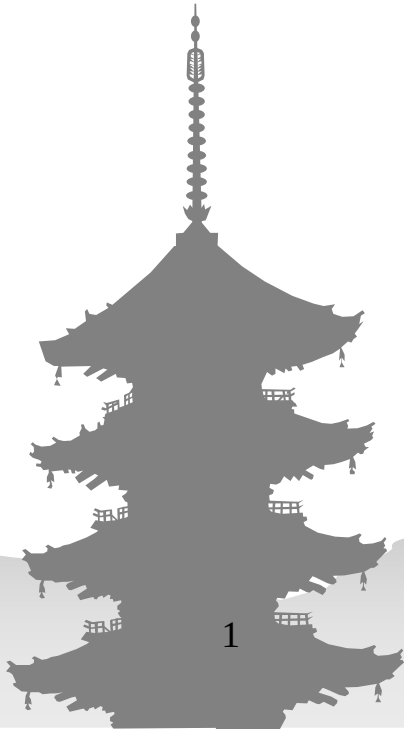
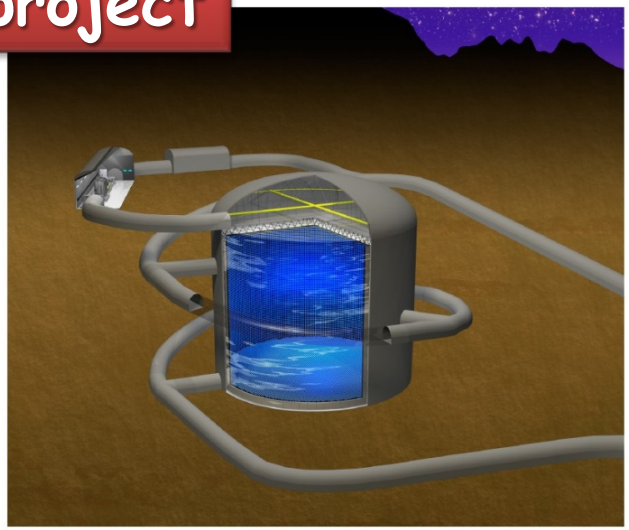
IN2P3 contributions to the Japanese neutrino program T2K, T2K-II, Hyper-K and Super-K

Michel Gonin
For the LLR and LPNHE neutrino groups

IN2P3 Scientific Council 28/06/2018



Hyper-Kamiokande project



NEUTRINO 2018 :

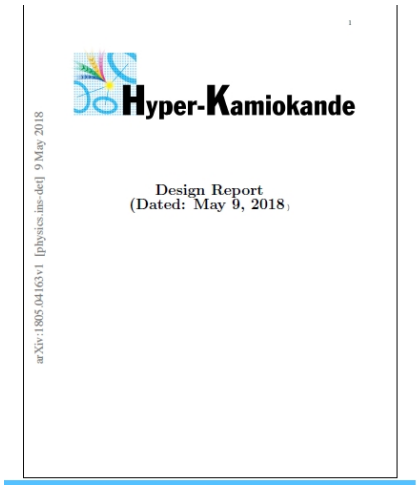
Toward construction start

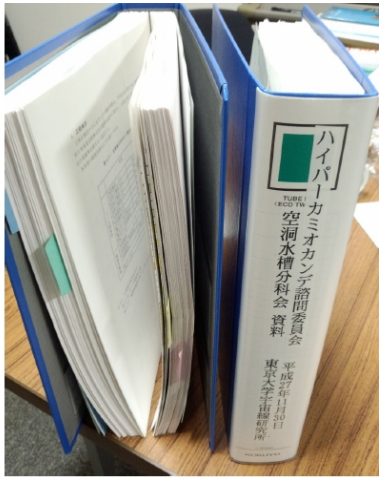
- MEXT lists the HK in its Roadmap2017
  - FY2018 budget includes 10 million JPY which can be used for Hyper-K
  - Next is approval for starting construction
- UTokyo is making all efforts to get funded with strong leadership of the president Gonokami.
  - Hyper-K is requested to MEXT as a top priority project
  - UTokyo launched "Next Next-Generation Neutrino Science Organization"
- External Advisory Committee urges the proto-collaboration to make a **design** and **organization** for construction start

- Important potential for discovery
- Well known technologies for the far and near Hyper-K detectors.
- Well defined timescale for the Hyper-K project once construction has began.
- Need for international contributions.

Hyper-K and DUNE will be complementary

Design Report has been released recently





"Hyper-Kamiokande Design Report", arXiv:1805.04163
May 9, 2018. 333 pp.

