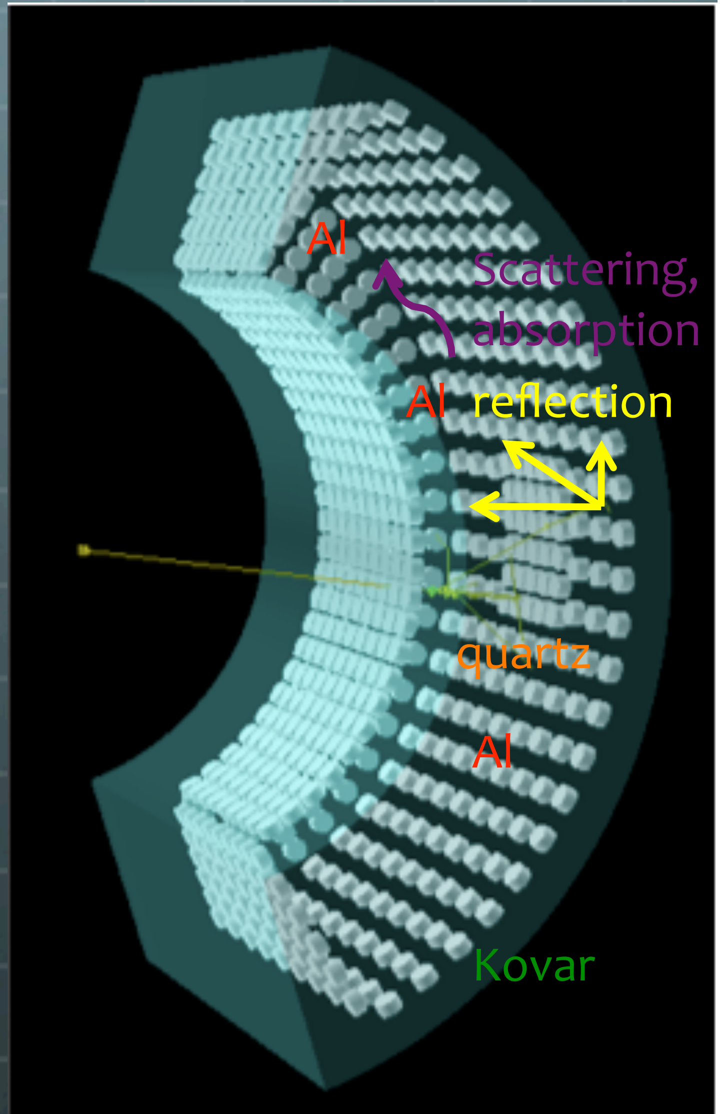




2D reconstructed position distribution of one Pb collimator before (left) and after (right) applying QE correction

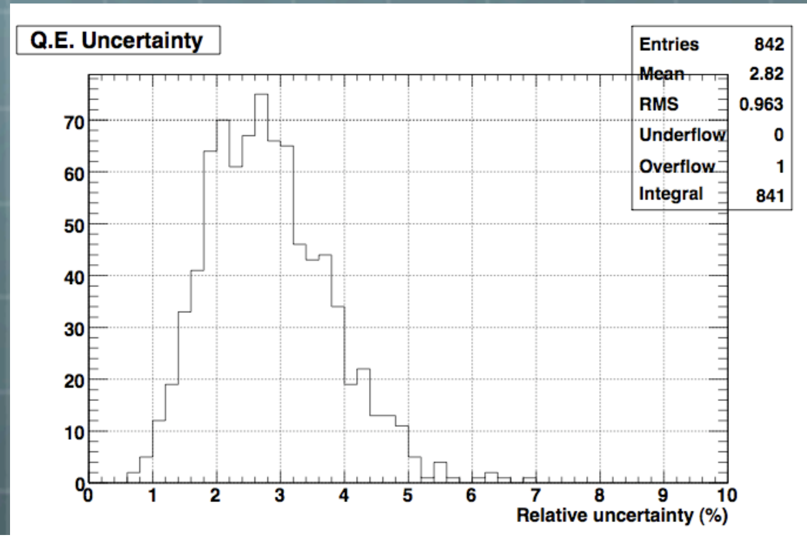
Challenges of Q.E. Calculation

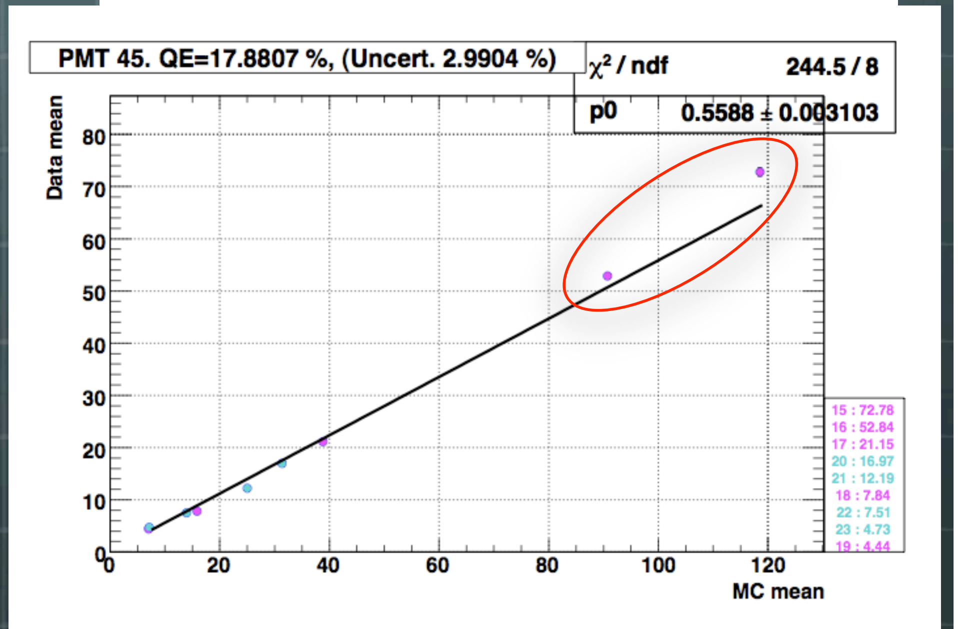
- VUV
- Optical properties of liquid xenon are not thoroughly known yet
- Several optical processes such as Rayleigh scattering, absorption by impurities, reflection on walls or PMT windows, transmittance of PMT window and efficiency of photoelectric effect on cathodes
- Reflection on various materials (PEEK, Kovar, Quartz, Aluminum, etc)
- Proximity of refractive index of xenon and quartz
- For large incidence angle, more complicated processes may occur that are difficult to fully understand



