



The Electronics Simulation Software in JUNO

Zhang Haosen^{1,2} on behalf of JUNO collaboration zhanghaosen@ihep.ac.cn

¹Institute of High Energy Physics

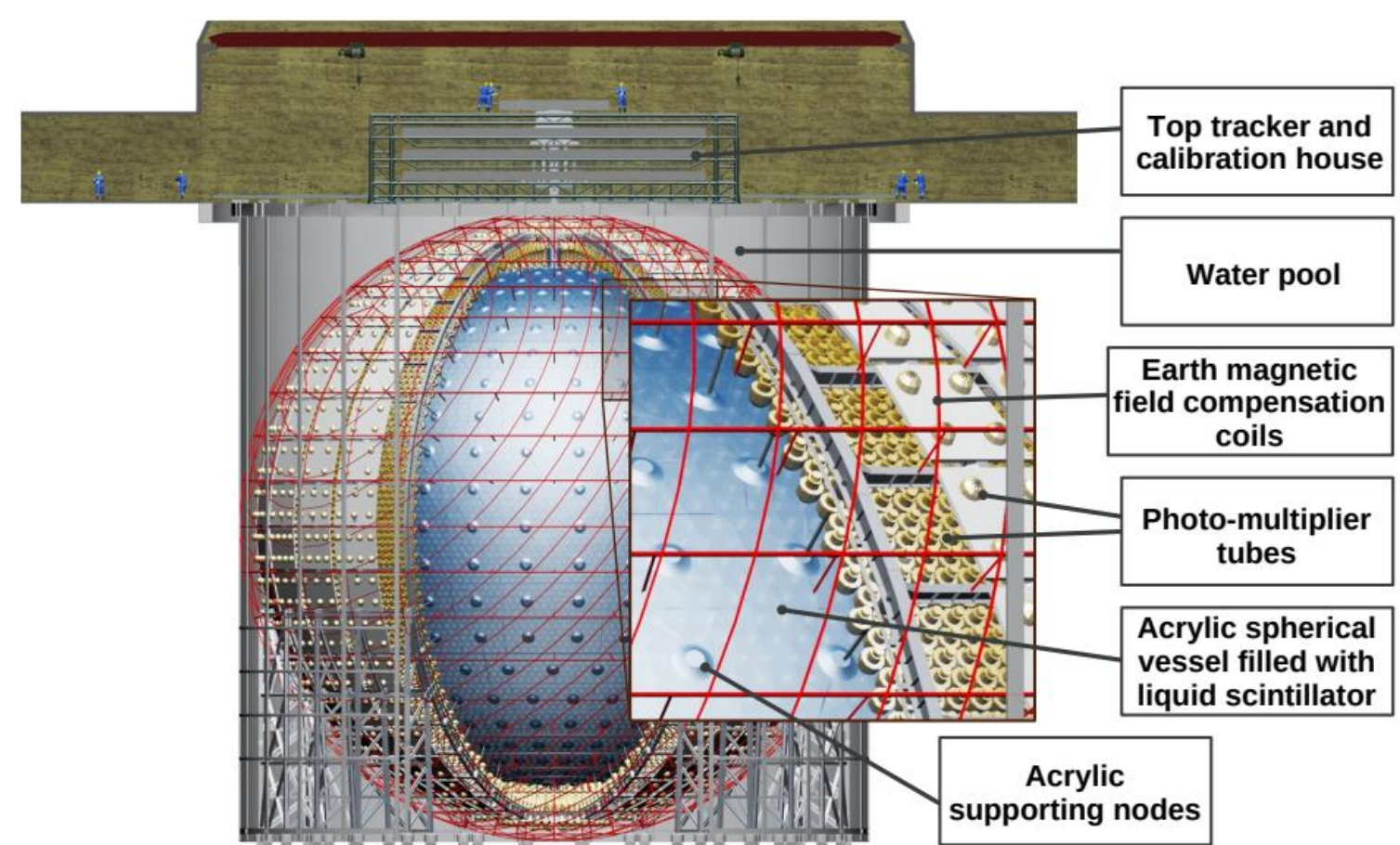
²University of Chinese Academy of Sciences



