2022/12/17

NA61++/SHINE WS

Neutron Beam and Neutrino Physics with 3 GeV proton at MLF

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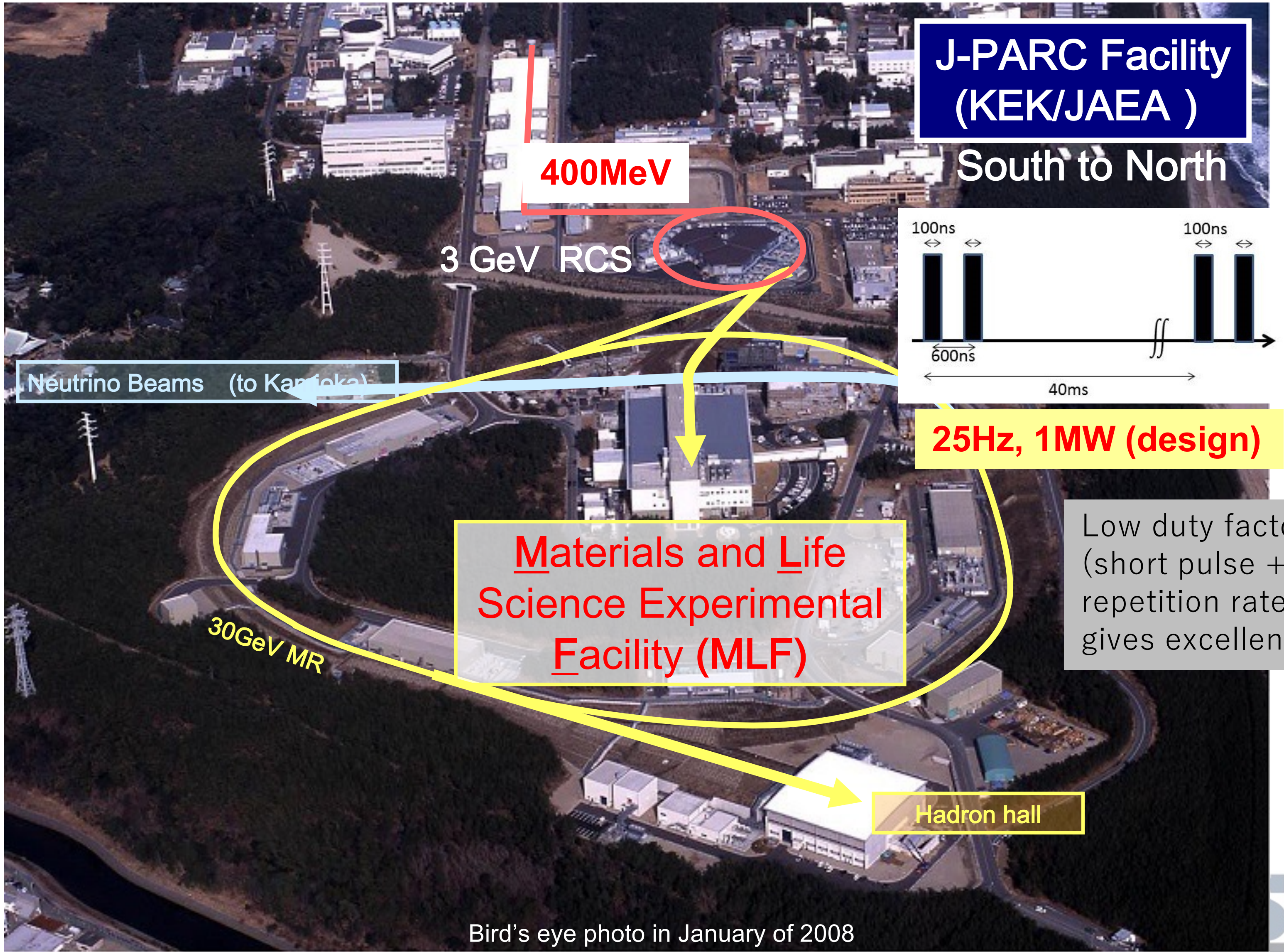
(JAEA; Japan Atomic Energy Agency) J-PARC

