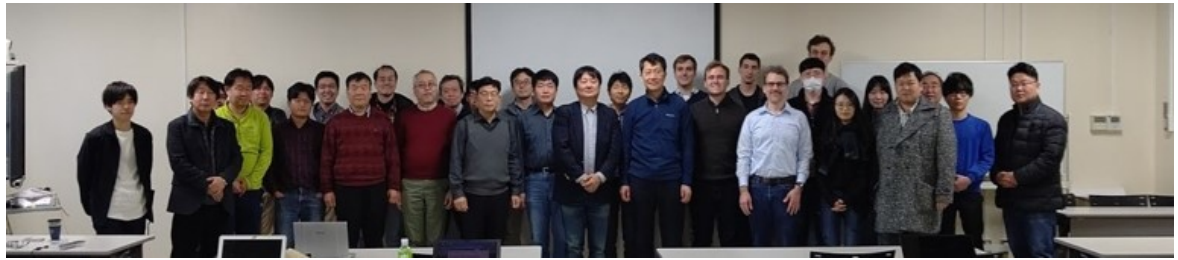
The JSNS^2 experiment

Jungsic Park (KEK)

計測システム研究会, Nov 26-27

J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source

Collaboration meeting @ J-PARC (2020/Feb)



JSNS^2 collaboration (61 collaborators)

- 6 Japanese institutions (27members)
- 10 Korean institutions (26 members)
- 1 UK institution (1 member)
- 4 US institutions (7 members)

JAEA
KEK
Kitasato
Kyoto
Osaka
Tohoku

Soongsil
Dongshin
GIST
Seoyeong
Chonnam National
Seoul National

Sussex

Alabama
BNL
Florida
Michigan

Contents

- Introduction of the JSNS^2 experiment
- DAQ system
- Quick glance of the data

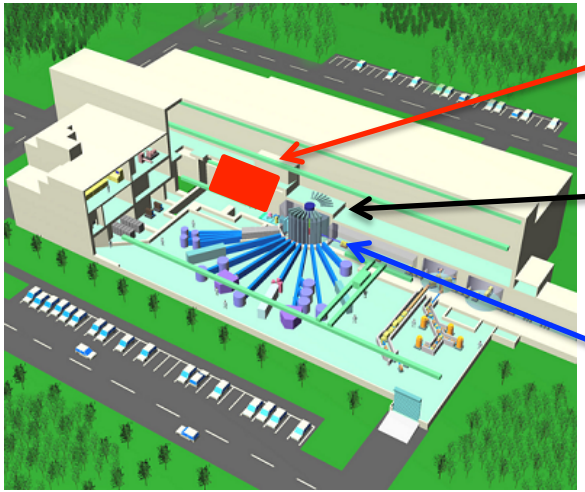
Jungsic Park, KEK

Indication of a sterile neutrino ($\Delta m^2 \sim 1 eV^2$)

Experiments	Neutrino source	signal	significance	E(MeV), L(m)
LSND	μ Deacy-At-Rest		3.8 σ	40, 30
MiniBooNE	π Decay-In-Flight		4.5 σ	800, 600
			2.8 σ	
		combined	4.8 σ	
	arXiv:1805.12028	+ LSND	6.1 σ	
Ga (calibration)	e capture		2.7 σ	<3, 10
Reactors	Beta decay		3.0 σ	1-8, 10-100

- Excess or deficit do really exist?
- Note: JSNS^2 uses the same neutrino source (μ), target (H) and detection principle (IBD) as the LSND → even if this is not due to the oscillation, we can catch this directly

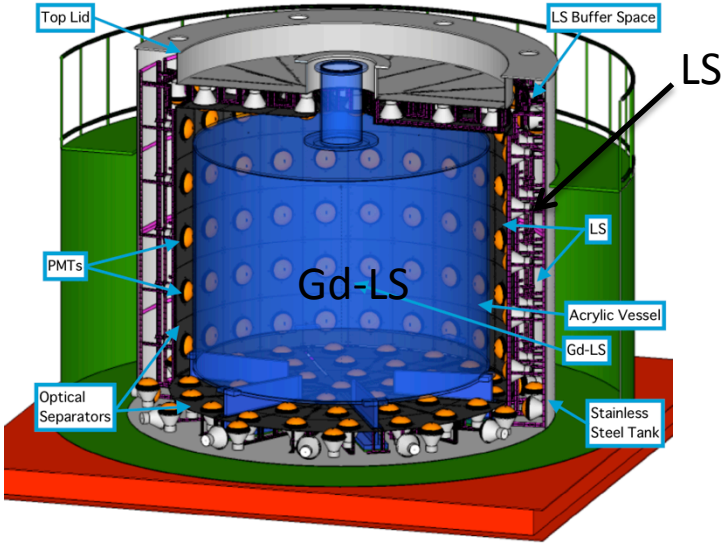
J-PARC MLF : one of the world best environments



Detector @ 3rd floor (24m from target)

