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Cosmic ray induced Background study at the JSNS^2 experiment

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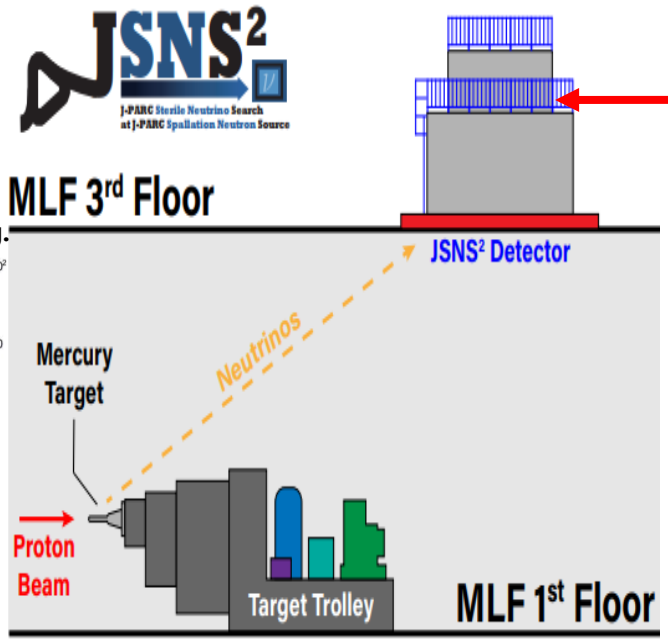
for the JSNS^2 collaboration

@ 10th JSNS^2 Collaboration meeting (7-9 Feb, 2020)

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

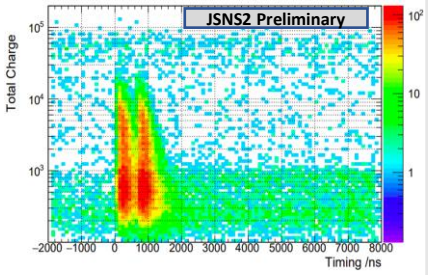
Introduction of JSNS^2 experiment

J-PARC MLF : Ideal environment for the JSNS^2 experiment



Gd-Loaded liquid scintillator
96 10" (inner) +
24 10" (Veto) PMTs

※ Activities around Beam timing.



The J-PARC Sterile Neutrino Search at the J-PARC Spallation Neutron Source (JSNS^2) experiment has started a study of neutrino oscillations with $\Delta m^2 \sim 1\ eV^2$ from anti-muon neutrinos to anti-electron neutrinos detected via inverse beta decays(IBD) which are tagged via gammas from neutron captures on Gadolinium.

JSNS^2 is the only experiment that can directly test the LSND anomaly without having to rely on theoretical scaling assumptions.

The JSNS^2 experiment successfully collected 10 days of data from the first physics run in June 2020 and a second physics data run has been started from Jan 2021.