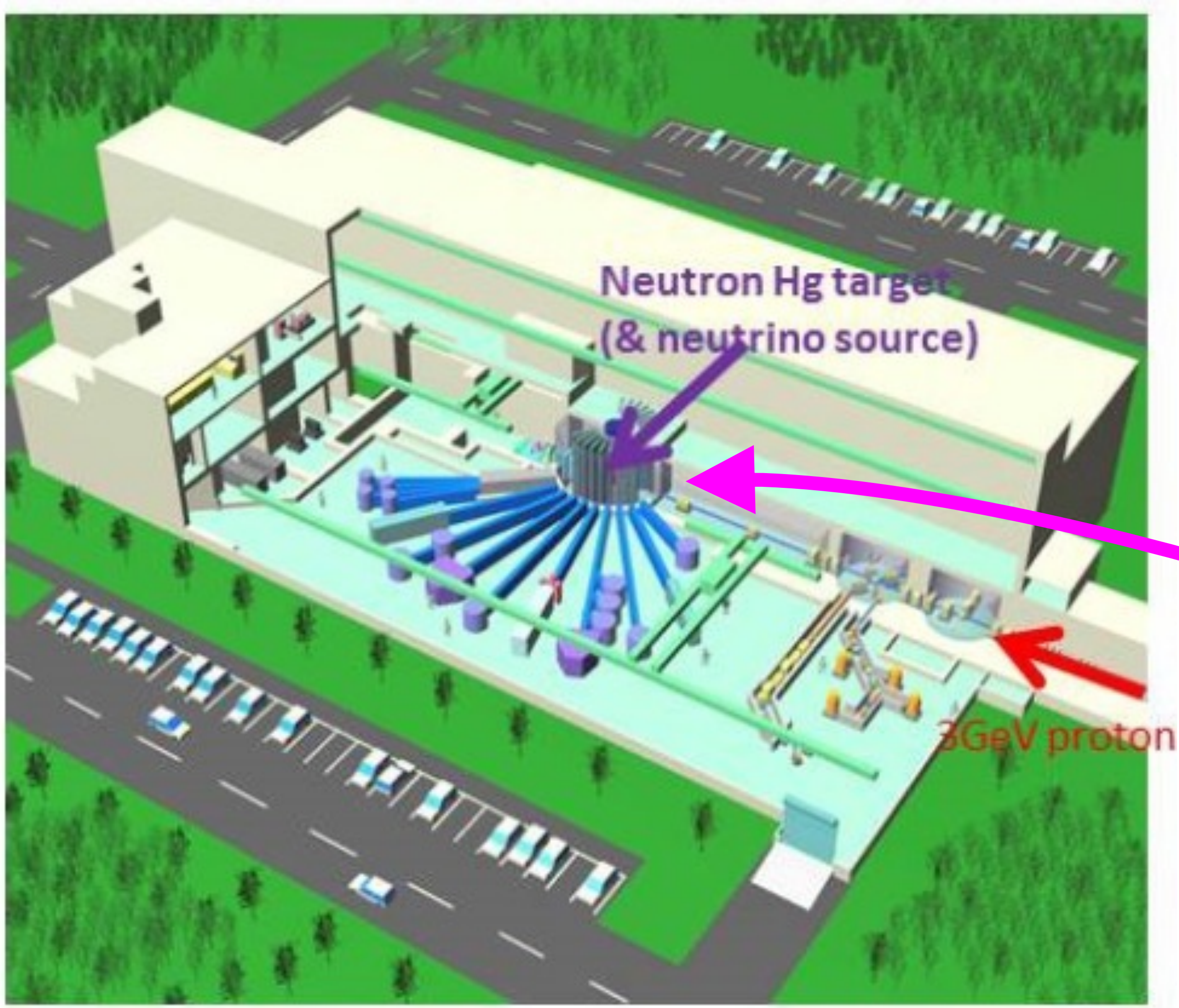
Experimental Site, J-PARC

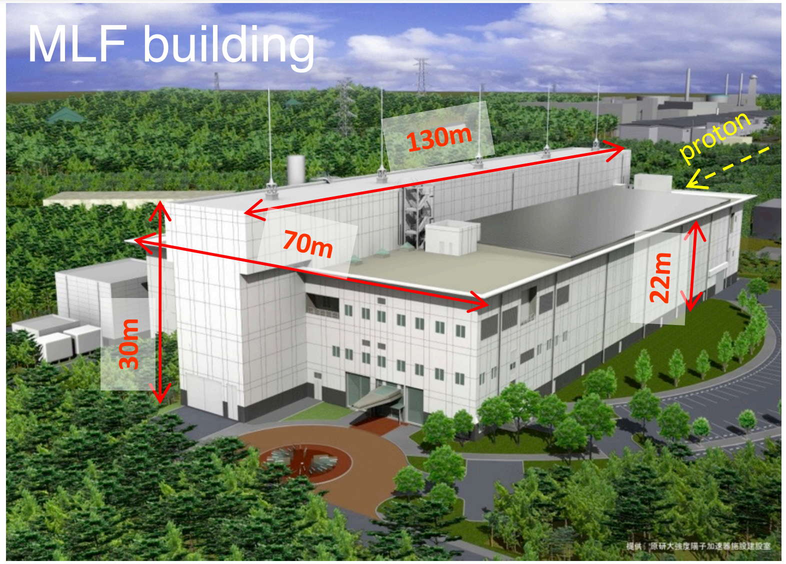


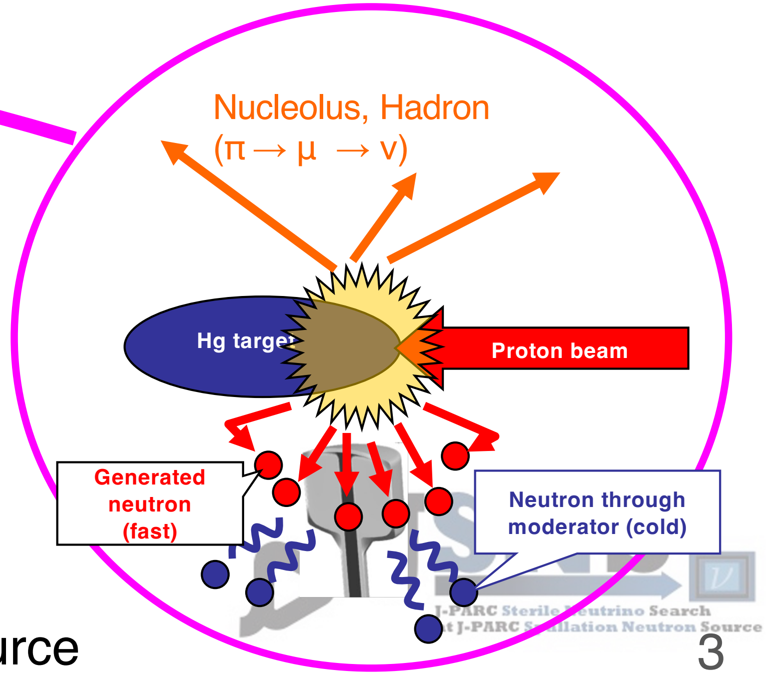
Bird's eye photo in January of 2008

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

MLF: Neutron and Muon source for Material and Life Science

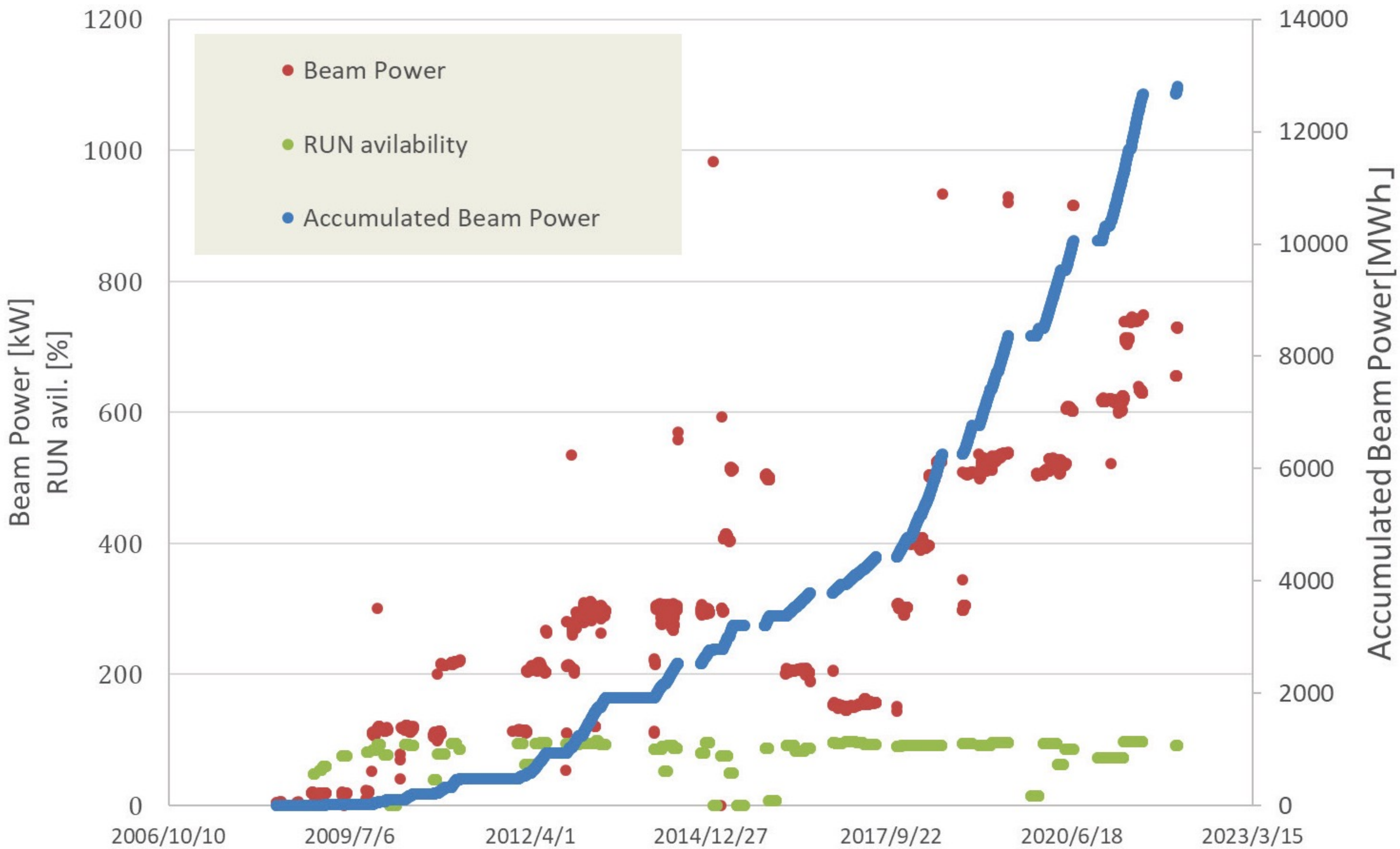




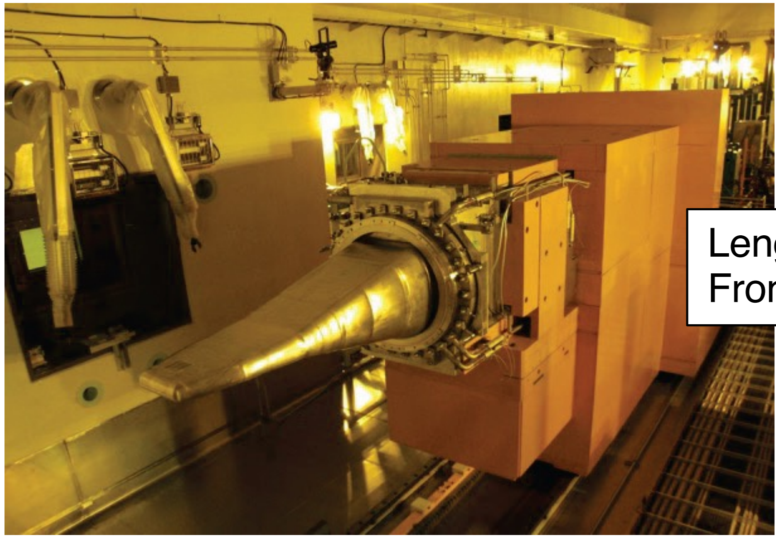


J-PARC Spallation Neutron Source

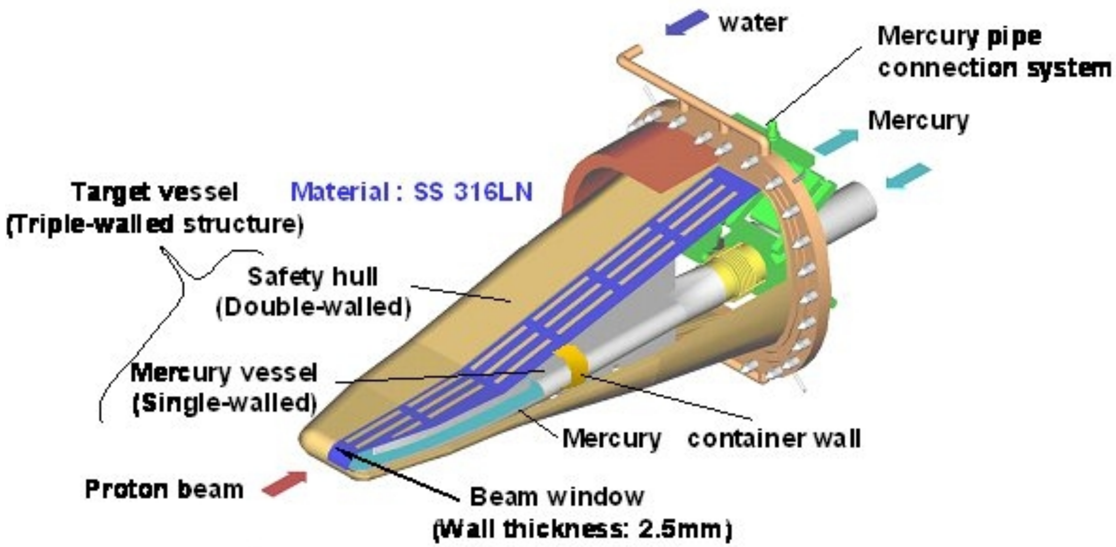
3 GeV Proton Beam



