Status of Sterile Neutrino Search at J-PARC MLF

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Outline

- Introduction
  -P56;A Search for Sterile Neutrino at J-PARC MLF
  - J-PARC, MLF
- Sterile neutrino experiment
  - LSND
  - P56
- MLF Background measurement
- P56 experimental setup
- Summary

P56;A Search for Sterile Neutrino at J-PARC MLF

- New Neutrino experiment at J-PARC
  Materials and Life science experimental Facility (MLF)

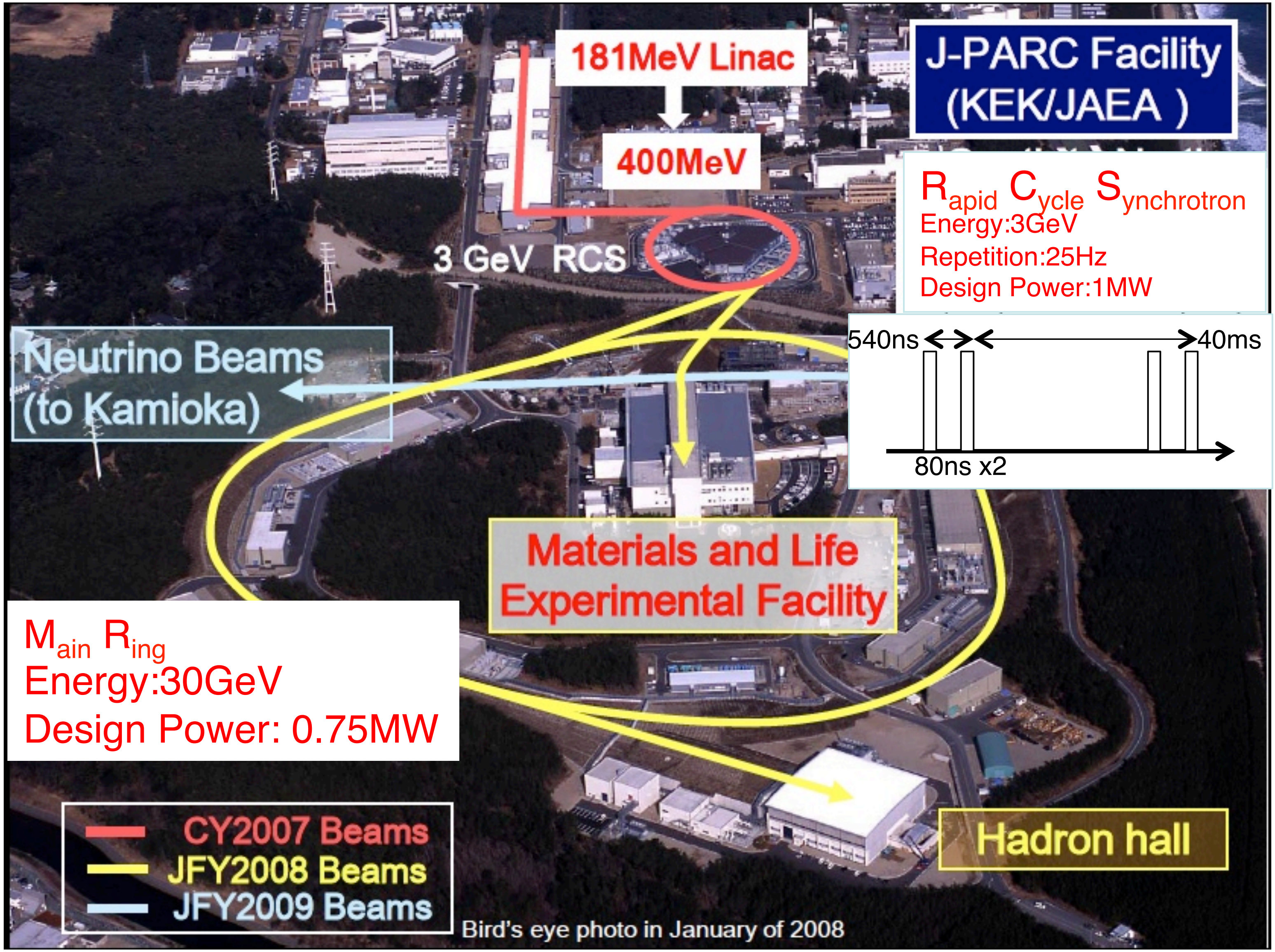
2013

- Begin consideration of the experiment
- March-May: 1st Test — Measurement of Background at MLF Ex2 Hall
- Sep: 17th J-PARC PAC — Submit Proposal (M.Harada, *et el.* arXiv: 1310.1437[physics.ins-det])

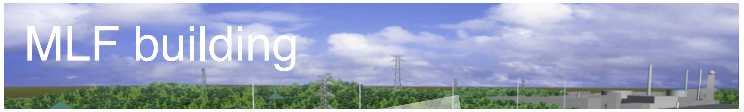
2014

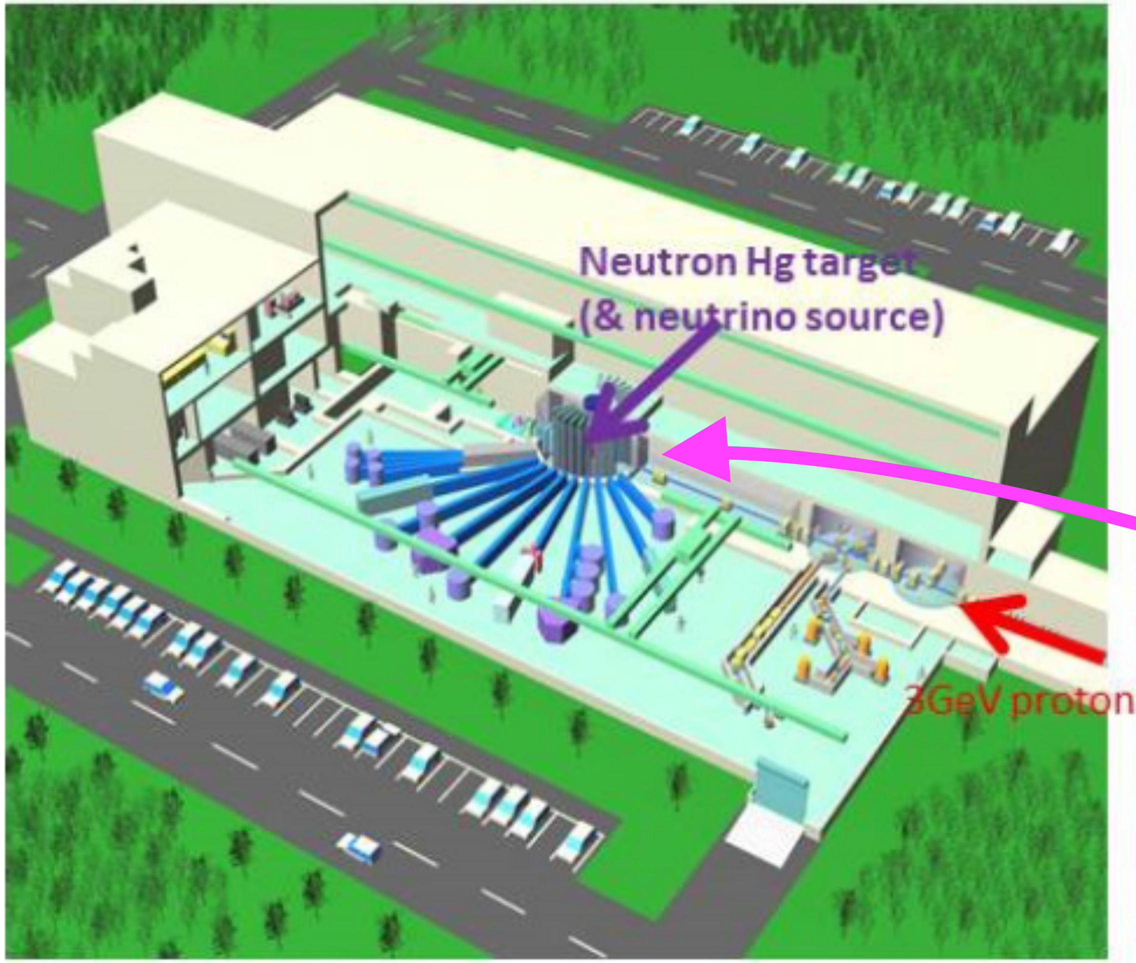
- April-June: 2nd Test — Measurement of Background at MLF 3F
- May: 18th J-PARC PAC — Status report
- Dec: 19th J-PARC PAC — Status report, Request for 1st stage approval