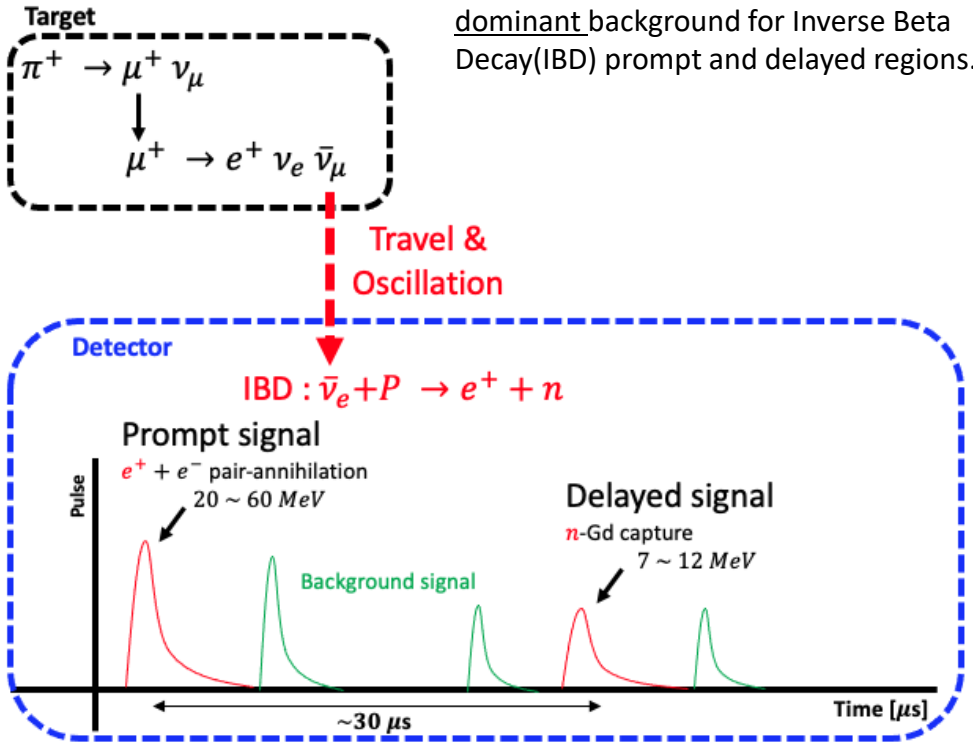
➔ related talk : **Current status & plan of JSNS2/JSNS2-II (Dongha) 25/Feb**

- This study shows the background single rate using 10 days of data of the first physics run.

Expected background sources:

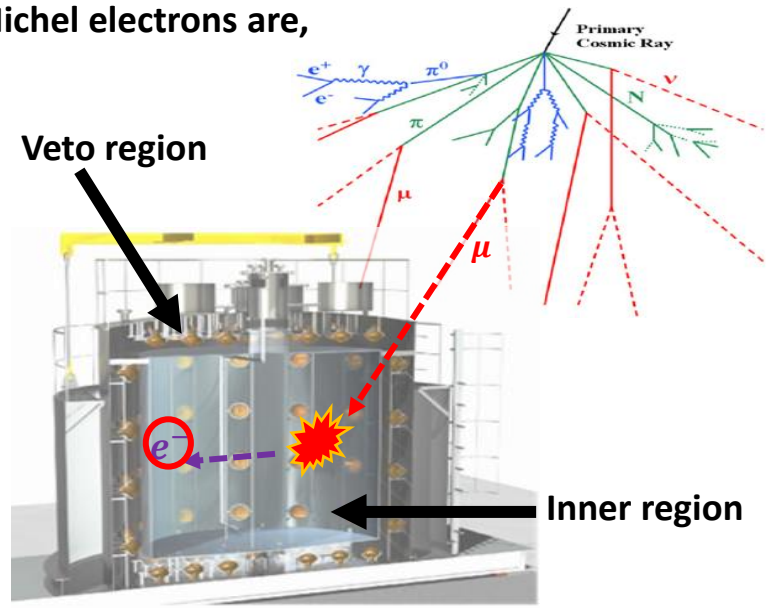
– Cosmic μ
– Michel electron
– fast neutron
– Additional N-Gd capture
– Cosmic γ

※ Cosmic γ's are expected to be the dominant background for Inverse Beta Decay(IBD) prompt and delayed regions.