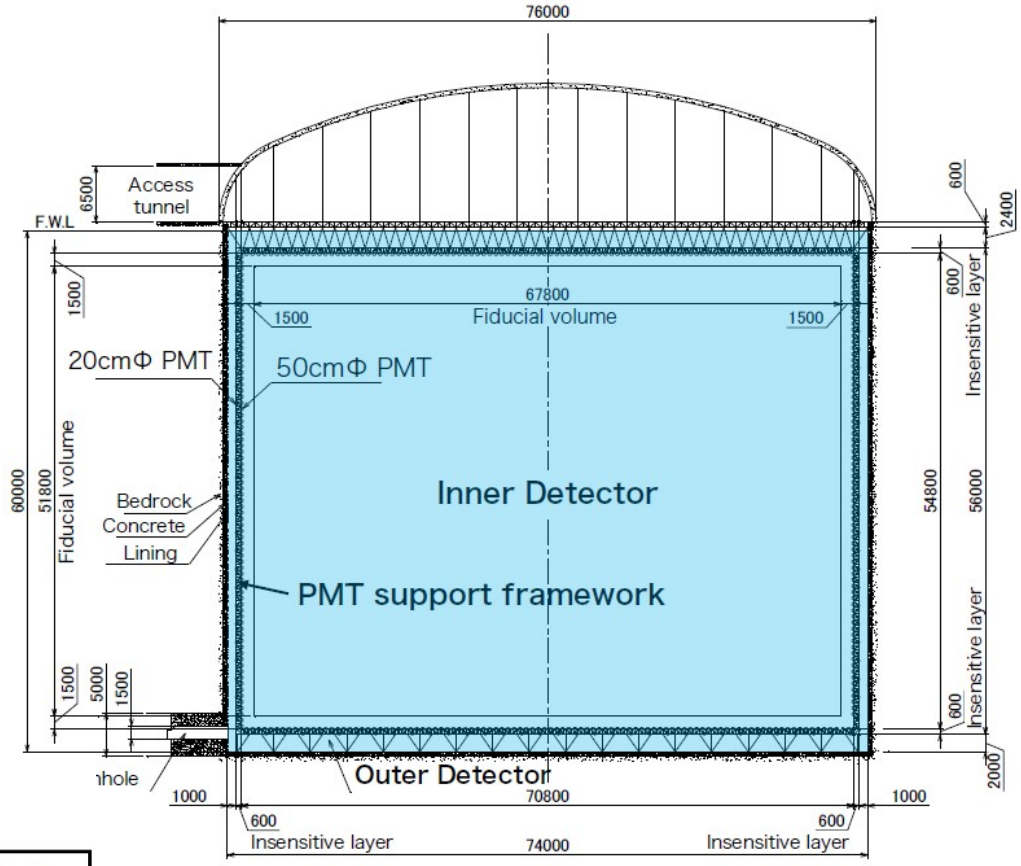
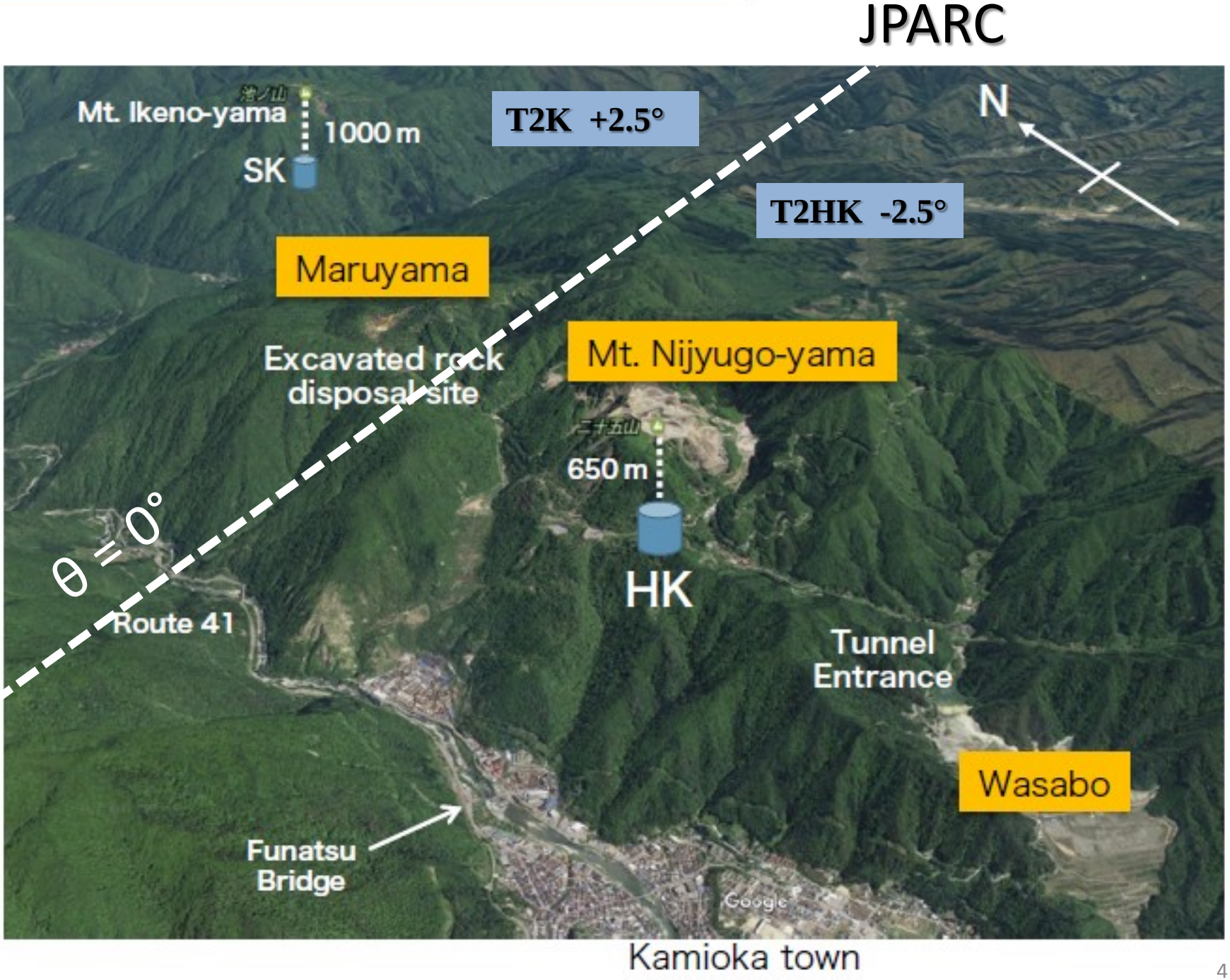


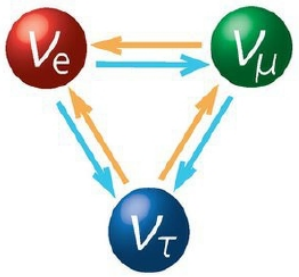
Figure 1: Schematic view of the Hyper-Kamiokande detector

Hyper-K Detector

	Super-K	Hyper-K (1st tank)
Site	Mozumi	Tochibora
Number of ID PMTs	11,129	40,000
Photo-coverage	40%	40% (×2 sensitivity)
Mass / Fiducial Mass	50 kton / 22.5 kton	260 kton / 187 kton

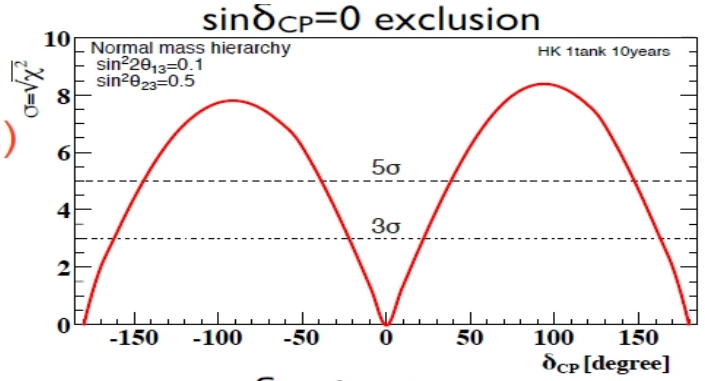

JPARC
Mt. Ikeno-yama
1000 m
SK
T2K +2.5°
N
T2HK -2.5°
Maruyama
Excavated rock disposal site
Mt. Nijyugo-yama
650 m
HK
θ = 0°
Route 41
Tunnel Entrance
Wasabo
Funatsu Bridge
Google
Kamioka town

