Data Analysis and Preliminary Results of One-Ton WbLS Detector

detector responde study

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- study the optical properties of WbLS and its performance in 1Ton dector.
- improve optical model of WbLS

- run detector with water ⇓
- calibrate dector response using data and MC simulation.⇓
- run dector with WbLS ⇓
- analysis data with calculation factors ⇓
- improve optical model of WbLS by tuning MC parameters.

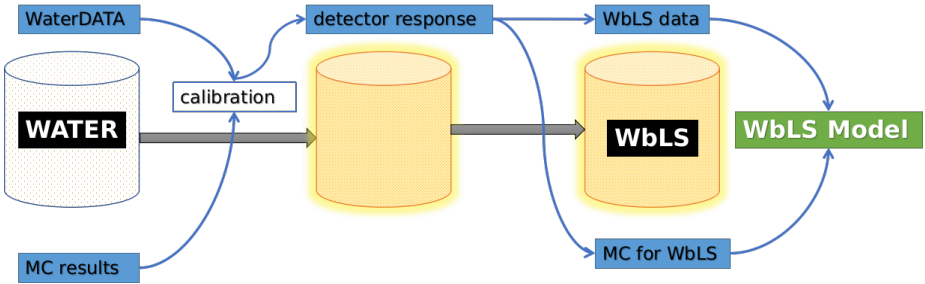


图: flowchart of analysis

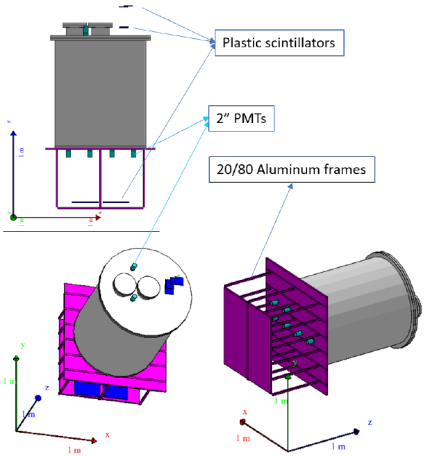


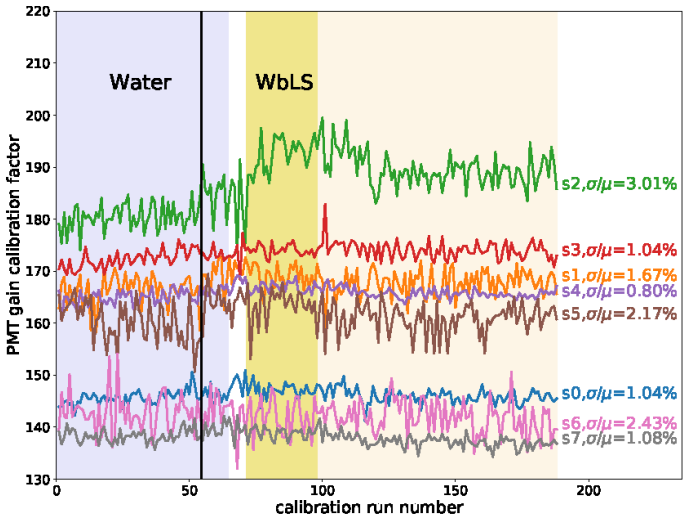
图: the 1Ton WbLS Dector

- $\sim$ 1Ton WbLS is cylinder tank.
- 8 PMTs(2") for photon readout.
- 6 Hodoscope as trigger system.
- one 410nm LED for PMT calibration.

the Data Trigger Types :

1. hodoscope trigger:
   (H0 ||H2) && (H3 || H1)|| H4 || H5
2. multiplicity trigger:
   $N_{fired-PMTs} \geq 6$
3. led trigger:
   PMT single p.e. calibration

The stability of detector during data taking from LED data:



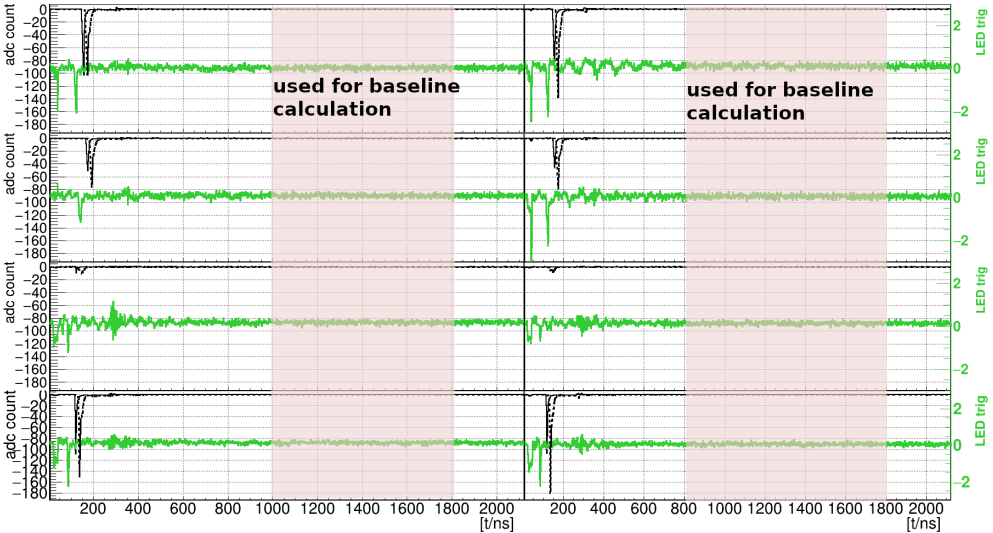


图: the 2560ns average waveform of PMTs, run 23456

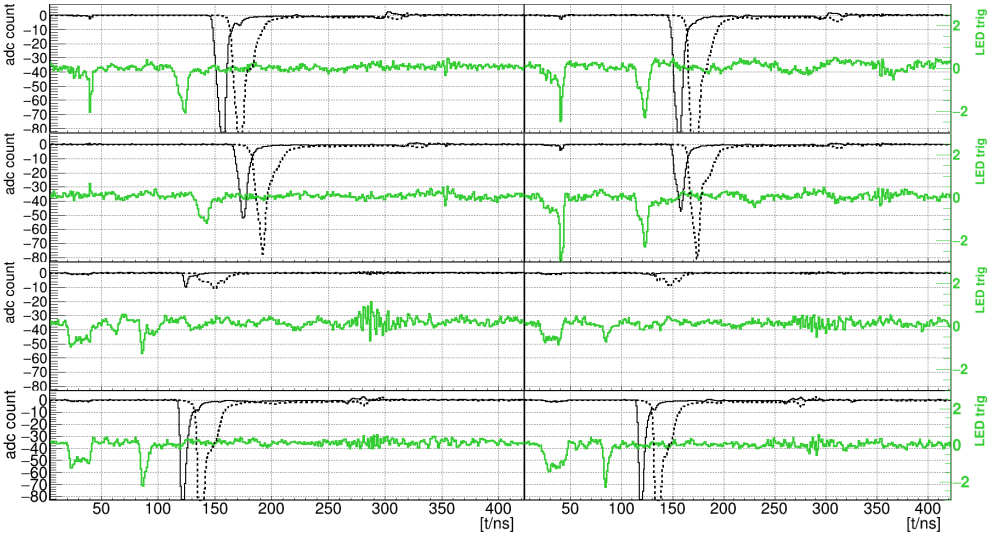


图: the first 400ns average waveform of PMTs, run 23456

here the example wave

1. baseline calculation: choose a fix window from 1000ns to 1800ns, get the mean value as baseline of one waveform.
2. signal seek threshold: $baseline - 3 \cdot \sigma_{baeline}$
3. charge integration: from risetime-2 to risetime+2
4. time coincidence: if the rise time of a group of signals are inside a ns window, if the arrive time match$\Rightarrow$ one effective group of signal; merge to peaks if the arrive time difference $< 25ns$