Study on improving accuracy of Q.E. measurement

- Accuracy evaluated by Q.E. Uncertainty
- Current uncertainty ~2.83%
- Uncertainty arises from discrepancy between data and simulation
- The nonlinearity is largely due to the inconsistency with MC, i.e., lack of knowledge of the LXe properties



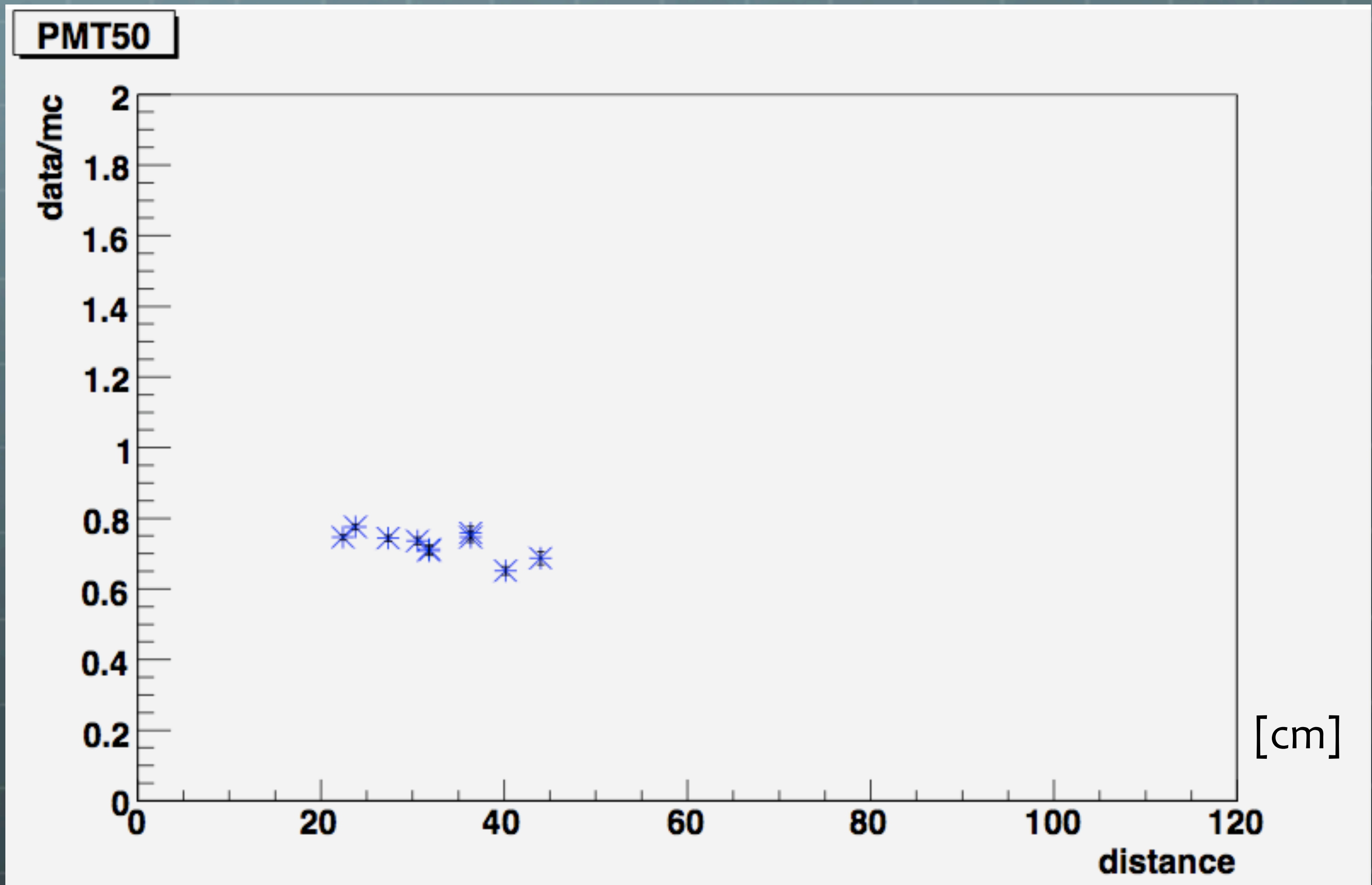


Factors in simulation

Parameter	Value(for λ=178nm)
Refractive index of liquid xenon	1.61
Wavelength	178nm
Rayleigh scattering length	45cm
Absorption length	∞
Reflection on PEEK	0.10
Reflection on Aluminium	0.2
Reflection on KOVAR	0.2
Refractive index of quartz	1.62
Transmittance rate of quartz	0.8

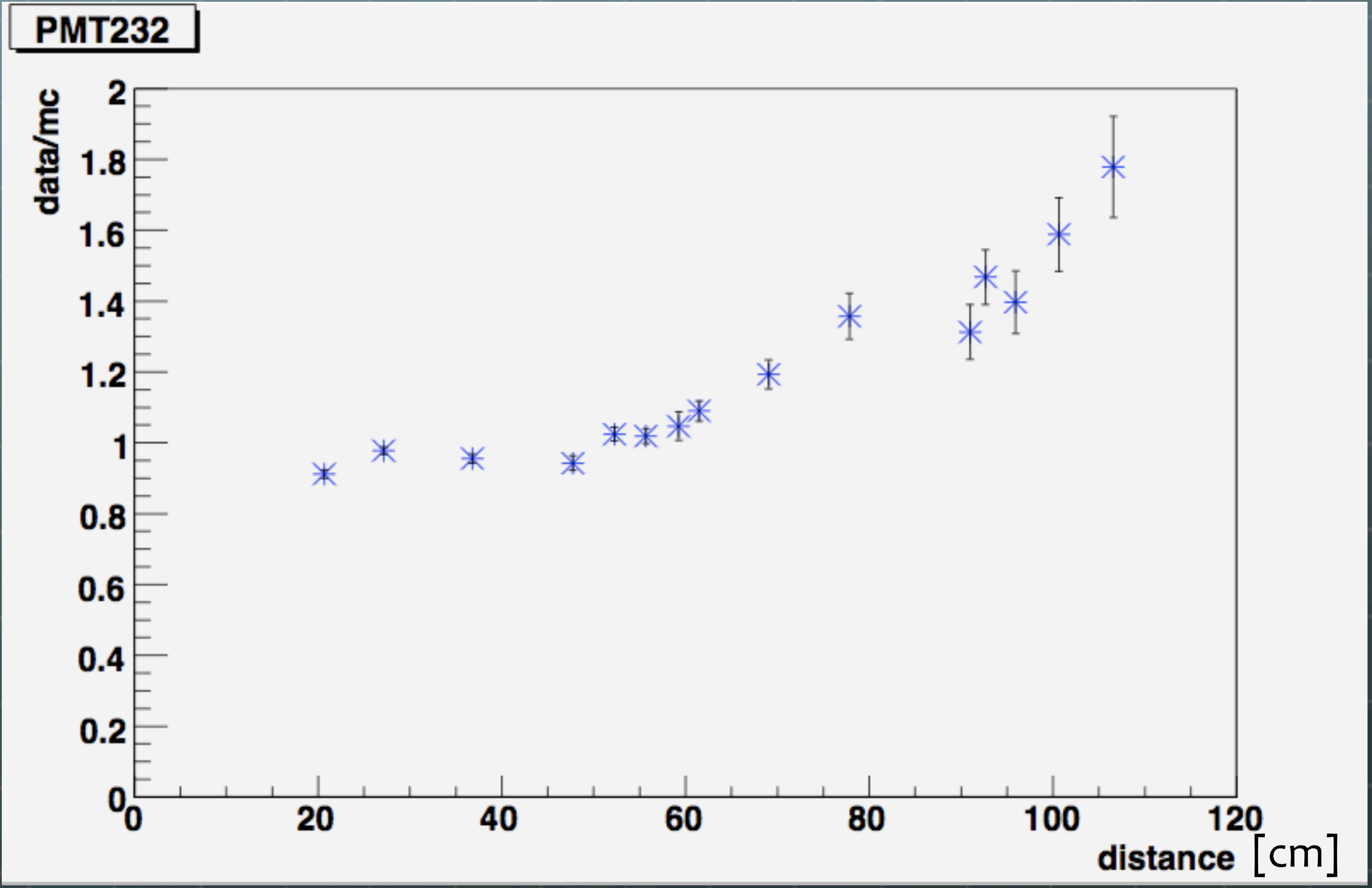
Correlation btw data/MC and distance (inner PMT)