Hg target = Neutron and Neutrino source

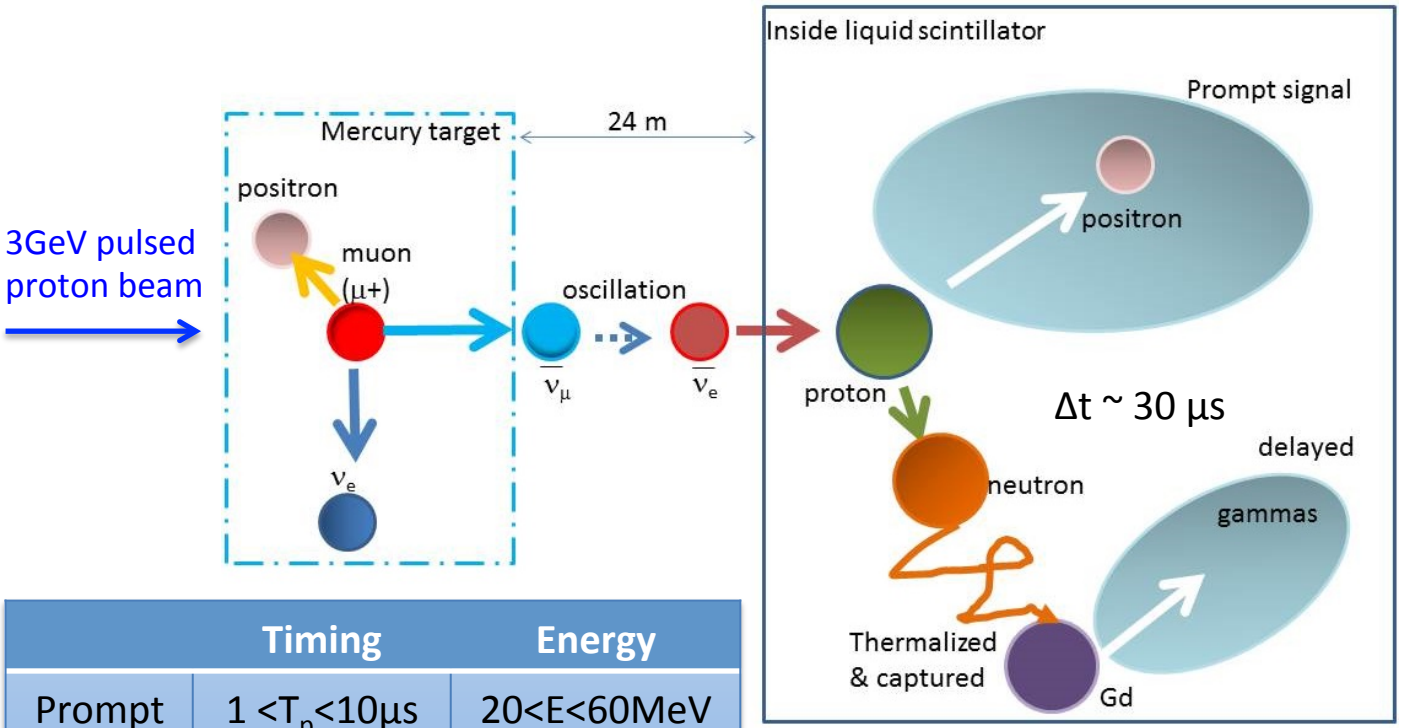
3GeV pulsed proton beam



- Searching for neutrino oscillations over a 24m baseline
- do not need new beam-line or building ➔ started !!

- 52t (Gd-loaded + unloaded) liquid scintillator detector
- 4.6m diameter x 4.0m height
- 120 10” PMTs

Production / Detection



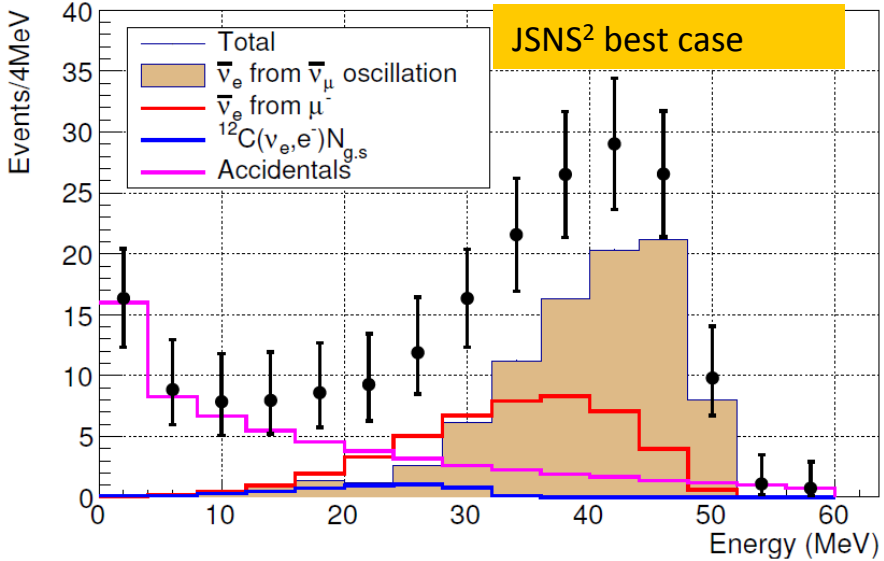
	Timing	Energy
Prompt	$1 < T_p < 10\mu s$	20<E<60MeV
Delayed	$T_p < T_d < 100\mu s$	7<E<12MeV

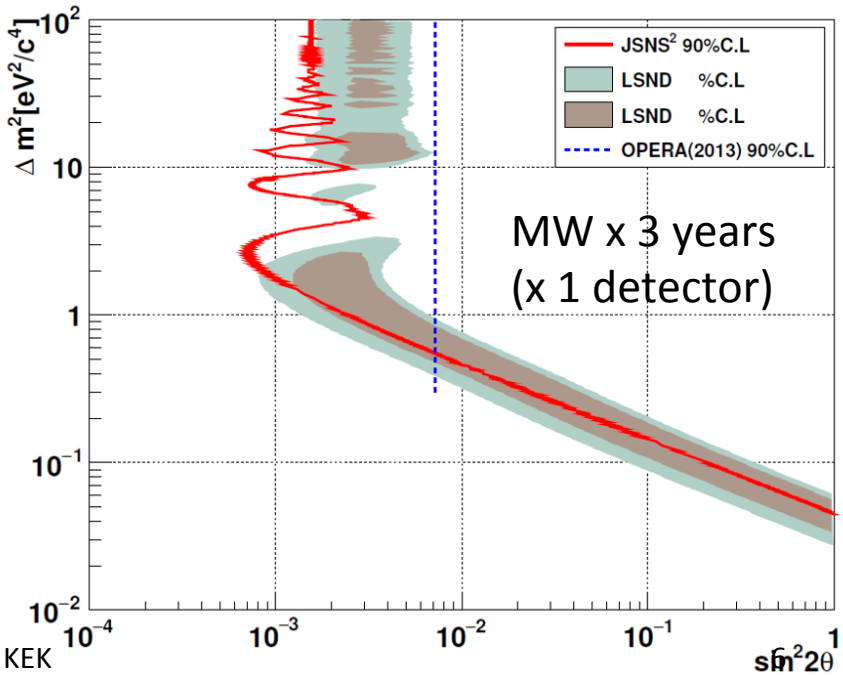
Most of them are same as the LSND.
→ Direct ultimate tests for LSND.

But use much better beam and Gd loaded LS.
→ Much better S/N
→ Much better systematics

Energy Spectrum and Sensitivity (by MC simulation)

- Left: Energy spectrum（$\Delta m^2 = 1.2eV^2$, $\sin^2 2\theta = 0.003$)
- Right: Sensitivity of 3 years physics running of JSNS^2 with one detector.



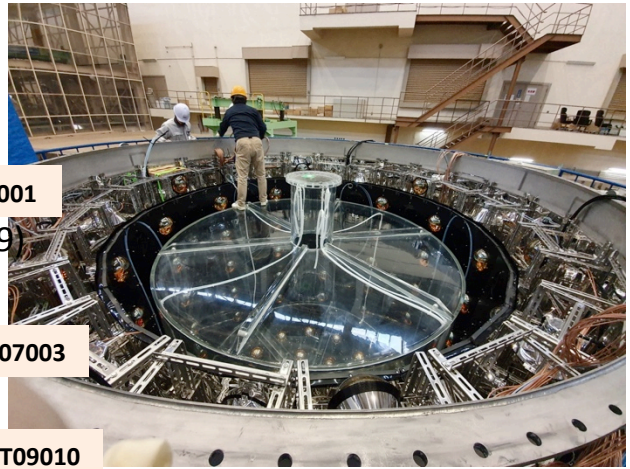


Detector construction (2017 – 2020)

Detector construction have been finished in February 2020.

