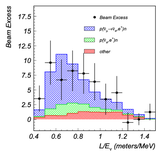
First result from the search for an excess of $\bar{\nu}_e$ events in JSNS²

Dongha Lee (KEK) on behalf of JSNS² / JSNS²-II collaborations

Introduction

LSND (Phys. Rev. D 64 (2001) 112007)

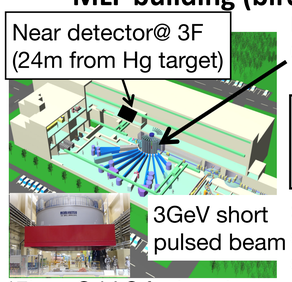


$\bar{\nu}_e$ excess (3.8σ)

- Same source (μ Decay-At-Rest), target (H), and detection principle with the LSND

-> "Direct Test of the LSND"

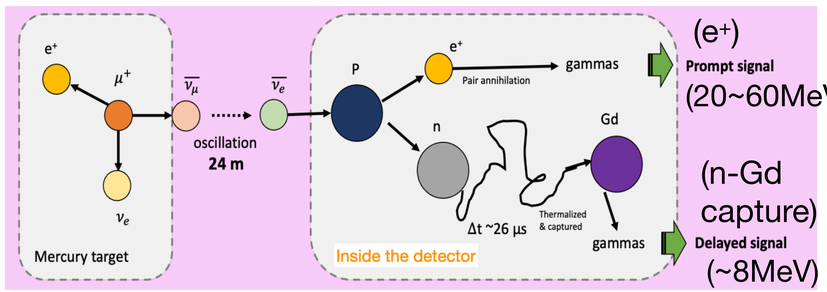
MLF building (bird's view)



(Low duty factor : short pulse + small repetition rate)

17tons Gd-LS for target

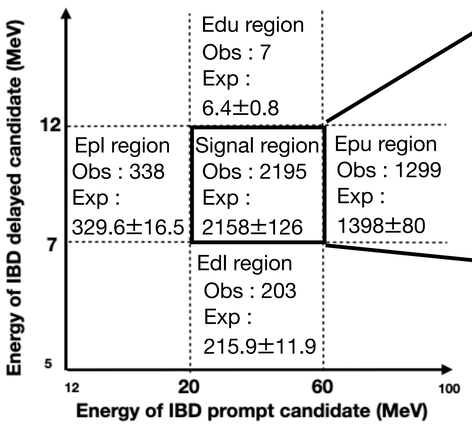
How to detect $\bar{\nu}_e$ signals?



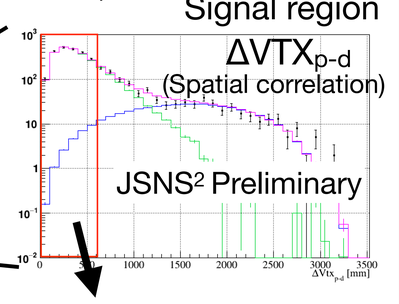
- Inverse Beta Decay (IBD) signals by coincidence of prompt / delayed

Studies with energy side-bands

2022 + 2024 physics data (1.95x10²² POT)



Signal region



- Cosmogenic Neutron : 2132±126
- Accidental : 24.8±0.2

(Expected IBD signal ≃ 3)

<Observation>

Physics data with criteria :
- Energy (E_p , E_d) selections
- 2μs < ΔT_{beam} < 10μs (Almost no Beam FN)
- ΔT_{p-d} < 100μs
- ΔVTX_{p-d} < 60cm (Accidental 95% rejection)

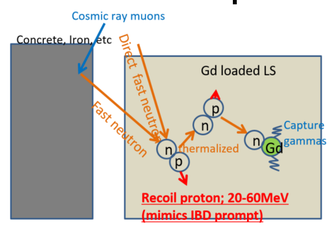
<Background Prediction>

Purely data-driven control sample

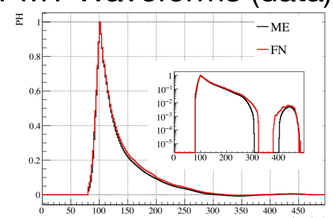
- Fast neutrons -> obtained at T_{beam} > 1ms
- Accidental background -> obtained with specific calibration runs

Background reduction is necessary

Background control (1) - Pulse Shape Discrimination (PSD)



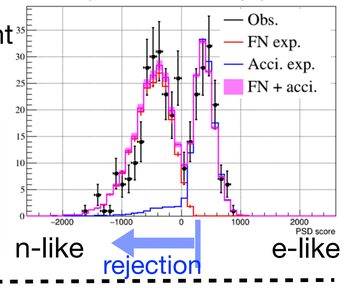
PMT Waveforms (data)



- Fast Neutrons : mimic the IBD signals
- Difference of PMT waveforms (data) ; e-like vs n-like
- Full information of waveform height
- All 96 PMTs have each separation power

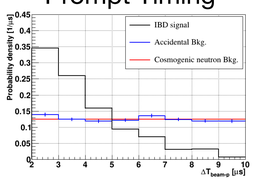
PSD cut :
IBD signal 90% efficiency
Neutron >99.5% rejection

PSD application (Side-band Epl)

