

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

Dongha Lee (KEK)

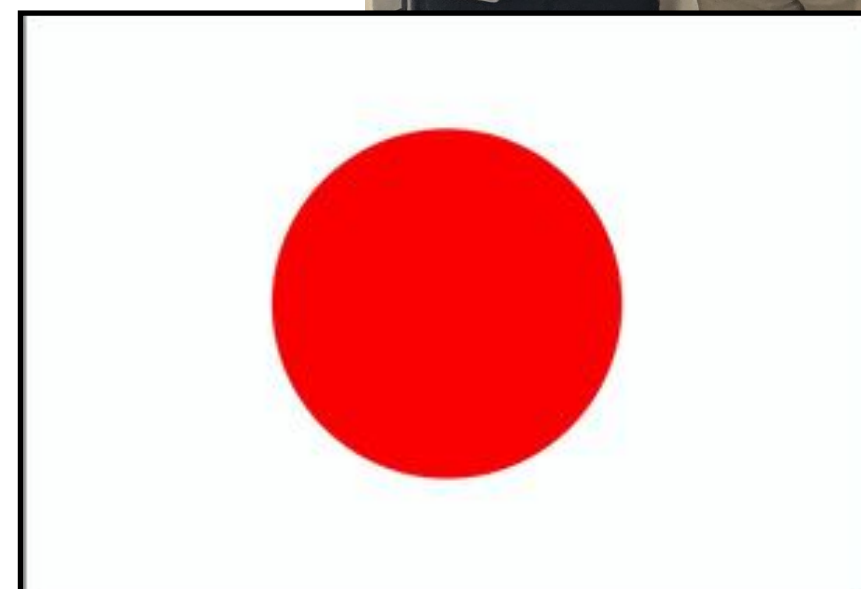
on behalf of JSNS² / JSNS²-II collaboration

NEUTRINO 2026, Jun 22 - 26,
University of California, Irvine

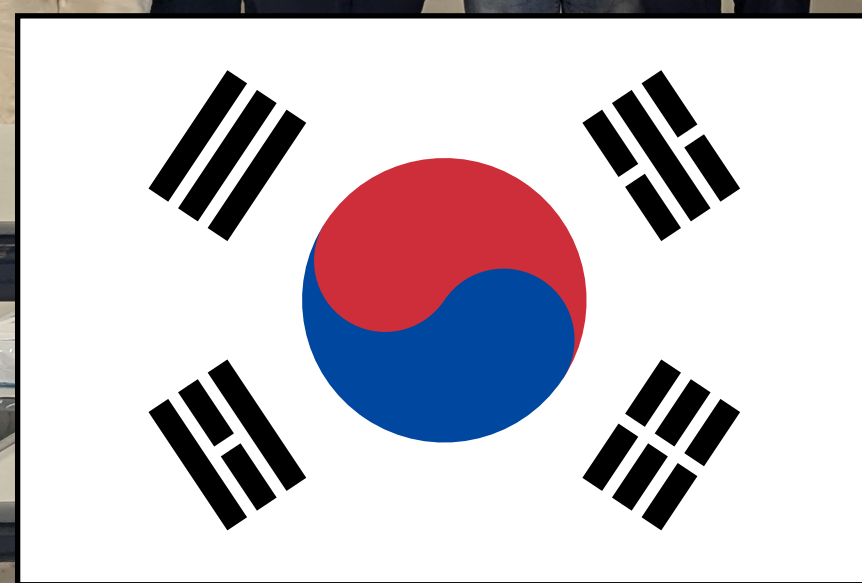
JSNS² / JSNS²-II Collaboration

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

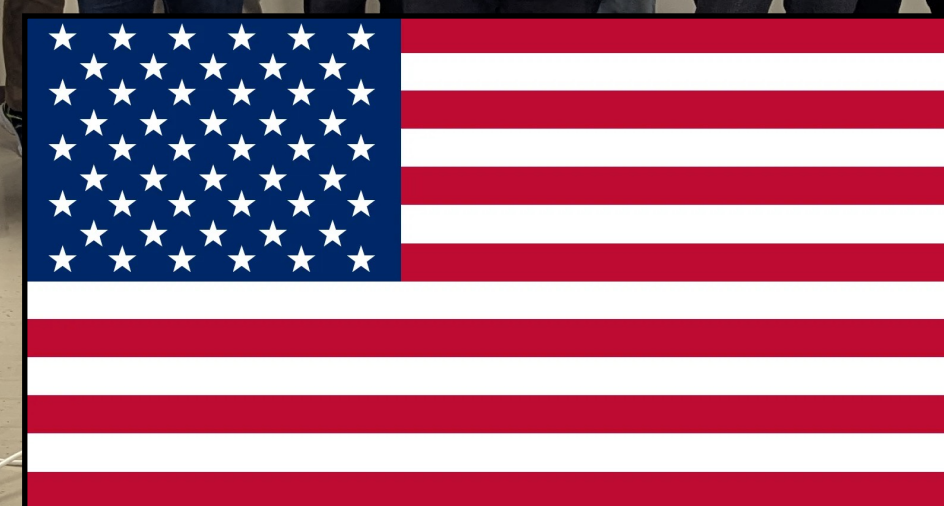
JSNS² Collaboration meeting - Feb 2026



KEK
JAEA
J-PARC
Tsukuba University
Osaka University
Tohoku University
Kitasato University
Kyoto Sangyo University



Soongsil University
Dongshin University
Seoyeong University
Kyung Hee University
Gwangju Institute of Science and Technology
Seoul National University of Science and Technology
Sungkyunkwan University
Chonnam National University
Jeonbuk National University
Kyungpook National University



Brookhaven National Laboratory
University of Michigan
University of Utah



Sun Yat-sen University

4 countries
~60 collaborators

Experimental tests of the LSND anomaly

- Recent experimental efforts to investigate the short-baseline anomalies are shown.

Experiments	Neutrino source	Signal	Detection
LSND / JSNS²	μ Decay-At-Rest	$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ LSND (3.8σ)	IBD (n-H) (LSND) IBD (n-Gd) (JSNS ²)
MiniBooNE / MicroBooNE, ICARUS	π Decay-In-Flight (BNB/NuMI)	$\nu_\mu \rightarrow \nu_e$ (MicroBooNE) $\nu_\mu, \bar{\nu}_\mu \rightarrow \nu_e, \bar{\nu}_e$ (ICARUS)	LArTPC

- MicroBooNE and ICARUS search for anomalies using π Decay-In-Flight beams and LArTPC, which are mainly motivated from MiniBooNE, whereas JSNS² directly tests the antineutrino channel ($\bar{\nu}_\mu \rightarrow \bar{\nu}_e$), identical to the LSND signal.

- Therefore, JSNS² provides complementary information to MicroBooNE and ICARUS by testing the LSND channel with a different neutrino source and detection technique, allowing comparisons between neutrino and antineutrino channels.

- Also, other physics topics : please refer to

https://conference-indico.kek.jp/event/361/contributions/7915/attachments/5280/8546/01-NPN_MH.pdf

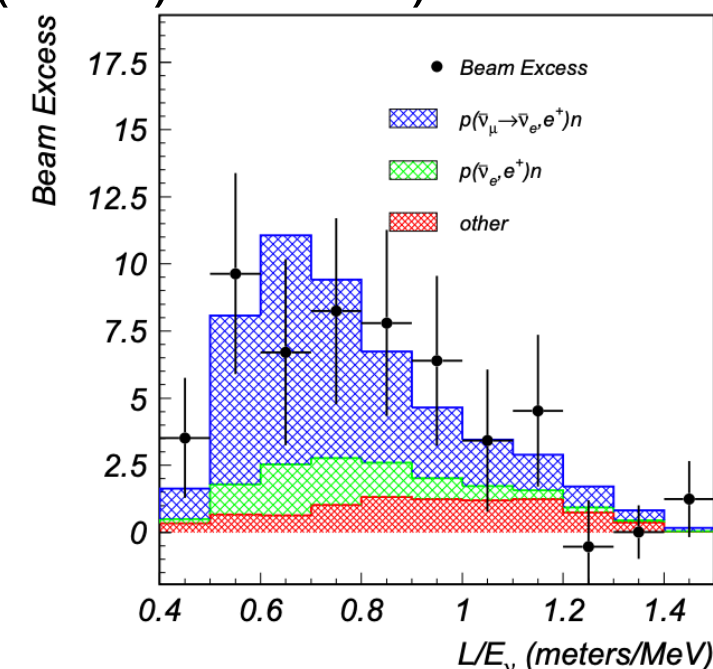
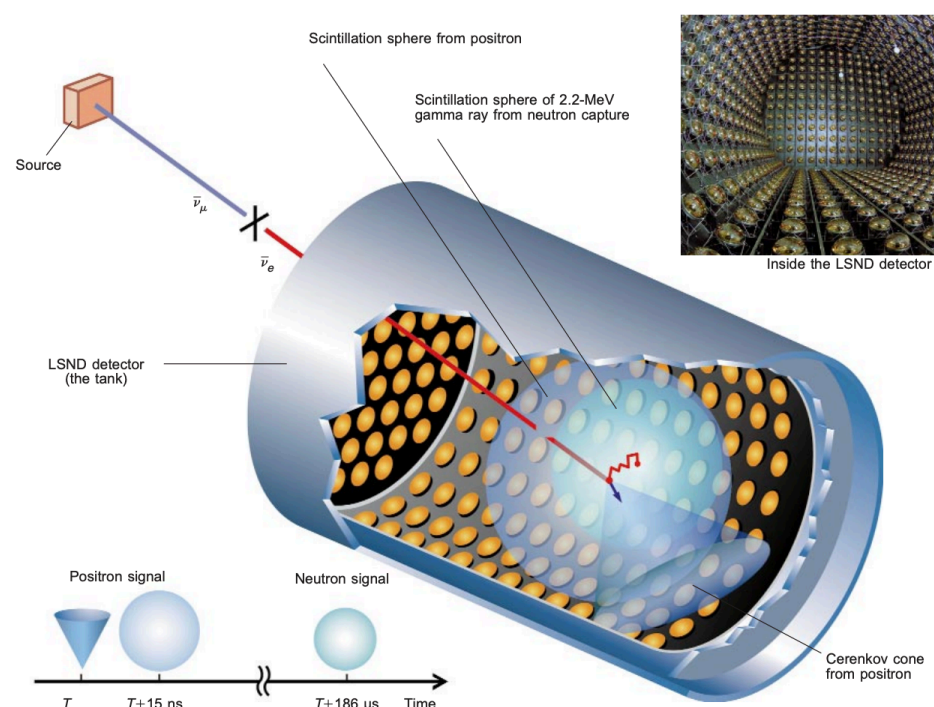
Direct test of LSND anomaly

	LSND	JSNS ² /JSNS ² -II
Target Mass	167 tons	17 tons (Near) , 32tons (Far)
Baseline	30 m	24 m (Near) , 48m (Far)
Beam Energy	0.8 GeV proton	3 GeV proton
# μ / p	0.079	0.48 +- 0.17 (*)
Beam duty factor	1/14 (by Linac)	8/40000 (by Synchrotron)
Energy Resolution	7% @ 45MeV	3% @ 53MeV
Liquid scintillator	Scintillation light	Gd-loaded Scintillation light + DIN is added
Delayed signal	E ~ 2.2MeV, Δt ~ 200 μ s	E ~ 8MeV, Δt ~ 30μs

• JSNS² / JSNS²-II use the same neutrino source (μ), target (H) and the detection principle (IBD) as the LSND.
 => **Direct test of the LSND anomaly**

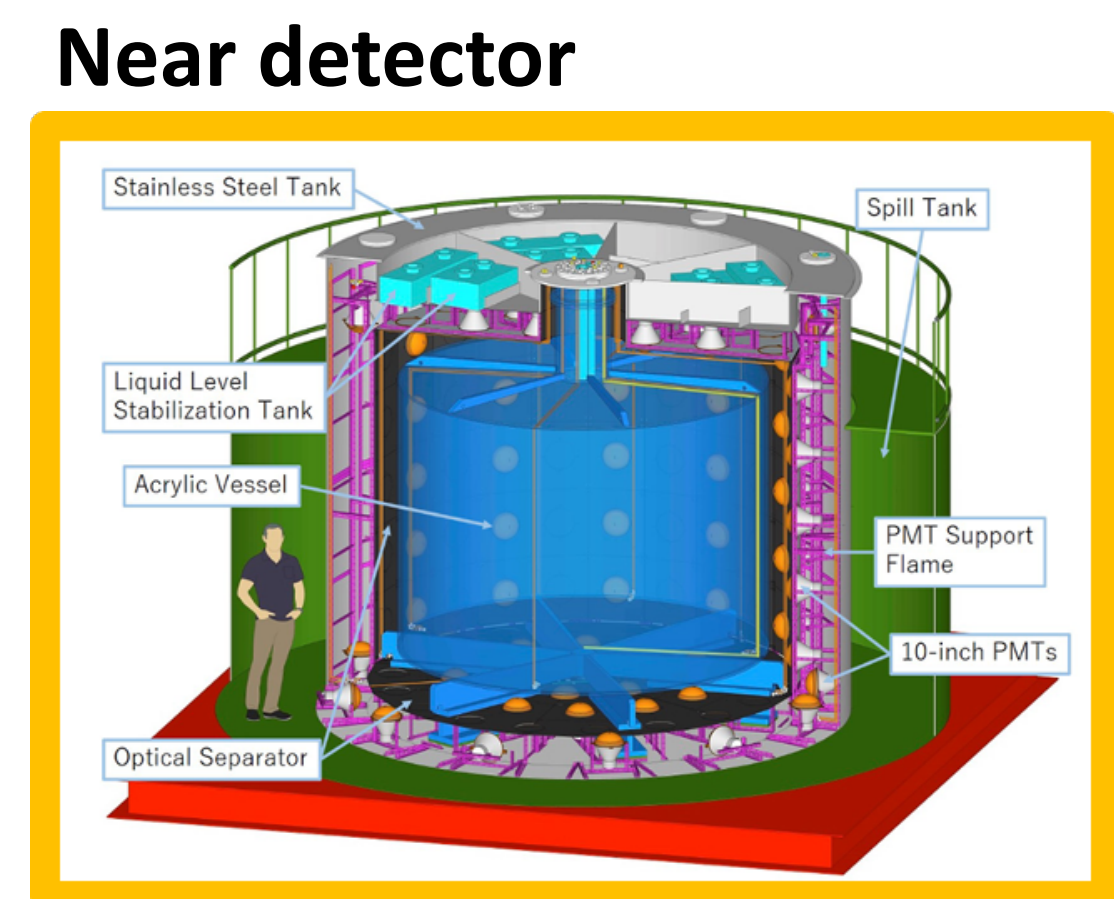
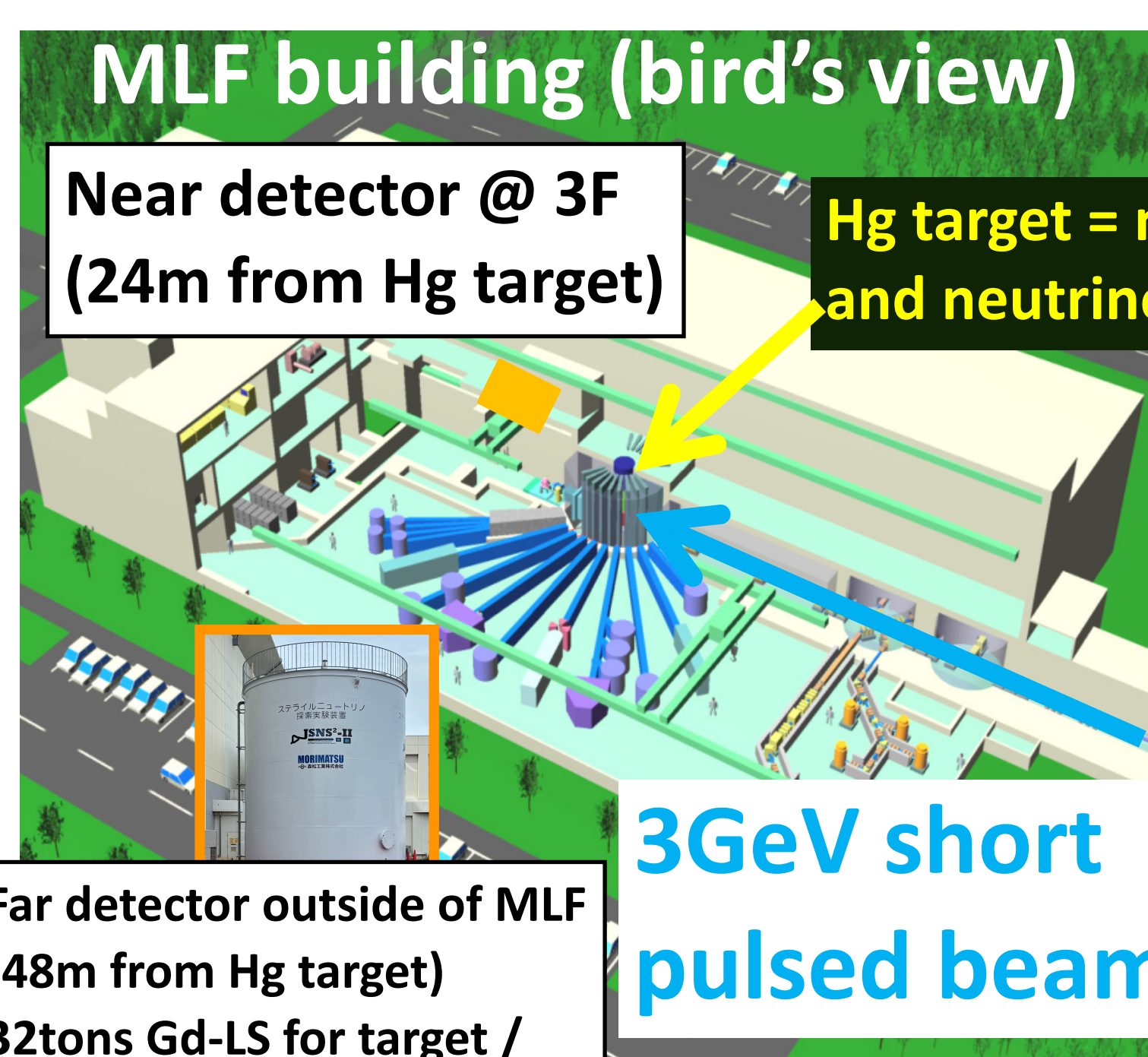
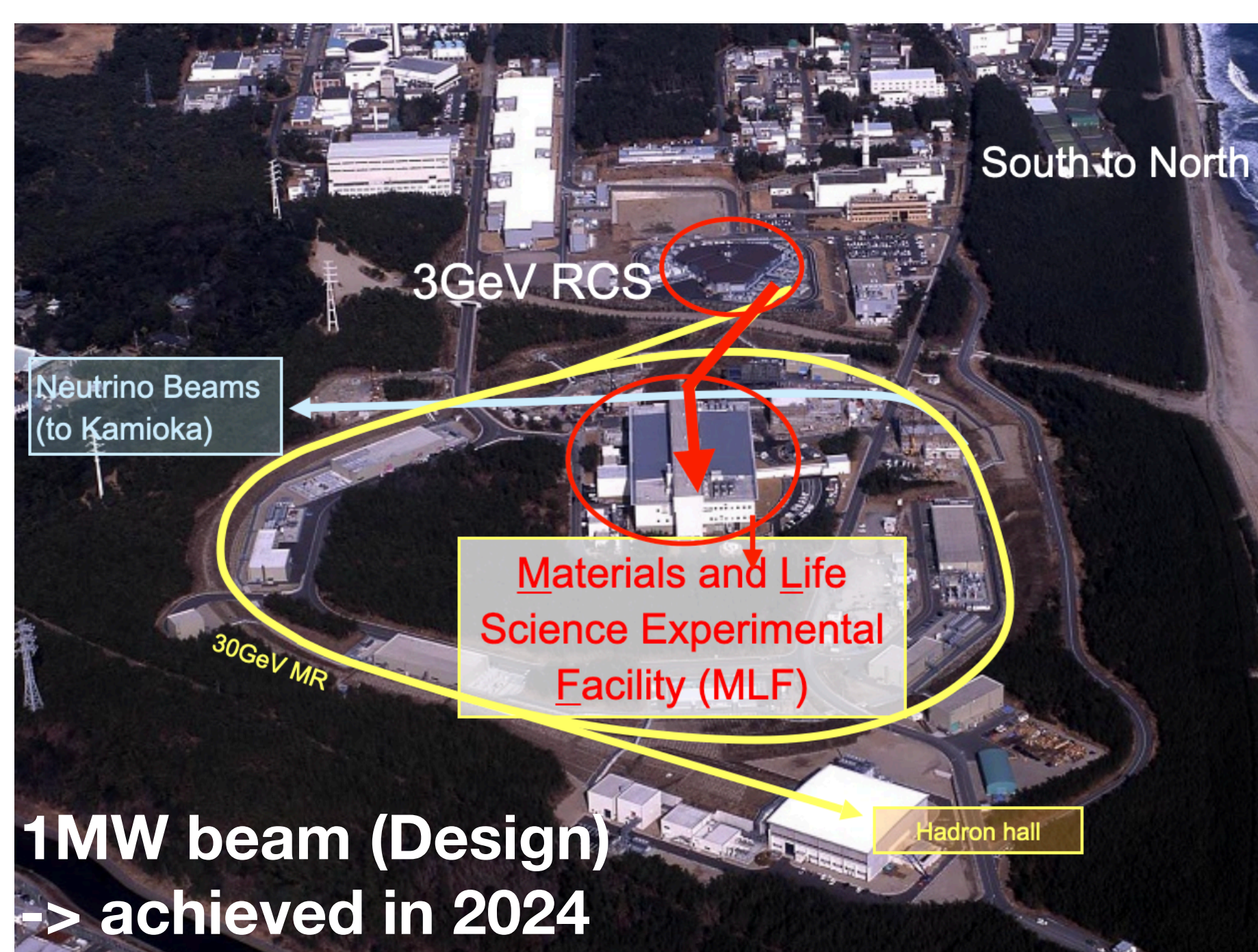
• Advantages over LSND :
 => Larger # μ / proton (due to 3GeV proton beam)
 => short-pulsed beam (much lower duty factor)
 => Gd-loaded liquid scintillator (suppress the accidental bkg.)
 => DIN + 500 MHz FADC DAQ (enhanced PSD capability)

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



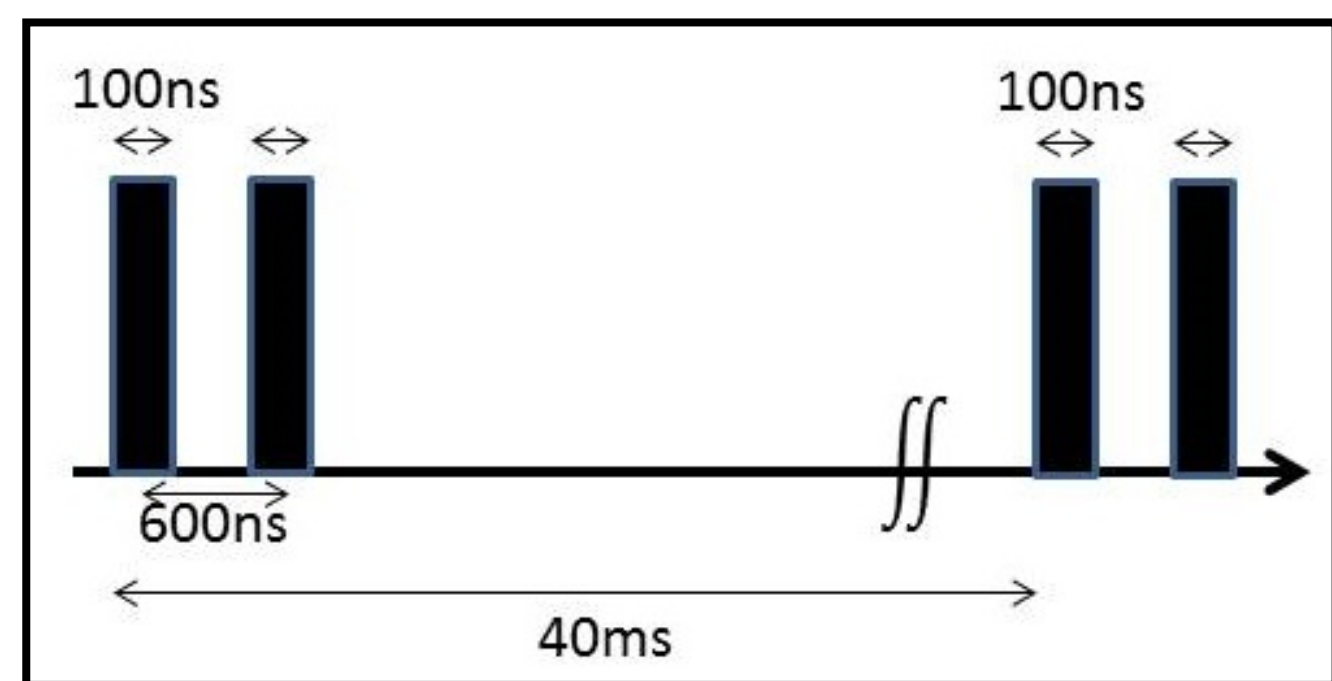
(3.8 σ $\bar{\nu}_e$ excess)

(*) Phys. Rev. D 112, 032012 (2025)



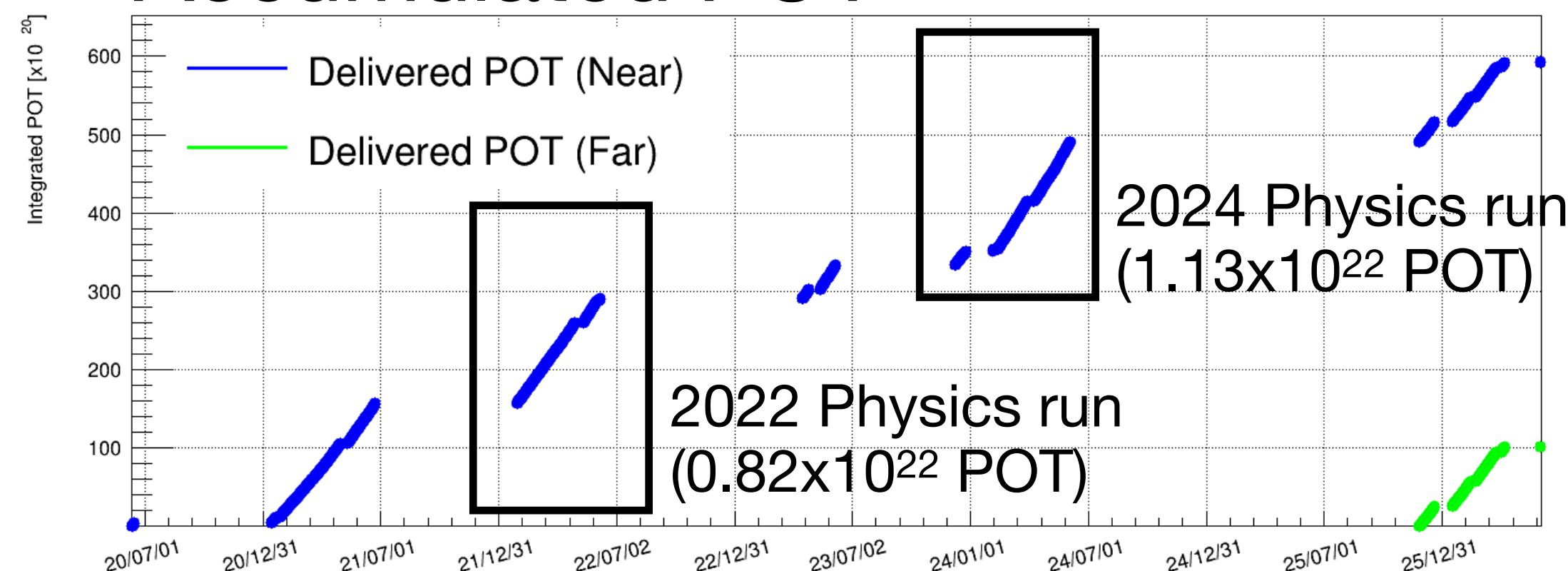
Nucl. Instrum. Methods A 1014 165742 (2021)

- **17tons** Gd-LS+DIN for target
- **96** 10" PMTs for the Inner Detector



- **Low duty factor beam** (short pulse + small repetition rate) gives excellent S/N ratio.

Accumulated POT



- Far Data taking => Commissioning (2025 Nov-)

- Near Data taking => 5 long term physics runs (2021-2026) => 6.0×10^{22} POT so far (~53% of approved POT)

- => **2022 + 2024 Physics run (1.95×10^{22} POT)** : Analysis results in this presentation

How to detect $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ signal

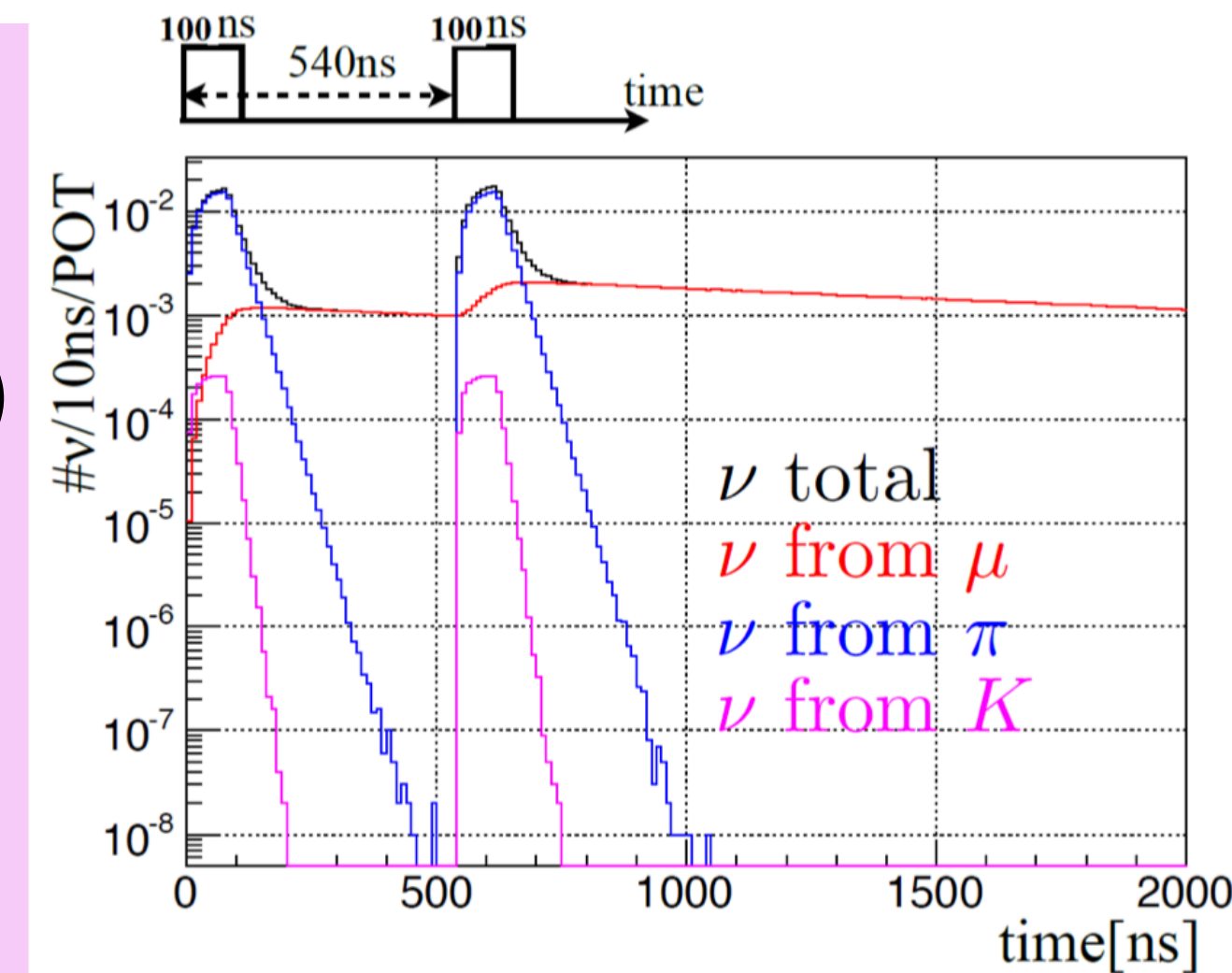
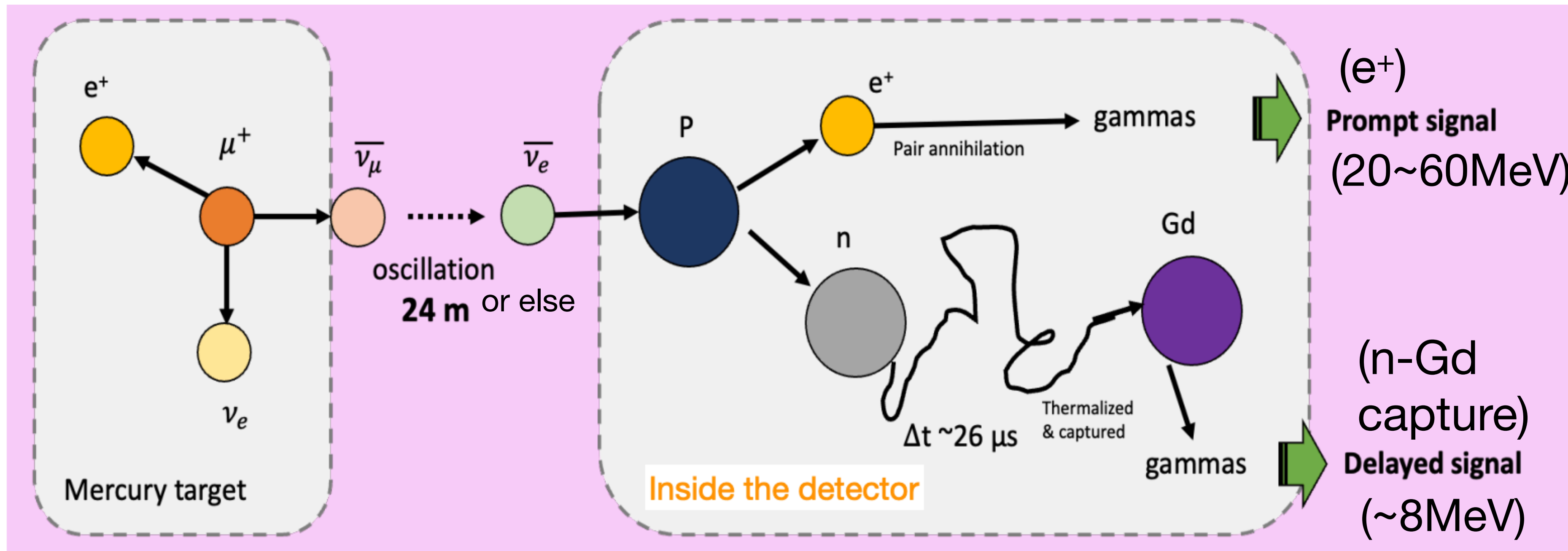
IBD selections

- $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ during 24m baseline.