- Stainless steel tank was produced by Morimatsu (2017-2018) **JINST 14 (2019) no.09, T09001**
- Acrylic tank was produced by Nakano(2018-2019)
- 10 inch PMTs from collaborators
  - RENO / Double Chooz
  - And newly purchased **JINST 15 (2020) no.07, T07003**
- 35 tons of LS was produced by Korean collaborators (2018) **JINST 14 (2019) no.09, T09010**
- 17 tons GdLS was donated by Daya-Bay (2019)
- Electronics were reused or donated by Double Chooz **JINST 15 (2020) no.09, T09002**
- Fast LED system

Very efficient experiment using reused or donated materials from various experiments. We do appreciate Daya-Bay, RENO and DC.



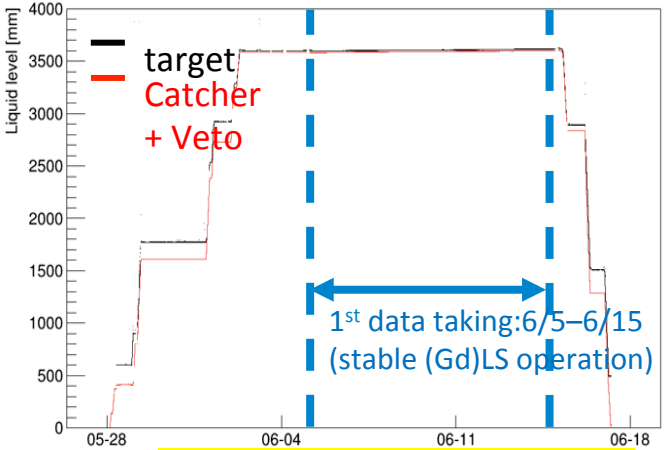
Detector operation cycle

- MLF 3rd floor is the maintenance area for the mercury target and beam equipment. Thus, we need to bring in and out the detector during summer beam shutdown every year (4 months).
- I.e. : we have to fill in and extract out (Gd)LS during short time also.

① Move the detector from detector assembly building (HENDEL) to MLF
② Scintillator filling in MLF 1st floor within 10 days
③ Data taking in MLF 3rd floor (1st physics run during 6/5 – 15 June 2020)
④ Scintillator extraction again in MLF 1st floor within 10 days again.
⑤ Move the detector to HENDEL

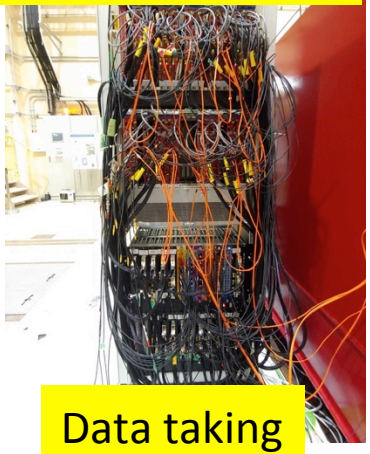
Move detector to MLF

Scintillator filling

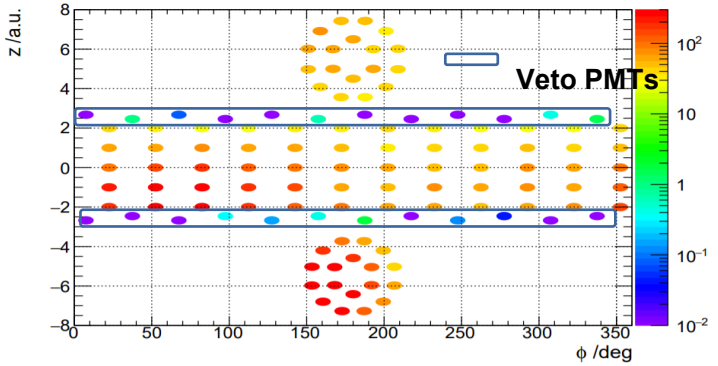


World fastest speed !!

Detector on the MLF



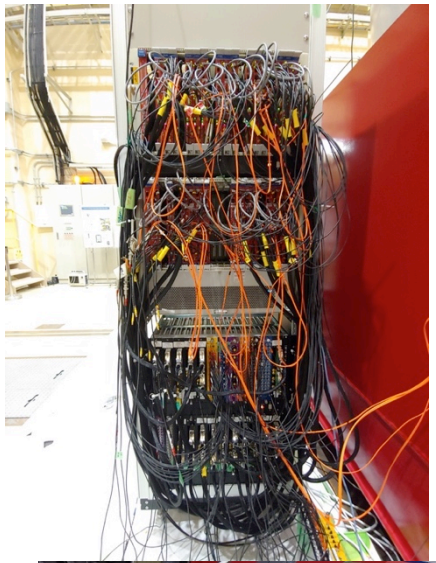
Data taking

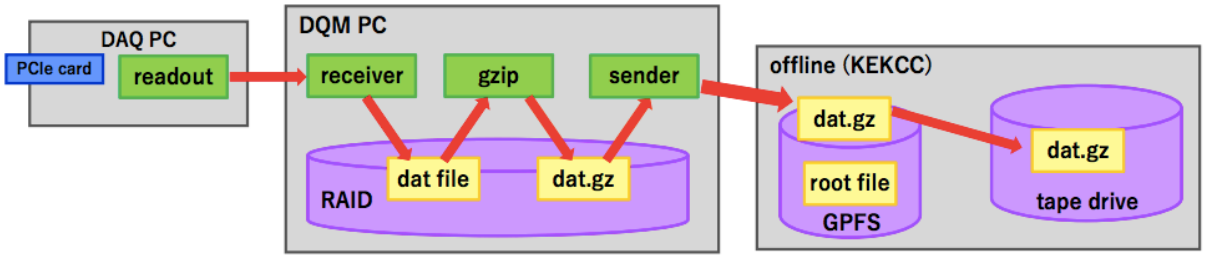


Event display

1st physics run

We took 1st physics data in June
- with 28 CAEN FADCs and 4 optical links
- one DAQ PC and one Data quality monitoring (DQM) PC
- Triggered by the Beam
- LED
- self-trigger (including ^{252}Cf)
- Several test runs for the next round
- Data is transferred to KEKCC





< Data flow from the DAQ PC to KEKCC >

DAQ + DQM

500 MHz FADCs (V1721) are donated from the DC.
- Arrived in Jan 2019.
- Optical link daisy chain (80MByte/each).

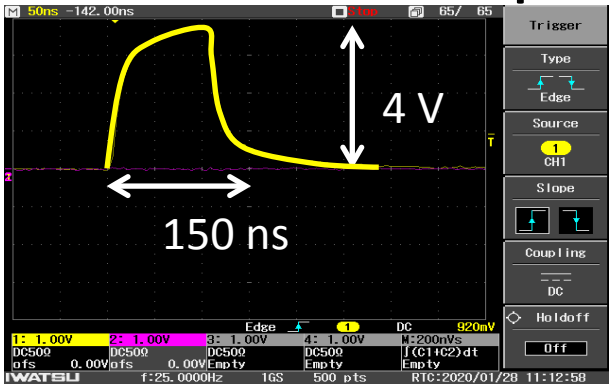
We transfer data with TCP / IP socket to the DQM PC.
- 1Gbps between the DAQ and the DQM PC
- Adler 32 is used to check the transfer status.