Introduction

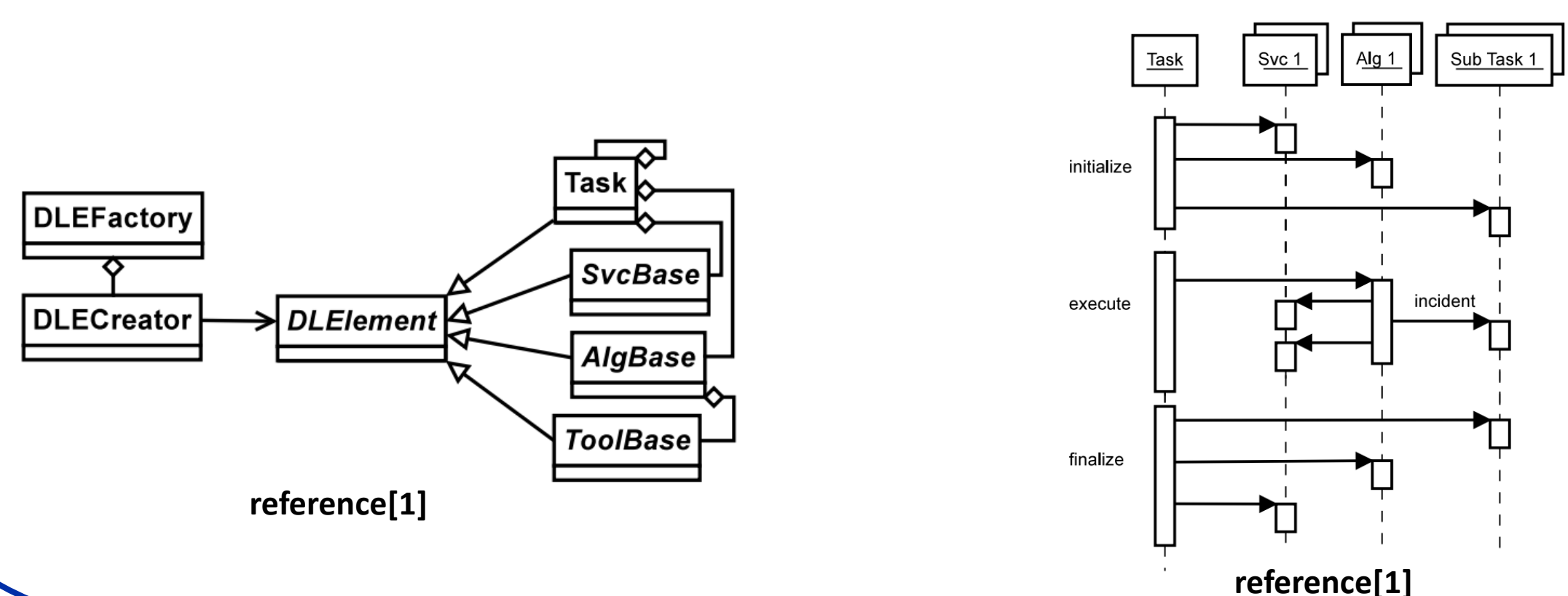
Jiangmen Underground Neutrino Observatory (JUNO):

- The Jiangmen Underground Neutrino Observatory is designed to determine neutrino mass hierarchy and precisely measure oscillation parameters, observe supernova neutrinos, study the atmospheric, solar neutrinos and geo-neutrinos, and perform exotic searches, with a 20-thousand-ton liquid scintillator detector of unprecedented 3% energy resolution (at 1 MeV).



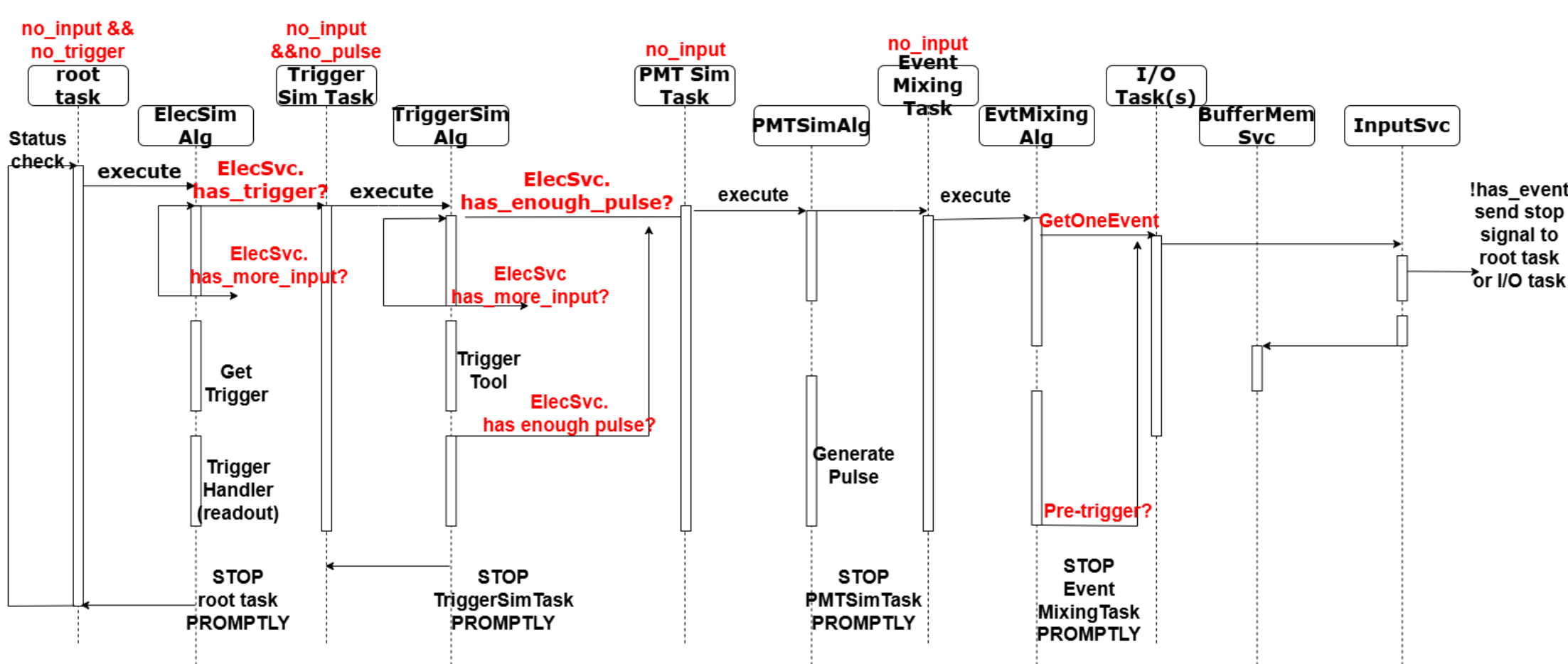
- The central detector of JUNO covered by 20000 20-inch PMTs and 25000 3-inch PMTs, electronics simulation(ElecSim) contain "hit" level of event mixing algorithm, PMT response, electronics response, trigger simulation, electronics simulation are an integral part of JUNO simulation