When distance is small (<60cm), the data/MC ratio remains relatively constant except for large incidence angles.



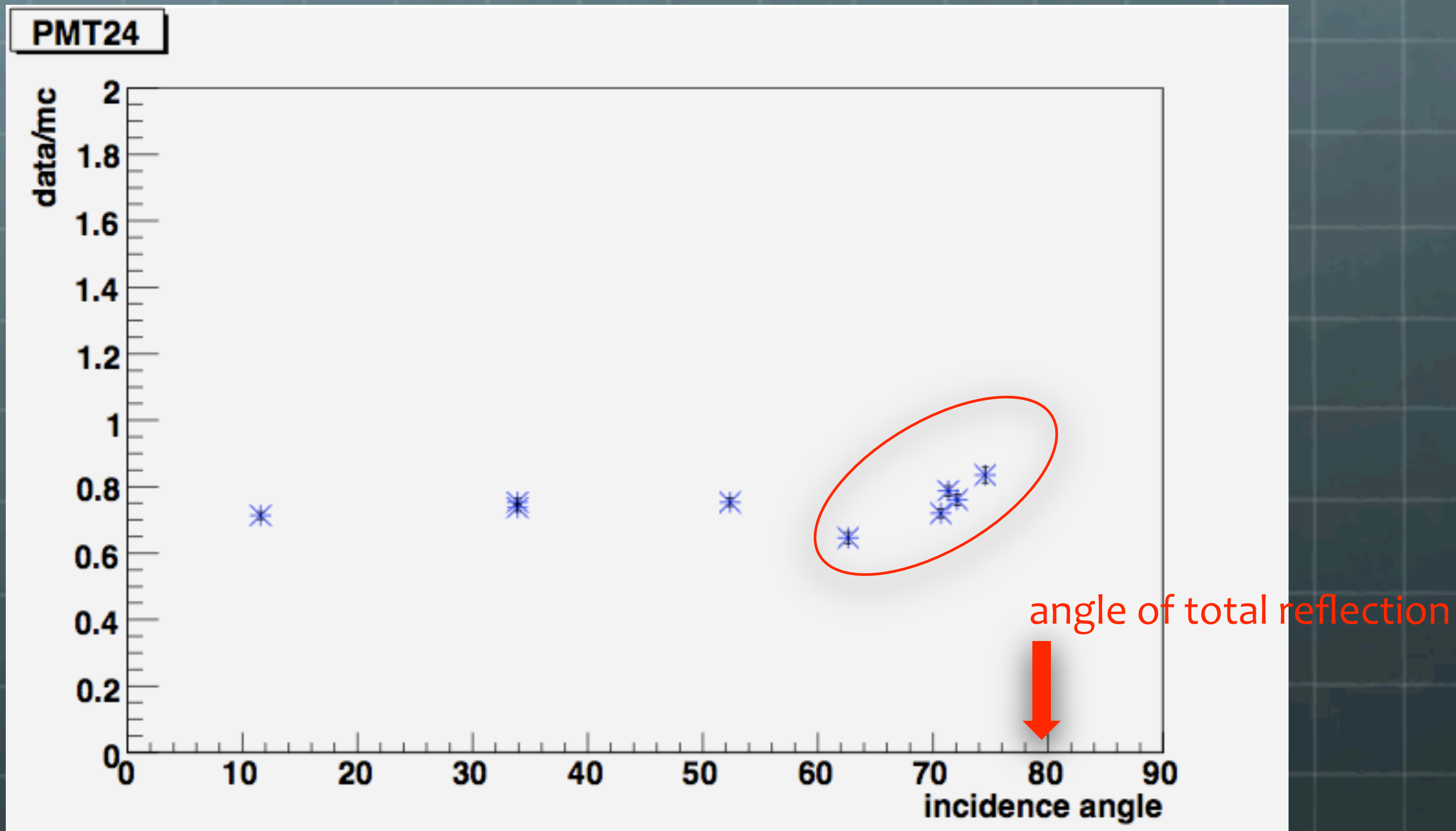
Correlation btw data/MC and distance (outer PMT)

When the distance is large (> 60cm), the data/MC ratio increased in relation to distance drastically.