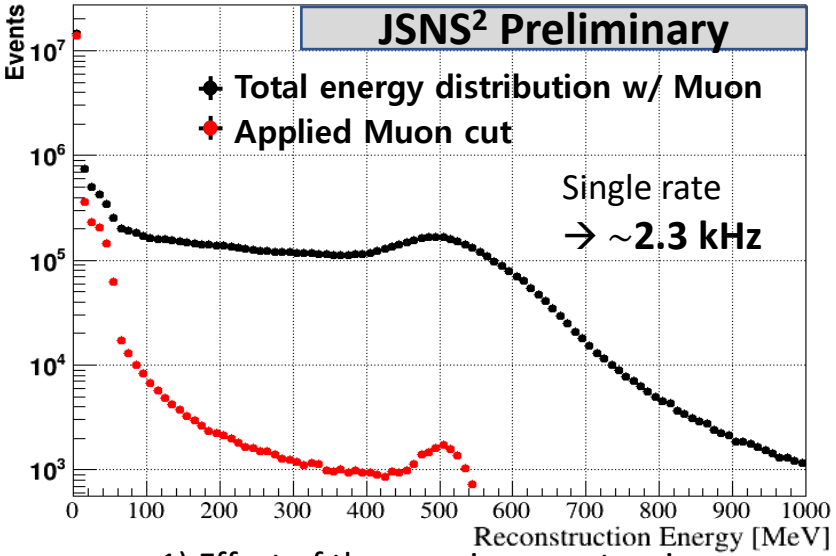
Cosmic-μ tagging & Michel electron

Michel electrons are,

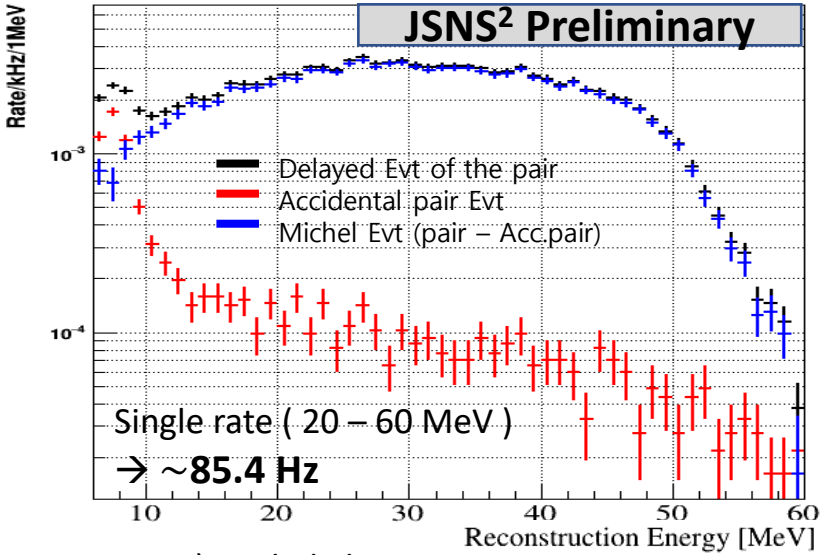


※ PE : photoelectron

Muon tagging condition (cut efficiency ~ 99%)
Top Veto Charge > 100 PE
or
Bottom Veto Charge > 100 PE



1) Effect of the cosmic muon tagging



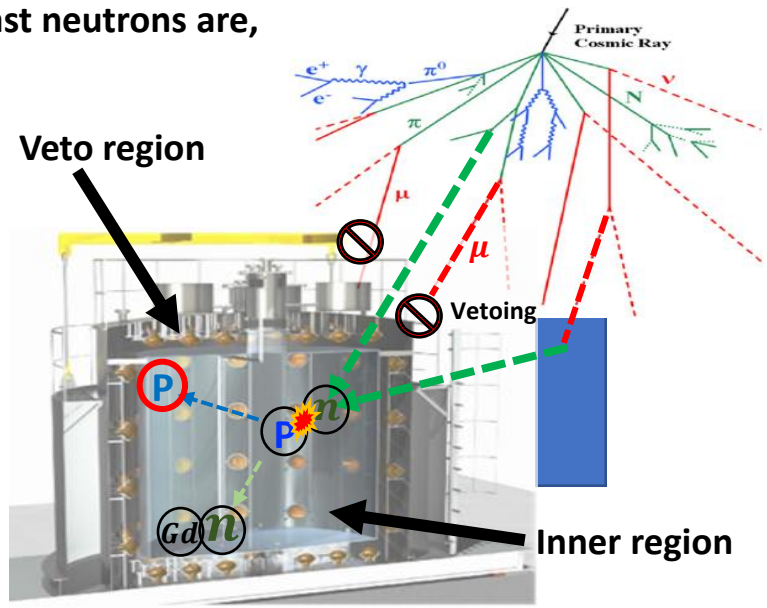
2) Michel electron energy spectrum

- **The events which get over the veto charge threshold are defined as cosmic-μ.**
- **The background single rate will contain a <u>20% systematic uncertainty.</u>**

