On-site test measurement for Decay-at-Rest ν_e cross section with Pb : DarVeX

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Poster ID #466

Abstract

Lead (Pb) has a novel potential as the ν_e target to open new physics channels using the MeV ν_e. But no one determines the cross-section yet. J-PARC/MLF spallation neutron source is a powerful source of μDecay at Rest ν_e. We constructed a test detector with 136kg of Lead at the MLF hole and 480 hours data with beam to investigate possibility of ν_e measurement. Accidental BGs rate is found to be low enough and we are continuing the data taking to study further backgrounds.

1. MeV scale ν_e scattering with Pb

μDecay at Rest (μDaR) ν_e has 10 MeV scale energy and is a key toward broad physics [Fig.1] including nuclear physics and cosmology. The largest cross-section with **Lead (Pb)** and MeV ν_e is predicted but no one determines it yet.

μDar ν_e cross section (**DarVeX**) with Pb is an exciting topic toward new physics programs

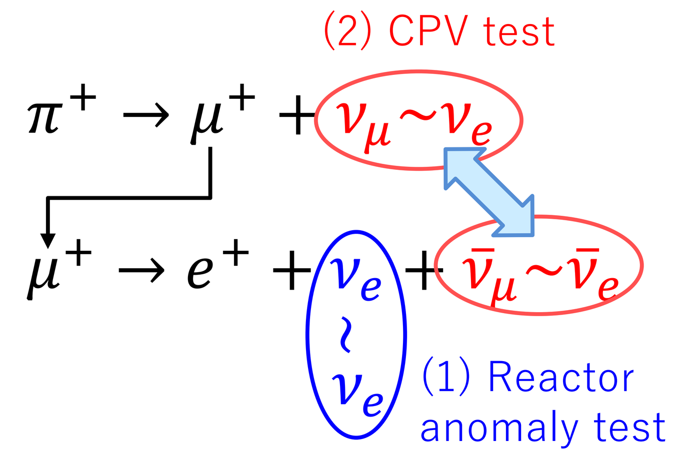

Fig. 1. Decay chain from π with CPV and reactor anomaly

2. J-PARC/MLF as ν_e source

J-PARC/MLF spallation neutron source is a powerful ν_e source. ~1MW of 3GeV proton beam produces a lot of πs at the mercury target.

- ν_es from 3GeV proton beam with 1MW at distance of 20m from the beam target ~ 1.6 × 10^{14} [ν /s]
- ν_e - Pb scatterings in a 136kg lead at distance of 20m from the target ~ 1.5 [ν/day]
- Possible to reach 20% stat error within 200 days,

3. ν_e detection principle

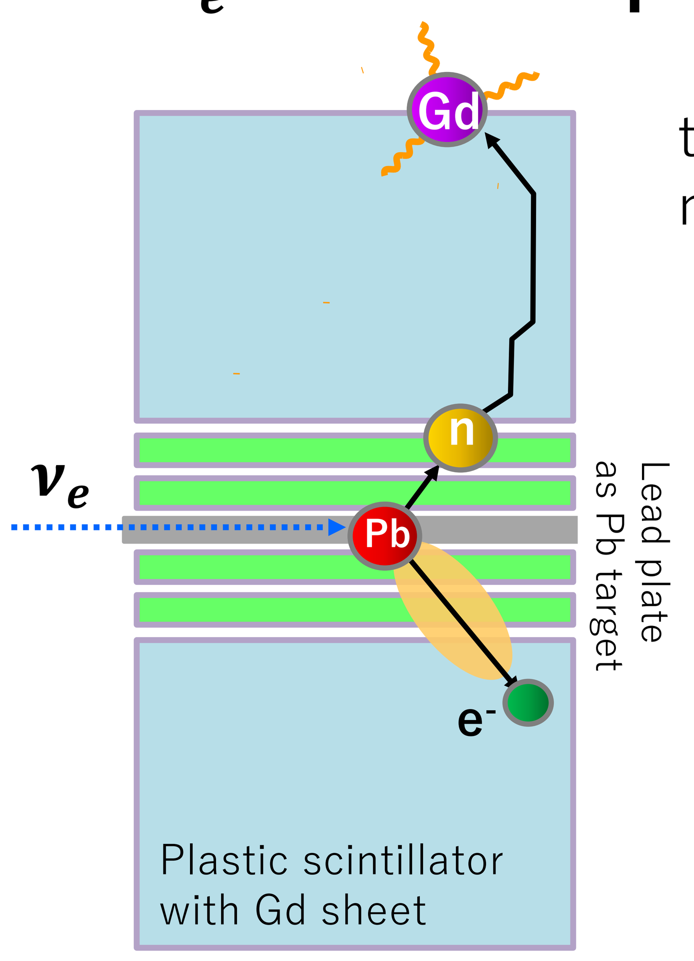

Fig. 2. ν_e detection with delayed coincidence.