	Timing	Energy
Prompt	1.7 or $2 < T_{\text{beam}} < 10 \mu\text{s}$	20~60 MeV
Delayed	$\Delta T_{\text{p-d}} < 100 \mu\text{s}$	7~12 MeV

- Detection by coincidence of IBD (Inverse Beta Decay)
 - => Prompt : e+ signal
 - => Delayed : gammas from neutron capture on gadolinium (Gd)

+ Spatial correlation cut
 $\Delta V_{\text{TX p-d}} < 60 \text{cm}$



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

<Papers so far regarding this search>

- Correlated background :
Eur. Phys. J. C (2022) 82: 331 (arXiv:2111.07482 [hep-ex])
- Pulse Shape Discrimination (PSD) :
PTEP 2025 023H02 (2025) (arXiv:2404.03679 [physics.ins-det])
- Accidental background :
Eur. Phys. J. C 84, 409 (2024) (arXiv:2308.02722 [hep-ex])
- 3D calibration :
Nucl. Instrum. Meth. A 1072 (2025) 170216 (arXiv:2404.04153 [hep-ex])
- Muon tagging with flash ADC waveform baselines :
2025 JINST 20 P09002 (arXiv:2502.16384 [physics.ins-det])
- First JSNS² measurement of the electron neutrino flux using CNGs reaction
Phys. Rev. D 112, 032012 (2025) (arXiv:2412.18509 [hep-ex])

- **First results from the search for an excess of $\bar{\nu}_e$ events in JSNS² :**
Phys. Rev. D 113, 112011 (2026) (arXiv:2602.06274 [hep-ex])
=> 2022 Physics run (0.82x10²² POT)

- **2022 + 2024 Physics run (1.95x10²² POT) results will be shown in this talk !!**

Energy side-bands for validation of backgrounds

2022 + 2024 Physics run
(1.95x10²² POT)

- Blind analysis to search $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ signal, w/ the energy side-bands.

- Background Prediction : data-driven control samples

- Background reduction : Pulse Shape Discrimination (PSD) & Multi-variated Likelihood method (LLK)

Observation

VS

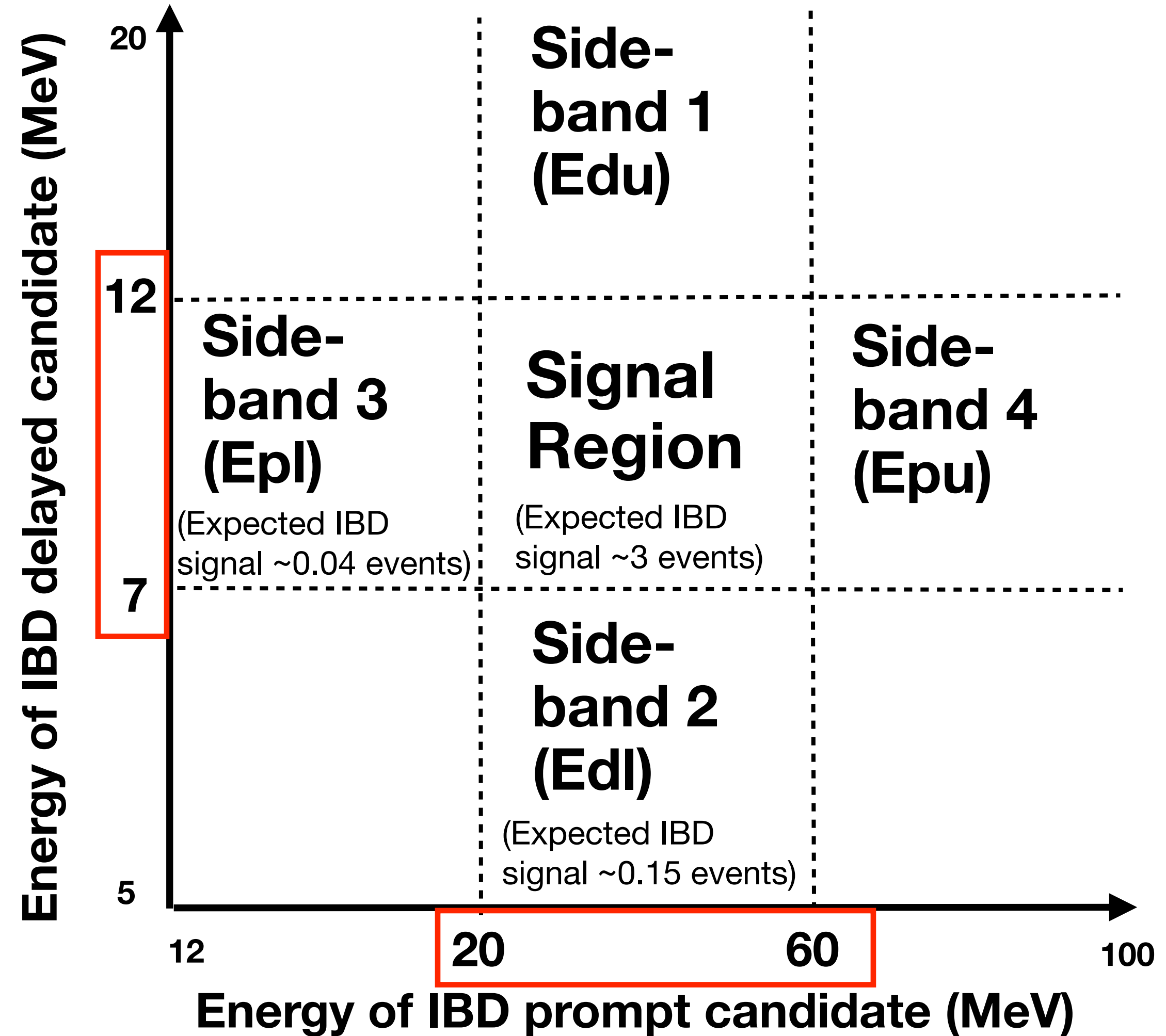
Bkg. Prediction

Physics data with criteria :

- Energy (E_p, E_d) -> right plot
- $1.7 \text{ or } 2\mu\text{s} < \Delta T_{\text{beam-p}} < 10\mu\text{s}$
- $\Delta T_{\text{p-d}} < 100\mu\text{s}$
- $\Delta VTX_{\text{p-d}} < 60\text{cm}$

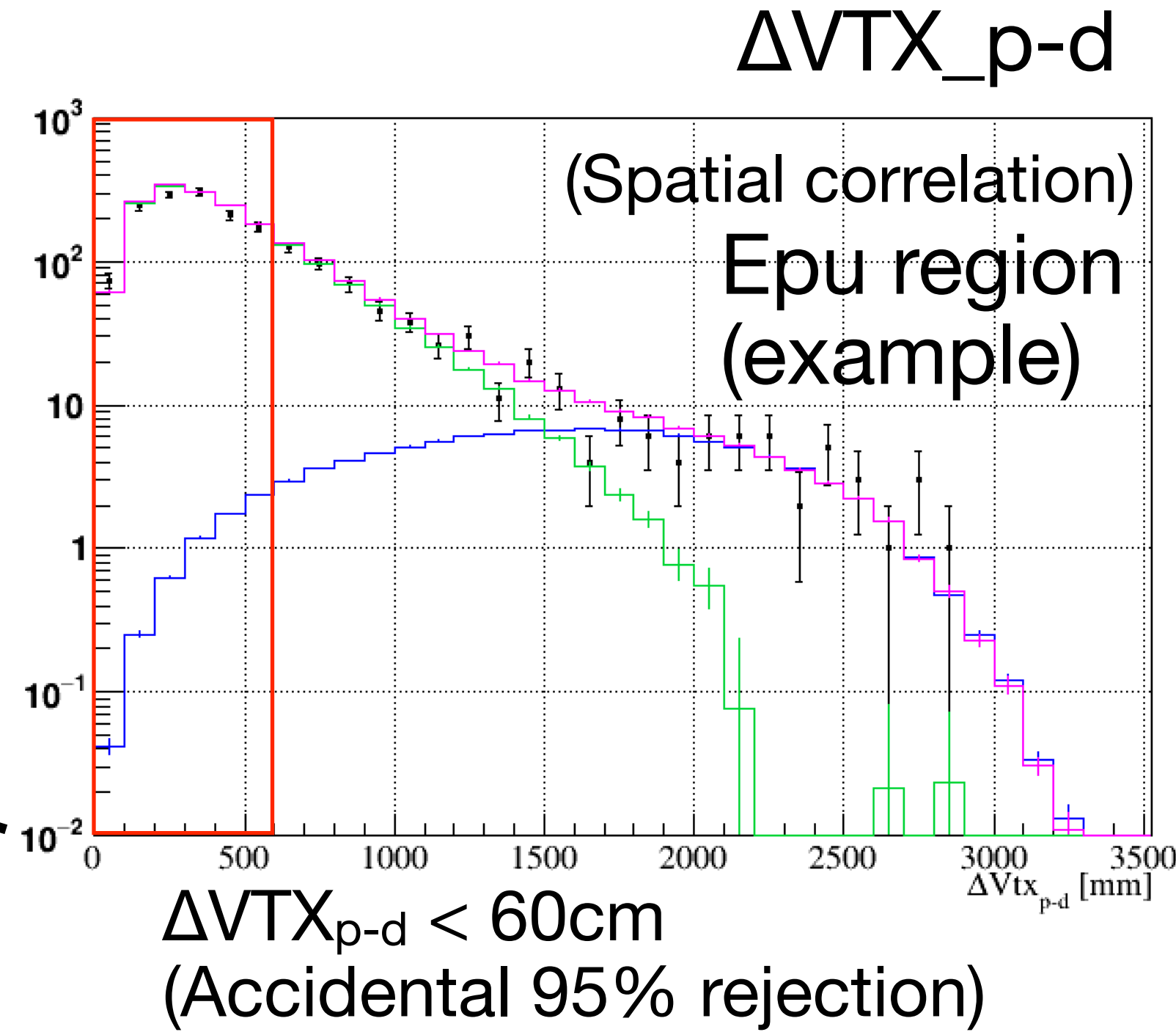
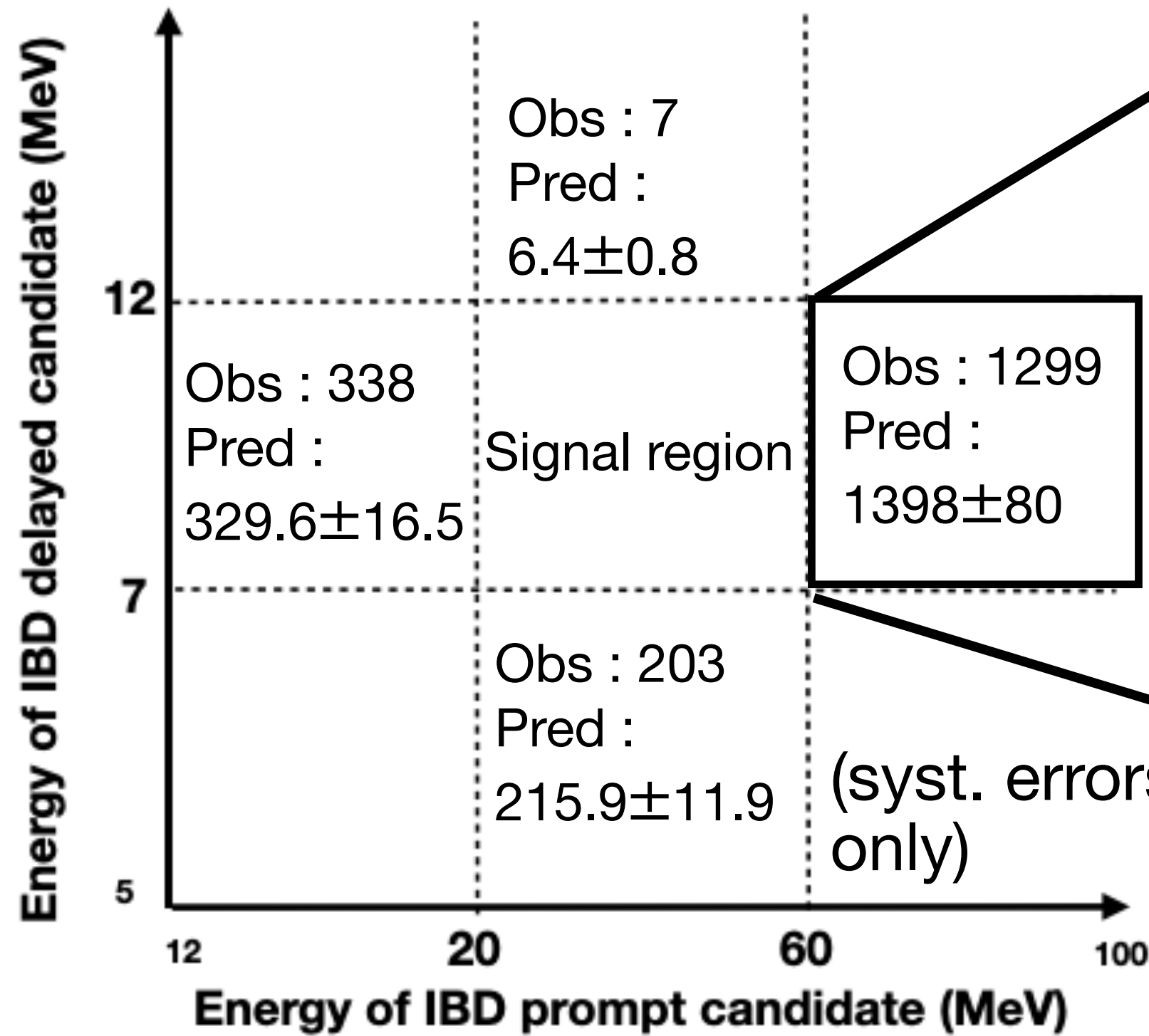
Purely data-driven control sample

- **Fast neutrons (Cosmogenic)**
=> obtained at $T_{\text{beam}} > 1\text{ms}$
- **Accidental background**
=> obtained with specific calibration runs



Observation vs Bkg. Prediction at side-bands (w/o PSD, w/o LLK)

2022 + 2024 Physics run
(1.95×10^{22} POT)



JSNS² Preliminary

Background Prediction (Epu) :

- Cosmogenic Neutron : 1391.9 ± 80
- Accidental : 6.2 ± 0.1

JSNS² detector is located **above ground**

=> severe cosmogenic backgrounds
=> “How to reduce Bkg.” is a key.
=> **~1/1000** reduction is necessary

• **Good consistency for Observation vs Background Prediction** for all side-bands regions

• Cosmogenic fast neutrons dominated => **PSD**

(~1/300 reduction)

• Accidental / Neutrons further reduction => **LLK**

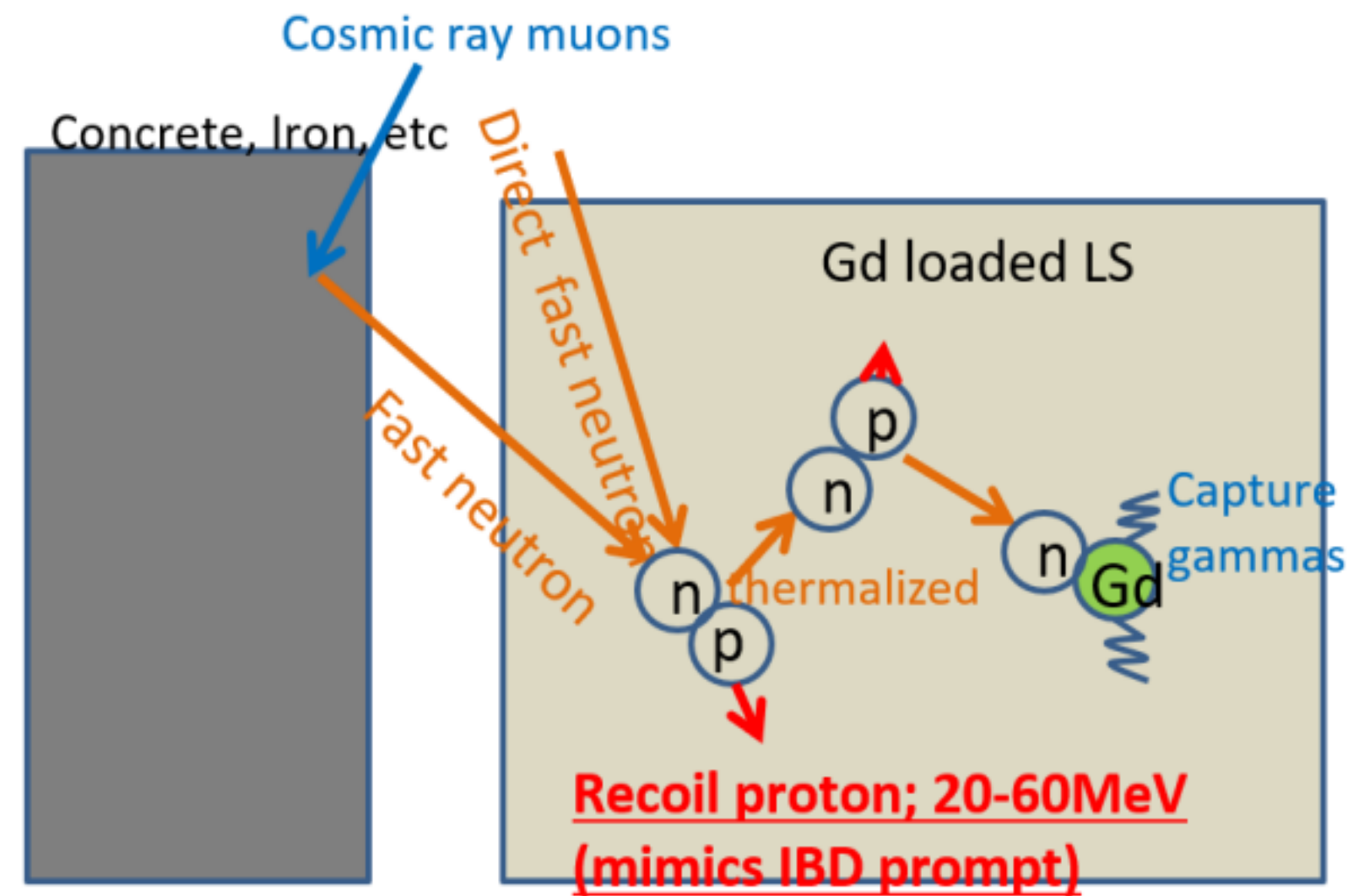
(~1/6, ~1/3 reduction)

Backgrounds Control : Pulse Shape Discrimination (PSD)

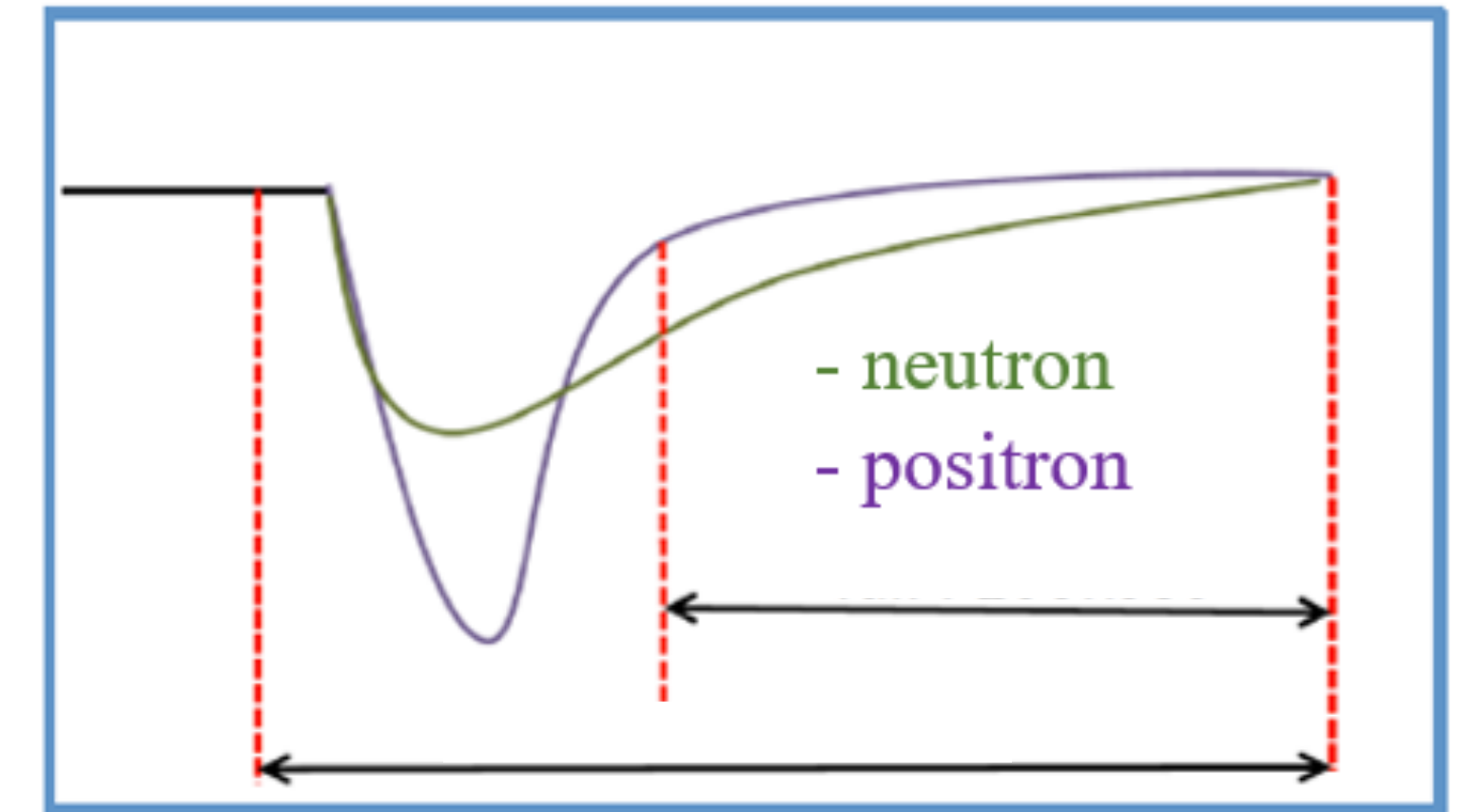
- **Fast neutrons**
=> Mimic the coincidence of IBD signals

- **PSD**
=> using the difference of PMT waveforms between e-like and n-like.

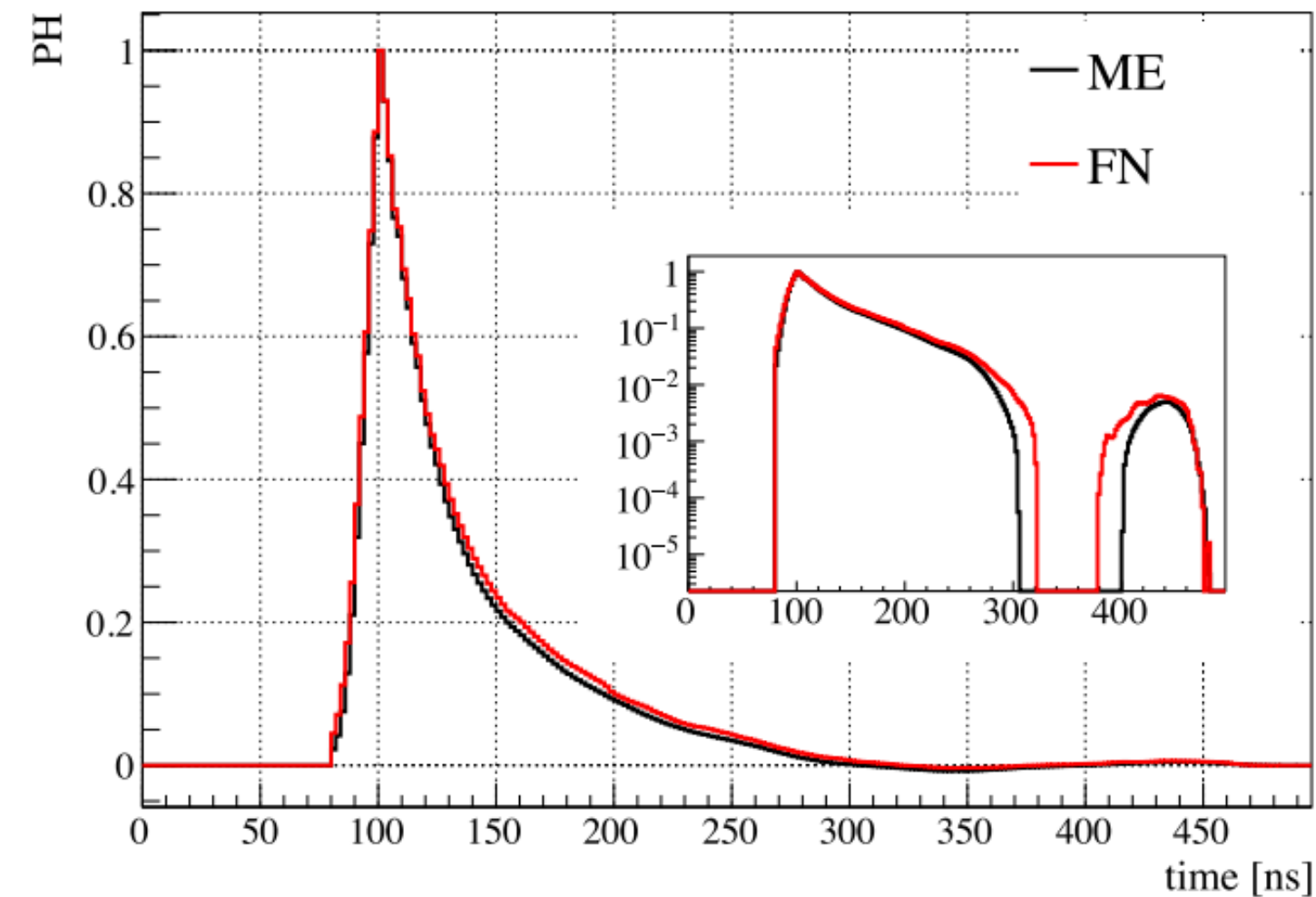
- PSD uses **Data-driven likelihood method** (Control sample : Michel electron / Fast neutron)
=> use Full information of waveform height.
=> Each 96 PMT own separation power.