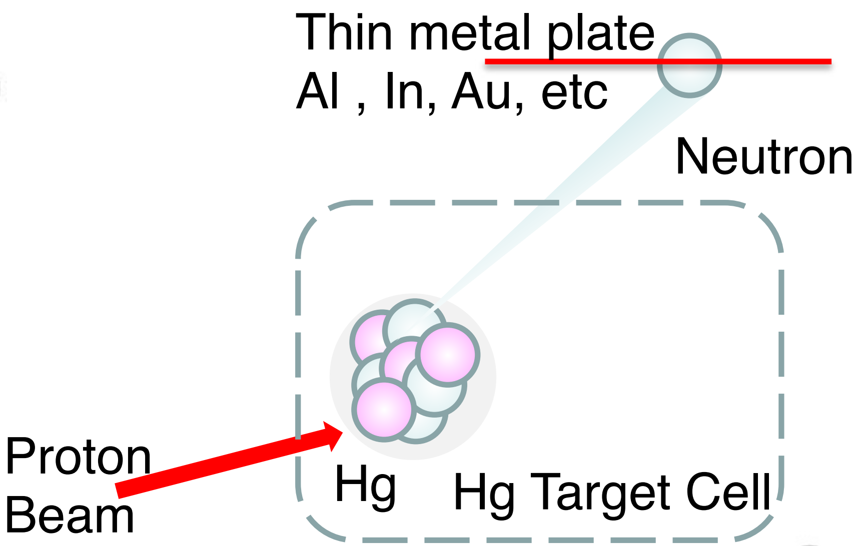
Neutron from Hg target



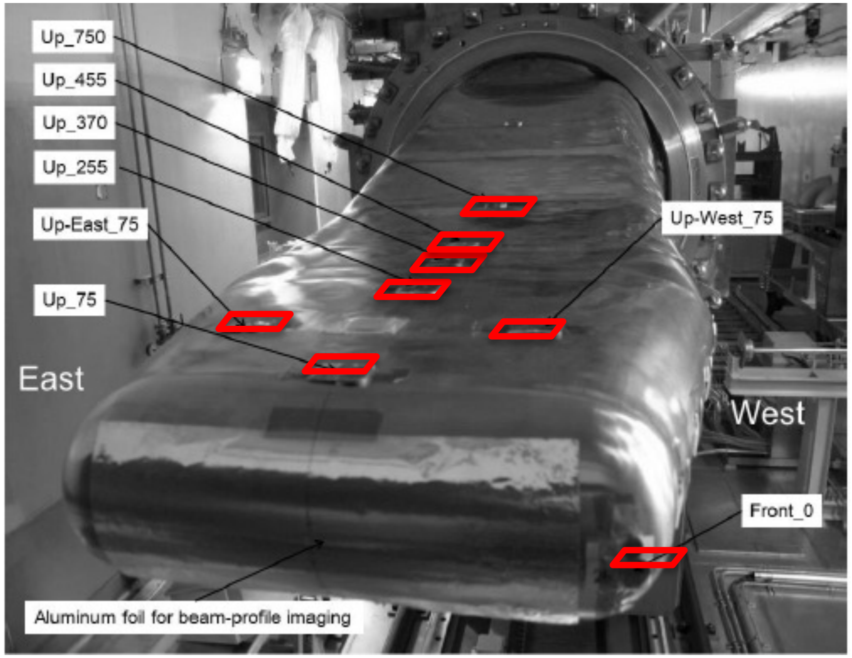
Length :2m
Front 0.3 (width) x 0.1 (Height) m



MLF measure the neutron flux



Motivation 1 to join NA61/SHINE low-E beamline



- The activities of the radioactive products were measured using Ge detector.
- Because of the time required for removal, only a relatively long half-life response can be measured.
- Self shield effect of mercury is large.
- Estimated results were in agreement within ±30%