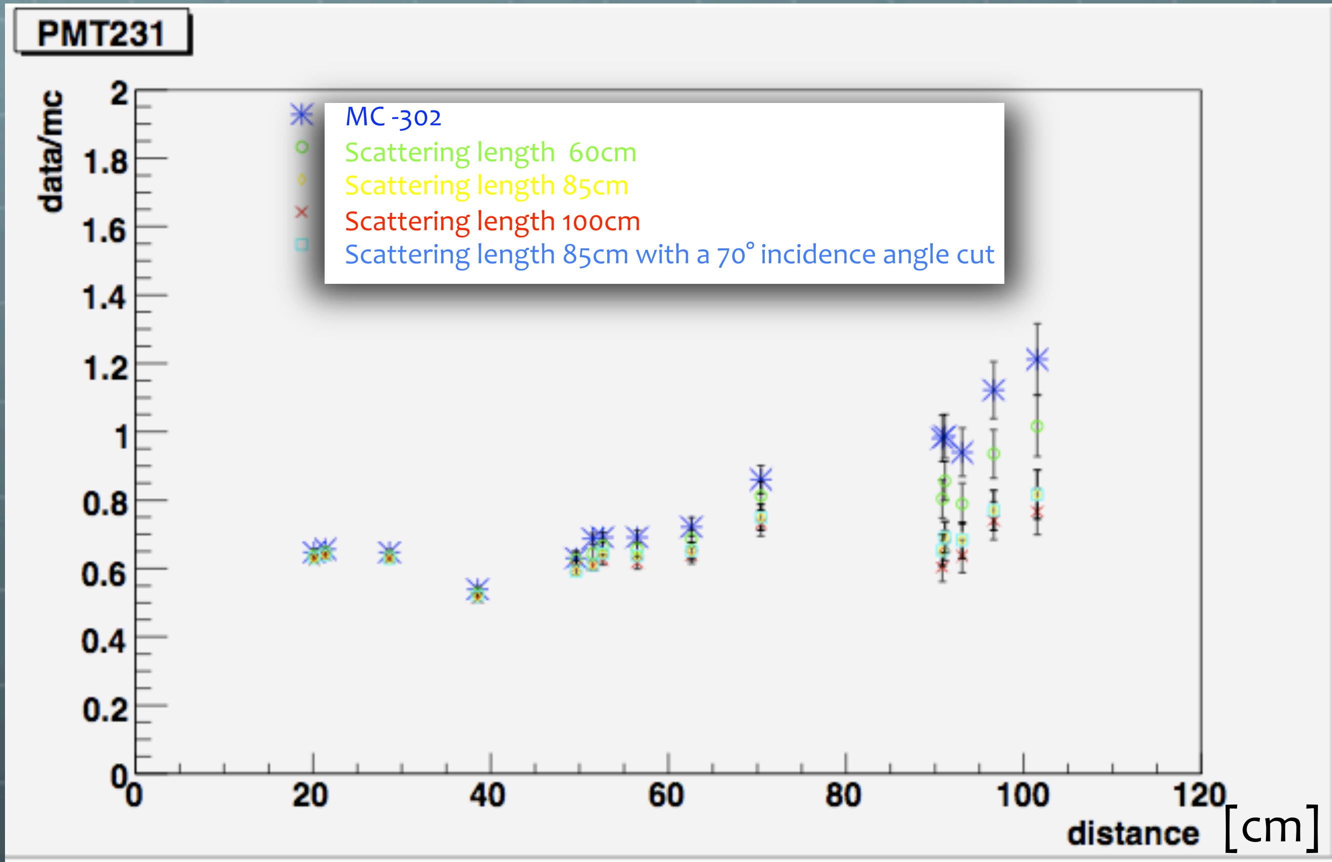
Correlation btw data/MC and incidence angle

For large incidence angles, there appears to be a slight drop followed by a slow rise in relation to incidence angle (>60°)



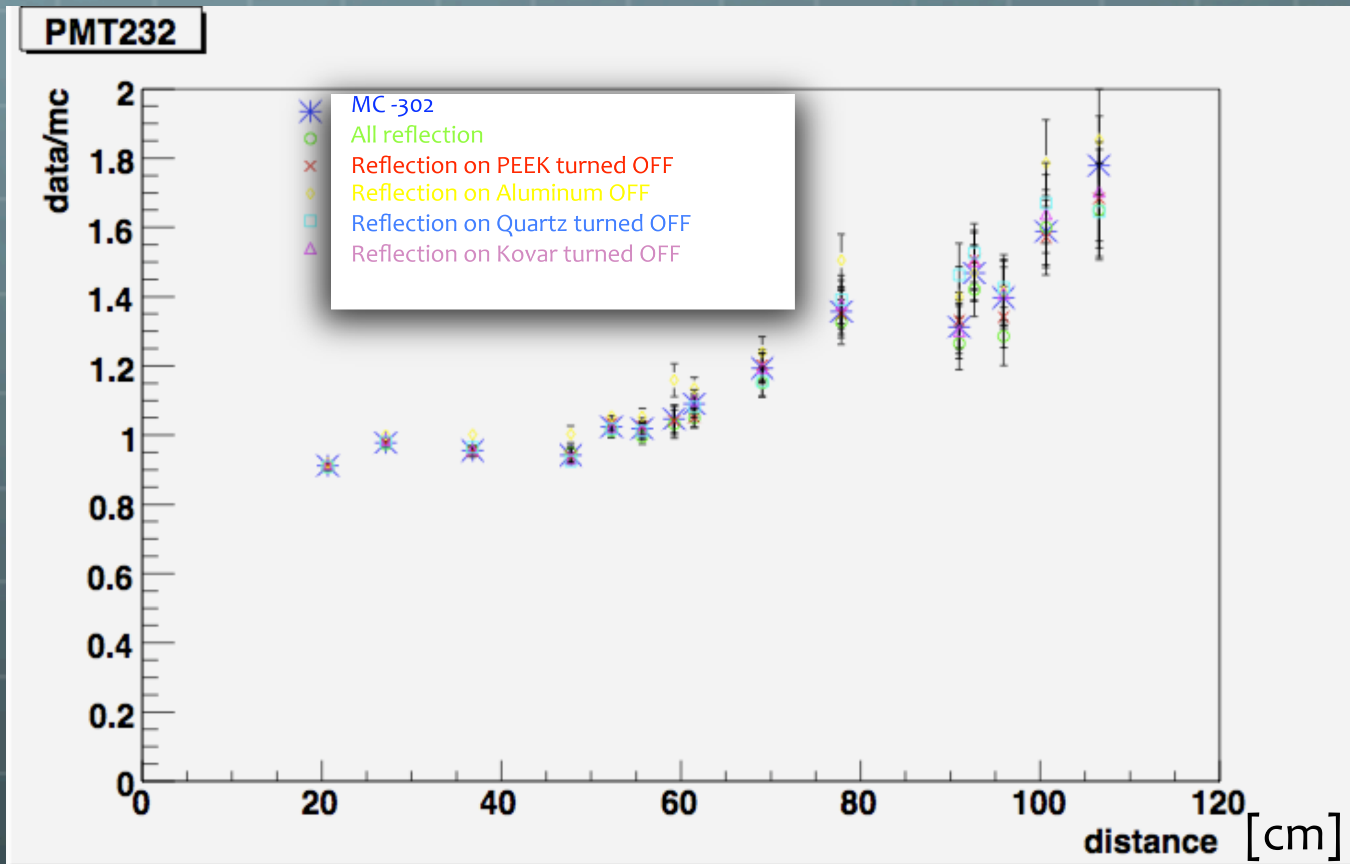
- A set of Monte Carlo simulation was made by increasing scattering length and turning off or increasing reflection from each material (quartz, Kovar, peek, aluminum, cathode)
- 100000 events were created for each setting
- Comparison between these settings and the default one (MC -302) is shown in the following figures