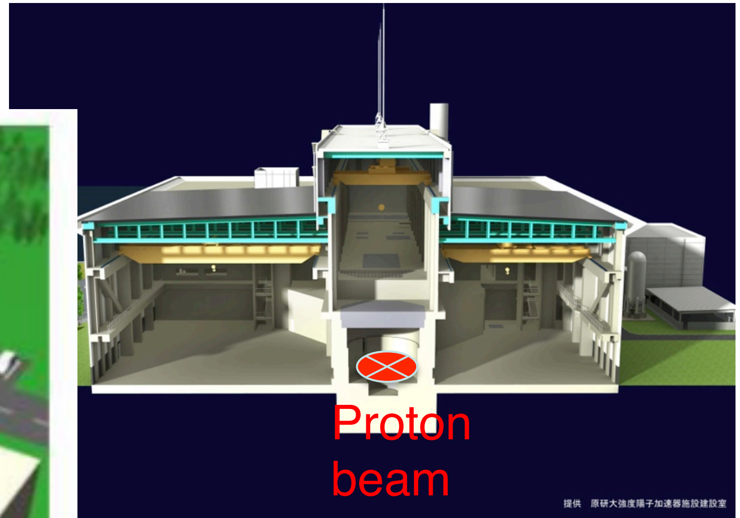
J-PARC bird view

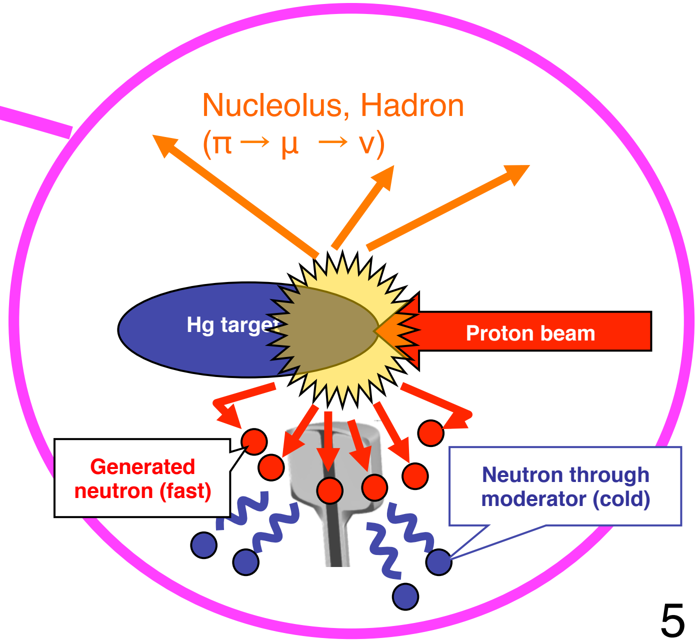


MLF:Neutron and Muon source for Material and Life Science





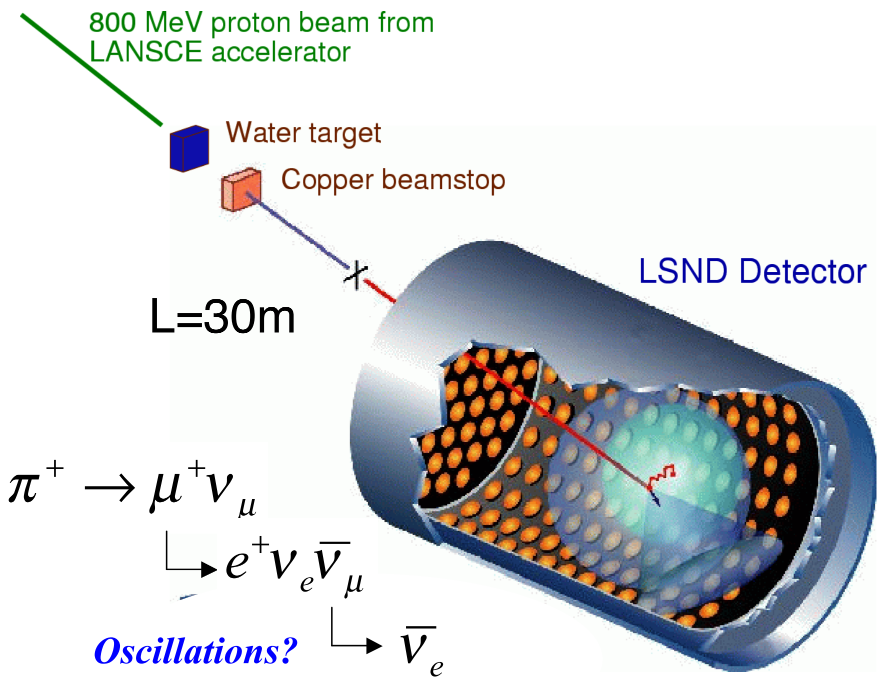


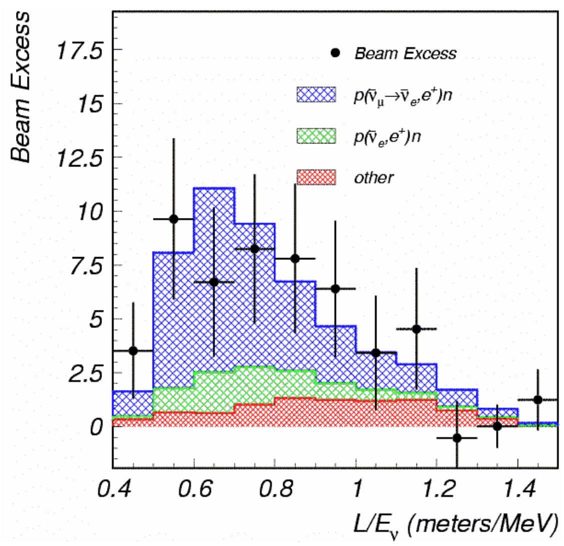


LSND

LSND $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ Signal

Appearance





Saw an excess of:
87.9 ± 22.4 ± 6.0 events.