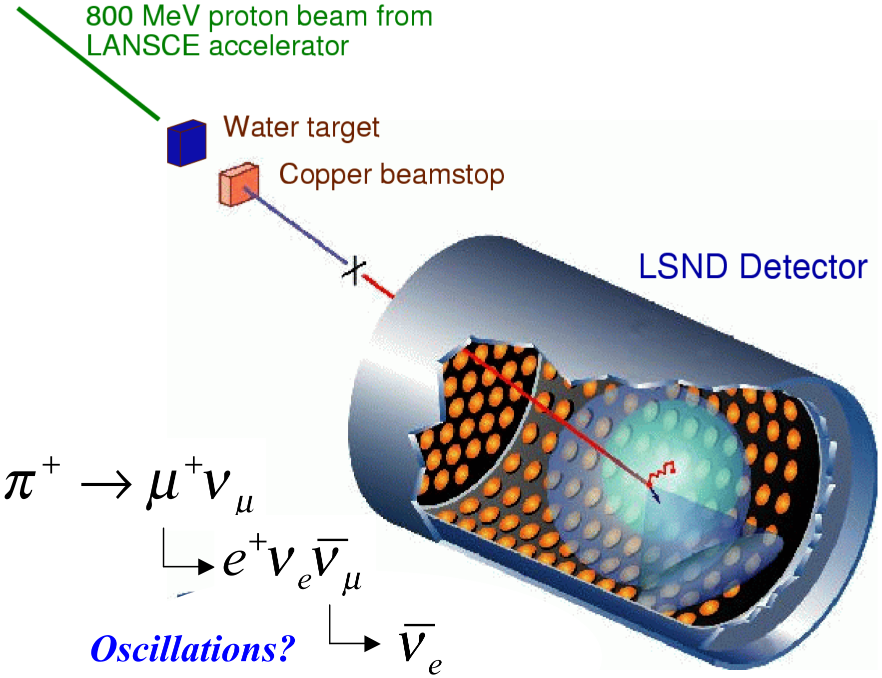
- MLF want to measure neutron production with thin mercury target.
- There is the 2nd MLF plan, then neutron production data is important to optimize for 2nd mercury target.

Motivation of JSNS^2 experiment

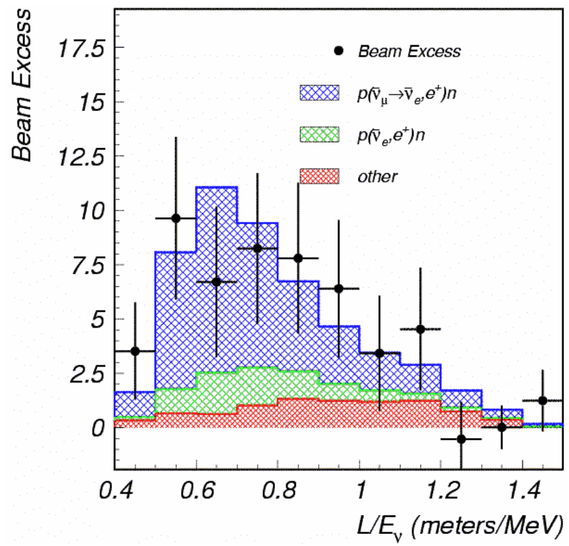
Direct test of the LSND result with modern technics

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

Appearance



$$\pi^+ \rightarrow \mu^+ \nu_\mu$$
$$\hookrightarrow e^+ \nu_e \bar{\nu}_\mu$$
$$\hookrightarrow \bar{\nu}_e$$



Los Alamos Meson Physics Facility,
LANL 1993-1998

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 $\nu_\mu \rightarrow \nu_e$

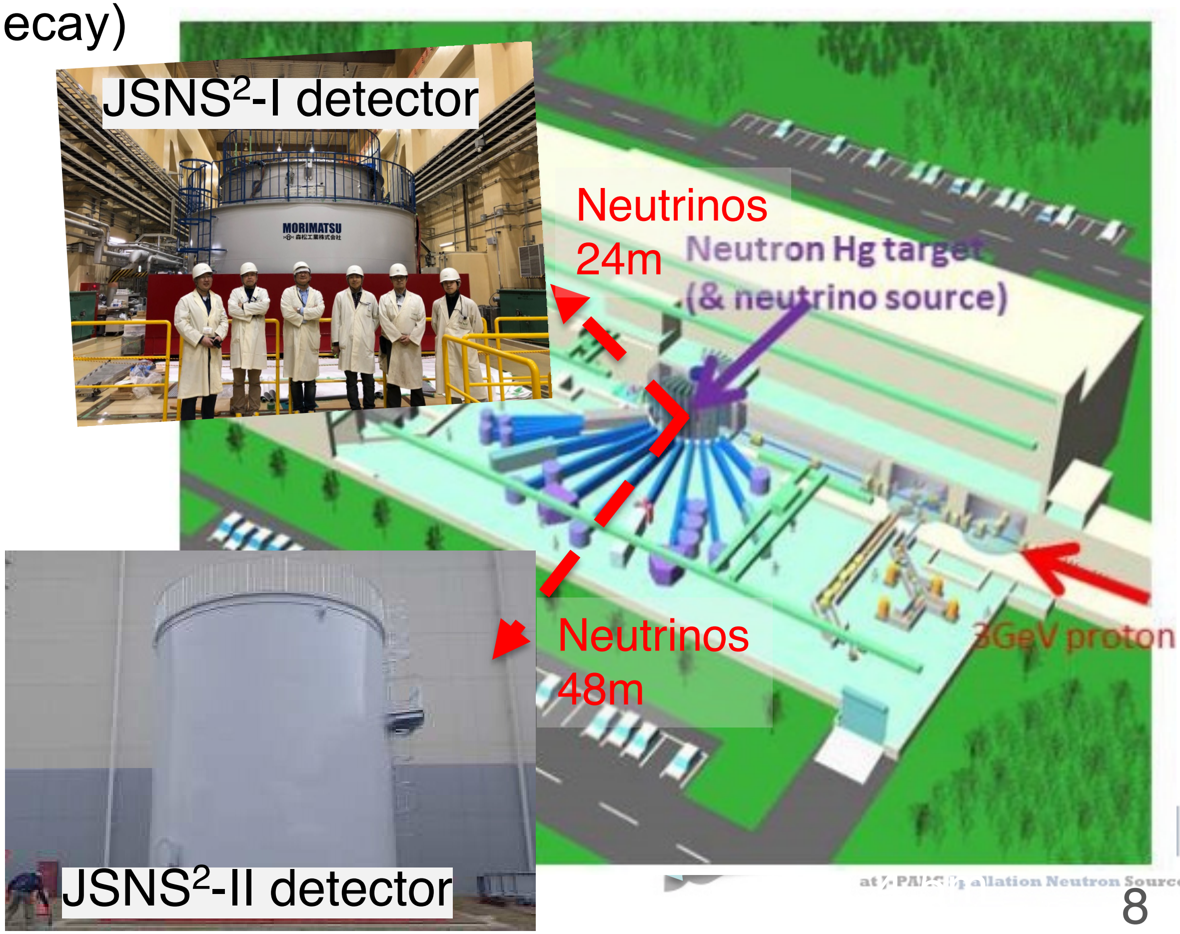
Sterile Neutrino search

JSNS^2 (J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source)