DQM PC
- Installed CentOS 7
- Has 12 TByte storage
- FADC raw data is stored in the DQM storage, compressed, and then transferred to the KEKCC. with 1Gbps ethernet.
- Monitoring the data quickly.
- Conversion of the data to the ROOT format.

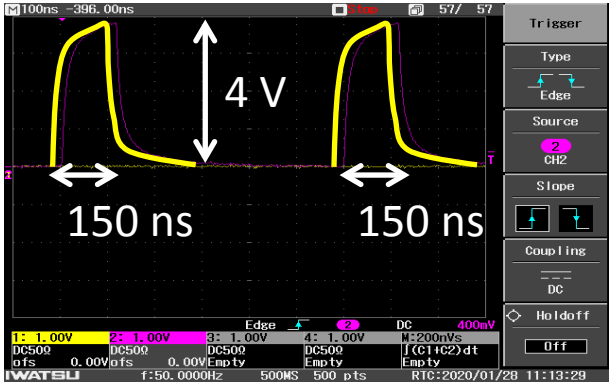
Consists of header, body, and trailer.

Header Size
Run Number
Trigger Time Tag
Event Number
Header magic, NBOARDS
FADC 1 Serial ID
FADC 1 data
FADC 2 Serial ID
FADC 2 data
FADC 3 Serial ID
FADC 3 data
..... (FADC Information)
Trailer magic

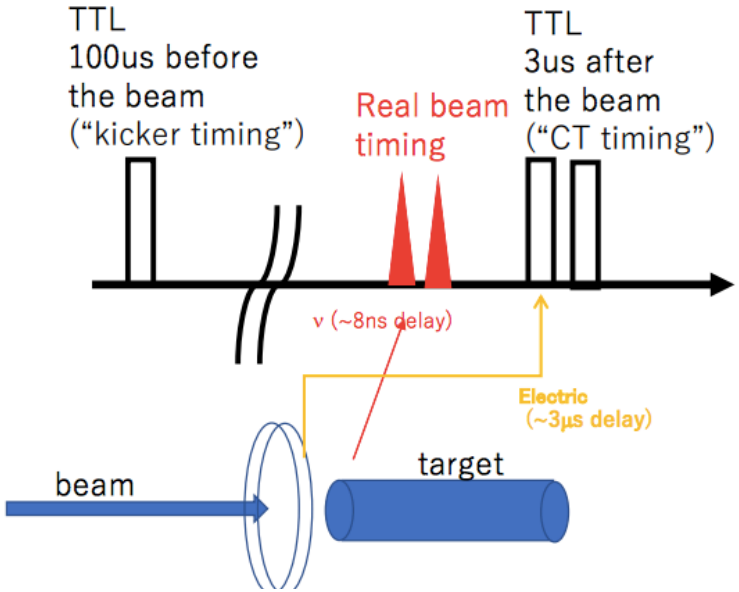
Beam Trigger Timing from the collision of the proton to mercury target



< Kicker >



< CT >

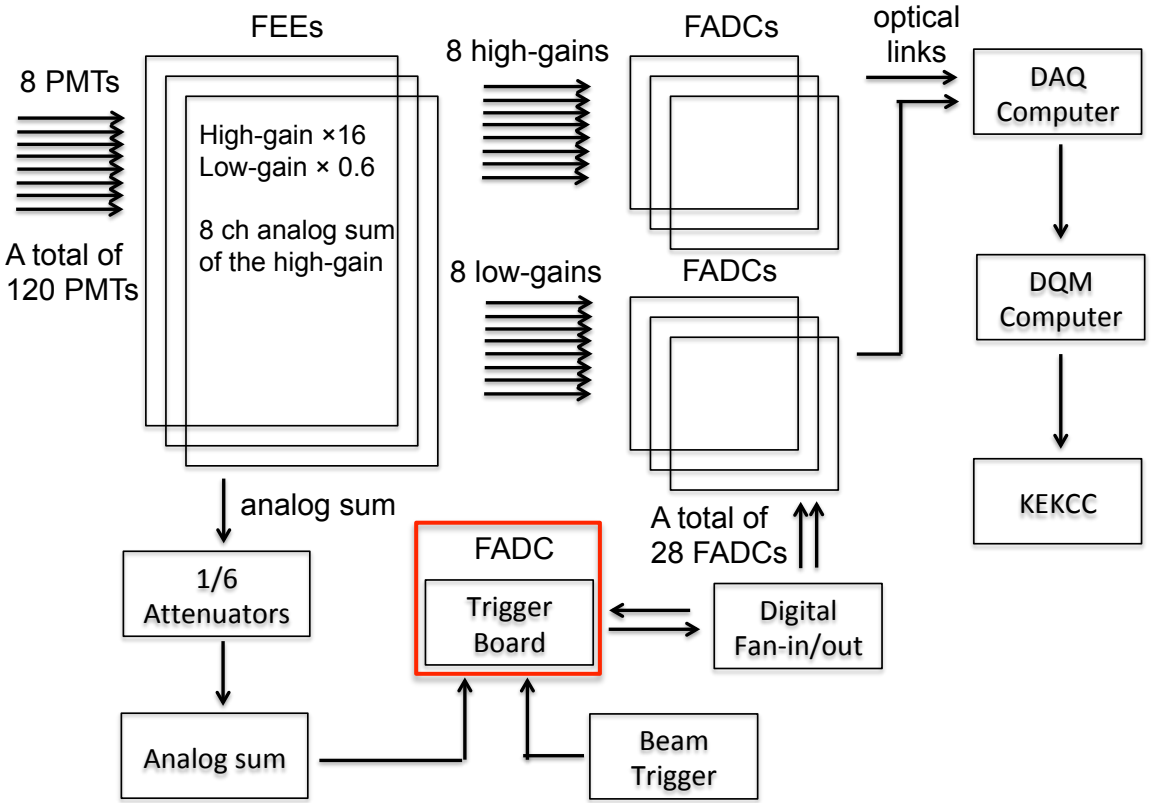


Current Transformer (CT) induced event from magnetic field changing.

- Available from the MLF
- Can confirm the beam "really" came or not

JINST 15 (2020) no.09, T09002

DAQ scheme



Using special amps with two different gains.