ν_e-Pb scattering provides e^- and ns to allow the delayed coincidence method[Fig.2] like the IBD in $\bar{\nu}_e$.

Prompt : $\nu_e + \mathrm{Pb} \to e^- + n + \mathrm{Bi}$

Delayed : $n + \mathrm{Gd}^{155}_{157} \to \mathrm{Gd}^{156}_{158} + \gamma\mathrm{s}$

Identification of e^- track from the lead is critical for further reduction

- 10 cm plastic scintillator block measures e^- and γ energies.
- Two of 1cm thin plastic scintillators work as e^- tracker.

Triple coincidence of the scintillators reduce the remaining backgrounds.

4. Test detector at the MLF experiment hole

A small-size detector[Fig.3] with 136kg Lead plates is constructed for on-site measurement in 2023.

- 40 Calorimeter modules
- 48 Tracker modules
- 4mm x 100 cm x 100 cm x 3 = 136kg Lead plates
- 650kg PE + B rubber / epoxy + 200 Lead blocks
- Cosmic vetos on the top
- PMTs on calorimeters are read out by CAEN V1721.
- MPPCs in the trackers are read out by NIM-EASIROC.

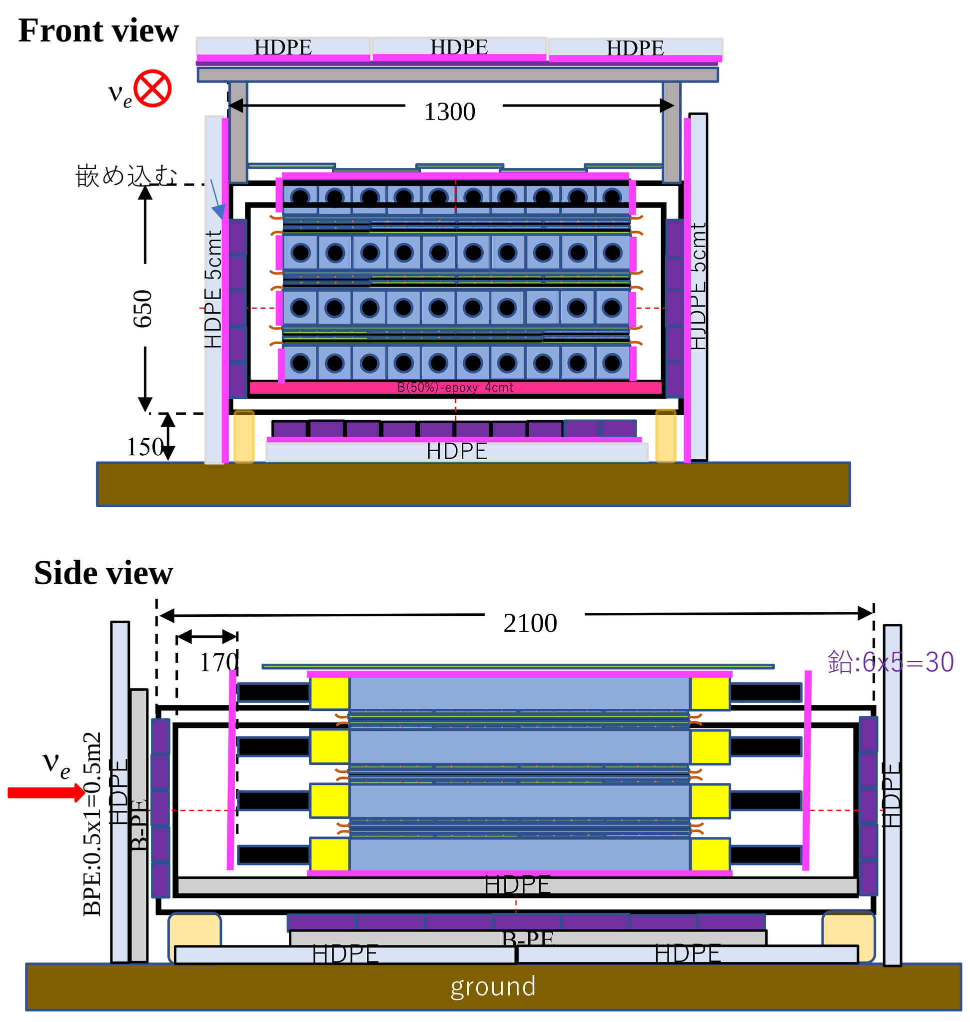

Fig. 3. Drawings of the half size detector

5. On-site test measurement in 2023

We constructed the test detector in the MLF experimental hole at the distance of 22m from the mercury target [Fig.4] and the test data taking started in March 2024. 578 hours of data set including 481 hours with beam are analyzed [Fig.5].