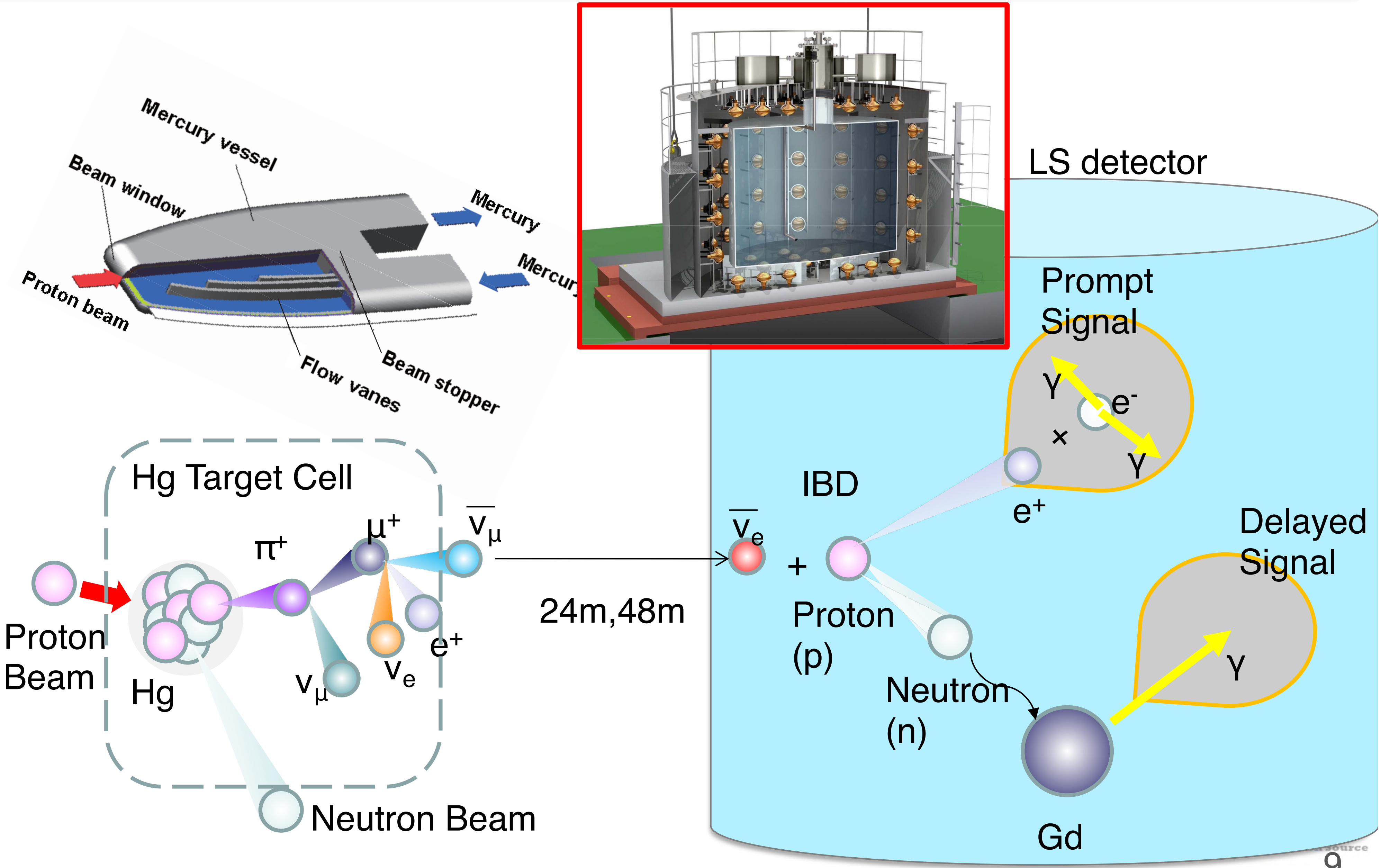
- Neutrino; μ^+(Decay at Rest) → $e^+ + \nu_e + \bar{\nu}_\mu$
- Target ; Gd-loaded + DIN Liquid Scintillator
- Detection; IBD(Inverse Beta Decay)

- JSNS^2-I; Operating
  - Construction; 2018 -2019
  - Setting facility area
    Bring out during Maintenance term
  - 1st Run; 2020
  - Physics Run ;2021,2022

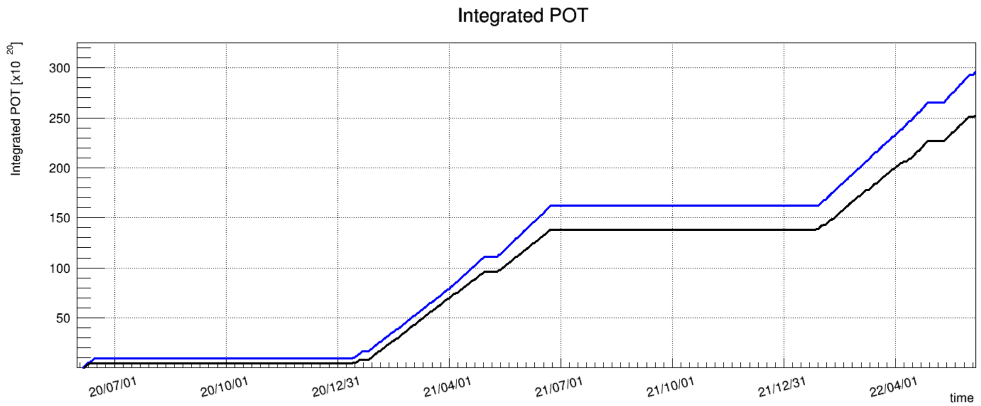
- JSNS^2-II; Constructing
  - Construction; 2021 –
  - Setting out side of facility
  - Schedule
    2022; Fin to construct
    2023; Fill LS,
    Run



Neutrino; source and detection

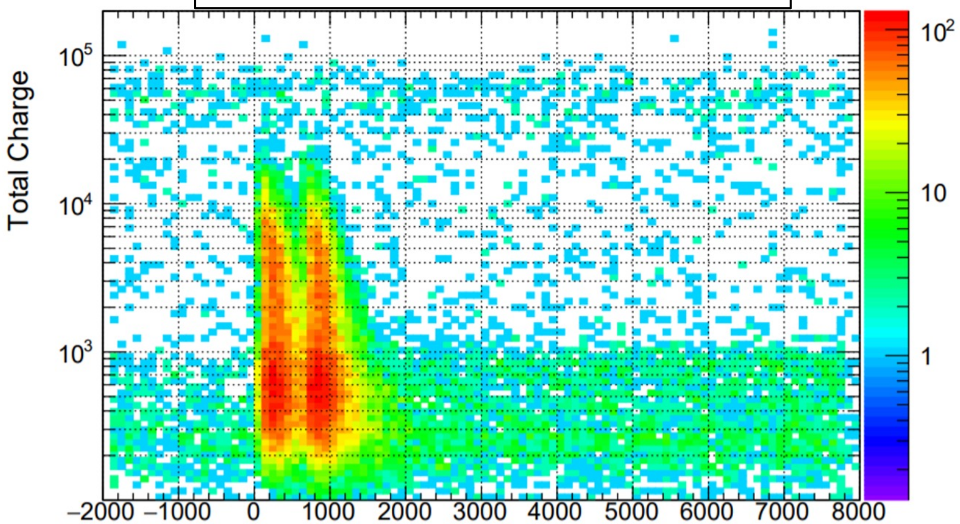


Status of JSNS^2 – I detector



- JSNS^2-I; Operating
  - 2020 Jun – 2022 Jun
  - Total POT; Acquired 2.77 x 10^{22}

