PMT Waveforms for Pulse Shape Discrimination in JSNS^2

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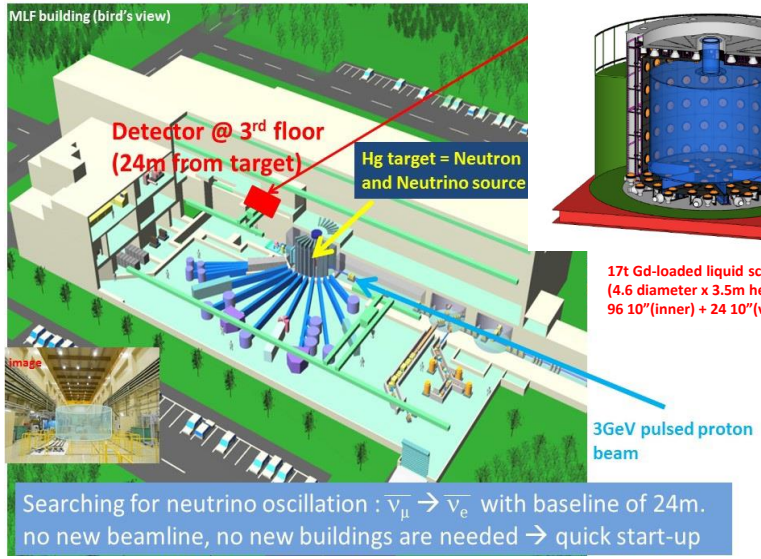
JSNS^2

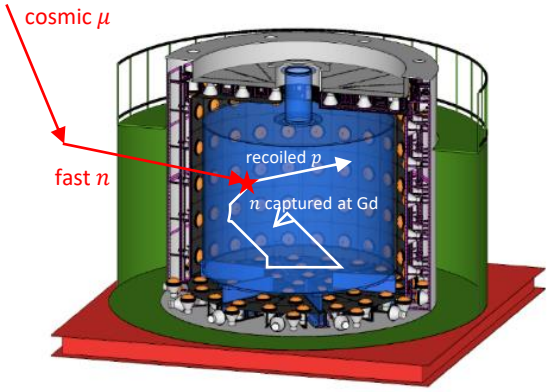
- J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source
- Searching for the existence of sterile neutrino with Δm^2 near 1 eV^2 at the J-PARC Material and Life Science Experimental Facility (MLF) and offering the ultimate direct test of the LSND anomaly.
- A 1 MW beam of 3 GeV protons incident on a spallation neutron target produces an intense neutrino beam from muon decay at rest.
- Search for $\bar{\nu}_\mu$ to $\bar{\nu}_e$ oscillations which are detected by the inverse beta decay interaction $\bar{\nu}_e + p \rightarrow e^+ + n$, followed by gammas from neutron capture on Gd.
- The detector has a fiducial volume of 17 tons and is located 24 meters away from the mercury target.

J-PARC MLF : World best environment



Cosmic Fast Neutron

- One of the dominant backgrounds of IBD events is fast neutrons induced by cosmic muons.
- In order to reject the background, the pulse shape discrimination (PSD) method is used to differentiate between neutron and gamma.