- **Michel electrons are produced by the decay at rest of cosmic muons that are stopped in the detector.**
- **To measure Michel electron events, A coincidence method was used.**
  - **→ Prompt event : Cosmic muon(μ) that was selected by muon tagging.**
  - **→ Delayed event : Michel electron(e^-) with energies 20 – 60 MeV.**
  - **→ ΔT_{p-d} : $0 \sim 10\ \mu s$, ΔT_{p-d}^{acc} : $10 \sim 20\ \mu s$**

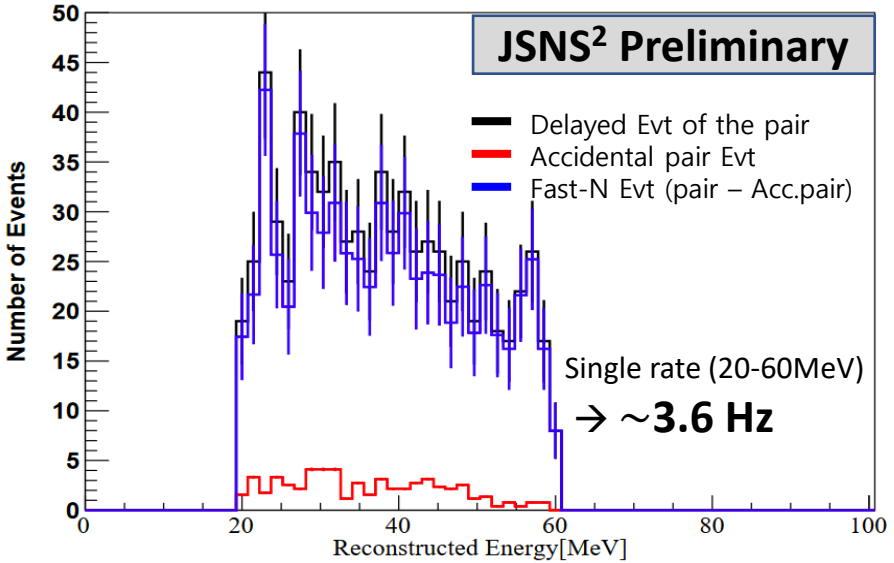
Fast neutron & additional n-Gd capture

Fast neutrons are,

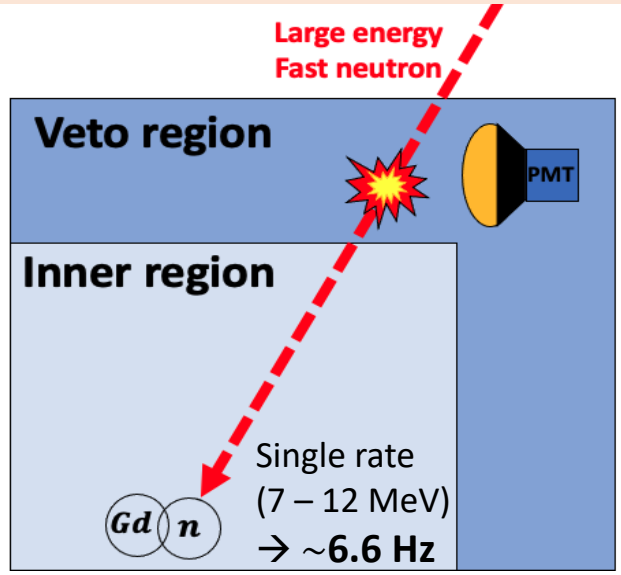


※ PE : photoelectron

Muon tagging condition (cut efficiency ~ 99%)
Top Veto Charge > 100 PE
or
Bottom Veto Charge > 100 PE