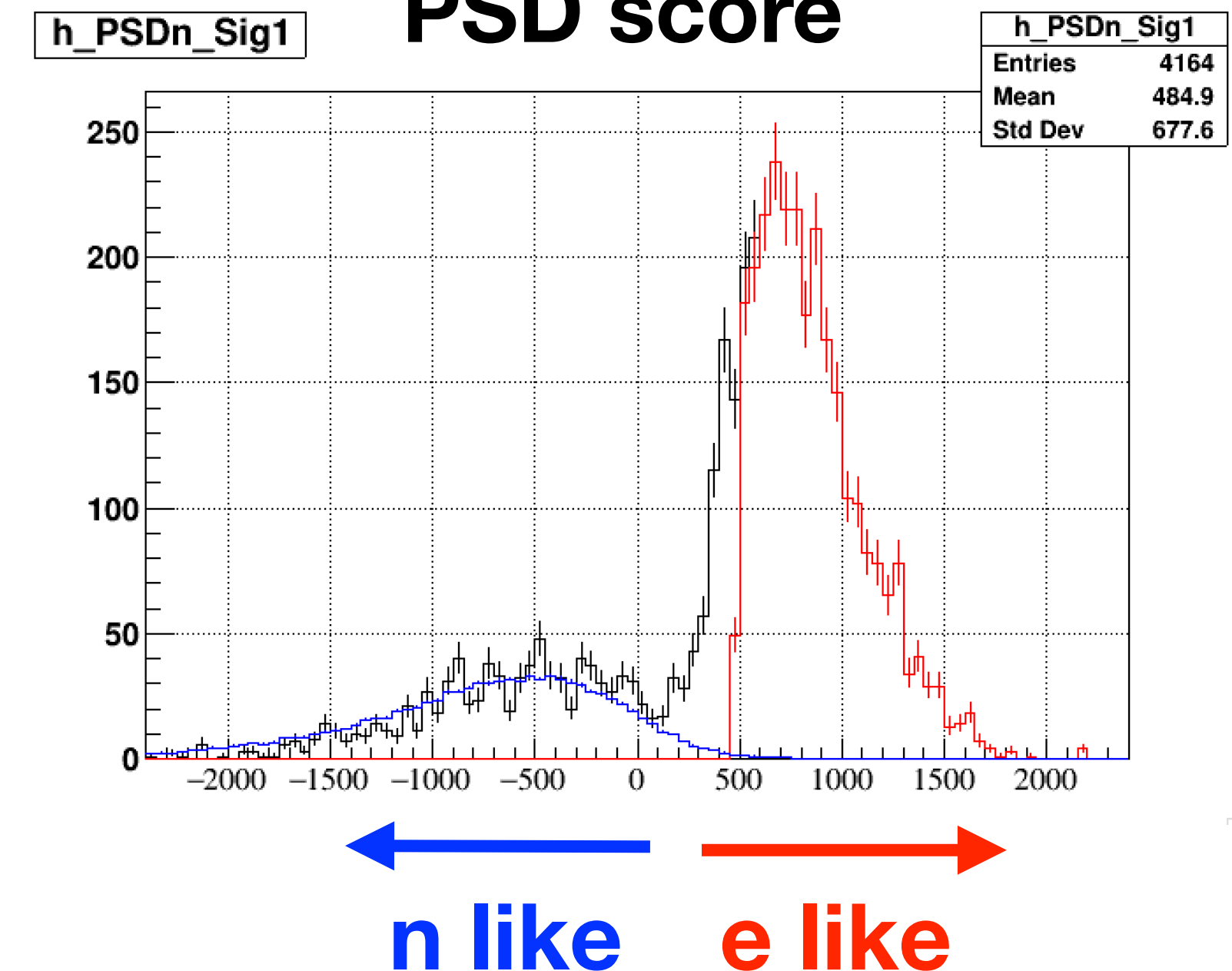
PMT waveform



Waveforms (data)

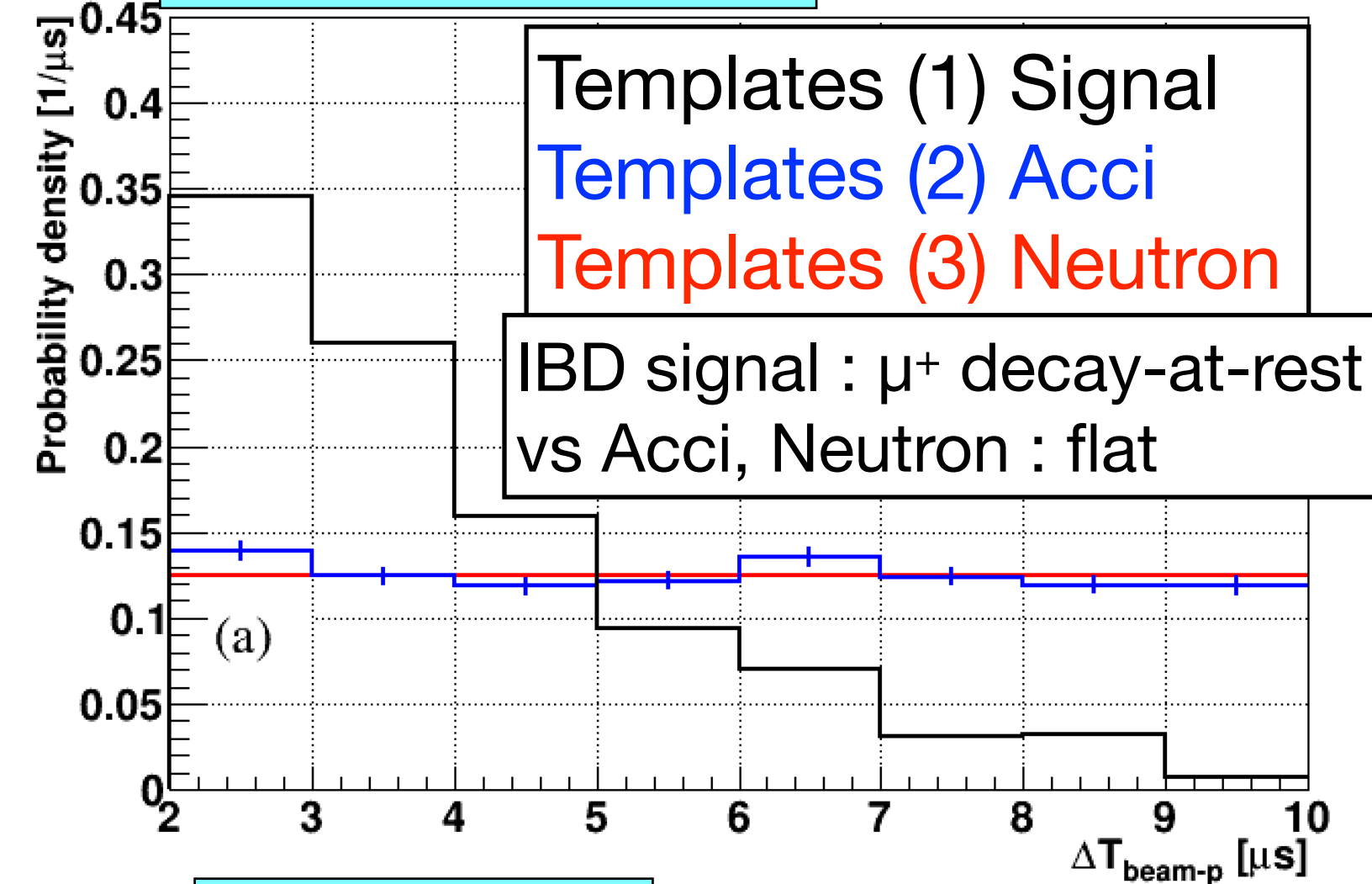


PSD score

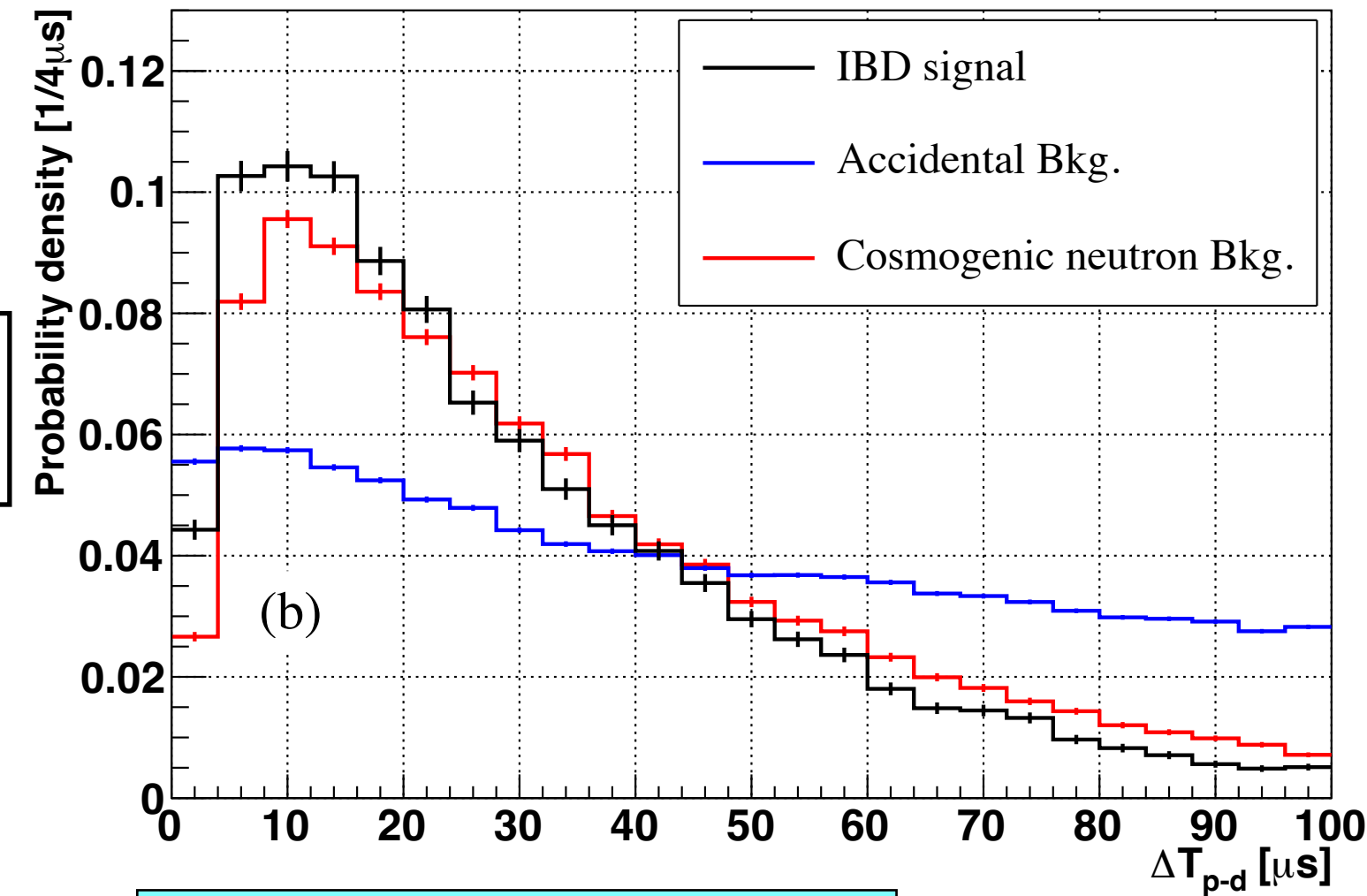


Backgrounds Control : Multi-variated Likelihood method (LLK)

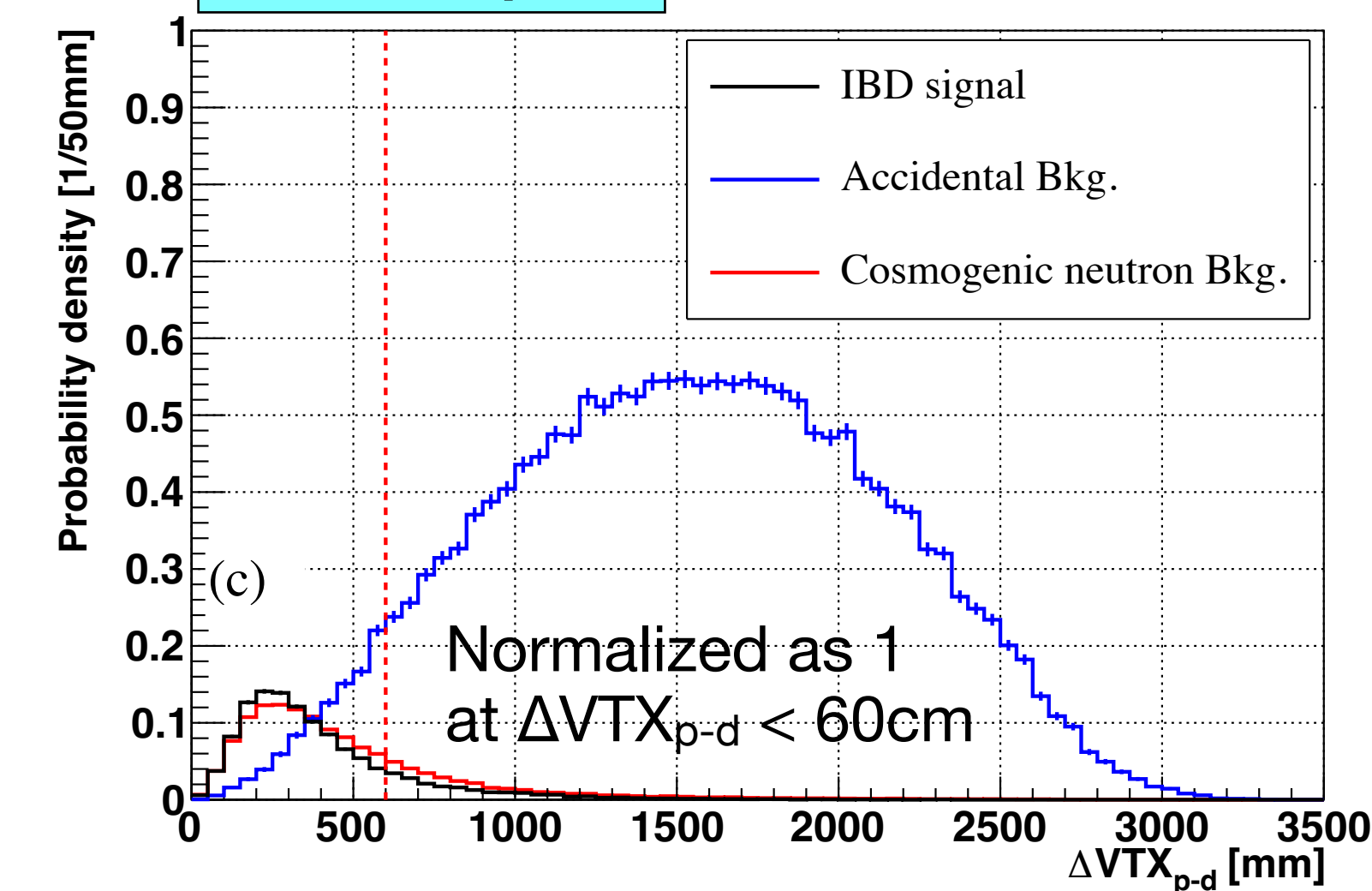
Prompt Timing



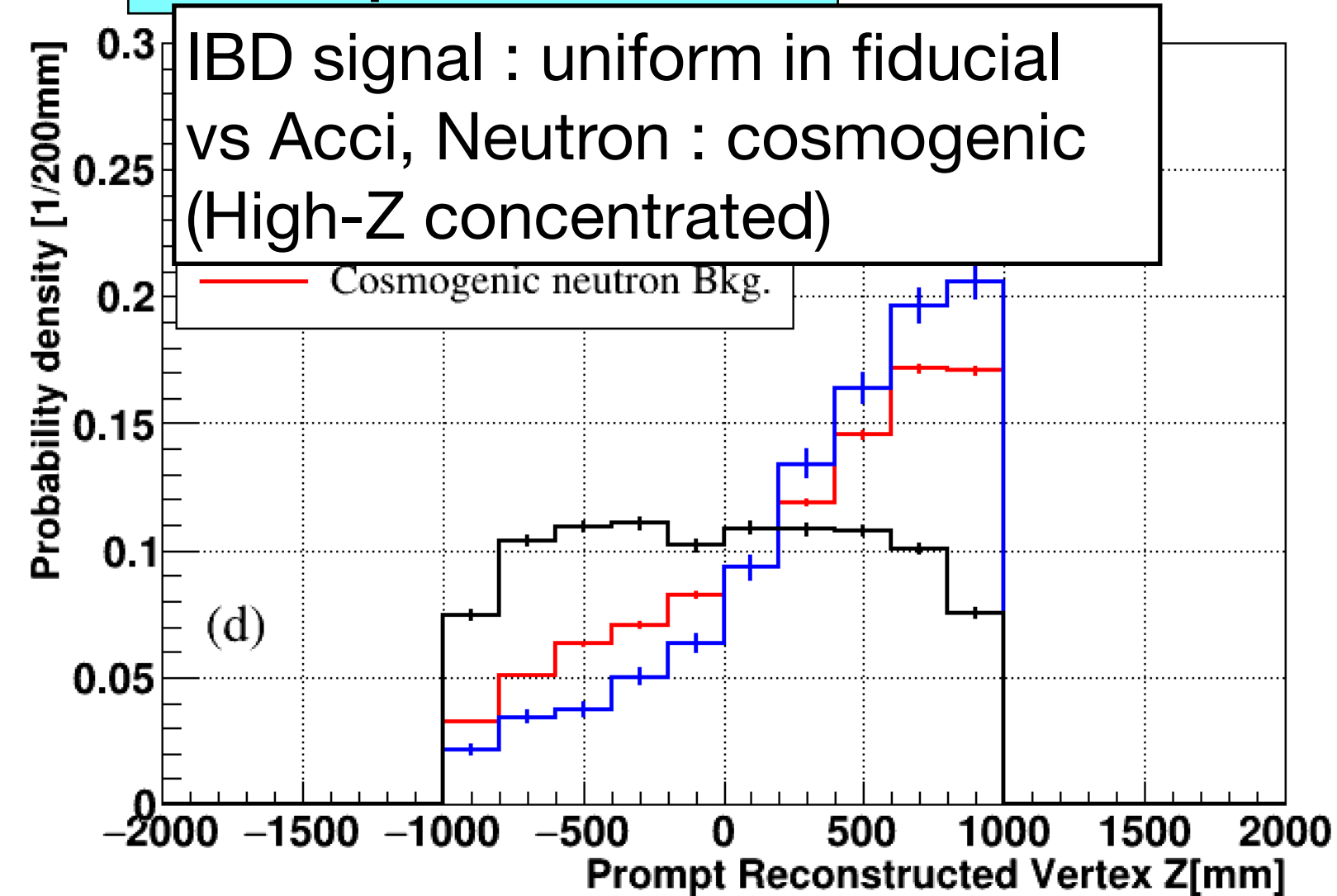
ΔT_p-d



ΔVTX_p-d



Prompt Vertex Z



- IBD Signal vs Neutron vs Acci.
=> Different shapes for [Energy, Timing, Vertex]

- Data-driven templates,
=> binned Likelihood scores

$$\text{Likelihood } L_j = \prod_n \text{prob}_{j,n, \text{i-th bin}}$$

- => j : IBD Signal / Neutron / Acci.

- => n : [Energy, Timing, Vertex]

- => **Log-Likelihood ratio** is used.

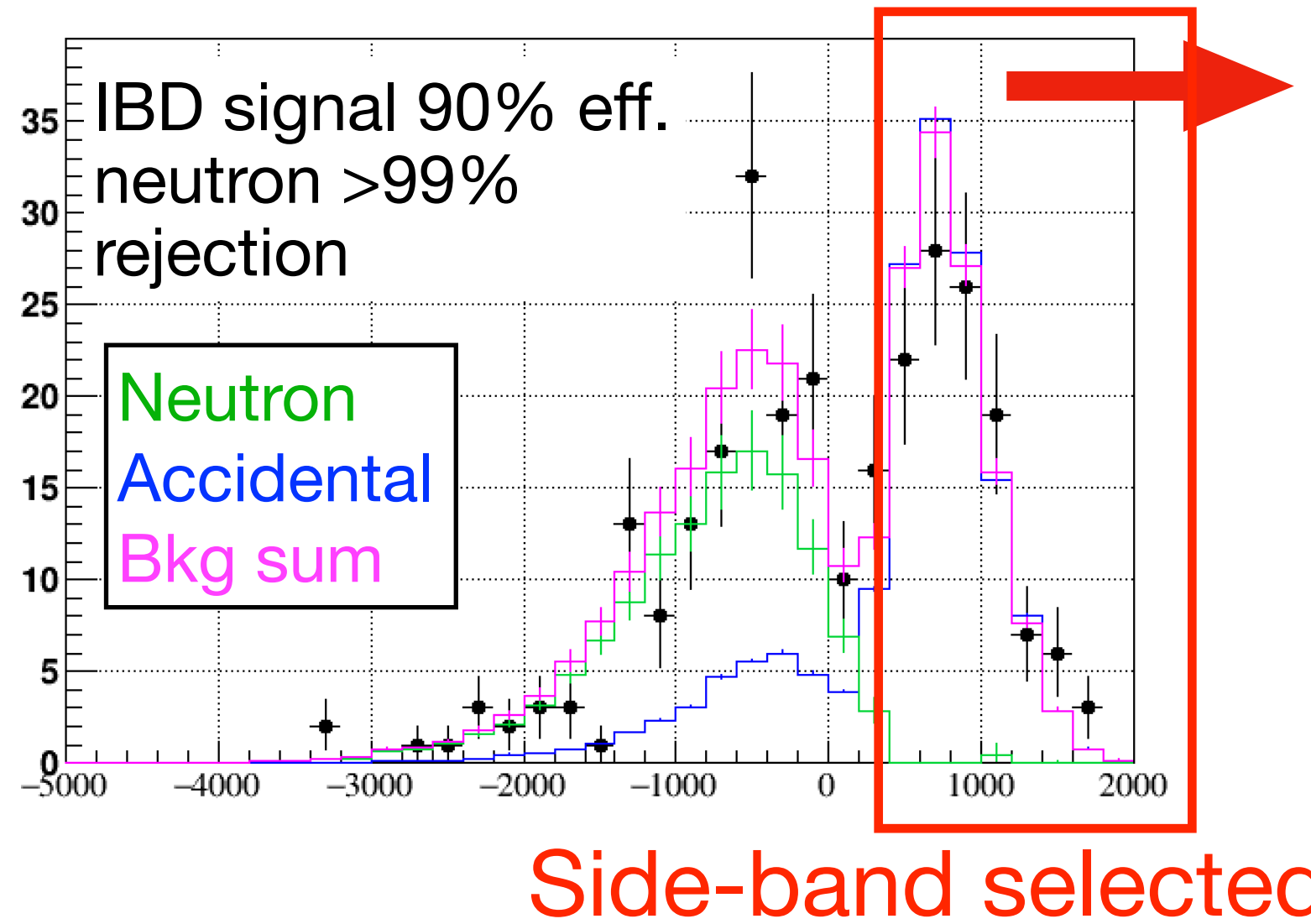
- By selecting **Signal-like events**,
=> factor of a few reduction for Neutron & Accidental Bkgs.

PSD and LLK check at side-bands

2022 + 2024 Physics run
(1.95×10^{22} POT)

JSNS² Preliminary

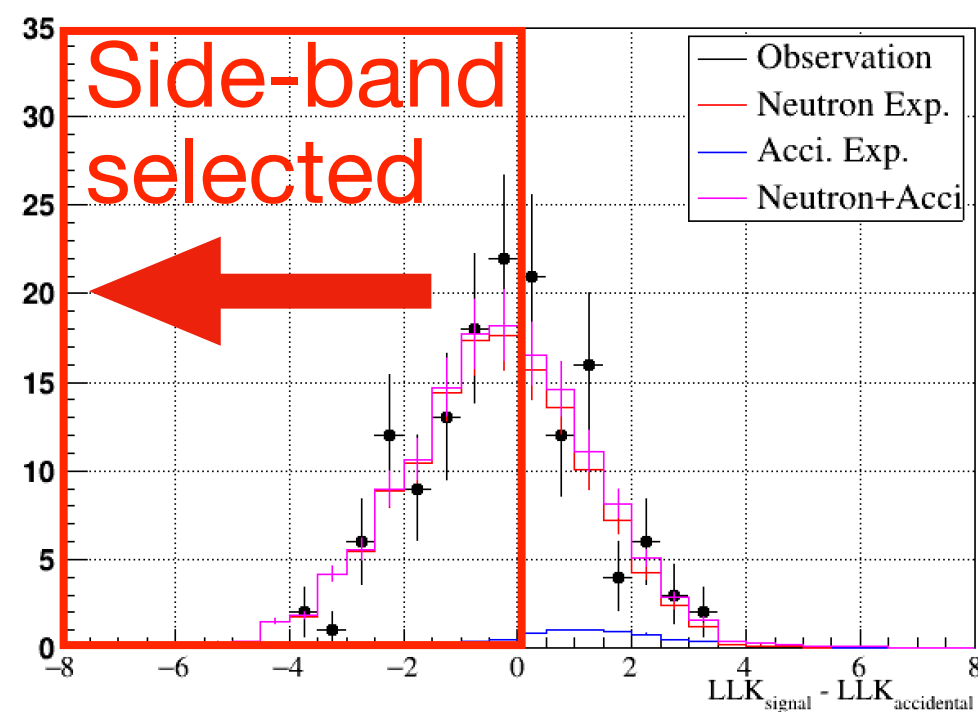
PSD application (side-band E_{dl})



cases	E_{du}		E_{dl}		E_{pu}		E_{pl}	
	obs.	pred.	obs.	pred.	obs.	pred.	obs.	pred.
w/o PSD w/o LLK	7	6.4 ± 0.8	203	215.9 ± 11.9	1299	1398.1 ± 79.5	338	329.6 ± 16.5
w/o PSD w/ LLK	—	—	47	55.3 ± 1.4	387	410.1 ± 23.0	91	92.8 ± 5.1
w/ PSD w/o LLK	—	—	8	13.0 ± 0.3	11	12.7 ± 0.9	11	7.2 ± 0.2
w/ PSD w/ LLK	—	—	2	1.9 ± 0.1	2	3.2 ± 0.3	2	1.1 ± 0.1

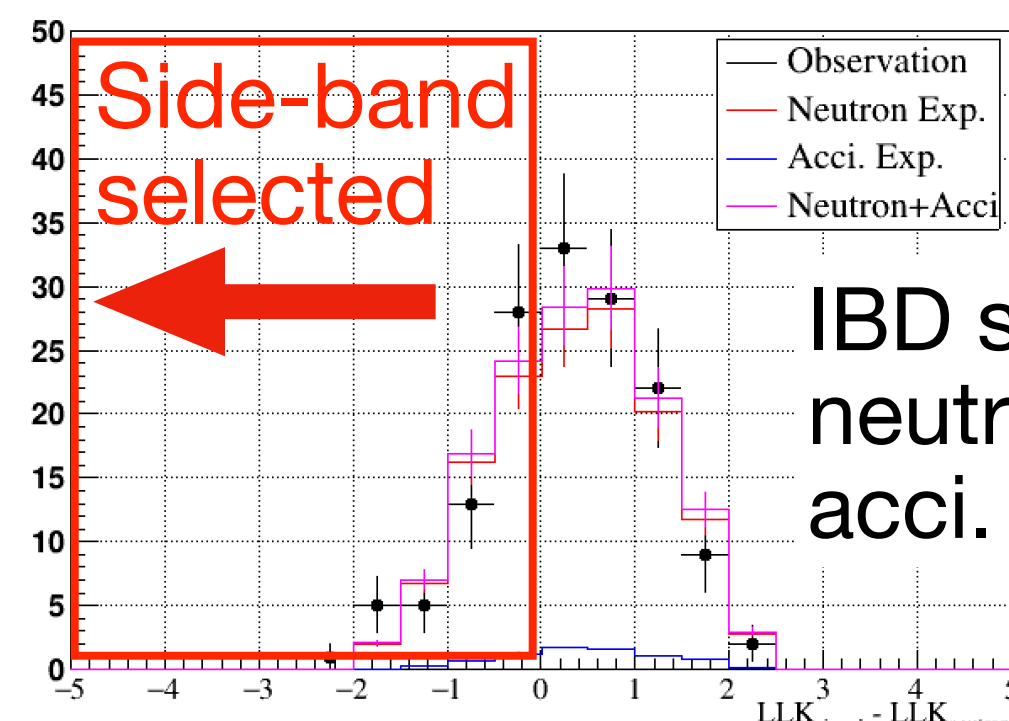
- Observation vs Bkg. Prediction (side-band regions)
-> Good consistency for all cases
(examples for PSD/LLK applications are shown in this page)

LLK application (side-band E_{pl}) ; 1D Log-Likelihood ratio



signal-like

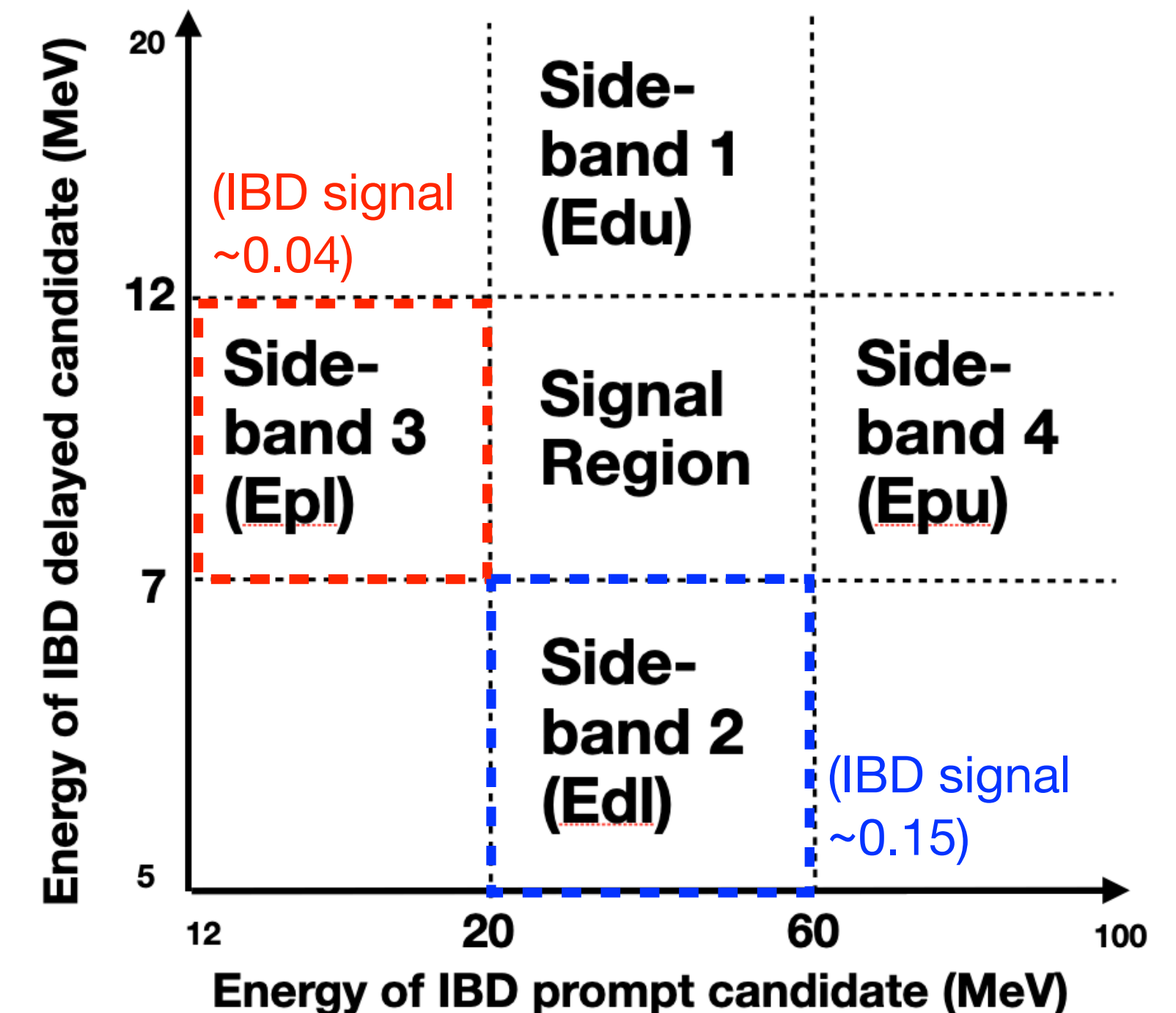
acci-like



signal-like

n-like

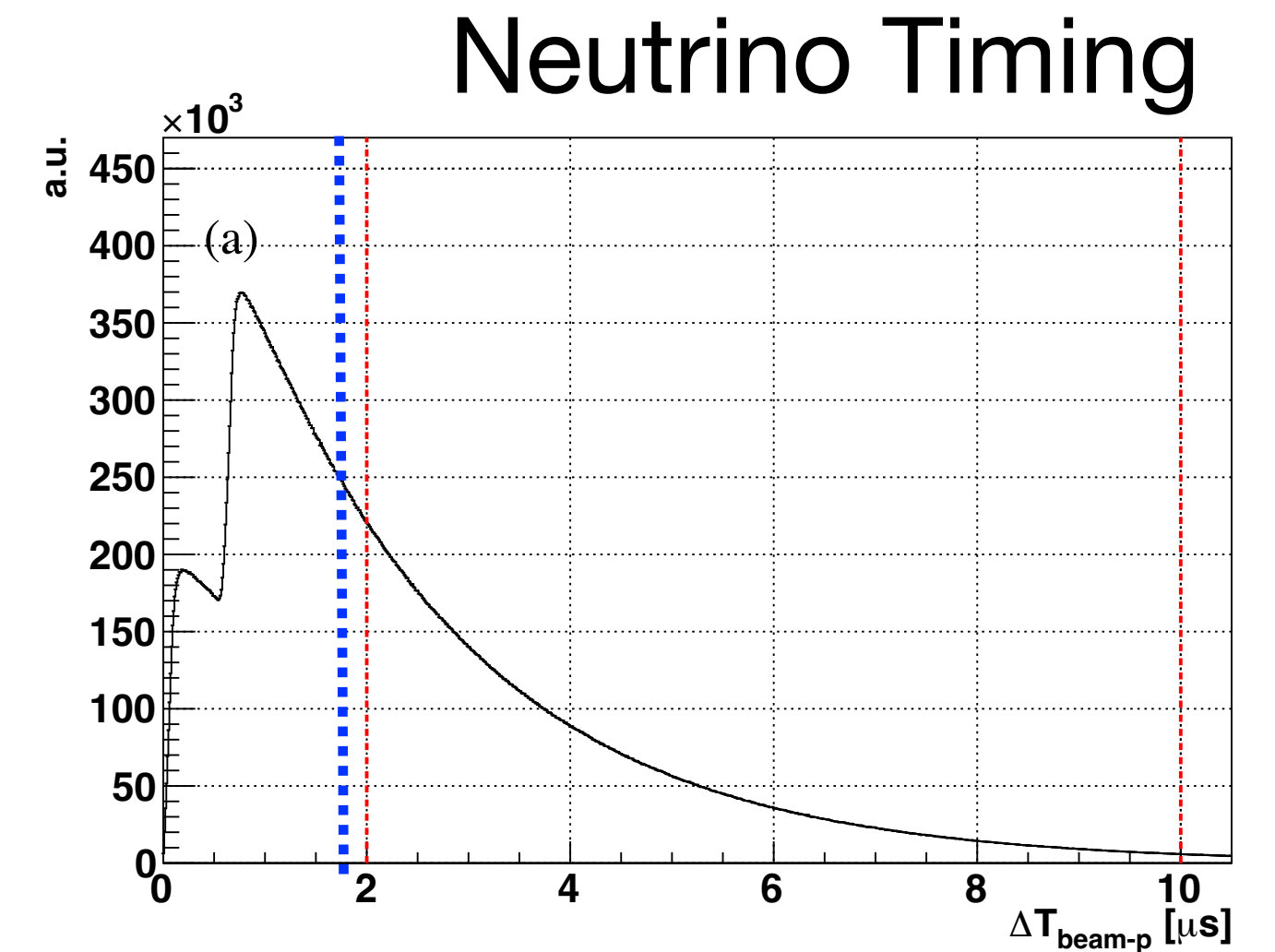
IBD signal 60% eff.
neutron 70% rej.
acci. 85% rej.