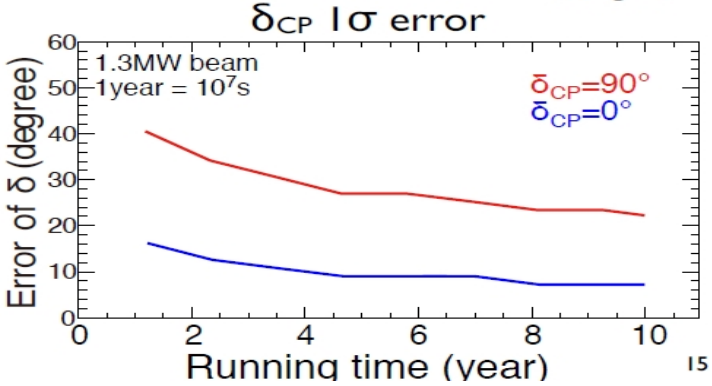
T2HK Oscillation physics



CPV studies

- Exclusion of $\sin\delta_{CP}=0$
  - 8σ for δ=-90° (T2K best fit)
  - 80% coverage of δ parameter space for CPV discovery w/ >3σ
  - Test of CPV origin
- δ_{CP} precision measurement
  - 22° for δ=-90°
  - 7° for δ=0°





Expected number of events for electron neutrinos and electron anti-neutrinos

		signal		BG						Total
		$\nu_\mu \to \nu_e$	$\bar{\nu}_\mu \to \bar{\nu}_e$	ν_μ CC	$\bar{\nu}_\mu$ CC	ν_e CC	$\bar{\nu}_e$ CC	NC	BG Total	
ν mode	Events	1643	15	7	0	248	11	134	400	2058
	Eff.(%)	63.6	47.3	0.1	0.0	24.5	12.6	1.4	1.6	—
$\bar{\nu}$ mode	Events	206	1183	2	2	101	216	196	517	1906
	Eff. (%)	45.0	70.8	0.03	0.02	13.5	30.8	1.6	1.6	—

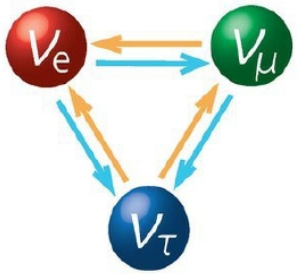
T2HK Oscillation physics

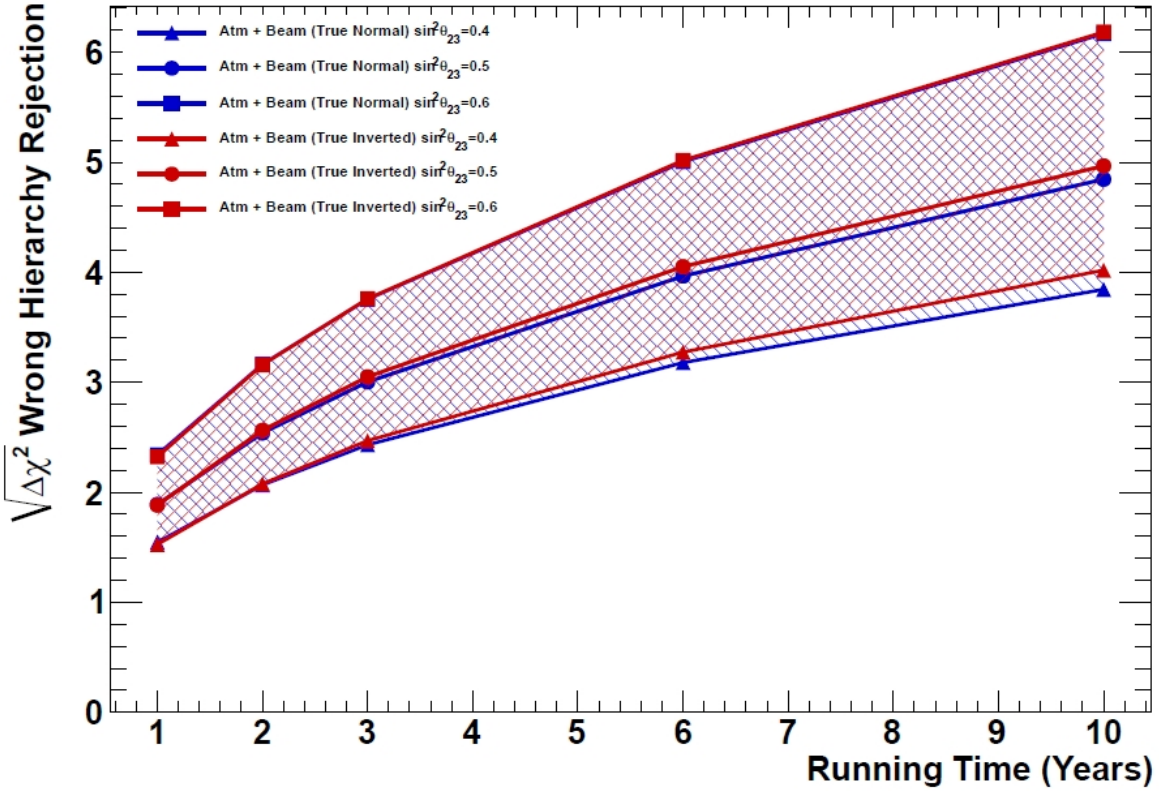
Mass hierarchy determination

Combination of T2HK and HK atmospheric data

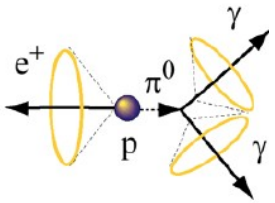
Expected sensitivity to the mass hierarchy as a function of time assuming $\sin^2\theta_{23} = 0.4$ (triangle), 0.5 (circle), and 0.6 (square)

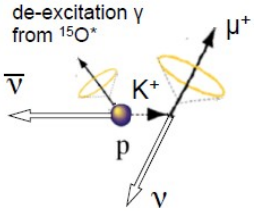
Blue (red) colors denote the normal (inverted) hierarchy.