3) Fast neutron energy spectrum

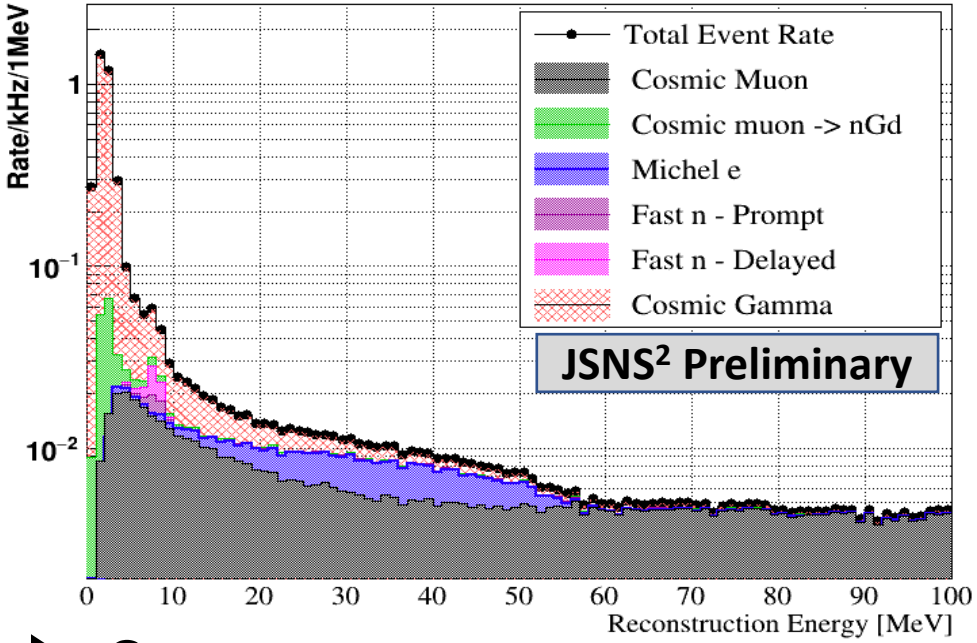


4) Schematic drawing of additional n-Gd events

- The fast neutron are also identified by a coincidence method with different selection criteria.
  → Prompt event : Recoil proton(p) due to the fast neutron with energies of 20 – 60 MeV.
  → Delayed event : A neutron(n) that is captured by Gadolinium(Gd) in the LS after thermalization.
  → ΔT_{p-d} : $0 \sim 100\ \mu s$ ΔT_{p-d}^{acc} : $100 \sim 200\ \mu s$

- Definition of additional n-Gd capture : the high-energy fast neutrons appear like cosmic muon events in the inner volume, followed by the n-Gd event.
- The criteria for additional n-Gd events are different from the prompt event of the fast neutron.
  → Prompt event : Events which are tagged as muons.

Cosmic gamma & Summary



JSNS² Preliminary

※ Rate/Spill : 9μs for prompt , 100 μs for delayed

BKG for IBD interaction	Component	Single Rate	Rate [#events/Spill]	Rate [#events/Spill] exptected
	Cosmic-μ	~2.3 kHz	-	-
Prompt	Michel e	~85 Hz	7.7×10^{-4}	-
	Fast n	~3.6 Hz	3.2×10^{-5}	1.4×10^{-6}
	Cosmic-γ	~58 Hz	5.2×10^{-4}	3.8×10^{-4}
Delayed	Additional n-Gd	~6.6 Hz	6.6×10^{-5}	-
	Cosmic-γ	~99 Hz	9.9×10^{-3}	4.4×10^{-3}