- JUNO ElecSim use an implementation based on Software for Non-collider Physics Experiment(SNiPER) managed Dynamically-Loadable Elements(DLE)

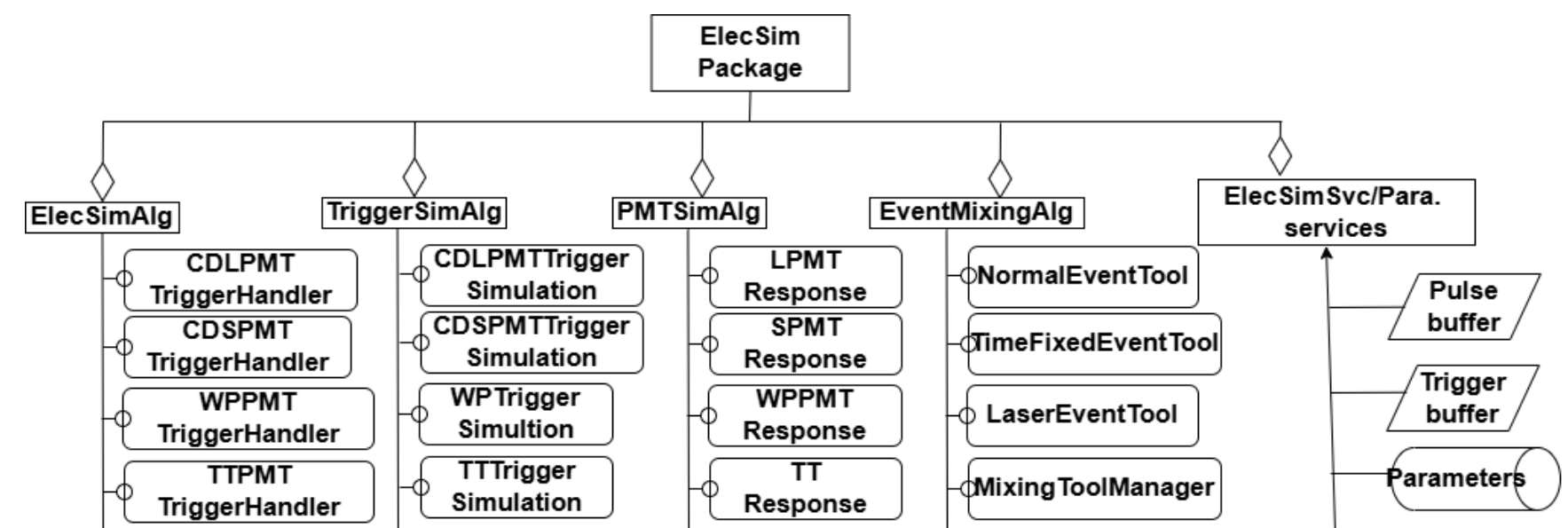


Electronics Simulation Software Design

- Electronics simulation has been designed and developed based on SNiPER's task and incident mechanism
- It works in "back-driven" strategy, to avoid complicated buffer/memory management
- The ElecSim is driven by "task" in SNiPER, so not only can ElecSim run independently, but it can also be a subtask of Online Event Classification (OEC) software(invoked by OEC).



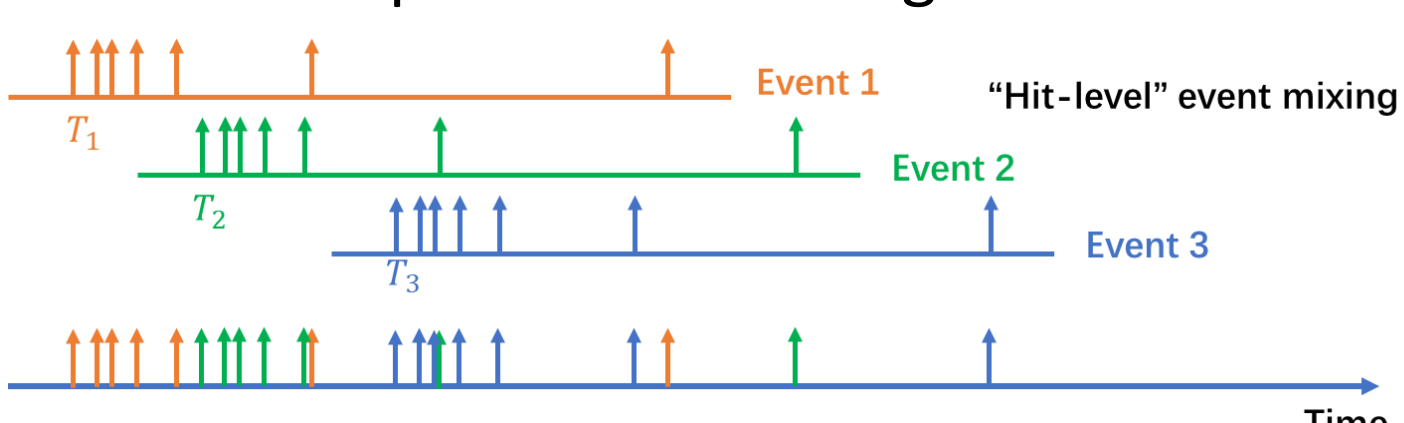
- The services provide communication between the algorithms and also provide parameters access. The algorithms handle event mixing, PMT response modelling, electronics response modelling and trigger response modelling