2 proton bunch structure

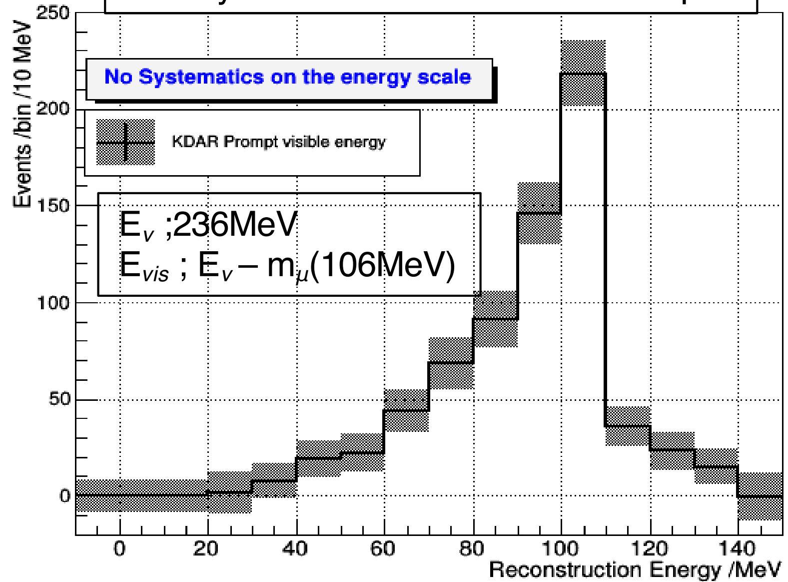


Total charge vs time

KDAR $K^+ \rightarrow \mu^+ + \nu_\mu$

Prompt $\nu_\mu + {}^{12}C \rightarrow X + \mu^-$

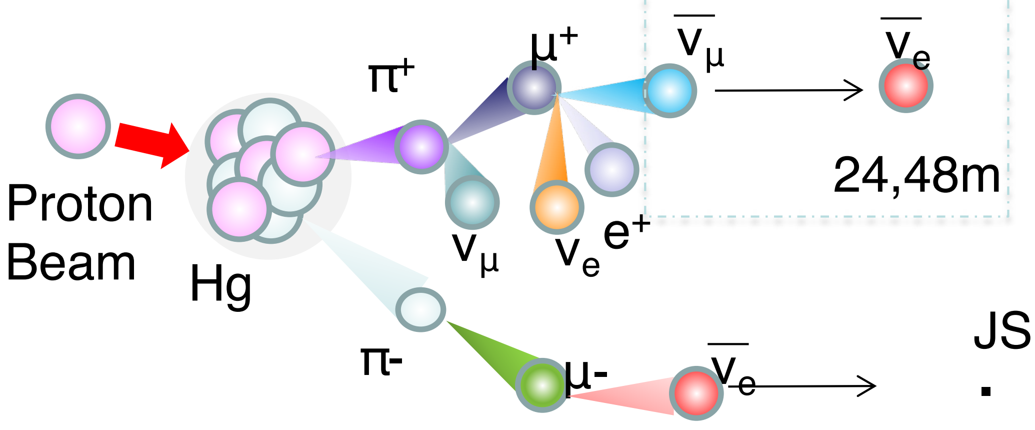
Delayed $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$



The detector performed as expected, and recorded a variety of data.

Neutrino flux from mercury target

- No data; 3 GeV proton injected mercury.

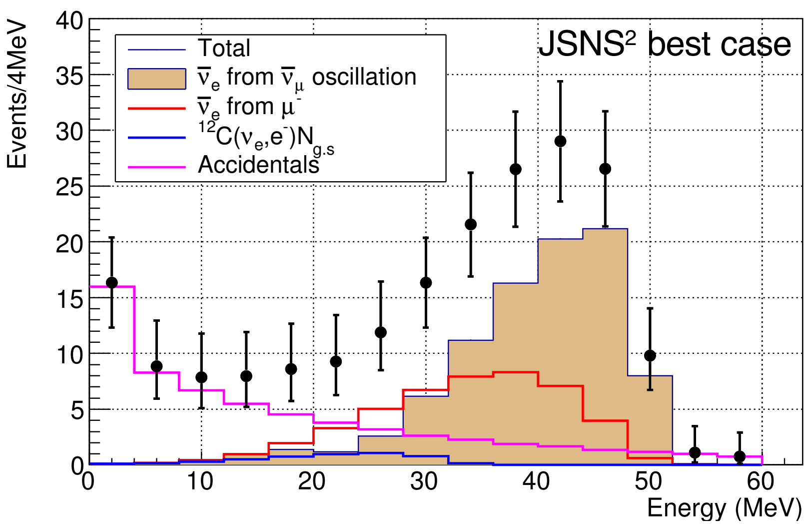


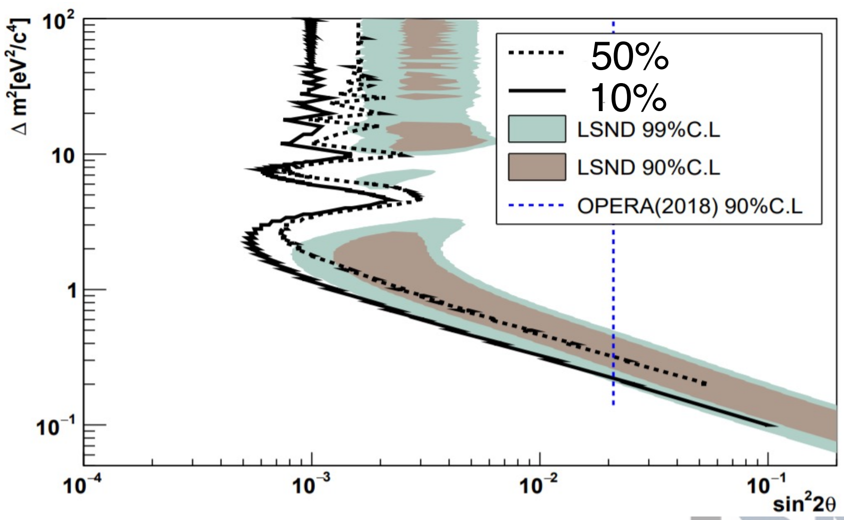
JSNS^2 target

- To measure μ+ decay, ν_e+C-> e+N_{gs}
  It can reduce error of flux (10%)

JSNS^2 Background

- No calibration with measurement(50%)





If error can reduce to 10%, Sensitivity is improved greatly

Comparison of MC Models

Various MCs are studied

- FLUKA (current default)
  - ✓ Targe simulation only
- Geant4
  - ✓ V9.4p04 with QGSP_BERT
- PHITS
  - ✓ Most precise geometry
  - ✓ Default MLF design

⇨ 1.2 – 2 times difference is obtained as MC uncertainty

FLUKA

	$\pi^+ \to \mu^+ \to \bar{\nu_\mu}$	$\pi^- \to \mu^- \to \bar{\nu_e}$
π/p	6.49×10^{-1}	4.02×10^{-1}
μ/p	3.44×10^{-1}	3.20×10^{-3}
ν/p	3.44×10^{-1}	7.66×10^{-4}
ν after $1\mu s$	2.52×10^{-1}	4.43×10^{-4}