With an oscillation probability of (0.264 ± 0.067 ± 0.045)%.

3.8σ evidence for $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

Los Alamos Meson Physics Facility,LANL 1993-1998

Summary of eV^2 region sterile experiment

Experiments	Neutrino source	signal	type	Significance σ
LSND	μ Decay-At-Rest	$\bar{\nu}_\mu \to \bar{\nu}_e$	appearance	3.8
MiniBooNE	π Decay-In-Flight	$\nu_\mu \to \nu_e$	appearance	3.4
		$\bar{\nu}_\mu \to \bar{\nu}_e$	appearance	2.8
		combined		3.8
Ga(calibration)	e capture	$\nu_e \to \nu_X$	disappearance	2.7
Reactors	Beta decay	$\bar{\nu}_e \to \bar{\nu}_X$	disappearance	3.0

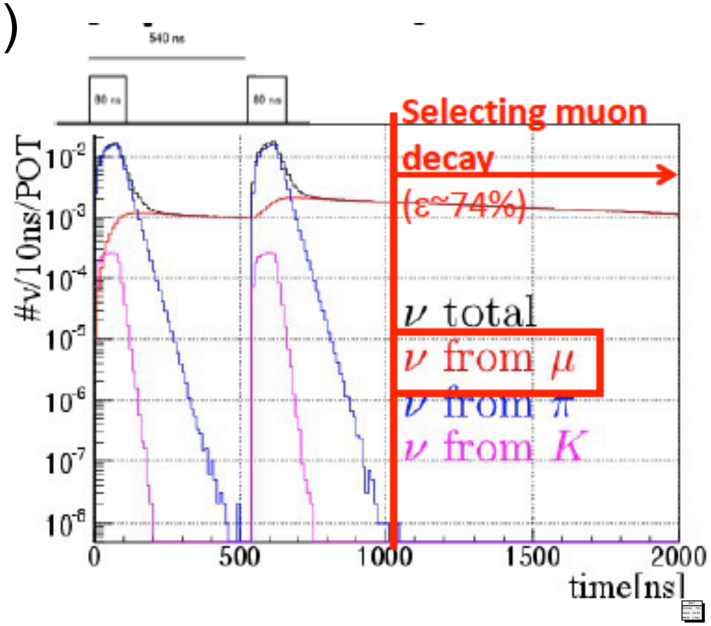
- P56 use same process and reaction of LSND
- P56 improve statics and signal/noise ratio
  → P56 confirm or refute the neutrino oscillation with sterile neutrino($\nu_\mu \to \nu_e$) completely

P56 vs LSND

	J-PARC P56	LSND
Beam	pulse	DC
Duty factor and background	30μs/40ms ～10^{-3}	6% not separate ν from π/ K Neutrino beam cont in Decay-in-flight
detector	LS＋Gd	LS + mineral Oil Cherenkov
Coincidence from Inversed Beta Decay	delayed E=8MeV, t=30μs	delayed E=2.2MeV, t=220μs
Beam intrinsic BG	$1.7x10^{-3}$	$7x10^{-4}$
PID	n/e = 1%	n/e = 1%
Signal detection	40%	10-20%
Baseline	24m(candidate location)	30m
Signal event	480/5years	88/6years

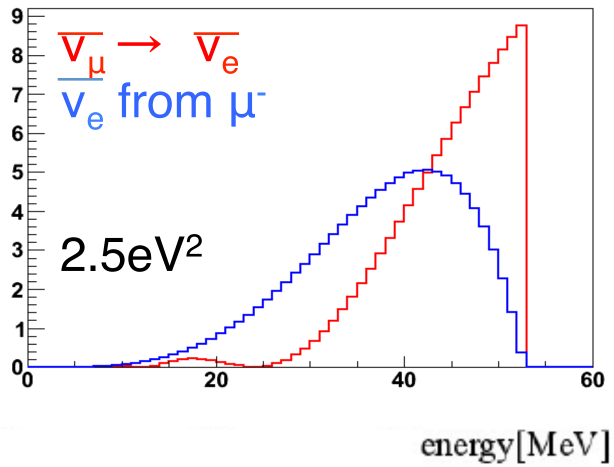
Advantage :signal separation

Using neutrinos from only μ^+ decay at rest(DAR)



- μ^+ has long lifetime.

- Energy spectrum of $\mu^+ \rightarrow e^+ \overline{\nu}_\mu \nu_e$ decay is well known.
  - Useful to examine the excess of $\overline{\nu}_e$.
  - $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ Oscillation can be searched.



- $\pi^- \rightarrow \mu^-$ decay chain is highly suppressed 10^{-3} compared to μ^+; π^- capture in nuclei

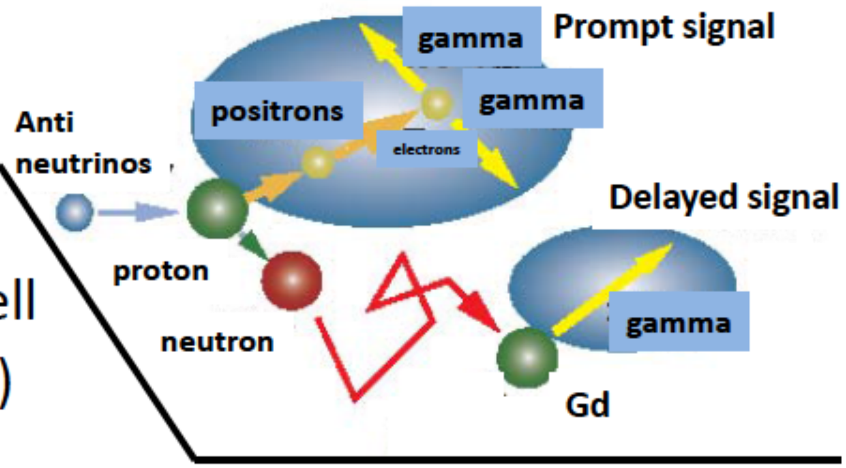
- Proton energy of J-PARC is 3GeV, thus π^+/p ratio is higher than LSND(0.8GeV) by 5-10 times

Improvement :signal detection

Detector; Liquid scintillator

- Coincidence between positron and neutron signal ($\overline{\nu_e}$ + p → e^+ + n; Inverse Beta Decay; IBD).
- Neutrons are captured by Gd, and emit gammas (totalE = 8MeV, lifetime; a few 10 μs.)