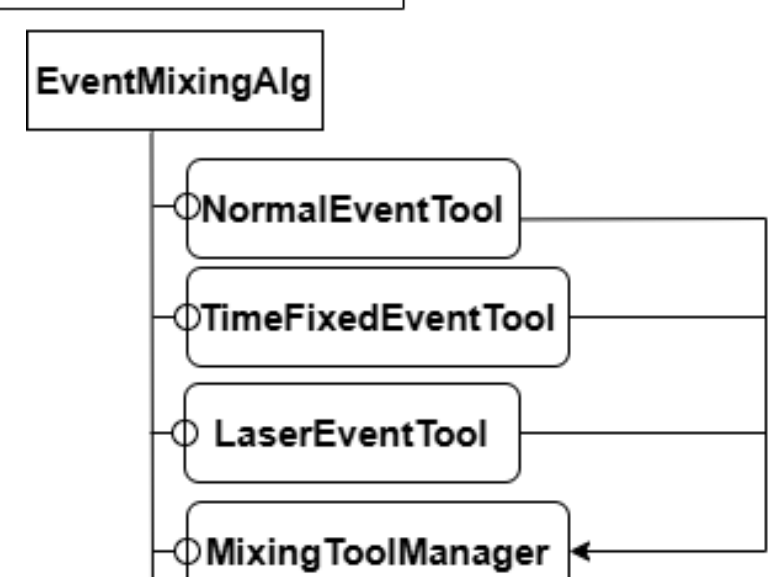
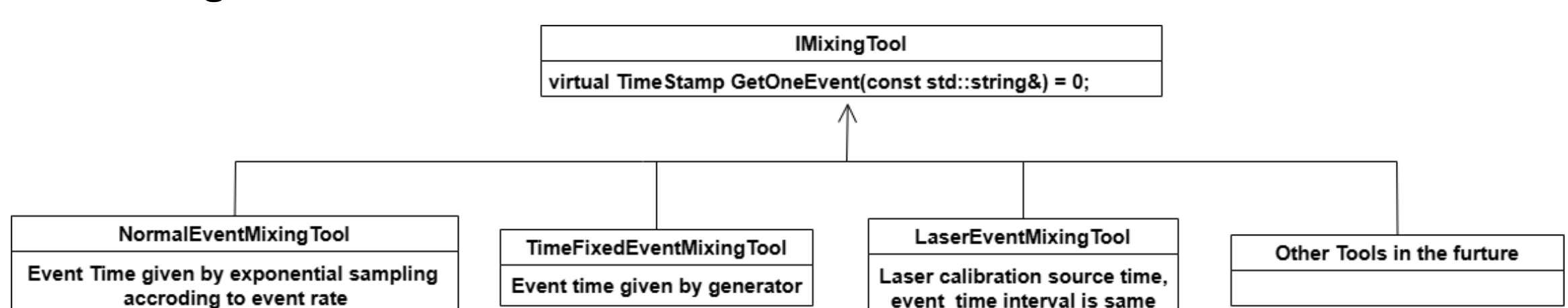
- ElecSim truth information : hit-level(pmt pulse-level) truth, track-level truth, correlation between detector simulation event and electronics simulation event

"Hit-level" Event Mixing in Electronics Simulation

- Load the detector simulation output according to their time character and unpacked , then mix their photoelectron together in time axis.



- Using different tools to handle different time mode

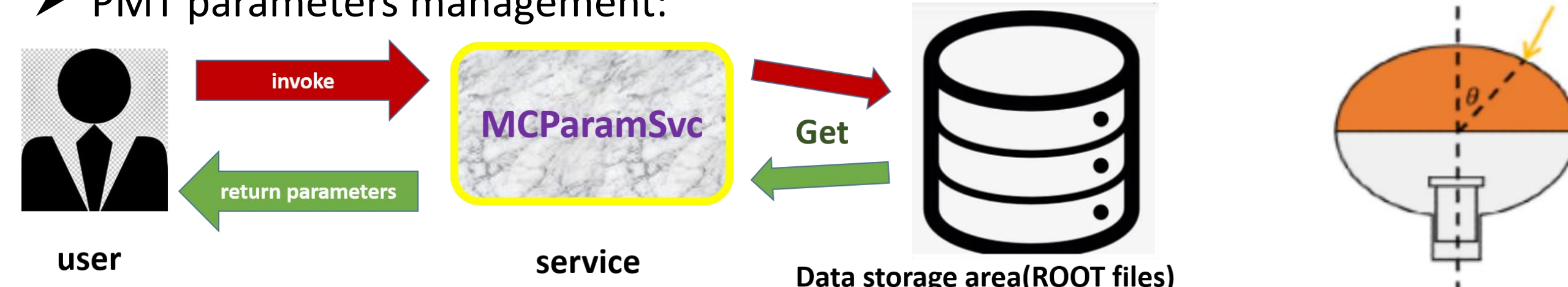


- Using another tool (MixingToolManager) to manage mixing tools and control ElecSim in inclusive or exclusive mode

