KamLANDにおける近傍超新星観測に対応したDAQシステムの開発

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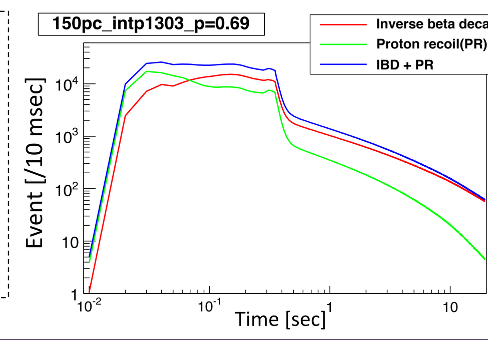
1. Motivation

Physics with supernova neutrino detection
- Mechanism of supernova
- Neutrino mass hierarchy

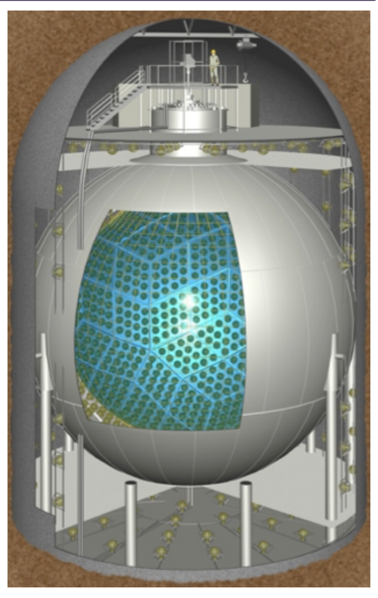
We want to take supernova neutrinos at KamLAND.
KamLAND will take ~300 inverse beta decay events when a supernova occurs at 10kpc distance (galactic supernova).
KamLAND electronics cannot take super-high rate events (>100 kHz) induced by nearby supernova neutrino.
->KamLAND electronics update is required to improve this problem.

Nearby supernova candidate
- Betelgeuse : 200 ± 50 pc
- Antares : ~170 pc
- Gamma Velorum : ~336 pc



Expectation (Betelgeuse like star)
0.5 – 2.4 MEvents/20 sec
Calculated by using Nakazato model.