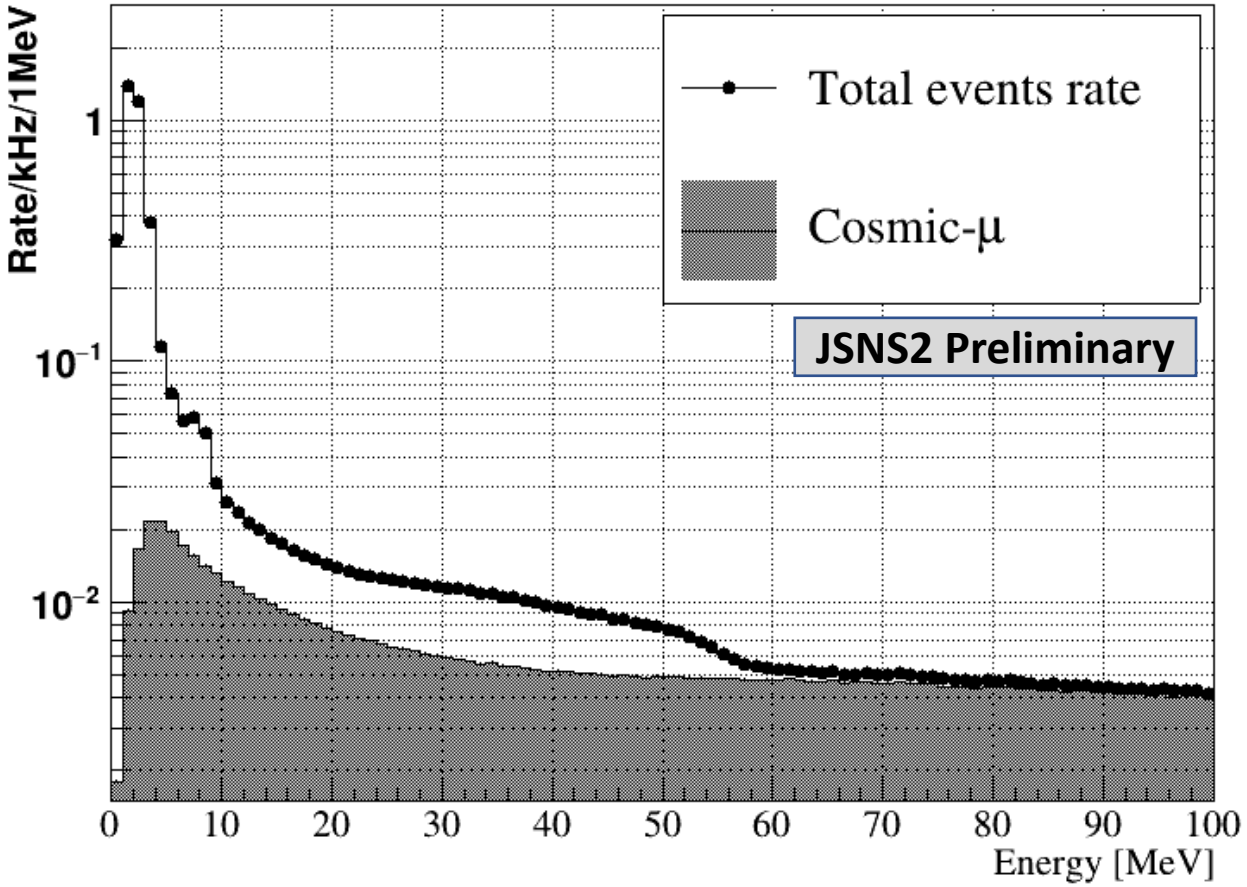
▶ Summary

- **JSNS² measured the IBD background's single event rate.**
- **In order to measure the Cosmic-γ rate, we subtracted the rate of other background components from the total event rate.**
  → Total event rate - Cosmic-μ & Michel electron & fast neutron = cosmic gamma
- **The Measured rate was slightly larger than we expected.**
  → the analysis has just started. We have a lot of an opportunity to improve our data selection.
- **A larger dataset is now being acquired, which will allow us to improve this measurement.**