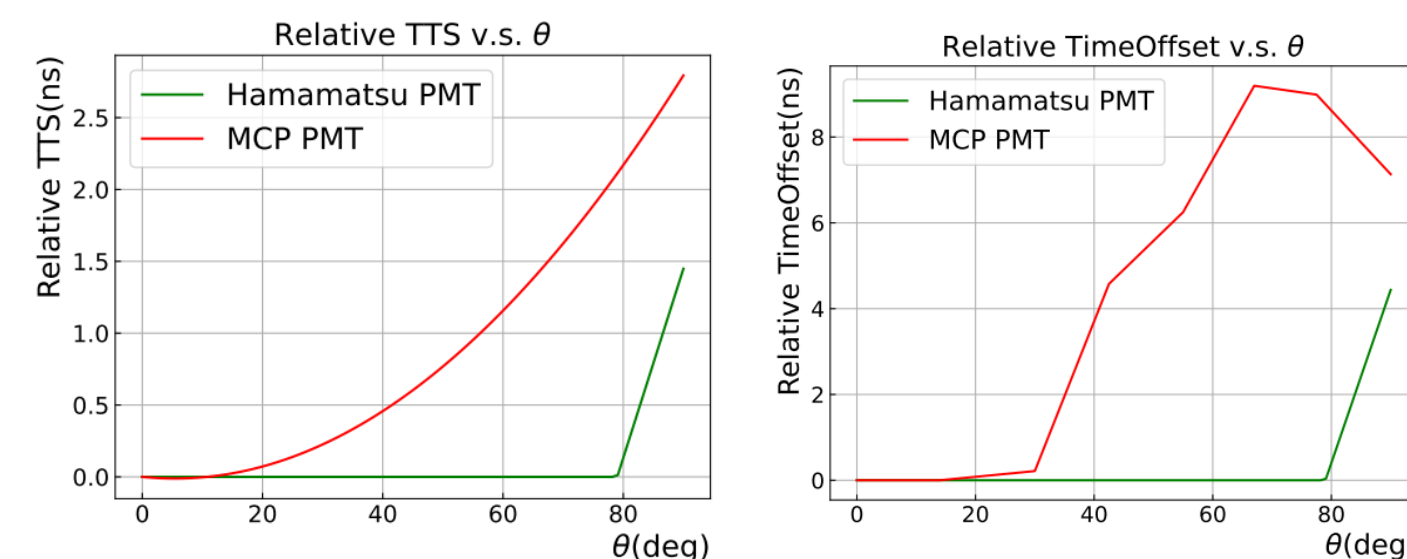


PMT Response Simulation

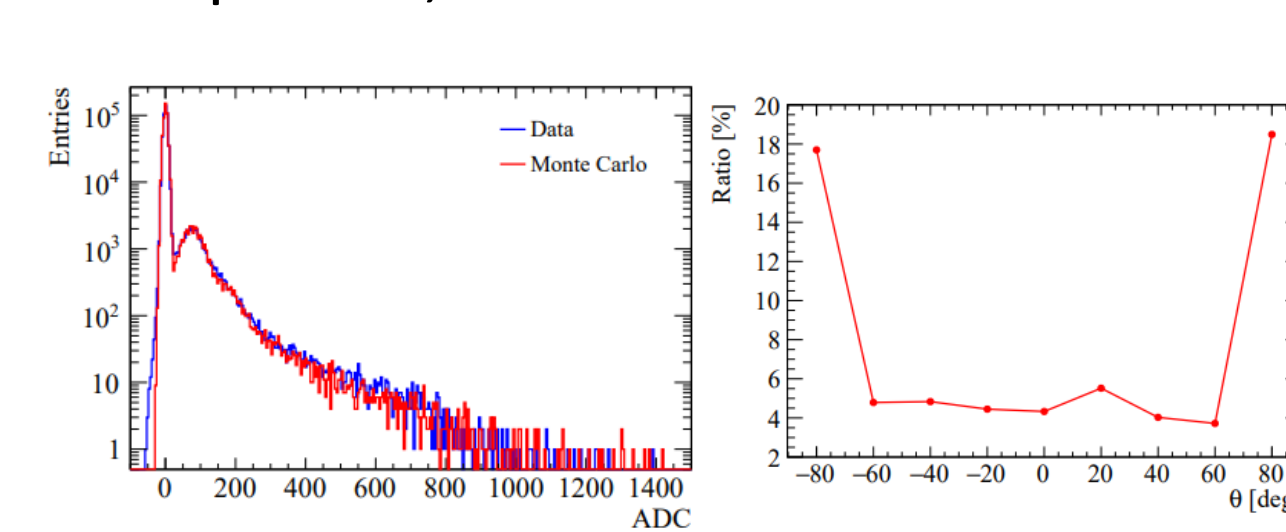
- PMT parameters (dark-pulse count rate, photon detector efficiency, transit time, transit time spread) are based on mass PMT test.[2]
- PMT parameters management:



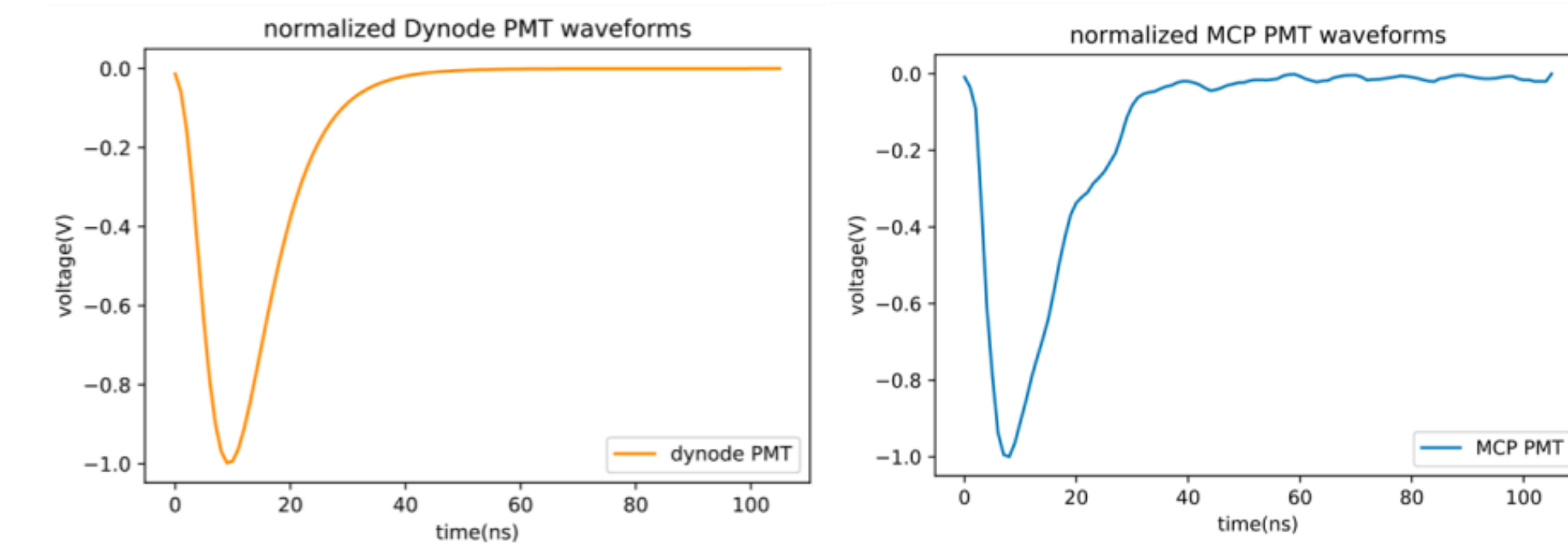
- PMT TTS(transit time spread) and TT(transit time) vs theta