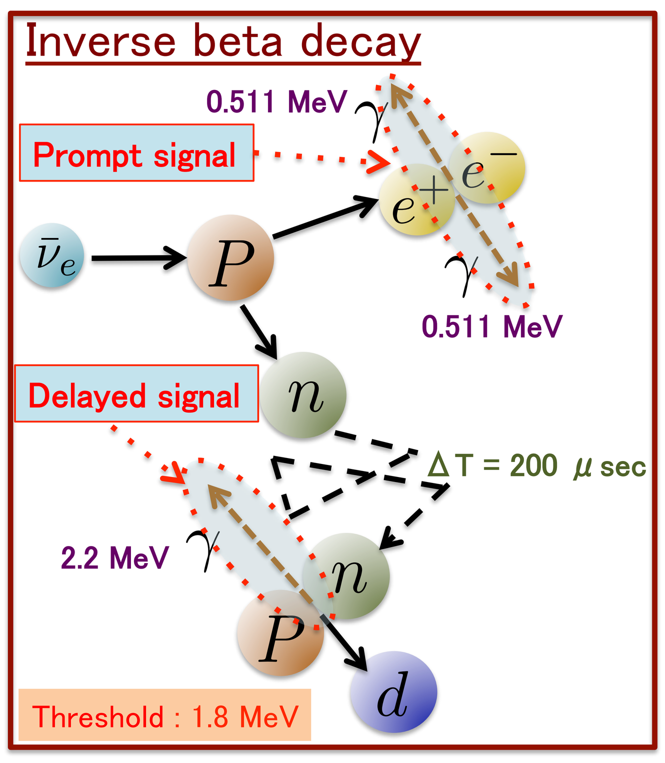
2. KamLAND

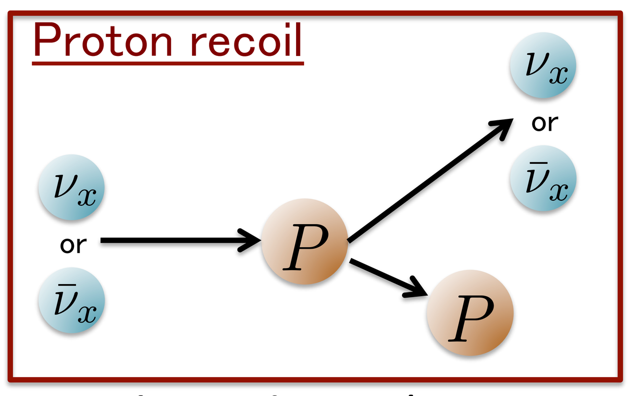


Kamioka Liquid Scintillator Anti-Neutrino Detector
1. 1,000 m underground
2. 1,000 t Liquid scintillator
3. 1,879 PMTs
4. Water Cherenkov detector for muon veto

The low energy neutrino detection for wide-range physics
ex) Neutrino oscillation, Geoneutrino, Solar neutrino, etc.

Supernova channels in KamLAND

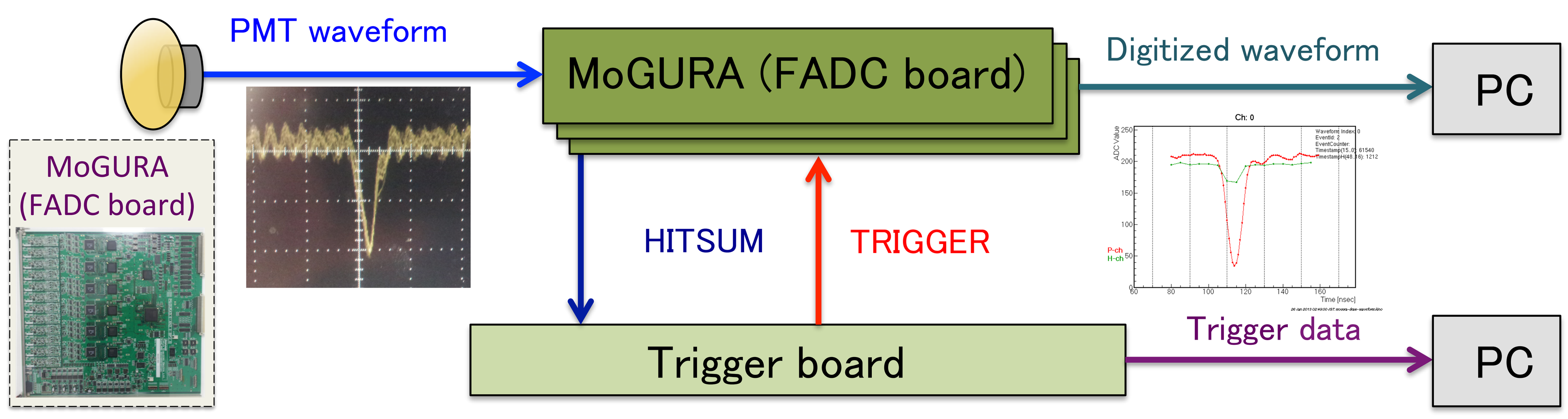




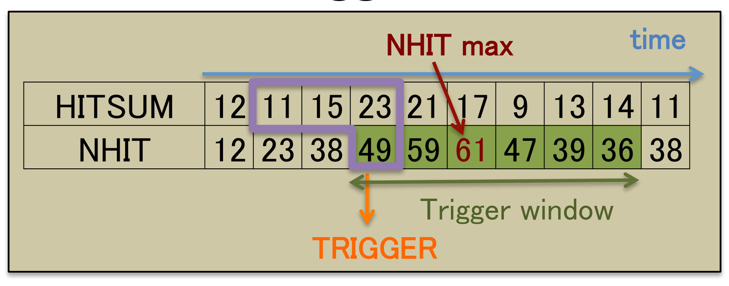
Inverse beta decay (sensitive to $\bar{\nu}_e$)
Almost background free with delayed coincidence method

Proton recoil (sensitive to all ν)
Advantage of KamLAND
->Water Cherenkov detector does not have

3.Status of KamLAND electronics



1. Scintillation light is detected by PMTs and its waveform is digitized by MoGURA.
2. Hit signal is generated by discriminating the waveform.
3. Sum of hit signal (HITSUM) is sent to trigger board.
4. When the trigger board finds events, it makes TRIGGER.