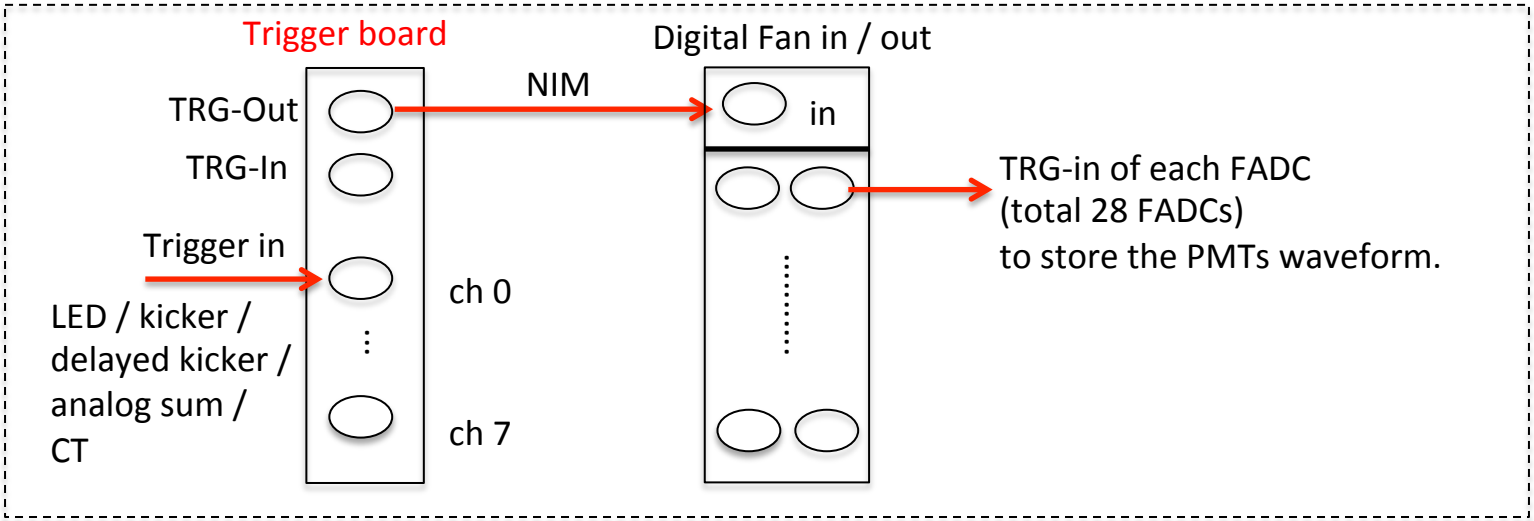
- high-gain for the low energy
- low-gain to increase the dynamic range
- analog-sum of 8 high-gain channels

Assigned one FADC board as a “trigger board”.

Trigger

We used “external triggers” to store the PMTs waveforms.

- Designated “a FADC Trigger board” to generate a global trigger.
- LED : The controller box generates a external NIM trigger.
- Kicker : Accelerator group provides with a TTL trigger.
- self (including ^{252}Cf) : Use the analog sum of inner PMTs waveform.
- Each trigger type can be distinguished with a trigger bit.

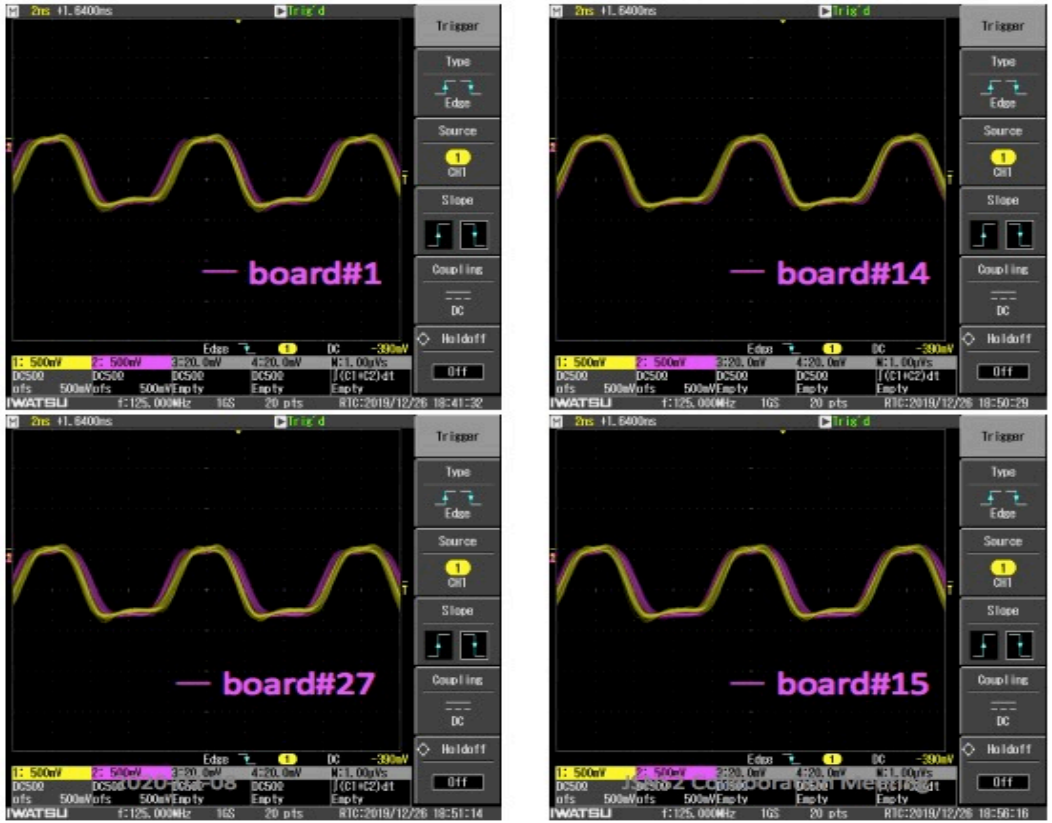


FADC timing synchronization

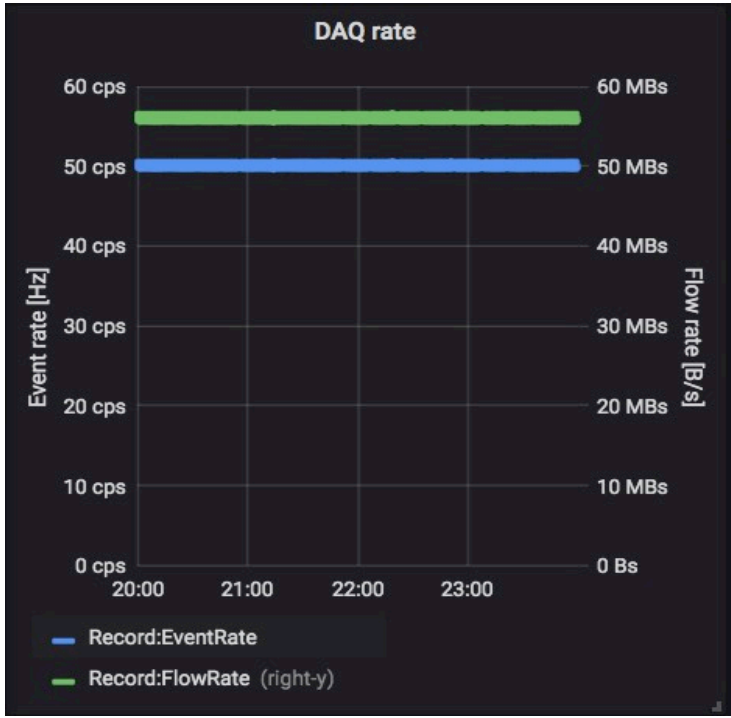
- Each FADC is equipped with an internal clock
- The clocks across the FADCs will, in general, be out of phase
- FADC's clock is synchronized using a daisy chain method
- Trigger board serves as a master clock

- In the oscilloscope screenshot, one can see the clock phase between the master clock (yellow) and each board (violet).