a fixed-window of 40ns width is selected for LED spe calibration and fitting with convolution of poisson and gaussianfunction:

$$S(x) = P(n;\mu) \circledast G_n(x) = \sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!} \frac{1}{\sigma_1 \sqrt{2n\pi}} exp(-\frac{(x-nQ_1)^2}{2n\sigma_1^2}) \quad (1)$$

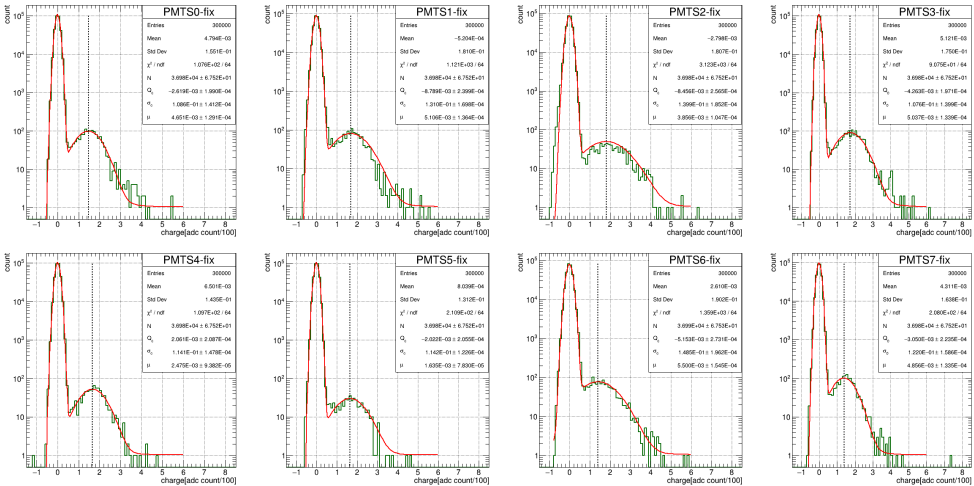


图: the LED single p.e. spectrum of PMTs for gain calibration

calibrate the "effective" efficiency factors:

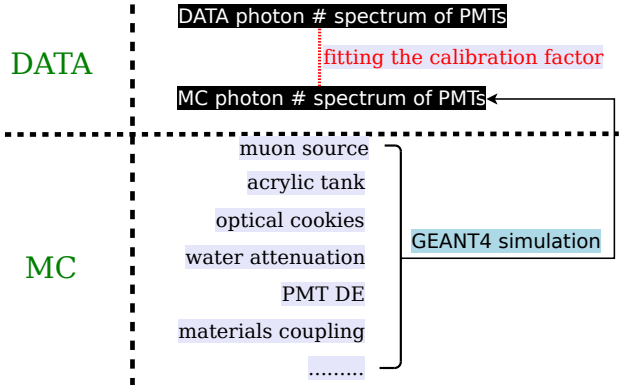


图: the LED single p.e. spectrum of PMTs for gain calibration

- CRY muon generator, @1m above the dector,
- Rat-Pac as framework
- use spe response of PMT data.
- the npe spectrum of each PMT.
- use nominal values of optical parameters for acrylic,cookie, PMT.
- 20m water attenuation by default.

Due to the limitation from muon generator, some high energy events can not be properly simulated,so choose a threshold of counts for the last bin of histogram.