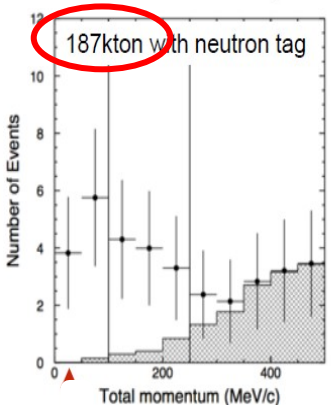


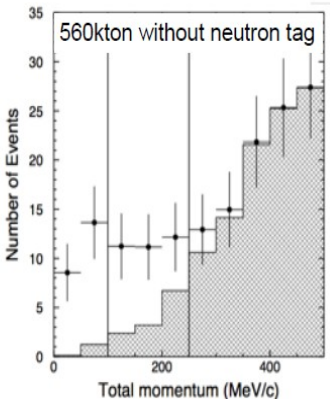


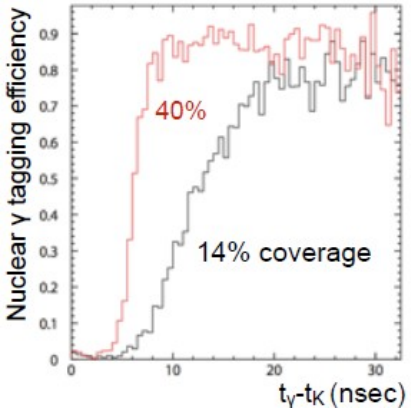
Hyper-K proton decay physics

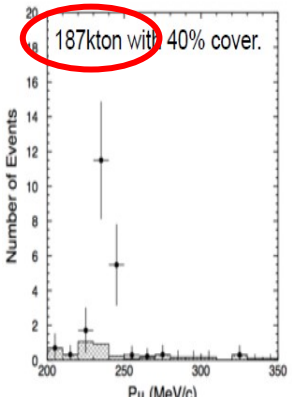


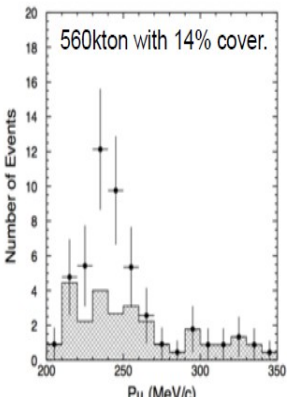


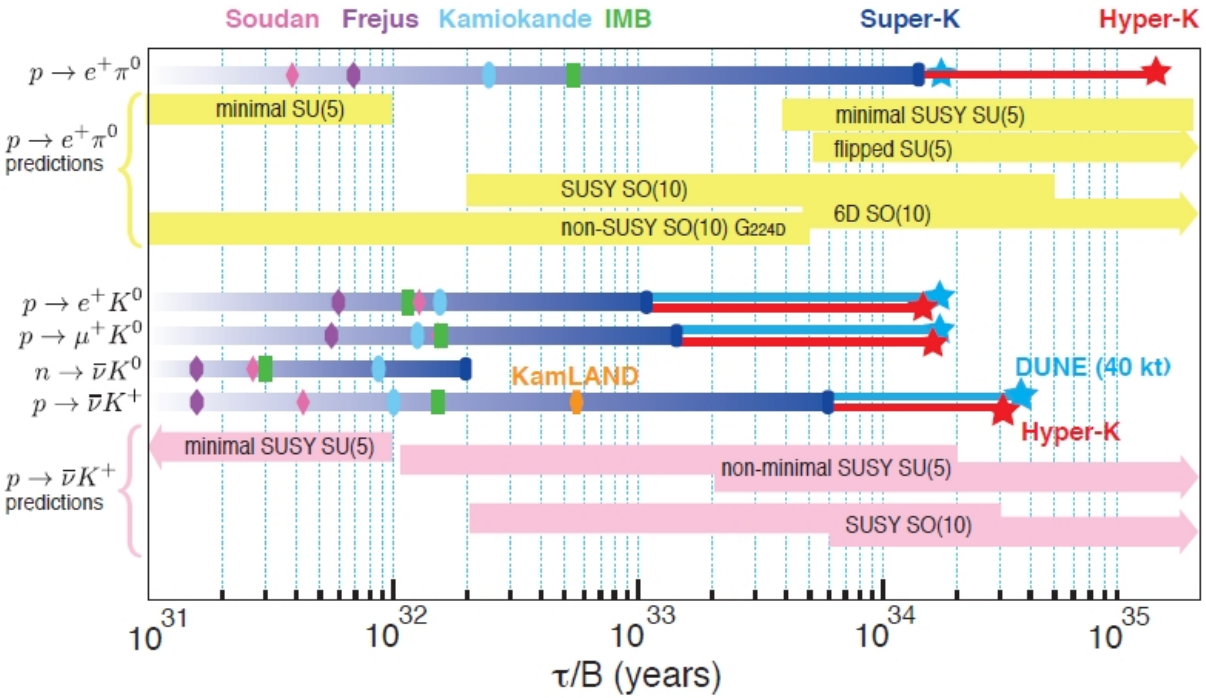












Hyper-K IN2P3 proposed contributions

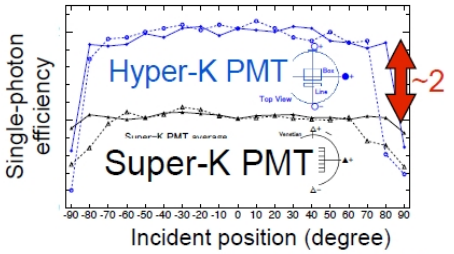
The T2K II upgrades will be part of the near detectors HK project
Our contribution should be considered as a first contribution

• 20-inch PMT electronics

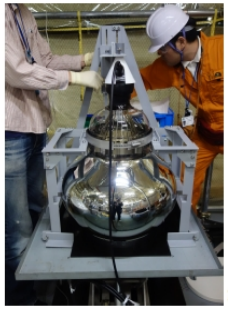
Newly developed for Hyper-K based on the well established and reliable design of the 50 cm R3600 PMT by Hamamatsu Photonics K.K. with a Venetian blind dynode type, which is used for Super-K, and the 43 cm PMT with a box-and-line dynode (Hamamatsu R7250), which is used for the KamLAND experiment.