- PMT charge spectrum: MCP: Gaussian + Exponent, Hamamatsu: Gaussian

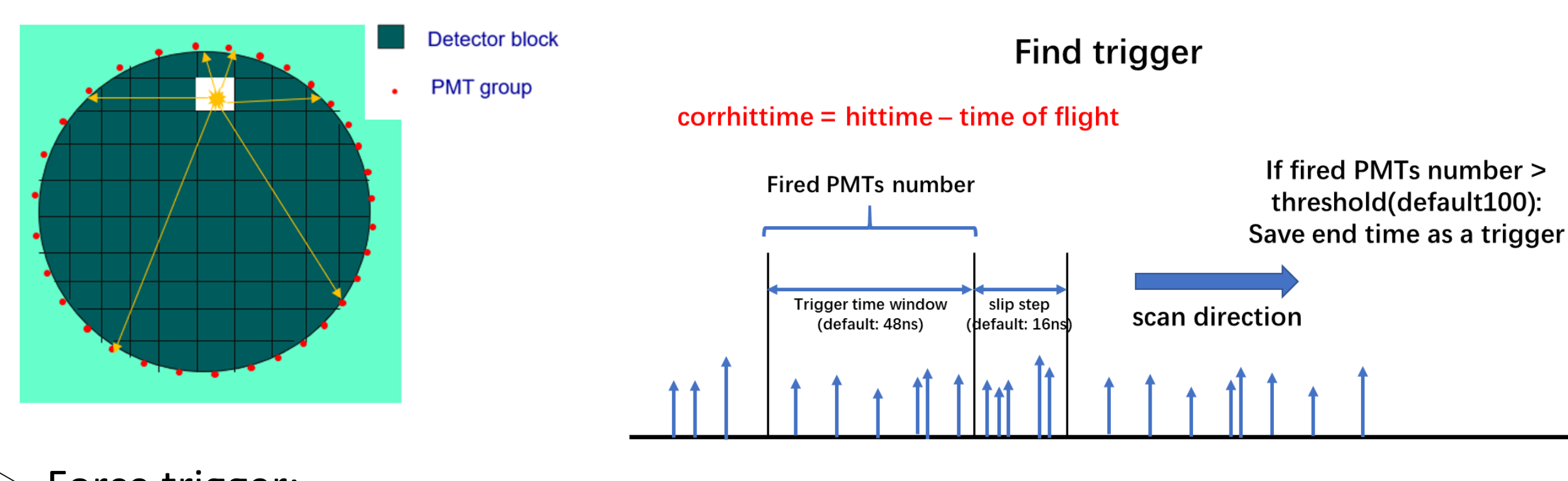


- PMT waveform templates are averaged from experimental data



Trigger Simulation

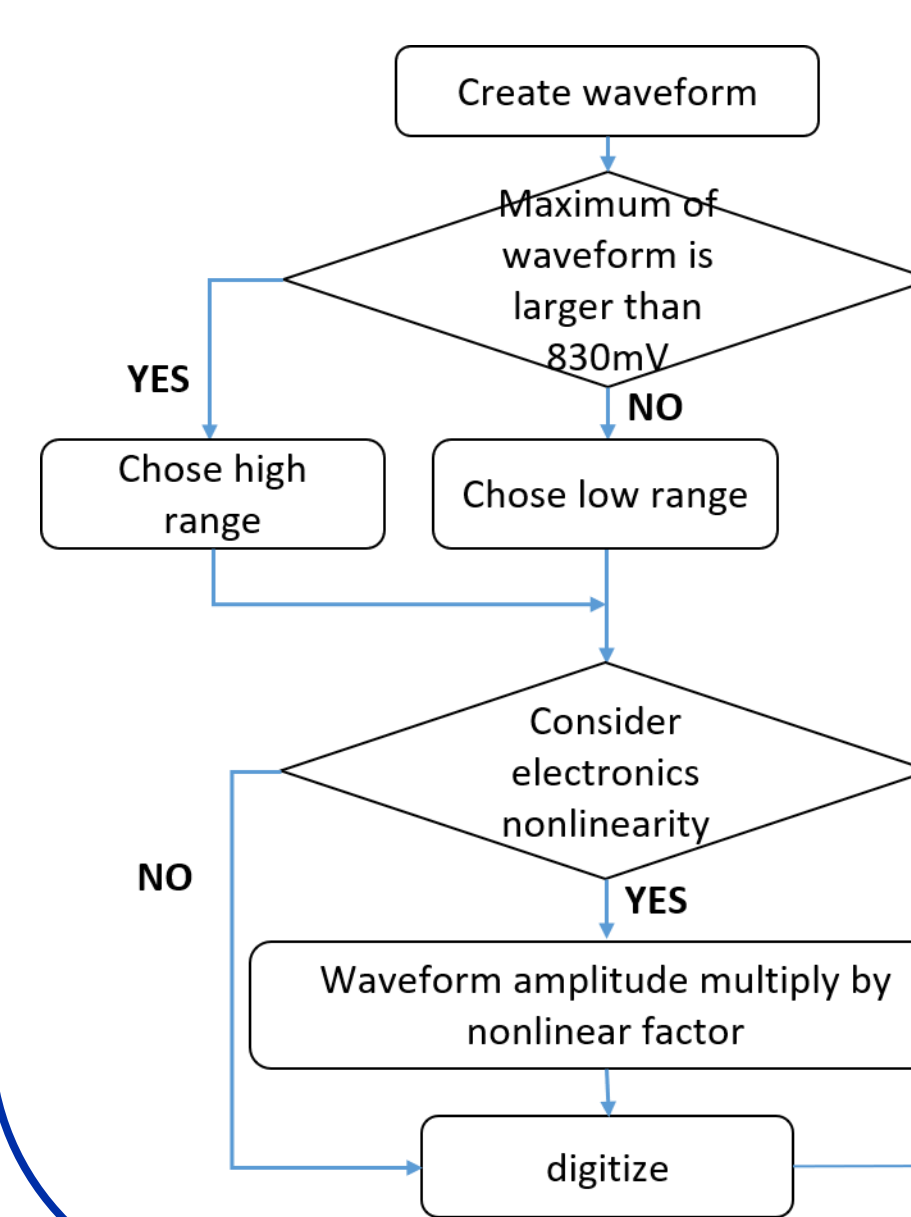
- Global trigger consistent with hardware.[3]



- Force trigger:
 - Force trigger is designed to generate a global trigger randomly without fired PMT number calculation
- Laser trigger
 - Trigger synchronized with the laser emission (for calibration).

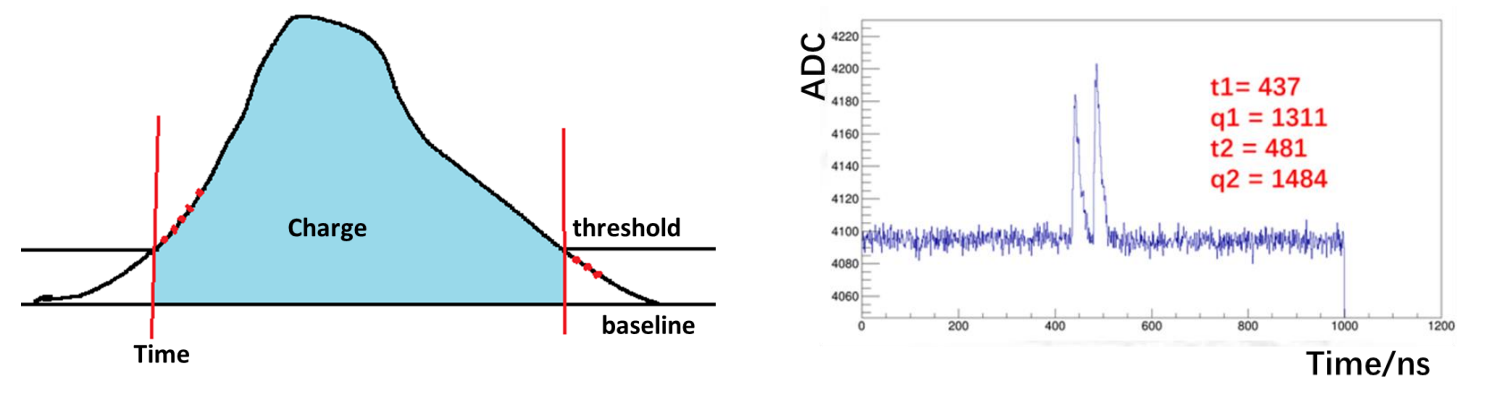
Electronics Response Simulation

- Flow chart of waveform readout



- FPGA T/Q Simulation: Continuous Over-Threshold Integral(COTI) algorithm

- Baseline: a dynamic 32ns length baseline buffer
- Threshold: 1.5 times RMS of baseline buffer points
- 5 point continuously over-threshold, start integral. 3 point continuously under-threshold, end integral
- Time: the time at which the integral start. Charge: integral value