- Positrons → "prompt" signal (Eν = Evis+0.8MeV)
- Neutrons → "delayed" signal

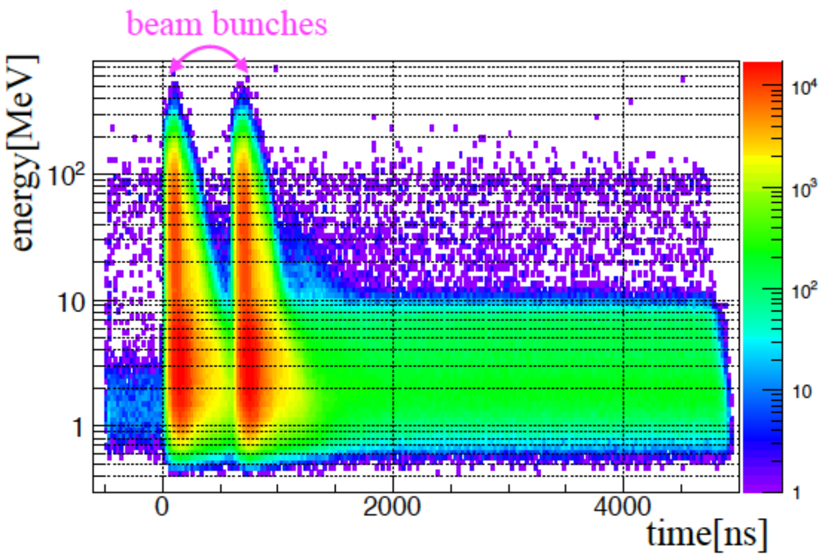


- Cross section of IBD is well known. (~2% uncertainty) ($\sigma = 9.3 \times E_\nu^2 \times 10^{-44}$ cm^2)

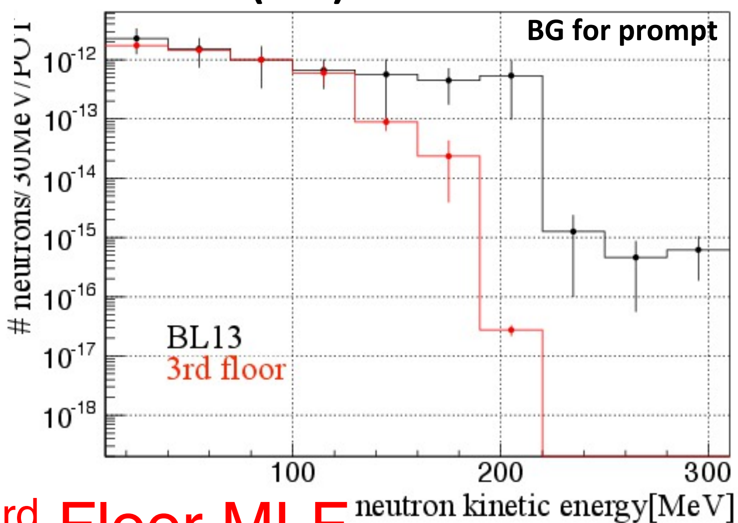
Background meas.BL13

- MLF No.2 experimental Hall

  1t plastic scintillator at BL13



PHITS (MC)

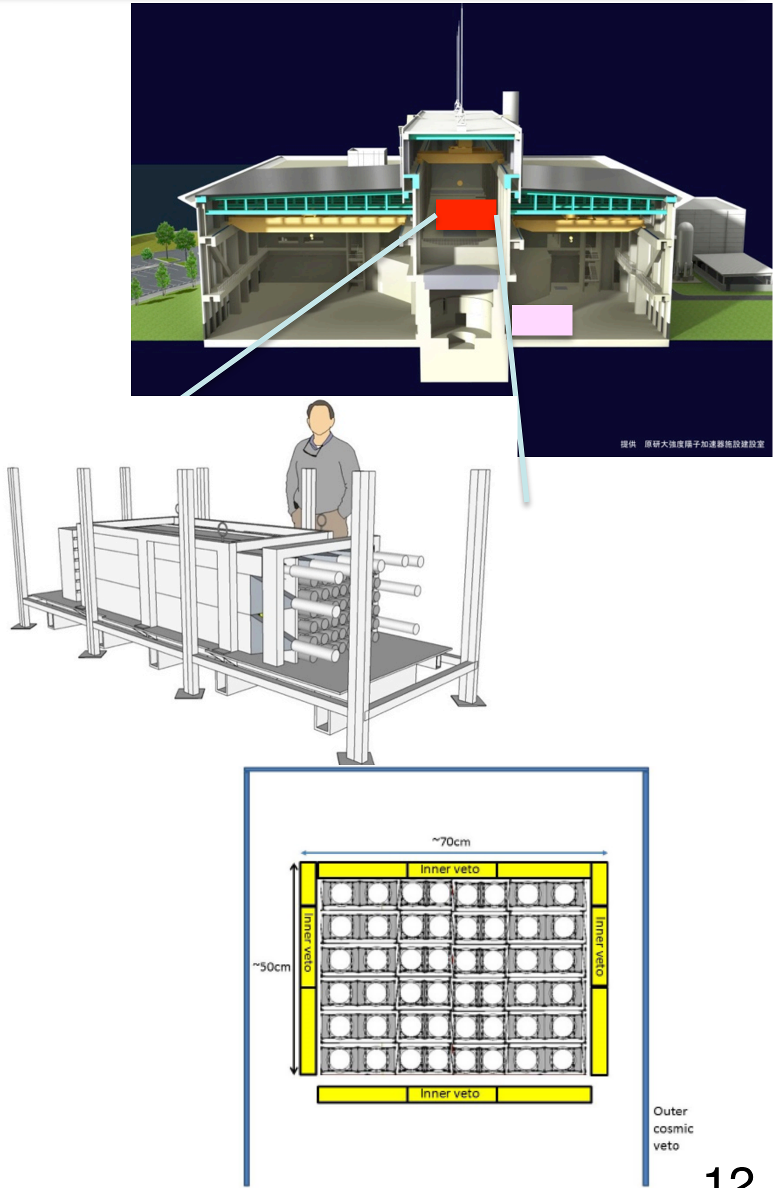


We should measure BKG at 3rd Floor MLF.