Improvements include a higher quantum efficiency photocathode and an optimized box-and-line dynode.

- sensitivity: 2 x SK
- Time resolution: 1/2 x SK
- Pressure: 2 x SK

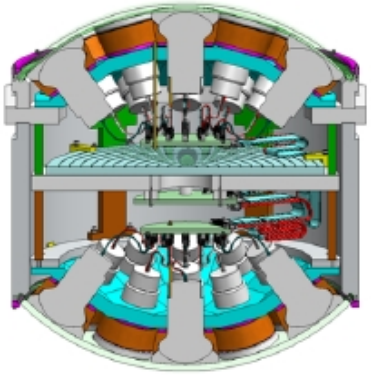


- ~140 new PMTs will be installed in Super-K this summer
  - Performance check w/ Cherenkov light, for years
- Continuous effort for improvements
  - Noise reduction, Cover design, Light concentrator under study



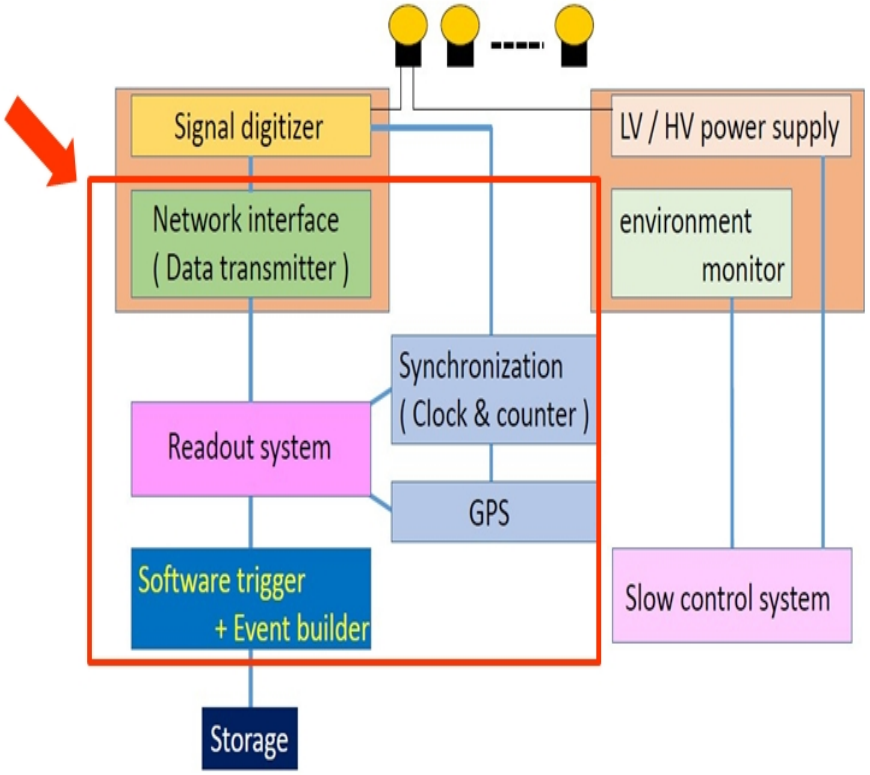
• Small Multi PMTS studies

Underwater tests using existing Memphyno tank at APC. Possible electronics R&D testing



Hyper-K IN2P3 proposed contributions

20-inch PMT electronics



- Due to the size of the tank and the number of channels, the FE electronics will be in the water (not the case for Super-K)
- QTC chips (used for Super-K) and TCD-FPGA are good candidates for the signal digitization
- IN2P3 R&D contribution (red rectangle) :
  - Clock and timing
  - Event builder and communication

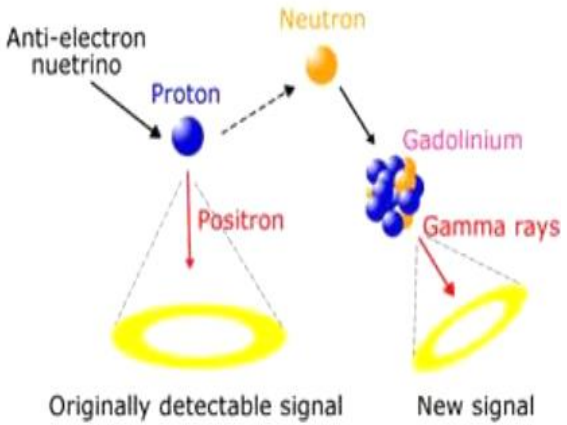
Spring 2020	*Final design review of the system*
Autumn 2020	*Start the design of the system based on the design review*
Autumn 2021	*Start bidding procedure*
Autumn 2022	*Start mass production*
Autumn 2023	*Start final system test*
Autumn 2024	*Complete mass production*
Autumn 2025	*Complete system test and get ready for install*

- 40 k€ for 2019 for R&D
- Research engineer positions will be necessary in the future

The Super-K experiment

LLR in the Super-K experiment since November 2016

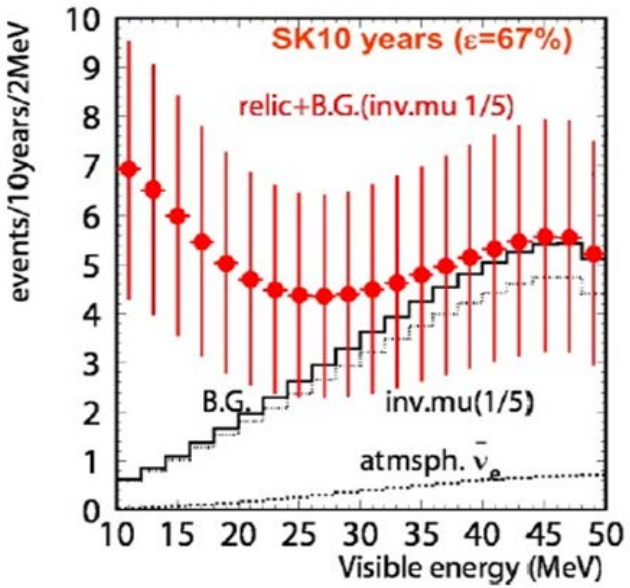
The goal of the upcoming upgrade is to improve neutron tagging
- electron anti-neutrino high efficiency detection
- background reduction at low energy



Diffuse Supernova Neutrino Background (DSNB)

Accumulation since the beginning of the Universe of past Supernova burst

Super-Kamiokande is expected to discover DSNB



The Super-K upgrade

Water sealing reinforcement work

About 1 ton of pure water leaks per day from the SK detector tank. The point of leakage is believed to be at the bottom of the tank. We will apply waterproof material to the interior of the tank in order to stop the water leakage and to prevent water from leaking from the SK tank even if a disaster such as an earthquake occurred in the neighborhood. In particular, we will apply waterproofing agents at all welding joints of the stainless steel panels that make up the tank.