➔ related talk : **PMT Waveforms for Pulse Shape Discrimination in JSNS2 (Sanghoon) 24/Feb**
Beam-related gamma background at the JSNS2 (Daeun) 26/Feb

Backup slide

Event Condition



- **Cosmic- μ**

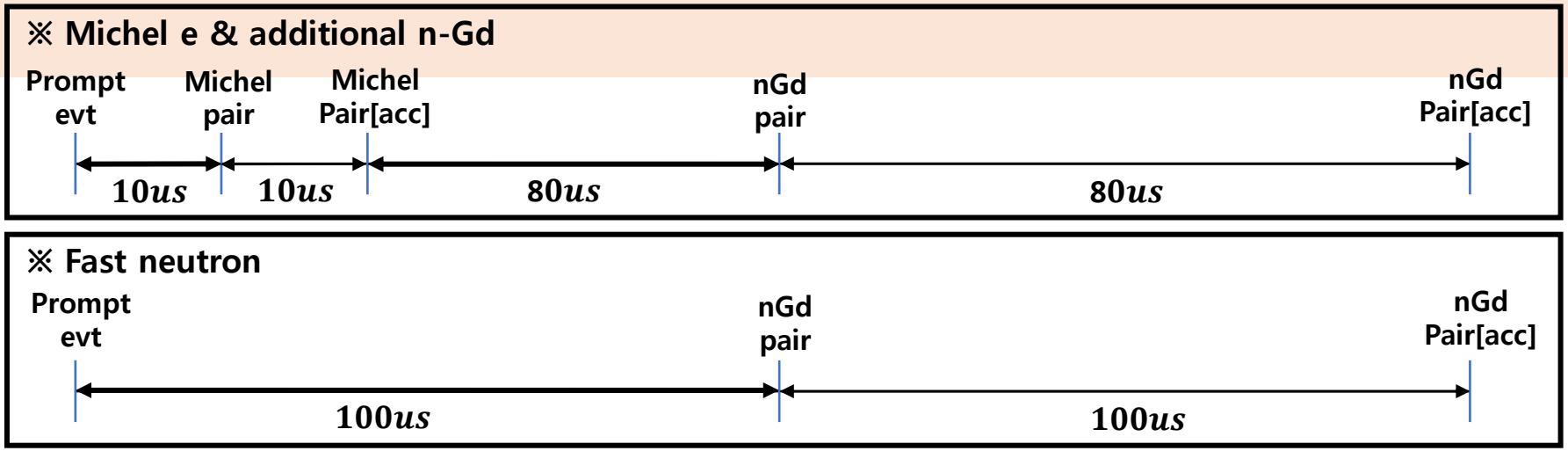
① Through-going muon
Veto Top > 100 pe
Veto Total > 100 pe

- **Michel electron**

① Prompt : Muon
$10 < E < 800$ MeV
② Delayed : Michel e
$20 < E < 60$ MeV
③ Time diff
$\Delta T < 10us$
④ Time diff[acc]
$10us < \Delta T < 20us$

- **Above plot shows the event rate of the Cosmic- μ with total event rate.**
- **From tagged muon, I searched the pair events which the candidate of Michel electron via event pair condition.**

► Event pairing condition



Muon Tagging
① TV > 100 PE
or
BV > 100 PE

Michel electron
① Prompt : Muon
0 < E < 800 MeV
② Delayed : Michel e
0 < E < 100 MeV
③ Time diff
$\Delta T < 10us$
Time diff [acc]
$10us < \Delta T < 20us$

Fast neutron
① Prompt
0 < E < 100 MeV
② Delayed : n-Gd
0 < E < 20 MeV
③ Time diff
$\Delta T < 100us$
Time diff [acc]
$100us < \Delta T < 200us$

Additional n-Gd
① Prompt : Muon
0 < E < 800 MeV
② Delayed : n-Gd
0 < E < 20 MeV
③ Time diff
$20us < \Delta T < 100us$
Time diff [acc]
$100us < \Delta T < 180us$