Data/MC vs distance with different scattering lengths



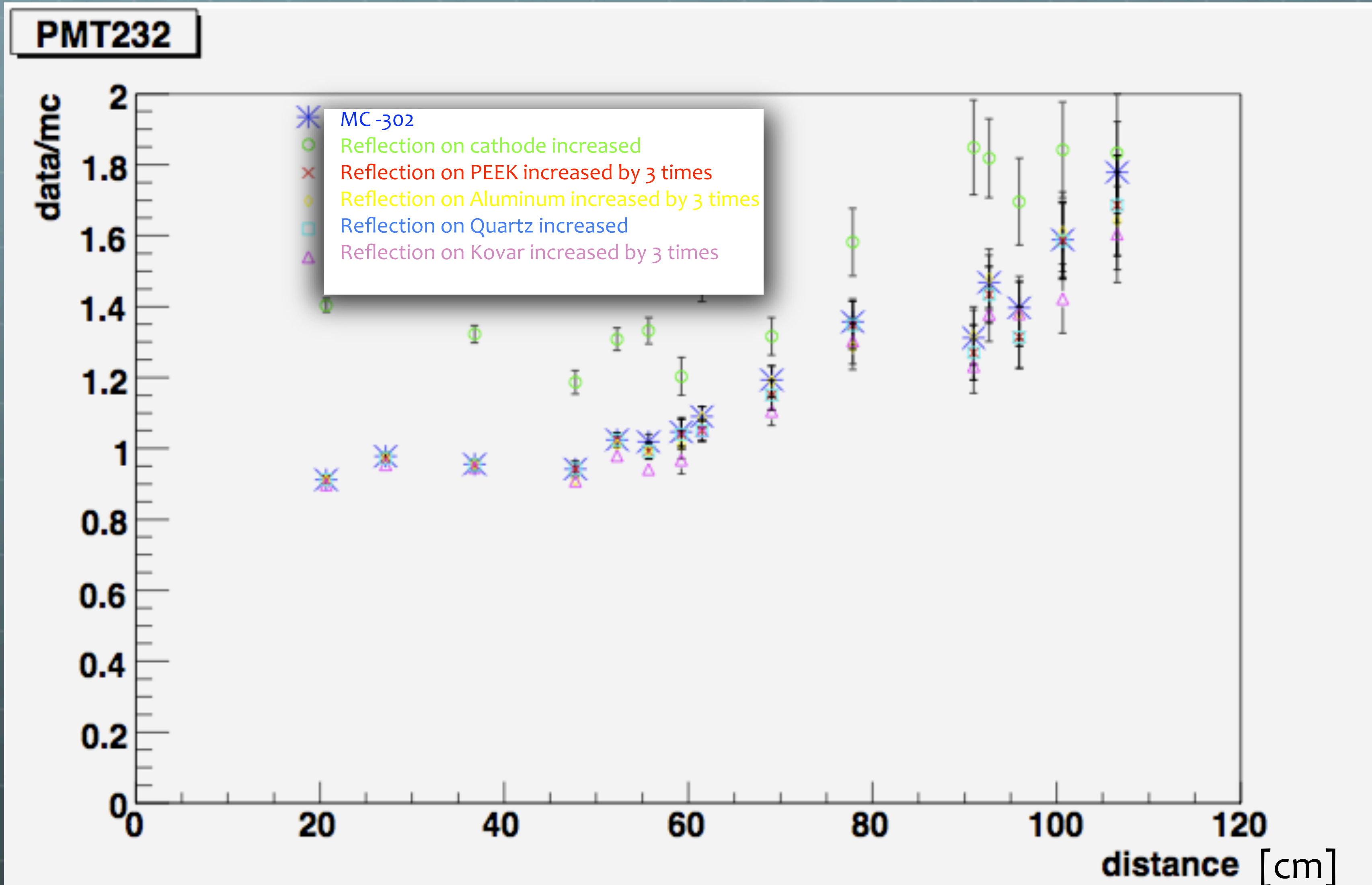
When scattering length was increased, the data/MC ratio in large distance dropped significantly and accuracy improved.