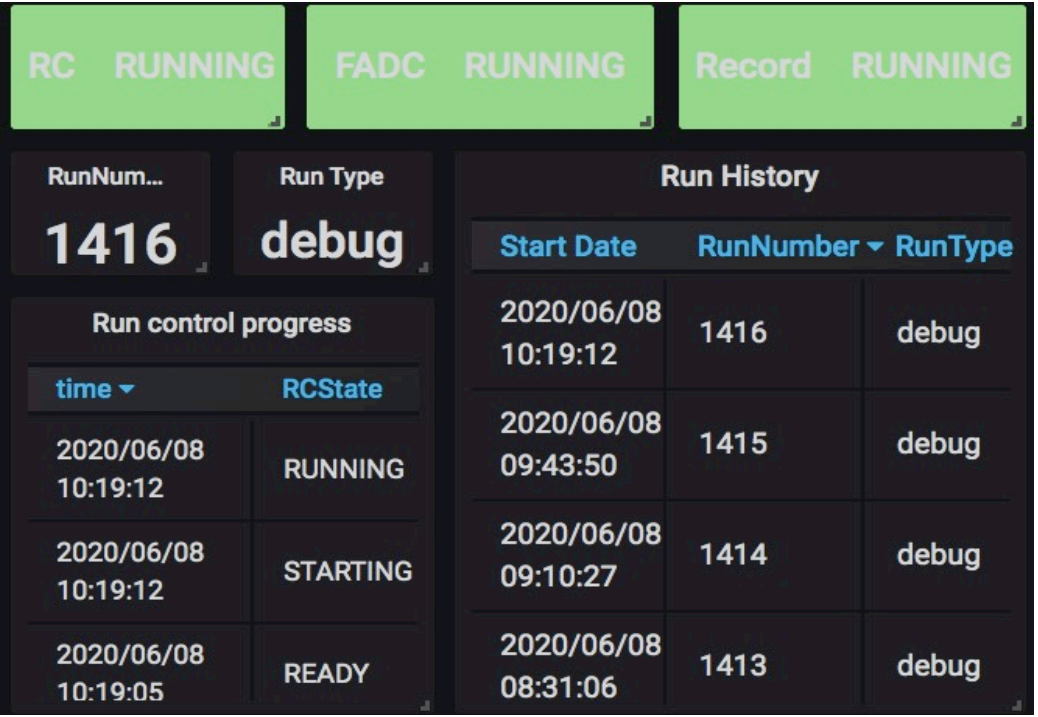
- referred "AN2086 − synchronization of CAEN digitizers in multiple board acquisition systems"



Monitoring of the data taking status



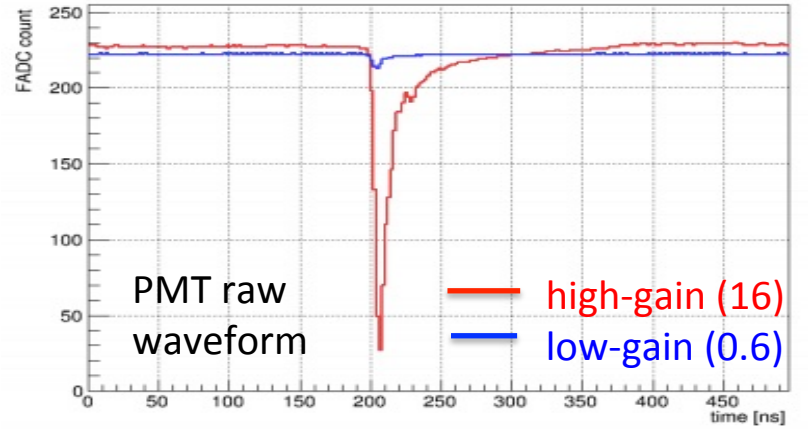
Trigger rate

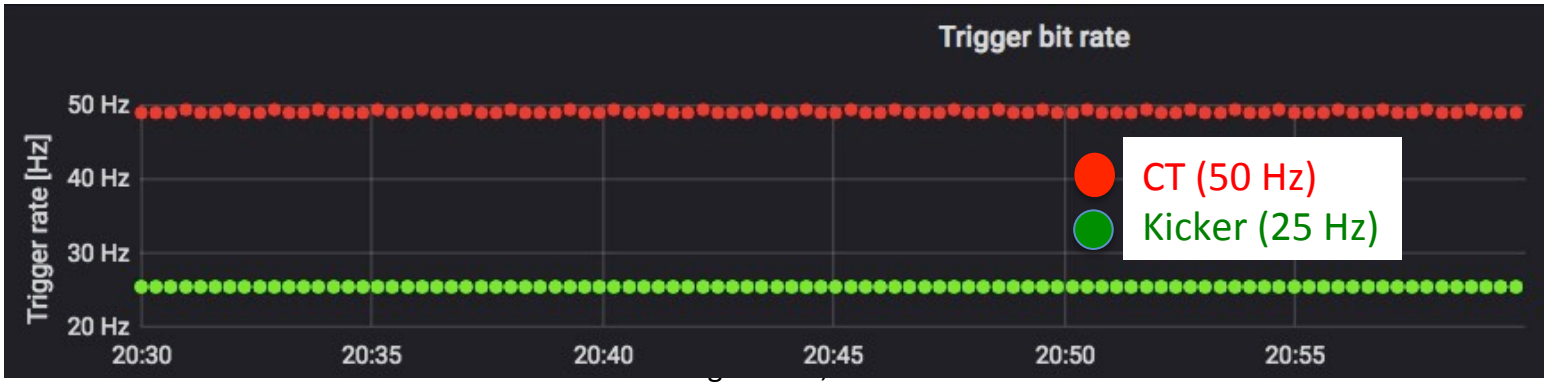


Run Status

Data quality monitoring (DQM) plots

The DQM PC produces useful plots
- PMT raw waveform
  (Both the high/low gain)
- Trigger bit
- Will add more plots to the next