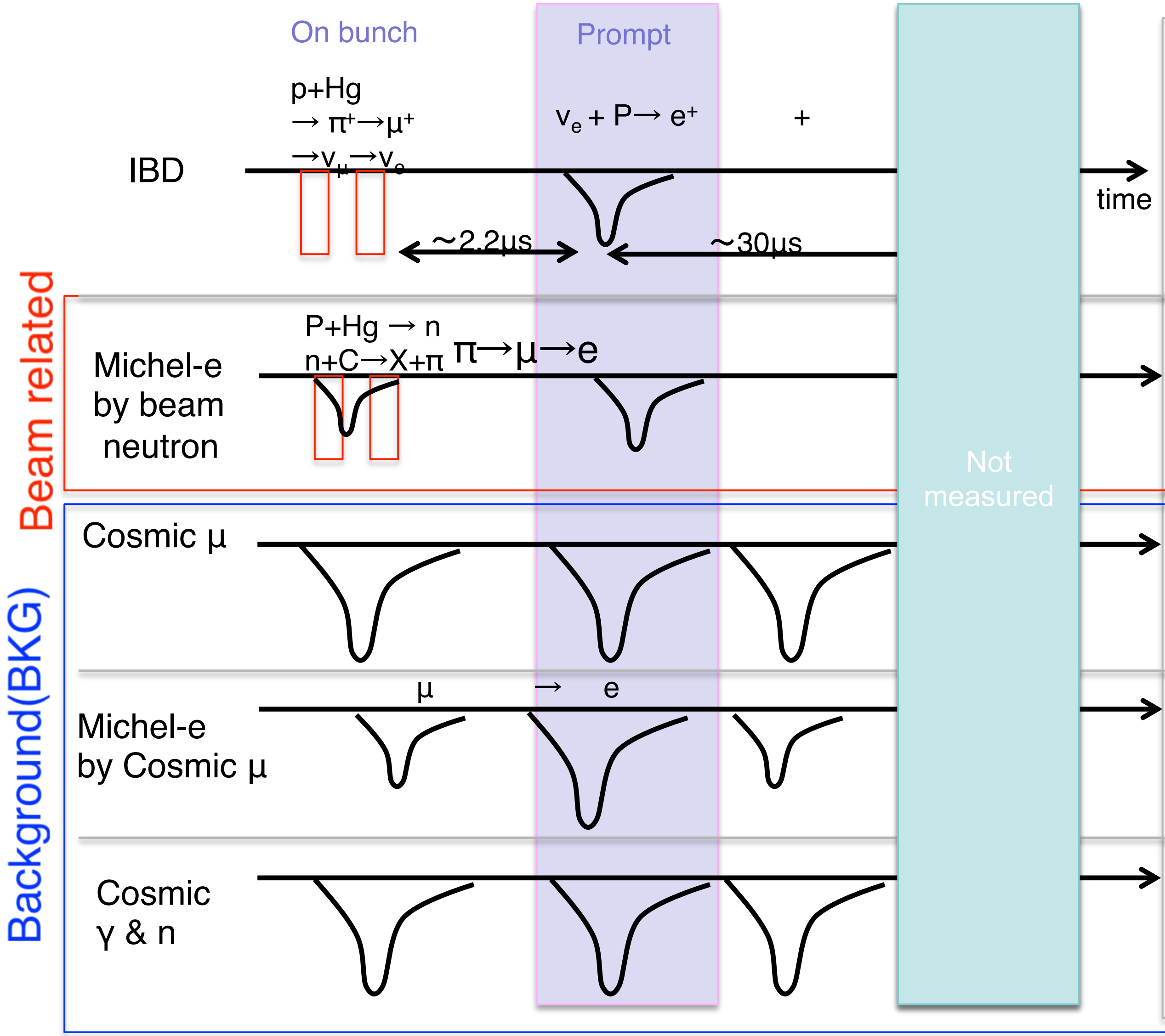
Background meas. 3F

- MLF 3F

- Main scintillators
  - 0.5t total weight
  - 4 scintillators / 6 layers = 24 bar
  - 4 PMTs for each scintillators, double size readout
- Inner cosmic veto (yellow)
  - 4.3 cm thickness scintillators
  - One side readout
  - rejection efficiency > 99.5%
- Outer cosmic veto
  - To Compensate dead space of inner Veto
  - 1 x 1m or 1 x 2 m, 1cm thickness scintillator



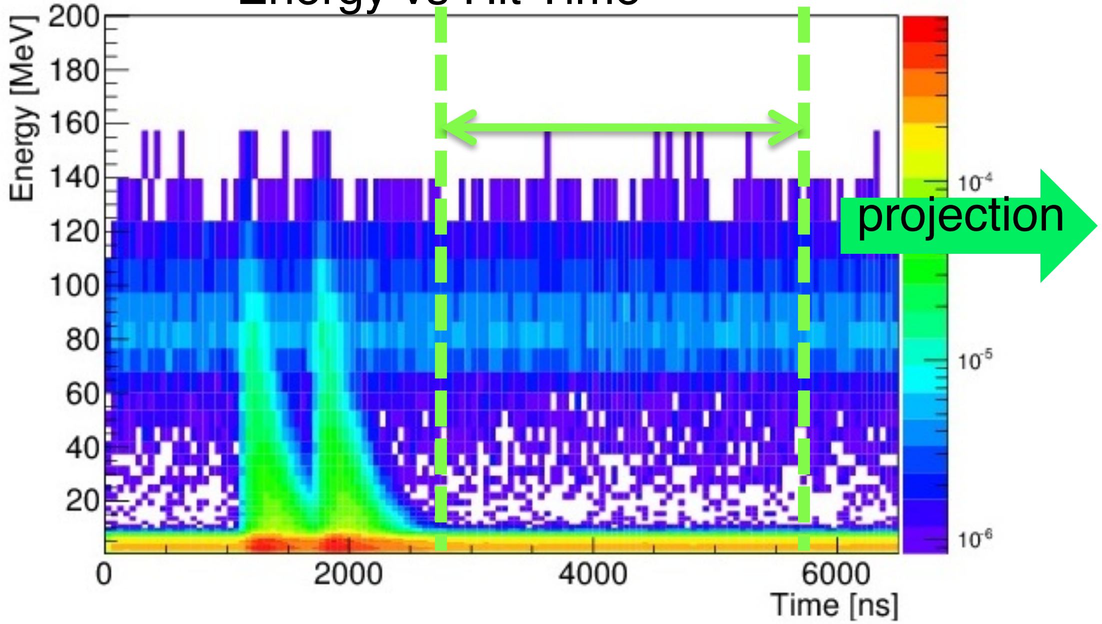
IBD & Backgrounds



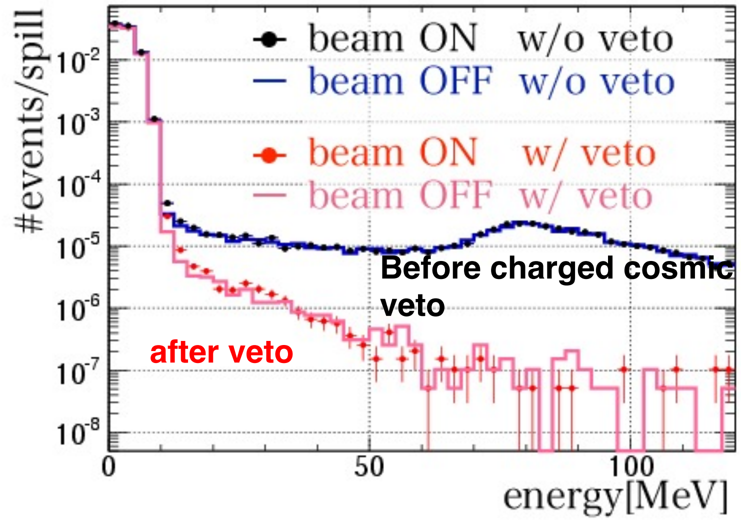
	Beam off	Comment
IBD	Not Exist	Prompt :E<52.8MeV、2.2μs Delayed :E=8MeV、30μs
Michel-e by beam neutron	Not Exist	
Cosmic μ	Exist	Huge, rejected by charged veto
Michel-e by Cosmic μ	Exist	rejected by charged activity of parent μ
Cosmic γ & n	Exist	Accidental coincidence

BG measurement; prompt

Energy vs Hit Time



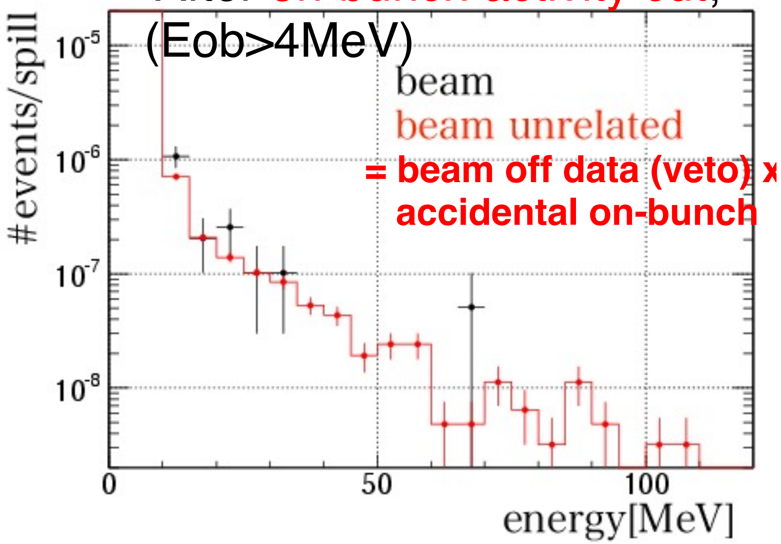
Before on-bunch activity cut



π(on bunch)→μ→e(fake prompt)