Event selection IBD signal efficiency

- Signal efficiency : estimated using both Data and MC

Requirement	2022 Physics run (%)	2024 Physics run (%)
–Prompt Candidate– $20 \leq E_p \leq 60$ MeV 1.7 or $2 \leq \Delta T_{beam-p} \leq 10$ μ s PSD	100.0 46.5 ± 0.5 87.2 ± 9.1	100.0 55.0 ± 0.4 89.4 ± 7.0
–Delayed Candidate– $7 \leq E_d \leq 12$ MeV Beam neutron rejection	75.3 ± 0.9 94.1 ± 0.1	75.3 ± 0.9 93.4 ± 0.1
–IBD paired Candidate– $\Delta T_{p-d} \leq 100$ μ s $\Delta VTX_{p-d} \leq 60$ cm Background rejection likelihood	$96.6^{+3.4}_{-5.6}$ 83.4 ± 10.0 70.5 ± 1.5	$96.6^{+3.4}_{-5.6}$ 83.4 ± 10.0 70.3 ± 1.5
–Muon and Michel electron rejections– Muon rejection	92.8 ± 0.5	93.6 ± 0.5
Michel electron rejections (veto layer)	97.0 ± 0.03	96.5 ± 0.1
Michel electron rejections (baseline)	86.1 ± 1.4	83.1 ± 1.9
Chimney passing muon rejections	98.7 ± 0.1	95.2 ± 0.1
Cumulative total efficiency	$12.5^{+2.1}_{-2.2}$	14.0 ± 1.9



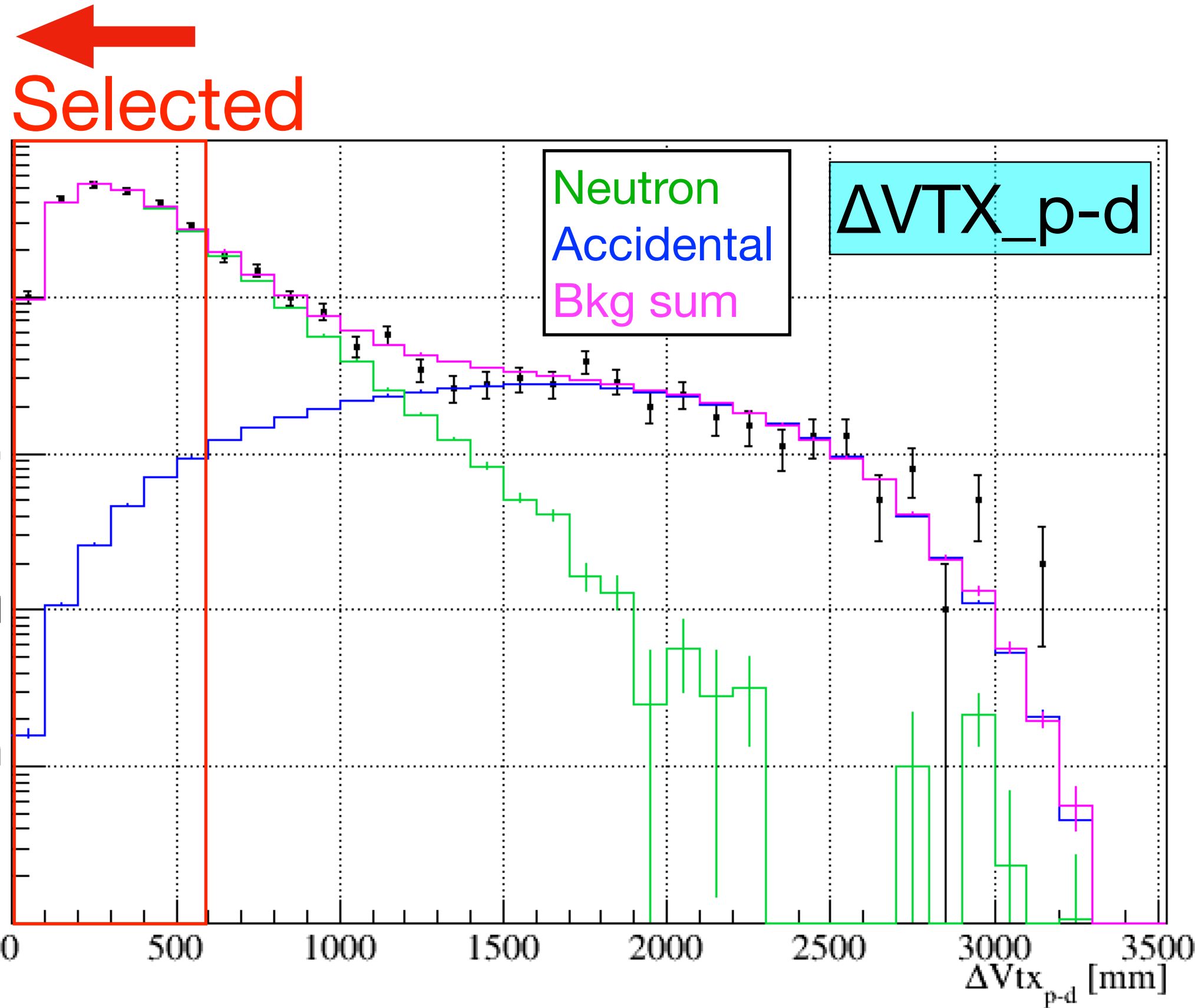
- Signal efficiency
 => already improved through a trigger upgrade.
 => 2022 run :
 $2 \mu\text{s} < \Delta T_{beam-p} < 10 \mu\text{s}$
 => Since mid-2024 :
 $1.7 \mu\text{s} < \Delta T_{beam-p} < 10 \mu\text{s}$
 => “**47 -> 55%** efficiency”.
 => Further improvements in the future.

JSNS² Preliminary

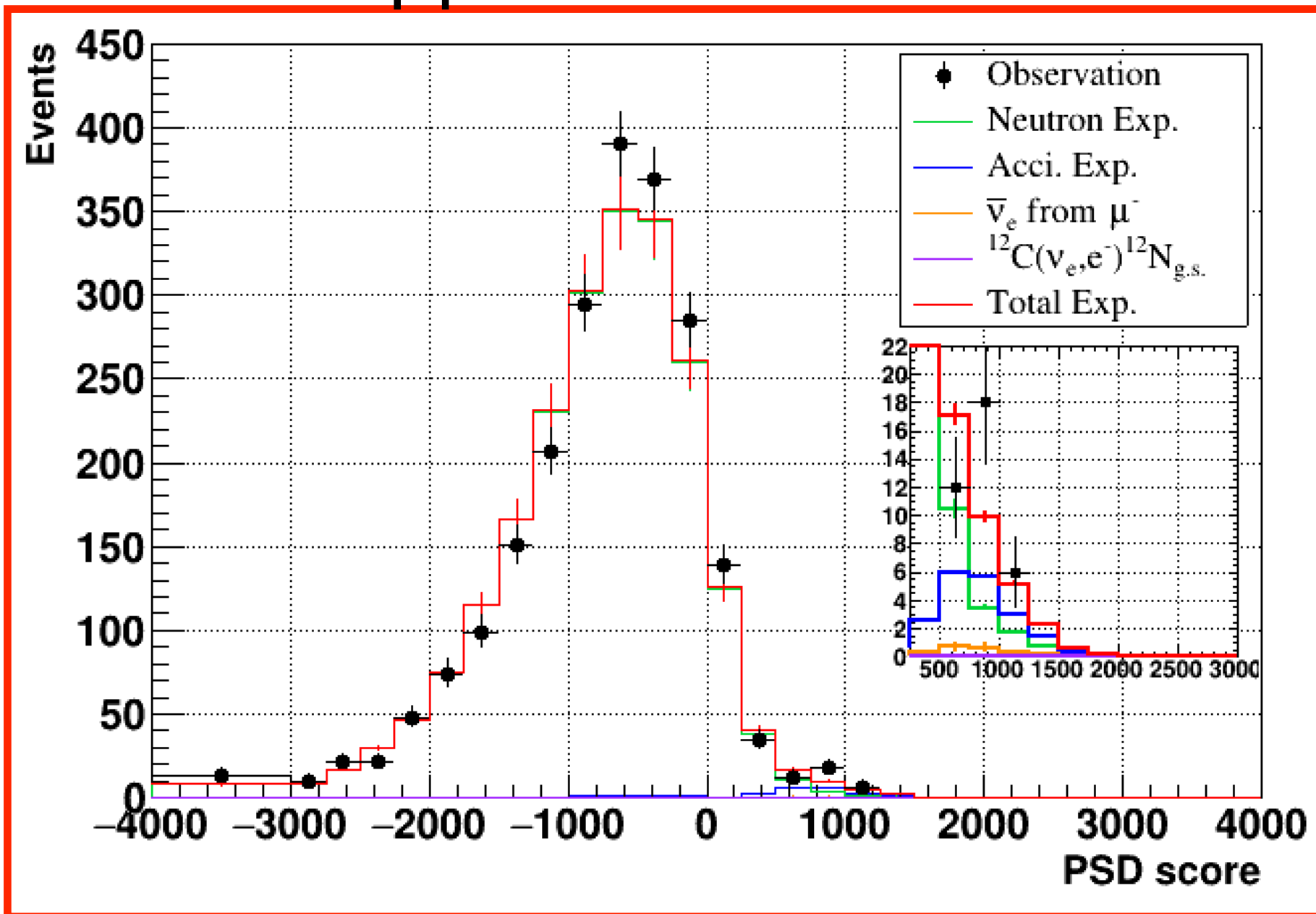
Unblind Results in signal region (w/o PSD w/o LLK)

- Observation vs Bkg. Prediction (signal region)
=> Good consistency (syst. errors only)

cases	Observation	Prediction
w/o PSD w/o LLK	2195	2160.3 +/- 128.6
w/o PSD w/ LLK		
w/ PSD w/o LLK		
w/ PSD w/ LLK		



PSD application



JSNS² Preliminary
2022 + 2024 Physics run
(1.95×10^{22} POT)

Background Prediction :

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

(Expected IBD signal $\simeq 3$)

Unblind Results in signal region (w/ PSD)

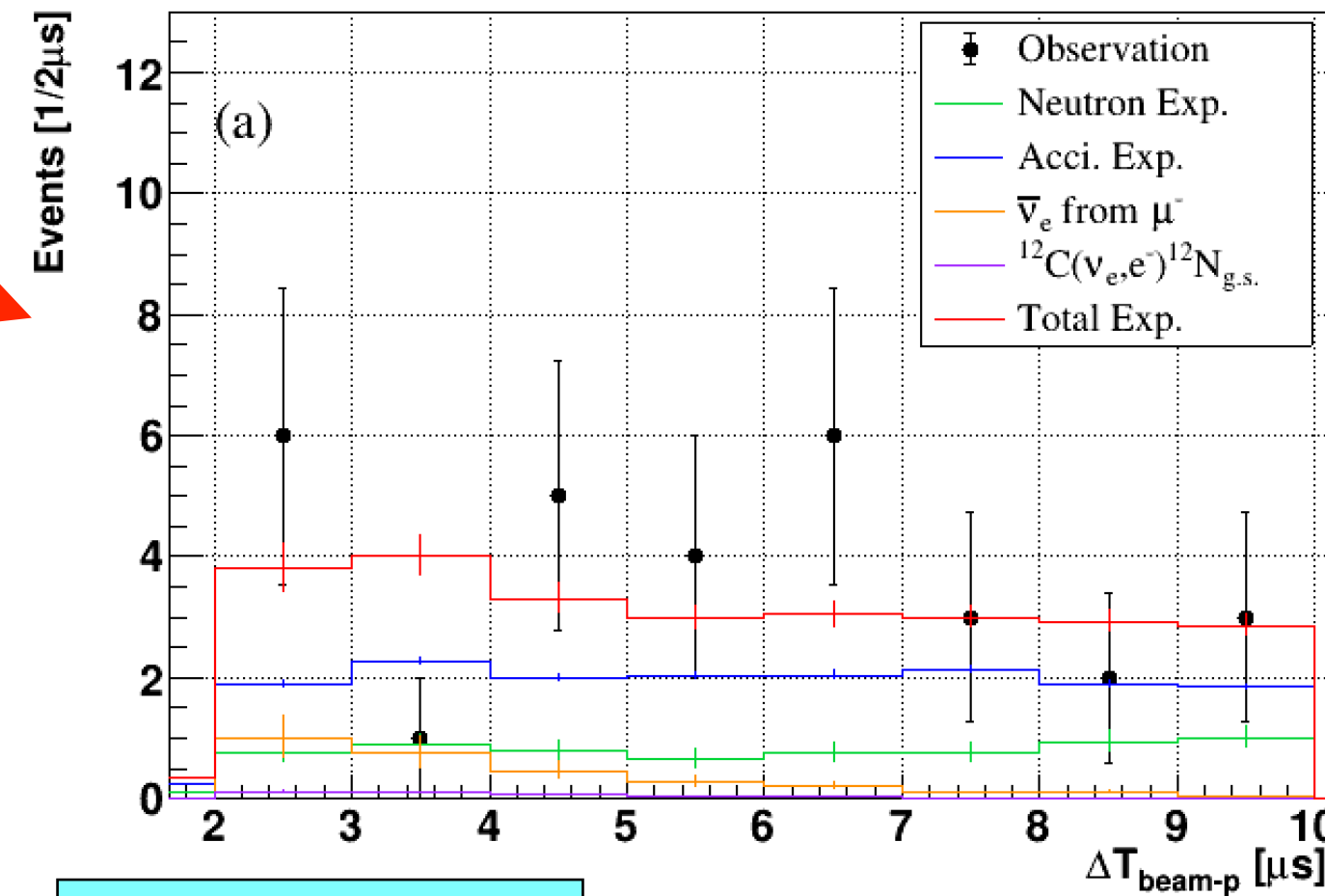
2022 + 2024 Physics run
(1.95×10^{22} POT)

JSNS² Preliminary

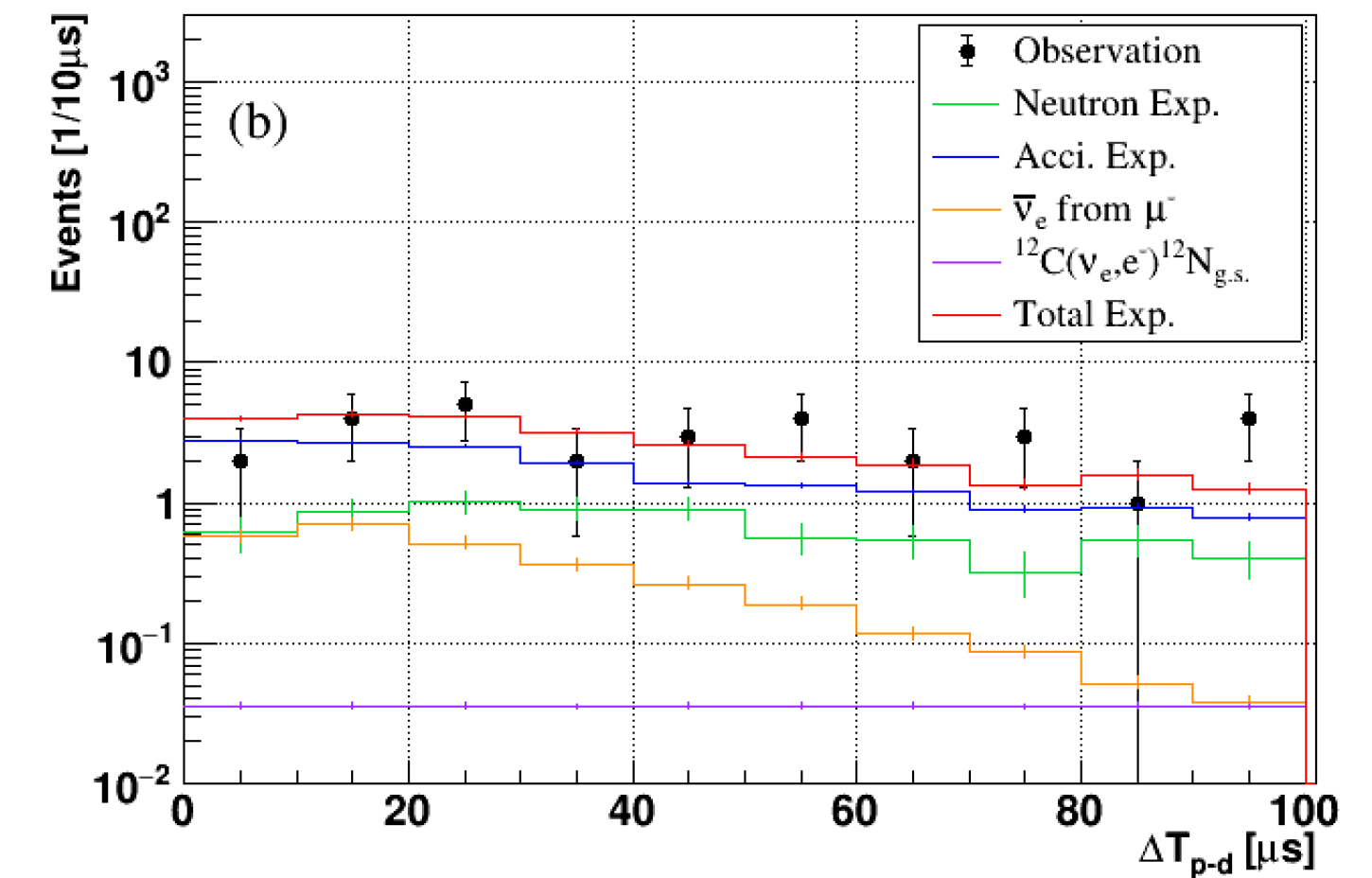
- Observation vs Bkg. Prediction (signal region)
(syst. errors only)

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		

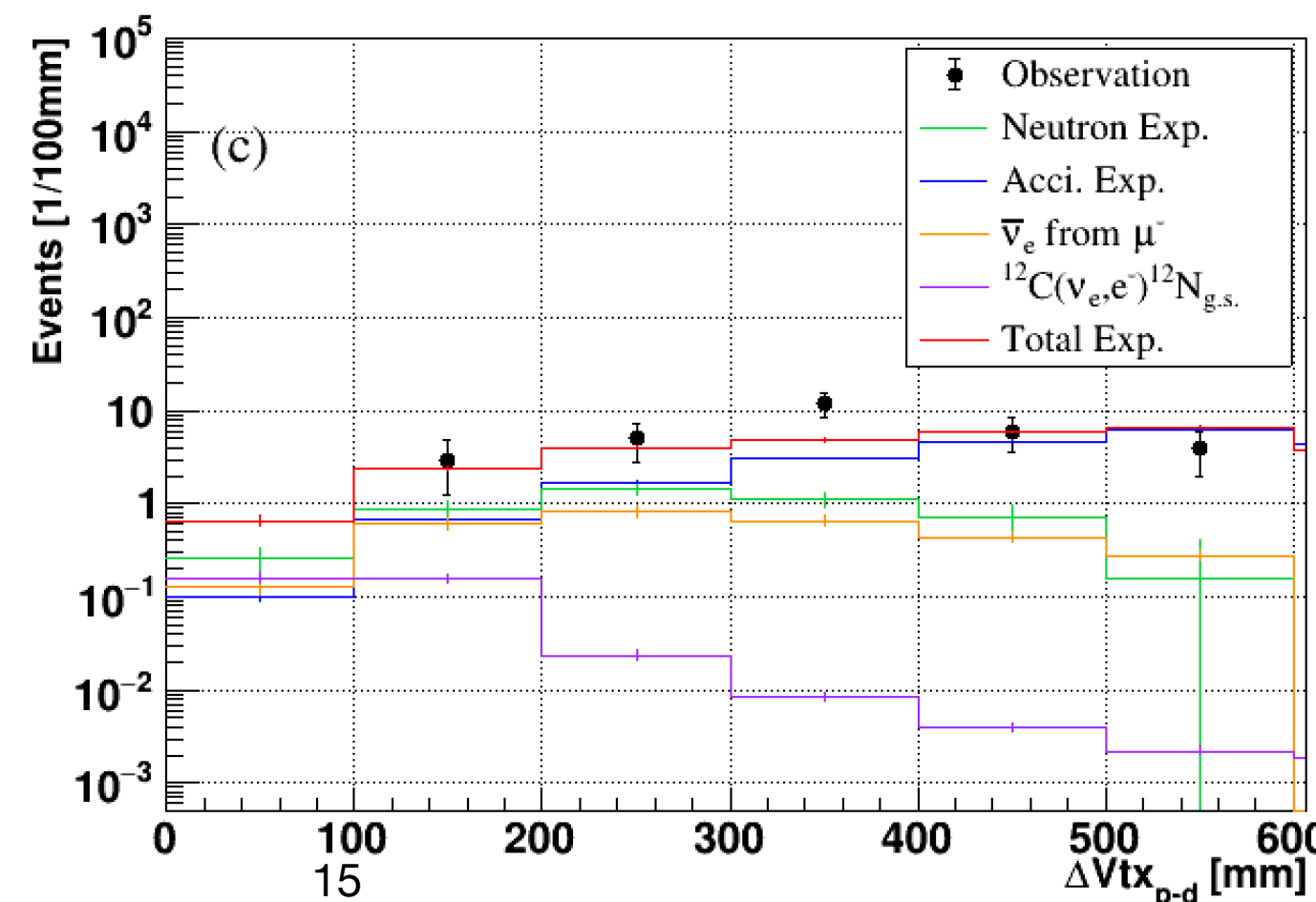
Prompt Timing



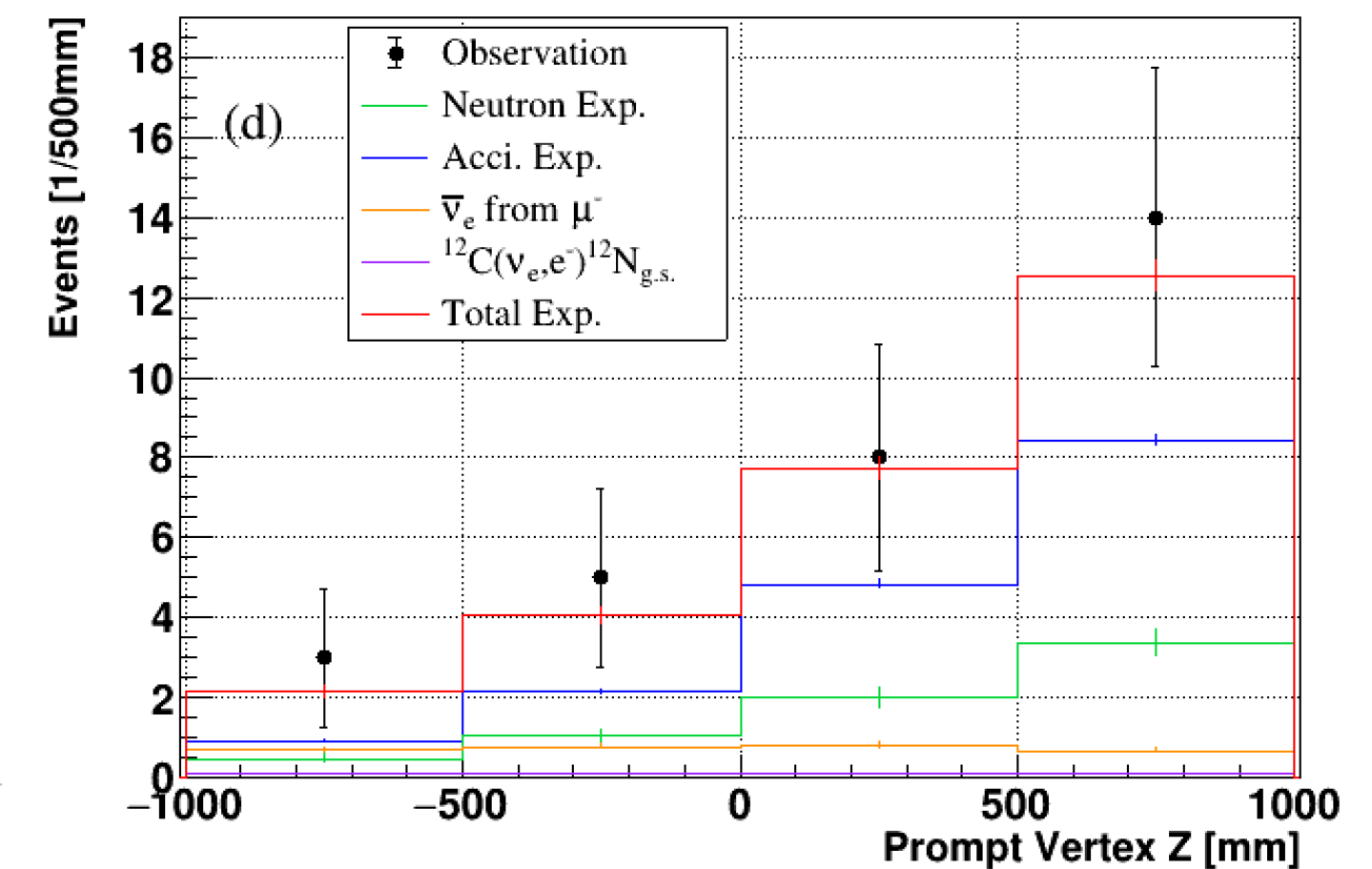
$\Delta T_{\text{p-d}}$



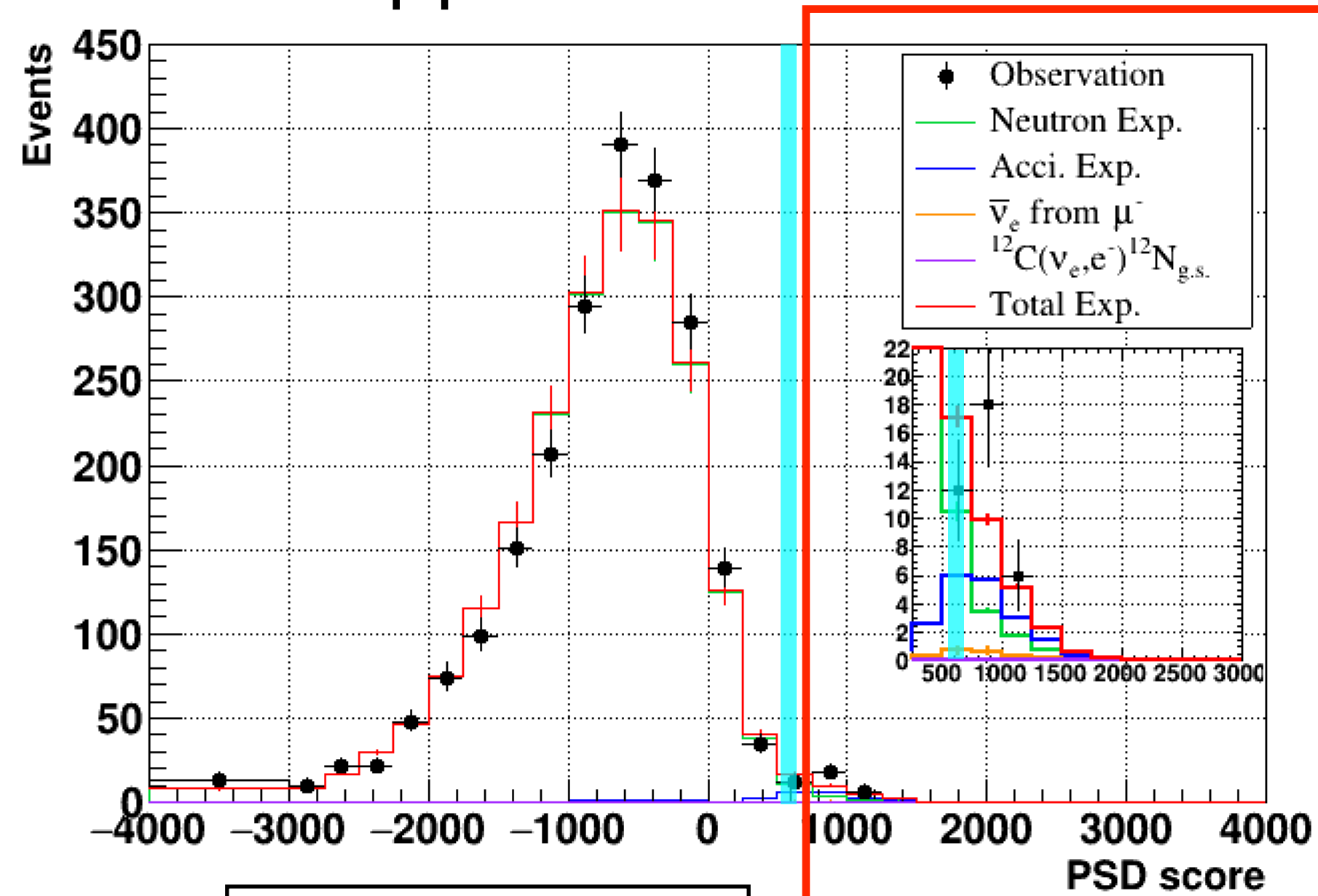
$\Delta VTX_{\text{p-d}}$



Prompt Vertex Z



PSD application



IBD signal 88% eff.
neutron 99.7%
rejection

Selected (e-like)

Unblind Results in signal region (w/ PSD and LLK)

- Observation vs Bkg. Prediction (signal region)

2022 + 2024 Physics run
(1.95×10^{22} POT)

JSNS² Preliminary

(syst. errors only)

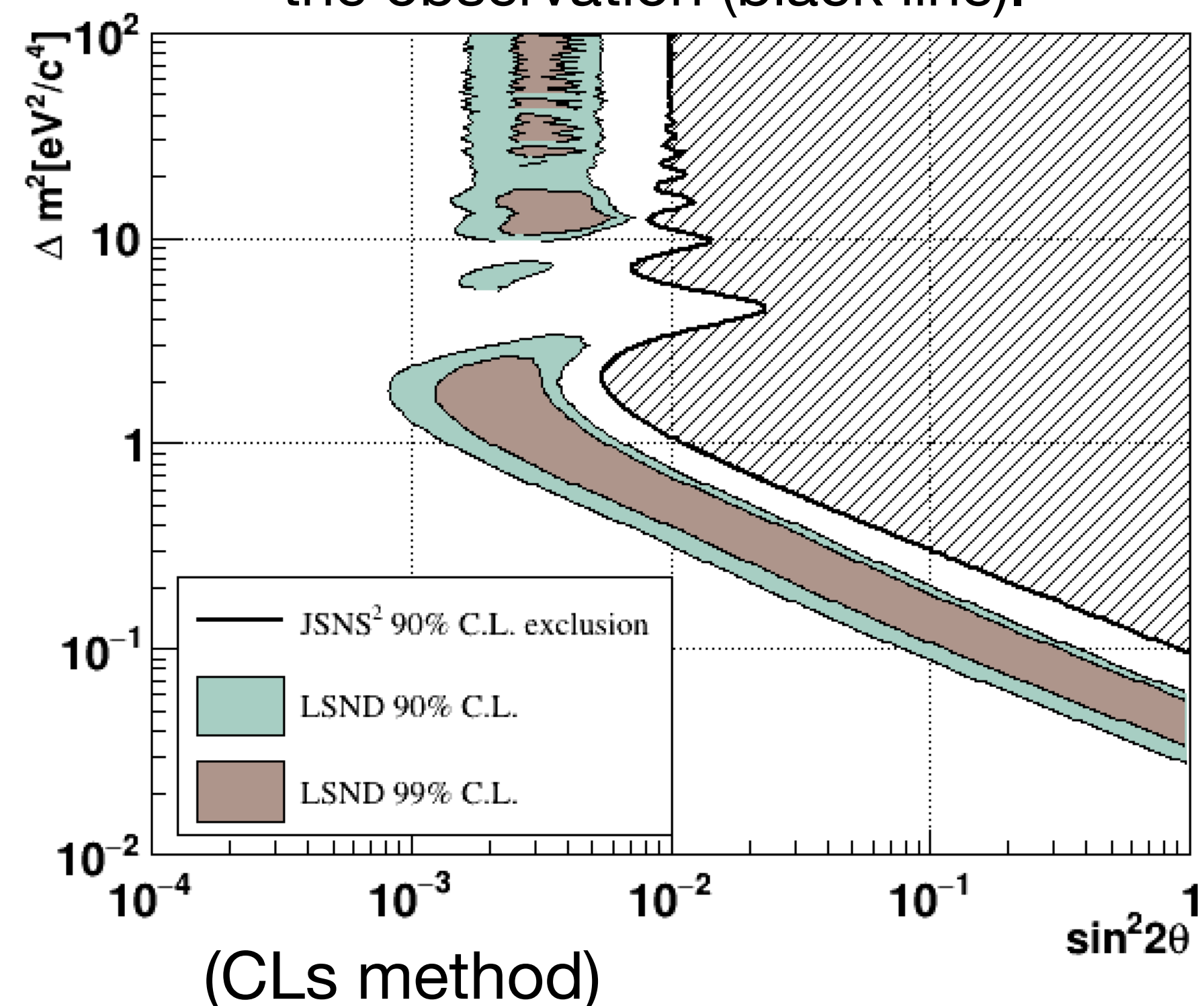
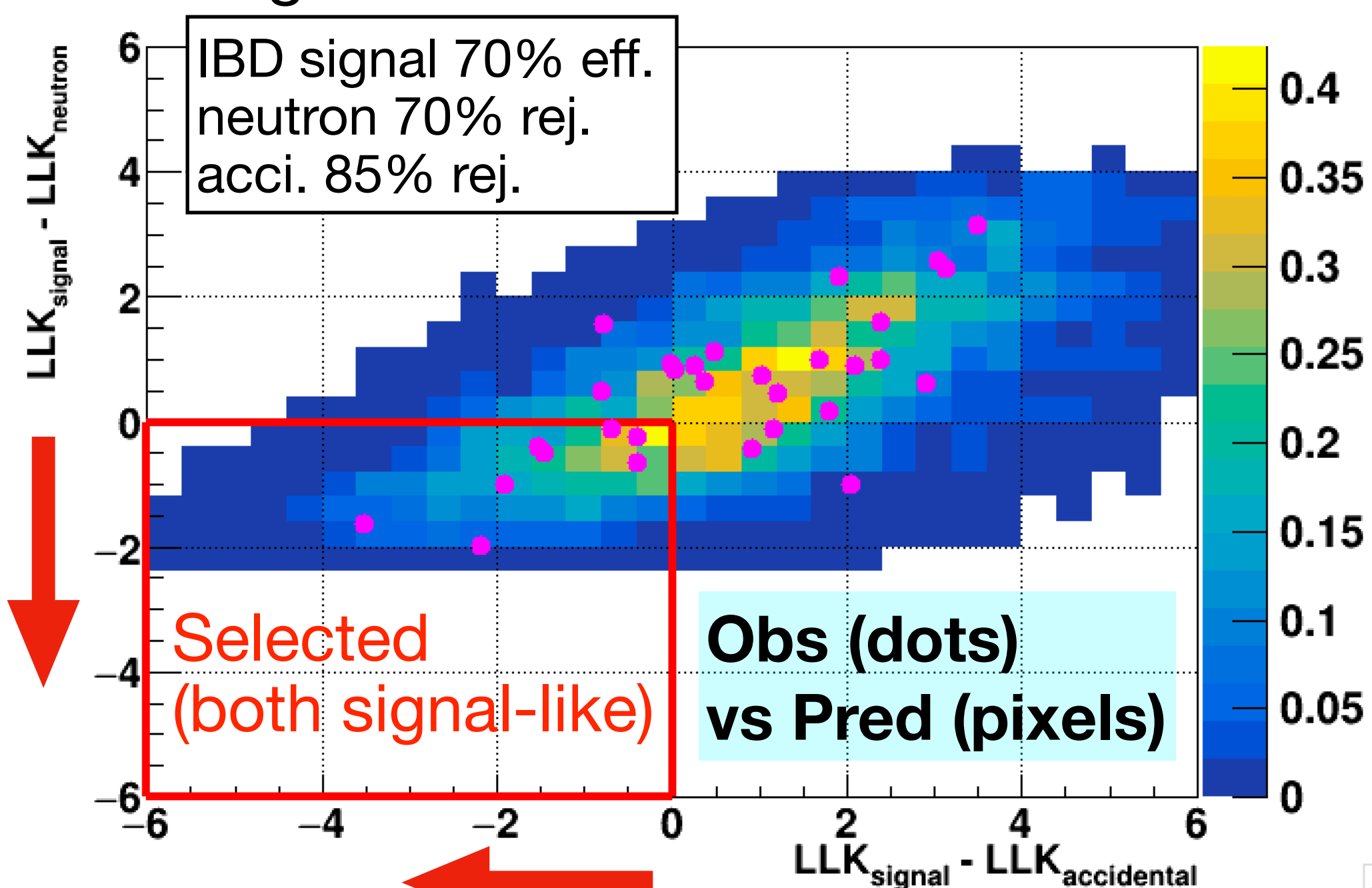
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w/o PSD w/o LLK	2195	2160.3 +- 128.6
w/o PSD w/ LLK	606	626.9 +- 37.0
w/ PSD w/o LLK	30	26.3 +- 1.6
w/ PSD w/ LLK	8	6.1 +- 1.0

Neutron 1.5 ± 0.3
 Acci 2.4 ± 0.01
 CNgs 0.20 ± 0.06
 Intrinsic Bkg ($\bar{\nu}_e$ from μ^-)
 2.0 ± 1.0

$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation contour

90% CL exclusion limit derived from the observation (black line).