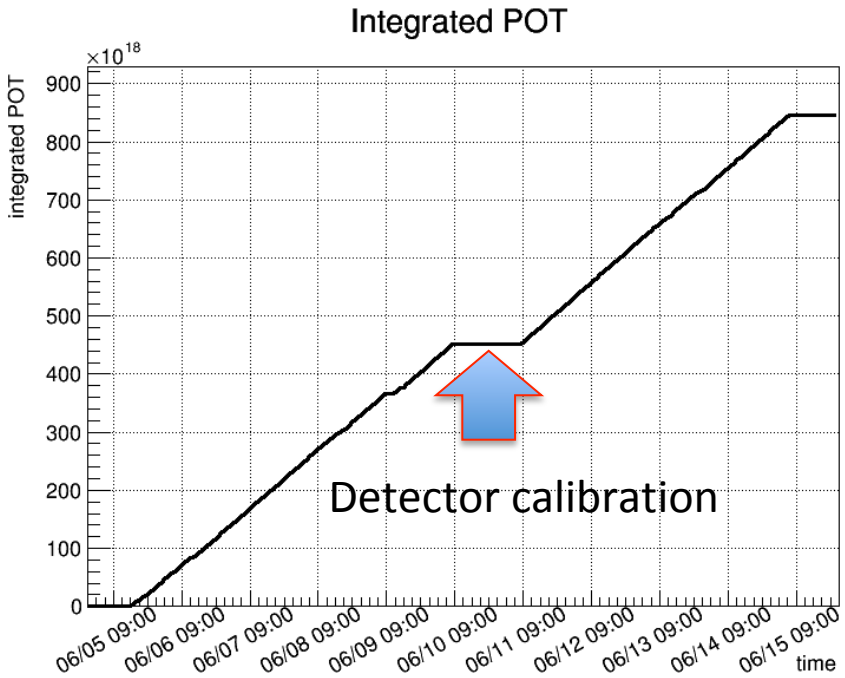
Beam power / POT

Average Beam power: 602kW (4.97 x 10^{13} POT/spill)

We have mini beam maintenance period on every Wed.
- June-10: 24 hours mini-shutdown.
- Used for the calibration campaign (LED, ^{252}Cf, run w/o beam)

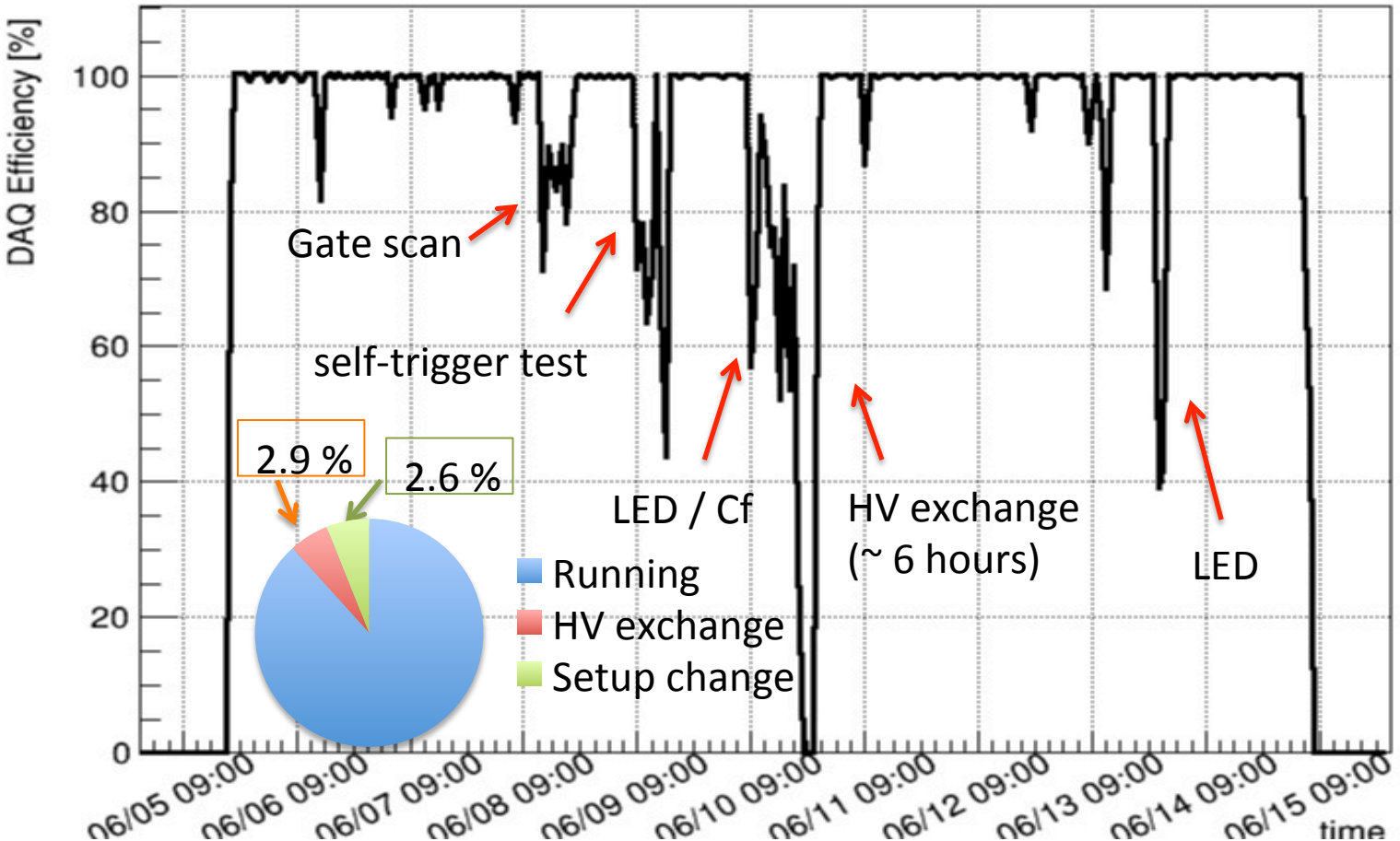
8.46 x 10^{20} POT for the 1st physics run
- 0.8% of approved POT (by J-PARC PAC)
- Less than 1 IBD event are expected.
- However, our detector is working well, and JSNS^2 shows strong potential from the next physics run. (from early of next year)

J-PARC and MLF aims to have a design beam power (1MW) as soon as possible and have succeeded the test from June-25 to 27.

