Data Analysis and Preliminary Results of One-Ton WbLS Detector detector responde study

Rong Zhao



NY·BNL Spring, 2020





R. Zhao

Brief Introductio about the

waveform analysis

PMT Waveform

Waveform Analysis Calibration

Dector Usir Water Data

Problems and Next-Steps Brief Introduction about the 1Ton Dector

waveform analysis

PMT Waveform Analysis

Calibration of Dector Using Water Data

Problems and Next-Steps

backup others







R. Zhao

Brief Introduction about the 1Ton Dector

waveform analysis

Waveform Analysis

Calibration Dector Usin Water Data

and Next-Steps ▶ study the optical properties of WbLS and its performance in 1Ton dector.

► improve optical model of WbLS







R. Zhao

Brief Introduction about the 1Ton Dector

waveform analysis

Waveform Analysis

Dector Using

Problems and Next-Steps

- ► 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.

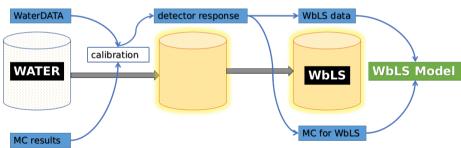


图: flowchart of analysis



Brief Introduction about the 1Ton Dector

waveform

Waveform Analysis

Dector Usin Water Data

Problems and Next-Steps

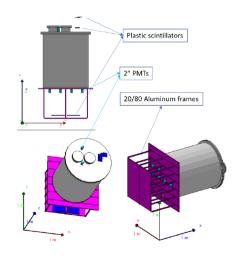


图: the 1Ton WbLS Dector

- ightharpoonup ~ 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 :

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





Water Run Information of 1TonDector

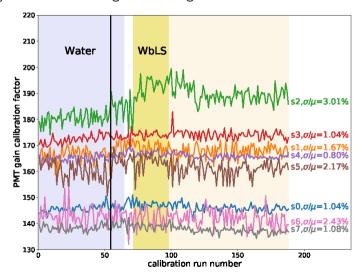
Data Analysis of WbLS Dector

R. Zhao

waveform analysis

Analysis

The stability of detector during data taking from LED data:





the Average Waveform of 3 Trigger Types

Data Analysis of WbLS Dector

R. Zhao

Brief Introduction about the 1Ton Decto

PMT Waveform

Analysis
Calibration

Dector Using Water Data

Problems and Next-Steps

about

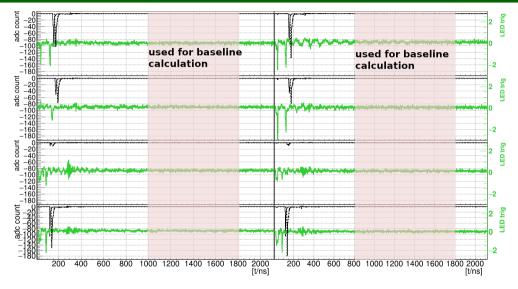


图: the 2560ns average waveform of PMTs, run 23456



the Average Waveform of 3 Trigger Types

Data Analysis of WbLS Dector

R. Zhao

Brief Introduction about the 1Ton Dector

analysis
PMT
Waveform
Analysis

Calibration of Dector Using

Problems and

about

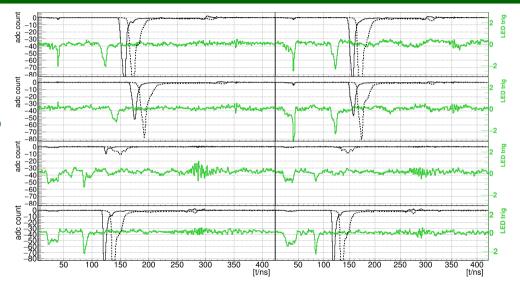


图: the first 400ns average waveform of PMTs, run 23456





R. Zhao

Brief Introduction about the 1Ton Dector

PMT Waveform

Waveform Analysis

Water Data Problems and 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:

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





R 7hao

waveform analysis PMT Waveform

Analysis

Next-Steps

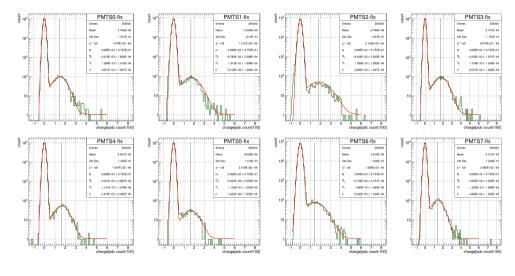


图: the LED single p.e. spectrum of PMTs for gain calibration





R. Zhao

Brief Introductio about the 1Ton Decto waveform

waveform analysis

Waveform Analysis

Calibration of 10 Dector Using

Water Data Problems

and Next-Steps calibrate the "effective" efficiency factors:

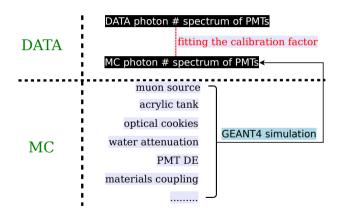


图: the LED single p.e. spectrum of PMTs for gain calibration





R. Zhao

Brief Introduction about the 1Ton Dector

waveform analysis

Waveform Analysis Calibration of 11

Dector Using Water Data

Problems and Next-Steps ► 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.





Data Analysis of WbLS Dector R. Zhao

Th

Introduction about the 1Ton Dect

analysis PMT

Waveform Analysis Calibration of 12

Dector Using Water Data

Problems and Next-Steps The defination of χ^2 function in spectrum fitting:

$$\chi^{2}(f) = \sum_{i=1}^{i=\max bin-1} \frac{N_{i}^{data} - N(f)_{i}^{MC}}{\sigma(f)_{i}}$$
(2)

where

- \triangleright 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.



fitting results N.p.e



R. Zhao

Brief Introduction about the 1Ton Decto

waveform analysis

PMT Waveform Analysis

Calibration of 13 Dector Using Water Data

Problems and Next-Steps about

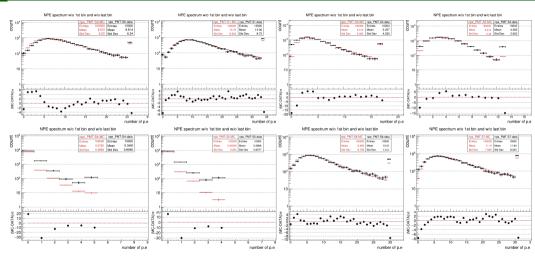


图: the N.p.e spectrum fitting of 8 PMTs, with 40 for last bin threshold, fitting without 1st bin without last bin

fitting χ^2 results N.p.e

WbLS



R. Zhao

Brief Introduction about the 1Ton Dector

analysis PMT

Waveform Analysis

Calibration of 14 Dector Using Water Data

Problems and Next-Steps

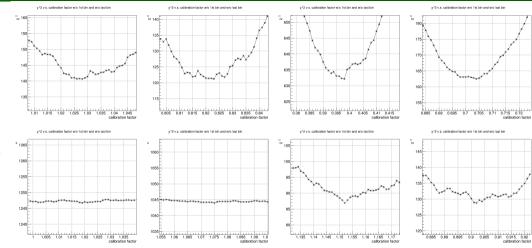


图: the fitting χ^2 of 8 PMTs, with 40 for last bin threshold, fitting without 1st bin without last bin