2D Log-Likelihood ratio score distribution



Direct comparison with the LSND excess

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

Expected number of events from the LSND anomaly

item	LSND	JSNS ²
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

- Fiducial volume : $R < 140\text{cm}$, $|Z| < 100\text{cm}$

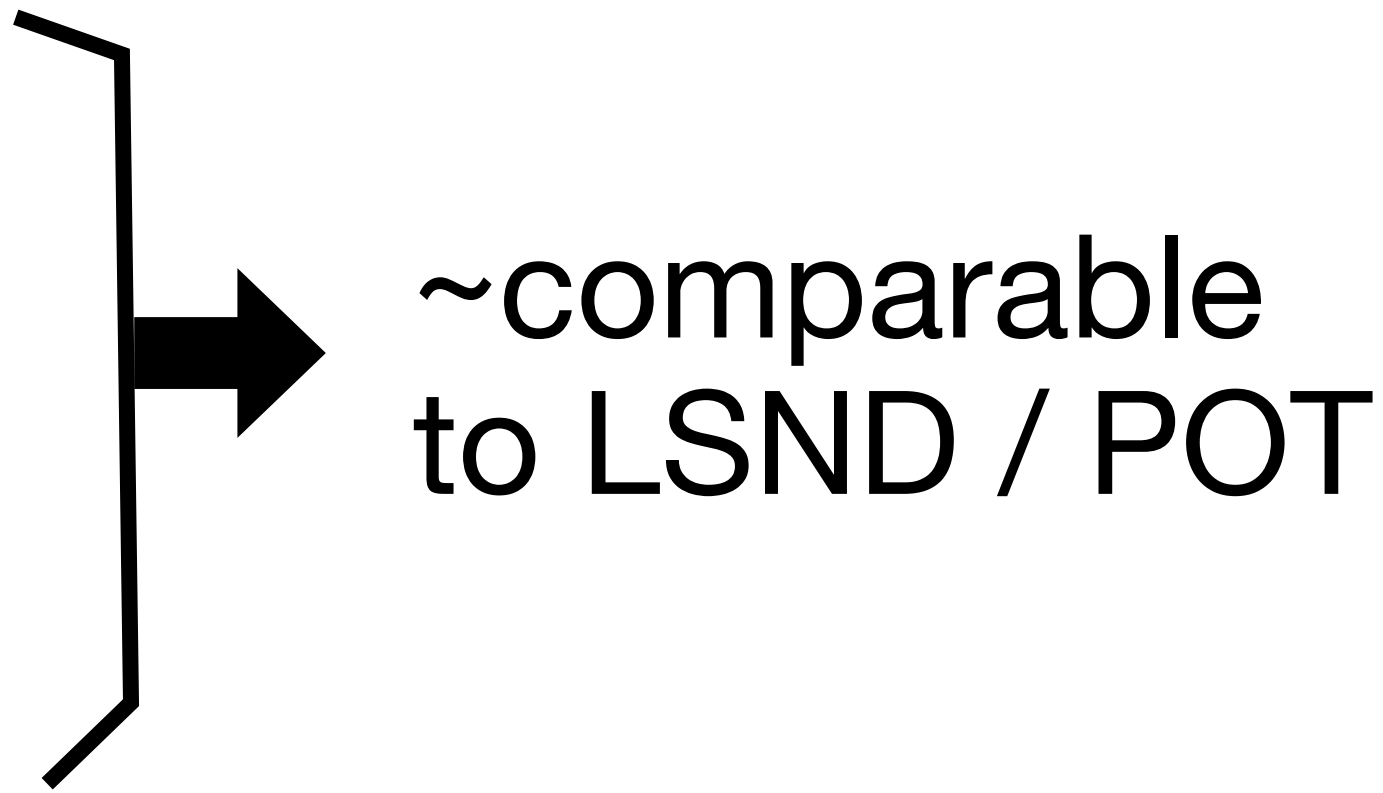
2022 + 2024 Physics run
(1.95×10^{22} POT)

JSNS² Preliminary

	Observed events	Prediction events
Total	8	8.9 +- 1.6
JSNS² Bkg.		6.1 +- 1.0
LSND excess (scaled)		2.8 +- 1.3

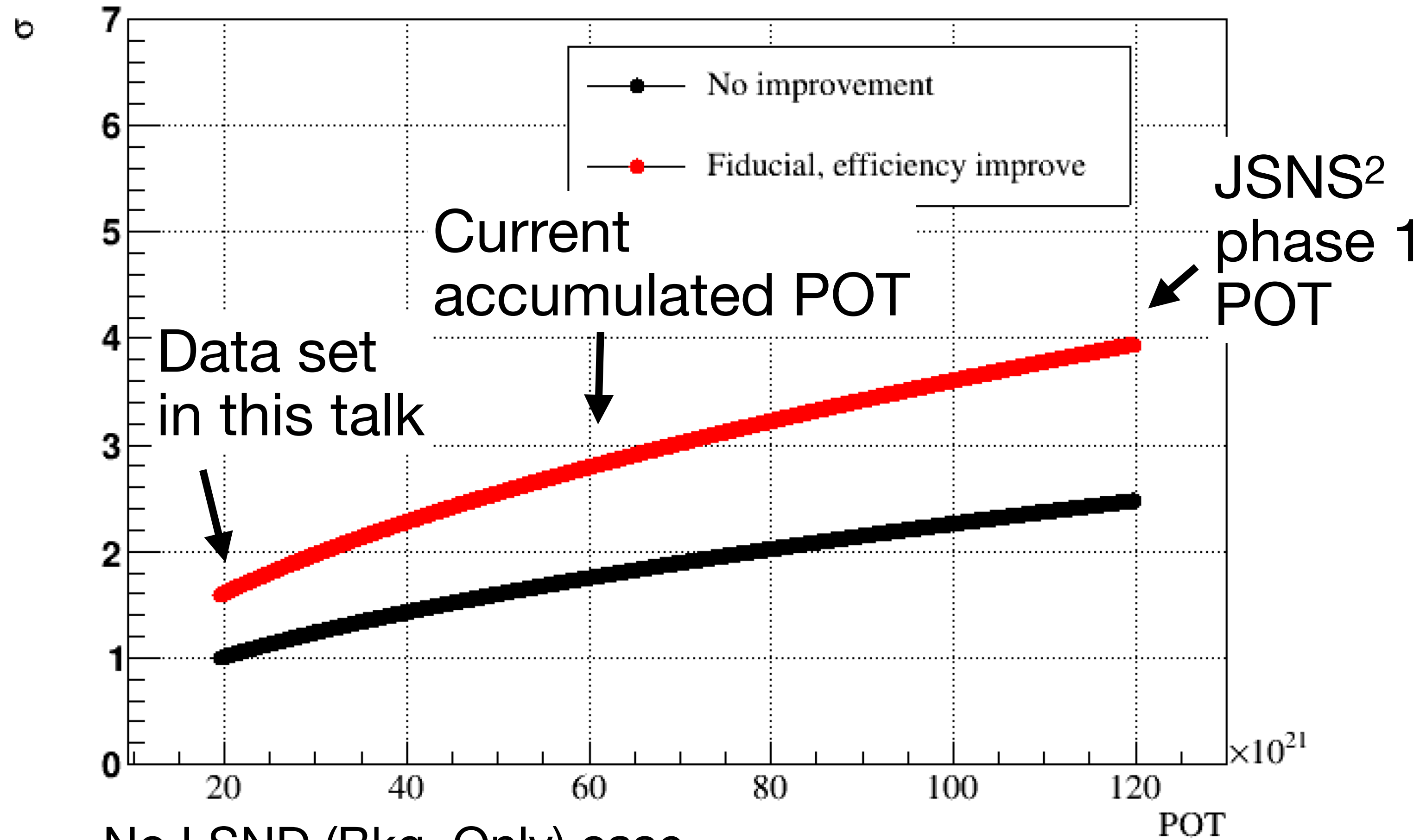
- LSND $\bar{\nu}_e$ excess is normalized to compare with JSNS² data set
- Bkg only expectation (No LSND excess) :
p-value ($N \geq 8 \mid \text{Bkg.} = 6.1$) = 0.27 (0.6σ)
- Bkg + LSND excess expectation :
 $P(N \leq 8 \mid \text{Bkg.} + \text{LSND} = 8.9) = 0.47$ (0.1σ)
- The observation is consistent with both the Bkg.-only and Bkg.+LSND expectations, so far.

Future prospects

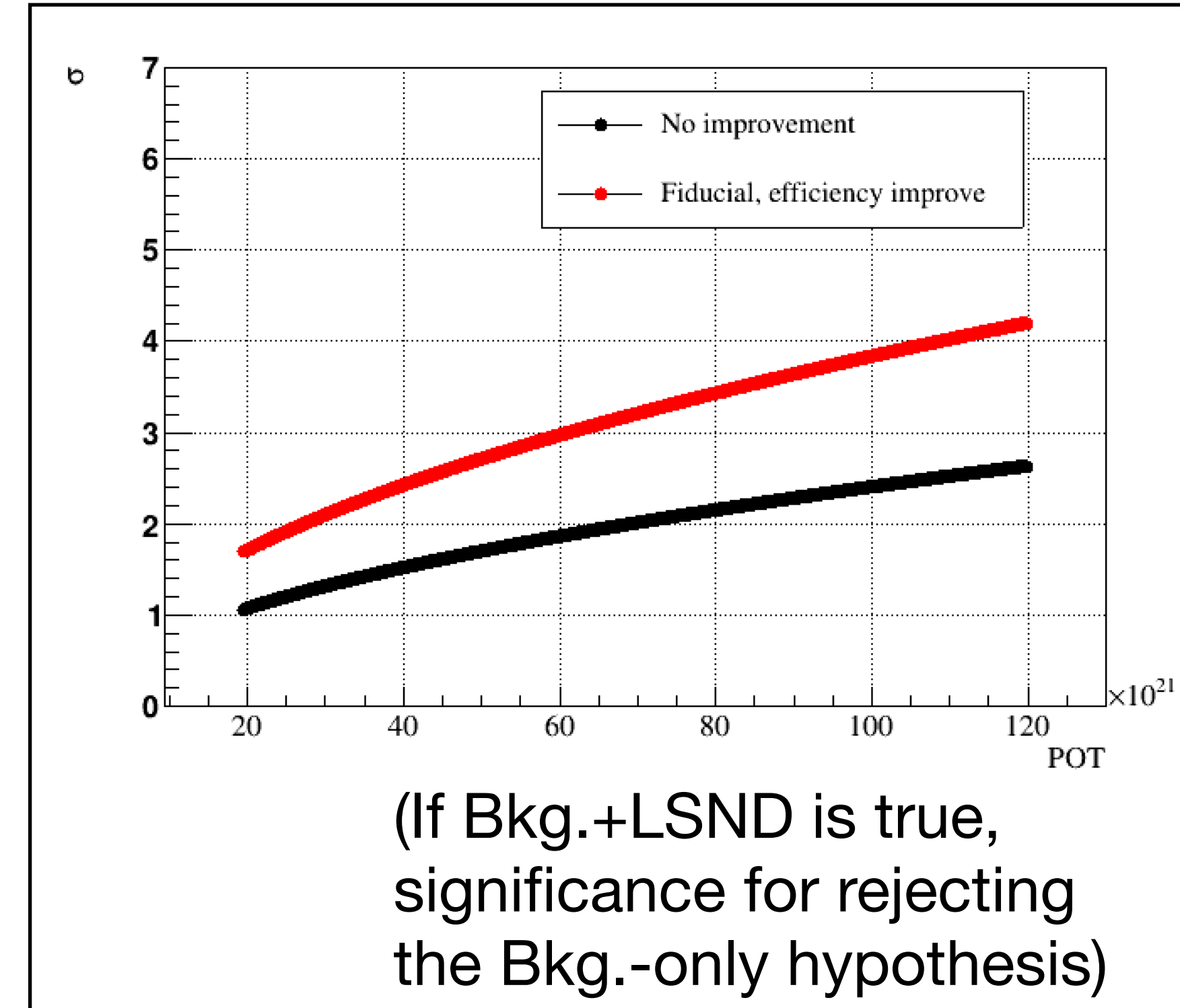
- Compared to LSND, JSNS² : **~10 times larger** #v/proton (3GeV proton beam)
fiducial 10 times smaller / detection efficiency 3 times smaller.
 - Possible Improvements in the future
 - JSNS² **Fiducial volume** : (We didn't use the full volume so far)
=> extend by **1.7 times** maximally w/ further analysis
 - **Detection efficiency** : a few **10%** improve
=> Trigger improvements : ~20% increment (already achieved in 2024)
=> Bkg. Reduction loosened cuts : ~10% w/ further analysis
 - Already accumulated **~3 times** more data than the current 2022+2024.
Also, **JSNS² phase 1** => **~6 times** of the current 2022+2024.
 - A new far detector
 - => Model-independent test of the LSND excess. (LSND signal uncertainty reduction)
 - => Different baseline (Near 24m & Far 48m) : Higher sensitivity at low Δm^2 region. (oscillation hypothesis)
 - => Reduction of common systematic uncertainties,
cosmogenic (veto layer) & beam-related (1/4 times) Bkgs.
- 
- ~comparable
to LSND / POT

Future prospects

- POT accumulation up-to full JSNS² phase 1 POT ($\sim 1.2 \times 10^{23}$ POT)
 => Prospects of Asimov significance (Poisson stat. hypothesis test)



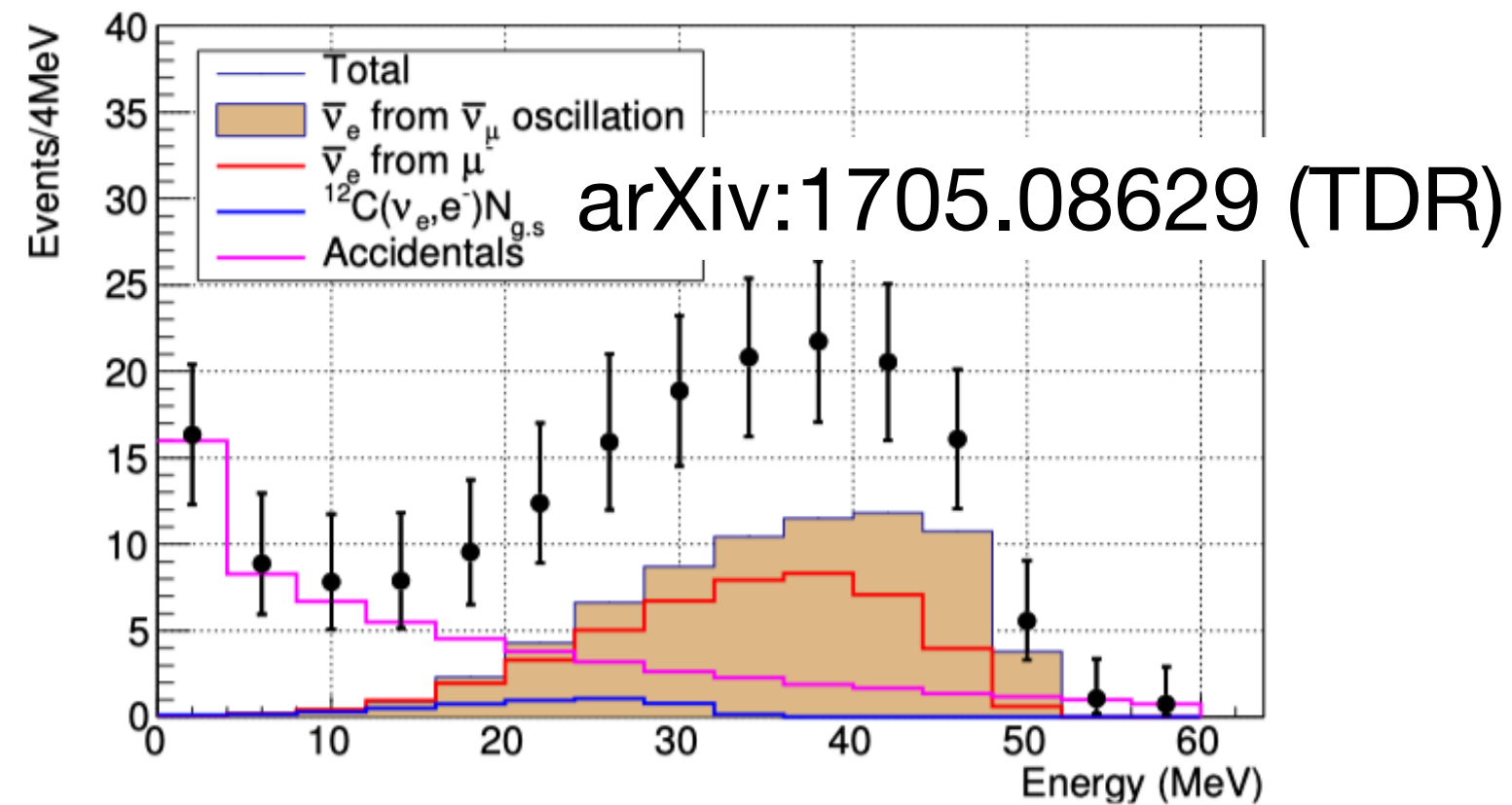
No LSND (Bkg. Only) case,
 => significance for rejecting the Bkg.+LSND hypothesis



(Mean value only)

Future prospects

- Also ...



[Spectral fit] w/ further statistics, prompt energy fitting (oscillation hypothesis) for IBD signal vs Backgrounds

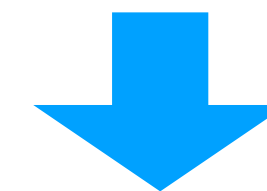
Our own efforts

[Machine-learning-based analysis]

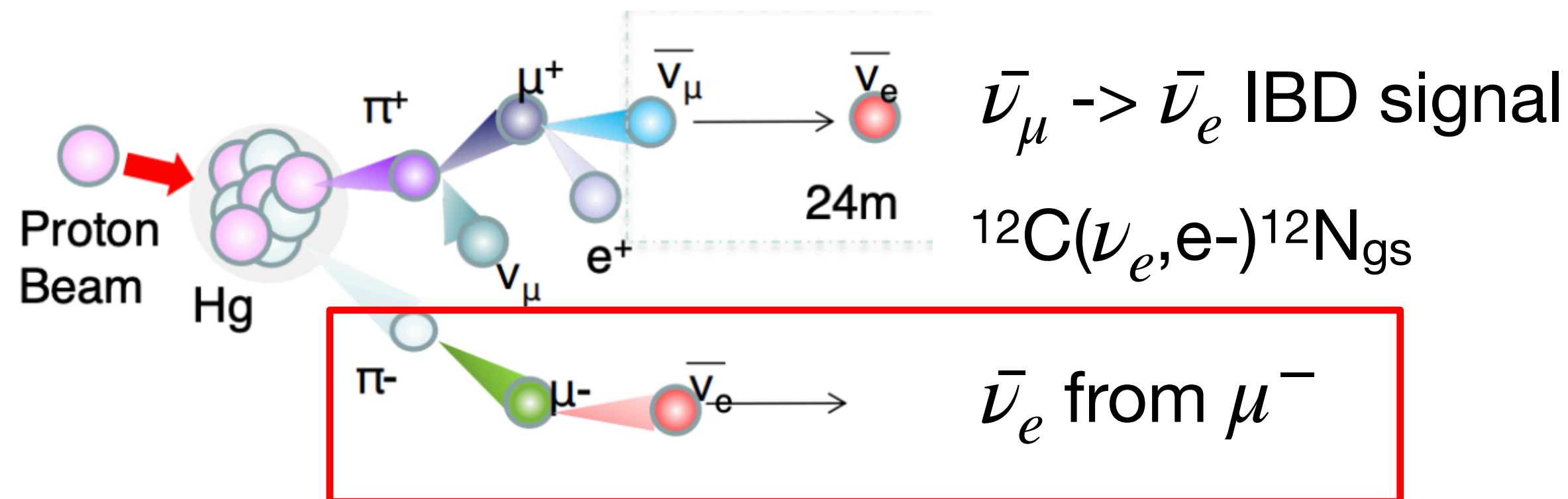
Detector observables (PSD, Bkg rejection Likelihood)



Machine-learning (Boosted Decision Trees (BDT) / Convolutional Neural Networks (CNN) ...)



Improved sensitivity



[Flux uncertainty reduction]

Insufficient information of the $p + \text{Hg} \rightarrow \pi^-$

=> **large uncertainty (~50%)** for Intrinsic Bkg. $\bar{\nu}_e$ from μ^- at current.

=> Other ex-situ measurements for the rates of $p + \text{Hg} \rightarrow \pi^-$
=> uncertainty reduce to **~10%**.

External meas.

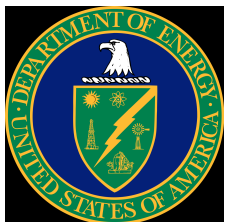
Summary

- 2022 + 2024 Physics run (1.95×10^{22} POT) results are shown.
- Energy side-bands for validation of backgrounds were performed carefully.
- In signal region,
 - => PSD : 90% IBD signal efficiency & > 99.5% Neutron rejection.
 - => LLK : 70% IBD signal efficiency & 70% Neutron rejection & 85% Accidental rejection.
- Direct comparison with LSND excess.
 - => Observation : 8 events
 - => Bkg. Only : 6.1 ± 1.0 , Bkg+LSND : 8.9 ± 1.6
- Future prospects
 - => 3 times more data are accumulated and under-study now.
 - => 6 times more data (JSNS² phase 1) is expected.
 - => Fiducial extension (~1.7times), Efficiency improve (~1.5times).
 - => Model-independent test of the LSND excess.
 - => Spectral fit / Machine-learning / (π^- production rate) Flux uncertainty reduction.
 - => Far detector is under commissioning phase and will be used for analysis.

Thank you for your attention



- Acknowledgements
 - MEXT, JSPS (Japan)
 - Korea Ministry of Science, NRF (Korea)
 - DOE, Heising-Simons Foundation (US)
 - Royal Society (UK)



- Also, JSNS² / JSNS²-II deeply appreciate
 - Donation of Gd-LS / LS from Daya-Bay
 - Donation of PMTs / LS from RENO
 - Donation of PMTs / electronics from Double-Chooz

- Posters

- First results for the $\bar{\nu}_e$ excess in the JSNS² experiment (Dongha Lee) : 133
- Energy Calibration of the JSNS² Detector Using Neutron Capture on Gadolinium (Wonsang Hwang) : 143
- Latest Status of the JSNS²-II Far Detector (Jisu Park) : 168
- Commissioning of the JSNS²-II far detector (Jiwon Ryu) : 219

BACKUP

Latest status of Far Detector ; commissioning now

Construction is completed,
and now in Commission Phase !!

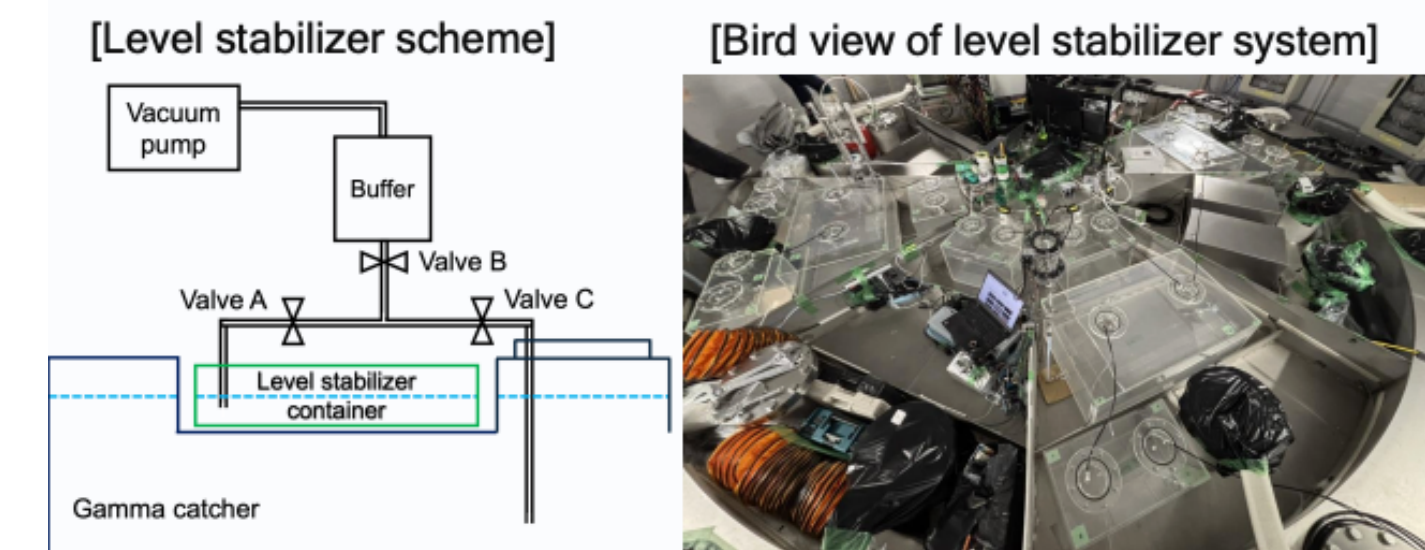
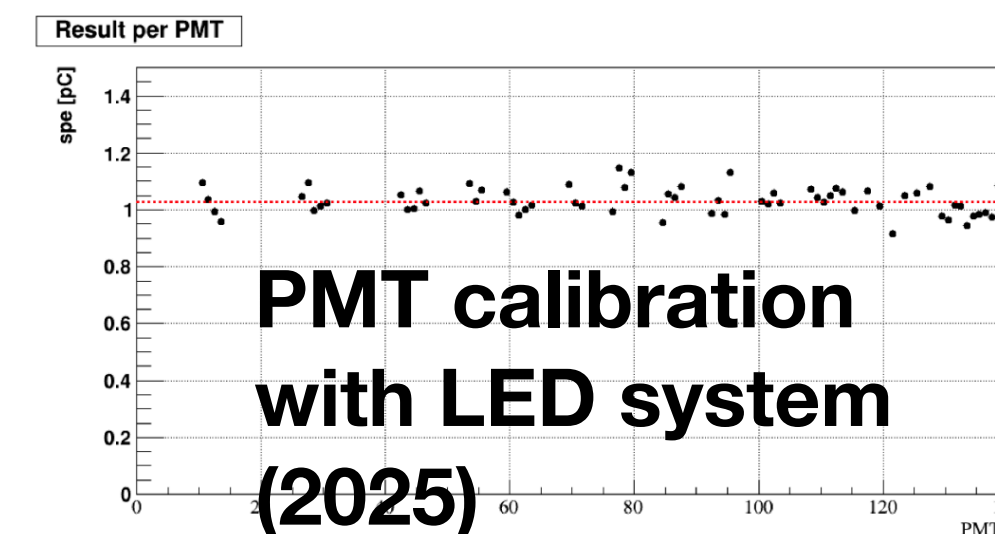
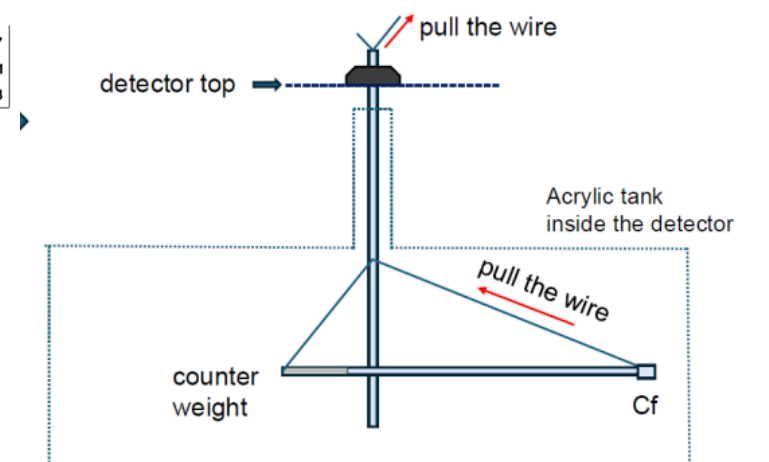
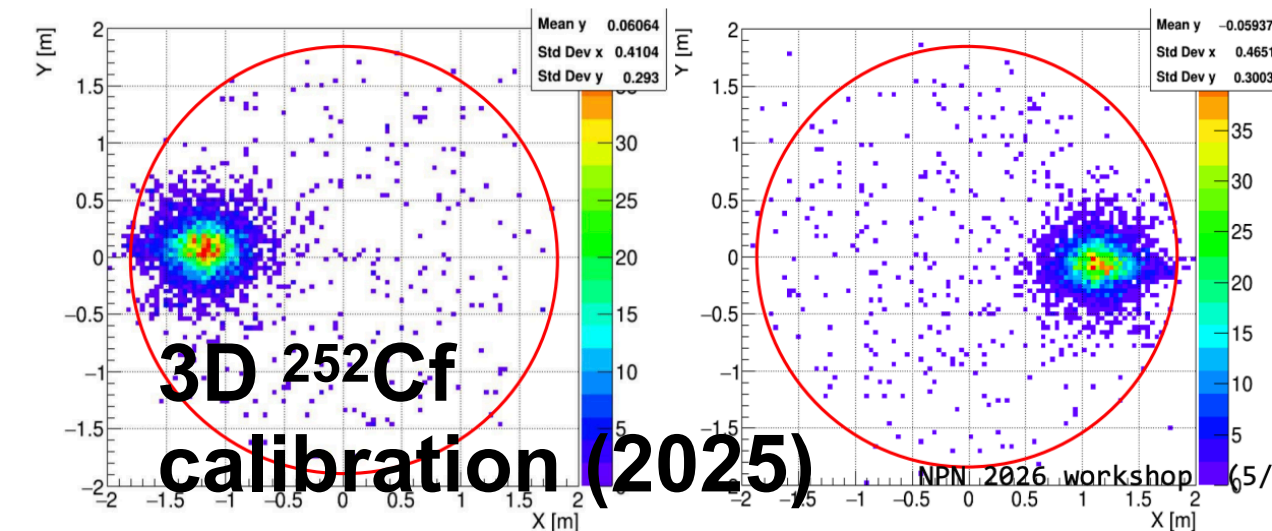
- Tank construction (2021-2022)
- PMT/acrylic target vessel (2023-2024)
- LS filling (Aug. 2024) JINST 18 T12001 (2023)

- DAQ/trigger development (2025-)
- => POT accumulation (Nov. 2025-)

- 3D ^{252}Cf calibration (2025)
- => $(x,y,z) = (R=60, 120\text{cm}, Z=0)$
- => first results look good.