20<E<60MeV 1.75<t(ms)<4.65	"beam on" /spill/ 300kW	"beam off" /spill/ 300kW	subtraction
Before cosmic veto	$(1.68\pm0.03)\times10^{-4}$	$(1.64\pm0.03)\times10^{-4}$	$(4.0\pm4.2)\times10^{-6}$
After veto	$(1.58\pm0.09)\times10^{-5}$	$(1.52\pm0.09)\times10^{-5}$	$(0.6\pm1.3)\times10^{-6}$
After on-bunch cut	$(4.60\pm1.53)\times10^{-7}$	$(4.91\pm0.28)\times10^{-7}$ (expectation)	$(-0.3\pm1.6)\times10^{-7}$ (90%C.L. UL ; = <8 /4y/50t/MW)

After on-bunch activity cut; (Eob>4MeV)



BG measurement; Accidental

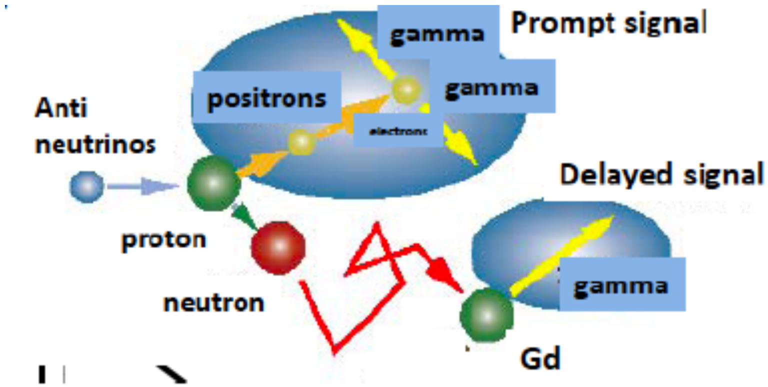
- Accidental background

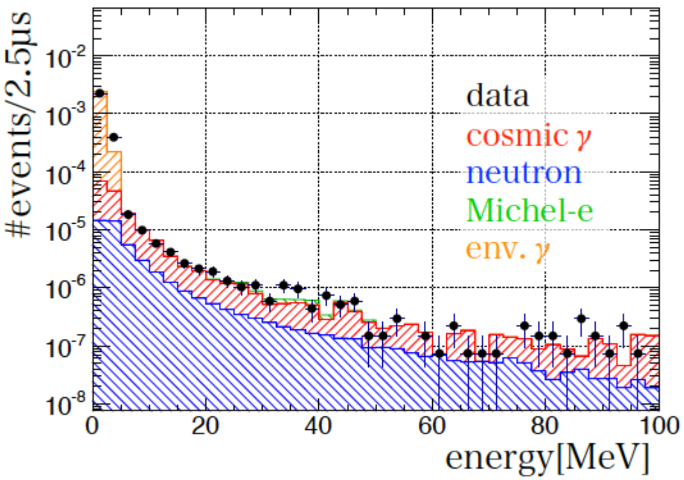
  $R_{acc}=R_{prompt} \times R_{delay} \times \Delta_{VTX} \times N_{spill}$

  -Δ_{VTX} :spatial correlation cut, rejection factor of 1/50

  -N_{spill} : number of spills 3×10^8/year

  -R_{prompt} , R_{delay} : BG for prompt and delay





-Apply cosmic charged veto (neutral; γ or neutron)
-PID measurement at Tohoku U NaI and NE213
(Rate is consistent within 6% Tohoku U and MLF)

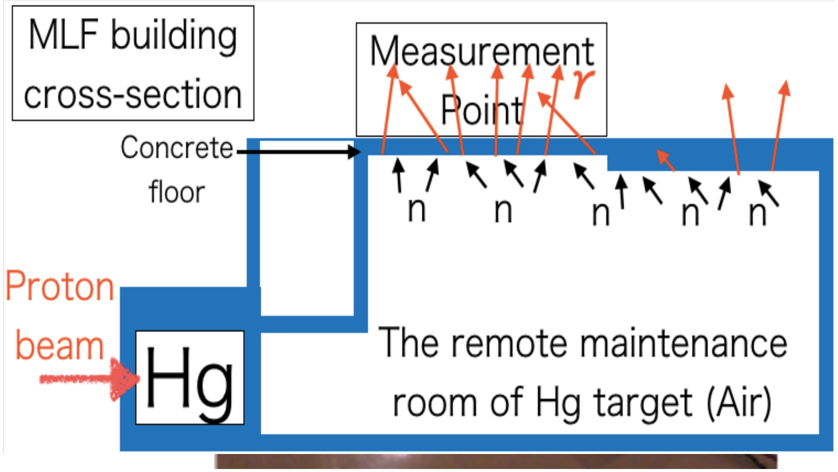
-γ, neutron are dominant BG in this prompt region.
γ:n =3:1(20<E<60MeV)

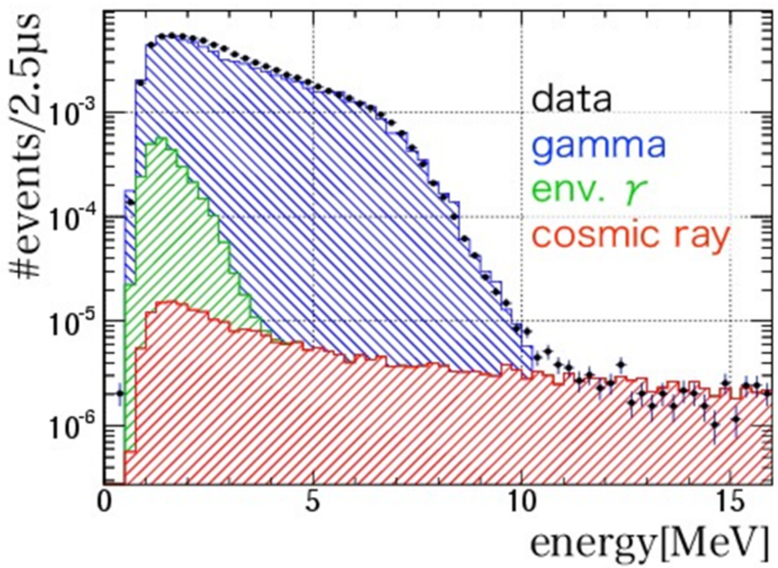
-Neutrons can be removed by PID in real experiment.
(rejection power is 100)

-γ should be reduced.