Two trigger types [Fig.6] is applied based on beam timing

- Prompt (calorimeter and tracker) : 1.5 ~ 5.5 us
- Delayed (calorimeter only) : 10 ~ 100 us

Fig. 4. Photos of the detector location at MLF

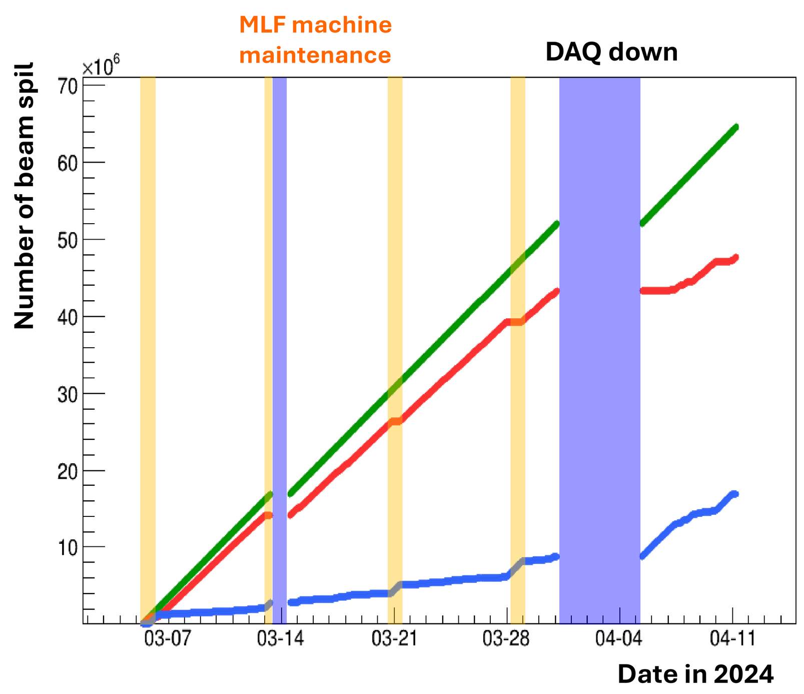

Fig. 5. Integrated # of beam spill

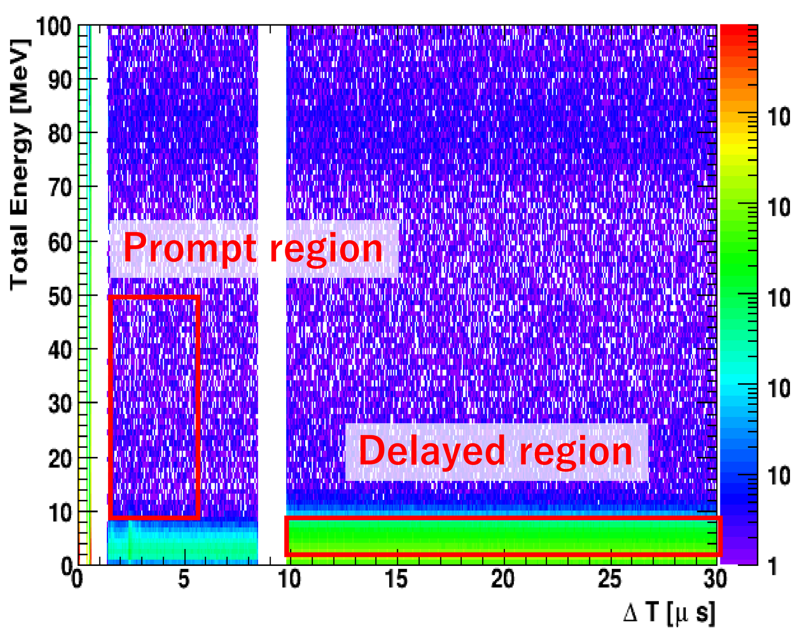

Fig. 6. Time - energy profile

Veto problem found

The central two rows of the calorimeters are found with higher event rates since gaps among the cosmic veto counters[Fig.7] was found.