- PMT calibration for the JSNS²-II far detector with an embedded LED system JINST 20 T10003 (2025)

- Level stabilizer system (2026-)



Level stabilizer system (2026-)

Unblind Results in signal region (w/ PSD)

2022 + 2024 Physics run
(1.95×10^{22} POT)

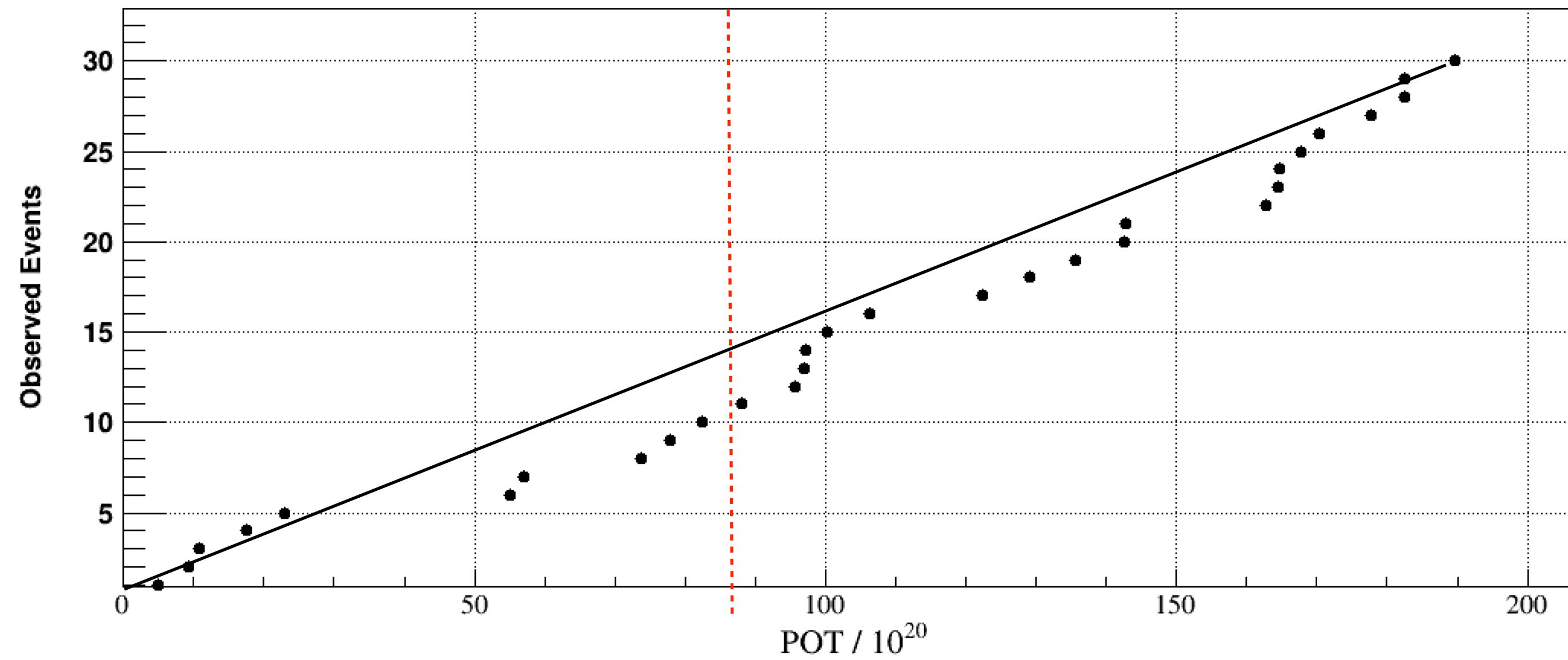
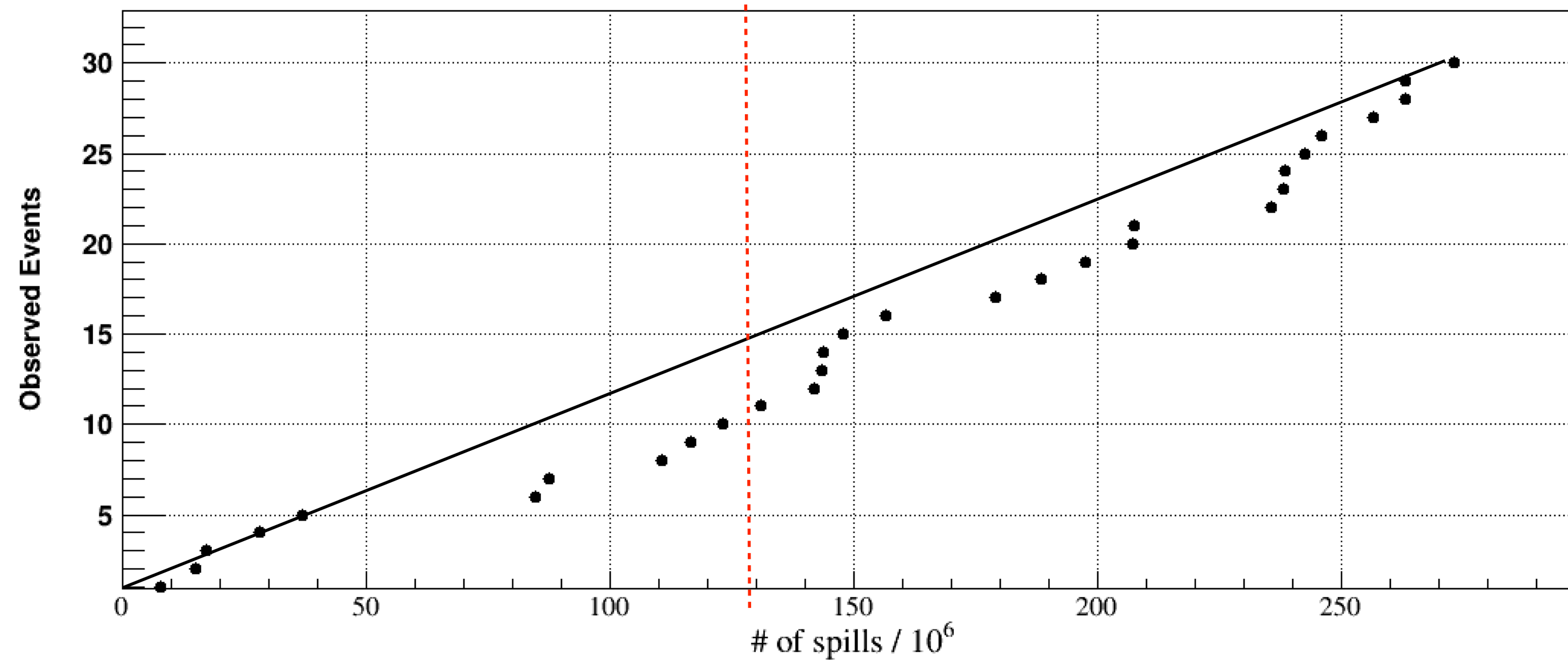
JSNS² Preliminary

- Observation vs Bkg. Prediction (signal region)

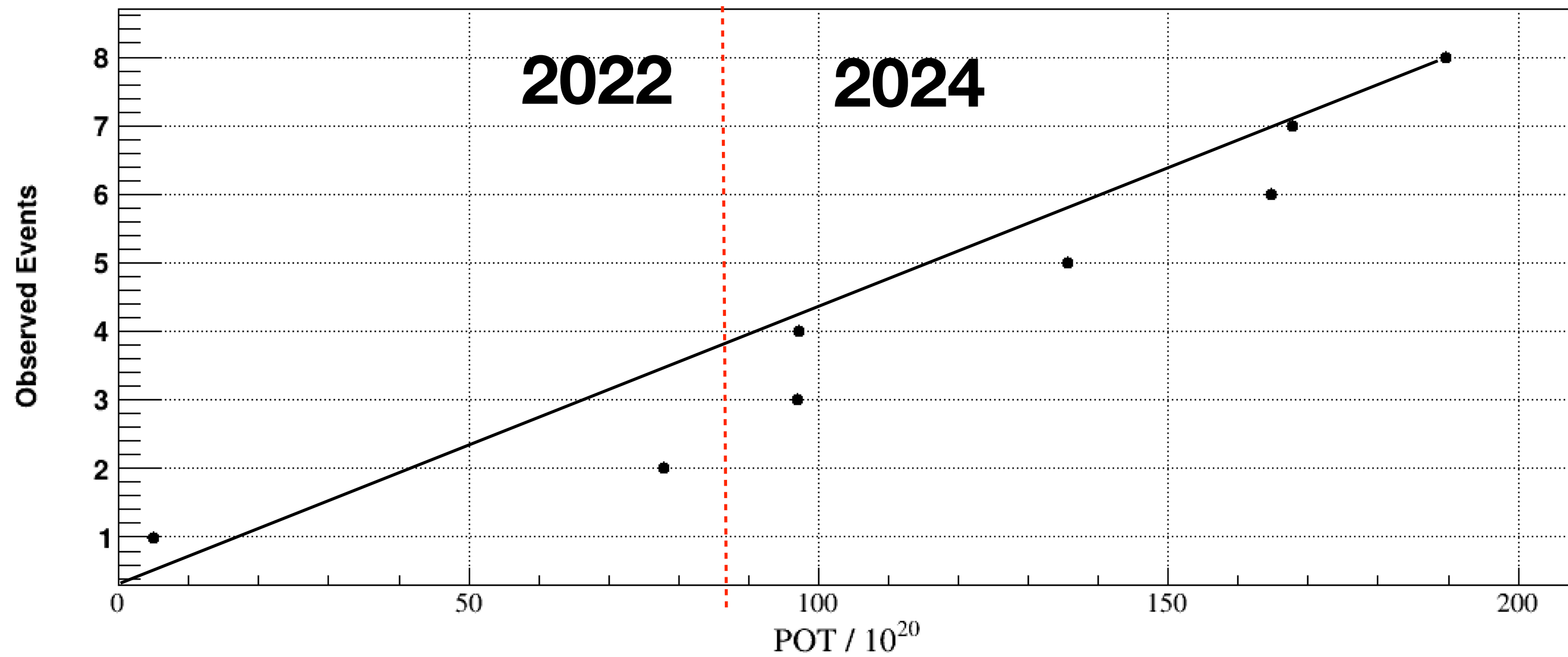
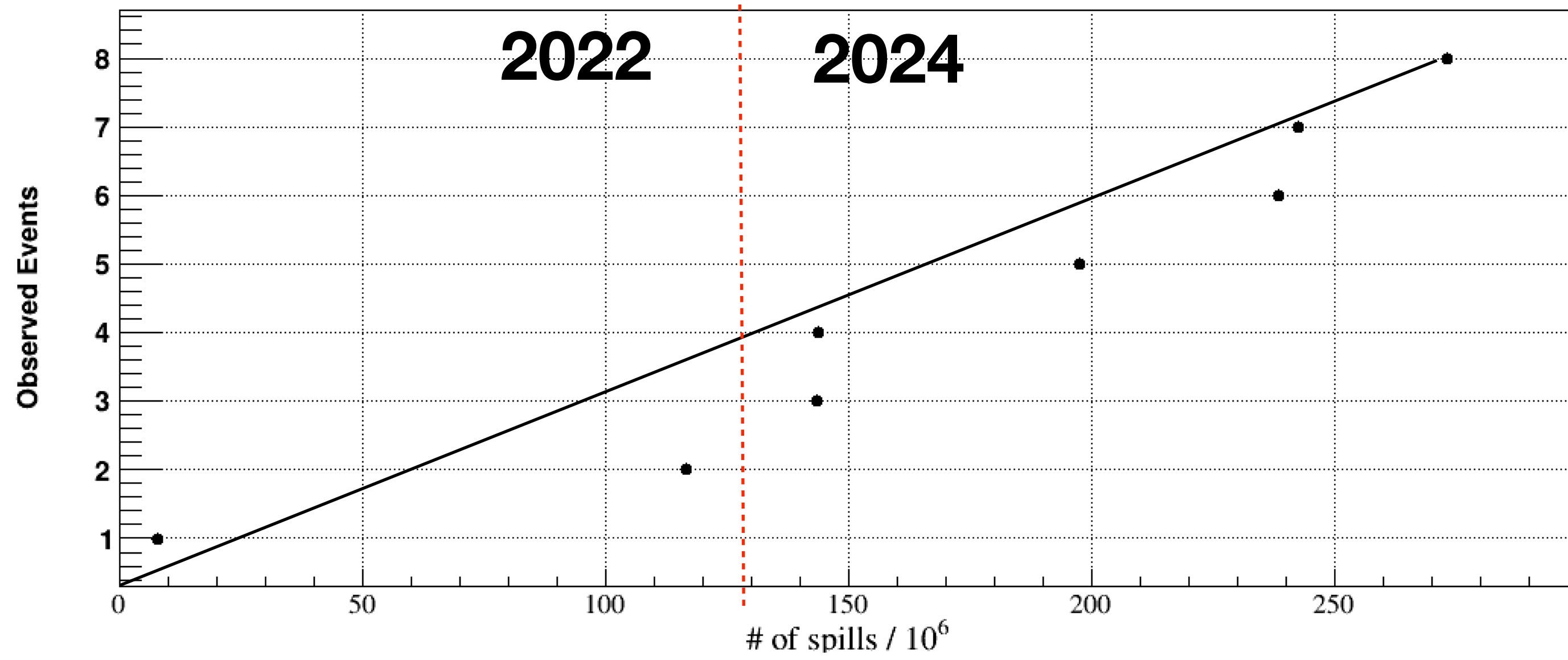
cases	Observation	Prediction
w/o PSD w/o LLK	2195	2160.3 +- 128.6
w/o PSD w/ LLK	606	626.9 +- 37.0
w/ PSD w/o LLK	30	26.3 +- 1.6
w/ PSD w/ LLK		

Neutron 6.7 ± 0.6
Acci 16.4 ± 0.1
CNgs 0.35 ± 0.07
Intrinsic Bkg ($\bar{\nu}_e$ from μ^-)
 2.8 ± 1.5

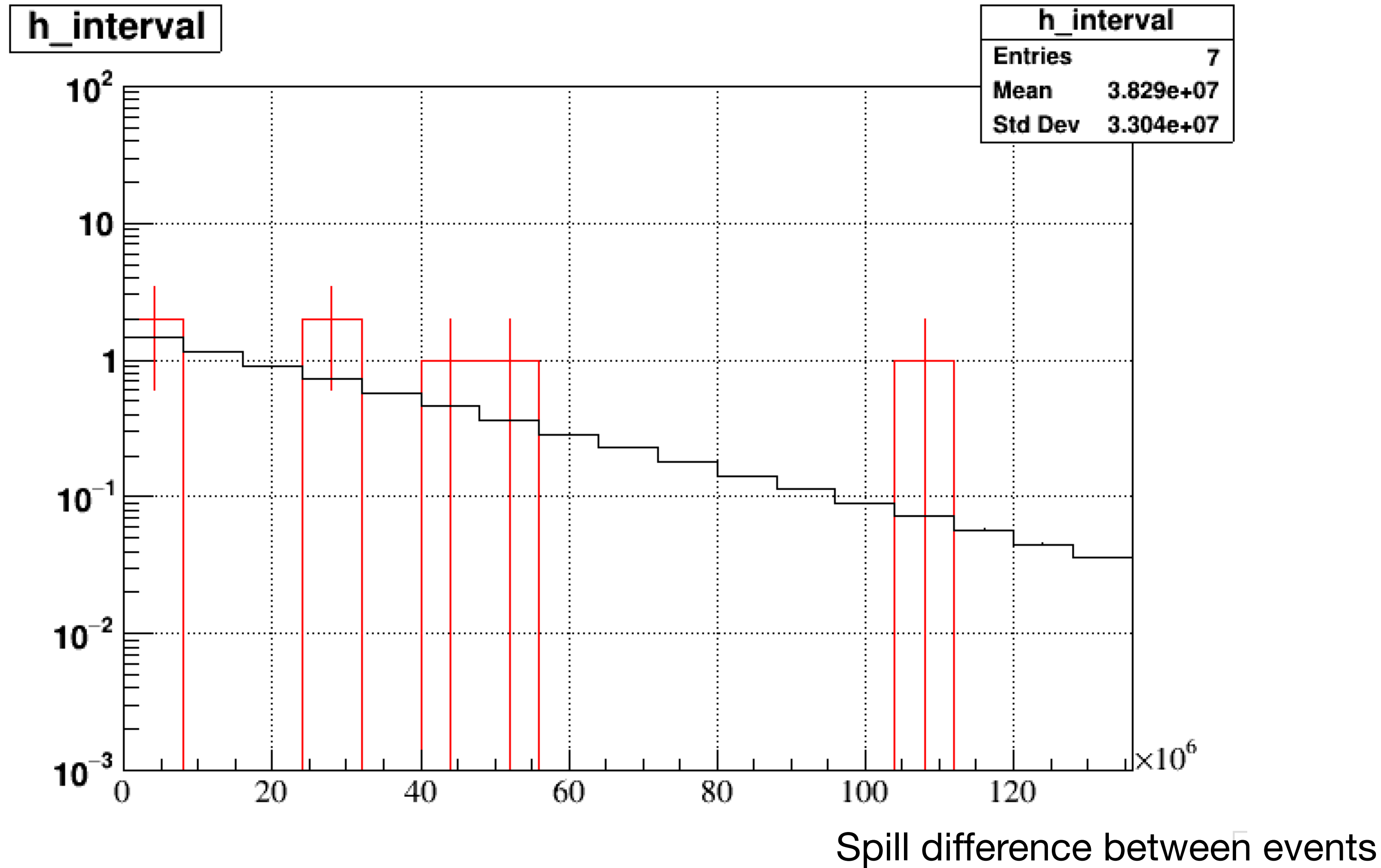
2022+2024 Physics run Observation events (in signal region, after PSD) as the function of # of accumulated spills / accumulated POT



2022+2024 Physics run Observation events (in signal region, after PSD+LLK) as the function of # of accumulated spills / accumulated POT



Spill difference between the events



Toy MC

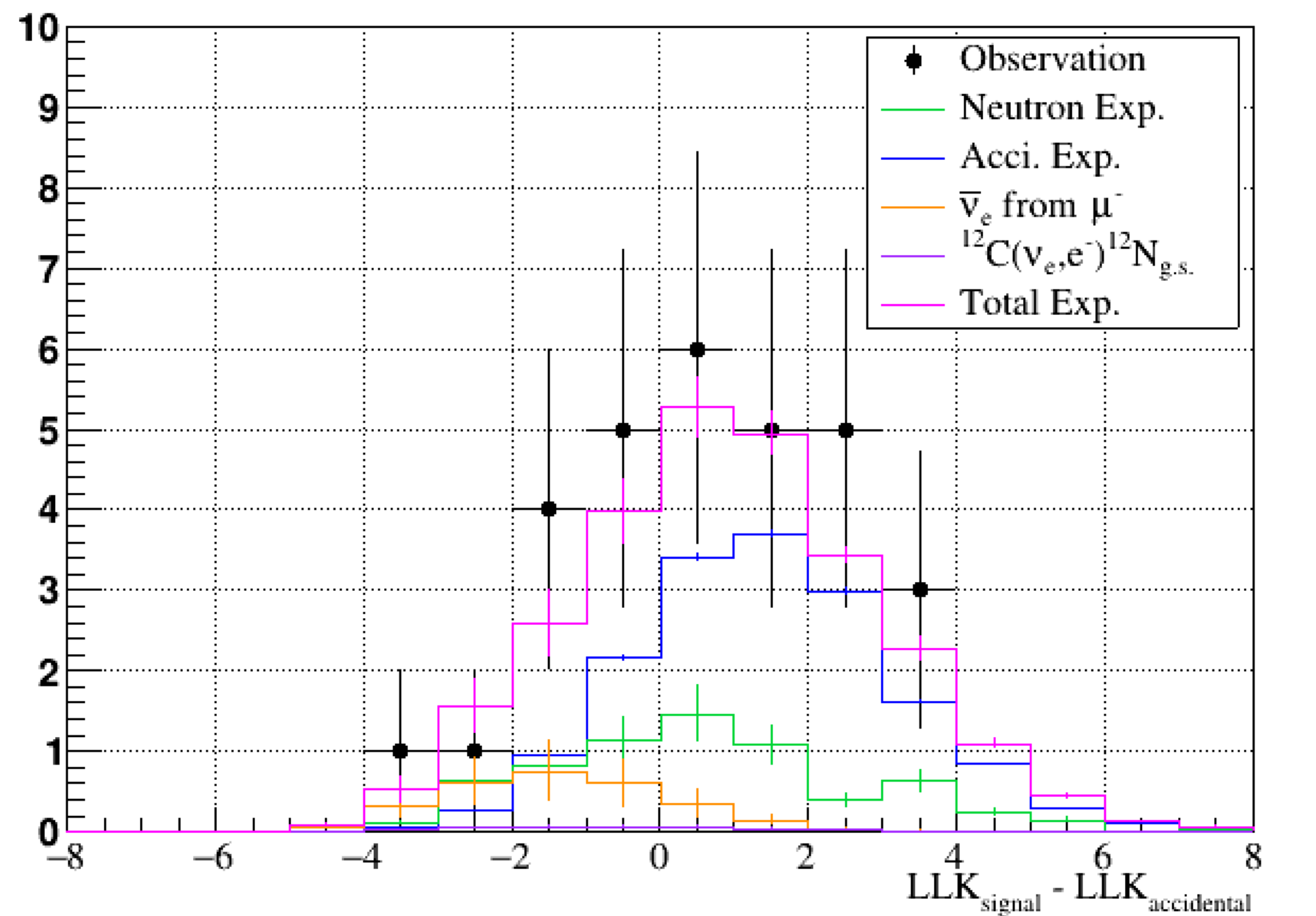
(Average event rate =
1 event per 3.46×10^7 spills)
(2022+2024 2.77×10^8 spills
/ 8events)

2022+2024 physics run
Observed data 8 events'
intervals

(1D) Likelihood score comparison for obs vs exp ; **Signal region**

	Observed events	Expectation events
Total	30	26.3 +- 1.6
nue bar from mu-		2.9 +- 1.5
CNGs		0.35 +- 0.07
Neutrons		6.67 +- 0.6
Accidental		16.4 +- 0.1

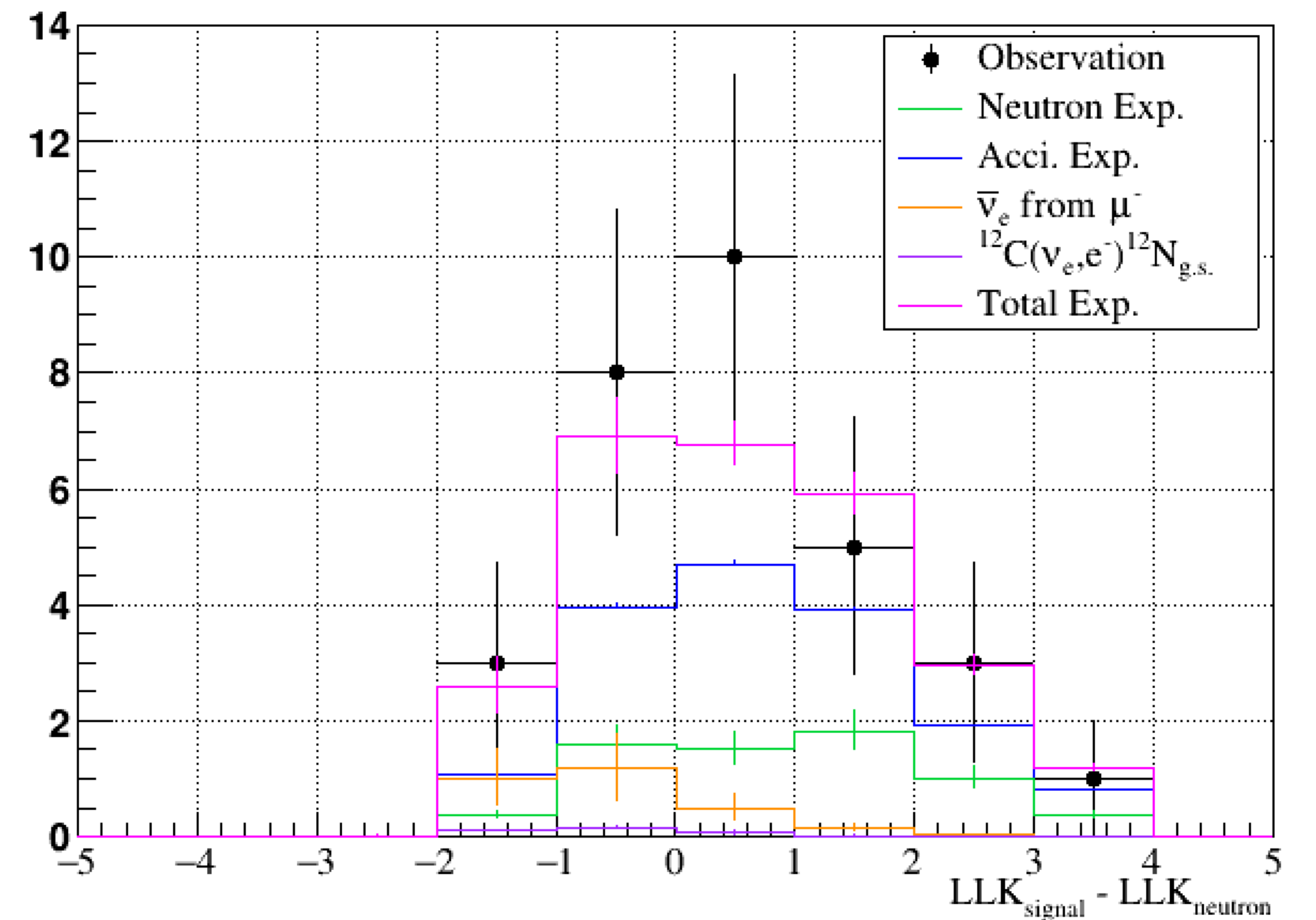
**2022+2024
Physics run
After PSD**



signal-like

acci-like

X-axis projection



signal-like

n-like

Y-axis projection

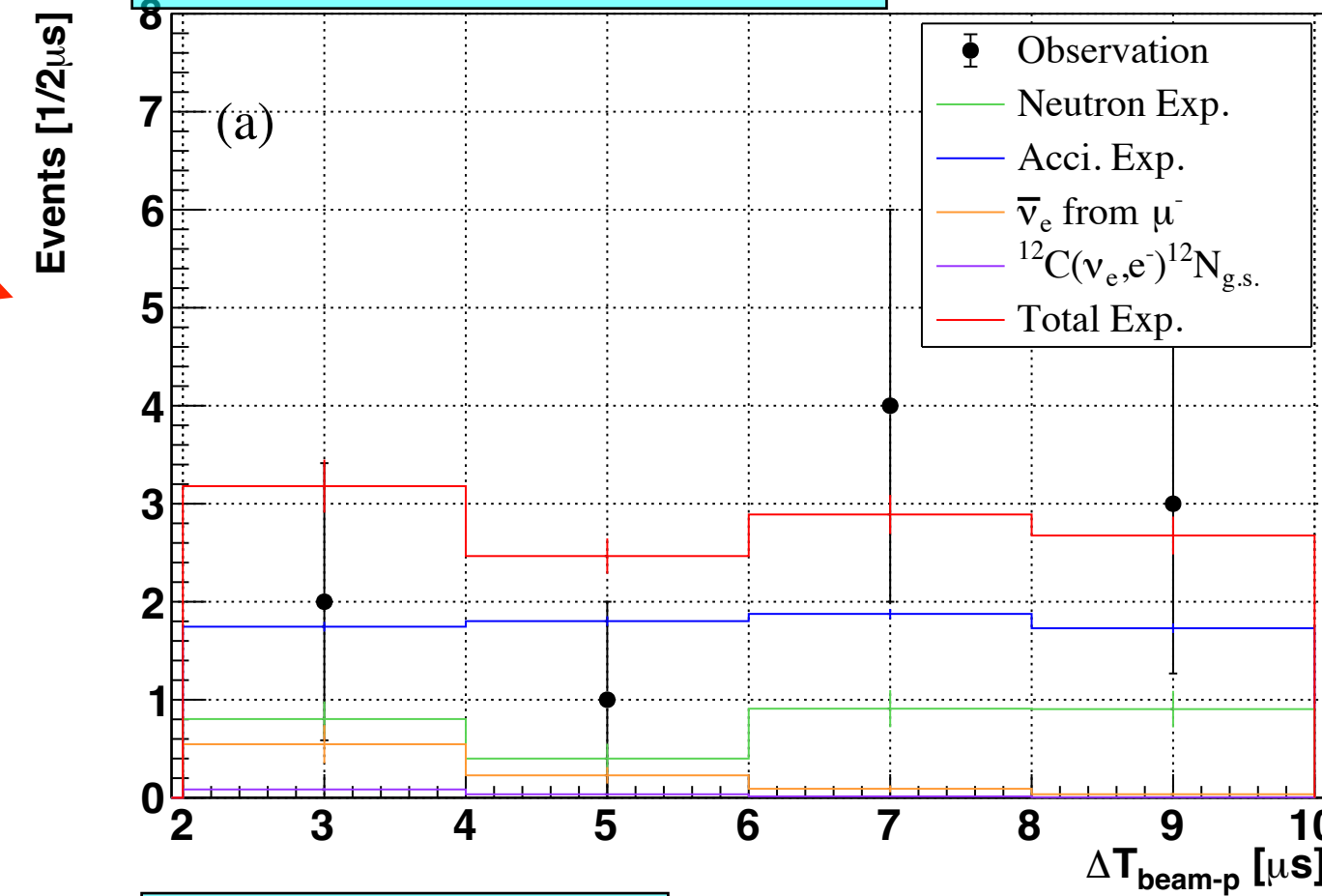
Unblind Results in signal region (w/ PSD)

2022 Physics run
(0.82×10^{22} POT)

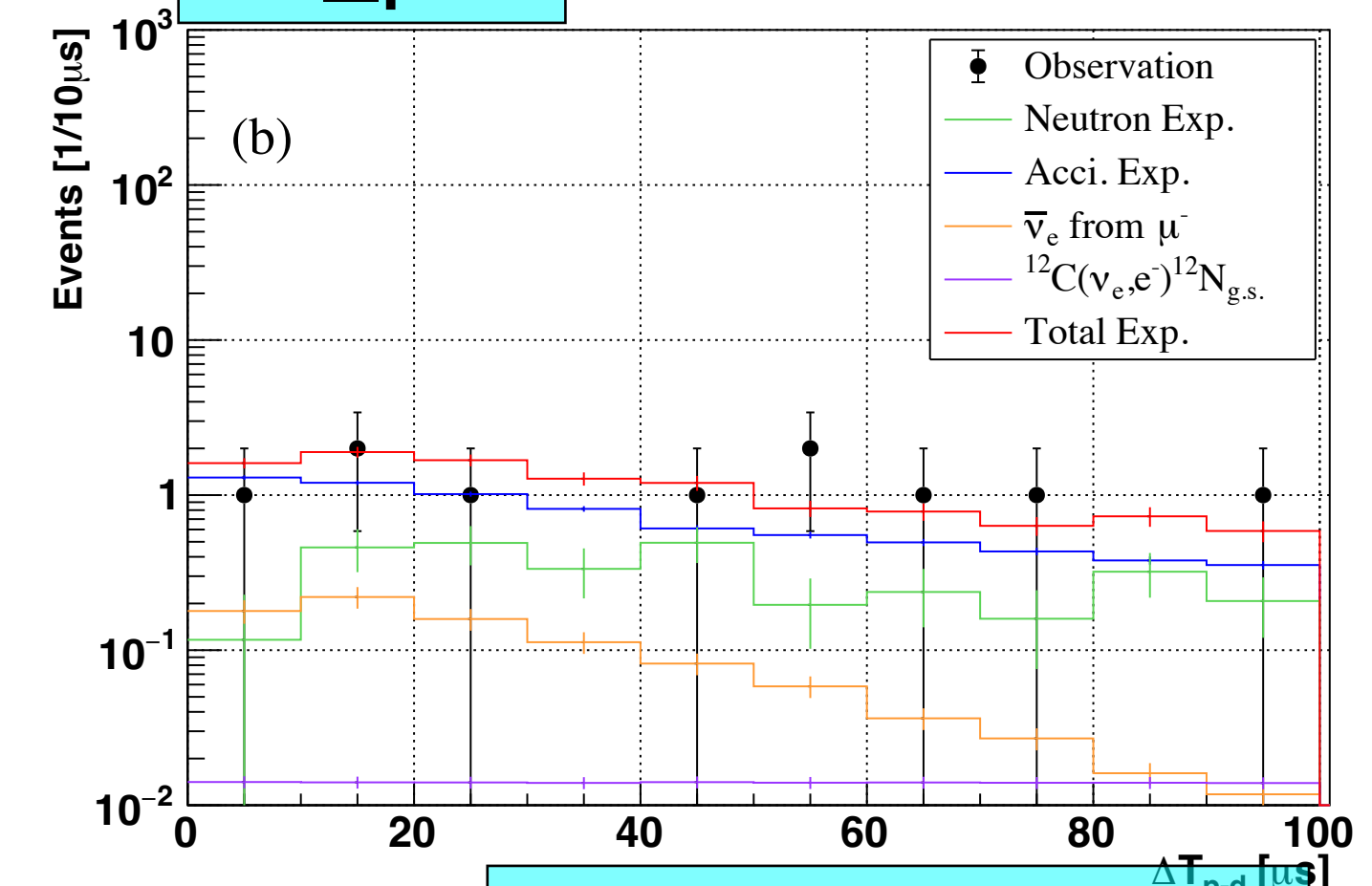
- Observation vs prediction (Bkg.) (signal region)
- > Good consistency for all cases

cases		observation	prediction
w/o PSD	w/o LLK	1079	1063.0 ± 25.7
w/o PSD	w/ LLK	304	315.8 ± 8.0
w/ PSD	w/o LLK	10	11.2 ± 0.7
w/ PSD	w/ LLK	2	2.3 ± 0.4