Geant4

	$\pi^+ \to \mu^+ \to \bar{\nu_\mu}$	$\pi^- \to \mu^- \to \bar{\nu_e}$
π/p	5.41×10^{-1}	4.90×10^{-1}
μ/p	2.68×10^{-1}	3.90×10^{-3}
ν/p	2.68×10^{-1}	9.34×10^{-4}
ν after $1\mu s$	1.97×10^{-1}	5.41×10^{-4}

PHITS

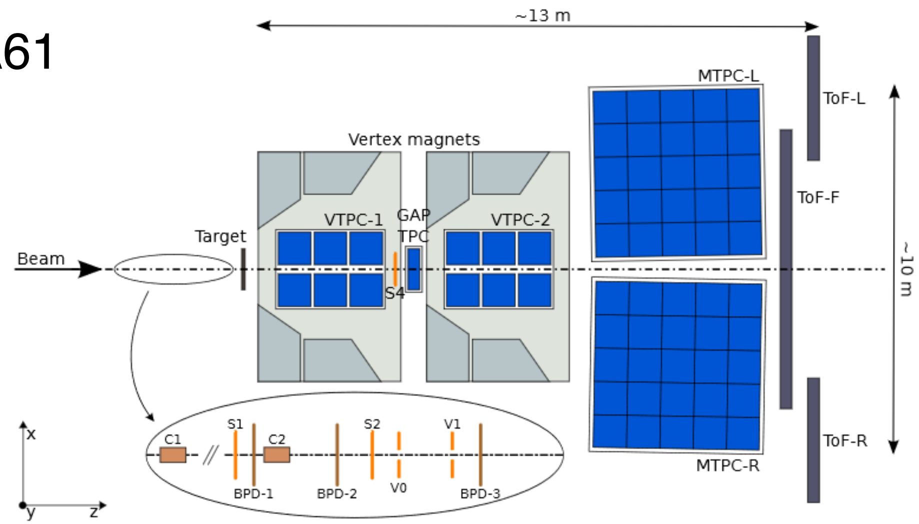
	$\pi^+ \to \mu^+ \to \bar{\nu_\mu}$	$\pi^- \to \mu^- \to \bar{\nu_e}$
π/p	6.93×10^{-1}	8.02×10^{-1}
μ/p	4.46×10^{-1}	2.76×10^{-2}
ν/p	N/A	N/A
ν after $1\mu s$	N/A	N/A

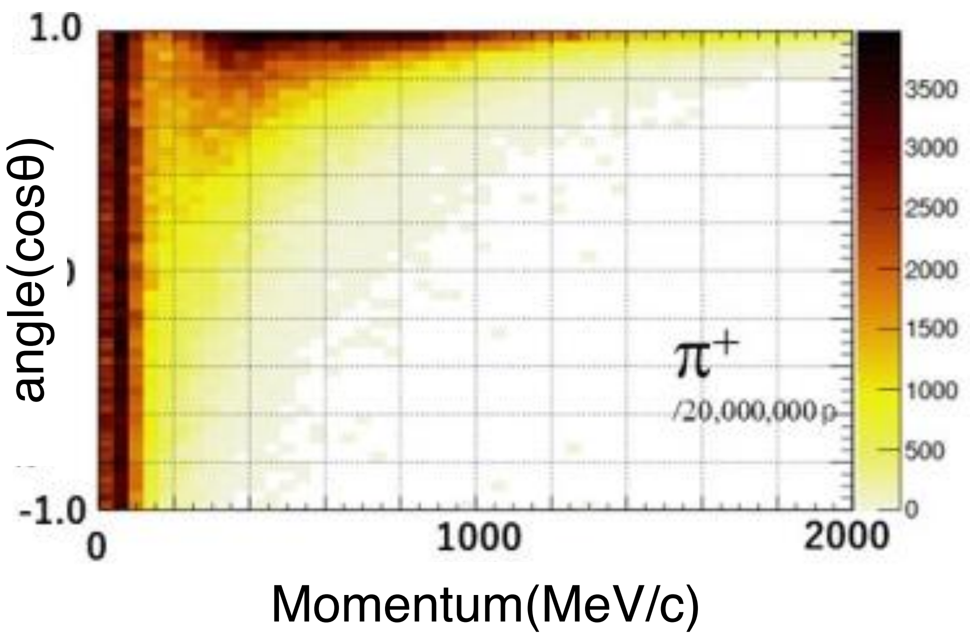
Need to cross-section data of 3GeV Proton + Mercury target

JSNS[2]
J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source

Set-up

NA61





- Beam condition
  Proton beam; 3(1,5,7)GeV

1) JSNS^2 Neutrino Flux

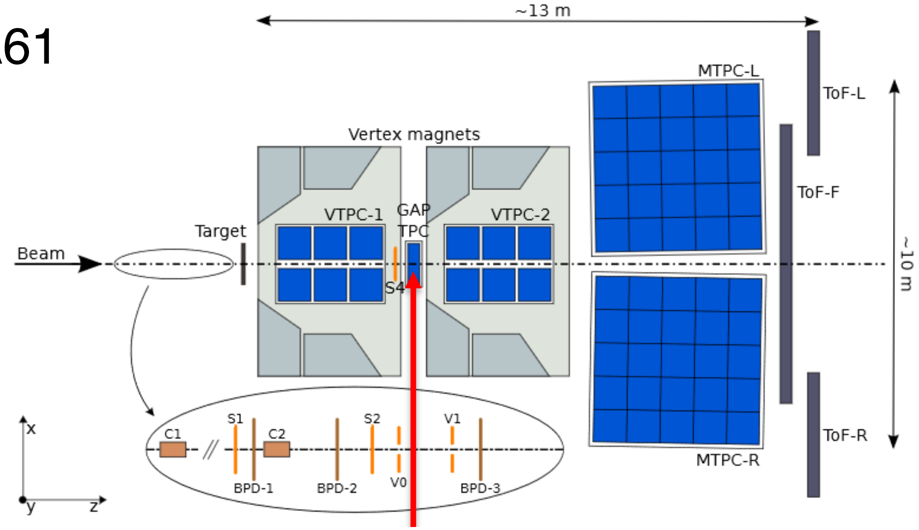
- P + Hg -> π, K cross section
  Using NA61 detector
  + thin Hg target

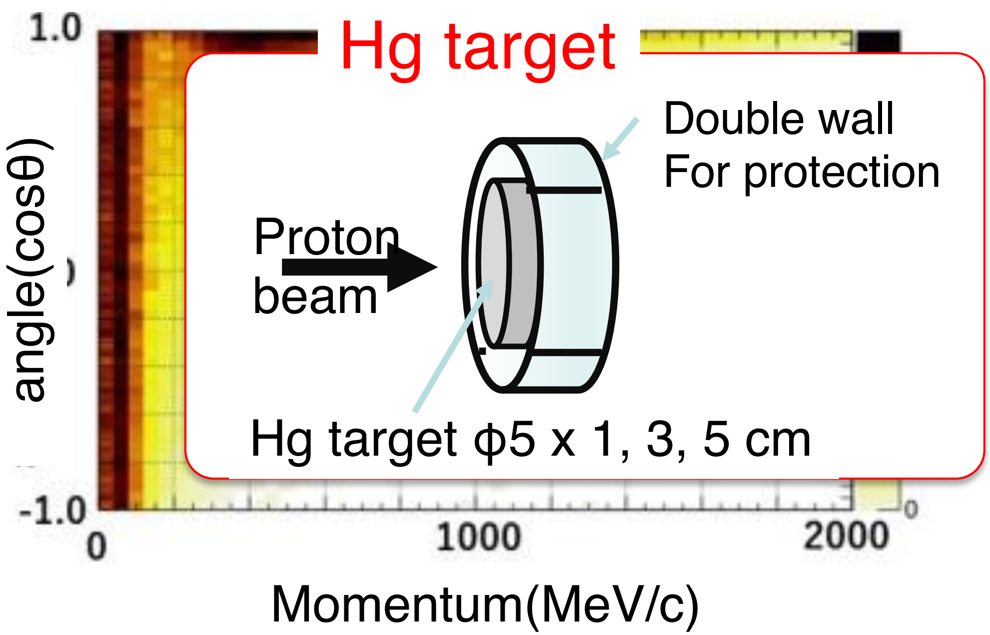
2) MLF Neutron production

- Set film around target. Then gamma spectrum of activated film is measured with our Ge-detector
- Set neutron detector if event rate is low.