Accidental delayed: Beam Gamma

- We try to measure background at many location with small Scintillator MLF 3rd floor.
- A maintenance space under location.
- Assumption; slow neutrons are captured at celling(made by concrete) and emit the isotropic γ



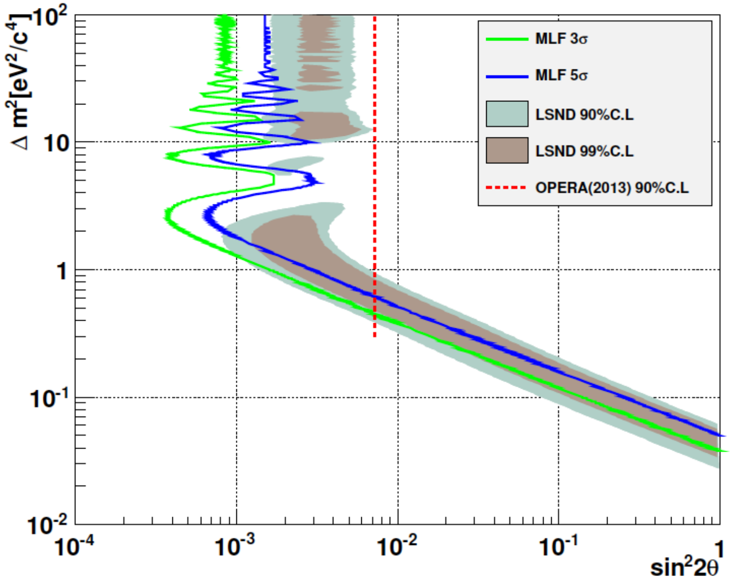


- This assumption makes good model of the γ production.
- **12.5 cm thick lead** under the detector is needed.

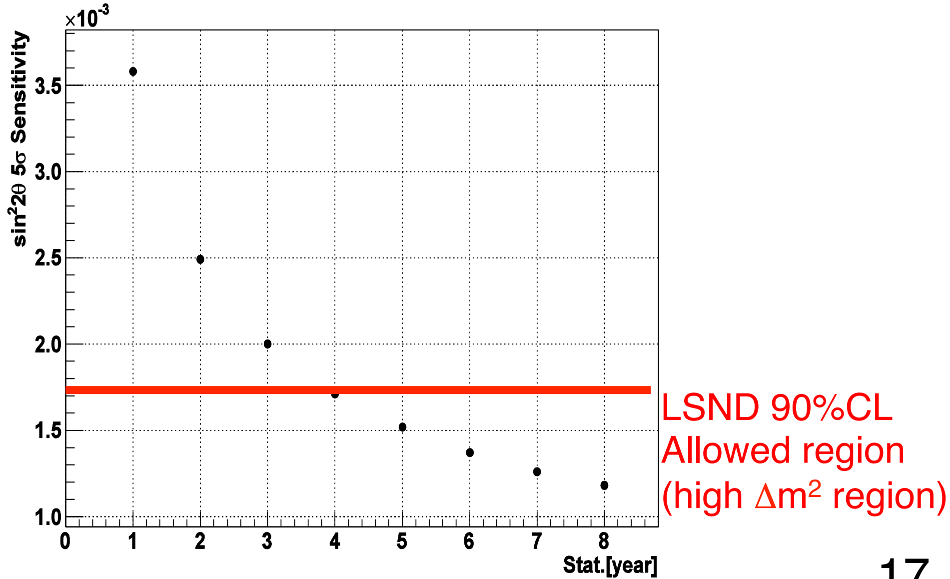
BKG and Sensitivity

Source	contents	Number of Event/50t/5y	comments
BG	ν_e from μ^-	237	L=24m
	$^{12}C(\nu_e,e_-)^{12}N_{g.s}$	16	
	Beam fast Neutrons	<13(90%Cl UL)	Based on meas.
	Beam fast(cosmic)	37	
	Accidental	32	Based on meas.
signal		480	Δm^2=3.0 $\sin^2\theta$=0.003
		342	Δm^2=1.2 $\sin^2\theta$=0.003

5σ, 3σ sensitivity



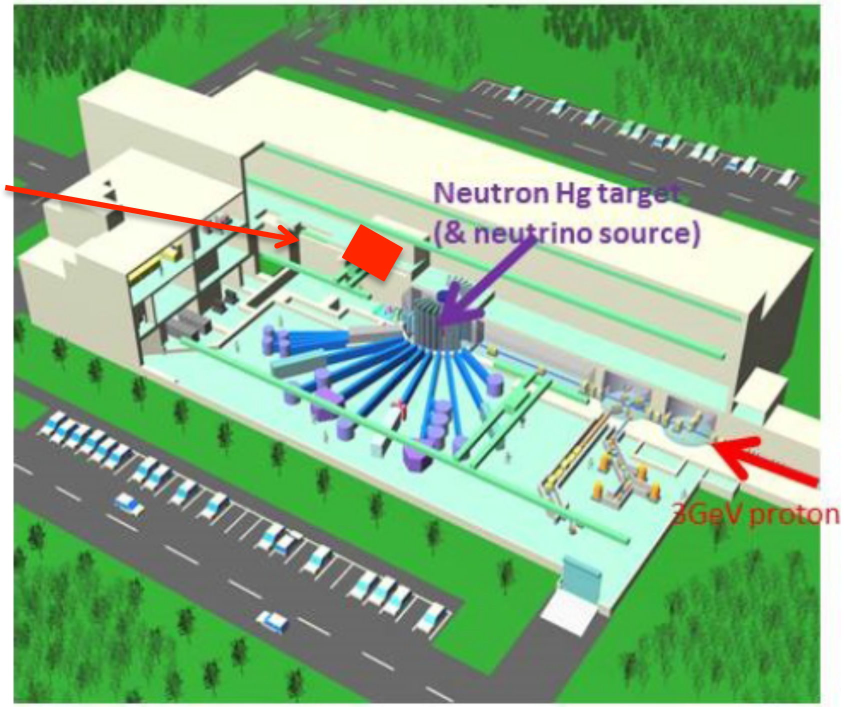
5σ sensitivity as a function of MW x years