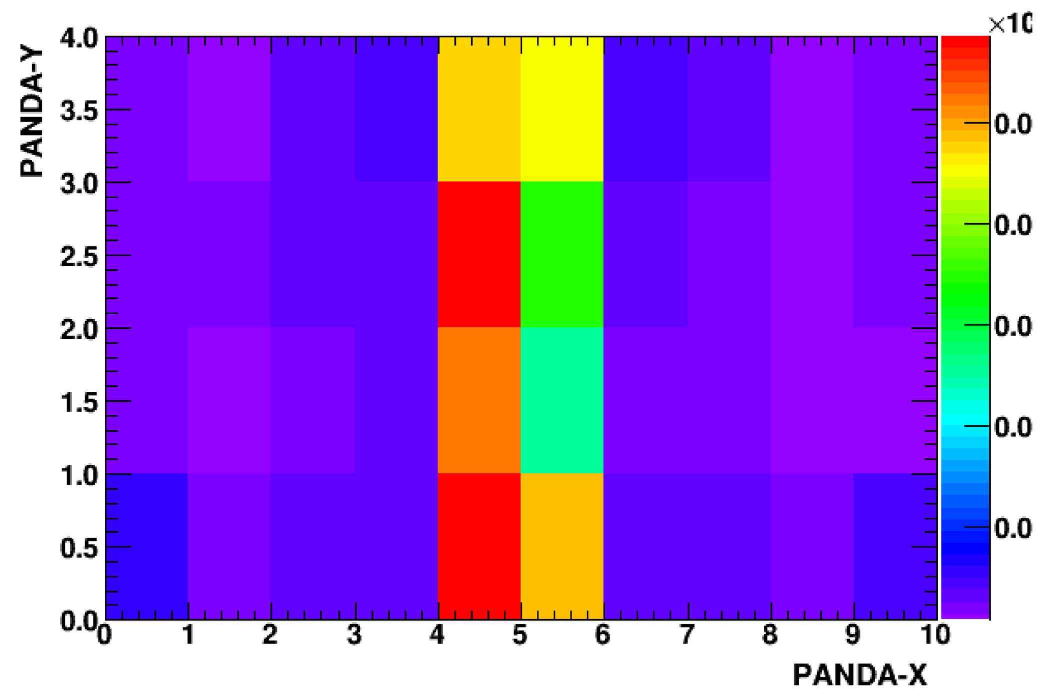

Fig. 7. Event rates per calorimeter modules from front view.

Background estimation

By masking the high-rate rows, no delayed coincidence is found. The accidental BG rate [Fig.8] is estimated to be

6.70 ± 1.24 x 10^{-9} [/spill]

(ν_e signal ~10^{-8}[/spill]). it is indicating that the accidental BG rate is low enough.

Background from beam induced fast neutron is also not detected. It is as expected but we plan to change the trigger conditions to enrich the background for further studies.

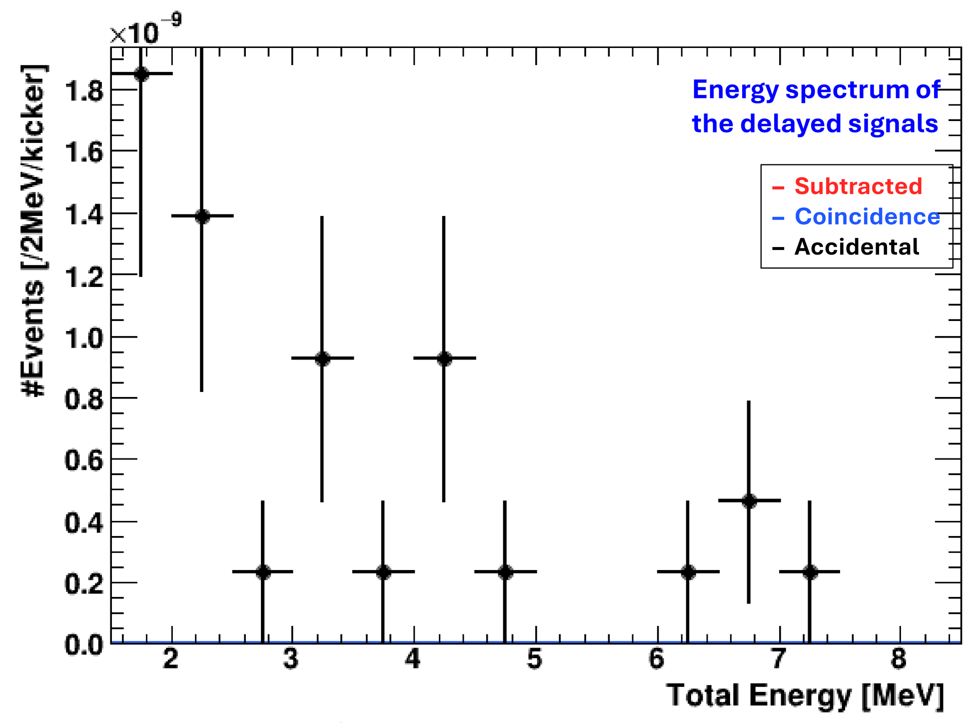

Fig. 8. Delayed energy spectrum

6. Summary and remark

We performed a test measurement for ν_e-Pb scattering at J-PARC/MLF and found the accidental background can be suppressed lower than ν_e signal. Now we have modified the cosmic veto and are continuing the data taking by the end of June 2024.

We are grateful to a lot of supports from the MLF staffs. This work was supported by JSPS KAKENHI Grant-in-Aid for Scientific Research (A) Grant Number 20H00146.