The defination of χ^2 function in spectrum fitting:

$$\chi^2(f) = \sum_{i=1}^{i=maxbin-1} \frac{N_i^{data} - N(f)_i^{MC}}{\sigma(f)_i} \quad (2)$$

where

- N_i^{data} is count in the i th bin of data N.p.e spectrum;
- f is the calibration factor;
- $N(f)_i^{MC}$ is count in the i th bin of MC N.p.e spectrum with f applied (multiplied) to each event;
- $\sigma(f)_i = \sqrt{N(f)_i^{MC}/r^2 + N_i^{data}}$ is the uncertainty of i th bin; r=10 is the ratio of total event number from MC and data [1].

[1] the MC histogram is scaled with $r = 10$ in the fitting

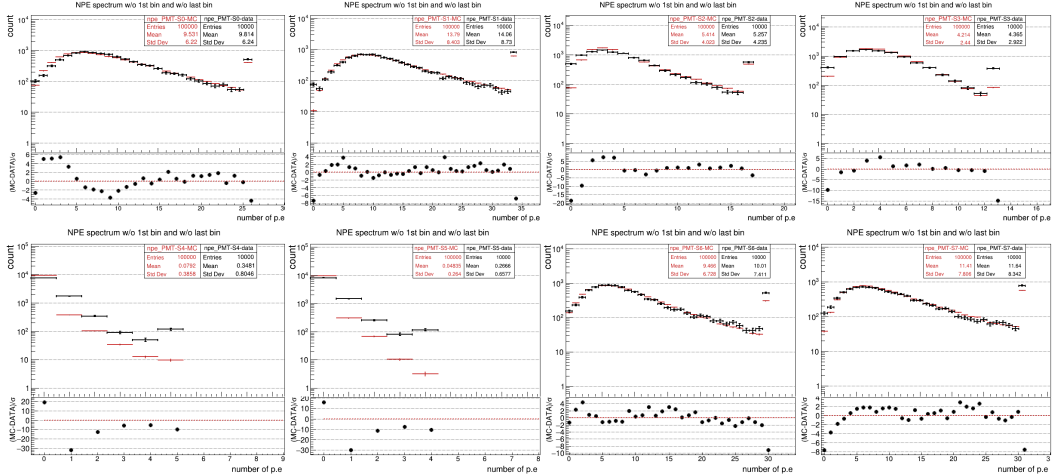


图: the N.p.e spectrum fitting of 8 PMTs, with 40 for last bin threshold, fitting without 1st bin without last bin

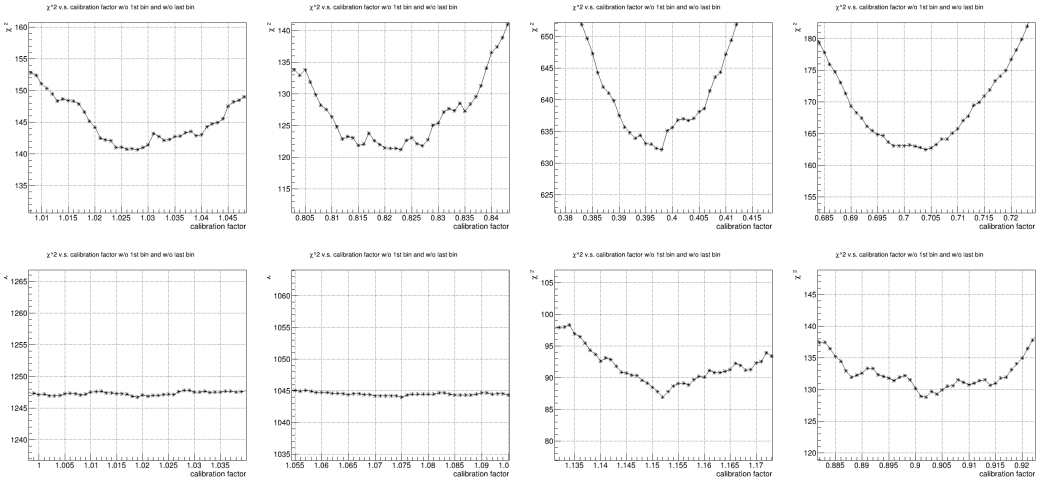


图: the fitting χ^2 of 8 PMTs, with 40 for last bin threshold, fitting without 1st bin without last bin

we considered several different factors in the fitting:

- the threshold of overbin
- uncertainty of water attenuation length
- first bin position
- influence of first and last bin in fitting
- PMT gain calibration uncertainty
- combinations top hodoscopes

表: mean value and uncertainty of calibration factors

pmt#	s0	s1	s2	s3	s4	s5	s6	s7
cf mean	1.032	0.823	0.395	0.708	0.984	1.089	1.152	0.902
uncertainty	0.051	0.052	0.025	0.057	0.041	0.016	0.043	0.03

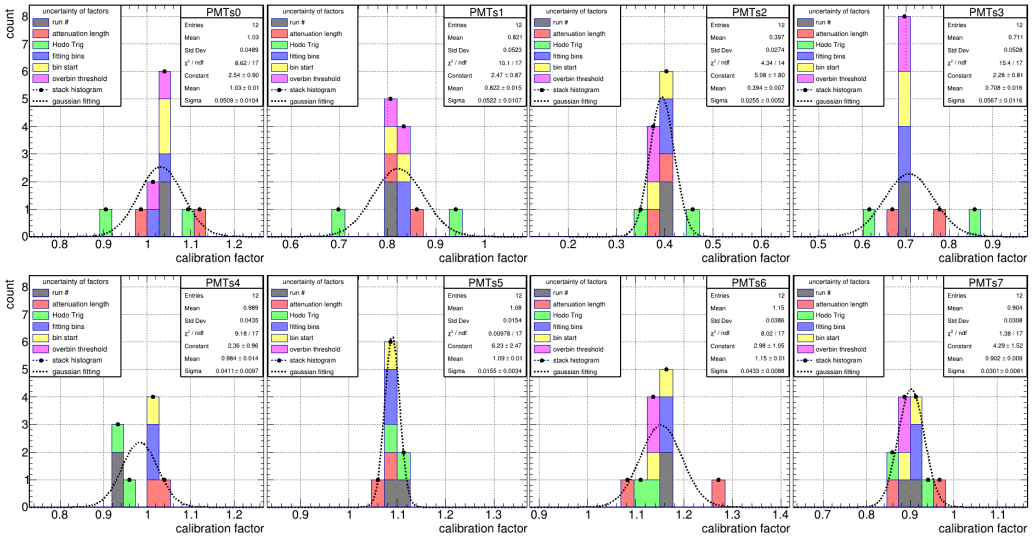


图: the stack histogram of calibration factor from different tests

Hodoscope trigger patterns

hodoscope#	1010	1001	0110	0101	1110	1101	0111	1011	1111
hohoscope 2	1	1	0	0	1	1	0	1	1
hohoscope 0	0	0	1	1	1	1	1	0	1
hohoscope 3	1	0	1	0	1	0	1	1	1
hohoscope 1	0	1	0	1	0	1	1	1	1