Current Set-up Plan

- Experimental location
  → MLF 3F, J-PARC

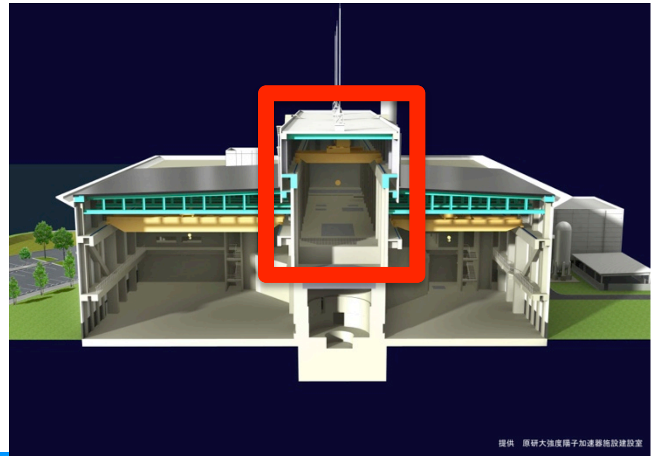
Detector
24m base line

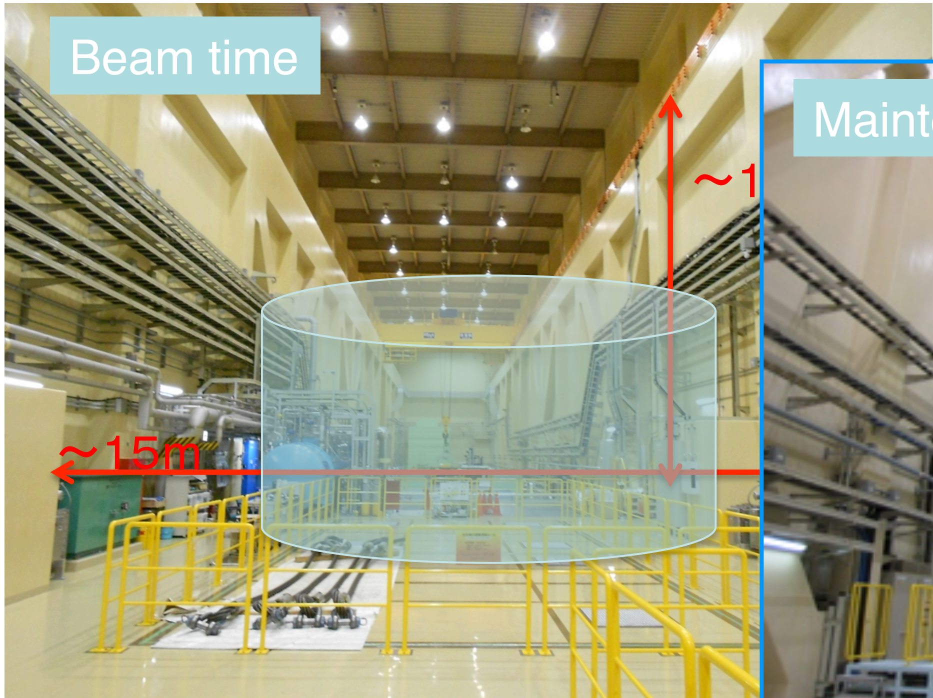


This location is candidate

MLF 3F floor

- Maintenance Area for facility





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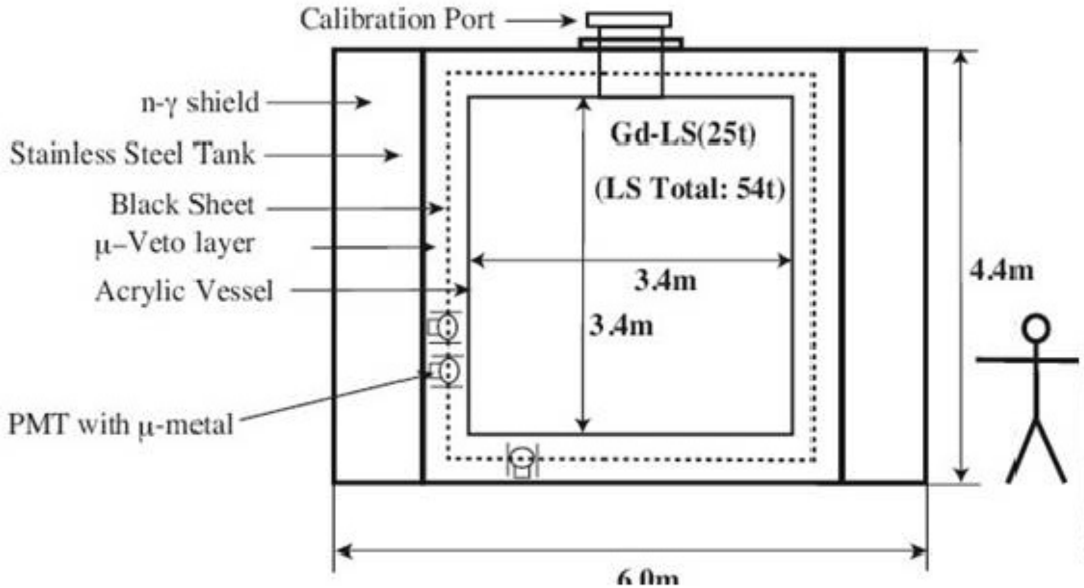

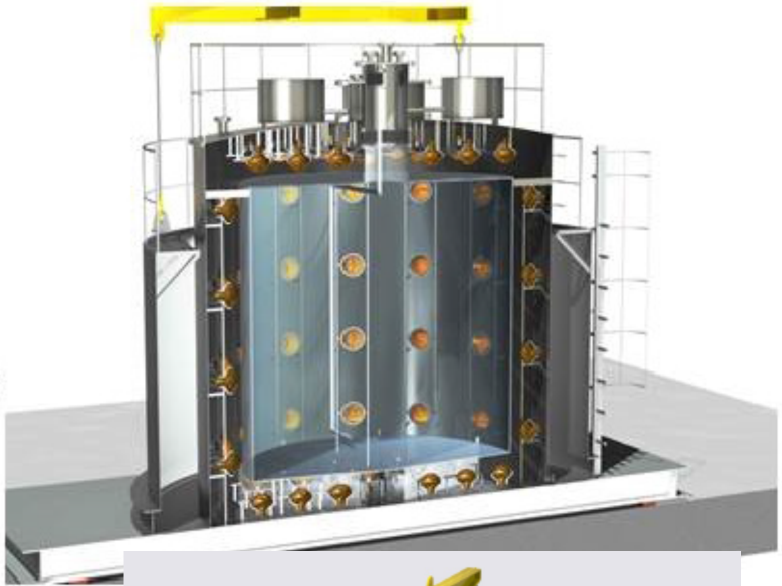

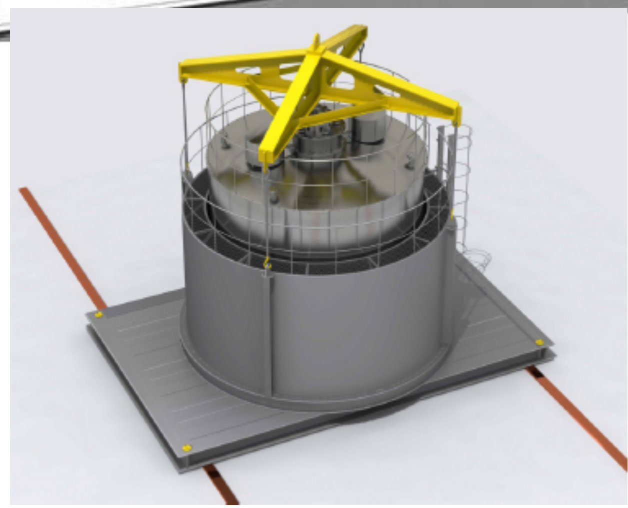

- Detector
  → Gd loading LS 50t
- Schedule
  → It takes two years to construct detector

P56 Collaboration

- Spokes Person; T. Maruyama(KEK)
- 34 members (… still evolving)
- 10 Institutions
- KEK, JAEA, RSNS Tohoku U, RCNP Osaka U, Kyoto U, Alabama U, BNL, Florida U, LANL, MIT
- 2 countries

&

- We invite more young physicists to join our efforts!

Including Young at Heart

November 25, 2014

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Summary

- P56 ; A Search for Sterile Neutrino at J-PARC MLF was proposed to 17th J-PARC PAC, Sep 2013
- First background measurement at No.2 Experimental hall , May 2013
- Second background measurement at MLF 3rd floor, June 2014. Background events is no problem for P56.
- For the experiments, it is necessary to discuss about experimental area, period and safety with the MLF. Currently, We start it.