Data/MC vs distance with different reflection factors



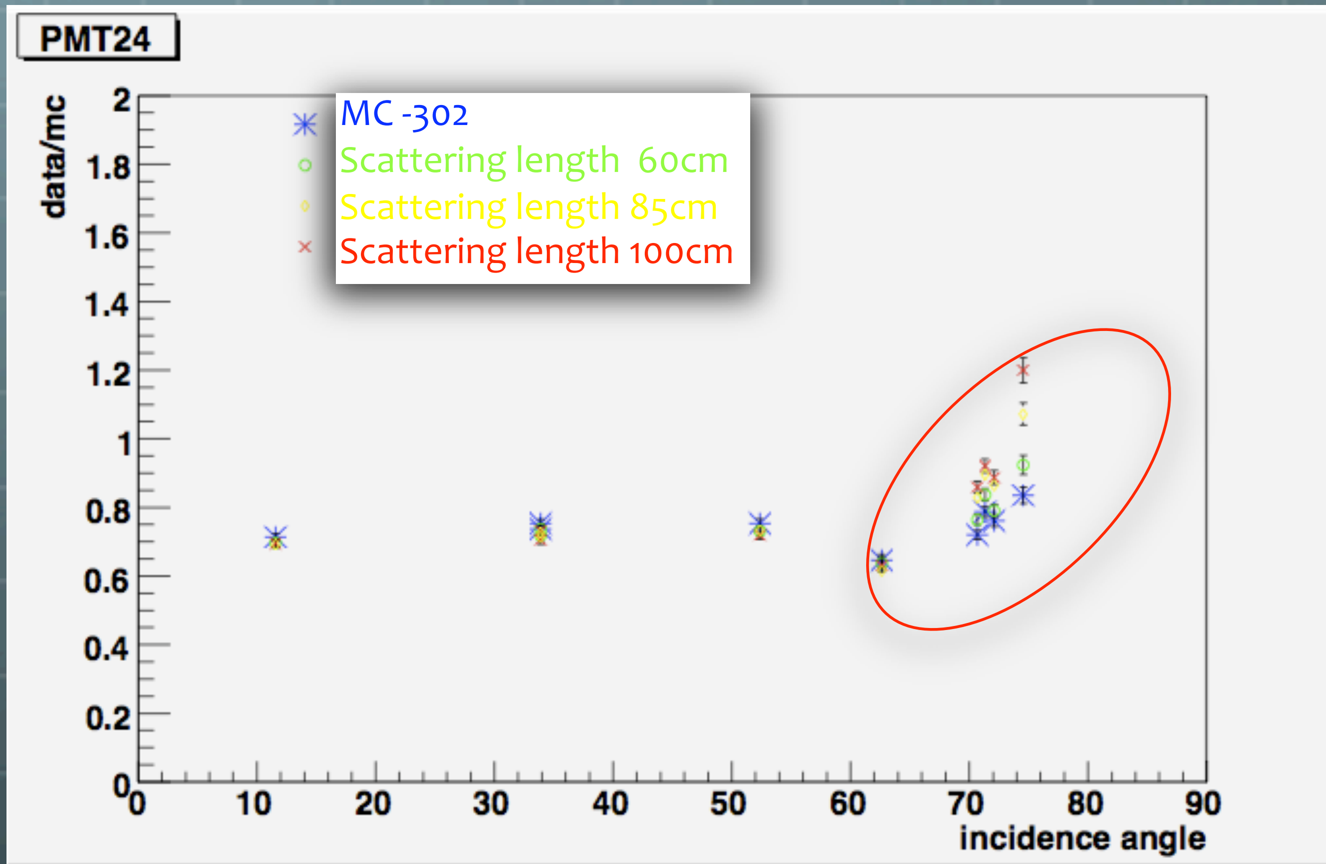
Turning off reflection on each material did not change the data/MC value much.

Data/MC vs distance with different reflection factors



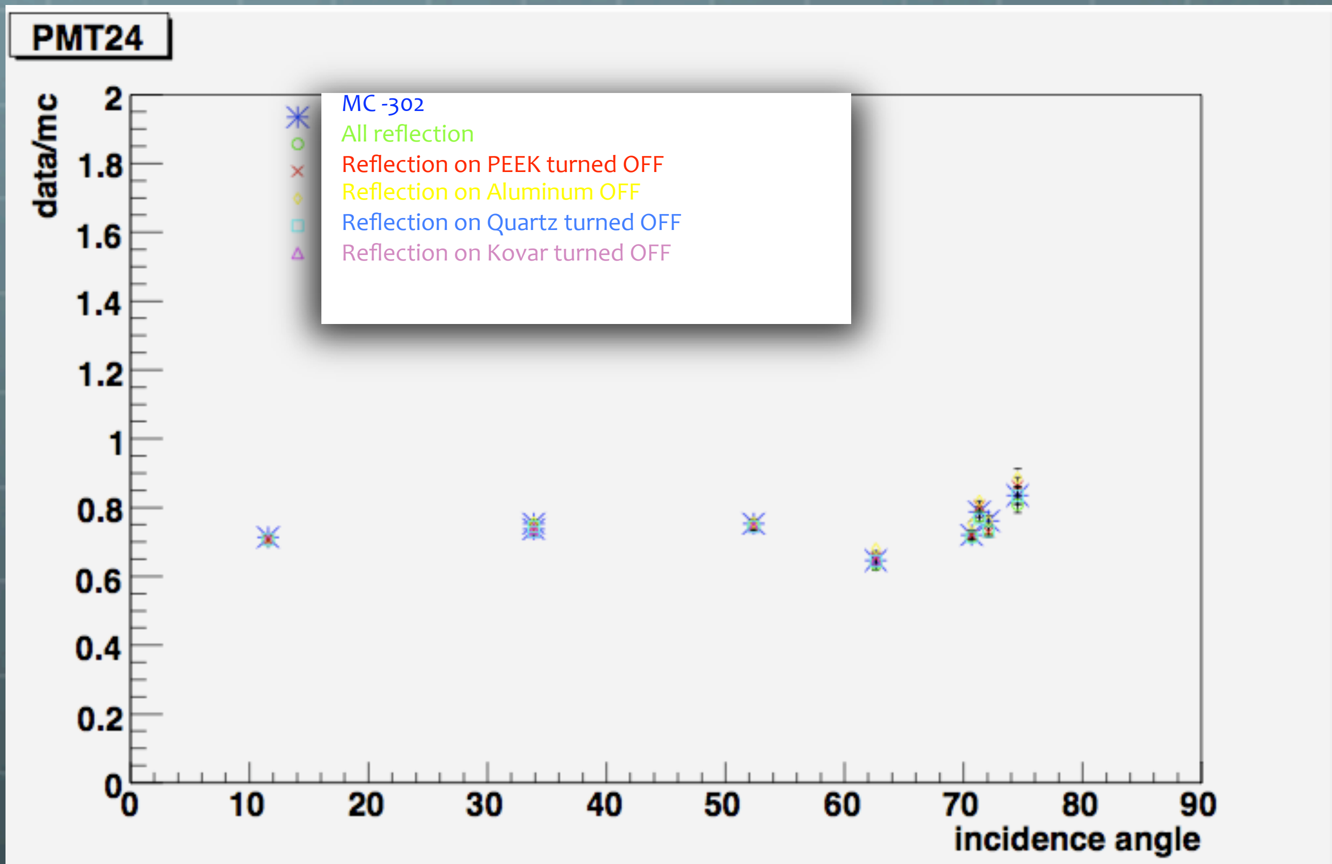
Increasing reflections brought some noticeable changes in data/MC.