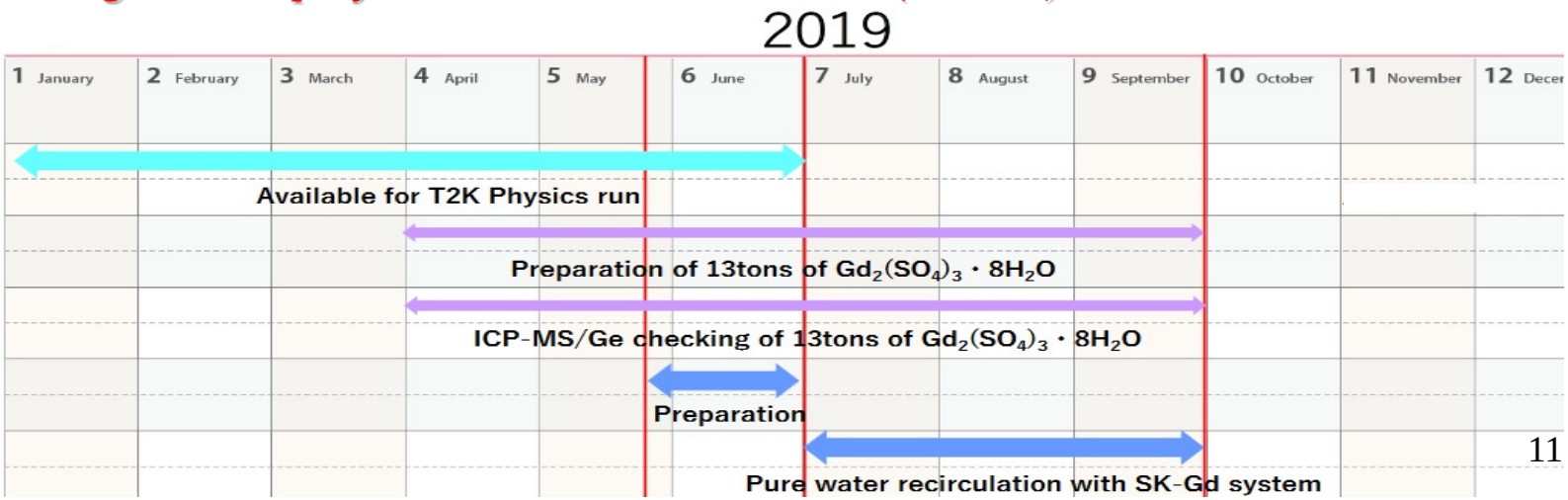
Improvement of tank piping

Ultra pure water in the tank was circulated at a flow rate of 60 tons per hour. After Gd dissolution, to adjust the inside of the tank to a uniform Gd concentration as quickly as possible and to maintain high water transparency, we plan to improve the water piping and water systems so that they can process and circulate water to the tank at 120 tons per hour.

Replace defective photomultiplier tubes (PMTs)

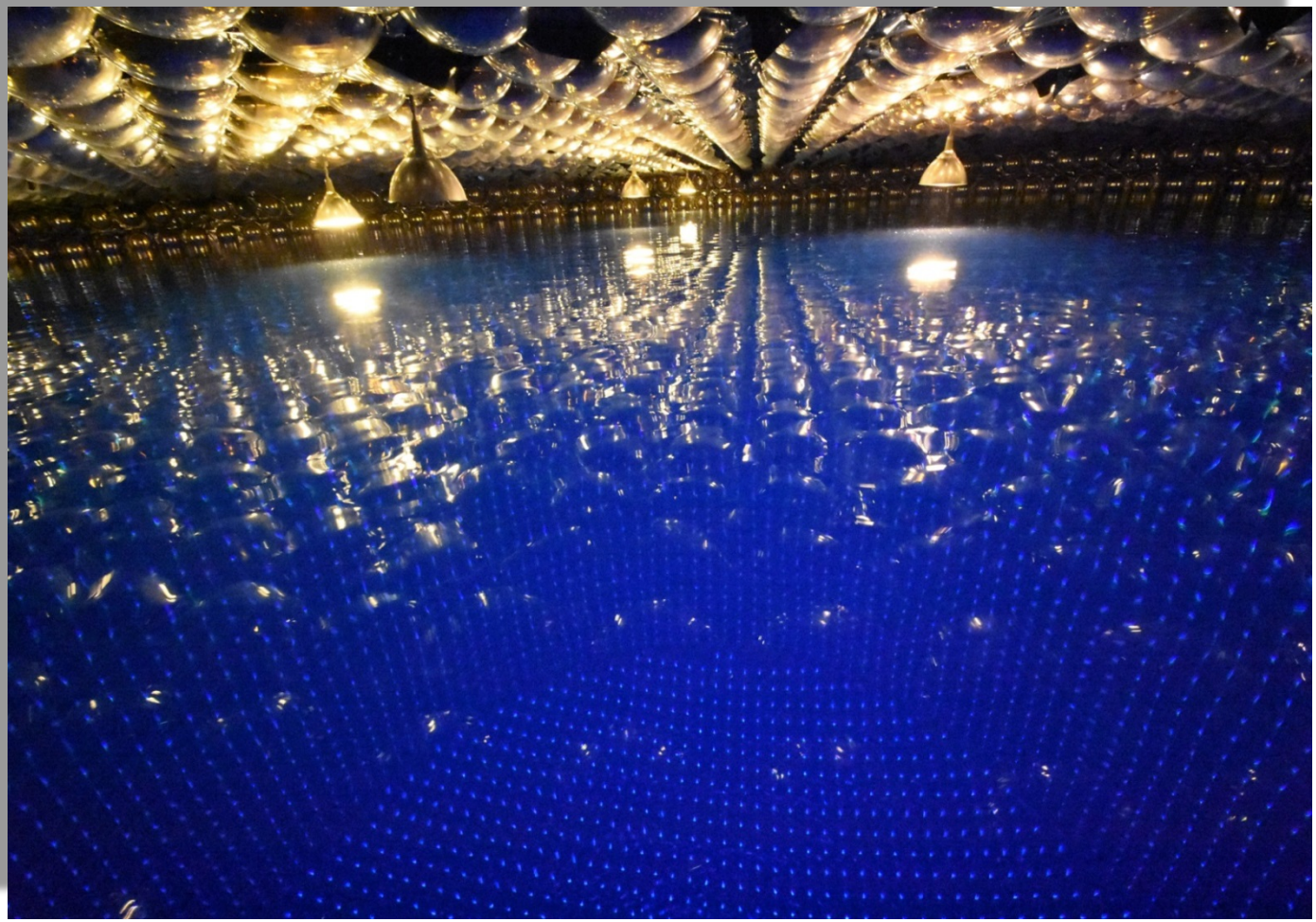
Since the last in-tank SK maintenance during 2005-2006, some malfunction has occurred in a few hundred PMTs out of the 13,000 in the tank. We will replace these tubes.

