Calibration of energy scale uncertainty based on understanding of Super-Kamiokande detector elements

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Abstract

The Super-Kamiokande is the water Cherenkov detector. In this experiment, the energy scale uncertainty is about 2%. To improve this energy scale uncertainty to 0.5%, I compared Data and MC of PMT hit pattern by using Ni/Cf source. As a result, I eliminated the possibility that water absorption is the cause of Data/MC disagreement of hit pattern.

1. Motivation

Purposes of Super-Kamiokande (SK) experiment

(1) Measure the oscillation parameters of neutrinos (solar ν, atmospheric ν and accelerator ν).
(2) Observe neutrinos from supernova explosions.
(3) Search for nucleon decay and verify the GUT etc.

Energy scale uncertainty

- **2%** for O(GeV) energy scale in current SK
- In HK, **0.5%** is required for CP phase angle measurement
  → want to demonstrate this goal in SK by **bottom-up** method

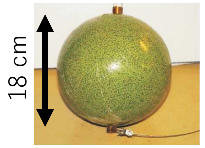


Fig.1 Ni/Cf source

2. Method

I used Ni/Cf source (emitting 9 MeV γ-rays, see Fig.1) Data to study the uncertainty of the detector response at hit level. To compare Data and MC, I analyzed Hit Rate* in each PMT.

Ni/Cf source (see Fig.2)

(1) The position of the light source can be clearly identified.
(2) Light can be isotropically emitted.

Data ←Apply the individual QE of each PMT to MC and match it with Run#1 Data.

I used two kinds of Ni/Cf source Data. (Period when water is convected.)

-Run#1 : source position Z=0 m (center of the tank)
-Run#2, #3 : source position Z=－12, +12 m (off-center)

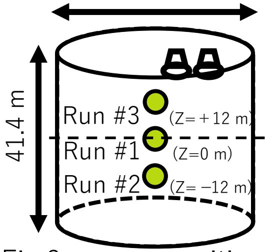
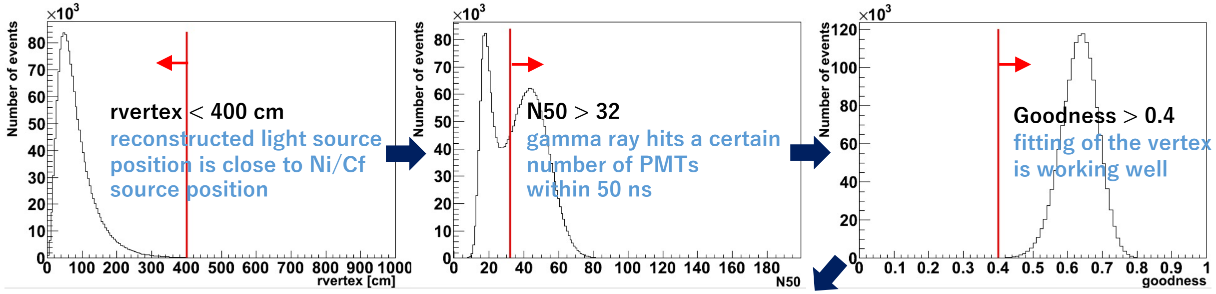


Fig.2 source position

*How to select Ni/Cf event and get Hit Rate



$$\text{Hit Rate}\,(i) = \frac{\text{Number of events with hit}(i) \times r(i)^2/F(\theta(i))}{\sum[\text{Number of events with hit}(i) \times r(i)^2/F(\theta(i))]\,/N}$$

[i : PMT cable number (1～11146), $r(i)$: distatnce (source to each PMT)
$F(\theta(i))$: acceptance of a PMT as a function of incident angle, N : Number of PMTs (11146)]

3. Results

Fig.3 shows Hit Rate ratio (= Data/MC) as a function of distance (Ni/Cf source to each PMT). The Ni/Cf source is located at Z=－12 m and +12 m. This histgram is mean value of the ratio in every 100 cm. The red, blue and black lines represent the each PMTs located at the Top, Bottom, Barrel of the tank respectively.

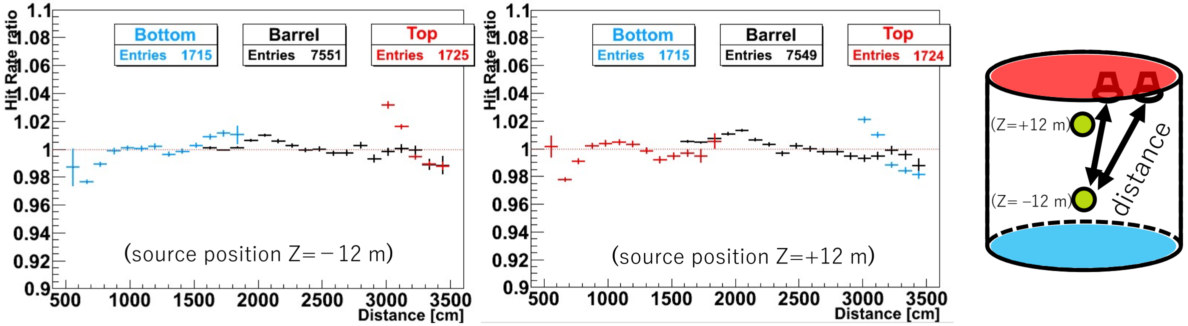


Fig.3 Distance distribution of Hit Rate ratio (Data/MC)

For Top PMT in left figure and Bottom PMT in right figure, Hit Rate ratio decreases with increasing distance, whereas this tendency is not seen in Barrel PMT. So it can be said that Data/MC disagreement is not caused by water absorption parameter.

4. Conclusion and Future Step

So far, I compared the Data and MC of Hit Rate in off center using MC that was calibrated in center data. As a result, I eliminated the possibility that water absorption is the cause of Data/MC disagreement of hit pattern. I want to identify the cause of uncertainty from the tendency of Data/MC agreement and change the parameters (reflection, scattering, angle dependence of PMT etc..) and calculation methods of MC in low energy. After that, I want to apply that method to MC in high energy.