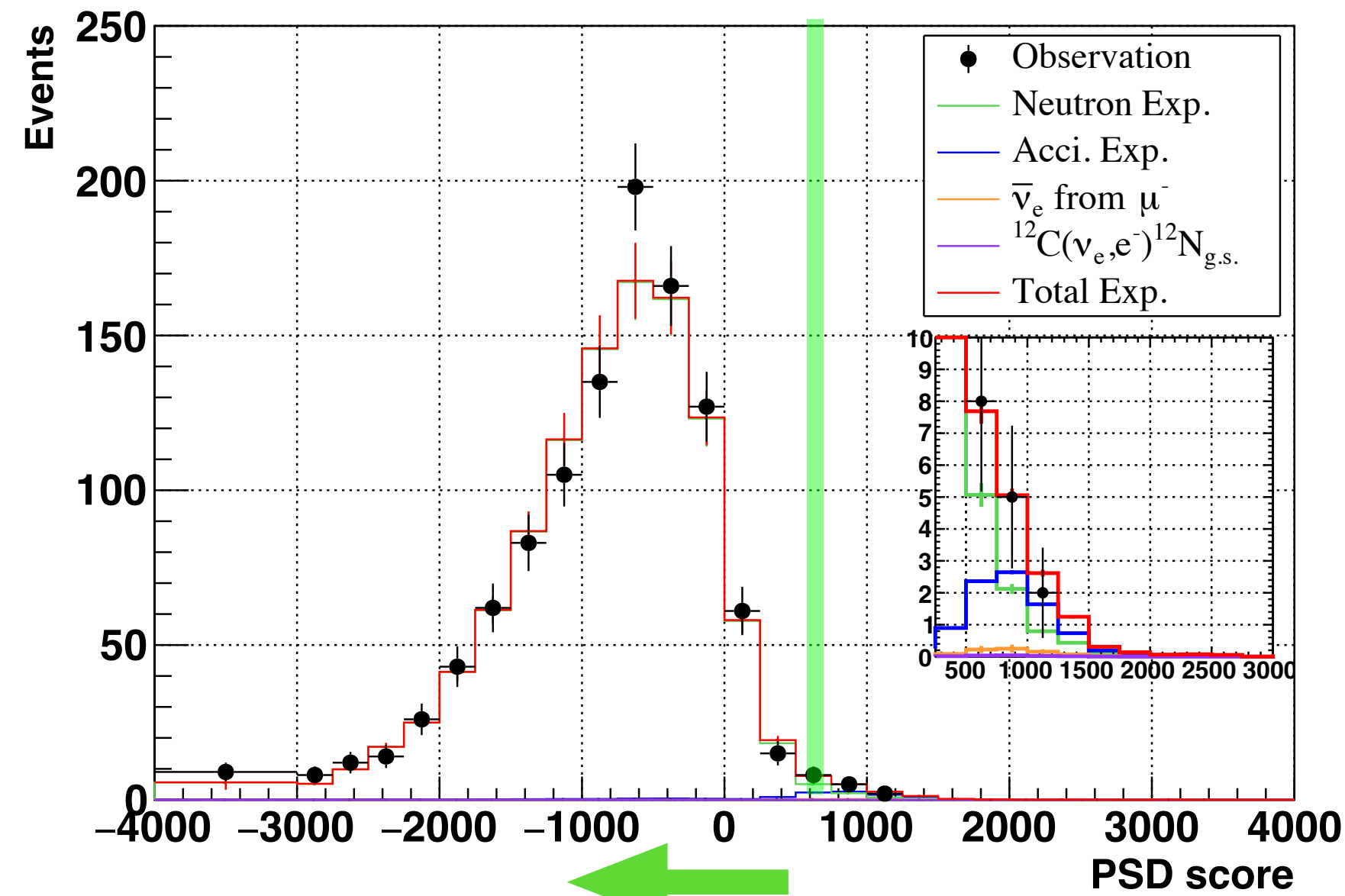
Prompt Timing



ΔT_{p-d}

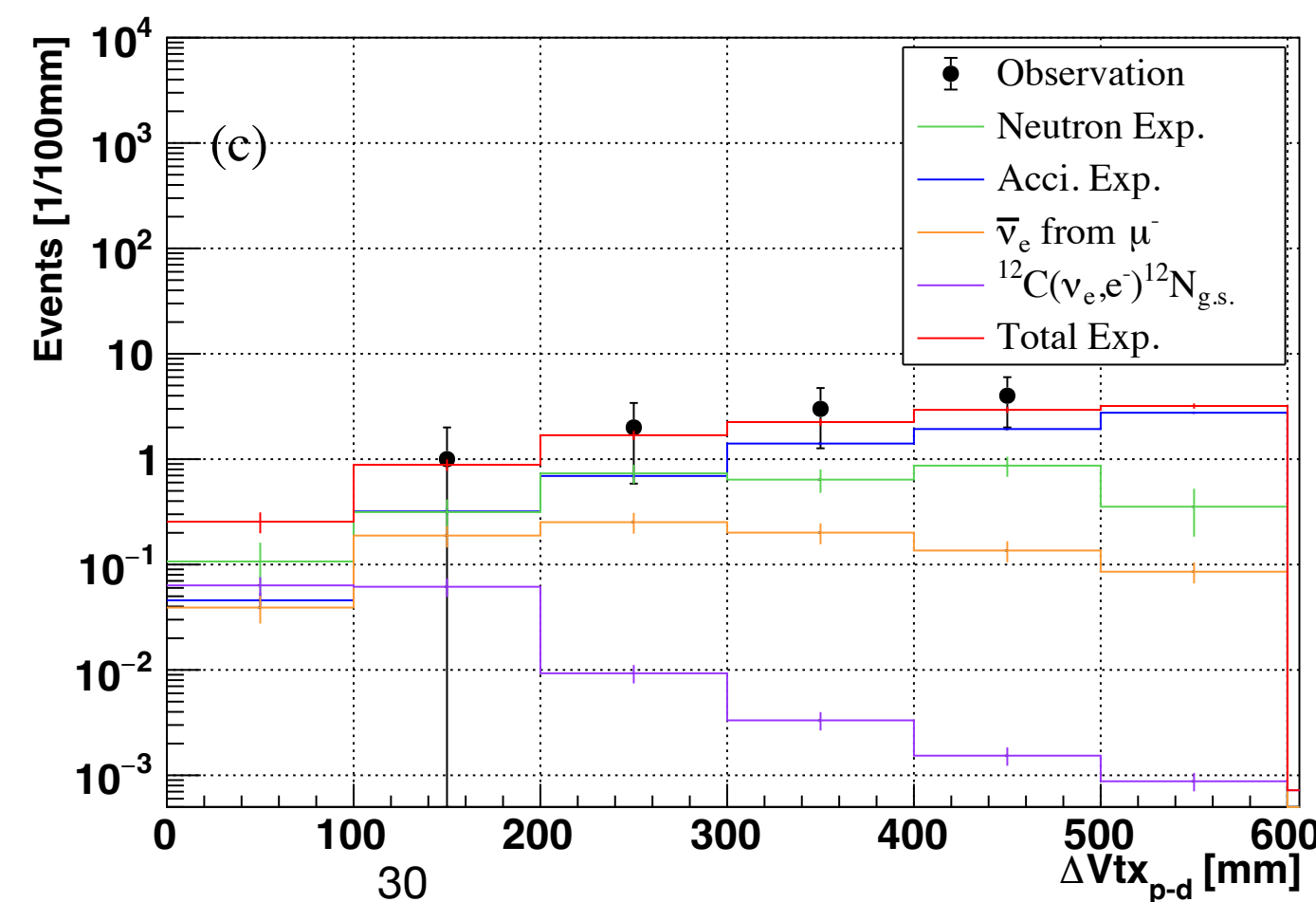


PSD application

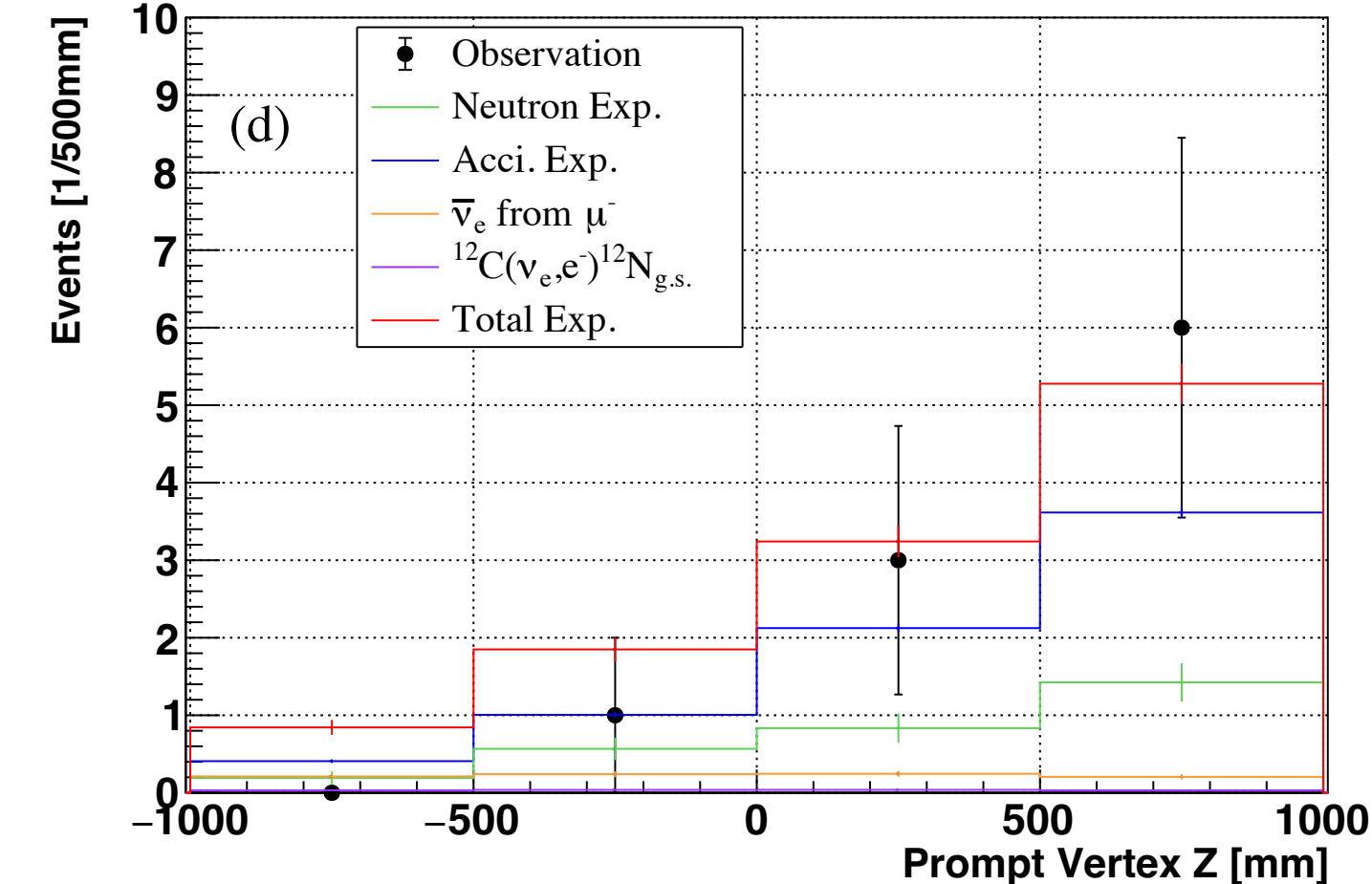


Neutron >99.5 % rejection

ΔVTX_{p-d}



Prompt Vertex Z



Unblind Results in signal region (w/ PSD and LLK)

- Observation vs prediction (Bkg.) (signal region)
- > Good consistency for all cases

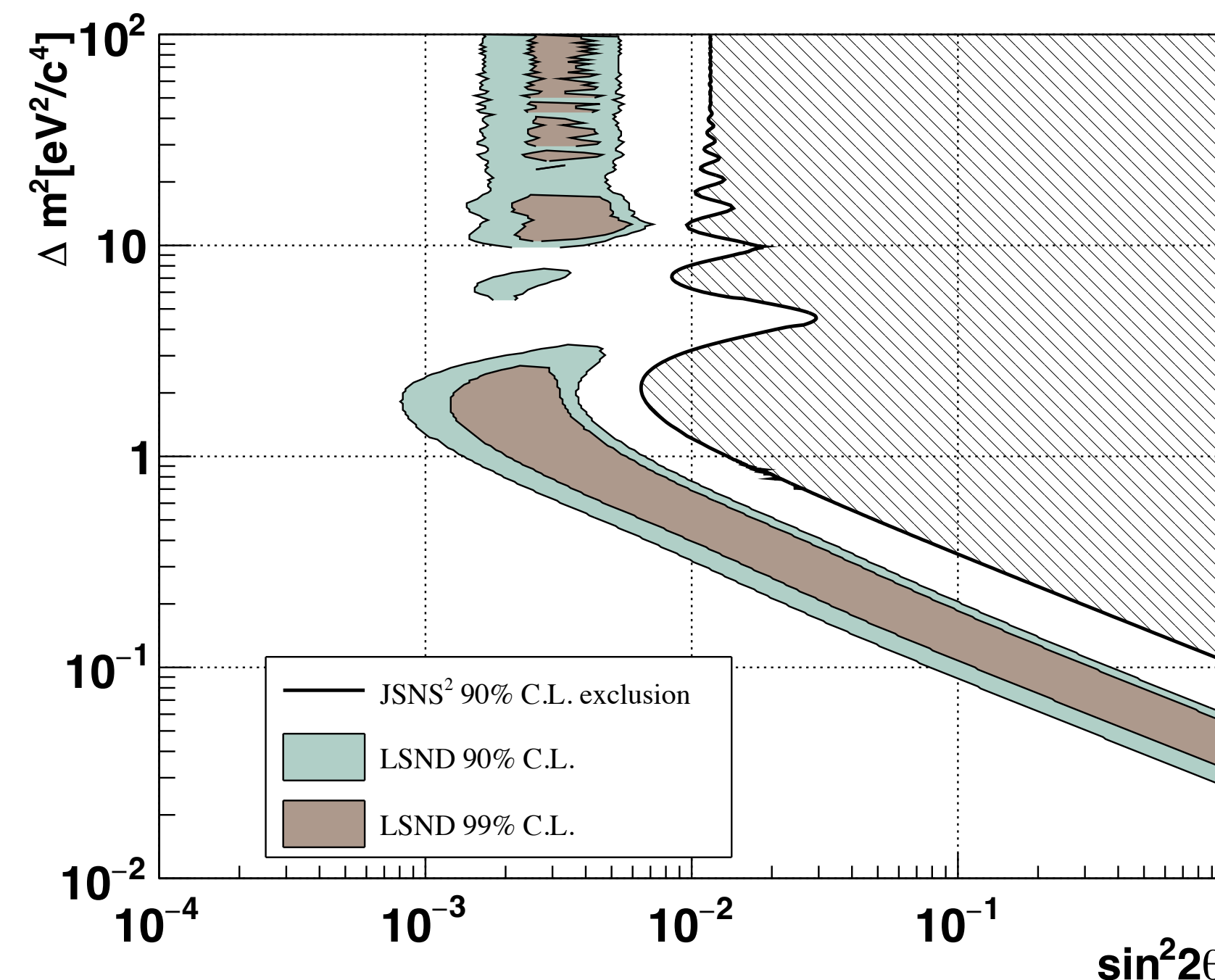
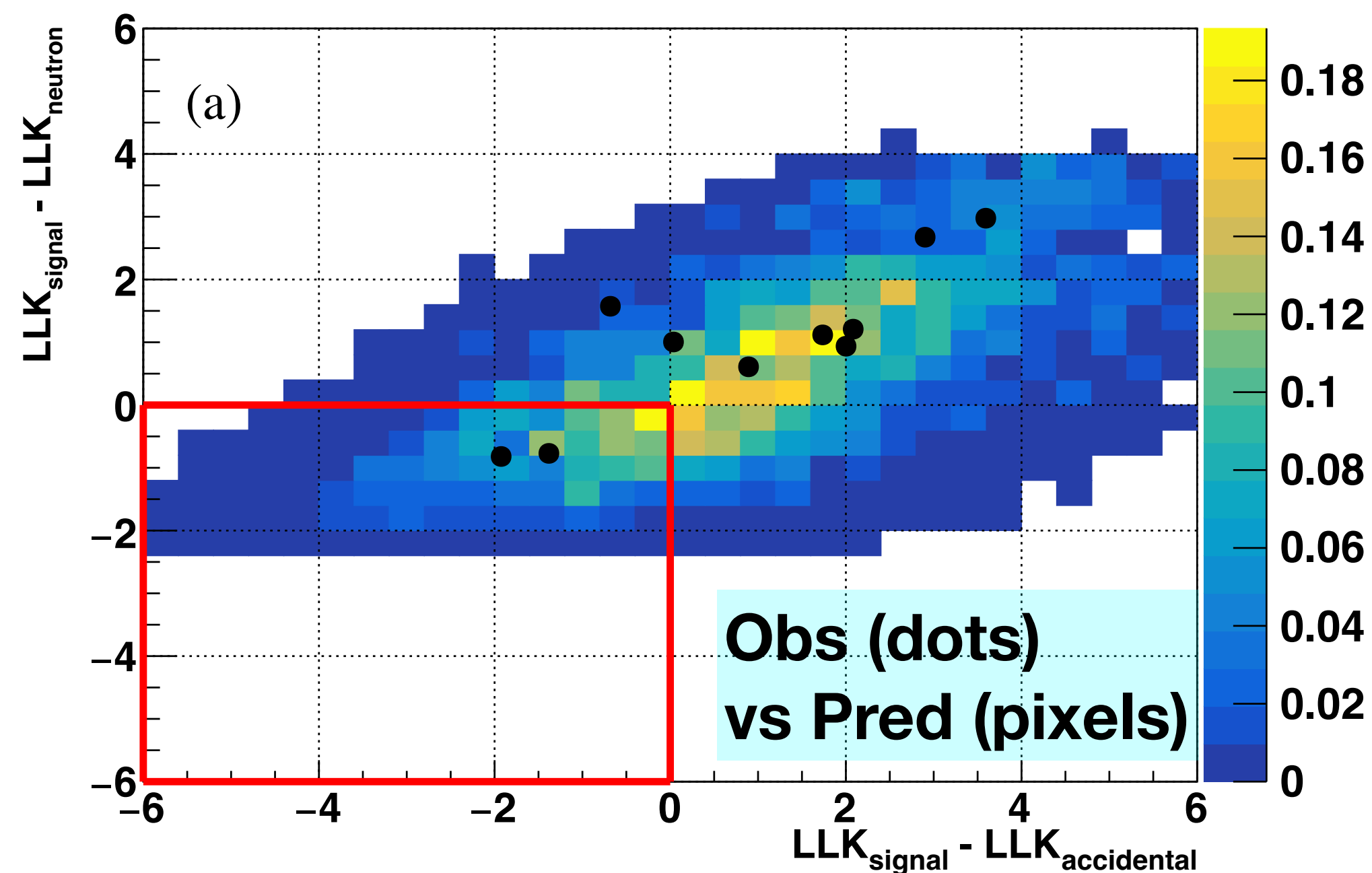
2022 Physics run
(0.82×10^{22} POT)

cases		observation	prediction
w/o PSD	w/o LLK	1079	1063.0 ± 25.7
w/o PSD	w/ LLK	304	315.8 ± 8.0
w/ PSD	w/o LLK	10	11.2 ± 0.7
w/ PSD	w/ LLK	2	2.3 ± 0.4

Neutron 0.6 ± 0.2
 Acci 1.00 ± 0.01
 CNgs 0.08 ± 0.02
 Intrinsic Bkg ($\bar{\nu}_e$ from μ^-)
 0.6 ± 0.3

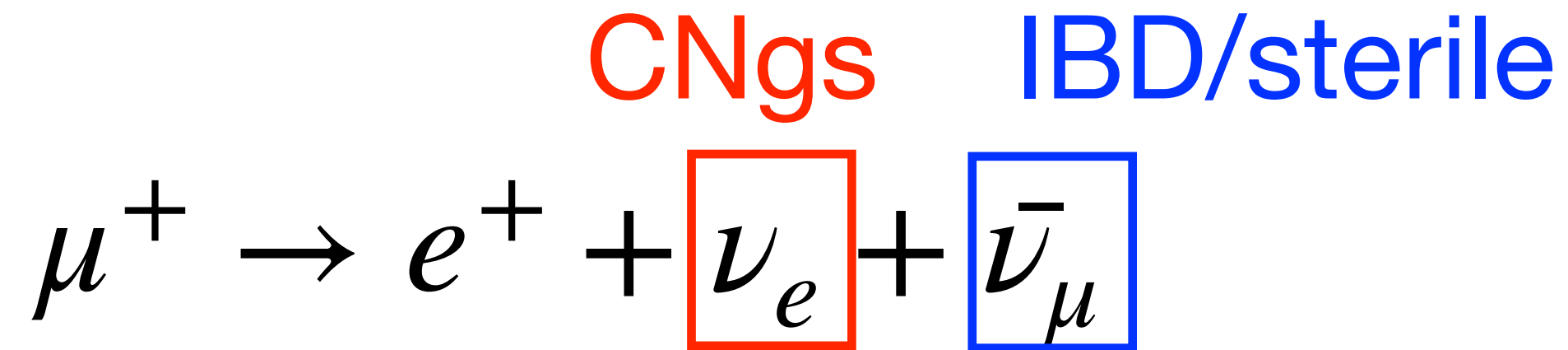
$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation contour
 90% CL exclusion limit derived from the observation (black line).

2D Log-Likelihood ratio score distribution



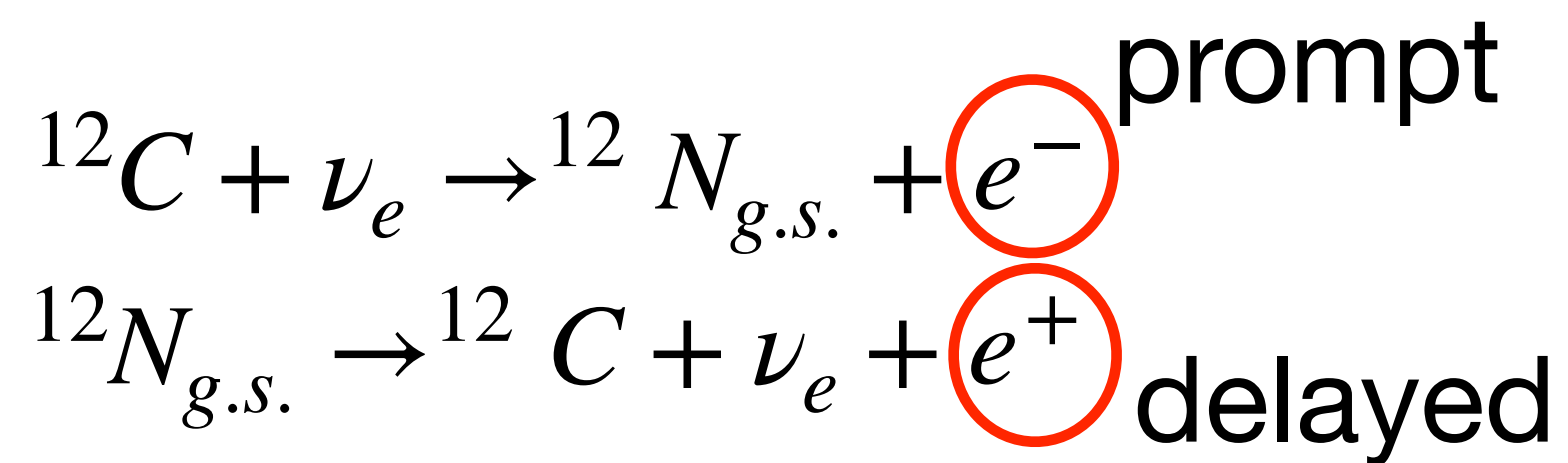
Motivation to measure $^{12}\text{C}(\nu_e, e^-)^{12}\text{N}_{g.s.}$

- The number of μ^+ can be estimated by CNgs
- > Normalization of IBD

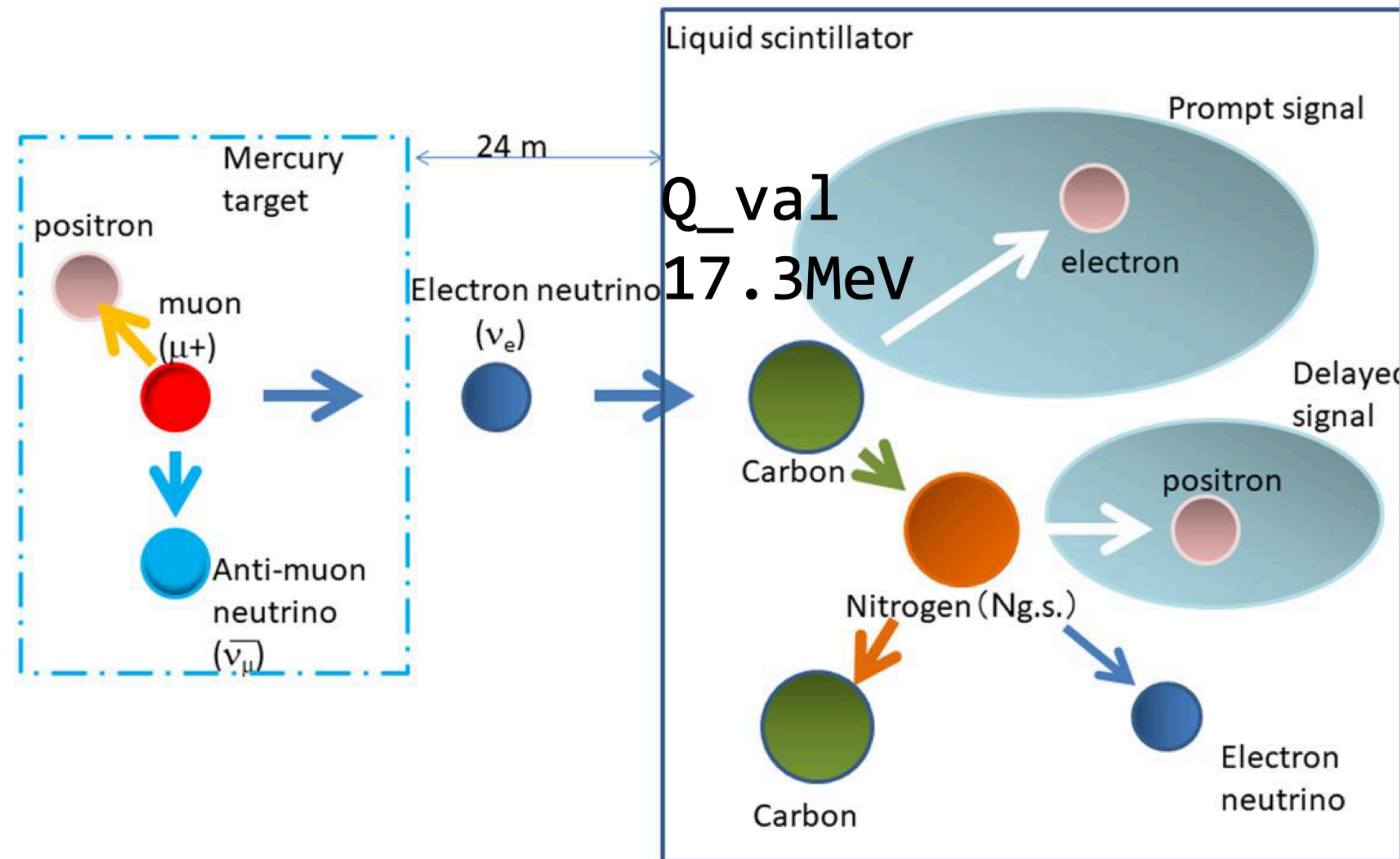


Lifetime ~16ms
 Max = 16.8MeV
 Qval = 17.3MeV

- $^{12}\text{C}(\nu_e, e^-)^{12}\text{N}_{g.s.}$
- > reaction of ν_e



- > CNgs is useful for understanding the Total number of $\nu_e (= \mu^+ / p)$



Selection criteria of $^{12}\text{C}(\nu_e, e^-)^{12}\text{N}_{g.s.}$

<Event Selection>

- Energy

Prompt : $20 < E_p < 40 \text{ MeV}$

Delayed : $10 < E_d < 18 \text{ MeV}$

- Timing

Prompt : $2 < T_{\text{beam}} < 10 \mu\text{s}$

- Prompt vs Delayed

Timing :

$0.2 < \Delta T_{p-d} < 12 \text{ ms}$ (2021)

$< 25 \text{ ms}$ (2022)