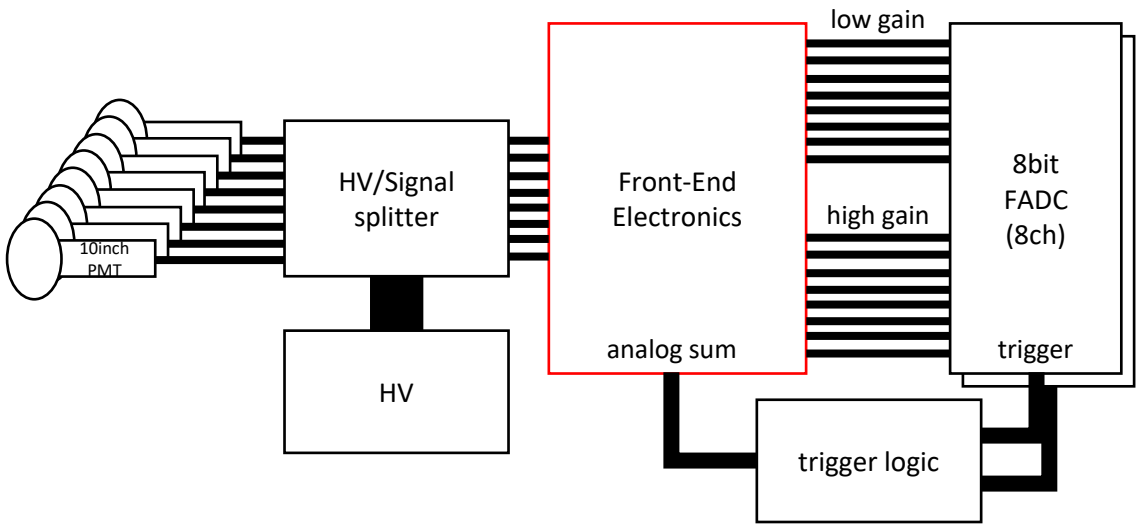


Fast neutron mimics the IBD coincidence.

In order to improve the PSD capability, 1600L of DIN, 8% of concentration, was dissolved into GdLS

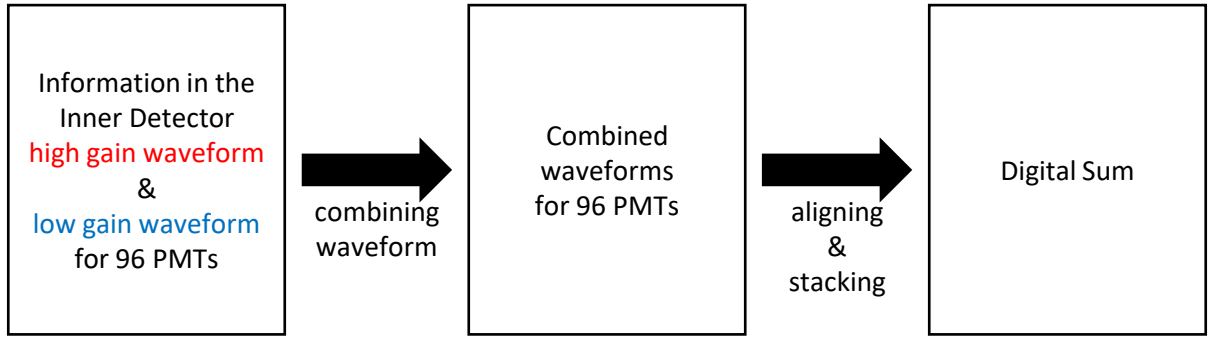
DAQ System

- JSNS^2 uses 10inch-PMTs, splitters, high voltage module, frontend electronics module (FEE), and 8bit-FADC.
- JSNS^2 uses 2 FADC channels for a PMT channel to get a broader dynamic range, better energy resolution and pulse shape discrimination (PSD) capability .



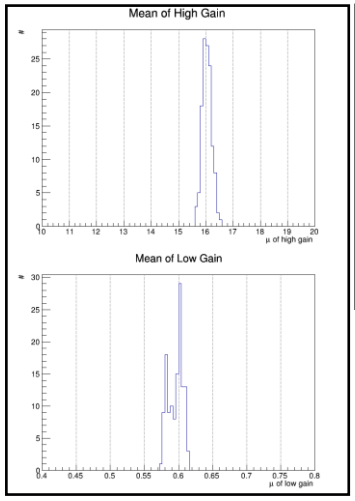
Digital Sum

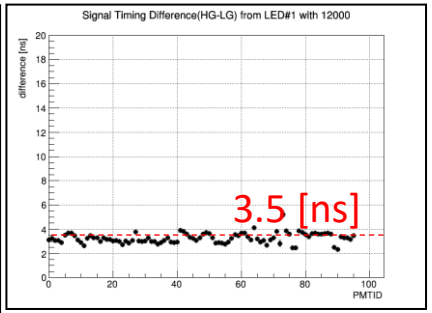
- Without any treatment, it is hard to discriminate the prompt signal & neutron background with 96 PMT waveforms.
- To make a PSD variable which can be easily understood by human, a digital sum which represents the 96 PMT waveforms is constructed.
- The construction of digital sum are shown in this slide.



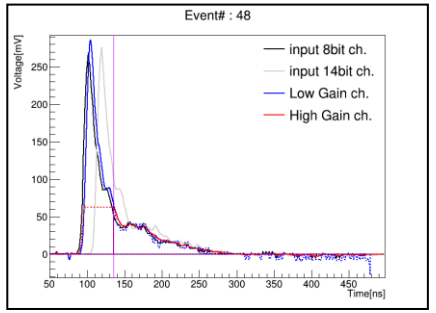
Combining Waveform

- Normalizing the high gain with 16. & the low gain with 0.6
- Aligning the high gain & low gain with 3.5[ns]
- Using high gain & low gain waveform, combined waveform is obtained.