Set-up

NA61





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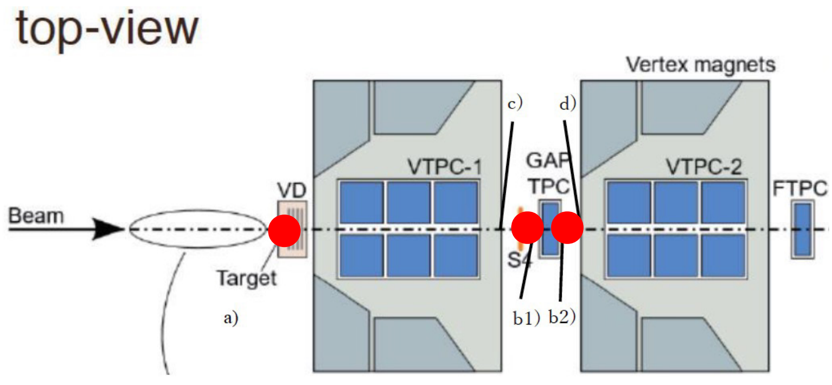
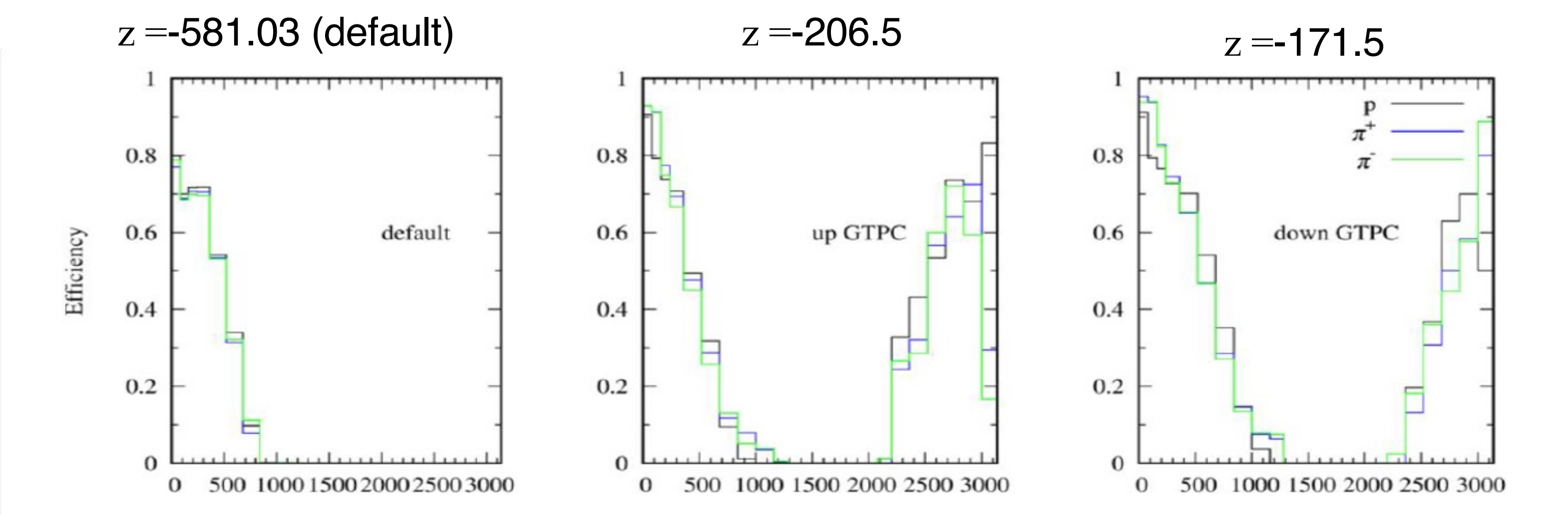
JSNS2
J-PARC Sterile Neutrino Search at J-PARC Spallation Neutron Source

Preliminary;G4 Simulation

- Detector NA61/SHINE default
- Beam Proton, 3.82 GeV/c, pencil
- Target Carbon (2.5 x 2.5 x 2.0 cm)
- Positions Default + 2 pos near GTPC
- Magnetic Field setting 0 – 160 GeV





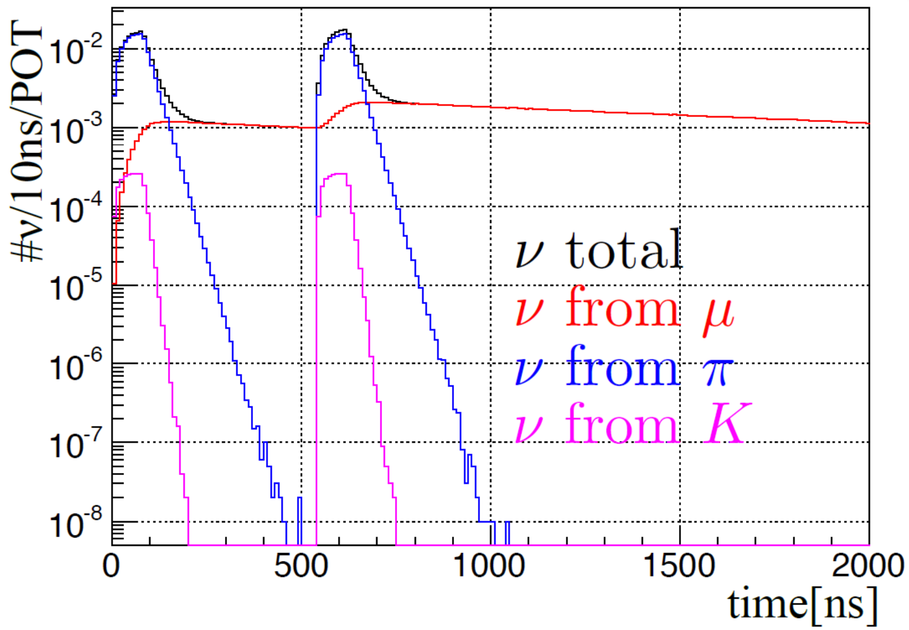
Measured by up GTPC and down GTPC, it covers 50% of the solid angles.

Summary

- 3 GeV proton experiment for MLF J-PARC
- MLF needs the neutron production data using 3GeV proton to improve the quality of neutron beam.
- JSNS^2 (the sterile neutrino search at MLF,J-PARC) requires the Pion, Kaon data to improve neutrino flux.
- For the improvement of beam and physics at MLF J-PARC, we want to take data using 3 GeV proton beam with mercury.

Thanks!

Back up



Direct test of LSND

- Similar Neutrino
- Better timing
- Similar baseline
- Better signal efficiency