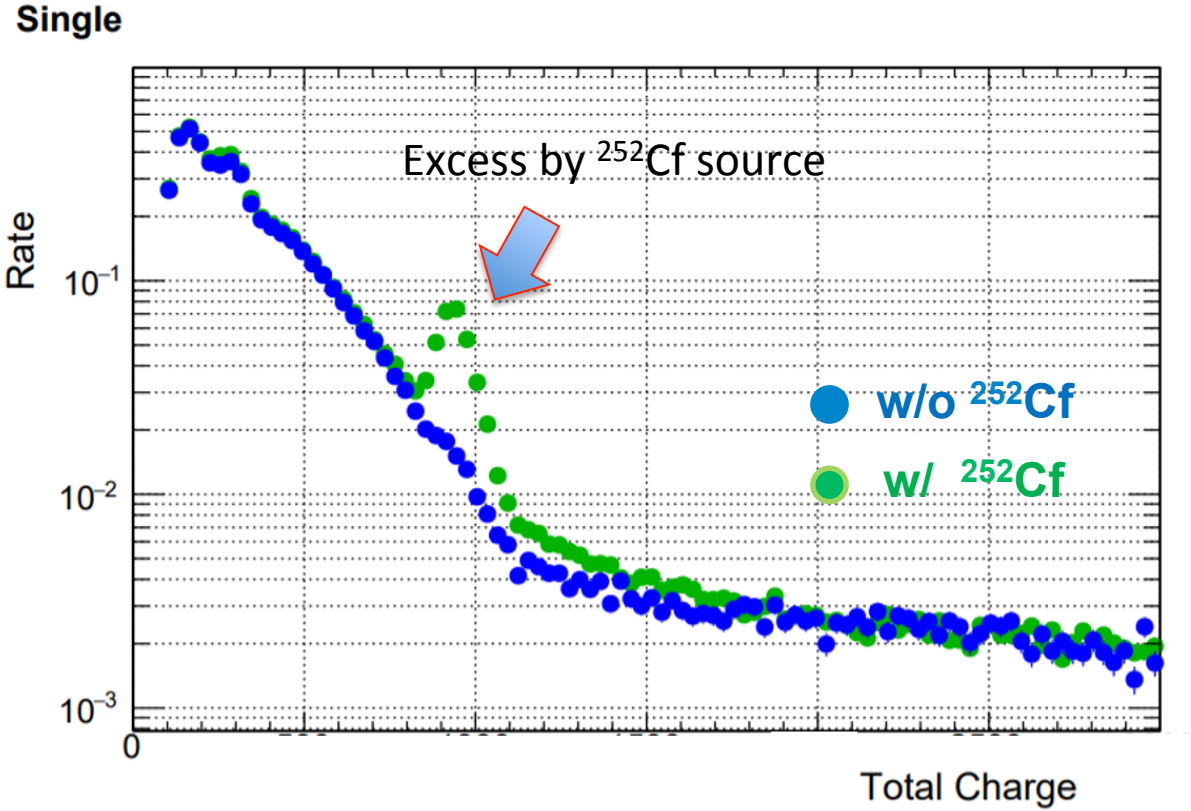


DAQ Efficiency

Total Efficiency : 94.5 %
(215.8 hour / 228.3 hour)



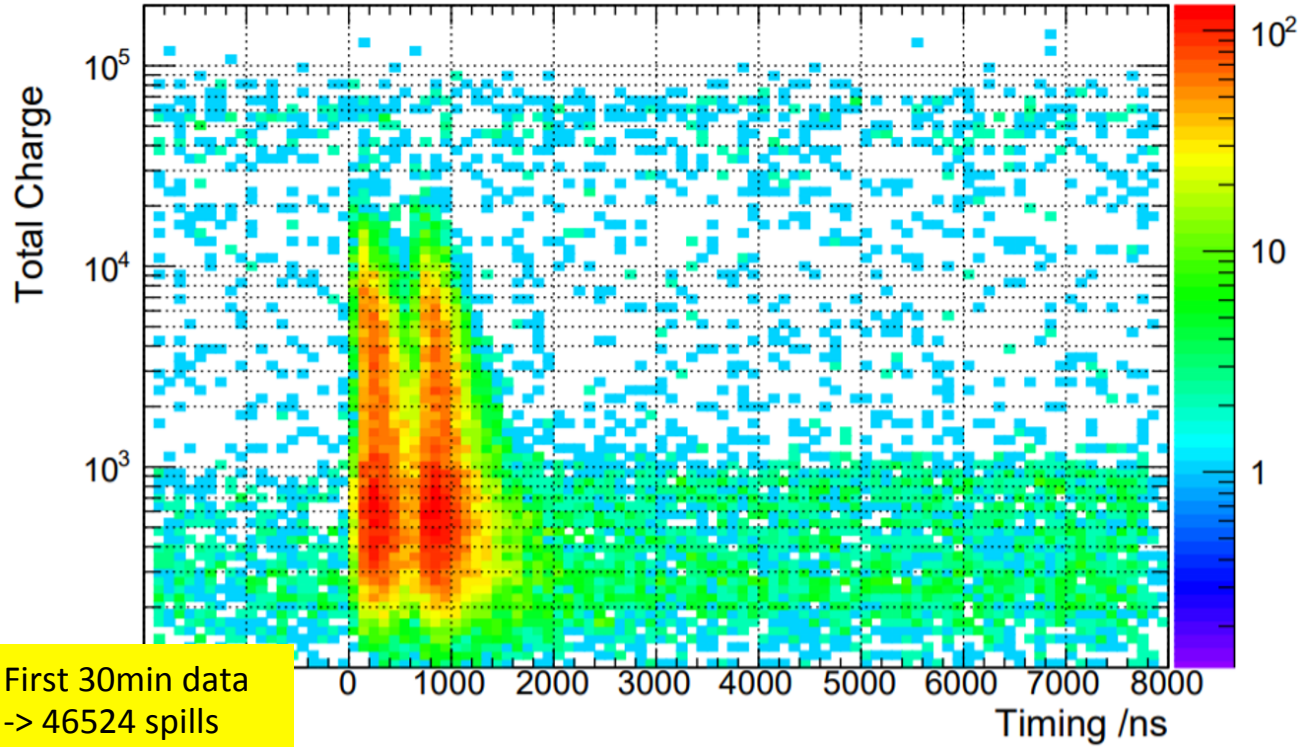
^{252}Cf calibration data (source is put on center)



Can see clear excess due to neutron capture on Gd.

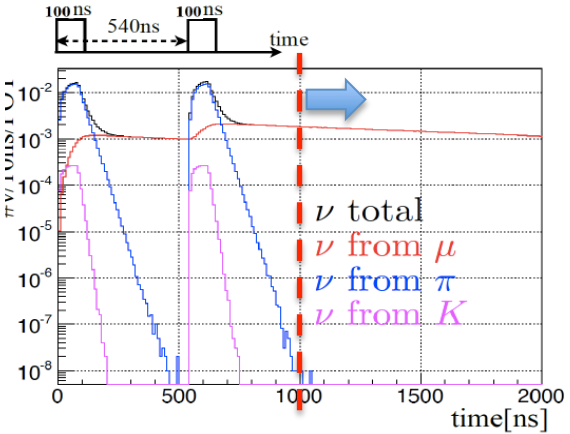
Detector is working well.

Activities around beam timing



First 30min data
-> 46524 spills

Two-bunch structure is clearly seen.



Summary

- JSNS^2 aims to test the LSND anomaly directly.
  + Uses the same neutrino source (μ), target (H) and detection principle (IBD), but much smaller accidental background due to Gd-loaded LS and low duty factor J-PARC MLF beam.
- Just started data taking from 2020-June.
  + Operation (filling/extraction) of (Gd)LS have been very smooth without any issues.
  + With data taking for 10 days (0.8% of data compared to the approved POT), we saw a good potential of this experiment as expected.
    - response of neutron capture signal is clear.
    - activities around beam timing looks as expected
    - similar to 2014 background measurements, and TDR.
- We plan to upgrade the detector and construct the 2nd detector
  + Essential to improve the sensitivity
  + Grant was approved !!