fitting results

Data Analysis of WbLS Dector

R. Zhao

Brief Introduction about the 1Ton Decto

waveform analysis

Waveform Analysis

Calibration of 15 Dector Using Water Data

Problems and Next-Steps 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





the uncertainty evaluation of fitting results

Data Analysis of WbLS Dector

R. Zhao

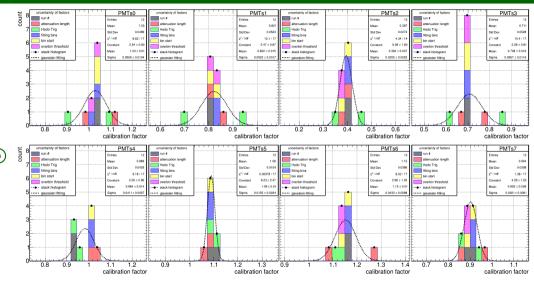
Brief Introductio about the 1Ton Decte

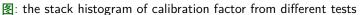
waveform analysis

PMT Waveform Analysis

Calibration of 16 Dector Using Water Data

Problems and Next-Steps







calibration factors for 9 trigger combinations

Data Analysis of WbLS Dector

R. Zhao

Brief Introduction about the 1Ton Decto

waveform analysis

PMT

Analysis Analysis

Calibration of 17 Dector Using Water Data

Problems and Next-Steps

25

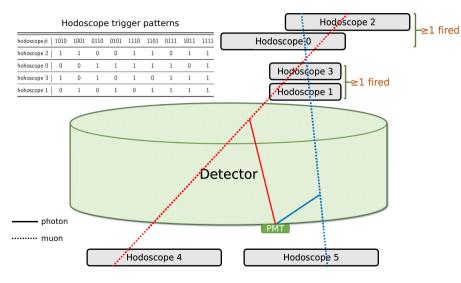


图: the trigger system





R. Zhao

Brief Introductio about the 1Ton Decto waveform analysis

Waveform Analysis

Calibration of 18 Dector Using Water Data

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







R. Zhao

Brief Introductior about the 1Ton Decto

waveform analysis

PMT Waveform Analysis

Calibration of Dector Using Water Data

Problems and Next-Steps

short summary:

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







R. Zhao

Brief Introduction about the 1Ton Decto

waveform analysis

Waveform Analysis

Calibration o Dector Using Water Data

Problems and Next-Steps

about

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







R. Zhao

Brief Introduction about the 1Ton Dector

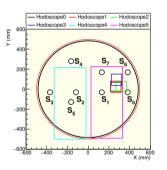
analysis PMT Waveform Analysis

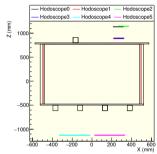
Calibration of Dector Using Water Data

Problems and Next-Steps

about

the projection view of detector





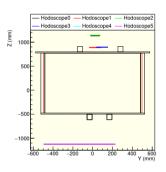


图: the geometry of 1Ton dector





R. Zhao

Brief Introduction about the 1Ton Dector

waveform analysis

PMT

Analysis
Calibration of Dector Using

Problems and Next-Steps

about

the 9 combinations table:

表: mean value and uncertainty of calibration factors

hodoscope# 101	.0 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





R. Zhao

Brief Introduction about the 1Ton Decto

waveform analysis

PMT Waveform Analysis

Calibration of Dector Using Water Data

Problems and Next-Steps

about

photon acceptance model : water, acrylic, optical cookie, pmt solid angle the model of attenuation and geometry $\frac{1}{2} \left(\frac{1}{2} \right) = \frac{1}{2} \left(\frac{1}{2} \right) \left(\frac{1}{2$







R. Zhao

Brief Introduction about the 1Ton Dector

analysis PMT Waveform

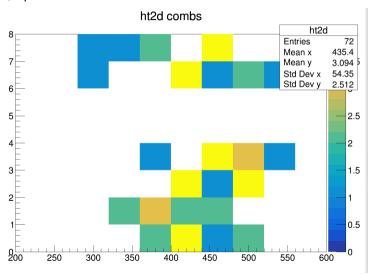
Analysis
Calibration
Dector Usir

Water Data Problems

and Next-Steps

about

2d histogram, update this







R. Zhao

Brief

waveform analysis

Analysis

Next-Steps

about

Rong Zhao

中山大学物理学院

zhaor25@mail2.sysu.edu.cn;













Thank You



NY.BNL