The Gd gadolium project in the SK tank : 0.02% (10 tons) in 2019 and 0.2% in 2020-21



The Super-K upgrade

Super-K tank was open on June 1th



The Super-K upgrade

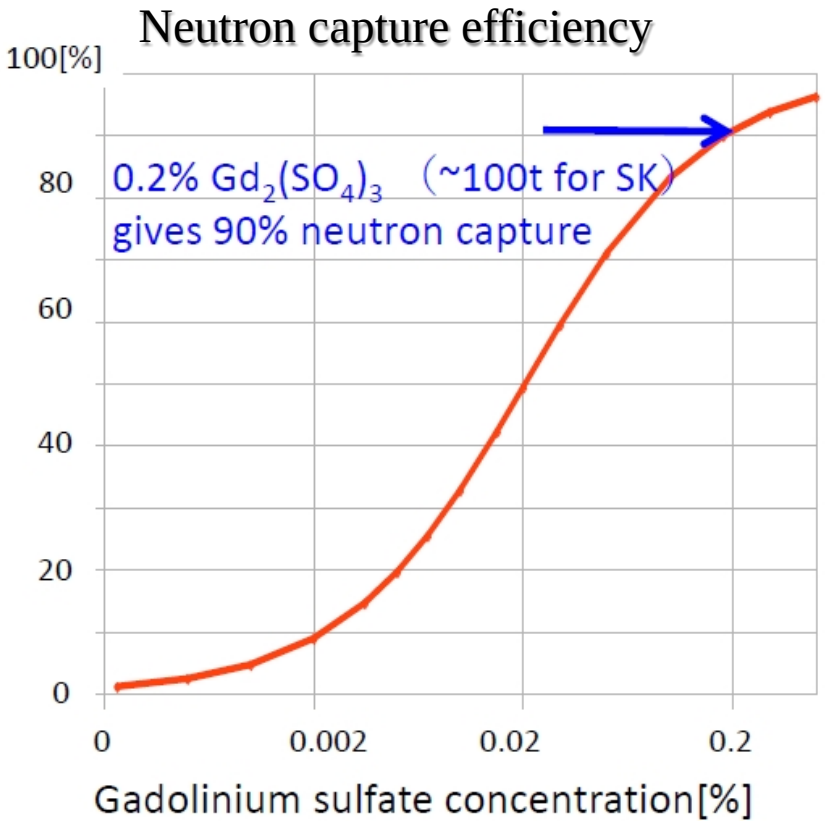
New project with support from IN2P3 and **Ecole Polytechnique for equipment (140 k€)**

2018
- PS module HV iseg EHS-F030p 16 channels for 25% of the OD PMTs
- Tank repairs (Tyvek, cables, …)
- 54 days of SK repairs shifts for LLR this summer

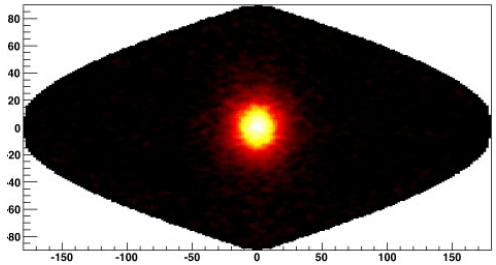
2019
- Filters in the water system

The Super-K experiment

Many interesting subjects to be studied at the very low energy domain E < 50 MeV



- Supernova relic neutrinos
- Improvement for the pointing accuracy for galactic supernovas burst
- Precursor of nearby supernova by Si-burning neutrinos
- Day - Night asymmetry studies
- Solar neutrino studies
- Reactor neutrinos