HITSUM	12	11	15	23	21	17	9	13	14	11
NHIT	12	23	38	49	59	61	47	39	36	38

NHIT : Summation of HITSUMs in 6 clock(120 nsec).
TRIGGER: NHIT becomes larger than threshold.
Trigger window : waveform taking window(120 - 480 nsec). Next trigger cannot output in this window.
NHIT max : Maximum NHIT in the Trigger window.

5. Triggered waveform and trigger data are buffed on-board SDRAM and then translated to PC respectively.

Electronics problem for nearby supernova

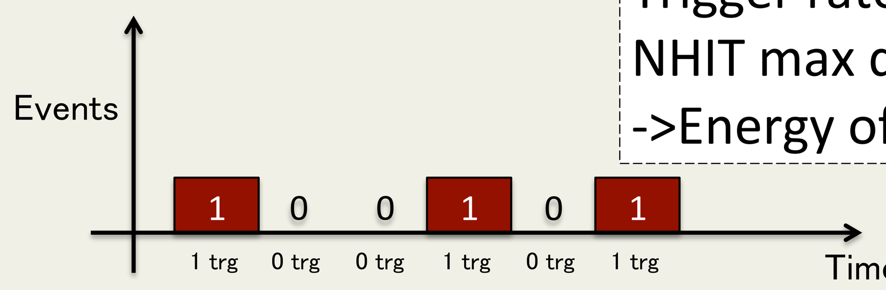
- Waveform taking stops immediately by buffer full on MoGURA.
  Usual trigger rate is ~100 Hz.
  -> Trigger rate is more than 100 kHz at nearby supernova event.
- Recording trigger data may fail even though it can be generated.
  Maximum transition speed of inside of trigger board is ~1 MHz.
  ->Trigger rate may be more than 1 MHz.

4. Event rate reconstruction by using the trigger data

Extract event information from trigger data

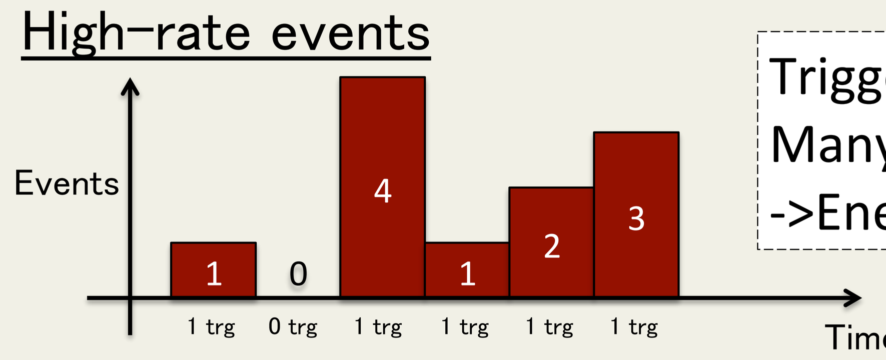
We want to know event rate and energy of event.

Low-rate events



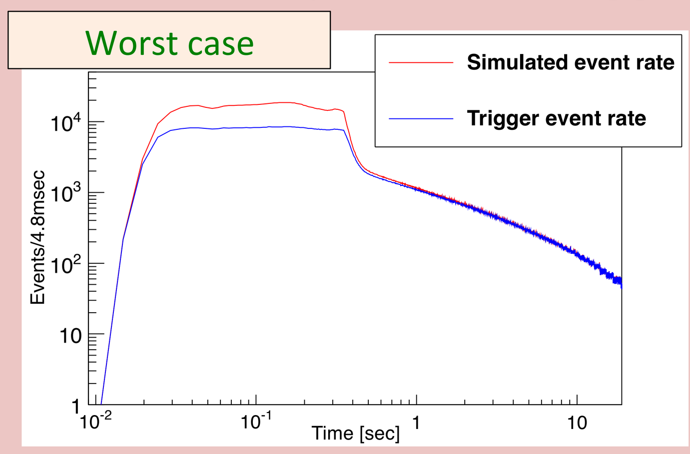
Trigger rate = Event rate
NHIT max depends on the energy of event.
->Energy of event can be derived from NHIT max.