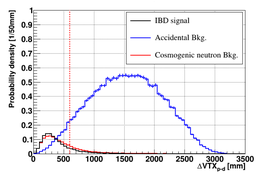


Background control (2) - Likelihood method

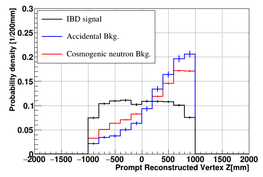
Prompt Timing



ΔVTX$_{p-d}$

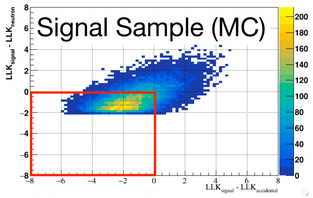


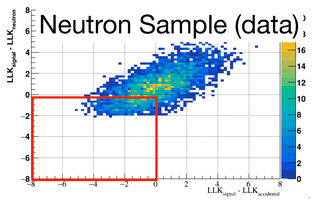
Prompt Vertex Z



- Different shapes of "Energy, Timing, vertex" (Evt. Recon.) for Signal vs Neutron vs Accidental
- Data-driven templates => binned Log-Likelihood scores

LLK application (side-band Edl) ; 2D Log Likelihood ratio

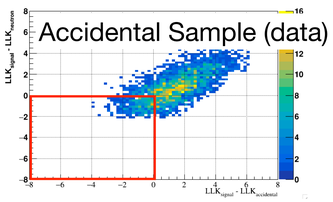




- Signal-like event selection

x-axis : LLK_signal - LLK_acci < 0

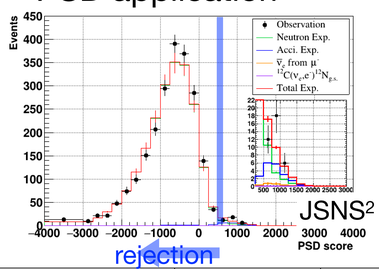
y-axis : LLK_signal - LLK_neutron < 0



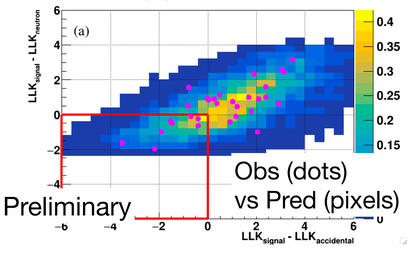
IBD signal 70% efficiency
Neutron 75% rejection
Accidental 85% rejection

Observation vs Bkg prediction [Signal region]

PSD application



LLK application

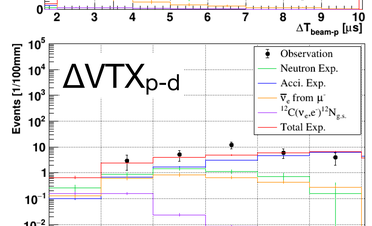


cases	Observation	Prediction
w/o PSD w/o LLK	2195	2160.3 +- 128.6
w/o PSD w/ LLK	606	626.9 +- 37.0
w/ PSD w/o LLK	30	26.3 +- 1.6
w/ PSD w/ LLK	8	6.1 +- 1.0

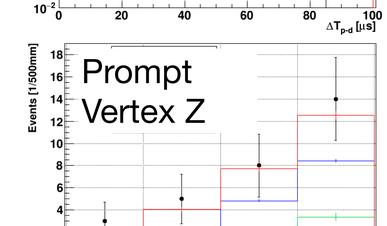
Neutron 1.5±0.3
Acci 2.4±0.01
CNgs 0.20±0.06
Intrinsic Bkg 2.0±1.0

JSNS² Preliminary

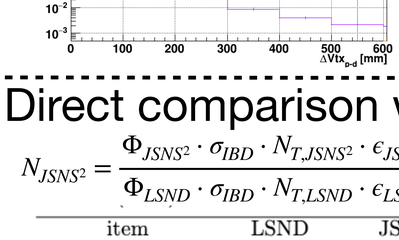
Prompt Timing



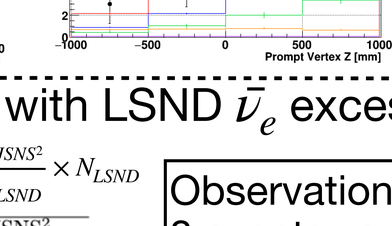
ΔT$_{p-d}$



ΔVTX$_{p-d}$



Prompt Vertex Z



Direct comparison with LSND $\bar{\nu}_e$ excess

$$N_{JSNS^2} = \frac{\Phi_{JSNS^2} \cdot \sigma_{IBD} \cdot N_{T,JSNS^2} \cdot \epsilon_{JSNS^2}}{\Phi_{LSND} \cdot \sigma_{IBD} \cdot N_{T,LSND} \cdot \epsilon_{LSND}} \times N_{LSND}$$

item	LSND	JSNS²
ν flux ($\#\nu/cm^2$)	1.26×10^{14}	1.29×10^{14}
(POT	1.81×10^{23}	1.95×10^{22})
($\#\mu$/p	0.079	0.48±0.17)
(baseline	30 m	24 m)
N_T	7.4×10^{30}	7.48×10^{29}
efficiency (%)	42.0±3.0	12.9±1.3
N_{eve}	87.9±23.1	2.8±1.3

Observation
8 events vs

Prediction
8.9 ± 1.6
(= JSNS² Bkg 6.1 + normalized LSND 2.8)

JSNS² Preliminary

(Expectation from LSND)

2022 only : arXiv:2602.06274 (accepted for publication at PRD)
2022 + 2024 : Stay tuned !! (Preparation Soon)