Data/MC vs angle with different scattering lengths



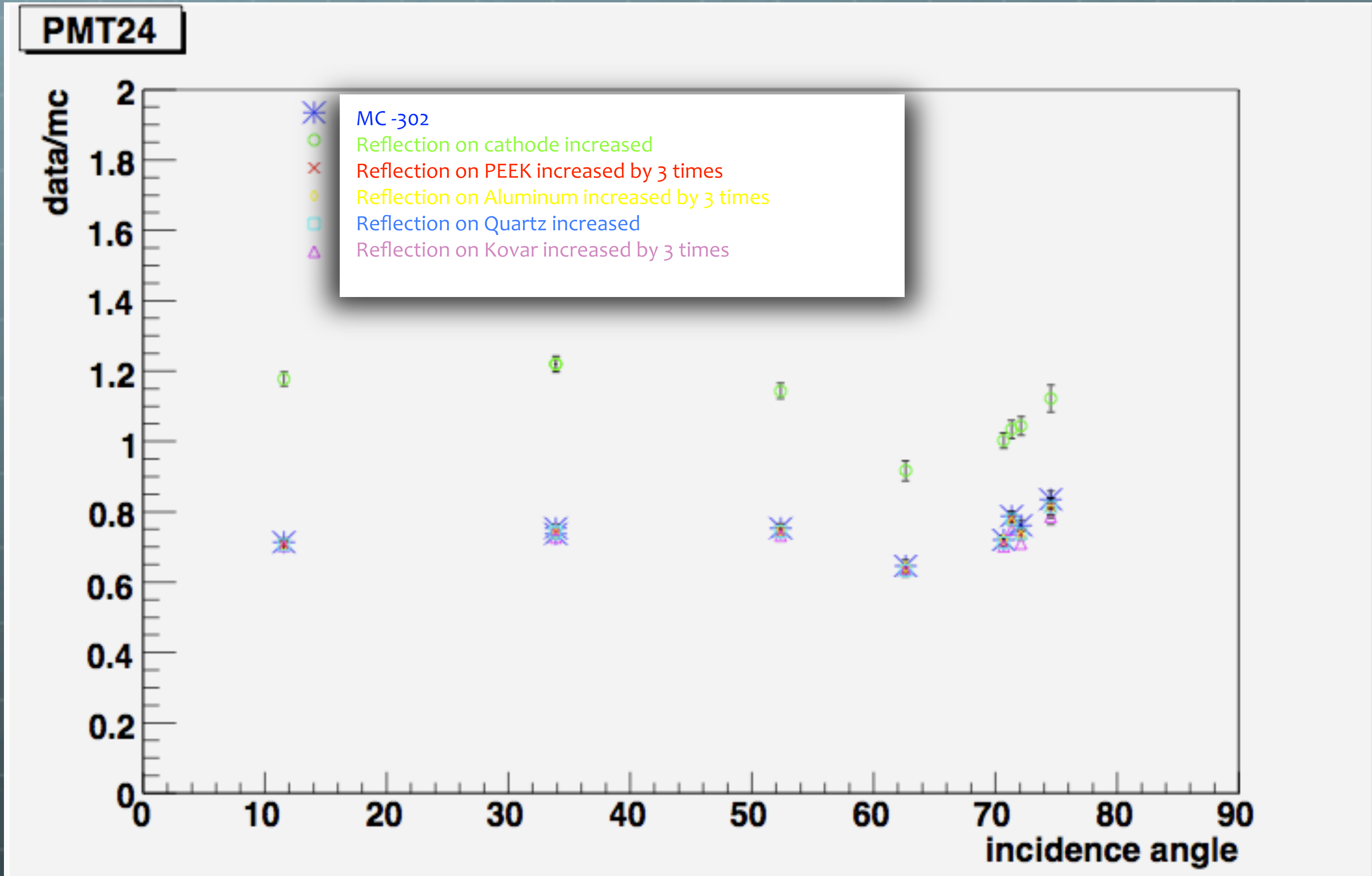
The inconsistency in large angle worsened when increasing scattering length.

Data/MC vs angle with different reflection factors



Turning off reflection on each material did not change the data/MC value much.