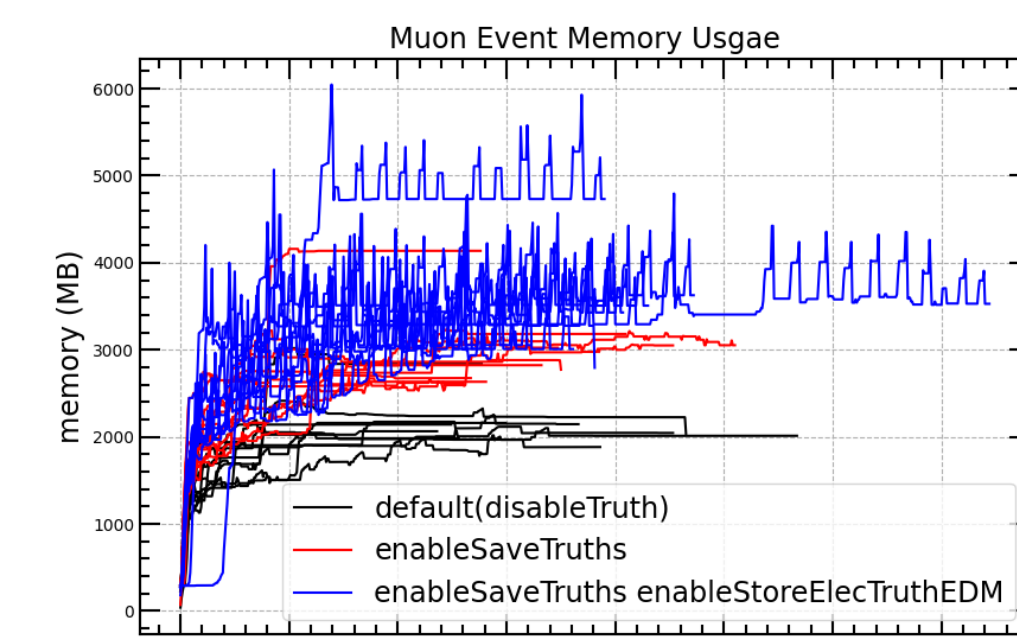
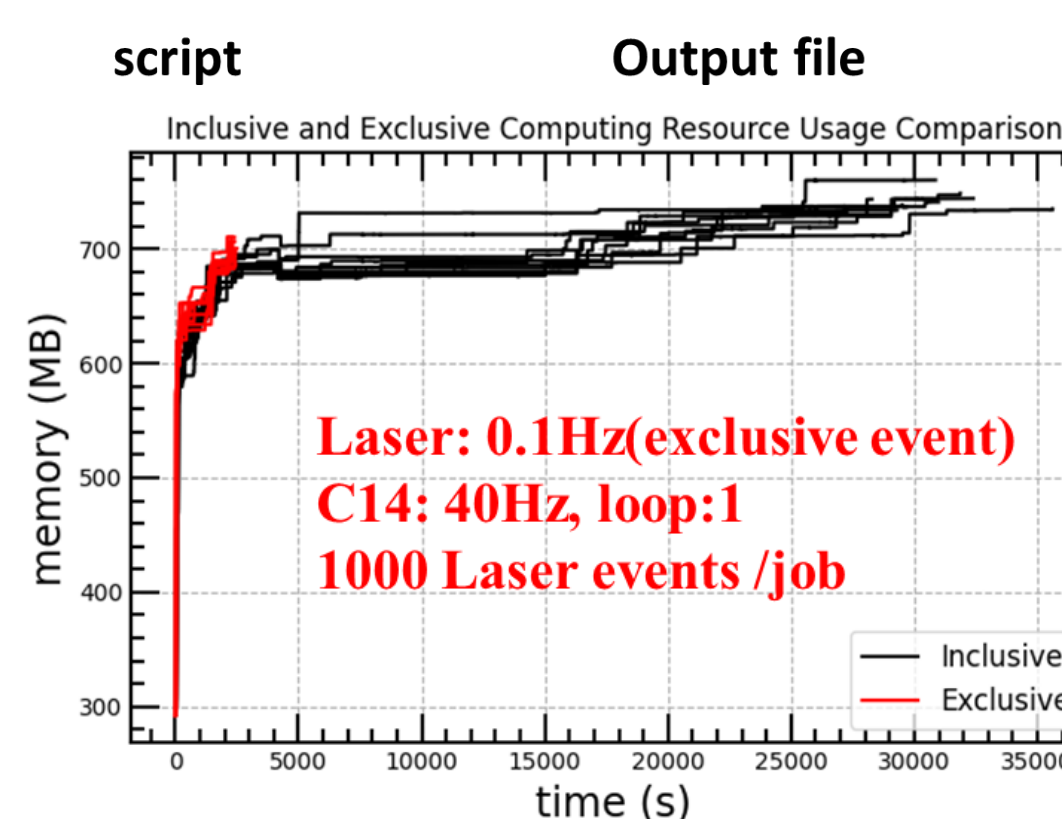


White Noise	0.56*Gaus(0,1)mV(~0.1p.e)
Readout window total length	1000ns
Baseline offset	1/4 full range

Computing Performance



- In ElecSim, to save memory usage, MC truth only be saved when user need



The input data of those test are simulated by JUNO official software

References

[1] Lin Tao. Doctoral dissertation -Research on the simulation framework software for the Jiangmen Underground Neutrino Observatory and the fast simulation of muons. 2016.
 [2]. Abusele, Angel, et al. "Mass testing and characterization of 20-inch PMTs for JUNO." The European Physical Journal C 82.12 (2022): 1-42.
 [3]. Gong, Guanghua, et al. "The global trigger with online vertex fitting for low energy neutrino research." ICALEPCS. 2015.