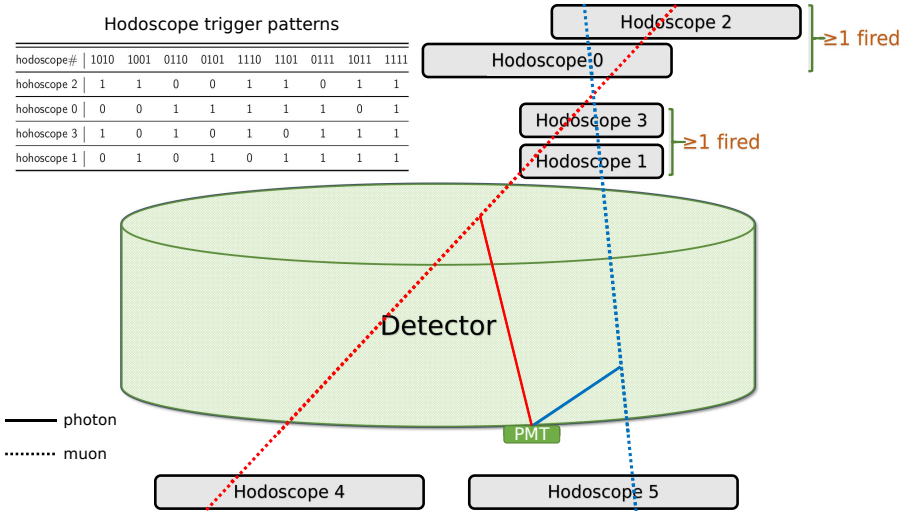


图: the trigger system

we expect the "calibration factors" to be independent of trigger pattern(the muon track), a pure linear efficiency factor.

short summary:

- a group of fitted effective efficiency of PMTs
- uncertainty estimation of these "calibration factors"
- the water attenuation length (not sensitive enough)

the optical model of WbLS
tuning parameters in the model by fitting

the projection view of detector

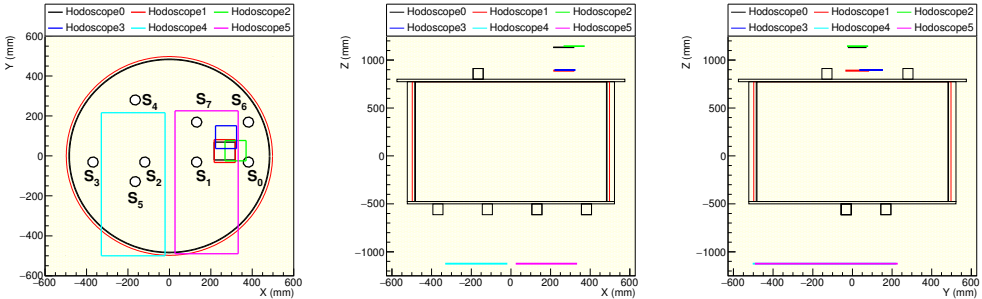


图: the geometry of 1Ton dector

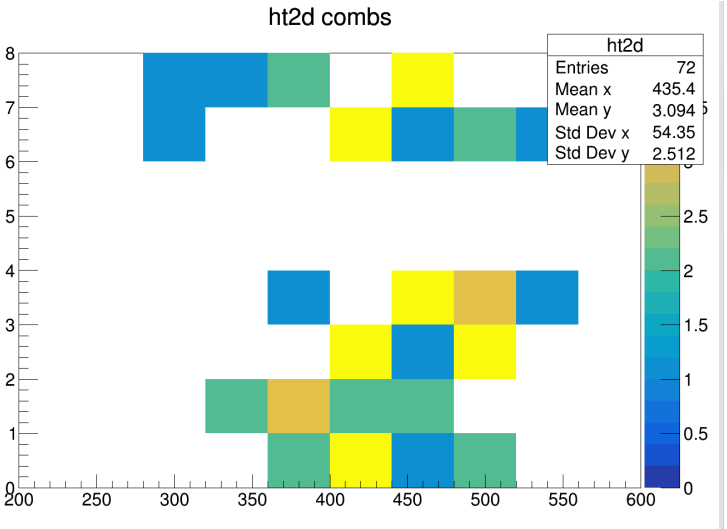
the 9 combinations table:

表: mean value and uncertainty of calibration factors

hodoscope#	1010	1001	0110	0101	1110	1101	0111	1011	1111
hohoscope 2	1	1	0	0	1	1	0	1	1
hohoscope 0	0	0	1	1	1	1	1	0	1
hohoscope 3	1	0	1	0	1	0	1	1	1
hohoscope 1	0	1	0	1	0	1	1	1	1

photon acceptance model : water, acrylic, optical cookie, pmt solid angle
the model of attenuation and geometry

2d histogram, update this



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Thank You

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