High-rate events



Trigger rate ≦ Event rate
Many events pile up.
->Energy of event cannot be derived.

Estimation of deriving event rate from trigger rate
(On the assumption that trigger data is recordable completely.)



Calculated by using Nakazato model.

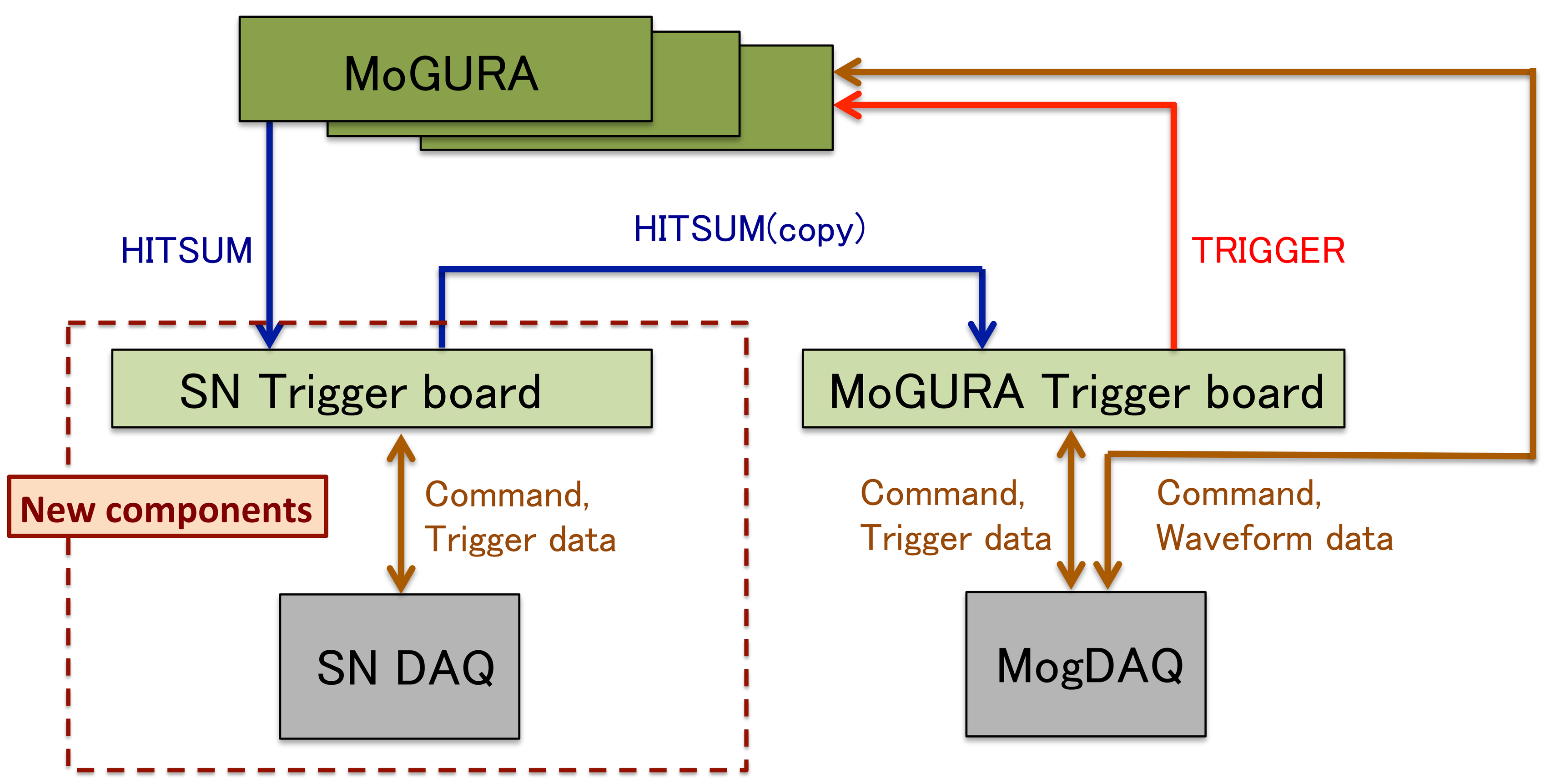
Betelgeuse like star
Distance : 150 pc
Mass : 13 Msolar
Metallicity : 0.02 Fe/H

Parameter
Revival time of shockwave : 300 msec
Survival probability : 0.69

More than 70% of events are detectable.
-> True event rate is reconstructed by using the trigger data.