neutrino / anti-neutrino discrimination in Super-K

Super-K and Hyper-K neutrino astronomy

1987

Kamiokande

Super-Kamiokande

Hyper-Kamiokande

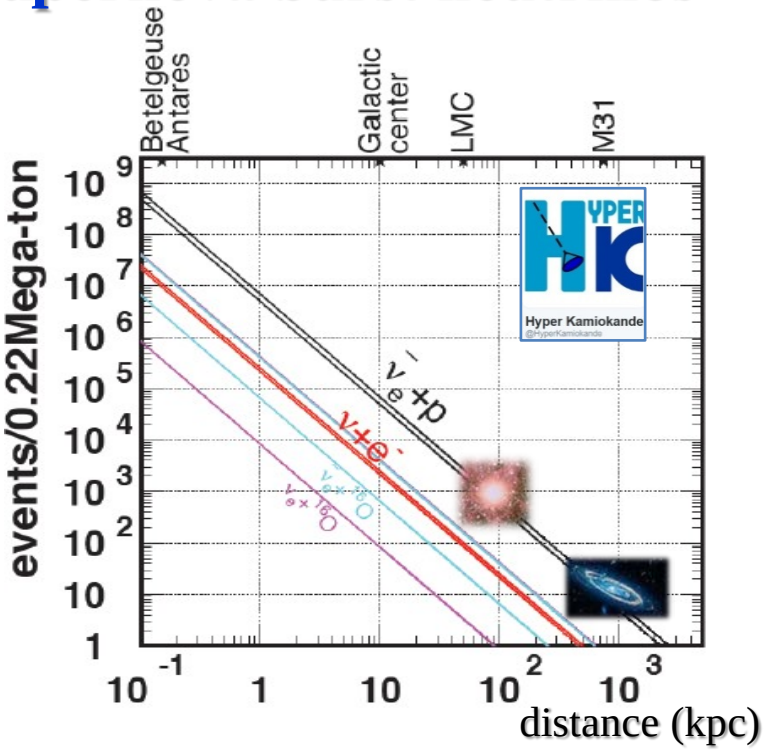
11 observed events

~ 250 events

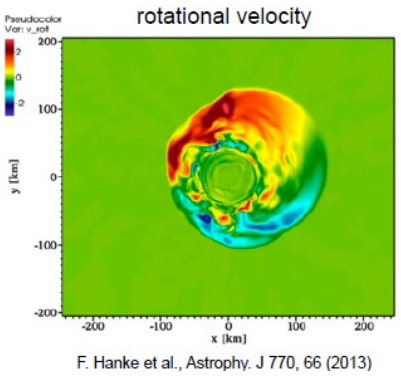
~ 3000 events

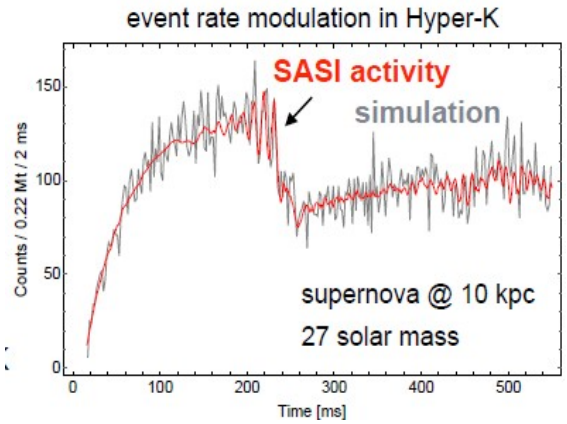
Increasing number of event, in addition to reduced background

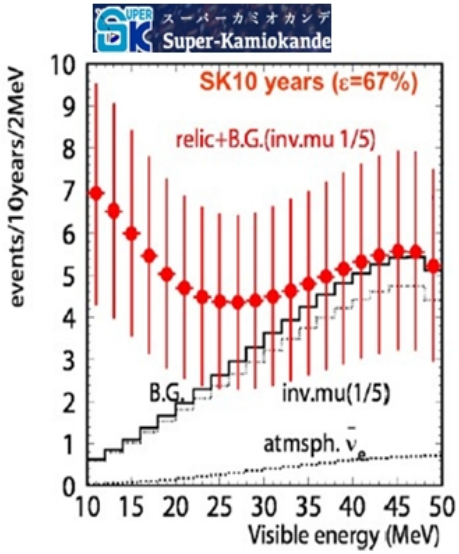
Supernova burst neutrinos



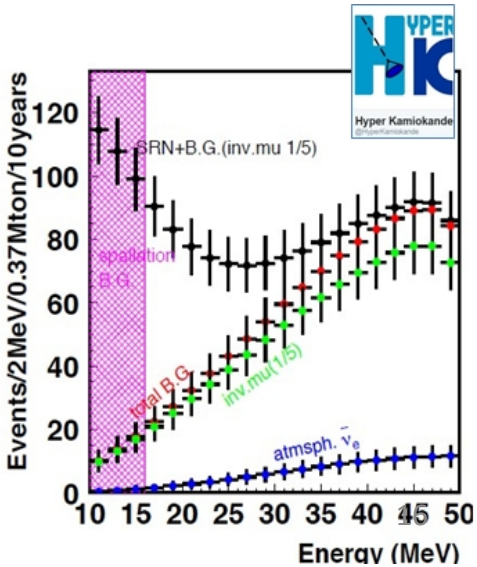
- Hyper-K can extend the supernova search distance to extra-galaxy such as Andromeda
- Hyper-K will test the supernova neutrino flux modulation







Supernova relic neutrinos

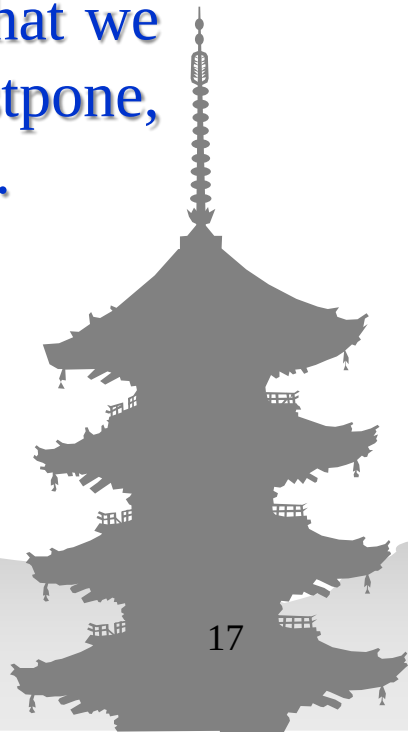


IN2P3 contributions to the Japanese neutrino program
T2K, T2K-II, Hyper-K and Super-K
SUMMARY

Japan Japan

We choose to go to ~~the moon~~. We choose to go to ~~the moon~~ in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.

LLR, LPNHE ….. and JFK



IN2P3 contributions to the Japanese neutrino program
T2K, T2K-II, Hyper-K and Super-K

- **Since 2006, LLR and LPHNE have been very active in the Japanese accelerator neutrino program**
- **Outstanding results and physics discovery with T2K. An opportunity to actively participate in T2K upgrades developing new technologies for neutrino detection**
- **The upgrade of SK opens a new window in cosmology for a major discovery**
- **The construction of HK should begin soon for CPV measurement IN2P3 support will probably be needed before the end of the year**
- **T2HK and non-accelerator HK physics will be one collaboration**

Over the next decade, IN2P3 will participate to some breathtaking high energy physics program in Japan