Data/MC vs angle with different reflection factors

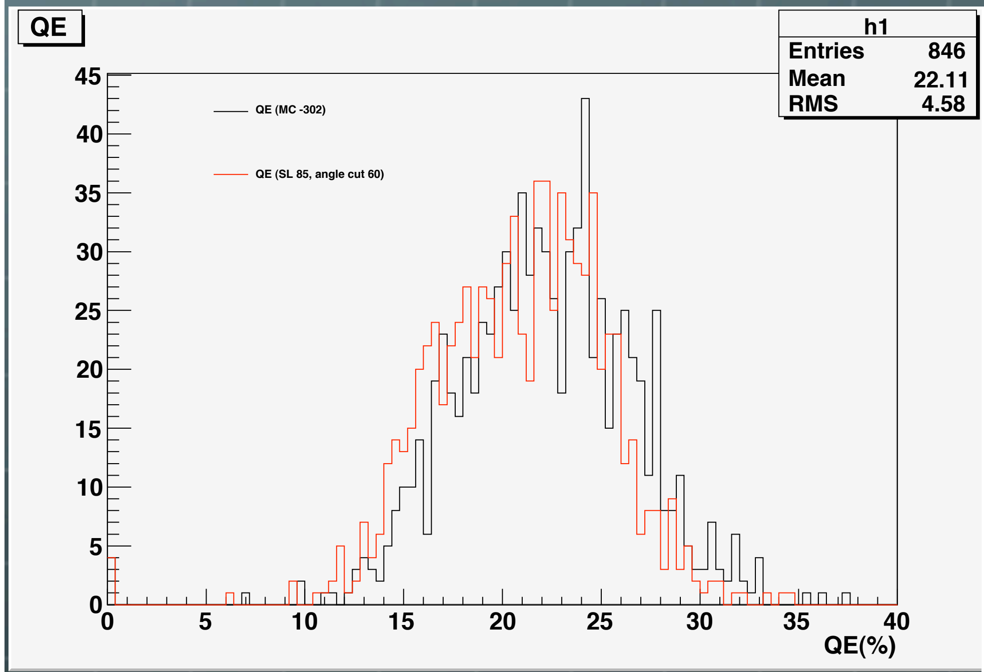


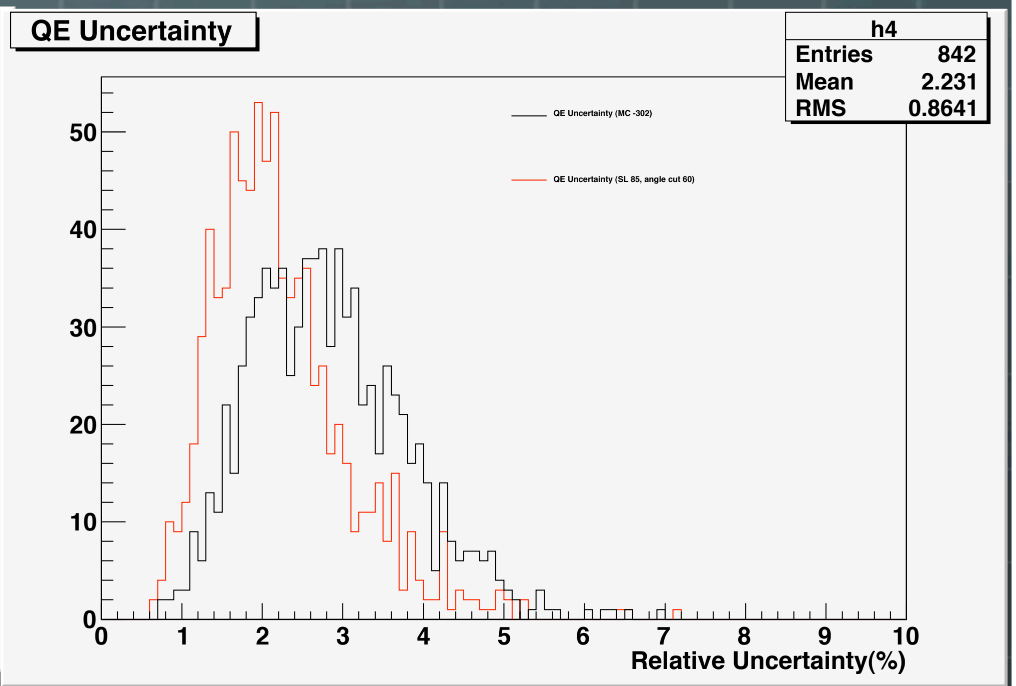
Increasing reflections brought some noticeable changes in data/MC.

Q.E. uncertainty

- Overall Q.E. uncertainty dropped from 2.83% to 2.32% when setting scattering length to 85cm and applying a 70° incidence angle cut

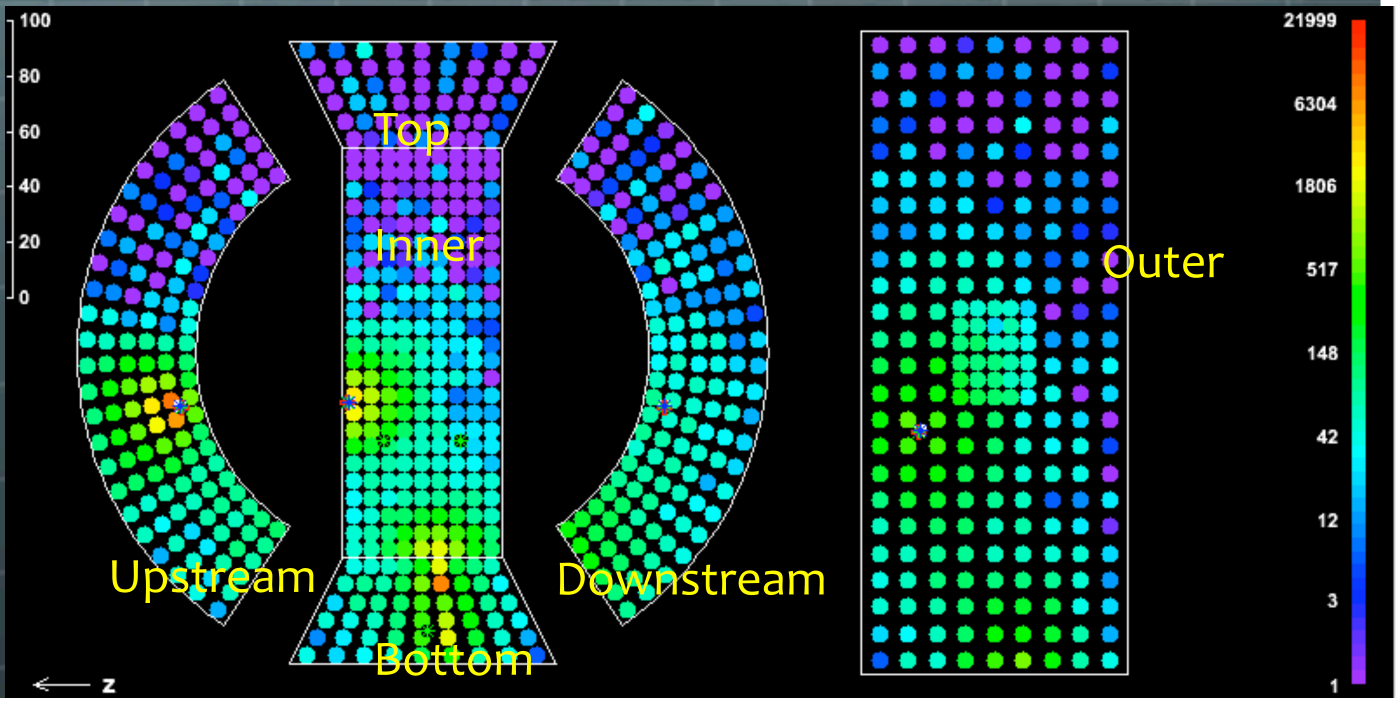
before
after





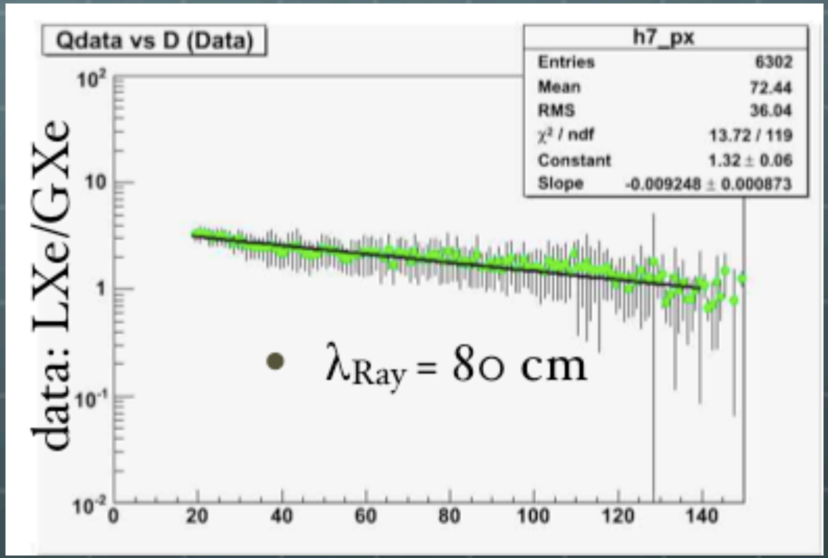
Q.E. Uncertainty Improvement for PMTs in different positions

	Before (%)	After (%)
Inner	1.996	1.917
Outer	2.555	2.137
Upstream	3.2	2.342
Downstream	3.105	2.497
Top	3.719	2.368
Bottom	3.747	2.129



Summary

- Scattering length might be significantly longer than previously thought



- Effects of reflection needs more investigation