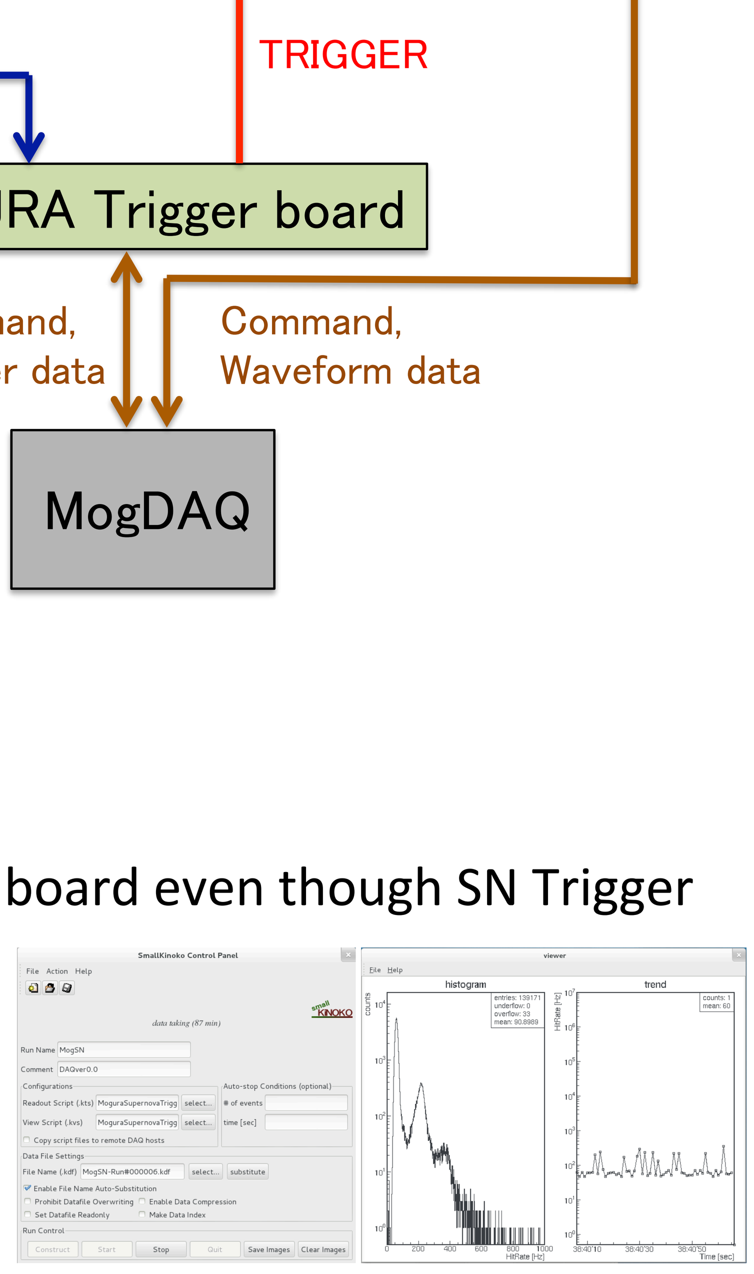
5. KamLAND electronics update

SN DAQ (SN Trigger board and SN DAQ PC) installed into electronics system in September, 2015.



SN Trigger board
- It can record ~4 MHz trigger data.
- It always copy HITSUM to MoGURA Trigger board even though SN Trigger board detect any error.

SN DAQ
- It operate SN Trigger board independently from MogDAQ.



SN DAQ controller & monitor

6. Conclusion

- SN DAQ was installed into electronics system of KamLAND.
- SN DAQ record trigger data when nearby supernovae occur.
- SN event rate is reconstructed by using the trigger data.

7. Future prospect

- Thin out trigger will be installed for taking a part of waveform.
  -> Time dependence of SN neutrinos energy spectra can be reconstructed
- Real time trigger threshold decrease function will be installed.
  -> More proton recoil events can be detected at galactic supernova

2016年1月6-7日　新学術「地下素核研究」第二回超新星ニュートリノ研究会