↑ time difference b/w the high & low gain

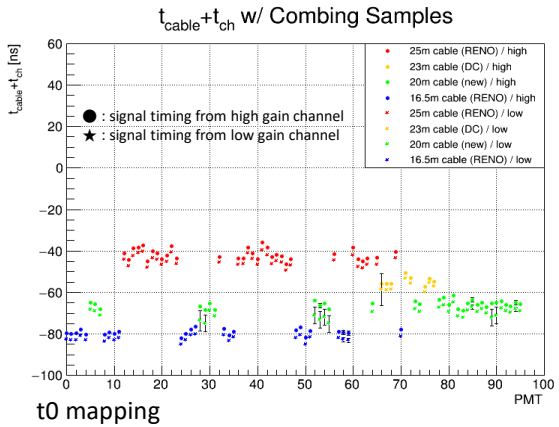


↑ combining the high & low gain

← gain factor of FEE

Aligning PMT Waveforms

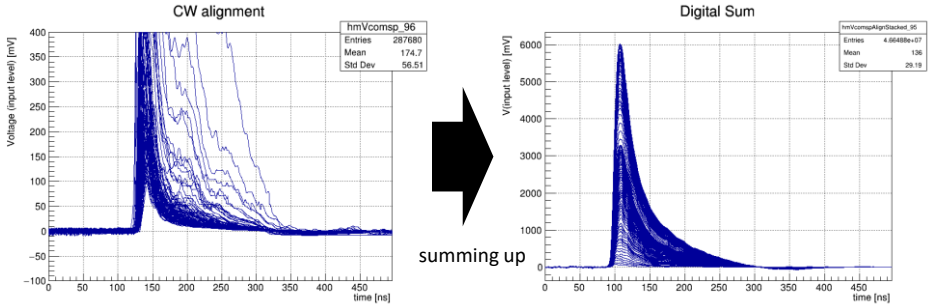
- PMT channels are aligned by using the following correction factor
  - correction = ToF + t0
  - ToF(time of flight) is obtained using the distance b/w reconstructed vertex and geometry of a PMT.
  - t0 is timing characteristics of each PMT channels which was obtained from t0 analysis with LED samples.



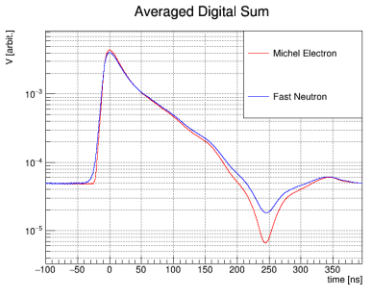
t0 mapping

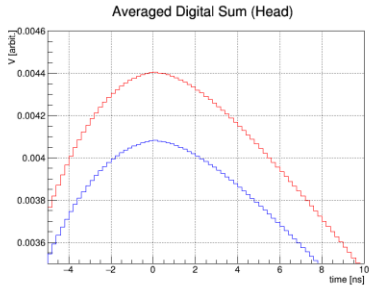
Stacking PMT Waveforms

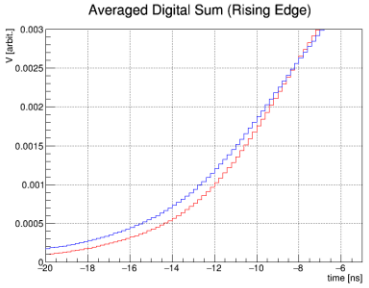
- Using the aligned PMT waveforms, digital sum is obtained by summing up them.
- In order to exclude the PMT channels with PMT saturation, only channels with charge less than 500PE contribute to the digital sum.

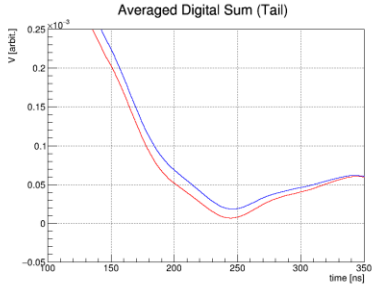


Averaged Digital Sum









The difference of dE/dx is clearly shown in the rising edge, the head, and the tail. Using the difference, it is being investigated how to define nice PSD variables.