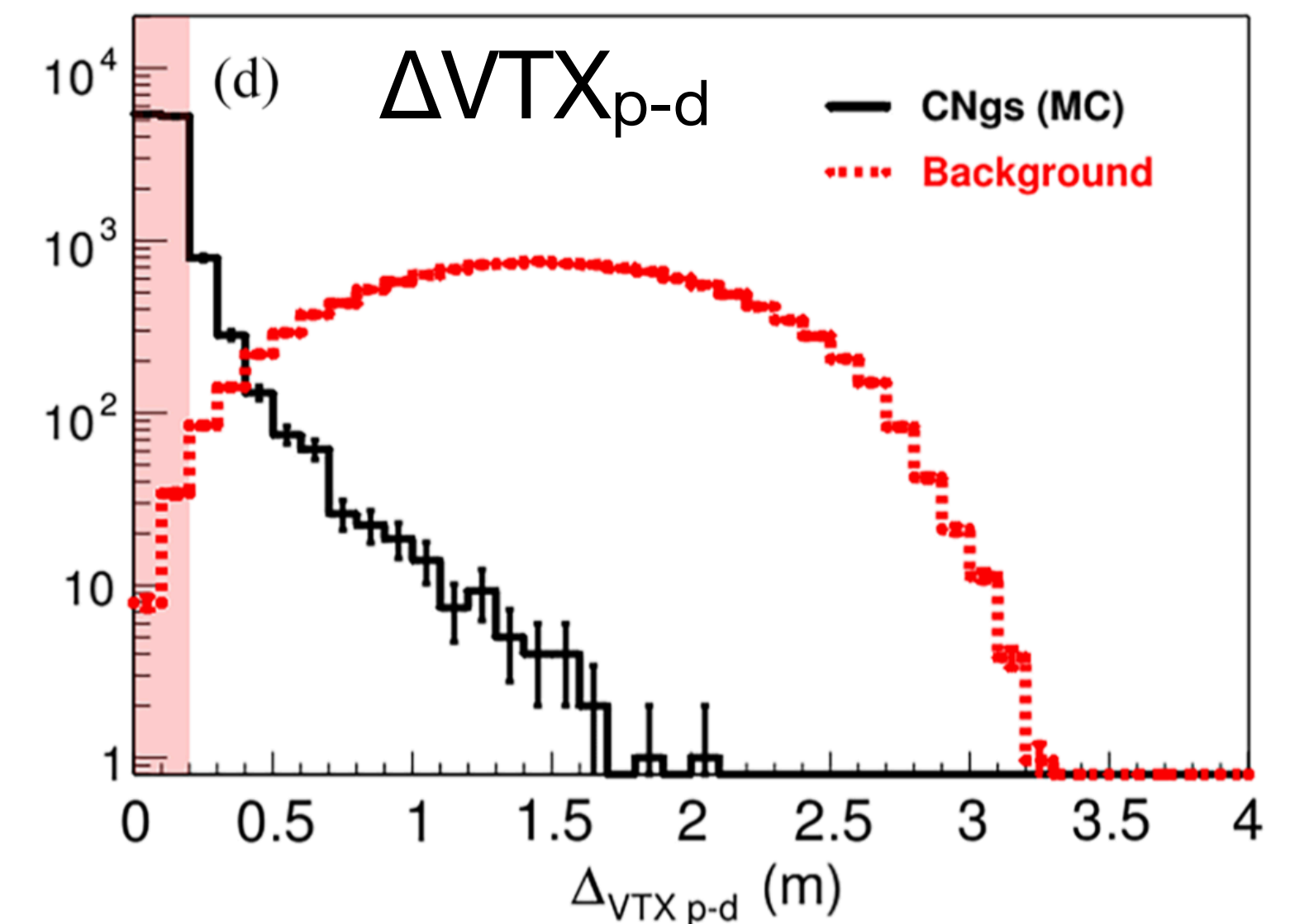
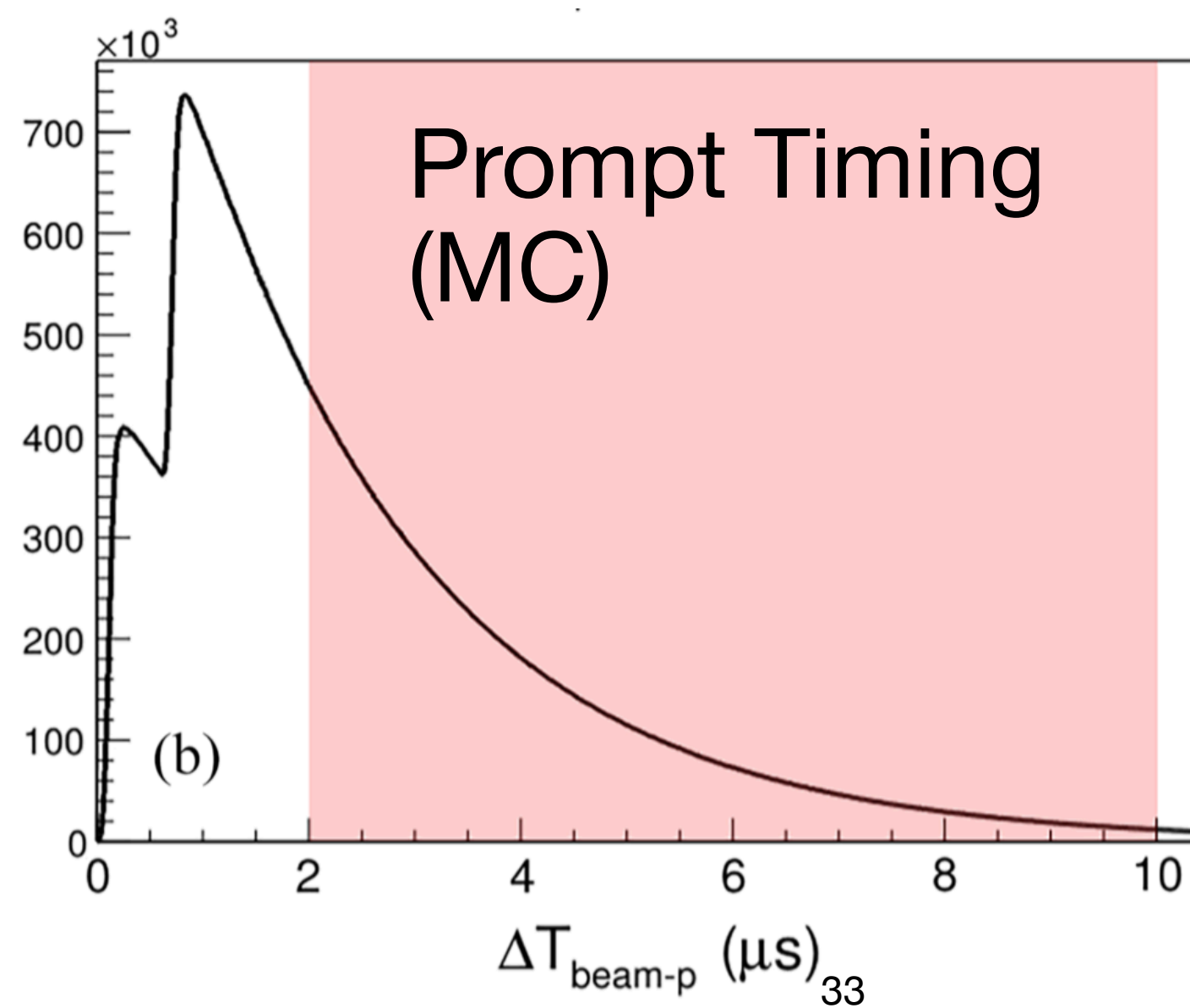
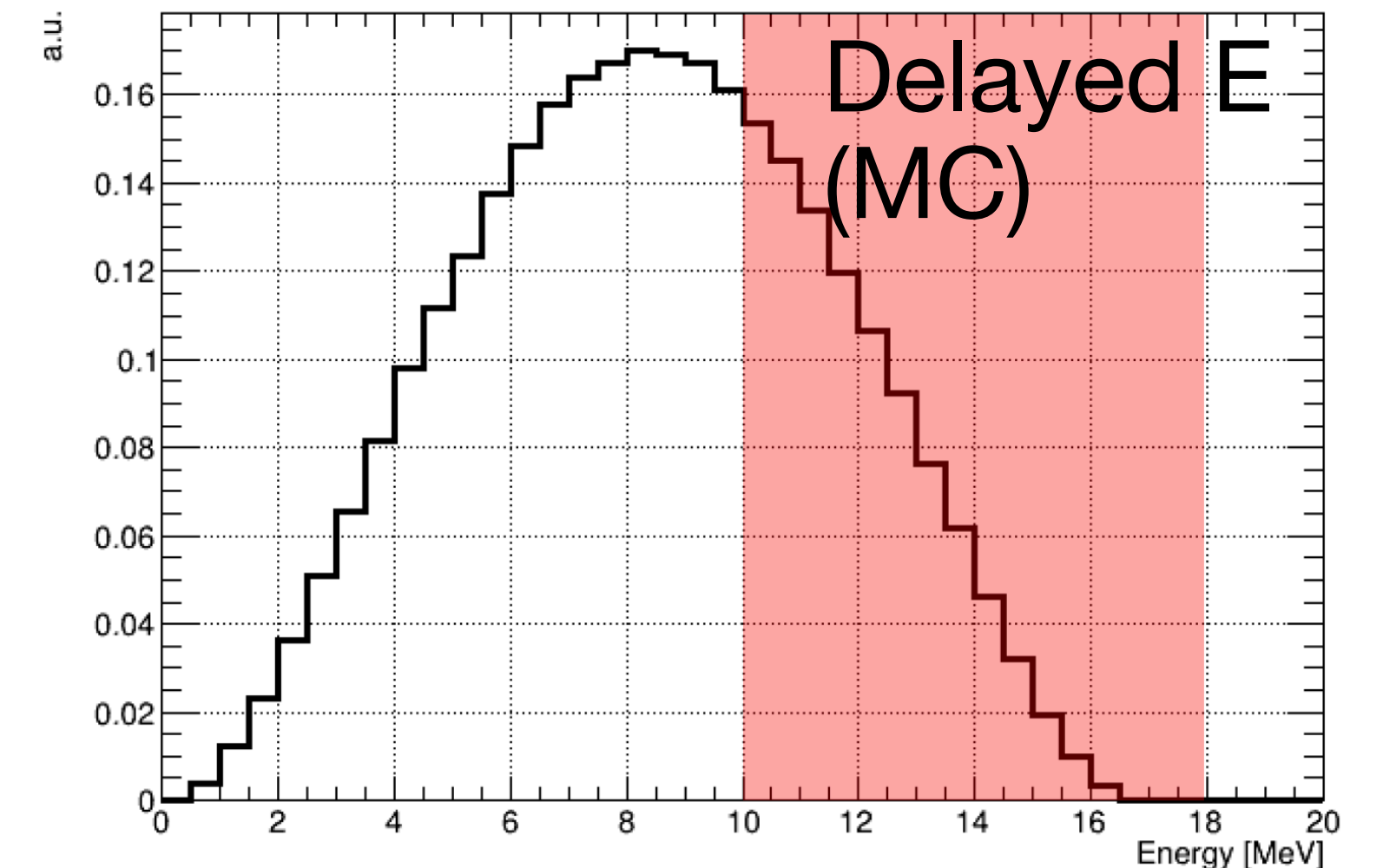
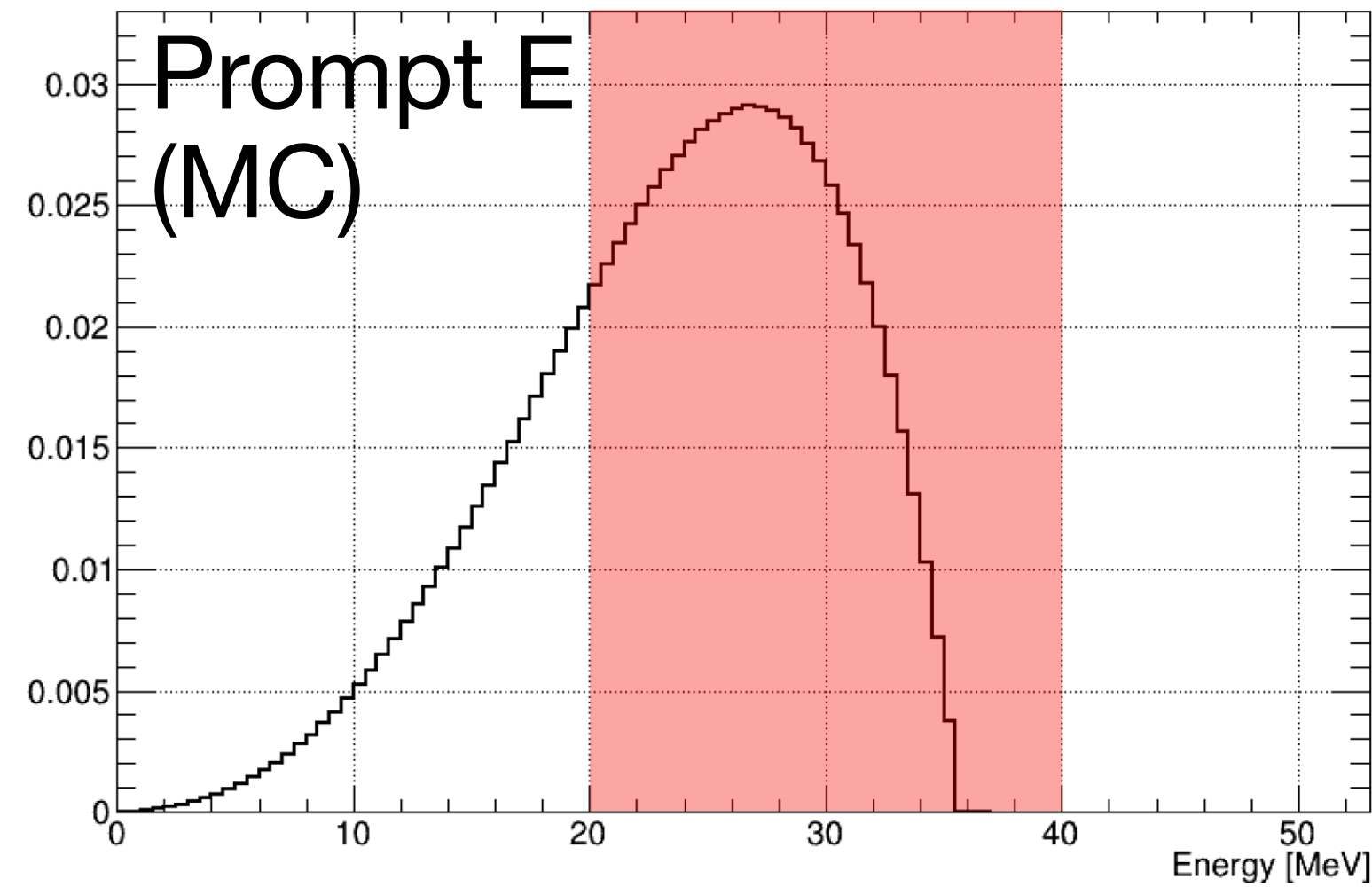
Spatial correlation :

$\Delta VTX_{p-d} < 20 \text{ cm}$

- Muon/Michel e veto

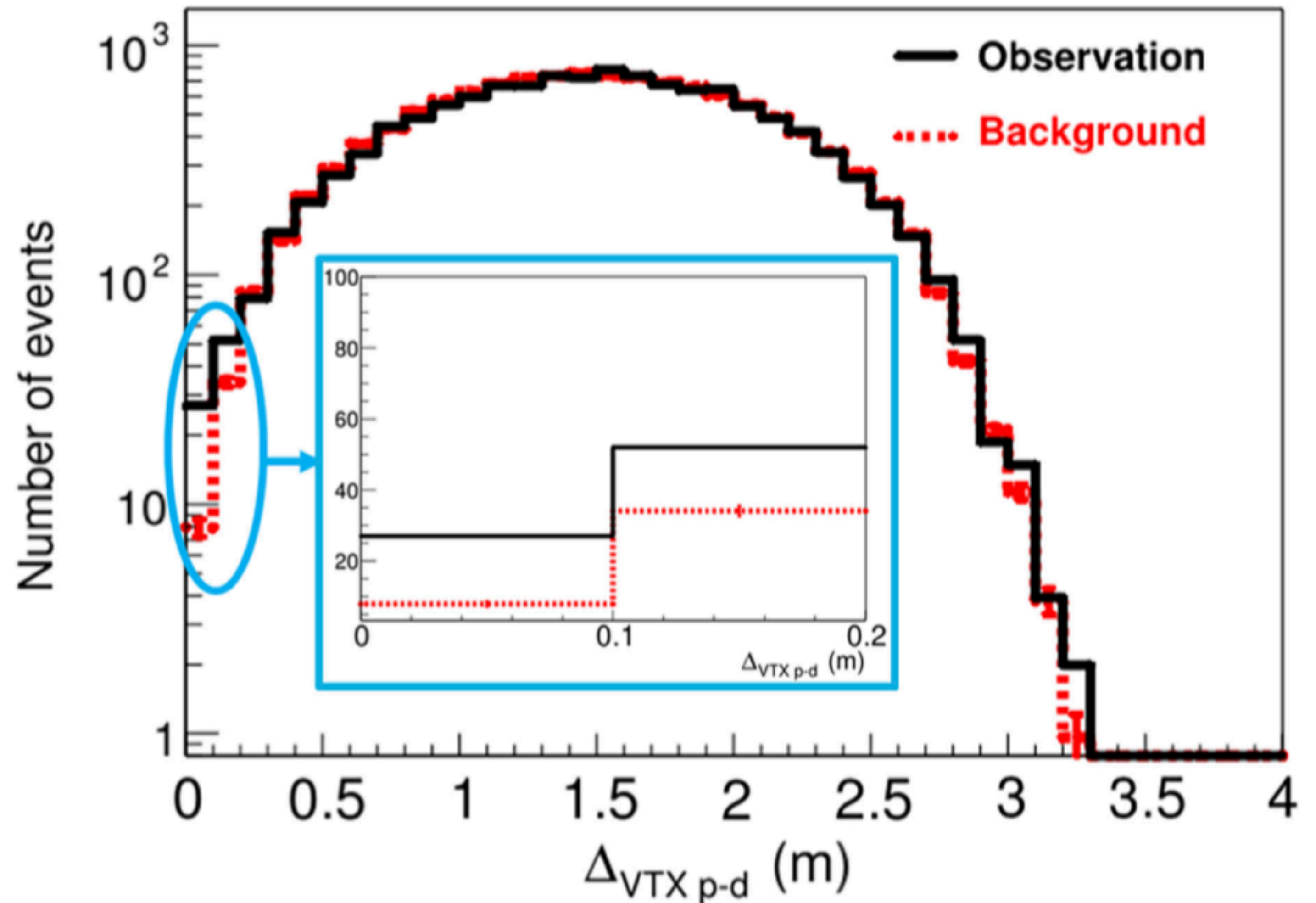
- Fiducial cut :

$R < 140 \text{ cm}, |Z| < 100 \text{ cm}$



Observed events of $^{12}\text{C}(\nu_e, e^-)^{12}\text{N}_{\text{g.s.}}$

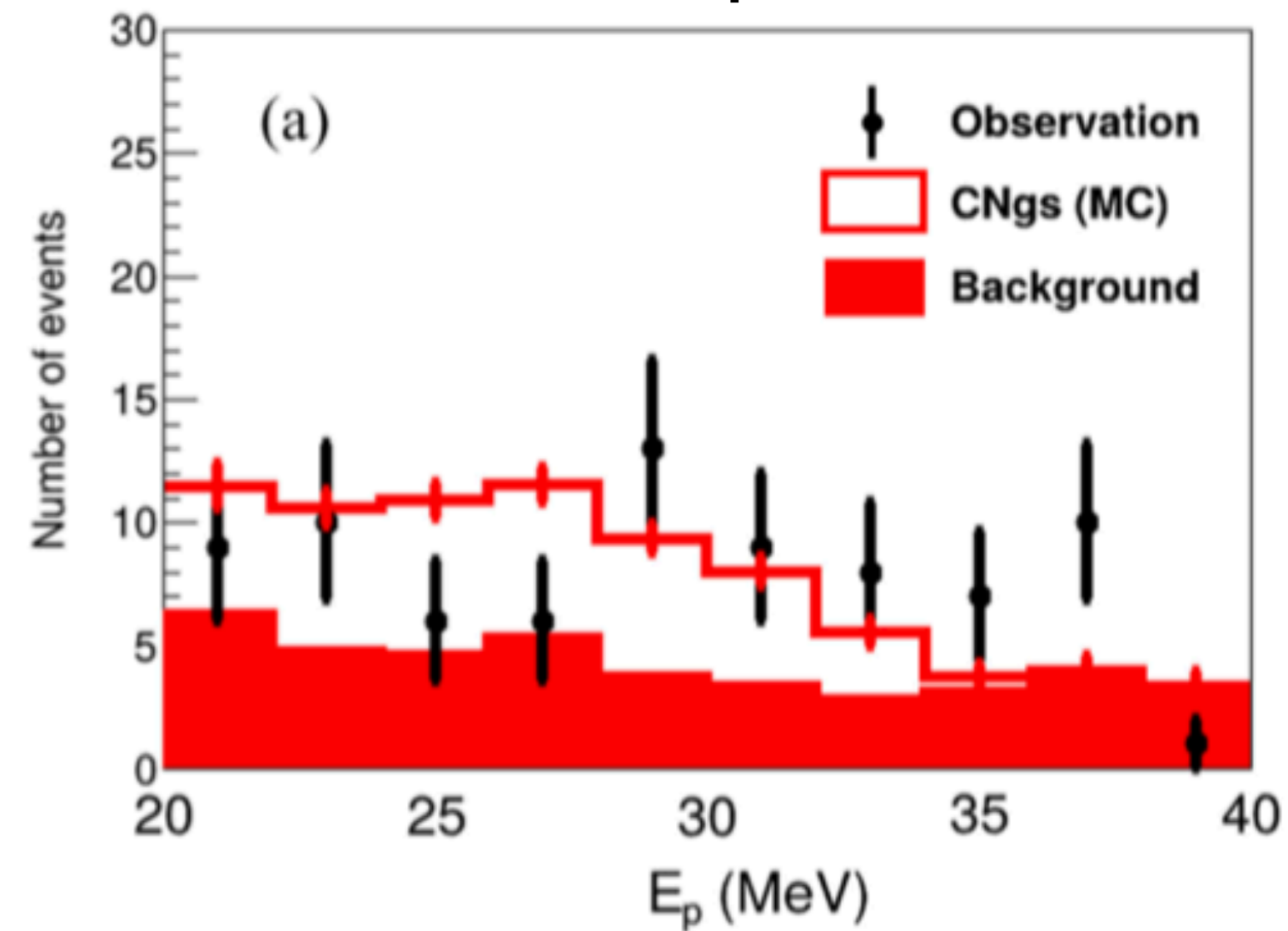
- 2021 & 2022 physics data (2.2×10^{22} POT)
- Clear excess is seen in the signal region
=> Observed : 79 events
=> Bkg : 42.2 ± 4.8
=> CNgs signal :
 36.8 ± 8.9 (stat.) ± 4.8 (syst.)
- p-value : 2.9×10^{-7}



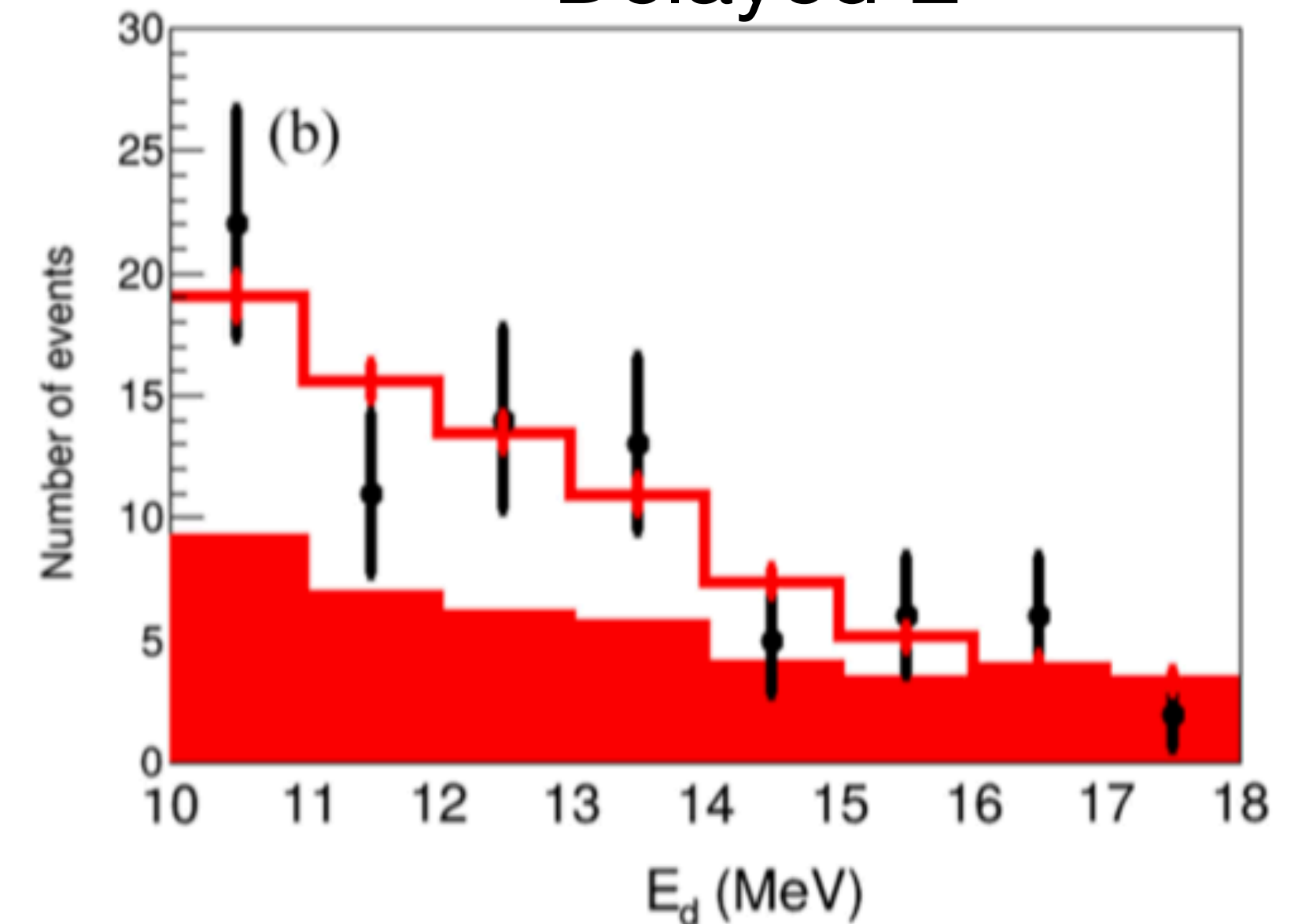
Variables of $^{12}\text{C}(\nu_e, e^-)^{12}\text{N}_{g.s.}$ Events

- All distributions for selected variables seem to be reasonable.

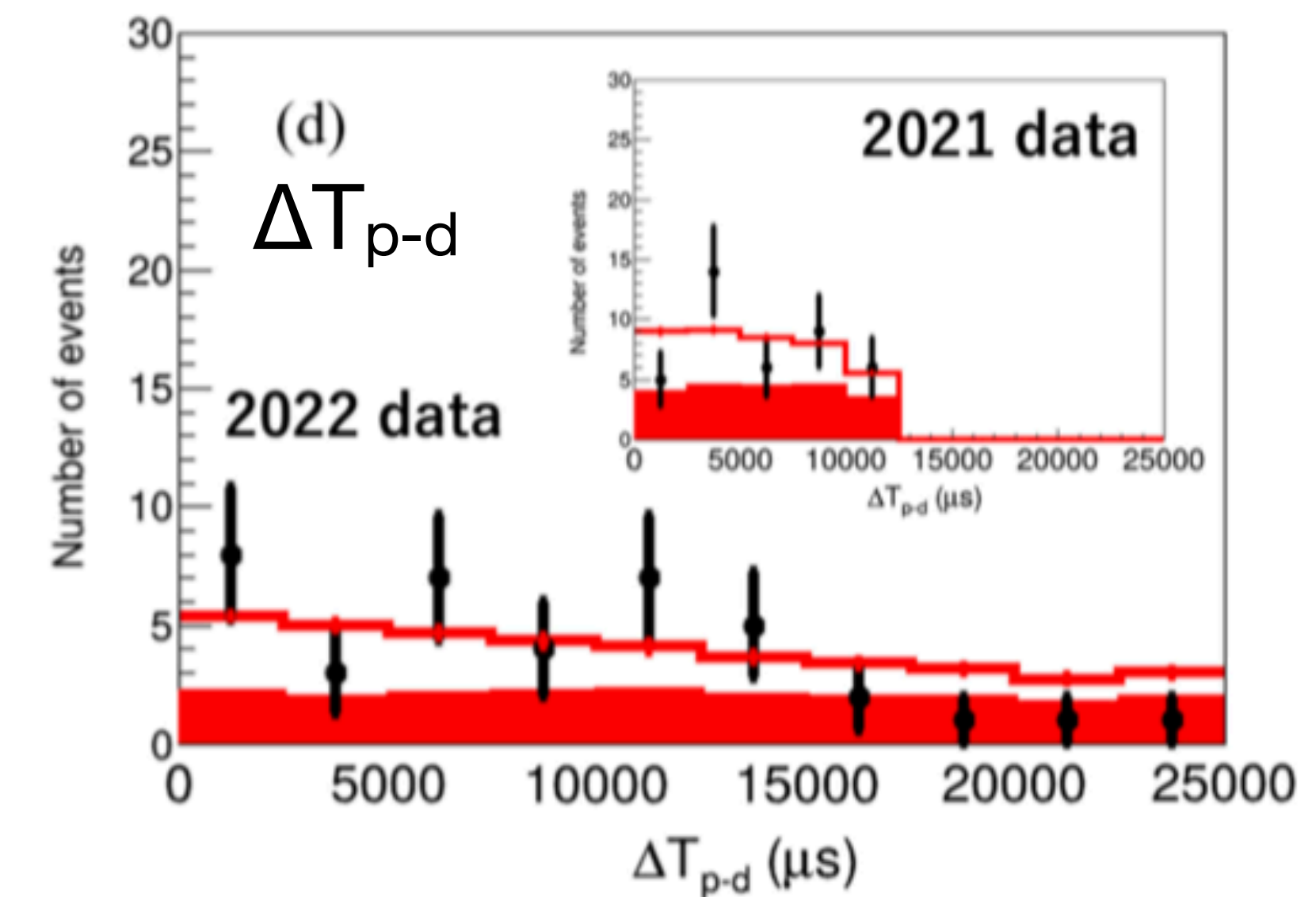
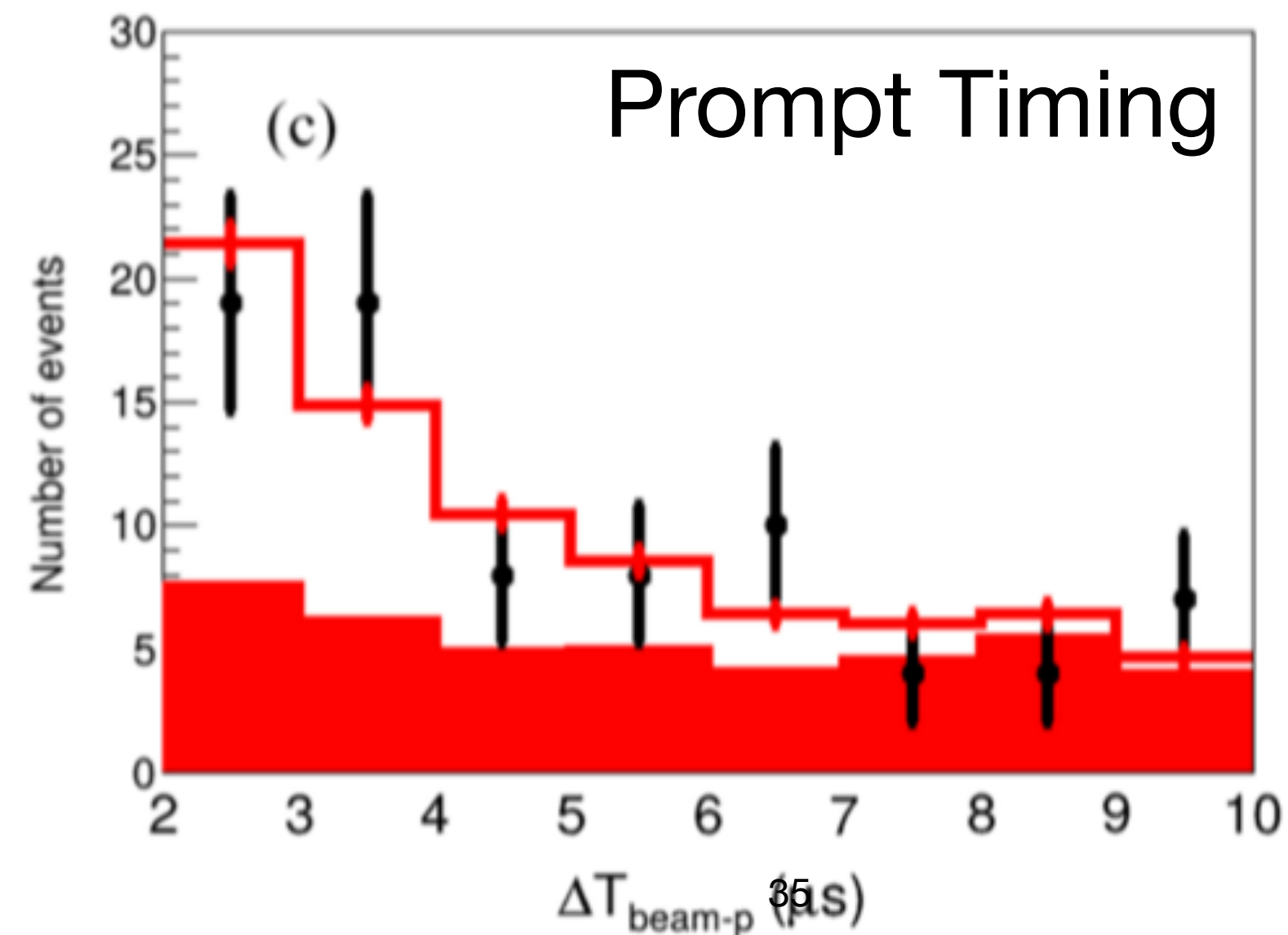
Prompt E



Delayed E



Prompt Timing



Interpretation to Number of ν_e

Observed Event rate $N_{CNg.s.}$ = $\frac{\Phi_{\nu_e} POT}{4\pi r^2} \epsilon \sigma N_C$

Labels: Φ_{ν_e} (Total number of $\nu_e (= \mu^+/p)$), POT (Cross Section), ϵ (Selection Efficiency), σ (Cross Section), N_C (Number of Carbons)

- 2.2×10^{22} POT
- $\epsilon = 5.88 \pm 0.21 \%$
- Cross section (LSND+KARMEN) = $(9.1 \pm 0.7) \times 10^{-42} \text{ cm}^2$
- Number of C = $(4.68 \pm 0.94) \times 10^{29}$ (<- Fiducial error 20%)

Total number of $\nu_e (= \mu^+/p) = 0.483 \pm 0.117$ (stat.) ± 0.123 (syst.)
vs 0.344 (FLUKA), 0.268 (QGSP-BERT)

- This μ^+/p can be **directly** used for **Normalization of IBD signals.** (already used in arXiv:2602.06274 [hep-ex])
- This measured μ^+/p from “CNgs measurement” is **40% larger** than FLUKA (assumed in TDR) (consistent within 1σ , though) -> **Better results** compared to the previous sensitivities by using FLUKA.

* For cross section, the combined value of LSND (Phys. Rev. C 64:065501 (2001)) +KARMEN (Prog. Part. Nucl. Phys. 40, 183 (1998)) is used.

